DESIGN EXAMPLE REPORT

Title	***0.75 W Anti-Tampering Energy Meter Power Supply Using LNK363DN***
Specification	85 VAC – 265 VAC Input, 5 V, 150 mA Output
Application	Tamper Resistant Energy Meter Supply
Author	Power Integrations Applications Engineering
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Summary and Features

- Powdered iron core material increases immunity from tampering
  - Normal operation maintained under influence of external magnetic fields
- Low operating flux density (400 Gauss) for low core losses (<40 mW)
- High efficiency (~ 50 %) at full load
- Maximized power available from input (2 W, 10 VA limit per IEC1036)
- Eliminated need for large output capacitor or second higher output voltage

PATENT INFORMATION

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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 engineering report describes a power supply design which utilizes the LinkSwitch-XT device LNK363DN. This power supply is ideal for use in tamper-resistant energy meters. The transformer uses a powdered-iron core, which makes core saturation, and therefore supply failure by external magnetic influence, much less likely.

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

Figure 1 – Populated Circuit Board Photograph.

2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	85		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)				0.3	W	
Output						
Output Voltage 1	V_{OUT1}	4.5	5	5.5	V	± 10%
Output Ripple Voltage 1	$V_{RIPPLE1}$			300	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}		150		mA	
Total Output Power						
Continuous Output Power	P_{OUT}		0.75	0	W	
Efficiency						
Full Load	η	46.3			%	Measured at P_{OUT} 25 °C, 265 VAC
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950 / UL1950 Class II				
Ambient Temperature	T_{AMB}	0		50	°C	Free convection, sea level

3 Schematic

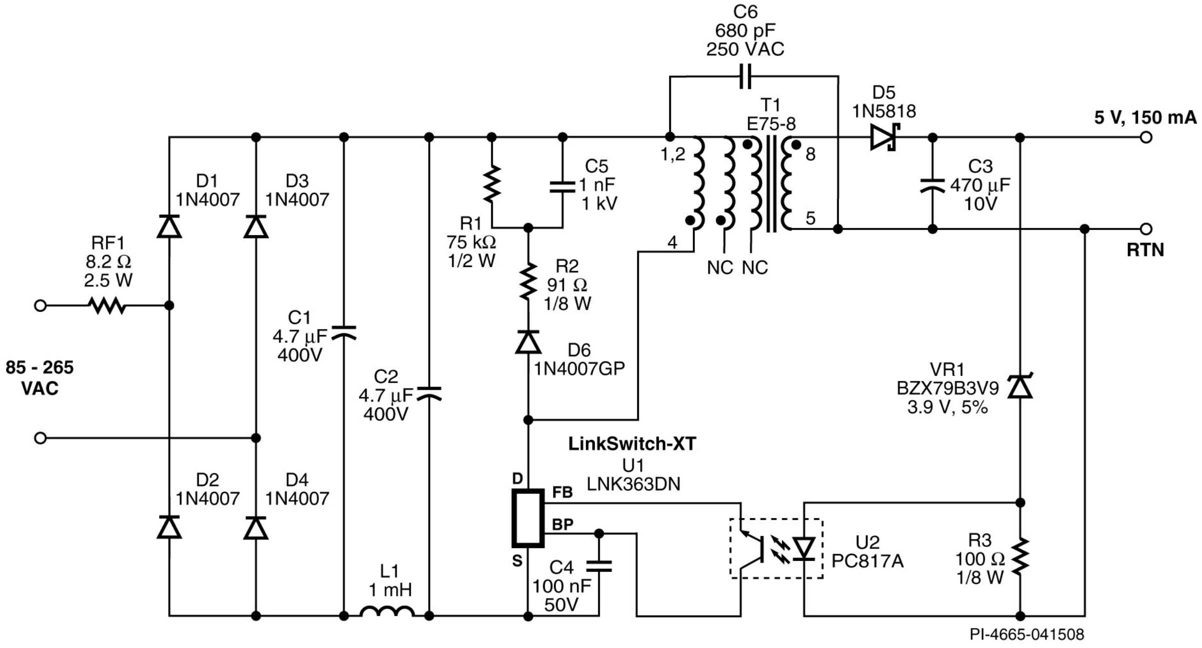


Figure 2 – Schematic.

4 Circuit Description

4.1 Introduction

The power supply shown in Figure 2 employs the LNK363DN in a flyback topology to generate a 5 V, 150 mA isolated output. The transformer, by design, provides sufficient inductance to deliver the output power even if the core has been forced into a soft saturation (which results from attempted meter tampering through the application of a large external magnetic field). The powdered iron core material has a softer, less abrupt saturation characteristic than ferrite-based core materials. Under a large external magnetic field the ferrite-based core reaches hard saturation (the rate of saturation is very high), a condition of possible irreparable damage, while the powdered-iron core remains in a steady, soft-saturation state (at a low saturation rate), still able to deliver power and to recover.

Using PI XIs Designer software, a large primary inductance tolerance value was chosen (in this case 40%) to ensure the transformer's inductance remained within operating specifications if the core entered a soft-saturation state. The software provides design parameters, such as the transformer specifications, based on both this tolerance value and the lowest operating transformer inductance value. The latter reflects worst-case conditions to ensure operation during core soft-saturation states.

4.2 Input Filtering and EMI

Diodes D1 through D4 rectify the AC input. Capacitors C1 and C2 filter the rectified DC signal. Inductor L1 forms a pi (π) filter with capacitors C1 and C2 which attenuates differential-mode conducted EMI. The primary shield and cancellation windings on the transformer attenuate common-mode noise by reducing capacitive coupling (via the transformer core) to the secondary.

4.3 Device Operation and Feedback

Using On/Off control, U1 skips switching cycles (based on feedback to its FB pin) to regulate the output voltage. Current greater than 49 µA going into the FB pin causes a low-logic level (disable) condition. The FB pin's state is sampled at the beginning of each cycle; if high, the power MOSFET is turned on (enabled) for that cycle. Otherwise the power MOSFET remains off (disabled).

The output voltage is determined by the series sum of two voltages: zener diode VR1's reference voltage (3.9 V) and the voltage across the LED in U2 (1.1 V). Resistor R3 provides a constant bias current for VR1.

4.4 Design Features

Energy meters with switching power supplies can be tampered with by applying a large external magnetic field to them. The external field couples into and saturates the power

supply’s transformer core, causing destructive failure in the MOSFET due to over-current conditions. Devices from Power Integrations have a fast current limit to protect the internal MOSFET; however, when this current limit is exceeded, the output falls out of regulation, stopping the meter.
Several solutions exist to disable such tampering, such as using an air-core transformer or a standard ferrite-core transformer with sufficient shielding, in the power-supply design. An air core transformer never saturates. However, it needs a very large number of turns to achieve the necessary inductance. The resulting high copper losses and leakage inductance lead to extremely poor efficiency (~20%). A standard ferrite-core transformer can be used with magnetic shielding material to box the transformer, shunting flux away from the core and preventing saturation. This solution has the disadvantage of added cost and complexity; a custom shield is needed for each new design.

The power-supply design using the LNK363DN solves these issues by replacing the transformer’s ferrite core with one having a high-reluctance powdered iron material with a distributed air gap. The latter core has very low relative permeability (μ_r between 10 and 35). Powdered iron cores have a much higher saturation flux density than do ferrite cores, (15,000 Gauss (1.5 T) for the former compared to 4,000 gauss (0.4 T) for the latter), and have much softer saturation characteristics.

The transformer used in this design underwent magnetic susceptibility tests using strong electromagnets as well as permanent earth magnets. One pole of the magnet was placed directly on top of the core, resulting in no core saturation. See Figure 18 for a drain current waveform under influence of the applied external field.

5 PCB Layout

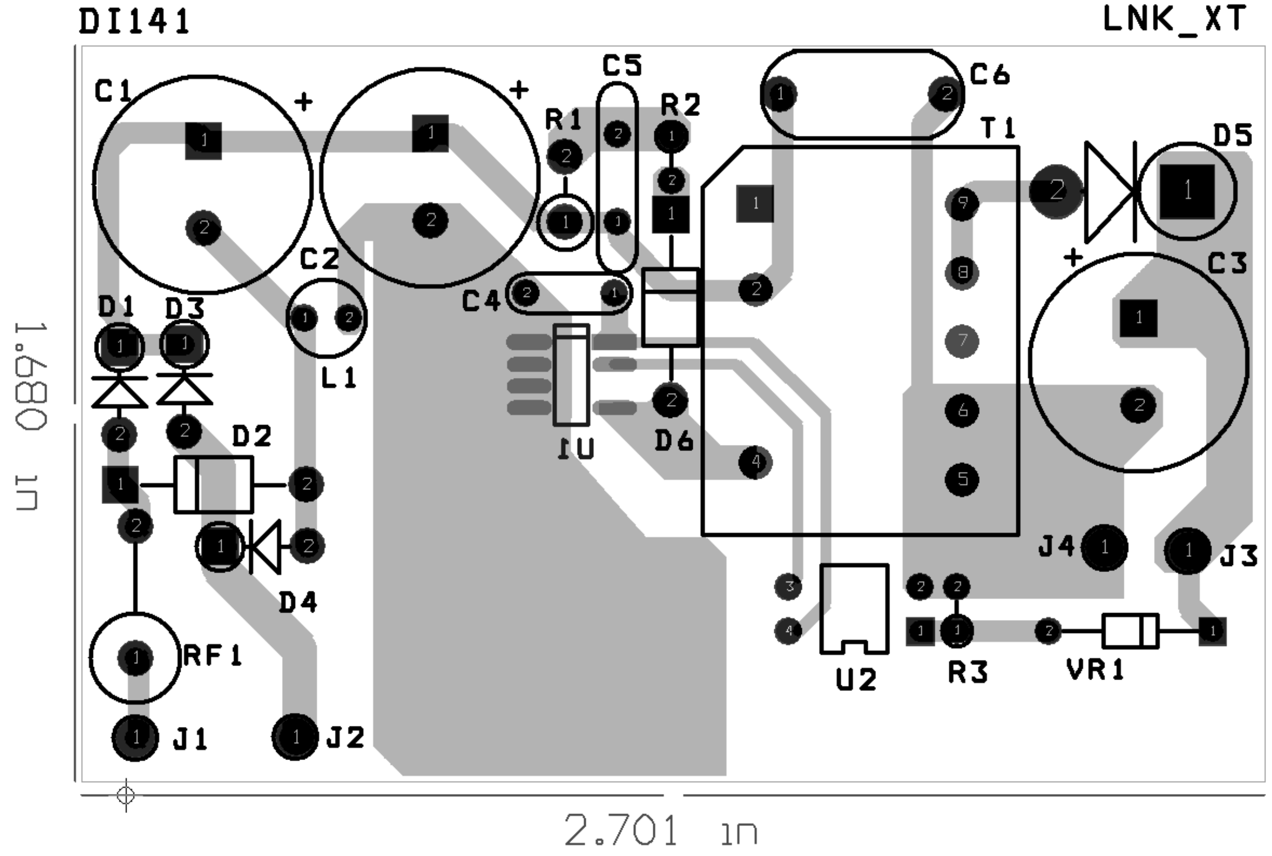


Figure 3 – Printed Circuit Layout.

6 Bill of Materials

Item	Qty	Ref	Description	P/N	Manufacturer
1	2	C1 C2	4.7 µF, 400 V, Electrolytic, (8 x 11.5)	SHD400WV 4.7uF	Sam Young
2	1	C3	470 µF, 10 V, Electrolytic, Low ESR, 120 mΩ, (8 x 12)	ELXZ100ELL471MH 12D	Nippon Chemi-Con
3	1	C4	100 nF, 50 V, Ceramic, Z5U, .2Lead Space	C317C104M5U5TA	Kemet
4	1	C5	1 nF, 1 kV, Disc Ceramic	ECK-D3A102KBP	Panasonic
5	1	C6	680 pF, Ceramic, Y1	440LT68-R	Vishay
6	4	D1 D2 D3 D4	1000 V, 1 A, Rectifier, DO-41	1N4007-E3/54	Vishay
7	1	D5	30 V, 1 A, Schottky, DO-41	1N5818	Vishay
8	1	D6	1000 V, 1 A, Rectifier, Glass Passivated, 2 us, DO-41	1N4007GP	Vishay
9	4	J1 J2 J3 J4	PCB Terminal Hole, 22 AWG	N/A	N/A
10	1	L1	1 mH, 0.15 A, Ferrite Core	SBCP-47HY102B	Tokin
11	1	R1	75 kΩ, 5%, 1/2 W, Carbon Film	CFR-50JB-75K	Yageo
12	1	R2	91 Ω, 5%, 1/8 W, Carbon Film	CFR-12JB-91R	Yageo
13	1	R3	100 Ω, 5%, 1/8 W, Carbon Film	CFR-12JB-100R	Yageo
14	1	RF1	8.2 Ω, 2.5 W, Fusible/Flame Proof Wire Wound	CRF253-4 5T 8R2	Vitrohm
15	1	T1	Bobbin, E75-8, Vertical, 9 pins, Extended Creepage	E75-8	Micrometals
16	1	U1	LinkSwitch-XT, LNK363DN, SO-8-DN	LNK363DN	Power Integrations
17	1	U2	Opto coupler, 35 V, CTR 80-160%, 4-DIP	LTV-817A	Liteon
18	1	VR1	3.9 V, 500 mW, 5%, DO-35	BZX79B3V9	Vishay

7 Transformer Specification

7.1 Electrical Diagram

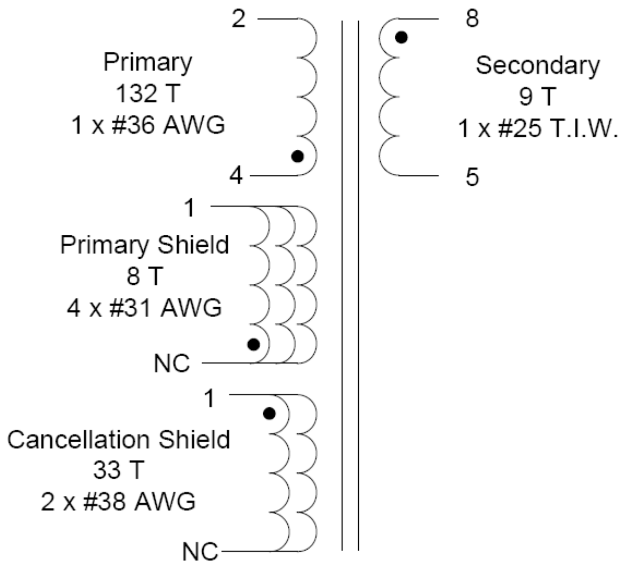


Figure 4 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pin 2 to Pin 4.	3000 VAC
Primary Inductance	Pins 2-4, all other windings open, measured at 100 kHz, 0.4 VRMS.	595 μH, ±10%
Resonant Frequency	Pins 2-4, all other windings open.	900 kHz (Min.)
Primary Leakage Inductance	Pins 2-4, with Pins 6-8 shorted, measured at 100 kHz, 0.4 VRMS.	80 μH (Max.)

7.3 Materials

Item	Description
[1]	Core: E75-8 powdered iron material with A_L of 34 nH/t^2, Manufacturer – Micrometals.
[2]	Bobbin: US LAM EI187, 9 pin.
[3]	Magnet Wire: 38 AWG, Double Coated.
[4]	Magnet Wire: 31 AWG, Double Coated.
[5]	Magnet Wire: 36 AWG, Double Coated.
[6]	Triple Insulated Wire: 25 AWG.
[7]	Tape: 1 mil base polyester film, 18mm wide.
[8]	Dip Varnish.

7.4 Transformer Build Diagram

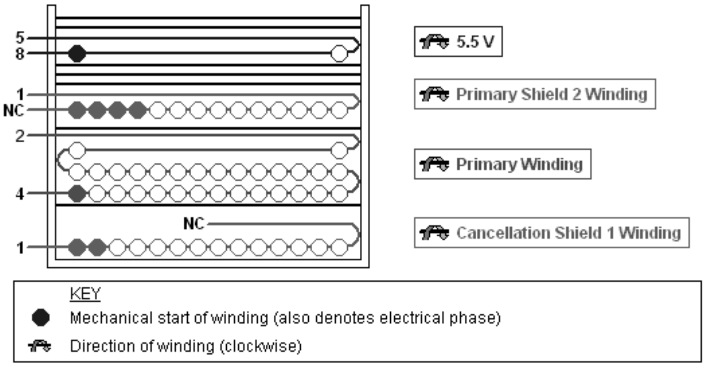


Figure 5 – Transformer Build Diagram.

7.5 Transformer Construction

Bobbin Preparation	Pull pin 3 on bobbin [2] to provide polarization.
Primary Cancellation Shield 1	Start on pin 1. Wind 33 bi-filar turns of item [3]. Temporarily terminate the winding on pin 4.
Basic Insulation	Half wind a layer of item [7] to keep the primary cancellation shield 1 winding tight. Cut the wire terminated on pin 4 of the primary cancellation shield winding. Finish winding the complete single layer of item [7].
Primary	Start at pin 4. Wind 132 turns of item [4] in approximately 3 layers. Terminate the winding on pin 2.
Basic Insulation	Use one layer of item [7] for basic insulation.
Primary Shield 2	Temporarily start the winding on pin 4 and wind 8 quad-filar turns of item [4]. Terminate this winding on pin 1.
Basic Insulation	Half wind a layer of item [7] to keep the primary shield 2 winding tight. Cut the wire terminated on pin 4 of the primary shield 2 winding. Finish winding 3 full layers of item [7].
Secondary Winding	Start at pin 8. Wind 9 turns of item [6]. Spread turns evenly across bobbin. Finish on pins 5.
Outer Wrap	Wrap windings with 1 layer of [item [7].
Final Assembly	Assemble and secure core halves so that the tape-wrapped E core is at the bottom of the transformer. Varnish impregnate (item [8]).

8 Transformer Spreadsheet

ACDC_LinkSwitch-XT_021307; Rev.1.20; Copyright Power Integrations 2007	**INPUT**	**INFO**	**OUTPUT**	**UNIT**	**ACDC_LinkSwitch-XT_021307_Rev1-20.xls; LinkSwitch-XT Continuous/Discontinuous Flyback Transformer Design Spreadsheet**
ENTER APPLICATION VARIABLES					**Customer**
VACMIN	85			Volts	Minimum AC Input Voltage
VACMAX	265			Volts	Maximum AC Input Voltage
fL	50			Hertz	AC Mains Frequency
VO	5.00			Volts	Output Voltage (main) (For CC designs enter upper CV tolerance limit)
IO	0.15			Amps	Power Supply Output Current (For CC designs enter upper CC tolerance limit)
CC Threshold Voltage	0.00			Volts	Voltage drop across sense resistor.
Output Cable Resistance			0.17	ohms	Enter the resistance of the output cable (if used)
PO			0.75	Watts	Output Power (VO x IO + CC dissipation)
Feedback Type	Opto		Opto		Choose 'BIAS' for Bias winding feedback and 'OPTO' for Optocoupler feedback from the 'Feedback Type' drop down box at the top of this spreadsheet
Add Bias Winding	No		No		Choose 'YES' in the 'Bias Winding' drop down box at the top of this spreadsheet to add a Bias winding. Choose 'NO' to continue design without a Bias winding. Addition of Bias winding can lower no load consumption
Clampless design (LNK 362 only)	No		External clamp		Choose 'YES' from the 'clampless Design' drop down box at the top of this spreadsheet for a clampless design. Choose 'NO' to add an external clamp circuit. Clampless design lowers the total cost of the power supply
n	0.56		0.56		Efficiency Estimate at output terminals.
Z	0.50		0.5		Loss Allocation Factor (suggest 0.5 for CC=0 V, 0.75 for CC=1 V)
tC	2.90			mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	9.40			uFarads	Input Capacitance
Input Rectification Type	F		***F***		Choose H for Half Wave Rectifier and F for Full Wave Rectification from the 'Rectification' drop down box at the top of this spreadsheet
ENTER LinkSwitch-XT VARIABLES					
LinkSwitch-XT	**LNK363**		**LNK363**		User selection for LinkSwitch-XT. Ordering info - Suffix P/G indicates DIP 8 package; suffix D indicates SO8 package; second suffix N indicates lead free RoHS compliance
Chosen Device		*LNK363*			
ILIMITMIN			*0.195*	Amps	Minimum Current Limit
ILIMITMAX			*0.225*	Amps	Maximum Current Limit
fSmin			*124000*	Hertz	Minimum Device Switching Frequency
I^2fmin			4948	A^2Hz	I^2f (product of current limit squared and frequency is trimmed for tighter tolerance)
VOR	80.67		80.67	Volts	Reflected Output Voltage
VDS			10	Volts	LinkSwitch-XT on-state Drain to Source Voltage
VD			0.5	Volts	Output Winding Diode Forward Voltage Drop
KP			4.82		Ripple to Peak Current Ratio (0.6 < KP < 6.0). For Clampless Designs use KP > 1.1
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**EE19**		**EE19**		User-Selected transformer core
Core		*EE19*		*P/N:*	PC40EE19-Z
Bobbin		*EE19_BO*		*P/N:*	EE19_BOBBIN

		BBIN			
AE			0.23	cm^2	Core Effective Cross Sectional Area
LE			3.94	cm	Core Effective Path Length
AL			1250	nH/T^2	Ungapped Core Effective Inductance
BW			9	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L			2		Number of Primary Layers
NS	9		9		Number of Secondary Turns
NB			N/A		Bias winding not used
VB			N/A	Volts	Bias winding not used
PIVB			N/A	Volts	N/A - Bias Winding not in use
DC INPUT VOLTAGE PARAMETERS					
VMIN			111	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.14		Maximum Duty Cycle
IAVG			0.01	Amps	Average Primary Current
IP			0.20	Amps	Minimum Peak Primary Current
IR			0.20	Amps	Primary Ripple Current
IRMS			0.04	Amps	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			594	uHenries	Typical Primary Inductance. +/- 40%
LP_TOLERANCE	40.00		40	%	Primary inductance tolerance
NP			132		Primary Winding Number of Turns
ALG			34	nH/T^2	Gapped Core Effective Inductance
BM			440	Gauss	Maximum Operating Flux Density, BM<1500 is recommended
BAC			220	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1704		Relative Permeability of Ungapped Core
LG			0.82	mm	Gap Length (Lg > 0.1 mm)
BWE			18	mm	Effective Bobbin Width
OD			0.14	mm	Maximum Primary Wire Diameter including insulation
INS			0.03	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.10	mm	Bare conductor diameter
AWG			38	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			16	Cmils	Bare conductor effective area in circular mils
CMA			404	Cmils/Amp	Primary Winding Current Capacity (150 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS					
Lumped parameters					
ISP			2.86	Amps	Peak Secondary Current
ISRMS			0.65	Amps	Secondary RMS Current
IRIPPLE			0.63	Amps	Output Capacitor RMS Ripple Current
CMS			130	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			28	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.32	mm	Secondary Minimum Bare Conductor Diameter
ODS			1.00	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			0.34	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS					

PARAMETERS					
VDRAIN			564	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			31	Volts	Output Rectifier Maximum Peak Inverse Voltage
FEEDBACK COMPONENTS					
Recommended Bias Diode			1N4003 - 1N4007		Recommended diode is 1N4003. Place diode on return leg of bias winding for optimal EMI. See LinkSwitch-XT Design Guide
R1			500 - 1000	ohms	CV bias resistor for CV/CC circuit. See LinkSwitch-XT Design Guide
R2			200 - 820	ohms	Resistor to set CC linearity for CV/CC circuit. See LinkSwitch-XT Design Guide
TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)					
1st output					
VO1			5.00	Volts	Main Output Voltage (if unused, defaults to single output design)
IO1			0.15	Amps	Output DC Current
PO1			0.75	Watts	Output Power
VD1			0.50	Volts	Output Diode Forward Voltage Drop
NS1			9.00		Output Winding Number of Turns
ISRMS1			0.65	Amps	Output Winding RMS Current
IRIPPLE1			0.64	Amps	Output Capacitor RMS Ripple Current
PIVS1			30.55	Volts	Output Rectifier Maximum Peak Inverse Voltage
Recommended Diodes			SB140, 1N5819		Recommended Diodes for this output
Pre-Load Resistor			2	k-Ohms	Recommended value of pre-load resistor
CMS1			130.99	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS1			28.00	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS1			0.32	mm	Minimum Bare Conductor Diameter
ODS1			1.00	mm	Maximum Outside Diameter for Triple Insulated Wire
Total power			0.75	Watts	Total Output Power
Negative Output			N/A		If negative output exists enter Output number; eg: If VO2 is negative output, enter 2

9 Performance Data

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

9.1 Efficiency

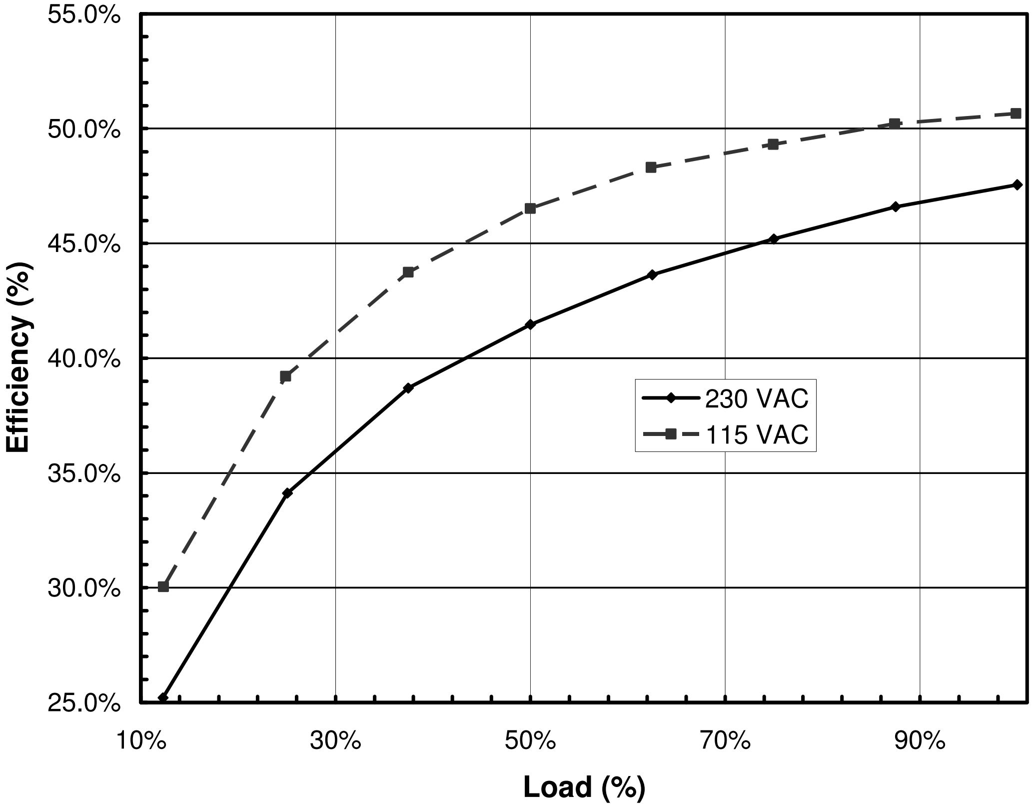


Figure 6 – Efficiency vs. Load, Room Temperature, 60 Hz.

9.2 No-load Input Power

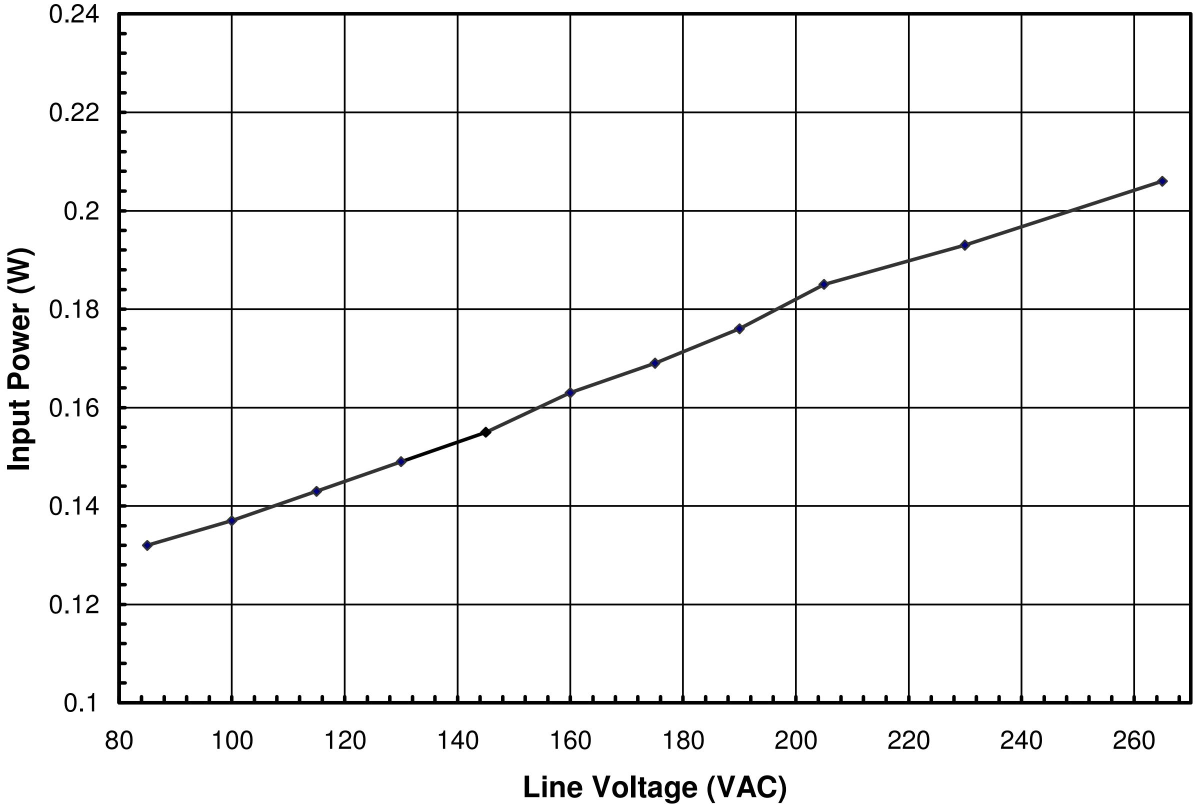


Figure 7 – Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.

9.3 Regulation

9.3.1 Load

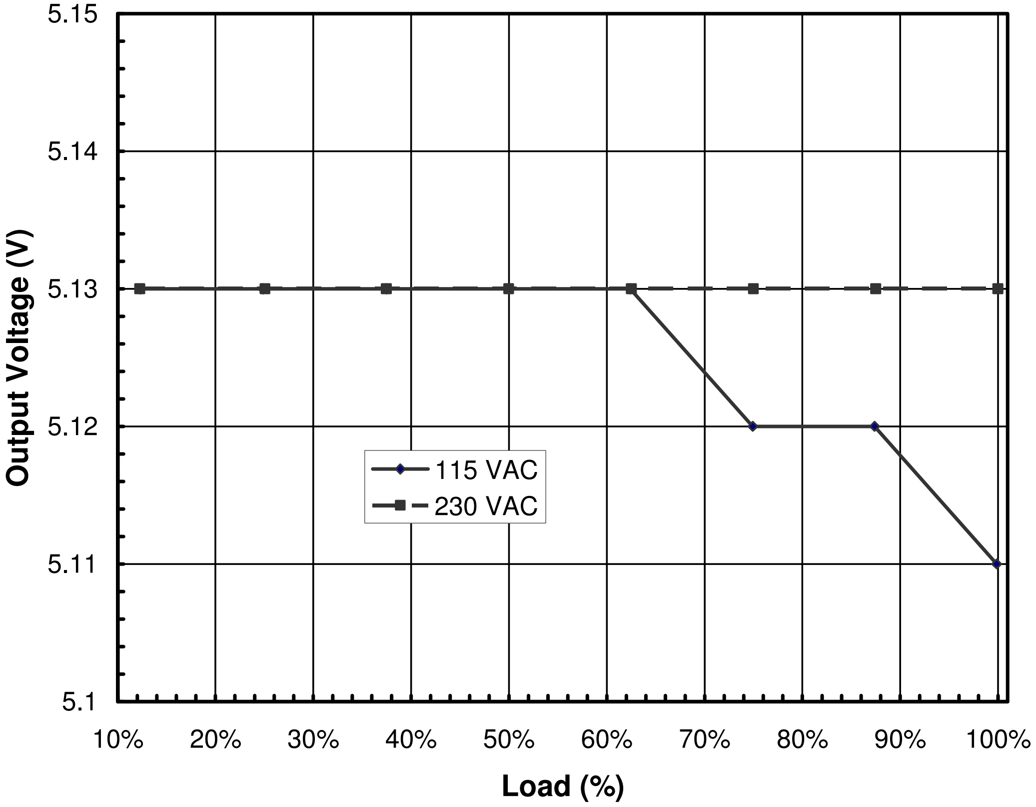


Figure 8 – Load Regulation, Room Temperature.

9.3.2 Line

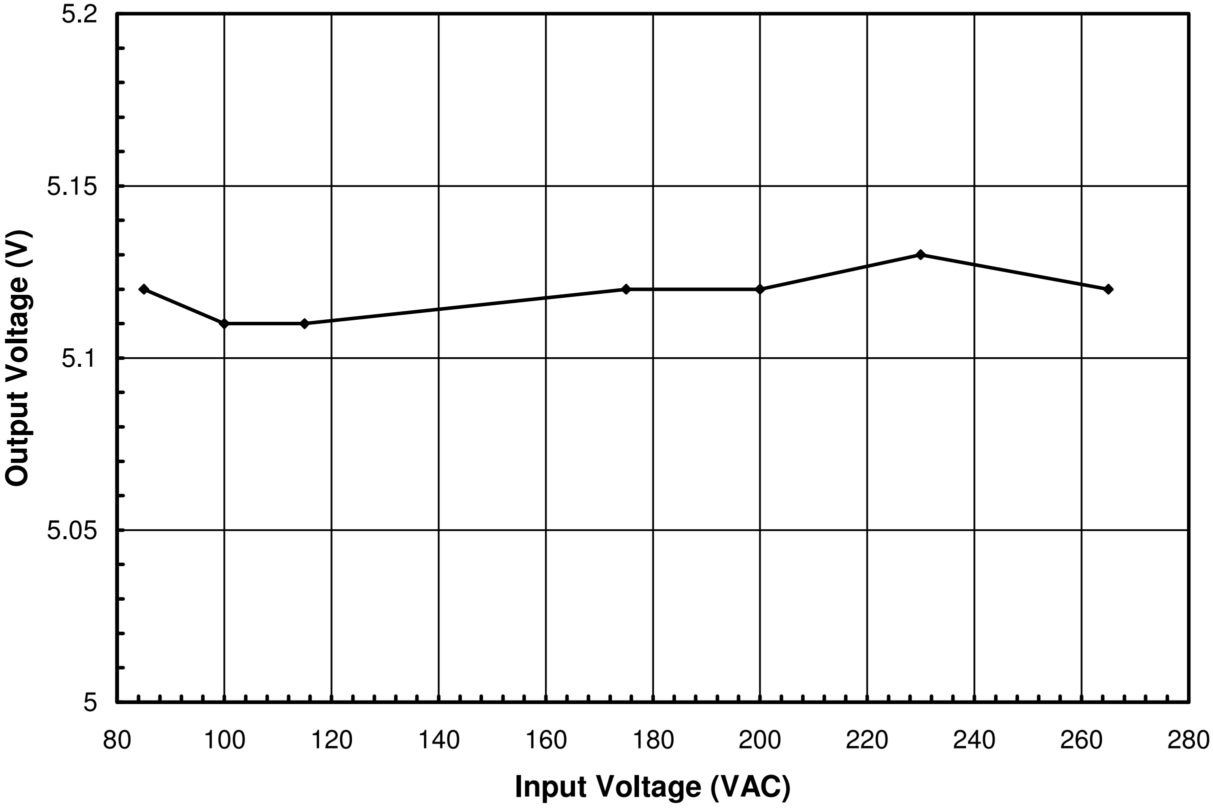


Figure 9 – Line Regulation, Room Temperature, Full Load.

10 Thermal Performance

The temperature of key components (three in this case) was recorded to ensure satisfactory thermal performance. Two of the thermocouples were soldered into place; one was soldered to U1 at its source (for measuring its source temperature) and the other was soldered to output diode D5. The third thermocouple, monitoring the transformer core temperature, was taped in place.

The supply was operated at full load using an external electronic load. The supply was placed in a small enclosure to prevent air circulation (within the chamber) from affecting the test. The ambient temperature within the enclosure was monitored via another, free-hanging, thermocouple.

Item	**Temperature (°C)**
	85 VAC
Ambient	30
Device Source (U1)	41
Output Diode (D5)	39
Transformer Core (T1)	38

11 Waveforms

11.1 Drain Voltage and Current, Normal Operation

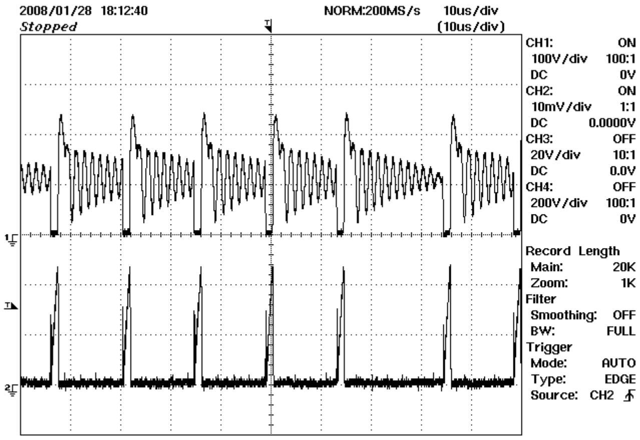


Figure 10 – 85 VAC, Full Load.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 100 mA / div.
Timebase: 10 µs / div.

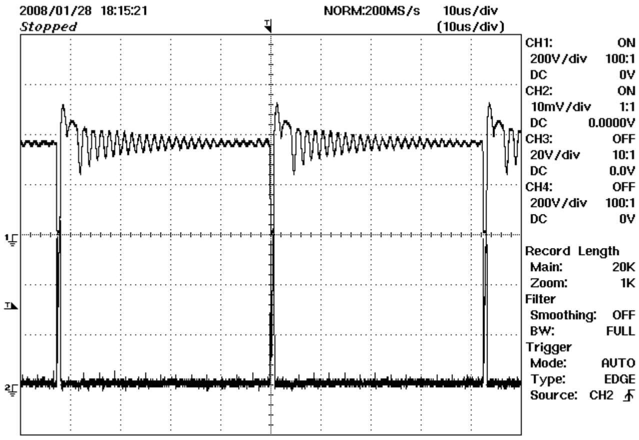


Figure 11 – 265 VAC, Full Load.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 100 mA / div.
Timebase: 10 µs / div.

11.2 Output Voltage Start-up Profile

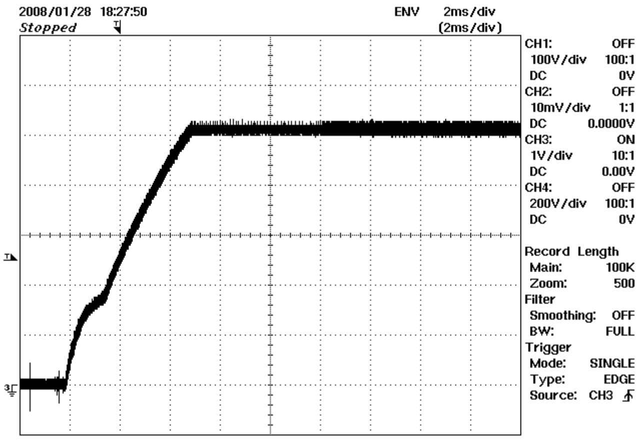


Figure 12 – Start-up Profile, 85 VAC.
1 V / div, 2 ms / div.

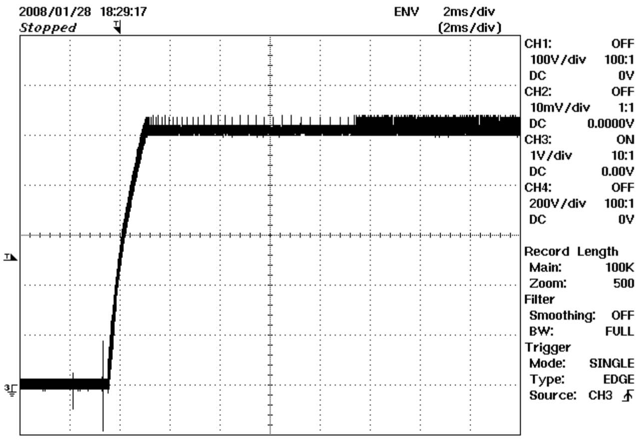
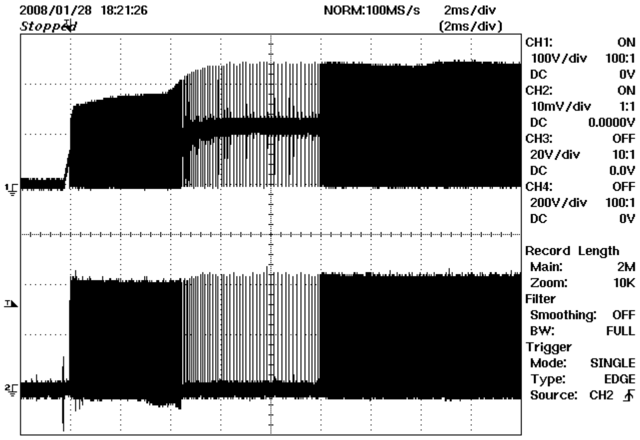


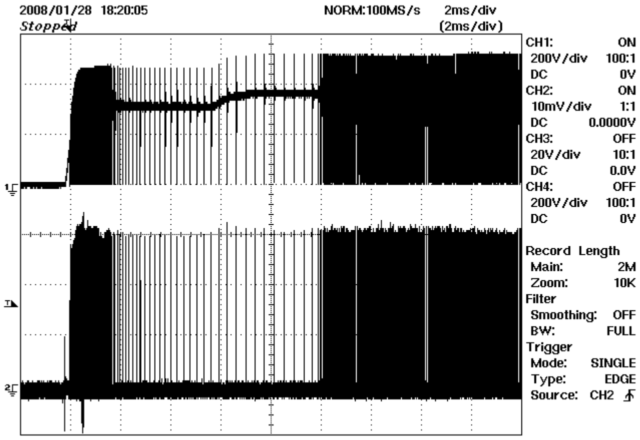
Figure 13 – Start-up Profile, 265 VAC.
1 V, 2 ms / div.

11.3 Drain Voltage and Current Start-up Profile



2008/01/28 18:21:26 NORM:100MS/s 2ms/div
Stopped (2ms/div)
CH1: ON
100V/div 100:1
DC 0V
CH2: ON
10mV/div 1:1
DC 0.0000V
CH3: OFF
20V/div 10:1
DC 0.0V
CH4: OFF
200V/div 100:1
DC 0V
Record Length
Main: 2M
Zoom: 10K
Filter
Smoothing: OFF
BW: FULL
Trigger
Mode: SINGLE
Type: EDGE
Source: CH2

Figure 14 – 85 VAC Input and Full Load.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 100 mA / div.
Timebase: 2 ms / div.

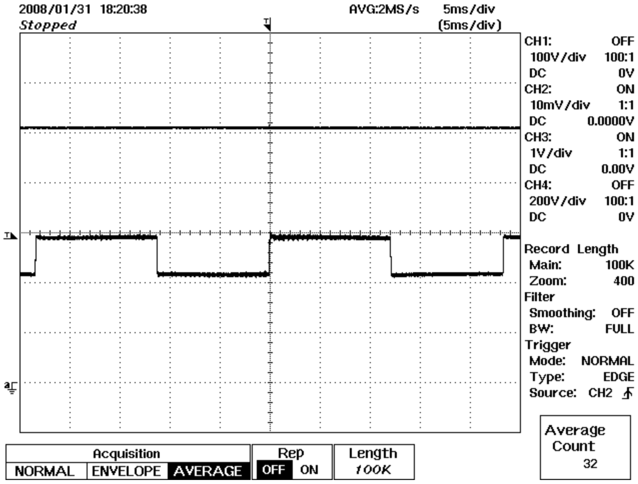


2008/01/28 18:20:05 NORM:100MS/s 2ms/div
Stopped (2ms/div)
CH1: ON
200V/div 100:1
DC 0V
CH2: ON
10mV/div 1:1
DC 0.0000V
CH3: OFF
20V/div 10:1
DC 0.0V
CH4: OFF
200V/div 100:1
DC 0V
Record Length
Main: 2M
Zoom: 10K
Filter
Smoothing: OFF
BW: FULL
Trigger
Mode: SINGLE
Type: EDGE
Source: CH2

Figure 15 – 265 VAC Input and Full Load.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 100 mA / div.
Timebase: 2 ms / div.

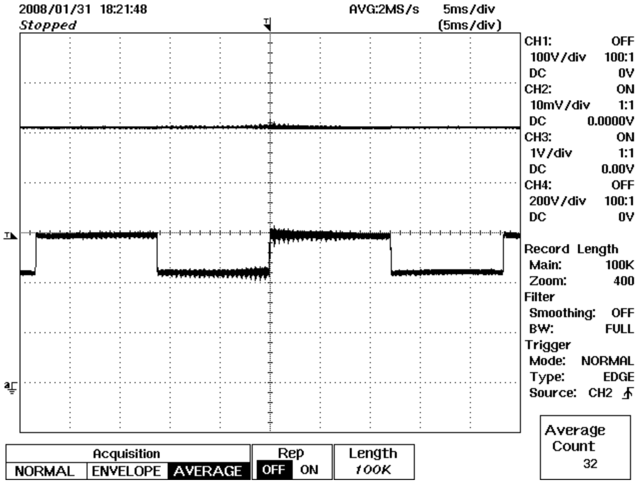
11.4 Load Transient Response (75% to 100% Load Step)

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



2008/01/31 18:20:38 AVG:2MS/s 5ms/div
Stopped (5ms/div)
CH1: OFF
100V/div 100:1
DC 0V
CH2: ON
10mV/div 1:1
DC 0.0000V
CH3: ON
1V/div 1:1
DC 0.00V
CH4: OFF
200V/div 100:1
DC 0V
Record Length
Main: 100K
Zoom: 400
Filter
Smoothing: OFF
BW: FULL
Trigger
Mode: NORMAL
Type: EDGE
Source: CH2
Acquisition: NORMAL ENVELOPE AVERAGE
Rep: OFF ON
Length: 100K
Average Count 32

Figure 16 – Transient Response, 85 VAC.
75-100-75% Load Step.
Top: Output Voltage, 1 V / div.
Bottom: Output Current, 100 mA / div.
Timebase: 5 ms / div.



2008/01/31 18:21:48 AVG:2MS/s 5ms/div
Stopped (5ms/div)
CH1: OFF
100V/div 100:1
DC 0V
CH2: ON
10mV/div 1:1
DC 0.0000V
CH3: ON
1V/div 1:1
DC 0.00V
CH4: OFF
200V/div 100:1
DC 0V
Record Length
Main: 100K
Zoom: 400
Filter
Smoothing: OFF
BW: FULL
Trigger
Mode: NORMAL
Type: EDGE
Source: CH2
Acquisition: NORMAL ENVELOPE AVERAGE
Rep: OFF ON
Length: 100K
Average Count 32

Figure 17 – Transient Response, 265 VAC.
75-100-75% Load Step.
Top: Output Voltage, 1 V / div.
Bottom: Output Current, 100 mA / div.
Timebase: 5 ms / div.

11.5 External Magnetic Field Influence

The transformer core was subjected to a strong magnetic field by placing a strong magnet dipole on the core halves. As can be seen in Figure 18, no saturation was observed.

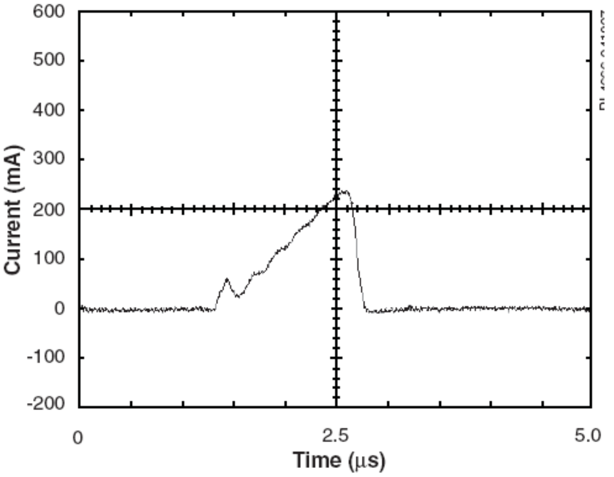


Figure 18 – Drain Current Under Influence of a Magnetic Dipole Indicating no Core Saturation
100 mA / div.

11.6 Output Ripple Measurements

11.6.1 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. The capacitors include a 0.1 μF / 50 V ceramic type and 1.0 μF / 50 V aluminum electrolytic. The aluminum-electrolytic capacitor is polarized, so always maintain proper polarity across DC outputs. (Refer to Figure 19 and Figure 20).

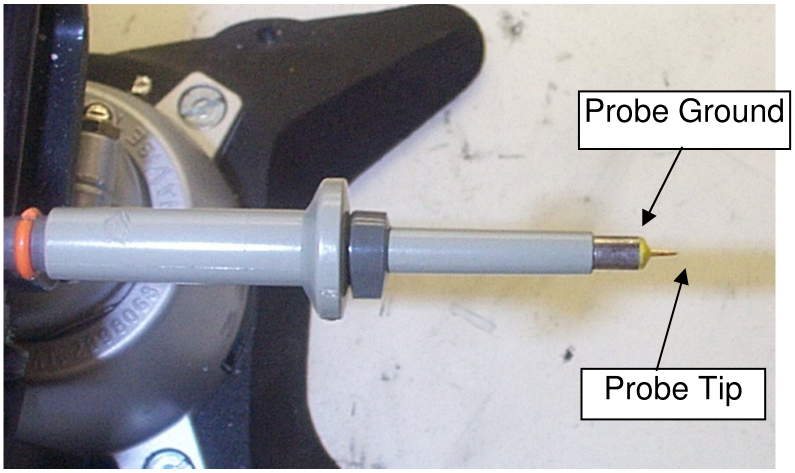


Figure 19 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

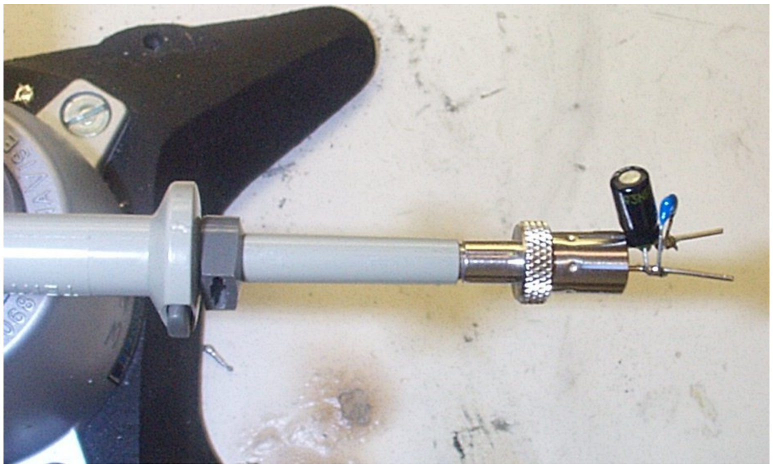


Figure 20 – Oscilloscope Probe with Probe Master (www.probemaster.com) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

11.6.2 Measurement Results

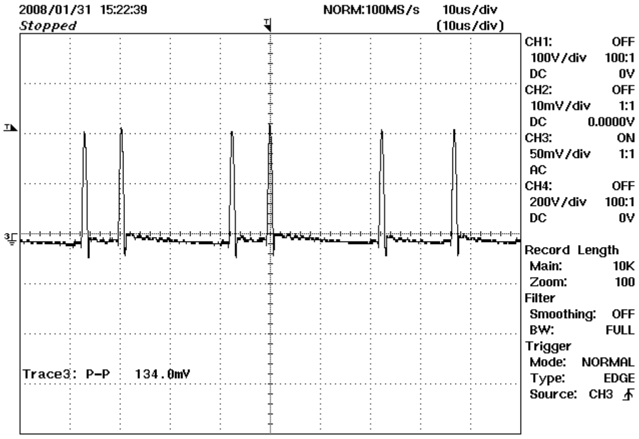


Figure 21 – Ripple, 85 VAC, Full Load.
10 µs / div, 50 mV / div.

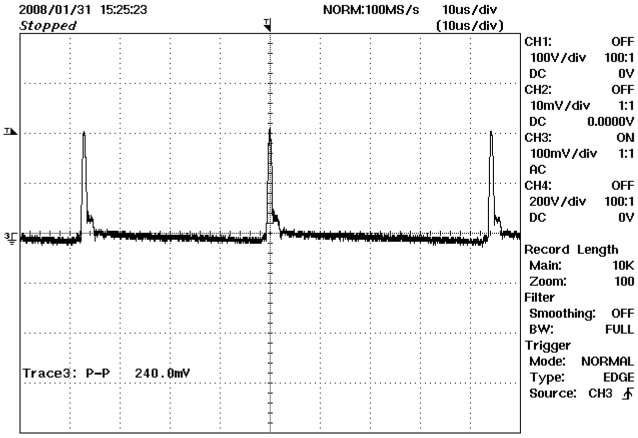


Figure 22 – Ripple, 265 VAC, Full Load.
10 µs / div, 100 mV / div.

12 Conducted EMI

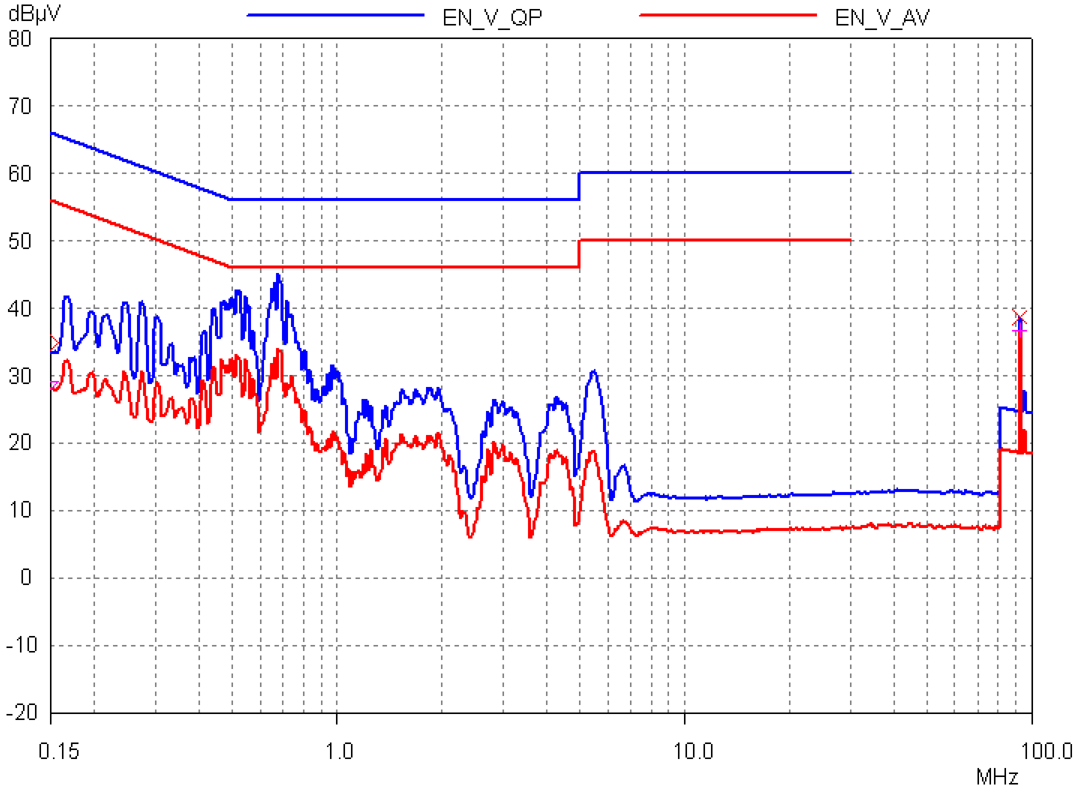


Figure 23 – Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits.

13 Revision History

Date	Author	Revision	Description & changes	Reviewed
17-Apr-08	JD	1.0	Final Release	SGK

Notes

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

PATENT INFORMATION

The products and applications illustrated herein (including transformer construction and circuits external to the products) may be covered by one or more U.S. and foreign patents, or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at www.powerint.com. Power Integrations grants its customers a license under certain patent rights as set forth at http://www.powerint.com/ip.htm.

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