RD7
TOPSwitch®-II
PC Standby Reference Design Board
90 to 375 VDC Input, 3.5 W Output

Product Highlights

Low Cost Production Worthy Reference Design
- Up to 3.5 W of output power
- Meets Blue Angel requirements (5 W)
- Single sided board
- Low cost through-hole components
- Fully assembled and tested
- Easy to evaluate and modify
- Extensive performance data
- Light weight - no heat sink required for *TOPSwitch-II*
- Non-isolated +12 V output option

Fully Protected by *TOPSwitch-II*
- Primary safety current limit
- Output short circuit protection
- Thermal shutdown protects entire supply

Designed for World Wide Operation
- Designed for IEC/UL safety requirements
- Designed for wide range of input voltage

Typical Applications
- Desktop PC stand-by power supply (PS98, ATX, NLX, SFX, Micro ATX)
- Consumer stand-by supply (e.g. TV, VCR, DVD)

Description

The RD7 reference design board is an example of a very low cost production worthy DC input standby power supply design using the *TOPSwitch-II* family of Three-terminal Off-line PWM switchers. The reference design board is intended to help *TOPSwitch-II* users quickly develop their products. It provides a basic design that can be easily modified to fit a particular application. The RD7 operates from a rectified and filtered AC mains voltage and provides 3.5 W output at 5 V. Features such as a 12 V non-isolated output or tighter output voltage tolerance may be implemented by changing only a few components (See Figure 4).

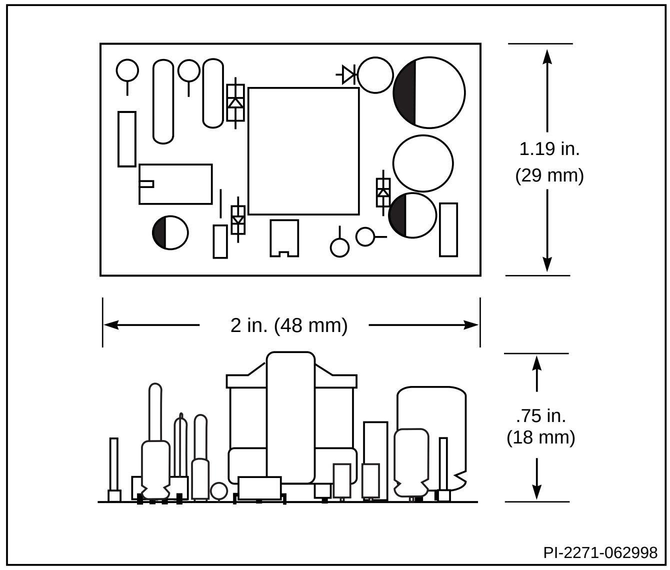


Figure 1. RD7 Overall Physical Dimensions.

PARAMETER	LIMITS
Input Voltage Range	90 to 375 VDC
Temperature Range	0 to 50° C
Output Voltage (I_o = 0.7 A)	5 V ± 5%
Output Power (continuous)	3.5 W
Line Regulation (90-375VDC)	± 1.0%
Load Regulation (10%-100%)	± 1.0%
Efficiency (At full load)	72%
Output Ripple Voltage	± 50 mV
Safety	IEC950/UL1950

Table 1. Table of Key Electrical Parameters.

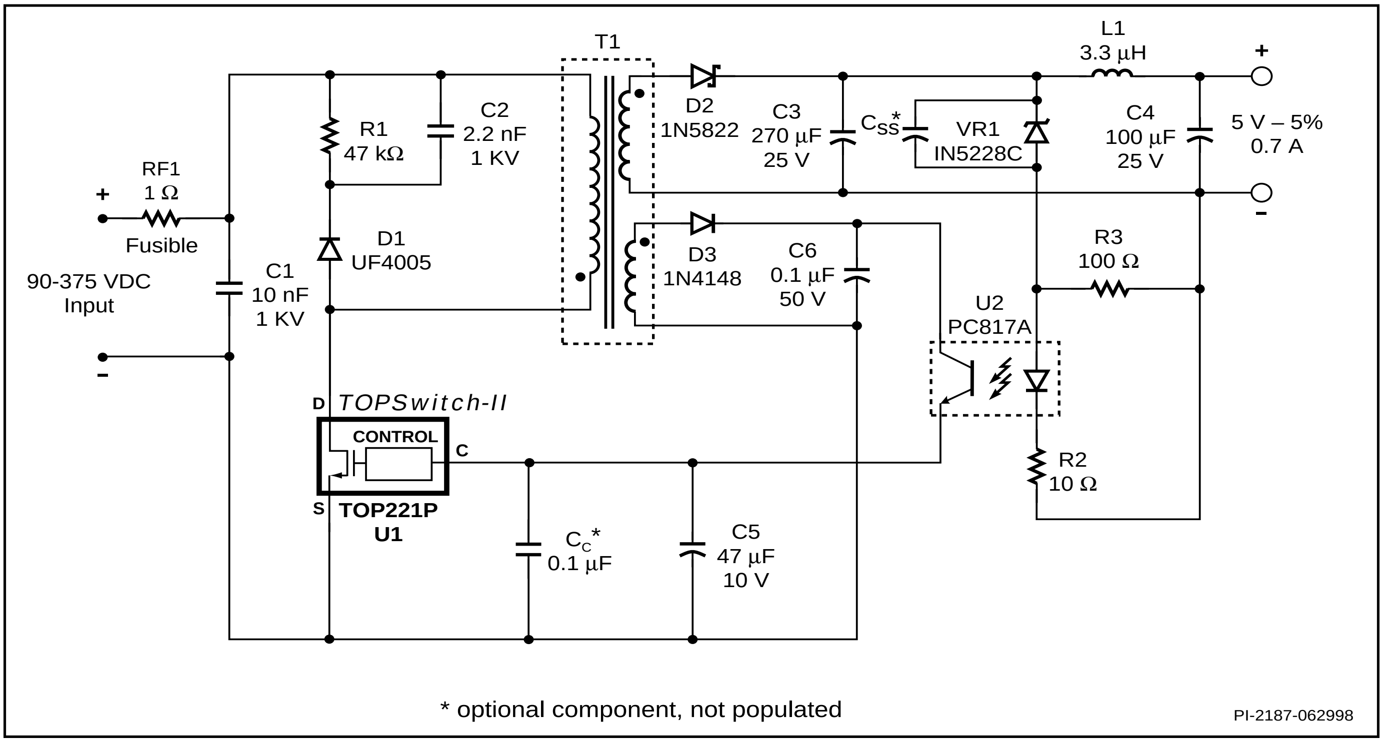


Figure 2. Schematic diagram of the RD7.

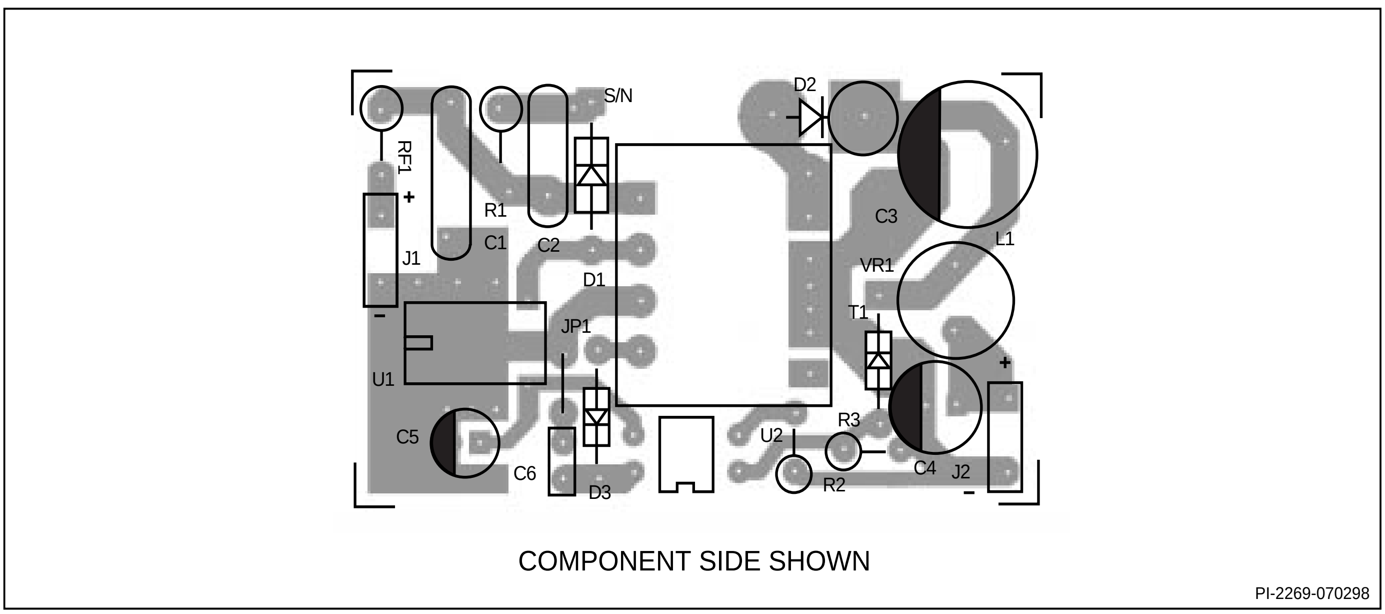


Figure 3. RD7 Pinout and Component Legend.

CAUTION

The RD7 is designed for DC input. Please observe the proper polarity when applying power to this board. Applying reverse polarity or AC power to the input terminals of the board can damage the *TOPSwitch*.

Component Listing

Reference	Value	Part Number	Manufacturer
C1	10 nF, 1 KV, Disc	5GAS10	Cera-Mite
C2	2.2 nF 1 KV, Disc	DD222	Philips
C3	270 µF 25 V	ECA-1EFQ271	Panasonic
C4	100 µF 25 V	ECE-A1EGE101	Panasonic
C5	47 µF, 10 V	ECE-A1AGE470	Panasonic
C6	0.1 µF, 50 V	ECU-S1H104MEA	Panasonic
C_c*	0.1 µF, 50 V	ECU-S1H104MEA	Panasonic
C_{ss}*			
D1	600 V, 1A, UFR	UF4005	General Instrument
D2	40 V, 3 A, Schottky	1N5822	General Instrument
D3	75 V, Switching	1N4148	Liteon
L1	3.3 µH, 5 A	622LY-3R3M	Toko
RF1	1 Ω Fuse Resistor 1/2 W	BW1/2F 1 Ω 5%	RCD
R1	47 K, 1/2 W	5053CX47K00J	Philips
R2	10 Ω, 1/4 W	5043CX10R00J	Philips
R3	100 Ω, 1/4 W	5043CX100R0J	Philips
T1**		TRD7	Custom
U1		TOP221P or TOP221G***	Power Integrations
U2	Optocoupler, Controlled CTR	LTV817A	Liteon
VR1	3.9 V, Zener, 2%	1N5228C	APD

Table 2. Parts List For the RD7. (Optional, for C_{ss} values see Figure 9. **T1 is available from Premier Magnetics (714) 362-4211 as P/N TDS-1185-9818, and from Coiltronics (561) 241-7876 as P/N CTX14-14193-X1. *** TOP221G can be used with layout modifications.)*

General Circuit Description

The RD7 is a low-cost, flyback switching power supply using the TOP221P. The circuit shown in Figure 2 provides a nominal output power of 3.5 W at 5 VDC output. The power supply operates from a DC voltage of 90 to 375 VDC. In a typical application this DC voltage is derived from a rectified and filtered AC main voltage of 85 to 265 VAC. The 5 V output is directly sensed by optocoupler U2 and Zener diode VR1. The output voltage is determined by the Zener diode (VR1) voltage and the voltage drop across the optocoupler (U2) LED and resistor R2. Other output voltages are possible by adjusting the transformer turns ratios and the value of the Zener diode VR1.

The positive rail of the high voltage DC input is connected to one side of the primary winding of T1. Capacitor C1 filters the high voltage supply, and is necessary only if the connections between the high voltage DC supply and the RD7 are long. The other side of the transformer primary is driven by the integrated, high-voltage MOSFET inside the TOP221. D1, R1, and C2 clamp voltage spikes caused by transformer leakage inductance to a safe value and reduce ringing at the DRAIN of U1.

The secondary winding is rectified and filtered by D2 and C3 to generate a 5 V output. L1 and C4 provide additional filtering to reduce high frequency ripple voltage. R3 and VR1 provide a slight pre-load on the 5 V output to improve load regulation at light loads. R3 also provides bias current for Zener VR1 to improve regulation.

Soft start can be added to eliminate turn-on overshoot. With C_{ss} placed across VR1, the optocoupler current is increased during turn-on time. This increased current limits the duty cycle and slows down the rising output voltage (See Figure 9). The bias winding output is rectified and filtered by D3 and C6 to provide a bias voltage for U2. C5 filters internal MOSFET gate drive charge current spikes on the CONTROL pin, determines the auto-restart frequency, and compensates the control loop. C_c is needed when the supply is operating in a noisy environment (e. g. when the power supply is sharing the same input rectifier and filter capacitor with another power supply). C_c filters high frequency noise.

The schematic of Figure 4 shows an enhanced version of the RD7. The circuit comprising R2, R3, R4, R5 and U3 improves overall output regulation to ±2%. Optional soft start capacitor C_{ss} is used to eliminate turn-on overshoot. The bias supply output can be used to provide a +12 V, non-isolated output by changing C6 to 100 µF as shown in Figure 4. C6 is added to reduce output ripple to a primary load.

The circuit performance data shown in Figures 5 to 12 was

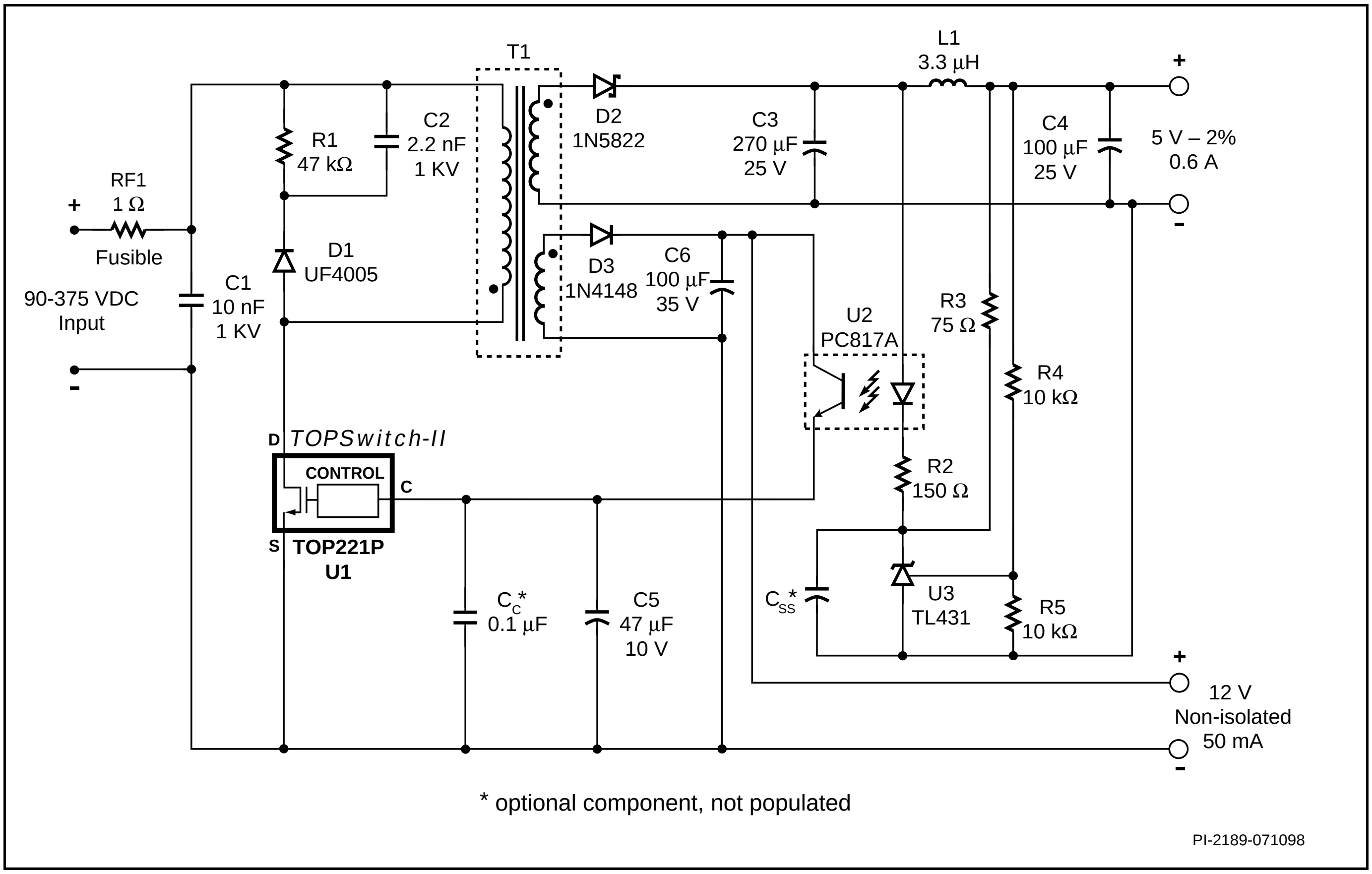


Figure 4. Schematic diagram of the RD7 with 12V Non-isolated output.

measured with DC voltage applied to RD7.

Load Regulation (Figure 5(a) and 5(b)) - The amount of change in the DC output voltage for a given change in output current is referred to as load regulation. The 5 V output stay within ±1.0% when the output current is between 0% to 100% of rated load current at the 5 V output. The *TOPSwitch-II* over-temperature protection circuit will safely shut down the power supply under prolonged overload conditions. When the output load is disconnected, R3 acts as a preload and the output stays in regulation.

Line Regulation (Figure 6(a) and 6(b)) - The amount of change in DC output voltage for a given change in the DC input voltage is called line regulation. The maximum change in output voltage is within ±1%.

Efficiency (Line Dependent). Efficiency is the ratio of output power to the input power. The curve in Figure 7 shows how the efficiency changes with input voltage using a 3.5 W load. The efficiency is greater than 72% throughout the input range.

Efficiency (Load Dependent). The curves in Figure 8 show how the efficiency changes with output power at 155 and 310 VDC inputs. The efficiency is greater than 70% for loads greater than 2.5 W.

Power Supply Turn On Sequence. An internal switched, high voltage current source provides the initial bias current for *TOPSwitch* when power is first applied. The waveforms shown in Figure 8 illustrates the timing relationship between the high voltage DC bus and 5 V output voltage for the RD7 circuit. Capacitor C1 charges to the DC input voltage before *TOPSwitch* turns on. The delay of 130 ms (typical) is caused by the time required to charge the auto-restart capacitor C5 to 5.7 V. At this point the power supply turns on as shown.

Figure 10 shows the output voltage turn on transient as well as a family of curves associated with the additional soft-start capacitor C_{ss}. The soft-start capacitor is placed across VR2 and can range in value from 10 µF to 47 µF as shown.

Switching frequency ripple voltage is shown in Figure 11 for the RD7 circuit at 155 VDC input and 3.5 W output. Peak to peak ripple is less than 50 mV at 3.5 W.

The RD7 power supply transient response to a step load change from 0.52 A to 0.75 A (75% to 100%) is shown in Figure 12. The response is quick and well damped.

The RD7 is designed to meet worldwide safety specifications.

Thermal Considerations

The RD7 utilizes the printed circuit copper for *TOPSwitch-II* heatsinking. With a copper area of approximately 0.227 in^2 (1.46 cm^2) and 2 oz. (610 g/m^2) copper cladding, the temperature of the *TOPSwitch-II* rises 6 °C at 50 °C ambient temperature and 3.5 W load.

Transformer Specifications

The electrical specifications and construction details for transformer TRD7 are shown in Figures 13 and 14. Transformer TRD7 is supplied with the RD7 reference design board. This design utilizes an EE16 core and a triple insulated wire secondary winding. The use of triple insulated wire allows the transformer to be constructed using a smaller core and bobbin than a conventional magnet wire design due to the elimination of the creepage margins required for safety spacing in a conventional design.

If a conventional margin wound transformer is desired, the design of Figures 15 and 16 can be used. This design (TRD7-1) uses an EEL16 core and bobbin to accommodate the 6 mm creepage required to meet international safety standards when using magnet wire rather than triple insulated wire, and has the same pinout and printed circuit foot print as TRD7. The transformer is approximately 50% taller than the triple insulated wire design due to the inclusion of creepage margins required to meet international safety standards.

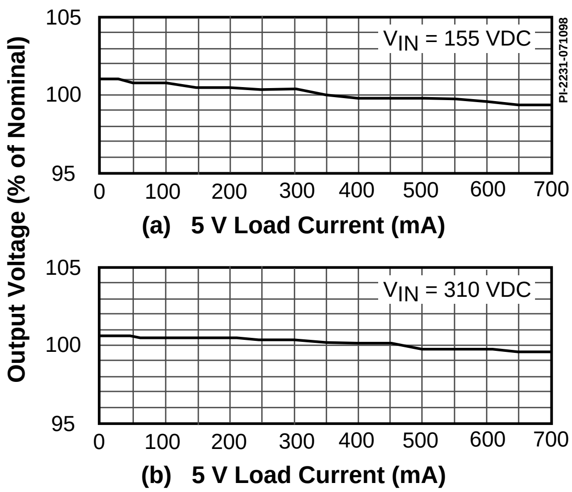


Figure 5 (a). Load Regulation at 155 VDC Input Voltage.
(b). Load Regulation at 310 VDC Input Voltage.

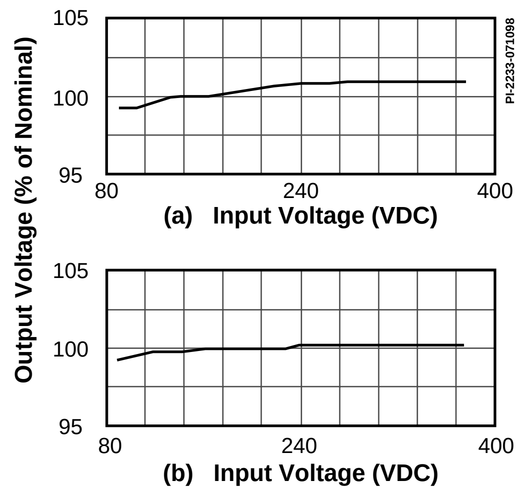


Figure 6 (a). Line Regulation at 3.5 W Output.
(b). Line Regulation at 0.35 W Output.

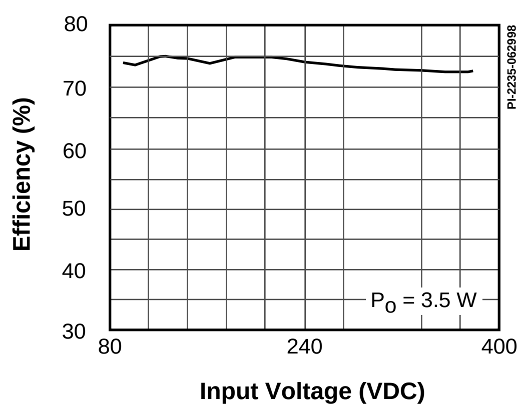


Figure 7. Efficiency vs. Input Voltage, 3.5 W Output.

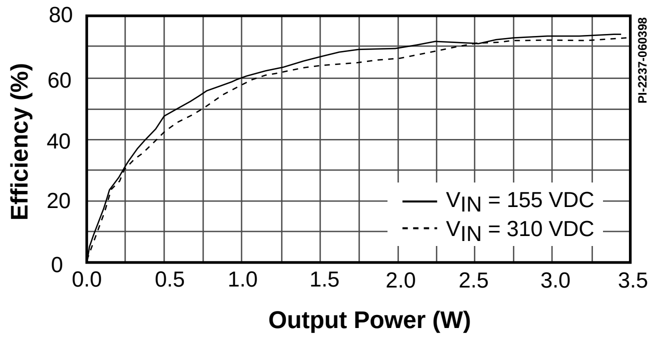


Figure 8. Efficiency vs. Output Power.

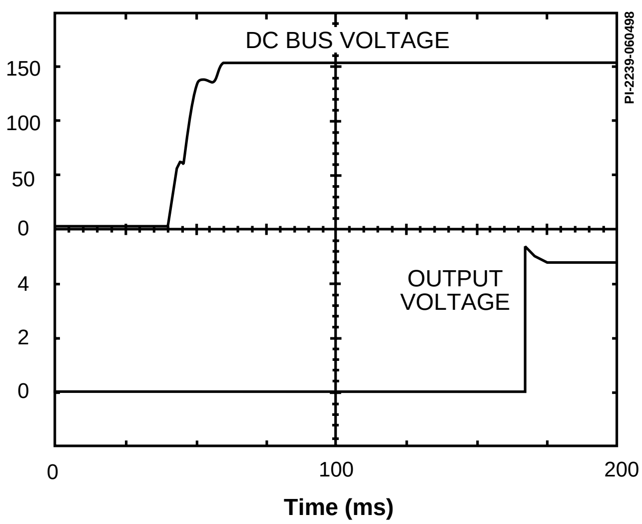


Figure 9. Turn on Delay.

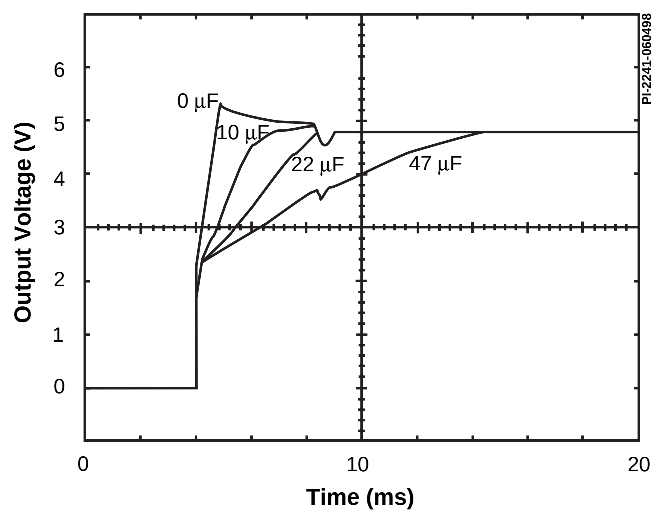


Figure 10. Output Voltage Turn On Transient vs. Soft Start Capacitor.

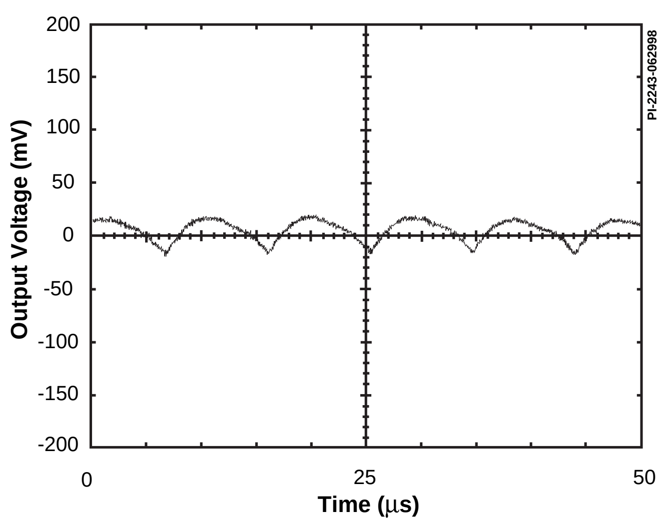


Figure 11. Switching Frequency Ripple, 155 VDC Input, 3.5 W Output.

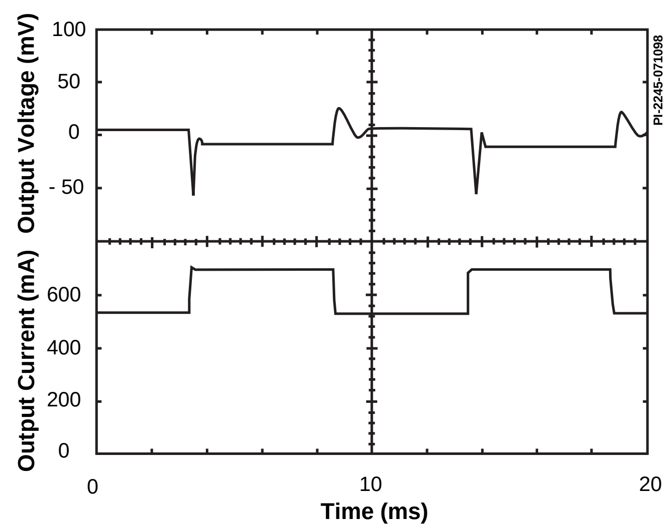
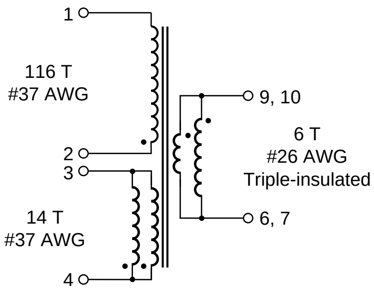
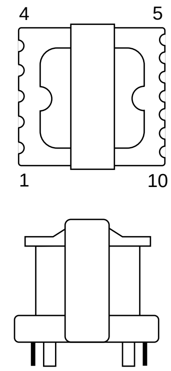


Figure 12. Transient Load Response (75% to 100% of load).

TRIPLE INSULATED SECONDARY TRANSFORMER (TRD1)



PIN	FUNCTION
1	HIGH-VOLTAGE DC BUS
2	*TOPSwitch* DRAIN
3	PRIMARY-SIDE COMMON
4	V_{BIAS}
6, 7	SECONDARY RETURN
9, 10	OUTPUT



CORE# - PC40 EE16-Z (TDK)
GAP FOR A_L OF 182 nH/T^2
BOBBIN# - YW-193 (Yih Hwa Enterprises)

ELECTRICAL SPECIFICATIONS		
Electrical Strength	60 Hz, 1 minute, from pins 1-4 to pins 5-10	3000 VAC
Creepage	Between pins 1-4 and pins 5-10	6.00 mm (min)
Primary Inductance	All windings open	2430 µH –10%
Resonant Frequency	All windings open	500 kHz (min)
Primary Leakage Inductance	Between pins 1-2 (pins 6-10 shorted)	63 µH (max)

NOTE: All inductance measurements should be made at 100 kHz

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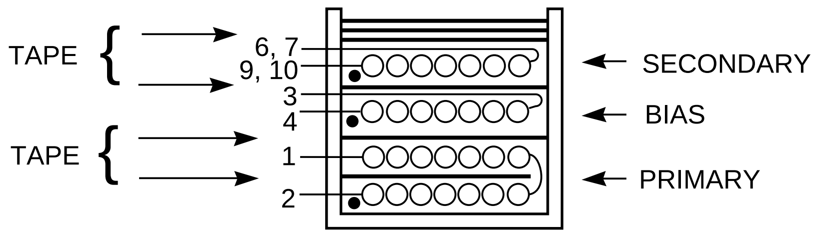
Figure 13. Electrical Specification of Transformer TRD7.

TRIPLE INSULATED SECONDARY TRANSFORMER CONSTRUCTION



WINDING INSTRUCTIONS	
Primary	Start at Pin 2. Wind one complete layer (about 58 turns) of 37 AWG heavy nyleze wire from left to right. Insulate first layer using 1 turn of polyester film tape, 8.3 mm wide, 0.056 mm thick. Wind remaining 58 turns from right to left for a total of 116 turns. Finish at Pin 1.
Basic Insulation	Apply 1 layer of tape for basic insulation.
Bias Winding	Start at Pin 4. Wind 14 turns parallel bifilar of 37 AWG wire from left to right in a single layer. Finish at Pin 3.
Basic Insulation	Apply 1 layer of tape for basic insulation.
Secondary Winding	Start at Pins 9, 10. Wind 6 turns parallel bifilar of 26 AWG triple insulated wire from left to right. Finish on Pin 6, 7.
Outer Insulation	Apply 3 layers of tape for basic insulation.
Final Assembly	Assemble and secure core halves. Impregnate uniformly with varnish.

* Triple insulated wire sources.

P/N: T27A01TXXX-3
Rubudue Wire Company
5150 E. La Palma Avenue
Suite 108
Anaheim Hills, CA 92807
(714) 693-5512
(714) 693-5515 FAX

P/N: order by description
Furukawa Electric America, Inc.
200 Westpark Drive
Suite 190
Peachtree City, GA 30269
(770) 487-1234
(770) 487-9910 FAX

P/N: order by description
The Furukawa Electric Co., Ltd
6-1, Marunouchi 2-chome,
Chiyoda-ku, Tokyo 100, Japan
81-3-3286-3226
81-3-3286-3747 FAX

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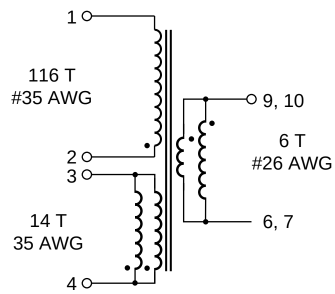
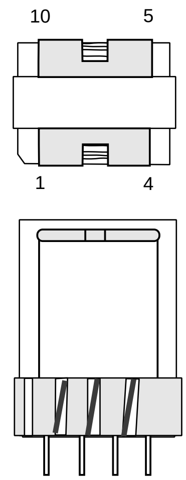
Figure 14. Construction Details of Transformer TRD7.

MARGIN WOUND TRANSFORMER



CORE# - PC40 EE16/24/5-Z (TDK)
GAP FOR A_L OF 182 nH/T^2
BOBBIN# - YW-035 (Yih Hwa Enterprises)

PIN	FUNCTION
1	HIGH-VOLTAGE DC BUS
2	TOPSwitch DRAIN
3	PRIMARY-SIDE COMMON
4	V_{BIAS}
6, 7	RETURN
9,10	OUTPUT



ELECTRICAL SPECIFICATIONS		
Electrical Strength	60 Hz, 1 minute, from pins 1-4 to pins 5-10	3000 VAC
Creepage	Between pins 1-4 and pins 5-10	6.0 mm (min)
Primary Inductance	All windings open	2430 µH –10%
Resonant Frequency	All windings open	300 kHz (min)
Primary Leakage Inductance	Between pins 1-2 (pins 6-10 shorted)	70 µH (max)

NOTE: All inductance measurements should be made at 100 kHz

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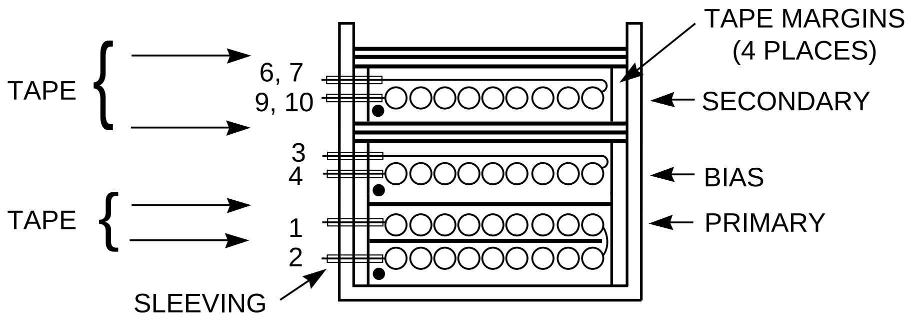
Figure 15. Electrical Specification of Transformer TRD7-1.

MARGIN WOUND TRANSFORMER CONSTRUCTION



WINDING INSTRUCTIONS	
Safety Margin	Construct margins on each side of bobbin using 3 mm wide tape. Match height of primary plus bias winding.
Primary	Start at Pin 2. Wind one complete layer (about 58 turns) of 35 AWG heavy nyleze wire from left to right between margins. Insulate first layer using 1 layer of polyester tape (polyester film 11.5 mm (0.456 in) wide and 0.056 (2.2 mil) thick) for basic insulation. Wind remaining 58 turns in second layer from right to left. Finish on Pin 1. Sleeve start and finish leads using safety approved insulating sleeving with 0.4 mm (0.016 in) minimum wall thickness.
Basic Insulation	Apply 1 layer of 11.5 mm wide tape for basic insulation.
Bias Winding	Start at Pin 4. Wind 14 parallel bifilar turns of 35 AWG heavy nyleze wire from left to right in a single layer. Finish on Pin 3. Sleeve start and finish leads as above.
Reinforced Insulation	Apply 3 layers of tape (polyester film, 17.5 mm (0.689 in) wide and 0.056 mm (2.2 mil) thick) for reinforced insulation.
Safety Margin	Construct margins on each side of bobbin using 3 mm wide tape. Match height of secondary winding.
Secondary Winding	Start at Pin 9 and 10. Wind 6 parallel bifilar turns of 26 AWG heavy nyleze wire from left to right in a single layer. Finish on Pin 6 and 7. Sleeve start and finish leads as above.
Outer Insulation	Apply 3 layers of 17.5 mm tape for outer insulation.
Final Assembly	Assemble and secure core halves. Impregnate uniformly with varnish.

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Figure 16. Contruction Details of Transformer TRD7-1.

Revision	Notes	Date
A	-	9/98
B	Measurement method for primary leakage inductance of TRD7 and TRD7-1 corrected.	4/99

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