# Design Example Report

| | |
|---|---|
| **Title** | ***32W (47W peak) Multiple Output supply using TOP245P*** |
| **Specification** | Input: 195 - 265 VAC<br>Output: 3.3V/3A, 5V/2A (2.5A Peak), 12V/0.5A (1.5A Peak), 20V/0.3A |
| **Application** | Set Top Box |
| **Author** | Power Integrations Applications Department |
| **Document Number** | DER-19 |
| **Date** | March 30, 2004 |
| **Revision** | 1.0 |


**Summary and Features**

This report describes a design for a multiple output power supply, such as required for a Set Top Box, featuring the following:

- Very high full power efficiency (> 83% at full power)
- 32W Continuous power rating
- <0.5W no-load consumption
- Efficiency >75% at 10% output power
- Small DIL08 package for TOP245P requiring no external heatsink
- 50W peak power capability allows for high peak output power demands (e.g. for hard disk spin-up)
- Low EMI (Meets EN55022 with output ground connected to Earth)





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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 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.



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# 1 Introduction

This engineering report describes a multiple output evaluation board designed using TOP245P. The specification chosen is targeted towards new Set Top Box systems that incorporate a hard disk. These systems require a peak power capability when the hard disk is first spun-up.

Peak power operation requires magnetics and diodes specified to handle the currents at the specified peak power point. If peak power operation is not required, designing the supply for maximum continuous power will save additional cost.

The document contains the power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, and measured performance data from the prototype unit shown in Figure 1.

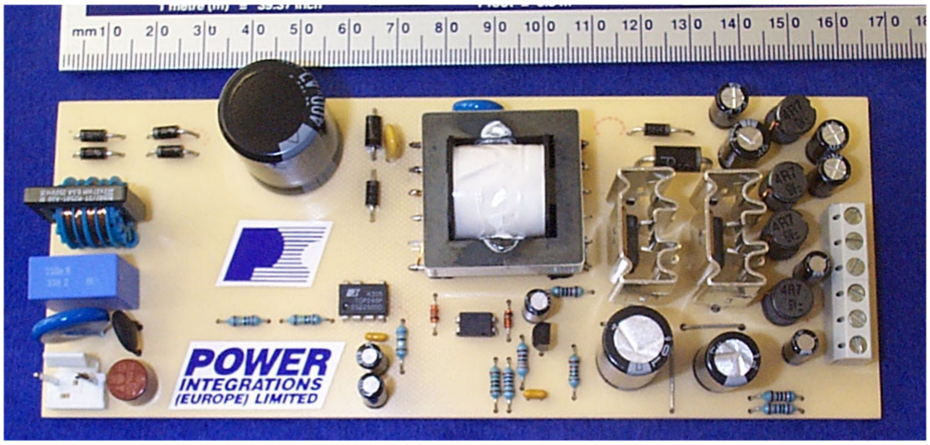


**Figure 1 –** Populated Circuit Board (Scale in cm)

## 2 Power Supply Specification

| Description | Symbol | Min | Typ | Max | Units | Comment |
|---|---|---|---|---|---|---|
| **Input** | | | | | | |
| Voltage | $V_{IN}$ | 195 | | 265 | VAC | 2 Wire – no P.E. |
| Frequency | $f_{LINE}$ | 47 | 50/60 | 64 | Hz | |
| **Output** | | | | | | |
| Output Voltage 1 | $V_{OUT1}$ | | 3.3 | | V | ± 5% |
| Output Ripple Voltage 1 | $V_{RIPPLE1}$ | | | | mV | 20 MHz Bandwidth |
| Output Current 1 | $I_{OUT1}$ | 1 | | 3 | A | |
| Output Voltage 2 | $V_{OUT2}$ | | 5 | | V | ± 5% |
| Output Ripple Voltage 2 | $V_{RIPPLE2}$ | | | | mV | 20 MHz Bandwidth |
| Output Current 2 | $I_{OUT2}$ | 1 | | 2 | A | 2.5A Peak for 10s |
| Output Voltage 3 | $V_{OUT3}$ | | 12 | | V | ± 7% |
| Output Ripple Voltage 3 | $V_{RIPPLE3}$ | | | | mV | 20 MHz Bandwidth |
| Output Current 3 | $I_{OUT3}$ | 0.35 | | 0.5 | A | 1.5A Peak for 10s |
| Output Voltage 4 | $V_{OUT4}$ | | 20 | | V | ± 7% |
| Output Ripple Voltage 4 | $V_{RIPPLE4}$ | | | | mV | 20 MHz Bandwidth |
| Output Current 4 | $I_{OUT4}$ | 0.1 | 0.3 | 0.3 | A | |
| **Total Output Power** | | | | | | |
| Continuous Output Power | $P_{OUT}$ | | | 31.9 | W | |
| Peak Output Power | $P_{OUT\_PEAK}$ | | | 46.4 | W | |
| **Efficiency** | $\eta$ | 75 | | | % | Measured at $P_{OUT}$ (32 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, 12 Ω series impedance, differential and common mode |
| Surge | | 3 | | | kV | 100 kHz ring wave, 500 A short circuit current, differential and common mode |
| Ambient Temperature | $T_{AMB}$ | 0 | | 50 | °C | Free convection, sea level |

**Table 1 - Power Supply Specification**


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# 3 Schematic

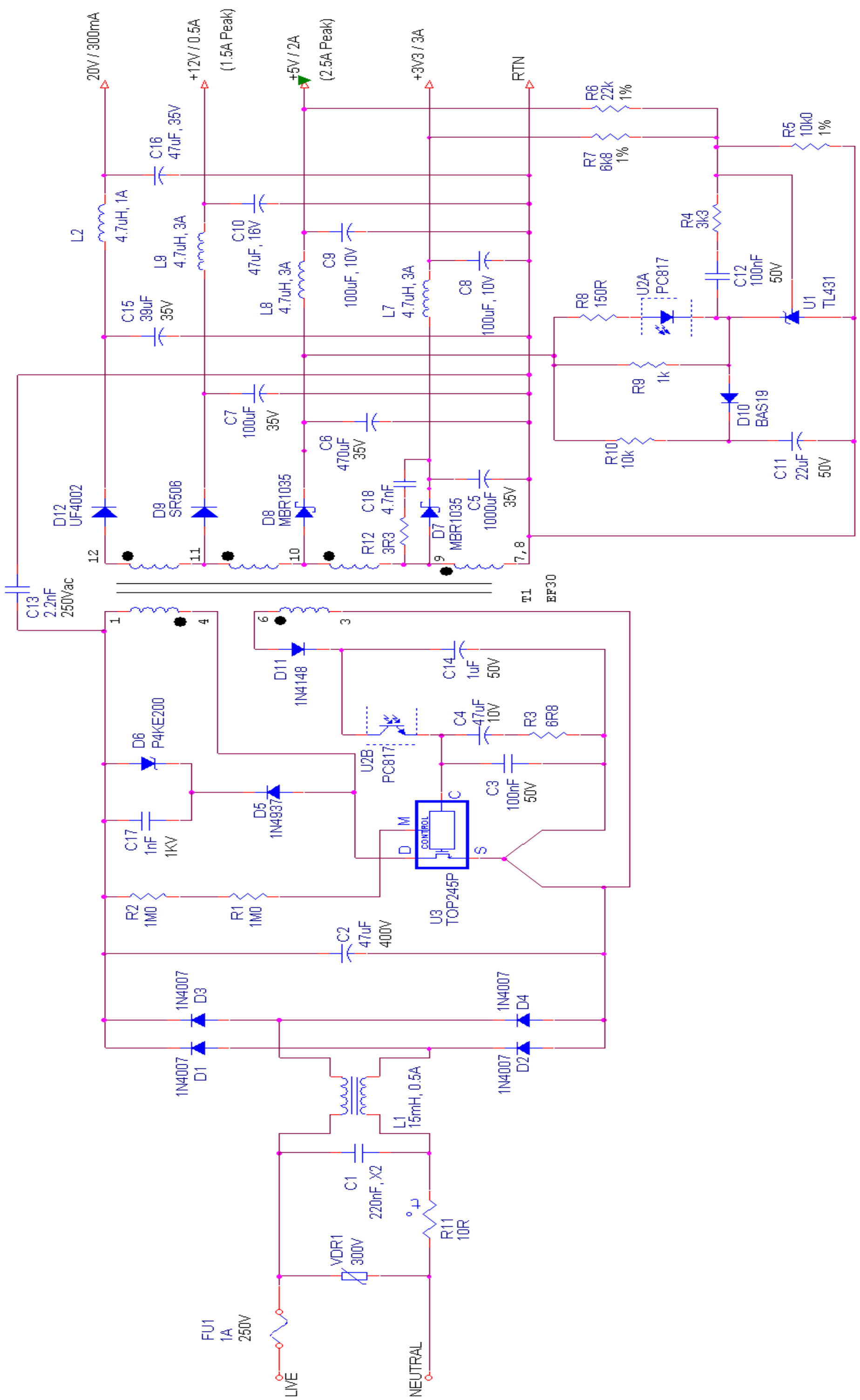


**Figure 2– TOP245P Schematic for 32W cont / 46W peak**

# 4 Circuit Description

This power supply uses the latest generation TOPSwitch in a DIL08 package to minimize heatsink requirements. It is designed for 32W continuous operation in a 50°C ambient with magnetics designed to allow short peak power levels of up to 50W.

## *4.1 Input EMI Filtering*

Due to the frequency jittering function of TOPSwitch, the input EMI filtering is minimal, consisting of a 15mH common-mode choke and 220nF x-capacitor. Protection is provided by a 1A, 250V antisurge fuse. Inrush limiting is provided by a thermistor. Surge protection is provided by a VDR on the input. If only 4kV surge is required, this part can be removed since the TOP245P incorporates over-voltage shutdown giving additional protection.

## *4.2 TOPSwitch Primary*

On the primary side of the supply, the TOPSwitch integrates a number of functions:-

- Frequency jitter which reduces the QP and AV EMI levels by up to 10dB
- Soft-Start which prevents transformer saturation during start-up. This increases long term reliability
- Line UV and OV detection to give additional differential surge withstand capability
- Regulation to zero load without pre-load due to very low minimum duty cycle capability
- Line feed forward which improves 100Hz ripple rejection
- Hysteretic thermal and short circuit protection to increase long term reliability

A 47uF input capacitor has been used to provide the high peak power capability. If peak power operation is not required, this can be reduced to 33uF, 400V which will save further cost.

## *4.3 Output Rectification*

A fully AC stacked design has been used to give good cross-regulation. A snubber is placed across D7 to reduce high frequency common-mode EMI emissions. Post filters are used on all outputs to meet noise and ripple requirements.

## *4.4 Output Feedback*

Full PWM feedback has been implemented using a TL431 reference and opto-coupler. Feedback is split over the 3V3 and 5V rails, each giving equal influence to the feedback network. D10, R10 and C11 provide a soft-finish function, ensuring a monotonic rise in the output voltages with zero overshoot.


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# 5 PCB Layout

The evaluation board was implemented using a single copper layer. Figure 3 shows the component placement and underside copper routing.

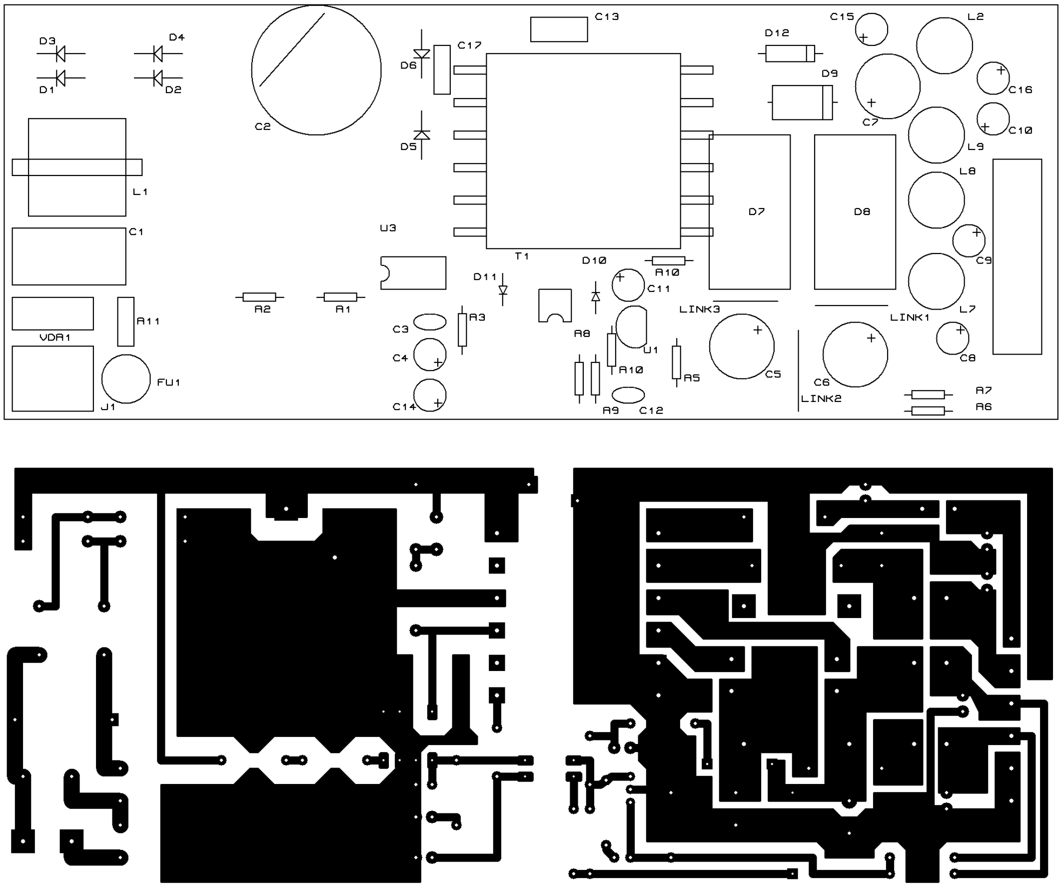


**Figure 3** – Printed Circuit Layout (Scale not 1:1)

# 6 Bill Of Materials

| Reference | Quantity | Value |
|---|---|---|
| R1,R2 | 2 | 1M |
| R3 | 1 | 6R8 |
| R4 | 1 | 3k3 |
| R5 | 1 | 10k, 1% |
| R6 | 1 | 22k, 1% |
| R7 | 1 | 6k8, 1% |
| R8 | 1 | 150R |
| R9 | 1 | 1k |
| R10 | 1 | 10k |
| R11 | 1 | 20R, 2W NTC |
| R12 | 1 | 3R3 |
| | | |
| C1 | 1 | 220nF, X2 CAP |
| C2 | 1 | 47uF, 400V |
| C3,C12 | 2 | 100nF |
| C4 | 1 | 47uF, 10V |
| C5 | 1 | 1000uF, 35V |
| C6 | 1 | 470uF, 35V |
| C7 | 1 | 100uF, 35V |
| C8,C9 | 2 | 100uF, 10V |
| C10 | 1 | 47uF, 16V |
| C11 | 1 | 22uF, 10V |
| C13 | 1 | 2.2nF, Y1_CLASS |
| C14 | 1 | 1uF, 50V |
| C15 | 1 | 39uF, 35V |
| C16 | 1 | 47uF, 35V |
| C17 | 1 | 1nF, 1kV |
| C18 | 1 | 4.7nF |
| | | |
| U1 | 1 | TL431 |
| U2 | 1 | PC817 |
| U3 | 1 | TOP245P |
| | | |
| D1,D2,D3,D4 | 4 | 1N4007 |
| D5 | 1 | 1N4937 |
| D6 | 1 | P4KE200 |
| D7,D8 | 2 | MBR1035 |
| D9 | 1 | SR506 |
| D10 | 1 | BAS19 |
| D11 | 1 | IN4148 |
| D12 | 1 | UF4002 |
| | | |
| FU1 | 1 | 1A, 250V |
| T1 | 1 | EF30 Custom Transformer |
| | | |
| L2 | 1 | 4.7uH, 1A |
| L7,L8,L9 | 3 | 4.7uH, 3.2A |
| VDR1 | 1 | 300V |

Total of 52 components


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# 7 Transformer Specification

## 7.1 Electrical Diagram

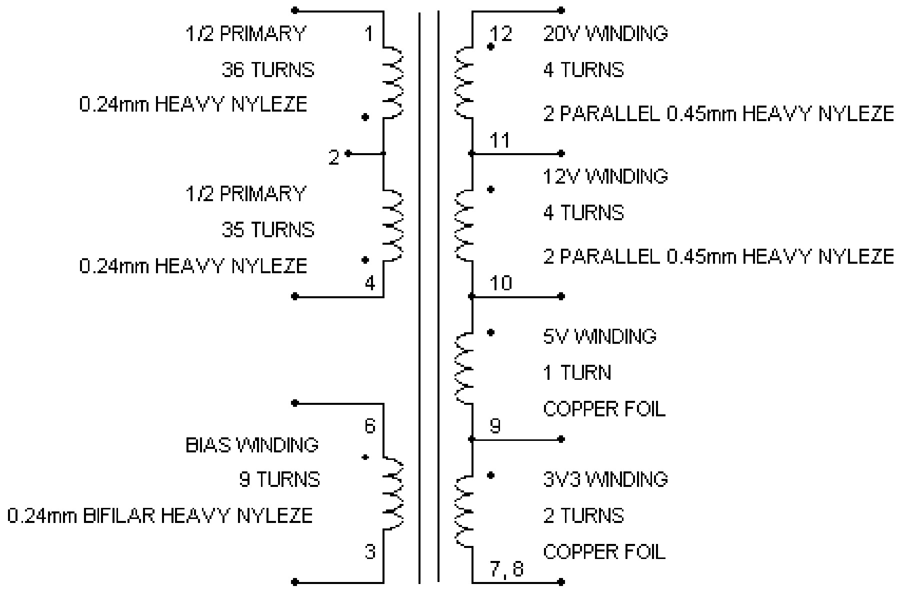



**Figure 4** –Transformer Electrical Diagram

## 7.2 Electrical Specifications

| | | |
|---|---|---|
| **Electrical Strength** | 1 second, 60 Hz, from Pins 1-4 to Pins 7-12 | 3000 VAC |
| **Primary Inductance** | Pins 1-4, all other windings open, measured at 100 kHz, 0.4 VRMS | 1180 μH, -0/+20% |
| **Resonant Frequency** | Pins 1-4, all other windings open | 600 kHz (Min.) |
| **Primary Leakage Inductance** | Pins 1-4, with Pins 7-8 shorted, measured at 100 kHz, 0.4 VRMS | 50 μH (Max.) |

## 7.3 Materials

| Item | Description |
|---|---|
| **[1]** | Core: EF30 CORE, 3C85, Gapped for 234nH/$T^2$ (Approximately 0.28mm) |
| **[2]** | Bobbin: EF30, 10 pin |
| **[3]** | Magnet Wire: 0.24mm Diameter Heavy Nyleze |
| **[4]** | Copper Foil: See section below |
| **[5]** | Tape: 16mm wide insulation tape |
| **[6]** | Tape: 3mm margin tape |
| **[7]** | Magnet Wire: 0.45mm Diameter Heavy Nyleze |
| **[8]** | Varnish |

## 7.4 Transformer Build Diagram

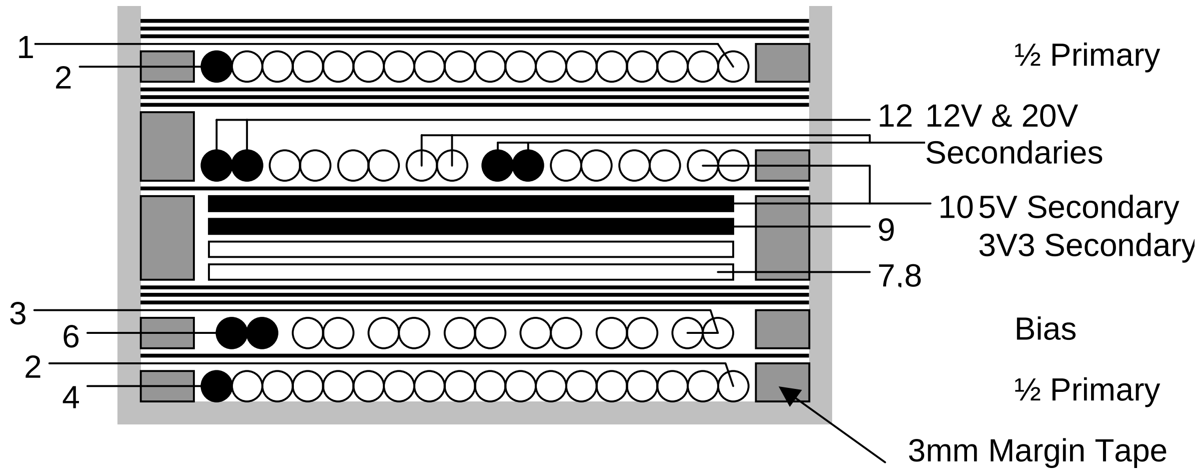
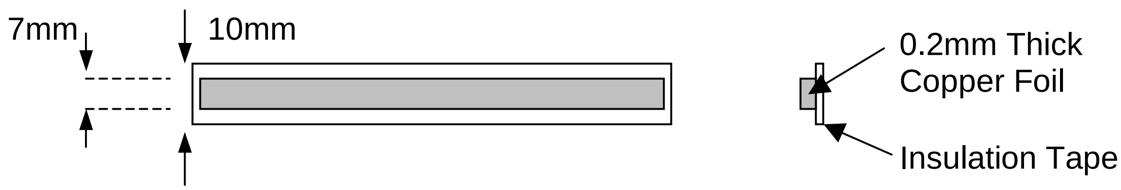



**Figure 5** – Transformer Build Diagram




## 7.5 Transformer Construction

| | |
|---|---|
| **Bobbin Preparation** | Place 3mm of Margin tape on each side of the EF30 Bobbin |
| **½ Primary** | Start at Pin 4. Wind 36 turns of item [3] in approximately 1 layer. Bring finish lead back to start. Finish on Pin 2. |
| **Basic Insulation** | Use two layers of item [5] for basic insulation. |
| **Bifilar Bias Winding** | Starting at Pin 6, wind 9 bifilar turns of item [3]. Spread turns evenly across bobbin. Finish at Pin 3. |
| **Insulation** | Use three layers of item [5] for safety insulation. |
| **3V3 and 5V Windings** | Start at Pins 7 and 8. Wind 2 turns of copper foil [4]. Bring termination wire out onto pin 9. Continue with one further copper foil turn and finish with termination on pin 10. |
| **12V and 20V Windings** | Start at Pin 10. Wind 4 turns of 4 parallel strands of item [7] using half the bobbin width. Terminate on pin 11. Continue with 4 further turns of 4 parallel strands of item [7] using the remaining half bobbin width. Finish on pin 12. |
| **½ Primary** | Start at Pin 2. Wind 35 turns of item [3] in approximately 1 layer. Bring finish lead back to start. Finish on Pin 1. |
| **Outer Wrap** | Wrap windings with 3 layers of tape item [5]. |
| **Final Assembly** | Assemble and secure core halves. Varnish impregnate (item [8]). |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# 8 Transformer Spreadsheets

This design was produced using PIExpert assuming a TOP245P device with a current limit capability of 1.1A and an Rdson of 4Ω. The data below reflects the full continuous load, which gives approximately 0.7A peak primary current. The transformer has been designed to operate with safe flux levels with primary currents of up to 1.2A allowing for the peak power capability.

## Power Supply Input

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VACMIN | Volts | 195 | | | | | Min Input AC Voltage |
| VACMAX | Volts | 265 | | | | | Max Input AC Voltage |
| FL | Hertz | 50 | | | | | AC Main Frequency |
| TC | mSeconds | 1.81 | | | | | Bridge Rectifier Conduction Time Estimate |
| Z | | 0.68 | | | | | Loss Allocation Factor |
| N | % | 74.0 | | | | | Efficiency Estimate |

## Power Supply Outputs

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VOx | Volts | | 3.30 | 5.00 | 12.00 | 20.00 | Output Voltage |
| IOx | Amps | | 3.000 | 2.000 | 0.500 | 0.300 | Output Current |
| VB | Volts | 15.00 | | | | | Bias Voltage |
| IB | Amps | 0.006 | | | | | Bias Current |

## Device Variables

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Device | | TOP245P | | | | | Device Name |
| PO | Watts | 31.99 | | | | | Total Output Power |
| VDRAIN | Volts | 678 | | | | | Maximum Drain Voltage Estimate (Includes Effect of Leakage Inductance) |
| FS | Hertz | 132000 | | | | | Device Switching Frequency |
| KRPKDP | | 0.70 | | | | | Ripple to Peak Current Ratio |
| KI | | 1.00 | | | | | External Current Limit Ratio |
| IP | Amps | 0.75 | | | | | Peak Primary Current |
| IRMS | Amps | 0.31 | | | | | Primary RMS Current |
| DMAX | | 0.36 | | | | | Maximum Duty Cycle |

## Power Supply Components Selection

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CIN | uFarads | 47.0 | | | | | Input Filter Capacitor |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VMIN | Volts | 247 | | | | | Minimum DC Input Voltage |
| VMAX | Volts | 375 | | | | | Maximum DC Input Voltage |
| VCLO | Volts | 200 | | | | | Clamp Zener Voltage |
| PZ | Watts | 2.0 | | | | | |
| VDB | Volts | 0.7 | | | | | Bias Winding Diode Forward Voltage Drop |
| PIVB | Volts | 59 | | | | | Bias Rectifier Maximum Peak Inverse Voltage |

## Power Supply Output Parameters

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VDx | Volts | | 0.5 | 0.5 | 0.7 | 0.7 | Output Winding Diode Forward Voltage Drop |
| PIVSx | Volts | | 14 | 20 | 47 | 77 | Output Rectifier Maximum Peak Inverse Voltage |
| ISPx | Amps | | 7.74 | 5.16 | 1.29 | 0.77 | Peak Secondary Current |
| ISRMSx | Amps | | 4.22 | 2.81 | 0.70 | 0.42 | Secondary RMS Current |
| IRIPPLEx | Amps | | 2.96 | 1.97 | 0.49 | 0.30 | Output Capacitor RMS Ripple Current |

## Transformer Construction Parameters

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Core/Bobbin | | E30/15/7 Margin | | | | | Core and Bobbin Type |
| Core Manuf. | | Generic | | | | | Core Manufacturing |
| Bobbin Manuf | | Generic | | | | | Bobbin Manufacturing |
| LP | uHenries | 1181 | | | | | Primary Inductance |
| NP | | 71 | | | | | Primary Winding Number of Turns |
| NB | | 8.26 | | | | | Bias Winding Number of Turns |
| OD Actual | mm | 0.25 | | | | | Primary Actual Wire Diameter |
| Primary Current Density | A/mm^2 | 6 | | | | | Primary Winding Current Density |
| VOR | Volts | 135.00 | | | | | Reflected Output Voltage |
| BW | mm | 17.30 | | | | | Bobbin Physical Winding Width |
| M | mm | 3.0 | | | | | Safety Margin Width |
| L | | 2.0 | | | | | Number of Primary Layers |


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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| AE | cm^2 | 0.60 | | | | | Core Effective Cross Section Area |
| ALG | nH/T^2 | 234 | | | | | Gapped Core Effective Inductance |
| BM | mTesla | 207 | | | | | Maximum Operating Flux Density |
| BP | mTesla | 267 | | | | | Peak Flux Density |
| BAC | mTesla | 73 | | | | | AC Flux Density for Core Curves |
| LG | mm | 0.28 | | | | | Gap Length |
| LL | uHenries | 17.7 | | | | | Estimated Transformer Primary Leakage Inductance |
| LSEC | nHenries | 20 | | | | | Estimated Secondary Trace Inductance |

## Secondary Parameters

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NSx | | | 2.00 | 2.89 | 6.68 | 10.89 | Secondary Number of Turns |
| Rounded Down NSx | | | | 2 | 6 | 10 | Rounded to Integer Secondary Number of Turns |
| Rounded Down Vox | Volts | | | 3.27 | 10.62 | 18.17 | Auxiliary Output Voltage for Rounded to Integer NSx |
| Rounded Up NSx | | | | 3 | 7 | 11 | Rounded to Next Integer Secondary Number of Turns |
| Rounded Up Vox | Volts | | | 5.16 | 12.51 | 20.05 | Auxiliary Output Voltage for Rounded to Next Integer NSx |
| ODS Actual Range | mm | | 0.64 - 1.03 | 0.51 - 0.81 | 0.25 - 0.40 | 0.20 - 0.32 | Secondary Actual Wire Diameter Range Comment: Wire diameter is greater than recommended maximum (0.40 mm) and may overheat. Tip: Consider a parallel winding technique (bifilar, trifilar), increase size of transformer (larger BW), reduce margin (M). |

# 9 Performance Data

All measurements performed at room temperature, 50 Hz input frequency.

## *9.1 Efficiency*

Full power efficiency was measured as a function of line voltage and Figure 6 gives the resulting profile.

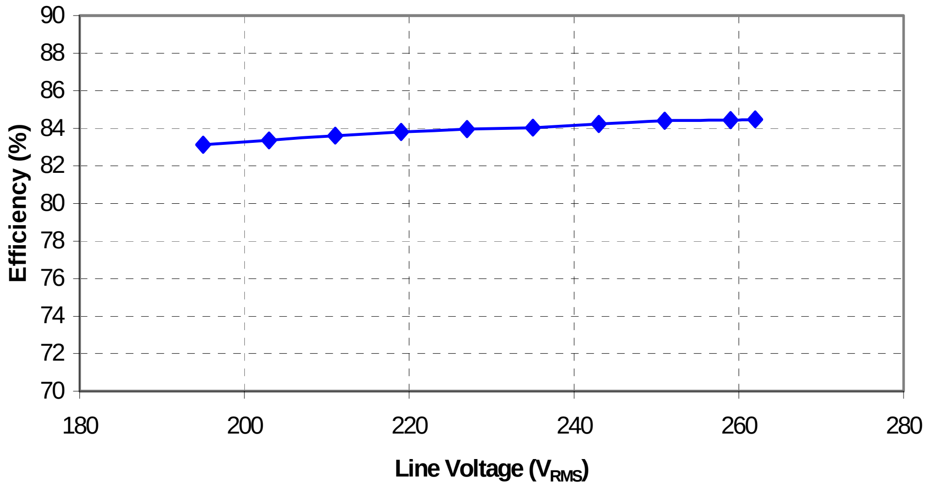


**Figure 6**- Full Continuous Power Conversion Efficiency

Efficiency as a function of output power was measured at 230V input, each rail load increased from zero to 100% load simultaneously in 10% load steps. Figure 7 shows the resulting efficiency profile.

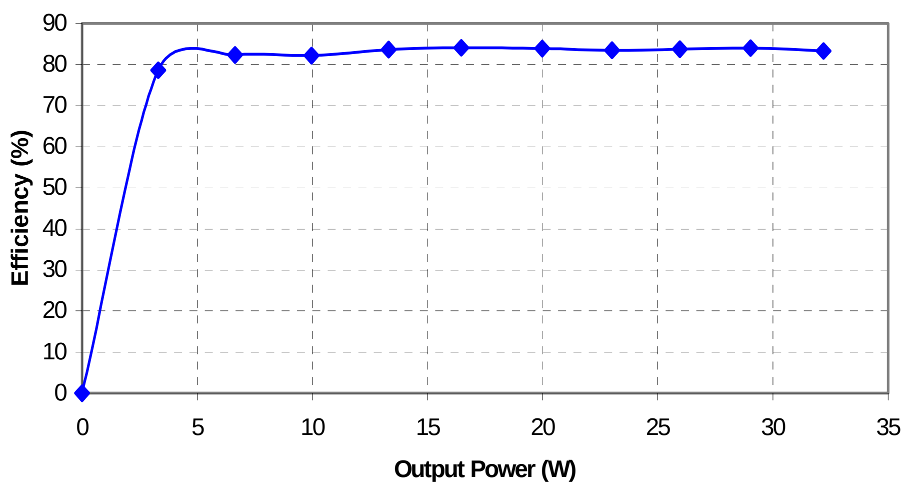


**Figure 7 - Efficiency Variation with Load**



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### 9.2 No-load Input Power

Under zero output load conditions, the input power was measured at 400mW at 265$V_{AC}$ input.

### 9.3 Peak Power

The prototype was loaded to the specified peak power levels in Table 1 and the temperature of the TOP245P monitored. The 46W peak power level can easily be supplied in 25°C ambient conditions. Under peak power levels, the TOP245P temperature was measured at 86°C. Thus, a peak power of 46W in 50°C ambient is achievable and only thermal shutdown will limit the time the peak power can be delivered for. With the high operating efficiency of this design, peak power levels of above 50W can be achieved for a few seconds.

### 9.4 Regulation

#### 9.4.1 Load

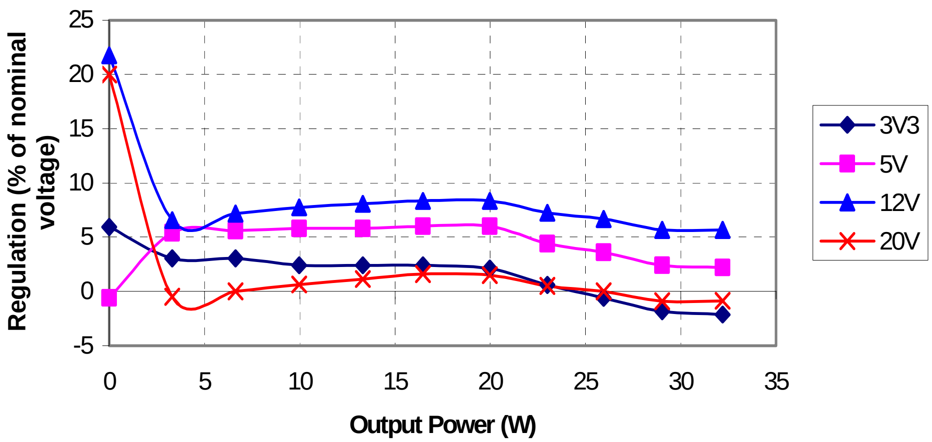


**Figure 8** – Load Regulation, Room Temperature, 230$V_{AC}$ Input

### 9.4.2 Line

Line regulation was measured at full continuous output power. The regulation, expressed as a percentage on nominal rail voltage, and as a function of line voltage is shown in Figure 9 below.

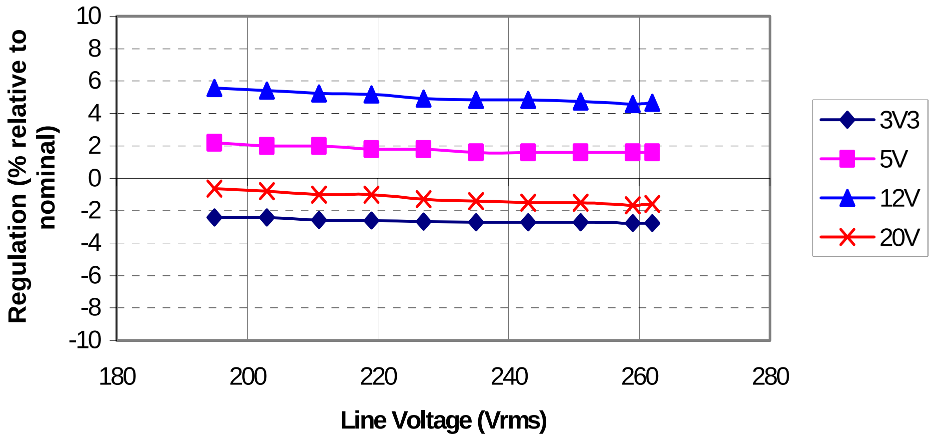


**Figure 9** – Line Regulation, Room Temperature, Full Load.

## *9.5 Cross Regulation*

Figure 10 gives the cross regulation results at 230V input.

| 3V3 - 5V - 12V - 20V | 3V3 | 5V | 12V | 20V |
|---|---|---|---|---|
| XXXX | 3.38 | 5.28 | 12.70 | 19.95 |
| XXXM | 3.39 | 5.28 | 12.67 | 19.63 |
| XXMX | 3.38 | 5.28 | 12.63 | 19.92 |
| XXMM | 3.39 | 5.00 | 12.62 | 19.64 |
| XMXX | 3.40 | 5.19 | 12.94 | 20.53 |
| XMXM | 3.39 | 5.18 | 12.79 | 19.86 |
| XMMX | 3.39 | 5.19 | 12.77 | 20.30 |
| XMMM | 3.33 | 5.10 | 12.55 | 19.58 |
| MXXX | 3.33 | 5.25 | 13.19 | 20.85 |
| MXXM | 3.28 | 5.20 | 12.87 | 20.00 |
| MXMX | 3.30 | 5.17 | 12.92 | 20.57 |
| MXMM | 3.27 | 5.10 | 12.72 | 19.80 |
| MMXX | 3.25 | 5.15 | 13.00 | 20.76 |
| MMXM | 3.24 | 5.12 | 12.80 | 19.93 |
| MMMX | 3.24 | 5.14 | 12.83 | 20.79 |
| MMMM | 3.22 | 5.12 | 12.69 | 19.84 |

| | | | | |
|---|---|---|---|---|
| Min (V) | 3.22 | 5.00 | 12.55 | 19.58 |
| Max (V) | 3.40 | 5.28 | 13.19 | 20.85 |
| % Below | -2.42 | 0.00 | 4.58 | -2.10 |
| % Above | 3.03 | 5.60 | 9.92 | 4.25 |

| | | | | |
|---|---|---|---|---|
| Min Load (X) | 1 | 1 | 0.35 | 0.1 |
| Max Load (M) | 3 | 2 | 0.5 | 0.3 |

**Figure 10 - Cross Regulation**


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# 10 Thermal Performance

At full continuous output power, the temperature of key components was monitored using thermocouples. In a 25°C ambient, Figure 11 gives the resulting temperature profiles.

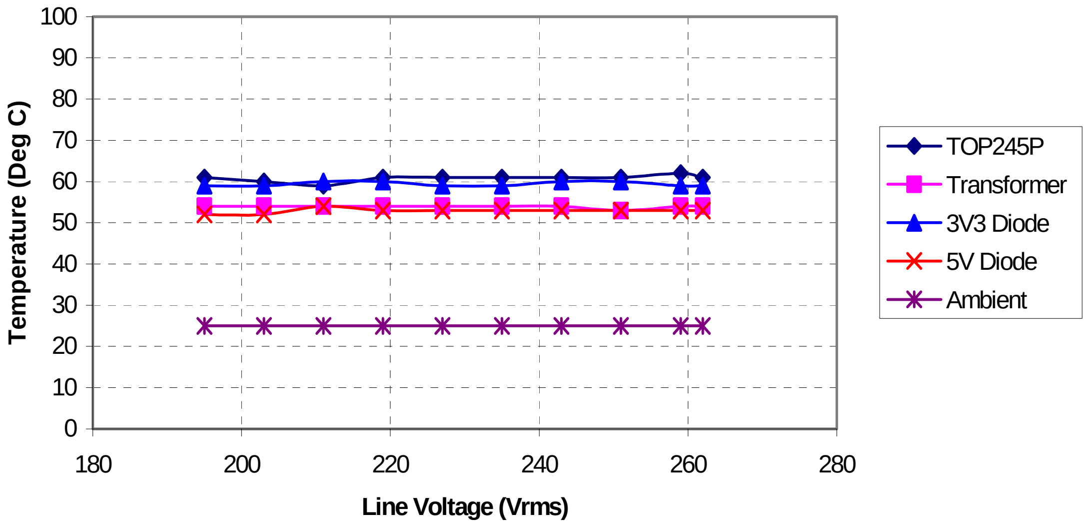


**Figure 11 -** Key Component Temperature Rise variation with Line Voltage

All key components are operating well within specified temperature ranges and this design would support operation in ambient levels up to 50°C.

# 11 Waveforms

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

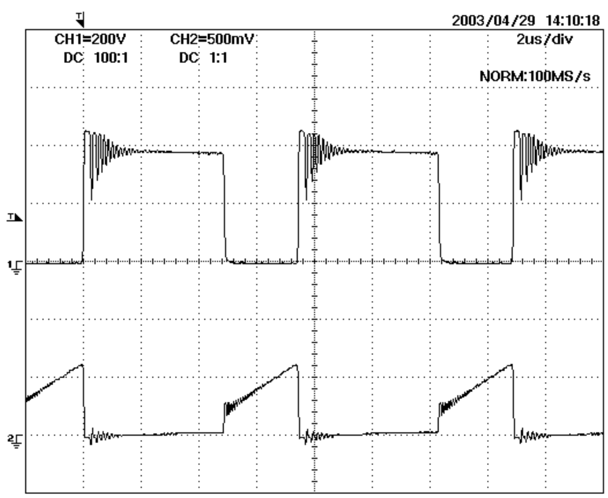


**Figure 12 -** 195 $V_{AC}$, Full Continuous Load

Lower: $I_{DRAIN}$, 0.5 A / div Upper: $V_{DRAIN}$, 200 V, 2 µs / div

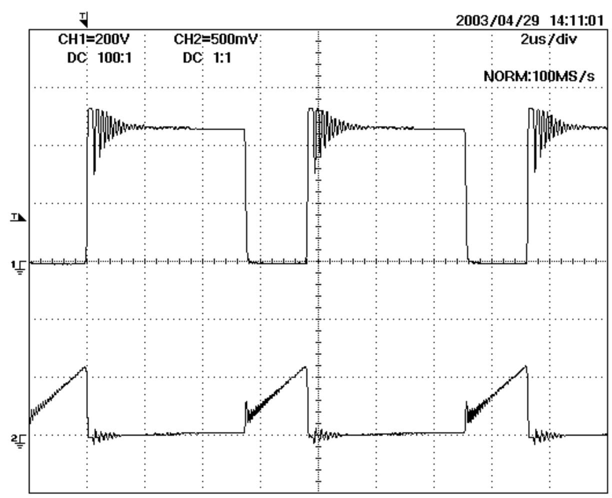


**Figure 13** - 265 VAC, Full Continuous Load

Lower: $I_{DRAIN}$, 0.5 A / div Upper: $V_{DRAIN}$, 200 V / div

## *11.2 Output Voltage Start-up Profile (Full Power)*

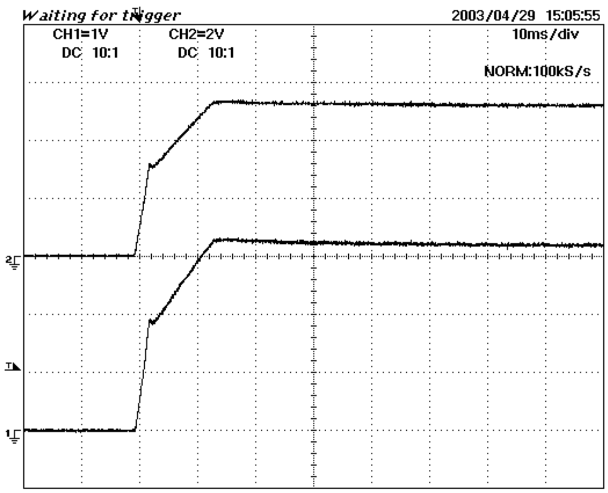


**Figure 14** -Start-up Profile, 230$V_{AC}$

Lower: 3V3, 1 V / div
Upper: 5V, 2 V / div

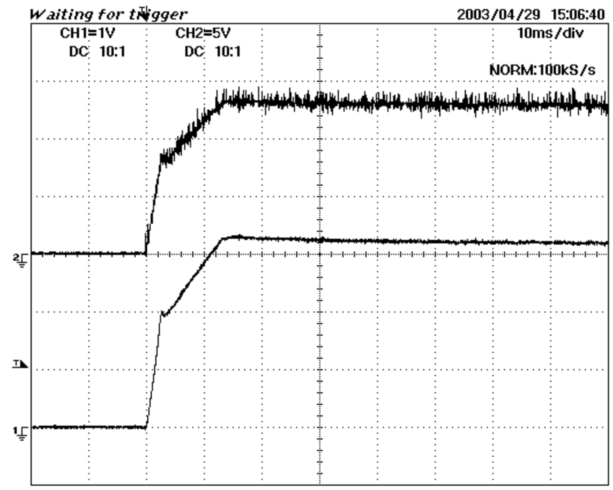


**Figure 15** - Start-up Profile, 230$V_{AC}$

Lower: 3V3, 1 V / div
Upper: 12V, 5 V / div

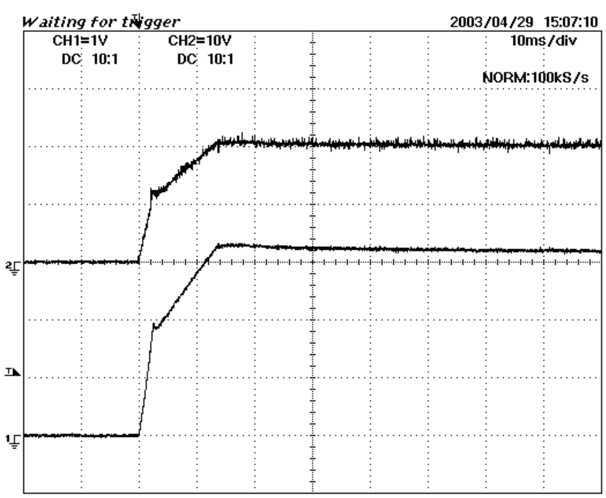


**Figure 16** - Start-up Profile, 230$V_{AC}$

Lower: 3V3, 1 V / div
Upper: 20V, 10 V / div



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## 11.3 Drain Voltage and Current Start-up Profile

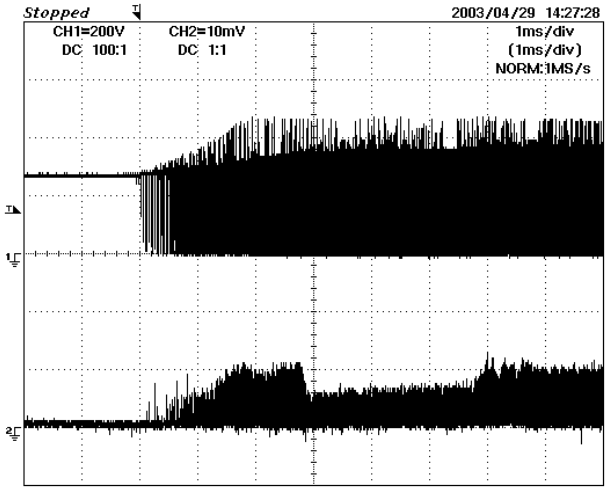


**Figure 17 -** 195 $V_{AC}$ Input and Maximum Load.

Lower: $I_{DRAIN}$, 0.5 A / div.
Upper: $V_{DRAIN}$, 200 V & 1 ms / div.

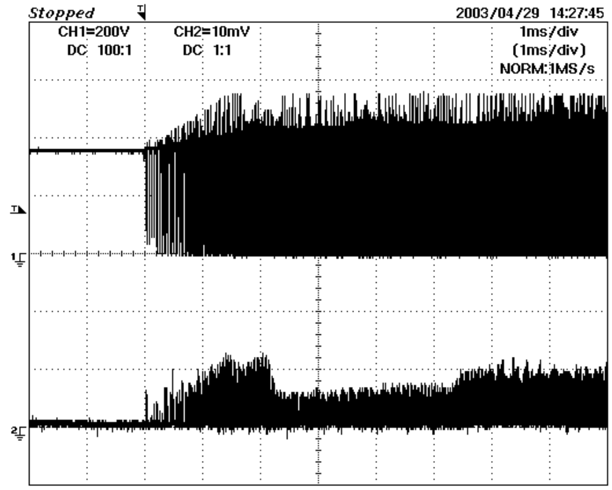


**Figure 18 -** 265 VAC Input and Maximum Load.

Lower: $I_{DRAIN}$, 0.5 A / div.
Upper: $V_{DRAIN}$, 200 V & 1 ms / div.

## 11.4 Load Transient Response

Figure 19 shows the load transient response of the 3V3 rail when subjected to a load change for 3A to 4A.

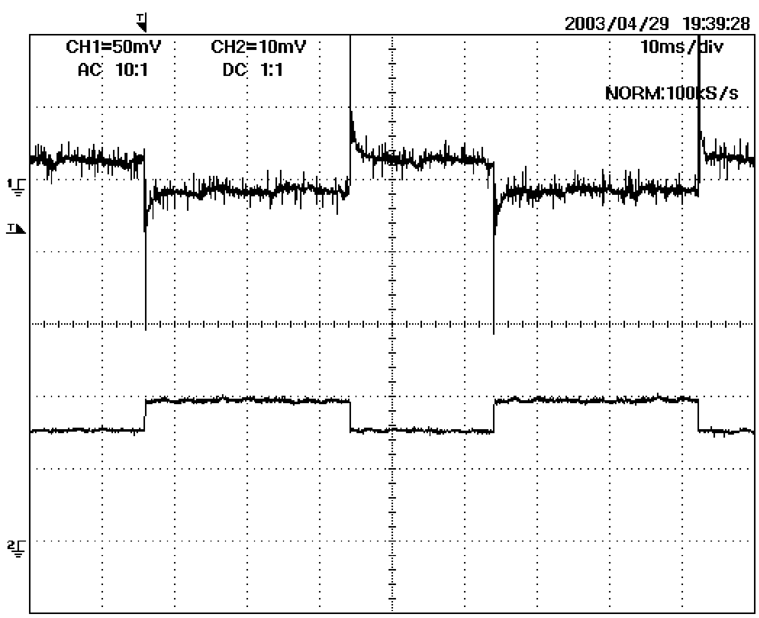


**Figure 19** – Transient Response, 230 $V_{AC}$, 3A to 4A Step load change on 3V3. Full Load.

Lower – Current at 2A / div, Upper – AC coupled 3V3 voltage at 50mV / div

## 11.5 Output Ripple Measurements

### 11.5.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to pickup. Details of the probe modification are provided in Figure 20 and Figure 21.

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).***

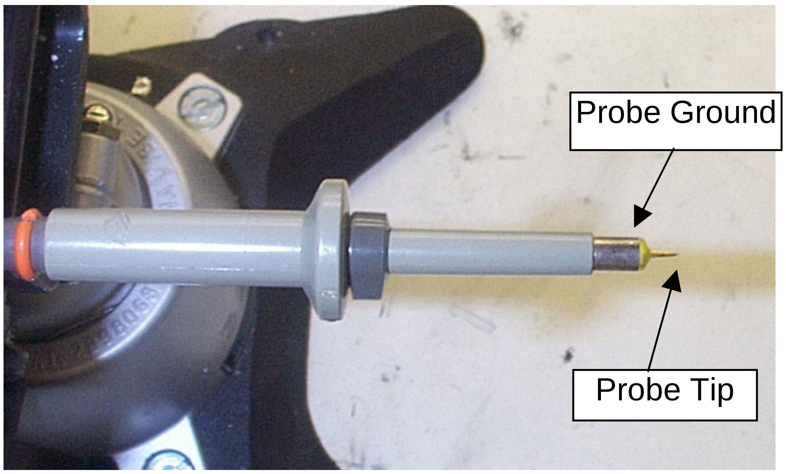


**Figure 20** - Oscilloscope Probe Prepared for Ripple Measurement.

(End Cap and Ground Lead Removed)

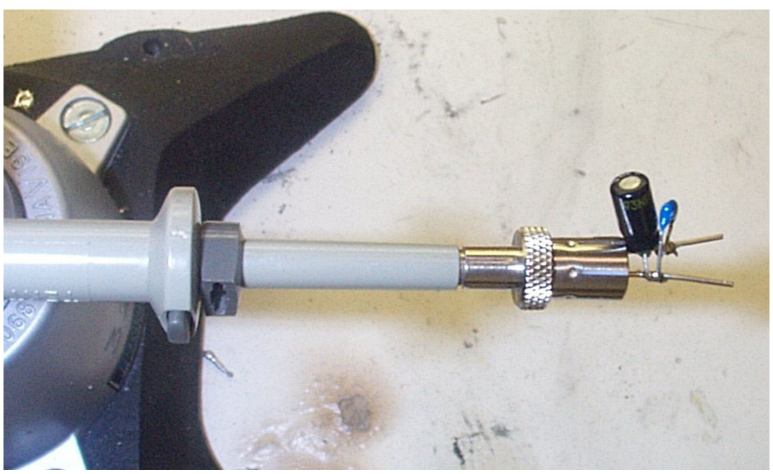

**Figure 21** - Oscilloscope Probe with Probe Master 5125BA BNC Adapter.

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



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### 11.5.2 Measurement Results

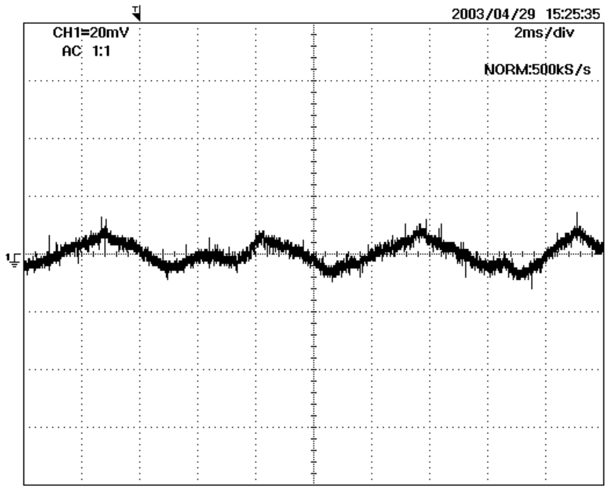


**Figure 22** – 3V3 Ripple, 230 $V_{AC}$, Full Load.

2 ms / div, 20 mV / div

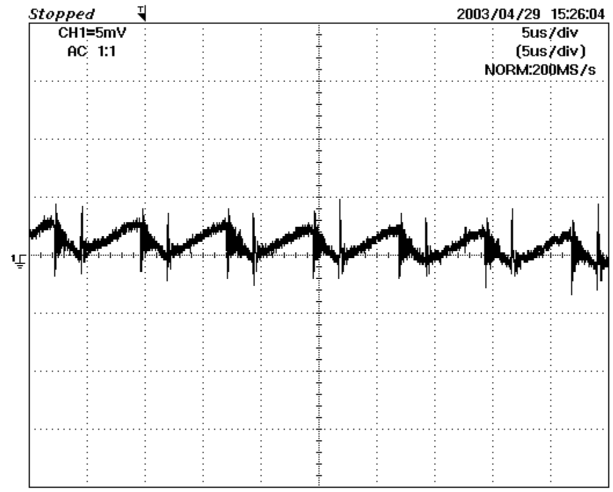


**Figure 23** – 3V3 Switching Noise, 230 $V_{AC}$, Full Load.

5us / div, 5 mV / div

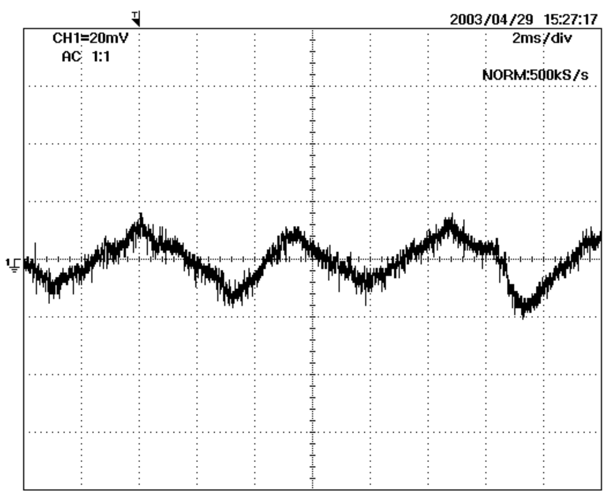


**Figure 24** – 5V Ripple, 230 $V_{AC}$, Full Load.

2 ms / div, 20 mV / div

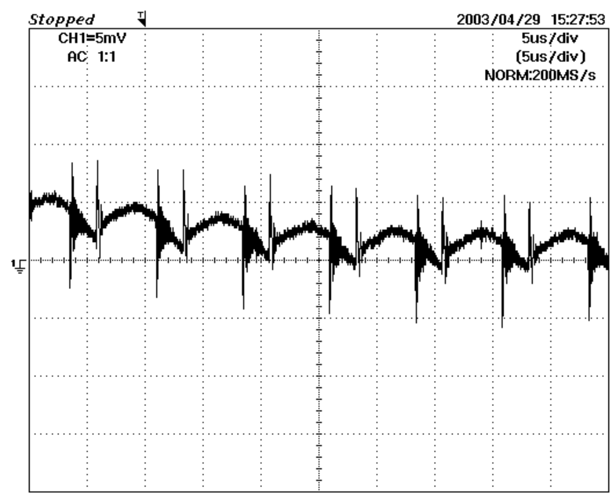


**Figure 25** – 5V Switching Noise, 230 $V_{AC}$, Full Load.

5 us / div, 5 mV / div

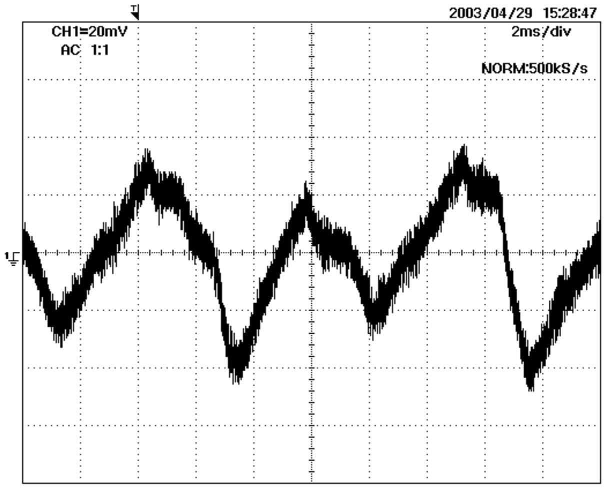


**Figure 26** – 12V Ripple, 230 $V_{AC}$, Full Load.

2 ms / div, 20 mV / div

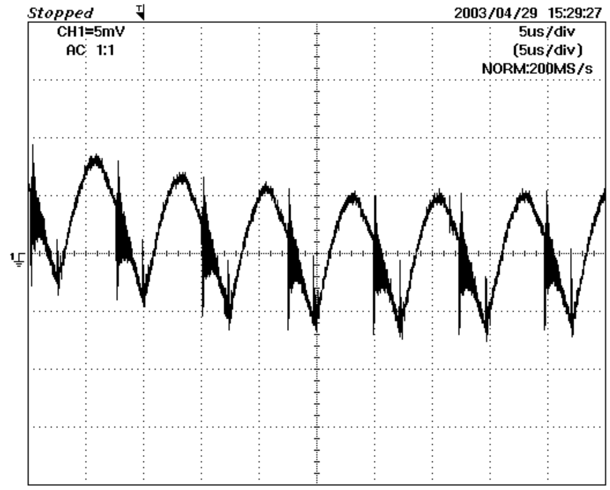


**Figure 27** – 12V Switching Noise, 230 $V_{AC}$, Full Load.

5us / div, 5 mV / div

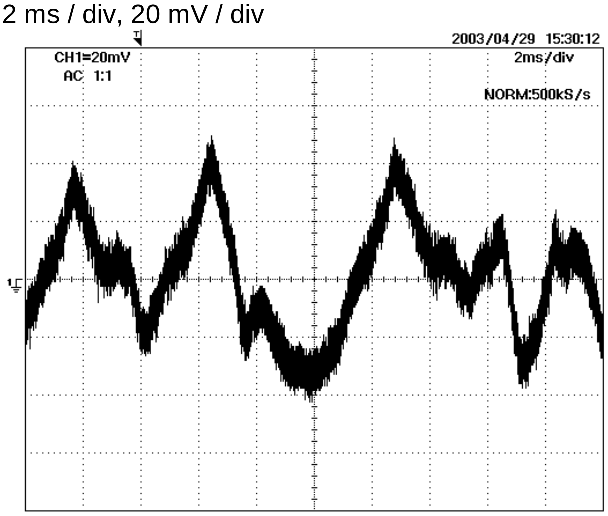


**Figure 28** – 20V Rail Ripple, 230 $V_{AC}$, Full Load.

2 ms / div, 20 mV / div

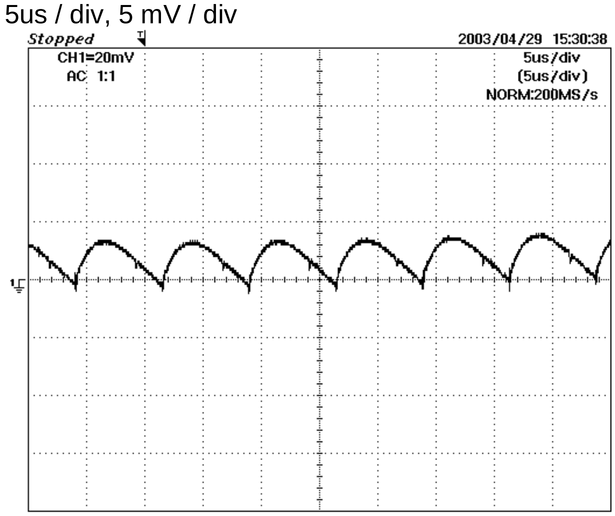


**Figure 29** – 20V Rail Switching Noise, 230 $V_{AC}$, Full Load.

5us / div, 20 mV / div



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## 12 Conducted EMI

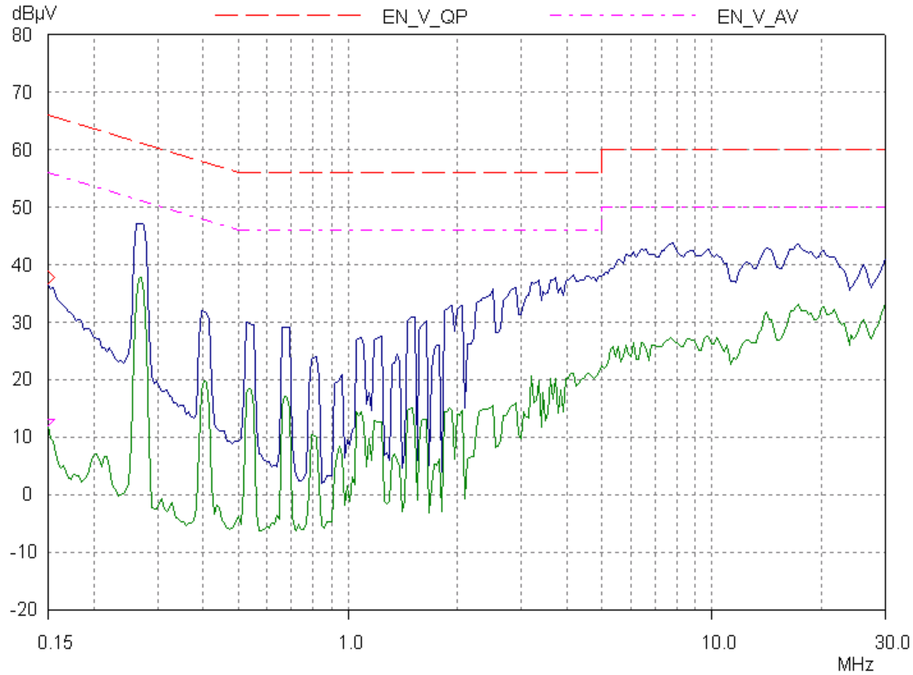


**Figure 30 -** Conducted EMI, Full Continuous Power, 230 $V_{AC}$, and EN55022 B Limits.

Output ground connected to protective earth. Worst case live/neutral measurement.

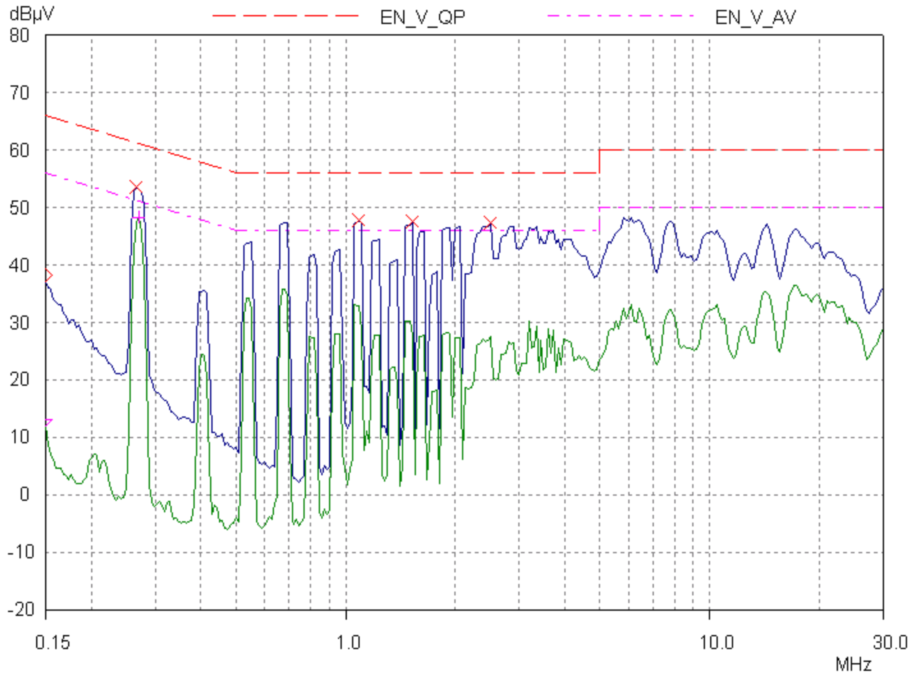


**Figure 31** - Conducted EMI, Full Continuous Power, 230 $V_{AC}$, and EN55022 B Limits.

Output ground floating. Worst case live/neutral measurement.

## 13 Revision History

| Date | Author | Revision | Description & changes | Reviewed |
|---|---|---|---|---|
| March 30, 2004 | IM | 1.0 | First Draft Released | VC / AM |

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