Design Example Report

Title	***3.5W CV/CC Adapter using TNY264P***
Specification	Input: 90 – 265 VAC Output: 5.5V /0.65A
Application	Cell Phone Charger
Author	Power Integrations Applications Department
Document Number	DER-35
Date	April 5, 2004
Revision	1.0

Summary and Features

This document is an engineering report describing a cell phone charger power supply utilizing a TNY264P, with the following features:

- Low cost
- No Y-cap
- Meets EMI
- Very Low Leakage Current
- Does not require a TL431

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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 report describing a cell phone charger power supply utilizing a TNY264P.

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

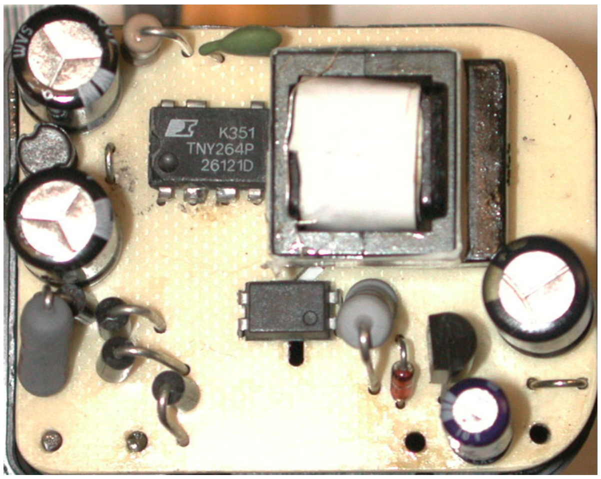

Figure 1 – Populated Circuit Board Photograph.

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2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90	115/230	264	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	63	Hz	
Output						
Output Voltage 1	V_{OUT1}	5.1	5.4	5.7	V	when in CV Mode
Output Ripple Voltage 1	$V_{RIPPLE1}$			100	mV	20 MHz Bandwidth
Output Current 1	I_{OUT1}	600		720	mA	when in CC mode
Total Output Power						
Continuous Output Power	P_{OUT}		3.5		W	
Efficiency	η		55		%	Measured at Full Load Nominal Input Voltage 25 °C
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950, UL1950 Class II				
Ambient Temperature	T_{AMB}	0	25	40	°C	Free convection, sea level

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3 Schematic

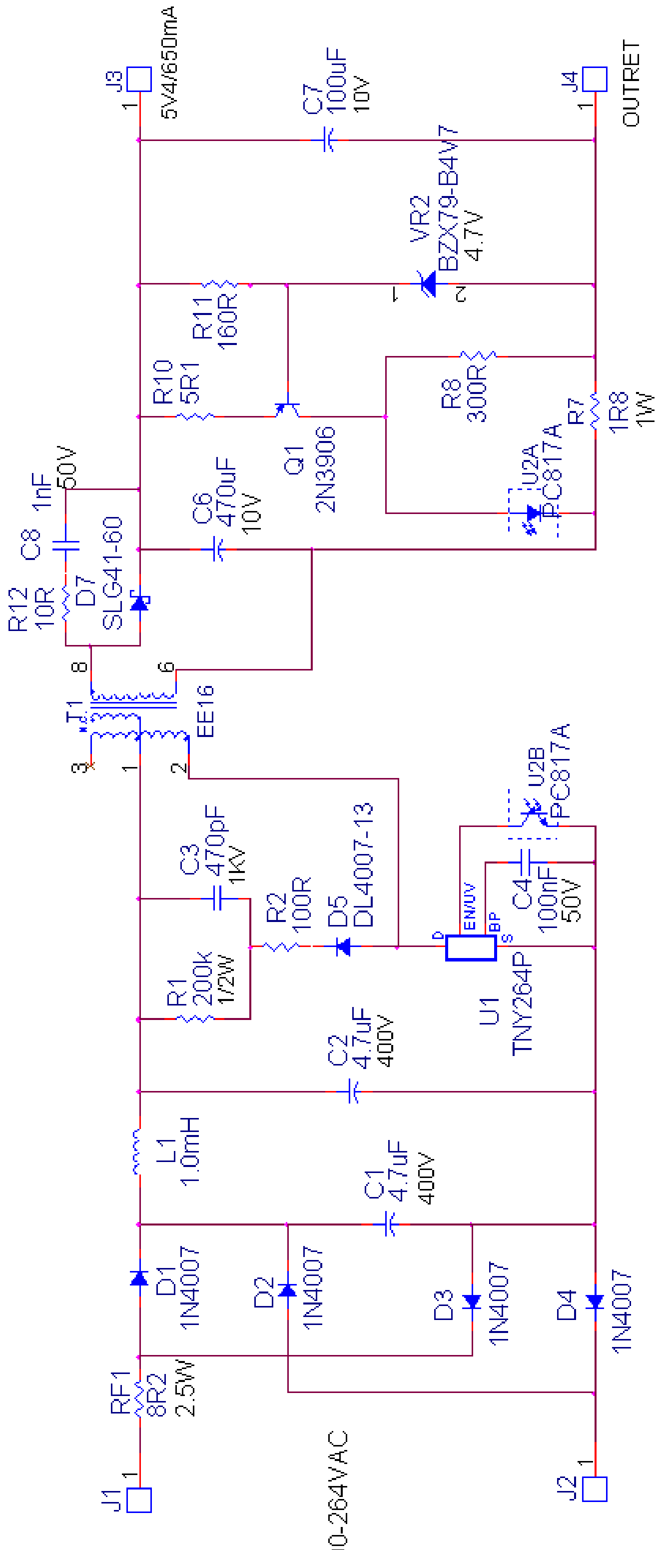

Figure 2 – Schematic.

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4 PCB Layout

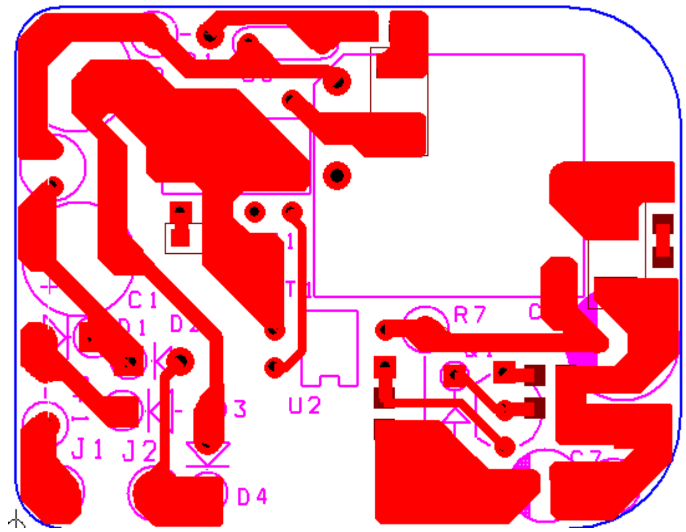

Figure 3 Printed Circuit Layout TOP Silk Screen and Copper Bottom Layers

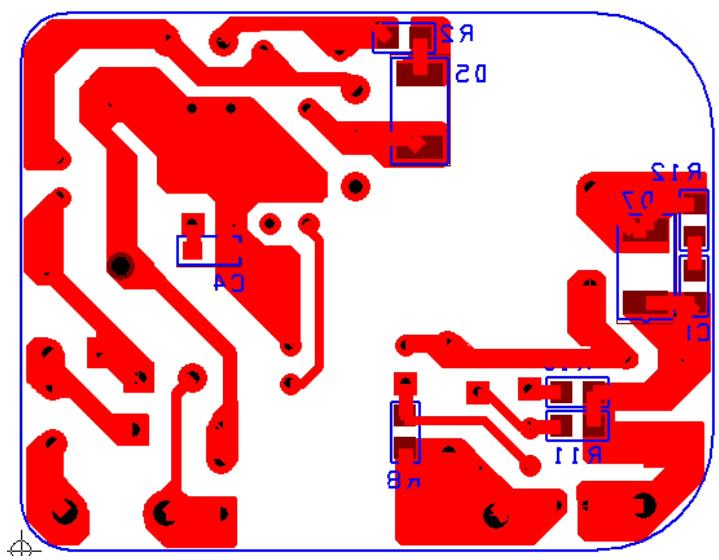

Figure 4 – Printed Circuit Layout. Bottom Silk Screen and Copper Bottom Layers.

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5 Bill Of Materials

Item Number	Quantity	Part Reference	Description
1	2	C1 C2	Cap,Al Elect,4.7uF,400V,8mmX11.5mm,Sam Young
2	1	C3	Cap,Cer,470pF, 1000V, 10%
3	1	C4	CAP 0.1uF 50V CERM CHIP X7R 0805 SMD
4	1	C6	Cap,Al Elect,470uF,10V,8mmX11.5mm,KZE Series,NIPPON CHEMI-CON
5	1	C7	Cap,Al Elect,100uF,10V,5mmX11.5mm,LXZ Series,NIPPON CHEMI-CON
6	1	C8	CAP 1000pF 50V CERM CHIP X7R 0805 SMD
7	4	D1 D2 D3 D4	Rectifier GPP 1000V 1A DO-41
8	1	D5	RECT,DL4007-13 PASSIVATED 1A 1000V SMD MELF
9	1	D7	SLG41-60 DIODE SCHOTTKY,60V 1A
10	4	J1 J2 J3 J4	Terminal,1Pin,18AWG
11	1	L1	CHOKE,1mH,SBCP_47HY102B,TOKIN
12	1	Q1	TRANS,2N3906, PNP SS GP 200MA TO-92
13	1	R1	Res, 200K, 1/2W, 5%, Carbon Film
14	1	R2	Res,100 1/10W 5% 0805 SMD
15	1	R7	Res, 1.8 ,1W, 5%, Metal Film
16	1	R8	Res,300 1/10W 5% 0805 SMD
17	1	R10	Res,5.1 1/10W 5% 0805 SMD
18	1	R11	Res,160 1/10W 5% 0805 SMD
19	1	R12	Res,10 1/10W 5% 0805 SMD
20	1	RF1	Res, Wirewound,8.2 Ohm,2.5W,Flame Retardant
21	1	T1	BEE16_H_LOPROFILE_10P
22	1	U1	IC,TNY264P,L POWER SWITCHER 6W,DIP-8B
23	1	U2	IC,PC817A,PHOTOCOUPLER TRAN OUT CTR 80-160% 4-DIP
24	1	VR2	Diode, Zener, 4.7V, 1/2W, 2%, DO-35

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6 Transformer Specification

6.1 Electrical Diagram

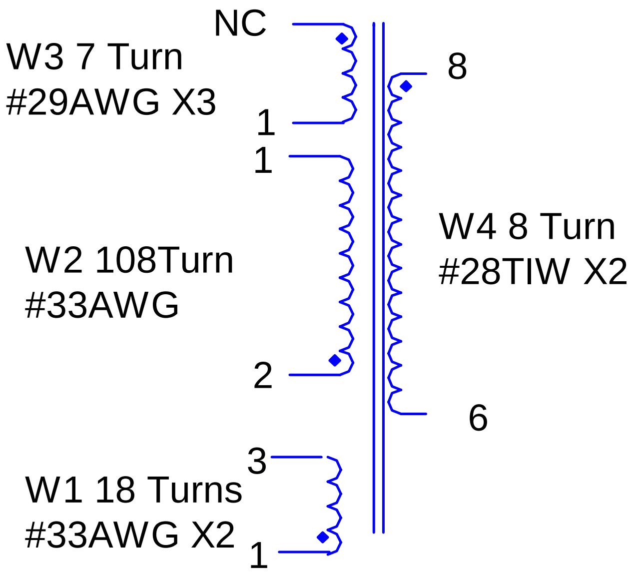

Figure 5 Transformer Electrical Diagram

6.2 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 132 kHz,	2030 µH, -/+10%
Resonant Frequency	Pins 1-2, all other windings open	620 kHz (Min.)
Primary Leakage Inductance	Pins 1-2, with Pins 6-8 shorted, measured at 132 kHz.	65 µH (Max.)

6.3 Materials

Item	Description
[1]	Core: PC40EE16, TDK or equivalent Gapped for AL of $173nH/T^2$
[2]	Bobbin: Horizontal 10 pin
[3]	Magnet Wire: #33 AWG
[4]	Magnet Wire: #29 AWG
[5]	Bus wire #29AWG
[6]	Triple Insulated Wire: #28 AWG.
[7]	Tape: 3M 1298 Polyester Film, 2.0 mils thick, 8.4 mm wide
[8]	Varnish

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6.4 Transformer Build Diagram

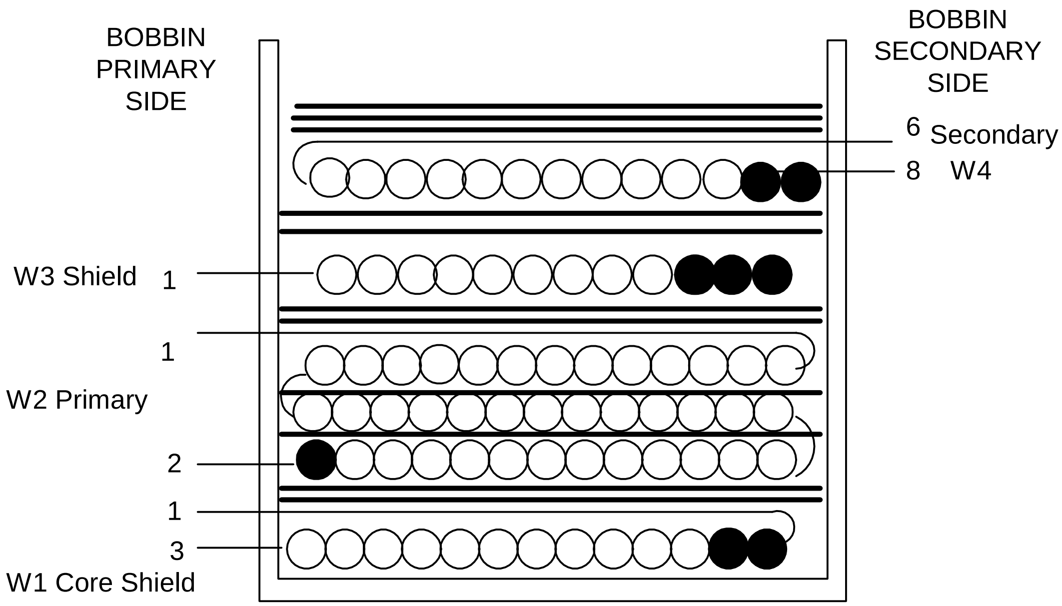

Figure 6 – Transformer Build Diagram.

6.5 Transformer Construction

Bobbin Preparation	Place the bobbin item [2] in the winding machine with primary side oriented to the left hand side.
Core Cancellation	Start at Pin 8 temporarily. Wind 18 bifilar turns of item [3] from right to left. Wind uniformly with tight tension across winding area. Finish on pin 3 Fold and attach the starting lead to pin 1
Basic Insulation	Use two layers of item [7] for basic insulation.
Primary	Start at pin 2 wind 36 turns of item [3] from left to right, apply one layer of item [7]. Continue winding on a second layer. Wind 36 turns from right to left, apply one layer of item [7]. On a third layer wind 36 turns from left to right. Wind with tight tension across entire bobbin. Finish at pin 1
Basic Insulation	Use two layers of item [7] for basic insulation.
Shield	Start at Pin 8 temporarily, wind 7 trifilar turns of item [4]. Wind from right to left with tight tension in a single layer across entire width of bobbin. Finish on Pin 1.
Shield	Cut the starting lead right where the winding begins
Basic Insulation	Use two layer of item [7] for basic insulation.
Secondary Winding	Start at Pins 8. Wind 8 bifilar turns of item [6] Spread turns evenly across bobbin. Finish on Pin 6.
Outer Wrap	Use two layer of item [7] for basic insulation.
Core Preparation	Assembly cores halves. Wind two turns of item [5] around the core. The wire should be placed very close to the primary pin side of the bobbin. Terminate the wire at pin 1.
Final Assembly	Varnish impregnate (item [8]). Cut pins 4,5,7,9,and 10 of Bobbin [2]

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7 Transformer Spreadsheets

ACDC_TNY-II_Rev1_1_032701 Copyright Power Integrations Inc. 2001	**INPUT**	**INFO**	**OUTPUT**	**UNIT**	**ACDC_TNYII_Rev1_1_032701.xls: TinySwitch-II Continuous/Discontinuous Flyback Transformer Design Spreadsheet**
ENTER APPLICATION VARIABLES					**TRANSFORMER 1**
VACMIN	90			Volts	Minimum AC Input Voltage
VACMAX	265			Volts	Maximum AC Input Voltage
fL	47			Hertz	AC Mains Frequency
VO	5.4			Volts	Output Voltage
PO	4.46897962			Watts	Output Power
n	0.67				Efficiency Estimate
Z	0.5				Loss Allocation Factor
tC	3			mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	9.4			uFarads	Input Filter Capacitor
ENTER TinySwitch-II VARIABLES					
TNY-II	**TNY264**			*Universal*	*115 Doubled/230V*
Chosen Device		*TNY264*	*Power Out*	*6W*	*9W*
ILIMITMIN			*0.233*	Amps	TINYSwitch Minimum Current Limit
ILIMITMAX			*0.267*	Amps	TINYSwitch Maximum Current Limit
fS			*132000*	Hertz	TINYSwitch Switching Frequency
fSmin			*120000*	Hertz	TINYSwitch Minimum Switching Frequency (inc. jitter)
fSmax			*144000*	Hertz	TINYSwitch Maximum Switching Frequency (inc. jitter)
VOR	80			Volts	Reflected Output Voltage
VDS	10			Volts	TINYSwitch on-state Drain to Source Voltage
VD	0.5			Volts	Output Winding Diode Forward Voltage Drop
KP			**0.60**		Ripple to Peak Current Ratio (0.6<KRP<1.0 : 1.0<KDP<6.0)
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**EE16**				
Core		*EE16*		*P/N:*	PC40EE16-Z
Bobbin			*EE16_BOBBIN*	*P/N:*	BE-16-118CPH
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	**8**				Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			73	Volts	Minimum DC Input Voltage
VMAX			375	Volts	Maximum DC Input Voltage
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.56		Maximum Duty Cycle
IAVG			0.09	Amps	Average Primary Current
IP			0.23	Amps	Minimum Peak Primary Current
IR			0.14	Amps	Primary Ripple Current
IRMS			0.13	Amps	Primary RMS Current
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			2035	uHenries	Primary Inductance
NP			108		Primary Winding Number of Turns
ALG			173	nH/T^2	Gapped Core Effective Inductance
BM			**2609**	Gauss	Flux Density, IP (BP<3000)
BAC			683	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1654		Relative Permeability of Ungapped Core
LG			**0.12**	mm	Gap Length (Lg > 0.1 mm)

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BWE			25.8	mm	Effective Bobbin Width
OD			0.24	mm	Maximum Primary Wire Diameter including insulation
INS			0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.19	mm	Bare conductor diameter
AWG			33	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			51	Cmils	Bare conductor effective area in circular mils
CMA			**405**	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT / SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			3.16	Amps	Peak Secondary Current
ISRMS			1.51	Amps	Secondary RMS Current
IO			0.83	Amps	Power Supply Output Current
IRIPPLE			1.27	Amps	Output Capacitor RMS Ripple Current
CMS			303	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			25	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.46	mm	Secondary Minimum Bare Conductor Diameter
ODS			1.08	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
INSS			0.31	mm	Maximum Secondary Insulation Wall Thickness
VOLTAGE STRESS PARAMETERS					
VDRAIN			563	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS			33	Volts	Output Rectifier Maximum Peak Inverse Voltage

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8 Performance Data

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

8.1 Efficiency

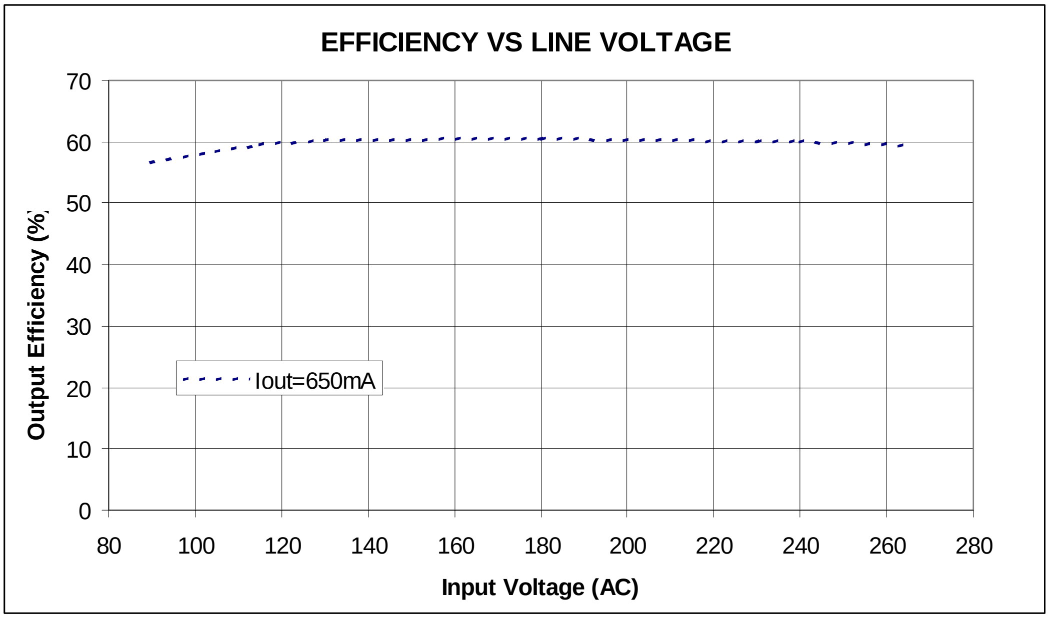

Figure 7- Efficiency vs. Input Voltage, Room Temperature, 60 Hz.

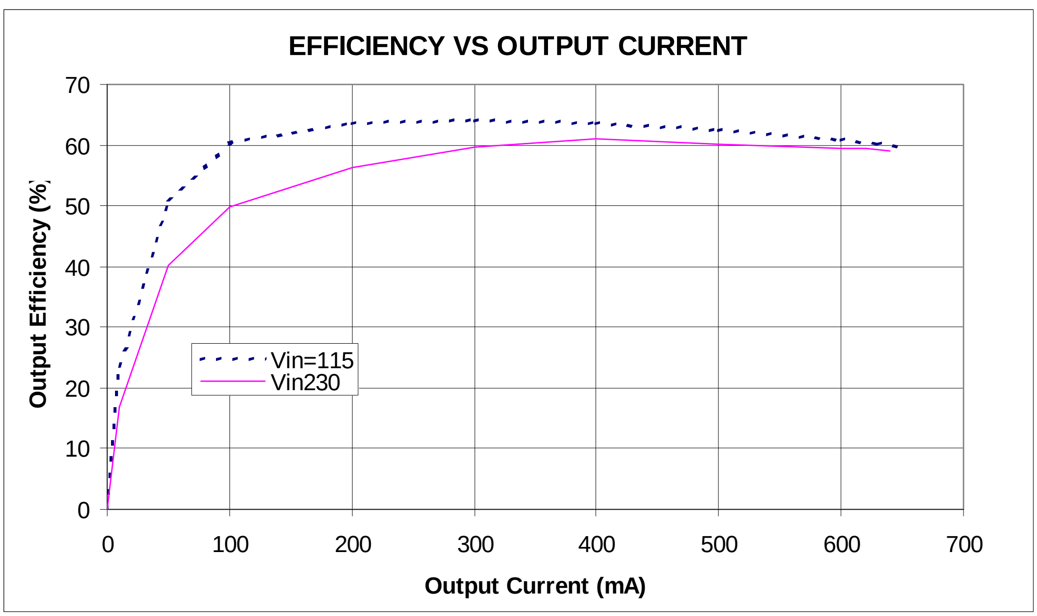

Figure 8. Efficiency VS Output Load. Room Temperature, 60 Hz.

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8.2 No-load Input Power

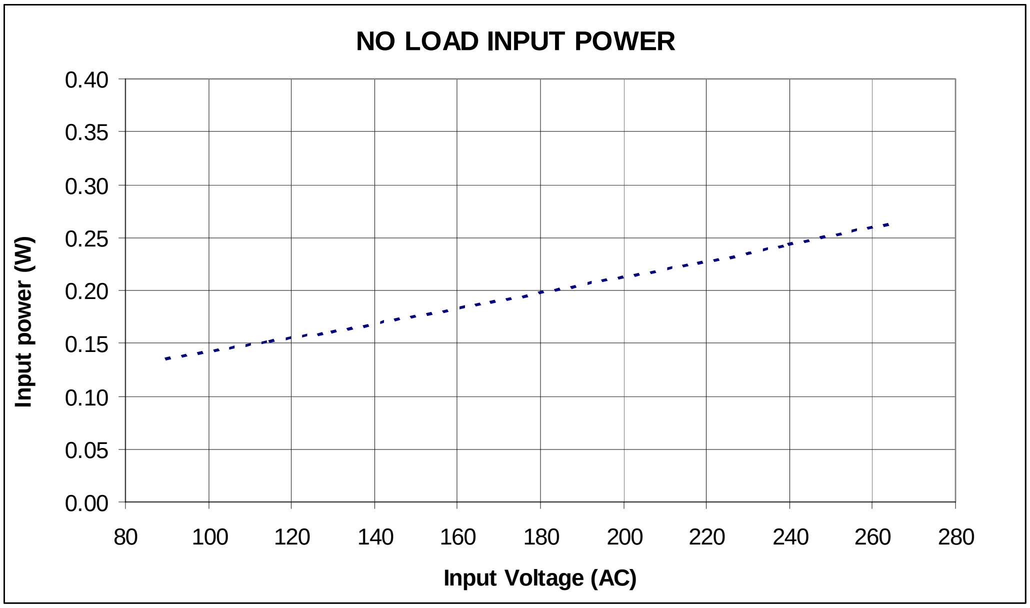

Figure 9- Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.

8.3 Output Characteristic.

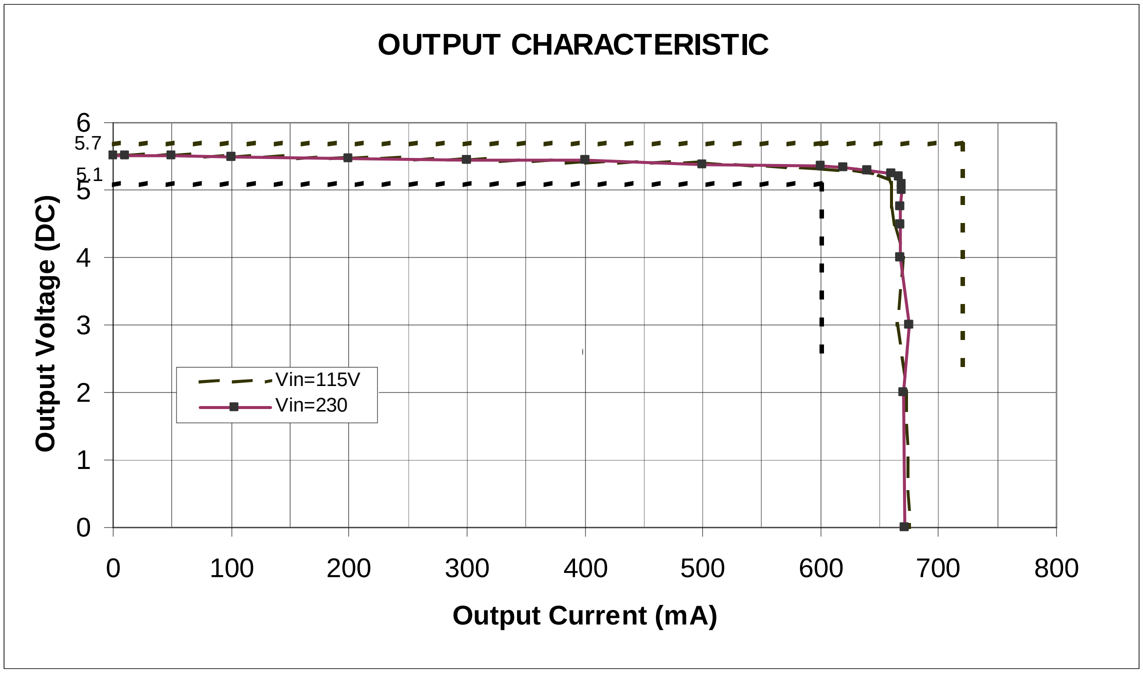

Figure 10 –Output Characteristic, 25 ^{o}C

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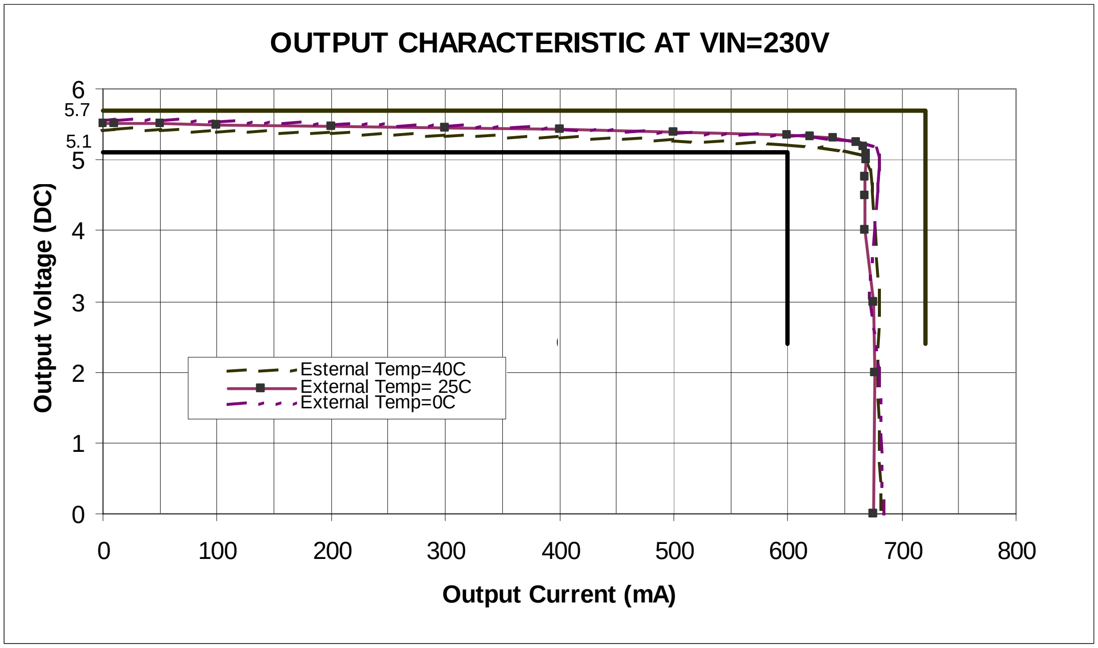

Figure 11. Output Characteristic at different ambient temperatures

8.4 Line Regulation

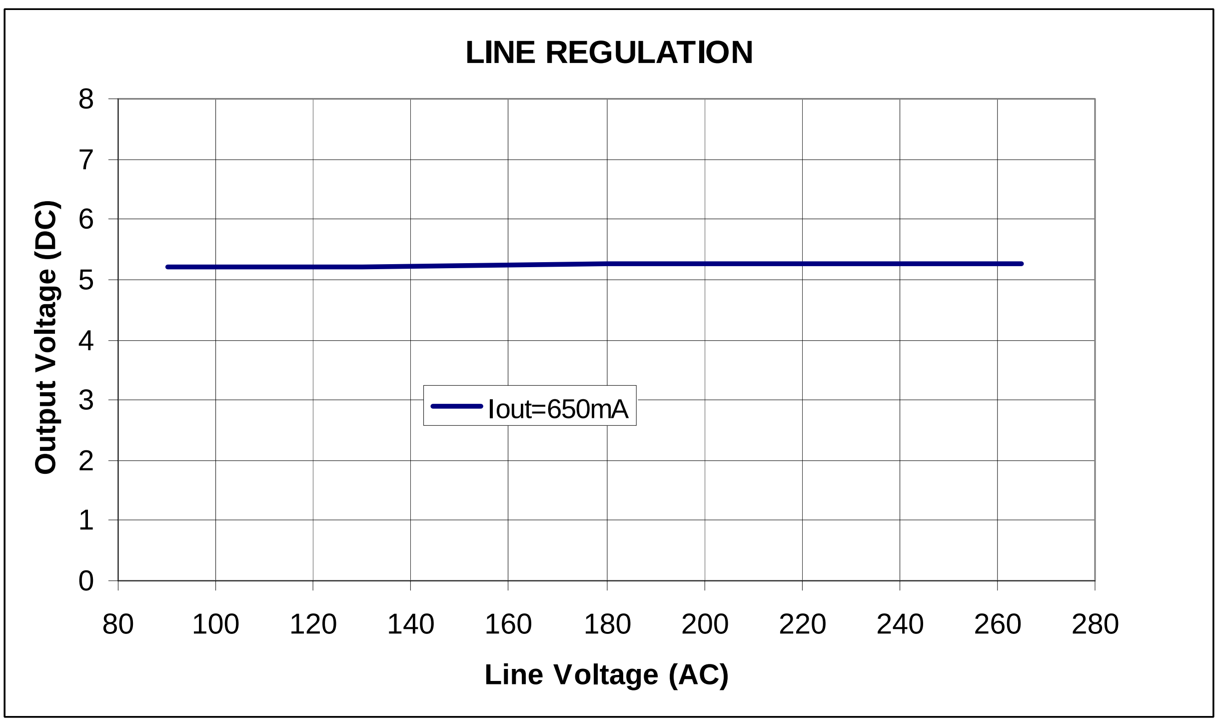

Figure 12 – Line Regulation, Room Temperature, Full Load.

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9 Thermal Performance

Measurements were done with the supply enclosed in its case.

Temperature (°C)			
Item	**Vin=90VAC**	**Vin=115VAC**	**Vin=230VAC**
Ambient (C)	25	25	25
Transformer (T1)	73	70	69
Blocking Diode (D5)	71	67	65
***TinySwitch-II* (U1)**	97	77	69
Output Rectifier (D7)	69	68	67

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10 Waveforms

10.1 Drain Voltage and Current, Normal Operation

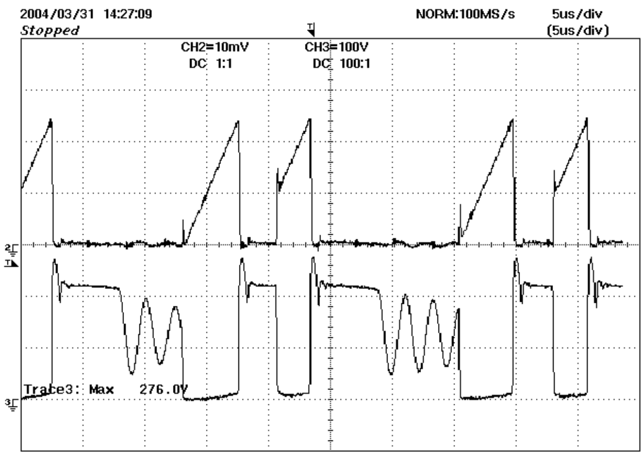

Figure 13 - 90 VAC, Full Load.
Upper: I_{DRAIN}, 0.1 A / div
Lower: V_{DRAIN}, 100 V, 5 µs / div

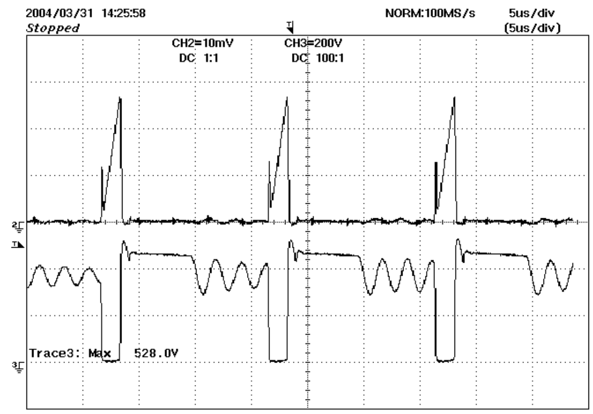

Figure 14 - 264 VAC, Full Load
Upper: I_{DRAIN}, 0.1 A / div
Lower: V_{DRAIN}, 200 V / div

10.2 Output Voltage Start-up Profile

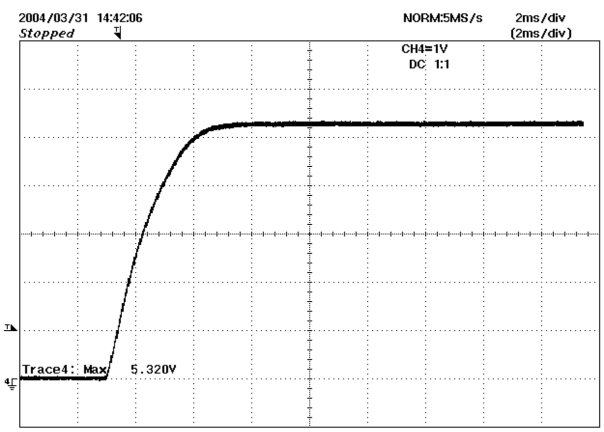

Figure 15 - Start-up Profile, 115VAC
1 V, 2 ms / div.

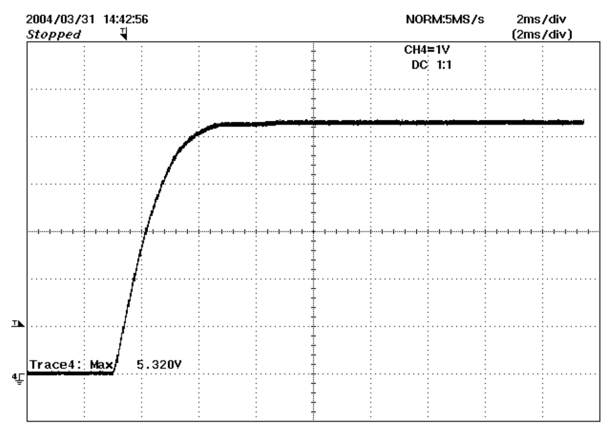

Figure 16 - Start-up Profile, 230 VAC
1 V, 2 ms / div.

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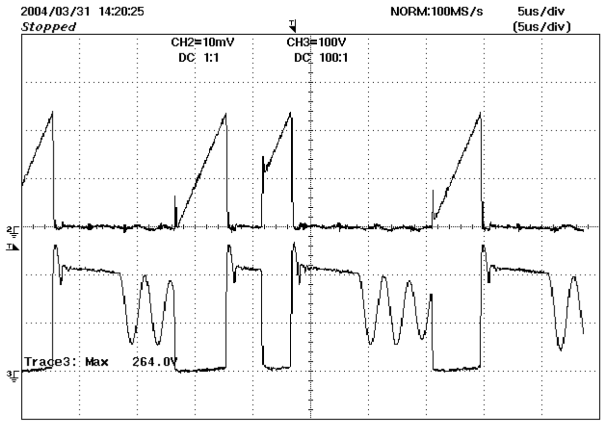
10.3 Drain Voltage and Current Start-up Profile



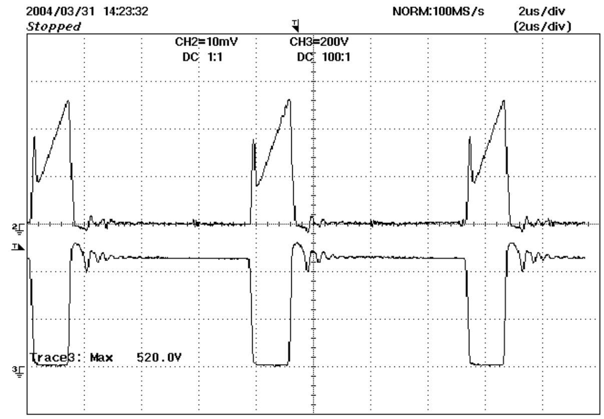
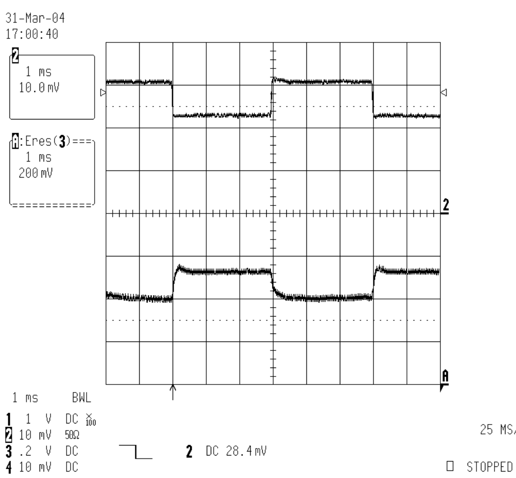


Figure 17 - 90 VAC Input and Maximum Load.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 100 V & 5us / div.

Figure 18 - 264 VAC Input and Maximum Load.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 200 V & 2us / div.

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

In the figures shown below, the oscilloscope was triggered using the load current step as a trigger source.



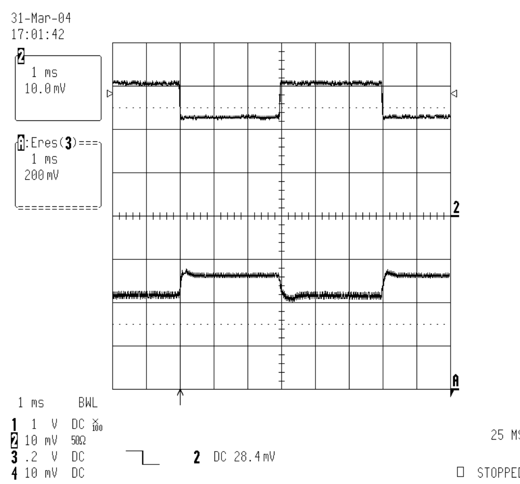


Figure 19 – Transient Response, 115 VAC, 75-100-75% Load Step.
Top: Load Current, 0.2 A/div.
Bottom: Output Voltage
200 mV, 1ms / div.

Figure 20 – Transient Response, 230 VAC, 75-100-75% Load Step
Upper: Load Current, 0.2 A/ div.
Bottom: Output Voltage
200mV, 1ms / div.

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10.5 Out put Ripple Measurements

10.5.1 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 21 and Figure 22.

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) 10.0 µF/50 V aluminum electrolytic. ***The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).***

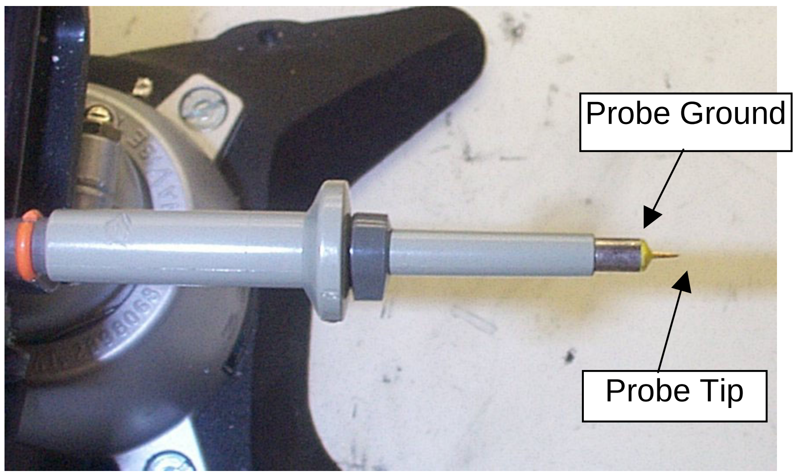

Figure 21 - Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

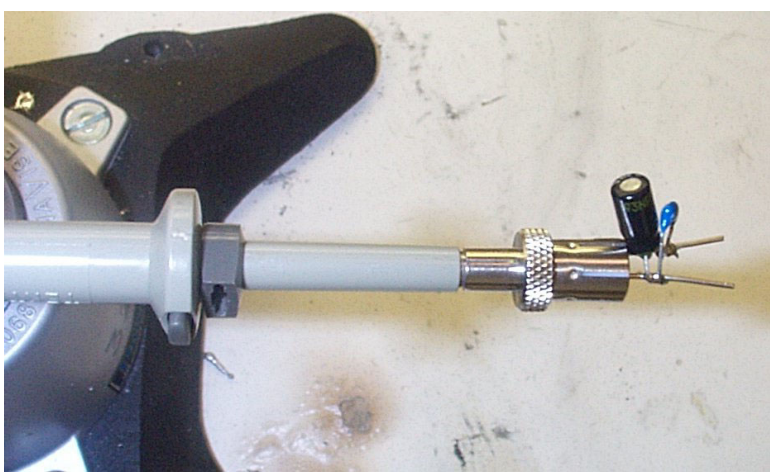

Figure 22 - Oscilloscope Probe with Probe Master 5125BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)

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10.5.2 Measurement Results

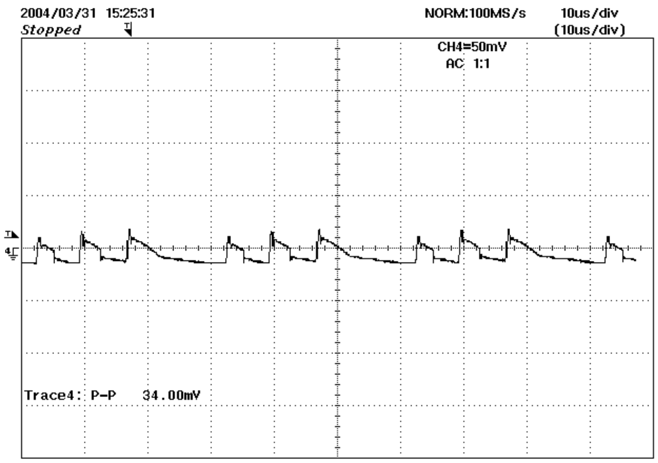

Figure 23 – Output Ripple, 85 VAC, Full Load.
10us, 50 mV / div

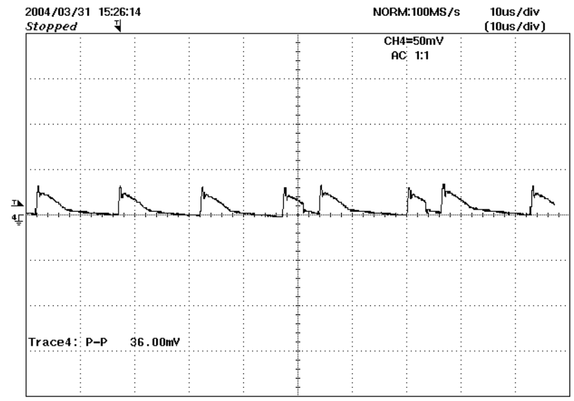

Figure 24 - Output Ripple, 115 VAC, Full Load.
10us, 50 mV / div

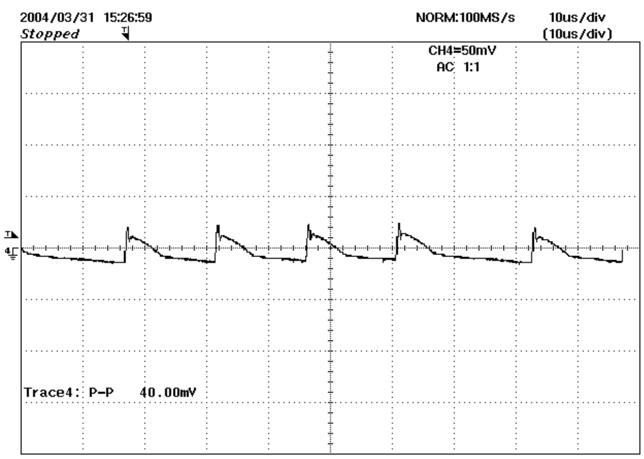

Figure 25 – Output Ripple, 230 VAC, Full Load.
10us, 50 mV /div

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11 Conducted EMI

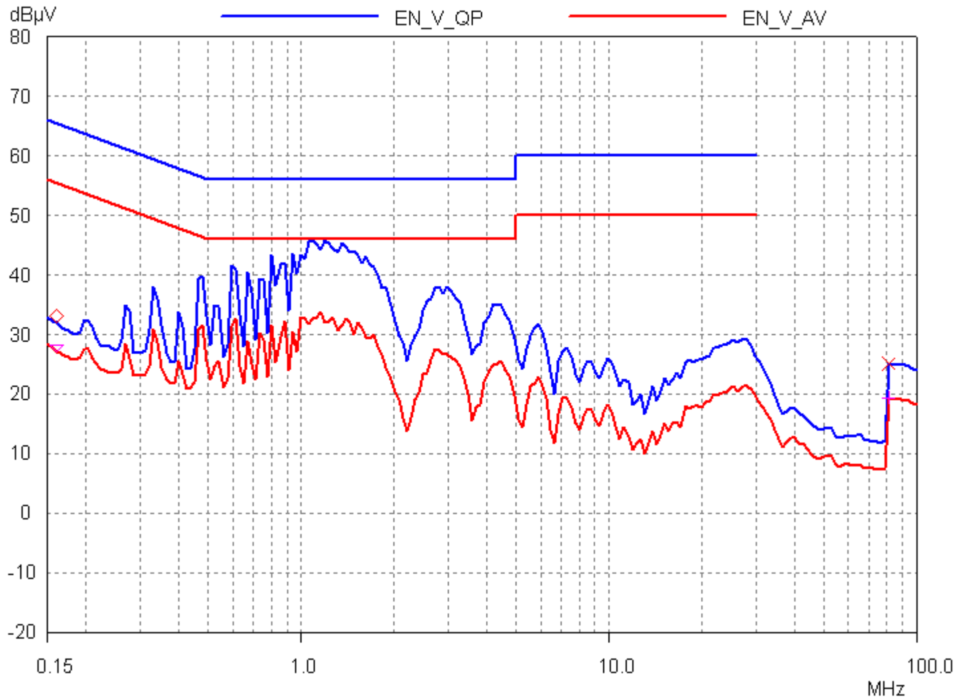

Figure 26 - Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits.

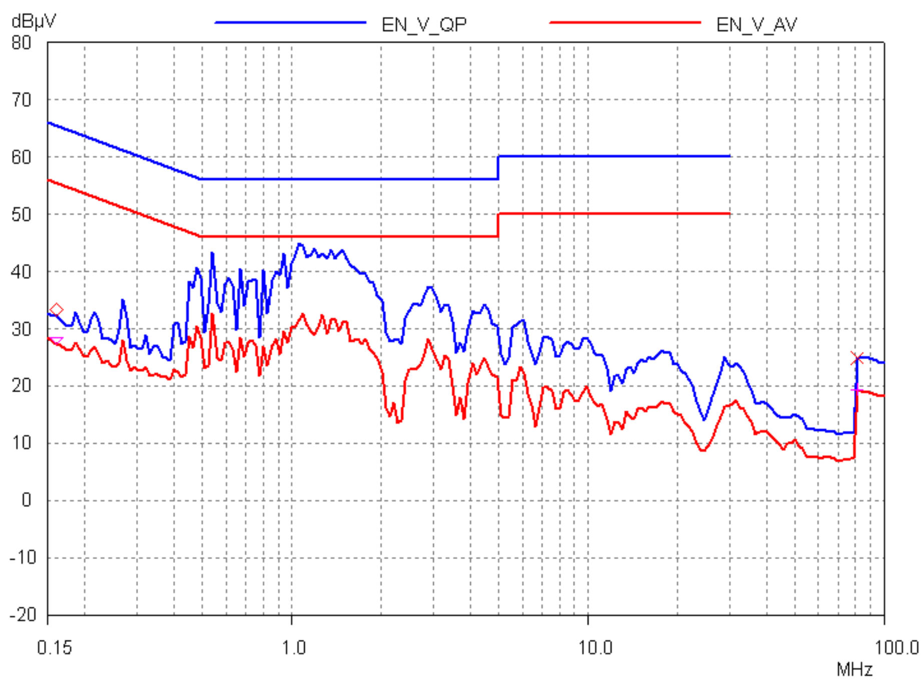

Figure 27 - Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits.

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12 Revision History

Date	Author	Revision	Description & changes	Reviewed
April 5, 2004	VC	1.0	Initial release	AM / VC

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