Design Example Report

Title	***30W Adapter using TOP245Y***
Specification	Input: 90 – 265 VAC Output: 9.7 V / 3.0 A
Application	Portable DVD
Author	Power Integrations Applications Department
Document Number	DER-95
Date	September 12, 2005
Revision	1.0

Summary and Features

- Low cost solution for 30 7W adapter
- EER28 core
- Small common mode choke
- Small X-cap

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Table Of Contents

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Important Notes:
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 isolated source to provide power 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 single output 30 W power supply utilizing a TOP245Y.

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

Figure 1 – Populated Board

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2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)				1.0	W	
Outputs						
Voltage	V_{DC}		9.7		VDC	
Current	I_O		3.0		A	
Efficiency	η		81		%	Measured at P_{OUT} (30 W), 25 °C
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950, UL1950 Class II				
Ambient Temperature	T_{AMB}	0		40	°C	Free convection, sea level

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3 Schematic

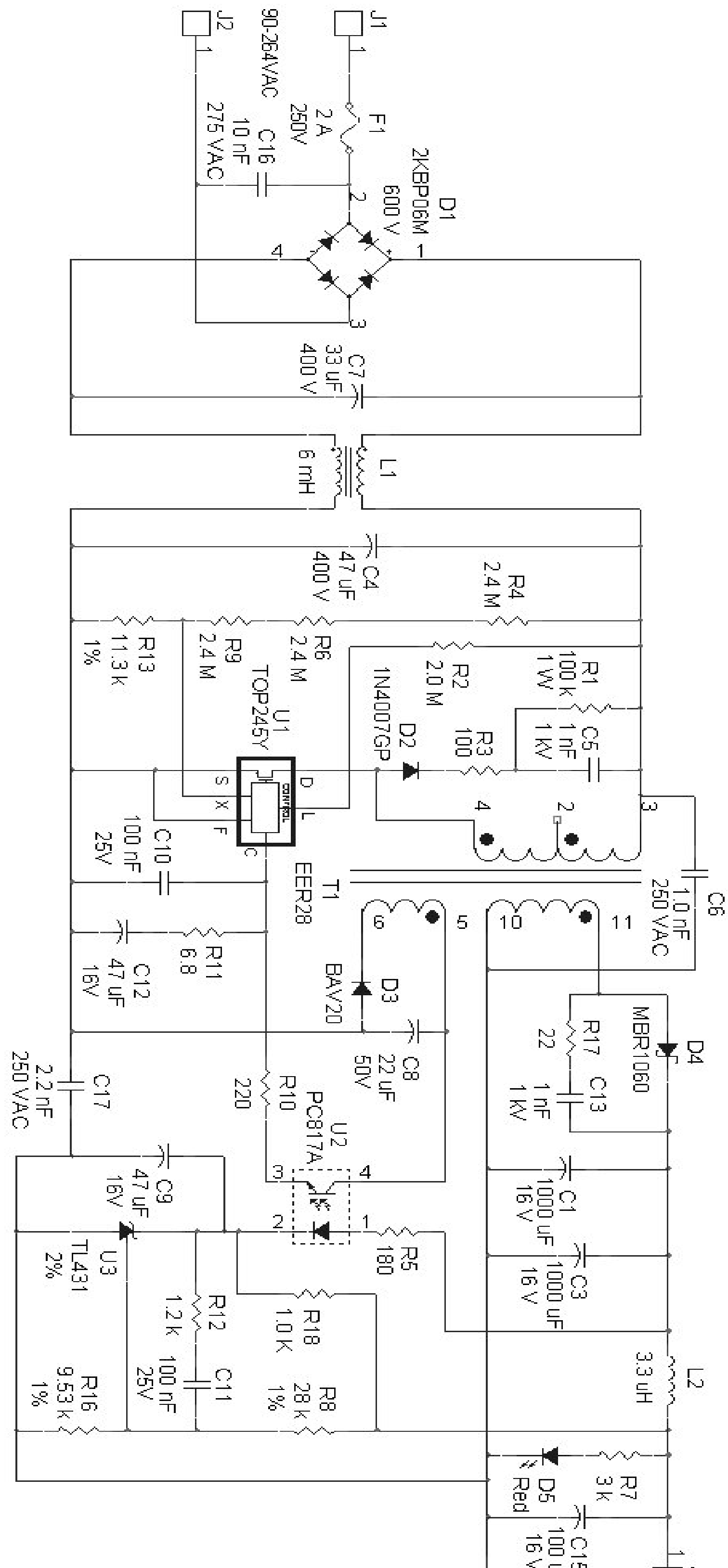

Figure 2 – Schematic

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4 Circuit Description

The schematic in Figure 2 shows an off-line flyback converter using the TOP245Y. The circuit is designed for 90 VAC to 265 VAC input and provides an isolated 9.7 V, 3.0 A continuous output.

4.1 Input EMI Filtering

Conducted EMI filtering is provided by pi formed filter C7, C4, L1, The switching frequency jitter feature of the TOPSwitch-GX family allows the use of a small, low cost common mode choke for L1.

To keep the peak DRAIN voltage acceptably below the BV_{DSS} (700V) of U1, diode D2, C5, R1 and R3 form a primary clamp. This network clamps the voltage spike seen on the DRAIN due to primary leakage inductance. Diode D3 and capacitor C8 provide rectified and filtered bias supply for U1.

4.2 Reduced current limit

Resistor R4, R6, R9 and R13 are used to set the maximum current limit for both high line and low line.

R2 is used for input undervoltage lockout (UVLO).

4.3 Output Rectification

The secondary of T1 is rectified and filtered by D4, C1 & C3. Post filter choke L2 and C15 provide additional high frequency filtering.

4.4 Output Feedback

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

C9 is a “soft finish” capacitor to eliminate output over shoot during start up.

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5 PCB Layout

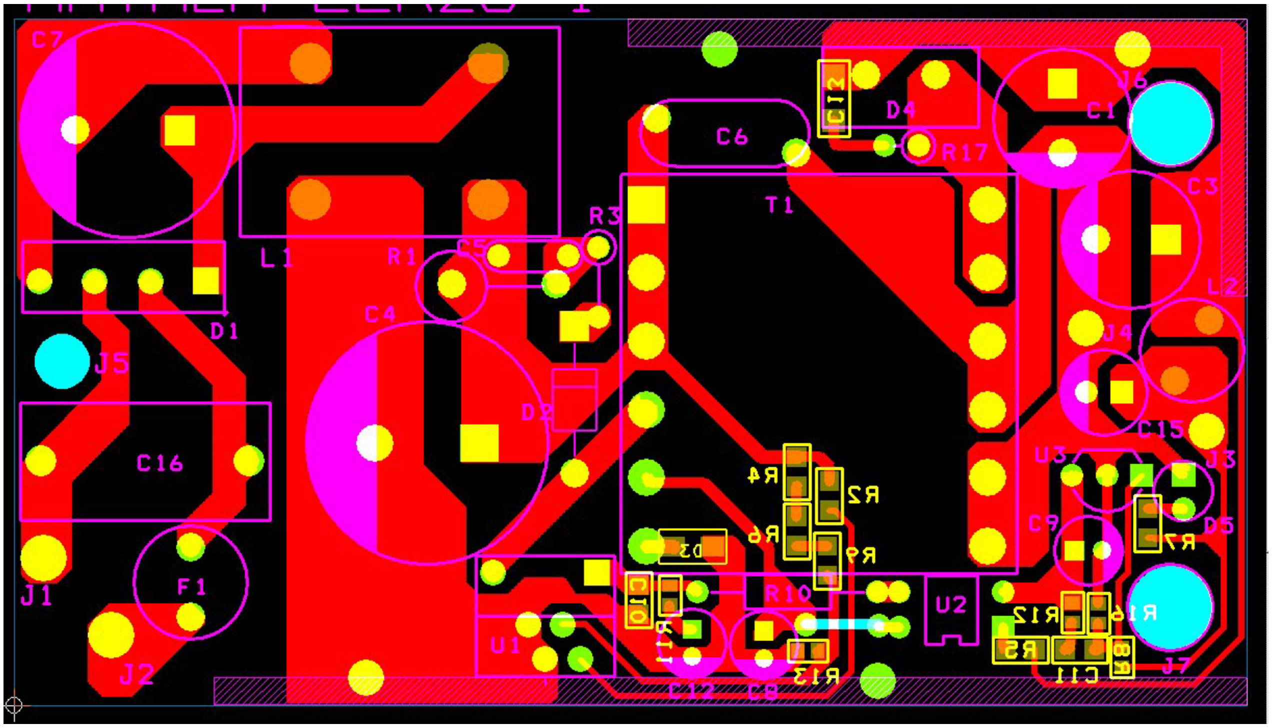

Figure 3 – Printed Circuit Layout

Note: R18 and C17 are not shown in this layout. They are added onto the bottom of the board.

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6 Bill Of Materials

1	2	C1,C3	1000 uF, 16V
2	2	C9,C12	47 uF, 16V
3	2	C5,C13	1 nF
4	1	C6	1.0 nF
5	1	C7	33 uF, 400V
6	1	C4	47 uF, 400V
7	1	C8	22 uF
8	2	C10,C11	100 nF
9	1	C15	100 uF
10	1	C16	10 nF
11	1	C17	2.2 nF
12	1	D1	2KBP06M
13	1	D2	1N4007GP
14	1	D3	BAV20
15	1	D4	MBR1060
16	1	D5	Red
17	1	F1	2 A
18	1	L1	6 mH
19	1	L2	3.3 uH
20	1	R1	100 k
21	1	R2	2.0 M
22	1	R3	100
23	3	R4,R6,R9	2.4 M
24	1	R5	180
25	1	R7	3 k
26	1	R8	28 k
27	1	R10	220
28	1	R11	6.8
29	1	R12	1.2 k
30	1	R13	11.3 k
31	1	R16	9.53 k
32	1	R17	22
33	1	R18	1.0 K
34	1	T1	EER28
35	1	U1	TOP245Y
36	1	U2	PC817A
37	1	U3	TL431

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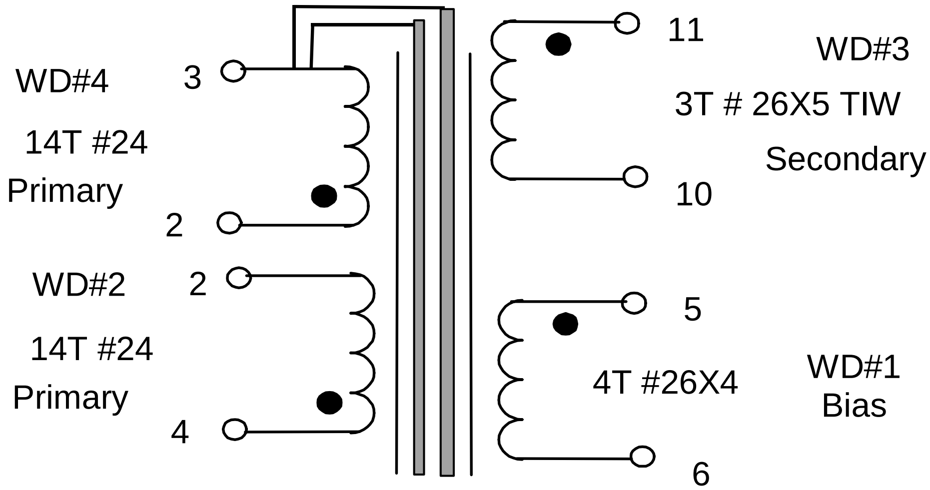
7 Transformer

7.1 Transformer Diagram



7.2 Electrical Specifications

Electrical Strength	60Hz 1minute, from Pins 1-6 to Pins 7-12	3000 V ac
Primary Inductance (Pin 4 to Pin 3)	All windings open	600 uH +/- 5% at 132 KHz
Resonant Frequency. (Pin 4 to Pin 3)	All windings open	900 KHz (Min.)
Primary Leakage Inductance. (Pin 4 to Pin 3)	Pins 10-11 shorted	4 uH Max.

7.3 Materials

Item	Description
[1]	Core: PC40EER28-Z, TDK or equivalent Gapped for AL of 765 nH/T^2
[2]	Bobbin: Horizontal 12 pin
[3]	Magnet Wire: #24 AWG
[4]	Magnet Wire: #26 AWG
[5]	Copper, 1 mil thick, 10 mm wide and 12.6 mm wide
[6]	Triple Insulated Wire: #26 AWG.
[7]	Tape: 3M 1298 Polyester Film, 2.0 mils thick, 10.6 mm wide and 16.0 mm wide
[8]	Varnish

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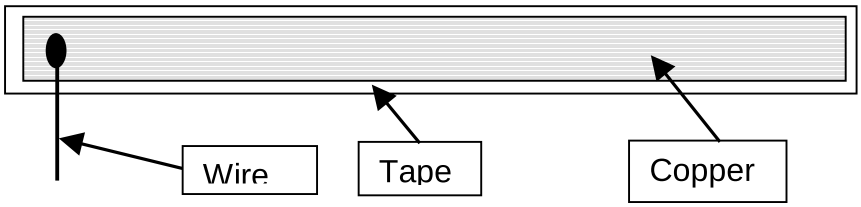
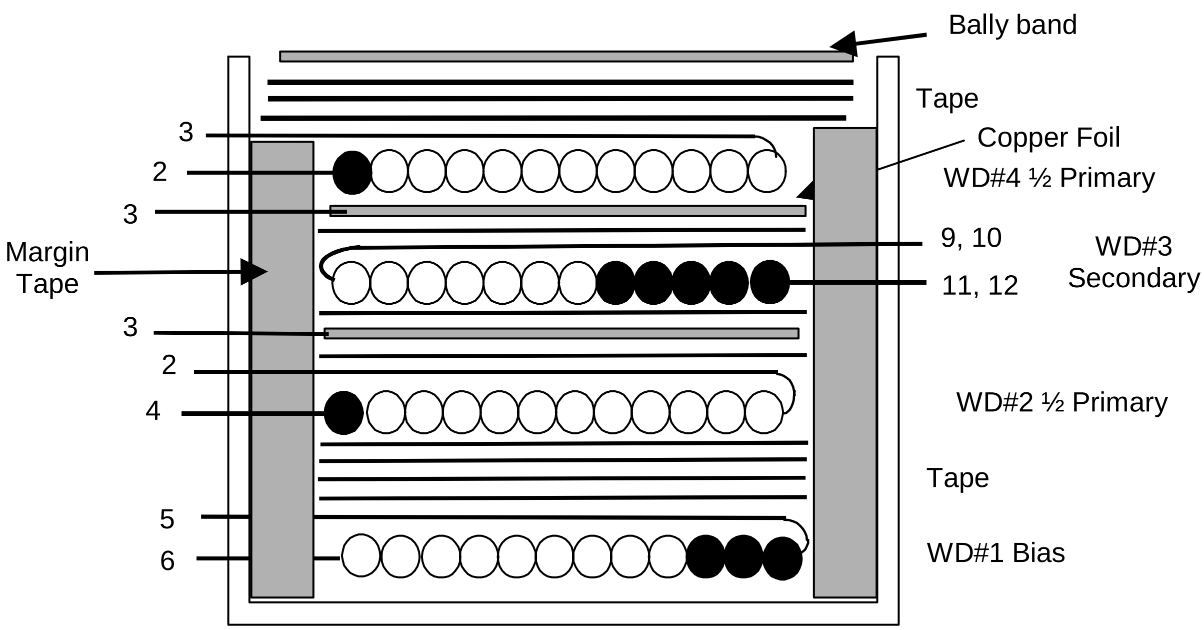
7.4 Detailed copper shield



7.5 Transformer Construction



7.6 Winding Instructions

WD1 Bias Winding	Primary pin side of the bobbin oriented to left hand side. Start at Pin 11 temporally wind 4 turns with 4 wires of item [4] parallel from right to left. Wind with tight tension. Finish on pin 6. Flip the starting lead over to pin 5.
Insulation	4 Layers of tape [7, 10.6 mm wide] for insulation.
WD#2 ½ Primary winding	Start at pin 4, wind 14 turns of item [3] from left to right. Finish at pin 2
Insulation	1 Layers of tape [7, 10.6 mm wide] for insulation.
Copper Foil [10 mm wide]	Using prepared copper foil in 7.4, start at Pin 3 wind 1 turn. Apply insulation tape of [7, 10.6 mm wide] before the end to avoid short circuit.
Insulation	1 Layers of tape [7, 10.6 mm wide] for insulation.
WD #3 Secondary Winding	Start at pin 11 and 12, wind 3 turns of item [6] with 5 wire parallel. from right to left. Wind uniformly, in a single layer across entire bobbin evenly. Finish on pin 9, 10.
Insulation	1 Layers of tape [7, 10.6 mm wide] for insulation.
Copper Foil [10 mm wide]	Using prepared copper foil in 7.4, start at Pin 3 wind 1 turn. Apply insulation tape of [7, 10.6 mm wide] before the end to avoid short circuit.
Insulation	1 Layers of tape [7, 10.6 mm wide] for insulation.

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WD#4 ½ Primary winding	Start at pin 2, wind 14 turns of item [3] from left to right. Finish at pin 3
Insulation [16 mm wide]	3 Layers of tape [7] for insulation.
Core Assembly	Assemble and secure core halves.
Balley band [12.6 mm wide]	Put one turn of copper contacting the core. Leave 22 AWG wire 50mm long for being connected to primary ground.
Varnish	Varnish

8 Transformer Spreadsheets

ACDC_TOPSwitchGX_032204; Rev.1.9; Copyright Power Integrations Inc. 2004	INPUT	INFO	INFO	OUTPUT	OUTPUT	UNIT	TOP_GX_FX_032204.xls: TOPSwitch-GX/FX Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES							
VACMIN	90					Volts	Minimum AC Input Voltage
VACMAX	265					Volts	Maximum AC Input Voltage
fL	50					Hertz	AC Mains Frequency
VO	10					Volts	Output Voltage
PO	30					Watts	Output Power
n	0.8						Efficiency Estimate
Z	0.5						Loss Allocation Factor
VB	15					Volts	Bias Voltage
tC	3					mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	80					uFarads	Input Filter Capacitor
ENTER TOPSWITCH-GX VARIABLES							
TOP-GX	TOP245					*Universal*	*115 Doubled/230V*
Chosen Device		*TOP245*	*TOP245*	*Power Out*	*Power Out*	*60W*	*85W*
KI	0.72						External Ilimit reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT)
ILIMITMIN				*1.166*	*1.166*	Amps	Use 1% resistor in setting external ILIMIT
ILIMITMAX				*1.426*	*1.426*	Amps	Use 1% resistor in setting external ILIMIT
Frequency (F)=132kHz, (H)=66kHz	F						Full (F) frequency option - 132kHz
fS				*132000*	*132000*	Hertz	TOPSwitch-GX Switching Frequency: Choose between 132 kHz and 66 kHz
fSmin				*124000*	*124000*	Hertz	TOPSwitch-GX Minimum Switching Frequency
fSmax				*140000*	*140000*	Hertz	TOPSwitch-GX Maximum Switching Frequency
VOR	97					Volts	Reflected Output Voltage
VDS	10					Volts	TOPSwitch on-state Drain to Source Voltage
VD	0.5					Volts	Output Winding Diode Forward Voltage Drop
VDB	0.7					Volts	Bias Winding Diode Forward Voltage Drop
KP	0.6						Ripple to Peak Current Ratio (0.4 < KRP < 1.0 : 1.0< KDP<6.0)
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES							
Core Type	eer28						
Core		*EER28*	*EER28*			*P/N:*	PC40EER28-Z
Bobbin		*EER28_BOBBIN*	*EER28_BOBBIN*			*P/N:*	BEER-28-1112CPH
AE	1.18			1.18	1.18	cm^2	Core Effective Cross Sectional Area
LE	5.55			5.55	5.55	cm	Core Effective Path Length
AL	4600			4600	4600	nH/T^2	Ungapped Core Effective Inductance
BW	12.7			12.7	12.7	mm	Bobbin Physical Winding Width
M						mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)

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L	1				Number of Primary Layers
NS	3				Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN		98	98	Volts	Minimum DC Input Voltage
VMAX		375	375	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX		0.52	0.52		Maximum Duty Cycle
IAVG		0.38	0.38	Amps	Average Primary Current
IP		1.04	1.04	Amps	Peak Primary Current
IR		0.63	0.63	Amps	Primary Ripple Current
IRMS		0.54	0.54	Amps	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP		597	597	uHenries	Primary Inductance
NP		28	28		Primary Winding Number of Turns
NB		4	4		Bias Winding Number of Turns
ALG		777	777	nH/T^2	Gapped Core Effective Inductance
BM		**1902**	**1902**	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP		**2603**	**2603**	Gauss	Peak Flux Density (BP<4200)
BAC		571	571	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur		1722	1722		Relative Permeability of Ungapped Core
LG		**0.16**	**0.16**	mm	Gap Length (Lg > 0.1 mm)
BWE		12.7	12.7	mm	Effective Bobbin Width
OD		0.46	0.46	mm	Maximum Primary Wire Diameter including insulation
INS		0.06	0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA		0.39	0.39	mm	Bare conductor diameter
AWG		27	27	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM		203	203	Cmils	Bare conductor effective area in circular mils
CMA		**374**	**374**	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT / SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP		9.62	9.62	Amps	Peak Secondary Current
ISRMS		4.79	4.79	Amps	Secondary RMS Current
IO		3.00	3.00	Amps	Power Supply Output Current
IRIPPLE		3.73	3.73	Amps	Output Capacitor RMS Ripple Current
CMS		958	958	Cmils	Secondary Bare Conductor minimum circular mils
AWGS		20	20	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS		0.81	0.81	mm	Secondary Minimum Bare Conductor Diameter
ODS		4.23	4.23	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS		1.71	1.71	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN		598	598	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS		51	51	Volts	Output Rectifier Maximum Peak Inverse Voltage
PIVB		76	76	Volts	Bias Rectifier Maximum Peak Inverse Voltage

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9 Performance Data

All measurements performed at room temperature, 60 Hz input frequency.
The data were taken at the end of the output cable. The DC resistance of the cable is about 0.05 ohm.

9.1 Efficiency

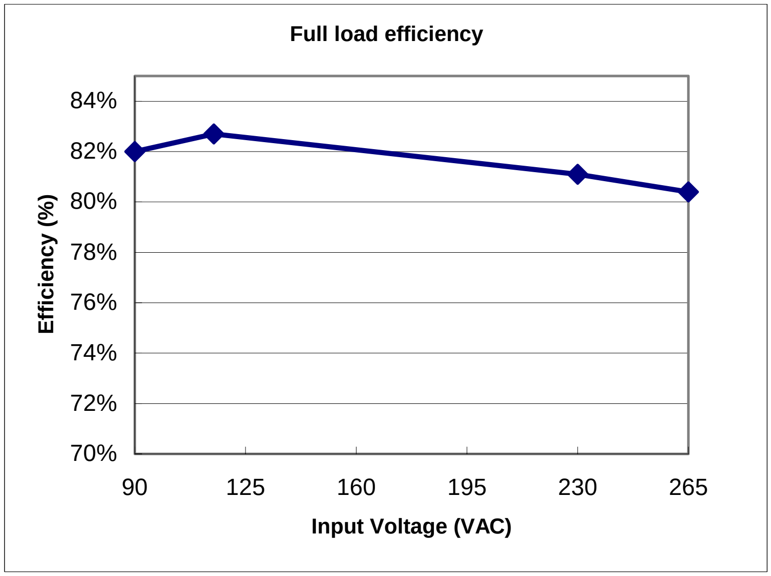

Figure 4 – Efficiency vs input voltage

9.2 No-Load Input Power Integrations

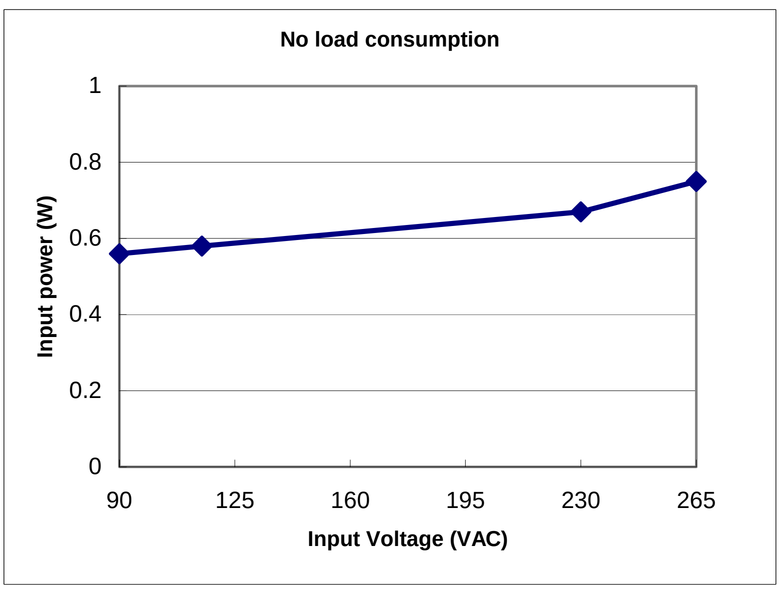

Figure 5 – No-load input vs input voltage, room temperature

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9.3 Output regulation

9.3.1 Line regulation

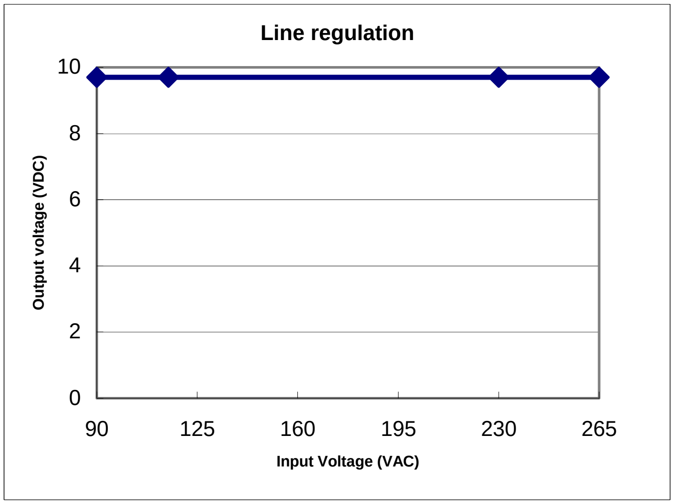

Figure 6 – Output voltage vs input voltage at 3.0 A load

9.3.2 Load regulation (taken at the end of the output cable)

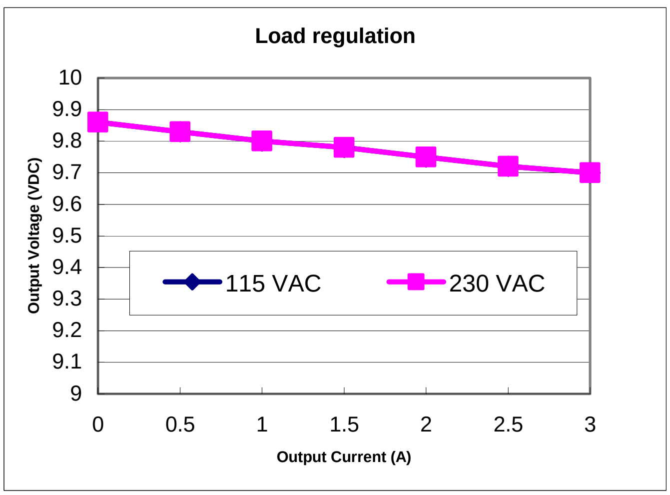

Figure 7 – Output voltage vs current

9.4 Thermal Performance

Thermal was measured inside the sealed case, at worst case, which is at high line 265 VAC input, 3.0 A load. PSU was placed in still air, with ambient temperature of 42°C.

Item	265 VAC
Ambient	42 °C
TOP245Y	101 °C

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9.5 Maximum output current

This is the load current beyond which the PSU goes into auto-restart.

Item	Max. Io
115 VAC	3.76 A
230 VAC	3.83 A

10 Waveforms

10.1 Drain Voltage, Normal Operation

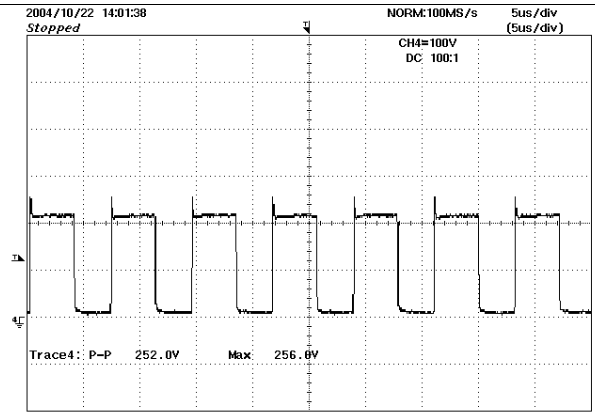

Figure 8 – Drain voltage, 90 VAC input, 3.0 A load

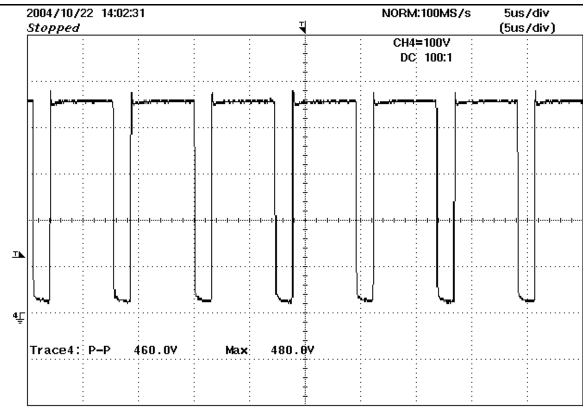

Figure 9 – Drain voltage 265 VAC, 3.0 A load

10.2 Output Voltage Start-up Profile

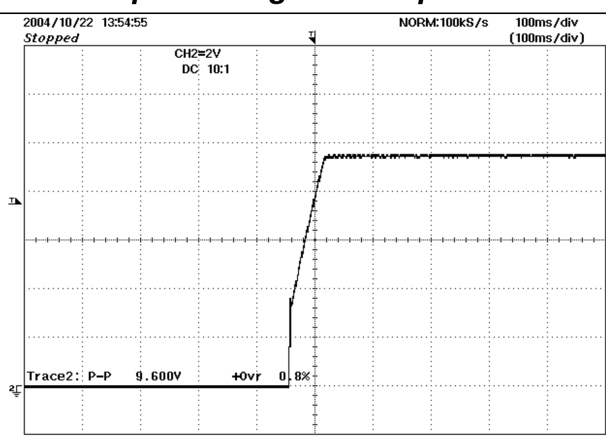

Figure 10 – 115 VAC input, 3.0 A load

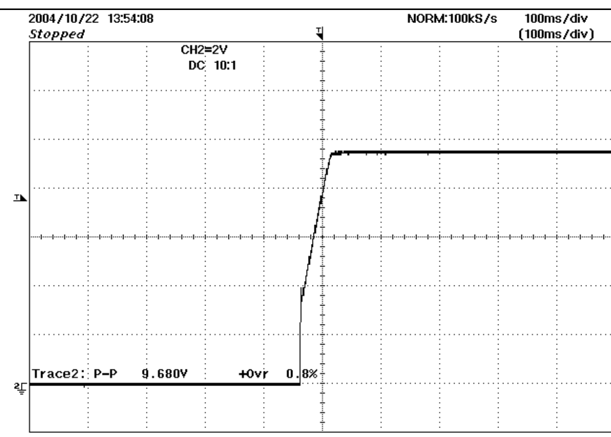

Figure 11 – 230 VAC, 3.0 A load

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11 Output Ripple Measurements

11.1.1 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 12 and Figure 13.

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).***

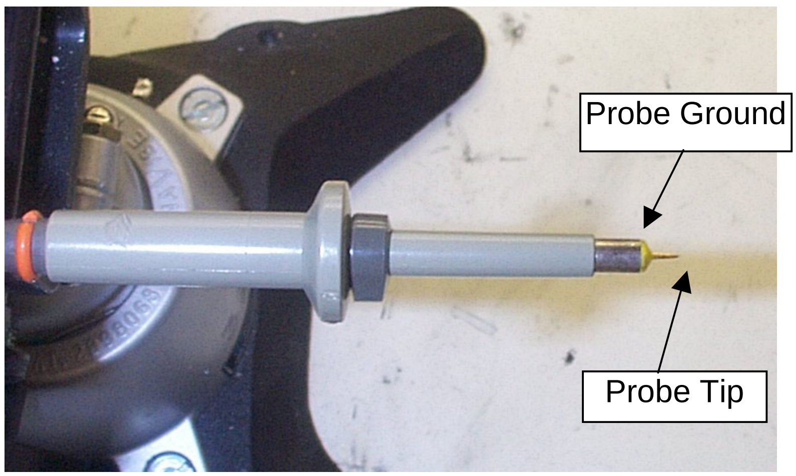

Figure 12 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

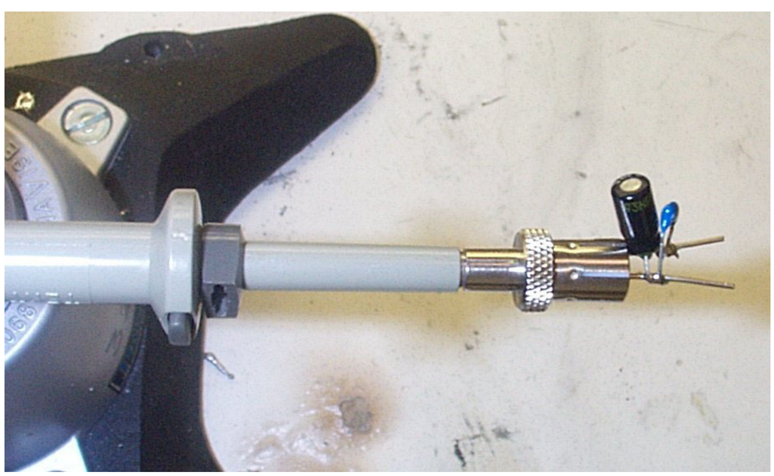

Figure 13 – Oscilloscope Probe with Probe Master 5125BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)

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11.1.2 Measurement Results

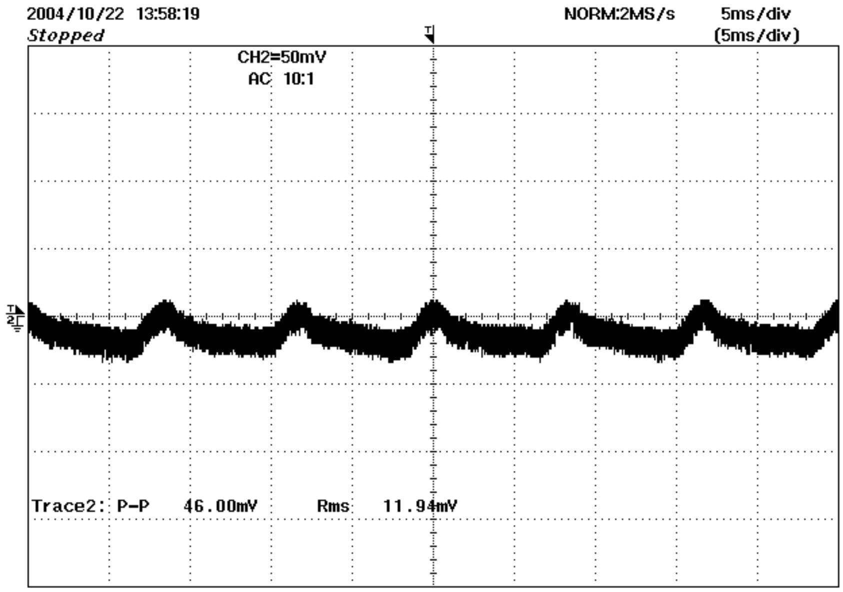

Figure 14 – Output Ripple, 115 VAC, 3.0 A load

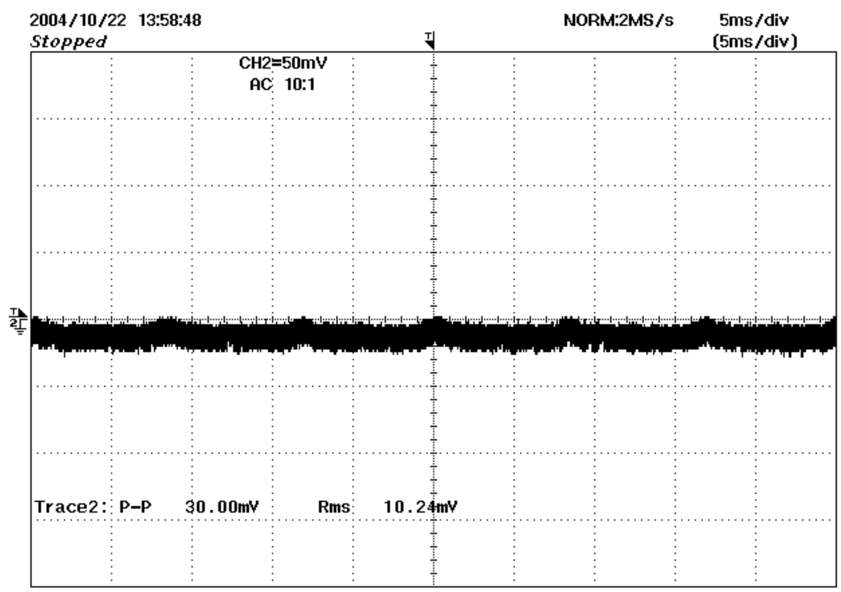

Figure 15 – Output Ripple, 230 VAC, 3.0 A load

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12 Loop performance

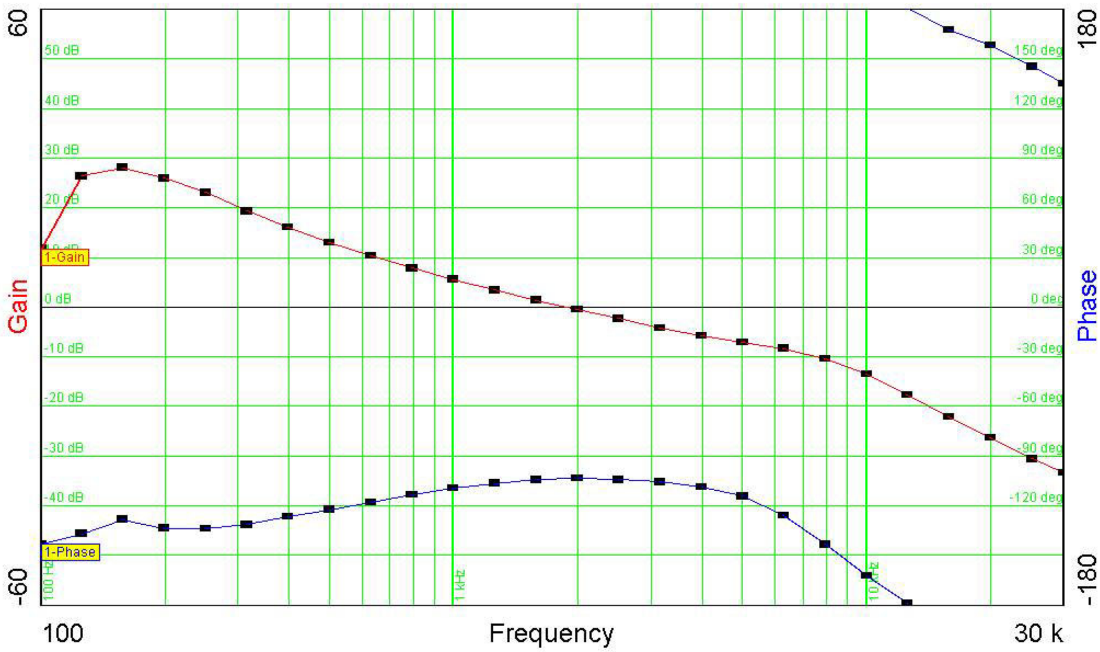

Figure 16 – Gain/phase at 115 VAC input, 3.0 A load

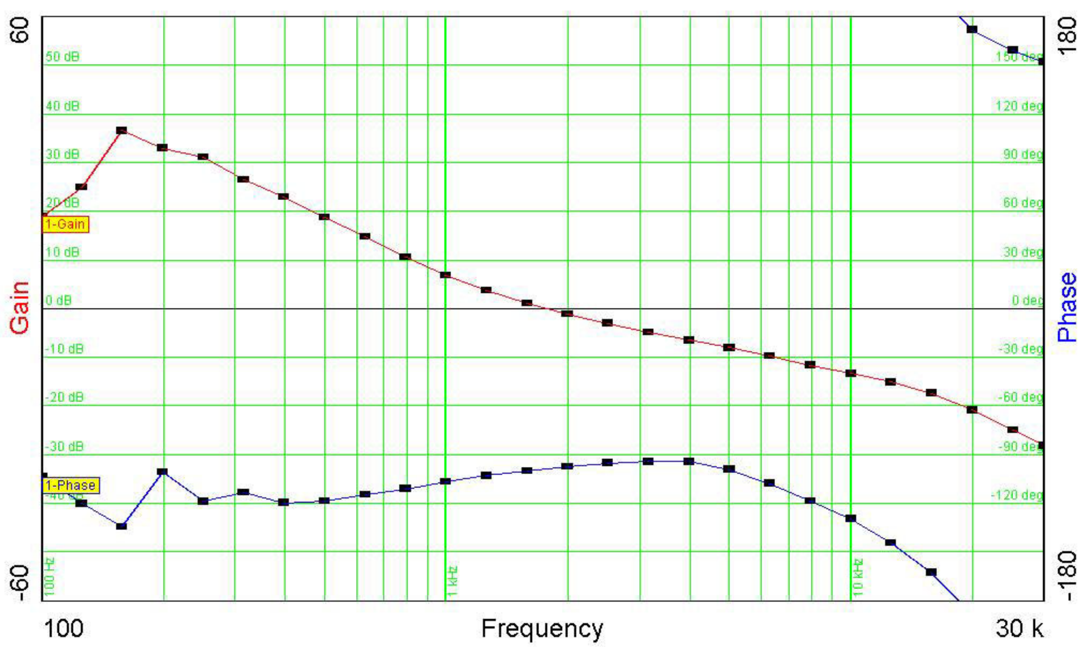

Figure 17 – Gain/Phase at 230 VAC input, 3.0 A load

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13 Conducted EMI

EMI was tested at 230 VAC input, 3.0 A resistive load. The worst case result occurs at 230VAC input with artificial hand.

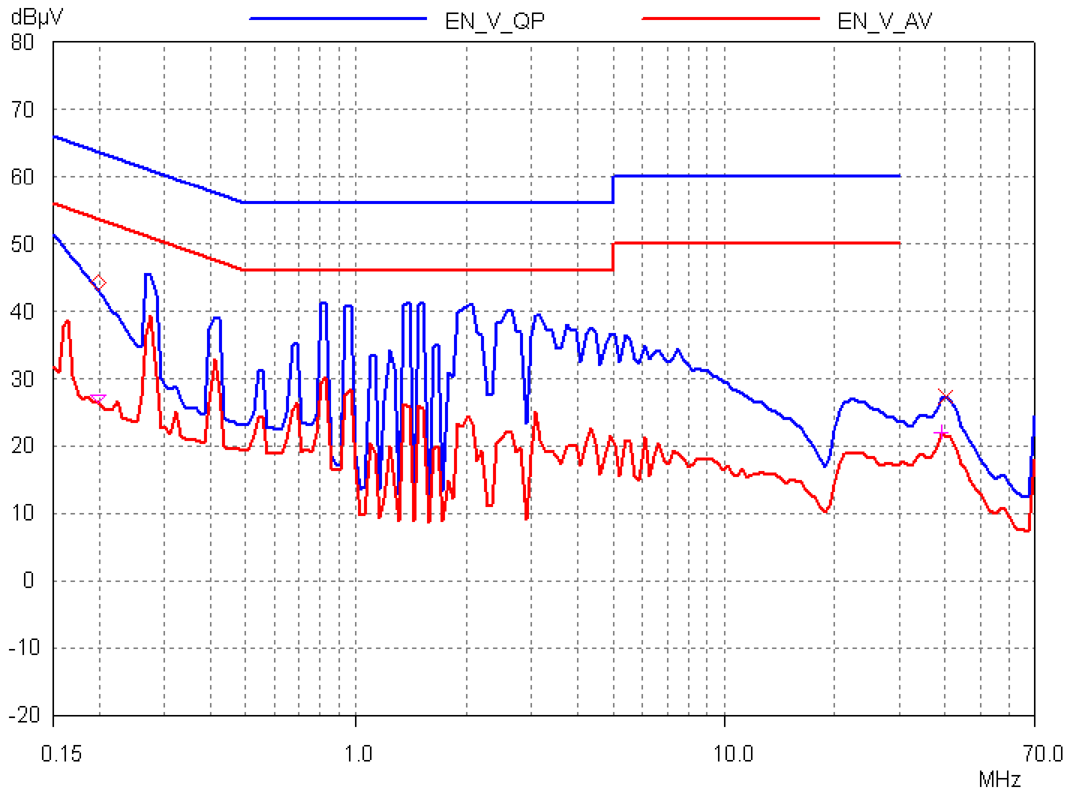

Figure 18 – Worst case conducted EMI, 230VAC, 3.0 A load

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14 Revision History

Date	Author	Revision	Description & changes	Reviewed
September 12, 2005	YG	1.0	First Release	VC / AM

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