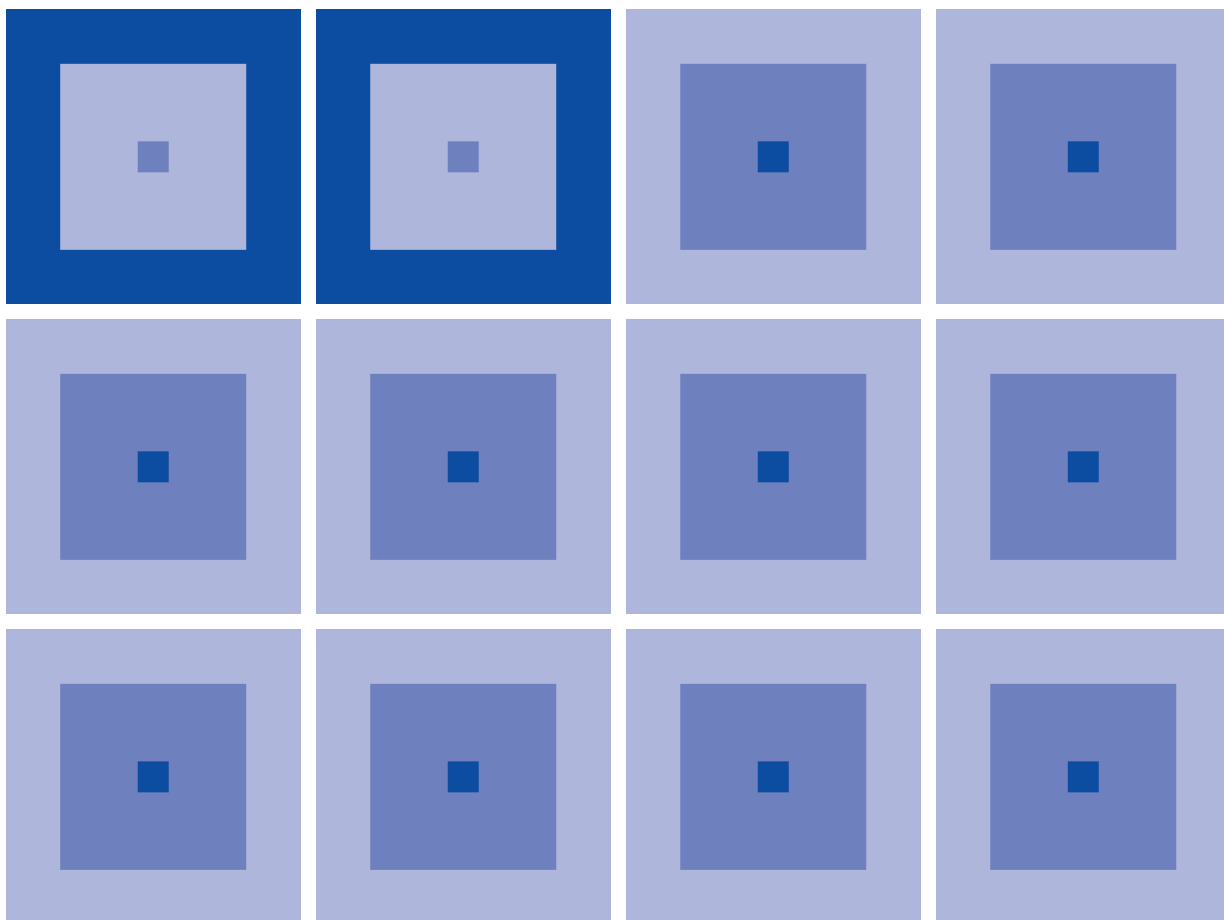


CMOS 8-BIT SINGLE CHIP MICROCOMPUTER

# S1C88409

## Technical Manual

S1C88409 Technical Hardware



**NOTICE**

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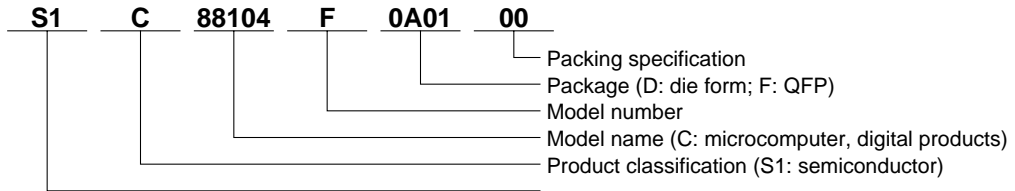
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## The information of the product number change

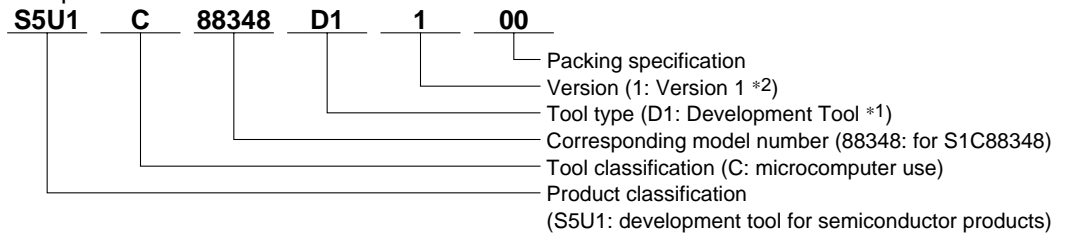
Starting April 1, 2001, the product number will be changed as listed below. To order from April 1, 2001 please use the new product number. For further information, please contact Epson sales representative.

## Configuration of product number

Devices



Development tools



\*1: For details about tool types, see the tables below. (In some manuals, tool types are represented by one digit.)

\*2: Actual versions are not written in the manuals.

## Comparison table between new and previous number

S1C88 Family processors

| Previous No. | New No.  | Previous No. | New No.  |
|--------------|----------|--------------|----------|
| E0C88104     | S1C88104 | E0C88365     | S1C88365 |
| E0C88112     | S1C88112 | E0C88F360    | S1C8F360 |
| E0C88308     | S1C88308 | E0C88408     | S1C88408 |
| E0C88316     | S1C88316 | E0C88409     | S1C88409 |
| E0C88317     | S1C88317 | E0C88816     | S1C88816 |
| E0C88348     | S1C88348 | E0C88832     | S1C88832 |
| E0C88P348    | S1C8P348 | E0C88862     | S1C88862 |
| E0C88349     | S1C88349 | E0C88F816    | S1C8F816 |

## Comparison table between new and previous number of development tools

Development tools for the S1C88 Family

| Previous No. | New No.      | Previous No. | New No.      |
|--------------|--------------|--------------|--------------|
| 88ISAIF      | S5U1C88000H4 | DEV88816     | S5U1C88816D  |
| ADP88348     | S5U1C88348X  | DEV88832     | S5U1C88832D  |
| ADP88360     | S5U1C88360X  | DEV88862     | S5U1C88862D  |
| DEV88104     | S5U1C88104D  | DMT88348-DB  | S5U1C88348T  |
| DEV88112     | S5U1C88112D  | ICE88UR      | S5U1C88000H5 |
| DEV88308     | S5U1C88308D  | PRC88316     | S5U1C88316P  |
| DEV88316     | S5U1C88316D  | PRC88348     | S5U1C88348P  |
| DEV88317     | S5U1C88317D  | PRC88365     | S5U1C88365P  |
| DEV88348     | S5U1C88348D  | PRC88409     | S5U1C88409P  |
| DEV88365     | S5U1C88365D  | PRC88816     | S5U1C88816P  |
| DEV88408     | S5U1C88408D  | SAP88        | S5U1C88000S  |
| DEV88409     | S5U1C88409D  | URS88348     | S5U1C88348Y  |

Development tools for the S1C63/88 Family

| Previous No. | New No.      |
|--------------|--------------|
| ADS00002     | S5U1C88000X1 |
| GWH00002     | S5U1C88000W2 |
| URM00002     | S5U1C88000W1 |



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# CHAPTER 1 OUTLINE

The S1C88409 is a single chip microcomputer which consists of a CMOS 8-bit core CPU S1C88 (MODEL3), 8KB ROM, 3.75KB RAM, dot-matrix LCD controller, 3 types of timers/counters, serial interface (IR input/output function is available), touch panel controller, A/D converter and D/A converter.

The S1C88409 operates faster even with low supply voltage, and is most suitable for various application equipment such as information terminals needing low power operation.

Furthermore, the S1C88409 can control up to  $4M \times 3$  bytes of memory with the 22-bit outside address bus and 3-bit chip enable signals, therefore it can also be applied to systems such as electronic dictionaries and organizers.

## 1.1 Features

Table 1.1.1 Features

|                                 |                                                                                                                                                                                                                  |                                                                                 |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Core CPU                        | CMOS 8-bit core CPU S1C88 (MODEL3)                                                                                                                                                                               |                                                                                 |
| OSC1 oscillation circuit        | Crystal oscillation circuit/CR oscillation circuit/external clock input 32.768 kHz (Typ.)                                                                                                                        |                                                                                 |
| OSC3 oscillation circuit        | Crystal oscillation circuit/ceramic oscillation circuit/CR oscillation circuit/external clock input 8 MHz (Max.)                                                                                                 |                                                                                 |
| Instruction set                 | Basic instruction: 54 types, Total: 608 types (multiplication/division instructions are usable)<br>Addressing mode: 12 types                                                                                     |                                                                                 |
| Min. instruction execution time | 0.25 μsec/8 MHz (2 clocks)                                                                                                                                                                                       |                                                                                 |
| Internal ROM capacity           | 8K bytes                                                                                                                                                                                                         |                                                                                 |
| Internal RAM capacity           | 3.75K bytes (display memory is included; data/display memory size can be set by mask option)                                                                                                                     |                                                                                 |
| Bus line                        | Address bus: 22 bits<br>Data bus: 8 bits<br>CE signal: 3 bits<br>WR signal: 1 bit<br>RD signal: 1 bit                                                                                                            | (usable as general output port or I/O port when it is not used as a bus signal) |
| Input port                      | 12 bits<br>• 2 bits are usable for event counter input                                                                                                                                                           |                                                                                 |
| Output port                     | 30 bits<br>• They are used as address bus and bus control signals when external bus is set<br>• Usable for clock output and buzzer output                                                                        |                                                                                 |
| I/O port                        | 28 bits<br>• 8 bits are used as data bus when external bus is set<br>• Usable for serial interface input/output, A/D converter input, D/A converter output and touch panel output                                |                                                                                 |
| Serial interface                | 1 channel<br>• Clock synchronous mode/asynchronous mode selectable<br>• Usable as IrDA interface                                                                                                                 |                                                                                 |
| 16-bit programmable timer       | 1 channel<br>• Usable for 16 bits × 1 channel or 8 bits × 2 channels<br>• Usable as event counter                                                                                                                |                                                                                 |
| 8-bit programmable timer        | 1 channel<br>• Usable as baud rate generator for serial interface                                                                                                                                                |                                                                                 |
| Clock timer                     | 1 channel<br>• Generating 1 sec signal with 32 kHz oscillation<br>• 60S counter available                                                                                                                        |                                                                                 |
| LCD controller                  | Dot-matrix type<br>• B&W or 4 gray scale display<br>• A 240 × 100 dot LCD panel can be driven with external drivers (S1D16305 or S1D16700, S1D16006 or S1D15700)<br>• Scroll function available                  |                                                                                 |
| Touch panel controller          | Supports pressure sensitive and resistive membrane type analog touch panels                                                                                                                                      |                                                                                 |
| A/D converter                   | Resolution 10 bits (input: 8 channels)                                                                                                                                                                           |                                                                                 |
| D/A converter                   | Resolution 8 bits (output: 2 channels)                                                                                                                                                                           |                                                                                 |
| Sound generator                 | Equipped with envelope and volume control functions                                                                                                                                                              |                                                                                 |
| Supply voltage detection (SVD)  | Possible to detect 3 voltage levels                                                                                                                                                                              |                                                                                 |
| Watchdog timer                  | Possible to generate NMI                                                                                                                                                                                         |                                                                                 |
| Interrupt                       | External:                                                                                                                                                                                                        | Input interrupt 2 systems (5 types)                                             |
|                                 | Internal:                                                                                                                                                                                                        | 16-bit programmable timer interrupt 2 systems (4 types)                         |
|                                 |                                                                                                                                                                                                                  | 8-bit programmable timer interrupt 1 system (1 type)                            |
|                                 |                                                                                                                                                                                                                  | Clock timer interrupt 1 system (5 types)                                        |
|                                 |                                                                                                                                                                                                                  | Watchdog timer interrupt 1 system (1 type)                                      |
|                                 |                                                                                                                                                                                                                  | Serial interface interrupt 1 system (3 types)                                   |
|                                 |                                                                                                                                                                                                                  | LCD controller interrupt 1 system (1 type)                                      |
|                                 |                                                                                                                                                                                                                  | Touch panel interrupt 1 system (2 types)                                        |
|                                 |                                                                                                                                                                                                                  | A/D converter interrupt 1 system (1 type)                                       |
| Supply voltage                  | 1.8 V to 5.5 V (operating frequency Max. 1.1 MHz)<br>2.6 V to 5.5 V (operating frequency Max. 4.4 MHz)<br>3.5 V to 5.5 V (operating frequency Max. 6.6 MHz)<br>4.5 V to 5.5 V (operating frequency Max. 8.8 MHz) |                                                                                 |
| Current consumption             | SLEEP                                                                                                                                                                                                            | 0.6 μA Typ. (at 3.0 V) (Normal mode)                                            |
|                                 | HALT (32 kHz)                                                                                                                                                                                                    | 3.0 μA Typ. (at 3.0 V) (Normal mode)                                            |
|                                 | Run (32 kHz)                                                                                                                                                                                                     | 15 μA Typ. (at 3.0 V) (Normal mode)                                             |
|                                 | Run (4 MHz)                                                                                                                                                                                                      | 2 mA Typ. (at 3.0 V) (Normal mode)                                              |
|                                 | Run (8 MHz)                                                                                                                                                                                                      | 9 mA Typ. (at 5.0 V) (High speed mode)                                          |
| Supply form                     | QFP15-100pin or chip                                                                                                                                                                                             |                                                                                 |

## 1.2 Block Diagram

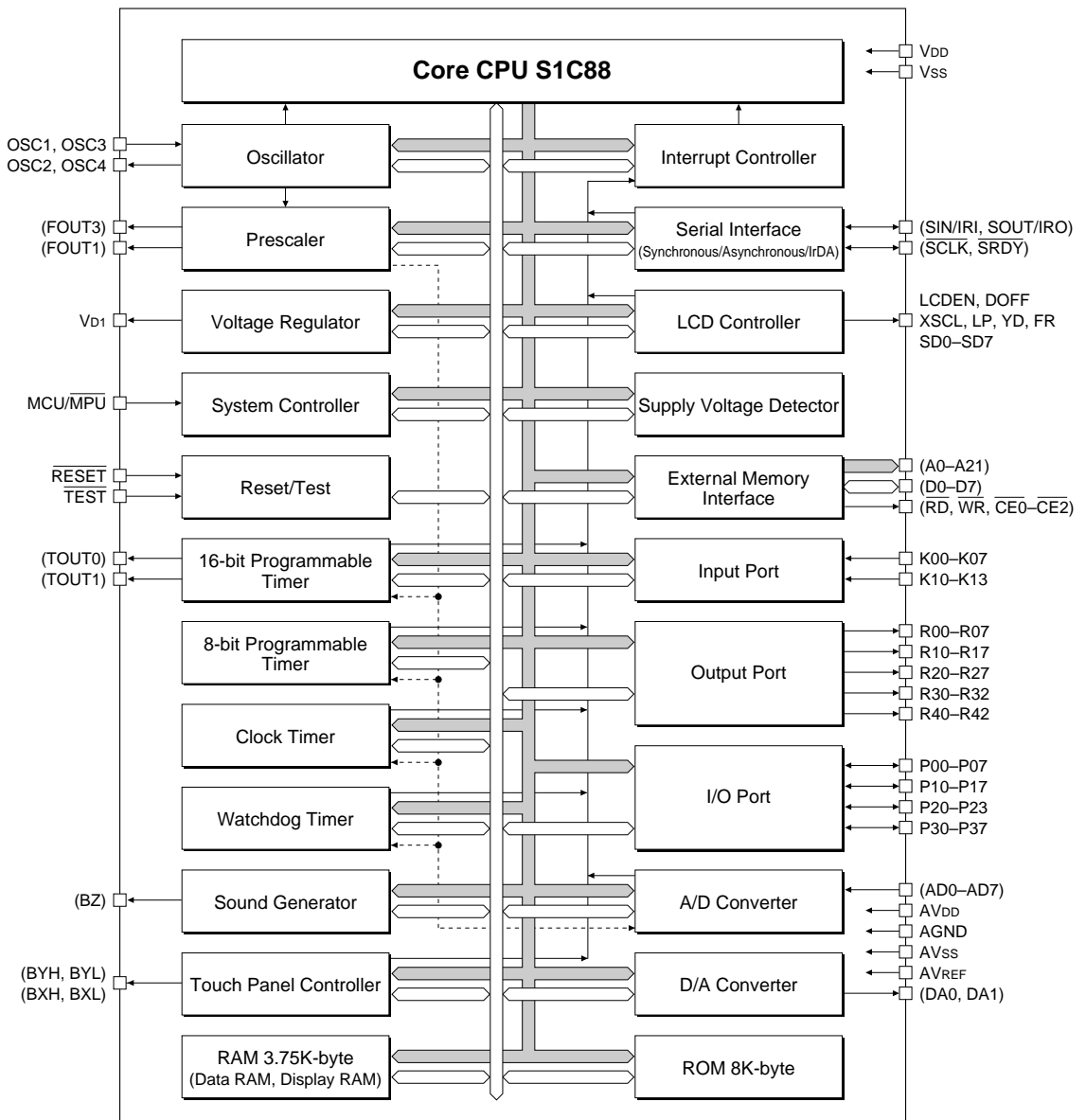


Fig. 1.2.1 S1C88409 block diagram

\* The terminals that are shown in ( ) are shared with Pxx or Rxx terminals.

### 1.3 System Configuration

System configuration of the S1C88409 is classified in 2 types according to use.

- 1) Single-chip system
- 2) Multi-chip system

To construct these systems, the S1C88409 has been designed to switch the bus mode (configuration of the external bus) by software and/or mask option.

#### 1.3.1 Single-chip system

The single-chip system has the smallest configuration that uses the S1C88409 as the CPU of the system and does not expand any memory and devices outside. It is suitable for various controller systems.

Since it does not use an external bus, the bus mode of the S1C88409 should be set to the MCU/ single-chip mode (see Section 3.5). (Initial setting)  
The memory that can be used is limited to the built-in area.

ROM ...8KB

RAM ...3.75KB (display memory is included)

The I/O ports shared with the external bus can be used entirely as general-purpose I/O ports.

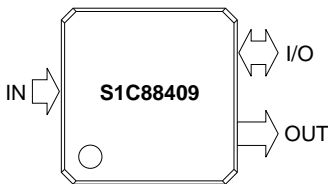


Fig. 1.3.1.1 Configuration of single-chip system

#### 1.3.2 Multi-chip system

With the S1C88409 as the CPU, the multi-chip system has expanded memory as well as other expanded devices. It covers a wide range of applications. Memory and devices are connected to the external bus of the S1C88409 and are all controlled by the S1C88409.

The bus mode of the S1C88409 can be set to the expanded mode (see Section 3.5) according to scale of the system.

MCU or MPU\*/Expanded 64K mode

For systems with 64KB or less expanded memory

MCU or MPU\*/Expanded 4M minimum mode

For systems with 64KB to 12MB (4M × 3) expanded memory (However, program memory is 64KB or less)

MCU or MPU\*/Expanded 4M maximum mode

For systems with 64KB to 12MB (4M × 3) expanded memory (For systems that require 64KB or more program memory)

\* The MCU mode is set when the internal ROM is used, and the MPU mode is set when the internal ROM is not used.

Refer to Section 3.6, "External Bus", for the bus configuration.

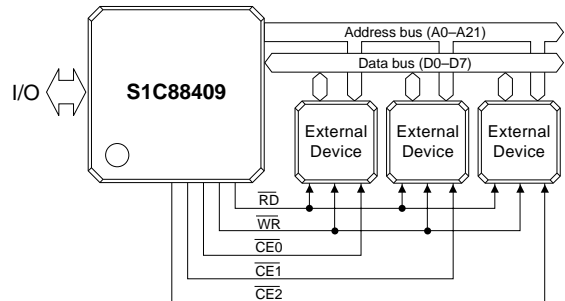


Fig. 1.3.2.1 Configuration of multi-chip system

## 1.4 Pin Layout Diagram

- Pin layout for single chip mode (initial setting)

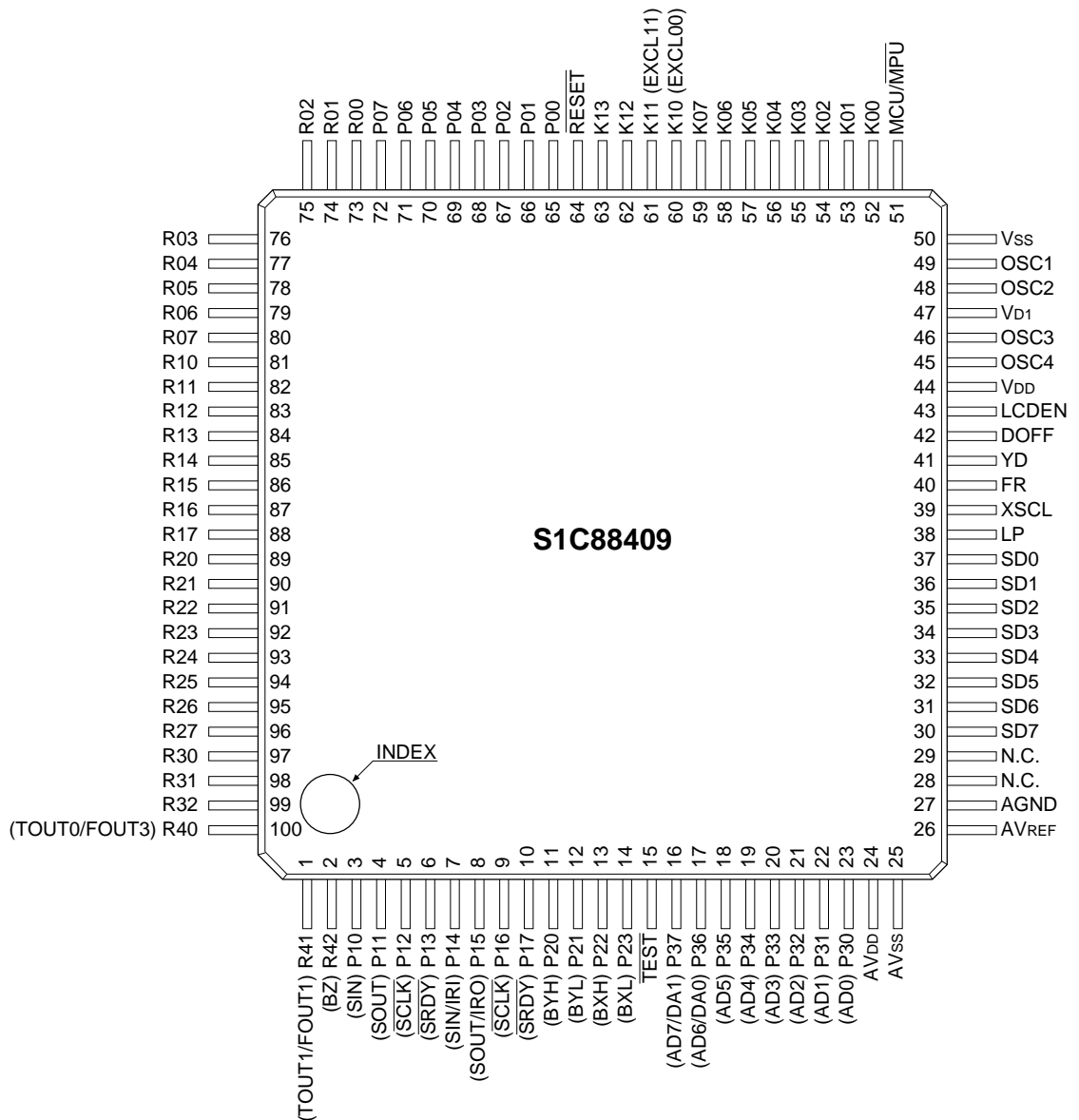


Fig. 1.4.1 S1C88409 pin layout (single chip mode)

Table 1.4.1 S1C88409 pin description (single chip mode)

| Pin name                    | Pin No. | I/O | Function                                                                                      |
|-----------------------------|---------|-----|-----------------------------------------------------------------------------------------------|
| VDD                         | 44      | –   | Power supply (+) pin                                                                          |
| VSS                         | 50      | –   | Power supply (GND) pin                                                                        |
| VD1                         | 47      | O   | Voltage regulator output pin                                                                  |
| AVDD                        | 24      | –   | Power supply (+) pin for analog circuit system                                                |
| AGND                        | 27      | –   | GND pin for analog circuit system                                                             |
| AVSS                        | 25      | –   | Power supply (GND) pin for analog circuit system                                              |
| AVREF                       | 26      | I   | Reference voltage input pin for analog circuit system                                         |
| OSC1                        | 49      | I   | OSC1 oscillation input pin (32 kHz crystal, CR oscillation, external clock input)             |
| OSC2                        | 48      | O   | OSC1 oscillation output pin                                                                   |
| OSC3                        | 46      | I   | OSC3 oscillation input pin (crystal/ceramic, CR oscillation, external clock input)            |
| OSC4                        | 45      | O   | OSC3 oscillation output pin                                                                   |
| MCU/MPU                     | 51      | I   | MCU/MPU mode stting pin*1                                                                     |
| K00~K07                     | 52~59   | I   | Input port pin                                                                                |
| K10 (EXCL00)                | 60      | I   | Input port pin or external clock input pin for event counter (Timer 0)                        |
| K11 (EXCL01)                | 61      | I   | Input port pin or external clock input pin for event counter (Timer 1)                        |
| K12~K13                     | 62~63   | I   | Input port pin                                                                                |
| R00~R07                     | 73~80   | O   | Output port pin                                                                               |
| R10~R17                     | 81~88   | O   | Output port pin                                                                               |
| R20~R27                     | 89~96   | O   | Output port pin                                                                               |
| R30~R32                     | 97~99   | O   | Output port pin                                                                               |
| R40 (TOUT0/FOUT3)           | 100     | O   | Output port pin or TOUT0/FOUT3 clock output pin                                               |
| R41 (TOUT1/FOUT1)           | 1       | O   | Output port pin or TOUT1/FOUT1 clock output pin                                               |
| R42 (BZ)                    | 2       | O   | Output port pin or buzzer signal output pin                                                   |
| P00~P07                     | 65~72   | I/O | I/O port pin                                                                                  |
| P10 (SIN)                   | 3       | I/O | I/O port pin or serial I/F data input pin                                                     |
| P11 (SOUT)                  | 4       | I/O | I/O port pin or serial I/F data output pin                                                    |
| P12 (SCLK)                  | 5       | I/O | I/O port pin or serial I/F clock input/output pin                                             |
| P13 (SRDY)                  | 6       | I/O | I/O port pin or serial I/F ready signal output pin                                            |
| P14 (SIN/IRI)               | 7       | I/O | I/O port pin, serial I/F data input or IR receiver input pin                                  |
| P15 (SOUT/IRO)              | 8       | I/O | I/O port pin, serial I/F data output or IR transmitter output pin                             |
| P16 (SCLK)                  | 9       | I/O | I/O port pin or serial I/F clock input/output pin                                             |
| P17 (SRDY)                  | 10      | I/O | I/O port pin or serial I/F ready signal output pin                                            |
| P20 (BYH)                   | 11      | I/O | I/O port pin or touch panel controller BYH signal output pin                                  |
| P21 (BYL)                   | 12      | I/O | I/O port pin or touch panel controller BYL signal output pin                                  |
| P22 (BXH)                   | 13      | I/O | I/O port pin or touch panel controller BXH signal output pin                                  |
| P23 (BXL)                   | 14      | I/O | I/O port pin or touch panel controller BXL signal output pin                                  |
| P30~P35 (AD0~AD5)           | 23~18   | I/O | I/O port pin or A/D converter analog signal input pin                                         |
| P36, P37 (AD6/DA0, AD7/DA1) | 17,16   | I/O | I/O port pin, A/D converter analog signal input pin or D/A converter analog signal output pin |
| LCDEN                       | 43      | O   | LCD controller enable signal output pin                                                       |
| DOFF                        | 42      | O   | LCD controller forced blank signal output pin                                                 |
| YD                          | 41      | O   | LCD controller scan start pulse output pin                                                    |
| FR                          | 40      | O   | LCD controller frame signal output pin                                                        |
| XSCL                        | 39      | O   | LCD controller shift clock output pin                                                         |
| LP                          | 38      | O   | LCD controller latch pulse output pin                                                         |
| SD0~SD7                     | 37~30   | O   | LCD controller data output pin                                                                |
| RESET                       | 64      | I   | Initial reset input pin                                                                       |
| TEST                        | 15      | I   | Test input pin*2                                                                              |

\*1 The MCU/MPU terminal should be connected to VDD.

\*2 TEST is the terminal used for factory inspection of the IC. For normal operation, be sure to connect the TEST terminal to VDD.



• Pin layout for expanded 64K mode (for multi-chip system)

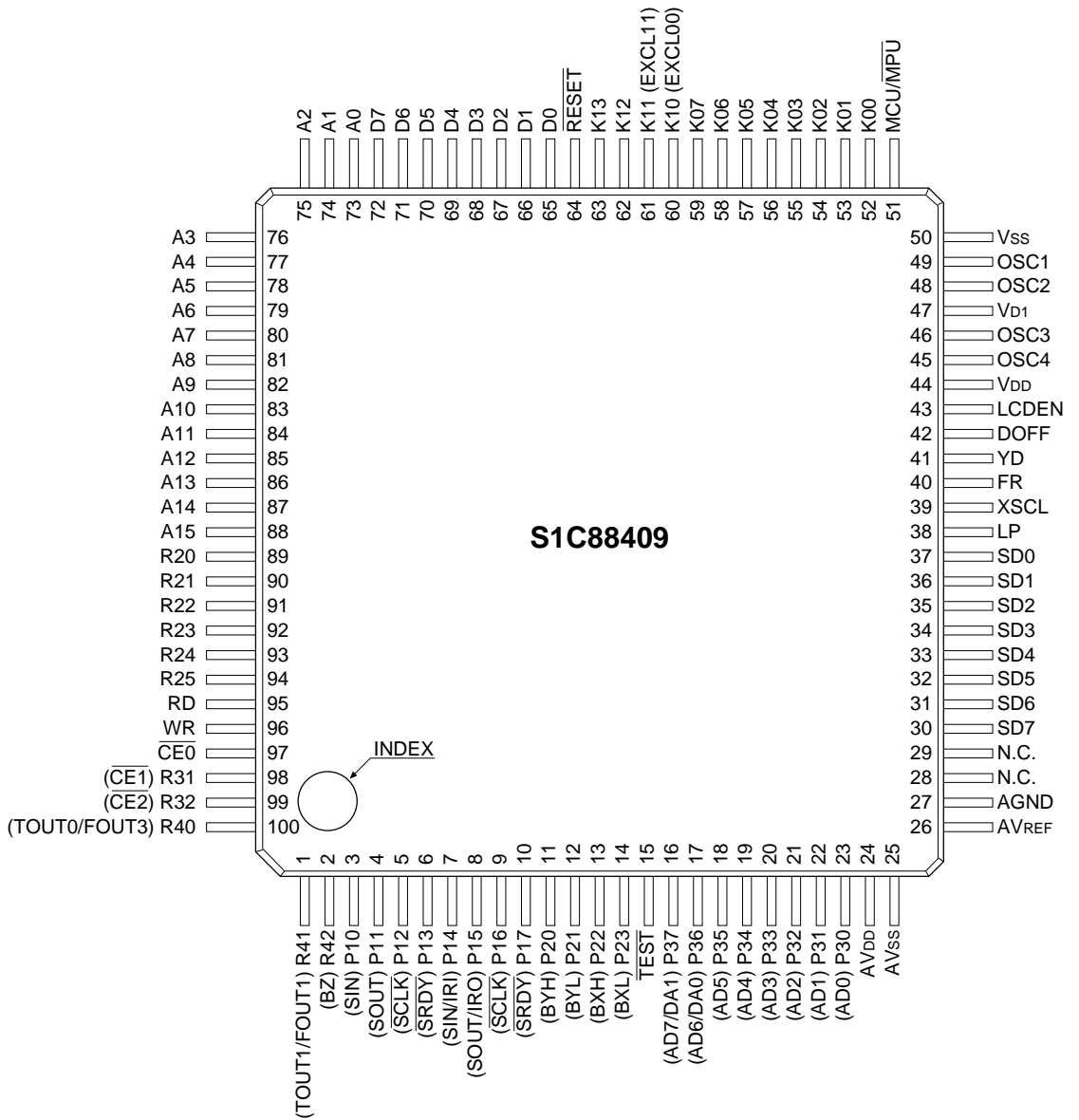


Fig. 1.4.2 S1C88409 pin layout (expanded 64K mode)

Table 1.4.2 S1C88409 pin description (expanded 64K mode)

| Pin name                    | Pin No. | I/O | Function                                                                                      |
|-----------------------------|---------|-----|-----------------------------------------------------------------------------------------------|
| VDD                         | 44      | –   | Power supply (+) pin                                                                          |
| VSS                         | 50      | –   | Power supply (GND) pin                                                                        |
| VD1                         | 47      | O   | Voltage regulator output pin                                                                  |
| AVDD                        | 24      | –   | Power supply (+) pin for analog circuit system                                                |
| AGND                        | 27      | –   | GND pin for analog circuit system                                                             |
| AVSS                        | 25      | –   | Power supply (GND) pin for analog circuit system                                              |
| AVREF                       | 26      | I   | Reference voltage input pin for analog circuit system                                         |
| OSC1                        | 49      | I   | OSC1 oscillation input pin (32 kHz crystal, CR oscillation, external clock input)             |
| OSC2                        | 48      | O   | OSC1 oscillation output pin                                                                   |
| OSC3                        | 46      | I   | OSC3 oscillation input pin (crystal/ceramic, CR oscillation, external clock input)            |
| OSC4                        | 45      | O   | OSC3 oscillation output pin                                                                   |
| MCU/MPU                     | 51      | I   | MCU/MPU mode stting pin                                                                       |
| K00~K07                     | 52~59   | I   | Input port pin                                                                                |
| K10 (EXCL00)                | 60      | I   | Input port pin or external clock input pin for event counter (Timer 0)                        |
| K11 (EXCL01)                | 61      | I   | Input port pin or external clock input pin for event counter (Timer 1)                        |
| K12~K13                     | 62~63   | I   | Input port pin                                                                                |
| A00~A15                     | 73~88   | O   | Address bus                                                                                   |
| R20~R25                     | 89~94   | O   | Output port pin                                                                               |
| $\overline{RD}$             | 95      | O   | Read signal output pin                                                                        |
| $\overline{WR}$             | 96      | O   | Write signal output pin                                                                       |
| $\overline{CE0}$            | 97      | O   | Chip enable signal output pin                                                                 |
| $\overline{CE1}$ (R31)      | 98      | O   | Chip enable signal output pin or output port pin                                              |
| $\overline{CE2}$ (R32)      | 99      | O   | Chip enable signal output pin or output port pin                                              |
| R40 (TOUT0/FOUT3)           | 100     | O   | Output port pin or TOUT0/FOUT3 clock output pin                                               |
| R41 (TOUT1/FOUT1)           | 1       | O   | Output port pin or TOUT1/FOUT1 clock output pin                                               |
| R42 (BZ)                    | 2       | O   | Output port pin or buzzer signal output pin                                                   |
| D0~D7                       | 65~72   | I/O | Data bus                                                                                      |
| P10 (SIN)                   | 3       | I/O | I/O port pin or serial I/F data input pin                                                     |
| P11 (SOUT)                  | 4       | I/O | I/O port pin or serial I/F data output pin                                                    |
| P12 (SCLK)                  | 5       | I/O | I/O port pin or serial I/F clock input/output pin                                             |
| P13 (SRDY)                  | 6       | I/O | I/O port pin or serial I/F ready signal output pin                                            |
| P14 (SIN/IRI)               | 7       | I/O | I/O port pin, serial I/F data input or IR receiver input pin                                  |
| P15 (SOUT/IRO)              | 8       | I/O | I/O port pin, serial I/F data output or IR transmitter output pin                             |
| P16 (SCLK)                  | 9       | I/O | I/O port pin or serial I/F clock input/output pin                                             |
| P17 (SRDY)                  | 10      | I/O | I/O port pin or serial I/F ready signal output pin                                            |
| P20 (BYH)                   | 11      | I/O | I/O port pin or touch panel controller BYH signal output pin                                  |
| P21 (BYL)                   | 12      | I/O | I/O port pin or touch panel controller BYL signal output pin                                  |
| P22 (BXH)                   | 13      | I/O | I/O port pin or touch panel controller BXH signal output pin                                  |
| P23 (BXL)                   | 14      | I/O | I/O port pin or touch panel controller BXL signal output pin                                  |
| P30~P35 (AD0~AD5)           | 23~18   | I/O | I/O port pin or A/D converter analog signal input pin                                         |
| P36, P37 (AD6/DA0, AD7/DA1) | 17,16   | I/O | I/O port pin, A/D converter analog signal input pin or D/A converter analog signal output pin |
| LCDEN                       | 43      | O   | LCD controller enable signal output pin                                                       |
| DOFF                        | 42      | O   | LCD controller forced blank signal output pin                                                 |
| YD                          | 41      | O   | LCD controller scan start pulse output pin                                                    |
| FR                          | 40      | O   | LCD controller frame signal output pin                                                        |
| XSCL                        | 39      | O   | LCD controller shift clock output pin                                                         |
| LP                          | 38      | O   | LCD controller latch pulse output pin                                                         |
| SD0~SD7                     | 37~30   | O   | LCD controller data output pin                                                                |
| $\overline{RESET}$          | 64      | I   | Initial reset input pin                                                                       |
| $\overline{TEST}$           | 15      | I   | Test input pin*1                                                                              |

\*1  $\overline{TEST}$  is the terminal used for factory inspection of the IC. For normal operation, be sure to connect the  $\overline{TEST}$  terminal to VDD.

• Pin layout for expanded 4M mode (for multi-chip system)

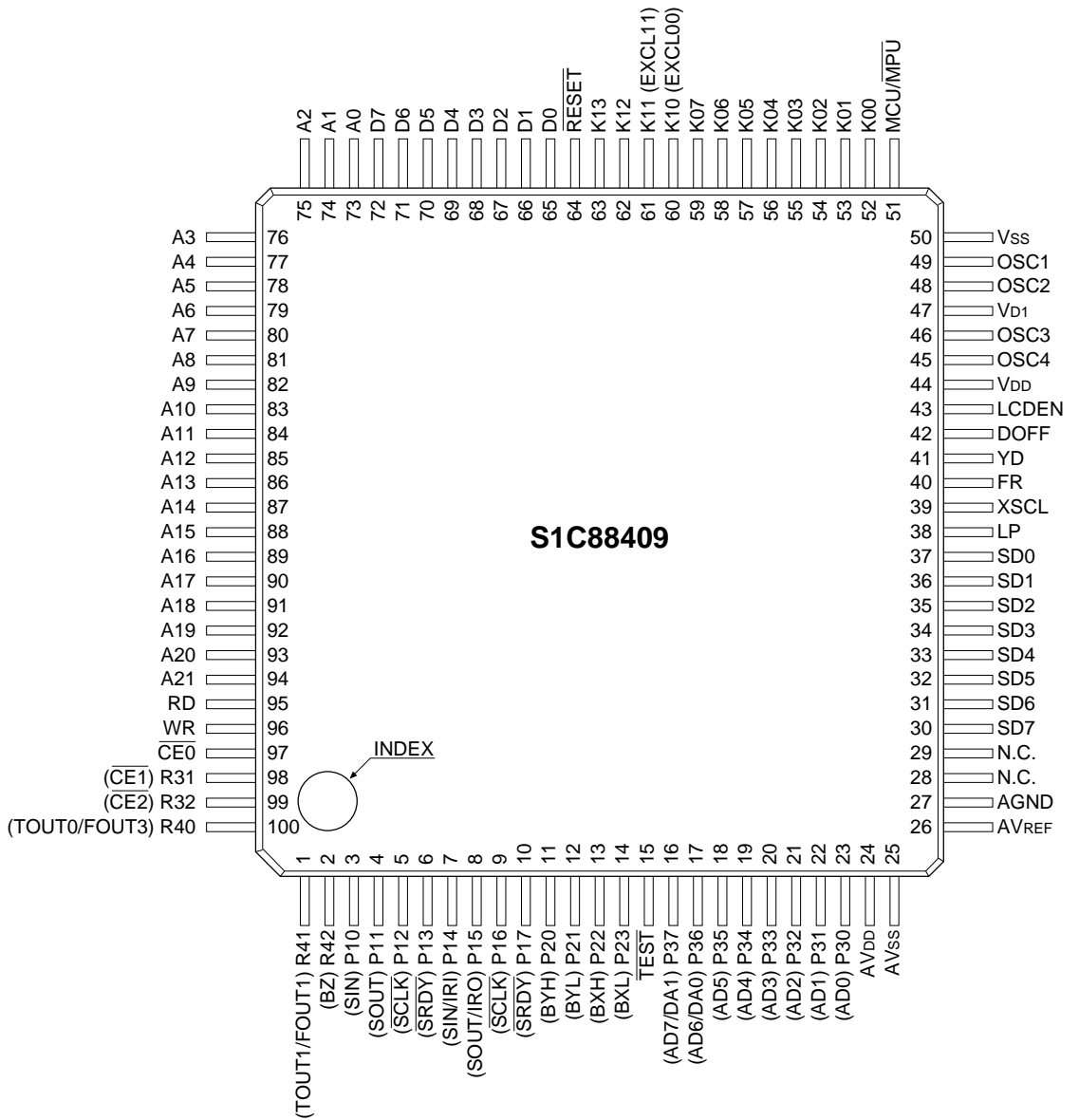


Fig. 1.4.3 S1C88409 pin layout (expanded 4M mode)

Table 1.4.3 S1C88409 pin description (expanded 4M mode)

| Pin name                    | Pin No. | I/O | Function                                                                                      |
|-----------------------------|---------|-----|-----------------------------------------------------------------------------------------------|
| VDD                         | 44      | –   | Power supply (+) pin                                                                          |
| VSS                         | 50      | –   | Power supply (GND) pin                                                                        |
| VD1                         | 47      | O   | Voltage regulator output pin                                                                  |
| AVDD                        | 24      | –   | Power supply (+) pin for analog circuit system                                                |
| AGND                        | 27      | –   | GND pin for analog circuit system                                                             |
| AVSS                        | 25      | –   | Power supply (GND) pin for analog circuit system                                              |
| AVREF                       | 26      | I   | Reference voltage input pin for analog circuit system                                         |
| OSC1                        | 49      | I   | OSC1 oscillation input pin (32 kHz crystal, CR oscillation, external clock input)             |
| OSC2                        | 48      | O   | OSC1 oscillation output pin                                                                   |
| OSC3                        | 46      | I   | OSC3 oscillation input pin (crystal/ceramic, CR oscillation, external clock input)            |
| OSC4                        | 45      | O   | OSC3 oscillation output pin                                                                   |
| MCU/MPU                     | 51      | I   | MCU/MPU mode setting pin                                                                      |
| K00~K07                     | 52~59   | I   | Input port pin                                                                                |
| K10 (EXCL00)                | 60      | I   | Input port pin or external clock input pin for event counter (Timer 0)                        |
| K11 (EXCL01)                | 61      | I   | Input port pin or external clock input pin for event counter (Timer 1)                        |
| K12~K13                     | 62~63   | I   | Input port pin                                                                                |
| A00~A21                     | 73~94   | O   | Address bus                                                                                   |
| RD                          | 95      | O   | Read signal output pin                                                                        |
| WR                          | 96      | O   | Write signal output pin                                                                       |
| CE0                         | 97      | O   | Chip enable signal output pin                                                                 |
| CE1 (R31)                   | 98      | O   | Chip enable signal output pin or output port pin                                              |
| CE2 (R32)                   | 99      | O   | Chip enable signal output pin or output port pin                                              |
| R40 (TOUT0/FOUT3)           | 100     | O   | Output port pin or TOUT0/FOUT3 clock output pin                                               |
| R41 (TOUT1/FOUT1)           | 1       | O   | Output port pin or TOUT1/FOUT1 clock output pin                                               |
| R42 (BZ)                    | 2       | O   | Output port pin or buzzer signal output pin                                                   |
| D0~D7                       | 65~72   | I/O | Data bus                                                                                      |
| P10 (SIN)                   | 3       | I/O | I/O port pin or serial I/F data input pin                                                     |
| P11 (SOUT)                  | 4       | I/O | I/O port pin or serial I/F data output pin                                                    |
| P12 (SCLK)                  | 5       | I/O | I/O port pin or serial I/F clock input/output pin                                             |
| P13 (SRDY)                  | 6       | I/O | I/O port pin or serial I/F ready signal output pin                                            |
| P14 (SIN/IRI)               | 7       | I/O | I/O port pin, serial I/F data input or IR receiver input pin                                  |
| P15 (SOUT/IRO)              | 8       | I/O | I/O port pin, serial I/F data output or IR transmitter output pin                             |
| P16 (SCLK)                  | 9       | I/O | I/O port pin or serial I/F clock input/output pin                                             |
| P17 (SRDY)                  | 10      | I/O | I/O port pin or serial I/F ready signal output pin                                            |
| P20 (BYH)                   | 11      | I/O | I/O port pin or touch panel controller BYH signal output pin                                  |
| P21 (BYL)                   | 12      | I/O | I/O port pin or touch panel controller BYL signal output pin                                  |
| P22 (BXH)                   | 13      | I/O | I/O port pin or touch panel controller BXH signal output pin                                  |
| P23 (BXL)                   | 14      | I/O | I/O port pin or touch panel controller BXL signal output pin                                  |
| P30~P35 (AD0~AD5)           | 23~18   | I/O | I/O port pin or A/D converter analog signal input pin                                         |
| P36, P37 (AD6/DA0, AD7/DA1) | 17,16   | I/O | I/O port pin, A/D converter analog signal input pin or D/A converter analog signal output pin |
| LCDEN                       | 43      | O   | LCD controller enable signal output pin                                                       |
| DOFF                        | 42      | O   | LCD controller forced blank signal output pin                                                 |
| YD                          | 41      | O   | LCD controller scan start pulse output pin                                                    |
| FR                          | 40      | O   | LCD controller frame signal output pin                                                        |
| XSCL                        | 39      | O   | LCD controller shift clock output pin                                                         |
| LP                          | 38      | O   | LCD controller latch pulse output pin                                                         |
| SD0~SD7                     | 37~30   | O   | LCD controller data output pin                                                                |
| RESET                       | 64      | I   | Initial reset input pin                                                                       |
| TEST                        | 15      | I   | Test input pin*1                                                                              |

\*1 TEST is the terminal used for factory inspection of the IC. For normal operation, be sure to connect the TEST terminal to VDD.

## 1.5 Mask Option

Mask options shown below are provided for the S1C88409. Several hardware specifications are prepared in each mask option, and one of them can be selected according to the application. The function option generator FOG88409, that has been prepared as the development software tool of the S1C88409, is used for this selection. Mask pattern of the IC is finally generated based on the data created by the FOG88409. Refer to the "S5U1C88409D Manual" for details on the FOG88409.

<Functions selectable with S1C88409 mask options>

### (1) Bus mode

The bus mode that is set at initial reset can be selected. It is necessary to select it when using the S1C88409 in the MPU mode. Refer to Section 5.2, "System Controller and Bus Control", for details.

### (2) OSC1 oscillation circuit

The specification of the OSC1 oscillation circuit can be selected from among four types: "Crystal oscillation", "CR oscillation", "Crystal oscillation (gate capacitor built-in)" and "External clock input". Refer to Section 5.4.3, "OSC1 oscillation circuit", for details.

### (3) OSC3 oscillation circuit

The specification of the OSC3 oscillation circuit can be selected from among four types: "Crystal oscillation", "Ceramic oscillation", "CR oscillation" and "External clock input". Refer to Section 5.4.4, "OSC3 oscillation circuit", for details.

### (4) $\overline{\text{MCU/MPU}}$ terminal pull-up resistor

This mask option can select whether the pull-up resistor for the  $\overline{\text{MCU/MPU}}$  terminal is used or not.

### (5) $\overline{\text{RESET}}$ terminal pull-up resistor

This mask option can select whether the pull-up resistor for the  $\overline{\text{RESET}}$  terminal is used or not.

### (6) Input port pull-up resistor

This mask option can select whether the pull-up resistor for the input port terminal is used or not. It is possible to select for each bit of the input ports. Refer to Section 5.6.2, "Mask option", for details.

### (7) I/O port pull-up resistor

This mask option can select whether the pull-up resistor for the I/O port terminal (it works during input mode) is used or not. It is possible to select for each bit of the input ports. Refer to Section 5.8.3, "Mask option", for details.

### (8) Data RAM, Display RAM capacity

The S1C88409 has built-in 3.75KB RAM. The data memory/display memory size can be selected from seven types (256/3584, 512/3328, 768/3072, 1024/2816, 1280/2560, 1536/2304, 1792/2048 bytes) according to the LCD panel to be used. Refer to Section 3.2.2, "RAM (Data Memory, Display Memory)", for details.

### (9) Touch panel control terminal

The control signal output terminals of the touch panel controller are shared with the I/O port terminals P20 to P23. The P20–P23 terminals can be set for either the touch panel controller or the I/O port. Refer to Section 5.17.2, "Terminal configuration", for details.

### (10) Touch panel controller input terminal

Two terminals can be selected from the I/O port terminals P30–P35 for inputting the X and Y coordinate detection signals of the touch panel to the A/D converter. Refer to Section 5.17.2, "Terminal configuration", for details.

# CHAPTER 2 POWER SUPPLY

This section explains the operating voltage and the configuration of the internal power supply circuit of the S1C88409.

## 2.1 Operating Voltage

Table 2.1.1 shows the operating voltage of the S1C88409.

Using a low voltage for VDD according to operating speed needs can reduce power consumption.

Table 2.1.1 Correspondence between operating voltage and operating frequency

| Operable voltage range (VDD) | Max. clock frequency (OSC3) |
|------------------------------|-----------------------------|
| 1.8 V to 5.5 V               | 1.1 MHz                     |
| 2.6 V to 5.5 V               | 4.4 MHz                     |
| 3.5 V to 5.5 V               | 6.6 MHz                     |
| 4.5 V to 5.5 V               | 8.8 MHz                     |

Note: I/O signal levels (high and low) that are described in this manual show the following voltage level if not otherwise noted.

High level = VDD  
Low level = VSS

## 2.2 Internal Power Supply Circuit

The S1C88409 has the built-in power supply circuit shown in Figure 2.2.1. The power supply circuit generates the voltage VD1 for the internal circuits by supplying a voltage within the range mentioned above between the VDD (+) and VSS (GND) terminals.

VD1 voltage can be selected from among four types: 4.2 V (Max. 8.8 MHz), 3.2 V (Max. 6.6 MHz), 2.4 V (Max. 4.4 MHz) and 1.6 V (Max. 1.1 MHz). It should be selected by a program to switch according to the supply voltage and oscillation frequency.

Refer to Section 5.4, "Oscillation Circuit" for switching VD1.

Note: Be sure not to use the VD1 terminal output for driving external circuits.

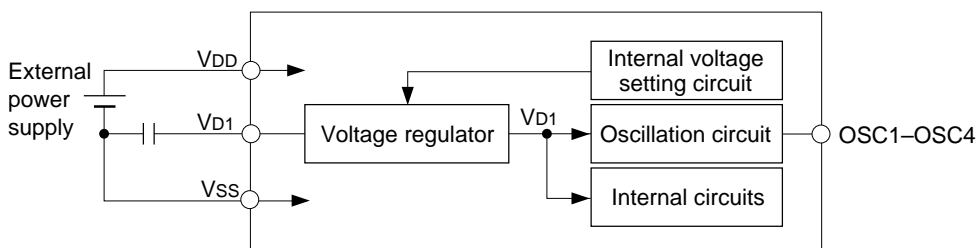


Fig. 2.2.1 Configuration of power supply circuit

## 2.3 Heavy Load Protection Mode

The S1C88409 has a heavy load protection function for stable operation even when the supply voltage fluctuates by driving a heavy load. The heavy load protection mode becomes valid when the peripheral circuits are in the following status:

- (1) The OSC3 oscillation circuit is switched ON (OSCC = "1" and not in SLEEP)
- (2) The buzzer output is switched ON (BZON = "1" or BZSHT = "1")

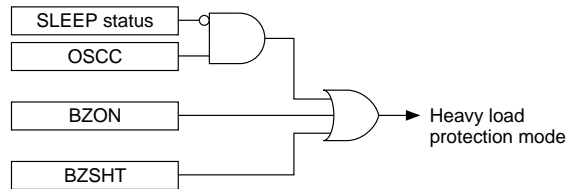


Fig. 2.3.1 Configuration of heavy load protection mode control circuit

For details of the OSC3 oscillation circuit and buzzer output, refer to Section 5.4, "Oscillation Circuit" and Section 5.15, "Sound Generator", respectively.

# CHAPTER 3 CPU AND MEMORY

This section explains the CPU, operating mode and bus configuration.

## 3.1 CPU

The S1C88409 employs the 8-bit core CPU S1C88 as the CPU, so that register configuration, instructions and so on are virtually identical to those in other family processors using the S1C88.

Refer to the "S1C88 Core CPU Manual" for details of the S1C88.

The S1C88 CPU model used is Model 3 and has up to  $4M \times 3$  address space that can be used for extended memory.

## 3.2 Internal Memory

The S1C88409 has built-in ROM and RAM as shown in Figure 3.2.1.

Small-scale applications can be realized with only this chip. The internal memory can be used together with the external memory.

Furthermore, the internal ROM can be disconnected from the bus so that the space is released to external memory.

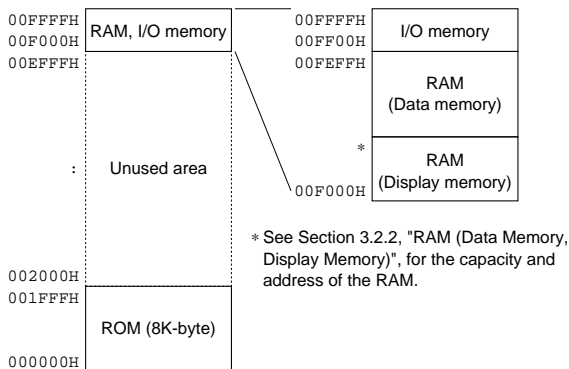


Fig. 3.2.1 Internal memory map

### 3.2.1 ROM

The internal ROM has a capacity of 8KB. Depending on the setting of the MCU/MPU terminal, the internal ROM area can be released to external memory. (See Section 3.5, "Chip Mode".)

### 3.2.2 RAM (Data Memory, Display Memory)

The internal RAM has a capacity of 3.75KB.

The data memory size and display memory size can be selected as shown in Table 3.2.2.1 by mask option.

Table 3.2.2.1 RAM size setting by mask option

|   | Data memory                   | Display memory                |
|---|-------------------------------|-------------------------------|
| 1 | 1792 bytes<br>00F800H–00FEFFH | 2048 bytes<br>00F000H–00F7FFH |
| 2 | 1536 bytes<br>00F900H–00FEFFH | 2304 bytes<br>00F000H–00F8FFH |
| 3 | 1280 bytes<br>00FA00H–00FEFFH | 2560 bytes<br>00F000H–00F9FFH |
| 4 | 1024 bytes<br>00FB00H–00FEFFH | 2816 bytes<br>00F000H–00FAFFH |
| 5 | 768 bytes<br>00FC00H–00FEFFH  | 3072 bytes<br>00F000H–00FBFFH |
| 6 | 512 bytes<br>00FD00H–00FEFFH  | 3328 bytes<br>00F000H–00FCFFH |
| 7 | 256 bytes<br>00FE00H–00FEFFH  | 3584 bytes<br>00F000H–00FDFFH |

The internal RAM area is not released to external memory even when the external memory which overlaps the internal RAM area is expanded. Access to this area affects the internal RAM.

*Note: The display memory area configured by mask option may be used as data memory. However, the stack area cannot be assigned there.*

Refer to Section 5.10, "LCD Controller", for details of the display memory.

### 3.2.3 I/O memory

A memory mapped I/O method is adopted in the S1C88409 for interface with internal peripheral circuits. The control bits and data registers of the peripheral circuits are arranged in the data memory space. Control and data transfer can be done with normal memory access instructions. I/O memory area is arranged in 00FF00H–00FFFFH. Refer to Section 5.1, "I/O Memory Map", for details of the I/O memory.

The I/O memory area is not released to the external memory even when the external memory which overlaps the I/O memory area is expanded. Access to this area affects the I/O memory.

### 3.3 Exception Processing Vectors

In the S1C88409, 000000H–000029H in the program area are assigned as exception processing vectors. Furthermore, from 000034H to 0000FFH, software interrupt vectors are assignable to any two bytes which begin with an even address.

Table 3.3.1 shows the correspondence between the vector addresses and the exception processing factors.

The start address of the exception processing routine should be written to the respective vector address and the next address in order of low and high-order start address. When an exception processing factor is generated, the exception processing routine which starts from the recorded address is executed.

When multiple exception processing factors are generated at the same time, the exception processing is executed according to priority.

The priority of interrupts shown in Table 3.3.1 assumes that the interrupt priority levels are all the same. The interrupt priority levels can be set by software in each interrupt system. (See Section 5.20, "Interrupt and Standby Mode".)

*Note: The exception processing not including reset saves the SC (system condition flag) and PC (program counter) to the stack before branching to the exception processing routine. Consequently, when returning to the main routine from exception processing routines, use the RETE instruction.*

Refer to the "S1C88 Core CPU Manual" for CPU operation when an exception processing factor is generated.

Table 3.3.1 Correspondence between vector addresses and exception processing factors

| Vector address | Symbol | Exception processing factor      |                                     | Priority  |
|----------------|--------|----------------------------------|-------------------------------------|-----------|
| 000000H        | RESET  | Reset                            |                                     | High<br>↑ |
| 000002H        | ZDIV   | Zero division                    |                                     |           |
| 000004H        | NMI    | NMI (Watchdog timer)             |                                     |           |
| 000006H        | IRK10  | Input port K1                    | K10 input interrupt                 |           |
| 000008H        | IRK11  |                                  | K11 input interrupt                 |           |
| 00000AH        | IRK12  |                                  | K12 input interrupt                 |           |
| 00000CH        | IRK13  |                                  | K13 input interrupt                 |           |
| 00000EH        | IRK0   | Input port K0                    | K00–K07 input interrupt             | ↓<br>Low  |
| 000010H        | IRTU0  | 16-bit programmable timer 0      | Underflow interrupt                 |           |
| 000012H        | IRTC0  |                                  | Compare match interrupt             |           |
| 000014H        | IRTU1  | 16-bit programmable timer 1      | Underflow interrupt                 |           |
| 000016H        | IRTC1  |                                  | Compare match interrupt             |           |
| 000018H        | IRTU2  | 8-bit programmable timer         | Underflow interrupt                 |           |
| 00001AH        | IRSER  | Serial interface                 | Receive error interrupt             |           |
| 00001CH        | IRSRX  |                                  | Receive completion interrupt        |           |
| 00001EH        | IRSTX  |                                  | Receive error interrupt             |           |
| 000020H        | IRTP1  | Touch panel controller           | Pen-down interrupt                  |           |
| 000022H        | IRTP2  |                                  | Converted data update interrupt     |           |
| 000024H        | IRLCD  | LCD controller                   | Data transfer completion interrupt  |           |
| 000026H        | IRAD   | A/D converter                    | A/D conversion completion interrupt |           |
| 000028H        | IRRTC  | Clock timer                      | 32Hz/8Hz/2Hz/1Hz/60S interrupt      |           |
| 000032H        | –      | System reserved (cannot be used) |                                     |           |
| 000034H        | –      | Software interrupt               |                                     |           |
| ↓<br>0000FEH   | –      |                                  |                                     |           |

### 3.4 CC (Customized Condition Flag)

The S1C88409 does not use the customized condition flag (CC) in the core CPU. Accordingly, it cannot be used as a branching condition for the conditional branching instruction (JRS, CARS).

### 3.5 Chip Mode

#### 3.5.1 MCU mode and MPU mode

The S1C88409 is set in two chip operating mode by the MCU/MPU terminal.



- **MCU mode...Set the  $\overline{\text{MCU/MPU}}$  terminal to HIGH ( $V_{DD}$ )**

The MCU mode should be set when using the internal ROM. External memory can be expanded to the addressable space except for the internal memory area. Refer to Section 3.5.2, "Bus mode", for the memory map.

In the MCU mode, an initial reset activates the S1C88409 as a system with the internal memory only. The internal ROM is allocated to the top of the common area (logical space 0000H–7FFFH) in the program memory. Exception processing vectors are assigned in the internal ROM.

Furthermore, the application initial routine that starts with reset exception processing must likewise be written to the internal ROM. Bus and other settings corresponding to the expanded memory can be done by software. This processing is executed in the initial routine written in the internal ROM. The external memory can be accessed after the bus mode setting.

In this mode, accessing the internal memory area does not output the chip enable ( $\overline{\text{CE}}$ ) or the read ( $\overline{\text{RD}}$ )/write ( $\overline{\text{WR}}$ ) signals to the external memory, and it sets the data bus (D0–D7) to high impedance status (or pull-up status when the pull-up resistors for P00–P07 are available by setting the mask option). Consequently, the external memory addresses that overlap with the internal memory are invalid.

- **MPU mode...Set the  $\overline{\text{MCU/MPU}}$  terminal to LOW ( $V_{SS}$ )**

The MPU mode releases the internal ROM area to an external memory, so the internal ROM cannot be used. When this area is accessed, a chip enable ( $\overline{\text{CE}}$ ) signal and a read ( $\overline{\text{RD}}$ )/write ( $\overline{\text{WR}}$ ) signal are output to the external memory and the data bus (D0–D7) goes to active status. Accessing other internal memory (RAM, I/O memory) does not output these signals outside of the IC.

In the MPU mode, the system is activated by the external memory. Therefore, the initial setting for the system configuration can be selected with mask option so that the bus is set according to the external memory at initial reset. (See Section 3.5.2, "Bus mode".)

When setting this mode, the exception processing vectors and the initial routine must be assigned within the common area (000000H–007FFFH).

The  $\overline{\text{MCU/MPU}}$  terminal has a built-in pull-up resistor, and it can be selected for use or not by the mask option.

*Note: The  $\overline{\text{MCU/MPU}}$  terminal status is latched at the rising edge of the  $\overline{\text{RESET}}$  input signal. Therefore, apply a low pulse to the  $\overline{\text{RESET}}$  terminal when switching the mode.*

### 3.5.2 Bus mode

The S1C88409 has four kind of bus modes in order to set the bus specification to match the configuration of expanded external memory. The four bus modes are as follows, and one of them can be selected with software.

- **Single chip mode**

The single chip mode should be set when using the S1C88409 as a single chip microcomputer without external memory expansion.

This mode is available only in the MCU mode shown in the previous section because the internal ROM is used. In the MPU mode, the single chip mode cannot be set.

The single chip mode does not need an external bus line. The terminals for the external bus can be used as general-purpose output ports or I/O ports. Accordingly, the output port consists of 30 bits and the I/O port consists of 28 bits.

This mode is equivalent to the Model 3/minimum mode of the S1C88 core CPU. Memory access is valid only for the internal memory area within the physical space 000000H to 00FFFFH.

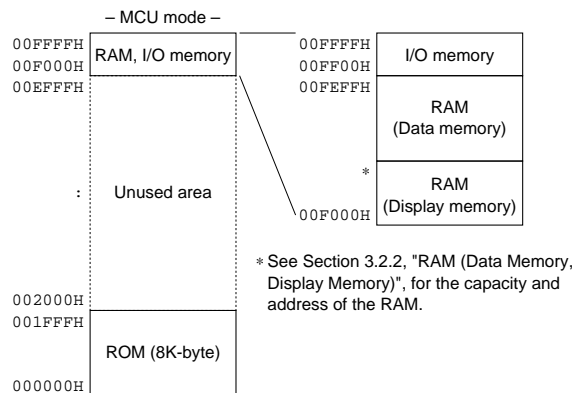


Fig. 3.5.2.1 Memory map for single chip mode

**Expanded 64K mode**

The expanded 64K mode should be set when 64KB or less of external memory is expanded to the S1C88409. This mode can be set regardless of the MCU/MPU mode setting.

In the MCU mode, the internal ROM is used. Therefore, the external memory in that area cannot be accessed. External memory can be assigned to the area from 007000H to 00EFFFH in the MCU/expanded 64K mode.

In the MPU mode, the internal ROM area is released to the external memory. Thus, external memory can be assigned to the area from 000000H to 00EFFFH in the MPU/expanded 64K mode.

The area from 00F000H to 00FFFFH is assigned to the internal RAM and I/O memory, therefore the area cannot be accessed as an external memory.

The expanded 64K mode is suitable for small- to mid-scale systems. This mode can output three (MCU mode) or four (MPU mode) kinds of chip enable ( $\overline{CE}$ ) signals for 8KB to 64KB memory chips. It can be selected by software according to the memory chip to be used. Refer to Section 3.6.4, "Chip enable ( $\overline{CE}$ ) signal", for details of the  $\overline{CE}$  signal.

This mode is equivalent to the Model 3/ minimum mode of the S1C88 core CPU. Memory access is valid only for the physical space 000000H to 00FFFFH.

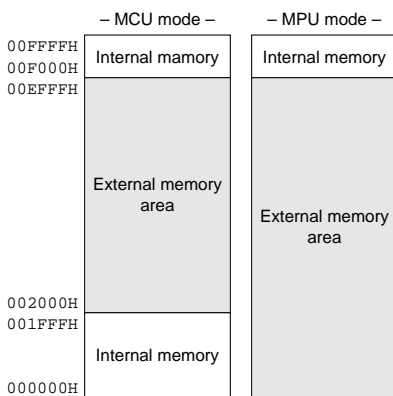


Fig. 3.5.2.2 Memory map for expanded 64K mode

**Expanded 4M minimum mode**

The expanded 4M minimum mode should be set when 64KB-4MB × 3 of external memory is expanded to the S1C88409. This mode can be set regardless of the MCU/MPU mode setting.

In the MCU mode, the internal ROM is used.

External memory can be assigned to the area from 400000H to FFFFFFFH in the MCU/ expanded 4M minimum mode.

In the MPU mode, the internal ROM area is released to the external memory. Thus, external memory can be assigned to the area from 000000H to BFFFFFFH in the MPU/expanded 4M minimum mode.

However, the area from 00F000H to 00FFFFH is assigned to the internal RAM and I/O memory, therefore the area cannot be accessed as an external memory.

This mode is equivalent to the Model 3/ minimum mode of the S1C88 core CPU.

Memory access is valid for the physical space 000000H to BFFFFFFH in the MPU mode or 400000H to FFFFFFFH + internal memory in the MCU mode. However, program memory expansion is limited to 64KB.

In the MPU mode, program memory can be assigned to the common area (000000H to 007FFFH) and one optional bank (32K) area. In the MCU mode, since the internal ROM is assigned to the common area, external program memory can be assigned to one optional bank (32K) only.

This mode is suitable for small- to mid-scale program memories and large-scale data memory systems.

This mode outputs the chip enable ( $\overline{CE}$ ) signals for the 4MB memory chip.

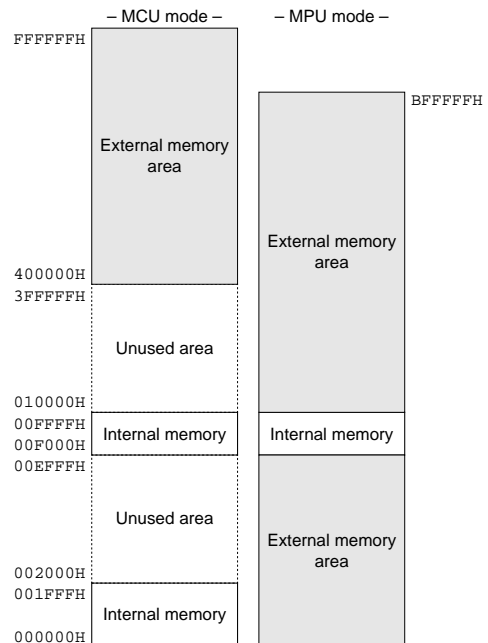


Fig. 3.5.2.3 Memory map for expanded 4M minimum mode

• **Expanded 4M maximum mode**

The expanded 4M maximum mode should be set when 64KB–4MB × 3 of external memory is expanded to the S1C88409. This mode can be set regardless of the MCU/MPU mode setting.

In the MCU mode, the internal ROM is used. External memory can be assigned to the area from 400000H to FFFFFFFH in the MCU/expanded 4M maximum mode.

In the MPU mode, the internal ROM area is released to the external memory. Thus, external memory can be assigned to the area from 000000H to BFFFFFFH in the MPU/expanded 4M maximum mode.

However, the area from 00F000H to 00FFFFH is assigned to the internal RAM and I/O memory, therefore the area cannot be accessed as an external memory.

This mode is equivalent to the Model 3/maximum mode of the S1C88 core CPU. Memory access is valid for the physical space 000000H to BFFFFFFH in the MPU mode or 400000H to FFFFFFFH + internal memory in the MCU mode.

Program memory and data memory can be assigned with an optional size (up to 4MB × 3 together), so this mode is suitable for systems with large-scale program and data capacity.

This mode outputs the chip enable ( $\overline{CE}$ ) signals for the 4MB memory chip.

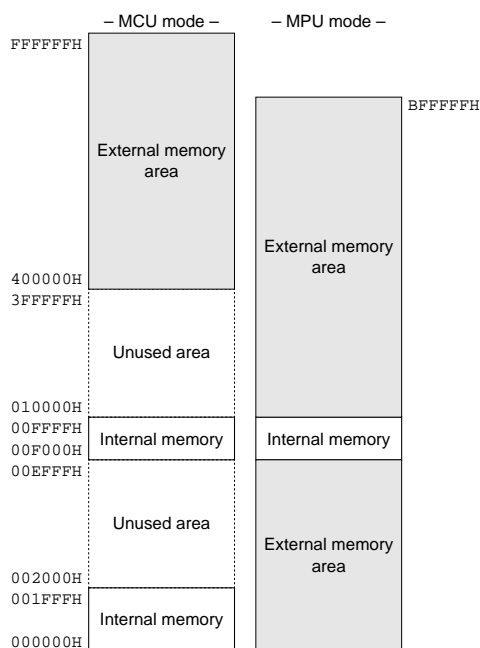


Fig. 3.5.2.4 Memory map for expanded 4M maximum mode

Refer to Section 5.2, "System Controller and Bus Control", for setting the mode.

**3.6 External Bus**

The S1C88409 has bus terminals that can address a maximum 4MB × 3 external memory. Memory and other devices can be expanded outside according to the range of each bus mode shown in the previous section.

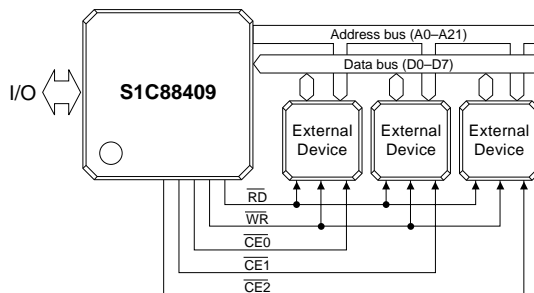


Fig. 3.6.1 External bus lines

The following explains the outline of the external bus terminals. Refer to Section 5.2, "System Controller and Bus Control", for controlling them.

**3.6.1 Data bus**

The S1C88409 has an 8-bit external data bus (D0–D7). The terminals and I/O circuits of the data bus D0–D7 are shared with the I/O port P00–P07, and the function switches according to the bus mode setting.

In the single chip mode, the 8-bit terminals are all set as the I/O port terminals P00–P07 and in the other expanded modes, they are set as the data bus (D0–D7).

When the data bus is set, the data register and I/O control register of the I/O port P00–P07 are disconnected from the I/O circuit and can be used as general purpose data registers with the ability to read/write.

Each data bus line has a built-in pull-up resistor that is activated during the input mode, and it can be selected for use or not by the mask option.

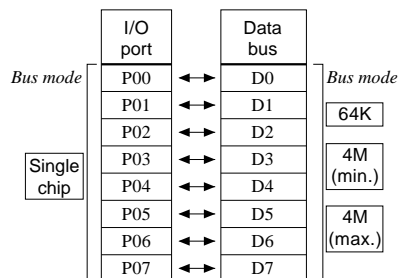


Fig. 3.6.1.1 Correspondence between data bus and I/O port

### 3.6.2 Address bus

The S1C88409 has a 22-bit external address bus (A0–A21). The terminals and output circuits of the address bus A0–A21 are shared with the output ports R00–R07 (=A0–A7), R10–R17 (=A8–A15) and R20–R25 (=A16–A21), and the function switches according to the bus mode setting.

In the single chip mode, the 22-bit terminals are all set as the output port terminals R00–R07, R10–R17 and R20–R25.

In the expanded 64K mode, 16-bit terminals within the 22 bits are set as the address bus A0–A15, while the remaining 6 bits, A16–A21, are set as output port R20–R25.

In the expanded 4M minimum and maximum modes, all of the 22-bit terminals are set as the address bus (A0–A21).

When the address bus is set, the data register and high impedance control register of each output port are disconnected from the output circuit and can be used as general-purpose data registers with the ability to read/write.

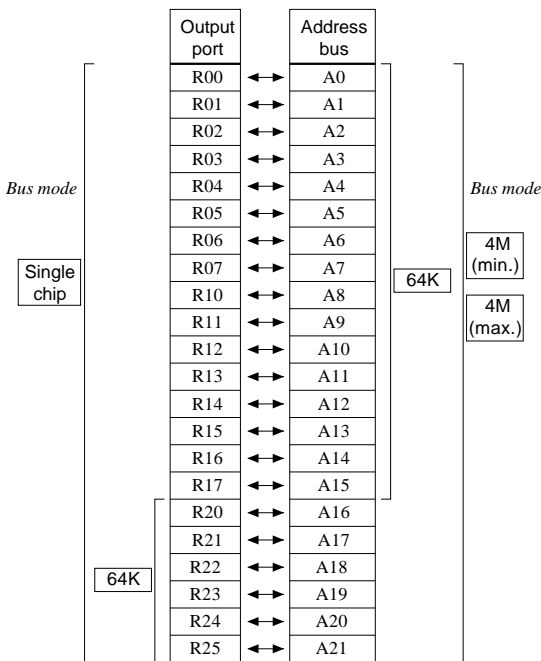


Fig. 3.6.2.1 Correspondence between address bus and output ports

### 3.6.3 Read ( $\overline{RD}$ )/write ( $\overline{WR}$ ) signals

The output terminals and output circuits for the read ( $\overline{RD}$ )/write ( $\overline{WR}$ ) signals are shared with the output ports R26 and R27, and the function switches according to the bus mode setting. In the single chip mode, both the terminals are set as output port terminals and in other expanded modes, they are set as read ( $\overline{RD}$ )/write ( $\overline{WR}$ ) signal output terminals. When they are set as read ( $\overline{RD}$ )/write ( $\overline{WR}$ ) signal output terminals, the data register and high impedance control register for each output port (R26, R27) are disconnected from the output circuit and can be used as a general-purpose data register with the ability to read/write.

These two signals are output only when the memory area for the external device is being accessed. They are not output when the internal memory is accessed.

Refer to Section 3.6.5, "WAIT control", for the signal output timing.

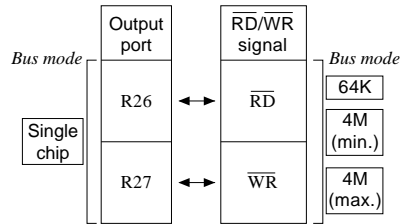


Fig. 3.6.3.1 Correspondence between read ( $\overline{RD}$ )/write ( $\overline{WR}$ ) signal and output port

### 3.6.4 Chip enable ( $\overline{CE}$ ) signal

The S1C88409 has a built-in address decoder which can output up to three chip enable ( $\overline{CE}$ ) signals. Consequently, three devices equipped with a chip enable ( $\overline{CE}$ ) or chip select ( $\overline{CS}$ ) terminal can be directly connected without an external address decoder.

The three chip enable ( $\overline{CE0}$ – $\overline{CE2}$ ) signal output terminals and output circuits are shared with output ports R30–R32. In the expanded modes, the function, either  $\overline{CE}$  or output port, can independently be selected by software according to the chips to be expanded.

When the chip enable ( $\overline{CE}$ ) output is set, the data register and high impedance control register of the output port are disconnected from the output circuit and can be used as general-purpose data registers with the ability to read/write.

In the single chip mode, they can be used as the output ports R30–R32.

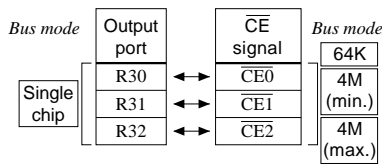


Fig. 3.6.4.1 Correspondence between  $\overline{CE}$  signals and output ports

The memory size assigned to three chip enable ( $\overline{CE}$ ) signals is determined by the bus mode setting.

In the expanded 64K mode, four decoder outputs can be selected by software according to the memory expanded.

Table 3.6.4.1 shows the addressable ranges which are assigned to the chip enable ( $\overline{CE}$ ) signal in each mode.

When the internal memory area is accessed, the  $\overline{CE}$  signal is not output. Be aware that the part has been irregular setting.

External devices can be allocated to an area selected by an optional chip enable signal. It is not necessary to continue from a lower address of the memory space.

The chip enable signal is output only when the external memory area is being accessed. It is not output when the internal memory is accessed. Furthermore, when the CPU is in standby status (HALT, SLEEP), all the  $\overline{CE}$  signals go HIGH. It prohibits external memory access and gets the CPU into power save mode.

Refer to Section 3.6.5, "WAIT control", for the signal output timing.

Table 3.6.4.1  $\overline{CE0}$ – $\overline{CE2}$  address settings

(1) Expanded 64K mode + MCU mode

| $\overline{CE}$ signal | Addressing range (selected with software) |                 |                 |
|------------------------|-------------------------------------------|-----------------|-----------------|
|                        | 8KB                                       | 16KB            | 32KB            |
| $\overline{CE0}$       | 008000H–009FFFH                           | 007000H–00AFFFH | 008000H–00EFFFH |
| $\overline{CE1}$       | 00A000H–00BFFFH                           | 00B000H–00EFFFH | –               |
| $\overline{CE2}$       | 00C000H–00DFFFH                           | –               | –               |

(2) Expanded 64K mode + MPU mode

| $\overline{CE}$ signal | Addressing range (selected with software) |                 |                 |                 |
|------------------------|-------------------------------------------|-----------------|-----------------|-----------------|
|                        | 8KB                                       | 16KB            | 32KB            | 64KB            |
| $\overline{CE0}$       | 000000H–001FFFH                           | 000000H–003FFFH | 000000H–007FFFH | 000000H–00EFFFH |
| $\overline{CE1}$       | 002000H–003FFFH                           | 004000H–007FFFH | 008000H–00EFFFH | –               |
| $\overline{CE2}$       | 004000H–005FFFH                           | 008000H–00BFFFH | –               | –               |

(3) Expanded 4M minimum/maximum mode

| $\overline{CE}$ signal | Addressing range (selected with software) |                                    |
|------------------------|-------------------------------------------|------------------------------------|
|                        | MCU mode                                  | MPU mode                           |
| $\overline{CE0}$       | C00000H–FFFFFFFH                          | 000000H–00EFFFH, 010000H–3FFFFFFFH |
| $\overline{CE1}$       | 400000H–7FFFFFFFH                         | 400000H–7FFFFFFFH                  |
| $\overline{CE2}$       | 800000H–BFFFFFFFH                         | 800000H–BFFFFFFFH                  |

### 3.6.5 WAIT control

In order to guarantee accessing of external low speed devices during high speed operation, the S1C88409 is equipped with a WAIT function that prolongs access time. (Refer to the "S1C88 Core CPU Manual" for details of the WAIT function.)

The WAIT state numbers to be inserted can be selected with software from four values as shown in Table 3.6.5.1.

Table 3.6.5.1 Selectable WAIT state numbers

|               |   |   |   |    |
|---------------|---|---|---|----|
| Selection No. | 1 | 2 | 3 | 4  |
| Insert states | 0 | 4 | 8 | 12 |

\* The length of one state is 1/2 a cycle of the clock.

The WAIT states that are set with software are inserted between bus cycle states T3 and T4. Note, however, that WAIT states cannot be inserted when an internal register or internal memory is being accessed and when the CPU operates with the OSC1 oscillation clock (see Section 5.4, "Oscillation Circuit"). Consequently, WAIT state settings are invalid in the single chip mode.

Figure 3.6.5.1 shows the memory read/write timing charts.

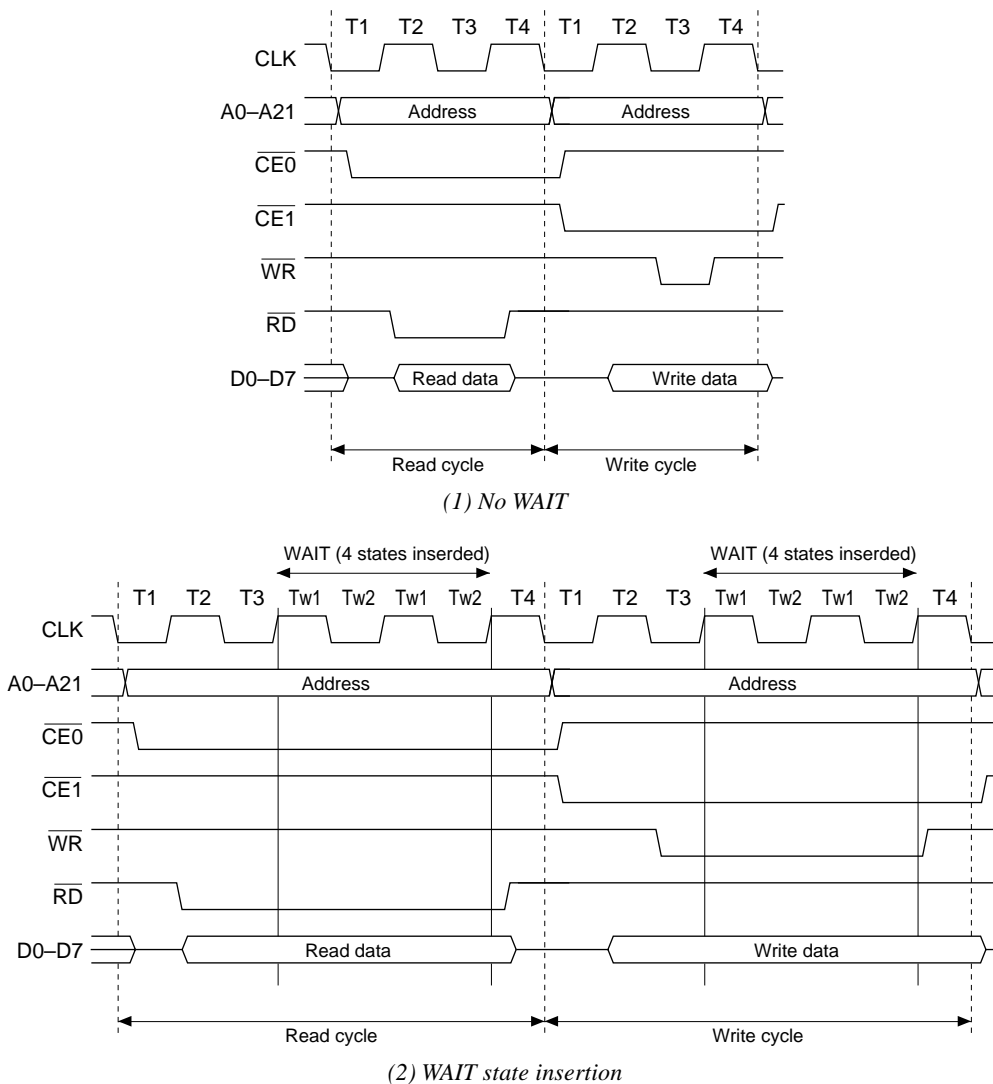


Fig. 3.6.5.1 Memory read/write cycle

## CHAPTER 4 INITIAL RESET

To initialize the S1C88409 circuits, initial reset must be executed. This section explains the initial reset factor and the initial settings for internal registers.

### 4.1 Initial Reset Factors

There are two initial reset factors for the S1C88409 as shown below.

- (1)  $\overline{\text{RESET}}$  terminal
- (2) Simultaneous LOW level input at input port terminals K00–K03.

Figure 4.1.1 shows the configuration of the initial reset circuit.

The CPU and peripheral circuits are initialized by means of initial reset factors. When the factor is canceled, the CPU commences reset exception processing. (See "S1C88 Core CPU Manual".)

When this occurs, reset exception processing vectors, Bank 0, 000000H–000001H from program memory are read out and the program (initialization routine) which begins at the readout address is executed.

#### 4.1.1 $\overline{\text{RESET}}$ terminal

Initial reset can be done by executed externally inputting a LOW level to the  $\overline{\text{RESET}}$  terminal. Be sure to maintain the  $\overline{\text{RESET}}$  terminal at LOW level for the regulation time after the power on to assure the initial reset.

In addition, be sure to use the  $\overline{\text{RESET}}$  terminal for the first initial reset after the power is turned on. The  $\overline{\text{RESET}}$  terminal is equipped with a pull-up resistor. You can select whether or not to use by mask option.

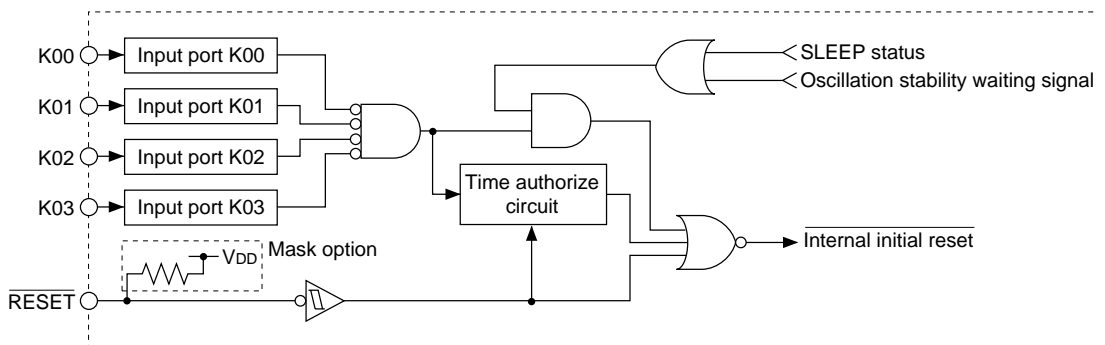


Fig. 4.1.1 Configuration of initial reset circuit

### 4.1.2 Simultaneous LOW level input at input port terminals K00–K03

Another way of executing initial reset externally is to input a LOW level simultaneously to the input ports (K00–K03) selected by mask option.

Since there is a built-in time authorize circuit, be sure to maintain the designated input port terminal at LOW level for two seconds (when the oscillation frequency is  $f_{osc1} = 32.768 \text{ kHz}$ ) or more to perform the initial reset by means of this function.

However, the time authorize circuit is bypassed during the SLEEP (standby) status and oscillation stabilization waiting period, and initial reset is executed immediately after the simultaneous LOW level input to the designated input ports.

The combination of input ports (K00–K03) that can be selected by mask option are as follows:

- (1) Not use
- (2) K00 & K01
- (3) K00 & K01 & K02
- (4) K00 & K01 & K02 & K03

For instance, let's say that mask option (4) "K00 & K01 & K02 & K03" is selected.

When the input level at input ports K00–K03 is simultaneously LOW, initial reset will take place.

When using this function, make sure that the designated input ports do not simultaneously switch to LOW level while the system is in normal operation.

### 4.2 Initial Reset Sequence

After cancellation of the LOW level input to the RESET terminal, when the power is turned on, the start-up of the CPU is held back until the oscillation stabilization waiting time ( $8,192/f_{osc1} \text{ sec.}$ ) has elapsed.

Figure 4.2.1 shows the operating sequence following initial reset release.

Also, when using the initial reset by simultaneous LOW level input into the input port, you should be careful of the following points.

- (1) During SLEEP status, since the time authorization circuit is bypassed, an initial reset is triggered immediately after a LOW level simultaneous input value. In this case, the CPU starts after waiting the oscillation stabilization time, following cancellation of the LOW level simultaneous input.
- (2) Other than during SLEEP status, an initial reset will be triggered 1–2 seconds after a LOW level simultaneous input. In this case, since a reset differential pulse ( $64/f_{osc1} \text{ sec.}$ ) is generated inside the S1C88409, the CPU will start even if the LOW level simultaneous input status is not canceled.

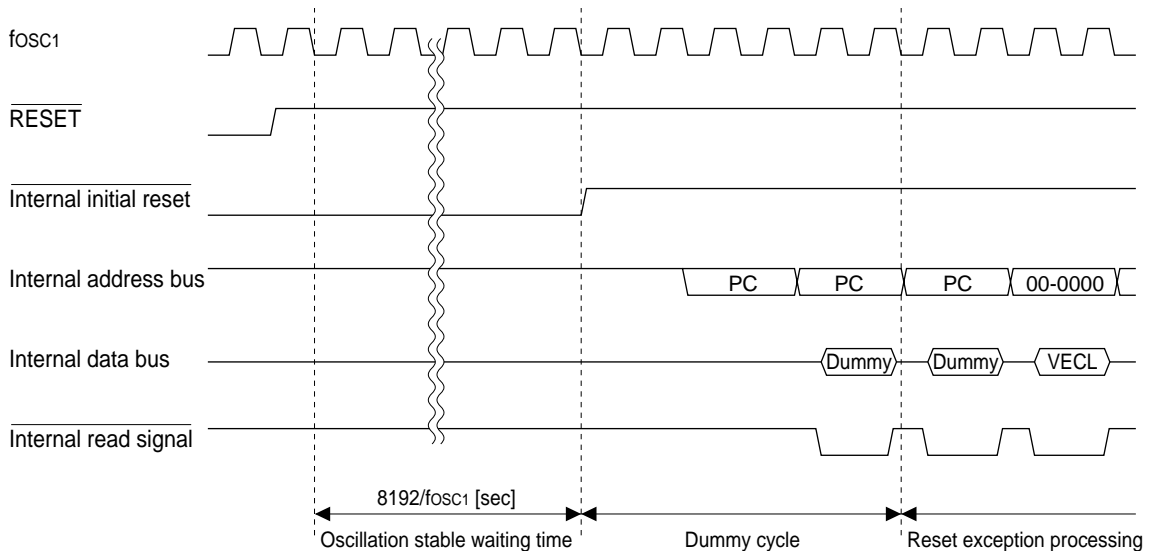


Fig. 4.2.1 Initial reset sequence



## 4.3 Initial Settings at Initial Reset

### Initial settings of internal registers

The internal registers in the CPU are initialized as follows during initial reset.

Table 4.3.1 Initial settings

| Register name               | Symbol | Bit length | Initial value |
|-----------------------------|--------|------------|---------------|
| Data register A             | A      | 8          | Undefined     |
| Data register B             | B      | 8          | Undefined     |
| Index (data) register L     | L      | 8          | Undefined     |
| Index (data) register H     | H      | 8          | Undefined     |
| Index register IX           | IX     | 16         | Undefined     |
| Index register IY           | IY     | 16         | Undefined     |
| Program counter             | PC     | 16         | Undefined*    |
| Stack pointer               | SP     | 16         | Undefined     |
| Base register               | BR     | 8          | Undefined     |
| Zero flag                   | Z      | 1          | 0             |
| Carry flag                  | C      | 1          | 0             |
| Overflow flag               | V      | 1          | 0             |
| Negative flag               | N      | 1          | 0             |
| Decimal flag                | D      | 1          | 0             |
| Unpack flag                 | U      | 1          | 0             |
| Interrupt flag 0            | I0     | 1          | 1             |
| Interrupt flag 1            | I1     | 1          | 1             |
| New code bank register      | NB     | 8          | 01H           |
| Code bank register          | CB     | 8          | Undefined*    |
| Expand page register        | EP     | 8          | 00H           |
| Expand page register for IX | XP     | 8          | 00H           |
| Expand page register for IY | YP     | 8          | 00H           |

- \* The reset exception processing loads the value stored in Bank 0, 00000H–000001H into the PC. At the same time, the NB initial value 01H is loaded into CB.

Registers which are not initialized at initial reset should be initialized using software.

### Stack

The stack pointer SP is undefined at initial reset. Be sure to initialize SP before subroutines and interrupts generate.

In the S1C88409, the stack page is fixed at Page 0. Therefore, reserve the stack area in the RAM expanded in Page 0 or the data memory area of the internal RAM (–00FEFFH).

*Note: The display memory area configured by mask option may be used as data memory. However, the stack area cannot be assigned there.*

### Internal RAM (Data memory, Display memory)

Since the internal RAM is not initialized at initial reset, initialize with software.

### System and terminal configuration

When the S1C88409 is used in the MCU mode, the bus mode is set to the single chip mode at initial reset. In the MPU mode, it is set to the mode selected by the mask option.

Refer to Section 1.4, "Pin Layout Diagram", for the terminal configuration depending on the bus mode setting.

### Internal peripheral circuit

The internal peripheral circuits are initialized to prescribed status. Initialize with software if necessary.

Especially the input/output terminals of the peripheral circuits are all set as the output port terminals and the I/O port terminals. Switch them according to the peripheral circuit to be used. Refer to Section 5.1, "I/O Memory Map", or respective sections of the peripheral circuits for details of the status and initial values.

### Interrupt

After initial reset, all the interrupts including NMI are masked until the appropriate values are written to the I/O memory addresses "00FF00H" and "00FF01H" to prevent malfunctions that may occur before setting the system configuration. Refer to Section 5.2, "System Controller and Bus Control", for the contents of the addresses.

# CHAPTER 5 PERIPHERAL CIRCUITS AND OPERATION

The peripheral circuits of the S1C88409 are interfaced with the CPU in the memory mapped I/O method. Thus, the peripheral circuits can be controlled by using the memory operation instructions to access the I/O memory. This chapter explains the operation and control of the peripheral circuits, individually.

## 5.1 I/O Memory Map

Table 5.1.1(a) I/O Memory map (00FF00H, 00FF01H)

| Address | Bit      | Name                            | Function                                 | 1                             | 0           | Init | R/W | Comment                                                       |                                                                                   |
|---------|----------|---------------------------------|------------------------------------------|-------------------------------|-------------|------|-----|---------------------------------------------------------------|-----------------------------------------------------------------------------------|
| 00FF00  | D7       | BSMD1                           | Bus mode (CPU mode) selection            |                               |             |      |     |                                                               |                                                                                   |
|         |          |                                 | BSMD1 BSMD0 Mode                         |                               |             |      |     |                                                               |                                                                                   |
|         | MCU mode | D6                              | BSMD0                                    | 1 1 4M(Maximum)               |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | 1 0 4M(Minimum)               |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | 0 1 64K                       |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | 0 0 Single chip               |             |      |     |                                                               |                                                                                   |
|         |          | D5                              | CEMD1                                    | Expanded 64K chip enable mode |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | CEMD1 CEMD0 Mode              |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | 1 1 -                         |             |      |     |                                                               |                                                                                   |
|         |          | D4                              | CEMD0                                    | 1 0 32K(CE0)                  |             |      |     |                                                               |                                                                                   |
|         |          |                                 | 0 1 16K(CE0, CE1)                        |                               |             |      |     |                                                               |                                                                                   |
|         |          |                                 | 0 0 8K(CE0-CE2)                          |                               |             |      |     |                                                               |                                                                                   |
|         | D3       | -                               | -                                        | -                             | -           | -    | -   | "0" when being read                                           |                                                                                   |
|         | D2       | CE2                             | CE2(R32) CE signal output enable/disable | CE2 enable                    | CE2 disable | 1    | R/W | In the single chip mode, these setting are fixed at DC output |                                                                                   |
|         | D1       | CE1                             | CE1(R31) enable: CE signal output        | CE1 enable                    | CE1 disable | 1    | R/W |                                                               |                                                                                   |
|         | D0       | CE0                             | CE0(R30) disable: DC output (R3x)        | CE0 enable                    | CE0 disable | 1    | R/W |                                                               |                                                                                   |
| 00FF00  | D7       | BSMD1                           | Bus mode (CPU mode) selection            |                               |             |      | *   | R/W                                                           | Initial setting can be selected from 3 types (64K, 4M min, 4M max) by mask option |
|         |          |                                 | BSMD1 BSMD0 Mode                         |                               |             |      |     |                                                               |                                                                                   |
|         | MPU mode | D6                              | BSMD0                                    | 1 1 4M(Maximum)               |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | 1 0 4M(Minimum)               |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | 0 1 64K                       |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | 0 0 Option selection          |             |      |     |                                                               |                                                                                   |
|         |          | D5                              | CEMD1                                    | Expanded 64K chip enable mode |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | CEMD1 CEMD0 Mode              |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | 1 1 64K(CE0)                  |             |      |     |                                                               |                                                                                   |
|         |          | D4                              | CEMD0                                    | 1 0 32K(CE0, CE1)             |             |      |     |                                                               |                                                                                   |
|         |          |                                 | 0 1 16K(CE0-CE2)                         |                               |             |      |     |                                                               |                                                                                   |
|         |          |                                 | 0 0 8K(CE0-CE2)                          |                               |             |      |     |                                                               |                                                                                   |
|         | D3       | -                               | -                                        | -                             | -           | -    | -   | "0" when being read                                           |                                                                                   |
|         | D2       | CE2                             | CE2(R32) CE signal output enable/disable | CE2 enable                    | CE2 disable | 1    | R/W |                                                               |                                                                                   |
|         | D1       | CE1                             | CE1(R31) enable: CE signal output        | CE1 enable                    | CE1 disable | 1    | R/W |                                                               |                                                                                   |
|         | D0       | CE0                             | CE0(R30) disable: DC output (R3x)        | CE0 enable                    | CE0 disable | 1    | R/W |                                                               |                                                                                   |
| 00FF01  | D7       | -                               | -                                        | -                             | -           | -    | -   | "0" when being read                                           |                                                                                   |
|         | D6       | -                               | -                                        | -                             | -           | -    | -   |                                                               |                                                                                   |
|         | D5       | WT1                             | Wait state control                       |                               |             |      |     |                                                               |                                                                                   |
|         |          |                                 | WT1 WT0 Number of states                 |                               |             |      |     |                                                               |                                                                                   |
|         |          |                                 |                                          | 1 1 12(3 cycles)              |             |      |     |                                                               |                                                                                   |
|         | D4       | WT0                             | 1 0 8(2 cycles)                          |                               |             |      |     |                                                               |                                                                                   |
|         |          |                                 | 0 1 4(1 cycle)                           |                               |             |      |     |                                                               |                                                                                   |
|         |          |                                 | 0 0 No wait                              |                               |             |      |     |                                                               |                                                                                   |
| D3      | CLKCHG   | CPU operating clock switch      | OSC3                                     | OSC1                          | 0           | R/W  |     |                                                               |                                                                                   |
| D2      | OSCC     | OSC3 oscillation ON/OFF control | On                                       | Off                           | 0           | R/W  |     |                                                               |                                                                                   |
| D1      | VD1C1    | VD1 output level setting        |                                          |                               |             |      |     |                                                               |                                                                                   |
|         |          | VD1C1 VD1C0 VD1 (Typ.)          |                                          |                               |             |      |     |                                                               |                                                                                   |
|         |          |                                 | 1 1 4.2 V                                |                               |             |      |     |                                                               |                                                                                   |
| D0      | VD1C0    | 1 0 3.2 V                       |                                          |                               |             |      |     |                                                               |                                                                                   |
|         |          | 0 1 1.6 V                       |                                          |                               |             |      |     |                                                               |                                                                                   |
|         |          | 0 0 2.4 V                       |                                          |                               |             |      |     |                                                               |                                                                                   |

Note: All the interrupts including NMI are masked until the appropriate values are written to both the "00FF00H" and "00FF01H" addresses.

Table 5.1.1(b) I/O Memory map (00FF10H–00FF13H)

| Address                                                | Bit   | Name                                                  | Function                                               | 1                 | 0                 | Init | R/W | Comment             |
|--------------------------------------------------------|-------|-------------------------------------------------------|--------------------------------------------------------|-------------------|-------------------|------|-----|---------------------|
| 00FF10                                                 | D7    | PRPRT1                                                | 16-bit programmable timer 1 clock control              | On                | Off               | 0    | R/W |                     |
|                                                        | D6    | PST12                                                 | 16-bit programmable timer 1 division ratio             |                   |                   | 0    | R/W |                     |
|                                                        |       |                                                       | PST12 PST11 PST10 (OSC3) (OSC1)                        |                   |                   |      |     |                     |
|                                                        |       |                                                       | 1 1 1 fosc <sub>3</sub> / 4096 fosc <sub>1</sub> / 128 |                   |                   |      |     |                     |
|                                                        | D5    | PST11                                                 | 1 1 0 fosc <sub>3</sub> / 1024 fosc <sub>1</sub> / 64  |                   |                   | 0    | R/W |                     |
|                                                        |       |                                                       | 1 0 1 fosc <sub>3</sub> / 256 fosc <sub>1</sub> / 32   |                   |                   |      |     |                     |
|                                                        |       |                                                       | 1 0 0 fosc <sub>3</sub> / 128 fosc <sub>1</sub> / 16   |                   |                   |      |     |                     |
|                                                        | D4    | PST10                                                 | 0 1 1 fosc <sub>3</sub> / 64 fosc <sub>1</sub> / 8     |                   |                   | 0    | R/W |                     |
|                                                        |       |                                                       | 0 1 0 fosc <sub>3</sub> / 32 fosc <sub>1</sub> / 4     |                   |                   |      |     |                     |
|                                                        |       |                                                       | 0 0 1 fosc <sub>3</sub> / 8 fosc <sub>1</sub> / 2      |                   |                   |      |     |                     |
|                                                        |       |                                                       | 0 0 0 fosc <sub>3</sub> / 2 fosc <sub>1</sub> / 1      |                   |                   |      |     |                     |
|                                                        | D3    | PRPRT0                                                | 16-bit programmable timer 0 clock control              | On                | Off               | 0    | R/W |                     |
|                                                        | D2    | PST02                                                 | 16-bit programmable timer 0 division ratio             |                   |                   | 0    | R/W |                     |
|                                                        |       |                                                       | PST02 PST01 PST00 (OSC3) (OSC1)                        |                   |                   |      |     |                     |
| 1 1 1 fosc <sub>3</sub> / 4096 fosc <sub>1</sub> / 128 |       |                                                       |                                                        |                   |                   |      |     |                     |
| D1                                                     | PST01 | 1 1 0 fosc <sub>3</sub> / 1024 fosc <sub>1</sub> / 64 |                                                        |                   | 0                 | R/W  |     |                     |
|                                                        |       | 1 0 1 fosc <sub>3</sub> / 256 fosc <sub>1</sub> / 32  |                                                        |                   |                   |      |     |                     |
|                                                        |       | 1 0 0 fosc <sub>3</sub> / 128 fosc <sub>1</sub> / 16  |                                                        |                   |                   |      |     |                     |
| D0                                                     | PST00 | 0 1 1 fosc <sub>3</sub> / 64 fosc <sub>1</sub> / 8    |                                                        |                   | 0                 | R/W  |     |                     |
|                                                        |       | 0 1 0 fosc <sub>3</sub> / 32 fosc <sub>1</sub> / 4    |                                                        |                   |                   |      |     |                     |
|                                                        |       | 0 0 1 fosc <sub>3</sub> / 8 fosc <sub>1</sub> / 2     |                                                        |                   |                   |      |     |                     |
|                                                        |       | 0 0 0 fosc <sub>3</sub> / 2 fosc <sub>1</sub> / 1     |                                                        |                   |                   |      |     |                     |
| 00FF11                                                 | D7    | –                                                     | –                                                      | –                 | –                 | –    | –   | "0" when being read |
|                                                        | D6    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D5    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D4    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D3    | PRPRT2                                                | 8-bit programmable timer clock control                 | On                | Off               | 0    | R/W |                     |
|                                                        | D2    | PST22                                                 | 8-bit programmable timer division ratio                |                   |                   | 0    | R/W |                     |
|                                                        |       |                                                       | PST22 PST21 PST20 Division ratio                       |                   |                   |      |     |                     |
|                                                        |       |                                                       | 1 1 1 fosc <sub>3</sub> / 256                          |                   |                   |      |     |                     |
| D1                                                     | PST21 | 1 1 0 fosc <sub>3</sub> / 128                         |                                                        |                   | 0                 | R/W  |     |                     |
|                                                        |       | 1 0 1 fosc <sub>3</sub> / 64                          |                                                        |                   |                   |      |     |                     |
|                                                        |       | 1 0 0 fosc <sub>3</sub> / 32                          |                                                        |                   |                   |      |     |                     |
| D0                                                     | PST20 | 0 1 1 fosc <sub>3</sub> / 16                          |                                                        |                   | 0                 | R/W  |     |                     |
|                                                        |       | 0 1 0 fosc <sub>3</sub> / 8                           |                                                        |                   |                   |      |     |                     |
|                                                        |       | 0 0 1 fosc <sub>3</sub> / 4                           |                                                        |                   |                   |      |     |                     |
|                                                        |       | 0 0 0 fosc <sub>3</sub> / 2                           |                                                        |                   |                   |      |     |                     |
| 00FF12                                                 | D7    | –                                                     | –                                                      | –                 | –                 | –    | –   | "0" when being read |
|                                                        | D6    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D5    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D4    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D3    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D2    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D1    | PRTF1                                                 | 16-bit programmable timer 1 source clock selection     | fosc <sub>1</sub> | fosc <sub>3</sub> | 0    | R/W |                     |
|                                                        | D0    | PRTF0                                                 | 16-bit programmable timer 0 source clock selection     | fosc <sub>1</sub> | fosc <sub>3</sub> | 0    | R/W |                     |
| 00FF13                                                 | D7    | –                                                     | –                                                      | –                 | –                 | –    | –   | "0" when being read |
|                                                        | D6    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D5    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D4    | –                                                     | –                                                      | –                 | –                 | –    | –   |                     |
|                                                        | D3    | PRAD                                                  | A/D converter clock control                            | On                | Off               | 0    | R/W |                     |
|                                                        | D2    | PSAD2                                                 | A/D converter division ratio                           |                   |                   | 0    | R/W |                     |
|                                                        |       |                                                       | PSAD2 PSAD1 PSAD0 Division ratio                       |                   |                   |      |     |                     |
|                                                        |       |                                                       | 1 × × fosc <sub>3</sub> / 16                           |                   |                   |      |     |                     |
| D1                                                     | PSAD1 | 0 1 1 fosc <sub>3</sub> / 8                           |                                                        |                   | 0                 | R/W  |     |                     |
|                                                        |       | 0 1 0 fosc <sub>3</sub> / 4                           |                                                        |                   |                   |      |     |                     |
|                                                        |       | 0 0 1 fosc <sub>3</sub> / 2                           |                                                        |                   |                   |      |     |                     |
| D0                                                     | PSAD0 | 0 0 0 fosc <sub>3</sub> / 1                           |                                                        |                   | 0                 | R/W  |     |                     |

Table 5.1.1(c) I/O Memory map (00FF14H–00FF16H)

| Address | Bit   | Name                               | Function                             | 1            | 0                       | Init                    | R/W | Comment             |     |
|---------|-------|------------------------------------|--------------------------------------|--------------|-------------------------|-------------------------|-----|---------------------|-----|
| 00FF14  | D7    | PRFO1                              | FOUT1 output control                 | On           | Off                     | 0                       | R/W |                     |     |
|         | D6    | PSF12                              | FOUT1 division ratio                 |              |                         |                         |     | 0                   | R/W |
|         |       |                                    | <u>PSF12</u>                         | <u>PSF11</u> | <u>PSF10</u>            | <u>Division ratio</u>   |     |                     |     |
|         |       |                                    | 1                                    | 1            | 1                       | fosc <sub>1</sub> / 128 |     |                     |     |
|         |       |                                    | 1                                    | 1            | 0                       | fosc <sub>1</sub> / 64  |     |                     |     |
|         | D5    | PSF11                              | FOUT1 division ratio                 |              |                         |                         |     | 0                   | R/W |
|         |       |                                    | 1                                    | 0            | 1                       | fosc <sub>1</sub> / 32  |     |                     |     |
|         |       |                                    | 1                                    | 0            | 0                       | fosc <sub>1</sub> / 16  |     |                     |     |
|         |       |                                    | 0                                    | 1            | 1                       | fosc <sub>1</sub> / 8   |     |                     |     |
|         | D4    | PSF10                              | FOUT1 division ratio                 |              |                         |                         |     | 0                   | R/W |
|         |       |                                    | 0                                    | 1            | 0                       | fosc <sub>1</sub> / 4   |     |                     |     |
|         |       |                                    | 0                                    | 0            | 1                       | fosc <sub>1</sub> / 2   |     |                     |     |
| 0       |       |                                    | 0                                    | 0            | fosc <sub>1</sub> / 1   |                         |     |                     |     |
| D3      | PRFO3 | FOUT3 output control               | On                                   | Off          | 0                       | R/W                     |     |                     |     |
| D2      | PSF32 | FOUT3 division ratio               |                                      |              |                         |                         | 0   | R/W                 |     |
|         |       | <u>PSF32</u>                       | <u>PSF31</u>                         | <u>PSF30</u> | <u>Division ratio</u>   |                         |     |                     |     |
|         |       | 1                                  | 1                                    | 1            | fosc <sub>3</sub> / 128 |                         |     |                     |     |
|         |       | 1                                  | 1                                    | 0            | fosc <sub>3</sub> / 64  |                         |     |                     |     |
| D1      | PSF31 | FOUT3 division ratio               |                                      |              |                         |                         | 0   | R/W                 |     |
|         |       | 1                                  | 0                                    | 1            | fosc <sub>3</sub> / 32  |                         |     |                     |     |
|         |       | 1                                  | 0                                    | 0            | fosc <sub>3</sub> / 16  |                         |     |                     |     |
|         |       | 0                                  | 1                                    | 1            | fosc <sub>3</sub> / 8   |                         |     |                     |     |
| D0      | PSF30 | FOUT3 division ratio               |                                      |              |                         |                         | 0   | R/W                 |     |
|         |       | 0                                  | 1                                    | 0            | fosc <sub>3</sub> / 4   |                         |     |                     |     |
|         |       | 0                                  | 0                                    | 1            | fosc <sub>3</sub> / 2   |                         |     |                     |     |
|         |       | 0                                  | 0                                    | 0            | fosc <sub>3</sub> / 1   |                         |     |                     |     |
| 00FF15  | D7    | –                                  | –                                    | –            | –                       | –                       | –   | "0" when being read |     |
|         | D6    | –                                  | –                                    | –            | –                       | –                       | –   |                     |     |
|         | D5    | –                                  | –                                    | –            | –                       | –                       | –   |                     |     |
|         | D4    | –                                  | –                                    | –            | –                       | –                       | –   |                     |     |
|         | D3    | –                                  | –                                    | –            | –                       | –                       | –   |                     |     |
|         | D2    | –                                  | –                                    | –            | –                       | –                       | –   |                     |     |
|         | D1    | PK11ON                             | EXCL01 input clock ON/OFF control    | On           | Off                     | 0                       | R/W |                     |     |
|         | D0    | PK10ON                             | EXCL00 input clock ON/OFF control    | On           | Off                     | 0                       | R/W |                     |     |
| 00FF16  | D7    | –                                  | –                                    | –            | –                       | –                       | –   | "0" when being read |     |
|         | D6    | –                                  | –                                    | –            | –                       | –                       | –   |                     |     |
|         | D5    | –                                  | –                                    | –            | –                       | –                       | –   |                     |     |
|         | D4    | –                                  | –                                    | –            | –                       | –                       | –   |                     |     |
|         | D3    | PRTP                               | Touch panel controller clock control | On           | Off                     | 0                       | R/W |                     |     |
|         | D2    | PSTP2                              | Touch panel controller clock ratio   |              |                         |                         |     | 0                   | R/W |
|         |       |                                    | <u>PSTP2</u>                         | <u>PSTP1</u> | <u>PSTP0</u>            | <u>Division ratio</u>   |     |                     |     |
|         |       |                                    | 1                                    | ×            | ×                       | fosc <sub>3</sub> / 16  |     |                     |     |
| 0       |       |                                    | 1                                    | 1            | fosc <sub>3</sub> / 8   |                         |     |                     |     |
| D1      | PSTP1 | Touch panel controller clock ratio |                                      |              |                         |                         | 0   | R/W                 |     |
|         |       | 0                                  | 1                                    | 0            | fosc <sub>3</sub> / 4   |                         |     |                     |     |
|         |       | 0                                  | 0                                    | 1            | fosc <sub>3</sub> / 2   |                         |     |                     |     |
|         |       | 0                                  | 0                                    | 0            | fosc <sub>3</sub> / 1   |                         |     |                     |     |
| D0      | PSTP0 | Touch panel controller clock ratio |                                      |              |                         |                         | 0   | R/W                 |     |
|         |       | 0                                  | 0                                    | 1            | fosc <sub>3</sub> / 2   |                         |     |                     |     |
|         |       | 0                                  | 0                                    | 0            | fosc <sub>3</sub> / 1   |                         |     |                     |     |
|         |       | 0                                  | 0                                    | 0            | fosc <sub>3</sub> / 1   |                         |     |                     |     |

Table 5.1.1(d) I/O Memory map (00FF20H–00FF25H)

| Address | Bit | Name   | Function                                                               | 1                    | 0                     | Init     | R/W | Comment |                     |                     |
|---------|-----|--------|------------------------------------------------------------------------|----------------------|-----------------------|----------|-----|---------|---------------------|---------------------|
| 00FF20  | D7  | PK11   | K10–K13                                                                | PK11                 | PK10                  | 0        | R/W |         |                     |                     |
|         | D6  | PK10   | interrupt priority register                                            | PK01                 | PK00                  | 0        | R/W |         |                     |                     |
|         | D5  | PK01   | K00–K07                                                                | PTM11                | PTM10                 | Priority | 0   | R/W     |                     |                     |
|         | D4  | PK00   | interrupt priority register                                            | PTM01                | PTM00                 | level    | 0   | R/W     |                     |                     |
|         | D3  | PTM11  | 16-bit programmable timer 1                                            | 1                    | 1                     | Level 3  | 0   | R/W     |                     |                     |
|         | D2  | PTM10  | interrupt priority register                                            | 1                    | 0                     | Level 2  | 0   | R/W     |                     |                     |
|         | D1  | PTM01  | 16-bit programmable timer 0                                            | 0                    | 1                     | Level 1  | 0   | R/W     |                     |                     |
|         | D0  | PTM00  | interrupt priority register                                            | 0                    | 0                     | Level 0  | 0   | R/W     |                     |                     |
| 00FF21  | D7  | PTM21  | 8-bit programmable timer                                               | PTM21                | PTM20                 | 0        | R/W |         |                     |                     |
|         | D6  | PTM20  | interrupt priority register                                            | PSI1                 | PSI0                  | 0        | R/W |         |                     |                     |
|         | D5  | PSI1   | Serial interface                                                       | PCTM1                | PCTM0                 | Priority | 0   | R/W     |                     |                     |
|         | D4  | PSI0   | interrupt priority register                                            | PLCD1                | PLCD0                 | level    | 0   | R/W     |                     |                     |
|         | D3  | PCTM1  | Clock timer                                                            | 1                    | 1                     | Level 3  | 0   | R/W     |                     |                     |
|         | D2  | PCTM0  | interrupt priority register                                            | 1                    | 0                     | Level 2  | 0   | R/W     |                     |                     |
|         | D1  | PLCD1  | LCD controller                                                         | 0                    | 1                     | Level 1  | 0   | R/W     |                     |                     |
|         | D0  | PLCD0  | interrupt priority register                                            | 0                    | 0                     | Level 0  | 0   | R/W     |                     |                     |
| 00FF22  | D7  | PAD1   | A/D converter                                                          | PAD1                 | PAD0                  | Priority | 0   | R/W     |                     |                     |
|         | D6  | PAD0   | interrupt priority register                                            | PTP1                 | PTP0                  | level    | 0   | R/W     |                     |                     |
|         | D5  | PTP1   | Touch panel controller                                                 | 1                    | 1                     | Level 3  | 0   | R/W     |                     |                     |
|         | D4  | PTP0   | interrupt priority register                                            | 1                    | 0                     | Level 2  | 0   | R/W     |                     |                     |
|         | D3  | –      | –                                                                      | 0                    | 1                     | Level 1  | –   | –       | "0" when being read |                     |
|         | D2  | –      | –                                                                      | 0                    | 0                     | Level 0  | –   | –       |                     |                     |
|         | D1  | –      | –                                                                      | –                    | –                     | –        | –   | –       |                     |                     |
|         | D0  | –      | –                                                                      | –                    | –                     | –        | –   | –       |                     |                     |
| 00FF23  | D7  | EK13   | K13 interrupt enable register                                          | Interrupt is enabled | Interrupt is disabled | 0        | R/W |         |                     |                     |
|         | D6  | EK12   | K12 interrupt enable register                                          |                      |                       | 0        | R/W |         |                     |                     |
|         | D5  | EK11   | K11 interrupt enable register                                          |                      |                       | 0        | R/W |         |                     |                     |
|         | D4  | EK10   | K10 interrupt enable register                                          |                      |                       | 0        | R/W |         |                     |                     |
|         | D3  | EK0    | K00–K07 interrupt enable register                                      |                      |                       | 0        | R/W |         |                     |                     |
|         | D2  | –      | –                                                                      |                      |                       | –        | –   | –       | –                   | "0" when being read |
|         | D1  | –      | –                                                                      |                      |                       | –        | –   | –       | –                   |                     |
|         | D0  | –      | –                                                                      |                      |                       | –        | –   | –       | –                   |                     |
| 00FF24  | D7  | ETU2   | 8-bit programmable timer<br>underflow interrupt enable register        | Interrupt is enabled | Interrupt is disabled | 0        | R/W |         |                     |                     |
|         | D6  | ETC1   | 16-bit programmable timer 1<br>compare match interrupt enable register |                      |                       | 0        | R/W |         |                     |                     |
|         | D5  | ETU1   | 16-bit programmable timer 1<br>underflow interrupt enable register     |                      |                       | 0        | R/W |         |                     |                     |
|         | D4  | ETC0   | 16-bit programmable timer 0<br>compare match interrupt enable register |                      |                       | 0        | R/W |         |                     |                     |
|         | D3  | ETU0   | 16-bit programmable timer 0<br>underflow interrupt enable register     |                      |                       | 0        | R/W |         |                     |                     |
|         | D2  | ESTX   | Serial interface<br>transmit completion interrupt enable register      |                      |                       | 0        | R/W |         |                     |                     |
|         | D1  | ESRX   | Serial interface<br>receive completion interrupt enable register       |                      |                       | 0        | R/W |         |                     |                     |
|         | D0  | ESERR  | Serial interface<br>receive error interrupt enable register            |                      |                       | 0        | R/W |         |                     |                     |
| 00FF25  | D7  | ET60S  | Clock timer 60 S interrupt enable register                             | Interrupt is enabled | Interrupt is disabled | 0        | R/W |         |                     |                     |
|         | D6  | ECTM1  | Clock timer 1 Hz interrupt enable register                             |                      |                       | 0        | R/W |         |                     |                     |
|         | D5  | ECTM2  | Clock timer 2 Hz interrupt enable register                             |                      |                       | 0        | R/W |         |                     |                     |
|         | D4  | ECTM8  | Clock timer 8 Hz interrupt enable register                             |                      |                       | 0        | R/W |         |                     |                     |
|         | D3  | ECTM32 | Clock timer 32 Hz interrupt enable register                            |                      |                       | 0        | R/W |         |                     |                     |
|         | D2  | ELCD   | LCD controller interrupt enable register                               |                      |                       | 0        | R/W |         |                     |                     |
|         | D1  | –      | –                                                                      |                      |                       | –        | –   | –       | –                   | "0" when being read |
|         | D0  | –      | –                                                                      |                      |                       | –        | –   | –       | –                   |                     |

Table 5.1.1(e) I/O Memory map (00FF26H–00FF2AH)

| Address | Bit | Name   | Function                                                               | 1                                     | 0                                         | Init | R/W   | Comment             |
|---------|-----|--------|------------------------------------------------------------------------|---------------------------------------|-------------------------------------------|------|-------|---------------------|
| 00FF26  | D7  | EAD    | A/D converter conversion completion interrupt enable register          | Interrupt is enabled                  | Interrupt is disabled                     | 0    | R/W   | "0" when being read |
|         | D6  | ETPPD  | Touch panel controller pen-down interrupt enable register              |                                       |                                           | 0    | R/W   |                     |
|         | D5  | ETPDR  | Touch panel controller converted data update interrupt enable register |                                       |                                           | 0    | R/W   |                     |
|         | D4  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D3  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D2  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D1  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D0  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
| 00FF27  | D7  | FK13   | K13 interrupt factor flag                                              | (R)                                   | (R)                                       | 0    | R/(W) | "0" when being read |
|         | D6  | FK12   | K12 interrupt factor flag                                              | Interrupt factor has generated        | Interrupt factor has not generated        | 0    | R/(W) |                     |
|         | D5  | FK11   | K11 interrupt factor flag                                              |                                       |                                           | 0    | R/(W) |                     |
|         | D4  | FK10   | K10 interrupt factor flag                                              |                                       |                                           | 0    | R/(W) |                     |
|         | D3  | FK0    | K00–K07 interrupt factor flag                                          | (W)<br>Reset                          | (W)<br>Invalid                            | 0    | R/(W) |                     |
|         | D2  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D1  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D0  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
| 00FF28  | D7  | FTU2   | 8-bit programmable timer underflow interrupt factor flag               | (R)<br>Interrupt factor has generated | (R)<br>Interrupt factor has not generated | 0    | R/(W) | "0" when being read |
|         | D6  | FTC1   | 16-bit programmable timer 1 compare match interrupt factor flag        |                                       |                                           | 0    | R/(W) |                     |
|         | D5  | FTU1   | 16-bit programmable timer 1 underflow interrupt factor flag            |                                       |                                           | 0    | R/(W) |                     |
|         | D4  | FTC0   | 16-bit programmable timer 0 compare match interrupt factor flag        |                                       |                                           | 0    | R/(W) |                     |
|         | D3  | FTU0   | 16-bit programmable timer 0 underflow interrupt factor flag            | (W)<br>Reset                          | (W)<br>Invalid                            | 0    | R/(W) |                     |
|         | D2  | FSTX   | Serial interface transmit completion interrupt factor flag             |                                       |                                           | 0    | R/(W) |                     |
|         | D1  | FSRX   | Serial interface receive completion interrupt factor flag              |                                       |                                           | 0    | R/(W) |                     |
|         | D0  | FSERR  | Serial interface receive error interrupt factor flag                   |                                       |                                           | 0    | R/(W) |                     |
| 00FF29  | D7  | FT60S  | Clock timer 60 S interrupt factor flag                                 | (R)<br>Interrupt factor has generated | (R)<br>Interrupt factor has not generated | 0    | R/(W) | "0" when being read |
|         | D6  | FCTM1  | Clock timer 1 Hz interrupt factor flag                                 |                                       |                                           | 0    | R/(W) |                     |
|         | D5  | FCTM2  | Clock timer 2 Hz interrupt factor flag                                 |                                       |                                           | 0    | R/(W) |                     |
|         | D4  | FCTM8  | Clock timer 8 Hz interrupt factor flag                                 |                                       |                                           | 0    | R/(W) |                     |
|         | D3  | FCTM32 | Clock timer 32 Hz interrupt factor flag                                | (W)<br>Reset                          | (W)<br>Invalid                            | 0    | R/(W) |                     |
|         | D2  | FLCD   | LCD controller interrupt factor flag                                   |                                       |                                           | 0    | R/(W) |                     |
|         | D1  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D0  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
| 00FF2A  | D7  | FAD    | A/D converter conversion completion interrupt factor flag              | (R)<br>Interrupt factor has generated | (R)<br>Interrupt factor has not generated | 0    | R/W   | "0" when being read |
|         | D6  | FTPPD  | Touch panel controller pen-down interrupt factor flag                  |                                       |                                           | 0    | R/W   |                     |
|         | D5  | FTPDR  | Touch panel controller converted data update interrupt factor flag     |                                       |                                           | 0    | R/W   |                     |
|         | D4  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D3  | –      | –                                                                      | (W)<br>Reset                          | (W)<br>Invalid                            | –    | –     |                     |
|         | D2  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D1  | –      | –                                                                      |                                       |                                           | –    | –     |                     |
|         | D0  | –      | –                                                                      |                                       |                                           | –    | –     |                     |

Table 5.1.1(f) I/O Memory map (00FF30H–00FF37H)

| Address | Bit | Name   | Function                                             | 1              | 0              | Init | R/W | Comment             |                                          |
|---------|-----|--------|------------------------------------------------------|----------------|----------------|------|-----|---------------------|------------------------------------------|
| 00FF30  | D7  | MODE16 | 16-bit PTM 8-/16-bit mode selection                  | 16-bit         | 8-bit × 2      | 0    | R/W |                     |                                          |
|         | D6  | –      | –                                                    | –              | –              | –    | –   | "0" when being read |                                          |
|         | D5  | –      | –                                                    | –              | –              | –    | –   |                     |                                          |
|         | D4  | –      | –                                                    | –              | –              | –    | –   |                     |                                          |
|         | D3  | PTOUT0 | 16-bit PTM0 clock output control                     | On             | Off            | 0    | R/W |                     |                                          |
|         | D2  | PTRUN0 | 16-bit PTM0 RUN/STOP control                         | Run            | Stop           | 0    | R/W |                     |                                          |
|         | D1  | PSET0  | 16-bit PTM0 preset                                   | Preset         | Invalid        | 0    | W   | "0" when being read |                                          |
|         | D0  | CKSEL0 | 16-bit PTM0 input clock selection                    | External clock | Internal clock | 0    | R/W |                     |                                          |
| 00FF31  | D7  | –      | –                                                    | –              | –              | –    | –   | "0" when being read |                                          |
|         | D6  | –      | –                                                    | –              | –              | –    | –   |                     |                                          |
|         | D5  | –      | –                                                    | –              | –              | –    | –   |                     |                                          |
|         | D4  | –      | –                                                    | –              | –              | –    | –   |                     |                                          |
|         | D3  | PTOUT1 | 16-bit PTM1 clock output control                     | On             | Off            | 0    | R/W |                     |                                          |
|         | D2  | PTRUN1 | 16-bit PTM1 RUN/STOP control                         | Run            | Stop           | 0    | R/W |                     |                                          |
|         | D1  | PSET1  | 16-bit PTM1 preset                                   | Preset         | Invalid        | 0    | W   | "0" when being read |                                          |
|         | D0  | CKSEL1 | 16-bit PTM1 input clock selection                    | External clock | Internal clock | 0    | R/W |                     |                                          |
| 00FF32  | D7  | RDR07  | 16-bit programmable timer 0<br>reload data register  | D7(MSB)        |                |      | 1   | R/W                 | Low-order 8 bits data<br>in 16-bit mode  |
|         | D6  | RDR06  |                                                      | D6             |                |      | 1   | R/W                 |                                          |
|         | D5  | RDR05  |                                                      | D5             |                |      | 1   | R/W                 |                                          |
|         | D4  | RDR04  |                                                      | D4             |                |      | 1   | R/W                 |                                          |
|         | D3  | RDR03  |                                                      | D3             |                |      | 1   | R/W                 |                                          |
|         | D2  | RDR02  |                                                      | D2             |                |      | 1   | R/W                 |                                          |
|         | D1  | RDR01  |                                                      | D1             |                |      | 1   | R/W                 |                                          |
|         | D0  | RDR00  |                                                      | D0(LSB)        |                |      | 1   | R/W                 |                                          |
| 00FF33  | D7  | RDR17  | 16-bit programmable timer 1<br>reload data register  | D7(MSB)        |                |      | 1   | R/W                 | High-order 8 bits data<br>in 16-bit mode |
|         | D6  | RDR16  |                                                      | D6             |                |      | 1   | R/W                 |                                          |
|         | D5  | RDR15  |                                                      | D5             |                |      | 1   | R/W                 |                                          |
|         | D4  | RDR14  |                                                      | D4             |                |      | 1   | R/W                 |                                          |
|         | D3  | RDR13  |                                                      | D3             |                |      | 1   | R/W                 |                                          |
|         | D2  | RDR12  |                                                      | D2             |                |      | 1   | R/W                 |                                          |
|         | D1  | RDR11  |                                                      | D1             |                |      | 1   | R/W                 |                                          |
|         | D0  | RDR10  |                                                      | D0(LSB)        |                |      | 1   | R/W                 |                                          |
| 00FF34  | D7  | CDR07  | 16-bit programmable timer 0<br>compare data register | D7(MSB)        |                |      | 0   | R/W                 | Low-order 8 bits data<br>in 16-bit mode  |
|         | D6  | CDR06  |                                                      | D6             |                |      | 0   | R/W                 |                                          |
|         | D5  | CDR05  |                                                      | D5             |                |      | 0   | R/W                 |                                          |
|         | D4  | CDR04  |                                                      | D4             |                |      | 0   | R/W                 |                                          |
|         | D3  | CDR03  |                                                      | D3             |                |      | 0   | R/W                 |                                          |
|         | D2  | CDR02  |                                                      | D2             |                |      | 0   | R/W                 |                                          |
|         | D1  | CDR01  |                                                      | D1             |                |      | 0   | R/W                 |                                          |
|         | D0  | CDR00  |                                                      | D0(LSB)        |                |      | 0   | R/W                 |                                          |
| 00FF35  | D7  | CDR17  | 16-bit programmable timer 1<br>compare data register | D7(MSB)        |                |      | 0   | R/W                 | High-order 8 bits data<br>in 16-bit mode |
|         | D6  | CDR16  |                                                      | D6             |                |      | 0   | R/W                 |                                          |
|         | D5  | CDR15  |                                                      | D5             |                |      | 0   | R/W                 |                                          |
|         | D4  | CDR14  |                                                      | D4             |                |      | 0   | R/W                 |                                          |
|         | D3  | CDR13  |                                                      | D3             |                |      | 0   | R/W                 |                                          |
|         | D2  | CDR12  |                                                      | D2             |                |      | 0   | R/W                 |                                          |
|         | D1  | CDR11  |                                                      | D1             |                |      | 0   | R/W                 |                                          |
|         | D0  | CDR10  |                                                      | D0(LSB)        |                |      | 0   | R/W                 |                                          |
| 00FF36  | D7  | PTM07  | 16-bit programmable timer 0<br>data register         | D7(MSB)        |                |      | 1   | R                   | Low-order 8 bits data<br>in 16-bit mode  |
|         | D6  | PTM06  |                                                      | D6             |                |      | 1   | R                   |                                          |
|         | D5  | PTM05  |                                                      | D5             |                |      | 1   | R                   |                                          |
|         | D4  | PTM04  |                                                      | D4             |                |      | 1   | R                   |                                          |
|         | D3  | PTM03  |                                                      | D3             |                |      | 1   | R                   |                                          |
|         | D2  | PTM02  |                                                      | D2             |                |      | 1   | R                   |                                          |
|         | D1  | PTM01  |                                                      | D1             |                |      | 1   | R                   |                                          |
|         | D0  | PTM00  |                                                      | D0(LSB)        |                |      | 1   | R                   |                                          |
| 00FF37  | D7  | PTM17  | 16-bit programmable timer 1<br>data register         | D7(MSB)        |                |      | 1   | R                   | High-order 8 bits data<br>in 16-bit mode |
|         | D6  | PTM16  |                                                      | D6             |                |      | 1   | R                   |                                          |
|         | D5  | PTM15  |                                                      | D5             |                |      | 1   | R                   |                                          |
|         | D4  | PTM14  |                                                      | D4             |                |      | 1   | R                   |                                          |
|         | D3  | PTM13  |                                                      | D3             |                |      | 1   | R                   |                                          |
|         | D2  | PTM12  |                                                      | D2             |                |      | 1   | R                   |                                          |
|         | D1  | PTM11  |                                                      | D1             |                |      | 1   | R                   |                                          |
|         | D0  | PTM10  |                                                      | D0(LSB)        |                |      | 1   | R                   |                                          |

Table 5.1.1(g) I/O Memory map (00FF38H–00FF3AH)

| Address | Bit  | Name                                      | Function                                         | 1       | 0      | Init    | R/W | Comment             |
|---------|------|-------------------------------------------|--------------------------------------------------|---------|--------|---------|-----|---------------------|
| 00FF38  | D7   | –                                         | –                                                | –       | –      | –       | –   | "0" when being read |
|         | D6   | –                                         | –                                                | –       | –      | –       | –   |                     |
|         | D5   | –                                         | –                                                | –       | –      | –       | –   |                     |
|         | D4   | –                                         | –                                                | –       | –      | –       | –   |                     |
|         | D3   | –                                         | –                                                | –       | –      | –       | –   |                     |
|         | D2   | PTOUT                                     | 8-bit programmable timer clock output control    |         | On     | Off     | 0   | R/W                 |
|         | D1   | PSET                                      | 8-bit programmable timer preset                  |         | Preset | Invalid | –   | W                   |
| D0      | PRUN | 8-bit programmable timer RUN/STOP control |                                                  | Run     | Stop   | 0       | R/W |                     |
| 00FF39  | D7   | RLD7                                      | 8-bit programmable timer<br>reload data register | D7(MSB) |        |         | 1   | R/W                 |
|         | D6   | RLD6                                      |                                                  | D6      |        |         | 1   | R/W                 |
|         | D5   | RLD5                                      |                                                  | D5      |        |         | 1   | R/W                 |
|         | D4   | RLD4                                      |                                                  | D4      |        |         | 1   | R/W                 |
|         | D3   | RLD3                                      |                                                  | D3      |        |         | 1   | R/W                 |
|         | D2   | RLD2                                      |                                                  | D2      |        |         | 1   | R/W                 |
|         | D1   | RLD1                                      |                                                  | D1      |        |         | 1   | R/W                 |
|         | D0   | RLD0                                      |                                                  | D0(LSB) |        |         | 1   | R/W                 |
| 00FF3A  | D7   | PTD7                                      | 8-bit programmable timer<br>data register        | D7(MSB) |        |         | 1   | R                   |
|         | D6   | PTD6                                      |                                                  | D6      |        |         | 1   | R                   |
|         | D5   | PTD5                                      |                                                  | D5      |        |         | 1   | R                   |
|         | D4   | PTD4                                      |                                                  | D4      |        |         | 1   | R                   |
|         | D3   | PTD3                                      |                                                  | D3      |        |         | 1   | R                   |
|         | D2   | PTD2                                      |                                                  | D2      |        |         | 1   | R                   |
|         | D1   | PTD1                                      |                                                  | D1      |        |         | 1   | R                   |
|         | D0   | PTD0                                      |                                                  | D0(LSB) |        |         | 1   | R                   |



Table 5.1.1(h) I/O Memory map (00FF40H–00FF43H)

| Address | Bit | Name   | Function                                  | 1                            | 0                               | Init | R/W    | Comment             |                                                   |
|---------|-----|--------|-------------------------------------------|------------------------------|---------------------------------|------|--------|---------------------|---------------------------------------------------|
| 00FF40  | D7  | SIOSEL | Serial I/F terminal selection             | P14–P17                      | P10–P13                         | 0    | R/W    |                     |                                                   |
|         | D6  | EPR    | Serial I/F parity enable                  | With parity                  | No parity                       | 0    | R/W    |                     |                                                   |
|         | D5  | PMD    | Serial I/F parity mode selection          | Odd                          | Even                            | 0    | R/W    |                     |                                                   |
|         | D4  | STPB   | Serial I/F stop bit selection             | 2 bits                       | 1 bit                           | 0    | R/W    |                     |                                                   |
|         | D3  | –      | –                                         | –                            | –                               | –    | –      | "0" when being read |                                                   |
|         | D2  | SMD1   | Serial I/F mode selection                 | SMD1    SMD0    Mode         |                                 |      | 0      | R/W                 |                                                   |
|         | D1  |        |                                           | SMD0                         | 1    1    8-bit asynchronous    |      | 0      | R/W                 |                                                   |
|         |     |        |                                           | 1    0    7-bit asynchronous |                                 |      |        |                     |                                                   |
|         |     |        | 0    1    Clock synchronous slave         |                              |                                 |      |        |                     |                                                   |
|         |     |        | 0    0    Clock synchronous master        |                              |                                 |      |        |                     |                                                   |
|         | D0  | ESIF   | Serial I/F enable                         | Serial I/F                   | I/O port                        | 0    | R/W    |                     |                                                   |
| 00FF41  | D7  | –      | –                                         | –                            | –                               | –    | –      | "0" when being read |                                                   |
|         | D6  | FER    | Serial I/F framing error flag             | Error<br>Reset (0)           | No error<br>Invalid             | 0    | R<br>W |                     |                                                   |
|         | D5  | PER    | Serial I/F parity error flag              | Error<br>Reset (0)           | No error<br>Invalid             | 0    | R<br>W |                     |                                                   |
|         | D4  | OER    | Serial I/F overrun error flag             | Error<br>Reset (0)           | No error<br>Invalid             | 0    | R<br>W |                     |                                                   |
|         | D3  | RXTRG  | Serial I/F receive trigger/status         | Run<br>Trigger               | Stop<br>Invalid                 | 0    | R<br>W |                     |                                                   |
|         | D2  | RXEN   | Serial I/F receive enable                 | Enable                       | Disable                         | 0    | R/W    |                     |                                                   |
|         | D1  | TXTRG  | Serial I/F transmit trigger/status        | Run<br>Trigger               | Stop<br>Invalid                 | 0    | R<br>W |                     |                                                   |
|         | D0  | TXEN   | Serial I/F transmit enable                | Enable                       | Disable                         | 0    | R/W    |                     |                                                   |
| 00FF42  | D7  | TRXD7  | Serial I/F transmit/receive data register | D7(MSB)                      | High                            | Low  | ×      | R/W                 | TRXD7 is invalid in 7-bit asynchronous mode       |
|         | D6  | TRXD6  |                                           | D6                           |                                 |      | ×      | R/W                 |                                                   |
|         | D5  | TRXD5  |                                           | D5                           |                                 |      | ×      | R/W                 |                                                   |
|         | D4  | TRXD4  |                                           | D4                           |                                 |      | ×      | R/W                 |                                                   |
|         | D3  | TRXD3  |                                           | D3                           |                                 |      | ×      | R/W                 |                                                   |
|         | D2  | TRXD2  |                                           | D2                           |                                 |      | ×      | R/W                 |                                                   |
|         | D1  | TRXD1  |                                           | D1                           |                                 |      | ×      | R/W                 |                                                   |
|         | D0  | TRXD0  |                                           | D0(LSB)                      |                                 |      | ×      | R/W                 |                                                   |
| 00FF43  | D7  | –      | –                                         | –                            | –                               | –    | –      | "0" when being read |                                                   |
|         | D6  | –      | –                                         | –                            | –                               | –    | –      |                     |                                                   |
|         | D5  | –      | –                                         | –                            | –                               | –    | –      |                     |                                                   |
|         | D4  | –      | –                                         | –                            | –                               | –    | –      |                     |                                                   |
|         | D3  | IRTL   | IrDA interface output logic inversion     | Inverse                      | Normal                          | 0    | R/W    |                     |                                                   |
|         | D2  | IRIL   | IrDA interface input logic inversion      | Inverse                      | Normal                          | 0    | R/W    |                     |                                                   |
|         | D1  | IRST1  | IrDA interface setting                    | IRST1    IRST0    Setting    |                                 |      | 0      | R/W                 | Valid only when SIOSEL = "1" in asynchronous mode |
|         | D0  |        |                                           | IRST0                        | 1    1    Reserved (do not set) |      | 0      | R/W                 |                                                   |
|         |     |        | 1    0    IrDA interface                  |                              |                                 |      |        |                     |                                                   |
|         |     |        | 0    1    Reserved (do not set)           |                              |                                 |      |        |                     |                                                   |
|         |     |        | 0    0    Normal interface                |                              |                                 |      |        |                     |                                                   |

Table 5.1.1(i) I/O Memory map (00FF50H–00FF53H)

| Address | Bit | Name  | Function                             | 1                    | 0             | Init    | R/W | Comment             |
|---------|-----|-------|--------------------------------------|----------------------|---------------|---------|-----|---------------------|
| 00FF50  | D7  | –     | –                                    | –                    | –             | –       | –   | "0" when being read |
|         | D6  | –     | –                                    | –                    | –             | –       | –   |                     |
|         | D5  | –     | –                                    | –                    | –             | –       | –   |                     |
|         | D4  | –     | –                                    | –                    | –             | –       | –   |                     |
|         | D3  | –     | –                                    | –                    | –             | –       | –   |                     |
|         | D2  | –     | –                                    | –                    | –             | –       | –   |                     |
|         | D1  | TMRST | Clock timer reset                    | Reset                | Invalid       | –       | W   |                     |
|         | D0  | TMRUN | Clock timer RUN/STOP                 | Run                  | Stop          | 0       | R/W |                     |
| 00FF51  | D7  | TMD7  | Clock timer data 1 Hz                | High                 | Low           | 0       | R   |                     |
|         | D6  | TMD6  | Clock timer data 2 Hz                |                      |               | 0       | R   |                     |
|         | D5  | TMD5  | Clock timer data 4 Hz                |                      |               | 0       | R   |                     |
|         | D4  | TMD4  | Clock timer data 8 Hz                |                      |               | 0       | R   |                     |
|         | D3  | TMD3  | Clock timer data 16 Hz               |                      |               | 0       | R   |                     |
|         | D2  | TMD2  | Clock timer data 32 Hz               |                      |               | 0       | R   |                     |
|         | D1  | TMD1  | Clock timer data 64 Hz               |                      |               | 0       | R   |                     |
|         | D0  | TMD0  | Clock timer data 128 Hz              |                      |               | 0       | R   |                     |
| 00FF52  | D7  | –     | –                                    | –                    | –             | –       | –   | "0" when being read |
|         | D6  | TMMD6 | Clock timer data 10 sec (BCD)        |                      |               | 0       | R/W |                     |
|         | D5  | TMMD5 |                                      |                      |               | 0       | R/W |                     |
|         | D4  | TMMD4 |                                      |                      |               | 0       | R/W |                     |
|         | D3  | TMMD3 | Clock timer data 1 sec (BCD)         |                      |               | 0       | R/W |                     |
|         | D2  | TMMD2 |                                      |                      |               | 0       | R/W |                     |
|         | D1  | TMMD1 |                                      |                      |               | 0       | R/W |                     |
|         | D0  | TMMD0 |                                      |                      |               | 0       | R/W |                     |
| 00FF53  | D7  | WRWD  | EWD, WDCL write enable               | Write enable         | Write disable | 0       | R/W | *1                  |
|         | D6  | EWD   | Watchdog timer NMI enable            | NMI enable           | NMI disable   | 1       | R/W | *1                  |
|         | D5  | WDCL  | Watchdog timer input clock selection | fosc3/16             | fosc1/16      | 0       | R/W | *1                  |
|         | D4  | –     | –                                    | –                    | –             | –       | –   | "0" when being read |
|         | D3  | –     | –                                    | –                    | –             | –       | –   |                     |
|         | D2  | –     | –                                    | –                    | –             | –       | –   |                     |
|         | D1  | –     | –                                    | –                    | –             | –       | –   |                     |
|         |     | D0    | WDRST                                | Watchdog timer reset | Reset         | Invalid | –   | W                   |

\*1 Writing to EWD or WDCL is valid after "1" is written to WRWD. WRWD is automatically returns to "0" after writing to EWD or WDCL.

Table 5.1.1(j) I/O Memory map (00FF54H–00FF55H)

| Address | Bit   | Name                       | Function                                 | 1                     | 0            | Init   | R/W                 | Comment             |  |
|---------|-------|----------------------------|------------------------------------------|-----------------------|--------------|--------|---------------------|---------------------|--|
| 00FF54  | D7    | –                          | –                                        | –                     | –            | –      | –                   | "0" when being read |  |
|         | D6    | BZSTP                      | One-shot buzzer forcibly stop            | Forcibly stop         | No operation | –      | W                   |                     |  |
|         | D5    | BZSHT                      | One-shot buzzer trigger/status           | Busy Trigger          | Ready        | 0      | R                   |                     |  |
|         | D4    | SHTPW                      | One-shot buzzer duration width selection | 125 msec              | 31.25 msec   | 0      | R/W                 |                     |  |
|         | D3    | ENRTM                      | Envelope attenuation time                | 1 sec                 | 0.5 sec      | 0      | R/W                 |                     |  |
|         | D2    | ENRST                      | Envelope reset                           | Reset                 | No operation | –      | W                   | "0" when being read |  |
|         | D1    | ENON                       | Envelope On/Off control                  | On                    | Off          | 0      | R/W                 | *1                  |  |
|         | D0    | BZON                       | Buzzer output control                    | On                    | Off          | 0      | R/W                 |                     |  |
| 00FF55  | D7    | –                          | –                                        | –                     | –            | –      | –                   | "0" when being read |  |
|         | D6    | DUTY2                      | Buzzer signal duty ratio selection       |                       |              |        | 0                   | R/W                 |  |
|         |       |                            | DUTY2–1                                  | Buzzer frequency (Hz) |              |        |                     |                     |  |
|         |       |                            |                                          | 4096.0                | 3276.8       | 2730.7 | 2340.6              |                     |  |
|         |       |                            | 2 1 0                                    | 2048.8                | 1638.4       | 1365.3 | 1170.3              |                     |  |
|         | D5    | DUTY1                      | 0 0 0                                    | 8/16                  | 8/20         | 12/24  | 12/28               |                     |  |
|         |       |                            | 0 0 1                                    | 7/16                  | 7/20         | 11/24  | 11/28               |                     |  |
|         |       |                            | 0 1 0                                    | 6/16                  | 6/20         | 10/24  | 10/28               |                     |  |
|         |       |                            | 0 1 1                                    | 5/16                  | 5/20         | 9/24   | 9/28                |                     |  |
|         | D4    | DUTY0                      | 1 0 0                                    | 4/16                  | 4/20         | 8/24   | 8/28                |                     |  |
|         |       |                            | 1 0 1                                    | 3/16                  | 3/20         | 7/24   | 7/28                |                     |  |
|         |       |                            | 1 1 0                                    | 2/16                  | 2/20         | 6/24   | 6/28                |                     |  |
| 1 1 1   |       |                            | 1/16                                     | 1/20                  | 5/24         | 5/28   |                     |                     |  |
| D3      | –     | –                          | –                                        | –                     | –            | –      | "0" when being read |                     |  |
| D2      | BZFQ2 | Buzzer frequency selection |                                          |                       |              | 0      | R/W                 |                     |  |
|         |       | BZFQ2 BZFQ1 BZFQ0          | Frequency (Hz)                           |                       |              |        |                     |                     |  |
| D1      | BZFQ1 | 0 0 0                      | 4096.0                                   |                       |              |        |                     |                     |  |
|         |       | 0 0 1                      | 3276.8                                   |                       |              |        |                     |                     |  |
| D0      | BZFQ0 | 0 1 0                      | 2730.7                                   |                       |              |        |                     |                     |  |
|         |       | 0 1 1                      | 2340.6                                   |                       |              |        |                     |                     |  |
|         |       | 1 0 0                      | 2048.0                                   |                       |              |        |                     |                     |  |
|         |       | 1 0 1                      | 1638.4                                   |                       |              |        |                     |                     |  |
|         |       | 1 1 0                      | 1365.3                                   |                       |              |        |                     |                     |  |
|         |       | 1 1 1                      | 1170.3                                   |                       |              |        |                     |                     |  |

\*1 ENON is reset to "0" during one-shot output.

Table 5.1.1(k) I/O Memory map (00FF56H)

| Address | Bit   | Name               | Function                     | 1           | 0 | Init | R/W | Comment             |  |
|---------|-------|--------------------|------------------------------|-------------|---|------|-----|---------------------|--|
| 00FF56  | D7    | –                  | –                            | –           | – | –    | –   | "0" when being read |  |
|         | D6    | –                  | –                            | –           | – | –    | –   |                     |  |
|         | D5    | –                  | –                            | –           | – | –    | –   |                     |  |
|         | D4    | –                  | –                            | –           | – | –    | –   |                     |  |
|         | D3    | SVD1               | SVD criteria voltage setting |             |   |      | 0   | R/W                 |  |
|         |       |                    | SVD1 SVD0                    | Voltage (V) |   |      |     |                     |  |
|         |       |                    | 1 ×                          | 3.4 V       |   |      |     |                     |  |
|         | D2    | SVD0               | 0 1                          | 2.8 V       |   |      |     | R/W                 |  |
| 0 0     |       |                    | 1.9 V                        |             |   |      |     |                     |  |
| D1      | SVDDT | SVD data           | Low                          | Normal      | 0 | R    |     |                     |  |
| D0      | SCDON | SVD On/Off control | On                           | Off         | 0 | R/W  |     |                     |  |

Table 5.1.1(1) I/O Memory map (00FF60H–00FF65H)

| Address | Bit    | Name                                | Function                             | 1                                    | 0       | Init        | R/W         | Comment             |     |       |        |             |
|---------|--------|-------------------------------------|--------------------------------------|--------------------------------------|---------|-------------|-------------|---------------------|-----|-------|--------|-------------|
| 00FF60  | D7     | DISP                                | Display On/Off control               | On                                   | Off     | 0           | R/W         |                     |     |       |        |             |
|         | D6     | REV                                 | Normal/Inverse display control       | Inverse                              | Normal  | 0           | R/W         |                     |     |       |        |             |
|         | D5     | CKCN2                               | Scanning line frequency selection    |                                      |         |             | 0           | R/W                 |     |       |        |             |
|         |        |                                     | CKCN2                                | CKCN1                                |         |             |             |                     |     | CKCNO | POINT5 | Frequency   |
|         |        |                                     | 0                                    | 0                                    |         |             |             |                     |     | 0     | 0      | fosc1       |
|         |        |                                     | 0                                    | 0                                    |         |             |             |                     |     | 0     | 1      | fosc1 / 1.5 |
|         |        |                                     | 0                                    | 0                                    |         |             |             |                     |     | 1     | 0      | fosc1 / 2   |
|         | D4     | CKCN1                               | 0                                    | 0                                    | 1       | 1           | fosc1 / 2.5 |                     |     |       |        |             |
|         |        |                                     | 0                                    | 1                                    | 0       | 0           | fosc1 / 3   |                     |     |       |        |             |
|         |        |                                     | 0                                    | 1                                    | 0       | 1           | fosc1 / 3.5 |                     |     |       |        |             |
|         |        |                                     | 0                                    | 1                                    | 1       | 0           | fosc1 / 4   |                     |     |       |        |             |
| D3      | CKCN0  | 0                                   | 1                                    | 1                                    | 1       | fosc1 / 4.5 |             |                     |     |       |        |             |
|         |        | 1                                   | 0                                    | 0                                    | 0       | fosc1 / 5   |             |                     |     |       |        |             |
|         |        | 1                                   | 0                                    | 0                                    | 1       | fosc1 / 5.5 |             |                     |     |       |        |             |
|         |        | 1                                   | 0                                    | 1                                    | 0       | fosc1 / 6   |             |                     |     |       |        |             |
| D2      | POINT5 | 1                                   | 0                                    | 1                                    | 1       | fosc1 / 6.5 |             |                     |     |       |        |             |
|         |        | 1                                   | 1                                    | 0                                    | 0       | fosc1 / 7   |             |                     |     |       |        |             |
|         |        | 1                                   | 1                                    | 0                                    | 1       | fosc1 / 7.5 |             |                     |     |       |        |             |
|         |        | 1                                   | 1                                    | 1                                    | 0       | fosc1 / 8   |             |                     |     |       |        |             |
|         |        | 1                                   | 1                                    | 1                                    | 1       | fosc1 / 8.5 |             |                     |     |       |        |             |
| D1      | GRAY   | Gray/B&W mode selection             | Gray                                 | B&W                                  | 0       | R/W         |             |                     |     |       |        |             |
| D0      | BITNO  | 8-bit/4-bit transfer selection      | 8 bits                               | 4 bits                               | 0       | R/W         |             |                     |     |       |        |             |
| 00FF61  | D7     | –                                   | –                                    | –                                    | –       | –           | –           | "0" when being read |     |       |        |             |
|         | D6     | –                                   | –                                    | –                                    | –       | –           | –           |                     |     |       |        |             |
|         | D5     | –                                   | –                                    | –                                    | –       | –           | –           |                     |     |       |        |             |
|         | D4     | S1570AS                             | Hardware auto-transfer status        | Busy                                 | Standby | 0           | R           |                     |     |       |        |             |
|         | D3     | LCDEN                               | LCD power On/Off control             | On                                   | Off     | 0           | R/W         |                     |     |       |        |             |
|         | D2     | S1570A                              | Hardware auto-transfer control       | On                                   | Off     | 0           | R/W         |                     |     |       |        |             |
|         | D1     | S1570O                              | One-shot transfer trigger/status     | Busy                                 | Standby | 0           | R           |                     |     |       |        |             |
|         |        |                                     |                                      | Trigger                              | Invalid | 0           | W           |                     |     |       |        |             |
| D0      | S1606  | Continuous refresh transfer control | On                                   | Off                                  | 1       | R/W         |             |                     |     |       |        |             |
| 00FF62  | D7     | –                                   | –                                    | –                                    | –       | –           | –           | "0" when being read |     |       |        |             |
|         | D6     | LBC6                                | Number of bytes per display line     | D6(MSB)                              | High    | Low         | 0           |                     | R/W |       |        |             |
|         | D5     | LBC5                                |                                      | D5                                   |         |             | 0           |                     | R/W |       |        |             |
|         | D4     | LBC4                                |                                      | D4                                   |         |             | 0           |                     | R/W |       |        |             |
|         | D3     | LBC3                                |                                      | D3                                   |         |             | 0           |                     | R/W |       |        |             |
|         | D2     | LBC2                                |                                      | D2                                   |         |             | 0           |                     | R/W |       |        |             |
|         | D1     | LBC1                                |                                      | D1                                   |         |             | 0           |                     | R/W |       |        |             |
|         | D0     | LBC0                                |                                      | D0(LSB)                              |         |             | 0           |                     | R/W |       |        |             |
| 00FF63  | D7     | SAD7                                |                                      | Display start address (lower 8 bits) |         |             | D7          | High                | Low | 0     | R/W    |             |
|         | D6     | SAD6                                | D6                                   |                                      | 0       | R/W         |             |                     |     |       |        |             |
|         | D5     | SAD5                                | D5                                   |                                      | 0       | R/W         |             |                     |     |       |        |             |
|         | D4     | SAD4                                | D4                                   |                                      | 0       | R/W         |             |                     |     |       |        |             |
|         | D3     | SAD3                                | D3                                   |                                      | 0       | R/W         |             |                     |     |       |        |             |
|         | D2     | SAD2                                | D2                                   |                                      | 0       | R/W         |             |                     |     |       |        |             |
|         | D1     | SAD1                                | D1                                   |                                      | 0       | R/W         |             |                     |     |       |        |             |
|         | D0     | SAD0                                | D0                                   |                                      | 0       | R/W         |             |                     |     |       |        |             |
| 00FF64  | D7     | SAD15                               | Display start address (upper 8 bits) | D15                                  | High    | Low         | 0           | R/W                 |     |       |        |             |
|         | D6     | SAD14                               |                                      | D14                                  |         |             | 0           | R/W                 |     |       |        |             |
|         | D5     | SAD13                               |                                      | D13                                  |         |             | 0           | R/W                 |     |       |        |             |
|         | D4     | SAD12                               |                                      | D12                                  |         |             | 0           | R/W                 |     |       |        |             |
|         | D3     | SAD11                               |                                      | D11                                  |         |             | 0           | R/W                 |     |       |        |             |
|         | D2     | SAD10                               |                                      | D10                                  |         |             | 0           | R/W                 |     |       |        |             |
|         | D1     | SAD9                                |                                      | D9                                   |         |             | 0           | R/W                 |     |       |        |             |
|         | D0     | SAD8                                |                                      | D8                                   |         |             | 0           | R/W                 |     |       |        |             |
| 00FF65  | D7     | SLT7                                | Total display lines                  | D7                                   | High    | Low         | 0           | R/W                 |     |       |        |             |
|         | D6     | SLT6                                |                                      | D6                                   |         |             | 0           | R/W                 |     |       |        |             |
|         | D5     | SLT5                                |                                      | D5                                   |         |             | 0           | R/W                 |     |       |        |             |
|         | D4     | SLT4                                |                                      | D4                                   |         |             | 0           | R/W                 |     |       |        |             |
|         | D3     | SLT3                                |                                      | D3                                   |         |             | 0           | R/W                 |     |       |        |             |
|         | D2     | SLT2                                |                                      | D2                                   |         |             | 0           | R/W                 |     |       |        |             |
|         | D1     | SLT1                                |                                      | D1                                   |         |             | 0           | R/W                 |     |       |        |             |
|         | D0     | SLT0                                |                                      | D0                                   |         |             | 0           | R/W                 |     |       |        |             |

Table 5.1.1(m) I/O Memory map (00FF66H–00FF6AH)

| Address | Bit | Name   | Function                         | 1  | 0    | Init | R/W | Comment             |
|---------|-----|--------|----------------------------------|----|------|------|-----|---------------------|
| 00FF66  | D7  | –      | –                                | –  | –    | –    | –   | "0" when being read |
|         | D6  | –      | –                                | –  | –    | –    | –   |                     |
|         | D5  | –      | –                                | –  | –    | –    | –   |                     |
|         | D4  | –      | –                                | –  | –    | –    | –   |                     |
|         | D3  | –      | –                                | –  | –    | –    | –   |                     |
|         | D2  | –      | –                                | –  | –    | –    | –   |                     |
|         | D1  | –      | –                                | –  | –    | –    | –   |                     |
|         | D0  | SLT8   | Total display lines (MSB)        |    | High | Low  | 0   |                     |
| 00FF67  | D7  | APADJ7 | Address pitch adjustment         | D7 | High | Low  | 0   | R/W                 |
|         | D6  | APADJ6 |                                  | D6 |      |      | 0   | R/W                 |
|         | D5  | APADJ5 |                                  | D5 |      |      | 0   | R/W                 |
|         | D4  | APADJ4 |                                  | D4 |      |      | 0   | R/W                 |
|         | D3  | APADJ3 |                                  | D3 |      |      | 0   | R/W                 |
|         | D2  | APADJ2 |                                  | D2 |      |      | 0   | R/W                 |
|         | D1  | APADJ1 |                                  | D1 |      |      | 0   | R/W                 |
|         | D0  | APADJ0 |                                  | D0 |      |      | 0   | R/W                 |
| 00FF68  | D7  | GS17   | Gray scale (0,1) conversion code | D7 | High | Low  | 0   | R/W                 |
|         | D6  | GS16   |                                  | D6 |      |      | 0   | R/W                 |
|         | D5  | GS15   |                                  | D5 |      |      | 0   | R/W                 |
|         | D4  | GS14   |                                  | D4 |      |      | 0   | R/W                 |
|         | D3  | GS13   |                                  | D3 |      |      | 0   | R/W                 |
|         | D2  | GS12   |                                  | D2 |      |      | 0   | R/W                 |
|         | D1  | GS11   |                                  | D1 |      |      | 0   | R/W                 |
|         | D0  | GS10   |                                  | D0 |      |      | 0   | R/W                 |
| 00FF69  | D7  | GS27   | Gray scale (1,0) conversion code | D7 | High | Low  | 0   | R/W                 |
|         | D6  | GS26   |                                  | D6 |      |      | 0   | R/W                 |
|         | D5  | GS25   |                                  | D5 |      |      | 0   | R/W                 |
|         | D4  | GS24   |                                  | D4 |      |      | 0   | R/W                 |
|         | D3  | GS23   |                                  | D3 |      |      | 0   | R/W                 |
|         | D2  | GS22   |                                  | D2 |      |      | 0   | R/W                 |
|         | D1  | GS21   |                                  | D1 |      |      | 0   | R/W                 |
|         | D0  | GS20   |                                  | D0 |      |      | 0   | R/W                 |
| 00FF6A  | D7  | GS37   | Gray scale (1,1) conversion code | D7 | High | Low  | 0   | R/W                 |
|         | D6  | GS36   |                                  | D6 |      |      | 0   | R/W                 |
|         | D5  | GS35   |                                  | D5 |      |      | 0   | R/W                 |
|         | D4  | GS34   |                                  | D4 |      |      | 0   | R/W                 |
|         | D3  | GS33   |                                  | D3 |      |      | 0   | R/W                 |
|         | D2  | GS32   |                                  | D2 |      |      | 0   | R/W                 |
|         | D1  | GS31   |                                  | D1 |      |      | 0   | R/W                 |
|         | D0  | GS30   |                                  | D0 |      |      | 0   | R/W                 |

Table 5.1.1(n) I/O Memory map (00FF80H–00FF82H)

| Address | Bit  | Name  | Function                               | 1       | 0       | Init | R/W | Comment             |  |
|---------|------|-------|----------------------------------------|---------|---------|------|-----|---------------------|--|
| 00FF80  | D7   | ADRUN | A/D conversion start control register  | Start   | Invalid | 0    | W   | "0" when being read |  |
|         | D6   | –     | –                                      | –       | –       | –    | –   |                     |  |
|         | D5   | –     | –                                      | –       | –       | –    | –   |                     |  |
|         | D4   | VRC   | AVREF control (Touch panel controller) | Enable  | Invalid | 0    | R/W |                     |  |
|         | D3   | VRO   | AVREF swich                            | On      | Off     | 0    | R/W |                     |  |
|         | D2   | CHS2  | Analog input channel selection         |         |         |      | 0   | R/W                 |  |
|         |      |       | CHS2                                   | CHS1    |         |      |     |                     |  |
|         |      |       | 1                                      | 1       | 1       | AD7  |     |                     |  |
|         | D1   | CHS1  | 1                                      | 1       | 0       | AD6  | 0   | R/W                 |  |
|         |      |       | 1                                      | 0       | 1       | AD5  |     |                     |  |
| 1       |      |       | 0                                      | 0       | AD4     |      |     |                     |  |
| 0       |      |       | 1                                      | 1       | AD3     |      |     |                     |  |
| D0      | CHS0 | 0     | 1                                      | 0       | AD2     | 0    | R/W |                     |  |
|         |      | 0     | 0                                      | 1       | AD1     |      |     |                     |  |
|         |      | 0     | 0                                      | 0       | AD0     |      |     |                     |  |
|         |      |       |                                        |         |         |      |     |                     |  |
| 00FF81  | D7   | ADDR9 | A/D conversion result                  | D9(MSB) |         |      | –   | R                   |  |
|         | D6   | ADDR8 |                                        | D8      |         |      | –   | R                   |  |
|         | D5   | ADDR7 |                                        | D7      |         |      | –   | R                   |  |
|         | D4   | ADDR6 |                                        | D6      |         |      | –   | R                   |  |
|         | D3   | ADDR5 |                                        | D5      |         |      | –   | R                   |  |
|         | D2   | ADDR4 |                                        | D4      |         |      | –   | R                   |  |
|         | D1   | ADDR3 |                                        | D3      |         |      | –   | R                   |  |
|         | D0   | ADDR2 |                                        | D2      |         |      | –   | R                   |  |
| 00FF82  | D7   | –     | –                                      | –       | –       | –    | –   | "0" when being read |  |
|         | D6   | –     | –                                      | –       | –       | –    | –   |                     |  |
|         | D5   | –     | –                                      | –       | –       | –    | –   |                     |  |
|         | D4   | –     | –                                      | –       | –       | –    | –   |                     |  |
|         | D3   | –     | –                                      | –       | –       | –    | –   |                     |  |
|         | D2   | –     | –                                      | –       | –       | –    | –   |                     |  |
|         | D1   | ADDR1 | A/D conversion result                  | D1      | –       | R    |     |                     |  |
|         | D0   | ADDR0 |                                        | D0(LSB) | –       | R    |     |                     |  |

Table 5.1.1(o) I/O Memory map (00FF90H–00FF91H)

| Address | Bit | Name  | Function                                    | 1       | 0       | Init | R/W | Comment             |  |
|---------|-----|-------|---------------------------------------------|---------|---------|------|-----|---------------------|--|
| 00FF90  | D7  | –     | –                                           | –       | –       | –    | –   | "0" when being read |  |
|         | D6  | –     | –                                           | –       | –       | –    | –   |                     |  |
|         | D5  | –     | –                                           | –       | –       | –    | –   |                     |  |
|         | D4  | –     | –                                           | –       | –       | –    | –   |                     |  |
|         | D3  | –     | –                                           | –       | –       | –    | –   |                     |  |
|         | D2  | –     | –                                           | –       | –       | –    | –   |                     |  |
|         | D1  | –     | –                                           | –       | –       | –    | –   |                     |  |
|         | D0  | DAE   | D/A conversion result analog output control | Enable  | Disable | 0    | R/W |                     |  |
| 00FF91  | D7  | DADR7 | D/A converter                               | D7(MSB) |         |      | 0   | R/W                 |  |
|         | D6  | DADR6 | D/A conversion output data register         | D6      |         |      | 0   | R/W                 |  |
|         | D5  | DADR5 |                                             | D5      |         |      | 0   | R/W                 |  |
|         | D4  | DADR4 |                                             | D4      |         |      | 0   | R/W                 |  |
|         | D3  | DADR3 |                                             | D3      |         |      | 0   | R/W                 |  |
|         | D2  | DADR2 |                                             | D2      |         |      | 0   | R/W                 |  |
|         | D1  | DADR1 |                                             | D1      |         |      | 0   | R/W                 |  |
|         | D0  | DADR0 |                                             | D0(LSB) |         |      | 0   | R/W                 |  |

Table 5.1.1(p) I/O Memory map (00FFA0H–00FFA2H)

| Address | Bit    | Name                     | Function                                                                                     | 1              | 0      | Init | R/W | Comment                  |   |                     |
|---------|--------|--------------------------|----------------------------------------------------------------------------------------------|----------------|--------|------|-----|--------------------------|---|---------------------|
| 00FFA0  | D7     | –                        | –                                                                                            | –              | –      | –    | –   | "0" when being read      |   |                     |
|         | D6     | PDC                      | Pen-down check control                                                                       | Check          | Cancel | 0    | R/W | Valid when "RST=0"       |   |                     |
|         | D5     | RST                      | TPC circuit reset control                                                                    | Cancel         | Reset  | 0    | R/W |                          |   |                     |
|         | D4     | CONST                    | Mode setting                                                                                 | Constant-speed | Normal | 0    | R/W |                          |   |                     |
|         | D3     | –                        | –                                                                                            | –              | –      | –    | –   | "0" when being read      |   |                     |
|         | D2     | AVN2                     | Mean count setting                                                                           |                |        | 0    | R/W | Invalid when Normal mode |   |                     |
|         |        |                          | AVN2 AVN1 AVN0 Mean count                                                                    |                |        |      |     |                          |   |                     |
|         | D1     | AVN1                     | 0 0 0 16×16<br>0 0 1 16×8<br>0 1 0 16×4                                                      |                |        | 0    | R/W |                          |   |                     |
| D0      | AVN0   | 0 1 1 16×2<br>1 × × 16×1 |                                                                                              |                | 0      | R/W  |     |                          |   |                     |
| 00FFA1  | D7     | –                        | –                                                                                            | –              | –      | –    | –   | "0" when being read      |   |                     |
|         | D6     | –                        | –                                                                                            | –              | –      | –    | –   |                          |   |                     |
|         | D5     | –                        | –                                                                                            | –              | –      | –    | –   |                          |   |                     |
|         | D4     | –                        | –                                                                                            | –              | –      | –    | –   |                          |   |                     |
|         | D3     | WAIT3                    | Voltage stabilization waiting time setting                                                   |                |        | 0    | R/W |                          |   |                     |
|         |        |                          | WAIT3 WAIT2 WAIT1 WAIT0 Waiting time                                                         |                |        |      |     |                          |   |                     |
|         |        |                          | 0 0 0 0 16×1/f<br>0 0 0 1 16×2/f                                                             |                |        |      |     |                          |   |                     |
|         | D2     | WAIT2                    | 0 0 1 0 16×3/f<br>0 0 1 1 16×4/f<br>0 1 0 0 16×5/f<br>0 1 0 1 16×6/f<br>0 1 1 0 16×7/f       |                |        | 1    | R/W |                          |   |                     |
|         | D1     | WAIT1                    | 0 1 1 1 16×8/f<br>1 0 0 0 16×9/f<br>1 0 0 1 16×10/f<br>1 0 1 0 16×11/f<br>1 0 1 1 16×12/f    |                |        | 0    | R/W |                          |   |                     |
|         | D0     | WAIT0                    | 1 1 0 0 16×13/f<br>1 1 0 1 16×14/f<br>1 1 1 0 16×15/f<br>1 1 1 1 16×16/f                     |                |        | 0    | R/W |                          |   |                     |
|         | 00FFA2 | D7                       | –                                                                                            | –              | –      | –    | –   |                          | – | "0" when being read |
|         |        | D6                       | –                                                                                            | –              | –      | –    | –   |                          | – |                     |
|         |        | D5                       | –                                                                                            | –              | –      | –    | –   |                          | – |                     |
| D4      |        | –                        | –                                                                                            | –              | –      | –    | –   |                          |   |                     |
| D3      |        | CND3                     | Noise judgment threshold value setting                                                       |                |        | 1    | R/W |                          |   |                     |
|         |        |                          | CND3 CND2 CND1 CND0 Value                                                                    |                |        |      |     |                          |   |                     |
|         |        |                          | 0 0 0 0 4<br>0 0 0 1 8<br>0 0 1 0 12<br>0 0 1 1 16<br>0 1 0 0 20<br>0 1 0 1 24<br>0 1 1 0 28 |                |        |      |     |                          |   |                     |
| D2      |        | CND2                     | 0 1 1 1 32<br>1 0 0 0 36<br>1 0 0 1 40<br>1 0 1 0 44<br>1 0 1 1 48                           |                |        | 0    | R/W |                          |   |                     |
| D1      |        | CND1                     | 1 1 0 0 52<br>1 1 0 1 56<br>1 1 1 0 60<br>1 1 1 1 64                                         |                |        | 0    | R/W |                          |   |                     |
| D0      |        | CND0                     |                                                                                              |                |        |      |     |                          |   |                     |

Table 5.1.1(q) I/O Memory map (00FFA3H–00FFA4H)

| Address | Bit  | Name  | Function                                          | 1            | 0            | Init         | R/W | Comment             |     |     |                                                                     |              |   |    |
|---------|------|-------|---------------------------------------------------|--------------|--------------|--------------|-----|---------------------|-----|-----|---------------------------------------------------------------------|--------------|---|----|
| 00FFA3  | D7   | –     | –                                                 | –            | –            | –            | –   | "0" when being read |     |     |                                                                     |              |   |    |
|         | D6   | –     | –                                                 | –            | –            | –            | –   |                     |     |     |                                                                     |              |   |    |
|         | D5   | –     | –                                                 | –            | –            | –            | –   |                     |     |     |                                                                     |              |   |    |
|         | D4   | –     | –                                                 | –            | –            | –            | –   |                     |     |     |                                                                     |              |   |    |
|         | D3   | PUD3  | Pen-up decision threshold value setting           |              |              |              |     | 1                   | R/W |     |                                                                     |              |   |    |
|         |      |       | <u>PUD3</u>                                       | <u>PUD2</u>  | <u>PUD1</u>  |              |     |                     |     |     | <u>PUD0</u>                                                         | <u>Value</u> |   |    |
|         |      |       | 0                                                 | 0            | 0            |              |     |                     |     |     | 0                                                                   | 4            |   |    |
|         |      |       | 0                                                 | 0            | 0            |              |     |                     |     |     | 1                                                                   | 8            |   |    |
|         |      |       | 0                                                 | 0            | 1            |              |     |                     |     |     | 0                                                                   | 12           |   |    |
|         |      |       | 0                                                 | 0            | 1            |              |     |                     |     |     | 1                                                                   | 16           |   |    |
|         |      |       | 0                                                 | 1            | 0            |              |     |                     |     |     | 0                                                                   | 20           |   |    |
|         |      |       | 0                                                 | 1            | 0            |              |     |                     |     |     | 1                                                                   | 24           |   |    |
|         |      |       | 0                                                 | 1            | 1            |              |     |                     |     |     | 0                                                                   | 28           |   |    |
|         |      |       | D1                                                | PUD1         | 0            |              |     |                     |     |     | 1                                                                   | 1            | 1 | 32 |
|         |      |       |                                                   |              | 1            |              |     |                     |     |     | 0                                                                   | 0            | 0 | 36 |
|         |      |       |                                                   |              | 1            |              |     |                     |     |     | 0                                                                   | 0            | 1 | 40 |
| 1       | 0    | 1     |                                                   |              | 0            | 44           |     |                     |     |     |                                                                     |              |   |    |
| D0      | PUD0 | 1     | 0                                                 | 1            | 1            | 48           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 1                                                 | 0            | 0            | 52           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 1                                                 | 0            | 1            | 56           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 1                                                 | 1            | 0            | 60           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 1                                                 | 1            | 1            | 64           |     |                     |     |     |                                                                     |              |   |    |
| 00FFA4  | D7   | MVML3 | Middle-low-speed judgment threshold value setting |              |              |              |     |                     | 0   | R/W | Invalid in constant-speed mode<br>MVH≥MVMH<br>MVMH≥MVML<br>MVML≥MVL |              |   |    |
|         |      |       | <u>MVML3</u>                                      | <u>MVML2</u> | <u>MVML1</u> | <u>MVML0</u> |     |                     |     |     |                                                                     | <u>Value</u> |   |    |
|         |      |       | 0                                                 | 0            | 0            | 0            |     |                     |     |     |                                                                     | 2            |   |    |
|         |      |       | 0                                                 | 0            | 0            | 1            |     |                     |     |     |                                                                     | 4            |   |    |
|         | D6   | MVML2 | 0                                                 | 0            | 1            | 0            | 6   |                     |     |     |                                                                     |              |   |    |
|         |      |       | 0                                                 | 0            | 1            | 1            | 8   |                     |     |     |                                                                     |              |   |    |
|         |      |       | 0                                                 | 1            | 0            | 0            | 10  |                     |     |     |                                                                     |              |   |    |
|         |      |       | 0                                                 | 1            | 0            | 1            | 12  |                     |     |     |                                                                     |              |   |    |
|         | D5   | MVML1 | 0                                                 | 1            | 1            | 0            | 14  |                     |     |     |                                                                     |              |   |    |
|         |      |       | 0                                                 | 1            | 1            | 1            | 16  |                     |     |     |                                                                     |              |   |    |
|         |      |       | 1                                                 | 0            | 0            | 0            | 18  |                     |     |     |                                                                     |              |   |    |
|         |      |       | 1                                                 | 0            | 0            | 1            | 20  |                     |     |     |                                                                     |              |   |    |
|         | D4   | MVML0 | 1                                                 | 0            | 1            | 0            | 22  |                     |     |     |                                                                     |              |   |    |
|         |      |       | 1                                                 | 0            | 1            | 1            | 24  |                     |     |     |                                                                     |              |   |    |
|         |      |       | 1                                                 | 1            | 0            | 0            | 26  |                     |     |     |                                                                     |              |   |    |
|         |      |       | 1                                                 | 1            | 0            | 1            | 28  |                     |     |     |                                                                     |              |   |    |
|         | D3   | MVL3  | 1                                                 | 1            | 1            | 0            | 30  |                     |     |     |                                                                     |              |   |    |
|         |      |       | 1                                                 | 1            | 1            | 1            | 32  |                     |     |     |                                                                     |              |   |    |
|         |      |       | Low-speed judgment threshold value setting        |              |              |              |     |                     | 0   | R/W | Invalid in constant-speed mode<br>MVH≥MVMH<br>MVMH≥MVML<br>MVML≥MVL |              |   |    |
|         |      |       | <u>MVL3</u>                                       | <u>MVL2</u>  | <u>MVL1</u>  | <u>MVL0</u>  |     |                     |     |     |                                                                     | <u>Value</u> |   |    |
|         | 0    | 0     | 0                                                 | 0            | 2            |              |     |                     |     |     |                                                                     |              |   |    |
|         | 0    | 0     | 0                                                 | 1            | 4            |              |     |                     |     |     |                                                                     |              |   |    |
|         | D2   | MVL2  | 0                                                 | 0            | 1            | 0            | 6   |                     |     |     |                                                                     |              |   |    |
|         |      |       | 0                                                 | 0            | 1            | 1            | 8   |                     |     |     |                                                                     |              |   |    |
| 0       |      |       | 1                                                 | 0            | 0            | 10           |     |                     |     |     |                                                                     |              |   |    |
| 0       |      |       | 1                                                 | 0            | 1            | 12           |     |                     |     |     |                                                                     |              |   |    |
| D1      | MVL1 | 0     | 1                                                 | 1            | 0            | 14           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 0     | 1                                                 | 1            | 1            | 16           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 0                                                 | 0            | 0            | 18           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 0                                                 | 0            | 1            | 20           |     |                     |     |     |                                                                     |              |   |    |
| D0      | MVL0 | 1     | 0                                                 | 1            | 0            | 22           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 0                                                 | 1            | 1            | 24           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 1                                                 | 0            | 0            | 26           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 1                                                 | 0            | 1            | 28           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 1                                                 | 1            | 0            | 30           |     |                     |     |     |                                                                     |              |   |    |
|         |      | 1     | 1                                                 | 1            | 1            | 32           |     |                     |     |     |                                                                     |              |   |    |



Table 5.1.1(r) I/O Memory map (00FFA5H–00FFA6H)

| Address | Bit    | Name  | Function                                    | 1                                                  | 0            | Init         | R/W          | Comment              |                     |                                                                                          |                                                                                          |
|---------|--------|-------|---------------------------------------------|----------------------------------------------------|--------------|--------------|--------------|----------------------|---------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| 00FFA5  | D7     | MVH3  | High-speed judgment threshold value setting |                                                    |              |              |              | 1                    | R/W                 | Invalid in constant-speed mode<br>MVH $\geq$ MVMH<br>MVMH $\geq$ MVML<br>MVML $\geq$ MVL |                                                                                          |
|         |        |       | <u>MVH3</u>                                 | <u>MVH2</u>                                        | <u>MVH1</u>  | <u>MVH0</u>  | <u>Value</u> |                      |                     |                                                                                          |                                                                                          |
|         | D6     | MVH2  | 0                                           | 0                                                  | 0            | 0            | 2            | 0                    | R/W                 |                                                                                          |                                                                                          |
|         |        |       | 0                                           | 0                                                  | 0            | 1            | 4            |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 0                                           | 0                                                  | 1            | 0            | 6            |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 0                                           | 0                                                  | 1            | 1            | 8            |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 0                                           | 1                                                  | 0            | 0            | 10           |                      |                     |                                                                                          |                                                                                          |
|         | D5     | MVH1  | 0                                           | 1                                                  | 1            | 0            | 14           | 0                    | R/W                 |                                                                                          |                                                                                          |
|         |        |       | 0                                           | 1                                                  | 1            | 1            | 16           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 0                                                  | 0            | 0            | 18           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 0                                                  | 0            | 1            | 20           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 0                                                  | 1            | 0            | 22           |                      |                     |                                                                                          |                                                                                          |
|         | D4     | MVH0  | 1                                           | 0                                                  | 1            | 1            | 24           | 0                    | R/W                 |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 1                                                  | 0            | 0            | 26           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 1                                                  | 0            | 1            | 28           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 1                                                  | 1            | 0            | 30           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 1                                                  | 1            | 1            | 32           |                      |                     |                                                                                          |                                                                                          |
|         | 00FFA5 | D3    | MVMH3                                       | Middle-high-speed judgment threshold value setting |              |              |              |                      | 0                   | R/W                                                                                      | Invalid in constant-speed mode<br>MVH $\geq$ MVMH<br>MVMH $\geq$ MVML<br>MVML $\geq$ MVL |
|         |        |       |                                             | <u>MVMH3</u>                                       | <u>MVMH2</u> | <u>MVMH1</u> | <u>MVMH0</u> | <u>Value</u>         |                     |                                                                                          |                                                                                          |
|         |        | D2    | MVMH2                                       | 0                                                  | 0            | 0            | 0            | 2                    | 1                   | R/W                                                                                      |                                                                                          |
|         |        |       |                                             | 0                                                  | 0            | 0            | 1            | 4                    |                     |                                                                                          |                                                                                          |
|         |        |       |                                             | 0                                                  | 0            | 1            | 0            | 6                    |                     |                                                                                          |                                                                                          |
|         |        |       |                                             | 0                                                  | 0            | 1            | 1            | 8                    |                     |                                                                                          |                                                                                          |
|         |        |       |                                             | 0                                                  | 1            | 0            | 0            | 10                   |                     |                                                                                          |                                                                                          |
| D1      |        | MVMH1 | 0                                           | 1                                                  | 0            | 1            | 12           | 1                    | R/W                 |                                                                                          |                                                                                          |
|         |        |       | 0                                           | 1                                                  | 1            | 0            | 14           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 0                                           | 1                                                  | 1            | 1            | 16           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 0                                                  | 0            | 0            | 18           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 0                                                  | 0            | 1            | 20           |                      |                     |                                                                                          |                                                                                          |
| D0      |        | MVMH0 | 1                                           | 0                                                  | 1            | 0            | 22           | 0                    | R/W                 |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 0                                                  | 1            | 1            | 24           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 1                                                  | 0            | 0            | 26           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 1                                                  | 0            | 1            | 28           |                      |                     |                                                                                          |                                                                                          |
|         |        |       | 1                                           | 1                                                  | 1            | 0            | 30           |                      |                     |                                                                                          |                                                                                          |
| 00FFA6  |        | D7    | –                                           | –                                                  | –            | –            | –            | –                    | "0" when being read |                                                                                          |                                                                                          |
|         |        | D6    | –                                           | –                                                  | –            | –            | –            | –                    |                     |                                                                                          |                                                                                          |
|         |        | D5    | –                                           | –                                                  | –            | –            | –            | –                    |                     |                                                                                          |                                                                                          |
|         |        | D4    | –                                           | –                                                  | –            | –            | –            | –                    |                     |                                                                                          |                                                                                          |
|         |        | D3    | IVL3                                        | Interval time setting                              |              |              |              |                      | 0                   | R/W                                                                                      |                                                                                          |
|         |        |       |                                             | <u>IVL3</u>                                        | <u>IVL2</u>  | <u>IVL1</u>  | <u>IVL0</u>  | <u>Interval time</u> |                     |                                                                                          |                                                                                          |
|         |        | D2    | IVL2                                        | 0                                                  | 0            | 0            | 0            | 128 $\times$ 1       | 0                   | R/W                                                                                      |                                                                                          |
|         | 0      |       |                                             | 0                                                  | 0            | 1            | $\times$ 2   |                      |                     |                                                                                          |                                                                                          |
|         | 0      |       |                                             | 0                                                  | 1            | 0            | $\times$ 3   |                      |                     |                                                                                          |                                                                                          |
|         | 0      |       |                                             | 0                                                  | 1            | 1            | $\times$ 4   |                      |                     |                                                                                          |                                                                                          |
| 0       | 1      |       |                                             | 0                                                  | 0            | $\times$ 5   |              |                      |                     |                                                                                          |                                                                                          |
| D1      | IVL1   | 0     | 1                                           | 0                                                  | 1            | $\times$ 6   | 1            | R/W                  |                     |                                                                                          |                                                                                          |
|         |        | 0     | 1                                           | 1                                                  | 0            | $\times$ 7   |              |                      |                     |                                                                                          |                                                                                          |
|         |        | 0     | 1                                           | 1                                                  | 1            | $\times$ 8   |              |                      |                     |                                                                                          |                                                                                          |
|         |        | 1     | 0                                           | 0                                                  | 0            | $\times$ 9   |              |                      |                     |                                                                                          |                                                                                          |
|         |        | 1     | 0                                           | 0                                                  | 1            | $\times$ 10  |              |                      |                     |                                                                                          |                                                                                          |
| D0      | IVL0   | 1     | 0                                           | 1                                                  | 0            | $\times$ 11  | 0            | R/W                  |                     |                                                                                          |                                                                                          |
|         |        | 1     | 0                                           | 1                                                  | 1            | $\times$ 12  |              |                      |                     |                                                                                          |                                                                                          |
|         |        | 1     | 1                                           | 0                                                  | 0            | $\times$ 13  |              |                      |                     |                                                                                          |                                                                                          |
|         |        | 1     | 1                                           | 0                                                  | 1            | $\times$ 14  |              |                      |                     |                                                                                          |                                                                                          |
|         |        | 1     | 1                                           | 1                                                  | 0            | $\times$ 15  |              |                      |                     |                                                                                          |                                                                                          |
|         |        | 1     | 1                                           | 1                                                  | 1            | $\times$ 16  |              |                      |                     |                                                                                          |                                                                                          |

Table 5.1.1(s) I/O Memory map (00FFA7H–00FFABH)

| Address | Bit | Name | Function               | 1                 | 0        | Init   | R/W | Comment             |   |
|---------|-----|------|------------------------|-------------------|----------|--------|-----|---------------------|---|
| 00FFA7  | D7  | –    | –                      | –                 | –        | –      | –   | "0" when being read |   |
|         | D6  | –    | –                      | –                 | –        | –      | –   |                     |   |
|         | D5  | –    | –                      | –                 | –        | –      | –   |                     |   |
|         | D4  | –    | –                      | –                 | –        | –      | –   |                     |   |
|         | D3  | –    | –                      | –                 | –        | –      | –   |                     |   |
|         | D2  | –    | –                      | –                 | –        | –      | –   |                     |   |
|         | D1  | –    | –                      | –                 | –        | –      | –   |                     |   |
|         | D0  | PEN  | Pen-up/pen-down status |                   | Pen-down | Pen-up | 0   |                     | R |
| 00FFA8  | D7  | DX11 | X coordinate data      | D11(MSB)          |          |        | 0   | R                   |   |
|         | D6  | DX10 |                        | D10               |          |        | 0   | R                   |   |
|         | D5  | DX9  |                        | D9                |          |        | 0   | R                   |   |
|         | D4  | DX8  |                        | D8                |          |        | 0   | R                   |   |
|         | D3  | DX7  |                        | D7                |          |        | 0   | R                   |   |
|         | D2  | DX6  |                        | D6                |          |        | 0   | R                   |   |
|         | D1  | DX5  |                        | D5                |          |        | 0   | R                   |   |
|         | D0  | DX4  |                        | D4                |          |        | 0   | R                   |   |
| 00FFA9  | D7  | –    | –                      |                   |          |        | –   | "0" when being read |   |
|         | D6  | –    | –                      |                   |          |        | –   |                     |   |
|         | D5  | –    | –                      |                   |          |        | –   |                     |   |
|         | D4  | –    | –                      |                   |          |        | –   |                     |   |
|         | D3  | DX3  | X coordinate data      | D3                |          |        | 0   |                     | R |
|         | D2  | DX2  |                        | D2                |          |        | 0   |                     | R |
|         | D1  | DX1  |                        | D1                |          |        | 0   |                     | R |
|         | D0  | DX0  |                        | D0(LSB)           |          |        | 0   |                     | R |
| 00FFAA  | D7  | DY11 |                        | Y coordinate data | D11(MSB) |        |     | 0                   | R |
|         | D6  | DY10 | D10                    |                   |          |        | 0   | R                   |   |
|         | D5  | DY9  | D9                     |                   |          |        | 0   | R                   |   |
|         | D4  | DY8  | D8                     |                   |          |        | 0   | R                   |   |
|         | D3  | DY7  | D7                     |                   |          |        | 0   | R                   |   |
|         | D2  | DY6  | D6                     |                   |          |        | 0   | R                   |   |
|         | D1  | DY5  | D5                     |                   |          |        | 0   | R                   |   |
|         | D0  | DY4  | D4                     |                   |          |        | 0   | R                   |   |
| 00FFAB  | D7  | –    | –                      |                   |          |        | –   | "0" when being read |   |
|         | D6  | –    | –                      |                   |          |        | –   |                     |   |
|         | D5  | –    | –                      |                   |          |        | –   |                     |   |
|         | D4  | –    | –                      |                   |          |        | –   |                     |   |
|         | D3  | DY3  | Y coordinate data      | D3                |          |        | 0   |                     | R |
|         | D2  | DY2  |                        | D2                |          |        | 0   |                     | R |
|         | D1  | DY1  |                        | D1                |          |        | 0   |                     | R |
|         | D0  | DY0  |                        | D0(LSB)           |          |        | 0   |                     | R |

Table 5.1.1(t) I/O Memory map (00FFC0H–00FFC4H)

| Address | Bit | Name  | Function                         | 1                                | 0                               | Init | R/W | Comment             |
|---------|-----|-------|----------------------------------|----------------------------------|---------------------------------|------|-----|---------------------|
| 00FFC0  | D7  | SIK07 | K07 interrupt selection register | Interrupt is enabled             | Interrupt is disabled           | 0    | R/W |                     |
|         | D6  | SIK06 | K06 interrupt selection register |                                  |                                 | 0    | R/W |                     |
|         | D5  | SIK05 | K05 interrupt selection register |                                  |                                 | 0    | R/W |                     |
|         | D4  | SIK04 | K04 interrupt selection register |                                  |                                 | 0    | R/W |                     |
|         | D3  | SIK03 | K03 interrupt selection register |                                  |                                 | 0    | R/W |                     |
|         | D2  | SIK02 | K02 interrupt selection register |                                  |                                 | 0    | R/W |                     |
|         | D1  | SIK01 | K01 interrupt selection register |                                  |                                 | 0    | R/W |                     |
|         | D0  | SIK00 | K00 interrupt selection register |                                  |                                 | 0    | R/W |                     |
| 00FFC1  | D7  | KCP07 | K07 input comparison register    | Falling edge generates interrupt | Rising edge generates interrupt | 1    | R/W |                     |
|         | D6  | KCP06 | K06 input comparison register    |                                  |                                 | 1    | R/W |                     |
|         | D5  | KCP05 | K05 input comparison register    |                                  |                                 | 1    | R/W |                     |
|         | D4  | KCP04 | K04 input comparison register    |                                  |                                 | 1    | R/W |                     |
|         | D3  | KCP03 | K03 input comparison register    |                                  |                                 | 1    | R/W |                     |
|         | D2  | KCP02 | K02 input comparison register    |                                  |                                 | 1    | R/W |                     |
|         | D1  | KCP01 | K01 input comparison register    |                                  |                                 | 1    | R/W |                     |
|         | D0  | KCP00 | K00 input comparison register    |                                  |                                 | 1    | R/W |                     |
| 00FFC2  | D7  | –     | –                                | –                                | –                               | –    | –   | "0" when being read |
|         | D6  | –     | –                                | –                                | –                               | –    | –   |                     |
|         | D5  | –     | –                                | –                                | –                               | –    | –   |                     |
|         | D4  | –     | –                                | –                                | –                               | –    | –   |                     |
|         | D3  | KCP13 | K13 input comparison register    | Falling edge generates interrupt | Rising edge generates interrupt | 1    | R/W |                     |
|         | D2  | KCP12 | K12 input comparison register    |                                  |                                 | 1    | R/W |                     |
|         | D1  | KCP11 | K11 input comparison register    |                                  |                                 | 1    | R/W |                     |
|         | D0  | KCP10 | K10 input comparison register    |                                  |                                 | 1    | R/W |                     |
| 00FFC3  | D7  | K07D  | K07 input port data              | High                             | Low                             | –    | R   |                     |
|         | D6  | K06D  | K06 input port data              |                                  |                                 | –    | R   |                     |
|         | D5  | K05D  | K05 input port data              |                                  |                                 | –    | R   |                     |
|         | D4  | K04D  | K04 input port data              |                                  |                                 | –    | R   |                     |
|         | D3  | K03D  | K03 input port data              |                                  |                                 | –    | R   |                     |
|         | D2  | K02D  | K02 input port data              |                                  |                                 | –    | R   |                     |
|         | D1  | K01D  | K01 input port data              |                                  |                                 | –    | R   |                     |
|         | D0  | K00D  | K00 input port data              |                                  |                                 | –    | R   |                     |
| 00FFC4  | D7  | –     | –                                | –                                | –                               | –    | –   | "0" when being read |
|         | D6  | –     | –                                | –                                | –                               | –    | –   |                     |
|         | D5  | –     | –                                | –                                | –                               | –    | –   |                     |
|         | D4  | –     | –                                | –                                | –                               | –    | –   |                     |
|         | D3  | K13D  | K13 input port data              | High                             | Low                             | –    | R   |                     |
|         | D2  | K12D  | K12 input port data              |                                  |                                 | –    | R   |                     |
|         | D1  | K11D  | K11 input port data              |                                  |                                 | –    | R   |                     |
|         | D0  | K10D  | K10 input port data              |                                  |                                 | –    | R   |                     |

Table 5.1.1(u) I/O Memory map (00FFD0H–00FFD4H)

| Address | Bit | Name  | Function                            | 1              | 0             | Init | R/W | Comment             |
|---------|-----|-------|-------------------------------------|----------------|---------------|------|-----|---------------------|
| 00FFD0  | D7  | HZR07 | R07 high impedance control register | High impedance | Complementary | 1    | R/W |                     |
|         | D6  | HZR06 | R06 high impedance control register |                |               | 1    | R/W |                     |
|         | D5  | HZR05 | R05 high impedance control register |                |               | 1    | R/W |                     |
|         | D4  | HZR04 | R04 high impedance control register |                |               | 1    | R/W |                     |
|         | D3  | HZR03 | R03 high impedance control register |                |               | 1    | R/W |                     |
|         | D2  | HZR02 | R02 high impedance control register |                |               | 1    | R/W |                     |
|         | D1  | HZR01 | R01 high impedance control register |                |               | 1    | R/W |                     |
|         | D0  | HZR00 | R00 high impedance control register |                |               | 1    | R/W |                     |
| 00FFD1  | D7  | HZR17 | R17 high impedance control register | High impedance | Complementary | 1    | R/W |                     |
|         | D6  | HZR16 | R16 high impedance control register |                |               | 1    | R/W |                     |
|         | D5  | HZR15 | R15 high impedance control register |                |               | 1    | R/W |                     |
|         | D4  | HZR14 | R14 high impedance control register |                |               | 1    | R/W |                     |
|         | D3  | HZR13 | R13 high impedance control register |                |               | 1    | R/W |                     |
|         | D2  | HZR12 | R12 high impedance control register |                |               | 1    | R/W |                     |
|         | D1  | HZR11 | R11 high impedance control register |                |               | 1    | R/W |                     |
|         | D0  | HZR10 | R10 high impedance control register |                |               | 1    | R/W |                     |
| 00FFD2  | D7  | HZR27 | R27 high impedance control register | High impedance | Complementary | 1    | R/W |                     |
|         | D6  | HZR26 | R26 high impedance control register |                |               | 1    | R/W |                     |
|         | D5  | HZR25 | R25 high impedance control register |                |               | 1    | R/W |                     |
|         | D4  | HZR24 | R24 high impedance control register |                |               | 1    | R/W |                     |
|         | D3  | HZR23 | R23 high impedance control register |                |               | 1    | R/W |                     |
|         | D2  | HZR22 | R22 high impedance control register |                |               | 1    | R/W |                     |
|         | D1  | HZR21 | R21 high impedance control register |                |               | 1    | R/W |                     |
|         | D0  | HZR20 | R20 high impedance control register |                |               | 1    | R/W |                     |
| 00FFD3  | D7  | –     | –                                   | –              | –             | –    | –   | "0" when being read |
|         | D6  | –     | –                                   | –              | –             | –    | –   |                     |
|         | D5  | –     | –                                   | –              | –             | –    | –   |                     |
|         | D4  | –     | –                                   | –              | –             | –    | –   |                     |
|         | D3  | –     | –                                   | –              | –             | –    | –   |                     |
|         | D2  | HZR32 | R32 high impedance control register | High impedance | Complementary | 1    | R/W |                     |
|         | D1  | HZR31 | R31 high impedance control register |                |               | 1    | R/W |                     |
|         | D0  | HZR30 | R30 high impedance control register |                |               | 1    | R/W |                     |
|         |     |       |                                     |                |               |      |     |                     |
| 00FFD4  | D7  | –     | –                                   | –              | –             | –    | –   | "0" when being read |
|         | D6  | –     | –                                   | –              | –             | –    | –   |                     |
|         | D5  | –     | –                                   | –              | –             | –    | –   |                     |
|         | D4  | –     | –                                   | –              | –             | –    | –   |                     |
|         | D3  | –     | –                                   | –              | –             | –    | –   |                     |
|         | D2  | HZR42 | R42 high impedance control register | High impedance | Complementary | 1    | R/W |                     |
|         | D1  | HZR41 | R41 high impedance control register |                |               | 1    | R/W |                     |
|         | D0  | HZR40 | R40 high impedance control register |                |               | 1    | R/W |                     |
|         |     |       |                                     |                |               |      |     |                     |

Table 5.1.1(v) I/O Memory map (00FFD5H–00FFD9H)

| Address | Bit | Name | Function                      | 1    | 0   | Init | R/W | Comment             |
|---------|-----|------|-------------------------------|------|-----|------|-----|---------------------|
| 00FFD5  | D7  | R07D | R07 output port data register | High | Low | 1    | R/W |                     |
|         | D6  | R06D | R06 output port data register |      |     | 1    | R/W |                     |
|         | D5  | R05D | R05 output port data register |      |     | 1    | R/W |                     |
|         | D4  | R04D | R04 output port data register |      |     | 1    | R/W |                     |
|         | D3  | R03D | R03 output port data register |      |     | 1    | R/W |                     |
|         | D2  | R02D | R02 output port data register |      |     | 1    | R/W |                     |
|         | D1  | R01D | R01 output port data register |      |     | 1    | R/W |                     |
|         | D0  | R00D | R00 output port data register |      |     | 1    | R/W |                     |
| 00FFD6  | D7  | R17D | R17 output port data register | High | Low | 1    | R/W |                     |
|         | D6  | R16D | R16 output port data register |      |     | 1    | R/W |                     |
|         | D5  | R15D | R15 output port data register |      |     | 1    | R/W |                     |
|         | D4  | R14D | R14 output port data register |      |     | 1    | R/W |                     |
|         | D3  | R13D | R13 output port data register |      |     | 1    | R/W |                     |
|         | D2  | R12D | R12 output port data register |      |     | 1    | R/W |                     |
|         | D1  | R11D | R11 output port data register |      |     | 1    | R/W |                     |
|         | D0  | R10D | R10 output port data register |      |     | 1    | R/W |                     |
| 00FFD7  | D7  | R27D | R27 output port data register | High | Low | 1    | R/W |                     |
|         | D6  | R26D | R26 output port data register |      |     | 1    | R/W |                     |
|         | D5  | R25D | R25 output port data register |      |     | 1    | R/W |                     |
|         | D4  | R24D | R24 output port data register |      |     | 1    | R/W |                     |
|         | D3  | R23D | R23 output port data register |      |     | 1    | R/W |                     |
|         | D2  | R22D | R22 output port data register |      |     | 1    | R/W |                     |
|         | D1  | R21D | R21 output port data register |      |     | 1    | R/W |                     |
|         | D0  | R20D | R20 output port data register |      |     | 1    | R/W |                     |
| 00FFD8  | D7  | –    | –                             | –    | –   | –    | –   | "0" when being read |
|         | D6  | –    | –                             | –    | –   | –    | –   |                     |
|         | D5  | –    | –                             | –    | –   | –    | –   |                     |
|         | D4  | –    | –                             | –    | –   | –    | –   |                     |
|         | D3  | –    | –                             | –    | –   | –    | –   |                     |
|         | D2  | R32D | R32 output port data register | High | Low | 1    | R/W |                     |
|         | D1  | R31D | R31 output port data register |      |     | 1    | R/W |                     |
|         | D0  | R30D | R30 output port data register |      |     | 1    | R/W |                     |
|         |     |      |                               |      |     |      |     |                     |
| 00FFD9  | D7  | –    | –                             | –    | –   | –    | –   | "0" when being read |
|         | D6  | –    | –                             | –    | –   | –    | –   |                     |
|         | D5  | –    | –                             | –    | –   | –    | –   |                     |
|         | D4  | –    | –                             | –    | –   | –    | –   |                     |
|         | D3  | –    | –                             | –    | –   | –    | –   |                     |
|         | D2  | R42D | R42 output port data register | High | Low | 1    | R/W |                     |
|         | D1  | R41D | R41 output port data register |      |     | 1    | R/W |                     |
|         | D0  | R40D | R40 output port data register |      |     | 1    | R/W |                     |
|         |     |      |                               |      |     |      |     |                     |

Table 5.1.1(w) I/O Memory map (00FFE0H–00FFE6H)

| Address | Bit    | Name  | Function                   | 1                          | 0      | Init  | R/W | Comment             |  |
|---------|--------|-------|----------------------------|----------------------------|--------|-------|-----|---------------------|--|
| 00FFE0  | D7     | IOC07 | P07 I/O control register   | Output                     | Input  | 0     | R/W |                     |  |
|         | D6     | IOC06 | P06 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D5     | IOC05 | P05 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D4     | IOC04 | P04 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D3     | IOC03 | P03 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D2     | IOC02 | P02 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D1     | IOC01 | P01 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D0     | IOC00 | P00 I/O control register   |                            |        | 0     | R/W |                     |  |
| 00FFE1  | D7     | IOC17 | P17 I/O control register   | Output                     | Input  | 0     | R/W |                     |  |
|         | D6     | IOC16 | P16 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D5     | IOC15 | P15 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D4     | IOC14 | P14 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D3     | IOC13 | P13 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D2     | IOC12 | P12 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D1     | IOC11 | P11 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D0     | IOC10 | P10 I/O control register   |                            |        | 0     | R/W |                     |  |
| 00FFE2  | D7     | –     | –                          | –                          | –      | –     | –   | "0" when being read |  |
|         | D6     | –     | –                          | –                          | –      | –     | –   |                     |  |
|         | D5     | –     | –                          | –                          | –      | –     | –   |                     |  |
|         | D4     | –     | –                          | –                          | –      | –     | –   |                     |  |
|         | 00FFE2 | D3    | IOC23                      | P23 I/O control register   | Output | Input | 0   | R/W                 |  |
|         |        | D2    | IOC22                      | P22 I/O control register   |        |       | 0   | R/W                 |  |
|         |        | D1    | IOC21                      | P21 I/O control register   |        |       | 0   | R/W                 |  |
|         |        | D0    | IOC20                      | P20 I/O control register   |        |       | 0   | R/W                 |  |
| 00FFE3  | D7     | IOC37 | P37 I/O control register   | Output                     | Input  | 0     | R/W |                     |  |
|         | D6     | IOC36 | P36 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D5     | IOC35 | P35 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D4     | IOC34 | P34 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D3     | IOC33 | P33 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D2     | IOC32 | P32 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D1     | IOC31 | P31 I/O control register   |                            |        | 0     | R/W |                     |  |
|         | D0     | IOC30 | P30 I/O control register   |                            |        | 0     | R/W |                     |  |
| 00FFE4  | D7     | P07D  | P07 I/O port data register | High                       | Low    | 1     | R/W |                     |  |
|         | D6     | P06D  | P06 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D5     | P05D  | P05 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D4     | P04D  | P04 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D3     | P03D  | P03 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D2     | P02D  | P02 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D1     | P01D  | P01 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D0     | P00D  | P00 I/O port data register |                            |        | 1     | R/W |                     |  |
| 00FFE5  | D7     | P17D  | P17 I/O port data register | High                       | Low    | 1     | R/W |                     |  |
|         | D6     | P16D  | P16 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D5     | P15D  | P15 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D4     | P14D  | P14 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D3     | P13D  | P13 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D2     | P12D  | P12 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D1     | P11D  | P11 I/O port data register |                            |        | 1     | R/W |                     |  |
|         | D0     | P10D  | P10 I/O port data register |                            |        | 1     | R/W |                     |  |
| 00FFE6  | D7     | –     | –                          | –                          | –      | –     | –   | "0" when being read |  |
|         | D6     | –     | –                          | –                          | –      | –     | –   |                     |  |
|         | D5     | –     | –                          | –                          | –      | –     | –   |                     |  |
|         | D4     | –     | –                          | –                          | –      | –     | –   |                     |  |
|         | 00FFE6 | D3    | P23D                       | P23 I/O port data register | High   | Low   | 1   | R/W                 |  |
|         |        | D2    | P22D                       | P22 I/O port data register |        |       | 1   | R/W                 |  |
|         |        | D1    | P21D                       | P21 I/O port data register |        |       | 1   | R/W                 |  |
|         |        | D0    | P20D                       | P20 I/O port data register |        |       | 1   | R/W                 |  |

Note: At initial reset, the data registers at addresses "00FFE4H", "00FFE5H" and "00FFE6H" are set to "1".

Table 5.1.1(x) I/O Memory map (00FFE7H–00FFE9H)

| Address | Bit | Name | Function                         | 1                       | 0        | Init | R/W | Comment             |
|---------|-----|------|----------------------------------|-------------------------|----------|------|-----|---------------------|
| 00FFE7  | D7  | P37D | P37 I/O port data register       | High                    | Low      | 1    | R/W |                     |
|         | D6  | P36D | P36 I/O port data register       |                         |          | 1    | R/W |                     |
|         | D5  | P35D | P35 I/O port data register       |                         |          | 1    | R/W |                     |
|         | D4  | P34D | P34 I/O port data register       |                         |          | 1    | R/W |                     |
|         | D3  | P33D | P33 I/O port data register       |                         |          | 1    | R/W |                     |
|         | D2  | P32D | P32 I/O port data register       |                         |          | 1    | R/W |                     |
|         | D1  | P31D | P31 I/O port data register       |                         |          | 1    | R/W |                     |
|         | D0  | P30D | P30 I/O port data register       |                         |          | 1    | R/W |                     |
| 00FFE8  | D7  | PAD7 | P37 A/D converter input control  | A/D converter<br>input  | I/O port | 0    | R/W |                     |
|         | D6  | PAD6 | P36 A/D converter input control  |                         |          | 0    | R/W |                     |
|         | D5  | PAD5 | P35 A/D converter input control  |                         |          | 0    | R/W |                     |
|         | D4  | PAD4 | P34 A/D converter input control  |                         |          | 0    | R/W |                     |
|         | D3  | PAD3 | P33 A/D converter input control  |                         |          | 0    | R/W |                     |
|         | D2  | PAD2 | P32 A/D converter input control  |                         |          | 0    | R/W |                     |
|         | D1  | PAD1 | P31 A/D converter input control  |                         |          | 0    | R/W |                     |
|         | D0  | PAD0 | P30 A/D converter input control  |                         |          | 0    | R/W |                     |
| 00FFE9  | D7  | PDA7 | P37 D/A converter output control | D/A converter<br>output | I/O port | 0    | R/W | "0" when being read |
|         | D6  | PDA6 | P36 D/A converter output control |                         |          | 0    | R/W |                     |
|         | D5  | –    | –                                | –                       | –        | –    | –   |                     |
|         | D4  | –    | –                                | –                       | –        | –    | –   |                     |
|         | D3  | –    | –                                | –                       | –        | –    | –   |                     |
|         | D2  | –    | –                                | –                       | –        | –    | –   |                     |
|         | D1  | –    | –                                | –                       | –        | –    | –   |                     |
|         | D0  | –    | –                                | –                       | –        | –    | –   |                     |

Note: At initial reset, the data register at address "00FFE7H" is set to "1".

## 5.2 System Controller and Bus Control

The system controller is a control unit which sets the bus mode according to the system configuration such as the external memory. The software can set the following items to control the system.

- (1) Bus mode (CPU mode)
- (2) Chip enable ( $\overline{CE}$ ) signal output
- (3) WAIT state for external memory

The following explains the settings.

### 5.2.1 Bus mode settings

The S1C88409 has four bus modes as shown in Section 3.5.2, "Bus mode". The bus mode should be set according to the capacity of the memory expanded.

The bus mode can be set by writing to the BSMD register (two bits) as shown in Table 5.2.1.1.

At initial reset, the bus mode is set as follows:

#### MCU mode:

At initial reset, the S1C88409 is set in the single chip mode.

Accordingly, the system is activated by the program written to the internal ROM in the MCU mode even if the external memory has been expanded.

When the external memory has been expanded, set the corresponding bus mode with the initial routine written in the internal ROM.

#### MPU mode:

When the MPU mode is used, the expanded mode (expanded 64K mode, expanded 4M minimum mode or expanded 4M maximum mode) at initial reset, has to have been previously selected by the mask option.

Set it according to the system configuration.

The function of I/O terminals is set as shown in Table 5.2.1.2 depending on the mode selection.

Table 5.2.1.1 Bus mode settings

| Setting value |       | Bus mode                                            | Configuration of external memory      |
|---------------|-------|-----------------------------------------------------|---------------------------------------|
| BSMD1         | BSMD0 |                                                     |                                       |
| 1             | 1     | Expanded 4M maximum mode                            | ROM+RAM>64K bytes (Program>64K bytes) |
| 1             | 0     | Expanded 4M minimum mode                            | ROM+RAM>64K bytes (Program≤64K bytes) |
| 0             | 1     | Expanded 64K mode                                   | ROM+RAM≤64K bytes                     |
| 0             | 0     | Single chip mode (MCU)                              | None                                  |
|               |       | Optional setting of one of the expanded modes (MPU) | See above                             |

\* The single chip mode can be set only when the S1C88409 is used in the MCU mode.

In the MPU mode, the single chip mode cannot be set since the MPU mode does not use the internal ROM.

When using the S1C88409 in the MPU mode, it is necessary to select the bus mode at initial reset (and when the BSMD register is set to "0") by mask option from the three types of expanded modes: expanded 64K mode, expanded 4M minimum mode and expanded 4M maximum mode.

Select the expanded 4M maximum mode, when the MPU mode is not used.



Table 5.2.1.2 I/O terminal settings

| Terminal | Bus mode        |              |                        |
|----------|-----------------|--------------|------------------------|
|          | Single chip     | Expanded 64K | Expanded 4M            |
| R00      | Output port R00 |              | Address bus A0         |
| R01      | Output port R01 |              | Address bus A1         |
| R02      | Output port R02 |              | Address bus A2         |
| R03      | Output port R03 |              | Address bus A3         |
| R04      | Output port R04 |              | Address bus A4         |
| R05      | Output port R05 |              | Address bus A5         |
| R06      | Output port R06 |              | Address bus A6         |
| R07      | Output port R07 |              | Address bus A7         |
| R10      | Output port R10 |              | Address bus A8         |
| R11      | Output port R11 |              | Address bus A9         |
| R12      | Output port R12 |              | Address bus A10        |
| R13      | Output port R13 |              | Address bus A11        |
| R14      | Output port R14 |              | Address bus A12        |
| R15      | Output port R15 |              | Address bus A13        |
| R16      | Output port R16 |              | Address bus A14        |
| R17      | Output port R17 |              | Address bus A15        |
| R20      | Output port R20 |              | Address bus A16        |
| R21      | Output port R21 |              | Address bus A17        |
| R22      | Output port R22 |              | Address bus A18        |
| R23      | Output port R23 |              | Address bus A19        |
| R24      | Output port R24 |              | Address bus A20        |
| R25      | Output port R25 |              | Address bus A21        |
| R26      | Output port R26 |              | $\overline{RD}$ signal |
| R27      | Output port R27 |              | $\overline{WR}$ signal |
| P00      | I/O port P00    |              | Data bus D0            |
| P01      | I/O port P01    |              | Data bus D1            |
| P02      | I/O port P02    |              | Data bus D2            |
| P03      | I/O port P03    |              | Data bus D3            |
| P04      | I/O port P04    |              | Data bus D4            |
| P05      | I/O port P05    |              | Data bus D5            |
| P06      | I/O port P06    |              | Data bus D6            |
| P07      | I/O port P07    |              | Data bus D7            |

**5.2.2 Address decoder ( $\overline{CE}$  output) settings**

As explained in Section 3.6.4, the S1C88409 has a built-in address decoder that can output up to three chip enable signals ( $\overline{CE0}$ – $\overline{CE2}$ ) to external devices.

The output terminals and output circuits for  $\overline{CE0}$ – $\overline{CE2}$  are shared with the output ports R30–R32. At initial reset, they are set as the  $\overline{CE}$  terminals. Unused  $\overline{CE}$  terminals can be set to general-purpose output port terminals by writing "0" to the  $\overline{CE0}$ – $\overline{CE2}$  registers.

Table 5.2.2.1 shows the address range assigned to the chip enable ( $\overline{CE}$ ) signals.

External devices can be allocated to an area selected with an optional chip enable signal.

It is not necessary to continue from a lower address of the memory space. However in the MPU mode, the program memory must be assigned to  $\overline{CE0}$ .

In the expanded 4M mode, the address range of each  $\overline{CE}$  signal is fixed.

In the expanded 64K mode, four address ranges can be selected using the CEMD register (two bits) according to the memory to be used.

These signals are output only when the corresponding external memory area is accessed and are not output when the internal memory is accessed.

Furthermore, when the CPU is in standby status (HALT, SLEEP), all the  $\overline{CE}$  signals go HIGH to disable external memory access.

Table 5.2.2.1 Address settings of  $\overline{CE0}$ – $\overline{CE2}$

(1) Expanded 64K mode + MCU mode

| CEMD1 | CEMD0 | Chip size | $\overline{CE0}$ | $\overline{CE1}$ | $\overline{CE2}$ |
|-------|-------|-----------|------------------|------------------|------------------|
| 1     | 1     | –         | –                | –                | –                |
| 1     | 0     | 32KB      | 008000H–00EFFFH  | –                | –                |
| 0     | 1     | 16KB      | 007000H–00AFFFH  | 00B000H–00EFFFH  | –                |
| 0     | 0     | 8KB       | 008000H–009FFFH  | 00A000H–00BFFFH  | 00C000H–00DFFFH  |

(2) Expanded 64K mode + MPU mode

| CEMD1 | CEMD0 | Chip size | $\overline{CE0}$ | $\overline{CE1}$ | $\overline{CE2}$ |
|-------|-------|-----------|------------------|------------------|------------------|
| 1     | 1     | 64KB      | 000000H–00EFFFH  | –                | –                |
| 1     | 0     | 32KB      | 000000H–007FFFH  | 008000H–00EFFFH  | –                |
| 0     | 1     | 16KB      | 000000H–003FFFH  | 004000H–007FFFH  | 008000H–00BFFFH  |
| 0     | 0     | 8KB       | 000000H–001FFFH  | 002000H–003FFFH  | 004000H–005FFFH  |

(3) Expanded 4M minimum/maximum mode

| $\overline{CE}$ signal | Address range    |                                   |
|------------------------|------------------|-----------------------------------|
|                        | MCU mode         | MPU mode                          |
| $\overline{CE0}$       | C00000H–FFFFFFH  | 000000H–00EFFFH, 010000H–3FFFFFFH |
| $\overline{CE1}$       | 400000H–7FFFFFFH | 400000H–7FFFFFFH                  |
| $\overline{CE2}$       | 800000H–BFFFFFFH | 800000H–BFFFFFFH                  |

**5.2.3 WAIT state settings**

In order to guarantee accessing of external low speed devices during high speed operation, the S1C88409 is equipped with a WAIT function that prolongs access time.

The number of wait states to be inserted can be selected from four values by the WT register (two bits) as shown in Table 5.2.3.1.

The WAIT states that are set with software are inserted between the bus cycle states T3 and T4. Note, however, that WAIT states cannot be inserted when an internal register or internal memory are being accessed and when the CPU operates with the OSC1 oscillation clock (see Section 5.4, "Oscillation Circuit").

Consequently, WAIT state settings are invalid in the single chip mode.

Table 5.2.3.1 Setting the number of WAIT states

| WT1 | WT0 | Number of inserted states |
|-----|-----|---------------------------|
| 1   | 1   | 12                        |
| 1   | 0   | 8                         |
| 0   | 1   | 4                         |
| 0   | 0   | No wait                   |

\* The length of one state is 1/2 a cycle of the clock.

Refer to Section 3.6.5, "WAIT control", for the timing chart for WAIT insertion.

### 5.2.4 I/O memory of system controller

Table 5.2.4.1 shows the control bits for the system controller.

Table 5.2.4.1 System controller control bits

| Address | Bit    | Name                            | Function                                                                                | 1                | 0             | Init | R/W | Comment                                                       |                                                                                   |                       |
|---------|--------|---------------------------------|-----------------------------------------------------------------------------------------|------------------|---------------|------|-----|---------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------|
| 00FF00  | D7     | BSMD1                           | Bus mode (CPU mode) selection                                                           |                  |               |      | 0   | R/W                                                           |                                                                                   |                       |
|         |        |                                 | BSMD1                                                                                   | BSMD0            | Mode          |      |     |                                                               |                                                                                   |                       |
|         | D6     | BSMD0                           | 1                                                                                       | 1                | 4M(Maximum)   |      |     | 0                                                             |                                                                                   | R/W                   |
|         |        |                                 | 1                                                                                       | 0                | 4M(Minimum)   |      |     |                                                               |                                                                                   |                       |
|         |        |                                 | 0                                                                                       | 1                | 64K           |      |     |                                                               |                                                                                   |                       |
|         | D5     | CEMD1                           | Expanded 64K chip enable mode                                                           |                  |               |      | 1   | R/W                                                           |                                                                                   | Only for 64K bus mode |
|         |        |                                 | CEMD1                                                                                   | CEMD0            | Mode          |      |     |                                                               |                                                                                   |                       |
|         |        |                                 | 1                                                                                       | 1                | -             |      |     |                                                               |                                                                                   |                       |
|         | D4     | CEMD0                           | 1                                                                                       | 0                | 32K(CE0)      |      |     | 1                                                             |                                                                                   | R/W                   |
| 0       |        |                                 | 1                                                                                       | 16K(CE0, CE1)    |               |      |     |                                                               |                                                                                   |                       |
| 0       |        |                                 | 0                                                                                       | 8K(CE0-CE2)      |               |      |     |                                                               |                                                                                   |                       |
| D3      | -      | -                               | -                                                                                       | -                | -             | -    | -   | "0" when being read                                           |                                                                                   |                       |
| D2      | CE2    | CE2(R32)                        | CE signal output enable/disable<br>enable: CE signal output<br>disable: DC output (R3x) | CE2 enable       | CE2 disable   | 1    | R/W | In the single chip mode, these setting are fixed at DC output |                                                                                   |                       |
| D1      | CE1    | CE1(R31)                        |                                                                                         | CE1 enable       | CE1 disable   | 1    | R/W |                                                               |                                                                                   |                       |
| D0      | CE0    | CE0(R30)                        |                                                                                         | CE0 enable       | CE0 disable   | 1    | R/W |                                                               |                                                                                   |                       |
| 00FF00  | D7     | BSMD1                           | Bus mode (CPU mode) selection                                                           |                  |               |      | *   | R/W                                                           | Initial setting can be selected from 3 types (64K, 4M min, 4M max) by mask option |                       |
|         |        |                                 | BSMD1                                                                                   | BSMD0            | Mode          |      |     |                                                               |                                                                                   |                       |
|         | D6     | BSMD0                           | 1                                                                                       | 1                | 4M(Maximum)   |      |     | *                                                             |                                                                                   | R/W                   |
|         |        |                                 | 1                                                                                       | 0                | 4M(Minimum)   |      |     |                                                               |                                                                                   |                       |
|         |        |                                 | 0                                                                                       | 1                | 64K           |      |     |                                                               |                                                                                   |                       |
|         | D5     | CEMD1                           | Expanded 64K chip enable mode                                                           |                  |               |      | 1   | R/W                                                           |                                                                                   | Only for 64K bus mode |
|         |        |                                 | CEMD1                                                                                   | CEMD0            | Mode          |      |     |                                                               |                                                                                   |                       |
|         |        |                                 | 1                                                                                       | 1                | 64K(CE0)      |      |     |                                                               |                                                                                   |                       |
|         | D4     | CEMD0                           | 1                                                                                       | 0                | 32K(CE0, CE1) |      |     | 1                                                             |                                                                                   | R/W                   |
| 0       |        |                                 | 1                                                                                       | 16K(CE0-CE2)     |               |      |     |                                                               |                                                                                   |                       |
| 0       |        |                                 | 0                                                                                       | 8K(CE0-CE2)      |               |      |     |                                                               |                                                                                   |                       |
| D3      | -      | -                               | -                                                                                       | -                | -             | -    | -   | "0" when being read                                           |                                                                                   |                       |
| D2      | CE2    | CE2(R32)                        | CE signal output enable/disable<br>enable: CE signal output<br>disable: DC output (R3x) | CE2 enable       | CE2 disable   | 1    | R/W |                                                               |                                                                                   |                       |
| D1      | CE1    | CE1(R31)                        |                                                                                         | CE1 enable       | CE1 disable   | 1    | R/W |                                                               |                                                                                   |                       |
| D0      | CE0    | CE0(R30)                        |                                                                                         | CE0 enable       | CE0 disable   | 1    | R/W |                                                               |                                                                                   |                       |
| 00FF01  | D7     | -                               | -                                                                                       | -                | -             | -    | -   | -                                                             | "0" when being read                                                               |                       |
|         | D6     | -                               | -                                                                                       | -                | -             | -    | -   | -                                                             |                                                                                   |                       |
|         | D5     | WT1                             | Wait state control                                                                      |                  |               |      | 0   | R/W                                                           |                                                                                   |                       |
|         |        | WT1                             | WT0                                                                                     | Number of states |               |      |     |                                                               |                                                                                   |                       |
|         |        | 1                               | 1                                                                                       | 12(3 cycles)     |               |      |     |                                                               |                                                                                   |                       |
|         | D4     | WT0                             | 1                                                                                       | 0                | 8(2 cycles)   |      |     | 0                                                             |                                                                                   | R/W                   |
|         |        |                                 | 0                                                                                       | 1                | 4(1 cycle)    |      |     |                                                               |                                                                                   |                       |
|         |        | 0                               | 0                                                                                       | No wait          |               |      |     |                                                               |                                                                                   |                       |
| D3      | CLKCHG | CPU operating clock switch      |                                                                                         | OSC3             | OSC1          | 0    | R/W |                                                               |                                                                                   |                       |
| D2      | OSCC   | OSC3 oscillation ON/OFF control |                                                                                         | On               | Off           | 0    | R/W |                                                               |                                                                                   |                       |
| D1      | VD1C1  | VD1 output level setting        |                                                                                         |                  |               | 0    | R/W |                                                               |                                                                                   |                       |
|         |        | VD1C1                           | VD1C0                                                                                   | VD1 (Typ.)       |               |      |     |                                                               |                                                                                   |                       |
|         |        | 1                               | 1                                                                                       | 4.2 V            |               |      |     |                                                               |                                                                                   |                       |
| D0      | VD1C0  | 1                               | 0                                                                                       | 3.2 V            |               |      | 0   | R/W                                                           |                                                                                   |                       |
|         |        | 0                               | 1                                                                                       | 1.6 V            |               |      |     |                                                               |                                                                                   |                       |
|         |        | 0                               | 0                                                                                       | 2.4 V            |               |      |     |                                                               |                                                                                   |                       |

Note: All the interrupts including NMI are masked until the appropriate values are written to both the "00FF00H" and "00FF01H" addresses.

**BSMD0, BSMD1: Bus mode selection register (00FF00H•D6, D7)**

Sets the bus mode as shown in Table 5.2.4.2.

Table 5.2.4.2 Bus mode settings

| Setting value |       | Bus mode                                                                              |
|---------------|-------|---------------------------------------------------------------------------------------|
| BSMD1         | BSMD0 |                                                                                       |
| 1             | 1     | Expanded 4M maximum mode                                                              |
| 1             | 0     | Expanded 4M minimum mode                                                              |
| 0             | 1     | Expanded 64K mode                                                                     |
| 0             | 0     | Single chip mode (MCU)<br>-----<br>Optional setting of one of the expanded mode (MPU) |

The single chip mode can be set only when the S1C88409 is used in the MCU mode.

When using the external MPU interface, only the single chip mode can be set.

In the MPU mode, the single chip mode cannot be set since the MPU mode does not use the internal ROM.

When using the S1C88409 in the MPU mode, it is necessary to select the bus mode set at initial reset (and when the BSMD register is set to "0") by mask option from the three types of expanded modes: expanded 64K mode, expanded 4M minimum mode and expanded 4M maximum mode. Select the expanded 4M maximum mode, when the MPU mode is not used.

At initial reset, the BSMD register is set to "0" (single chip mode in the MCU mode or an expanded mode selected by mask option in the MPU mode).

*Note: After initial reset, all the interrupts including NMI are masked until the appropriate values are written to the I/O memory addresses "00FF00H" and "00FF01H" to prevent malfunctions that may occur before setting the system configuration. Therefore, write data to the addresses in the initial routine even though operating the S1C88409 in the initial settings (single chip mode). Furthermore, set the stack pointer SP prior to writing so that interrupt processing will operate normally.*

**CEMD0, CEMD1: Expanded 64K chip enable mode selection register (00FF00H•D4, D5)**

Sets the  $\overline{CE}$  signal address range (valid only in the expanded 64K mode).

Set this register according to the external memory chip size as shown in Table 5.2.4.3.

Table 5.2.4.3  $\overline{CE}$  signal settings

| CEMD1 | CEMD0 | Address range | Usable terminals                 |                                  |
|-------|-------|---------------|----------------------------------|----------------------------------|
|       |       |               | MCU mode                         | MPU mode                         |
| 1     | 1     | 64K bytes     | Invalid                          | $\overline{CE0}$                 |
| 1     | 0     | 32K bytes     | $\overline{CE0}$                 | $\overline{CE0}, \overline{CE1}$ |
| 0     | 1     | 16K bytes     | $\overline{CE0}, \overline{CE1}$ | $\overline{CE0}-\overline{CE2}$  |
| 0     | 0     | 8K bytes      | $\overline{CE0}-\overline{CE2}$  | $\overline{CE0}-\overline{CE2}$  |

This setting is invalid for modes other than the expanded 64K mode.

At initial reset, the CEMD register is set to "11B". However, since "11B" is invalid in the MCU mode, set it to another value.

**CE0-CE2:  $\overline{CE}$  signal output enable register (00FF00H•D0-D2)**

Sets the  $\overline{CE}$  output terminals to be used.

When "1" is written:  $\overline{CE}$  output enabled

When "0" is written:  $\overline{CE}$  output disabled

Reading: Valid

Writing "1" to the CE0-CE2 register enables the corresponding  $\overline{CE}$  signal to output.

Writing "0" to the register disables the  $\overline{CE}$  signal to output, and the terminal functions as the output port (R30-R32).

At initial reset, the CE registers are all set to "1".

**WT0, WT1: WAIT state control register (00FF01H•D4, D5)**

Controls the WAIT state insertion.

Table 5.2.4.4 shows the register setting and the number of WAIT states inserted.

Table 5.2.4.4 WAIT state settings

| WT1 | WT0 | Number of inserted states |
|-----|-----|---------------------------|
| 1   | 1   | 12                        |
| 1   | 0   | 8                         |
| 0   | 1   | 4                         |
| 0   | 0   | No wait                   |

\* The length of one state is 1/2 a cycle of the clock.

At initial reset, the WT register is set to "0" (no wait).

**5.2.5 Programming note**

After initial reset, all the interrupts including NMI are masked until the appropriate values are written to the I/O memory addresses "00FF00H" and "00FF01H" to prevent malfunctions that may occur before setting the system configuration. Therefore, write data to the addresses in the initial routine even though the initial settings are used. Furthermore, set the stack pointer SP prior to writing so that interrupt processing will operate normally.

## 5.3 Watchdog Timer

### 5.3.1 Configuration of watchdog timer

The S1C88409 has a built-in watchdog timer that detects CPU runaway.

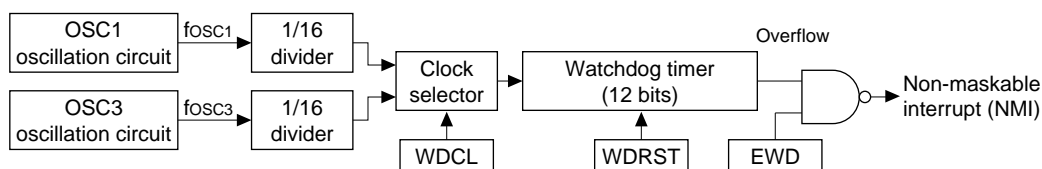


Fig. 5.3.1.1 Block diagram of watchdog timer

The watchdog timer is composed of a 12-bit up-counter that uses the OSC1 or OSC3 oscillation circuit as a clock source. This counter must be reset cyclically by software. If the counter is not reset and an overflow occurs, the watchdog timer generates NMI (non-maskable interrupt) to the CPU.

Figure 5.3.1.1 is a block diagram of the watchdog timer.

### 5.3.2 Control of watchdog timer

#### Input clock selection

The input clock of the watchdog timer can be selected using the input clock selection register WDCL from the two listed below.

WDCL = "1": 1/16 OSC1 dividing clock

WDCL = "0": 1/16 OSC3 dividing clock

At initial reset, the input clock is set to  $f_{osc1}/16$ . The following shows an example of a watchdog timer reset cycle according to the input clock selected.

When  $f_{osc1}/16$  is selected:

$f_{osc1} = 32.768$  kHz within 2 sec

When  $f_{osc3}/16$  is selected:

$f_{osc3} = 1$  MHz within 64 msec

$f_{osc3} = 6$  MHz within 10 msec

$f_{osc3} = 8$  MHz within 8 msec

The WDCL register is set to write disabling status usually to prevent modification of the reset cycle by a wrong writing. To change the input clock, it is necessary to set the WDCL register in write authorized status by writing "1" to the write enable register WRWD beforehand. The write authorization by the WRWD register enables only one write for the WDCL register. When data is written to the WDCL register after setting in write authorization, the WRWD register returns to "0", and the WDCL register is also returned to write disabling status.

#### Resetting the watchdog timer

When the watchdog timer is used, it is necessary to reset the counter before an overflow is generated. The watchdog timer is reset by writing "1" to the watchdog timer reset bit WDRST.

By resetting the watchdog timer on the main routine, program runaway that does not pass the reset routine can be detected. Ordinarily this routine is incorporated to a place where it is executed regularly.

#### Operation in HALT/SLEEP status

##### (1) HALT status

The OSC1 oscillation circuit and the OSC3 oscillation circuit operate in HALT status. Therefore, the watchdog timer also operates. The watchdog timer generates NMI when HALT status continues more than a reset cycle. HALT status is released at that point.

##### (2) SLEEP status

The OSC1 oscillation circuit and the OSC3 oscillation circuit stop in SLEEP status. Therefore, the watchdog timer also stops. Since the counter maintains the value at the point it stops, the counter resumes counting from the value after SLEEP status is canceled. However, the oscillation clock becomes unstable immediately after SLEEP is canceled. Therefore, reset the watchdog timer before shifting to SLEEP status and after SLEEP status is canceled so that an unnecessary NMI will not be generated.

**When watchdog timer is not used**

The watchdog timer always operates unless the oscillation circuit specified for the input clock stops. If monitoring the system by the watchdog timer is unnecessary, it is possible to disable the watchdog timer interrupt (NMI) by writing "0" to the watchdog timer enable register EWD. At initial reset, the watchdog timer starts counting by inputting the fosc1/16 clock and is set to generate NMI. When the watchdog timer is not used, write "0" to the EWD register before the first overflow is generated.

The EWD register is set to write disabling status same as the WDCL register. Set it in write authorized status using the WRWD register before writing to the EWD register. In this case, only one write is enabled for the EWD register.

**5.3.3 Interrupt function**

When the watchdog timer is not reset cyclically by software, the watchdog timer outputs an interrupt signal to the NMI (level 4) input of the core CPU. This interrupt cannot be masked and the exception processing has priority over other interrupts. Refer to the "S1C88 Core CPU Manual" for details of the NMI exception processing. This exception processing vector address is set to 000004H.

When the EWD register is set to "0", this interrupt is not generated.

**5.3.4 I/O memory of watchdog timer**

Table 5.3.4.1 shows the control bits for the watchdog timer.

Table 5.3.4.1 Watchdog timer control bits

| Address | Bit | Name  | Function                             | 1            | 0             | Init | R/W | Comment             |
|---------|-----|-------|--------------------------------------|--------------|---------------|------|-----|---------------------|
| 00FF53  | D7  | WRWD  | EWD, WDCL write enable               | Write enable | Write disable | 0    | R/W | *1                  |
|         | D6  | EWD   | Watchdog timer NMI enable            | NMI enable   | NMI disable   | 1    | R/W | *1                  |
|         | D5  | WDCL  | Watchdog timer input clock selection | fosc3/16     | fosc1/16      | 0    | R/W | *1                  |
|         | D4  | -     | -                                    | -            | -             | -    | -   | "0" when being read |
|         | D3  | -     | -                                    | -            | -             | -    | -   |                     |
|         | D2  | -     | -                                    | -            | -             | -    | -   |                     |
|         | D1  | -     | -                                    | -            | -             | -    | -   |                     |
|         | D0  | WDRST | Watchdog timer reset                 | Reset        | Invalid       | -    | W   |                     |

\*1 Writing to EWD or WDCL is valid after "1" is written to WRWD. WRWD is automatically returns to "0" after writing to EWD or WDCL.

**WRWD: EWD, WDCL write enable register (00FF53H•D7)**

Enables writing to the EWD and WDCL register.

- When "1" is written: Write is enabled
- When "0" is written: Write is disabled
- Reading: Valid

The EWD and WDCL registers are set to write disabling status usually to prevent unnecessary modification. When "1" is written to the WRWD register, only one write is permitted. When data is written to either the EWD or WDCL registers or both, the WRWD register returns to "0", and the EWD and WDCL registers go to write disabling status.

Writing "0" to the WRWD register during a write authorized state (WRWD="1") also returns to write disabling status.

At initial reset, the WRWD register is set to "0" (write is disabled).

**EWD: NMI enable register (00FF53H•D6)**

Controls non-maskable interrupt (NMI) generation by watchdog timer.

- When "1" is written: NMI is valid
- When "0" is written: NMI is invalid
- Reading: Valid

When "0" is written to the EWD register, the watchdog timer interrupt signal is masked and NMI is not generated to the CPU. When the EWD register is set to "1", NMI is generated due to an overflow of the counter.

Writing to the EWD register is effective only when the WRWD register is set to "1".

The count operation is continued even when the EWD register is set to "0" if the clock is input. Therefore, when NMI is invalidated temporarily, reset the watchdog timer before changing back the EWD register to "1".

At initial reset, the EWD register is set to "1" (NMI is valid).

**WDCL: Input clock selection register (00FF53H•D5)**

Selects the input clock for the watchdog timer.

When "1" is written:  $f_{OSC3}/16$

When "0" is written:  $f_{OSC1}/16$

Reading: Valid

When "1" is written to the WDCL register,  $f_{OSC3}/16$  clock is input to the watchdog timer as the count clock. When "0" is written,  $f_{OSC1}/16$  clock is input. When  $f_{OSC3}/16$  clock is used, the watchdog timer stops if the OSC3 oscillation circuit stops (including SLEEP). In this case, the counter value at stop is maintained.

Writing to the WDCL register is effective only when the WRWD register is set to "1".

At initial reset, the WDCL register is set to "0" ( $f_{OSC1}/16$ ).

**WDRST: Watchdog timer reset (00FF53H•D0)**

Resets the watchdog timer.

When "1" is written: Watchdog timer is reset

When "0" is written: No operation

Reading: Always "0"

By writing "1" to WDRST, the watchdog timer is reset and restarts immediately after. When "0" is written, no operation results.

WDRST is dedicated for writing, and is always "0" for reading.

**5.3.5 Programming notes**

- (1) When the watchdog timer NMI is authorized, it is necessary to reset the counter by software before an overflow is generated.
- (2) At initial reset, the watchdog timer starts counting by inputting the  $f_{OSC1}/16$  clock and is set to generate NMI. When the watchdog timer is not used, write "0" to the EWD register before the first overflow is generated.
- (3) The count operation is continued even when the EWD register is set to "0" if the clock is input. Therefore, when NMI is invalidated temporarily, reset the watchdog timer before changing back the EWD register to "1".
- (4) The oscillation clock becomes unstable immediately after SLEEP is canceled. Therefore, reset the watchdog timer before shifting to SLEEP status and after SLEEP status is canceled so that an unnecessary NMI will not be generated.

## 5.4 Oscillation Circuit

### 5.4.1 Configuration of oscillation circuit

The S1C88409 has been designed as a twin clock system with two internal oscillation circuits (OSC1 and OSC3). The OSC1 oscillation circuit generates the 32.768 kHz (Typ.) operating clock, and the OSC3 oscillation circuit generates the high-speed clock for the CPU and the peripheral circuits (serial interface, programmable timer, A/D converter, etc.).

Figure 5.4.1.1 shows the configuration of the oscillation circuit.

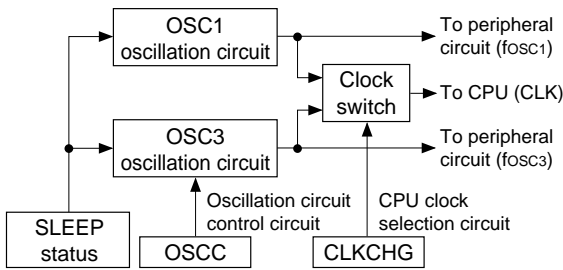


Fig. 5.4.1.1 Configuration of oscillation circuit

At initial reset, the OSC1 oscillation clock is selected for the CPU operating clock. Turning the OSC3 oscillation circuit on/off and switching the system clock (OSC1↔OSC3) can be controlled by software. The OSC3 oscillation circuit is used when the CPU and the peripheral circuits require high-speed operation. When the CPU has to handle low-speed operation (e.g. clock control), stop the OSC3 oscillation and use OSC1 as the operating clock to reduce current consumption.

### 5.4.2 Mask option

- |                                                                                |
|--------------------------------------------------------------------------------|
| OSC1 oscillation circuit                                                       |
| <input type="checkbox"/> Crystal oscillation circuit                           |
| <input type="checkbox"/> CR oscillation circuit                                |
| <input type="checkbox"/> External clock input                                  |
| <input type="checkbox"/> Crystal oscillation circuit (gate capacitor built-in) |
| OSC3 oscillation circuit                                                       |
| <input type="checkbox"/> Crystal oscillation circuit                           |
| <input type="checkbox"/> Ceramic oscillation circuit                           |
| <input type="checkbox"/> CR oscillation circuit                                |
| <input type="checkbox"/> External clock input                                  |

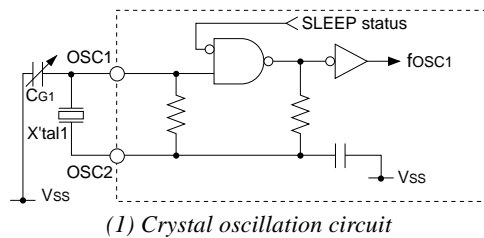
Either "Crystal oscillation", "CR oscillation", "Crystal oscillation (gate capacitor built-in)" or "External clock input" can be selected by mask option as a kind of OSC1 oscillation circuit.

Either "Crystal oscillation", "Ceramic oscillation", "CR oscillation" or "External clock input" can be selected as a kind of OSC3 oscillation circuit same as the OSC1.

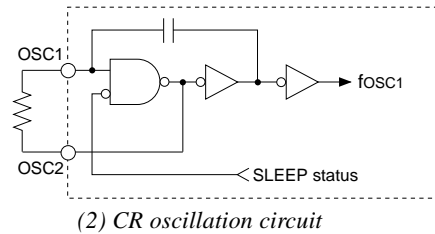
### 5.4.3 OSC1 oscillation circuit

The OSC1 oscillation circuit generates the 32.768 kHz (Typ.) system clock. The OSC1 oscillation clock is used for the low-speed (low power) operation clock of the CPU. Furthermore, it is used as the source clock for the clock timer and watchdog timer even when OSC3 is used as the system clock. The OSC1 oscillation circuit stops when the SLP instruction is executed.

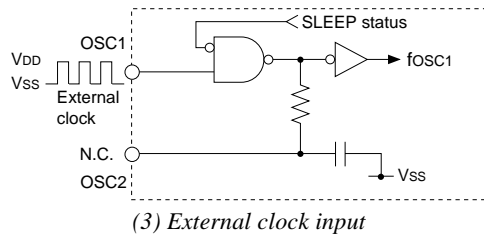
Either "Crystal oscillation", "CR oscillation", "Crystal oscillation (gate capacitor built-in)" or "External clock input" can be selected by mask option as a kind of OSC1 oscillation circuit. Figure 5.4.3.1 shows the structure of the OSC1 oscillation circuit.



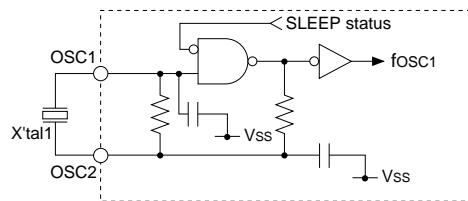
(1) Crystal oscillation circuit



(2) CR oscillation circuit



(3) External clock input



(4) Crystal oscillation circuit (gate capacitor built-in)

Fig. 5.4.3.1 OSC1 oscillation circuit



When crystal oscillation is selected, the crystal oscillation circuit can be configured simply by connecting a crystal oscillator X'tal1 (Typ. 32.768 kHz) between the OSC1 and OSC2 terminals and a trimmer capacitor CG1 (5–25pF) between the OSC1 terminal and Vss.

For the CG1, the built-in capacitor can also be selected by mask option.

When CR oscillation is selected, the CR oscillation circuit can be configured by connecting a resistor between the OSC1 and OSC2 terminals.

When external clock input is selected, open the OSC2 terminal and input a square wave clock to the OSC1 terminal.

### 5.4.4 OSC3 oscillation circuit

The OSC3 oscillation circuit generates the system clock for the CPU and peripheral circuits (serial interface, programmable timer, A/D converter, etc.). The OSC3 oscillation circuit stops when the SLP instruction is executed, or the OSCC register is set to "0".

Either "Crystal oscillation", "Ceramic oscillation", "CR oscillation" or "External clock input" can be selected by mask option as a kind of OSC3 oscillation circuit.

Figure 5.4.4.1 shows the structure of the OSC3 oscillation circuit.

When crystal/ceramic oscillation circuit is selected, the crystal or ceramic oscillation circuit is configured by connecting either a crystal oscillator (X'tal2) or a ceramic oscillator (Ceramic) and a feedback resistor (Rf) between the OSC3 and OSC4 terminals and two capacitors (CG2, CD2) between the OSC3 terminal and Vss, and between the OSC4 terminal and Vss, respectively.

When CR oscillation is selected, the CR oscillation circuit can be configured by connecting a resistor (Rcr3) between the OSC3 and OSC4 terminals.

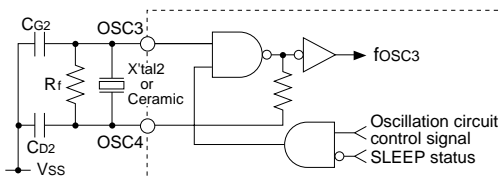
When external clock input is selected, open the OSC4 terminal and input a square wave clock to the OSC3 terminal.

When the OSC3 oscillation circuit is not used, select external clock input by mask option, and pull down the OSC3 terminal to Vss.

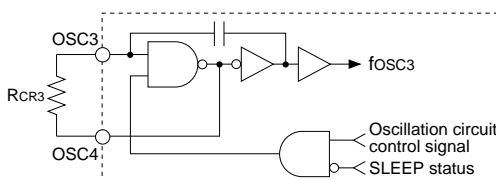
The maximum frequency of the clock, which can be generated by the OSC3 oscillation circuit or can be input to the OSC3 oscillation circuit, is limited depending on the supply voltage as shown in Table 5.4.4.1.

Table 5.4.4.1 Limit of OSC3 clock frequency depending on supply voltage

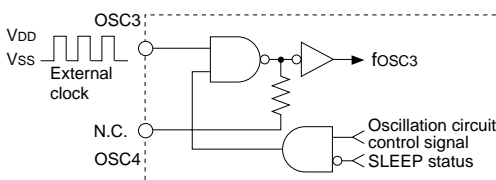
| Operable voltage range (VDD) | Max. operable frequency |
|------------------------------|-------------------------|
| 1.8 V–5.5 V                  | 1.1 MHz                 |
| 2.6 V–5.5 V                  | 4.4 MHz                 |
| 3.5 V–5.5 V                  | 6.6 MHz                 |
| 4.5 V–5.5 V                  | 8.8 MHz                 |



(1) Crystal/Ceramic oscillation circuit



(2) CR oscillation circuit



(3) External clock input

Fig. 5.4.4.1 OSC3 oscillation circuit

### 5.4.5 Switching of CPU clock and operating voltage $V_{D1}$

The OSC3 oscillation circuit can be turned on and off. It should be turned on when operating peripheral circuit (serial interface, programmable timer, A/D converter, etc.) that needs a high-speed clock. Further, the CPU operating clock can be switched from OSC1 to OSC3 to execute the program in high-speed.

In the S1C88409, the internal operating voltage  $V_{D1}$  can also be switched by software for stable operation in large supply voltage and operating frequency ranges and for saving power.

#### Switching operating voltage $V_{D1}$

When operating the OSC3 oscillation circuit, it is necessary to switch the internal operating voltage  $V_{D1}$  according to the oscillation frequency. Table 5.4.5.1 shows the relation between the supply voltage to be used, oscillation frequency and the internal operating voltage  $V_{D1}$  that should be set.

Table 5.4.5.1 Oscillation frequency and internal operating voltage  $V_{D1}$

| OSC3 oscillator | OSC3 frequency | Supply voltage | $V_{D1}$ |       |       |       |
|-----------------|----------------|----------------|----------|-------|-------|-------|
|                 |                |                | 1.6 V    | 2.4 V | 3.2 V | 4.2 V |
| OFF             | *              | 1.8–5.5 V      | ○        | △     | △     | △     |
| ON              | 0.03–1.1 MHz   | 1.8–5.5 V      | ○        | △     | △     | △     |
|                 | 0.03–4.4 MHz   | 2.6–5.5 V      | ×        | ○     | △     | △     |
|                 | 0.03–6.6 MHz   | 3.5–5.5 V      | ×        | ×     | ○     | △     |
|                 | 0.03–8.8 MHz   | 4.5–5.5 V      | ×        | ×     | ×     | ○     |

- \* Operation with OSC1 clock
- Can be set
- △ Can be set (However, it increases current consumption)
- × Cannot be set

$V_{D1}$  is switched with the  $V_{D1}$  level setting register VD1C.

Table 5.4.5.2  $V_{D1}$  settings

| VD1C1 | VD1C0 | Operating voltage $V_{D1}$ |
|-------|-------|----------------------------|
| 1     | 1     | 4.2 V                      |
| 1     | 0     | 3.2 V                      |
| 0     | 1     | 1.6 V                      |
| 0     | 0     | 2.4 V                      |

At initial reset,  $V_{D1}$  is set to 2.4 V (Typ.).  $V_{D1}$  should be switched to 1.6 V (Typ.) when using an OSC3 clock lower than 1.1 MHz or the OSC3 oscillation is stopped.

*Note:* • The  $V_{D1}$  level must be switched while the OSC3 oscillation circuit is off (before turning on and after turning off). Switching during operation may cause malfunction.

- The  $V_{D1}$  voltage required at least 5 msec of voltage stabilizing time after switching. Do not turn the OSC3 oscillation circuit on during this period.

- $V_{D1}$  cannot be switched directly to a level that is two or three levels different from the current level. The middle level must be set between switching.

To switch from 1,6 (3.2) V to 3.2 (1.6) V:

1.6 V → 2.4 V → 3.2 V

1.6 V ← 2.4 V ← 3.2 V

To switch from 1.6 (4.2) V to 4.2 (1.6) V:

1.6 V → 2.4 V → 3.2 V → 4.2 V

1.6 V ← 2.4 V ← 3.2 V ← 4.2 V

To switch from 2.4 (4.2) V to 4.2 (2.4) V:

2.4 V → 3.2 V → 4.2 V

2.4 V ← 3.2 V ← 4.2 V

A 5 msec interval is required for each switching step.

#### Turning the OSC3 oscillation circuit on and off

The OSC3 oscillation circuit can be turned on and off using the OSCC register. It is necessary to switch the  $V_{D1}$  voltage.

The switching procedure is as follows. The following procedures are described assuming the  $V_{D1}$  has been set to 1.6 V before turning the OSC3 oscillation on.

#### [OSC3 on sequence]

- **OSC3 = 0.03 MHz–1.1 MHz**

1. Write "1" to the OSCC register. (turning the OSC3 oscillation circuit on)
2. Wait at least 20 msec.

- **OSC3 = 0.03 MHz–4.4 MHz**

1. Write "00B" to the VD1C register. ( $V_{D1}$  = 2.4 V)
2. Wait at least 5 msec.
3. Write "1" to the OSCC register. (turning the OSC3 oscillation circuit on)
4. Wait at least 20 msec.

- **OSC3 = 0.03 MHz–6.6 MHz**

1. Write "00B" to the VD1C register. ( $V_{D1}$  = 2.4 V)
2. Wait at least 5 msec.
3. Write "10B" to the VD1C register. ( $V_{D1}$  = 3.2 V)
4. Wait at least 5 msec.
5. Write "1" to the OSCC register. (turning the OSC3 oscillation circuit on)
6. Wait at least 20 msec.

• *OSC3 = 0.03 MHz–8.8 MHz*

1. Write "00B" to the VD1C register. (VD1 = 2.4 V)
2. Wait at least 5 msec.
3. Write "10B" to the VD1C register. (VD1 = 3.2 V)
4. Wait at least 5 msec.
5. Write "11B" to the VD1C register. (VD1 = 4.2 V)
6. Wait at least 5 msec.
7. Write "1" to the OSCC register.  
(turning the OSC3 oscillation circuit on)
8. Wait at least 20 msec.

- Note:*
- *The OSC3 oscillation circuit takes a maximum 20 msec for stabilizing oscillation after turning the OSC3 oscillation circuit on. Therefore, take an enough interval after the OSC3 oscillation goes on before starting control of the peripheral circuit, such as the programmable timer, serial interface and A/D converter, that uses the OSC3 oscillation circuit as the clock source. (The oscillation start time varies depending on the oscillator and external component to be used. Refer to Chapter 8, "ELECTRICAL CHARACTERISTICS", in which an example of oscillation start time is indicated.)*
  - *Do not turn the OSC3 oscillation circuit on to reduce current consumption when the OSC3 clock is not necessary.*

**[OSC3 off sequence]**

• *OSC3 = 0.03 MHz–1.1 MHz*

1. Write "0" to the OSCC register.  
(turning the OSC3 oscillation circuit off)

• *OSC3 = 0.03 MHz–4.4 MHz*

1. Write "0" to the OSCC register.  
(turning the OSC3 oscillation circuit off)
2. Write "01B" to the VD1C register. (VD1 = 1.6 V)

• *OSC3 = 0.03 MHz–6.6 MHz*

1. Write "0" to the OSCC register.  
(turning the OSC3 oscillation circuit off)
2. Write "00B" to the VD1C register. (VD1 = 2.4 V)
3. Wait at least 5 msec.
4. Write "01B" to the VD1C register. (VD1 = 1.6 V)

• *OSC3 = 0.03 MHz–8.8 MHz*

1. Write "0" to the OSCC register.  
(turning the OSC3 oscillation circuit off)
2. Write "10B" to the VD1C register. (VD1 = 3.2 V)
3. Wait at least 5 msec.
4. Write "00B" to the VD1C register. (VD1 = 2.4 V)
5. Wait at least 5 msec.
6. Write "01B" to the VD1C register. (VD1 = 1.6 V)

*Note:* To prevent malfunction, before stopping the OSC3 oscillation, stop the operation of the peripheral circuits that use the OSC3 oscillation circuit as the clock source, such as programmable timer, serial interface and A/D converter.

Furthermore, when turning the OSC3 oscillation circuit off, make sure that the CPU operating clock is OSC1.

**Switching the CPU operating clock from OSC1 to OSC3**

When operating the CPU in high speed, the CPU operating clock should be switched from the OSC1 clock to the OSC3 clock using the CLKCHG register. The switching procedure is as follows:

1. Execute the OSC3 on sequence as described above.
2. Write "1" to the CLKCHG register.  
(OSC1 → OSC3)

*Note:* Be sure to wait 20 msec or more for oscillation stabilizing time between turning the OSC3 oscillation circuit on and switching the CPU operating clock.

**Switching the CPU operating clock from OSC3 to OSC1**

When the CPU has to handle low-speed operation (e.g. clock control), the OSC3 oscillation can be stopped and OSC1 can be used as the operating clock to reduce current consumption.

The switching procedure is as follows:

1. Write "0" to the CLKCHG register.  
(OSC3 → OSC1)
2. Execute the OSC3 off sequence described above.

*Note:* Use a separate instruction for switching the clock from OSC3 to OSC1 and turning the OSC3 oscillation off. Handling with one instruction may cause malfunction of the CPU.

### 5.4.6 I/O memory of oscillation circuit

Table 5.4.6.1 shows the control bits for the oscillation circuit.

Table 5.4.6.1 Oscillation circuit control bits

| Address | Bit   | Name                     | Function                        | 1     | 0          | Init | R/W | Comment             |            |                  |
|---------|-------|--------------------------|---------------------------------|-------|------------|------|-----|---------------------|------------|------------------|
| 00FF01  | D7    | —                        | —                               | —     | —          | —    | —   | "0" when being read |            |                  |
|         | D6    | —                        | —                               | —     | —          | —    | —   |                     |            |                  |
|         | D5    | WT1                      | Wait state control              |       |            |      | 0   | R/W                 |            |                  |
|         |       |                          | WT1                             | WT0   |            |      |     |                     |            | Number of states |
|         |       |                          | 1                               | 1     |            |      |     |                     |            | 12(3 cycles)     |
|         |       |                          | 1                               | 0     |            |      |     |                     |            | 8(2 cycles)      |
|         | D4    | WT0                      | 0                               | 1     | 4(1 cycle) |      |     | 0                   | R/W        |                  |
|         |       |                          | 0                               | 0     | No wait    |      |     |                     |            |                  |
|         |       |                          | CPU operating clock switch      |       | OSC3       |      |     |                     |            | OSC1             |
|         | D2    | OSCC                     | OSC3 oscillation ON/OFF control |       | On         | Off  | 0   | R/W                 |            |                  |
| D1      | VD1C1 | VD1 output level setting |                                 |       |            | 0    | R/W |                     |            |                  |
|         |       | VD1C1                    | VD1C0                           |       |            |      |     |                     | VD1 (Typ.) |                  |
|         |       | 1                        | 1                               |       |            |      |     |                     | 4.2 V      |                  |
| D0      | VD1C0 | 1                        | 0                               | 3.2 V |            |      | 0   | R/W                 |            |                  |
|         |       | 0                        | 1                               | 1.6 V |            |      |     |                     |            |                  |
|         |       | 0                        | 0                               | 2.4 V |            |      |     |                     |            |                  |

#### VD1C0, VD1C1: VD1 output level setting register (00FF01H•D0, D1)

Selects the VD1 level.

Table 5.4.6.2 VD1 settings

| VD1C1 | VD1C0 | Operating voltage VD1 | OSC3 oscillation         |
|-------|-------|-----------------------|--------------------------|
| 1     | 1     | 4.2 V                 | ON (0.03–8.8 MHz)        |
| 1     | 0     | 3.2 V                 | ON (0.03–6.6 MHz)        |
| 0     | 1     | 1.6 V                 | ON (0.03–1.1 MHz) or OFF |
| 0     | 0     | 2.4 V                 | ON (0.03–4.4 MHz)        |

The VD1 level should be switched according to the operation of the OSC3 oscillation circuit.

The OSC3 oscillation circuit must be off when switching the VD1 voltage.

VD1 cannot be switched directly to a level that is two or three levels different from the current level. The middle level must be set between switching.

To switch from 1,6 (3.2) V to 3.2 (1.6) V:

1.6 V → 2.4 V → 3.2 V

1.6 V ← 2.4 V ← 3.2 V

To switch from 1.6 (4.2) V to 4.2 (1.6) V:

1.6 V → 2.4 V → 3.2 V → 4.2 V

1.6 V ← 2.4 V ← 3.2 V ← 4.2 V

To switch from 2.4 (4.2) V to 4.2 (2.4) V:

2.4 V → 3.2 V → 4.2 V

2.4 V ← 3.2 V ← 4.2 V

A 5 msec interval is required for each switching step.

At initial reset, the VD1C register is set to "0" (2.4 V, Typ.).

#### OSCC: OSC3 oscillation control register (00FF01H•D2)

Turns the OSC3 oscillation circuit on and off.

When "1" is written: OSC3 oscillation ON

When "0" is written: OSC3 oscillation OFF

Reading: Valid

When it is necessary to operate the CPU and peripheral circuits (serial interface, programmable timer, A/D converter, etc.) at high-speed, write "1" to the OSCC register. At other times, set it to "0" to reduce current consumption.

At initial reset, the OSCC register is set to "0" (OSC3 oscillation OFF).

#### CLKCHG: CPU operating clock switching register (00FF01H•D3)

Selects the operating clock for the CPU.

When "1" is written: OSC3 clock

When "0" is written: OSC1 clock

Reading: Valid

When the CPU operating clock is to be OSC3, write "1" to the CLKCHG register; for OSC1, write "0".

The OSC3 oscillation circuit takes a maximum 20 msec to stabilize oscillation after turning the OSC3 oscillation circuit on. Therefore, switching the system clock should be done after the stabilization time has passed.

At initial reset, the CLKCHG register is set to "0" (OSC1 clock).

### 5.4.7 Programming notes

- (1) The VD1 level must be switched while the OSC3 oscillation circuit is off (before turning on and after turning off). Switching during operation may cause malfunction. Furthermore, the VD1 voltage required at least 5 msec of voltage stabilizing time after switching. Do not turn the OSC3 oscillation circuit on during this period.
- (2) VD1 cannot be switched directly to a level that is two or three levels different from the current level. The middle level must be set between switching.  
 To switch from 1.6 (3.2) V to 3.2 (1.6) V:  
     1.6 V → 2.4 V → 3.2 V  
     1.6 V ← 2.4 V ← 3.2 V  
 To switch from 1.6 (4.2) V to 4.2 (1.6) V:  
     1.6 V → 2.4 V → 3.2 V → 4.2 V  
     1.6 V ← 2.4 V ← 3.2 V ← 4.2 V  
 To switch from 2.4 (4.2) V to 4.2 (2.4) V:  
     2.4 V → 3.2 V → 4.2 V  
     2.4 V ← 3.2 V ← 4.2 V  
 A 5 msec interval is required for each switching step.
- (3) To generate VD1 with specified voltage, the supply voltage must be higher than the specified voltage.  
 To prevent malfunction, make sure that the supply voltage is not lowered under the VD1 value to be set using the SVD circuit before switching VD1. Do not switch VD1 to a voltage higher than the supply voltage if the supply voltage drops.
- (4) The OSC3 oscillation circuit takes a maximum 20 msec for stabilizing oscillation after turning the OSC3 oscillation circuit on. Therefore, take an enough interval after the OSC3 oscillation goes on before starting control of the peripheral circuit, such as the programmable timer, serial interface and A/D converter, that uses the OSC3 oscillation circuit as the clock source. (The oscillation start time varies depending on the oscillator and external component to be used. Refer to Chapter 8, "ELECTRICAL CHARACTERISTICS", in which an example of oscillation start time is indicated.)
- (5) Use a separate instruction for switching the clock from OSC3 to OSC1 and turning the OSC3 oscillation off. Handling with one instruction may cause malfunction of the CPU.
- (6) To prevent malfunction, before stopping the OSC3 oscillation, stop the operation of the peripheral circuits that use the OSC3 oscillation circuit as the clock source, such as programmable timer, serial interface and A/D converter.
- (7) Do not turn the OSC3 oscillation circuit on to reduce current consumption when the OSC3 clock is not necessary.

## 5.5 Prescaler and Clock Control Circuit for Peripheral Circuits

### 5.5.1 Configuration of prescaler

The S1C88409 has a prescaler that generates the clocks for the internal peripheral circuit by dividing the output clock of the OSC1 oscillation circuit and OSC3 oscillation circuit.

The division ratio of the prescaler can be selected individually for each peripheral circuit by software.

Furthermore, the clock control circuit is provided to control clock supply to each peripheral circuit. The peripheral circuits which use the output clock are as follows:

- 16-bit programmable timer 0
- 16-bit programmable timer 1
- 8-bit programmable timer
- Clock output (FOUT1, FOUT3)
- A/D converter
- Touch panel controller

Figure 5.5.1.1 shows the configuration of the prescaler.

For control of each peripheral circuit, refer to respective section.

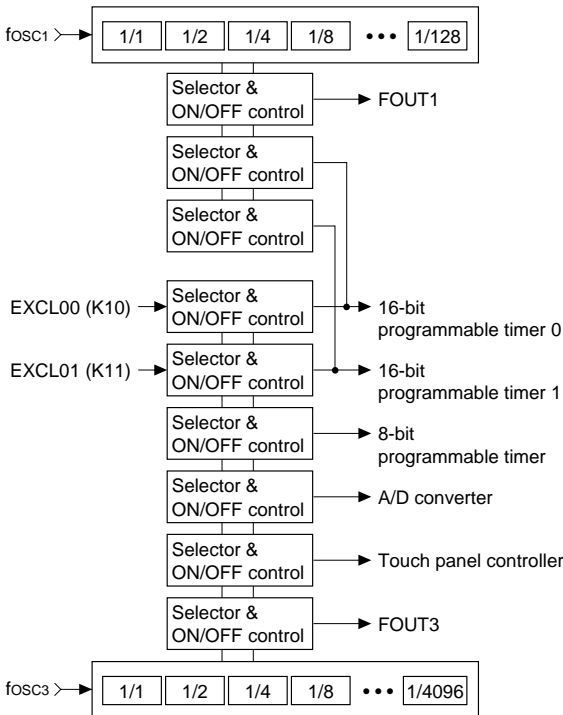


Fig. 5.5.1.1 Configuration of prescaler and clock control circuit

### 5.5.2 Setting of source clock

The prescaler uses the OSC1 clock and OSC3 clock as the source clocks.

The OSC1 prescaler always operates except for SLEEP status. When using an output clock from the OSC3 prescaler, it is necessary to turn the OSC3 oscillation circuit on.

Refer to Section 5.4.5, "Switching of CPU clock and operating voltage  $V_{D1}$ " for control of the OSC3 oscillation circuit and switching of the CPU operating clock.

At initial reset, the OSC3 oscillation circuit stops. The OSC3 oscillation circuit takes a maximum 20 msec for stabilizing oscillation after turning the OSC3 oscillation circuit on. Therefore, wait a long enough interval after the OSC3 oscillation goes on before turning the clock output of the OSC3 prescaler on. (The oscillation start time varies depending on the oscillator and external components to be used. Refer to Chapter 8, "ELECTRICAL CHARACTERISTICS", in which an example of oscillation start time is indicated.)

Among the peripheral circuits that use the clock output from the prescaler, the 16-bit programmable timer can select the clock source from either OSC1 or OSC3. Select the clock source before supplying the clock to the 16-bit programmable timer.

### 5.5.3 Prescaler division ratio selection and output control

The prescaler has division ratio selection registers and clock output control registers for the peripheral circuits, so the division ratio and the clock output for each circuit can be controlled individually.

The prescaler division ratio is selected by the division ratio selection register from 8 types set for each peripheral circuit. The dividing clock is output to the peripheral circuit by writing "1" to the clock output control register.

The following shows the division ratio selection register and the clock output control register for each peripheral circuit.

#### 16-bit programmable timer 0

Table 5.5.3.1 Division ratio and control registers

16-bit programmable timer 0 (Clock source: OSC3)

| Selection register |       |       | Division ratio | Output control                         |
|--------------------|-------|-------|----------------|----------------------------------------|
| PST02              | PST01 | PST00 |                |                                        |
| 1                  | 1     | 1     | fosc3/4096     | PRPRT0 register<br>"1": ON<br>"0": OFF |
| 1                  | 1     | 0     | fosc3/1024     |                                        |
| 1                  | 0     | 1     | fosc3/256      |                                        |
| 1                  | 0     | 0     | fosc3/128      |                                        |
| 0                  | 1     | 1     | fosc3/64       |                                        |
| 0                  | 1     | 0     | fosc3/32       |                                        |
| 0                  | 0     | 1     | fosc3/8        |                                        |
| 0                  | 0     | 0     | fosc3/2        |                                        |

Table 5.5.3.2 Division ratio and control registers

16-bit programmable timer 0 (Clock source: OSC1)

| Selection register |       |       | Division ratio | Output control                         |
|--------------------|-------|-------|----------------|----------------------------------------|
| PST02              | PST01 | PST00 |                |                                        |
| 1                  | 1     | 1     | fosc1/128      | PRPRT0 register<br>"1": ON<br>"0": OFF |
| 1                  | 1     | 0     | fosc1/64       |                                        |
| 1                  | 0     | 1     | fosc1/32       |                                        |
| 1                  | 0     | 0     | fosc1/16       |                                        |
| 0                  | 1     | 1     | fosc1/8        |                                        |
| 0                  | 1     | 0     | fosc1/4        |                                        |
| 0                  | 0     | 1     | fosc1/2        |                                        |
| 0                  | 0     | 0     | fosc1/1        |                                        |

The source clock (OSC1, OSC3) is selected by the PRPT0 register.

#### 16-bit programmable timer 1

Table 5.5.3.3 Division ratio and control registers

16-bit programmable timer 1 (Clock source: OSC3)

| Selection register |       |       | Division ratio | Output control                         |
|--------------------|-------|-------|----------------|----------------------------------------|
| PST12              | PST11 | PST10 |                |                                        |
| 1                  | 1     | 1     | fosc3/4096     | PRPRT1 register<br>"1": ON<br>"0": OFF |
| 1                  | 1     | 0     | fosc3/1024     |                                        |
| 1                  | 0     | 1     | fosc3/256      |                                        |
| 1                  | 0     | 0     | fosc3/128      |                                        |
| 0                  | 1     | 1     | fosc3/64       |                                        |
| 0                  | 1     | 0     | fosc3/32       |                                        |
| 0                  | 0     | 1     | fosc3/8        |                                        |
| 0                  | 0     | 0     | fosc3/2        |                                        |

Table 5.5.3.4 Division ratio and control registers

16-bit programmable timer 1 (Clock source: OSC1)

| Selection register |       |       | Division ratio | Output control                         |
|--------------------|-------|-------|----------------|----------------------------------------|
| PST12              | PST11 | PST10 |                |                                        |
| 1                  | 1     | 1     | fosc1/128      | PRPRT1 register<br>"1": ON<br>"0": OFF |
| 1                  | 1     | 0     | fosc1/64       |                                        |
| 1                  | 0     | 1     | fosc1/32       |                                        |
| 1                  | 0     | 0     | fosc1/16       |                                        |
| 0                  | 1     | 1     | fosc1/8        |                                        |
| 0                  | 1     | 0     | fosc1/4        |                                        |
| 0                  | 0     | 1     | fosc1/2        |                                        |
| 0                  | 0     | 0     | fosc1/1        |                                        |

The source clock (OSC1, OSC3) is selected by the PRTF1 register.

#### 8-bit programmable timer

Table 5.5.3.5 Division ratio and control registers

8-bit programmable timer

| Selection register |       |       | Division ratio | Output control                         |
|--------------------|-------|-------|----------------|----------------------------------------|
| PST22              | PST21 | PST20 |                |                                        |
| 1                  | 1     | 1     | fosc3/256      | PRPRT2 register<br>"1": ON<br>"0": OFF |
| 1                  | 1     | 0     | fosc3/128      |                                        |
| 1                  | 0     | 1     | fosc3/64       |                                        |
| 1                  | 0     | 0     | fosc3/32       |                                        |
| 0                  | 1     | 1     | fosc3/16       |                                        |
| 0                  | 1     | 0     | fosc3/8        |                                        |
| 0                  | 0     | 1     | fosc3/4        |                                        |
| 0                  | 0     | 0     | fosc3/2        |                                        |

#### FOUT1/FOUT3 clock output

Table 5.5.3.6 Division ratio and control registers

FOUT1 clock

| Selection register |       |       | Division ratio | Output control                        |
|--------------------|-------|-------|----------------|---------------------------------------|
| PSF12              | PSF11 | PSF10 |                |                                       |
| 1                  | 1     | 1     | fosc1/128      | PRFO1 register<br>"1": ON<br>"0": OFF |
| 1                  | 1     | 0     | fosc1/64       |                                       |
| 1                  | 0     | 1     | fosc1/32       |                                       |
| 1                  | 0     | 0     | fosc1/16       |                                       |
| 0                  | 1     | 1     | fosc1/8        |                                       |
| 0                  | 1     | 0     | fosc1/4        |                                       |
| 0                  | 0     | 1     | fosc1/2        |                                       |
| 0                  | 0     | 0     | fosc1/1        |                                       |

Table 5.5.3.7 Division ratio and control registers

FOUT3 clock

| Selection register |       |       | Division ratio | Output control                        |
|--------------------|-------|-------|----------------|---------------------------------------|
| PSF32              | PSF31 | PSF30 |                |                                       |
| 1                  | 1     | 1     | fosc3/128      | PRFO3 register<br>"1": ON<br>"0": OFF |
| 1                  | 1     | 0     | fosc3/64       |                                       |
| 1                  | 0     | 1     | fosc3/32       |                                       |
| 1                  | 0     | 0     | fosc3/16       |                                       |
| 0                  | 1     | 1     | fosc3/8        |                                       |
| 0                  | 1     | 0     | fosc3/4        |                                       |
| 0                  | 0     | 1     | fosc3/2        |                                       |
| 0                  | 0     | 0     | fosc3/1        |                                       |

**A/D converter**

Table 5.5.3.8 Division ratio and control registers

A/D converter

| Selection register |       |       | Division ratio | Output control |
|--------------------|-------|-------|----------------|----------------|
| PSAD2              | PSAD1 | PSAD0 |                |                |
| 1                  | ×     | ×     | fosc3/16       | PRAD register  |
| 0                  | 1     | 1     | fosc3/8        |                |
| 0                  | 1     | 0     | fosc3/4        |                |
| 0                  | 0     | 1     | fosc3/2        | "1": ON        |
| 0                  | 0     | 0     | fosc3/1        | "0": OFF       |

**Touch panel controller**

Table 5.5.3.9 Division ratio and control registers

Touch panel controller

| Selection register |       |       | Division ratio | Output control |
|--------------------|-------|-------|----------------|----------------|
| PSTP2              | PSTP1 | PSTP0 |                |                |
| 1                  | ×     | ×     | fosc3/16       | PRTP register  |
| 0                  | 1     | 1     | fosc3/8        |                |
| 0                  | 1     | 0     | fosc3/4        |                |
| 0                  | 0     | 1     | fosc3/2        | "1": ON        |
| 0                  | 0     | 0     | fosc3/1        | "0": OFF       |

**5.5.4 Control of external clock for event counter**

The 16-bit programmable timer can operate as an event counter with the clock input from the EXCL00, EXCL01 (K10, K11) input terminals. These external clocks are controlled to supply the 16-bit programmable timer by the individual input control registers.

Table 5.5.4.1 shows the input terminals, the input control registers and the timers.

Table 5.5.4.1 Input control registers for an event counter clock

| Input terminal | Input control register | Event counter |
|----------------|------------------------|---------------|
| EXCL00 (K10)   | PK10ON                 | Timer 0       |
| EXCL01 (K11)   | PK11ON                 | Timer 1       |



## 5.5.5 I/O memory of prescaler

Table 5.5.5.1 shows the control bits for the prescaler.

Table 5.5.5.1(a) Prescaler control bits

| Address | Bit    | Name                                                   | Function                                               | 1                 | 0                 | Init | R/W | Comment             |
|---------|--------|--------------------------------------------------------|--------------------------------------------------------|-------------------|-------------------|------|-----|---------------------|
| 00FF01  | D7     | –                                                      | –                                                      | –                 | –                 | –    | –   | "0" when being read |
|         | D6     | –                                                      | –                                                      | –                 | –                 | –    | –   |                     |
|         | D5     | WT1                                                    | Wait state control                                     |                   |                   | 0    | R/W |                     |
|         |        |                                                        | WT1 WT0 Number of states                               |                   |                   |      |     |                     |
|         |        |                                                        | 1 1 12(3 cycles)                                       |                   |                   |      |     |                     |
|         | D4     | WT0                                                    | 1 0 8(2 cycles)                                        |                   |                   | 0    | R/W |                     |
|         |        |                                                        | 0 1 4(1 cycles)                                        |                   |                   |      |     |                     |
|         |        |                                                        | 0 0 No wait                                            |                   |                   |      |     |                     |
| D3      | CLKCHG | CPU operating clock switch                             | OSC3                                                   | OSC1              | 0                 | R/W  |     |                     |
| D2      | OSCC   | OSC3 oscillation ON/OFF control                        | On                                                     | Off               | 0                 | R/W  |     |                     |
| D1      | VD1C1  | V <sub>D1</sub> output level setting                   |                                                        |                   | 0                 | R/W  |     |                     |
|         |        | VD1C1 VD1C0 V <sub>D1</sub> (Typ.)                     |                                                        |                   |                   |      |     |                     |
|         |        | 1 1 4.2 V                                              |                                                        |                   |                   |      |     |                     |
| D0      | VD1C0  | 1 0 3.2 V                                              |                                                        |                   | 0                 | R/W  |     |                     |
|         |        | 0 1 1.6 V                                              |                                                        |                   |                   |      |     |                     |
|         |        | 0 0 2.4 V                                              |                                                        |                   |                   |      |     |                     |
| 00FF10  | D7     | PRPRT1                                                 | 16-bit programmable timer 1 clock control              | On                | Off               | 0    | R/W |                     |
|         | D6     | PST12                                                  | 16-bit programmable timer 1 division ratio             |                   |                   | 0    | R/W |                     |
|         |        |                                                        | PST12 PST11 PST10 (OSC3) (OSC1)                        |                   |                   |      |     |                     |
|         |        |                                                        | 1 1 1 fosc <sub>3</sub> / 4096 fosc <sub>1</sub> / 128 |                   |                   |      |     |                     |
|         | D5     | PST11                                                  | 1 1 0 fosc <sub>3</sub> / 1024 fosc <sub>1</sub> / 64  |                   |                   | 0    | R/W |                     |
|         |        |                                                        | 1 0 1 fosc <sub>3</sub> / 256 fosc <sub>1</sub> / 32   |                   |                   |      |     |                     |
|         |        |                                                        | 1 0 0 fosc <sub>3</sub> / 128 fosc <sub>1</sub> / 16   |                   |                   |      |     |                     |
|         | D4     | PST10                                                  | 0 1 1 fosc <sub>3</sub> / 64 fosc <sub>1</sub> / 8     |                   |                   | 0    | R/W |                     |
|         |        |                                                        | 0 1 0 fosc <sub>3</sub> / 32 fosc <sub>1</sub> / 4     |                   |                   |      |     |                     |
|         |        |                                                        | 0 0 1 fosc <sub>3</sub> / 8 fosc <sub>1</sub> / 2      |                   |                   |      |     |                     |
|         |        |                                                        | 0 0 0 fosc <sub>3</sub> / 2 fosc <sub>1</sub> / 1      |                   |                   |      |     |                     |
|         | D3     | PRPRT0                                                 | 16-bit programmable timer 0 clock control              | On                | Off               | 0    | R/W |                     |
| D2      | PST02  | 16-bit programmable timer 0 division ratio             |                                                        |                   | 0                 | R/W  |     |                     |
|         |        | PST02 PST01 PST00 (OSC3) (OSC1)                        |                                                        |                   |                   |      |     |                     |
|         |        | 1 1 1 fosc <sub>3</sub> / 4096 fosc <sub>1</sub> / 128 |                                                        |                   |                   |      |     |                     |
| D1      | PST01  | 1 1 0 fosc <sub>3</sub> / 1024 fosc <sub>1</sub> / 64  |                                                        |                   | 0                 | R/W  |     |                     |
|         |        | 1 0 1 fosc <sub>3</sub> / 256 fosc <sub>1</sub> / 32   |                                                        |                   |                   |      |     |                     |
|         |        | 1 0 0 fosc <sub>3</sub> / 128 fosc <sub>1</sub> / 16   |                                                        |                   |                   |      |     |                     |
| D0      | PST00  | 0 1 1 fosc <sub>3</sub> / 64 fosc <sub>1</sub> / 8     |                                                        |                   | 0                 | R/W  |     |                     |
|         |        | 0 1 0 fosc <sub>3</sub> / 32 fosc <sub>1</sub> / 4     |                                                        |                   |                   |      |     |                     |
|         |        | 0 0 1 fosc <sub>3</sub> / 8 fosc <sub>1</sub> / 2      |                                                        |                   |                   |      |     |                     |
|         |        | 0 0 0 fosc <sub>3</sub> / 2 fosc <sub>1</sub> / 1      |                                                        |                   |                   |      |     |                     |
| 00FF11  | D7     | –                                                      | –                                                      | –                 | –                 | –    | –   | "0" when being read |
|         | D6     | –                                                      | –                                                      | –                 | –                 | –    | –   |                     |
|         | D5     | –                                                      | –                                                      | –                 | –                 | –    | –   |                     |
|         | D4     | –                                                      | –                                                      | –                 | –                 | –    | –   |                     |
|         | D3     | PRPRT2                                                 | 8-bit programmable timer clock control                 | On                | Off               | 0    | R/W |                     |
|         | D2     | PST22                                                  | 8-bit programmable timer division ratio                |                   |                   | 0    | R/W |                     |
|         |        |                                                        | PST22 PST21 PST20 Division ratio                       |                   |                   |      |     |                     |
|         |        |                                                        | 1 1 1 fosc <sub>3</sub> / 256                          |                   |                   |      |     |                     |
| D1      | PST21  | 1 1 0 fosc <sub>3</sub> / 128                          |                                                        |                   | 0                 | R/W  |     |                     |
|         |        | 1 0 1 fosc <sub>3</sub> / 64                           |                                                        |                   |                   |      |     |                     |
|         |        | 1 0 0 fosc <sub>3</sub> / 32                           |                                                        |                   |                   |      |     |                     |
| D0      | PST20  | 0 1 1 fosc <sub>3</sub> / 16                           |                                                        |                   | 0                 | R/W  |     |                     |
|         |        | 0 1 0 fosc <sub>3</sub> / 8                            |                                                        |                   |                   |      |     |                     |
|         |        | 0 0 1 fosc <sub>3</sub> / 4                            |                                                        |                   |                   |      |     |                     |
|         |        | 0 0 0 fosc <sub>3</sub> / 2                            |                                                        |                   |                   |      |     |                     |
| 00FF12  | D7     | –                                                      | –                                                      | –                 | –                 | –    | –   | "0" when being read |
|         | D6     | –                                                      | –                                                      | –                 | –                 | –    | –   |                     |
|         | D5     | –                                                      | –                                                      | –                 | –                 | –    | –   |                     |
|         | D4     | –                                                      | –                                                      | –                 | –                 | –    | –   |                     |
|         | D3     | –                                                      | –                                                      | –                 | –                 | –    | –   |                     |
|         | D2     | –                                                      | –                                                      | –                 | –                 | –    | –   |                     |
|         | D1     | PRTF1                                                  | 16-bit programmable timer 1 source clock selection     | fosc <sub>1</sub> | fosc <sub>3</sub> | 0    | R/W |                     |
|         | D0     | PRTF0                                                  | 16-bit programmable timer 0 source clock selection     | fosc <sub>1</sub> | fosc <sub>3</sub> | 0    | R/W |                     |

Table 5.5.5.1(b) Prescaler control bits

| Address | Bit    | Name                               | Function                             | 1              | 0   | Init | R/W | Comment             |
|---------|--------|------------------------------------|--------------------------------------|----------------|-----|------|-----|---------------------|
| 00FF13  | D7     | –                                  | –                                    | –              | –   | –    | –   | "0" when being read |
|         | D6     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D5     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D4     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D3     | PRAD                               | A/D converter clock control          |                | On  | Off  | 0   | R/W                 |
|         | D2     | PSAD2                              | A/D converter division ratio         |                |     |      | 0   | R/W                 |
|         | D1     | PSAD1                              | PSAD2 PSAD1 PSAD0                    | Division ratio |     |      | 0   | R/W                 |
| 00FF14  | D7     | PRFO1                              | FOUT1 output control                 | On             | Off | 0    | R/W |                     |
|         | D6     | PSF12                              | FOUT1 division ratio                 |                |     | 0    | R/W |                     |
|         | D5     | PSF11                              | PSF12 PSF11 PSF10                    | Division ratio |     |      | 0   | R/W                 |
|         | D4     | PSF10                              | PSF12 PSF11 PSF10                    | Division ratio |     |      | 0   | R/W                 |
|         | D3     | PRFO3                              | FOUT3 output control                 |                | On  | Off  | 0   | R/W                 |
|         | D2     | PSF32                              | FOUT3 division ratio                 |                |     |      | 0   | R/W                 |
|         | D1     | PSF31                              | PSF32 PSF31 PSF30                    | Division ratio |     |      | 0   | R/W                 |
| 00FF15  | D7     | –                                  | –                                    | –              | –   | –    | –   | "0" when being read |
|         | D6     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D5     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D4     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D3     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D2     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D1     | PK11ON                             | EXCL01 input clock ON/OFF control    |                | On  | Off  | 0   | R/W                 |
| D0      | PK10ON | EXCL00 input clock ON/OFF control  |                                      | On             | Off | 0    | R/W |                     |
| 00FF16  | D7     | –                                  | –                                    | –              | –   | –    | –   | "0" when being read |
|         | D6     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D5     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D4     | –                                  | –                                    | –              | –   | –    | –   |                     |
|         | D3     | PRTP                               | Touch panel controller clock control |                | On  | Off  | 0   | R/W                 |
| D2      | PSTP2  | Touch panel controller clock ratio |                                      |                |     | 0    | R/W |                     |
| D1      | PSTP1  | PSTP2 PSTP1 PSTP0                  | Division ratio                       |                |     | 0    | R/W |                     |
| D0      | PSTP0  | PSTP2 PSTP1 PSTP0                  | Division ratio                       |                |     | 0    | R/W |                     |

**OSCC: OSC3 oscillation control register (00FF01H•D2)**

Turns the OSC3 oscillation circuit on and off.

When "1" is written: OSC3 oscillation ON

When "0" is written: OSC3 oscillation OFF

Reading: Valid

When using the clock of which the clock source is OSC3, set the OSCC register to "1". Refer to Section 5.4, "Oscillation Circuit", for details of the oscillation control.

At initial reset, the OSCC register is set to "0" (OSC3 oscillation OFF).

**PRTF0: 16-bit programmable timer 0 source clock selection register (00FF12H•D0)**

Selects the source clock for the 16-bit programmable timer 0.

When "1" is written: fosc1

When "0" is written: fosc3

Reading: Valid

When "1" is written to the PRTF0 register, the OSC1 clock is selected as the source clock for the 16-bit programmable timer 0.

When "0" is written, the OSC3 clock is selected.

At initial reset, the PRTF0 register is set to "0" (fosc3).

**PST00–PST02: 16-bit programmable timer 0 division ratio selection register (00FF10H•D0–D2)**

Selects the clock for the 16-bit programmable timer 0.

It can be selected from 8 types of division ratio shown in Table 5.5.5.1(a).

This register can also be read.

At initial reset, the PST0 register is set to "0".

**PRPRT0: 16-bit programmable timer 0 clock control register (00FF10H•D3)**

Controls the clock supply of the 16-bit programmable timer 0.

When "1" is written: ON

When "0" is written: OFF

Reading: Valid

By writing "1" to the PRPRT0 register, the clock that is selected with the PST0 register is output to the 16-bit programmable timer 0.

When "0" is written, the clock is not output.

At initial reset, the PRPRT0 register is set to "0" (OFF).

**PK100N: EXCL00 clock control register (00FF15H•D0)**

Controls the event counter clock of the 16-bit programmable timer 0.

When "1" is written: ON

When "0" is written: OFF

Reading: Valid

By writing "1" to the PK100N register, the EXCL00 (K10 input) clock is output to the 16-bit programmable timer 0.

When "0" is written, the clock is not output.

At initial reset, the PK100N register is set to "0" (OFF).

**PRTF1: 16-bit programmable timer 1 source clock selection register (00FF12H•D1)**

Selects the source clock for the 16-bit programmable timer 1.

When "1" is written: fosc1

When "0" is written: fosc3

Reading: Valid

When "1" is written to the PRTF1 register, the OSC1 clock is selected as the source clock for the 16-bit programmable timer 1.

When "0" is written, the OSC3 clock is selected.

At initial reset, the PRTF1 register is set to "0" (fosc3).

**PST10–PST12: 16-bit programmable timer 1 division ratio selection register (00FF10H•D4–D6)**

Selects the clock for the 16-bit programmable timer 1.

It can be selected from 8 types of division ratio shown in Table 5.5.5.1(a).

This register can also be read.

At initial reset, the PST1 register is set to "0".

**PRPRT1: 16-bit programmable timer 1 clock control register (00FF10H•D7)**

Controls the clock supply of the 16-bit programmable timer 1.

When "1" is written: ON

When "0" is written: OFF

Reading: Valid

By writing "1" to the PRPRT1 register, the clock that is selected with the PST1 register is output to the 16-bit programmable timer 1.

When "0" is written, the clock is not output.

At initial reset, the PRPRT1 register is set to "0" (OFF).

**PK11ON: EXCL01 clock control register (00FF15H•D1)**

Controls the event counter clock of the 16-bit programmable timer 1.

When "1" is written: ON  
 When "0" is written: OFF  
 Reading: Valid

By writing "1" to the PK11ON register, the EXCL01 (K11 input) clock is output to the 16-bit programmable timer 1.

When "0" is written, the clock is not output.  
 At initial reset, the PK11ON register is set to "0" (OFF).

**PST20–PST22: 8-bit programmable timer division ratio selection register (00FF11H•D0–D2)**

Selects the clock for the 8-bit programmable timer. It can be selected from 8 types of division ratio shown in Table 5.5.5.1(a).

This register can also be read.  
 At initial reset, the PST2 register is set to "0" ( $f_{OSC3}/2$ ).

**PRPRT2: 8-bit programmable timer clock control register (00FF11H•D3)**

Controls the clock supply of the 8-bit programmable timer.

When "1" is written: ON  
 When "0" is written: OFF  
 Reading: Valid

By writing "1" to the PRPRT2 register, the clock that is selected with the PST2 register is output to the 8-bit programmable timer.

When "0" is written, the clock is not output.  
 At initial reset, the PRPRT2 register is set to "0" (OFF).

**PSAD0–PSAD2: A/D converter clock division ratio selection register (00FF13H•D0–D2)**

Selects the clock for the A/D converter. It can be selected from 5 types of division ratio as shown in Table 5.5.5.1(b).

This register can also be read.  
 At initial reset, the PSAD register is set to "0" ( $f_{OSC3}/1$ ).

**PRAD: A/D converter clock control register (00FF13H•D3)**

Controls the clock supply of the A/D converter.

When "1" is written: ON  
 When "0" is written: OFF  
 Reading: Valid

By writing "1" to the PRAD register, the clock that is selected with the PSAD register is output to the A/D converter.

When "0" is written, the clock is not output.  
 At initial reset, the PRAD register is set to "0" (OFF).

**PSF10–PSF12: FOUT1 division ratio selection register (00FF14H•D4–D6)**

Selects the frequency for the FOUT1 clock. It can be selected from 8 types of division ratio shown in Table 5.5.5.1(b).

This register can also be read.  
 At initial reset, the PSF1 register is set to "0" ( $f_{OSC1}/1$ ).

**PRFO1: FOUT1 output control register (00FF14H•D7)**

Controls the FOUT1 output.

When "1" is written: ON  
 When "0" is written: OFF  
 Reading: Valid

When "1" is written to the PRFO1 register, the FOUT1 (R41) terminal outputs the clock selected with the PSF1 register. However, the high-impedance control register HZR41 of the output port R41 must be set to "0" and the data register R41D must be set to "1".

When "0" is written, the clock is not output.  
 At initial reset, the PRFO1 register is set to "0" (OFF).

**PSF30–PSF32: FOUT3 division ratio selection register (00FF14H•D0–D2)**

Selects the frequency for the FOUT3 clock. It can be selected from 8 types of division ratio shown in Table 5.5.5.1(b).

This register can also be read.  
 At initial reset, the PSF3 register is set to "0" ( $f_{OSC3}/1$ ).

**PRFO3: FOUT3 output control register (00FF14H•D3)**

Controls the FOUT3 output.

When "1" is written: ON  
 When "0" is written: OFF  
 Reading: Valid

When "1" is written to the PRFO3 register, the FOUT3 (R40) terminal outputs the clock selected with the PSF3 register. However, the high-impedance control register HZR40 of the output port R40 must be set to "0" and the data register R40D must be set to "1".

When "0" is written, the clock is not output. At initial reset, the PRFO3 register is set to "0" (OFF).

**PSTP0–PSTP2: Touch panel controller clock division ratio selection register (00FF16H•D0–D2)**

Selects the clock for the touch panel controller.

It can be selected from 5 types of division ratio as shown in Table 5.5.5.1(b).

This register can also be read.

At initial reset, the PSTP register is set to "0" ( $f_{OSC3}/1$ ).

**PRTP: Touch panel controller clock control register (00FF16H•D3)**

Controls the clock supply of the touch panel controller.

When "1" is written: ON  
 When "0" is written: OFF  
 Reading: Valid

By writing "1" to the PRTP register, the clock that is selected with the PSTP register is output to the touch panel controller.

When "0" is written, the clock is not output. At initial reset, the PRTP register is set to "0" (OFF).

**5.5.6 Programming note**

When using an output clock from the OSC3 prescaler, it is necessary to turn the OSC3 oscillation circuit on. Furthermore, the OSC3 oscillation circuit takes a maximum 20 msec for stabilizing oscillation after turning the OSC3 oscillation circuit on. Therefore, wait a long enough interval after the OSC3 oscillation goes on before turning the clock output of the OSC3 prescaler on. (The oscillation start time varies depending on the oscillator and external components to be used. Refer to Chapter 8, "ELECTRICAL CHARACTERISTICS", in which an example of oscillation start time is indicated.)

## 5.6 Input Ports (K ports)

### 5.6.1 Configuration of input ports

The S1C88409 has 12 bits of input ports built-in, and all the ports can be used as a general-purpose input port that has an interrupt function.

K0 port: K00–K07 8 bits  
 K1 port: K10–K13 4 bits

The K10 and K11 terminals serve both as the general-purpose input port terminal and the external clock (EXCL00, EXCL01) input terminal for the 16-bit programmable timer (event counter), and the input signal is common used. (Refer to Section 5.12, "16-bit Programmable Timer")

Figure 5.6.1.1 shows the structure of the input port.

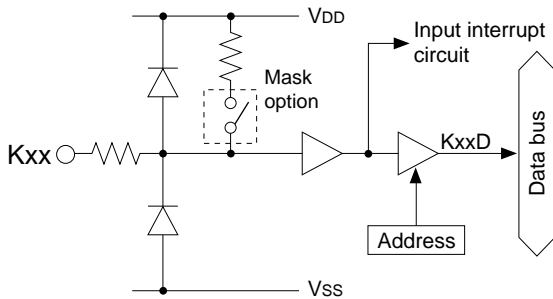


Fig. 5.6.1.1 Structure of input port

Each input port terminal is directly connected to the data bus via a three-state buffer. The input signal status can be read via the I/O memory as data.

### 5.6.2 Mask option

| Input port pull-up resistors |                                        |                                      |
|------------------------------|----------------------------------------|--------------------------------------|
| K00                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K01                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K02                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K03                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K04                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K05                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K06                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K07                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K10                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K11                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K12                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| K13                          | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |

The input port has a built-in pull-up resistor, and it can be individually selected for use or not by the mask option.

The "With resistor" option is suitable for push switch and key matrix input.

When the input terminal is changed from a low level to a high level by the built-in pull-up resistor, the rise of the waveform is delayed on account of the time constant of the pull-up resistor and load capacitance of the terminal. Hence, when reading the input port, it is necessary to wait an appropriate amount of time. Particular care must be taken of the key scan for the key matrix configuration. Make this waiting time the amount of time or more calculated by the following expression.

$$\text{Waiting time} = R_{IN} \times (C_{IN} + C_L) \times 1.6 \text{ [sec]}$$

R<sub>IN</sub>: Pull-up resistance Max. value

C<sub>IN</sub>: Terminal capacitance Max. value

C<sub>L</sub>: Load capacitance on the board

When "Gate direct" is selected, the pull-up resistor is disconnected and the port is suitable for slide switch input and interfacing with other LSIs. In this case, take care that a floating status does not occur in the input.

For unused input ports, select "With resistor" as the default setting.

### 5.6.3 Interrupt function

All the input ports provide the interrupt function. The input ports are divided into five systems: K0 (K00–K07), K10, K11, K12 and K13. The interrupt generation condition for each system can be set with software.

When the interrupt generation condition set for each terminal system is met, the interrupt factor flag (FK0, FK10, FK11, FK12 and FK13) corresponding to the terminal system is set to "1", and an interrupt is generated.

The interrupt can be prohibited by setting the interrupt enable register (EK0, EK10, EK11, EK12 and EK13) corresponding to each interrupt factor flag.

Furthermore, the priority level of the input interrupt for the CPU can be set at an optional level (0–3) using the interrupt priority registers PK0 and PK1 (two bits each) corresponding to two systems K0 and K1.

Refer to Section 5.20, "Interrupt and Standby Mode", for details of the interrupt control registers and operations subsequent to interrupt generation.

The exception processing vectors for each interrupt factor are set as follows:

K10 input interrupt: 000006H  
 K11 input interrupt: 000008H  
 K12 input interrupt: 00000AH  
 K13 input interrupt: 00000CH  
 K0 input interrupt: 00000EH

#### K0 input interrupt

Figure 5.6.3.1 shows the configuration of the K0 (K00–K07) input interrupt circuit.

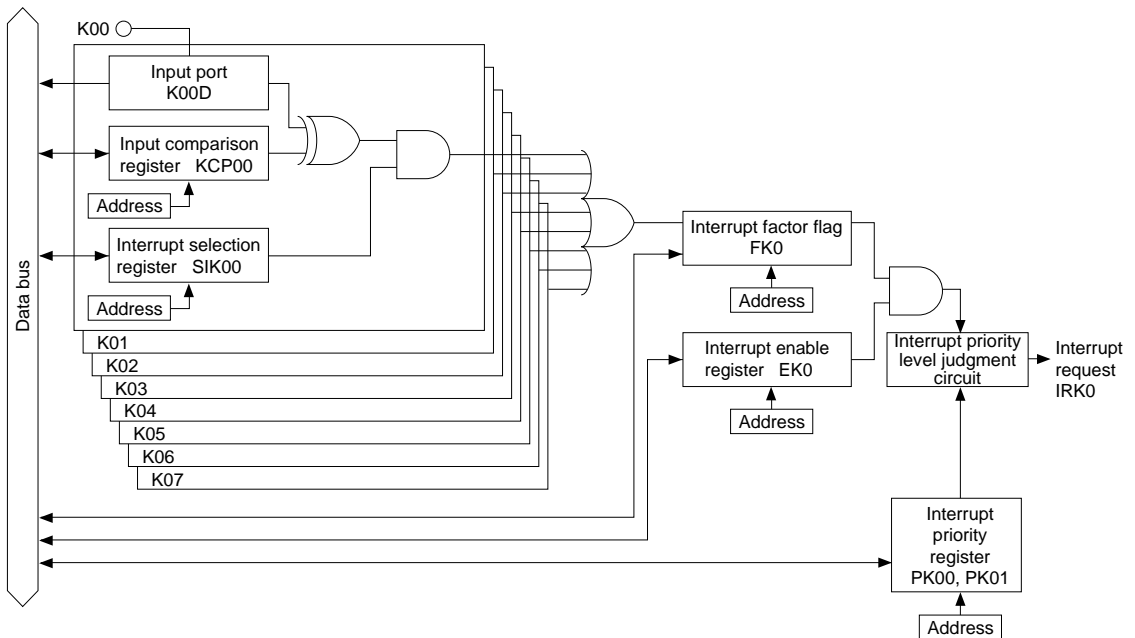


Fig. 5.6.3.1 Configuration of K0 input interrupt circuit

The interrupt selection register SIK0 and input comparison register KCP0 for the K0 port is used to set the interrupt generation condition.

Input port interrupt can be enabled or disabled by the setting of the interrupt selection registers SIK0. While the interrupt enable register EK0 masks the interrupt factor for the terminal system (8 bits), the interrupt selection register SIK0 masks in bit units.

The input comparison register KCP0 selects the interrupt generation timing that an interrupt is to be generated at the rising edge or the falling edge for each input.

When the status of the input terminals in which an interrupt has been enabled by the interrupt selection register SIK0 and the content of the input comparison register KCP0 change from a matching to no matching, the interrupt factor flag FK0 is set to "1" and an interrupt is generated.

Figure 5.6.3.2 shows an example of interrupt generation in the K0 terminal system.

K00 interrupt is disabled by the interrupt selection register (SIK00), so that an interrupt does not occur at (2). At (3), K03 changes to "0"; the data of the terminals K01–K07 in which an interrupt is enabled no longer match the data of the input comparison registers KCP01–KCP07, so that interrupt occurs. As already explained, the condition for the interrupt to occur is the change in the port data and contents of the input comparison registers from matching to no matching. Hence, in (4), when the no matching status changes to another no matching status, an interrupt does not occur. Therefore, to generate the interrupt again after an interrupt is generated, it is necessary to return the input terminal status to the same content as the input comparison register KCP0 or re-set the input comparison register KCP0. Further, terminals that have been disabled for interrupt do not affect the conditions for interrupt generation.

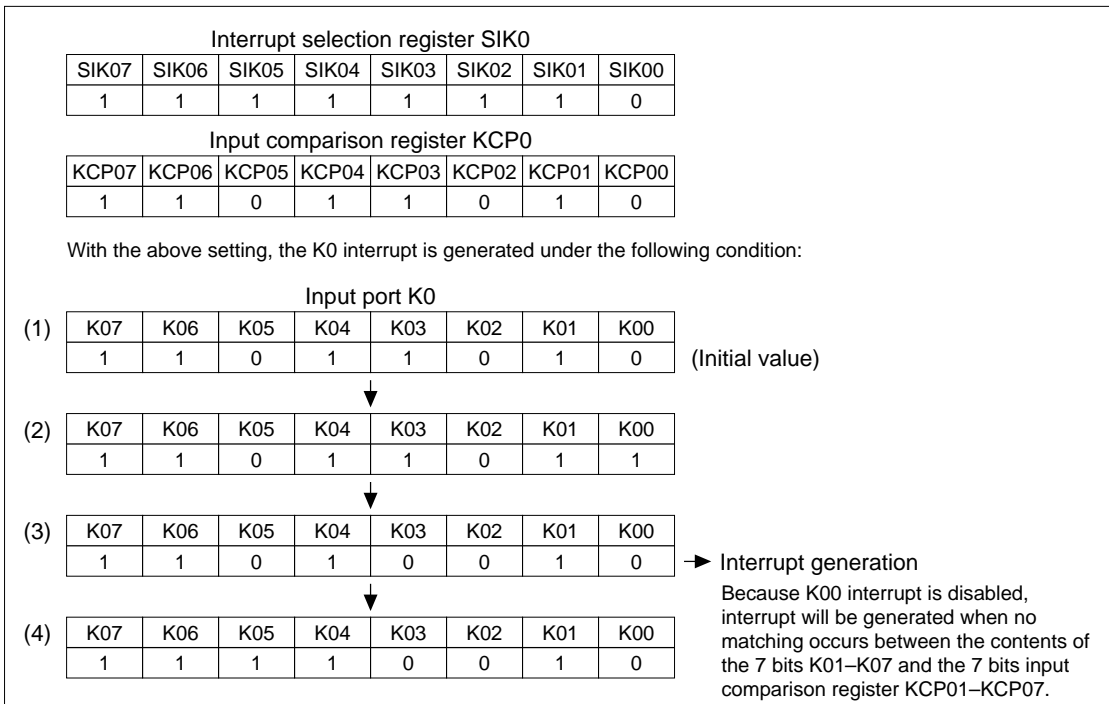


Fig. 5.6.3.2 Example of K0 (K00–K07) interrupt generation



**K10–K13 input interrupt**

Figure 5.6.3.3 shows the configuration of the K10–K13 input interrupt circuit.

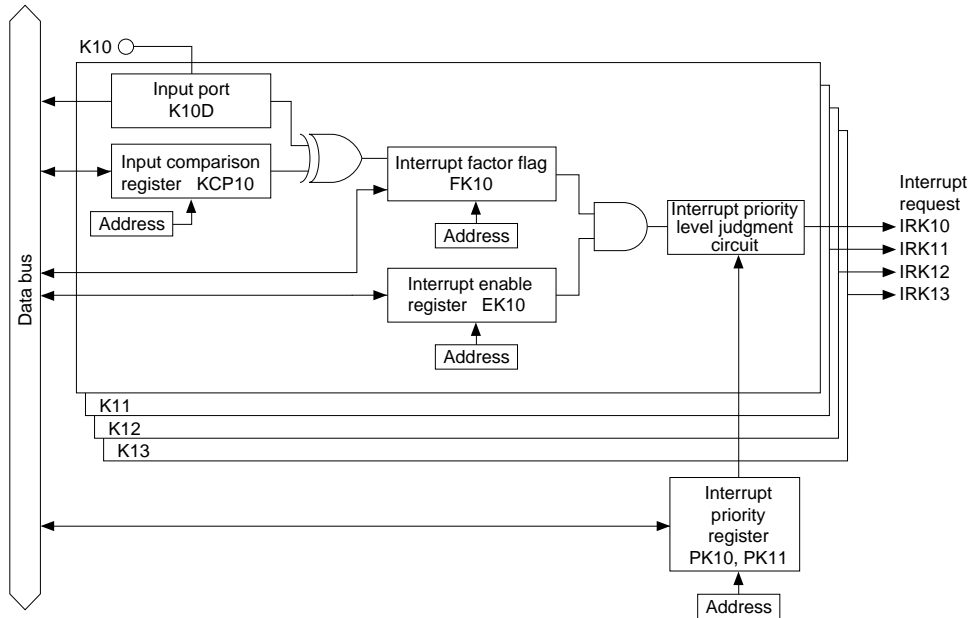


Fig. 5.6.3.3 Configuration of K10–K13 input interrupt circuit

Since the K10–K13 input ports can generate an interrupt by each bit, an interrupt selection register is not provided. The interrupts are enabled or disabled by the interrupt enable register EK1. The input comparison register KCP1 selects the interrupt generation timing that an interrupt is to be generated at the rising edge or the falling edge for each input.

Each interrupt of the K10–K13 input ports is generated at the rising edge or the falling edge (depending on the setting of the input comparison register KCP1) when the interrupt has been enabled with the interrupt enable register EK1.

5.6.4 I/O memory of input ports

Table 5.6.4.1 shows the input port control bits.

Table 5.6.4.1 Input port control bits

| Address | Bit | Name  | Function                          | 1                                | 0                               | Init     | R/W | Comment             |   |                     |
|---------|-----|-------|-----------------------------------|----------------------------------|---------------------------------|----------|-----|---------------------|---|---------------------|
| 00FF20  | D7  | PK11  | K10–K13                           | PK11                             | PK10                            | 0        | R/W |                     |   |                     |
|         | D6  | PK10  | interrupt priority register       | PK01                             | PK00                            | 0        | R/W |                     |   |                     |
|         | D5  | PK01  | K00–K07                           | PTM11                            | PTM10                           | Priority | 0   | R/W                 |   |                     |
|         | D4  | PK00  | interrupt priority register       | PTM01                            | PTM00                           | level    | 0   | R/W                 |   |                     |
|         | D3  | PTM11 | 16-bit programmable timer 1       | 1                                | 1                               | Level 3  | 0   | R/W                 |   |                     |
|         | D2  | PTM10 | interrupt priority register       | 1                                | 0                               | Level 2  | 0   | R/W                 |   |                     |
|         | D1  | PTM01 | 16-bit programmable timer 0       | 0                                | 1                               | Level 1  | 0   | R/W                 |   |                     |
|         | D0  | PTM00 | interrupt priority register       | 0                                | 0                               | Level 0  | 0   | R/W                 |   |                     |
| 00FF23  | D7  | EK13  | K13 interrupt enable register     | Interrupt is enabled             | Interrupt is disabled           | 0        | R/W |                     |   |                     |
|         | D6  | EK12  | K12 interrupt enable register     |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D5  | EK11  | K11 interrupt enable register     |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D4  | EK10  | K10 interrupt enable register     |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D3  | EK0   | K00–K07 interrupt enable register |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D2  | –     | –                                 |                                  |                                 | –        | –   | –                   | – | "0" when being read |
|         | D1  | –     | –                                 |                                  |                                 | –        | –   | –                   | – |                     |
|         | D0  | –     | –                                 |                                  |                                 | –        | –   | –                   | – |                     |
| 00FF27  | D7  | FK13  | K13 interrupt factor flag         | (R)                              | (R)                             | 0        | R/W |                     |   |                     |
|         | D6  | FK12  | K12 interrupt factor flag         | Interrupt                        | Interrupt                       | 0        | R/W |                     |   |                     |
|         | D5  | FK11  | K11 interrupt factor flag         | factor has                       | factor has not                  | 0        | R/W |                     |   |                     |
|         | D4  | FK10  | K10 interrupt factor flag         | generated                        | generated                       | 0        | R/W |                     |   |                     |
|         | D3  | FK0   | K00–K07 interrupt factor flag     | –                                | –                               | 0        | R/W |                     |   |                     |
|         | D2  | –     | –                                 | (W)                              | (W)                             | –        | –   | "0" when being read |   |                     |
|         | D1  | –     | –                                 | Reset                            | Invalid                         | –        | –   |                     |   |                     |
|         | D0  | –     | –                                 | –                                | –                               | –        | –   |                     |   |                     |
| 00FFC0  | D7  | SIK07 | K07 interrupt selection register  | Interrupt is enabled             | Interrupt is disabled           | 0        | R/W |                     |   |                     |
|         | D6  | SIK06 | K06 interrupt selection register  |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D5  | SIK05 | K05 interrupt selection register  |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D4  | SIK04 | K04 interrupt selection register  |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D3  | SIK03 | K03 interrupt selection register  |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D2  | SIK02 | K02 interrupt selection register  |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D1  | SIK01 | K01 interrupt selection register  |                                  |                                 | 0        | R/W |                     |   |                     |
|         | D0  | SIK00 | K00 interrupt selection register  |                                  |                                 | 0        | R/W |                     |   |                     |
| 00FFC1  | D7  | KCP07 | K07 input comparison register     | Falling edge generates interrupt | Rising edge generates interrupt | 1        | R/W |                     |   |                     |
|         | D6  | KCP06 | K06 input comparison register     |                                  |                                 | 1        | R/W |                     |   |                     |
|         | D5  | KCP05 | K05 input comparison register     |                                  |                                 | 1        | R/W |                     |   |                     |
|         | D4  | KCP04 | K04 input comparison register     |                                  |                                 | 1        | R/W |                     |   |                     |
|         | D3  | KCP03 | K03 input comparison register     |                                  |                                 | 1        | R/W |                     |   |                     |
|         | D2  | KCP02 | K02 input comparison register     |                                  |                                 | 1        | R/W |                     |   |                     |
|         | D1  | KCP01 | K01 input comparison register     |                                  |                                 | 1        | R/W |                     |   |                     |
|         | D0  | KCP00 | K00 input comparison register     |                                  |                                 | 1        | R/W |                     |   |                     |
| 00FFC2  | D7  | –     | –                                 | –                                | –                               | –        | –   | "0" when being read |   |                     |
|         | D6  | –     | –                                 | –                                | –                               | –        | –   |                     |   |                     |
|         | D5  | –     | –                                 | –                                | –                               | –        | –   |                     |   |                     |
|         | D4  | –     | –                                 | –                                | –                               | –        | –   |                     |   |                     |
|         | D3  | KCP13 | K13 input comparison register     | Falling edge                     | Rising edge                     | 1        | R/W |                     |   |                     |
|         | D2  | KCP12 | K12 input comparison register     | generates                        | generates                       | 1        | R/W |                     |   |                     |
|         | D1  | KCP11 | K11 input comparison register     | interrupt                        | interrupt                       | 1        | R/W |                     |   |                     |
|         | D0  | KCP10 | K10 input comparison register     | –                                | –                               | 1        | R/W |                     |   |                     |
| 00FFC3  | D7  | K07D  | K07 input port data               | High                             | Low                             | –        | R   |                     |   |                     |
|         | D6  | K06D  | K06 input port data               |                                  |                                 | –        | R   |                     |   |                     |
|         | D5  | K05D  | K05 input port data               |                                  |                                 | –        | R   |                     |   |                     |
|         | D4  | K04D  | K04 input port data               |                                  |                                 | –        | R   |                     |   |                     |
|         | D3  | K03D  | K03 input port data               |                                  |                                 | –        | R   |                     |   |                     |
|         | D2  | K02D  | K02 input port data               |                                  |                                 | –        | R   |                     |   |                     |
|         | D1  | K01D  | K01 input port data               |                                  |                                 | –        | R   |                     |   |                     |
|         | D0  | K00D  | K00 input port data               |                                  |                                 | –        | R   |                     |   |                     |
| 00FFC4  | D7  | –     | –                                 | –                                | –                               | –        | –   | "0" when being read |   |                     |
|         | D6  | –     | –                                 | –                                | –                               | –        | –   |                     |   |                     |
|         | D5  | –     | –                                 | –                                | –                               | –        | –   |                     |   |                     |
|         | D4  | –     | –                                 | –                                | –                               | –        | –   |                     |   |                     |
|         | D3  | K13D  | K13 input port data               | High                             | Low                             | –        | R   |                     |   |                     |
|         | D2  | K12D  | K12 input port data               |                                  |                                 | –        | R   |                     |   |                     |
|         | D1  | K11D  | K11 input port data               |                                  |                                 | –        | R   |                     |   |                     |
|         | D0  | K10D  | K10 input port data               |                                  |                                 | –        | R   |                     |   |                     |
|         |     |       | –                                 |                                  |                                 | R        |     |                     |   |                     |

**K00D–K07D: K0 input port data (00FFC3H)****K10D–K13D: K1 input port data (00FFC4H•D0–D3)**

Input data of the input port terminals can be read out.

When "1" is read: HIGH level

When "0" is read: LOW level

Writing: Invalid

The terminal voltage of each of the input ports K00–K07 and K10–K13 can be directly read as either a "1" when the terminal is high (VDD) level or a "0" when the terminal is low (VSS) level. These bits are dedicated for reading, so writing cannot be done.

**SIK00–SIK07: K0 port interrupt selection register (00FFC0H)**

Sets the interrupt generation condition (enables/disables interrupt) for the K0 input port.

When "1" is written: Interrupt is enabled

When "0" is written: Interrupt is disabled

Reading: Valid

SIK0 is the interrupt selection register corresponding to the input port K0. An interrupt of the port in which the SIK0 bit is set to "1" is enabled, and the others in which the SIK0 bit is set to "0" are disabled. Change of the input terminal in which the interrupt is disabled does not affect the interrupt generation.

At initial reset, the SIK0 register is set to "0" (interrupt is disabled).

The K10–K13 input port has no interrupt selection register because the port can generate interrupts in bit units.

**KCP00–KCP07: K0 port input comparison register (00FFC1H)****KCP10–KCP13: K1 port input comparison register (00FFC2H•D0–D3)**

Sets the interrupt generation condition (interrupt generation timing) for the K0 or K1 input port.

When "1" is written: Falling edge

When "0" is written: Rising edge

Reading: Valid

KCP is the input comparison register corresponding to each input port. An interrupt of the port in which the KCP bit is set to "1" is generated at the falling edge of the input and an interrupt in which the KCP bit is set to "0" is generated at the rising edge.

At initial reset, the KCP register is set to "1" (falling edge).

**PK00, PK01: K0 input interrupt priority register (00FF20H•D4, D5)****PK10, PK11: K1 input interrupt priority register (00FF20H•D6, D7)**

Sets the input interrupt priority level.

PK0 and PK1 are the interrupt priority registers corresponding to the K0, K1 input interrupts.

Table 5.6.4.2 shows the interrupt priority level which can be set by this register.

Table 5.6.4.2 Interrupt priority level settings

| PK11<br>PK01 | PK10<br>PK00 | Interrupt priority level             |
|--------------|--------------|--------------------------------------|
| 1            | 1            | Level 3 ( $\overline{\text{IRQ3}}$ ) |
| 1            | 0            | Level 2 ( $\overline{\text{IRQ2}}$ ) |
| 0            | 1            | Level 1 ( $\overline{\text{IRQ1}}$ ) |
| 0            | 0            | Level 0 (None)                       |

At initial reset, the PK register is set to "0" (level 0).

**EK0: K0 input interrupt enable register (00FF23H•D3)****EK10–EK13: K1 input interrupt enable register (00FF23H•D4–D7)**

Enables or disables the interrupt generation to the CPU.

When "1" is written: Interrupt is enabled

When "0" is written: Interrupt is disabled

Reading: Valid

EK0 is the interrupt enable register corresponding to eight bits of the K0 port and EK10–EK13 correspond to each bit of the K10–K13 ports.

An interrupt of the port in which the EK register is set to "1" is enabled, and the others in which the EK register is set to "0" are disabled.

At initial reset, the EK register is set to "0" (interrupt is disabled).

**FK0: K0 input interrupt factor flag (00FF27H•D3)****FK10–FK13: K1 input interrupt factor flag (00FF27H•D4–D7)**

Indicates the generation of input interrupt factor.

When "1" is read: Int. factor has generated

When "0" is read: Int. factor has not generated

When "1" is written: Factor flag is reset

When "0" is written: Invalid

FK0 is the interrupt factor flag corresponding to eight bits of the K0 port and FK10–FK13 correspond to each bit of the K10–K13 ports.

The interrupt factor flag is set to "1" when the interrupt generation condition is met.

At this point, if the corresponding interrupt enable register is set to "1" and the corresponding interrupt priority register is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.

Regardless of the interrupt enable register and interrupt priority register settings, the interrupt factor flag is set to "1" when the interrupt generation condition is met.

To accept the subsequent interrupt after an interrupt generation, it is necessary to re-set the interrupt flags (set the interrupt flag to a lower level than the level indicated by the interrupt priority registers, or execute the RETE instruction) and to reset the interrupt factor flag. The interrupt factor flag is reset to "0" by writing "1".

At initial reset, the FK flags are all reset to "0".

### 5.6.5 Programming note

When the input terminal is changed from a low level to a high level by the built-in pull-up resistor, the rise of the waveform is delayed on account of the time constant of the pull-up resistor and load capacitance of the terminal. Hence, when reading the input port, it is necessary to wait an appropriate amount of time. Particular care must be taken of the key scan for the key matrix configuration. Make this waiting time the amount of time or more calculated by the following expression.

Waiting time =  $R_{IN} \times (C_{IN} + C_L) \times 1.6$  [sec]

R<sub>IN</sub>: Pull-up resistance Max. value

C<sub>IN</sub>: Terminal capacitance Max. value

C<sub>L</sub>: Load capacitance on the board

## 5.7 Output Ports (R ports)

### 5.7.1 Configuration of output ports

The S1C88409 has 30 bits of output ports.

|          |         |        |
|----------|---------|--------|
| R0 port: | R00–R07 | 8 bits |
| R1 port: | R10–R17 | 8 bits |
| R2 port: | R20–R27 | 8 bits |
| R3 port: | R30–R32 | 3 bits |
| R4 port: | R40–R42 | 3 bits |

Depending on the bus mode setting, the configuration of the output ports may vary as shown in the table below.

Table 5.7.1.1 Configuration of output ports

| Terminal | Bus mode        |                                          |             |
|----------|-----------------|------------------------------------------|-------------|
|          | Single chip     | Expanded 64K                             | Expanded 4M |
| R00      | Output port R00 | Address A0                               |             |
| R01      | Output port R01 | Address A1                               |             |
| R02      | Output port R02 | Address A2                               |             |
| R03      | Output port R03 | Address A3                               |             |
| R04      | Output port R04 | Address A4                               |             |
| R05      | Output port R05 | Address A5                               |             |
| R06      | Output port R06 | Address A6                               |             |
| R07      | Output port R07 | Address A7                               |             |
| R10      | Output port R10 | Address A8                               |             |
| R11      | Output port R11 | Address A9                               |             |
| R12      | Output port R12 | Address A10                              |             |
| R13      | Output port R13 | Address A11                              |             |
| R14      | Output port R14 | Address A12                              |             |
| R15      | Output port R15 | Address A13                              |             |
| R16      | Output port R16 | Address A14                              |             |
| R17      | Output port R17 | Address A15                              |             |
| R20      | Output port R20 | Address A16                              |             |
| R21      | Output port R21 | Address A17                              |             |
| R22      | Output port R22 | Address A18                              |             |
| R23      | Output port R23 | Address A19                              |             |
| R24      | Output port R24 | Address A20                              |             |
| R25      | Output port R25 | Address A21                              |             |
| R26      | Output port R26 | $\overline{RD}$ signal                   |             |
| R27      | Output port R27 | $\overline{WR}$ signal                   |             |
| R30      | Output port R30 | Output port R30/ $\overline{CE0}$ signal |             |
| R31      | Output port R31 | Output port R31/ $\overline{CE1}$ signal |             |
| R32      | Output port R32 | Output port R32/ $\overline{CE2}$ signal |             |
| R40      | Output port R40 |                                          |             |
| R41      | Output port R41 |                                          |             |
| R42      | Output port R42 |                                          |             |

This section explains only the control of general-purpose output ports. Refer to Section 5.2, "System Controller and Bus Control", for the bus control. Figure 5.7.1.1 shows the structure of the output port.

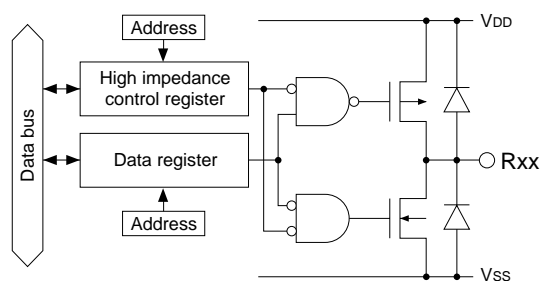


Fig. 5.7.1.1 Structure of output port

The data register and high impedance control register of the output port which is used for the bus function can be used as general purpose registers with the ability to read and write. They do not affect the bus signal output.

### 5.7.2 High impedance control

Each output port can be set in high impedance by software. Thus the output signal lines can be shared with other external devices.

By setting the bits of the high impedance control register to "1", the corresponding output ports go to a high impedance status. The output port in which the register is set to "0" becomes a complementary output.

### 5.7.3 DC output

As shown in Figure 5.7.1.1, when "1" is written to the output port data register, the output terminal goes high (VDD) level and when "0" is written it goes low (Vss) level.

The data written to the data register during high impedance status is output from the terminal when the output is switched to complementary.

### 5.7.4 Special output

The R40 to R42 terminals are shared with the special output terminals shown in Table 5.7.4.1.

Table 5.7.4.1 Special outputs

| Output port | Special output             |
|-------------|----------------------------|
| R40         | Clock output : TOUT0/FOUT3 |
| R41         | Clock output : TOUT1/FOUT1 |
| R42         | Buzzer output : BZ         |

When using a special output, fix the high-impedance control register HZR4x of the port to "0" and the output data register R4xD to "1". Refer to Section 5.9, "Clock Output", for the TOUT and FOUT outputs, and to Section 5.15, "Sound Generator", for the BZ output.

## 5.7.5 I/O memory of output ports

Table 5.7.5.1 shows the output port control bits.

Table 5.7.5.1(a) Output port control bits

| Address | Bit    | Name  | Function                            | 1                                   | 0              | Init          | R/W | Comment             |  |
|---------|--------|-------|-------------------------------------|-------------------------------------|----------------|---------------|-----|---------------------|--|
| 00FFD0  | D7     | HZR07 | R07 high impedance control register | High impedance                      | Complementary  | 1             | R/W |                     |  |
|         | D6     | HZR06 | R06 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D5     | HZR05 | R05 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D4     | HZR04 | R04 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D3     | HZR03 | R03 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D2     | HZR02 | R02 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D1     | HZR01 | R01 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D0     | HZR00 | R00 high impedance control register |                                     |                | 1             | R/W |                     |  |
| 00FFD1  | D7     | HZR17 | R17 high impedance control register | High impedance                      | Complementary  | 1             | R/W |                     |  |
|         | D6     | HZR16 | R16 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D5     | HZR15 | R15 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D4     | HZR14 | R14 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D3     | HZR13 | R13 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D2     | HZR12 | R12 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D1     | HZR11 | R11 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D0     | HZR10 | R10 high impedance control register |                                     |                | 1             | R/W |                     |  |
| 00FFD2  | D7     | HZR27 | R27 high impedance control register | High impedance                      | Complementary  | 1             | R/W |                     |  |
|         | D6     | HZR26 | R26 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D5     | HZR25 | R25 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D4     | HZR24 | R24 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D3     | HZR23 | R23 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D2     | HZR22 | R22 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D1     | HZR21 | R21 high impedance control register |                                     |                | 1             | R/W |                     |  |
|         | D0     | HZR20 | R20 high impedance control register |                                     |                | 1             | R/W |                     |  |
| 00FFD3  | D7     | –     | –                                   | –                                   | –              | –             | –   | "0" when being read |  |
|         | D6     | –     | –                                   | –                                   | –              | –             | –   |                     |  |
|         | D5     | –     | –                                   | –                                   | –              | –             | –   |                     |  |
|         | D4     | –     | –                                   | –                                   | –              | –             | –   |                     |  |
|         | 00FFD3 | D3    | –                                   | –                                   | –              | –             | –   | –                   |  |
|         |        | D2    | HZR32                               | R32 high impedance control register | High impedance | Complementary | 1   | R/W                 |  |
|         |        | D1    | HZR31                               | R31 high impedance control register |                |               | 1   | R/W                 |  |
|         |        | D0    | HZR30                               | R30 high impedance control register |                |               | 1   | R/W                 |  |
|         |        |       |                                     |                                     |                |               |     |                     |  |
| 00FFD4  | D7     | –     | –                                   | –                                   | –              | –             | –   | "0" when being read |  |
|         | D6     | –     | –                                   | –                                   | –              | –             | –   |                     |  |
|         | D5     | –     | –                                   | –                                   | –              | –             | –   |                     |  |
|         | D4     | –     | –                                   | –                                   | –              | –             | –   |                     |  |
|         | 00FFD4 | D3    | –                                   | –                                   | –              | –             | –   | –                   |  |
|         |        | D2    | HZR42                               | R42 high impedance control register | High impedance | Complementary | 1   | R/W                 |  |
|         |        | D1    | HZR41                               | R41 high impedance control register |                |               | 1   | R/W                 |  |
|         |        | D0    | HZR40                               | R40 high impedance control register |                |               | 1   | R/W                 |  |
|         |        |       |                                     |                                     |                |               |     |                     |  |
| 00FFD5  | D7     | R07D  | R07 output port data register       | High                                | Low            | 1             | R/W |                     |  |
|         | D6     | R06D  | R06 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D5     | R05D  | R05 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D4     | R04D  | R04 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D3     | R03D  | R03 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D2     | R02D  | R02 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D1     | R01D  | R01 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D0     | R00D  | R00 output port data register       |                                     |                | 1             | R/W |                     |  |
| 00FFD6  | D7     | R17D  | R17 output port data register       | High                                | Low            | 1             | R/W |                     |  |
|         | D6     | R16D  | R16 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D5     | R15D  | R15 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D4     | R14D  | R14 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D3     | R13D  | R13 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D2     | R12D  | R12 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D1     | R11D  | R11 output port data register       |                                     |                | 1             | R/W |                     |  |
|         | D0     | R10D  | R10 output port data register       |                                     |                | 1             | R/W |                     |  |

Table 5.7.5.1(b) Output port control bits

| Address | Bit | Name | Function                      | 1    | 0   | Init | R/W | Comment             |
|---------|-----|------|-------------------------------|------|-----|------|-----|---------------------|
| 00FFD7  | D7  | R27D | R27 output port data register | High | Low | 1    | R/W |                     |
|         | D6  | R26D | R26 output port data register |      |     | 1    | R/W |                     |
|         | D5  | R25D | R25 output port data register |      |     | 1    | R/W |                     |
|         | D4  | R24D | R24 output port data register |      |     | 1    | R/W |                     |
|         | D3  | R23D | R23 output port data register |      |     | 1    | R/W |                     |
|         | D2  | R22D | R22 output port data register |      |     | 1    | R/W |                     |
|         | D1  | R21D | R21 output port data register |      |     | 1    | R/W |                     |
|         | D0  | R20D | R20 output port data register |      |     | 1    | R/W |                     |
| 00FFD8  | D7  | –    | –                             | –    | –   | –    | –   | "0" when being read |
|         | D6  | –    | –                             | –    | –   | –    | –   |                     |
|         | D5  | –    | –                             | –    | –   | –    | –   |                     |
|         | D4  | –    | –                             | –    | –   | –    | –   |                     |
|         | D3  | –    | –                             | –    | –   | –    | –   |                     |
|         | D2  | R32D | R32 output port data register | High | Low | 1    | R/W |                     |
|         | D1  | R31D | R31 output port data register |      |     | 1    | R/W |                     |
|         | D0  | R30D | R30 output port data register |      |     | 1    | R/W |                     |
|         |     |      |                               |      |     |      |     |                     |
| 00FFD9  | D7  | –    | –                             | –    | –   | –    | –   | "0" when being read |
|         | D6  | –    | –                             | –    | –   | –    | –   |                     |
|         | D5  | –    | –                             | –    | –   | –    | –   |                     |
|         | D4  | –    | –                             | –    | –   | –    | –   |                     |
|         | D3  | –    | –                             | –    | –   | –    | –   |                     |
|         | D2  | R42D | R42 output port data register | High | Low | 1    | R/W |                     |
|         | D1  | R41D | R41 output port data register |      |     | 1    | R/W |                     |
|         | D0  | R40D | R40 output port data register |      |     | 1    | R/W |                     |
|         |     |      |                               |      |     |      |     |                     |

**HZR00–HZR07: R0 port high impedance control register (00FFD0H)**

**HZR10–HZR17: R1 port high impedance control register (00FFD1H)**

**HZR20–HZR27: R2 port high impedance control register (00FFD2H)**

**HZR30–HZR32: R3 port high impedance control register (00FFD3H•D0–D2)**

**HZR40–HZR42: R4 port high impedance control register (00FFD4H•D0–D2)**

Sets the output terminals into a high impedance state.

When "1" is written: High impedance

When "0" is written: Complementary

Reading: Valid

The HZR register is the high impedance control register corresponding to each output port.

When a HZR bit is set to "1", the corresponding output port terminal goes to a high impedance status and when "0" is set, it becomes a complementary output.

The high impedance control register of the output port which is used for bus function can be used as a general purpose register with the ability to read and write. It does not affect the bus signal output. Among R40 to R42, the high-impedance control register of the port which is used for special output (TOUT/FOUT, BZ) should be fixed at "0". At initial reset, the HZR register is set to "1" (high impedance).

**R00D–R07D: R0 port output data register (00FFD5H)**

**R10D–R17D: R1 port output data register (00FFD6H)**

**R20D–R27D: R2 port output data register (00FFD7H)**

**R30D–R32D: R3 port output data register (00FFD8H•D0–D2)**

**R40D–R42D: R4 port output data register (00FFD9H•D0–D2)**

Sets the data output from the output port terminal.

When "1" is written: HIGH level output

When "0" is written: LOW level output

Reading: Valid

RxxD is the data register for each output port. When "1" is set, the corresponding output port terminal goes high (VDD) level, and when "0" is set, it goes low (VSS) level.

The data register of the output port which is used for the bus function can be used as general purpose register with the ability to read and write. It does not affect the bus signal output.

Among R40 to R42, the data register of the port which is used for special output (TOUT/FOUT, BZ) should be fixed at "1".

At initial reset, all the data bits are set to "1" (HIGH level output).

## 5.8 I/O Ports (P ports)

### 5.8.1 Configuration of I/O ports

The S1C88409 has 28 bits of I/O ports.

- P0 port: P00–P07 8 bits
- P1 port: P10–P17 8 bits
- P2 port: P20–P23 4 bits
- P3 port: P30–P37 8 bits

These ports can be switched between general-purpose I/O ports and input/output ports for the following functions by software.

- Data bus for external memory access
- Serial interface
- Touch panel controller
- A/D converter
- D/A converter

This section explains control only when using these ports as general-purpose I/O ports. Refer to respective sections for other functions.

Figure 5.8.1.1 shows the structure of the I/O port.

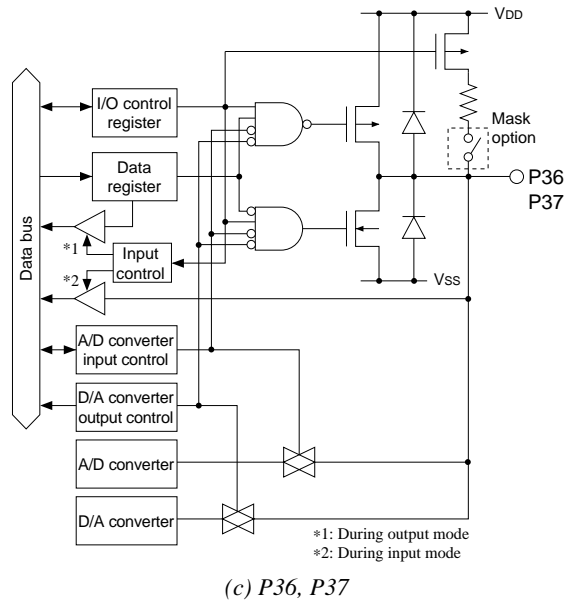
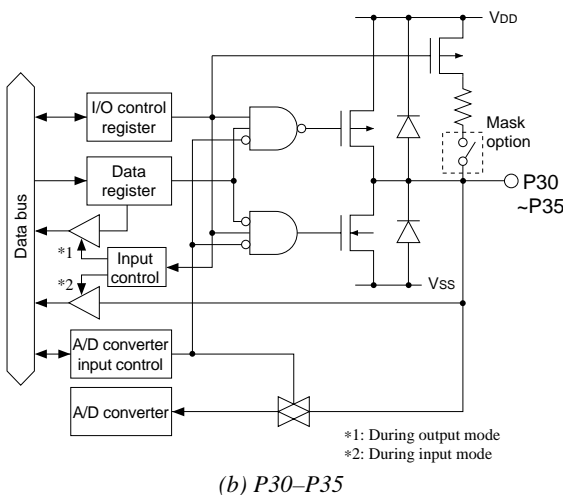
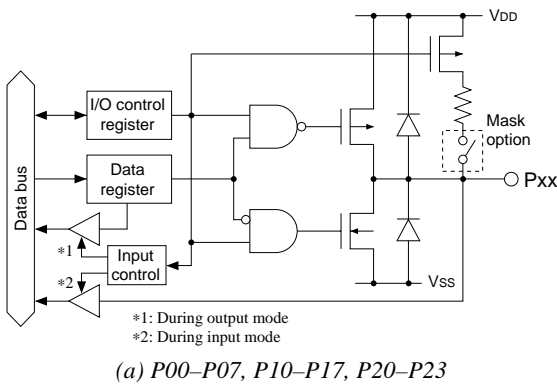


Fig. 5.8.1.1 Structure of I/O port

The port can be set individually in input mode or output mode when it is used as a general-purpose I/O port. This setting is done by writing data to the I/O control register (IOC).

### 5.8.2 Terminal configuration of I/O port and change of function

The I/O port terminals are shared with two or three functions. Therefore, the configuration of the terminals changes depending on the setting of each function. Since all the terminals are set for the I/O port at initial reset except for the MPU mode, switch them using software according to the functions to be used.

Table 5.8.2.1 lists the terminal functions.

#### When the expanded bus mode is set (P00–P07)

When a bus mode except for the single chip mode is set, P00–P07 functions as the data bus D0–D7. In this case, the data register P00D–P07D and the I/O control register IOC00–IOC07 can be used as a general-purpose register that does not affect the input/output for the data bus.

Refer to Section 5.2, "System Controller and Bus Control", for setting of bus mode.



Table 5.8.2.1 Terminal function list

| Terminal | Standard function |     | Sub-function |                                                                            |            |        |
|----------|-------------------|-----|--------------|----------------------------------------------------------------------------|------------|--------|
|          |                   | I/O |              |                                                                            | I/O        |        |
| P00      | I/O port          | P00 | I/O          | Data bus for external memory<br>(Expanded mode)                            | D0         | I/O    |
| P01      |                   | P01 |              |                                                                            | D1         | I/O    |
| P02      |                   | P02 |              |                                                                            | D2         | I/O    |
| P03      |                   | P03 |              |                                                                            | D3         | I/O    |
| P04      |                   | P04 |              |                                                                            | D4         | I/O    |
| P05      |                   | P05 |              |                                                                            | D5         | I/O    |
| P06      |                   | P06 |              |                                                                            | D6         | I/O    |
| P07      |                   | P07 |              |                                                                            | D7         | I/O    |
| P10      | I/O port          | P10 | I/O          | Serial I/F data input                                                      | SIN        | I      |
| P11      |                   | P11 |              | Serial I/F data output                                                     | SOUT       | O      |
| P12      |                   | P12 |              | Serial I/F clock input/output                                              | SCLK       | I/O    |
| P13      |                   | P13 |              | Serial I/F ready output                                                    | SRDY       | O      |
| P14      |                   | P14 |              | Serial I/F data input/IR input                                             | SIN/IRI    | I      |
| P15      |                   | P15 |              | Serial I/F data output/IR output                                           | SOUT/IRO   | O      |
| P16      |                   | P16 |              | Serial I/F clock input/output                                              | SCLK       | I/O    |
| P17      |                   | P17 |              | Serial I/F ready output                                                    | SRDY       | O      |
| P20      | I/O port          | P20 | I/O          | Touch panel controller control signal output                               | BYH        | O      |
| P21      |                   | P21 |              | Touch panel controller control signal output                               | BYL        | O      |
| P22      |                   | P22 |              | Touch panel controller control signal output                               | BXH        | O      |
| P23      |                   | P23 |              | Touch panel controller control signal output                               | BXL        | O      |
| P30      | I/O port          | P30 | I/O          | A/D converter analog signal input                                          | AD0        | I      |
| P31      |                   | P31 |              | A/D converter analog signal input                                          | AD1        | I      |
| P32      |                   | P32 |              | A/D converter analog signal input                                          | AD2        | I      |
| P33      |                   | P33 |              | A/D converter analog signal input                                          | AD3        | I      |
| P34      |                   | P34 |              | A/D converter analog signal input                                          | AD4        | I      |
| P35      |                   | P35 |              | A/D converter analog signal input                                          | AD5        | I      |
| P36      |                   | P36 |              | A/D converter analog signal input or<br>D/A converter analog signal output | AD6<br>DA0 | I<br>O |
| P37      |                   | P37 |              | A/D converter analog signal input or<br>D/A converter analog signal output | AD7<br>DA1 | I<br>O |

### When the serial interface is used (P10–P17)

The S1C88409 has a serial interface built-in. The serial interface uses the following terminals and unused terminals can be used as a general-purpose I/O ports.

| Transfer mode      | Terminals used for serial I/F<br>(P10–P17) |
|--------------------|--------------------------------------------|
| Asynchronous       | P10, P11 (or P14, P15)                     |
| Clock sync. slave  | P10–P13 (or P14–P17)                       |
| Clock sync. master | P10–P12 (or P14–P16)                       |
| IrDA interface     | P14, P15                                   |

The data register and the I/O control register of the port which is assigned to the serial interface can be used as a general-purpose register that does not affect the input/output.

Refer to Section 5.14, "Serial Interface", for setting of the serial interface.

### When the touch panel controller is used (P20–P23)

The S1C88409 has a built-in touch panel controller. When the touch panel controller is used, the P20–P23 terminals work as the touch panel control signal output terminals (BYH, BYL, BXH, BXL).

*Note:* When the touch panel function is selected by mask option, the P20–P23 terminals are configured as follows at initial reset:

|           |            |
|-----------|------------|
| P20 (BYH) | High level |
| P21 (BYL) | Low level  |
| P22 (BXH) | High level |
| P23 (BXL) | Low level  |

The P20–P23 terminals are disconnected from the I/O control and data registers, and are controlled from the touch panel controller. Thus it is unnecessary to configure these terminals by software. The I/O control and data registers for these ports can be used as general-purpose registers.

Refer to Section 5.17, "Touch Panel Controller" for setting the touch panel controller.

Since the touch panel controller uses the A/D converter, the P3x terminals used for inputting analog signals cannot be used as I/O ports.

**When A/D converter and/or D/A converter is used (P30–P37)**

It is possible to set any terminals in the P30–P37 terminals as the analog input terminal for the A/D converter. Further, either the P36 or P37 terminal or both can also be set as the analog output terminal of the D/A converter.

The data register and the I/O control register of the port which is set to the A/D converter input or D/A converter output do not affect the terminal status, but the port reading can be done the same as the I/O port. In the input mode, the terminal status is read out (as binary data), and in the output mode, the content of the data register is read out. The content of the data register is not output to the terminal even in the output mode.

The port which is not used for the A/D converter and D/A converter within P30–P37 can be used as a general-purpose I/O port.

Refer to Section 5.18, "A/D Converter", for setting of the A/D converter and to Section 5.19, "D/A Converter" for setting of the D/A converter.

**5.8.3 Mask option**

| I/O port pull-up resistors |                                        |                                      |
|----------------------------|----------------------------------------|--------------------------------------|
| P00                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P01                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P02                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P03                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P04                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P05                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P06                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P07                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P10                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P11                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P12                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P13                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P14                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P15                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P16                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P17                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P20                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P21                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P22                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P23                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P30                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P31                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P32                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P33                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P34                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P35                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P36                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |
| P37                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |

The I/O port has a built-in pull-up resistor that is activated during the input mode, and it can be individually selected for use or not by the mask option.

When "With resistor" is selected, the pull-up resistor of the port turns on during the input mode.

When the port terminal is changed from a low level to a high level by the built-in pull-up resistor, the rise of the waveform is delayed on account of the time constant of the pull-up resistor and load capacitance of the terminal. So, when reading the I/O port, it is necessary to wait an appropriate amount of time. Make this waiting time the amount of time or more calculated by the following expression.

$$\text{Waiting time} = R_{IN} \times (C_{IN} + C_L) \times 1.6 \text{ [sec]}$$

R<sub>IN</sub>: Pull-up resistance Max. value

C<sub>IN</sub>: Terminal capacitance Max. value

C<sub>L</sub>: Load capacitance on the board

For unused I/O port, select "With resistor" default setting.

When using the A/D converter and/or D/A converter, select "Gate direct" for the port to obtain the conversion precision.

**5.8.4 I/O control registers and I/O mode**

The I/O port is set in the input mode or output mode by writing data to the corresponding I/O control register (IOC).

To set an I/O port to the input mode, write "0" to the I/O control register. The I/O port which is set in the input mode shifts to high impedance status and functions as an input port.

Reading during the input mode gets the input terminal status directly: the data being "1" when the terminal is at high (V<sub>DD</sub>) level and "0" when it is at low (V<sub>SS</sub>) level.

When "With resistor" is selected by mask option, the port terminal is pulled up during the input mode.

Data can be written to the data registers without affecting the terminal status even in the input mode.

To set an I/O port to the output mode, write "1" to the I/O control register. The I/O port which is set to output mode functions as an output port.

When the data register is set to "1", the port goes high (V<sub>DD</sub>) level and when it is set to "0", the port goes low (V<sub>SS</sub>) level.

Reading during the output mode gets the content of the data register.

At initial reset, the I/O control registers are set to "0" (I/O ports are set in the input mode).

### 5.8.5 I/O memory of I/O ports

Table 5.8.5.1 shows the I/O port control bits.

Table 5.8.5.1(a) I/O port control bits

| Address | Bit    | Name  | Function                   | 1                        | 0      | Init  | R/W | Comment             |  |
|---------|--------|-------|----------------------------|--------------------------|--------|-------|-----|---------------------|--|
| 00FFE0  | D7     | IOC07 | P07 I/O control register   | Output                   | Input  | 0     | R/W |                     |  |
|         | D6     | IOC06 | P06 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D5     | IOC05 | P05 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D4     | IOC04 | P04 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D3     | IOC03 | P03 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D2     | IOC02 | P02 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D1     | IOC01 | P01 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D0     | IOC00 | P00 I/O control register   |                          |        | 0     | R/W |                     |  |
| 00FFE1  | D7     | IOC17 | P17 I/O control register   | Output                   | Input  | 0     | R/W |                     |  |
|         | D6     | IOC16 | P16 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D5     | IOC15 | P15 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D4     | IOC14 | P14 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D3     | IOC13 | P13 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D2     | IOC12 | P12 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D1     | IOC11 | P11 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D0     | IOC10 | P10 I/O control register   |                          |        | 0     | R/W |                     |  |
| 00FFE2  | D7     | –     | –                          | –                        | –      | –     | –   | "0" when being read |  |
|         | D6     | –     | –                          | –                        | –      | –     | –   |                     |  |
|         | D5     | –     | –                          | –                        | –      | –     | –   |                     |  |
|         | D4     | –     | –                          | –                        | –      | –     | –   |                     |  |
|         | 00FFE3 | D3    | IOC23                      | P23 I/O control register | Output | Input | 0   | R/W                 |  |
|         |        | D2    | IOC22                      | P22 I/O control register |        |       | 0   | R/W                 |  |
|         |        | D1    | IOC21                      | P21 I/O control register |        |       | 0   | R/W                 |  |
|         |        | D0    | IOC20                      | P20 I/O control register |        |       | 0   | R/W                 |  |
| 00FFE3  | D7     | IOC37 | P37 I/O control register   | Output                   | Input  | 0     | R/W |                     |  |
|         | D6     | IOC36 | P36 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D5     | IOC35 | P35 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D4     | IOC34 | P34 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D3     | IOC33 | P33 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D2     | IOC32 | P32 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D1     | IOC31 | P31 I/O control register   |                          |        | 0     | R/W |                     |  |
|         | D0     | IOC30 | P30 I/O control register   |                          |        | 0     | R/W |                     |  |
| 00FFE4  | D7     | P07D  | P07 I/O port data register | High                     | Low    | 1     | R/W |                     |  |
|         | D6     | P06D  | P06 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D5     | P05D  | P05 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D4     | P04D  | P04 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D3     | P03D  | P03 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D2     | P02D  | P02 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D1     | P01D  | P01 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D0     | P00D  | P00 I/O port data register |                          |        | 1     | R/W |                     |  |
| 00FFE5  | D7     | P17D  | P17 I/O port data register | High                     | Low    | 1     | R/W |                     |  |
|         | D6     | P16D  | P16 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D5     | P15D  | P15 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D4     | P14D  | P14 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D3     | P13D  | P13 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D2     | P12D  | P12 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D1     | P11D  | P11 I/O port data register |                          |        | 1     | R/W |                     |  |
|         | D0     | P10D  | P10 I/O port data register |                          |        | 1     | R/W |                     |  |

Table 5.8.5.1(b) I/O port control bits

| Address | Bit | Name | Function                   | 1    | 0   | Init | R/W | Comment             |  |
|---------|-----|------|----------------------------|------|-----|------|-----|---------------------|--|
| 00FFE6  | D7  | –    | –                          | –    | –   | –    | –   | "0" when being read |  |
|         | D6  | –    | –                          | –    | –   | –    | –   |                     |  |
|         | D5  | –    | –                          | –    | –   | –    | –   |                     |  |
|         | D4  | –    | –                          | –    | –   | –    | –   |                     |  |
|         | D3  | P23D | P23 I/O port data register | High | Low | 1    | R/W |                     |  |
|         | D2  | P22D | P22 I/O port data register |      |     | 1    | R/W |                     |  |
|         | D1  | P21D | P21 I/O port data register |      |     | 1    | R/W |                     |  |
|         | D0  | P20D | P20 I/O port data register |      |     | 1    | R/W |                     |  |
| 00FFE7  | D7  | P37D | P37 I/O port data register | High | Low | 1    | R/W |                     |  |
|         | D6  | P36D | P36 I/O port data register |      |     | 1    | R/W |                     |  |
|         | D5  | P35D | P35 I/O port data register |      |     | 1    | R/W |                     |  |
|         | D4  | P34D | P34 I/O port data register |      |     | 1    | R/W |                     |  |
|         | D3  | P33D | P33 I/O port data register |      |     | 1    | R/W |                     |  |
|         | D2  | P32D | P32 I/O port data register |      |     | 1    | R/W |                     |  |
|         | D1  | P31D | P31 I/O port data register |      |     | 1    | R/W |                     |  |
|         | D0  | P30D | P30 I/O port data register |      |     | 1    | R/W |                     |  |

**P00D–P07D: P0 port data register (00FFE4H)**

**P10D–P17D: P1 port data register (00FFE5H)**

**P20D–P23D: P2 port data register (00FFE6H•D0–D3)**

**P30D–P37D: P3 port data register (00FFE7H)**

I/O port data can be read and output data can be set through these registers.

When writing:

When "1" is written: HIGH level

When "0" is written: LOW level

When the I/O port is set in the output mode, the written data is output from the I/O port terminal. When "1" is written as the port data, the port terminal goes high (VDD) level, and when "0" is written, the terminal goes low (VSS) level. Port data can be written even in the input mode.

When reading:

When "1" is read: HIGH level ("1")

When "0" is read: LOW level ("0")

When the I/O port is in the input mode, the voltage level being input to the port terminal can be read. When the terminal voltage is high (VDD) level, "1" is read, and "0" is read when it is low (VSS) level.

In the output mode, the content of the data register is read.

At initial reset, the data bits are all set to "1" (HIGH level).

Refer to Section 5.8.2 for the data register of the ports set in a function other than I/O port.

**IOC00–IOC07: P0 port I/O control register (00FFE0H)**

**IOC10–IOC17: P1 port I/O control register (00FFE1H)**

**IOC20–IOC23: P2 port I/O control register (00FFE2H•D0–D3)**

**IOC30–IOC37: P3 port I/O control register (00FFE3H)**

Sets the I/O port to the input or output mode.

When "1" is written: Output mode

When "0" is written: Input mode

Reading: Valid

The IOC register is the I/O control register corresponding to each I/O port individually.

When an IOC bit is set to "1", the corresponding I/O port enters the output mode. When it is set to "0", the port enters the input mode.

At initial reset, the IOC register is set to "0" (input mode).

Refer to Section 5.8.2 for the I/O control register of the ports set in a function other than I/O port.

### 5.8.6 Programming note

When the port terminal is changed from a low level to a high level by the built-in pull-up resistor, the rise of the waveform is delayed on account of the time constant of the pull-up resistor and load capacitance of the terminal. So, when reading the I/O port, it is necessary to wait an appropriate amount of time. Make this waiting time the amount of time or more calculated by the following expression.

$$\text{Waiting time} = R_{IN} \times (C_{IN} + C_L) \times 1.6 \text{ [sec]}$$

R<sub>IN</sub>: Pull-up resistance Max. value

C<sub>IN</sub>: Terminal capacitance Max. value

C<sub>L</sub>: Load capacitance on the board

## 5.9 Clock Output

### 5.9.1 Configuration of clock output control circuit

The S1C88409 can output 4 kinds of clocks to external devices.

The kinds of clocks are as follows:

- OSC3 dividing clock (FOUT3)
- OSC1 dividing clock (FOUT1)
- The output clock of the 16-bit programmable timer 0 (TOUT0)
- The output clock of the 16-bit programmable timer 1 (TOUT1)

The output ports R40 and R41 are used for these outputs.

Figure 5.9.1.1 shows the configuration of the clock output control circuit.

The FOUT3 clock and TOUT0 clock cannot be output simultaneously, because they use the same port, similar to the FOUT1 clock and TOUT1 clock. The TOUT0 clock can be output when the 16-bit programmable timer operates in the 8-bit mode.

Refer to Section 5.12, "16-bit Programmable Timer", for the output clock of the 16-bit programmable timer.

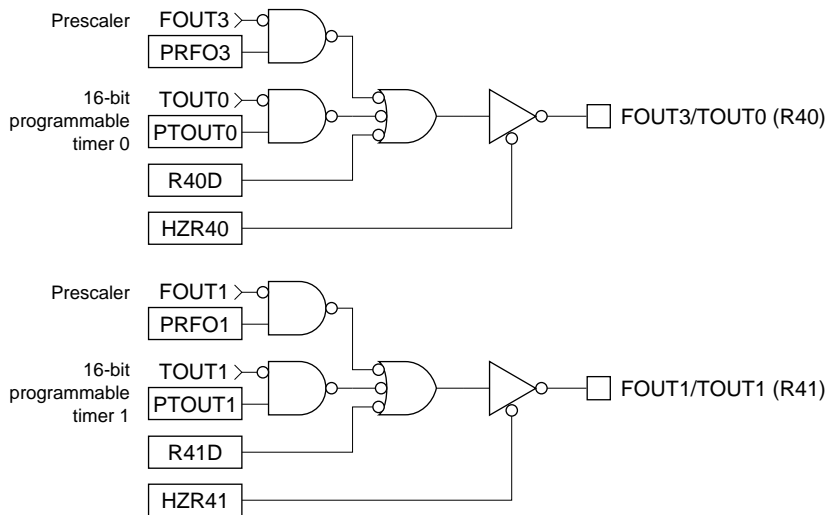


Fig. 5.9.1.1 Configuration of clock output control circuit

### 5.9.2 Clock output control

Table 5.9.2.1 shows the output control register of each clock.

To output the clock, fix the high-impedance control register of the output port to "0" and the output data register to "1". The output port terminal outputs the clock by writing "1" to the clock output control register in this status. The terminal goes high (VDD) level when "0" is written.

Figure 5.9.2.1 shows the output waveform by this control.

The frequencies of the FOUT3 and FOUT1 clocks can be selected from eight types by setting the prescaler.

- Note:
- Be aware that the output is fixed at low (Vss) level when the data register of the output port used for the clock output is set to "0".
  - A hazard may occur on the output signal when the clock output control register is changed.
  - Since the output clock becomes unstable when SLEEP mode is canceled, stop the output before shifting to SLEEP mode.

Table 5.9.2.1 Clock output control registers

| Clock | Output control register | Hi-Z control register | Data register     |
|-------|-------------------------|-----------------------|-------------------|
| FOUT3 | PRFO3 (00FF14H·D3)      | HZR40 (00FFD4H·D0)    | R40D (00FFD9H·D0) |
| FOUT1 | PRFO1 (00FF14H·D7)      | HZR41 (00FFD4H·D1)    | R41D (00FFD9H·D1) |
| TOUT0 | PTOUT0 (00FF30H·D3)     | HZR40 (00FFD4H·D0)    | R40D (00FFD9H·D0) |
| TOUT1 | PTOUT1 (00FF31H·D3)     | HZR41 (00FFD4H·D1)    | R41D (00FFD9H·D1) |

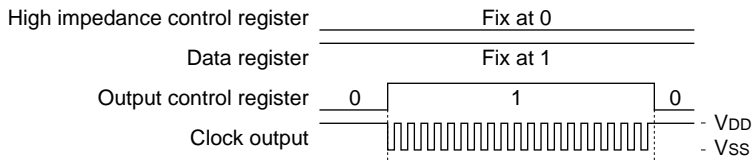


Fig. 5.9.2.1 Clock output waveform

## 5.9.3 I/O memory of clock output

Table 5.9.3.1 shows the clock output control bits.

Table 5.9.3.1 Clock output control bits

| Address | Bit   | Name                                | Function                            | 1              | 0                | Init             | R/W | Comment             |  |
|---------|-------|-------------------------------------|-------------------------------------|----------------|------------------|------------------|-----|---------------------|--|
| 00FF14  | D7    | PRFO1                               | FOUT1 output control                | On             | Off              | 0                | R/W |                     |  |
|         | D6    | PSF12                               | FOUT1 division ratio                |                |                  |                  | 0   | R/W                 |  |
|         |       |                                     | PSF12                               | PSF11          | PSF10            | Division ratio   |     |                     |  |
|         |       |                                     | 1                                   | 1              | 1                | $f_{osc1} / 128$ |     |                     |  |
|         |       |                                     | 1                                   | 1              | 0                | $f_{osc1} / 64$  |     |                     |  |
|         |       |                                     | 1                                   | 0              | 1                | $f_{osc1} / 32$  |     |                     |  |
|         |       |                                     | 1                                   | 0              | 0                | $f_{osc1} / 16$  |     |                     |  |
|         | D5    | PSF11                               | 0                                   | 1              | 1                | $f_{osc1} / 8$   |     |                     |  |
|         |       |                                     | 0                                   | 1              | 0                | $f_{osc1} / 4$   |     |                     |  |
|         |       |                                     | 0                                   | 0              | 1                | $f_{osc1} / 2$   |     |                     |  |
|         |       |                                     | 0                                   | 0              | 0                | $f_{osc1} / 1$   |     |                     |  |
|         | D3    | PRFO3                               | FOUT3 output control                | On             | Off              | 0                | R/W |                     |  |
|         | D2    | PSF32                               | FOUT3 division ratio                |                |                  |                  | 0   | R/W                 |  |
|         |       |                                     | PSF32                               | PSF31          | PSF30            | Division ratio   |     |                     |  |
| 1       |       |                                     | 1                                   | 1              | $f_{osc3} / 128$ |                  |     |                     |  |
| 1       |       |                                     | 1                                   | 0              | $f_{osc3} / 64$  |                  |     |                     |  |
| 1       |       |                                     | 0                                   | 1              | $f_{osc3} / 32$  |                  |     |                     |  |
| 1       |       |                                     | 0                                   | 0              | $f_{osc3} / 16$  |                  |     |                     |  |
| 0       |       |                                     | 1                                   | 1              | $f_{osc3} / 8$   |                  |     |                     |  |
| 0       |       |                                     | 1                                   | 0              | $f_{osc3} / 4$   |                  |     |                     |  |
| 0       |       |                                     | 0                                   | 1              | $f_{osc3} / 2$   |                  |     |                     |  |
| 0       |       |                                     | 0                                   | 0              | $f_{osc3} / 1$   |                  |     |                     |  |
| 00FF30  | D7    | MODE16                              | 16-bit PTM 8-/16-bit mode selection | 16-bit         | 8-bit × 2        | 0                | R/W |                     |  |
|         | D6    | –                                   | –                                   | –              | –                | –                | –   | "0" when being read |  |
|         | D5    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D4    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D3    | PTOUT0                              | 16-bit PTM0 clock output control    | On             | Off              | 0                | R/W |                     |  |
|         | D2    | PTRUN0                              | 16-bit PTM0 RUN/STOP control        | Run            | Stop             | 0                | R/W |                     |  |
|         | D1    | PSET0                               | 16-bit PTM0 preset                  | Preset         | Invalid          | 0                | W   | "0" when being read |  |
|         | D0    | CKSEL0                              | 16-bit PTM0 input clock selection   | External clock | Internal clock   | 0                | R/W |                     |  |
| 00FF31  | D7    | –                                   | –                                   | –              | –                | –                | –   | "0" when being read |  |
|         | D6    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D5    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D4    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D3    | PTOUT1                              | 16-bit PTM1 clock output control    | On             | Off              | 0                | R/W |                     |  |
|         | D2    | PTRUN1                              | 16-bit PTM1 RUN/STOP control        | Run            | Stop             | 0                | R/W |                     |  |
|         | D1    | PSET1                               | 16-bit PTM1 preset                  | Preset         | Invalid          | 0                | W   | "0" when being read |  |
|         | D0    | CKSEL1                              | 16-bit PTM1 input clock selection   | External clock | Internal clock   | 0                | R/W |                     |  |
| 00FFD4  | D7    | –                                   | –                                   | –              | –                | –                | –   | "0" when being read |  |
|         | D6    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D5    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D4    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D3    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D2    | HZR42                               | R42 high impedance control register | High impedance | Complementary    | 1                | R/W |                     |  |
|         | D1    | HZR41                               | R41 high impedance control register |                |                  | 1                | R/W |                     |  |
| D0      | HZR40 | R40 high impedance control register | 1                                   |                |                  | R/W              |     |                     |  |
| 00FFD9  | D7    | –                                   | –                                   | –              | –                | –                | –   | "0" when being read |  |
|         | D6    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D5    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D4    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D3    | –                                   | –                                   | –              | –                | –                | –   |                     |  |
|         | D2    | R42D                                | R42 output port data register       | High           | Low              | 1                | R/W |                     |  |
|         | D1    | R41D                                | R41 output port data register       |                |                  | 1                | R/W |                     |  |
|         | D0    | R40D                                | R40 output port data register       |                |                  | 1                | R/W |                     |  |

**HZR40, HZR41: R4 port high impedance control register (00FFD4H•D0, D1)**

Sets the output terminals into a high impedance state.

- When "1" is written: High impedance
- When "0" is written: Complementary
- Reading: Valid

The HZR40 and HZR41 registers are the high impedance control registers for the output ports R40 and R41 used for the clock output. Fix data of the port used for the clock output at "0". At initial reset, the HZR register is set to "1" (high impedance).

**R40D, R41D: R4 port output data register (00FFD9H•D0, D1)**

They are the data registers for the output ports R40, R41 used for the clock output.

- When "1" is written: Clock output is possible
- When "0" is written: LOW (Vss) level is output
- Reading: Valid

Fix data of the port used for the clock output at "1". At initial reset, the data bits are all set to "1".

**PSF10–PSF12: FOUT1 division ratio selection register (00FF14H•D4–D6)**

Selects the frequency for the FOUT1 clock.

It can be selected from 8 types of division ratio shown in Table 5.9.3.1.

This register can also be read.

At initial reset, the PSF1 register is set to "0" (fosc1/1).

**PRFO1: FOUT1 output control register (00FF14H•D7)**

Controls the FOUT1 output.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

When "1" is written to the PRFO1 register, the FOUT1 (R41) terminal outputs the clock selected with the PSF1 register. However, the high-impedance control register HZR41 of the output port R41 must be set to "0" and the data register R41D must be set to "1".

When "0" is written, the clock is not output. At initial reset, the PRFO1 register is set to "0" (OFF).

**PSF30–PSF32: FOUT3 division ratio selection register (00FF14H•D0–D2)**

Selects the frequency for the FOUT3 clock.

It can be selected from 8 types of division ratio shown in Table 5.9.3.1.

This register can also be read.

At initial reset, the PSF3 register is set to "0" (fosc3/1).

**PRFO3: FOUT3 output control register (00FF14H•D3)**

Controls the FOUT3 output.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

When "1" is written to the PRFO3 register, the FOUT3 (R40) terminal outputs the clock selected with the PSF3 register. However, the high-impedance control register HZR40 of the output port R40 must be set to "0" and the data register R40D must be set to "1". Furthermore, the OSC3 oscillation circuit must be used.

When "0" is written, the clock is not output. At initial reset, the PRFO3 register is set to "0" (OFF).

**PTOUT0: 16-bit programmable timer 0 clock output control register (00FF30H•D3)**

Controls the output of the TOUT0 signal (16-bit programmable timer 0 clock).

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

The PTOUT0 register is the output control register for the TOUT0 signal. When "1" is written to this register, the TOUT0 signal is output from the TOUT0 (R40) terminal. When "0" is written, the terminal goes high (VDD) level. However, the high-impedance control register HZR40 of the output port R40 must be set to "0" and the data register R40D must be set to "1".

The TOUT0 clock cannot be output simultaneously with the FOUT3 clock.

Refer to Section 5.12, "16-bit Programmable Timer", for setting of clock frequency.

At initial reset, the PTOUT0 register is set to "0" (OFF).



**PTOUT1: 16-bit programmable timer 1  
clock output control register (00FF31H•D3)**

Controls the output of the TOUT1 signal (16-bit programmable timer 1 clock).

When "1" is written: ON

When "0" is written: OFF

Reading: Valid

The PTOUT1 register is the output control register for the TOUT1 signal. When "1" is written to this register, the TOUT0 signal is output from the TOUT1 (R41) terminal. When "0" is written, the terminal goes high (V<sub>DD</sub>) level. However, the high-impedance control register HZR41 of the output port R41 must be set to "0" and the data register R41D must be set to "1".

The TOUT1 clock cannot be output simultaneously with the FOUT1 clock.

Refer to Section 5.12, "16-bit Programmable Timer", for setting of clock frequency.

At initial reset, the PTOUT1 register is set to "0" (OFF).

### 5.9.4 Programming notes

- (1) The FOUT3 clock and TOUT0 clock cannot be output simultaneously, because they use the same port, similar to the FOUT1 clock and TOUT1 clock.
- (2) Be aware that the output is fixed at low (V<sub>SS</sub>) level when the data register of the output port used for the clock output is set to "0".
- (3) A hazard may occur on the output signal when the clock output control register is changed.
- (4) Since the output clock becomes unstable when SLEEP mode is canceled, stop the output before shifting to SLEEP mode.

## 5.10 LCD Controller

### 5.10.1 Configuration of LCD controller

The S1C88409 has a built-in dot-matrix LCD controller and can drive a middle-scale LCD panel (eg., 240 × 100 dots, B&W) by connecting external common drivers (S1D16305 or S1D16700) and segment drivers (S1D16006 or S1D15700).

This LCD controller can drive 4-level gray scale LCD panels in addition to B&W (black and white) LCD panels. It also allows software to control scrolling display.

Figure 5.10.1.1 shows the configuration of the LCD controller and Figure 5.10.1.2 shows an example how to connect external LCD drivers.

The S1D16006 or S1D15700 are available for external segment drivers. Select the S1D16006 for cost down. The S1D15700 is better to reduce power.

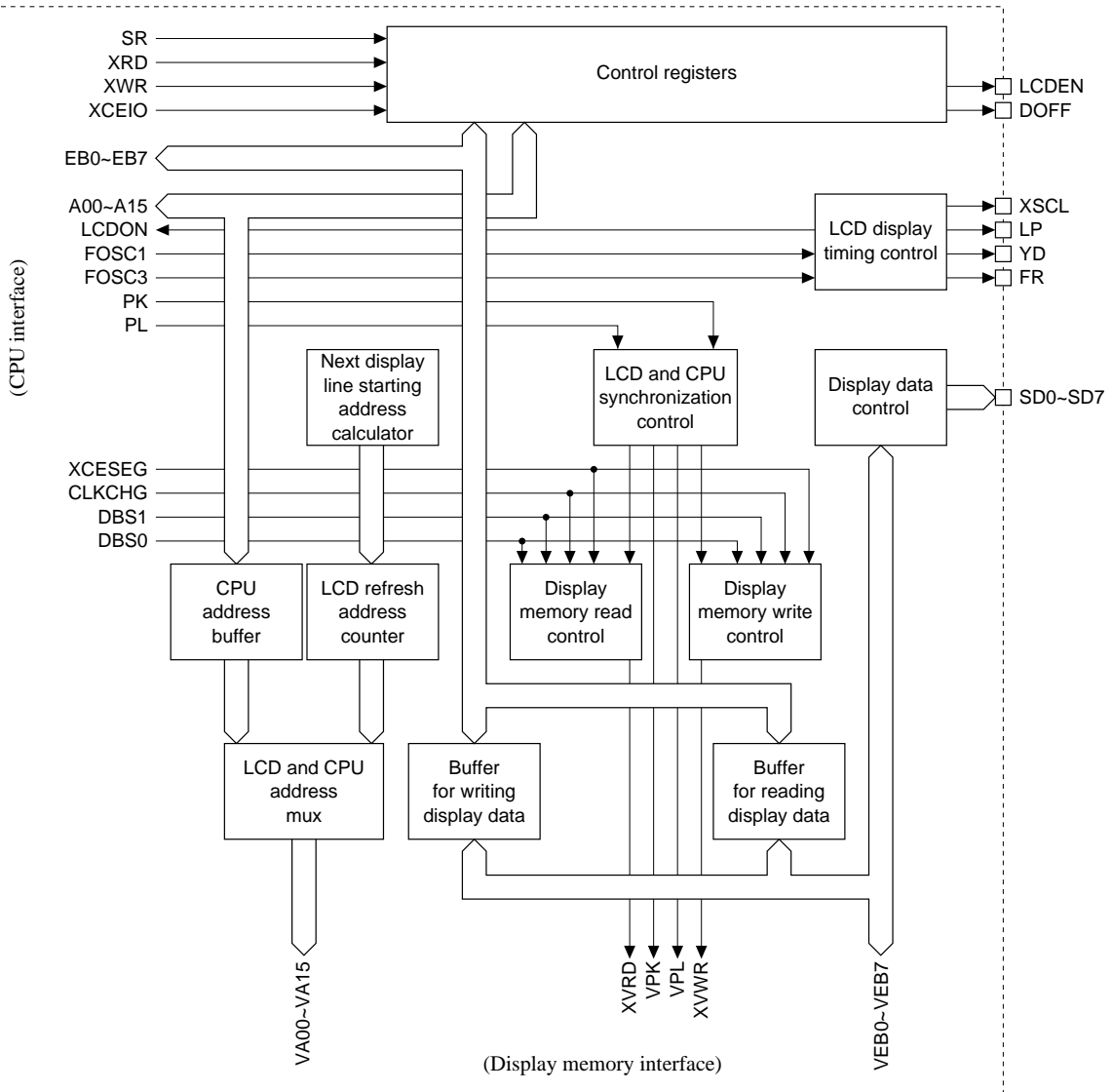


Fig. 5.10.1.1 Configuration of LCD controller

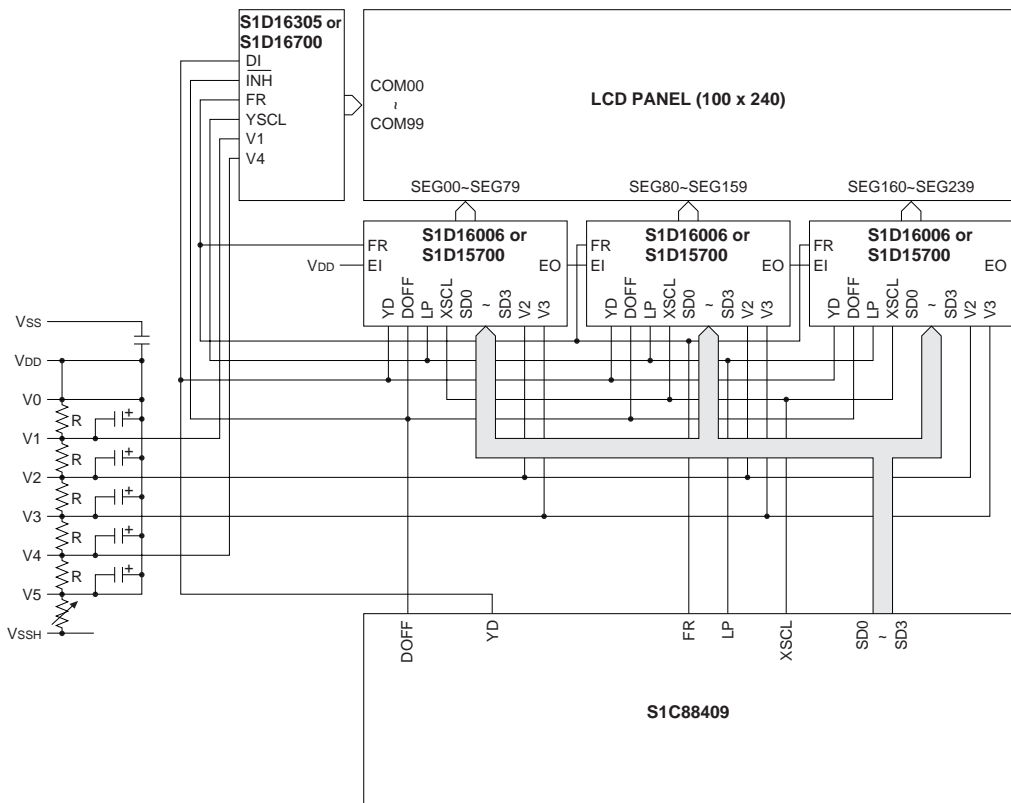


Fig. 5.10.1.2 Connection example of external LCD drivers

### 5.10.2 Output signals

This LCD controller outputs the following signals for controlling the S1D16305 (or S1D16700) common driver and the S1D16006 (or S1D15700) segment driver:

#### LCDEN

A LCD power control signal. It goes high level (VDD) or low level (VSS) according to the value set in the LCDEN register.

*Note:* When the LCD drive voltage is supplied to the LCD panel before supplying the power voltage (VDD) to the S1C88409, the LCD panel may be damaged. To prevent this problem, design the circuit so that the LCD power is supplied to the LCD panel by switching the LCDEN signal to high level with the software. At initial reset, the LCDEN signal goes low level. This power control is also necessary when turning the S1C88409 off. Be sure to turn the LCD panel off before turning the S1C88409 off.

#### DOFF

A forced blank signal to turn the display off. Connect this signal to the  $\overline{\text{INH}}$  terminal of the S1D16305 (or S1D16700) and the DOFF terminal of the S1D16006 (or S1D15700) and control the signal using the DISP register.

#### XSCl

A display data shift clock. Connect this signal to the XSCl terminal of the S1D16006 (or S1D15700).

#### LP

A display data latch pulse. Connect this signal to the YSCl terminal of the S1D16305 (or S1D16700) and the LP terminal of the S1D16006 (or S1D15700).

#### YD

A scan start pulse. Connect this signal to the DI terminal of the S1D16305 (or S1D16700) and the YD terminal of the S1D16006 (or S1D15700).

#### FR

A frame signal. Connect this signal to the FR terminals of the S1D16305 (or S1D16700) and S1D16006 (or S1D15700).

#### SD0–SD7

Display data signals. SD0 to SD3 are used in the 4-bit transfer mode. In the 8-bit transfer mode, SD0 to SD7 are all used.

### 5.10.3 Display control

To use the LCD controller, the following control procedures are necessary:

#### Setup of the LCD controller

(1) *Selecting B&W or gray-scale mode*

This LCD controller has two display mode: B&W (black and white) mode and 4-level gray scale mode. Select either one according to the LCD panel to be used. See Section 5.10.4, "B&W mode and gray-scale mode setting", for more information.

(2) *Selecting the transfer data size*

Select the size of data to be transferred to the segment drivers. 8-bit transfer and 4-bit transfer are available in this LCD controller. Select 4-bit transfer when using the S1D16006 or S1D15700. See Section 5.10.9, "Data transfer", for more information.

(3) *Setting the LCD panel size and display start address*

To correspond the display memory bits to the LCD panel dots one to one, it is necessary to set the LCD panel size in the LCD controller. Also a display start address should be set. See Section 5.10.6, "LCD panel", for more information.

(4) *Setting the frame frequency*

The frame frequency can be selected from 16 frequencies according to the LCD panel to be used. See Section 5.10.6, "LCD panel", for more information.

(5) *Back light LCD panel*

Since this LCD controller can reverse display by the REV register (REV = "1"), set in reverse display when using an LCD panel with a back light. The REV register can also be used to reverse display during normal display.

#### Turning display on and off

By writing "1" to the LCDEN register, the LCD controller turns on and starts outputting the signals to the external drivers. The content of the LCDEN register is output from the LCDEN terminal. Use the signal to control the LCD power supply. When "0" is written to the LCDEN register, the LCD controller stops operating.

*Note: The power of the LCD panel must be turned on/off while the LCDEN register is "1". Switching while the LCD controller is off (LCDEN = "0") may damage the LCD panel.*

Besides the LCDEN register, the DISP register is provided for forced blanking function. When "1" is written to the DISP register, the LCD panel displays data in the display memory. When "0" is written, the display goes out. The control signals are output to the external drivers during forced blanking.

#### Data transfer control

The data transfer method can be selected according to the segment driver to be used. See Section 5.10.9, "Data transfer", for more information. The data transfer uses the OSC3 clock. Therefore, turn the OSC3 oscillation on before writing "1" to the LCDEN register. Furthermore, wait 20 msec or more after turning the OSC3 oscillation on for stabilizing oscillation. Do not turn the OSC3 oscillation off during data transfer.

### 5.10.4 B&W and gray-scale mode setting

This LCD controller has two display mode: B&W (black and white) mode and 4-level gray scale mode. Select either one with the GRAY register according to the LCD panel to be used.

GRAY register = "0": B&W mode  
 GRAY register = "1": Gray-scale mode

In the B&W mode, the display memory bits correspond to the LCD panel dots one to one. When a memory bit is "0", the corresponding dot goes off and when the bit is "1", the dot goes on.

In the gray-scale mode, each two bits of the display memory corresponds to an LCD panel dot. When a display data is 00B, the corresponding dot goes off. As for the display data 01B, 10B and 11B, the intensity (gray-scale conversion code) can be specified using the GS1, GS2 and GS3 registers (8 bits each), respectively.

The specified gray-scale conversion code controls the 8 frame cycles for turning the dots on and off as shown in Figure 5.10.4.1.

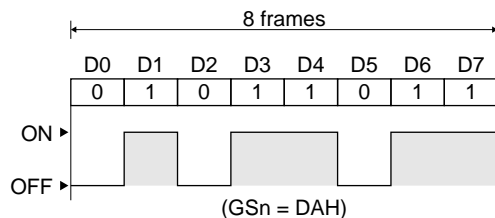


Fig. 5.10.4.1 Gray-scale conversion code

See LCD panel examples in Section 5.10.6 for correspondence between the display memory data and dots.

### 5.10.5 Display memory

The S1C88409 has a 3.75KB of RAM built-in and the display memory is allocated in the RAM. The display memory size can be selected from seven types listed in Table 5.10.5.1 by mask option.

Table 5.10.5.1 Display memory size

|   | Data memory                   | Display memory                |
|---|-------------------------------|-------------------------------|
| 1 | 1792 bytes<br>00F800H–00FEFFH | 2048 bytes<br>00F000H–00F7FFH |
| 2 | 1536 bytes<br>00F900H–00FEFFH | 2304 bytes<br>00F000H–00F8FFH |
| 3 | 1280 bytes<br>00FA00H–00FEFFH | 2560 bytes<br>00F000H–00F9FFH |
| 4 | 1024 bytes<br>00FB00H–00FEFFH | 2816 bytes<br>00F000H–00FAFFH |
| 5 | 768 bytes<br>00FC00H–00FEFFH  | 3072 bytes<br>00F000H–00FBFFH |
| 6 | 512 bytes<br>00FD00H–00FEFFH  | 3328 bytes<br>00F000H–00FCFFH |
| 7 | 256 bytes<br>00FE00H–00FEFFH  | 3584 bytes<br>00F000H–00FDFFH |

*Note:* The display memory area configured by mask option may be used as data memory. However, the stack area cannot be assigned there.

The required display memory size is calculated by the following expressions according to the LCD panel size:

**B&W LCD panel:**

Memory size = (number of horizontal dots / 8) ×  
Number of vertical dots

**Gray-scale panel:**

Memory size = (number of horizontal dots / 4) ×  
Number of vertical dots

When using the vertical scroll function or virtual screen function, the display memory size should be increased for the scroll area or virtual area. Use the LCD panel examples in Sections 5.10.6 to 5.10.8 as reference for deciding the memory size.

### 5.10.6 LCD panel

#### FR frequency

The FR (frame) signal is generated by dividing the OSC1 clock. The dividing ratio can be selected using the CKCN and POINT5 registers. Select one according to the LCD panel to be used so that it is not out of the permissible range.

Table 5.10.6.1 FR frequency setting

| CKCN2 | CKCN1 | CKCN0 | POINT5 | FR frequency      |
|-------|-------|-------|--------|-------------------|
| 0     | 0     | 0     | 0      | fosc1/(SLT+1)     |
| 0     | 0     | 0     | 1      | fosc1/1.5/(SLT+1) |
| 0     | 0     | 1     | 0      | fosc1/2/(SLT+1)   |
| 0     | 0     | 1     | 1      | fosc1/2.5/(SLT+1) |
| 0     | 1     | 0     | 0      | fosc1/3/(SLT+1)   |
| 0     | 1     | 0     | 1      | fosc1/3.5/(SLT+1) |
| 0     | 1     | 1     | 0      | fosc1/4/(SLT+1)   |
| 0     | 1     | 1     | 1      | fosc1/4.5/(SLT+1) |
| 1     | 0     | 0     | 0      | fosc1/5/(SLT+1)   |
| 1     | 0     | 0     | 1      | fosc1/5.5/(SLT+1) |
| 1     | 0     | 1     | 0      | fosc1/6/(SLT+1)   |
| 1     | 0     | 1     | 1      | fosc1/6.5/(SLT+1) |
| 1     | 1     | 0     | 0      | fosc1/7/(SLT+1)   |
| 1     | 1     | 0     | 1      | fosc1/7.5/(SLT+1) |
| 1     | 1     | 1     | 0      | fosc1/8/(SLT+1)   |
| 1     | 1     | 1     | 1      | fosc1/8.5/(SLT+1) |

#### Setting the panel size

To correspond the display memory bits to the LCD panel dots one to one, it is necessary to set the LCD panel size in the LCD controller. The following registers should be used for this setting.

- LBC6–LBC0: Sets the number of bytes for one line of display data.  
Specify [Number of horizontal dots / 8] in the B&W mode or [Number of horizontal dots / 4] in the gray-scale mode.
- SLT7–SLT0: Sets the number of lines (number of vertical dots) of the LCD panel.
- SAD15–SAD0: Sets the display start address in the display memory.

**LCD panel examples**

*(1) 240 × 100 dot B&W panel*

Display memory setting  
 3072 byte memory size is selected by mask option (00F000H–00FBFFH)  
 In the B&W mode, the display memory bits correspond to the LCD panel dots one to one.

Register settings  
 LBC register: 1EH (240/8 = 30 bytes)  
 SLT register: 64H (100 dots)  
 SAD register: F000H

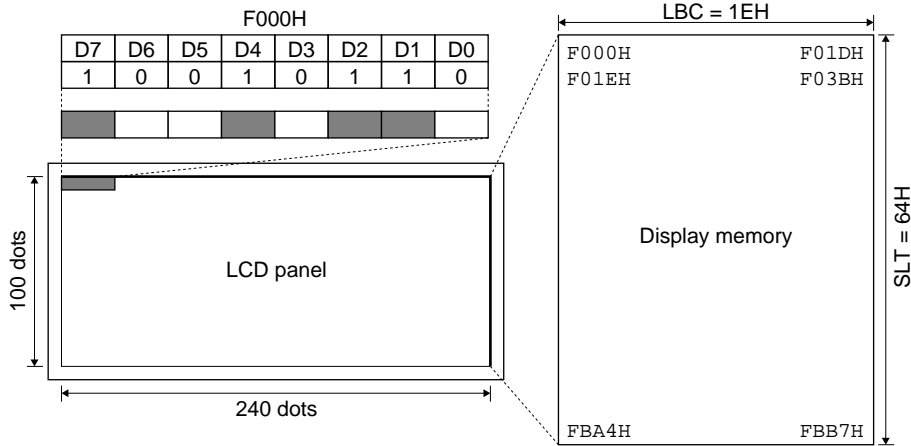


Fig. 5.10.6.1 Correspondence between LCD panel and display memory

*(2) 160 × 80 dot gray-scale panel*

Display memory setting  
 3328 byte memory size is selected by mask option (00F000H–00FCFFH)  
 In the gray-scale mode, each two bits of the display memory corresponds to an LCD panel dot.

Register settings  
 LBC register: 28H (160/4 = 40 bytes)  
 SLT register: 50H (80 dots)  
 SAD register: F000H

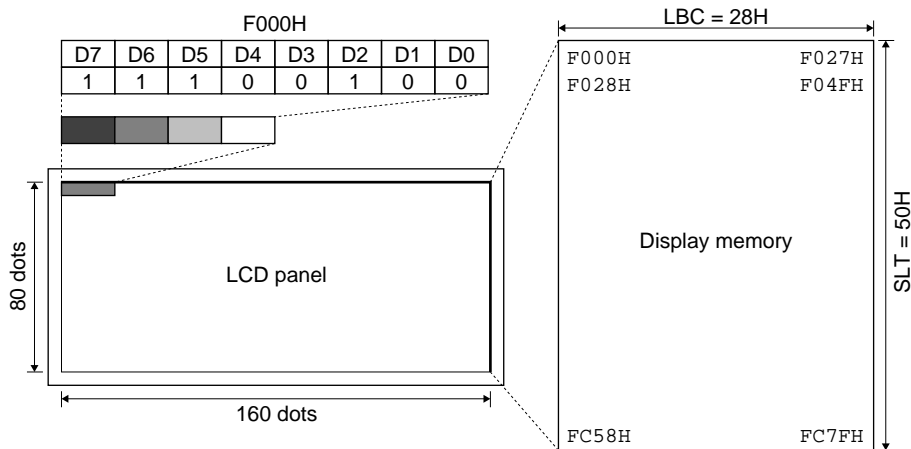


Fig. 5.10.6.2 Correspondence between LCD panel and display memory

The above examples are basic settings. See Sections 5.10.7 and 5.10.8 for examples when using the vertical scroll and virtual memory functions.

### 5.10.7 Vertical scroll function

Since the display start address is specified by the SAD register, vertical scroll can be done by increasing/decreasing the address by one line at a step.

*Note: When using the vertical scroll function, it is necessary to reserve the display memory for the scroll area in addition to the memory for the LCD panel size.  
Do not specify a display start address that cannot entirely display one screen (as exceeding the last display memory address in the middle of the LCD panel).*

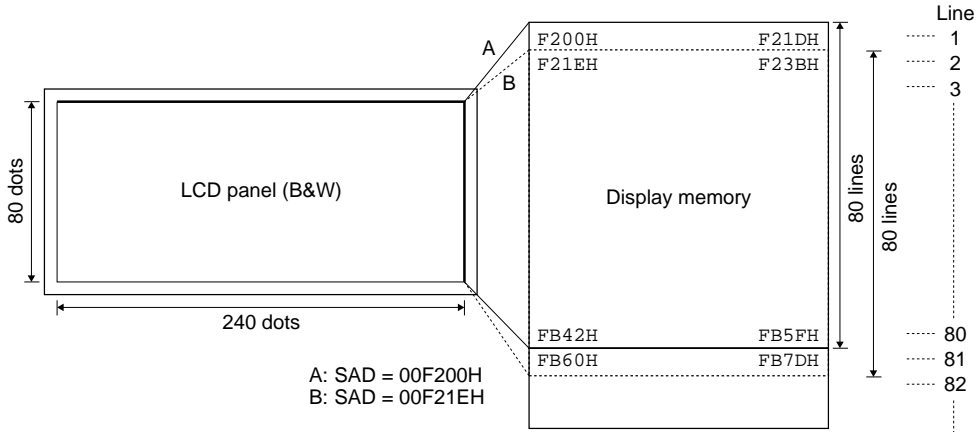


Fig. 5.10.7.1 Vertical scroll

### 5.10.8 Virtual screen function

In normal display, the beginning address of a line follows the end address of the previous line. In this LCD controller, the interval between the addresses can be specified using the APADJ register in byte units. This function can configure a virtual screen larger than the actual display size as shown in Figure 5.10.8.1. By controlling the display start address with the SAD register, the screen can be scrolled horizontally in byte units (B&W: 8-dot units, gray-scale: 4-dot units) or any part of the virtual screen can be displayed.

Furthermore, when a virtual screen with a two page size is assigned, the page can simply be switched.

*Note: When using the virtual screen function, enough display memory must be reserved for the screen size.  
Do not specify a display start address that cannot entirely display one screen (as exceeding the last display memory address in the middle of the LCD panel).*

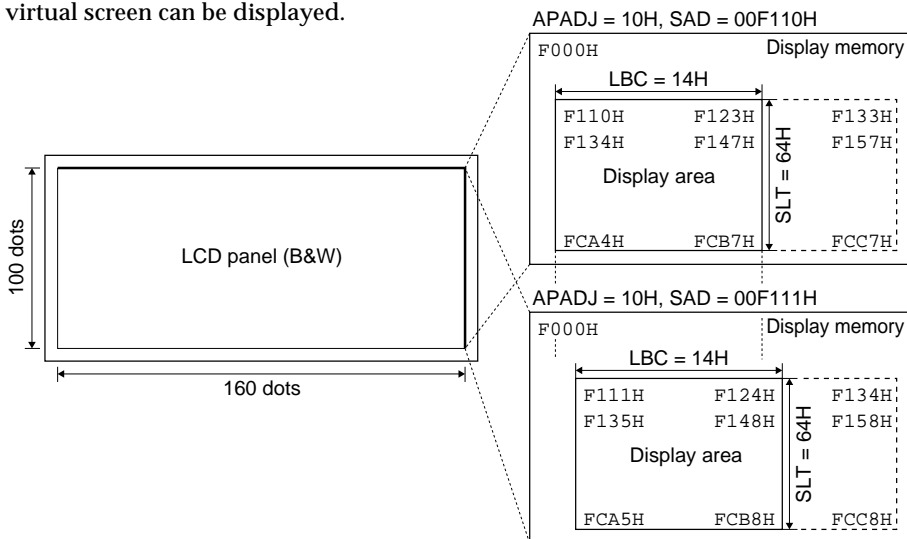


Fig. 5.10.8.1 Virtual screen function

### 5.10.9 Data transfer

#### Transfer data size

The transfer data size can be set to either 8 bits or 4 bits using the BITNO register.

4-bit data transfer only is available for the S1D16006 and S1D15700 drivers.

(1) 4-bit data transfer (BITNO = "0")

In 4-bit data transfer, data is sent as shown in Figure 5.10.9.1.

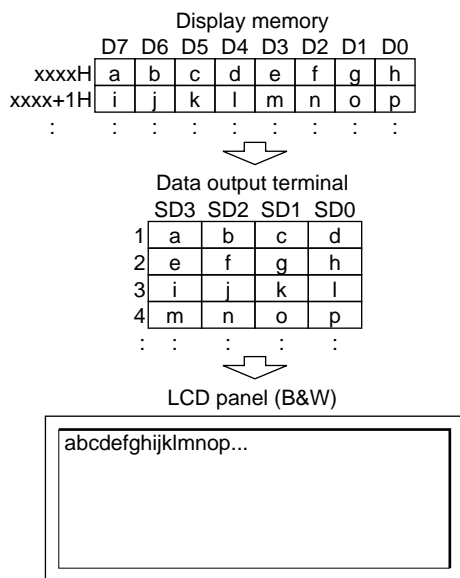


Fig. 5.10.9.1 4-bit data transfer

(2) 8-bit data transfer (BITNO = "1")

In 8-bit data transfer, data is sent as shown in Figure 5.10.9.2.

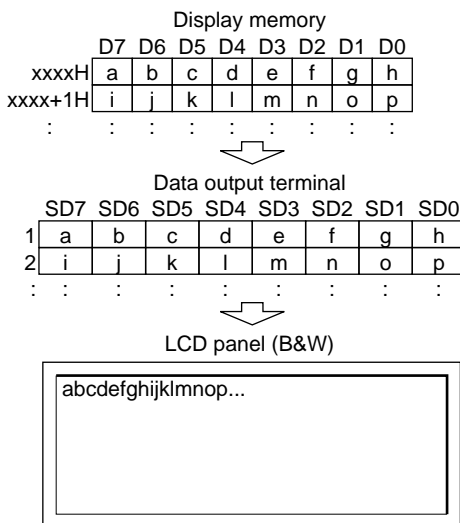


Fig. 5.10.9.2 8-bit data transfer

#### Data transfer method

The LCD controller has three data transfer modes for sending data to the segment drivers.

(1) Continuous data refresh mode

This mode is available for both the S1D16006 and S1D15700 segment drivers. The S1D16006 and the gray-scale display can be controlled only in this mode.

The continuous data refresh mode is set by writing "1" to the S1606 register. It is also set at initial reset.

In this mode, the display memory data is continuously sent to the segment driver in every frames while the LCDEN register is "1". Figures 5.10.9.3 to 5.10.9.5 show the timing charts in the continuous data refresh mode.

(2) One-shot transfer mode (software control)

This mode is available only for the S1D15700 segment driver and only in the B&W mode. The S1D16006 and the gray-scale display cannot use this mode.

To set the one-shot transfer mode, write "0" to the S1606 and S1570A registers.

When "1" is written to the LCDEN register, the LCD controller outputs only the FR, LP and YD signals for a self-refresh of the S1D15700.

When updating the display, rewrite the display memory then write "1" to the S15700 register. The LCD controller outputs one-frame data in the frame cycle immediately after the writing. After that, the LCD controller outputs the FR, LP and YD signals only.

This mode is best to reduce current consumption in the three transfer mode because data is transferred only when it is necessary.

Figure 5.10.9.6 shows the timing chart in the one-shot transfer mode.

The S15700 register, which is used for a trigger of the one-shot transfer, can be read as a status. After "1" is written to the S15700 register, the register maintains "1" until the data transfer has completed to indicate that the data transfer circuit is in busy status. A new data transfer cannot be started during this period (writing "1" to the S15700 register is ignored).

Further this mode can generate an interrupt at the end of a data transfer (see the next section). When updating the display, check to see if the data transfer is possible using these functions.



**(3) Hardware auto-transfer mode**

This mode is available only for the S1D15700 segment driver and only in the B&W mode. The S1D16006 and the gray-scale display cannot use this mode.

To set the hardware auto-transfer mode, write "0" to the S1606 register and write "1" to the S1570A register.

When "1" is written to the LCDEN register, the LCD controller outputs only the FR, LP and YD signals for a self-refresh of the S1D15700.

When data is written to the display memory, the LCD controller outputs one-frame data in the frame cycle immediately after the writing. After that, the LCD controller outputs the FR, LP and YD signals only.

This mode does not need other software controls because data is automatically transferred by only writing display data.

This mode can reduce current consumption better than the continuous data refresh mode. However, display data is transferred even if data is written in the scroll area or virtual screen that are out of the display range. To avoid such a transfer or to write display data separately from display update, use the one-shot transfer with software control.

Figure 5.10.9.7 shows the timing chart in the hardware auto-transfer mode.

The data transfer status in this mode can be read from the S1570AS register. The S1570AS register maintains "1" during data transfer to indicate that the data transfer circuit is in busy status. It goes to "0" while the segment drivers are in self-refresh operation (the data transfer circuit is in standby status).

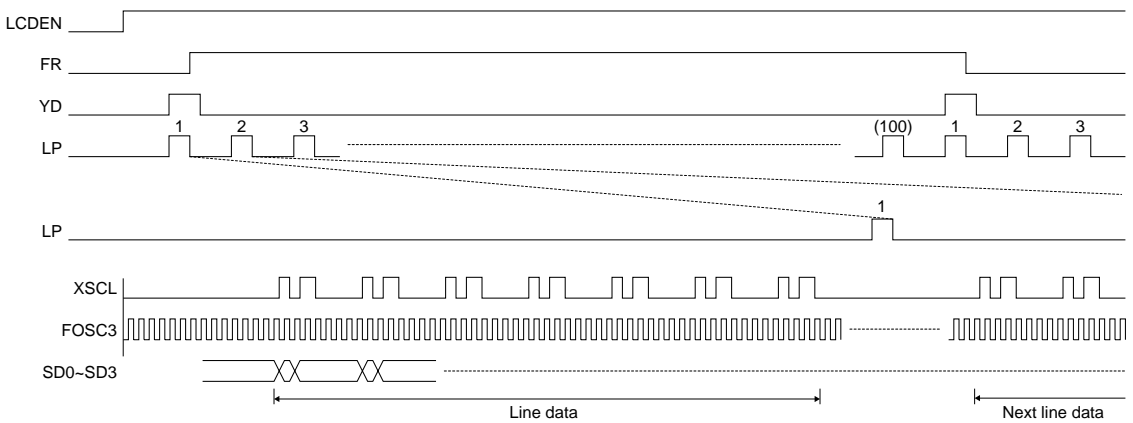


Fig. 5.10.9.3 Data transfer in continuous data refresh mode (B&W, 4-bit transfer)

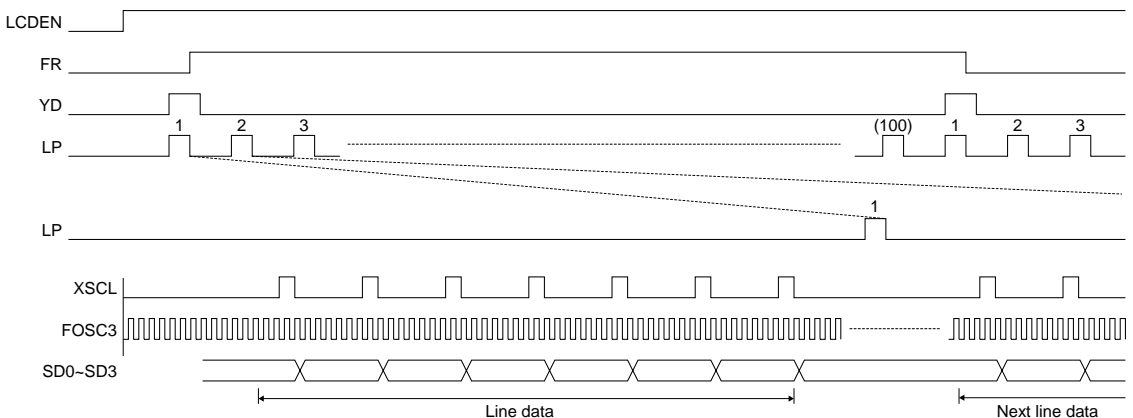


Fig. 5.10.9.4 Data transfer in continuous data refresh mode (gray-scale, 4-bit transfer)

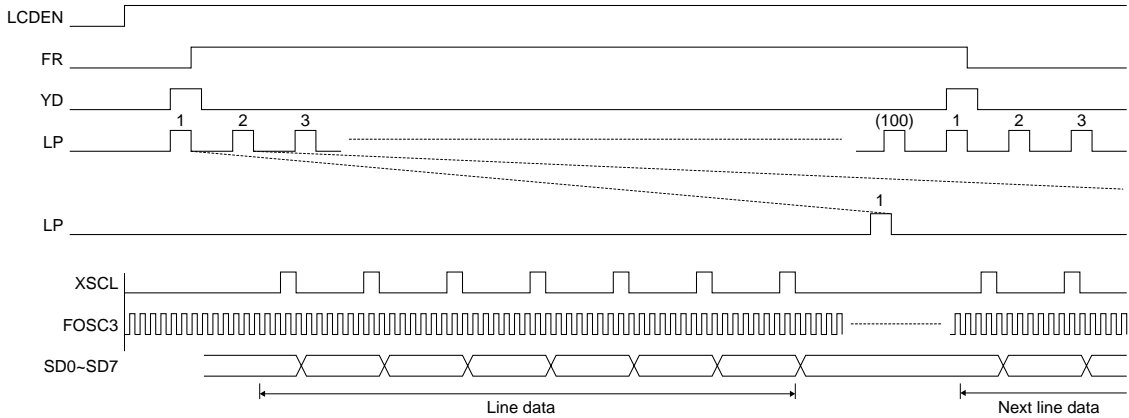


Fig. 5.10.9.5 Data transfer in continuous data refresh mode (B&W, 8-bit transfer)

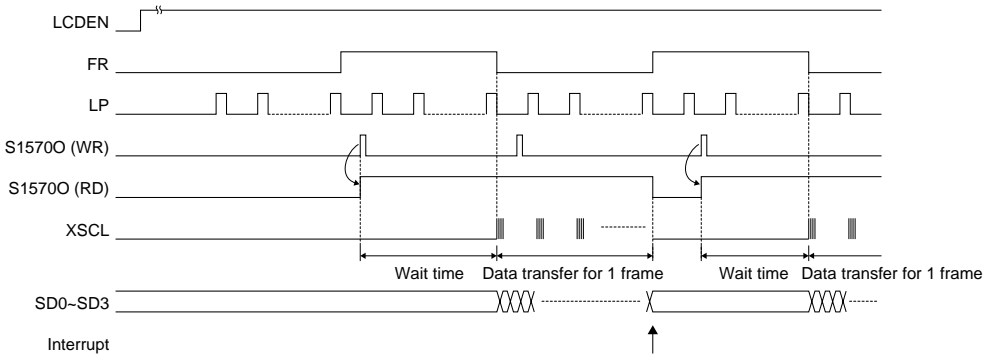


Fig. 5.10.9.6 Data transfer in one-shot transfer mode

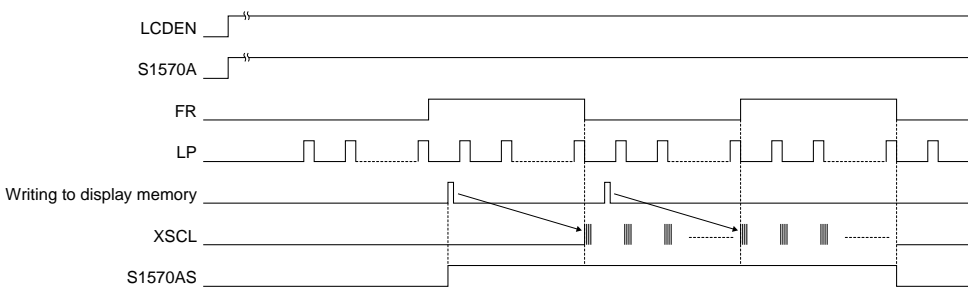


Fig. 5.10.9.7 Data transfer in hardware auto-transfer mode

### 5.10.10 Interrupt function

The LCD controller can generate an interrupt when a software one-shot data transfer or a hardware auto transfer has completed.

Figure 5.10.10.1 shows the configuration of the LCD controller interrupt circuit.

When a one-shot data transfer has completed, the interrupt factor flag FLCD is set to "1" and an interrupt is generated. The interrupt can be disabled using the interrupt enable register ELCD corresponding to the interrupt factor flag. See Figure 5.10.9.6 for the interrupt timing.

In addition, a priority level of the LCD controller interrupt for the CPU can be optionally set at levels 0 to 3 by the interrupt priority register PLCD.

For details on the above mentioned interrupt control registers and the operation following an interrupt generation, see Section 5.20, "Interrupt and Standby Mode".

The exception processing vector address of the interrupt factor is set as below.

LCD controller interrupt: 000024H

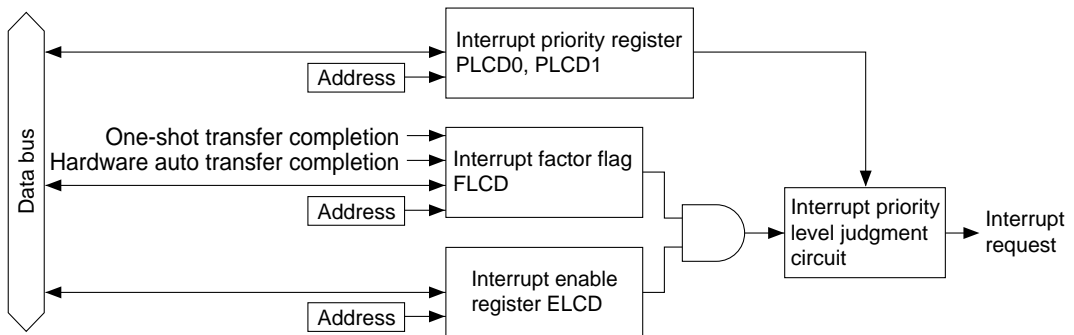


Fig. 5.10.10.1 Configuration of LCD interrupt circuit

5.10.11 I/O memory of LCD controller

Table 5.10.11.1 shows the control bits of the LCD controller.

Table 5.10.11.1(a) LCD controller control bits

| Address | Bit    | Name                           | Function                             | 1                                    | 0            | Init            | R/W         | Comment             |     |       |        |             |
|---------|--------|--------------------------------|--------------------------------------|--------------------------------------|--------------|-----------------|-------------|---------------------|-----|-------|--------|-------------|
| 00FF60  | D7     | DISP                           | Display On/Off control               | On                                   | Off          | 0               | R/W         |                     |     |       |        |             |
|         | D6     | REV                            | Normal/Inverse display control       | Inverse                              | Normal       | 0               | R/W         |                     |     |       |        |             |
|         | D5     | CKCN2                          | Scanning line frequency selection    |                                      |              |                 | 0           | R/W                 |     |       |        |             |
|         |        |                                | CKCN2                                | CKCN1                                |              |                 |             |                     |     | CKCN0 | POINT5 | Frequency   |
|         |        |                                | 0                                    | 0                                    |              |                 |             |                     |     | 0     | 0      | fosc1       |
|         |        |                                | 0                                    | 0                                    |              |                 |             |                     |     | 0     | 1      | fosc1 / 1.5 |
|         |        |                                | 0                                    | 0                                    |              |                 |             |                     |     | 1     | 0      | fosc1 / 2   |
|         | D4     | CKCN1                          | 0                                    | 0                                    | 1            | 1               | fosc1 / 2.5 | 0                   | R/W |       |        |             |
|         |        |                                | 0                                    | 1                                    | 0            | 0               | fosc1 / 3   |                     |     |       |        |             |
|         |        |                                | 0                                    | 1                                    | 0            | 1               | fosc1 / 3.5 |                     |     |       |        |             |
|         | D3     | CKCN0                          | 0                                    | 1                                    | 1            | 0               | fosc1 / 4   | 0                   | R/W |       |        |             |
|         |        |                                | 0                                    | 1                                    | 1            | 1               | fosc1 / 4.5 |                     |     |       |        |             |
|         |        |                                | 1                                    | 0                                    | 0            | 0               | fosc1 / 5   |                     |     |       |        |             |
| 1       |        |                                | 0                                    | 0                                    | 1            | fosc1 / 5.5     |             |                     |     |       |        |             |
| D2      | POINT5 | 1                              | 0                                    | 1                                    | 0            | fosc1 / 6       | 0           | R/W                 |     |       |        |             |
|         |        | 1                              | 0                                    | 1                                    | 1            | fosc1 / 6.5     |             |                     |     |       |        |             |
|         |        | 1                              | 1                                    | 0                                    | 0            | fosc1 / 7       |             |                     |     |       |        |             |
|         |        | 1                              | 1                                    | 0                                    | 1            | fosc1 / 7.5     |             |                     |     |       |        |             |
|         |        | 1                              | 1                                    | 1                                    | 0            | fosc1 / 8       |             |                     |     |       |        |             |
| D1      | GRAY   | Gray/B&W mode selection        |                                      | Gray                                 | B&W          | 0               | R/W         |                     |     |       |        |             |
| D0      | BITNO  | 8-bit/4-bit transfer selection |                                      | 8 bits                               | 4 bits       | 0               | R/W         |                     |     |       |        |             |
| 00FF61  | D7     | -                              | -                                    | -                                    | -            | -               | -           | "0" when being read |     |       |        |             |
|         | D6     | -                              | -                                    | -                                    | -            | -               | -           |                     |     |       |        |             |
|         | D5     | -                              | -                                    | -                                    | -            | -               | -           |                     |     |       |        |             |
|         | D4     | S1570AS                        | Hardware auto-transfer status        |                                      | Busy         | Standby         | 0           |                     | R   |       |        |             |
|         | D3     | LCDEN                          | LCD power On/Off control             |                                      | On           | Off             | 0           | R/W                 |     |       |        |             |
|         | D2     | S1570A                         | Hardware auto-transfer control       |                                      | On           | Off             | 0           | R/W                 |     |       |        |             |
|         | D1     | S1570O                         | One-shot transfer trigger/status     |                                      | Busy Trigger | Standby Invalid | 0           | R/W                 |     |       |        |             |
|         | D0     | S1606                          | Continuous refresh transfer control  |                                      | On           | Off             | 1           | R/W                 |     |       |        |             |
| 00FF62  | D7     | -                              | -                                    | -                                    | -            | -               | -           | "0" when being read |     |       |        |             |
|         | D6     | LBC6                           | Number of bytes per display line     | D6(MSB)                              | High         | Low             | 0           |                     | R/W |       |        |             |
|         | D5     | LBC5                           |                                      | D5                                   |              |                 | 0           |                     | R/W |       |        |             |
|         | D4     | LBC4                           |                                      | D4                                   |              |                 | 0           |                     | R/W |       |        |             |
|         | D3     | LBC3                           |                                      | D3                                   |              |                 | 0           |                     | R/W |       |        |             |
|         | D2     | LBC2                           |                                      | D2                                   |              |                 | 0           |                     | R/W |       |        |             |
|         | D1     | LBC1                           |                                      | D1                                   |              |                 | 0           |                     | R/W |       |        |             |
|         | D0     | LBC0                           |                                      | D0(LSB)                              |              |                 | 0           |                     | R/W |       |        |             |
| 00FF63  | D7     | SAD7                           |                                      | Display start address (lower 8 bits) |              |                 | D7          | High                | Low | 0     | R/W    |             |
|         | D6     | SAD6                           | D6                                   |                                      | 0            | R/W             |             |                     |     |       |        |             |
|         | D5     | SAD5                           | D5                                   |                                      | 0            | R/W             |             |                     |     |       |        |             |
|         | D4     | SAD4                           | D4                                   |                                      | 0            | R/W             |             |                     |     |       |        |             |
|         | D3     | SAD3                           | D3                                   |                                      | 0            | R/W             |             |                     |     |       |        |             |
|         | D2     | SAD2                           | D2                                   |                                      | 0            | R/W             |             |                     |     |       |        |             |
|         | D1     | SAD1                           | D1                                   |                                      | 0            | R/W             |             |                     |     |       |        |             |
|         | D0     | SAD0                           | D0                                   |                                      | 0            | R/W             |             |                     |     |       |        |             |
| 00FF64  | D7     | SAD15                          | Display start address (upper 8 bits) | D15                                  | High         | Low             | 0           | R/W                 |     |       |        |             |
|         | D6     | SAD14                          |                                      | D14                                  |              |                 | 0           | R/W                 |     |       |        |             |
|         | D5     | SAD13                          |                                      | D13                                  |              |                 | 0           | R/W                 |     |       |        |             |
|         | D4     | SAD12                          |                                      | D12                                  |              |                 | 0           | R/W                 |     |       |        |             |
|         | D3     | SAD11                          |                                      | D11                                  |              |                 | 0           | R/W                 |     |       |        |             |
|         | D2     | SAD10                          |                                      | D10                                  |              |                 | 0           | R/W                 |     |       |        |             |
|         | D1     | SAD9                           |                                      | D9                                   |              |                 | 0           | R/W                 |     |       |        |             |
|         | D0     | SAD8                           |                                      | D8                                   |              |                 | 0           | R/W                 |     |       |        |             |
| 00FF65  | D7     | SLT7                           | Total display lines                  | D7                                   | High         | Low             | 0           | R/W                 |     |       |        |             |
|         | D6     | SLT6                           |                                      | D6                                   |              |                 | 0           | R/W                 |     |       |        |             |
|         | D5     | SLT5                           |                                      | D5                                   |              |                 | 0           | R/W                 |     |       |        |             |
|         | D4     | SLT4                           |                                      | D4                                   |              |                 | 0           | R/W                 |     |       |        |             |
|         | D3     | SLT3                           |                                      | D3                                   |              |                 | 0           | R/W                 |     |       |        |             |
|         | D2     | SLT2                           |                                      | D2                                   |              |                 | 0           | R/W                 |     |       |        |             |
|         | D1     | SLT1                           |                                      | D1                                   |              |                 | 0           | R/W                 |     |       |        |             |
|         | D0     | SLT0                           |                                      | D0                                   |              |                 | 0           | R/W                 |     |       |        |             |

Table 5.10.11.1(b) LCD controller control bits

| Address | Bit | Name   | Function                                             | 1                              | 0                                  | Init           | R/W   | Comment             |                     |
|---------|-----|--------|------------------------------------------------------|--------------------------------|------------------------------------|----------------|-------|---------------------|---------------------|
| 00FF66  | D7  | –      | –                                                    | –                              | –                                  | –              | –     | "0" when being read |                     |
|         | D6  | –      | –                                                    | –                              | –                                  | –              | –     |                     |                     |
|         | D5  | –      | –                                                    | –                              | –                                  | –              | –     |                     |                     |
|         | D4  | –      | –                                                    | –                              | –                                  | –              | –     |                     |                     |
|         | D3  | –      | –                                                    | –                              | –                                  | –              | –     |                     |                     |
|         | D2  | –      | –                                                    | –                              | –                                  | –              | –     |                     |                     |
|         | D1  | –      | –                                                    | –                              | –                                  | –              | –     |                     |                     |
|         | D0  | SLT8   | Total display lines (MSB)                            |                                | High                               | Low            | 0     |                     | R/W                 |
| 00FF67  | D7  | APADJ7 | Address pitch adjustment                             | D7                             | High                               | Low            | 0     | R/W                 |                     |
|         | D6  | APADJ6 |                                                      | D6                             |                                    |                | 0     | R/W                 |                     |
|         | D5  | APADJ5 |                                                      | D5                             |                                    |                | 0     | R/W                 |                     |
|         | D4  | APADJ4 |                                                      | D4                             |                                    |                | 0     | R/W                 |                     |
|         | D3  | APADJ3 |                                                      | D3                             |                                    |                | 0     | R/W                 |                     |
|         | D2  | APADJ2 |                                                      | D2                             |                                    |                | 0     | R/W                 |                     |
|         | D1  | APADJ1 |                                                      | D1                             |                                    |                | 0     | R/W                 |                     |
|         | D0  | APADJ0 |                                                      | D0                             |                                    |                | 0     | R/W                 |                     |
| 00FF68  | D7  | GS17   | Gray scale (0,1) conversion code                     | D7                             | High                               | Low            | 0     | R/W                 |                     |
|         | D6  | GS16   |                                                      | D6                             |                                    |                | 0     | R/W                 |                     |
|         | D5  | GS15   |                                                      | D5                             |                                    |                | 0     | R/W                 |                     |
|         | D4  | GS14   |                                                      | D4                             |                                    |                | 0     | R/W                 |                     |
|         | D3  | GS13   |                                                      | D3                             |                                    |                | 0     | R/W                 |                     |
|         | D2  | GS12   |                                                      | D2                             |                                    |                | 0     | R/W                 |                     |
|         | D1  | GS11   |                                                      | D1                             |                                    |                | 0     | R/W                 |                     |
|         | D0  | GS10   |                                                      | D0                             |                                    |                | 0     | R/W                 |                     |
| 00FF69  | D7  | GS27   | Gray scale (1,0) conversion code                     | D7                             | High                               | Low            | 0     | R/W                 |                     |
|         | D6  | GS26   |                                                      | D6                             |                                    |                | 0     | R/W                 |                     |
|         | D5  | GS25   |                                                      | D5                             |                                    |                | 0     | R/W                 |                     |
|         | D4  | GS24   |                                                      | D4                             |                                    |                | 0     | R/W                 |                     |
|         | D3  | GS23   |                                                      | D3                             |                                    |                | 0     | R/W                 |                     |
|         | D2  | GS22   |                                                      | D2                             |                                    |                | 0     | R/W                 |                     |
|         | D1  | GS21   |                                                      | D1                             |                                    |                | 0     | R/W                 |                     |
|         | D0  | GS20   |                                                      | D0                             |                                    |                | 0     | R/W                 |                     |
| 00FF6A  | D7  | GS37   | Gray scale (1,1) conversion code                     | D7                             | High                               | Low            | 0     | R/W                 |                     |
|         | D6  | GS36   |                                                      | D6                             |                                    |                | 0     | R/W                 |                     |
|         | D5  | GS35   |                                                      | D5                             |                                    |                | 0     | R/W                 |                     |
|         | D4  | GS34   |                                                      | D4                             |                                    |                | 0     | R/W                 |                     |
|         | D3  | GS33   |                                                      | D3                             |                                    |                | 0     | R/W                 |                     |
|         | D2  | GS32   |                                                      | D2                             |                                    |                | 0     | R/W                 |                     |
|         | D1  | GS31   |                                                      | D1                             |                                    |                | 0     | R/W                 |                     |
|         | D0  | GS30   |                                                      | D0                             |                                    |                | 0     | R/W                 |                     |
| 00FF21  | D7  | PTM21  | 8-bit programmable timer interrupt priority register | PTM21                          | PTM20                              | 0              | R/W   |                     |                     |
|         | D6  | PTM20  |                                                      | PSI1                           | PSI0                               | 0              | R/W   |                     |                     |
|         | D5  | PSI1   | Serial interface interrupt priority register         | PCTM1                          | PCTM0                              | Priority level | 0     | R/W                 |                     |
|         | D4  | PSI0   |                                                      | PLCD1                          | PLCD0                              | Level 3        | 0     | R/W                 |                     |
|         | D3  | PCTM1  | Clock timer interrupt priority register              | 1                              | 1                                  | Level 2        | 0     | R/W                 |                     |
|         | D2  | PCTM0  | Clock timer interrupt priority register              | 1                              | 0                                  | Level 1        | 0     | R/W                 |                     |
|         | D1  | PLCD1  | LCD controller interrupt priority register           | 0                              | 1                                  | Level 0        | 0     | R/W                 |                     |
|         | D0  | PLCD0  | LCD controller interrupt priority register           | 0                              | 0                                  | Level 0        | 0     | R/W                 |                     |
| 00FF25  | D7  | ET60S  | Clock timer 60 S interrupt enable register           | Interrupt is enabled           | Interrupt is disabled              | 0              | R/W   |                     |                     |
|         | D6  | ECTM1  | Clock timer 1 Hz interrupt enable register           |                                |                                    | 0              | R/W   |                     |                     |
|         | D5  | ECTM2  | Clock timer 2 Hz interrupt enable register           |                                |                                    | 0              | R/W   |                     |                     |
|         | D4  | ECTM8  | Clock timer 8 Hz interrupt enable register           |                                |                                    | 0              | R/W   |                     |                     |
|         | D3  | ECTM32 | Clock timer 32 Hz interrupt enable register          |                                |                                    | 0              | R/W   |                     |                     |
|         | D2  | ELCD   | LCD controller interrupt enable register             |                                |                                    | 0              | R/W   |                     |                     |
|         | D1  | –      | –                                                    |                                |                                    | –              | –     | –                   | "0" when being read |
|         | D0  | –      | –                                                    |                                |                                    | –              | –     | –                   |                     |
| 00FF29  | D7  | FT60S  | Clock timer 60 S interrupt factor flag               | (R)                            | (R)                                | 0              | R/(W) |                     |                     |
|         | D6  | FCTM1  | Clock timer 1 Hz interrupt factor flag               | Interrupt factor has generated | Interrupt factor has not generated | 0              | R/(W) |                     |                     |
|         | D5  | FCTM2  | Clock timer 2 Hz interrupt factor flag               |                                |                                    | 0              | R/(W) |                     |                     |
|         | D4  | FCTM8  | Clock timer 8 Hz interrupt factor flag               |                                |                                    | 0              | R/(W) |                     |                     |
|         | D3  | FCTM32 | Clock timer 32 Hz interrupt factor flag              |                                |                                    | 0              | R/(W) |                     |                     |
|         | D2  | FLCD   | LCD controller interrupt factor flag                 | (W)                            | (W)                                | 0              | R/(W) |                     |                     |
|         | D1  | –      | –                                                    | Reset                          | Invalid                            | –              | –     | "0" when being read |                     |
|         | D0  | –      | –                                                    | –                              | –                                  | –              | –     |                     |                     |

**DISP: Display ON/OFF control register (00FF60H•D7)**

Turns the display on and off.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

When "1" is written to the DISP register, the DOFF terminal goes low and when "0" is written, the DOFF terminal goes high.

This signal controls the external driver to turn the display on and off.

At initial reset, the DISP register is set to "0" (OFF).

**REV: Normal/reverse display control register (00FF60H•D6)**

Controls reverse display.

- When "1" is written: Reverse display
- When "0" is written: Normal display
- Reading: Valid

When "1" is written to the REV register, the display reverses and when "0" is written, it returns to the normal. When using an LCD panel with a back light, the setting reverses.

At initial reset, the REV register is set to "0" (normal).

**POINT5, CKCN0–CKCN2: Scanning line frequency selection register (00FF60H•D2–D5)**

Selects a scanning line frequency from 16 types as shown in Table 5.10.11.2.

Table 5.10.11.2 Selection of scanning line frequency

| CKCN2 | CKCN1 | CKCN0 | POINT5 | Frequency |
|-------|-------|-------|--------|-----------|
| 0     | 0     | 0     | 0      | fosc1     |
| 0     | 0     | 0     | 1      | fosc1/1.5 |
| 0     | 0     | 1     | 0      | fosc1/2   |
| 0     | 0     | 1     | 1      | fosc1/2.5 |
| 0     | 1     | 0     | 0      | fosc1/3   |
| 0     | 1     | 0     | 1      | fosc1/3.5 |
| 0     | 1     | 1     | 0      | fosc1/4   |
| 0     | 1     | 1     | 1      | fosc1/4.5 |
| 1     | 0     | 0     | 0      | fosc1/5   |
| 1     | 0     | 0     | 1      | fosc1/5.5 |
| 1     | 0     | 1     | 0      | fosc1/6   |
| 1     | 0     | 1     | 1      | fosc1/6.5 |
| 1     | 1     | 0     | 0      | fosc1/7   |
| 1     | 1     | 0     | 1      | fosc1/7.5 |
| 1     | 1     | 1     | 0      | fosc1/8   |
| 1     | 1     | 1     | 1      | fosc1/8.5 |

The frame frequency is set as "scanning frequency / (SLT+1)".

At initial reset, these registers are set to "0" (fosc1).

**GRAY: Gray-scale/B&W mode selection register (00FF60H•D1)**

Selects the gray-scale mode or B&W mode.

- When "1" is written: Gray-scale mode
- When "0" is written: B&W mode
- Reading: Valid

When "1" is written to the GRAY register, the gray-scale mode is set and it displays a dot with 2 bits of the display memory.

When "0" is written, the B&W mode is set and each bit of the display memory corresponds to a dot on the LCD panel one to one.

At initial reset, the GRAY register is set to "0" (B&W mode).

**BITNO: 8-bit/4-bit transfer selection register (00FF60H•D0)**

Set the transfer data size.

- When "1" is written: 8 bits
- When "0" is written: 4 bits
- Reading: Valid

BITNO sets the size of data to be transferred to the segment drivers. When "1" is written to the BITNO register, 8-bit transfer is set and when "0" is written, 4-bit transfer is set. The 4-bit transfer uses the data output terminals SD0 to SD3 only.

When using S1606 or S1570 as the segment driver, fix this register at "0".

When the gray-scale mode is selected, 4-bit transfer only is available regardless of the BITNO register setting.

At initial reset, the BITNO register is set to "0" (4 bits).

**LCDEN: LCD power control register (00FF61H•D3)**

Controls the power of the LCD controller.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

When "1" is written to the LCDEN register, the power of the LCD controller turns on and when "0" is written, it turns off.

The LCDEN terminal goes high while the LCDEN register is "1" and goes low while the register is "0". Use this signal for controlling the power of the LCD panel so that the LCD panel does not turn on while the LCDEN is "0".

At initial reset, the LCDEN register is set to "0" (OFF).

**S1606: Continuous refresh transfer selection register (00FF61H•D0)**

Sets the continuous refresh transfer mode.

When "1" is written: ON  
 When "0" is written: OFF  
 Reading: Valid

When "1" is written to the S1606 register, the continuous refresh transfer mode is set. In this mode, the display data is transferred to the segment drivers while the LCDEN register is "1". When using the S1606 segment driver and/or in gray-scale mode, fix this register at "1". When using other transfer mode, fix this register at "0". At initial reset, the S1606 register is set to "1" (ON).

**S15700: One-shot transfer trigger/status (00FF61H•D1)**

Starts one-shot transfer and indicates the transfer status.

When "1" is written: Trigger  
 When "0" is written: Invalid  
 When "1" is read: Busy  
 When "0" is read: Standby

By writing "1" to S15700 after rewriting the display memory, the LCD controller sends the display data to the segment drivers to update the display. Writing "0" and writing "1" during data transfer are invalid.

S15700 also indicates the status of the data transfer circuit when reading. It goes "1" during data transfer and goes "0" in standby status. S15700 cannot be used for transferring data when using the S1606 segment driver and/or in gray-scale mode.

At initial reset, S15700 is set to "0" (standby).

**S1570A: Hardware auto-transfer control register (00FF61H•D2)**

Sets the hardware auto-transfer mode.

When "1" is written: ON  
 When "0" is written: OFF  
 Reading: Valid

When "1" is written to the S1570A register, the hardware auto-transfer mode is set. In this mode, the hardware automatically sends the display data to the segment drivers by writing data to the display memory while the LCDEN register is "1".

When using other transfer modes, fix this register at "0". This transfer mode cannot be selected when using the S1606 segment driver and/or in gray-scale mode.

At initial reset, the S1570A register is set to "0" (OFF).

**S1570AS: Hardware auto-transfer status (00FF61H•D4)**

Indicates the hardware auto-transfer status.

When "1" is read: Busy  
 When "0" is read: Standby  
 Writing: Invalid

S1570AS indicates the status of the data transfer circuit; it goes "1" during hardware auto-transfer and "0" in standby status.

S1570AS is a read only bit, so writing is invalid. At initial reset, S1570AS is set to "0" (standby).

**LBC0–LBC6: Horizontal LCD panel size setting register (00FF62H•D0–D6)**

The display line size should be specified as the number of bytes with this register.

Specify [Number of dots / 8] in the B&W mode or [Number of dots / 4] in the gray-scale mode.

At initial reset, the LBC register is set to "00H".

**SLT0–SLT8: Vertical LCD panel size setting register (00FF65H, 00FF66H•D0)**

Number of display lines (vertical dot number) should be specified with this register.

At initial reset, the SLT register is set to "000H".

**SAD0–SAD15: Display start address setting register (00FF63H, 00FF64H)**

Specifies the display memory address that contains the data to be displayed at the first dot of the LCD panel.

By changing this address successively, the screen scrolls.

At initial reset, the SAD register is set to "0000H".

**APADJ0–APADJ7: Address pitch adjustment register (00FF67H)**

Specifies the address pitch between lines as number of bytes.

After a line has been displayed, the specified number of addresses in the display memory are skipped and the next line begins from the following address.

At initial reset, the APADJ register is set to "00H".

**GS10–GS17: Gray-scale (0, 1) conversion code setting register (00FF68H)**  
**GS20–GS27: Gray-scale (1, 0) conversion code setting register (00FF69H)**  
**GS30–GS37: Gray-scale (1, 1) conversion code setting register (00FF6AH)**

Sets the gray-scale conversion code.

- When "1" is written: Dot goes ON
- When "0" is written: Dot goes OFF
- Reading: Valid

The GS1, GS2 and GS3 registers correspond to gray levels 01B, 10B and 11B, respectively. Each register specifies a display pattern for eight frame cycles, thus the intensity of each gray level can be set. D0 to D7 in the register control dots on (1) and off (0) in each frame cycle. At initial reset, the GS register is set to "00H" (OFF).

**PLCD0, PLCD1: LCD controller interrupt priority register (00FF21H•D0, D1)**

Sets the priority level of the LCD controller interrupt.

Table 5.10.11.3 shows the interrupt priority level which can be set by the PLCD register.

*Table 5.10.11.3 Interrupt priority level settings*

| PLCD1 | PLCD0 | Interrupt priority level             |
|-------|-------|--------------------------------------|
| 1     | 1     | Level 3 ( $\overline{\text{IRQ3}}$ ) |
| 1     | 0     | Level 2 ( $\overline{\text{IRQ2}}$ ) |
| 0     | 1     | Level 1 ( $\overline{\text{IRQ1}}$ ) |
| 0     | 0     | Level 0 (None)                       |

At initial reset, the PLCD register is set to "0" (level 0).

**ELCD: LCD controller interrupt enable register (00FF25H•D2)**

Enables or disables the LCD controller interrupt generation to the CPU.

- When "1" is written: Interrupt is enabled
- When "0" is written: Interrupt is disabled
- Reading: Valid

The ELCD register is the interrupt enable register corresponding to the LCD controller interrupt factor. When this register is set to "1", the interrupt is enabled, and when it is set to "0", the interrupt is disabled.

At initial reset, the ELCD register is set to "0" (interrupt is disabled).

**FLCD: LCD controller interrupt factor flag (00FF29H•D2)**

Indicates the generation of LCD controller interrupt factor.

- When "1" is read: Int. factor has generated
- When "0" is read: Int. factor has not generated

- When "1" is written: Factor flag is reset
- When "0" is written: Invalid

FLCD is the interrupt factor flag corresponding to the LCD controller interrupt. It is set to "1" when a software one-shot data transfer or a hardware auto transfer has completed.

At this point, if the corresponding interrupt enable register is set to "1" and the corresponding interrupt priority register is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.

Regardless of the interrupt enable register and interrupt priority register settings, the interrupt factor flag is set to "1" when the interrupt generation condition is met.

To accept the subsequent interrupt after an interrupt generation, it is necessary to reset the interrupt flag (set the interrupt flag to a lower level than the level indicated by the interrupt priority registers, or execute the RETE instruction) and to reset the interrupt factor flag. The interrupt factor flag is reset to "0" by writing "1".

At initial reset, the FLCD flag is reset to "0".



### 5.10.12 Programming notes

- (1) Do not write "0" to the LCDEN register while the LCD panel is ON. The LCD panel may be damaged.
- (2) Only the 4-bit continuous data refresh mode is available in the gray-scale mode. Do not use 8-bit data transfer or another transfer mode.
- (3) The data transfer uses the OSC3 clock. Therefore, turn the OSC3 oscillation on before writing "1" to the LCDEN register. Furthermore, wait 20 msec or more after turning the OSC3 oscillation on for stabilizing oscillation. In the one-shot transfer mode or hardware auto-transfer mode, do not turn the OSC3 oscillation off before finishing data transfer. When the segment driver is in self-refresh status, the OSC3 oscillation can be stopped to reduce current consumption.
- (4) When setting the CPU in SLEEP status, be sure to turn the LCD panel power off and stop operation of the LCD controller.

## 5.11 Clock Timer

### 5.11.1 Configuration of clock timer

The S1C88409 has a built-in clock timer that uses the OSC1 oscillation circuit as the clock source. The clock timer is composed of an 8-bit binary counter that inputs a 256 Hz clock divided from fosc1 and a 7-bit BCD counter for counting up to 60 seconds. The 128-1 Hz and 0-60 second counter data can be read by software. The 60-second counter can preset data. Ordinarily, this clock timer is used for various timing functions such as clocks. Figure 5.11.1.1 shows the configuration of the clock timer.

### 5.11.2 Interrupt function

The clock timer can generate an interrupt by each of the 32 Hz, 8 Hz, 2 Hz and 1 Hz signals or when the 60-second counter overflows. Figure 5.11.2.1 shows the configuration of the clock timer interrupt circuit.

The interrupt factor flags FCTM32, FCTM8, FCTM2 and FCTM1 are set to "1" at the falling edge of the 32 Hz, 8 Hz, 2 Hz and 1 Hz signals, respectively. At that point, the interrupt is generated. When the 60-second counter overflows, FT60S is set to "1" to generate the 60S interrupt. The interrupt can also be prohibited by setting the interrupt enable registers ECTM32, ECTM8, ECTM2, ECTM1 and ET60S corresponding to the interrupt factor flags. Furthermore, the priority level of the input interrupt for the CPU can be set in an optional level (0-3) using the interrupt priority register PCTM (two bits).

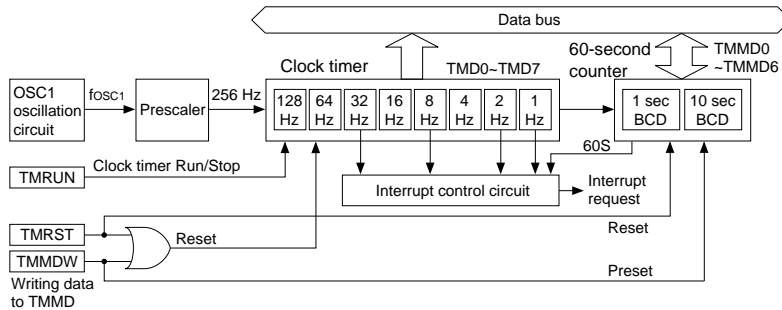


Fig. 5.11.1.1 Configuration of clock timer

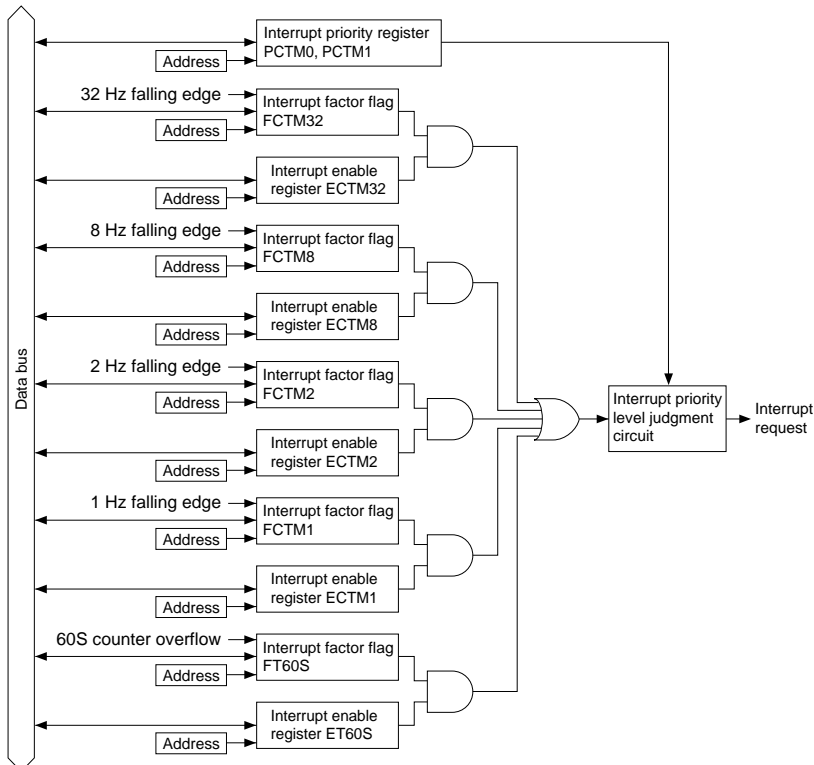


Fig. 5.11.2.1 Configuration of clock timer interrupt circuit

Refer to Section 5.20, "Interrupt and Standby Mode", for details of the interrupt control registers and operations subsequent to interrupt generation.

The exception processing vector address for the clock timer interrupt is set to 000028H.

Figures 5.11.2.2 and 5.11.2.3 show the timing chart for the clock timer.

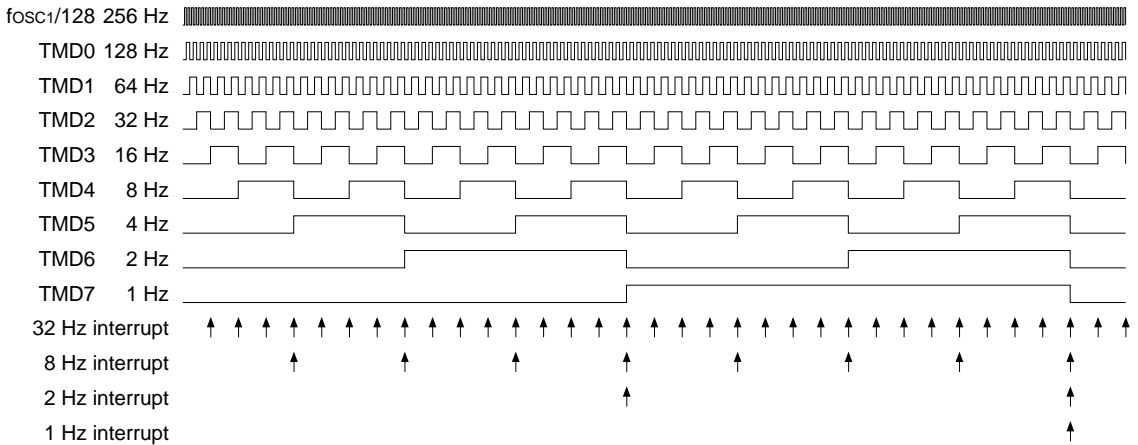


Fig. 5.11.2.2 Timing chart of clock timer (128 Hz-1 Hz)

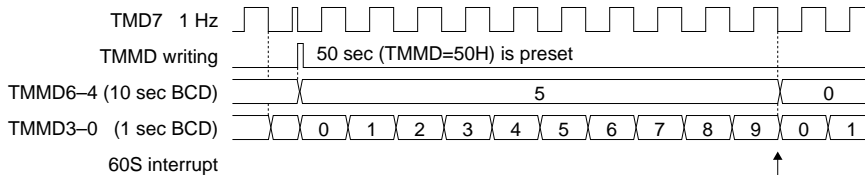


Fig. 5.11.2.3 Timing chart of clock timer (60-second counter)

5.11.3 I/O memory of clock timer

Table 5.11.3.1 shows the clock timer control bits.

Table 5.11.3.1 Clock timer control bits

| Address | Bit | Name   | Function                                    | 1                              | 0                                  | Init     | R/W   | Comment             |   |                     |
|---------|-----|--------|---------------------------------------------|--------------------------------|------------------------------------|----------|-------|---------------------|---|---------------------|
| 00FF21  | D7  | PTM21  | 8-bit programmable timer                    | PTM21                          | PTM20                              | 0        | R/W   |                     |   |                     |
|         | D6  | PTM20  | interrupt priority register                 | PSI1                           | PSI0                               | 0        | R/W   |                     |   |                     |
|         | D5  | PSI1   | Serial interface                            | PCTM1                          | PCTM0                              | Priority | 0     | R/W                 |   |                     |
|         | D4  | PSI0   | interrupt priority register                 | PLCD1                          | PLCD0                              | level    | 0     | R/W                 |   |                     |
|         | D3  | PCTM1  | Clock timer                                 | 1                              | 1                                  | Level 3  | 0     | R/W                 |   |                     |
|         | D2  | PCTM0  | interrupt priority register                 | 1                              | 0                                  | Level 2  | 0     | R/W                 |   |                     |
|         | D1  | PLCD1  | LCD controller                              | 0                              | 1                                  | Level 1  | 0     | R/W                 |   |                     |
|         | D0  | PLCD0  | interrupt priority register                 | 0                              | 0                                  | Level 0  | 0     | R/W                 |   |                     |
| 00FF25  | D7  | ET60S  | Clock timer 60 S interrupt enable register  | Interrupt is enabled           | Interrupt is disabled              | 0        | R/W   |                     |   |                     |
|         | D6  | ECTM1  | Clock timer 1 Hz interrupt enable register  |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D5  | ECTM2  | Clock timer 2 Hz interrupt enable register  |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D4  | ECTM8  | Clock timer 8 Hz interrupt enable register  |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D3  | ECTM32 | Clock timer 32 Hz interrupt enable register |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D2  | ELCD   | LCD controller interrupt enable register    |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D1  | -      | -                                           |                                |                                    | -        | -     | -                   | - | "0" when being read |
|         | D0  | -      | -                                           |                                |                                    | -        | -     | -                   | - |                     |
| 00FF29  | D7  | FT60S  | Clock timer 60 S interrupt factor flag      | (R)                            | (R)                                | 0        | R/(W) |                     |   |                     |
|         | D6  | FCTM1  | Clock timer 1 Hz interrupt factor flag      | Interrupt factor has generated | Interrupt factor has not generated | 0        | R/(W) |                     |   |                     |
|         | D5  | FCTM2  | Clock timer 2 Hz interrupt factor flag      |                                |                                    | 0        | R/(W) |                     |   |                     |
|         | D4  | FCTM8  | Clock timer 8 Hz interrupt factor flag      |                                |                                    | 0        | R/(W) |                     |   |                     |
|         | D3  | FCTM32 | Clock timer 32 Hz interrupt factor flag     |                                |                                    | 0        | R/(W) |                     |   |                     |
|         | D2  | FLCD   | LCD controller interrupt factor flag        | (W)                            | (W)                                | 0        | R/(W) |                     |   |                     |
|         | D1  | -      | -                                           | Reset                          | Invalid                            | -        | -     | "0" when being read |   |                     |
|         | D0  | -      | -                                           | -                              | -                                  | -        | -     |                     |   |                     |
| 00FF50  | D7  | -      | -                                           | -                              | -                                  | -        | -     | "0" when being read |   |                     |
|         | D6  | -      | -                                           | -                              | -                                  | -        | -     |                     |   |                     |
|         | D5  | -      | -                                           | -                              | -                                  | -        | -     |                     |   |                     |
|         | D4  | -      | -                                           | -                              | -                                  | -        | -     |                     |   |                     |
|         | D3  | -      | -                                           | -                              | -                                  | -        | -     |                     |   |                     |
|         | D2  | -      | -                                           | -                              | -                                  | -        | -     |                     |   |                     |
|         | D1  | TMRST  | Clock timer reset                           | Reset                          | Invalid                            | -        | W     |                     |   |                     |
|         | D0  | TMRUN  | Clock timer RUN/STOP                        | Run                            | Stop                               | 0        | R/W   |                     |   |                     |
| 00FF51  | D7  | TMD7   | Clock timer data 1 Hz                       | High                           | Low                                | 0        | R     |                     |   |                     |
|         | D6  | TMD6   | Clock timer data 2 Hz                       |                                |                                    | 0        | R     |                     |   |                     |
|         | D5  | TMD5   | Clock timer data 4 Hz                       |                                |                                    | 0        | R     |                     |   |                     |
|         | D4  | TMD4   | Clock timer data 8 Hz                       |                                |                                    | 0        | R     |                     |   |                     |
|         | D3  | TMD3   | Clock timer data 16 Hz                      |                                |                                    | 0        | R     |                     |   |                     |
|         | D2  | TMD2   | Clock timer data 32 Hz                      |                                |                                    | 0        | R     |                     |   |                     |
|         | D1  | TMD1   | Clock timer data 64 Hz                      |                                |                                    | 0        | R     |                     |   |                     |
|         | D0  | TMD0   | Clock timer data 128 Hz                     |                                |                                    | 0        | R     |                     |   |                     |
| 00FF52  | D7  | -      | -                                           | -                              | -                                  | -        | -     | "0" when being read |   |                     |
|         | D6  | TMMD6  | Clock timer data 10 sec (BCD)               |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D5  | TMMD5  |                                             |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D4  | TMMD4  |                                             |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D3  | TMMD3  | Clock timer data 1 sec (BCD)                |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D2  | TMMD2  |                                             |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D1  | TMMD1  |                                             |                                |                                    | 0        | R/W   |                     |   |                     |
|         | D0  | TMMD0  |                                             |                                |                                    | 0        | R/W   |                     |   |                     |

**TMD0–TMD7: Clock timer data (00FF51H)**

The clock timer data (128 Hz–1 Hz) can be read. Correspondence between TMD bit and frequency is as follows:

|              |            |
|--------------|------------|
| TMD0: 128 Hz | TMD4: 8 Hz |
| TMD1: 64 Hz  | TMD5: 4 Hz |
| TMD2: 32 Hz  | TMD6: 2 Hz |
| TMD3: 16 Hz  | TMD7: 1 Hz |

Since TMD is read only, the writing operation is invalid.

At initial reset, the timer data is set to "00H".

**TMMD0–TMMD6: 60-second counter data (00FF52H•D0–D6)**

The 60-second counter data can be read. Correspondence between TMMD bit and data is as follows:

|              |                 |
|--------------|-----------------|
| TMMD6–TMMD4: | 10 sec BCD data |
| TMMD3–TMMD0: | 1 sec BCD data  |

When data is written to the TMMD register, it is preset to the 60-second counter. At the same time, the timer for 128 Hz to 1 Hz is also reset.

The counter is preset only when data is written to the TMMD register. The register does not maintain the preset data and returns to 0-second when the counter overflows.

To prevent the counter from abnormal operation, do not preset data without a range of 0 to 59 (BCD).

At initial reset, the counter data is set to "0".

**TMRST: Clock timer reset (00FF50H•D1)**

Resets the clock timer.

When "1" is written: Clock timer reset

When "0" is written: No operation

Reading: Always "0"

The clock timer TMD and the 60S counter TMMD are reset by writing "1" to TMRST. When the clock timer is reset in RUN status, it restarts immediately after resetting. In the case of STOP status, the reset data "00H" is maintained.

No operation results when "0" is written to TMRST. TMRST is write only, and so it is always "0" at reading.

**TMRUN: Clock timer RUN/STOP control register (00FF50H•D0)**

Controls RUN/STOP of the clock timer.

When "1" is written: RUN

When "0" is written: STOP

Reading: Valid

The clock timer starts counting by writing "1" to the TMRUN register and stops by writing "0".

In STOP status, the count data is maintained until the timer is reset or is set in the next RUN status. Also, when STOP status changes to RUN status, the data that was maintained can be used for resuming the count.

At initial reset, the TMRUN register is set to "0" (STOP).

**PCTM0, PCTM1: Clock timer interrupt priority register (00FF21H•D2, D3)**

Sets the priority level of the clock timer interrupt. The PCTM register is the interrupt priority register corresponding to the clock timer interrupt. Table 5.11.3.2 shows the interrupt priority level which can be set by this register.

Table 5.11.3.2 Interrupt priority level settings

| PCTM1 | PCTM0 | Interrupt priority level              |
|-------|-------|---------------------------------------|
| 1     | 1     | Level 3 ( $\overline{\text{IRQ}}_3$ ) |
| 1     | 0     | Level 2 ( $\overline{\text{IRQ}}_2$ ) |
| 0     | 1     | Level 1 ( $\overline{\text{IRQ}}_1$ ) |
| 0     | 0     | Level 0 (None)                        |

At initial reset, the PCTM register is set to "0" (level 0).

**ECTM32: Clock timer 32 Hz interrupt enable register (00FF25H•D3)****ECTM8: Clock timer 8 Hz interrupt enable register (00FF25H•D4)****ECTM2: Clock timer 2 Hz interrupt enable register (00FF25H•D5)****ECTM1: Clock timer 1 Hz interrupt enable register (00FF25H•D6)****ET60S: Clock timer 60S interrupt enable register (00FF25H•D7)**

Enables or disables the interrupt generation to the CPU.

When "1" is written: Interrupt is enabled

When "0" is written: Interrupt is disabled

Reading: Valid

ECTM32, ECTM8, ECTM2, ECTM1 and ET60S are the interrupt enable registers corresponding to 32 Hz, 8 Hz, 2 Hz, 1 Hz and 60S interrupt factors. Interrupt of the frequency in which the ECTM register is set to "1" is enabled, and the others in which the ECTM register is set to "0" are disabled. At initial reset, the interrupt enable registers are all set to "0" (interrupt is disabled).

- FCTM32: Clock timer 32 Hz interrupt factor flag (00FF29H•D3)**
- FCTM8: Clock timer 8 Hz interrupt factor flag (00FF29H•D4)**
- FCTM2: Clock timer 2 Hz interrupt factor flag (00FF29H•D5)**
- FCTM1: Clock timer 1 Hz interrupt factor flag (00FF29H•D6)**
- FT60S: Clock timer 60S interrupt factor flag (00FF29H•D7)**

Indicates the generation of clock timer interrupt factor.

- When "1" is read: Int. factor has generated
- When "0" is read: Int. factor has not generated

- When "1" is written: Factor flag is reset
- When "0" is written: Invalid

FCTM32, FCTM8, FCTM2 and FCTM1 are the interrupt factor flags corresponding to the 32 Hz, 8 Hz, 2 Hz and 1 Hz interrupt, and are set to "1" at the falling edge of the respective signals. FT60S is the interrupt factor flag corresponding to the 60S interrupt and is set to "1" due to an overflow of the 60-second counter.

At this point, if the corresponding interrupt enable register is set to "1" and the corresponding interrupt priority register is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.

Regardless of the interrupt enable register and interrupt priority register settings, the interrupt factor flag is set to "1" when the interrupt generation condition is met.

To accept the subsequent interrupt after an interrupt generation, it is necessary to re-set the interrupt flags (set the interrupt flag to a lower level than the level indicated by the interrupt priority registers, or execute the RETE instruction) and to reset the interrupt factor flag. The interrupt factor flag is reset to "0" by writing "1".

At initial reset, the interrupt factor flags are all reset to "0".

### 5.11.4 Programming notes

- (1) The clock timer actually enters into RUN or STOP status at the falling edge of the 256 Hz signal after writing to the TMRUN register. Consequently, when "0" is written to TMRUN, the timer stops after counting once more (+1). TMRUN is read as "1" until the timer actually stops.

Figure 5.11.4.1 shows the timing chart at the RUN/STOP control.

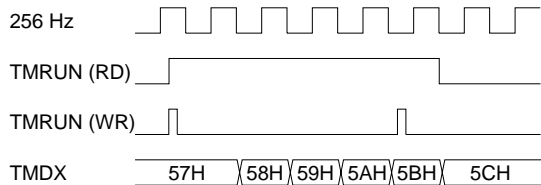


Fig. 5.11.4.1 Timing chart at RUN/STOP control

- (2) The 60-second counter is preset only when data is written to the TMMD register. The register does not maintain the preset data and returns to 0-second when the counter overflows. To prevent the counter from abnormal operation, do not preset data without a range of 0 to 59 (BCD).

## 5.12 16-bit Programmable Timer

### 5.12.1 Configuration of 16-bit programmable timer

The S1C88409 has a 16-bit programmable timer built-in. The timer consists of a 16-bit presetable down counter, and can be used as 16-bit  $\times$  1 channel or 8-bit  $\times$  2 channels of programmable timer. Furthermore, they function as event counters using the input port terminal.

Figure 5.12.1.1 shows the configuration of the 16-bit programmable timer.

Two 8-bit down counters, two reload data registers (RDR0, RDR1) and the compare data registers (CDR0, CDR1) corresponding to each down counter are arranged in the 16-bit programmable timer.

The reload data register is used to set an initial value to the down counter.

The compare data register stores data for comparison with the content of the down counter.

By setting these registers, a TOUT signal is generated, and it can be output to external devices.

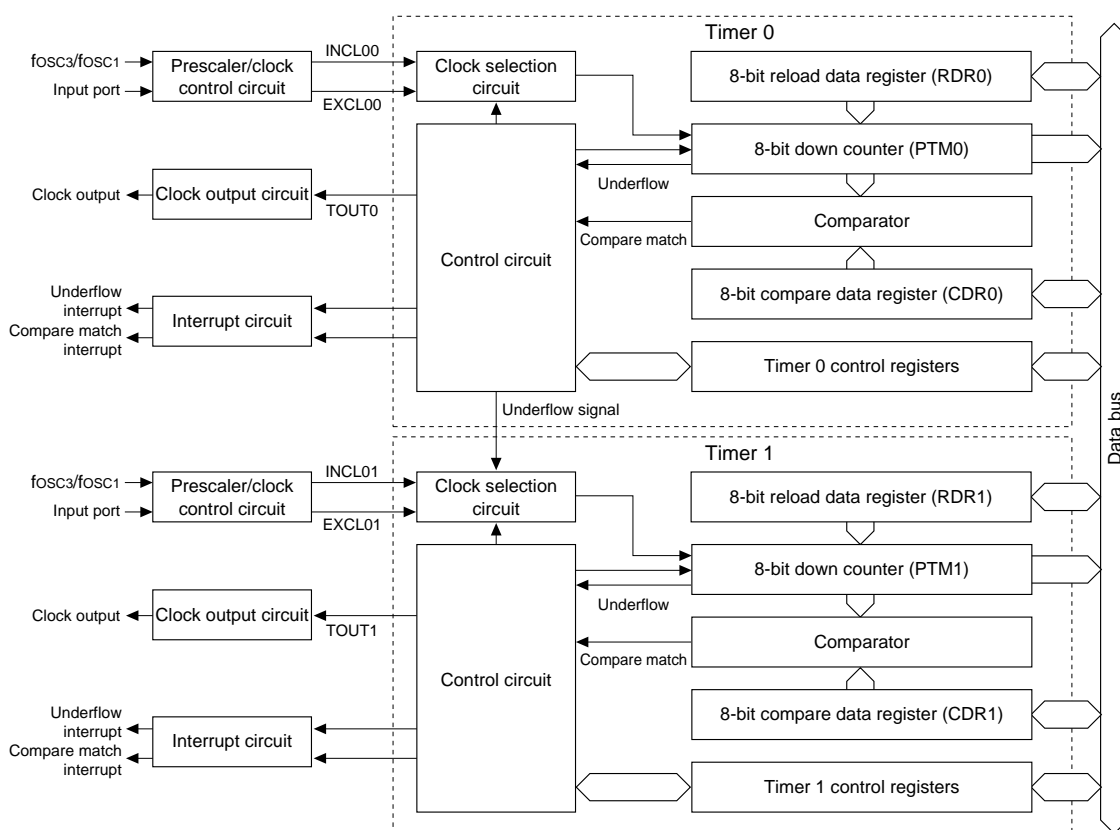


Fig. 5.12.1.1 Configuration of 16-bit programmable timer

### 5.12.2 Operation mode

The 16-bit programmable timer can be used as two channels of 8-bit timers or one channel of 16-bit timer. Two kinds of operation modes are provided corresponding to this configuration, and it can be selected by the 8-/16-bit mode selection register MODE16.

MODE16 register = "0": 8-bit mode  
(8 bits × 2 channels)

MODE16 register = "1": 16-bit mode  
(16 bits × 1 channel)

In the 8-bit mode, Timer 0 and Timer 1 can be controlled individually.

In the 16-bit mode, the underflow signal of Timer 0 is used as the input clock of Timer 1 so that the down counters operate as a 16-bit counter.

The timer in the 16-bit mode is controlled with the control registers for Timer 0 except for the clock output.

Figure 5.12.2.1 shows the timer configuration depending on the operation mode and Table 5.12.2.1 shows the configuration of the control registers.

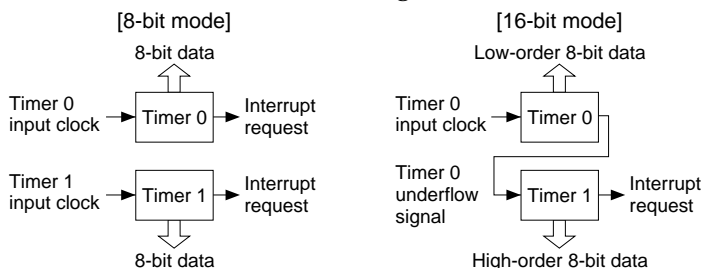


Fig. 5.12.2.1 Counter configuration in 8- and 16-bit mode

Table 5.12.2.1(a) Control registers in 8-bit mode

| Address | Bit | Name   | Function                            | 1              | 0              | Init | R/W | Comment             |
|---------|-----|--------|-------------------------------------|----------------|----------------|------|-----|---------------------|
| 00FF30  | D7  | MODE16 | 16-bit PTM 8-/16-bit mode selection | 16-bit         | 8-bit × 2      | 0    | R/W |                     |
|         | D6  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D5  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D4  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D3  | PTOUT0 | 16-bit PTM0 clock output control    | On             | Off            | 0    | R/W |                     |
|         | D2  | PTRUN0 | 16-bit PTM0 RUN/STOP control        | Run            | Stop           | 0    | R/W |                     |
|         | D1  | PSET0  | 16-bit PTM0 preset                  | Preset         | Invalid        | 0    | W   | "0" when being read |
|         | D0  | CKSEL0 | 16-bit PTM0 input clock selection   | External clock | Internal clock | 0    | R/W |                     |
| 00FF31  | D7  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D6  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D5  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D4  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D3  | PTOUT1 | 16-bit PTM1 clock output control    | On             | Off            | 0    | R/W |                     |
|         | D2  | PTRUN1 | 16-bit PTM1 RUN/STOP control        | Run            | Stop           | 0    | R/W |                     |
|         | D1  | PSET1  | 16-bit PTM1 preset                  | Preset         | Invalid        | 0    | W   | "0" when being read |
|         | D0  | CKSEL1 | 16-bit PTM1 input clock selection   | External clock | Internal clock | 0    | R/W |                     |

Table 5.12.2.1(b) Control registers in 16-bit mode

| Address | Bit | Name   | Function                            | 1              | 0              | Init | R/W | Comment             |
|---------|-----|--------|-------------------------------------|----------------|----------------|------|-----|---------------------|
| 00FF30  | D7  | MODE16 | 16-bit PTM 8-/16-bit mode selection | 16-bit         | 8-bit × 2      | 0    | R/W |                     |
|         | D6  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D5  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D4  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D3  | PTOUT0 | Invalid (fixed at "0")              | Invalid        | Fixed at "0"   | 0    | R/W |                     |
|         | D2  | PTRUN0 | 16-bit PTM RUN/STOP control         | Run            | Stop           | 0    | R/W |                     |
|         | D1  | PSET0  | 16-bit PTM preset                   | Preset         | Invalid        | 0    | W   | "0" when being read |
|         | D0  | CKSEL0 | 16-bit PTM input clock selection    | External clock | Internal clock | 0    | R/W |                     |
| 00FF31  | D7  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D6  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D5  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D4  | -      | -                                   | -              | -              | -    | -   | "0" when being read |
|         | D3  | PTOUT1 | 16-bit PTM clock output control     | On             | Off            | 0    | R/W |                     |
|         | D2  | PTRUN1 | Invalid (fixed at "0")              | Invalid        | Fixed at "0"   | 0    | R/W |                     |
|         | D1  | PSET1  | Invalid (fixed at "0")              | Invalid        | Fixed at "0"   | 0    | W   | "0" when being read |
|         | D0  | CKSEL1 | Invalid (fixed at "0")              | Invalid        | Fixed at "0"   | 0    | R/W |                     |



### 5.12.3 Setting of input clock

The clock to be input to the counter can be selected from either the internal clock or external clock by the input clock selection register (CKSEL) provided for each timer. The internal clock is an output of the prescaler. The external clock is used for the event counter function. A signal from the input port is used as the count clock.

Table 5.12.3.1 shows the input clock selection register and input clock of each timer.

Table 5.12.3.1 Input clock selection

| Timer   | Register setting | Input clock        |
|---------|------------------|--------------------|
| Timer 0 | CKSEL0 = "0"     | INCL00 (Prescaler) |
|         | CKSEL0 = "1"     | EXCL00 (K10 input) |
| Timer 1 | CKSEL1 = "0"     | INCL01 (Prescaler) |
|         | CKSEL1 = "1"     | EXCL01 (K11 input) |

When the internal clock is used, the clock frequency is set by selecting a source clock and a division ratio of the prescaler.

When the external clock is selected, a signal from the input port is directly input to the programmable timer.

However, it is necessary to control the output from the clock control circuit and to input the internal clock and external clock to the timers.

Refer to Section 5.5, "Prescaler and Clock Control Circuit for Peripheral Circuits", for selection of the division ratio and clock output control.

When the 16-bit mode is selected, the programmable timer operates with the clock input to Timer 0, and Timer 1 inputs the Timer 0 underflow signal as the clock. Therefore, the setting of Timer 1 input clock is invalid.

### 5.12.4 Operation and control of timer

#### Reload data register and setting of initial value

The reload data register (RDR) is used to set an initial value of the down counter.

In the 8-bit mode, it is used as two 8-bit registers RDR0 (Timer 0) and RDR1 (Timer 1) separate for each timer.

In the 16-bit mode, the RDR0 register is handled as low-order 8 bits of reload data, and the RDR1 register is as high-order 8 bits.

The reload data register can be read and written, and both the RDR0 and RDR1 registers are set to FFH at initial reset.

Data written in this register is loaded into the down counter, and a down counting starts from the value.

The preset to down counter is done in the following two cases:

#### 1) When software presets

The software preset can be done using the preset control bits PSET0 (Timer 0) and PSET1 (Timer 1). When the preset control bit is set to "1", the content of the reload data register is loaded into the down counter at that point. In the 16-bit mode, a 16-bit reload data is loaded all at one time by setting PSET0. In this case, writing to PSET1 is invalid.

#### 2) When down counter has underflowed during a count

Since the down counter presets the reload data by the underflow, the underflow period is decided according to the value set in the reload data register. This underflow generates an interrupt, and controls the clock (TOUT signal) output.

**Compare data register**

The programmable timer has a built-in data comparator so that count data can be compared with an optional value. The compare data register (CDR) is used to set the value to be compared.

In the 8-bit mode, it is used as two 8-bit registers CDR0 (Timer 0) and CDR1 (Timer 1) separate for each timer.

In the 16-bit mode, the CDR0 register is handled as low-order 8 bits of compare data, and the CDR1 register is as high-order 8 bits.

The compare data register can be read and written, and both the CDR0 and CDR1 registers are set to 00H at initial reset.

The programmable timer compares count data with the compare data register (CDR), and generates a compare match signal when they become the same value. This compare match signal generates an interrupt, and controls the clock (TOUT signal) output.

**Timer operation**

Timer 0 and Timer 1 are equipped with PTRUN0 (Timer 0) and PTRUN1 (Timer 1) registers which control the RUN/STOP of the timer. The programmable timer starts down counting by writing "1" to the PTRUN register. However, it is necessary to control the input clock and to preset the reload data before starting a count.

When "0" is written to PTRUN register, clock input is prohibited, and the count stops.

This RUN/STOP control does not affect data in the counter. The data in the counter is maintained during count deactivation, so it is possible to resume counting from the data.

In the 8-bit mode, the channels can be controlled individually by the PTRUN0 register and the PTRUN1 register.

In the 16-bit mode, the PTRUN0 register controls both channels as a 16-bit timer. In this case, control of the PTRUN1 register is invalid.

The buffers PTM0 (Timer 0) and PTM1 (Timer 1) are attached to the counter, and reading is possible in optional timing.

When the counter agrees with the data set in the compare data register during down counting, the timer generates a compare match interrupt.

And, when the counter underflows, an underflow interrupt is generated, and the initial value set in the reload data register is loaded to the counter. The interrupt generated does not stop the down counting.

After an underflow interrupt is generated, the counter continues counting from the initial value reloaded.

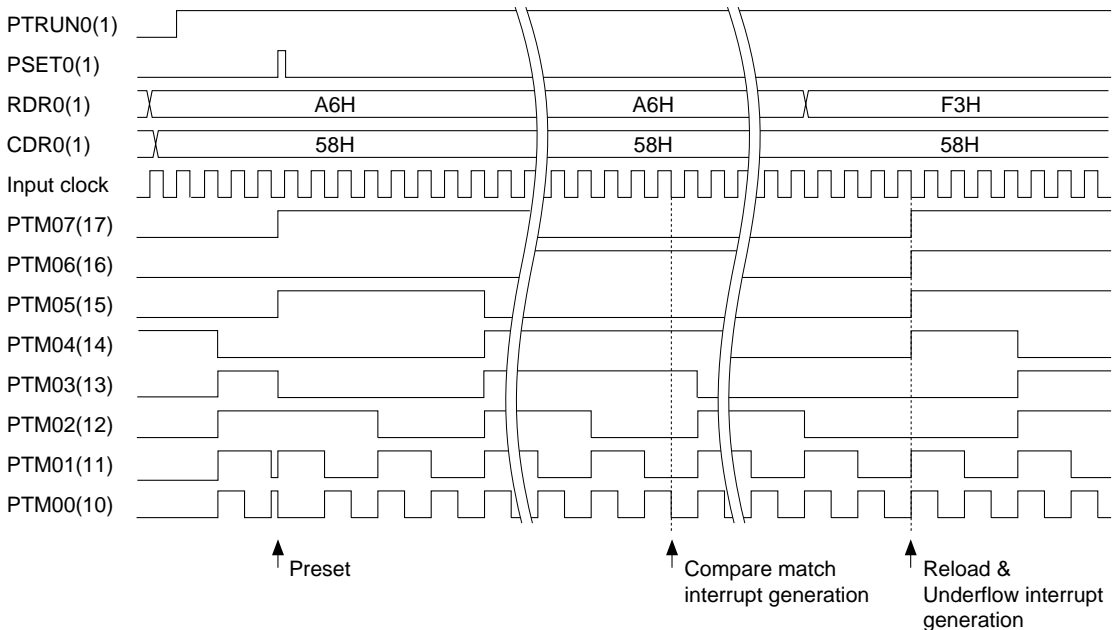


Fig. 5.12.4.1 Basic operation timing of counter (an example of 8-bit mode)

### 5.12.5 Interrupt function

The 16-bit programmable timer can generate an interrupt with the compare match signal and underflow signal of each timer.

Figure 5.12.5.1 shows the configuration of the 16-bit programmable timer interrupt circuit.

The compare match signal and underflow signal of each timer set the corresponding interrupt factor flag to "1". At that point, the interrupt is generated. The interrupt can also be prohibited by setting the interrupt enable register to correspond with the interrupt factor flag.

Furthermore, the priority level of the interrupt for the CPU can be set to an optional level (0–3) using the interrupt priority register.

Table 5.12.5.1 shows the interrupt factor flags, interrupt enable registers and interrupt priority registers corresponding to the interrupt factors.

In the 8-bit mode, the compare match interrupt factor flag and underflow interrupt factor flag are individually set to "1" by the timers.

In the 16-bit mode, the interrupt factor flags of Timer 1 are set to "1" by the compare match and underflow of 16 bits.

Refer to Section 5.20, "Interrupt and Standby Mode", for details of the interrupt control registers and operations subsequent to interrupt generation.

The exception processing vector addresses for the 16-bit programmable timer interrupt are set as follows:

- Timer 0 underflow interrupt: 000010H
- Timer 0 compare match interrupt: 000012H
- Timer 1 underflow interrupt: 000014H
- Timer 1 compare match interrupt: 000016H

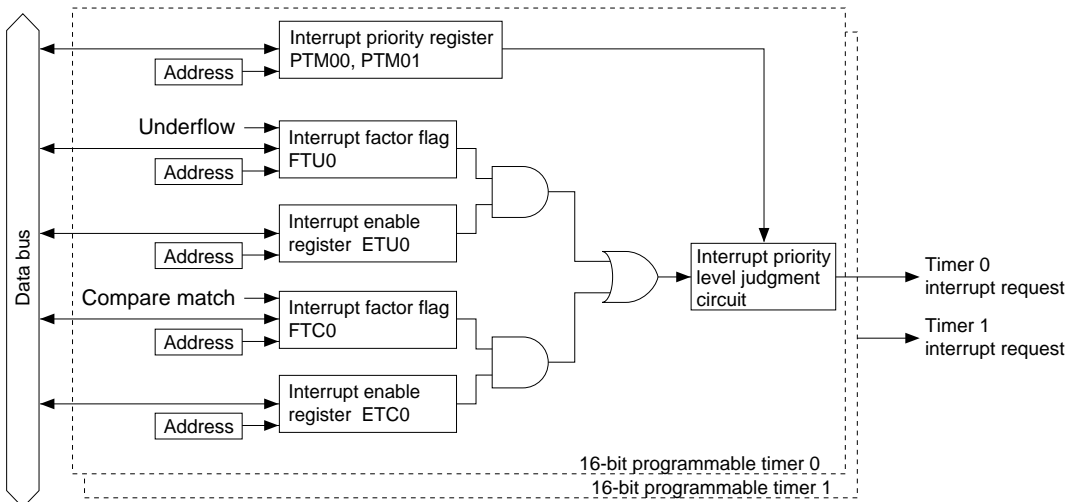


Fig. 5.12.5.1 Configuration of 16-bit programmable timer interrupt circuit

Table 5.12.5.1 Interrupt control registers

| Interrupt factor            |                                                              | Interrupt factor flag |            | Interrupt enable register |            | Interrupt priority register |            |
|-----------------------------|--------------------------------------------------------------|-----------------------|------------|---------------------------|------------|-----------------------------|------------|
|                             |                                                              | Name                  | Address-Dx | Name                      | Address-Dx | Name                        | Address-Dx |
| 16-bit programmable timer 0 | Counter underflow                                            | FTU0                  | 00FF28H-D3 | ETU0                      | 00FF24H-D3 | PTM00                       | 00FF20H-D0 |
|                             | Compare match between counter and compare data register CDR0 | FTC0                  | 00FF28H-D4 | ETC0                      | 00FF24H-D4 | PTM01                       | 00FF20H-D1 |
| 16-bit programmable timer 1 | Counter underflow                                            | FTU1                  | 00FF28H-D5 | ETU1                      | 00FF24H-D5 | PTM10                       | 00FF20H-D2 |
|                             | Compare match between counter and compare data register CDR1 | FTC1                  | 00FF28H-D6 | ETC1                      | 00FF24H-D6 | PTM11                       | 00FF20H-D3 |

**5.12.6 Setting of TOUT output**

The 16-bit programmable timer can generate TOUT signals with the underflow and compare match signals of Timer 0 and Timer 1. The TOUT signal generated in the 16-bit programmable timer can be output from the output port terminal shown in Table 5.12.6.1 so that a programmable clock can be supplied for external devices.

*Table 5.12.6.1 TOUT output terminal*

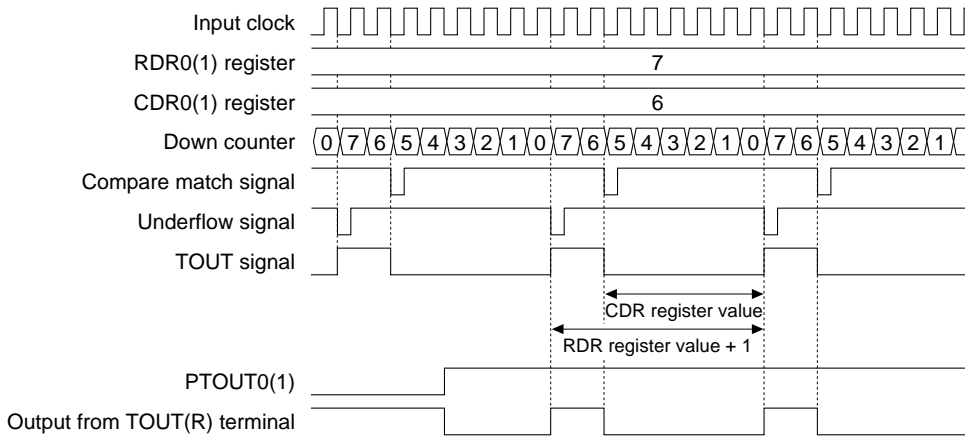
| Timer   | Output clock name | Output terminal |
|---------|-------------------|-----------------|
| Timer 0 | TOUT0             | R40             |
| Timer 1 | TOUT1             | R41             |

The TOUT signal rises at the falling edge of the underflow signal and falls at the falling edge of the compare match signal. Therefore, it is possible to change the frequency and duty ratio of the TOUT signal by setting the reload data register (RDR) and compare data register (CDR). However, it needs a condition setting:  $RDR > CDR$ ,  $CDR \neq 0$ . In the case of  $RDR \leq CDR$ , TOUT signal is fixed at "1".

The TOUT output can be controlled by the TOUT output control register of each timer (Timer 0: PTOUT0, Timer 1: PTOUT1).

In the 16-bit mode, the output is controlled by the control register PTOUT1 for Timer 1. The clock is output from Timer 1.

Figure 5.12.6.1 shows the output waveform of TOUT signal.



*Fig. 5.12.6.1 Output waveform of TOUT signal*

Refer to Section 5.9, "Clock Output", for output control of TOUT signal to the outside.

### 5.12.7 I/O memory of 16-bit programmable timer

Table 5.12.7.1 shows the 16-bit programmable timer control bits.

Table 5.12.7.1(a) 16-bit programmable timer control bits

| Address                        | Bit   | Name                       | Function                                                            | 1                    | 0                     | Init     | R/W | Comment             |
|--------------------------------|-------|----------------------------|---------------------------------------------------------------------|----------------------|-----------------------|----------|-----|---------------------|
| 00FF10                         | D7    | PRPRT1                     | 16-bit programmable timer 1 clock control                           | On                   | Off                   | 0        | R/W |                     |
|                                | D6    | PST12                      | 16-bit programmable timer 1 division ratio                          |                      |                       | 0        | R/W |                     |
|                                |       |                            | PST12 PST11 PST10 (OSC3) (OSC1)                                     |                      |                       |          |     |                     |
|                                |       |                            | 1 1 1 fosc3 / 4096 fosc1 / 128                                      |                      |                       |          |     |                     |
|                                |       |                            | 1 1 0 fosc3 / 1024 fosc1 / 64                                       |                      |                       |          |     |                     |
|                                |       |                            | 1 0 1 fosc3 / 256 fosc1 / 32                                        |                      |                       |          |     |                     |
|                                |       |                            | 1 0 0 fosc3 / 128 fosc1 / 16                                        |                      |                       |          |     |                     |
|                                | D5    | PST11                      | 0 1 1 fosc3 / 64 fosc1 / 8                                          |                      |                       | 0        | R/W |                     |
|                                |       |                            | 0 1 0 fosc3 / 32 fosc1 / 4                                          |                      |                       |          |     |                     |
|                                |       |                            | 0 0 1 fosc3 / 8 fosc1 / 2                                           |                      |                       |          |     |                     |
|                                |       |                            | 0 0 0 fosc3 / 2 fosc1 / 1                                           |                      |                       |          |     |                     |
|                                | D3    | PRPRT0                     | 16-bit programmable timer 0 clock control                           | On                   | Off                   | 0        | R/W |                     |
|                                | D2    | PST02                      | 16-bit programmable timer 0 division ratio                          |                      |                       | 0        | R/W |                     |
|                                |       |                            | PST02 PST01 PST00 (OSC3) (OSC1)                                     |                      |                       |          |     |                     |
| 1 1 1 fosc3 / 4096 fosc1 / 128 |       |                            |                                                                     |                      |                       |          |     |                     |
| 1 1 0 fosc3 / 1024 fosc1 / 64  |       |                            |                                                                     |                      |                       |          |     |                     |
| 1 0 1 fosc3 / 256 fosc1 / 32   |       |                            |                                                                     |                      |                       |          |     |                     |
| 1 0 0 fosc3 / 128 fosc1 / 16   |       |                            |                                                                     |                      |                       |          |     |                     |
| D1                             | PST01 | 0 1 1 fosc3 / 64 fosc1 / 8 |                                                                     |                      | 0                     | R/W      |     |                     |
|                                |       | 0 1 0 fosc3 / 32 fosc1 / 4 |                                                                     |                      |                       |          |     |                     |
|                                |       | 0 0 1 fosc3 / 8 fosc1 / 2  |                                                                     |                      |                       |          |     |                     |
|                                |       | 0 0 0 fosc3 / 2 fosc1 / 1  |                                                                     |                      |                       |          |     |                     |
| 00FF12                         | D7    | –                          | –                                                                   | –                    | –                     | –        | –   | "0" when being read |
|                                | D6    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D5    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D4    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D3    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D2    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D1    | PRTF1                      | 16-bit programmable timer 1 source clock selection                  | fosc1                | fosc3                 | 0        | R/W |                     |
|                                | D0    | PRTF0                      | 16-bit programmable timer 0 source clock selection                  | fosc1                | fosc3                 | 0        | R/W |                     |
| 00FF15                         | D7    | –                          | –                                                                   | –                    | –                     | –        | –   | "0" when being read |
|                                | D6    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D5    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D4    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D3    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D2    | –                          | –                                                                   | –                    | –                     | –        | –   |                     |
|                                | D1    | PK11ON                     | EXCL01 input clock ON/OFF control                                   | On                   | Off                   | 0        | R/W |                     |
|                                | D0    | PK10ON                     | EXCL00 input clock ON/OFF control                                   | On                   | Off                   | 0        | R/W |                     |
| 00FF20                         | D7    | PK11                       | K10–K13                                                             | PK11                 | PK10                  | 0        | R/W |                     |
|                                | D6    | PK10                       | interrupt priority register                                         | PK01                 | PK00                  | 0        | R/W |                     |
|                                | D5    | PK01                       | K00–K07                                                             | PTM11                | PTM10                 | Priority | 0   | R/W                 |
|                                | D4    | PK00                       | interrupt priority register                                         | PTM01                | PTM00                 | level    | 0   | R/W                 |
|                                | D3    | PTM11                      | 16-bit programmable timer 1                                         | 1                    | 1                     | Level 3  | 0   | R/W                 |
|                                | D2    | PTM10                      | interrupt priority register                                         | 1                    | 0                     | Level 2  | 0   | R/W                 |
|                                | D1    | PTM01                      | 16-bit programmable timer 0                                         | 0                    | 1                     | Level 1  | 0   | R/W                 |
|                                | D0    | PTM00                      | interrupt priority register                                         | 0                    | 0                     | Level 0  | 0   | R/W                 |
| 00FF24                         | D7    | ETU2                       | 8-bit programmable timer underflow interrupt enable register        | Interrupt is enabled | Interrupt is disabled | 0        | R/W |                     |
|                                | D6    | ETC1                       | 16-bit programmable timer 1 compare match interrupt enable register |                      |                       | 0        | R/W |                     |
|                                | D5    | ETU1                       | 16-bit programmable timer 1 underflow interrupt enable register     |                      |                       | 0        | R/W |                     |
|                                | D4    | ETC0                       | 16-bit programmable timer 0 compare match interrupt enable register |                      |                       | 0        | R/W |                     |
|                                | D3    | ETU0                       | 16-bit programmable timer 0 underflow interrupt enable register     |                      |                       | 0        | R/W |                     |
|                                | D2    | ESTX                       | Serial interface transmit completion interrupt enable register      |                      |                       | 0        | R/W |                     |
|                                | D1    | ESRX                       | Serial interface receive completion interrupt enable register       |                      |                       | 0        | R/W |                     |
|                                | D0    | ESERR                      | Serial interface receive error interrupt enable register            |                      |                       | 0        | R/W |                     |

Table 5.12.7.1(b) 16-bit programmable timer control bits

| Address | Bit | Name   | Function                                                        | 1                                     | 0                                         | Init | R/W   | Comment                               |
|---------|-----|--------|-----------------------------------------------------------------|---------------------------------------|-------------------------------------------|------|-------|---------------------------------------|
| 00FF28  | D7  | FTU2   | 8-bit programmable timer underflow interrupt factor flag        | (R)<br>Interrupt factor has generated | (R)<br>Interrupt factor has not generated | 0    | R/(W) |                                       |
|         | D6  | FTC1   | 16-bit programmable timer 1 compare match interrupt factor flag |                                       |                                           | 0    | R/(W) |                                       |
|         | D5  | FTU1   | 16-bit programmable timer 1 underflow interrupt factor flag     |                                       |                                           | 0    | R/(W) |                                       |
|         | D4  | FTC0   | 16-bit programmable timer 0 compare match interrupt factor flag |                                       |                                           | 0    | R/(W) |                                       |
|         | D3  | FTU0   | 16-bit programmable timer 0 underflow interrupt factor flag     | (W)<br>Reset                          | (W)<br>Invalid                            | 0    | R/(W) |                                       |
|         | D2  | FSTX   | Serial interface transmit completion interrupt factor flag      |                                       |                                           | 0    | R/(W) |                                       |
|         | D1  | FSRX   | Serial interface receive completion interrupt factor flag       |                                       |                                           | 0    | R/(W) |                                       |
|         | D0  | FSERR  | Serial interface receive error interrupt factor flag            |                                       |                                           | 0    | R/(W) |                                       |
| 00FF30  | D7  | MODE16 | 16-bit PTM 8-/16-bit mode selection                             | 16-bit                                | 8-bit × 2                                 | 0    | R/W   |                                       |
|         | D6  | –      | –                                                               | –                                     | –                                         | –    | –     | "0" when being read                   |
|         | D5  | –      | –                                                               | –                                     | –                                         | –    | –     |                                       |
|         | D4  | –      | –                                                               | –                                     | –                                         | –    | –     |                                       |
|         | D3  | PTOUT0 | 16-bit PTM0 clock output control                                | On                                    | Off                                       | 0    | R/W   |                                       |
|         | D2  | PTRUN0 | 16-bit PTM0 RUN/STOP control                                    | Run                                   | Stop                                      | 0    | R/W   |                                       |
|         | D1  | PSET0  | 16-bit PTM0 preset                                              | Preset                                | Invalid                                   | 0    | W     | "0" when being read                   |
|         | D0  | CKSEL0 | 16-bit PTM0 input clock selection                               | External clock                        | Internal clock                            | 0    | R/W   |                                       |
| 00FF31  | D7  | –      | –                                                               | –                                     | –                                         | –    | –     | "0" when being read                   |
|         | D6  | –      | –                                                               | –                                     | –                                         | –    | –     |                                       |
|         | D5  | –      | –                                                               | –                                     | –                                         | –    | –     |                                       |
|         | D4  | –      | –                                                               | –                                     | –                                         | –    | –     |                                       |
|         | D3  | PTOUT1 | 16-bit PTM1 clock output control                                | On                                    | Off                                       | 0    | R/W   |                                       |
|         | D2  | PTRUN1 | 16-bit PTM1 RUN/STOP control                                    | Run                                   | Stop                                      | 0    | R/W   |                                       |
|         | D1  | PSET1  | 16-bit PTM1 preset                                              | Preset                                | Invalid                                   | 0    | W     | "0" when being read                   |
|         | D0  | CKSEL1 | 16-bit PTM1 input clock selection                               | External clock                        | Internal clock                            | 0    | R/W   |                                       |
| 00FF32  | D7  | RDR07  | 16-bit programmable timer 0 reload data register                | D7(MSB)                               |                                           | 1    | R/W   | Low-order 8 bits data in 16-bit mode  |
|         | D6  | RDR06  |                                                                 | D6                                    | 1                                         | R/W  |       |                                       |
|         | D5  | RDR05  |                                                                 | D5                                    | 1                                         | R/W  |       |                                       |
|         | D4  | RDR04  |                                                                 | D4                                    | 1                                         | R/W  |       |                                       |
|         | D3  | RDR03  |                                                                 | D3                                    | 1                                         | R/W  |       |                                       |
|         | D2  | RDR02  |                                                                 | D2                                    | 1                                         | R/W  |       |                                       |
|         | D1  | RDR01  |                                                                 | D1                                    | 1                                         | R/W  |       |                                       |
|         | D0  | RDR00  |                                                                 | D0(LSB)                               | 1                                         | R/W  |       |                                       |
| 00FF33  | D7  | RDR17  | 16-bit programmable timer 1 reload data register                | D7(MSB)                               |                                           | 1    | R/W   | High-order 8 bits data in 16-bit mode |
|         | D6  | RDR16  |                                                                 | D6                                    | 1                                         | R/W  |       |                                       |
|         | D5  | RDR15  |                                                                 | D5                                    | 1                                         | R/W  |       |                                       |
|         | D4  | RDR14  |                                                                 | D4                                    | 1                                         | R/W  |       |                                       |
|         | D3  | RDR13  |                                                                 | D3                                    | 1                                         | R/W  |       |                                       |
|         | D2  | RDR12  |                                                                 | D2                                    | 1                                         | R/W  |       |                                       |
|         | D1  | RDR11  |                                                                 | D1                                    | 1                                         | R/W  |       |                                       |
|         | D0  | RDR10  |                                                                 | D0(LSB)                               | 1                                         | R/W  |       |                                       |
| 00FF34  | D7  | CDR07  | 16-bit programmable timer 0 compare data register               | D7(MSB)                               |                                           | 0    | R/W   | Low-order 8 bits data in 16-bit mode  |
|         | D6  | CDR06  |                                                                 | D6                                    | 0                                         | R/W  |       |                                       |
|         | D5  | CDR05  |                                                                 | D5                                    | 0                                         | R/W  |       |                                       |
|         | D4  | CDR04  |                                                                 | D4                                    | 0                                         | R/W  |       |                                       |
|         | D3  | CDR03  |                                                                 | D3                                    | 0                                         | R/W  |       |                                       |
|         | D2  | CDR02  |                                                                 | D2                                    | 0                                         | R/W  |       |                                       |
|         | D1  | CDR01  |                                                                 | D1                                    | 0                                         | R/W  |       |                                       |
|         | D0  | CDR00  |                                                                 | D0(LSB)                               | 0                                         | R/W  |       |                                       |
| 00FF35  | D7  | CDR17  | 16-bit programmable timer 1 compare data register               | D7(MSB)                               |                                           | 0    | R/W   | High-order 8 bits data in 16-bit mode |
|         | D6  | CDR16  |                                                                 | D6                                    | 0                                         | R/W  |       |                                       |
|         | D5  | CDR15  |                                                                 | D5                                    | 0                                         | R/W  |       |                                       |
|         | D4  | CDR14  |                                                                 | D4                                    | 0                                         | R/W  |       |                                       |
|         | D3  | CDR13  |                                                                 | D3                                    | 0                                         | R/W  |       |                                       |
|         | D2  | CDR12  |                                                                 | D2                                    | 0                                         | R/W  |       |                                       |
|         | D1  | CDR11  |                                                                 | D1                                    | 0                                         | R/W  |       |                                       |
|         | D0  | CDR10  |                                                                 | D0(LSB)                               | 0                                         | R/W  |       |                                       |

Table 5.12.7.1(c) 16-bit programmable timer control bits

| Address | Bit   | Name                                | Function                                     | 1                 | 0                  | Init | R/W | Comment |                                          |
|---------|-------|-------------------------------------|----------------------------------------------|-------------------|--------------------|------|-----|---------|------------------------------------------|
| 00FF36  | D7    | PTM07                               | 16-bit programmable timer 0<br>data register | D7(MSB)           |                    |      | 1   | R       | Low-order 8 bits data<br>in 16-bit mode  |
|         | D6    | PTM06                               |                                              | D6                |                    |      | 1   | R       |                                          |
|         | D5    | PTM05                               |                                              | D5                |                    |      | 1   | R       |                                          |
|         | D4    | PTM04                               |                                              | D4                |                    |      | 1   | R       |                                          |
|         | D3    | PTM03                               |                                              | D3                |                    |      | 1   | R       |                                          |
|         | D2    | PTM02                               |                                              | D2                |                    |      | 1   | R       |                                          |
|         | D1    | PTM01                               |                                              | D1                |                    |      | 1   | R       |                                          |
|         | D0    | PTM00                               |                                              | D0(LSB)           |                    |      | 1   | R       |                                          |
| 00FF37  | D7    | PTM17                               | 16-bit programmable timer 1<br>data register | D7(MSB)           |                    |      | 1   | R       | High-order 8 bits data<br>in 16-bit mode |
|         | D6    | PTM16                               |                                              | D6                |                    |      | 1   | R       |                                          |
|         | D5    | PTM15                               |                                              | D5                |                    |      | 1   | R       |                                          |
|         | D4    | PTM14                               |                                              | D4                |                    |      | 1   | R       |                                          |
|         | D3    | PTM13                               |                                              | D3                |                    |      | 1   | R       |                                          |
|         | D2    | PTM12                               |                                              | D2                |                    |      | 1   | R       |                                          |
|         | D1    | PTM11                               |                                              | D1                |                    |      | 1   | R       |                                          |
|         | D0    | PTM10                               |                                              | D0(LSB)           |                    |      | 1   | R       |                                          |
| 00FFD4  | D7    | –                                   | –                                            | –                 | –                  | –    | –   | –       | "0" when being read                      |
|         | D6    | –                                   | –                                            | –                 | –                  | –    | –   | –       |                                          |
|         | D5    | –                                   | –                                            | –                 | –                  | –    | –   | –       |                                          |
|         | D4    | –                                   | –                                            | –                 | –                  | –    | –   | –       |                                          |
|         | D3    | –                                   | –                                            | –                 | –                  | –    | –   | –       |                                          |
|         | D2    | HZR42                               | R42 high impedance control register          | High<br>impedance | Comple-<br>mentary | 1    | R/W |         |                                          |
|         | D1    | HZR41                               | R41 high impedance control register          |                   |                    | 1    | R/W |         |                                          |
| D0      | HZR40 | R40 high impedance control register | 1                                            |                   |                    | R/W  |     |         |                                          |
| 00FFD9  | D7    | –                                   | –                                            | –                 | –                  | –    | –   | –       | "0" when being read                      |
|         | D6    | –                                   | –                                            | –                 | –                  | –    | –   | –       |                                          |
|         | D5    | –                                   | –                                            | –                 | –                  | –    | –   | –       |                                          |
|         | D4    | –                                   | –                                            | –                 | –                  | –    | –   | –       |                                          |
|         | D3    | –                                   | –                                            | –                 | –                  | –    | –   | –       |                                          |
|         | D2    | R42D                                | R42 output port data register                | High              | Low                | 1    | R/W |         |                                          |
|         | D1    | R41D                                | R41 output port data register                |                   |                    | 1    | R/W |         |                                          |
| D0      | R40D  | R40 output port data register       | 1                                            |                   |                    | R/W  |     |         |                                          |

#### MODE16: 8-/16-bit mode selection register (00FF30H•D7)

Selects either the 8-bit or 16-bit mode.

When "1" is written: 16 bits × 1 channel

When "0" is written: 8 bits × 2 channels

Reading: Valid

Select whether Timer 0 and Timer 1 are used as 2 channels independent 8-bit timers or as 1 channel combined 16-bit timer. When "0" is written to the MODE16 register, 8-bit × 2 channels is selected and when "1" is written, 16-bit × 1 channel is selected. At initial reset, the MODE16 register is set to "0" (8-bit × 2 channels).

#### CKSEL0: Timer 0 input clock selection register (00FF30H•D0)

#### CKSEL1: Timer 1 input clock selection register (00FF31H•D0)

Selects the input clock for each timer.

When "1" is written: External clock

When "0" is written: Internal clock

Reading: Valid

The clock to be input to each timer is selected from either the external clock (input signal of input port) or the internal clock (prescaler output clock).

When "0" is written to the CKSEL0 register, the internal clock (prescaler output INCL00) is selected as the input clock for Timer 0. When "1" is written, the external clock (K10 input EXCL00) is selected and the timer functions as an event counter.

Same as above, when "0" is written to the CKSEL1 register, the internal clock (prescaler output INCL01) is selected as the input clock for Timer 1. When "1" is written, the external clock (K11 input EXCL01) is selected.

In the 16-bit mode, the setting of the CKSEL1 register is invalid.

At initial reset, the CKSEL register is set to "0" (internal clock).

**PRTF0: 16-bit programmable timer 0  
source clock selection register (00FF12H•D0)**

Selects the source clock for the 16-bit programmable timer 0.

When "1" is written: fosc1  
When "0" is written: fosc3  
Reading: Valid

When "1" is written to the PRTF0 register, the OSC1 clock is selected as the source clock for the 16-bit programmable timer 0.  
When "0" is written, the OSC3 clock is selected.  
At initial reset, the PRTF0 register is set to "0" (fosc3).

**PST00–PST02: 16-bit programmable timer 0  
division ratio selection register (00FF10H•D0–D2)**

Selects the clock for the 16-bit programmable timer 0.

It can be selected from 8 types of division ratio shown in Table 5.12.7.1(a).  
This register can also be read.  
At initial reset, the PST0 register is set to "0".

**PRPRT0: 16-bit programmable timer 0  
clock control register (00FF10H•D3)**

Controls the clock supply of the 16-bit programmable timer 0.

When "1" is written: ON  
When "0" is written: OFF  
Reading: Valid

By writing "1" to the PRPRT0 register, the clock that is selected with the PST0 register is output to the 16-bit programmable timer 0.  
When "0" is written, the clock is not output.  
At initial reset, the PRPRT0 register is set to "0" (OFF).

**PK10ON: EXCL00 clock control register (00FF15H•D0)**

Controls the event counter clock of the 16-bit programmable timer 0.

When "1" is written: ON  
When "0" is written: OFF  
Reading: Valid

By writing "1" to the PK10ON register, the EXCL00 (K10 input) clock is output to the 16-bit programmable timer 0.  
When "0" is written, the clock is not output.  
At initial reset, the PK10ON register is set to "0" (OFF).

**PRTF1: 16-bit programmable timer 1  
source clock selection register (00FF12H•D1)**

Selects the source clock for the 16-bit programmable timer 1.

When "1" is written: fosc1  
When "0" is written: fosc3  
Reading: Valid

When "1" is written to the PRTF1 register, the OSC1 clock is selected as the source clock for the 16-bit programmable timer 1.  
When "0" is written, the OSC3 clock is selected.  
At initial reset, the PRTF1 register is set to "0" (fosc3).

**PST10–PST12: 16-bit programmable timer 1  
division ratio selection register (00FF10H•D4–D6)**

Selects the clock for the 16-bit programmable timer 1.

It can be selected from 8 types of division ratio shown in Table 5.12.7.1(a).  
This register can also be read.  
At initial reset, the PST1 register is set to "0".

**PRPRT1: 16-bit programmable timer 1  
clock control register (00FF10H•D7)**

Controls the clock supply of the 16-bit programmable timer 1.

When "1" is written: ON  
When "0" is written: OFF  
Reading: Valid

By writing "1" to the PRPRT1 register, the clock that is selected with the PST1 register is output to the 16-bit programmable timer 1.  
When "0" is written, the clock is not output.  
At initial reset, the PRPRT1 register is set to "0" (OFF).

**PK11ON: EXCL01 clock control register (00FF15H•D1)**

Controls the event counter clock of the 16-bit programmable timer 1.

When "1" is written: ON  
When "0" is written: OFF  
Reading: Valid

By writing "1" to the PK11ON register, the EXCL01 (K11 input) clock is output to the 16-bit programmable timer 1.  
When "0" is written, the clock is not output.  
At initial reset, the PK11ON register is set to "0" (OFF).



**RDR00–RDR07: Timer 0 reload data register (00FF32H)****RDR10–RDR17: Timer 1 reload data register (00FF33H)**

Sets the initial value for the counter of each timer. Each counter loads the reload data set in this register and counts using it as the initial value. The reload data set in this register is loaded into the counter when "1" is written to PSET0 or PSET1, or when a counter underflow occurs. This register can be read. At initial reset, the RDR register is set to "FFH".

**CDR00–CDR07: Timer 0 compare data register (00FF34H)****CDR10–CDR17: Timer 1 compare data register (00FF35H)**

Sets the compare data for each timer. The timer compares the data set in this register with the corresponding counter data, and outputs the compare match signals when they are the same. The compare match signal controls the interrupt and the TOUT output waveform. This register can be read. At initial reset, the CDR register is set to "00H".

**PTM00–PTM07: Timer 0 counter data (00FF36H)****PTM10–PTM17: Timer 1 counter data (00FF37H)**

The counter data of each timer can be read. Data can be read at any given time. However, in the 16-bit mode, reading PTM0 does not latch the timer 1 counter data in PTM1. To avoid generating a borrow from timer 0 to timer 1, read the counter data after stopping the timer by writing "0" to PTRUN0. PTM0 and PTM1 can only be read, so writing operation is invalid. At initial reset, PTM is set to "FFH".

**PSET0: Timer 0 preset (00FF30H•D1)****PSET1: Timer 1 preset (00FF31H•D1)**

Presets the reload data to the counter.

When "1" is written: Preset  
When "0" is written: Invalid  
Reading: Always "0"

Writing "1" to PSET0 presets the reload data in the RDR0 register to the counter of Timer 0. When the counter of Timer 0 is in RUN status, the counter restarts immediately after presetting.

In the case of STOP status, the counter maintains the preset data.

No operation results when "0" is written.

Same as above, PSET1 presets the reload data in the RDR1 register to the counter of Timer 1.

In the 16-bit mode, writing "1" to PSET1 is invalid because 16-bit data is preset by PSET0 only.

This bit is only for writing, and it is always "0" during reading.

**PTRUN0: Timer 0 RUN/STOP control register (00FF30H•D2)****PTRUN1: Timer 1 RUN/STOP control register (00FF31H•D2)**

Controls the RUN/STOP of the counter.

When "1" is written: RUN  
When "0" is written: STOP  
Reading: Valid

The counter of Timer 0 starts down-counting by writing "1" to the PTRUN0 register and stops by writing "0".

In STOP status, the counter data is maintained until it is preset or the counter restarts. When STOP status changes to RUN status, the counter resumes counting from the data maintained.

Same as above, the PTRUN1 register controls the counter of Timer 1.

In the 16-bit mode, both channels are controlled with the PTRUN0 register, and the PTRUN1 register is fixed at "0".

At initial reset, the PTRUN register is set to "0" (STOP).

**PTOUT0: Timer 0 clock output control register (00FF30H•D3)**

**PTOUT1: Timer 1 clock output control register (00FF31H•D3)**

Controls the output of the TOUT signal.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

The PTOUT0 is the output control register for the TOUT0 signal (Timer 0 output clock). When "1" is written to this register, the TOUT0 signal is output from the R40 terminal. When "0" is written, the terminal goes high (VDD) level. However, the high-impedance control register HZR40 of the output port R40 must be set to "0" and the data register R40D must be set to "1".

The TOUT0 clock cannot be output simultaneously with the FOUT3 clock.

The PTOUT1 is the output control register for the TOUT1 signal (Timer 1 output clock). When "1" is written to this register, the TOUT1 signal is output from the R41 terminal. When "0" is written, the terminal goes high (VDD) level. However, the high-impedance control register HZR41 of the output port R41 must be set to "0" and the data register R41D must be set to "1".

The TOUT1 clock cannot be output simultaneously with the FOUT1 clock.

At initial reset, the PTOUT register is set to "0" (OFF).

**HZR40, HZR41: R4 port high impedance control register (00FFD4H•D0, D1)**

Sets the output terminals into a high impedance state.

- When "1" is written: High impedance
- When "0" is written: Complementary
- Reading: Valid

The HZR40 and HZR41 registers are the high impedance control registers for the output ports R40 and R41 used for the clock output.

Fix data of the port used for the TOUT output at "0".

At initial reset, the HZR register is set to "1" (high impedance).

**R40D, R41D: R4 port output data register (00FFD9H•D0, D1)**

They are the data registers for the output ports R40, R41 used for the clock output.

- When "1" is written: Clock output is possible
- When "0" is written: LOW (Vss) level is output
- Reading: Valid

Fix data of the port used for the TOUT output at "1".

At initial reset, the data bits are all set to "1".

**PTM00, PTM01: Timer 0 interrupt priority register (00FF20H•D0, D1)**

**PTM10, PTM11: Timer 1 interrupt priority register (00FF20H•D2, D3)**

Sets the priority level of the 16-bit programmable timer interrupt.

The PTM register is the interrupt priority register corresponding to each timer interrupt.

Table 5.12.7.2 shows the interrupt priority level which can be set by this register.

Table 5.12.7.2 Interrupt priority level settings

| PTM11<br>PTM01 | PTM10<br>PTM00 | Interrupt priority level              |
|----------------|----------------|---------------------------------------|
| 1              | 1              | Level 3 ( $\overline{\text{IRQ}}_3$ ) |
| 1              | 0              | Level 2 ( $\overline{\text{IRQ}}_2$ ) |
| 0              | 1              | Level 1 ( $\overline{\text{IRQ}}_1$ ) |
| 0              | 0              | Level 0 (None)                        |

At initial reset, the PTM register is set to "0" (level 0).

**ETU0: Timer 0 underflow interrupt enable register (00FF24H•D3)**

**ETU1: Timer 1 underflow interrupt enable register (00FF24H•D5)**

Enables or disables the underflow interrupt generation to the CPU.

- When "1" is written: Interrupt is enabled
- When "0" is written: Interrupt is disabled
- Reading: Valid

The ETU register is the interrupt enable register corresponding to the underflow interrupt factor of each timer.

Interrupt in which the ETU register is set to "1" is enabled, and the others in which the ETU register is set to "0" are disabled.

In the 16-bit mode, the setting of the ETU0 is invalid.

At initial reset, the ETU register is set to "0" (interrupt is disabled).

**ETC0: Timer 0 compare match interrupt enable register (00FF24H•D4)****ETC1: Timer 1 compare match interrupt enable register (00FF24H•D6)**

Enables or disables the compare match interrupt generation to the CPU.

- When "1" is written: Interrupt is enabled
- When "0" is written: Interrupt is disabled
- Reading: Valid

The ETC register is the interrupt enable register corresponding to the compare match interrupt factor of each timer.

Interrupt in which the ETC register is set to "1" is enabled, and the others in which the ETC register is set to "0" are disabled.

In the 16-bit mode, the setting of the ETC0 is invalid.

At initial reset, the ETC register is set to "0" (interrupt is disabled).

**FTU0: Timer 0 underflow interrupt factor flag (00FF28H•D3)****FTU1: Timer 1 underflow interrupt factor flag (00FF28H•D5)**

Indicates the generation of underflow interrupt factor.

- When "1" is read: Int. factor has generated
- When "0" is read: Int. factor has not generated

- When "1" is written: Factor flag is reset
- When "0" is written: Invalid

FTU is the interrupt factor flag corresponding to interrupt of each timer, and is set to "1" due to the counter underflow.

At this point, if the corresponding interrupt enable register is set to "1" and the corresponding interrupt priority register is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.

Regardless of the interrupt enable register and interrupt priority register settings, the interrupt factor flag is set to "1" when the interrupt generation condition is met.

To accept the subsequent interrupt after an interrupt generation, it is necessary to re-set the interrupt flags (set the interrupt flag to a lower level than the level indicated by the interrupt priority registers, or execute the RETE instruction) and to reset the interrupt factor flag. The interrupt factor flag is reset to "0" by writing "1".

In the 16-bit mode, the interrupt factor flag FTU0 is not set to "1" and Timer 0 interrupt is not generated. In this mode, the interrupt factor flag FTU1 is set to "1" by the underflow of the 16-bit counter.

At initial reset, the FTU flag is reset to "0".

**FTC0: Timer 0 compare match interrupt factor flag (00FF28H•D4)****FTC1: Timer 1 compare match interrupt factor flag (00FF28H•D6)**

Indicates the generation of compare match interrupt factor.

- When "1" is read: Int. factor has generated
- When "0" is read: Int. factor has not generated

- When "1" is written: Factor flag is reset
- When "0" is written: Invalid

FTC is the interrupt factor flag corresponding to interrupt of each timer, and is set to "1" due to the compare match signal.

At this point, if the corresponding interrupt enable register is set to "1" and the corresponding interrupt priority register is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.

Regardless of the interrupt enable register and interrupt priority register settings, the interrupt factor flag is set to "1" when the interrupt generation condition is met.

To accept the subsequent interrupt after an interrupt generation, it is necessary to re-set the interrupt flags (set the interrupt flag to a lower level than the level indicated by the interrupt priority registers, or execute the RETE instruction) and to reset the interrupt factor flag. The interrupt factor flag is reset to "0" by writing "1".

In the 16-bit mode, the interrupt factor flag FTC0 is not set to "1" and Timer 0 interrupt is not generated. In this mode, the interrupt factor flag FTC1 is set to "1" by the compare match of the 16-bit counter.

At initial reset, the FTC flag is reset to "0".

**5.12.8 Programming notes**

- (1) The 16-bit programmable timer actually enters into RUN or STOP status at the falling edge of the input clock after writing to the PTRUN0(1) register. Consequently, when "0" is written to PTRUN0(1), the timer stops after counting once more (+1). PTRUN0(1) is read as "1" until the timer actually stops.

Figure 5.12.8.1 shows the timing chart at the RUN/STOP control.

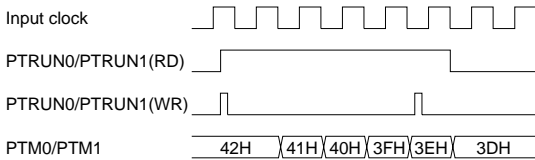


Fig. 5.12.8.1 Timing chart at RUN/STOP control

- (2) When the SLP instruction is executed while the 16-bit programmable timer is running (PTRUN0(1) = "1"), the timer stops counting during SLEEP status. When SLEEP status is canceled, the timer starts counting. However, the operation becomes unstable immediately after SLEEP status is canceled. Therefore, when shifting to SLEEP status, stop the 16-bit programmable timer (PTRUN0(1) = "0") prior to executing the SLP instruction. Same as above, the TOUT signal output should be disabled (PTOUT0(1) = "0") so that an unstable clock is not output to the clock output port terminal.
- (3) In the 16-bit mode, reading PTM0 does not latch the timer 1 counter data in PTM1. To avoid generating a borrow from timer 0 to timer 1, read the counter data after stopping the timer by writing "0" to PTRUN0.

## 5.13 8-bit Programmable Timer

### 5.13.1 Configuration of 8-bit programmable timer

The S1C88409 has a built-in 8-bit programmable timer. The timer consists of an 8-bit presettable down counter, and can be used as 8 bits  $\times$  1 channel of programmable timer.

Figure 5.13.1.1 shows the configuration of the 8-bit programmable timer.

The serial interface uses the underflow signal of the 8-bit programmable timer as the synchronous clock, so programmable setting of the transfer rate is possible.

### 5.13.2 Setting of input clock

The prescaler supplies the clocks to the timer. The prescaler generates the clocks for the timer by dividing the source clock supplied from the OSC3 oscillation circuit.

*Note: The prescaler, which supplies the clock to the 8-bit programmable timer, can operate only when the OSC3 oscillation has been set to ON. Be aware that the 8-bit programmable timer does not operate when the OSC3 oscillation circuit has been turned off.*

Division ratio of the prescaler can be individually selected by software.

The division ratio can be selected from eight kinds using the prescaler division ratio selection register PST2.

Further, it is necessary to control the prescaler output using the clock control register PRPRT2. Refer to Section 5.5, "Prescaler and Clock Control Circuit for Peripheral Circuits", or Section 5.13.6, "I/O memory of 8-bit programmable timer", for setting of the division ratio.

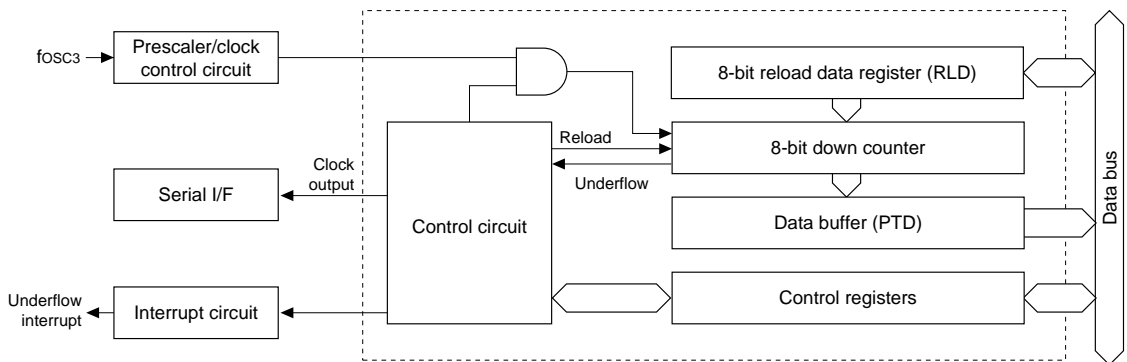


Fig. 5.13.1.1 Configuration of 8-bit programmable timer

### 5.13.3 Operation and control of timer

#### Reload data register and setting of initial value

The reload data register RLD is used to set the initial value of the down counter.

The reload data register can be read and written, and is set to FFH at initial reset.

Data written in this register is loaded into the down counter, and down counting starts from the value. A preset to down counter is done in the following two cases:

1) *When software presets*

The software preset can be done using the preset control bit PSET. When the preset control bit is set to "1", the content of the reload data register is loaded into the down counter at that point.

2) *When down counter has underflowed during a count*

Since the down counter presets the reload data by the underflow, the underflow period is decided according to the value set in the reload data register. This underflow generates an interrupt, and controls the clock output to the serial interface.

#### Timer operation

The 8-bit programmable timer is equipped with the register PRUN which control the RUN/STOP of the timer. The programmable timer starts down counting by writing "1" to the PRUN register. However, it is necessary to control the input clock and to preset the reload data before starting a count.

When "0" is written to the PRUN register, clock input is prohibited, and the count stops. This RUN/STOP control does not affect data in the counter. The data in the counter is maintained during count deactivation, so it is possible to resume counting from the data.

The counter data can be read via the buffer PTD in optional timing.

When the counter underflows, an underflow interrupt is generated, and the initial value set in the reload data register is loaded to the counter. This underflow signal controls supplying the clock to the serial interface.

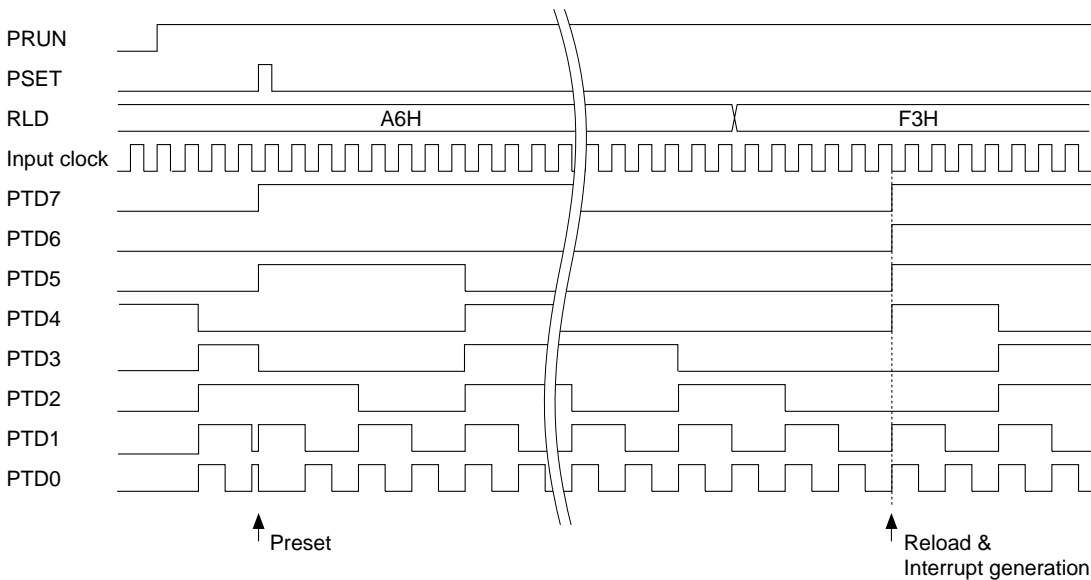


Fig. 5.13.3.1 Operation timing of counter

### 5.13.4 Interrupt function

The 8-bit programmable timer can generate an interrupt by the underflow signal of the counter. Figure 5.13.4.1 shows the configuration of the 8-bit programmable timer interrupt circuit.

The underflow signal of the timer sets the interrupt factor flag FTU2 to "1". At that point, the interrupt is generated. The interrupt can also be prohibited by setting the interrupt enable register ETU2.

Furthermore, the priority level of the interrupt for the CPU can be set to an optional level (0-3) using the interrupt priority register PTM2.

Refer to Section 5.20, "Interrupt and Standby Mode", for details of the interrupt control registers and operations subsequent to interrupt generation.

The exception processing vector address for the 8-bit programmable timer interrupt is set as follows:

8-bit programmable timer interrupt: 000018H

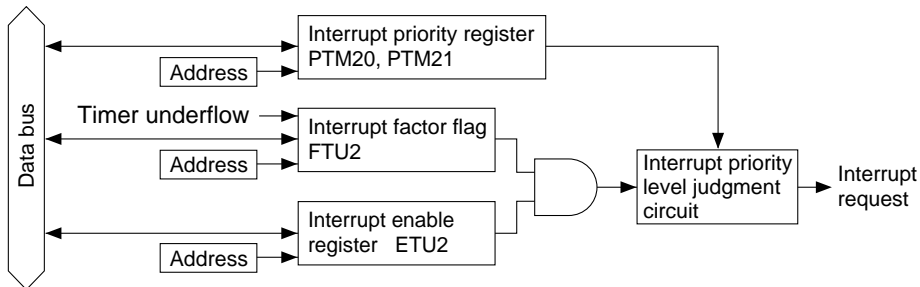


Fig. 5.13.4.1 Configuration of 8-bit programmable timer interrupt circuit

### 5.13.5 Transfer rate setting for serial interface

The 8-bit programmable timer can supply the clock, generated by dividing the underflow of the counter in 1/2, to the serial interface. The clock output control register PTOUT controls the clock output from the 8-bit programmable timer.

Figure 5.13.5.1 shows the output waveform of the clock.

The transfer rate of the serial interface is decided by the clock output from the prescaler and the value set in the reload register.

The output clock is divided by 16 in the serial interface. Therefore, the setting value of the reload data register according to the transfer rate can be calculated with the expression below.

$$RLD = fosc3 * dr / (32 * bps) - 1$$

RLD: Setting value of the reload register

fosc3: OSC3 oscillation frequency

bps: Transfer rate

dr: Prescaler division ratio (1/2 to 1/256)

(00H can be set to RLD)

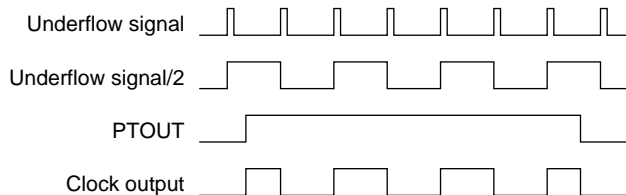


Fig. 5.13.5.1 Clock output waveform

5.13.6 I/O memory of 8-bit programmable timer

Table 5.13.6.1 shows the 8-bit programmable timer control bits.

Table 5.13.6.1(a) 8-bit programmable timer control bits

| Address                             | Bit   | Name             | Function                                                            | 1                                     | 0                                         | Init           | R/W   | Comment             |
|-------------------------------------|-------|------------------|---------------------------------------------------------------------|---------------------------------------|-------------------------------------------|----------------|-------|---------------------|
| 00FF11                              | D7    | —                | —                                                                   | —                                     | —                                         | —              | —     | "0" when being read |
|                                     | D6    | —                | —                                                                   | —                                     | —                                         | —              | —     |                     |
|                                     | D5    | —                | —                                                                   | —                                     | —                                         | —              | —     |                     |
|                                     | D4    | —                | —                                                                   | —                                     | —                                         | —              | —     |                     |
|                                     | D3    | PRPRT2           | 8-bit programmable timer clock control                              | On                                    | Off                                       | 0              | R/W   |                     |
|                                     | D2    | PST22            | 8-bit programmable timer division ratio                             |                                       |                                           | 0              | R/W   |                     |
|                                     | D1    | PST21            | PST22 PST21 PST20 Division ratio                                    | 1 1 1 fosc3 / 256                     |                                           |                |       |                     |
|                                     |       |                  | 1 1 0 fosc3 / 128                                                   |                                       |                                           | 0              | R/W   |                     |
| 1 0 1 fosc3 / 64                    |       |                  |                                                                     |                                       |                                           |                |       |                     |
| 1 0 0 fosc3 / 32                    |       |                  |                                                                     |                                       |                                           |                |       |                     |
| D0                                  | PST20 | 0 1 1 fosc3 / 16 |                                                                     |                                       |                                           |                |       |                     |
|                                     |       | 0 1 0 fosc3 / 8  |                                                                     |                                       | 0                                         | R/W            |       |                     |
|                                     |       | 0 0 1 fosc3 / 4  |                                                                     |                                       |                                           |                |       |                     |
|                                     |       | 0 0 0 fosc3 / 2  |                                                                     |                                       |                                           |                |       |                     |
| 00FF21                              | D7    | PTM21            | 8-bit programmable timer                                            | PTM21                                 | PTM20                                     | 0              | R/W   |                     |
|                                     | D6    | PTM20            | interrupt priority register                                         | PSI1                                  | PSI0                                      | 0              | R/W   |                     |
|                                     | D5    | PSI1             | Serial interface                                                    | PCTM1                                 | PCTM0                                     | Priority level | 0     | R/W                 |
|                                     | D4    | PSI0             | interrupt priority register                                         | PLCD1                                 | PLCD0                                     | Level          | 0     | R/W                 |
|                                     | D3    | PCTM1            | Clock timer                                                         | 1                                     | 1                                         | Level 3        | 0     | R/W                 |
|                                     | D2    | PCTM0            | interrupt priority register                                         | 1                                     | 0                                         | Level 2        | 0     | R/W                 |
|                                     | D1    | PLCD1            | LCD controller                                                      | 0                                     | 1                                         | Level 1        | 0     | R/W                 |
|                                     | D0    | PLCD0            | interrupt priority register                                         | 0                                     | 0                                         | Level 0        | 0     | R/W                 |
| 00FF24                              | D7    | ETU2             | 8-bit programmable timer underflow interrupt enable register        | Interrupt is enabled                  | Interrupt is disabled                     | 0              | R/W   |                     |
|                                     | D6    | ETC1             | 16-bit programmable timer 1 compare match interrupt enable register |                                       |                                           | 0              | R/W   |                     |
|                                     | D5    | ETU1             | 16-bit programmable timer 1 underflow interrupt enable register     |                                       |                                           | 0              | R/W   |                     |
|                                     | D4    | ETC0             | 16-bit programmable timer 0 compare match interrupt enable register |                                       |                                           | 0              | R/W   |                     |
|                                     | D3    | ETU0             | 16-bit programmable timer 0 underflow interrupt enable register     |                                       |                                           | 0              | R/W   |                     |
|                                     | D2    | ESTX             | Serial interface transmit completion interrupt enable register      |                                       |                                           | 0              | R/W   |                     |
|                                     | D1    | ESRX             | Serial interface receive completion interrupt enable register       |                                       |                                           | 0              | R/W   |                     |
|                                     | D0    | ESERR            | Serial interface receive error interrupt enable register            |                                       |                                           | 0              | R/W   |                     |
| 00FF28                              | D7    | FTU2             | 8-bit programmable timer underflow interrupt factor flag            | (R)<br>Interrupt factor has generated | (R)<br>Interrupt factor has not generated | 0              | R/(W) |                     |
|                                     | D6    | FTC1             | 16-bit programmable timer 1 compare match interrupt factor flag     |                                       |                                           | 0              | R/(W) |                     |
|                                     | D5    | FTU1             | 16-bit programmable timer 1 underflow interrupt factor flag         |                                       |                                           | 0              | R/(W) |                     |
|                                     | D4    | FTC0             | 16-bit programmable timer 0 compare match interrupt factor flag     |                                       |                                           | 0              | R/(W) |                     |
|                                     | D3    | FTU0             | 16-bit programmable timer 0 underflow interrupt factor flag         |                                       |                                           | 0              | R/(W) |                     |
|                                     | D2    | FSTX             | Serial interface transmit completion interrupt factor flag          | (W)<br>Reset                          | (W)<br>Invalid                            | 0              | R/(W) |                     |
|                                     | D1    | FSRX             | Serial interface receive completion interrupt factor flag           |                                       |                                           | 0              | R/(W) |                     |
|                                     | D0    | FSERR            | Serial interface                                                    |                                       |                                           | 0              | R/(W) |                     |
| receive error interrupt factor flag |       |                  | 0                                                                   |                                       |                                           | R/(W)          |       |                     |



Table 5.13.6.1(b) 8-bit programmable timer control bits

| Address | Bit  | Name                                      | Function                                      | 1       | 0       | Init | R/W | Comment             |
|---------|------|-------------------------------------------|-----------------------------------------------|---------|---------|------|-----|---------------------|
| 00FF38  | D7   | –                                         | –                                             | –       | –       | –    | –   | "0" when being read |
|         | D6   | –                                         | –                                             | –       | –       | –    | –   |                     |
|         | D5   | –                                         | –                                             | –       | –       | –    | –   |                     |
|         | D4   | –                                         | –                                             | –       | –       | –    | –   |                     |
|         | D3   | –                                         | –                                             | –       | –       | –    | –   |                     |
|         | D2   | PTOUT                                     | 8-bit programmable timer clock output control | On      | Off     | 0    | R/W |                     |
|         | D1   | PSET                                      | 8-bit programmable timer preset               | Preset  | Invalid | –    | W   |                     |
| D0      | PRUN | 8-bit programmable timer RUN/STOP control | Run                                           | Stop    | 0       | R/W  |     |                     |
| 00FF39  | D7   | RLD7                                      | 8-bit programmable timer reload data register | D7(MSB) |         |      | 1   | R/W                 |
|         | D6   | RLD6                                      |                                               | D6      |         |      | 1   | R/W                 |
|         | D5   | RLD5                                      |                                               | D5      |         |      | 1   | R/W                 |
|         | D4   | RLD4                                      |                                               | D4      |         |      | 1   | R/W                 |
|         | D3   | RLD3                                      |                                               | D3      |         |      | 1   | R/W                 |
|         | D2   | RLD2                                      |                                               | D2      |         |      | 1   | R/W                 |
|         | D1   | RLD1                                      |                                               | D1      |         |      | 1   | R/W                 |
|         | D0   | RLD0                                      |                                               | D0(LSB) |         |      | 1   | R/W                 |
| 00FF3A  | D7   | PTD7                                      | 8-bit programmable timer data register        | D7(MSB) |         |      | 1   | R                   |
|         | D6   | PTD6                                      |                                               | D6      |         |      | 1   | R                   |
|         | D5   | PTD5                                      |                                               | D5      |         |      | 1   | R                   |
|         | D4   | PTD4                                      |                                               | D4      |         |      | 1   | R                   |
|         | D3   | PTD3                                      |                                               | D3      |         |      | 1   | R                   |
|         | D2   | PTD2                                      |                                               | D2      |         |      | 1   | R                   |
|         | D1   | PTD1                                      |                                               | D1      |         |      | 1   | R                   |
|         | D0   | PTD0                                      |                                               | D0(LSB) |         |      | 1   | R                   |

#### **PST20–PST22: 8-bit programmable timer division ratio selection register (00FF11H•D0–D2)**

Selects the clock for the 8-bit programmable timer. It can be selected from 8 types of division ratio shown in Table 5.13.6.1(a). This register can also be read. At initial reset, the PST2 register is set to "0" ( $f_{osc3}/2$ ).

#### **PRPRT2: 8-bit programmable timer clock control register (00FF11H•D3)**

Controls the clock supply of the 8-bit programmable timer.

When "1" is written: ON  
When "0" is written: OFF  
Reading: Valid

By writing "1" to the PRPRT2 register, the clock that is selected with the PST2 register is output to the 8-bit programmable timer. However, the OSC3 oscillation circuit must be used.

When "0" is written, the clock is not output. At initial reset, the PRPRT2 register is set to "0" (OFF).

#### **RLD0–RLD7: Reload data register (00FF39H)**

Sets the initial value for the counter. The counter loads the reload data set in this register and counts using it as the initial value. The reload data set in this register is loaded into the counter when "1" is written to PSET, or when a counter underflow occurs. This register can be read. At initial reset, the RLD register is set to "FFH".

#### **PTD0–PTD7: Counter data (00FF3AH)**

The counter data of the 8-bit programmable timer can be read. PTD is a buffer to maintain the count data during reading, and the data can be read in optional timing. At initial reset, PTD is set to "FFH".

#### **PSET: Preset (00FF38H•D1)**

Presets the reload data to the counter.

When "1" is written: Preset  
When "0" is written: Invalid  
Reading: Always "0"

Writing "1" to PSET presets the reload data in the RLD register to the counter. When the counter is in RUN status, the counter restarts immediately after presetting.

In the case of STOP status, the counter maintains the preset data.  
 No operation results when "0" is written.  
 This bit is valid only for writing, and it is always "0" during reading.

**PRUN: RUN/STOP control register (00FF38H•D0)**

Controls the RUN/STOP of the counter.

- When "1" is written: RUN
- When "0" is written: STOP
- Reading: Valid

The counter starts down-counting by writing "1" to the PRUN register and stops by writing "0".  
 In STOP status, the counter data is maintained until it is preset or the counter restarts. When STOP status changes to RUN status, the counter resumes counting from the data maintained.  
 At initial reset, the PRUN register is set to "0" (STOP).

**PTOUT: Clock output control register (00FF38H•D2)**

Controls the clock output to the serial interface.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

The PTOUT register is the output control register. When "1" is written to this register, the clock (underflow \* 1/2) that is generated by the 8-bit programmable timer is output to the serial interface.  
 When "0" is written, the clock is not output to the serial interface.  
 At initial reset, the PTOUT register is set to "0" (OFF).

**PTM20, PTM21: Interrupt priority register (00FF21H•D6, D7)**

Sets the priority level of the 8-bit programmable timer interrupt.

Table 5.13.6.2 shows the interrupt priority level which can be set by this register.

Table 5.13.6.2 Interrupt priority level settings

| PTM21 | PTM20 | Interrupt priority level              |
|-------|-------|---------------------------------------|
| 1     | 1     | Level 3 ( $\overline{\text{IRQ}}_3$ ) |
| 1     | 0     | Level 2 ( $\overline{\text{IRQ}}_2$ ) |
| 0     | 1     | Level 1 ( $\overline{\text{IRQ}}_1$ ) |
| 0     | 0     | Level 0 (None)                        |

At initial reset, the PTM2 register is set to "0" (level 0).

**ETU2: Underflow interrupt enable register (00FF24H•D7)**

Enables or disables the underflow interrupt generation to the CPU.

- When "1" is written: Interrupt is enabled
- When "0" is written: Interrupt is disabled
- Reading: Valid

The ETU2 register is the interrupt enable register corresponding to the interrupt factor of the 8-bit programmable timer.  
 Interrupt in which the ETU2 register is set to "1" is enabled, and the others in which the ETU2 register is set to "0" are disabled.  
 At initial reset, the ETU2 register is set to "0" (interrupt is disabled).

**FTU2: Underflow interrupt factor flag (00FF28H•D7)**

Indicates the generation of underflow interrupt factor.

- When "1" is read: Int. factor has generated
- When "0" is read: Int. factor has not generated

- When "1" is written: Factor flag is reset
- When "0" is written: Invalid

FTU2 is the interrupt factor flag corresponding to the 8-bit programmable timer interrupt, and is set to "1" due to the counter underflow.  
 At this point, if the corresponding interrupt enable register is set to "1" and the corresponding interrupt priority register is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.  
 Regardless of the interrupt enable register and interrupt priority register settings, the interrupt factor flag is set to "1" when the interrupt generation condition is met.  
 To accept the subsequent interrupt after an interrupt generation, it is necessary to re-set the interrupt flags (set the interrupt flag to a lower level than the level indicated by the interrupt priority registers, or execute the RETE instruction) and to reset the interrupt factor flag. The interrupt factor flag is reset to "0" by writing "1".  
 At initial reset, the FTU2 flag is reset to "0".

### 5.13.7 Programming notes

- (1) The 8-bit programmable timer actually enters RUN or STOP status at the falling edge of the input clock after writing to the PRUN register. Consequently, when "0" is written to PRUN, the timer stops after counting once more (+1). PRUN is read as "1" until the timer actually stops.

Figure 5.13.7.1 shows the timing chart of the RUN/STOP control.

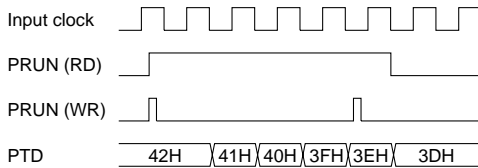


Fig. 5.13.7.1 Timing chart at RUN/STOP control

- (2) When the SLP instruction is executed while the 8-bit programmable timer is running (PRUN = "1"), the timer stops counting during SLEEP status. When SLEEP status is canceled, the timer starts counting. However, the operation becomes unstable immediately after SLEEP status is canceled. Therefore, when shifting to SLEEP status, stop the 8-bit programmable timer (PRUN = "0") prior to executing the SLP instruction.
- (3) The prescaler, which supplies the clock to the 8-bit programmable timer, can operate only when the OSC3 oscillation has been set to ON. Be aware that the 8-bit programmable timer does not operate when the OSC3 oscillation circuit has been turned off.

## 5.14 Serial Interface

### 5.14.1 Configuration of serial interface

The S1C88409 has a serial interface built-in. The following shows the features.

- 8-bit clock synchronous system/8(7)-bit asynchronous system (full duplex) are switchable
- Two systems of input/output terminals (P10–P13, P14–P17) are selectable
- Data bit length, stop bit length and parity bit are selectable with software for the asynchronous system
- IrDA interface compatible

Figure 5.14.1.1 shows the configuration of the serial interface.

The input/output port of the serial interface is shared with an I/O port, and it is set in the I/O port at initial reset. Therefore, when using the serial interface, enable the serial interface by writing "1" to the serial interface enable register (ESIF).

The serial interface in which the ESIF register is "0" cannot be used.

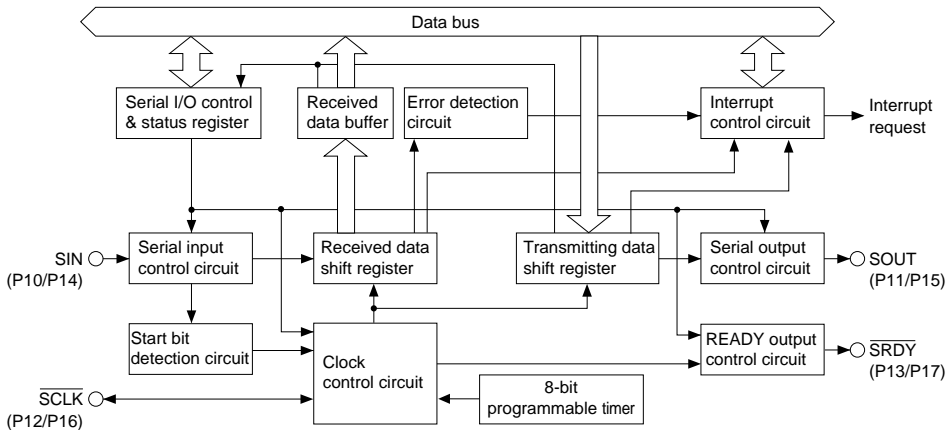


Fig. 5.14.1.1 Configuration of serial interface

### 5.14.2 Transfer mode and input/output terminals

In this serial interface, the transfer mode can be selected by software.

#### Transfer mode summary

Clock synchronous transfer is the formula that transfers 8-bit data by synchronizing each bit to a clock common to transmitter and receiver.

Asynchronous transfer is the formula that transfers the serial converted data in which a start bit is added to the front and a stop bit is added to the rear. In this formula, it is not necessary to use the same synchronous clock for transmitter and receiver. Data transfer is done by synchronizing the start/stop bit attached in front and rear of each data. The asynchronous interface has separate transmit and receive shift registers and is designed to permit full duplex transmission to be done simultaneously for transmitting and receiving.

Four transfer modes shown below are available in this interface.

#### (1) Clock synchronous master mode

In this mode, clock synchronous 8-bit serial data transfer can be done. This serial interface becomes the master and uses the internal clock as the synchronous clock for the built-in shift register.

The synchronous clock is output from the  $\overline{\text{SCLK}}$  terminal and can control the external serial I/O device (the slave side).

Figure 5.14.2.1 shows a connection example of input/output terminals in clock synchronous master mode.

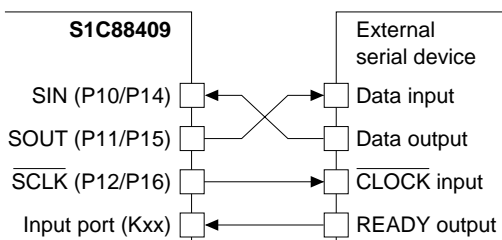


Fig. 5.14.2.1 Connection example of clock synchronous master mode

#### (2) Clock synchronous slave mode

In this mode, clock synchronous 8-bit serial data transfer can be done. This serial interface becomes the slave and uses the synchronous clock supplied externally (the master side).

The synchronous clock is input from the  $\overline{\text{SCLK}}$  terminal and is used in this serial interface.

Further, this mode can output the  $\overline{\text{SRDY}}$  signal that indicates transmit/receive ready status from the  $\overline{\text{SRDY}}$  terminal.

Figure 5.14.2.2 shows a connection example of input/output terminals in clock synchronous slave mode.

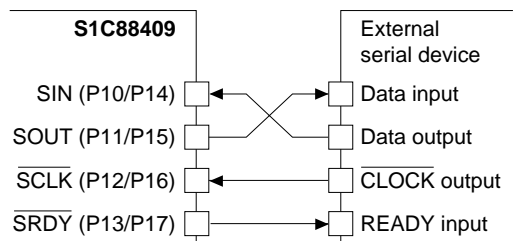


Fig. 5.14.2.2 Connection example of clock synchronous slave mode

#### (3) 7-bit asynchronous mode

In this mode, start stop synchronous transfer can be done. Data length is 7 bits. It is possible to select a stop bit length, addition of a parity bit and even/odd parity.

Further, this mode works only with the internal clock.

Figure 5.14.2.3 shows a connection example of input/output terminals in asynchronous mode.

#### (4) 8-bit asynchronous mode

In this mode, start stop synchronous transfer can be done. Data length is 8 bits. It is possible to select a stop bit length, addition of a parity bit and even/odd parity.

Further, this mode works only with the internal clock.

Figure 5.14.2.3 shows a connection example of input/output terminals in asynchronous mode.

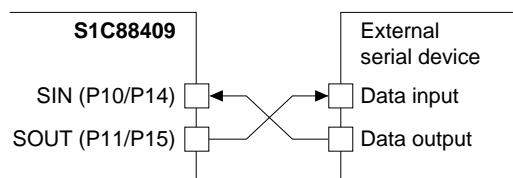


Fig. 5.14.2.3 Connection example of clock asynchronous mode

**Setting of serial interface**

**(1) Transfer mode**

The transfer mode is set with the SMD register (2 bits) as shown in Table 5.14.2.1.

Table 5.14.2.1 Transfer mode

| SMD1 | SMD0 | Mode                     |
|------|------|--------------------------|
| 1    | 1    | 8-bit asynchronous       |
| 1    | 0    | 7-bit asynchronous       |
| 0    | 1    | Clock synchronous slave  |
| 0    | 0    | Clock synchronous master |

It is set to the clock synchronous master mode at initial reset.

In the clock synchronous mode, start/stop bit and parity bit cannot be added.

The clock synchronous slave mode outputs the  $\overline{\text{SRDY}}$  signal showing transmit/receive ready status from the  $\overline{\text{SRDY}}$  terminal.

When using the IR interface, set the 7-bit asynchronous mode or 8-bit asynchronous mode.

The input/output terminals of the serial interface can be assigned to P10–P13 or P14–P17. Select either one using the SIOSEL register.

Table 5.14.2.2 Input/output terminals

| Terminal                 | SIOSEL="0" | SIOSEL="1" |
|--------------------------|------------|------------|
| SIN                      | P10        | P14        |
| SOUT                     | P11        | P15        |
| $\overline{\text{SCLK}}$ | P12        | P16        |
| $\overline{\text{SRDY}}$ | P13        | P17        |

(ESIF="1")

It is set to P10–P13 at initial reset.

When using the IR interface, select P14–P17.

The ports which are not used in the serial interface can be used as the I/O port.

Input/output configuration of the four lines differs depending on the transfer mode. Table 5.14.2.3 shows the terminal configuration of each mode.

The clock synchronous slave mode uses all four lines.

The clock synchronous master mode does not use  $\overline{\text{SRDY}}$ , so P13 (P17) can be used as the I/O port.

Table 5.14.2.3 Terminal setting for each transfer mode

| Mode                     | SIN        | SOUT        | $\overline{\text{SCLK}}$ | $\overline{\text{SRDY}}$ |
|--------------------------|------------|-------------|--------------------------|--------------------------|
| 8-bit asynchronous       | Data input | Data output | P12/P16                  | P13/P17                  |
| 7-bit asynchronous       | Data input | Data output | P12/P16                  | P13/P17                  |
| Clock synchronous slave  | Data input | Data output | Clock input              | Ready output             |
| Clock synchronous master | Data input | Data output | Clock output             | P13/P17                  |

The asynchronous mode does not use  $\overline{\text{SCLK}}$  and  $\overline{\text{SRDY}}$ , so P12 and P13 (P16 and P17) can be used as the I/O port.

The I/O control registers and data registers of the I/O port which is used with the serial interface can be used as a general-purpose register.

**(2) Data format of clock synchronous transfer**

In the clock synchronous mode, data format is stationary as follows:

Data length: 8 bits  
 Start bit: none  
 Stop bit: none  
 Parity bit: none

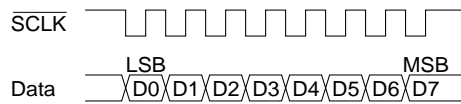


Fig. 5.14.2.4 Clock synchronous transfer data format

**(3) Data format of asynchronous transfer**

The data format of asynchronous transfer is as follows:

Data length: 7 bits or 8 bits  
 (decided by transfer mode selection)  
 Start bit: 1 bit stationary  
 Stop bit: 1 bit or 2 bits  
 Parity bit: even parity, odd parity or none

The stop bit can be set with the STPB register, and the parity bit can be set with the EPR register and the PMD register shown in Table 5.14.2.4.

Table 5.14.2.4 Setting of stop bit and parity bit

| STPB | EPR | PMD | Setting  |            |
|------|-----|-----|----------|------------|
|      |     |     | Stop bit | Parity bit |
| 1    | 1   | 1   | 2 bits   | Odd        |
|      |     | 0   | 2 bits   | Even       |
|      | 0   | –   | 2 bits   | None       |
| 0    | 1   | 1   | 1 bit    | Odd        |
|      |     | 0   | 1 bit    | Even       |
|      | 0   | –   | 1 bit    | None       |

At initial reset, they are set in 1 stop bit and no parity.

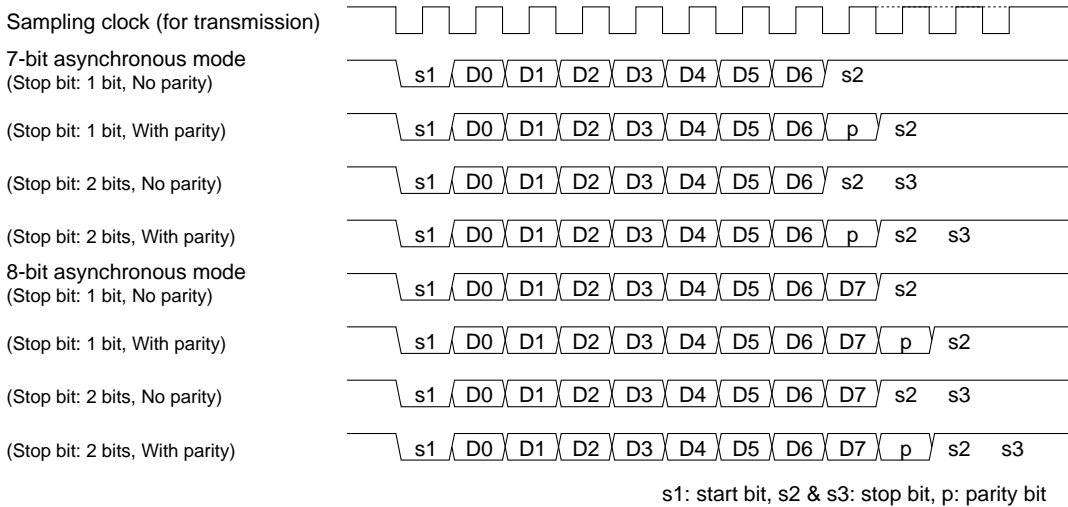


Fig. 5.14.2.5 Asynchronous transfer data format

### 5.14.3 Mask option

The input/output terminals of the serial interface are shared with the I/O port terminals. Therefore, the terminal specification of the serial interface is decided by setting the I/O port mask option.

|                                  |                                        |                                      |  |
|----------------------------------|----------------------------------------|--------------------------------------|--|
| I/O port pull-up resistor        |                                        |                                      |  |
| P10 (SIN)                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |  |
| P12 ( $\overline{\text{SCLK}}$ ) | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |  |
| P14 (SIN)                        | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |  |
| P16 ( $\overline{\text{SCLK}}$ ) | <input type="checkbox"/> With resistor | <input type="checkbox"/> Gate direct |  |

*Note: The configuration of the ports which are used for the serial interface input differs depending on the transfer mode setting.*

The I/O port has a built-in pull-up resistor that is activated during the input mode, and it can be individually selected for use or not by the mask option. This mask option (pull-up resistor) is effective for the input lines of the serial interface.

When "Gate direct" is selected, take care that a floating status does not occur in the input terminal.

### 5.14.4 Clock source

The clock source of the serial interface is the 8-bit programmable timer.

When using the internal clock, it is necessary to output the clock from the 8-bit programmable timer beforehand.

Refer to Section 5.13, "8-bit Programmable Timer", for control of the 8-bit programmable timer.

Be aware that the serial interface does not operate when the OSC3 oscillation circuit has been turned off, because in this case the 8-bit programmable timer does not operate.

#### Synchronous clock in clock synchronous mode

The clock synchronous master mode divides the output clock of the 8-bit programmable timer in 1/16, and uses it as the synchronous clock  $\overline{\text{SCLK}}$ .

The clock synchronous slave mode uses an external clock input from the  $\overline{\text{SCLK}}$  terminal. In this mode, it is not necessary to control the 8-bit programmable timer.

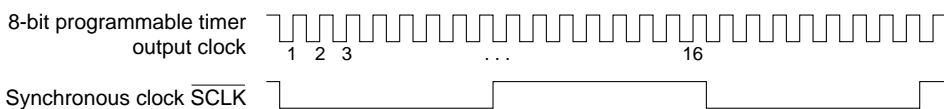


Fig. 5.14.4.1 Synchronous clock  $\overline{\text{SCLK}}$

**Sampling clock of asynchronous mode**

The asynchronous system in this interface generates a sampling clock on the basis of the output clock of the 8-bit programmable timer.

However, it is necessary that the 8-bits programmable timer has output a clock of 16 times the baud rate.

*(1) At receiving*

As shown in Figure 5.14.4.2, duty of the internal sampling clock is not 50 %. The sampling clock changes from "1" to "0" with the second input clock after recognizing a start bit, and returns to "1" with the eighth clock so that sampling will be done at the middle of each bit data received. This sampling waveform is continuously output until sampling of the stop bit has completed. Each bit data is sampled at

the rising edge of the sampling clock. When the stop bit is sampled, the sampling signal is fixed at "1" until the next start bit is detected.

If the serial input is not "0" at the time of start bit sampling with the eighth input clock because the baud rate set in this interface is different from the transmitter or noise is input to the SIN terminal, the following data sampling is stopped and the interface shifts into standby status for the next start bit detection.

*(2) At transmission*

In transmission, the serial interface generates a clock for transmission by dividing the output clock of the 8-bit programmable timer in 1/16 and outputs each bit in synchronization with the clock.

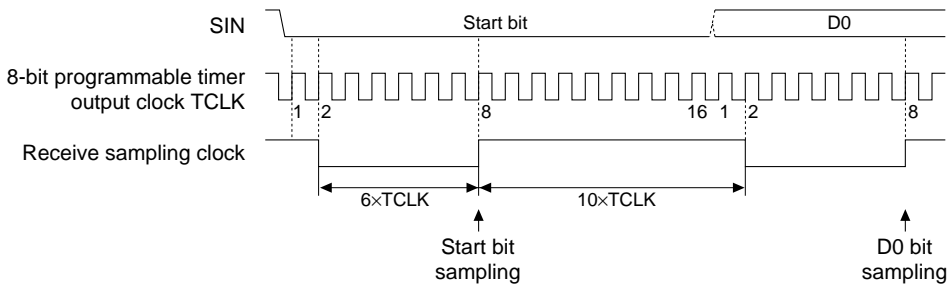


Fig. 5.14.4.2 Sampling clock for receiving in asynchronous system

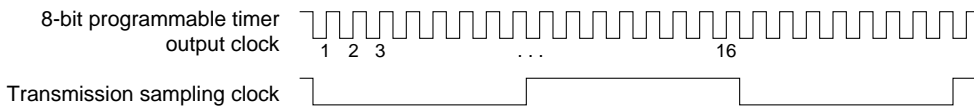


Fig. 5.14.4.3 Sampling clock for sending in asynchronous system



### 5.14.5 Control procedure to transmit/receive

This section explains the control registers used to transmit and receive.

#### Shift register and receive data buffer

The serial interface is equipped with a shift register for serial/parallel conversion.

Transmit data written in the transmit/receive data register TRXD is converted to serial data through the shift register and is output from the SOUT terminal.

Besides the shift register, the receiver is equipped with a receive data buffer.

At the time of receiving, data input from the SIN terminal is converted to parallel data through the shift register and loaded into the receive data buffer. However, the buffering function cannot be used in the clock synchronous mode. Therefore, it is necessary to read the received data before starting the next data receiving.

#### Transmission enable register and transmission control bit

The transmission enable register TXEN and the transmission control bit TXTRG are used to control transmissions.

The transmission enable register TXEN enables and disables transmission. Writing "1" to this register enables transmission. In this status, clock input of the shift register is authorized, and the transmitter shifts into transmit standby status. In the clock synchronous mode, the synchronous clock input and output of the SCLK terminal is authorized, too.

The transmission control bit TXTRG is used as a trigger for starting transmissions.

To start a transmission, write "1" to TXTRG after a preparation to transmit has been completed by writing transmit data to the transmit/receive data register TRXD.

When the transmission is completed, an interrupt is generated when the interrupt has been enabled. After the interrupt is generated, the next transmit data can be written.

TXTRG can also be read as a status. It goes "1" during transmission and goes "0" during standby (stopped) status.

Refer to Section 5.14.9, "Timing charts", for timing of transmission.

*Note: Do not set interface conditions, such as transfer mode, when the TXEN register is "1" (transmission authorize status). Setting except for transmission control must be done after writing "0" to the TXEN register.*

#### Receiving enable register and receiving control bit

The receiving enable register RXEN and receiving control bit RXTRG are used to control receiving. The receiving enable register RXEN enables and disables receiving. Writing "1" to this register enables receiving. In this status, clock input of the shift register is authorized, and the receiver shifts into receive standby status. In the clock synchronous mode, the synchronous clock input and output of the SCLK terminal is authorized, too. When serial data is sent from the transmitter in this status, the data is loaded in the shift register. When receiving has completed, an interrupt is generated when the interrupt has been enabled.

The operation of the receiving control bit RXTRG is slightly different depending on whether the clock synchronous mode or the asynchronous mode is being used.

In the clock synchronous mode, RXTRG is used as a trigger to start receiving.

When received data has been read and the preparation for the next data receiving is completed, write "1" in RXTRG to start receiving. (In the slave mode, the  $\overline{\text{SRDY}}$  signal goes "0" when "1" is written to RXTRG.)

In the asynchronous mode, RXTRG is used to prepare for the next data receiving. After reading the received data from the receive data buffer, write "1" in RXTRG to signify that the receive data buffer is empty. If "1" is not written in RXTRG, the overrun error flag OER will be set to "1" when the next receiving is completed. (An overrun error will be generated when the next receiving is completed between reading the previously received data and the writing of "1" to RXTRG.)

RXTRG can also be read as a status. It goes "1" during receiving and goes "0" during standby (stopped) status. This function is the same in either the clock synchronous mode or the asynchronous mode.

Refer to Section 5.14.9, "Timing charts", for timing of receiving.

*Note: Do not set interface conditions, such as transfer mode, when the RXEN register is "1" (receiving authorize status). Setting except for receiving control must be done after writing "0" to the RXEN register.*

### 5.14.6 Receive error

During receiving the following three kinds of errors can be detected by an interrupt.

#### Parity error

When the EPR register has been set to "1" (with parity), a parity check is executing during receiving (except for the clock synchronous mode). The parity check is done when data received in the shift register is transferred to the receive data buffer. It checks matching with the receive data and the setting of the PMD register (odd parity or even parity). If they are not matched, it is recognized as a parity error and the parity error flag PER and the error interrupt factor flag FSERR are set to "1". An error interrupt is generated at this point when the interrupt has been enabled. The PER flag is reset to "0" by writing "1". The received data is transferred to the receive data buffer even when a parity error has generated, and the receiving operation also continues. However, the received data cannot be assured.

#### Framing error

When the serial interface receives a stop bit as "0", it judges that the synchronization is deviated and generates a framing error. When a framing error is generated, the framing error flag FER and the error interrupt factor flag FSERR are set to "1". An error interrupt is generated at this point when the interrupt has been enabled. The FER flag is reset to "0" by writing "1". The received data is transferred to the receive data buffer even when a framing error has generated, and the receiving operation also continues. However, even when the following data receiving does not generate a framing error, the data cannot be assured.

#### Overrun error

In the asynchronous mode, an overrun error occurs when the next data is received before writing "1" to RXTRG.

In the clock synchronous slave mode, an overrun error occurs when the next data is received before reading the received data.

When an overrun error is generated, the overrun error flag OER and the error interrupt factor flag FSERR are set to "1". An error interrupt is generated at this point when the interrupt has been enabled.

The OER flag is reset to "0" by writing "1".

The received data is transferred to the receive data buffer even when an overrun error has generated, and the receiving operation also continues. Furthermore, when the received data is transferred to the receive data buffer at the same time "1" is written to RXTRG in the asynchronous mode, it is recognized as an overrun error.

### 5.14.7 Interrupt function

The serial interface can generate the following three interrupts.

- Transmit completion interrupt
- Receive completion interrupt
- Receive error interrupt

The interrupt factor flag that indicates an interrupt factor generation and the interrupt enable register that enables and disables the interrupt are provided for each interrupt factor.

Furthermore, the priority level of the interrupt for the CPU can be set to an optional level (0-3) using the interrupt priority register.

Table 5.14.7.1 shows the interrupt control registers.

Refer to Section 5.20 "Interrupt and Standby Mode", for details of the interrupt control registers and operations subsequent to interrupt generation.

Figure 5.14.7.1 shows the configuration of the serial interface interrupt circuit.

Table 5.14.7.1 Interrupt control registers

| Interrupt factor    | Interrupt factor flag |            | Interrupt enable register |            | Interrupt priority register |            |
|---------------------|-----------------------|------------|---------------------------|------------|-----------------------------|------------|
|                     | Name                  | Address-Dx | Name                      | Address-Dx | Name                        | Address-Dx |
| Receive error       | FSERR                 | 00FF28H-D0 | ESERR                     | 00FF24H-D0 | PSI0                        | 00FF21H-D4 |
| Receive completion  | FSRX                  | 00FF28H-D1 | ESRX                      | 00FF24H-D1 | PSI1                        | 00FF21H-D5 |
| Transmit completion | FSTX                  | 00FF28H-D2 | ESTX                      | 00FF24H-D2 |                             |            |

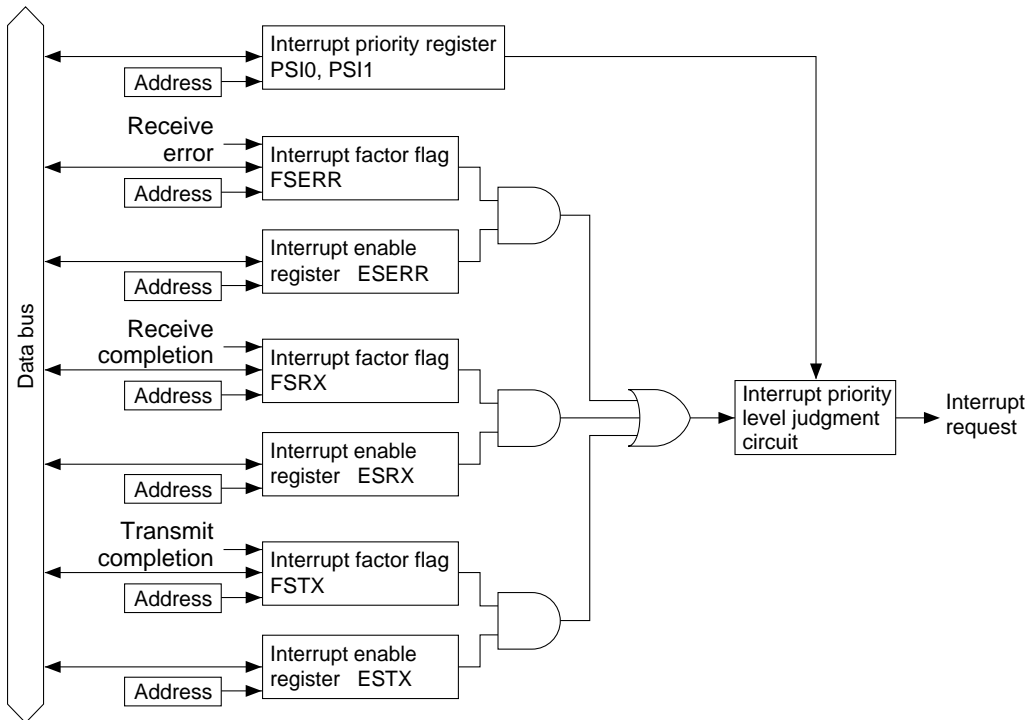


Fig. 5.14.7.1 Configuration of serial interface interrupt circuit

**Transmit completion interrupt**

This interrupt factor occurs when the transmission of the data written in the shift register has completed, and sets the interrupt factor flag FSTX to "1". It generates an interrupt to the CPU when the interrupt enable register ESTX has been set to "1" and the interrupt priority register PSI has been set to a higher level than the setting of the interrupt flag (I0, I1).

When the interrupt is disabled by setting the ESTX register to "0", interrupt does not occur to the CPU. However, even in this case the FSTX flag is set to "1".

The interrupt factor flag FSTX is reset to "0" by writing "1".

After the interrupt factor occurs, it is possible to write the next transmission data and to start the transmission (writing "1" to TXTRG).

The exception processing vector addresses for the transmit completion interrupt are set as follows:

Transmit completion interrupt: 00001EH

**Receive completion interrupt**

This interrupt factor occurs when the data received into the shift register is transferred to the receive data buffer after receiving is completed, and sets the interrupt factor flag FSRX to "1". It generates an interrupt to the CPU when the interrupt enable register ESRX has been set to "1" and the interrupt priority register PSI has been set to a higher level than the setting of the interrupt flag (I0, I1).

When the interrupt is disabled by setting the ESRX register to "0", interrupt does not occur to the CPU. However, even in this case the FSRX flag is set to "1".

The interrupt factor flag FSRX is reset to "0" by writing "1".

After the interrupt factor occurs, it is possible to read the received data.

The interrupt factor flag FSRX is set to "1" even when a parity error or a framing error has occurred.

The exception processing vector addresses for the receive completion interrupt are set as follows:

Receive completion interrupt: 00001CH

**Receive error interrupt**

This interrupt factor occurs when a parity error, a framing error or an overrun error is detected during receiving, and sets the interrupt factor flag FSERR to "1" at the same point of the receive completion interrupt generation. It generates an interrupt to the CPU when the interrupt enable register ESERR has been set to "1" and the interrupt priority register PSI has been set to a higher level than the setting of the interrupt flag (I0, I1). When the interrupt is disabled by setting the ESERR register to "0", interrupt does not occur to the CPU. However, even in this case the FSERR flag is set to "1".

The interrupt factor flag FSERR is reset to "0" by writing "1".

Since all three kinds of errors result in the same interrupt factor, the error generated should be distinguished using the error flags PER (parity error), OER (overrun error) and FER (framing error).

The exception processing vector addresses for the receive error interrupt are set as follows:

Receive error interrupt: 00001AH

*Note: When a parity error or a framing error occurs, both the receive error interrupt factor flag FSERR and the receive completion interrupt factor flag FSRX are simultaneously set to "1". However, since the receive error interrupt has priority over the receive completion interrupt, the receive error interrupt process is executed first. Therefore, it is necessary to reset the FSRX flag in the receive error handling routine. When a receive error interrupt occurs due to an overrun, receive completion interrupt does not occur.*

### 5.14.8 IR (Infrared-ray) interface

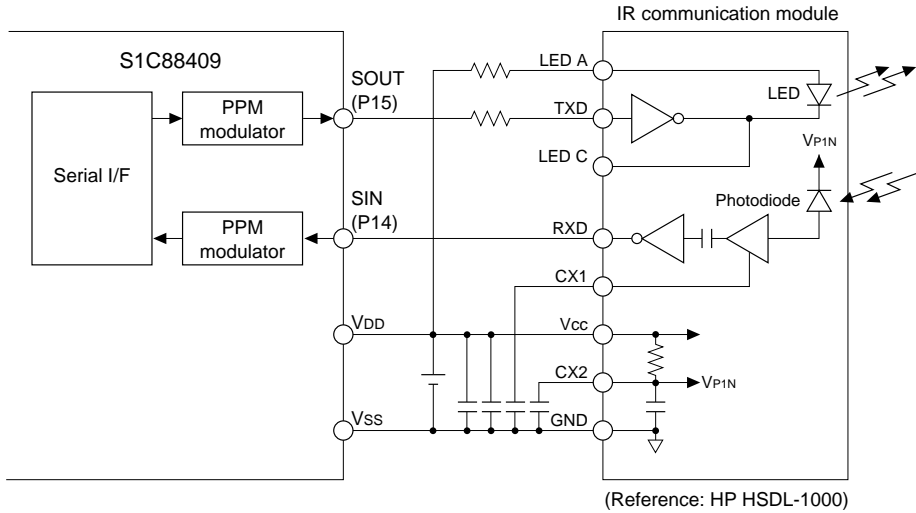


Fig. 5.14.8.1 Configuration example of IR interface

The serial interface has a built-in PPM modulator. Thus a circuit for infrared-ray communication based on IrDA (Infrared Data Association) standard can be configured by adding a simple external circuit.

#### Setting of IR interface

The PPM modulator is only available when the P14–P17 terminals are selected and the asynchronous mode is set.

When using the IR interface, change the function of the serial interface using the IRST register. (See Table 5.14.8.1.)

At initial reset, the serial interface is set as general interface.

When IR interface function is set, the serial interface can reverse the logic polarity of the input/output signal according to the infrared-ray communication module to be connected to the outside. It is negative logic usually. Reverse the logic when inputting and outputting positive logic signal.

The logic of the SIN input and SOUT output can be individually set by the IRIL register and the IRTL register. (See Tables 5.14.8.2 and 5.14.8.3.)

At initial reset, both the IRIL register and IRTL register are set to "0" (logic not reversed).

Table 5.14.8.1 Setting of IR interface

| IRST1 | IRST0 | Setting                                            |
|-------|-------|----------------------------------------------------|
| 1     | 1     | Reserved (do not set)                              |
| 1     | 0     | IR interface is used                               |
| 0     | 1     | Reserved (do not set)                              |
| 0     | 0     | IR interface is not used (normal interface is set) |

Table 5.14.8.2 Input logic of IR interface

| IRIL | Setting                                      |
|------|----------------------------------------------|
| 1    | SIN input logic is reversed (HIGH active)    |
| 0    | SIN input logic is not reversed (LOW active) |

Table 5.14.8.3 Output logic of IR interface

| IRTL | Setting                                        |
|------|------------------------------------------------|
| 1    | SOUT output logic is reversed (HIGH active)    |
| 0    | SOUT output logic is not reversed (LOW active) |

**Control of IR interface**

The PPM modulator converts input/output signals so that an IR pulse width becomes 3/16 of the pulse width asynchronous input/output signal.

The control procedure of data transfer is the same as in case of the asynchronous mode. Refer to Section 5.14.5 "Control procedure to transmit/receive".

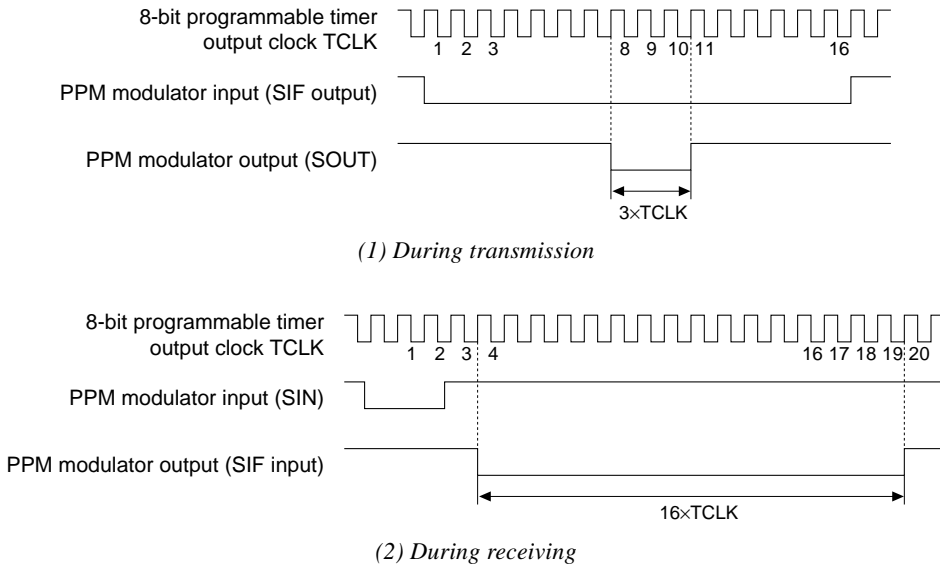


Fig. 5.14.8.2 Input/output signal

### 5.14.9 Timing charts

The following shows the transmit/receive timing chart for each transfer mode.

#### Clock synchronous master mode

This mode uses a clock generated by dividing the 8-bit programmable timer output in 1/16 as the synchronous clock  $\overline{\text{SCLK}}$ . (See Figure 5.14.4.1.)

##### (1) Transmission timing in clock synchronous master mode

Figure 5.14.9.1 shows the transmission timing in clock synchronous master mode.

By writing "1" to the TXTRG bit, the synchronous clock is output from the  $\overline{\text{SCLK}}$  terminal. Each bit of transmission data is output from the SOUT terminal at the falling edge of the synchronous clock. When the last bit is output, a transmit completion interrupt is generated at the rising edge of the synchronous clock.

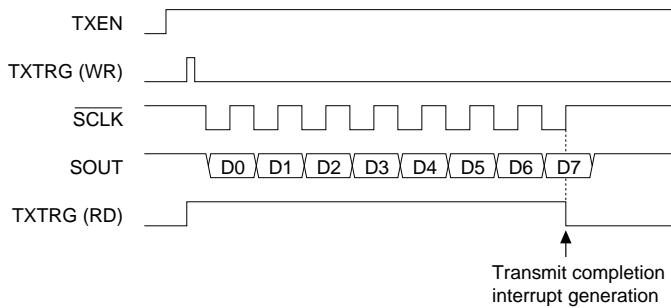


Fig. 5.14.9.1 Transmission timing (clock synchronous master mode)

Note: Do not write data to TXTRG, RXTRG and the TRXD register during transmission (while reading of TXTRG is "1").

##### (2) Receiving timing in clock synchronous master mode

Figure 5.14.9.2 shows the receiving timing in clock synchronous master mode.

By writing "1" to the RXTRG bit, the synchronous clock is output from the  $\overline{\text{SCLK}}$  terminal. The status of the SIN terminal is input at each rising edge of the synchronous clock. When the last bit is input, a receive completion interrupt is generated simultaneously. After the interrupt is generated, the received data can be read from the TRXD register.

Note: Do not write data to TXTRG, RXTRG and the TRXD register during receiving (while reading of RXTRG is "1").

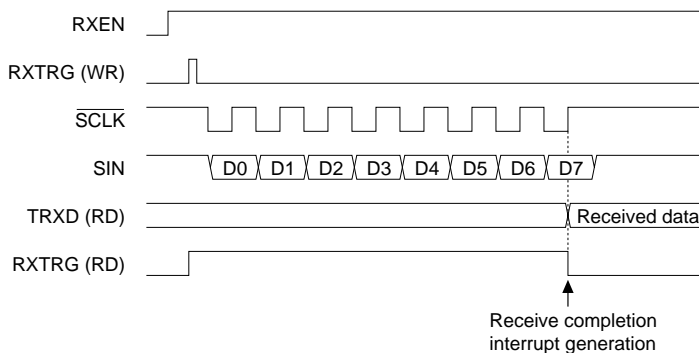


Fig. 5.14.9.2 Receiving timing (clock synchronous master mode)

**Clock synchronous slave mode**

This mode uses a clock input from the  $\overline{\text{SCLK}}$  terminal (output from the master device) as the synchronous clock  $\text{SCLK}$ .

**(1) Transmission timing in clock synchronous slave mode**

Figure 5.14.9.3 shows the transmission timing in clock synchronous slave mode. After writing "1" to the TXTRG bit each bit of transmission data is output from the SOUT terminal at the falling edge of the synchronous clock input from the  $\overline{\text{SCLK}}$  terminal. When the last bit is output, a transmit completion interrupt is generated at the rising edge of the synchronous clock.

*Note: Do not write data to TXTRG, RXTRG and the TRXD register during transmission (while reading of TXTRG is "1").*

**(2) Receiving timing in clock synchronous slave mode**

Figure 5.14.9.4 shows the receiving timing in clock synchronous slave mode. After writing "1" to the RXTRG bit, the status of the SIN terminal is input at each rising edge of the synchronous clock input from the  $\overline{\text{SCLK}}$  terminal. When the last bit is input, a receive completion interrupt is generated simultaneously.

After the interrupt is generated, the received data can be read from the TRXD register. When a parity error or a framing error (stop bit = "0") occurs, the error interrupt is generated at the same time as the receive completion interrupt. An overrun error occurs when the next data is received before reading the previous received data. In this case, the interrupt generation timing is the same as other interrupts.

*Note: Do not write data to TXTRG, RXTRG and the TRXD register during receiving (while reading of RXTRG is "1").*

**(3) Transmit/receive ready ( $\overline{\text{SRDY}}$ ) signal**

When the serial interface is used in the clock synchronous slave mode, it can output the  $\overline{\text{SRDY}}$  signal that indicates whether the serial interface is ready to transmit/receive or not. The  $\overline{\text{SRDY}}$  signal is output from the  $\overline{\text{SRDY}}$  terminal as "0" (low level) when the serial interface is in ready status (ready to transmit/receive) and as "1" (high level) when it is in busy status (during transmission/receiving). The  $\overline{\text{SRDY}}$  signal changes from "1" to "0" immediately after writing "1" to TXTRG or RXTRG, and returns from "0" to "1" when the first synchronous clock is input (at rising edge). (See Figure 5.14.9.3, Figure 5.14.9.4.)

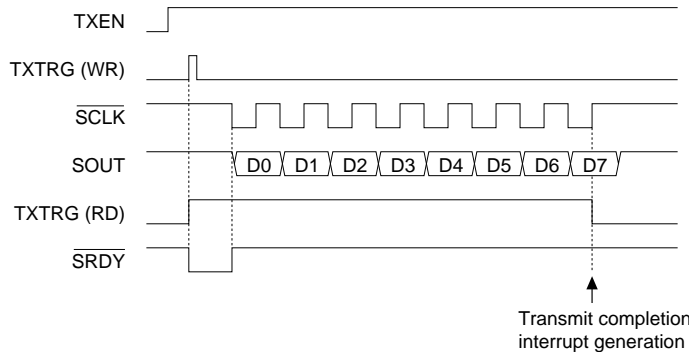


Fig. 5.14.9.3 Transmission timing (clock synchronous slave mode)

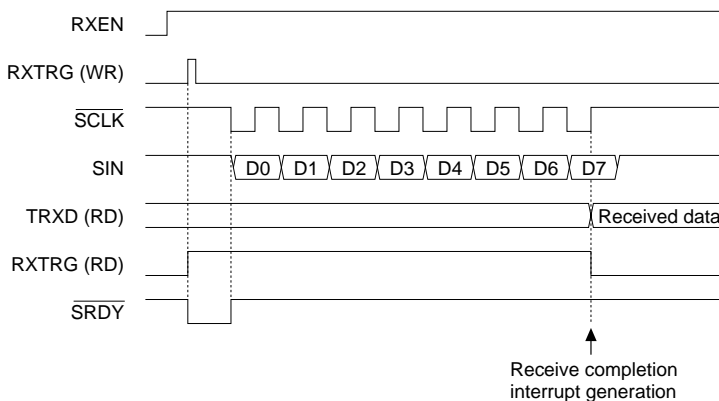


Fig. 5.14.9.4 Receiving timing (clock synchronous slave mode)



### Asynchronous mode

#### (1) Transmission timing in asynchronous mode

Figure 5.14.9.5 shows the transmission timing of the 8-bit asynchronous mode (stop bit = 2 bits, with parity).

After writing "1" to the TXTRG bit, each bit of transmission data is output from the SOUT terminal at the falling edge of the sampling clock generated internally. When the last bit is output, a transmit completion interrupt is generated at the rising edge of the clock. The sampling clock is generated by dividing the 8-bit programmable timer output in 1/16. (See Figure 5.14.4.3.)

#### (2) Receiving timing in asynchronous mode

Figure 5.14.9.6 shows the receiving timing of the 8-bit asynchronous mode (stop bit = 1 bit, with parity).

When a start bit is input from the SIN terminal, a sampling clock for data receiving is generated (see Figure 4.14.4.2). The status of the SIN terminal is input at each rising edge of the sampling clock. When the last stop bit is input, a receive completion interrupt is generated simultaneously. After the interrupt is generated, the received data can be read from the TRXD register. When a parity error or a framing error (stop bit = "0") occurs, the error interrupt is generated at the same time as the receive completion interrupt.

When receiving data in the asynchronous mode, it is necessary to write "1" to the RXTRG bit after reading received data. An internal signal OERCS checks overrun error. It goes "1" at the end of every data data receiving (immediately after inputting the stop bit), and goes "0" by writing "1" to the RXTRG bit. An overrun error occurs if the OERCS signal has not returned to "0" when the stop bit is input. In this case, the error interrupt is generated at the same time as the receive completion interrupt. When the received data is transferred to the receive data buffer at the same time "1" is written to RXTRG, it is recognized as an overrun error. Pay attention to the write timing.

*Note: When a parity error or a framing error occurs, both the receive error interrupt factor flag FSERR and the receive completion interrupt factor flag FSRX are simultaneously set to "1". However, since the receive error interrupt has priority over the receive completion interrupt, the receive error interrupt process is executed first. Therefore, it is necessary to reset the FSRX flag in the receive error handling routine. When a receive error interrupt occurs due to an overrun, receive completion interrupt does not occur.*

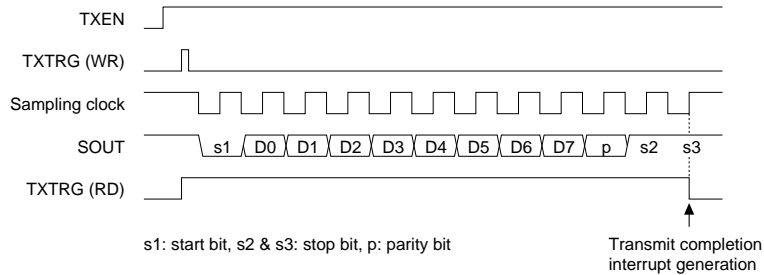


Fig. 5.14.9.5 Transmission timing (8-bit asynchronous mode, stop bit = 2 bits, with parity)

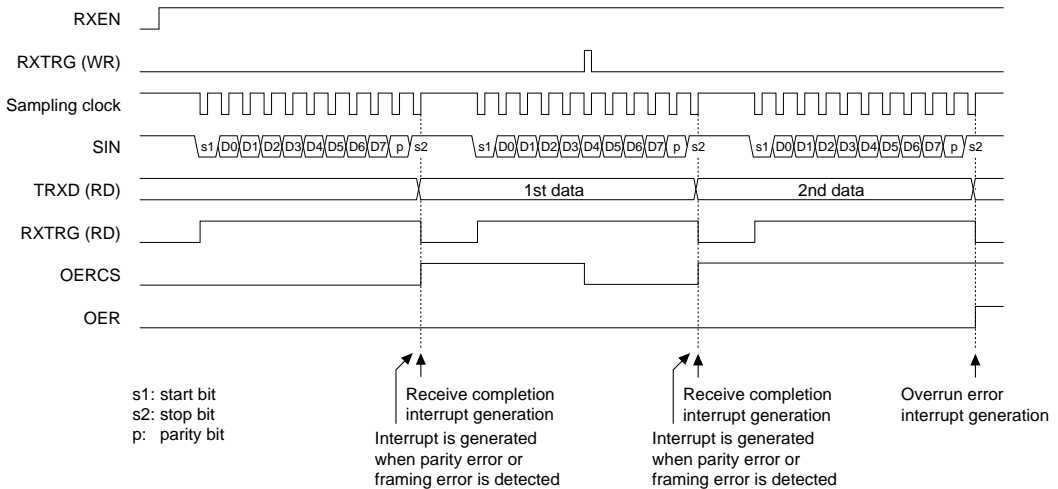


Fig. 5.14.9.6 Receiving timing (8-bit asynchronous mode, stop bit = 1 bit, with parity)

5.14.10 I/O memory of serial interface

Table 5.14.10.1 shows the serial interface control bits.

Table 5.14.10.1(a) Serial interface control bits

| Address                | Bit  | Name                         | Function                                                               | 1                                           | 0                                               | Init     | R/W   | Comment             |
|------------------------|------|------------------------------|------------------------------------------------------------------------|---------------------------------------------|-------------------------------------------------|----------|-------|---------------------|
| 00FF21                 | D7   | PTM21                        | 8-bit programmable timer                                               | PTM21                                       | PTM20                                           | 0        | R/W   |                     |
|                        | D6   | PTM20                        | interrupt priority register                                            | PSI1                                        | PSI0                                            | 0        | R/W   |                     |
|                        | D5   | PSI1                         | Serial interface                                                       | PCTM1                                       | PCTM0                                           | Priority | 0     | R/W                 |
|                        | D4   | PSI0                         | interrupt priority register                                            | PLCD1                                       | PLCD0                                           | level    | 0     | R/W                 |
|                        | D3   | PCTM1                        | Clock timer                                                            | 1                                           | 1                                               | Level 3  | 0     | R/W                 |
|                        | D2   | PCTM0                        | interrupt priority register                                            | 1                                           | 0                                               | Level 2  | 0     | R/W                 |
|                        | D1   | PLCD1                        | LCD controller                                                         | 0                                           | 1                                               | Level 1  | 0     | R/W                 |
|                        | D0   | PLCD0                        | interrupt priority register                                            | 0                                           | 0                                               | Level 0  | 0     | R/W                 |
| 00FF24                 | D7   | ETU2                         | 8-bit programmable timer<br>underflow interrupt enable register        | Interrupt is<br>enabled                     | Interrupt is<br>disabled                        | 0        | R/W   |                     |
|                        | D6   | ETC1                         | 16-bit programmable timer 1<br>compare match interrupt enable register |                                             |                                                 | 0        | R/W   |                     |
|                        | D5   | ETU1                         | 16-bit programmable timer 1<br>underflow interrupt enable register     |                                             |                                                 | 0        | R/W   |                     |
|                        | D4   | ETC0                         | 16-bit programmable timer 0<br>compare match interrupt enable register |                                             |                                                 | 0        | R/W   |                     |
|                        | D3   | ETU0                         | 16-bit programmable timer 0<br>underflow interrupt enable register     |                                             |                                                 | 0        | R/W   |                     |
|                        | D2   | ESTX                         | Serial interface<br>transmit completion interrupt enable register      |                                             |                                                 | 0        | R/W   |                     |
|                        | D1   | ESRX                         | Serial interface<br>receive completion interrupt enable register       |                                             |                                                 | 0        | R/W   |                     |
|                        | D0   | ESERR                        | Serial interface<br>receive error interrupt enable register            |                                             |                                                 | 0        | R/W   |                     |
| 00FF28                 | D7   | FTU2                         | 8-bit programmable timer<br>underflow interrupt factor flag            | (R)<br>Interrupt<br>factor has<br>generated | (R)<br>Interrupt<br>factor has not<br>generated | 0        | R/(W) |                     |
|                        | D6   | FTC1                         | 16-bit programmable timer 1<br>compare match interrupt factor flag     |                                             |                                                 | 0        | R/(W) |                     |
|                        | D5   | FTU1                         | 16-bit programmable timer 1<br>underflow interrupt factor flag         |                                             |                                                 | 0        | R/(W) |                     |
|                        | D4   | FTC0                         | 16-bit programmable timer 0<br>compare match interrupt factor flag     |                                             |                                                 | 0        | R/(W) |                     |
|                        | D3   | FTU0                         | 16-bit programmable timer 0<br>underflow interrupt factor flag         | (W)<br>Reset                                | (W)<br>Invalid                                  | 0        | R/(W) |                     |
|                        | D2   | FSTX                         | Serial interface<br>transmit completion interrupt factor flag          |                                             |                                                 | 0        | R/(W) |                     |
|                        | D1   | FSRX                         | Serial interface<br>receive completion interrupt factor flag           |                                             |                                                 | 0        | R/(W) |                     |
|                        | D0   | FSERR                        | Serial interface<br>receive error interrupt factor flag                |                                             |                                                 | 0        | R/(W) |                     |
| 00FF38                 | D7   | –                            | –                                                                      | –                                           | –                                               | –        | –     | "0" when being read |
|                        | D6   | –                            | –                                                                      | –                                           | –                                               | –        | –     |                     |
|                        | D5   | –                            | –                                                                      | –                                           | –                                               | –        | –     |                     |
|                        | D4   | –                            | –                                                                      | –                                           | –                                               | –        | –     |                     |
|                        | D3   | –                            | –                                                                      | –                                           | –                                               | –        | –     |                     |
|                        | D2   | PTOUT                        | 8-bit programmable timer clock output control                          | On                                          | Off                                             | 0        | R/W   |                     |
|                        | D1   | PSET                         | 8-bit programmable timer preset                                        | Preset                                      | Invalid                                         | –        | W     | "0" when being read |
|                        | D0   | PRUN                         | 8-bit programmable timer RUN/STOP control                              | Run                                         | Stop                                            | 0        | R/W   |                     |
| 00FF40                 | D7   | SIOSEL                       | Serial I/F terminal selection                                          | P14–P17                                     | P10–P13                                         | 0        | R/W   |                     |
|                        | D6   | EPR                          | Serial I/F parity enable                                               | With parity                                 | No parity                                       | 0        | R/W   |                     |
|                        | D5   | PMD                          | Serial I/F parity mode selection                                       | Odd                                         | Even                                            | 0        | R/W   |                     |
|                        | D4   | STPB                         | Serial I/F stop bit selection                                          | 2 bits                                      | 1 bit                                           | 0        | R/W   |                     |
|                        | D3   | –                            | –                                                                      | –                                           | –                                               | –        | –     | "0" when being read |
|                        | D2   | SMD1                         | Serial I/F mode selection                                              |                                             |                                                 | 0        | R/W   |                     |
|                        | D1   | SMD0                         | SMD1 SMD0 Mode                                                         |                                             |                                                 | 0        | R/W   |                     |
|                        |      |                              | 1 1 8-bit asynchronous                                                 |                                             |                                                 | 0        | R/W   |                     |
| 1 0 7-bit asynchronous |      |                              | 0                                                                      |                                             |                                                 | R/W      |       |                     |
| D0                     | ESIF | 0 1 Clock synchronous slave  | 0                                                                      | R/W                                         |                                                 |          |       |                     |
|                        |      | 0 0 Clock synchronous master | 0                                                                      | R/W                                         |                                                 |          |       |                     |
| D0                     | ESIF | Serial I/F enable            | Serial I/F                                                             | I/O port                                    | 0                                               | R/W      |       |                     |

Table 5.14.10.1(b) Serial interface control bits

| Address | Bit   | Name  | Function                                  | 1                     | 0                | Init   | R/W | Comment             |                                             |                                                   |
|---------|-------|-------|-------------------------------------------|-----------------------|------------------|--------|-----|---------------------|---------------------------------------------|---------------------------------------------------|
| 00FF41  | D7    | –     | –                                         | –                     | –                | –      | –   | "0" when being read |                                             |                                                   |
|         | D6    | FER   | Serial I/F framing error flag             | Error Reset (0)       | No error Invalid | 0      | R/W |                     |                                             |                                                   |
|         | D5    | PER   | Serial I/F parity error flag              | Error Reset (0)       | No error Invalid | 0      | R/W |                     |                                             |                                                   |
|         | D4    | OER   | Serial I/F overrun error flag             | Error Reset (0)       | No error Invalid | 0      | R/W |                     |                                             |                                                   |
|         | D3    | RXTRG | Serial I/F receive trigger/status         | Run Trigger           | Stop Invalid     | 0      | R/W |                     |                                             |                                                   |
|         | D2    | RXEN  | Serial I/F receive enable                 | Enable                | Disable          | 0      | R/W |                     |                                             |                                                   |
|         | D1    | TXTRG | Serial I/F transmit trigger/status        | Run Trigger           | Stop Invalid     | 0      | R/W |                     |                                             |                                                   |
|         | D0    | TXEN  | Serial I/F transmit enable                | Enable                | Disable          | 0      | R/W |                     |                                             |                                                   |
| 00FF42  | D7    | TRXD7 | Serial I/F transmit/receive data register | D7(MSB)               | High             | Low    | ×   | R/W                 | TRXD7 is invalid in 7-bit asynchronous mode |                                                   |
|         | D6    | TRXD6 |                                           | D6                    |                  |        | ×   | R/W                 |                                             |                                                   |
|         | D5    | TRXD5 |                                           | D5                    |                  |        | ×   | R/W                 |                                             |                                                   |
|         | D4    | TRXD4 |                                           | D4                    |                  |        | ×   | R/W                 |                                             |                                                   |
|         | D3    | TRXD3 |                                           | D3                    |                  |        | ×   | R/W                 |                                             |                                                   |
|         | D2    | TRXD2 |                                           | D2                    |                  |        | ×   | R/W                 |                                             |                                                   |
|         | D1    | TRXD1 |                                           | D1                    |                  |        | ×   | R/W                 |                                             |                                                   |
|         | D0    | TRXD0 |                                           | D0(LSB)               |                  |        | ×   | R/W                 |                                             |                                                   |
| 00FF43  | D7    | –     | –                                         | –                     | –                | –      | –   | "0" when being read |                                             |                                                   |
|         | D6    | –     | –                                         | –                     | –                | –      | –   |                     |                                             |                                                   |
|         | D5    | –     | –                                         | –                     | –                | –      | –   |                     |                                             |                                                   |
|         | D4    | –     | –                                         | –                     | –                | –      | –   |                     |                                             |                                                   |
|         | D3    | IRTL  | IrDA interface output logic inversion     |                       | Inverse          | Normal | 0   | R/W                 |                                             |                                                   |
|         | D2    | IRIL  | IrDA interface input logic inversion      |                       | Inverse          | Normal | 0   | R/W                 |                                             |                                                   |
|         | D1    | IRST1 | IrDA interface setting                    |                       |                  |        |     | 0                   | R/W                                         | Valid only when SIOSEL = "1" in asynchronous mode |
|         |       |       | IRST1                                     | IRST0                 | Setting          |        |     |                     |                                             |                                                   |
| D0      | IRST0 | 1     | 1                                         | Reserved (do not set) |                  |        | 0   | R/W                 |                                             |                                                   |
|         |       | 1     | 0                                         | IrDA interface        |                  |        |     |                     |                                             |                                                   |
|         |       | 0     | 1                                         | Reserved (do not set) |                  |        |     |                     |                                             |                                                   |
|         |       | 0     | 0                                         | Normal interface      |                  |        |     |                     |                                             |                                                   |

**ESIF: Serial interface enable register (00FF40H•D0)**

Sets the input/output terminals for serial interface.

- When "1" is written: Serial I/F I/O terminal
- When "0" is written: I/O port terminal
- Reading: Valid

The ESIF register is the serial interface enable register. When "1" is written to the register, specified I/O port terminals are set to the terminals for the serial interface. Refer to Section 5.14.2, "Transfer mode and input/output terminals", for the terminal configurations.

When "0" is written, they become the I/O port terminals.

At initial reset, the ESIF register is set to "0" (I/O port terminal).

**PTOUT: 8-bit programmable timer clock output control register (00FF38H•D2)**

Controls the clock output to the serial interface.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

The PTOUT register is the output control register of the 8-bit programmable timer. When "1" is written to this register, the clock (underflow \* 1/2) that is generated by the 8-bit programmable timer is output to the serial interface.

When "0" is written, the clock is not output to the serial interface.

Refer to Section 5.13, "8-bit Programmable Timer", for control of the 8-bit programmable timer.

At initial reset, the PTOUT register is set to "0" (OFF).

**SIOSEL: Terminal selection register (00FF40H•D7)**

Selects the terminals to be used for the serial interface input/output.

- When "1" is written: P14–P17
- When "0" is written: P10–P13
- Reading: Valid

When "1" is written to the SIOSEL register, the input/output terminals of the serial interface are assigned to P14–P17. When "0" is written, they are assigned to P10–P13. However, the terminals which are actually used within four the terminals are decided by the transfer mode setting (SMD register).

When using IR interface, be sure to set the SIOSEL register to "1" (P14–P17).

At initial reset, the SIOSEL register is set to "0" (P10–P13).

**SMD0, SMD1: Mode selection register (00FF40H•D1, D2)**

Sets the transfer mode as shown in Table 5.14.10.2.

Table 5.14.10.2 Transfer mode settings

| SMD1 | SMD0 | Mode                     |
|------|------|--------------------------|
| 1    | 1    | 8-bit asynchronous       |
| 1    | 0    | 7-bit asynchronous       |
| 0    | 1    | Clock synchronous slave  |
| 0    | 0    | Clock synchronous master |

The SMD register can also be read.

When using IR interface, be sure to set in the asynchronous mode.

At initial reset, the SMD register is set to "0" (clock synchronous master mode).

**STPB: Stop bit selection register (00FF40H•D4)**

Selects the stop bit length asynchronous transfer.

- When "1" is written: 2 bits
- When "0" is written: 1 bit
- Reading: Valid

The STPB register is the stop bit selection register that is valid only for asynchronous transfer. When "1" is written to the register, the stop bit length is set in 2 bits. When "0" is written, it is set in 1 bit. The start bit length is fixed at 1 bit.

The start/stop bit cannot be added for clock synchronous transfer. Therefore, the setting of the STPB register is invalid.

At initial reset, the STPB register is set to "0" (1 bit).

**EPR: Parity enable register (00FF40H•D6)**

Selects the parity function.

- When "1" is written: With parity
- When "0" is written: No parity
- Reading: Valid

The EPR register is the parity enable register. By setting this register, parity check for received data and addition of a parity bit to transmission data can be enabled. When "1" is written to the register, the most significant bit of received data is regarded as a parity bit and a parity check is executed and a parity bit is added to transmission data. When "0" is written, neither a parity check nor adding a parity bit is done.

This setting is valid only in the asynchronous mode. It is invalid in the clock synchronous mode. At initial reset, the EPR register is set to "0" (no parity).

**PMD: Parity mode selection register (00FF40H•D5)**

Selects odd parity or even parity.

- When "1" is written: Odd parity
- When "0" is written: Even parity
- Reading: Valid

The PMD register is the parity mode selection register. When "1" is written to the register, odd parity is selected. When "0" is written, even parity is selected. The parity check and addition of a parity bit are valid only when "1" has been written to the EPR register. When "0" has been written to the EPR register, parity setting by the PMD register is invalid. At initial reset, the PMD register is set to "0" (even parity).

**TXEN: Transmission enable register (00FF41H•D0)**

Sets the serial interface to the transmission authorize status.

- When "1" is written: Transmission is enabled
- When "0" is written: Transmission is disabled
- Reading: Valid

The TXEN register is the transmission enable register. When "1" is written to the register, the serial interface shifts to a transmission authorize status. When "0" is written, it shifts to a transmission disabling status.

Set the TXEN register to "0" when setting the transfer mode.

At initial reset, the TXEN register is set to "0" (transmission is disabled).

**TXTRG: Transmission trigger/status (00FF41H•D1)**

This bit is used as the transmission start trigger and the operation status indicator (transmission/stop status).

When "1" is read: During transmission  
When "0" is read: During stop

When "1" is written: Transmission trigger  
When "0" is written: Invalid

TXTRG is the transmission control bits (trigger/status). Transmission starts when "1" is written to TXTRG after writing the transmission data. TXTRG can be read as the status. When it is "1", it indicates transmission, and "0" indicates stoppage. At initial reset, TXTRG is set to "0" (during stop).

**RXEN: Receiving enable register (00FF41H•D2)**

Sets the serial interface to the receiving authorize status.

When "1" is written: Receiving is enabled  
When "0" is written: Receiving is disabled  
Reading: Valid

The RXEN register is the receiving enable register. When "1" is written to the register, the serial interface shifts to a receiving authorize status. When "0" is written, it shifts to a receiving disabling status.

Set the RXEN register to "0" when setting the transfer mode.

At initial reset, the RXEN is set to "0" (receiving is disabled).

**RXTRG: Receiving trigger/status (00FF41H•D3)**

This bit is used as the receiving start trigger, ready to receive and the operation status indicator (receiving/stop status).

When "1" is read: During receiving  
When "0" is read: During stop

When "1" is written: Receiving trigger  
/Ready to receive  
When "0" is written: Invalid

RXTRG is the receiving control bits (trigger/status).

In the clock synchronous mode, RXTRG is used as a trigger to start receiving.

When received data has been read and the preparation for the next data receiving is completed, write "1" in RXTRG to start receiving.

In the asynchronous mode, RXTRG is used to prepare for the next data receiving. After reading the received data from the receive data buffer, write "1" in RXTRG to signify that the receive data buffer is empty. If "1" is not written in RXTRG, the overrun error flag OER will be set to "1" when the next receiving is completed. (An overrun error will be generated when the next receiving is completed between reading the previous received data and the writing of "1" to RXTRG.)

RXTRG can also be read as a status. When it is "1", it indicates receiving, and "0" indicates stoppage. This function is the same in both the clock synchronous mode and the asynchronous mode. At initial reset, RXTRG is set to "0" (during stop).

**TRXD0–TRXD7: Transmit/receive data register (00FF42H)**

The TRXD register is the transmit/receive data register for the serial interface.

During transmission

Write a transmission data to this register.

When "1" is written: HIGH level  
When "0" is written: LOW level

Write the transmitting data prior to start transmission.

When transmitting data continuously, following data should be written after the transmit completion interrupt occurs.

In the 7-bit asynchronous mode, TRXD7 is invalid. The data written in this register is converted into serial data, and output from the SOUT terminal as the bit set to "1" is a high (VDD) level and the bit set to "0" is a low (VSS) level.

During receiving

Received data can be read from this register.

When "1" is read: HIGH level  
When "0" is read: LOW level

The data in the receive data buffer can be read. Received data should be read after the receive completion interrupt occurs.

In the asynchronous mode, the received data can be read even while the next data is being received because the receive data buffer is provided separately from the shift register. (The buffer function is not used in the clock synchronous mode.)

In the 7-bit asynchronous mode, TRXD7 is always read as "0".

The serial data input from the SIN terminal is loaded into this buffer after converting into parallel data as the bit of a high (VDD) level is "1" and the bit of a low (VSS) level is "0".

At initial reset, the content of the TRXD register is undefined.

**OER: Overrun error flag (00FF41H•D4)**

Indicates the occurrence of an overrun error.

- When "1" is read: Error
- When "0" is read: No error
- When "1" is written: Reset to "0"
- When "0" is written: Invalid

OER is the error flag that indicates the occurrence of an overrun error. The flag goes "1" when an overrun error occurs.

In the asynchronous mode, an overrun error occurs when the next data is received prior to writing "1" to RXTRG.

In the clock synchronous slave mode, an overrun error occurs when the next data is received prior to reading the received data.

In the clock synchronous master mode, overrun error does not occur.

The OER flag is reset to "0" by writing "1".

At initial reset and when the RXEN register is "0", the OER flag is set to "0" (no error).

**PER: Parity error flag (00FF41H•D5)**

Indicates the occurrence of a parity error.

- When "1" is read: Error
- When "0" is read: No error
- When "1" is written: Reset to "0"
- When "0" is written: Invalid

PER is the error flag that indicates the occurrence of a parity error. The flag goes "1" when a parity error occurs.

The PER flag is reset to "0" by writing "1".

At initial reset and when the RXEN register is "0", the PER flag is set to "0" (no error).

**FER: Framing error flag (00FF41H•D6)**

Indicates the occurrence of a framing error.

- When "1" is read: Error
- When "0" is read: No error
- When "1" is written: Reset to "0"
- When "0" is written: Invalid

FER is the error flag that indicates the occurrence of a framing error. The flag goes "1" when a framing error occurs.

Framing error occurs when a stop bit is received as "0".

The FER flag is reset to "0" by writing "1".

At initial reset and when the RXEN register is "0", the FER flag is set to "0" (no error).

**PSI0, PSI1: Interrupt priority register (00FF21H•D4, D5)**

Sets the priority level of the serial interface interrupt.

The PSI register is the interrupt priority register corresponding to the serial interface interrupt.

Table 5.14.10.3 shows the interrupt priority level which can be set by this register.

Table 5.14.10.3 Interrupt priority level settings

| PSI1 | PSI0 | Interrupt priority level |
|------|------|--------------------------|
| 1    | 1    | Level 3 (IRQ3)           |
| 1    | 0    | Level 2 (IRQ2)           |
| 0    | 1    | Level 1 (IRQ1)           |
| 0    | 0    | Level 0 (None)           |

At initial reset, the PSI register is set to "0" (level 0).

**ESERR, ESRX, ESTX: Interrupt enable register (00FF24H•D0, D1, D2)**

Enables or disables the serial interface interrupt generation to the CPU.

- When "1" is written: Interrupt is enabled
- When "0" is written: Interrupt is disabled
- Reading: Valid

The ESERR, ESRX and ESTX registers are interrupt enable registers corresponding to the receive error, receive completion and transmit completion interrupt factors, respectively.

Interrupt in which the interrupt enable register is set to "1" is enabled, and the others in which the register is set to "0" are disabled.

At initial reset, the interrupt enable registers are all set to "0" (interrupt is disabled).

**FSERR, FSRX, FSTX: Interrupt factor flag  
(00FF28H•D0, D1, D2)**

Indicates the generation of the serial interface interrupt factor.

When "1" is read: Int. factor has generated

When "0" is read: Int. factor has not generated

When "1" is written: Factor flag is reset

When "0" is written: Invalid

The FSERR, FSRX and FSTX flags are interrupt factor flags corresponding to the receive error, receive completion and transmit completion interrupts, respectively. They are set to "1" by a generation of each factor.

Transmit completion interrupt factor is generated when a transmission of the shift register data is completed.

Receive completion interrupt factor is generated when the received data is transferred to the receive data buffer.

Receive error interrupt factor is generated when a parity error, framing error or overrun error has been detected during data receiving.

At this point, if the corresponding interrupt enable register is set to "1" and the corresponding interrupt priority register is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.

Regardless of the interrupt enable register and interrupt priority register settings, the interrupt factor flag is set to "1" when the interrupt generation condition is met.

To accept the subsequent interrupt after an interrupt generation, it is necessary to re-set the interrupt flags (set the interrupt flag to a lower level than the level indicated by the interrupt priority registers, or execute the RETE instruction) and to reset the interrupt factor flag. The interrupt factor flag is reset to "0" by writing "1".

At initial reset, the interrupt factor flags are all reset to "0".

**5.14.11 Programming notes**

- (1) Setting of the serial interface mode must be done in the transmission/receiving disabling status (TXEN = RXEN = "0").
- (2) Do not perform double trigger (writing "1" to TXTRG (RXTRG) during transmission (receiving). Furthermore, do not execute the SLP instruction. (When executing the SLP instruction, set TXEN and RXEN to "0".)
- (3) Transmission and receiving cannot be done simultaneously in the clock synchronous mode because the clock line (SCLK) is shared with transmit and receive operation. Therefore, do not write "1" to RXTRG (TXTRG) when TXTRG (RXTRG) is "1".
- (4) When a parity error or a framing error occurs, both the receive error interrupt factor flag FSERR and the receive completion interrupt factor flag FSRX are simultaneously set to "1". However, since the receive error interrupt has priority over the receive completion interrupt, the receive error interrupt process is executed first. Therefore, it is necessary to reset the FSRX flag in the receive error handling routine. When a receive error interrupt occurs due to an overrun, receive completion interrupt does not occur.

## 5.15 Sound Generator

### 5.15.1 Configuration of sound generator

The S1C88409 has a built-in sound generator for generating BZ (buzzer) signal. BZ signals generated from the sound generator can be output from the R42 output port terminal. Aside permitting the respective setting of the buzzer signal frequency and sound level (duty adjustment) to 8 stages, it permits the adding of a digital envelope by means of duty ratio control. It also has a one-shot output function for outputting key operated sounds. Figure 5.15.1.1 shows the configuration of the sound generator.

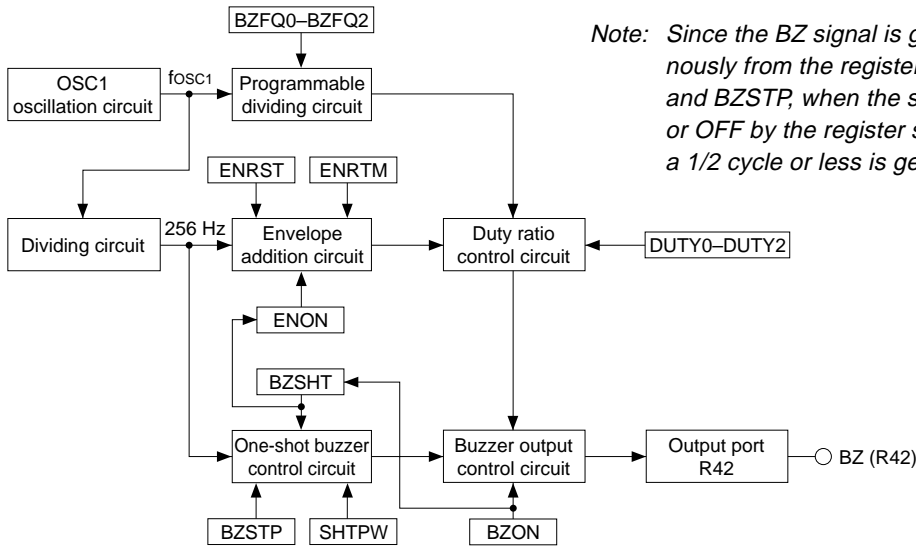


Fig. 5.15.1.1 Configuration of sound generator

### 5.15.2 Control of buzzer output

BZ signal can be output from the R42 output port terminal. The configuration of the output port R42 is shown in Figure 5.15.2.1.

The output control for the BZ signal generated by the sound generator is done by the buzzer output control register BZON, one-shot buzzer trigger bit BZSHT and one-shot buzzer forced stop bit BZSTP. When "1" is set to BZON or BZSHT, the BZ signal is output from the R42 output port terminal and when "0" is set to BZON or "1" is set to BZSTP, the high (VDD) level is output. At this time, "1" must always be set for the output data register R42D. Figure 5.15.2.2 shows the output waveform of the BZ signal.

*Note: Since the BZ signal is generated asynchronously from the registers BZON, BZSHT and BZSTP, when the signal is turned ON or OFF by the register settings, a hazard of a 1/2 cycle or less is generated.*

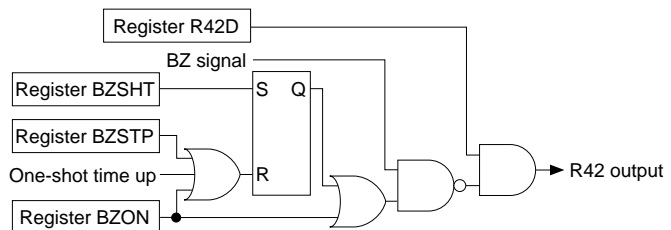


Fig. 5.15.2.1 Configuration of R42

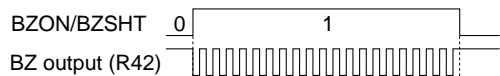


Fig. 5.15.2.2 Output waveform of BZ signal



### 5.15.3 Setting of buzzer frequency and sound level

The BZ signal is a divided signal using the OSC1 oscillation circuit (32.768 kHz) as the clock source and 8 frequencies can be selected. This selection is done by the buzzer frequency selection register BZFQ0–BZFQ2. The setting value and buzzer frequency correspondence is shown in Table 5.15.3.1.

By selecting the duty ratio of the BZ signal from among 8 types, the buzzer sound level can be adjusted. This selection is made in the duty ratio selection register DUTY0–DUTY2. The setting value and duty ratio correspondence is shown in Table 5.15.3.2.

Table 5.15.3.1 Buzzer signal frequency settings

| BZFQ2 | BZFQ1 | BZFQ0 | Buzzer frequency (Hz) |
|-------|-------|-------|-----------------------|
| 0     | 0     | 0     | 4096.0                |
| 0     | 0     | 1     | 3276.8                |
| 0     | 1     | 0     | 2730.7                |
| 0     | 1     | 1     | 2340.6                |
| 1     | 0     | 0     | 2048.0                |
| 1     | 0     | 1     | 1638.4                |
| 1     | 1     | 0     | 1365.3                |
| 1     | 1     | 1     | 1170.3                |

Table 5.15.3.2 Duty ratio settings

| Level         | DUTY2 | DUTY1 | DUTY0 | Duty ratio by buzzer frequencies (Hz) |        |        |        |
|---------------|-------|-------|-------|---------------------------------------|--------|--------|--------|
|               |       |       |       | 4096.0                                | 3276.8 | 2730.7 | 2340.6 |
|               |       |       |       | 2048.0                                | 1638.4 | 1365.3 | 1170.3 |
| Level 1 (Max) | 0     | 0     | 0     | 8/16                                  | 8/20   | 12/24  | 12/28  |
| Level 2       | 0     | 0     | 1     | 7/16                                  | 7/20   | 11/24  | 11/28  |
| Level 3       | 0     | 1     | 0     | 6/16                                  | 6/20   | 10/24  | 10/28  |
| Level 4       | 0     | 1     | 1     | 5/16                                  | 5/20   | 9/24   | 9/28   |
| Level 5       | 1     | 0     | 0     | 4/16                                  | 4/20   | 8/24   | 8/28   |
| Level 6       | 1     | 0     | 1     | 3/16                                  | 3/20   | 7/24   | 7/28   |
| Level 7       | 1     | 1     | 0     | 2/16                                  | 2/20   | 6/24   | 6/28   |
| Level 8 (Min) | 1     | 1     | 1     | 1/16                                  | 1/20   | 5/24   | 5/28   |

Duty ratio refers to the ratio of pulse width to the pulse cycle; given that HIGH level output time is TH, and low level output time is TL the BZ signal becomes  $TL/(TH+TL)$ .

When DUTY0–DUTY2 have all been set to "0", the duty ratio becomes maximum and the sound level also becomes maximum. Conversely, when DUTY0–DUTY2 have all been set to "1", the duty ratio becomes minimum and the sound level also becomes minimum.

Note that the duty ratio setting differ depending on frequency. See Table 5.15.3.2.

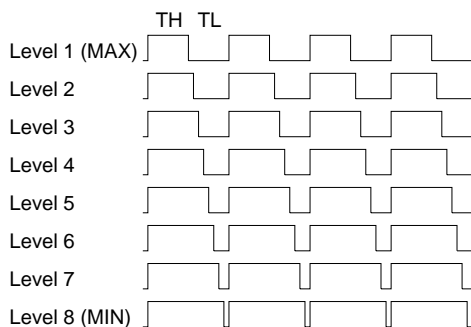


Fig. 5.15.3.1 Duty ratio of buzzer signal waveform

Note: When using the digital envelope, the DUTY0–DUTY2 setting becomes invalid.

### 5.15.4 Digital envelope

A digital envelope with duty control can be added to the BZ signal.

The envelope can be realized by staged changing of the same duty ratio as detailed in Table 5.15.3.2 in the preceding section from level 1 (maximum) to level 8 (minimum).

The addition of an envelope to the buzzer signal can be done by writing "1" to the envelope control register ENON. When "0" is written, the duty ratio is set at the level selected in DUTY0–DUTY2.

By writing "1" to ENON and turning the buzzer output ON (writing "1" to BZON), a BZ signal with a level 1 duty ratio is output, and then the duty ratio can be attenuated in stages to level 8. The attenuated envelope can be returned to level 1 by writing "1" to the envelope reset bit ENRST. When attenuated to level 8, the duty level remains at level 8 until the buzzer output is turned OFF (writing "0" to BZON) or writing "1" to ENRST. The stage changing time for the envelope level can be selected either 125 msec or 62.5 msec by the envelope attenuation time selection register ENRTM.

Figure 5.15.4.1 shows the timing chart of the digital envelope.

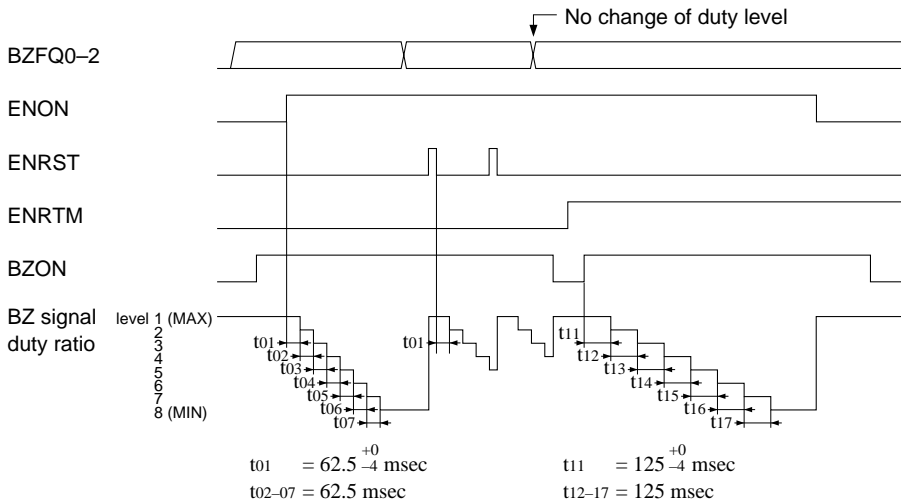


Fig. 5.15.4.1 Timing chart of digital envelope

### 5.15.5 One-shot output

The sound generator has a built-in one-shot output function for outputting a short duration buzzer signal for key operation sounds and similar effects. Either 125 msec or 31.25 msec can be selected by the one-shot buzzer duration selection register SHTPW for buzzer signal output time.

The output control of the one-shot buzzer is done by writing "1" to the one-shot buzzer trigger BZSHT, then the BZ signal is output in synchronization with the internal 256 Hz signal from the R42 output port terminal. Thereafter, when the set time has elapsed, the BZ signal in synchronization with the 256 Hz signal automatically goes OFF in the same manner.

The BZSHT can be read to determine status. When BZSHT is "1", it indicates a BUSY status (during one-shot output) and when BZSHT is "0", it indicates a READY status (during stop).

When you want to turn the BZ signal OFF prior to the elapse of the set time, the BZ signal can be immediately stopped (goes OFF in asynchronization with 256 Hz signal) by writing "1" to the one-shot forced stop bit BZSTP.

Since the one-shot output has a short duration, an envelope cannot be added. (When "1" is written to BZSHT, ENON is automatically reset to "0".)

Consequently, only the frequency and sound level can be set for one-shot output.

The control for the one-shot output is invalid during normal buzzer output.

Figure 5.15.5.1 shows the timing chart of the one-shot output.

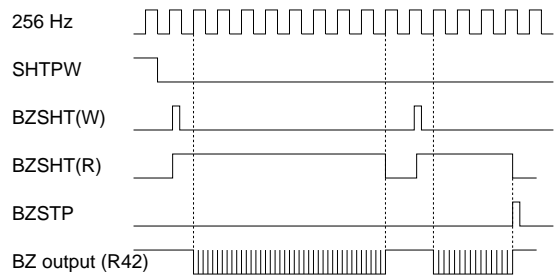


Fig. 5.15.5.1 Timing chart of one-shot output

### 5.15.6 I/O memory of sound generator

Table 5.15.6.1 shows the sound generator control bits.

Table 5.15.6.1 Sound generator control bits

| Address | Bit   | Name                       | Function                                      | 1                     | 0            | Init   | R/W  | Comment             |                     |        |        |        |        |
|---------|-------|----------------------------|-----------------------------------------------|-----------------------|--------------|--------|------|---------------------|---------------------|--------|--------|--------|--------|
| 00FF54  | D7    | –                          | –                                             | –                     | –            | –      | –    | "0" when being read |                     |        |        |        |        |
|         | D6    | BZSTP                      | One-shot buzzer forcibly stop                 | Forcibly stop         | No operation | –      | W    |                     |                     |        |        |        |        |
|         | D5    | BZSHT                      | One-shot buzzer trigger/status                | Busy                  | Ready        | 0      | R    |                     |                     |        |        |        |        |
|         |       |                            |                                               | Trigger               | No operation | 0      | W    |                     |                     |        |        |        |        |
|         | D4    | SHTPW                      | One-shot buzzer duration width selection      | 125 msec              | 31.25 msec   | 0      | R/W  |                     |                     |        |        |        |        |
|         | D3    | ENRTM                      | Envelope attenuation time                     | 1 sec                 | 0.5 sec      | 0      | R/W  |                     |                     |        |        |        |        |
|         | D2    | ENRST                      | Envelope reset                                | Reset                 | No operation | –      | W    | "0" when being read |                     |        |        |        |        |
|         | D1    | ENON                       | Envelope On/Off control                       | On                    | Off          | 0      | R/W  | *1                  |                     |        |        |        |        |
| D0      | BZON  | Buzzer output control      | On                                            | Off                   | 0            | R/W    |      |                     |                     |        |        |        |        |
| 00FF55  | D7    | –                          | –                                             | –                     | –            | –      | –    | "0" when being read |                     |        |        |        |        |
|         | D6    | DUTY2                      | Buzzer signal duty ratio selection<br>DUTY2–1 | Buzzer frequency (Hz) |              |        | 0    | R/W                 |                     |        |        |        |        |
|         |       |                            |                                               | 2                     | 1            | 0      |      |                     |                     | 4096.0 | 3276.8 | 2730.7 | 2340.6 |
|         | D5    | DUTY1                      |                                               | 0                     | 0            | 0      | 8/16 | 8/20                | 12/24               | 12/28  | 0      | R/W    |        |
|         |       |                            |                                               | 0                     | 0            | 1      | 7/16 | 7/20                | 11/24               | 11/28  |        |        |        |
|         |       |                            |                                               | 0                     | 1            | 0      | 6/16 | 6/20                | 10/24               | 10/28  |        |        |        |
|         |       |                            |                                               | 0                     | 1            | 1      | 5/16 | 5/20                | 9/24                | 9/28   |        |        |        |
|         | D4    | DUTY0                      |                                               | 1                     | 0            | 0      | 4/16 | 4/20                | 8/24                | 8/28   | 0      | R/W    |        |
|         |       |                            |                                               | 1                     | 0            | 1      | 3/16 | 3/20                | 7/24                | 7/28   |        |        |        |
|         |       |                            |                                               | 1                     | 1            | 0      | 2/16 | 2/20                | 6/24                | 6/28   |        |        |        |
|         |       |                            |                                               | 1                     | 1            | 1      | 1/16 | 1/20                | 5/24                | 5/28   |        |        |        |
|         | D3    | –                          | –                                             | –                     | –            | –      | –    | –                   | "0" when being read |        |        |        |        |
| D2      | BZFQ2 | Buzzer frequency selection | BZFQ2 BZFQ1 BZFQ0                             |                       |              | 0      | R/W  |                     |                     |        |        |        |        |
|         |       |                            | Frequency (Hz)                                |                       |              |        |      |                     |                     |        |        |        |        |
| D1      | BZFQ1 |                            | 0                                             | 0                     | 0            | 4096.0 | 0    | R/W                 |                     |        |        |        |        |
|         |       |                            | 0                                             | 0                     | 1            | 3276.8 |      |                     |                     |        |        |        |        |
|         |       |                            | 0                                             | 1                     | 0            | 2730.7 |      |                     |                     |        |        |        |        |
|         |       |                            | 0                                             | 1                     | 1            | 2340.6 |      |                     |                     |        |        |        |        |
| D0      | BZFQ0 |                            | 1                                             | 0                     | 0            | 2048.0 | 0    | R/W                 |                     |        |        |        |        |
|         |       |                            | 1                                             | 0                     | 1            | 1638.4 |      |                     |                     |        |        |        |        |
|         |       |                            | 1                                             | 1                     | 0            | 1365.3 |      |                     |                     |        |        |        |        |
|         |       |                            | 1                                             | 1                     | 1            | 1170.3 |      |                     |                     |        |        |        |        |

\*1 ENON is reset to "0" during one-shot output.

#### BZON: Buzzer output control register (00FF54H•D0)

Controls the BZ signal output.

When "1" is written: BZ signal output

When "0" is written: HIGH level (DC) output

Reading: Valid

BZON is the output control register for BZ signal. When "1" is set, the BZ signal is output from the output port terminal R42 and when "0" is set, high (VDD) level is output. At this time, the high-impedance control register of the output port R42 must be set to "0" and the data register must be set to "1".

At initial reset, BZON is set to "0" (high level output).

#### BZFQ0–BZFQ2: Buzzer frequency selection register (00FF55H•D0–D2)

Selects the BZ signal frequency.

Table 5.15.6.2 Buzzer frequency settings

| BZFQ2 | BZFQ1 | BZFQ0 | Buzzer frequency (Hz) |
|-------|-------|-------|-----------------------|
| 0     | 0     | 0     | 4096.0                |
| 0     | 0     | 1     | 3276.8                |
| 0     | 1     | 0     | 2730.7                |
| 0     | 1     | 1     | 2340.6                |
| 1     | 0     | 0     | 2048.0                |
| 1     | 0     | 1     | 1638.4                |
| 1     | 1     | 0     | 1365.3                |
| 1     | 1     | 1     | 1170.3                |

The buzzer frequency can be selected from among the above 8 types that have divided the OSC1 clock.

At initial reset, the BZFQ register is set to "0" (4096.0 Hz).

**DUTY0–DUTY2: Duty ratio selection register (00FF55H•D4–D6)**

Selects the duty ratio of the BZ signal.

Table 5.15.6.3 Duty ratio settings

| Level         | DUTY2 | DUTY1 | DUTY0 | Duty ratio by buzzer frequencies (Hz) |        |        |        |
|---------------|-------|-------|-------|---------------------------------------|--------|--------|--------|
|               |       |       |       | 4096.0                                | 3276.8 | 2730.7 | 2340.6 |
|               |       |       |       | 2048.0                                | 1638.4 | 1365.3 | 1170.3 |
| Level 1 (Max) | 0     | 0     | 0     | 8/16                                  | 8/20   | 12/24  | 12/28  |
| Level 2       | 0     | 0     | 1     | 7/16                                  | 7/20   | 11/24  | 11/28  |
| Level 3       | 0     | 1     | 0     | 6/16                                  | 6/20   | 10/24  | 10/28  |
| Level 4       | 0     | 1     | 1     | 5/16                                  | 5/20   | 9/24   | 9/28   |
| Level 5       | 1     | 0     | 0     | 4/16                                  | 4/20   | 8/24   | 8/28   |
| Level 6       | 1     | 0     | 1     | 3/16                                  | 3/20   | 7/24   | 7/28   |
| Level 7       | 1     | 1     | 0     | 2/16                                  | 2/20   | 6/24   | 6/28   |
| Level 8 (Min) | 1     | 1     | 1     | 1/16                                  | 1/20   | 5/24   | 5/28   |

The buzzer sound level can be adjusted by selecting the duty ratio from among the above 8 types. However, when the envelope has been set to ON (ENON = "1"), this setting becomes invalid.

At initial reset, the DUTY register is set to "0" (level 1).

**ENRST: Envelope reset (00FF54H•D2)**

Resets the envelope.

- When "1" is written: Reset
- When "0" is written: No operation
- Reading: Always "0"

The envelope is reset by writing "1" to ENRST and the duty ratio returns to level 1 (maximum). Writing "0" to ENRST and writing "1" when an envelope has not been added become invalid. Since ENRST is exclusively for writing, it always becomes "0" during reading.

**ENON: Envelope ON/OFF control register (00FF54H•D1)**

Controls the addition of an envelope to the BZ signal.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

By writing "1" to ENON, an envelope can be added to BZ signal output. When "0" is written, an envelope is not added and the BZ signal is fixed at the duty ratio selected in DUTY0–DUTY2. At initial reset and when "1" is written to BZSHT, the ENON register is set to "0" (OFF).

**ENRTM: Envelope attenuation time selection register (00FF54H•D3)**

Selects the envelope attenuation time that is added to the BZ signal.

- When "1" is written: 1.0 sec  
(125 msec × 7 = 875 msec)
- When "0" is written: 0.5 sec  
(62.5 msec × 7 = 437.5 msec)
- Reading: Valid

The attenuation time of the digital envelope is determined by the time for changing the duty ratio.

The duty ratio is changed in 125 msec (8 Hz) units when "1" is written to ENRTM and in 62.5 msec (16 Hz) units, when "0" is written.

This setting becomes invalid when an envelope has been set to OFF (ENON = "0").

At initial reset, the ENRTM register is set to "0" (0.5 sec).

**SHTPW: One-shot buzzer output duration width selection register (00FF54H•D4)**

Selects the output duration width of the one-shot buzzer.

- When "1" is written: 125 msec
- When "0" is written: 31.25 msec
- Reading: Valid

The one-shot buzzer output duration width is set to 125 msec when "1" is written to SHTPW and 31.25 msec, when "0" is written.

At initial reset, the SHTPW register is set to "0" (31.25 msec).

**BZSHT: One-shot buzzer trigger/status  
(00FF54H•D5)**


---

Controls the one-shot buzzer output.

When "1" is written: Trigger

When "0" is written: No operation

When "1" is read: Busy

When "0" is read: Ready

Writing "1" into BZSHT causes the one-shot output circuit to operate and the BZ signal to be output. The buzzer output is automatically turned OFF after the time set by SHTPW has elapsed. At this time, the high-impedance control register of the output port R42 must be set to "0" and the data register must be "1".

The one-shot output is only valid when the normal buzzer output is OFF (BZON = "0") status. The trigger is invalid during ON (BZON = "1") status. When a re-trigger is assigned during a one-shot output, the one-shot output time set with SHTPW is measured again from that point. (time extension) The operation status of the one-shot output circuit can be confirmed by reading BZSHT, when the one-shot output is ON (busy), BZSHT is read as "1" and when the output is OFF (ready), it is read as "0".

At initial reset, BZSHT is set to "0" (ready).

**BZSTP: One-shot buzzer forcibly stop  
(00FF54H•D6)**


---

Forcibly stops the one-shot buzzer output.

When "1" is written: Forcibly stop

When "0" is written: No operation

Reading: Constantly "0"

By writing "1" into BZSTP, the one-shot buzzer output can be stopped prior to the elapsing of the time set with SHTPW.

Writing "0" is invalid and writing "1" except during one-shot output is also invalid.

When "1" is written to BZSHT and BZSTP simultaneously, BZSTP takes precedence and one-shot output becomes stop status.

Since BZSTP is for writing only, during readout it is constantly set to "0".

**5.15.7 Programming notes**

- (1) Since the BZ signal is generated asynchronously from the register BZON, when the signal is turned ON or OFF by the register setting, a hazard of a 1/2 cycle or less is generated.
- (2) The SLP instruction has executed when the BZ signal is in the enable status (BZON = "1" or BZSHT = "1"), an unstable clock is output from the R42 output port terminal at the time of return from the SLEEP status. Consequently, when shifting to the SLEEP status, you should set the BZ signal to the disable status (BZON = BZSHT = "0") prior to executing the SLP instruction.
- (3) The one-shot output is only valid when the normal buzzer output is OFF (BZON = "0") status. The trigger is invalid during ON (BZON = "1") status.

## 5.16 SVD (Supply Voltage Detection) Circuit

### 5.16.1 Configuration of SVD circuit

The S1C88409 has a built-in SVD (supply voltage detection) circuit, so that the software can find when the source voltage lowers. Turning the SVD circuit ON/OFF and the SVD criteria voltage setting can be done with software.

Figure 5.16.1.1 shows the configuration of the SVD circuit.

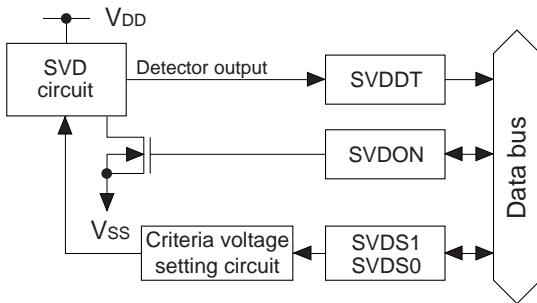


Fig. 5.16.1.1 Configuration of SVD circuit

### 5.16.2 SVD operation

The SVD circuit compares the criteria voltage set by software and the supply voltage ( $V_{DD}-V_{SS}$ ) and sets its results into the SVDDT latch. By reading the data of this SVDDT latch, it can be determined by means of software whether the supply voltage is normal or has dropped.

The criteria voltage can be set for the 3 types shown in Table 5.16.2.1 by the SVD register.

Table 5.16.2.1 Criteria voltage setting

| SVD1 | SVD0 | Criteria voltage |
|------|------|------------------|
| 1    | ×    | 3.4 V            |
| 0    | 1    | 2.8 V            |
| 0    | 0    | 1.9 V            |

When the SVDON register is set to "1", source voltage detection by the SVD circuit is executed. As soon as the SVDON register is reset to "0", the result is loaded to the SVDDT latch and the SVD circuit goes OFF.

To obtain a stable detection result, the SVD circuit must be ON for at least 100  $\mu$ sec. So, to obtain the SVD detection result, follow the programming sequence below.

1. Set SVDON to "1"
2. Maintain for 100  $\mu$ sec minimum
3. Set SVDON to "0"
4. Read SVDDT

The SVD operation increases current consumption, so turn the SVD circuit off when voltage detection is unnecessary or executing the SLP instruction.

### 5.16.3 I/O memory of SVD circuit

Table 5.16.3.1 shows the control bits for the SVD circuit.

Table 5.16.3.1 SVD circuit control bits

| Address | Bit   | Name               | Function                     | 1     | 0           | Init | R/W | Comment             |  |
|---------|-------|--------------------|------------------------------|-------|-------------|------|-----|---------------------|--|
| 00FF56  | D7    | –                  | –                            | –     | –           | –    | –   | "0" when being read |  |
|         | D6    | –                  | –                            | –     | –           | –    | –   |                     |  |
|         | D5    | –                  | –                            | –     | –           | –    | –   |                     |  |
|         | D4    | –                  | –                            | –     | –           | –    | –   |                     |  |
|         | D3    | SVD1               | SVD criteria voltage setting |       |             |      | 0   | R/W                 |  |
|         |       |                    | SVD1                         | SVD0  | Voltage (V) |      |     |                     |  |
|         | D2    | SVD0               | 1                            | ×     | 3.4 V       |      | 0   | R/W                 |  |
|         |       | 0                  | 1                            | 2.8 V |             |      |     |                     |  |
|         |       | 0                  | 0                            | 1.9 V |             |      |     |                     |  |
| D1      | SVDDT | SVD data           |                              | Low   | Normal      | 0    | R   |                     |  |
| D0      | SCDON | SVD On/Off control |                              | On    | Off         | 0    | R/W |                     |  |

#### SVD0, SVD1: SVD criteria voltage setting register (FF56H•D2, D3)

Criteria voltage for SVD is set as shown in Table 5.16.3.1.

At initial reset, this SVD register is set to "0" (1.9 V).

#### SVDON: SVD control (ON/OFF) register (FF56H•D0)

Turns the SVD circuit ON and OFF.

When "1" is written: SVD circuit ON

When "0" is written: SVD circuit OFF

Reading: Valid

When the SVDON register is set to "1", a source voltage detection is executed by the SVD circuit. As soon as SVDON is reset to "0", the result is loaded to the SVDDT latch. To obtain a stable detection result, the SVD circuit must be ON for at least 100  $\mu$ sec.

At initial reset, this SVD register is set to "0" (Off).

#### SVDDT: SVD data (FF56H•D1)

This is the result of supply voltage detection.

When "0" is read: Supply voltage ( $V_{DD}-V_{SS}$ )  
 $\geq$  Criteria voltage

When "1" is read: Supply voltage ( $V_{DD}-V_{SS}$ )  
 $<$  Criteria voltage

Writing: Invalid

The result of supply voltage detection at time of SVDON is set to "0" can be read from this latch.

At initial reset, SVDDT is set to "0" (Normal).

### 5.16.4 Programming notes

- To obtain a stable detection result, the SVD circuit must be ON for at least 100  $\mu$ sec. So, to obtain the SVD detection result, follow the programming sequence below.
  - Set SVDON to "1"
  - Maintain for 100  $\mu$ sec minimum
  - Set SVDON to "0"
  - Read SVDDT
- The SVD operation increases current consumption, so turn the SVD circuit off when voltage detection is unnecessary or executing the SLP instruction.

## 5.17 Touch Panel Controller

### 5.17.1 Configuration of touch panel controller

The S1C88409 has a built-in touch panel controller. It can reduce external devices and load software for designing systems. This touch panel controller also features a capacity to resist noise.

The touch panel controller detects the coordinates on a touch panel using two channels of the 10-bit A/D converter.

Figure 5.17.1.1 shows the block diagram of the touch panel controller.

### 5.17.2 Terminal configuration

The following signals are used to control a touch panel.

**BXH, BXL** These signals control the supply voltage to the electrodes for detecting X coordinates. BXH is the positive electrode control signal and BXL is the negative electrode control signal.

**BYH, BYL** These signals control the supply voltage to the electrodes for detecting Y coordinates. BYH is the positive electrode control signal and BYL is the negative electrode control signal.

The output terminals for the signals are shared with the I/O port terminals and they can be set for controlling a touch panel by selecting the mask option.

Table 5.17.2.1 Touch panel control signal output terminals

| Output signal | I/O port |
|---------------|----------|
| BYH           | P20      |
| BYL           | P21      |
| BXH           | P22      |
| BXL           | P23      |

The following two options are available:

- 1) Touch panel is used (The P20 to P23 terminals are set as the touch panel control signal output terminals.)
- 2) Touch panel is not used (The P20 to P23 terminals are set as the I/O port terminals.)

*Note:* When the touch panel function is selected by mask option, the P20–P23 terminals are configured as follows at initial reset:

- P20 (BYH) High level
- P21 (BYL) Low level
- P22 (BXH) High level
- P23 (BXL) Low level

The P20–P23 terminals are disconnected from the I/O control and data registers, and are controlled from the touch panel controller. Thus it is unnecessary to configure these terminals by software. The I/O control and data registers for these ports can be used as general-purpose registers.

Two channels of the A/D converter that is built into the S1C88409 are used to input coordinates from a touch panel. Two analog signal input terminals can be selected from among the I/O port terminals P30–P35 by mask option.

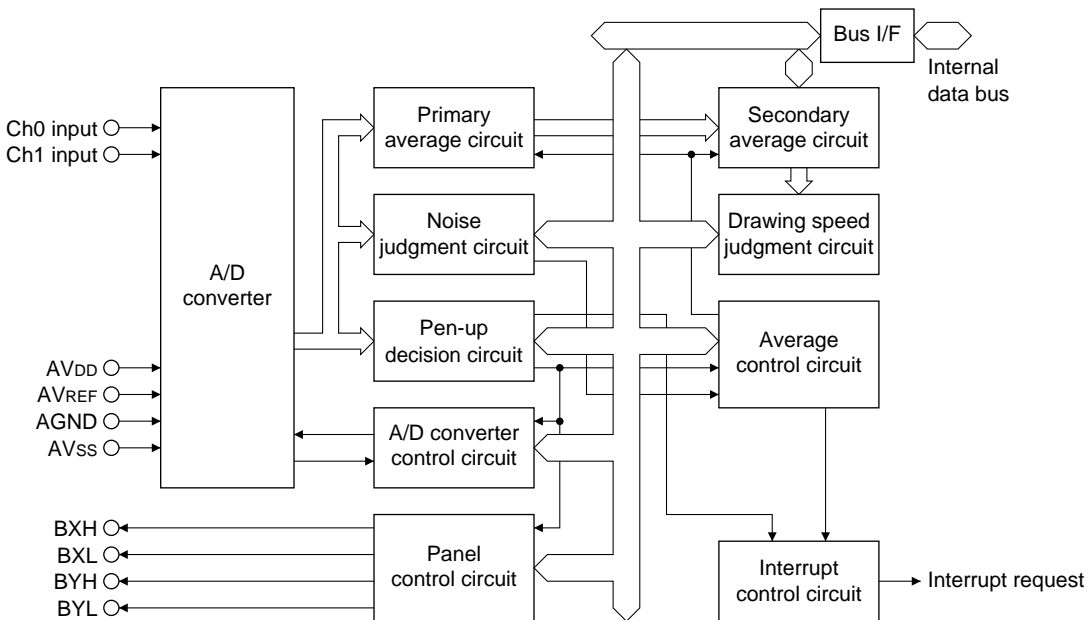


Fig. 5.17.1.1 Block diagram of touch panel controller



### Connecting a touch panel

A touch panel consists of two panels for X coordinate detection and Y coordinate detection that are equipped with two electrodes each. The BXH, BXL, BYH and BYL signals should be connected as shown in Figure 5.17.2.1 to control the electrodes individually. Further the negative electrodes should be connected to the analog input terminals selected by mask option to input the detection results. The capacitors to connect to Ch0 and Ch1 should be 1000 pF or less.

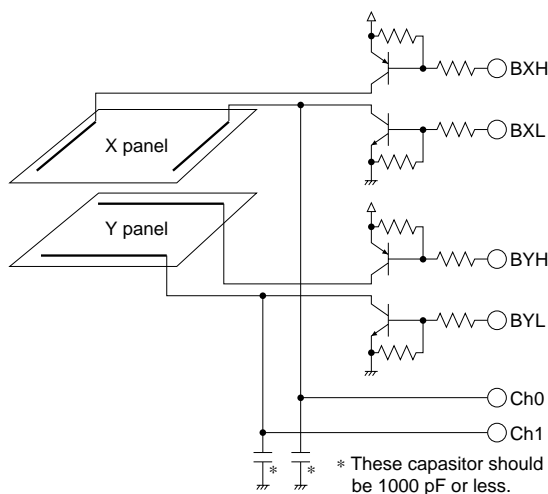


Fig. 5.17.2.1 Connecting touch panel

### 5.17.3 Operation of touch panel controller

#### Control of A/D converter

Since the touch panel controller controls A/D conversion for coordinate values, it is unnecessary to control with software. However, the clock to be supplied to the A/D converter must be controlled by software. Furthermore, since the A/D converter interrupt can occur even when used for the touch panel, mask the interrupt by software.

Refer to Section 5.18, "A/D Converter", for details of the A/D converter.

#### Pen-down check

Coordinate detection increases current consumption because it always operates in high speed. Therefore, coordinate detection should be stopped to suppress current consumption when the touch panel operation is not necessary. To detect a start of touch panel operation (pen down), the pen-down check mode is provided.

The pen-down check mode controls the signals as follows:

- BXH=HIGH (The positive electrode on the X panel goes off.)
- BXL=LOW (The negative electrode on the X panel goes on.)
- BYH=Pen-down check pulse (The positive electrode on the Y panel goes off.)
- BYL=HIGH (The negative electrode on the Y panel goes off.)

In the pen-down check mode, the pen-down detection input is pulled up in the touch panel controller and it goes high in pen-up status. In pen-down status, the output becomes low level due to the pressurization on the X panel. The pen-down check starts by writing "1" to the PDC register and stops by writing "0". When the touch panel controller judges pen-down status due to a low level input, a pen-down interrupt occurs.

The pen-down check by the PDC register uses the OSC1 clock and does not need the OSC3 clock. This makes it possible to reduce current consumption by controlling OSC3 and coordinate detection using the pen-down interrupt. Therefore, it is necessary to enable the pen-down interrupt before starting pen-down check.

The pen-down check is invalid during coordinate detection (RST register = "1").

The pen-down detector has a built-in noise rejecter at the input line in order to prevent unnecessary pen-down detection due to noise. This circuit can detect a pen-down when a low-level pulse longer than one cycle of the OSC1 clock is input.

**Starting coordinate detection**

The touch panel controller starts coordinate detection by writing "1" to the RST register. When "1" is written to the RST register, the controller first performs a pen-down check and is on standby to touch panel driving and A/D conversion for coordinate detection similar to the pen-down check by writing "1" to the PDC register. When a pen-down is detected, the controller starts coordinate detection. At the same time, a pen-down interrupt occurs if the interrupt is enabled. However, the coordinate detection uses the clock generated by the prescaler with the OSC3 clock as the source clock. Therefore, it is necessary to turn the OSC3 oscillation circuit on and to control the prescaler so that the clock for the touch panel controller is output before writing "1" to the RST register.

Refer to Section 5.4 "Oscillation Circuit" and Section 5.5 "Prescaler and Clock Control Circuit for Peripheral Circuits" for controlling the clock.

The touch panel controller controls the signals as follows and detects an X coordinate and a Y coordinate separately.

*X coordinate detection*

- BXH: LOW (Positive electrode on X panel: ON)
- BXL: HIGH (Negative electrode on X panel: ON)
- BYH: HIGH (Positive electrode on Y panel: OFF)
- BYL: LOW (Negative electrode on Y panel: OFF)
- A/D channel: Ch0\*

*Y coordinate detection*

- BXH: HIGH (Positive electrode on X panel: OFF)
- BXL: LOW (Negative electrode on X panel: OFF)
- BYH: LOW (Positive electrode on Y panel: ON)
- BYL: HIGH (Negative electrode on Y panel: ON)
- A/D channel: Ch1\*

\* Selected by mask option.

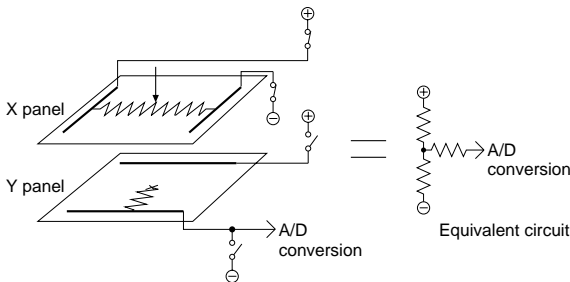


Fig. 5.17.3.1 Coordinate detection (X coordinate)

The touch panel is regarded as the equivalent circuit shown in Figure 5.17.3.1. It outputs the voltage to the A/D converter according to the pointed coordinate.

The touch panel controller performs A/D conversion at least 32 times (16 times each for X and Y coordinates) per one coordinate and stores the arithmetic mean to the coordinate data register as the detection result.

Since the touch panel controller controls A/D conversion during coordinate detection, do not control the A/D converter with software. While the RST register is set to "1", coordinate detection is repeatedly performed as long as the pen is touching the panel. It can be stopped by writing "0" to the RST register. In this case, turn off the clock output from the prescaler to the touch panel controller and A/D converter.

**Deciding pen-up status during coordinate detection**

In pen-down status (the pen is touching the panel), the A/D conversion result indicates the coordinates on the touch panel. If the result is smaller than the value at the corner of the panel, it can be regarded as pen-up status (the pen is not touching the panel).

In this touch panel controller, a threshold value for pen-up decision can be set according to the panel to be used. When the mean value of the A/D conversion result is smaller than the set value, the touch panel controller decides it as pen-up status. The threshold value for pen-up decision can be set using the PUD register.

Table 5.17.3.1 Threshold value for pen-up decision

| PUD3 | PUD2 | PUD1 | PUD0 | Pen-up decision threshold value |
|------|------|------|------|---------------------------------|
| 0    | 0    | 0    | 0    | 4                               |
| 0    | 0    | 0    | 1    | 8                               |
| 0    | 0    | 1    | 0    | 12                              |
| 0    | 0    | 1    | 1    | 16                              |
| 0    | 1    | 0    | 0    | 20                              |
| 0    | 1    | 0    | 1    | 24                              |
| 0    | 1    | 1    | 0    | 28                              |
| 0    | 1    | 1    | 1    | 32                              |
| 1    | 0    | 0    | 0    | 36                              |
| 1    | 0    | 0    | 1    | 40                              |
| 1    | 0    | 1    | 0    | 44                              |
| 1    | 0    | 1    | 1    | 48                              |
| 1    | 1    | 0    | 0    | 52                              |
| 1    | 1    | 0    | 1    | 56                              |
| 1    | 1    | 1    | 0    | 60                              |
| 1    | 1    | 1    | 1    | 64                              |

The result of pen-up/down decision can be read from the PEN bit (00FFA7H•D0). The PEN bit goes "0" in pen-up status and goes "1" in pen-down status. During coordinate detection, a pen-up is judged based on the determined data that is not regarded as noise. If the input data is regarded as noise at pen-up, it is not judged as pen-up and the PEN bit maintains "1" (pen-down status).

## Deciding drawing speed and getting coordinates

The touch panel controller performs A/D conversion for getting a coordinate at least 16 times (256 times maximum) each for X and Y, and takes the arithmetic mean. The mean result is written to the coordinate data register as the coordinate value.

X coordinate data register: DX11–DX0

(00FFA8H•D7–D0, 00FFA9H•D3–D0)

Y coordinate data register: DY11–DY0

(00FFAAH•D7–D0, 00FFABH•D3–D0)

The touch panel controller can generate an interrupt when the detected coordinate values are written to both the X and Y coordinate data registers. Thus coordinate values can be read and processed using the interrupt.

The number of A/D conversions for getting a coordinate differs depending on the mode described below.

### (1) Constant-speed mode

The constant-speed mode is set by writing "1" to the CONST (00FFA0H•D4) register.

This mode always performs the same number of A/D conversions regardless of drawing speed and takes the mean for detecting one coordinate.

Consequently, the coordinate detection speed is always constant.

The number of A/D conversions for averaging can be selected from the five types shown in Table 5.17.3.2 using the AVN register.

Table 5.17.3.2 Number of A/D conversion in constant-speed mode

| AVN2 | AVN1 | AVN0 | Number of A/D conversion |
|------|------|------|--------------------------|
| 0    | 0    | 0    | 16×16                    |
| 0    | 0    | 1    | 16×8                     |
| 0    | 1    | 0    | 16×4                     |
| 0    | 1    | 1    | 16×2                     |
| 1    | ×    | ×    | 16×1                     |

The set number of A/D conversions are performed for both the X and Y coordinates.

### (2) Normal mode

The normal mode is set by writing "0" to the CONST register. It is also set at initial reset.

In the normal mode, the hardware changes the number of A/D conversions according to the drawing speed. A low-speed drawing increases the number of A/D conversions, it raises coordinate detection precision. A high-speed drawing decreases the number of A/D conversion, it makes it easy to track the pen.

The drawing speed is detected by the adder-subtractor shown in Figure 5.17.3.2 as the approximation expression.

$$|(\text{previous X coordinate}) - (\text{current X coordinate})| + |(\text{previous Y coordinate}) - (\text{current Y coordinate})|$$

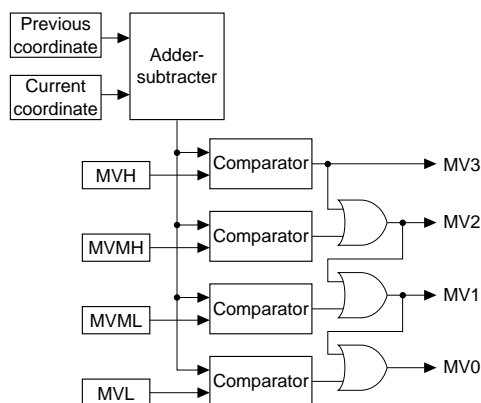


Fig. 5.17.3.2 Drawing speed judgment circuit

The drawing speed judgment circuit compares the output from the adder-subtractor with the following four threshold values to decide the number of A/D conversions for the next coordinate detection.

MVH (00FFA5H•D7–D4): Threshold value for high-speed judgment

MVMH (00FFA5H•D3–D0): Threshold value for middle-high-speed judgment

MVML (00FFA4H•D7–D4): Threshold value for middle-low-speed judgment

MVL (00FFA4H•D3–D0): Threshold value for low-speed judgment

Table 5.17.3.3 Threshold value setting for drawing speed judgment

| MVH3  | MVH2  | MVH1  | MVH0  | High-speed        |
|-------|-------|-------|-------|-------------------|
| MVMH3 | MVMH2 | MVMH1 | MVMH0 | Middle-high-speed |
| MVML3 | MVML2 | MVML1 | MVML0 | Middle-low-speed  |
| MVL3  | MVL2  | MVL1  | MVL0  | Low-speed         |
| 0     | 0     | 0     | 0     | 2                 |
| 0     | 0     | 0     | 1     | 4                 |
| 0     | 0     | 1     | 0     | 6                 |
| 0     | 0     | 1     | 1     | 8                 |
| 0     | 1     | 0     | 0     | 10                |
| 0     | 1     | 0     | 1     | 12                |
| 0     | 1     | 1     | 0     | 14                |
| 0     | 1     | 1     | 1     | 16                |
| 1     | 0     | 0     | 0     | 18                |
| 1     | 0     | 0     | 1     | 20                |
| 1     | 0     | 1     | 0     | 22                |
| 1     | 0     | 1     | 1     | 24                |
| 1     | 1     | 0     | 0     | 26                |
| 1     | 1     | 0     | 1     | 28                |
| 1     | 1     | 1     | 0     | 30                |
| 1     | 1     | 1     | 1     | 32                |

The settings must meet the following conditions:  
 $MVH \geq MVMH \geq MVML \geq MVL$

Figure 5.17.3.3 shows the relation between the comparison results and the number of A/D conversions for the next detection.

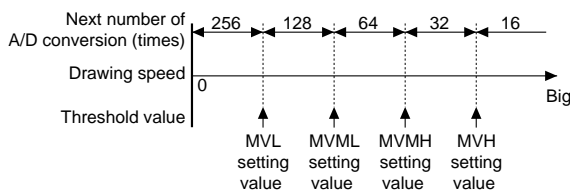


Fig. 5.17.3.3 Drawing speed and number of A/D conversions

The set number of A/D conversions are performed for both the X and Y coordinates.

### Noise judgment

In order to avoid unnecessary coordinate detection due to noise, the threshold value for noise judgment can be set. This controller performs at least 16 A/D conversions for getting coordinate data for each X and Y. At this time, the controller also finds the difference between the maximum conversion data and minimum conversion data. When the difference is larger than the threshold value set for noise judgment, it is regarded as noise and the result is not written to the coordinate data register. When the difference is smaller than the threshold value, the arithmetic mean of the A/D conversion data is written to the register as coordinate data. The threshold value for noise judgment can be set using the CND register.

Table 5.17.3.4 Threshold value for noise judgment

| CND3 | CND2 | CND1 | CND0 | Noise judgment threshold value |
|------|------|------|------|--------------------------------|
| 0    | 0    | 0    | 0    | 4                              |
| 0    | 0    | 0    | 1    | 8                              |
| 0    | 0    | 1    | 0    | 12                             |
| 0    | 0    | 1    | 1    | 16                             |
| 0    | 1    | 0    | 0    | 20                             |
| 0    | 1    | 0    | 1    | 24                             |
| 0    | 1    | 1    | 0    | 28                             |
| 0    | 1    | 1    | 1    | 32                             |
| 1    | 0    | 0    | 0    | 36                             |
| 1    | 0    | 0    | 1    | 40                             |
| 1    | 0    | 1    | 0    | 44                             |
| 1    | 0    | 1    | 1    | 48                             |
| 1    | 1    | 0    | 0    | 52                             |
| 1    | 1    | 0    | 1    | 56                             |
| 1    | 1    | 1    | 0    | 60                             |
| 1    | 1    | 1    | 1    | 64                             |

At initial reset, threshold value for noise judgment is set to 36 (CND=1000B).

Increase the threshold value if pen speed is important, or decrease if noise rejection is important.

### Waiting time setting for stable detection result

#### (1) Waiting time for voltage stabilization

It is possible to set a waiting time for voltage stabilization between supplying a voltage to the electrode of the panel to be detected a coordinate and starting an A/D conversion.

The waiting time can be selected from 16 types as shown in Table 5.17.3.5 using the WAIT register.

Table 5.17.3.5 Waiting time setting for voltage stabilization

| WAIT3 | WAIT2 | WAIT1 | WAIT0 | Voltage stabilization waiting time |
|-------|-------|-------|-------|------------------------------------|
| 0     | 0     | 0     | 0     | 16×1/f                             |
| 0     | 0     | 0     | 1     | 16×2/f                             |
| 0     | 0     | 1     | 0     | 16×3/f                             |
| 0     | 0     | 1     | 1     | 16×4/f                             |
| 0     | 1     | 0     | 0     | 16×5/f                             |
| 0     | 1     | 0     | 1     | 16×6/f                             |
| 0     | 1     | 1     | 0     | 16×7/f                             |
| 0     | 1     | 1     | 1     | 16×8/f                             |
| 1     | 0     | 0     | 0     | 16×9/f                             |
| 1     | 0     | 0     | 1     | 16×10/f                            |
| 1     | 0     | 1     | 0     | 16×11/f                            |
| 1     | 0     | 1     | 1     | 16×12/f                            |
| 1     | 1     | 0     | 0     | 16×13/f                            |
| 1     | 1     | 0     | 1     | 16×14/f                            |
| 1     | 1     | 1     | 0     | 16×15/f                            |
| 1     | 1     | 1     | 1     | 16×16/f                            |

\*f: Frequency of the clock input from the prescaler

Note: The waiting time to be set using the WAIT register must be longer than 3 cycles of the OSC1 clock.

$$16 \times n/f > 3/f_{OSC1}$$

(\*f: Input clock frequency from the prescaler)

At initial reset, it is set to  $16 \times 5/f$  (WAIT="0100B").

(2) Interval time

It is possible to set an interval after an A/D conversion processing for noise resistance improvement, saving power and setting the number of points to be detected for 1 second.

The interval can be selected from 16 types as shown in Table 5.17.3.6 using the INV register. The A/D conversion processing for coordinate detection performs four A/D conversions at a time. The set interval is inserted after the processing (four A/D conversions have finished) and no voltage is supplied to the touch panel during this period.

Table 5.17.3.6 Interval time setting

| IVL3 | IVL2 | IVL1 | IVL0 | Interval time |
|------|------|------|------|---------------|
| 0    | 0    | 0    | 0    | 128×1/f       |
| 0    | 0    | 0    | 1    | 128×2/f       |
| 0    | 0    | 1    | 0    | 128×3/f       |
| 0    | 0    | 1    | 1    | 128×4/f       |
| 0    | 1    | 0    | 0    | 128×5/f       |
| 0    | 1    | 0    | 1    | 128×6/f       |
| 0    | 1    | 1    | 0    | 128×7/f       |
| 0    | 1    | 1    | 1    | 128×8/f       |
| 1    | 0    | 0    | 0    | 128×9/f       |
| 1    | 0    | 0    | 1    | 128×10/f      |
| 1    | 0    | 1    | 0    | 128×11/f      |
| 1    | 0    | 1    | 1    | 128×12/f      |
| 1    | 1    | 0    | 0    | 128×13/f      |
| 1    | 1    | 0    | 1    | 128×14/f      |
| 1    | 1    | 1    | 0    | 128×15/f      |
| 1    | 1    | 1    | 1    | 128×16/f      |

\*f: Input clock frequency from the prescaler

At initial reset, the interval is set to  $128 \times 3/f$  (INV="0010B").

When setting the interval shorter, current consumption will increase and coordinate values unnecessary for drawing will be detected. Set an appropriate interval according to the drawing contents.

Operation of coordinate detection

When "1" is written to the RST register, the touch panel controller starts operating for coordinate detection and continues a process as shown in Figure 5.17.3.4 until "0" is written to the RST register.

The number of conversions per second while the pen is tracing on the panel is calculated as an approximate value by the expression below:

$$N = 1 / (AV \times 8 (CNT + WAIT + 4 AD + IVL))$$

AV: Number of A/D conversions

CNT:  $10 \times$  input clock cycle time (prescaler output clock)

WAIT: WAIT register setting time

AD:  $22 \times$  A/D conversion clock cycle [00FF17H•D3–D0]

IVL: IVL register setting time

Figure 5.17.3.4 shows the operation when the number of conversions is set to  $16 \times 1$ . When a pen-up is detected in the coordinate conversion period, the following cycle starts from (1) after finishing the current cycle. When no pen-up is detected, the following cycle starts from (2). If the detected data is regarded as noise, the data register is not updated.

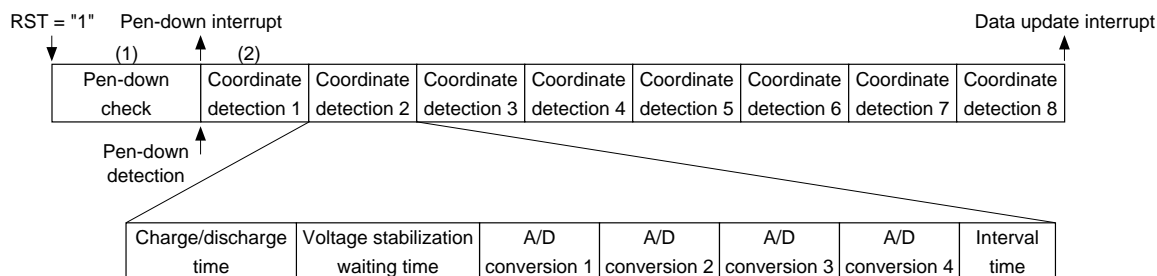


Fig. 5.17.3.4 Coordinate detection operation

### 5.17.4 Interrupt function

The touch panel controller can generate an interrupt when a pen-down is detected during pen-down check and converted coordinate data is updated.

Figure 5.17.4.1 shows the configuration of the touch panel controller interrupt circuit.

When a pen-down status is detected during pen-down check using the PDC register or RST register, the interrupt factor flag FTPPD is set to "1" and an interrupt is generated.

When the coordinate data register is updated after finishing A/D conversions for a coordinate detection, the interrupt factor flag FTPDR is set to "1" and an interrupt is generated.

The interrupts can be disabled using the interrupt enable registers ETPPD and ETPDR corresponding to each interrupt factor flag.

In addition, a priority level of the touch panel controller interrupt for the CPU can be optionally set at levels 0 to 3 by the interrupt priority register PTP.

For details on the above mentioned interrupt control registers and the operation following an interrupt generation, see Section 5.20, "Interrupt and Standby Status".

The exception processing vector address of each interrupt factor is set as below.

Pen-down interrupt: 000020H  
 Converted data update interrupt: 000022H

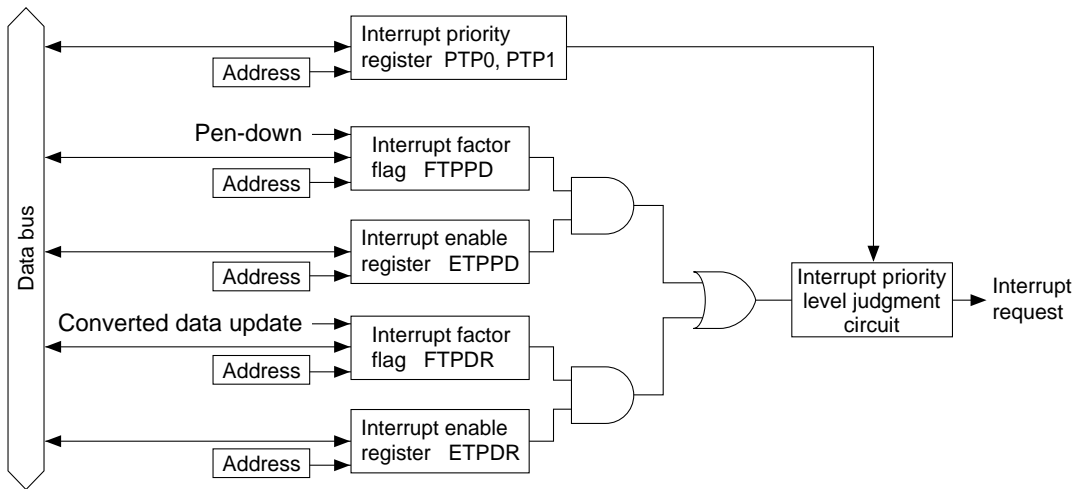


Fig. 5.17.4.1 Configuration of touch panel controller interrupt circuit

### 5.17.5 Touch panel controller control flow

Figure 5.17.5.1 shows the control flow for the touch panel controller

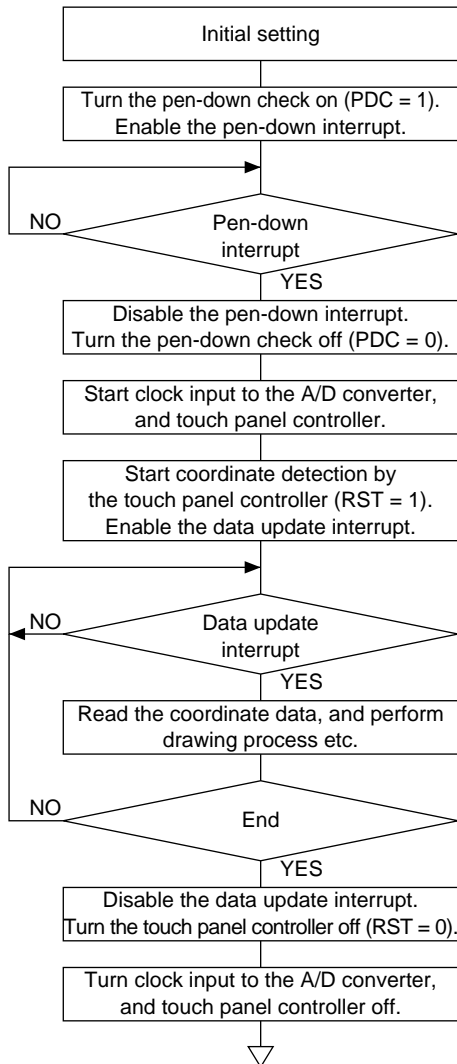


Fig. 5.17.5.1 Touch panel controller control flow

### Initial setting

Set the following registers.

#### Setting other circuits

OSCC: Write "1" to turn the OSC3 oscillation circuit on.

PSAD: Select an A/D converter operating clock.

PSTP: Select a touch panel controller operating clock.

VRC: Write "1" to enable the AVREF control by the touch panel controller.

IOC30–IOC37, P30D–P37D:

Configure the terminal for switching the AVREF voltage of the A/D converter on and off. Any I/O port from P30 to P37 which is not used for inputting analog signals can be used for this control. Set the I/O port in the output mode and write "1" to the data register.

#### Setting touch panel controller

CONST: Select either constant speed mode or normal mode.

AVN: Set a number of A/D conversions for an arithmetic mean when the controller is used in the constant speed mode.

WAIT: Set a waiting time for voltage stabilization.

CND: Set a threshold value for noise judgment.

PUD: Set a threshold value for pen-up decision.

MVH, MVMH, MVML, MVL:

Set threshold values for drawing speed judgment when the controller is used in the normal mode.

IVL: Set an interval time.

#### Setting for interrupt

PTP: Set a priority level of the touch panel controller interrupt.

FTPPD, FTPDR: Write "1" to reset the touch panel controller interrupt factor flags.

ETPPD, ETPDR: Write "1" to enable the touch panel controller interrupt.

To avoid unnecessary interrupts during coordinate detection, disable the A/D converter interrupt.

### Pen-down check

Write "1" to the PDC register to start pen-down check.

When checking a pen-down after turning OSC3 off, the internal power supply circuit, OSCC and stabilization waiting time must be controlled after a pen-down is detected. To increase the response time until the coordinate detection starts, the pen-down should be checked when OSC3 is on or using the RST register not the PDC register. However, this method increases current consumption.

### Starting coordinate detection

Coordinate detection should be started using a pen-down interrupt.

Write "1" to the PRAD and PRTP registers so that the prescaler supplies the clocks to the A/D converter and the touch panel controller.

Then write "1" to the RST register to start coordinate detection.

### Reading coordinate values

An interrupt occurs when coordinate values for a point are written to the coordinate data registers (DX, DY). Read coordinate data using the interrupt and then execute the necessary processing.

Coordinate data varies according to the panel to be used and operating environment. Therefore, first get data of the panel origin point and used area to make a correction value for converting the register data into an actual coordinate. Drawing processing should be done by correcting coordinate data using the correction value.

Be sure to read all the coordinate data registers (00FFA8, 00FFA9, 00FFAA, 00FFAB) after a data update interrupt is generated. This process is required if the coordinate data at that point is unnecessary because the next data update interrupt cannot be generated if all the register data are not read.



## 5.17.6 I/O memory of touch panel controller

Table 5.17.6.1 shows the control bits of the touch panel controller.

Table 5.17.6.1(a) Touch panel controller control bits

| Address | Bit   | Name  | Function                                                               | 1                              | 0                                  | Init           | R/W | Comment             |
|---------|-------|-------|------------------------------------------------------------------------|--------------------------------|------------------------------------|----------------|-----|---------------------|
| 00FF13  | D7    | –     | –                                                                      | –                              | –                                  | –              | –   | "0" when being read |
|         | D6    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |
|         | D5    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |
|         | D4    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |
|         | D3    | PRAD  | A/D converter clock control                                            |                                | On                                 | Off            | 0   | R/W                 |
|         | D2    | PSAD2 | A/D converter division ratio                                           |                                |                                    |                | 0   | R/W                 |
|         |       |       | PSAD2                                                                  | PSAD1                          | PSAD0                              | Division ratio |     |                     |
| D1      | PSAD1 | 1     | ×                                                                      | ×                              | fosc3 / 16                         | 0              | R/W |                     |
|         |       | 0     | 1                                                                      | 1                              | fosc3 / 8                          |                |     |                     |
| D0      | PSAD0 | 0     | 1                                                                      | 0                              | fosc3 / 4                          | 0              | R/W |                     |
|         |       | 0     | 0                                                                      | 1                              | fosc3 / 2                          |                |     |                     |
|         |       | 0     | 0                                                                      | 0                              | fosc3 / 1                          |                |     |                     |
| 00FF16  | D7    | –     | –                                                                      | –                              | –                                  | –              | –   | "0" when being read |
|         | D6    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |
|         | D5    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |
|         | D4    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |
|         | D3    | PRTP  | Touch panel controller clock control                                   |                                | On                                 | Off            | 0   | R/W                 |
|         | D2    | PSTP2 | Touch panel controller clock ratio                                     |                                |                                    |                | 0   | R/W                 |
|         |       |       | PSTP2                                                                  | PSTP1                          | PSTP0                              | Division ratio |     |                     |
| D1      | PSTP1 | 1     | ×                                                                      | ×                              | fosc3 / 16                         | 0              | R/W |                     |
|         |       | 0     | 1                                                                      | 1                              | fosc3 / 8                          |                |     |                     |
| D0      | PSTP0 | 0     | 1                                                                      | 0                              | fosc3 / 4                          | 0              | R/W |                     |
|         |       | 0     | 0                                                                      | 1                              | fosc3 / 2                          |                |     |                     |
|         |       | 0     | 0                                                                      | 0                              | fosc3 / 1                          |                |     |                     |
| 00FF22  | D7    | PAD1  | A/D converter interrupt priority register                              | PAD1                           | PAD0                               | Priority       | 0   | R/W                 |
|         | D6    | PAD0  |                                                                        | PTP1                           | PTP0                               | level          | 0   | R/W                 |
|         | D5    | PTP1  | Touch panel controller                                                 | 1                              | 1                                  | Level 3        | 0   | R/W                 |
|         | D4    | PTP0  | interrupt priority register                                            | 1                              | 0                                  | Level 2        | 0   | R/W                 |
|         | D3    | –     | –                                                                      | 0                              | 1                                  | Level 1        | –   | –                   |
|         | D2    | –     | –                                                                      | 0                              | 0                                  | Level 0        | –   | –                   |
|         | D1    | –     | –                                                                      | –                              | –                                  | –              | –   | –                   |
| D0      | –     | –     | –                                                                      | –                              | –                                  | –              | –   |                     |
| 00FF26  | D7    | EAD   | A/D converter conversion completion interrupt enable register          |                                |                                    |                | 0   | R/W                 |
|         | D6    | ETPPD | Touch panel controller pen-down interrupt enable register              |                                |                                    |                | 0   | R/W                 |
|         | D5    | ETPDR | Touch panel controller converted data update interrupt enable register | Interrupt is enabled           | Interrupt is disabled              |                | 0   | R/W                 |
|         | D4    | –     | –                                                                      |                                |                                    |                | –   | –                   |
|         | D3    | –     | –                                                                      |                                |                                    |                | –   | –                   |
|         | D2    | –     | –                                                                      |                                |                                    |                | –   | –                   |
|         | D1    | –     | –                                                                      |                                |                                    |                | –   | –                   |
| D0      | –     | –     |                                                                        |                                |                                    | –              | –   |                     |
| 00FF2A  | D7    | FAD   | A/D converter conversion completion interrupt factor flag              | (R)                            | (R)                                |                | 0   | R/W                 |
|         | D6    | FTPPD | Touch panel controller pen-down interrupt factor flag                  | Interrupt factor has generated | Interrupt factor has not generated |                | 0   | R/W                 |
|         | D5    | FTPDR | Touch panel controller converted data update interrupt factor flag     |                                |                                    |                | 0   | R/W                 |
|         | D4    | –     | –                                                                      |                                |                                    |                | –   | –                   |
|         | D3    | –     | –                                                                      |                                |                                    |                | –   | –                   |
|         | D2    | –     | –                                                                      | (W)                            | (W)                                |                | –   | –                   |
|         | D1    | –     | –                                                                      | Reset                          | Invalid                            |                | –   | –                   |
| D0      | –     | –     |                                                                        |                                |                                    | –              | –   |                     |

Table 5.17.6.1(b) Touch panel controller control bits

| Address | Bit  | Name  | Function                                                       | 1              | 0       | Init | R/W | Comment                  |
|---------|------|-------|----------------------------------------------------------------|----------------|---------|------|-----|--------------------------|
| 00FF80  | D7   | ADRUN | A/D conversion start control register                          | Start          | Invalid | 0    | W   | "0" when being read      |
|         | D6   | —     | —                                                              | —              | —       | —    | —   |                          |
|         | D5   | —     | —                                                              | —              | —       | —    | —   |                          |
|         | D4   | VRC   | AVREF control (Touch panel controller)                         | Enable         | Invalid | 0    | R/W |                          |
|         | D3   | VRO   | AVREF swich                                                    | On             | Off     | 0    | R/W |                          |
|         | D2   | CHS2  | Analog input channel selection<br>CHS2 CHS1 CHS0 Input channel |                |         | 0    | R/W |                          |
|         | D1   | CHS1  | 1 1 1                                                          | AD7            |         |      | 0   | R/W                      |
|         |      |       | 1 1 0                                                          | AD6            |         |      |     |                          |
|         |      |       | 1 0 1                                                          | AD5            |         |      |     |                          |
|         |      |       | 1 0 0                                                          | AD4            |         |      |     |                          |
| D0      | CHS0 | 0 1 1 | AD3                                                            |                |         | 0    | R/W |                          |
|         |      | 0 1 0 | AD2                                                            |                |         |      |     |                          |
|         |      | 0 0 1 | AD1                                                            |                |         |      |     |                          |
|         |      | 0 0 0 | AD0                                                            |                |         |      |     |                          |
| 00FFA0  | D7   | —     | —                                                              | —              | —       | —    | —   | "0" when being read      |
|         | D6   | PDC   | Pen-down check control                                         | Check          | Cancel  | 0    | R/W | Valid when "RST=0"       |
|         | D5   | RST   | TPC circuit reset control                                      | Cancel         | Reset   | 0    | R/W |                          |
|         | D4   | CONST | Mode setting                                                   | Constant-speed | Normal  | 0    | R/W |                          |
|         | D3   | —     | —                                                              | —              | —       | —    | —   | "0" when being read      |
|         | D2   | AVN2  | Mean count setting<br>AVN2 AVN1 AVN0 Mean count                |                |         | 0    | R/W | Invalid when Normal mode |
|         | D1   | AVN1  | 0 0 0                                                          | 16 × 16        |         |      | 0   | R/W                      |
|         |      |       | 0 0 1                                                          | 16 × 8         |         |      |     |                          |
| D0      | AVN0 | 0 1 0 | 16 × 4                                                         |                |         | 0    | R/W |                          |
|         |      | 0 1 1 | 16 × 2                                                         |                |         |      |     |                          |
| 00FFA1  | D7   | —     | —                                                              | —              | —       | —    | —   | "0" when being read      |
|         | D6   | —     | —                                                              | —              | —       | —    | —   |                          |
|         | D5   | —     | —                                                              | —              | —       | —    | —   |                          |
|         | D4   | —     | —                                                              | —              | —       | —    | —   |                          |
|         | D3   | WAIT3 | 0 0 0                                                          | 16 × 1/f       |         |      | 0   | R/W                      |
|         |      |       | 0 0 1                                                          | 16 × 2/f       |         |      |     |                          |
|         | D2   | WAIT2 | 0 0 1                                                          | 16 × 3/f       |         |      | 1   | R/W                      |
|         |      |       | 0 0 1                                                          | 16 × 4/f       |         |      |     |                          |
|         |      |       | 0 1 0                                                          | 16 × 5/f       |         |      |     |                          |
|         |      |       | 0 1 0                                                          | 16 × 6/f       |         |      |     |                          |
|         | D1   | WAIT1 | 0 1 1                                                          | 16 × 7/f       |         |      | 0   | R/W                      |
|         |      |       | 0 1 1                                                          | 16 × 8/f       |         |      |     |                          |
|         |      |       | 1 0 0                                                          | 16 × 9/f       |         |      |     |                          |
|         |      |       | 1 0 0                                                          | 16 × 10/f      |         |      |     |                          |
|         | D0   | WAIT0 | 1 0 1                                                          | 16 × 11/f      |         |      | 0   | R/W                      |
|         |      |       | 1 0 1                                                          | 16 × 12/f      |         |      |     |                          |
| 1 1 0   |      |       | 16 × 13/f                                                      |                |         |      |     |                          |
| 1 1 0   |      |       | 16 × 14/f                                                      |                |         |      |     |                          |
| 00FFA2  | D7   | —     | —                                                              | —              | —       | —    | —   | "0" when being read      |
|         | D6   | —     | —                                                              | —              | —       | —    | —   |                          |
|         | D5   | —     | —                                                              | —              | —       | —    | —   |                          |
|         | D4   | —     | —                                                              | —              | —       | —    | —   |                          |
|         | D3   | CND3  | 0 0 0                                                          | 4              |         |      | 1   | R/W                      |
|         |      |       | 0 0 0                                                          | 8              |         |      |     |                          |
|         | D2   | CND2  | 0 0 1                                                          | 12             |         |      | 0   | R/W                      |
|         |      |       | 0 0 1                                                          | 16             |         |      |     |                          |
|         |      |       | 0 1 0                                                          | 20             |         |      |     |                          |
|         |      |       | 0 1 0                                                          | 24             |         |      |     |                          |
|         | D1   | CND1  | 0 1 1                                                          | 28             |         |      | 0   | R/W                      |
|         |      |       | 0 1 1                                                          | 32             |         |      |     |                          |
|         |      |       | 1 0 0                                                          | 36             |         |      |     |                          |
|         |      |       | 1 0 0                                                          | 40             |         |      |     |                          |
|         | D0   | CND0  | 1 0 1                                                          | 44             |         |      | 0   | R/W                      |
|         |      |       | 1 0 1                                                          | 48             |         |      |     |                          |
| 1 1 0   |      |       | 52                                                             |                |         |      |     |                          |
| 1 1 0   |      |       | 56                                                             |                |         |      |     |                          |
| D0      | CND0 | 1 1 1 | 60                                                             |                |         | 0    | R/W |                          |
|         |      | 1 1 1 | 64                                                             |                |         |      |     |                          |
|         |      | 1 1 1 | 64                                                             |                |         |      |     |                          |
|         |      | 1 1 1 | 64                                                             |                |         |      |     |                          |

Table 5.17.6.1(c) Touch panel controller control bits

| Address | Bit  | Name  | Function                                          | 1            | 0            | Init         | R/W | Comment             |                                                                     |                                                                     |              |
|---------|------|-------|---------------------------------------------------|--------------|--------------|--------------|-----|---------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|--------------|
| 00FFA3  | D7   | –     | –                                                 | –            | –            | –            | –   | "0" when being read |                                                                     |                                                                     |              |
|         | D6   | –     | –                                                 | –            | –            | –            | –   |                     |                                                                     |                                                                     |              |
|         | D5   | –     | –                                                 | –            | –            | –            | –   |                     |                                                                     |                                                                     |              |
|         | D4   | –     | –                                                 | –            | –            | –            | –   |                     |                                                                     |                                                                     |              |
|         | D3   | PUD3  | Pen-up decision threshold value setting           |              |              |              | 1   | R/W                 |                                                                     |                                                                     |              |
|         |      |       | <u>PUD3</u>                                       | <u>PUD2</u>  | <u>PUD1</u>  | <u>PUD0</u>  |     |                     |                                                                     | <u>Value</u>                                                        |              |
|         |      |       | 0                                                 | 0            | 0            | 0            | 4   |                     |                                                                     |                                                                     |              |
|         |      |       | 0                                                 | 0            | 0            | 1            | 8   |                     |                                                                     |                                                                     |              |
|         |      | D2    | PUD2                                              | 0            | 0            | 1            | 0   | 12                  |                                                                     | 0                                                                   | R/W          |
|         |      |       |                                                   | 0            | 0            | 1            | 1   | 16                  |                                                                     |                                                                     |              |
|         |      |       |                                                   | 0            | 1            | 0            | 0   | 20                  |                                                                     |                                                                     |              |
|         |      |       |                                                   | 0            | 1            | 0            | 1   | 24                  |                                                                     |                                                                     |              |
|         |      |       |                                                   | 0            | 1            | 1            | 0   | 28                  |                                                                     |                                                                     |              |
| D1      |      | PUD1  | 0                                                 | 1            | 1            | 1            | 32  | 1                   |                                                                     | R/W                                                                 |              |
|         |      |       | 1                                                 | 0            | 0            | 0            | 36  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 0            | 0            | 1            | 40  |                     |                                                                     |                                                                     |              |
|         | 1    |       | 0                                                 | 1            | 0            | 44           |     |                     |                                                                     |                                                                     |              |
| D0      | PUD0 | 1     | 0                                                 | 1            | 1            | 48           | 0   | R/W                 |                                                                     |                                                                     |              |
|         |      | 1     | 1                                                 | 0            | 0            | 52           |     |                     |                                                                     |                                                                     |              |
|         |      | 1     | 1                                                 | 0            | 1            | 56           |     |                     |                                                                     |                                                                     |              |
|         |      | 1     | 1                                                 | 1            | 0            | 60           |     |                     |                                                                     |                                                                     |              |
|         |      | 1     | 1                                                 | 1            | 1            | 64           |     |                     |                                                                     |                                                                     |              |
| 00FFA4  | D7   | MVML3 | Middle-low-speed judgment threshold value setting |              |              |              | 0   | R/W                 | Invalid in constant-speed mode<br>MVH≥MVMH<br>MVMH≥MVML<br>MVML≥MVL |                                                                     |              |
|         |      |       | <u>MVML3</u>                                      | <u>MVML2</u> | <u>MVML1</u> | <u>MVML0</u> |     |                     |                                                                     | <u>Value</u>                                                        |              |
|         |      | 0     | 0                                                 | 0            | 0            | 2            |     |                     |                                                                     |                                                                     |              |
|         |      | 0     | 0                                                 | 0            | 1            | 4            |     |                     |                                                                     |                                                                     |              |
|         | D6   | MVML2 | 0                                                 | 0            | 1            | 0            | 6   | 1                   |                                                                     | R/W                                                                 |              |
|         |      |       | 0                                                 | 0            | 1            | 1            | 8   |                     |                                                                     |                                                                     |              |
|         |      |       | 0                                                 | 1            | 0            | 0            | 10  |                     |                                                                     |                                                                     |              |
|         |      |       | 0                                                 | 1            | 0            | 1            | 12  |                     |                                                                     |                                                                     |              |
|         |      |       | 0                                                 | 1            | 1            | 0            | 14  |                     |                                                                     |                                                                     |              |
|         | D5   | MVML1 | 0                                                 | 1            | 1            | 1            | 16  | 0                   |                                                                     | R/W                                                                 |              |
|         |      |       | 1                                                 | 0            | 0            | 0            | 18  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 0            | 0            | 1            | 20  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 0            | 1            | 0            | 22  |                     |                                                                     |                                                                     |              |
|         | D4   | MVML0 | 1                                                 | 0            | 1            | 1            | 24  | 0                   |                                                                     | R/W                                                                 |              |
|         |      |       | 1                                                 | 1            | 0            | 0            | 26  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 1            | 0            | 1            | 28  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 1            | 1            | 0            | 30  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 1            | 1            | 1            | 32  |                     |                                                                     |                                                                     |              |
|         | D3   | MVL3  | Low-speed judgment threshold value setting        |              |              |              | 0   | R/W                 |                                                                     | Invalid in constant-speed mode<br>MVH≥MVMH<br>MVMH≥MVML<br>MVML≥MVL |              |
|         |      |       | <u>MVL3</u>                                       | <u>MVL2</u>  | <u>MVL1</u>  | <u>MVL0</u>  |     |                     |                                                                     |                                                                     | <u>Value</u> |
|         |      | 0     | 0                                                 | 0            | 0            | 2            |     |                     |                                                                     |                                                                     |              |
|         |      | 0     | 0                                                 | 0            | 1            | 4            |     |                     |                                                                     |                                                                     |              |
| D2      |      | MVL2  | 0                                                 | 0            | 1            | 0            | 6   | 0                   | R/W                                                                 |                                                                     |              |
|         |      |       | 0                                                 | 0            | 1            | 1            | 8   |                     |                                                                     |                                                                     |              |
|         |      |       | 0                                                 | 1            | 0            | 0            | 10  |                     |                                                                     |                                                                     |              |
|         |      |       | 0                                                 | 1            | 0            | 1            | 12  |                     |                                                                     |                                                                     |              |
|         |      |       | 0                                                 | 1            | 1            | 0            | 14  |                     |                                                                     |                                                                     |              |
| D1      |      | MVL1  | 0                                                 | 1            | 1            | 1            | 16  | 1                   | R/W                                                                 |                                                                     |              |
|         |      |       | 1                                                 | 0            | 0            | 0            | 18  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 0            | 0            | 1            | 20  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 0            | 1            | 0            | 22  |                     |                                                                     |                                                                     |              |
| D0      |      | MVL0  | 1                                                 | 0            | 1            | 1            | 24  | 0                   | R/W                                                                 |                                                                     |              |
|         |      |       | 1                                                 | 1            | 0            | 0            | 26  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 1            | 0            | 1            | 28  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 1            | 1            | 0            | 30  |                     |                                                                     |                                                                     |              |
|         |      |       | 1                                                 | 1            | 1            | 1            | 32  |                     |                                                                     |                                                                     |              |

Table 5.17.6.1(d) Touch panel controller control bits

| Address    | Bit    | Name         | Function                                                     | 1                                                                    | 0 | Init | R/W | Comment                                                               |                                                                       |
|------------|--------|--------------|--------------------------------------------------------------|----------------------------------------------------------------------|---|------|-----|-----------------------------------------------------------------------|-----------------------------------------------------------------------|
| 00FFA5     | D7     | MVH3         | High-speed judgment threshold value setting                  |                                                                      |   | 1    | R/W | Invalid in constant-speed mode<br>MVH $\geq$ MVMH<br>MVMH $\geq$ MVML |                                                                       |
|            |        |              | <u>MVH3</u> <u>MVH2</u> <u>MVH1</u> <u>MVH0</u> <u>Value</u> |                                                                      |   |      |     |                                                                       |                                                                       |
|            | D6     | MVH2         | 0 0 0 1 4                                                    |                                                                      |   | 0    | R/W | MVML $\geq$ MVL                                                       |                                                                       |
|            |        |              | 0 0 1 1 8                                                    |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 0 1 0 0 10                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 0 1 0 1 12                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 0 1 1 0 14                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 1 1 1 16                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            | D5     | MVH1         | 1 0 0 0 18                                                   |                                                                      |   | 0    | R/W |                                                                       |                                                                       |
|            |        |              | 1 0 0 1 20                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 0 1 0 22                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 0 1 1 24                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            | D4     | MVH0         | 1 1 0 0 26                                                   |                                                                      |   | 0    | R/W |                                                                       |                                                                       |
|            |        |              | 1 1 0 1 28                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 1 1 0 30                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 1 1 1 32                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            | 00FFA6 | D3           | MVMH3                                                        | Middle-high-speed judgment threshold value setting                   |   |      | 0   | R/W                                                                   | Invalid in constant-speed mode<br>MVH $\geq$ MVMH<br>MVMH $\geq$ MVML |
|            |        |              |                                                              | <u>MVMH3</u> <u>MVMH2</u> <u>MVMH1</u> <u>MVMH0</u> <u>Value</u>     |   |      |     |                                                                       |                                                                       |
|            |        | D2           | MVMH2                                                        | 0 0 0 1 6                                                            |   |      | 1   | R/W                                                                   | MVML $\geq$ MVL                                                       |
|            |        |              |                                                              | 0 0 1 1 8                                                            |   |      |     |                                                                       |                                                                       |
| 0 1 0 0 10 |        |              |                                                              |                                                                      |   |      |     |                                                                       |                                                                       |
| 0 1 0 1 12 |        |              |                                                              |                                                                      |   |      |     |                                                                       |                                                                       |
| 0 1 1 0 14 |        |              |                                                              |                                                                      |   |      |     |                                                                       |                                                                       |
| 1 1 1 1 16 |        |              |                                                              |                                                                      |   |      |     |                                                                       |                                                                       |
| D1         |        | MVMH1        | 1 0 0 0 18                                                   |                                                                      |   | 1    | R/W |                                                                       |                                                                       |
|            |        |              | 1 0 0 1 20                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 0 1 0 22                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 0 1 1 24                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
| D0         |        | MVMH0        | 1 1 0 0 26                                                   |                                                                      |   | 0    | R/W |                                                                       |                                                                       |
|            |        |              | 1 1 0 1 28                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 1 1 0 30                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 1 1 1 32                                                   |                                                                      |   |      |     |                                                                       |                                                                       |
| 00FFA6     |        | D7           | –                                                            | –                                                                    | – | –    | –   | –                                                                     | "0" when being read                                                   |
|            |        | D6           | –                                                            | –                                                                    | – | –    | –   | –                                                                     |                                                                       |
|            |        | D5           | –                                                            | –                                                                    | – | –    | –   | –                                                                     |                                                                       |
|            |        | D4           | –                                                            | –                                                                    | – | –    | –   | –                                                                     |                                                                       |
|            | 00FFA6 | D3           | IVL3                                                         | Interval time setting                                                |   |      | 0   | R/W                                                                   |                                                                       |
|            |        |              |                                                              | <u>IVL3</u> <u>IVL2</u> <u>IVL1</u> <u>IVL0</u> <u>Interval time</u> |   |      |     |                                                                       |                                                                       |
|            |        | D2           | IVL2                                                         | 0 0 0 1 128 × 1                                                      |   |      | 0   | R/W                                                                   |                                                                       |
|            |        |              |                                                              | 0 0 0 1 × 2                                                          |   |      |     |                                                                       |                                                                       |
|            |        |              |                                                              | 0 0 1 1 × 3                                                          |   |      |     |                                                                       |                                                                       |
|            |        |              |                                                              | 0 0 1 1 × 4                                                          |   |      |     |                                                                       |                                                                       |
|            |        |              |                                                              | 0 1 0 0 × 5                                                          |   |      |     |                                                                       |                                                                       |
|            |        |              |                                                              | 0 1 0 1 × 6                                                          |   |      |     |                                                                       |                                                                       |
| D1         |        | IVL1         | 0 1 1 1 × 7                                                  |                                                                      |   | 1    | R/W |                                                                       |                                                                       |
|            |        |              | 1 0 0 0 × 8                                                  |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 0 0 1 × 9                                                  |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 0 1 1 × 10                                                 |                                                                      |   |      |     |                                                                       |                                                                       |
| D0         | IVL0   | 1 0 1 1 × 11 |                                                              |                                                                      | 0 | R/W  |     |                                                                       |                                                                       |
|            |        | 1 0 1 1 × 12 |                                                              |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        | 1 1 0 0 × 13 |                                                              |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        | 1 1 0 1 × 14 |                                                              |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 1 0 1 × 15                                                 |                                                                      |   |      |     |                                                                       |                                                                       |
|            |        |              | 1 1 1 1 × 16                                                 |                                                                      |   |      |     |                                                                       |                                                                       |

Table 5.17.6.1(e) Touch panel controller control bits

| Address | Bit | Name | Function               | 1        | 0      | Init | R/W | Comment             |  |
|---------|-----|------|------------------------|----------|--------|------|-----|---------------------|--|
| 00FFA7  | D7  | –    | –                      | –        | –      | –    | –   | "0" when being read |  |
|         | D6  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D5  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D4  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D3  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D2  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D1  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D0  | PEN  | Pen-up/pen-down status | Pen-down | Pen-up | 0    | R   |                     |  |
| 00FFA8  | D7  | DX11 | X coordinate data      | D11(MSB) |        | 0    | R   |                     |  |
|         | D6  | DX10 |                        | D10      |        | 0    | R   |                     |  |
|         | D5  | DX9  |                        | D9       |        | 0    | R   |                     |  |
|         | D4  | DX8  |                        | D8       |        | 0    | R   |                     |  |
|         | D3  | DX7  |                        | D7       |        | 0    | R   |                     |  |
|         | D2  | DX6  |                        | D6       |        | 0    | R   |                     |  |
|         | D1  | DX5  |                        | D5       |        | 0    | R   |                     |  |
|         | D0  | DX4  |                        | D4       |        | 0    | R   |                     |  |
| 00FFA9  | D7  | –    | –                      | –        | –      | –    | –   | "0" when being read |  |
|         | D6  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D5  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D4  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D3  | DX3  | X coordinate data      | D3       |        | 0    | R   |                     |  |
|         | D2  | DX2  |                        | D2       |        | 0    | R   |                     |  |
|         | D1  | DX1  |                        | D1       |        | 0    | R   |                     |  |
|         | D0  | DX0  |                        | D0(LSB)  |        | 0    | R   |                     |  |
|         |     |      |                        |          |        |      |     |                     |  |
| 00FFAA  | D7  | DY11 | Y coordinate data      | D11(MSB) |        | 0    | R   |                     |  |
|         | D6  | DY10 |                        | D10      |        | 0    | R   |                     |  |
|         | D5  | DY9  |                        | D9       |        | 0    | R   |                     |  |
|         | D4  | DY8  |                        | D8       |        | 0    | R   |                     |  |
|         | D3  | DY7  |                        | D7       |        | 0    | R   |                     |  |
|         | D2  | DY6  |                        | D6       |        | 0    | R   |                     |  |
|         | D1  | DY5  |                        | D5       |        | 0    | R   |                     |  |
|         | D0  | DY4  |                        | D4       |        | 0    | R   |                     |  |
| 00FFAB  | D7  | –    | –                      | –        | –      | –    | –   | "0" when being read |  |
|         | D6  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D5  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D4  | –    | –                      | –        | –      | –    | –   |                     |  |
|         | D3  | DY3  | Y coordinate data      | D3       |        | 0    | R   |                     |  |
|         | D2  | DY2  |                        | D2       |        | 0    | R   |                     |  |
|         | D1  | DY1  |                        | D1       |        | 0    | R   |                     |  |
|         | D0  | DY0  |                        | D0(LSB)  |        | 0    | R   |                     |  |
|         |     |      |                        |          |        |      |     |                     |  |

**PSAD0–PSAD2: A/D converter clock division ratio selection register (00FF13H•D0–D2)**

Selects the clock for the A/D converter.

It can be selected from 5 types of division ratio as shown in Table 5.17.6.1(a).

This register can also be read.

At initial reset, the PSAD register is set to "0" (fosc3/1).

**PRAD: A/D converter clock control register (00FF13H•D3)**

Controls the clock supply of the A/D converter.

When "1" is written: ON

When "0" is written: OFF

Reading: Valid

By writing "1" to the PRAD register, the clock that is selected with the PSAD register is output to the A/D converter.

When "0" is written, the clock is not output.

At initial reset, the PRAD register is set to "0" (OFF).

**PSTP0–PSTP2: Touch panel controller clock division ratio selection register (00FF16H•D0–D2)**

Selects the clock for the touch panel controller.

It can be selected from 5 types of division ratio as shown in Table 5.17.6.1(a).

This register can also be read.

At initial reset, the PSTP register is set to "0" (fosc3/1).

**PRTP: Touch panel controller clock control register (00FF16H•D3)**

Controls the clock supply of the touch panel controller.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Valid

By writing "1" to the PRTP register, the clock that is selected with the PSTP register is output to the touch panel controller.

When "0" is written, the clock is not output. At initial reset, the PRTP register is set to "0" (OFF).

**VRC: AVREF control register (00FF80H•D4)**

Enables the AVREF control function.

- When "1" is written: Enabled
- When "0" is written: Disabled
- Reading: Valid

Writing "1" to the VRC register enables the AVREF control function.

An I/O port (P30–P37) which is not used for inputting analog signals can be used to switch the external AVREF input. Set the I/O port in the output mode and write "1" to the data register. When the touch panel controller needs A/D conversion, it turns the I/O port terminal to low. The signal drives the external transistor to supply AVREF to the A/D converter.

**PDC: Pen-down check control register (00FFA0H•D6)**

Controls the pen-down check operation.

- When "1" is written: Check
- When "0" is written: Cancel
- Reading: Valid

When "1" is written to the PDC register, the pen-down check starts. The pen-down check generates an interrupt when a pen-down is detected. Start coordinate detection using the interrupt. It is necessary to enable the pen-down interrupt before starting pen-down check.

When "0" is written to the PDC register, the pen-down check stops.

The pen-down function is effective only when the touch panel controller is in reset status (RST="0"). At initial reset, the PDC register is set to "0" (cancel).

**RST: TPC circuit reset control register (00FFA0H•D5)**

Controls coordinate detection.

- When "1" is written: Cancel
- When "0" is written: Reset
- Reading: Valid

When "1" is written to the RST register, the touch panel controller circuit starts coordinate detection. When "0" is written, the circuit stops coordinate detection and goes into reset status.

Set the touch panel controller circuit to reset status to reduce current consumption when the touch panel operation is not necessary.

At initial reset, the RST register is set to "0" (reset).

**CONST: Mode setting register (00FFA0H•D4)**

Sets the operating mode of the touch panel controller.

- When "1" is written: Constant-speed mode
- When "0" is written: Normal mode
- Reading: Valid

When "1" is written to the CONST register, the touch panel controller is set in the constant-speed mode. When "0" is written. It is set in the normal mode. The constant-speed mode does not judge drawing speed and gets coordinate values by constant arithmetic mean set with the AVN register. The coordinate detection speed is always constant in this mode.

In the normal mode, the hardware changes the number of A/D conversions for arithmetic mean in five stages according to the drawing speed. At initial reset, the CONST register is set to "0" (normal mode).

**AVN0–AVN2: Mean count setting register for constant-speed mode (00FFA0H•D0–D2)**

Sets the arithmetic mean count (number of A/D conversion) for constant-speed mode.

Table 5.17.6.2 Mean count for constant-speed mode

| AVN2 | AVN1 | AVN0 | Number of A/D conversion |
|------|------|------|--------------------------|
| 0    | 0    | 0    | 16×16                    |
| 0    | 0    | 1    | 16×8                     |
| 0    | 1    | 0    | 16×4                     |
| 0    | 1    | 1    | 16×2                     |
| 1    | ×    | ×    | 16×1                     |

The setting in this register is invalid in the normal mode.

The set number of A/D conversions are performed for both the X and Y coordinates.

At initial reset, the AVN register is set to "0" (256 times).

**WAIT0–WAIT3: Voltage stabilization waiting time setting register (00FFA1H•D0–D3)**

Sets a waiting time for voltage stabilization between supplying a voltage to the electrode of the panel to be detected a coordinate and starting an A/D conversion.

Table 5.17.6.3 Waiting time for voltage stabilization

| WAIT3 | WAIT2 | WAIT1 | WAIT0 | Voltage stabilization waiting time |
|-------|-------|-------|-------|------------------------------------|
| 0     | 0     | 0     | 0     | 16×1/f                             |
| 0     | 0     | 0     | 1     | 16×2/f                             |
| 0     | 0     | 1     | 0     | 16×3/f                             |
| 0     | 0     | 1     | 1     | 16×4/f                             |
| 0     | 1     | 0     | 0     | 16×5/f                             |
| 0     | 1     | 0     | 1     | 16×6/f                             |
| 0     | 1     | 1     | 0     | 16×7/f                             |
| 0     | 1     | 1     | 1     | 16×8/f                             |
| 1     | 0     | 0     | 0     | 16×9/f                             |
| 1     | 0     | 0     | 1     | 16×10/f                            |
| 1     | 0     | 1     | 0     | 16×11/f                            |
| 1     | 0     | 1     | 1     | 16×12/f                            |
| 1     | 1     | 0     | 0     | 16×13/f                            |
| 1     | 1     | 0     | 1     | 16×14/f                            |
| 1     | 1     | 1     | 0     | 16×15/f                            |
| 1     | 1     | 1     | 1     | 16×16/f                            |

At initial reset, the WAIT register is set to "0100B" (16 × 5/f).

**CND0–CND3: Noise judgment threshold value setting register (00FFA2H•D0–D3)**

Sets a threshold value for noise judgment.

Table 5.17.6.4 Threshold value for noise judgment

| CND3 | CND2 | CND1 | CND0 | Noise judgment threshold value |
|------|------|------|------|--------------------------------|
| 0    | 0    | 0    | 0    | 4                              |
| 0    | 0    | 0    | 1    | 8                              |
| 0    | 0    | 1    | 0    | 12                             |
| 0    | 0    | 1    | 1    | 16                             |
| 0    | 1    | 0    | 0    | 20                             |
| 0    | 1    | 0    | 1    | 24                             |
| 0    | 1    | 1    | 0    | 28                             |
| 0    | 1    | 1    | 1    | 32                             |
| 1    | 0    | 0    | 0    | 36                             |
| 1    | 0    | 0    | 1    | 40                             |
| 1    | 0    | 1    | 0    | 44                             |
| 1    | 0    | 1    | 1    | 48                             |
| 1    | 1    | 0    | 0    | 52                             |
| 1    | 1    | 0    | 1    | 56                             |
| 1    | 1    | 1    | 0    | 60                             |
| 1    | 1    | 1    | 1    | 64                             |

When the difference between the maximum value and minimum value of the A/D conversions for a coordinate detection is bigger than the set threshold value, it is regarded as a noise and the result is not written to the coordinate data register.

Increase the threshold value if high drawing speed is important, or decrease if noise rejection is important. At initial reset, the CND register is set to "1000B" (36).

**PUD0–PUD3: Pen-up decision threshold value setting register (00FFA3H•D0–D3)**

Sets the threshold value for pen-up decision.

Table 5.17.6.5 Threshold value for pen-up decision

| PUD3 | PUD2 | PUD1 | PUD0 | Pen-up decision threshold value |
|------|------|------|------|---------------------------------|
| 0    | 0    | 0    | 0    | 4                               |
| 0    | 0    | 0    | 1    | 8                               |
| 0    | 0    | 1    | 0    | 12                              |
| 0    | 0    | 1    | 1    | 16                              |
| 0    | 1    | 0    | 0    | 20                              |
| 0    | 1    | 0    | 1    | 24                              |
| 0    | 1    | 1    | 0    | 28                              |
| 0    | 1    | 1    | 1    | 32                              |
| 1    | 0    | 0    | 0    | 36                              |
| 1    | 0    | 0    | 1    | 40                              |
| 1    | 0    | 1    | 0    | 44                              |
| 1    | 0    | 1    | 1    | 48                              |
| 1    | 1    | 0    | 0    | 52                              |
| 1    | 1    | 0    | 1    | 56                              |
| 1    | 1    | 1    | 0    | 60                              |
| 1    | 1    | 1    | 1    | 64                              |

By setting a smaller value than the minimum detection result (A/D conversion data) on the touch panel, pen-up status can be detected.

At initial reset, the PUD register is set to "1010B" (44).

**MVL0–MVL3: Low-speed judgment threshold value setting register (00FFA4H•D0–D3)****MVML0–MVML3: Middle-low-speed judgment threshold value setting register (00FFA4H•D4–D7)****MVMH0–MVMH3: Middle-high-speed judgment threshold value setting register (00FFA5H•D0–D3)****MVH0–MVH3: High-speed judgment threshold value setting register (00FFA5H•D4–D7)**

Sets the threshold value for judging drawing speed in the normal mode.

Table 5.17.6.6 Threshold value for speed judgment

| MVH3  | MVH2  | MVH1  | MVH0  | High-speed        |
|-------|-------|-------|-------|-------------------|
| MVMH3 | MVMH2 | MVMH1 | MVMH0 | Middle-high-speed |
| MVML3 | MVML2 | MVML1 | MVML0 | Middle-low-speed  |
| MVL3  | MVL2  | MVL1  | MVL0  | Low-speed         |
| 0     | 0     | 0     | 0     | 2                 |
| 0     | 0     | 0     | 1     | 4                 |
| 0     | 0     | 1     | 0     | 6                 |
| 0     | 0     | 1     | 1     | 8                 |
| 0     | 1     | 0     | 0     | 10                |
| 0     | 1     | 0     | 1     | 12                |
| 0     | 1     | 1     | 0     | 14                |
| 0     | 1     | 1     | 1     | 16                |
| 1     | 0     | 0     | 0     | 18                |
| 1     | 0     | 0     | 1     | 20                |
| 1     | 0     | 1     | 0     | 22                |
| 1     | 0     | 1     | 1     | 24                |
| 1     | 1     | 0     | 0     | 26                |
| 1     | 1     | 0     | 1     | 28                |
| 1     | 1     | 1     | 0     | 30                |
| 1     | 1     | 1     | 1     | 32                |

The setting must meet following conditions.  
 $MVH \geq MVMH \geq MVML \geq MVL$   
 In the normal mode, the controller gets the drawing speed from the difference between the previous coordinate values and current coordinate values, and decides the next arithmetic mean count according to the threshold values set in these registers.  
 Table 5.17.6.7 shows the mean count that will be set.

Table 5.17.6.7 Arithmetic mean count in normal mode

| Judgment speed   | Next number of A/D conversion |
|------------------|-------------------------------|
| ~MVL             | 256 times                     |
| $MVL \leq MVML$  | 128 times                     |
| $MVML \leq MVMH$ | 64 times                      |
| $MVMH \leq MVH$  | 32 times                      |
| $MVH \sim$       | 16 times                      |

The set number of A/D conversions are performed for both the X and Y coordinates.  
 The settings of these registers are invalid in the constant-speed mode.  
 At initial reset, the registers are set as follows:  
 MVH: 1000B (18)  
 MVMH: 0110B (14)  
 MVML: 0100B (10)  
 MVL: 0010B (6)

**IVL0–IVL3: Interval time setting register (00FFA6H•D0–D3)**

Sets the interval time after A/D conversion.

Table 5.17.6.8 Interval time

| IVL3 | IVL2 | IVL1 | IVL0 | Interval time |
|------|------|------|------|---------------|
| 0    | 0    | 0    | 0    | 128×1/f       |
| 0    | 0    | 0    | 1    | 128×2/f       |
| 0    | 0    | 1    | 0    | 128×3/f       |
| 0    | 0    | 1    | 1    | 128×4/f       |
| 0    | 1    | 0    | 0    | 128×5/f       |
| 0    | 1    | 0    | 1    | 128×6/f       |
| 0    | 1    | 1    | 0    | 128×7/f       |
| 0    | 1    | 1    | 1    | 128×8/f       |
| 1    | 0    | 0    | 0    | 128×9/f       |
| 1    | 0    | 0    | 1    | 128×10/f      |
| 1    | 0    | 1    | 0    | 128×11/f      |
| 1    | 0    | 1    | 1    | 128×12/f      |
| 1    | 1    | 0    | 0    | 128×13/f      |
| 1    | 1    | 0    | 1    | 128×14/f      |
| 1    | 1    | 1    | 0    | 128×15/f      |
| 1    | 1    | 1    | 1    | 128×16/f      |

The selected interval is inserted after four A/D conversions are finished.  
 At initial reset, the IVL register is set to "0010B" (128 × 3).

**PEN: Pen-up/pen-down status (00FFA7H•D0)**

Indicates pen-up status and pen-down status.

When "1" is read: Pen-down  
 When "0" is read: Pen-up  
 Writing: Invalid

The pen status during coordinate detection can be found by reading the PEN bit.  
 When the controller detects a value bigger than the threshold value for pen-up judgment set with the PUD register, the PEN bit goes "1" and when a smaller value is detected goes "0".  
 Writing operation is invalid because PEN is a read-only bit.  
 At initial reset, PEN is set to "0" (pen-up).

**DX0–DX11: X coordinate data register (00FFA9H•D0–D3, 00FFA8)**

**DY0–DY11: Y coordinate data register (00FFABH•D0–D3, 00FFAA)**

The A/D conversion result is written to this register through arithmetic mean.  
 Data is not written if it is judged as a noise.  
 Be sure to read all the coordinate data registers (00FFA8, 00FFA9, 00FFAA, 00FFAB) after a data update interrupt is generated. This process is required if the coordinate data at that point is unnecessary because the next data update interrupt cannot be generated if all the register data are not read.  
 Writing operation is invalid because they are read-only registers.  
 At initial reset, both the DX and DY registers are set to "0".

**PTP0, PTP1: Interrupt priority register (00FF22H•D4, D5)**

Sets the priority level of the touch panel controller interrupt.  
 Table 5.17.6.9 shows the interrupt priority level which can be set by the PTP register.

Table 5.17.6.9 Interrupt priority level settings

| PTP1 | PTP0 | Interrupt priority level      |
|------|------|-------------------------------|
| 1    | 1    | Level 3 ( $\overline{IRQ3}$ ) |
| 1    | 0    | Level 2 ( $\overline{IRQ2}$ ) |
| 0    | 1    | Level 1 ( $\overline{IRQ1}$ ) |
| 0    | 0    | Level 0 (None)                |

At initial reset, the PTPD register is set to "0" (level 0).



**ETPPD, ETPDR: Interrupt enable register  
(00FF26H•D6, D5)**

Enables or disables the touch panel controller interrupt generation to the CPU.

- When "1" is written: Interrupt is enabled
- When "0" is written: Interrupt is disabled
- Reading: Valid

The ETPPD and ETPDR registers are the interrupt enable registers corresponding to the pen-down interrupt and conversion data update interrupt factors, respectively. When the register is set to "1", the interrupt is enabled, and when it is set to "0", the interrupt is disabled.

At initial reset, the EPD and EDLP registers are set to "0" (interrupt is disabled).

**FTPPD, FTPDR: Interrupt factor flag  
(00F2AH•D6, D5)**

Indicates the generation of touch panel controller interrupt factor.

- When "1" is read: Int. factor has generated
- When "0" is read: Int. factor has not generated
- When "1" is written: Factor flag is reset
- When "0" is written: Invalid

FTPPD and FTPDR are the interrupt factor flags corresponding to the pen-down interrupt and conversion data update interrupt, respectively. They are set to "1" when the corresponding factor occurs. The pen-down interrupt factor occurs when a pen-down status is detected during pen-down check. The conversion data update interrupt factor occurs when the coordinate values (result of arithmetic mean) after A/D conversions are written to the coordinate data registers.

At this point, if the corresponding interrupt enable register is set to "1" and the corresponding interrupt priority register is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.

Regardless of the interrupt enable register and interrupt priority register settings, the interrupt factor flag is set to "1" when the interrupt generation conditions are met.

To accept the subsequent interrupt after an interrupt generation, it is necessary to reset the interrupt flag (set the interrupt flag to a lower level than the level indicated by the interrupt priority registers, or execute the RETE instruction) and to reset the interrupt factor flag. The interrupt factor flag is reset to "0" by writing "1".

At initial reset, the FPD and FDLP flags are reset to "0".

**5.17.7 Programming notes**

- (1) The setting of the threshold value for drawing speed judgment in the normal mode must meet following conditions.  
 $MVH \geq MVMH \geq MVML \geq MVL$
- (2) Do not stop the clocks output from the OSC3 oscillation circuit and prescaler during coordinate detection.
- (3) Do not operate the A/D converter independently while the touch panel controller is used.
- (4) The waiting time to be set using the WAIT register must be longer than 3 cycles of the OSC1 clock.  
 $16 \times n / f > 3 / f_{OSC1}$   
 (\*f: Input clock frequency from the prescaler)
 

When the A/D converter reference voltage control function is used (VRC = "1"), the time set in the WAIT register also applies to the reference voltage setup time. Therefore, design the peripheral circuit taking the charge time into consideration. If the reference voltage ( $AV_{REF}$ ) cannot be set up within the time set in the WAIT register, the reference voltage should be switched on and off by software so that the setup time is secured.
- (5) The capacitors connected to Ch0 and Ch1 of the touch panel controller (see Figure 5.17.2.1) affect the pen-down judgement time. They must be 1000 pF or less.

## 5.18 A/D Converter

### 5.18.1 Characteristics and configuration of A/D converter

The S1C88409 has a built-in A/D converter with the following characteristics.

- Conversion formula: Successive-approximation type
- Resolution: 10 bits
- Input channel: Maximum 8 channels
- Conversion time: Minimum 11  $\mu$ sec (in 2 MHz operation)
- Setting of analog conversion voltage range is possible with reference voltage terminal (AVREF)
- A/D conversion result is possible to read from 10-bit data register
- Sample & hold circuit built-in
- A/D conversion completion generates an interrupt

Figure 5.18.1.1 shows the configuration of the A/D converter.

### 5.18.2 Terminal configuration of A/D converter

The terminals used with the A/D converter are as follows:

#### AVDD, AGND, AVSS (power supply input terminal)

The AVDD, AGND and AVSS terminals are power supply terminals for the A/D converter. The voltage should be input as  $AVDD \leq VDD$  and  $AGND \geq AVSS = VSS$ . These power supply terminals are common with the D/A converter.

#### AVREF (reference voltage input terminal)

The AVREF terminal is the reference voltage terminal of the analog block. Input voltage range of the A/D conversion is decided by this input (AGND–AVREF). The voltage should be input as  $AVREF \leq AVDD$ .

This terminal is used as the reference voltage input of the D/A converter.

#### AD0–AD7 (analog input terminal)

The analog input terminals AD0–AD7 are shared with the I/O port terminals P30–P37. Further, the AD6 (P36) and AD7 (P37) terminals can be used as the analog output terminals DA0 and DA1 of the D/A converter. Therefore, it is necessary to set them for the A/D converter by software when using them as analog input terminals. This setting can be done for each terminal. (Refer to Section 5.18.4 for setting.)

At initial reset, all the terminals are set in the I/O port terminal.

Analog voltage value  $AVIN$  that can be input is in the range of  $AVSS \leq AGND \leq AVIN \leq AVREF$ .

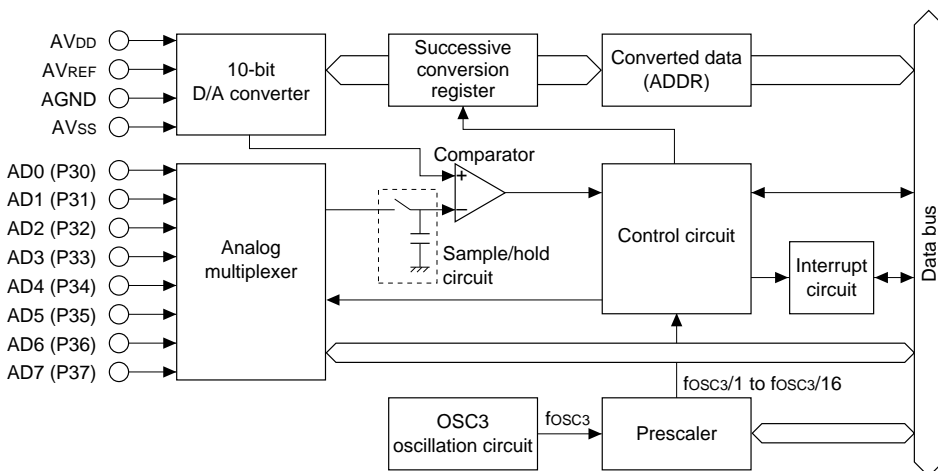


Fig. 5.18.1.1 Configuration of A/D converter

### 5.18.3 Mask option

#### Pull-up resistor

| I/O port pull-up resistor |                                        |               |
|---------------------------|----------------------------------------|---------------|
| P30 (AD0)                 | <input type="checkbox"/> With resistor | ✓ Gate direct |
| P31 (AD1)                 | <input type="checkbox"/> With resistor | ✓ Gate direct |
| P32 (AD2)                 | <input type="checkbox"/> With resistor | ✓ Gate direct |
| P33 (AD3)                 | <input type="checkbox"/> With resistor | ✓ Gate direct |
| P34 (AD4)                 | <input type="checkbox"/> With resistor | ✓ Gate direct |
| P35 (AD5)                 | <input type="checkbox"/> With resistor | ✓ Gate direct |
| P36 (AD6)                 | <input type="checkbox"/> With resistor | ✓ Gate direct |
| P37 (AD7)                 | <input type="checkbox"/> With resistor | ✓ Gate direct |

The input terminals of the A/D converter are shared with the I/O port terminals P30–P37. Therefore, the terminal specification of the A/D converter is decided by setting the I/O port mask option. Select "Gate direct" for the port corresponding to the channel to be used to obtain the conversion precision.

### 5.18.4 Control of A/D converter

#### Setting of A/D input terminal

When using the A/D converter, it is necessary to set up the terminals used for analog input from the P30–P37 initialized as the I/O port terminals. Eight terminals can all be used as analog input terminals. However, one of the AD6 (P36) and AD7 (P37) terminals or both cannot be used as the analog input terminal of the A/D converter when the D/A converter is used, because it is used as the analog output terminal.

The PAD (PAD0–PAD7) register is used to set analog input terminals. When the PAD register bits are set to "1", the corresponding terminals function as the analog input terminals. When using the P36 terminal as an analog input terminal, write "1" to PAD6 and write "0" to PDA6 (for setting an analog output terminal of the D/A converter) to disable the analog output.

When both the PAD6 and PDA6 registers are set to "1", the P36 terminal is set for analog output, and it cannot be used with the A/D converter. It is the same for the P37 terminal. Set PAD7 to "1" and PDA7 to "0".

Table 5.18.4.1 Correspondence between A/D input terminal and PAD register

| Terminal  | A/D input control register | Remarks         |
|-----------|----------------------------|-----------------|
| P30 (AD0) | PAD0                       |                 |
| P31 (AD1) | PAD1                       |                 |
| P32 (AD2) | PAD2                       |                 |
| P33 (AD3) | PAD3                       |                 |
| P34 (AD4) | PAD4                       |                 |
| P35 (AD5) | PAD5                       |                 |
| P36 (AD6) | PAD6                       | Set PDA6 to "0" |
| P37 (AD7) | PAD7                       | Set PDA7 to "0" |

The touch panel controller uses two terminals from P30 to P35 for inputting coordinate signals. These two terminals are selected by mask option and fixed as the analog signal input terminals. Thus the above software settings are unnecessary.

At initial reset, the terminal except for 2 channels of the touch panel controller are set as I/O ports and goes to high-impedance status.

#### Setting of input clock

As explained in Section 5.5, "Prescaler and Clock Control Circuit for Peripheral Circuits", the A/D conversion clock can be selected from 5 types shown in Table 5.18.4.2. The selection is done using the PSAD register.

Table 5.18.4.2 Input clock selection

| Selection register |       |       | Division ratio | Output control      |
|--------------------|-------|-------|----------------|---------------------|
| PSAD2              | PSAD1 | PSAD0 |                |                     |
| 1                  | ×     | ×     | fosc3/16       | PRAD register       |
| 0                  | 1     | 1     | fosc3/8        |                     |
| 0                  | 1     | 0     | fosc3/4        | "1": ON<br>"0": OFF |
| 0                  | 0     | 1     | fosc3/2        |                     |
| 0                  | 0     | 0     | fosc3/1        |                     |

The prescaler outputs the selected clock to the A/D converter by writing "1" to the PRAD register.

- Note:*
- The prescaler can output a clock to the A/D converter only when the OSC3 oscillation goes on. (Refer to Section 5.5, "Prescaler and Clock Control Circuit for Peripheral Circuits".)
  - The frequency of the input clock should be lower than the maximum value shown in Section 8.7, "A/D Converter Characteristics".
  - The input clock should be set when the A/D converter stops. Changing in the A/D converter operation may cause a malfunction.
  - To prevent malfunction, do not start A/D conversion (writing to the CHS register) when the A/D conversion clock is not being output from the prescaler, and do not turn the prescaler output clock off during A/D conversion.

**AVREF control**

**VRO**

The VRO register is used to turn the reference voltage AVREF for the A/D converter on and off. AVREF is turned on and off by an external transistor. An I/O port (P30–P37) which is not used for inputting analog signals (including two terminals used with the touch panel controller) is used to drive the transistor using the VRO register value. To set an I/O port for this function, set the I/O port in the output mode and write "1" to the data register. When "1" is written to the VRO register, the I/O port terminal goes low. When "0" is written, the terminal returns to high. If two or more I/O ports are set in this status, all the terminals are controlled with the VRO register. Therefore, P30–P37 cannot be used as general-purpose output ports.

When using P30 to P37 as general-purpose I/O ports, the VRO and VRC registers must be set to "0".

**VRC**

The VRC register enables the AVREF to be controlled by the touch panel controller. The touch panel controller controls the A/D converter during its operation. By writing "1" to the VRC register, the touch panel controller also controls AVREF in the same way as the VRO register. Thus it is unnecessary to change the VRO register while the touch panel controller operates.

**Input signal selection**

The analog signals from the AD0 (P30)–AD7 (P37) terminals are input to the multiplexer, and the analog input channel for A/D conversion is selected by software. This selection can be done using the CHS register as shown in Table 5.18.4.3.

Table 5.18.4.3 Selection of analog input channel

| CHS2 | CHS1 | CHS0 | Input channel |
|------|------|------|---------------|
| 1    | 1    | 1    | AD7           |
| 1    | 1    | 0    | AD6           |
| 1    | 0    | 1    | AD5           |
| 1    | 0    | 0    | AD4           |
| 0    | 1    | 1    | AD3           |
| 0    | 1    | 0    | AD2           |
| 0    | 0    | 1    | AD1           |
| 0    | 0    | 0    | AD0           |

**A/D conversion operation**

An A/D conversion starts by writing data to the ADRUN register. For example, when performing A/D conversion using AD1 as the analog input, write "1" (0, 0, 1) to the CHS register (CHS2, CHS1, CHS0) and then write "1" to the ADRUN register. The A/D input channel is selected and the A/D conversion starts. However, it is necessary that the P31 terminal has been set as an analog input terminal.

The built-in sample/hold circuit starts sampling of the analog input specified from TAD after writing. When the sampling is completed, the held analog input voltage is converted into a 10-bit digital value in successive-approximation architecture.

The conversion result is loaded into the ADDR (ADDR0–ADDR9) register. ADDR0 is the LSB and ADDR9 is the MSB.

*Note: If the CHS register selects an input channel which is not included in the analog input terminals set by the PAD register (the PAD register can select several terminals simultaneously), the A/D conversion does not result in a correct converted value.*

*Example)*

*Terminal setting:*

*PAD5=1, PAD7=PAD6=PAD4=PAD0=0  
(AD5 terminal is used)*

*Selection of input channel:*

*CHS2=1, CHS1=0, CHS0=0  
(AD4 is selected)*

*In a setting like this, the A/D conversion result will be invalid because the contents of the settings are not matched.*

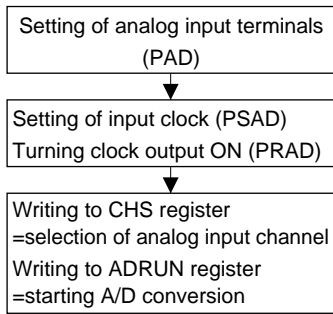


Fig. 5.18.4.1 Flowchart for starting A/D conversion

An A/D conversion is completed when the conversion result is loaded into the ADDR register. At that point, the A/D converter generates an interrupt (explained in the next section).

Figure 5.18.4.2 shows the timing chart of A/D conversion.

### 5.18.5 Interrupt function

The A/D converter can generate an interrupt when an A/D conversion has completed. Figure 5.18.5.1 shows the configuration of the A/D converter interrupt circuit.

The A/D converter sets the interrupt factor flag FAD to "1" when it stores the conversion. At this time, if the interrupt enable register EAD is "1" and the interrupt priority register PAD (2 bits) is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.

By setting the EAD register to "0", the interrupt to the CPU can also be disabled. However, the interrupt factor flag is set to "1" when an A/D conversion has completed regardless of the interrupt enable register and interrupt priority register settings.

The interrupt factor flag set in "1" is reset to "0" by writing "1".

Refer to Section 5.20, "Interrupt and Standby Mode", for details of the interrupt control registers and operations subsequent to interrupt generation. The exception processing vector address for the A/D conversion completion interrupt has been set in 000026H.

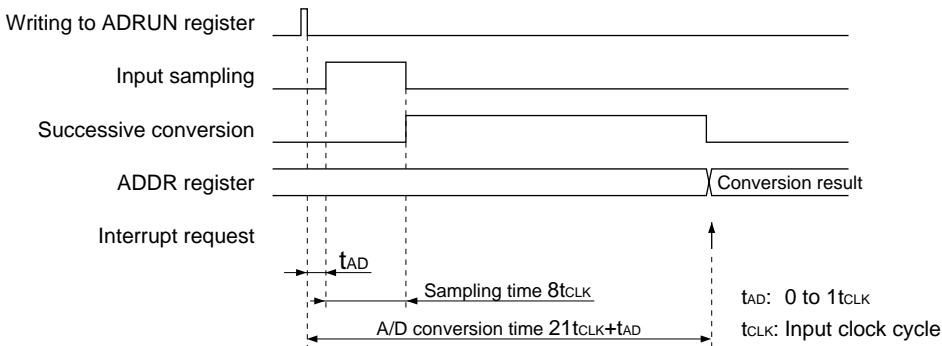


Fig. 5.18.4.2 Timing chart of A/D conversion

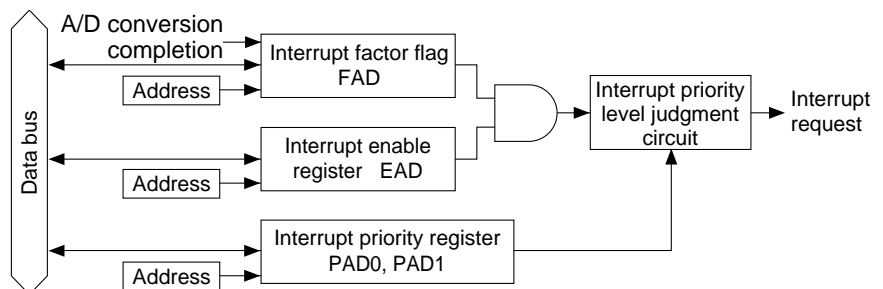


Fig. 5.18.5.1 Configuration of A/D converter interrupt circuit

5.18.6 I/O memory of A/D converter

Table 5.18.6.1 shows the A/D converter control bits.

Table 5.18.6.1(a) A/D converter control bits

| Address | Bit  | Name  | Function                                                               | 1                              | 0                                  | Init     | R/W | Comment             |                     |
|---------|------|-------|------------------------------------------------------------------------|--------------------------------|------------------------------------|----------|-----|---------------------|---------------------|
| 00FF13  | D7   | –     | –                                                                      | –                              | –                                  | –        | –   | "0" when being read |                     |
|         | D6   | –     | –                                                                      | –                              | –                                  | –        | –   |                     |                     |
|         | D5   | –     | –                                                                      | –                              | –                                  | –        | –   |                     |                     |
|         | D4   | –     | –                                                                      | –                              | –                                  | –        | –   |                     |                     |
|         | D3   | PRAD  | A/D converter clock control                                            |                                | On                                 | Off      | 0   | R/W                 |                     |
|         | D2   | PSAD2 | A/D converter division ratio                                           |                                |                                    |          | 0   | R/W                 |                     |
|         | D1   | PSAD1 | PSAD2 PSAD1 PSAD0                                                      | Division ratio                 |                                    |          | 0   | R/W                 |                     |
| 00FF22  | D7   | PAD1  | A/D converter                                                          | PAD1                           | PAD0                               | Priority | 0   | R/W                 |                     |
|         | D6   | PAD0  | interrupt priority register                                            | PTP1                           | PTP0                               | level    | 0   | R/W                 |                     |
|         | D5   | PTP1  | Touch panel controller                                                 | 1                              | 1                                  | Level 3  | 0   | R/W                 |                     |
|         | D4   | PTP0  | interrupt priority register                                            | 1                              | 0                                  | Level 2  | 0   | R/W                 |                     |
|         | D3   | –     | –                                                                      | 0                              | 1                                  | Level 1  | –   | –                   | "0" when being read |
|         | D2   | –     | –                                                                      | 0                              | 0                                  | Level 0  | –   | –                   |                     |
|         | D1   | –     | –                                                                      | –                              | –                                  | –        | –   | –                   |                     |
| D0      | –    | –     | –                                                                      | –                              | –                                  | –        | –   |                     |                     |
| 00FF26  | D7   | EAD   | A/D converter conversion completion interrupt enable register          |                                |                                    |          | 0   | R/W                 |                     |
|         | D6   | ETPPD | Touch panel controller pen-down interrupt enable register              |                                |                                    |          | 0   | R/W                 |                     |
|         | D5   | ETPDR | Touch panel controller converted data update interrupt enable register | Interrupt is enabled           | Interrupt is disabled              |          | 0   | R/W                 |                     |
|         | D4   | –     | –                                                                      |                                |                                    |          | –   | –                   | "0" when being read |
|         | D3   | –     | –                                                                      |                                |                                    |          | –   | –                   |                     |
|         | D2   | –     | –                                                                      |                                |                                    |          | –   | –                   |                     |
|         | D1   | –     | –                                                                      |                                |                                    |          | –   | –                   |                     |
| 00FF2A  | D7   | FAD   | A/D converter conversion completion interrupt factor flag              | (R)                            | (R)                                |          | 0   | R/W                 |                     |
|         | D6   | FTPPD | Touch panel controller pen-down interrupt factor flag                  | Interrupt factor has generated | Interrupt factor has not generated |          | 0   | R/W                 |                     |
|         | D5   | FTPDR | Touch panel controller converted data update interrupt factor flag     |                                |                                    |          | 0   | R/W                 |                     |
|         | D4   | –     | –                                                                      |                                |                                    |          | –   | –                   | "0" when being read |
|         | D3   | –     | –                                                                      |                                |                                    |          | –   | –                   |                     |
|         | D2   | –     | –                                                                      |                                |                                    |          | –   | –                   |                     |
|         | D1   | –     | –                                                                      |                                |                                    |          | –   | –                   |                     |
| 00FF80  | D7   | ADRUN | A/D conversion start control register                                  | Start                          | Invalid                            |          | 0   | W                   | "0" when being read |
|         | D6   | –     | –                                                                      | –                              | –                                  | –        | –   | –                   |                     |
|         | D5   | –     | –                                                                      | –                              | –                                  | –        | –   | –                   |                     |
|         | D4   | VRC   | AVREF control (Touch panel controller)                                 |                                | Enable                             | Invalid  | 0   | R/W                 |                     |
|         | D3   | VRO   | AVREF swich                                                            |                                | On                                 | Off      | 0   | R/W                 |                     |
|         | D2   | CHS2  | Analog input channel selection                                         |                                |                                    |          | 0   | R/W                 |                     |
|         | D1   | CHS1  | CHS2 CHS1 CHS0                                                         | Input channel                  |                                    |          | 0   | R/W                 |                     |
| D0      | CHS0 | 1     | 1                                                                      | 1                              | AD7                                |          |     |                     |                     |
|         |      | 1     | 1                                                                      | 0                              | AD6                                |          |     |                     |                     |
|         |      | 1     | 0                                                                      | 1                              | AD5                                |          |     |                     |                     |
|         |      | 1     | 0                                                                      | 0                              | AD4                                |          |     |                     |                     |
| 0       | 1    | 1     | AD3                                                                    |                                |                                    |          |     |                     |                     |
| 0       | 1    | 0     | AD2                                                                    |                                |                                    |          |     |                     |                     |
| 0       | 0    | 1     | AD1                                                                    |                                |                                    |          |     |                     |                     |
| 0       | 0    | 0     | AD0                                                                    |                                |                                    |          |     |                     |                     |

Table 5.18.6.1(b) A/D converter control bits

| Address | Bit | Name  | Function                         | 1                    | 0        | Init | R/W | Comment             |   |
|---------|-----|-------|----------------------------------|----------------------|----------|------|-----|---------------------|---|
| 00FF81  | D7  | ADDR9 | A/D conversion result            | D9(MSB)              |          |      | -   | R                   |   |
|         | D6  | ADDR8 |                                  | D8                   |          |      | -   | R                   |   |
|         | D5  | ADDR7 |                                  | D7                   |          |      | -   | R                   |   |
|         | D4  | ADDR6 |                                  | D6                   |          |      | -   | R                   |   |
|         | D3  | ADDR5 |                                  | D5                   |          |      | -   | R                   |   |
|         | D2  | ADDR4 |                                  | D4                   |          |      | -   | R                   |   |
|         | D1  | ADDR3 |                                  | D3                   |          |      | -   | R                   |   |
|         | D0  | ADDR2 |                                  | D2                   |          |      | -   | R                   |   |
| 00FF82  | D7  | -     | -                                | -                    | -        | -    | -   | "0" when being read |   |
|         | D6  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D5  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D4  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D3  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D2  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D1  | ADDR1 | A/D conversion result            | D1                   |          |      | -   |                     | R |
|         | D0  | ADDR0 |                                  | D0(LSB)              |          |      | -   |                     | R |
| 00FFE8  | D7  | PAD7  | P37 A/D converter input control  | A/D converter input  | I/O port | 0    | R/W |                     |   |
|         | D6  | PAD6  | P36 A/D converter input control  |                      |          | 0    | R/W |                     |   |
|         | D5  | PAD5  | P35 A/D converter input control  |                      |          | 0    | R/W |                     |   |
|         | D4  | PAD4  | P34 A/D converter input control  |                      |          | 0    | R/W |                     |   |
|         | D3  | PAD3  | P33 A/D converter input control  |                      |          | 0    | R/W |                     |   |
|         | D2  | PAD2  | P32 A/D converter input control  |                      |          | 0    | R/W |                     |   |
|         | D1  | PAD1  | P31 A/D converter input control  |                      |          | 0    | R/W |                     |   |
|         | D0  | PAD0  | P30 A/D converter input control  |                      |          | 0    | R/W |                     |   |
| 00FFE9  | D7  | PDA7  | P37 D/A converter output control | D/A converter output | I/O port | 0    | R/W | "0" when being read |   |
|         | D6  | PDA6  | P36 D/A converter output control |                      |          | 0    | R/W |                     |   |
|         | D5  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D4  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D3  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D2  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D1  | -     | -                                | -                    | -        | -    | -   |                     |   |
|         | D0  | -     | -                                | -                    | -        | -    | -   |                     |   |

**PAD0–PAD7: A/D converter input control register (00FFE8H)**

Sets the P30–P37 terminals as the analog input terminals for the A/D converter.

- When "1" is written: A/D converter input
- When "0" is written: I/O port
- Reading: Valid

When "1" is written to PADn, the P3n terminal is set to the analog input terminal ADn. (n=0–7)  
 When "0" is written, the terminal is used with the I/O port.

At initial reset, the PAD register is set to "0" (I/O port).

**PDA6, PDA7: D/A converter output control register (00FFE9H•D6, D7)**

The PDA6 and PDA7 registers set the P36 and P37 terminals to the analog output terminal of the D/A converter, respectively. Those register settings have priority over the PAD6 and PAD7 settings.

Therefore, when using the P36 terminal (P37 terminal) as the analog input for the A/D converter, fix the PDA6 (PDA7) register at "0". At initial reset, the PDA register is set to "0" (I/O port).

**PSAD0–PSAD2: A/D converter division ratio selection register (00FF13H•D0–D2)**

Selects the clock for the A/D converter.

Table 5.18.6.2 Input clock selection

| PSAD2 | PSAD1 | PSAD0 | Division ratio |
|-------|-------|-------|----------------|
| 1     | ×     | ×     | fosc3/16       |
| 0     | 1     | 1     | fosc3/8        |
| 0     | 1     | 0     | fosc3/4        |
| 0     | 0     | 1     | fosc3/2        |
| 0     | 0     | 0     | fosc3/1        |

This setting controls the division ratio of the prescaler.  
 At initial reset, the PSAD register is set to "0" (fosc3/1).

**PRAD: A/D converter clock control register (00FF13H•D3)**

Controls the clock supply to the A/D converter.

- When "1" is written: ON
- When "0" is written: OFF
- Reading: Invalid

By writing "1" to the PRAD register, the prescaler outputs the clock selected with the PSAD register to the A/D converter. However, it is necessary that the CPU operating clock be set to OSC3.

When "0" is written, the clock is not output to the A/D converter.

At initial reset, the PRAD register is set to "0" (OFF).

**ADRUN: A/D conversion start trigger (00FF80H•D7)**

Starts A/D conversion.

- When "1" is written: Start A/D conversion
- When "0" is written: Invalid
- Reading: Always "0"

By writing "1" to this register, the A/D converter starts A/D conversion of the channel selected by the CHS register, and stores the conversion result to the ADDR register.

**VRO: AVREF switch (00FF80H•D3)**

Turns AVREF on and off.

- When "1" is written: On
- When "0" is written: Off
- Reading: Valid

When "1" is written to the VRO register, AVREF turns on and when "0" is written turns off. An I/O port (P30–P37) which is not used for inputting analog signals can be used to switch the external AVREF input. Set the I/O port in the output mode and write "1" to the data register. Writing "1" to the VRO register in this status turns the I/O port terminal to low. The signal drives the external transistor to supply AVREF to the A/D converter.

At initial reset, the VRO register is set to "0" (OFF).

**VRC: AVREF control register (00FF80H•D4)**

Enables the AVREF to be controlled by the touch panel controller.

- When "1" is written: Enabled
- When "0" is written: Disabled
- Reading: Valid

Writing "1" to the VRC register sets the touch panel controller so that it controls the AVREF without the VRO register.

At initial reset, the VRC register is set to "0" (disabled).

**CHS0–CHS2: Analog input channel selection register (00FF80H•D0–D2)**

Selects an analog input channel.

Table 5.18.6.3 Selection of analog input channel

| CHS2 | CHS1 | CHS0 | Input channel |
|------|------|------|---------------|
| 1    | 1    | 1    | AD7           |
| 1    | 1    | 0    | AD6           |
| 1    | 0    | 1    | AD5           |
| 1    | 0    | 0    | AD4           |
| 0    | 1    | 1    | AD3           |
| 0    | 1    | 0    | AD2           |
| 0    | 0    | 1    | AD1           |
| 0    | 0    | 0    | AD0           |

At initial reset, the CHS register is set to "0" (AD0).

**ADDR0–ADDR9: A/D conversion result (00FF82H/low-order 2 bits, 00FF81H/high-order 8 bits)**

A/D conversion result is stored.

ADDR0 is the LSB and ADDR9 is the MSB.

ADDR0 and ADDR1 are assigned in D0 bit and D1 bit of the address 00FF82H. D2–D7 bits in this address are always "0" when being read.

At initial reset, data is set to "0".

**PAD0, PAD1: A/D converter interrupt priority register (00FF22H•D6, D7)**

Sets the priority level of the A/D conversion completion interrupt.

Table 5.18.6.4 shows the interrupt priority level which can be set by the PAD register.

Table 5.18.6.4 Interrupt priority level settings

| PAD1 | PAD0 | Interrupt priority level             |
|------|------|--------------------------------------|
| 1    | 1    | Level 3 ( $\overline{\text{IRQ}}3$ ) |
| 1    | 0    | Level 2 ( $\overline{\text{IRQ}}2$ ) |
| 0    | 1    | Level 1 ( $\overline{\text{IRQ}}1$ ) |
| 0    | 0    | Level 0 (None)                       |

At initial reset, the PAD register is set to "0" (level 0).



**EAD: A/D conversion completion interrupt enable register (00FF26H•D7)**

Enables or disables the A/D conversion completion interrupt generation to the CPU.

When "1" is written: Interrupt is enabled  
 When "0" is written: Interrupt is disabled  
 Reading: Valid

The EAD register is the interrupt enable register corresponding to the A/D conversion completion interrupt factor. When this register is set to "1", the interrupt is enabled, and when it is set to "0", the interrupt is disabled.

At initial reset, the EAD register is set to "0" (interrupt is disabled).

**FAD: A/D conversion completion interrupt factor flag (00FF2AH•D7)**

Indicates the generation of A/D conversion completion interrupt factor.

When "1" is read: Int. factor has generated  
 When "0" is read: Int. factor has not generated

When "1" is written: Factor flag is reset  
 When "0" is written: Invalid

FAD is the interrupt factor flag corresponding to the A/D conversion completion interrupt. It is set to "1" when an A/D conversion is completed. At this point, if the corresponding interrupt enable register is set to "1" and the corresponding interrupt priority register is set to a higher level than the setting of the interrupt flags (I0 and I1), an interrupt is generated to the CPU.

Regardless of the interrupt enable register and interrupt priority register settings, the interrupt factor flag is set to "1" when the interrupt generation condition is met.

To accept the subsequent interrupt after an interrupt generation, it is necessary to re-set the interrupt flags (set the interrupt flag to a lower level than the level indicated by the interrupt priority registers, or execute the RETE instruction) and to reset the interrupt factor flag. The interrupt factor flag is reset to "0" by writing "1".

At initial reset, the FAD flag is reset to "0".

**5.18.7 Programming notes**

- (1) The A/D converter can operate by inputting the clock from the prescaler. Therefore, it is necessary to set the division ratio of the prescaler and to turn the clock output on before starting A/D conversion. Furthermore, it is also necessary that the OSC3 oscillation circuit is operating because the prescaler can operate only when the OSC3 is set as the CPU clock. (Refer to Section 5.5, "Prescaler and Clock Control Circuit for Peripheral Circuits".)
- (2) When SLEEP mode is set during A/D conversion, correct A/D conversion result cannot be obtained because the OSC3 oscillation circuit stops. Do not set in SLEEP mode during A/D conversion.
- (3) The input clock and analog input terminals should be set when the A/D converter stops. Changing in the A/D converter operation may cause a malfunction.
- (4) The frequency of the input clock should be lower than the maximum value shown in Section 8.7, "A/D Converter Characteristics".
- (5) To prevent malfunction, do not start A/D conversion (writing to the CHS register) when the A/D conversion clock is not being output from the prescaler, and do not turn the prescaler output clock off during A/D conversion.
- (6) If the CHS register selects an input channel which is not included in the analog input terminals set by the PAD register (the PAD register can select several terminals simultaneously), the A/D conversion does not result in a correct converted value.
- (7) During A/D conversion, do not operate the P3n terminals which are not used for analog inputs of the A/D converter (for input/output of digital signal and for D/A conversion). It affects the A/D conversion precision.

## 5.19 D/A Converter

### 5.19.1 Characteristics and configuration of D/A converter

The S1C88409 has built-in two channels of D/A converter with the following characteristics.

- Conversion formula: R-2R ladder type
- Resolution: 8 bits
- Output channel: 2 channels
- Conversion time: Minimum 30  $\mu$ sec  
(load capacitance: 100 pF)
- Output voltage range: 0 V to  $AV_{REF}$   
( $AV_{REF}/256$  steps)

Figure 5.19.1.1 shows the configuration of the D/A converter.

### 5.19.2 Terminal configuration of D/A converter

The terminals used with the D/A converter are as follows:

#### **$AV_{DD}$ , AGND, $AV_{SS}$** (power supply input terminal)

The  $AV_{DD}$ , AGND and  $AV_{SS}$  terminals are power supply terminals for the A/D converter. The voltage should be input as  $AV_{DD} \leq V_{DD}$  and  $AGND \geq AV_{SS} = V_{SS}$ . These power supply terminals are common with the A/D converter.

#### **$AV_{REF}$ (reference voltage input terminal)**

The  $AV_{REF}$  terminal is the reference voltage terminal of the analog block. Output voltage range of the D/A conversion is decided by this input ( $AGND - AV_{REF}$ ). The voltage should be input as  $AV_{REF} \leq AV_{DD}$ .

This terminal is used as the reference voltage input of the A/D converter.

It is possible to turn  $AV_{REF}$  on and off by software. Refer to Section 5.18, "A/D Converter", for details.

#### **DA0, DA1 (analog output terminal)**

The analog output terminals DA0 and DA1 are shared with the I/O port terminals P36 and P37. Further, those terminals can be used as the analog input terminals AD6 and AD7 of the A/D converter. Therefore, it is necessary to set them for the D/A converter by software when using them as an analog output terminal. This setting can be done for each terminal. (Refer to Section 5.19.4 for setting.)

At initial reset, both the terminals are set in the I/O port terminals.

### 5.19.3 Mask option

|                           |                                        |                                                 |
|---------------------------|----------------------------------------|-------------------------------------------------|
| I/O port pull-up resistor |                                        |                                                 |
| P36 (DA0)                 | <input type="checkbox"/> With resistor | <input checked="" type="checkbox"/> Gate direct |
| P37 (DA1)                 | <input type="checkbox"/> With resistor | <input checked="" type="checkbox"/> Gate direct |

The output terminals of the D/A converter are shared with the I/O port terminals P36 and P37. Therefore, the terminal specification of the D/A converter is decided by setting the I/O port mask option. Select "Gate direct" for the port corresponding to the channel to be used to obtain the conversion precision.

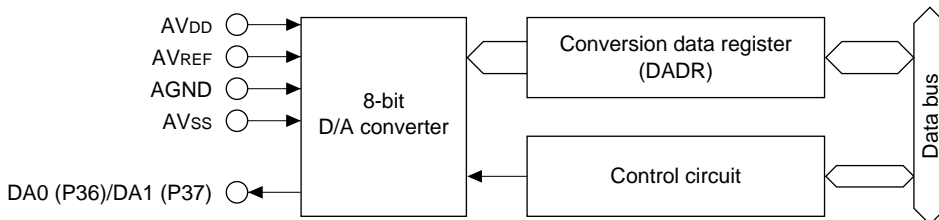


Fig. 5.19.1.1 Configuration of D/A converter

### 5.19.4 Control of D/A converter

#### Initial settings

When using the D/A converter, it is necessary to set up the terminals used for analog output from the P36 and P37 initialized as the I/O port terminals.

When using DA0 (P36) as the analog output terminal, write "1" to the PDA6 register and "0" to the PAD6 register.

When using DA1 (P37) as the analog output terminal, write "1" to the PDA7 register and "0" to the PAD7 register.

Do not set both the terminals as analog outputs simultaneously.

The analog output terminal goes to AGND level until the D/A conversion result is output.

#### D/A conversion operation

The DADR (DADR0–DADR7) register is used to write 8-bit data to be D/A converted.

To start D/A conversion, write "1" to the DAE register.

By this writing, data set in the DADR register is converted into analog value and the conversion result is output from the corresponding analog output terminal.

The D/A converter takes a maximum 30  $\mu$ sec of D/A conversion time until it outputs the conversion result to the analog output terminal after starting D/A conversion with the DAE register. When "0" is written to the DAE register, the corresponding analog output terminal goes to AGND level.

Table 5.19.4.1 Analog output level on DA0 and DA1

| DAE | DA0<br>DA1            |
|-----|-----------------------|
| 0   | AGND                  |
| 1   | D/A conversion output |

Furthermore, when new data is written to the DADR register keeping "1" of the DAE register, the data is converted by this writing and the result is output to the analog output terminal after a maximum 30  $\mu$ sec have passed after the writing.

The following shows the analog output voltage according to the data written in the DADR register (0–255).

Output voltage

$$= AV_{REF} * [\text{Value set in DADR register}] / 256 \text{ (V)}$$

*Note: When the status of the P37 (P36) terminal is changed while DA0 (1) is outputting the D/A conversion result, the DA0 (1) terminal may change its output level.*

*The D/A converter has no built-in output buffer, so use an external amplifier to drive loads. In this case, make sure that the amplifier input current is 1  $\mu$ A or less.*

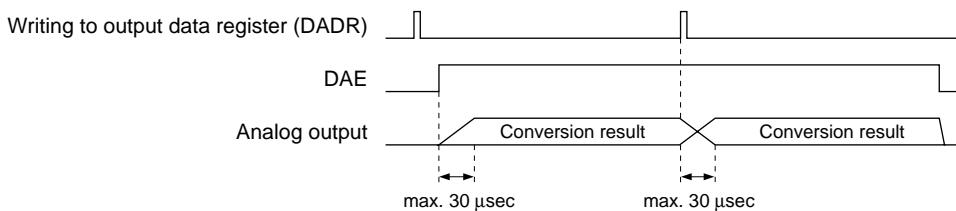


Fig. 5.19.4.1 Timing chart of D/A conversion

### 5.19.5 I/O memory of D/A converter

Table 5.19.5.1 shows the D/A converter control bits.

Table 5.19.5.1 D/A converter control bits

| Address | Bit | Name  | Function                             | 1                    | 0       | Init     | R/W | Comment             |   |                     |
|---------|-----|-------|--------------------------------------|----------------------|---------|----------|-----|---------------------|---|---------------------|
| 00FF90  | D7  | –     | –                                    | –                    | –       | –        | –   | "0" when being read |   |                     |
|         | D6  | –     | –                                    | –                    | –       | –        | –   |                     |   |                     |
|         | D5  | –     | –                                    | –                    | –       | –        | –   |                     |   |                     |
|         | D4  | –     | –                                    | –                    | –       | –        | –   |                     |   |                     |
|         | D3  | –     | –                                    | –                    | –       | –        | –   |                     |   |                     |
|         | D2  | –     | –                                    | –                    | –       | –        | –   |                     |   |                     |
|         | D1  | –     | –                                    | –                    | –       | –        | –   |                     |   |                     |
|         | D0  | DAE   | D/A conversion result output control | Enable               | Disable | 0        | R/W |                     |   |                     |
| 00FF91  | D7  | DADR7 | D/A converter                        | D7(MSB)              |         |          | 0   | R/W                 |   |                     |
|         | D6  | DADR6 | D/A conversion output data register  |                      |         |          | 0   | R/W                 |   |                     |
|         | D5  | DADR5 |                                      |                      |         |          | 0   | R/W                 |   |                     |
|         | D4  | DADR4 |                                      |                      |         |          | 0   | R/W                 |   |                     |
|         | D3  | DADR3 |                                      |                      |         |          | 0   | R/W                 |   |                     |
|         | D2  | DADR2 |                                      |                      |         |          | 0   | R/W                 |   |                     |
|         | D1  | DADR1 |                                      |                      |         |          | 0   | R/W                 |   |                     |
|         | D0  | DADR0 |                                      |                      |         |          | 0   | R/W                 |   |                     |
| 00FE8   | D7  | PAD7  | P37 A/D converter input control      | A/D converter input  |         | I/O port | 0   | R/W                 |   |                     |
|         | D6  | PAD6  | P36 A/D converter input control      |                      |         |          | 0   | R/W                 |   |                     |
|         | D5  | PAD5  | P35 A/D converter input control      |                      |         |          | 0   | R/W                 |   |                     |
|         | D4  | PAD4  | P34 A/D converter input control      |                      |         |          | 0   | R/W                 |   |                     |
|         | D3  | PAD3  | P33 A/D converter input control      |                      |         |          | 0   | R/W                 |   |                     |
|         | D2  | PAD2  | P32 A/D converter input control      |                      |         |          | 0   | R/W                 |   |                     |
|         | D1  | PAD1  | P31 A/D converter input control      |                      |         |          | 0   | R/W                 |   |                     |
|         | D0  | PAD0  | P30 A/D converter input control      |                      |         |          | 0   | R/W                 |   |                     |
| 00FE9   | D7  | PDA7  | P37 D/A converter output control     | D/A converter output |         | I/O port | 0   | R/W                 |   |                     |
|         | D6  | PDA6  | P36 D/A converter output control     |                      |         |          | 0   | R/W                 |   |                     |
|         | D5  | –     | –                                    | –                    |         |          | –   | –                   | – | "0" when being read |
|         | D4  | –     | –                                    | –                    |         |          | –   | –                   |   |                     |
|         | D3  | –     | –                                    | –                    |         |          | –   | –                   |   |                     |
|         | D2  | –     | –                                    | –                    |         |          | –   | –                   |   |                     |
|         | D1  | –     | –                                    | –                    |         |          | –   | –                   |   |                     |
|         | D0  | –     | –                                    | –                    |         |          | –   | –                   |   |                     |

#### PDA6, PDA7: D/A converter output control register (00FE9H•D6, D7)

Sets the P36 and P37 terminals as the analog output terminals for the D/A converter.

When "1" is written: D/A converter output

When "0" is written: I/O port

Reading: Valid

When "1" is written to the PDA6 register, the P36 terminal is set as the analog output terminal DA0 for the D/A converter.

When "1" is written to the PDA7 register, the P37 terminal is set as the analog output terminal DA1 for the D/A converter.

When "0" is written, the terminal is used with the I/O port.

Both terminals output the same signal, however, do not set them as analog output terminals at the same time.

At initial reset, the PDA register is set to "0" (I/O port).

#### PAD6, PAD7: A/D converter input control register (00FE8H•D6, D7)

The PAD6 and PAD7 registers set the P36 and P37 terminals to the analog input terminal of the A/D converter, respectively. The setting of the PDA6 and PDA7 registers have priority over those registers' settings. However, fix the PAD6 (PAD7) register at "0".

At initial reset, the PAD register is set to "0" (I/O port).

**DAE: D/A conversion result output enable register (00FF90H•D0)**


---

Enables D/A conversion output.

When "1" is written: D/A conversion  
output is enabled

When "0" is written: D/A conversion  
output is disabled

Reading: Valid

When "1" is written to the DAE register, D/A conversion is enabled.

When "0" is written, it is disabled.

At initial reset, the DAE register is set to "0" (D/A conversion output is disabled).

**DADR0–DADR7: D/A conversion output data register (00FF91H)**


---

Data for D/A conversion is set in this register.

The data written in this register is converted to the analog value and is output to the corresponding analog output terminal when the DAE register is set to "1".

The analog voltage value output will be  $AV_{REF} * [\text{setting value in DADR register}] / 256$ .

When "1" is written to the DAE register after writing data to this register, a delay for a D/A conversion time (30  $\mu$ sec max.) occurs from writing of the DAE register until the conversion result is actually output.

Also when this register is changed keeping the DAE register at "1", the new data is converted by this writing and the result is output to the analog output terminal after the D/A conversion time has passed.

**5.19.6 Programming note**

The D/A converter should be operated only when it is necessary in order to reduce current consumption. Stop D/A conversion by writing "0" to the DAE register if unnecessary.

## 5.20 *Interrupt and Standby Mode*

### 5.20.1 *Types of interrupts*

The S1C88409 allows one line of non-maskable interrupt, and 10 systems (22 types) of hardware interrupts.

#### **Non-maskable interrupts (NMI)**

- Watchdog timer interrupt (1 type)

NMI is the interrupt that cannot be masked with software. It is accepted prior to all hardware interrupts. However, the watchdog timer can be set by software so that it does not generate NMI. Refer to Section 5.3, "Watchdog Timer", for the control of the watchdog timer.

NMI is exceptionally masked at initial reset and it is not input to the CPU in order to prevent malfunction caused by an NMI generation before setting the system configuration. The masking is released when data is written to the addresses 00FF00H and 00FF01H in the I/O memory.

#### **Hardware interrupts**

##### *External interrupts*

- K00–K07 input interrupt (1 type)
- K10–K13 input interrupt (4 types)

##### *Internal interrupts*

- 16-bit programmable timer 0 interrupt (2 types)
- 16-bit programmable timer 1 interrupt (2 types)
- 8-bit programmable timer interrupt (1 type)
- Serial interface interrupt (3 types)
- Touch panel controller interrupt (2 types)
- LCD controller interrupt (1 type)
- A/D converter interrupt (1 type)
- Clock timer interrupt (5 types)

An interrupt factor flag that indicates a generation of the interrupt factor and an interrupt enable register to enable/disable the interrupt request have been provided for each interrupt. By using those, interrupt generation can be controlled by each factor.

In addition, an interrupt priority register has been provided for each system of interrupts and the priority of interrupt processing can be set to 3 levels in each system.

Figure 5.20.1.1 shows the configuration of the interrupt circuit.

Refer to the explanations of the respective peripheral circuits for details of each interrupt.

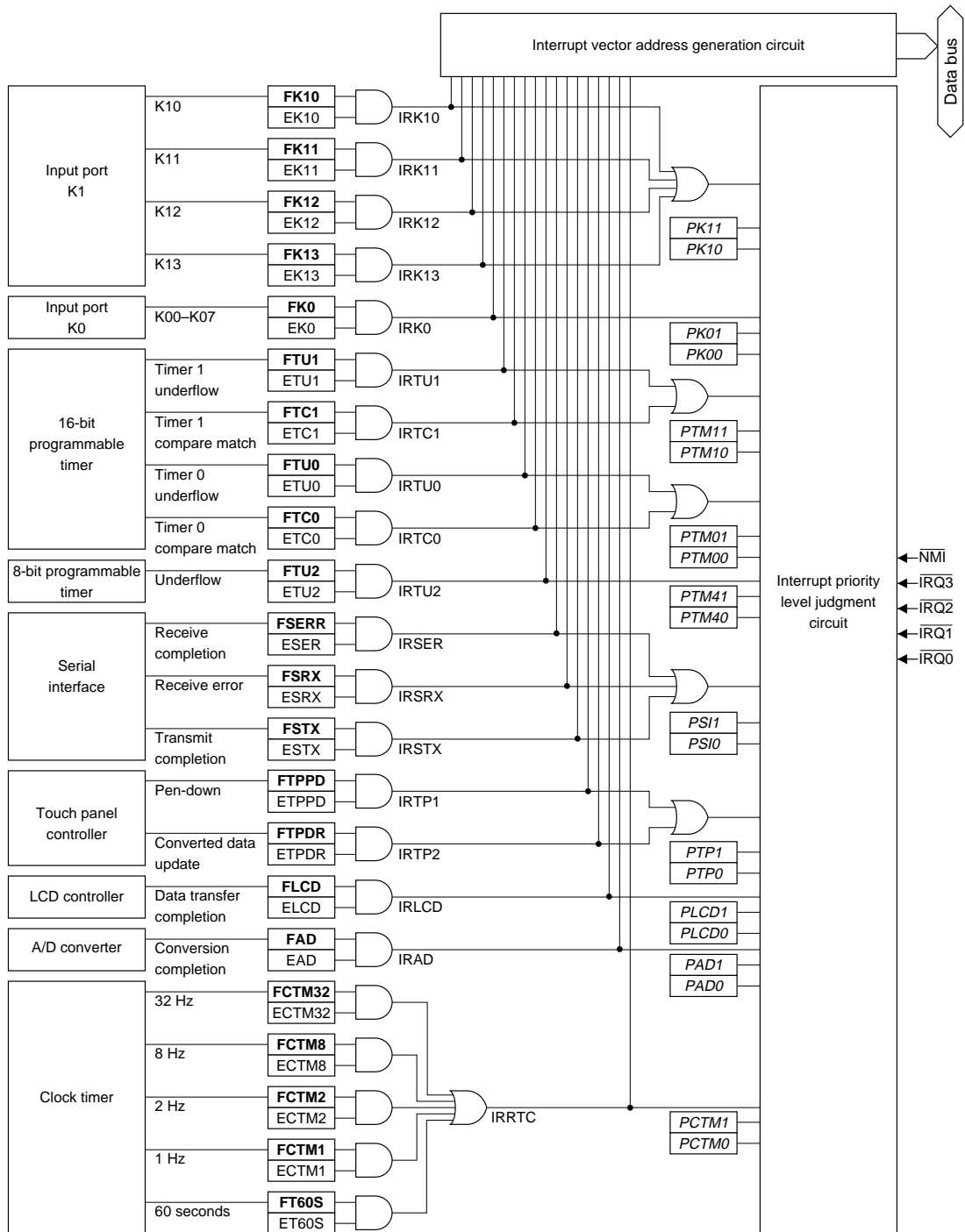


Fig. 5.20.1.1 Configuration of interrupt circuit

### 5.20.2 Standby mode

The S1C88409 has two standby modes, HALT mode and SLEEP mode, for saving power. The following explains each standby mode.

#### HALT mode

The S1C88409 enters into HALT mode by executing the HALT instruction.

In HALT mode, the peripheral circuits operate but the CPU stops operating. Thus, saving power can be realized.

HALT mode is canceled by initial reset or an optional interrupt request, and the CPU resumes program execution from the exception processing routine.

Refer to the "S1C88 Core CPU Manual" for HALT status and reactivating sequence.

#### SLEEP mode

The S1C88409 enters into SLEEP mode by executing the SLP instruction.

In SLEEP mode, the CPU and the oscillation circuits (OSC1 and OSC3) stop operating. Consequently, a greater power saving than HALT mode can be realized.

SLEEP status is canceled by initial reset, NMI or an input interrupt from the input port. The oscillation circuit, that has stopped by shifting to SLEEP mode, resumes oscillating when SLEEP mode is canceled. The CPU resumes program execution from the exception processing routine.

### 5.20.3 Interrupt generation conditions

For all interrupts (10 systems, 22 types) except for NMI, interrupt factor flags that indicate the generation of the interrupt factors are provided. They are set to "1" when the corresponding interrupt factor is generated.

In addition, interrupt enable registers corresponding to the interrupt factor flags are provided. Writing "1" to the interrupt enable register enables the interrupt to the CPU, and writing "0" disables the interrupt.

The CPU controls interrupt requests with the interrupt priority level. The priority level of each interrupt can be set with the interrupt priority registers, and the CPU accepts only the interrupts which have a level higher than the setting of the interrupt flags (I0 and I1).

Therefore, it is necessary to meet the following three conditions so that the CPU accepts the interrupt.

- (1) The interrupt factor flag has been set to "1" by generation of an interrupt factor.
- (2) The interrupt enable register corresponding to the interrupt factor has been set to "1".
- (3) The interrupt priority register corresponding to the interrupt factor has been set to a priority level higher than the interrupt flag (I0 and I1) setting.

The CPU samples interrupt requests in the first op-code fetch cycle for every instruction, and shifts to exception processing when the above mentioned conditions have been met.

Refer to the "S1C88 Core CPU Manual" for the exception processing sequence.

Table 5.20.3.1 shows the interrupt factors, interrupt enable registers and interrupt priority registers corresponding to the interrupt factors.



Table 5.20.3.1 Interrupt factors and control registers

| Interrupt factor          |                                                                       | Interrupt factor flag |            | Interrupt enable register |            | Interrupt priority register |                          |
|---------------------------|-----------------------------------------------------------------------|-----------------------|------------|---------------------------|------------|-----------------------------|--------------------------|
|                           |                                                                       | Name                  | Address-Dx | Name                      | Address-Dx | Name                        | Address-Dx               |
| Input port K1             | No match between K10 input and input comparison register KCP10        | FK10                  | 00FF27H-D4 | EK10                      | 00FF23H-D4 | PK10<br>PK11                | 00FF20H-D6<br>00FF20H-D7 |
|                           | No match between K11 input and input comparison register KCP11        | FK11                  | 00FF27H-D5 | EK11                      | 00FF23H-D5 |                             |                          |
|                           | No match between K12 input and input comparison register KCP12        | FK12                  | 00FF27H-D6 | EK12                      | 00FF23H-D6 |                             |                          |
|                           | No match between K13 input and input comparison register KCP13        | FK13                  | 00FF27H-D7 | EK13                      | 00FF23H-D7 |                             |                          |
| Input port K0             | No match between K0 input (8 bits) and input comparison register KCP0 | FK0                   | 00FF27H-D3 | EK0                       | 00FF23H-D3 | PK00<br>PK01                | 00FF20H-D4<br>00FF20H-D5 |
|                           |                                                                       |                       |            |                           |            |                             |                          |
| 16-bit programmable timer | Timer 0 underflow                                                     | FTU0                  | 00FF28H-D3 | ETU0                      | 00FF24H-D3 | PTM00                       | 00FF20H-D0               |
|                           | Compare match between timer 0 and compare data register CDR0          | FTC0                  | 00FF28H-D4 | ETC0                      | 00FF24H-D4 | PTM01                       | 00FF20H-D1               |
|                           | Timer 1 underflow                                                     | FTU1                  | 00FF28H-D5 | ETU1                      | 00FF24H-D5 | PTM10                       | 00FF20H-D2               |
|                           | Compare match between timer 1 and compare data register CDR1          | FTC1                  | 00FF28H-D6 | ETC1                      | 00FF24H-D6 | PTM11                       | 00FF20H-D3               |
| 8-bit programmable timer  | Counter underflow                                                     | FTU2                  | 00FF28H-D7 | ETU2                      | 00FF24H-D7 | PTM20<br>PTM21              | 00FF21H-D6<br>00FF21H-D7 |
|                           |                                                                       |                       |            |                           |            |                             |                          |
| Serial I/F                | Receive error                                                         | FSERR                 | 00FF28H-D0 | ESERR                     | 00FF24H-D0 | PSI0                        | 00FF21H-D4               |
|                           | Receive completion                                                    | FSRX                  | 00FF28H-D1 | ESRX                      | 00FF24H-D1 | PSI1                        | 00FF21H-D5               |
|                           | Transmit completion                                                   | FSTX                  | 00FF28H-D2 | ESTX                      | 00FF24H-D2 |                             |                          |
| Touch panel controller    | Pen-down                                                              | FTPPD                 | 00FF2AH-D6 | ETPPD                     | 00FF26H-D6 | PTP0                        | 00FF22H-D4               |
|                           | Converted data update                                                 | FTPDR                 | 00FF2AH-D5 | ETPDR                     | 00FF26H-D5 | PTP1                        | 00FF22H-D5               |
| LCD controller            | Data transfer completion                                              | FLCD                  | 00FF29H-D2 | ELCD                      | 00FF25H-D2 | PLCD0<br>PLCD1              | 00FF21H-D0<br>00FF21H-D1 |
|                           |                                                                       |                       |            |                           |            |                             |                          |
| A/D converter             | A/D conversion completion                                             | FAD                   | 00FF2AH-D7 | EAD                       | 00FF26H-D7 | PAD0<br>PAD1                | 00FF22H-D6<br>00FF22H-D7 |
| Clock timer               | Falling edge of 32 Hz signal                                          | FCTM32                | 00FF29H-D3 | ECTM32                    | 00FF25H-D3 | PCTM0                       | 00FF21H-D2               |
|                           | Falling edge of 8 Hz signal                                           | FCTM8                 | 00FF29H-D4 | ECTM8                     | 00FF25H-D4 | PCTM1                       | 00FF21H-D3               |
|                           | Falling edge of 2 Hz signal                                           | FCTM2                 | 00FF29H-D5 | ECTM2                     | 00FF25H-D5 |                             |                          |
|                           | Falling edge of 1 Hz signal                                           | FCTM1                 | 00FF29H-D6 | ECTM1                     | 00FF25H-D6 |                             |                          |
|                           | 60S counter overflow                                                  | FT60S                 | 00FF29H-D7 | ET60S                     | 00FF25H-D7 |                             |                          |

### 5.20.4 Interrupt factor flag

The interrupt factor flag is set to "1" when the corresponding interrupt factor generates. By reading the interrupt factor flag, it is possible to confirm the interrupt factor that has been generated.

Interrupt factor flag that has been set to "1" is reset to "0" by writing "1".

At initial reset, all the interrupt factor flags are reset to "0".

*Note: When the RETE instruction is executed without resetting the interrupt factor flag after an interrupt has been generated, the same interrupt is generated again. Therefore, the interrupt factor flag must be reset (writing "1") in the interrupt handler routine.*

### 5.20.5 Interrupt enable register

The interrupt enable registers corresponding to all interrupt factor flags are provided to enable/disable the interrupt requests to the CPU.

When "1" is written to the interrupt enable register, the interrupt request is enabled and when "0" is written, it is disabled. This register can also be read, thus making it possible to confirm the setting status.

At initial reset, all the interrupt enable registers are set to "0" and all the interrupts except for NMI are disabled.

### 5.20.6 Interrupt priority register and interrupt priority level

Each interrupt system provides the interrupt priority register shown in Table 5.20.3.1. By using the interrupt priority register, the priority of each interrupt can be changed so that the CPU can process interrupt in order of priority. Consequently, it is possible to make a multiple interrupt system that meets the demand of the application.

The priority level of each interrupt system can be optionally set to four levels (0 to 3) by the interrupt priority register. However, when two or more systems are set to the same priority level, they are processed according to the default priority level.

Table 5.20.6.1 Setting of interrupt priority level

| P*1 | P*0 | Interrupt priority level             |
|-----|-----|--------------------------------------|
| 1   | 1   | Level 3 ( $\overline{\text{IRQ3}}$ ) |
| 1   | 0   | Level 2 ( $\overline{\text{IRQ2}}$ ) |
| 0   | 1   | Level 1 ( $\overline{\text{IRQ1}}$ ) |
| 0   | 0   | Level 0 (None)                       |

At initial reset, all the interrupt priority registers are set to "0" and all interrupts are set to level 0. Furthermore, the priorities inside of each system have been previously decided and they cannot be changed.

The CPU can mask each interrupt by setting the interrupt flags (I0 and I1). The relation between the interrupt priority level of each system and interrupt flags is shown in Table 5.20.6.2. The CPU accepts only interrupts set in a higher level than the interrupt flag setting.

The priority level of NMI (watchdog timer) is set in level 4, so it is always accepted regardless of the interrupt flag setting.

Table 5.20.6.2 Interrupt mask setting for CPU

| I1 | I0 | Acceptable interrupt                                            |
|----|----|-----------------------------------------------------------------|
| 1  | 1  | Level 4 (NMI)                                                   |
| 1  | 0  | Level 4, Level 3 ( $\overline{\text{IRQ3}}$ )                   |
| 0  | 1  | Level 4, Level 3, Level 2 ( $\overline{\text{IRQ2}}$ )          |
| 0  | 0  | Level 4, Level 3, Level 2, Level 1 ( $\overline{\text{IRQ1}}$ ) |

After an interrupt is accepted, the interrupt flags are changed to the same level of the interrupt accepted as shown in Table 5.20.6.3 in order to mask interrupt requests with the same priority level or less. However, it is set to level 3 after an NMI is accepted.

Table 5.20.6.3 Interrupt flags after acceptance of interrupt

| Accepted interrupt priority level    | I1 | I0 |
|--------------------------------------|----|----|
| Level 4 ( $\overline{\text{NMI}}$ )  | 1  | 1  |
| Level 3 ( $\overline{\text{IRQ3}}$ ) | 1  | 1  |
| Level 2 ( $\overline{\text{IRQ2}}$ ) | 1  | 0  |
| Level 1 ( $\overline{\text{IRQ1}}$ ) | 0  | 1  |

The interrupt flags changed are returned to the previous value at return from the interrupt handler routine.

Multiple interrupts up to 3 levels can be controlled by only setting the interrupt priority registers. Multiple interrupts exceeding 3 levels can be realized by rewriting the interrupt flags and interrupt enable register in the interrupt handler routine.

*Note: Be aware if the interrupt flags are rewritten (set to lower priority) prior to resetting the interrupt factor flag after an interrupt is generated, the same interrupt will be generated again.*

### 5.20.7 Exception processing vectors

When the CPU accepts an interrupt request, it starts exception processing immediately after completing the instruction being executed. The CPU executes the following sequence as an exception processing for branching the program.

- (1) In the minimum mode, the program counter (PC) and system condition flag (SC) are saved in the stack. In the maximum mode, the code bank register (CB), PC and SC are saved.
- (2) The branch destination address is read from the exception processing vector corresponding to each exception processing (interrupt) factor and is set in the PC.

Exception processing vector is a 2-byte data to address the top of each exception (interrupt) handler routine. The vector addresses correspond to the exception processing factors as shown in Table 5.20.7.1.

*Note: An exception processing vector is fixed at 2 bytes, so it cannot specify a branch destination bank address. Therefore, to branch from two or more banks to a common exception handler routine, the top portion of the exception handler routine must be described within the common area (000000H–007FFFH).*

Table 5.20.7.1 Vector address and exception processing vector

| Vector address | Symbol | Exception processing factor      |                                     | Priority  |                          |
|----------------|--------|----------------------------------|-------------------------------------|-----------|--------------------------|
| 000000H        | RESET  | Reset                            |                                     | High<br>↑ |                          |
| 000002H        | ZDIV   | Zero division                    |                                     |           |                          |
| 000004H        | NMI    | NMI (Watchdog timer)             |                                     |           |                          |
| 000006H        | IRK10  | Input port K1                    | K10 input interrupt                 |           |                          |
| 000008H        | IRK11  |                                  | K11 input interrupt                 |           |                          |
| 00000AH        | IRK12  |                                  | K12 input interrupt                 |           |                          |
| 00000CH        | IRK13  |                                  | K13 input interrupt                 |           |                          |
| 00000EH        | IRK0   | Input port K0                    | K00–K07 input interrupt             | ↓<br>Low  |                          |
| 000010H        | IRTU0  | 16-bit programmable timer 0      | Underflow interrupt                 |           |                          |
| 000012H        | IRTC0  |                                  | Compare match interrupt             |           |                          |
| 000014H        | IRTU1  | 16-bit programmable timer 1      | Underflow interrupt                 |           |                          |
| 000016H        | IRTC1  |                                  | Compare match interrupt             |           |                          |
| 000018H        | IRTU2  | 8-bit programmable timer         | Underflow interrupt                 |           |                          |
| 00001AH        | IRSER  | Serial interface                 | Receive error interrupt             |           |                          |
| 00001CH        | IRSRX  |                                  | Receive completion interrupt        |           |                          |
| 00001EH        | IRSTX  |                                  | Receive error interrupt             |           |                          |
| 000020H        | IRTP1  | Touch panel controller           | Pen-down interrupt                  |           |                          |
| 000022H        | IRTP2  |                                  | Converted data update interrupt     |           |                          |
| 000024H        | IRLCD  | LCD controller                   | Data transfer completion interrupt  |           |                          |
| 000026H        | IRAD   | A/D converter                    | A/D conversion completion interrupt |           |                          |
| 000028H        | IRRTC  | Clock timer                      | 32Hz/8Hz/2Hz/1Hz/60S interrupt      |           |                          |
| 000032H        | –      | System reserved (cannot be used) |                                     |           | No<br>Priority<br>rating |
| 000034H        | –      | Software interrupt               |                                     |           |                          |
| ↓<br>0000FEH   | –      |                                  |                                     |           |                          |

### 5.20.8 I/O memory of interrupt

Table 5.20.8.1 shows the interrupt control bits.

Table 5.20.8.1(a) Interrupt control bits

| Address | Bit | Name   | Function                                                            |                      |                       | Init     | R/W | Comment |   |                     |
|---------|-----|--------|---------------------------------------------------------------------|----------------------|-----------------------|----------|-----|---------|---|---------------------|
|         |     |        |                                                                     | 1                    | 0                     |          |     |         |   |                     |
| 00FF20  | D7  | PK11   | K10–K13                                                             | PK11                 | PK10                  | 0        | R/W |         |   |                     |
|         | D6  | PK10   | interrupt priority register                                         | PK01                 | PK00                  | 0        | R/W |         |   |                     |
|         | D5  | PK01   | K00–K07                                                             | PTM11                | PTM10                 | Priority | 0   | R/W     |   |                     |
|         | D4  | PK00   | interrupt priority register                                         | PTM01                | PTM00                 | level    | 0   | R/W     |   |                     |
|         | D3  | PTM11  | 16-bit programmable timer 1                                         | 1                    | 1                     | Level 3  | 0   | R/W     |   |                     |
|         | D2  | PTM10  | interrupt priority register                                         | 1                    | 0                     | Level 2  | 0   | R/W     |   |                     |
|         | D1  | PTM01  | 16-bit programmable timer 0                                         | 0                    | 1                     | Level 1  | 0   | R/W     |   |                     |
|         | D0  | PTM00  | interrupt priority register                                         | 0                    | 0                     | Level 0  | 0   | R/W     |   |                     |
| 00FF21  | D7  | PTM21  | 8-bit programmable timer                                            | PTM21                | PTM20                 | 0        | R/W |         |   |                     |
|         | D6  | PTM20  | interrupt priority register                                         | PSI1                 | PSI0                  | 0        | R/W |         |   |                     |
|         | D5  | PSI1   | Serial interface                                                    | PCTM1                | PCTM0                 | Priority | 0   | R/W     |   |                     |
|         | D4  | PSI0   | interrupt priority register                                         | PLCD1                | PLCD0                 | level    | 0   | R/W     |   |                     |
|         | D3  | PCTM1  | Clock timer                                                         | 1                    | 1                     | Level 3  | 0   | R/W     |   |                     |
|         | D2  | PCTM0  | interrupt priority register                                         | 1                    | 0                     | Level 2  | 0   | R/W     |   |                     |
|         | D1  | PLCD1  | LCD controller                                                      | 0                    | 1                     | Level 1  | 0   | R/W     |   |                     |
|         | D0  | PLCD0  | interrupt priority register                                         | 0                    | 0                     | Level 0  | 0   | R/W     |   |                     |
| 00FF22  | D7  | PAD1   | A/D converter                                                       | PAD1                 | PAD0                  | Priority | 0   | R/W     |   |                     |
|         | D6  | PAD0   | interrupt priority register                                         | PTP1                 | PTP0                  | level    | 0   | R/W     |   |                     |
|         | D5  | PTP1   | Touch panel controller                                              | 1                    | 1                     | Level 3  | 0   | R/W     |   |                     |
|         | D4  | PTP0   | interrupt priority register                                         | 1                    | 0                     | Level 2  | 0   | R/W     |   |                     |
|         | D3  | –      | –                                                                   | 0                    | 1                     | Level 1  | –   | –       |   |                     |
|         | D2  | –      | –                                                                   | 0                    | 0                     | Level 0  | –   | –       |   |                     |
|         | D1  | –      | –                                                                   | –                    | –                     | –        | –   | –       |   |                     |
|         | D0  | –      | –                                                                   | –                    | –                     | –        | –   | –       |   |                     |
| 00FF23  | D7  | EK13   | K13 interrupt enable register                                       | Interrupt is enabled | Interrupt is disabled | 0        | R/W |         |   |                     |
|         | D6  | EK12   | K12 interrupt enable register                                       |                      |                       | 0        | R/W |         |   |                     |
|         | D5  | EK11   | K11 interrupt enable register                                       |                      |                       | 0        | R/W |         |   |                     |
|         | D4  | EK10   | K10 interrupt enable register                                       |                      |                       | 0        | R/W |         |   |                     |
|         | D3  | EK0    | K00–K07 interrupt enable register                                   |                      |                       | 0        | R/W |         |   |                     |
|         | D2  | –      | –                                                                   |                      |                       | –        | –   | –       | – | "0" when being read |
|         | D1  | –      | –                                                                   |                      |                       | –        | –   | –       | – |                     |
|         | D0  | –      | –                                                                   |                      |                       | –        | –   | –       | – |                     |
| 00FF24  | D7  | ETU2   | 8-bit programmable timer underflow interrupt enable register        | Interrupt is enabled | Interrupt is disabled | 0        | R/W |         |   |                     |
|         | D6  | ETC1   | 16-bit programmable timer 1 compare match interrupt enable register |                      |                       | 0        | R/W |         |   |                     |
|         | D5  | ETU1   | 16-bit programmable timer 1 underflow interrupt enable register     |                      |                       | 0        | R/W |         |   |                     |
|         | D4  | ETC0   | 16-bit programmable timer 0 compare match interrupt enable register |                      |                       | 0        | R/W |         |   |                     |
|         | D3  | ETU0   | 16-bit programmable timer 0 underflow interrupt enable register     |                      |                       | 0        | R/W |         |   |                     |
|         | D2  | ESTX   | Serial interface transmit completion interrupt enable register      |                      |                       | 0        | R/W |         |   |                     |
|         | D1  | ESRX   | Serial interface receive completion interrupt enable register       |                      |                       | 0        | R/W |         |   |                     |
|         | D0  | ESERR  | Serial interface receive error interrupt enable register            |                      |                       | 0        | R/W |         |   |                     |
| 00FF25  | D7  | ET60S  | Clock timer 60 S interrupt enable register                          | Interrupt is enabled | Interrupt is disabled | 0        | R/W |         |   |                     |
|         | D6  | ECTM1  | Clock timer 1 Hz interrupt enable register                          |                      |                       | 0        | R/W |         |   |                     |
|         | D5  | ECTM2  | Clock timer 2 Hz interrupt enable register                          |                      |                       | 0        | R/W |         |   |                     |
|         | D4  | ECTM8  | Clock timer 8 Hz interrupt enable register                          |                      |                       | 0        | R/W |         |   |                     |
|         | D3  | ECTM32 | Clock timer 32 Hz interrupt enable register                         |                      |                       | 0        | R/W |         |   |                     |
|         | D2  | ELCD   | LCD controller interrupt enable register                            |                      |                       | 0        | R/W |         |   |                     |
|         | D1  | –      | –                                                                   |                      |                       | –        | –   | –       | – | "0" when being read |
|         | D0  | –      | –                                                                   |                      |                       | –        | –   | –       | – |                     |

Table 5.20.8.1(b) Interrupt control bits

| Address | Bit | Name   | Function                                                               | 1                              | 0                                  | Init | R/W | Comment             |
|---------|-----|--------|------------------------------------------------------------------------|--------------------------------|------------------------------------|------|-----|---------------------|
| 00FF26  | D7  | EAD    | A/D converter conversion completion interrupt enable register          | Interrupt is enabled           | Interrupt is disabled              | 0    | R/W | "0" when being read |
|         | D6  | ETPPD  | Touch panel controller pen-down interrupt enable register              |                                |                                    | 0    | R/W |                     |
|         | D5  | ETPDR  | Touch panel controller converted data update interrupt enable register |                                |                                    | 0    | R/W |                     |
|         | D4  | –      | –                                                                      |                                |                                    | –    | –   |                     |
|         | D3  | –      | –                                                                      |                                |                                    | –    | –   |                     |
|         | D2  | –      | –                                                                      |                                |                                    | –    | –   |                     |
|         | D1  | –      | –                                                                      |                                |                                    | –    | –   |                     |
|         | D0  | –      | –                                                                      |                                |                                    | –    | –   |                     |
| 00FF27  | D7  | FK13   | K13 interrupt factor flag                                              | (R)                            | (R)                                | 0    | R/W | "0" when being read |
|         | D6  | FK12   | K12 interrupt factor flag                                              | Interrupt factor has generated | Interrupt factor has not generated | 0    | R/W |                     |
|         | D5  | FK11   | K11 interrupt factor flag                                              |                                |                                    | 0    | R/W |                     |
|         | D4  | FK10   | K10 interrupt factor flag                                              |                                |                                    | 0    | R/W |                     |
|         | D3  | FK0    | K00–K07 interrupt factor flag                                          | 0                              | R/W                                |      |     |                     |
|         | D2  | –      | –                                                                      | (W)                            | (W)                                | –    | –   |                     |
|         | D1  | –      | –                                                                      | Reset                          | Invalid                            | –    | –   |                     |
|         | D0  | –      | –                                                                      |                                |                                    | –    | –   |                     |
| 00FF28  | D7  | FTU2   | 8-bit programmable timer underflow interrupt factor flag               | Interrupt factor has generated | Interrupt factor has not generated | 0    | R/W | "0" when being read |
|         | D6  | FTC1   | 16-bit programmable timer 1 compare match interrupt factor flag        |                                |                                    | 0    | R/W |                     |
|         | D5  | FTU1   | 16-bit programmable timer 1 underflow interrupt factor flag            |                                |                                    | 0    | R/W |                     |
|         | D4  | FTC0   | 16-bit programmable timer 0 compare match interrupt factor flag        |                                |                                    | 0    | R/W |                     |
|         | D3  | FTU0   | 16-bit programmable timer 0 underflow interrupt factor flag            | (W)                            | Invalid                            | 0    | R/W |                     |
|         | D2  | FSTX   | Serial interface transmit completion interrupt factor flag             |                                |                                    | 0    | R/W |                     |
|         | D1  | FSRX   | Serial interface receive completion interrupt factor flag              |                                |                                    | 0    | R/W |                     |
|         | D0  | FSERR  | Serial interface receive error interrupt factor flag                   |                                |                                    | 0    | R/W |                     |
| 00FF29  | D7  | FT60S  | Clock timer 60 S interrupt factor flag                                 | (R)                            | (R)                                | 0    | R/W | "0" when being read |
|         | D6  | FCTM1  | Clock timer 1 Hz interrupt factor flag                                 | Interrupt factor has generated | Interrupt factor has not generated | 0    | R/W |                     |
|         | D5  | FCTM2  | Clock timer 2 Hz interrupt factor flag                                 |                                |                                    | 0    | R/W |                     |
|         | D4  | FCTM8  | Clock timer 8 Hz interrupt factor flag                                 |                                |                                    | 0    | R/W |                     |
|         | D3  | FCTM32 | Clock timer 32 Hz interrupt factor flag                                | 0                              | R/W                                |      |     |                     |
|         | D2  | FLCD   | LCD controller interrupt factor flag                                   | (W)                            | (W)                                | 0    | R/W |                     |
|         | D1  | –      | –                                                                      | Reset                          | Invalid                            | –    | –   |                     |
|         | D0  | –      | –                                                                      |                                |                                    | –    | –   |                     |
| 00FF2A  | D7  | FAD    | A/D converter conversion completion interrupt factor flag              | Interrupt factor has generated | Interrupt factor has not generated | 0    | R/W | "0" when being read |
|         | D6  | FTPPD  | Touch panel controller pen-down interrupt factor flag                  |                                |                                    | 0    | R/W |                     |
|         | D5  | FTPDR  | Touch panel controller converted data update interrupt factor flag     |                                |                                    | 0    | R/W |                     |
|         | D4  | –      | –                                                                      | (W)                            | Invalid                            | –    | –   |                     |
|         | D3  | –      | –                                                                      |                                |                                    | –    | –   |                     |
|         | D2  | –      | –                                                                      |                                |                                    | –    | –   |                     |
|         | D1  | –      | –                                                                      |                                |                                    | –    | –   |                     |
|         | D0  | –      | –                                                                      | –                              | –                                  |      |     |                     |
| 00FF53  | D7  | WRWD   | EWD, WDCL write enable                                                 | Write enable                   | Write disable                      | 0    | R/W | *1                  |
|         | D6  | EWD    | Watchdog timer NMI enable                                              | NMI enable                     | NMI disable                        | 1    | R/W | *1                  |
|         | D5  | WDCL   | Watchdog timer input clock selection                                   | fosc3/16                       | fosc1/16                           | 0    | R/W | *1                  |
|         | D4  | –      | –                                                                      | –                              | –                                  | –    | –   | "0" when being read |
|         | D3  | –      | –                                                                      | –                              | –                                  | –    |     |                     |
|         | D2  | –      | –                                                                      | –                              | –                                  | –    |     |                     |
|         | D1  | –      | –                                                                      | –                              | –                                  | –    |     |                     |
|         | D0  | WDRST  | Watchdog timer reset                                                   | Reset                          | Invalid                            | –    | W   |                     |

\*1 Writing to EWD or WDCL is valid after "1" is written to WRWD. WRWD is automatically returns to "0" after writing to EWD or WDCL.

Table 5.20.8.1(c) Interrupt control bits

| Address | Bit | Name  | Function                         | 1                                      | 0                                     | Init | R/W | Comment             |
|---------|-----|-------|----------------------------------|----------------------------------------|---------------------------------------|------|-----|---------------------|
| 00FFC0  | D7  | SIK07 | K07 interrupt selection register | Interrupt<br>is enabled                | Interrupt<br>is disabled              | 0    | R/W |                     |
|         | D6  | SIK06 | K06 interrupt selection register |                                        |                                       | 0    | R/W |                     |
|         | D5  | SIK05 | K05 interrupt selection register |                                        |                                       | 0    | R/W |                     |
|         | D4  | SIK04 | K04 interrupt selection register |                                        |                                       | 0    | R/W |                     |
|         | D3  | SIK03 | K03 interrupt selection register |                                        |                                       | 0    | R/W |                     |
|         | D2  | SIK02 | K02 interrupt selection register |                                        |                                       | 0    | R/W |                     |
|         | D1  | SIK01 | K01 interrupt selection register |                                        |                                       | 0    | R/W |                     |
|         | D0  | SIK00 | K00 interrupt selection register |                                        |                                       | 0    | R/W |                     |
| 00FFC1  | D7  | KCP07 | K07 input comparison register    | Falling edge<br>generates<br>interrupt | Rising edge<br>generates<br>interrupt | 1    | R/W |                     |
|         | D6  | KCP06 | K06 input comparison register    |                                        |                                       | 1    | R/W |                     |
|         | D5  | KCP05 | K05 input comparison register    |                                        |                                       | 1    | R/W |                     |
|         | D4  | KCP04 | K04 input comparison register    |                                        |                                       | 1    | R/W |                     |
|         | D3  | KCP03 | K03 input comparison register    |                                        |                                       | 1    | R/W |                     |
|         | D2  | KCP02 | K02 input comparison register    |                                        |                                       | 1    | R/W |                     |
|         | D1  | KCP01 | K01 input comparison register    |                                        |                                       | 1    | R/W |                     |
|         | D0  | KCP00 | K00 input comparison register    |                                        |                                       | 1    | R/W |                     |
| 00FFC2  | D7  | –     | –                                | –                                      | –                                     | –    | –   | "0" when being read |
|         | D6  | –     | –                                | –                                      | –                                     | –    | –   |                     |
|         | D5  | –     | –                                | –                                      | –                                     | –    | –   |                     |
|         | D4  | –     | –                                | –                                      | –                                     | –    | –   |                     |
|         | D3  | KCP13 | K13 input comparison register    | Falling edge<br>generates<br>interrupt | Rising edge<br>generates<br>interrupt | 1    | R/W |                     |
|         | D2  | KCP12 | K12 input comparison register    |                                        |                                       | 1    | R/W |                     |
|         | D1  | KCP11 | K11 input comparison register    |                                        |                                       | 1    | R/W |                     |
|         | D0  | KCP10 | K10 input comparison register    |                                        |                                       | 1    | R/W |                     |

Refer to the explanations on the respective peripheral circuits for the setting contents and control for each bit.

### 5.20.9 Programming notes

- (1) When the RETE instruction is executed without resetting the interrupt factor flag after an interrupt has been generated, the same interrupt is generated again. Therefore, the interrupt factor flag must be reset (writing "1") in the interrupt handler routine.
- (2) Be aware if the interrupt flags (I0, I1) are rewritten (set to lower priority) prior to resetting the interrupt factor flag after an interrupt is generated, the same interrupt will be generated again.
- (3) An exception processing vector is fixed at 2 bytes, so it cannot specify a branch destination bank address. Therefore, to branch from two or more banks to a common exception handler routine, the top portion of the exception handler routine must be described within the common area (000000H–007FFFH).

# CHAPTER 6 SUMMARY OF NOTES

## 6.1 Notes for Low Current Consumption

The S1C88409 can turn circuits, which consume a large amount of power, ON or OFF by the control registers.

These control registers lower the current consumption through programs that operate the circuits at the minimum levels. Table 6.1.1 shows the circuits and the control registers (instructions).

Refer to Chapter 8, "ELECTRICAL CHARACTERISTICS" for the current consumption.

Table 6.1.1 Circuits and control registers

| Circuit                           | Control register/instruction | Status at initial reset                                    |
|-----------------------------------|------------------------------|------------------------------------------------------------|
| CPU                               | HALT and SLP instructions    | Operating                                                  |
| Oscillation circuit               | CLKCHG, OSCC                 | OSC1 clock (CLKCHG="0")<br>OSC3 oscillation OFF (OSCC="0") |
| Operating voltage V <sub>D1</sub> | VDIC                         | 2.4 V (VD1C="00B")                                         |
| SVD circuit                       | SVDON                        | OFF status (SVDON="0")                                     |
| A/D converter                     | ADRUN                        | OFF status (ADRUN="0")                                     |
| D/A converter                     | DAE                          | OFF status (DAE="0")                                       |
| Touch panel controller            | RST                          | OFF status (RST="0")                                       |

## 6.2 Summary of Notes by Function

Here, the cautionary notes are summed up by function category. Keep these notes well in mind when programming.

### System controller and bus control

After initial reset, all the interrupts including NMI are masked until the appropriate values are written to the I/O memory addresses "00FF00H" and "00FF01H" to prevent malfunctions that may occur before setting the system configuration. Therefore, write data to the addresses in the initial routine even though the initial settings are used. Furthermore, set the stack pointer SP prior to writing so that interrupt processing will operate normally.

### Watchdog timer

- (1) When the watchdog timer NMI is authorized, it is necessary to reset the counter by software before an overflow is generated.
- (2) At initial reset, the watchdog timer starts counting by inputting the fOSC1/16 clock and is set to generate NMI. When the watchdog timer is not used, write "0" to the EWD register before the first overflow is generated.
- (3) The count operation is continued even when the EWD register is set to "0" if the clock is input. Therefore, when NMI is invalidated temporarily, reset the watchdog timer before changing back the EWD register to "1".

- (4) The oscillation clock becomes unstable immediately after SLEEP is canceled. Therefore, reset the watchdog timer before shifting to SLEEP status and after SLEEP status is canceled so that an unnecessary NMI will not be generated.

### Oscillation circuit

- (1) The V<sub>D1</sub> level must be switched while the OSC3 oscillation circuit is off (before turning on and after turning off). Switching during operation may cause malfunction. Furthermore, the V<sub>D1</sub> voltage required at least 5 msec of voltage stabilizing time after switching. Do not turn the OSC3 oscillation circuit on during this period.
- (2) V<sub>D1</sub> cannot be switched directly to a level that is two or three levels different from the current level. The middle level must be set between the switching.

To switch from 1.6 (3.2) V to 3.2 (1.6) V:

1.6 V → 2.4 V → 3.2 V

1.6 V ← 2.4 V ← 3.2 V

To switch from 1.6 (4.2) V to 4.2 (1.6) V:

1.6 V → 2.4 V → 3.2 V → 4.2 V

1.6 V ← 2.4 V ← 3.2 V ← 4.2 V

To switch from 2.4 (4.2) V to 4.2 (2.4) V:  
 2.4 V → 3.2 V → 4.2 V  
 2.4 V ← 3.2 V ← 4.2 V

A 5 msec interval is required for each switching steps.

- (3) To generate V<sub>D1</sub> with specified voltage, the supply voltage must be higher than the specified voltage.  
 To prevent malfunction, make sure that the supply voltage is not lowered under the V<sub>D1</sub> value to be set using the SVD circuit before switching V<sub>D1</sub>. Do not switch V<sub>D1</sub> to a voltage higher than the supply voltage if the supply voltage drops.
- (4) The OSC3 oscillation circuit takes a maximum 20 msec for stabilizing oscillation after turning the OSC3 oscillation circuit on. Therefore, take an enough interval after the OSC3 oscillation goes on before starting control of the peripheral circuit, such as the programmable timer, serial interface and A/D converter, that uses the OSC3 oscillation circuit as the clock source. (The oscillation start time varies depending on the oscillator and external component to be used. Refer to Chapter 8, "ELECTRICAL CHARACTERISTICS", in which an example of oscillation start time is indicated.)
- (5) Use a separate instruction for switching the clock from OSC3 to OSC1 and turning the OSC3 oscillation off. Handling with one instruction may cause malfunction of the CPU.
- (6) To prevent malfunction, before stopping the OSC3 oscillation, stop the operation of the peripheral circuits that use the OSC3 oscillation circuit as the clock source, such as programmable timer, serial interface and A/D converter.
- (7) Do not turn the OSC3 oscillation circuit on to reduce current consumption when the OSC3 clock is not necessary.

**Prescaler**

When using an output clock from the OSC3 prescaler, it is necessary to turn the OSC3 oscillation circuit on. Furthermore, the OSC3 oscillation circuit takes a maximum 20 msec for stabilizing oscillation after turning the OSC3 oscillation circuit on. Therefore, wait a long enough interval after the OSC3 oscillation goes on before turning the clock output of the OSC3 prescaler on. (The oscillation start time varies depending on the oscillator and external components to be used.

Refer to Chapter 8, "ELECTRICAL CHARACTERISTICS", in which an example of oscillation start time is indicated.)

**Input port (K port)  
 I/O port (P port)**

When the input terminal is changed from a low level to a high level by the built-in pull-up resistor, the rise of the waveform is delayed on account of the time constant of the pull-up resistor and load capacitance of the terminal. Hence, when reading the input port, it is necessary to wait an appropriate amount of time. Particular care must be taken of the key scan for the key matrix configuration. Make this waiting time the amount of time or more calculated by the following expression.

$$\text{Waiting time} = R_{IN} \times (C_{IN} + C_L) \times 1.6 \text{ [sec]}$$

R<sub>IN</sub>: Pull-up resistance Max. value

C<sub>IN</sub>: Terminal capacitance Max. value

C<sub>L</sub>: Load capacitance on the board

**Clock output**

- (1) The FOUT3 clock and TOUT0 clock cannot be output simultaneously, because they use the same port, similar to the FOUT1 clock and TOUT1 clock.
- (2) Be aware that the output is fixed at low (V<sub>SS</sub>) level when the data register of the output port used for the clock output is set to "0".
- (3) A hazard may occur on the output signal when the clock output control register is changed.
- (4) Since the output clock becomes unstable when SLEEP mode is canceled, stop the output before shifting to SLEEP mode.

**LCD controller**

- (1) Do not write "0" to the LCDEN register while the LCD panel is ON. The LCD panel may be damaged.
- (2) Only the 4-bit continuous data refresh mode is available in the gray-scale mode. Do not use 8-bit data transfer or another transfer mode.
- (3) The data transfer uses the OSC3 clock. Therefore, turn the OSC3 oscillation on before writing "1" to the LCDEN register. Furthermore, wait 20 msec or more after turning the OSC3 oscillation on for stabilizing oscillation. In the one-shot transfer mode or hardware auto-transfer mode, do not turn the OSC3 oscillation off before finishing data transfer.



When the segment driver is in self-refresh status, the OSC3 oscillation can be stopped to reduce current consumption.

- (4) When setting the CPU in SLEEP status, be sure to turn the LCD panel power off and stop operation of the LCD controller.

### Clock timer

- (1) The clock timer actually enters into RUN or STOP status at the falling edge of the 256 Hz signal after writing to the TMRUN register. Consequently, when "0" is written to TMRUN, the timer stops after counting once more (+1). TMRUN is read as "1" until the timer actually stops.

Figure 6.2.1 shows the timing chart at the RUN/STOP control.

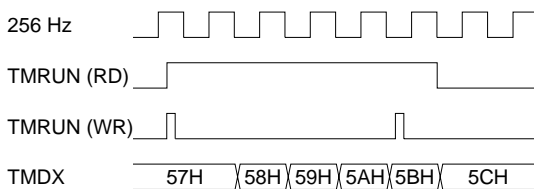


Fig. 6.2.1 Timing chart at RUN/STOP control

- (2) The 60-second counter is preset only when data is written to the TMMD register. The register does not maintain the preset data and returns to 0-second when the counter overflows. To prevent the counter from abnormal operation, do not preset data without a range of 0 to 59 (BCD).

### 16-bit programmable timer

- (1) The 16-bit programmable timer actually enters into RUN or STOP status at the falling edge of the input clock after writing to the PTRUN0(1) register. Consequently, when "0" is written to PTRUN0(1), the timer stops after counting once more (+1). PTRUN0(1) is read as "1" until the timer actually stops.

Figure 6.2.2 shows the timing chart at the RUN/STOP control.

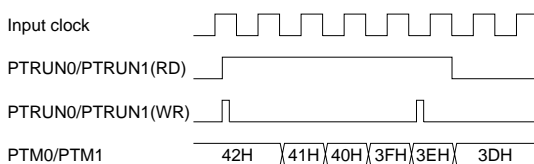


Fig. 6.2.2 Timing chart at RUN/STOP control

- (2) When the SLP instruction is executed while the 16-bit programmable timer is running (PTRUN0(1) = "1"), the timer stops counting during SLEEP status. When SLEEP status is canceled, the timer starts counting. However, the operation becomes unstable immediately after SLEEP status is canceled. Therefore, when shifting to SLEEP status, stop the 16-bit programmable timer (PTRUN0(1) = "0") prior to executing the SLP instruction. Same as above, the TOUT signal output should be disabled (PTOUT0(1) = "0") so that an unstable clock is not output to the clock output port terminal.
- (3) In the 16-bit mode, reading PTM0 does not latch the timer 1 counter data in PTM1. To avoid generating a borrow from timer 0 to timer 1, read the counter data after stopping the timer by writing "0" to PTRUN0.

### 8-bit programmable timer

- (1) The 8-bit programmable timer actually enters into RUN or STOP status at the falling edge of the input clock after writing to the PRUN register. Consequently, when "0" is written to PRUN, the timer stops after counting once more (+1). PRUN is read as "1" until the timer actually stops.

Figure 6.2.3 shows the timing chart of the RUN/STOP control.

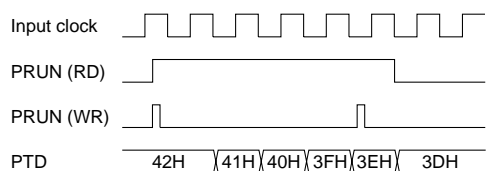


Fig. 6.2.3 Timing chart at RUN/STOP control

- (2) When the SLP instruction is executed while the 8-bit programmable timer is running (PRUN = "1"), the timer stops counting during SLEEP status. When SLEEP status is canceled, the timer starts counting. However, the operation becomes unstable immediately after SLEEP status is canceled. Therefore, when shifting to SLEEP status, stop the 8-bit programmable timer (PRUN = "0") prior to executing the SLP instruction.
- (3) The prescaler, which supplies the clock to the 8-bit programmable timer, can operate only when the OSC3 oscillation has been set to ON. Be aware that the 8-bit programmable timer does not operate when the OSC3 oscillation circuit has been turned off.

### Serial interface

- (1) Setting of the serial interface mode must be done in the transmission/receiving disabling status (TXEN = RXEN = "0").
- (2) Do not perform double trigger (writing "1" to TXTRG (RXTRG) during transmission (receiving). Furthermore, do not execute the SLP instruction. (When executing the SLP instruction, set TXEN and RXEN to "0".)
- (3) Transmission and receiving cannot be done simultaneously in the clock synchronous mode because the clock line ( $\overline{\text{SCLK}}$ ) is shared with transmit and receive operation. Therefore, do not write "1" to RXTRG (TXTRG) when TXTRG (RXTRG) is "1".
- (4) When a parity error or a framing error occurs, both the receive error interrupt factor flag FSERR and the receive completion interrupt factor flag FSRX are simultaneously set to "1". However, since the receive error interrupt has priority over the receive completion interrupt, the receive error interrupt process is executed first. Therefore, it is necessary to reset the FSRX flag in the receive error handling routine. When a receive error interrupt occurs due to an overrun, receive completion interrupt does not occur.

### Sound generator

- (1) Since the BZ signal is generated asynchronously from the register BZON, when the signal is turned ON or OFF by the register setting, a hazard of a 1/2 cycle or less is generated.
- (2) The SLP instruction has executed when the BZ signal is in the enable status (BZON = "1" or BZSHT = "1"), an unstable clock is output from the R42 output port terminal at the time of return from the SLEEP status. Consequently, when shifting to the SLEEP status, you should set the BZ signal to the disable status (BZON = BZSHT = "0") prior to executing the SLP instruction.
- (3) The one-shot output is only valid when the normal buzzer output is OFF (BZON = "0") status. The trigger is invalid during ON (BZON = "1") status.

### SVD circuit

- (1) To obtain a stable detection result, the SVD circuit must be ON for at least 100  $\mu\text{sec}$ . So, to obtain the SVD detection result, follow the programming sequence below.
  1. Set SVDON to "1"
  2. Maintain for 100  $\mu\text{sec}$  minimum
  3. Set SVDON to "0"
  4. Read SVDDT
- (2) The SVD operation increases current consumption, so turn the SVD circuit off when voltage detection is unnecessary or executing the SLP instruction.

### Touch panel controller

- (1) The setting of the threshold value for drawing speed judgment in the normal mode must meet following conditions.  

$$\text{MVH} \geq \text{MVMH} \geq \text{MVML} \geq \text{MVL}$$
- (2) Do not stop the clocks output from the OSC3 oscillation circuit and prescaler during coordinate detection.
- (3) Do not operate the A/D converter independently while the touch panel controller is used.
- (4) The waiting time to be set using the WAIT register must be longer than 3 cycles of the OSC1 clock.

$$16 \times n/f > 3/f_{\text{OSC1}}$$

(\*f: Input clock frequency from the prescaler)

When the A/D converter reference voltage control function is used (VRC = "1"), the time set in the WAIT register also applies to the reference voltage setup time. Therefore, design the peripheral circuit taking the charge time into consideration. If the reference voltage (AVREF) cannot be set up within the time set in the WAIT register, the reference voltage should be switched on and off by software so that the setup time is secured.

- (5) The capacitors connected to Ch0 and Ch1 of the touch panel controller (see Figure 5.17.2.1) affect the pen-down judgement time. They must be 1000 pF or less.

### A/D converter

- (1) The A/D converter can operate by inputting the clock from the prescaler. Therefore, it is necessary to set the division ratio of the prescaler and to turn the clock output on before starting A/D conversion. Furthermore, it is also necessary that the OSC3 oscillation circuit is operating because the prescaler can operate only when the OSC3 is set as the CPU clock. (Refer to Section 5.5, "Prescaler and Clock Control Circuit for Peripheral Circuits".)
- (2) When SLEEP mode is set during A/D conversion, correct A/D conversion result cannot be obtained because the OSC3 oscillation circuit stops. Do not set in SLEEP mode during A/D conversion.
- (3) The input clock and analog input terminals should be set when the A/D converter stops. Changing in the A/D converter operation may cause a malfunction.
- (4) The frequency of the input clock should be lower than the maximum value shown in Section 8.7, "A/D Converter Characteristics".
- (5) To prevent malfunction, do not start A/D conversion (writing to the CHS register) when the A/D conversion clock is not being output from the prescaler, and do not turn the prescaler output clock off during A/D conversion.
- (6) If the CHS register selects an input channel which is not included in the analog input terminals set by the PAD register (the PAD register can select several terminals simultaneously), the A/D conversion does not result in a correct converted value.
- (7) During A/D conversion, do not operate the P3n terminals which are not used for analog inputs of the A/D converter (for input/output of digital signal and for D/A conversion). It affects the A/D conversion precision.

### D/A converter

The D/A converter should be operated only when it is necessary in order to reduce current consumption. Stop D/A conversion by writing "0" to the DAE register if unnecessary.

### Interrupt

- (1) When the RETE instruction is executed without resetting the interrupt factor flag after an interrupt has been generated, the same interrupt is generated again. Therefore, the interrupt factor flag must be reset (writing "1") in the interrupt handler routine.
- (2) Be aware if the interrupt flags (I0, I1) are rewritten (set to lower priority) prior to resetting the interrupt factor flag after an interrupt is generated, the same interrupt will be generated again.
- (3) An exception processing vector is fixed at 2 bytes, so it cannot specify a branch destination bank address. Therefore, to branch from two or more banks to a common exception handler routine, the top portion of the exception handler routine must be described within the common area (000000H-007FFFH).

### 6.3 Precautions on Mounting

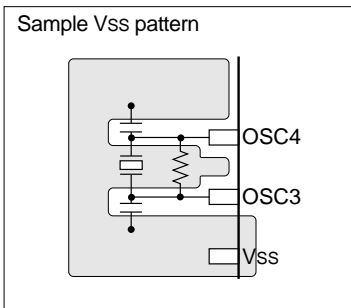
#### <Oscillation Circuit>

- Oscillation characteristics change depending on conditions (board pattern, components used, etc.).

In particular, when a ceramic oscillator or crystal oscillator is used, use the oscillator manufacturer's recommended values for constants such as capacitance and resistance.

- Disturbances of the oscillation clock due to noise may cause a malfunction. Consider the following points to prevent this:

- (1) Components which are connected to the OSC1, OSC2, OSC3, OSC4 terminals, such as oscillators, resistors and capacitors, should be connected in the shortest line.
- (2) As shown in the right hand figure, make a Vss pattern as large as possible at circumscription of the OSC1, OSC2, OSC3, OSC4 terminals and the components connected to these terminals.  
Furthermore, do not use this Vss pattern for any purpose other than the oscillation system.



- (3) When supplying an external clock to the OSC1 (OSC3) terminal, the clock source should be connected to the OSC1 (OSC3) terminal in the shortest line.  
Furthermore, do not connect anything else to the OSC2 (OSC4) terminal.

- In order to prevent unstable operation of the oscillation circuit due to current leak between OSC3 and VDD, please keep enough distance between OSC3 and VDD or other signals on the board pattern.

#### <Reset Circuit>

- The power-on reset signal which is input to the  $\overline{\text{RESET}}$  terminal changes depending on conditions (power rise time, components used, board pattern, etc.).

Decide the time constant of the capacitor and resistor after enough tests have been completed with the application product.

When the built-in pull-up resistor is added to the  $\overline{\text{RESET}}$  terminal by mask option, take into consideration dispersion of the resistance for setting the constant.

- In order to prevent any occurrences of unnecessary resetting caused by noise during operating, components such as capacitors and resistors should be connected to the  $\overline{\text{RESET}}$  terminal in the shortest line.

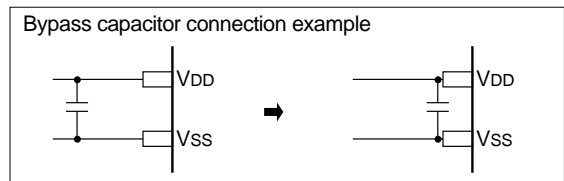
#### <Power Supply Circuit>

- Sudden power supply variation due to noise may cause malfunction. Consider the following points to prevent this:

- (1) The power supply should be connected to the VDD, VSS, AVDD, AVSS and AGND, AVREF terminals with patterns as short and large as possible.

In particular, the power supply for AVDD, AVSS, AGND and AVREF affects A/D conversion and D/A conversion accuracy.

- (2) When connecting between the VDD and Vss terminals with a bypass capacitor, the terminals should be connected as short as possible.



**<A/D Converter, D/A Converter>**

- When the A/D converter and D/A converter are not used, the power supply terminals for the analog system should be connected as shown below.

AVDD → VDD

AVSS → VSS

AVREF → VSS

AGND → VSS

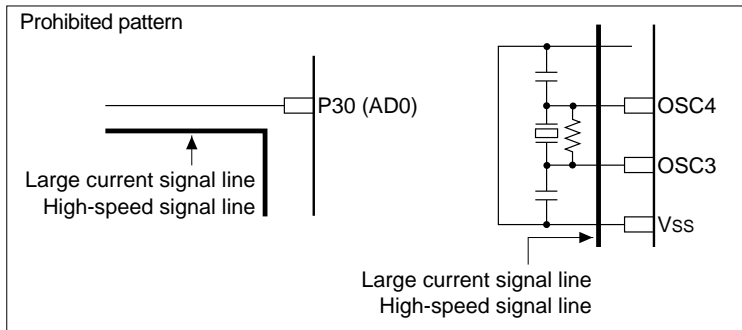
**<Arrangement of Signal Lines>**

- In order to prevent generation of electromagnetic induction noise caused by mutual inductance, do not arrange a large current signal line near the circuits that are sensitive to noise such as the oscillation unit and analog input unit.
- When a signal line is parallel with a high-speed line in long distance or intersects a high-speed line, noise may be generated by mutual interference between the signals and it may cause a malfunction.

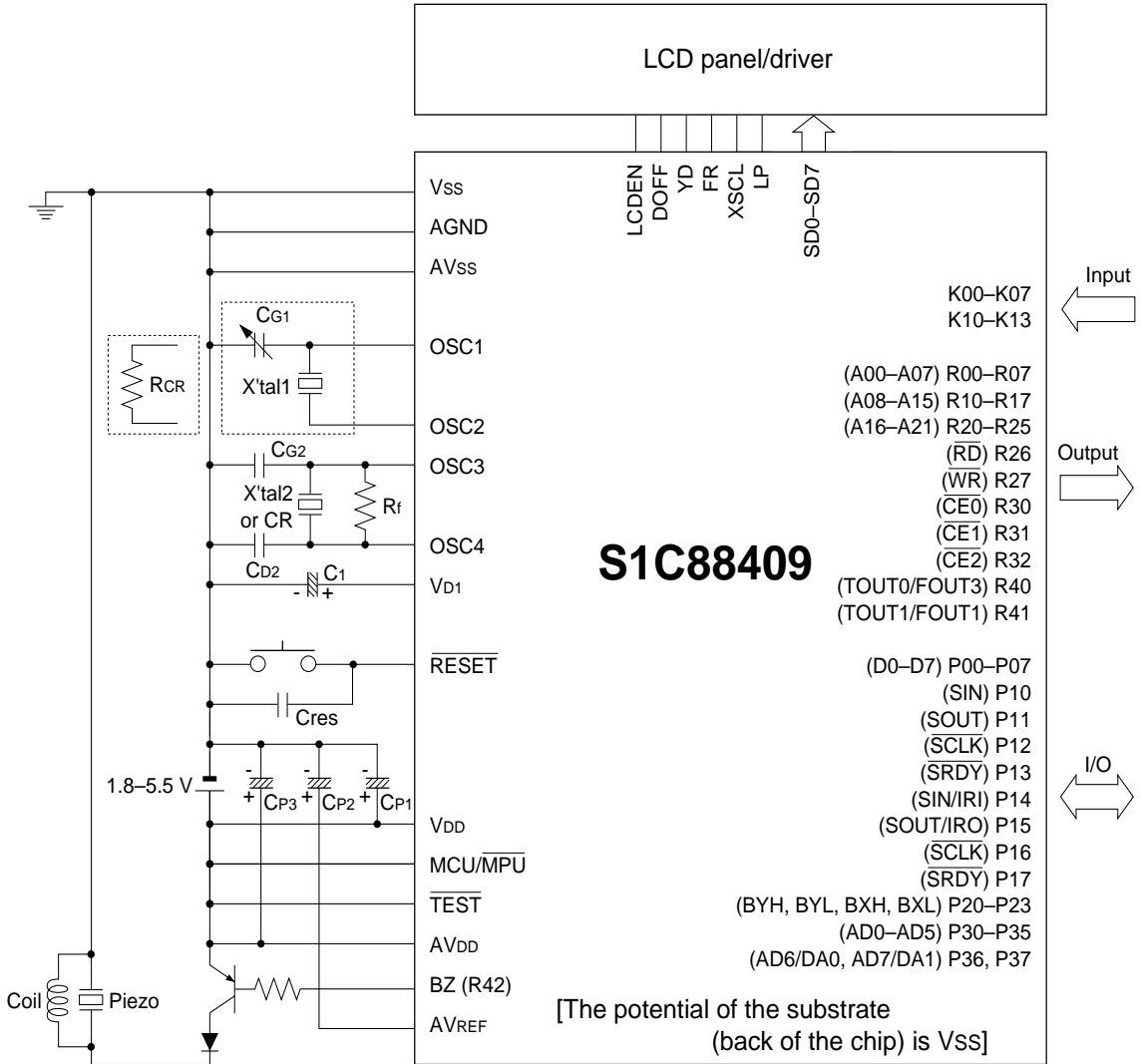
Do not arrange a high-speed signal line especially near circuits that are sensitive to noise such as the oscillation unit and analog input unit.

**<Precautions for Visible Radiation (when bare chip is mounted)>**

- Visible radiation causes semiconductor devices to change the electrical characteristics. It may cause this IC to malfunction. When developing products which use this IC, consider the following precautions to prevent malfunctions caused by visible radiations.
  - (1) Design the product and implement the IC on the board so that it is shielded from visible radiation in actual use.
  - (2) The inspection process of the product needs an environment that shields the IC from visible radiation.
  - (3) As well as the face of the IC, shield the back and side too.



# CHAPTER 7 BASIC EXTERNAL WIRING DIAGRAM



Recommended values for external parts

| Symbol | Name                           | Recommended value            |
|--------|--------------------------------|------------------------------|
| X'tal1 | Crystal oscillator             | 32.768 kHz, CI(Max.) = 35 kΩ |
| RCR    | Resistor for CR oscillation    | 1.8 MΩ                       |
| X'tal2 | Crystal oscillator             | 4, 6, 8 MHz                  |
| CR     | Ceramic oscillator             | 4, 6, 8 MHz                  |
| Rf     | Feedback resistor              | 1 MΩ                         |
| CG1    | Trimmer capacitor              | 5-25 pF                      |
| CG2    | Gate capacitor                 | 15 pF                        |
| CD2    | Drain capacitor                | 15 pF                        |
| C1-3   | Capacitor between Vss and VDD1 | 0.1 μF                       |
| CP     | Capacitor for power supply     | 3.3 μF                       |
| Cres   | Capacitor for RESET terminal   | 0.47 μF                      |

# CHAPTER 8 ELECTRICAL CHARACTERISTICS

## 8.1 Absolute Maximum Rating

| (V <sub>SS</sub> =0 V)    |                   |                        |                               |      |      |   |
|---------------------------|-------------------|------------------------|-------------------------------|------|------|---|
| Item                      | Symbol            | Condition              | Rated value                   | Unit | Note |   |
| Supply voltage            | V <sub>DD</sub>   |                        | -0.3 to +7.0                  | V    |      |   |
| Analog supply voltage     | AV <sub>DD</sub>  |                        | -0.3 to +7.0                  | V    |      |   |
| Reference supply voltage  | AV <sub>REF</sub> |                        | -0.3 to AV <sub>DD</sub> +0.3 | V    |      |   |
| Input voltage             | V <sub>I</sub>    |                        | -0.3 to V <sub>DD</sub> +0.3  | V    |      |   |
| Output voltage            | V <sub>O</sub>    |                        | -0.3 to V <sub>DD</sub> +0.3  | V    |      |   |
| High-level output current | I <sub>OH</sub>   | 1 terminal             | -5                            | mA   |      |   |
|                           |                   | Total of all terminals | -20                           | mA   |      |   |
| Low-level output current  | I <sub>OL</sub>   | 1 terminal             | -5                            | mA   |      |   |
|                           |                   | Total of all terminals | -20                           | mA   |      |   |
| Operating temperature     | T <sub>opr</sub>  |                        | -20 to +70                    | °C   |      |   |
| Storage temperature       | T <sub>stg</sub>  |                        | -65 to +150                   | °C   |      |   |
| Permissible dissipation   | P <sub>D</sub>    | T <sub>a</sub> =25°C   | 200                           | mW   |      | 1 |

Note) 1. In case of plastic package.

## 8.2 Recommended Operating Conditions

| (V <sub>SS</sub> =0 V)                                |                                        |                               |                       |        |                       |      |      |
|-------------------------------------------------------|----------------------------------------|-------------------------------|-----------------------|--------|-----------------------|------|------|
| Item                                                  | Symbol                                 | Condition                     | Min.                  | Typ.   | Max.                  | Unit | Note |
| Supply voltage                                        | V <sub>DD</sub>                        |                               | 1.8                   |        | 5.5                   | V    |      |
| Analog supply voltage                                 | AV <sub>DD</sub>                       | AV <sub>DD</sub> ≥2.7 V       | V <sub>DD</sub> -0.05 |        | V <sub>DD</sub> +0.05 | V    |      |
| Clock frequency                                       | f <sub>OSC1</sub><br>f <sub>OSC3</sub> | V <sub>DD</sub> =1.8 to 5.5 V | 30.000                | 32.768 | 50.000                | kHz  | 1    |
|                                                       |                                        | V <sub>DD</sub> =1.8 to 5.5 V | 0.03                  |        | 1.1                   | MHz  | 1    |
|                                                       |                                        | V <sub>DD</sub> =2.6 to 5.5 V | 0.03                  |        | 4.4                   | MHz  | 1    |
|                                                       |                                        | V <sub>DD</sub> =3.5 to 5.5 V | 0.03                  |        | 6.6                   | MHz  | 1    |
|                                                       |                                        | V <sub>DD</sub> =4.5 to 5.5 V | 0.03                  |        | 8.8                   | MHz  | 1    |
| Operating temperature                                 | T <sub>opr</sub>                       |                               | -20                   |        | +70                   | °C   |      |
| Capacitor between V <sub>SS</sub> and V <sub>D1</sub> | C <sub>1</sub>                         |                               |                       | 0.1    |                       | μF   |      |

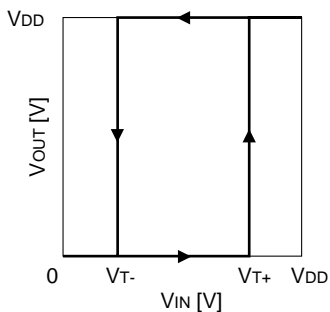
Note) 1. When an external clock is input from the OSC1 terminal by setting the mask option, do not connect anything to the OSC2 terminal. When an external clock is input from the OSC3 terminal, do not connect anything to the OSC4 terminal.

### 8.3 DC Characteristics

Unless otherwise specified: VDD=1.8 to 5.5 V, VSS=0 V, Ta=-20 to 70°C

| Item                                     | Symbol           | Condition                                                                   | Min.               | Typ. | Max.               | Unit | Note |
|------------------------------------------|------------------|-----------------------------------------------------------------------------|--------------------|------|--------------------|------|------|
| High-level input voltage                 | V <sub>IH1</sub> | P <sub>XX</sub> , MCU/MPU, K <sub>XX</sub>                                  | 0.8V <sub>DD</sub> |      | V <sub>DD</sub>    | V    |      |
| Low-level input voltage                  | V <sub>IL1</sub> | P <sub>XX</sub> , MCU/MPU, K <sub>XX</sub>                                  | 0                  |      | 0.2V <sub>DD</sub> | V    |      |
| High-level input voltage                 | V <sub>IH2</sub> | OSC1, OSC3, V <sub>D1</sub> = 1.6V                                          | 1.3                |      | V <sub>DD</sub>    | V    | 1,3  |
|                                          |                  | OSC1, OSC3, V <sub>D1</sub> = 2.4V                                          | 1.8                |      | V <sub>DD</sub>    | V    | 1,4  |
|                                          |                  | OSC1, OSC3, V <sub>D1</sub> = 3.2V                                          | 2.4                |      | V <sub>DD</sub>    | V    | 1,5  |
|                                          |                  | OSC1, OSC3, V <sub>D1</sub> = 4.2V                                          | 3.2                |      | V <sub>DD</sub>    | V    | 1,6  |
| Low-level input voltage                  | V <sub>IL2</sub> | OSC1, OSC3, V <sub>D1</sub> = 1.6V                                          | 0                  |      | 0.3                | V    | 1,3  |
|                                          |                  | OSC1, OSC3, V <sub>D1</sub> = 2.4V                                          | 0                  |      | 0.6                | V    | 1,4  |
|                                          |                  | OSC1, OSC3, V <sub>D1</sub> = 3.2V                                          | 0                  |      | 0.8                | V    | 1,5  |
|                                          |                  | OSC1, OSC3, V <sub>D1</sub> = 4.2V                                          | 0                  |      | 1.0                | V    | 1,6  |
| High-level schmitt trigger input voltage | V <sub>T+</sub>  | RESET                                                                       | 0.5V <sub>DD</sub> |      | 0.9V <sub>DD</sub> | V    |      |
| Low-level schmitt trigger input voltage  | V <sub>T-</sub>  | RESET                                                                       | 0.1V <sub>DD</sub> |      | 0.5V <sub>DD</sub> | V    |      |
| Schmitt trigger hysteresis voltage       | V <sub>HS</sub>  | RESET<br>V <sub>HS</sub> =V <sub>T+</sub> -V <sub>T-</sub>                  | 0.2                |      |                    | V    |      |
| High-level output current                | I <sub>OH</sub>  | P <sub>XX</sub> , R <sub>XX</sub> , V <sub>OH</sub> =V <sub>DD</sub> -0.2 V | -0.5               |      |                    | mA   | 7    |
| Low-level output current                 | I <sub>OL</sub>  | P <sub>XX</sub> , R <sub>XX</sub> , V <sub>OL</sub> =0.2 V                  |                    |      | 0.5                | mA   | 7    |
| Input leak current                       | I <sub>LI1</sub> | K <sub>XX</sub> , P <sub>XX</sub> , MCU/MPU, RESET                          | -1                 |      | 1                  | μA   |      |
| Input leak current                       | I <sub>LI2</sub> | OSC1, OSC3                                                                  | -1                 |      | 1                  | μA   | 1    |
| Output leak current                      | I <sub>LO</sub>  | P <sub>XX</sub> , R <sub>XX</sub>                                           | -1                 |      | 1                  | μA   |      |
| Input pull-up resistance                 | R <sub>IN</sub>  | K <sub>XX</sub> , P <sub>XX</sub> , MCU/MPU, RESET                          | 100                |      | 500                | kΩ   | 2    |
| Input terminal capacitance               | C <sub>IN</sub>  | K <sub>XX</sub> , P <sub>XX</sub><br>V <sub>IN</sub> =0 V, φ=1 MHz, Ta=25°C |                    |      | 15                 | pF   |      |

- Note) 1. When external clock is selected by mask option.  
 2. When pull-up resistor is added by mask option.  
 3. Low-power mode (VD1C1 = "0", VD1C0 = "1")  
 4. Normal mode (VD1C1 = "0", VD1C0 = "0")  
 5. High-speed mode 1 (VD1C1 = "1", VD1C0 = "0")  
 6. High-speed mode 2 (VD1C1 = "1", VD1C0 = "1")  
 7. Characteristics when only one terminal is driven. If two or more terminals are driven simultaneously, the characteristics had happen to reduced because the V<sub>OH</sub> and V<sub>OL</sub> voltages drop due to the parasitic resistance on the power line in the IC.





## 8.4 Analog Circuit Characteristics and Current Consumption

Unless otherwise specified: VDD=1.8 to 5.5 V, VSS=0 V, Ta=25°C, OSC1=32.768 kHz crystal oscillation,  
OSC3=external clock input

| Item                                                       | Symbol | Condition                        | Min. | Typ. | Max. | Unit | Note |
|------------------------------------------------------------|--------|----------------------------------|------|------|------|------|------|
| SVD voltage                                                | VSVD   | SVD1="1", SVD0=X                 | 3.05 | 3.4  | 3.75 | V    |      |
|                                                            |        | SVD1="0", SVD0="1"               | 2.55 | 2.8  | 3.05 | V    |      |
|                                                            |        | SVD1="0", SVD0="0"               | 1.7  | 1.9  | 2.1  | V    |      |
| SVD circuit response time                                  | tSVD   |                                  |      | 100  | μs   |      |      |
| Power current<br>Low-power mode<br>VD1C1="0", VD1C0="1"    | IDD1   | In SLEEP status                  |      | 0.45 | 1.0  | μA   | 1    |
|                                                            | IDD2   | In HALT status                   |      | 1.8  | 5.0  | μA   | 2    |
|                                                            | IDD3   | CPU is in operating (32.768 kHz) |      | 9.0  | 20.0 | μA   | 3    |
|                                                            | IDD4   | CPU is in operating (1 MHz)      |      | 0.3  | 0.5  | mA   | 4    |
| Power current<br>Normal mode<br>VD1C1="0", VD1C0="0"       | IDD1   | In SLEEP status                  |      | 0.55 | 1.5  | μA   | 1    |
|                                                            | IDD2   | In HALT status                   |      | 3.0  | 7.0  | μA   | 2    |
|                                                            | IDD3   | CPU is in operating (32.768 kHz) |      | 14.0 | 25.0 | μA   | 3    |
|                                                            | IDD4   | CPU is in operating (1 MHz)      |      | 0.45 | 0.7  | mA   | 4    |
| Power current<br>High-speed mode 1<br>VD1C1="1", VD1C0="0" | IDD1   | In SLEEP status                  |      | 0.65 | 2.0  | μA   | 1    |
|                                                            | IDD2   | In HALT status                   |      | 5.0  | 12.0 | μA   | 2    |
|                                                            | IDD3   | CPU is in operating (32.768 kHz) |      | 21.0 | 35.0 | μA   | 3    |
|                                                            | IDD4   | CPU is in operating (1 MHz)      |      | 0.65 | 1.0  | mA   | 4    |
| Power current<br>High-speed mode 2<br>VD1C1="1", VD1C0="1" | IDD1   | In SLEEP status                  |      | 0.75 | 3.0  | μA   | 1    |
|                                                            | IDD2   | In HALT status                   |      | 9.0  | 20.0 | μA   | 2    |
|                                                            | IDD3   | CPU is in operating (32.768 kHz) |      | 32.0 | 50.0 | μA   | 3    |
|                                                            | IDD4   | CPU is in operating (1 MHz)      |      | 0.9  | 1.4  | mA   | 4    |
| SVD circuit current                                        | ISVDN  | VDD=5.0 V                        |      | 7    | 15   | μA   | 5    |
| OSC1 CR oscillation current                                | ICR1   | RCR=1.5 MΩ, normal mode          |      | 20   | 50   | μA   | 6    |

- Note) 1. OSC1: Stop    OSC3: Stop    CPU, ROM, RAM: Stop    Clock Timer: Stop    SVD: Off    Others: Stop  
 2. OSC1: On    OSC3: Stop    CPU, ROM, RAM: Stop    Clock Timer: Run    SVD: Off    Others: Stop  
 3. OSC1: On    OSC3: Stop    CPU, ROM, RAM: Run    Clock Timer: Run    SVD: Off    Others: Stop  
 4. OSC1: On    OSC3: On    CPU, ROM, RAM: Run    Clock Timer: Run    SVD: Off    Others: Stop  
 5. OSC1: On    OSC3: Stop    CPU, ROM, RAM: Stop    Clock Timer: Run    SVD: On    Others: Stop  
 6. When the OSC1 CR oscillation circuit is selected by mask option.

## 8.5 AC Characteristics

### 8.5.1 External memory access

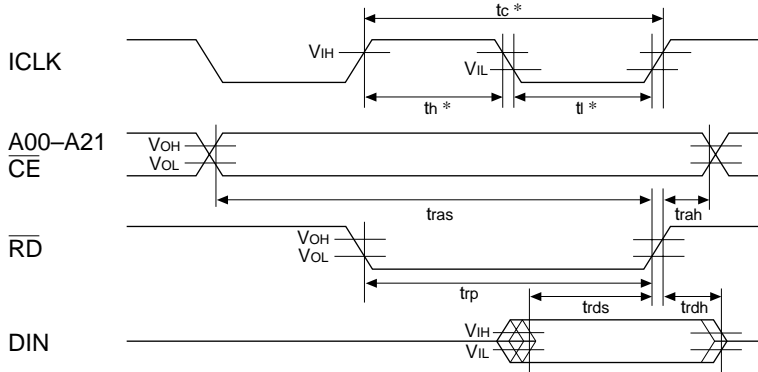
#### Read cycle

Unless otherwise specified:  $V_{DD}=5.5\text{ V}$ ,  $V_{SS}=0\text{ V}$ ,  $f_{osc1}=32.768\text{ kHz}$ ,  $f_{osc3}=1.0\text{ MHz}$ ,  $T_a=-20\text{ to }70^\circ\text{C}$ ,  $C_L=100\text{ pF}$ ,  $V_{IH}=0.8V_{DD}$ ,  $V_{IL}=0.2V_{DD}$ ,  $V_{OH}=0.8V_{DD}$ ,  $V_{OL}=0.2V_{DD}$

| Item                                 | Symbol | Condition                                                    | Min.               | Typ. | Max. | Unit | Note |
|--------------------------------------|--------|--------------------------------------------------------------|--------------------|------|------|------|------|
| Address set-up time in read cycle    | tras   | $V_{DD}=1.8\text{ to }5.5\text{ V}$<br>$V_{D1}=1.6\text{ V}$ | $tc+tl-200+n*tc/2$ | -    | -    | ns   | 1    |
| Address hold time in read cycle      | trah   |                                                              | th-160             | -    | -    | ns   |      |
| Read signal pulse width              | trp    |                                                              | $tc-40+n*tc/2$     | -    | -    | ns   | 1    |
| Data input set-up time in read cycle | trds   |                                                              | 600                | -    | -    | ns   |      |
| Data input hold time in read cycle   | trdh   |                                                              | 0                  | -    | -    | ns   |      |
| Address set-up time in read cycle    | tras   | $V_{DD}=2.6\text{ to }5.5\text{ V}$<br>$V_{D1}=2.4\text{ V}$ | $tc+tl-100+n*tc/2$ | -    | -    | ns   | 1    |
| Address hold time in read cycle      | trah   |                                                              | th-80              | -    | -    | ns   |      |
| Read signal pulse width              | trp    |                                                              | $tc-20+n*tc/2$     | -    | -    | ns   | 1    |
| Data input set-up time in read cycle | trds   |                                                              | 300                | -    | -    | ns   |      |
| Data input hold time in read cycle   | trdh   |                                                              | 0                  | -    | -    | ns   |      |
| Address set-up time in read cycle    | tras   | $V_{DD}=3.5\text{ to }5.5\text{ V}$<br>$V_{D1}=3.2\text{ V}$ | $tc+tl-50+n*tc/2$  | -    | -    | ns   | 1    |
| Address hold time in read cycle      | trah   |                                                              | th-40              | -    | -    | ns   |      |
| Read signal pulse width              | trp    |                                                              | $tc-10+n*tc/2$     | -    | -    | ns   | 1    |
| Data input set-up time in read cycle | trds   |                                                              | 150                | -    | -    | ns   |      |
| Data input hold time in read cycle   | trdh   |                                                              | 0                  | -    | -    | ns   |      |
| Address set-up time in read cycle    | tras   | $V_{DD}=4.5\text{ to }5.5\text{ V}$<br>$V_{D1}=4.2\text{ V}$ | $tc+tl-50+n*tc/2$  | -    | -    | ns   | 1    |
| Address hold time in read cycle      | trah   |                                                              | th-40              | -    | -    | ns   |      |
| Read signal pulse width              | trp    |                                                              | $tc-10+n*tc/2$     | -    | -    | ns   | 1    |
| Data input set-up time in read cycle | trds   |                                                              | 150                | -    | -    | ns   |      |
| Data input hold time in read cycle   | trdh   |                                                              | 0                  | -    | -    | ns   |      |

$tc$ =input clock cycle time,  $th$ =input clock H pulse width,  $tl$ =input clock L pulse width

Note) 1. Substitute the number of states for wait insertion in n.



\* In the case of crystal or ceramic oscillation:  $th=0.5tc\pm0.05tc$ ,  $tl=tc-th$   
 In the case of CR oscillation:  $th=0.5tc\pm0.10tc$ ,  $tl=tc-th$   
 ( $1/tc$ : oscillation frequency)

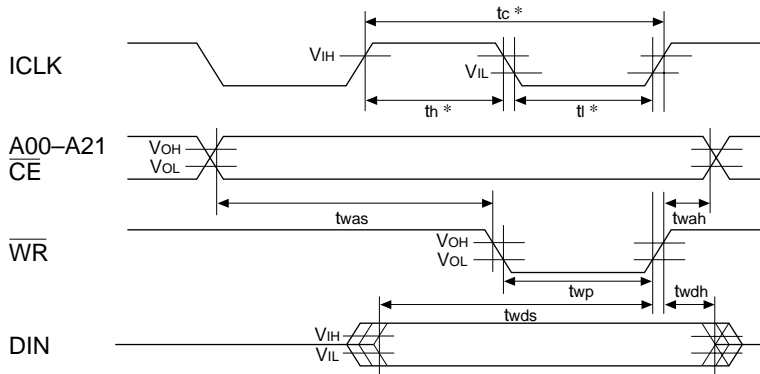
**Write cycle**

Unless otherwise specified:  $V_{DD}=5.5\text{ V}$ ,  $V_{SS}=0\text{ V}$ ,  $f_{osc1}=32.768\text{ kHz}$ ,  $f_{osc3}=1.0\text{ MHz}$ ,  $T_a=-20\text{ to }70^\circ\text{C}$ ,  $C_L=100\text{ pF}$ ,  
 $V_{IH}=0.8V_{DD}$ ,  $V_{IL}=0.2V_{DD}$ ,  $V_{OH}=0.8V_{DD}$ ,  $V_{OL}=0.2V_{DD}$

| Item                                   | Symbol | Condition                                                    | Min.          | Typ. | Max.   | Unit | Note |
|----------------------------------------|--------|--------------------------------------------------------------|---------------|------|--------|------|------|
| Address set-up time in write cycle     | twas   | $V_{DD}=1.8\text{ to }5.5\text{ V}$<br>$V_{D1}=1.6\text{ V}$ | tc-360        | -    | -      | ns   |      |
| Address hold time in write cycle       | twah   |                                                              | th-160        | -    | -      | ns   |      |
| Write signal pulse width               | twp    |                                                              | tl-80+n*tc/2  | -    | -      | ns   | 1    |
| Data output set-up time in write cycle | twds   |                                                              | tc-360+n*tc/2 | -    | -      | ns   | 1    |
| Data output hold time in write cycle   | twdh   |                                                              | th-160        | -    | th+160 | ns   |      |
| Address set-up time in write cycle     | twas   | $V_{DD}=2.6\text{ to }5.5\text{ V}$<br>$V_{D1}=2.4\text{ V}$ | tc-180        | -    | -      | ns   |      |
| Address hold time in write cycle       | twah   |                                                              | th-80         | -    | -      | ns   |      |
| Write signal pulse width               | twp    |                                                              | tl-40+n*tc/2  | -    | -      | ns   | 1    |
| Data output set-up time in write cycle | twds   |                                                              | tc-180+n*tc/2 | -    | -      | ns   | 1    |
| Data output hold time in write cycle   | twdh   |                                                              | th-160        | -    | th+160 | ns   |      |
| Address set-up time in write cycle     | twas   | $V_{DD}=3.5\text{ to }5.5\text{ V}$<br>$V_{D1}=3.2\text{ V}$ | tc-90         | -    | -      | ns   |      |
| Address hold time in write cycle       | twah   |                                                              | th-40         | -    | -      | ns   |      |
| Write signal pulse width               | twp    |                                                              | tl-20+n*tc/2  | -    | -      | ns   | 1    |
| Data output set-up time in write cycle | twds   |                                                              | tc-90+n*tc/2  | -    | -      | ns   | 1    |
| Data output hold time in write cycle   | twdh   |                                                              | th-160        | -    | th+160 | ns   |      |
| Address set-up time in write cycle     | twas   | $V_{DD}=4.5\text{ to }5.5\text{ V}$<br>$V_{D1}=4.2\text{ V}$ | tc-90         | -    | -      | ns   |      |
| Address hold time in write cycle       | twah   |                                                              | th-40         | -    | -      | ns   |      |
| Write signal pulse width               | twp    |                                                              | tl-20+n*tc/2  | -    | -      | ns   | 1    |
| Data output set-up time in write cycle | twds   |                                                              | tc-90+n*tc/2  | -    | -      | ns   | 1    |
| Data output hold time in write cycle   | twdh   |                                                              | th-160        | -    | th+160 | ns   |      |

tc=input clock cycle time, th=input clock H pulse width, tl=input clock L pulse width

Note) 1. Substitute the number of states for wait insertion in n.



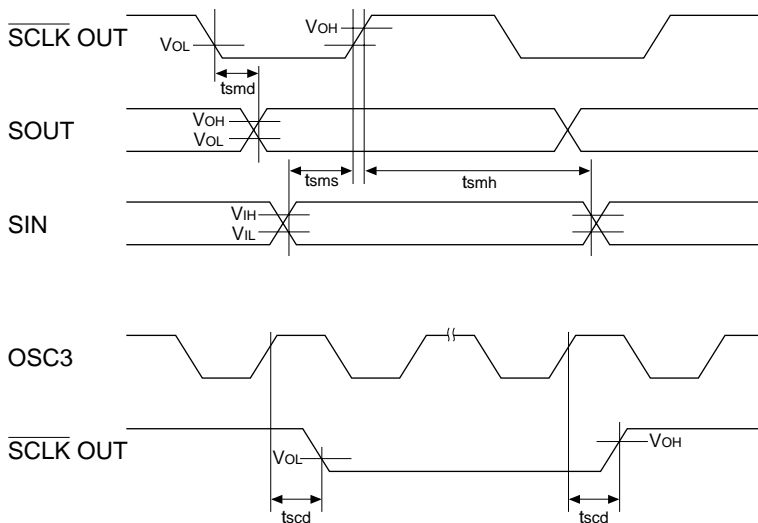
\* In the case of crystal or ceramic oscillation:  $th=0.5tc\pm 0.05tc$ ,  $tl=tc-th$   
 In the case of CR oscillation:  $th=0.5tc\pm 0.10tc$ ,  $tl=tc-th$   
 (1/tc: oscillation frequency)

### 8.5.2 Serial interface

#### Clock synchronous master mode

Unless otherwise specified:  $V_{DD}=5.5\text{ V}$ ,  $V_{SS}=0\text{ V}$ ,  $f_{OSC1}=32.768\text{ kHz}$ ,  $f_{OSC3}=100\text{ kHz}$ ,  $T_a=-20\text{ to }70^\circ\text{C}$ ,  $C_L=100\text{ pF}$ ,  
 $V_{IH}=0.8V_{DD}$ ,  $V_{IL}=0.2V_{DD}$ ,  $V_{OH}=0.8V_{DD}$ ,  $V_{OL}=0.2V_{DD}$

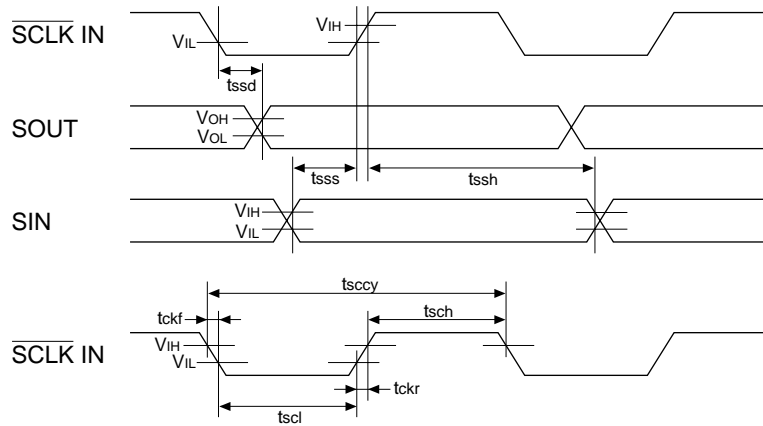
| Item                            | Symbol           | Condition                           | Min. | Typ. | Max. | Unit | Note |
|---------------------------------|------------------|-------------------------------------|------|------|------|------|------|
| Transmit data output delay time | t <sub>smd</sub> | $V_{DD}=1.8\text{ to }5.5\text{ V}$ | –    | –    | 400  | ns   |      |
| Receive data input set-up time  | t <sub>sms</sub> | $V_{D1}=1.6\text{ V}$               | 1000 | –    | –    | ns   |      |
| Receive data input hold time    | t <sub>smh</sub> |                                     | 400  | –    | –    | ns   |      |
| Transmit data output delay time | t <sub>smd</sub> | $V_{DD}=2.6\text{ to }5.5\text{ V}$ | –    | –    | 200  | ns   |      |
| Receive data input set-up time  | t <sub>sms</sub> | $V_{D1}=2.4\text{ V}$               | 500  | –    | –    | ns   |      |
| Receive data input hold time    | t <sub>smh</sub> |                                     | 200  | –    | –    | ns   |      |
| Transmit data output delay time | t <sub>smd</sub> | $V_{DD}=3.5\text{ to }5.5\text{ V}$ | –    | –    | 100  | ns   |      |
| Receive data input set-up time  | t <sub>sms</sub> | $V_{D1}=3.2\text{ V}$               | 250  | –    | –    | ns   |      |
| Receive data input hold time    | t <sub>smh</sub> |                                     | 100  | –    | –    | ns   |      |
| Transmit data output delay time | t <sub>smd</sub> | $V_{DD}=4.5\text{ to }5.5\text{ V}$ | –    | –    | 100  | ns   |      |
| Receive data input set-up time  | t <sub>sms</sub> | $V_{D1}=4.2\text{ V}$               | 250  | –    | –    | ns   |      |
| Receive data input hold time    | t <sub>smh</sub> |                                     | 100  | –    | –    | ns   |      |



#### Clock synchronous slave mode

Unless otherwise specified:  $V_{DD}=5.5\text{ V}$ ,  $V_{SS}=0\text{ V}$ ,  $f_{OSC1}=32.768\text{ kHz}$ ,  $f_{OSC3}=100\text{ kHz}$ ,  $T_a=-20\text{ to }70^\circ\text{C}$ ,  $C_L=100\text{ pF}$ ,  
 $V_{IH}=0.8V_{DD}$ ,  $V_{IL}=0.2V_{DD}$ ,  $V_{OH}=0.8V_{DD}$ ,  $V_{OL}=0.2V_{DD}$

| Item                            | Symbol           | Condition                           | Min. | Typ. | Max. | Unit | Note |
|---------------------------------|------------------|-------------------------------------|------|------|------|------|------|
| Transmit data output delay time | t <sub>ssd</sub> | $V_{DD}=1.8\text{ to }5.5\text{ V}$ | –    | –    | 1000 | ns   |      |
| Receive data input set-up time  | t <sub>sss</sub> | $V_{D1}=1.6\text{ V}$               | 400  | –    | –    | ns   |      |
| Receive data input hold time    | t <sub>ssh</sub> | SCKIN=100 kHz                       | 400  | –    | –    | ns   |      |
| Transmit data output delay time | t <sub>ssd</sub> | $V_{DD}=2.6\text{ to }5.5\text{ V}$ | –    | –    | 500  | ns   |      |
| Receive data input set-up time  | t <sub>sss</sub> | $V_{D1}=2.4\text{ V}$               | 200  | –    | –    | ns   |      |
| Receive data input hold time    | t <sub>ssh</sub> | SCKIN=100 kHz                       | 200  | –    | –    | ns   |      |
| Transmit data output delay time | t <sub>ssd</sub> | $V_{DD}=3.5\text{ to }5.5\text{ V}$ | –    | –    | 250  | ns   |      |
| Receive data input set-up time  | t <sub>sss</sub> | $V_{D1}=3.2\text{ V}$               | 100  | –    | –    | ns   |      |
| Receive data input hold time    | t <sub>ssh</sub> | SCKIN=100 kHz                       | 100  | –    | –    | ns   |      |
| Transmit data output delay time | t <sub>ssd</sub> | $V_{DD}=4.5\text{ to }5.5\text{ V}$ | –    | –    | 250  | ns   |      |
| Receive data input set-up time  | t <sub>sss</sub> | $V_{D1}=4.2\text{ V}$               | 100  | –    | –    | ns   |      |
| Receive data input hold time    | t <sub>ssh</sub> | SCKIN=100 kHz                       | 100  | –    | –    | ns   |      |

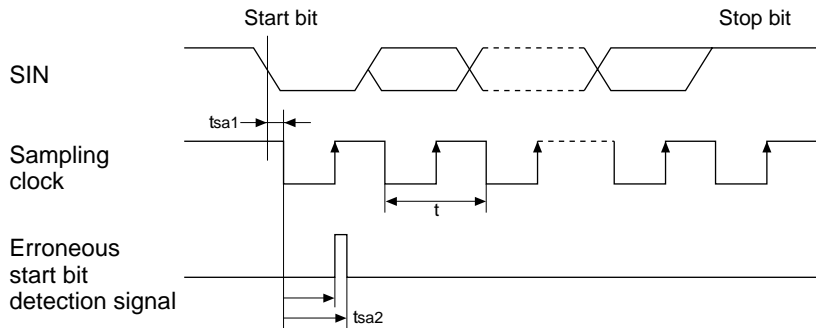


### Asynchronous mode

Unless otherwise specified:  $V_{DD}=1.8$  to  $5.5$  V,  $V_{SS}=0$  V,  $T_a=-20$  to  $70^{\circ}\text{C}$ ,  $V_{IH}=0.7V_{DD}$ ,  $V_{IL}=0.3V_{DD}$ ,  $V_{OH}=0.7V_{DD}$ ,  $V_{OL}=0.3V_{DD}$

| Item                                     | Symbol    | Condition | Min.    | Typ. | Max.    | Unit | Note |
|------------------------------------------|-----------|-----------|---------|------|---------|------|------|
| Start bit detection error time           | $t_{sa1}$ |           | 0       | –    | $t/16$  | s    | 1    |
| Erroneous start bit detection range time | $t_{sa2}$ |           | $8t/16$ | –    | $9t/16$ | s    | 2    |

- Note) 1. Start bit detection error time is a logical delay time from inputting a start bit until the internal sampling starts operating. (AC time is not included.)
2. Erroneous start bit detection range time is a logical time from starting sampling clock (detecting a start bit) until the start bit is detected again whether a low level (start bit) has still been input. When a high level is detected, the start bit detection circuit is reset and goes into a start bit waiting status. (AC time is not included.)

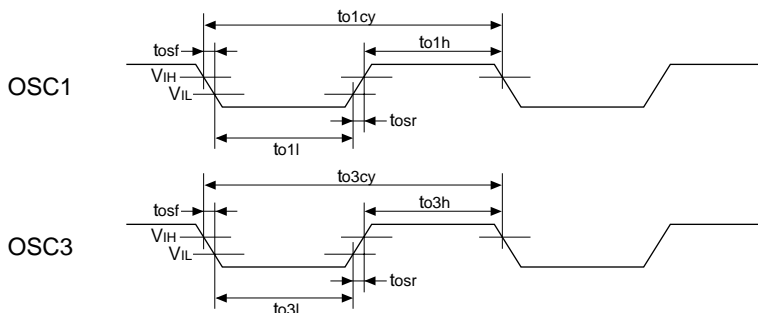


### 8.5.3 Input clock

#### OSC1, OSC3 external clock

Unless otherwise specified:  $V_{SS}=0\text{ V}$ ,  $T_a=-20\text{ to }70^\circ\text{C}$

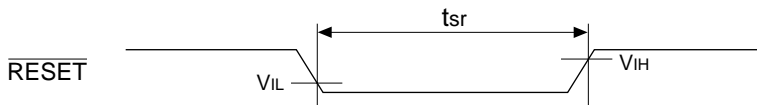
| Item                     | Symbol          | Condition  | Min.                                | Typ. | Max. | Unit | Note  |               |
|--------------------------|-----------------|------------|-------------------------------------|------|------|------|-------|---------------|
| OSC1 input clock time    | Cycle time      | $t_{01cy}$ | $V_{DD}=1.8\text{ to }5.5\text{ V}$ |      | 20   | –    | 32    | $\mu\text{s}$ |
|                          | "H" pulse width | $t_{01h}$  | $V_{D1}=1.6\text{ V}$               |      | 10   | –    | 16    | $\mu\text{s}$ |
|                          | "L" pulse width | $t_{01l}$  | $V_{IH}=1.3\text{ V}$               |      | 10   | –    | 16    | $\mu\text{s}$ |
| OSC3 input clock time    | Cycle time      | $t_{03cy}$ | $V_{IL}=0.3\text{ V}$               |      | 1000 | –    | 32000 | ns            |
|                          | "H" pulse width | $t_{03h}$  |                                     |      | 500  | –    | 16000 | ns            |
|                          | "L" pulse width | $t_{03l}$  |                                     |      | 500  | –    | 16000 | ns            |
| Input clock rising time  | $t_{0sr}$       |            | –                                   | –    | 25   |      | ns    |               |
| Input clock falling time | $t_{0sf}$       |            | –                                   | –    | 25   |      | ns    |               |
| OSC1 input clock time    | Cycle time      | $t_{01cy}$ | $V_{DD}=2.6\text{ to }5.5\text{ V}$ |      | 20   | –    | 32    | $\mu\text{s}$ |
|                          | "H" pulse width | $t_{01h}$  | $V_{D1}=2.4\text{ V}$               |      | 10   | –    | 16    | $\mu\text{s}$ |
|                          | "L" pulse width | $t_{01l}$  | $V_{IH}=1.8\text{ V}$               |      | 10   | –    | 16    | $\mu\text{s}$ |
| OSC3 input clock time    | Cycle time      | $t_{03cy}$ | $V_{IL}=0.6\text{ V}$               |      | 240  | –    | 32000 | ns            |
|                          | "H" pulse width | $t_{03h}$  |                                     |      | 120  | –    | 16000 | ns            |
|                          | "L" pulse width | $t_{03l}$  |                                     |      | 120  | –    | 16000 | ns            |
| Input clock rising time  | $t_{0sr}$       |            | –                                   | –    | 25   |      | ns    |               |
| Input clock falling time | $t_{0sf}$       |            | –                                   | –    | 25   |      | ns    |               |
| OSC1 input clock time    | Cycle time      | $t_{01cy}$ | $V_{DD}=3.5\text{ to }5.5\text{ V}$ |      | 20   | –    | 32    | $\mu\text{s}$ |
|                          | "H" pulse width | $t_{01h}$  | $V_{D1}=3.2\text{ V}$               |      | 10   | –    | 16    | $\mu\text{s}$ |
|                          | "L" pulse width | $t_{01l}$  | $V_{IH}=2.4\text{ V}$               |      | 10   | –    | 16    | $\mu\text{s}$ |
| OSC3 input clock time    | Cycle time      | $t_{03cy}$ | $V_{IL}=0.8\text{ V}$               |      | 155  | –    | 32000 | ns            |
|                          | "H" pulse width | $t_{03h}$  |                                     |      | 77.5 | –    | 16000 | ns            |
|                          | "L" pulse width | $t_{03l}$  |                                     |      | 77.5 | –    | 16000 | ns            |
| Input clock rising time  | $t_{0sr}$       |            | –                                   | –    | 25   |      | ns    |               |
| Input clock falling time | $t_{0sf}$       |            | –                                   | –    | 25   |      | ns    |               |
| OSC1 input clock time    | Cycle time      | $t_{01cy}$ | $V_{DD}=4.5\text{ to }5.5\text{ V}$ |      | 20   | –    | 32    | $\mu\text{s}$ |
|                          | "H" pulse width | $t_{01h}$  | $V_{D1}=4.2\text{ V}$               |      | 10   | –    | 16    | $\mu\text{s}$ |
|                          | "L" pulse width | $t_{01l}$  | $V_{IH}=3.2\text{ V}$               |      | 10   | –    | 16    | $\mu\text{s}$ |
| OSC3 input clock time    | Cycle time      | $t_{03cy}$ | $V_{IL}=1.0\text{ V}$               |      | 115  | –    | 32000 | ns            |
|                          | "H" pulse width | $t_{03h}$  |                                     |      | 57.5 | –    | 16000 | ns            |
|                          | "L" pulse width | $t_{03l}$  |                                     |      | 57.5 | –    | 16000 | ns            |
| Input clock rising time  | $t_{0sr}$       |            | –                                   | –    | 25   |      | ns    |               |
| Input clock falling time | $t_{0sf}$       |            | –                                   | –    | 25   |      | ns    |               |



#### RESET input clock

Unless otherwise specified:  $V_{DD}=1.8\text{ to }5.5\text{ V}$ ,  $V_{SS}=0\text{ V}$ ,  $T_a=-20\text{ to }70^\circ\text{C}$ ,  $V_{IH}=0.5V_{DD}$ ,  $V_{IL}=0.1V_{DD}$

| Item              | Symbol   | Condition | Min. | Typ. | Max. | Unit          | Note |
|-------------------|----------|-----------|------|------|------|---------------|------|
| RESET pulse width | $t_{sr}$ |           | 100  | –    | –    | $\mu\text{s}$ |      |

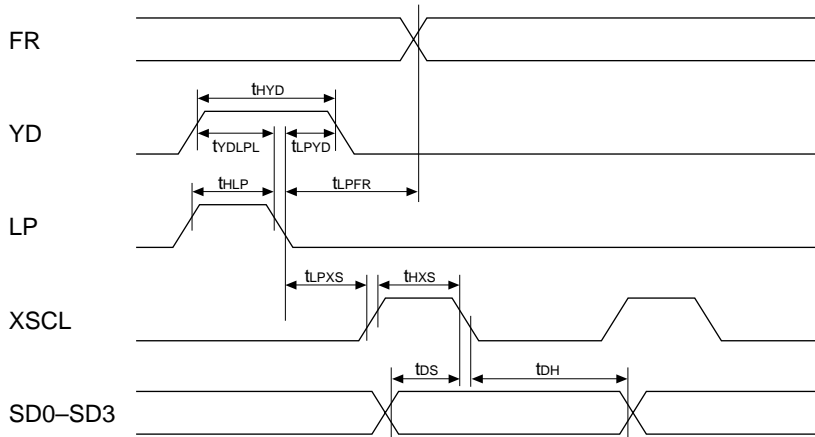


### 8.5.4 LCD controller

Unless otherwise specified:  $V_{DD}=5.5\text{ V}$ ,  $V_{SS}=0\text{ V}$ ,  $f_{OSC1}=32.768\text{ kHz}$ ,  $f_{OSC3}=2.0\text{ MHz}$ ,  $T_a=-20\text{ to }70^\circ\text{C}$ ,  $C_L=100\text{ pF}$ ,  
 $V_{IH}=0.8V_{DD}$ ,  $V_{IL}=0.2V_{DD}$ ,  $V_{OH}=0.8V_{DD}$ ,  $V_{OL}=0.2V_{DD}$

| Item                                    | Symbol  | Condition                                                    | Min.                                                         | Typ.      | Max. | Unit          | Note |  |
|-----------------------------------------|---------|--------------------------------------------------------------|--------------------------------------------------------------|-----------|------|---------------|------|--|
| XSCL H-level pulse width (B&W, 4 bits)  | tHXS(1) | $V_{DD}=1.8\text{ to }5.5\text{ V}$<br>$V_{D1}=1.6\text{ V}$ | tc-360                                                       | -         | -    | ns            |      |  |
| XSCL H-level pulse width (gray, 4 bits) | tHXS(2) |                                                              | tc-tl-360                                                    | -         | -    | ns            |      |  |
| LP falling edge to XSCL rising edge     | tLPXS   |                                                              | 6*tc-360                                                     | -         | -    | ns            |      |  |
| LCD data setup time                     | tDS     |                                                              | tc-360                                                       | -         | -    | ns            |      |  |
| LCD data hold time                      | tDH     |                                                              | tc-360                                                       | -         | -    | ns            |      |  |
| YD H-level pulse width                  | tHYD    |                                                              | tc(fosc1)-3                                                  | -         | -    | $\mu\text{s}$ |      |  |
| LP H-level pulse width                  | tHLP    |                                                              | tl(fosc1)-1.5                                                | -         | -    | $\mu\text{s}$ |      |  |
| YD setup time                           | tYDLPL  |                                                              | tl(fosc1)-1.5                                                | -         | -    | $\mu\text{s}$ |      |  |
| YD hold time                            | tLPYD   |                                                              | th(fosc1)-1.5                                                | -         | -    | $\mu\text{s}$ |      |  |
| FR change from LP falling edge          | tLPFR   |                                                              | -300                                                         | -         | 300  | ns            |      |  |
| XSCL H-level pulse width (B&W, 4 bits)  | tHXS(1) |                                                              | $V_{DD}=2.6\text{ to }5.5\text{ V}$<br>$V_{D1}=2.4\text{ V}$ | tc-180    | -    | -             | ns   |  |
| XSCL H-level pulse width (gray, 4 bits) | tHXS(2) |                                                              |                                                              | tc-tl-180 | -    | -             | ns   |  |
| LP falling edge to XSCL rising edge     | tLPXS   |                                                              |                                                              | 6*tc-180  | -    | -             | ns   |  |
| LCD data setup time                     | tDS     |                                                              |                                                              | tc-180    | -    | -             | ns   |  |
| LCD data hold time                      | tDH     | tc-180                                                       |                                                              | -         | -    | ns            |      |  |
| YD H-level pulse width                  | tHYD    | tc(fosc1)-3                                                  |                                                              | -         | -    | $\mu\text{s}$ |      |  |
| LP H-level pulse width                  | tHLP    | tl(fosc1)-1.5                                                |                                                              | -         | -    | $\mu\text{s}$ |      |  |
| YD setup time                           | tYDLPL  | tl(fosc1)-1.5                                                |                                                              | -         | -    | $\mu\text{s}$ |      |  |
| YD hold time                            | tLPYD   | th(fosc1)-1.5                                                |                                                              | -         | -    | $\mu\text{s}$ |      |  |
| FR change from LP falling edge          | tLPFR   | -200                                                         |                                                              | -         | 200  | ns            |      |  |
| XSCL H-level pulse width (B&W, 4 bits)  | tHXS(1) | $V_{DD}=3.5\text{ to }5.5\text{ V}$<br>$V_{D1}=3.2\text{ V}$ |                                                              | tc-90     | -    | -             | ns   |  |
| XSCL H-level pulse width (gray, 4 bits) | tHXS(2) |                                                              |                                                              | tc-tl-90  | -    | -             | ns   |  |
| LP falling edge to XSCL rising edge     | tLPXS   |                                                              |                                                              | 6*tc-90   | -    | -             | ns   |  |
| LCD data setup time                     | tDS     |                                                              |                                                              | tc-90     | -    | -             | ns   |  |
| LCD data hold time                      | tDH     |                                                              | tc-90                                                        | -         | -    | ns            |      |  |
| YD H-level pulse width                  | tHYD    |                                                              | tc(fosc1)-3                                                  | -         | -    | $\mu\text{s}$ |      |  |
| LP H-level pulse width                  | tHLP    |                                                              | tl(fosc1)-1.5                                                | -         | -    | $\mu\text{s}$ |      |  |
| YD setup time                           | tYDLPL  |                                                              | tl(fosc1)-1.5                                                | -         | -    | $\mu\text{s}$ |      |  |
| YD hold time                            | tLPYD   |                                                              | th(fosc1)-1.5                                                | -         | -    | $\mu\text{s}$ |      |  |
| FR change from LP falling edge          | tLPFR   |                                                              | -100                                                         | -         | 100  | ns            |      |  |
| XSCL H-level pulse width (B&W, 4 bits)  | tHXS(1) |                                                              | $V_{DD}=4.5\text{ to }5.5\text{ V}$<br>$V_{D1}=4.2\text{ V}$ | tc-90     | -    | -             | ns   |  |
| XSCL H-level pulse width (gray, 4 bits) | tHXS(2) |                                                              |                                                              | tc-tl-90  | -    | -             | ns   |  |
| LP falling edge to XSCL rising edge     | tLPXS   |                                                              |                                                              | 6*tc-90   | -    | -             | ns   |  |
| LCD data setup time                     | tDS     |                                                              |                                                              | tc-90     | -    | -             | ns   |  |
| LCD data hold time                      | tDH     | tc-90                                                        |                                                              | -         | -    | ns            |      |  |
| YD H-level pulse width                  | tHYD    | tc(fosc1)-3                                                  |                                                              | -         | -    | $\mu\text{s}$ |      |  |
| LP H-level pulse width                  | tHLP    | tl(fosc1)-1.5                                                |                                                              | -         | -    | $\mu\text{s}$ |      |  |
| YD setup time                           | tYDLPL  | tl(fosc1)-1.5                                                |                                                              | -         | -    | $\mu\text{s}$ |      |  |
| YD hold time                            | tLPYD   | th(fosc1)-1.5                                                |                                                              | -         | -    | $\mu\text{s}$ |      |  |
| FR change from LP falling edge          | tLPFR   | -100                                                         |                                                              | -         | 100  | ns            |      |  |

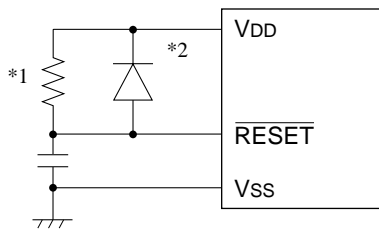
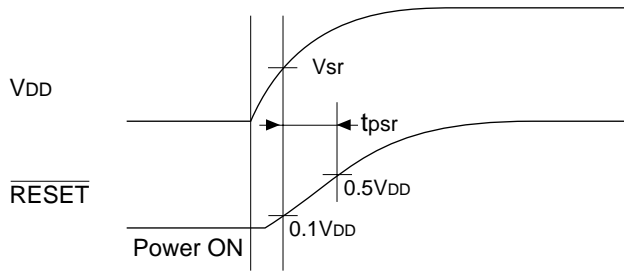
tc=OSC3 clock cycle time, th=OSC3 clock H pulse width, tl=OSC3 clock L pulse width, tc(fosc1)=OSC1 clock cycle time  
th(fosc1)=OSC1 clock H pulse width, tl(fosc1)=OSC1 clock L pulse width



### 8.5.5 Power-on reset

Unless otherwise specified:  $V_{SS}=0\text{ V}$ ,  $T_a=-20\text{ to }70^\circ\text{C}$

| Item              | Symbol    | Condition | Min. | Typ. | Max. | Unit | Note |
|-------------------|-----------|-----------|------|------|------|------|------|
| Operating voltage | $V_{sr}$  |           | 2.6  | –    | –    | V    |      |
| RESET input width | $t_{psr}$ |           | 10   | –    | –    | ms   |      |



- \*1 When the built-in pull up resistor is not used.
- \*2 Because the potential of the RESET terminal not reached  $V_{DD}$  level or higher.

### 8.5.6 Switching operating mode

Unless otherwise specified:  $V_{DD}=1.8\text{ to }5.5\text{ V}$ ,  $V_{SS}=0\text{ V}$ ,  $T_a=-20\text{ to }70^\circ\text{C}$

| Item               | Symbol    | Condition | Min. | Typ. | Max. | Unit | Note |
|--------------------|-----------|-----------|------|------|------|------|------|
| Stabilization time | $t_{vdc}$ |           | 5    | –    | –    | ms   | 1    |

Note) 1. Stabilization time is the time from switching on the operating mode until operating mode is stabilized. For example, when turning the OSC3 oscillation circuit on, stabilization time is needed after the operating mode is switched on.



## 8.6 Oscillation Characteristics

Oscillation characteristics change depending on conditions (board pattern, components used, etc.). Use the following characteristics as reference values. In particular, when a ceramic oscillator or crystal oscillator is used for OSC3, use the oscillator manufacturer's recommended values for constants such as capacitance and resistance. The oscillation start time is important because it becomes the waiting time when OSC3 clock is used. (If OSC3 is used as CPU clock before oscillation stabilizes, the CPU may malfunction.)

### OSC1 crystal oscillation

Unless otherwise specified:  $V_{DD}=1.8$  to  $5.5$  V,  $V_{SS}=0$  V,  $T_a=25^\circ\text{C}$ ,

Crystal oscillator=Q12C2(made by Seiko Epson corporation),  $C_{G1}=25$  pF(External),  $C_{D1}$ =Built-in

| Item                               | Symbol                    | Condition                                     | Min. | Typ. | Max. | Unit  | Note |
|------------------------------------|---------------------------|-----------------------------------------------|------|------|------|-------|------|
| Oscillation start time             | tsta                      |                                               |      |      | 3    | s     |      |
| External gate capacitance          | $C_{G1}$                  | Including board capacitance                   | 5    |      | 25   | pF    | 1    |
| Built-in drain capacitance         | $C_{D1}$                  | In case of the chip                           |      | 15   |      | pF    |      |
| Frequency/IC deviation             | $\partial f/\partial IC$  | $V_{DD}=\text{constant}$                      | -10  |      | 10   | ppm   |      |
| Frequency/supply voltage deviation | $\partial f/\partial V$   |                                               |      |      | 1    | ppm/V |      |
| Frequency adjustment range         | $\partial f/\partial C_G$ | $V_{DD}=\text{constant}$ , $C_G=5$ to $25$ pF | 25   |      |      | ppm   |      |
| Frequency/operating mode deviation | $\partial f/\partial MD$  | $V_{DD}=\text{constant}$                      |      |      | 20   | ppm   |      |

Note) 1. When crystal oscillation is selected by mask option.

### OSC1 CR oscillation

Unless otherwise specified:  $V_{DD}=1.8$  to  $5.5$  V,  $V_{SS}=0$  V,  $T_a=25^\circ\text{C}$ ,  $R_{CR}=1.8$  M $\Omega$

| Item                   | Symbol                   | Condition                | Min. | Typ. | Max. | Unit | Note |
|------------------------|--------------------------|--------------------------|------|------|------|------|------|
| Oscillation start time | tsta                     |                          |      |      | 3    | ms   |      |
| Frequenc/IC deviation  | $\partial f/\partial IC$ | $R_{CR}=\text{constant}$ | -25  |      | 25   | %    |      |

### OSC3 crystal oscillation

Unless otherwise specified:  $V_{DD}=2.6/3.5/4.5$  to  $5.5$  V,  $V_{SS}=0$  V,  $T_a=25^\circ\text{C}$ , Crystal oscillator=Q21CA301xxx(made by Seiko Epson corporation),  $R_F=1$  M $\Omega$ ,  $C_{G2}=C_{D2}=15$  pF

| Item                   | Symbol | Condition | Min. | Typ. | Max. | Unit | Note |
|------------------------|--------|-----------|------|------|------|------|------|
| Oscillation start time | tsta   |           |      |      | 20   | ms   | 1    |

Note) 1. The crystal oscillation start time changes by the crystal oscillator to be used,  $C_{G2}$  and  $C_{D2}$ .

### OSC3 ceramic oscillation

Unless otherwise specified:  $V_{DD}=2.6/3.5/4.5$  to  $5.5$  V,  $V_{SS}=0$  V,  $T_a=25^\circ\text{C}$ , Ceramic oscillator=CSA4.00MG/CSA8.00MTZ(made by Murata Mfg. corporation),  $R_F=1$  M $\Omega$ ,  $C_{G2}=C_{D2}=30$  pF

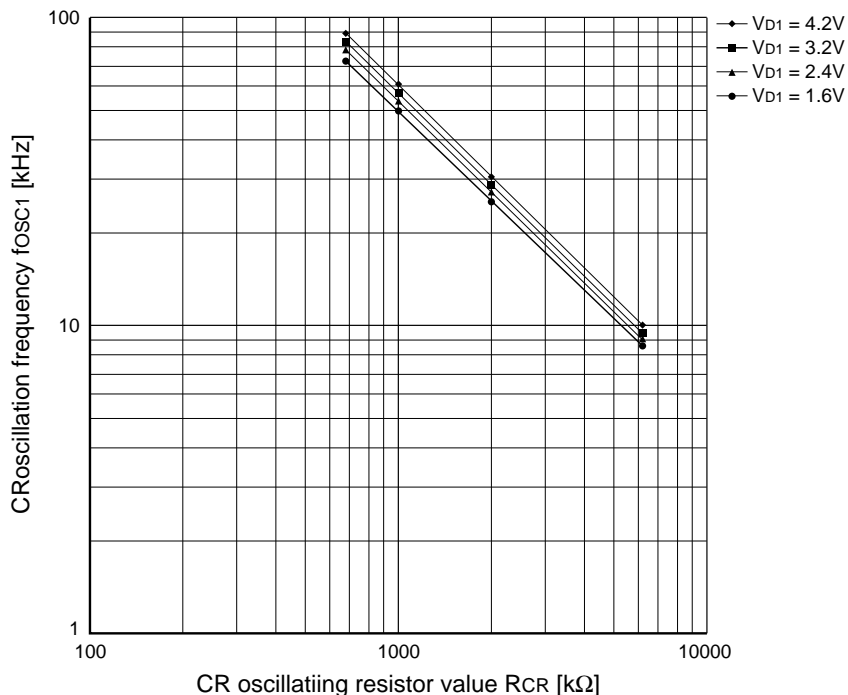
| Item                   | Symbol | Condition | Min. | Typ. | Max. | Unit | Note |
|------------------------|--------|-----------|------|------|------|------|------|
| Oscillation start time | tsta   |           |      |      | 5    | ms   |      |

### OSC3 CR oscillation

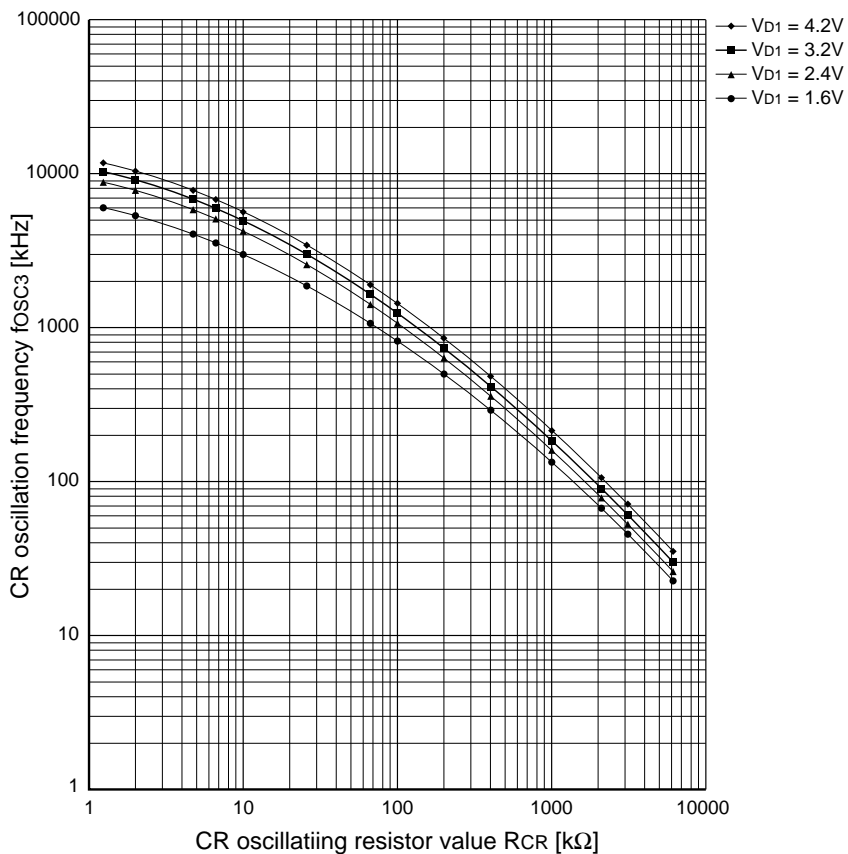
Unless otherwise specified:  $V_{DD}=2.6/3.5/4.5$  to  $5.5$  V,  $V_{SS}=0$  V,  $T_a=25^\circ\text{C}$

| Item                   | Symbol                   | Condition                | Min. | Typ. | Max. | Unit | Note |
|------------------------|--------------------------|--------------------------|------|------|------|------|------|
| Oscillation start time | tsta                     |                          |      |      | 1    | ms   |      |
| Frequenc/IC deviation  | $\partial f/\partial IC$ | $R_{CR}=\text{constant}$ | -25  |      | 25   | %    |      |

**OSC1 CR oscillation characteristics (for reference)**



**OSC3 CR oscillation characteristics (for reference)**



## 8.7 A/D Converter Characteristics

The following characteristics apply to the plastic package model only.

Unless otherwise specified:  $V_{DD}=AV_{DD}=AV_{REF}=5.0\text{ V}$ ,  $V_{SS}=AV_{SS}=AGND=0\text{ V}$ ,  $f_{osc1}=32.768\text{ kHz}$ ,  $f_{osc3}=4.0\text{ MHz}$ ,  $T_a=25^\circ\text{C}$

| Item                              | Symbol          | Condition                                                                                                                                     | Min.  | Typ. | Max. | Unit | Note |
|-----------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-------|------|------|------|------|
| Zero-scale error                  | Ezs             | $V_{DD}=AV_{DD}=AV_{REF}=2.7\text{ to }5.5\text{ V}$ , $AV_{SS}=0\text{ V}$ ,<br>$ADCLK=2\text{ MHz}$ , $T_a=25^\circ\text{C}$                | -1.50 | –    | 1.50 | LSB  |      |
| Full-scale error                  | Efs             |                                                                                                                                               | -1.50 | –    | 1.50 | LSB  |      |
| Non-linearity error               | EI              |                                                                                                                                               | -1.50 | –    | 1.50 | LSB  |      |
| Total error                       | Et              |                                                                                                                                               | -3.00 | –    | 3.00 | LSB  |      |
| A/D converter current consumption | I <sub>AD</sub> | $V_{DD}=AV_{DD}=AV_{REF}=3.0\text{ V}$ , $ADCLK=2\text{ MHz}$ , $T_a=25^\circ\text{C}$<br>$AV_{REF}$ and $ADCLK$ divider current not included | –     | 0.50 | 1.00 | mA   |      |
|                                   |                 | $V_{DD}=AV_{DD}=AV_{REF}=5.0\text{ V}$ , $ADCLK=2\text{ MHz}$ , $T_a=25^\circ\text{C}$<br>$AV_{REF}$ and $ADCLK$ divider current not included | –     | 1.80 | 3.50 | mA   |      |
| Input clock frequency             | f               | $V_{DD}=AV_{DD}=AV_{REF}=2.7\text{ to }5.5\text{ V}$ , $T_a=25^\circ\text{C}$                                                                 | –     | 2    | 4    | MHz  |      |

\* Zero-scale error: Ezs = deviation from the ideal value at zero point

\* Full-scale error: Efs = deviation from the ideal value at the full scale point

\* Non-linearity error: EI = deviation of the real conversion curve from the end point line

\* Total error: Et = max(Ezs, Efs, Eabs), Eabs = deviation from the ideal line (including quantization error)

## 8.8 D/A Converter Characteristics

The following characteristics apply to the plastic package model only.

Unless otherwise specified:  $V_{DD}=AV_{DD}=AV_{REF}=5.0\text{ V}$ ,  $V_{SS}=AV_{SS}=AGND=0\text{ V}$ ,  $f_{osc1}=32.768\text{ kHz}$ ,  $f_{osc3}=1.0\text{ MHz}$ ,  $T_a=25^\circ\text{C}$

| Item                              | Symbol           | Condition                                                                                                               | Min.  | Typ. | Max. | Unit | Note |
|-----------------------------------|------------------|-------------------------------------------------------------------------------------------------------------------------|-------|------|------|------|------|
| D/A conversion speed              | t <sub>DA</sub>  | $V_{DD}=AV_{DD}=AV_{REF}=VD_1=5.5\text{ V}$<br>Load capacitance=parasitic capacitance only                              | –     | –    | 10   | μs   |      |
|                                   |                  | $V_{DD}=AV_{DD}=AV_{REF}=VD_1=5.5\text{ V}$<br>Load capacitance=100 pF+parasitic capacitance                            | –     | –    | 30   | μs   |      |
| Integral linearity error          | E <sub>IDA</sub> | $V_{DD}=AV_{DD}=VD_1=AV_{REF}=3.0\text{ V}$ ,<br>$I_L=1\text{ μA}$ , $T_a=-20\text{ to }70^\circ\text{C}$               | -1.50 | –    | 1.50 | LSB  |      |
|                                   |                  | $V_{DD}=AV_{DD}=VD_1=AV_{REF}=5.0\text{ V}$ ,<br>$I_L=1\text{ μA}$ , $T_a=-20\text{ to }70^\circ\text{C}$               | -1.50 | –    | 1.50 | LSB  |      |
| Differential linearity error      | E <sub>dDA</sub> | $V_{DD}=AV_{DD}=VD_1=AV_{REF}=3.0\text{ V}$ ,<br>$I_L=1\text{ μA}$ , $T_a=-20\text{ to }70^\circ\text{C}$               | -1.00 | –    | 1.00 | LSB  |      |
|                                   |                  | $V_{DD}=AV_{DD}=VD_1=AV_{REF}=5.0\text{ V}$ ,<br>$I_L=1\text{ μA}$ , $T_a=-20\text{ to }70^\circ\text{C}$               | -1.00 | –    | 1.00 | LSB  |      |
| Total error                       | E <sub>tDA</sub> | $V_{DD}=AV_{DD}=VD_1=AV_{REF}=3.0\text{ V}$ ,<br>$I_L=1\text{ μA}$ , $T_a=-20\text{ to }70^\circ\text{C}$               | -2.50 | –    | 2.50 | LSB  |      |
|                                   |                  | $V_{DD}=AV_{DD}=VD_1=AV_{REF}=5.0\text{ V}$ ,<br>$I_L=1\text{ μA}$ , $T_a=-20\text{ to }70^\circ\text{C}$               | -2.50 | –    | 2.50 | LSB  |      |
| D/A converter current consumption | I <sub>DA</sub>  | $V_{DD}=AV_{DD}=AV_{REF}=3.0\text{ V}$ , $T_a=25^\circ\text{C}$ , 55H output<br>Reference resistor current not included | –     | 0.35 | 1    | mA   |      |
|                                   |                  | $V_{DD}=AV_{DD}=AV_{REF}=5.5\text{ V}$ , $T_a=25^\circ\text{C}$ , 55H output<br>Reference resistor current not included | –     | 0.7  | 2    | mA   |      |

\* Integral linearity error: E<sub>IDA</sub> = difference between the real conversion characteristic and the end point line

\* Differential linearity error: E<sub>dDA</sub> = difference between the real step width and the ideal step width

\* Total error: E<sub>tDA</sub> = max(Ezs, Efs, Eabs)

Eabs = deviation from the ideal line (including quantization error)

Ezs = deviation from the ideal value at zero point (zero-scale error)

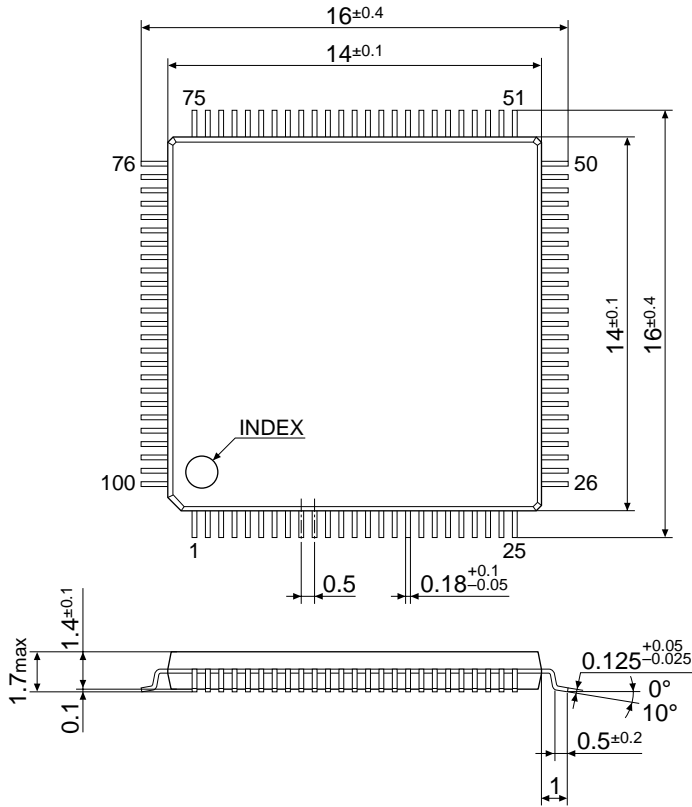
Efs = deviation from the ideal value at the full scale point (full-scale error)

# CHAPTER 9 PACKAGE

## 9.1 Plastic Package

QFP15-100pin

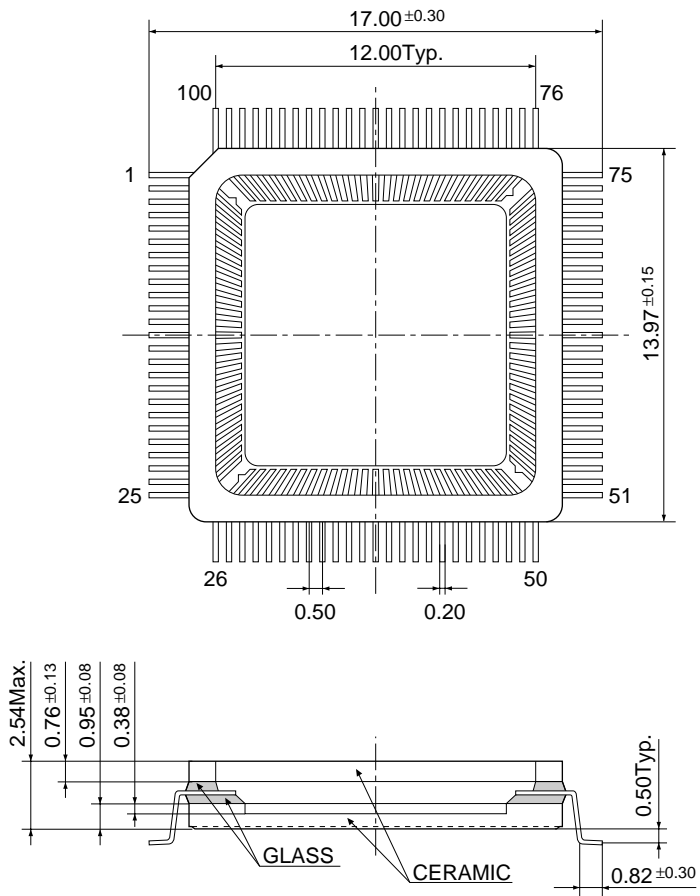
(Unit: mm)



Note: The dimensions are subject to change without notice.

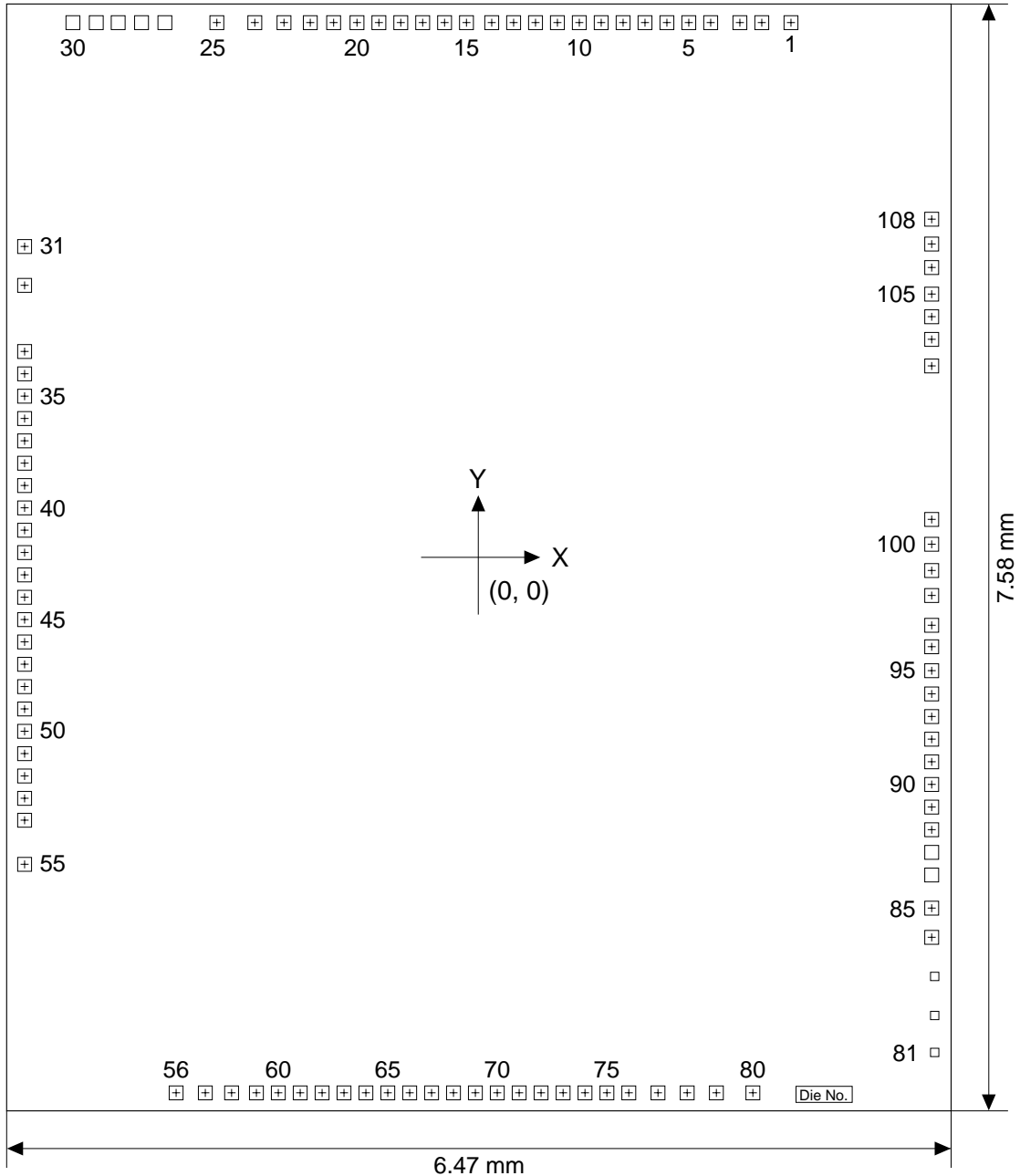
## 9.2 Ceramic Package for Test Samples

(Unit: mm)



# CHAPTER 10 PAD LAYOUT

## 10.1 Diagram of Pad Layout



Chip thickness: 400  $\mu$ m  
 Pad opening: 100  $\mu$ m (PAD No. 1-80, 84-108)  
 60  $\mu$ m (PAD No. 81-83)

## 10.2 Pad Coordinates

Table 10.2.1 Pad coordinate

| No. | Pad name   | X      | Y      | No. | Pad name        | X      | Y      |
|-----|------------|--------|--------|-----|-----------------|--------|--------|
| 1   | MCU/MPU    | 2,143  | 3,664  | 55  | R40/TOUT0/FOUT3 | -3,107 | -2,100 |
| 2   | K00        | 1,943  | 3,664  | 56  | R41/TOUT1/FOUT1 | -2,069 | -3,665 |
| 3   | K01        | 1,793  | 3,664  | 57  | R42/BZ          | -1,869 | -3,665 |
| 4   | K02        | 1,593  | 3,664  | 58  | P10/SIN         | -1,689 | -3,665 |
| 5   | K03        | 1,443  | 3,664  | 59  | P11/SOUT        | -1,519 | -3,665 |
| 6   | K04        | 1,293  | 3,664  | 60  | P12/SCLK        | -1,369 | -3,665 |
| 7   | K05        | 1,143  | 3,664  | 61  | P13/SRDY        | -1,219 | -3,665 |
| 8   | K06        | 993    | 3,664  | 62  | P14/SIN/IRI     | -1,069 | -3,665 |
| 9   | K07        | 843    | 3,664  | 63  | P15/SOUT/IRO    | -919   | -3,665 |
| 10  | K10/EXCL00 | 693    | 3,664  | 64  | P16/SCLK        | -769   | -3,665 |
| 11  | K11/EXCL11 | 543    | 3,664  | 65  | P17/SRDY        | -619   | -3,665 |
| 12  | K12        | 393    | 3,664  | 66  | P20/BYH         | -469   | -3,665 |
| 13  | K13        | 243    | 3,664  | 67  | P21/BYL         | -319   | -3,665 |
| 14  | RESET      | 93     | 3,664  | 68  | P22/BXH         | -169   | -3,665 |
| 15  | P00/D0     | -80    | 3,664  | 69  | P23/BXL         | -19    | -3,665 |
| 16  | P01/D1     | -230   | 3,664  | 70  | TEST            | 131    | -3,665 |
| 17  | P02/D2     | -380   | 3,664  | 71  | P37/AD7/DA1     | 281    | -3,665 |
| 18  | P03/D3     | -530   | 3,664  | 72  | P36/AD6/DA0     | 431    | -3,665 |
| 19  | P04/D4     | -680   | 3,664  | 73  | P35/AD5         | 582    | -3,665 |
| 20  | P05/D5     | -830   | 3,664  | 74  | P34/AD4         | 732    | -3,665 |
| 21  | P06/D6     | -990   | 3,664  | 75  | P33/AD3         | 882    | -3,665 |
| 22  | P07/D7     | -1,150 | 3,664  | 76  | P32/AD2         | 1,032  | -3,665 |
| 23  | R00/A0     | -1,330 | 3,664  | 77  | P31/AD1         | 1,232  | -3,665 |
| 24  | R01/A1     | -1,530 | 3,664  | 78  | P30/AD0         | 1,432  | -3,665 |
| 25  | R02/A2     | -1,790 | 3,664  | 79  | AVDD            | 1,632  | -3,665 |
| 26  | N.C.       | -2,146 | 3,664  | 80  | AVSS            | 1,882  | -3,665 |
| 27  | N.C.       | -2,306 | 3,664  | 81  | N.C.            | 3,127  | -3,390 |
| 28  | N.C.       | -2,466 | 3,664  | 82  | N.C.            | 3,127  | -3,137 |
| 29  | N.C.       | -2,616 | 3,664  | 83  | N.C.            | 3,127  | -2,870 |
| 30  | N.C.       | -2,776 | 3,664  | 84  | AVREF           | 3,107  | -2,600 |
| 31  | R03/A3     | -3,107 | 2,131  | 85  | AGND            | 3,107  | -2,400 |
| 32  | R04/A4     | -3,107 | 1,865  | 86  | N.C.            | 3,107  | -2,173 |
| 33  | R05/A5     | -3,107 | 1,412  | 87  | N.C.            | 3,107  | -2,018 |
| 34  | R06/A6     | -3,107 | 1,259  | 88  | SD7             | 3,107  | -1,863 |
| 35  | R07/A7     | -3,107 | 1,106  | 89  | SD6             | 3,107  | -1,708 |
| 36  | R10/A8     | -3,107 | 953    | 90  | SD5             | 3,107  | -1,553 |
| 37  | R11/A9     | -3,107 | 800    | 91  | SD4             | 3,107  | -1,398 |
| 38  | R12/A10    | -3,107 | 647    | 92  | SD3             | 3,107  | -1,243 |
| 39  | R13/A11    | -3,107 | 494    | 93  | SD2             | 3,107  | -1,088 |
| 40  | R14/A12    | -3,107 | 341    | 94  | SD1             | 3,107  | -933   |
| 41  | R15/A13    | -3,107 | 188    | 95  | SD0             | 3,107  | -774   |
| 42  | R16/A14    | -3,107 | 35     | 96  | LP              | 3,107  | -610   |
| 43  | R17/A15    | -3,107 | -118   | 97  | XSCL            | 3,107  | -463   |
| 44  | R20/A16    | -3,107 | -271   | 98  | FR              | 3,107  | -259   |
| 45  | R21/A17    | -3,107 | -424   | 99  | YD              | 3,107  | -88    |
| 46  | R22/A18    | -3,107 | -577   | 100 | DOFF            | 3,107  | 92     |
| 47  | R23/A19    | -3,107 | -730   | 101 | LCDEN           | 3,107  | 262    |
| 48  | R24/A20    | -3,107 | -883   | 102 | VDD             | 3,107  | 1,313  |
| 49  | R25/A21    | -3,107 | -1,036 | 103 | OSC4            | 3,107  | 1,495  |
| 50  | R26/RD     | -3,107 | -1,189 | 104 | OSC3            | 3,107  | 1,650  |
| 51  | R27/WR     | -3,107 | -1,342 | 105 | Vd1             | 3,107  | 1,805  |
| 52  | R30/CE0    | -3,107 | -1,495 | 106 | OSC2            | 3,107  | 1,987  |
| 53  | R31/CE1    | -3,107 | -1,648 | 107 | OSC1            | 3,107  | 2,148  |
| 54  | R32/CE2    | -3,107 | -1,798 | 108 | VSS             | 3,107  | 2,318  |

(Unit:  $\mu\text{m}$ )

# APPENDIX CONTROLLING THE TOUCH PANEL CONTROLLER

## A.1 I/O Map

Table A.1.1(a) Touch panel I/O map

| Address | Bit   | Name  | Function                                                               | 1                              | 0                                  | Init           | R/W | Comment             |                     |                     |
|---------|-------|-------|------------------------------------------------------------------------|--------------------------------|------------------------------------|----------------|-----|---------------------|---------------------|---------------------|
| 00FF13  | D7    | –     | –                                                                      | –                              | –                                  | –              | –   | "0" when being read |                     |                     |
|         | D6    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |                     |                     |
|         | D5    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |                     |                     |
|         | D4    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |                     |                     |
|         | D3    | PRAD  | A/D converter clock control                                            |                                | On                                 | Off            | 0   | R/W                 |                     |                     |
|         | D2    | PSAD2 | A/D converter division ratio                                           |                                |                                    |                | 0   | R/W                 |                     |                     |
|         |       |       | PSAD2                                                                  | PSAD1                          | PSAD0                              | Division ratio |     |                     |                     |                     |
|         | D1    | PSAD1 | 1                                                                      | ×                              | ×                                  | fosc3 / 16     | 0   | R/W                 |                     |                     |
|         |       | 0     | 1                                                                      | 1                              | fosc3 / 8                          |                |     |                     |                     |                     |
| D0      | PSAD0 | 0     | 1                                                                      | 0                              | fosc3 / 4                          | 0              | R/W |                     |                     |                     |
|         |       | 0     | 0                                                                      | 1                              | fosc3 / 2                          |                |     |                     |                     |                     |
|         |       | 0     | 0                                                                      | 0                              | fosc3 / 1                          |                |     |                     |                     |                     |
| 00FF16  | D7    | –     | –                                                                      | –                              | –                                  | –              | –   | "0" when being read |                     |                     |
|         | D6    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |                     |                     |
|         | D5    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |                     |                     |
|         | D4    | –     | –                                                                      | –                              | –                                  | –              | –   |                     |                     |                     |
|         | D3    | PRTP  | Touch panel controller clock control                                   |                                | On                                 | Off            | 0   | R/W                 |                     |                     |
|         | D2    | PSTP2 | Touch panel controller clock ratio                                     |                                |                                    |                | 0   | R/W                 |                     |                     |
|         |       |       | PSTP2                                                                  | PSTP1                          | PSTP0                              | Division ratio |     |                     |                     |                     |
|         | D1    | PSTP1 | 1                                                                      | ×                              | ×                                  | fosc3 / 16     | 0   | R/W                 |                     |                     |
|         |       | 0     | 1                                                                      | 1                              | fosc3 / 8                          |                |     |                     |                     |                     |
| D0      | PSTP0 | 0     | 1                                                                      | 0                              | fosc3 / 4                          | 0              | R/W |                     |                     |                     |
|         |       | 0     | 0                                                                      | 1                              | fosc3 / 2                          |                |     |                     |                     |                     |
|         |       | 0     | 0                                                                      | 0                              | fosc3 / 1                          |                |     |                     |                     |                     |
| 00FF22  | D7    | PAD1  | A/D converter interrupt priority register                              | PAD1                           | PAD0                               | Priority       | 0   | R/W                 |                     |                     |
|         | D6    | PAD0  |                                                                        | PTP1                           | PTP0                               | level          | 0   | R/W                 |                     |                     |
|         | D5    | PTP1  | Touch panel controller interrupt priority register                     | 1                              | 1                                  | Level 3        | 0   | R/W                 |                     |                     |
|         | D4    | PTP0  |                                                                        | 1                              | 0                                  | Level 2        | 0   | R/W                 |                     |                     |
|         | D3    | –     | –                                                                      | 0                              | 1                                  | Level 1        | –   | –                   | "0" when being read |                     |
|         | D2    | –     | –                                                                      | 0                              | 0                                  | Level 0        | –   | –                   |                     |                     |
|         | D1    | –     | –                                                                      | –                              | –                                  | –              | –   | –                   |                     |                     |
|         | D0    | –     | –                                                                      | –                              | –                                  | –              | –   | –                   |                     |                     |
| 00FF26  | D7    | EAD   | A/D converter conversion completion interrupt enable register          |                                |                                    |                | 0   | R/W                 |                     |                     |
|         | D6    | ETPPD | Touch panel controller pen-down interrupt enable register              |                                |                                    |                | 0   | R/W                 |                     |                     |
|         | D5    | ETPDR | Touch panel controller converted data update interrupt enable register | Interrupt is enabled           | Interrupt is disabled              |                | 0   | R/W                 |                     |                     |
|         | D4    | –     | –                                                                      |                                |                                    | –              | –   | –                   | –                   | "0" when being read |
|         | D3    | –     | –                                                                      |                                |                                    | –              | –   | –                   | –                   |                     |
|         | D2    | –     | –                                                                      |                                |                                    | –              | –   | –                   | –                   |                     |
|         | D1    | –     | –                                                                      | –                              | –                                  | –              | –   | –                   |                     |                     |
|         | D0    | –     | –                                                                      | –                              | –                                  | –              | –   | –                   | –                   |                     |
| 00FF2A  | D7    | FAD   | A/D converter conversion completion interrupt factor flag              | (R)                            | (R)                                |                | 0   | R/W                 |                     |                     |
|         | D6    | FTPPD | Touch panel controller pen-down interrupt factor flag                  | Interrupt factor has generated | Interrupt factor has not generated |                | 0   | R/W                 |                     |                     |
|         | D5    | FTPDR | Touch panel controller converted data update interrupt factor flag     |                                |                                    |                | 0   | R/W                 |                     |                     |
|         | D4    | –     | –                                                                      |                                |                                    |                | –   | –                   | "0" when being read |                     |
|         | D3    | –     | –                                                                      |                                |                                    | –              | –   |                     |                     |                     |
|         | D2    | –     | –                                                                      |                                |                                    | –              | –   |                     |                     |                     |
|         | D1    | –     | –                                                                      |                                |                                    | –              | –   |                     |                     |                     |
|         | D0    | –     | –                                                                      |                                | (W) Reset                          | (W) Invalid    | –   | –                   |                     |                     |



Table A.1.1(b) Touch panel I/O map

| Address | Bit   | Name  | Function                                   | 1              | 0       | Init          | R/W          | Comment             |                          |
|---------|-------|-------|--------------------------------------------|----------------|---------|---------------|--------------|---------------------|--------------------------|
| 00FF80  | D7    | ADRUN | A/D conversion start control register      | Start          | Invalid | 0             | W            | "0" when being read |                          |
|         | D6    | —     | —                                          | —              | —       | —             | —            |                     |                          |
|         | D5    | —     | —                                          | —              | —       | —             | —            |                     |                          |
|         | D4    | VRC   | AVREF control (Touch panel controller)     | Enable         | Invalid | 0             | R/W          |                     |                          |
|         | D3    | VRO   | AVREF swich                                | On             | Off     | 0             | R/W          |                     |                          |
|         | D2    | CHS2  | Analog input channel selection             |                |         |               | 0            | R/W                 |                          |
|         |       |       | CHS2                                       | CHS1           | CHS0    | Input channel |              |                     |                          |
|         | D1    | CHS1  | 1                                          | 1              | 1       | AD7           |              |                     |                          |
|         | 1     |       | 1                                          | 0              | AD6     |               |              |                     |                          |
| D0      | CHS0  | 1     | 0                                          | 1              | AD5     |               |              |                     |                          |
|         |       | 1     | 0                                          | 0              | AD4     |               |              |                     |                          |
|         |       | 0     | 1                                          | 1              | AD3     |               |              |                     |                          |
|         |       | 0     | 1                                          | 0              | AD2     |               |              |                     |                          |
|         |       | 0     | 0                                          | 1              | AD1     |               |              |                     |                          |
|         |       | 0     | 0                                          | 0              | AD0     |               |              |                     |                          |
| 00FFA0  | D7    | —     | —                                          | —              | —       | —             | —            | "0" when being read |                          |
|         | D6    | PDC   | Pen-down check control                     | Check          | Cancel  | 0             | R/W          | Valid when "RST=0"  |                          |
|         | D5    | RST   | TPC circuit reset control                  | Cancel         | Reset   | 0             | R/W          |                     |                          |
|         | D4    | CONST | Mode setting                               | Constant-speed | Normal  | 0             | R/W          |                     |                          |
|         | D3    | —     | —                                          | —              | —       | —             | —            | "0" when being read |                          |
|         | D2    | AVN2  | Mean count setting                         |                |         |               | 0            | R/W                 | Invalid when Normal mode |
|         |       |       | AVN2                                       | AVN1           | AVN0    | Mean count    |              |                     |                          |
|         | D1    | AVN1  | 0                                          | 0              | 0       | 16 × 16       |              |                     |                          |
|         | 0     |       | 0                                          | 1              | 16 × 8  |               |              |                     |                          |
| D0      | AVN0  | 0     | 1                                          | 0              | 16 × 4  |               |              |                     |                          |
|         |       | 0     | 1                                          | 1              | 16 × 2  |               |              |                     |                          |
|         |       | 1     | ×                                          | ×              | 16 × 1  |               |              |                     |                          |
| 00FFA1  | D7    | —     | —                                          | —              | —       | —             | —            | "0" when being read |                          |
|         | D6    | —     | —                                          | —              | —       | —             | —            |                     |                          |
|         | D5    | —     | —                                          | —              | —       | —             | —            |                     |                          |
|         | D4    | —     | —                                          | —              | —       | —             | —            |                     |                          |
|         | D3    | WAIT3 | Voltage stabilization waiting time setting |                |         |               | 0            | R/W                 |                          |
|         |       |       | WAIT3                                      | WAIT2          | WAIT1   | WAIT0         | Waiting time |                     |                          |
|         | D2    | WAIT2 | 0                                          | 0              | 0       | 0             | 16 × 1/f     |                     |                          |
|         |       |       | 0                                          | 0              | 0       | 1             | 16 × 2/f     |                     |                          |
|         |       |       | 0                                          | 0              | 1       | 0             | 16 × 3/f     |                     |                          |
|         |       |       | 0                                          | 0              | 1       | 1             | 16 × 4/f     |                     |                          |
| D1      | WAIT1 | 0     | 1                                          | 0              | 0       | 16 × 5/f      |              |                     |                          |
|         |       | 0     | 1                                          | 0              | 1       | 16 × 6/f      |              |                     |                          |
|         |       | 0     | 1                                          | 1              | 0       | 16 × 7/f      |              |                     |                          |
|         |       | 0     | 1                                          | 1              | 1       | 16 × 8/f      |              |                     |                          |
| D0      | WAIT0 | 1     | 0                                          | 0              | 0       | 16 × 9/f      |              |                     |                          |
|         |       | 1     | 0                                          | 0              | 1       | 16 × 10/f     |              |                     |                          |
|         |       | 1     | 0                                          | 1              | 0       | 16 × 11/f     |              |                     |                          |
|         |       | 1     | 0                                          | 1              | 1       | 16 × 12/f     |              |                     |                          |
|         |       | 1     | 1                                          | 0              | 0       | 16 × 13/f     |              |                     |                          |
|         |       | 1     | 1                                          | 0              | 1       | 16 × 14/f     |              |                     |                          |
|         |       | 1     | 1                                          | 1              | 0       | 16 × 15/f     |              |                     |                          |
|         |       | 1     | 1                                          | 1              | 1       | 16 × 16/f     |              |                     |                          |
| 00FFA2  | D7    | —     | —                                          | —              | —       | —             | —            | "0" when being read |                          |
|         | D6    | —     | —                                          | —              | —       | —             | —            |                     |                          |
|         | D5    | —     | —                                          | —              | —       | —             | —            |                     |                          |
|         | D4    | —     | —                                          | —              | —       | —             | —            |                     |                          |
|         | D3    | CND3  | Noise judgment threshold value setting     |                |         |               | 1            | R/W                 |                          |
|         |       |       | CND3                                       | CND2           | CND1    | CND0          | Value        |                     |                          |
|         | D2    | CND2  | 0                                          | 0              | 0       | 0             | 4            |                     |                          |
|         |       |       | 0                                          | 0              | 0       | 1             | 8            |                     |                          |
|         |       |       | 0                                          | 0              | 1       | 0             | 12           |                     |                          |
|         |       |       | 0                                          | 0              | 1       | 1             | 16           |                     |                          |
| D1      | CND1  | 0     | 1                                          | 0              | 0       | 20            |              |                     |                          |
|         |       | 0     | 1                                          | 0              | 1       | 24            |              |                     |                          |
|         |       | 0     | 1                                          | 1              | 0       | 28            |              |                     |                          |
|         |       | 0     | 1                                          | 1              | 1       | 32            |              |                     |                          |
| D0      | CND0  | 1     | 0                                          | 0              | 0       | 36            |              |                     |                          |
|         |       | 1     | 0                                          | 0              | 1       | 40            |              |                     |                          |
|         |       | 1     | 0                                          | 1              | 0       | 44            |              |                     |                          |
|         |       | 1     | 0                                          | 1              | 1       | 48            |              |                     |                          |
|         |       | 1     | 1                                          | 0              | 0       | 52            |              |                     |                          |
|         |       | 1     | 1                                          | 0              | 1       | 56            |              |                     |                          |
|         |       | 1     | 1                                          | 1              | 0       | 60            |              |                     |                          |
|         |       | 1     | 1                                          | 1              | 1       | 64            |              |                     |                          |

APPENDIX: CONTROLLING THE TOUCH PANEL CONTROLLER

Table A.1.1(c) Touch panel I/O map

| Address | Bit  | Name       | Function                                          | 1 | 0 | Init | R/W | Comment             |                                                                                          |                                                                                          |
|---------|------|------------|---------------------------------------------------|---|---|------|-----|---------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| 00FFA3  | D7   | –          | –                                                 | – | – | –    | –   | "0" when being read |                                                                                          |                                                                                          |
|         | D6   | –          | –                                                 | – | – | –    | –   |                     |                                                                                          |                                                                                          |
|         | D5   | –          | –                                                 | – | – | –    | –   |                     |                                                                                          |                                                                                          |
|         | D4   | –          | –                                                 | – | – | –    | –   |                     |                                                                                          |                                                                                          |
|         | D3   | PUD3       | Pen-up decision threshold value setting           |   |   |      | 1   | R/W                 |                                                                                          |                                                                                          |
|         |      |            | PUD3 PUD2 PUD1 PUD0 Value                         |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 0 0 0 4                                         |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 0 0 1 8                                         |   |   |      |     |                     |                                                                                          |                                                                                          |
|         | D2   | PUD2       | 0 0 1 0 12                                        |   |   |      | 0   | R/W                 |                                                                                          |                                                                                          |
|         |      |            | 0 0 1 1 16                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 1 0 0 20                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 1 0 1 24                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         | D1   | PUD1       | 0 1 1 0 28                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 1 1 1 32                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 1 0 0 0 36                                        |   |   |      | 1   | R/W                 |                                                                                          |                                                                                          |
|         |      |            | 1 0 0 1 40                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
| D0      | PUD0 | 1 0 1 1 44 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 1 0 1 1 48 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 1 1 0 0 52 |                                                   |   |   | 0    | R/W |                     |                                                                                          |                                                                                          |
|         |      | 1 1 0 1 56 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 1 1 1 0 60 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 1 1 1 1 64 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
| 00FFA4  | D7   | MVML3      | Middle-low-speed judgment threshold value setting |   |   |      | 0   | R/W                 | Invalid in constant-speed mode<br>MVH $\geq$ MVMH<br>MVMH $\geq$ MVML<br>MVML $\geq$ MVL |                                                                                          |
|         |      |            | MVML3 MVML2 MVML1 MVML0 Value                     |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 0 0 0 2                                         |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 0 0 1 4                                         |   |   |      |     |                     |                                                                                          |                                                                                          |
|         | D6   | MVML2      | 0 0 1 0 6                                         |   |   |      | 1   | R/W                 |                                                                                          |                                                                                          |
|         |      |            | 0 0 1 1 8                                         |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 1 0 0 10                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 1 0 1 12                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         | D5   | MVML1      | 0 1 1 0 14                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 0 1 1 1 16                                        |   |   |      | 0   | R/W                 |                                                                                          |                                                                                          |
|         |      |            | 1 0 0 0 18                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 1 0 0 1 20                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         | D4   | MVML0      | 1 0 1 0 22                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 1 0 1 1 24                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 1 1 0 0 26                                        |   |   |      | 0   | R/W                 |                                                                                          |                                                                                          |
|         |      |            | 1 1 0 1 28                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 1 1 1 0 30                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      |            | 1 1 1 1 32                                        |   |   |      |     |                     |                                                                                          |                                                                                          |
|         | D3   | MVL3       | Low-speed judgment threshold value setting        |   |   |      | 0   | R/W                 |                                                                                          | Invalid in constant-speed mode<br>MVH $\geq$ MVMH<br>MVMH $\geq$ MVML<br>MVML $\geq$ MVL |
|         |      |            | MVL3 MVL2 MVL1 MVL0 Value                         |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 0 0 0 0 2  |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 0 0 0 1 4  |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
| D2      | MVL2 | 0 0 1 0 6  |                                                   |   |   | 0    | R/W |                     |                                                                                          |                                                                                          |
|         |      | 0 0 1 1 8  |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 0 1 0 0 10 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 0 1 0 1 12 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
| D1      | MVL1 | 0 1 1 0 14 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 0 1 1 1 16 |                                                   |   |   | 1    | R/W |                     |                                                                                          |                                                                                          |
|         |      | 1 0 0 0 18 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 1 0 0 1 20 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
| D0      | MVL0 | 1 0 1 0 22 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 1 0 1 1 24 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 1 1 0 0 26 |                                                   |   |   | 0    | R/W |                     |                                                                                          |                                                                                          |
|         |      | 1 1 0 1 28 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 1 1 1 0 30 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |
|         |      | 1 1 1 1 32 |                                                   |   |   |      |     |                     |                                                                                          |                                                                                          |

Table A.1.1(d) Touch panel I/O map

| Address | Bit    | Name  | Function                                    | 1                                                  | 0            | Init         | R/W          | Comment |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|---------|--------|-------|---------------------------------------------|----------------------------------------------------|--------------|--------------|--------------|---------|-------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|----------------------|--|-------|--|---|------------|
| 00FFA5  | D7     | MVH3  | High-speed judgment threshold value setting |                                                    |              |              |              |         | 1 R/W | Invalid in constant-speed mode<br>MVH $\geq$ MVMH<br>MVMH $\geq$ MVML<br>MVML $\geq$ MVL |                                                                                          |                      |  |       |  |   |            |
|         |        |       | <u>MVH3</u>                                 | <u>MVH2</u>                                        | <u>MVH1</u>  | <u>MVH0</u>  |              |         |       |                                                                                          | <u>Value</u>                                                                             |                      |  |       |  |   |            |
|         |        |       | 0                                           | 0                                                  | 0            | 0            |              |         |       |                                                                                          | 2                                                                                        |                      |  |       |  |   |            |
|         |        |       | 0                                           | 0                                                  | 0            | 1            |              |         |       |                                                                                          | 4                                                                                        |                      |  |       |  |   |            |
|         |        |       | 0                                           | 0                                                  | 1            | 0            |              |         |       |                                                                                          | 6                                                                                        |                      |  |       |  |   |            |
|         | D6     | MVH2  |                                             |                                                    |              |              |              |         | 0 R/W |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         |        |       | 0                                           | 0                                                  | 1            | 1            |              |         |       |                                                                                          | 8                                                                                        |                      |  |       |  |   |            |
|         |        |       | 0                                           | 1                                                  | 0            | 0            |              |         |       |                                                                                          | 10                                                                                       |                      |  |       |  |   |            |
|         |        |       | 0                                           | 1                                                  | 0            | 1            |              |         |       |                                                                                          | 12                                                                                       |                      |  |       |  |   |            |
|         |        |       | 0                                           | 1                                                  | 1            | 0            |              |         |       |                                                                                          | 14                                                                                       |                      |  |       |  |   |            |
|         | D5     | MVH1  |                                             |                                                    |              |              |              |         | 0 R/W |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         |        |       | 0                                           | 1                                                  | 1            | 1            |              |         |       |                                                                                          | 16                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 0                                                  | 0            | 0            |              |         |       |                                                                                          | 18                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 0                                                  | 0            | 1            |              |         |       |                                                                                          | 20                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 0                                                  | 1            | 0            |              |         |       |                                                                                          | 22                                                                                       |                      |  |       |  |   |            |
|         | D4     | MVH0  |                                             |                                                    |              |              |              |         | 0 R/W |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         |        |       | 1                                           | 0                                                  | 1            | 1            |              |         |       |                                                                                          | 24                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 1                                                  | 0            | 0            |              |         |       |                                                                                          | 26                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 1                                                  | 0            | 1            |              |         |       |                                                                                          | 28                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 1                                                  | 1            | 0            |              |         |       |                                                                                          | 30                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 1                                                  | 1            | 1            | 32           |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         | 00FFA6 | D3    | MVMH3                                       | Middle-high-speed judgment threshold value setting |              |              |              |         |       | 0 R/W                                                                                    | Invalid in constant-speed mode<br>MVH $\geq$ MVMH<br>MVMH $\geq$ MVML<br>MVML $\geq$ MVL |                      |  |       |  |   |            |
|         |        |       |                                             | <u>MVMH3</u>                                       | <u>MVMH2</u> | <u>MVMH1</u> | <u>MVMH0</u> |         |       |                                                                                          |                                                                                          | <u>Value</u>         |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 0            | 0            | 0            |         |       |                                                                                          |                                                                                          | 2                    |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 0            | 0            | 1            |         |       |                                                                                          |                                                                                          | 4                    |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 0            | 1            | 0            |         |       |                                                                                          |                                                                                          | 6                    |  |       |  |   |            |
|         |        | D2    | MVMH2                                       |                                                    |              |              |              |         |       | 1 R/W                                                                                    |                                                                                          |                      |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 0            | 1            | 1            |         |       |                                                                                          |                                                                                          | 8                    |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 1            | 0            | 0            |         |       |                                                                                          |                                                                                          | 10                   |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 1            | 0            | 1            |         |       |                                                                                          |                                                                                          | 12                   |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 1            | 1            | 0            |         |       |                                                                                          |                                                                                          | 14                   |  |       |  |   |            |
|         |        | D1    | MVMH1                                       |                                                    |              |              |              |         |       | 1 R/W                                                                                    |                                                                                          |                      |  |       |  |   |            |
| 0       |        |       |                                             | 1                                                  | 1            | 1            | 16           |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
| 1       |        |       |                                             | 0                                                  | 0            | 0            | 18           |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
| 1       |        |       |                                             | 0                                                  | 0            | 1            | 20           |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
| 1       |        |       |                                             | 0                                                  | 1            | 0            | 22           |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
| D0      |        | MVMH0 |                                             |                                                    |              |              |              |         | 0 R/W |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         |        |       | 1                                           | 0                                                  | 1            | 1            |              |         |       |                                                                                          | 24                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 1                                                  | 0            | 0            |              |         |       |                                                                                          | 26                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 1                                                  | 0            | 1            |              |         |       |                                                                                          | 28                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 1                                                  | 1            | 0            |              |         |       |                                                                                          | 30                                                                                       |                      |  |       |  |   |            |
|         |        |       | 1                                           | 1                                                  | 1            | 1            | 32           |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
| 00FFA6  |        | D7    | –                                           | –                                                  | –            | –            | –            | –       | –     | "0" when being read                                                                      |                                                                                          |                      |  |       |  |   |            |
|         |        | D6    | –                                           | –                                                  | –            | –            | –            | –       | –     |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         |        | D5    | –                                           | –                                                  | –            | –            | –            | –       | –     |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         |        | D4    | –                                           | –                                                  | –            | –            | –            | –       | –     |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         |        | D3    | IVL3                                        | Interval time setting                              |              |              |              |         |       | 0 R/W                                                                                    |                                                                                          |                      |  |       |  |   |            |
|         |        |       |                                             | <u>IVL3</u>                                        | <u>IVL2</u>  | <u>IVL1</u>  | <u>IVL0</u>  |         |       |                                                                                          |                                                                                          | <u>Interval time</u> |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 0            | 0            | 0            |         |       |                                                                                          |                                                                                          | 128 $\times$ 1       |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 0            | 0            | 1            |         |       |                                                                                          |                                                                                          | $\times$ 2           |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 0            | 1            | 0            |         |       |                                                                                          |                                                                                          | $\times$ 3           |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 0            | 1            | 1            |         |       |                                                                                          |                                                                                          | $\times$ 4           |  |       |  |   |            |
|         |        |       |                                             | 0                                                  | 1            | 0            | 0            |         |       |                                                                                          |                                                                                          | $\times$ 5           |  |       |  |   |            |
|         | 0      |       |                                             | 1                                                  | 0            | 1            | $\times$ 6   |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         | 0      |       |                                             | 1                                                  | 1            | 0            | $\times$ 7   |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         | D1     |       |                                             | IVL1                                               |              |              |              |         |       |                                                                                          |                                                                                          |                      |  | 1 R/W |  |   |            |
|         |        |       |                                             |                                                    | 0            | 1            | 1            |         |       |                                                                                          |                                                                                          |                      |  |       |  | 1 | $\times$ 8 |
|         |        |       |                                             |                                                    | 1            | 0            | 0            |         |       |                                                                                          |                                                                                          |                      |  |       |  | 0 | $\times$ 9 |
| 1       |        | 0     | 0                                           |                                                    | 1            | $\times$ 10  |              |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
| 1       |        | 0     | 1                                           |                                                    | 0            | $\times$ 11  |              |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
| D0      | IVL0   |       |                                             |                                                    |              |              |              | 0 R/W   |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |
|         |        | 1     | 0                                           | 1                                                  | 1            |              |              |         |       | $\times$ 12                                                                              |                                                                                          |                      |  |       |  |   |            |
|         |        | 1     | 1                                           | 0                                                  | 0            |              |              |         |       | $\times$ 13                                                                              |                                                                                          |                      |  |       |  |   |            |
|         |        | 1     | 1                                           | 0                                                  | 1            |              |              |         |       | $\times$ 14                                                                              |                                                                                          |                      |  |       |  |   |            |
|         |        | 1     | 1                                           | 1                                                  | 0            |              |              |         |       | $\times$ 15                                                                              |                                                                                          |                      |  |       |  |   |            |
|         |        | 1     | 1                                           | 1                                                  | 1            | $\times$ 16  |              |         |       |                                                                                          |                                                                                          |                      |  |       |  |   |            |

APPENDIX: CONTROLLING THE TOUCH PANEL CONTROLLER

Table A.1.1(e) Touch panel I/O map

| Address | Bit | Name    | Function               | 1                 | 0      | Init | R/W      | Comment             |   |
|---------|-----|---------|------------------------|-------------------|--------|------|----------|---------------------|---|
| 00FFA7  | D7  | -       | -                      | -                 | -      | -    | -        | "0" when being read |   |
|         | D6  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D5  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D4  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D3  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D2  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D1  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D0  | PEN     | Pen-up/pen-down status | Pen-down          | Pen-up | 0    | R        |                     |   |
| 00FFA8  | D7  | DX11    | X coordinate data      | D11(MSB)          |        |      | 0        | R                   |   |
|         | D6  | DX10    |                        | D10               |        |      | 0        | R                   |   |
|         | D5  | DX9     |                        | D9                |        |      | 0        | R                   |   |
|         | D4  | DX8     |                        | D8                |        |      | 0        | R                   |   |
|         | D3  | DX7     |                        | D7                |        |      | 0        | R                   |   |
|         | D2  | DX6     |                        | D6                |        |      | 0        | R                   |   |
|         | D1  | DX5     |                        | D5                |        |      | 0        | R                   |   |
|         | D0  | DX4     |                        | D4                |        |      | 0        | R                   |   |
| 00FFA9  | D7  | -       | -                      | -                 | -      | -    | -        | "0" when being read |   |
|         | D6  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D5  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D4  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D3  | DX3     | X coordinate data      | D3                |        |      | 0        |                     | R |
|         | D2  | DX2     |                        | D2                |        |      | 0        |                     | R |
|         | D1  | DX1     |                        | D1                |        |      | 0        |                     | R |
|         | D0  | DX0     |                        | D0(LSB)           |        |      | 0        |                     | R |
| 00FFAA  | D7  | DY11    |                        | Y coordinate data |        |      | D11(MSB) |                     |   |
|         | D6  | DY10    | D10                    |                   | 0      | R    |          |                     |   |
|         | D5  | DY9     | D9                     |                   | 0      | R    |          |                     |   |
|         | D4  | DY8     | D8                     |                   | 0      | R    |          |                     |   |
|         | D3  | DY7     | D7                     |                   | 0      | R    |          |                     |   |
|         | D2  | DY6     | D6                     |                   | 0      | R    |          |                     |   |
|         | D1  | DY5     | D5                     |                   | 0      | R    |          |                     |   |
|         | D0  | DY4     | D4                     |                   | 0      | R    |          |                     |   |
| 00FFAB  | D7  | -       | -                      | -                 | -      | -    | -        | "0" when being read |   |
|         | D6  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D5  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D4  | -       | -                      | -                 | -      | -    | -        |                     |   |
|         | D3  | DY3     | Y coordinate data      | D3                |        |      | 0        |                     | R |
|         | D2  | DY2     |                        | D2                |        |      | 0        |                     | R |
|         | D1  | DY1     |                        | D1                |        |      | 0        |                     | R |
| D0      | DY0 | D0(LSB) |                        | 0                 |        |      | R        |                     |   |

## A.2 Description

### A.2.1 Circuit connection

Refer to Section 5.17, "Touch Panel Controller".

### A.2.2 Mask option configuration

Refer to Section 5.17, "Touch Panel Controller".

### A.2.3 Reducing power consumption and improving response

#### (1) How to reduce power consumption

To reduce current consumption, the high-speed clock (OSC3) should be used to operate the touch panel controller (TPC) only while the touch panel is being used.

The coordinate update interrupt should be enabled (ETPDR = "1").

When the touch panel is not being used, set the operating clock to the low-speed clock (OSC1), turn off the clock supply to the A/D converter and TPC (PRAD = "0", PRTP = "0"), and reset the TPC circuit (RST = "0").

Furthermore, enable the pen-down check circuit (PDC = "1") to check a pen-down, then reset the pen-down interrupt factor flag (FTPPD = "1") a set period of time, and then enable the pen-down interrupt (ETPDR = "1"). When a pen-down interrupt has occurred due to the first pen-down, switch the operating clock to the high-speed clock (OSC3) and turn on the clock supply to the A/D converter and TPC (PRAD = "1", PRTP = "1"). Then reset the pen-down check circuit (PDC = "0") and activate the TPC (RST = "1"). The pen-down interrupt should be disabled (ETPDR = "0").

After that read the detected coordinate data every time a coordinate update interrupt has occurred.

If coordinate data is not updated for a set period of time, assume that the touch panel is not being used, and return the configuration to the standby status for \*awaiting the next pen-down.

Note, however, that the user's first operation may not be detected in this method because there is a time lag of several hundred msec between the first pen-down detection and when the TPC becomes ready to detect coordinates.

#### (2) How to improve the response against user's operation

To improve the response against user's operation, always activate the TPC with the high-speed clock (OSC3).

The pen-down check control and pen-down interrupt should be disabled (PDC = "0", ETPPD = "0").

Set the operating clock to the high-speed clock (OSC3), turn on the clock supply to the A/D converter and TPC (PRAD = "1", PRTP = "1") and activate the TPC (RST = "1"). The coordinate update interrupt should be enabled after resetting the coordinate update interrupt factor flag.

After that read the detected coordinate data every time a coordinate update interrupt has occurred due to the user's pen-trace operation.

Note, however, that this method increases power consumption because the TPC has to always operate with the high-speed clock. The sample program described later uses this method.

#### (3) How to obtain the intermediate characteristics

To obtain the intermediate characteristics between methods (1) and (2), the operating clock should be always set to the high-speed clock (OSC3) and the TPC and A/D converter should be activated after a pen-down is detected by the pen-down check.

### A.2.4 Reading coordinate data from the TPC

#### (1) Method 1

Read the detected coordinate data and the switch status information (DX0-DX11, DY0-DY11, PEN) and store them in the temporary area, then set a flag indicating that coordinate data is updated. The detected coordinate data and the switch status information is guaranteed against change by the hardware until they are read by software after a coordinate update interrupt has occurred (they are not rewritten during read). These processes should be performed in the coordinate update interrupt service routine.

Monitor the above flag in the main routine to check if coordinate data is updated. If the flag has been set, disable the interrupt and read the data stored in the temporary area.

In this method, the coordinate data and switch status information in the temporary area are not rewritten while they are being read, so the values can be guaranteed.

## (2) Method 2

Set only a flag indicating that coordinate data is updated in the coordinate update interrupt service routine. The coordinate data and switch status information (DX0–DX11, DY0–DY11, PEN) are read in the main routine.

### A.2.5 Calculating the LCD dot position

#### (1) Initial setting

The first process needs registration of dot position between the touch panel and the LCD panel. The following explains the X axis only as the same applies to the Y axis. It assumes that the origin of both the LCD and touch panels are located at the left edge (in other words, the leftmost dot on the LCD is dot 0; the touch panel's A/D conversion value increase at the right side).

First pen down at the leftmost dot position on the LCD, and the touch-panel A/D converted value is stored as  $x_{min}$ . Then pen down at the rightmost dot position on the LCD, and the touch-panel A/D converted value is stored as  $x_{max}$ .

#### (2) LCD dot position calculation

The LCD dot position corresponding to the pen-down position within the LCD display area is calculated by the following expressions:

For x axis:

$$x_{dot} = (x_{addat} - x_{min}) \times \frac{DXMAX}{(x_{max} - x_{min})}$$

For y axis:

$$y_{dot} = (y_{addat} - y_{min}) \times \frac{DYMAX}{(y_{max} - y_{min})}$$

Where  $x_{addat}$  ( $y_{addat}$ ) is the A/D converted value and DXMAX (DYMAX) is the LCD resolution (number of dots).

## A.3 Precautions

### A.3.1 Interrupt processing

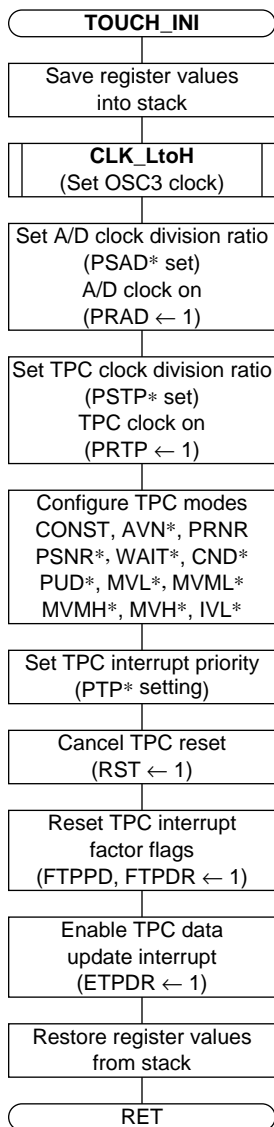
- (1) Only a pen-down interrupt may be generated when only the pen-down check circuit is activated (PDC = "1" and RST = "0"). When the TPC circuit is activated, both the pen-down and coordinate data update interrupts may be generated. Therefore, disable the pen-down interrupt when the TPC circuit is activated.
- (2) The coordinate data registers DX0–DX11 and DY0–DY11 (0FFA8h–0FFABh) must all be read regardless of the TPC operating status (RST = "1" or "0"). If only a part of the data, for example address 0FFA8h, is read leaving other addresses, the next coordinate update interrupt will not be generated.
- (3) When a coordinate update interrupt is generated, the coordinate data registers DX0–DX11 and DY0–DY11 (0FFA8h–0FFABh) must be read. If the set data is not read, the next coordinate update interrupt will not be generated.

### A.3.2 Others

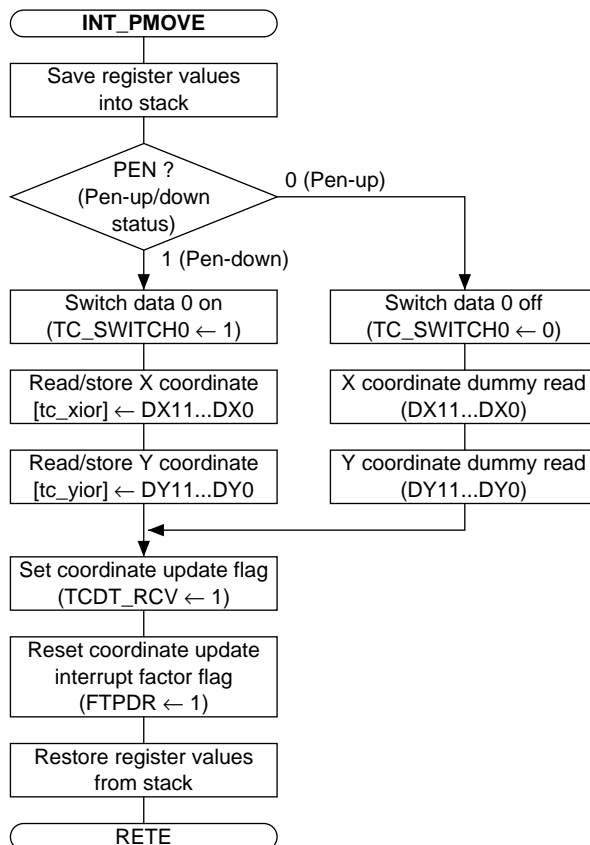
- (1) A part of or all of the reference flowcharts and programs may be used freely. However, they cannot be guaranteed to work. Therefore Seiko Epson does not assume liability of any kind arising out of partial or complete use of the reference flowcharts and programs.
- (2) The reference program is a part of an executable program. To execute as a completed executable program, other processing routines such as a system initialization are necessary.

## A.4 Reference Flowchart

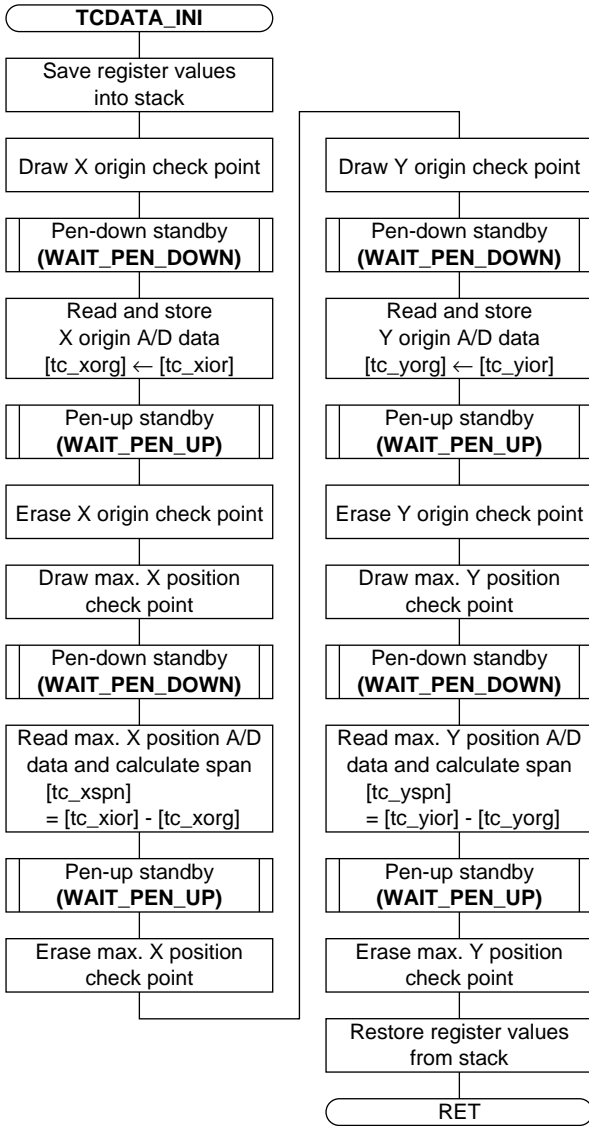
### A.4.1 Initializing the TPC



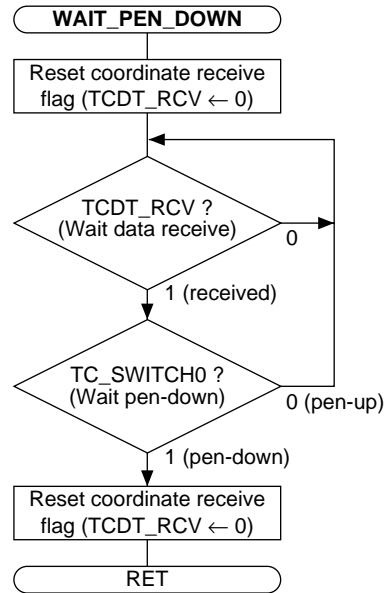
### A.4.2 TPC data update interrupt processing



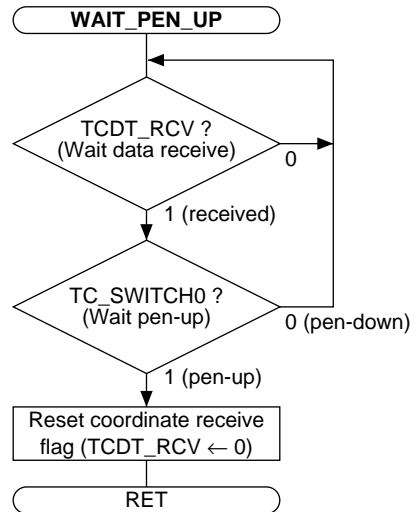
**A.4.3 TP initial data configuration**



**A.4.3.1 Pen-down standby**

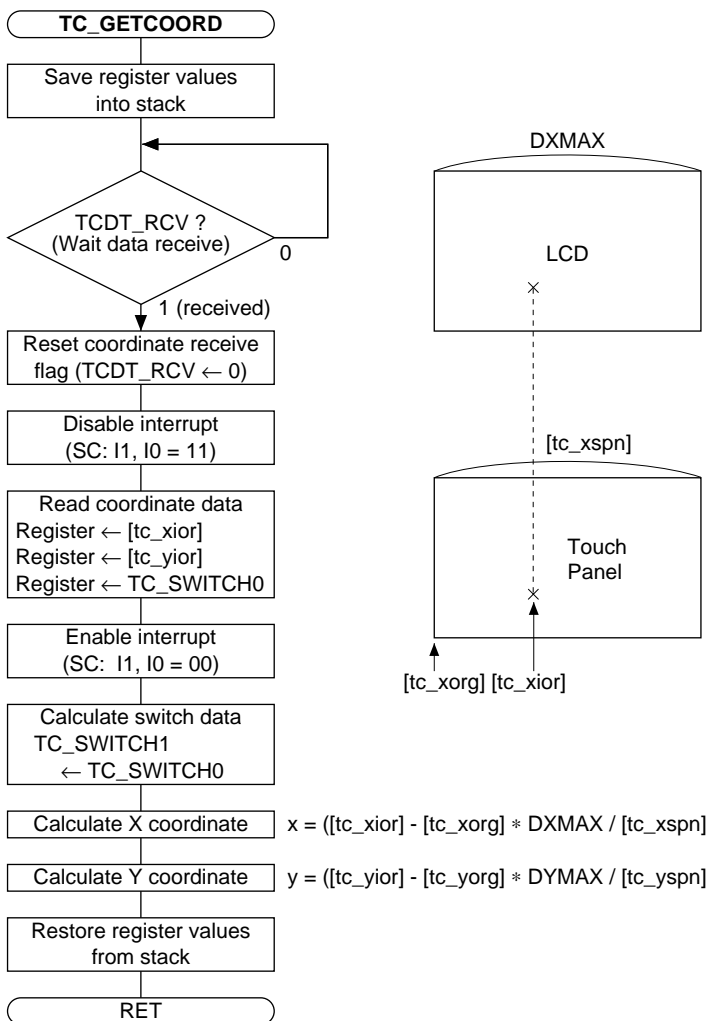


**A.4.3.2 Pen-up standby**





### A.4.4 Coordinate data calculation



## A.5 Reference Program

### A.5.1 Setting constants and macros (include file)

```

;*****
;          SYS_CONST.INC                system constant data
;          -----
;          Copyright(C) 1997 Seiko Epson Co.,Ltd
;*****

```

**(1) Set flags**

```

;===== tpc_flg0 =====
TCDT_RCV EQU 00000001B ;1: coordinate calculation is finished
TC_SWITCH0 EQU 00000010B ;switch detected in pen-move interrupt
TC_SWITCH1 EQU 00000100B ;switch translated in coordinate calc.loutine
WAITTIMER EQU 00001000B ;wait timer for pen down setting

```

**(2) Define Macros**

```

;----- macro declaration -----
; <bit set macro>
M_BSET MACRO DATA,DBIT,REG
LD REG,[DATA]
OR REG,#DBIT
LD [DATA],REG
ENDM

; <bit clear macro>
M_BCLR MACRO DATA,DBIT,REG
LD REG,#DBIT
XOR REG,#0FFH
AND REG,[DATA]
LD [DATA],REG
ENDM

; <I/O register bit clear macro>
M_IO_BCLR MACRO DATA,DBIT
AND [BR:@LOW(DATA)],#DBIT^0FFH
ENDM

; <I/O register bit set macro>
M_IO_BSET MACRO DATA,DBIT
OR [BR:@LOW(DATA)],#DBIT
ENDM

```

### A.5.2 TPC initialization

```

;#####
;          touch panel controller initialize

;          input      none
;          output     none
;          destroyed  none
;#####
GLOBAL TOUCH_INI
TOUCH_INI:
;ETPPD,ETPDR,PDC,RST is initial 0
;TP interrupt priority PTP* is set in other previous routine

```

**(1) Save the register values into the stack**

```

PUSH SC
PUSH A

```

**(2) Switch to the high-speed clock**

```

CARL CLK_LtoH ;change the clock to high

```

**(3) Supply clocks to the A/D converter and TPC**

```

LD [BR:@LOW(IO_PRE3)],#00001010B ;A/D clock = fosc3/4
;A/D clock is turned on

```

```

LD      [BR:@LOW(IO_PRE6)],#00001100B      ;TPC clock = fosc3/16
                                              ;TPC clock is turned on

(4) Set the TPC modes
LD      [BR:@LOW(IO_PRE7)],#00000000B      ;TPC noise rejection on
                                              ;TPC noise rejection
                                              ;f.ratio = fosc1/1
LD      [BR:@LOW(IO_TPCR0)],#00010011B     ;CONST moving average
                                              ;average times = 16 * 2
LD      [BR:@LOW(IO_TPCR1)],#00001111B     ;voltage stability wait
                                              ;time = 16 * 16/f
LD      [BR:@LOW(IO_TPCR2)],#00001111B     ;noise detection threshold
                                              ;= 64
LD      [BR:@LOW(IO_TPCR3)],#00001111B     ;pen up detection threshold
                                              ;= 64
                                              ;setting speed detection
                                              ;threshold
LD      [BR:@LOW(IO_TPCR4)],#01000010B     ;SSDT = 6
                                              ;MSSDT = 10
LD      [BR:@LOW(IO_TPCR5)],#10000110B     ;MFSDT = 14
                                              ;FSDT = 18
LD      [BR:@LOW(IO_TPCR6)],#00000010B     ;wait time after A/D conv.
                                              ;= 128 * 3

(5) Activate the TPC circuit
OR      [BR:@LOW(IO_TPCR0)],#00100000B     ;lift a reset of TPC circuit

(8) Reset the coordinate update interrupt flag and enable the interrupt
LD      [BR:@LOW(IO_INTFA3)],#01100000B    ;TP pen down interrupt
                                              ;factor flag reset
OR      [BR:@LOW(IO_INTEA3)],#00100000B    ;TP data renewal interrupt
                                              ;enable

(9) Restore the saved registers
POP     A
POP     SC

RET

```

### A.5.3 TPC data update interrupt processing

```

;#####
;      pen move interrupt routine

;      input      none
;      output     none
;      destroyed  none
;#####
GLOBAL      INT_PMOVE
INT_PMOVE:

(1) Save the registers
PUSH     BA
PUSH     L

(2) Pen-down check
BIT      [BR:@LOW(IO_TPCR7)],#00000001B    ;if pen down is detected
JRS      Z,INT_PMOVE10                       ;then read the coordinate
                                              ;data

(3) Process when a pen-down is detected
Set the switch data to "1"
M_BSET   tpc_flg0,TC_SWITCH0,A             ;switch0 = 1

Load X coordinate data
LD       B,[BR:@LOW(IO_TPCR8)]              ;B = x11 - x04
LD       A,[BR:@LOW(IO_TPCR9)]              ;A = x03 - x00
PACK
LD       L,A                                 ;L = A
LD       A,B                                 ;A = B

```

```

UPCK                                ;B = x11 - x08
LD      A,L                          ;A = x07 - x00
LD      [tc_xior],BA                 ;data save
    
```

**Load Y coordinate data**

```

LD      B,[BR:@LOW(IO_TPCRA)]        ;B = x11 - x04
LD      A,[BR:@LOW(IO_TPCRB)]        ;A = x03 - x00
PACK                                ;A = x07 - x00
LD      L,A                          ;L = A
LD      A,B                          ;A = B
UPCK                                ;B = x11 - x08
LD      A,L                          ;A = x07 - x00
LD      [tc_yior],BA                 ;data save
JRS     INTPMOVE20
    
```

**(4) Process when no pen-down is detected**

INTPMOVE10:

**Set the switch data to "1"**

```

M_BCLR  tpc_flg0,TC_SWITCH0,A       ;switch0 = 0
    
```

**Dummy read of coordinate data**

```

LD      A,[BR:@LOW(IO_TPCR8)]        ;dummy read
LD      A,[BR:@LOW(IO_TPCR9)]        ;dummy read
LD      A,[BR:@LOW(IO_TPCRA)]        ;dummy read
LD      A,[BR:@LOW(IO_TPCRB)]        ;dummy read
    
```

**(5) Set the coordinate data update flag**

INTPMOVE20:

```

M_BSET  tpc_flg0,TCDT_RCV,A         ;set the coordinate data
                                           ;receive flag
    
```

**(6) Reset the coordinate update interrupt factor flag**

```

LD      [BR:@LOW(IO_INTFA3)],#0010000B
    
```

**(7) Restore the saved register**

```

POP      L
POP      BA

RETE
    
```

**A.5.4 TP initial data setting**

```

;#####
;      set the base data for coordinate calculation
;
;      input      none
;      output     none
;      destroyed  none
;#####
GLOBAL  TCDATA_INI
TCDATA_INI:
    
```

**(1) Save the registers**

```

PUSH    SC                            ;SC register is stored
PUSH    BA                            ;BA register is stored
PUSH    HL                            ;HL register is stored
    
```

**(2) Obtain the X origin reference coordinate**

**Draw check point**  
 <omitted>

**Pen-down standby**

```

CARL    WAIT_PEN_DOWN
    
```

**Load TP data**

```

LD      BA,[tc_xior]
LD      [tc_xorg],BA                 ;save x origin data
    
```

**Pen-up standby**

CARL      WAIT\_PEN\_UP

**Erase check point**

<omitted>

**(3) Obtain the max. X reference coordinate**

**Draw check point**

<omitted>

**Pen-down standby**

CARL      WAIT\_PEN\_DOWN

**Load TP data**

```

LD      BA,[tc_xior]                    ;BA = x max data
LD      HL,[tc_xorg]                  ;HL = x org data
SUB     BA,HL                         ;BA = x span data

LD      L,#0                         ;shift counter = tc_xsft

TCDTI_LP20:
CP      B,#0                         ;if B = 0 (data is included
JRS     Z,TCDTI_210                  ;in 8 bit) then out of loop
SRL     B
RR      A                             ;bit shift
INC     L                             ;shift counter increment
JRS     TCDTI_LP20

TCDTI_210:
LD      [tc_xspn],A                  ;x span data
LD      [tc_xsft],L                  ;x bit shift times
    
```

**Pen-up standby**

CARL      WAIT\_PEN\_UP

**Erase check point**

<omitted>

**(4) Obtain the Y origin reference coordinate**

<omitted. similar to the process to obtain the X origin reference coordinate>

**(5) Obtain the max. Y reference coordinate**

<omitted. similar to the process to obtain the Y origin reference coordinate>

**(6) Restore the saved registers**

```

POP     HL                           ;HL = register is returned
POP     BA                           ;BA = register is returned
POP     SC                           ;SC = register is returned

RET
    
```

**(7) <Subroutine> Pen-down standby processing**

```

;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
;            Wait Pen Down
;            (A register is destroyed)
;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
WAIT_PEN_DOWN:
M_BCLR    tpc_flg0,TCDT_RCV,A       ;reset the coordinate receive flag

WTPNDNLP:
LD        A,[tpc_flg0]              ;check the coordinate receive flag
BIT       A,#TCDT_RCV
JRS       Z,WTPNDNLP

LD        A,[tpc_flg0]
BIT       A,#TC_SWITCH0             ;check pen is down
JRS       Z,WTPNDNLP
    
```

## APPENDIX: CONTROLLING THE TOUCH PANEL CONTROLLER

```

M_BCLR    tpc_flg0,TCDT_RCV,A        ;reset the coordinate receive flag
RET

```

### (8) <Subroutine> Pen-up standby processing

```

;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
;      Wait Pen UP
;      (A,B register is destroyed)
;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
WAIT_PEN_UP:
LD        A,[tpc_flg0]                ;check the coordinate receive flag
BIT      A,#TCDT_RCV
JRS      Z,WAIT_PEN_UP

LD        A,[tpc_flg0]
BIT      A,#TC_SWITCH0                ;check pen is up
JRS      NZ,WAIT_PEN_UP

M_BCLR    tpc_flg0,TCDT_RCV,A        ;reset the coordinate receive flag
RET

```

## A.5.5 Coordinate data calculation

```

;#####
;      get coordinate data from touch panel

;      input    none
;      output   A:y axis coordinate
;              B:x axis coordinate
;      destroyed(A,B)
;#####
GLOBAL    TC_GETCOORD
TC_GETCOORD:

```

### (1) Save registers and reserve work area

```

PUSH     SC                            ;SC register is stored
PUSH     IX                            ;IX register is stored
PUSH     HL                            ;HL register is stored
SUB      SP,#2                          ;2 byte reserved for work in stack
;area
LD       IX,SP                          ;stack pointer address

```

### (2) Wait for receiving coordinate data

```

TCGETCD10:
LD       A,[tpc_flg0]                  ;check the coordinate
;receive flag
BIT     A,#TCDT_RCV
JRS     Z,TCGETCD10

```

### (3) Reset the coordinate data receive flag

```

M_BCLR    tpc_flg0,TCDT_RCV,A        ;reset the coordinate receive flag

```

### (4) Disable the interrupt

```

OR        SC,#11000000B                ;interrupt disable

```

### (5) Read coordinate data

```

LD       BA,[tc_yior]
LD       [IX],BA                        ;wk0, wk1 = y data (ytgt)
LD       HL,[tc_xior]
LD       A,[tpc_flg0]                  ;switch data

```

### (6) Enable the interrupt

```

AND      SC,#00111111B                ;interrupt enable

```

### (7) Calculate switch data

```

BIT     A,#TC_SWITCH0
JRS     NZ,TCGETCD12                  ;if switch0 = 0 then
M_BCLR    tpc_flg0,TC_SWITCH1,A        ;      switch1 = 0

```

```

TCGETCD12:   JRS      TCGETCD14
              M_BSET   tpc_flg0,TC_SWITCH1,A
TCGETCD14:
(8) Calculate X coordinate
              LD       BA,HL           ;BA = x axis data (xtgt)
              LD       HL,[tc_xorg]    ;HL = x axis origin data (xorg)
              SUB      BA,HL           ;BA=xtgt - xorg
              JRS      NC,TCGETCD20    ;if xtgt - xorg < 0 then
              LD       BA,#0           ; xtgt - xorg = 0
TCGETCD20:
              LD       L,[tc_xsft]     ;L = shift counter
              INC      L
TCGETCD30:
              DEC      L
              JRS      Z,TCGETCD40
              SRL      B               ;shift 1 bit to right
              RR       A
              JRS      TCGETCD30
TCGETCD40:
              SRL      B
              JRS      C,TCGETCD45    ;if B reg is not 0 then over flow
              LD       L,#D_PXL_X     ;L = display dot number (DMAX)
              MLT      HL,[tc_xspn]    ;HL = DMAX * (xtgt - xorg)
              LD       A,[tc_xspn]    ;A = x axis coordinate span (xspn)
              DIV      L,[#D_PXL_X]    ;L = DMAX * (xtgt - xorg) / xspn
              CP       L,#D_PXL_X     ;if x coord ≥ MAX then
              JRS      C,TCGETCD50
TCGETCD45:
              LD       L,#D_PXL_X-1   ; x coord = MAX-1
TCGETCD50:
              LD       BA,[IX]         ;BA = y axis data (ytgt)
              LD       [IX],L         ;wk0 = x axis coordinate

```

**(9) Calculate Y coordinate**

```

              LD       HL,[tc_yorg]    ;HL = y axis origin data (yorg)
              SUB      BA,HL           ;BA = ytgt - yorg
              JRS      NC,TCGETCD60    ;if ytgt - yorg < 0 then
              LD       BA,#0           ; ytgt - yorg = 0
TCGETCD60:
              LD       L,[tc_ysft]     ;L = shift counter
              INC      L
TCGETCD70:
              DEC      L
              JRS      Z,TCGETCD80
              SRL      B               ;shift 1 bit to right
              RR       A
              JRS      TCGETCD70
TCGETCD80:
              SRL      B
              JRS      C,TCGETCD85    ;if B reg is not 0 then over flow
              LD       L,#D_PXL_Y     ;L = display dot number (DMAX)
              MLT      HL,[tc_yspn]    ;HL = DMAX * (ytgt - yorg)
              LD       A,[tc_yspn]    ;A = y axis coordinate span (yspn)
              DIV      L,[#D_PXL_Y]    ;L = DMAX * (ytgt - yorg) / yspn
              CP       L,#D_PXL_Y     ;if y coord ≥ MAX then
              JRS      C,TCGETCD90
TCGETCD85:
              LD       L,#D_PXL_Y-1   ; y coord = MAX - 1
TCGETCD90:
              LD       A,L             ;A = y axis coordinate
              LD       B,[IX]         ;A = x axis coordinate

```

**(10) Restore the saved register and release the work area**

```

              ADD      SP,#2           ;2 byte returned
              POP      HL             ;HL register is returned
              POP      IX             ;IX register is returned
              POP      SC             ;SC register is returned

              RET

```

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