Design Example Report

Title	***7.2 W Dual Output Power Supply using TNY267G***
Specification	Input: 90 – 265 VAC Output: 24V/150mA, 24V/150mA
Application	Network Interface
Author	Power Integrations Applications Department
Document Number	DER-108
Date	October 26, 2005
Revision	1.0

Summary

- Dual output design featuring primary-side regulation to eliminate opto-coupler
- ESHIELD® Transformer construction allows for simple input pi-filter and no safety X or Y capacitors
- 27 total components including EMI filter
- Short Circuit Protection
- Hysteretic Thermal Shutdown
- Frequency Jitter
- Excellent Conducted EMI (>8 dB margin across spectrum)
- EcoSmart Technology
- Extremely low standby power consumption (<700 mW with 250 mW pre-load)

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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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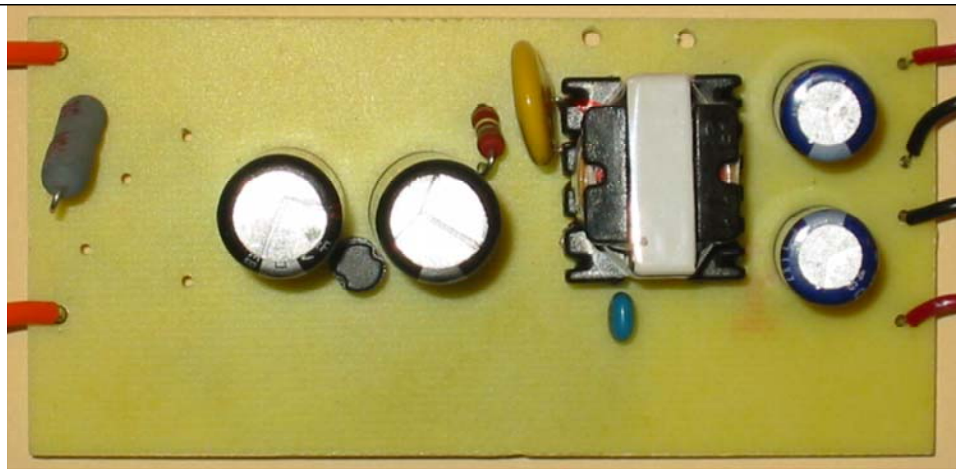
1 Introduction

This document is an engineering report describing a dual output power supply utilizing a TNY267G. This power supply is intended as a bias power supply.

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



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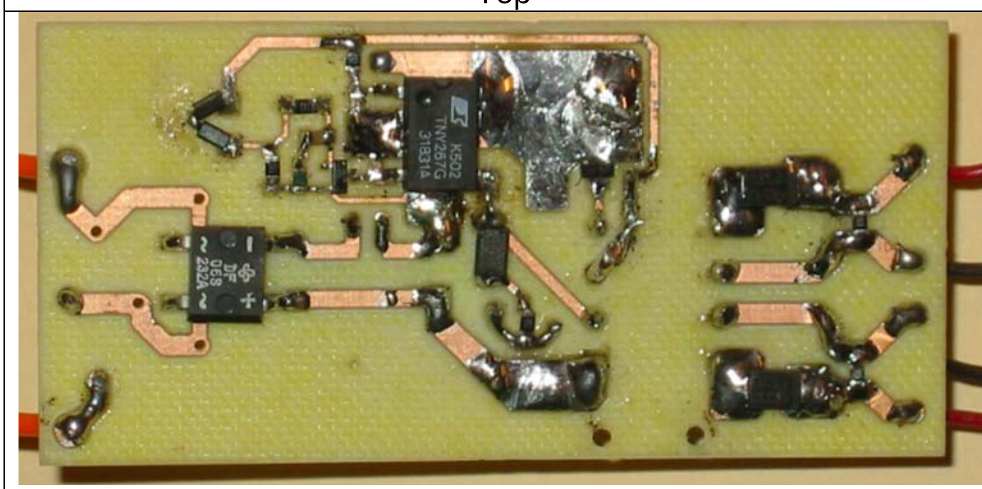

Bottom

Figure 1 – Populated Circuit Board Photograph

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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	W	
Output						
Output Voltage 1	V_{OUT1}	19.2	24	28.2	V	± 20%
Output Ripple Voltage 1	$V_{RIPPLE1}$		500		mV	20 MHz bandwidth
Output Current 1	I_{OUT1}		0.15		A	
Output Voltage 2	V_{OUT2}	19.2	24	28.2	V	± 20%
Output Ripple Voltage 2	$V_{RIPPLE2}$		500		mV	20 MHz bandwidth
Output Current 2	I_{OUT2}		0.15		A	
Total Output Power						
Continuous Output Power	P_{OUT}			7.2	W	
Efficiency	η	72			%	Measured at P_{OUT} (7.2 W), 25 °C
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950, UL1950 Class II				
Surge			TBD		kV	1.2/50 µs surge, IEC 1000-4-5, Series Impedance: Differential Mode: 2 Ω Common Mode: 12 Ω
Surge			TBD		kV	100 kHz ring wave, 500 A short circuit current, differential and common mode
Ambient Temperature	T_{AMB}	0		40	°C	Free convection, sea level

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3 Schematic

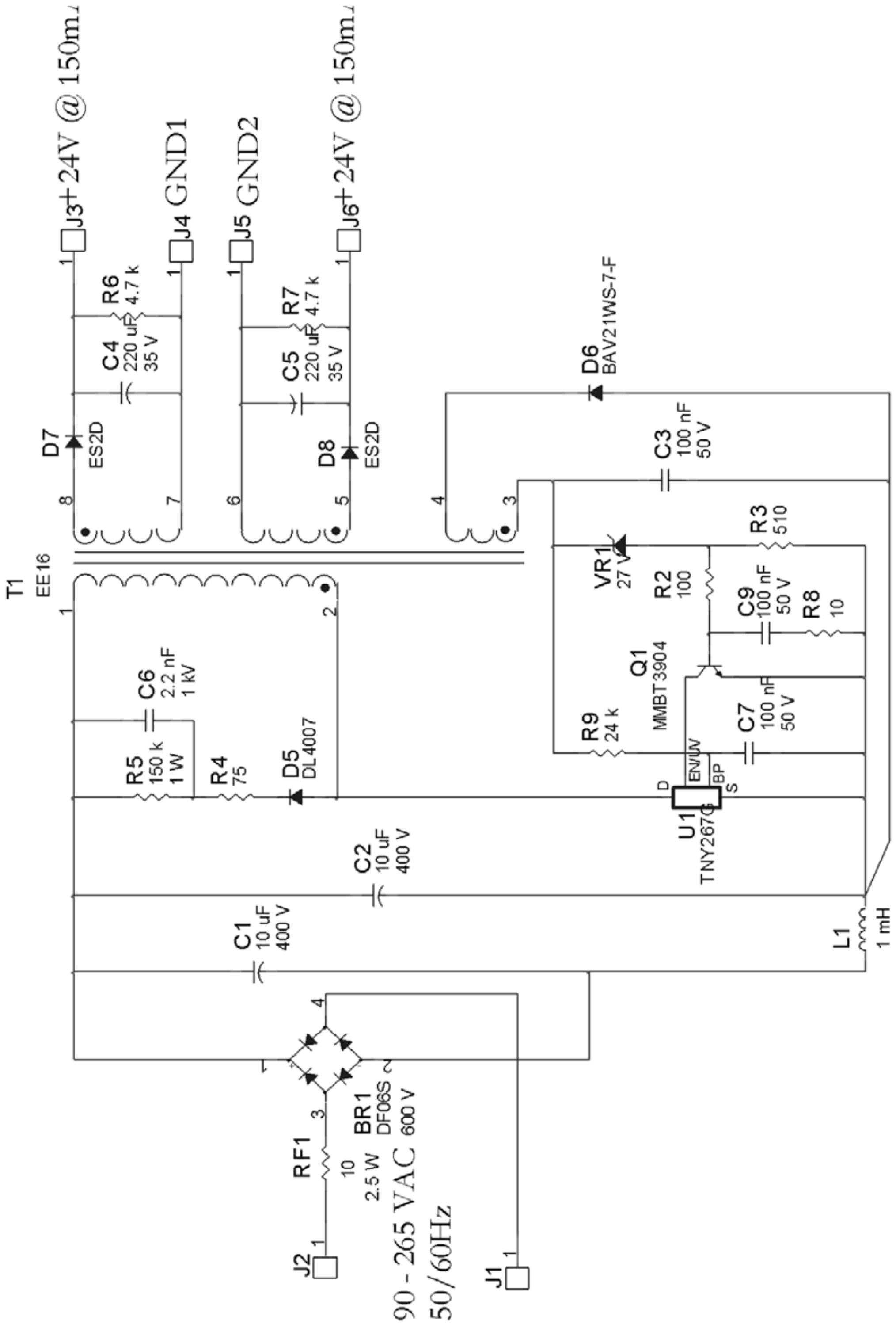

Figure 2 – Schematic

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4 PCB Layout

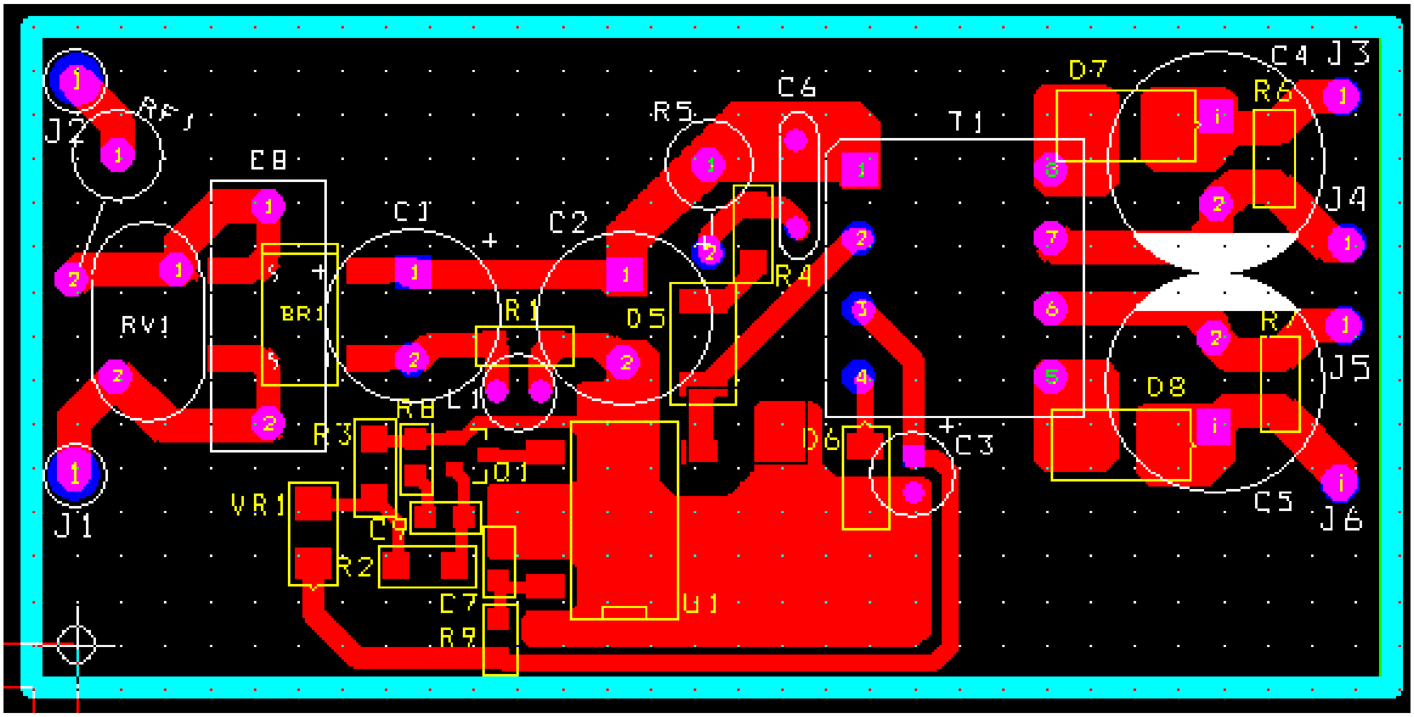

Figure 3 – Printed Circuit Layout

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5 Bill Of Materials

Item	QTY	Ref. Des.	Description	Mfg	Mfg Part Number
1	1	BR1	600 V, 1 A, Bridge Rectifier, SMD, DFS	Vishay	
2	2	C1 C2	10 uF, 400 V, Electrolytic, Low ESR, 2.9 Ohms, (10 x 20)	United Chemi-Con	KMX400VB10RM10X20L L
3	3	C3 C7 C9	100 nF, 50 V, Ceramic, X7R, 0805	Panasonic	ECU-V1H221KBN
4	2	C4 C5	220 uF, 35 V, Electrolytic, Very Low ESR, 56 mOhm, (8 x 15)	United Chemi-Con	KZE35VB221MH15LL
5	1	C6	2.2 nF, 1 kV, Disc Ceramic	NIC Components Corp	NCD222K1KVY5F
6	1	D5	1000 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)	Diodes Inc	DL4007
7	1	D6	200 V, 0.2 A, Fast Switching, 50 ns, SOD-323	Diode Inc.	BAV21WS-7-F
8	2	D7 D8	200 V, 2 A, Ultrafast Recovery, 20 ns, DO-214AA	Diodes Inc	ES2D
9	1	L1	1 mH, 0.15 A, Ferrite Core	Tokin	SBCP-47HY102B
10	1	Q1	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	Vishay	MMBT3904
11	1	R2	100 R, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF1000V
12	1	R3	510 R, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ511V
13	1	R4	75 R, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ750V
14	1	R5	150 k, 5%, 1 W, Metal Oxide	Yageo	RSF100JB-150K
15	2	R6 R7	4.7 k, 5%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8GEYJ472V
16	1	R8	10 R, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF10R0V
17	1	R9	24 k, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ243V
18	1	RF1	8.2 R, 2.5 W, Fusible/Flame Proof Wire Wound	Vitrohm	CRF253-4 5T 8R2
19	1	T1	Bobbin, EE16, Vertical, 10 pins		
20	1	U1	TinySwitch-II, TNY267G, SMD-8B	Power Integrations	TNY267G
21	1	VR1	27 V, 5%, 500 mW, DO-213AA (MELF)	Diodes Inc	ZMM5254B-7

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6 Transformer Specification

Note: Winding the bias winding after the secondary winding (using triple insulated wire) will result in better load regulation.

6.1 Electrical Diagram

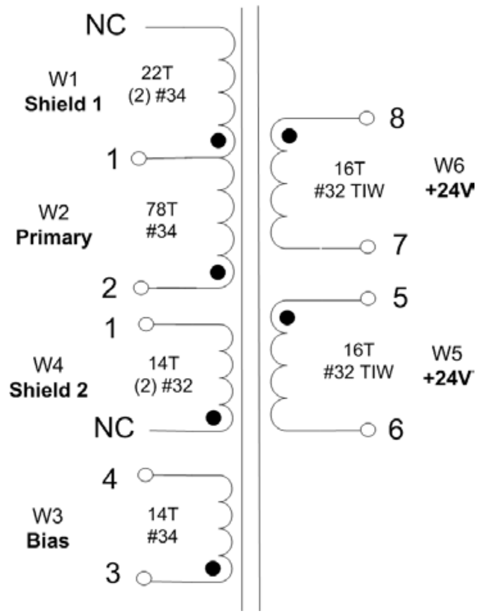

Figure 4 – Transformer Electrical Diagram

6.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pins 1-4 to Pins 5-8	3000 VAC
Primary Inductance	Pins 1-2, all other windings open, measured at 100 kHz, 0.4 VRMS	855µH, -0/+20%
Resonant Frequency	Pins 1-2, all other windings open	800 kHz (Min.)
Primary Leakage Inductance	Pins 1-2, with Pins 5-8 shorted, measured at 100 kHz, 0.4 VRMS	35 µH (Max.)

6.3 Materials

Item	Description
[1]	Core: EE16 ALG=140nH/T^2
[2]	Bobbin: 8-pin bobbin
[3]	Magnet Wire: #34 Heavy Nyleze
[4]	Magnet Wire: #32 Heavy Nyleze
[5]	Triple Insulated Wire: #30 TEX-E
[6]	Tape, 3M
[7]	Varnish

6.4 Transformer Build Diagram

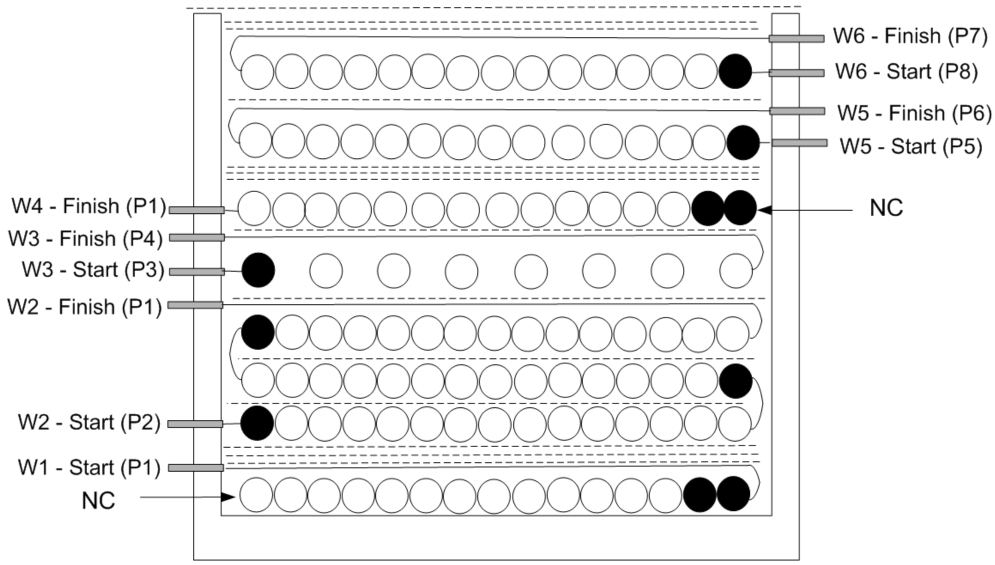

Figure 5 – Transformer Build Diagram

6.5 Transformer Construction

Shield Winding 1	Start on pin1 and wind 22 turns (x 2 filar) of item [3] in exactly 1 layer. Leave this end of cancellation shield winding not connected. Bend the end 90 deg and cut the wire in the middle of the bobbin.
Basic Insulation	Use three layers of item [6] for basic insulation.
Primary	Start at Pin 2. Wind 78 turns of item [3] in approximately 3 layers, finish on Pin1.
Basic Insulation	Use one layer of item [6] for basic insulation.
Bias Winding	Starting at Pin 3, wind 14 turns of item [3]. Spread turns evenly across bobbin. Finish at Pin 4.
Basic Insulation	Use one layer of item [6] for basic insulation.
Shield Winding 2	Start temporarily on pin 8 and wind 14 turns (x 2 filar) of item [4] in exactly 1 layer. Finish winding on pin 1, cut the beginning end wire in the middle of the bobbin.
Reinforced Insulation	Use three layers of item [6] for reinforced insulation.
Secondary Winding	Start at Pin 5. Wind 16 turns of item [5] in 1 layer. Finish on Pins 6.
Basic Insulation	Use one layer of item [6] for basic insulation.
Secondary Winding	Start at Pin 8. Wind 16 turns of item [5] in 1 layer. Finish on Pins 7.
Outer Wrap	Wrap windings with 3 layers of tape [item [6].
Final Assembly	Assemble and secure core halves. Dip varnish cores (item [7]).

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7 Transformer Spreadsheets

A	B	C	D	E	F
ACDC_TNY-II_020105; Rev.2.4; Copyright Power Integrations Inc. 2005	INPUT	INFO	OUTPUT	UNIT	ACDC_TNYII_020105_Rev2-4.xls; TinySwitch-II Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					**Customer**
VACMIN	90			Volts	
VACMAX	265			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	22			Volts	Output Voltage
PO	7.42			Watts	Output Power
n	0.7				Efficiency Estimate
Z			0.5		Loss Allocation Factor
tC			3	mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	20			uFarads	Input Filter Capacitor
ENTER TinySwitch-II VARIABLES					
TinySwitch-II	tny267			*Universal*	*115 Doubled/230V*
Chosen Device		*TNY267*	*Power Out*	*12W*	*19W*
ILIMITMIN			*0.419*	Amps	TinySwitch-II Minimum Current Limit
ILIMITMAX			*0.481*	Amps	TinySwitch-II Maximum Current Limit
fS			*132000*	Hertz	TinySwitch-II Switching Frequency
fSmin			*120000*	Hertz	TinySwitch-II Minimum Switching Frequency (inc. jitter)
fSmax			*144000*	Hertz	TinySwitch-II Maximum Switching Frequency (inc. jitter)
VOR	126			Volts	Reflected Output Voltage
VDS			10	Volts	TinySwitch-II on-state Drain to Source Voltage
VD	0.6			Volts	Output Winding Diode Forward Voltage Drop
KP			1.28		Ripple to Peak Current Ratio (0.6<KRP<1.0 : 1.0<KDP<6.0)
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	EE16				
Core		*EE16*		*P/N:*	PC40EE16-Z
Bobbin		*EE16_BOBBIN*		*P/N:*	BE-16-118CPH
AE			0.192	cm^2	Core Effective Cross Sectional Area
LE			3.5	cm	Core Effective Path Length
AL			1140	nH/T^2	Ungapped Core Effective Inductance
BW			8.5	mm	Bobbin Physical Winding Width
M	0			mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	2				Number of Primary Layers
NS	14				Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			94	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.60		Maximum Duty Cycle
IAVG			0.11	Amps	Average Primary Current
IP			0.42	Amps	Minimum Peak Primary Current
IR			0.46	Amps	Primary Ripple Current
IRMS			0.18	Amps	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			855	uHenries	Primary Inductance
NP			78		Primary Winding Number of Turns
ALG			140	nH/T^2	Gapped Core Effective Inductance
BM			2745	Gauss	Maximum Flux Density, (BP<3100)
BAC			1373	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1654		Relative Permeability of Ungapped Core
LG			0.15	mm	Gap Length (Lg > 0.1 mm)
BWE			17	mm	Effective Bobbin Width
OD			0.22	mm	Maximum Primary Wire Diameter including insulation
INS			0.04	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.17	mm	Bare conductor diameter
AWG			34	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			40	Cmils	Bare conductor effective area in circular mils
CMA			227	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS					
Lumped parameters					
ISP			2.34	Amps	Peak Secondary Current
ISRMS			0.81	Amps	Secondary RMS Current
IO			0.34	Amps	Power Supply Output Current
IRIPPLE			0.73	Amps	Output Capacitor RMS Ripple Current
CMS			162	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			28	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.32	mm	Secondary Minimum Bare Conductor Diameter
ODS			0.61	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			0.14	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN			659	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			89	Volts	Output Rectifier Maximum Peak Inverse Voltage
TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)					
1st output					
VO1	22		22	Volts	Output Voltage (if unused, defaults to single output design)
IO1	0.01		0.010	Amps	Output DC Current
PO1			0.22	Watts	Output Power
VD1			0.6	Volts	Output Diode Forward Voltage Drop
NS1			14.00		Output Winding Number of Turns
ISRMS1			0.024	Amps	Output Winding RMS Current
IRIPPLE1			0.02	Amps	Output Capacitor RMS Ripple Current
PIVS1			89	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS1			5	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS1			43	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS1			0.06	mm	Minimum Bare Conductor Diameter
ODS1			0.61	mm	Maximum Outside Diameter for Triple Insulated Wire
2nd output					

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A	B	C	D	E	F
VO2	24			Volts	Output Voltage
IO2	0.15			Amps	Output DC Current
PO2			3.60	Watts	Output Power
VD2	0.6			Volts	Output Diode Forward Voltage Drop
NS2			15.24		Output Winding Number of Turns
ISRMS2			0.359	Amps	Output Winding RMS Current
IRIPPLE2			0.33	Amps	Output Capacitor RMS Ripple Current
PIVS2			97	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS2			72	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS2			31	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS2			0.23	mm	Minimum Bare Conductor Diameter
ODS2			0.56	mm	Maximum Outside Diameter for Triple Insulated Wire
3rd output					
VO3	24			Volts	Output Voltage
IO3	0.15			Amps	Output DC Current
PO3			3.60	Watts	Output Power
VD3	0.6			Volts	Output Diode Forward Voltage Drop
NS3			15.24		Output Winding Number of Turns
ISRMS3			0.359	Amps	Output Winding RMS Current
IRIPPLE3			0.33	Amps	Output Capacitor RMS Ripple Current
PIVS3			97	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS3			72	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS3			31	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS3			0.23	mm	Minimum Bare Conductor Diameter
ODS3			0.56	mm	Maximum Outside Diameter for Triple Insulated Wire
Total power			7.42	Watts	Total Output Power
Negative Output			N/A		If negative output exists enter Output number; eg: If VO2 is negative output, enter 2

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8 Performance Data

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

8.1 Efficiency

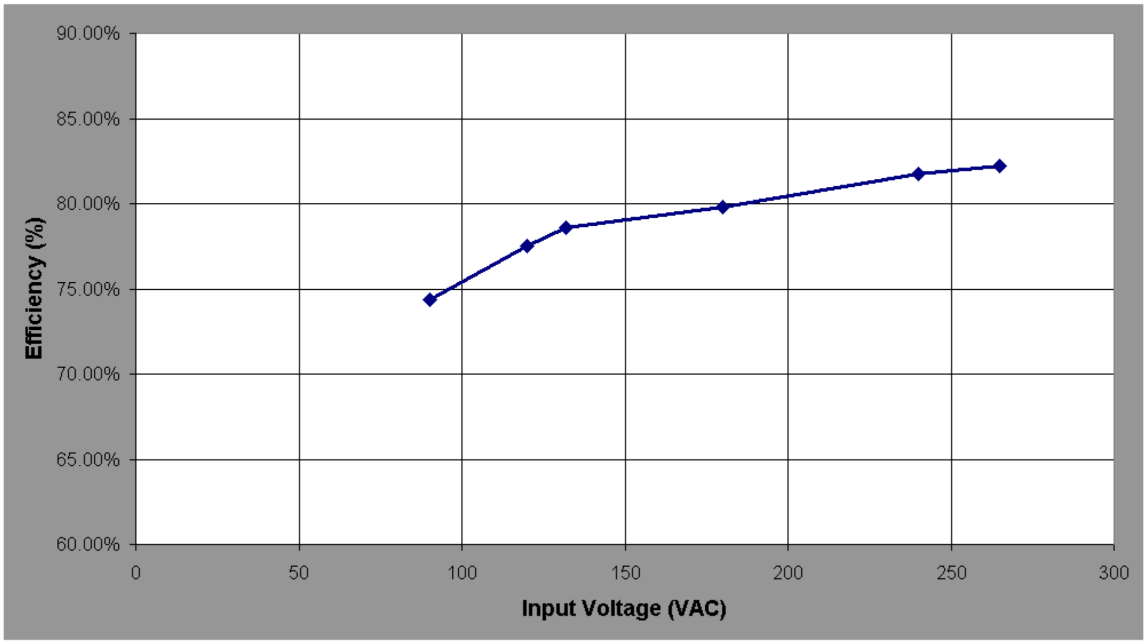

Figure 6 – Efficiency vs. Input Voltage, Room Temperature, 60 Hz.

8.2 No-load Input Power

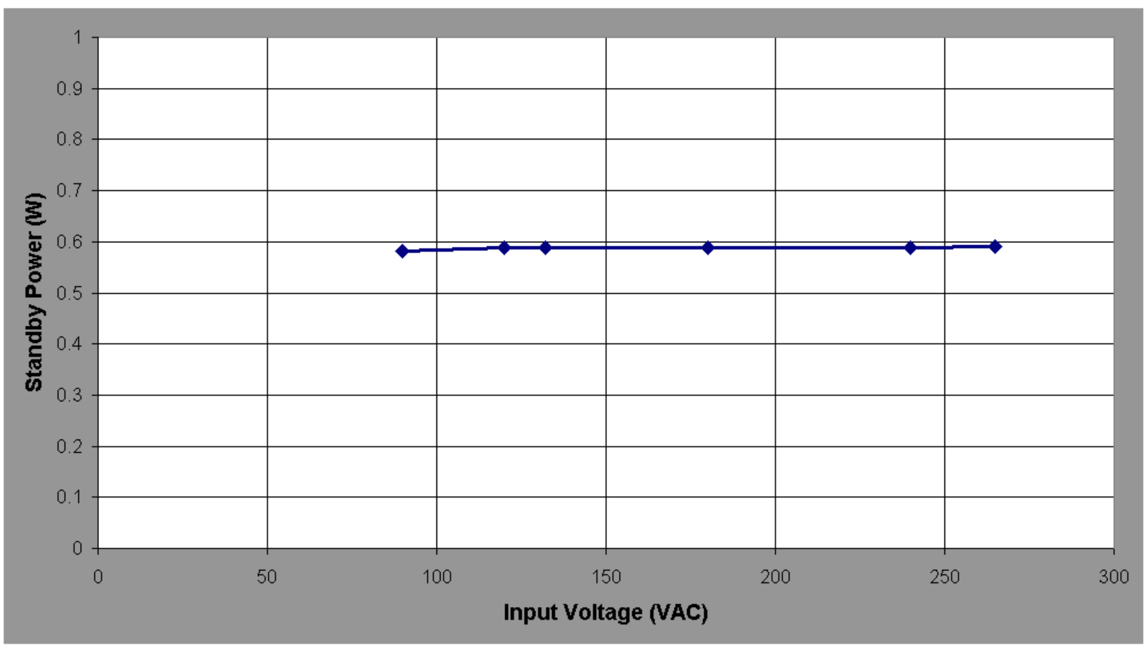

Figure 7 – Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.

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8.3 Regulation

Note: Winding the bias winding after the secondary winding (using triple insulated wire) will result in better load regulation.

Load Current	90VAC v1	90VAC v2	120VAC v1	120VAC v2	132VAC v1	132VAC v2	180VAC v1	180VAC v2	240VAC v1	240VAC v2	265VAC v1	265VAC v2
0	28.78	31.03	28.78	31.03	28.77	31.02	28.79	31.04	28.78	31.03	28.76	31.01
0.02	25.26	27.33	25.04	27.08	24.98	27.02	24.86	26.90	24.62	26.64	24.48	26.49
0.04	24.15	26.09	23.88	25.79	23.78	25.69	23.47	25.35	23.07	24.92	22.87	24.73
0.06	23.43	25.38	23.13	25.03	23.00	24.90	22.70	24.58	22.15	23.99	21.97	23.81
0.08	22.96	24.83	22.68	24.50	22.50	24.31	22.08	23.87	21.48	23.25	21.34	23.09
0.1	22.68	24.50	22.42	24.22	22.25	24.03	21.83	23.60	21.18	22.91	20.98	22.70
0.12	22.37	24.17	22.08	23.81	21.94	23.66	21.39	23.07	20.70	22.36	20.53	22.17
0.14	22.19	24.01	21.94	23.71	21.69	23.45	21.23	22.96	20.56	22.26	20.29	21.97
0.16	21.90	23.67	21.72	23.43	21.49	23.20	20.89	22.56	20.11	21.74	19.92	21.53

Figure 8 – Line/Load Regulation Data, Room Temperature

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9 Waveforms

9.1 Drain Voltage and Current, Normal Operation

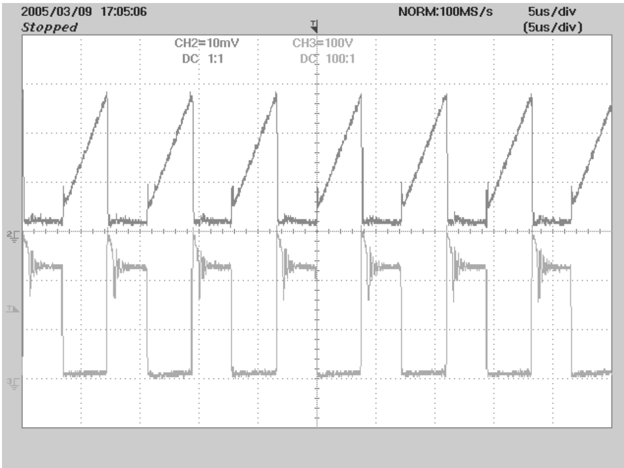

Figure 9 – 90 VAC, Full Load.
Upper: I_{DRAIN}, 0.2 A / div
Lower: V_{DRAIN}, 100 V, 5 μs / div

Figure 10 – 265 VAC, Full Load
Upper: I_{DRAIN}, 0.2 A / div
Lower: V_{DRAIN}, 200 V / div

9.2 Output Voltage Start-up Profile

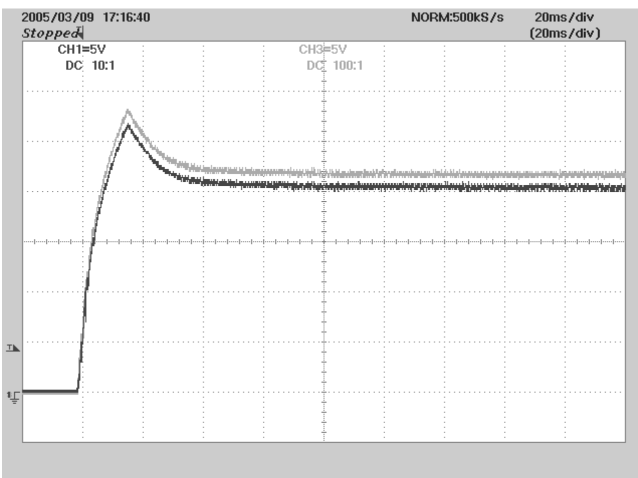

Figure 11 – Start-up Profile, 90VAC
5 V, 20 ms / div.

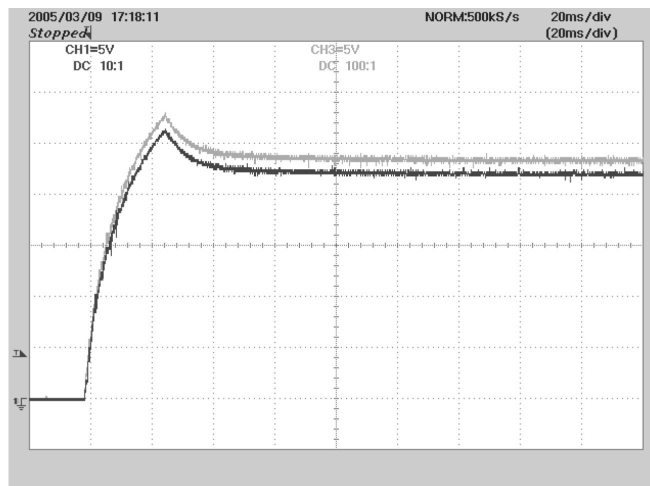

Figure 12 – Start-up Profile, 265 VAC
5 V, 20 ms / div.

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9.3 Output Ripple Measurements

9.3.1 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 13 and Figure 14.

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).***

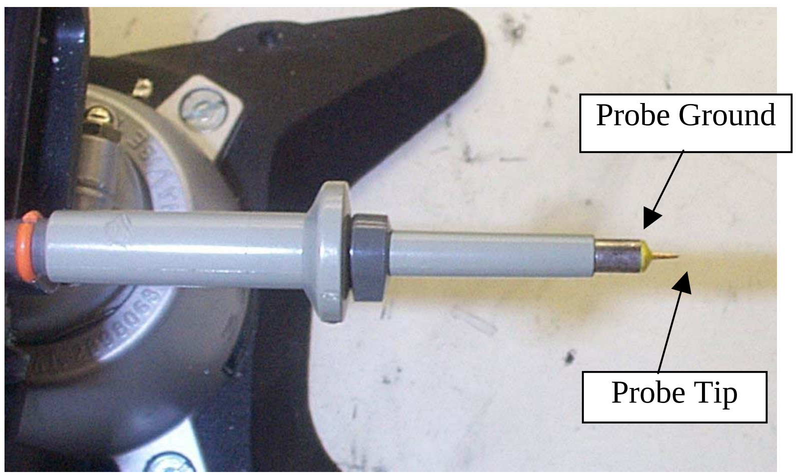

Figure 13 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

Figure 14 – 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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9.3.2 Measurement Results

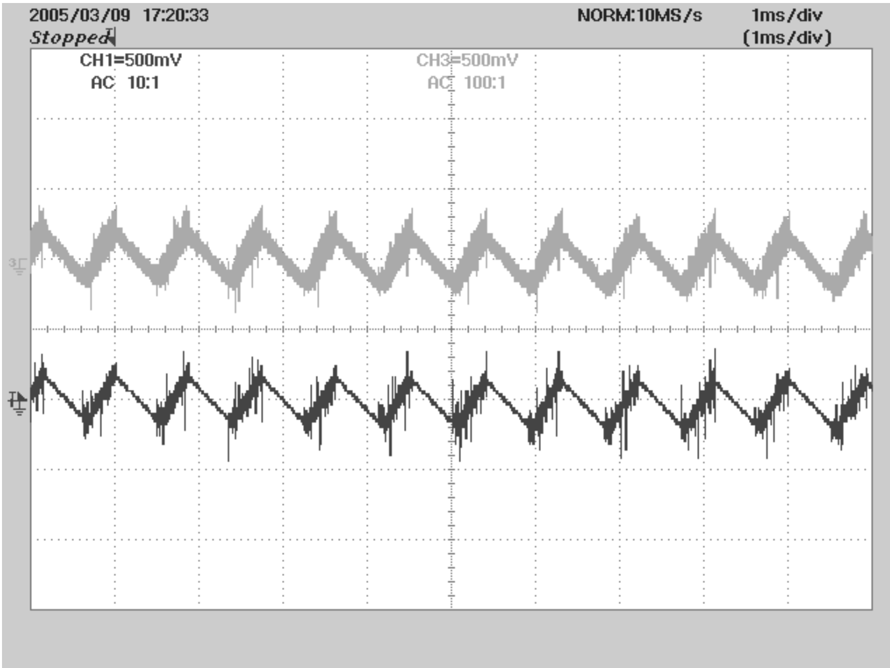

Figure 15 – Ripple, 120 VAC, Full Load.
1 ms, 500 mV / div

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10 Conducted EMI

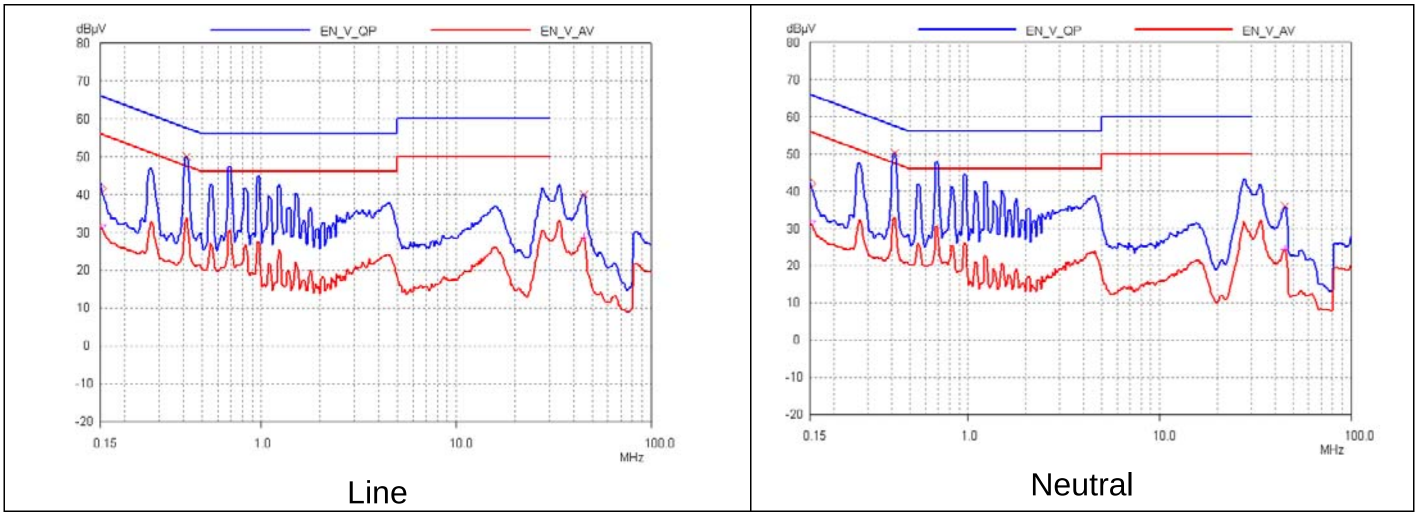

Figure 16 – Conducted EMI, Maximum Steady State Load, 120 VAC, 60 Hz, and EN55022 B Limits

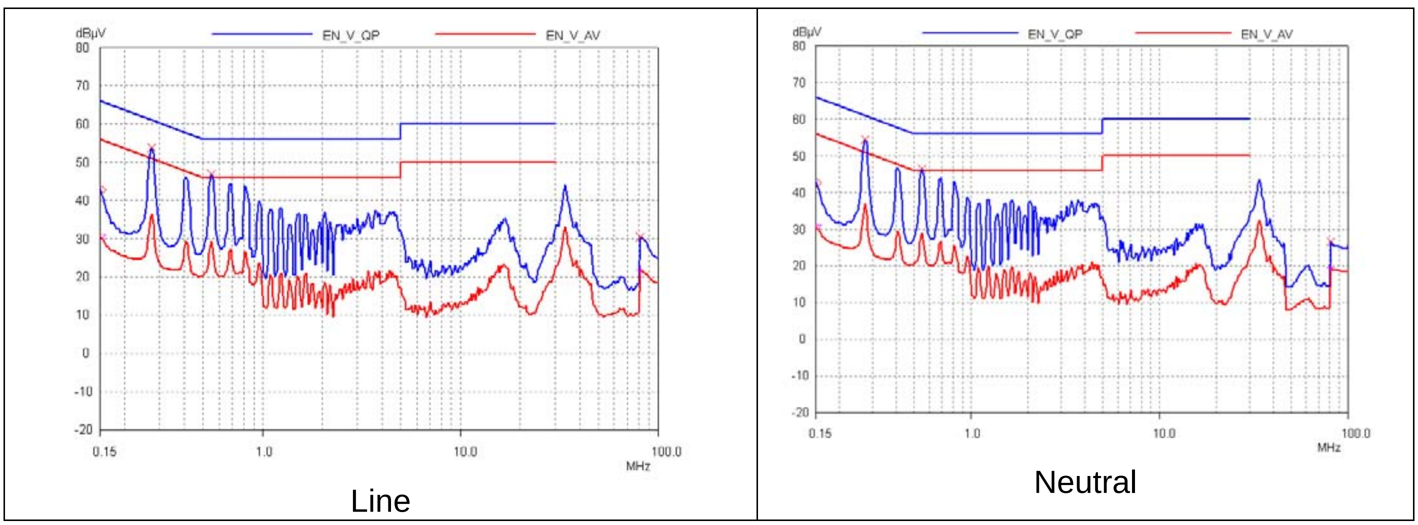

Figure 17 – Conducted EMI, Maximum Steady State Load, 240 VAC, 60 Hz, and EN55022 B Limits

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11 Revision History

Date	Author	Revision	Description & changes	Reviewed
10-26-05	RSP	1.0	Initial Release	KM/JC/VC

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