標題	***採用 LYTSwitch™-0 LYT0006P 之 6 W 非調光、非隔離降壓式 LED 驅動器的參考設計報告***
規格	90 VAC – 265 VAC 輸入；54 V、110 mA 輸出
應用	替換 GU10 LED 驅動器燈具
作者	應用工程部門
文件編號	RDR-355
日期	2013 年 6 月 18 日
修訂	1.0

摘要與功能

- Single-stage 功率因數修正 (PFC) (在 120 V 和 230 V 條件下分別大於 0.75 和 0.5) 和精準的定電流 (CC) 輸出
- 所需元件極少且 PCB 佔位面積小的低成本解決方案
- 高度節能，在 120 VAC 輸入條件下效率大於 91 %
- 高度節能，在 240 VAC 輸入條件下效率大於 90 %
- 優異的效能和使用者體驗
  - 快速啓動 (小於 20 ms) – 無可感延遲
- 整合式保護與信賴度特性
  - 藉由自動恢復功能提供單擊 (Single shot) 無負載保護/輸出短路保護
  - 具有高磁滯時間的自動恢復回復過溫保護，同時保護元件和 PCB
  - 在電壓關閉情況下，不會發生任何損壞
- 符合 IEC 振盪波、線差動電壓突波和 EN55015 傳導性 EMI 規定

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目錄

1 簡介 4
2 電源供應器規格 6
3 電路圖....7
4 電路說明....8
4.1 輸入 EMI 濾波....8
4.2 LYTSwitch-0....8
4.3 輸出整流....8
4.4 輸出回授....8
4.5 無負載保護 9
5 PCB 佈局....10
6 物料清單 12
7 電感器規格....13
7.1 電氣圖....13
7.2 電氣規格....13
7.3 材料 13
7.4 電感構建圖 14
7.5 變壓器結構 14
8 電感器設計試算表....15
9 效能資料 17
9.1 工作模式效率....18
9.2 輸出電流調節....19
9.2.1 輸入線間與負載電壓至輸出電流調節....19
10 散熱效能....20
10.1 使用設備 20
11 散熱成效....21
11.1 感熱掃描 22
12 波形....23
12.1 正常運作下的汲極電壓....23
12.2 正常運作下的汲極電流....24
12.3 輸出短路時的汲極電壓和電流 26
12.4 汲極電壓和電流啓動分析 26
12.5 輸出電流啓動分析 27
12.6 輸入-輸出分析....28
12.7 線電壓弛波和突波....29
12.8 電壓關閉/電壓啓動....30
13 線電壓突波....31
14 傳導性 EMI....33
15 噪音....35

16 附錄......36
17 修訂記錄......39

重要事項：
雖然此電路板的設計符合安全隔離要求，但工程原型尚未取得相關機構之認證。因此，執行所有測試應使用隔離變壓器才能提供 AC 輸入給原型板。

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1 簡介

本文件說明採用 LYTSwitch™-0 系列 (LYT0006P) 且具有極輕薄小巧型降壓式架構的成本效益型電源供應器。

此電源供應器在 90 VAC 至 264 VAC 的輸入電壓範圍內運作。使用降壓式架構時，DC 匯流排電壓足夠高，可支援 54 V 輸出。在降壓式轉換器中，輸出電壓必須始終低於輸入電壓。輸出電壓還受到 LYTSwitch-0 最大工作週期的限制，此裝置也要求輸入電壓必須大於輸出電壓。

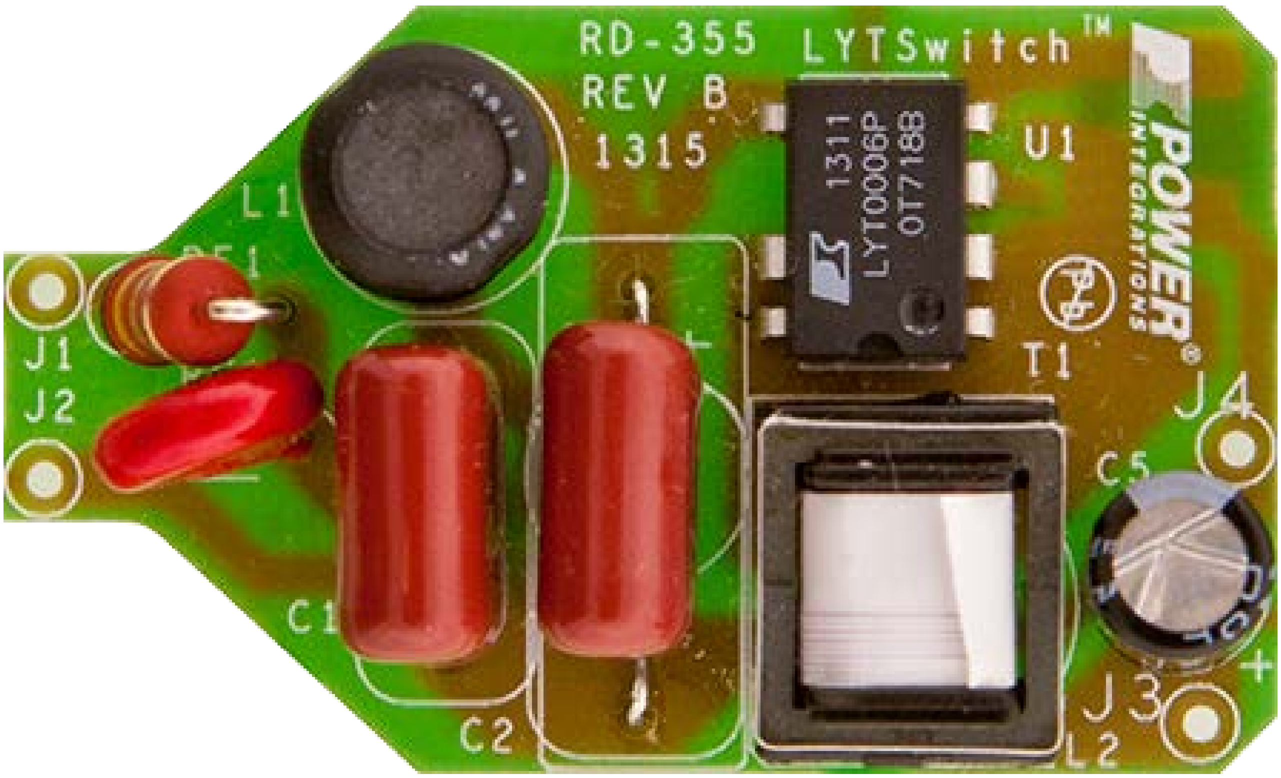

Figure 1 – Populated Circuit Board Photograph, Top.

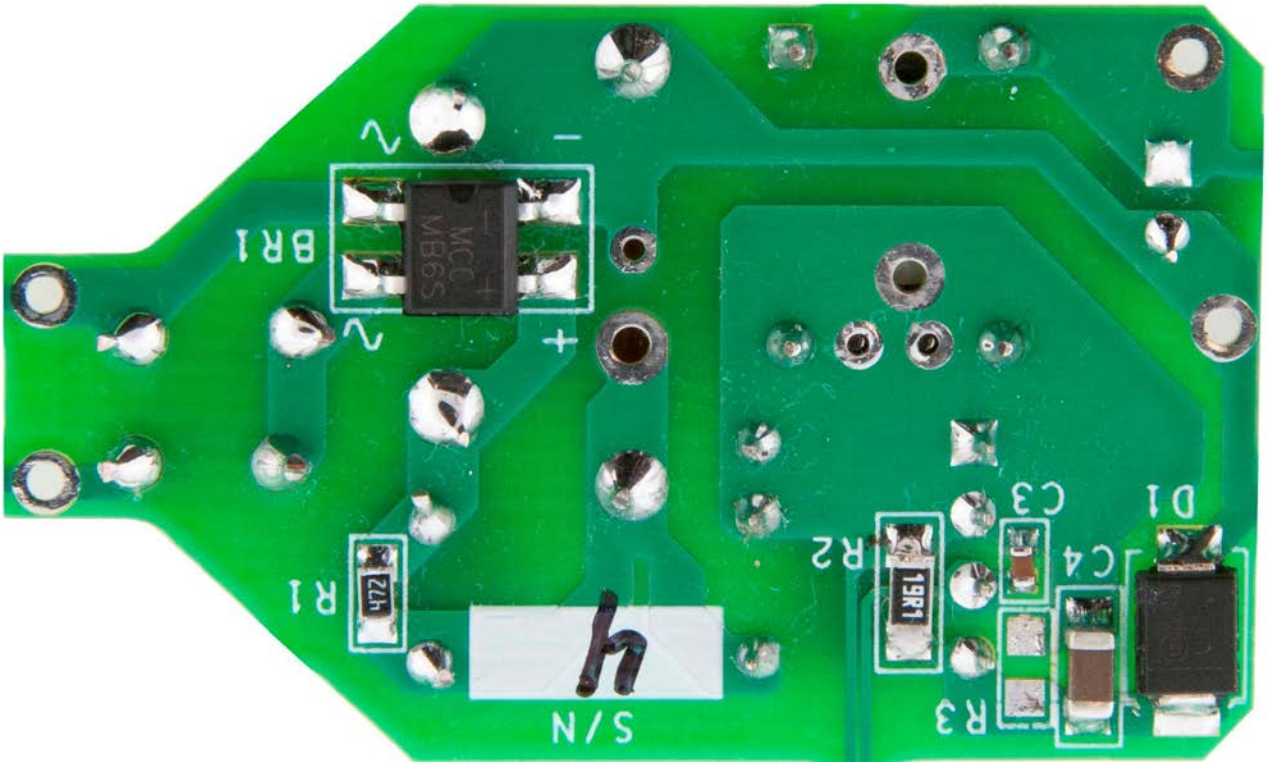

Figure 2 – Populated Circuit Board Photograph, Bottom.

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2 電源供應器規格

說明	符號	最小值	典型值	最大值	單位	註解
輸入						
電壓操作	V_{IN}	90		265	VAC	雙線 – 無 P.E.
頻率	f_{LINE}	47	50/60		Hz	工作頻率不受限制。如果是針對 400 Hz 的線電壓頻率，請調整感測電阻器。
輸出						
輸出電壓	V_{OUT}	52	54	56	V	在 100 VAC - 240 VAC 條件下 ±4%
輸出電流	I_{OUT}		110		mA	
總輸出功率						
連續輸出功率	P_{OUT}		6	6.5	W	
效率						
120 VAC；54 V LED	η	91			%	在 P_{OUT} 25 °C 時測量
240 VAC；54 V LED	η	90			%	
功率因數 (PF)						
120 VAC；54 V LED	功率因數 (PF)	0.75				在 P_{OUT} 25 °C 時測量
240 VAC；54 V LED	功率因數 (PF)	0.5				
環境						
傳導性 EMI		符合 CISPR22B / EN55015B 標準				
線電壓突波 差模 (L1-L2)			0.5		kV	1.2/50 µs 突波，IEC 1000-4-5，串聯阻抗： 差模： 2 Ω
振盪波 (100 kHz) 差模 (L1-L2)			2.5		kV	500 A 短路 串聯阻抗： 差模： 2 Ω
環境溫度	T_{AMB}	-10	25		°C	自然對流，海平面 UUT 可在 – (負) 40 ºC 條件下啟動

3 電路圖

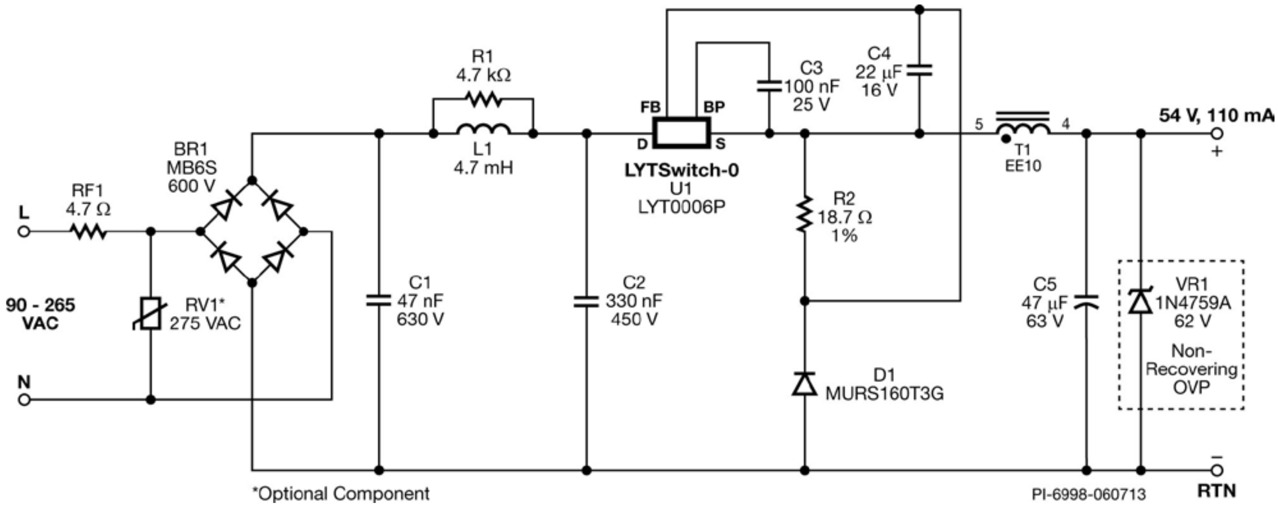

Figure 3 – Schematic. T1 can be replaced by a drum core inductor if final casing/housing has sufficient room to avoid shorting the magnetic flux. Zener diode VR1 is an option and provides one-time no-load protection.

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4 電路說明

圖 3 中所示的電源供應器採用高壓降壓式結構的 LYT0006P (U1)，可在 54 VDC 輸出電壓下提供恆定的 110 mA 電流。該電源供應器專用於驅動 LED，而 LED 應始終透過定電流 (CC) 驅動。

4.1 輸入 EMI 濾波

保險絲 RF1 提供短路保護。橋式整流器 BR1 提供全波整流，以實現良好的功率因數 (PF)。電容器 C1 和 C2 及共模電感器 L1 構成 π 濾波器，以符合傳導性 EMI 標準。電容器 C1 和 C2 還用於能量儲存，以減少線間噪音並防止線電壓突波。

4.2 LYTSwitch-0

LYTSwitch-0 已經過最佳化，使得 LED 驅動器簡單易用、具有成本效益，且在 0 至 100°C (LYTSwitch-0 殼體溫度) 內提供良好的線間電壓與溫度調節。PIXls 試算表用於平衡功率電感器和感測電阻器，進而實現最佳線電壓調節。總輸入電容也有一定的效應，但可透過調整感測電阻器 (R2) 進行補償，以最佳化效能。

LYTSwitch-0 系列具有內建過熱限制，可在燈泡承受過高工作溫度時保護電源供應器。

降壓式轉換器階段由 LYT0006P (U1) 內的整合式功率 MOSFET 切換開關、飛輪二極體 (D1)、感測電阻器 (R2)、功率電感器 L2 和輸出電容器 (C5) 組成。轉換器通常在 DCM 中運作，以限制反向電流的週期。選用了快速飛輪二極體以將切換損失降至最低。

電感器 L2 是標準的 EE10，用於限制磁通路徑並確保在任何殼體中均存在適當電感。若是置於對電感器磁通具有已知效應的特定外殼中，則可使用成本較低的鼓式鐵芯電感器來取代此電感器。

4.3 輸出整流

快速輸出二極體 (D1) 用於實現良好效率和散熱管理。在 LED 應用中，環境溫度通常高於 70°C。建議使用具有低 t_{RR} (小於 35 nS) 的裝置。

4.4 輸出回授

透過跳離切換週期來維持調節。當輸出電流上升時，流入 FB 接腳的電壓也會上升。如果此電壓超過 V_{FB} ，則將跳離後續週期，直到電壓降至低於 V_{FB}。電流從 R2 進行感測並由 C4 進行濾波，然後饋送至 FB 接腳進行精確調節。實現良好線電壓調節的關鍵在於，計算出最低電感後平衡功率電感器和感測電阻器的值。

BYPASS 電容器 (C4) 連接回授接腳和源極接腳，有助於降低輸出電流感測期間的功率損失。該電容器用於對 FB 接腳的回授電流資訊進行取樣與保持。FB 接腳與 C4 之間無需限制電阻器，因爲峰值電壓不會超過裝置的最大額定值。

4.5 無負載保護

此設計整合了選用的單擊無負載保護電路。發生意外的無負載運作時，輸出電容器會受到 VR1 的保護。發生故障後需要更換積納二極體 VR1。

在運作中 (LED 改良式燈具)，負載始終是接通的，因此可移除 VR1 以節省成本。若要在電路板等級測試 (製造中) 期間提供保護，可對輸入施加 40 VAC 電壓；如果未測量輸出電流，則不會接通負載。此測試可讓電路板安全無損地進行初始通電，而無需使用 OV 保護電路。

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5 PCB 佈局

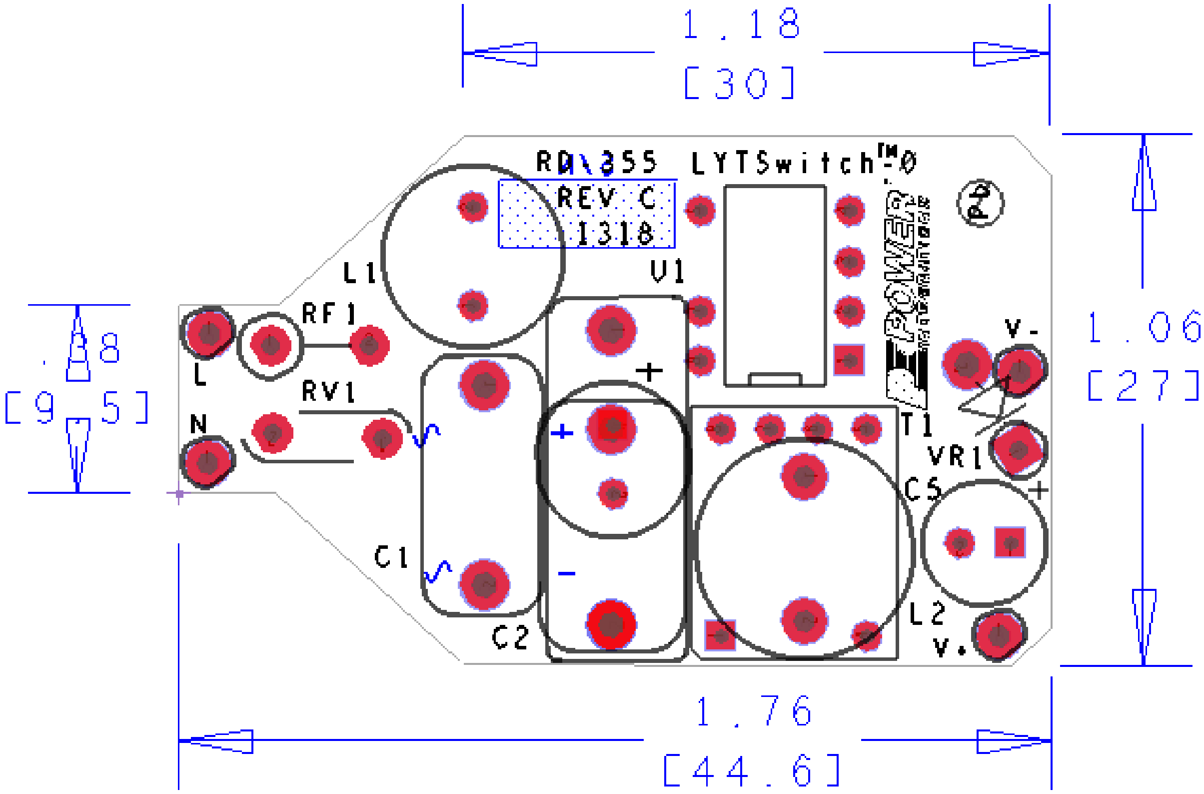

Figure 4 – Printed Circuit Layout. Top view.

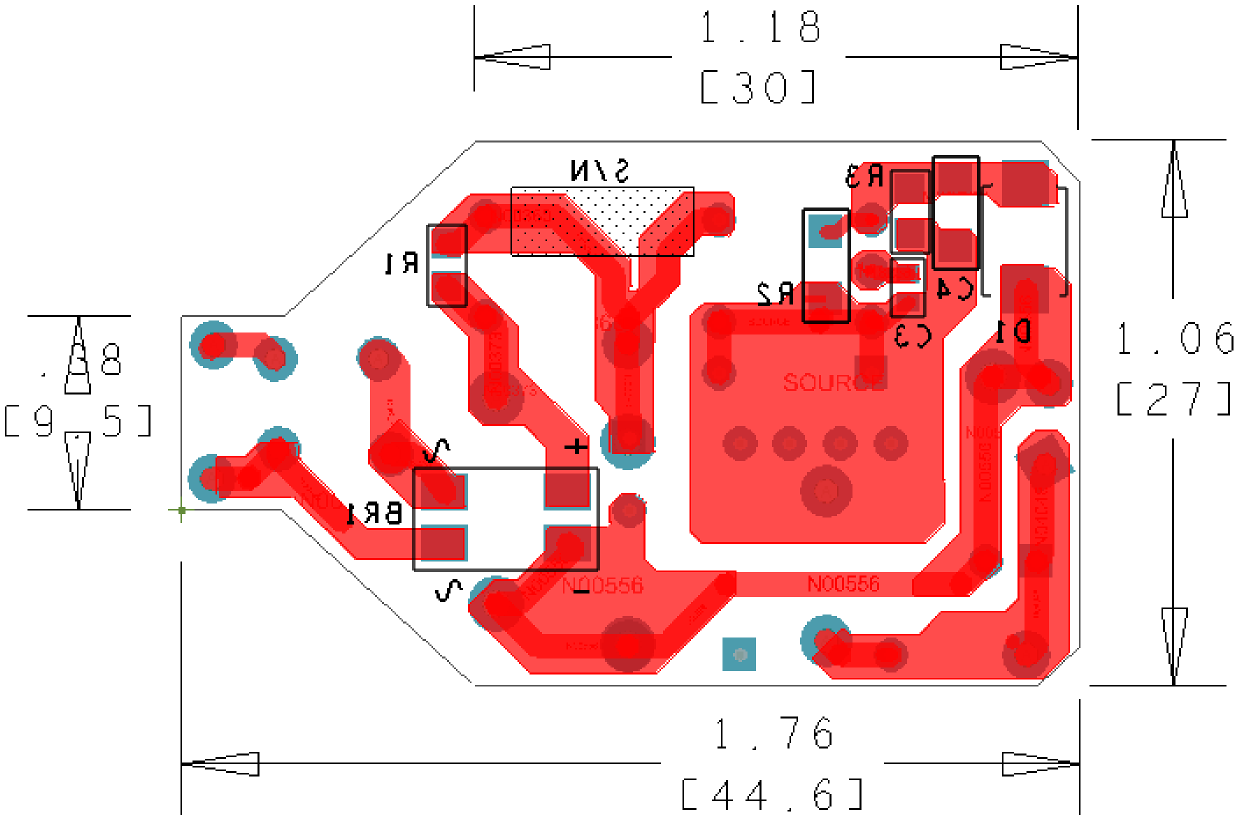

Figure 5 – Printed Circuit Layout. Bottom View.

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6 物料清單

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 Inductor	Custom SNX-R1699	Kunshan Fengshunhe 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 電感器規格

7.1 電氣圖

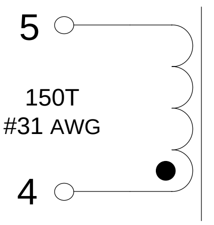

Figure 6 – Inductor Electrical Diagram.

7.2 電氣規格

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.

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7.4 電感構建圖

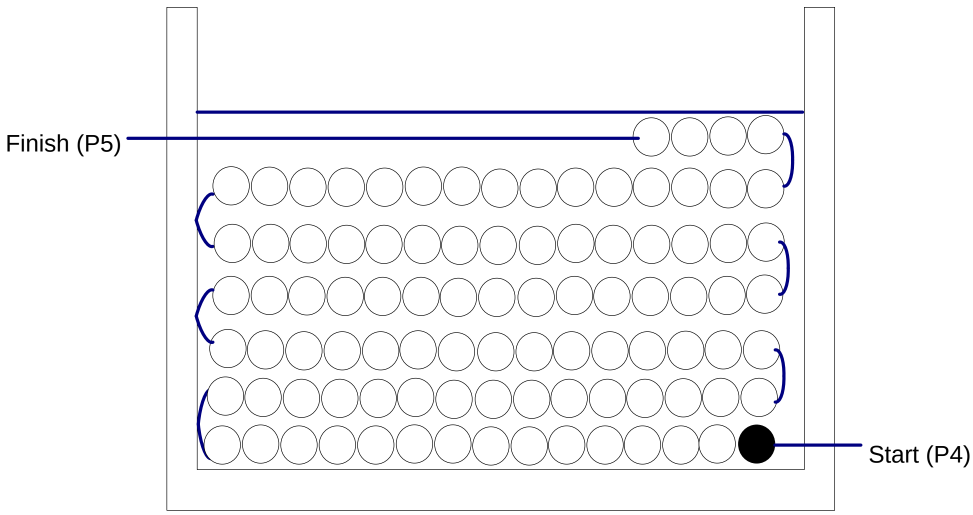

Figure 7 – Inductor Build Diagram.

7.5 變壓器結構

Winding Preparation	Place bobbin item [2] on the mandrel with pin side 1-4 on the right side. 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.

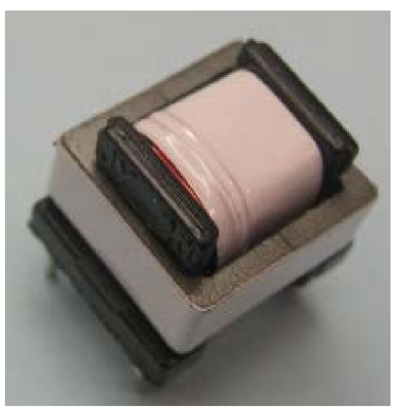

Figure 8 – Transformer Assembly Sample.

8 電感器設計試算表

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)

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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 效能資料

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

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9.1 工作模式效率

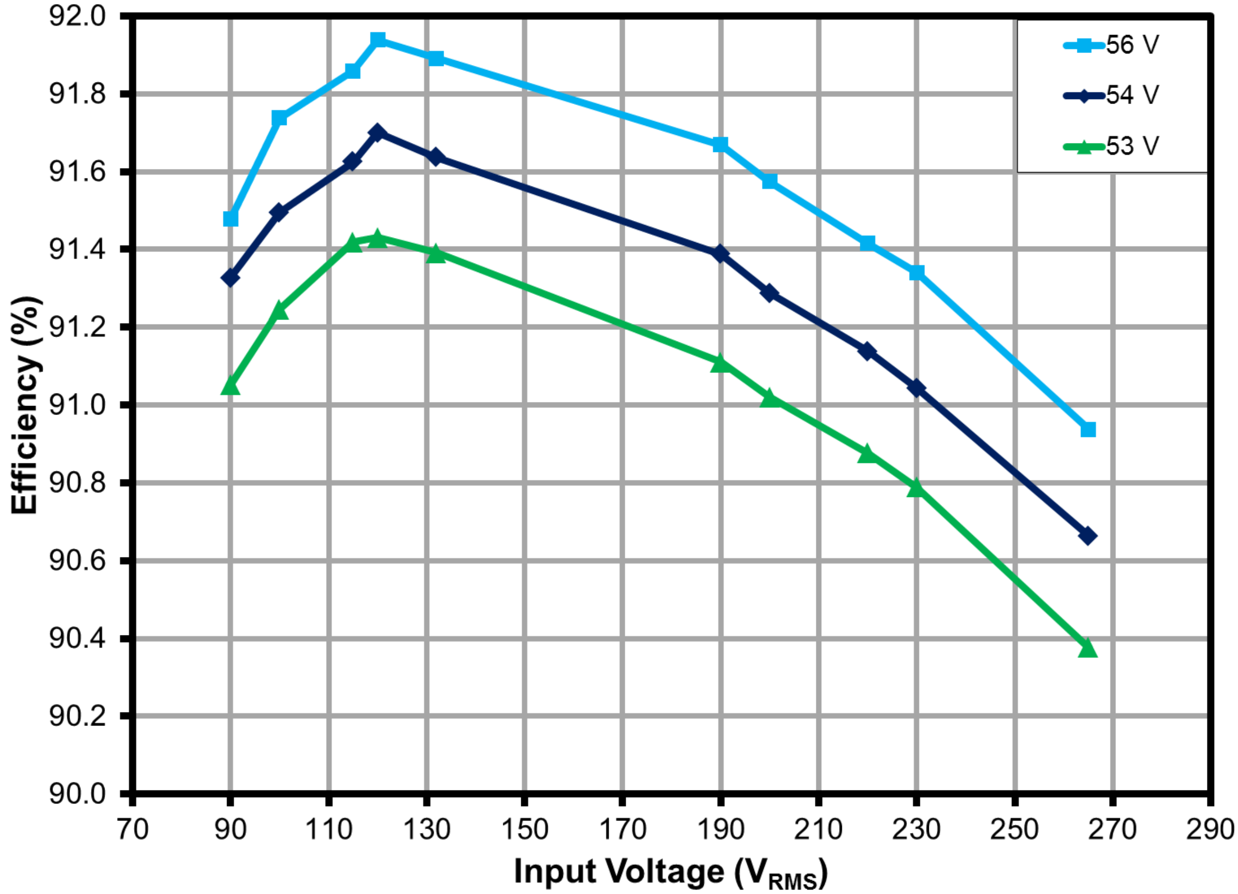

Figure 9 – Efficiency with Respect to AC Input Voltage. 90-132 VAC (50 Hz) and 190-265 VAC (60 Hz) Input.

9.2 輸出電流調節

9.2.1 輸入線間與負載電壓至輸出電流調節

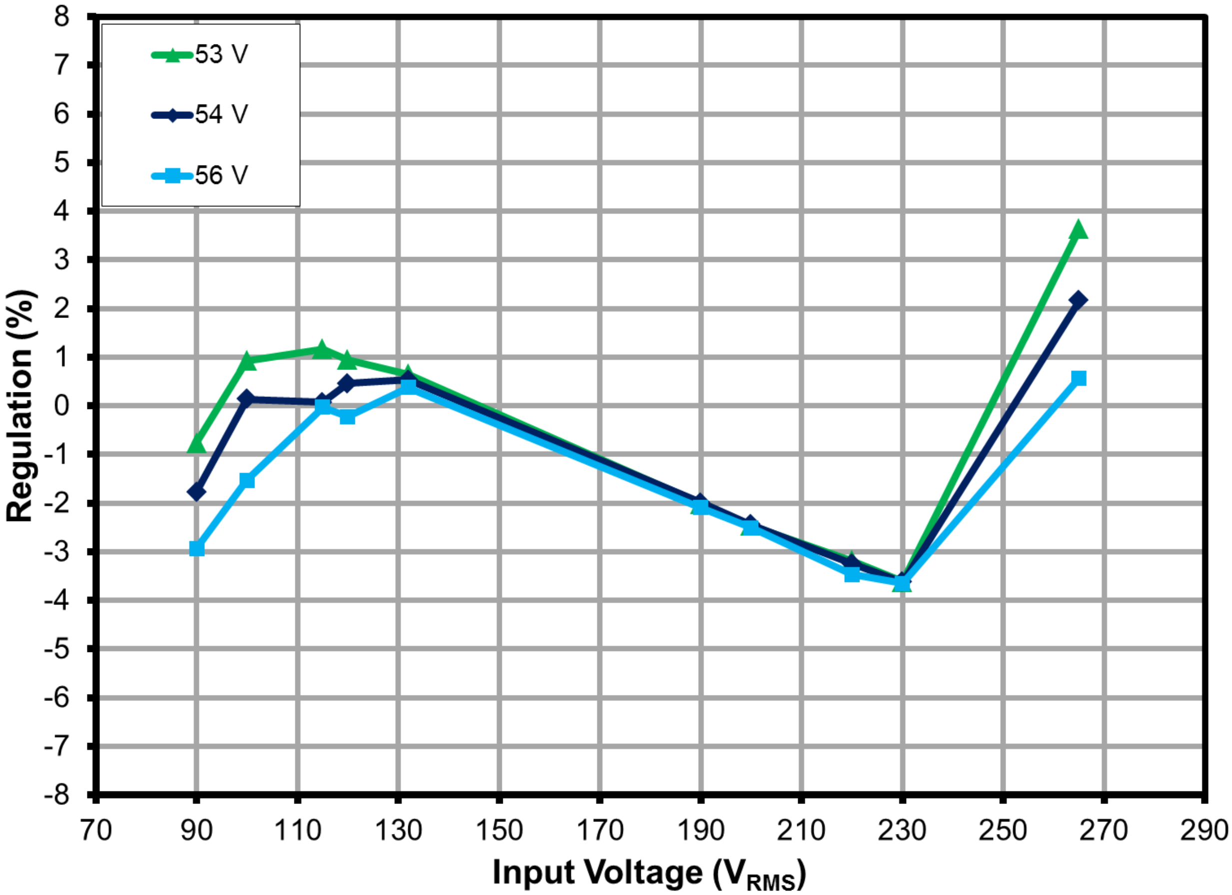

Figure 10 – Load Regulation, Room Temperature.

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10 散熱效能

10.1 使用設備

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

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

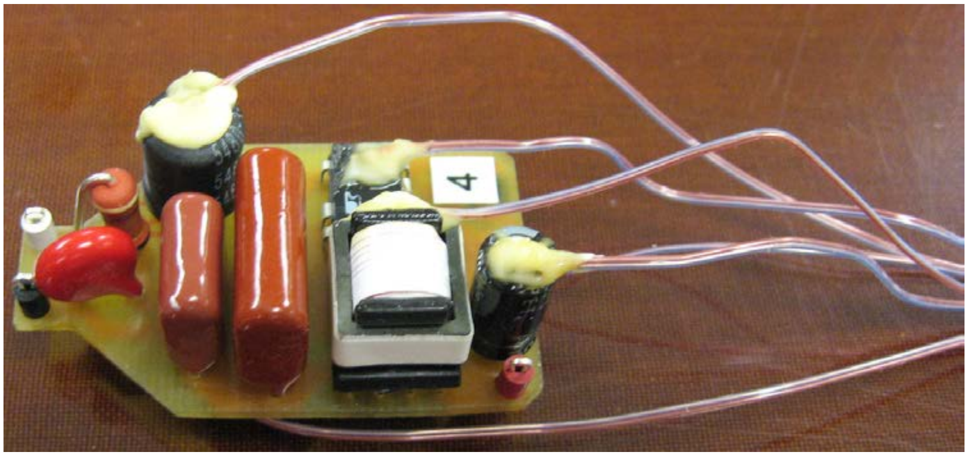

Figure 12 – Thermal Unit Thermocouple Measurement Set-up.

11 散熱成效

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.

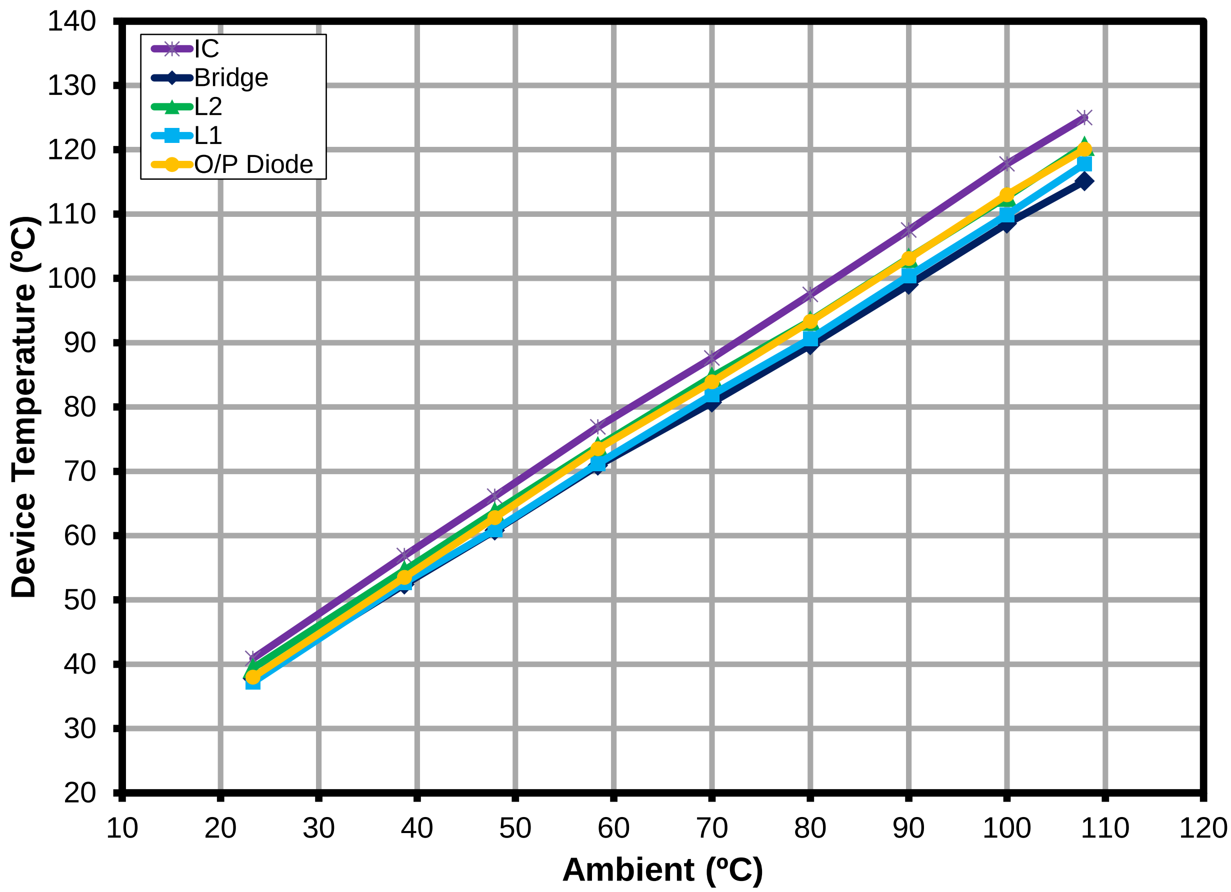

Figure 13 – Thermal Performance Curve.

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11.1 感熱掃描

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

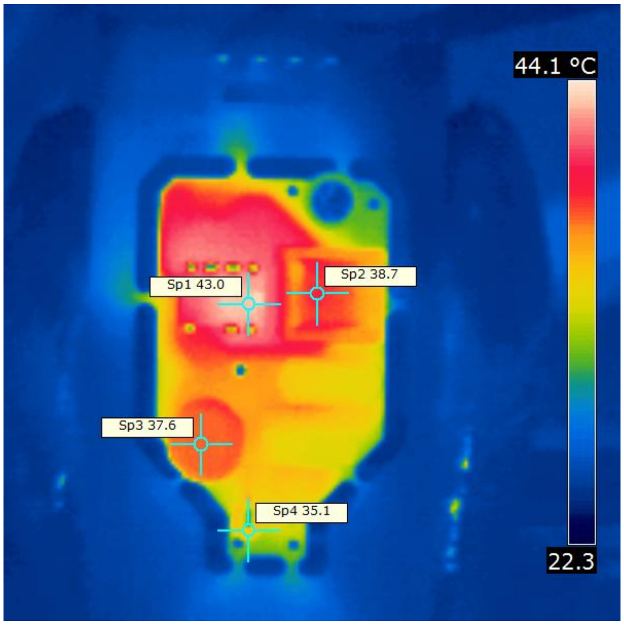

Figure 14 – Temperature (°C) at Top Side of PCB.
SP1 – U1, LYT0006P.
SP2 – L2, Power Inductor.
SP3 – L1, EMI Choke.
SP4 – FR1, Fusible Resistor.

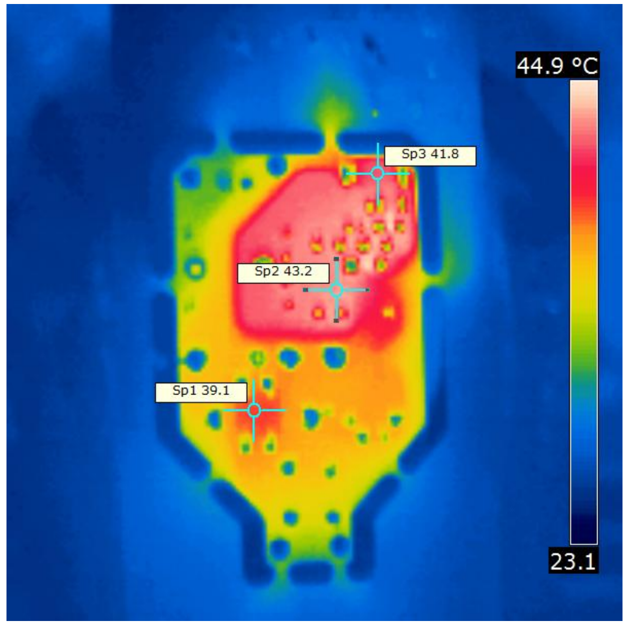

Figure 15 – Temperature (°C) at Bottom Side of PCB.
SP1 – BR1, Bridge Rectifier.
SP2 – PCB, Trace Temperature.
SP3 – D1, Freewheeling Diode.

12 波形

12.1 正常運作下的汲極電壓

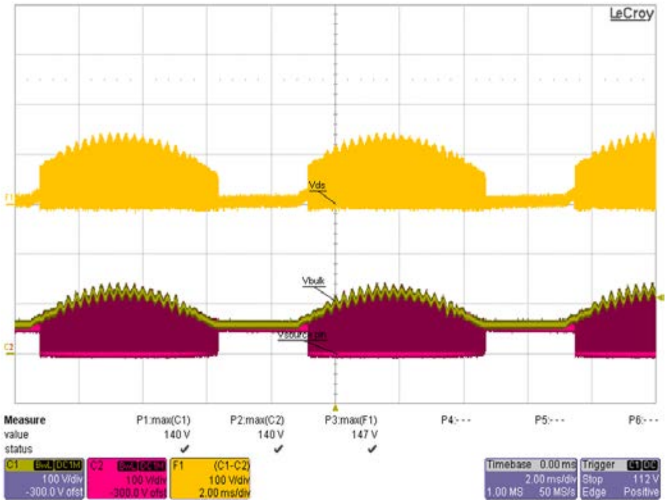

Figure 16 – 90 VAC, 60Hz, Full Load
F1(Orange): $V_{DRAIN\text{-}SOURCE}$, 100 V / div.
Ch1(Yellow): $V_{DRAIN\text{-}GND}$, 100 V / div.
Ch2(Red): $V_{SOURCE\text{-}GND}$, 100 V, 2 ms / div.

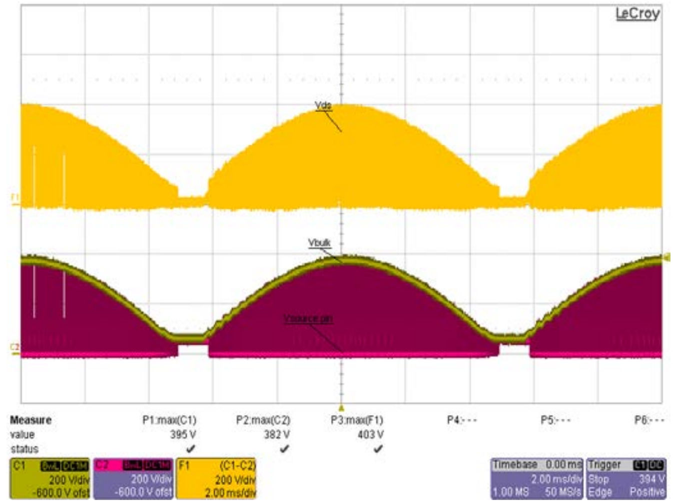

Figure 17 – 265 VAC, Full Load
F1(Orange): $V_{DRAIN\text{-}SOURCE}$, 200 V / div.
Ch1(Yellow): $V_{DRAIN\text{-}GND}$, 200 V / div.
Ch2(Red): $V_{SOURCE\text{-}GND}$, 200 V, 2 ms / div.

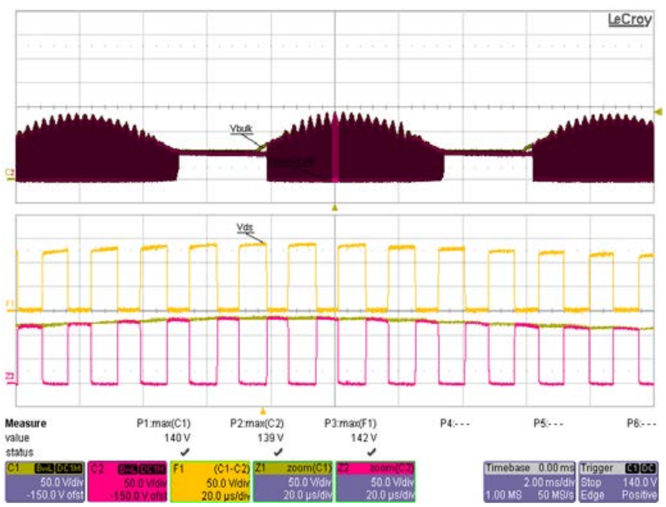

Figure 18 – 90 VAC, 60Hz, Full Load
F1(Orange): $V_{DRAIN\text{-}SOURCE}$, 50 V / div.
Ch1(Yellow): $V_{DRAIN\text{-}GND}$, 50 V / div.
Ch2(Red): $V_{SOURCE\text{-}GND}$, 50 V, 2 ms / div.
Z1(Yellow): $V_{DRAIN\text{-}GND}$, 50 V / div.
Z2(Red): $V_{SOURCE\text{-}GND}$, 50 V, 20 µs / div.

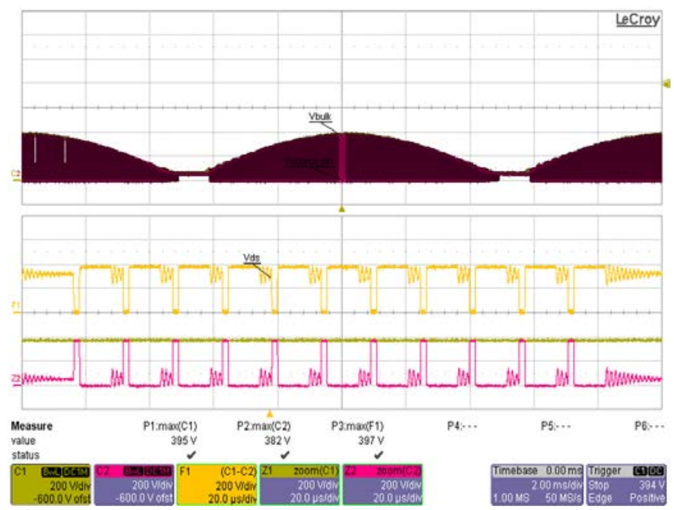

Figure 19 – 265 VAC, Full Load
F1(Orange): $V_{DRAIN\text{-}SOURCE}$, 200 V / div.
Ch1(Yellow): $V_{DRAIN\text{-}GND}$, 200 V / div.
Ch2(Red): $V_{SOURCE\text{-}GND}$, 200 V, 2 ms / div.
Z1(Yellow): $V_{DRAIN\text{-}GND}$, 200V / div.
Z2(Red): $V_{SOURCE\text{-}GND}$, 200 V, 20 µs / div.

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12.2 正常運作下的汲極電流

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.

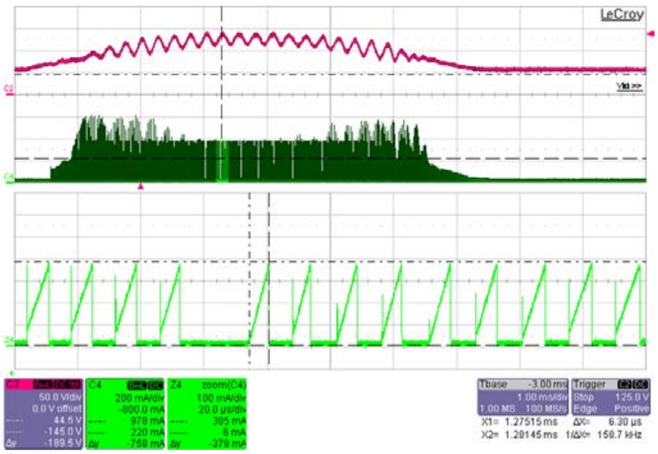

Figure 20 – 90 VAC, 60 Hz, 54 V_{LED}
Ch2(Red): V_{BULK}, 50V / div.
Ch4(Green): I_{DRAIN}, 200 mA / div., 1 ms / div.
Z2(Green): I_{DRAIN}, 100 mA / div., 20 μs / div.

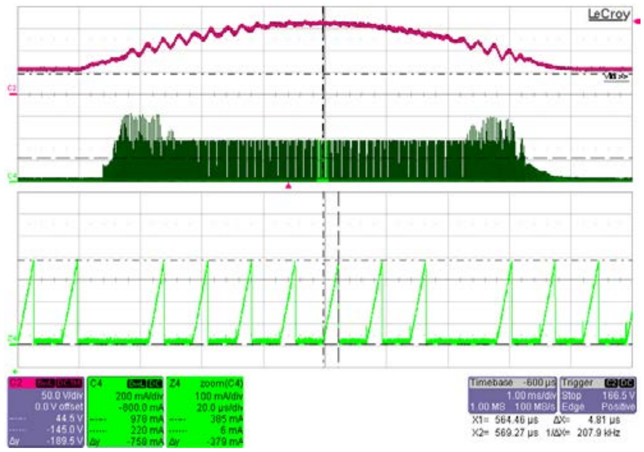

Figure 21 – 115 VAC, 60 Hz, 54 V_{LED}
Ch2(Red): V_{BULK}, 50 V / div.
Ch4(Green): I_{DRAIN}, 200 mA / div., 1 ms / div.
Z2(Green): I_{DRAIN}, 100 mA / div., 20 μs / div.

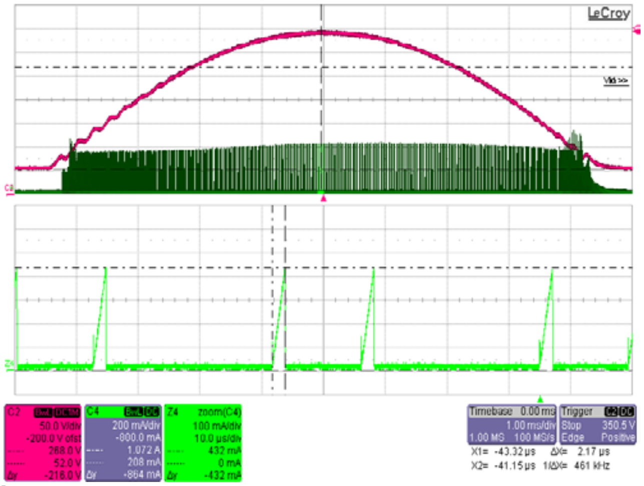

Figure 22 – 240 VAC, 60 Hz, 54 V_{LED}
Ch2(Red): V_{BULK}, 50 V / div.
Ch4(Green): I_{DRAIN}, 200 mA / div., 1 ms / div.
Z2(Green): I_{DRAIN}, 100 mA / div., 20 μs / div.

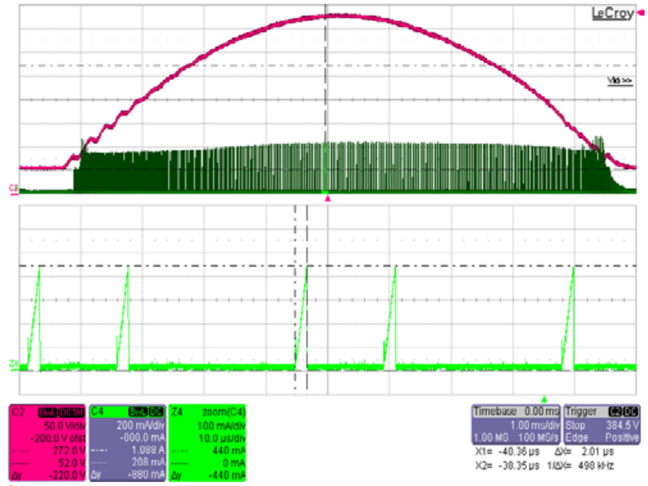

Figure 23 – 265 VAC, 60 Hz, 54 V_{LED}
Ch2(Red): V_{BULK}, 50 V / div.
Ch4(Green): I_{DRAIN}, 200 mA / div., 1 ms / div.
Z2(Green): I_{DRAIN}, 100 mA / div., 20 μs / div.

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12.3 輸出短路時的汲極電壓和電流

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

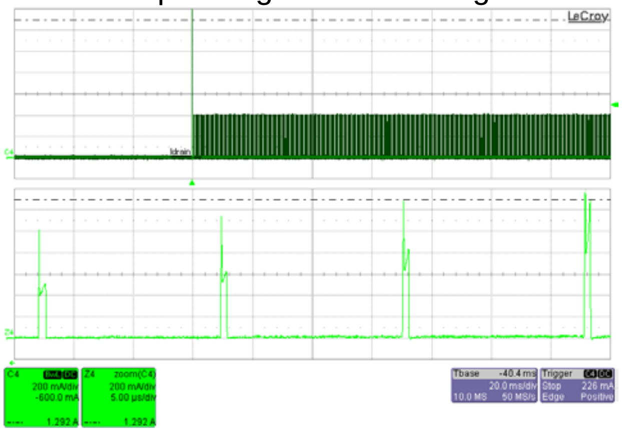

Figure 24 – LYT0006P Output Short.
Ch4: I_{DRAIN}; 0.2 A / div.
Time Scale: 20 ms / div.
Z4: V_{DS}; 0.2 A / div.
Zoom Time Scale: 5 µs / div.

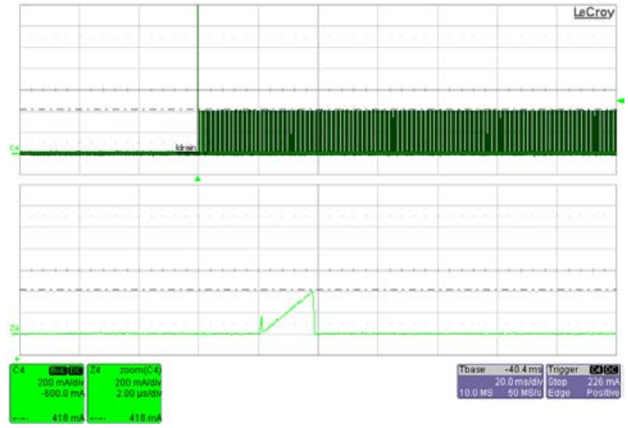

Figure 25 – LYT0006P Output Short.
Ch4: I_{DRAIN}; 0.2 A / div.
Time Scale: 20 ms / div.
Z4: V_{DS}; 0.2 A / div.
Zoom Time Scale: 2 µs / div.

12.4 汲極電壓和電流啓動分析

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

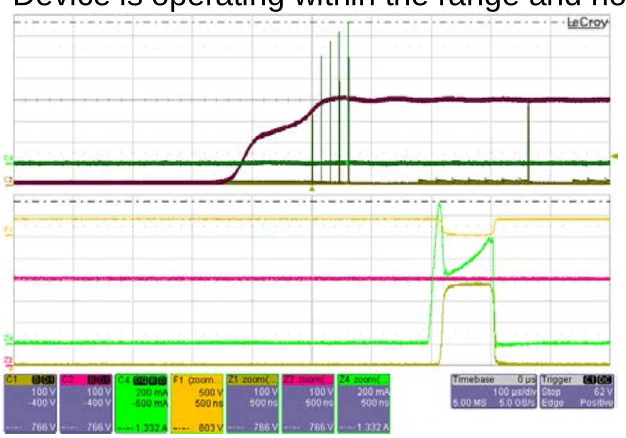

Figure 26 – 265 VAC / 50 Hz Start-up.
Ch1, Z1: SOURCE Pin to Ground; 100 V / div.
Ch2, Z2: Bulk Input; 100 V / div.
Ch4, Z4: I_{DRAIN}; 0.2 A / div.
Time Scale: 100 µs / div.
F1: V_{DS}; 100 V / div.
Zoom Time Scale: 500 ns / div.

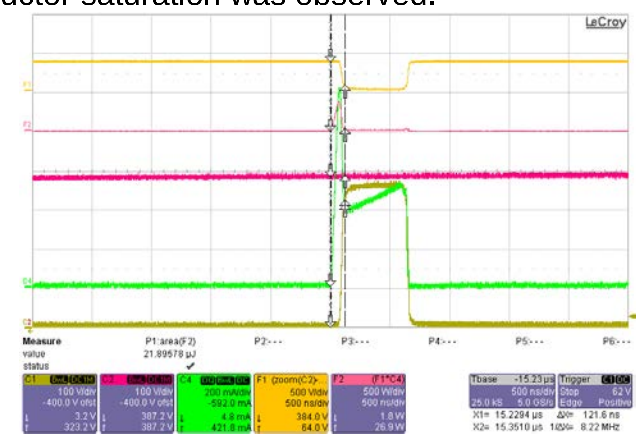

Figure 27 – 265 VAC / 50 Hz Start-up.
Ch1: SOURCE Pin to Ground; 100 V / div.
Ch2: Bulk Input; 100 V / div.
Ch4: I_{DRAIN}; 0.2 A / div.
Time Scale: 500 ns / div.
F1: V_{DS}; 100 V / div.
F2: Switching Power; 500 W / div.
Zoom Time Scale: 500 ns / div.

12.5 輸出電流啓動分析

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

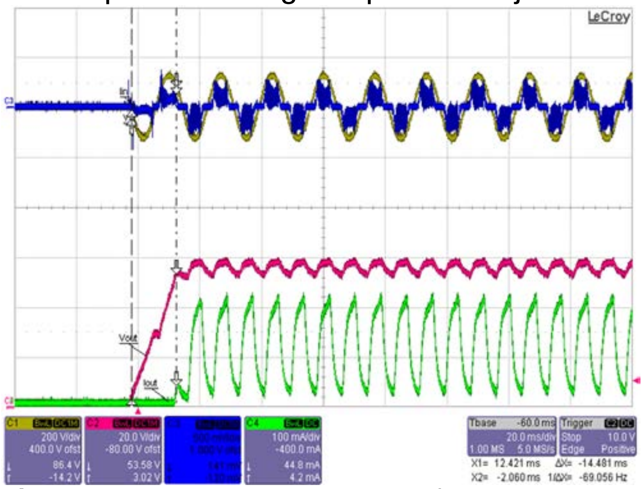

Figure 28 – 90 VAC, 60Hz, Full Load
Ch1(Yellow): V_{IN}, 200 V / div.
Ch2(Red): V_{OUT}, 20 V,
Ch3(Blue): I_{IN}, 0.5 A / div.
Ch4(Green): I_{OUT}, 100 mA / div., 20 ms / div.

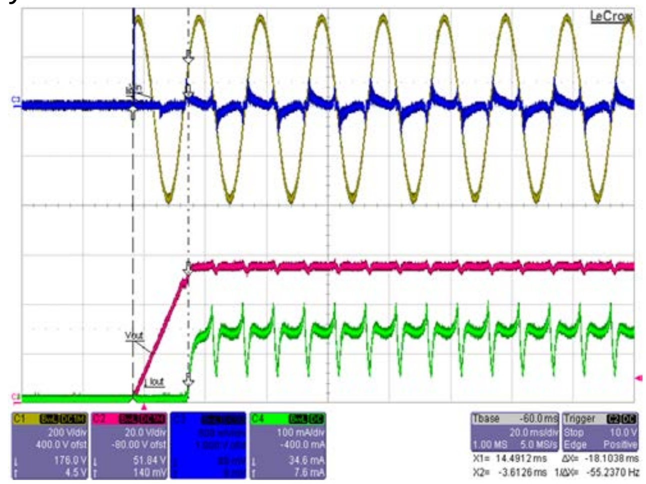

Figure 29 – 265 VAC, Full Load
Ch1(Yellow): V_{IN}, 200 V / div.
Ch2(Red): V_{OUT}, 20 V,
Ch3(Blue): I_{IN}, 0.5 A / div.
Ch4(Green): I_{OUT}, 100 mA / div., 20 ms / div.

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12.6 輸入-輸出分析

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.

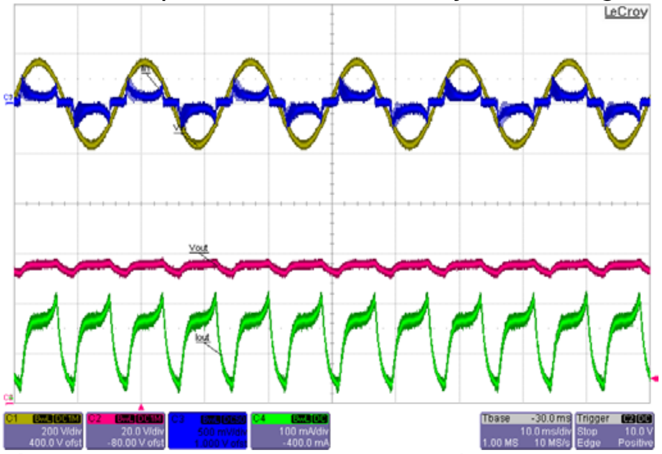

Figure 30 – 120 VAC, 60 Hz, Full Load
Ch1(Yellow): V_{IN}, 200 V / div.
Ch2(Red): V_{OUT}, 20 V.
Ch3(Blue): I_{IN}, 0.5 A / div.
Ch4(Green): I_{OUT}, 100 mA / div, 10 ms / div.

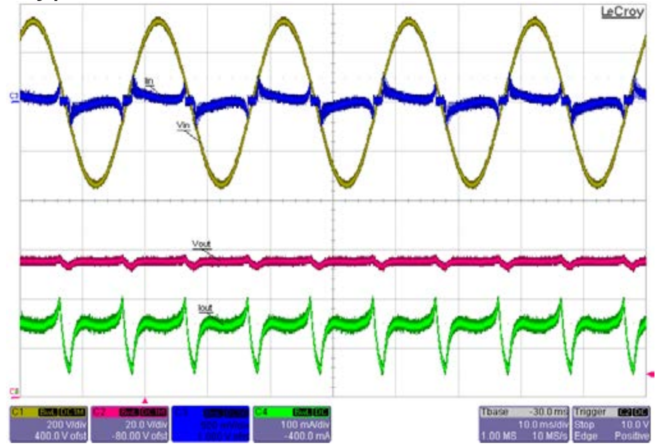

Figure 31 – 240 VAC, Full Load
Ch1(Yellow): V_{IN}, 200 V / div.
Ch2(Red): V_{OUT}, 20 V.
Ch3(Blue): I_{IN}, 0.5 A / div.
Ch4(Green): I_{OUT}, 100 mA / div, 10 ms / div.

12.7 線電壓弛波和突波

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.

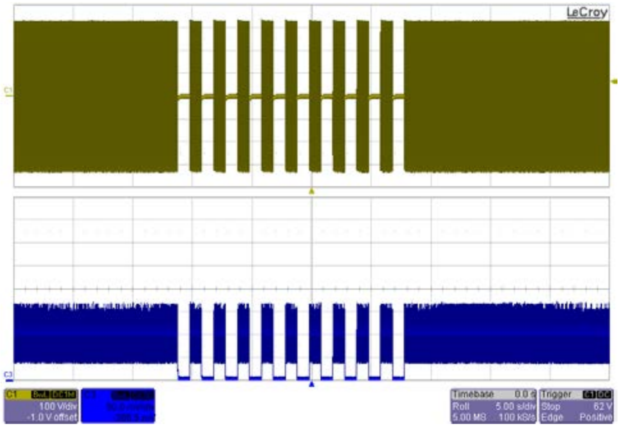

Figure 32 – Line sag test at 230 - 0 V at 1 Sec Interval.
Ch1: V_{IN}; 100 V / div.
Ch2: I_{OUT}; 50 mA / div.
Time Scale: 5 s / div.

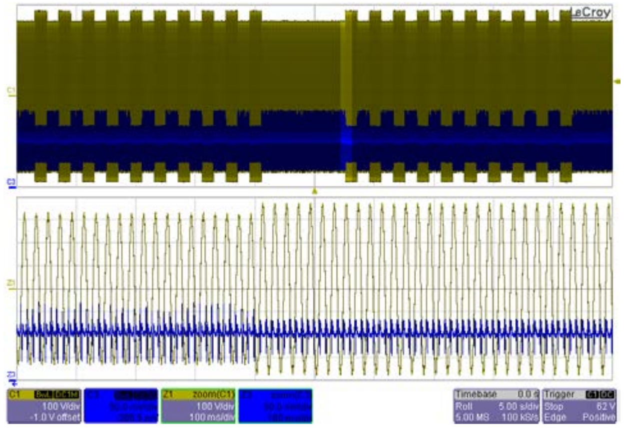

Figure 33 – Line Surge Test at 230 - 265 V at 1 Sec Interval.
Ch1: V_{IN}; 100 V / div.
Ch2: I_{OUT}; 50 mA / div.
Time Scale: 5 s / div.

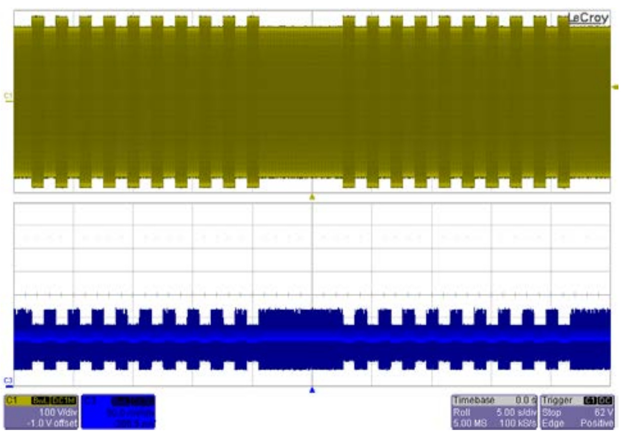

Figure 34 – Line Surge Test at 230 - 265 V at 1 Sec Interval.
Ch1: V_{IN}; 100 V / div.
Ch2: I_{OUT}; 50 mA / div.
Time Scale: 5 s / div.

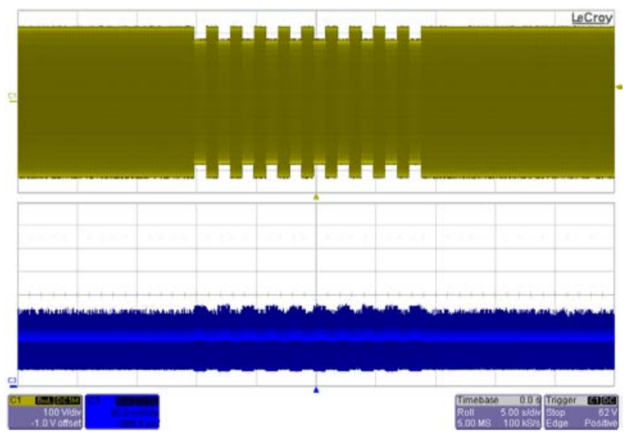

Figure 35 – Line Sag Test at 230 - 265 V at 1 Sec Interval.
Ch1: V_{IN}; 100 V / div.
Ch2: I_{OUT}; 50 mA / div.
Time Scale: 5 s / div.

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12.8 電壓關閉/電壓啓動

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

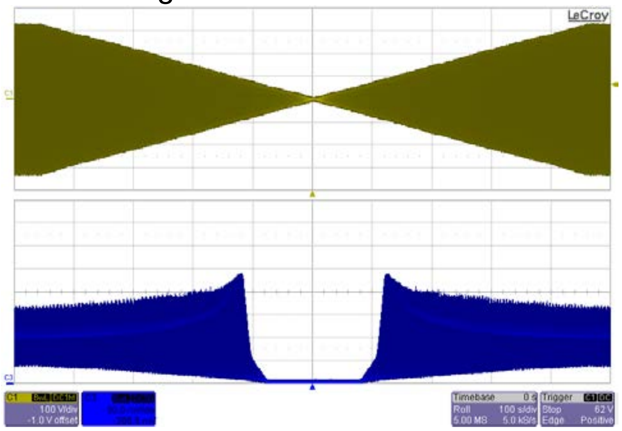

Figure 36 – Brown-out Test at 0.5 V / s. The Unit is Able to Operate Normally Without Any Failure and Without Flicker.
Ch1: V_{IN}; 100 V / div.
Ch2: I_{OUT}; 50 mA / div.
Time Scale: 100 s / div.

13 線電壓突波

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.

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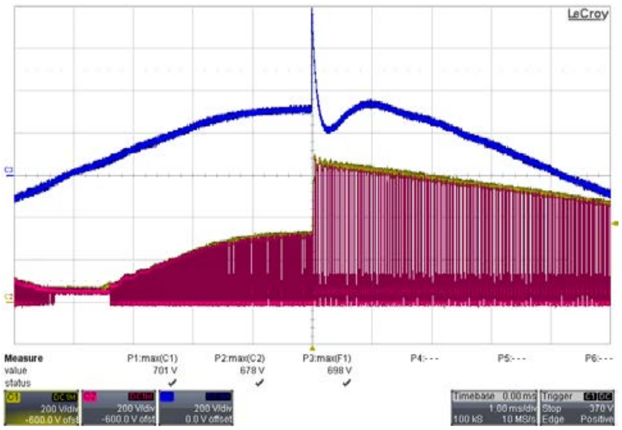

Figure 37 – Differential Line Surge at 500 V / 90°.
Peak Drain Voltage Recorded is 678 V.
Ch1: V_{IN}; 200 V / div.
Ch2: V_{DRAIN}; 200 V / div.
Ch3: V_{BULK}; 200 V / div.
Time Scale: 1 ms / div.

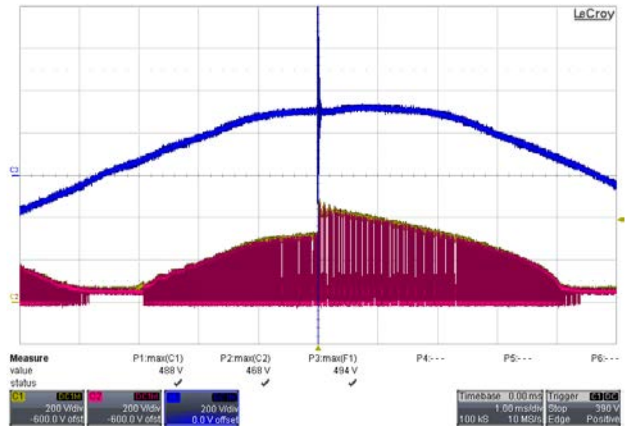

Figure 38 – Differential Ring Surge at 2500 V / 90°.
Peak Drain Voltage Recorded is 468 V.
Ch1: V_{IN}; 200 V / div.
Ch2: V_{DRAIN}; 200 V / div.
Ch3: V_{BULK}; 200 V / div.
Time Scale:1 ms / div.

14 傳導性 EMI

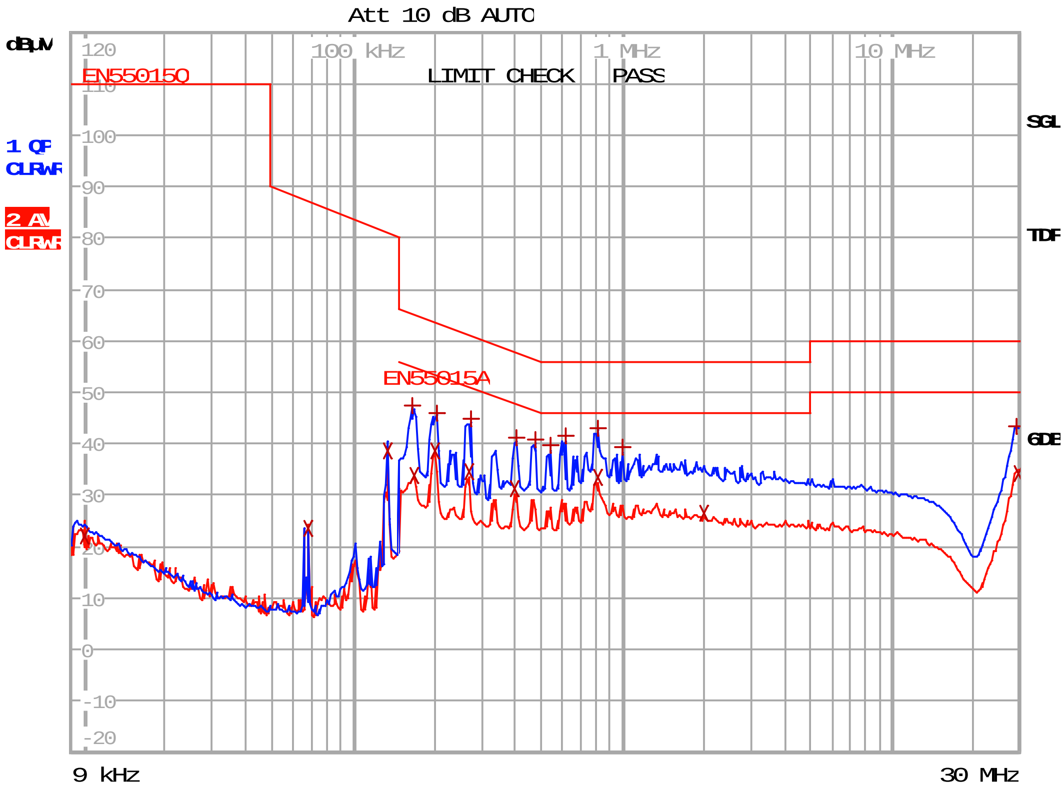

Figure 26 – Conducted EMI, Maximum Steady State Load, 120 VAC, 60 Hz, and EN55015 B Limits.

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

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

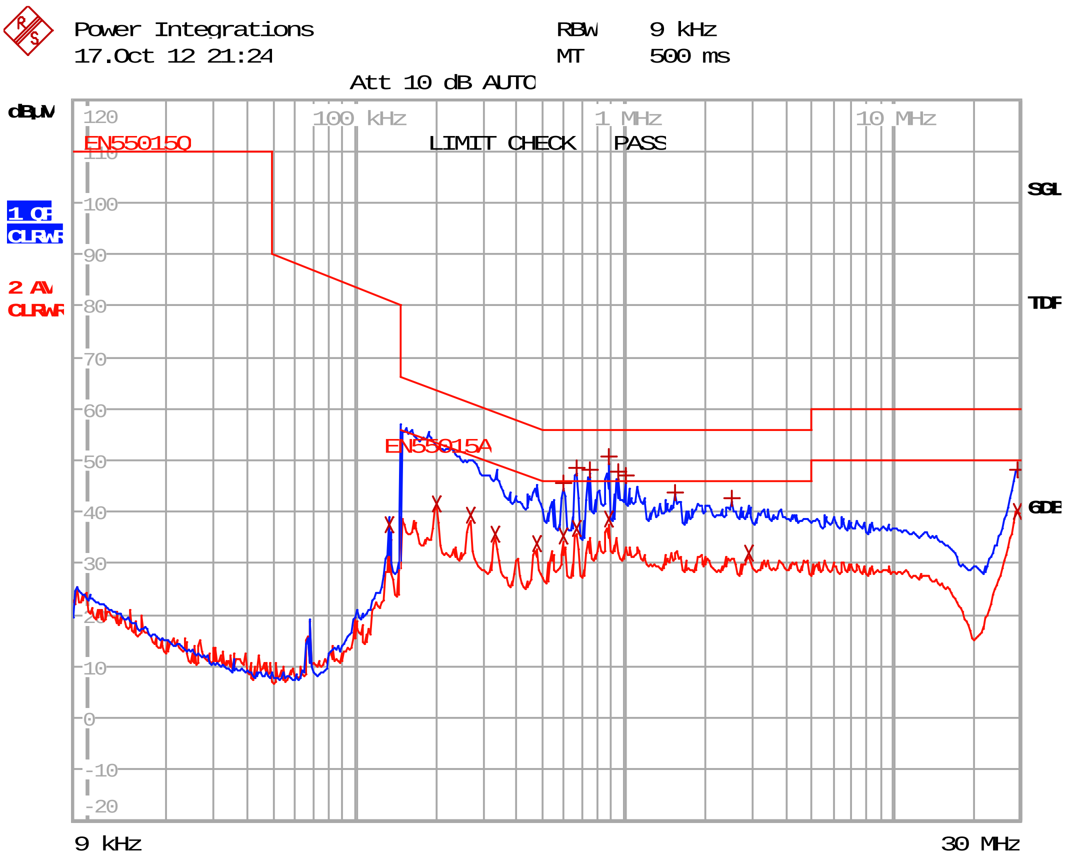

Figure 27 – Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55015 B Limits.

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 噪音

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

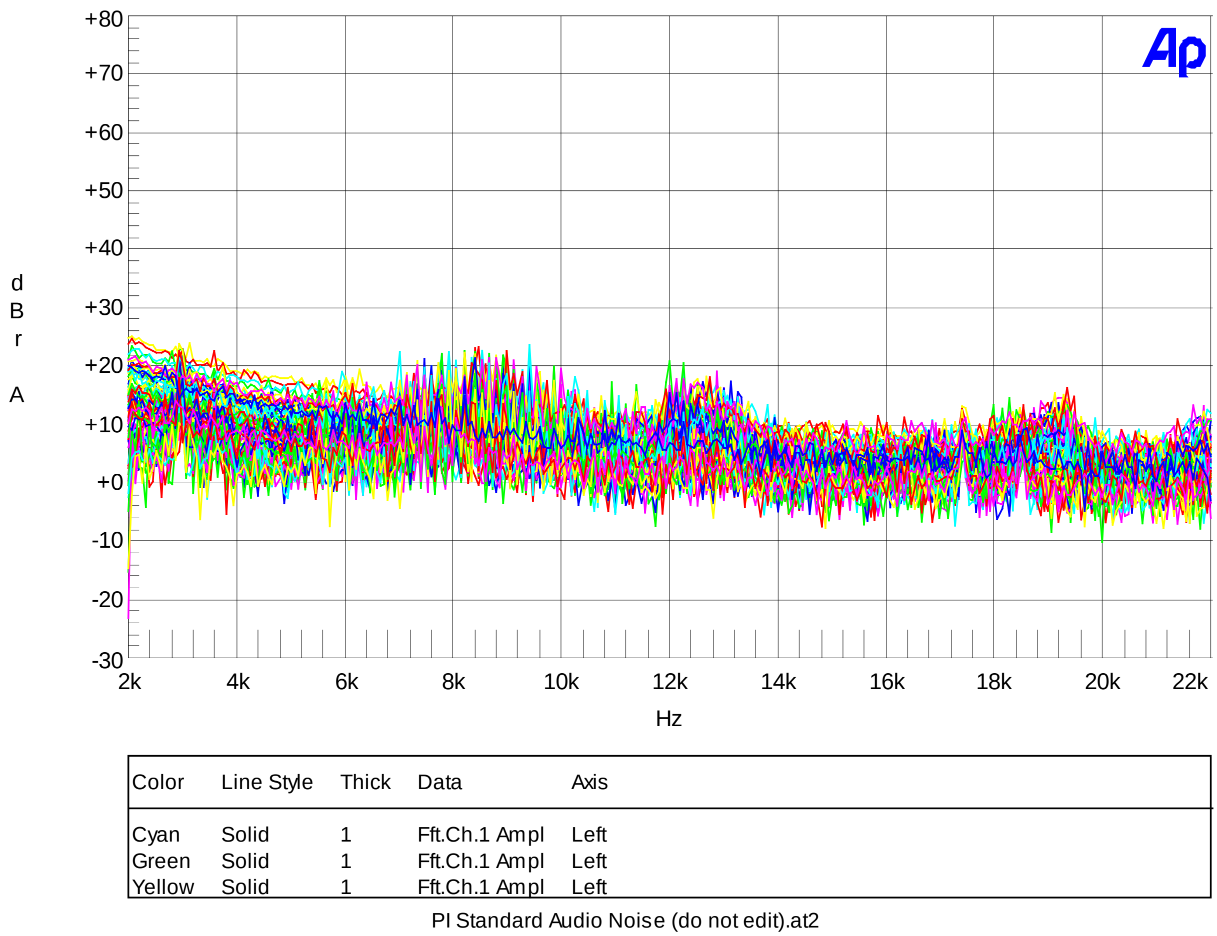

Figure 39 – Noise from the UUT at 1 cm from the Center of the Board to Microphone Receiver Position.

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16 附錄

Types of overvoltage protection for a buck converter:

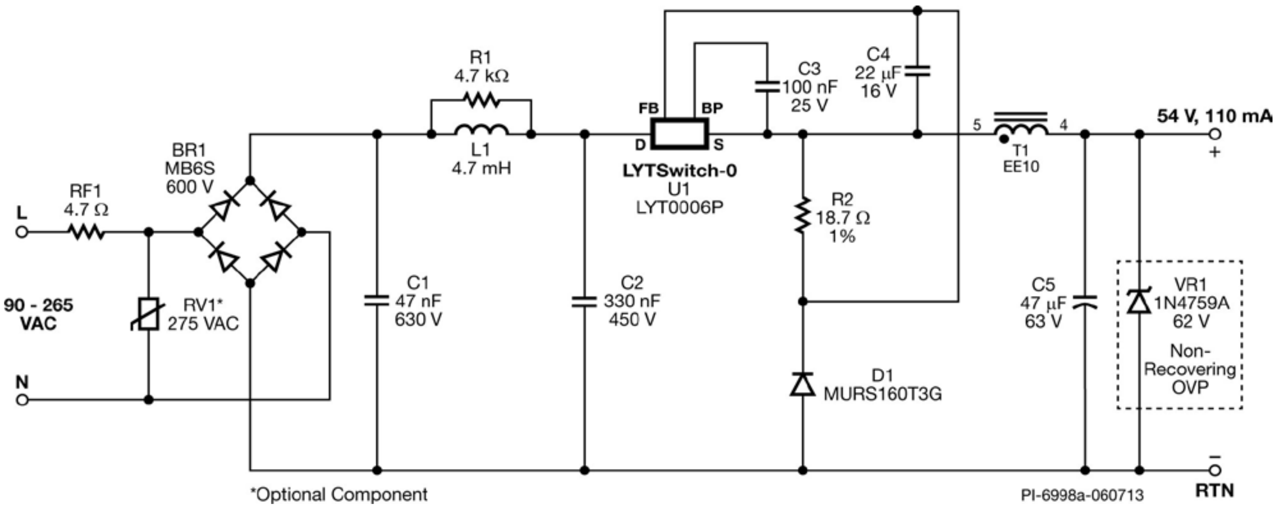

Figure 40 – Simple and cheapest approach is to add a Zener diode across the output terminals. In case of no load, the Zener diode will short in order and protect the output capacitor. IC U1 will be limited by the primary current limit. Note that the Zener diode will need to be replaced after this event.

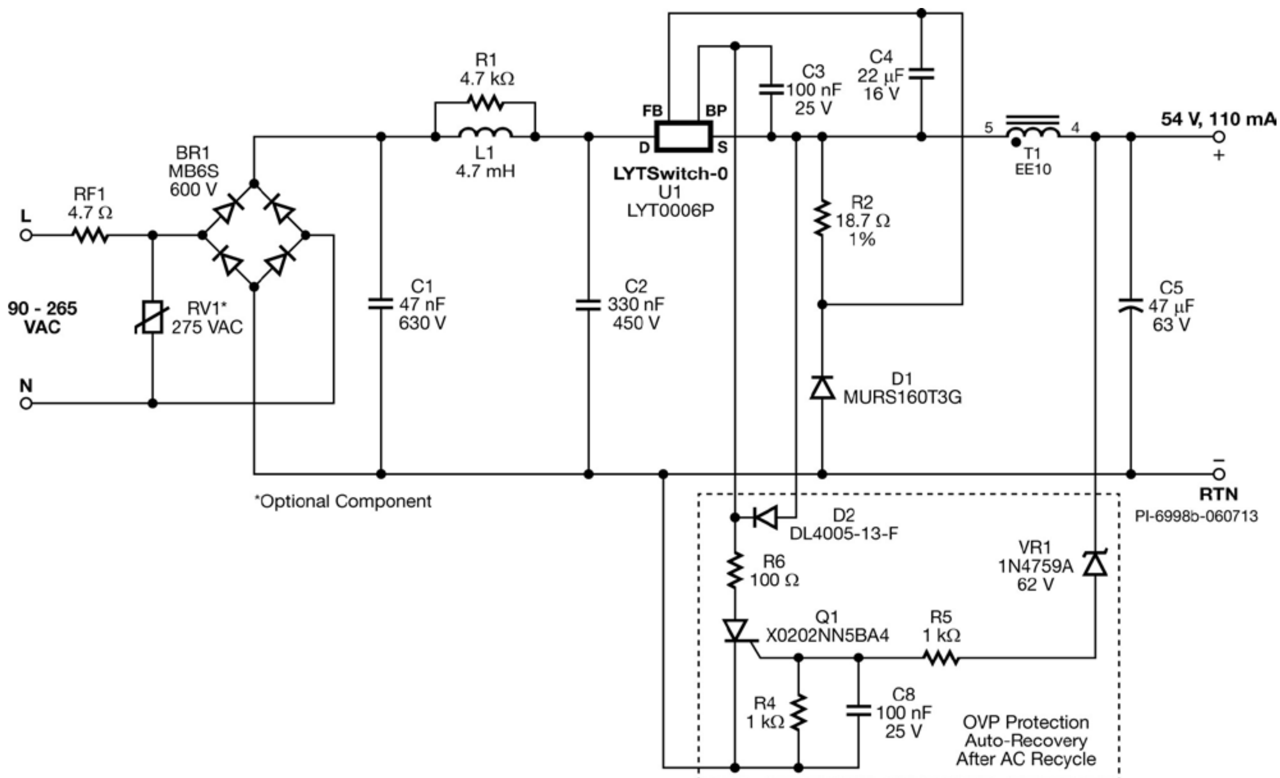

Figure 41 – Auto-recovery OVP latch protection. Once AC input is recycled for 2s, the unit will function normally once load is connected. Advantage is lowest no-load consumption and non-damaging failure.

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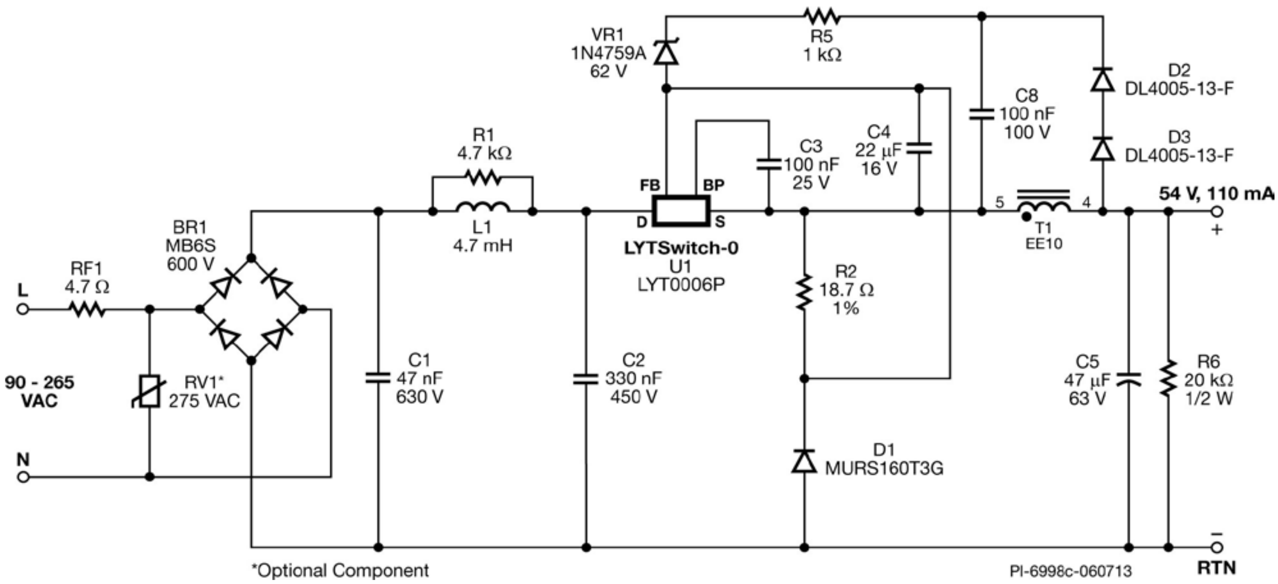

Figure 42 – Constant voltage (CV) mode protection. Load can be connected anytime without AC recycle. Disadvantage is it will require some pre-load in order to regulate, which decreases efficiency. Pre-load can be replaced by a appropriately rated Zener in series with a resistor if efficiency is a concern.

OVP Protection	Pros	Cons
Zener	1. Cheapest and simple. 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. 2. Lowest no-load consumption. 3. $V_{OUT} \approx 0$ V at no-load; safe.	1. Cost. 2. Requires AC recycle for recovery.
Constant Voltage Mode	1. Hot-plug, load can be connected anytime.	1. Consumes extra power. 2. Residual voltage at no-load. 3. Cost.

Table 4 – Overvoltage Protection Comparison.

17 修訂記錄

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

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Power Integrations 全球銷售支援地點

全球總部
5245 Hellyer Avenue
San Jose, CA 95138, USA.
總機： +1-408-414-9200
客戶服務：
電話： +1-408-414-9665
傳真： +1-408-414-9765
電子郵件：
usasales@powerint.com

德國
Lindwurmstrasse 114
80337, Munich
Germany
電話： +49-895-527-39110
傳真： +49-895-527-39200
電子郵件：
eurosales@powerint.com

日本
Kosei Dai-3 Building
2-12-11, Shin-Yokohama,
Kohoku-ku, Yokohama-shi,
Kanagawa 222-0033
Japan
電話： +81-45-471-1021
傳真： +81-45-471-3717
電子郵件：
japansales@powerint.com

台灣
5F, No. 318, Nei Hu Rd.,
Sec. 1
Nei Hu District
Taipei 11493, Taiwan R.O.C.
電話： +886-2-2659-4570
傳真： +886-2-2659-4550
電子郵件：
taiwansales@powerint.com

中國 (上海)
Rm 1601/1610, Tower 1,
Kerry Everbright City
No. 218 Tianmu Road West,
Shanghai, P.R.C. 200070
電話： +86-21-6354-6323
傳真： +86-21-6354-6325
電子郵件：
chinasales@powerint.com

印度
#1, 14th Main Road
Vasanthanagar
Bangalore-560052
India
電話： +91-80-4113-8020
傳真： +91-80-4113-8023
電子郵件：
indiasales@powerint.com

韓國
RM 602, 6FL
Korea City Air Terminal B/D,
159-6
Samsung-Dong, Kangnam-Gu,
Seoul, 135-728 Korea
電話： +82-2-2016-6610
傳真： +82-2-2016-6630
電子郵件：
koreasales@powerint.com

歐洲總部
1st Floor, St. James's House
East Street, Farnham
Surrey GU9 7TJ
United Kingdom
電話：+44 (0) 1252-730-141
傳真： +44 (0) 1252-727-689
電子郵件：
eurosales@powerint.com

中國 (深圳)
3rd Floor, Block A,
Zhongtou International Business
Center, No. 1061, Xiang Mei Rd,
FuTian District, ShenZhen,
China, 518040
電話： +86-755-8379-3243
傳真： +86-755-8379-5828
電子郵件：
chinasales@powerint.com

義大利
Via Milanese 20, 3rd.Fl.
20099 Sesto San Giovanni
(MI) Italy
電話： +39-024-550-8701
傳真： +39-028-928-6009
電子郵件：
eurosales@powerint.com

新加坡
51 Newton Road,
#19-01/05 Goldhill Plaza
Singapore, 308900
電話： +65-6358-2160
傳真： +65-6358-2015
電子郵件：
singaporesales@powerint.com

應用服務專線
全球 +1-408-414-9660

應用服務傳真
全球 +1-408-414-9760