Design Example Report

Title	***13.1 W AC-DC Flyback Converter Using TNY268P***
Specification	Input: 90 – 264 VAC Output: 5.25 V / 2.5 A
Application	Adapter
Author	Power Integrations Applications Department
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Revision	1.0

Summary and Features

- Universal Input 90 VAC to 264 VAC
- Low Cost, Low Parts Count
- Minimum No Load Power Consumption <0.3 W at 264 VAC
- Meets CISPR22B EMI with Margin
- Efficiency >70% minimum.
- Meet CEC efficiency requirement with 5.25V2.5A.
- Meets +/-6KV-200A Lightning Surge.
- Cost reduced circuit does not require TVS

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Important Note:
This board is designed to be non-isolated. However the outputs are high voltage so please take the necessary safety precautions.

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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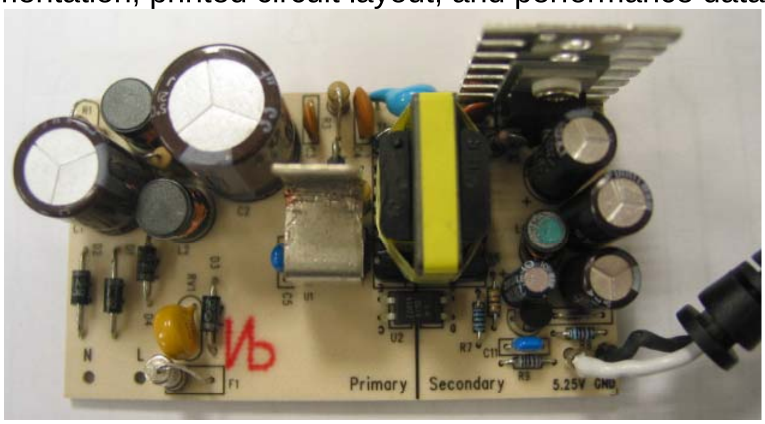
1 Introduction

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.



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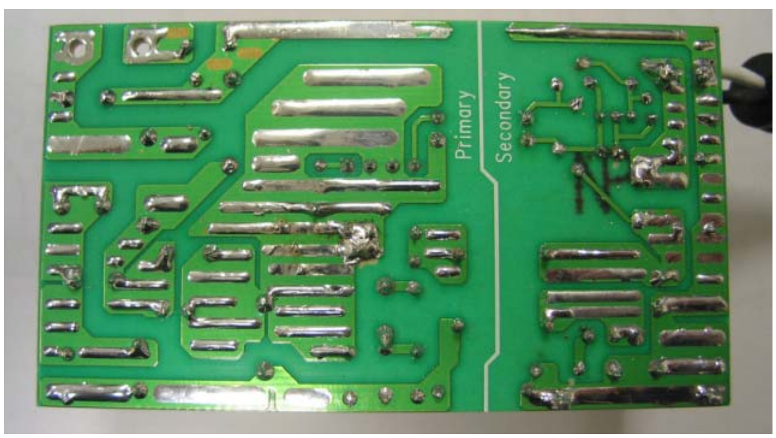

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Figure 1 – Populated Circuit Board Photograph.

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2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		264	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	63	Hz	
No-load Input Power (264 VAC)				0.3	W	
Output						
Output Voltage 1	V_{OUT1}	5	5.25	5.5	V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			50	mV	20 MHz bandwidth
Output Current 1	I_{OUT1}	0		2.5	A	
Total Output Power						
Continuous Output Power	P_{OUT}			13.1	W	
Efficiency	η	70			%	Measured at P_{OUT} (13.1 W), 25 ^{o}C
CEC Efficiency (115 VAC and 230 VAC)	**Avg.** η	72.2			%	Avg. Eff. At 25%, 50%, 75% and 100% load
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950, UL1950 Class II				
Surge		6			kV	100 kHz ring wave, 200 A short circuit current, differential and common mode
Ambient Temperature	T_{AMB}	0		40	^{o}C	Free convection, sea level

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3 Schematic

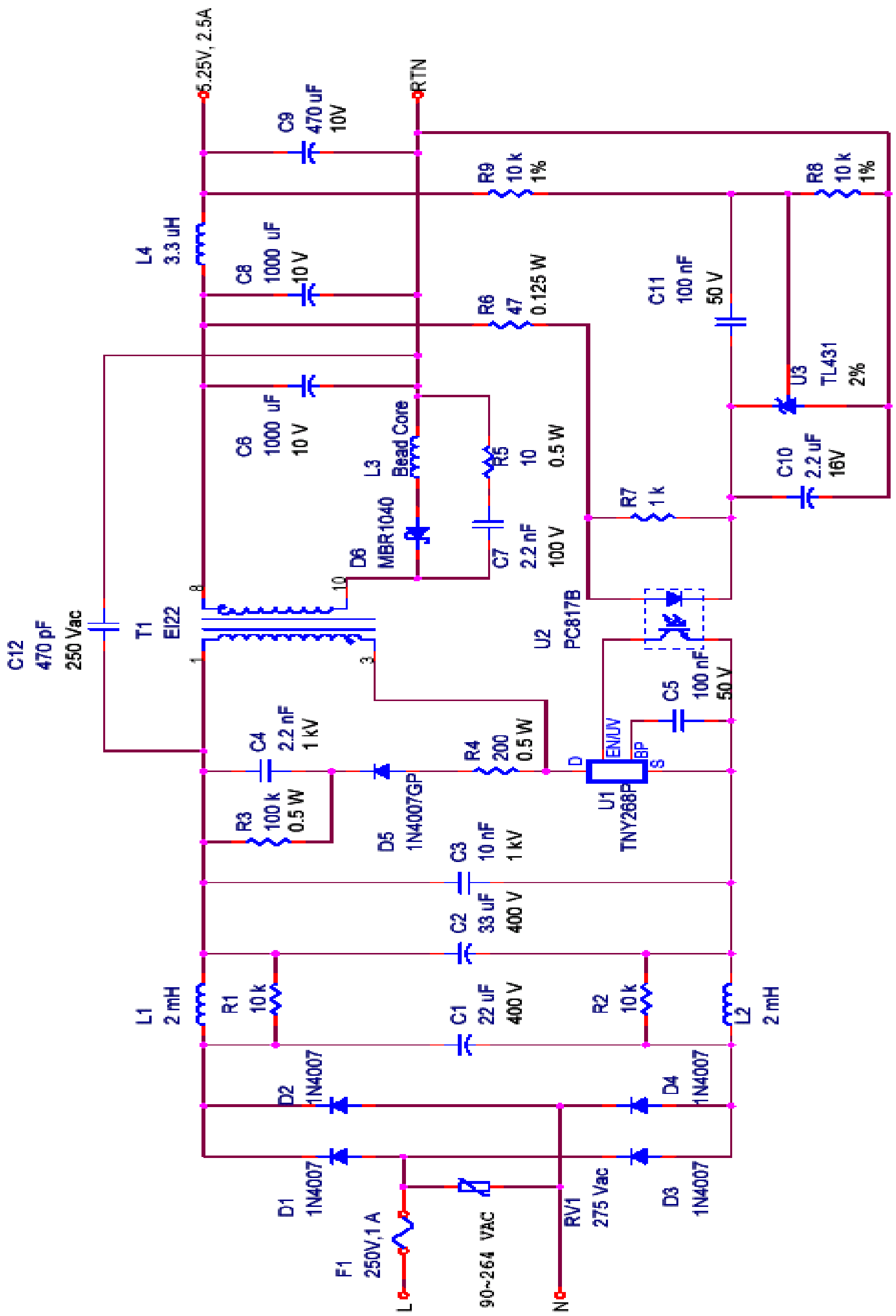

Figure 2 – Schematic.

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4 Circuit Description

A Flyback converter is used to obtain 5.25 V / 2.5 A output from 90-264 VAC input. Using technical skill of core cancellation and balance shield windings reduce EMI noise.

4.1 Input Rectification and EMI Filtering

Fuse F1 protects the charger against any fault condition, and input current exceeds 1 A. 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 (C4, D5, R3, and R4) clamping across primary winding to limit the drain voltage below 700V, when the Mosfet inside U1 turns OFF. The capacitor C5 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. The opto-coupler transistor pulls down enable (EN) pin of U1. TinySwitch-II keeps on switching as long as the pull down current < 240 µA. U1 will stop switching if the pull down current exceeds 240 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 D6 is OFF. When the U1 Mosfet is OFF, D6 is forward biased, and the stored energy is transferred to the secondary and stores in C6, C8 and C9. The snubber C7 and R5 across output diode D6 and a bead core in series with output diode D6 will improve EMI.

4.4 Output Feedback

Resistors R8, R9 divide down the supply output voltage and apply it to the reference pin of error amplifier U3. Shunt regulator U3 drives optocoupler U2 through resistor R6 to provide feedback information to the U1 EN pin. Capacitor C10 drive to the optocoupler during supply startup to reduce output voltage overshoot. C11 plays a role in compensating of the power supply feedback loop.

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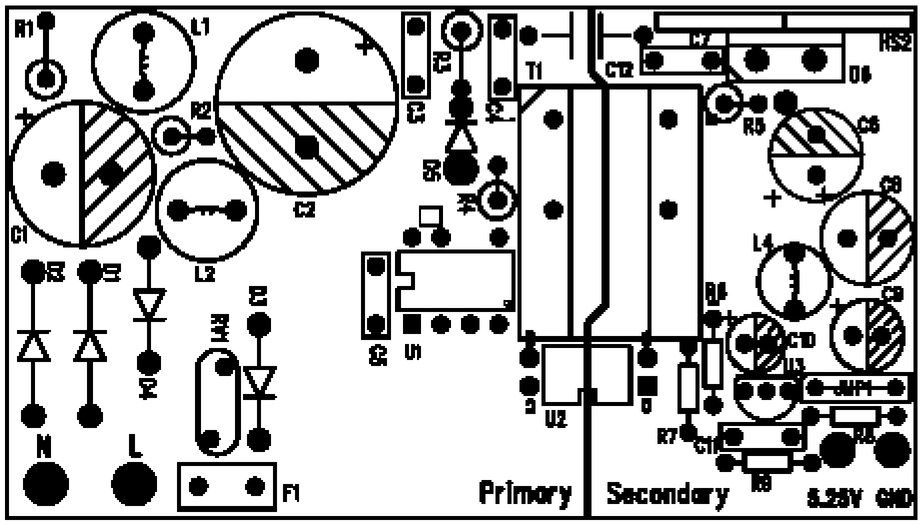
5 PCB Layout



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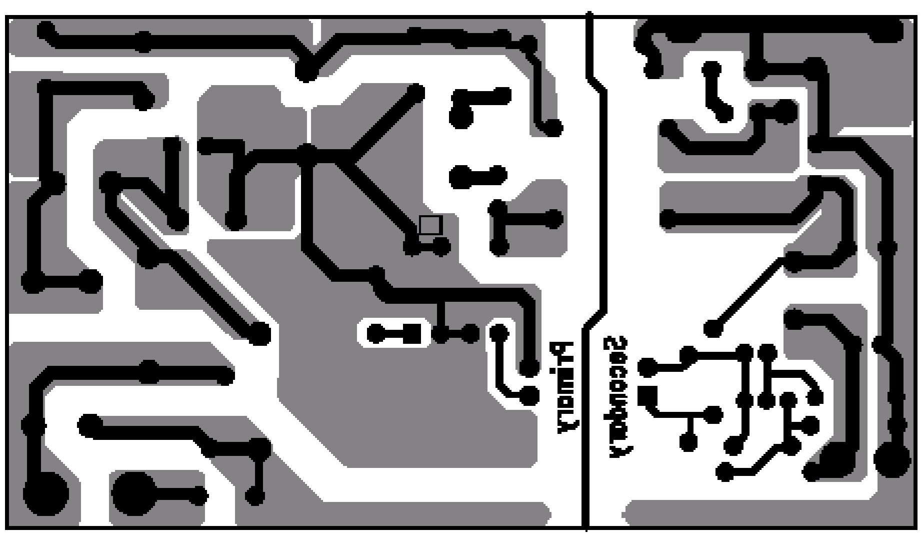

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Figure 3 – Printed Circuit Layout.

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6 Bill Of Materials

Item	Qty	Part Reference	Value	Description
1	1	C1	22 uF	22 uF, 400 V, Electrolytic, Low ESR, 2.9 Ohms, (12 x 20)
2	1	C2	33 uF	33 uF, 400 V, Electrolytic, Low ESR, 901 mOhm, (16 x 20)
3	1	C3	10 nF	10 nF, 1 kV, Disc Ceramic
4	1	C4	2.2 nF	2.2 nF, 1 kV, Disc Ceramic
5	1	C5	100 nF	100 nF, 50 V, Ceramic
6	2	C6 C8	1000 uF	1000 uF, 10 V, Electrolytic, Very Low ESR, 41 mOhm, (8 x 20)
7	1	C7	2.2 nF	2.2 nF, 100 V, Ceramic, COG
8	1	C9	470 uF	470 uF, 10 V, Electrolytic, Gen. Purpose, (8 x 12)
9	1	C10	2.2 uF	2.2 uF, 50 V, Electrolytic, (5 x 11)
10	1	C11	10 nF	10 nF, 50 V, Ceramic
11	1	C12	470 pF	470 pF, 250 Vac, Thru Hole, Ceramic Y-Capacitor
12	4	D1 D2 D3 D4	1N4007	1000 V, 1 A, Rectifier, DO-41
13	1	D5	1N4007GP	1000 V, 1 A, Rectifier, Glass Passivated, 2 us, DO-41
14	1	D6	MBR1040	40 V, 10 A, Schottky, TO-220AC
15	1	F1	250V,1 A	1 A, 250V, Fast, Picofuse, Axial
16	2	L1 L2	2 mH	2mH, 0.15A
17	1	L3	Bead Core	3.5 mm x 10 mm, 213 Ohms at 10 MHz, 24 AWG hole, Ferrite Bead
18	1	L4	3.3 uH	3.3 uH, 2.66 A
19	2	R1 R2	10 k	10 k, 5%, 1/4 W, Carbon Film
20	1	R3	100 k	100 k, 5%, 1/2 W, Carbon Film
21	1	R4	200	200 R, 5%, 1/2 W, Carbon Film
22	1	R5	10	10 R, 5%, 1/2 W, Carbon Film
23	1	R6	47	47 R, 5%, 1/8 W, Carbon Film
24	1	R7	1 k	1 k, 5%, 1/8 W, Carbon Film
25	1	R8	10 k	10 k, 1%, 1/8 W, Carbon Film
26	1	R9	11k	11 k, 1%, 1/8 W, Carbon Film
27	1	RV1	275 Vac	275 V, 45 J, 10 mm, RADIAL
28	1	T1	EI22	Transformer, EI22 10pins
29	1	U1	TNY268P	TinySwitch-II, TNY268P, DIP-8B
30	1	U2	PC817B	Opto coupler, 35 V, 4-DIP
31	1	U3	TL431	2.495 V Shunt Regulator IC, 2%, 0 to 70C, TO-92

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7 Transformer Specification

7.1 Electrical Diagram

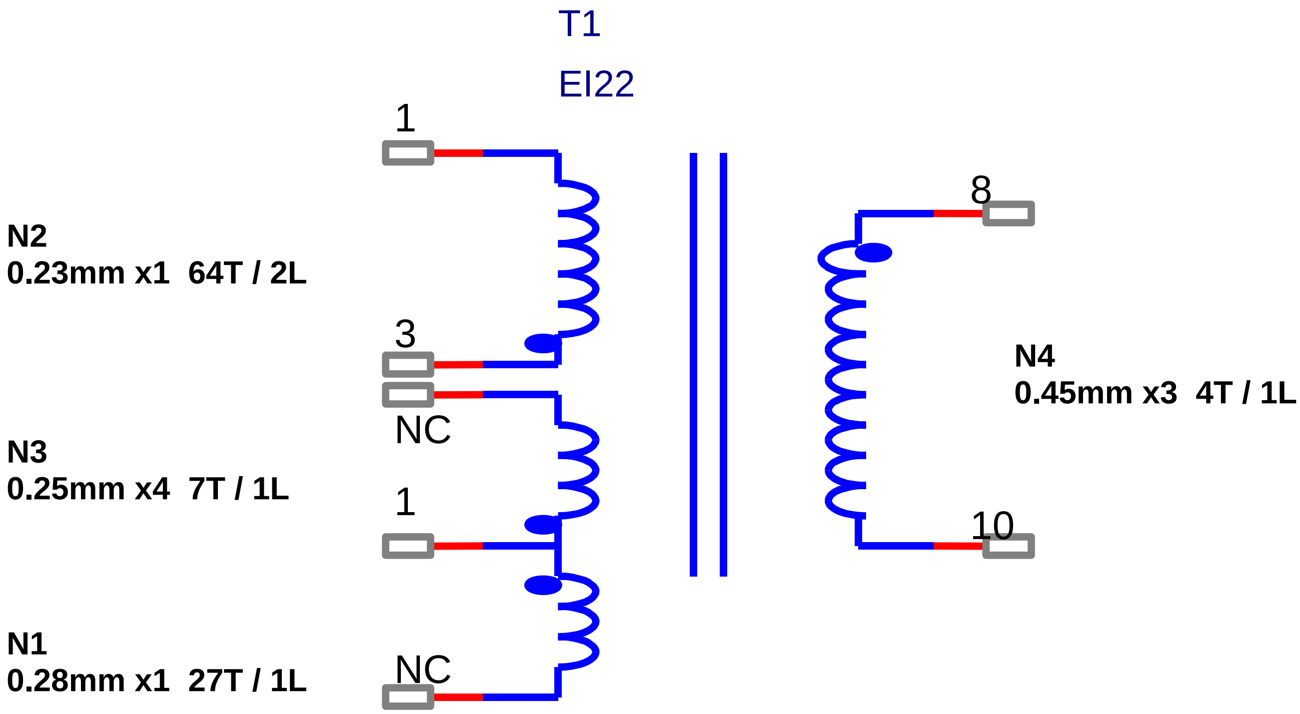

Figure 4 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Electrical Strength	1 second, 60 Hz, from Pins 1-5 to Pins 6-10	3000 VAC
Primary Inductance	Pins 1-3, all other windings open, measured at 100 kHz, 0.4 VRMS	1.32mH, -/+5%
Resonant Frequency	Pins 1-3, all other windings open	1MHz (Min.)
Primary Leakage Inductance	Pin 1-3 with Pin 8-10 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: 0.28mm heavy Nyleaze
[4]	Magnet Wire: 0.23mm heavy Nyleaze
[5]	Magnet Wire: 0.25mm heavy Nyleaze
[6]	Triple Insulated Wire: 0.45mm
[7]	Tape: 3M 1298 Polyester Film (yellow) 15mm, 0.26m Thick.
[8]	Tape: 3M 1298 Polyester Film (yellow) 10mm, 0.25mm Thick.
[9]	Varnish

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7.4 Transformer Build Diagram

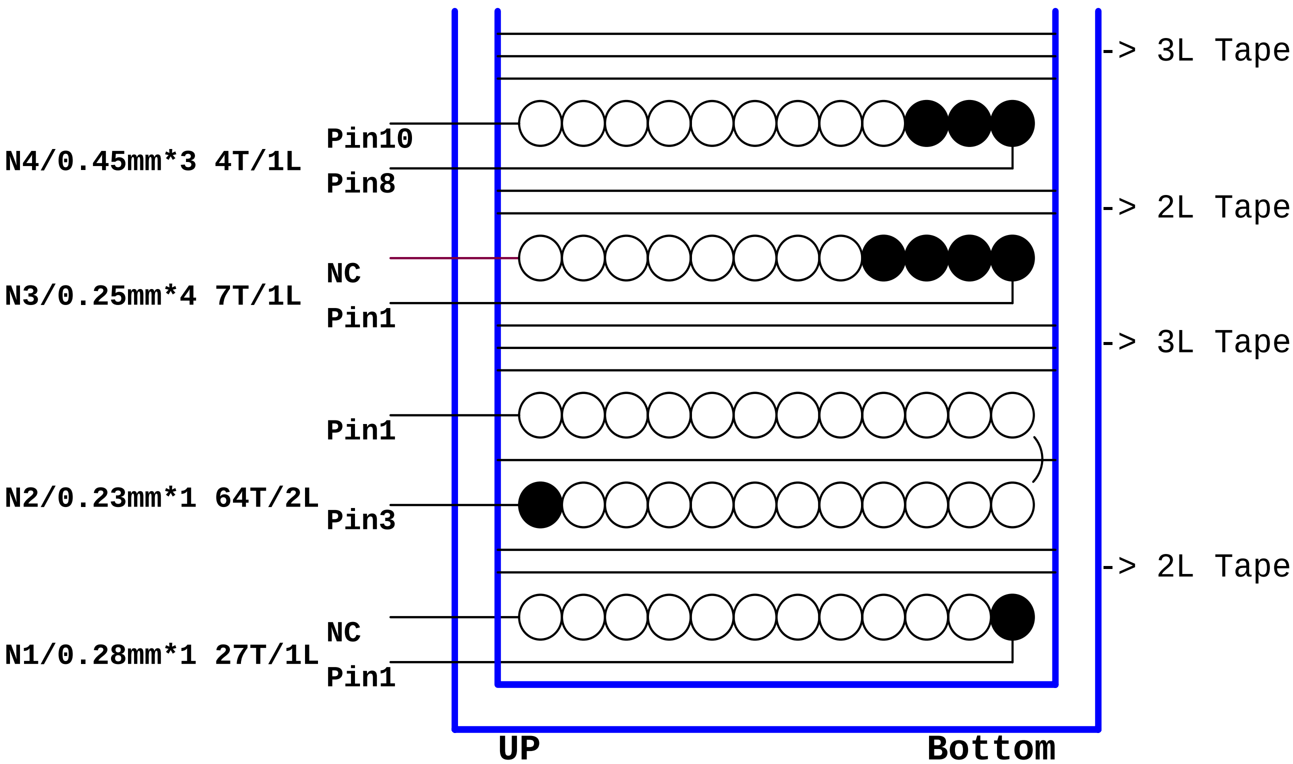

Figure 5 – Transformer Build Diagram.

7.5 Transformer Construction

Core Canceling Winding	Start at Pin 1.wind 27 turns of item [3] from right to left. Finish at Pin NC.
Insulation	2 Layers of tape [7] for insulation
Primary Layer	Start at Pin 3. Wind 64 turns / 2Layers of item [4]. Wind 1'st layer from left to right; and add 1 layer of tape [7] for insulation; and then wind 2'nd layer from right to left. Finish at Pin 1.
Insulation	3 Layers of tape [7] for insulation
Balance Shield Winding	Start at Pin 1. Wind quad–filar 7 turns of item [5] from right to left. Finish at NC.
Insulation	2 Layers of tape [7] for insulation.
Secondary Winding	Start at Pin 8 Wind tri-filar 4 turns of item [6] from right to left. Finish at Pin 10.
Insulation	3 Layers of tape [7] for insulation.
Final Assembly	Assemble and secure core halves. Put 3 Layers of item [8]. Impregnate uniformly with dip varnish [9] and bake.

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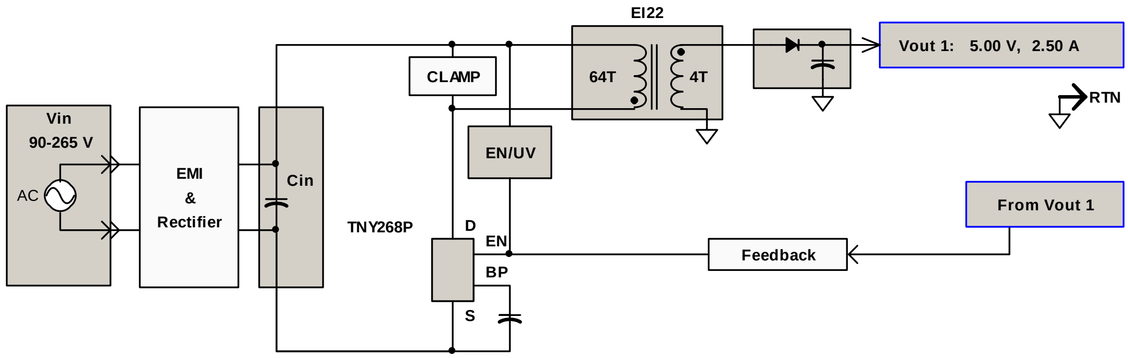
8 *Transformer Spreadsheets*

Design Warning (No Optimization)



9 Design Results

Power Supply Input

Var	*Value*	*Output 1. (main)*	*Units*	*Description*
VACMIN	**90**		Volts	Min Input AC Voltage.
VACMAX	**265**		Volts	Max Input AC Voltage
FL	**50**		Hertz	Line Frequency
TC	**2.59**		mSeconds	Diode Conduction Time
Z	**0.56**			Loss Allocation Factor
N	**70.0**		%	Efficiency Estimate

Power Supply Outputs

Var	*Value*	*Output 1. (main)*	*Units*	*Description*
VOx		**5.00**	Volts	Output Voltage
IOx		**2.50**	Amps	Output Current

9.1 *Device Variables*

Var	*Value*	*Output 1. (main)*	*Units*	*Description*
Device	**TNY268P**			PI Device Name
PO	**12.5**		Watts	Total Output Power
VDRAIN	**580**		Volts	Maximum Drain Voltage
VDS	**3.04**		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	**0.53**			**Continuous/Discontinuous Operating Ratio. See Errors, Warnings, Information section for detail**

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ILIMITMIN	**0.51**		Amps	Current Limit Minimum
ILIMITMAX	**0.59**		Amps	Current Limit Maximum
IRMS	**0.27**		Amps	Primary RMS Current
DMAX	**0.46**			Maximum Duty Cycle

Power Supply Components Selection

Var	Value	Output 1. (main)	Units	Description
VBRIDGE	**600**		Volts	Diode Bridge Voltage Rating
IAVG	**0.17**		Amps	Average Diode Bridge Current
CIN	**55.0**		uFarads	Input Capacitance
VMIN	**106.7**		Volts	Minimum DC Input Voltage
VMAX	**374.8**		Volts	Maximum DC Input Voltage
VCLO	**130**		Volts	Clamp Zener Voltage
PZ	**1.5**		Watts	Primary Zener Clamp Loss

Power Supply Output Parameters

Var	Value	Output 1. (main)	Units	Description
VDx		**0.50**	Volts	Output Winding Diode Forward Voltage Drop
PIVSx		**28**	Volts	Output Rectifier Maximum Peak Inverse Voltage
ISPx		**7.88**	Amps	Peak Secondary Current
ISRMSx		**4.35**	Amps	Secondary RMS Current
IRIPPLEx		**3.56**	Amps	Output Capacitor RMS Ripple Current

Transformer Construction Parameters

Var	Value	Output 1. (main)	Units	Description
Core/Bobbin	EI22			Core Type
Core Manuf.	9.1.1 Generic			Core Manufacturer
Bobbin Manuf	Generic			Bobbin Manufacturer
LPmin	1263		uHenries	Minimum Primary Inductance
NP	64.0			Primary Number of Turns
AWG	32		AWG	Primary Wire Gauge
CMA	238		Cmils/A	Primary Winding Current Capacity
VOR	88.00		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	308		nH/T^2	Gapped Core Effective Inductance

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BM	**2863**		Gauss	Maximum Flux Density
BAC	**659**		Gauss	AC Flux Density for Core Loss
LG	**0.149**		mm	Estimated Gap Length
LL	**25.3**		uHenries	Primary Leakage Inductance
LSEC	**20**		nHenries	Secondary Trace Inductance

Secondary Parameters

Var	***Value***	***Output 1. (main)***	***Units***	***Description***
NSx		4.0		Secondary Number of Turns
Rounded Down NSx				Rounded to Integer Secondary Number of Turns
Rounded Down Vox			Volts	Auxiliary Output Voltage for Rounded down to Integer Secondary Number of Turns
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
AWGSx Range		17 - 21	AWG	Secondary Wire Gauge Range. See Errors, Warnings, Information section for detail

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10 Performance Data

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

10.1 Efficiency

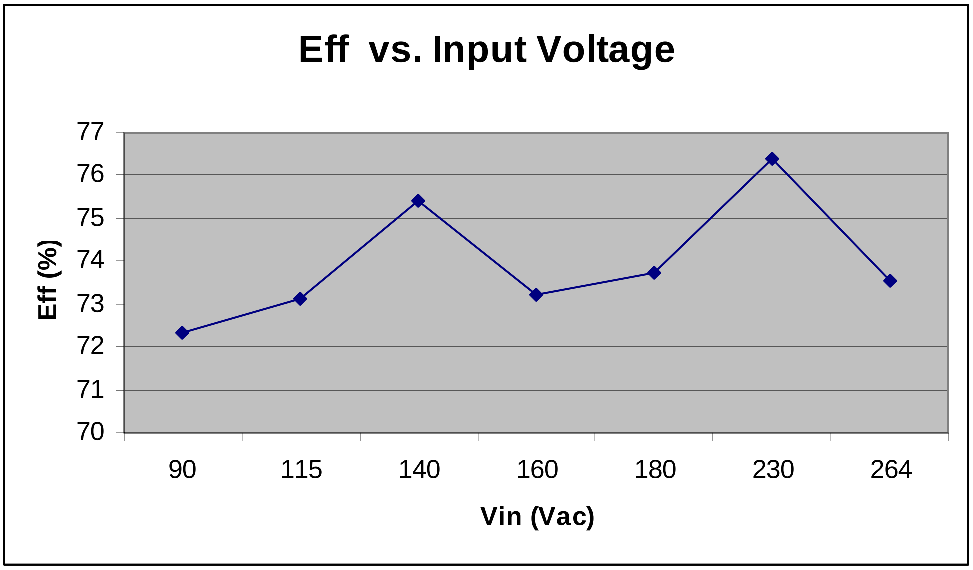

Figure 6 – Efficiency vs. Input Voltage, Room Temperature, 60 Hz.

10.2 No-load Input Power

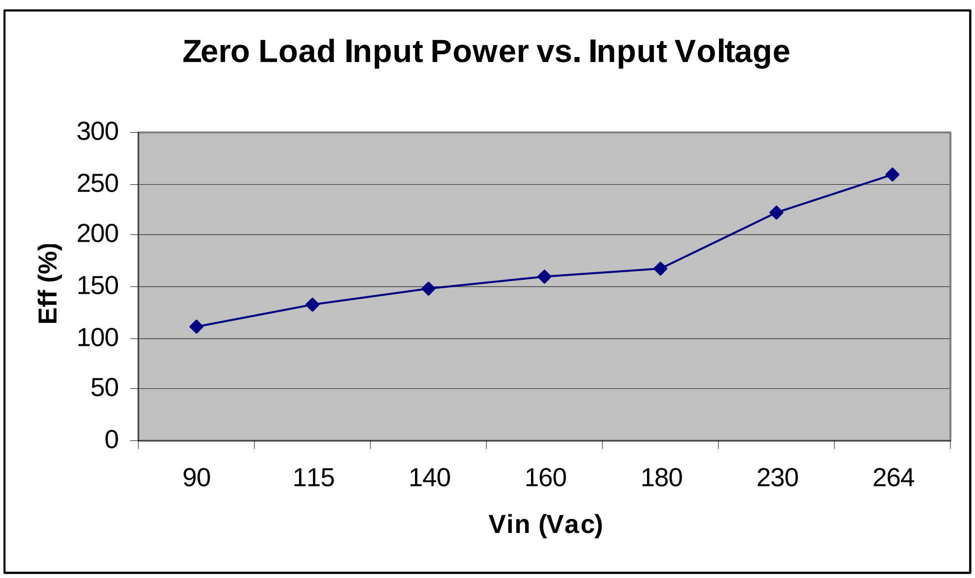

Figure 7 – Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.

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10.3 Regulation

10.3.1 Load (Vin: 115 VAC)

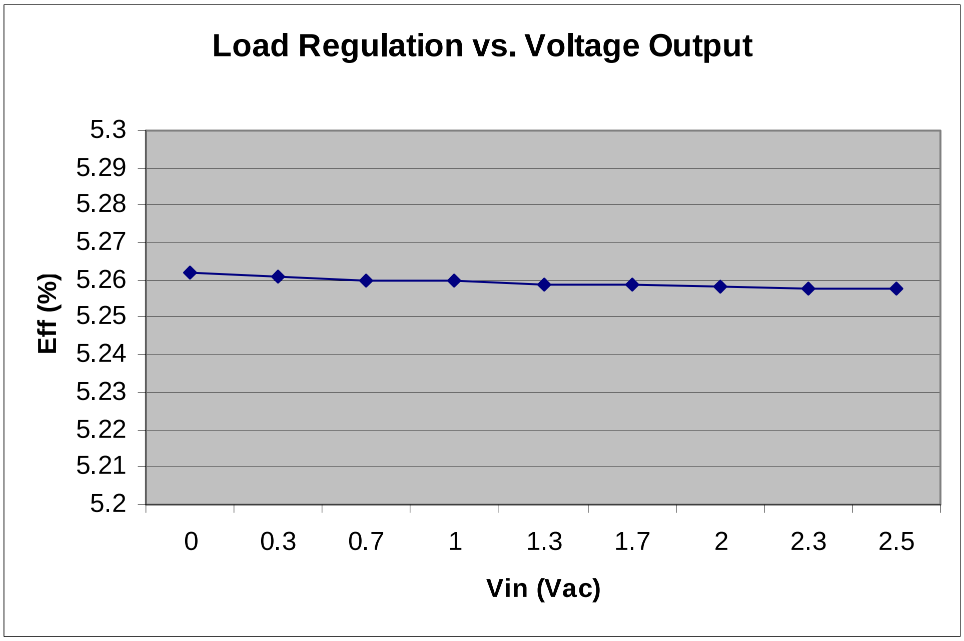

Figure 8 – Load Regulation, Room Temperature.

10.3.2 Line (Load: 2.5A)

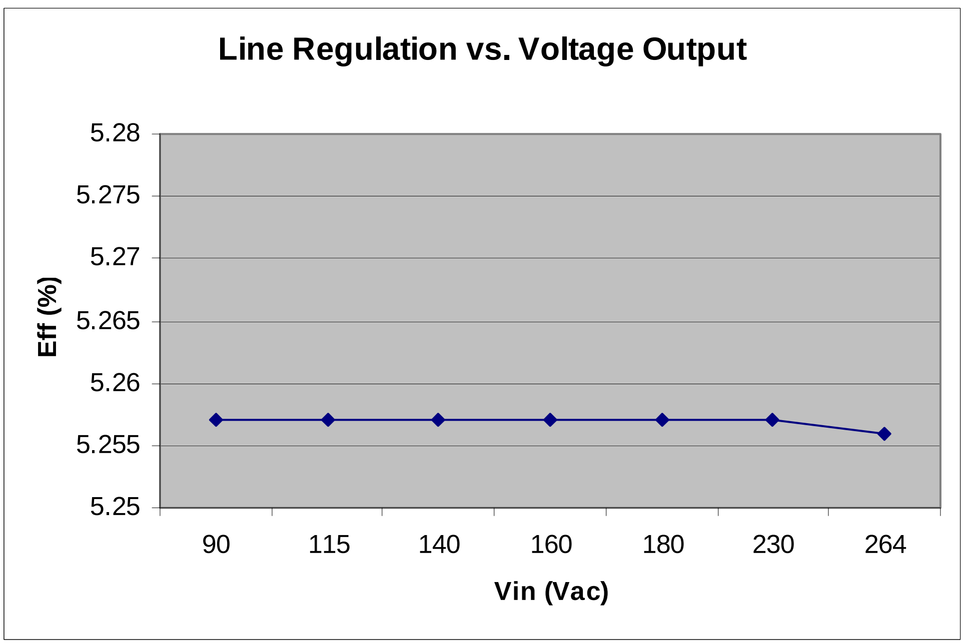

Figure 9 – Line Regulation, Room Temperature, Full Load.

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10.4 CEC Efficiency

CEC Specification: Eff. > 0.09 x ln (Po)+0.49 = 72.17 % @ 115 VAC and 230 VAC.

Load (%) / Vin (VAC)	25% (0.625 A)	50% (1.25 A)	75% (1.875 A)	100% (2.5 A)	Avg. Eff (%)
115	72.3%	73.3%	74.3%	73.2%	***73.2%***
230	73.5%	75.8%	74.8%	74.63%	***74.625%***

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11 Waveforms

11.1 Drain Voltage and Current, Normal Operation

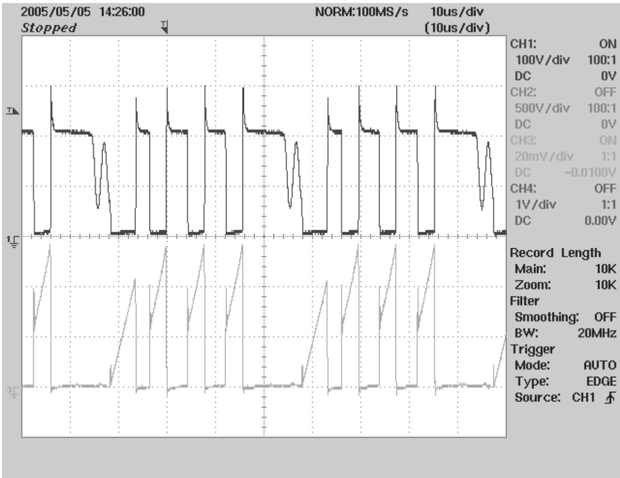

Figure 10 – 90 VAC, Full Load.
Lower: I_{DRAIN}, 0.2 A / div
Upper: V_{DRAIN}, 100 V, 10 μs / div

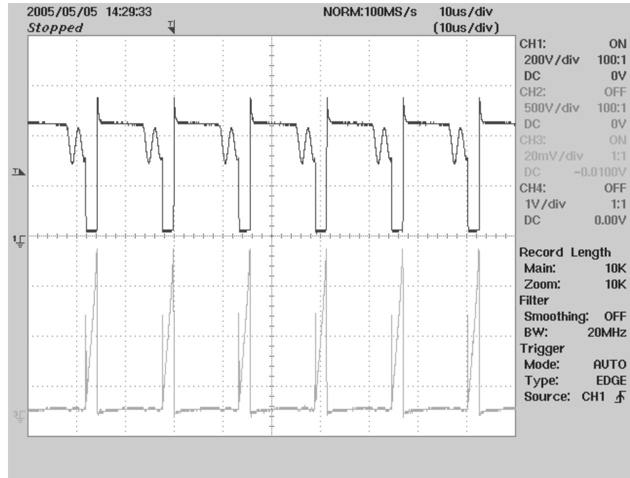

Figure 11 – 264 VAC, Full Load
Lower: I_{DRAIN}, 0.2 A / div
Upper: V_{DRAIN}, 200 V / div, 10 μs / div

11.2 Output Voltage Start-up Profile

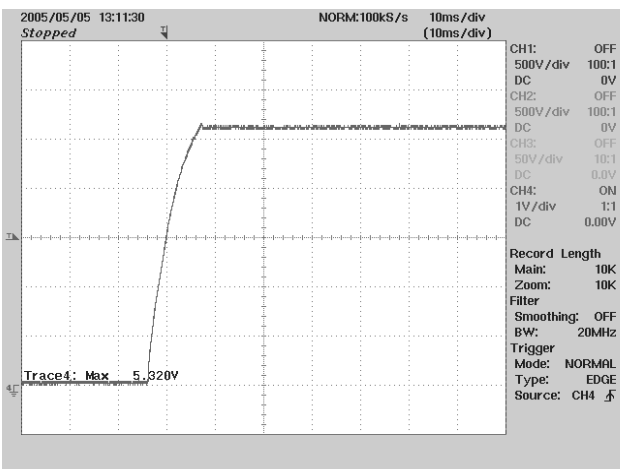

Figure 12 – Start-up Profile, 90 VAC, Full load
1 V/ div, 10 ms / div.

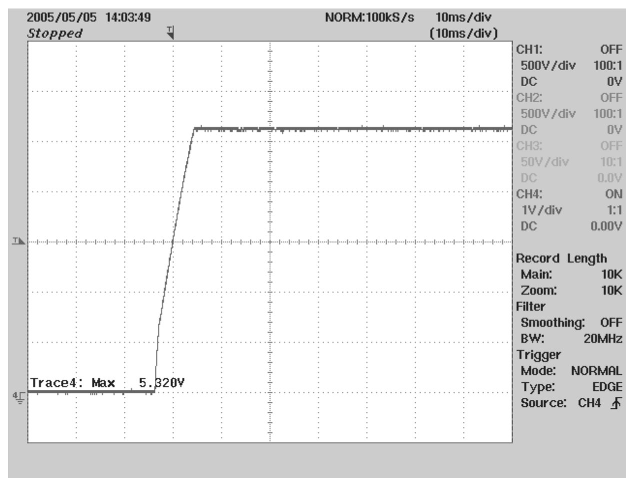

Figure 13 – Start-up Profile, 264 VAC, Full load
1 V/ div, 10 ms / div.

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11.3 Drain Voltage and Current Start-up Profile

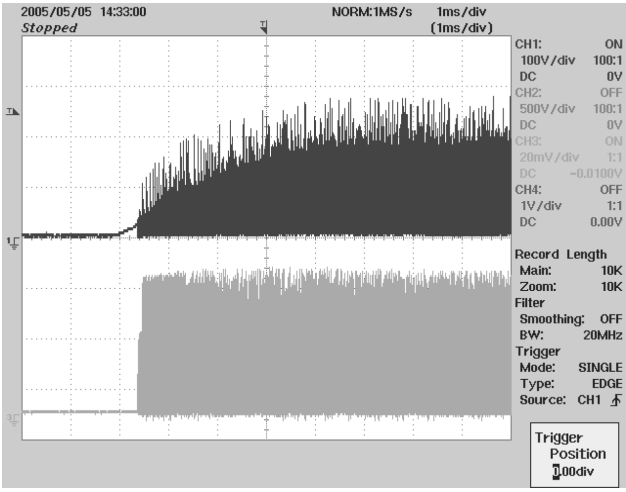

Figure 14 – 90 VAC Input and Maximum Load.
Lower: I_{DRAIN}, 0.2 A / div.
Upper: V_{DRAIN}, 100 V & 1 ms / div.

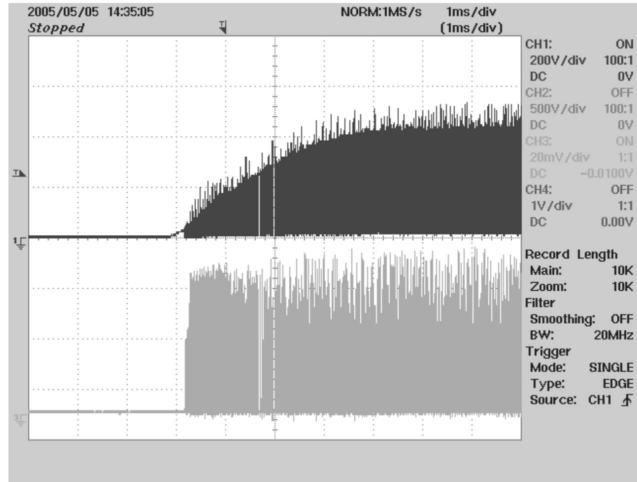

Figure 15 – 264 VAC Input and Maximum Load.
Lower: I_{DRAIN}, 0.2 A / div.
Upper: V_{DRAIN}, 200 V & 1 ms / div.

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

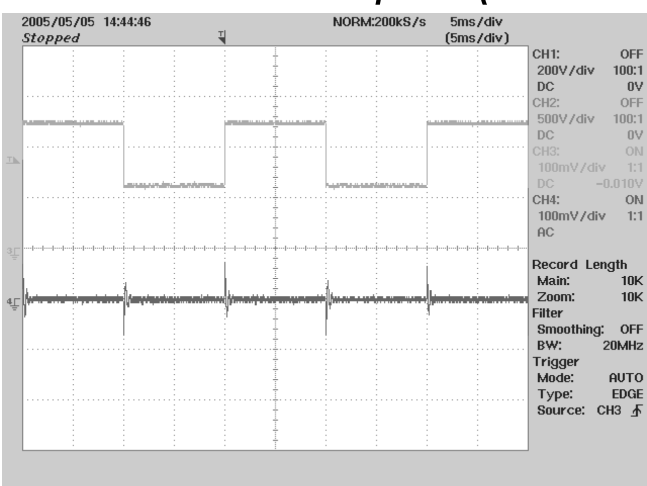

Figure 16 – Transient Response, 90 VAC, 50-100-50% Load Step.
Upper: Load Current, 1 A/div.
Lower: Output Voltage
100 mV/ div, 5 ms / div.

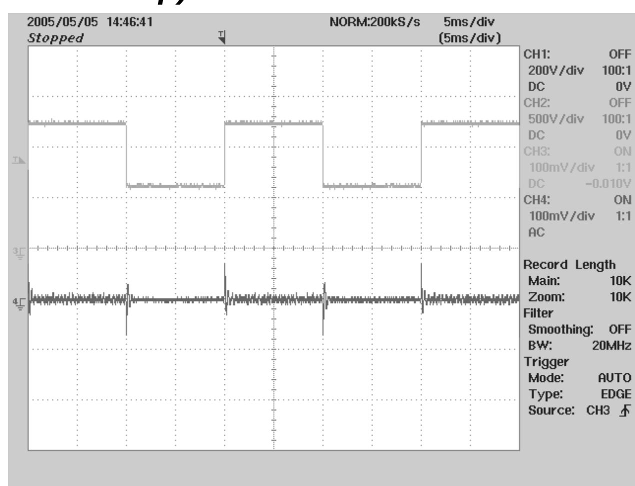

Figure 17 – Transient Response, 264 VAC, 50-100-50% Load Step
Upper: Load Current, 1 A/ div.
Lower: Output Voltage
100 mV/ div, 5 ms / div.

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11.5 Output Ripple Measurements

11.5.1 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 18 and Figure 19.

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).***

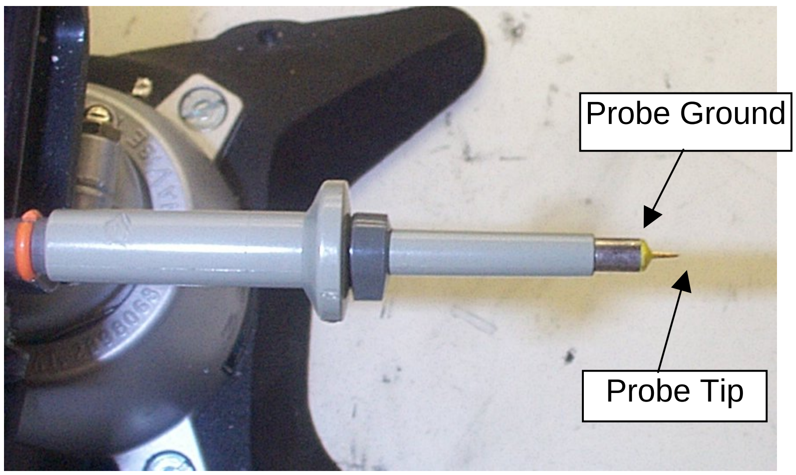

Figure 18 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed).

Figure 19 – 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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11.5.2 Measurement Results

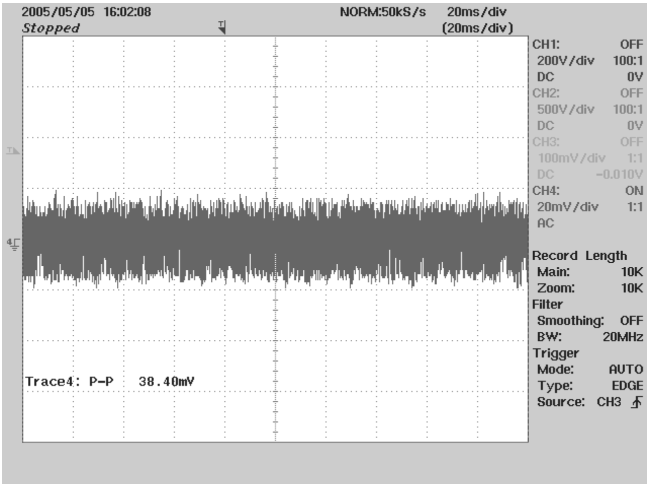

Figure 20 – 5.25V Ripple, 90 VAC, Full Load.
20 ms/ div, 20 mV / div

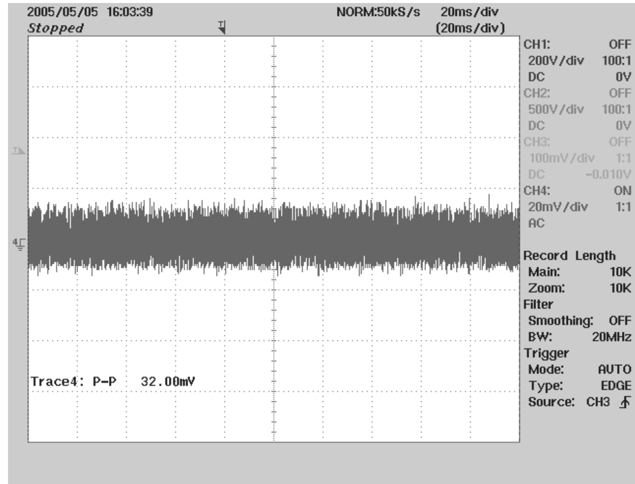

Figure 21 – 5.25V Ripple, 115 VAC, Full Load.
20 ms/ div, 20 mV / div

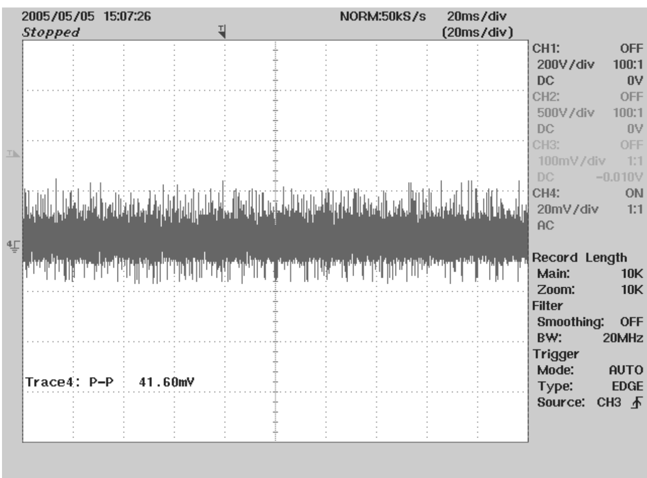

Figure 22 – 5.25V Ripple, 230 VAC, Full Load.
20 ms/ div, 20 mV / div

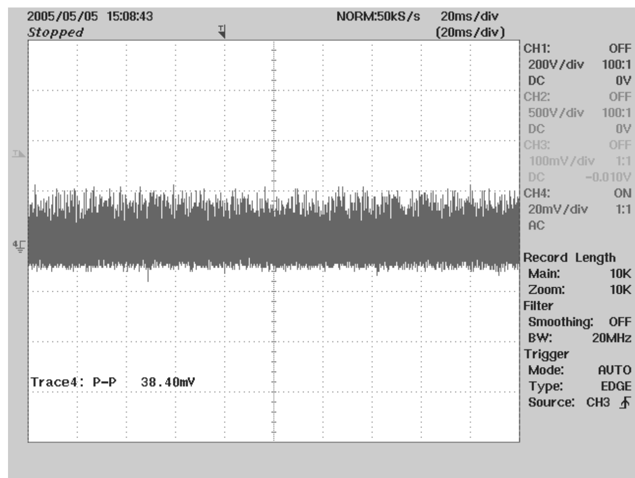

Figure 23 – 5.25V Ripple, 264 VAC, Full Load.
20 ms/ div, 20 mV / div

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12 Conducted EMI

115 VAC

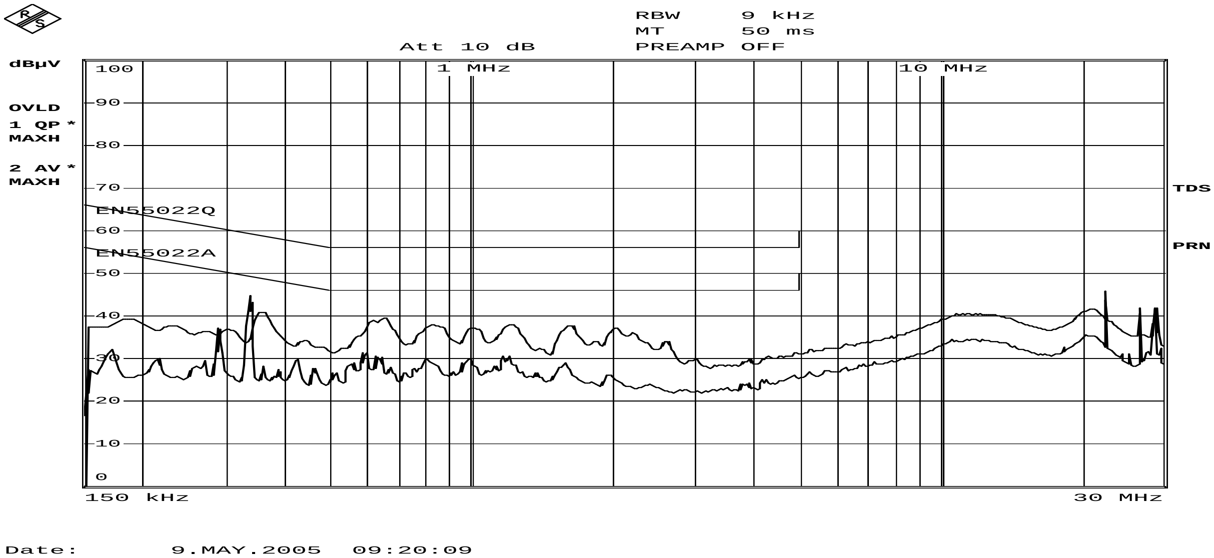

Figure 24 – Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits

220 VAC

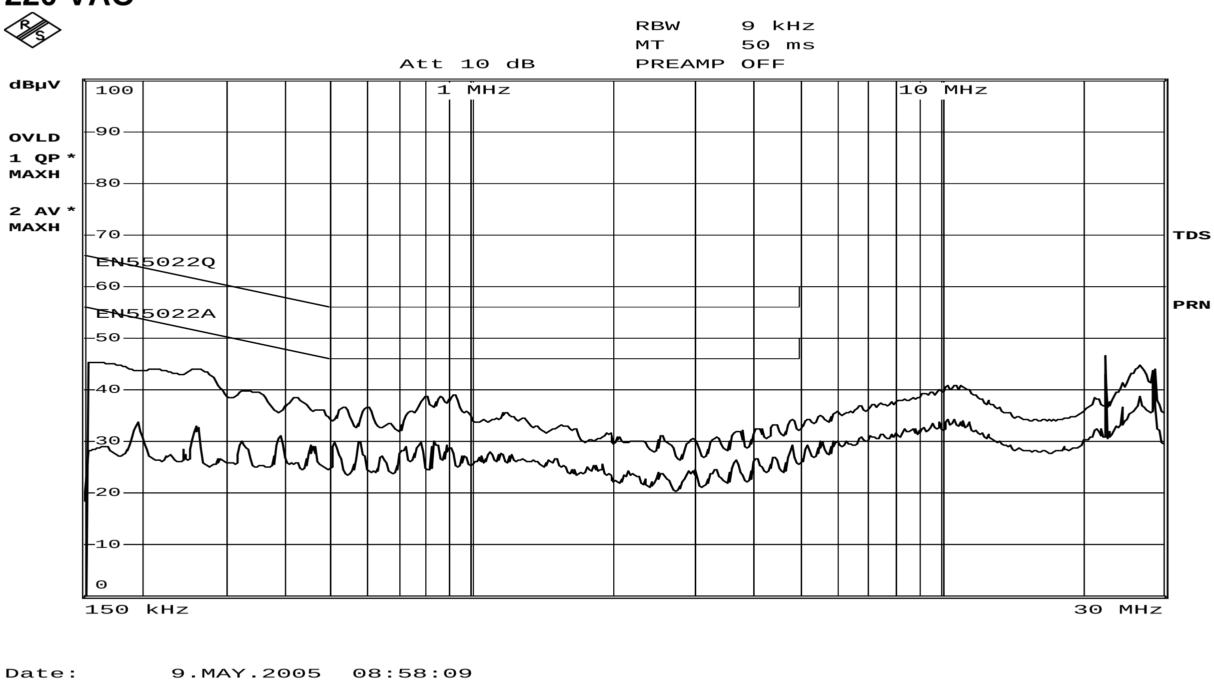

Figure 25 – Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits

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13 Revision History

Date	Author	Revision	Description & changes	Reviewed
11-3-05	Ralph Sung	1.0	Initial Release	JC/KM

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