# Design Example Report

| | |
|---|---|
| **Title** | ***3.9W CV/CC Charger using TNY266P with < 100 mW standby*** |
| **Specification** | Input: 85 – 265 VAC<br>Output: 6.5V / 0.6A |
| **Application** | Cell Phone Charger |
| **Author** | Power Integrations Applications Department |
| **Document Number** | DER-33 |
| **Date** | April 1, 2004 |
| **Revision** | 1.0 |


## Summary and Features

This document is an engineering report describing a 6.5 VDC, 600 mA CV/CC Charger utilizing a TNY266P featuring:

- No load power consumption ~69 mW @ 230V
- Achieves cable-drop compensation with no TL431
- Uses TNY266P
- Low cost , low parts count
- No Y-cap needed to meet CISPR-22 EMI even with artificial hand
- Very low AC leakage current





**Power Integrations**
5245 Hellyer Avenue, San Jose, CA 95138 USA.
Tel: +1 408 414 9200 Fax: +1 408 414 9201
*www.powerint.com*

# Table Of Contents

1 Introduction ....... 3
2 Photograph ....... 3
3 Power Supply Specification ....... 4
4 Schematic ....... 5
5 Circuit Description ....... 6
5.1 Input Rectification, Bulk Capacitance and EMI Filtering ....... 6
5.2 Primary DRAIN Voltage Clamp Circuit ....... 6
5.3 Auxiliary Bias Supply ....... 6
5.4 Output Rectification and Filtering ....... 6
5.5 Output Voltage Sensing and Feedback ....... 7
6 PCB Layout ....... 8
7 Bill Of Materials ....... 9
8 Transformer Specification ....... 10
8.1 Electrical Diagram ....... 10
8.2 Electrical Specifications ....... 10
8.3 Materials ....... 11
8.4 Transformer Build Diagram ....... 11
8.5 Transformer Construction ....... 12
9 Transformer Spreadsheets ....... 13
10 Performance Data ....... 15
10.1 Output Characteristic ....... 15
10.2 Efficiency ....... 15
10.3 No-load Input Power ....... 16
10.4 Load and Line Regulation in CV mode ....... 16
11 Thermal Performance ....... 17
12 Waveforms ....... 18
12.1 Drain Voltage Normal Operation ....... 18
12.2 Output Voltage Start-up Profile ....... 18
12.3 Drain Voltage Start-up Profile ....... 19
12.4 Output Ripple Measurements ....... 20
12.4.1 Ripple Measurement Technique ....... 20
12.4.2 Measurement Results ....... 21
13 Conducted EMI ....... 22
14 Revision History ....... 23

**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.



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 1 Introduction

This document is an engineering report describing a 6.5 VDC, 600 mA CV/CC Charger utilizing a TNY266P.

The TNY266P is implemented as both a switch and controller into a Flyback converter. Cancellation techniques are adopted in the transformer design to make the power supply meet EMI without Y capacitors.

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

# 2 Photograph

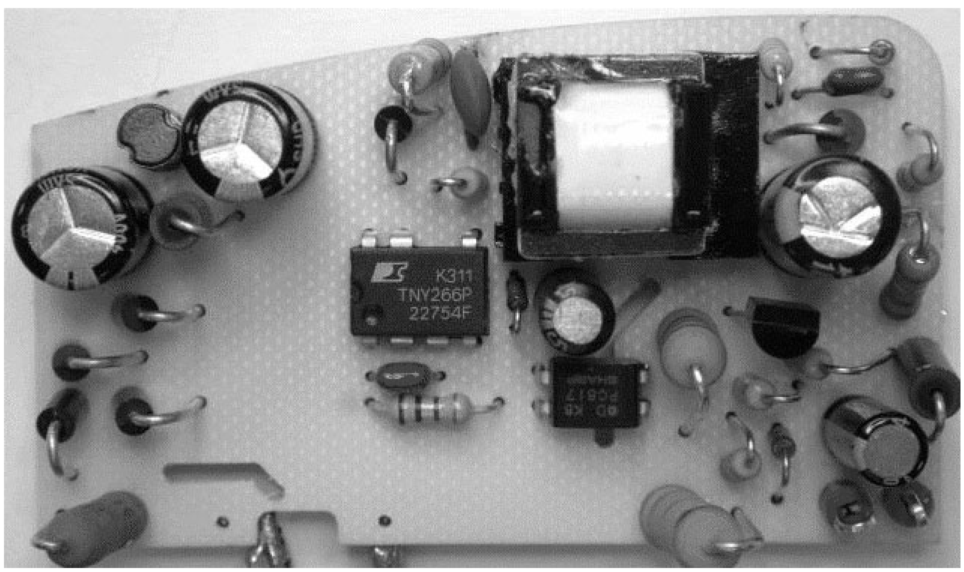


**Figure 1 –** Populated Circuit Board Photograph.


**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 3 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) | | | | 0.1 | W | |
| **Output** | | | | | | |
| Output Voltage 1 | $V_{OUT1}$ | | 6.5 | | V | ±7% |
| Output Ripple Voltage 1 | $V_{RIPPLE1}$ | | | 100 | mV | 20 MHz Bandwidth |
| Output Current 1 | $I_{OUT1}$ | | | 0.6 | A | |
| **Efficiency** | $\eta$ | | 62 | | % | Measured at $P_{OUT}$ (3.9 W), 25 °C |
| **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 |



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

## 4 Schematic

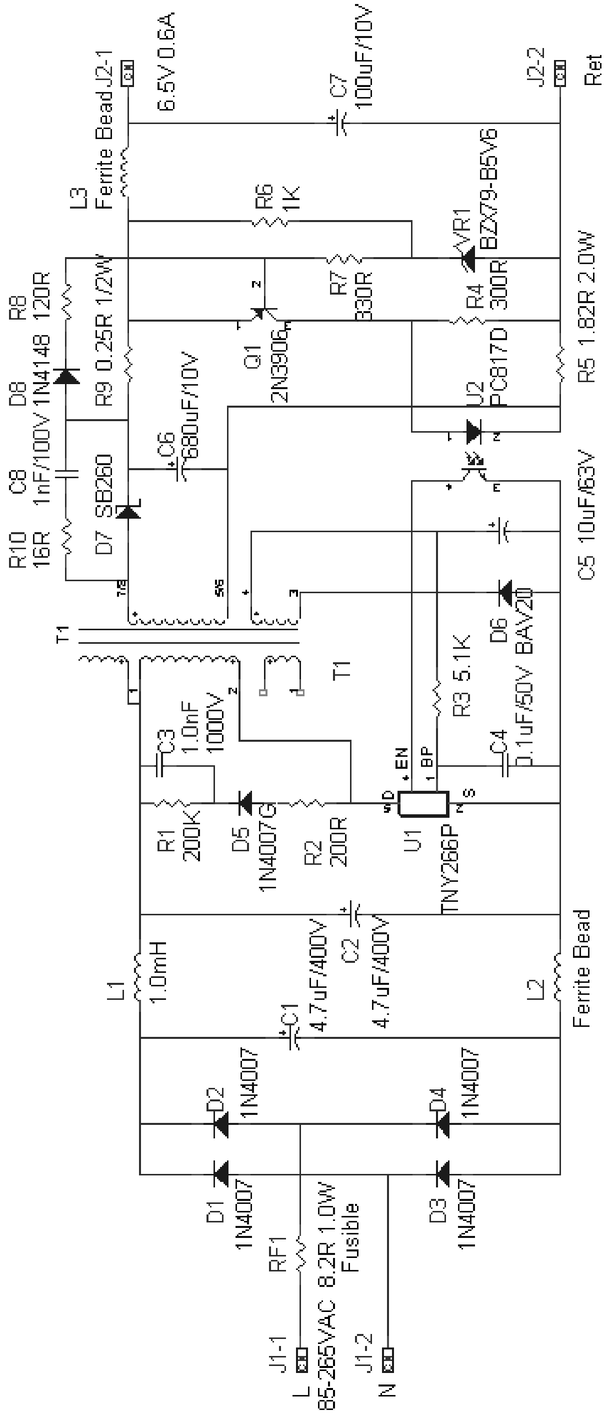


**Figure 2 –** Schematic.


**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 5 Circuit Description

This circuit is configured as a Flyback operating in both continuous and discontinuous conduction mode. The low standby consumption is achieved by using a high gain opto-coupler, using a bias winding that provides about 10V during no-load, and by designing a low-capacitance transformer.

## *5.1 Input Rectification, Bulk Capacitance and EMI Filtering*

AC input power is rectified by a full bridge, consisting of D1 through D4. The rectified DC is then filtered by the bulk storage capacitors C1 and C2. Inductor L1 and Ferrite bead L2 separate C1 and C2 from each other. L1, C1 and C2 form a pi ($\pi$) filter, which attenuates conducted differential-mode EMI noise. Fusible resistor RF1 has multiple functions. It is a fuse, an in-rush current limiting device, a final low pass filter stage (with C1) for conducted EMI attenuation and an initial stage of input surge voltage attenuation.

## *5.2 Primary DRAIN Voltage Clamp Circuit*

The DRAIN voltage clamp circuit is comprised of C3, R1, R2 and diode D5. D5 and C3 clamp the amplitude of the voltage spike that the transformer leakage inductance generates, at switch turn-off, to keep it beneath the device's maximum DRAIN to SOURCE voltage rating (700 V). R2 damps the high frequency ringing caused by leakage inductance, which improves the conducted EMI performance of the circuit.

## *5.3 Auxiliary Bias Supply*

The TinySwitch-II normally does not need a bias supply because it has a high voltage current source to supply the internal chip consumption. If an external current is applied to the BP pin (which is the internal power supply of the chip), it turns off the HV current source and regulates the voltage on the BP pin like a zener. The power dissipated in the HV current source is saved. This power savings is on the order of 50-100 mW. This is needed to achieve a <100mW standby consumption.

The auxiliary bias supply circuit is made up of the primary-side transformer bias winding, diode D6 and capacitor C5. D6 rectifies the output of the winding and C5 filters it. The winding was given just enough turns so that its minimum output voltage stays at 10V at no-load to minimize power consumption. C4 is the standard BP pin decoupling capacitor, which should always be a 50 V 0.1μF ceramic capacitor that is located close to the IC. R3 is used to regulate the current into the BP pin.

## *5.4 Output Rectification and Filtering*

Output rectification and filtering are accomplished by Schottky diode D7, capacitors C6 and C7. D7 rectifies the output of the transformer, T1. R10 and C8 dampen out the high frequency interaction between D7, T1 and U1, to reduce conducted EMI noise generation. C6 filters the initial rectified output, while L3 and C7 serve as a secondary low-pass filter stage, which further reduce the output ripple voltage.


**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

### *5.5 Output Voltage Sensing and Feedback*

Transistor Q1, resistors R4, R5, R6, R7, R8, R9, diode D8, Zener diode VR2 and opto-isolator U2 form the CV, CC, and cable drop compensation circuit. Q1, R6, R7, R8, R9, VR2, D8 and U2 comprise the Constant Voltage (CV) mode control loop and cable compensation control loop while R4, R5 and U2 make up the Constant Current (CC) mode control loop.

<u>CC Mode Operation</u>

The CC mode set-point is determined by the voltage drop on the optocoupler LED and the voltage drop on R5. The voltage drop on R4 is quite small and can be ignored. The TinySwitch-II has an EN pin current that is very constant with power delivery, so therefore the current in the optocoupler LED is very constant. For this reason the CC set-point does not change with load voltage.

<u>CV Mode and Cable Drop Compensation Operation</u>

The CV mode set-point is set by the voltage drops on VR1, R7, and the Vbe of Q1. The voltage on R7 depends on the operation of the cable drop compensation circuit. In order to have a regulated voltage at the end of the cable, the load current produces a voltage drop on R9 which feeds to the Base of Q1, through R8. The net effect is that the voltage set-point increases as the load increases, canceling the voltage drop in the output cable. D6 provides temperature compensation for the temperature coefficient of Q1.



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 6 PCB Layout

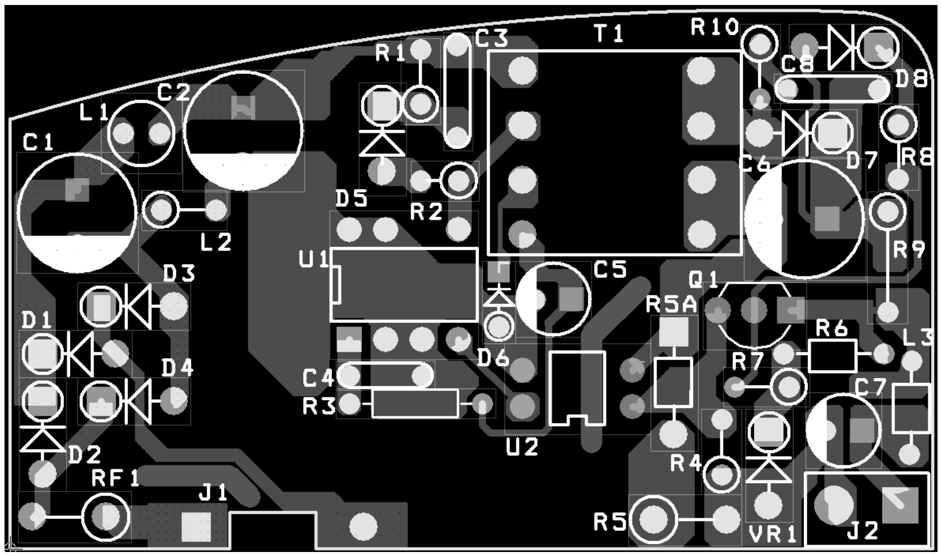


**Figure 3** – Printed Circuit Layout.

**Note:** The total value of R5 and R5A is the value shown in schematic.



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 7 Bill Of Materials

| Item | Qty | Ref | Description | P/N | Mfg |
|---|---|---|---|---|---|
| 1 | 2 | C1, C2 | 4.7uF 400V, electrolytic capacitor | KMG400VB4R7M | Nippon Chemi-Con |
| 2 | 1 | C3 | 1.0nF, 1 kV, ceramic Z5U dielectric | | Any |
| 3 | 1 | C4 | 0.1 µF, 50 V, ceramic X7R dielectric | | Any |
| 4 | 1 | C8 | 1nF, 100 V, ceramic X7R dielectric | | Any |
| 5 | 1 | C5 | 10 µF, 63 V | KMG63VB10RM | Nippon Chemi-Con |
| 6 | 1 | C6 | 680uF, 10V, low esr | KZE10VB681M | Nippon Chemi-Con |
| 7 | 1 | C7 | 100 µF, 10 V, low esr | KZE10VB101M | Nippon Chemi-Con |
| 8 | 4 | D1, D2, D3, D4 | 1 A, 1000 V | 1N4007 | Any |
| 9 | 1 | D5 | 1 A, 1000 V, Glass Passivated | 1N4007G | Any |
| 10 | 1 | D6 | 200V, 200mA, Fast | BAV20 | Any |
| 11 | 1 | D7 | 60V, 2A, Schottky | SB260 | Any |
| 12 | 1 | D8 | 75V, 150mA, Fast | 1N4148 | Any |
| 13 | 1 | J1, | AC Input Connector | | Any |
| 14 | 1 | J2 | DC output Connector | | Any |
| 15 | 1 | L1 | 1.0mH | | Any |
| 16 | 2 | L2, L3 | Ferrite Bead | | Any |
| 17 | 1 | Q1 | 40V, 200mA, PNP | 2N3906 | Any |
| 18 | 1 | RF1 | 8.2R, 1.0W | | Any |
| 19 | 1 | R1 | 200K, 1/2W | | Any |
| 20 | 1 | R2 | 200R, 1/4W | | Any |
| 21 | 1 | R3 | 5.1K, 1/4W | | Any |
| 22 | 1 | R4 | 300R, 1/4W | | Any |
| 23 | 1 | R5 | 1.82R, 2.0W | | Any |
| 24 | 1 | R6 | 1K, 1/4W | | Any |
| 25 | 1 | R7 | 330R, 1/4W | | Any |
| 26 | 1 | R8 | 120R, 1/4W | | Any |
| 27 | 1 | R9 | 0.25R, 1/2W | | Any |
| 28 | 1 | R10 | 16R, 1/4W | | Any |
| 29 | 1 | T1 | EE13 Transformer | Custom | Any |
| 30 | 1 | U1 | *TinySwitch-II* | TNY266P | Power Integrations |
| 31 | 1 | U2 | Opto-coupler | PC817D | Isocom / Any |
| 32 | 1 | VR1 | 5.6V, 1/4 W, 2% | BZX79-B5V6 | Any |


**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 8 Transformer Specification

## *8.1 Electrical Diagram*

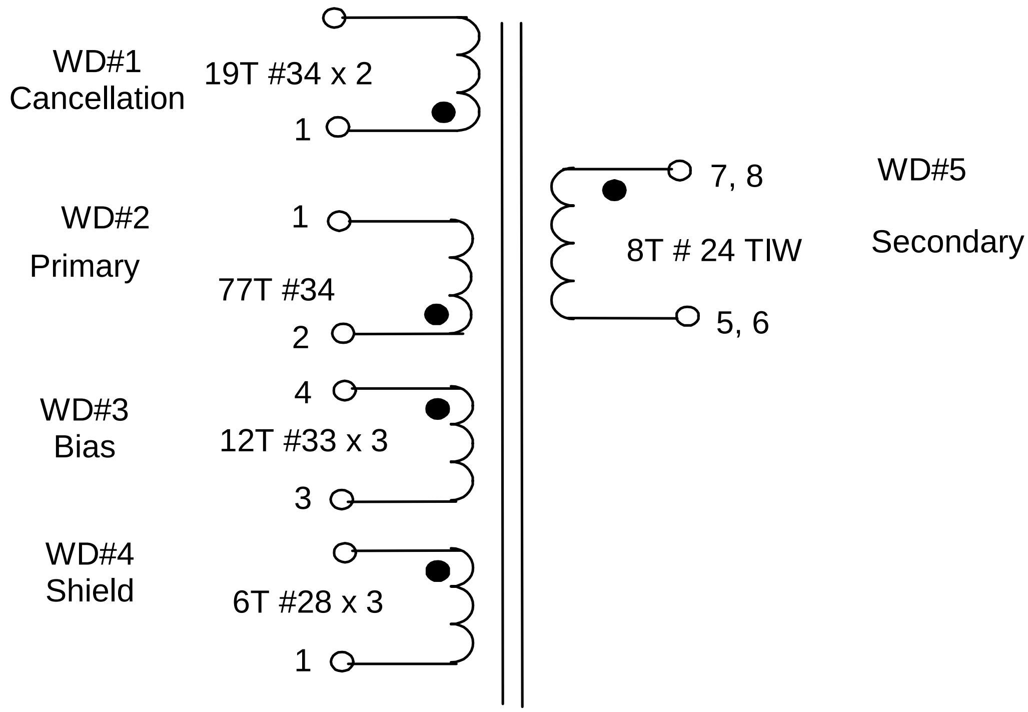


**Figure 4** –Transformer Electrical Diagram

## *8.2 Electrical Specifications*

| | | |
|---|---|---|
| **Electrical Strength** | 1 second, 60 Hz, from Pins 1 - 4 to Pins 5 -8 | 3000 VAC |
| **Primary Inductance** | Pins 1-2, all other windings open, measured at 132 kHz, 0.4 VRMS | 1.11 mH, -10/+10% |
| **Resonant Frequency** | Pins 1-2, all other windings open | 600 kHz (Min.) |
| **Primary Leakage Inductance** | Pins 1-2, with Pins 6-7 shorted, measured at 132 kHz, 0.4 VRMS | 50 µH (Max.) |


Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

### *8.3 Materials*

| Item | Description |
|---|---|
| **[1]** | Core: PC40EE13-Z, TDK or equivalent Gapped for AL of 187 nH/T$^2$ |
| **[2]** | Bobbin: Horizontal 8 pins |
| **[3]** | Magnet Wire: #34 AWG |
| **[4]** | Magnet Wire: #33 AWG |
| **[5]** | Magnet Wire: #28 AWG |
| **[6]** | Triple Insulated Wire: #24 AWG. |
| **[7]** | Tape: 3M 1298 Polyester Film, 2.0 mils thick, 7.6 mm wide |
| **[8]** | Varnish |

### *8.4 Transformer Build Diagram*

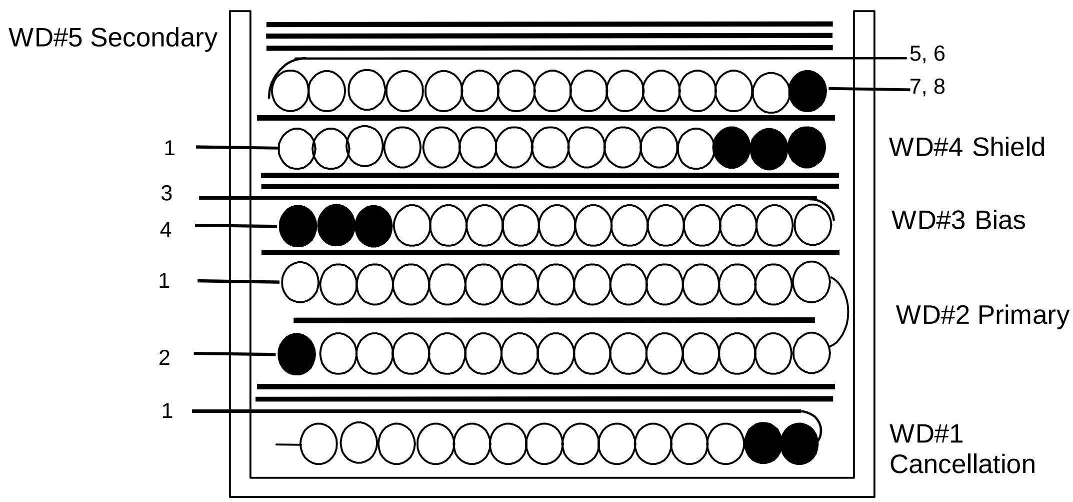


**Figure 5** – Transformer Build Diagram.



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

### 8.5 Transformer Construction

| | |
|---|---|
| **Bobbin Preparation** | Primary pin side of the bobbin orients to the left hand side. |
| **WD#1 Cancellation** | Start on Pin 8 temporarily. Wind 19 turns bifilar of item [3] from right to left. Wind with tight tension across entire bobbin evenly. Cut the wire after finishing 19th turn. Fold the starting lead back and finish it on Pin 1. |
| **Insulation** | 2 Layers of tape [7] for insulation |
| **WD#2 Primary** | Start on pin 2, wind 38 turns of item [3] from left to right. Apply one layer of type [7]. Wind another 39 turns from right to left and finish it on pin 1. Apply one layer of type [7]. |
| **Insulation** | 1 Layers of tape [7] for insulation. |
| **WD#3 Bias** | Start on Pin 4, wind 12 trifilar turns of item [4]. Wind from left to right with tight tension. Wind uniformly, in a single layer across entire width of bobbin. Fold back the wire and finish on Pin 3. |
| **Insulation** | 2 Layers of tape [7] for insulation. |
| **WD #4 Shield** | Start at Pin 8 temporarily, wind 6 trifilar turns of item [5]. Wind from right to left with tight tension. Wind uniformly, in a single layer across entire width of bobbin. Finish on Pin 1. Cut the starting lead. |
| **Insulation** | 1 Layers of tape [7] for insulation. |
| **WD #5** | Start at pin 7, wind 8 turns of item [6] from right to left. Wind uniformly, in a single layer across entire bobbin evenly. Bring the wire back and finish on pin 6 |
| **Insulation** | 3 Layers of tape [7] for insulation. |
| **Finish** | Grind the core to get 1.11mH. Secure the core with tape. Vanish the transformer |


**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 9 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** | | | | | **Customer** |
| VACMIN | 85 | | | Volts | Minimum AC Input Voltage |
| VACMAX | 265 | | | Volts | Maximum AC Input Voltage |
| fL | 50 | | | Hertz | AC Mains Frequency |
| VO | 7.8 | | | Volts | Output Voltage |
| PO | 5.26 | | | Watts | Output Power |
| n | 0.7 | | | | 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** | **TNY266** | | | *Universal* | *115 Doubled/230V* |
| *Chosen Device* | | *TNY266* | *Power Out* | *9.5W* | *15W* |
| ILIMITMIN | | | *0.325* | Amps | TINYSwitch Minimum Current Limit |
| ILIMITMAX | | | *0.375* | 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 | 7.9 | | | Volts | TINYSwitch on-state Drain to Source Voltage |
| VD | 0.5 | | | Volts | Output Winding Diode Forward Voltage Drop |
| **KP** | | | **0.69** | | Ripple to Peak Current Ratio (0.6<KRP<1.0 : 1.0<KDP<6.0) |
| | | | | | |
| **ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES** | | | | | |
| **Core Type** | **ee13** | | | | |
| *Core* | | *#N/A* | | *P/N:* | #N/A |
| *Bobbin* | | *#N/A* | | *P/N:* | #N/A |
| AE | | 0.171 | 0.171 | cm^2 | Core Effective Cross Sectional Area |
| LE | | 3.02 | 3.02 | cm | Core Effective Path Length |
| AL | | 1130 | 1130 | nH/T^2 | Ungapped Core Effective Inductance |
| BW | | 7.4 | 7.4 | mm | Bobbin Physical Winding Width |
| M | | | | mm | Safety Margin Width (Half the Primary to Secondary Creepage Distance) |
| **L** | **2** | | | | Number of Primary Layers |
| **NS** | **8** | | | | Number of Secondary Turns |
| | | | | | |
| **DC INPUT VOLTAGE PARAMETERS** | | | | | |
| VMIN | | | 57 | Volts | Minimum DC Input Voltage |
| VMAX | | | 375 | Volts | Maximum DC Input Voltage |
| | | | | | |
| **CURRENT WAVEFORM SHAPE PARAMETERS** | | | | | |
| DMAX | | | 0.62 | | Maximum Duty Cycle |
| IAVG | | | 0.13 | Amps | Average Primary Current |
| IP | | | 0.33 | Amps | Minimum Peak Primary Current |
| IR | | | 0.22 | Amps | Primary Ripple Current |
| IRMS | | | 0.17 | Amps | Primary RMS Current |
| | | | | | |
| **TRANSFORMER PRIMARY DESIGN PARAMETERS** | | | | | |
| LP | | | 1114 | uHenries | Primary Inductance |
| NP | | | 77 | | Primary Winding Number of Turns |
| ALG | | | 187 | nH/T^2 | Gapped Core Effective Inductance |
| BM | | | **3167** | Gauss | !!!!!!!!!! REDUCE BP<3000 (increase NS,smaller TINYSwitch, larger Core,increase VOR) |


**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

| | | | | | |
|---|---|---|---|---|---|
| BAC | | | 950 | Gauss | AC Flux Density for Core Loss Curves (0.5 X Peak to Peak) |
| ur | | | 1588 | | Relative Permeability of Ungapped Core |
| **LG** | | Warning | **0.10** | mm | !!!!!!!!!! INCREASE GAP>>0.1 (increase NS, decrease VOR,bigger Core |
| BWE | | | 14.8 | mm | Effective Bobbin Width |
| OD | | | 0.19 | mm | Maximum Primary Wire Diameter including insulation |
| INS | | | 0.04 | mm | Estimated Total Insulation Thickness (= 2 * film thickness) |
| DIA | | | 0.15 | mm | Bare conductor diameter |
| AWG | | | 35 | AWG | Primary Wire Gauge (Rounded to next smaller standard AWG value) |
| CM | | | 32 | Cmils | Bare conductor effective area in circular mils |
| **CMA** | | Warning | **183** | Cmils/Amp | !!!!!!!!!! INCREASE CMA>200 (increase L(primary layers),decrease NS,larger Core) |
| | | | | | |
| **TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT / SINGLE OUTPUT EQUIVALENT)** | | | | | |
| **Lumped parameters** | | | | | |
| ISP | | | 3.13 | Amps | Peak Secondary Current |
| ISRMS | | | 1.32 | Amps | Secondary RMS Current |
| IO | | | 0.67 | Amps | Power Supply Output Current |
| IRIPPLE | | | 1.14 | Amps | Output Capacitor RMS Ripple Current |
| CMS | | | 264 | 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 | | | 0.93 | mm | Secondary Maximum Outside Diameter for Triple Insulated Wire |
| INSS | | | 0.23 | mm | Maximum Secondary Insulation Wall Thickness |
| | | | | | |
| **VOLTAGE STRESS PARAMETERS** | | | | | |
| VDRAIN | | | 563 | Volts | Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance) |
| PIVS | | | 47 | Volts | Output Rectifier Maximum Peak Inverse Voltage |
| | | | | | |
| **TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)** | | | | | |
| **1st output** | | | | | |
| VO1 | 11.0 | | | Volts | Output Voltage |
| IO1 | 0.010 | | | Amps | Output DC Current |
| PO1 | | | 0.11 | Watts | Output Power |
| VD1 | 0.7 | | | Volts | Output Diode Forward Voltage Drop |
| NS1 | | | 11.28 | | Output Winding Number of Turns |
| ISRMS1 | | | 0.020 | Amps | Output Winding RMS Current |
| IRIPPLE1 | | | 0.02 | Amps | Output Capacitor RMS Ripple Current |
| PIVS1 | | | 66 | Volts | Output Rectifier Maximum Peak Inverse Voltage |



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 10 Performance Data

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

## *10.1 Output Characteristic*

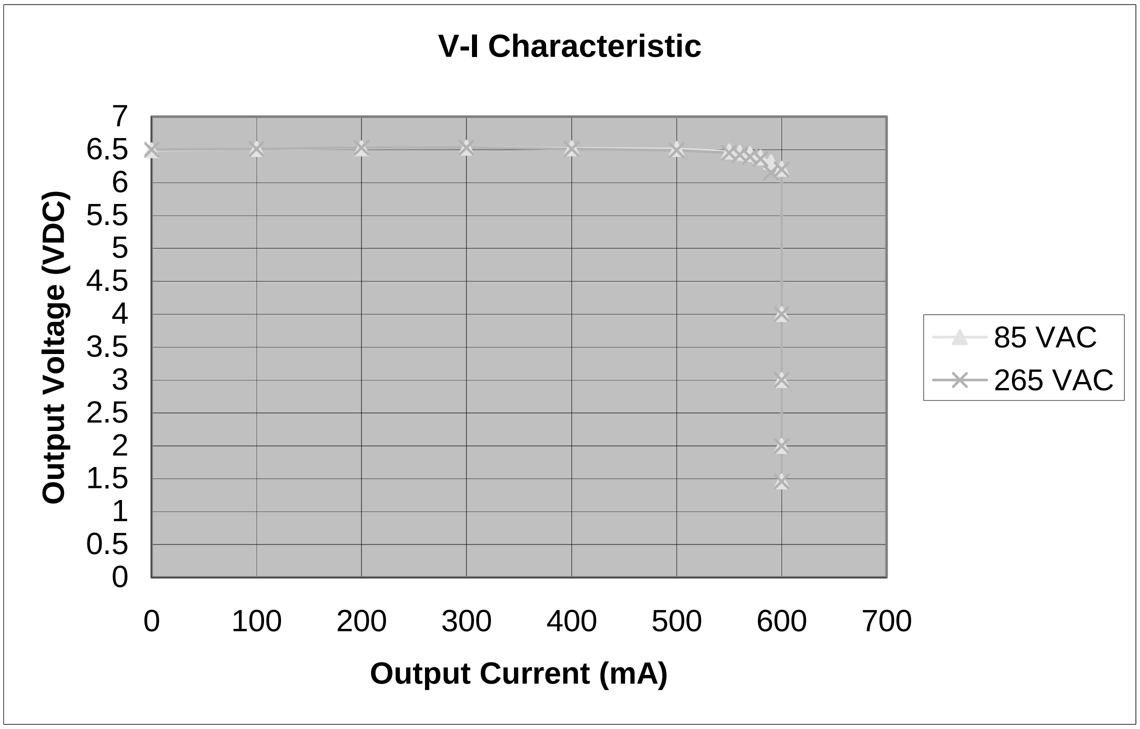


Figure 4 - Typical output characteristic.

## *10.2 Efficiency*

Measured at 0.6A load.

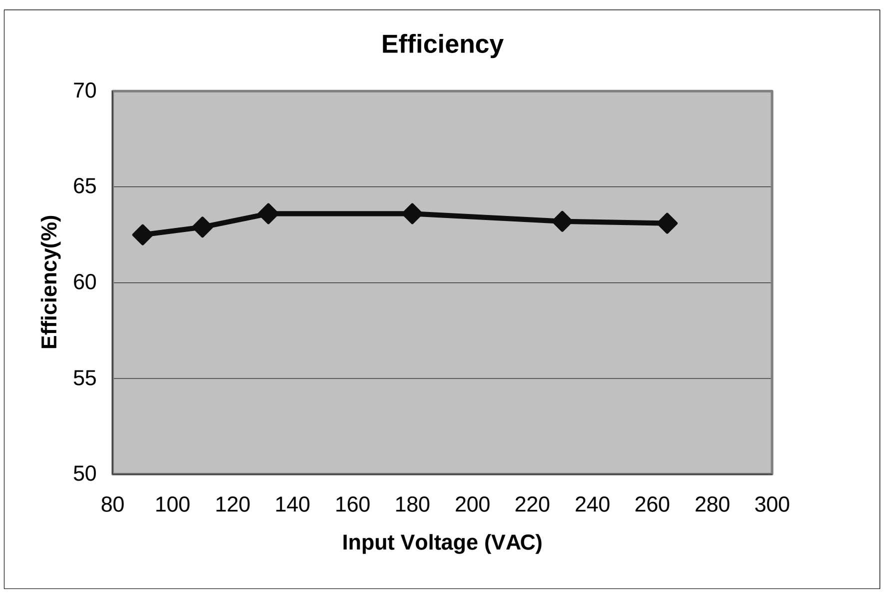


**Figure 6**- Efficiency vs. Input Voltage at full load, Room Temperature, 60 Hz.


Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

## 10.3 No-load Input Power

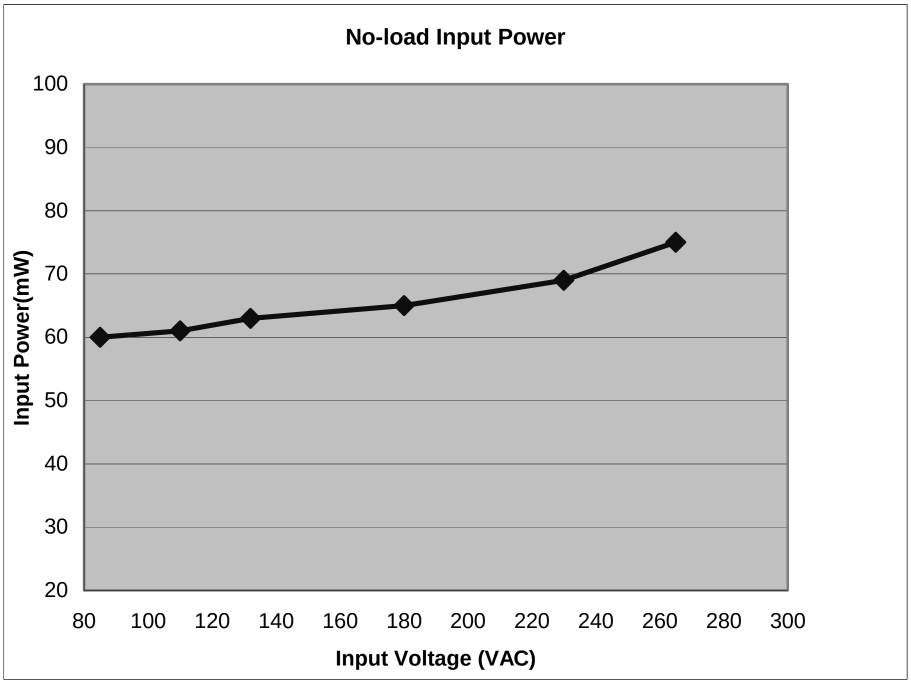


**Figure 7**- Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz.

## 10.4 Load and Line Regulation in CV mode

Measured at the end of a cable with 0.25 Ω resistance. Note the very flat voltage characteristic because of the cable drop compensation.

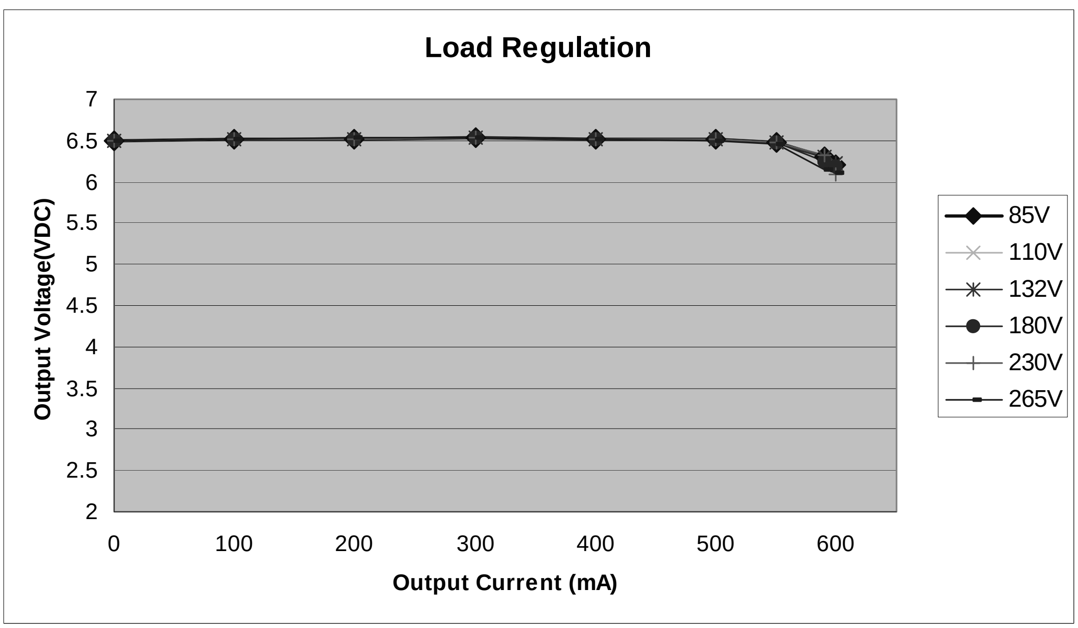


**Figure 8** –Load Regulation, Room Temperature.



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

## 11 Thermal Performance

Test Condition: Open Air, 0.6A load

| Temperature (°C) | | |
|---|---|---|
| **Item** | **85 VAC** | **265 VAC** |
| **Ambient (Deg.C)** | 25 | 25 |
| **Transformer (T1)** | 38 | 40 |
| ***TinySwitch-II* (U1)** | 53 | 53 |
| **Rectifier (D7)** | 56 | 59 |



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 12 Waveforms

## 12.1 Drain Voltage Normal Operation

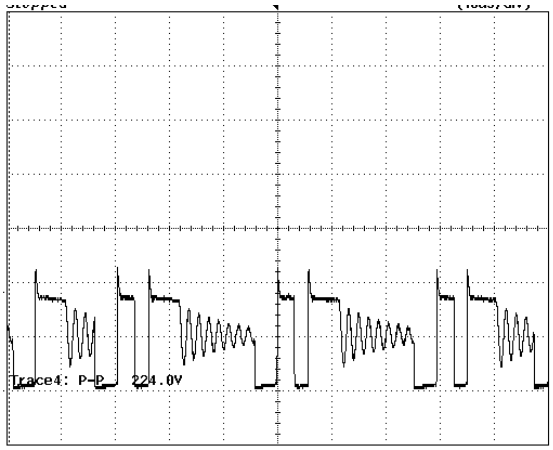


**Figure 9** - 85 VAC, Full Load.
Lower: $V_{DRAIN}$, 100 V, 10 µs / div

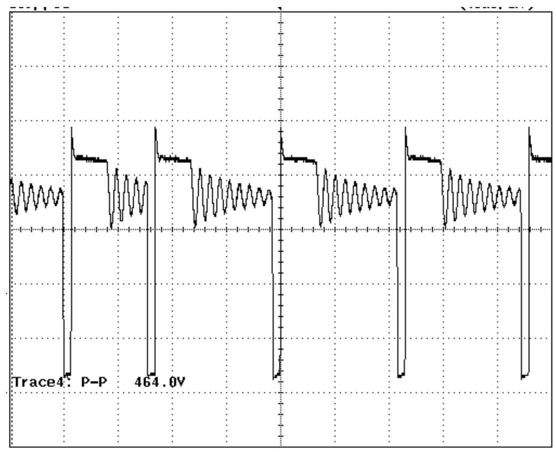


**Figure 10** - 265 VAC, Full Load
$V_{DRAIN}$, 100 V, 10 µs / div

## 12.2 Output Voltage Start-up Profile

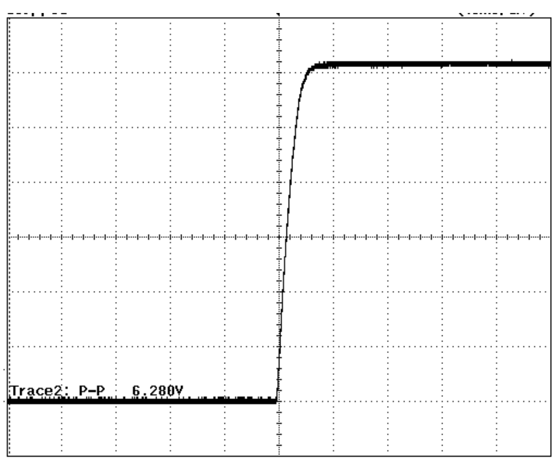


**Figure 11** - Start-up Profile, 85VAC
1 V, 10 ms / div.

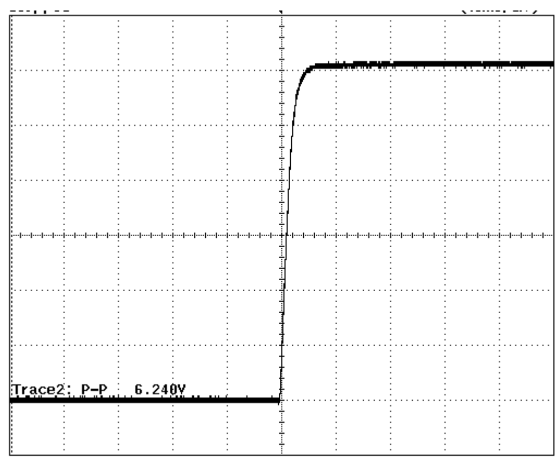


**Figure 12** - Start-up Profile, 265 VAC
1 V, 10 ms / div.



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

## 12.3 Drain Voltage Start-up Profile

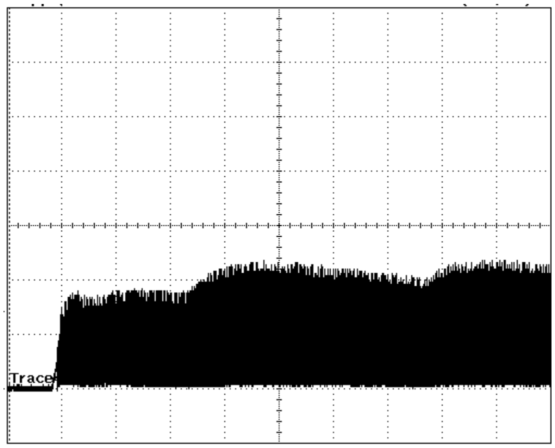

**Figure 13** - 85 VAC Input and Maximum Load. $V_{DRAIN}$, 100 V & 2 ms / div.

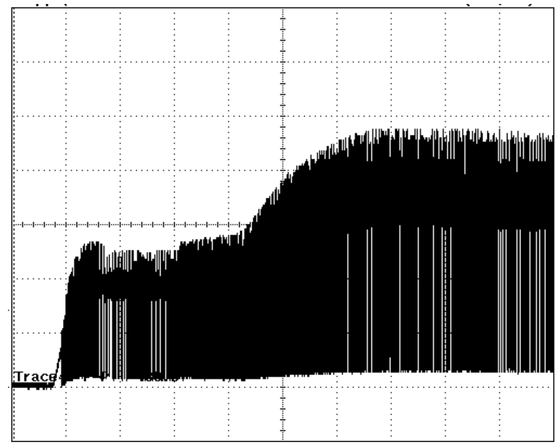

**Figure 14** - 265 VAC Input and Maximum Load. $V_{DRAIN}$, 100 V & 1 ms / div.



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

### *12.4 Output Ripple Measurements*

12.4.1 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).***

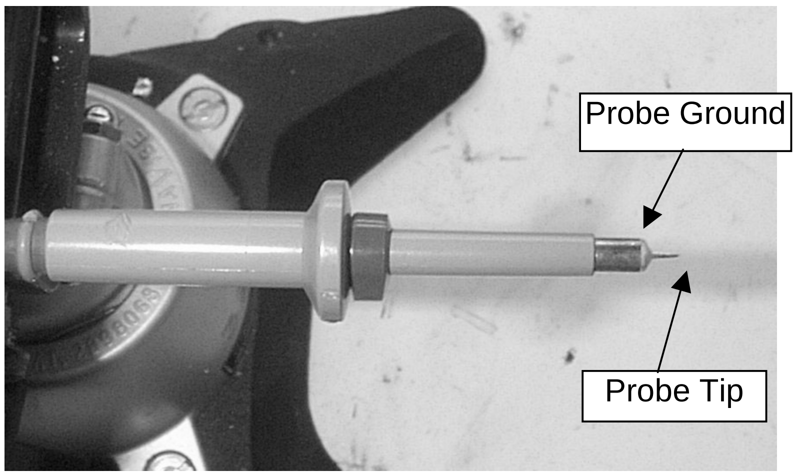


**Figure 15** - Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

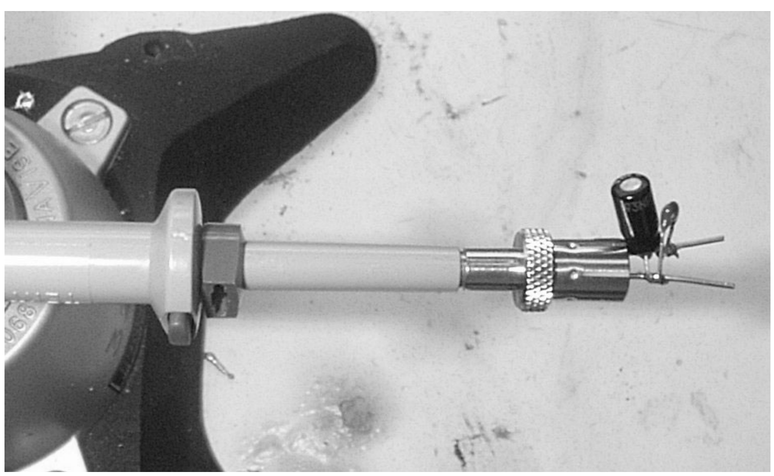

**Figure 16** - Oscilloscope Probe with Probe Master 5125BA BNC Adapter. (Modified with wires for probe ground for ripple measurement, and two parallel decoupling capacitors added)



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

### 12.4.2 Measurement Results

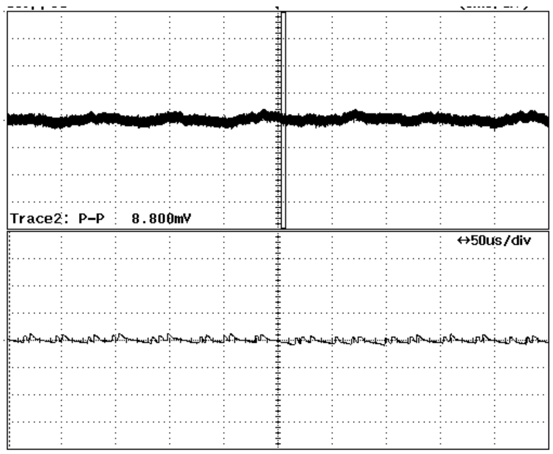


**Figure 17** - Ripple, 85 VAC, Full Load.
5 ms, 20 mV / div

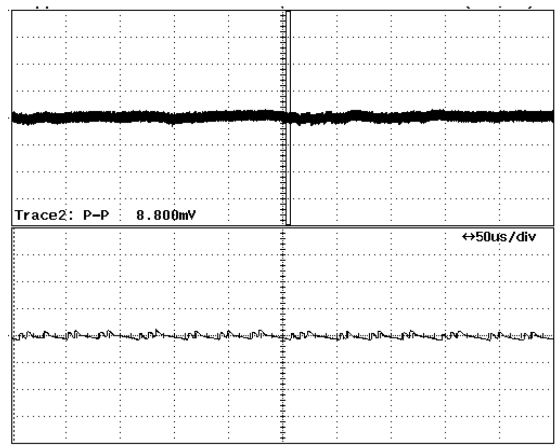


**Figure 18** - 5 V Ripple, 110 VAC, Full Load.
5 ms, 20 mV / div

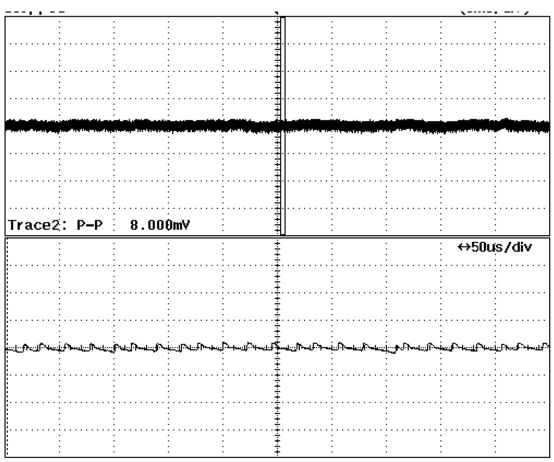


**Figure 19** - Ripple, 230 VAC, Full Load.
5 ms, 20 mV /div



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

# 13 Conducted EMI

EMI was tested at room temperature, 230 VAC input, full load

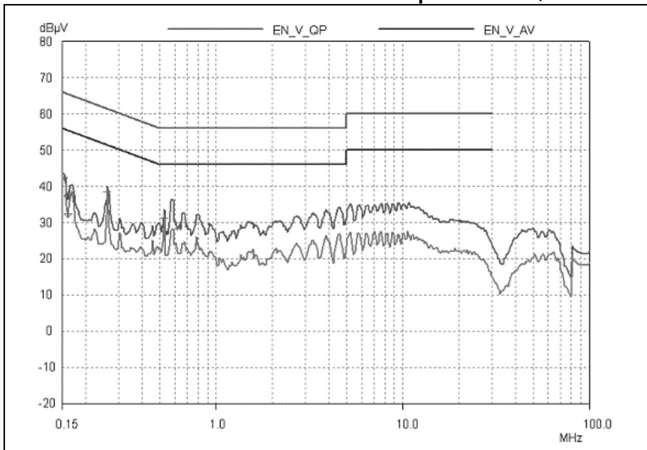


**Figure 20 Line, floating**

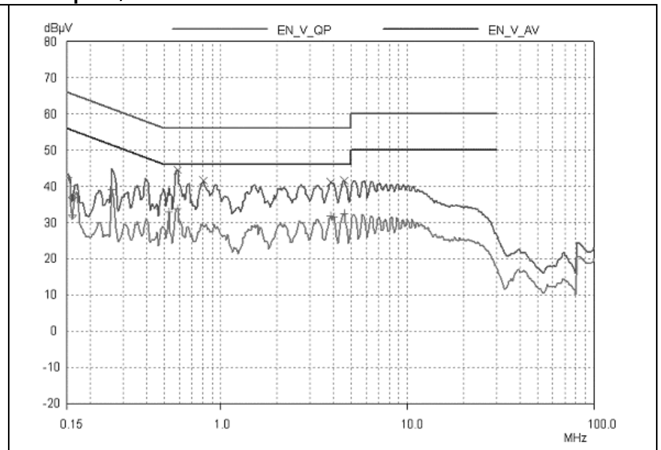


**Figure 21 Line, artificial hand**

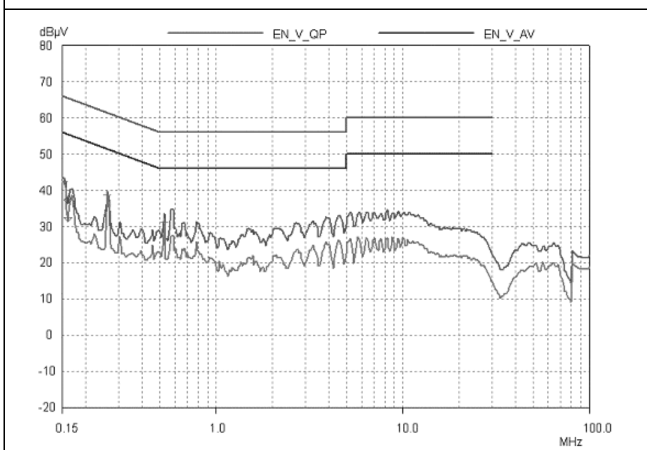


**Figure 22 Neutral, floating**

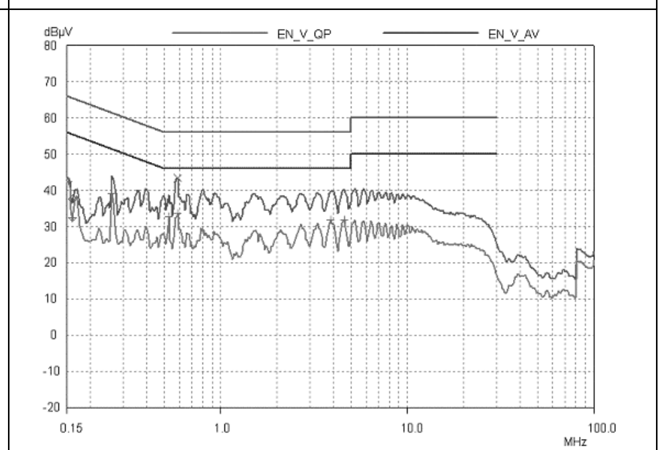


**Figure 24 Neutral, artificial hand**



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

## 14 Revision History

| Date | Author | Revision | Description & changes | Reviewed |
|---|---|---|---|---|
| April 1, 2004 | DZ | 1.0 | First Release | VC /AM |



**Power Integrations**
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com

**For the latest updates, visit our Web site: *www.powerint.com***



**WORLD HEADQUARTERS**
Power Integrations
5245 Hellyer Avenue,
San Jose, CA 95138, USA
Main: +1-408-414-9200
Customer Service:
Phone: +1-408-414-9665
Fax: +1-408-414-9765
*e-mail: usasales@powerint.com*

**AMERICAS**
Power Integrations, Inc.
4335 South Lee Street,
Suite G,
Buford, GA 30518, USA
Phone: +1-678-714-6033
Fax: +1-678-714-6012
*e-mail: usasales@powerint.com*

**CHINA (SHANGHAI)**
Power Integrations
International Holdings, Inc.
Rm 807, Pacheer,
Commercial Centre,
555 Nanjing West Road,
Shanghai, 200041, China
Phone: +86-21-6215-5548
Fax: +86-21-6215-2468
*e-mail: chinasales@powerint.com*

**APPLICATIONS HOTLINE**
World Wide +1-408-414-9660

**CHINA (SHENZHEN)**
Power Integrations
International Holdings, Inc.
Rm# 1705, Bao Hua Bldg.
1016 Hua Qiang Bei Lu,
Shenzhen, Guangdong,
518031, China
Phone: +86-755-8367-5143
Fax: +86-755-8377-9610
*e-mail: chinasales@powerint.com*

**GERMANY**
Power Integrations, GmbH
Rueckerstrasse 3,
D-80336, Munich, Germany
Phone: +49-895-527-3910
Fax: +49-895-527-3920
*e-mail: eurosales@powerint.com*

**INDIA** (TECHNICAL SUPPORT)
Innovatech
#1, (New #42) 8th Main Road,
Vasanthnagar, Bangalore,
India, 560052
Phone: +91-80-226-6023
Fax: +91-80-228-9727
*e-mail: indiasales@powerint.com*

**APPLICATIONS FAX**
World Wide +1-408-414-9760

**ITALY**
Power Integrations s.r.l.
Via Vittorio Veneto 12,
Bresso, Milano,
20091, Italy
Phone: +39-028-928-6001
Fax: +39-028-928-6009
*e-mail: eurosales@powerint.com*

**JAPAN**
Power Integrations, K.K.
Keihin-Tatemono 1st Bldg.
12-20 Shin-Yokohama,
2-Chome,
Kohoku-ku, Yokohama-shi,
Kanagawa 222-0033, Japan
Phone: +81-45-471-1021
Fax: +81-45-471-3717
*e-mail: japansales@powerint.com*

**KOREA**
Power Integrations
International Holdings, Inc.
8th Floor, DongSung Bldg.
17-8 Yoido-dong,
Youngdeungpo-gu,
Seoul, 150-874, Korea
Phone: +82-2-782-2840
Fax: +82-2-782-4427
*e-mail: koreasales@powerint.com*

**SINGAPORE (ASIA PACIFIC HEADQUARTERS)**
Power Integrations, Singapore
51 Newton Road,
#15-08/10 Goldhill Plaza,
Singapore, 308900
Phone: +65-6358-2160
Fax: +65-6358-2015
*e-mail: singaporesales@powerint.com*

**TAIWAN**
Power Integrations
International Holdings, Inc.
17F-3, No. 510,
Chung Hsiao E. Rd., Sec. 5,
Taipei, Taiwan 110, R.O.C.
Phone: +886-2-2727-1221
Fax: +886-2-2727-1223
*e-mail: taiwansales@powerint.com*

**UK (EUROPE & AFRICA HEADQUARTERS)**
Power Integrations (Europe) Ltd.
Centennial Court,
Easthampstead Road,
Bracknell, Berkshire RG12 1YQ,
United Kingdom
Phone: +44-1344-462-300
Fax: +44-1344-311-732
*e-mail: eurosales@powerint.com*