# Design Example Report

| | |
|---|---|
| **Title** | ***10W Compact Power Supply using TOP245R*** |
| **Specification** | Input: 90 – 300 VAC<br>Output: 6V / 1.67A |
| **Application** | Water Purifier |
| **Author** | Power Integrations Applications Department |
| **Document Number** | DER-107 |
| **Date** | October 26, 2005 |
| **Revision** | 1.0 |


**Summary and Features**

- 66kHz operation to reduce switching losses in ***TOPSwitch-GX***, reduce standby power consumption and reduce burden on input EMI Filter
- Low profile EFD20 ESHEILD™ transformer construction
- Simple input π-filter
- No Y-cap No X-cap
- 450 VDC input capacitors for increased reliability for continuous 300 $V_{RMS}$ operation
- No heat sink design - D²PAK ***TOPSwitch-GX*** and D-PAK output rectifier
- 10 W (continuous) / 18 W (peak) in 1.6 X 2.5 X 1"





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**Important Notes:**
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 isolated source to provide power to the prototype board.

Design Reports contain a power supply design specification, schematic, bill of materials, and transformer documentation. Performance data and typical operation characteristics are included. Typically only a single prototype has been built.



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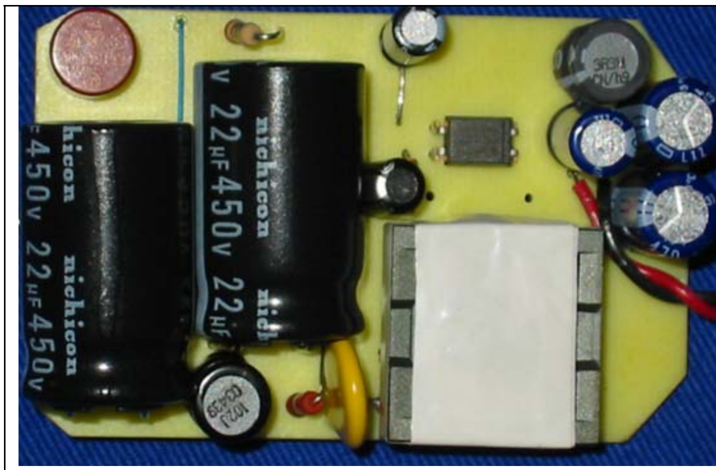
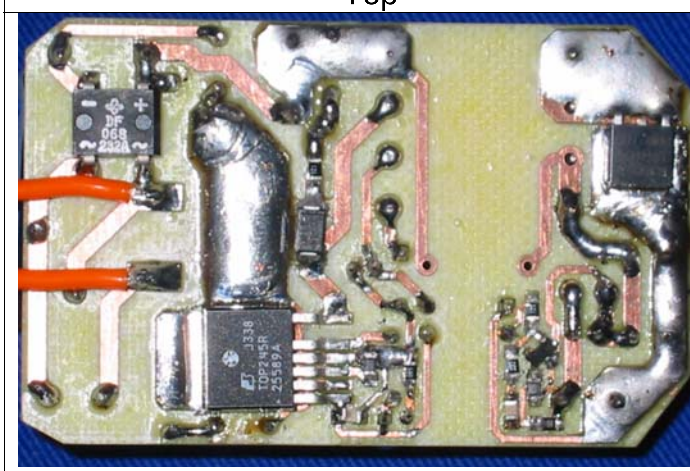
## 1 Introduction

This document is an engineering report describing a universal input 6 V / 10 W power supply utilizing a TOP245R. This power supply is intended to be used in a compact adapter for a water purification application. This supply has been design to operate at 300 VAC input continuously as well as provide a peak output current of 3 A for two minutes.

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




Top



Bottom

**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 | | 300 | VAC | 2 Wire – no P.E. |
| Frequency | $f_{LINE}$ | 47 | 50/60 | 64 | Hz | |
| No-load Input Power (240 VAC) | | | | 0.5 | W | |
| **Output** | | | | | | |
| Output Voltage 1 | $V_{OUT1}$ | | 6 | | V | ± 5% |
| Output Ripple Voltage 1 | $V_{RIPPLE1}$ | | 100 | | mV | 20 MHz bandwidth |
| Output Current 1 | $I_{OUT1}$ | | 1.67 | | A | |
| **Total Output Power** | | | | | | |
| Continuous Output Power | $P_{OUT}$ | | | 10 | W | |
| Peak Output Power | $P_{OUT\_PEAK}$ | | | 18 | W | 2 minute duration |
| **Efficiency** | $\eta$ | 75 | | | % | Measured at $P_{OUT}$ (10 W), 25 °C |
| **Environmental** | | | | | | |
| Conducted EMI | | Meets CISPR22B / EN55022B | | | | |
| Safety | | Designed to meet IEC950, UL1950 Class II | | | | |
| Surge | | 4 | | | kV | 1.2/50 µs surge, IEC 1000-4-5, Series Impedance: Differential Mode: 2 Ω Common Mode: 12 Ω |
| Surge | | 4 | | | kV | 100 kHz ring wave, 500 A short circuit current, differential and common mode |
| Ambient Temperature | $T_{AMB}$ | 0 | | 40 | °C | Free convection, sea level |


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# 3 Schematic

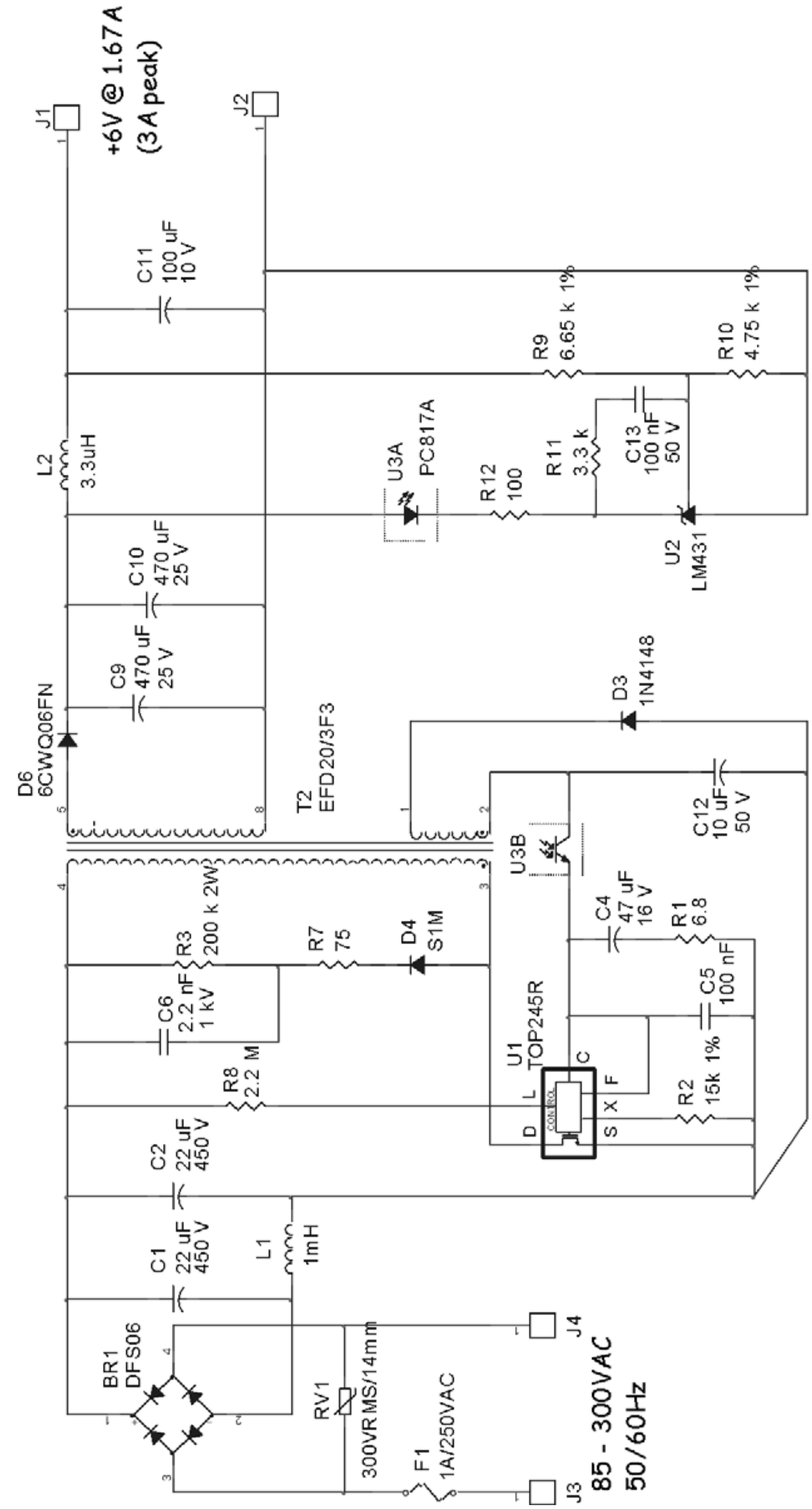


**Figure 2 –** Schematic


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# 4 Circuit Description

The schematic in Figure 2 shows an off-line Flyback converter using the TOP245R. The circuit is designed for 90 VAC to 300 VAC input and 6 V, 1.67 A output, with a transient load requirement of 3 A for 2 minutes in duration.

## 4.1 Input EMI Filtering

Capacitor C1, C2 and L1 form in input p-filter for differential-mode conducted EMI. Common-mode conducted EMI is reduced with the ESHIELD winding technique employed in the transformer construction. A input X-capacitor and a Y-capacitor to bridge the isolation barrier are not required, due to the ESHIELD transformer construction and frequency dithering of the ***TOPSwitch-GX***.

## 4.2 TOPSwitch Primary

Rectifier bridge BR1 and C1, C2 provide a high voltage DC BUS for the primary circuitry. The DC rail is applied to the primary winding of T2. The other side of the transformer primary is driven by the integrated MOSFET in U1. Diode D4, R7, R3 and C6 clamp leakage spikes generated when the MOSFET in U1 switches off. Resistor R8 sets the low-line turn-on threshold to approximately 69 VAC, and also sets the over-voltage shutdown level to approximately 320 VAC. R2 sets the U1 current limit to approximately 75% of its nominal value. This limits the output power delivered during fault conditions. C5 bypasses the U1 CONTROL pin. C4 has 3 functions. It provides the energy required by U1 during startup, sets the auto-restart frequency during fault conditions, and also acts to roll off the gain of U1 as a function of frequency. R1 adds a zero to stabilize the power supply control loop. Diode D3 and C12 provide rectified and filtered bias power for U3 and U1. The Frequency pin (F-pin) of U1 is tied to the Control pin (C-pin) to set the operating frequency of the U1 to 66kHz.

## 4.3 Output Rectification

The output of T2 is rectified and filtered by D6, C9, and C10. Inductor L2 and C11 provide additional high frequency filtering.

## 4.4 Output Feedback

Resistors R9 and R10 divide down the supply output voltage and apply it to the reference pin of error amplifier U2. Shunt regulator U2 drives optocoupler U3 through resistor R12 to provide feedback information to the U1 CONTROL pin. The optocoupler output also provides power to U1 during normal operating conditions.

Components C4, C13, R1, R11, and R12 all play a role in compensating the power supply control loop. Capacitor C4 rolls off the gain of U1 at relatively low frequency. Resistor R1 provides a zero to cancel the phase shift of C4. Resistor R12 sets the gain of the direct signal path from the supply output through U2 and U3. Components C13 and R11 roll off the gain of U2.


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# 5 PCB Layout

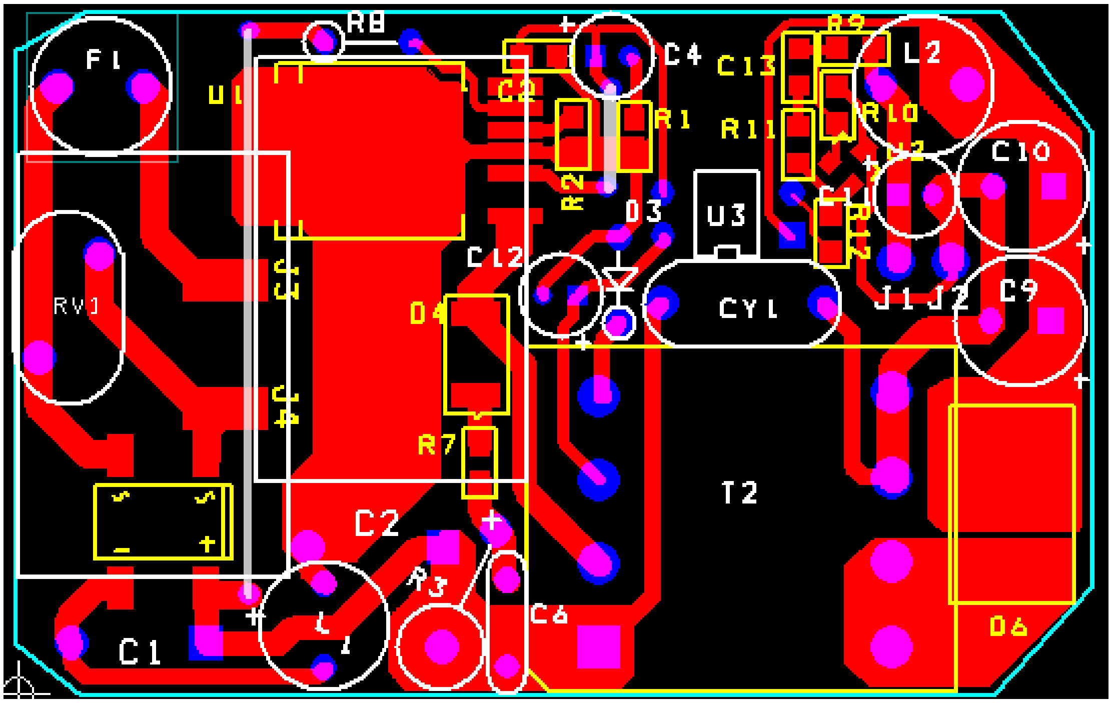


**Figure 3** – Printed Circuit Layout


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# 6 Bill Of Materials

| Item | QTY | Ref Des | Description | Value | Mfg | Mfg Part Number |
|---|---|---|---|---|---|---|
| 1 | 1 | BR1 | 600 V, 1 A, Bridge Rectifier, SMD, DFS | DFS06 | Vishay | DFS06 |
| 2 | 2 | C1 C2 | 22 uF, 450 V, Electrolytic, 105C (16 x 25) | 22 uF | Nichicon | UVZ2W220MHD |
| 3 | 1 | C4 | 47 uF, 16 V, Electrolytic, Gen. Purpose, (5 x 11) | 47 uF | United Chemi-Con | KME16VB47RM5X11LL |
| 4 | 2 | C5 C13 | 100 nF, 50 V, Ceramic, X7R | 100 nF | Panasonic | ECU-S1H104KBB |
| 5 | 1 | C6 | 2.2 nF, 1 kV, Disc Ceramic | 2.2 nF | NIC Components Corp | NCD222K1KVY5F |
| 6 | 2 | C9 C10 | 560 uF, 25 V, Electrolytic, Very Low ESR, 29 mOhm, (8 x 20) | 560 uF | Rubycon | 1EZLH560K8X20 |
| 7 | 1 | C11 | 100 uF, 10 V, Electrolytic, Low ESR, 500 mOhm, (5 x 11.5) | 100 uF | United Chemi-Con | LXZ10VB101ME11LL |
| 8 | 1 | C12 | 10 uF, 50 V, Electrolytic, Gen. Purpose, (5 x 11) | 10 uF | United Chemi-Con | KMG50VB10RM5X11LL |
| 9 | 1 | D3 | 200 V, 300 mA, Fast Switching, DO-35 | BAV21 | Vishay | BAV21 |
| 10 | 1 | D4 | 1000 V, 1 A, Rectifier, Glass Passivated, SMA | S1M | Vishay | S1M |
| 11 | 1 | D6 | 60 V, 6 A, Schottky, SMD, DPAK | 6CWQ06 | IR | 6CWQ06 |
| 12 | 1 | F1 | 3.15 A, 250V, Slow, TR5 | FUSE | Wickman | 3821315041 |
| 13 | 1 | L1 | 1000 uH, 0.28 A | 1mH | Tokin | SBC3-102-281 |
| 14 | 1 | L2 | 3.3 uH, 5.5 A, 8.5 x 11 mm | 3.3uH | Toko | R622LY-3R3M |
| 15 | 1 | R1 | 6.8 R, 5%, 0805 | 6.8 | | |
| 16 | 1 | R2 | 13.7 k, 1%, 0805 | 13.7 k | | |
| 17 | 1 | R3 | 200 k, 5%, 1 W, Metal Oxide | 200 k | Yageo | RSF200JB-200K |
| 18 | 1 | R7 | 75 R, 5%, 1/8 W, Metal Film, 0805 | 75 | | |
| 19 | 1 | R8 | 2.2 M, 5%, 1/4 W, Carbon Film | 2.2 M | | |
| 20 | 1 | R9 | 6.65 k, 1%, 1/4 W, Metal Film, 1206 | 6.65 k | | |
| 21 | 1 | R10 | 4.75 k, 1%, 1/4 W, Metal Film, 1206 | 4.75 k | | |
| 22 | 1 | R11 | 3.3 k, 5%, 1/8 W, Metal Film, 0805 | 3.3 k | | |
| 23 | 1 | R12 | 100 R, 1%, 1/8 W, Metal Film, 0805 | 100 | | |
| 24 | 1 | RV1 | 300 V, 23 J, 7 mm, RADIAL | VARISTOR | Littlefuse | V300LA4 |
| 25 | 1 | T2 | Bobbin, EFD20, Horizontal, 8 pins | BEFD20_8P | Yih-Hwa Enterprises | YW-272-03B |
| 26 | 1 | U1 | TOPSwitch-GX, TOP245R, TO-263-7C | TOP245R | Power Integrations | TOP245R |
| 27 | 1 | U2 | 2.495 V Shunt Regulator IC, 1%, -40 to 85C, SOT23 | LM431 | National Semiconductor | LM431BCM |
| 28 | 1 | U3 | Opto coupler, 35 V, CTR 80-160%, 4-DIP | PC817A | Isocom, Sharp | ISP817A, PC817X1 |


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# 7 Transformer Specification

## 7.1 Electrical Diagram

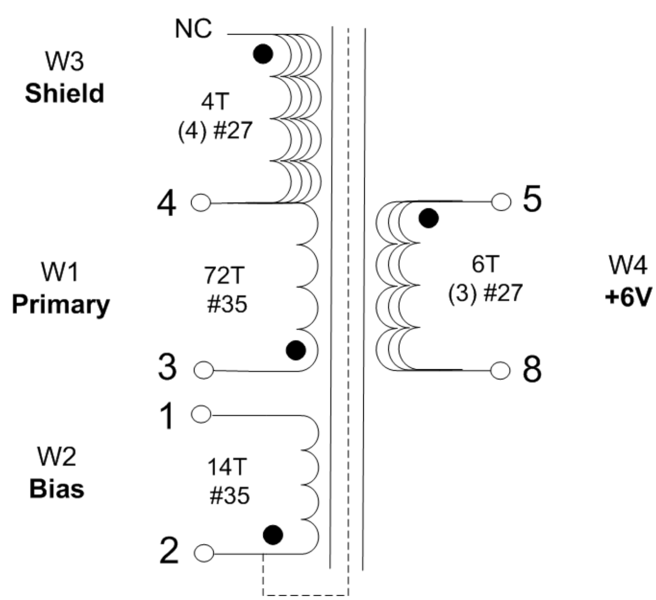


**Figure 4** – Transformer Electrical Diagram

## 7.2 Electrical Specifications

| | | |
|---|---|---|
| **Electrical Strength** | 1 second, 60 Hz, from Pins 1-4 to Pins 5-8 | 3000 VAC |
| **Primary Inductance** | Pins 3-4, all other windings open, measured at 100 kHz, 0.4 VRMS | 606 µH, -7/+7% |
| **Resonant Frequency** | Pins 3-4, all other windings open | 800 kHz (Min.) |
| **Primary Leakage Inductance** | Pins 3-4, with Pins 5-8 shorted, measured at 100 kHz, 0.4 VRMS | 100 µH (Max.) |

## 7.3 Materials

| Item | Description |
|---|---|
| **[1]** | Core: EFD20/3F3 AL = 104nH/$T^2$ |
| **[2]** | Bobbin: 8-pin |
| **[3]** | Magnet Wire: #35 AWG Heavy Build |
| **[4]** | Magnet Wire: #27 AWG Heavy Build |
| **[5]** | Tape: 3M 3mm wide |
| **[6]** | Tape, 3M |
| **[7]** | Tape, 3M |
| **[8]** | Copper tape 1.5 mil thick X 8mm wide |
| **[9]** | Varnish |


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## 7.4 Transformer Build Diagram

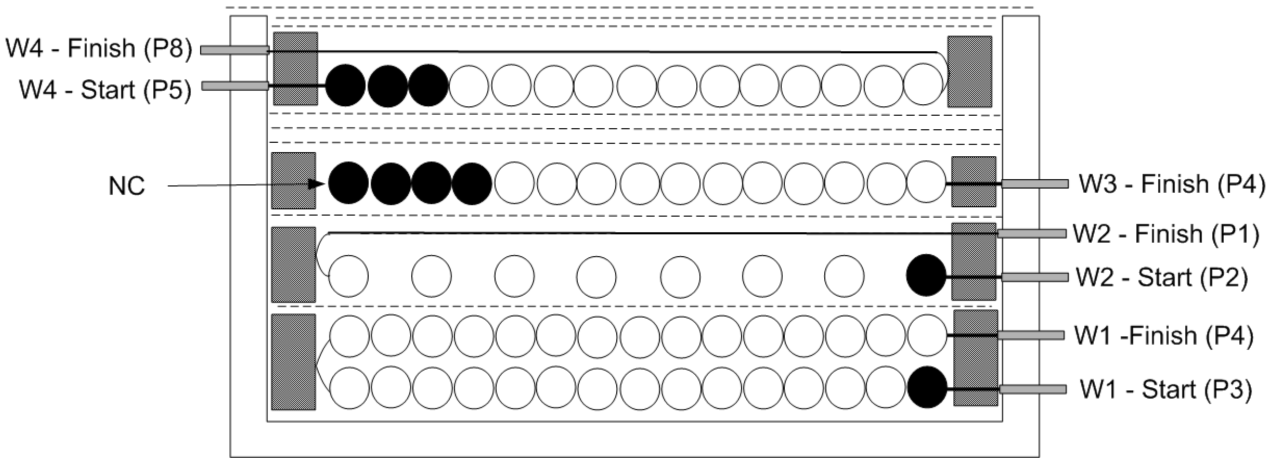


**Figure 5** – Transformer Build Diagram

## 7.5 Transformer Construction

| | |
|---|---|
| **Bobbin Preparation** | Align bobbin to have pins 1-4 facing the mandrill |
| **Primary Margin** | Apply 3 mm wide margin on either side of bobbin with item [5]. Match height of primary and bias windings. |
| **Primary** | Start at Pin 3. Wind 76 turns of item [3] in approximately 2 layers, finish on Pin 4. |
| **Basic Insulation** | Use one layer of item [6] for basic insulation. |
| **Bias Winding** | Starting at Pin 2, wind 14 turns of item [3] uniformly across bobbin width in a single layer. Finish at Pin 1. |
| **Basic Insulation** | Use one layer of item [6] for basic insulation. |
| **Primary Margin** | Apply 3 mm wide margin on either side of bobbin with item [5]. Match height of balanced shield winding. |
| **Balanced Shield Winding** | Start temporarily on pin 6. Wind 4 turns of quadrifilar item [4] uniformly across the bobbin width in a single layer. Finish on pin 4. Cut start of winding at 90-degree bend to center of bobbin window. |
| **Reinforced Insulation** | Use three layers of item [7] for reinforced insulation. |
| **Secondary Margin** | Apply 3 mm wide margin on either side of bobbin with item [5]. Match height of secondary winding. |
| **Secondary Winding** | Start at Pin 5. Wind 6 trifilar turns of item [4]. Spread turns evenly across bobbin in a single layer. Finish on Pin 8. |
| **Outer Wrap** | Wrap windings with 3 layers of tape (item [7]). |
| **Core Preparation** | Affix cores (item [1]) with tape [5]. |
| **Outer Belly band** | Wrap one turn of copper tape [8] around outer core. Ensure copper tape makes contact with core halves. Solder wire from pin 2 of bobbin to copper bellyband. |
| **Final Assembly** | Wrap three layers of tape [7]. Varnish impregnate (item [9]). |


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# 8 PIXL Transformer Spreadsheet

| **ACDC_TOPSwitchGX_113004; Rev.2.2; Copyright Power Integrations Inc. 2004** | **INPUT** | **INFO** | **OUTPUT** | **UNIT** | **TOP_GX_FX_113004.xls: TOPSwitch-GX/FX Continuous/Discontinuous Flyback Transformer Design Spreadsheet** |
|---|---|---|---|---|---|
| **ENTER APPLICATION VARIABLES** | | | | | |
| VACMIN | 85 | | | Volts | |
| VACMAX | 300 | | | Volts | Maximum AC Input Voltage |
| fL | 50 | | | Hertz | AC Mains Frequency |
| VO | 6 | | | Volts | Output Voltage |
| PO | 18 | | | Watts | Output Power |
| n | 0.73 | | | | Efficiency Estimate |
| Z | 0.5 | | | | Loss Allocation Factor |
| VB | 15 | | | Volts | Bias Voltage |
| tC | 3 | | | mSeconds | Bridge Rectifier Conduction Time Estimate |
| CIN | 44 | | | uFarads | Input Filter Capacitor |
| | | | | | |
| **ENTER TOPSWITCH-GX VARIABLES** | | | | | |
| **TOP-GX** | **TOP245** | | | *Universal* | *115 Doubled/230V* |
| *Chosen Device* | | *TOP245* | *Power Out* | *60W* | *85W* |
| KI | 0.8 | | | | External Ilimit reduction factor (KI=1.0 for default ILIMIT, KI <1.0 for lower ILIMIT) |
| ILIMITMIN | | | *1.296* | Amps | Use 1% resistor in setting external ILIMIT |
| ILIMITMAX | | | *1.584* | Amps | Use 1% resistor in setting external ILIMIT |
| Frequency (F)=132kHz, (H)=66kHz | **h** | | | | Half (H) frequency option - 66kHz |
| fS | | | *66000* | Hertz | TOPSwitch-GX Switching Frequency: Choose between 132 kHz and 66 kHz |
| fSmin | | | *61500* | Hertz | TOPSwitch-GX Minimum Switching Frequency |
| fSmax | | | *70500* | Hertz | TOPSwitch-GX Maximum Switching Frequency |
| VOR | 82 | | | Volts | Reflected Output Voltage |
| VDS | 10 | | | Volts | TOPSwitch on-state Drain to Source Voltage |
| VD | 0.5 | | | Volts | Output Winding Diode Forward Voltage Drop |
| VDB | 0.7 | | | Volts | Bias Winding Diode Forward Voltage Drop |
| KP | 0.9415 | | | | Ripple to Peak Current Ratio (0.4 < KRP < 1.0 : 1.0< KDP<6.0) |
| | | | | | |
| **ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES** | | | | | |
| **Core Type** | **efd20** | | | | |
| *Core* | | *EFD20* | | *P/N:* | EFD20-3F3 |



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| | | | | | |
|---|---|---|---|---|---|
| *Bobbin* | | *EFD20_BOBBIN* | | *P/N:* | CSH-EFD20-1S-8P |
| AE | 0.58 | | 0.58 | cm^2 | Core Effective Cross Sectional Area |
| LE | 5.7 | | 5.7 | cm | Core Effective Path Length |
| AL | 1800 | | 1800 | nH/T^2 | Ungapped Core Effective Inductance |
| BW | 16.4 | | 16.4 | mm | Bobbin Physical Winding Width |
| M | 3 | | | mm | Safety Margin Width (Half the Primary to Secondary Creepage Distance) |
| L | 2 | | | | Number of Primary Layers |
| NS | 6 | | | | Number of Secondary Turns |
| | | | | | |
| **DC INPUT VOLTAGE PARAMETERS** | | | | | |
| VMIN | | | 81 | Volts | Minimum DC Input Voltage |
| VMAX | | | 424 | Volts | Maximum DC Input Voltage |
| | | | | | |
| **CURRENT WAVEFORM SHAPE PARAMETERS** | | | | | |
| DMAX | | | 0.54 | | Maximum Duty Cycle |
| IAVG | | | 0.30 | Amps | Average Primary Current |
| IP | | | 1.07 | Amps | Peak Primary Current |
| IR | | | 1.01 | Amps | Primary Ripple Current |
| IRMS | | | 0.47 | Amps | Primary RMS Current |
| **TRANSFORMER PRIMARY DESIGN PARAMETERS** | | | | | |
| LP | | | 606 | uHenries | Primary Inductance |
| NP | | | 76 | | Primary Winding Number of Turns |
| NB | | | 14 | | Bias Winding Number of Turns |
| ALG | | | 106 | nH/T^2 | Gapped Core Effective Inductance |
| BM | | | 1480 | Gauss | Maximum Flux Density at PO, VMIN (BM<3000) |
| BP | | | 2187 | Gauss | Peak Flux Density (BP<4200) |
| BAC | | | 696 | Gauss | AC Flux Density for Core Loss Curves (0.5 X Peak to Peak) |
| ur | | | 1408 | | Relative Permeability of Ungapped Core |
| LG | | | 0.65 | mm | Gap Length (Lg > 0.1 mm) |
| BWE | | | 20.8 | 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 | | *Warning* | 137 | Cmils/Amp | !!!!!!!!! INCREASE CMA>200 (increase L(primary layers),decrease NS, larger Core) |
| | | | | | |
| **TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)** | | | | | |
| **Lumped parameters** | | | | | |
| ISP | | | 13.52 | Amps | Peak Secondary Current |


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| | | | | | |
|---|---|---|---|---|---|
| ISRMS | | | 5.48 | Amps | Secondary RMS Current |
| IO | | | 3.00 | Amps | Power Supply Output Current |
| IRIPPLE | | | 4.59 | Amps | Output Capacitor RMS Ripple Current |
| | | | | | |
| CMS | | | 1097 | Cmils | Secondary Bare Conductor minimum circular mils |
| AWGS | | | 19 | AWG | Secondary Wire Gauge (Rounded up to next larger standard AWG value) |
| DIAS | | | 0.91 | mm | Secondary Minimum Bare Conductor Diameter |
| ODS | | | 1.73 | mm | Secondary Maximum Outside Diameter for Triple Insulated Wire |
| INSS | | | 0.41 | mm | Maximum Secondary Insulation Wall Thickness |
| | | | | | |
| **VOLTAGE STRESS PARAMETERS** | | | | | |
| VDRAIN | | | 616 | Volts | Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance) |
| PIVS | | | 40 | Volts | Output Rectifier Maximum Peak Inverse Voltage |
| PIVB | | | 96 | Volts | Bias Rectifier Maximum Peak Inverse Voltage |
| | | | | | |
| **TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)** | | | | | |
| **1st output** | | | | | |
| VO1 | 6.0 | | 6 | Volts | Output Voltage |
| IO1 | 3.000 | | 3 | Amps | Output DC Current |
| PO1 | | | 18.00 | Watts | Output Power |
| VD1 | 0.5 | | 0.5 | Volts | Output Diode Forward Voltage Drop |
| NS1 | | | 6.00 | | Output Winding Number of Turns |
| ISRMS1 | | | 5.484 | Amps | Output Winding RMS Current |
| IRIPPLE1 | | | 4.59 | Amps | Output Capacitor RMS Ripple Current |
| PIVS1 | | | 40 | Volts | Output Rectifier Maximum Peak Inverse Voltage |
| | | | | | |
| CMS1 | | | 1097 | Cmils | Output Winding Bare Conductor minimum circular mils |
| AWGS1 | | | 19 | AWG | Wire Gauge (Rounded up to next larger standard AWG value) |
| DIAS1 | | | 0.91 | mm | Minimum Bare Conductor Diameter |
| ODS1 | | | 1.73 | mm | Maximum Outside Diameter for Triple Insulated Wire |
| | | | | | |
| **2nd output** | | | | | |
| VO2 | 6.0 | | | Volts | Output Voltage |
| IO2 | 1.670 | | | Amps | Output DC Current |
| PO2 | | | 10.02 | Watts | Output Power |
| VD2 | 0.5 | | | Volts | Output Diode Forward Voltage Drop |
| NS2 | | | 6.00 | | Output Winding Number of Turns |



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| | | | | | |
|---|---|---|---|---|---|
| ISRMS2 | | | 3.053 | Amps | Output Winding RMS Current |
| IRIPPLE2 | | | 2.56 | Amps | Output Capacitor RMS Ripple Current |
| PIVS2 | | | 40 | Volts | Output Rectifier Maximum Peak Inverse Voltage |
| | | | | | |
| CMS2 | | | 611 | Cmils | Output Winding Bare Conductor minimum circular mils |
| AWGS2 | | | 22 | AWG | Wire Gauge (Rounded up to next larger standard AWG value) |
| DIAS2 | | | 0.65 | mm | Minimum Bare Conductor Diameter |
| ODS2 | | | 1.73 | mm | Maximum Outside Diameter for Triple Insulated Wire |


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# 9 Performance Data

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

## 9.1 Efficiency

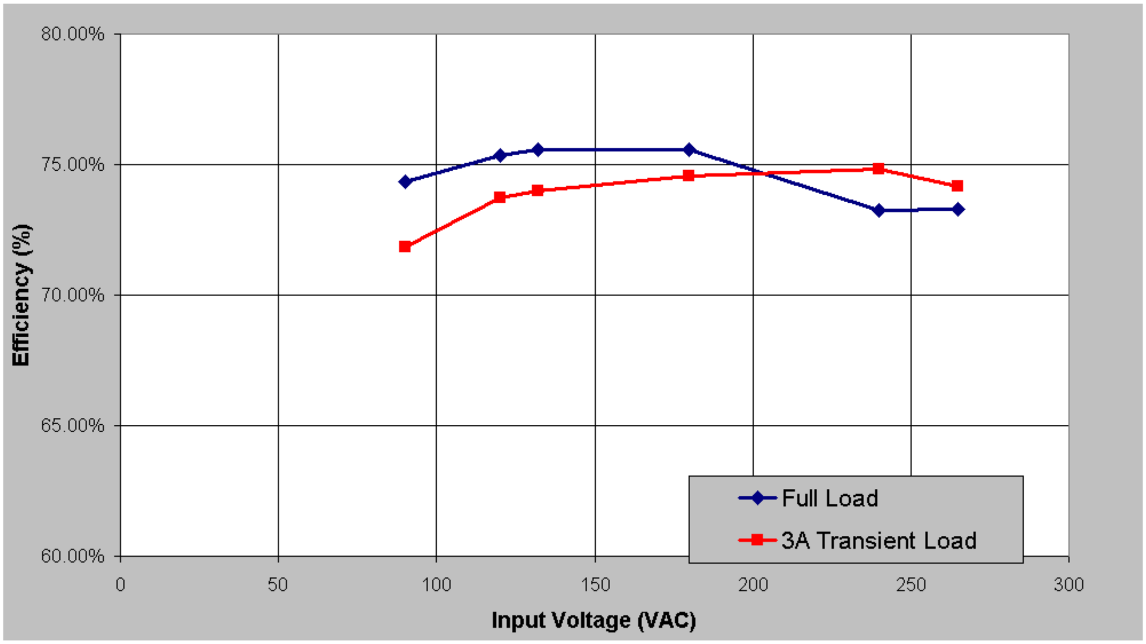


**Figure 6** – Efficiency vs. Input Voltage, Room Temperature, 60 Hz.

## 9.2 No-load Input Power

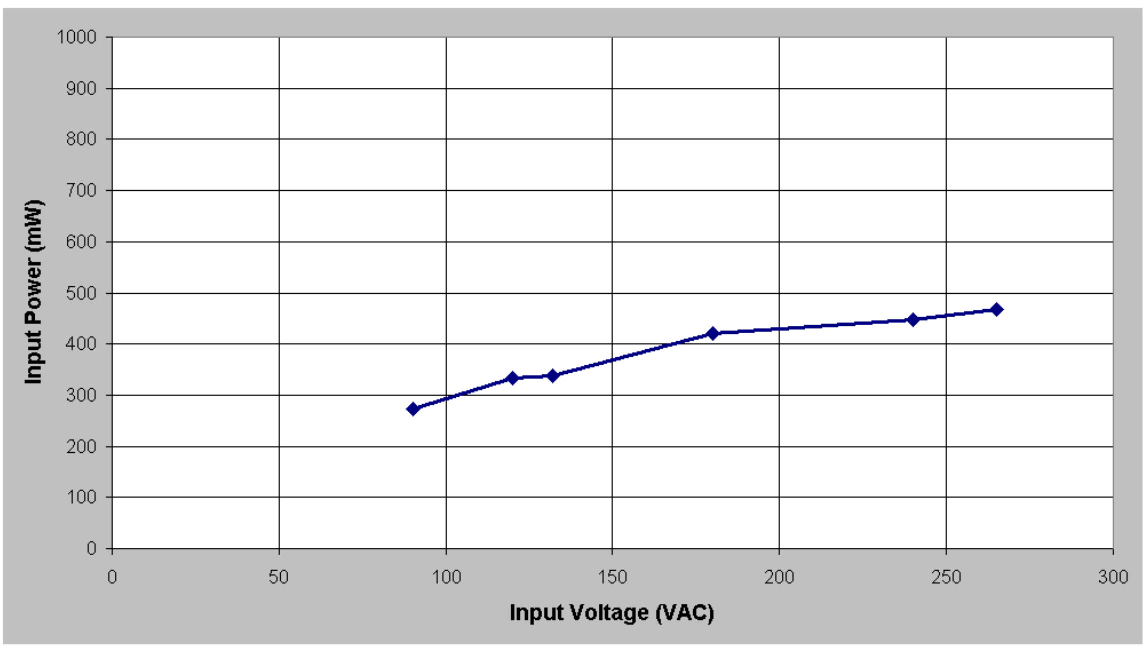


**Figure 7 –** Zero Load Input Power vs. Input Line Voltage, Room Temperature, 60 Hz


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## *9.3 Regulation*

### 9.3.1 Load

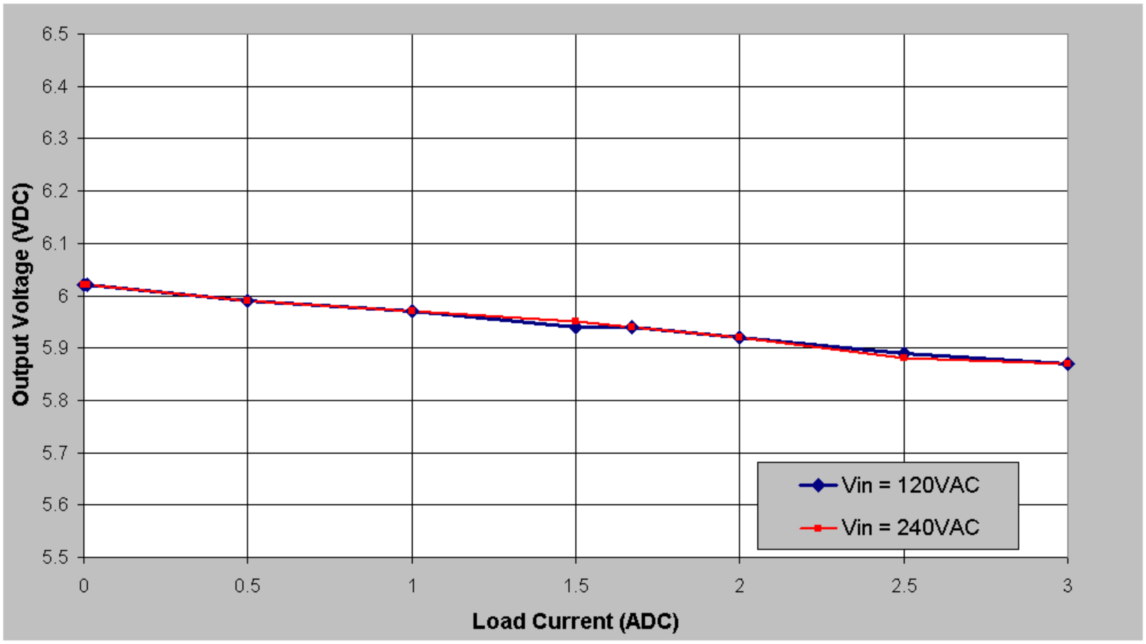


**Figure 8** – Load Regulation, Room Temperature

### 9.3.2 Line

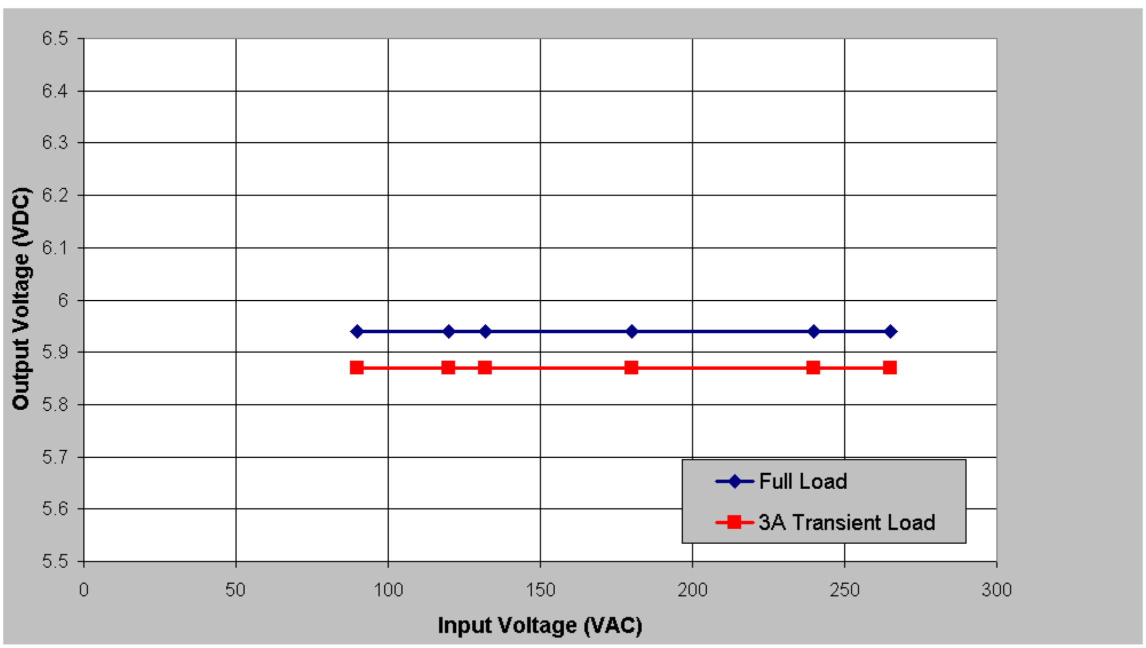


**Figure 9** – Line Regulation, Room Temperature, Full Load


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# 10 Waveforms

## *10.1 Drain Voltage and Current, Normal Operation*

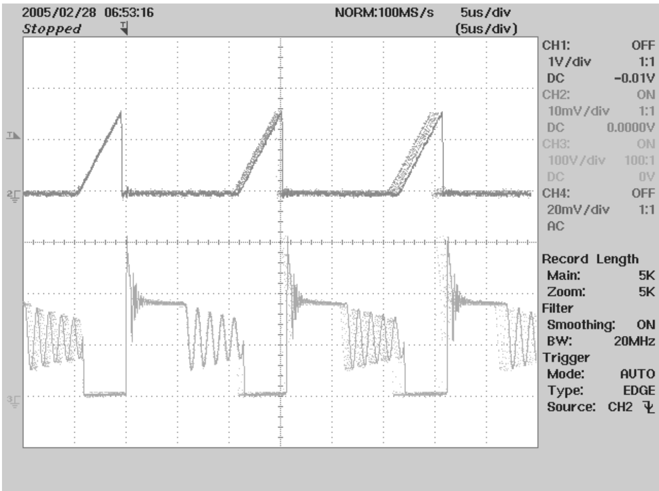


**Figure 10** – 90 VAC, Full Load.
Upper: $I_{DRAIN}$, 0.5 A / div
Lower: $V_{DRAIN}$, 100 V, 2 µs / div

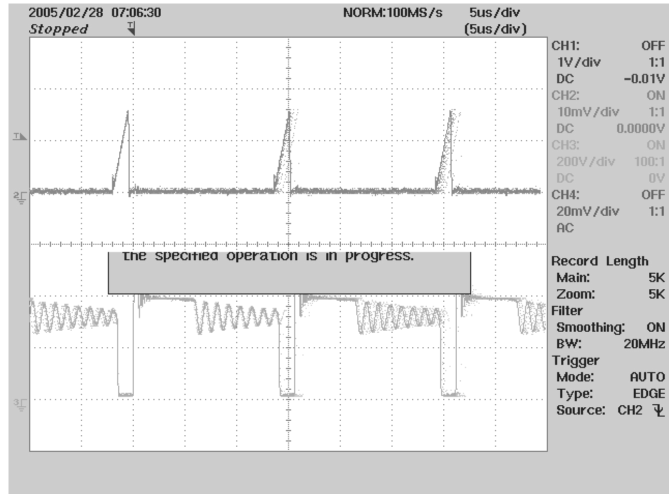


**Figure 11** – 265 VAC, Full Load
Upper: $I_{DRAIN}$, 0.5 A / div
Lower: $V_{DRAIN}$, 200 V / div

## *10.2 Output Voltage Start-up Profile at Full Load*

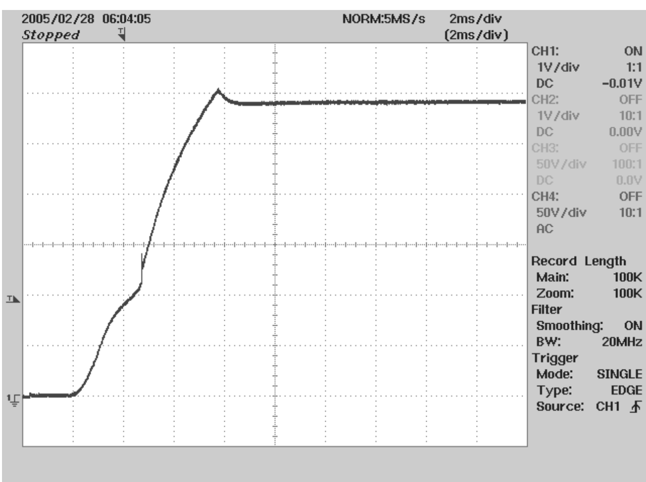


**Figure 12** – Start-up Profile, 120VAC
1 V, 2 ms / div.

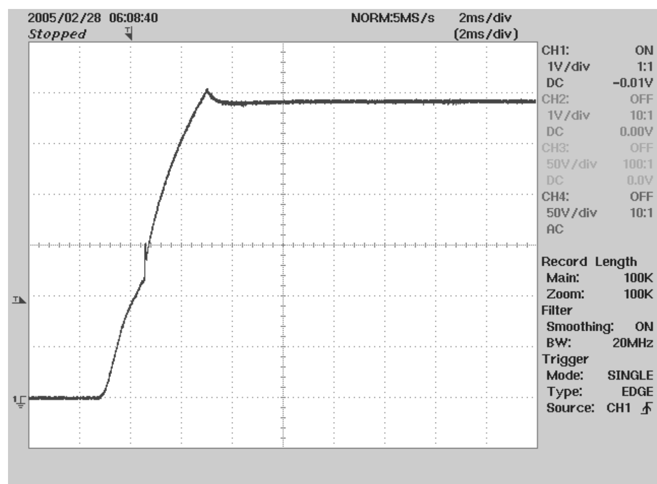


**Figure 13** – Start-up Profile, 240 VAC
1 V, 2 ms / div.



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## 10.3 Drain Voltage and Current Start-up Profile

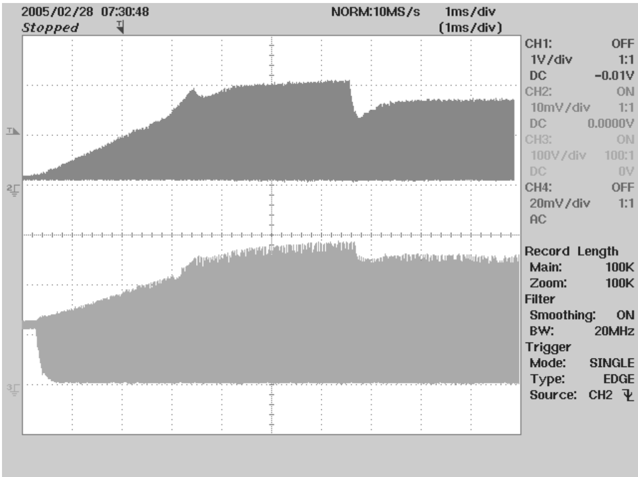


**Figure 14** – 90 VAC Input and Maximum Load.
Upper: $I_{DRAIN}$, 0.5 A / div.
Lower: $V_{DRAIN}$, 100 V & 1 ms / div.

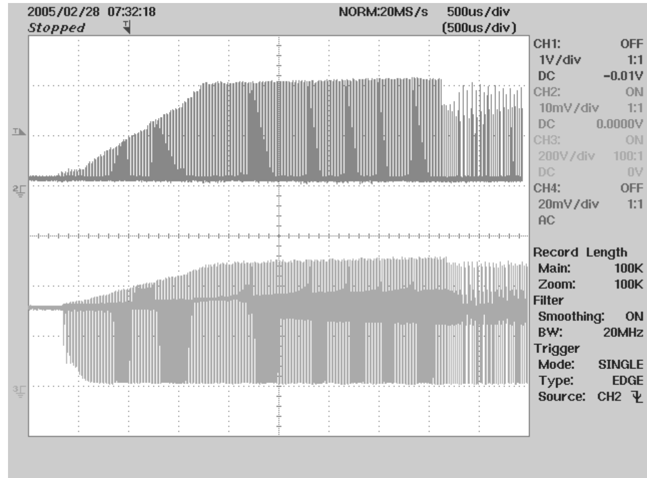


**Figure 15** – 265 VAC Input and Maximum Load.
Upper: $I_{DRAIN}$, 0.5 A / div.
Lower: $V_{DRAIN}$, 200 V & 1 ms / div.


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### 10.4 Load Transient Response (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.

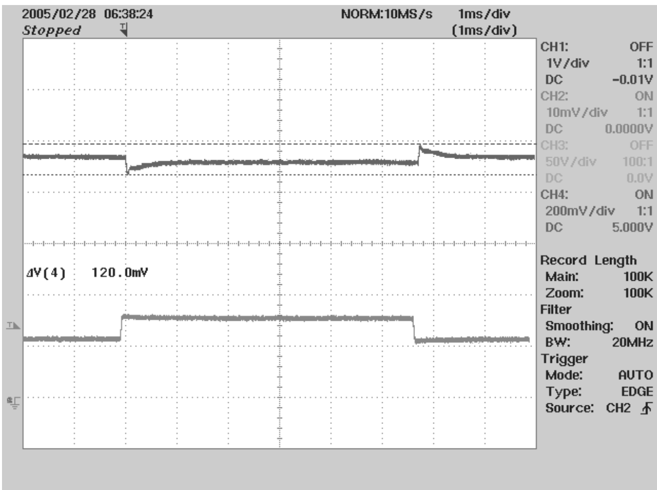


**Figure 16** – Transient Response, 120 VAC, 75-100-75% Load Step.
Bottom: Load Current, 1 A/div.
Top: Output Voltage
2000 mV, 5V offset, 1ms / div.

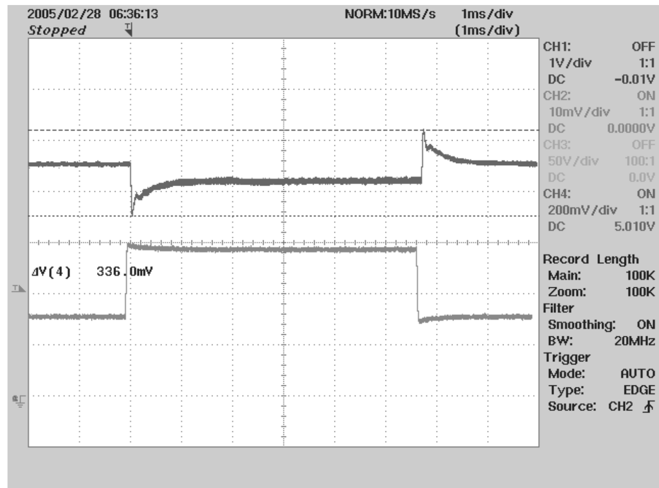


**Figure 17** – Transient Response, 120 VAC, 100-180-100% Load Step
Bottom: Load Current, 1 A/ div.
Top: Output Voltage
200 mV 5V offset, 1 ms / div.


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### 10.5 Output Ripple Measurements

#### 10.5.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to pickup. Details of the probe modification are provided in Figure 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).***

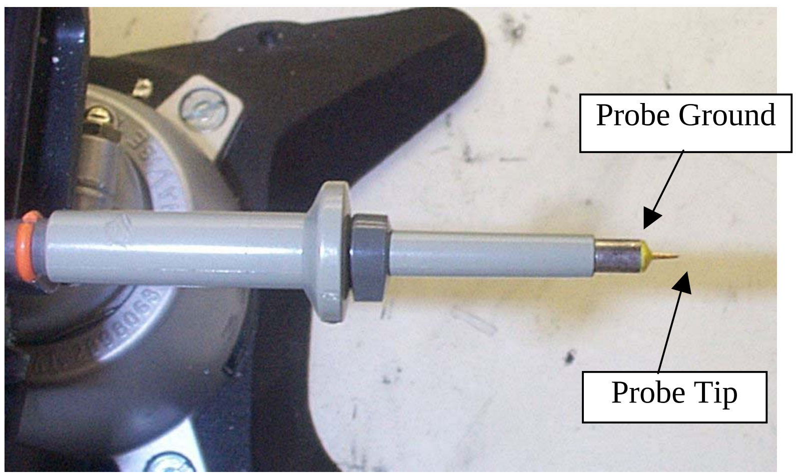


**Figure 18** – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

**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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### 10.5.2 Measurement Results

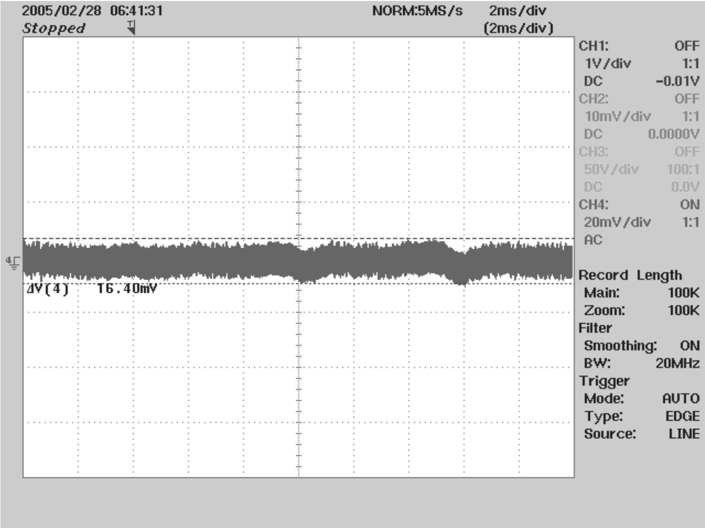


**Figure 20** – Ripple, 120VAC, Full Load.
2 ms, 20 mV / div

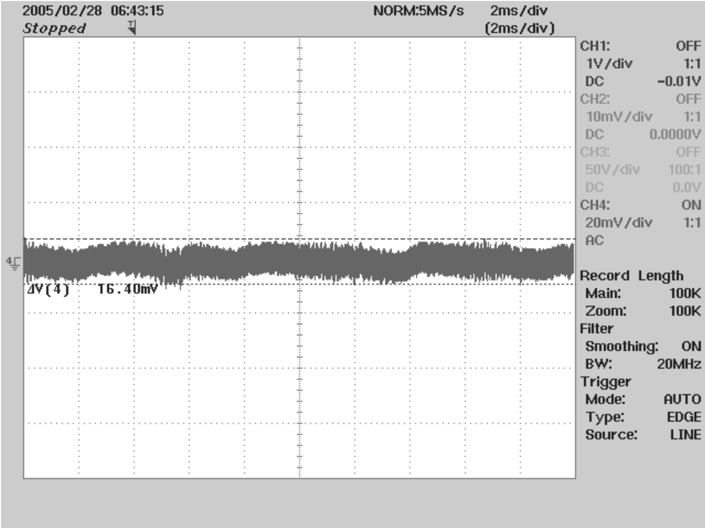


**Figure 21** – Ripple, 240VAC, Full Load.
2 ms, 20 mV / div



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# 11 Control Loop Measurements

## *11.1 120 VAC Maximum and 3A Load*

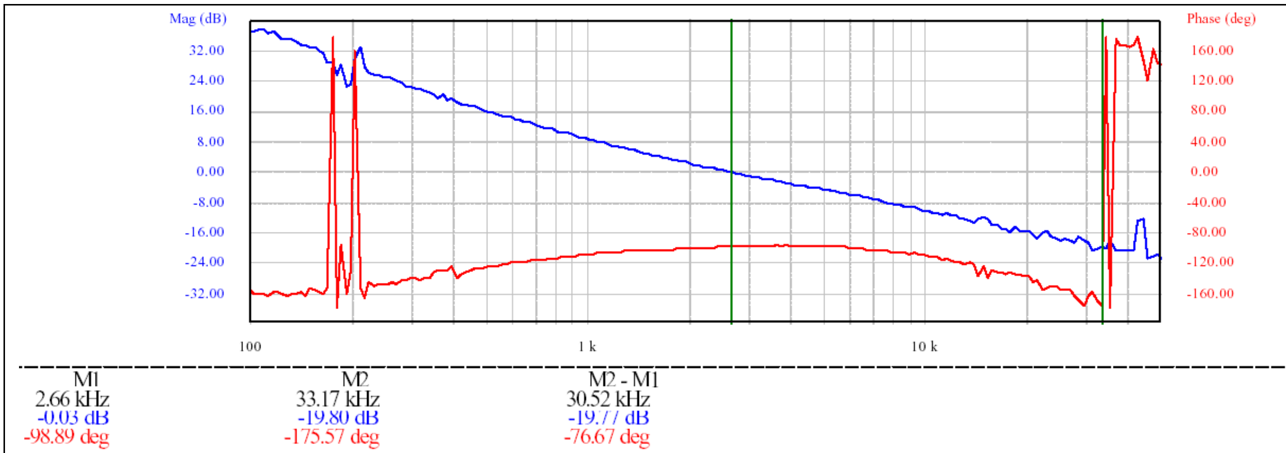


**Figure 22** – Gain-Phase Plot, 120 VAC, Maximum Steady State Load
Vertical Scale: Gain = 8 dB/div, Phase = 40 °/div.
Crossover Frequency = 2.66 kHz Phase Margin = 88.11°

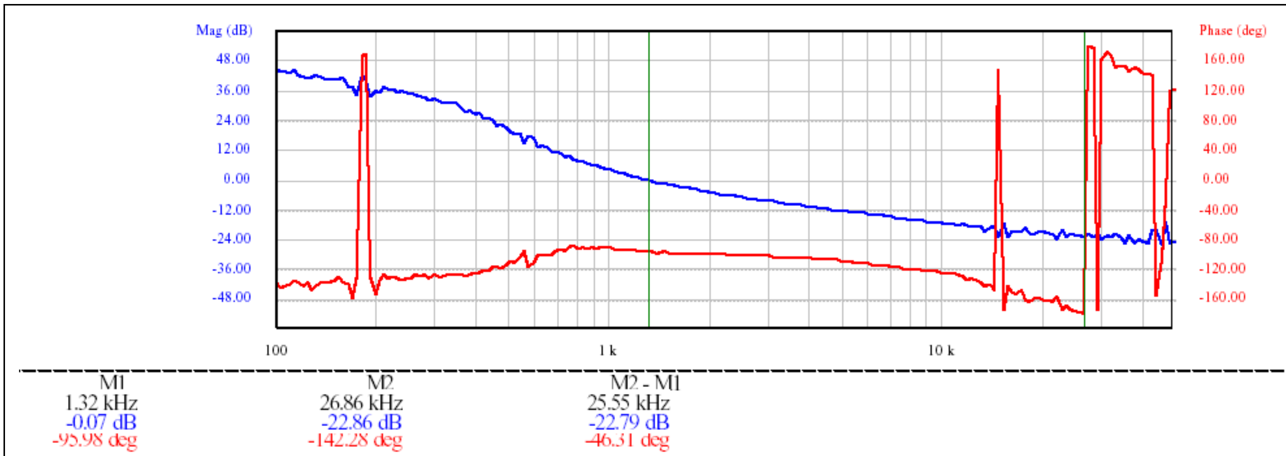


**Figure 23** – Gain-Phase Plot, 120 VAC, 3A Load
Vertical Scale: Gain = 12 dB/div, Phase = 40 °/div.
Crossover Frequency = 1.32 kHz Phase Margin = 84.02°


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## *11.2 240 VAC Maximum and 3A Load*

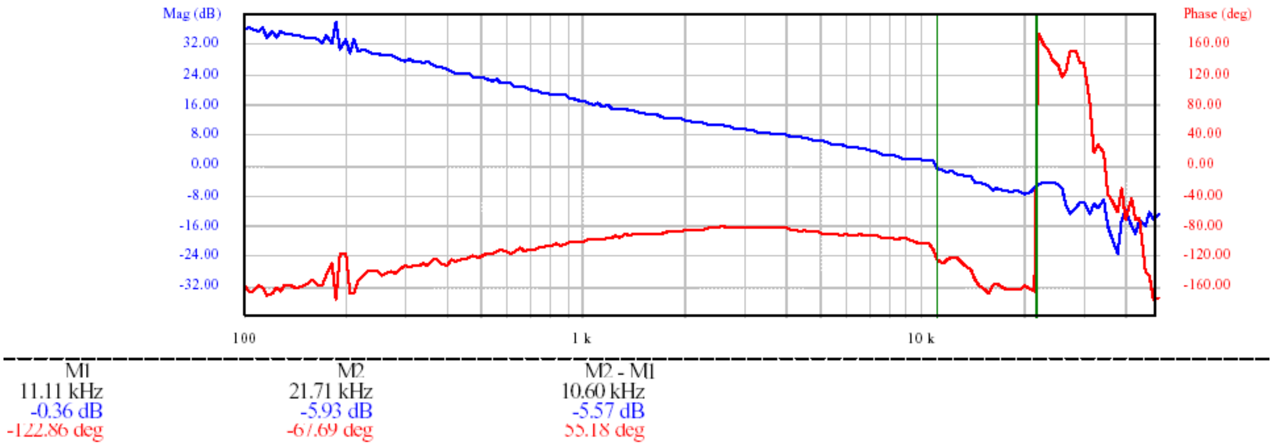


**Figure 24** – Gain-Phase Plot, 240 VAC, Maximum Steady State Load
Vertical Scale: Gain = 8 dB/div, Phase = 40 °/div.
Crossover Frequency = 11.11 kHz Phase Margin = 57.14°

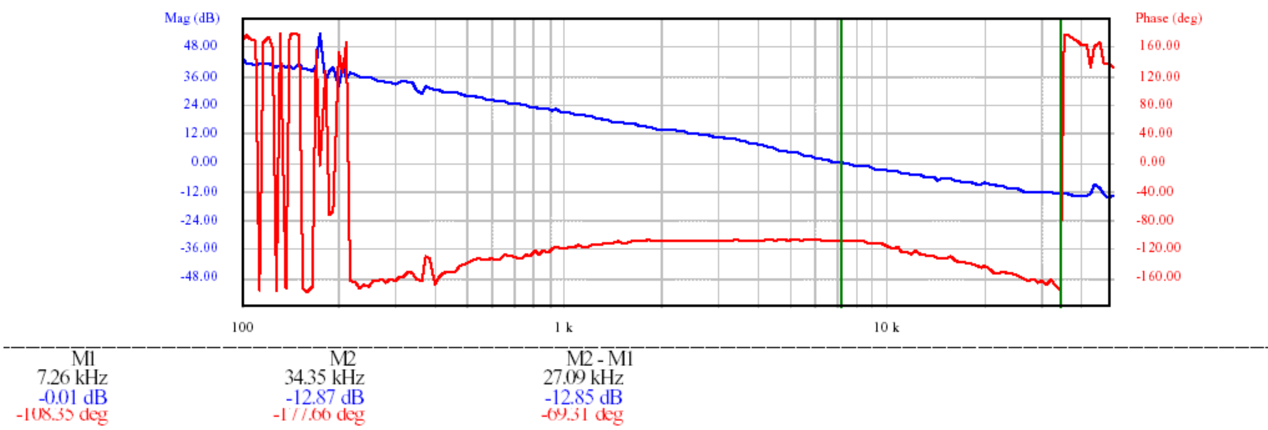


**Figure 25** – Gain-Phase Plot, 240 VAC, 3A Load
Vertical Scale: Gain = 12 dB/div, Phase = 40 °/div.
Crossover Frequency = 7.26 kHz Phase Margin = 71.65°


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# 12 Conducted EMI

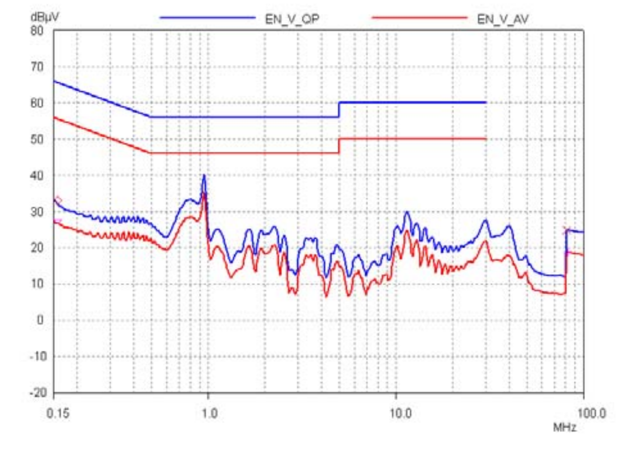


**Figure 26** – Maximum Steady State Load, 120 VAC/ 60 Hz, and EN55022 B Limits (LINE)

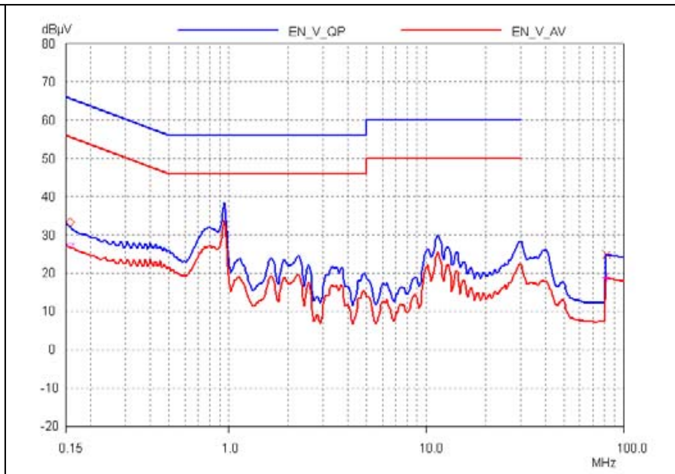


**Figure 27** – Maximum Steady State Load, 120VAC/60 Hz, and EN55022 B Limits (Neutral)

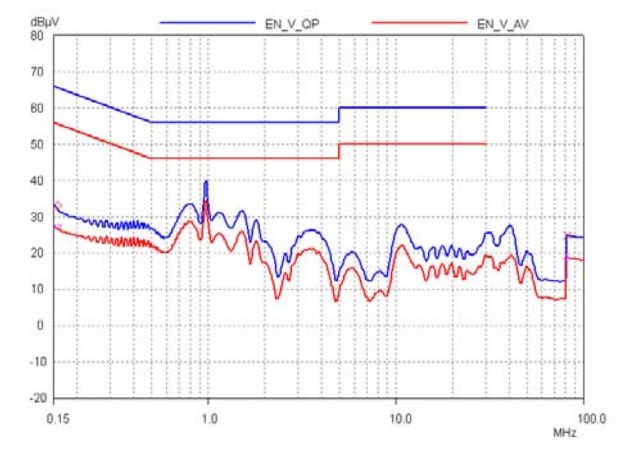


**Figure 28** – Maximum Steady State Load, 240 VAC/ 60 Hz, and EN55022 B Limits (LINE)

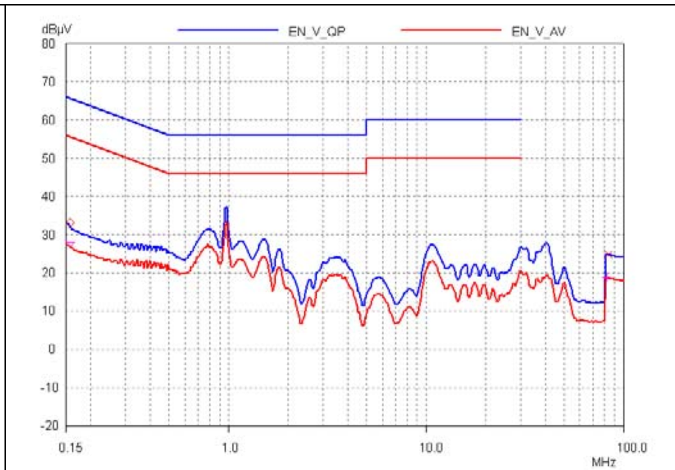


**Figure 29** – Maximum Steady State Load, 240VAC/60 Hz, and EN55022 B Limits (Neutral)



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## 13 Revision History

| Date | Author | Revision | Description & changes | Reviewed |
|---|---|---|---|---|
| 10-26-05 | RSP | 1.0 | Initial Release | KM/JC/VC |



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