|  |  |
|---|---|
| **标题** | ***参考设计报告：使用LYTSwitch™-0 LYT0006P 设计的6 W非调光、非隔离降压式LED驱动器*** |
| **规格** | 90 VAC – 265 VAC输入；54 V，110 mA输出 |
| **应用** | GU10 LED驱动器（灯替换） |
| **作者** | 应用工程部 |
| **文档编号** | RDR-355 |
| **日期** | 2013年6月18日 |
| **修订版本** | 1.0 |

**特色概述**

- 单级功率因数校正（在120 V下PF>0.75，在230 V下PF>0.5）及精确恒流(CC)输出
- 元件数量少、PCB占板面积小的低成本解决方案
- 极高能效，在120 VAC输入下效率>91%
- 极高能效，在240 VAC输入下效率>90%
- 卓越的性能及最终用户体验
    - 快速启动时间(<20 ms) – 无可见延迟
- 集成的保护及可靠性能
    - 单脉冲空载保护/输出短路保护，带自动恢复功能
    - 更大迟滞的自动恢复热关断可同时保护元件和印刷电路板
    - 在AC电压缓降期间不会造成任何损坏
- 满足IEC振铃波、差模输入浪涌和EN55015传导EMI要求

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# 目录

**重要说明：**
虽然本电路板的设计满足安全隔离要求，但工程原型尚未获得机构认证。因此，必须使用隔离变压器向原型板提供AC输入，以执行所有测试。

## 1 简介

本文档介绍的是一款使用LYTSwitch$^{TM}$-0系列器件(LYT0006P)设计的高度紧凑、高性价比的降压式电源。

该电源可以在90至264 VAC的输入电压范围内进行工作。DC总线电压非常高，足以在使用降压拓扑时支持54 V输出。在降压式转换器中，输出电压必须始终低于输入电压。此外，输出电压还受到LYTSwitch-0最大占空比的限制，这也要求输入电压必须高于输出电压。

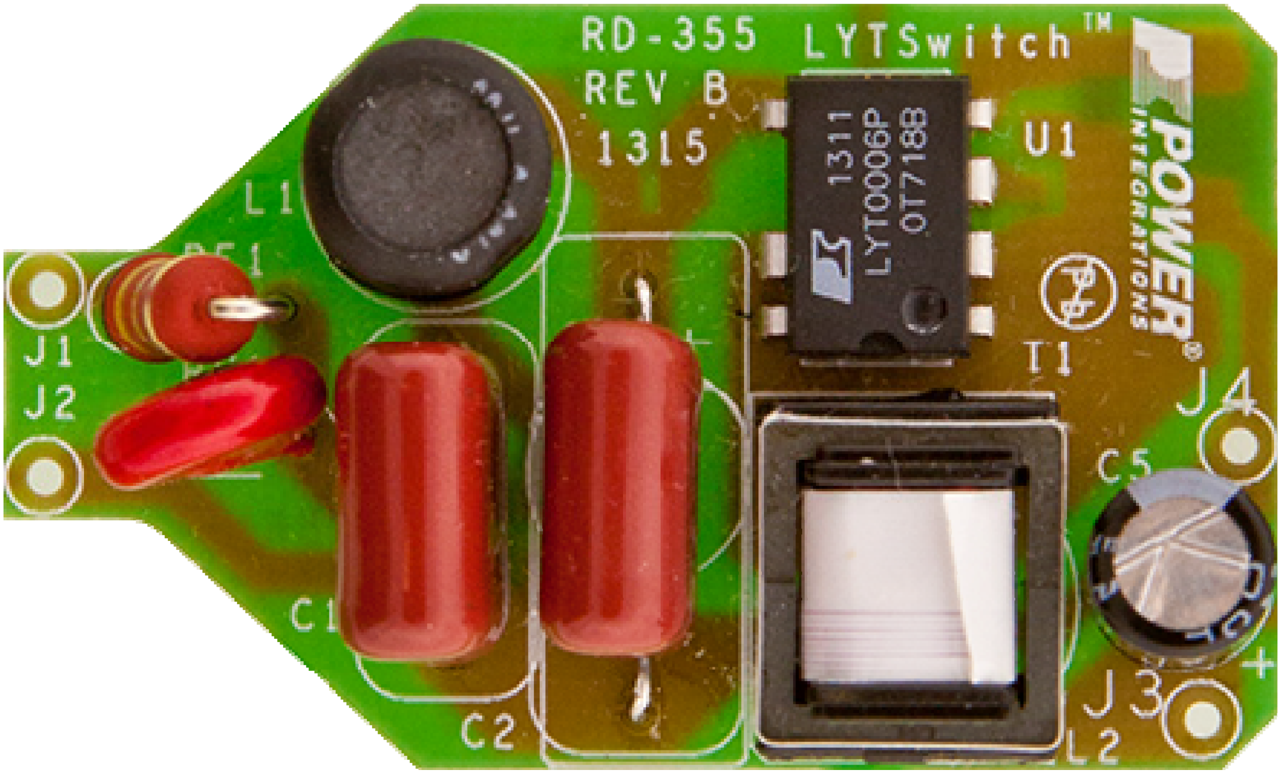


**Figure 1 –** Populated Circuit Board Photograph, Top.

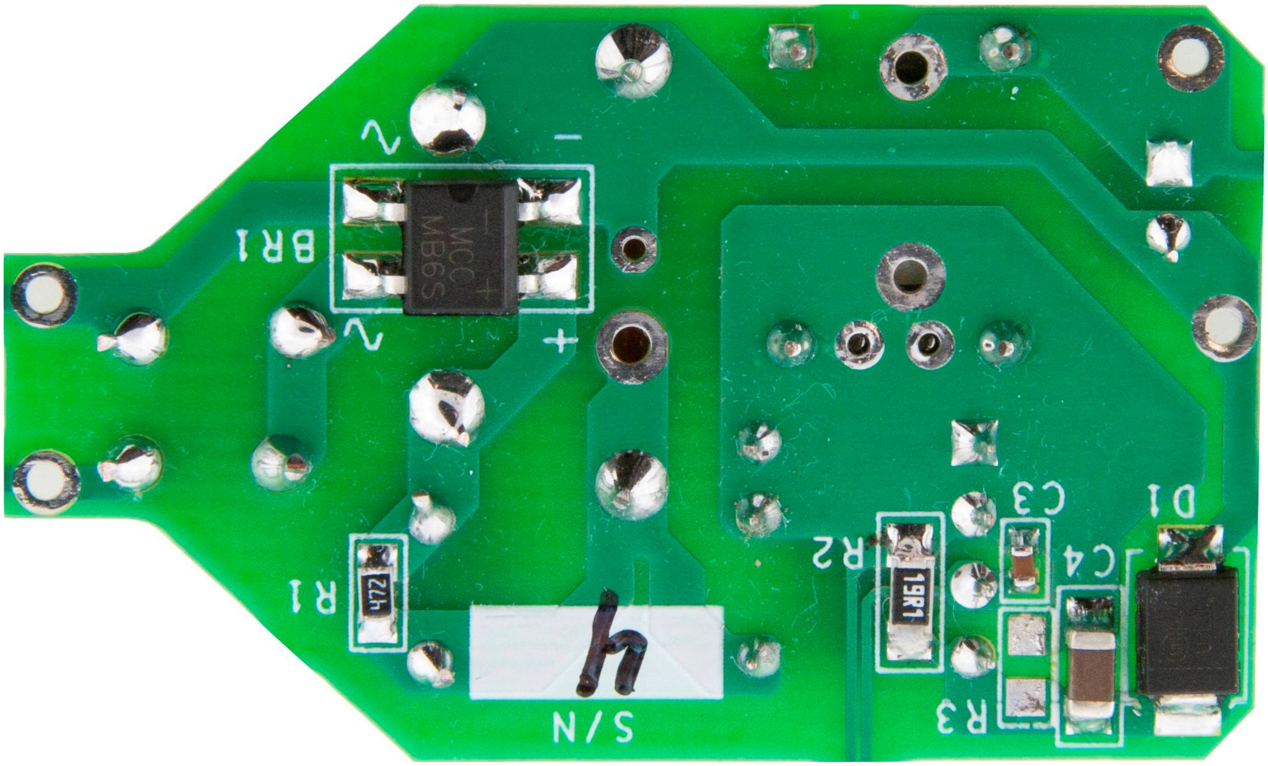


**Figure 2 –** Populated Circuit Board Photograph, Bottom.

# 2 电源规格

| 说明 | 符号 | 最小值 | 典型值 | 最大值 | 单位 | 备注 |
|---|---|---|---|---|---|---|
| **输入** | | | | | | |
| 输入电压 | $V_{IN}$ | 90 | | 265 | VAC | 双导线 – 无P.E. |
| 频率 | $f_{LINE}$ | 47 | 50/60 | | Hz | 工作频率不受限制。如果应用采用400 Hz线电压频率，则请调整检测电阻。 |
| **输出** | | | | | | |
| 输出电压 | $V_{OUT}$ | 52 | 54 | 56 | V | 在100 VAC - 240 VAC输入下为±4% |
| 输出电流 | $I_{OUT}$ | | 110 | | mA | |
| **总输出功率** | | | | | | |
| 连续输出功率 | $P_{OUT}$ | | 6 | 6.5 | W | |
| **效率** | | | | | | |
| 120 VAC; 54 V LED | $\eta$ | 91 | | | % | 在$P_{OUT}$ 25 °C条件下测得 |
| 240 VAC; 54 V LED | $\eta$ | 90 | | | % | |
| **功率因数** | | | | | | |
| 120 VAC; 54 V LED | PF | 0.75 | | | | 在$P_{OUT}$ 25 °C条件下测得 |
| 240 VAC; 54 V LED | PF | 0.5 | | | | |
| **环境** | | | | | | |
| 传导EMI | | 满足CISPR22B / EN55015B要求 | | | | |
| 输入浪涌<br>差模(L1-L2) | | | 0.5 | | kV | 1.2/50 µs浪涌，IEC 1000-4-5，<br>串联电阻：<br>差模：2 Ω |
| 振铃波(100 kHz)<br>差模(L1-L2) | | | 2.5 | | kV | 500 A短路<br>串联电阻：<br>差模： 2 Ω |
| 环境温度 | $T_{AMB}$ | -10 | 25 | | °C | 自然对流，海平面<br>UUT（被测电源）<br>可在–40 ºC下启动 |

# 3 电路原理图

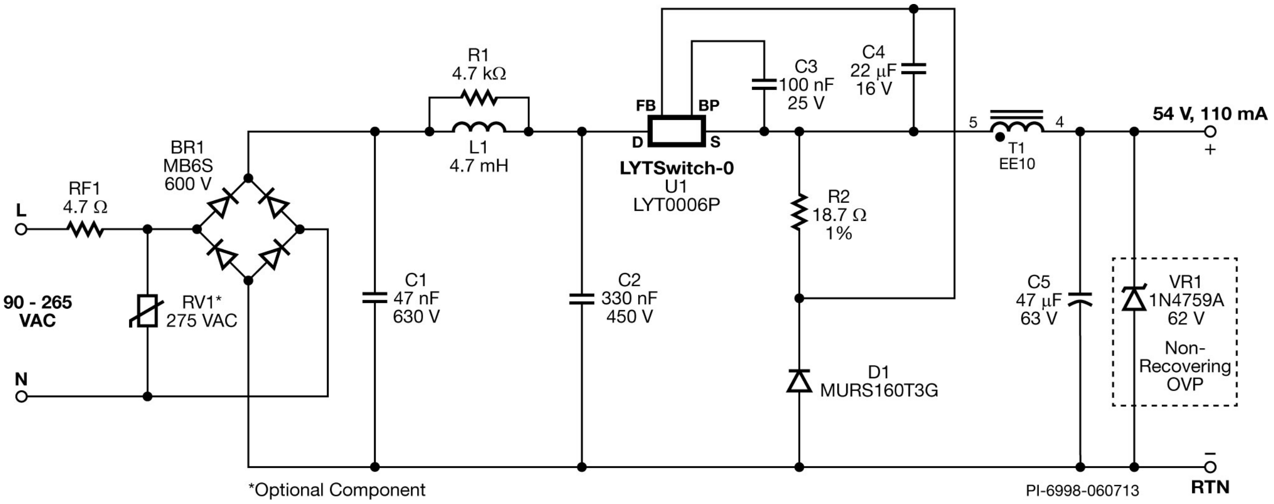


**Figure 3 –** Schematic. T1 can be replaced by a drum core inductor if final casing/housing has sufficient room to avoid shorting the magnetic flux. Zener diode VR1 is an option and provides one-time no-load protection.

# 4 电路描述

图3所示的电源在高端降压式配置中采用了LYT0006P (U1)，用以提供110 mA的恒流输出，输出电压为54 VDC。该电源用于驱动LED，而LED需要始终获得恒流(CC)驱动。

## *4.1 输入EMI滤波*

保险丝RF1提供短路保护。桥式整流管BR1提供全波整流，以获得更高的功率因数。电容C1和C2以及共模扼流圈L1形成一个π滤波器，用以满足传导EMI标准。电容C1和C2还可用来储存能量，以降低线路噪声和提供输入浪涌保护。

## *4.2 LYTSwitch-0*

使用LYTSwitch-0能够设计出简单的高性价比LED驱动器，它不仅具有良好的线电压调整率，而且温度调整范围介于0至100°C之间（LYTSwitch-0壳体温度）。PIXls设计表格通过平衡功率电感和检测电阻可以实现最佳的线电压调整率。总输入电容也会有一些影响，但可以通过调整检测电阻(R2/R3)来对其进行补偿，从而优化性能。

LYTSwitch-0产品系列具有内置的发热限制，可以在灯泡的工作温度过高时对电源提供保护。

降压式转换器级包括LYT0006P (U1)内的集成功率MOSFET开关、续流二极管(D1)、检测电阻(R2)、功率电感L2和输出电容(C5)。转换器大部分时间都在DCM模式下工作，以便限制反向电流的周期数。该设计选用了一个快速续流二极管，用来将开关损耗降至最小。

电感L2是标准EE10电感，它将用来限制磁通路径并确保在任何壳体内都获得正确的电感。在特定的壳体（该壳体对电感的磁通量有已知的影响）中放置后，可以用成本较低的鼓状磁芯电感将其替换。

## *4.3 输出整流*

快速输出二极管(D1)用来实现良好的效率和进行热管理。对于LED应用，环境温度通常高于70°C，因此推荐使用具有较低$t_{RR}$值(<35 nS)的器件。

## *4.4 输出反馈*

调整通过跳过开关周期得以维持。当输出电流增大时，进入FB引脚的电压将随之升高。如果电压超过$V_{FB}$，将跳过随后的周期，直到电压降低到$V_{FB}$以下。电流由R2检测并由C4滤波，然后反馈至FB引脚，从而提高调整精度实现良好的线电压调整率的关键在于，在计算出最小电感量后平衡功率电感和检测电阻的取值。

旁路电容(C4)连接在反馈引脚和源极引脚之间，有助于在检测输出电流时降低功耗。电容可以为FB引脚提供采样和维持反馈电流的信息。在FB引脚和C4之间不需要放置限流电阻，因为峰值电压不会超出器件的最大额定值。

### *4.5 空载保护*

本设计中集成了可选的一次性空载保护电路。在出现意外空载工作的情况，输出电容将受到VR1的保护。齐纳二极管VR1需要在故障后进行更换。

在工作中（LED替换灯），负载始终保持连接，因此可去掉VR1以节省成本。为在板级测试中（制造过程中）提供保护，可对输入施加40 VAC的电压；如果测不到输出电流，则说明负载未连接。这种测试允许对电路板进行安全无损的初始上电，而不需要过压保护电路。

## 5 PCB布局

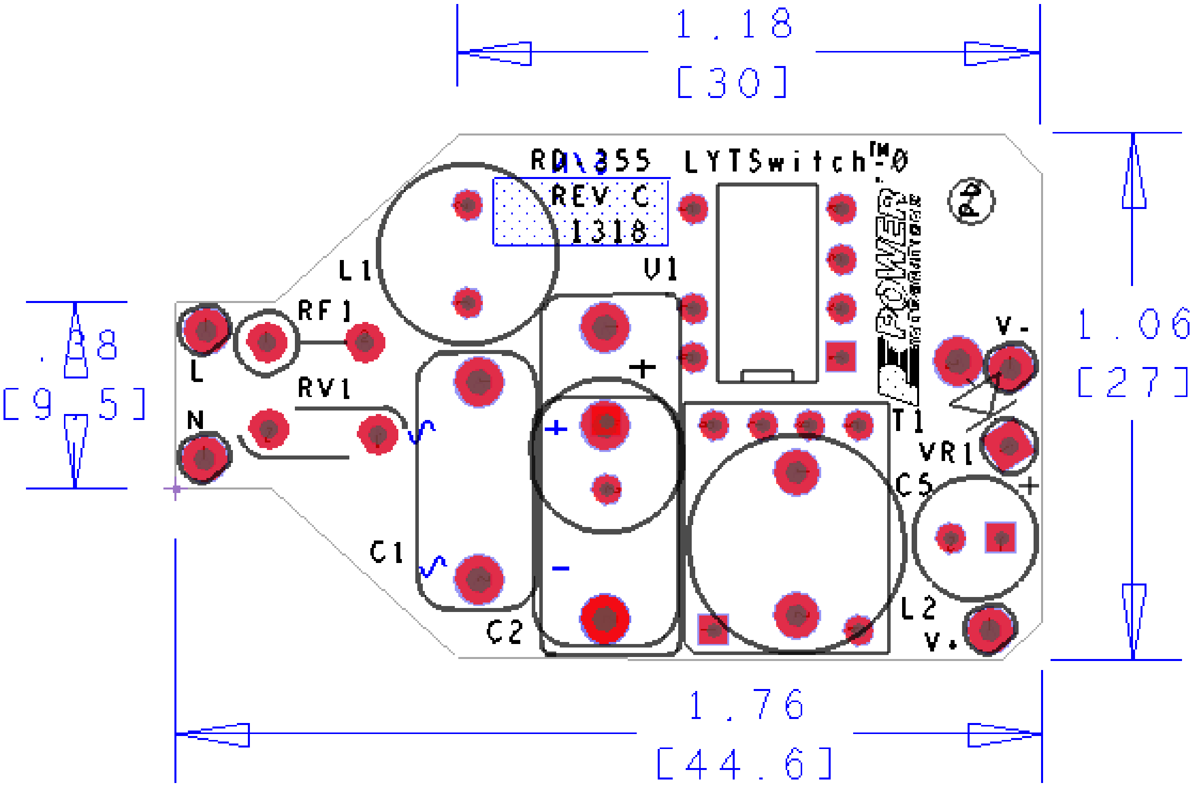


**Figure 4 –** Printed Circuit Layout. Top view.

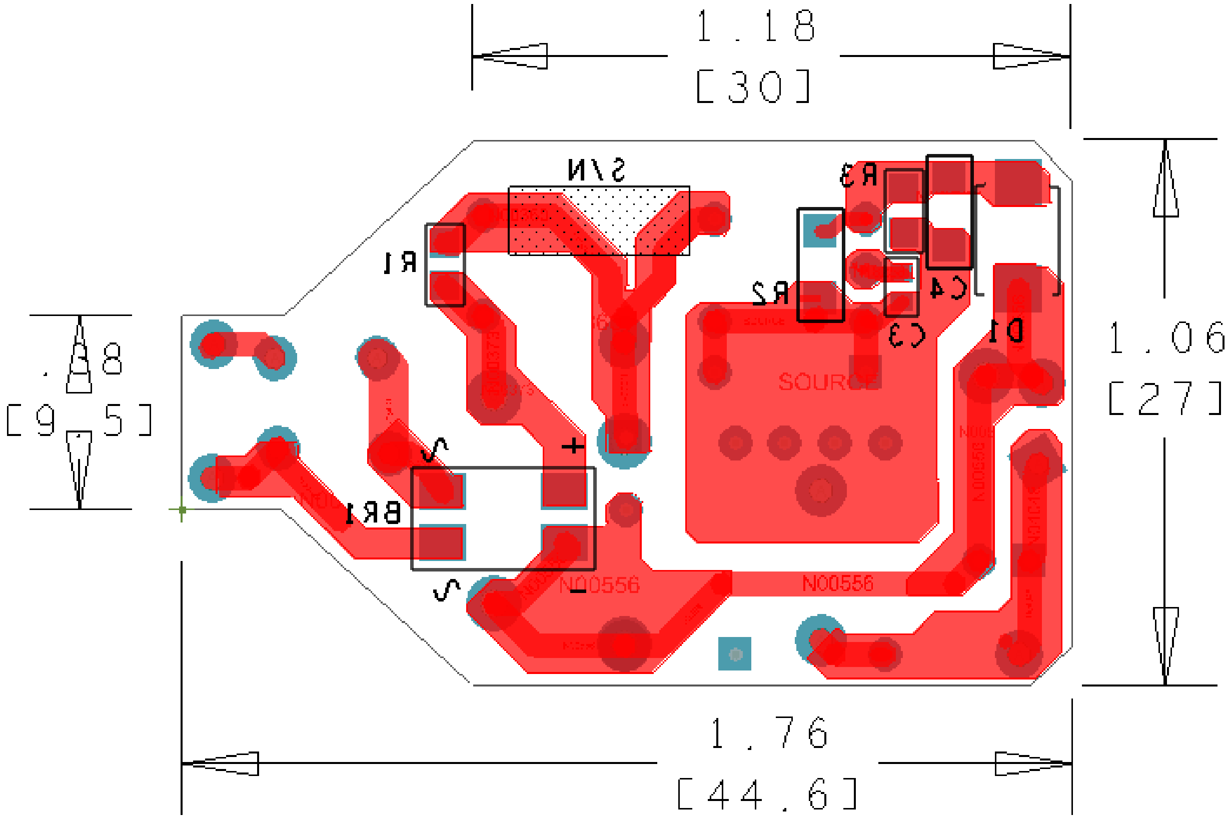


**Figure 5 –** Printed Circuit Layout. Bottom View.

## 6 物料清单(BOM)

| Item | Qty | Ref Des | Description | Manufacturer P/N | Manufacturer |
|---|---|---|---|---|---|
| 1 | 1 | BR1 | 600 V, 0.5 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC | MB6S-TP | Micro Commercial |
| 2 | 1 | C1 | 47 nF, 630 V, Film | ECQ-E6473KF | Panasonic |
| 3 | 1 | C2 | 330 nF, 450 V, METALPOLYPRO | ECW-F2W334JAQ | Panasonic |
| 4 | 1 | C3 | 100 nF, 25 V, Ceramic, X7R, 0603 | VJ0603Y104KNXAO | Vishay |
| 5 | 1 | C4 | 22 μF, 16 V, Ceramic, X5R, 1206 | EMK316BJ226ML-T | Taiyo Yuden |
| 6 | 1 | C5 | 47 μF, 63 V, Electrolytic, Gen. Purpose, (6.3 x 13) | 63YXJ47M6.3X11 | Rubycon |
| 7 | 1 | D1 | 600 V, 1 A, Ultrafast Recovery, 35 ns, SMB Case | MURS160T3G | On Semi |
| 8 | 1 | L1 | 4.7 mH, 0.150 A, 20% | RL-5480-3-4700 | Renco |
| 9 | 1 | R1 | 4.7 k Ω, 5%, 1/8 W, Thick Film, 0805 | ERJ-6GEYJ472V | Panasonic |
| 10 | 1 | R2 | 18.7 Ω, 1%, 1/4 W, Thick Film, 1206 | ERJ-8ENF18R7V | Panasonic |
| 11 | 1 | RF1 | 4.7 Ω, 5%, 2 W, Metal Film Fusible | FW20A4R70JA | Bourns |
| 12 | 1 | RV1 | 275 V, 23 J, 7 mm, RADIAL | V275LA4P | Littlefuse |
| 13 | 1 | T1 | EE10, Bobbin<br>Inductor | Custom<br>SNX-R1699 | Kunshan Fengshunhe<br>Santronics USA |
| 14 | 1 | U1 | LinkSwitch-0, DIP-8B | LYT0006P | Power Integrations |
| 15 | 1 | VR1 | 62 V, 5%, 1 W, DO-41 | 1N4759A | Vishay |

# 7 电感规格

## 7.1 电气原理图

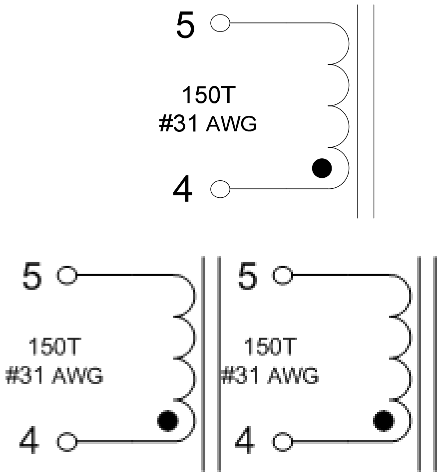


**Figure 6 –** Inductor Electrical Diagram.

## 7.2 电气规格

| | | |
|---|---|---|
| **Primary Inductance** | Pins 4-5, all other windings open, measured at 100 kHz, 0.4 $V_{RMS.}$ | 1.4 mH ±7% |

## 7.3 材料

| Item | Description |
|---|---|
| **[1]** | Core: EE10; TDK-PC40EE10/11-Z; or equivalent. |
| **[2]** | Bobbin: EE10; 8 pins (4/4), Horizontal, PI#: 25-00956-00. |
| **[3]** | Magnet Wire: #31 AWG, double coated. |
| **[4]** | Tape: Polyester film, 3M 1350-1, 6.5mm wide. |
| **[5]** | Varnish. |

## 7.4 电感结构图

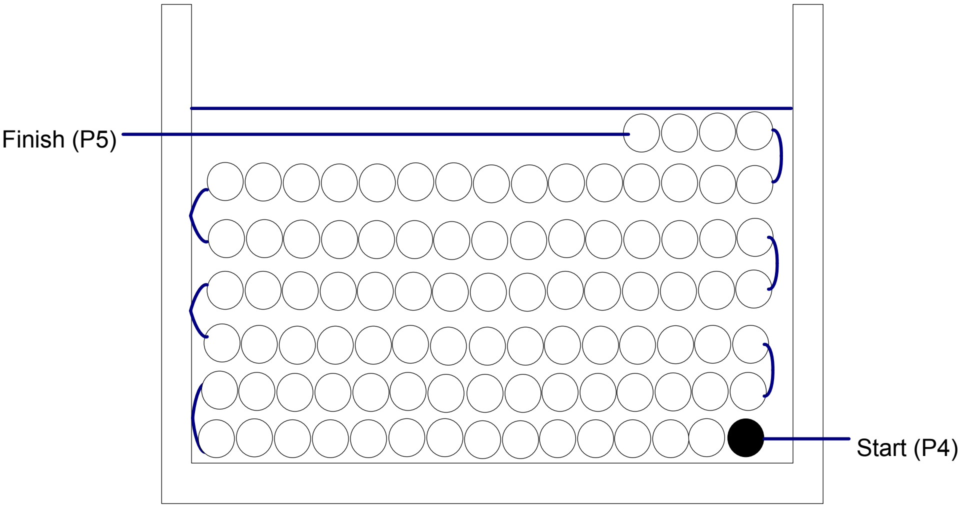


**Figure 7 –** Inductor Build Diagram.

## 7.5 变压器构造

| | |
|---|---|
| **Winding Preparation** | Place bobbin item [2] on the mandrel with pin side 1-4 on the right side.<br>Winding direction is clockwise direction. |
| **Winding** | Start pin 4, wind 150 turns of wire item [3] from right to left then left to right in ~6 layers and finish at pin 5. |
| **Tape** | Secure winding with tape item [4]. |
| **Final Assembly** | Gap cores to get the 1.35 mH inductance. Apply tape to secure both cores. Remove pins: 2 and 3. |

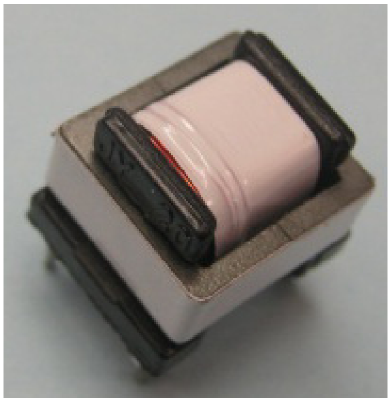


**Figure 8 –** Transformer Assembly Sample.

# 8 电感设计表格

| **ACDC_LYTSwitchZero_052813; Rev.0.8; Copyright Power Integrations 2013** | **INPUT** | **INFO** | **OUTPUT** | **UNIT** | **LYTSwitchZero_Rev_0-8.xls: LYTSwitchZero Design Spreadsheet** |
|---|---|---|---|---|---|
| **INPUT VARIABLES** | | | | | |
| VACMIN | 90 | | 90 | Volts | Minimum AC Input Voltage |
| VACNOM | 120 | | 120 | | |
| VACMAX | 265 | | 265 | Volts | Maximum AC Input Voltage |
| FL | 60 | | 60 | Hertz | Line Frequency |
| VO | 54 | | 54 | Volts | Output Voltage |
| IO | 110 | | 110 | mA | Output Current |
| Pout | | | 5.94 | W | |
| EFFICIENCY | 0.9 | | 0.9 | | Overall Efficiency Estimate (Adjust to match Calculated, or enter Measured Efficiency) |
| CIN | 0.38 | | 0.38 | uF | Input Filter Capacitor |
| Input Stage Resistance | 4.7 | | 4.7 | ohms | Input Stage Resistance, Fuse & Filtering |
| Switching Topology | | | Buck | | Type of Switching topology |
| **DC INPUT VARIABLES** | | | | | |
| VMIN | | | 54.00068302 | Volts | Minimum DC Bus Voltage |
| VMAX | | | 374.766594 | Volts | |
| **LYTSwitchZero** | | | | | |
| LYTSwitchZero | LYT0006 | | LYT0006 | | |
| ILIMIT | | | 0.375 | Amps | Typical Current Limit |
| ILIMIT_MIN | | | 0.33275 | Amps | Minimum Current Limit |
| ILIMIT_MAX | | | 0.401 | Amps | Maximum Current Limit |
| FSMIN | | | 62000 | Hertz | Minimum Switching Frequency |
| VDS | | | 4.8375 | Volts | Maximum On-State Drain To Source Voltage drop |
| **DIODE** | | | | | |
| VD | | | 0.7 | Volts | Freewheeling Diode Forward Voltage Drop |
| VRR | | | 600 | Volts | Recommended PIV rating of Freewheeling Diode |
| IF | | | 1 | Amps | Recommended Diode Continuous Current Rating |
| Diode Recommendation | | | BYV26C | | Suggested Freewheeling Diode |
| **OUTPUT INDUCTOR** | | | | | |
| Core type | Ferrite | | Ferrite | | Select core type between Ferrite and Off-the-Shelf |
| Core size | EE10 | | EE10 | | Select core size |
| Custom Core | | | | | Enter custom core description (if used) |
| AE | | | 12.1 | mm^2 | Core Effective Cross Sectional Area |
| LE | | | 26.1 | mm | Core Effective Path Length |
| AL | | | 850 | nH/T^2 | Ungapped Core Effective Inductance |
| BW | | | 6.6 | mm | Bobbin Physical Winding Width |
| NL | | | 149.6667555 | | Number of turns on inductor |
| BP | | | 3100 | Gauss | Peak flux density |
| LG | | | 2.253983597 | mm | Gap length |
| OD | | | 0.132293908 | | Maximum Primary Wire Diameter including insulation |
| INS | | | 0.031219467 | | Estimated Total Insulation Thickness (= 2 * film thickness) |
| DIA | | | 0.101074441 | | Bare conductor diameter |

| | | | | | |
|---|---|---|---|---|---|
| AWG | | | 39 | | Primary Wire Gauge (Rounded to next smaller standard AWG value) |
| CM | | | 12.69920842 | | Bare conductor effective area in circular mils |
| CMA | | | 0.112907248 | | !!! INCREASE CMA > 200 (increase L(primary layers),decrease NS, use larger Core) |
| L | | | 3 | | |
| LP | 1400 | | 1400 | uH | Output Inductor, Recommended Standard Value |
| L_R | 2 | | 2 | Ohms | DC Resistance of Inductor |
| IO_Average | | | 112.474696 | | Average output current |
| ILRMS | | | 112.474696 | mA | Estimated RMS inductor current (at VMAX) |
| **FEEDBACK COMPONENTS** | | | | | |
| RFB | 18.7 | | 18.7 | Ohms | Feedback Resistor. Use closest standard 1% value |
| CFB | | | 22 | uF | Feedback Capacitor |
| **OUTPUT REGULATION** | | | | | |
| IO_VACMIN | | | 109.393596 | mA | Output Current at VACMIN |
| IO_VACNOM | | | 112.474696 | mA | Output Current at VACNOM |
| IO_VACMAX | | | 114.3382366 | mA | Output Current at VACMAX |

# 9 性能数据

All measurements performed at room temperature (≈25 ºC) otherwise specified.

| Input | | Input Measurement | | | | LED Load Measurement | | | Efficiency (%) | Regulation (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| VAC ($V_{RMS}$) | Freq (Hz) | $V_{IN}$ ($V_{RMS}$) | $I_{IN}$ ($mA_{RMS}$) | $P_{IN}$ (W) | PF | $V_{OUT}$ ($V_{DC}$) | $I_{OUT}$ ($mA_{DC}$) | $P_{OUT}$ (W) | | |
| 90 | 60 | 90.07 | 82.57 | 6.480 | 0.871 | 54.0400 | 108.050 | 5.918 | 91.33 | -1.77 |
| 100 | 60 | 100.11 | 78.53 | 6.584 | 0.838 | 54.1400 | 110.150 | 6.024 | 91.49 | 0.14 |
| 115 | 60 | 110.12 | 73.24 | 6.555 | 0.813 | 54.1400 | 110.080 | 6.006 | 91.62 | 0.07 |
| 120 | 60 | 120.12 | 69.70 | 6.566 | 0.784 | 54.1600 | 110.500 | 6.021 | 91.70 | 0.45 |
| 132 | 60 | 135.16 | 67.07 | 6.564 | 0.724 | 54.1600 | 110.590 | 6.015 | 91.64 | 0.54 |
| 190 | 50 | 190.30 | 57.15 | 6.386 | 0.587 | 54.0200 | 107.810 | 5.836 | 91.39 | -1.99 |
| 200 | 50 | 200.41 | 56.02 | 6.359 | 0.566 | 53.9900 | 107.310 | 5.805 | 91.29 | -2.45 |
| 220 | 50 | 220.35 | 54.16 | 6.308 | 0.529 | 53.9400 | 106.430 | 5.749 | 91.14 | -3.25 |
| 230 | 50 | 230.37 | 53.68 | 6.286 | 0.508 | 53.9200 | 106.010 | 5.723 | 91.04 | -3.63 |
| 240 | 50 | 264.15 | 55.86 | 6.726 | 0.456 | 54.2500 | 112.380 | 6.098 | 90.66 | 2.16 |
| 265 | 50 | 90.07 | 82.57 | 6.480 | 0.871 | 54.0400 | 108.050 | 5.918 | 91.33 | -1.77 |

### *9.1 带载模式效率*

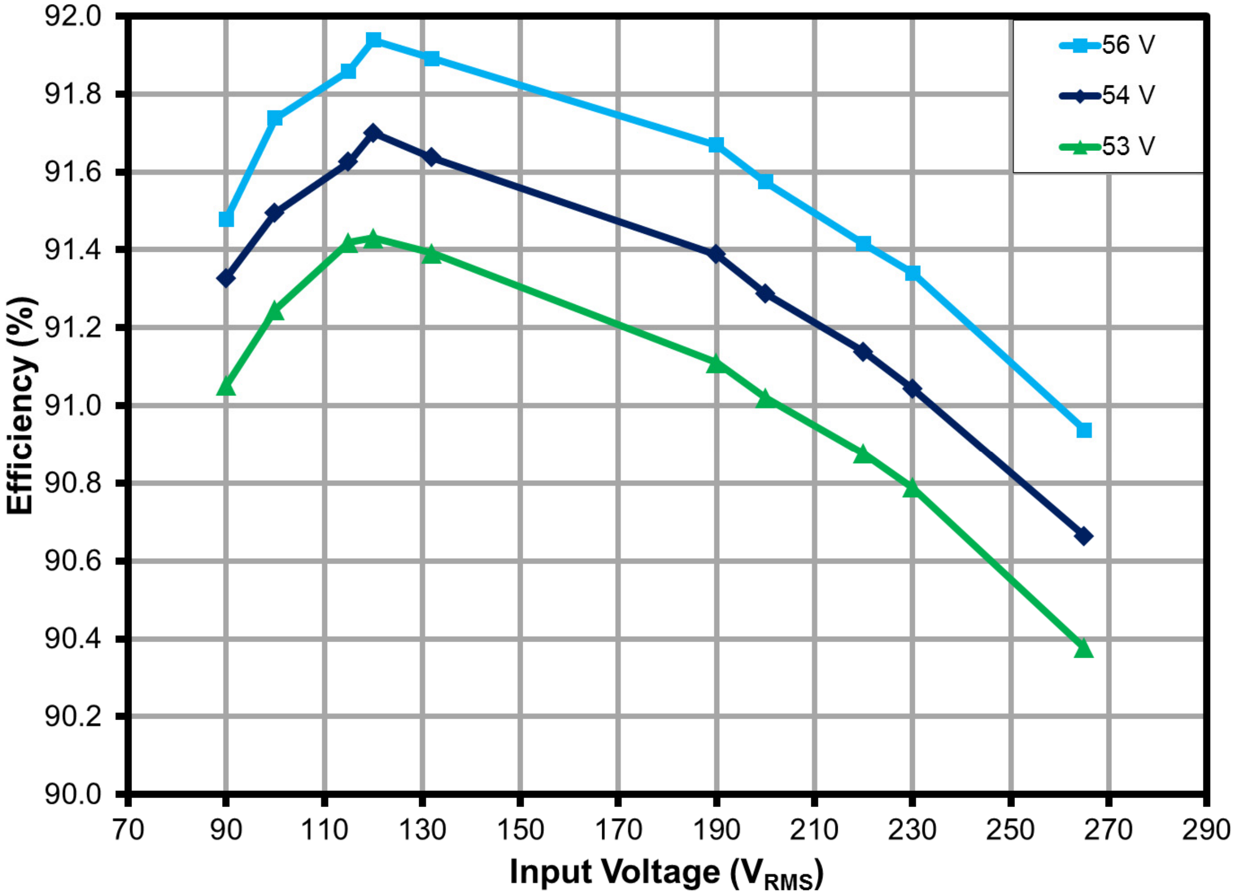


**Figure 9 –** Efficiency with Respect to AC Input Voltage. 90-132 VAC (50 Hz) and 190-265 VAC (60 Hz) Input.

## *9.2 输出电流调整*

### 9.2.1 输入线电压和负载电压到输出电流的调整

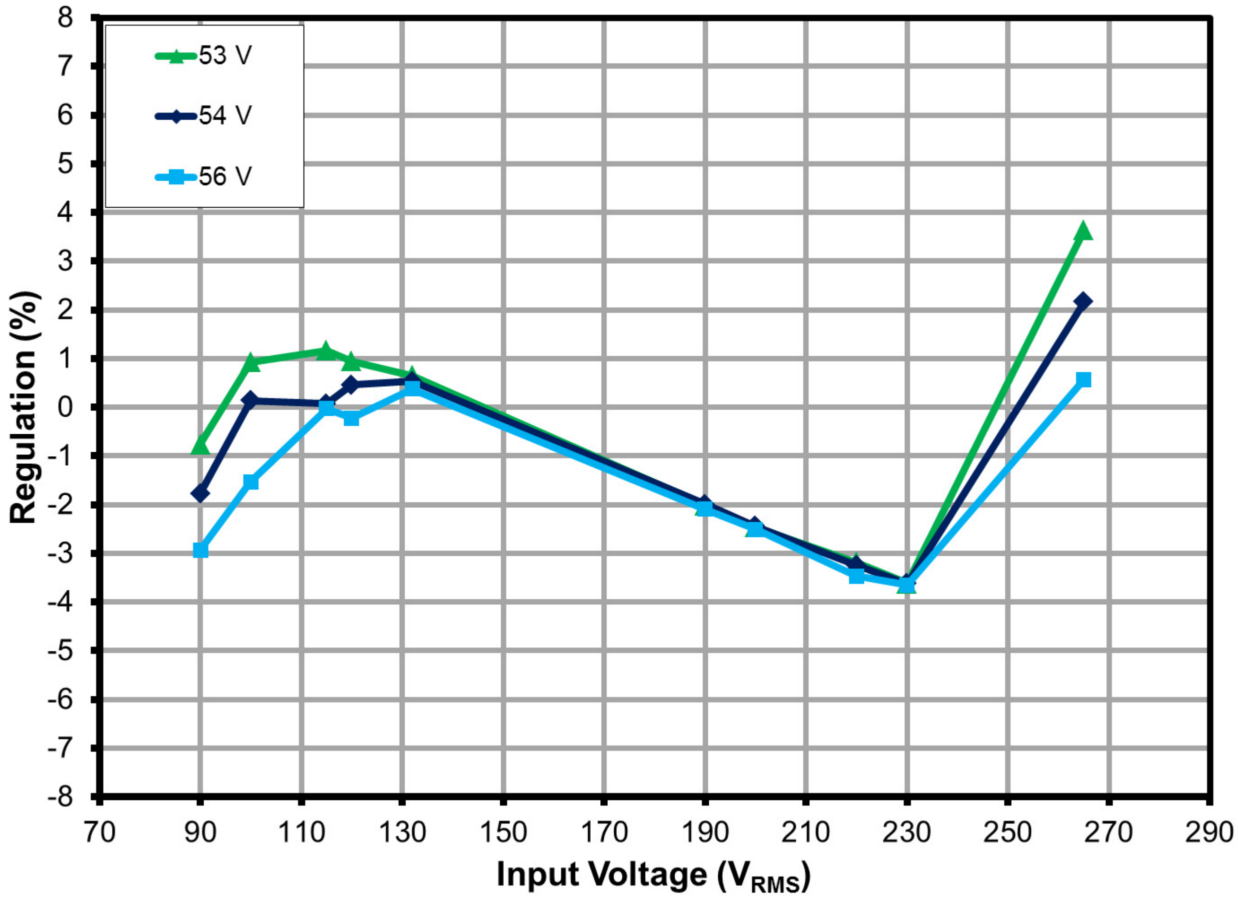


**Figure 10 –** Load Regulation, Room Temperature.

# 10 热性能

## 10.1 所用设备

| | | | |
|---|---|---|---|
| Chamber: | Tenney Environmental Chamber<br>Model No: TJR-17 942 | Wattmeter: | Yokogawa Power Meter<br>Model No: WT2000 |
| AC Source: | Chroma Programmable AC Source<br>Model No: 6415 | Data Logger: | Yokogawa<br>Model: 2008-3-4-2-2-1D<br>SN: S5L409310 |

**Figure 11 –** Thermal Chamber Set-up Showing Box Used to Prevent Airflow Over UUT.

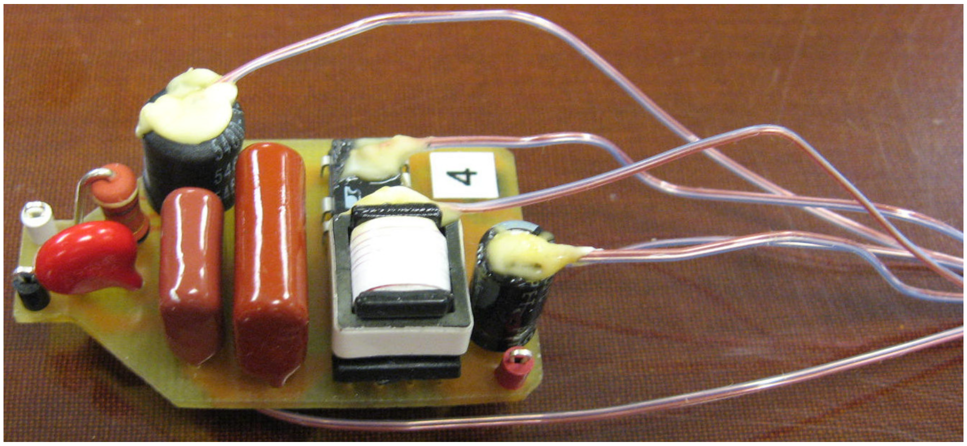


**Figure 12 –** Thermal Unit Thermocouple Measurement Set-up.

## 11 热结果

Input: 90 VAC / 60 Hz
Load: 54 V / 110 m A LED load.

| **Location** | **Temperature** | | | | | | | | **Thermal Shutdown** | **Thermal Recovery** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ambient** | 23.3 | 38.7 | 47.9 | 58.4 | 70.0 | 80.0 | 90.0 | 100.0 | 107.9 | 40.5 |
| **Bridge** | 37.8 | 52.4 | 60.8 | 70.9 | 80.7 | 89.6 | 99.0 | 108.5 | 115.1 | 64.4 |
| **L1** | 37.2 | 52.7 | 60.9 | 71.2 | 81.9 | 90.6 | 100.4 | 109.9 | 117.8 | 60.2 |
| **L2** | 39.4 | 54.6 | 63.7 | 73.9 | 84.7 | 93.4 | 103.2 | 112.7 | 120.6 | 63.0 |
| **IC** | 40.9 | 56.9 | 66.1 | 76.9 | 87.6 | 97.5 | 107.5 | 117.8 | 125.0 | 61.7 |
| **Diode** | 38.0 | 53.5 | 62.8 | 73.5 | 83.9 | 93.3 | 103.1 | 113.0 | 120.1 | 59.4 |

**Table 1 –** Thermal Measurement.

**Note:** Unit will start reliably at -40 °C. Tests were performed but are not shown here.

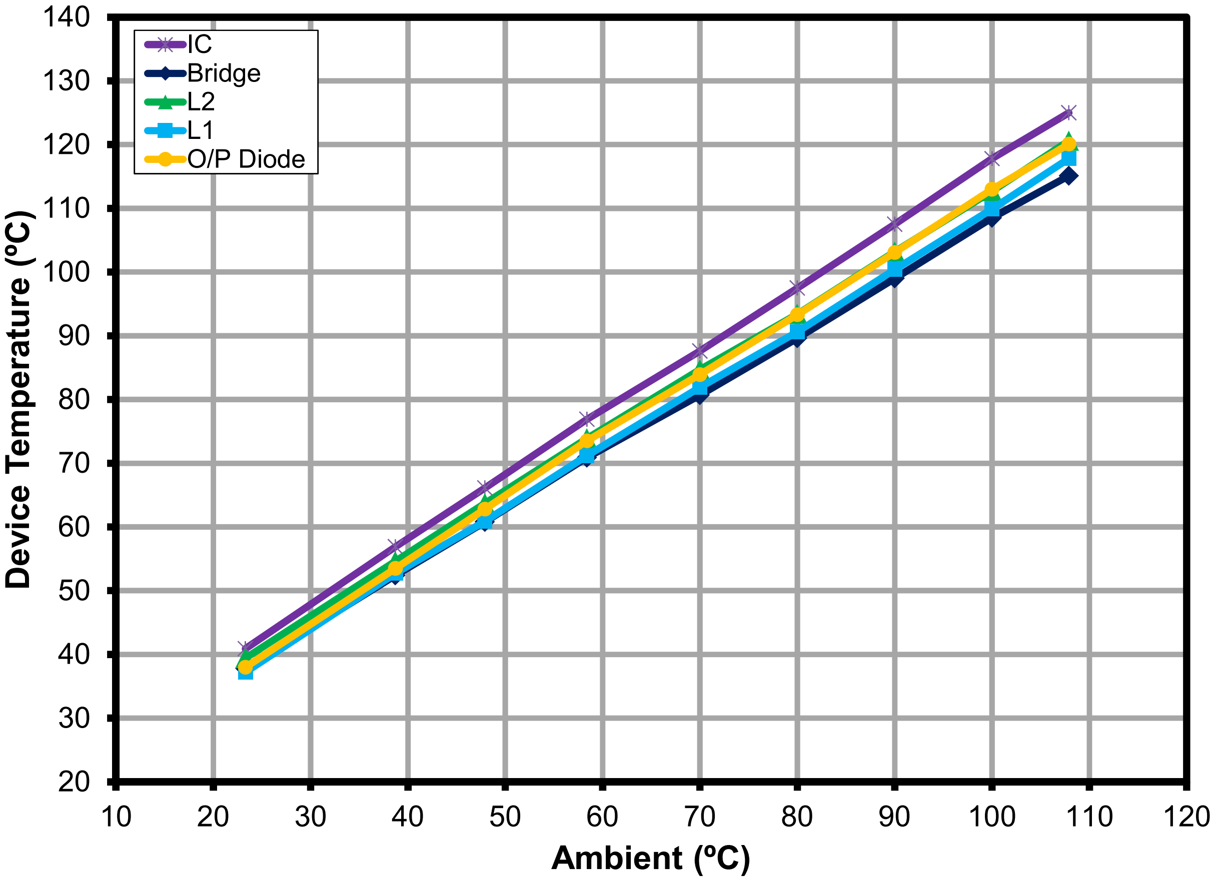


**Figure 13 –** Thermal Performance Curve.

### *11.1 热扫描*

Open-frame thermal measurement at 25°C ambient. UUT was soaked for 1 hour to achieve steady-state before the measurement.

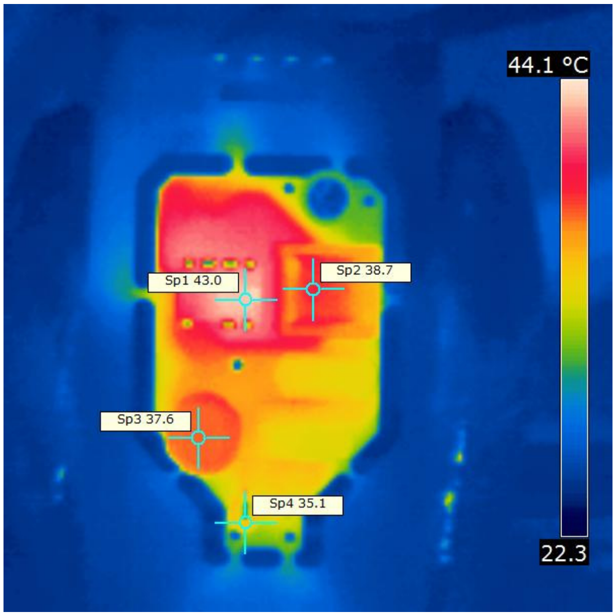


**Figure 14 –** Temperature (°C) at Top Side of PCB.
SP1 – U1, LYT0006P.
SP2 – L2, Power Inductor.
SP3 – L1, EMI Choke.
SP4 – FR1, Fusible Resistor.

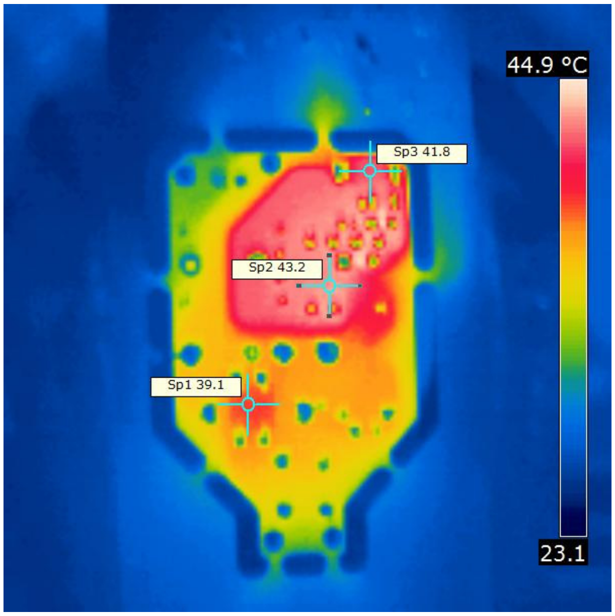


**Figure 15 –** Temperature (°C) at Bottom Side of PCB.
SP1 – BR1, Bridge Rectifier.
SP2 – PCB, Trace Temperature.
SP3 – D1, Freewheeling Diode.

# 12 波形

## *12.1 正常工作时的漏极电压*

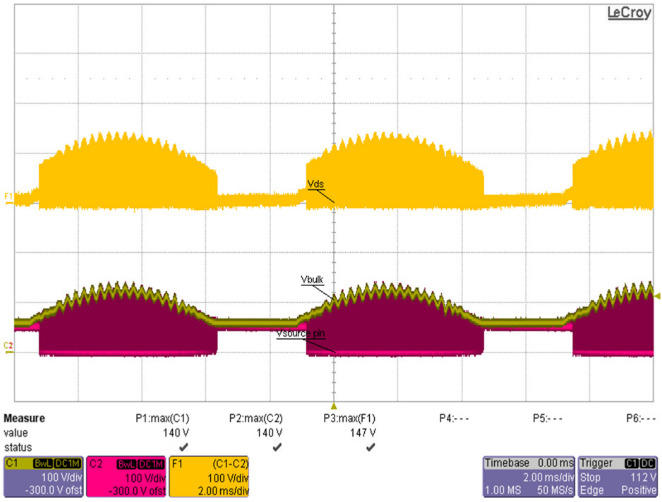


**Figure 16 –** 90 VAC, 60Hz, Full Load
F1(Orange): $V_{DRAIN-SOURCE}$, 100 V / div.
Ch1(Yellow): $V_{DRAIN-GND}$, 100 V / div.
Ch2(Red): $V_{SOURCE-GND}$, 100 V, 2 ms / div.

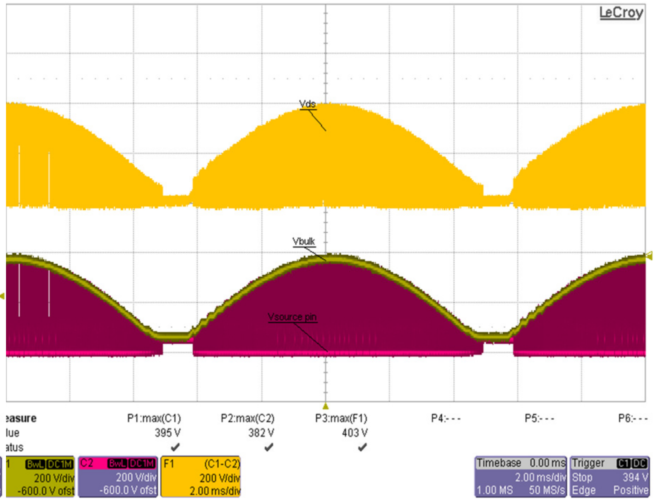


**Figure 17 –** 265 VAC, Full Load
F1(Orange): $V_{DRAIN-SOURCE}$, 200 V / div.
Ch1(Yellow): $V_{DRAIN-GND}$, 200 V / div.
Ch2(Red): $V_{SOURCE-GND}$, 200 V, 2 ms / div.

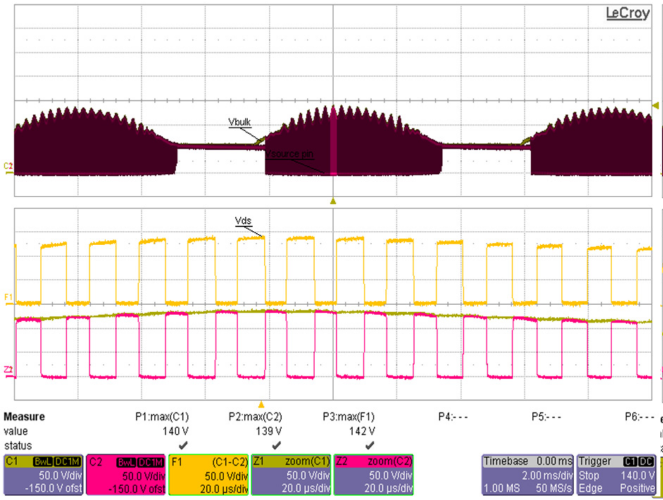


**Figure 18 –** 90 VAC, 60Hz, Full Load
F1(Orange): $V_{DRAIN-SOURCE}$, 50 V / div.
Ch1(Yellow): $V_{DRAIN-GND}$, 50 V / div.
Ch2(Red): $V_{SOURCE-GND}$, 50 V, 2 ms / div.
Z1(Yellow): $V_{DRAIN-GND}$, 50 V / div.
Z2(Red): $V_{SOURCE-GND}$, 50 V, 20 µs / div.

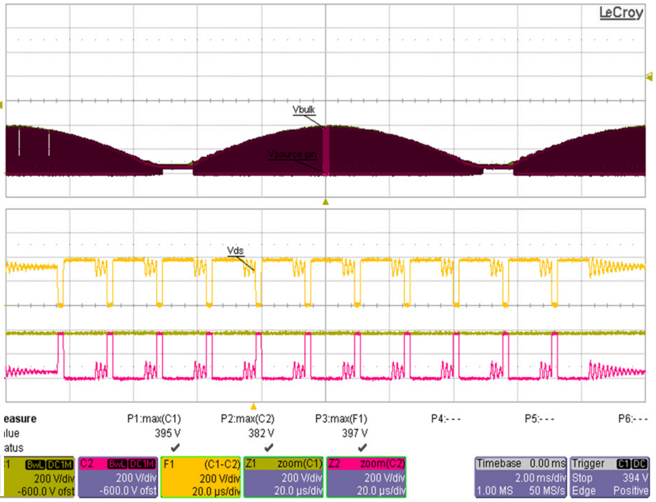


**Figure 19 –** 265 VAC, Full Load
F1(Orange): $V_{DRAIN-SOURCE}$, 200 V / div.
Ch1(Yellow): $V_{DRAIN-GND}$, 200 V / div.
Ch2(Red): $V_{SOURCE-GND}$, 200 V, 2 ms /
div. Z1(Yellow): $V_{DRAIN-GND}$, 200V / div.
Z2(Red): $V_{SOURCE-GND}$, 200 V, 20 µs / div.

### 12.2 正常工作时的漏极电流

Missing pulses are normal and are used to regulate the output current. These missing pulses are present every time the sense resistor (R2) voltage-drop reaches 1.65 V. The unit will enter into auto-restart if there is not at least one missing pulse within 50 ms. For some designs wherein the power inductance is high and operating mostly in CCM, a reverse current may be present. One way to avoid this is by increasing the device size or increase input capacitance or adding a blocking diode in the drain. See AN-60 for more details.

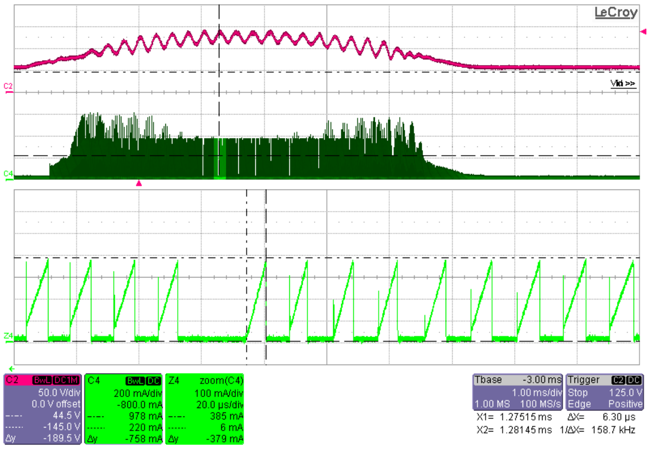


**Figure 20 –** 90 VAC, 60 Hz, 54 $V_{LED}$
Ch2(Red): $V_{BULK}$, 50V / div.
Ch4(Green): $I_{DRAIN}$, 200 mA / div., 1 ms / div.
Z2(Green): $I_{DRAIN}$, 100 mA / div., 20 μs / div.

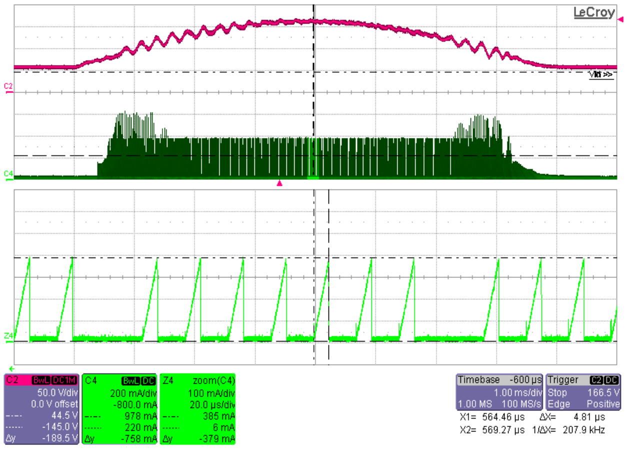
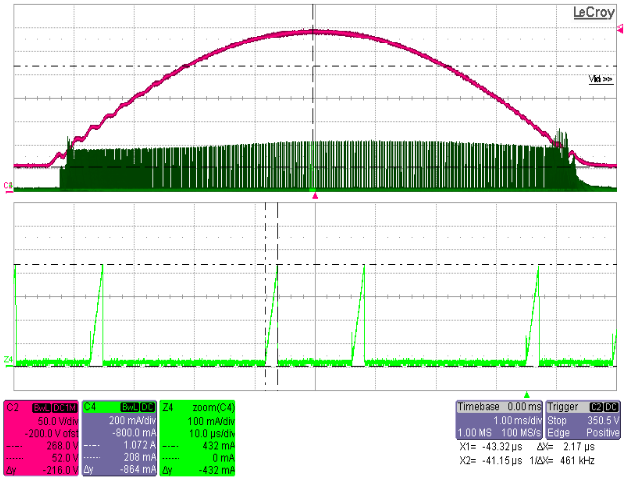


**Figure 21 –** 115 VAC, 60 Hz, 54 $V_{LED}$
Ch2(Red): $V_{BULK}$, 50 V / div.
Ch4(Green): $I_{DRAIN}$, 200 mA / div., 1 ms / div.
Z2(Green): $I_{DRAIN}$, 100 mA / div., 20 μs / div.



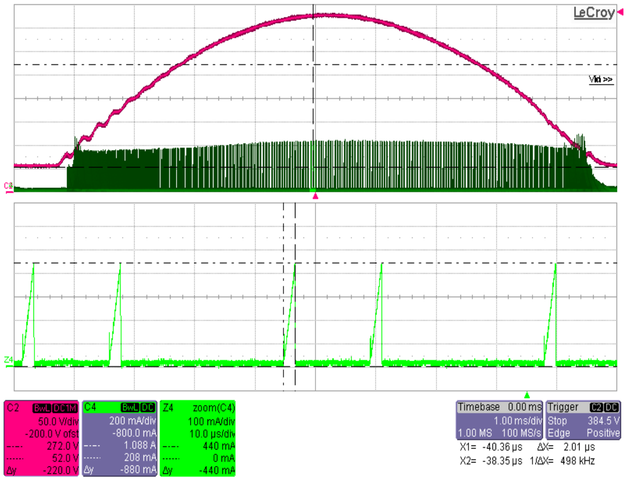


**Figure 22 –** 240 VAC, 60 Hz, 54 $V_{LED}$
Ch2(Red): $V_{BULK}$, 50 V / div.
Ch4(Green): $I_{DRAIN}$, 200 mA / div., 1 ms / div.
Z2(Green): $I_{DRAIN}$, 100 mA / div., 20 $\mu$s / div.

**Figure 23 –** 265 VAC, 60 Hz, 54 $V_{LED}$
Ch2(Red): $V_{BULK}$, 50 V / div.
Ch4(Green): $I_{DRAIN}$, 200 mA / div., 1 ms / div.
Z2(Green): $I_{DRAIN}$, 100 mA / div., 20 $\mu$s / div.

## 12.3 输出短路时的漏极电压和电流

Device is operating within the range and no inductor saturation was observed.

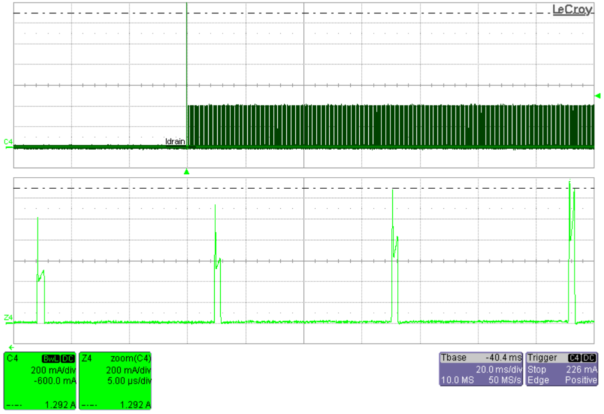


**Figure 24 –** LYT0006P Output Short.
Ch4: $I_{DRAIN}$; 0.2 A / div.
Time Scale: 20 ms / div.
Z4: $V_{DS}$; 0.2 A / div.
Zoom Time Scale: 5 µs / div.

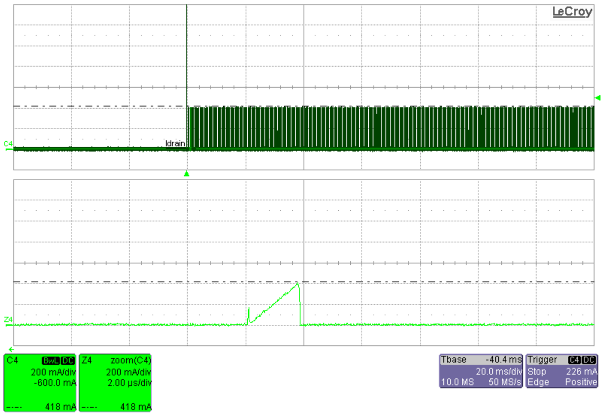


**Figure 25 –** LYT0006P Output Short.
Ch4: $I_{DRAIN}$; 0.2 A / div.
Time Scale: 20 ms / div.
Z4: $V_{DS}$; 0.2 A / div.
Zoom Time Scale: 2 µs / div.

## 12.4 漏极电压和电流启动特征

Device is operating within the range and no inductor saturation was observed.

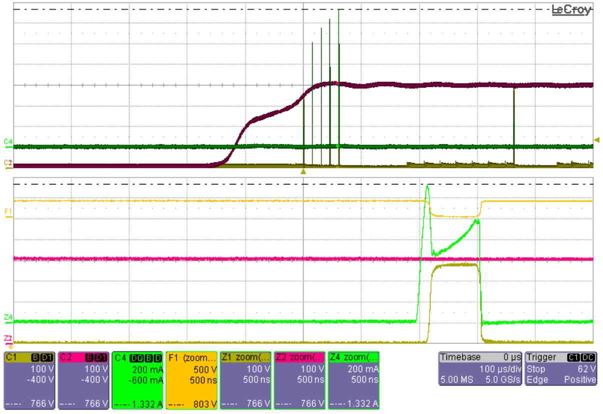


**Figure 26 –** 265 VAC / 50 Hz Start-up.
Ch1, Z1: SOURCE Pin to Ground; 100 V / div.
Ch2, Z2: Bulk Input; 100 V / div.
Ch4, Z4: $I_{DRAIN}$; 0.2 A / div.
Time Scale: 100 µs / div.
F1: $V_{DS}$; 100 V / div.
Zoom Time Scale: 500 ns / div.

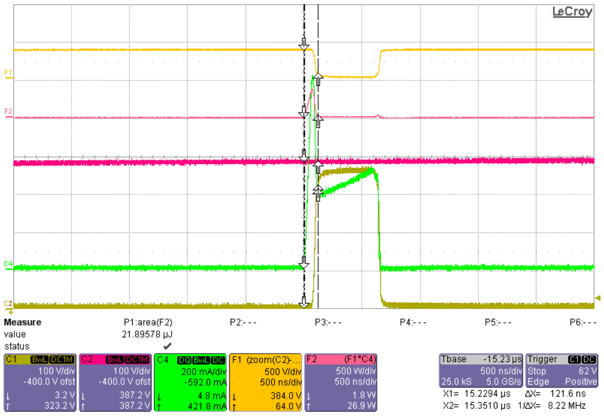


**Figure 27 –** 265 VAC / 50 Hz Start-up.
Ch1: SOURCE Pin to Ground; 100 V / div.
Ch2: Bulk Input; 100 V / div.
Ch4: $I_{DRAIN}$; 0.2 A / div.
Time Scale: 500 ns / div.
F1: $V_{DS}$; 100 V / div.
F2: Switching Power; 500 W / div.
Zoom Time Scale: 500 ns / div.

### *12.5 输出电流启动特征*

Output current/light is present in just one AC cycle. <20 ms

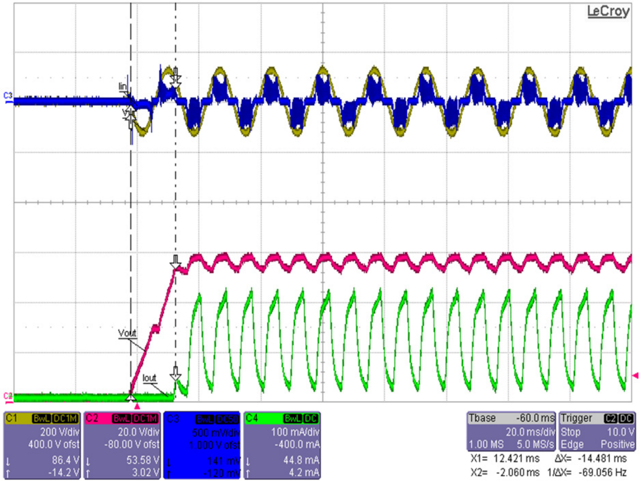


**Figure 28 –** 90 VAC, 60Hz, Full Load
Ch1(Yellow): $V_{IN}$, 200 V / div.
Ch2(Red): $V_{OUT}$, 20 V,
Ch3(Blue): $I_{IN}$, 0.5 A / div.
Ch4(Green): $I_{OUT}$, 100 mA / div., 20 ms / div.

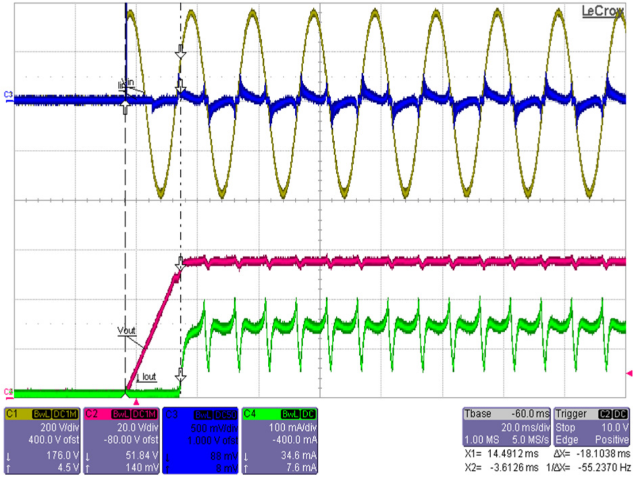


**Figure 29 –** 265 VAC, Full Load
Ch1(Yellow): $V_{IN}$, 200 V / div.
Ch2(Red): $V_{OUT}$, 20 V,
Ch3(Blue): $I_{IN}$, 0.5 A / div.
Ch4(Green): $I_{OUT}$, 100 mA / div., 20 ms / div.

### *12.6 输入-输出特征*

There is no limitation to the amount of output capacitance that can be added. If the application requires less output current ripple then increasing the output capacitance is straight forward. Note that the output current waveform below will vary depending on LED load impedance and will vary according to LED type.

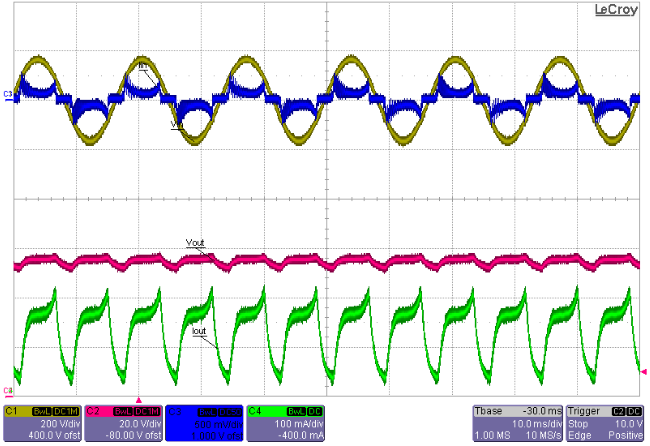


**Figure 30 –** 120 VAC, 60 Hz, Full Load
Ch1(Yellow): $V_{IN}$, 200 V / div.
Ch2(Red): $V_{OUT}$, 20 V.
Ch3(Blue): $I_{IN}$, 0.5 A / div.
Ch4(Green): $I_{OUT}$, 100 mA / div, 10 ms / div.

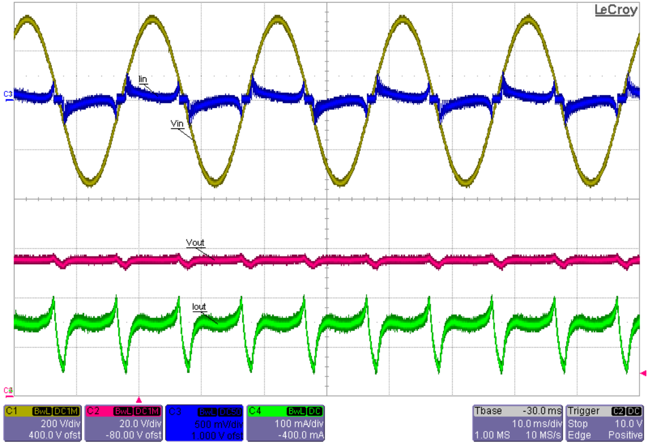


**Figure 31 –** 240 VAC, Full Load
Ch1(Yellow): $V_{IN}$, 200 V / div.
Ch2(Red): $V_{OUT}$, 20 V.
Ch3(Blue): $I_{IN}$, 0.5 A / div.
Ch4(Green): $I_{OUT}$, 100 mA / div, 10 ms / div.

### *12.7 电压跌落和浪涌*

The inherent advantage of the buck converter implemented with LYTSwitch-0 is the imperceptible start-up delay, the driver will turn-on within 20 ms as shown in the figures below. No failure of any component occurred during line fluctuation tests.

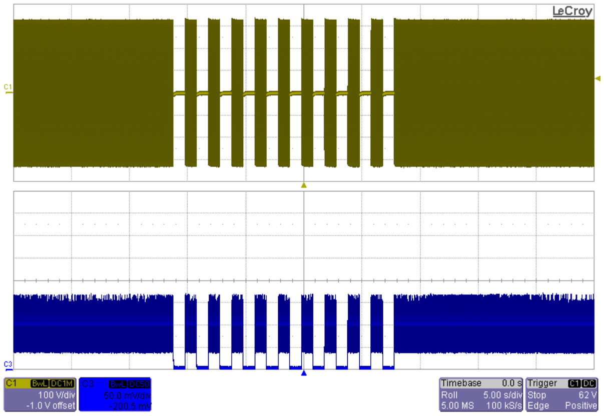


**Figure 32 –** Line sag test at 230 - 0 V at 1 Sec Interval.
Ch1: $V_{IN}$; 100 V / div.
Ch2: $I_{OUT}$; 50 mA / div.
Time Scale: 5 s / div.

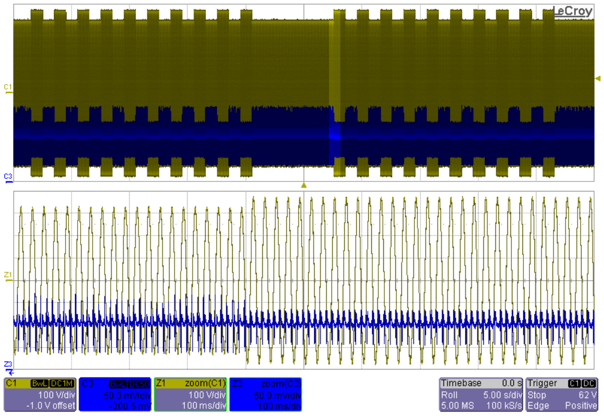


**Figure 33 –** Line Surge Test at 230 - 265 V at 1 Sec Interval.
Ch1: $V_{IN}$; 100 V / div.
Ch2: $I_{OUT}$; 50 mA / div.
Time Scale: 5 s / div.

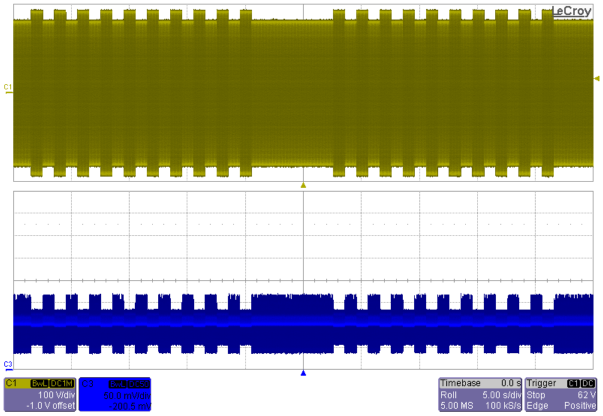


**Figure 34 –** Line Surge Test at 230 - 265 V at 1 Sec Interval.
Ch1: $V_{IN}$; 100 V / div.
Ch2: $I_{OUT}$; 50 mA / div.
Time Scale: 5 s / div.

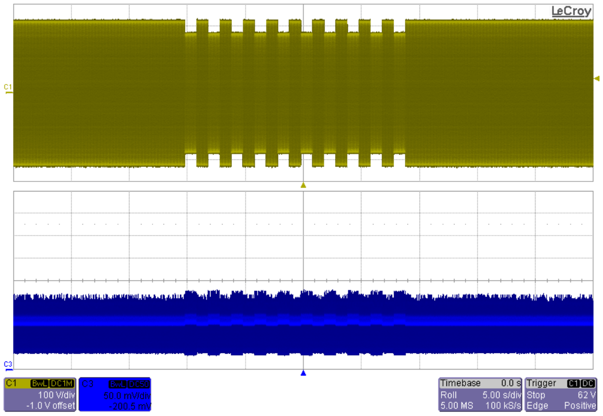


**Figure 35 –** Line Sag Test at 230 - 265 V at 1 Sec Interval.
Ch1: $V_{IN}$; 100 V / div.
Ch2: $I_{OUT}$; 50 mA / div.
Time Scale: 5 s / div.

### *12.8 电压跌落/缓升*

No failure of any component during brownout test of 0.5 V / sec AC cut-in and cut-off.

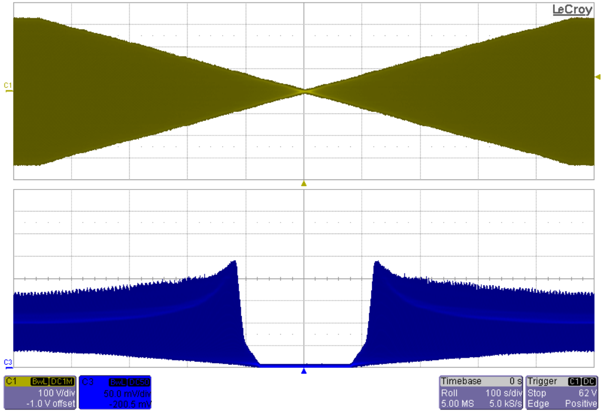


**Figure 36 –** Brown-out Test at 0.5 V / s. The Unit is Able to Operate Normally Without Any Failure and Without Flicker.
Ch1: $V_{IN}$; 100 V / div.
Ch2: $I_{OUT}$; 50 mA / div.
Time Scale: 100 s / div.

## 13 输入浪涌

Differential input line 1.2 kV / 50 μs surge testing was completed on a single test unit to IEC61000-4-5. Input voltage was set at 230 VAC / 60 Hz. Output was loaded at full load and operation was verified following each surge event.

| Surge Level (V) | Input Voltage (VAC) | Injection Location | Injection Phase (°) | Test Result (Pass/Fail) |
|---|---|---|---|---|
| +500 | 230 | L to N | 90 | Pass |
| -500 | 230 | L to N | 90 | Pass |
| +500 | 230 | L to N | 270 | Pass |
| -500 | 230 | L to N | 270 | Pass |
| +500 | 230 | L to N | 0 | Pass |
| -500 | 230 | L to N | 0 | Pass |

Unit passed under all test conditions.

Differential ring input line surge testing was completed on a single test unit to IEC61000-4-5. Input voltage was set at 230 VAC / 60 Hz. Output was loaded at full load and operation was verified following each surge event.

| Surge Level (V) | Input Voltage (VAC) | Injection Location | Injection Phase (°) | Test Result (Pass/Fail) |
|---|---|---|---|---|
| +2500 | 230 | L to N | 90 | Pass |
| -2500 | 230 | L to N | 90 | Pass |
| +2500 | 230 | L to N | 270 | Pass |
| -2500 | 230 | L to N | 270 | Pass |
| +2500 | 230 | L to N | 0 | Pass |
| -2500 | 230 | L to N | 0 | Pass |

Unit passed under all test conditions.

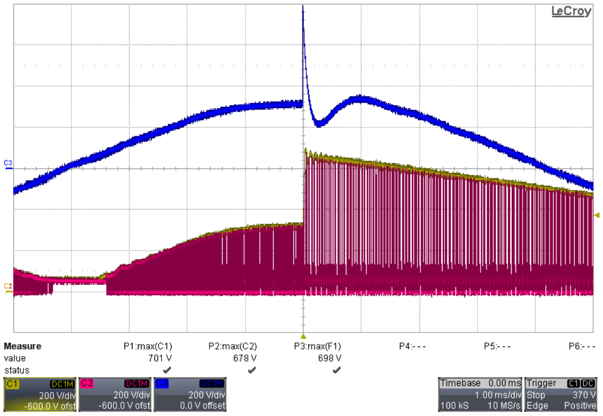


**Figure 37 –** Differential Line Surge at 500 V / 90°.
Peak Drain Voltage Recorded is 678 V.
Ch1: $V_{IN}$; 200 V / div.
Ch2: $V_{DRAIN}$; 200 V / div.
Ch3: $V_{BULK}$; 200 V / div.
Time Scale: 1 ms / div.

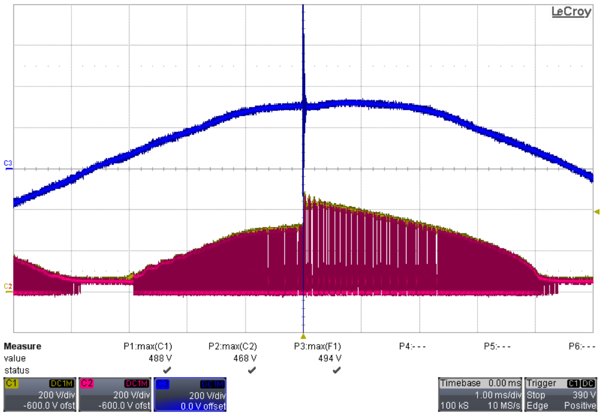


**Figure 38 –** Differential Ring Surge at 2500 V / 90°.
Peak Drain Voltage Recorded is 468 V.
Ch1: $V_{IN}$; 200 V / div.
Ch2: $V_{DRAIN}$; 200 V / div.
Ch3: $V_{BULK}$; 200 V / div.
Time Scale:1 ms / div.

# 14 传导EMI

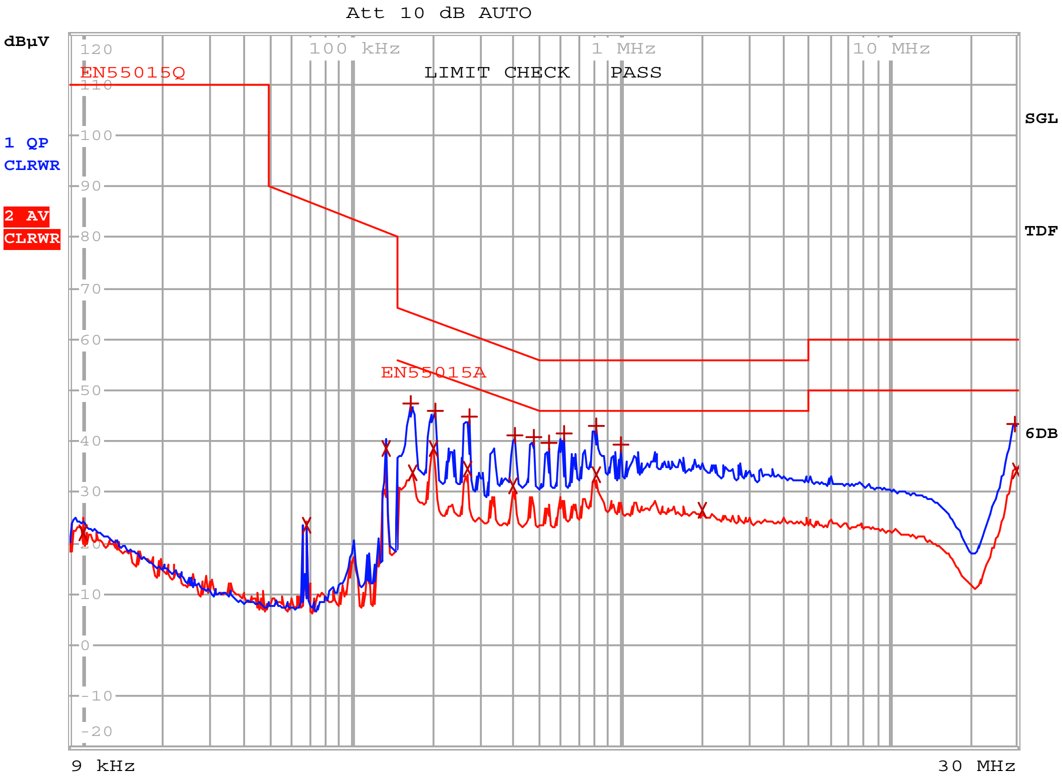
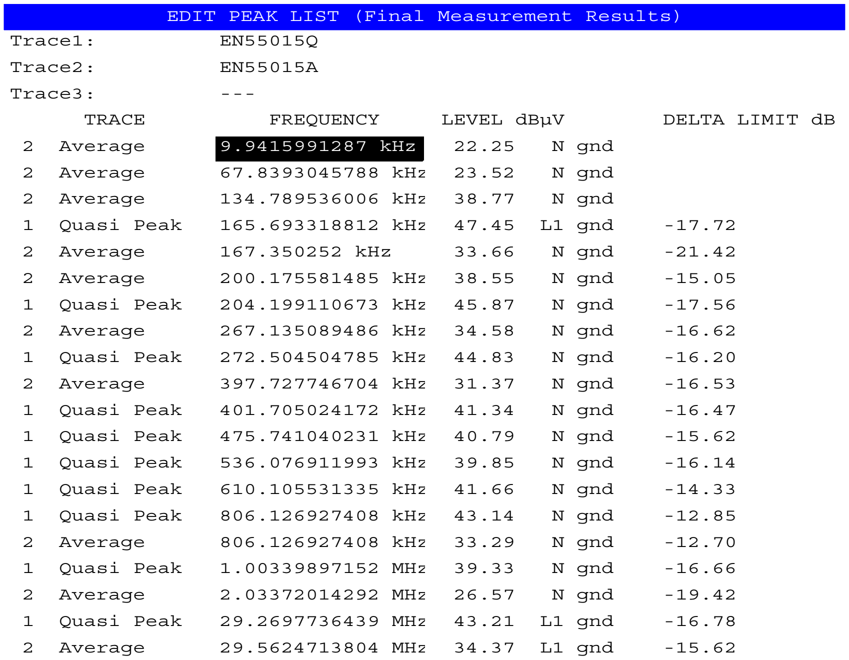


**Figure 26 –** Conducted EMI, Maximum Steady State Load, 120 VAC, 60 Hz, and EN55015 B Limits.



```
            EDIT PEAK LIST (Final Measurement Results)
Trace1:           EN55015Q
Trace2:           EN55015A
Trace3:           ---
      TRACE            FREQUENCY        LEVEL dBµV         DELTA LIMIT dB
  2  Average      9.9415991287 kHz    22.25    N gnd
  2  Average      67.8393045788 kHz   23.52    N gnd
  2  Average      134.789536006 kHz   38.77    N gnd
  1  Quasi Peak   165.693318812 kHz   47.45   L1 gnd     -17.72
  2  Average      167.350252 kHz      33.66    N gnd     -21.42
  2  Average      200.175581485 kHz   38.55    N gnd     -15.05
  1  Quasi Peak   204.199110673 kHz   45.87    N gnd     -17.56
  2  Average      267.135089486 kHz   34.58    N gnd     -16.62
  1  Quasi Peak   272.504504785 kHz   44.83    N gnd     -16.20
  2  Average      397.727746704 kHz   31.37    N gnd     -16.53
  1  Quasi Peak   401.705024172 kHz   41.34    N gnd     -16.47
  1  Quasi Peak   475.741040231 kHz   40.79    N gnd     -15.62
  1  Quasi Peak   536.076911993 kHz   39.85    N gnd     -16.14
  1  Quasi Peak   610.105531335 kHz   41.66    N gnd     -14.33
  1  Quasi Peak   806.126927408 kHz   43.14    N gnd     -12.85
  2  Average      806.126927408 kHz   33.29    N gnd     -12.70
  1  Quasi Peak   1.00339897152 MHz   39.33    N gnd     -16.66
  2  Average      2.03372014292 MHz   26.57    N gnd     -19.42
  1  Quasi Peak   29.2697736439 MHz   43.21   L1 gnd     -16.78
  2  Average      29.5624713804 MHz   34.37   L1 gnd     -15.62
```

**Table 2 –** Conducted EMI, Maximum Steady State Load, 120 VAC, 60 Hz, and EN55015 B Limits.

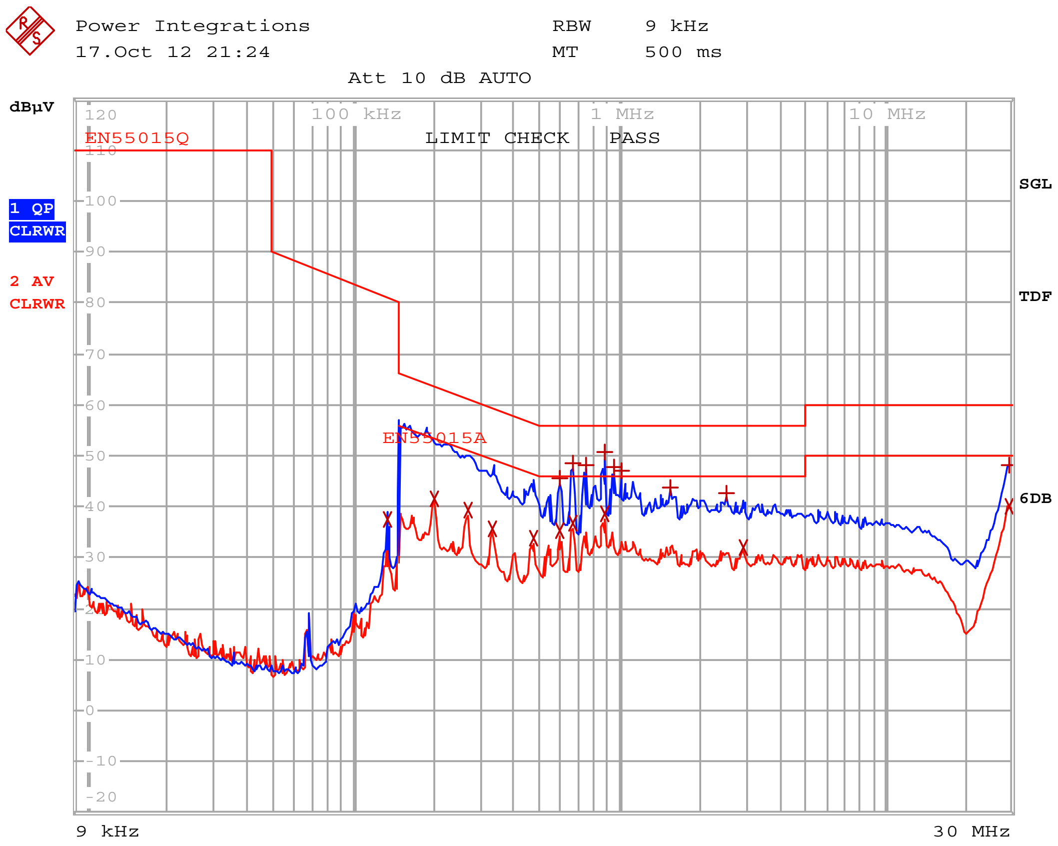


**Figure 27 –** Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55015 B Limits.

EDIT PEAK LIST (Final Measurement Results)

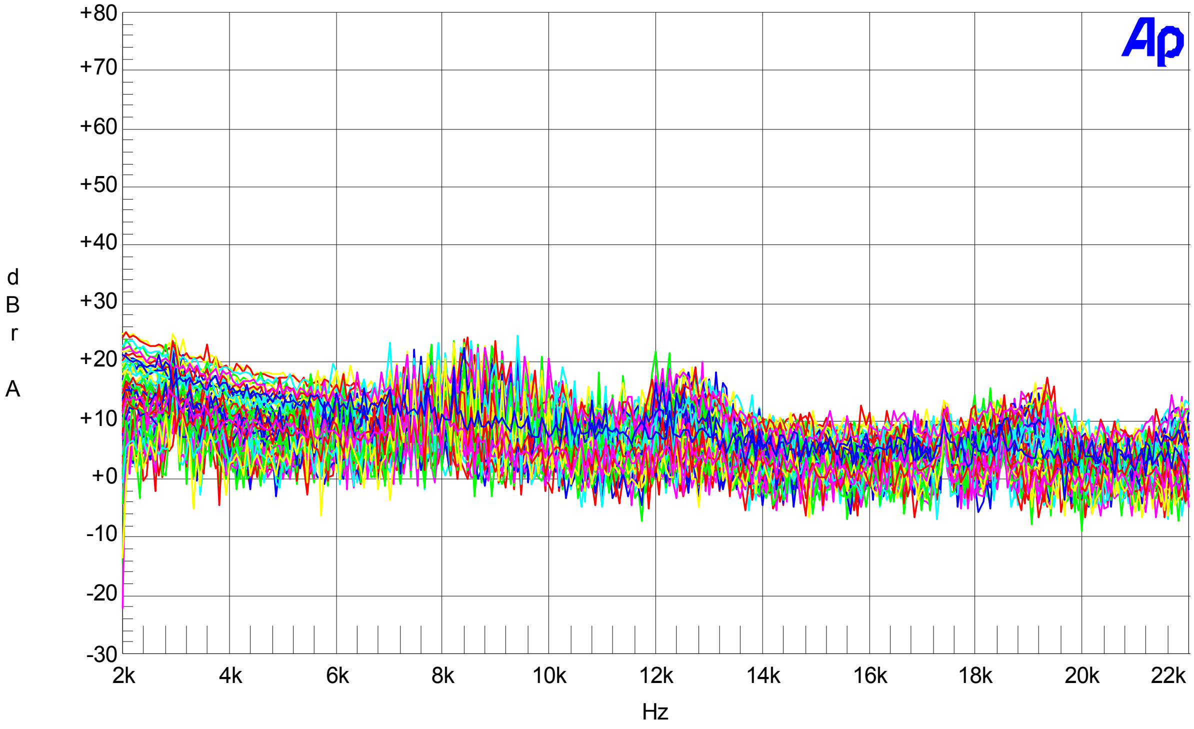
Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

| TRACE | | FREQUENCY | LEVEL dBµV | | DELTA LIMIT dB |
|---|---|---|---|---|---|
| 2 | Average | 134.789536006 kHz | 37.65 | L1 gnd | |
| 2 | Average | 200.175581485 kHz | 41.49 | N gnd | -12.10 |
| 2 | Average | 267.135089486 kHz | 39.23 | N gnd | -11.97 |
| 2 | Average | 332.507282579 kHz | 35.66 | N gnd | -13.72 |
| 2 | Average | 475.741040231 kHz | 33.70 | N gnd | -12.71 |
| 1 | Quasi Peak | 592.16241791 kHz | 45.66 | N gnd | -10.33 |
| 2 | Average | 592.16241791 kHz | 35.36 | N gnd | -10.63 |
| 1 | Quasi Peak | 667.263434405 kHz | 48.66 | N gnd | -7.33 |
| 2 | Average | 667.263434405 kHz | 36.60 | N gnd | -9.39 |
| 1 | Quasi Peak | 744.444692652 kHz | 48.12 | N gnd | -7.87 |
| 1 | Quasi Peak | 872.919948931 kHz | 50.67 | N gnd | -5.32 |
| 2 | Average | 872.919948931 kHz | 38.46 | N gnd | -7.53 |
| 1 | Quasi Peak | 954.699692378 kHz | 47.91 | N gnd | -8.08 |
| 1 | Quasi Peak | 1.02356729084 MHz | 47.16 | N gnd | -8.83 |
| 1 | Quasi Peak | 1.55458365781 MHz | 43.77 | N gnd | -12.22 |
| 1 | Quasi Peak | 2.50634031306 MHz | 42.47 | N gnd | -13.53 |
| 2 | Average | 2.93888112801 MHz | 31.88 | N gnd | -14.11 |
| 1 | Quasi Peak | 29.2697736439 MHz | 48.08 | L1 gnd | -11.91 |
| 2 | Average | 29.2697736439 MHz | 40.24 | L1 gnd | -9.75 |

**Table 3 –** Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55015 B Limits.

## 15 音频噪声

Input voltage were sweep from 90V to 265Vac at 60Hz line input.



| Color | Line Style | Thick | Data | Axis |
|---|---|---|---|---|
| Cyan | Solid | 1 | Fft.Ch.1 Ampl | Left |
| Green | Solid | 1 | Fft.Ch.1 Ampl | Left |
| Yellow | Solid | 1 | Fft.Ch.1 Ampl | Left |

PI Standard Audio Noise (do not edit).at2

**Figure 39 –** Noise from the UUT at 1 cm from the Center of the Board to Microphone Receiver Position.

## 16 附录

Types of overvoltage protection for a buck converter:

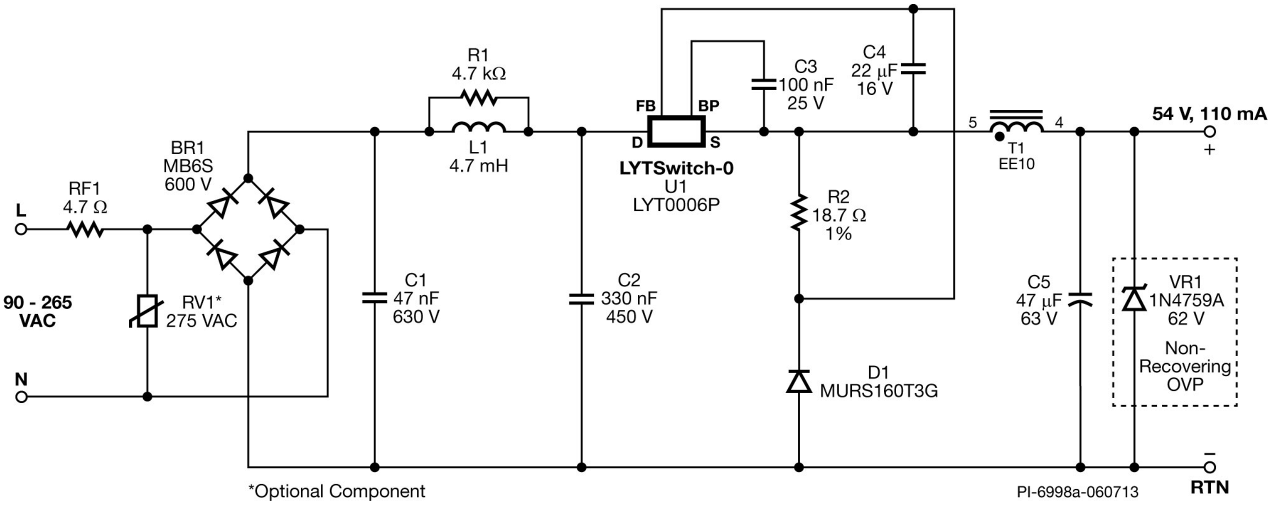


**Figure 40 –** Simple and cheapest approach is to add a Zener diode across the output terminals. In case of no load, the Zener diode will short in order and protect the output capacitor. IC U1 will be limited by the primary current limit. Note that the Zener diode will need to be replaced after this event.

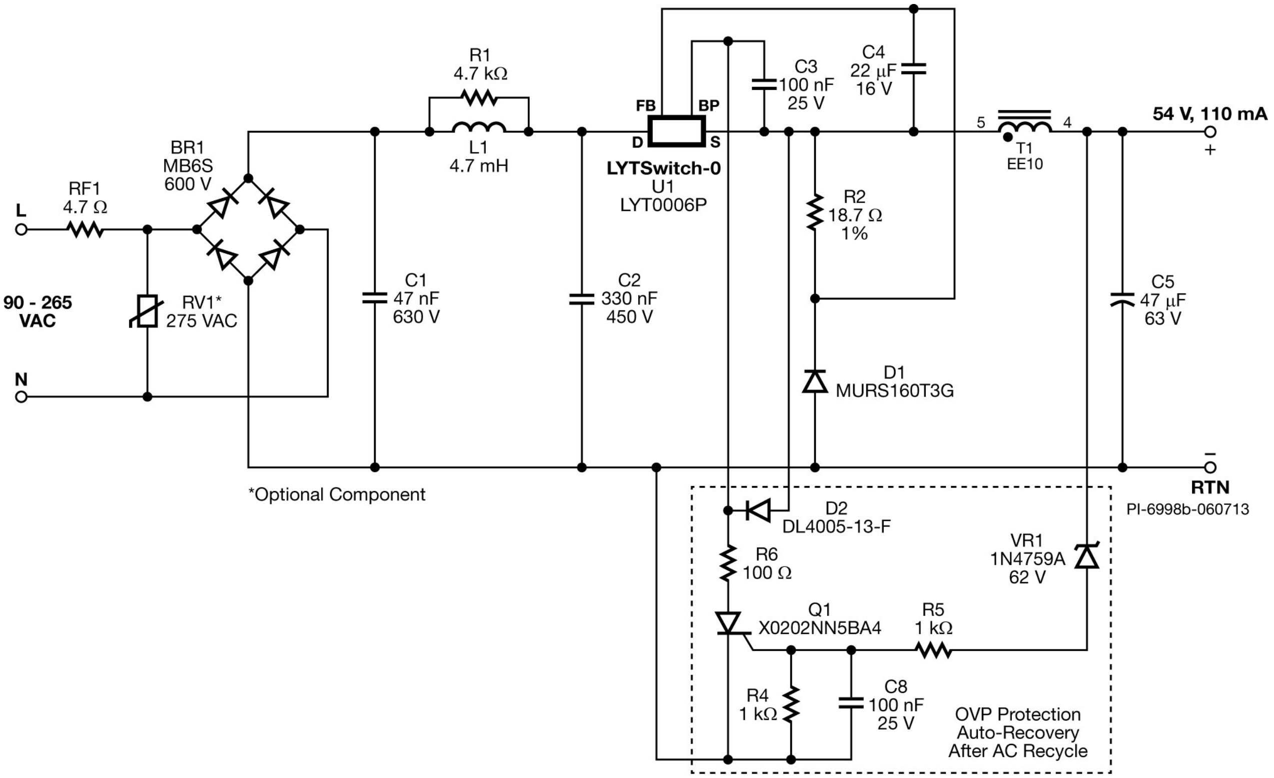


**Figure 41 –** Auto-recovery OVP latch protection. Once AC input is recycled for 2s, the unit will function normally once load is connected. Advantage is lowest no-load consumption and non-damaging failure.

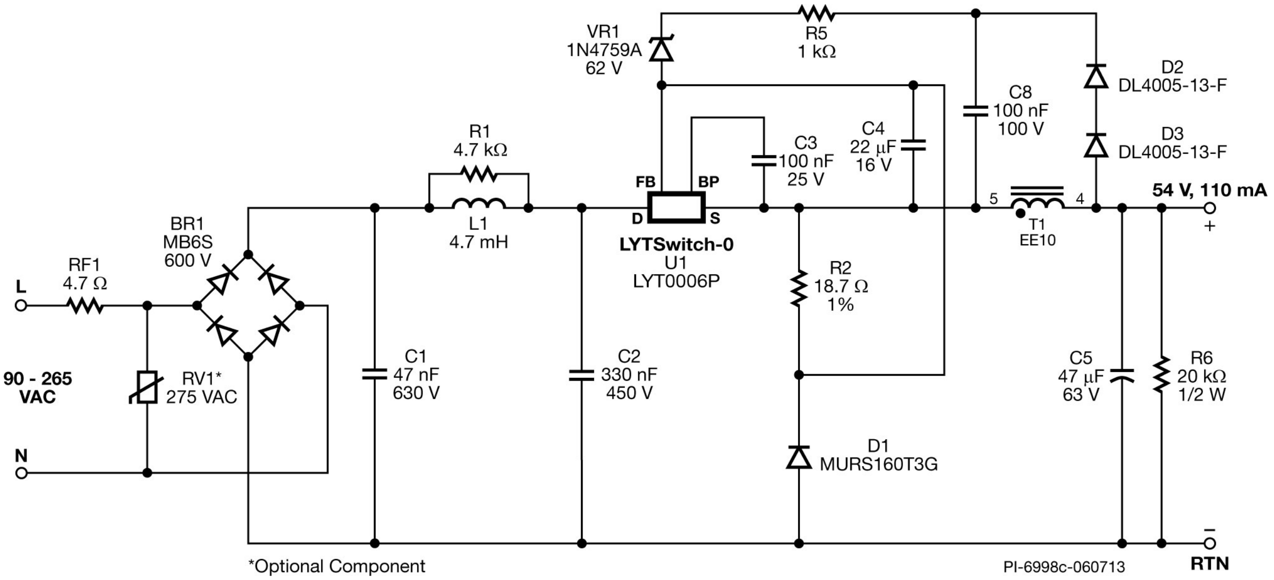


**Figure 42 –** Constant voltage (CV) mode protection. Load can be connected anytime without AC recycle. Disadvantage is it will require some pre-load in order to regulate, which decreases efficiency. Pre-load can be replaced by a appropriately rated Zener in series with a resistor if efficiency is a concern.

| OVP Protection | Pros | Cons |
|---|---|---|
| Zener | 1. Cheapest and simple.<br>2. $V_{OUT} \approx 0$ V at no-load; safe. | 1. Non-auto recovery. Replace Zener once fault is removed. |
| SCR Latch | 1. Auto-recovery.<br>2. Lowest no-load consumption.<br>3. $V_{OUT} \approx 0$ V at no-load; safe. | 1. Cost.<br>2. Requires AC recycle for recovery. |
| Constant Voltage Mode | 1. Hot-plug, load can be connected anytime. | 1. Consumes extra power.<br>2. Residual voltage at no-load.<br>3. Cost. |

Table 4 – Overvoltage Protection Comparison.

## 17 版本历史

| Date | Author | Revision | Description & changes | Reviewed |
|---|---|---|---|---|
| 18-Jun-13 | JDC | 1.0 | Initial Release | Apps & Mktg |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

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