Design Example Report

Title	***8.75 W Power Supply using TNY268P***
Specification	Input: 90 – 265VAC Output: 3.5V / 2.5A (4A peak)
Application	Adapter
Author	Power Integrations Applications Department
Document Number	DER-60
Date	May 27, 2005
Revision	1.0

Summary and Features

- Low cost, low parts count.
- No Y1 Safety capacitor to pass EN55022B.
- No load input power < 300mw @ 265VAC.
- Meet CEC requirement with 3.3V2.5A/ 1.8M 18AWG output cable.
- Meet LPS < 17.5W with full range input.
- OTP, OVP latch function.

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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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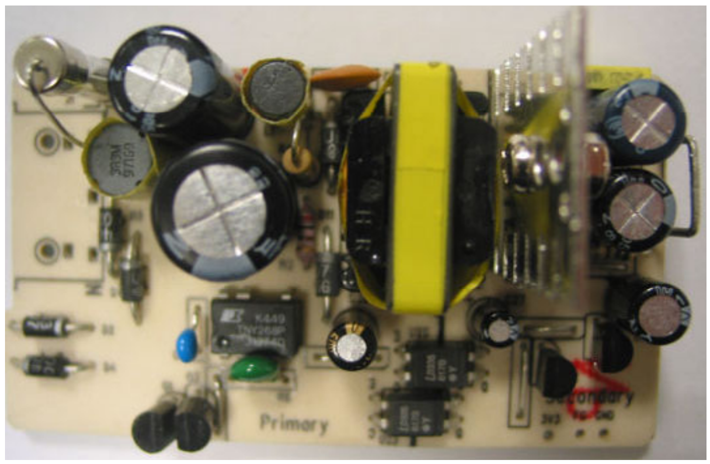
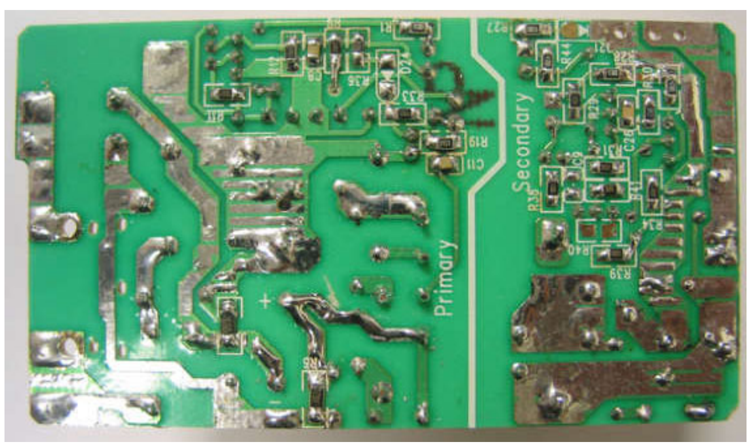
1 Introduction

This document is an engineering report describing an adapter power supply utilizing a TNY268P. This power supply is intended as a general purpose evaluation platform for TNY268P.

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



(Component side)



(Solder side)

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}	85		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (240 VAC)				0.3	W	
Output						
Output Voltage 1	V_{OUT1}	3.3	3.5	3.7	V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$		300	400	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}			2.5	A	
Total Output Power						
Continuous Output Power	P_{OUT}			8.75	W	
Peak Output Power	P_{OUT_PEAK}			14	W	
Efficiency	η		70		%	Measured at P_{OUT} (8.75 W), 25 °C
CEC Efficiency (115VAC and 230VAC)	**Avg.** η	68.6			%	Avg. Eff. At 25%, 50%, 75% and 100% load
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950, UL1950 Class II				
Ambient Temperature	T_{AMB}	0		40	°C	Free convection, sea level

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3 Schematic

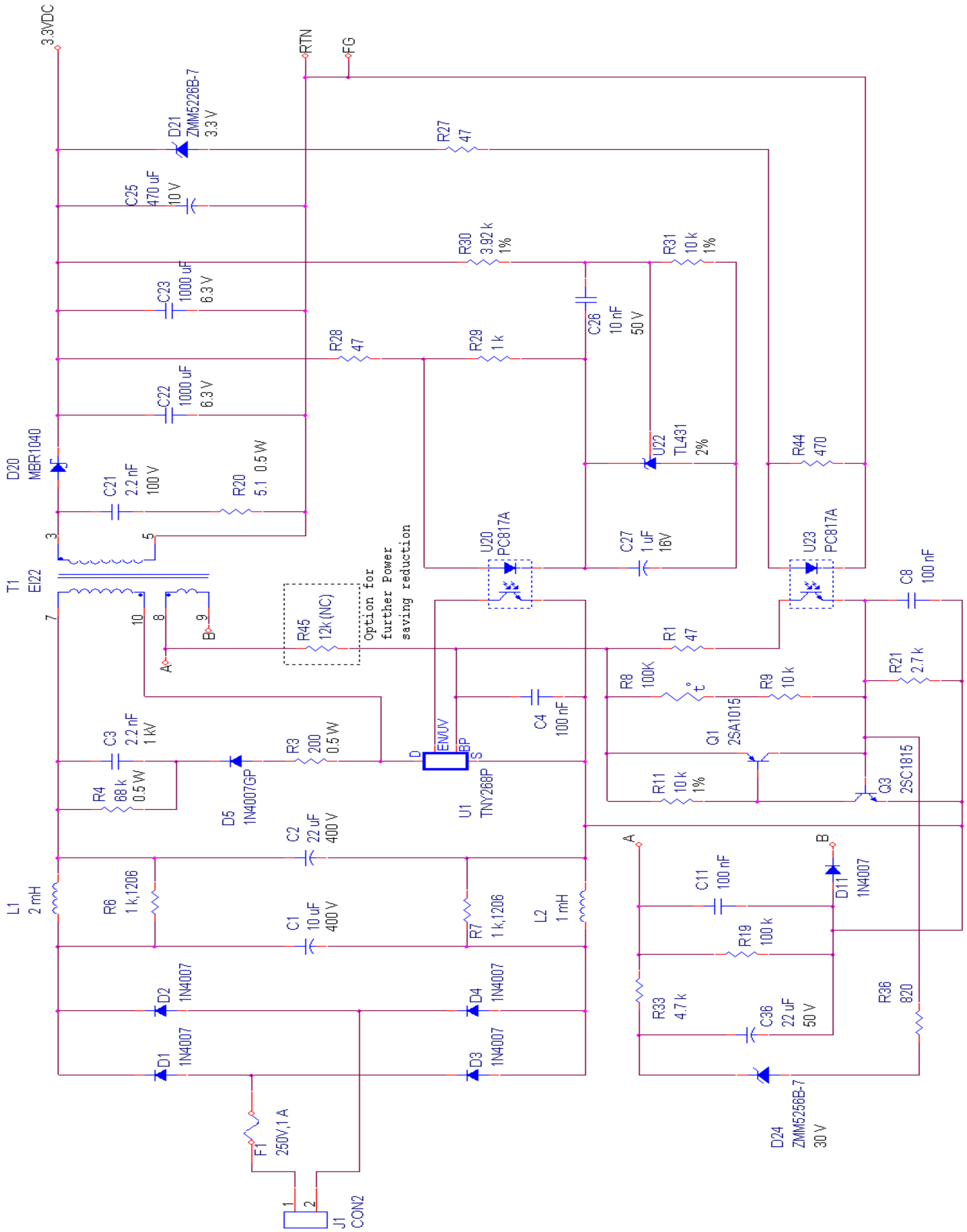

Figure 2 – Schematic

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4 Circuit Description

A Flyback converter is used to obtain 3.5V 2.5A output from 90-265 VAC input. The bias winding, which also serves as core cancellation winding to reduce EMI noise, provides current to the BP pin of TNY268P, to reduce the No-Load Input Power consumption by about 0.1 W.

4.1 Input Rectification and EMI Filtering

Fuse F1 protects the charger against any fault condition, and input current exceeds 1A. Diodes D1, D2, D3, and D4 form Full-bridge rectifier, and rectify the AC voltage into DC voltage and charge the capacitors C1 and C2. L1, L2, C1, and C2 form π – filter and attenuate EMI noise. Here, C1 and C2 act as both storage capacitors and part of EMI filter, which reduces the total cost.

4.2 TOPSwitch Primary

This design uses RCD (C3, D5, R4, and R3) clamping across primary winding to limit the drain voltage below 700V, when the Mosfet inside U1 turns OFF. The capacitor C4 connected to BP (by-pass) pin of U1 stores energy and provide power for the internal circuit of U1 and also to turn ON the U1's Mosfet, during power-up and steady state operation. C11, D11, and R19 form bias supply components, which provide power to the BP pin during steady state operation. This will reduce the No-load input power consumption. R45 limits the current flowing to BP pin, and it is tuned to reduce the No-load input power to minimum. The opto-coupler transistor pulls down enable (EN) pin of U1. TinySwitch-II keeps on switching as long as the pull down current < 250 μA. U1 will stop switching if the pull down current exceeds 250 μA.

4.3 Output Rectification

When U1 Mosfet is turned ON, current flows through transformer primary and stores energy. When U1 is ON, output diode D20 is OFF. When the U1 Mosfet is OFF, D20 is forward biased, and the stored energy is transferred to the secondary and stores in C22, C23 and C25. The snubber C21 and R20 across secondary winding will improve EMI.

4.4 Output Feedback

Resistors R30, R31 divide down the supply output voltage and apply it to the reference pin of error amplifier U22. Shunt regulator U22 drives optocoupler U20 through resistor R28 to provide feedback information to the U1 EN pin. Capacitor C27 drives the optocoupler during supply startup to reduce output voltage overshoot. C26 plays a role in compensating of the power supply feedback loop.

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4.5 OTP, OVP and LPS Protection Circuit

Q1, Q3, R11 and R21 from a SCR to pull BP pin act as a latch circuit. R8 is a thermal resistor of a NTC type. R8 and R9 from an OTP's trigger circuit of the SCR. The SCR will be triggered when temperature raise to OTP setting point.

D21, R27, R44, U23 and R1 form an OVP trigger circuit of the SCR. When output voltage raise to let D21 conducted, it will trigger the SCR for protection.

R33, C36, D24 and R36 form a LPS trigger circuit of the SCR. R33 and C36 set at about 300ms delay time for peak 4A output current testing. (The peak current testing is 4A/200ms/ 1A/us and 0.25A/ 1800ms/ 1A/us, and then the output voltage can't be less than 3V.) If the output load is increased, the bias voltage will be increased too. When the bias voltage increased to LPS setting point, it will let D24 conducted to trigger the SCR for protection.

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5 PCB Layout

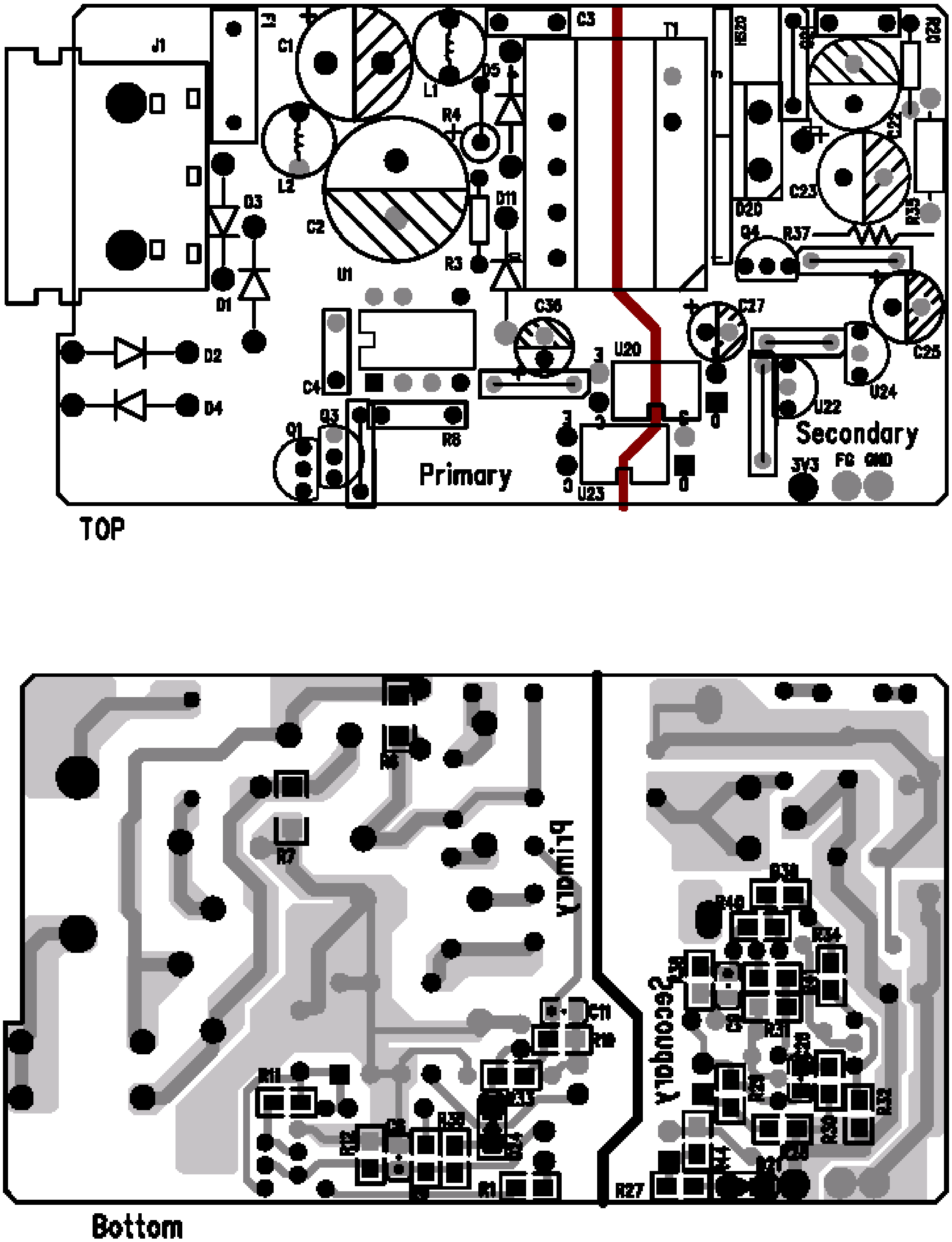

Figure 3 – Printed Circuit Layout

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6 Bill Of Materials

Item	Quantity	Reference	Description	Part NO.
1	1	C1	10UF/400V	
2	1	C2	22UF/400V	
3	1	C3	2200pF/1KV	
4	4	C4,C8,C11,C26	100n	
5	1	C14	0.01U/250VAC	
6	1	C21	2.2nF/100V	
7	2	C22,C24	1000uF/6.3V	
8	1	C27	1U/16V	
9	1	C36	22U/50V	
10	5	D1,D2,D3,D4,D11	1A / 1000V	1N4007
11	1	D5	1A / 1000V	1N4007GP
12	1	D20	10A / 40V	MBR1040
13	1	D21	3V3/0.5W	
14	1	D24	30V/0.5W	
16	1	F1	FUSE 250V / 1A	
17	1	J1	AC INLET	AC INLET
18	1	L1	CHOKE 2mH	DR CORE
19	1	L2	CHOKE 1mH	DR CORE
20	1	Q1	PNP Transistor	2SA1015(PNP)
21	1	Q3	NPN Transistor	2SC1815(NPN)
22	3	R1,R27,R28	47R / 0805	
23	1	R3	200R / 0.5W	
24	1	R4	68K / 0.5W	
25	2	R6,R7	1K / 1206	
26	2	R8,R19	100K / 0805	
27	2	R9,R11	10K / 0805	
28	1	R12	2K7 / 0805	
29	1	R20	5R1/ 0.5W	
30	1	R29	1K / 0805	
31	1	R30	4K32,1%	
32	1	R31	10K,1%	
33	1	R33	4K7 / 0805	
34	1	R36	820R / 0805	
35	1	R44	470R / 0805	
36	1	T1	Transformer	EI22
37	1	U1	Tiny switch	TNY268P
38	2	U20,U23	Photo coupler	LTV817B
39	1	U22	TL431	

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7 Transformer Specification

7.1 Electrical Diagram

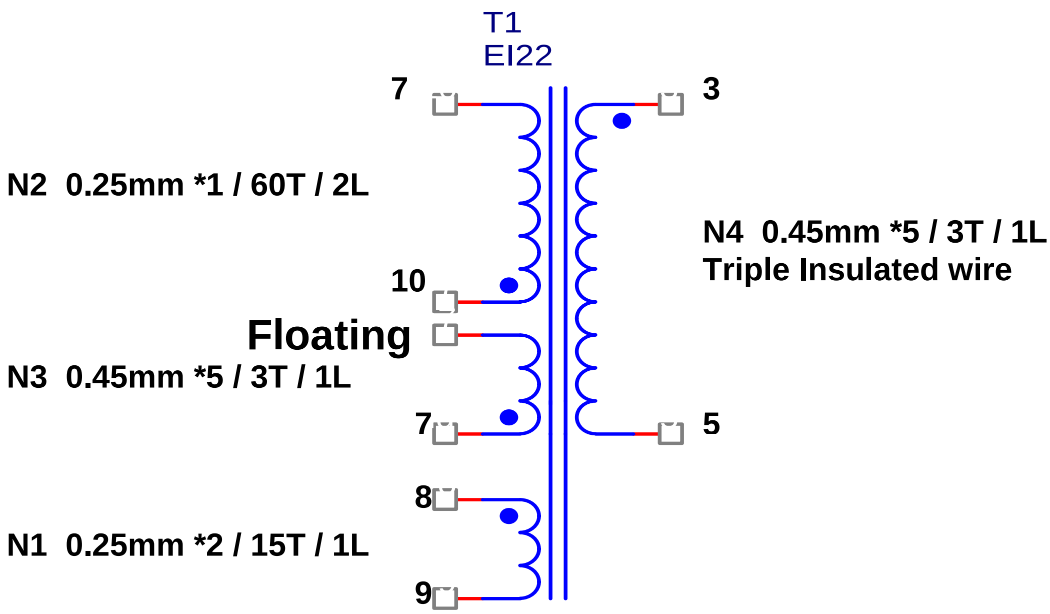

Figure 4 – Transformer Electrical Diagram

7.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pins 1-5 to Pins 6-10	3000 VAC
Primary Inductance	Pins 7-10, all other windings open, measured at 100 kHz, 0.4 VRMS	1.18mH, -/+10%
Resonant Frequency	Pins 7-10, all other windings open	1MHz (Min.)
Primary Leakage Inductance	Pin 7-10 with Pin 3-5 shorted, measured at 100 kHz, 0.4 VRMS	30 µH (Max.)

7.3 Materials

Item	Description
[1]	Core: PC40 EI22
[2]	Bobbin: EI 22, 10 Pin
[3]	Magnet Wire: 0.25mm heavy Nyleaze
[4]	Magnet Wire: 0.45mm heavy Nyleaze
[5]	Triple Insulated Wire: 0.55mm
[6]	Tape: 3M 1298 Polyester Film (yellow) 15mm, 0.26m Thick.
[7]	Tape: 3M 1298 Polyester Film (yellow) 10mm, 0.25mm Thick.
[8]	Varnish

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7.4 Transformer Build Diagram

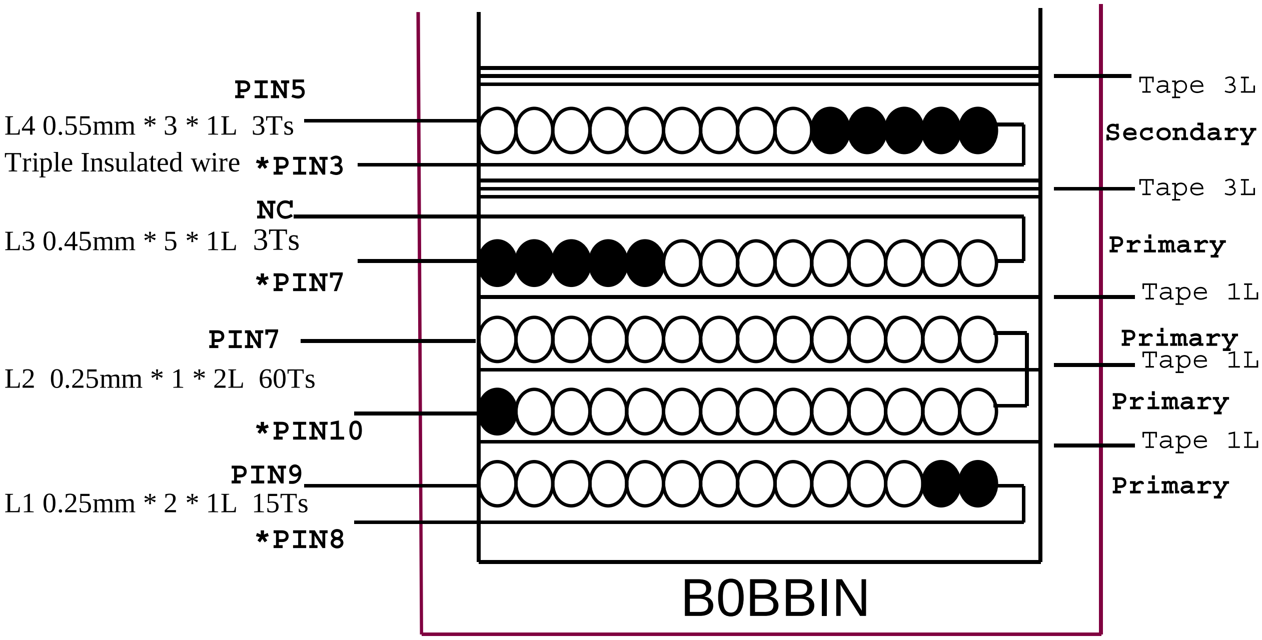

Figure 5 – Transformer Build Diagram

7.5 Transformer Construction

Primary Layer	Start at Pin 8. Wind 15 turns of item [3] from right to left. Finish at Pin 9.
Insulation	1Layer of tape [6] for insulation
Primary Layer	Start at Pin 10. Wind 60 turns / 2Layers of item [3]. Wind 1'st layer from left to right; and add 1 layer of tape [6] for insulation; and then wind 2'nd layer from right to left. Finish at Pin 7.
Insulation	1Layer of tape [6] for insulation
Primary Layer	Start at Pin 7. Wind 5–filar 3 turns of item [4] from right to left. Finish at NC.
Insulation	3Layers of tape [6] for insulation.
Secondary Winding	Start at Pin 3 Wind tri-filar 3 turns of item [5] from left to right. Finish at Pin 5.
Insulation	3Layers of tape [6 for insulation.
Final Assembly	Assemble and secure core halves. Put 3 Layers of item [7]. Impregnate uniformly with dip varnish [8]and bake.

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8 Transformer Spreadsheets

Power Supply Input

Var	Value	Output 1 (main)	Units	Description
VACMIN	85		Volts	Min Input AC Voltage
VACMAX	265		Volts	Max Input AC Voltage
FL	50		Hertz	Line Frequency
TC	2.51		mSeconds	Diode Conduction Time
Z	0.58			Loss Allocation Factor

Power Supply Outputs

Var	Value	Output 1 (main)	Units	Description
VOx		3.50	Volts	Output Voltage
IOx		3.00	Amps	Output Current

Device Variables

Var	Value	Output 1 (main)	Units	Description
Device	TNY268P			PI Device Name
PO	10.5		Watts	Total Output Power
VDRAIN	563		Volts	Maximum Drain Voltage
VDS	3.18		Volts	Drain to Source Voltage
FSNOM	132000		Hertz	TinySwitch-II Switching Frequency
FSMIN	120000		Hertz	Minimum Switching Frequency
FSMAX	144000		Hertz	Maximum Switching Frequency
KRPKDP	0.47			Continuous/Discontinuous Operating Ratio Warning! KRP/KDP is too low Tip: Increase size of TinySwitch-II device, increase efficiency (N), increase reflected output voltage (VOR), increase minimum input voltage (VACMIN) or consider device family with larger power capability.
ILIMITMIN	0.51		Amps	Current Limit Minimum
ILIMITMAX	0.59		Amps	Current Limit Maximum
IRMS	0.29		Amps	Primary RMS Current
DMAX	0.50			Maximum Duty Cycle

Power Supply Components Selection

Var	Value	Output 1 (main)	Units	Description
CIN	33.0		uFarads	Input Capacitance
VMIN	85.0		Volts	Minimum DC Input Voltage
VMAX	374.8		Volts	Maximum DC Input Voltage
VCLO	200		Volts	Clamp Zener Voltage
PZ	2.0		Watts	Primary Zener Clamp Loss
RLS1	2.0		MOhms	Line sense resistor

Power Supply Output Parameters

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Var	Value	Output 1 (main)	Units	Description
VDx		0.50	Volts	Output Winding Diode Forward Voltage Drop
PIVSx		22	Volts	Output Rectifier Maximum Peak Inverse Voltage
ISPx		9.88	Amps	Peak Secondary Current
ISRMSx		5.44	Amps	Secondary RMS Current
IRIPPLEx		4.54	Amps	Output Capacitor RMS Ripple Current

Transformer Construction Parameters

Var	Value	Output 1 (main)	Units	Description
Core/Bobbin	EI22			Core Type
Core Manuf.	Generic			Core Manufacturer
Bobbin Manuf	Generic			Bobbin Manufacturer
LPmin	1207		uHenries	Minimum Primary Inductance
NP	60.0			Primary Number of Turns
OD Actual	0.23		mm	Primary Actual Wire Diameter
Primary Current Density	7		A/mm^2	Primary Winding Current Density
VOR	80.00		Volts	Reflected Output Voltage
BW	8.45		mm	Bobbin Winding Width
M	0.0		mm	Safety Margin Width
L	2.00			Primary Number of Layers
AE	42.00		mm^2	Core Cross Sectional Area
ALG	335		nH/T^2	Gapped Core Effective Inductance
BM	291		milliTesla	Maximum Flux Density
BAC	59		milliTesla	AC Flux Density for Core Loss
LG	0.14		mm	Gap Length
LL	24.1		uHenries	Primary Leakage Inductance
LSEC	20		nHenries	Secondary Trace Inductance

Secondary Parameters

Var	Value	Output 1 (main)	Units	Description
NSx		3.0		Secondary Number of Turns
Rounded Down NSx				Rounded to Integer Secondary Number of Turns
Rounded Down Vox			Volts	Volts
Rounded Up NSx				Rounded to Next Integer Secondary Number of Turns
Rounded Up Vox			Volts	Auxiliary Output Voltage for Rounded up to Next Integer Secondary Number of Turns

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ODS Actual Range		0.91 - 1.45	mm	Secondary Actual Wire Diameter Range Comment: Secondary wire size is greater than recommended maximum (0.4 mm) Tip: Consider a parallel winding technique (bifilar, trifilar) for >1.5 A outputs, increase size of transformer (larger BW), reduce margin (M).

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9 Performance Data

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

9.1 Efficiency

9.1.1 Efficiency vs. input voltage at full load.

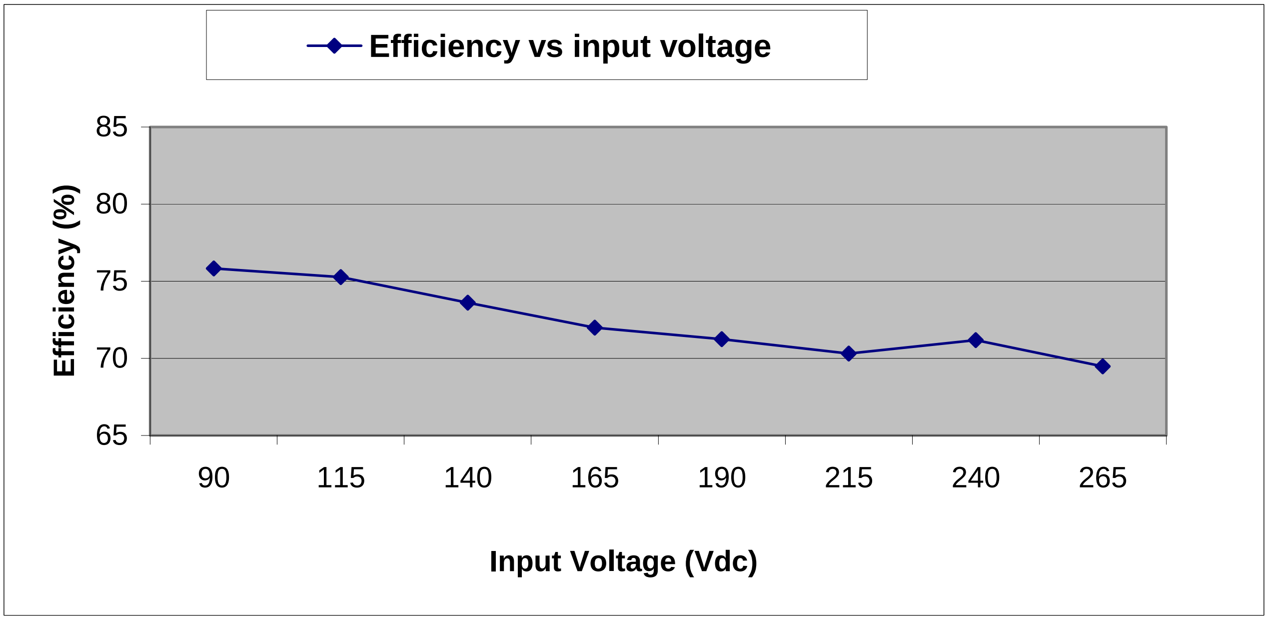

Figure 6 – Efficiency vs. Input Voltage, Room Temperature, 60 Hz.

9.1.2 Efficiency vs. output current at 115VAC / 230VAC

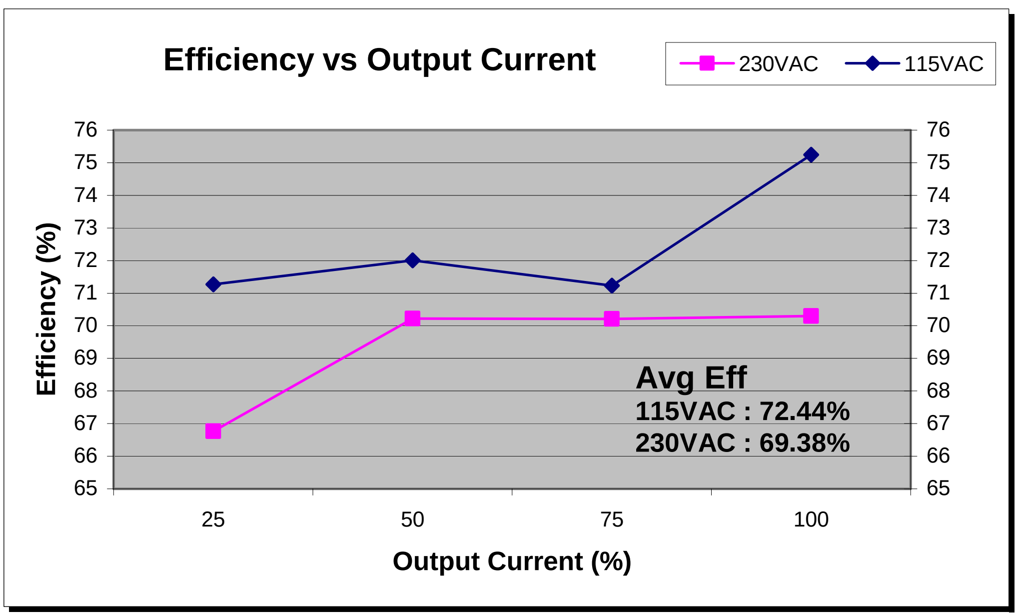

Figure 7 – Efficiency vs. Input Voltage, Room Temperature, 60 Hz.

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9.2 No-load Input Power

9.2.1 Input voltage vs. standby input power

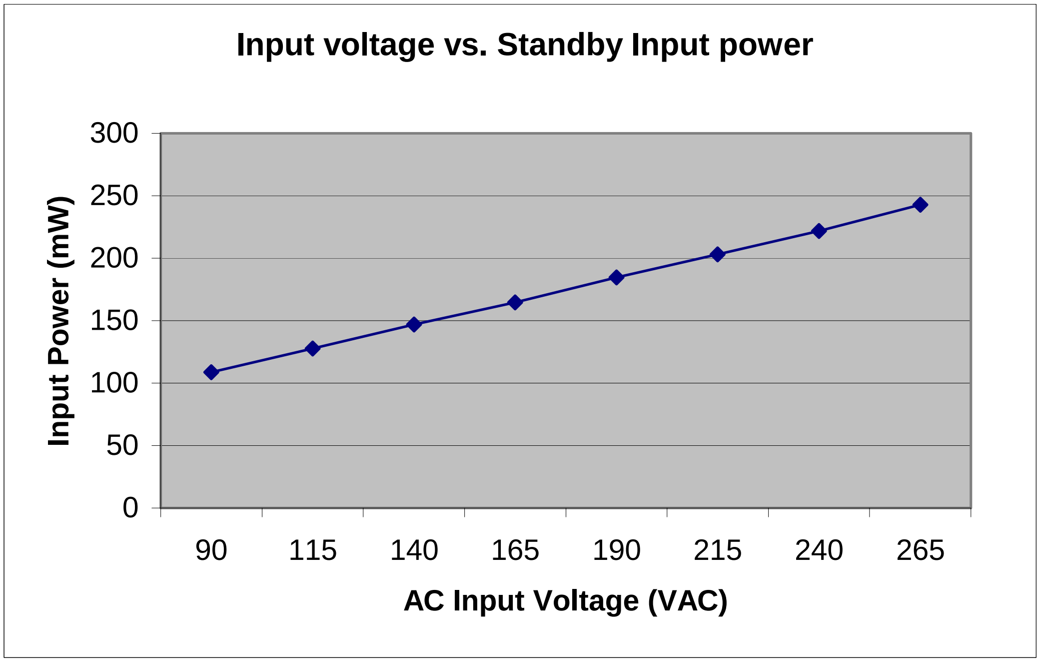

Figure 8 – Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.

9.2.2 Input voltage vs. Input power (Po: 0.5W)

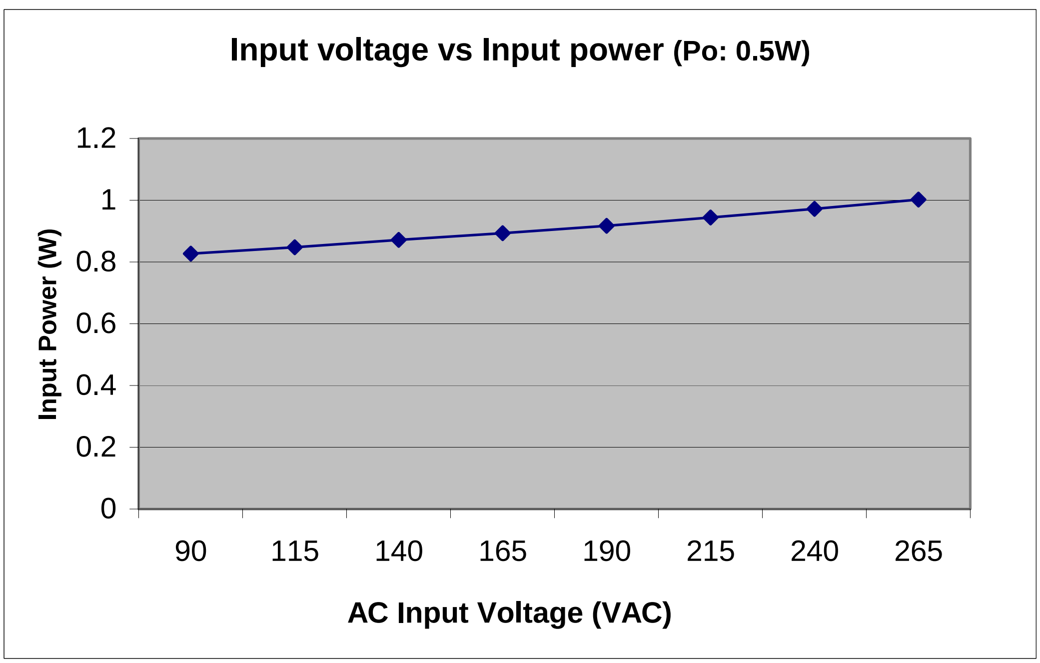

Figure 9 – Input Line Voltage vs. Input Power (Po: 0.5w), Room Temperature, 60 Hz.

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9.3 Regulation

9.3.1 Load

Io (A) / Vin (AC)	0	0.4	0.8	1.2	1.6	2	2.5
90V	3.594	3.56	3.525	3.49	3.457	3.423	3.38
265V	3.594	3.56	3.527	3.49	3.457	3.422	3.38

Figure 10 – Load Regulation, Room Temperature

9.3.2 Line

Vin (ac) / Vo (dc)	90	115	140	165	190	215	240
3.5V / 0A	3.59	3.59	3.59	3.59	3.59	3.59	3.59
3.5V / 2.5A	3.37	3.37	3.37	3.37	3.37	3.37	3.37

Figure 11 – Line Regulation, Room Temperature, Full Load

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10 Waveforms

10.1 Drain Voltage and Current, Normal Operation

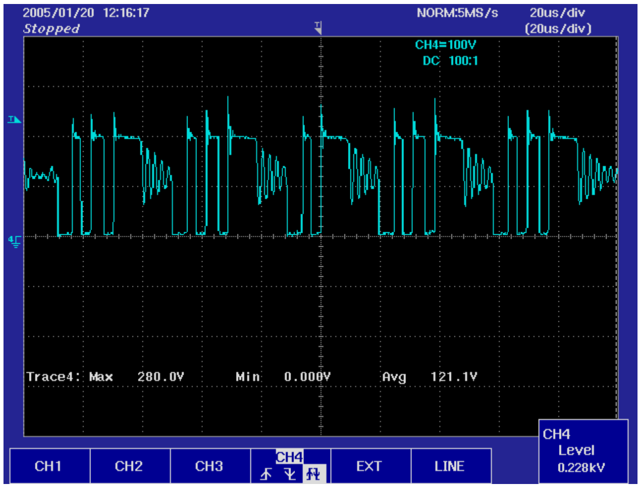

Figure 12– 90 VAC, Full Load.
Lower: V_{DRAIN}, 100 V/ div, 20 µs / div

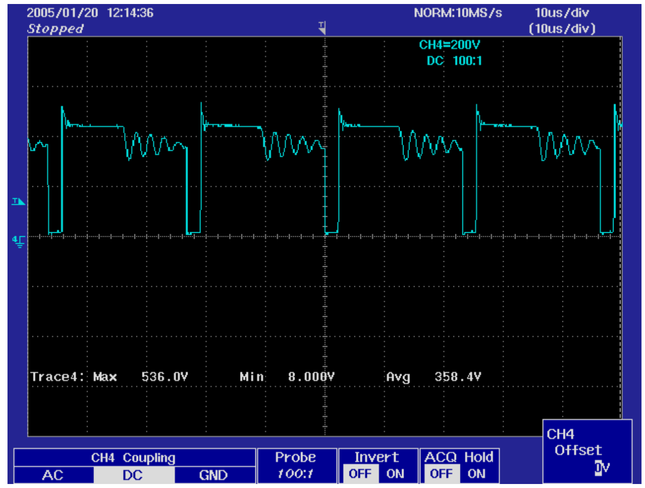

Figure 13 – 265 VAC, Full Load
Lower: V_{DRAIN}, 200 V / div,10 µs / div

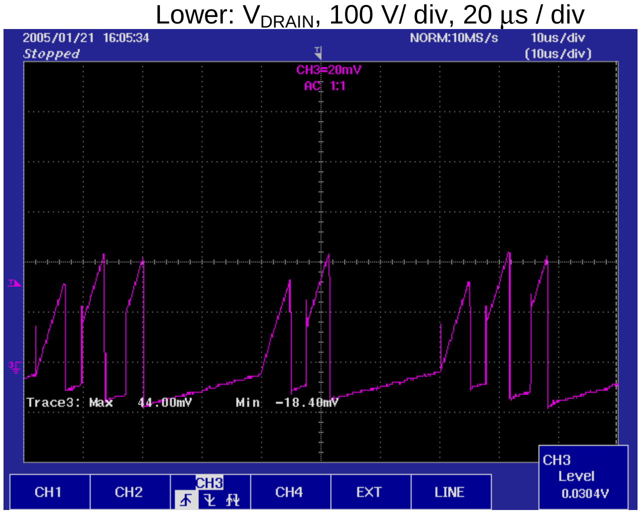

Figure 14 – 90 VAC, Full Load.
Lower: I_{DRAIN}, 200ma/ div, 10 µs / div

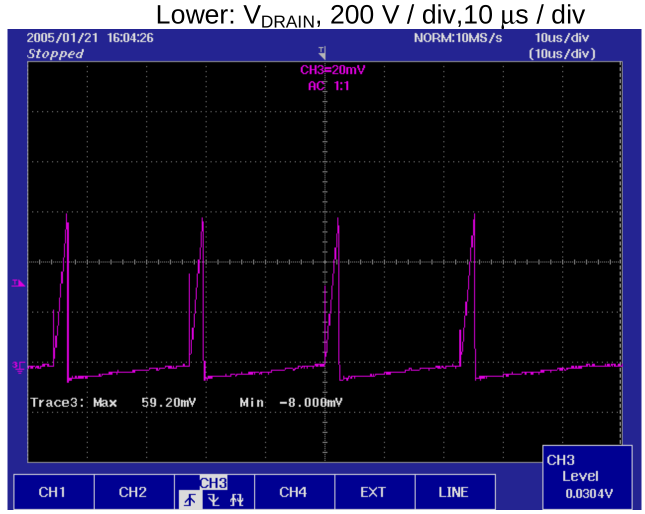

Figure 15 – 265 VAC, Full Load
Lower: I_{DRAIN}, 200ma/ div, 10 µs / div

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10.2 Output Voltage Start-up Profile

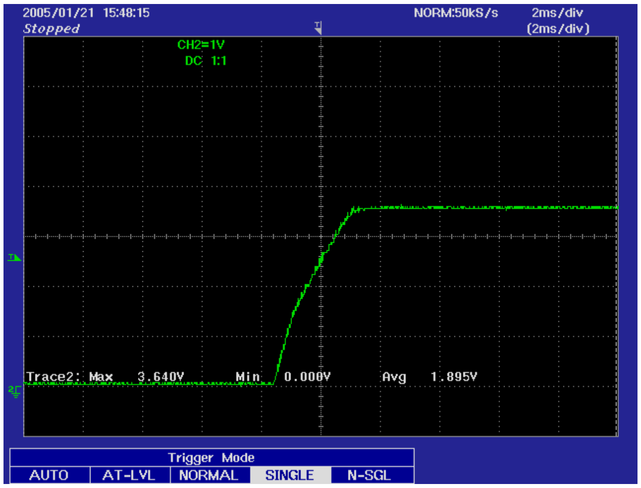

Figure16 – Start-up Profile, 90VAC No Load
1 V/ div, 2 ms / div.

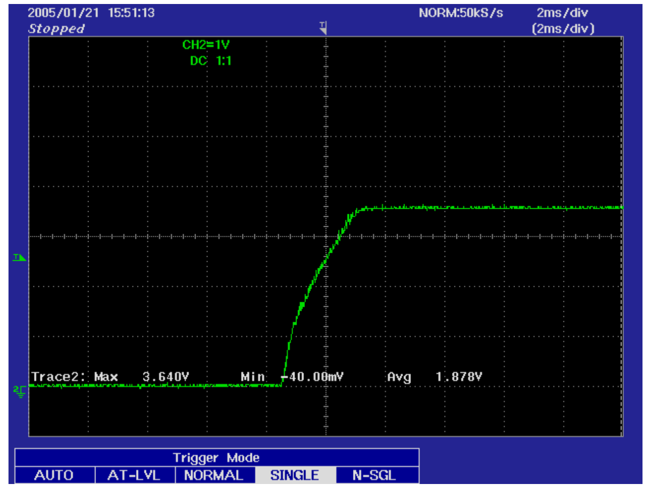

Figure 17 – Start-up Profile, 265 VAC No Load
1V/ div, 2 ms / div.

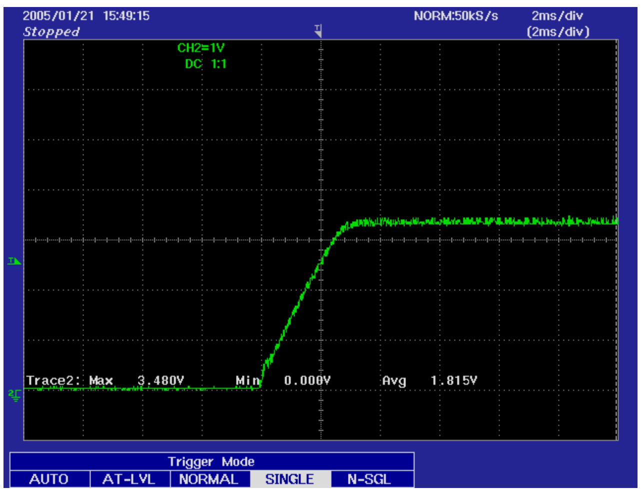

Figure 18 – Start-up Profile, 90VAC Full Load
1 V/ div, 2 ms / div.

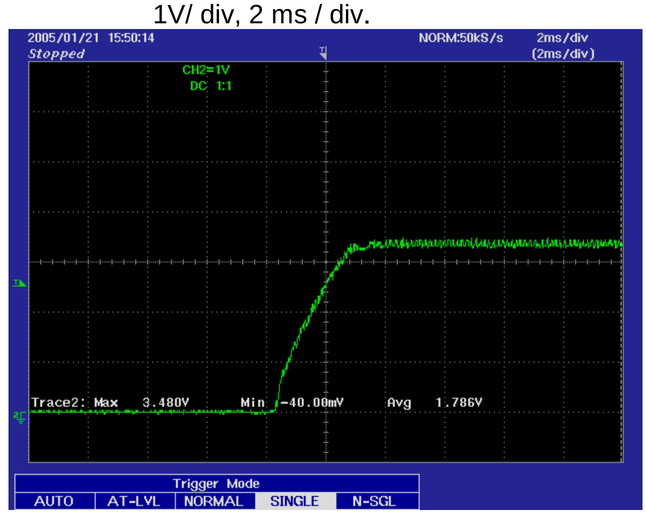

Figure 19 – Start-up Profile, 265 VAC Full Load
1V/ div, 2 ms / div.

10.3 Max Output Power (LPS) Testing (Specification Po < 17.5w)

Vin	Po < 17.5W
90VAC	12.5W
264VAC	13.0W

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10.4 Load Transient Response

Peak Load Transient Response, its Test Condition: 4A 200ms with 0.25A 2000ms, slew rate 1A/us

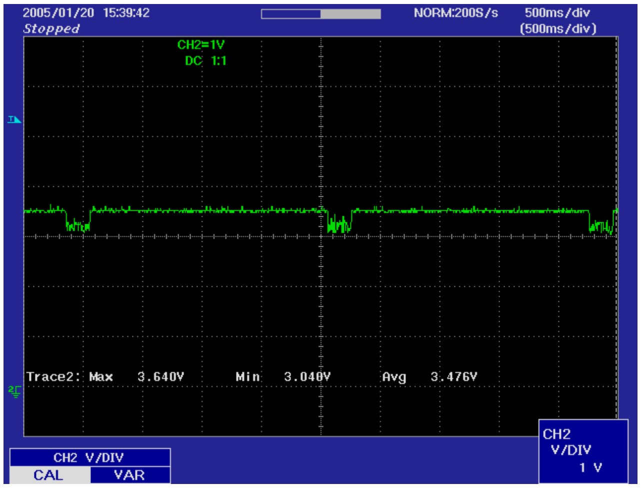

Figure 20 – 90 VAC, 3.5V output; 1V/ Div; 500ms/ Div.

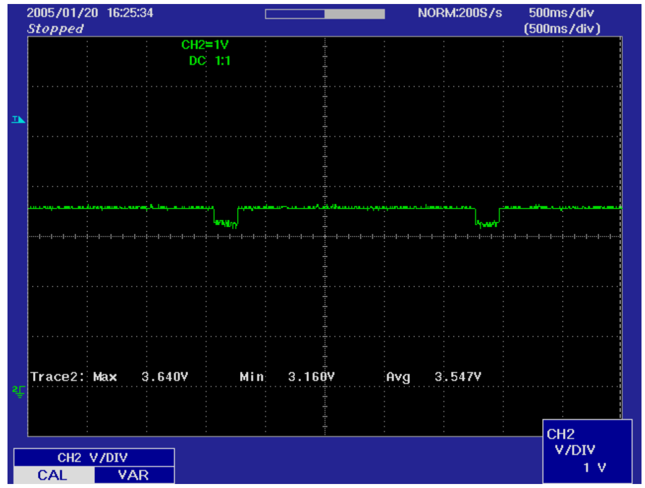

Figure 21 – 90 VAC, 3.5V output; 1V/ Div; 500ms/ Div.

Dynamic Load Response, its Test Condition: Test Condition: 2.5A 50ms with 0.25A 50ms, slew rate 1A/us

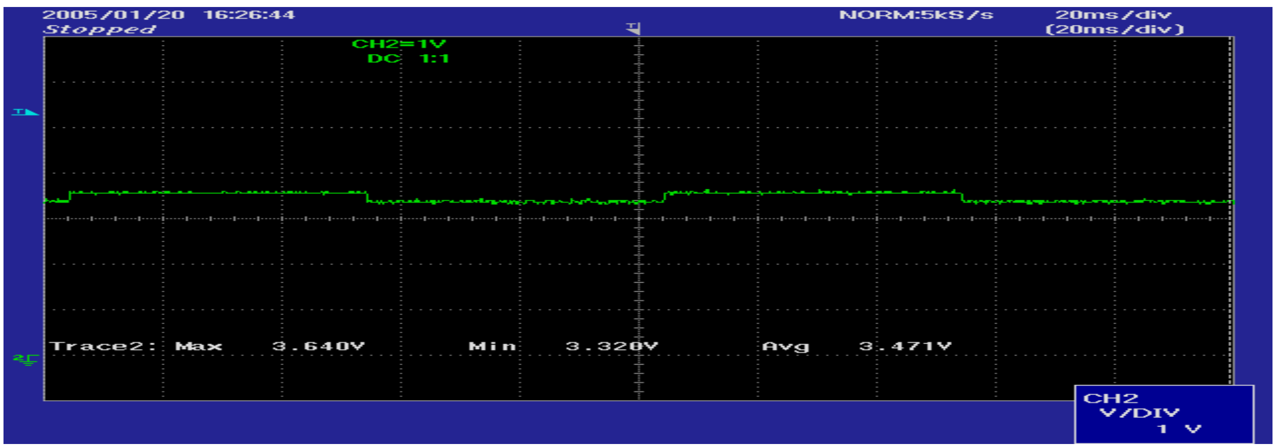

Figure 22 – 3.5V output; 1V/ Div; 20ms/ Div

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10.5 Output 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 23 and Figure 24.

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).***

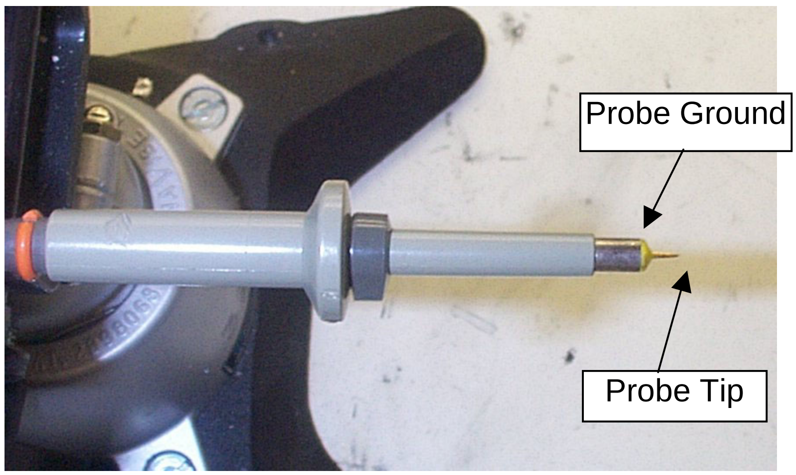

Figure 23 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

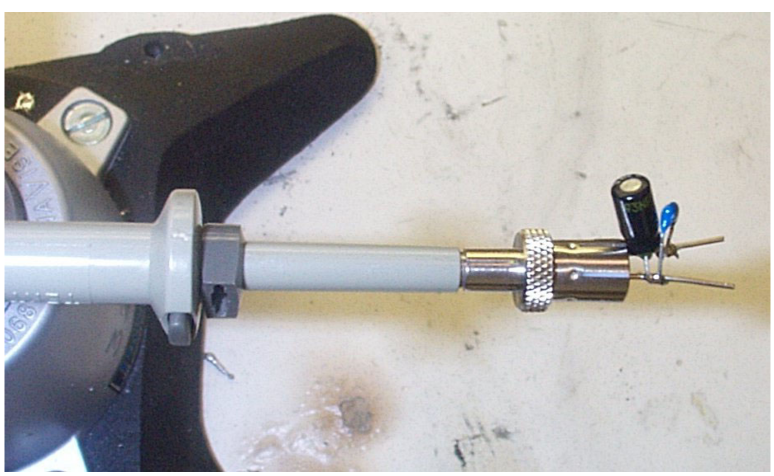

Figure 24 – Oscilloscope Probe with Probe Master 5125BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)

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10.5.2 Measurement Results

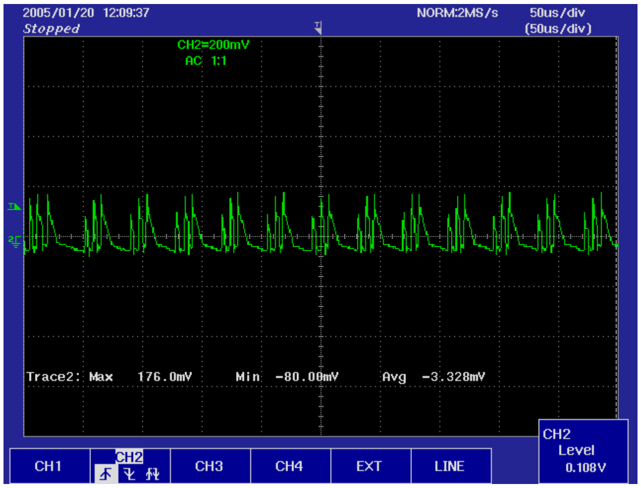

Figure 25 – 3.5V Ripple, 90 VAC, Full Load.
50us/ div, 200 mV / div

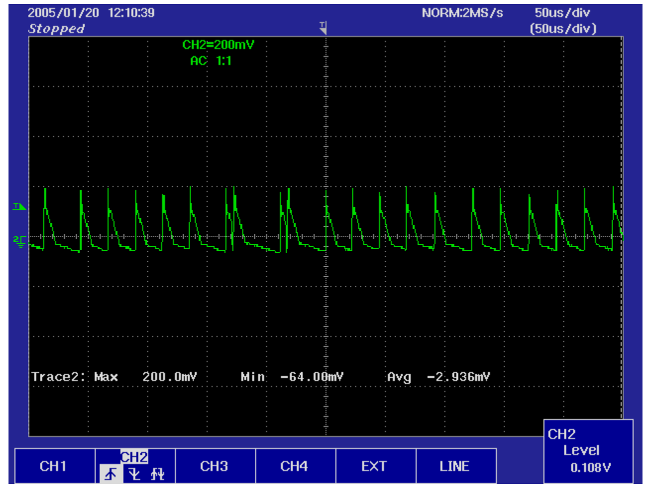

Figure 26 – 3.5V Ripple, 265 VAC, Full Load.
50us/ div, 200 mV / div

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11 Conducted EMI

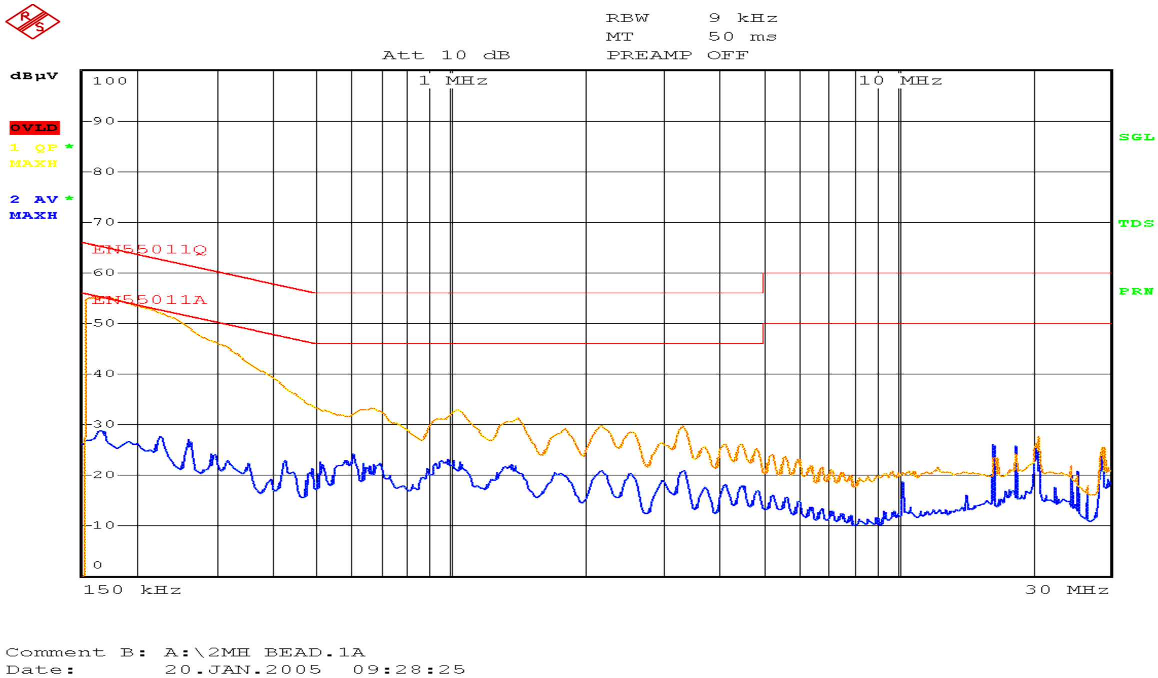

Figure 27 – EMI Result: 115VAC, 60Hz, 3.5V 2.6A load, and EN55022 B Limits.

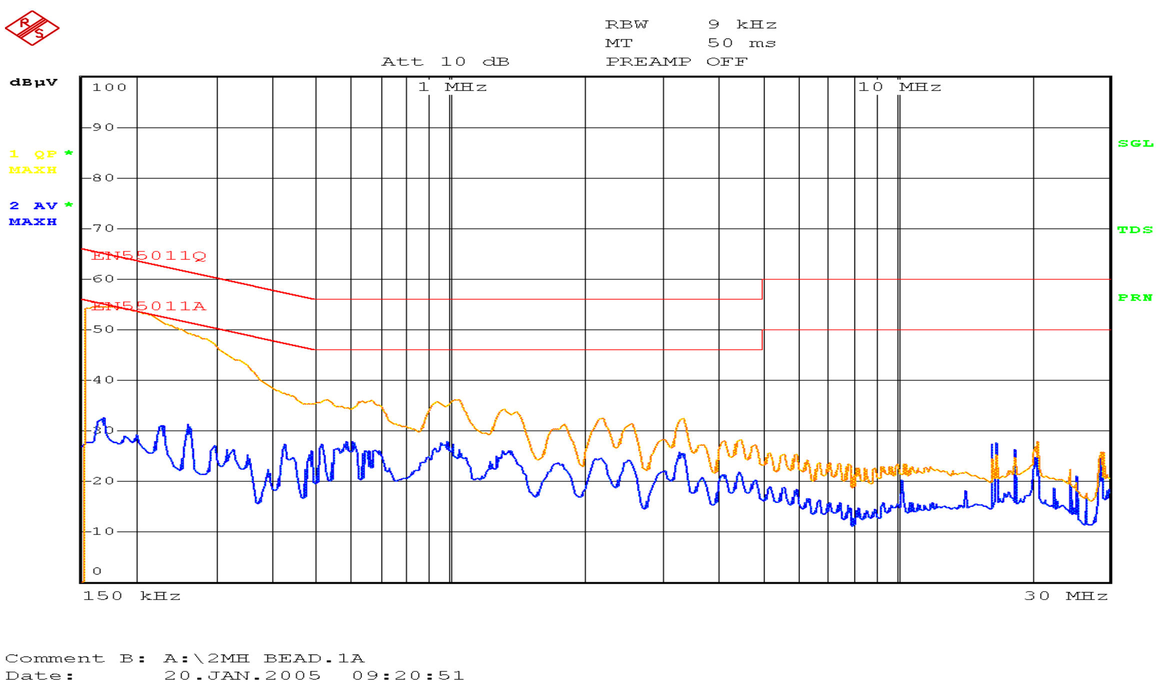

Figure 28 – EMI Result: 230VAC, 60Hz, 3.5V 2.6A load, and EN55022 B Limits.

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12 Revision History

Date	Author	Revision	Description & changes	Reviewed
5-27-05	RS	1.0	Initial Release	KM / VC

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PATENT INFORMATION

The products and applications illustrated herein (including circuits external to the products and transformer construction) 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*.

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