RD6
TOPSwitch®-II
USB Reference Design Board
85 to 265 VAC Input, 15W Output

POWER INTEGRATIONS, INC.

Product Highlights

Low Cost Production Worthy Reference Design
- Complete self-powered USB power supply
- Supports 4 ports and hub controller
- Single sided board
- Fully assembled and tested
- Easy to evaluate and modify
- Extensive performance data
- Over 69% efficiency

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
- Meets VDE Class B EMI specifications

Description

The RD6 reference design board is an example of a low cost production worthy design for a self-powered, 4-port USB hub. The design is a complete solution for powering hubs found in products such as monitors and printers. A total of 15 W of power is delivered through two outputs. The main output supplies 3 A at 5 V. This meets the USB specification of 500 mA for each port (4 port total) with additional power available for a 5 V hub controller. A second 3.3 V (100 mA) output provides power for low voltage hub controllers.

The RD6 utilizes the TOP223Y member of the *TOPSwitch-II* 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 production ready design which needs little or no modification to meet system requirements.

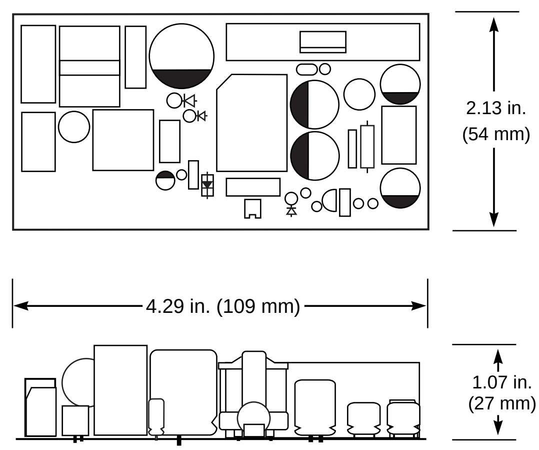


Figure 1. RD6 Overall Physical Dimensions.

PARAMETER	LIMITS
Input Voltage Range	85 to 265 VAC
Input Frequency Range	47 to 440 Hz
Temperature Range	0 to 70° C
Output Voltage (I_O = 3.0 A)	5 V ± 4%
(I_O = 0.1 A)	3.3 V ± 3%
Output Power (continuous)	15 W
Output Power (peak)	30 W
Line Regulation (85-265 VAC)	± 0.7%
Load Regulation (0%-100%)	± 1.1%
Efficiency	69% (min)
Output Ripple Voltage	5V ± 40 mV MAX
	3.3V ± 25 mV MAX
Safety	IEC 950 / UL1950
EMI	VDE B (VFG243 B) CISPR22

Figure 2. Table of Key Electrical Parameters.

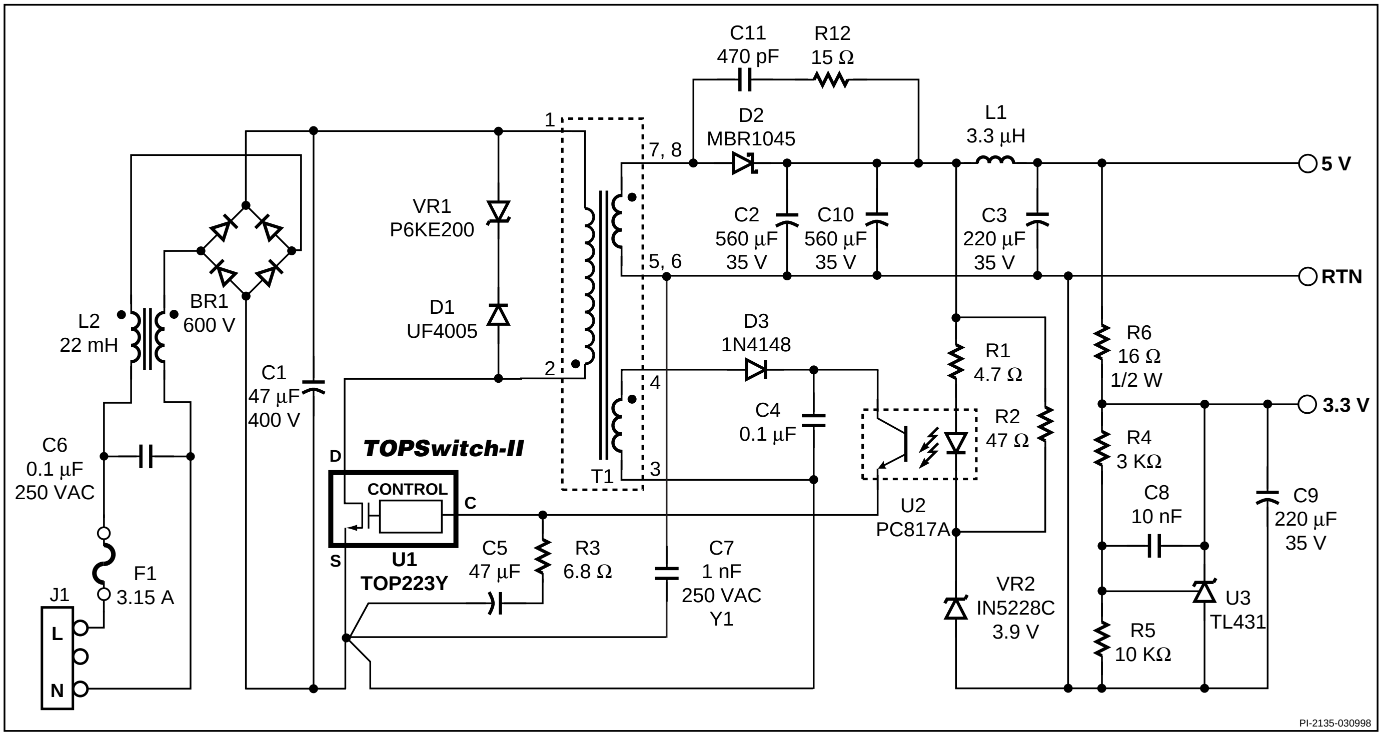


Figure 3. Schematic Diagram of the 15 W RD6 Power Supply.

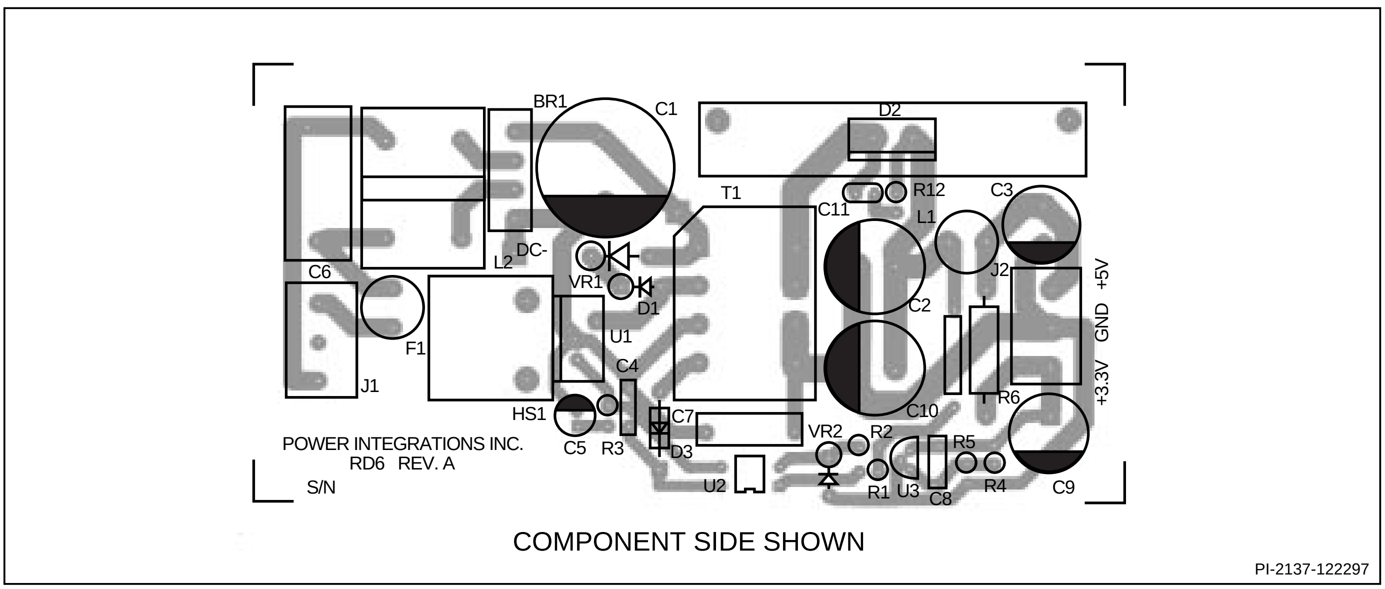


Figure 4. Component Legend of the RD6.

General Circuit Description

The RD6 is a low-cost flyback switching power supply using the TOP223Y integrated circuit. The circuit shown in Figure 3 details a 5 V, 15 W power supply that operates from 85 to 265 VAC input voltage, suitable for powering a USB hub with as many as 4 ports, and a 3.3 V, 100 mA auxiliary output for powering a hub controller. 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 TOP223. D1 and VR1 clamp the voltage spike caused by transformer leakage inductance to a safe value and reduce ringing. The power secondary winding is rectified and filtered by D2, C2, C10, L1, and C3 to create the 5 V output voltage. The 5 V output is directly sensed by optocoupler U2 and Zener diode VR2. The output voltage is determined by the Zener diode VR2 plus the voltage drops across the LED of the optocoupler U2 and resistor R1. Other output voltages are also possible by adjusting the transformer turns ratios and the value

Component Listing

Reference	Value	Part Number	Manufacturer
BR1	600 V, 2 A	2KBPC06M	General Instrument
C1	47 µF, 400 V	ECA-2GG470YE	Panasonic
C2, C10	560 µF, 35 V	ECA-1VFQ561	Panasonic
C3, C9	220 µF, 35 V	ECE-1AVGE221	Panasonic
C4	0.1 µF, 50 V	RPE121Z5U104M50V	Murata
C5	47 µF, 10 V	ECE-A1AG470	Panasonic
C6	0.1 µF, 250 VAC, X2	F1772-410-2000	Roederstein
C7	1.0 nF, 250 VAC, Y1*	WKP102MCPE.OK	Roederstein
		DE1110E102M ACT4K-KD	Murata
		440LD10	Cera-Mite
C8	10 nF, 50 V	RPE110Z5U103M50V	Murata
C11	470 pF, 50 V	RPE110X7R471K50V	Murata
D1	600 V, 1 A, UFR	UF4005	General Instrument
D2	45 V, 10 A Schottky	MBR1045	Motorola
D3	75 V, Switching	1N4148	National Semiconductor
L1	3.3 µH, 5.5 A	6000-3R3M	J. W. Miller
L2	22 µH, 0.4 A	ELF-18D290C	Panasonic
R1	4.7 Ω, 1/4 W	5043CX4R700J	Philips
R2	47 Ω, 1/4 W	5043CX47R00J	Philips
R3	6.8 Ω, 1/4 W	5043CX6R800J	Philips
R4	3.16 KΩ, 1/4 W, 1%	5043EM3K160F	Philips
R5	10.0 KΩ, 1/4 W, 1%	5043EM10K00F	Philips
R6	16 Ω, 1/2 W	5053CX16R00J	Philips
R12	15 Ω, 1/4 W	5043CX15R00J	Philips
T1**		TRD6	Custom
U1		TOP223Y	Power Integrations
U2	Optocoupler, Controlled CTR	PC817A	Sharp
U3	Adj. Shunt Regulator	TL431CLP	Motorola
VR1	200 V Zener TVS	P6KE200	Motorola
VR2	3.9 V 2% Zener	1N5228C	APD
F1	3.15 A, 250 VAC	19372, 3.15A	Wickman

Figure 5. Parts List for the RD6 (Two Series-Connected 2.2 nF, Y2 Capaciors such as Murata P/N DE7100F222MVA1-KC can replace C7) ** T1 is available from Premier Magnetics (714) 362-4211 as P/N TSD-1106, and from Coiltronics (561) 241-7876 as P/N CTX14-13598*

of Zener diode VR2. The 3.3 V output is derived from the 5 V output using R6 and shunt regulator U3. C11 and R12 form a snubber circuit across D2 to reduce ringing. This improves conducted RFI performance of the supply at high frequency (15-20 MHz) and reduces leakage spikes, improving the reliability of D2. R2 provides bias current for Zener VR2 to improve regulation.

The primary bias winding is rectified and filtered by D3 and C4 to create a bias voltage to power the TOP223Y. 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 5 V control loop. R6 and shunt regulator U3 are used to derive a 3.3 V supply from the 5V output. R4 and R5, along with the 2.5 V internal band gap reference in U3, are used to set the output voltage. C8 provides compensation for the 3.3 V control loop. C9 provides additional filtering for the 3.3 V output. As a shunt regulator, U3 provides a constant load of approximately 100 mA on the 5 V output, regardless of whether a load is present on the 3.3 V output. This provides a substantial preload for the 5 V output, greatly improving regulation at light or zero load. The circuit performance data shown in Figures 6-21 were measured with AC voltage applied to the RD6.

Load Regulation (Figure 6) – The change in the DC output voltage for a given change in output current is referred to as load regulation. Both the 5 V and 3.3 V outputs stay within

General Circuit Description (cont.)

±1.1 % of nominal from 0% to 100% of rated load current. The *TOPSwitch* on–chip over-temperature protection circuit will safely shut down the power supply under persistent overload conditions.

Line Regulation (Figure 7) - The 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 vs line for both the 5 V and 3.3 V outputs is within ± 0.7%.

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 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 150 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 5 V output 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 10 uF to 47 uF as shown.

Line frequency ripple voltage for the 5 V output is shown in Figure 14 for 115 VAC input and 15 W output. Switching frequency ripple voltage on the 5 V output is shown in Figure 15 for the same test condition Line frequency and switching frequency ripple for the 3.3 V output are shown in Figures 17 and 18, respectively.

The 5 V output transient response to a step load change from 2.25 to 3 A (75% to 100%) is shown in Figure 19. Note that the response is quick and well damped. The initial voltage spike in response to the load step is due to the interaction of the load current with the ESR of C3. If desired, the amplitude of this spike can be reduced by substituting a low ESR capcitor for C3.

The RD6 is designed to meet worldwide safety and EMI (VDE B) specifications. Measured conduction emissions are shown in Figure 20 for 115 VAC and Figure 21 for 230 VAC.

Transformer Specification

The electrical specifications and construction details for transformer TRD6 are shown in Figures 22 and 23. Transformer TRD6 is supplied with the RD6 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 24-25 can be used. This design (TRD6-1) 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 TRD6. 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.

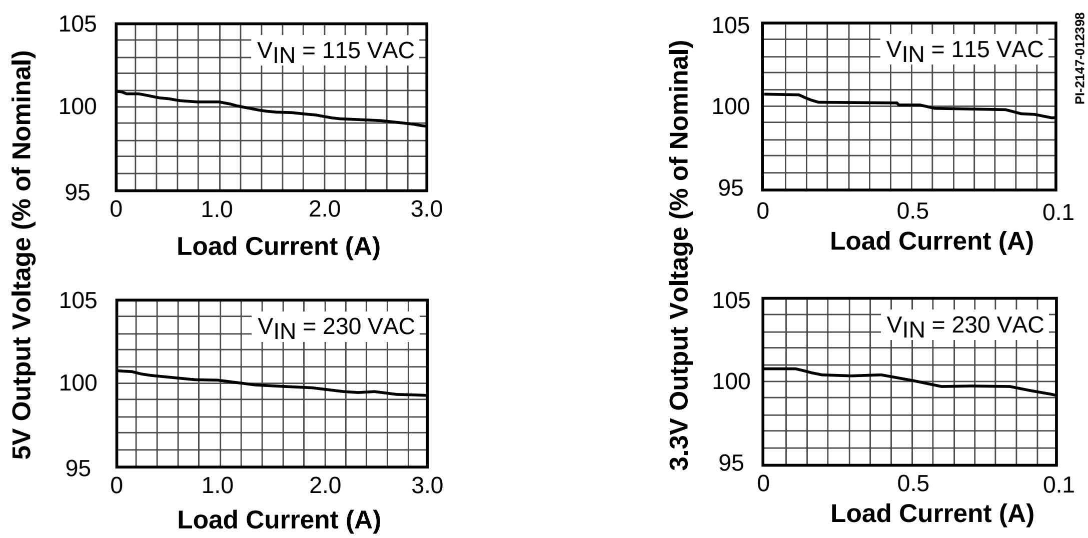


Figure 6. Load Regulation

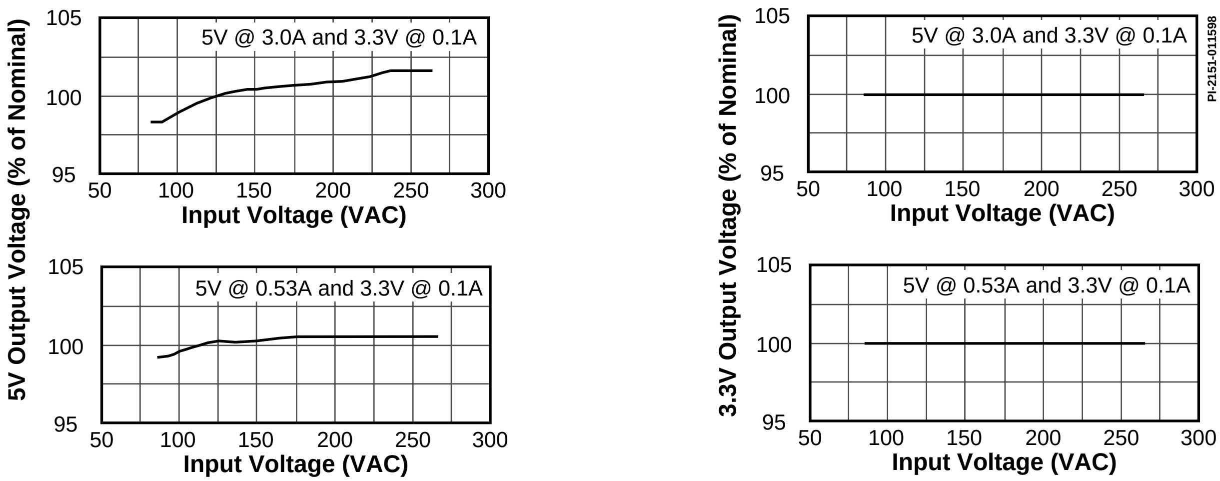


Figure 7. Line Regulation

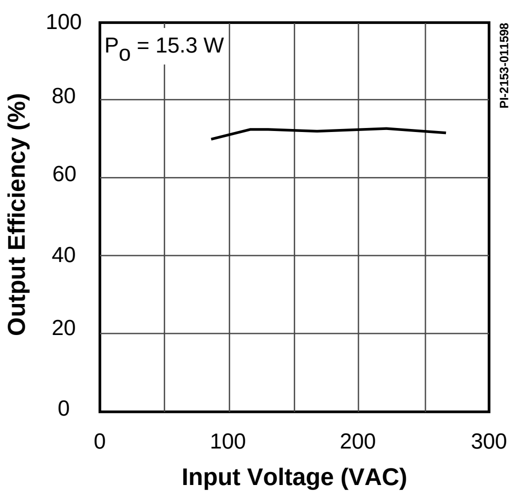


Figure 8. Efficiency vs. Input Voltage, 15.3 W Output

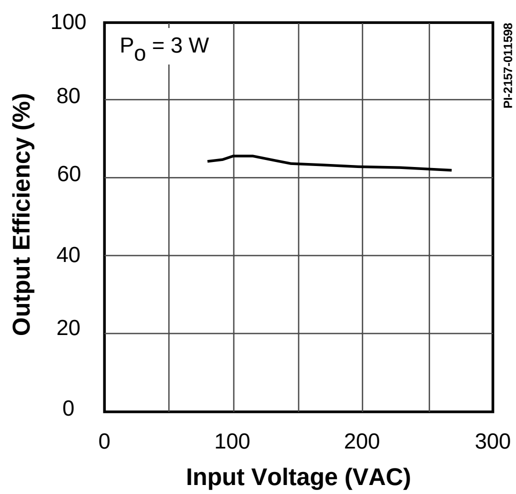


Figure 9. Efficiency vs. Input Voltage, 3 W Output

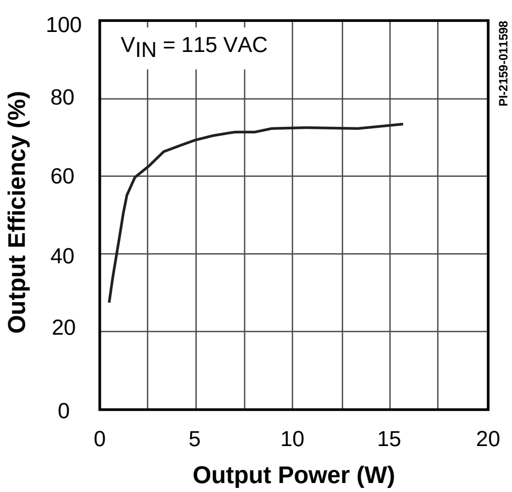


Figure 10. Output Efficiency vs. Output Power, 115 VAC Input

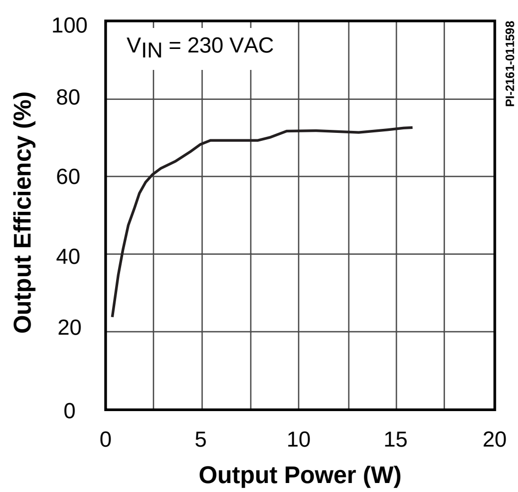


Figure 11. Output Efficiency vs. Output Power, 230 VAC Input

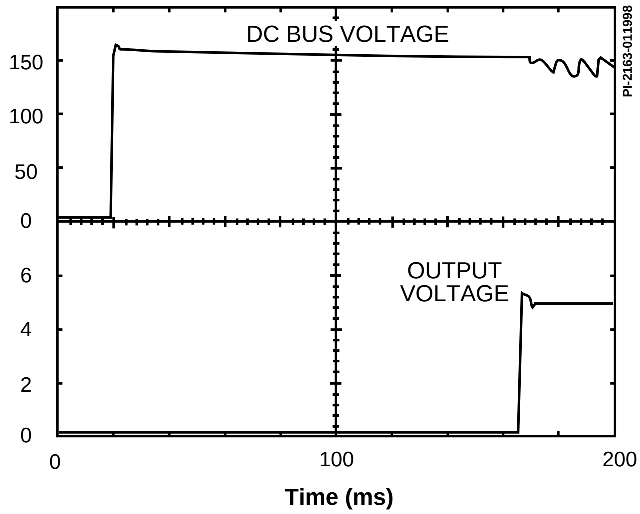


Figure 12. Turn On Delay

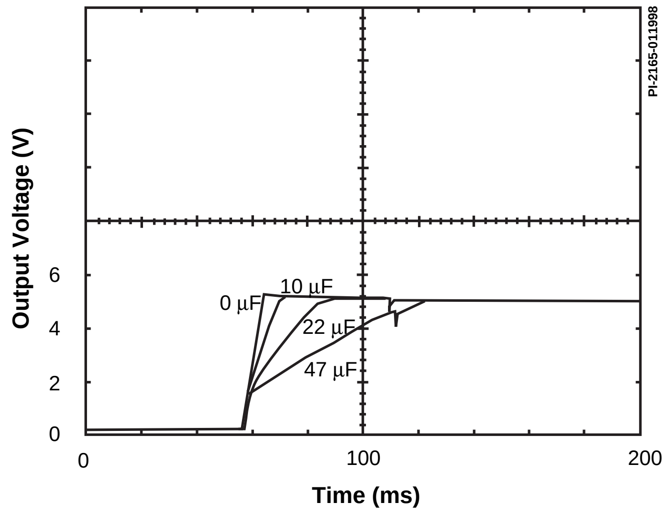


Figure 13. Output Voltage Turn On Transient vs Soft Start Capacitor

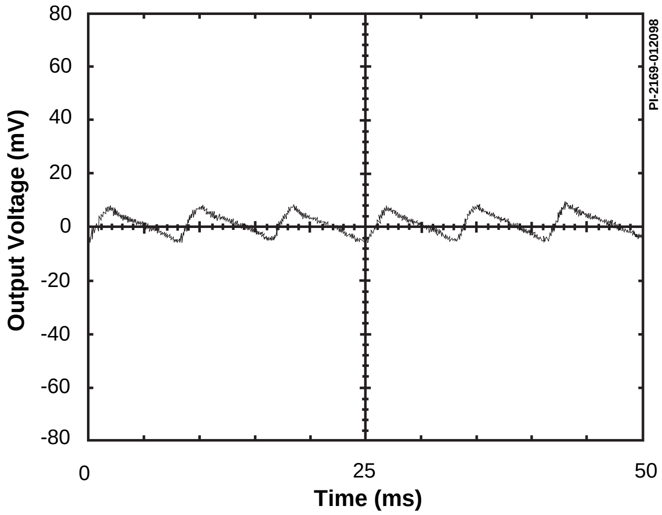


Figure 14. 5V LineFrequency Ripple, 115 VAC Input, 15.3 W Output

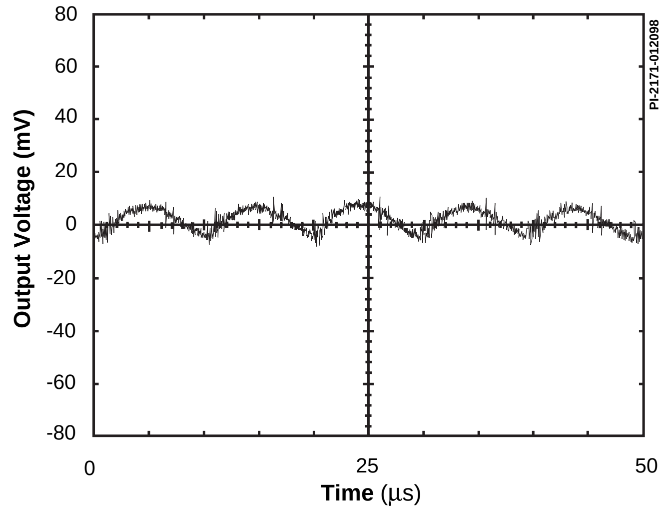


Figure 15. 5 V Switching Frequency Ripple, 115 VAC Input, 15.3 W Output

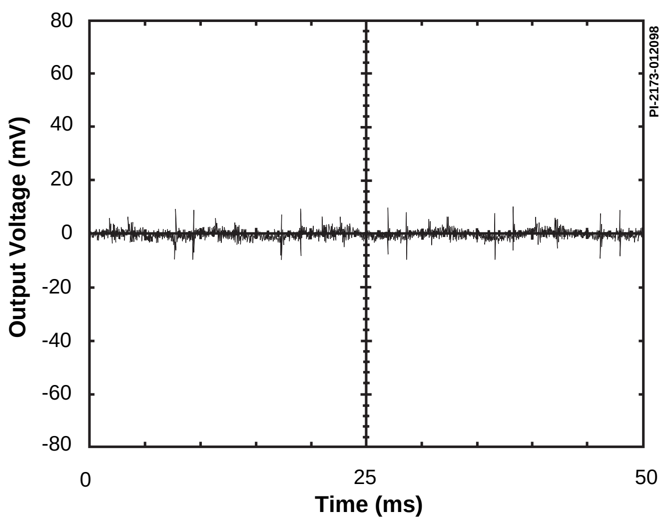


Figure 16. 3.3 V Line Frequency Ripple, 115 VAC Input, 15.3 W Output

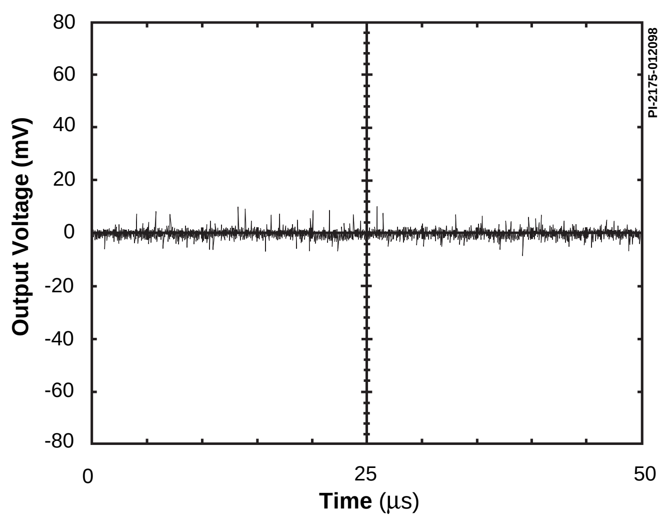


Figure 17. 3.3 V Switching Frequency Ripple, 115 VAC Input, 15.3 W Output

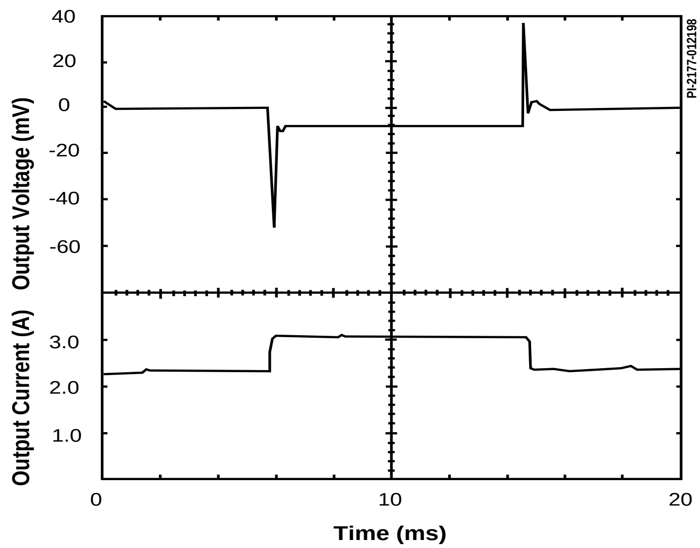


Figure 19. 5 V Transient Load Response (75% to 100% Load)

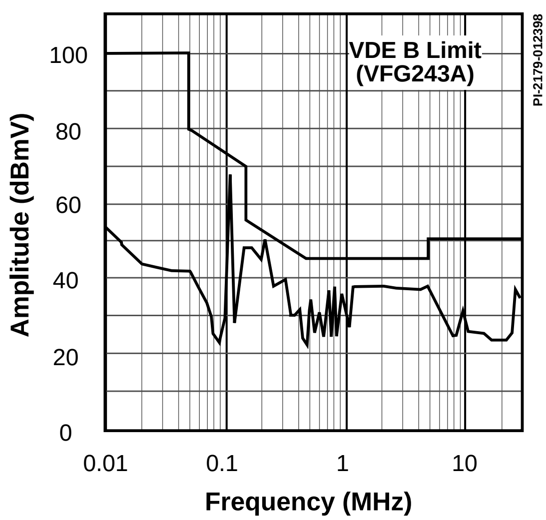


Figure 20. EMI Characteristics at 115 VAC Input

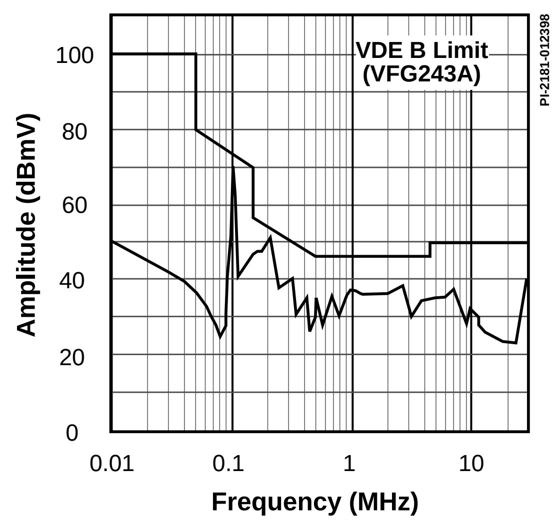
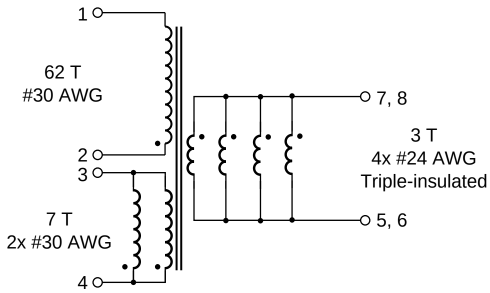
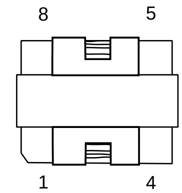
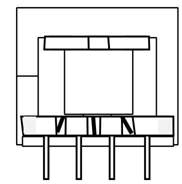


Figure 21. EMI Characteristics at 230 VAC Input



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





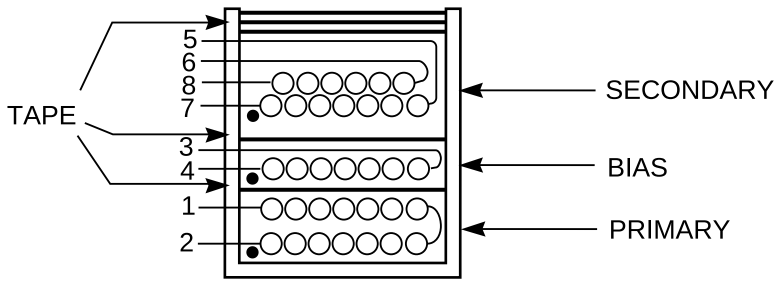
CORE# - PC40 EI25-Z (TDK)
GAP FOR A_L OF 245 nH/T^2
BOBBIN# - BE-25-118CP (TDK)

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)	980 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)	40 µH (max)

NOTE: All inductance measurements should be made at 100 kHz

PI-2139-121897

Figure 22. Electrical specification of transformer TRD6



WINDING INSTRUCTIONS	
Primary (2 layers)	Start at pin 2. Wind 62 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 7 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 3 quadrifilar 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.

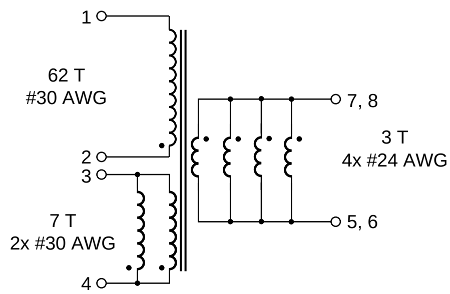
P/N: T28A01TXXX-3
Rubudue Wire Company
5150 E. La Palma Avenue
Suite 108
Anaheim Hills, CA 92807
(714) 693-5512
(714) 693-5515 FAX

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

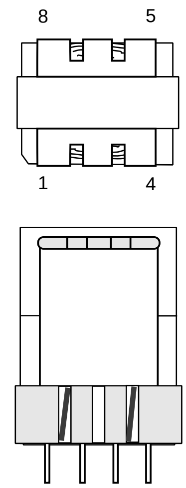
P/N: order by description
The Furukawa Electric Co., Ltd
6-1, Marunouchi 2-chome,
Chiyoda-ku, Tokyo 100, Japan
81-3-3286-3226
81-3-3286-3747 FAX

PI-2145-121897

Figure 23. Construction details of transformer TRD6



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



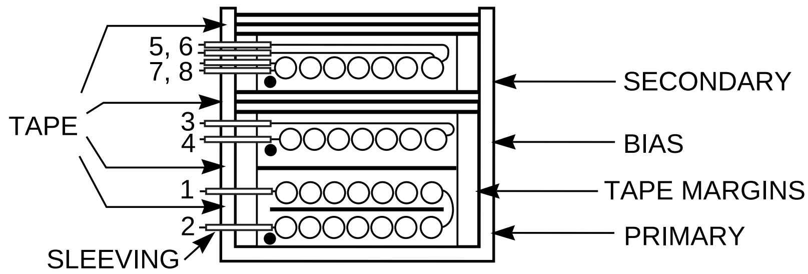
CORE# - PC40 EE22/29/6-Z (TDK)
GAP FOR A_L OF 145 nH/T^2
BOBBIN# - YC 2204 (Ying Chin)

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)	840 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)	40 µH (max)

NOTE: All inductance measurements should be made at 100 kHz

PI-2143-121897

Figure 24. Electrical specification of transformer TRD6-1



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 38 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 7 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 3 quadrifilar 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-2141-121897

Figure 25. Construction details of transformer TRD6-1

WORLD HEADQUARTERS
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

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•727•1221
Fax: +886•2•727•1223

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

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

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

ASIA & OCEANIA
For Your Nearest Sales/Rep Office
Please Contact Customer Service
Phone: +1•408•523•9265
Fax: +1•408•523•9365

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

APPLICATIONS FAX
Americas +1•408•523•9361
Europe/Africa +44•(0)•1753•622•209
Japan +81•(0)•45•471•3717
Asia/Oceania +1•408•523•9364