DESIGN EXAMPLE REPORT

Title	***35 W Power Supply Using TOP257EN***
Specification	90 VAC – 264 VAC Input; 13 V, 2.69 A Output
Application	LCD Monitor
Author	Applications Engineering Department
Document Number	DER-187
Date	June 24, 2008
Revision	1.0

Summary and Features

- Low cost, low component count, high efficiency
  - Delivers 35 W in a 50 °C ambient temperature environment
- EcoSmart® – meets requirements for low no-load and standby power consumption
  - 0.55 W output power for <1 W input power
  - No-load power consumption: <200 mW at 230 VAC
  - >82% Full-load efficiency
- Integrated safety and reliability features
  - Accurate, auto-recovering, hysteretic thermal shutdown function maintains safe PCB temperatures under all conditions
  - Auto-restart protects against output short circuits and feedback open- loop failures
  - Output overvoltage protection (OVP) configurable for latching or self-recovery
  - Input under-voltage (UV) protection prevents power up or power-down output glitches
- Easily meets EN55022 and CISPR-22 Class B conducted EMI: >6 dB margin

Power Integrations

5245 Hellyer Avenue, San Jose, CA 95138 USA.

Tel: +1 408 414 9200 Fax: +1 408 414 9201

www.powerint.com

Table of Contents

1 Introduction....3
2 Power Supply Specification....4
3 Schematic....5
4 Circuit Description....6
4.1 Input EMI Filtering....6
4.2 TOPSwitch HX Primary....6
4.3 Output Rectification....7
4.4 Output Feedback....8
5 PCB Layout....9
6 Bill of Materials....10
7 Inductor (L1) Electrical and Build Diagram....12
8 Transformer Specification....13
8.1 Electrical Diagram....13
8.2 Electrical Specifications....13
8.3 Materials....13
8.4 Transformer Build Diagram....14
8.5 Transformer Construction....14
9 Transformer Spreadsheets....15
10 Performance Data....18
10.1 Efficiency....18
10.2 No-load Input Power....19
10.3 Available Standby Output Power....19
10.4 Regulation....20
10.4.1 Load....20
10.4.2 Line....20
11 Thermal Performance....21
12 Waveforms....22
12.1 Drain Voltage and Current, Normal Operation....22
12.2 Output Voltage Start-up Profile....22
12.3 Drain Voltage and Current Start-up Profile....23
12.4 Load Transient Response (50% to 100% Load Step)....23
12.5 Open-loop Protection....24
12.6 Output Ripple Measurements....25
12.6.1 Ripple Measurement Technique....25
12.6.2 Measurement Results....26
13 Control Loop Measurements....27
14 Line Surge....29
15 Conducted EMI....30
16 Revision History....31

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 engineering report describes an LCD monitor power supply utilizing the TOPSwitch®-HX TOP257EN in a universal input, single output (13 V, 2.69 A) flyback-converter configuration.

This document contains specifications for the power supply and transformer, the design schematic, bill of materials, printed circuit board layout, and power supply performance specifications.

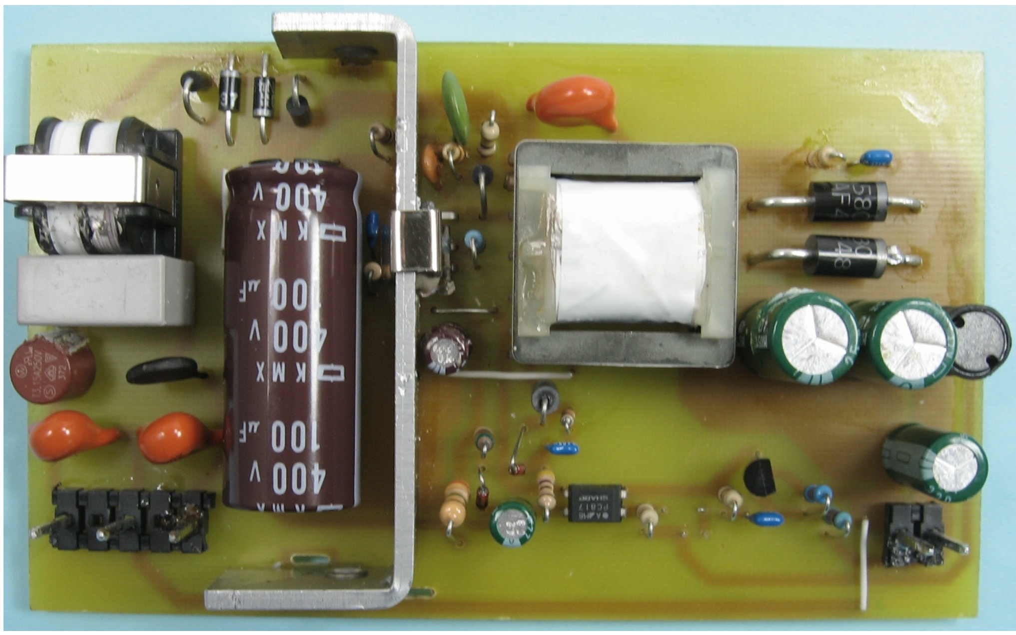


Figure 1 – Populated Circuit Board Photograph.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		264	VAC	
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (265 VAC)			0.18	0.3	W	
Output						
Output Voltage 1	V_{OUT1}		13		V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			100	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}		2.69		A	
Total Output Power						
Continuous Output Power	P_{OUT}		35		W	
Efficiency						
Full Load	η	82			%	Vin 90 VAC measured at P_{OUT} 25 °C
Average active efficiency 25%, 50%, 75%, 100 % of P_{OUT}	η_{CEC}	82	84		%	Per California Energy Commission (CEC) / Energy Star requirements
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950, UL1950 Class II				
Surge						1.2/50 µs surge, IEC 1000-4-5, series impedance: differential mode: 2 Ω common mode: 12 Ω
Differential		1			kV	
Common Mode		2			kV	
Surge Ring Wave		1			kV	100 kHz ring wave, 500 A short-circuit current; differential and common modes
Ambient Temperature	T_{AMB}	0		50	°C	Free convection, sea level

3 Schematic

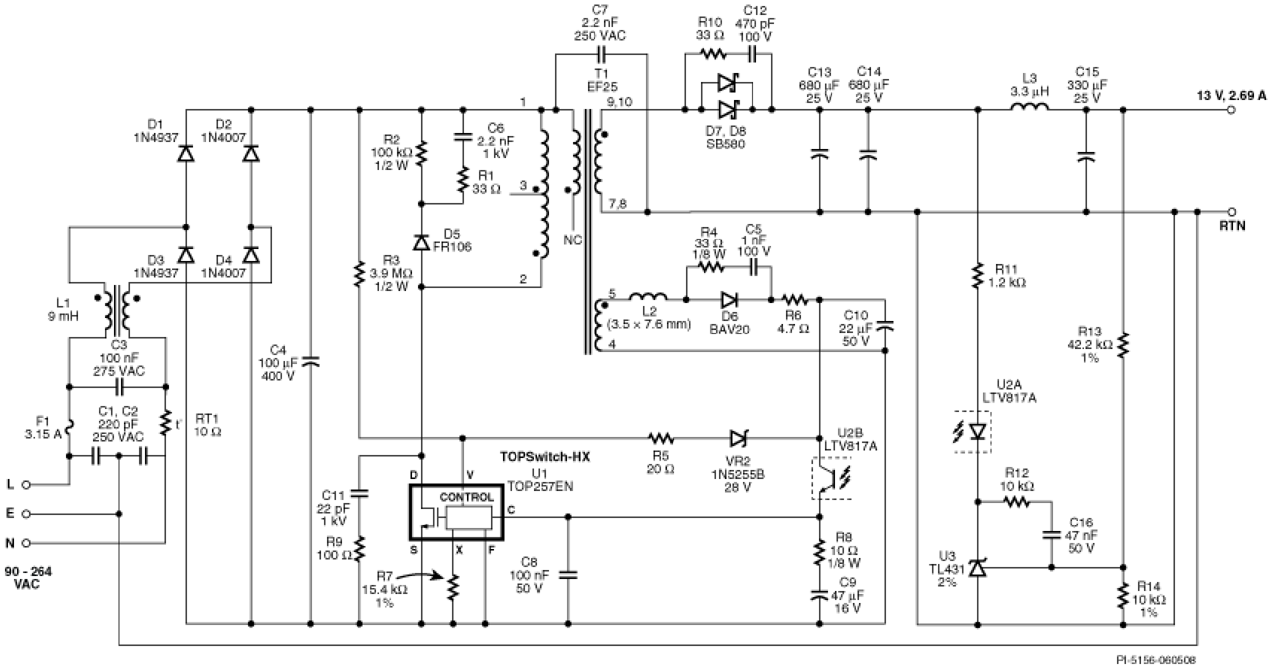


Figure 2 – Schematic.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

4 Circuit Description

This power supply design uses the TOP257EN in a flyback converter configuration to obtain a single 13 V, 2.69 A output from a universal voltage input (90 – 264 VAC). A TL431 voltage reference (shunt regulator) IC provides the tight regulation required in this design.

4.1 Input EMI Filtering

The three-wire AC supply is connected to the circuit. Fuse F1 provides protection against circuit faults and effectively isolates the circuit from the AC supply source. Thermistor RT1 limits the inrush current drawn by the circuit at start up. Optional Y-capacitors C1 and C2, connected from line/neutral to earth ground, reduce common-mode EMI.

An X capacitor, C3, reduces differential-mode EMI. Common-mode inductor L1 and Y-capacitor C7 provide common-mode EMI filtering. Ferrite bead L2 is placed on the bias winding to reduce high-frequency radiated EMI.

Diodes D1, D2, D3, and D4 form a bridge rectifier which rectifies the incoming AC supply to DC. Capacitor C4 filters the resulting DC.

Diodes D1 and D3 are fast-recovery diodes; they recover very quickly when the voltage across them reverses. This reduces excitation caused by stray line inductance in the AC input by reducing the subsequent high frequency turnoff snap. This also reduces any resulting EMI. Only one fast-recovery diode is needed per half cycle, since only two bridge diodes conduct in each half cycle. Choosing D1 and D3 as the fast-recovery diodes ensures each half cycle has one fast-recovery diode available to it.

4.2 TOPSwitch HX Primary

Resistor R3 provides line voltage sensing by feeding current from the DC bus into U1's V pin. The current is proportional to the DC voltage across capacitor C4. When this voltage reaches approximately 95 V DC, the current through this resistor becomes greater than 25 µA. This causes the line undervoltage threshold to be exceeded, which enables U1. (Resistor R3 is rated for ½ W to withstand the DC voltage expected across this resistor; two ¼ W resistors for R3 may also be used.)

The TOPSwitch-HX regulates the output using PWM-based voltage-mode control. At high loads the controller operates at full switching frequency (132 kHz for this design). Changes in the control pin current cause changes to the duty cycle. This regulates the output voltage.

The internal current limit provides cycle-by-cycle peak current limit protection. The TOPSwitch-HX controller has a second current limit comparator for monitoring the actual peak drain current (I_P) relative to the programmed current limit $I_{LIMITEXT}$. As soon as the ratio $I_P/I_{LIMITEXT}$ falls below 55%, the peak drain current is held constant. The output is then regulated by modulating the switching frequency. (This is the variable frequency PWM control mode.) As the load continues to decrease, the switching frequency also decreases linearly down to 30 kHz.

Once the switching frequency drops to 30 kHz, the controller keeps it constant and reduces the peak current to regulate the output. (This is the fixed frequency, direct duty cycle PWM control mode.)

As the load continues to decrease and the ratio $I_P/I_{LIMITEXT}$ falls below 25%, the controller enters multi-cycle-modulation mode. This mode offers excellent efficiency under light-load conditions (such as in standby operation), and low no-load input power consumption.

Diode D5 forms a clamp network with C6, R1, and R2 that limits the drain voltage of U1 at the instant of turn-off. Using a fast-recovery (rather than an ultra-fast) diode for D5, allows some of the clamp energy to be recovered. Resistor R1 limits reverse diode current and dampens high frequency ringing.

The output of the bias winding is rectified by diode D6 and filtered by the combination of resistor R6 and capacitor C10. Capacitor C5 and resistor R4 dampen any high-frequency ringing caused by D6. This rectified and filtered output is used by optocoupler U2B to provide the control and supply current to the CONTROL terminal (C pin) of U1.

Failure in the feedback circuit (caused by an open-loop condition) may cause the power supply output to exceed the regulation limit. The increased output voltage causes the voltage at the bias winding output to also increase. Under these conditions Zener diode VR2 breaks down and current flows into U1’s V pin, causing a latch-OVP shutdown.

The power supply’s output voltage is regulated by the feedback circuit on the secondary side, which controls the output voltage by changing the optocoupler current. A change in the optocoupler current causes a change in current flowing into the C pin of U1. Variation of the current into the C pin results in a variation of the duty cycle, which regulates the power supply’s output voltage.

4.3 Output Rectification

Diodes D7 and D8 provide output rectification. Low-ESR capacitors C13 and C14 provide filtering. Inductor L3 and capacitor C15 form a second stage filter that significantly attenuates the switching noise across C13 and C14, ensuring a low noise output.

The snubber network comprised of R10 and C12 dampens high-frequency ringing across diodes D7 and D8. The ringing results from transformer winding leakage inductance and secondary trace inductances.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

4.4 Output Feedback

The output voltage is controlled using shunt regulator U3. Resistors R13 and R14 form a voltage-divider network that senses the output, keeping the voltage in regulation.

Resistor R12 and capacitor C16 are compensation elements around error amplifier U3 which set the feedback circuit frequency response. Resistor R11 sets the overall DC loop gain and limits the current through U2A during transient state conditions.

5 PCB Layout

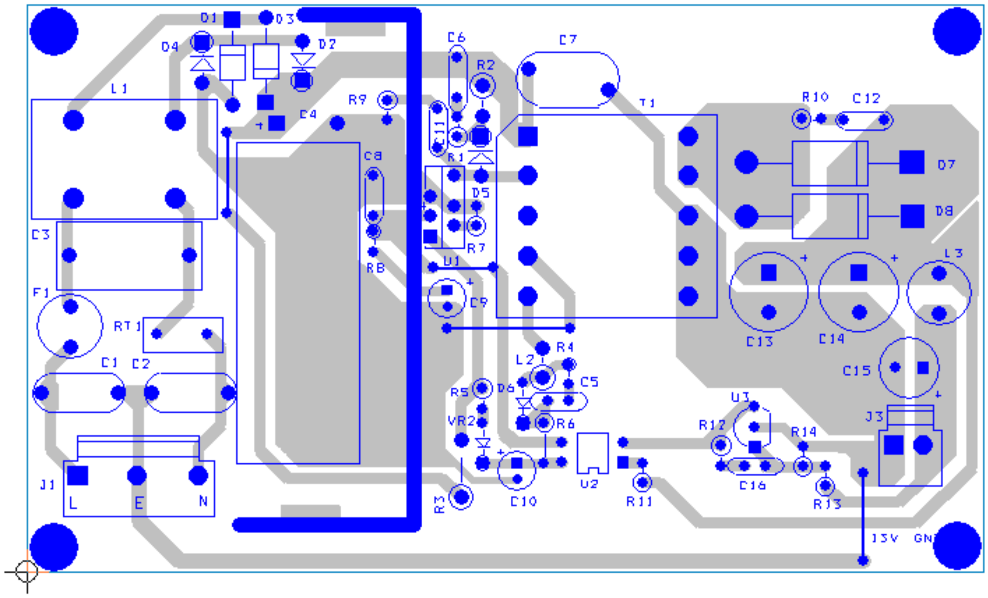


Figure 3 – Printed Circuit Layout.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

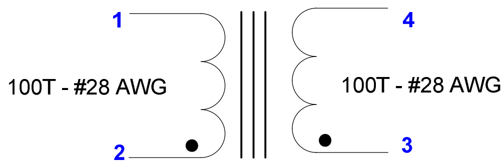
6 Bill of Materials

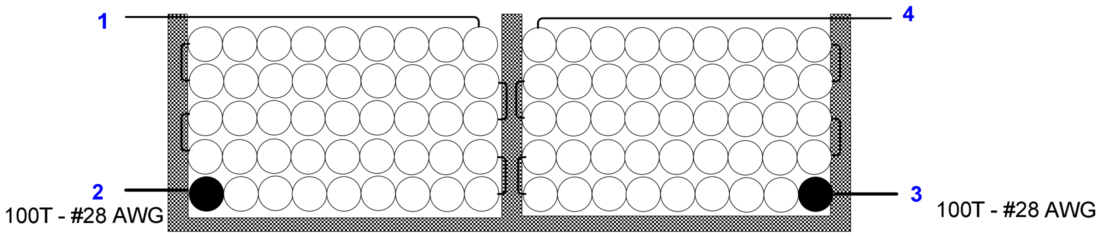
Item	Qty	Ref Des	Description	Mfg	Mfg Part Number
1	2	C1 C2	220 pF, Ceramic Y1	Vishay	440LT33-R
2	1	C3	100 nF, 275VAC, Film, X2	Vishay/Roederstein	F1772-410-2000
3	1	C4	100 µF, 400 V, Electrolytic, Low ESR, 630 mΩ, (16 x 40)	Nippon Chemi-Con	EKMX401ELL101ML40S
4	1	C5	1 nF, 100 V, Ceramic, X7R	Epcos	B37981M1102K000
5	1	C6	2.2 nF, 1 kV, Disc Ceramic	NIC Components Corp	NCD222K1KVY5FF
6	1	C7	2.2 nF, Ceramic, Y1	Vishay	440LD22-R
7	1	C8	100 nF, 50 V, Ceramic, Z5U, .2Lead Space	Kemet	C317C104M5U5TA
8	1	C9	47 µF, 16 V, Electrolytic, Gen Purpose, (5 x 11.5)	Panasonic	ECA-1CHG470
9	1	C10	22 µF, 50 V, Electrolytic, Very Low ESR, 340 mΩ, (5 x 11)	Nippon Chemi-Con	EKZE500ELL220ME11D
10	1	C11	22 pF, 1 kV, Disc Ceramic	Panasonic	ECC-D3A220JGE
11	1	C12	470 pF, 100 V, Ceramic, COG	AVX Corp	5NK471KOBAM
12	2	C13 C14	680 µF, 25 V, Electrolytic, Very Low ESR, 23 mΩ, (10 x 20)	Nippon Chemi-Con	EKZE250ELL681MJ20S
13	1	C15	330 µF, 25 V, Electrolytic, Very Low ESR, 56 mΩ, (8 x 15)	Nippon Chemi-Con	EKZE250ELL331MH15D
14	1	C16	47 nF, 50 V, Ceramic, Z5U	Epcos	B37982N5473M000
15	2	D1 D3	600 V, 1 A, Fast Recovery Diode, 200 ns, DO-41	On Semiconductor	1N4937RLG
16	2	D2 D4	1000 V, 1 A, Rectifier, DO-41	Vishay	1N4007-E3/54
17	1	D5	800 V, 1 A, Fast Recovery Diode, 500 ns, DO-41	Diodes Inc.	FR106
18	1	D6	200 V, 200 mA, Fast Switching, 50 ns, DO-35	Vishay	BAV20
19	2	D7 D8	80 V, 5 A, Schottky, DO-201AD	Vishay	SB580
20	1	F1	3.15 A, 250V,Fast, TR5	Wickman	37013150410
21	1	J1	5 Position (1 x 5) header, 0.156 pitch, Vertical	Molex	26-48-1055
22	1	J3	2 Position (1 x 2) header, 0.156 pitch, Vertical, Straight-Friction Lock Header	Molex	26-48-1025
23	1	L1	9 mH, Common Mode Choke	Custom	
24	1	L2	3.5 mm x 7.6 mm, 75 Ohms at 25 MHz, 22 AWG hole, Ferrite Bead	Fair-Rite	2743004112
25	1	L3	3.3 µH, 5.5 A	JW Miller	RL622-3R3K-RC
26	2	R1 R10	33 Ω, 5%, 1/4 W, Carbon Film	Yageo	CFR-25JB-33R
27	1	R2	100 kΩ, 5%, 1/2 W, Carbon Film	Yageo	CFR-50JB-100K
28	1	R3	3.9 MΩ, 5%, 1/2 W, Carbon Film	Yageo	CFR-50JB-3M9
29	1	R4	33 Ω, 5%, 1/8 W, Carbon Film	Yageo	CFR-12JB-33R
30	1	R5	20 Ω, 5%, 1/4 W, Carbon Film	Yageo	CFR-25JB-20R
31	1	R6	4.7 Ω, 5%, 1/4 W, Carbon Film	Yageo	CFR-25JB-4R7
32	1	R7	15.4 kΩ, 1%, 1/4 W, Metal Film	Yageo	MFR-25FBF-15K4
33	1	R8	10 Ω, 5%, 1/8 W, Carbon Film	Yageo	CFR-12JB-10R
34	1	R9	100 Ω, 5%, 1/4 W, Carbon Film	Yageo	CFR-25JB-100R
35	1	R11	1.2 kΩ, 5%, 1/4 W, Carbon Film	Yageo	CFR-25JB-1K2
36	1	R12	10 kΩ 5%, 1/4 W, Carbon Film	Yageo	CFR-25JB-10K

37	1	R13	42.2 kΩ 1%, 1/4 W, Metal Film	Yageo	MFR-25FBF-42K2
38	1	R14	10 kΩ, 1%, 1/4 W, Metal Film	Panasonic	ERO-S2PHF1002
39	1	RT1	NTC Thermistor, 10 Ω, 1.7 A	Thermometrics	CL-120
40	1	T1	Bobbin, EF25,(E25/13/7) Horizontal, 10 pins	Epcos	B66208-A1110-T1
41	1	U1	TOPSwitch-HX, TOP257EN, eSIP-7C	Power Integrations	TOP257EN
42	1	U2	Optocoupler, 35 V, CTR 80-160%, 4-DIP	Liteon	LTV-817A
43	1	U3	2.495 V Shunt Regulator IC, 2%, 0 to 70C, TO-92	On Semiconductor	TL431CLPG
44	1	VR2	28 V, 5%, 500 mW, DO-35	Diodes Inc	1N5255B-T

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

7 Inductor (L1) Electrical and Build Diagram





Core - HS72UU10.5 TDK
Bobbin - BUU10.5 PI_Korea
Inductance at 100kHz = 9mH

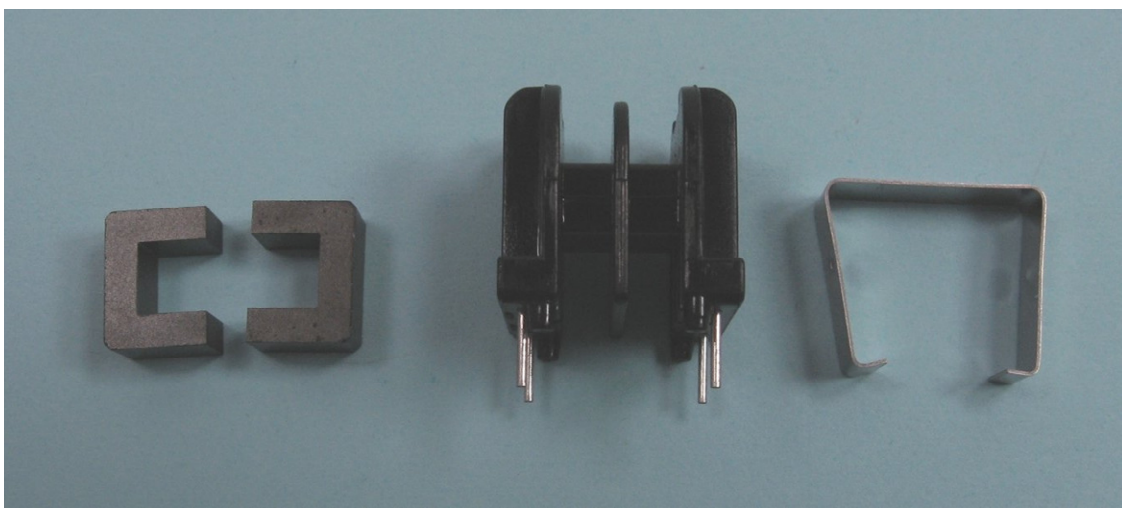


Figure Showing Core, Bobbin and Core Clip

Figure 4 – L1 Common-mode Inductor Specifications.

8 Transformer Specification

8.1 Electrical Diagram

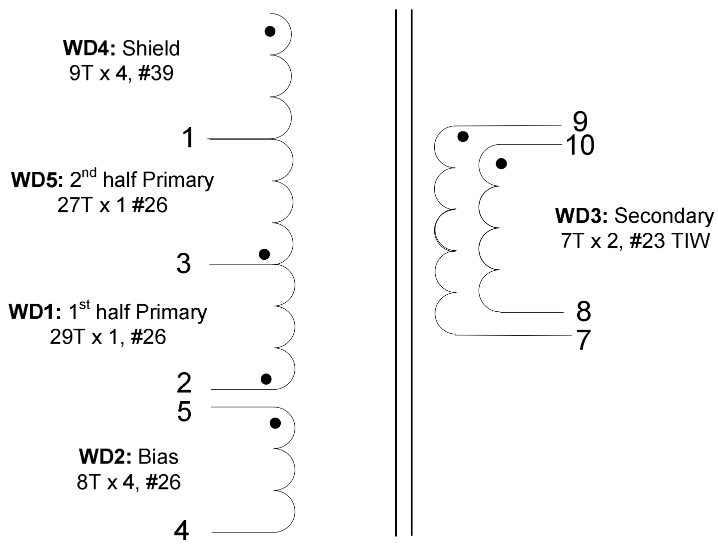


Figure 5 – Transformer Electrical Diagram.

8.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pins 1-5 to Pins 6-10	3000 VAC
Primary Inductance	Pins 1-2, all other windings open, measured at 100 kHz.	690 µH, ± 5%
Resonant Frequency	Pins 1-2, all other windings open	1.8 MHz (Min.)
Primary Leakage Inductance	Pins 1-2, with Pins 4-10 shorted, measured at 100 kHz.	13 µH (Max.)

8.3 Materials

Item	Description
[1]	Core: EF25 Gapped For ALG=220 nH/T^2
[2]	Bobbin: EF25 10 Pins Horizontal. *See Note Below*
[3]	Magnet Wire #26 AWG
[4]	Magnet Wire #30 AWG
[5]	Magnet Wire #39 AWG
[6]	Triple Insulated Wire: #23 AWG
[7]	Margin Tape 2 mm wide
[8]	Tape, 3M1350F-1 13.6 mm Wide
[9]	Tape, 3M1350F-1 15.6 mm Wide
[10]	Varnish

NOTE: The bobbin used on this transformer design does not meet safety requirements. To meet safety regulations using this design, replace it with bobbin YC-2504 from Ying Chin Co Ltd.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

8.4 Transformer Build Diagram

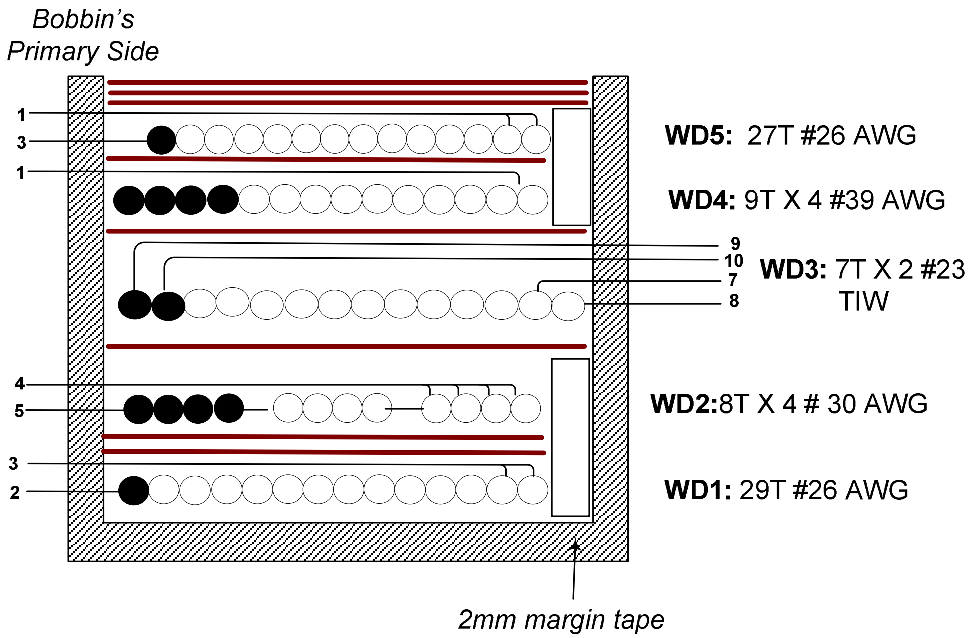


Figure 6 – Transformer Build Diagram.

8.5 Transformer Construction

Bobbin Preparation	Place bobbin (item [2]) on the winding machine with the primary-pins side oriented to the left-hand side.
Primary Margin	Apply 2 mm wide margin of tape (item [7]) on secondary side. Match height of primary and bias windings.
WD1 First Half Primary	Start at Pin 2. Wind 29 turns of item [3] from left to right in 1 layer. Finish on Pin 3.
Basic Insulation	Use two layers of item [8] for basic insulation.
WD2 Bias Winding	Starting at Pin 5, wind 8 quad-filar turns of item [4]. Wind from left to right and spread turns evenly across bobbin. Finish at Pin 4.
Basic Insulation	Use one layer of item [9] for basic insulation.
WD3 Secondary Winding	Start temporarily on pins 3 and 4. Wind 7 bi-filar turns of item [6] in 1 layer. Wind from left to right and finish on pins 7 and 8. Bend the starting leads toward the secondary side and connect them, respectively, to pins 9 and 10.
Basic Insulation	Use one layer of item [9] for basic insulation.
Primary Margin	Apply 2 mm wide margin of Item [7] on secondary side. Match height of shield and primary windings.
WD4 Shield	Start Temporarily on pin 3, wind from left to right 9 quad-filar turns of item [5]. Finish on Pin 1. Cut the starting terminal at the beginning of the winding.
Basic Insulation	Use one layer of item [8] for basic insulation.
WD5 Second Half Primary.	Start at Pin 3. Wind 27 turns of item [3] from left to right in 1 layer. Finish on Pin 1.
Outer Wrap	Wrap windings with 3 layers of tape (item [9]).
Final Assembly	Assemble and secure core halves. Varnish impregnate (item [10]).

9 Transformer Spreadsheets

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					Customer
VACMIN	90			Volts	Minimum AC Input Voltage
VACMAX	264			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	13.00			Volts	Output Voltage (main)
PO_AVG	35.00			Watts	Average Output Power
PO_PEAK			35.00	Watts	Peak Output Power
n	0.83			%/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	TOP257EN			Universal / Peak	115 Doubled/230 V
Chosen Device		*TOP257EN*	Power Out	119 W / 119 W	157 W
KI	0.37				External ILIMIT reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT)
ILIMITMIN_EXT			1.170	Amps	Use 1% resistor in setting external ILIMIT
ILIMITMAX_EXT			1.346	Amps	Use 1% resistor in setting external ILIMIT
Frequency (F)=132kHz, (H)=66kHz	F		F		Select 'H' for Half frequency – 66 kHz, or 'F' for Full frequency – 132 kHz
fS			132000	Hertz	TOPSwitch-HX Switching Frequency: Choose between 132 kHz and 66 kHz
fSmin			119000	Hertz	TOPSwitch-HX Minimum Switching Frequency
fSmax			145000	Hertz	TOPSwitch-HX Maximum Switching Frequency
High Line Operating Mode			FF		Full Frequency, Jitter enabled
VOR	108.00			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	0.59				Ripple to Peak Current Ratio (0.3 < KRP < 1.0 : 1.0< KDP<6.0)
PROTECTION FEATURES					
LINE SENSING					
VUV_STARTUP	95		95	Volts	Minimum DC Bus Voltage at which the power supply will start-up
VOV_SHUTDOWN			490	Volts	Typical DC Bus Voltage at which power supply will shut-down (Max)
RLS			4	M-ohms	Use two standard, 2.2 M-Ohm, 5% resistors in series for line sense functionality.
OUTPUT OVERVOLTAGE					

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

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% higher than peak primary current at VMAX
Overload Current Ratio at VMIN			1.06		Margin to current limit at low line.
ILIMIT_EXT_VMIN			1.09	A	Peak primary Current at VMIN
ILIMIT_EXT_VMAX			1.04	A	Peak Primary Current at VMAX
RIL			15.49	k-ohms	Current limit/Power Limiting resistor.
RPL			N/A	M-ohms	Resistor not required. Use RIL resistor only
Core Type	EF25		EF25		Core Type
Core		*EF25*		*P/N:*	PC40EF25-Z
Bobbin		*EF25_BOBBIN*		*P/N:*	*
AE			0.518	cm^2	Core Effective Cross Sectional Area
LE			5.78	cm	Core Effective Path Length
AL			2000	nH/T^2	Ungapped Core Effective Inductance
BW			15.6	mm	Bobbin Physical Winding Width
M	1.00			mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	2.00				Number of Primary Layers
NS	7		7		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			101	Volts	Minimum DC Input Voltage
VMAX			373	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.54		Maximum Duty Cycle (calculated at PO_PEAK)
IAVG			0.42	Amps	Average Primary Current (calculated at average output power)
IP			1.09	Amps	Peak Primary Current (calculated at Peak output power)
IR			0.64	Amps	Primary Ripple Current (calculated at average output power)
IRMS			0.58	Amps	Primary RMS Current (calculated at average output power)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			690	uHenries	Primary Inductance
LP Tolerance	5		5		Tolerance of Primary Inductance
NP			56		Primary Winding Number of Turns
NB			8		Bias Winding Number of Turns
ALG			220	nH/T^2	Gapped Core Effective Inductance
BM			2590	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)

BP	3362	Gauss	Peak Flux Density (BP<4200) at ILIMITMAX and LP_MAX. Note: Recommended values for adapters and external power supplies <=3600 Gauss
BAC	765	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur	1776		Relative Permeability of Ungapped Core
LG	0.26	mm	Gap Length (Lg > 0.1 mm)
BWE	27.2	mm	Effective Bobbin Width
OD	0.49	mm	Maximum Primary Wire Diameter including insulation
INS	0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA	0.42	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	441	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
Primary Current Density (J)	4.54	Amps/mm^2	Primary Winding Current density (3.8 < J < 9.75)
Lumped parameters			
ISP	8.71	Amps	Peak Secondary Current
ISRMS	4.28	Amps	Secondary RMS Current
IO_PEAK	2.69	Amps	Secondary Peak Output Current
IO	2.69	Amps	Average Power Supply Output Current
IRIPPLE	3.32	Amps	Output Capacitor RMS Ripple Current
CMS	856	Cmils	Secondary Bare Conductor minimum circular mils
AWGS	20	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS	0.81	mm	Secondary Minimum Bare Conductor Diameter
ODS	1.94	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS	0.56	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS			
VDRAIN	588	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS	60	Volts	Output Rectifier Maximum Peak Inverse Voltage
PIVB	69	Volts	Bias Rectifier Maximum Peak Inverse Voltage

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

10 Performance Data

All measurements performed at room temperature.

10.1 Efficiency

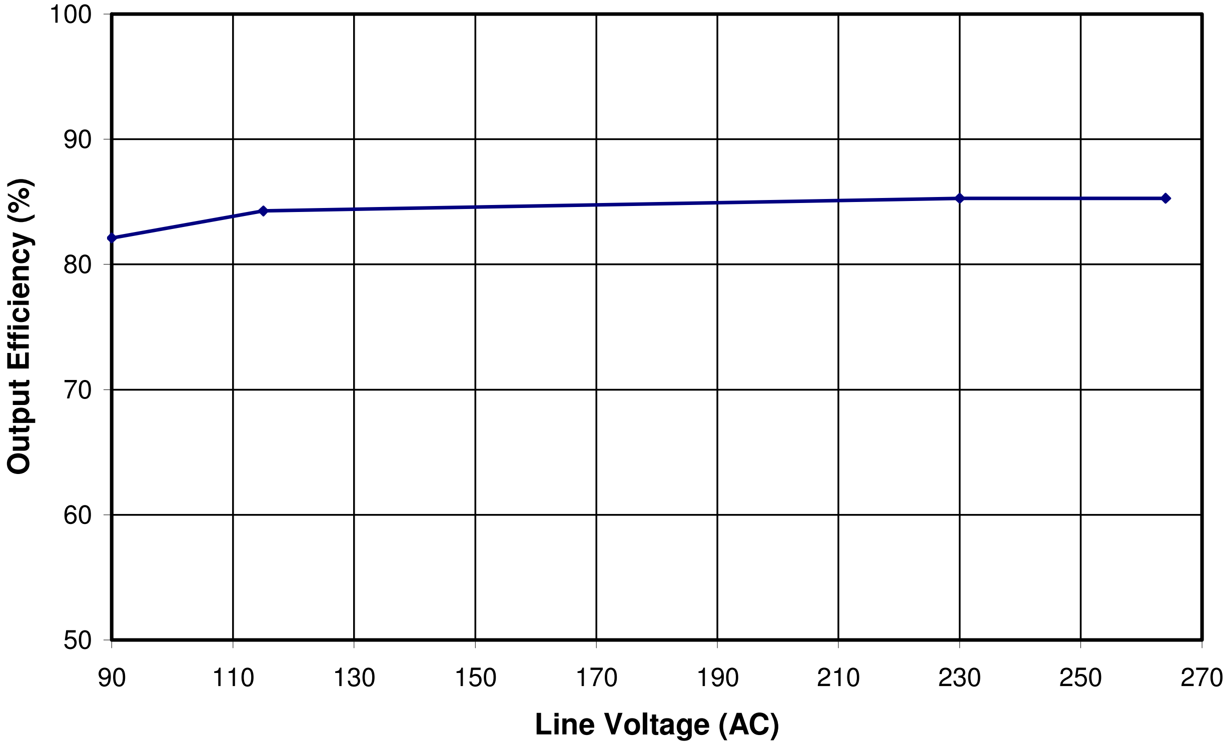


Figure 7 – Efficiency vs. Input Voltage, Room Temperature.

10.2 No-load Input Power

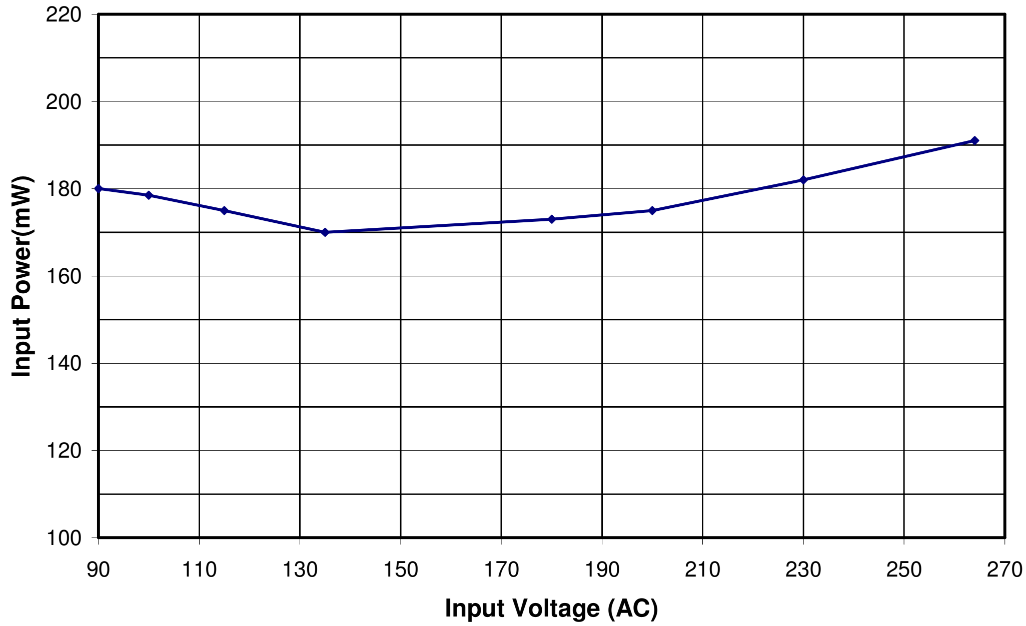


Figure 8 – Zero Load Input Power vs. Input Line Voltage, Room Temperature.

10.3 Available Standby Output Power

The chart below shows the available output power vs. line voltage, corresponding to input power levels of 0.5 W, 1 W, 2 W, and 3 W.

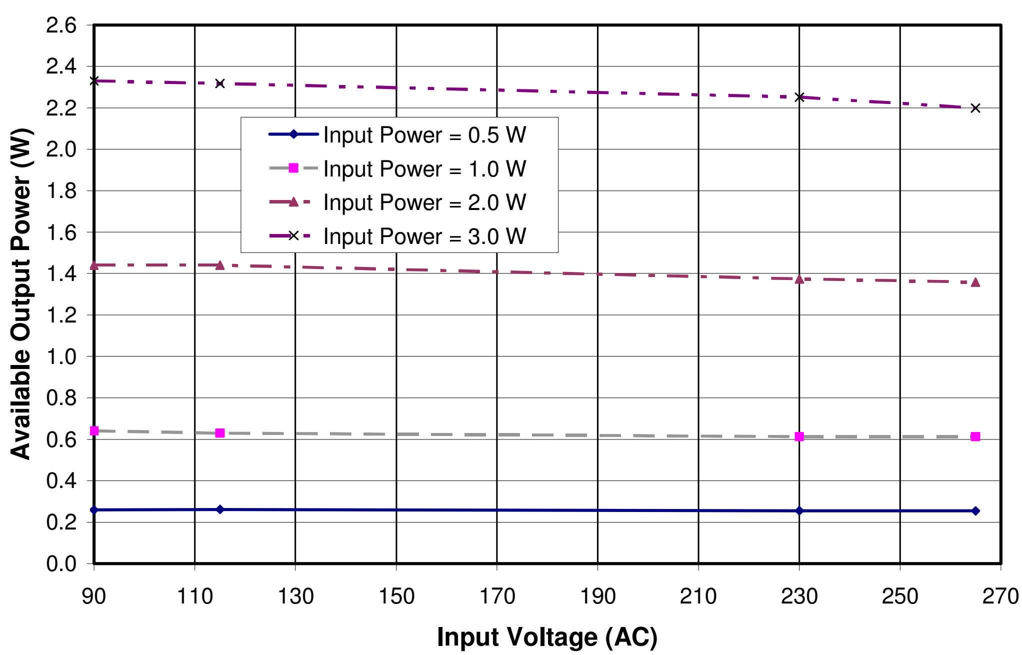


Figure 9 – Available Power at Standby.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

10.4 Regulation

10.4.1 Load

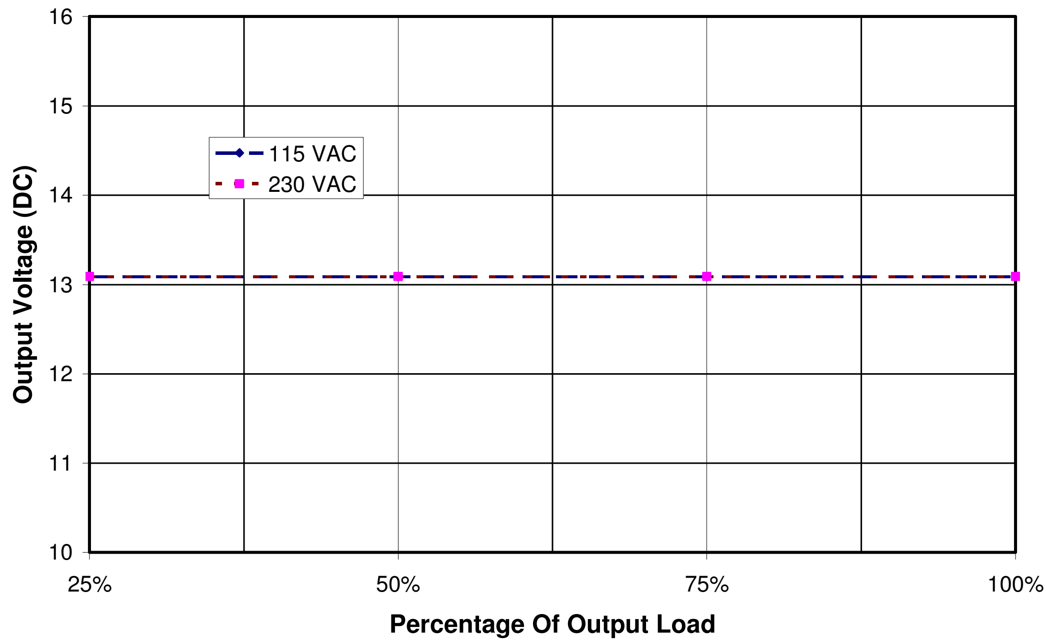


Figure 10 – Load Regulation, 25 °C.

10.4.2 Line

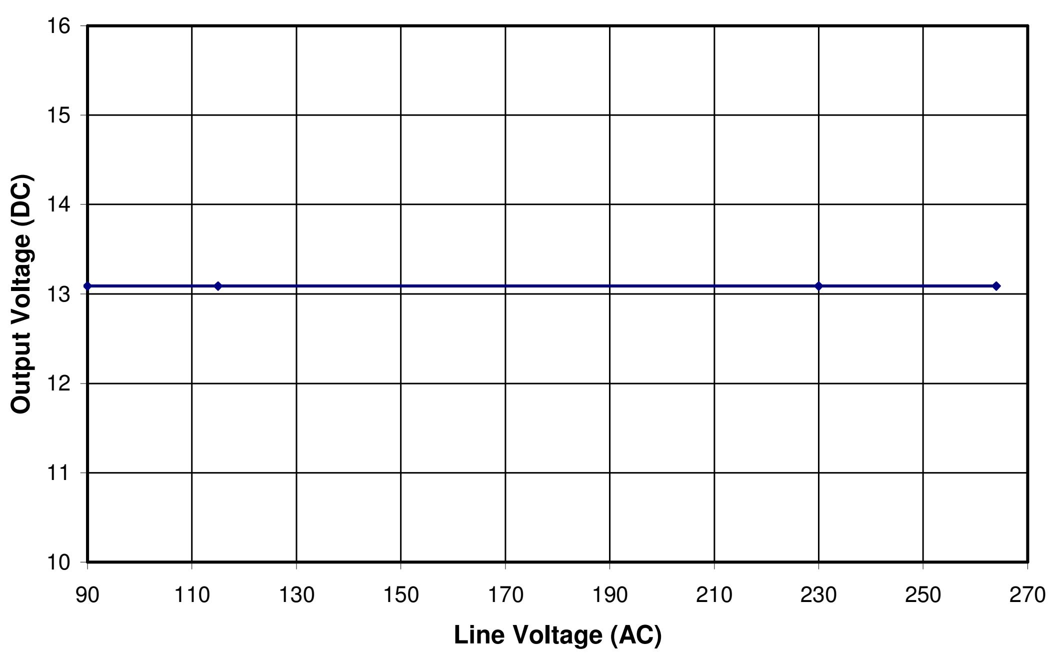


Figure 11 – Line Regulation, 25 °C, Full Load.

11 Thermal Performance

Thermal performance was measured by placing the power supply in a cardboard box, and placing the box inside a thermal chamber. The temperature in the chamber was adjusted to maintain an ambient temperature (inside the cardboard box) of 50 °C. The power supply was allowed to run for approximately 2 hours to stabilize before data was collected.

To measure U1's temperature, a T-type thermocouple was attached to its exposed pad, close to the heatsink of the device. The output diode (D7 and D8) temperatures were measured by soldering a T-type thermocouple to the cathode close to the plastic case of each diode. Temperatures for T1 and L1 were measured by attaching a T-type thermocouple firmly to their respective cores.

Item	Temperature (°C)	Temperature (°C)
	90 VAC	264 VAC
Ambient Temperature	50	50
T1	89	86
U1	94	79
L1	98	60
D7	106	103
D8	106	103

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

12 Waveforms

12.1 Drain Voltage and Current, Normal Operation

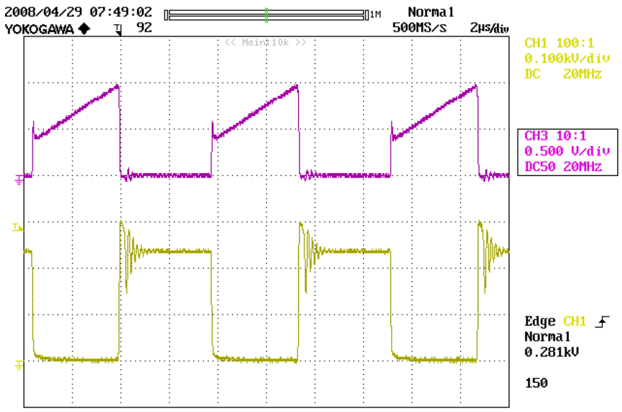


Figure 12 – 90 VAC, Full Load.
Upper: I_{DRAIN}, 0.5 A/div.
Lower: V_{DRAIN}, 100 V, 2 µs/div.

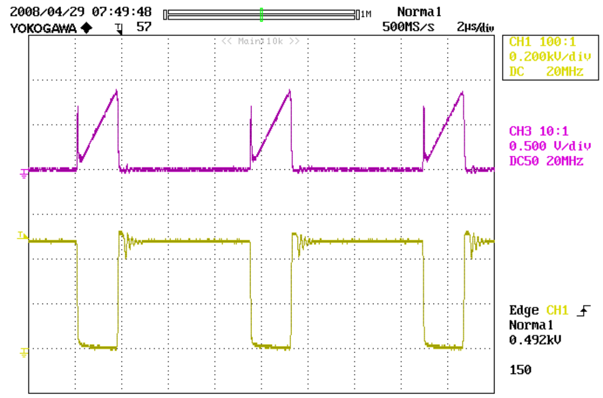


Figure 13 – 264 VAC, Full Load.
Upper: I_{DRAIN}, 0.5 A/div.
Lower: V_{DRAIN}, 200 V/div, 2 µs/div.

12.2 Output Voltage Start-up Profile

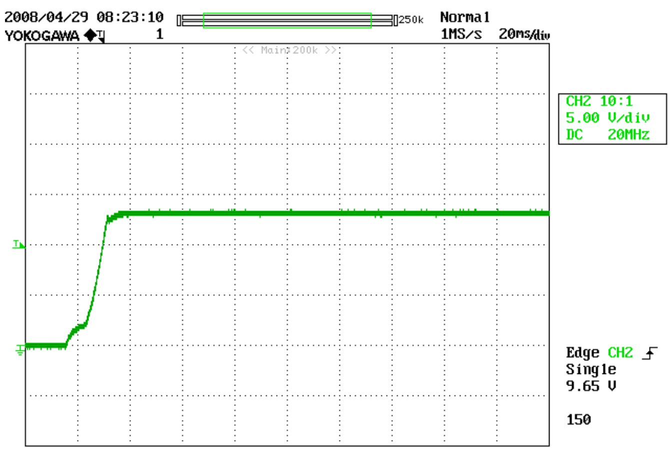


Figure 14 – Start-up Profile, 115 VAC
5 V, 20 ms/div. Resistive Load.

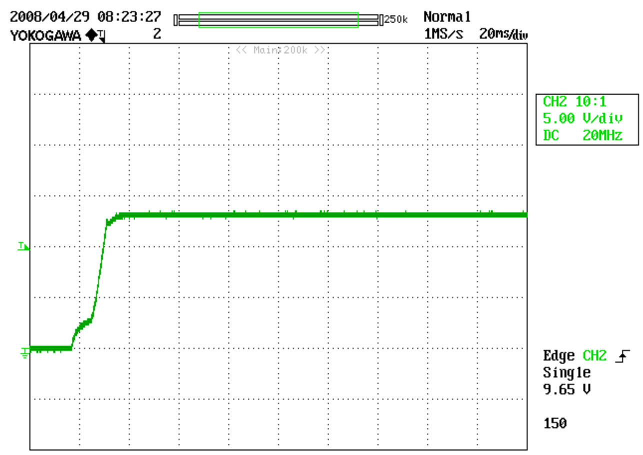


Figure 15 – Start-up Profile, 230 VAC
5 V, 20 ms/div.

12.3 Drain Voltage and Current Start-up Profile

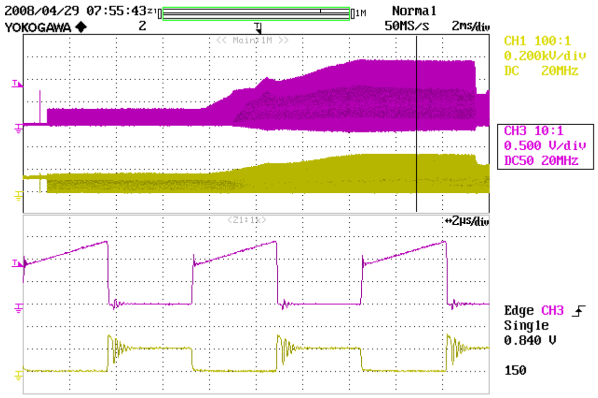


Figure 16 – 90 VAC Input and Maximum Load.
Upper: I_{DRAIN}, 0.5 A/div.
Lower: V_{DRAIN}, 200 V. 2 ms/div and 2 µs /div.

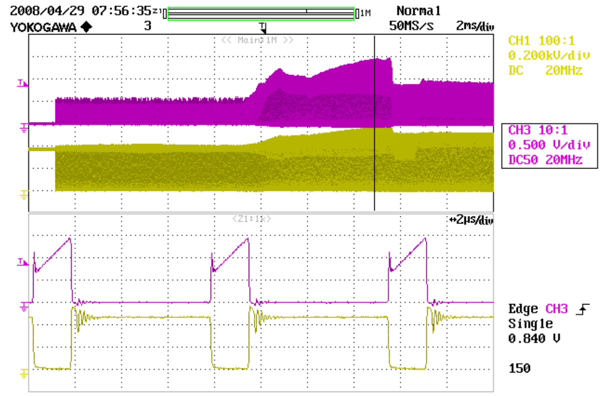


Figure 17 – 265 VAC Input and Maximum Load.
Upper: I_{DRAIN}, 0.5 A/div.
Lower: V_{DRAIN}, 200 V. 2 ms/div and 2 µs/div.

12.4 Load Transient Response (50% to 100% Load Step)

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

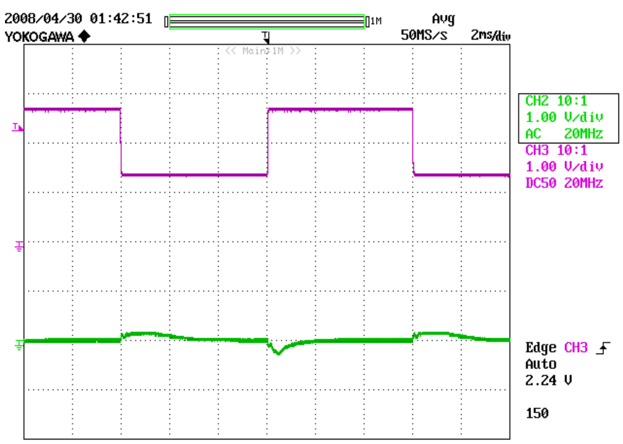


Figure 18 – Transient Response, 90 VAC, 50%-100%-50% Load Step.
Upper: Load Current, 1 A/div.
Lower: Output Voltage, 1 V, 2 ms/div.

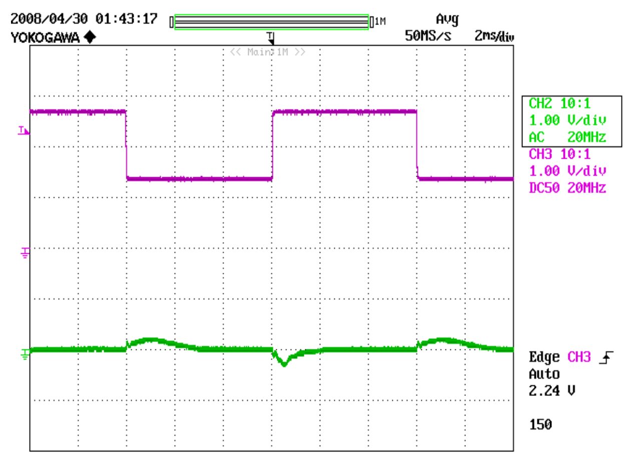


Figure 19 – Transient Response, 115 VAC, 50%-100%-50% Load Step
Upper: Load Current, 1 A/ div.
Lower: Output Voltage, 1 V, 2 ms/div.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

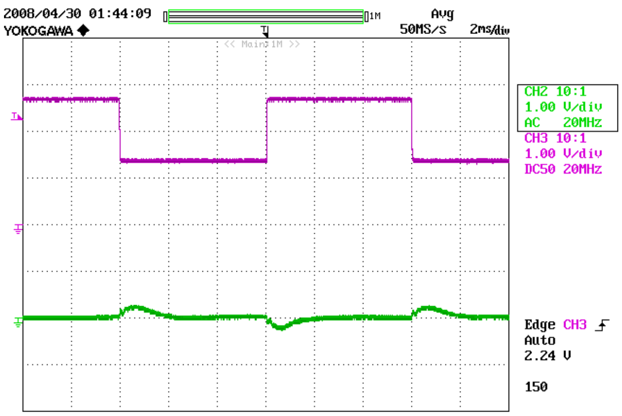


Figure 20 – Transient Response, 230 VAC, 50%-100%-50% Load Step.
Upper: Load Current, 1 A/div.
Lower: Output Voltage, 1 V, 2 ms/div.

12.5 Open-loop Protection

Optocoupler U2A was shorted, which opened the control loop. The output voltage was measured at no load (which is the worst-case condition for this test). Results are shown below.

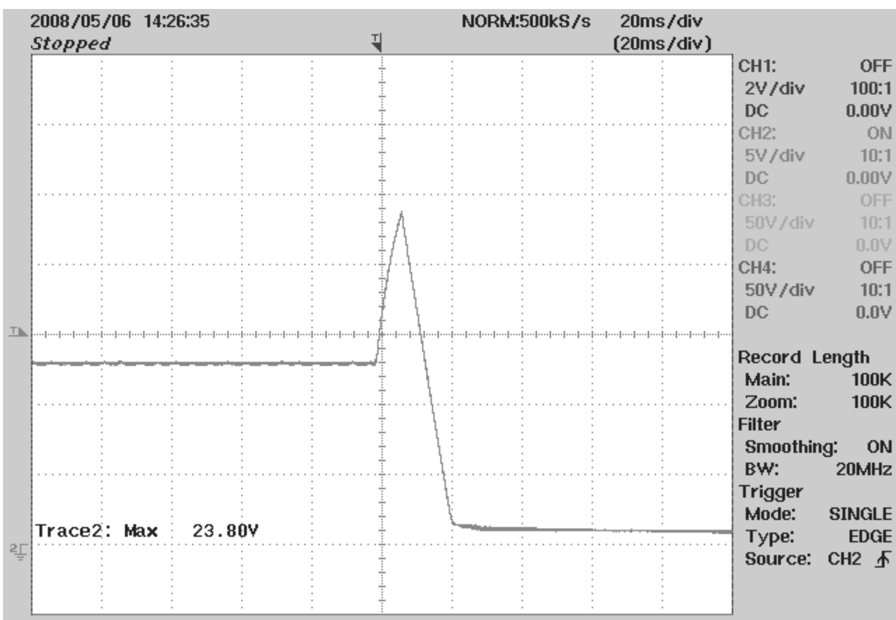


Figure 21 – Output Voltage, Open-loop Test. Vin = 264 VAC.

12.6 Output Ripple Measurements

12.6.1 Ripple Measurement Technique

For DC output ripple measurements, use a modified oscilloscope test probe to reduce spurious signals. Details of the probe modification are provided in figures below.

Tie two capacitors in parallel across the probe tip of the 4987BA probe adapter. Use a 0.1 µF/50 V ceramic capacitor and a 1.0 µF/50 V aluminum-electrolytic capacitor. The aluminum-electrolytic capacitor is polarized, so always maintain proper polarity across DC outputs.

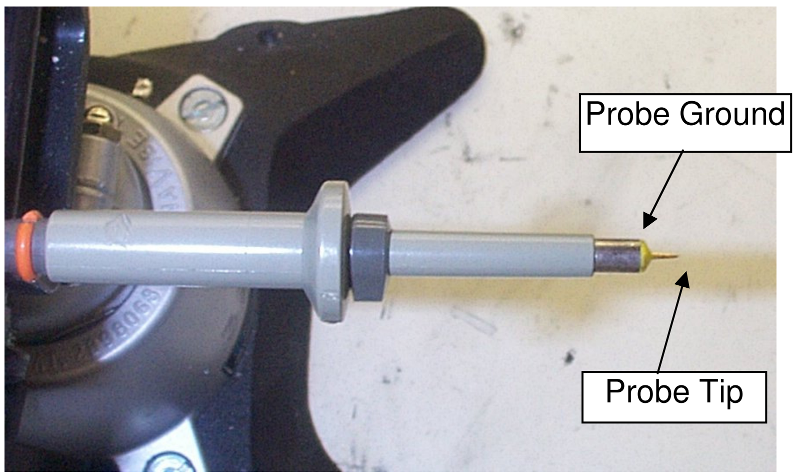


Figure 22 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

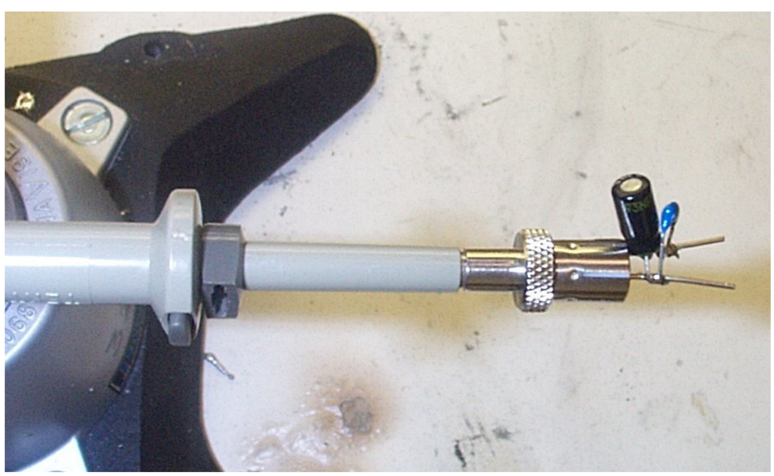


Figure 23 – Oscilloscope Probe with Probe Master 4987BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

12.6.2 Measurement Results

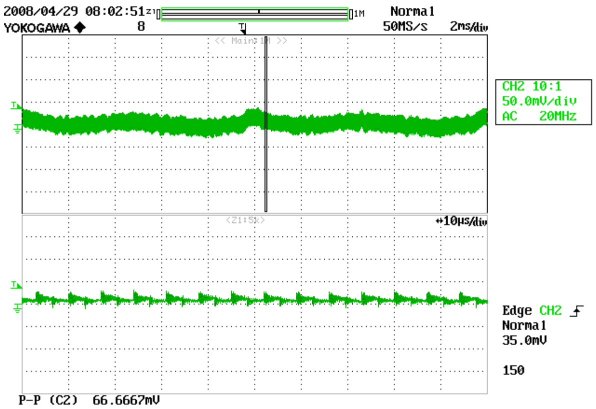


Figure 24 – Ripple, 90 VAC, Full Load.
2 ms, 50 mV/div.

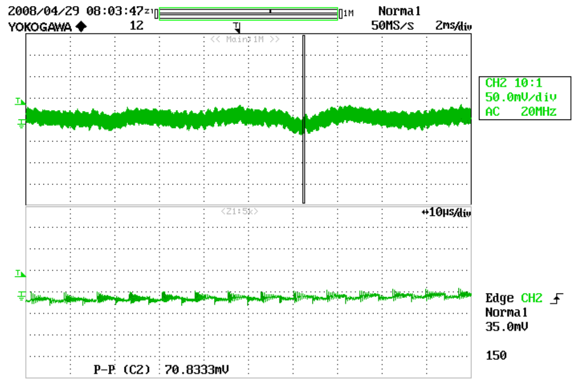


Figure 25 – Ripple, 115 VAC, Full Load.
2 ms, 50 mV/div.

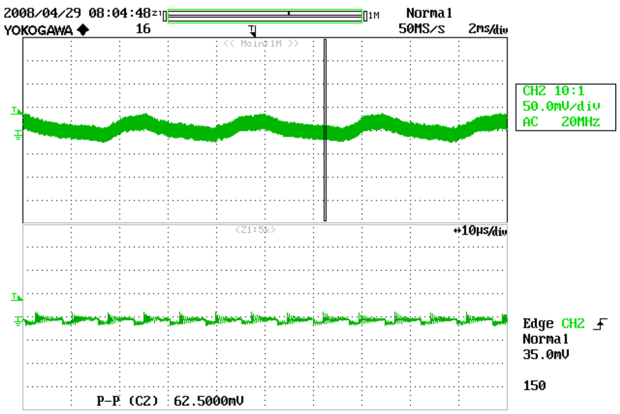


Figure 26 – Ripple, 230 VAC, Full Load.
2 ms, 50 mV/div.

13 Control Loop Measurements

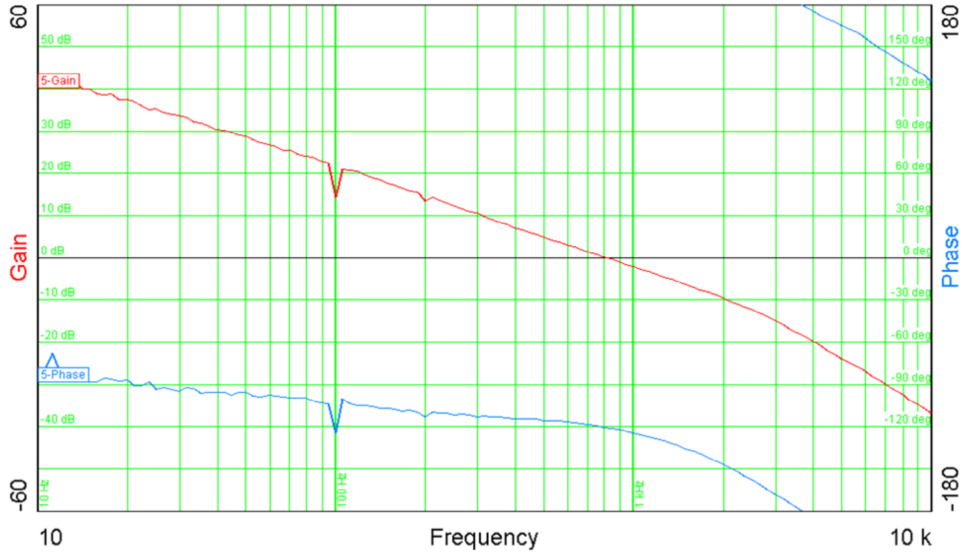


Figure 27 – Gain-phase Plot, 90 VAC, Maximum Steady-state Load.
Vertical Scale: Gain = 10 dB/div, Phase = 30 °/div.
Crossover Frequency = 800 Hz, Phase Margin = 60°.

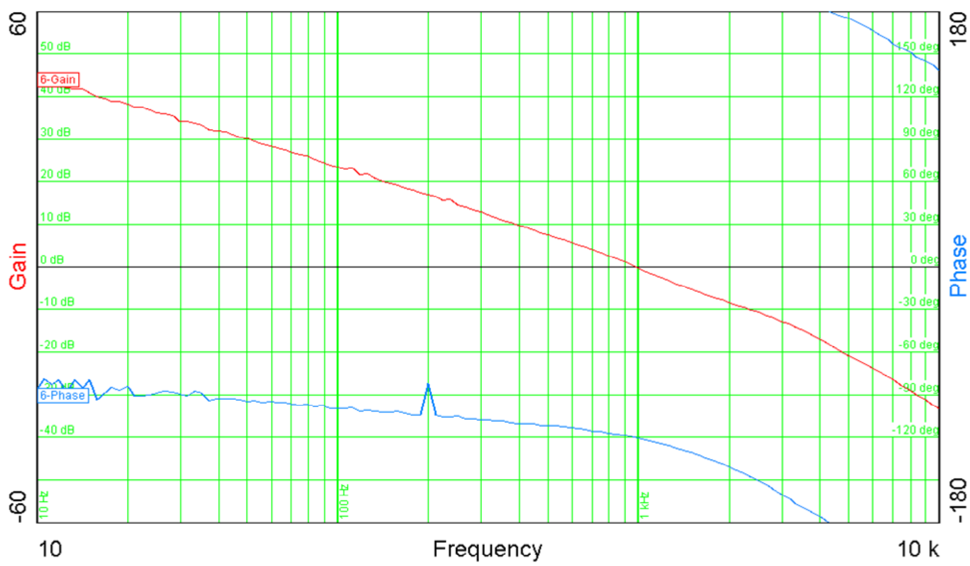


Figure 28 – Gain-phase Plot, 115 VAC, Maximum Steady-state Load.
Vertical Scale: Gain = 10 dB/div, Phase = 30 °/div.
Crossover Frequency = 1.0 kHz, Phase Margin = 60°.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

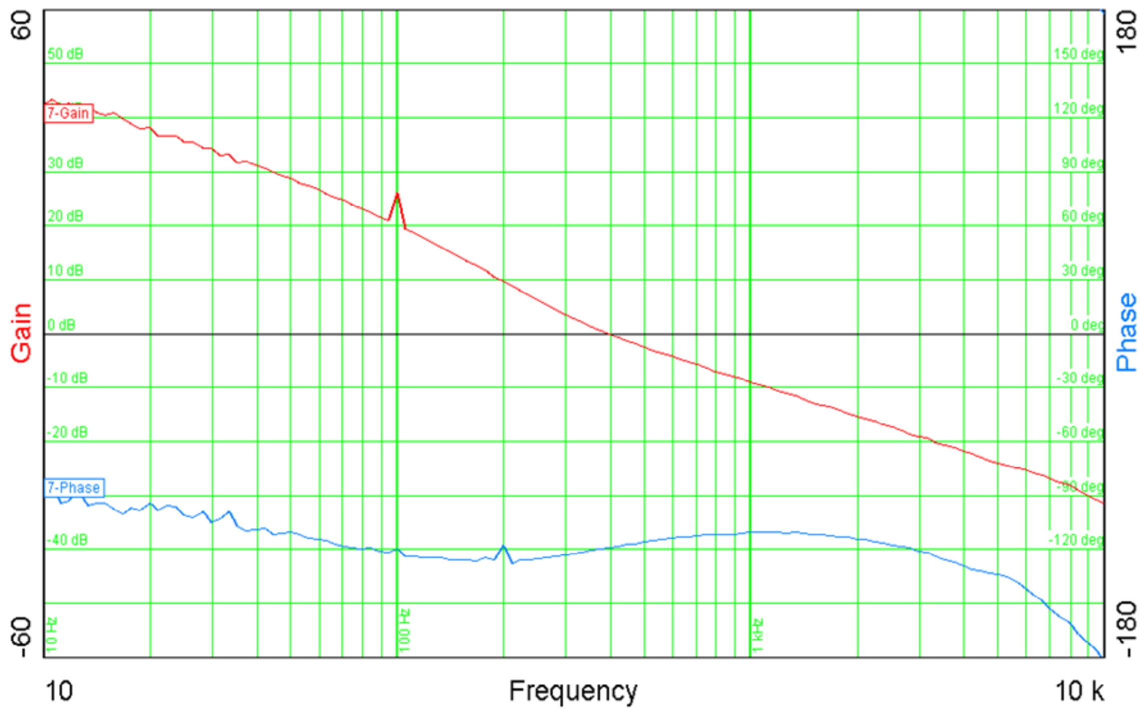


Figure 29 – Gain-phase Plot, 230 VAC, Maximum Steady-state Load.
Vertical Scale: Gain = 10 dB/div, Phase = 30 °/div.
Crossover Frequency = 400 Hz, Phase Margin = 60°.

These results show the supply is always stable. The worst case phase margin is 60°. The gain margin is in excess of 10 dB.

14 Line Surge

A single test unit underwent IEC61000-4-5 differential input line 1.2/50 µs surge testing. The input voltage was set to 230 VAC with a 60 Hz frequency. The output was driving a full load, and operation was verified following each surge event.

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)	Generator Output Impedance (Ω)
+250	230	L to N	90	Pass	2
-250	230	L to N	270	Pass	2
+500	230	L to N	90	Pass	2
-500	230	L to N	270	Pass	2
+750	230	L to N	90	Pass	2
-750	230	L to N	270	Pass	2
+1000	230	L to N	90	Pass	2
-1000	230	L to N	270	Pass	2
+500	230	L and N to PE	90	Pass	12
-500	230	L and N to PE	270	Pass	12
+1000	230	L and N to PE	90	Pass	12
-1000	230	L and N to PE	270	Pass	12
+1500	230	L and N to PE	90	Pass	12
-1500	230	L and N to PE	270	Pass	12
+2000	230	L and N to PE	90	Pass	12
-2000	230	L and N to PE	270	Pass	12

The unit passed under all test conditions.

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

15 Conducted EMI

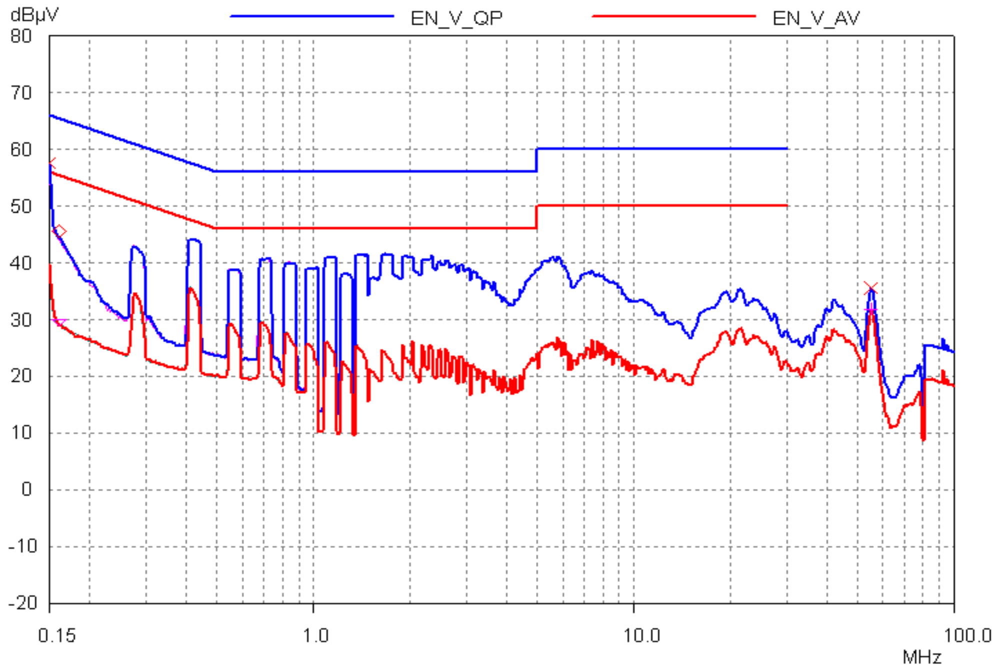


Figure 30 – Conducted EMI, Maximum Steady-state Load, 115 VAC, 60 Hz, EN55022 B Limits.

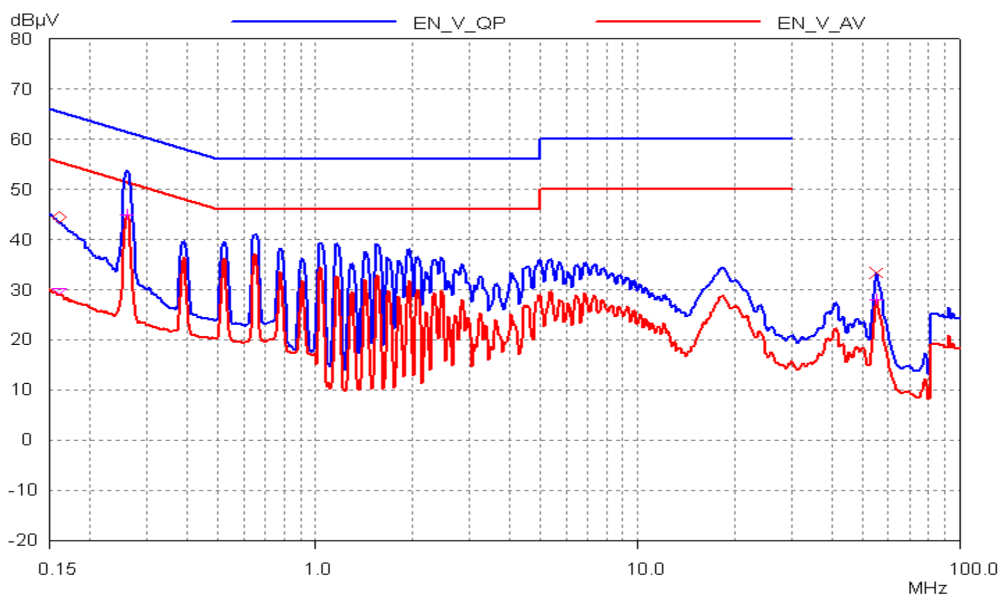


Figure 31 – Conducted EMI, Maximum Steady-state Load, 230 VAC, 60 Hz, EN55022 B Limits.

16 Revision History

Date	Author	Revision	Description and changes	Reviewed
24-Jun-08	SGK	1.0	Initial Release	JD

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

For the latest updates, visit our website: *www.powerint.com*

Power Integrations Worldwide Sales Support Locations

WORLD HEADQUARTERS
5245 Hellyer Avenue
San Jose, CA 95138, USA.
Main: +1-408-414-9200
Customer Service:
Phone: +1-408-414-9665
Fax: +1-408-414-9765
e-mail: usasales@powerint.com

GERMANY
Rueckertstrasse 3
D-80336, Munich
Germany
Phone: +49-89-5527-3911
Fax: +49-89-5527-3920
e-mail: eurosales@powerint.com

JAPAN
Kosei Dai-3 Bldg.,
2-12-11, Shin-Yokohama,
Kohoku-ku, Yokohama-shi,
Kanagawa 222-0033
Phone: +81-45-471-1021
Fax: +81-45-471-3717
e-mail: japansales@powerint.com

TAIWAN
5F, No. 318, Nei Hu Rd., Sec. 1
Nei Hu Dist.
Taipei, Taiwan 114, R.O.C.
Phone: +886-2-2659-4570
Fax: +886-2-2659-4550
e-mail: taiwansales@powerint.com

CHINA (SHANGHAI)
Rm 1601/1610, Tower 1,
Kerry Everbright City
No. 218 Tianmu Road West,
Shanghai, P.R.C. 200070
Phone: +86-21-6354-6323
Fax: +86-21-6354-6325
e-mail: chinasales@powerint.com

INDIA
#1, 14th Main Road
Vasanthanagar
Bangalore-560052 India
Phone: +91-80-41138020
Fax: +91-80-41138023
e-mail: indiasales@powerint.com

KOREA
RM 602, 6FL
Korea City Air Terminal B/D, 159-6
Samsung-Dong, Kangnam-Gu,
Seoul, 135-728, Korea
Phone: +82-2-2016-6610
Fax: +82-2-2016-6630
e-mail: koreasales@powerint.com

UNITED KINGDOM
1st Floor, St. James's House
East Street, Farnham
Surrey, GU9 7TJ
United Kingdom
Phone: +44 (0) 1252-730-141
Fax: +44 (0) 1252-727-689
e-mail: eurosales@powerint.com

CHINA (SHENZHEN)
Rm A, B & C 4th Floor, Block C,
Electronics Science and Technology Building, 2070
Shennan Zhong Rd,
Shenzhen, Guangdong,
China, 518031
Phone: +86-755-8379-3243
Fax: +86-755-8379-5828
e-mail: chinasales@powerint.com

ITALY
Via De Amicis 2
20091 Bresso MI – Italy
Phone: +39-028-928-6000
Fax: +39-028-928-6009
e-mail: eurosales@powerint.com

SINGAPORE
51 Newton Road,
#15-08/10 Goldhill Plaza,
Singapore, 308900
Phone: +65-6358-2160
Fax: +65-6358-2015
e-mail: singaporesales@powerint.com

APPLICATIONS HOTLINE
World Wide +1-408-414-9660

APPLICATIONS FAX
World Wide +1-408-414-9760