Design Example Report

Title	***3.0 W Charger using LNK363P***
Specification	Input: 85 – 265 VAC Output: 5.0V / 600 mA
Application	Cell Phone Charger
Author	Power Integrations Applications Department
Document Number	DER-62
Date	August 24, 2005
Revision	1.0

Summary and Features

- Low cost CV/CC cell phone charger
- No Load consumption less than 300 mW
- Meets CEC efficiency and no-load specification

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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.

Design Reports contain a power supply design specification, schematic, bill of materials, and transformer documentation. Performance data and typical operation characteristics are included. Typically only a single prototype has been built.

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1 Introduction

This document is an engineering prototype report describing a 3.0 W power supply utilizing a LNK363P. This power supply is intended as a cell phone charger evaluation platform. Power Integrations E-shield technology of transformer construction allows this design to meet EMI requirement without using a common mode choke.

The document contains the power supply specification, schematic, bill of materials, transformer documentation.

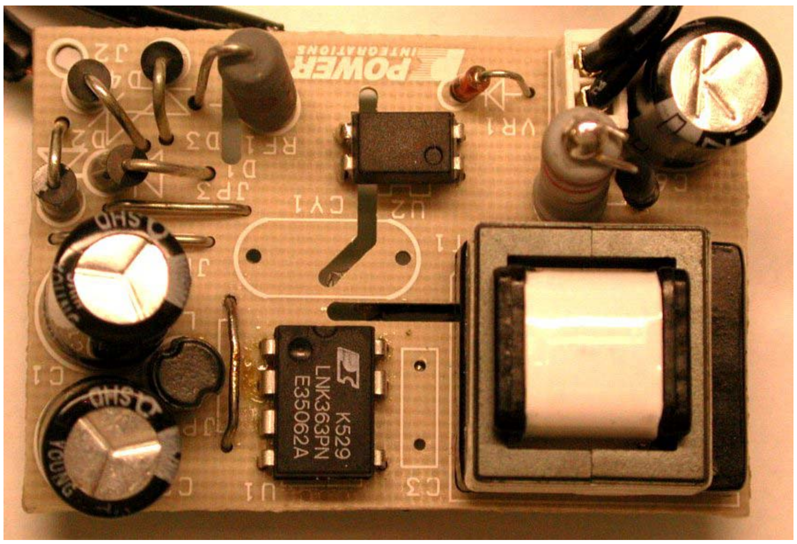

Figure 1 – Populated circuit board – Top view

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)				0.5	W	
Output						
Output Voltage 1	V_{OUT1}	4.75	5.0	5.75	V	
Output Ripple Voltage 1	$V_{RIPPLE1}$		60		mV	20 MHz Bandwidth
Output Current 1	I_{OUT1}	534	600	666	mA	
Total Output Power						
Continuous Output Power	P_{OUT}		3.0		W	
Efficiency	η	59			%	typical at full load, 25 °C
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

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3 Schematic

3.1 With RCD clamp

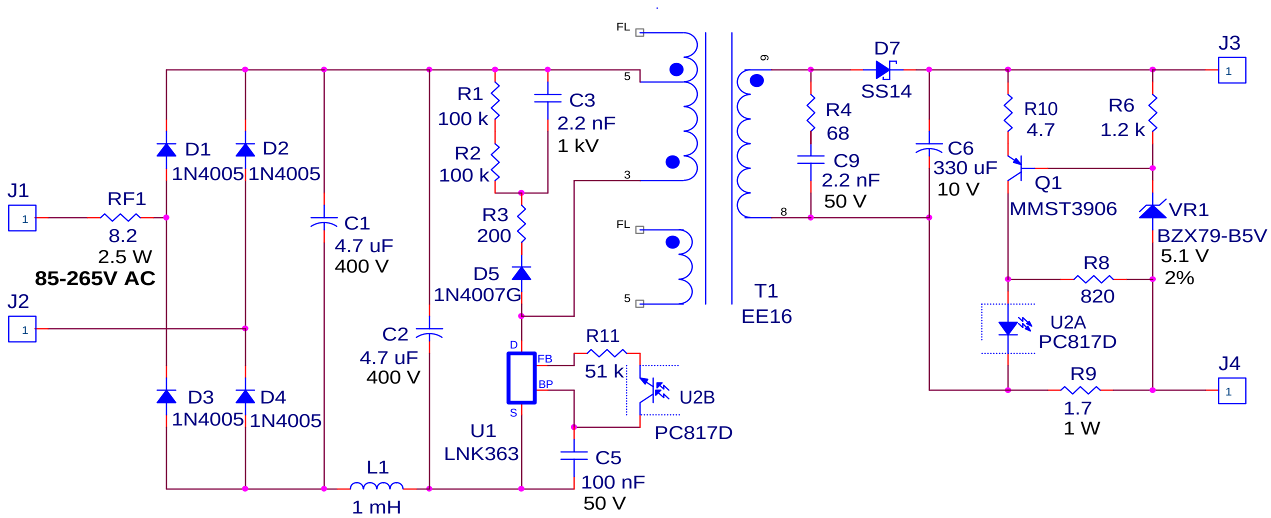

Figure 2 – Schematic with RCD clamp.

3.2 With Zener clamp and bias winding

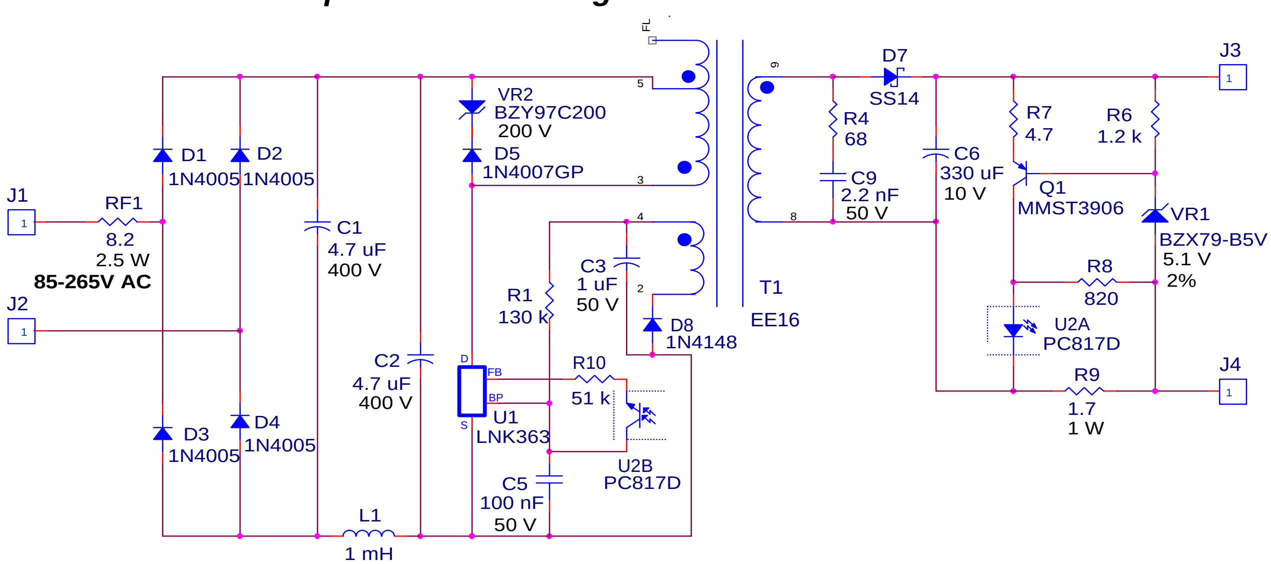

Figure 3 - Schematic with zener clamp and bias winding.

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4 PCB

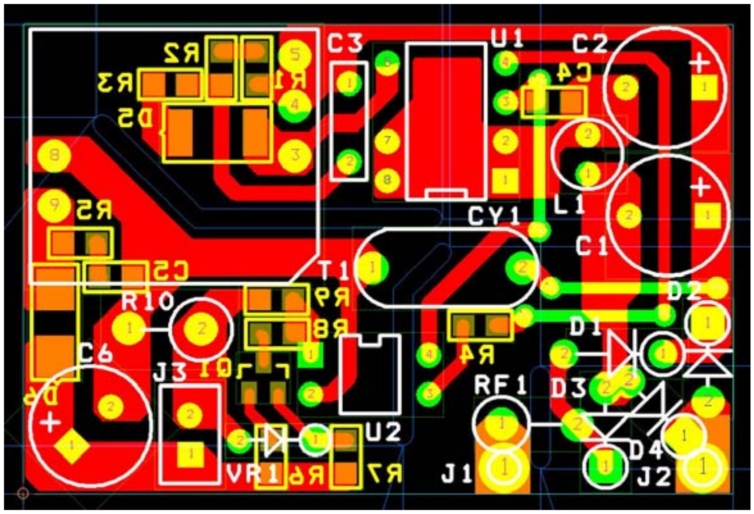

Figure 4 – Printed circuit board

5 Bill Of Materials—RCD clamp

Item	Qty	Value	Description	Ref
1	2	4.7 uF	4.7 uF, 400 V, Electrolytic, (8 x 11.5)	C1 C2
2	1	2.2 nF	2.2 nF, 1 kV, Disc Ceramic	C3
3	1	100 nF	100 nF, 50 V, Ceramic, X7R, 0805	C5
4	1	330 uF	330 uF, 10 V, Electrolytic, Low ESR, 180 mOhm	C6
5	1	2.2 nF	2.2 nF, 50 V, Ceramic, X7R, 0805	C9
6	4	1N4005	600 V, 1 A, Rectifier, DO-41	D1 D2 D3 D4
7	1	1N4007G	1000 V, 1 A, Rectifier, Glass Passivated, 2 us, DO-41	D5
8	1	SS14	40 V, 1 A, Schottky, DO-214AC	D7
13	1	1 mH	1 mH, 0.15 A, Ferrite Core	L1
14	1	MMST3906	PNP, Small Signal BJT, 40 V, 0.2 A, SOT-323	Q1
15	2	100 k	100 k, 5%, 1/4 W, Metal Film, 1206	R1 R2
16	1	200	200 R, 5%, 1/8 W, Metal Film, 0805	R3
17	1	68	68 R, 5%, 1/8 W, Metal Film, 0805	R4
18	1	1.2 k	1.0k 5%, 1/8 W, Metal Film, 0805	R6
19	1	820	820 R, 5%, 1/8 W, Metal Film, 0805	R8
20	1	1.7	1.7 R, 5%, 1 W, Metal Oxide	R9
21	1	8.2	8.2 R, 2.5 W, Fusible/Flame Proof Wire Wound	RF1
22	1	4.7	4.7 R, 5% Metal film 0805	R10
23	1	51 k	51 k, 5% Metal film 0805	R11
24	1	EE16	Bobbin, EE16 Horizontal, 10 Pins	T1
25	1	LNK363P	PI's device	U1
26	1	PC817D	Opto coupler, 35 V, CTR 300-600%, 4-DIP	U2
27	1	BZX79-B5V1	5.1 V, 500 mW, 2%, DO-35	VR1

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6 Transformer Specification

6.1 Electrical Diagram

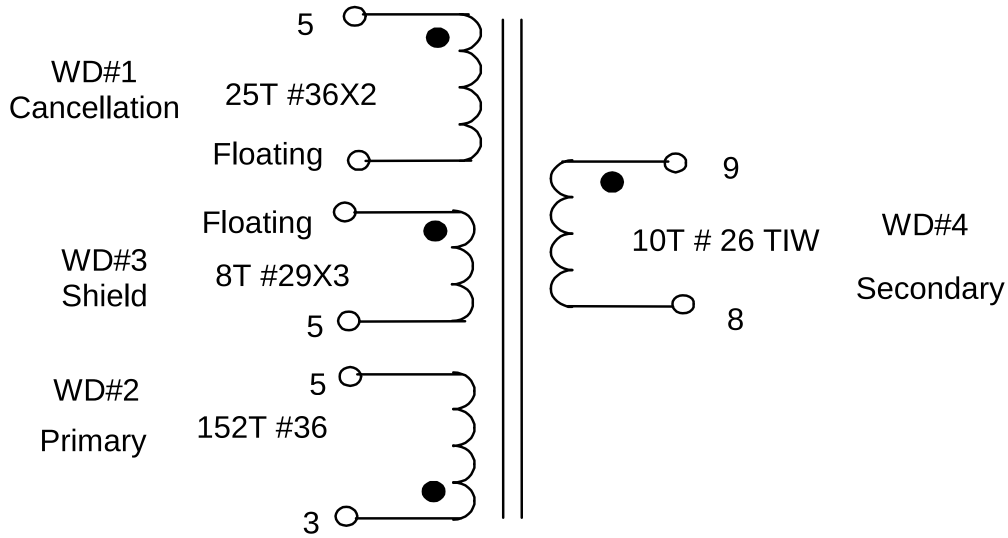

Figure 5 – Transformer Electrical Diagram

6.2 Electrical Specifications

Electrical Strength	60Hz 1minute, from Pins 1-5 to Pins 6-10	3000 V ac
Primary Inductance (Pin 3 to Pin 5)	All windings open	1940 uH +/- 5% at 132 KHz
Resonant Frequency. (Pin 3 to Pin 5)	All windings open	700 kHz (Min.)
Primary Leakage Inductance. (Pin 3 to Pin 5)	Pins 9-8 shorted	110 uH Max.

6.3 Materials

Item	Description
[1]	Core: PC40EE16-Z, TDK or equivalent Gapped for AL of 84 nH/T^2
[2]	Bobbin: Horizontal 10 pin
[3]	Magnet Wire: #36AWG
[4]	Magnet Wire: #29 AWG
[5]	Triple Insulated Wire: #26 AWG.
[6]	Tape: 3M 1298 Polyester Film, 2.0 mils thick, 8.2 mm wide
[7]	Varnish

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6.4 Transformer Build Diagram

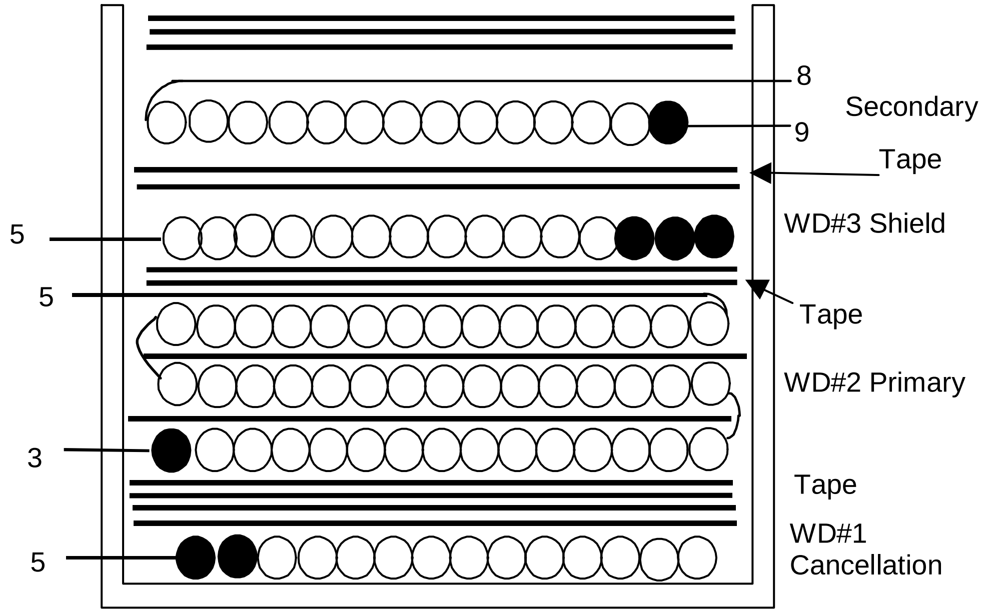

Figure 6 – Transformer Build Diagram

6.5 Transformer Construction

WD1 Cancellation Winding	Primary pin side of the bobbin oriented to left hand side. Start at Pin 5. Wind 25 bifilar turns of item [8] from right to left. Wind with tight tension across entire bobbin evenly. Cut at the end.
Insulation	4 Layers of tape [6] for insulation.
WD#2 Primary winding	Start at pin 3 wind 51 turns of item [3] from left to right. Apply 1 layer tape of [6]. Then wind another 50 turns next layer from right to left. Apply 1 layer tape of [6]. Wind the rest 51 turns in third layer from left to right. Wind with tight tension across entire bobbin evenly Finish at pin 5
Insulation	2 Layers of tape [6] for insulation.
WD #3 Shield Winding	Start at Pin 8 temporarily, wind 8 Trifilar turns of item [4]. Wind from right to left with tight tension. Wind uniformly, in a single layer across entire width of bobbin. Finish at pin5. Cut at the start lead.
Insulation	2 Layers of tape [6] for insulation.
WD #4 Secondary Winding	Start at pin 9, wind 10 turns of item [5] from right to left. Wind uniformly, in a single layer across entire bobbin evenly. Finish on pin 8.
Outer Insulation	3 Layers of tape [6] for insulation.
Core Assembly	Assemble and secure core halves.
Varnish	Varnish

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7 Transformer Spreadsheets

ACDC_LinkSwitch-XT_063005; Rev.0.2; Copyright Power Integrations 2005	INPUT	INFO	OUTPUT	UNIT	ACDC_LinkSwitch-XT_063005_Rev0-2.xls; LinkSwitch-XT 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	5.00			Volts	Output Voltage (main)
IO	0.60			Amps	Power Supply Output Current
CC Threshold Voltage	1.00			Volts	Voltage drop across sense resistor. For CV only circuits enter "0"
PO			3.6	Watts	Output Power (VO x IO + CC dissipation)
n	0.60				Efficiency Estimate at output terminals. For CV only designs enter 0.7 if no better data available
Z	0.75		0.75		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
ENTER LinkSwitch-HF VARIABLES					
LinkSwitch-XT	**LNK363**			*Universal*	*115 Doubled/230V*
Chosen Device		*LNK363*	*Power Out*	*10 W*	*10 W*
ILIMITMIN			*0.195*	Amps	Minimum Current Limit
ILIMITMAX			*0.225*	Amps	Maximum Current Limit
fSmin			*124000*	Hertz	Minimum Device Switching Frequency
I^2fmin			5471.74	Hertz	I^2f (product of current limit squared and frequency is trimmed for tighter tolerance)
VOR	99.00		99	Volts	Reflected Output Voltage
VDS			10	Volts	LinkSwitch-HF on-state Drain to Source Voltage
VD			0.5	Volts	Output Winding Diode Forward Voltage Drop
KP			0.90		Ripple to Peak Current Ratio (0.6<KRP<1.0 : 1.0<KDP<6.0)
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type			**EE16**		Suggested smallest commonly available core
Core		*EE16*		*P/N:*	PC40EE16-Z
Bobbin		*EE16_BOBBIN*		*P/N:*	EE16_BOBBIN
AE			0.192	cm^2	Core Effective Cross Sectional Area
LE			3.5	cm	Core Effective Path Length
AL			1140	nH/T^2	Ungapped Core Effective Inductance
BW			8.6	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L			3		Number of Primary Layers
NS	10		10		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			83	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.61		Maximum Duty Cycle

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IAVG			0.07	Amps	Average Primary Current
IP			0.1950	Amps	Minimum Peak Primary Current
IR			0.1746	Amps	Primary Ripple Current
IRMS			0.09	Amps	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			1942	uHenries	Typical Primary Inductance. +/- 12%
LP_TOLERANCE	12.00		12	%	Primary inductance tolerance
NP			152		Primary Winding Number of Turns
ALG			84	nH/T^2	Gapped Core Effective Inductance
BM			1494	Gauss	Maximum Operating Flux Density, BM<1500 is recommended
BAC			600	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1654		Relative Permeability of Ungapped Core
LG			0.27	mm	Gap Length (Lg > 0.1 mm)
BWE			25.8	mm	Effective Bobbin Width
OD			0.169	mm	Maximum Primary Wire Diameter including insulation
INS			0.04	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.132	mm	Bare conductor diameter
AWG			36	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			25	Cmils	Bare conductor effective area in circular mils
CMA			286	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS					
Lumped parameters					
ISP			2.97	Amps	Peak Secondary Current
ISRMS			1.16	Amps	Secondary RMS Current
IRIPPLE			0.99	Amps	Output Capacitor RMS Ripple Current
CMS			232	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			26	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.41	mm	Secondary Minimum Bare Conductor Diameter
ODS			0.86	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			0.23	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN			603	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			30	Volts	Output Rectifier Maximum Peak Inverse Voltage
TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)					
1st output					
VO1	5.50		5.5	Volts	Main Output Voltage (if unused, defaults to single output design)
IO1	0.60		0.600	Amps	Output DC Current
PO1			3.30	Watts	Output Power
VD1			0.500	Volts	Output Diode Forward Voltage Drop
NS1			10.91		Output Winding Number of Turns
ISRMS1			1.160	Amps	Output Winding RMS Current
IRIPPLE1			0.99	Amps	Output Capacitor RMS Ripple Current
PIVS1			32	Volts	Output Rectifier Maximum Peak Inverse Voltage
CMS1			232	Cmils	Output Winding Bare Conductor minimum circular mils
AWGS1			26	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
DIAS1			0.41	mm	Minimum Bare Conductor Diameter
ODS1			0.79	mm	Maximum Outside Diameter for Triple Insulated Wire

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8 Performance Data

All measurements performed at room temperature, 60 Hz input frequency. The data were taken at the end of a 6 feet long output cable. The DC resistance of the cable is about 0.2 ohm.

8.1 Efficiency vs CEC

8.1.1 With RCD Clamp, no bias winding

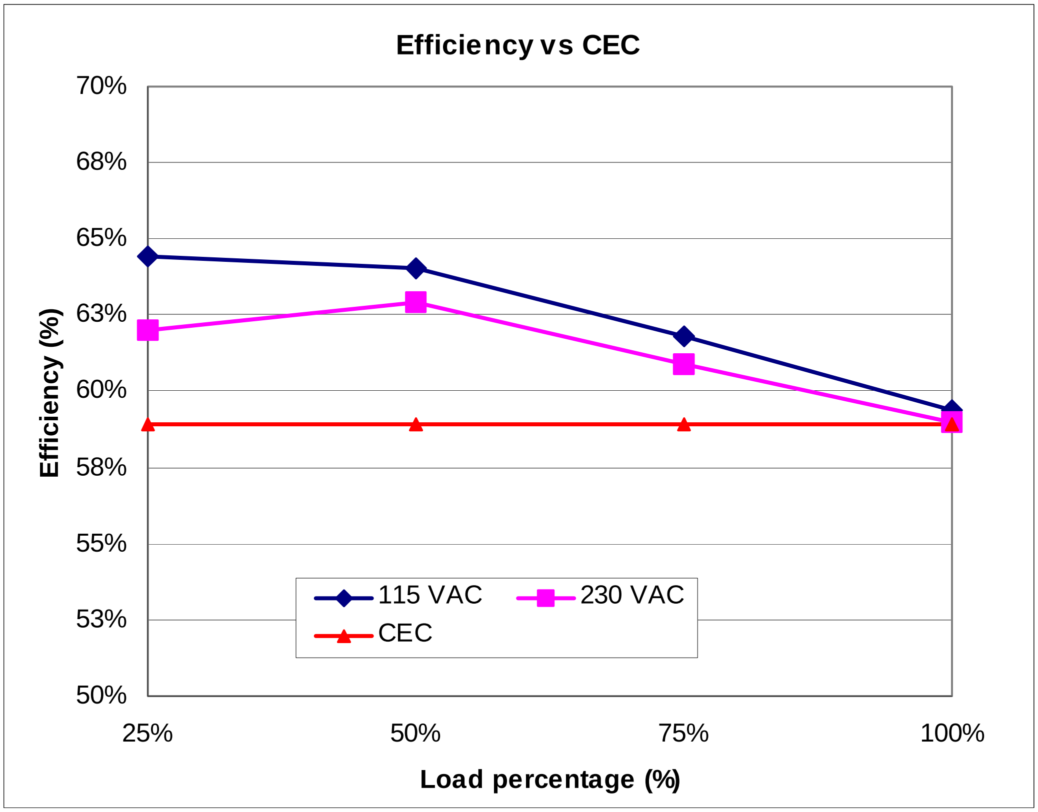

Figure 7 – Efficiency vs load, RCD clamp.

Note the CEC requirement is 58.9%, Tested average efficiency: 115VAC, 62.4%; 230VAC, 61.2%

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8.1.2 With Zener Clamp and Bias winding

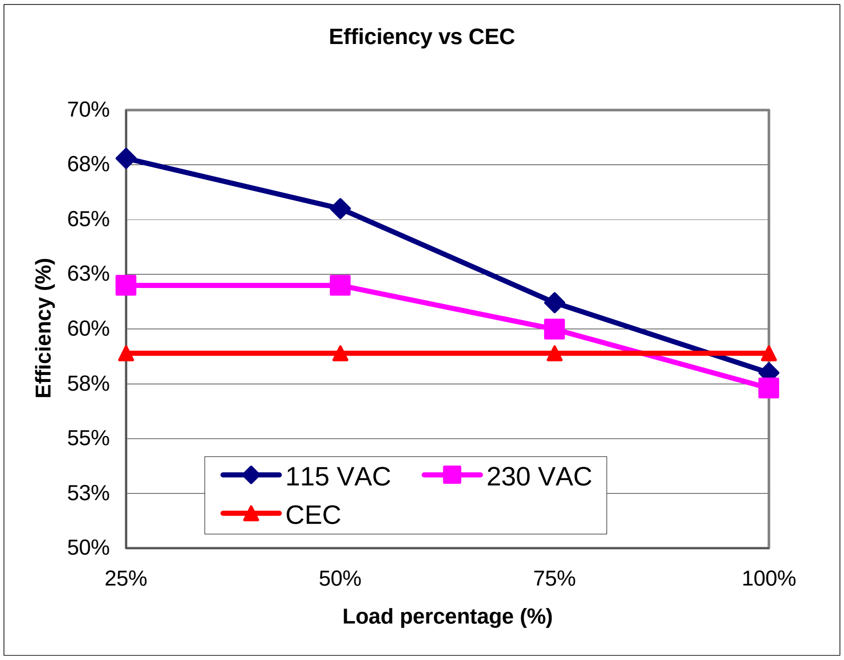

Figure 8 - Efficiency vs output current with Zener clamp and bias winding.

Note the CEC requirement is 58.9%, Tested average efficiency: 115VAC, 62.9%; 230VAC, 60.4%

8.2 Efficiency vs Input Voltage

8.2.1 With RCD clamp, no bias winding

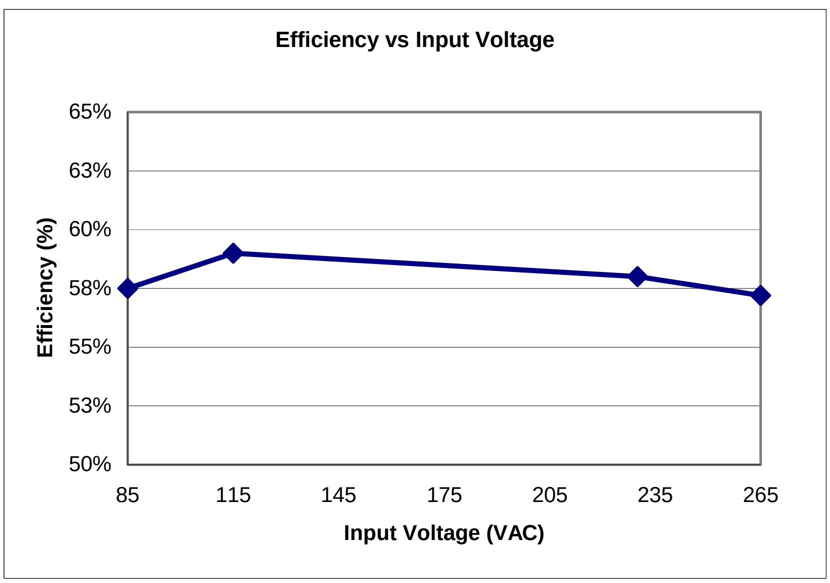

Figure 9 - Efficiency vs input voltage, RCD clamp , no bias winding. Tested at 3.03W output.

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8.2.2 With zener clamp and bias winding

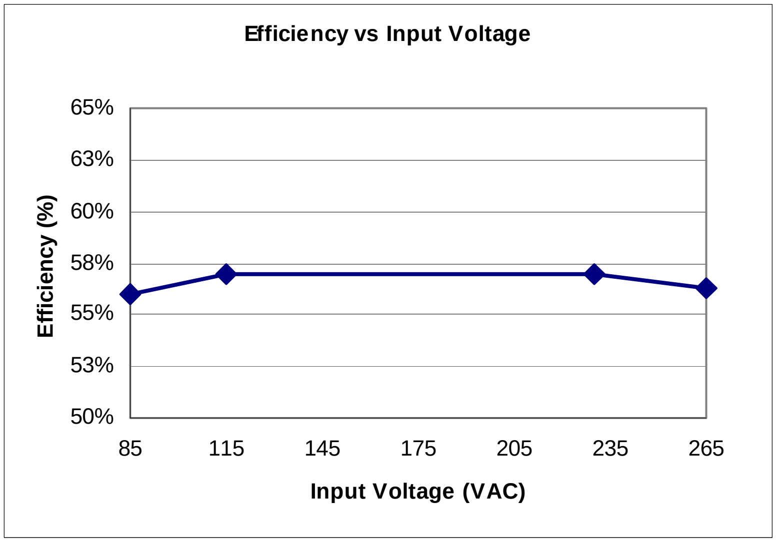

Figure 10 - Full load efficiency vs input voltage, zener clamp and bias winding.

8.3 No-Load Input Power

8.3.1 RCD clamp, no bias winding

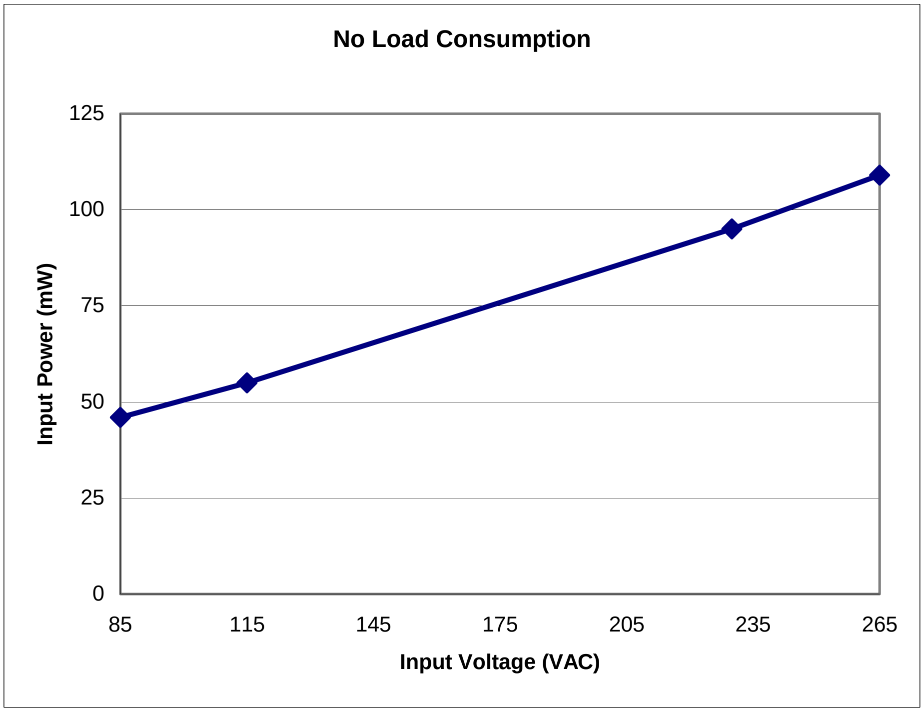

Figure 11 - No load consumption RCD clamp, no bias winding.

Note the CEC requirement is < 500mW

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8.3.2 Zener clamp clamp and bias winding

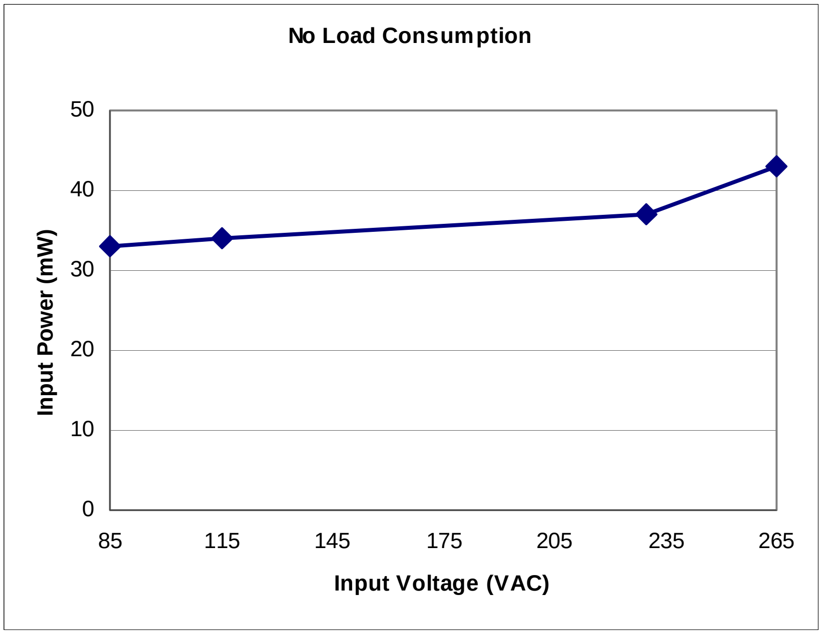

Figure 12 - No load consumption, zener clamp with bias winding.

8.4 Output Regulation

Output characteristic was tested at the end of a 6 feet long output cable. The DC resistance of the cable is about 0.2 ohm.

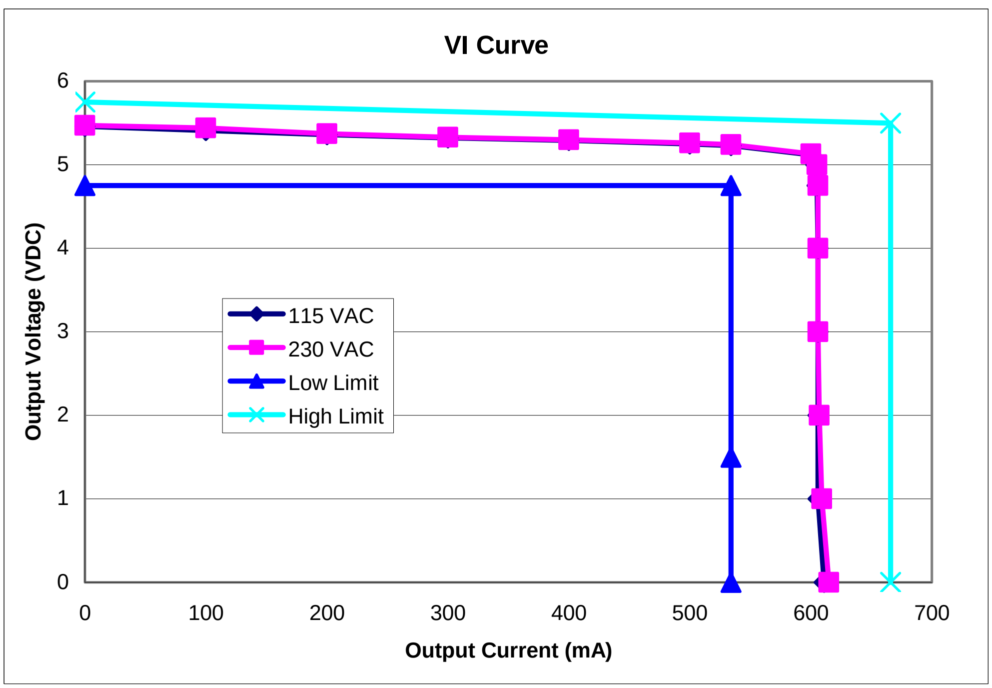

Figure 13 – Output characteristic

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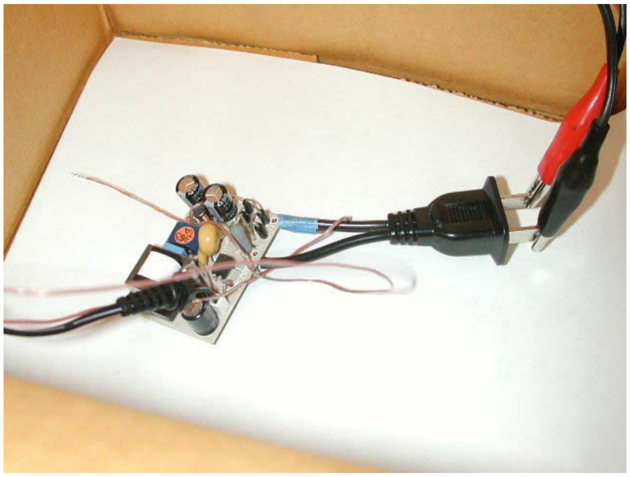
8.5 Thermal Performance

Thermal performance was measured inside an enclosure, full load, with no airflow. The ambient thermal probe was about 1 inch away from the device.

8.5.1 Thermal testing set up



8.5.2 Test results of RCD clamp

Item	85 VAC	265 VAC
Ambient	50°C	50°C
LNK363P	108°C at 2.82 W output (5.22V, 540mA)	103°C at 2.84 W output (5.23V, 542mA).

8.5.3 Thermal performance of Zener clamp and bias winding.

Item	85 VAC	265 VAC
Ambient	50°C	50°C
LNK363P	96°C at 2.82 W output (5.22V, 544mA)	89°C at 2.82 W output (5.22V, 544mA).

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9 Waveforms

9.1 Drain Voltage, Normal Operation

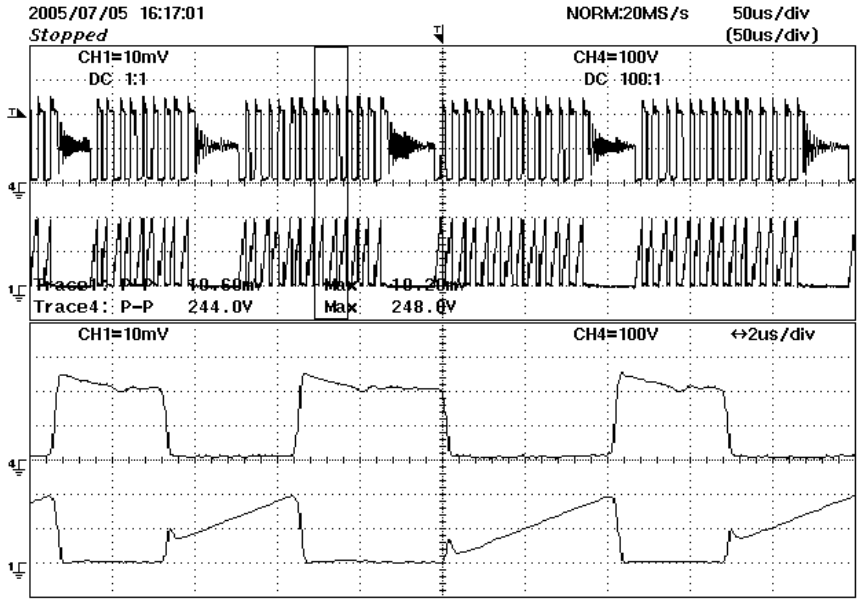

Figure 14 – Drain voltage at 85 VAC input, full load.

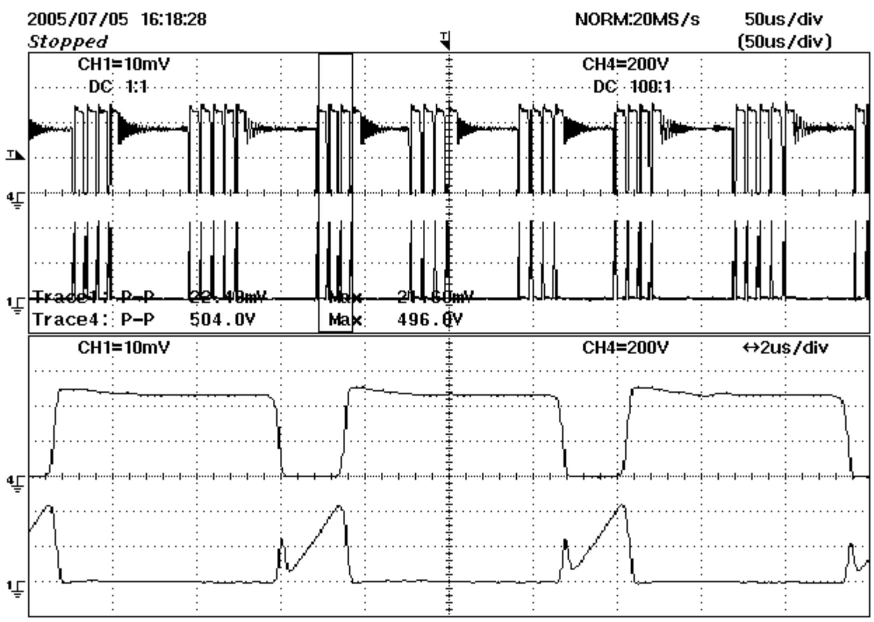

Figure 15 – Drain voltage at 265 VAC, full load.

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9.2 Drain Voltage During Startup

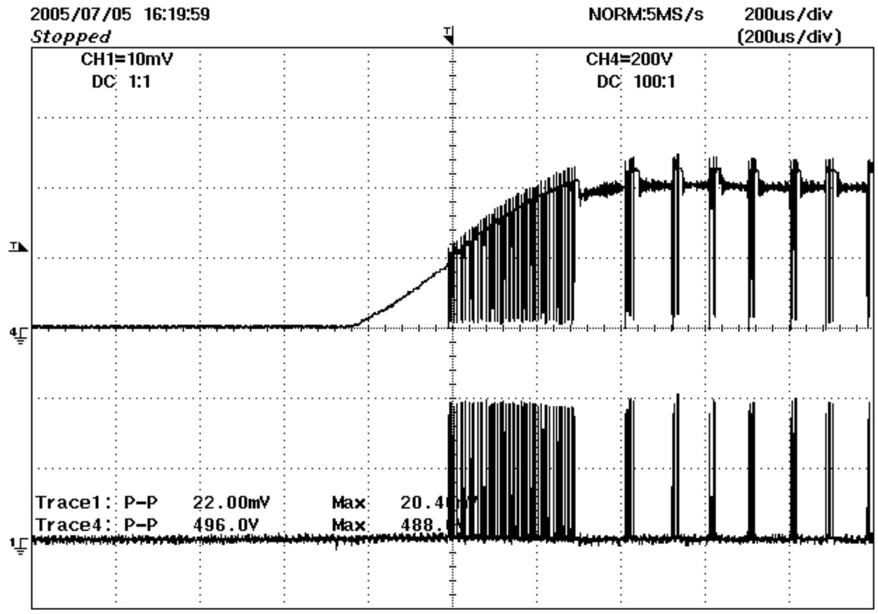

Figure 16 – Drain voltage during startup, 264 VAC, full load.

9.3 Output Voltage Start-up Profile

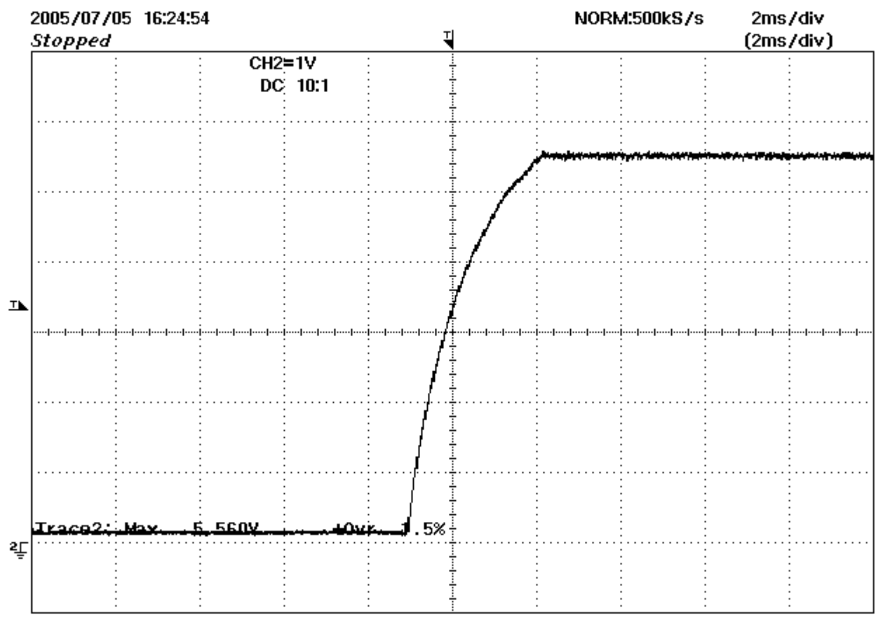

Figure 17 – Output voltage overshoot at 85 VAC, full load.

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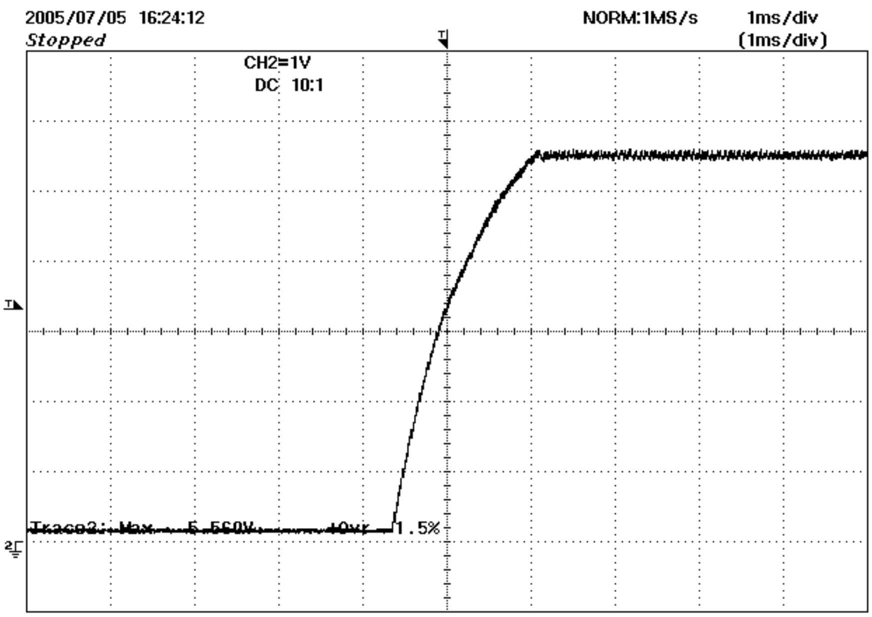

Figure 18 – Output voltage overshoot at 265 VAC, full load.

10 Output Ripple Measurements

10.1.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to pickup. Details of the probe modification are provided in Figure 19 and Figure 20.

The 5125BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 μF/50 V ceramic type and one (1) 1.0 μF/50 V aluminum electrolytic. ***The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).***

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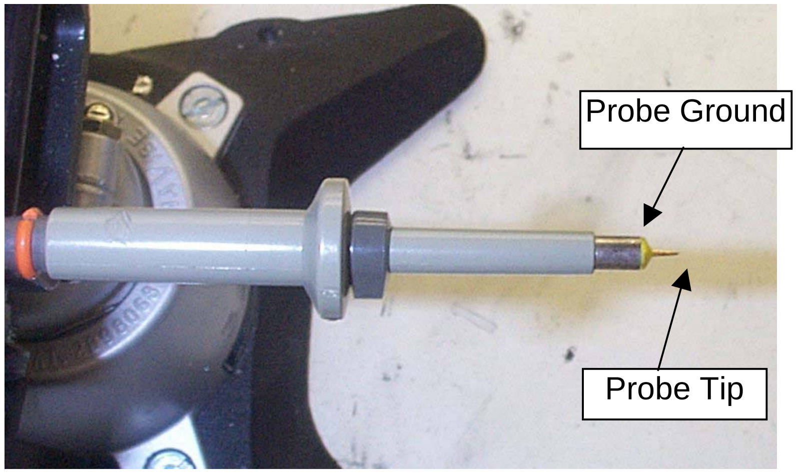

Figure 19 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

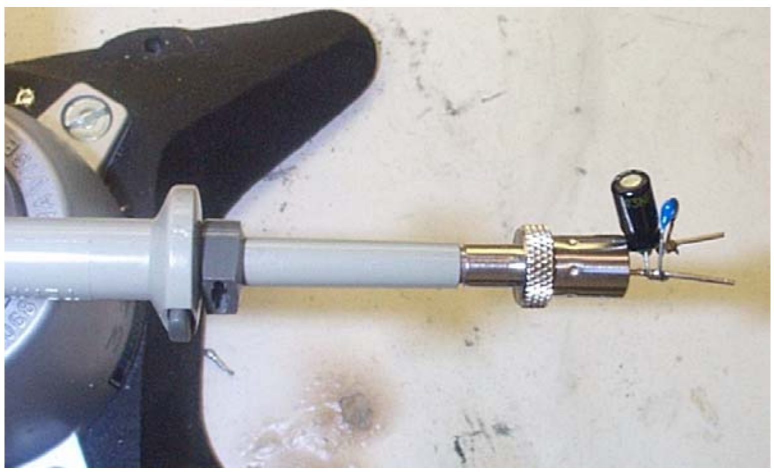

Figure 20 – Oscilloscope Probe with Probe Master 5125BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)

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10.1.2 Measurement Results

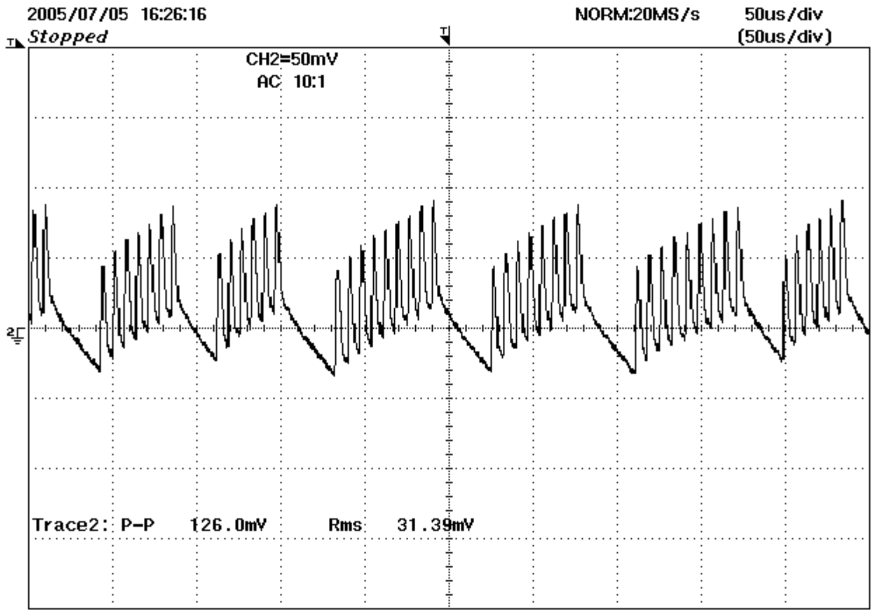

Figure 21 – Output Ripple at 115 VAC, full load.

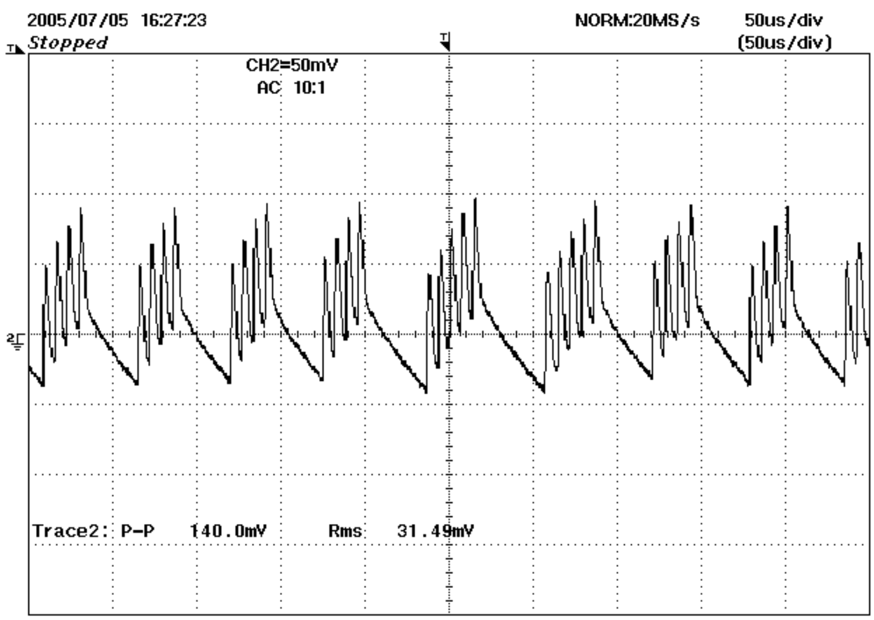

Figure 22 – Output Ripple at 230 VAC input, full load.

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11 Conducted EMI

Conducted EMI was tested at full load. The worst case results shown below.

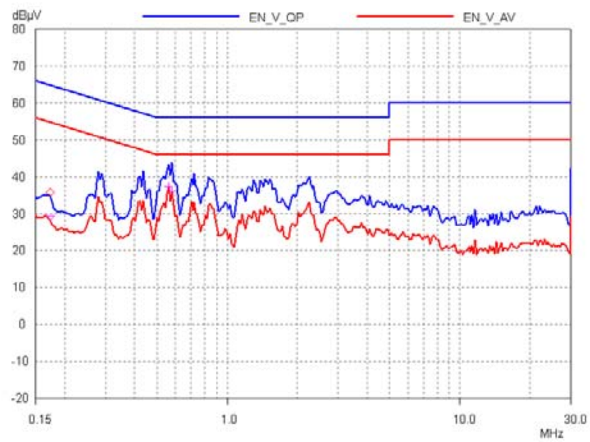

Figure 23 – 120VAC, Line with artificial hand. RCD clamp.

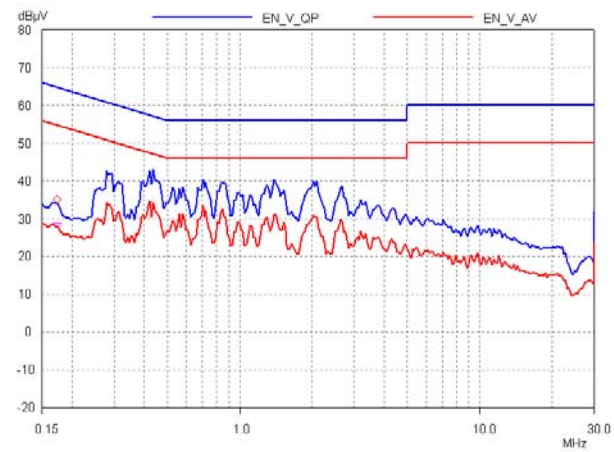

Figure 24 – 230VAC**,** Line with artificial hand, RCD clamp.

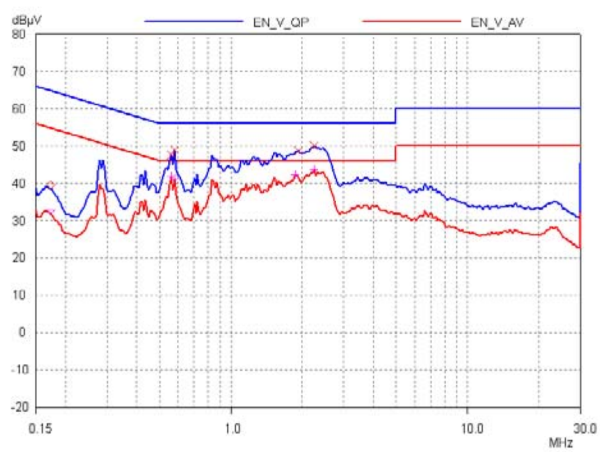

Figure 25 – 120VAC, Line with artificial hand. zener clamp.

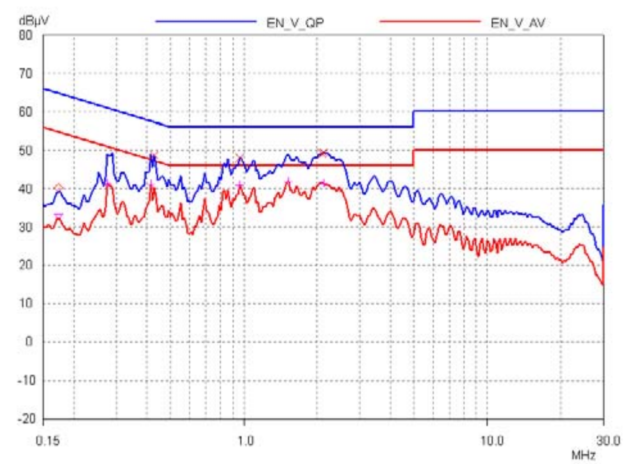

Figure 26 – 230VAC, Line with artificial hand, zener clamp.

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12 Transformer construction with bias winding

12.1 Electrical Diagram

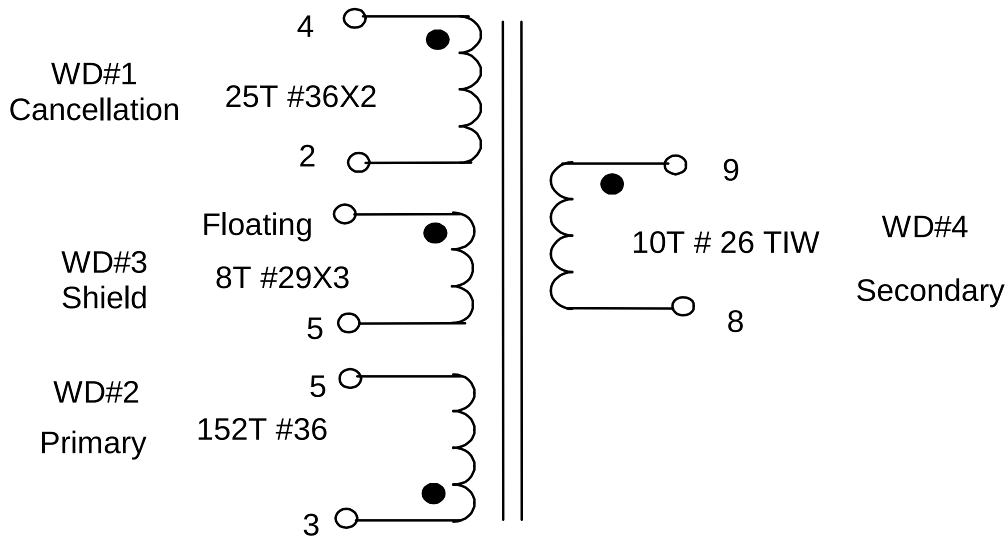

Figure 27 – Transformer Electrical Diagram

12.2 Transformer Build Diagram

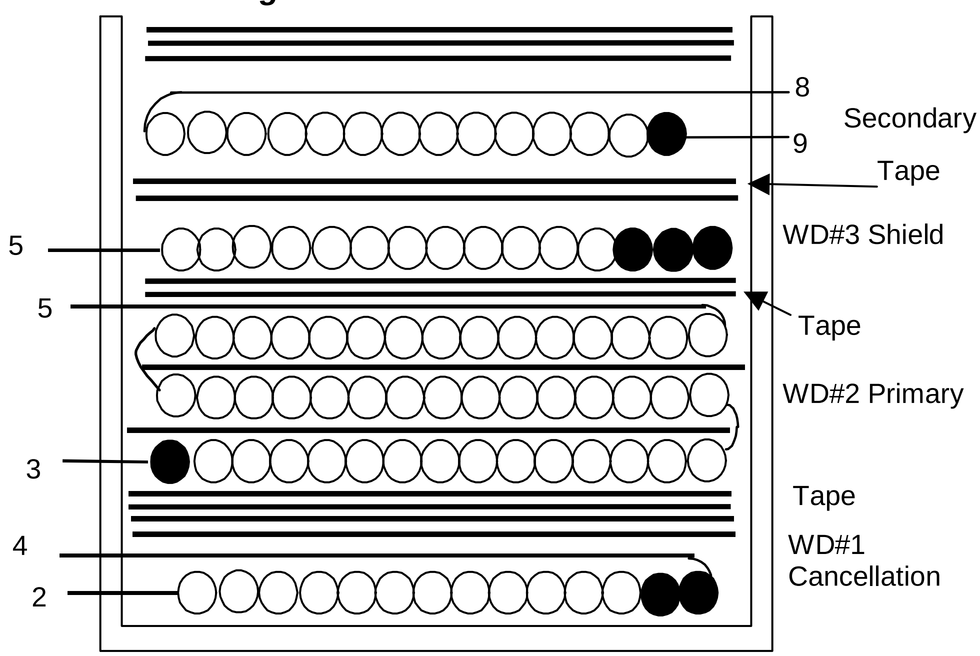

Figure 28 – Transformer Build Diagram

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13 Revision History

Date	Author	Revision	Description & changes	Reviewed
August 24, 2005	YG	1.0	Initial release	AM / VC

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