# Design Example Report

| | |
|---|---|
| **Title** | ***16W Low Profile Adapter Supply using TOP245P*** |
| **Specification** | Input: 90 – 265 VAC<br>Output: 5.25V / 3A |
| **Application** | Video Game |
| **Author** | Power Integrations Applications Department |
| **Document Number** | DER-37 |
| **Date** | April 27, 2004 |
| **Revision** | 1.0 |


**Summary and Features**

A TOP245P is used to create a low profile video game adapter that features the following:

- Very low no-load consumption of <100mW @ 230 VAC
- Low parts count / Low cost
- Low profile, high power density
- EMI has 10 dB margin even with output grounded
- No Safety X-cap needed
- Meets thermal requirements at 45$^{o}$C ambient with good margin
- No heatsinks
- >80% Efficiency even at high temp
- Tight Built-in Over Power Protection (no need for OCP)
- < 50uA Safety 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




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

**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 prototype16W power supply utilizing a TOP245P. This power supply is designed for a sealed adapter supply.

This design is low cost, low parts count and meets EMI with no X-cap. It meets thermal requirements with no heatsink in either primary or secondary side.

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

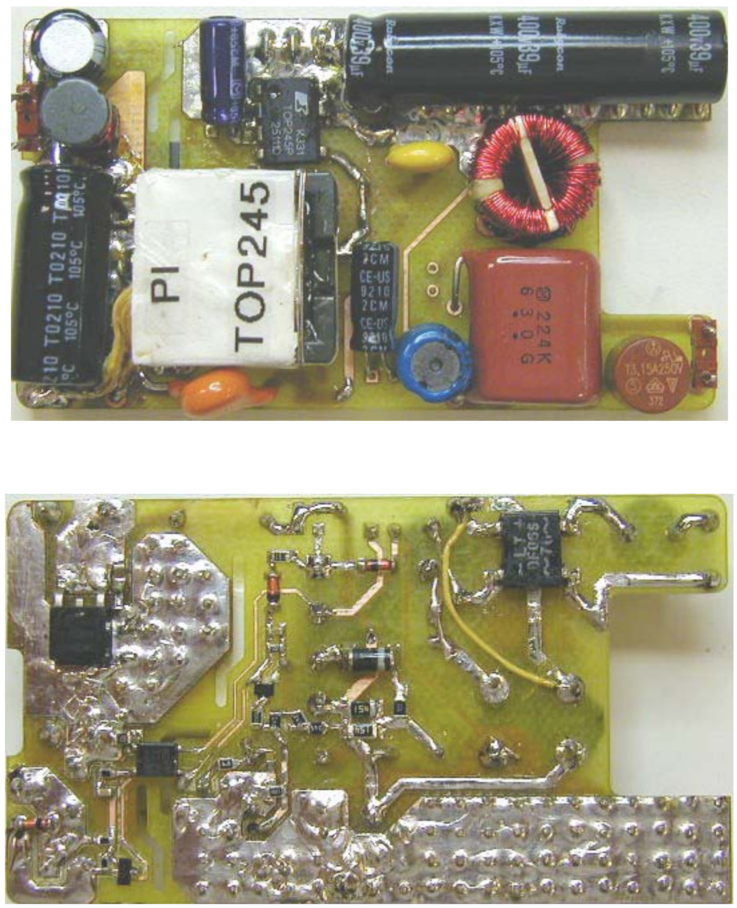



**Figure 1 –** Populated Circuit Board Photograph. Component side (Top) and Solder side (Bottom).

Note an additional wire jumper was required on this prototype layout as shown above.



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

# 2 Power Supply Specification

| Description | Symbol | Min | Typ | Max | Units | Comment |
|---|---|---|---|---|---|---|
| **Input** | | | | | | |
| Voltage | $V_{IN}$ | 90 | | 265 | VAC | 2 Wire – Output ground connected to P.E. |
| Frequency | $f_{LINE}$ | 47 | 50/60 | 64 | Hz | |
| No-load Input Power (230 VAC) | | | | 0.1 | W | |
| **Output** | | | | | | |
| Output Voltage 1 | $V_{OUT1}$ | | 5.25 | | V | ± 5% |
| Output Ripple Voltage 1 | $V_{RIPPLE1}$ | | | 50 | mV | 20 MHz bandwidth |
| Output Current 1 | $I_{OUT1}$ | | | 3 | A | |
| **Total Output Power** | | | | | | |
| Continuous Output Power | $P_{OUT}$ | | | 15.75 | W | |
| Over Power protection | $P_{OUT\_PEAK}$ | 20 | | 24 | W | Auto-restart |
| Over Voltage Protection | | | | 6.8 | V | Zener on output |
| **Efficiency** | $\eta$ | 80 | | | % | Measured at the board O/P terminals, $P_{OUT}$ (15.75 W), 25 °C |
| **Environmental** | | | | | | |
| Conducted EMI | | Meets CISPR22B / EN55022B | | | | |
| Safety | | Designed to meet IEC950, UL1950 Class II | | | | |
| Ambient Temperature | $T_{AMB}$ | 0 | | 45 | °C | Free convection, sea level |


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

## 3 Schematic

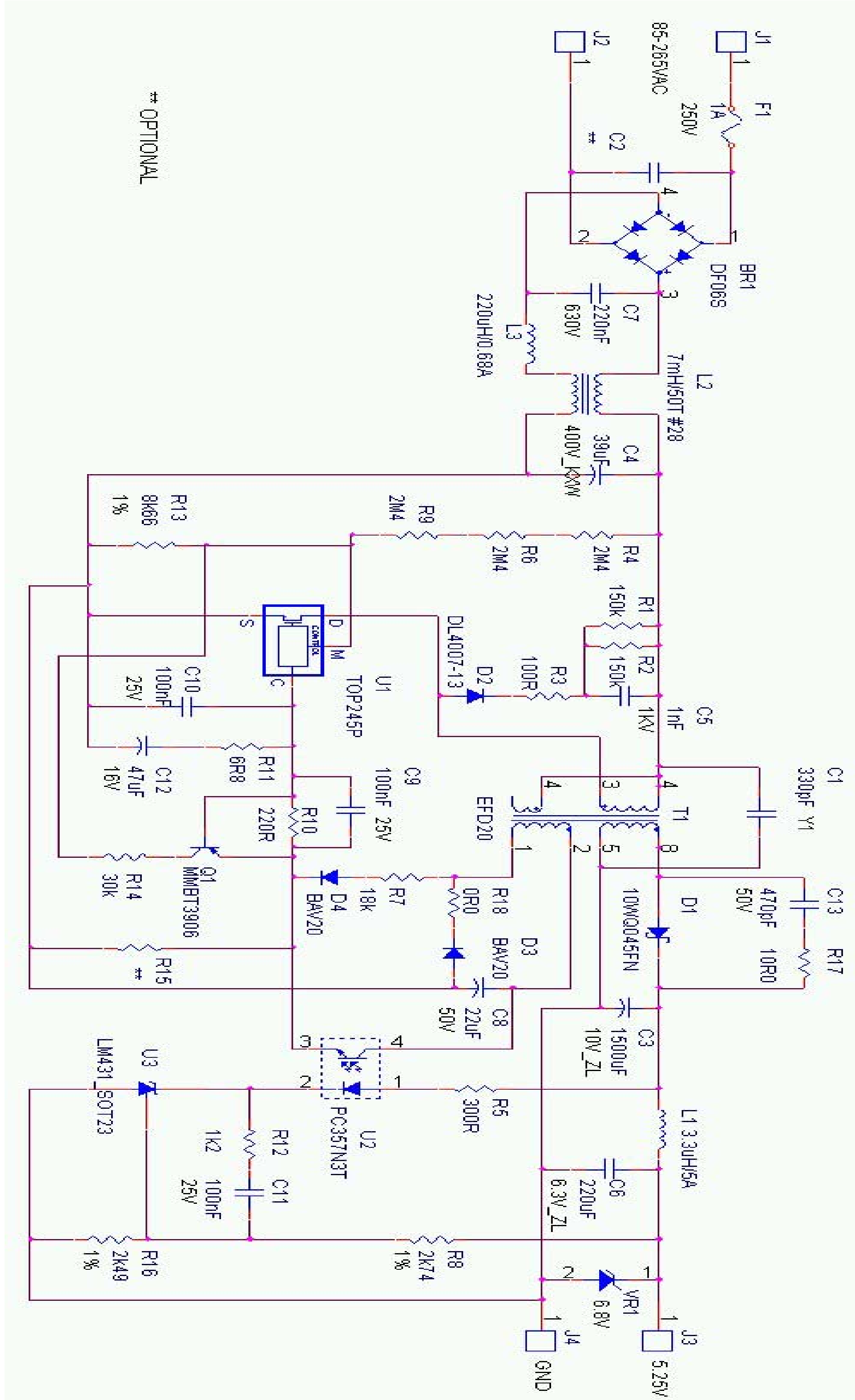



**Figure 2 –** Schematic.



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

# 4 Circuit Description

The schematic in Figure 2 shows an off-line flyback converter using the TOP245P. The circuit is designed for 90 VAC to 265 VAC input and provides an isolated 5.25V, 3A continuous output.

To provide <100m W no-load consumption at 230 VAC, a frequency reduction circuit is implemented using the X pin feature of the TOPSwitch-GX. More details of this operation provided below.

## *4.1 Input EMI Filtering*

Conducted EMI filtering is provided by pi formed filter C4, C7, L2, & L3. The switching frequency jitter feature of the TOPSwitch-GX family allows the use of a small, low cost common mode choke for L2.

To keep the peak DRAIN voltage acceptably below the $BV_{DSS}$ (700V) of U1, diode D2, C5 and R1&R2 form a primary clamp. This network clamps the voltage spike seen on the DRAIN due to primary and secondary reflected leakage inductance. Diode D3 and capacitor C8 provide rectified and filtered bias supply for U1.

## *4.2 Output Rectification*

The secondary of T1 is rectified and filtered by D1, & C3. Post filter choke L1 and C6 provide additional high frequency filtering and help suppress high frequency EMI.

## *4.3 Output Feedback*

DC feedback to the output voltage regulator error amplifier (U3) comes from a divider network R8 and R16. The center point is tied to the 2.5 V REF pin of U2. Capacitor C11 and resistor R12 roll off the high frequency gain of U3 while R5 sets the overall gain.

In a typical TOPSwitch-GX design, regulation of the output is normally provided by voltage mode PWM control. The current into the CONTROL pin sets the duty cycle of the internal MOSFET. The duty cycle control operates over a CONTROL pin current of 2mA to 6mA. Current below this level is used to supply power to the IC.

In this design the control is accomplished by employing the externally programmable current limit function of the TOPSwitch-GX family, which is the X pin. This allows the TOPSwitch-GX to operate at lower frequency in order to further improve light load efficiency.


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

The CONTROL pin requires 2 mA to power the internal circuitry of the chip. Any current beyond that normally would be shunted, and commands the duty cycle to reduce. With 2 mA of current the duty cycle is set to maximum.

Feedback current above ~2mA forward biases Q1 through R10 and pulls up R13 via R14. The X pin looks like a 1.2V voltage source. The current it is sourcing determines the output MOSFET peak current limit. As current decreases, the peak current limit is reduced from maximum (when X-pin current is 170 uA), down to a minimum of 40% of nominal peak current limit (when X-pin is at 30 uA). Therefore, as the feedback current increases, the sink current decreases and the primary current limit reduces, thereby allowing the output voltage feedback loop to control the primary peak current. Resistor R14 sets the peak current limit (startup and overload). Any feedback current above 2 mA engages the X pin control, the current into the CONTROL pin is limited to this level and therefore, the PWM function of the CONTROL pin does not determine the duty cycle.

As the load is reduced, the primary current limit reduces until it reaches 40% of peak current limit. At this point, another X-pin function is activated. The remote ON/OFF (inhibit) threshold is reached at an X pin sink current of approximately 27 μA. The supply then operates with fixed 25% current limit, but with a variable off-time, resulting in a variable switching frequency. To maintain regulation, as the load is further reduced, the frequency reduces. This greatly reduces switching losses, maintaining high standby efficiency and low no-load power consumption.

Slope compensation is provided by a ramp signal generated from the bias winding via D4, R7 and C9. C9 also serves as a high frequency roll off filter.



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

# 5 PCB Layout

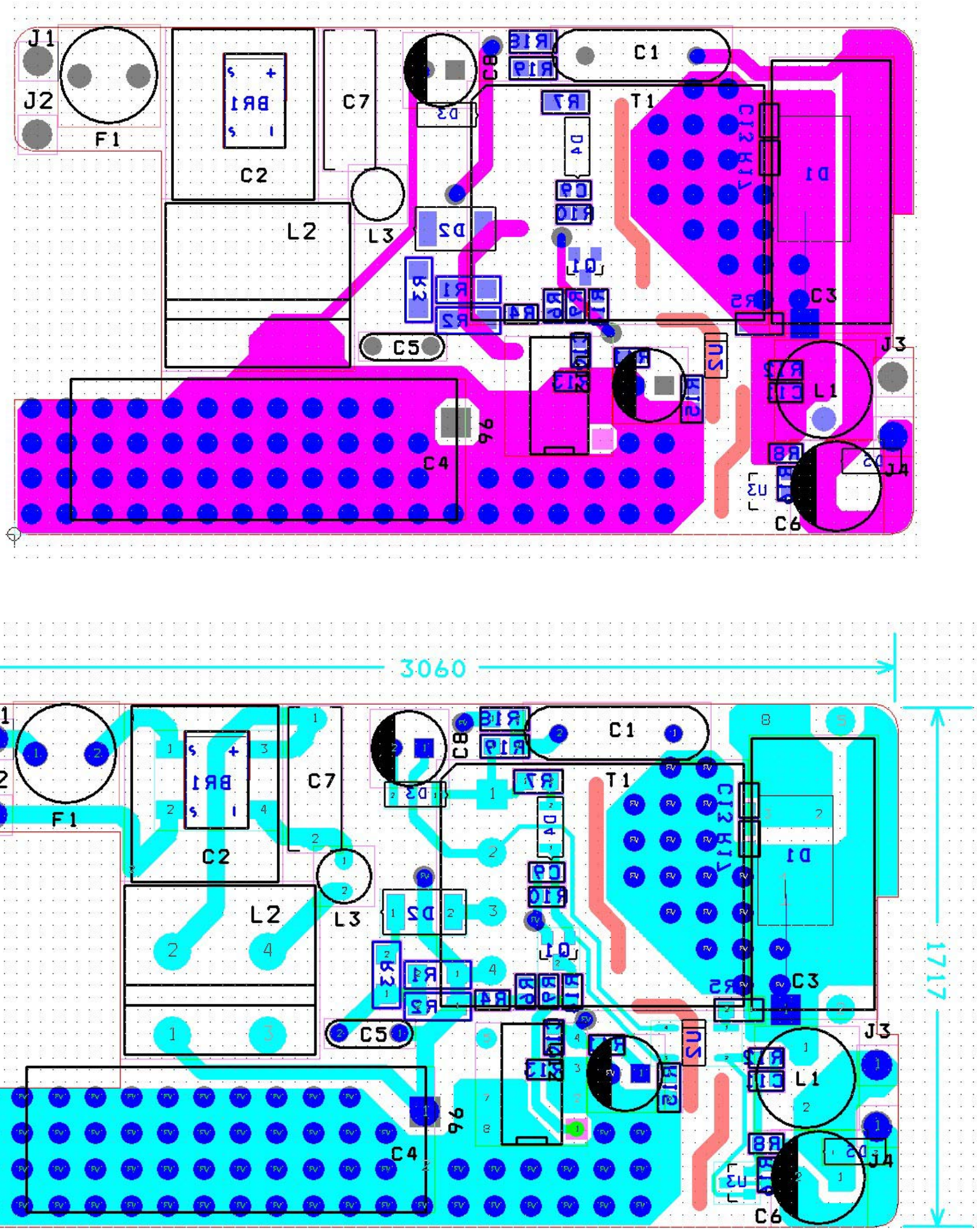



**Figure 3** – Printed Circuit Layout. Top layer (TOP), Bottom layer (BOTTOM)

**Note**: Some rework was done on the actual sample board as shown in the photos above



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

## 6 Bill Of Materials

| Item | QTY | Part Reference | Value | Description | Mfg Part Number | Mfg |
|---|---|---|---|---|---|---|
| 1 | 1 | BR1 | DF06S | Bridge Rectifier, 600v, 1A, SMD | DF06S | Gen. Semi. |
| 2 | 1 | C1 | 330pF | Cap,Cer,330pF,Y1, 250Vac | 440LT330 | Panasonic |
| 3 | 1 | C2 | ** | optional | | |
| 4 | 1 | C3 | 1500uF | Cap,Al Elect,1500uF,10V,10mmX25mm,ZL Series,Rubycon | 10ZL1500M10X25 | Rubycon |
| 5 | 1 | C4 | 39uF | Cap,Al Elect,39uF,400V,10mmX40mm,KXW Series, Rubycon | 400KXW39M10X40 | Rubycon |
| 6 | 1 | C5 | 1nF | Cap,Cer,1000pF, 1000V, 10% | NCD102K1KVY5F | NIC Components Corp |
| 7 | 1 | C6 | 220uF | Cap,Al Elect,220uF, 6.3V, 8mmX7mm, ZL series Rubycon | 6.3ZL220M8x7 | Rubycon |
| 8 | 1 | C7 | 220nF | Cap,Metal Poly ,0.22uF, 630V, 10% | ECQ-E63224KF | Panasonic |
| 9 | 1 | C8 | 22uF | Cap,Al Elect,22uF,50V,5mmX11mm,KZE Series,NIPPON CHEMI-CON | KZE50VB22RME11LL | Nippon Chemi-Con |
| 10 | 1 | C12 | 47uF | Cap,Al Elect,47uF,16V,5mmX11.5mm,LXZ Series,NIPPON CHEMI-CON | LXZ16VB47RME11LL | Nippon Chemi-Con |
| 11 | 3 | C9 C10 C11 | 100nF | CAP 0.1uF 25V CERM CHIP X7R 0805 SMD | ECU-V1H221KBN | Panasonic |
| 12 | 1 | C13 | 470pF | CAP 470pF 50V CERM CHIP X7R 0805 SMD | ECJ-1VC1H471J | Panasonic |
| 13 | 1 | D1 | 10WQ045FN | Schottky 45V, 10A D-PAK | 10WQ045FN | IR |
| 14 | 1 | D2 | DL4007-13 | RECT,DL4007-13 PASSIVATED 1A 1000V SMD MELF | DL4007-13 | Diodes Inc |
| 15 | 2 | D3 D4 | BAV20 | RECT,BAV20, 500mW 200V SMD MELF | BAV20 | Diode Inc. |
| 16 | 1 | F1 | 1A | FUSE T-LAG 1A, 250V Slo-Blo IEC SHORT TR5 | 3,721,100,041 | Wickman |
| 17 | 4 | J1 J2 J3 J4 | TERM_1Pin22AWG | Terminal,1Pin,22AWG | | |
| 18 | 1 | L1 | 3.3uH/5A | Inductor,3.3uH,5A 22AWG | custom | |
| 19 | 1 | L2 | 7mH/50T #28 | custom (see spec) | custom | |
| 20 | 1 | L3 | 220uH/0.68A | CHOKE,220uH, 0.68A Barrel | SBC3-221-681 | TOKIN |
| 21 | 1 | Q1 | MMBT3906 | TRANSISTOR,2N3906, PNP 40V SOT-323 | MMBT3606 | Diode Inc. |
| 22 | 2 | R1 R2 | 150k | Res,150K 1/8W 1% 1206 SMD | ERJ-8ENF1503V | Panasonic |
| 23 | 1 | R3 | 100R | Res,100 1/8W 5% 1206 SMD | ERJ-8GEYJ101V | Panasonic |
| 24 | 3 | R4 R6 R9 | 2M4 | Res,2.4M 1/10W 5% 0805 SMD | ERJ-6GEYJ245V | Panasonic |
| 25 | 1 | R5 | 300R | Res,300 1/16W 5% 0603 SMD | ERJ-3GEYJ301V | Panasonic |
| 26 | 1 | R7 | 18k | Res,18K 1/16W 5% 0603 SMD | ERJ-3GEYJ183V | Panasonic |
| 27 | 1 | R8 | 2k74 | Res,2.74K 1/16W 1% 0603 SMD | ERJ-3EKF2741V | Panasonic |
| 28 | 1 | R10 | 220R | Res,220 1/16W 5% 0603 SMD | ERJ-3GEYJ221V | Panasonic |
| 29 | 1 | R11 | 6R8 | Res,6.8 1/16W 5% 0603 SMD | ERJ-3GEYJ6R8V | Panasonic |
| 30 | 1 | R12 | 1k2 | Res,1.2K 1/16W 5% 0603 SMD | ERJ-3GEYJ122V | Panasonic |
| 31 | 1 | R13 | 8k66 | Res,8.66K 1/16W 1% 0603 SMD | ERJ-3EKF8661V | Panasonic |
| 32 | 1 | R14 | 30k | Res,15K 1/10W 5% 0805 SMD | ERJ-6GEYJ153V | Panasonic |
| 33 | 1 | R15 | ** | optional | | |
| 34 | 1 | R16 | 2k49 | Res,2.49K 1/16W 1% 0603 SMD | ERJ-3EKF2491V | Panasonic |
| 35 | 1 | R17 | 10R0 | Res,10.0 1/16W 1% 0603 SMD | ERJ-3EKF10R0V | Panasonic |
| 36 | 1 | R18 | 0R0 | Res,0 1/16W 1% 0603 SMD | ERJ-3EKF0R0V | Panasonic |
| 37 | 1 | T1 | EFD20 | custom (see spec) | custom | |
| 38 | 1 | U1 | TOP245P | IC,TOP245P,INT. OFF-LINE SWITCHER,DIP-8B | TOP246P | Power Int. |
| 39 | 1 | U2 | PC357N3T | IC,PC357N3T,PHOTOCOUPLER 1CH TRAN OUT,CTR 200-400%, 4-SMD | PC357N3T | Sharp |
| 40 | 1 | U3 | LM431_SOT23 | Shunt regulator 2.5V LM431_SOT23 | LM431_SOT23 | Generic |
| 41 | 1 | VR1 | ZMM535B | Diode, Zener, 6.8V, 1/2W, 5%, DO-35 | ZMM535B | Siemens |


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

# 7 Transformer Specification

## 7.1 Electrical Diagram

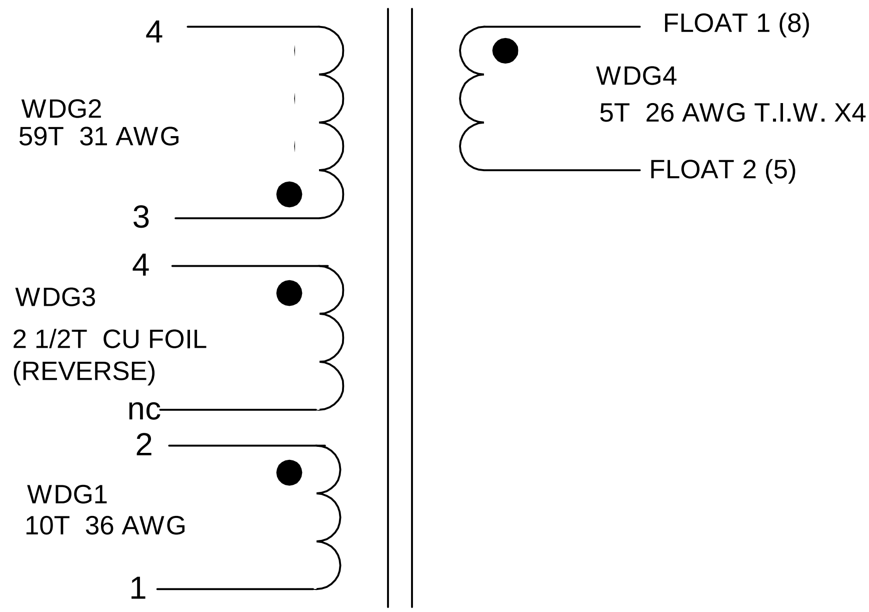



**Figure 4** –Transformer Electrical Diagram

## 7.2 Electrical Specifications

| | | |
|---|---|---|
| **Electrical Strength** | 1 second, 60 Hz, from Pins 1-4 to Pins FLOAT 1-2 | 3000 VAC |
| **Primary Inductance** | Pins 3-4, all other windings open, measured at 100 kHz, 0.4 VRMS | 750 µH, -0/+20% |
| **Resonant Frequency** | Pins 3-4, all other windings open | 1000 kHz (Min.) |
| **Primary Leakage Inductance** | Pins 3-4, with Pins FLOAT 1&2 shorted, measured at 100 kHz, 0.4 VRMS | 15 µH (Max.) |



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

## 7.3 Materials

| Item | Description |
|---|---|
| **[1]** | Core: EFD20 AND GAPPED ALG 211nH/T2 |
| **[2]** | Bobbin: BEFD20 8 PIN HORIZONTAL ; EPCOS P/N B66418-B1008-D1 |
| **[3]** | Magnet Wire: 36 AWG |
| **[4]** | Magnet Wire: 31 AWG |
| **[5]** | Triple Insulated Wire: 26 AWG |
| **[6]** | Copper Tape: 1mil 12.2mm WIDE X 95mm LONG |
| **[7]** | Tape: 3M 1298 Polyester Film, 13.7mm wide |
| **[8]** | Tape: 3M 1298 Polyester Film, 16.5mm wide |
| **[9]** | Jumper wire: 30 AWG |
| **[10]** | Varnish |


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

## *7.4 Transformer Build Diagram*

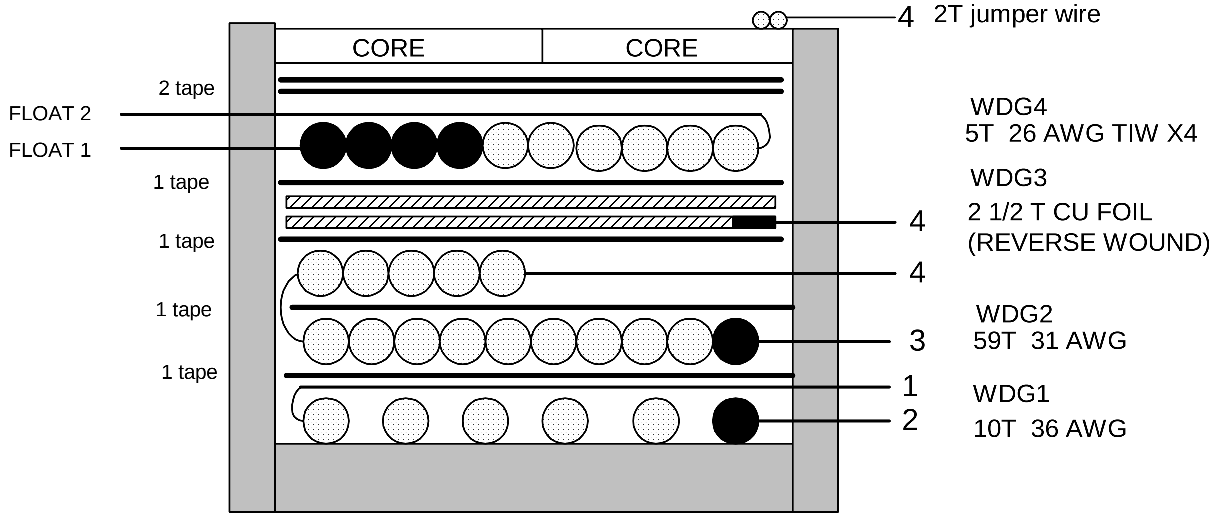



**Figure 5** – Transformer Build Diagram.

### 7.4.1 SHLD Build diagram

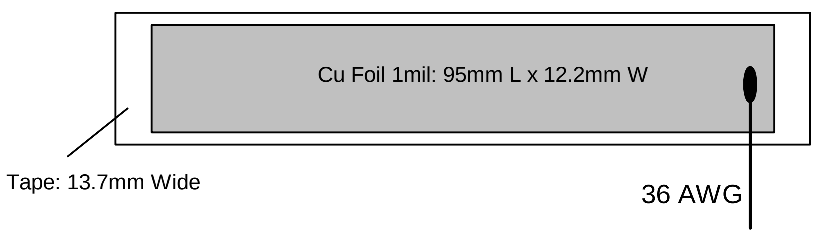



**Figure 6** – Copper shield Build Diagram.


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

## 7.5 Transformer Construction

| | |
|---|---|
| **Bobbin Preparation** | Pull Pin 6&7 on bobbin [2] to provide polarization. Position bobbin in the winding machine such that pins 1-4 are on the right side |
| **WDG1: Vbias** | Start at Pin 2. Wind 10 turns of 36 AWG wire in 1 layer. Spread turns evenly across the bobbin. Finish on Pin1. |
| **Basic Insulation** | Use one layer of 13.7mm tape for basic insulation. |
| **WDG2: Primary 1st layer** | Start at Pin 3. Wind 46 turns of 31 AWG wire in 1 layer. Avoid overlapping turns. |
| **Basic Insulation** | Use one layer of 13.7mm tape for basic insulation. |
| **WDG2: Primary 2nd layer** | Continue winding 13 turns of 31 AWG wire in the second layer. Do not spread the turns. Finish on Pin 4 |
| **Basic Insulation** | Use one layer of 13.7mm tape for basic insulation. |
| **WDG3: SHLD** | Use prepared copper shield shown in Figure 6. Start at Pin 4, wind 2 ½ turns in reverse direction. |
| **Basic Insulation** | Use one layer of 13.7mm tape for basic insulation. |
| **WDG4: SEC** | Start at pin 8 temporarily. Starting from the topside of the bobbin wind 5 turns of quadfilar 26 AWG TIW. Finish on pin 5 temporarily. |
| **Basic Insulation** | Use two layers of 13.7mm tape for basic insulation. |
| | Pull out pins 8 and 5, and let the secondary leads to float, mark the start lead. |
| **Core Assembly** | Insert gapped cores into the bobbin and glue them together |
| **Core Wrap** | Wrap the secondary side of the core with two layers of 16.5mm tape as shown in Figure 7 and Figure 8 |
| **Varnish** | Dip varnish the finished transformer |

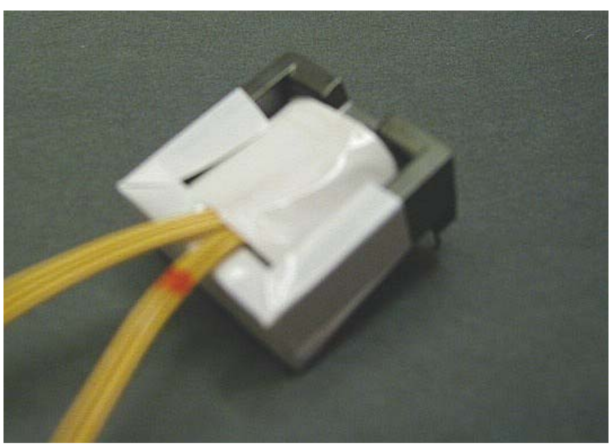


**Figure 7** – Core 1st wrapping

**Figure 8** – Core 2nd wrapping



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

# 8 Common Mode Choke

## 8.1 Electrical Diagram

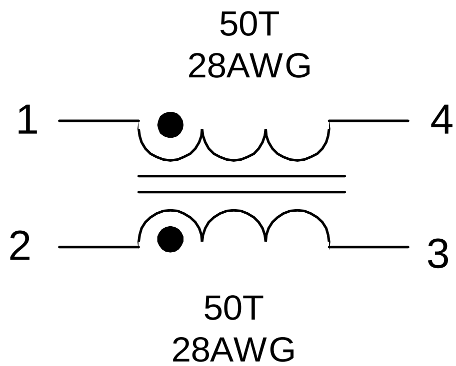



**Figure 9** – Common Mode Choke Electrical Diagram

## 8.2 Electrical Specifications

| | | |
|---|---|---|
| **Inductance** | Pins 1-4, all other windings open, measured at 10kHz, 0.4 VRMS | 7 mH, -0/+20% |
| **Resonant Frequency** | Pins 1-4, all other windings open | 300 kHz (Min.) |

## 8.3 Materials

| Item | Description |
|---|---|
| **[1]** | Core: Ferrite Toroid P/N 5975001121 (Fair-Rite)<br>(Distributor Lodestone Pacific USA Tel# (714) 970-0900) |
| **[2]** | Magnet Wire: 28 AWG |
| **[3]** | Varnish |


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

### 8.4 Common Mode Choke Build Diagram

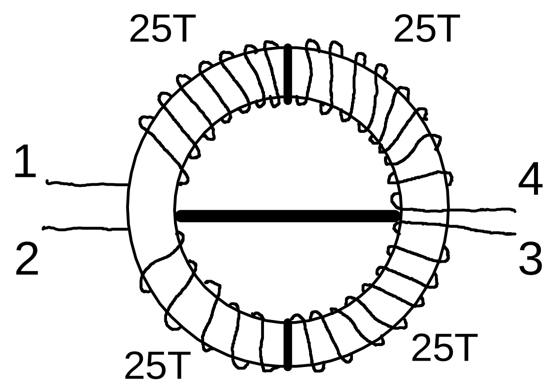



**Figure 10** – Common Mode Choke Build Diagram.



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

# 9 Transformer Spreadsheets

| ACDC_TOPGX_Rev1.2_052901 Copyright Power Integrations Inc. 2001 | INPUT | INFO | OUTPUT | UNIT | TOP_GX_052901.xls: TOPSwitch-GX 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 | 5.25 | | | Volts | Output Voltage |
| PO | 15.75 | | | Watts | Output Power |
| n | 0.81 | | | | Efficiency Estimate |
| Z | 0.5 | | | | Loss Allocation Factor |
| VB | 15 | | | Volts | Bias Voltage |
| tC | 3 | | | mSeconds | Bridge Rectifier Conduction Time Estimate |
| CIN | 39 | | | uFarads | Input Filter Capacitor |
| | | | | | |
| ENTER TOPSWITCH-GX VARIABLES | | | | | |
| **TOP-GX** | top245 | | | Universal | 115 Doubled/230V |
| *Chosen Device* | | TOP245 | Power Out | 60W' | 100W' |
| KI | 0.45 | | | | External Ilimit reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT) |
| ILIMITMIN | | | 0.729 | Amps | Use 1% resistor in setting external ILIMIT |
| ILIMITMAX | | | 0.897 | Amps | Use 1% resistor in setting external ILIMIT |
| **Frequency - (F)=132kHz, (H)=66kHz** | f | | | | Full (F) frequency option - 132kHz |
| fS | 132000 | | 1.32E+05 | Hertz | TOPSwitch-GX Switching Frequency: Choose between 132 kHz and 66 kHz |
| fSmin | | | 1.24E+05 | Hertz | TOPSwitch-GX Minimum Switching Frequency |
| fSmax | | | 1.40E+05 | Hertz | TOPSwitch-GX Maximum Switching Frequency |
| VOR | 70 | | | Volts | Reflected Output Voltage |
| VDS | 10 | | | Volts | TOPSwitch on-state Drain to Source Voltage |
| VD | 0.7 | | | Volts | Output Winding Diode Forward Voltage Drop |
| VDB | 0.7 | | | Volts | Bias Winding Diode Forward Voltage Drop |
| **KP** | **0.61** | | | | Ripple to Peak Current Ratio (0.4 < KRP < 1.0 : 1.0< KDP<6.0) |
| | | | | | |
| ENTER TRANSFORMER CORE/CONSTRUCT | | | | | |
| **Core Type** | efd20 | | | | |
| *Core* | | EFD20 | | P/N: | EFD20-3F3 |
| *Bobbin* | | EFD20_BOBBIN | | P/N: | CSH-EFD20-1S-8P |
| AE | | | 0.31 | cm^2 | Core Effective Cross Sectional Area |
| LE | | | 4.7 | cm | Core Effective Path Length |
| AL | | | 1200 | nH/T^2 | Ungapped Core Effective Inductance |
| BW | | | 13.2 | mm | Bobbin Physical Winding Width |
| M | 0 | | | mm | Safety Margin Width (Half the Primary to Secondary Creepage Distance) |
| **L** | **1.5** | | | | Number of Primary Layers |
| **NS** | **5** | | | | Number of Secondary Turns |
| | | | | | |
| DC INPUT VOLTAGE PARAMETERS | | | | | |
| VMIN | | | 86 | Volts | Minimum DC Input Voltage |
| VMAX | | | 375 | Volts | Maximum DC Input Voltage |
| | | | | | |
| CURRENT WAVEFORM SHAPE PARAMETEF | | | | | |
| DMAX | | | 0.48 | | Maximum Duty Cycle |
| IAVG | | | 0.22 | Amps | Average Primary Current |
| IP | | | 0.68 | Amps | Peak Primary Current |
| IR | | | 0.41 | Amps | Primary Ripple Current |
| IRMS | | | 0.34 | Amps | Primary RMS Current |
| | | | | | |
| TRANSFORMER PRIMARY DESIGN PARAMI | | | | | |
| LP | | | 730 | uHenries | Primary Inductance |
| NP | | | 59 | | Primary Winding Number of Turns |
| NB | | | 13 | | Bias Winding Number of Turns |
| ALG | | | 211 | nH/T^2 | Gapped Core Effective Inductance |
| BM | | | **2711** | Gauss | Maximum Flux Density at PO, VMIN (BM<3000) |
| **BP** | | | **3567** | Gauss | Peak Flux Density (BP<4200) |
| BAC | | | 827 | Gauss | AC Flux Density for Core Loss Curves (0.5 X Peak to Peak) |
| ur | | | 1448 | | Relative Permeability of Ungapped Core |
| **LG** | | | **0.15** | mm | Gap Length (Lg > 0.1 mm) |
| BWE | | | 19.8 | mm | Effective Bobbin Width |
| OD | | | 0.34 | mm | Maximum Primary Wire Diameter including insulation |
| INS | | | 0.06 | mm | Estimated Total Insulation Thickness (= 2 * film thickness) |
| DIA | | | 0.28 | mm | Bare conductor diameter |
| AWG | | | 30 | AWG | Primary Wire Gauge (Rounded to next smaller standard AWG value) |
| CM | | | 102 | Cmils | Bare conductor effective area in circular mils |
| **CMA** | | | **303** | Cmils/Amp | Primary Winding Current Capacity (200 < CMA < 500) |
| | | | | | |
| TRANSFORMER SECONDARY DESIGN PAR/ | | | | | |
| **Lumped parameters** | | | | | |
| ISP | | | 7.97 | Amps | Peak Secondary Current |
| ISRMS | | | 4.13 | Amps | Secondary RMS Current |
| IO | | | 3.00 | Amps | Power Supply Output Current |
| IRIPPLE | | | 2.83 | Amps | Output Capacitor RMS Ripple Current |
| | | | | | |
| CMS | | | 825 | 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 | | | 2.64 | mm | Secondary Maximum Outside Diameter for Triple Insulated Wire |
| INSS | | | 0.91 | mm | Maximum Secondary Insulation Wall Thickness |
| | | | | | |
| VOLTAGE STRESS PARAMETERS | | | | | |
| VDRAIN | | | 542 | Volts | Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance) |
| PIVS | | | 37 | Volts | Output Rectifier Maximum Peak Inverse Voltage |
| PIVB | | | 99 | Volts | Bias 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 Efficiency*

Efficiency was measured at the output terminals of the board (no cables).

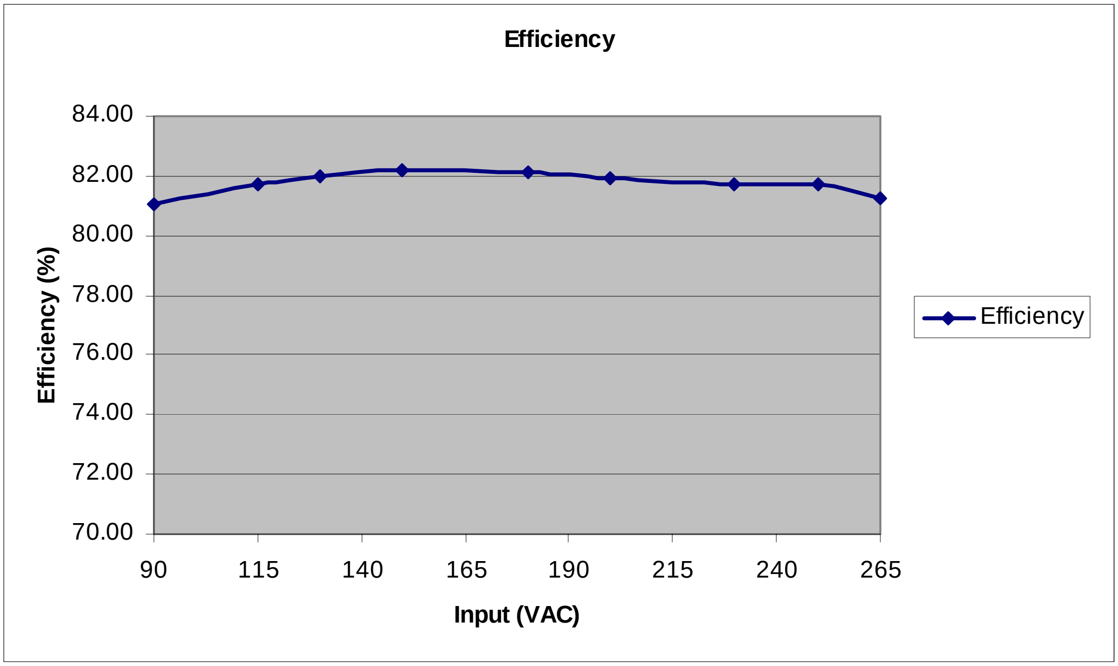



**Figure 11** - Efficiency vs. Input Voltage, Room Temperature, 60 Hz. Efficiency at 115 VAC and 230VAC were 81.7 % and 81.8% respectively.



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

## 10.2 No-load Input Power

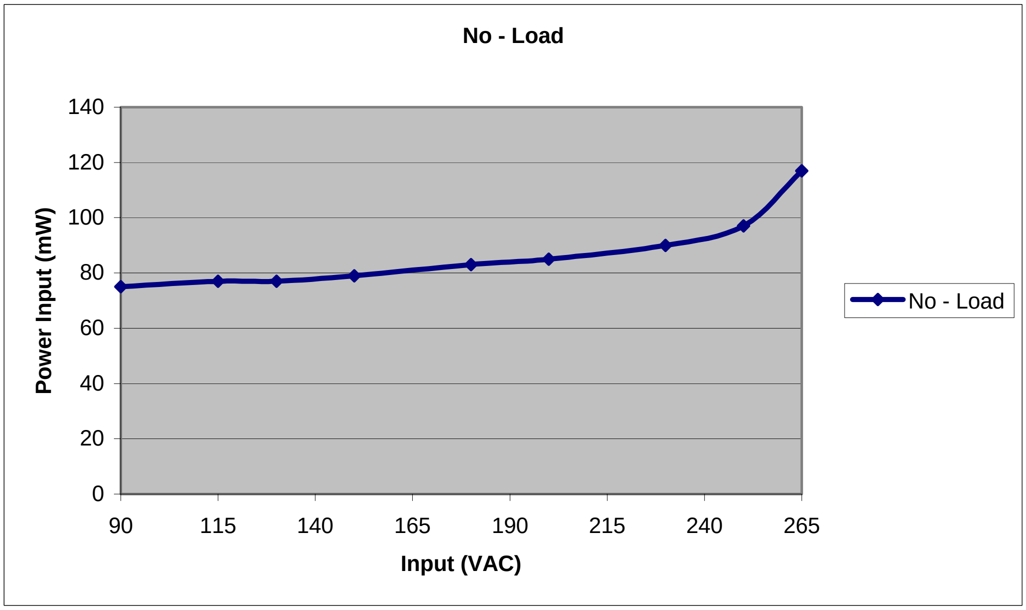



**Figure 12** - Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz. No load input power at 230V was 90mW

## 10.3 Regulation

### 10.3.1 Load

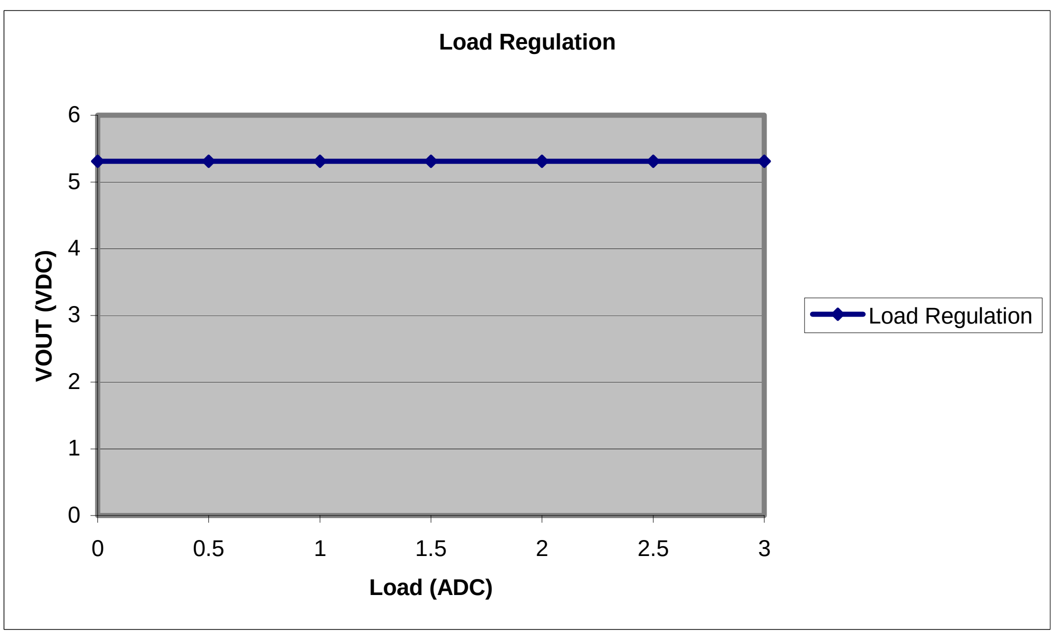



**Figure 13** – Load Regulation, Room Temperature.


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

10.3.2 Line

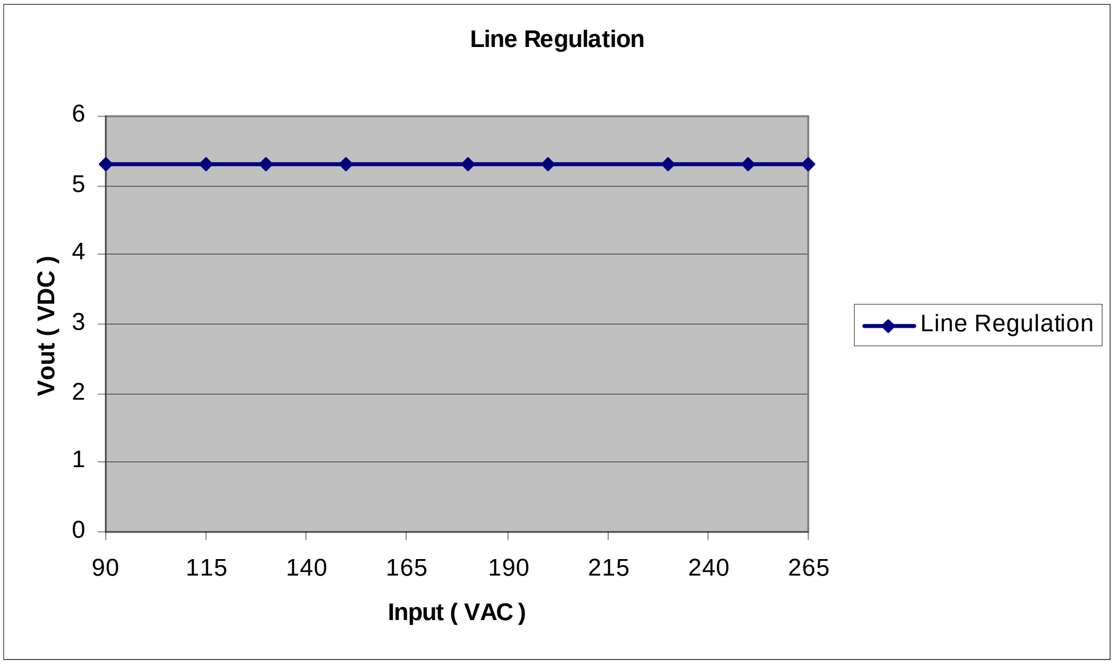



**Figure 14** – Line Regulation, Room Temperature, Full Load.

### *10.4 Over Power Protection*

| | 90VAC | 115VAC | 230VAC | 265VAC |
|---|---|---|---|---|
| **Output Current before Auto-restart** | 3.9A | 4.1A | 4.4A | 4.4A |
| **VOUT** | 5.31 VDC | 5.31 VDC | 5.31 VDC | 5.31 VDC |
| **Output Power before Auto-restart** | 20.7 W | 21.7 W | 23.3 W | 23.3 W |

### *10.5 Leakage Current*

The leakage current measured at 230VAC was 47uA.



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

# 11 Thermal Performance

## *11.1 Thermal measurements at max ambient*

The power supply was placed inside a mock-up plastic case of the specified dimensions. The case was placed inside a large closed carton box, and the carton was placed in an oven. The carton box was to prevent airflow on the unit under test. The ambient temperature was monitored inside the carton. The internal temperatures stabilized after 1 hour of continuous full load operation.

| Temperature (°C) | | |
|---|---|---|
| **Item** | **90 VAC** | **265VAC** |
| **External Ambient** | 45 | 45 |
| **Bridge (BR1)** | 84 | 74 |
| **Transformer (T1)** | 81 | 87 |
| **Rectifier (D1)** | 120 | 122 |
| ***TOP245P* (U1)** | 110 | 112 |

## *11.2 Thermal margin test*

As a test of thermal margin, the unit was operated at $10^{o}$ above max rated external ambient, or $55^{o}$C. The unit *did not go into thermal shutdown*. This implies plenty of thermal margin.


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

# 12 Waveforms

## 12.1 Drain Voltage and Current, Normal Operation

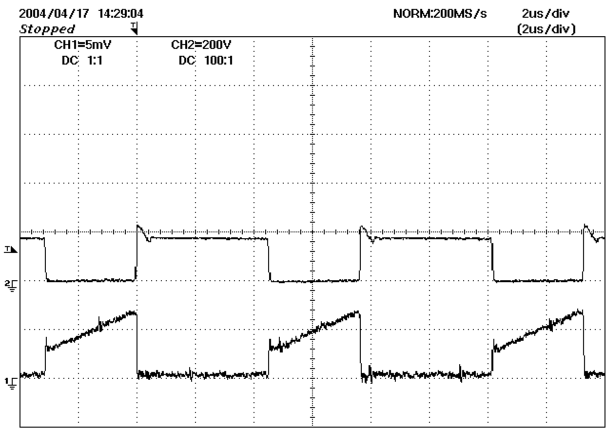



**Figure 15** – 90 VAC, Full Load.
Upper: $V_{DRAIN}$, 200 V, 2 µs / div
Lower: $I_{DRAIN}$, 0.5 A / div

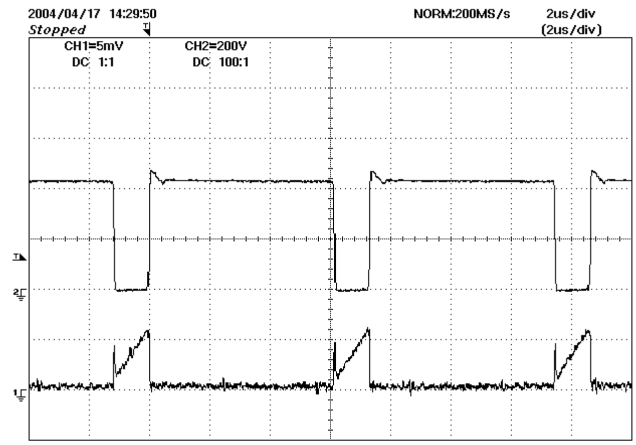



**Figure 16** - 265 VAC, Full Load
Upper: $V_{DRAIN}$, 200 V / div
Lower: $I_{DRAIN}$, 0.5 A / div

## 12.2 Output Voltage Start-up Profile

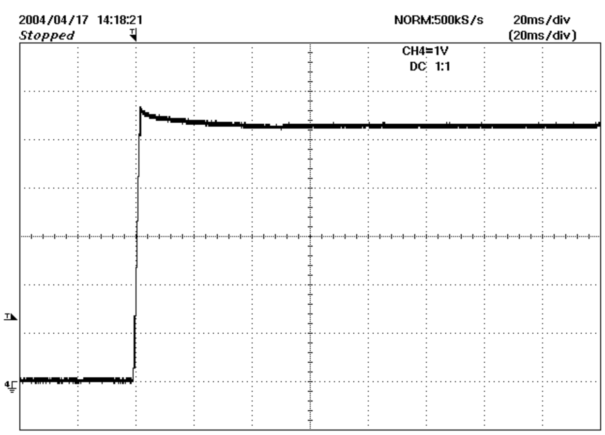



**Figure 17** - Start-up Profile, NO LOAD 230VAC
1 V, 20 ms / div.

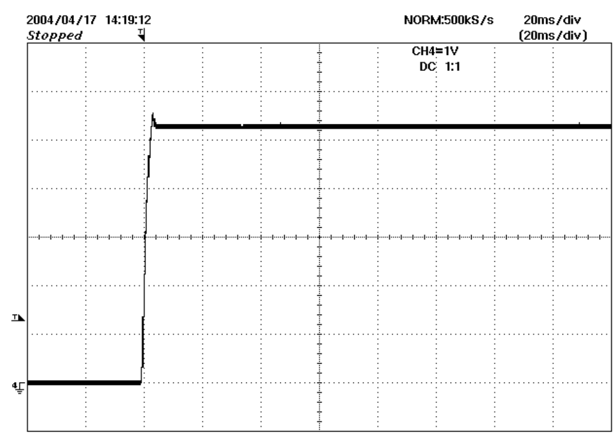
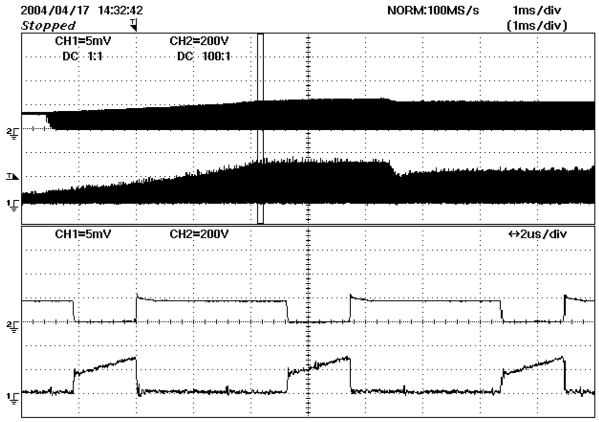



**Figure 18** - Start-up Profile, FULL LOAD 230 VAC
1 V, 20 ms / div.


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

### 12.3 Drain Voltage and Current Start-up Profile



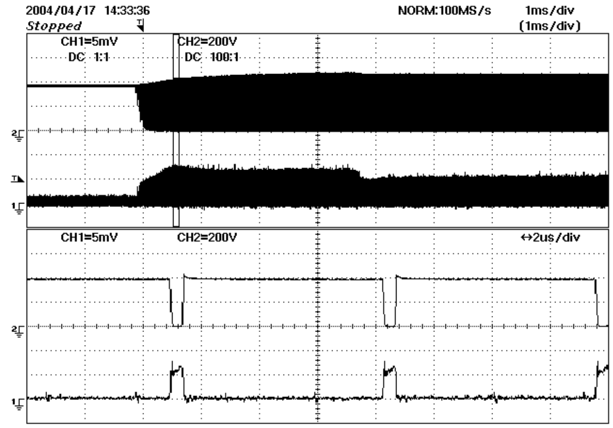
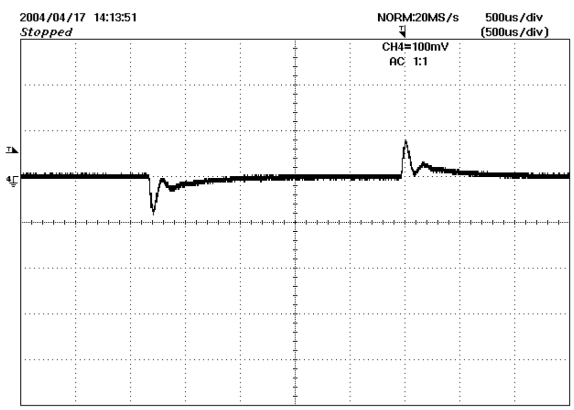




**Figure 19** - 90 VAC Input and Maximum Load.
Upper: $V_{DRAIN}$, 200 V & 1 ms / div.
Lower: $I_{DRAIN}$, 0.5 A / div.

**Figure 20** - 265 VAC Input and Maximum Load.
Upper: $V_{DRAIN}$, 200 V & 1 ms / div.
Lower: $I_{DRAIN}$, 0.5 A / div.

### 12.4 Load Transient Response (75% to 100% Load Step)

In the figures shown below, signal averaging was used to better enable viewing the load transient response. The oscilloscope was triggered using the load current step as a trigger source. Since the output switching and line frequency occur essentially at random with respect to the load transient, contributions to the output ripple from these sources will average out, leaving the contribution only from the load step response.



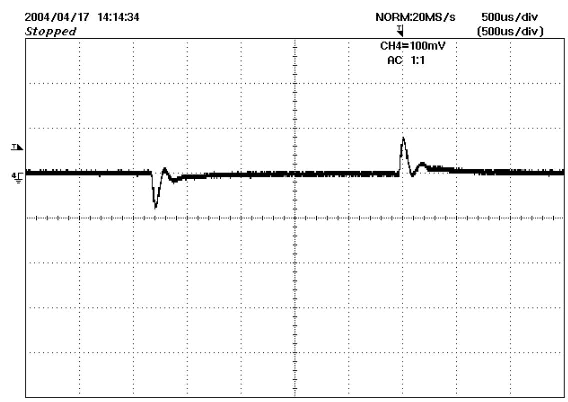




**Figure 21** – Transient Response, 115 VAC, 75-100-75% Load Step.

Waveform: Output Voltage
100 mV, 500 μs / div.

**Figure 22** – Transient Response, 230 VAC, 75-100-75% Load Step

Waveform: Output Voltage
100 mV, 500uS / div.


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

### *12.5 Output Ripple Measurements*

12.5.1 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).***

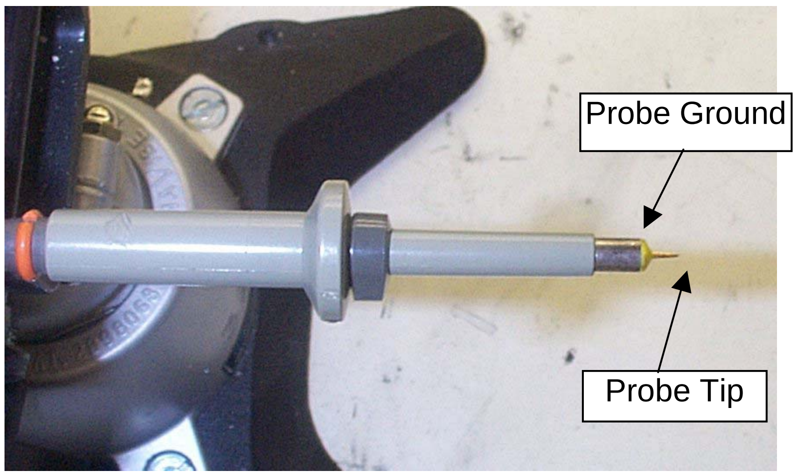



**Figure 23** - Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

**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)



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

## 12.5.2 Measurement Results

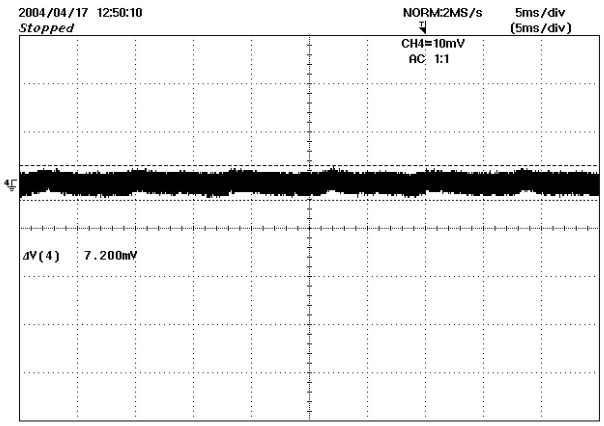



**Figure 25** – 5V Ripple, 90 VAC, Full Load.
5 ms, 10 mV / div

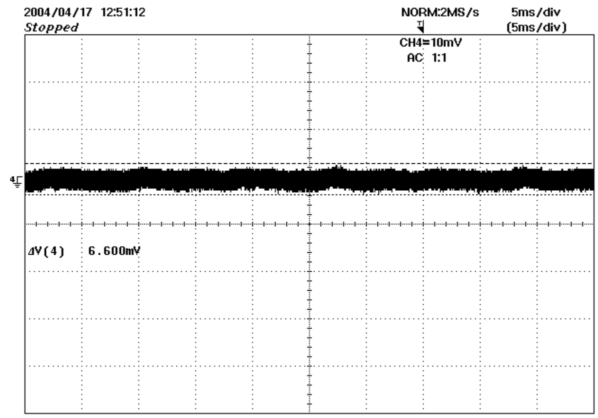



**Figure 26** - 5 V Ripple, 115 VAC, Full Load.
5 ms, 10 mV / div

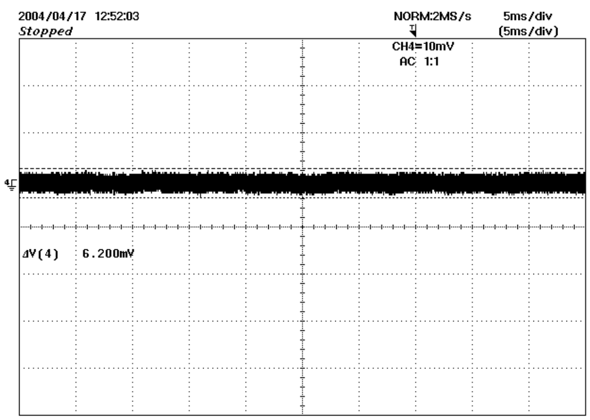



**Figure 27** – 5V Ripple, 230 VAC, Full Load.
5 ms, 10 mV /div

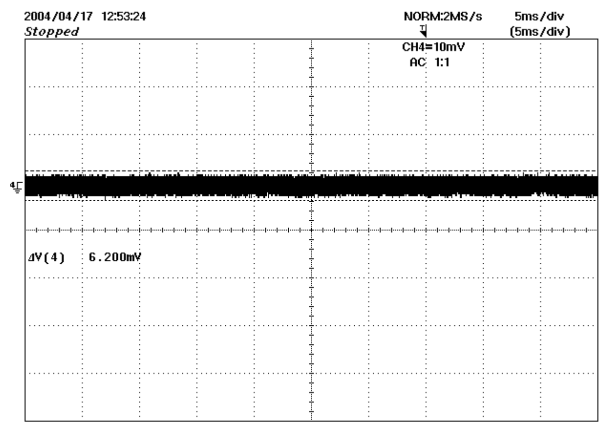



**Figure 28** – 5V Ripple, 265 VAC, Full Load.
5 ms, 10 mV /div



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

# 13 Control Loop Measurements

## 13.1 115 VAC Maximum Load

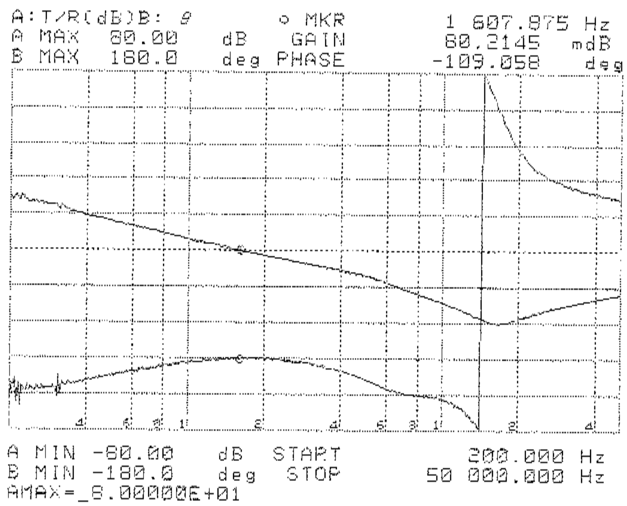



**Figure 29 -** Gain-Phase Plot, 115 VAC, Maximum Steady State Load
Vertical Scale: Gain = 16 dB/div, Phase = 36 °/div.
Crossover Frequency = 1.6 kHz Phase Margin = 71°

## 13.2 230 VAC Maximum Load

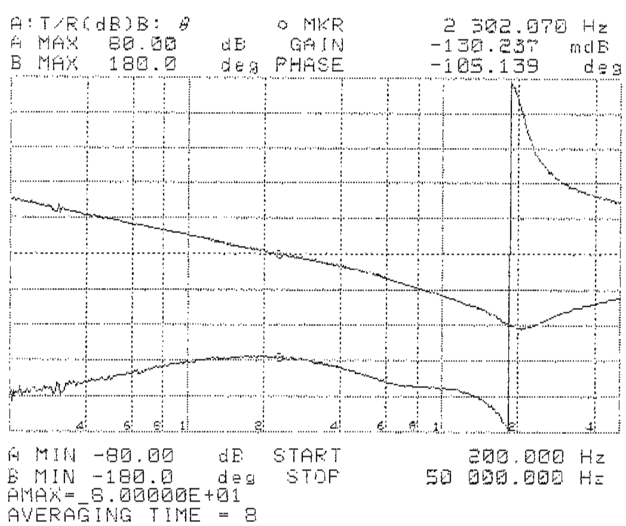



**Figure 30 -** Gain-Phase Plot, 230 VAC, Maximum Steady State Load
Vertical Scale: Gain = 16 dB/div, Phase = 36 °/div.
Crossover Frequency = 2.3 KHz, Phase Margin = 75°


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

# 14 Conducted EMI

EMI was tested at room temperature, at 115 VAC & 230 VAC input, with a resistor load of 2 ohms at the end of a 1.5 meter cable. Scans are shown for both cases, with and without a ground wire connecting the load to the LISN's Protective Earth (PE) jack.

## *14.1 230Vac*

### 14.1.1 Output grounded

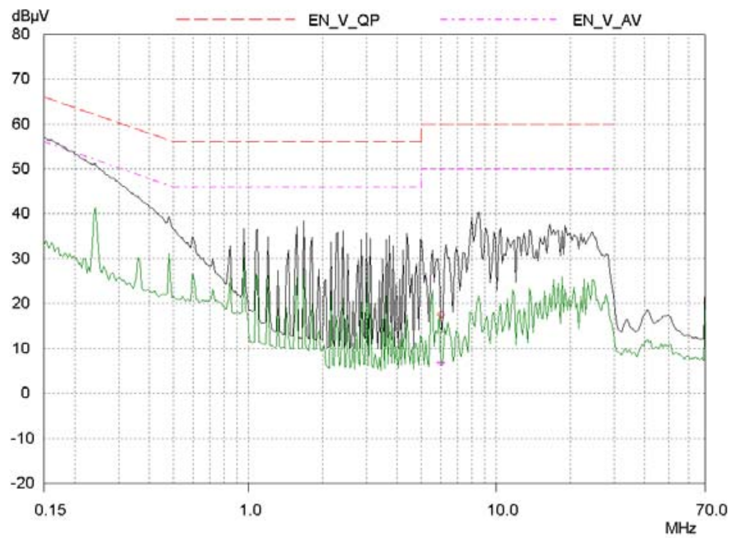



**Figure 31** – NEUTRAL Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits. With the LISN's PE connected to secondary ground.

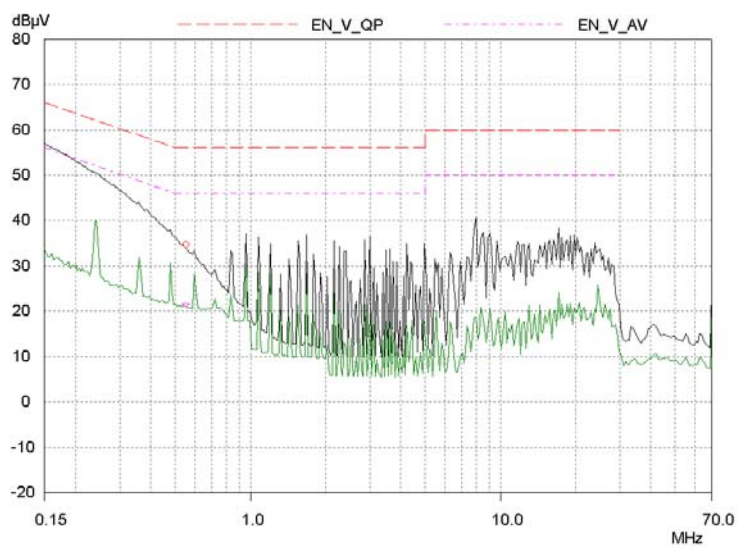



**Figure 32** – LINE Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits. With the LISN's PE connected to secondary ground.



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

### 14.1.2 Output floating

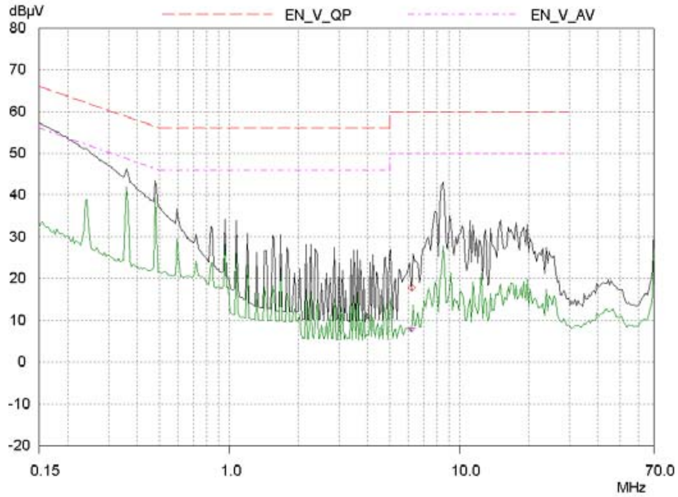



**Figure 33** – NEUTRAL Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits. Without the LISN's PE connection to secondary ground.

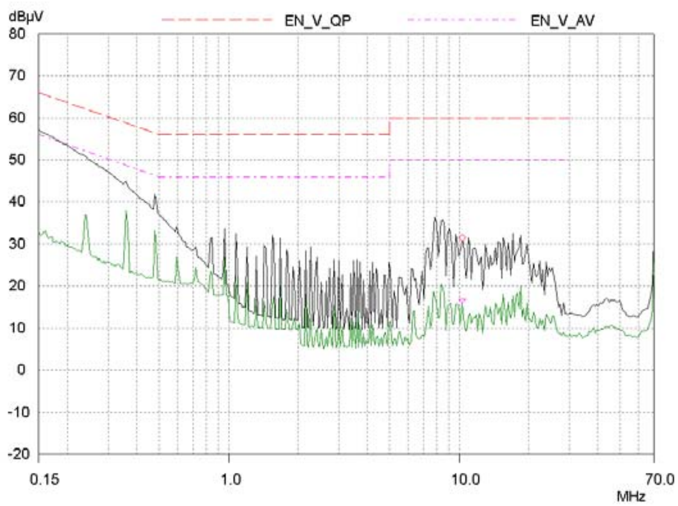



**Figure 34** – LINE Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55022 B Limits. Without the LISN's PE connection to secondary ground.



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

## 14.2 115Vac

### 14.2.1 Output grounded

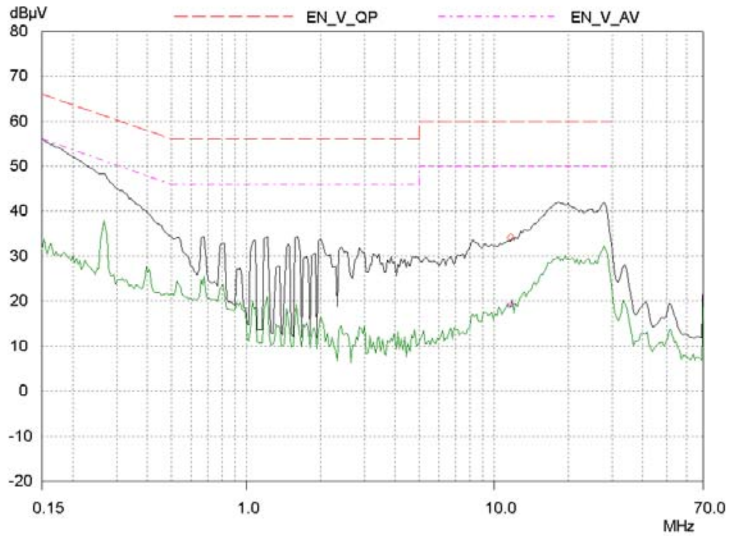



**Figure 35** – NEUTRAL Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits. With the LISN's PE connected to secondary ground.

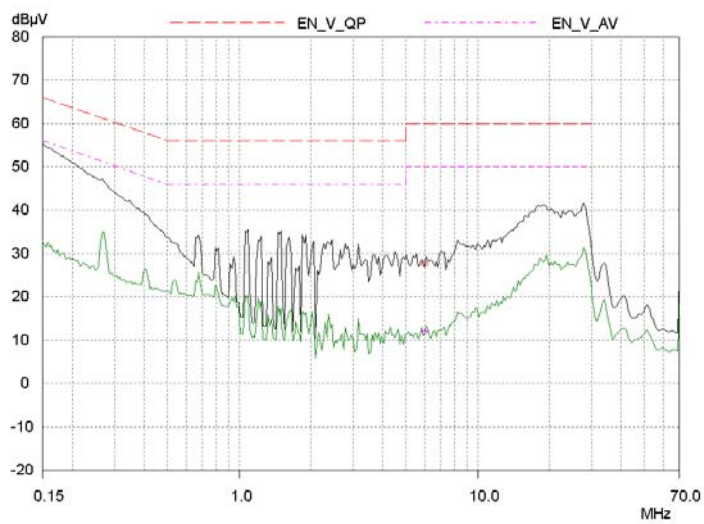



**Figure 36** – LINE Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits. With the LISN's PE connected to secondary ground.


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

### 14.2.2 Output floating

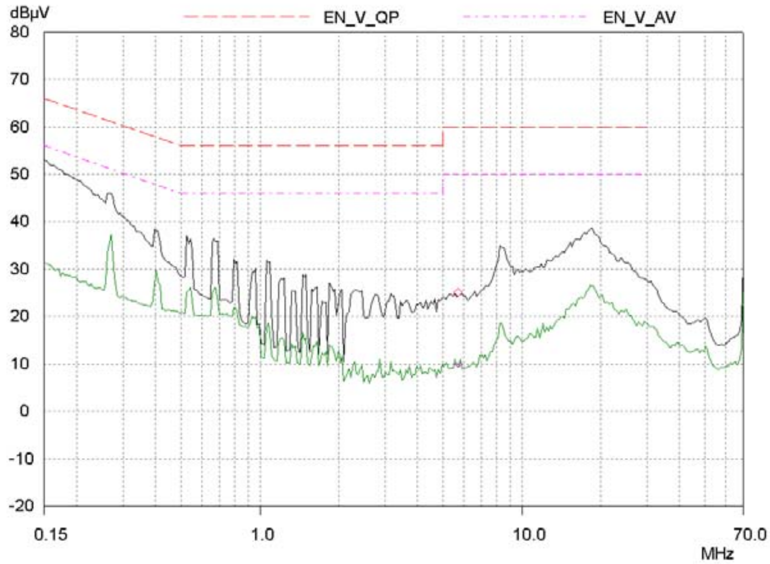



**Figure 37** – NEUTRAL Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits. Without the LISN's PE connection to secondary ground.

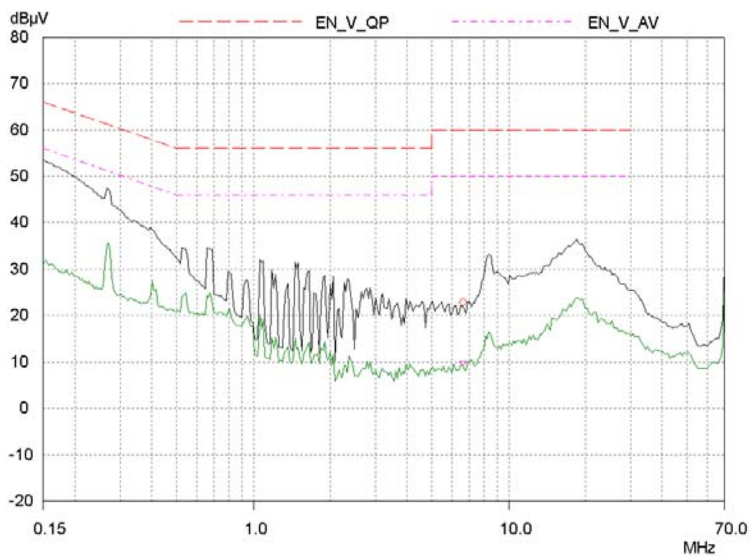



**Figure 38** – LINE Conducted EMI, Maximum Steady State Load, 115 VAC, 60 Hz, and EN55022 B Limits. Without the LISN's PE connection to secondary ground.



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

# 15 Revision History

| Date | Author | Revision | Description & changes | Reviewed |
|---|---|---|---|---|
| April 27, 2004 | ME | 1.0 | Initial 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***



**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*.



**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*

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

**INDIA** (TECHNICAL SUPPORT)
Innovatech
261/A, Ground Floor
7th Main, 17th Cross,
Sadashivanagar
Bangalore, India, 560080
Phone: +91-80-5113-8020
Fax: +91-80-5113-8023
*e-mail: indiasales@powerint.com*

**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)**
1st Floor, St. James's House
East Street
Farnham, Surrey GU9 7TJ
United Kingdom
Phone: +44-1252-730-140
Fax: +44-1252-727-689
*e-mail: eurosales@powerint.com*

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

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

ER or EPR template – Rev 3.5 – Single sided