# Design Example Report

| | |
|---|---|
| **Title** | ***2.2W Charger using LNK501P*** |
| **Specification** | Input: 90 - 265 Vac<br>Output: 5.5V / 0.4A |
| **Application** | Cell Phone Charger |
| **Author** | Power Integrations Applications Department |
| **Document Number** | DER-13 |
| **Date** | February 4, 2004 |
| **Revision** | 1.0 |


**Summary and Features**

- Uses an EF12.6 transformer
- No Y1 capacitor
- Meets CISPR-22B
- No optocoupler
- Low component count
- Very low earth leakage current





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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 document is an engineering report giving performance characteristics of a 2.2W charger/adapter. The supply uses LinkSwitch – an integrated IC combining a 700V high voltage MOSFET, PWM controller, start-up, thermal shutdown, and fault protection circuitry.

This document contains the power supply specification, schematic, bill of materials, transformer documentation, and performance data.


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## 2 Power Supply Specification

| Description | Symbol | Min | Typ | Max | Units | Comment |
|---|---|---|---|---|---|---|
| **Input** | | | | | | |
| Voltage | $V_{IN}$ | 90 | | 265 | Vac | 2 Wire- No protective ground |
| Frequency | $f_{LINE}$ | 47 | 50/60 | 64 | Hz | |
| No-load Input Power (230Vac) | | | | 0.3 | W | |
| **Output** | | | | | | |
| Output Voltage 1 | $V_{OUT}$ | | 5.5 | | V | see Figure 1 |
| Output Current 1 | $I_{OUT}$ | | 0.4 | | A | see Figure 1 |
| Continuous Output Power | $P_{OUT}$ | | 2.2 | | W | |
| **Efficiency** | $\eta$ | | 67 | | % | At full load @ 230V |
| **Operating Temperature** | $T_{AMB}$ | -5 | | 50 | C | |
| **Conducted EMI** | CISP22B/EN55022B with Artificial hand connected to output return | | | | | |

**Table 1 –** Power Supply Specification

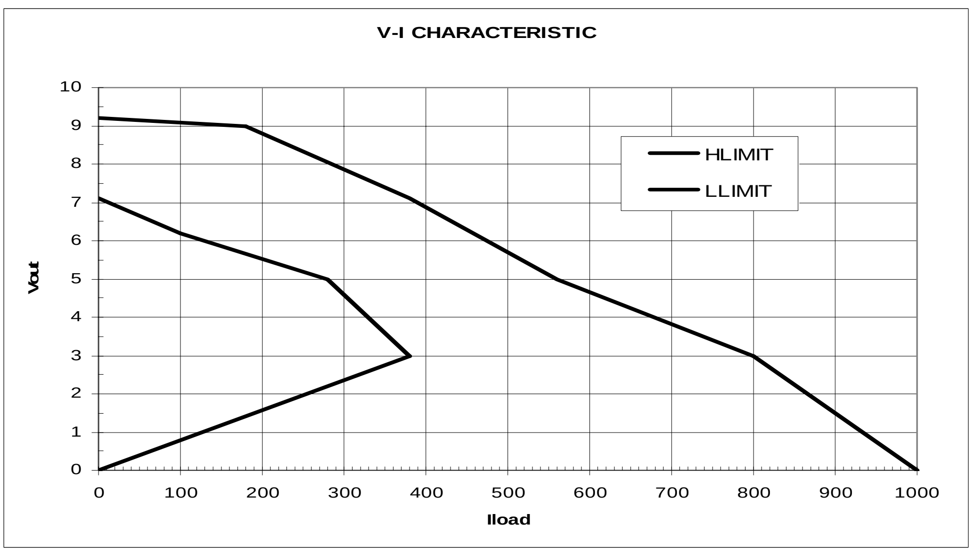


**Figure 1:** Output V-I Characteristic Envelope Specification



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## 3 Schematic

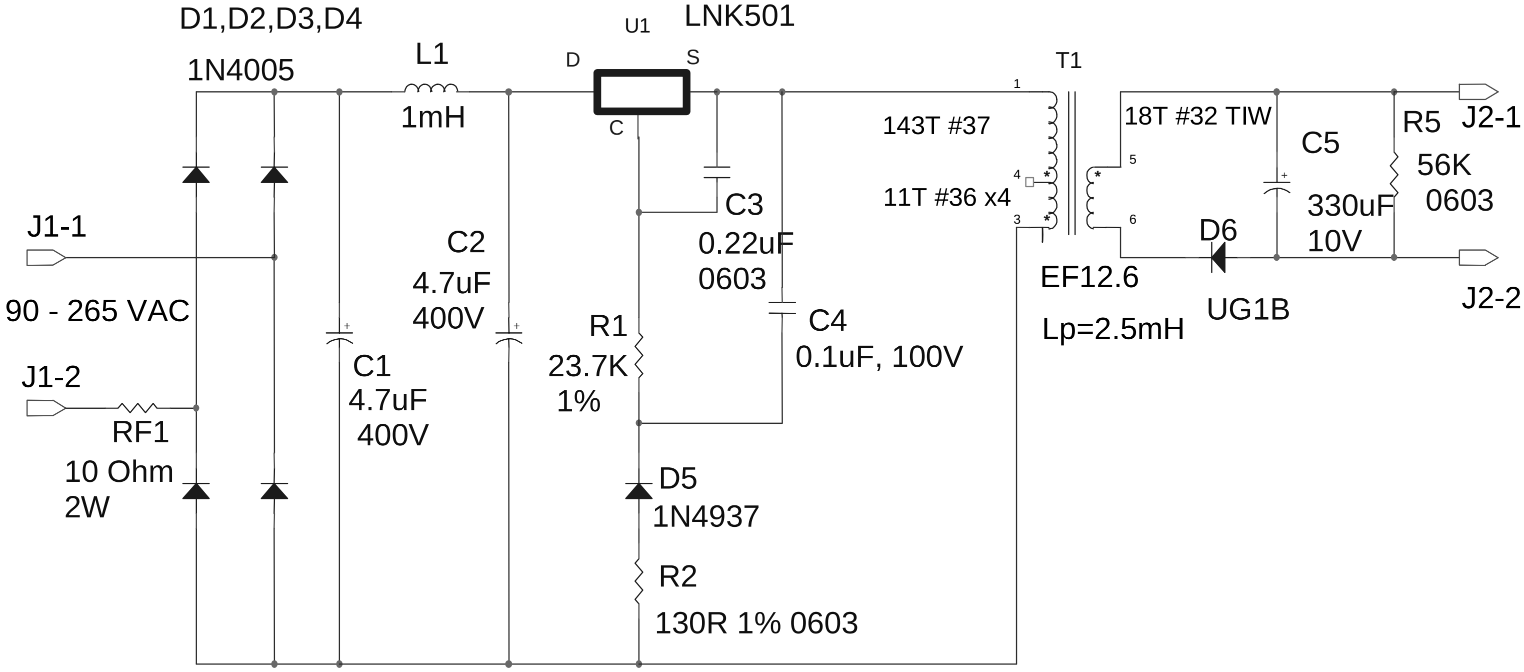


**Figure 2:** Schematic diagram

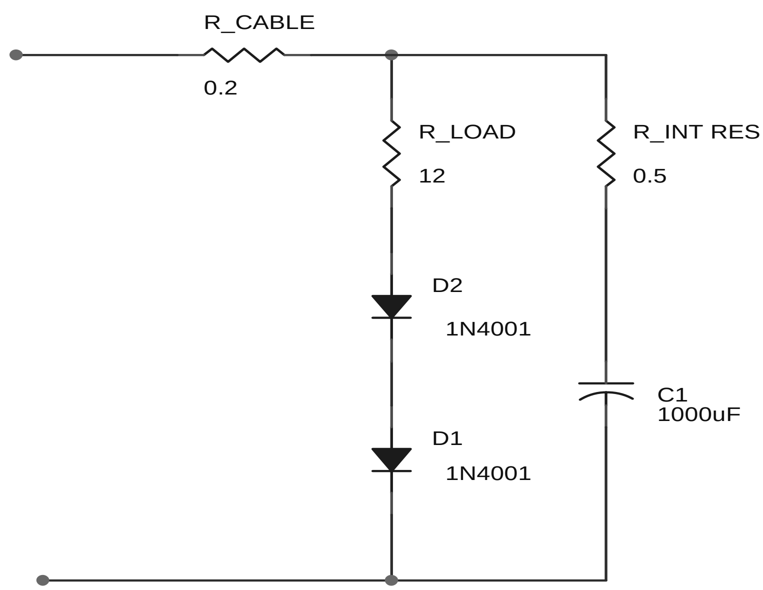


**Figure 3:** Typical Battery Model

Note: The LinkSwitch is designed for a battery load (see model in Figure 3). If a resistive or electronic load is used, the supply may fail to start up at full load. This is normal. If startup is needed into a resistive load, increase C3 to 1uF.



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# 4 PCB Layout

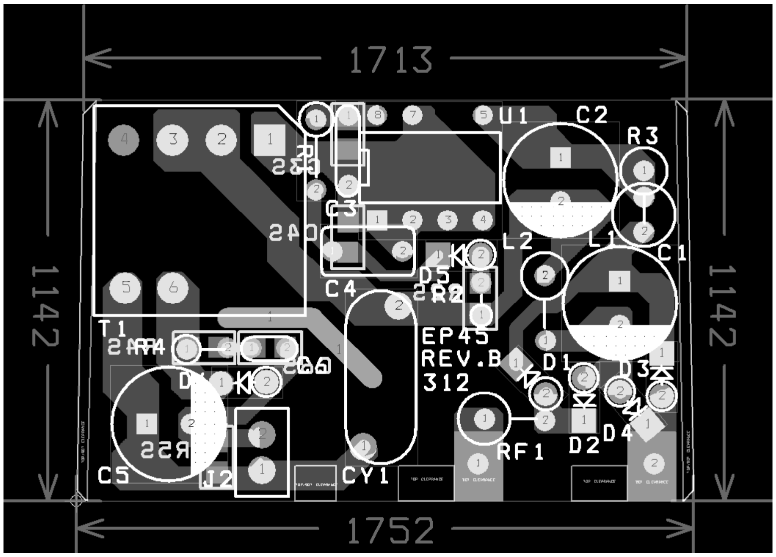


**Figure 4:** PCB Layout and Dimensions (0.001 inch)


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# 5 Bill of Materials

| Item | Quantity | Reference | Part Description |
|---|---|---|---|
| 1 | 2 | C1, C2 | 4.7uF, 400V |
| 2 | 1 | C3 | 0.22uF, 25V,Y5V, 0603 SMD ceramic |
| 3 | 1 | C4 | 0.1uF, 100V, X7R ceramic |
| 4 | 1 | C5 | 330uF, 10V Low ESR E-cap Panasonic FC series |
| 5 | 4 | D1, D2, D3, D4 | 1N4005, 1A, 600V |
| 6 | 1 | D5 | 1N4937, 1A, 600V 200nS, Fast Rectifier |
| 7 | 1 | D6 | UG1B, 1A, 100V, 15nS Ultra Fast Rectifier |
| 8 | 1 | L1 | 1mH Inductor- Tokin part #SBCP-47HY102B |
| 9 | 1 | RF1 | 10 ohm, 2W, Fusible- Vitrohm 253-4 Series |
| 10 | 1 | R2 | 130 ohms, 1% 0603 SMD resistor |
| 11 | 1 | R1 | 23.7 ohm 1%; 1/4W resistor |
| 12 | 1 | R5 | 56 ohm; 0603 SMD resistor |
| 3 | 1 | T1 | Custom EF12.6 – Core & Bobbin |
| 14 | 1 | U1 | LINK501P- High Voltage IC; Power Integrations, Inc |
| 15 | 1 | PCB | FR1 – 1oz copper DIM: 1.7” x 1.1”; 1.0mm thick |


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# 6 Transformer

## 6.1 Transformer Winding

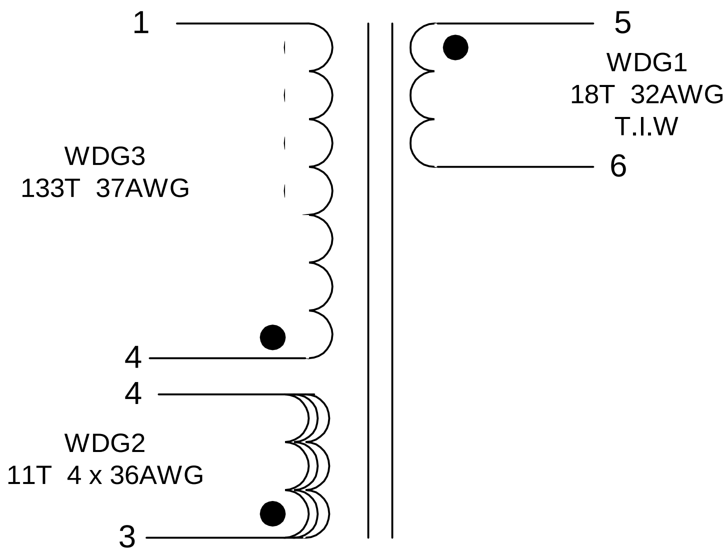


**Figure 5–** Transformer Schematic EF12.6

## 6.2 Electrical Specifications

| | | |
|---|---|---|
| Electrical Strength | 60Hz 1minute, from Pins 1-3 to Pins 5-6 | 3 kV for 1 minute |
| Primary Inductance (Pin 1 -Pin 3 @ 42KHZ | All windings open | 2450 uH – 2700uH |
| Primary Leakage Inductance @42KHZ | $L_K$ with pins 5-6 shorted | < 60 uH |


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### 6.3 Transformer Construction

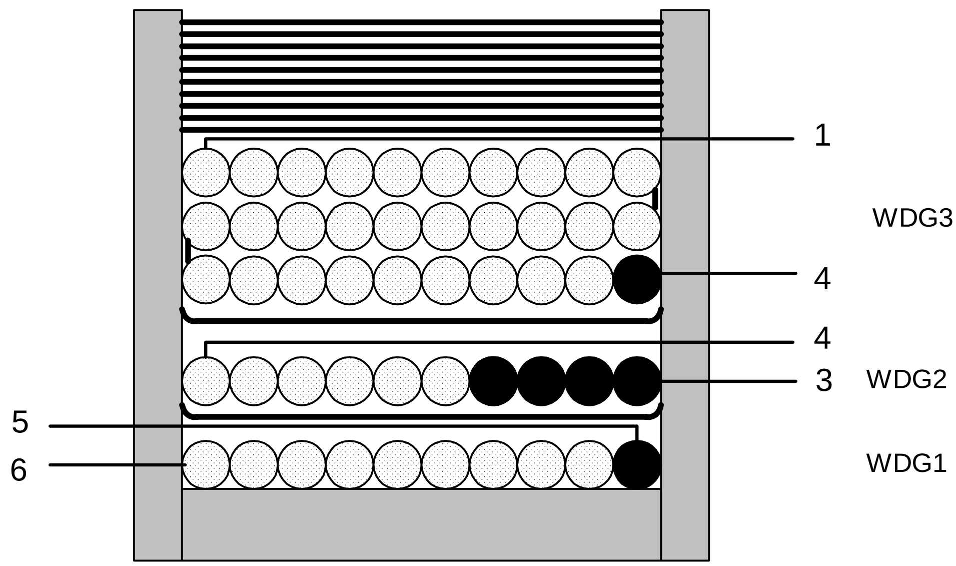


**Figure 6–** Transformer Cross-section EF12.6

### 6.4 Winding Instructions

Place the bobbin on the winding machine with pins 1-4 on the right side. Winding should be in forward direction.

| | |
|---|---|
| WDG1: Secondary Winding | Start at pin 4 temporarily. Wind 18 turns of item 5 from right to left with tight tension. Wind uniformly in a single layer across entire width of bobbin. Finish on pin 6. |
| Basic Insulation | Secure winding partially using item 6. |
| WDG1: Secondary Winding | Change the start pin connection of secondary winding from pin 4 to pin 5. |
| Basic Insulation | Continue winding the tape previously placed for one layer with overlap to secure the end wire of WDG1. |
| WDG2: Cancellation Winding | Start at pin 3. Wind 11 turns with quadfilar of item 3 from right to left with tight tension. Wind uniformly in a single layer across entire width of bobbin. Finish on pin 4. |
| Basic Insulation | 1 layer of tape (Item 6) for insulation. |


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| | |
|---|---|
| WDG3: Primary winding 3 layers. | Start at pin 4. Wind 143 turns of item 4 from right to left in three layers across entire width of bobbin. Wind uniformly all layers with tight tension. Finish on pin 1. |
| Outer Insulation | 10 Layer of tape using item 7. |
| Core Assembly | Assemble and secure core halves with glue. |
| Shield / Belly Bans | Place outside 1 turn of item 8 with tight contact to winding surface. Connect item 8 to pin 3 by item 3. |
| Crop unused pins | Remove pin 7 and 8 |

## *6.5 Materials*

| Item | Description |
|---|---|
| [1] | Core: EF12.6 |
| [2] | Bobbin: BEF12.6- Horizontal 8-PINS |
| [3] | Magnet Wire: #36 AWG |
| [4] | Magnet Wire: #37 AWG |
| [5] | Triple Insulated wire: # 32 AWG |
| [6] | Tape: 3M 1298 Polyester Film (white) 0.311 x 2 mils |
| [7] | Tape: 3M 1298 Polyester Film (white) 0.275 x 2 mils |
| [8] | Copper Foil: 0.01mils x 6mm |
| [9] | Varnish |
| | |

## *6.6 Design Notes*

| | |
|---|---|
| Power Integrations Device | LNK501P |
| Frequency of Operation | 42KHZ |
| Mode | Discontinuous |
| Peak current | 0.263 A |
| Reflected Voltage (Secondary to Primary) | 47 V |
| AC Input Voltage Range | 90-265VAC |



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# 7 Performance Data

Measurements were done at room temperature unless otherwise specified.

## *7.1 Line and Load Regulation*

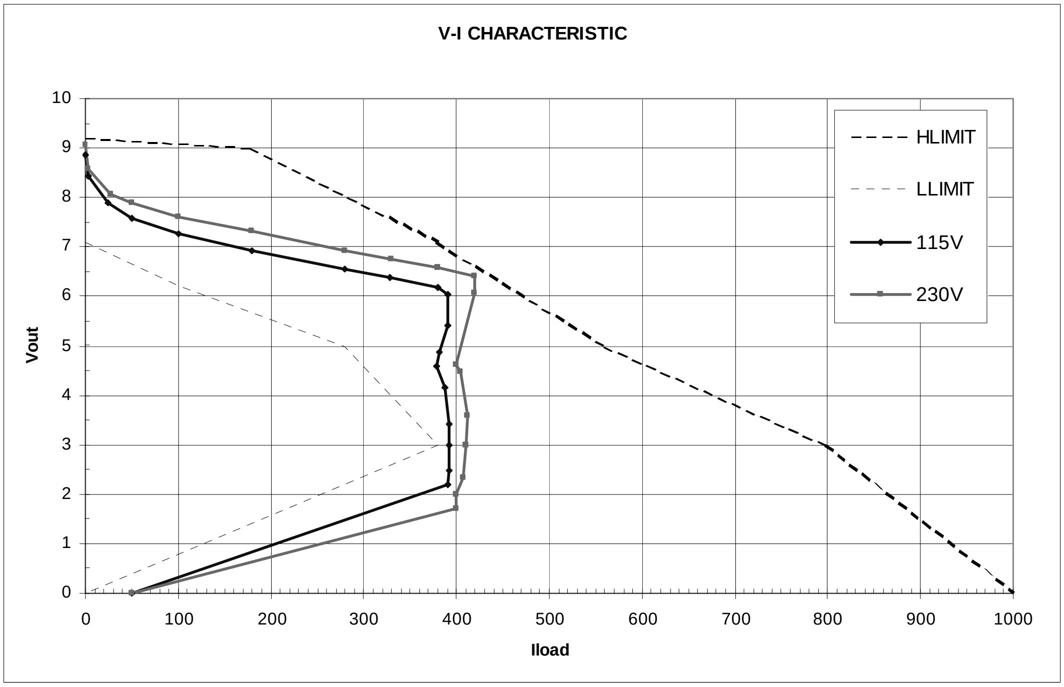


**Figure 7**– Output VI Characteristic at selected input voltages (115V & 230V)

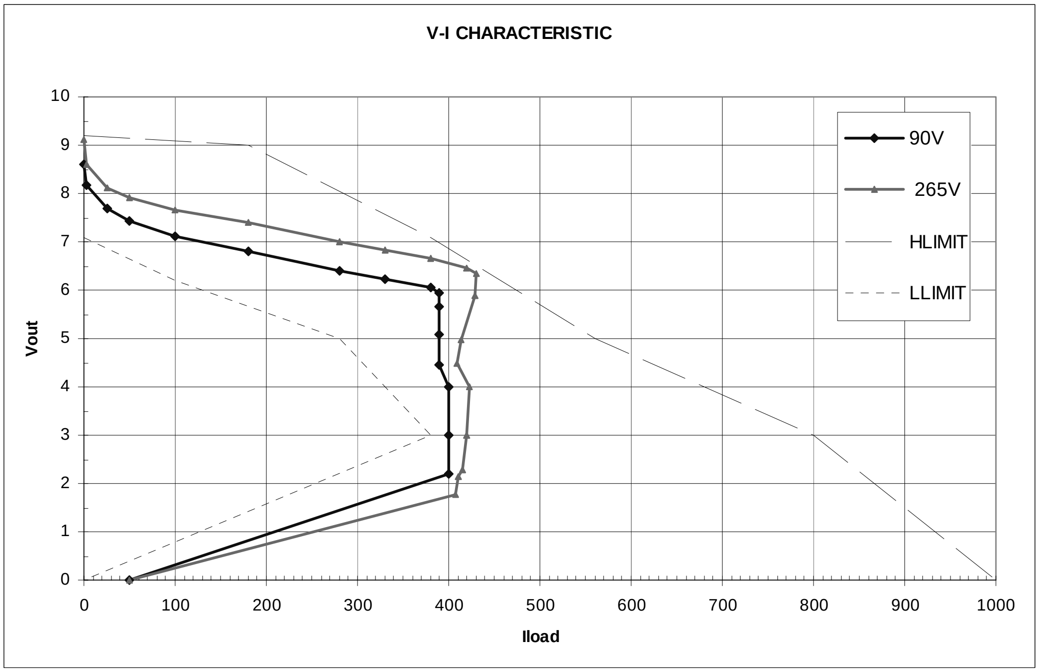


**Figure 8**– Output VI Characteristic at selected input voltages (90V & 265V)



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## 7.2 Efficiency

The efficiency was measured at max power (~6.4V, 0.4A), using a 16Ω resistor, at room temperature.

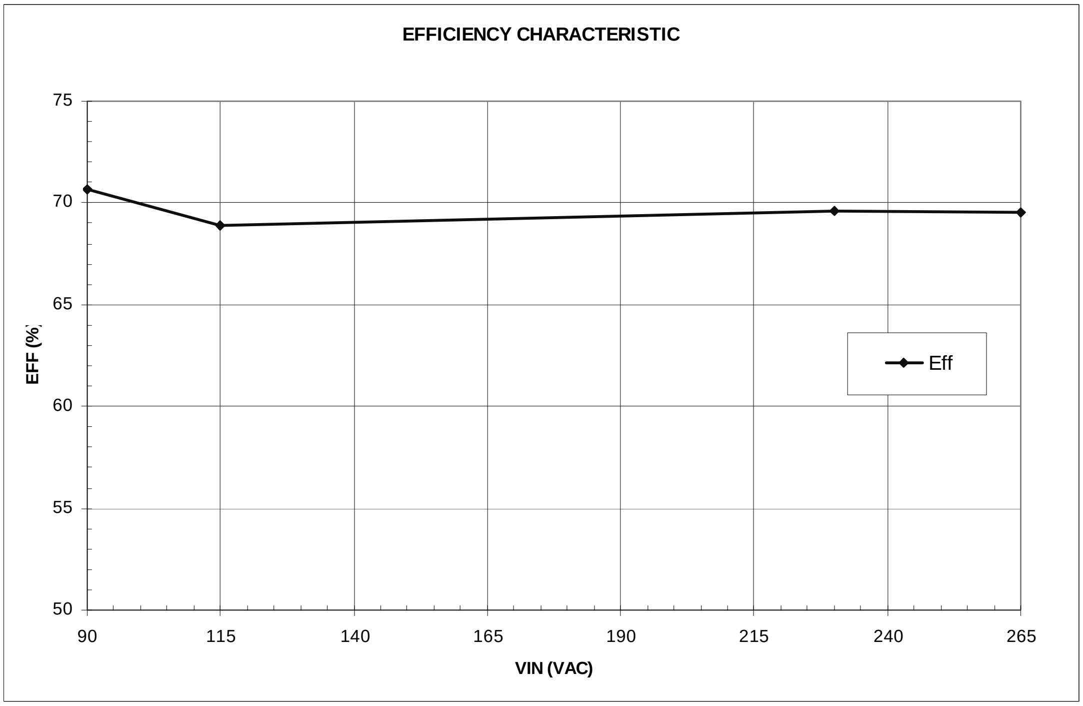


**Figure 9**– Efficiency vs. Input voltage



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### 7.3 No-Load Input Power

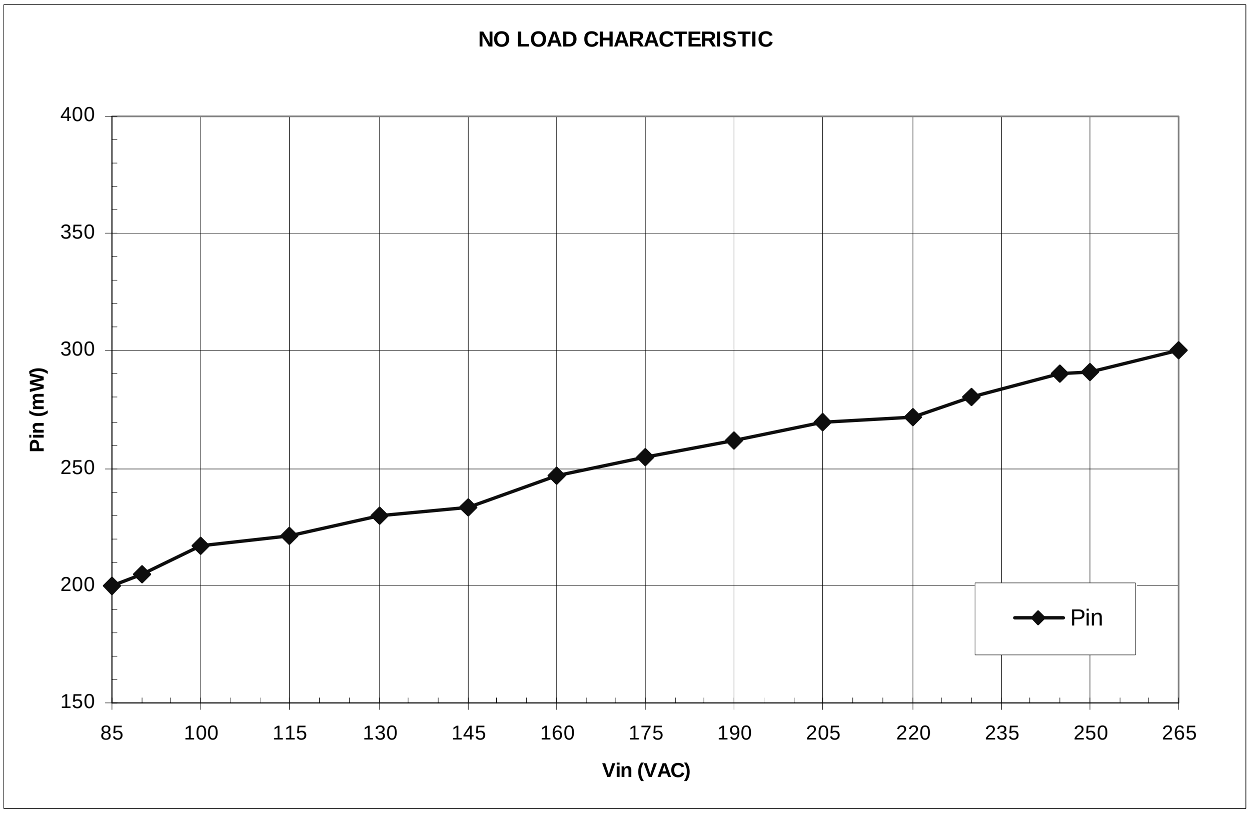


**Figure 10**– Zero load input power vs. Input line voltage

### 7.4 Thermal Measurement of Critical Parts

Measurement was done with a 16Ω resistor load, (~6.4 V, 0.4A) inside a plastic enclosure at 25°C with no airflow.

| Reference | Description | Temperature |
|---|---|---|
| U1 | LNK501P | ***65ºC*** |
| T1 | EF12.6 Transformer | ***58ºC*** |
| D6 | UG1B | ***69ºC*** |


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# 8 Waveforms

## *8.1 Drain Voltage and Current*

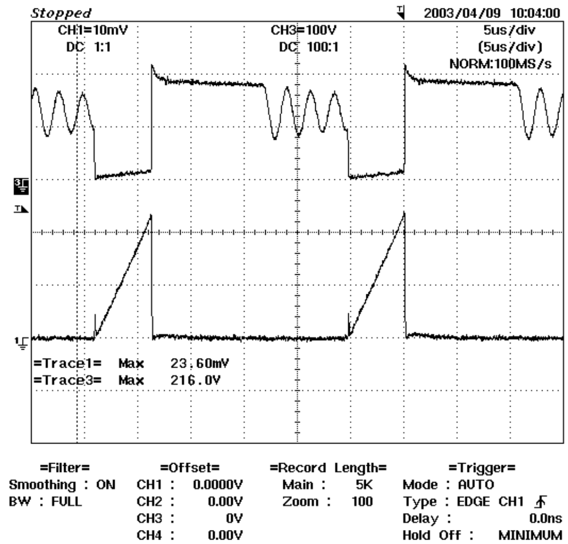


**Figure 11**– Linkswitch (U1) Vdrain and I drain Waveform. Vin=90Vac, Full load; CH3: Vdrain (100V/DIV); CH1: Idrain (0.1A/DIV)

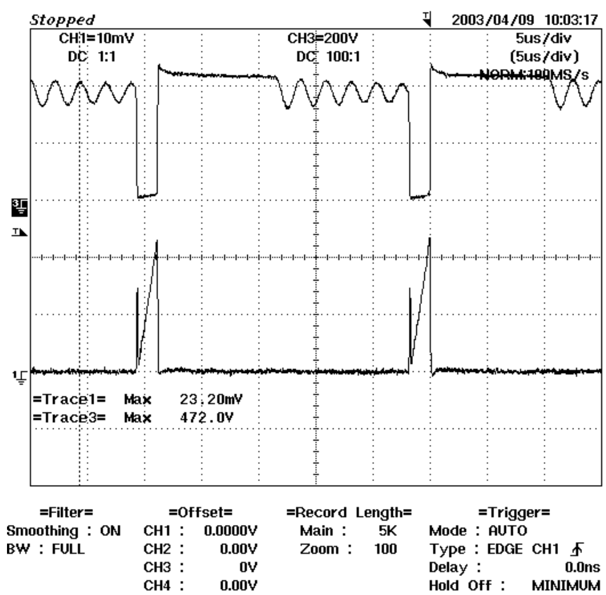


**Figure 12**– Linkswitch (U1) Vdrain and I drain Waveform. Vin=265Vac, Full load; CH3: Vdrain (100V/DIV); CH1: Idrain (0.1A/DIV)


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### 8.2 Output Voltage Start-up Profile

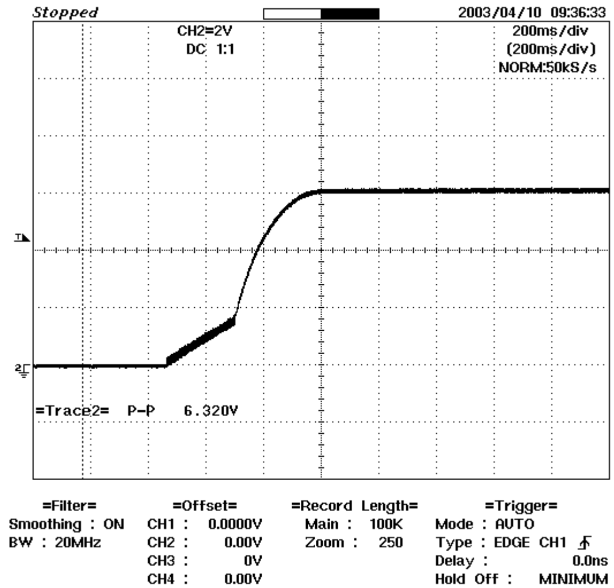


**Figure 13**– Output voltage at start-up, Battery model, Vin=90 Vac

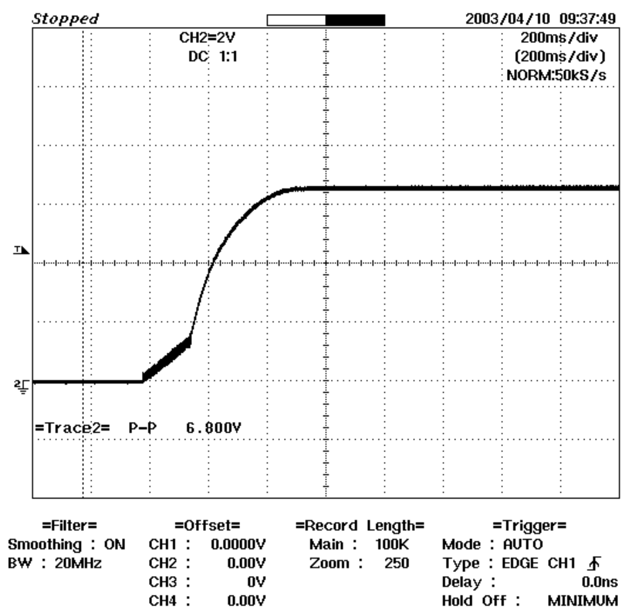


**Figure 14**– Output voltage at start-up, Battery model, Vin=265 Vac


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### *8.3 Load Transient Response (0.2 A to 0.4 A Load Step)*

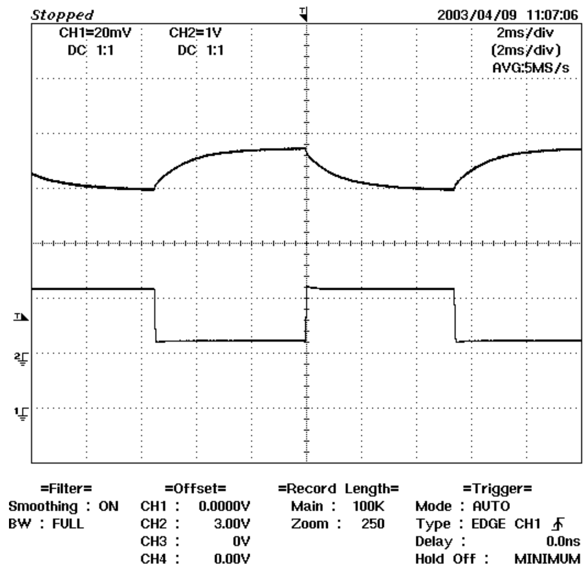


**Figure 15**– Dynamic Load Transient
0.2 A to 0.4 A step load at Vin= 90 Vac
CH2: Output Voltage (1V/DIV); CH3: Load Current

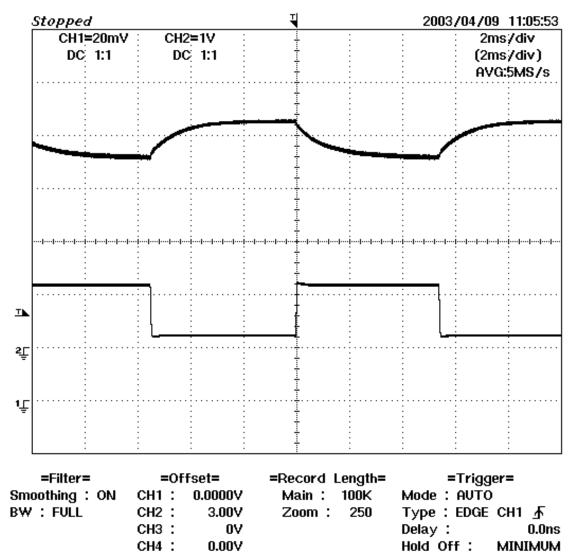


**Figure 16**– Dynamic Load Transient
0.2 A to 0.4 A step load at Vin= 265 Vac
CH2: Output Voltage (1V/DIV); CH3: Load Current


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## *8.4 Output Ripple Measurement*

### 8.4.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order to reduce spurious signals due to pickup. Details of the probe modification are provided in Figure 17 and Figure 18.

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).*

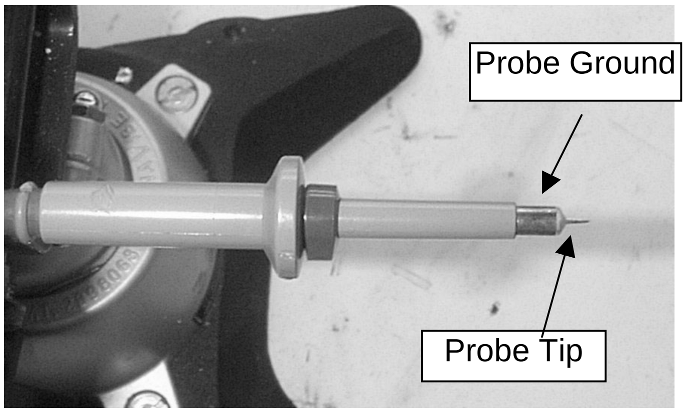


**Figure 17** – Oscilloscope Probe Prepared for Ripple Measurement.

(End Cap and Ground Lead Removed)

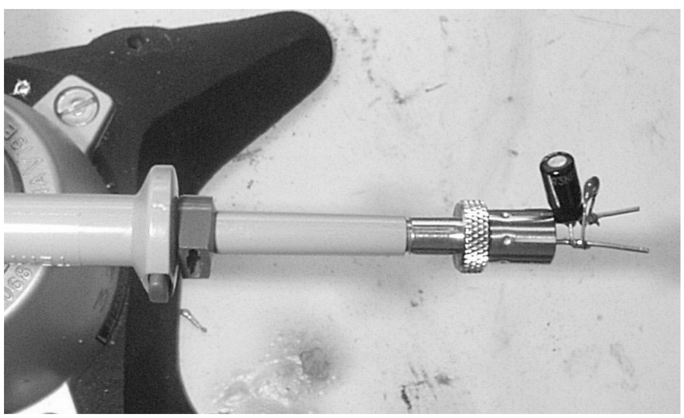

**Figure 18** – Oscilloscope Probe with Probe Master 5125BA BNC Adapter

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



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### 8.4.2 Output Voltage Ripple

Measurements were made using resistive load.

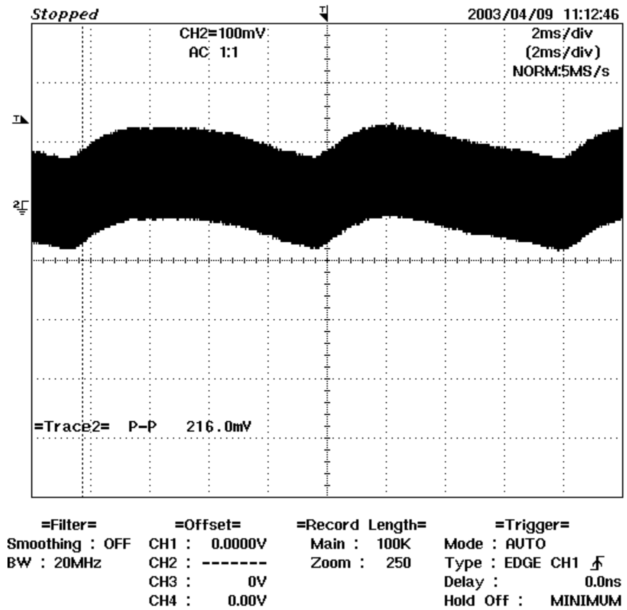


**Figure 19**: Vin= 90 Vac at full load

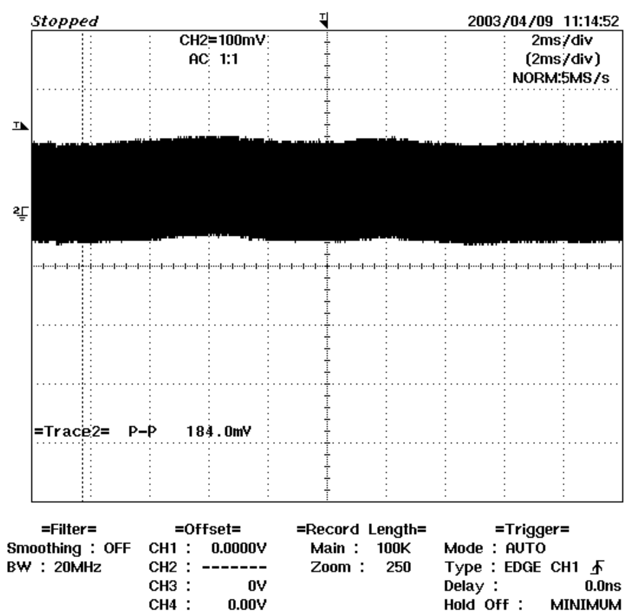


**Figure 20**: Vin= 265 Vac at full load


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# 9 EMI Tests

The EMI tests were done at 230Vac & 115V (Line & Neutral), with a 20 Ω resistive load.

## *9.1 CSPR22B at 230 Vac*

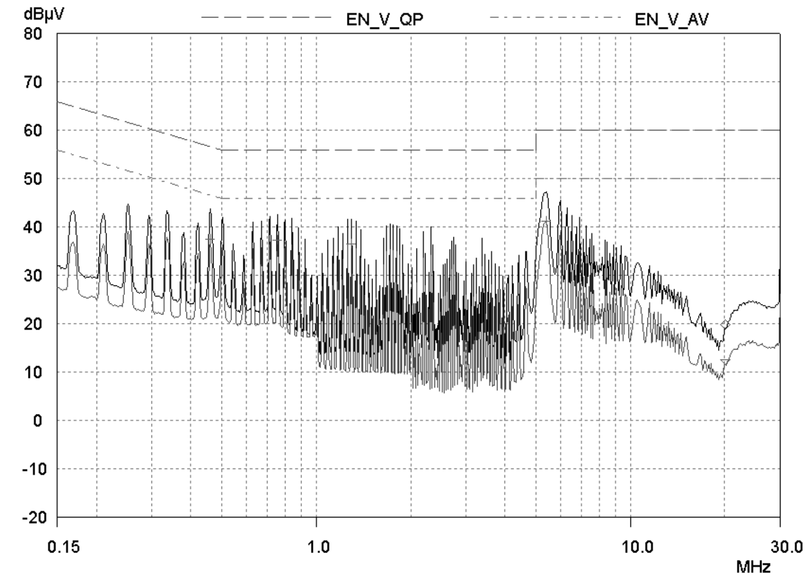


**Figure 21 –** Conducted EMI, Vin= 230 Vac, 60 Hz line, CSPR22B Limits, NEUTRAL; Output return connected to Artificial hand

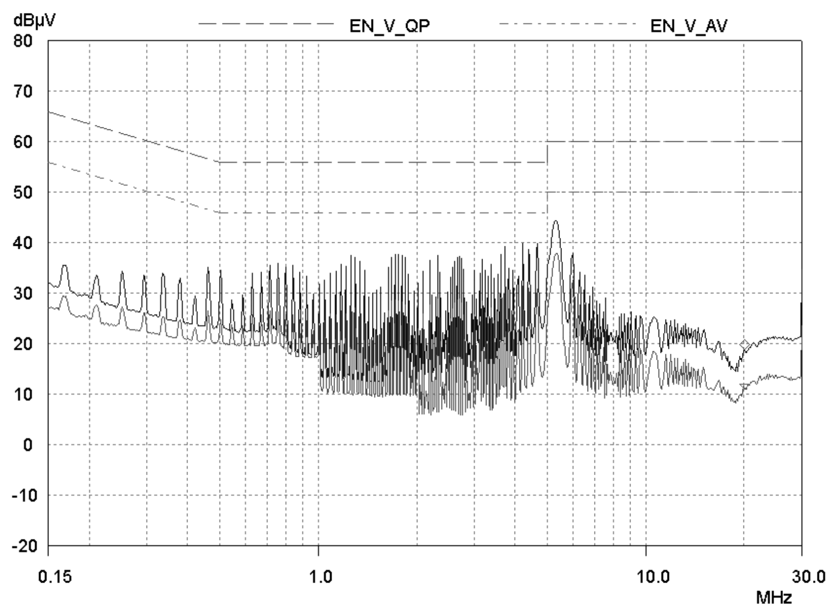


**Figure 22 –** Conducted EMI, Vin= 230 Vac, 60 Hz line, CSPR22B Limits, LINE; Output return floating


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## 9.2 CSPR22B at 115 Vac

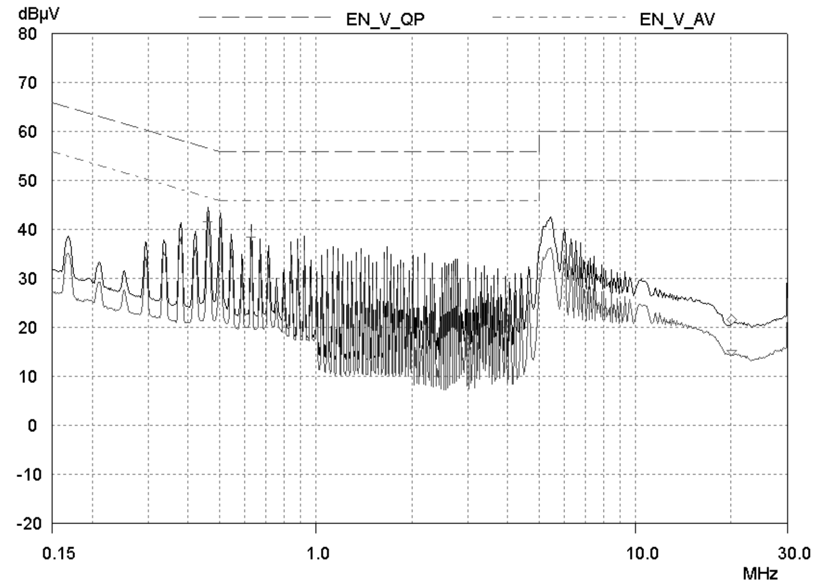


**Figure 23–** Conducted EMI, Vin= 115V Vac, 60 Hz line, CSPR22B Limits, NEUTRAL, Output return connected to Artificial hand

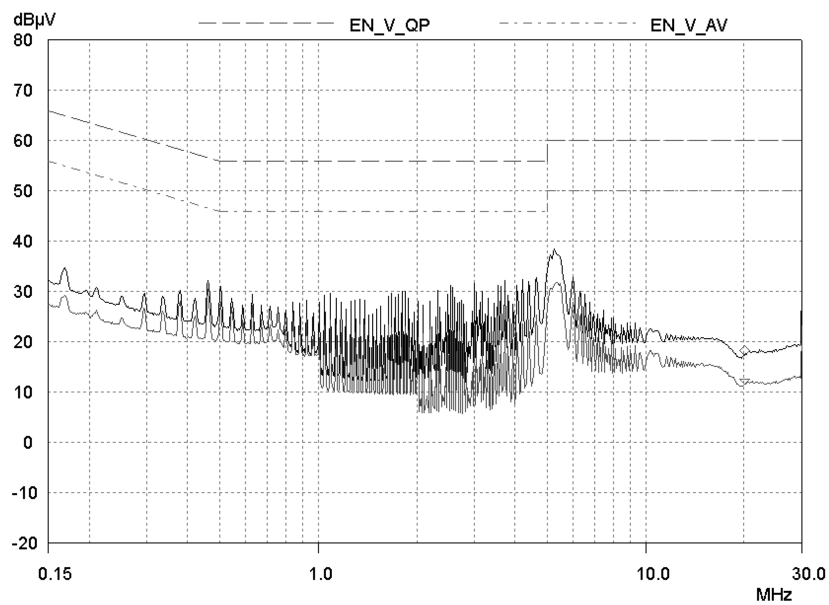


**Figure 24 –** Conducted EMI, Vin= 115V Vac, 60 Hz line, CSPR22B Limits, LINE, Output return connected to Artificial hand



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# 10 Revision History

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



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## Notes


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