Design Example Report

Title	***16W Low Profile Adapter Supply using TOP245P***
Specification	Input: 90 – 265 VAC Output: 5.25V / 3A
Application	Video Game
Author	Power Integrations Applications Department
Document Number	DER-37
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Revision	1.0

Summary and Features

A TOP245P is used to create a low profile video game adapter that features the following:

- Very low no-load consumption of <100mW @ 230 VAC
- Low parts count / Low cost
- Low profile, high power density
- EMI has 10 dB margin even with output grounded
- No Safety X-cap needed
- Meets thermal requirements at 45^{o}C ambient with good margin
- No heatsinks
- >80% Efficiency even at high temp
- Tight Built-in Over Power Protection (no need for OCP)
- < 50uA Safety leakage current

The products and applications illustrated herein (including circuits external to the products and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at *www.powerint.com*.

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Table Of Contents

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Important Note:
Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

Design Reports contain a power supply design specification, schematic, bill of materials, and transformer documentation. Performance data and typical operation characteristics are included. Typically only a single prototype has been built.

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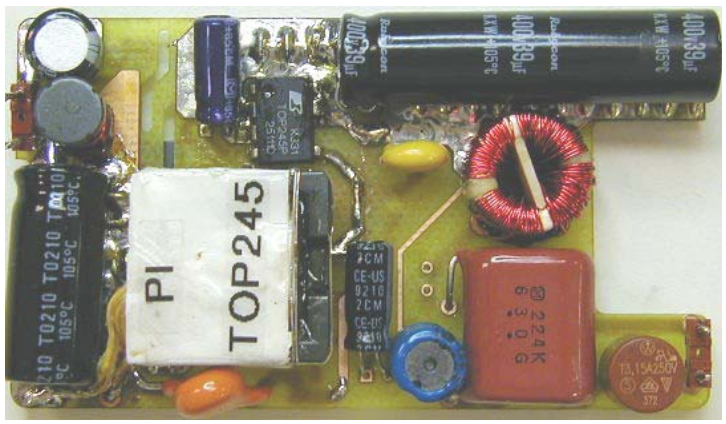
1 Introduction

This document is an engineering report describing a prototype16W power supply utilizing a TOP245P. This power supply is designed for a sealed adapter supply.

This design is low cost, low parts count and meets EMI with no X-cap. It meets thermal requirements with no heatsink in either primary or secondary side.

The document contains the power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, and performance data.



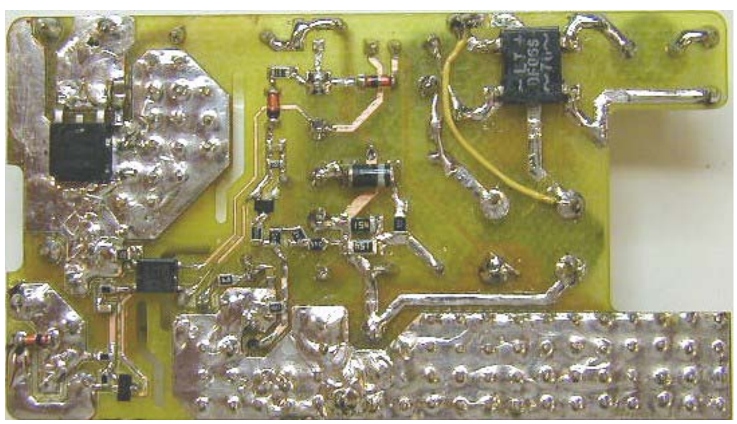


Figure 1 – Populated Circuit Board Photograph. Component side (Top) and Solder side (Bottom).

Note an additional wire jumper was required on this prototype layout as shown above.

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2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		265	VAC	2 Wire – Output ground connected to P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)				0.1	W	
Output						
Output Voltage 1	V_{OUT1}		5.25		V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			50	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}			3	A	
Total Output Power						
Continuous Output Power	P_{OUT}			15.75	W	
Over Power protection	P_{OUT_PEAK}	20		24	W	Auto-restart
Over Voltage Protection				6.8	V	Zener on output
Efficiency	η	80			%	Measured at the board O/P terminals, P_{OUT} (15.75 W), 25 °C
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950, UL1950 Class II				
Ambient Temperature	T_{AMB}	0		45	°C	Free convection, sea level

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3 Schematic

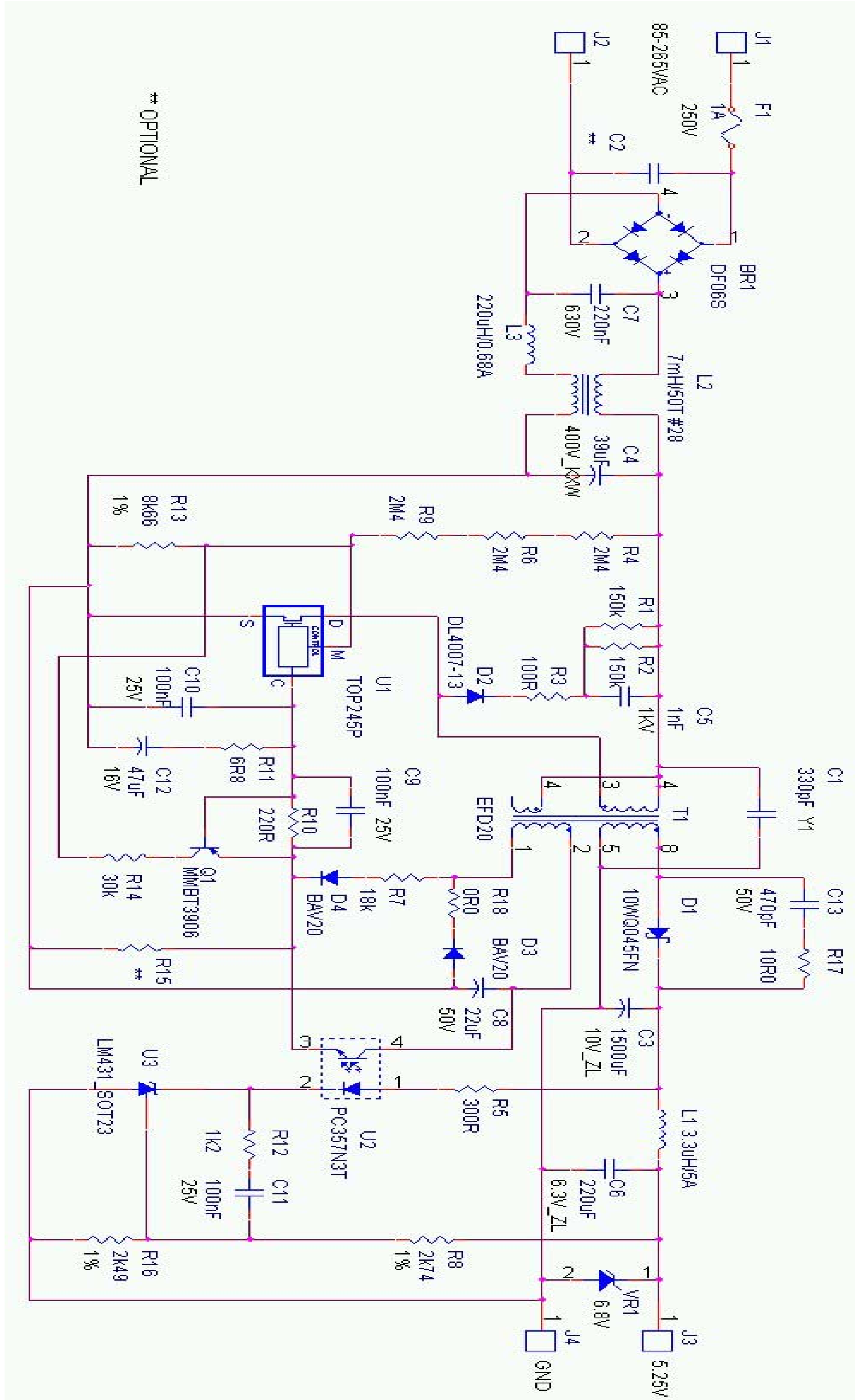

Figure 2 – Schematic.

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4 Circuit Description

The schematic in Figure 2 shows an off-line flyback converter using the TOP245P. The circuit is designed for 90 VAC to 265 VAC input and provides an isolated 5.25V, 3A continuous output.

To provide <100m W no-load consumption at 230 VAC, a frequency reduction circuit is implemented using the X pin feature of the TOPSwitch-GX. More details of this operation provided below.

4.1 Input EMI Filtering

Conducted EMI filtering is provided by pi formed filter C4, C7, L2, & L3. The switching frequency jitter feature of the TOPSwitch-GX family allows the use of a small, low cost common mode choke for L2.

To keep the peak DRAIN voltage acceptably below the BV_{DSS} (700V) of U1, diode D2, C5 and R1&R2 form a primary clamp. This network clamps the voltage spike seen on the DRAIN due to primary and secondary reflected leakage inductance. Diode D3 and capacitor C8 provide rectified and filtered bias supply for U1.

4.2 Output Rectification

The secondary of T1 is rectified and filtered by D1, & C3. Post filter choke L1 and C6 provide additional high frequency filtering and help suppress high frequency EMI.

4.3 Output Feedback

DC feedback to the output voltage regulator error amplifier (U3) comes from a divider network R8 and R16. The center point is tied to the 2.5 V REF pin of U2. Capacitor C11 and resistor R12 roll off the high frequency gain of U3 while R5 sets the overall gain.

In a typical TOPSwitch-GX design, regulation of the output is normally provided by voltage mode PWM control. The current into the CONTROL pin sets the duty cycle of the internal MOSFET. The duty cycle control operates over a CONTROL pin current of 2mA to 6mA. Current below this level is used to supply power to the IC.

In this design the control is accomplished by employing the externally programmable current limit function of the TOPSwitch-GX family, which is the X pin. This allows the TOPSwitch-GX to operate at lower frequency in order to further improve light load efficiency.

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The CONTROL pin requires 2 mA to power the internal circuitry of the chip. Any current beyond that normally would be shunted, and commands the duty cycle to reduce. With 2 mA of current the duty cycle is set to maximum.

Feedback current above ~2mA forward biases Q1 through R10 and pulls up R13 via R14. The X pin looks like a 1.2V voltage source. The current it is sourcing determines the output MOSFET peak current limit. As current decreases, the peak current limit is reduced from maximum (when X-pin current is 170 uA), down to a minimum of 40% of nominal peak current limit (when X-pin is at 30 uA). Therefore, as the feedback current increases, the sink current decreases and the primary current limit reduces, thereby allowing the output voltage feedback loop to control the primary peak current. Resistor R14 sets the peak current limit (startup and overload). Any feedback current above 2 mA engages the X pin control, the current into the CONTROL pin is limited to this level and therefore, the PWM function of the CONTROL pin does not determine the duty cycle.

As the load is reduced, the primary current limit reduces until it reaches 40% of peak current limit. At this point, another X-pin function is activated. The remote ON/OFF (inhibit) threshold is reached at an X pin sink current of approximately 27 µA. The supply then operates with fixed 25% current limit, but with a variable off-time, resulting in a variable switching frequency. To maintain regulation, as the load is further reduced, the frequency reduces. This greatly reduces switching losses, maintaining high standby efficiency and low no-load power consumption.

Slope compensation is provided by a ramp signal generated from the bias winding via D4, R7 and C9. C9 also serves as a high frequency roll off filter.

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5 PCB Layout

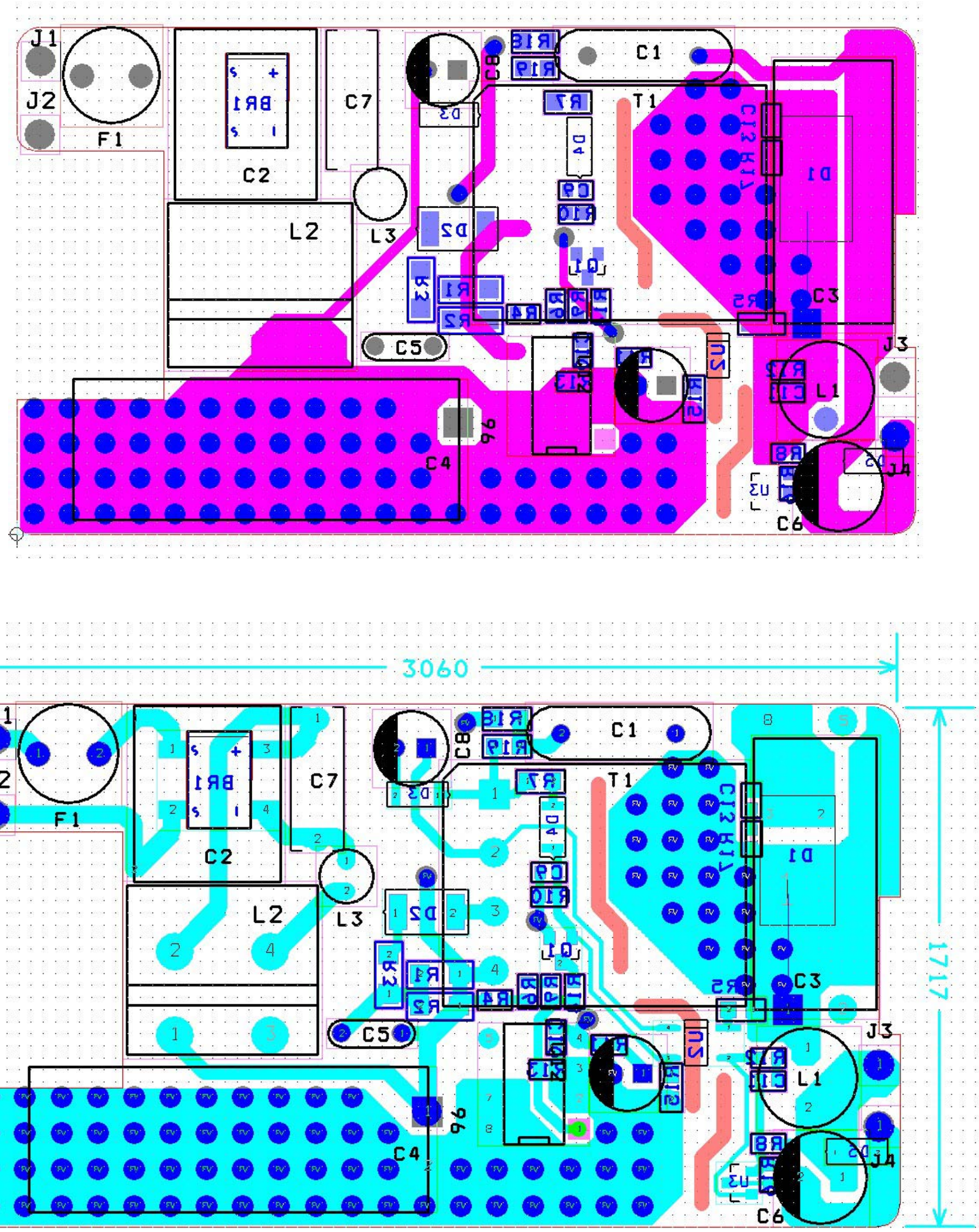

Figure 3 – Printed Circuit Layout. Top layer (TOP), Bottom layer (BOTTOM)

Note: Some rework was done on the actual sample board as shown in the photos above

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6 Bill Of Materials

Item	QTY	Part Reference	Value	Description	Mfg Part Number	Mfg
1	1	BR1	DF06S	Bridge Rectifier, 600v, 1A, SMD	DF06S	Gen. Semi.
2	1	C1	330pF	Cap,Cer,330pF,Y1, 250Vac	440LT330	Panasonic
3	1	C2	**	optional		
4	1	C3	1500uF	Cap,Al Elect,1500uF,10V,10mmX25mm,ZL Series,Rubycon	10ZL1500M10X25	Rubycon
5	1	C4	39uF	Cap,Al Elect,39uF,400V,10mmX40mm,KXW Series, Rubycon	400KXW39M10X40	Rubycon
6	1	C5	1nF	Cap,Cer,1000pF, 1000V, 10%	NCD102K1KVY5F	NIC Components Corp
7	1	C6	220uF	Cap,Al Elect,220uF, 6.3V, 8mmX7mm, ZL series Rubycon	6.3ZL220M8x7	Rubycon
8	1	C7	220nF	Cap,Metal Poly ,0.22uF, 630V, 10%	ECQ-E63224KF	Panasonic
9	1	C8	22uF	Cap,Al Elect,22uF,50V,5mmX11mm,KZE Series,NIPPON CHEMI-CON	KZE50VB22RME11LL	Nippon Chemi-Con
10	1	C12	47uF	Cap,Al Elect,47uF,16V,5mmX11.5mm,LXZ Series,NIPPON CHEMI-CON	LXZ16VB47RME11LL	Nippon Chemi-Con
11	3	C9 C10 C11	100nF	CAP 0.1uF 25V CERM CHIP X7R 0805 SMD	ECU-V1H221KBN	Panasonic
12	1	C13	470pF	CAP 470pF 50V CERM CHIP X7R 0805 SMD	ECJ-1VC1H471J	Panasonic
13	1	D1	10WQ045FN	Schottky 45V, 10A D-PAK	10WQ045FN	IR
14	1	D2	DL4007-13	RECT,DL4007-13 PASSIVATED 1A 1000V SMD MELF	DL4007-13	Diodes Inc
15	2	D3 D4	BAV20	RECT,BAV20, 500mW 200V SMD MELF	BAV20	Diode Inc.
16	1	F1	1A	FUSE T-LAG 1A, 250V Slo-Blo IEC SHORT TR5	3,721,100,041	Wickman
17	4	J1 J2 J3 J4	TERM_1Pin22AWG	Terminal,1Pin,22AWG		
18	1	L1	3.3uH/5A	Inductor,3.3uH,5A 22AWG	custom	
19	1	L2	7mH/50T #28	custom (see spec)	custom	
20	1	L3	220uH/0.68A	CHOKE,220uH, 0.68A Barrel	SBC3-221-681	TOKIN
21	1	Q1	MMBT3906	TRANSISTOR,2N3906, PNP 40V SOT-323	MMBT3606	Diode Inc.
22	2	R1 R2	150k	Res,150K 1/8W 1% 1206 SMD	ERJ-8ENF1503V	Panasonic
23	1	R3	100R	Res,100 1/8W 5% 1206 SMD	ERJ-8GEYJ101V	Panasonic
24	3	R4 R6 R9	2M4	Res,2.4M 1/10W 5% 0805 SMD	ERJ-6GEYJ245V	Panasonic
25	1	R5	300R	Res,300 1/16W 5% 0603 SMD	ERJ-3GEYJ301V	Panasonic
26	1	R7	18k	Res,18K 1/16W 5% 0603 SMD	ERJ-3GEYJ183V	Panasonic
27	1	R8	2k74	Res,2.74K 1/16W 1% 0603 SMD	ERJ-3EKF2741V	Panasonic
28	1	R10	220R	Res,220 1/16W 5% 0603 SMD	ERJ-3GEYJ221V	Panasonic
29	1	R11	6R8	Res,6.8 1/16W 5% 0603 SMD	ERJ-3GEYJ6R8V	Panasonic
30	1	R12	1k2	Res,1.2K 1/16W 5% 0603 SMD	ERJ-3GEYJ122V	Panasonic
31	1	R13	8k66	Res,8.66K 1/16W 1% 0603 SMD	ERJ-3EKF8661V	Panasonic
32	1	R14	30k	Res,15K 1/10W 5% 0805 SMD	ERJ-6GEYJ153V	Panasonic
33	1	R15	**	optional		
34	1	R16	2k49	Res,2.49K 1/16W 1% 0603 SMD	ERJ-3EKF2491V	Panasonic
35	1	R17	10R0	Res,10.0 1/16W 1% 0603 SMD	ERJ-3EKF10R0V	Panasonic
36	1	R18	0R0	Res,0 1/16W 1% 0603 SMD	ERJ-3EKF0R0V	Panasonic
37	1	T1	EFD20	custom (see spec)	custom	
38	1	U1	TOP245P	IC,TOP245P,INT. OFF-LINE SWITCHER,DIP-8B	TOP246P	Power Int.
39	1	U2	PC357N3T	IC,PC357N3T,PHOTOCOUPLER 1CH TRAN OUT,CTR 200-400%, 4-SMD	PC357N3T	Sharp
40	1	U3	LM431_SOT23	Shunt regulator 2.5V LM431_SOT23	LM431_SOT23	Generic
41	1	VR1	ZMM535B	Diode, Zener, 6.8V, 1/2W, 5%, DO-35	ZMM535B	Siemens

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7 Transformer Specification

7.1 Electrical Diagram

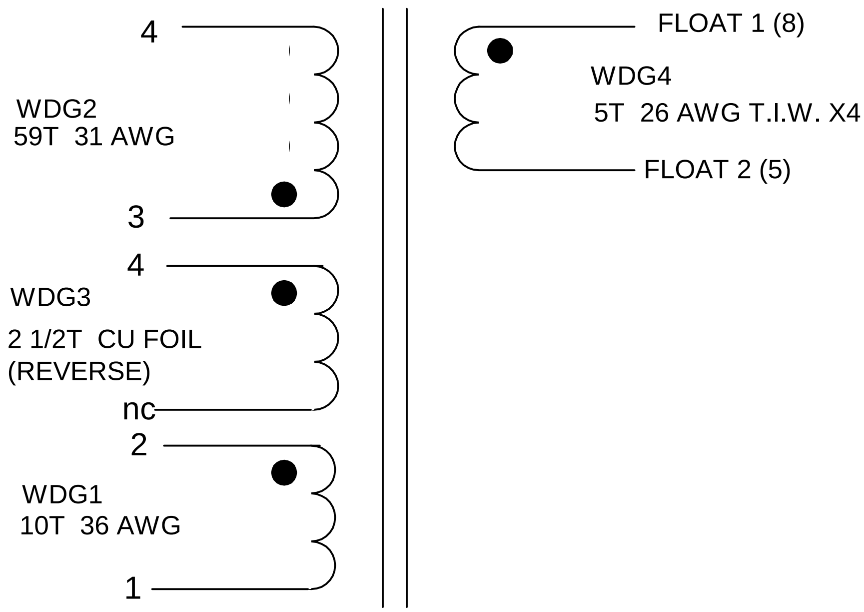

Figure 4 –Transformer Electrical Diagram

7.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pins 1-4 to Pins FLOAT 1-2	3000 VAC
Primary Inductance	Pins 3-4, all other windings open, measured at 100 kHz, 0.4 VRMS	750 µH, -0/+20%
Resonant Frequency	Pins 3-4, all other windings open	1000 kHz (Min.)
Primary Leakage Inductance	Pins 3-4, with Pins FLOAT 1&2 shorted, measured at 100 kHz, 0.4 VRMS	15 µH (Max.)

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7.3 Materials

Item	Description
[1]	Core: EFD20 AND GAPPED ALG 211nH/T2
[2]	Bobbin: BEFD20 8 PIN HORIZONTAL ; EPCOS P/N B66418-B1008-D1
[3]	Magnet Wire: 36 AWG
[4]	Magnet Wire: 31 AWG
[5]	Triple Insulated Wire: 26 AWG
[6]	Copper Tape: 1mil 12.2mm WIDE X 95mm LONG
[7]	Tape: 3M 1298 Polyester Film, 13.7mm wide
[8]	Tape: 3M 1298 Polyester Film, 16.5mm wide
[9]	Jumper wire: 30 AWG
[10]	Varnish

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7.4 Transformer Build Diagram

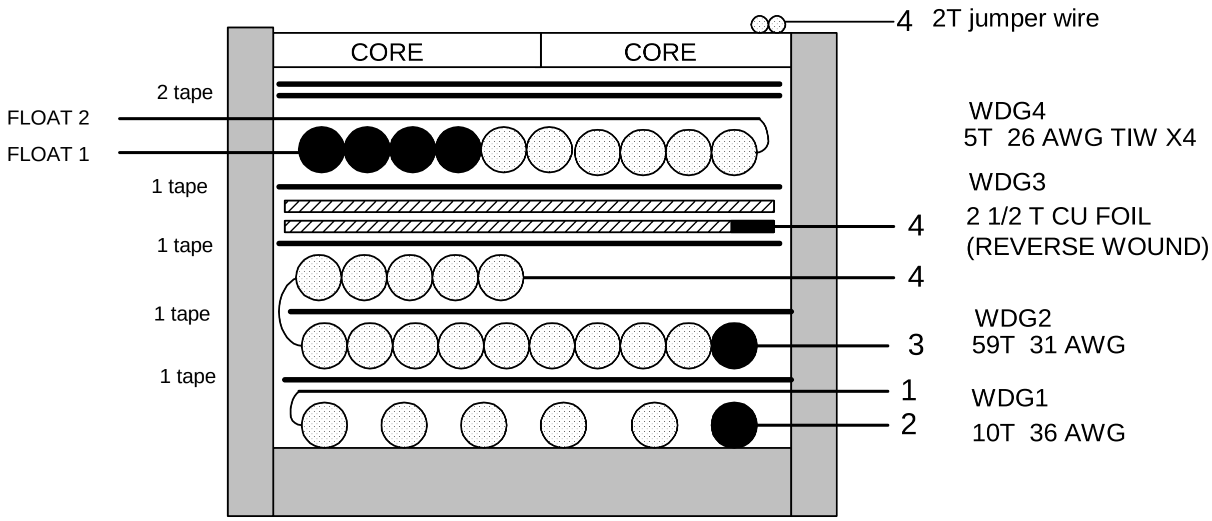

Figure 5 – Transformer Build Diagram.

7.4.1 SHLD Build diagram

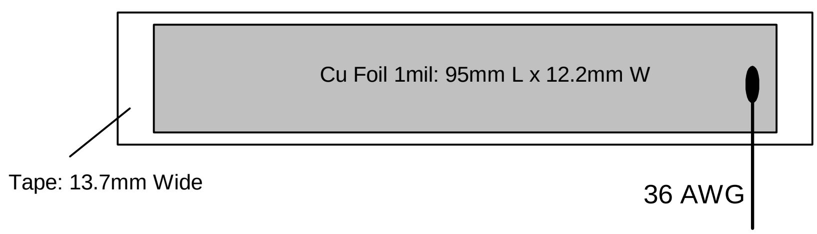

Figure 6 – Copper shield Build Diagram.

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7.5 Transformer Construction

Bobbin Preparation	Pull Pin 6&7 on bobbin [2] to provide polarization. Position bobbin in the winding machine such that pins 1-4 are on the right side
WDG1: Vbias	Start at Pin 2. Wind 10 turns of 36 AWG wire in 1 layer. Spread turns evenly across the bobbin. Finish on Pin1.
Basic Insulation	Use one layer of 13.7mm tape for basic insulation.
WDG2: Primary 1st layer	Start at Pin 3. Wind 46 turns of 31 AWG wire in 1 layer. Avoid overlapping turns.
Basic Insulation	Use one layer of 13.7mm tape for basic insulation.
WDG2: Primary 2nd layer	Continue winding 13 turns of 31 AWG wire in the second layer. Do not spread the turns. Finish on Pin 4
Basic Insulation	Use one layer of 13.7mm tape for basic insulation.
WDG3: SHLD	Use prepared copper shield shown in Figure 6. Start at Pin 4, wind 2 ½ turns in reverse direction.
Basic Insulation	Use one layer of 13.7mm tape for basic insulation.
WDG4: SEC	Start at pin 8 temporarily. Starting from the topside of the bobbin wind 5 turns of quadfilar 26 AWG TIW. Finish on pin 5 temporarily.
Basic Insulation	Use two layers of 13.7mm tape for basic insulation.
	Pull out pins 8 and 5, and let the secondary leads to float, mark the start lead.
Core Assembly	Insert gapped cores into the bobbin and glue them together
Core Wrap	Wrap the secondary side of the core with two layers of 16.5mm tape as shown in Figure 7 and Figure 8
Varnish	Dip varnish the finished transformer

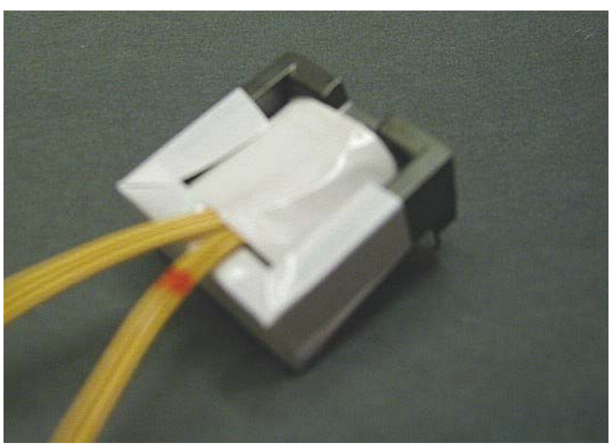

Figure 7 – Core 1st wrapping

Figure 8 – Core 2nd wrapping

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8 Common Mode Choke

8.1 Electrical Diagram

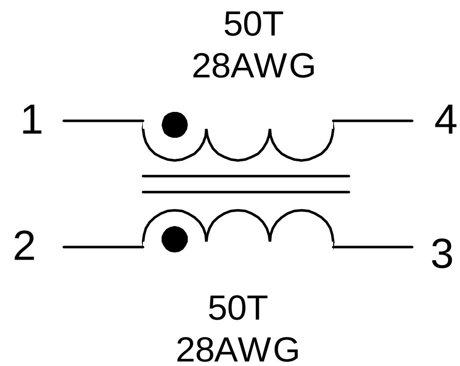

Figure 9 – Common Mode Choke Electrical Diagram

8.2 Electrical Specifications

Inductance	Pins 1-4, all other windings open, measured at 10kHz, 0.4 VRMS	7 mH, -0/+20%
Resonant Frequency	Pins 1-4, all other windings open	300 kHz (Min.)

8.3 Materials

Item	Description
[1]	Core: Ferrite Toroid P/N 5975001121 (Fair-Rite) (Distributor Lodestone Pacific USA Tel# (714) 970-0900)
[2]	Magnet Wire: 28 AWG
[3]	Varnish

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8.4 Common Mode Choke Build Diagram

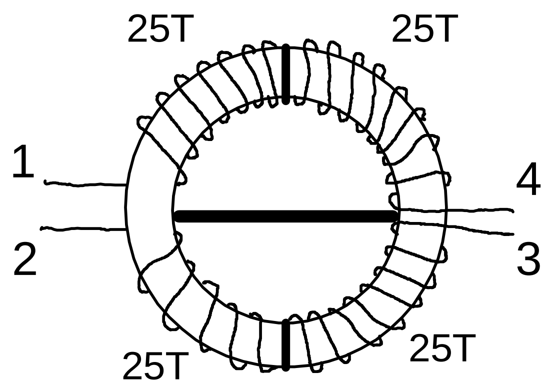

Figure 10 – Common Mode Choke Build Diagram.

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9 Transformer Spreadsheets

ACDC_TOPGX_Rev1.2_052901 Copyright Power Integrations Inc. 2001	INPUT	INFO	OUTPUT	UNIT	TOP_GX_052901.xls: TOPSwitch-GX Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					Customer
VACMIN	85			Volts	Minimum AC Input Voltage
VACMAX	265			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	5.25			Volts	Output Voltage
PO	15.75			Watts	Output Power
n	0.81				Efficiency Estimate
Z	0.5				Loss Allocation Factor
VB	15			Volts	Bias Voltage
tC	3			mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	39			uFarads	Input Filter Capacitor
ENTER TOPSWITCH-GX VARIABLES					
TOP-GX	top245			*Universal*	*115 Doubled/230V*
Chosen Device		*TOP245*	*Power Out*	*60W*	*100W*
KI	0.45				External Ilimit reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT)
ILIMITMIN			*0.729*	Amps	Use 1% resistor in setting external ILIMIT
ILIMITMAX			*0.891*	Amps	Use 1% resistor in setting external ILIMIT
Frequency - (F)=132kHz, (H)=66kHz	f				Full (F) frequency option - 132kHz
fS	132000		*1.32E+05*	Hertz	TOPSwitch-GX Switching Frequency: Choose between 132 kHz and 66 kHz
fSmin			*1.24E+05*	Hertz	TOPSwitch-GX Minimum Switching Frequency
fSmax			*1.40E+05*	Hertz	TOPSwitch-GX Maximum Switching Frequency
VOR	70			Volts	Reflected Output Voltage
VDS	10			Volts	TOPSwitch on-state Drain to Source Voltage
VD	0.7			Volts	Output Winding Diode Forward Voltage Drop
VDB	0.7			Volts	Bias Winding Diode Forward Voltage Drop
KP	**0.61**				Ripple to Peak Current Ratio (0.4 < KRP < 1.0 : 1.0< KDP<6.0)
ENTER TRANSFORMER CORE/CONSTRUCT					
Core Type	efd20				
Core		*EFD20*		*P/N:*	EFD20-3F3
Bobbin		*EFD20_BOBBIN*		*P/N:*	CSH-EFD20-1S-8P
AE			0.31	cm^2	Core Effective Cross Sectional Area
LE			4.7	cm	Core Effective Path Length
AL			1200	nH/T^2	Ungapped Core Effective Inductance
BW			13.2	mm	Bobbin Physical Winding Width
M	0			mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	**1.5**				Number of Primary Layers
NS	**5**				Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			86	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETER					
DMAX			0.48		Maximum Duty Cycle
IAVG			0.22	Amps	Average Primary Current
IP			0.68	Amps	Peak Primary Current
IR			0.41	Amps	Primary Ripple Current
IRMS			0.34	Amps	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAM					
LP			730	uHenries	Primary Inductance
NP			59		Primary Winding Number of Turns
NB			13		Bias Winding Number of Turns
ALG			211	nH/T^2	Gapped Core Effective Inductance
BM			**2711**	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP			**3567**	Gauss	Peak Flux Density (BP<4200)
BAC			827	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1448		Relative Permeability of Ungapped Core
LG			**0.15**	mm	Gap Length (Lg > 0.1 mm)
BWE			19.8	mm	Effective Bobbin Width
OD			0.34	mm	Maximum Primary Wire Diameter including insulation
INS			0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.28	mm	Bare conductor diameter
AWG			30	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			102	Cmils	Bare conductor effective area in circular mils
CMA			**303**	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PAR					
Lumped parameters					
ISP			7.97	Amps	Peak Secondary Current
ISRMS			4.13	Amps	Secondary RMS Current
IO			3.00	Amps	Power Supply Output Current
IRIPPLE			2.83	Amps	Output Capacitor RMS Ripple Current
CMS			825	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			20	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.81	mm	Secondary Minimum Bare Conductor Diameter
ODS			2.64	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			0.91	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN			542	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			37	Volts	Output Rectifier Maximum Peak Inverse Voltage
PIVB			99	Volts	Bias Rectifier Maximum Peak Inverse Voltage

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10 Performance Data

All measurements performed at room temperature, 60 Hz input frequency.

10.1 Efficiency

Efficiency was measured at the output terminals of the board (no cables).

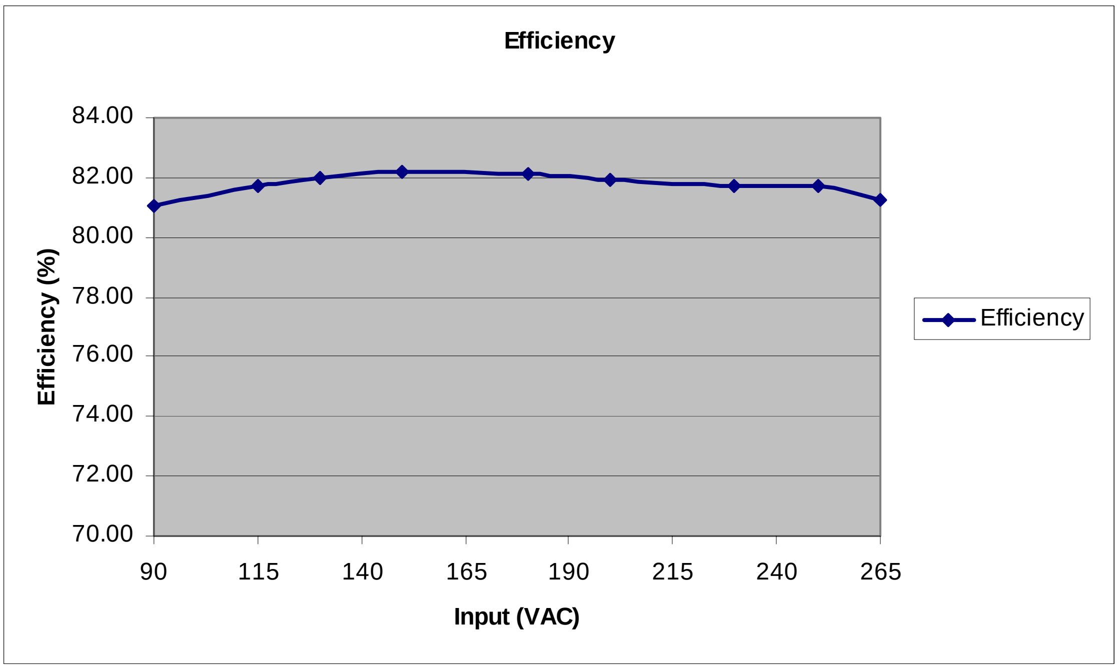

Figure 11 - Efficiency vs. Input Voltage, Room Temperature, 60 Hz. Efficiency at 115 VAC and 230VAC were 81.7 % and 81.8% respectively.

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10.2 No-load Input Power

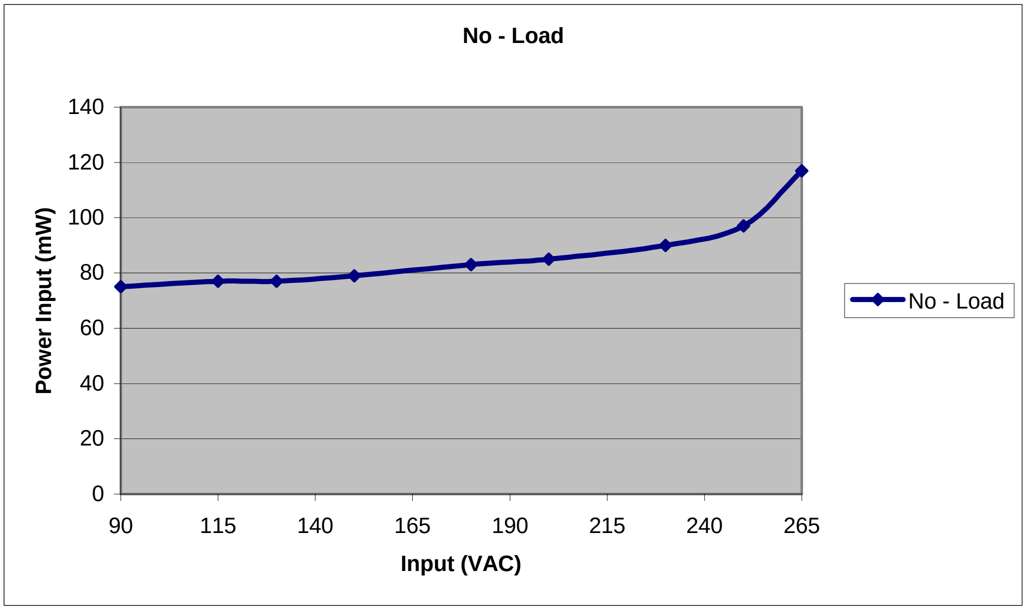

Figure 12 - Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz. No load input power at 230V was 90mW

10.3 Regulation

10.3.1 Load

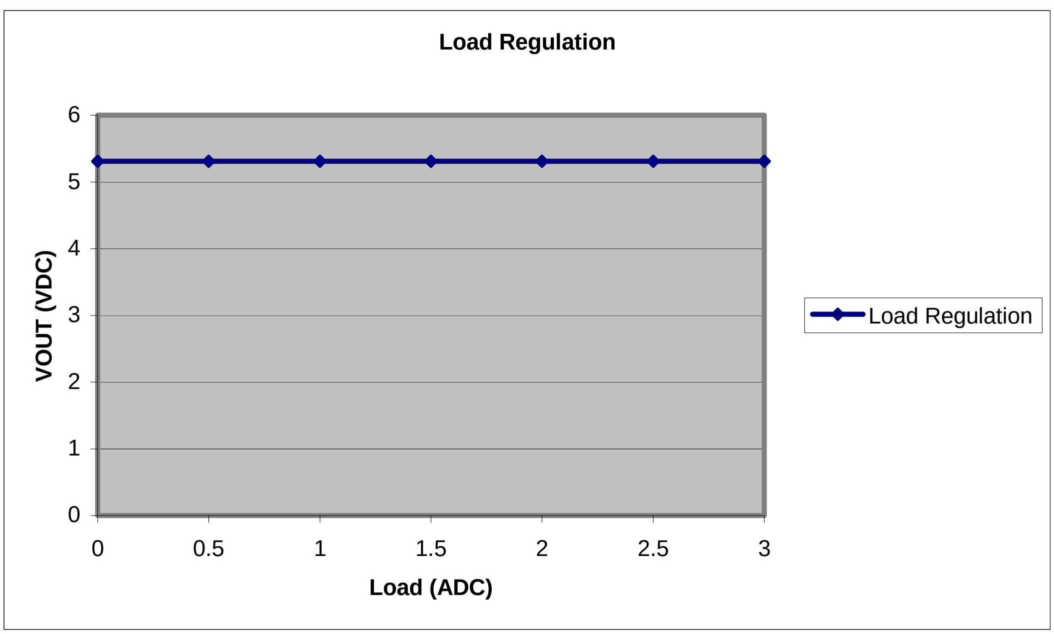

Figure 13 – Load Regulation, Room Temperature.

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10.3.2 Line

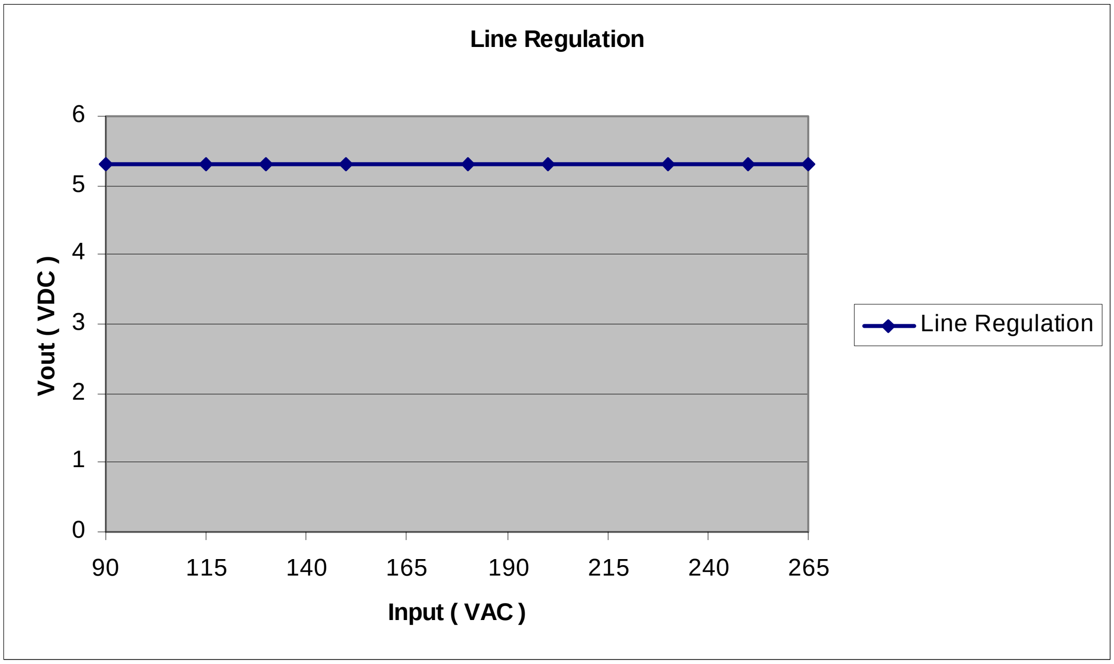

Figure 14 – Line Regulation, Room Temperature, Full Load.

10.4 Over Power Protection

	90VAC	115VAC	230VAC	265VAC
Output Current before Auto-restart	3.9A	4.1A	4.4A	4.4A
VOUT	5.31 VDC	5.31 VDC	5.31 VDC	5.31 VDC
Output Power before Auto-restart	20.7 W	21.7 W	23.3 W	23.3 W

10.5 Leakage Current

The leakage current measured at 230VAC was 47uA.

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11 Thermal Performance

11.1 Thermal measurements at max ambient

The power supply was placed inside a mock-up plastic case of the specified dimensions. The case was placed inside a large closed carton box, and the carton was placed in an oven. The carton box was to prevent airflow on the unit under test. The ambient temperature was monitored inside the carton. The internal temperatures stabilized after 1 hour of continuous full load operation.

Temperature (°C)		
Item	**90 VAC**	**265VAC**
External Ambient	45	45
Bridge (BR1)	84	74
Transformer (T1)	81	87
Rectifier (D1)	120	122
***TOP245P* (U1)**	110	112

11.2 Thermal margin test

As a test of thermal margin, the unit was operated at 10^{o} above max rated external ambient, or $55^{o}C$. The unit *did not go into thermal shutdown*. This implies plenty of thermal margin.

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12 Waveforms

12.1 Drain Voltage and Current, Normal Operation

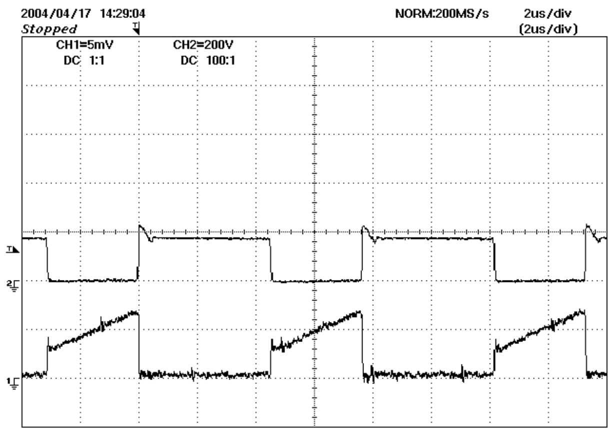

Figure 15 – 90 VAC, Full Load.
Upper: V_{DRAIN}, 200 V, 2 µs / div
Lower: I_{DRAIN}, 0.5 A / div

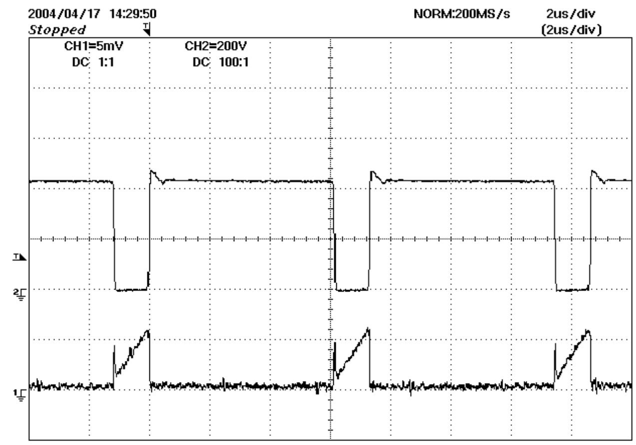

Figure 16 - 265 VAC, Full Load
Upper: V_{DRAIN}, 200 V / div
Lower: I_{DRAIN}, 0.5 A / div

12.2 Output Voltage Start-up Profile

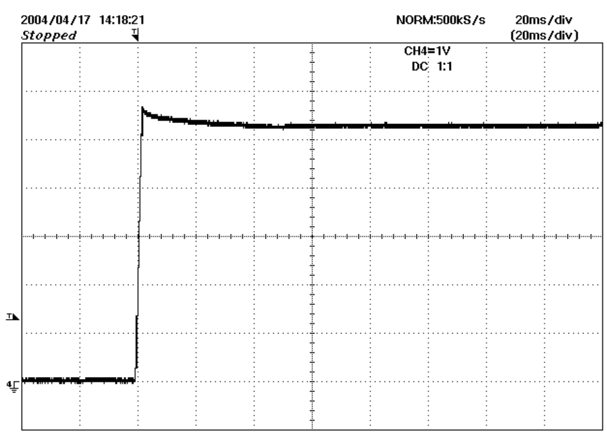

Figure 17 - Start-up Profile, NO LOAD 230VAC
1 V, 20 ms / div.

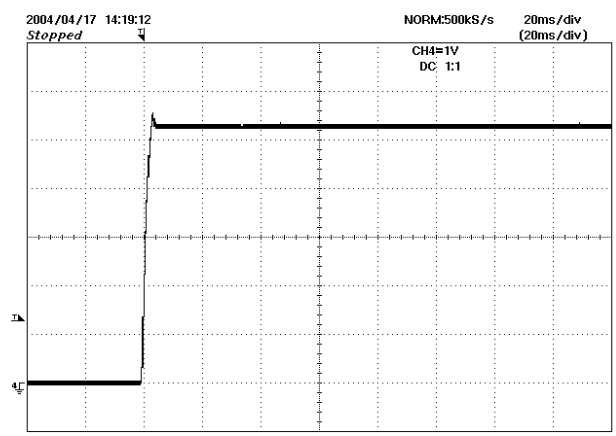

Figure 18 - Start-up Profile, FULL LOAD 230 VAC
1 V, 20 ms / div.

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12.3 Drain Voltage and Current Start-up Profile

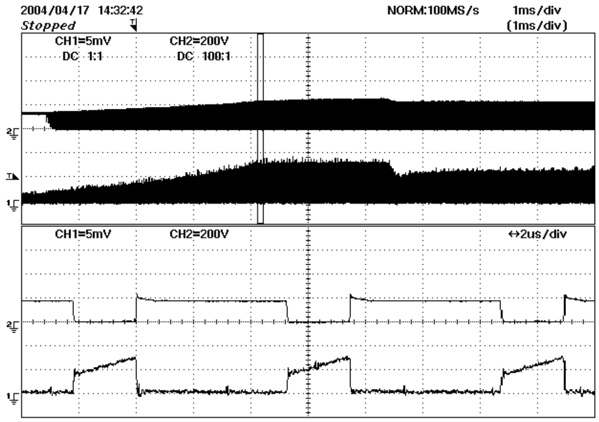

Figure 19 - 90 VAC Input and Maximum Load.
Upper: V_{DRAIN}, 200 V & 1 ms / div.
Lower: I_{DRAIN}, 0.5 A / div.

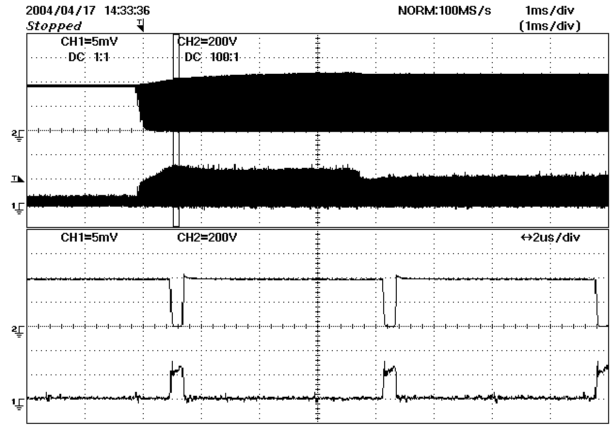

Figure 20 - 265 VAC Input and Maximum Load.
Upper: V_{DRAIN}, 200 V & 1 ms / div.
Lower: I_{DRAIN}, 0.5 A / div.

12.4 Load Transient Response (75% to 100% Load Step)

In the figures shown below, signal averaging was used to better enable viewing the load transient response. The oscilloscope was triggered using the load current step as a trigger source. Since the output switching and line frequency occur essentially at random with respect to the load transient, contributions to the output ripple from these sources will average out, leaving the contribution only from the load step response.

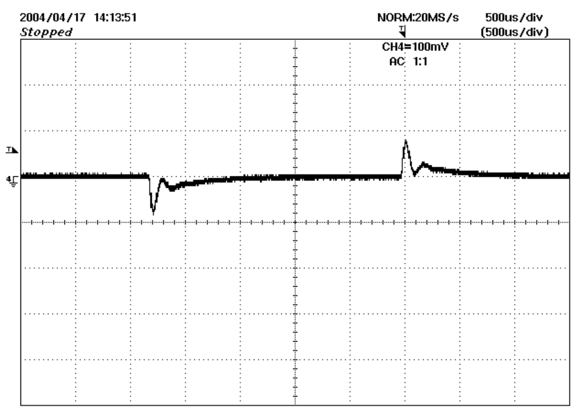

Figure 21 – Transient Response, 115 VAC, 75-100-75% Load Step.

Waveform: Output Voltage
100 mV, 500 μs / div.

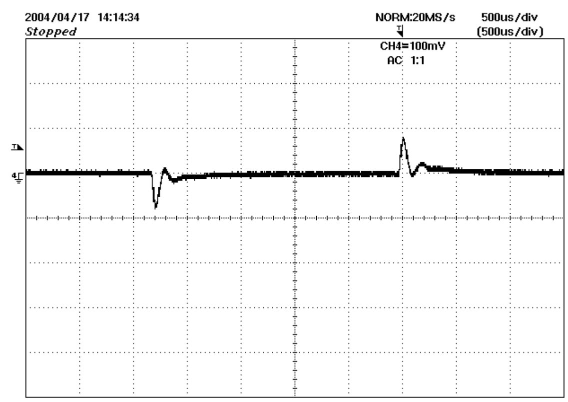

Figure 22 – Transient Response, 230 VAC, 75-100-75% Load Step

Waveform: Output Voltage
100 mV, 500uS / div.

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12.5 Output Ripple Measurements

12.5.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to pickup. Details of the probe modification are provided in Figure 23 and Figure 24.

The 5125BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 μF/50 V ceramic type and one (1) 1.0 μF/50 V aluminum electrolytic. ***The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).***

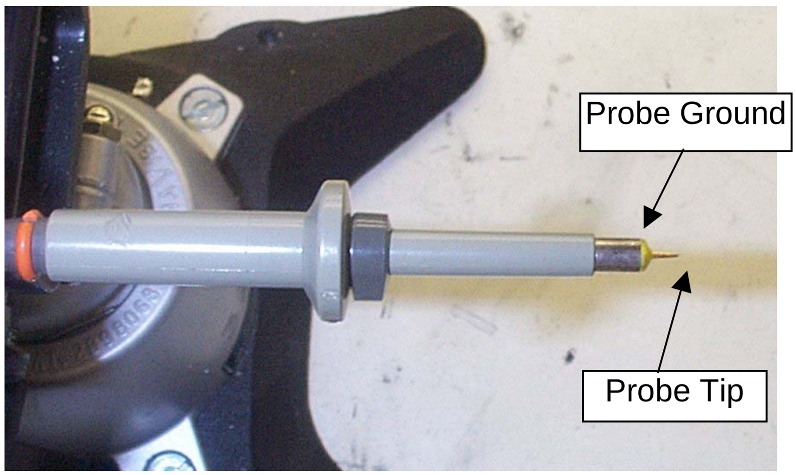

Figure 23 - Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

Figure 24 - Oscilloscope Probe with Probe Master 5125BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)

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12.5.2 Measurement Results

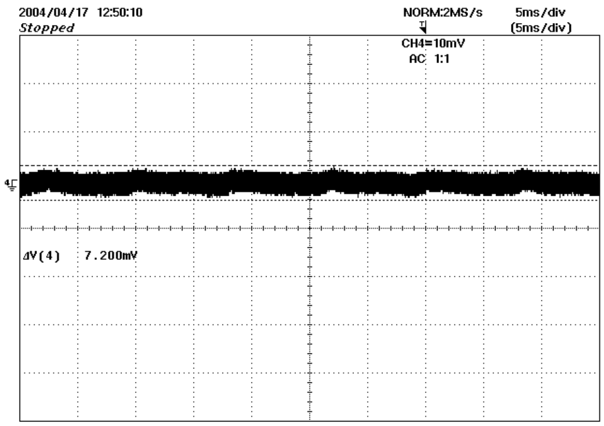

Figure 25 – 5V Ripple, 90 VAC, Full Load.
5 ms, 10 mV / div

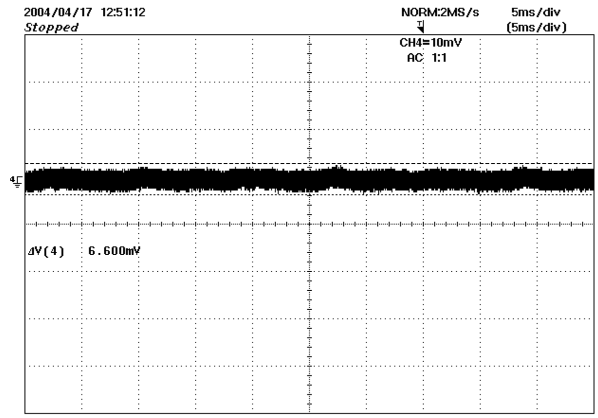

Figure 26 - 5 V Ripple, 115 VAC, Full Load.
5 ms, 10 mV / div

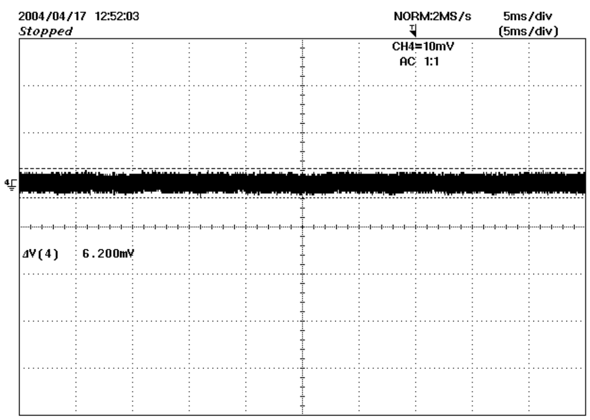

Figure 27 – 5V Ripple, 230 VAC, Full Load.
5 ms, 10 mV /div

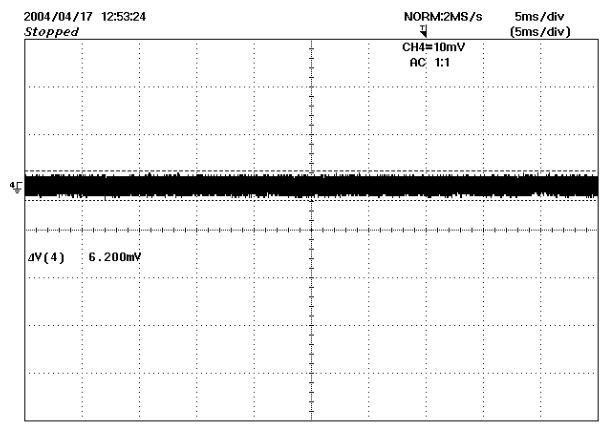

Figure 28 – 5V Ripple, 265 VAC, Full Load.
5 ms, 10 mV /div

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13 Control Loop Measurements

13.1 115 VAC Maximum Load

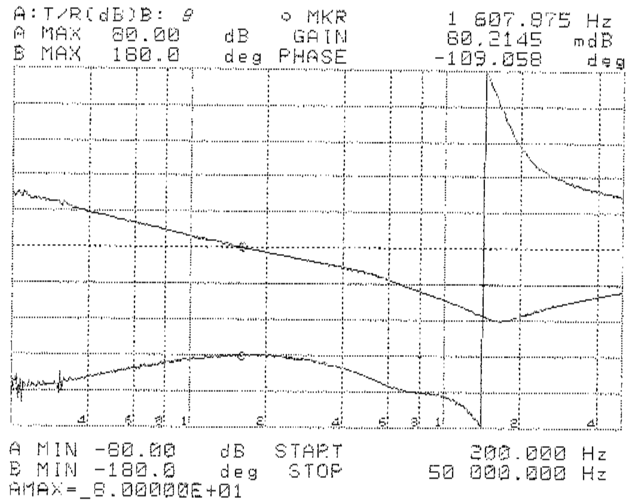

Figure 29 - Gain-Phase Plot, 115 VAC, Maximum Steady State Load
Vertical Scale: Gain = 16 dB/div, Phase = 36 °/div.
Crossover Frequency = 1.6 kHz Phase Margin = 71°

13.2 230 VAC Maximum Load

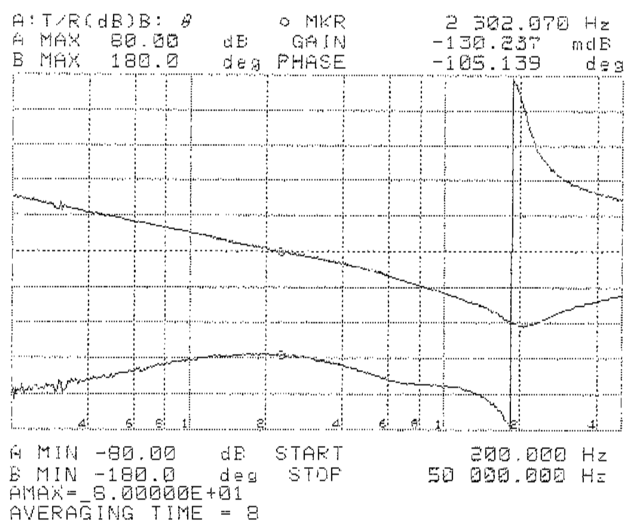

Figure 30 - Gain-Phase Plot, 230 VAC, Maximum Steady State Load
Vertical Scale: Gain = 16 dB/div, Phase = 36 °/div.
Crossover Frequency = 2.3 KHz, Phase Margin = 75°

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14 Conducted EMI

EMI was tested at room temperature, at 115 VAC & 230 VAC input, with a resistor load of 2 ohms at the end of a 1.5 meter cable. Scans are shown for both cases, with and without a ground wire connecting the load to the LISN's Protective Earth (PE) jack.

14.1 230Vac

14.1.1 Output grounded

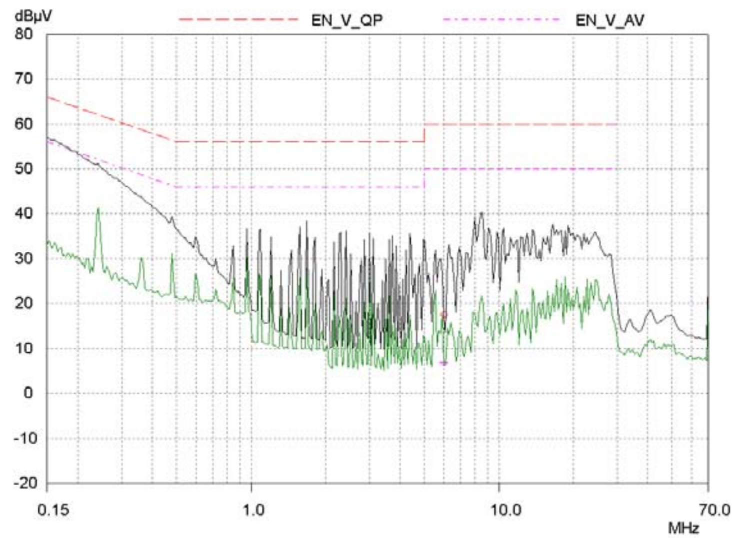

Figure 31 – NEUTRAL Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits. With the LISN's PE connected to secondary ground.

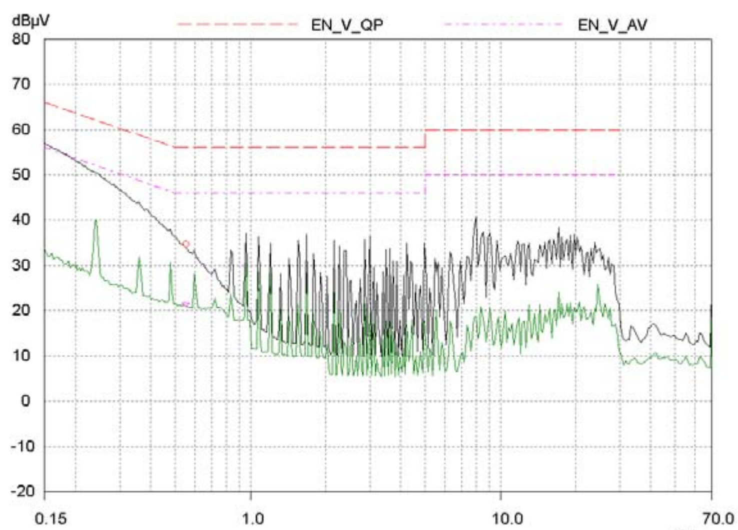

Figure 32 – LINE Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits. With the LISN's PE connected to secondary ground.

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14.1.2 Output floating

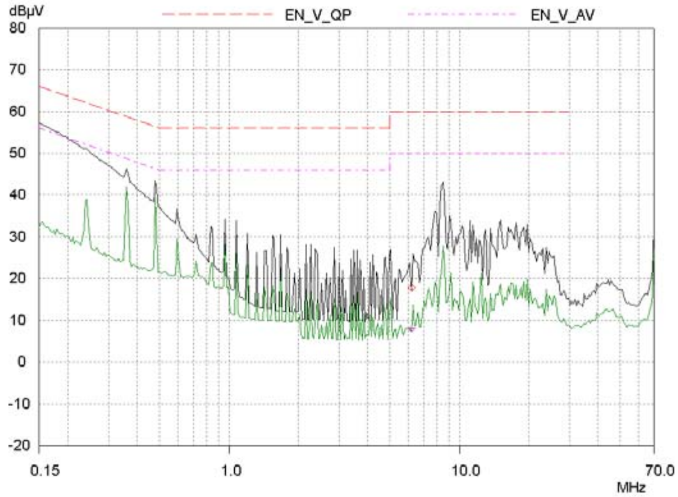

Figure 33 – NEUTRAL Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits. Without the LISN's PE connection to secondary ground.

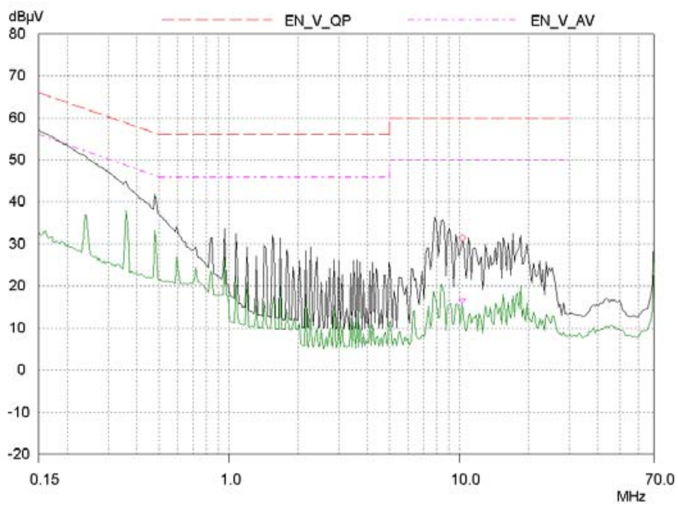

Figure 34 – LINE Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits. Without the LISN's PE connection to secondary ground.

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14.2 115Vac

14.2.1 Output grounded

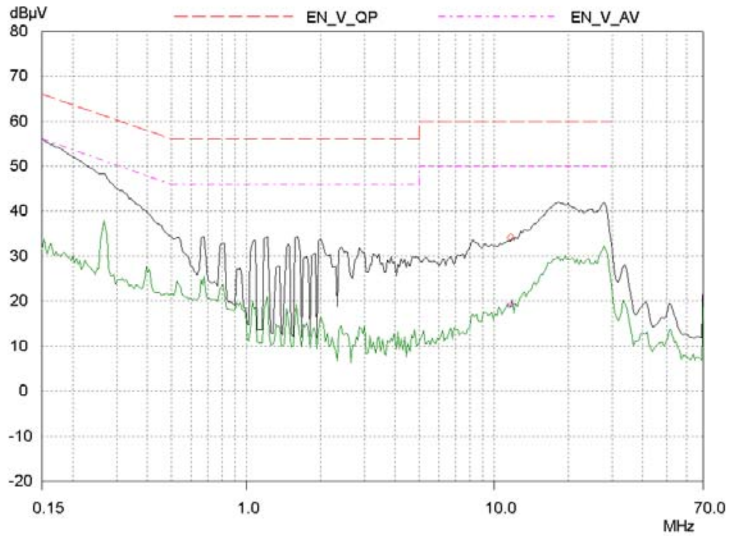

Figure 35 – NEUTRAL Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits. With the LISN's PE connected to secondary ground.

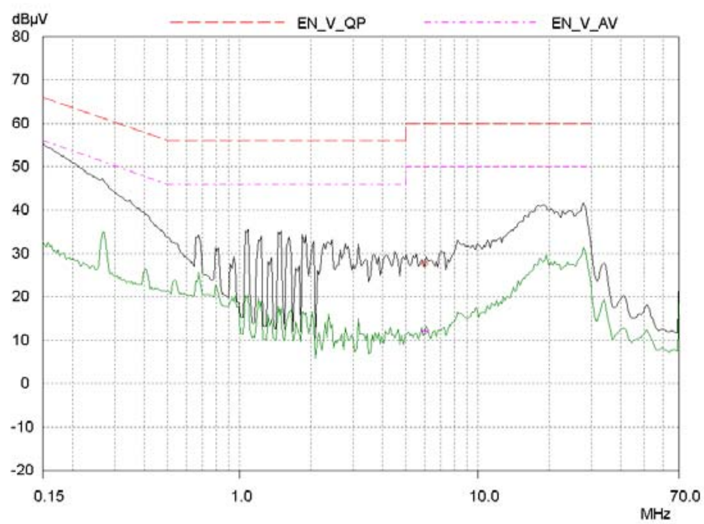

Figure 36 – LINE Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits. With the LISN's PE connected to secondary ground.

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14.2.2 Output floating

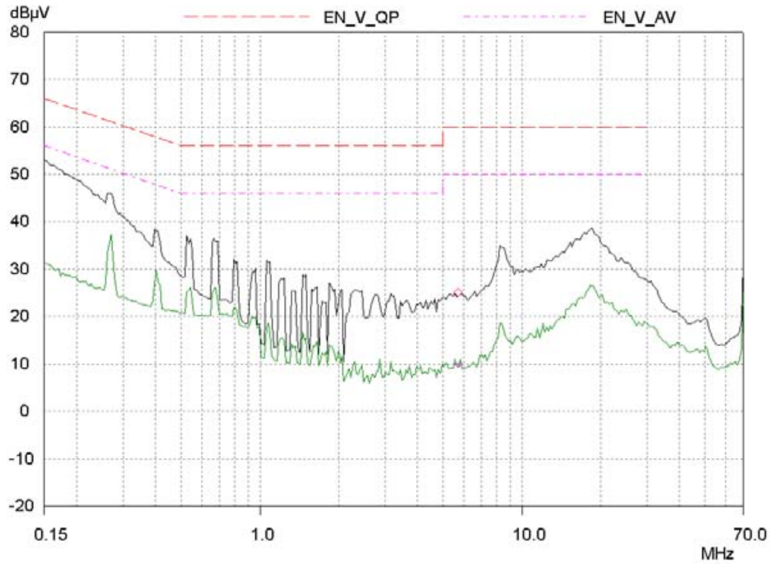

Figure 37 – NEUTRAL Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits. Without the LISN's PE connection to secondary ground.

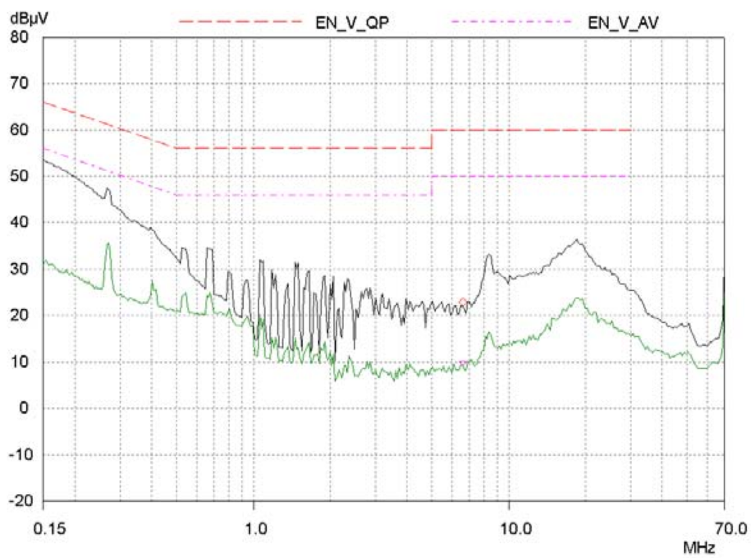

Figure 38 – LINE Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits. Without the LISN's PE connection to secondary ground.

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15 Revision History

Date	Author	Revision	Description & changes	Reviewed
April 27, 2004	ME	1.0	Initial release	VC / AM

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