RD5
TOPSwitch®-II
Reference Design Board
85 to 265 VAC Input, 20W (30W Peak) Output

Product Highlights

Low Cost Production Worthy Reference Design
- Only 22 components!
- Single sided board
- Low cost thru-hole components
- Fully assembled and tested
- Easy to evaluate and modify
- Extensive performance data
- Up to 80% efficiency
- Light weight – no heat sink required for *TOPSwitch-II*

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

Designed for World Wide Operation
- Designed for IEC/UL safety requirements
- Meets VDE Class B EMI specifications

Description

The RD5 reference design board is an example of a very low cost production worthy power supply design using the *TOPSwitch* family of Three-terminal Off-line PWM Switchers from Power Integrations. It is intended to help *TOPSwitch* users to develop their products quickly by providing a basic design that can be easily modified to fit a particular application. In most cases, a minor change to the transformer for a different output voltage is all that is needed. Multiple output voltages are obtained just as easily. A constant current or constant power output may be implemented with the addition of a few low cost components.

Typical applications include AC-DC adapters for laptops, notebooks and PDAs, battery chargers for cellular telephones, power tools and camcorders, VTR/VCR, video game, appliance and satellite decoder power supplies.

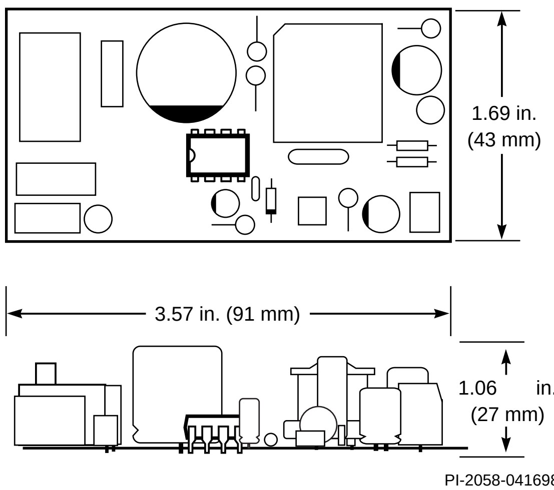


Figure 1. RD5 Board Overall Physical Dimensions.

PARAMETER	LIMITS	
Input Voltage Range	85 to 265 VAC	
Input Frequency Range	47 to 440 Hz	
Temperature Range	0 to 50°C	
Output Voltage (I_o = 1.0A)	12 V ± 5%	
Output Power (continuous)	25˚C	20W
	50˚C	15W
Output Power (peak)	30W	
Line Regulation (85-265 VAC)	± 1%	
Load Regulation (10%-100%)	± 1%	
Efficiency	78%	
Output Ripple Voltage	± 60 mV MAX	
Safety	IEC 950 / UL1950	
EMI	VDE B (VFG243 B) CISPR22	

Figure 2. Table of Key Electrical Parameters.

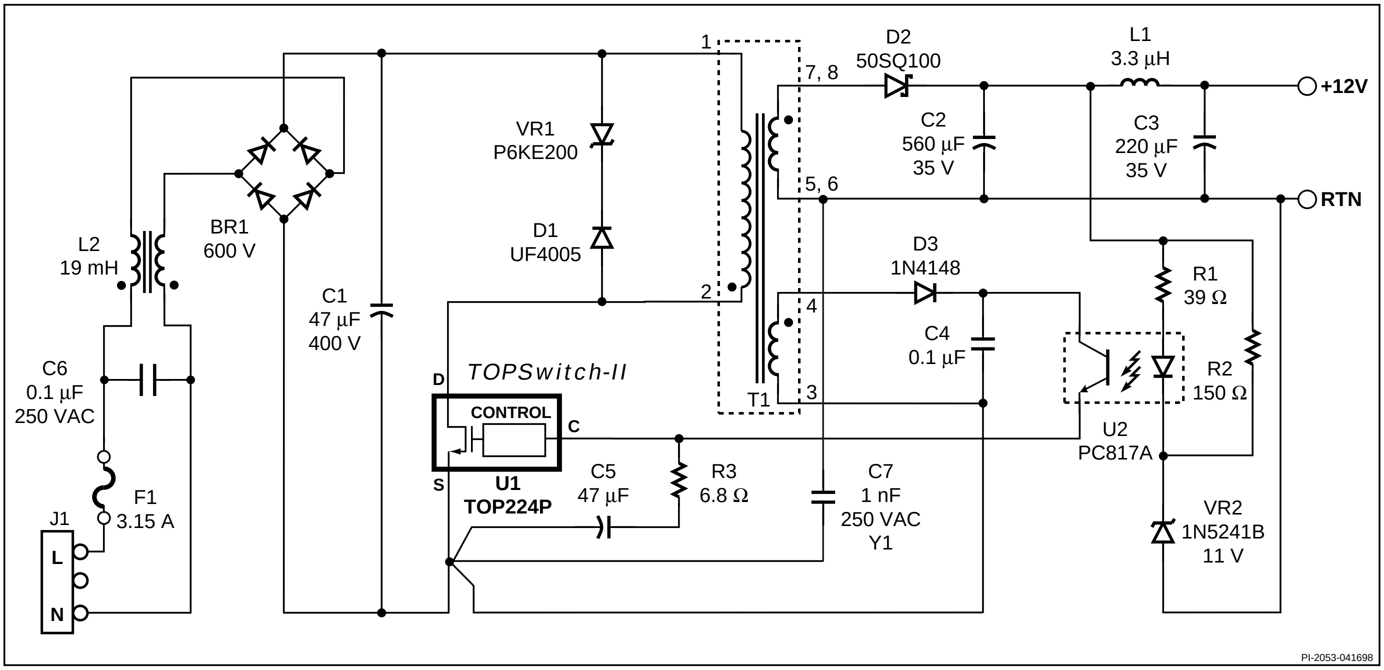


Figure 3. Schematic Diagram of the 12V RD5 Power Supply.

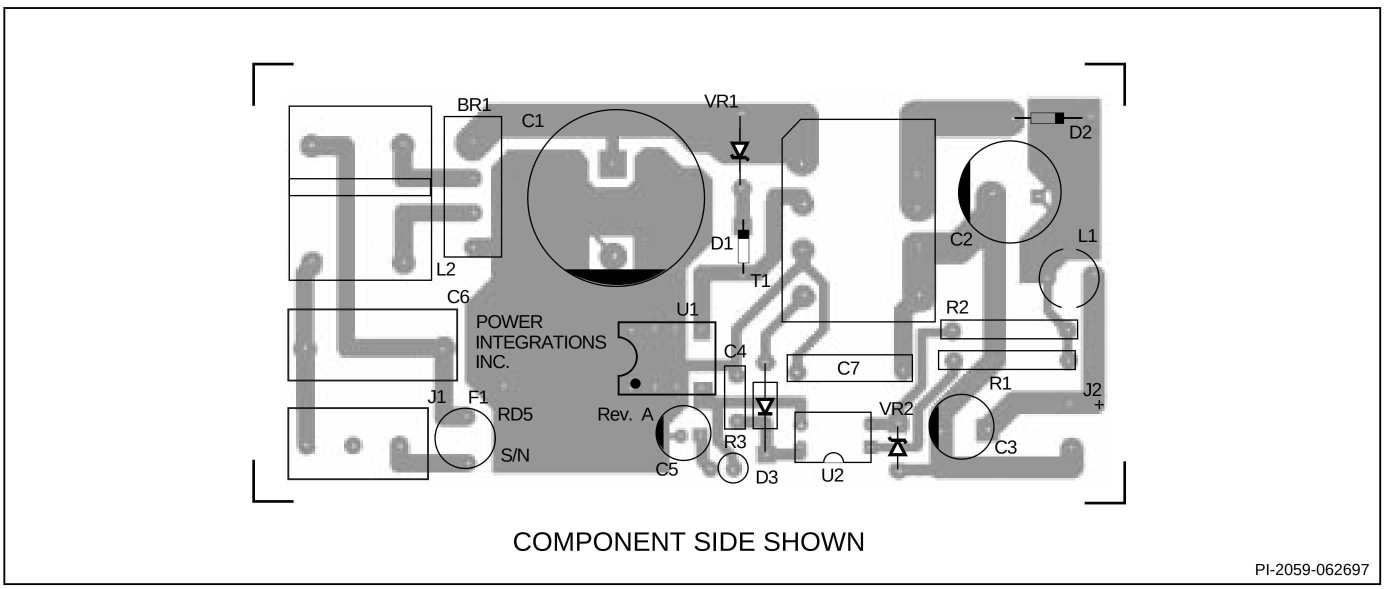


Figure 4. Component Legend of the RD5.

General Circuit Description

The RD5 is a low-cost, flyback switching power supply using the TOP224P integrated circuit. The circuit shown in Figure 3 produces a 12 V, 20 W power supply that operates from 85 to 265 VAC input voltage. The 12 V output is directly sensed by optocoupler U2 and Zener diode VR2. The output voltage is determined by the Zener diode (VR2) voltage and the voltage drops across the optocoupler (U2) LED and resistor R1. Other output voltages are also possible by adjusting the transformer turns ratios and value of Zener diode VR2.

AC power is rectified and filtered by BR1 and C1 to create the high voltage DC bus applied to the primary winding of T1. The other side of the transformer primary is driven by the integrated high-voltage MOSFET within the TOP224. D1 and VR1 clamp the leading-edge voltage spike caused by transformer leakage inductance to a safe value and reduce ringing. The

Component Listing

Reference	Value	Part Number	Manufacturer
BR1	600 V, 2 A	2KBPC06M	General Instrument
C1	47 µF, 400 V	381LX470M400H012	Cornell-Dubilier
C2	560 µF, 35 V	ECA-1VFQ561	Panasonic
C3	220 µF, 35 V	ECE-A1VGE221	Panasonic
C4	0.1 µF, 50 V	RPE131R104M50	Murata
C5	47 µF, 10 V	ECE-A1AG470	Panasonic
C6	0.1 µF, 250 VAC, X	F1772-410-2000	Roederstein
C7*	1.0 nF, 400 VAC, Y1*	DE1110E102M ACT4K-KD	Murata
		(or WKP102MCPE.OK	Roederstein)
		(or PME294RB4100M	Rifa)
D1	600 V, 1A, UFR	UF4005	General Instrument
D2	100 V, 5A, Schottky	50SQ100	International Rectifier
D3	75 V, Switching	1N4148	National Semiconductor
L1	3.3 µH, 6.5 A	622LY-3R3M	Toko
L2	19 mH, 400 mA	ELF15N005A	Panasonic
R1	39 Ω, 1/4 W	5043CX39R00J	Philips
R2	150 Ω, 1/4 W	5043CX150R0J	Philips
R3	6.8 Ω, 1/4 W	5043CX6R800J	Philips
T1**		TRD5	Custom
U1		TOP224P	Power Integrations
U2		PC817A	Sharp
VR1	200 V Zener TVS	P6KE200	General Instrument
VR2	11 V Zener	1N5241B	Motorola
F1	3.15 A, 250 VAC	19372K, 3.15A	Wickman

Figure 5. Parts List for the RD5 (Two Series Connected, 2.2 nF, Y2-Capacitors Such as Murata DE7100F222MVA1-KC can replace C7). ** T1 is available from Premier Magnetics (714) 362-4211 as P/N POL-12017, and from Coiltronics (561) 241-7876 as P/N CTX00-13742.*

power secondary winding is rectified and filtered by D2, C2, L1, and C3 to create the 12 V output voltage. R2 and VR2 provide a slight pre-load on the 12 V output to improve load regulation at light loads. R2 also provides bias current for Zener VR2 to improve regulation. The bias winding is rectified and filtered by D3 and C4 to create a bias voltage to the TOP224P. L2 and Y1-capacitor C7 attenuate common-mode emission currents caused by high-voltage switching waveforms on the DRAIN side of the primary winding and the primary to secondary capacitance. L2 and C6 attenuate differential-mode emission currents caused by the fundamental and harmonics of the primary current waveform. C5 filters internal MOSFET gate drive charge current spikes on the CONTROL pin, determines the auto-restart frequency, and together with R1 and R3, compensates the control loop.

The circuit performance data shown in Figures 6-18 were measured with AC voltage applied to the RD5.

Load Regulation (Figure 6) – The amount of change in the DC output voltage for a given change in output current is referred to as load regulation. The 12 V output stays within ±1% from 10% to 100% of rated load current. The *TOPSwitch* on–chip overtemperature protection circuit will safely shut down the power supply under persisting overload conditions. Below minimum load, the 12 V output rises slightly due to the *TOPSwitch* minimum duty cycle.

Line Regulation (Figure 7) - The amount of change in the DC output voltage for a given change in the AC input voltage is called line regulation. The maximum change in output voltage is within ± 1%.

Efficiency (Line Dependent) – Efficiency is the ratio of the output power to the input power. The curves in Figures 8 and 9 show how the efficiency changes with input voltage.

Efficiency (Load Dependent) – The curves in Figures 10 and 11 show how the efficiency changes with output power for 115 VAC and 230 VAC inputs.

Power Supply Turn On Sequence – The internal switched, high-voltage current source provides the initial bias current for *TOPSwitch* when power is first applied. The waveforms shown

General Circuit Description (cont.)

in Figure 12 illustrate the relationship between the high-voltage DC bus and the 12 V output voltage. Capacitor C1 charges to the peak of the AC input voltage before *TOPSwitch* turns on. The delay of 160 ms (typical) is caused by the time required to charge the auto-restart capacitor C5 to 5.8 V. At this point the power supply turns on as shown.

Figure 13 shows the output voltage turn on transient as well as a family of curves associated with an additional soft-start capacitor. The soft-start capacitor is placed across VR2 and can range in value from 4.7 uF to 47 uF as shown.

Line frequency ripple voltage is shown in Figure 14 for 115 VAC input and 20 W output. Switching frequency ripple voltage is shown in Figure 15 for the same test condition.

The power supply transient response to a step load change from 1.25 to 1.67 A (75% to 100%) is shown in Figure 16. Note that the response is quick and well damped.

The RD5 is designed to meet worldwide safety and EMI (VDE B) specifications. Measured conduction emissions are shown in Figure 17 for 115 VAC and Figure 18 for 230 VAC.

Thermal Considerations

The RD5 utilizes the printed circuit copper for *TOPSwitch* heatsinking. For 20 W output, the heatsink area is approximately 1.25 in^2 (8 cm^2). The copper area required for heatsinking at 15 W output is outlined on the non-component side of the board, and is approximately 0.56 in^2 (3.6 cm^2). The RD5 printed circuit board utilizes 2 oz. copper cladding. Printed circuit boards with lighter cladding will require apertures in the solder mask to build-up effective trace thickness.

Transformer Specification

The electrical specifications and construction details for transformer TRD5 are shown in Figures 19 and 20. Transformer TRD5 is supplied with the RD5 reference design board. This design utilizes an EI25 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 margins required for safety spacing in a conventional design.

If a conventional margin wound transformer is desired, the design of Figures 21-22 can be used. This design (TRD5-1) uses a EEL22 core and bobbin to accommodate the 3 mm margins 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 TRD5. 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.

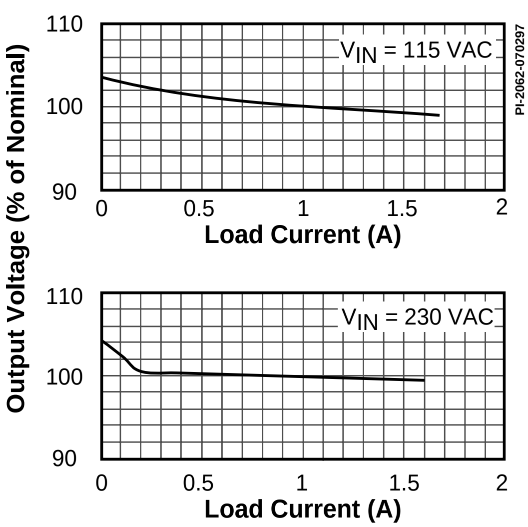


Figure 6. Load Regulation

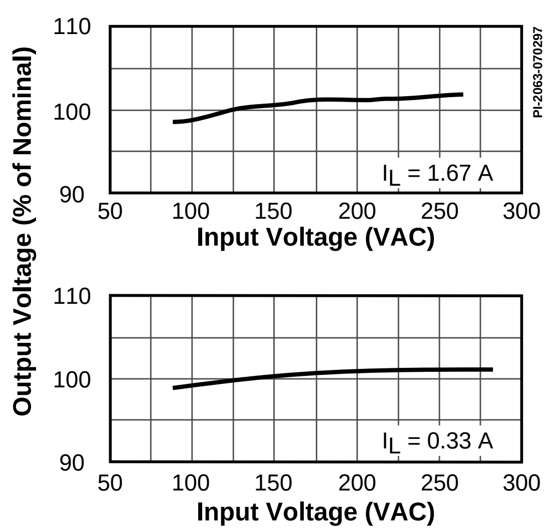


Figure 7. Line Regulation

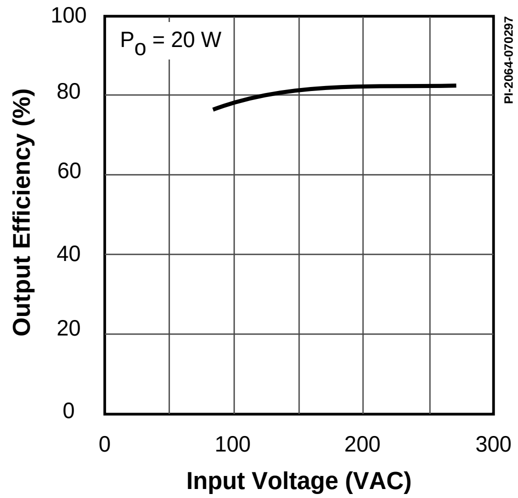


Figure 8. Efficiency vs. Input Voltage, 20 W Output

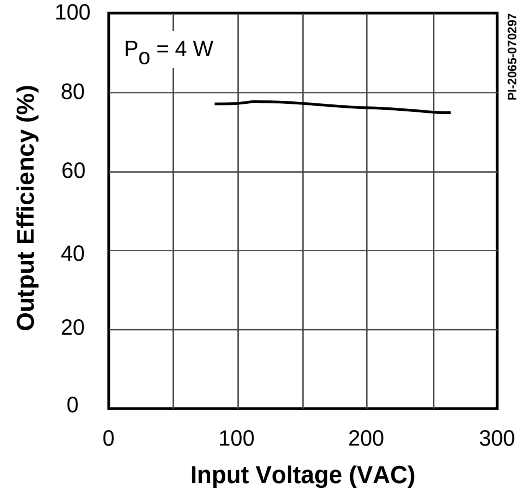


Figure 9. Efficiency vs. Input Voltage, 4 W Output

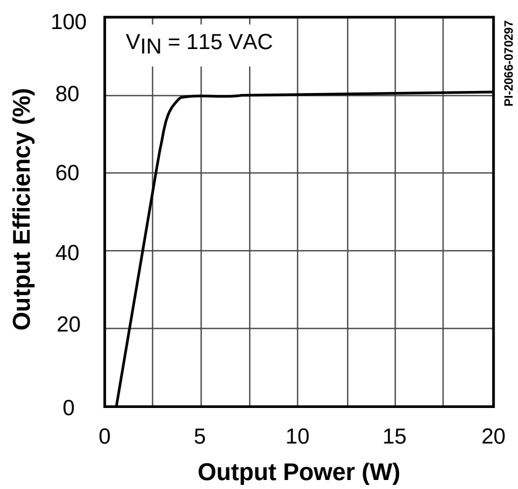


Figure 10. Efficiency vs. Output Power, 115 VAC Input

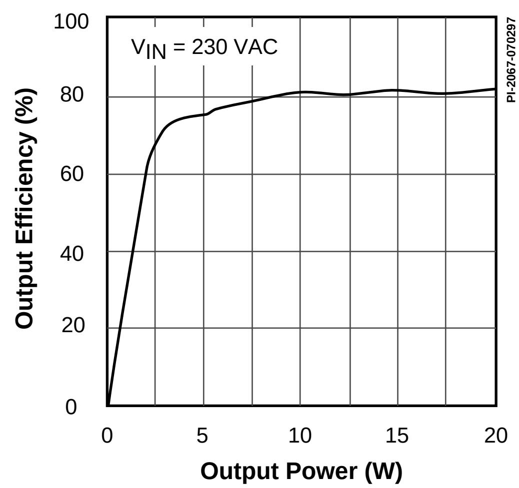


Figure 11. Efficiency vs. Output Power, 230 VAC Input

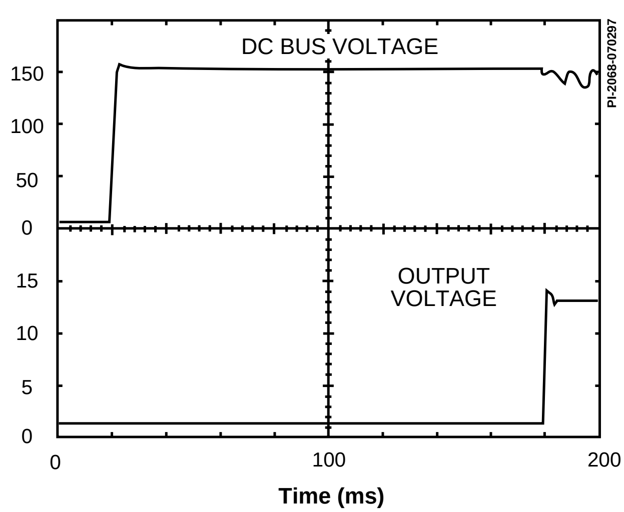


Figure 12. Turn On Delay

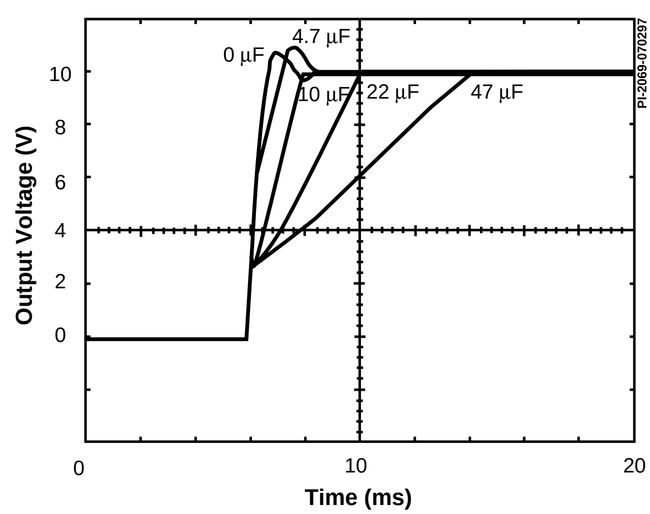


Figure 13. Output Voltage Turn On Transient vs. Soft Start Capacitor

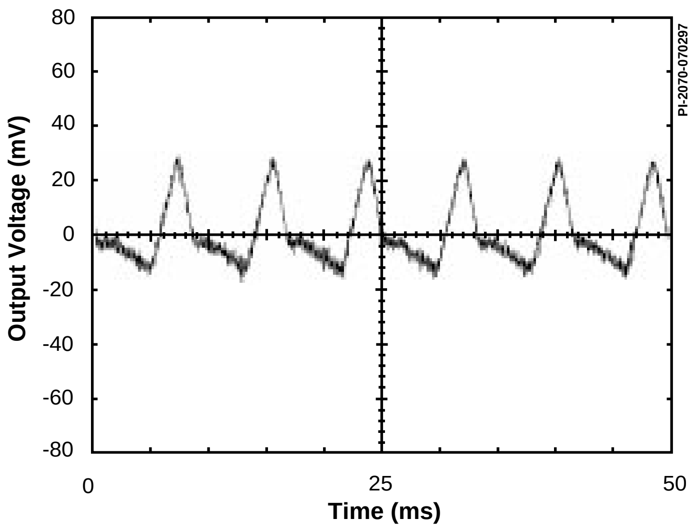


Figure 14. Line Frequency Ripple, 115 VAC In, 20 W Output

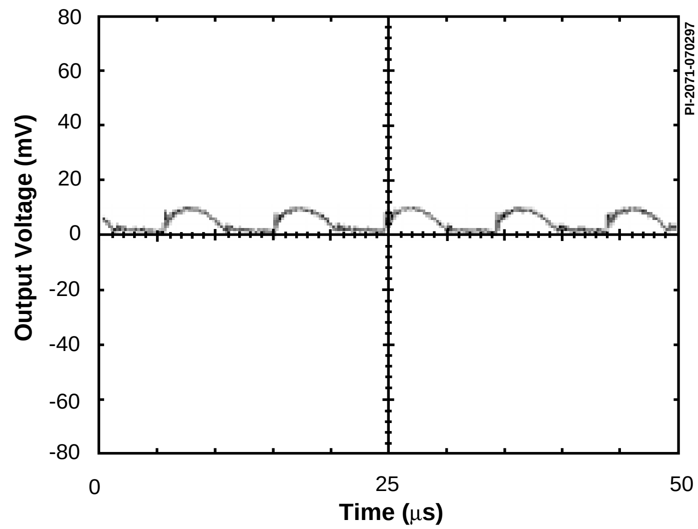


Figure 15. Switching Frequency Ripple, 115 VAC In, 20 W Output

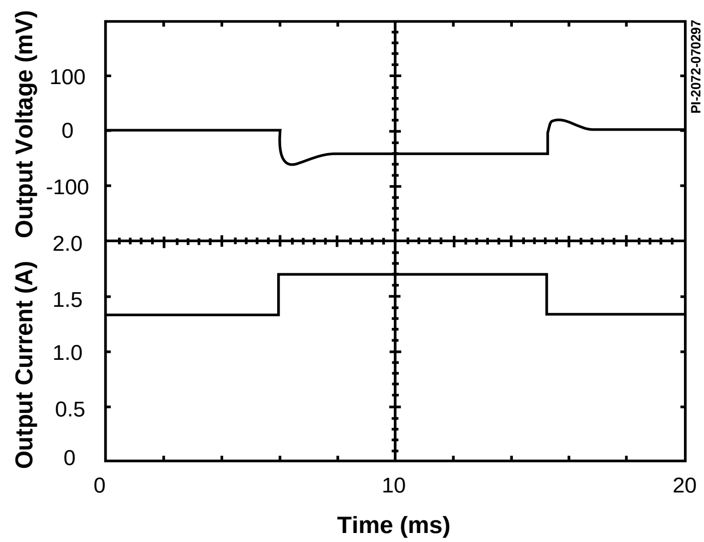


Figure 16. Transient Load Response (75% to 100% of load)

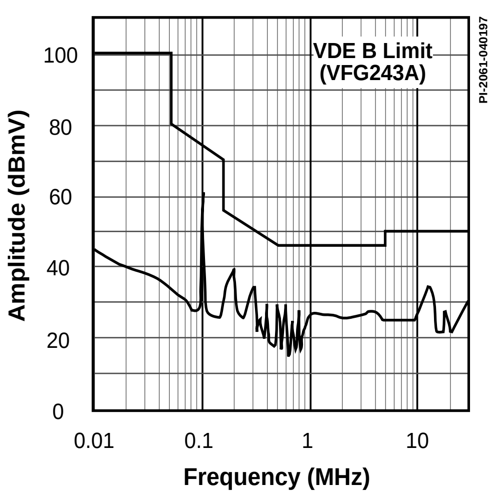


Figure 17. EMI Characteristics at 115 VAC Input.

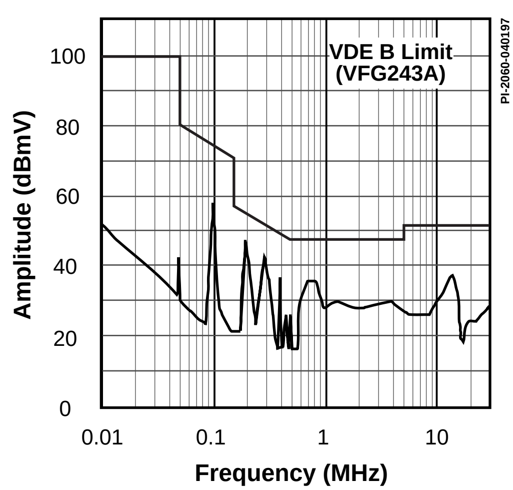
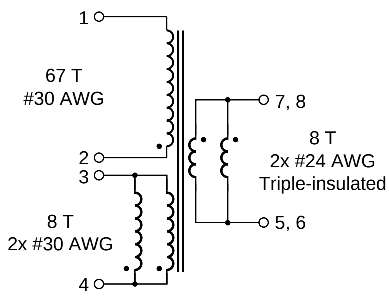
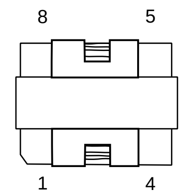
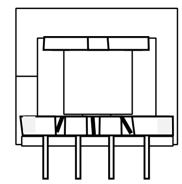


Figure 18. EMI Characteristics at 230 VAC Input.



PIN	FUNCTION
1	HIGH-VOLTAGE DC BUS
2	TOPSwitch DRAIN
3	PRIMARY-SIDE COMMON
4	V_{BIAS}
5, 6	RETURN
7, 8	OUTPUT





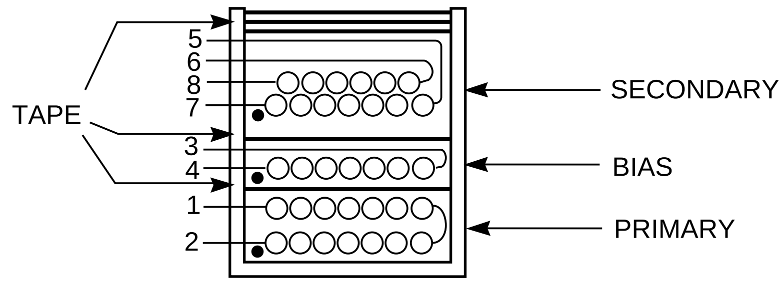
CORE# - PC40 EI25-Z (TDK)
GAP FOR A_L OF 145 nH/T^2
BOBBIN# - BE-25-118CP (TDK)

ELECTRICAL SPECIFICATIONS		
Electrical Strength	60 Hz, 1 minute, from pins 1-4 to pins 5-8	3000 VAC
Creepage	Between pins 1-4 and pins 5-8	6.0 mm (min)
Primary Inductance	Between Pins 1-2 (All other windings open)	650 µH, ±10%
Resonant Frequency	Between Pins 1-2 (All other windings open)	700 KHz (min)
Primary Leakage Inductance	Between Pins 1-2 (Pins 5-8 shorted)	35 µH (max)

NOTE: All inductance measurements should be made at 100 kHz

PI-2054-050798

Figure 19. Electrical specification of transformer TRD5



WINDING INSTRUCTIONS	
Primary (2 layers)	Start at pin 2. Wind 67 turns of #30 AWG heavy nyleze magnet wire in two layers. Finish on Pin 1
Basic Insulation	1 layer of 10.8 mm wide polyester tape for basic insulation.
Bifilar Bias Winding	Start at Pin 4. Wind 8 turns of 2 parallel strands of #30 AWG heavy nyleze magnet wire. Space turns evenly across bobbin to form a single layer. Finish on Pin 3.
Basic Insulation	1 layer of 10.8 mm wide polyester tape for basic insulation.
24 V Double Bifilar Secondary Winding	Start at Pins 7 and 8. Wind 8 bifilar turns of #24 AWG Triple Insulated Wire. Finish on Pins 5 and 6.
Outer Insulation	3 layers of 10.8 mm wide polyester tape for insulation.
Final Assembly	Assemble and secure core halves. Impregnate uniformly using varnish.

* Triple insulated wire sources.

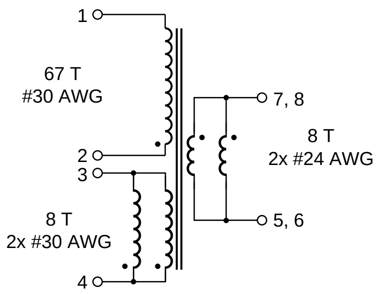
P/N: T28A01TXXX-3
Rubudue Wire Company
5150 E. La Palma Avenue
Suite 108
Anaheim Hills, CA 92807
(714) 693-5512
(714) 693-5515 FAX

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

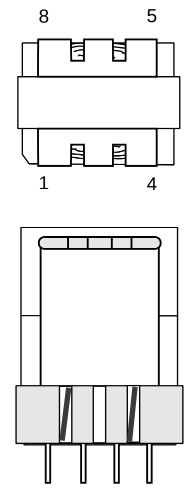
P/N: order by description
The Furukawa Electric Co., Ltd
6-1, Marunouchi 2-chome,
Chiyoda-ku, Tokyo 100, Japan
81-3-3286-3226
81-3-3286-3747 FAX

PI-2055-050798

Figure 20. Construction details of transformer TRD5.



PIN	FUNCTION
1	HIGH-VOLTAGE DC BUS
2	TOPSwitch DRAIN
3	PRIMARY-SIDE COMMON
4	V_{BIAS}
5, 6	RETURN
7, 8	OUTPUT



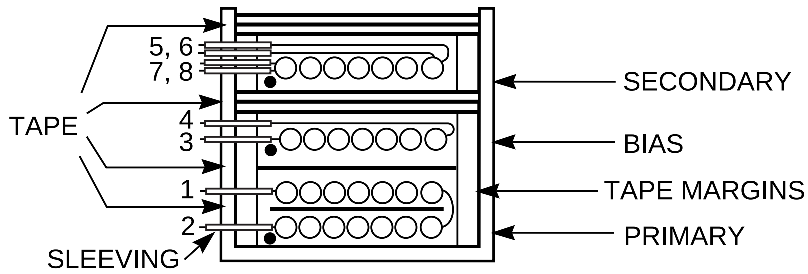
CORE# - PC40 EE22/29/6-Z (TDK)
GAP FOR A_L OF 145 nH/T^2
BOBBIN# - YC 2204 (Ying Chin)

ELECTRICAL SPECIFICATIONS		
Electrical Strength	60 Hz, 1 minute, from pins 1-4 to pins 5-8	3000 VAC
Creepage	Between pins 1-4 and pins 5-8	6.0 mm (min)
Primary Inductance	Between Pins 1-2 (All other windings open)	650 µH, ±10%
Resonant Frequency	Between Pins 1-2 (All other windings open)	700 KHz (min)
Primary Leakage Inductance	Between Pins 1-2 (Pins 5-8 shorted)	35 µH (max)

NOTE: All inductance measurements should be made at 100 kHz

PI-2057-050798

Figure 21. Electrical specification of transformer TRD5-1.



WINDING INSTRUCTIONS	
Primary Margins	Tape margins with 3 mm wide polyester tape. Match height with primary and bias windings.
Primary Windings	Start at pin 2. Wind one layer (approximately 40 turns) of 30 AWG heavy nyleze magnet wire from bottom (pin side) to top. Use one layer of 12.2 mm wide polyester tape over first primary layer for basic insulation. Continue winding remaining primary turns from top to bottom. Finish on Pin 1. Sleeve start and finish with 24 AWG Teflon sleeving.
Basic Insulation	Use 1 layer of 12.2 mm wide tape for basic insulation.
Bias Winding	Start at Pin 4. Wind 8 bifilar turns 30 AWG heavy nyleze magnet wire from bottom to top. Spread turns evenly across bobbin. Finish on Pin 3. Sleeve start and finish leads with 24 AWG Teflon sleeving.
Reinforced Insulation	Use 3 layers of 18.2 mm wide polyester tape for reinforced insulation.
Secondary Windings	Tape margins with 3 mm wide polyester tape. Match height with secondary winding.
12V Secondary Winding	Start at Pins 7 and 8. Wind 8 bifilar turns of 24 AWG heavy nyleze magnet wire from bottom to top. Spread turns evenly across bobbin. Finish on Pins 5 and 6. Sleeve start and finish leads with 24 AWG Teflon sleeving.
Outer Insulation	Apply 3 layers of 18.2 mm wide polyester tape for outer insulation.
Final Assembly	Assemble and secure core halves. Impregnate uniformly with varnish.

PI-2056-050798

Figure 22. Construction details of transformer TRD5-1.

WORLD HEADQUARTERS
NORTH AMERICA - WEST
Power Integrations, Inc.
477 N. Mathilda Avenue
Sunnyvale, CA 94086 USA
Main: +1•408•523•9200
Customer Service:
Phone: +1•408•523•9265
Fax: +1•408•523•9365

NORTH AMERICA - EAST
& SOUTH AMERICA
Power Integrations, Inc.
Eastern Area Sales Office
1343 Canton Road, Suite C1
Marietta, GA 30066 USA
Phone: +1•770•424•5152
Fax: +1•770•424•6567

EUROPE & AFRICA
Power Integrations (Europe) Ltd.
Mountbatten House
Fair Acres Windsor
Berkshire SL4 4LE,
United Kingdom
Phone: +44•(0)•1753•622•208
Fax: +44•(0)•1753•622•209

TAIWAN
Power Integrations International
Holdings, Inc.
2F, #508, Chung Hsiao E. Rd., Sec. 5,
Taipei 105, Taiwan
Phone: +886•2•2727•1221
Fax: +886•2•2727•1223

KOREA
Power Integrations International
Holdings, Inc.
Rm# 402, Handuk Building,
649-4 Yeoksam-Dong, Kangnam-Gu,
Seoul, Korea
Phone: +82•2•568•7520
Fax: +82•2•568•7474

JAPAN
Power Integrations, K.K.
Keihin-Tatemono 1st Bldg.
12-20 Shin-Yokohama 2-Chome,
Kohoku-ku, Yokohama-shi,
Kanagawa 222, Japan
Phone: +81•(0)•45•471•1021
Fax: +81•(0)•45•471•3717

INDIA (Technical Support)
Innovatech
#1, 8th Main Road
Vasanthnagar
Bangalore 560052, India
Phone: +91•80•226•6023
Fax: +91•80•228•2191

APPLICATIONS HOTLINE
World Wide +1•408•523•9260

APPLICATIONS FAX
World Wide +1•408•523•9361