Design Example Report

Title	***15W power supply using TNY268P***
Specification	Input: 120 - 420 Vdc Output: 5V/3A, 13V/10mA
Application	PC Standby
Author	Power Integrations Applications Department
Document Number	DER-11
Date	February 4, 2004
Revision	1.0

Summary and Features

This report details the design of an isolated Flyback converter for a PC Standby power supply.

- High light load efficiency
- Over 0.4W out at 1W in, as measured in the PC PSU
- Total output power 15 W with TNY268P and EE19 core
- Typical Efficiency 79 %
- Meets ± 5 % output voltage regulation over line and load changes

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Important Notes:
Although the prototype hardware is designed to satisfy safety isolation requirements, this 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.

The layout shown in this report has been engineered to follow Power Integrations' design guidelines to minimize EMI and susceptibility. Changing the layout may worsen EMI and other aspects of performance.

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 showing the performance characteristics of a 15W Flyback converter with 120–420Vdc (PFC application) input, 5V 3A isolated output, and 13V 10mA non-isolated output. This design uses *TinySwitch-II* – an integrated IC comprising a high voltage *MOSFET,* and *PWM* controller.

This document contains power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, and performance data. The photos of power supply prototype are shown in Figure 1 and Figure 2.

Measurements were taken both with the prototype standalone, and in the PC power supply.

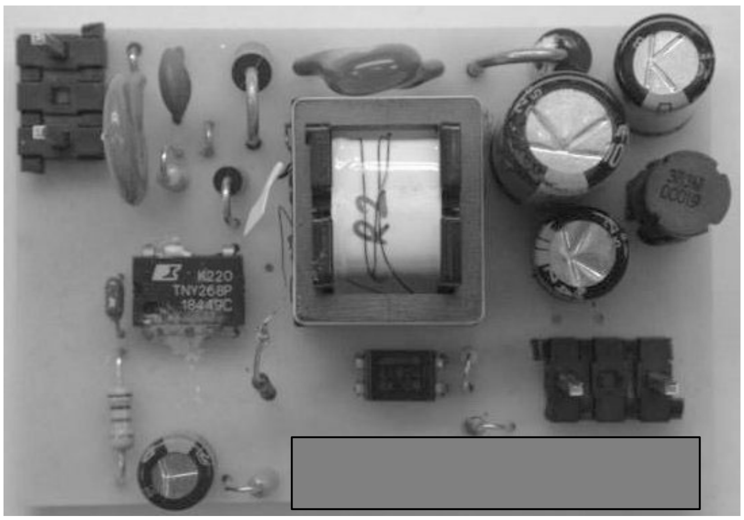

Figure 1 – Power Supply Prototype – Top View

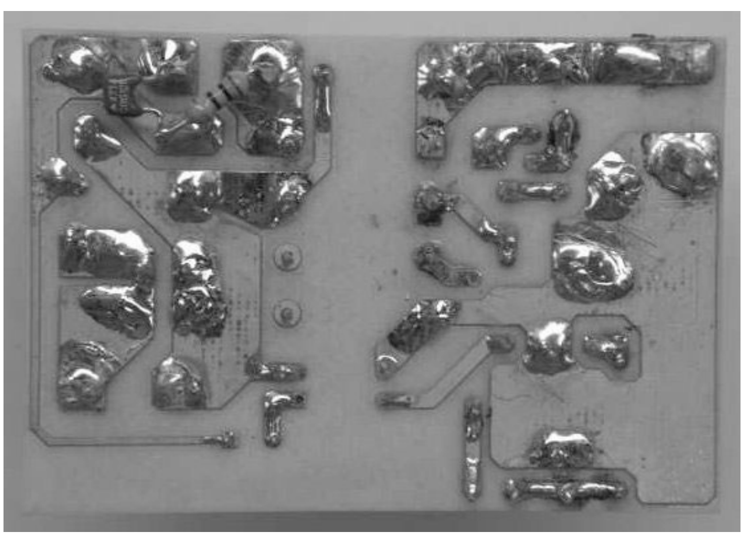

Figure 2 – Power Supply Prototype – Bottom View

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Note: Y-cap is for testing the unit standalone. Otherwise, The common-mode noise may affect the input power measurements.

2 Power Supply Specification

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	120		420	Vdc	PFC Standby
Outputs						
Output Voltage 1	V_{OUT1}	4.75	5.0	5.25	V	± 5%
Output Ripple Voltage 1	$V_{RIPPLE1}$			50	mV	20 MHz Bandwidth
Output Current 1	I_{OUT1}			3	A	isolated
Output Voltage 2	V_{OUT2}		13		V	
Output Ripple Voltage 2	$V_{RIPPLE2}$			130	mV	20 MHz Bandwidth
Output Current 2	I_{OUT2}			10	mA	non-isolated
Continuous Output Power	P_{OUT}		15		W	
Efficiency	η		79		%	At full load
Ambient Temperature	T_{AMB}	0		40	^{o}C	Free convection, Sea level

Table 1 – Power Supply Specification

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3 Schematic

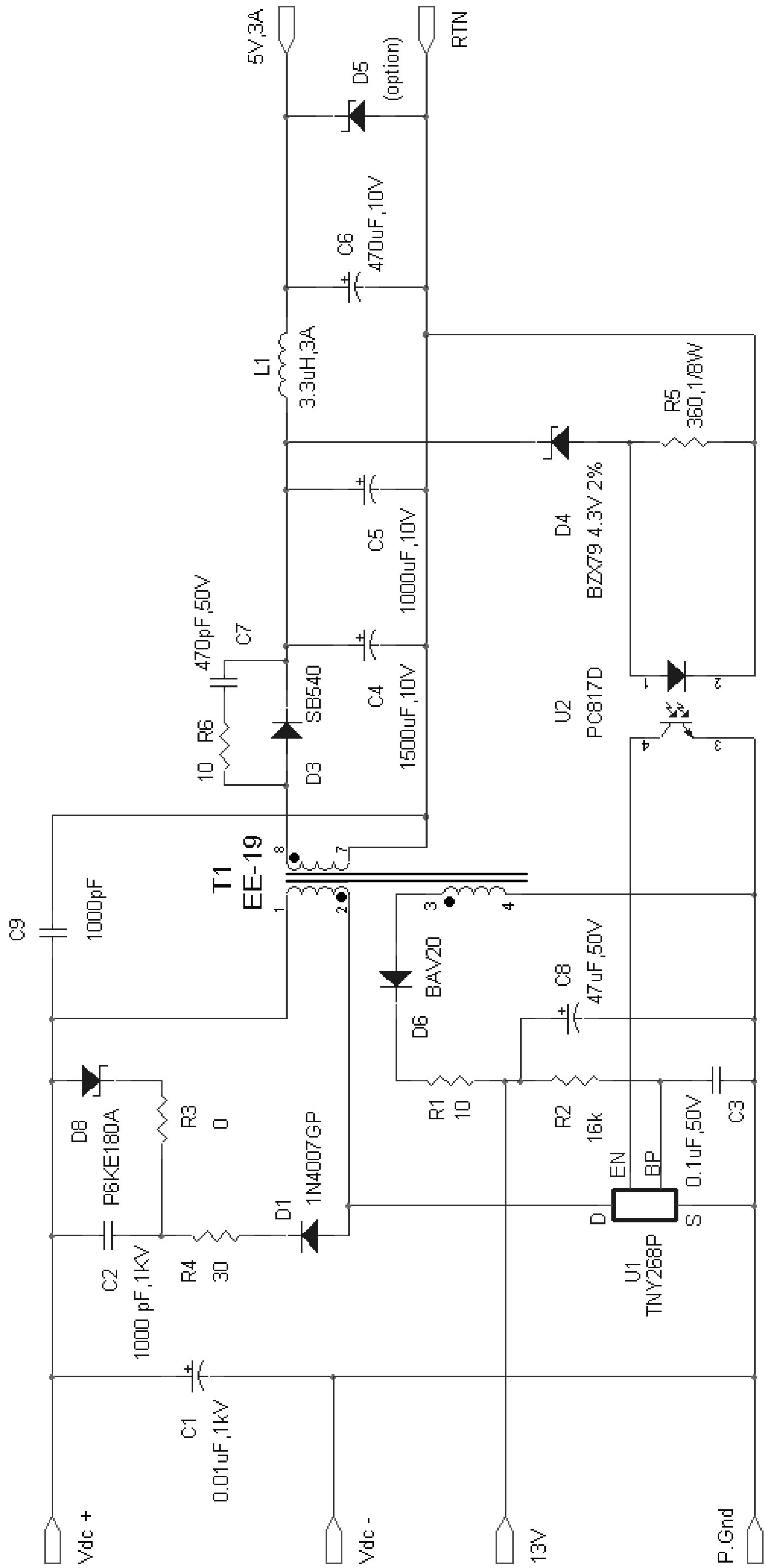

Figure 3 – TNY268 Flyback Converter – 15 W, 5V 3A, 13V 10 mA

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4 PCB Layout

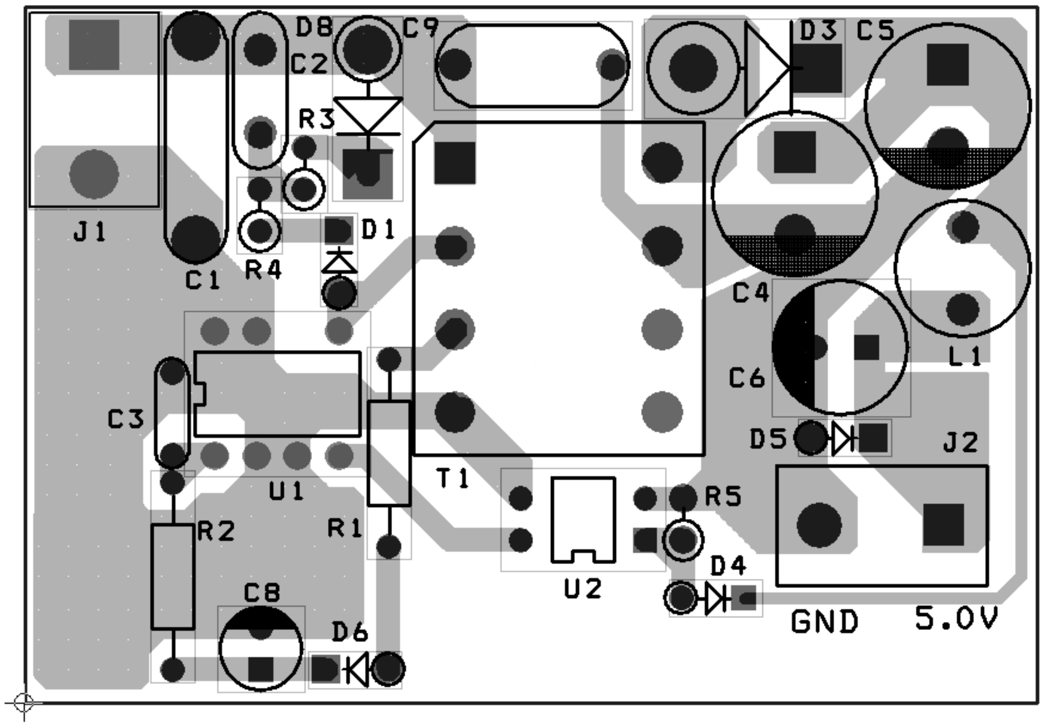

Figure 4 – PCB Layout

Note:

1. The schematic and PCB layout have some components as OPTIONS, which are not used in the prototype.
2. The prototype PCB layout may not match the schematic, due to modifications made to meet the specifications.

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5 Bill Of Materials

Item	Qty	Reference	Description
1	1	C1	0.01 µF, 1KV, Ceramic capacitor, Z5U
2	1	C2	1000 pF, 1KV, Ceramic capacitor, Z5U
3	1	C3	0.1 µF, 50V, Ceramic capacitor, X7R
4	1	C4	1500 µF, 10V, Electrolytic capacitor Low ESR, (Rubycon ZL series or equivalent)
5	1	C5	1000 µF, 10V, Electrolytic capacitor Low ESR, (Rubycon ZL series or equivalent)
6	1	C6	470 µF, 10V, Electrolytic capacitor Low ESR, (Rubycon ZL series or equivalent)
7	1	C7	470 pF, 50V, Ceramic capacitor, NPO
8	1	C8	47 µF, 50V, Electrolytic capacitor
9	1	C9	1000 pF, Y1 safety capacitor
10	1	D1	1N4007GP, 1000V, 1A, glass passivated diode $t_{rr} = 2\ \mu S$ (typical)
11	1	D3	SB540, 40V 5A Schottky diode
12	1	D4	BZX79 4.3V, 4.3V, 2%, 0.5 W, Zener diode
13	1	D5	Zener diode option for over voltage protection
14	1	D6	BAV20, small signal diode, 200V, 200mA
15	1	D8	P6KE180A, TVS zener, 5W, 180V, 5%
16	1	L1	3.3 µH, 3A, Ferrite drum core inductor, # 22 AWG magnet wire
17	2	R1, R6	10 Ω, 1/4W, 5%, resistor
18	1	R2	16 KΩ, 1/4W, 5%, resistor
19	1	R3	0 Ω, 1/8W, 5%, resistor
20	1	R4	30 Ω, 1/4W, 5%, resistor
21	1	R5	360 Ω, 1/8W, resistor
22	1	T1	Transformer EE19 core
23	1	U1	TNY268P
24	1	U2	PC817D, Optocoupler

Table 2 – Bill of Materials

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6 Transformer

6.1 Transformer Winding

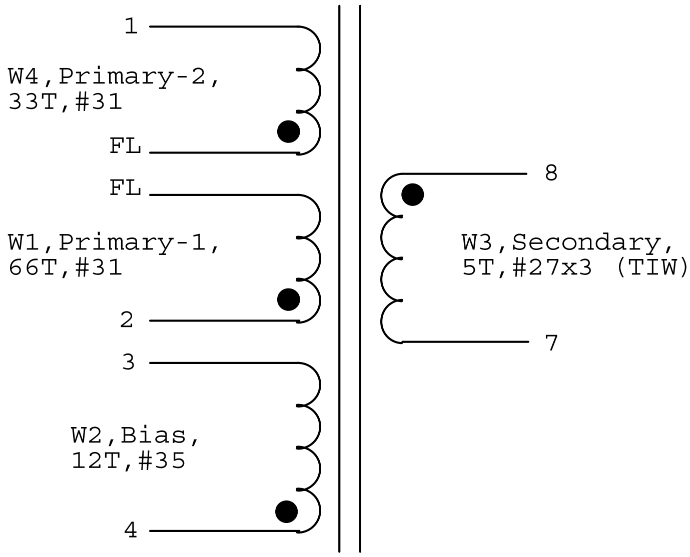

Figure 5 – Transformer Winding

Note:

1. W1 and W2 are interleaved primary winding. Both flying leads (FL) should be soldered together and wrap with tape for insulation.

6.2 Electrical Specifications

Electrical Strength	60Hz 1minute, from Pins 1-4 to Pins 7-8	3 kV for 1 minute
Primary Inductance (Pin 1 to Pin 2)	All windings open	1.12 mH – 1.18 mH – 1.24 mH
Resonant Frequency	All windings open	300 kHz min.
Primary Leakage Inductance	L_{12} with pins 3-8 shorted	25 µH max.

Table 3 – Transformer Electrical Parameters

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6.3 Transformer Construction

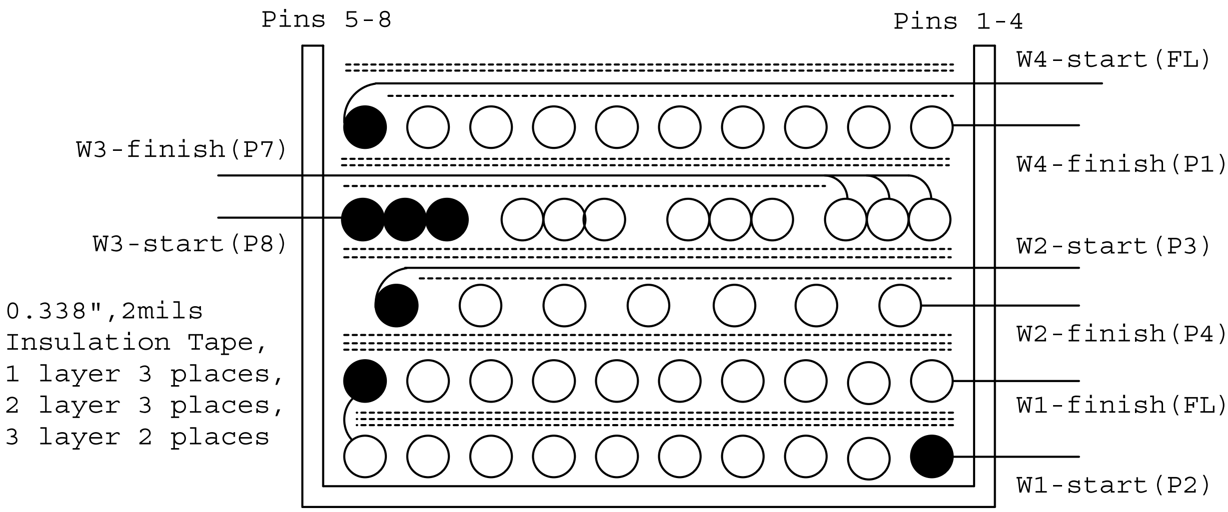

Figure 6 – Transformer Construction

6.4 Materials

Item	Description
[1]	Core: EE19, Gapped for AL = 114 nH/T^2 - 120 nH/T^2 - 127 nH/T^2
[2]	Bobbin: Horizontal 8 pins
[3]	Magnet Wire: # 31 AWG
[4]	Magnet Wire: # 35 AWG
[5]	Triple Insulated Wire # 27 AWG
[6]	Tape: 3M 1298 Polyester Film (white) 0.338" x 2 mils
[7]	Tape: 3M 1298 Polyester Film (white) 0.135" x 2 mils (to wrap the core together)
[8]	Varnish

Table 4 – Transformer BOM

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6.5 Winding Instructions

All windings should be wound in the forward direction.

Bobbin orientation	Place the bobbin on the winding machine with pins 1-4 on the right side and pins 5-8 on the left side.
W1 (Primary winding-1)	Wind 66 turns in 2 layers with # 31 AWG magnet wire – first layer 33T from right to left starting from pin 2 – 3 layers of insulation tape – second layer 33T from left to right and finish as flying lead.
Basic Insulation	3 layers of tape for insulation.
W2 (Bias winding)	Wind 12 turns in one layer from left to right with # 35 AWG magnet wire starting temporarily from pin 6 and finish at pin 4, wind evenly across the width of the bobbin – one layer of tape – bring the starting end from pin 6 to pin 3.
Basic Insulation	2 layers of tape for insulation.
W3 (5V Winding)	Wind 5 turns in one layer from left to right with # 27 x 3 (trifilar) triple insulated wire, starting from pin 8 – one layer of tape – and finish at pin 7.
Basic Insulation	2 layers of tape for insulation.
W4 (Primary winding-2)	Wind 33 turns in one layer with # 31 AWG magnet wire from left to right starting temporarily from pin 8 and finishing at pin 1 – one layer of tape – bring the starting end from pin 8 and terminate as flying lead. Twist the flying leads (W1 and W4 FLs) together.
Outer Insulation	2 layers of tape for insulation.
Core Assembly	Assemble and secure core halves.
Final Assembly	Impregnate transformer uniformly with varnish.

6.6 Design Notes:

Power Integrations Device	TNY268P
Frequency of Operation	132 KHz
Mode	Continuous/ discontinuous
Peak Current	0.55 A
Reflected Voltage (Secondary to Primary)	109 V
Maximum AC Input Voltage	301 Vac
Minimum AC Input Voltage	85 Vac

Table 5 – Power Supply Design Parameters

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7 Transformer Design Spread Sheet

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					**Customer**
VACMIN	85			Volts	Minimum AC Input Voltage
VACMAX	301			Volts	Maximum AC Input Voltage
fL	60			Hertz	AC Mains Frequency
VO	5			Volts	Output Voltage
PO	15			Watts	Output Power
n	0.79				Efficiency Estimate
Z	0.5				Loss Allocation Factor
tC	3			mSeconds	Bridge Rectifier Conduction Time Estimate
CIN	220			uFarads	Input Filter Capacitor
ENTER TinySwitch-II VARIABLES					
TNY-II	**TNY268**			*Universal*	*115 Doubled/230V*
Chosen Device		*TNY268*	*Power Out*	*15W*	*23W*
ILIMITMIN			*0.512*	Amps	TINYSwitch Minimum Current Limit
ILIMITMAX			*0.588*	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	109			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			**0.74**		Ripple to Peak Current Ratio (0.6<KRP<1.0 : 1.0<KDP<6.0)
Core Type	**ee19**				
Core		*EE19*		*P/N:*	PC40EE19-Z
Bobbin		*EE19_BOBBIN*		*P/N:*	BE-19-118CPH
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)

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L	**3**		Number of Primary Layers
NS	**5**		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS			
VMIN	116	Volts	Minimum DC Input Voltage
VMAX	426	Volts	Maximum DC Input Voltage
DMAX	0.51		Maximum Duty Cycle
IAVG	0.16	Amps	Average Primary Current
IP	0.51	Amps	Minimum Peak Primary Current
IR	0.38	Amps	Primary Ripple Current
IRMS	0.24	Amps	Primary RMS Current
LP	1159	uHenries	Primary Inductance
NP	99		Primary Winding Number of Turns
ALG	118	nH/T^2	Gapped Core Effective Inductance
BM	**2989**	Gauss	Flux Density, IP (BP<3000)
BAC	963	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur	1704		Relative Permeability of Ungapped Core
LG	**0.22**	mm	Gap Length (Lg > 0.1 mm)
BWE	27	mm	Effective Bobbin Width
OD	0.27	mm	Maximum Primary Wire Diameter including insulation
INS	0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA	0.22	mm	Bare conductor diameter
AWG	32	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM	64	Cmils	Bare conductor effective area in circular mils
CMA	**264**	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
Lumped parameters			
ISP	10.15	Amps	Peak Secondary Current
ISRMS	4.74	Amps	Secondary RMS Current
IO	3.00	Amps	Power Supply Output Current
IRIPPLE	3.67	Amps	Output Capacitor RMS Ripple Current
CMS	948	Cmils	Secondary Bare Conductor minimum circular mils
AWGS	20	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS	0.81	mm	Secondary Minimum Bare Conductor Diameter
ODS	1.80	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire

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INSS	0.49	mm	Maximum Secondary Insulation Wall Thickness
VDRAIN	675	Volts	Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance)
PIVS	26	Volts	Output Rectifier Maximum Peak Inverse Voltage

8 Performance Data

The measurements were taken for the power supply in two ways:

1) As a stand-alone unit, and

2) In a PC power supply, operating in standby mode

A comparison was made against the original standby power supply (*TOP244P* design) in the PC power supply.

The measurements as stand-alone unit are given in the table below. 13V output is not loaded.

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8.1 Light Load Input and Output Power Comparison

These measurements were taken of the whole PSU, in standby mode. A comparison is made with the original standby design, against the TinySwitch-II design. For the measurements, the original standby supply was removed and the TinySwitch-II prototype was wired in. In both cases, the standby supply was powering the primary-side 13V circuits in the PSU.

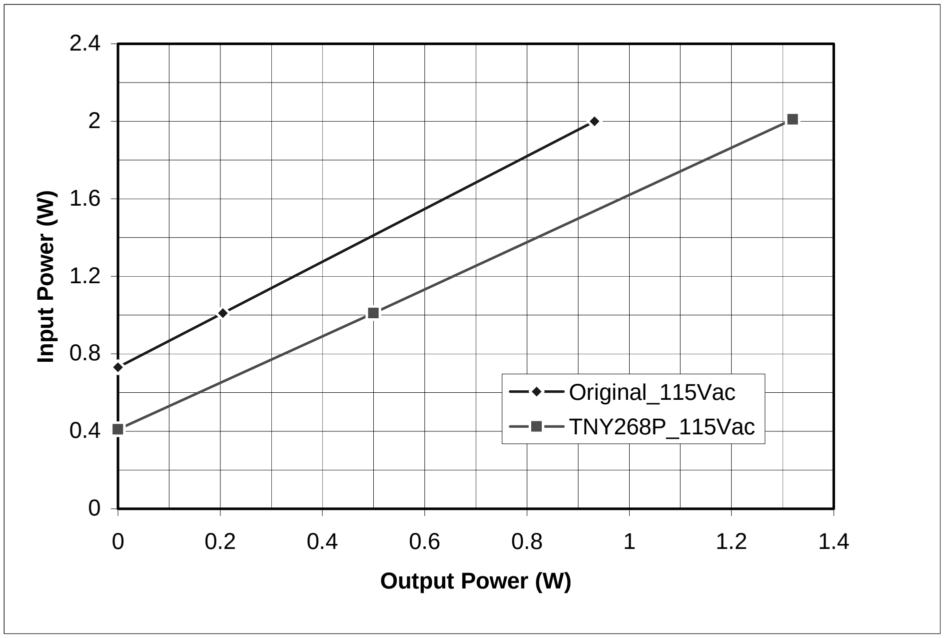

Figure 7 – Input vs. Output power at 115 Vac

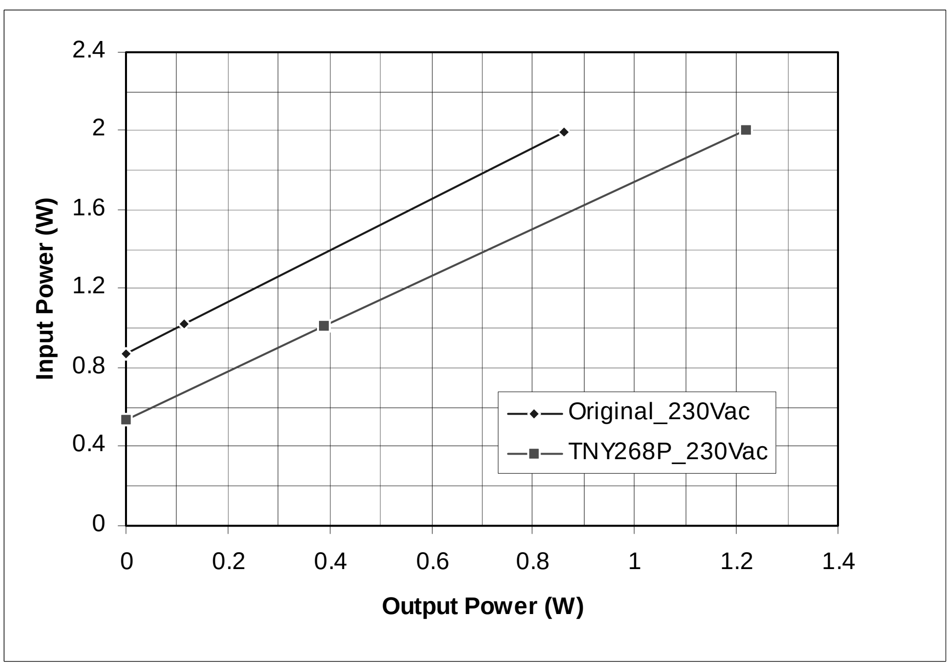

Figure 8 – Input vs. Output power at 230 Vac

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8.2 Efficiency comparison, standalone

The efficiency of the TNY268P design is % higher than the TOP244P design, especially at light load.

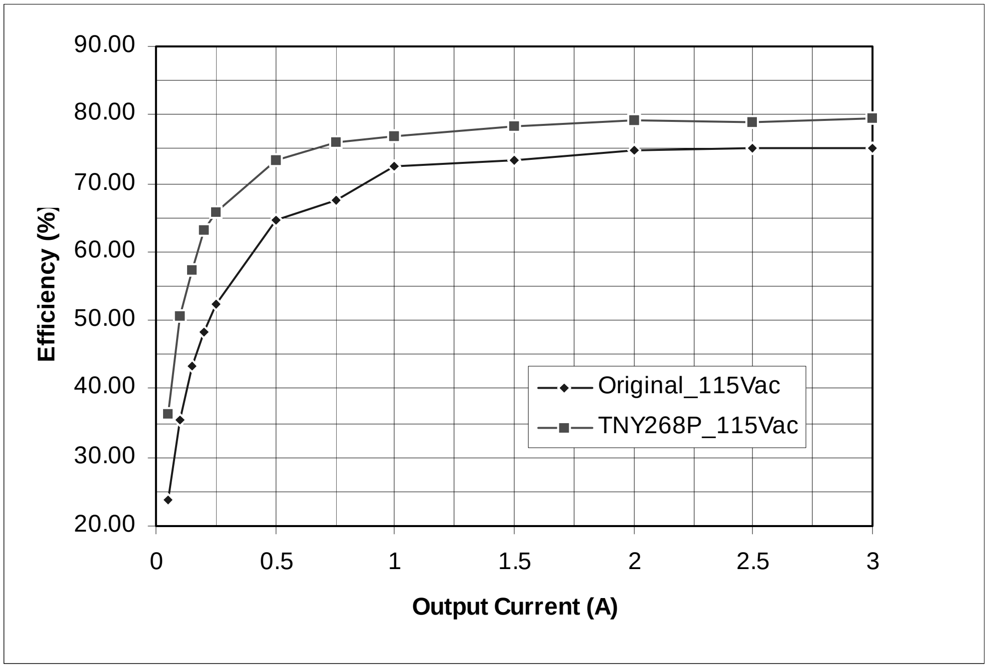

Figure 9 – Efficiency versus output current at 115 Vac

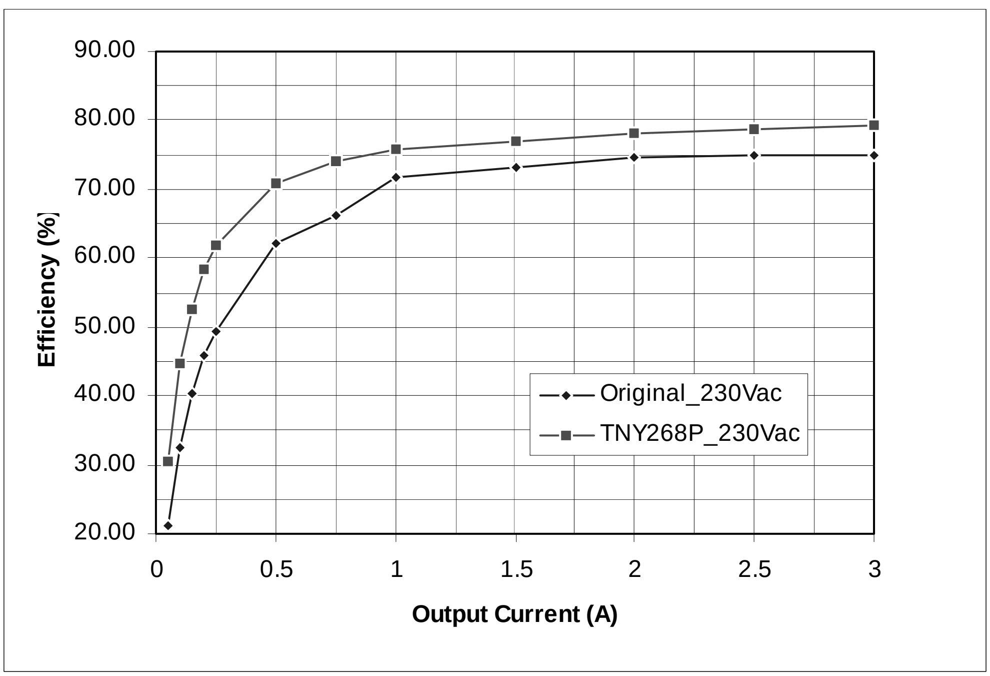

Figure 10 – Efficiency versus output current at 230 Vac

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9 Output Ripple Measurements

9.1 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 11 and Figure 12.

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).*

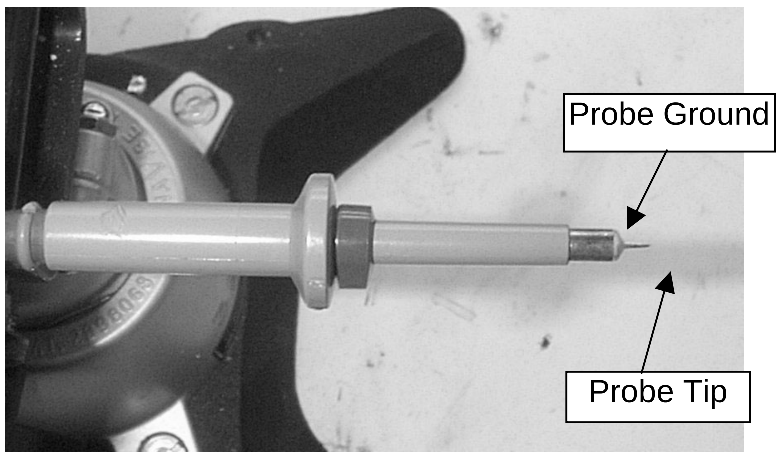

Figure 11 – Oscilloscope Probe Prepared for Ripple Measurement.

(End Cap and Ground Lead Removed)

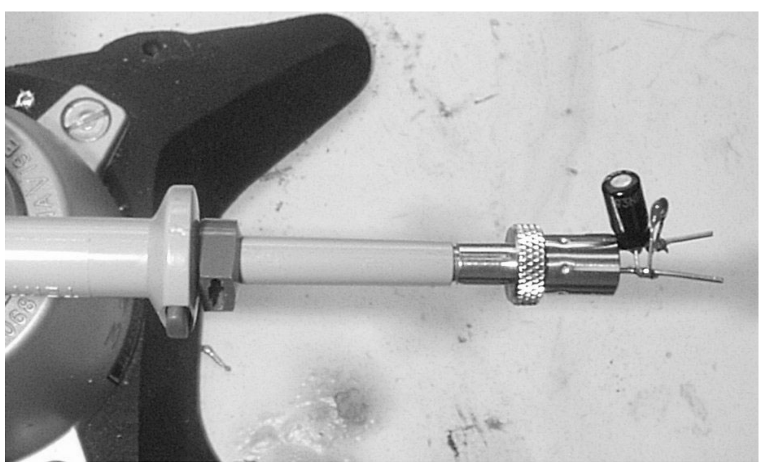

Figure 12 – Oscilloscope Probe with Probe Master 5125BA BNC Adapter

(Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added).

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9.2 Output Voltage Ripple

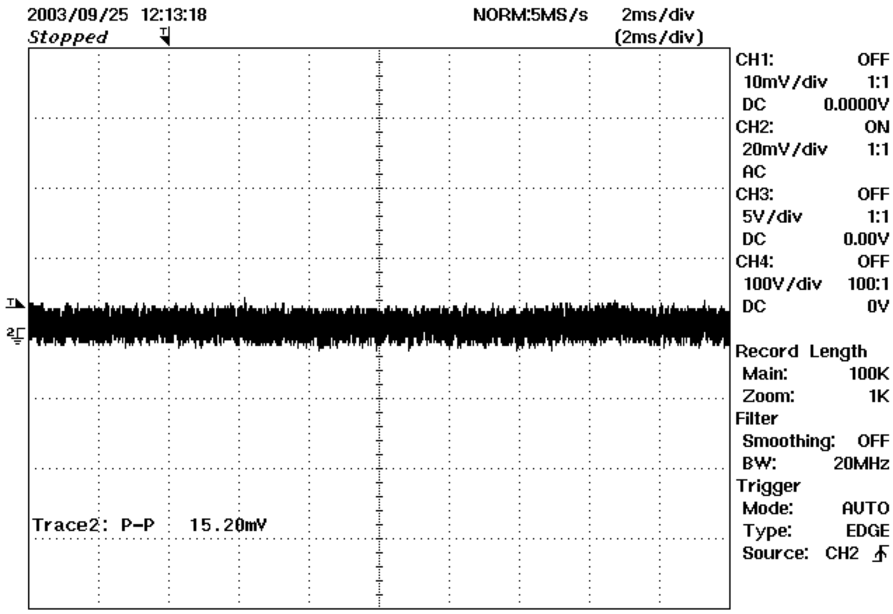

Figure 13 – 5V Output Voltage Ripple at V_{IN} = 115 Vac, I_{5V} = 3 A

10 Revision History

Date	Author	Revision	Description & changes	Reviewed
February 4, 2004	MJ	1.0	Initial release	VC/AM

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