Design Example Report

Title	***100 W Refrigeration Power Supply Using TOP260EN***
Specification	102 – 265 VAC Input; 12 V, 8 A and 8 V, 0.4 A Outputs (0 to +40 °C)
Application	Appliance
Author	Applications Engineering Department
Document Number	DER-218
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Revision	1.0

Summary and Features

- Typical efficiency (>82%) using TOP260EN
- Meets Class B, EN5022 EMI requirements with 10dB margin
- Low parts count

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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.

1 Introduction

This document is an engineering report describing a power supply for an appliance refrigerator application utilizing TOP260EN (TOPSwitch®-HX family). The power supply has two outputs: 12 V, 8 A and 8 V, 0.4 A.

This document contains the power supply specification, schematic, bill of materials, transformer documentation and performance data.

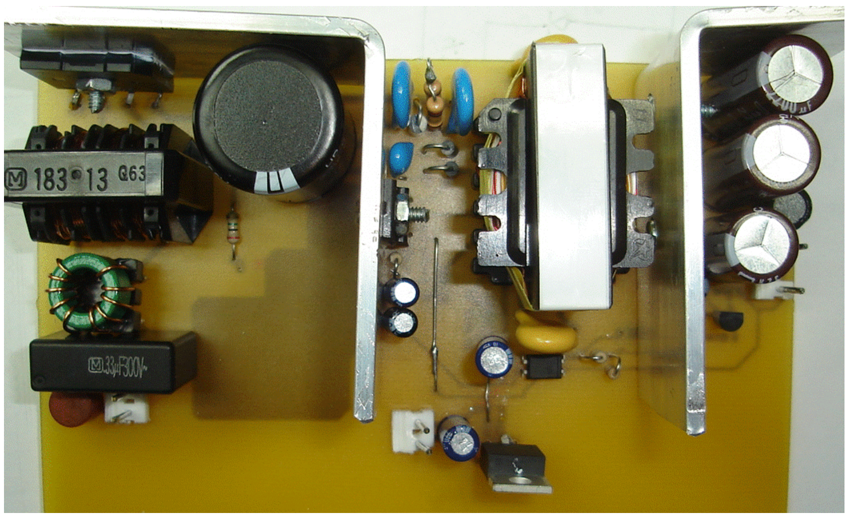

Figure 1 – Populated Circuit Board Photograph.

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2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	102		265	VAC	3 Wire system
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (265 VAC)				400	mW	
Output						
Output Voltage 1	V_{OUT1}		12		V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			500	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}	0.0		8	A	
Output Voltage 2	V_{OUT1}		8		V	± 5%
Output Ripple Voltage 2	$V_{RIPPLE1}$			500	mV	20 MHz bandwidth
Output Current 2	I_{OUT1}	0.0		0.4	A	
Total Output Power						
Continuous Output Power	P_{OUT}		100		W	
Efficiency						
Full Load	η		82		%	Measured at 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

3 Schematic

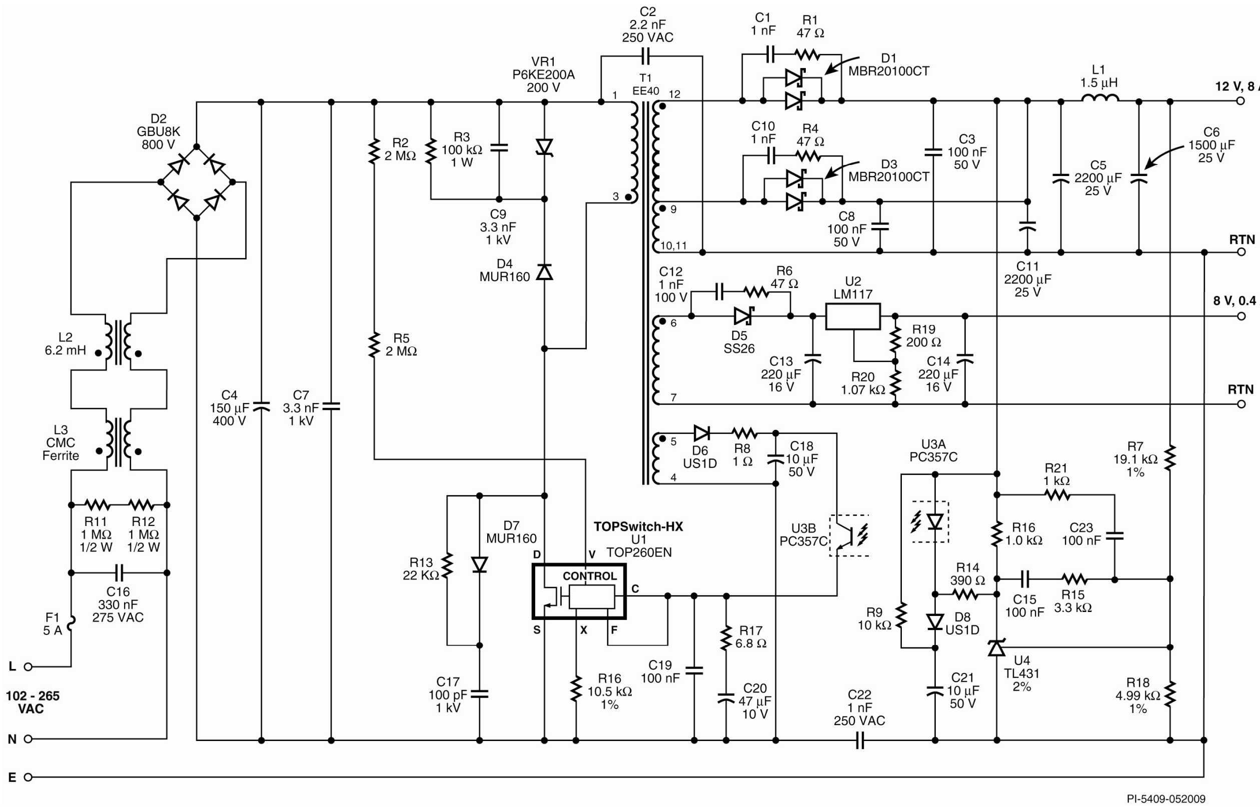

Figure 2 – Schematic.

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4 Circuit Description

This circuit is a flyback converter for an appliance application using TOP260EN. It is designed to operate from 102 VAC to 265 VAC. The power supply has two outputs, 12 V 8 A and 8 V 0.4 A, with a total power of up to 100 W. Figure 2 shows the schematic.

4.1 Input stage and EMI Filtering

Fuse F1 protects the power supply against circuit faults such as short circuits. The bridge rectifier D2 rectifies the AC voltage into DC voltage. Capacitor C4 acts as a filtering capacitor for the AC rectified waveform and also as the energy storage element for the power supply.

The Common mode chokes L2, L3 and X-capacitor C16 are placed before the bridge rectifier to attenuate common mode noise for conducted as well as radiated EMI. The EMI filter components together with the built in frequency jitter of TOPSwitch-HX help the power supply meet EMI requirements. Resistors R11, R12 discharge the X-capacitor within one second after input AC is turned off to prevent shock hazard. Capacitor C7 is a bypass capacitor which reduces the input voltage loop size.

4.2 TOPSwitch-HX Primary

The clamp snubber circuit consists of D4, R3, VR1, and C9. During turn off of the primary switching MOSFET, the energy stored in the leakage inductance of the primary winding of the transformer creates a voltage spike whose voltage level can exceed the breakdown voltage (V_{DSS}) of the MOSFET. During turn off, diode D5 conducts and TVS (Transient Voltage Suppressor) VR1 prevents the voltage across the primary winding from rising above its rated value (200 V in this case).

The rate-of-rise snubber consists of D7, R13, and C17. During turn-off of the MOSFET, the leakage energy is dumped into the capacitor C17 through D7 and limits dv/dt of the drain waveform, reducing EMI. The capacitor discharges through R13 at turn-on.

4.3 Output Rectification

There are two outputs for this design.

The 12 V output uses two windings paralleled together with Schottky diodes to increase efficiency. RC snubbers (R1-C1 and R4-C10) on D1 and D3 provide filtering of the voltage spike during turn-off of the diodes due to the reverse recovery characteristics and output leakage inductance which are responsible for significant EMI. Additional factors such as diode capacitance and trace inductance that affect the turn-off characteristic are also controlled by this snubber. The post LC filters (L1-C6) at the output reduce ripple.
The 8 V output is a non isolated floating output. It is considered to be on the primary side despite having a separate return. Regular magnet wire can be used to construct this output, rather than triple insulated wire. This output is rectified by diode D5 and is connected to a Low Drop Out (LDO) adjustable linear regulator. Regulator IC U2 is

adjusted by voltage divider formed by R19 and R20. Capacitors C13 and C14 act as output filtering capacitors. This output is designed such that the input voltage to U2 is close to 9 V when both outputs are at full load, reducing the power dissipation in the linear regulator.

4.4 Output Feedback

The main output is regulated using a TL431 circuit to maintain 5% regulation. The TL431 pulls the current through the photodiode of U3 when the voltage on the reference pin set by the voltage divider (R7 and R18) goes higher than 2.5 V. Device U1 feeds current into the CONTROL pin and reduces the duty cycle. An additional soft-finish circuit has also been implemented using C21, R9, and D8. During startup, C21 charges via U3 providing feedback prior to the output reaching regulation. This both extends the allowable time for output to reach regulation (soft-start) and prevents output overshoot. Resistor R9 discharges the soft-finish capacitor during turn off. Capacitor C15 and R15 are responsible for providing loop compensation. To improve the transient response, phase margin and the cross over frequency, additional compensation components R21 and C23 are used.

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5 PCB Layout

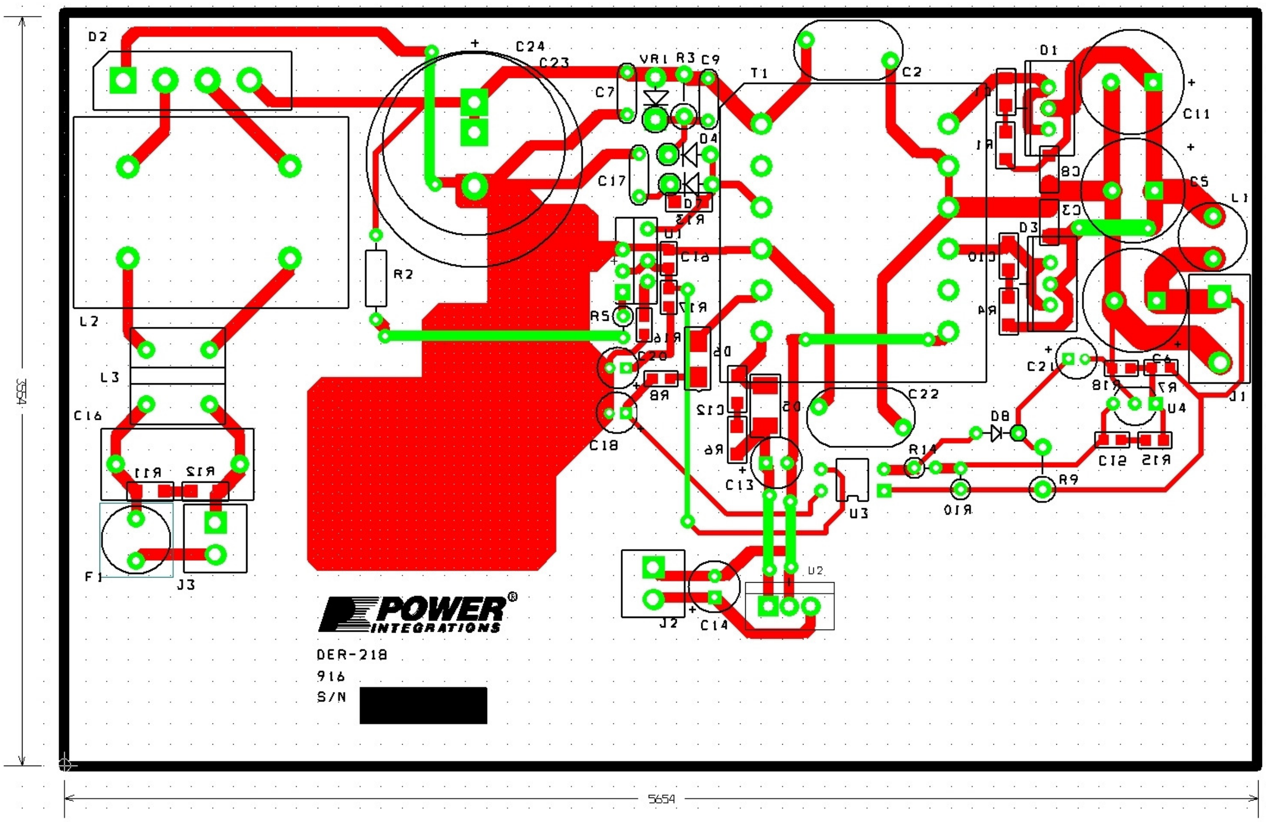

Figure 3 – PCB Layout.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	3	C1 C10 C12	1 nF, 100 V, Ceramic, X7R, 1206	Panasonic	
2	1	C2	2.2 nF, Ceramic, Y1	Vishay	440LD22-R
3	2	C3 C8	100 nF, 50 V, Ceramic, X7R, 1206	Panasonic	ECJ-3VB1H104K
4	1	C4	150 µF, 400 V, Electrolytic, Low ESR	Nippon Chemi-Con	EKMX401ELL151ML60S
5	2	C5 C11	2200 µF, 25 V, Electrolytic, Very Low ESR	Nippon Chemi-Con	EKZE250ELL222MK35S
6	1	C6	1500 µF, 25 V, Electrolytic, Very Low ESR	Nippon Chemi-Con	EKZE250ELL
7	2	C7 C9	3.3 nF, 1 kV, Disc Ceramic	NIC Components Corp	NCD332M1KVZ5U
8	2	C13 C14	220 µF, 16 V, Electrolytic, Low ESR	Nippon Chemi-Con	ELXZ160ELL221MF15D
9	3	C15 C19 C23	100 nF, 50 V, Ceramic, X7R, 0805	Panasonic	ECJ-2YB1H104K
10	1	C16	220 nF, 275 VAC, Film, X2	Panasonic	ECQ-U2A224ML
11	1	C17	100 pF, 1 kV, Disc Ceramic	Panasonic - ECG	ECC-D3A101JGE
12	1	C18	10 µF, 50 V, Electrolytic, Gen. Purpose, (5 x 11)	Nippon Chemi-Con	EKMG500ELL100ME11D
13	1	C20	47 µF, 10 V, Electrolytic, Gen. Purpose, (5 x 11)	Nippon Chemi-Con	KME10VB22RM5X11LL
14	1	C21	10 µF, 50 V, Electrolytic, Gen. Purpose, (5 x 11)	Nippon Chemi-Con	KME50VB10RM5X11LL
15	1	C22	1 nF, Ceramic, Y1	Vishay	440LD10-R
16	2	D1 D3	100 V, 20 A, Dual Schotkky, TO-220AB	Vishay	MBR20100CT
17	1	D2	800 V, 8 A, Bridge Rectifier, Glass Passivated	Rectron Semiconductor	GBU8K
18	2	D4 D7	800 V, 1 A, Ultrafast Recovery, 75 ns, DO-41	Vishay	MUR160
19	1	D5	60 V, 2 A, Schottky, SMD	Vishay	SS26
20	1	D6	DIODE ULTRA FAST, SW, 200 V, 1A, SMA	Diodes, Inc	US1D-13-F
21	1	D8	100 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	Vishay	UF4002-E3
22	1	F1	5 A, 250V, Slow, TR5	Wickman	3721500041
23	1	L1	1.5 µH, 8.5 A, 9 x 12 mm	JW MIller	6000-1R5M
24	1	L2	6.2 mH, 2.2 A, Common Mode Choke	Panasonic	ELF20N022A
25	1	L3	CMC, Ferrrite	Elytone	
26	3	R1 R4 R6	47 Ω, 5%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8GEYJ470V
27	2	R2 R5	2 MΩ, 5%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8GEYJ205V
28	1	R3	100 kΩ, 5%, 1 W, Metal Oxide	Yageo	RSF100JB-100K
29	1	R7	19.1 kΩ, 1%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6ENF1912V
30	1	R8	1 Ω, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ1R0V
31	1	R9	10 kΩ, 5%, 1/4 W, Carbon Film	Yageo	CFR-25JB-10K
32	2	R10,21	1 kΩ, 5%, 1/4 W, Carbon Film	Yageo	CFR-25JB-1K0
33	2	R11 R12	1 MΩ, 5%, 1/2 W, Carbon Film	Yageo	CFR-50JB-1M0
34	1	R13	22 kΩ, 5%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8GEYJ223V

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35	1	R14	390 Ω, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ391V
36	1	R15	3.3 kΩ, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ332V
37	1	R16	10.5 kΩ, 1%, 1/4 W, Metal Film	Yageo	MFR-25FBF-10K5
38	1	R17	6.8 Ω, 5%, 1/8 W, Metal Film, 0805	Panasonic	ERJ-6GEYJ6R8V
39	1	R18	4.99 kΩ, 1%, 1/4 W, Metal Film, 1206	Panasonic	ERJ-8ENF4991V
40	1	R19	Resistor, 200 Ω SMD 0805	Panasonic	
41	1	R20	Resistor, 1.07 kΩ SMD 0805	Yageo	RC0805FR-07200RL
42	1	T1	Bobbin, EE40, Vertical, 12 pins		
43	1	U1	TOPSwitch-HX, TNY260EN, eSIP-7C	Power Integrations	TOP260EN
44	1	U2	I.C. Linear regulator, Adjustable TO-220, LDO	National	LM117
45	1	U3	Optocoupler, 35 V, CTR 300-600%, 4-DIP	Sharp	PC817X4
46	1	U4	2.495 V Shunt Regulator IC, 2%, 0 to 70C, TO-92	On Semiconductor	TL431CLPG
47	1	VR1	200 V, TVS	On Semiconductor	1.5KE200A

7 Transformer Specification

7.1 Electrical Diagram

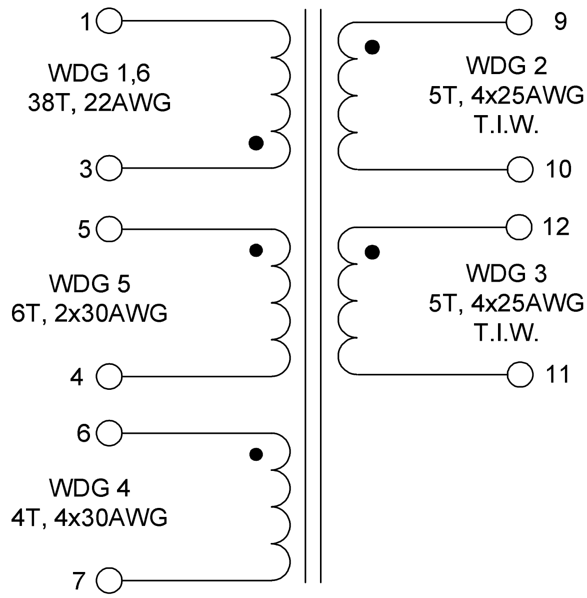

Figure 4 – Transformer Electrical Diagram.

7.2 Electrical Specification

Electrical Strength	60 Hz 1 second, from pins 1-6 to pins 7-12	3000 VAC
Primary Inductance	Pins 1 to pin 3, all other windings open, measured at 100 kHz, 1 VRMS	340 µH, ±10%
Resonant Frequency	All windings open.	850 kHz (Min.)
Primary Leakage Inductance	Pin 1 to pin 3, all other pins shorted.	5 µH (Max.)

7.3 Materials

Item	Description
[1]	3 mm margin tape
[2]	3M Barrier Tape: polyester film
[3]	Core: 1 Pair EE40 TDK PC44 or equivalent
[4]	Bobbin: 12 pin EE40, vertical
[5]	Magnet Wire: #22 AWG double coated
[6]	Magnet Wire: #30 AWG double coated
[7]	Triple Insulated Wire: #25 AWG
[8]	Copper foil
[9]	Varnish

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7.4 Transformer Build Diagram

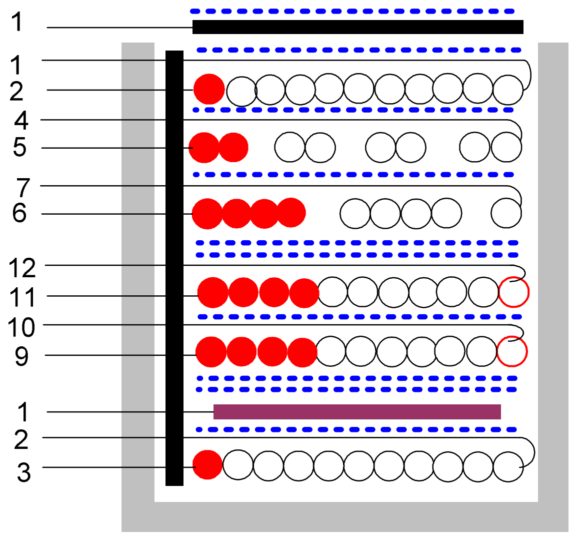

Figure 5 – Transformer Build Diagram.

7.5 Transformer Construction

Margin tape	Wind 3 mm margin on bottom side close to pins.
Primary Winding	Start from left to right from Pin 3. Wind 19 turns of 22 AWG wire on one layer. Terminate at pin 2.
Insulation	Place one layer of tape.
Shield	Place one layer of copper foil for shield. Terminate at pin 1.
Insulation	Use two layers of tape.
Secondary Winding	Start from left to right from pin 9 and wind 5 turns of 4x25 AWG Triple-Insulated Wire on one layer. Terminate on pin 10.
Insulation	Use one layer of tape.
Secondary Winding	Start from left to right from pin 11 and wind 5 turns of 4x25 AWG Triple-Insulated Wire on one layer. Terminate on pin 12.
Insulation	Use two layers of tape.
Output winding	Start from left to right from pin 6 and wind 4 turns of 4x30 AWG wire on one layer. Terminate on pin 7.
Insulation	Use one layer of tape.
Bias Winding	Start from left to right from Pin 5. Wind 6 turns (spread evenly) of 2x30 AWG wire on one layer. Terminate on pin 4.
Insulation	Place one layer of tape.
Primary Winding	Start from left to right from Pin 2. Wind 19 turns of 22 AWG wire on one layer. Terminate at pin 1.
Insulation	Place one layer of tape.
Assembly	Assembly and secure core halves.
Flux band	Place one turn of shorted copper foil touching the core and terminate to pin 1.
Final Assembly	Dip varnish – DO NOT VACUUM IMPREGNATE

8 Transformer Design Spreadsheet

ACDC_TOPSwitchHX_021308; Rev.1.8; Copyright Power Integrations 2008	INPUT	INFO	OUTPUT	UNIT	TOPSwitch-HX Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
VACMIN	102			Volts	Minimum AC Input Voltage
VACMAX	265			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	12.00			Volts	Output Voltage (main)
PO_AVG	100.00			Watts	Average Output Power
PO_PEAK			100.00	Watts	Peak Output Power
n	0.80			%/100	Efficiency Estimate
Z	0.50				Loss Allocation Factor
VB	15			Volts	Bias Voltage
tC	3.00			mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	150.0		150	uFarads	Input Filter Capacitor
ENTER TOPSWITCH-HX VARIABLES					
TOPSwitch-HX	**TOP260EN**			Universal / Peak	115 Doubled/230V
Chosen Device		*TOP260 EN*	Power Out	200 W / 200 W	275W
KI	0.71				External Ilimit reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT)
ILIMITMIN_EXT			3.962	Amps	Use 1% resistor in setting external ILIMIT
ILIMITMAX_EXT			4.558	Amps	Use 1% resistor in setting external ILIMIT
Frequency (F)=132kHz, (H)=66kHz	**H**		H		Select 'H' for Half frequency - 66kHz, or 'F' for Full frequency - 132kHz
fS			66000	Hertz	TOPSwitch-HX Switching Frequency: Choose between 132 kHz and 66 kHz
fSmin			59400	Hertz	TOPSwitch-HX Minimum Switching Frequency
fSmax			72600	Hertz	TOPSwitch-HX Maximum Switching Frequency
High Line Operating Mode			FF		Full Frequency, Jitter enabled
VOR	95.00			Volts	Reflected Output Voltage
VDS			10	Volts	TOPSwitch on-state Drain to Source Voltage
VD	0.50			Volts	Output Winding Diode Forward Voltage Drop
VDB	0.70			Volts	Bias Winding Diode Forward Voltage Drop
KP	0.60				Ripple to Peak Current Ratio (0.3 < KRP < 1.0 : 1.0< KDP<6.0)
PROTECTION FEATURES					
LINE SENSING					
VUV_STARTUP			114	Volts	Minimum DC Bus Voltage at which the power supply will start-up
VOV_SHUTDOWN			535	Volts	Typical DC Bus Voltage at which power supply will shut-down (Max)
RLS			4.8	M-ohms	Use two standard, 2.4 M-Ohm, 5% resistors in series for line sense functionality.
OUTPUT OVERVOLTAGE					
VZ			27	Volts	Zener Diode rated voltage for Output Overvoltage shutdown protection
RZ			5.1	k-ohms	Output OVP resistor. For latching shutdown use 20 ohm resistor instead
OVERLOAD POWER LIMITING					
Overload Current Ratio at VMAX			1.2		Enter the desired margin to current limit at VMAX. A value of 1.2 indicates that the current limit should be 20%

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					higher than peak primary current at VMAX
Overload Current Ratio at VMIN			1.06		Margin to current limit at low line.
ILIMIT_EXT_VMIN			3.55	A	Peak primary Current at VMIN
ILIMIT_EXT_VMAX			3.61	A	Peak Primary Current at VMAX
RIL			8.92	k-ohms	Current limit/Power Limiting resistor.
RPL			N/A	M-ohms	Resistor not required. Use RIL resistor only
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	EI40		EI40		Core Type
Core		*EI40*		*P/N:*	PC40EI40-Z
Bobbin		*EI40_BOBBIN*		*P/N:*	BE-40-1112CPN
AE			1.48	cm^2	Core Effective Cross Sectional Area
LE			7.7	cm	Core Effective Path Length
AL			4860	nH/T^2	Ungapped Core Effective Inductance
BW			17.3	mm	Bobbin Physical Winding Width
M	1.50			mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	2.00				Number of Primary Layers
NS	5		5		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			96	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.53		Maximum Duty Cycle (calculated at PO_PEAK)
IAVG			1.31	Amps	Average Primary Current (calculated at average output power)
IP			3.55	Amps	Peak Primary Current (calculated at Peak output power)
IR			2.13	Amps	Primary Ripple Current (calculated at average output power)
IRMS			1.86	Amps	Primary RMS Current (calculated at average output power)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			340	uHenries	Primary Inductance
LP Tolerance			10		Tolerance of Primary Inductance
NP			38		Primary Winding Number of Turns
NB			6		Bias Winding Number of Turns
ALG			236	nH/T^2	Gapped Core Effective Inductance
BM			2148	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP			3034	Gauss	Peak Flux Density (BP<4200) at ILIMITMAX and LP_MAX. Note: Recommended values for adapters and external power supplies <=3600 Gauss
BAC			645	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			2012		Relative Permeability of Ungapped Core
LG			0.75	mm	Gap Length (Lg > 0.1 mm)
BWE			28.6	mm	Effective Bobbin Width
OD			0.75	mm	Maximum Primary Wire Diameter including insulation
INS			0.08	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.68	mm	Bare conductor diameter
AWG			22	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			645	Cmils	Bare conductor effective area in circular mils
CMA			347	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)

Primary Current Density (J)			5.72	Amps/mm^2	Primary Winding Current density (3.8 < J < 9.75)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			26.99	Amps	Peak Secondary Current
ISRMS			13.40	Amps	Secondary RMS Current
IO_PEAK			8.33	Amps	Secondary Peak Output Current
IO			8.33	Amps	Average Power Supply Output Current
IRIPPLE			10.49	Amps	Output Capacitor RMS Ripple Current
CMS			2680	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			15	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			1.45	mm	Secondary Minimum Bare Conductor Diameter
ODS			2.86	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			0.70	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN			566	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			61	Volts	Output Rectifier Maximum Peak Inverse Voltage
PIVB			77	Volts	Bias Rectifier Maximum Peak Inverse Voltage
TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)					
1st output					
VO1	12.00		12	Volts	Output Voltage
IO1_AVG	8.00		8.00	Amps	Average DC Output Current
PO1_AVG			96.00	Watts	Average Output Power
VD1	0.80		0.8	Volts	Output Diode Forward Voltage Drop
NS1			5.12		Output Winding Number of Turns
ISRMS1			12.862	Amps	Output Winding RMS Current
IRIPPLE1			10.07	Amps	Output Capacitor RMS Ripple Current
PIVS1			62	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS1			2572	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS1			16	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS1			1.29	mm	Minimum Bare Conductor Diameter
ODS1			2.79	mm	Maximum Outside Diameter for Triple Insulated Wire
2nd output					
VO2	9.00			Volts	Output Voltage
IO2_AVG	0.40			Amps	Average DC Output Current
PO2_AVG			3.60	Watts	Average Output Power
VD2	0.40		0.4	Volts	Output Diode Forward Voltage Drop
NS2			3.76		Output Winding Number of Turns
ISRMS2			0.643	Amps	Output Winding RMS Current
IRIPPLE2			0.50	Amps	Output Capacitor RMS Ripple Current
PIVS2			46	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS2			129	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS2			28	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS2			0.32	mm	Minimum Bare Conductor Diameter
ODS2			3.80	mm	Maximum Outside Diameter for Triple Insulated Wire
Total Continuous Output Power			99.6	Watts	Total Continuous Output Power

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9 Performance Data

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

9.1 Efficiency

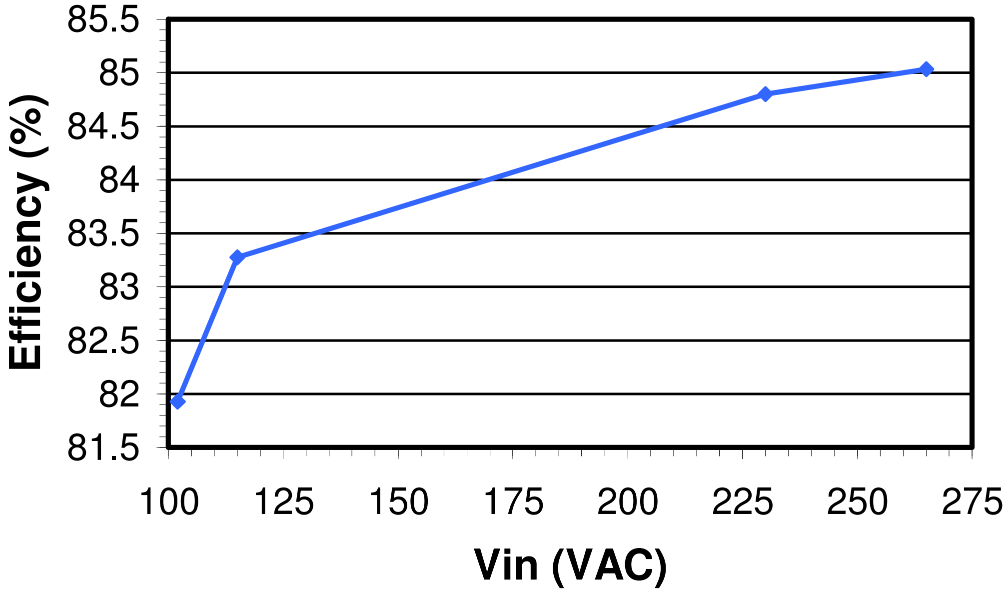

Figure 6 – Full Load Efficiency vs. Input Voltage.

9.2 No-load Input Power

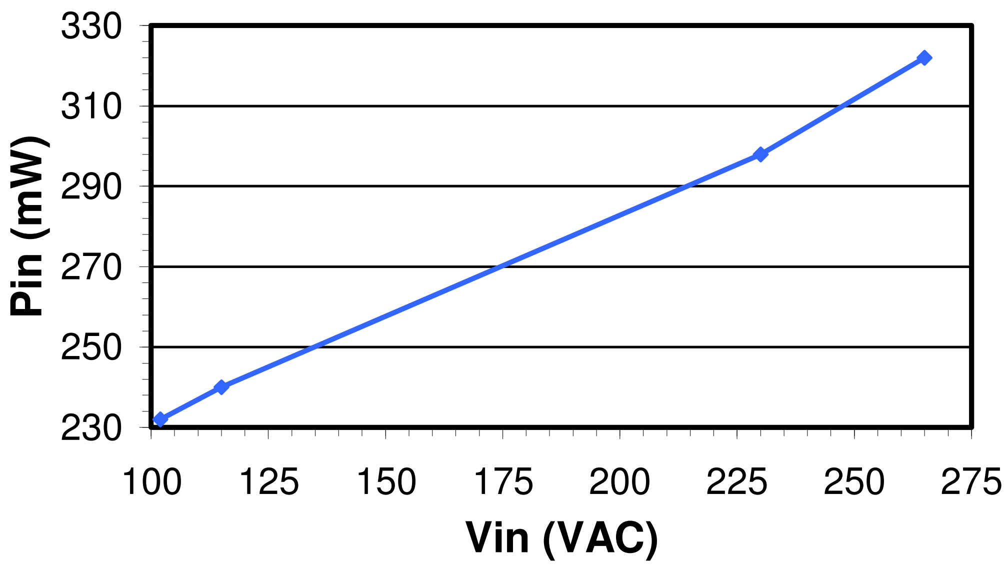

Figure 7 – Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.

10 Thermal Performance

Thermal tests were conducted at worst case condition of 102 VAC with rated load on the output.

Component	Measured at 25 ºC	Calculated for 40 ºC
CMC (L2)	82	97
Bridge rectifier	75	90
Bulk capacitor	46	61
TVS Zener	85	100
Snubber clamp diode	81	96
Snubber dv/dt diode	78	93
TOP260EN	89.5	104.5
Transformer	82.2	97.2
Output diode (12 V)	95	110
Output capacitor (12 V)	77	92
Output diode (8 V)	55	70
Output capacitor (8 V)	40	55
CMC (L3)	42	57
Linear regulator (with heatsink)	60	75

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11 Waveforms

11.1 Drain Voltage at 265 VAC Full Load

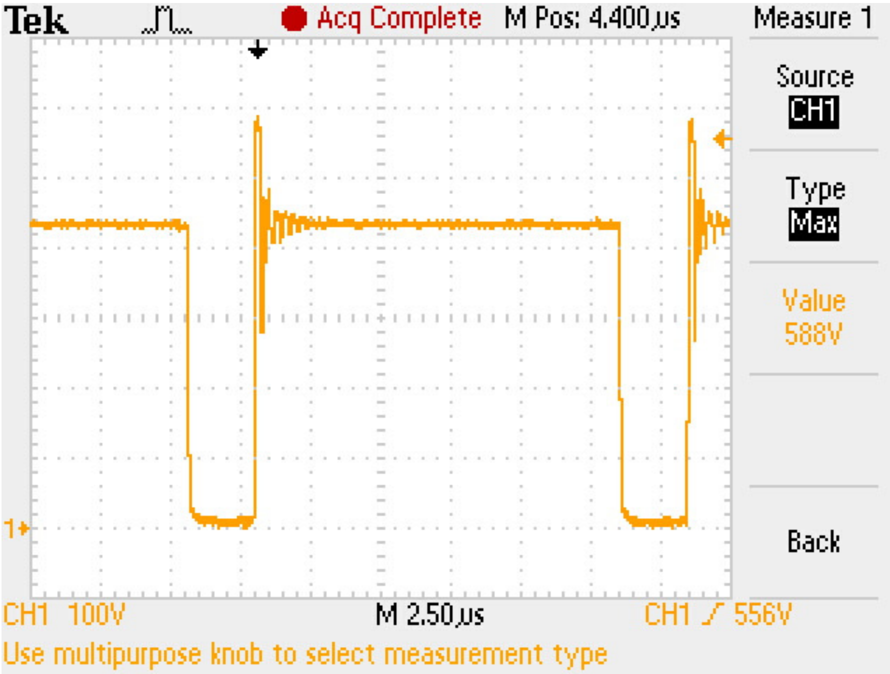

Figure 8 – 265 VAC. V_{DRAIN}, 100 V / div, 2.5 µs / div.

11.2 Output Voltage Start-up Profile at Zero Load

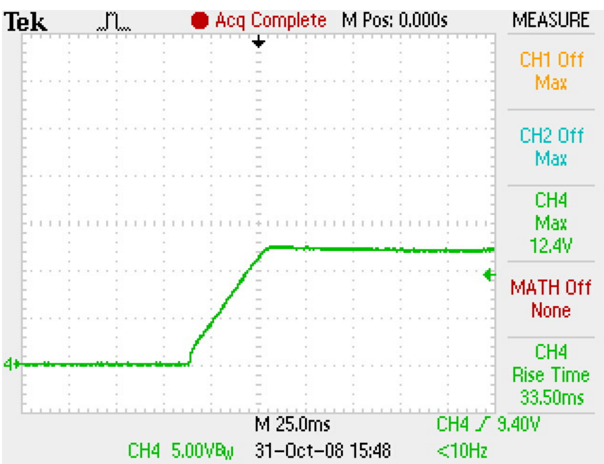

Figure 9 – Start-up Profile. No load: 102 VAC, 5 V / div, 10 ms / div.

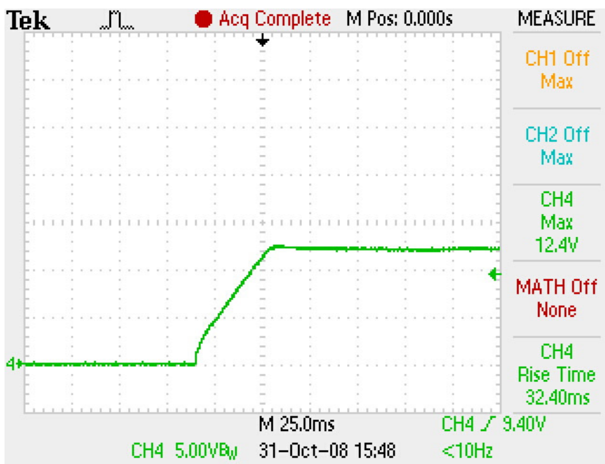

Figure 10 – Start-up Profile. No load: 265 VAC, 5 V / div, 10 ms / div.

11.3 Output Voltage Start-up Profile at Full Load

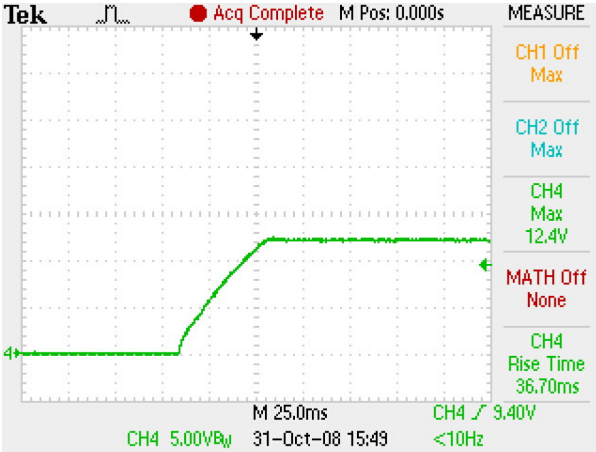

Figure 11 – Start-up Profile. Full load: 102 VAC, 5 V / div, 10 ms / div.

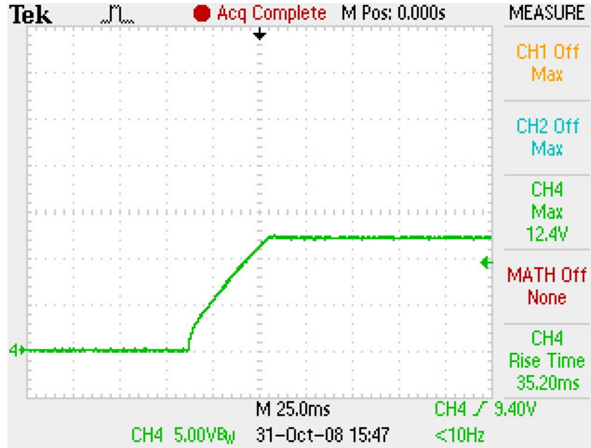

Figure 12 – Start-up Profile. Full load: 265 VAC, 5 V / div, 10 ms / div.

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11.4 Output Ripple Measurements

11.4.1 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 the figures below.

The 4987BA 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).

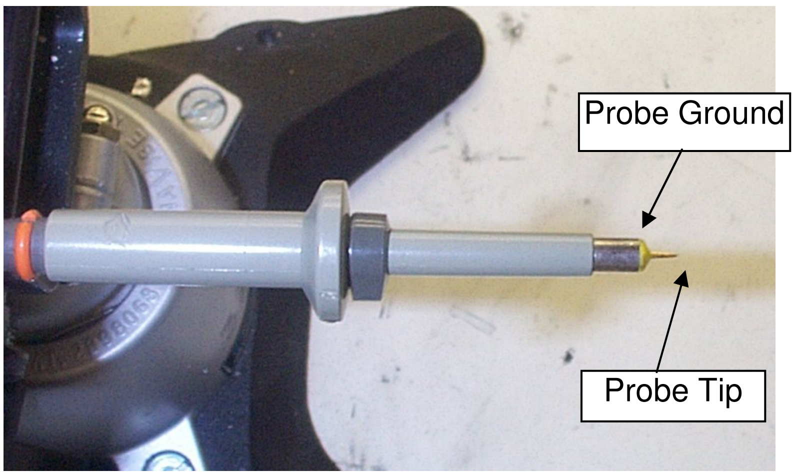

Figure 13 – Oscilloscope Probe Prepared for Ripple Measurement. (End cap and ground lead removed)

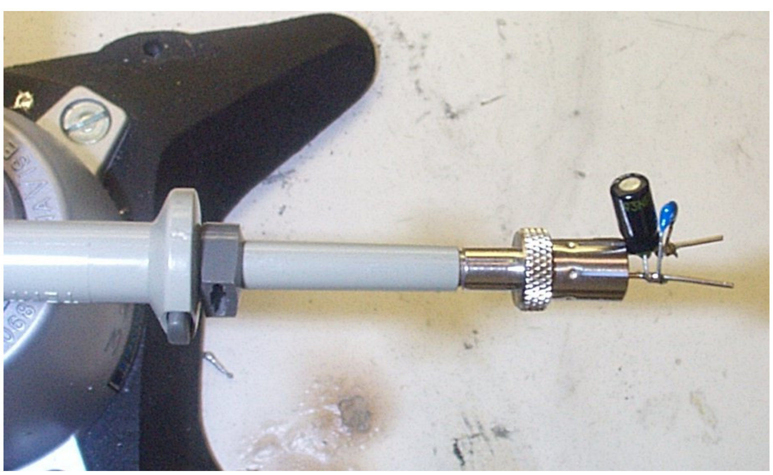

Figure 14 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

11.4.1 Measurement Results

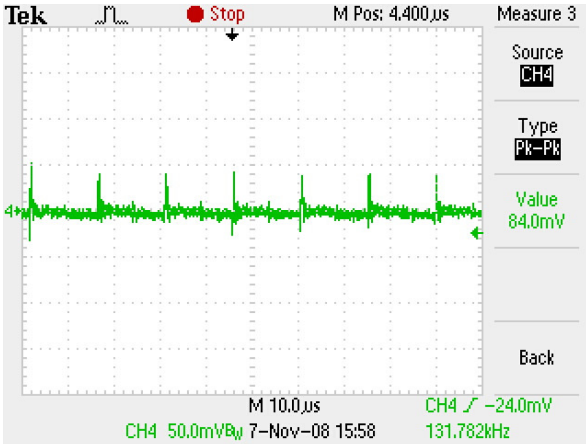

Figure 15 – 12 V Ripple, 102 VAC at Full Load. 50 mV / div, 10 µs / div.

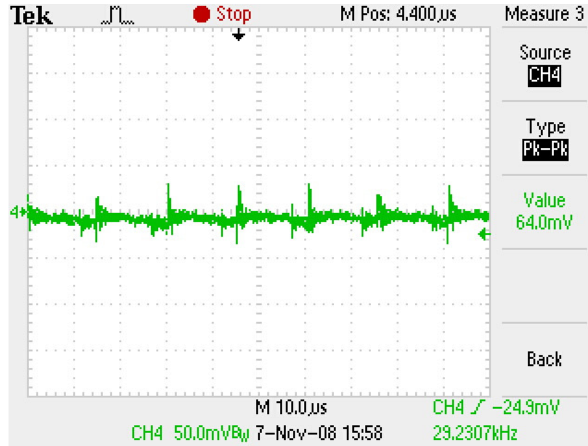

Figure 16 – 12 V Ripple, 265 VAC at Full Load. 50 mV / div, 10 µs / div.

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12 Control Loop Measurements

12.1 Low Line (115 VDC)

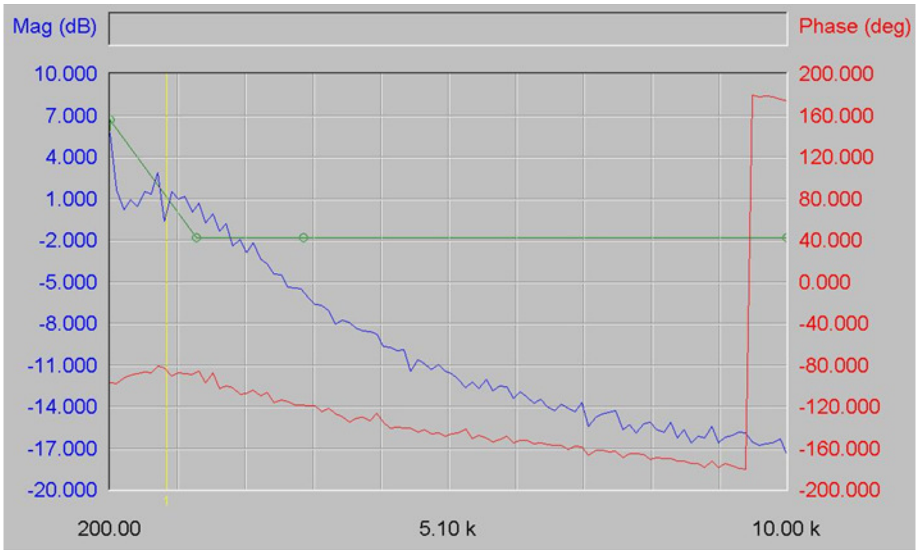

Figure 17 – Gain Phase Plot, 115 VDC, Full load. Cross Over Frequency: 1.02 kHz Phase Margin: 95°.
Note: The green line indicates oscillator injection level. Normally a higher injection signal is used at low frequencies. The yellow lines are cursors to indicate gain and phase

12.2 High Line (325 VDC)

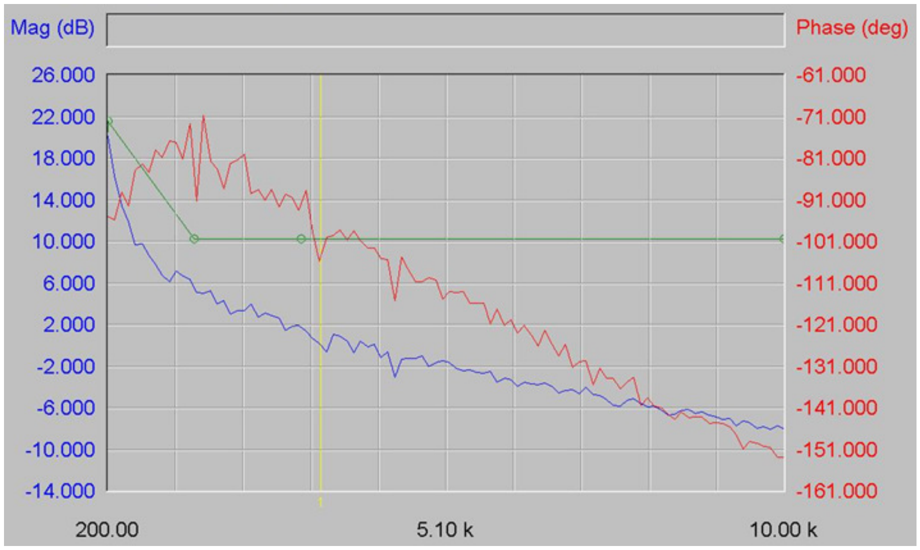

Figure 18 – Gain Phase Plot, 325 VDC, Full Load. Cross Over Frequency: 3.2 kHz Phase Margin: 95°.

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13 Conducted EMI

The upper and lower limits shown are quasi peak and the average limits as per EN55022 Class B. A resistive load was connected to DC output terminals. Measurements shown are peak measurements vs. QP and AVG limits.

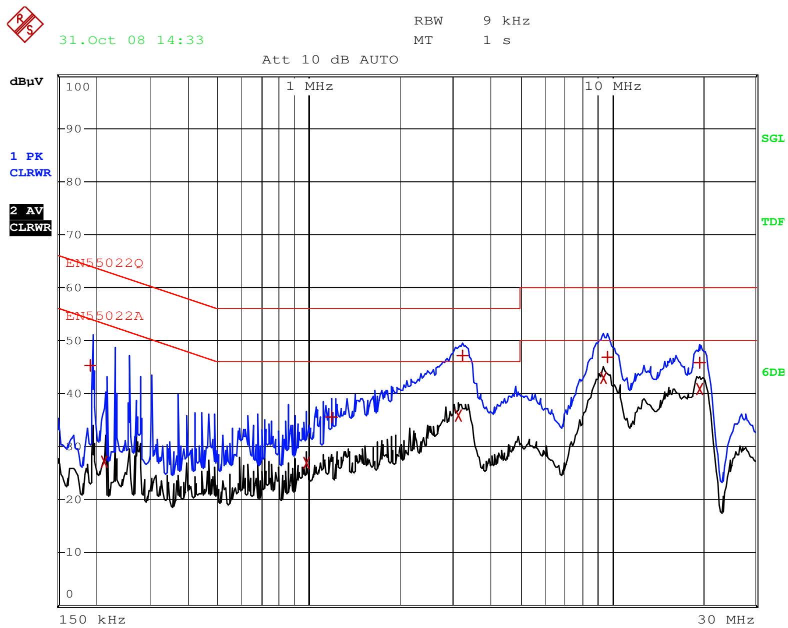

Figure 19 – Conducted EMI, Full Load, 115 VAC, Neutral.

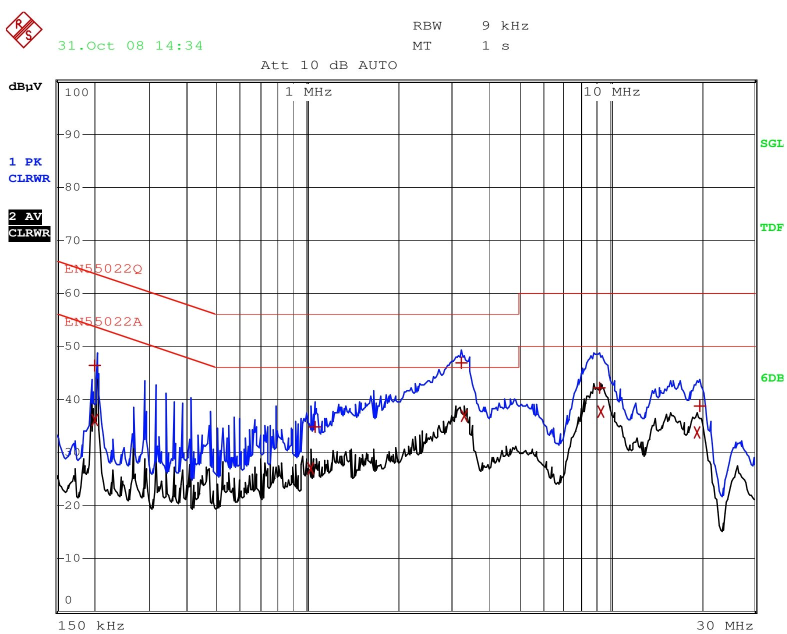

Figure 20 – Conducted EMI, Full Load, 265 VAC, Neutral.

14 Revision History

Date	Author	Revision	Description & changes	Reviewed
09-Apr-09	EC, SPM	1.0	Initial Release	Apps and Mktg

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