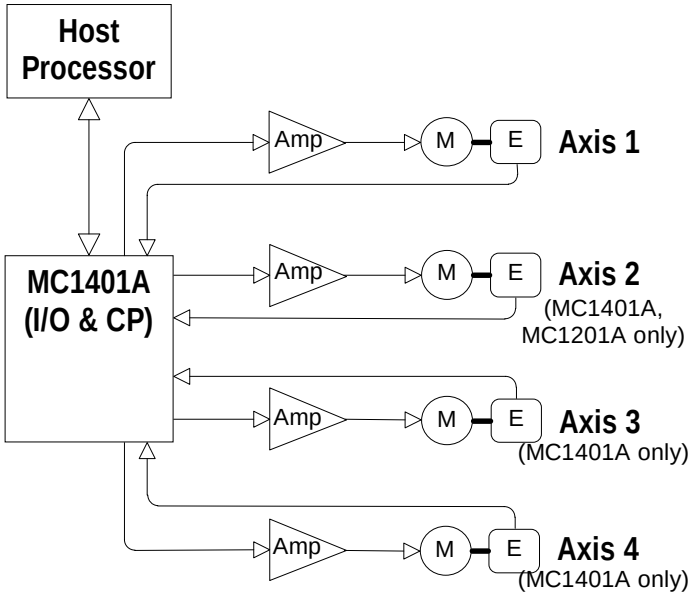
Advanced Multi-Axis Motion Control Chipset

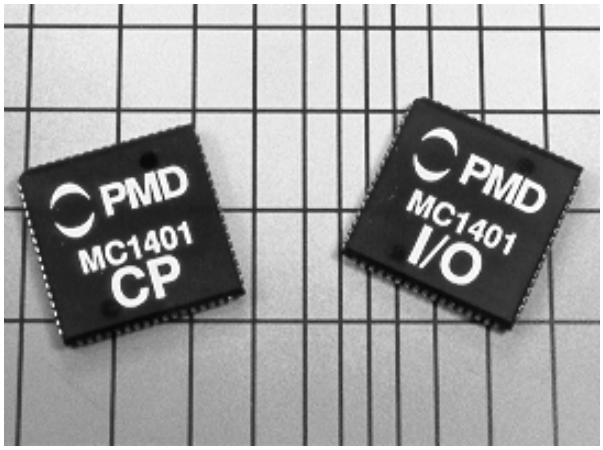
MC1401A, MC1401A-P
MC1201A, MC1201A-P
MC1101A, MC1101A-P

Features

- Available in 1, 2, or 4 axes configurations
- Provides trajectory generation and servo loop closure
- 32-bit position, velocity, acceleration and jerk registers
- Two directional travel-limit switches per axis
- Choice of S-curve, trapezoidal, or contoured velocity profile modes
- Programmable loop rate to 100 micro sec
- Electronic gearing
- Choice of either PID or PI with velocity feedforward servo control loops
- 1.0 megacount/sec quadrature incremental encoder with index position capture
- Parallel encoder and resolver input support
- Choice of PWM or DAC motor output signals
- High speed home-signal position capture
- "On the fly" control of profile and filter parameters with pre-load
- Programmable torque limit
- Easy to use packet-oriented host protocol
- Programmable host interrupts

Typical Configuration





General Description

The MC1401A is a 2-IC general purpose motion control chipset available in one, two, or four axis configurations. It provides trajectory generation and closed-loop digital servo control for a large variety of servo motors. It uses incremental or absolute encoder position feedback signals, and a DAC or PWM compatible output drive. Axes can be programmed either independently or in synchrony to allow advanced multi-axis motion such as circular and continuous-path profiles.

The MC1401A is functionally similar to other members of PMD's 1st generation chipset family, providing software and architectural compatibility with these chipsets. All of these products support advanced features such as S-curve profile generation, bi-directional motion-travel limit switches, and separate home and index position capture signals.

The chipset is controlled by a host processor which interfaces with the chipset via an 8-bit, bi-directional port. Communications to/from the chipset consist of packet-oriented messages. A host interrupt line is provided so that the chipset can signal the host when special conditions occur such as encoder index pulse received.

Each axis interfaces to either a quadrature encoder with an optional index pulse, or a parallel-word device such as an absolute encoder or resolver. For motor amplifier output, PWM signals are provided, as well as DAC-compatible signals with up to 16 bits of resolution.

The chipset is packaged in 2 68-pin PLCC packages. Both chips utilize CMOS technology and are powered by 5 volts.

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Product Family Overview

	MC1401 series	*MC1231 series*	*MC1241 series*	*MC1451 series*
# of axes	*4, 2, or 1*	*2 or 1*	*2 or 1*	*4, 2, or 1*
Motors Supported	*DC Servo*	*Brushless Servo*	*Stepper*	*Stepper*
Encoder Format	*Incremental (no dash version) and Parallel ('-P' version)*	*Incremental*	*Incremental*	*Incremental (-E version)*
Output Format	*DC servo*	*Sinusoidally commutated*	*Microstepping*	*Pulse and Direction*
S-curve profiling	*Yes*	*Yes*	*Yes*	*Yes*
Electronic gearing	*Yes*	*Yes*	*Yes*	*Yes*
On-the-fly changes	*Yes*	*Yes*	*Yes*	*Yes*
Limit switches	*Yes*	*Yes*	*Yes*	*Yes*
PID & feedforward	*Yes*	*Yes*	*-*	*-*
PWM output	*Yes*	*Yes*	*Yes*	*-*
DAC-compatible output	*Yes*	*Yes*	*Yes*	*-*
Pulse & direction output	*-*	*-*	*-*	*Yes*
Index & Home signal	*Yes*	*Yes*	*Yes*	*Yes (-E version)*
Chipset p/n's	*MC1401A, MC1401A-P (4 axes)* *MC1201A, MC1201A-P (2 axes)* *MC1101A, MC1101A-P (1 axis)*	*MC1231A (2 axes)* *MC1131A (1 axis)*	*MC1241A (2 axes)* *MC1141A (1 axis)*	*MC1451A, MC1451A-E (4 axes)* *MC1251A, MC1251A-E (2 axes)* *MC1151A, MC1151A-E (1 axis)*
Developer's Kit p/n's:	*DK1401A, DK1401A-P*	*DK1231A*	*DK1241A*	*DK1451A*

Introduction

This manual describes the operational characteristics of the MC1401A, MC1201A, MC1101A, MC1401A-P, MC1201A-P, and MC1101A-P Motion Processors. These devices are members of PMD's 1st generation motion processor family, which consists of 16 separate products organized into four groups.

Each of these devices are complete chip-based motion controllers. They provide trajectory generation and related motion control functions. Depending on the type of motor controlled they provide servo loop closure, on-board commutation for brushless motors, and high speed pulse and direction outputs. Together these products provide a software-compatible family of dedicated motion processor chips which can handle a large variety of system configurations.

Each of these chips utilize a similar architecture, consisting of a high-speed DSP (Digital Signal Processor) computation unit , along with an ASIC (Application Specific Integrated Circuit). The computation unit contains special on-board hardware such as a multiply instruction that makes it well suited for the task of motion control.

Along with a similar hardware architecture these chips also share most software commands, so that software written for one chipset may be re-used with another, even though the type of motor may be different.

This manual describes the operation of the MC1401A, MC1201A, MC1101A, MC1401A-P, MC1201A-P, and MC1101A-P chipsets. For technical details on other members of PMD's first generation motion processors see the corresponding product manual.

Family Summary

MC1401 series (MC1401A, MC1201A, MC1101A, MC1401A-P, MC1201A-P, MC1101A-P) - These chipsets take in incremental encoder signals (standard version) or parallel word encoder signals (-P version) and output a motor command in either PWM or DAC-compatible format. These chipsets come in 1, 2 or 4 axis versions and can be used with DC brushed motors, or brushless motors using external commutation.

MC1231 series (MC1231A, MC1131A) - These chipsets take in incremental quadrature encoder signals and output sinusoidally commutated motor signals appropriate for driving brushless motors. They are available in one or two axis versions. Depending on the motor type they output two or three phased signals per axis in either PWM or DAC-compatible format.

MC1241 series (MC1241A, MC1141A) - These chipsets provide internal microstepping generation for stepping motors. They are available in a one or a two-axis version. Two phased signals are output per axis in either PWM or DAC-compatible format. An incremental encoder signal can be input to confirm motor position.

MC1451 series (MC1451A, MC1251A, MC1151A, MC1451A-E, MC1251A-E, MC1151A-E) - These chipsets provide very high speed pulse and direction signal output appropriate for driving step motor-based systems. They are available in a one, two, or four-axis version and are also available with quadrature encoder input.

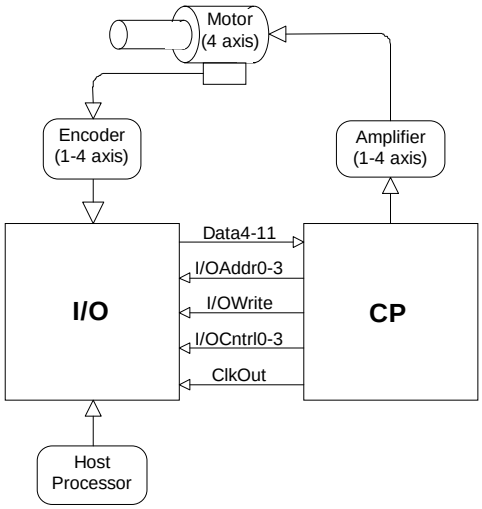
Each of these chipsets has an associated Chipset Developer's Kit available for it. For more information contact your PMD representative.

Electrical Characteristics

Overview

The MC1401A-consists of two 68 pin PLCC's both fabricated in CMOS. The Peripheral Input/Output IC (I/O chip) is responsible for interfacing to the host processor and to the position input encoders. The Command Processor IC (CP chip) is responsible for all host command, profile and servo computations, as well as for outputting the PWM and DAC signals.

The following figure shows a typical system block diagram, along with the pin connections between the I/O chip and the CP chip.



The CP and I/O chips function together as one integrated motion processor. The major components connected to the chip set are the Encoder (4, 2, or 1 axes), the motor amplifier (4, 2, or 1 axes), and the host processor.

For the standard MC1401A parts (non '-P' parts), the encoder signals are input to the I/O chip in quadrature format. For the '-P' parts the encoder information is input directly into the CP chip, via an 8 bit data bus and various control signals.

The chipset's motor output signals are connected to the motor amplifier. Two types of output are provided; PWM (pulse width modulation), and DAC-compatible signals used with an external DAC (digital to analog converter).

The host processor is interfaced via an 8-bit bi-directional bus and various control signals. Host communication is coordinated by a ready/busy signal, which indicates when communication is allowed.

Interconnections between the two chips consist of a data bus and various control and synchronization signals. The following table summarizes the signals that must be interconnected for the chipset to function properly. For each listed signal the I/O chip pin on the left side of the table is directly connected to the pin to the right.

I/O Chip Signal Name	I/O Chip Pin	CP Chip Signal Name	CP Chip Pin
CPData4	18	Data4	50
CPData5	5	Data5	49
CPData6	6	Data6	46
CPData7	7	Data7	43
CPData8	8	Data8	40
CPData9	17	Data8	39
CPData10	3	Data10	36
CPData11	1	Data11	35
CPAddr0	68	I/OAddr0	28
CPAddr1	27	I/OAddr1	9
CPAddr2	29	I/OAddr2	6
CPAddr3	12	I/OAddr3	5
CPCntr0	20	I/OCntr0	16
CPCntr1	36	I/OCntr1	18
CPCntr2	22	I/OCntr2	68
CPCntr3	63	I/OCntr3	67
CPWrite	2	I/OWrite	15
CPClk	46	ClkOut	19

For a complete description of all pins see the 'Pin Descriptions' section of this manual.

Unless specifically noted otherwise, the term 'MC1401A' refers to the MC1401A, MC1201A, MC1101A, MC1401A-P, MC1201A-P, and MC1101A-P Motion Processors.

Absolute Maximum Ratings

Unless otherwise stated, all electrical specifications are for both the I/O and CP chips.

Storage Temperature, Ts.....-55 deg. C to +150 deg. C
Supply Voltage, Vcc.....-0.3 V to +7.0 V
Power Dissipation, Pd.....650 mW (I/O and CP combined)

Operating Ratings

Operating Temperature, Ta .....0 deg. C to +70 deg. C*
Nominal Clock Frequency, Fclk.....25.0 Mhz
Supply Voltage, Vcc.....4.75 V to 5.25 V

** Industrial and Military operating ranges also available. Contact your PMD representative for more information.*

DC Electrical Characteristics

(Vcc and Ta per operating ratings, Fclk = 25.0 Mhz)

Symbol	Parameter	Min.	Max.	Units	Conditions
Vcc	Supply Voltage	4.75	5.25	V	
Idd	Supply Current		100	mA	open outputs
Input Voltages					
Vih	Logic 1 input voltage	2.0	Vcc + 0.3	V	
Vil	Logic 0 input voltage	-0.3	0.8	V	
Vihclk	Logic 1 voltage for clock pin (ClkIn)	3.0	Vcc+0.3	V	
Vihreset	Logic 1 voltage for reset pin (reset)	4.0	Vcc+0.3	V	
Output Voltages					
Voh	Logic 1 Output Voltage	2.4		V	@CP Io = 300 uA @I/O Io = 4 mA
Vol	Logic 0 Output Voltage		0.33	V	@CP Io = 2 mA @I/O Io = 4 mA
Iout	Tri-State output leakage current	-20	20	uA	0 < Vout < Vcc
Iin	Input current	-50	50	uA	0 < Vi < Vcc
Iinclk	Input current ClkIn	-20	20	uA	0 < Vi < Vcc

AC Electrical Characteristics

(see reference timing diagrams)
(Vcc and Ta per operating ratings; Fclk = 25.0 Mhz)
(~ character indicates active low signal)

Timing Interval	T#	Min.	Max.	Units
Encoder and Index Pulse Timing				
Motor-Phase Pulse Width	T1	1.6		uS
Dwell Time Per State	T2	0.8		uS
Index Pulse Setup and Hold (relative to Quad A and Quad B low)	T3	0		uS
Reset Timing				
Stable Power to Reset		0.25		Sec
Reset Low Pulse Width		1.0		uS
Clock Timing				
Clock Frequency (Fclk)		6.7	25.6	Mhz
Clock Pulse Width	T4	19.5	75 (note 2)	nS
Clock Period	T5	39	149 (note 2)	nS

Timing Interval	T#	Min.	Max.	Units
Command Byte Write Timing				
~HostSlct Hold Time	T6	15	2000 (note 3)	nS
~HostSlct Setup Time	T7	10		nS
HostCmd Setup Time	T8	10		nS
Host Cmd Hold Time	T9	25		nS
HostRdy Delay Time	T13		70	nS
~HostWrite Pulse Width	T14	50		nS
Write Data Setup Time	T15	35		nS
Write Data Hold Time	T16	30		nS
Data Word Read Timing				
~HostSlct Hold Time	T6	15	2000 (note 3)	nS
~HostSlct Setup Time	T7 (read only)	- 20		nS
HostCmd Setup Time	T8 (read only)	- 20		nS
HostCmd Hold Time	T9	25		nS
Read Data Access Time	T10		50	nS
Read Data Hold Time	T11	10		nS
~HostRead high to HI-Z Time	T12		50	nS
HostRdy Delay Time	T13		70	nS
Read Recovery Time	T17	60		nS
Data Word Write Timing				
~HostSlct Hold Time	T6	15	2000 (note 3)	nS
~HostSlct Setup Time	T7	10		nS
HostCmd Setup Time	T8	10		nS
HostCmd Hold Time	T9	25		nS
HostRdy Delay Time	T13		70	nS
~HostWrite Pulse Width	T14	50		nS
Write Data Setup Time	T15	35		nS
Write Data Hold Time	T16	30		nS
Write Recovery Time	T18	60		nS
DAC Interface Timing				
I/OAddr Stable to ~I/OWrite setup time	T19	35		nS
~I/OWrite Pulse Width	T20	56	95	nS
Data Hold Time After ~I/OWrite	T21	17		nS
ClkOut Low to I/OAddr stable	T22	10	40	nS
ClkOut Low to ~I/OWrite Low	T23	75	92	nS
ClkOut Low to Data Valid	T24		92	nS
ClkOut Cycle Time	T25	160 typical (note 4)		nS
I/OAddr Stable to DACSlct High	T26		66	nS
~I/OWrite Low to DACSlct High	T27		44.5	nS
PWM Output Timing				
PWM Output Frequency		24.5		Khz
Parallel-Word Encoder Timing (-P versions only)				
ClkOut Period	T28	160 typical (note 4)		nS
I/OCtrnl0 Delay Time	T29	35	47	nS
Data Setup Time to ClkOut	T30	40		nS
I/OAddr Stable to DACSlct High	T31	22.0	27.0	uSec
Convert Pulse Width	T32	320		nSec

note 1 ~HostSlct and HostCmd may optionally be de-asserted if setup and hold times are met.

note 2 Chip-set performance figures and timing information valid at Fclk = 25.0 only. For timing information & performance parameters at Fclk < 25.0 Mhz, call PMD.

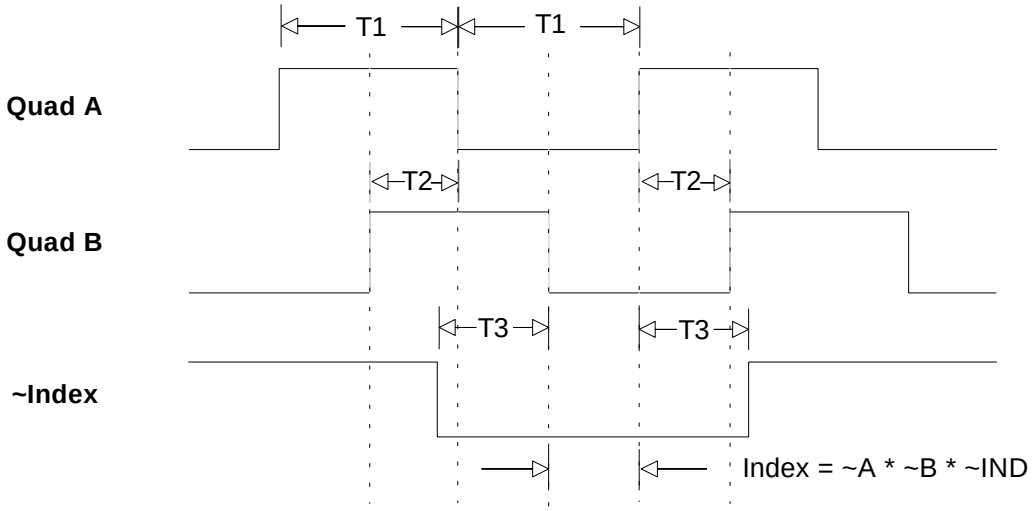
note 3 Two micro seconds maximum to release interface before chip set responds to command

note 4 ClkOut from CP is 1/4 frequency of ClkIn (CP chip).

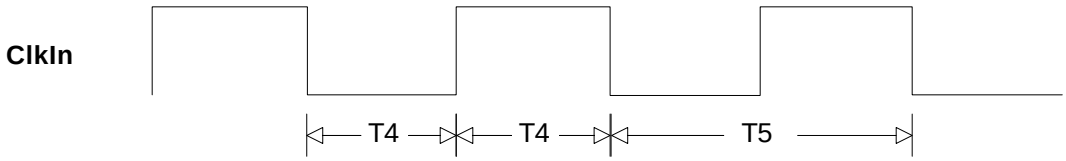
I/O Timing Diagrams

The following diagrams show the MC1401A electrical interface timing. T#' values are listed in the above timing chart.

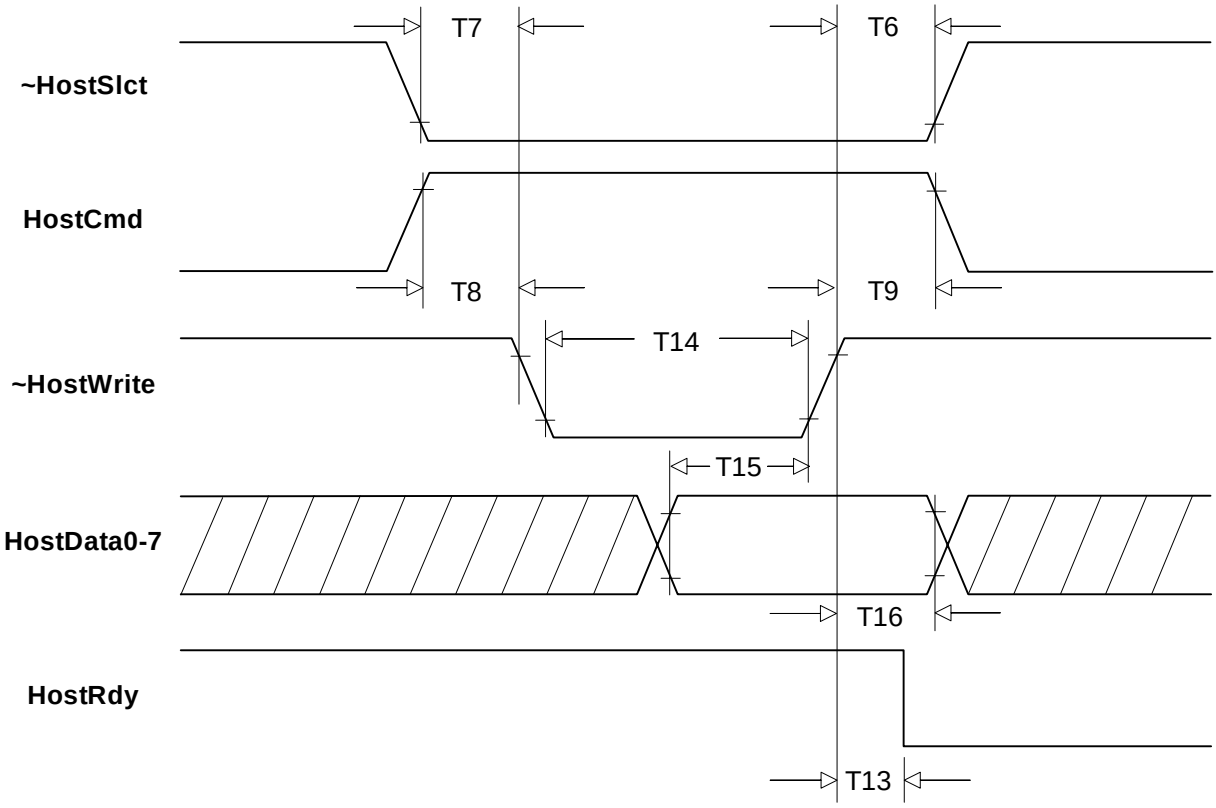
Quadrature Encoder Input Timing



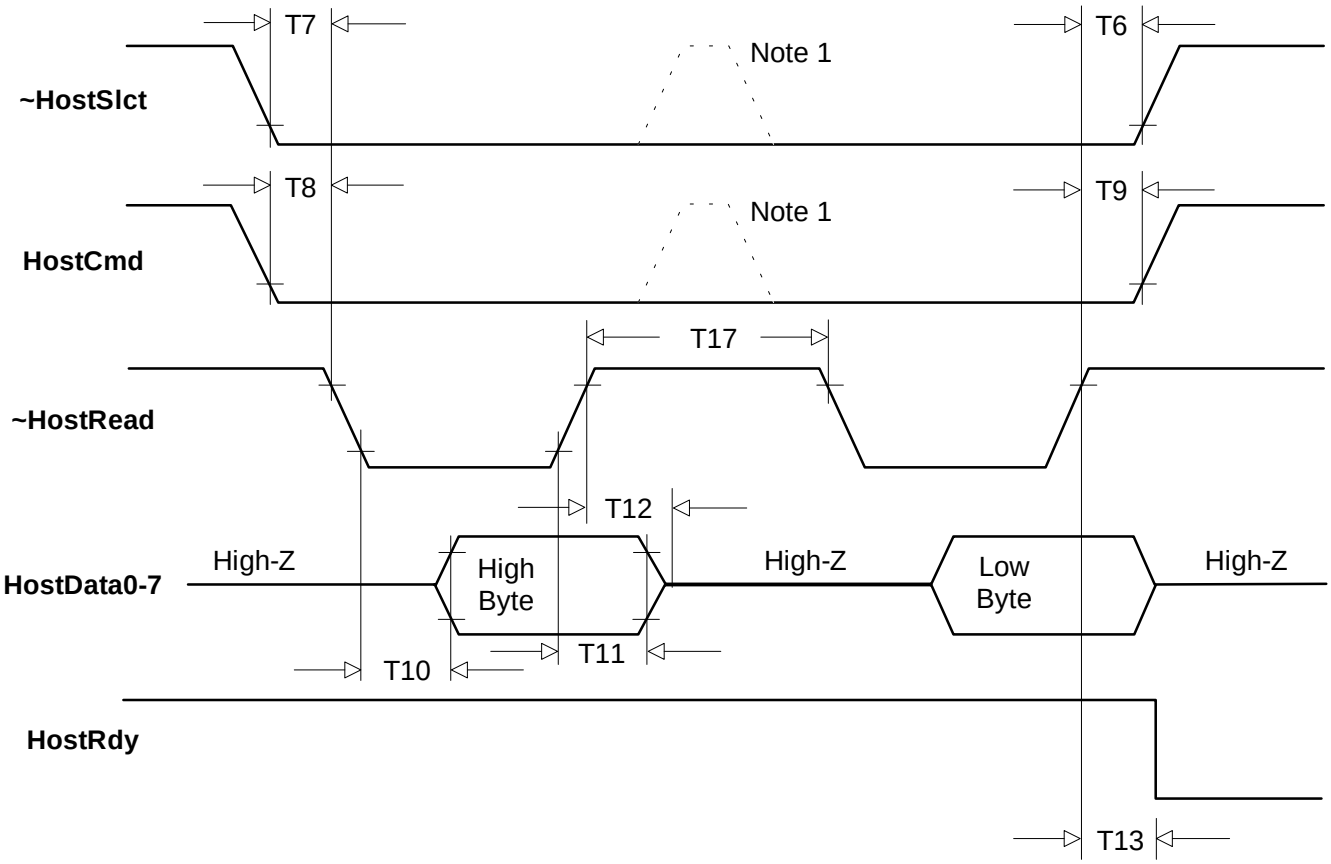
Clock Timing



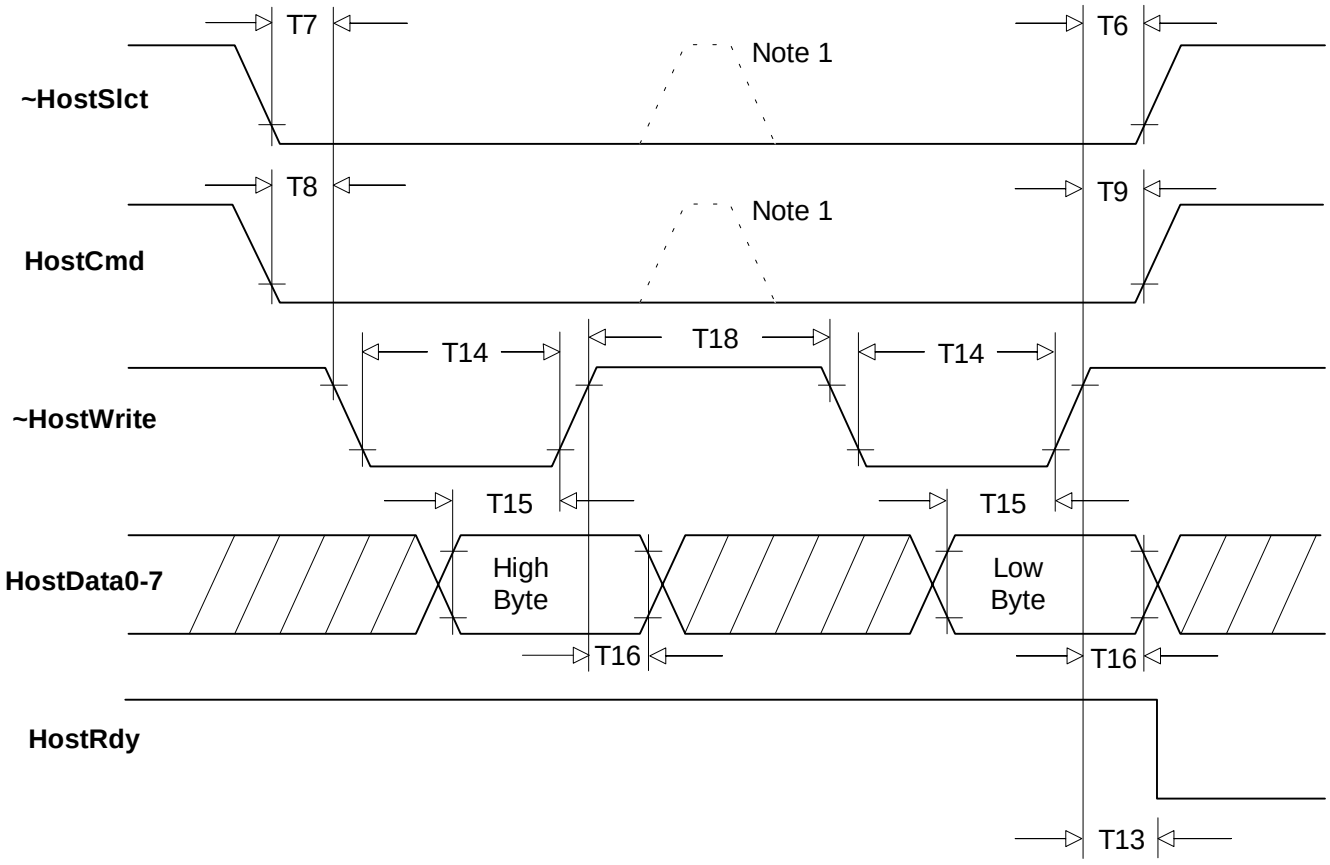
Command Byte Write TIming



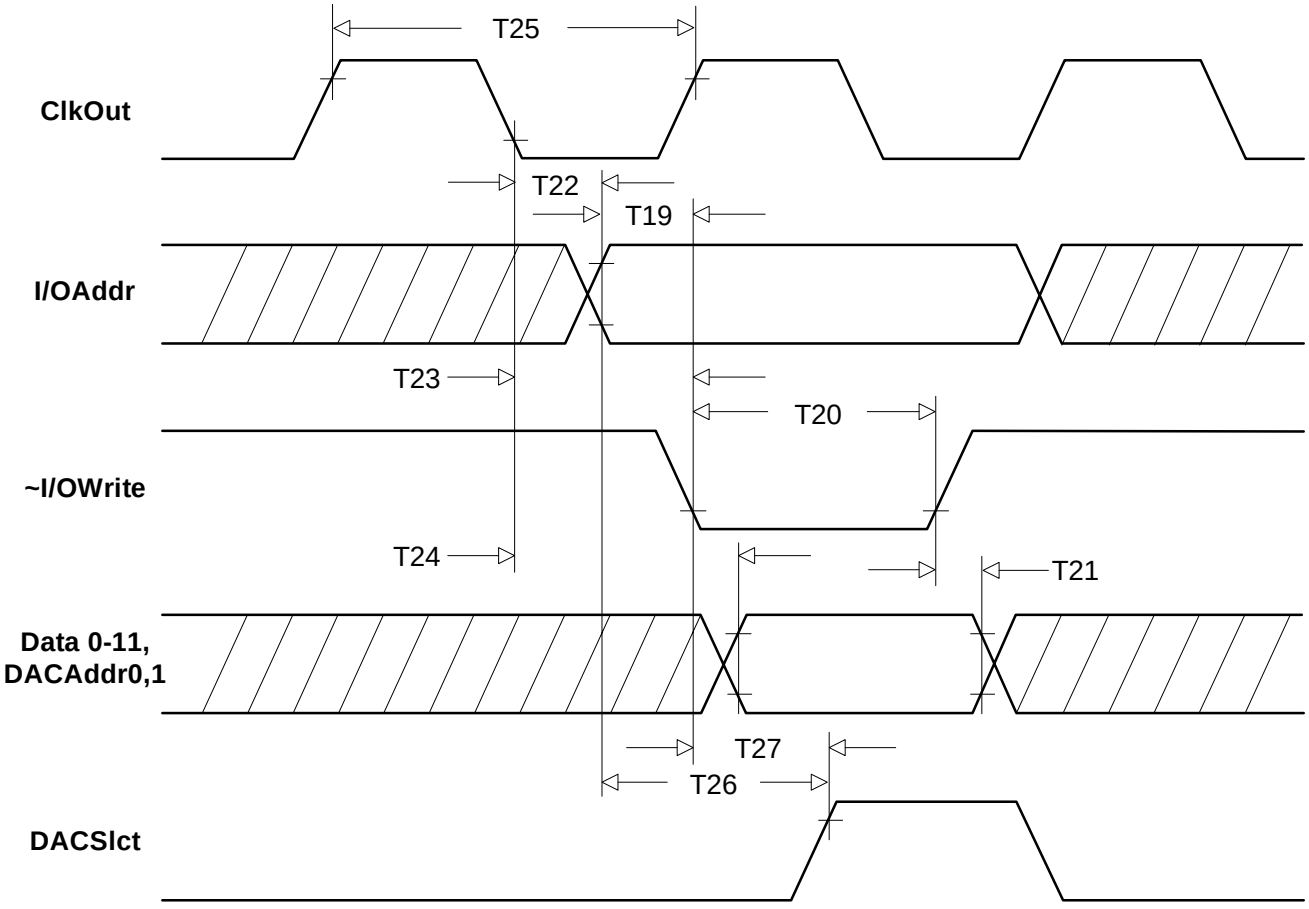
Data Word Read TIming



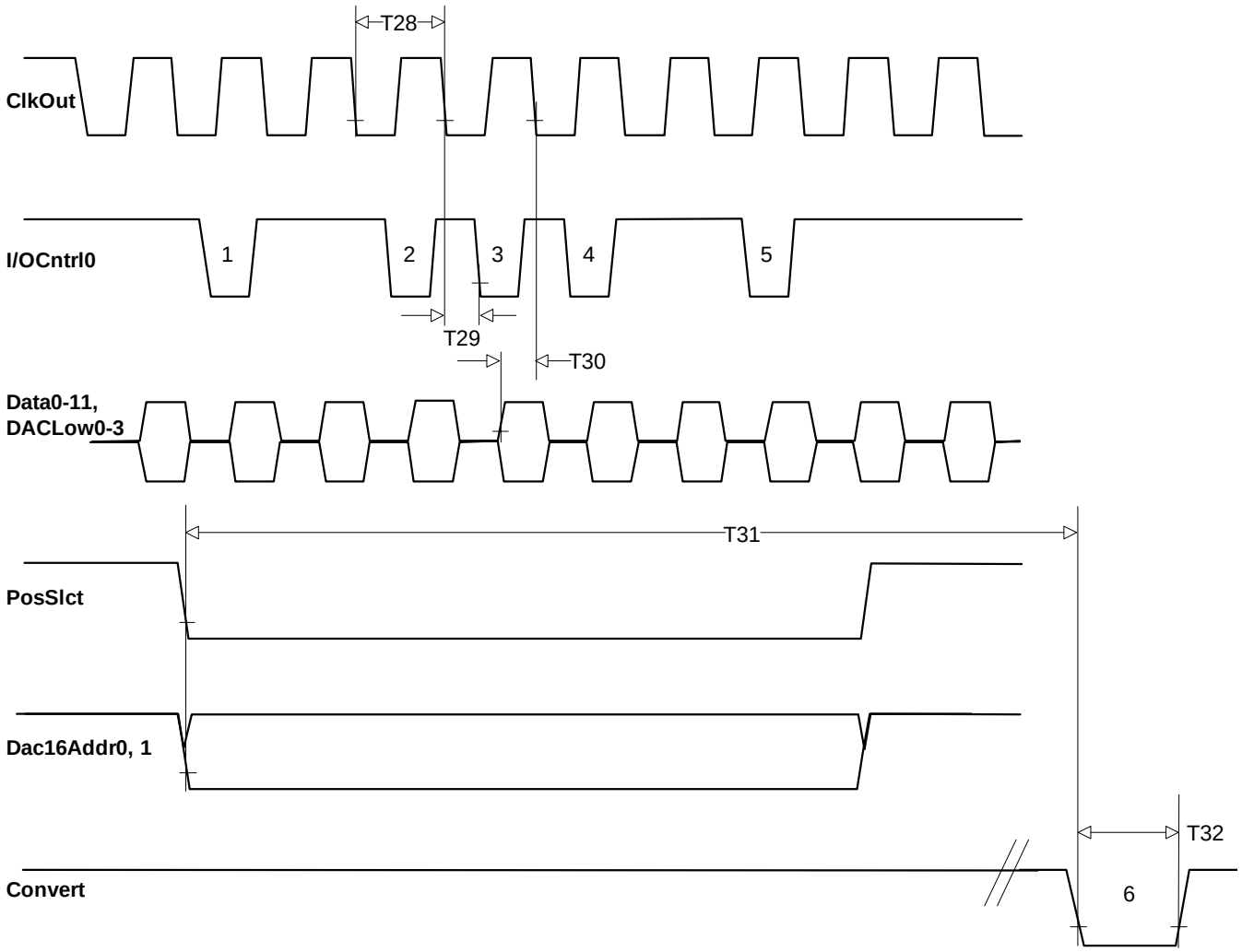
Data Word Write TIming



DAC Interface Timing



Parallel Word Device Read Timing

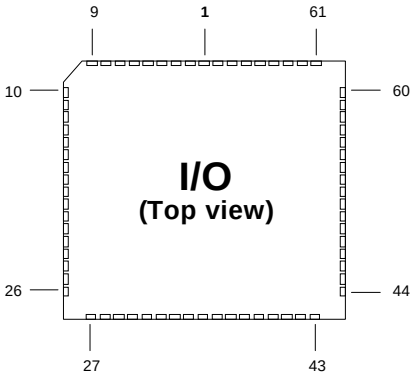


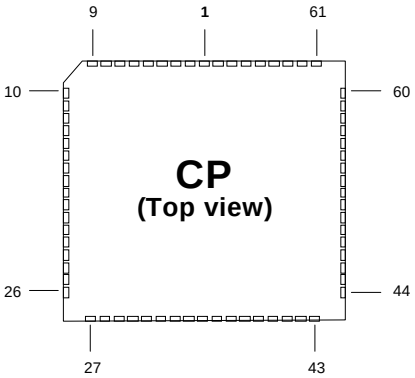
One data read shown. Axis address read sequence is 1, 2, 4, 3

Legend

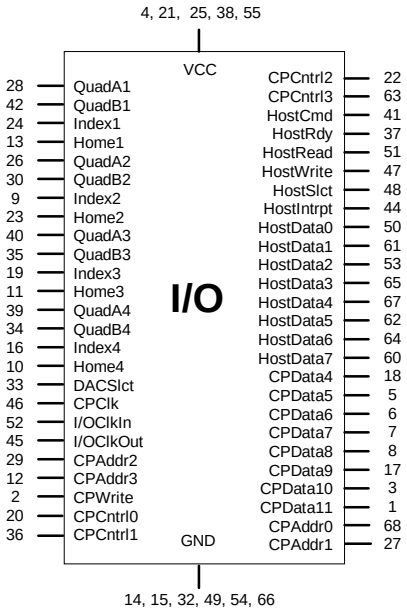
1 - Instruction Fetch
2 - Instruction Fetch
3 - Read the data value
4 - Instruction Fetch
5 - Instruction Fetch
6 - Convert strobe

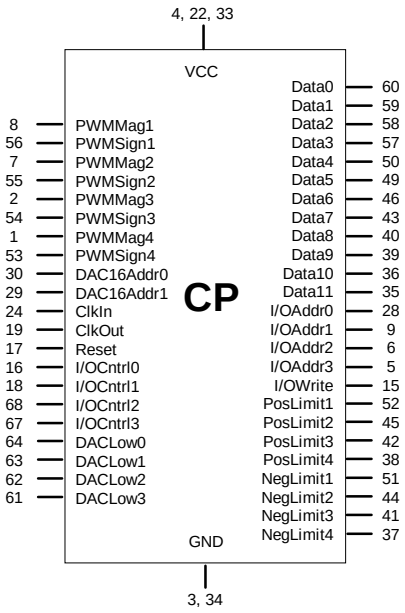
Pinouts



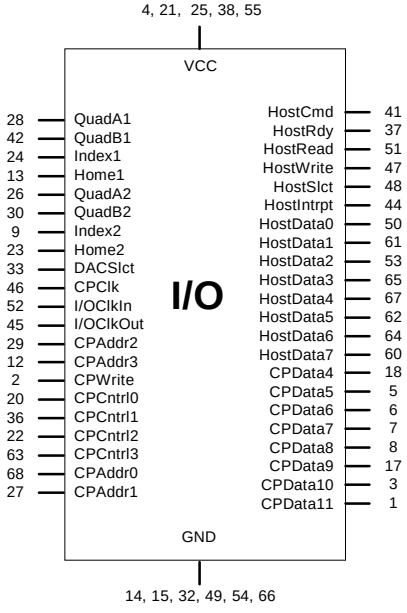


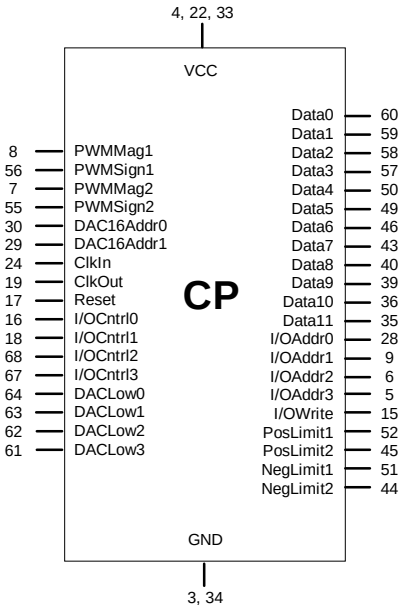
MC1401A Pinouts



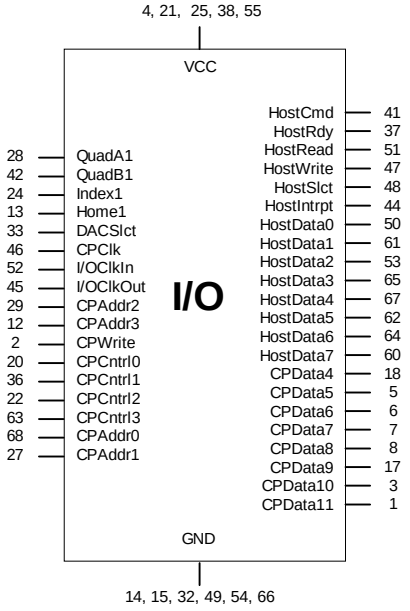


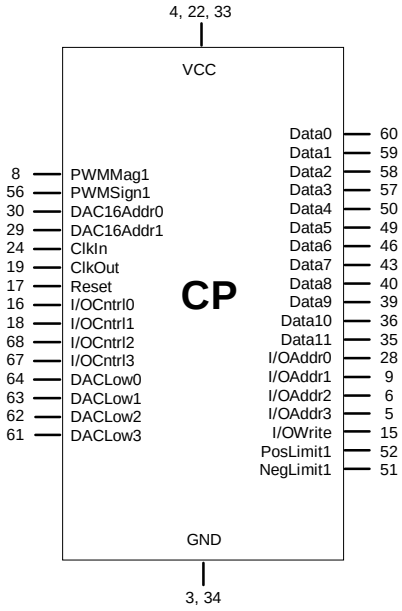
MC1201A Pinouts



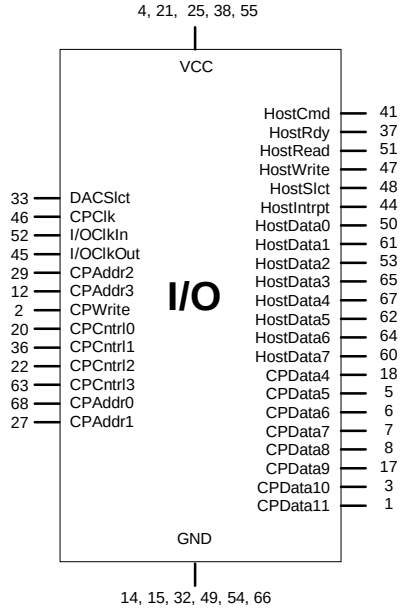


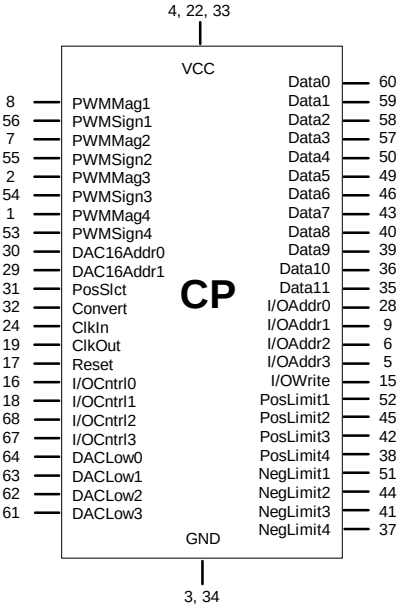
MC1101A Pinouts



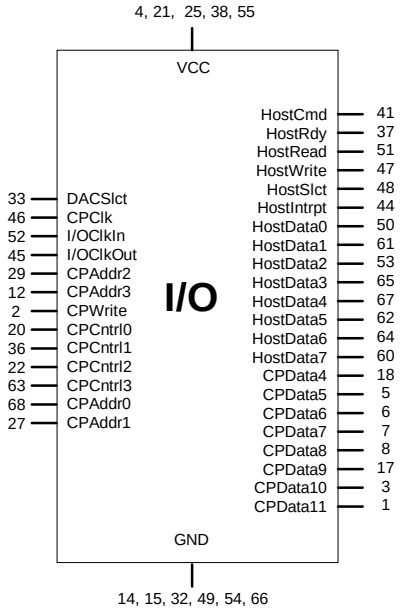


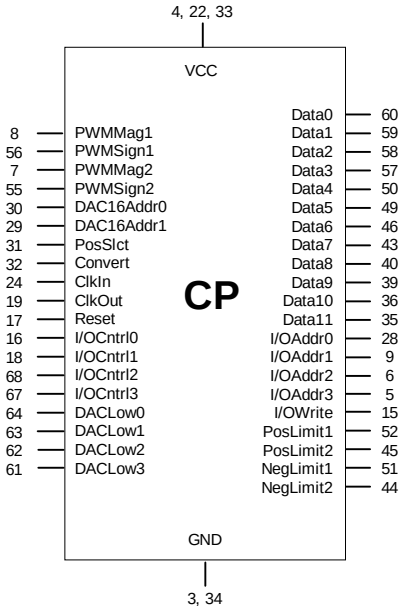
MC1401A-P Pinouts



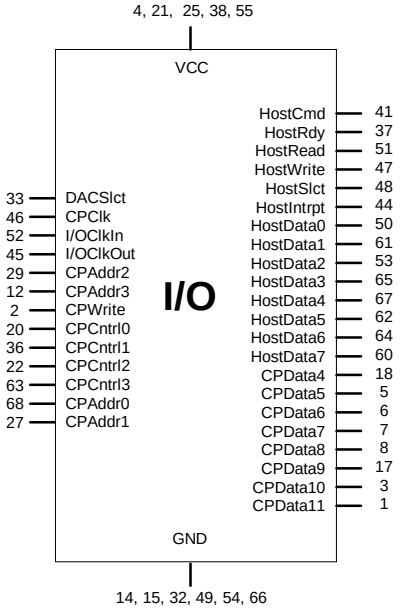


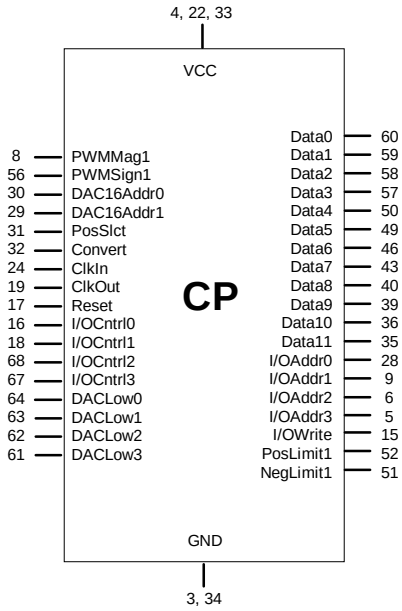
MC1201A-P Pinouts





MC1101A-P Pinouts





Pin Descriptions

The following tables provide pin descriptions for the MC1401A and MC1401A-P series chipsets.

IC	Pin Name	Pin #	Description/Functionality
I/O Chip Pinouts			
I/O	QuadA1 QuadB1 QuadA2 QuadB2 QuadA3 QuadB3 QuadA4 QuadB4	28 42 26 30 40 35 39 34	Quadrature A, B channels for axis 1 - 4 (input). Each of these 4 pairs of quadrature (A, B) signals provide the position feedback for an incremental encoder. When the encoder is moving in the positive, or forward direction, the A signal leads the B signal by 90 degs. The quadrature signals must stay in the same state for .8 uSec to register a valid encoder state, resulting in a maximum theoretical encoder state capture rate of 1.2 Mcounts/sec. Actual maximum rate will vary depending on signal noise. Typical maximum is 1.0 Mcounts/sec. NOTE: Many encoders require a pull-up resistor on each of these signals to establish a proper high signal (check the encoder electrical specifications) NOTE: For MC1401A all 8 pins are valid. For MC1201A pins for axes 1 & 2 only are valid. For MC1101A pins for axis 1 only are valid. Invalid axis pins can be left unconnected. NOTE: Not valid for -P parts.
I/O	~Index1 ~Index2 ~Index3 ~Index4	24 9 19 16	Index encoder signals for axis 1-4 (input). Each of these 4 signals indicate the index flag state from the encoder. A valid index pulse is recognized by the chip set when the index flag transitions low, followed by the corresponding A and B channels of the encoder transitioning low. The index pulse is recognized at the later of the A or B transitions. If not used this signal must be tied high. NOTE: For MC1401A all 4 pins are valid. For MC1201A pins for axes 1 & 2 only are valid. For MC1101A pin for axis 1 only is valid. Invalid axis pins can be left unconnected. NOTE: Not valid for -P parts.
I/O	~Home1 ~Home2 ~Home3 ~Home4	13 23 11 10	Home signals for axis 1-4 (input). Each of these signals provide a general purpose input to the hardware position capture mechanism. A valid home signal is recognized by the chipset when the home flag transitions low. These signals have a similar function as the ~Index signals, but are not gated by the A and B encoder channels. For valid axis pins, If not used, this signal must be tied high. See below for valid pin definitions for the MC1401A, MC1201A, and MC1101A. NOTE: For MC1401A all 4 pins are valid. For MC1201A pins for axes 1 & 2 only are valid. For MC1101A pin for axis 1 only is valid. Invalid axis pins can be left unconnected. NOTE: Not valid for -P parts.
I/O	DACSlct	33	DAC Select (output). This signal is asserted high to select any of the available DAC output channels. For details on DAC decoding see description of DACAddr0-1 and DAC16Addr0-3 signals.
I/O	CPClk	46	I/O chip clock (input). This signal is connected directly to the ClkOut pin (CP chip) and provides the clock signal for the I/O chip. The frequency of this signal is 1/4 the user-provided ClkIn (CP chip) frequency.
I/O	I/OClkIn	52	Phase shifted clock (input). This signal is connected to I/OClkOut (I/O chip), and inputs a phase shifted clock signal.
I/O	I/OClkOut	45	Phase shifted clock (output). This signal is connected to I/OClkIn (I/O chip), and outputs a phase shifted clock signal.
I/O	CPAddr0 CPAddr1 CPAddr2 CPAddr3	68 27 29 12	I/O chip to CP chip communication address (input). These 4 signals are connected to the corresponding I/OAddr0-3 pins (CP chip), and together provide addressing signals to facilitate CP to I/O chip communication.

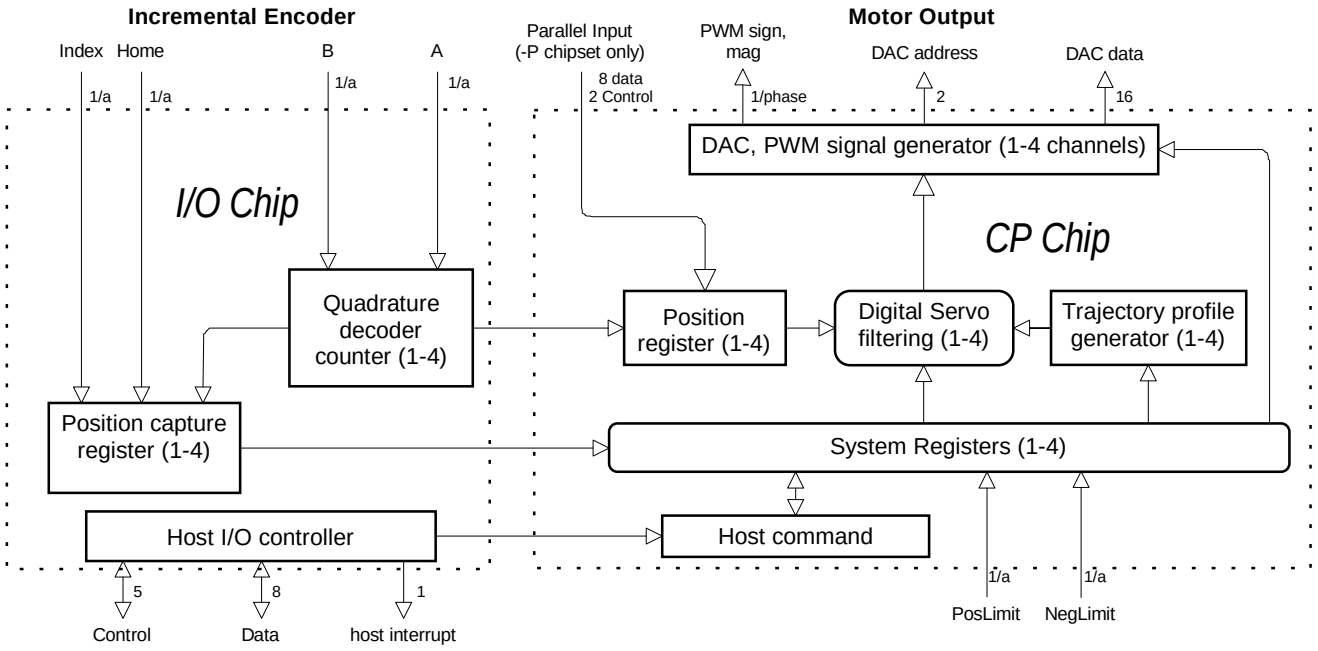
IC	Pin Name	Pin #	Description/Functionality
I/O	~CPWrite	2	I/O chip to CP chip communication write (input). This signal is connected to the ~I/OWrite pin (CP chip) and provides a write strobe to facilitate CP to I/O chip communication.
I/O	CPCntrl0 CPCntrl1 CPCntrl2 CPCntrl3	20 36 22 63	I/O chip to CP chip communication control (mixed). These 4 signals are connected to the corresponding I/OCntrl0-3 pins (CP chip), and provide control signals to facilitate CP to I/O chip communication.
I/O	HostCmd	41	Host Port Command (input). This signal is asserted high to write a host command to the chip set. It is asserted low to read or write a host data word to the chipset
I/O	HostRdy	37	Host Port Ready/Busy (output). This signal is used to synchronize communication between the DSP and the host. HostRdy will go low (indicating host port busy) at the end of a host command write or after the second byte of a data write or read. HostRdy will go high (indicating host port ready) when the command or data word has been processed and the chip set is ready for more I/O operations. All host port communications must be made with HostRdy high (indicating ready). Typical busy to ready cycle is 100.0 uSec.
I/O	~HostRead	51	Host Port Read data (input). Used to indicate that a data word is being read from the chip set (low asserts read).
I/O	~HostWrite	47	Host Port Write data (input). Used to indicate that a data word or command is being written to the chip set (low asserts write).
I/O	~HostSlct	48	Host Port Select (input). Used to select the host port for reading or writing operations (low assertion selects port). ~HostSlct must remain inactive (high) when the host port is not in use.
I/O	~HostIntrpt	44	Host Interrupt (output). A low assertion on this pin indicates that a host interrupt condition exists that may require special host action.
I/O	HostData0 HostData1 HostData2 HostData3 HostData4 HostData5 HostData6 HostData7	50 61 53 65 67 62 64 60	Host Port Data 0-7 (bi-directional, tri-stated). These signals form the 8 bit host data port used during communication to/from the chip set. This port is controlled by ~HostSlct, ~HostWrite, ~HostRead and HostCmd.
I/O	CPData4 CPData5 CPData6 CPData7 CPData8 CPData9 CPData10 CPData11	18 5 6 7 8 17 3 1	I/O chip to CP chip data port (bi-directional). These 8 bits are connected to the corresponding Data4-11 pins on the CP chip, and facilitate communication to/from the I/O and CP chips..
I/O	Vcc	4, 21, 25, 38, 55	I/O chip supply voltage pin. All of these pins must be connected to the supply voltage. Supply voltage = 4.75 to 5.25 V
I/O	GND	14, 15, 32, 49, 54, 66	I/O chip ground pin. All of these pins must be connected to the power supply return.

IC	Pin Name	Pin #	Description/Functionality
CP Chip Pinouts			
CP	PWMMag1 PWMMag2 PWMMag3 PWMMag4	8 7 2 1	PWM motor output magnitude signals (output). When the chip set is in PWM output mode these pins provide the Pulse Width Modulated magnitude signal to the motor amplifier. Each PWM signal output directly corresponds to the axis # being driven.
CP	PWMSign1 PWMSign2 PWMSign3 PWMSign4	56 55 54 53	PWM motor output sign signals for axis 1-4 (output). When the chip set is in PWM output mode these pins provide the Pulse Width Modulated sign signal to the motor amplifier for each axis.
CP	PosLimit1 PosLimit2 PosLimit3 PosLimit4	52 45 42 38	Positive limit switch input for axis 1-4. These signals provide directional limit inputs for the positive-side travel limit of the axis. Upon powerup these signals default to "active high" interpretation, but the interpretation can be set explicitly using the SET_LMT_SENSE command. If not used these signals should be tied low for the default interpretation, or tied high if the interpretation is reversed. NOTE: For MC1401A all 4 pins are valid. For MC1201A pins for axes 1 & 2 only are valid. For MC1101A pin for axis 1 only is valid. Invalid axis pins can be left un connected.
CP	NegLimit1 NegLimit2 NegLimit3 NegLimit4	51 44 41 37	Negative limit switch input for axis 1-4. These signals provide directional limit inputs for the negative-side travel limit of the axis. Upon powerup these signals default to "active high" interpretation, but the interpretation can be set explicitly using the SET_LMT_SENSE command. If not used these signals should be tied low for the default interpretation, or tied high if the interpretation is reversed. NOTE: For MC1401A all 4 pins are valid. For MC1201A pins for axes 1 & 2 only are valid. For MC1101A pin for axis 1 only is valid. Invalid axis pins can be left un connected.
CP	DAC16Addr0 DAC16Addr1	30 29	Axis Address used during 16-bit DAC motor command output and parallel-word encoder input (output). When used to encode the motor DAC address or the parallel word encoder address these signals are encoded as follows: Dac16Addr1 Dac16Addr0 Addressed Encoder Low Low Axis 1 Low High Axis 2 High Low Axis 3 High High Axis 4 To read a parallel position word from an external device, the chipset loads DAC16Addr0-1 with the axis # and PosSlct is asserted low. To write a valid DAC motor command value DACSlct (I/O chip) and I/OAddr0-3 (CP chip) must be high, and I/OWrite (CP chip) must be low. The 16 bit DAC data word is organized as follows: High twelve bits are in Data0-11 (CP chip), and low 4 bits are in DACLow0-3 (CP chip).
CP	ClkIn	24	Clock In (input). This pin provides the chip set master clock (Fclk = 25.0 Mhz)
CP	ClkOut	19	Clock Out (output). This pin provides a clock output which is 1/4 the ClkIn frequency. This pin is connected to CPClk (I/O chip).
CP	~Reset	17	Master chip set reset (input). When brought low, this pin resets the chip set to its initial condition. Reset should occur no less than 250 mSec after stable power has been provided to the chip set.
CP	I/OCntrl0 I/OCntrl1 I/OCntrl2 I/OCntrl3	16 18 68 67	I/O chip to CP chip communication control (mixed). These signals provide various inter-chip control signals and are connected to the corresponding CPCntrl0-3 pins on the I/O chip.

IC	Pin Name	Pin #	Description/Functionality
CP	Data0 Data1 Data2 Data3 Data4 Data5 Data6 Data7 Data8 Data9 Data10 Data11	60 59 58 57 50 49 46 43 40 39 36 35	Multi-purpose Data0-11. (Bi-directional). These pins have 3 functions: 1) Pins Data4-11 (8 bits total) are connected to the corresponding CPData4-11 pins on the I/O chip, and are used to communicate between the CP and I/O chips 2) Pins Data0-11 hold the high 12 bits of the DAC output value when the output mode is set to 16-bit DAC. 3) Pins Data0-11 input the high 12 bits of the parallel-word position data (-P version chipsets only).
CP	DACLow0 DACLow1 DACLow2 DACLow3	64 63 62 61	DACLow0-3 (output). These pins hold the lowest 4 bits of the 16 bit DAC output word when DAC16 motor output mode is selected. In addition they input the low 4 bits of the parallel word (-P version chipset only).
CP	I/OAddr0 I/OAddr1 I/OAddr2 I/OAddr3	28 9 6 5	Multi-purpose Address0-3 (output). These pins are connected to the corresponding CPAddr0-3 pins on the I/O chip. They have 2 functions; They provide addressing signals to facilitate communication between the I/O chip and CP chip, and they are used during DAC data decoding.
CP	PosSlct	31	Parallel-word position-input device select (output). This pin selects the parallel word device(s) for reading. To read a parallel position word from an external device, the chipset loads DAC16Addr0-1 with the axis # and PosSlct is asserted low. Note: Only valid for -P parts.
CP	Convert	32	Parallel-word conversion start signal (output). This pin provides a signal which momentarily strobes low at the end of the parallel word read sequence. This signal is useful for starting A/D converters or for synchronizing external latch hardware associated with the parallel-word read circuitry Note: Only valid for -P parts.
CP	I/OWrite	15	Multi-purpose write (output). This pin is connected to CPWrite on the I/O chip. It has 2 functions: 1) It provides a control signal to the I/O chip to facilitate communication between the I/O chip and CP chip. 2) It is used during DAC data decoding.
CP	Vcc	4, 22, 33	CP chip supply voltage pin. All of these pins must be connected to the supply voltage. Supply voltage = 4.75 to 5,.25 V
CP	GND	3, 34	CP chip ground pin. All of these pins must be connected to the power supply return.

Theory of Operations

Internal Block Diagram



The above figure shows an internal block diagram for the MC1401A and MC1401A-P series motion processors.

Each servo axis inputs the actual location of the axis using either incremental encoder signals or signals from a parallel-word input device such as an absolute encoder or resolver. If incremental signals are used then the incoming A, and B quadrature data stream is digitally filtered, and then passed on to a high speed up/down counter. Using the parallel-word interface a direct binary-encoded position of up to 16 bits is read by the chipset. Regardless of the encoder input method this position information is then used to maintain a 32-bit actual axis position counter.

If incremental feedback is used, then the chipset also supports the ability to capture the instantaneous position of each axis using an external trigger signal. The captured value may then later be retrieved by the host processor.

The chipset can be operated in two modes. Closed loop mode, which is the normal operating mode of the chipset, performs trajectory generation and digital servo loop closure. In this mode the motor output value is controlled by the servo filter. Open loop mode, which is used for direct motor-control operations only, does not use the output of the servo filter, and allows the motor output value to be controlled directly by the host processor.

When closed loop mode operations are used the actual axis position is combined with the target position generated by the trajectory profile generator to calculate a position error, which is passed through a PID filter. The resultant value is then output by the chipset to an external amplifier using either PWM or DAC signals.

The following table summarizes the operational parameters of the MC1401-series chipsets.

MC1401-series Chipset Operational Parameters

Available configurations:	4 axes with incremental quadrature encoder input (MC1401A) 2 axes with incremental quadrature input (MC1201A) 1 axis with incremental quadrature input (MC1101A) 4 axes with parallel word encoder input (MC1401A-P) 2 axes with parallel word encoder input (MC1201A-P) 1 axes with parallel word encoder input (MC1101A-P)
Operating modes:	Closed loop (motor command is driven from output of servo filter) Open loop (motor command is driven from user-programmed register)
Position range:	-1,073,741,824 to 1,073,741,823 counts
Velocity range:	-16,384 to 16,383 counts/sample with a resolution of 1/65,536 counts/sample
Acceleration range:	S-curve profile: - 1/2 to + 1/2 counts/sample^2 with a resolution of 1/65,536 counts/sample^2. All others: -16,384 to 16,383 counts/sample^2 with a resolution of 1/65,536 counts/sample^2
Jerk range:	-1/2 to +1/2 counts/sample^3, with a resolution of 1/4,294,967,296 counts/sample^3
Trajectory profile generator modes:	S-curve (host commands final position, max velocity, max acceleration, and jerk) Trapezoidal (host commands final position, max velocity and acceleration) Velocity contouring (host commands max. velocity, acceleration) Electronic Gear (Encoder position of one axis is used as position command for another axis). A total of 2 electronic gears are supported (2 encoders and 1 output each). Not available in MC1101A
Electronic gear ratio range:	32768:1 to 1:32768 (negative and positive direction)
Filter modes:	PID+Vff (standard PID loop plus velocity feedforward plus bias offset)
Filter parameter resolution:	16 bits
Motor output modes:	PWM (10 bits resolution @ 24.5 Khz) DAC 16 bits
Max incremental. encoder rate:	Incremental: 1.0 Mcounts/sec Parallel-word: 80.0 Mcounts/sec
Parallel encoder word size:	16 bits (read in 2 byte reads) (-P version parts only)
Parallel encoder read rate:	10 kHz (reads all axes every 100 uSec)
Servo loop rate range:	standard, -P parts: 100* uSec minimum, 3,276 mSec max.
Max servo loop rate:	standard, -P parts: 100* uSec per enabled axis.
# of limit switches per axis	2 (one for each direction of travel)
# of position capture triggers:	2 (index, home signal)
Capture trigger latency:	160 nSec
# of host commands:	94

** Exact servo loop time is 101.12 uSec, 100 uSec is an approximation*

Trajectory Profile Generation

The trajectory profile generator performs calculations to determine the target position, velocity and acceleration at each servo loop. These calculations are performed taking into account the current profile mode, as well as the current profile parameters set by the host. Four trajectory profile modes are supported:

- S-curve point to point
- Trapezoidal point to point
- Velocity contouring
- Electronic Gear

The commands to select these profile modes are

SET_PRFL_S_CRV (to select the s-curve mode), SET_PRFL_TRAP (to select the trapezoidal mode) SET_PRFL_VEL (to select the velocity contouring mode) and SET_PRFL_GEAR (to select the electronic gear mode).

Throughout this manual various command mnemonics will be shown to clarify chipset usage or provide specific examples. See the Host Communications section for a description of host command nomenclature.

The profile mode may be programmed independently for each axis. For example axis #1 may be in trapezoidal point to point mode while axis #2 is in S-curve point to point.

Generally, the axis should be at rest when switching profile modes. Under certain conditions however, switching into certain profile modes "on-the-fly" is allowed. See specific profile descriptions for details.

S-curve Point to Point

The following table summarizes the host specified profile parameters for the S-curve point to point profile mode:

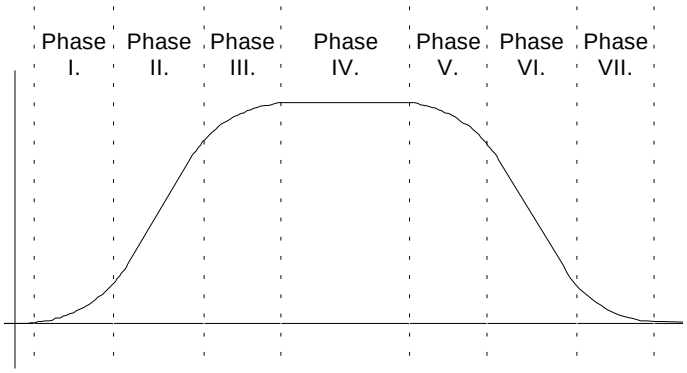
Profile Parameter	Representation & Range	Units
Destination Position	signed 32 bits -1,073,741,824 to 1,073,741,823	counts
Maximum Velocity	unsigned 32 bits* ($1/2^{16}$ scaling) 0 to 1,073,741,823	counts/smpl
Max. Accel.	unsigned 16 bits ** ($1/2^{16}$ scaling) 0 to 32,767	counts/smpl^2
Jerk	unsigned 32 bits *** ($1/2^{32}$ scaling) 0 to 2,147,483,647	counts/smpl^3

* uses $1/2^{16}$ scaling. Chipset expects a 32 bit number which has been scaled by a factor of 65,536 from units of counts/sample time. For example to specify a velocity of 2.75 counts/sample time, 2.75 is multiplied by 65,536 and the result is sent to the chipset as a 32 bit integer (180,224 dec. or 2c000 hex.).

** uses $1/2^{16}$ scaling. Chipset expects a 16 bit number which has been scaled by a factor of 65,536 from units of counts/sample time^2. For example to specify an acceleration of .175 counts/sample time^2, .175 is multiplied by 65,536 and the result is sent to the chipset as a 16 bit integer (11,469 dec. or 2ccd hex).

*** uses $1/2^{32}$ scaling. Chipset expects a 32 bit number which has been scaled by a factor of 4,294,967,296 (2^{32}) from units of counts/sample time^3. For example to specify a jerk value of .0075 counts/sample time^3, .0075 is multiplied by 4,294,967,296 and the result is sent to the chipset as a 32 bit integer (32,212,256 dec. or 1eb8520 hex).

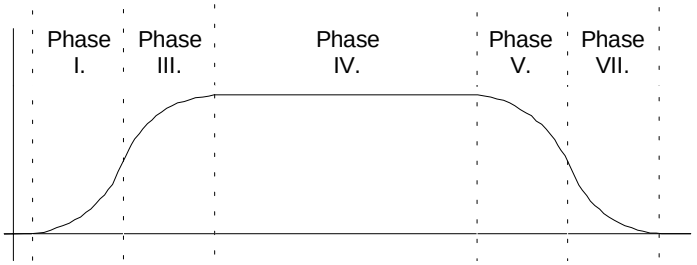
Use the following figure showing a typical S-curve velocity vs. time graph for reference in reading the next section:



S-curve profile

The S-curve profile drives the axis at the specified jerk until the maximum acceleration is reached. (phase I). it will then drive the axis at jerk = 0 (constant acceleration) through phase II. It will then drive the axis at the negative of the specified jerk though phase III, such that the axis reaches the specified maximum velocity with acceleration = 0. This completes the acceleration phase. At the end of the acceleration phase of the move, the velocity will be constant, and the acceleration will be 0. At the appropriate time, the profile will then decelerate (phases V, VI and VII) symmetrically to the acceleration phase such that it arrives at the destination position with acceleration and velocity = 0.

There are several conditions where the actual velocity graph of an S-curve motion will not contain all of the segments shown in the above figure. For example, if the max. acceleration is not reached before the "half-way" point to the max. velocity, then the actual velocity profile will not contain a phase II or a phase VI segment (they will have a duration of 0 servo loops). Such a profile is shown below:



S-curve that doesn't reach max. acceleration

Another such condition is if the position is specified such that max. velocity is not reached. In this case there will be no phase IV, and there may also be no phase II and VI, depending on where the profile is "truncated".

While the S-curve profile is in motion, the user is not allowed to change any of the profile parameters. The axis must be at rest before a new set of profile parameters can be executed. If parameters are changed during motion then a 'command error'

will occur, and all new parameters will be ignored except the position. See the section of this manual entitled "Command Error" for more information..

Before switching to the S-curve point to point profile mode, the axis should be at a complete rest.

When the axis is in the S-curve profile mode, the SET_MAX_ACC command should be used to load the max. acceleration value. The alternate acceleration loading command SET_ACC can not be used.

Trapezoidal Point to Point

The following table summarizes the host specified profile parameters for the trapezoidal point to point profile mode:

Profile Parameter	Representation & Range	Units
Destination Position	signed 32 bits -1,073,741,824 to 1,073,741,823	counts
Maximum Velocity	unsigned 32 bits ($1/2^{16}$ scaling) 0 to 1,073,741,823	counts/smpl
Accel.	unsigned 32 bits ($1/2^{16}$ scaling) 0 to1,073,741,823	counts/smpl^2

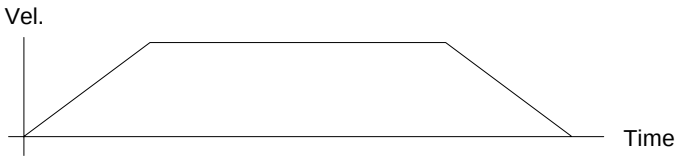
In the trapezoidal point to point profile mode the host specifies a destination position, a maximum velocity, and an acceleration. The trajectory is executed by accelerating at the commanded acceleration to the maximum velocity where it coasts until decelerating such that the destination position is reached with the axis at rest (zero velocity). If it is not possible to reach the maximum velocity (because deceleration must begin) then the velocity profile will have no "coasting" phase. The acceleration rate is the same as the deceleration rate.

A new maximum velocity and destination position can be specified while the axis is in motion. When this occurs the axis will accelerate or decelerate toward the new destination position while attempting to satisfy the new maximum velocity condition.

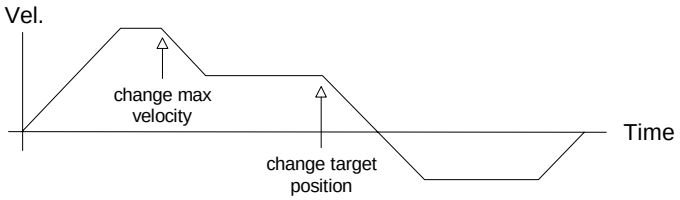
When in Trapezoidal point to point profile mode, to change the acceleration, the axis must come to a complete stop. After this has occurred, a new acceleration value can be loaded. If the acceleration parameter is changed during motion then a 'command error' will occur, and all updated parameters will be ignored except the position. See the section of this manual entitled "Command Errors" for more information.

Before switching to the Trapezoidal point to point profile mode, the axis should be at a complete rest.

The following figure shows a velocity profile for a typical point to point trapezoidal move, along with a more complicated move involving on the fly changes to the maximum velocity and the destination position.



Simple trapezoidal mode motion



Complex trapezoidal mode motion

Velocity Contouring

The following table summarizes the host specified profile parameters for the Velocity contouring profile mode:

Profile Parameter	Representation & Range	Units
Maximum Velocity	unsigned 32 bits ($1/2^{16}$ scaling) 0 to 1,073,741,823	counts/smpl
Acceleration	signed 32 bits* ($1/2^{16}$ scaling) -1,073,741,824 to 1,073,741,823	counts/smpl^2

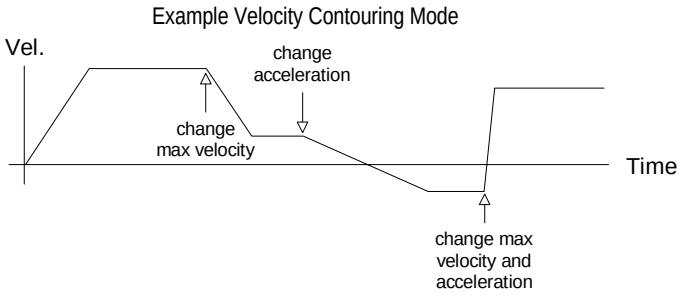
* negative numbers using $1/2^{16}$ scaling are handled no differently than positive numbers. For example if an acceration value of -1.95 counts/sample time^2 is desired, -1.95 is multipled by 65,536 and the result is sent to the chipset (-127,795 dec. or fffe0ccd hex).

In this profile mode the host specifies two parameters, the commanded acceleration, and the maximum velocity. The trajectory is executed by continuously accelerating the axis at the commanded rate until the max. velocity is reached, or until a new acceleration command is given.

The maximum velocity value must always be positive. Motion direction is controlled using the acceleration value. Positive acceleration values result in positive motion, and negative acceleration values result in negative motion.

There are no restrictions on changing the profile parameters on the fly. Note that the motion is not bounded by position however. It is the responsibility of the host to generate acceleration and max. velocity command values which result in safe motion, within acceptable position limits.

The following figure shows a typical velocity profile using this mode.



There are no restrictions on switching the profile mode to velocity contouring while the axis is in motion.

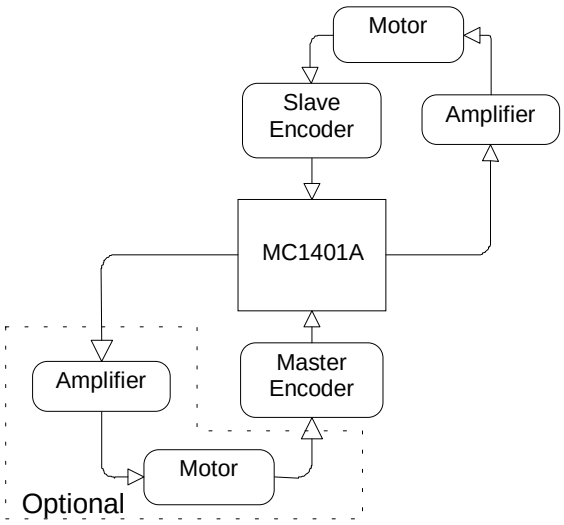
Electronic Gear

The following table summarizes the host specified profile parameters for the electronic gear profile mode:

Profile Parameter	Representation & Range	Units
Gear Ratio	signed 32 bits* ($1/2^{16}$ scaling) -1,073,741,824 to +1,073,741,823	-

* for example to specify a gear ratio of +1.5 to 1 the value 1.5*65,536 is sent to the chipset (98,304). Alternatively to set the gear ratio as -11.39 to 1 the value -11.39*65,536 is sent (-746,455 dec. or fff49c29 hex.).

In this profile mode, the host specifies one parameter, the gear ratio. The target position is generated by applying the specified gear ratio to the current position of another axis, slaving the driven axis to the axis providing the position input. The following figure shows the arrangement for encoders and motor drives in a typical electronic gearing application.



Because a geared axis takes up two encoder channels, the total number of geared axes supported per chipset is 1/2 the total # of axes.

In addition, the master /slave axis combinations are fixed. The following chart shows the allowed master/slave combinations for each chipset:

chipset p/n	gear pairs (master -> slave)
MC1401A	#3 -> #1, #4 -> #2
MC1201A	#2 -> #1
MC1101A	not available

Typically the master axis is only used for encoder input. It is possible however to use the master axis as a normal driven axis by leaving it enabled, and using one of the three trajectory modes other than electronic gear for the master axis. The net effect of this will be to run two servo motors off of the same trajectory profile (although at a different ratio if so programmed).

This configuration is shown in the previous diagram as 'optional' components. Using this configuration the chipset can be made to perform useful functions such as linear interpolation of two axis.

There are no restrictions on changing the gear ratio when the axis is in motion, although care should be taken to select ratios such that safe motion is maintained.

The specified gear ratio (SET_RATIO command) indicates the number of target counts generated per input encoder count. For example a gear ratio of 1.5 means 1.5 counts of the slave axis are generated for every count of the master axis.

There are also no restrictions on changing to this profile mode while the axes is in motion.

Trajectory Control

Normally each of the above trajectory modes will execute the specified trajectory, within the specified parameter limits, until the profile conditions are satisfied. For example for the point-to-point profile modes this means that the profile will move the axis until the final destination position has been reached, at which point the axis will have a velocity of zero.

Halting The Trajectory

In some cases however it is necessary to halt the trajectory manually, for safety reasons, or simply to achieve a particular desired profile. This can be accomplished using one of two methods; abrupt stop, or smooth stop.

Abrupt stops are accomplished using the STOP command. This command instantaneously stops the trajectory generator by setting the velocity of the axis to zero. This control mode is typically used during an emergency stop, when no deceleration phase is desired.

Smooth stops are accomplished using the SMOOTH_STOP command. This command causes the trajectory to decelerate at a rate equal to the specified acceleration rate, until a velocity of zero is reached. In

addition the form of the deceleration is symmetric to the acceleration phase. For example if the profile mode is S-curve, and a SMOOTH_STOP command is given, the profile will decelerate in a manner exactly equal and opposite to the acceleration phase.

The STOP command functions in all profile modes; S-curve point-to-point, Trajectory point-to-point, Velocity Contouring, and Electronic Gear.

The SMOOTH_STOP functions in S-curve point-to-point, Trajectory point-to-point, and Velocity Contouring profiling mode. It does not function in Electronic Gear mode.

Caution should be exercised when using the STOP command due to the large and abrupt changes in motion that may occur.

Motion Complete Status

To simplify the programming of a complete motion system it is convenient to have the motion chipset indicate when a particular profile move has been completed.

This function is provided by two status bits in the chipset's status word (See the section of this manual entitled "Axis Status " for more information on the axis status word). These two bits are called the motion complete bit, and the in-motion bit.

The motion complete bit is controlled interactively by the chipset and the host. After a motion has completed, the chipset sets the motion complete bit on. The host may then poll this bit to determine that motion is complete, or if desired, the host can program the chipset to automatically signal when the motion is complete (using an interrupt). In either case once the host has recognized that the motion has been completed the host clears the motion complete bit, enabling the bit to indicate the end of motion for the next move.

The following list shows the conditions that will cause the motion complete bit to occur:

- Profile has reached the destination position (point-to-point profile modes only)
- Axis trajectory reaches a velocity of zero and the current velocity command is zero
- SMOOTH_STOP command is given and axis trajectory reaches a velocity of zero
- STOP command is given
- Limit switch condition occurs

The in-motion bit is similar to the motion complete bit except that it continuously indicates the status of the axis without interaction with the host. In addition this bit is used exclusively for polled mode operations. It can not cause an interrupt to the host to be generated.

The motion complete and the in-motion indicator bits function in the S-curve point-to-point, Trapezoidal point-to-point, and Velocity Contouring profile modes only. They do not function when the profile mode is set to electronic gearing.

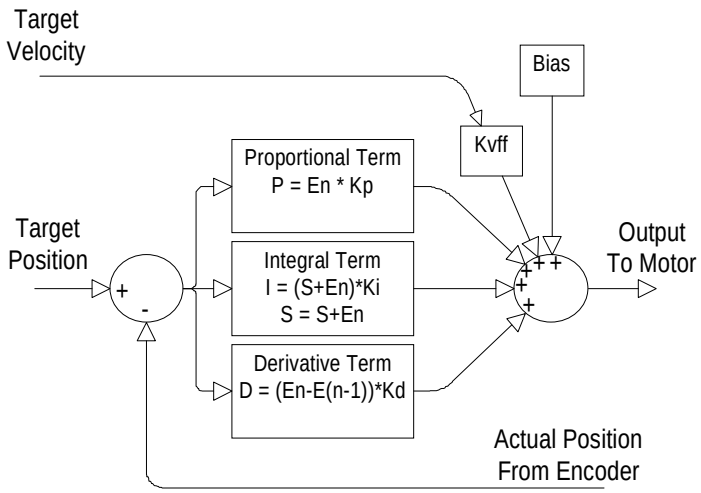
The motion complete and in-motion bits indicate the state of the trajectory generator, not the actual motor. Even if the trajectory generator has completed a motion, the actual axis position may or may not be at rest depending on servo lag, stability, and other system conditions.

Digital Servo Filtering

A digital filter is available for use in calculating a motor output signal. The filter used is a PID (proportional, integral, derivative) filter, along with a velocity feedforward term and a term to adjust the offset, also called the DC bias value. This filter type is known as a PID+Vff filter.

This filter uses programmable gain values which can be tuned to provide excellent control accuracy and stability over a large range of systems.

The following schematic diagram shows the computational flow for the PID+Vff digital filter.



In the PID+Vff filter, the host-specified parameters are:

Symbol	Name	Representation & Range
Kp	Proportional Gain	unsigned 16 bits (0 to 32767)
Ki	Integral Gain	unsigned 16 bits (0 to 32767)
Kd	Derivative Gain	unsigned 16 bits (0 to 32767)
Ilim	Integration Limit	unsigned 16 bits (0 to 32767)
Kvff	Velocity Feedforward gain	unsigned 16 bits (0 to 32767)
MtrBias	DC motor offset	signed 16 bits (-32767 to 32767)

The PID+Vff filter is calculated as follows:

$\text{Position Error}_n = E_n = TP_n - AP_n$

$\text{Output}_n = E_n*Kp + (E_n-E_{n-1})*Kd + \text{Int}(E_n)*Ki/256 + \text{TrgtVel}*Kvff/4 + \text{MtrBias}$

where: E_n is the position error at sample time n

TP_n is the target position at sample time n

AP_n is the actual position at sample time n

$Int(E_n)$ is the integration sum at time sample n

TrgtVel is the current desired velocity in counts/sample

MtrBias is the motor bias value

All multiplied error quantities are saturated to fit within a 16 bit number so that no discontinuities in the output signal occur at values beyond +/- 2^{15}. The integral term is actually maintained to an accuracy of 24 bits, but only the top 16 bits are used. This results in a more useful range for Ki, the integral gain.

The result of this calculation is a 16 bit number. The top 11 bits of this result become the output value if the motor output mode is PWM (1 bit sign, 10 bits magnitude and the entire word is used if the mode is DAC16.

Care should be taken when setting a Ki value for the first time. If the system has already been running and the integration value is unknown, an abrupt 'jump' may occur when the Ki value is set to a non-zero value. To avoid this set the I_LM (integration limit) to 0, set the Ki to the desired value, and then set I_LM to the desired integration limit value. This will 'clear' all prior integration values, smoothly enabling the integration function from that point forward.

Motor Limit

In addition to setting various PID gain values the MC1401A also allows the maximum value output by the filter to be set. This motor limit value is set using the command SET_MTR_LMT. It can be read back using the command GET_MTR_LMT.

The specified motor limit affects the filter output such that if the magnitude of the filter output value (positive as well as negative) exceeds the motor limit than the output value is maintained at the motor limit value. Once the filter output value returns below the specified limit than normal servo filter values are output

The motor limit is only applied during closed loop servo operations, when the servo filter controls the motor output value. It does not affect the output motor value applied during open loop operations

Motor Bias

When using an axis which has a net force in one direction or the other (such as a vertical axis which experiences the force of gravity) the motor bias function of the PID compensation filter may be useful. By adding a constant bias value to the filter output, the overall position error of the filter can be reduced by directly compensating for the constant force.

The motor bias value is set using the command SET_MTR_BIAS. It can be read back using the command GET_MTR_BIAS.

The motor bias value is applied to the filter value at all times when the chipset is in closed loop mode. If the chipset transitions to open loop mode (MTR_OFF command is given or a motion error occurs with automatic motor stop enabled) than the motor bias value will be output to the motor by itself, until a manual motor command value is given (SET_MTR_CMD command), at which point this host-provided motor command value, without modification by the motor bias value, becomes the active motor command.

The following example illustrates this: If the chipset is in closed loop mode with a motor bias value of 100, then if a motor off command is given (MTR_OFF), then the output motor command will be exactly 100. Thereafter if the host sends a manual motor command of 200 (using the SET_MTR_CMD command), then the output motor command will be 200. At this instant the chipset is returned to closed loop mode however (MTR_ON command), the motor bias value will again be added to the filter output.

If the specified motor bias value does not properly compensate for the offsetting DC load, then after a motion error with automatic motor stop enabled or after a MTR_OFF command the axis may move suddenly in one direction or another. It is the responsibility of the host to select a motor bias value such that safe motion is maintained.

Parameter Loading & Updating

Various profile & servo parameters must be specified by the host for an axis to be controlled in the desired manner. To facilitate precisely synchronized motion, these parameters and related control commands are loaded into the chip using a double-buffered scheme. In this scheme, the parameters and action commands being loaded are not acted upon (copied from the double-buffered to the active registers) until an update signal is given.

This update signal can consist of either a "manual" update command, or one of several conditional breakpoints. Whichever update method is used, at the time the update occurs, all of the double buffered registers and commands will be copied to the active registers. Conversely, before the update occurs, loading the double-buffered registers or executing the double buffered commands will have no effect on the system behavior.

The double buffered registers are listed below.

Register Name	Command to set
destination position	SET_POS
maximum velocity	SET_VEL
acceleration	SET_ACC
maximum acceleration	SET_MAX_ACC
jerk	SET_JERK
ratio	SET_RATIO
Kp	SET_KP
Ki	SET_KI
Kd	SET_KD
Kvff	SET_KVFF
Integration limit	SET_I_LM

The double-buffered commands are: STOP, SMOOTH_STOP, and SYNCH_PRFL.

Manual Update

There are two methods of manually updating the double-buffered parameters, one for a single axis instantaneous update and one for a multiple-axis update.

The single axis instantaneous update, which is specified using the UPDATE command, forces the parameters for the current axis to be updated at the next servo loop.

The multiple axis instantaneous update, which is specified using the MULTI_UPDATE command, causes multiple axes to be updated simultaneously. This can be useful when synchronized multi-axis profiling is desired. This command takes a 1 word argument which consists of a bit mask, with 1 bit assigned to each axis. Executing this command has the same affect as instantaneously switching to each desired axes, and executing an UPDATE command.

Breakpoints

A breakpoint is a convenient way of programming a profile or filter change upon some specific condition. There are two types of breakpoints, those that have a 32-bit comparitor value associated with them and those that do not. For those that have the comparitor, a 32-bit comparitor value is loaded into the breakpoint compare register first, and then one of the breakpoint conditions is specified. For those breakpoint modes without associated comparitor values only the breakpoint condition needs to be specified.

The double-buffered registers and commands will be updated upon satisfaction of the specified breakpoint condition.

Here is a list of all of the available breakpoint conditions.

Positive **Target** Position Breakpoint

A 32 bit position breakpoint can be specified which will result in the parameters being updated when the current target position (the instantaneous desired axis position output from the profile generator) equals or exceeds the specified breakpoint value. This breakpoint is set using the SET_POS_BRK command.

Negative **Target** Position Breakpoint:.

A 32 bit position breakpoint can be specified which will result in the parameters being updated when the current target position (the instantaneous desired axis position output from the profile generator) equals or is less than the specified breakpoint value.This breakpoint is set using the SET_NEG_BRK command.

Positive **Actual** Position Breakpoint

A 32 bit position breakpoint can be specified which will result in the parameters being updated when the current actual position (the instantaneous position of the actual axis hardware) equals or exceeds the specified breakpoint value.This breakpoint is set using the SET_ACTL_POS_BRK command.

Negative **Actual** Position Breakpoint:.

A 32 bit position breakpoint can be specified which will result in the parameters being updated when the current actual position (the instantaneous position of the actual axis hardware) equals or is less than the specified breakpoint value.This breakpoint is set using the SET_ACTL_NEG_BRK command.

Time Breakpoint

A 32 bit time breakpoint can be specified which will result in the parameters being updated when the # of servo loops executed since chip set reset (the current chip set time) is equal to the time breakpoint value.The # of servo loops continuously increases until it rolls over from 2^{32} - 1 back to 0.The time breakpoint is set using the SET_TIME_BRK command.

Motion Complete Breakpoint

A breakpoint can be specified which will result in the parameters being updated when the previous motion has been completed (motion complete bit is set). When using this breakpoint no 32 bit compare value is required.

External Breakpoint

A breakpoint can be specified which will result in the parameters being updated when the home signal of the corresponding axis becomes active (low). When using this breakpoint no 32 bit compare value is required. This breakpoint is useful whenever it is desired that an external signal starts, stops, or otherwise modifies the profile movement.

Normally, whenever one of these conditions has been programmed and the condition occurs, the double-buffered parameters will automatically be shifted to the active registers. There is a mechanism to disable this "automatic update upon breakpoint" however. This is discussed in the next section.

The above breakpoint modes are particularly useful during multi-axis motion. This is because the next profile commands (set of host-specified trajectory commands) can be pre-loaded and activated at the precise position or time required, with no delay incurred to send an update or load parameters command.

After a breakpoint condition has been satisfied it is no longer active. To set up another breakpoint condition, a new one must be explicitly set by the host.

The double-buffered registers that are shifted to the active registers do not change upon being shifted, only the active registers change.

Except for the MULTI_AXIS command, parameter loading and updating is controlled individually for each axis. In addition each axis has a separate 32-bit breakpoint register, and can be set to various individual breakpoint conditions.

External Breakpoints and Homing

By connecting a home input sensor to the home signal input of the MC1401-series chipsets it is possible to cause the chipset to halt a motion at the moment it receives the home signal. This capability makes it ideal for performing a home sequence. The following host I/O sequence illustrates this:

```
GET_HOME            ; check to make sure axis not already at
                    ; home. If so, then a 'reverse' move must
                    ; be made to retract axis from home switch.
                    ; This 'reverse' sequence is not indicated
                    ;  here for simplicity sake
SET_CAPT_HOME       ; set trigger capture to home signal
CLR_STATUS          ; clear status register
GET_CAPT            ; clear out any previous captures
SET_POS 12345       ; load home move parameters
SET_VEL 23456
SET_ACC 345
UPDATE              ; start home move
SET_EXT_BRK         ; initiate external breakpoint mode
SMOOTH_STOP         ; load (but do not update) a stop command
```

This sequence will start a homing move which will come to a smooth stop as soon as the axis encounters the home switch. In addition the capture register will be loaded with the exact location of the home sensor. This register can be used in conjunction with the GET_ACTL_POS and SET_ACTL_POS commands to set the position to any desired location. For example if it is desired that the home sensor be located at a position of 0, then the new position should be set to the current actual axis position minus the capture position. This is shown in the sequence below, which should be executed after the axis has come to a stop.

```
current_pos = GET_ACTL_POS
capture_pos = GET_CAPT
SET_ACTL_POS   (current _pos - capture_pos)
```

As is the case for all of the breakpoint modes, the external breakpoint can not only be used to stop an ongoing move, but to start or otherwise modify a move as well. This flexibility makes it well suited for applications such as cut-on-the-fly or other externally-initiated motions.

Disabling Automatic Profile Update

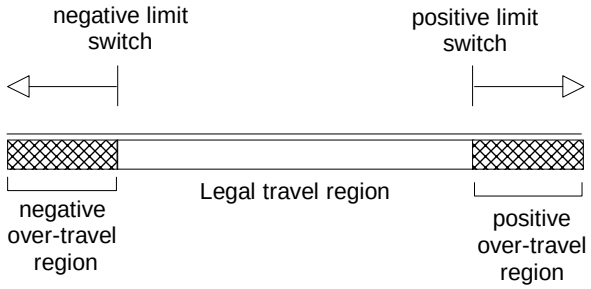
Normally, when a breakpoint condition has been satisfied, it causes the profile & filter parameters to be automatically updated. For certain types of profiles however, it may be desirable to still use the breakpoint mechanism (to allow it to generate a host interrupt for example), but not to have the profile update.

Whether the profiles are automatically updated or not for a given axis is controlled by the commands SET_AUTO_UPDATE_ON and SET_AUTO_UPDATE_OFF. When auto update is set to on, the breakpoint/profile mechanism behaves as described above. When set to off, upon a breakpoint condition, no profile update will occur. When in this mode the only way to update the profile is to use the UPDATE command or the MULTI_UPDATE command.

Travel Limit Switches

The MC1401-series chipsets support motion travel limit switches that can be used to automatically recognize an "end of travel" condition.

The following figure shows a schematic representation of an axis with travel-limit switches installed, indicating the "legal" motion area and the over-travel regions.



There are two primary services that the MC1401A provides in connection with the over-travel limit switch inputs:

1) The host can be automatically notified that an axis has entered an over-travel condition, allowing the host to take appropriate special action to manage the over-travel condition.

2) Upon entering an over-travel condition, the trajectory generator will automatically be halted, so that the motor does not travel further into the over travel region.

To recover from an over-travel condition the corresponding status bits in the status word should be reset (see the section of this manual on axis status for details on resetting status word bits). Once this has been performed the host can command a trajectory move to bring the axis out of the over-travel region.

The over-travel detector is 're-armed' when the axis exits the over travel condition.
Only one over-travel signal can be processed at a time. For example if the negative over travel switch becomes active, the corresponding status bits must be cleared, and the axis moved

into the legal travel range before a positive over travel switch will be recognized.

Motion Error Detection and Recovery

Under certain circumstances, the actual axis position may differ from the target (desired) axis position by an excessive amount. Such an excessive position error often indicates a potentially dangerous condition such as motor or encoder failure, or excessive mechanical friction.

To detect this condition, thereby increasing safety and equipment longevity, the MC1401A includes a programmable maximum position error.

The maximum position error is set using the command SET_POS_ERR, and read back using the command GET_POS_ERR. To determine whether a motion error has occurred the maximum position error is continuously compared against the actual position error. If the maximum position error value is exceeded, then the axis is said to be in "motion error". When this occurs the motion error bit in the axis status word is set, and the axis motor may be turned off, depending on the state of the automatic motor shutdown mode (see SET_AUTO_STOP_ON and SET_AUTO_STOP_OFF host command descriptions).

At the moment motion error occurs several events occur simultaneously. The following list describes these events:

- Motion Error bit of the axis status word is set
- If automatic motor stop is enabled the motor is set off (set to open loop control mode)
- If the automatic stop is enabled the trajectory generator is stopped

If the automatic motor stop mode is not set than only the motion error status bit is set.

Recovering From A Motion Error

To recover from a motion error which results in the motor being turned off, the following sequence should be performed:

1) Determine cause of motion error and correct problem (this may require human intervention).

2) Turn motor on using MTR_ON command.

After the above sequence, the axis will be servoing correctly, and the profile generator will be at rest, ready for another move.

Axis Timing

Each of the axes on the MC1401-series chipsets can be individually enabled or disabled *. Each enabled axis receives a "time slice" of the available computation power of the CP chip.

> * This is true even for the MC1101A, which has only one axis, although generally disabling the only axis has no utility.

Disabled axes do not use any computing power; thus it is possible to increase the servo loop rate when less than the supported number of axes are used.

To set the servo loop rate to a value other than the default value, use the command SET_SMPL_TIME. The value GET_SMPL_TIME can be used to read this value back from the chipset.

The formula for determining the minimum loop time (maximum sampling frequency) for a given number of enabled axis is 100 uSec for each enabled axis.

The following table summarizes the minimum loop time for the standard and -P parts.

# Axes enabled	Minimum time
4	400
3	300
2	200
1	100

The loop time is specified to the chip set as an integer number from 1 to 32,767 with units of 100 uSec For example to set the standard MC1401A part for the minimum loop time with two axes enabled, a value of 2 (2*100 = 200 uSec) would be sent to the chipset using the SET_SMPL_TIME command.

Changing the loop time to increase servo loop rate when axes are disabled is not required. It is available as an option if greater loop speed is desired.

The servo loop rate should generally not be changed while axes are in motion.

It is the responsibility of the host to insure that the servo loop rate that is commanded can be supported for the # of axes enabled. Failure to observe the maximums specified in the above table may result in unexpected axis behavior.

Host Communications

Electrical Interface

The MC1401A communicates to the host processor via an 8-bit bi-directional data port. 5* additional signals are used to synchronize communication operations. The following table gives a brief description of the control signals used during host communication:

Signal	Description
~HostSlct	Selects the host port for operations
~HostWrite	Writes a byte of data (or a command) to the chip set. A write operation can only occur when the ready/busy line indicates ready
~HostRead	Reads a byte of data from the chip set. A read operation can only occur when the ready/busy line indicates ready
HostCmd	Is asserted in combination with the HostWrite signal when a command is being written to the chip set.
HostRdy	Indicates to the host that the host port is available for operations

*An additional signal, HostIntrpt is provided to the host. This signal is not used directly in communication operations, and is discussed in a separate section

Three types of hardware communication operations are possible between the host processor and the chip set; Command Write, Data Write and Data Read. Each of these operations transfers information to or from the chip set, and is coordinated using the 5 control signals listed above.

A **Command Write** operation involves the transfer of a single byte command to the chip set. To perform a write command operation, the desired command is loaded on the 8 data pins and ~HostSlct and ~HostWrite are brought low, while HostCmd is brought high.

A **Data Write** operation involves the transfer of two bytes of data (1 word) to the chip set. To transfer the first byte (high byte), the desired data byte is loaded on the 8 data bits and ~HostSlct, ~HostWrite and HostCmd are brought low. The HostWrite signal is then brought high to end the transfer of the first byte. To transfer the second byte (low byte), the desired data byte is loaded on the 8 data bits and ~HostSlct, ~HostWrite and HostCmd are again brought low.

A **Data Read** operation involves the transfer of two bytes of data (1 word) from the chip set to the host. To transfer the first (high) byte, ~HostSlct, ~HostRead,and ~HostCmd signals should be brought low, and the data should be read from the 8 bit data bus. The HostRead signal is then brought high to end the transfer of the first byte. To transfer the second (low) byte, ~HostSlct, ~HostRead, and ~HostCmd are again brought low and the data should be read from the data bus.

Before any command write, data write or data read operations are performed, the user must check that the HostRdy signal indicates ready. After a command write, or after the second byte of each read or write, this signal will go busy. It will return to ready when the chipset can receive another I/O operation.

For more specific electrical information on the host interface operations, see the pin descriptions and the timing diagram.

Packet Format

All communications to/from the chip set take the form of packets. A packet is a sequence of transfers to/from the host resulting in a chip set action or data transfer. Packets can consist of a command with no data (Dataless Command), a command with associated data that is written to the chip set (Write Command) or a command with associated data that is read from the chip set (Read Command).

All commands with associated data (read or write) have either 1 or 2 words of data. See the host commands section for more information on the length of specific commands.

If a read or a write command has 2 words of associated data (a 32 bit quantity) the high word is loaded/read first, and the low word is loaded/read second.

The following charts show the generic command packet sequence for a Dataless Command, a Write Command, and a Read Command. The hardware communication operation described in the previous section to accomplish each type of transfer is shown in the left column.

Dataless Command

Time	-->	-->	-->	-->
Cmd Write:	**Cmd byte**			
Data Write:				
Data Read:		**[pkt checksum]**		

Write Command

Time	-->	-->	-->	-->
Cmd Write:	**Cmd byte**			
Data Write:		**word 1 [word 2]**		
Data Read:				**[pkt checksum]**

Read Command

Time	-->	-->	-->	->
Cmd Write:	**Cmd byte**			
Data Write:				
Data Read:		**Word 1 [Word 2] [pkt checksum]**		

[ ] Indicates an optional operation

Packet Checksum

The above charts show that at the end of each packet, a checksum word is available for reading.

Although host to chip set I/O operations are extremely reliable, for critical applications the checksum can provide a further reliability enhancement (particularly in very noisy electrical environments, or when the communication signals are routed over a media that may have data losses such as a serial link).

This checksum consists of a 16-bit sum of all previous communications that have occurred for the associated command. The command byte is included in the low byte of the 1st checksum word (high byte set to 0). Data words are added as is to the checksum value.

For example if a SET_VEL command (which takes two 16-bit words of data) was sent with a data value of fedcba98 (hex), the checksum would be:

```
  0011     (code for SET_VEL command)
+ fedc     (high data word)
+ ba98     (low data word)
----------
1b985
check sum = b985 (keep bottom 16 bits only)
```

Reading the checksum is optional. Recovering from an incorrect packet transfer (bad checksum) will depend on the nature of the packet. Read and Write operations can always be re-transmitted, while a command resulting in an action may or may not be re-tried, depending on the command and the state of the axis.

Illegal Commands

When the MC1401A receives a command that is illegal (see host command summary for listing of illegal commands), it will signal this condition by returning a checksum of 0, regardless of the illegal command value or the value of any subsequent data written to the host as part of the illegal command sequence.

In this manner the host processor checksum can be used to detect communication problems as well as an illegal command sequence, resulting in a simplification of the host processor communication code.

Command Errors

If a command, or command sequence is sent to the chipset that is not valid at a given operating condition of the chipset, but is valid at other times, this command is said to cause a command error.

When a command error occurs this condition is indicated by the 'command error' bit of the axis status word (See the section of this manual entitled "Axis Status" for more information on the axis status word).

The following list indicates the command sequences that result in a command error:

- Changing and updating the acceleration (SET_ACC, UPDATE) when in the trapezoidal profile mode and when the axis trajectory is still in motion.

- Changing and updating either the velocity, max acceleration, or jerk (SET_VEL or SET_MAX_ACC or SET_JERK, and then UPDATE) when in the S-curve profiling mode and when the trajectory is in motion

- Commanding a move in the same direction as a limit switch condition when in Trapezoidal or S-curve profile mode. For example if travelling in the positive direction and a limit switch is encountered, a further move in the positive direction will be ignored and a command error will be generated.

Once a command error occurs the command error bit is set, and the illegal profile changes are ignored. If additional parameters are also changed such as position or any filter values as part of the same UPDATE command then these parameters will not be rejected at the time of the UPDATE, and they will become the active values.

Axis Addressing

Most chip set commands alter the parameters or the operating state of one axis at a time. In this way each axis can be controlled separately. To facilitate efficient communication for these types of commands, the chip set maintains the concept of a current axis number, which can be set explicitly by the host. After setting the current axis number, commands that are addressed to the current axis will automatically operate on this axis. The current axis number will stay the same until it is changed by one of the commands that alter the current axis number.

As an illustration of this, the following sequence sets the current axis to #3, updates some motion parameters, and switches to axis #1, and alters some other motion parameters.

SET_3		-> sets current axis to #3
SET_POS	**02345678**	-> loads current axis (#3) dest. position with value of 2345678
UPDATE		-> causes the loaded value to take effect (axis # 3)
SET_1		-> sets current axis to #1
SET_ACCEL	**00001234**	-> loads current axis (#1) with acceleration value 1234
UPDATE		-> causes the loaded value to take effect (axis # 1)

Axis Status

The MC1401A supports a status word for each axis, which contains various information about the state of the axis.

The status word is a 16-bit register which can be queried using the command GET_STATUS. It contains the following information (Bit encoding is 0 = LSB, 15 = MSB):

Bit #	Description
0	Motion complete flag. This bit is set (1) when the axis trajectory has completed. This flag is only valid for the S-curve and trapezoidal, and velocity contouring profile modes.
1	Wrap-around condition flag. This bit is set (1) when the axis has reached the end of its travel range,and has wrapped to the other end of the travel range. Specifically, when travelling in a positive direction past the position +1,073,741,823, the axis will wrap to position -1,073,741,824, and vice-versa.
2	Breakpoint reached flag. This bit is set (1) when one of the breakpoint conditions has occurred.
3	Index pulse received flag. This bit is set (1) when an index pulse has been received.
4	Motion error flag. This bit is set (1) when the position error is exceeded (see filter section for more information). This bit can only be reset when the axis is no longer in a motion error condition
5	Positive limit switch flag. This bit is set (1) when the positive limit switch goes active.
6	Negative limit switch flag. This bit is set (1) when the negative limit switch goes active.
7	Command error flag. This bit is set (1) when a command error has occurred.
8	motor on/off status (1 indicates motor is on, 0 indicates motor is off).
9	axis on/off status (1 indicates on, 0 indicates off).
10	In-motion flag. This bit continuously indicates whether or not the axis trajectory is in motion. This bit is set (1) when the axis is in motion, and cleared (0) when the axis trajectory is not in motion.
11	reserved (may contain 0 or 1)
12,13	current axis # (13 bit = high bit, 12 bit = low bit). Therefore axis encoding is as follows: Bit 13 Bit12 Axis 0 0 1 0 1 2 1 0 3 1 1 4
14,15	reserved (may contain 0 or 1)

Bits 8-10 and 12-13 indicate continuous status information, and do not need to be reset by the host.

Bits 0-7 of the status word indicate various status flags that can also generate host interrupts (see next section for details). These flags are set by the chipset, and must be reset by the host (They will not be cleared by the chipset).

Bits 0-7 of the status word operate using a set/reset mechanism. These flags are set by the chipset, and must be reset by the host. If they are not reset by the host they will remain active indefinitely.

Miscellaneous Mode Status Word

There is another status word available that indicates the current status of various mode settings or conditions.

The miscellaneous mode status word is a 16-bit register which can be queried using the command GET_MODE. It contains the following information (Bit encoding is 0 = LSB, 15 = MSB):

Bit #	Description
0-6	Used internally by chipset. Contains no host-useable information.
7	Stop on motion error mode flag. This bit indicates the state of the stop on motion error mode, set by the commands SET_AUTO_STOP_ON and SET_AUTO_STOP_OFF. A 1 indicates auto stop is on.
8-9	Used internally by chipset. Contains no host-useable information.
10	Auto update flag. This bit indicates the state of the auto update mode, set using the commands SET_AUTO_UPDATE_ON and SET_AUTO_UPDATE_OFF. A 1 indicates that auto update is disabled.
11,12	Trajectory generator mode. This bit indicates the mode of the trajectory generator, set using the commands SET_PRFL_S_CRV, SET_PRFL_TRAP, SET_PRFL_VEL, SET_PRFL_GEAR. The encoding is as follows: Bit 12 Bit11 Profile Mode 0 0 trapezoidal 0 1 velocity contouring 1 0 s-curve 1 1 electronic gear
13-15	Phase #. These bits indicate the current phase # of the S-curve profile (only valid if the current profile mode is S-curve). A 0 indicates that the profile has not started yet, and phases 1-7 indicate the phase #'s corresponding to the phases described in the S-curve profiling mode. The 3-bit phase # word is encoded bit 15 MSB, and bit 13 LSB.

Host Interrupts

In many situations, during axis motion or at other times, it is useful to have the chip set signal the host that a special condition has occurred. This is generally more convenient and efficient than having the host poll the chip set for various possible conditions. This chip set-initiated signal is known as a host interrupt.

Several chip set conditions may occur that can result in the generation of a host interrupt. Whether these conditions in fact interrupt the host is controllable for each condition and for each axis. The mechanism used to control each condition is a mask register.

The interrupt conditions correspond to bits 0-7 of the status register (the axis event flags), described in the previous section. These conditions are summarized below:

Motion Complete	Occurs when the profile is complete
Wrap-around condition	Occurs when the axis position wraps.
Break Point Reached	Occurs when a breakpoint condition has been satisfied.
Position Capture Received	Occurs when the encoder index pulse or home pulse has been captured
Motion Error	Occurs when the maximum position error set for a particular axis has been exceeded
Negative Limit Switch	Occurs when the negative over-travel limit switch is active
Positive Limit Switch	Occurs when the positive over travel limit switch is active
Command Error	Occurs when a host communication sequence causes a command error condition

When one of these interrupt conditions occur for a particular axis, the host interrupt line is made active. At this point the host can respond to the interrupt (although the current I/O operation should be completed), but it is not required to do so

When the host has completed processing the interrupt, it sends a command that clears the interrupt conditions for a particular axis, the RST_INTRPT command.

This command includes a "clearing mask" as an argument, which allows one interrupt to be cleared at a time.

Bits cleared by the RST_INTRPT command are the exact same bits as those cleared by non-interrupt commands such as RST_STATUS and CLR_STATUS. In each case the bits affected are the status word bits 0-7.

Interrupts occur for a particular axis. If the user is currently programming parameters on axis #1 and an interrupt occurs on axis #3, it is the host's responsibility to change axis number to 3 if this is the appropriate response to an interrupt on that axis. If more than one axis interrupt condition becomes active at exactly the same time, then the axis with the lowest number will generate the interrupt first.

The following host commands are used in managing interrupts:
(See Host Command reference for complete information)

SET_INTRPT_MASK	Sets the interrupt conditions mask
GET_INTRPT	Returns the status of the interrupting axis (including the interrupting axis #). The current axis # is not altered by this command
SET_I	Changes the current axis # to the interrupting axis. This is a 'time saver' command which performs the dual operations of getting the interrupting axis # and switching to that axis in one command.
RST_INTRPT	Clears particular conditions for the interrupting axis. The current axis # is not altered by this command.

To facilitate determining the nature of the interrupt, the status register holds the axis #, allowing the interrupting axis # to be determined.

The following represents a typical sequence of interrupt conditions and host responses. Assume for the purposes of this example that an axis (not the current axis) has hit a "hard stop" causing an essentially instantaneous motion error, as well as a positive limit switch trip. Also assume that the interrupt mask for this axis was set so that either motion errors or limit switch trips will cause an interrupt

Event	Host action
motion Error & limit switch trip generates interrupt	host sends SET_I command
interrupting axis status returned by chipset, current axis set to interrupting axis.	host detects motion error & limit switch flags are set, recovers from motion error first. host sends: RST_INTRPT 00EF, clearing motion error bit
chipset clears motion error bit and disables host interrupt line	-
Because limit switch interrupt is still active chipset immediately generates interrupt for limit switch	host sends SET_I command
interrupting axis status returned by chipset, current axis set to interrupting axis.	host detects that neg. limit switch trip flag is set, performs recovery for limit switch trip. host sends RST_INTRPT 00DF, clearing pos. limit switch bit
chipset clears limit switch bit and disables host interrupt line	-

At the end of this sequence, all status bits are clear, the interrupt line is inactive, and no interrupts are pending.

Note that it is not required to process multiple interrupts separately (as is shown in the example). It is perfectly valid to process 2 or more interrupt conditions at the same time, and to then send a RST_INTRPT command with a mask that clears multiple bits at the same time.

The RST_INTRPT and GET_I commands are only effective when there is an interrupt present. If no interrupt is present than alternative 'polled-mode' commands such as RST_STATUS or GET_STATUS should be used.

Encoder Position Feedback

The MC1401-series of chipsets support two modes for inputting motor position information to the chipset, although they are supported in separate chipset products These modes are listed below:

- Incremental encoder (standard parts)
- parallel-word device (-P parts)

To operate the MC1401A in one encoder mode or another, the correct part # must be installed.

Incremental Encoder Input

For standard (no dash) parts an incremental encoder is used for input. In this mode four position input and control signals are supported:

- A quadrature channel
- B quadrature channel
- Index pulse
- Home signal

Each quadrature channel consists of a square wave offset 90 deg. from the other. Positive motion consists of the A channel leading the B channel by 90 deg., and negative motion consists of the A channel lagging the B channel by 90 deg. For each full phase of one channel, four resolved quadrature counts will occur, resulting in a 4 to 1 resolution enhancement over the basic channel resolution.

The index pulse is typically located on the encoder and will be active once per revolution. The chip set recognizes that an index has occurred (i.e. when the 32-bit index location is captured) when the index signal transitions low, followed by the A, B channels transitioning low.

Encoder Filtering

To enhance reliability of the received encoder information the MC1401A provides digital filtering of the quadrature data lines (A and B quadrature count) as well as the index and home signals.

For all of these signals a valid high or low condition is recognized only when the condition has been maintained for 3 clock cycles of 160 nSec each (total required duration of 480 nSec)

For example if a brief spurious noise signal on one of the lines occurs for 300 nSec, then this noise will be rejected until a valid state change lasting over 480nSec occurs.

Although this digital filtering scheme can dramatically increase the overall reliability of the quadrature data, to achieve the highest possible reliability additional techniques may be required, such as differential line drivers/receivers, or analog filtering. Whether these additional schemes are required depends on the specific system, and the amount and type of noise sources.

High Speed Position Capture

Each axis of the MC1401A supports a high speed position capture register that allows the current axis location to be saved using an external trigger signal. When in incremental encoder mode, The MC1401A allows either the index signal or the home signal to be used as the capture trigger. These two input triggers differ however in that the index signal will cause a position capture when it, as well as the A and B index signals, transition low, while the home signal will result in a capture when it alone goes low.

The commands SET_CAPT_INDEX and SET_CAPT_HOME select which input signal is used.

After an index or home signal has been captured by the MC1401A, the index value must be read by the host processor before another position capture can occur. In addition, if the index signal is being used as the trigger, the index signal,along with the A and B quadrature signals, must transition high before another index pulse can be registered.

The captured position is equal to the axis position at the moment the trigger pulse was encountered (including other required signal states defined above) +/- 1 count. Note that the capture register is located in hardware. Its accuracy is therefore not affected by the velocity of the axis.

Parallel-Word Device Input

For -P parts, a parallel-word device input mechanism is provided which can be used with a large variety of devices including the following:

- Resolvers (after Resolver to Digital conversion)
- Absolute optical encoders
- Laser interferometers with parallel word read-out
- Incremental encoders with external quadrature decoder circuit
- A/D converters reading an analog feedback signal

In this encoder input mode, the MC1401A reads the encoder position directly through its external bus, and inputs the absolute word as a 16 bit value.

Depending on the nature of the feedback device fewer than 16 bits of resolution may be available, in which case the unused high order data bits should be arranged to indicate a 0 value when read by the MC1401A.

The value input by the chipset should be binary coded. The MC1401A assumes that the position data provided by the external device is a two-s complemented signed number. If the value returned instead ranges from 0 to 2^n-1 where n is the number of bits provided by the feedback

device than the only difference in behavior will be the interpretation of the start location, which will be 'shifted' by 1/2 the full scale feedback range. If desired this initial position may be altered using the SET_ACTL_POS command.

In addition to supporting position tracking across the full numeric feedback range the MC1401A also provides the ability to support multi-turn systems. The MC1401A continuously examines the parallel encoder values being read in, and automatically recognizes an axis "wrap" condition, whether from largest encoder value to smallest encoder value (negative wrap) or from smallest value to largest value (positive wrap).

Using this "virtual" multi turn counter, the MC1401A continuously maintains the axis location to a full 32 bits. Of course if the axis does not wrap around (non multi-turn system), the range will stay within a 16 bit value.

To facilitate the multi-turn mechanism, the host must specify the number of counts per rotation to the chipset. This should be done at setup time using the command SET_CNTS. The actual counts per rotation value specified to the chipset is 1/2 the number of counts per motor rotation. See the Host Command section of this manual for details.

For systems that use a position counter with a modulo smaller than the encoder counts per revolution, set the counts/rev value equal to the position counter size. For example, if a rotary laser interferometer is being used which provides a 16 bit output value, but provides 16,777,216 counts per revolution, use a counts/rev value of 32,768 ($2^{16}/2$)

For the multi-turn mechanism to work properly the axis can not rotate faster than 2,000 revolutions per second. Also, the input word must be binary-coded. Grey-encoded input words, or other encoding formats must be converted external to the chipset.

Parallel-Word Device Interfacing

In the parallel-word position input mode, the following signals are used by the chipset:

Signal Name	Comments
Data0-11	High 12 bits of external data bus signals used to input position data.
DACLow0-3	Low 4 bits of external data bus signals used to input position data.
PosSlct	Signal set by chipset indicating data is being read from parallel-word device
DAC16Addr0-1	Axis # address signals set by chipset used to select correct position input device
Convert	'Start conversion' signal strobed by chipset after all position data has been input. Typically used to start another A/D conversion cycle so data is ready by next read.

To read a 16-bit word from a parallel-word device, the chipset sets up the DAC16Addr0-1 signals for the selected axis number and brings PosSlct low (selecting the position input operation). The chipset then reads in the 16 bit data word. The chipset then de-asserts PosSlct and any asserted address bits and starts the above cycle again, for up to a total of four axes.

At the end of the position reads the Convert signal is briefly strobed low. This signal is typically used to synchronize external latch hardware, or to start an A/D convert cycle.

For more information on the parallel-word read signal timing & conditions, see the pin descriptions and interface timing diagram.

Although the chipset will attempt to read all of the parallel-word devices whether or not the axis is enabled, unused axes can be left un-interfaced.

The axis read sequence is #1, 2, 4, 3.

No high-speed position capture is supported in the parallel-word device input mode. Therefore the index and home signals, as well as the quadrature A and B signals are unused in this mode.

Motor Outputs

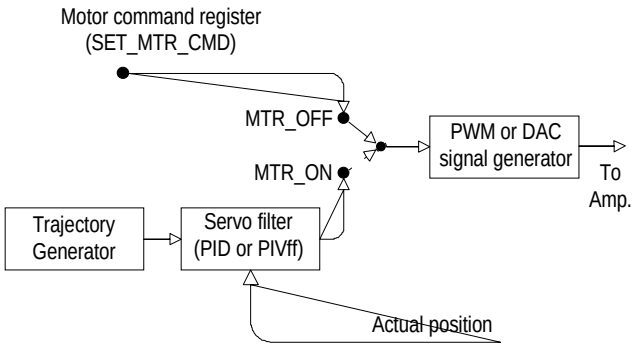
The MC1401-series of chipsets provides two motor amplifier interfaces:

- 10-bit 24.5 Khz PWM interface
- 16-bit DAC output.

For each chipset the supported output modes are host-selectable. The selected method affects all axes (motor output mode is **not** individually programmable for each axis). The host commands to select these output modes are SET_OUTPUT_PWM (to select PWM mode) and SET_OUTPUT_DAC16 (to select 16 bit DAC mode).

Motor Output Control

The following diagram shows the control flow for the motor command output by the chipset.



The chipset can be run in either closed loop mode, or open loop mode. In closed loop mode the motor command is determined by the output of the servo filter, which in turn is determined by the output of the trajectory generator and the actual axis position. Closed loop mode is the normal operating mode of the chipset.

Open loop mode allows the motor command to be directly set by the host. Open loop mode is typically used when one or more axes require torque control only, or to calibrate the amplifier.

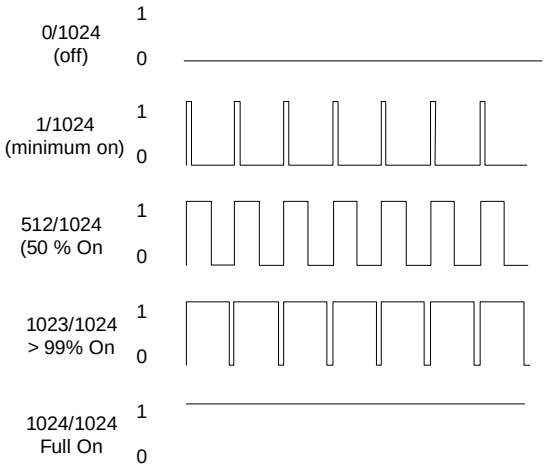
Here is a summary of the motor control commands.

Command	Description
MTR_ON	Enables closed loop servo control. In this mode the source of motor command is the servo filter and the motor command register has no effect on motor output.
MTR_OFF	Disables closed loop servo operations (enables open loop control). In this mode the motor command is determined by the motor command register, which is set by the host.
SET_MTR_CMD	Sets the motor command register, used to control the motor output value during open loop operations. For this command to take effect the motor must be off (MTR_OFF command).
GET_MTR_CMD	Retrieves the current motor command output by the chipset. When in closed loop mode this command will return the current output value of the servo filter. When in open loop mode this command will return the value set using the SET_MTR_CMD command.

PWM Output

When PWM output is selected, the magnitude and sign pins for each axis will continuously reflect the motor amplifier signal being output by the chip set. The sign bit will be active (high) when the motor is driven in the positive direction, and inactive (low) when in the negative direction.

The following figure shows the magnitude output wave forms:



16 Bit DAC Output

When 16 bit DAC output is selected, for each active axis, the DAC control pins will continuously load a 16-bit DAC value into the addressed DAC. To load a particular DAC, The DAC address (1 of 4) is output on the signals DAC16Addr0-1, the 16 bits of DAC data are output on pins Data0-11 (high 12 bits), as well as DACLow0-3 (low 4 bits), I/OAddr0-3 and DACSlct are high, and I/OWrite is low.
For more information on the DAC signal timing & conditions, see the DAC pin descriptions and interface timing diagram.

DACs with lower resolution than 16 bits can also be used. To connect to a DAC with less resolution, the high order bits of the 16-bit data word should be used. For example, to connect to an 8-bit DAC, bits Data4-Data11 should be used. The low order 8 bits are written to, but ignored.

The 16-bit data word that is put out as an unsigned 16-bit number with a range of 0 to 65535. An output value of 0 indicates the largest negative direction motor command, a value of 32768 indicates no motor output, and a value of 65535 indicates the largest positive direction motor command.

NOTES

Command Summary

Command Mnemonic	Code (hex)	Available on	Axes acted on	Double Buffered	data words /direction.	Description
Axis Control						
SET_1	01	all axes	set by cmd.	-	1/read	Set current axis # to 1
SET_2	02	all axes	set by cmd.	-	1/read	Set current axis # to 2
SET_3	03	all axes	set by cmd.	-	1/read	Set current axis # to 3
SET_4	04	all axes	set by cmd.	-	1/read	Set current axis # to 4
SET_I	08	all axes	interrupting axis	-	1/read	Set current axis # to the interrupting axis
Profile Generation						
SET_PRFL_S_CRV	0b	all axes	current axis	no	0	Set profile to S-curve
SET_PRFL_TRAP	09	all axes	current axis	no	0	Set profile to trapezoidal point to point
SET_PRFL_VEL	0a	all axes	current axis	no	0	Set profile to velocity-contouring
SET_PRFL_GEAR	0c	1, 2	current axis	no	0	Set profile to electronic gear
SET_POS	10	all axes	current axis	yes	2/write	Set command position
SET_VEL	11	all axes	current axis	yes	2/write	Set command velocity
SET_ACC	12	all axes	current axis	yes	2/write	Set command acceleration
SET_MAX_ACC	15	all axes	current axis	yes	1/write	Set max accel. (S-curve profile only)
SET_JERK	13	all axes	current axis	yes	2/write	Set command jerk
SET_RATIO	14	1, 2	current axis	yes	2/write	Set command electronic gear ratio
STOP/CLR_PRFL	46	all axes	current axis	yes	0	Abruptly stop axis trajectory motion
SMOOTH_STOP	4e	all axes	current axis	yes	0	Smoothly stop axis trajectory motion
SYNCH_PRFL	47	all axes	current axis	yes	0	Set servo following error to zero
GET_POS	4a	all axes	current axis	-	2/read	Get command position
GET_VEL	4b	all axes	current axis	-	2/read	Get command velocity
GET_ACC	4c	all axes	current axis	-	2/read	Get command acceleration
GET_MAX_ACC	4f	all axes	current axis	-	1/read	Get max. accel. (S-curve profile only)
GET_JERK	58	all axes	current axis	-	2/read	Get command jerk
GET_RATIO	59	1, 2	current axis	-	2/read	Get command electronic gear rate
GET_TRGT_POS	1d	all axes	current axis	-	2/read	Get current target position
GET_TRGT_VEL	1e	all axes	current axis	-	2/read	Get current target velocity
Digital Filter						
SET_KP	25	all axes	current axis	yes	1/write	Set proportional gain
SET_KD	27	all axes	current axis	yes	1/write	Set derivative gain
SET_KI	26	all axes	current axis	yes	1/write	Set integral gain
SET_KVFF	2b	all axes	current axis	yes	1/write	Set feedforward gain
SET_I_LM	28	all axes	current axis	yes	1/write	Set integration limit
SET_MTR_LMT	06	all axes	current axis	no	1/write	Set motor output limit
SET_MTR_BIAS	0f	all axes	current axis	no	1/write	Set motor output bias
SET_POS_ERR	29	all axes	current axis	no	1/write	Set maximum position error limit
GET_KP	50	all axes	current axis	-	1/read	Get proportional gain
GET_KD	52	all axes	current axis	-	1/read	Get derivative gain
GET_KI	51	all axes	current axis	-	1/read	Get integral gain
GET_KVFF	54	all axes	current axis	-	1/read	Get velocity feedforward gain
GET_I_LM	53	all axes	current axis	-	1/read	Get integration limit
GET_MTR_LMT	07	all axes	current axis	-	1/read	Get motor output limit
GET_MTR_BIAS	2d	all axes	current axis	-	1/read	Get motor output bias
GET_POS_ERR	55	all axes	current axis	-	1/read	Get position error
GET_INTGR	2e	all axes	current axis	-	1/read	Get integrated position error value
GET_ACTL_POS_ERR	60	all axes	current axis	-	1/read	Get actual position error
SET_AUTO_STOP_ON	45	all axes	current axis	-	0	Set auto stop on motion error mode on
SET_AUTO_STOP_OFF	44	all axes	current axis	-	0	Set auto stop on motion error mode off

Command Mnemonic	Code (hex)	Available on	Axes acted on	Double Buffered	data words /direction	Description
Parameter Update						
SET_TIME_BRK	17	all axes	current axis	no	0	Set breakpoint mode to time
SET_POS_BRK	18	all axes	current axis	no	0	Set breakpoint mode to pos. target position
SET_NEG_BRK	19	all axes	current axis	no	0	Set breakpoint mode to neg. target position
SET_ACTL_POS_BRK	1b	all axes	current axis	no	0	Set breakpoint mode to pos. actual position
SET_ACTL_NEG_BRK	1c	all axes	current axis	no	0	Set breakpoint mode to neg. actual position
SET_MTN_CMPLT_BRK	35	all axes	current axis	no	0	Set breakpoint mode to motion complete
SET_EXT_BRK	5e	all axes	current axis	no	0	Set breakpoint mode to external
SET_BRK_OFF	6d	all axes	current axis	no	0	Set breakpoint mode off
SET_BRK_PNT	16	all axes	current axis	no	2/write	Set breakpoint comparison value
UPDATE	1a	all axes	current axis	-	0	Immediate parameter update
MULTI_UPDATE	5b	all axes	set by mask	-	1/write	Multiple axis immediate parameter update
SET_AUTO_UPDATE_ON	5c	all axes	current axis	no	0	Set automatic profile update on
SET_AUTO_UPDATE_OFF	5d	all axes	current axis	no	0	Set automatic profile update off
GET_BRK_PNT	57	all axes	current axis	-	2/read	Get breakpoint comparison value
Interrupt Processing						
SET_INTRPT_MASK	2f	all axes	current axis	no	1/write	Set interrupt mask
GET_INTRPT	30	all axes	interrupting axis	-	1/read	Get status of interrupting axis
RST_INTRPT	32	all axes	interrupting axis	no	1/write	Reset interrupting events
GET_INTRPT_MASK	56	all axes	current axis	-	1/read	Get interrupt mask
Status/Mode						
CLR_STATUS	33	all axes	current axis	no	0	Reset status of current axis
RST_STATUS	34	all axes	current axis	no	1/write	Reset events for current axis
GET_STATUS	31	all axes	current axis	-	1/read	Get axis status word
GET_MODE	48	all axes	current axis	-	1/read	Get axis mode word
Encoder						
SET_CNTS	68	all axes	current axis	no	1/write	Set # of counts/motor rotation (-P vrsn only)
SET_CAPT_INDEX	64	all axes	current axis	no	0	Set index signal as position trigger
SET_CAPT_HOME	65	all axes	current axis	no	0	Set home signal as position trigger
GET_CAPT	36	all axes	current axis	-	2/read	Get current axis position capture location
GET_CNTS	6f	all axes	current axis	-	1/read	Get # of counts/motor rotation (-P vrsn only)
Motor						
SET_OUTPUT_PWM	3c	all axes	global	no	0	Set motor output mode to PWM
SET_OUTPUT_DAC16	3b	all axes	global	no	0	Set motor output mode to 16-bit DAC
MTR_ON	43	all axes	current axis	no	0	Enable motor output
MTR_OFF	42	all axes	current axis	no	0	Disable motor output
SET_MTR_CMD	62	all axes	current axis	no	1/write	Write direct value to motor output
GET_MTR_CMD	3a	all axes	current axis	-	1/read	Read motor output command
GET_OUTPUT_MODE	6e	all axes	global	-	1/read	Get current output mode
Miscellaneous						
AXIS_ON	41	all axes	current axis	no	0	Enable axis
AXIS_OFF	40	all axes	current axis	no	0	Disable axis
SET_ACTL_POS	4d	all axes	current axis	no	2/write	Set current actual axis location
GET_ACTL_POS	37	all axes	current axis	-	2/read	Get current actual axis location
SET_LMT_SENSE	66	all axes	global	no	1/write	Set limit switch bit sense
GET_LMT_SWTCH	67	all axes	global	-	1/read	Get state of limit switches
LMTS_ON	70	all axes	global	no	0	Set limit switch sensing on
LMTS_OFF	71	all axes	global	no	0	Set limit switch sensing off
GET_HOME	05	all axes	global	-	1/read	Get state of home switches
SET_SMPL_TIME	38	all axes	global	no	1/write	Set servo loop sample time
GET_SMPL_TIME	61	all axes	global	-	1/read	Get servo loop sample time
RESET	39	all axes	global	no	0	Reset chipset
GET_VRSN	6c	all axes	global	-	1/read	Get chipset software version information
GET_TIME	3e	all axes	global	-	2/read	Get current chip set time (# servo loops)

Command Reference

Each command consists of a single byte, with a command code value as described in the "encoding" description for each command. Data is transmitted to/from the chip set in 16-bit words. All data is encoded "high to low" i.e. each 16-bit word is encoded high byte first, low byte second, and two word data values are encoded high word first, low word second.

Signed data is represented in two's complement format. In the case of 32-bit quantities, the entire 32-bit number is two's complemented. For example to transmit the decimal number 1,234,567, which has a hexadecimal representation of 12d687, the high word is sent first (12 hex) and then the low word is sent (d687 hex). Negative numbers are treated in the same way. For example to transmit the decimal number -746,455 , which has a hexadecimal value of fff49c29, then the high word is transmitted first (fff4 hex.) followed by the low word (9c29 hex.).

Some chipset quantities such as position are provided with 'unity scaling', meaning that the value provided is used by the chipset without internal scaling.

Other chipset quantities are scaled by various constants to allow a more useful operating range. The non-unity scaling constants that are used by the chipset are either $1/2^{16}$ or $1/2^{32}$.

If $1/2^{16}$ scaling is used then the chipset expects a number which has been scaled by a factor of 65,536 from the 'user' units. For example to specify a velocity (SET_VEL command) of 2.75 counts/sample time, 2.75 is multiplied by 65,536 and the result is sent to the chipset as a 32 bit integer (180,224 dec. or 2c000 hex.). $1/2^{16}$ scaling is used with 16 bit as well as 32 bit quantities. The size of the data word does not affect how the scaling is performed.

If $1/2^{32}$ scaling is indicated the chipset expects a number which has been scaled by a factor of 4,294,967,296. For example to specify a jerk value (SET_JERK command) of .0075 counts/sample time^3, .0075 is multiplied by 4,294,967,296 and the result is sent to the chipset as a 32 bit integer (32,212,256 dec. or 1eb8520 hex).

All transmissions to/from the chip set are checksummed. The checksum is a 16-bit quantity that can be read at the end of each command transmission. The checksum value consists of the 16-bit sum of all 16-bit transmissions to or from the chip set, including the command byte which occupies the low byte of the first 16-bit transmission word. For example if a SET_VEL command (which takes two 16-bit words of data) was sent with a data value of fedcba98 (hex), the checksum would be:

```
  0011     (code for SET_VEL command)
+ fedc     (high data word)
+ ba98     (low data word)
----------
1b985
check sum = b985 (keep bottom 16 bits only)
```

The following hex code commands are reserved for future use, or are currently used during manufacturing/test. They return a valid checksum, although they should not be used during normal chipset operations. The hex command codes are: 49, 4e

The following hex code commands are illegal, and will return a checksum of 0. They should not be used during normal chipset operations. The hex command codes are: 00, 0e, 1f, 20, 23, 24, 2c, 5f, 63, 72 through ff

Unless otherwise noted, all numerical values presented in this command summary are in decimal.

Axis Control

SET_1	**Set current axis to #1**
Data/direction:	1/read
Encoding:	01 (hex)
Axis acted on:	set by command
Available on:	all axes
Double buffered:	No

SET_1 changes the current axis number to 1. All commands that operate on the current axis will be affected by this command. The status of axis #1 is returned. See GET_STATUS command for the status word format.

SET_2	**Set current axis to #2**
Data/direction:	1/read
Encoding:	02 (hex)
Axis acted on:	set by command
Available on:	all axes
Double buffered:	No

SET_2 changes the current axis number to 2. All commands that operate on the current axis will be affected by this command. The status of the axis #2 is returned. See GET_STATUS command for the status word format.

SET_3	**Set current axis to #3**
Data/direction:	1/read
Encoding:	03 (hex)
Axis acted on:	set by command
Available on:	all axes
Double buffered:	No

SET_3 changes the current axis number to 3. All commands that operate on the current axis will be affected by this command. The status of the axis #3 is returned. See GET_STATUS command for the status word format.

SET_4	**Set current axis to #4**
Data/direction:	1/read
Encoding:	04(hex)
Axis acted on:	set by command
Available on:	all axes
Double buffered:	No

SET_4 changes the current axis number to 4. All commands that operate on the current axis will be affected by this command. The status of the axis #4 is returned. See GET_STATUS command for the status word format.

SET_I	**Set current axis to interrupting axis**
Data/direction:	1/read
Encoding:	08 (hex)
Axis acted on:	interrupting axis
Available on:	all axes
Double buffered:	No

SET_I changes the current axis number to the interrupting axis, which is the axis that has caused the host interrupt to become active. All commands that operate on the current axis will be affected by this command. The status of the interrupting axis is returned. See GET_STATUS command for the status word format.

Profile Generation

SET_PRFL_S_CRV	**Set profile mode to S-curve point to point**
Data/direction:	none
Encoding:	0b (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	No

SET_PRFL_S_CRV sets the trajectory profile mode to S-curve point to point. In this mode, the host specifies the destination position (SET_POS cmd), the maximum velocity (SET_VEL cmd) the maximum acceleration (SET_MAX_ACC cmd), and the jerk (SET_JERK cmd). Once in this mode, the trajectory profile generator will drive the axis to the destination position at the specified jerk while not exceeding the maximum velocity and max. acceleration. The axis will stay in this profile mode until another profile mode is explicitly set.

While in this profile mode, no parameters should be changed while the axis is in motion.

Before setting the current profile mode to S-curve point to point, the axis should be completely at rest.

SET_PRFL_TRAP	**Set profile mode to trapezoidal point to point**
Data/direction:	none
Encoding:	09 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	No

SET_PRFL_TRAP sets the trajectory profile mode to trapezoidal point to point. In this mode, the host specifies the destination position (SET_POS cmd), the maximum velocity (SET_VEL cmd) and the acceleration (SET_ACC cmd). Once in this mode, the trajectory profile generator will drive the axis to the destination position at the specified acceleration while not exceeding the maximum velocity. Position and velocity may be changed on the fly when in this profile mode; acceleration may not. The axis will stay in this profile mode until another profile mode is explicitly set.

Before setting the current profile mode to trapezoidal point to point, the axis should be completely at rest.

While in this mode, the acceleration should not be changed until the axis has come to a stop.

SET_PRFL_VEL	**Set profile mode to velocity contouring.**
Data/direction:	none
Encoding:	0a (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	No

SET_PRFL_VEL sets the trajectory profile mode to velocity contouring. In this mode the host specifies the command acceleration (SET_ACC cmd), and the maximum velocity (SET_VEL cmd). Once in this mode, the trajectory profile generator will drive the axis at the specified acceleration while not exceeding the maximum velocity. The acceleration and the maximum velocity may be changed on the fly. The axis will stay in this profile mode until another profile mode is explicitly set. There are no limitations on changing the profile mode to velocity contouring while the axis is in motion.

There are no host-specified limits on the position in this mode. It is the responsibility of the host to specify profile parameters that maintain the axis within safe position limits.

SET_PRFL_GEAR	**Set profile mode to electronic gear**
Data/direction:	none
Encoding:	0c (hex)
Axis acted on:	current axis
Available on:	axis #1, #2 (see chart)
Double buffered:	No

SET_PRFL_GEAR, sets the trajectory profile mode to electronic gear. In this mode the host specifies the gear ratio (SET_RATIO cmd). Once in this mode the trajectory profile generator will drive the current (slave) axis to the position specified by the master axis factored by the

specified gear ratio. The gear ratio may be changed on the fly. The axis will stay in this profile mode until another profile mode is explicitly set. The electronic gear mode is available on the following axis for each chipset:

chipset p/n	gear pairs (master -> slave)
MC1401A	#3 -> #1, #4 -> #2
MC1201A	#2 -> #1
MC1101A	not available

There are no host-specified limits to axis motion in this mode. It is the responsibility of the host to specify a gear ratio that maintains the axis within safe motion limits.

SET_POS	**Set command position**
Data/direction	2/write
Encoding:	10 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_POS sets the final position used during the S-curve and trapezoidal trajectory profile generator modes. The position is specified as a signed 32-bit number with units of counts. The range is -1,073,741,824 to 1,073,741,823. The loaded position is not utilized until a parameter update occurs.

SET_VEL	**Set command velocity**
Data/direction:	2/write
Encoding:	11 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_VEL sets the maximum velocity magnitude used during the S-curve, trapezoidal, and velocity contouring profile modes. The velocity is specified as an unsigned 32-bit number with units of counts/sample. The data word scaling is $1/2^{16}$. The range is 0 to +1,073,741,823. The loaded velocity is not utilized until a parameter update occurs.

SET_ACC	**Set command acceleration**
Data/direction:	2/write
Encoding:	12 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_ACC sets the command acceleration. When in trapezoidal point-to-point mode, the acceleration is specified as an unsigned 32-bit number with units of counts/sample^2, represented using $1/2^{16}$ scaling. The range is 0 to +1,073,741,823. When in the velocity contouring mode, the acceleration is specified as a signed 32-bit number with units of counts/sample^2, represented in $1/2^{16}$ format.The range is -1,073,741,824 to +1,073,741,823. The loaded acceleration is not utilized until a parameter update occurs.

This command is used when the profile mode is set to trapezoidal point-to-point or velocity contouring.

SET_MAX_ACC	**Set maximum acceleration**
Data/direction:	1/write
Encoding:	15 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_MAX_ACC sets the maximum acceleration. The acceleration is specified as an unsigned 16-bit number with units of counts/sample^2 represented using $1/2^{16}$ scaling. The range is 0 to +1,073,741,823. The loaded max. acceleration is not utilized until a parameter update occurs.

This command is used when the profile mode is set to S-curve point to point.

SET_JERK	**Set command jerk**
Data written:	2 words
Data read:	none
Encoding:	13 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_JERK sets the command jerk used during the S-curve profile generation mode. The jerk is specified as an unsigned 32-bit number with units of counts/sample^3. The scaling is $1/2^{32}$. The range is 0 to 2,147,483,647. The loaded jerk is not utilized until a parameter update occurs.

SET_RATIO	**Set command gear ratio**
Data/direction:	2/write
Encoding:	14 (hex)
Axis acted on:	current axis
Available on:	axis #1, #2
Double buffered:	yes

SET_RATIO sets the electronic gear ratio used by the trajectory profile generator. It is used when the profile mode is set to electronic gear. The gear ratio is specified as a signed 32-bit number represented using $1/2^{16}$ scaling. The range is -1,073,741,824 to +1,073,741,823. The specified ratio value is defined as the number of counts of the slave axis per master axis count with a positive number indicating motion in the same direction. For example a value of +8000 hex (1/2) will result in 1/2 turn in the positive direction of the slave axis for each full turn of the master axis in the positive direction, and a value of -FFFE0000 hex (-2) will result in 2 turns in the negative direction of the slave axis for each full turn of the master axis in the positive direction. The loaded ratio is not utilized until a parameter update occurs.

STOP/CLR_PRFL	**Abruptly stop current axis motion**
Data/direction:	none
Encoding:	46 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

STOP, also known as CLR_PRFL in earlier chipset versions, stops the current axis by setting the target velocity to zero. This function will not be performed until a parameter update occurs. After the update occurs the axis trajectory generator will stop and the motion complete bit will be set. This command is useful for stopping the axis abruptly.

SMOOTH_STOP	**Smoothly stop current axis motion**
Data/direction:	none
Encoding:	4e (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SMOOTH_STOP stops the current axis by setting the desired velocity to zero, resulting in a controlled deceleration of the axis eventually to a velocity of 0. The deceleration profile will mirror the acceleration profile for the current profile mode. For example if the SMOOTH_STOP command is given during an s-curve profile the deceleration profile may have up to three phases, depending on the # of phases during the acceleration profile, and if the SMOOTH_STOP command is given during a trapezoidal profile or a velocity mode profile the deceleration will be linear, with a value equal to the acceleration parameter.

This command does not function when the profile mode is set to Electronic Gear.

SYNCH_PRFL	**Set target position equal to the actual position**
Data/direction:	none
Encoding:	47 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SYNCH_PRFL sets the trajectory profile generator target position equal to the actual axis position, clearing the following error. This command is available for all profile types. This function will not be performed until a parameter update occurs.

The SYNCH_PRFL command does not set the target velocity to zero. If it is desired that the axis not move after a SYNCH_PRFL command then a STOP command, in addition to the SYNCH_PRFL command should be used.

GET_POS	**Get command position**
Data/direction:	2/read
Encoding:	4a (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_POS returns the destination position set using the SET_POS command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the profile parameters have been updated. The returned position is a signed 32-bit number with units of counts.

GET_VEL	**Get command velocity**
Data/direction:	2/read
Encoding:	4b (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_VEL returns the maximum velocity set using the SET_VEL command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the profile parameters have been updated. The returned velocity is an unsigned 32-bit number in $1/2^{16}$ format with units of counts/sample.

GET_ACC	**Get command acceleration**
Data/direction:	2/read
Encoding:	4c (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_ACC returns the acceleration value set using the SET_ACC command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the profile parameters have been updated. The returned position is either an unsigned 32-bit number in $1/2^{16}$ format with units of counts/sample^2, or a signed 32 bit number in $1/2^{16}$ format with units of counts/sample^2.

This command is used when the profile mode is set to trapezoidal point-to-point or velocity contouring.

GET_MAX_ACC	**Get maximum acceleration**
Data/direction:	1/read
Encoding:	4f (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_MAX_ACC returns the max. acceleration value set using the SET_MAX_ACC command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the profile parameters have been updated. The returned value is an unsigned 16-bit number in $1/2^{16}$ format with units of counts/sample^2.

This command is used when the profile mode is set to S-curve point to point.

GET_JERK	**Get command jerk**
Data/direction:	2/read
Encoding:	58 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_JERK returns the jerk value set using the SET_JERK command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the profile parameters have been updated. The returned jerk is an unsigned 32-bit number with $1/2^{32}$ scaling with units of counts/sample^3.

GET_RATIO	**Get command gear ratio**
Data/direction:	2/read
Encoding:	59 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_RATIO returns the gear ratio set using the SET_RATIO command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the profile parameters have been updated. The returned ratio is a signed 32-bit number in $1/2^{16}$ format.

GET_TRGT_POS	**Return target position**
Data/direction:	2/read
Encoding:	1d (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_TRGT_POS returns the current desired position value being generated by the trajectory profile generator. This value represents the target position for the axis at the current sample time, i.e. the position being output by the trajectory profile generator at the time of the command. This command operates for all profile modes. The value returned is a 32-bit signed number with units of counts. The range is -1,073,741,824 to 1,073,741,823. This command is useful to monitor the profile being generated by the chip set, or to verify servo performance.

GET_TRGT_VEL	**Return target velocity**
Data/direction:	2/read
Encoding:	1e (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_TRGT_VEL returns the current desired velocity value being generated by the trajectory profile generator. This value represents the target velocity for the axis at the current sample time, i.e. the velocity being output by the trajectory profile generator at the time of the command. This command operates for all profile modes. The value returned is a 32 bit signed number with units of counts/sample, represented in $1/2^{16}$ format. The range is -1,073,741,824 to +1,073,741,823. This command is useful to monitor the profile being generated by the chip set, or to verify servo performance.

Digital Filter

SET_KP	**Set proportional gain**
Data/direction:	1/write
Encoding:	25 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_KP sets the proportional gain for the digital filter. The gain is specified as an unsigned 16-bit number. The range is 0 to 32,767. The loaded gain is not utilized until a parameter update occurs.

SET_KD	**Set derivative gain**
Data/direction:	1/write
Encoding:	27 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_KD sets the derivative gain for the digital filter. The gain is specified as an unsigned 16-bit number. The range is 0 to 32,767. The loaded gain is not utilized until a parameter update occurs.

SET_KI	**Set integral gain**
Data/direction:	1/write
Encoding:	26 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_KI sets the integral gain for the digital filter. The gain is specified as an unsigned 16-bit number. The range is 0 to 32,767. The loaded gain is not utilized until a parameter update occurs.

SET_KVFF	**Set velocity feed forward gain**
Data/direction:	1/write
Encoding:	2b (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_KVFF sets the velocity feed forward gain for the digital filter. The gain is specified as an unsigned 16 bit number. The range is 0 to 32,767. The loaded gain is not utilized until a parameter update occurs.

SET_I_LM	**Set integration limit**
Data/direction:	1/write
Encoding:	28 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	yes

SET_I_LM sets the integration limit for the digital filter. The integration limit is specified as an unsigned 16-bit number. The range is 0 to 32,767. The loaded integration limit is not utilized until a parameter update occurs.

SET_MTR_LMT	**Set motor output limit**
Data/direction:	1/write
Encoding:	06 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_MTR_LMT sets the maximum allowed motor command value output by the servo filter. The motor limit is specified as an unsigned 16-bit number with a range of 0 to 32,767. If the magnitude of the filter output value (whether positive or negative) exceeds the motor limit than the output value is maintained at the motor limit value. Once the filter output value returns below the specified limit than normal servo filter values are output.

The loaded motor output limit is utilized immediately. No UPDATE command is required.

The SET_MTR_LMT command only functions during closed loop operations.

SET_MTR_BIAS	**Set motor output bias**
Data/direction:	1/write
Encoding:	0f (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_MTR_BIAS sets the filter DC bias value, used to offset constant uni-directional forces (typically a vertical axis which is not balanced by a counter-weight). The specified motor bias value is added directly to the output of the servo filter. The motor bias is specified as a signed 16-bit number with a range of -32,767 to 32,767.

The loaded motor bias value is utilized immediately. No UPDATE command is required.

The SET_MTR_BIAS command functions during closed loop operations, as well as after a transition to open loop before a SET_MTR_CMD manual motor output command has been given. Caution should be used when selecting a motor bias value to avoid uncontrolled axis motion when transitioning to open loop mode.

SET_POS_ERR	**Set position error limit**
Data/direction:	1/write
Encoding:	29 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_POS_ERR sets the position error limit for the digital filter. The error is specified as an unsigned 16-bit number. The range is 0 to 32,767. At each servo loop the magnitude of the position error calculated by the digital filter is compared with the specified position error limit. If the actual position error exceeds the specified value, the motion error interrupt bit is set. In addition, if the axis has been set for automatic motor stop upon motion error, the axis motor output may be turned off (all power to motor is turned off). The loaded maximum position error is utilized immediately.

The value set by this command specifies the limit of the valid motion error range, but not necessarily the maximum error value. If the position error limit value is set to less than 32,767 than the actual position error may exceed the specified limit.

GET_KP	**Get proportional gain**
Data/direction:	1/read
Encoding:	50 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_KP returns the proportional gain set using the SET_KP command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the filter parameters have been updated. The returned gain value is an unsigned 16-bit number.

GET_KD	**Get derivative gain**
Data/direction:	1/read
Encoding:	52 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_KD returns the derivative gain set using the SET_KD command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the filter parameters have been updated. The returned gain value is an unsigned 16-bit number.

GET_KI	**Get integral gain**
Data/direction:	1/read
Encoding:	51 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_KI returns the integral gain set using the SET_KI command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the filter parameters have been updated. The returned gain value is an unsigned 16-bit number.

GET_KVFF	**Get velocity feedforward gain**
Data/direction:	1/read
Encoding:	54 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_KVFF returns the proportional gain set using the SET_KVFF command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the filter parameters have been updated. The returned gain value is an unsigned 16-bit number.

GET_I_LM	**Get integration limit**
Data/direction:	1/read
Encoding:	53 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_I_LM returns the integration limit value set using the SET_I_LM command. It returns the double-buffered value (set directly by the host), which may or may not correspond to the active value, depending on whether the filter parameters have been updated. The returned integration limit value is an unsigned 16-bit number.

GET_MTR_LMT	**Get motor output limit**
Data/direction:	1/read
Encoding:	07 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_MTR_LMT returns the maximum allowed motor command value output by the servo filter set using the SET_MTR_LMT command. The returned value is an unsigned 16-bit number with a range of 0 to 32,767.

GET_MTR_BIAS	**Get motor output bias**
Data/direction:	1/read
Encoding:	2d (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_MTR_BIAS returns the filter DC bias value set using the SET_MTR_BIAS command. The returned value is a signed 16-bit number with a range of -32767 to 32,767.

GET_POS_ERR	**Get maximum position error**
Data/direction:	1/read
Encoding:	55 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_POS_ERR returns the maximum position error value set using the SET_POS_ERR command. The returned maximum position error value is an un signed 16-bit number.

GET_INTGR	Return current integrated position error value
Data/direction:	1/read
Encoding:	2e (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_INTGR returns the current integrated position error value maintained by the digital filter. The value returned represents the top 16 bit word of the 24-bit integration value. The value returned is a 16-bit signed number. The range is -32,768 to +32,767. This command is useful to monitor the loading on the axis, since increases or decreases in the axis load may be reflected in the value of the integration limit.

GET_ACTL_POS_ERR	Return current position error
Data/direction:	1/read
Encoding:	60 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_ACTL_POS_ERR returns the current instantaneous position error of the axis. The returned value represents the difference between the target position and the actual position (actual position minus target position), and is a signed 16-bit number. The range is -32,768 to +32,767. This command is useful to monitor and analyze the tracking error of the axis.

SET_AUTO_STOP_ON	Enable automatic motor shutdown
Data/direction:	none
Encoding:	45 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_AUTO_STOP_ON enables automatic motor shutdown upon motion error. In this mode the motor will be disabled (equivalent to MTR_OFF cmd) when a motion error occurs (see SET_POS_ERR cmd). The motor output can be re-enabled using the MTR_ON cmd.

SET_AUTO_STOP_OFF	Disables automatic motor shutdown
Data/direction:	none
Encoding:	44 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_AUTO_STOP_OFF disables the automatic motor shutdown upon motion error mode. In this mode the motor will not be disabled when a motion error occurs.

Parameter Update

SET_TIME_BRK	Set break point mode to time based
Data/direction:	none
Encoding:	17 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_TIME_BRK sets the current breakpoint mode to time based. In this mode the value loaded into the breakpoint register (SET_BRK_PNT cmd) will represent the number of sample loops since chip set power on. After the SET_TIME_BRK command is executed, at each servo loop the break point value will be compared against the current chip set time. If the values are equal all profile and filter parameters will be loaded in to the active registers. See GET_TIME cmd for information on the chip set time. After this breakpoint condition has been satisfied, the breakpoint mode is reset i.e. no additional breakpoints will occur until a new breakpoint condition is set.

SET_POS_BRK	Set break point mode to positive target position based
Data/direction:	none
Encoding:	18 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_POS_BRK sets the current breakpoint mode to positive target position based. In this mode the value loaded into the breakpoint register (SET_BRK_PNT cmd) will represent the axis position in counts. After the SET_POS_BRK command is executed, at each servo loop the break point value will be compared against the current axis target position. If the target position has a value equal to or greater than the breakpoint register then all profile and all filter parameters will be loaded in to the active registers. After this breakpoint condition has been satisfied, the breakpoint mode is reset i.e. no additional breakpoints will occur until a new breakpoint condition is set.

SET_NEG_BRK	Set break point mode to negative target position based
Data/direction:	none
Encoding:	19 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_NEG_BRK sets the current breakpoint mode to negative target position based. In this mode the value loaded into the breakpoint register (SET_BRK_PNT cmd) will represent the axis position in counts After the SET_NEG_BRK command is executed, at each servo loop the break point value will be compared against the current axis target position. If the target position has a value equal to or less than the breakpoint register then all profile and all filter parameters will be loaded into the active registers. After this breakpoint condition has been

satisfied, the breakpoint mode is reset i.e. no additional breakpoints will occur until a new breakpoint condition is set.

SET_ACTL_POS_BRK	**Set break point mode to positive actual position based**
Data/direction:	none
Encoding:	1b (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_ACTL_POS_BRK sets the current breakpoint mode to positive actual position based. In this mode the value loaded into the breakpoint register (SET_BRK_PNT cmd) will represent the axis position in counts. After the SET_ACTL_POS_BRK command is executed, at each servo loop the break point value will be compared against the current axis actual position. If the actual position has a value equal to or greater than the breakpoint register then all profile and all filter parameters will be loaded in to the active registers. After this breakpoint condition has been satisfied, the breakpoint mode is reset i.e. no additional breakpoints will occur until a new breakpoint condition is set..

SET_ACTL_NEG_BRK	**Set break point mode to negative actual position based**
Data/direction:	none
Encoding:	1c (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_ACTL_NEG_BRK sets the current breakpoint mode to negative actual position based. In this mode the value loaded into the breakpoint register (SET_BRK_PNT cmd) will represent the axis position in counts After the SET_ACTL_NEG_BRK command is executed, at each servo loop the break point value will be compared against the current axis actual position. If the actual position has a value equal to or less than the breakpoint register then all profile and all filter parameters will be loaded into the active registers. After this breakpoint condition has been satisfied, the breakpoint mode is reset i.e. no additional breakpoints will occur until a new breakpoint condition is set.

SET_MTN_CMPLT_BRK	**Set break point mode to motion complete**
Data/direction:	none
Encoding:	35 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_MTN_CMPLT_BRK sets the current breakpoint mode to motion complete. In this mode the breakpoint condition is satisfied when the motion complete bit in the axis status word becomes active (axis motion is complete). This breakpoint mode is useful for immediately starting a new profile at the end of the current profile. Once the motion complete bit becomes active all double-buffered profile parameters will be loaded in to the active registers. After this breakpoint condition has been satisfied, the breakpoint mode is reset i.e. no additional breakpoints will occur until a new breakpoint condition is set.

No 32-bit compare value is required to be loaded when using this breakpoint mode.

It is the responsibility of the host to ensure that the motion complete bit is not set when this breakpoint is initiated.

SET_EXT_BRK	**Set break point mode to external**
Data/direction:	none
Encoding:	5e (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_EXT_BRK sets the current breakpoint mode to external. In this mode the breakpoint condition is satisfied when the home signal for the current axis becomes active (goes low). This breakpoint mode is useful for executing a profile change based on some external signal condition. Once the home signal becomes active all double-buffered profile parameters will be loaded in to the active registers. After this breakpoint condition has been satisfied, the breakpoint mode is reset i.e. no additional breakpoints will occur until a new breakpoint condition is set.

No 32-bit compare value is required to be loaded when using this breakpoint mode.

SET_BRK_OFF	**Set break point mode off**
Data/direction:	none
Encoding:	6d (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_BRK_OFF sets the breakpoint mode to "off". Any breakpoint mode that has been set previously (SET_TIME_BRK, SET_POS_BRK, SET_NEG_BRK, SET_ACTL_POS_BRK or SET_ACTL_NEG_BRK) and is still active (the breakpoint condition has not occurred), is disabled with this command. After this command has been executed no additional breakpoints will occur until a new breakpoint condition is set.

SET_BRK_PNT	**Set break point comparison value**
Data/direction:	2/write
Encoding:	16 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_BRK_PNT sets the breakpoint comparison value. Its contents are interpreted based on the type of breakpoint set; time based (SET_TIME_BRK cmd) or position based (SET_POS_BRK cmd, SET_NEG_BRK cmd, SET_POS_ACTL_BRK cmd, and SET_NEG_ACTL_BRK cmd). When set to time-based the loaded value is compared with the current chip set time at each servo loop, and the value loaded is a 32-bit number with units of servo loops. When set to position-based the loaded value is compared with the current axis target or actual position at each servo loop, and the value loaded is a 32-bit number with units of counts.

UPDATE	**Immediately update parameters**
Data/direction:	none
Encoding:	1a (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

UPDATE immediately updates all double buffered parameters.

MULTI_UPDATE	**Immediately update parameters for multiple axis**
Data/direction:	1/write
Encoding:	5b (hex)
Axis acted on:	set by data word
Available on:	all axes
Double buffered:	no

MULTI_UPDATE immediately updates the profile and filter parameters for 1 or more axis simultaneously. For each updated axis, the axis behaves as if a separate UPDATE command had been given for each axis. The associated data word contains a "positive-sense" bit mask for each axis. A one (1) in the axis bit position indicates the axis will be updated. A zero (0) indicates it will not. The following table shows this bit encoding:

Bit #	Axis # updated
0	1
1	2
2	3
3	4
4-15	unused, must be set to 0

SET_AUTO_UPDATE_ON	**Set automatic profile update on**
Data/direction:	none
Encoding:	5c (hex)
Axis acted on:	current
Available on:	all axes
Double buffered:	no

SET_AUTO_UPDATE_ON sets the automatic profile update mechanism on. After this command is sent, a satisfied breakpoint condition will result in all of the double-buffered profile and filter parameters automatically being transferred to the active registers. Once set to this mode, the axis will stay in this mode until explicitly commanded out using the SET_AUTO_UPDATE_OFF command.

SET_AUTO_UPDATE_OFF	**Set automatic profile update off**
Data/direction:	none
Encoding:	5d (hex)
Axis acted on:	current
Available on:	all axes
Double buffered:	no

SET_AUTO_UPDATE_OFF sets the automatic profile update mechanism off. After this command is sent, a satisfied breakpoint condition will **not** result in the double-buffered profile and filter parameters automatically being transferred to the active registers. Once set to this mode, the axis will stay in this mode until explicitly commanded out using the SET_AUTO_UPDATE_ON command.

When in this mode, the only way that profile parameters can be updated is through the UPDATE or the MULTI_UPDATE commands.

GET_BRK_PNT	**Get break point comparison value**
Data/direction:	2/read
Encoding:	57 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

GET_BRK_PNT returns the breakpoint comparison value set using the SET_BRK_PNT command. The returned value is a 32-bit number with units of either servo loops or counts (depending on the current breakpoint mode).

Interrupt Processing

SET_INTRPT_MASK	**Set host interrupt mask**
Data/direction:	1/write
Encoding:	2f (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_INTRPT_MASK sets the interrupt mask so that interrupt events can be individually masked off. When a non-masked interrupt occurs in any axis, the interrupt signal to the host is activated (HostIntrpt pin on I/O chip). The host can choose to ignore or respond to the interrupt. Once an interrupt has been generated, no new interrupts will be generated until a RST_INTRPT command is given, after which the interrupt signal to the host will be cleared, and a new interrupt (on any axis) can be generated. The associated data word is encoded as a field of bits, with each bit representing a possible interrupting condition. A 1 value in the mask bit will cause the corresponding event to generate an interrupt, while a 0 will stop the corresponding event from interrupting the host. The bit encoding is as follows:

Bit #	**Event**
0	Motion complete
1	position wrap-around
2	update breakpoint reached
3	position capture received
4	motion error
5	positive limit switch
6	negative limit switch
7	command error
8-15	not used, must be set to 0

GET_INTRPT	**Return status of the interrupting axis**
Data/direction:	1/read
Encoding:	30 (hex)
Axis acted on:	interrupting axis
Available on:	all axes
Double buffered:	-

GET_INTRPT returns the status of the axis that generated a host interrupt. The current axis number will not be changed after executing this command. See GET_STATUS for a definition of the returned status word. If this command is executed when no interrupt condition is present, the status of the current axis will be returned.

If this command is executed when no interrupt condition is present, the command will return the status of the current axis (same as GET_STATUS command).

RST_INTRPT	**Reset interrupting condition events**
Data/direction:	1/write
Encoding:	32 (hex)
Axis acted on:	interrupting axis
Available on:	all axes
Double buffered:	no

RST_INTRPT resets (clears) the interrupt condition bits for the axis that caused a host interrupt by masking the interrupting axis status word with the specified data word. In addition, the host interrupt signal (HostIntrpt pin on I/O chip) is de-activated.The data word is encoded as a field of bits, with each bit representing a possible interrupting condition. For each status word event bit a 1 value in the specified word will cause the status bit to remain unchanged, while a 0 will reset the corresponding event. The bit encoding is as follows:

Bit #	Event
0	Motion complete
1	position wrap-around
2	breakpoint reached
3	position capture received
4	motion error
5	positive limit switch
6	negative limit switch
7	command error
8-15	not used, must be set to 0

If this command is executed when no interrupt condition is present, the command will have no effect.

GET_INTRPT_MASK	**Get host interrupt mask**
Data/direction:	1/read
Encoding:	56 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

GET_INTRPT_MASK returns the interrupt mask set by the SET_INTRPT_MASK command. The returned value is a bit-encoded mask, described in the SET_INTRPT_MASK command.

Status/Mode

CLR_STATUS	**Clear all event bit conditions**
Data/direction:	none
Encoding:	33 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

CLR_STATUS resets (clears) all of the event bit conditions for the axis (bits 0-7 of the status word). The host interrupt line is not affected by this command. This command is useful for clearing all event bits during

initialization, or during on-line usage if the interrupt line and associated commands are not being used. For a detailed description of the status word event bits, see the GET_STATUS command.

This command does not affect the status of the host interrupt line, only the status event-bits themselves. To reset the host interrupt line, a RST_INTRPT command must be sent.

RST_STATUS	**Reset specific event bit conditions**
Data/direction:	1/write
Encoding:	34 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

RST_STATUS resets (clears) the condition event bits for the current axis, using a data word mask. The data word is encoded as a field of bits, with each bit representing a possible condition event. For each status word event bit a 1 value in the specified data word will cause the status bit to remain unchanged, while a 0 will reset the corresponding event. The bit encoding is as follows:

Bit #	Event
0	Motion complete
1	position wrap-around
2	breakpoint reached
3	position capture received
4	motion error
5	positive limit switch
6	negative limit switch
7	command error
8-15	not used, must be set to 0

GET_STATUS	**Get axis status word**
Data/direction:	1/read
Encoding:	31 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_STATUS returns the status of the current axis.The bit encoding of the returned word is as follows:

Bit #	Event
0	motion complete (1 indicates complete)
1	position wrap-around (1 indicates wrap)
2	update breakpoint reached (1 indicates reached)
3	position capture received (1 indicates capture has occurred)
4	motion error (1 indicates motion error)
5	positive limit switch (1 indicates limit switch trip)
6	negative limit switch (1 indicates limit switch trip)
7	command error (1 indicates command error)
8	motor on/off status (1 indicates on)
9	axis on/off status (1 indicates on)
10	In-motion bit (1 indicates axis is in motion)
11	reserved (may be 0 or 1)
12,13	current axis # (13 bit = high bit, 12 bit = low bit)
14,15	reserved (may be 0 or 1)

Bits 0-7 are set by the chipset, and must be reset by the host (using CLR_STATUS, RST_STATUS, or RST_INTRPT commands). Bits 8, 9, 10, 12, and 13 are continuously maintained by the chipset and are not set or reset by the host.

GET_MODE	**Get axis mode word**
Data/direction:	1/read
Encoding:	48 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_MODE returns the mode word for the axis.The bit encoding of the returned word is as follows:

Bit #	Event
0-6	Contains no host-useable information.
7	Stop on motion error mode flag. 1 indicates auto stop is on.
8	Internal use only. Contains no host-useable data
9	Contains no host-useable information
10	Auto update flag. 1 indicates auto update is disabled.
11,12	Trajectory profile mode, encoded as follows: Bit 12 / Bit 11 / Profile Mode 0 / 0 / trapezoidal 0 / 1 / velocity contouring 1 / 0 / s-curve 1 / 1 / electronic gear
13-15	Phase # (S-curve profile only). 3-bit word encodes phase #. Bit 15 is MSB, bit 13 is LSB.

Encoder

SET_CNTS	**Set # of counts per motor revolution**
Data/direction:	1/write
Encoding:	68 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_CNTS sets the number of counts per motor revolution for the current axis. The actual value that should be sent to the chipset is 1/2 the desired number of counts per motor revolution. For example if a 12 bit resolver is used (total of 4096 output states) then the value 2048 should be specified. The associated data word is an unsigned 16 bit number, with an allowed range of 256 to 32,767.

This command can only be used with the -P version parts.

SET_CAPT_INDEX	Set position capture trigger source to the index signal
Data/direction:	none
Encoding:	64 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_CAPT_INDEX sets the high-speed position register trigger source to the index signal. When the index is used as the trigger source, it is gated by the A and B quadrature signals (see theory of operations for details).

SET_CAPT_HOME	Set position capture trigger source to the home signal
Data/direction:	none
Encoding:	65 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_CAPT_HOME sets the high-speed position register trigger source to the home signal.

GET_CAPT	Return high speed capture register
Data/direction:	2/read
Encoding:	36 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_CAPT returns the current value of the high-speed position capture register, as well as resets the capture hardware so that subsequent positions may be captured. The value returned is a 32 bit signed number with units of counts.

GET_CNTS	Return # of counts per motor revolution
Data/direction:	1/read
Encoding:	6f (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_CNTS returns the # of counts per motor revolution value set using the SET_CNTS command. The returned value is a 16 bit unsigned number. This command is only valid with the -P version parts.

Motor

SET_OUTPUT_PWM	Set motor output mode to PWM
Data/direction:	none
Encoding:	3c (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	no

SET_OUTPUT_PWM sets the motor output mode to PWM. PWM mode outputs the motor output value on 2 output signals (sign and magnitude) for each enabled axis. This command affects the output mode for all axes.

SET_OUTPUT_DAC16	Set motor output mode to 16-bit DAC
Data/direction:	none
Encoding:	3b (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	no

SET_OUTPUT_DAC16 sets the motor output mode to 16-bit DAC. This motor output mode uses a 16-bit data bus, along with various control signals to load a DAC value for each enabled axis. This command affects the output mode for all axes.

MTR_ON	Enable servo motor output
Data/direction:	none
Encoding:	43 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

MTR_ON enables closed loop servo control. When motor output is enabled, motor output values generated by the digital filter are output to the selected output hardware circuitry (PWM, DAC12 or DAC16).

MTR_OFF	Disable servo motor output
Data/direction:	none
Encoding:	42 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

MTR_OFF disables closed loop servo operations. After this command is executed the motor output is taken from the motor command register, set using the SET_MTR_CMD command. This register is loaded with a value of 0 at the moment the motor is disabled. This command can be used for emergency shutdowns, for calibrating the motor amplifier, or for running an axis in open loop mode.

SET_MTR_CMD	**Write direct value to motor output**
Data/direction:	1/write
Encoding:	62 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_MTR_CMD loads the motor command register with the specified value. This register replaces the motor command value from the servo filter when the motor is shut off (MTR_OFF command). The specified motor command is a 16-bit signed number with range -32,767 to +32,767. Regardless of the motor output mode (PWM, DAC12 or DAC16), a value of -32,767 represents the largest negative direction motor command, a value of 0 represents no motor (0) output command, and a value of 32,767 represents the largest positive motor command.

For this command to work properly, the chipset must be in open loop mode (MTR_OFF cmd or after a motion error with automatic motor stop enabled)

GET_MTR_CMD	**Read current motor output value**
Data/direction:	1/read
Encoding:	3a (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_MTR_CMD returns the current motor output command. When the chipset is in closed loop mode this command returns the output of the servo filter. When the chipset is in open loop mode this command returns the contents of the manual output register, set using the SET_MTR_CMD command.

GET_OUTPUT_MODE	**Get current motor output mode**
Data/direction:	1/read
Encoding:	6e (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	-

GET_OUTPUT_MODE returns the current motor output mode set using the SET_OUTPUT_PWM, SET_OUTPUT_DAC12, and SET_OUTPUT_DAC16 commands. The returned 16 bit word contains the motor output mode. The encoding is as follows:

Returned Word Value	Output Mode
0	PWM
1	DAC12
2	DAC16

Miscellaneous

AXIS_ON	**Enable current axis**
Data/direction:	none
Encoding:	41 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

AXIS_ON enables the current axis. Axes that are on are serviced normally. Axes that are off are not serviced, and will not support any axis features. Axes can be enabled or disabled at any time, although care should be taken not to disable an axis such that unsafe motion occurs.

AXIS_OFF	**Disable current axis**
Data/direction:	none
Encoding:	40 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

AXIS_OFF disables the current axis. Axis that are on are serviced normally. Axis that are off are not serviced, and will not support any axis features. Axes can be enabled or disabled at any time, although care should be taken not to disable an axis such that unsafe motion occurs.

SET_ACTL_POS	**Set actual axis position**
Data/direction:	2/write
Encoding:	4d (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	no

SET_ACTL_POS sets the current actual position to the specified value. In addition, it sets the current target position equal to the specified actual position minus the current actual position error. In this way the current actual position error is maintained, allowing the SET_ACTL_POS command to be used while the axis is moving without causing the servo axis to jump. The desired actual axis position is specified as a signed 32 bit number with an allowed range of -1,073,741,824 to 1,073,741,823.

The loaded position is utilized immediately. No UPDATE is required for the command to take effect.

GET_ACTL_POS	**Return actual axis position**
Data/direction:	2/read
Encoding:	37 (hex)
Axis acted on:	current axis
Available on:	all axes
Double buffered:	-

GET_ACTL_POS returns the current actual position of the current axis. The value read is up to date to within a servo sample time.The value returned is a 32 bit signed number with units of counts.

SET_LMT_SENSE	**Set limit switch bit sense**
Data/direction:	1/write
Encoding:	66 (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	-

SET_LMT_SENSE sets the interpretation of the limit switch input bits. This command provides added flexibility in interfacing to various switch/sensor components. The signal level interpretation for the positive and negative switch inputs are bit-programmable. A 0 in the corresponding bit of the sense word indicates that the input will be active high. A 1 in the sense word indicates that the input will be active low. The sense word is encoded as follows:

Bit #	Description
0	Axis 1 positive limit switch (0 = active high)
1	Axis 1 negative limit switch (0 = active high)
2	Axis 2 positive limit switch (0 = active high)
3	Axis 2 negative limit switch (0 = active high)
4	Axis 3 positive limit switch (0 = active high)
5	Axis 3 negative limit switch (0 = active high)
6	Axis 4 positive limit switch (0 = active high)
7	Axis 4 negative limit switch (0 = active high)
8-15	not used (must set to 0)

The above bits are encoded as shown for the MC1401A. For the MC1201A Axis 3 & 4 are not used, and for the MC1101A Axis 2,3 & 4 are not used.

GET_LMT_SWTCH	**Get state of over-travel limit switches**
Data/direction:	1/read
Encoding:	67 (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	-

GET_LMT_SWTCH returns the value of the limit switch input signals for all valid axis. The returned word is encoded as follows:

Bit #	Description
0	Axis 1 positive limit switch (1 = high)
1	Axis 1 negative limit switch (1 = high)
2	Axis 2 positive limit switch (1 = high)
3	Axis 2 negative limit switch (1 = high)
4	Axis 3 positive limit switch (1 = high)
5	Axis 3 negative limit switch (1 = high)
6	Axis 4 positive limit switch (1 = high)
7	Axis 4 negative limit switch (1 = high)
8-15	not used (set to 0)

The above bits are encoded as shown for the MC1401A. For the MC1201A Axis 3 & 4 will always be set to 0, and for the MC1101A Axis 2,3 & 4 will always be set to 0.

The values returned by this command are not affected by the SET_LMT_SENSE command.

LMTS_ON	**Set limit switch sensing on**
Data/direction:	none
Encoding:	70 (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	-

LMTS_ON turns the limit switch sensing mechanism on. This command is primarily intended for compatibility with the MC1400 chipset, although it can also be used to re-enable limit switch sensing whenever it has been disabled using the LMTS_OFF command.

LMTS_OFF	**Set limit switch sensing off**
Data/direction:	none
Encoding:	71 (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	-

LMTS_OFF turns the limit switch sensing mechanism off. This command is primarily intended for compatibility with the MC1400 chipset, although it can also be used whenever it is desired that limit switch sensing not be active.

This command only disables the automatic setting of the negative and positive limit switch bits in the status word. It does not affect the status of these bits if they have already been set, nor does it affect the GET_LMT_SWTCH command.

GET_HOME	**Get state of home signal inputs**
Data/direction:	1/read
Encoding:	05 (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	-

GET_HOME returns the value of the home signal inputs for all valid axes. The returned word is encoded as follows:

Bit #	Description
0	Axis 1 home signal (1 = high)
0	Axis 2 home signal (1 = high)
0	Axis 3 home signal (1 = high)
0	Axis 4 home signal (1 = high)
4-15	not used (set to 0)

The above bits are encoded as shown for the MC1401A. For the MC1201A Axis 3 & 4 will always be set to 0, and for the MC1101A Axis 2,3 & 4 will always be set to 0.

SET_SMPL_TIME	**Set servo loop sample time**
Data/direction:	1/write
Encoding:	38 (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	No

SET_SMPL_TIME sets the servo sampling time which is the amount of time between servo updates. All axes operate at the same sample rate, and therefore are all affected by this command. The written value consists of the sample time expressed in units of 100 micro-seconds. For example a written value of 4 sets the loop time to 400 uSec. The allowed range is 1 to 32,767, however see theory of operations section for guidelines on the minimum values that can be used.

GET_SMPL_TIME	**Get servo loop sample time**
Data/direction:	1/read
Encoding:	61 (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	No

GET_SMPL_TIME returns the sample time set using the command SET_SMPL_TIME. The returned value is a 16 bit unsigned number with units of 100 uSecs.

RESET	**Reset chip set**
Data/direction:	none
Encoding:	39 (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	No

RESET resets the entire chip set. This command performs the same sequence as a hardware reset. At the end of this operation the chip set will be in the default or powerup condition, defined as follows:

Condition	Initial Value
all actual axis positions	0
all capture registers	0
all event conditions	cleared
host interrupt (HostIntrpt) signal	not active
all interrupt masks	0
all profile modes	trapezoidal
all filter modes	PID
all profile parameter values	0
all filter gains	0
all integration limits	32,767
all max. position error values	32,767
all motor biases	0
all motor limits	32,767
all brkpnt comparison values	0
all auto updates	enabled (on)
all axes	enabled (on)
all capture input modes	index
all counts per motor rev.	0
operational Mode	Closed loop (MTR_ON)
all auto stop modes	enabled (on)
limit switch sensing	enabled (on)
limit switch sense	0 (all active high)
output mode	PWM
all motor output values	0
current axis number	1
sample time	4 - MC1401A 2 - MC1201A 1 - MC1101A

GET_VRSN	**Return chipset software information**
Data/direction:	1read
Encoding:	6c (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	-

GET_VRSN returns various information on the chipset part number and software version. The encoding is as follows:

Bit #	Interpretation
0-2	minor software version
3-4	major software version. Major software versions 2 and above indicate 'A' versions parts
5-7	"dash" version # (no dash = 0, -P = 1
8-10	part number code 0 = 00 (MC1400-series), 1 = 01 (MC1401-series), 2 = 31 (MC1231-series) , 3 = 41 (MC1241-series), 4 = 51 (MC1451-series)
11-13	# axes supported (0 = 1)
14-15	generation # (1)

For example, the returned version code for the MC1401 (version 1.0 software) is 5908 (hex), the returned version code for the MC1201-P (version 1.0 software) is 4928, and the returned version code for the MC1231 (version 1.3 software) is 4a0b

GET_TIME	**Return current chip set time.**
Data/direction:	2/read
Encoding:	3e (hex)
Axis acted on:	global (all axes)
Available on:	all axes
Double buffered:	-

GET_TIME returns the current system time, expressed as the number of servo loops since chip set power on.The chip set clock starts at 0 after a power on or reset and will count indefinitely, wrapping from a value of 4,294,967,295 to 0. The returned value is a 32 bit number with units of sample times.

NOTES

Application Notes

Interfacing MC1401A to ISA bus.

A complete, ready-to-use ISA (PC/AT) bus interface circuit has been provided to illustrate MC1401A host interfacing, as well as to make it easier for the customer to build an MC1401A development system.

The interface between the PMD MC1401A chip set and the ISA (PC-AT) Bus is shown on the following page.

Comments on Schematic

This interface uses a 22V10 PAL and a 74LS245 to buffer the data lines.This interface assumes a base address is assigned in the address space of A9-A0. 300-400 hex These addresses are generally available for prototyping and other system-specific uses without interfering with system assignments. This interface occupies 16 addresses from XX0 to XXF hex though it does not use all the addresses. Two select lines are provided allowing the base address to be set to 340,350,370 and 390 hex for the select lines S1,S0 equal to 0,1,2,and 3 respectively.The address assignments used are as follows, where BADR is the base address, 340 hex for example:

Address	use
340h	read-write data
342h	write command
344h	read status (HostRdy) [D7 only]
348h	write reset [Data= don't care]

The base address (BADR) is decoded in ADRDEC. It is nanded with SA2:SA3, BADR+0, (B+0) to form -HSEL to select the I/O chip. B+0 nanded with IOR* forms -HRD, host read, directly. The 22V10 tail-bites the write pulse since the setup time is greater than necessary on the bus some of the bus duration is used to generate data hold time at the I/O chip. -HWR, host write is set the first clock after B+0 and IOW* is recognized. The next clock sets TOG and clears -HWR. TOG remains set holding -HWR clear until IOW* is unasserted on the bus indicating the end of the bus cycle. B+4 and IOR* out enables HRDY to SD7 so the status of HRDY may be tested. SD7 is used since the sign bit of a byte may be easily tested. The rest of the data bits are left floating and should be ignored. B+8 and IOW* generate a reset pulse which will init the interface by clearing the two write registers and outputs a reset pulse, -RS, for the CP chip. The reset instruction is OR'd with RESET on the bus to initialize the PMD chip set when the PC is reset.

Parallel-Word Device Interface

The following schematic shows a typical interface circuit between the MC1401A and a parallel-word position input device.

Using the same basic circuit, any number of parallel-word devices such as a resolver (after R/D conversion), an absolute encoder, or a laser interferometer could be used).

Comments on Schematic

The parallel word device interface schematic is illustrated using a 74HCT374. The CP does not distinguish between internal fetches from program memory and external reads so, as can be seen from the timing diagram (in the Electrical Characteristics section of the manual), multiple reads will take place on the external bus. The CP will ignore the external timing during instruction fetches. As a result the external device can put data on the bus during the instruction fetches but auto-increment addressing of words or bytes can not be used. The CP selects the device with PosSlct. The address of the selected axis, DACAddr[0:1] is also set at the beginning of the transfer and maintained through the transfer. The address bits are decoded by the 74HCT138 and enabled by PosSlct and I/OCntrl0 (the CP read signal).

PWM Motor Interface

The following schematic shows a typical interface circuit between the MC1401A used in PWM output mode.

The LMD18200 H-bridge driver is used. To simplify the schematic, a diode bridge has been shown for 1 axis only. The diode bridge for the other 3 axis is identical.

16-bit Parallel DAC Interface

The Interface between the MC1401A chip set and one or more 16 bit DACs is shown in the following figure.

Comments on Schematic

The 16 Data bits and 2 address bits from the CP chip are latched in the two 74FCT841 latches when the CP writes to address F hex, in the address bits A0:A3. Three 74C373 latches could also be used. If this is a write to the DAC, DACSLCT will be asserted during this CP bus cycle. The assertion of DACSLCT will be latched by the fed-back and-or gate and the next clock will set the DACWR flop. The second clock will set the second shift flop which will clear the DACL latch. Since this latch has been cleared the third clock will clear DACWR providing a two clock DACWR level. The fourth clock will clear the second shift flop returning the system to its original state waiting for the next DACSLCT. The DACWR assertion will enable the decoder causing the DAC selected by the address bits stored in the transparent latch. The timing described will produce a two clock write pulse to the DACs. This will be about 320 nSec using I/OClk.

16-Bit Serial DAC Interface

The following schematic shows an interface circuit between the MC1401A and a dual 16-bit serial DAC

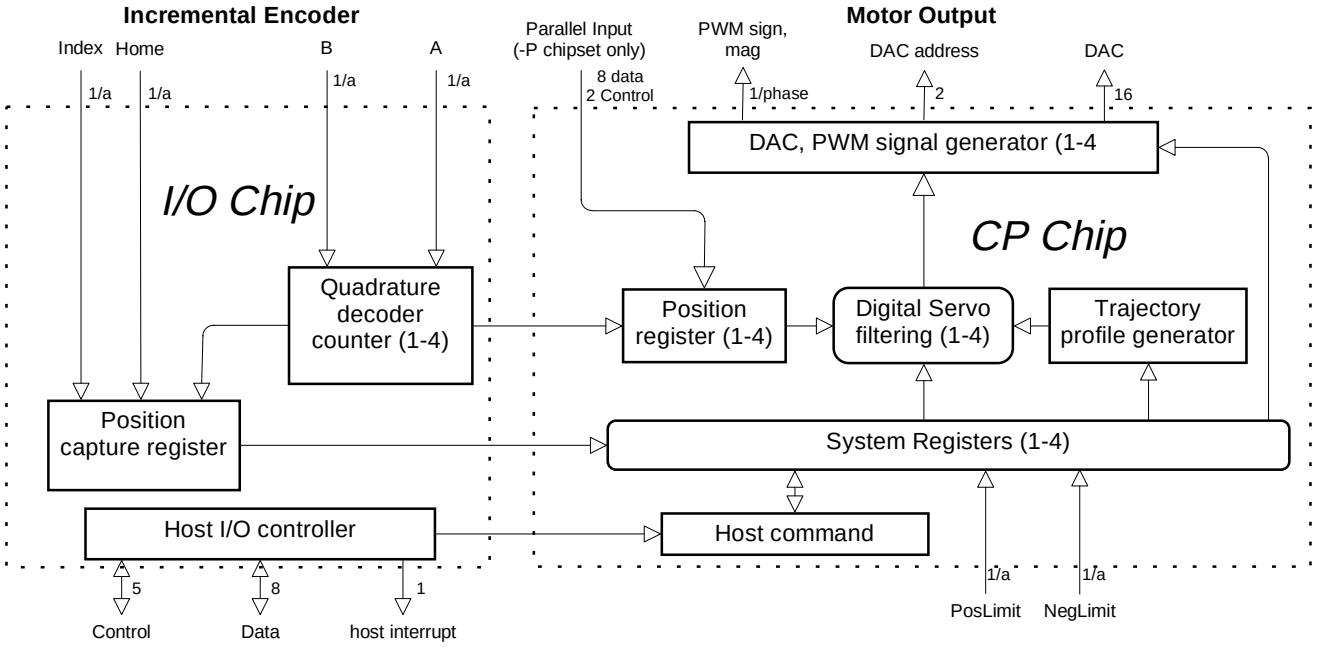
Comments on Schematic

The 16 data bits and the two address bits from the CP chip are latched in the two 74HC821 latches when the CP writes to address F hex, in the address bits A0-A3. Three 74HC373 latches could also be used. If this is a write to the DAC, DACSlct will be asserted during this CPU cycle. The assertion of DACSlct will be latched by the fed-back and-or gate, and the next clock will set the DACWR latch. The second clock will set the second shift flop which will clear the DACL latch. Since this latch has been cleared the third clock will clear DACWR providing a two clock DACWR level. The fourth clock will clear the second shift flop returning the system to its original state waiting for the next DACSlct.

When the DACWR flop is set the 16 bit shift register implemented by the 2 74FCT299's are parallel loaded with the 16 bits of data for the DAC. The 4 bit counter, 74FCT161, is also parallel loaded to 0, and the counter is enabled by clearing the ENP flop, which is contained in half of the 74HCT109. The counter will not start counting nor the shift register start shifting until the clock after the DACWR flop clears since the load overrides the count enable. When the DACWR flop is cleared the shift register will start shifting and the counter will count the shifts. After 15 shifts CNT15 from the counter will go high and the next clock will set the DACLAT flop and clear ENP flop. This will stop the shift after 16 shifts and assert L1 through L4 depending on the address stored in the latch. The 16th clock also was counted causing the counter to roll over to 0 and CNT15 to go low. The next clock will therefore clear the DACLAT flop causing the DAC latch signal L1 through L4 to terminate and the 16 bits of data to be latched in the addressed DAC. The control logic is now back in its original state waiting for the next write to the DACs by the CP.

NOTES

Internal Block Diagram



Technical Specifications

Available Configurations:	4 axes with incremental quadrature encoder input (MC1401A) 2 axes with incremental quadrature encoder input (MC1201A) 1 axes with incremental quadrature encoder input (MC1101A) 4 axes with parallel word encoder input (MC1401A-P) 2 axes with parallel word encoder input (MC1201A-P) 1 axes with parallel word encoder input (MC1101A-P)
Operating Modes:	Closed loop (motor command is driven from output of servo filter) Open loop (motor command is driven from user-programmed register)
Position Range:	-1,073,741,824 to 1,073,741,823 counts
Velocity Range:	-16,384 to 16,383 counts/sample with a resolution of 1/65,536 counts/sample
Acceleration Range:	S-curve profile: -1/2 to 1/2 counts/sample^2 with a resolution of 1/65,536 counts/sample^2 All other profiles: -16,384 to 16,383 counts/sample^2 with a resolution of 1/65,536 counts/sample^2
Jerk Range:	-1/2 to 1/2 counts/sample^3, with a resolution of 1/4,294,967,296 counts/sample^3
Trajectory Profile Generator Modes:	S-curve (host commands final position, maximum velocity, maximum acceleration, and jerk) Trapezoidal (host commands final position, maximum velocity, and acceleration) Velocity contouring (host commands maximum velocity, acceleration) Electronic Gear (Encoder position of one axis is used as position command for another axis).
Electronic Gear Ratio Range:	32768:1 to 1:32768 (negative and positive direction)
Filter Modes:	PID+Vff (Proportional, Integral, Derivative, velocity feedforward, DC bias)
Filter Parameter Resolution:	16 bits
Motor Output Formats:	PWM (10 bits resolution @ 24.5 Khz) DAC (16 bits)
Max. Encoder Rate:	Incremental: 1.0 Megacounts/sec, Parallel-word: 80.0 Mcounts/sec.
Parallel Encoder Word Size:	16 bits (read in 2 byte reads, -P version only)
Max. Servo Loop Rate:	100 uSec per enabled axis
# of Limit Switches Per Axis:	2 (one for each direction of travel)
# Of Position Capture Triggers:	2 (index, home signal)
Capture Trigger Latency:	160 nSec
# of Host Commands:	94

Chipset

P/N: MC1☐01A -☐

4 - 4 axis
2 - 2 axis
1 - 1 axis

No dash - Incremental encoder
P - parallel encoder

Ordering Information

Custom versions of chipset available upon request. Call

Chipset Developer's Kit

p/n: DK1401A -☐ *

*Supports MC1401A, MC1201A, MC1101A,

No dash - Incremental encoder
P - parallel encoder

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