RD2 *TOPSwitch*®

Reference Design Board

85 to 132 VAC or 170 to 265 VAC Input, 8W(10W Peak) Output

Product Highlights

Low Cost Production Worthy Reference Design
- Only 21 components!
- Single sided board
- Low cost thru-hole components
- Fully assembled and tested
- Easy to evaluate and modify
- Extensive performance data
- Up to 77% efficiency
- Light weight - no heat sink required for *TOPSwitch*

Fully Protected by *TOPSwitch*
- 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

Typical Applications
- Replacement for low power linear adapters
- Auxiliary power supply for appliance, motor control, utility meters, smart building, UPS, etc.

Description

The RD2 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 Switchers from Power Integrations. It is intended to help *TOPSwitch* users to quickly develop their products 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 or voltages is all that is needed. A complete set of performance curves, the parts list, the board layout and details on transformer design are provided to speed up the *TOPSwitch* based switcher design.

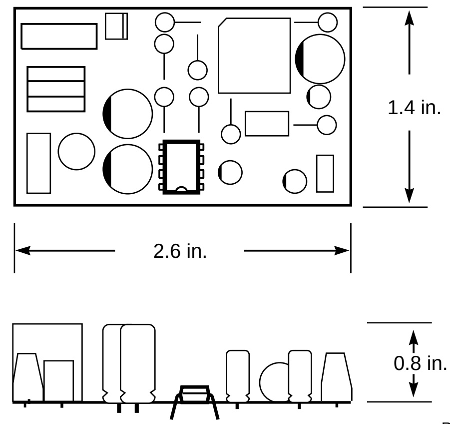


Figure 1. RD2 Board Overall Physical Dimensions.

PARAMETER	LIMITS
Input Voltage Range	85 to 132 VAC or 170 to 265 VAC
Input Frequency Range	47 to 440 Hz
Temperature Range	0 to 70°C
Output Voltage (I_o = 0.67A)	12 V ± 10%
Output Power (continuous)	8 W
Output Power (peak)	10 W
Line Regulation (85-132 VAC) (170-265 VAC)	± 0.7%
Load Regulation (10%-100%)	± 5%
Efficiency (115 V input, 8 W out)	75%
Output Ripple Voltage	± 50 mV MAX
Safety	IEC 950 / UL1950
EMI	VDE B (VFG243 B) CISPR22

Figure 2. Table of Key Electrical Parameters.

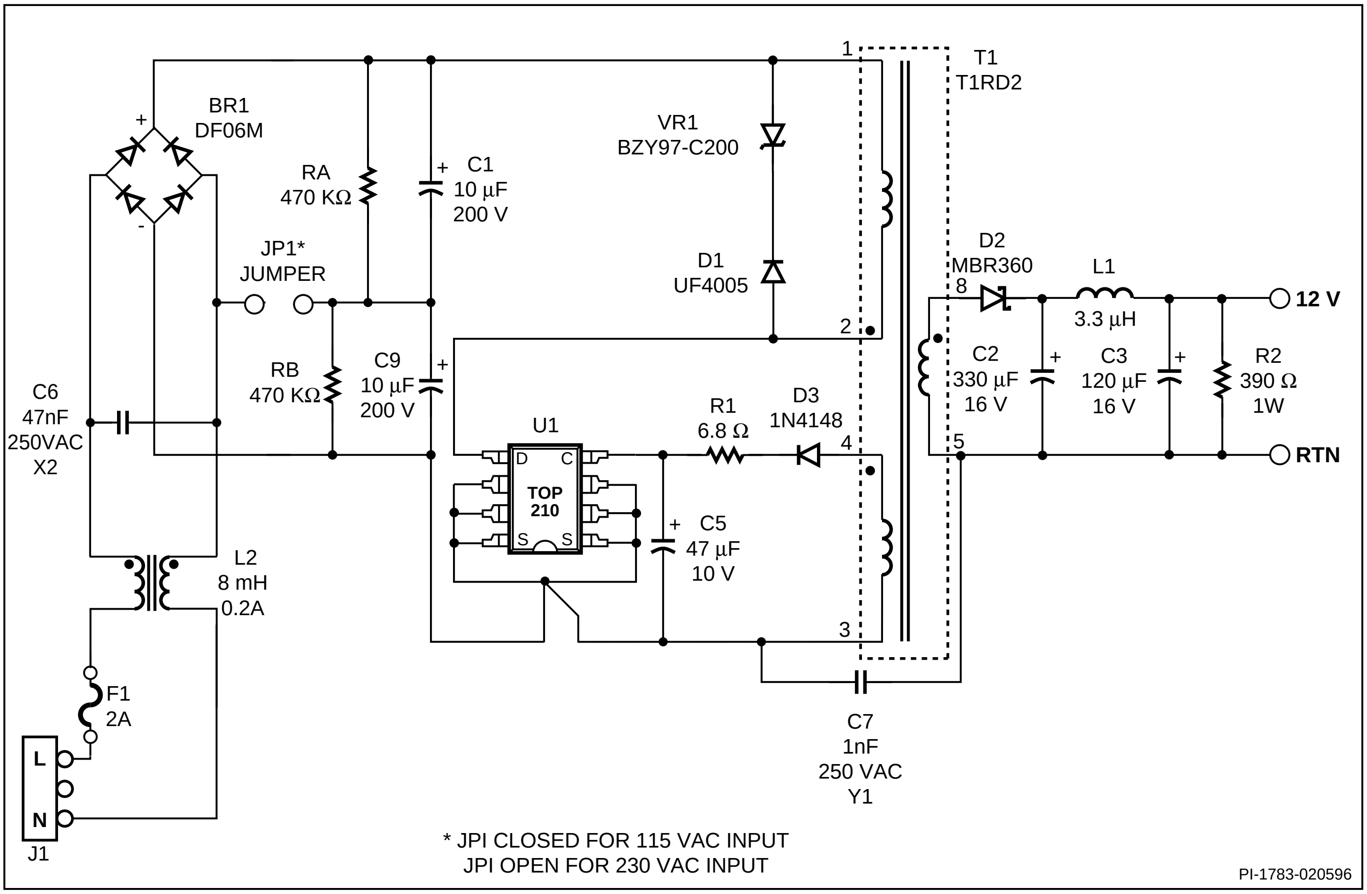


Figure 3. Schematic Diagram of the RD2 Power Supply.

CAUTION

The RD2 features a 115/230 VAC selectable input, and is shipped configured for 230 VAC operation (JP1 open). If JP1 is used for 115 VAC operation, it must be removed before applying 230 VAC.

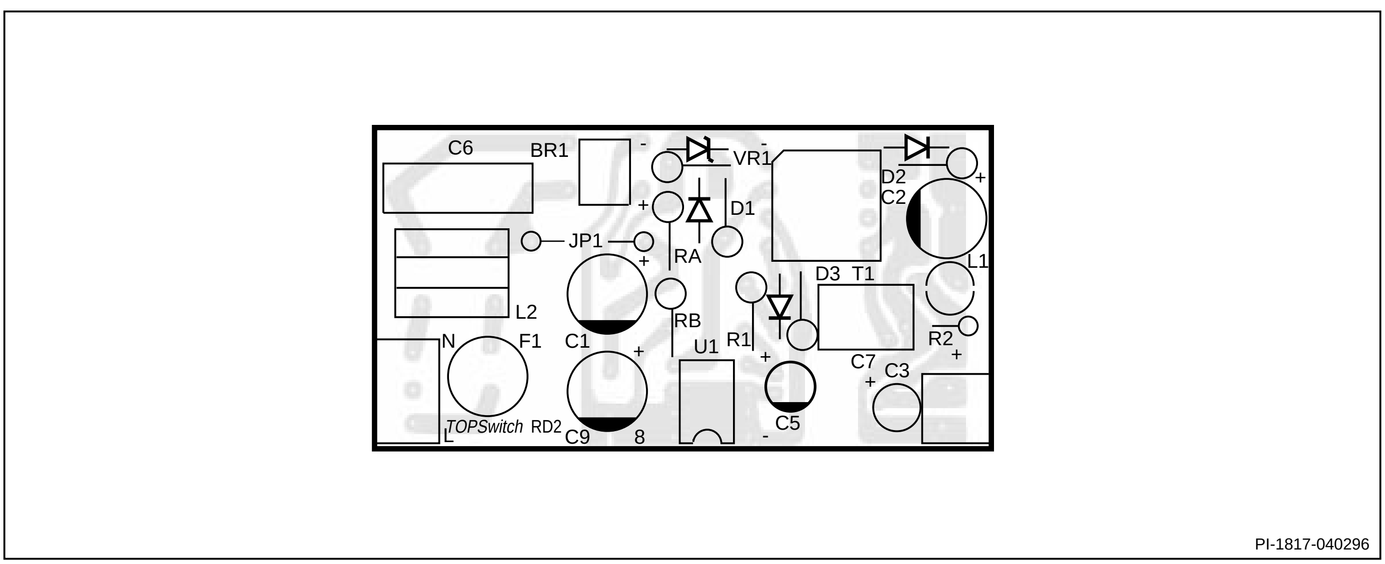


Figure 4. Component Legend of the RD2.

Component Listing

Reference	Value	Part Number	Manufacturer
U1		TOP210PFI	Power Integrations
D1	600V, 1A, UFR	UF4005	General Instruments
D2	Schottky, 3A, 60V	MBR360	Motorola
D3	75 V Switching	1N4148	Rohm
BR1	1 A, 600 V	DF06M	General Instruments
VR1	200 V Zener, 1.5 W	BZY97-C200	SGS/Thomson, Fagor
L1	3.3 µH, 4A	Custom	
L2	8 mH, 0.2A	SU9V-02080	Tokin
C1, C9	10 µF, 200V	KMG200VB10RM10X16	United Chemicon
C2	330 µF, 16V	LXF16VB331M8X15	United Chemicon
C3	120 µF, 16V	LXF16VB121M6.3X11.5	United Chemicon
C5	47 µF, 10V	KME10VB47RM5X12.5	United Chemicon
C6	47 nF, 250 VAC, X 2	F1772-347-2000	Roederstein
C7	1 nF, 250 VAC, Y1	DE1110 E 102M ACT4K-KD	Murata
RA, RB	470 K, 1/4 W	5043CX470K0J	Philips
R1	6.8 Ω, 1/4 W	5043CX6R800J	Philips
R2	390 ohms, 1 W	MO-1 391J	Koa/Speer
T1	Custom	T1RD2	
F1	2A, 250 VAC	19372, 2A	Wickman

Figure 5. Parts List for the RD2.

General Circuit Description

The RD2 is a low-cost, isolated Buck-Boost or flyback switching power supply using the TOP210 integrated circuit. The circuit shown in Figure 3 produces a 12 V, 8 W power supply that operates from 85 to 132 VAC or 170 to 264 VAC input voltage. The 12 V output voltage is determined by the *TOPSwitch* control pin shunt regulator voltage, the voltage drop of D3, and the turns ratio between the bias and output windings of T1. Other output voltages are also possible by adjusting the transformer turns ratios. R1 and C5 provide filtering of the bias winding to improve line and load regulation.

AC power is rectified and filtered by BR1, C1 and C9 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 inside the TOP210. JP1 is a jumper used to select 115 V or 230 V operation. Adding JP1 selects 115 V operation. Leaving JP1 open selects 230 V operation. RD2 is supplied with JP1 open. RA and RB equalize leakage currents between C1 and C9. D1 and VR1 clamp the leading-edge 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, L1, and C3 to create the 12 V output voltage. R2 provides a pre-load on the 12 V output to improve load regulation at light loads. The bias winding is rectified and filtered by D3, R1, and C5 to create a bias voltage to the TOP210. Common-mode EMI currents which flow between the primary windings of the transformer and the secondary output circuitry are attenuated by L2 and C7. Differential-mode EMI currents caused by pulsating currents at the input of the power supply are attenuated by C6 and L2. C5 filters the internal MOSFET gate drive charge current spikes on the Control pin, determines the auto-restart frequency, and together with R1, compensates the control loop.

The circuit performance data shown in Figures 6-18 was measured with AC voltage applied to the RD2.

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 ±5% from 10% to 100% of rated load current. The *TOPSwitch* on-chip overtemperature protection circuit will safely shut down the power supply under sustained overload conditions.

General Circuit Description (cont.)

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 less than ±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. Curves are also given to show the difference in efficiency when C1 and C9 are changed from 10 µF to 22 µF.

Efficiency (Load Dependent) - The curves in Figures 10 and 11 show how the efficiency changes with output power at 115 and 230 VAC inputs. The curves also show the increase in efficiency when C1 and C9 are changed from 10 µF to 22 µF.

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 12 V output voltage. Capacitors C1 and C9 charge 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 5.7 V. At this point the power supply turns on as shown.

Figure 13 shows the output voltage turn on transient.

Line frequency ripple voltage is shown in Figure 14 for 115 VAC input and 8W 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 0.5 A to 0.67 A (75% to 100%) is shown in Figure 16. Note that the response is quick and well damped.

The RD2 is designed to meet worldwide safety and EMI (VDE B) specifications. Measured conducted emissions are shown in Figure 17 for 115 VAC and Figure 18 for 230 VAC.

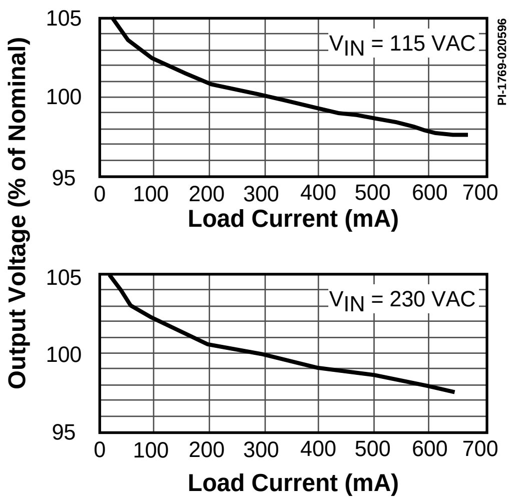


Figure 6. Load Regulation

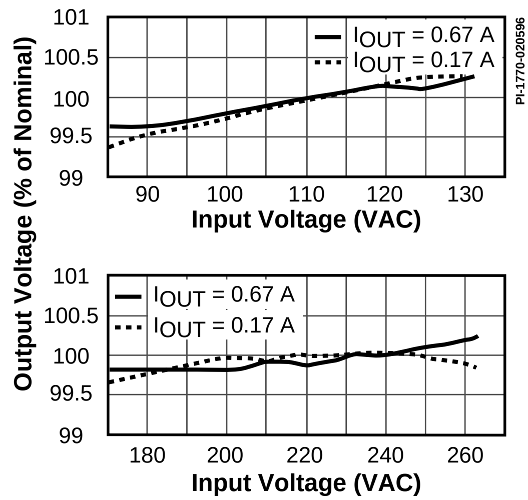


Figure 7. Line Regulation

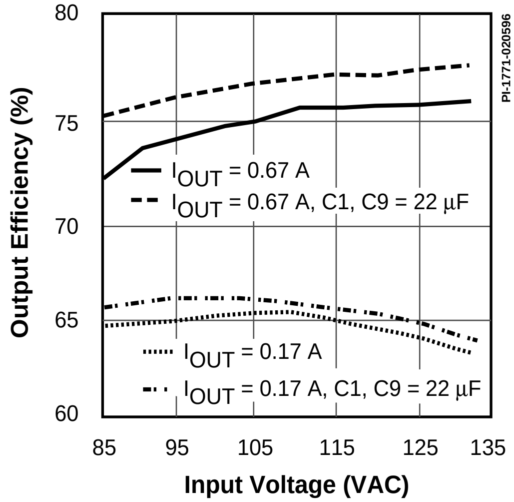


Figure 8. Efficiency vs. Input Voltage, 85-132 VAC

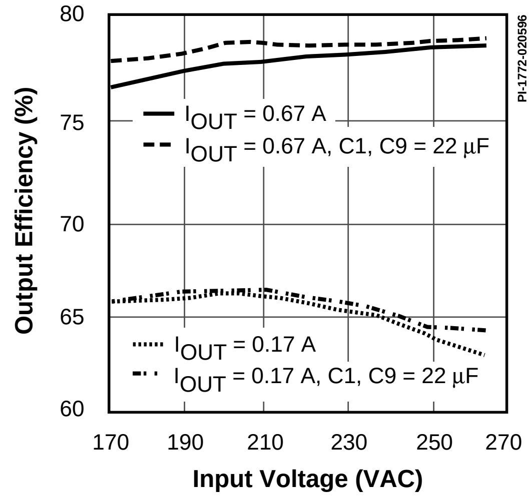


Figure 9. Efficiency vs. Input Voltage, 170-265 VAC

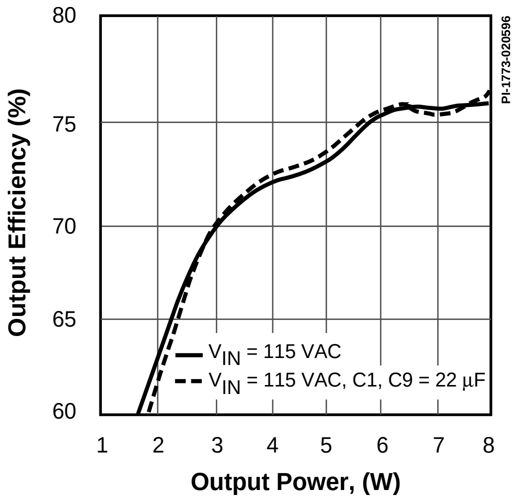


Figure 10. Efficiency vs. Output Power, 115 VAC Input

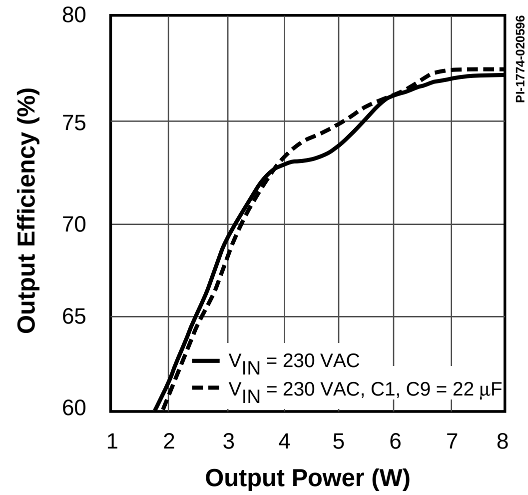


Figure 11. Efficiency vs. Output Power, 230 VAC Input

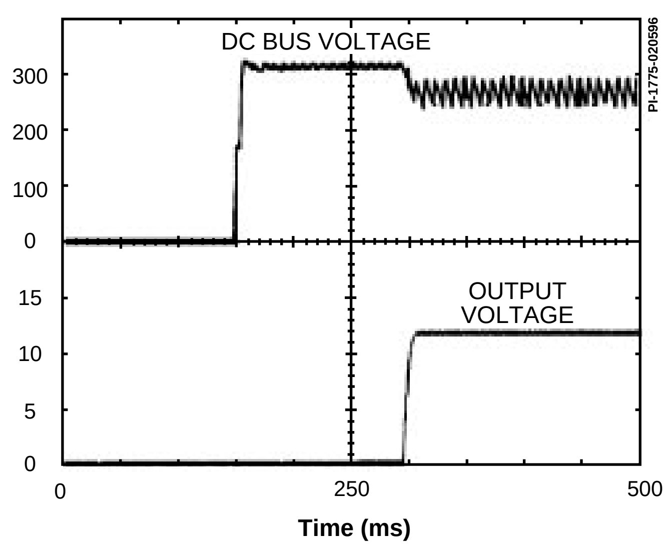


Figure 12. Turn On Delay

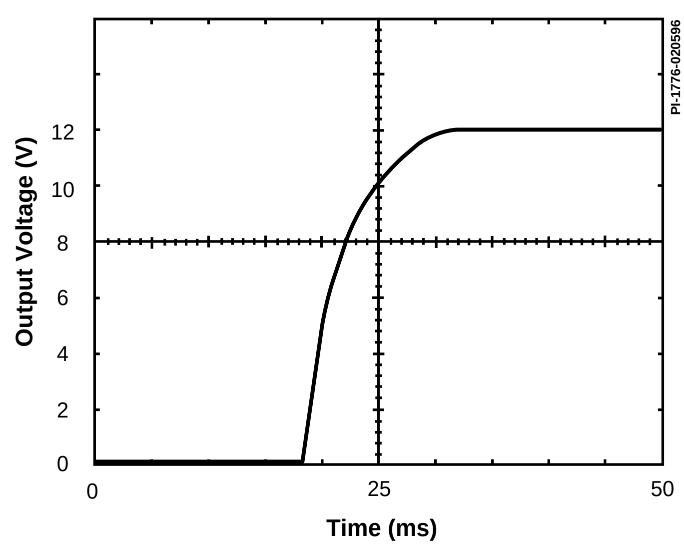


Figure 13. Output Voltage Turn On Transient

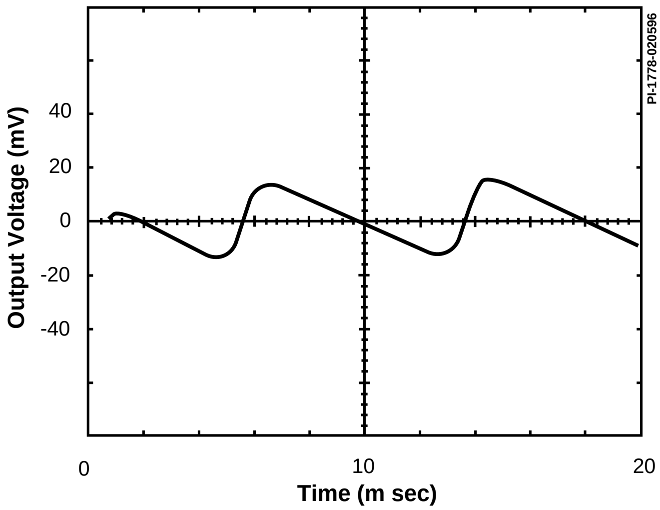


Figure 14. Line Frequency Ripple, 115VAC In, 8W Output

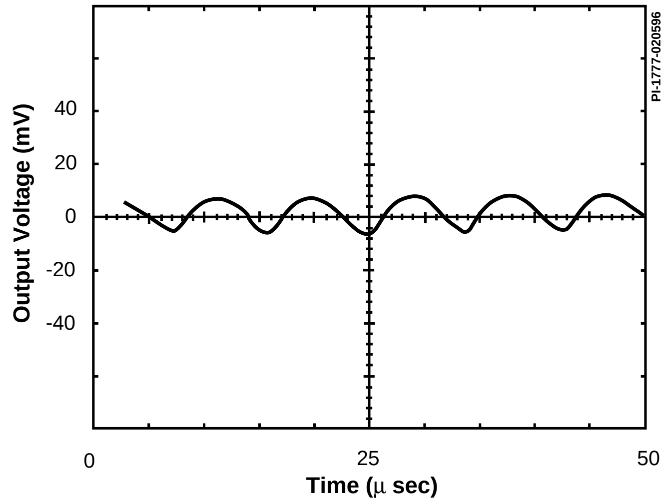


Figure 15. Switching Frequency Ripple, 115 VAC In, 8W Output

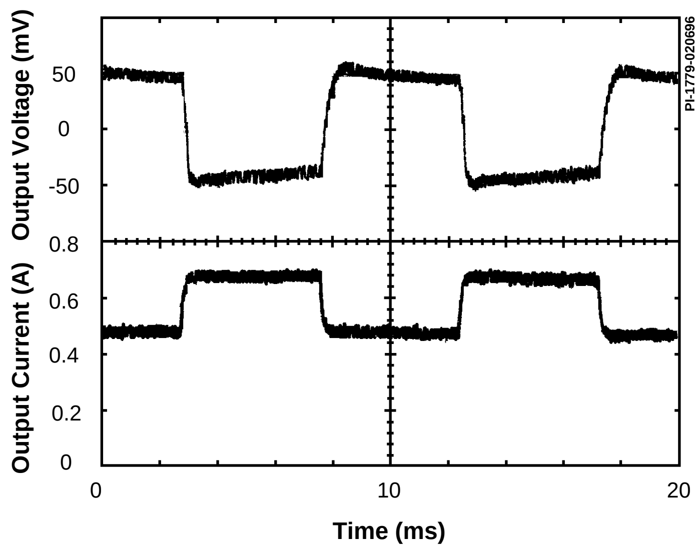


Figure 16. Transient Load Response (75% to 100% of load)

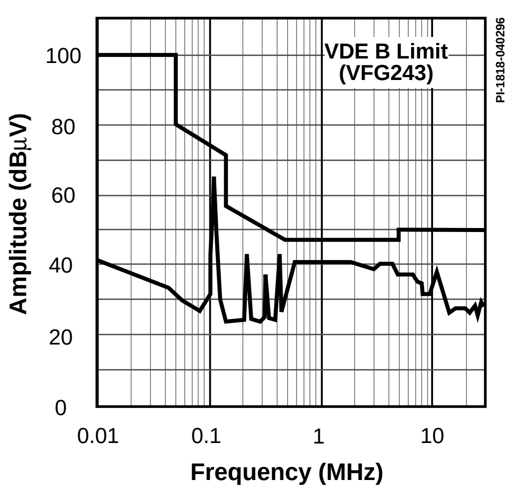


Figure 17. EMI Characteristics at 115 VAC Input.

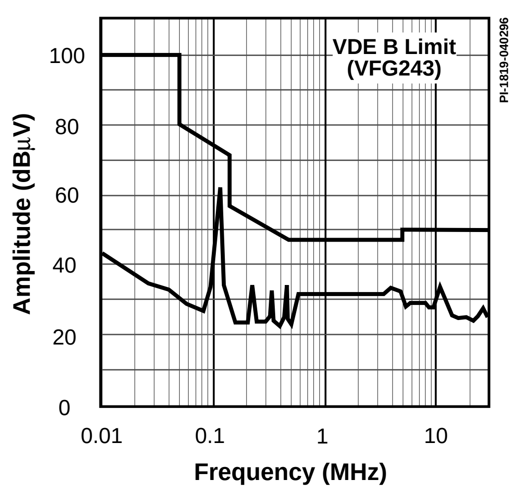
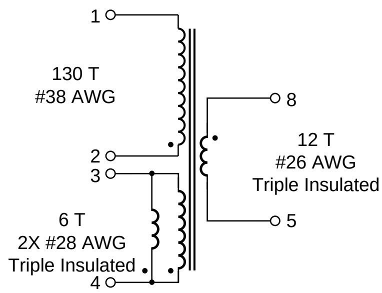
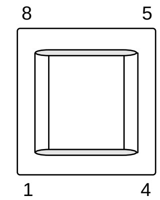


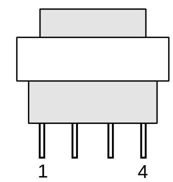
Figure 18. EMI Characteristics at 230 VAC Input.



CORE# - PC40 EE16 (TDK)
GAP FOR A_L OF 250 nH/T^2
BOBBIN# - BE-16-118CPH (TDK)

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



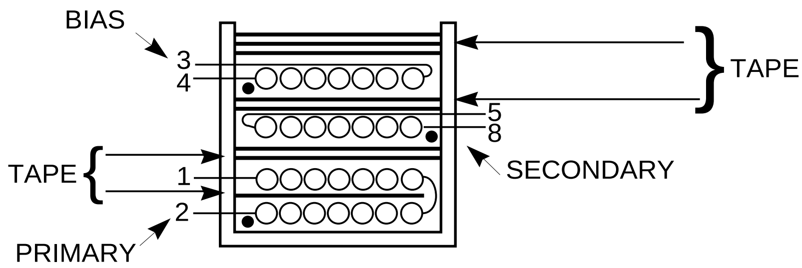


ELECTRICAL SPECIFICATIONS		
Electrical Strength	60 Hz, 1 minute, from pins 1-4 to pins 5, 8	3000 VAC
Creepage	Between pins 1-4 and pins 5, 8	5.0 mm (min)
Primary Inductance	All windings open	4.3 mH, ±10%
Resonant Frequency	All windings open	700 kHz (min)
Primary Leakage Inductance	Pins 5 and 8 shorted	50 µH (max)

NOTE: All inductance measurements should be made at 100 kHz

PI-1820-040296

Figure 19. Electrical specification of transformer T1RD2



WINDING INSTRUCTIONS	
Two-layer "C" Wound Primary	Start at pin 2. Wind 65 turns of 38 AWG heavy nyleze wire from left to right. Apply 1 layer of tape (white polyester film 8.3 mm (0.32 in.) wide by 0.056 mm (2.2 mil) thick) for basic insulation. Continue winding 65 turns from right to left. Finish at pin1.
Basic Insulation	Apply 2 layers of tape for basic insulation.
Triple Insulated Secondary	Start at pin 8. Wind12 turns of triple-insulated 26 AWG wire* from right to left. Finish at pin 5.
Basic Insulation	Apply 2 layers of tape for basic insulation.
Parallel Bifilar Primary Bias	Start at pin 4. Wind 6 turns of 28 AWG triple insulated wire* parallel bifilar in a single layer, from left to right. Finish at pin 3.
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: order by description
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-1740-010596

Figure 20. Construction details of transformer T1RD2

Notes

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