Design Example Report

Title	***22 W (48.6 W peak) 3 Output Power Supply Using TOP258MN***
Specification	85 VAC – 265 VAC Input; 12 V, 40 - 800 mA (3 A peak, 50 ms); 8 V, 25 - 75 mA; 40 V, 30 - 300 mA Outputs 0 to +65°C
Application	Fresh Air Filter
Author	Applications Engineering Department
Document Number	DER-217
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Revision	1.0

Summary and Features

- 48.6 W peak power from a DIP package with no heatsink
- Highly energy efficient
  - Full load efficiency >80%
  - Peak load efficiency >83%
- Low cost, low component count and small PCB footprint solution
  - Performance met without TOPSwitch®-HX heatsink
  - 132 kHz operation optimized core size and efficiency performance
- Integrated Protection and Reliability Features
  - Line under-voltage lock out (UVLO)
  - Auto recovery output over current (OCP)
  - Accurate thermal shutdown with large hysteresis

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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 a fresh-air filter application utilizing TOP258MN (TOPSwitch®-HX family). The power supply has three outputs as follows: 40 V, 0.3 A, 12 V, 0.8 A (3 A peak) and 8 V, 75 mA.

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

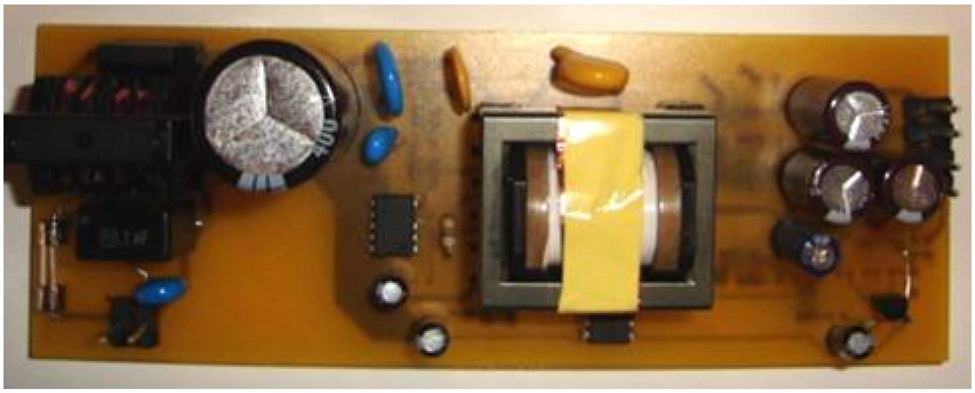

Figure 1 – Populated Circuit Board Photograph.

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2 Power Supply Specification

The table below represents the minimum acceptable performance of the design. Actual performance is listed in the results section.

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	85		265	VAC	2 wire
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (265 VAC)				300	mW	
Output						
Output Voltage 1	V_{OUT1}		8		V	± 15%
Output Ripple Voltage 1	$V_{RIPPLE1}$			500	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}	25	75	75	mA	
Output Voltage 2	V_{OUT2}		12		V	± 5%
Output Ripple Voltage 2	$V_{RIPPLE2}$			500	mV	20 MHz bandwidth
Output Current 2	I_{OUT2}	0.04	0.8	3	A	0.8 A in steady state, 3 A peak for 50 ms
Output Voltage 3	V_{OUT3}		40		V	± 10%
Output Ripple Voltage 3	$V_{RIPPLE3}$			500	mV	20 MHz bandwidth
Output Current 3	I_{OUT3}	0.03	0.3	0.3	A	
Total Output Power						
Continuous Output Power	P_{OUT}		22	48.6	W	
Efficiency						
Full Load	η		84		%	Measured at 25 °C
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950, UL1950 Class II				
Ambient Temperature	T_{AMB}	0		65	°C	Free convection, sea level

3 Schematic

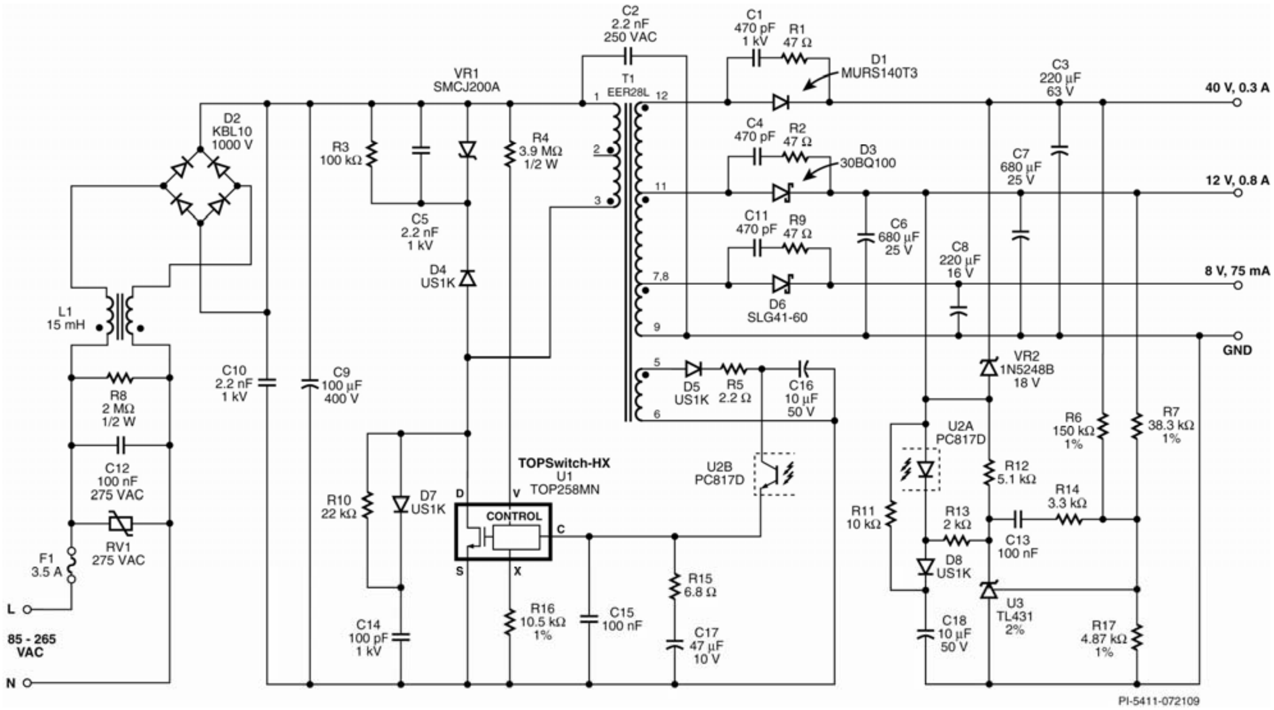

Figure 2 – Schematic.

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4 Circuit Description

This circuit is an isolated flyback converter for a fresh air filter using TOP258MN. It is designed to operate from 85 VAC to 265 VAC. The power supply has three outputs, 40 V, 0.3 A, 12 V, 0.8 A (3 A peak), and 8 V, 75 mA. It delivers a steady state power of 22 W and a peak power of 48.6 W for 50 msec. 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 (e.g. failure of the bridge rectifier). The bridge rectifier D2 is a full bridge rectifier circuit that rectifies the AC voltage into DC voltage. Capacitor C9 acts as filtering capacitor of the AC rectified waveform and also as the energy storage element of the power supply to provide a constant DC voltage.

The common-mode choke L1, X capacitor C12, and Y capacitor C2 are used for EMI filtering. Resistor R8 aids in discharging the X capacitor within one second after input AC is turned off to prevent shock hazard but is not required to meet safety as C12 is only 100 nF. Capacitor C10 reduces the PCB layout primary switching current loop size, reducing EMI.

The frequency jitter function of the TOPSwitch-HX family greatly reduces the size and complexity of the EMI filter components

4.2 TOPSwitch-HX Primary

This design uses two clamp networks, one to limit maximum drain voltage across the primary winding and a snubber to limit rate-of-rise of the drain voltage connected across DRAIN and SOURCE of U1.

The clamp circuit consists of D4, R3, VR1, and C5. 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 could exceed breakdown voltage (BV_{DSS}) of the MOSFET. During turn-off, when the drain voltage rises to a voltage above the DC bus plus the voltage across C5, D4 conducts and C5 is charged. The voltage across C5 is maintained to between 1.5 and 2 times the reflected output voltage (V_{OR}), determined by the value or R3. During a transient condition such as startup or a step change in load, the TVS (Transient Voltage Suppressor) VR1 prevents the voltage across the primary winding from rising above its rated value (200 V in this case). This allows the values of C5 and R3 to be optimized for normal operation, maximizing efficiency and reducing EMI while VR1 guarantees sufficient margin to BV_{DSS} during peak and over-load conditions.

The rate-of-rise snubber consists of D7, R10, and C14. During turn-off of the MOSFET, the leakage energy is dumped into the capacitor C13 through D6 and prevents the high drain dv/dt. The capacitor discharges through R10 at turn on. This snubber helps in improving high frequency (radiated) EMI by decreasing the slope of the rising voltage on the drain of the MOSFET.

4.3 Output Rectification

The output uses a combination of Schottky and ultrafast diodes. Schottky barrier type are used on the lower voltage outputs (where the diode reverse voltage stress allows their use) to improve efficiency due to their lower forward voltage (V_F). RC snubbers (R1-C1, R9-C11, and R2-C4 on D1, D6, and D3 respectively) provide filtering of the voltage spike during turn-off of the diodes due to the reverse recovery characteristics and output leakage inductance which can cause significant EMI.

4.4 Output Feedback

The output is regulated using a TL431 circuit to maintain 5% regulation. The TL431 pulls current through the photodiode of U2 when the voltage on the reference pin set by the voltage divider (R6, R7 and R17) goes higher than 2.5 V. As the current through the opto-coupler increases current into the CONTROL pin of U1 also increases, reducing the duty cycle of the internal MOSFET and therefore maintaining output regulation. An additional soft-start circuit has also been implemented using C18, D8, and R11. Once the output voltage exceeds approximately 1.8 V (V_F of the LED within U2 + V_F of D8) C18 will begin to charge. As this charging current flows through U2 current will be also fed into the CONTROL pin of U1 (once the bias winding voltage is high enough to bias the opto-coupler transistor). This effectively closes the control loop prior to the output reaching regulation and allows the output voltage rise time to be controlled during startup to prevent output overshoot. Resistor R11 discharges the soft-start capacitor during power supply shut down. Capacitor C13 and Resistor R14 are responsible for providing loop compensation.

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5 PCB Layout

The transformer secondary ground pin (pin 9) was selected to be in the center of the bobbin to reduce the loop areas of the individual outputs to reduce leakage inductance, improving cross regulation and EMI generation. As the SOURCE pins of U1 were connected to the large area of copper on the PCB as these pins provide heatsinking of the device.

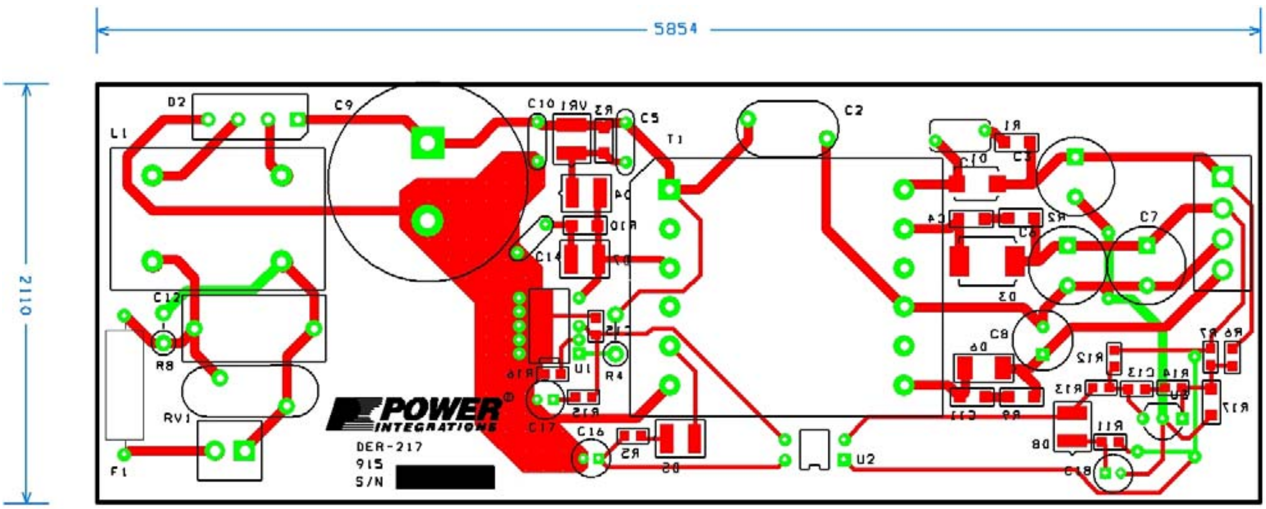

Figure 3 – PCB Layout.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	C1	Capacitor, 470 pF, 1 kV, Disc Ceramic	562R10TST47	Vishay
2	1	C2	Capacitor, 2.2 nF, Ceramic, Y1, 250VAC	440LD22-R	Vishay
3	1	C3	Capacitor, 220 μF, 63 V, Electrolytic, Low ESR	ELXZ630ELL221MJ25S	Nippon Chemi-Con
4	2	C4 C11	Capacitor, 470 pF, 100 V, Ceramic, X7R, 1206		Epcos
5	2	C5 C10	Capacitor, 2.2 nF, 1 kV, Disc Ceramic	NCD222K1KVY5FF	NIC Components
6	2	C6 C7	Capacitor, 680 μF, 25 V, Electrolytic, Very Low ESR	EKZE250ELL681MJ20S	Nippon Chemi-Con
7	1	C8	Capacitor, 220 μF, 16 V, Electrolytic	KME16VB221M8X11LL	Nippon Chemi-Con
8	1	C9	Capacitor, 100 μF, 400 V, Electrolytic	ECO-S2GP101CA	Panasonic
9	1	C12	Capacitor, 100 nF, 275VAC, Film, X2	F1772-410-2000	Vishay/Roederstein
10	2	C13 C15	Capacitor, 100 nF, 50 V, Ceramic, X7R, 0805	ECJ-2YB1H104K	Panasonic
11	1	C14	Capacitor, 100 pF, 1 kV, Disc Ceramic	ECC-D3A101JGE	Panasonic - ECG
12	1	C16 C18	Capacitor, 10 μF, 50 V, Electrolytic, Gen. Purpose	EKMG500ELL100ME11D	Nippon Chemi-Con
13	1	C17	Capacitor, 47 μF, 10 V, Electrolytic, Gen. Purpose	KME10VB22RM5X11LL	Nippon Chemi-Con
14	1	D1	Diode, 400 V, 1 A, Ultrafast Recovery, 35 ns, SMB	MURS140T3	On Semi
15	1	D2	Diode, 1000 V, 4 A, Bridge Rectifier	KBL10-E4/51	Vishay
16	1	D3	Diode, 100 V, 3 A, Schottky, SMC	30BQ100	International Rectifier
17	4	D4 D5 D7 D8	Diode, Ultra Fast, 800V, 1 A, SMA	US1K-13-F	Diodes, Inc
18	1	D6	Diode, 60 V, 1 A, Schottky, SMD, DO-213AB	SGL41-60/96	Vishay
19	1	F1	Fuse, 3.5 A, 250 V, Slow, 5 mm x 20 mm, Axial	23003.5	Littelfuse
20	1	L1	Inductor, 15 mH, 1.0 A, Common Mode Choke	ELF-18D431F	Panasonic
21	3	R1 R2 R9	Resistor, 47 Ω, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ470V	Panasonic
22	1	R3	Resistor, 100 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ104V	Panasonic
23	1	R4	Resistor, 3.9 MΩ, 5%, 1/2 W, Carbon Film	CFR-50JB-3M9	Yageo
24	1	R5	Resistor, 2.2 Ω, 5%, 1/8 W, Metal Film, 0805	ERJ-6GEYJ2R2V	Panasonic
25	1	R6	Resistor, 150 kΩ, 1%, 1/8 W, Metal Film, 0805	ERJ-6ENF1503V	Panasonic
26	1	R7	Resistor, 38.3 kΩ, 1%, 1/8 W, Metal Film, 0805	ERJ-6ENF3832V	Panasonic
27	1	R8	Resistor, 2 MΩ, 5%, 1/2 W, Carbon Film	CFR-50JB-2M0	Yageo
28	1	R10	Resistor, 22 kΩ, 5%, 1/4 W, Metal Film, 1206	ERJ-8GEYJ223V	Panasonic
29	1	R11	Resistor, 10 kΩ, 5%, 1/8 W, Metal Film, 0805	ERJ-6GEYJ103V	Panasonic
30	1	R12	Resistor, 5.1 kΩ, 5%, 1/8 W, Metal Film, 0805	ERF-6ENF1503V	Panasonic
31	1	R13	Resistor, 2 kΩ, 5%, 1/8 W, Metal Film, 0805	ERJ-6GEYJ202V	Panasonic
32	1	R14	Resistor, 3.3 kΩ, 5%, 1/8 W, Metal Film, 0805	ERJ-6GEYJ332V	Panasonic
33	1	R15	Resistor, 6.8 Ω, 5%, 1/8 W, Metal Film, 0805	ERJ-6GEYJ6R8V	Panasonic
34	1	R16	Resistor, 10.5 kΩ, 1%, 1/8 W, Metal Film, 0805	ERJ-6ENF1052V	Panasonic
35	1	R17	Resistor, 4.87 kΩ, 1%, 1/4 W, Metal Film, 1206	ERJ-8ENF4871V	Panasonic
36	1	RV1	MOV, 275 V, 75 J, 14 mm, RADIAL	V275LA20A	Littlefuse
37	1	T1	Bobbin, EER28L, Horizontal, 12 pins	YC2806	Ying Chin
38	1	U1	IC, TOPSwitch-HX, TOP258MN, SDIP-10	TOP258MN	Power Integrations
39	1	U2	IC, Optocoupler, 35 V, CTR 300-600%, 4-DIP	PC817X4	Sharp

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40	1	U3	IC, 2.495 V Shunt Regulator IC, 2%, 0 to 70C	TL431CLPG	On Semiconductor
41	1	VR2	Diode, Zener, 18W, 500mW	1N5248B	Diodes, Inc
42	1	VR1	Diode, TVS, 200 V, 1500 W, SMC	SMCJ200A-13-F	Diodes, Inc

7 Transformer Specification

7.1 Electrical Diagram

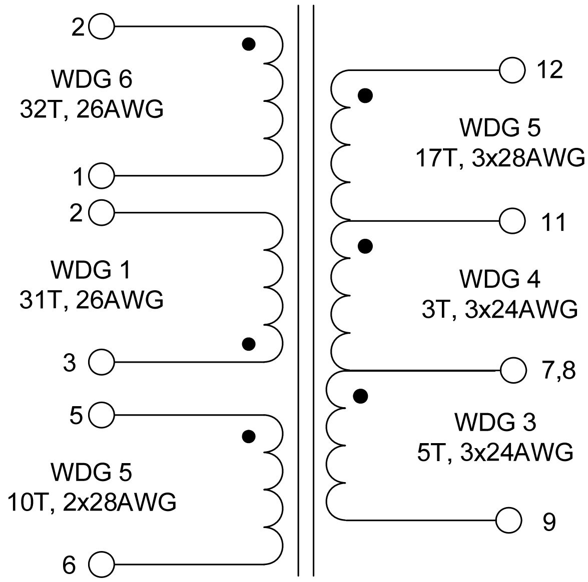

Figure 4 – Transformer Electrical Diagram.

7.2 Electrical Specification

Electrical Strength	60 Hz 1 second, from pins 1-6 to pins 7-12.	3000 VAC
Primary Inductance	Pin 1 to pin 3, all other windings open, measured at 100 kHz, 1 VRMS.	590 μH, ±10%
Resonant Frequency	All windings open.	850 kHz (Min.)
Primary Leakage Inductance	Pins 1-3, all other pins shorted.	7 μH (Max.)

7.3 Materials

Item	Description
[1]	3 mm margin tape
[2]	3M barrier tape: polyester film
[3]	Core: 1 pair EER28L TDK PC44 or equivalent
[4]	Bobbin: 12 pin EER28L, horizontal, Ying Chin, YC2806
[5]	Magnet wire: #24 AWG double coated
[6]	Magnet wire: #26 AWG double coated
[7]	Magnet wire: #28 AWG double coated
[8]	Copper foil
[9]	Varnish

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7.4 Transformer Build Diagram

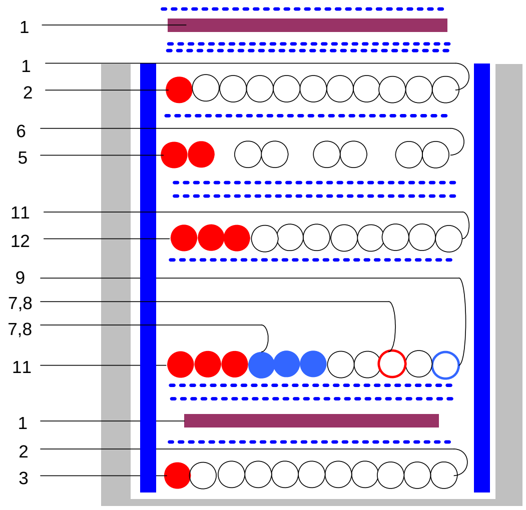

Figure 5 – Transformer Build Diagram.

7.5 Transformer Construction

All windings are wound in the same direction.

Margin tape	Wind 3mm margin tape on both sides of the bobbin to match the height of the first half of the primary winding. Repeat for each subsequent layer.
Primary Winding	Start from left to right from pin 3. Wind 31 turns of #26 AWG wire on one layer. Return end back to start side and terminate on pin 2.
Insulation	Use one layer of tape.
Shield	Place one layer of copper foil for shield and terminate at pin 1.
Insulation	Place two layers of tape.
Secondary Winding	Start from left to right start 3 turns of 3x #24 AWG wire from pin 11 and started 5 turns of 3x #24 AWG wire from pin 7 and 8 in bifilar fashion. Terminate the first winding at pin 7 and 8 and the second winding at pin 9.
Insulation	Place one layer of tape.
Secondary Winding	Start from left to right from pin 12. Wind 17 turns of 3x #28 AWG magnet wire on one layer. Terminate at pin 11.
Insulation	Place two layers of tape.
Bias Winding	Start from left to right from pin 5. Wind 10 turns of 2x #28 AWG wire on one layer. Terminate on pin 6. Spread winding evenly in the bobbin.
Insulation	Use one layer of tape.
Primary Winding	Start from left to right from pin 2. Wind 32 turns of #26 AWG wire on one layer. Terminate at pin 1.
Insulation	Place two layers 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.
Insulation	Place two layers of tape.
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	TOP_HX_021308: TOPSwitch-HX Continuous/Discontinuous Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
VACMIN	85			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	22.00			Watts	Average Output Power
PO_PEAK	48.64		48.64	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	100.0		100	uFarads	Input Filter Capacitor
ENTER TOPSWITCH-HX VARIABLES					
TOPSwitch-HX	**TOP258MN**			Universal / Peak	115 Doubled/230V
Chosen Device		*TOP258MN*	Power Out	35 W / 92 W	48W
KI	0.72				External Ilimit reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT)
ILIMITMIN_EXT			2.009	Amps	Use 1% resistor in setting external ILIMIT
ILIMITMAX_EXT			2.311	Amps	Use 1% resistor in setting external ILIMIT
Frequency (F)=132kHz, (H)=66kHz	**H**		H		Half frequency option is only available for P, G and M packages in addition to TOP259-TOP261YN devices. For full frequency operation choose E package or TOP254-TOP258YN devices.
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	100.00			Volts	Reflected Output Voltage
VDS			10	Volts	TOPSwitch on-state Drain to Source Voltage
VD	0.60			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			95	Volts	Minimum DC Bus Voltage at which the power supply will start-up
VOV_SHUTDOWN			445	Volts	Typical DC Bus Voltage at which power supply will shut-down (Max)
RLS			4.0	M-ohms	Use two standard, 2 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

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					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% higher than peak primary current at VMAX
Overload Current Ratio at VMIN		*Info*	5.08		Your margin to current limit at low line is high. Reduce KI to 0.24 (if possible).
ILIMIT_EXT_VMIN			1.88	A	Peak primary Current at VMIN
ILIMIT_EXT_VMAX			1.92	A	Peak Primary Current at VMAX
RIL			8.78	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	**EER28L**		EER28L		Core Type
Core		*EER28L*		*P/N:*	PC40EER28L-Z
Bobbin		*EER28L_ BOBBIN*		*P/N:*	BEER-28L-1112CPH
AE			0.814	cm^2	Core Effective Cross Sectional Area
LE			7.55	cm	Core Effective Path Length
AL			2520	nH/T^2	Ungapped Core Effective Inductance
BW			21.8	mm	Bobbin Physical Winding Width
M	3.00			mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	2.00				Number of Primary Layers
NS	8		8		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			77	Volts	Minimum DC Input Voltage
VMAX			373	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.60		Maximum Duty Cycle (calculated at PO_PEAK)
IAVG			0.36	Amps	Average Primary Current (calculated at average output power)
IP			1.88	Amps	Peak Primary Current (calculated at Peak output power)
IR			0.51	Amps	Primary Ripple Current (calculated at average output power)
IRMS			0.48	Amps	Primary RMS Current (calculated at average output power)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			589	uHenries	Primary Inductance
LP Tolerance			10		Tolerance of Primary Inductance
NP			63		Primary Winding Number of Turns
NB			10		Bias Winding Number of Turns
ALG			146	nH/T^2	Gapped Core Effective Inductance
BM			2144	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP			2895	Gauss	Peak Flux Density (BP<4200) at ILIMITMAX and LP_MAX. Note: Recommended values for adapters and external power supplies <=3600 Gauss
BAC			643	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1860		Relative Permeability of Ungapped Core
LG			0.66	mm	Gap Length (Lg > 0.1 mm)
BWE			31.6	mm	Effective Bobbin Width
OD			0.50	mm	Maximum Primary Wire Diameter including insulation
INS			0.07	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.43	mm	Bare conductor diameter

AWG			26	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			256	Cmils	Bare conductor effective area in circular mils
CMA		*Warning*	539	Cmils/Amp	!!! DECREASE CMA> (decrease L(primary layers),increase NS,smaller Core)
Primary Current Density (J)			3.71	Amps/mm^2	!!! Info. Primary current density is low. Can increase Primary current density. Reduce primary layers, or use smaller core
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			14.94	Amps	Peak Secondary Current
ISRMS			3.09	Amps	Secondary RMS Current
IO_PEAK			4.05	Amps	Secondary Peak Output Current
IO			1.83	Amps	Average Power Supply Output Current
IRIPPLE			2.49	Amps	Output Capacitor RMS Ripple Current
CMS			618	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			22	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.65	mm	Secondary Minimum Bare Conductor Diameter
ODS			1.98	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			0.66	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN			573	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			59	Volts	Output Rectifier Maximum Peak Inverse Voltage
PIVB			74	Volts	Bias Rectifier Maximum Peak Inverse Voltage
TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)					
1st output					
VO1	12.00		12	Volts	Output Voltage
IO1_AVG	3.00		3.00	Amps	Average DC Output Current
PO1_AVG			36.00	Watts	Average Output Power
VD1	0.70		0.7	Volts	Output Diode Forward Voltage Drop
NS1			8.06		Output Winding Number of Turns
ISRMS1			5.053	Amps	Output Winding RMS Current
IRIPPLE1			4.07	Amps	Output Capacitor RMS Ripple Current
PIVS1			59	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS1			1011	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS1			20	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS1			0.81	mm	Minimum Bare Conductor Diameter
ODS1			1.96	mm	Maximum Outside Diameter for Triple Insulated Wire
2nd output					
VO2	40.00			Volts	Output Voltage
IO2_AVG	0.30			Amps	Average DC Output Current
PO2_AVG			12.00	Watts	Average Output Power
VD2	0.60		0.6	Volts	Output Diode Forward Voltage Drop
NS2			25.78		Output Winding Number of Turns
ISRMS2			0.505	Amps	Output Winding RMS Current
IRIPPLE2			0.41	Amps	Output Capacitor RMS Ripple Current
PIVS2			192	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS2			101	Cmils	Output Winding Bare Conductor minimum circular mils

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AWGS2			30	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS2			0.26	mm	Minimum Bare Conductor Diameter
ODS2			0.61	mm	Maximum Outside Diameter for Triple Insulated Wire
3rd output					
VO3	7.50			Volts	Output Voltage
IO3_AVG	0.08			Amps	Average DC Output Current
PO3_AVG			0.60	Watts	Average Output Power
VD3	0.60		0.6	Volts	Output Diode Forward Voltage Drop
NS3			5.14		Output Winding Number of Turns
ISRMS3			0.135	Amps	Output Winding RMS Current
IRIPPLE3			0.11	Amps	Output Capacitor RMS Ripple Current
PIVS3			38	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS3			27	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS3			35	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS3			0.14	mm	Minimum Bare Conductor Diameter
ODS3			3.07	mm	Maximum Outside Diameter for Triple Insulated Wire
Total Continuous Output Power		*Warning*	48.6	Watts	!!! Warning. Total Continuous Output power does not match with the power entered under 'Applications Variables' section
Negative Output			N/A		If negative output exists enter Output number; eg: If VO2 is negative output, enter 2

Note: The CMA warning can be ignored as this indicates more copper area is available than needed for the secondary winding. High CMA (low current density) in a winding does not create a design problem.

The continuous power warning at the end of the design spreadsheet is the result of a rounding error 48.6 W vs. 48.64 W entered at top of spreadsheet

9 Performance Data

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

9.1 Efficiency

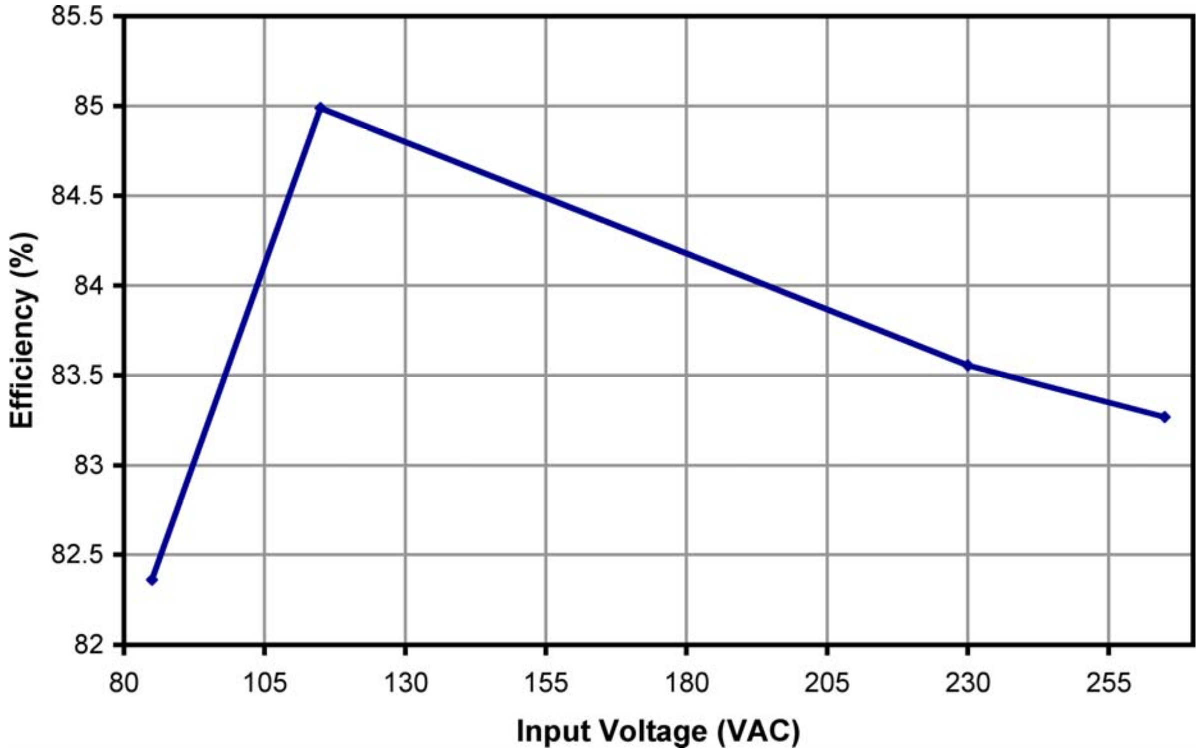

Figure 6 – Efficiency at Steady State Load 22.2 W vs. Input Voltage.

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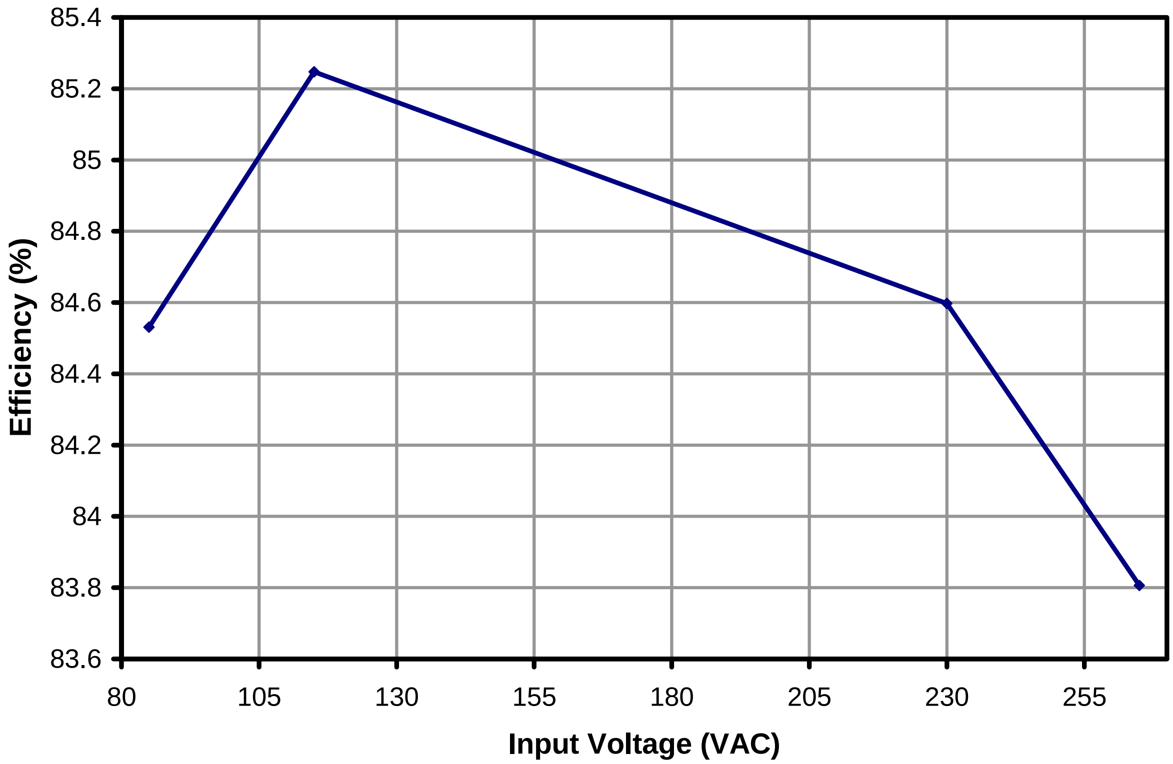

Figure 7 – Efficiency at Peak Load vs. Input Voltage.

9.2 Cross Regulation

9.2.1 Cross Regulation at 85 VAC

Minimum load: 8 V at 25 mA, 12 V at 40 mA, 40 V at 30 mA
Full load: 8 V at 75 mA, 12 V at 800 mA, 40 V at 300 mA

Output Load			**Measured Output Voltage**		
8 V	**12 V**	**40 V**	**8 V**	**12 V**	**40 V**
Min. load	Min. load	Min. load	7.5	12.41	39.5
Min. load	Min. load	Full load	7.63	12.5	39.2
Min. load	Full load	Min. load	7.55	12.01	41
Min. load	Full load	Full load	7.73	12.32	39.9
Full load	Min. load	Min. load	7.28	12.41	39.5
Full load	Min. load	Full load	7.48	12.52	39.1
Full load	Full load	Min. load	7.41	12.02	40.9
Full load	Full load	Full load	7.63	12.31	39.7

9.2.2 Cross Regulation at 265 VAC

Minimum load: 8 V at 25 mA, 12 V at 40 mA, 40 V at 30 mA
Full load: 8 V at 75 mA, 12 V at 800 mA, 40 V at 300 mA

Output Load			**Measured Output Voltage**		
8 V	**12 V**	**40 V**	**8 V**	**12 V**	**40 V**
Min. load	Min. load	Min. load	7.47	12.4	39.6
Min. load	Min. load	Full load	7.62	12.51	39.1
Min. load	Full load	Min. load	7.56	12.04	40.8
Min. load	Full load	Full load	7.22	12.32	39.9
Full load	Min. load	Min. load	7.22	12.4	39.6
Full load	Min. load	Full load	7.49	12.5	39.1
Full load	Full load	Min. load	7.43	12.04	40.9
Full load	Full load	Full load	7.63	12.31	39.9

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10 Thermal Performance

Thermal tests were conducted at worst case condition of 85 VAC with 22 W Load.

Component	Measured at 25 ºC	Calculated for 65 ºC
Bulk capacitor	35	75
Drain snubber diode	45	85
Output diode (8 V)	42.1	82.1
Output diode (12 V)	68	108
Output diode (40 V)	64.5	104.5
Output capacitor (8 V)	37.9	77.9
Output capacitor (12 V)	42.4	82.4
Output capacitor (40 V)	38.7	78.7
Transformer	53.9	93.9
TOP258MN	51.3	91.3
Bridge rectifier	40.6	80.6
TVS	47.8	87.8
dv/dt snubber diode	45.2	85.2

11 Waveforms

11.1 Drain Voltage at 265 VAC (Peak Load)

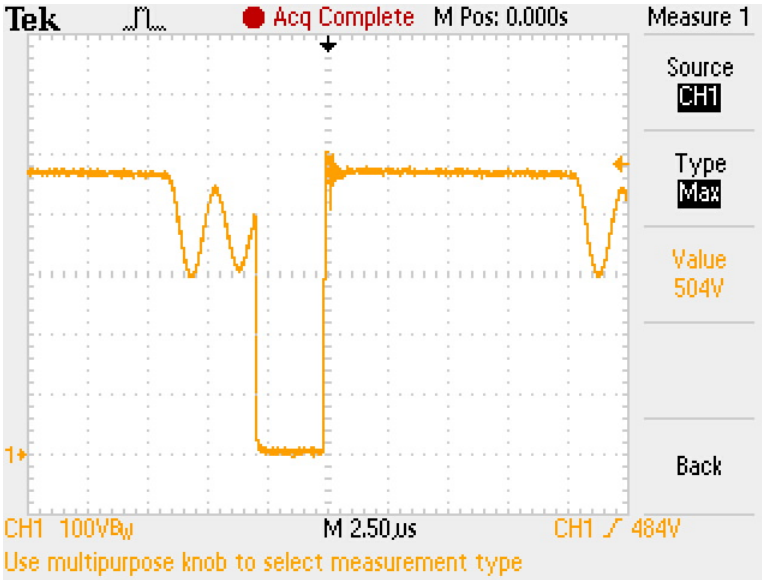

Figure 8 – 265 VAC. V_{DRAIN}, 100 V / div., 2.5 µs / div.

11.2 Start-up Voltage Profile

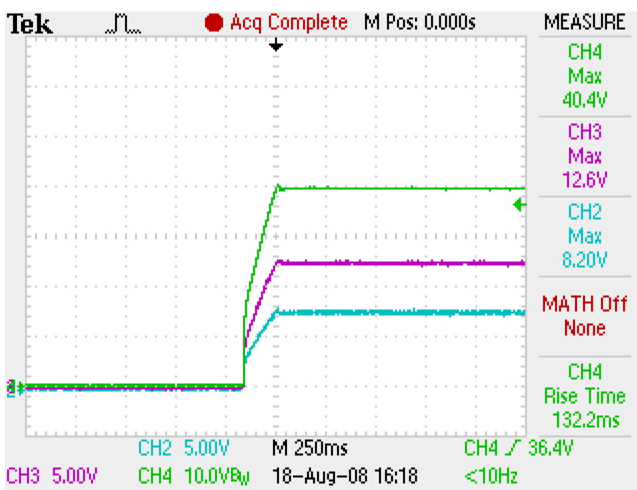

Figure 9 – Output Voltage at 85 VAC, 8 V at 25 mA,
12 V at 40 mA, 40 V at 30 mA.
Upper Trace: 40 V, 10 V / div., 250 ms / div.
Middle Trace: 12 V, 5 V / div., 250 ms / div.
Bottom Trace: 8 V, 5 V / div., 250 ms / div.

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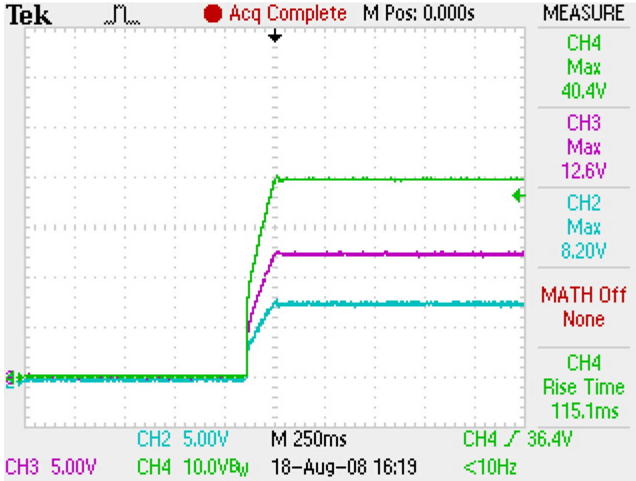

Figure 10 – Output Voltage at 265 VAC, 8 V at 25 mA, 12 V at 40 mA, 40 V at 30 mA.
Upper Trace: 40 V, 10 V / div., 250 ms / div.
Middle Trace: 12 V, 5 V / div., 250 ms / div.
Bottom Trace: 8 V, 5 V / div., 250 ms / div.

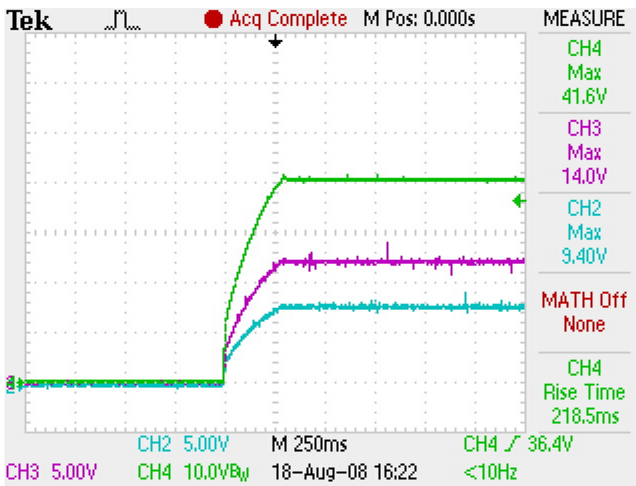

Figure 11 – Output Voltage at 85 VAC, Peak Load.
Upper Trace: 40 V, 10 V / div., 250 ms / div.
Middle Trace: 12 V, 5 V / div., 250 ms / div.
Bottom Trace: 8 V, 5 V / div., 250 ms / div.

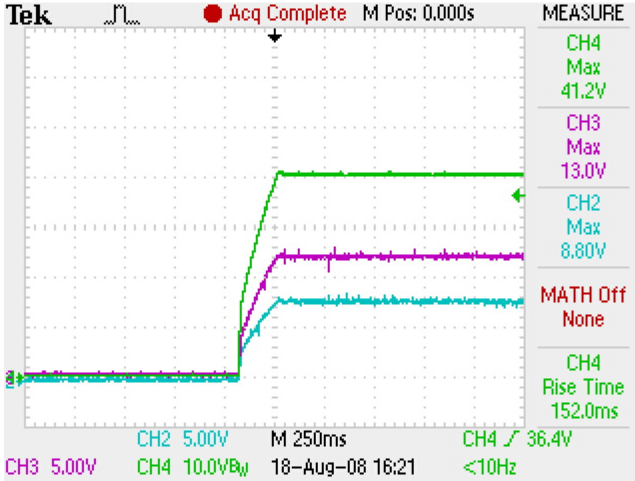

Figure 12 – Output Voltage at 265 VAC, Peak Load.
Upper Trace: 40 V, 10 V / div., 250 ms / div.
Middle Trace: 12 V, 5 V / div., 250 ms / div.
Bottom Trace: 8 V, 5 V / div., 250 ms / div.

11.3 Diode Peak Inverse Voltage

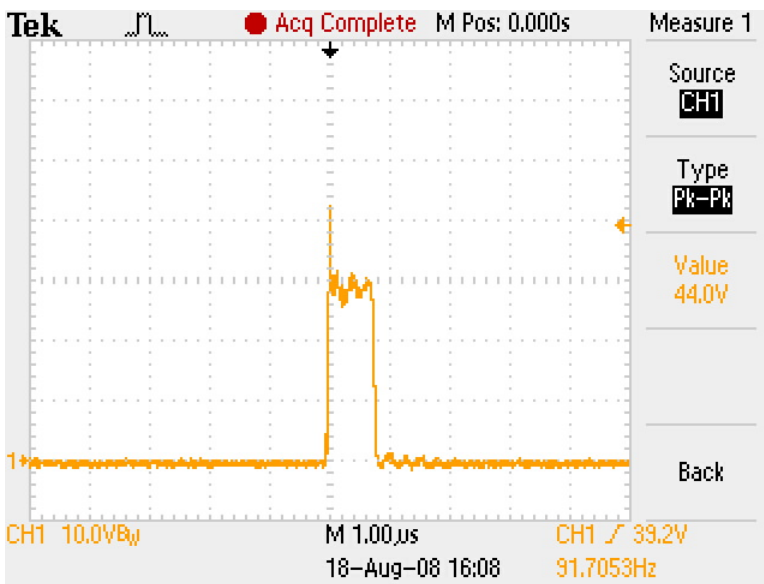

Figure 13 – Output Diode PIV, 8 V Diode, 265 VAC, Peak Load
10 V / div., 1 µs / div.

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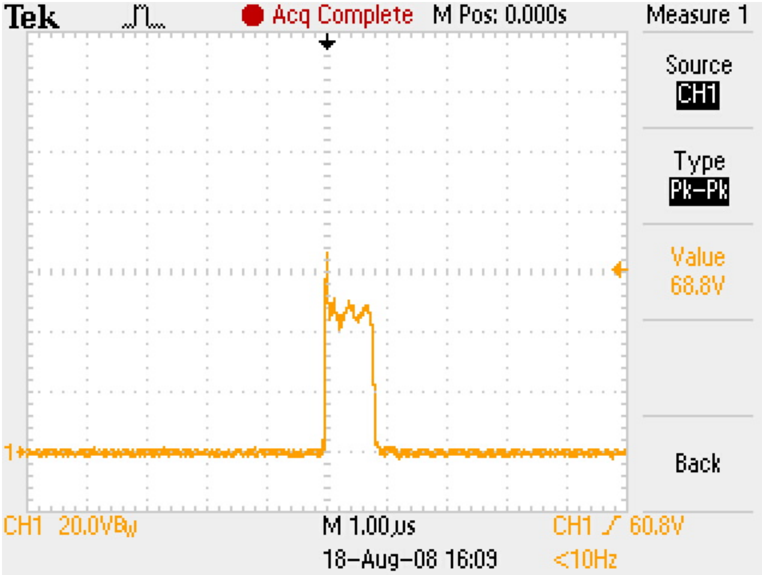

Figure 14 – Output Diode PIV, 12 V Diode, 265 VAC, Peak Load
20 V / div., 1 µs / div.

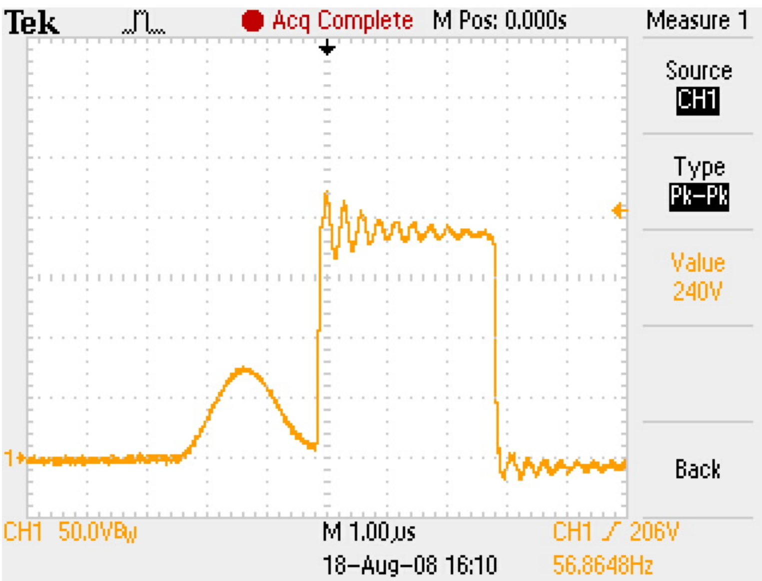

Figure 15 – Output Diode PIV, 40 V Diode, 265 VAC, Peak Load
50 V / div., 1 µs / div.

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).

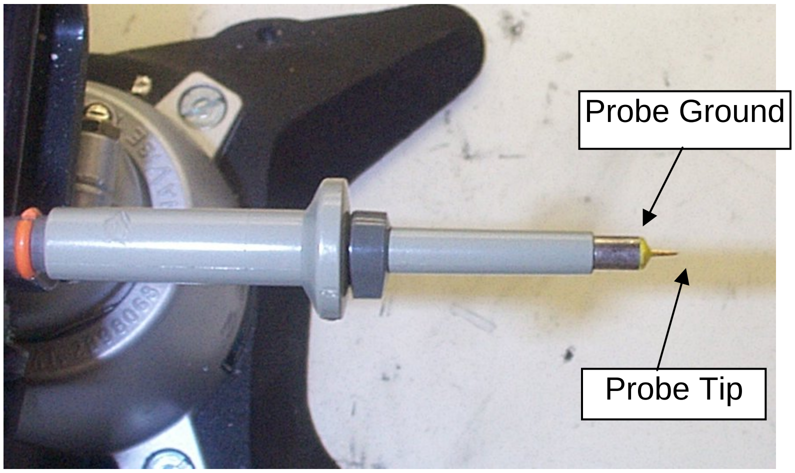

Figure 16 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

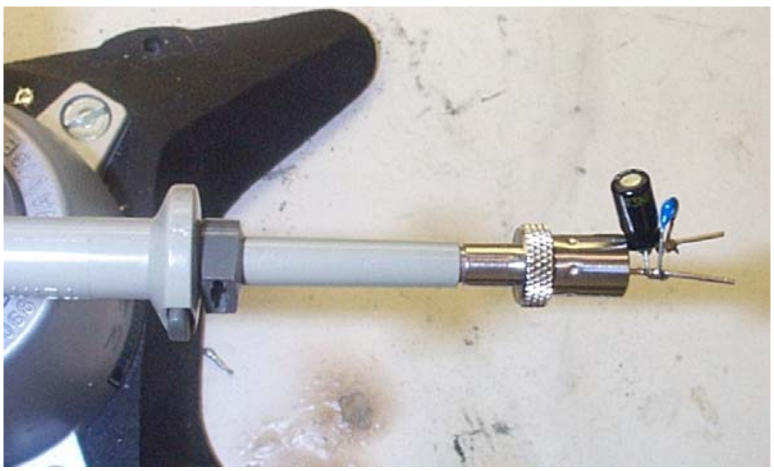

Figure 17 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

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11.4.1 Measurement Results

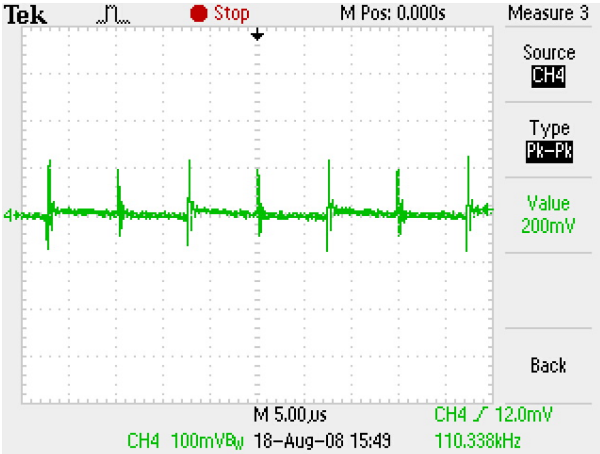

Figure 18 – Output Voltage Ripple 8 V, 85 VAC at Peak Load. 100 mV / div., 5 µs / div.

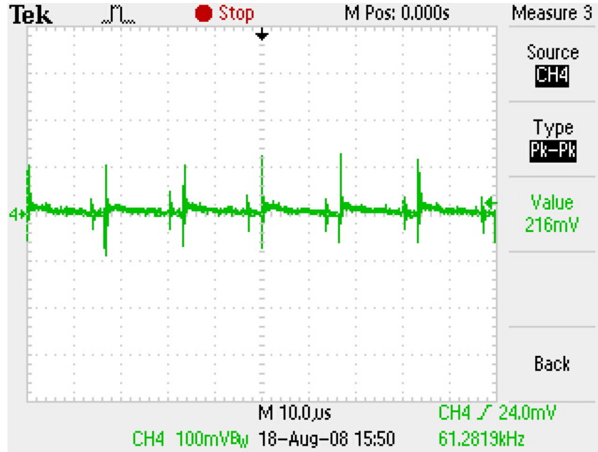

Figure 19 – Output Voltage Ripple 8 V, 265 VAC at Peak Load. 100 mV / div., 10 µs / div.

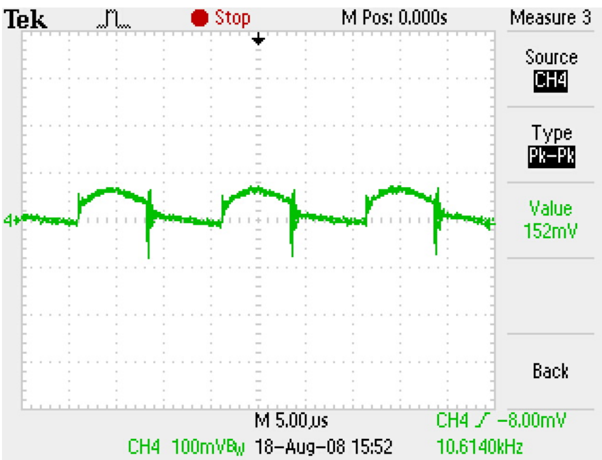

Figure 20 – Output Voltage Ripple 12 V, 85 VAC at Peak Load. 100 mV /div., 5 µs / div.

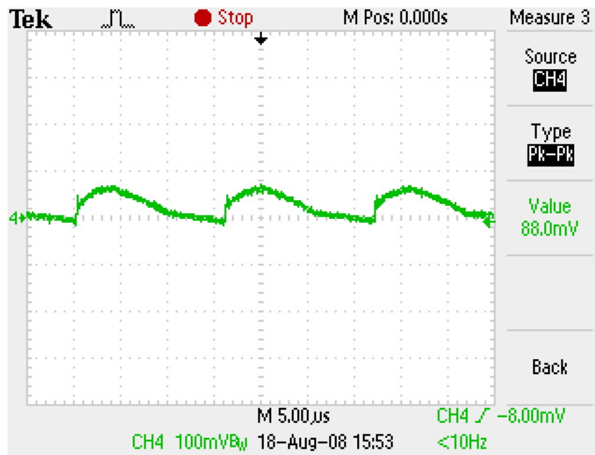

Figure 21 – Output Voltage Ripple 12 V, 265 VAC at Peak Load. 100 mV / div., 5 µs / div.

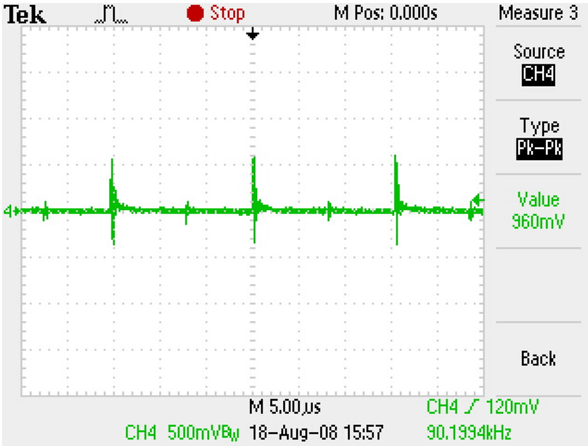

Figure 22 – Output Voltage Ripple 40 V, 85 VAC at Peak Load.500 mV / div., 5 µs / div.

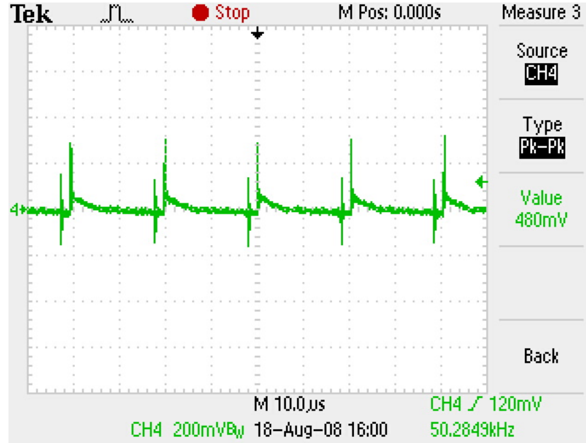

Figure 23 – Output Voltage Ripple 40 V, 265 VAC at Peak Load. 200 mV / div., 10 µs / div.

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12 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.

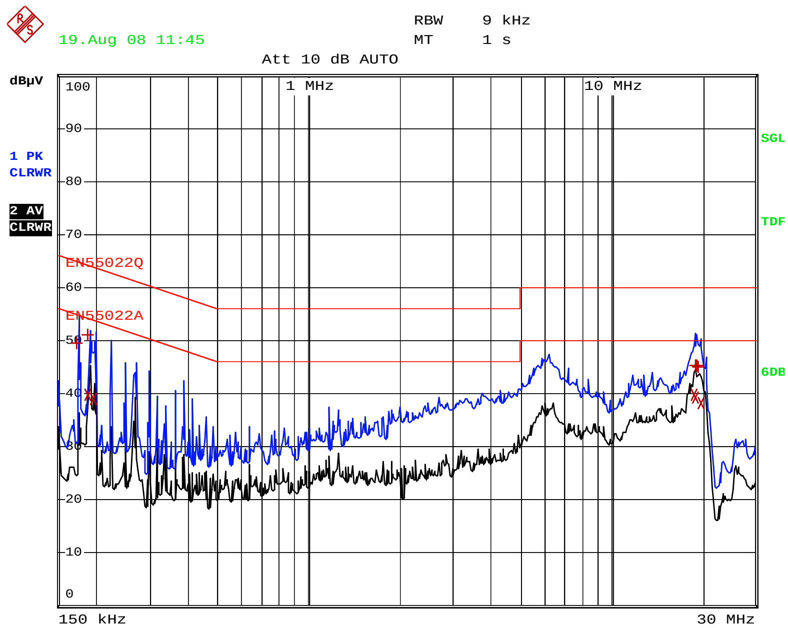

Figure 24 – Conducted EMI, 115 VAC, Neutral.

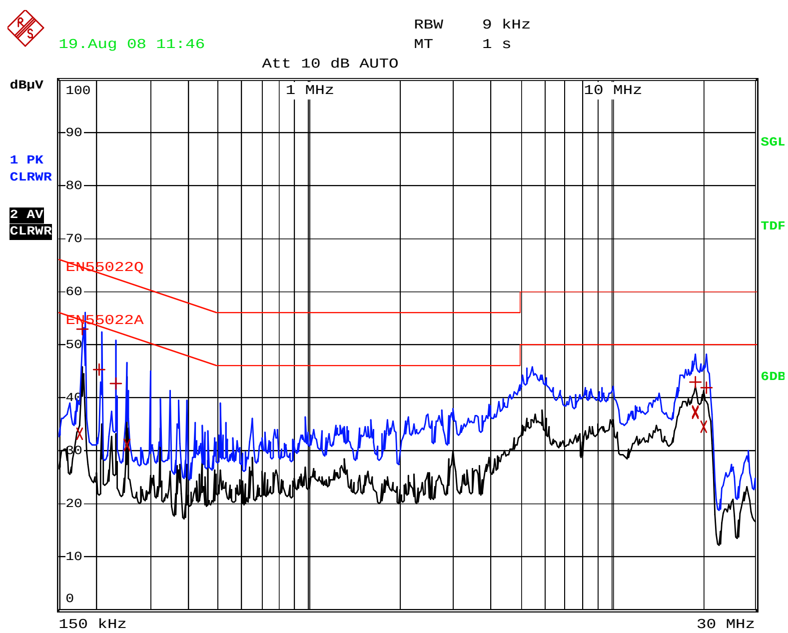

Figure 25 – Conducted EMI, 265 VAC, Neutral.

13 Revision History

Date	Author	Revision	Description & changes	Reviewed
11-Feb-10	EC, SPM	1.0	Initial release	Apps & Mktg

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