設計範例報告

標題	***採用 LYTSwitch™-0 LYT0006P/D 的 12 W 非調光、非隔離降壓式 LED 驅動器***
規格	190 VAC – 265 VAC 輸入；85 V_{NOM}，135 mA 輸出
應用	T8 型燈管替換品
作者	應用工程部門
文件編號	DER-384
日期	2013 年 10 月 8 日
修訂	1.0

<u>摘要與功能</u>

- Single-stage 高功率因數 (PF) (在 230 V 條件下大於 0.7) 結合精準的定電流 (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，在整個輸入範圍內效率大於 90 %
- 快速啟動 (小於 100 ms) – 無可感延遲
- 整合式保護與信賴度特性
  - 單擊 (Single shot) 無負載保護
  - 藉由自動恢復功能提供輸出短路保護
  - 自動恢復磁滯回復過溫保護，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

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 (LYT0006D) 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。

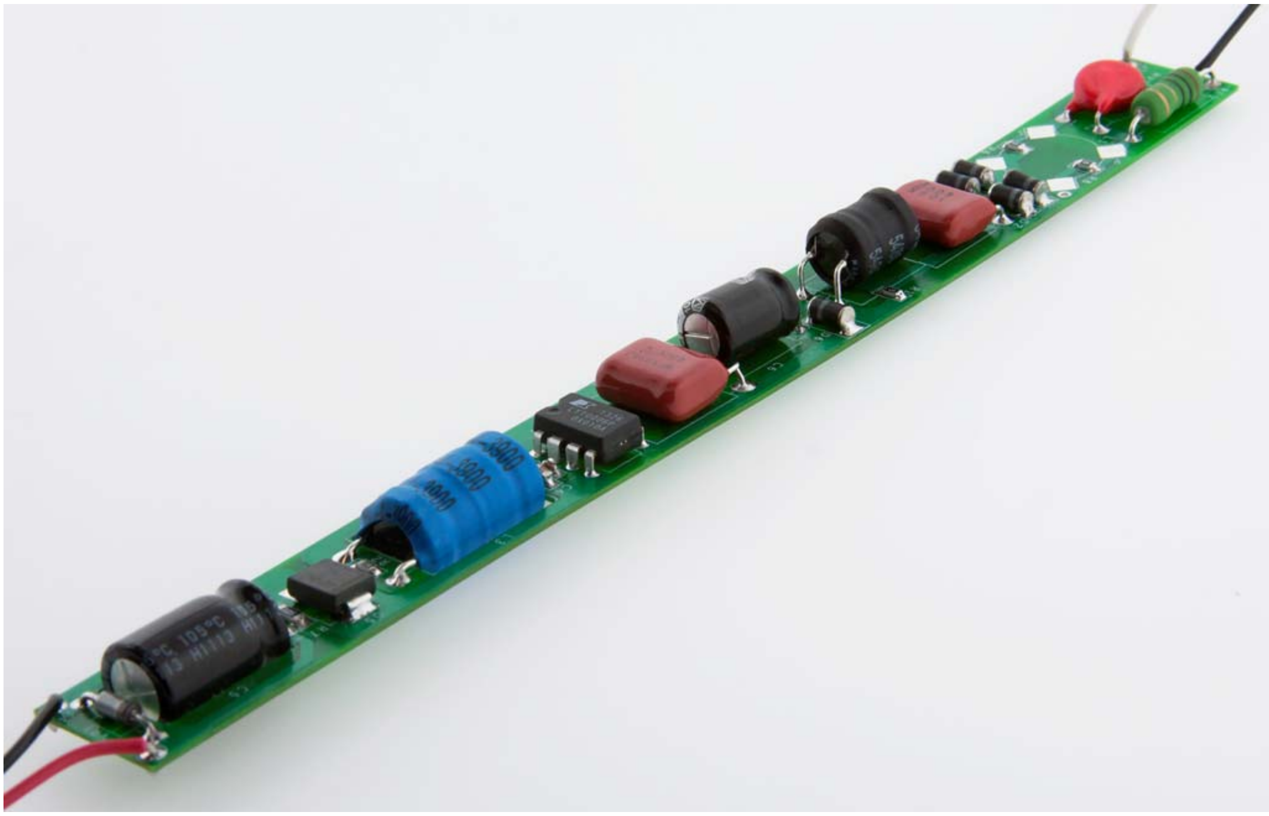

Figure 1 – Populated Circuit Board.

此電源供應器在 190 VAC 至 265 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 85 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。

參考設計並不限於電子安定器燈泡應用的 LED 燈管；由於其簡易性，設計佈局可輕鬆進行修改以用於改良式燈具應用。

Figure 2 – Populated Circuit Board, P Package, Top.

Figure 3 – Populated Circuit Board, P Package, Bottom.

Figure 4 – Populated Circuit Board, D Package, Top.

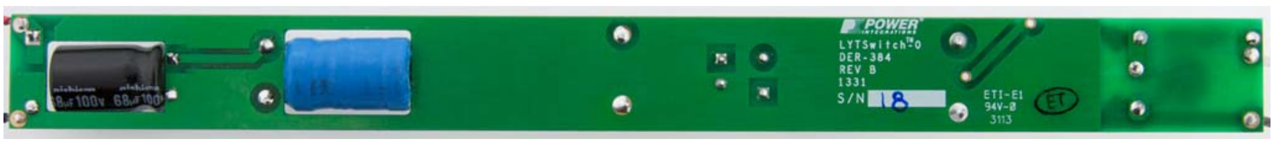

Figure 5 – Populated Circuit Board, D Package, Bottom.

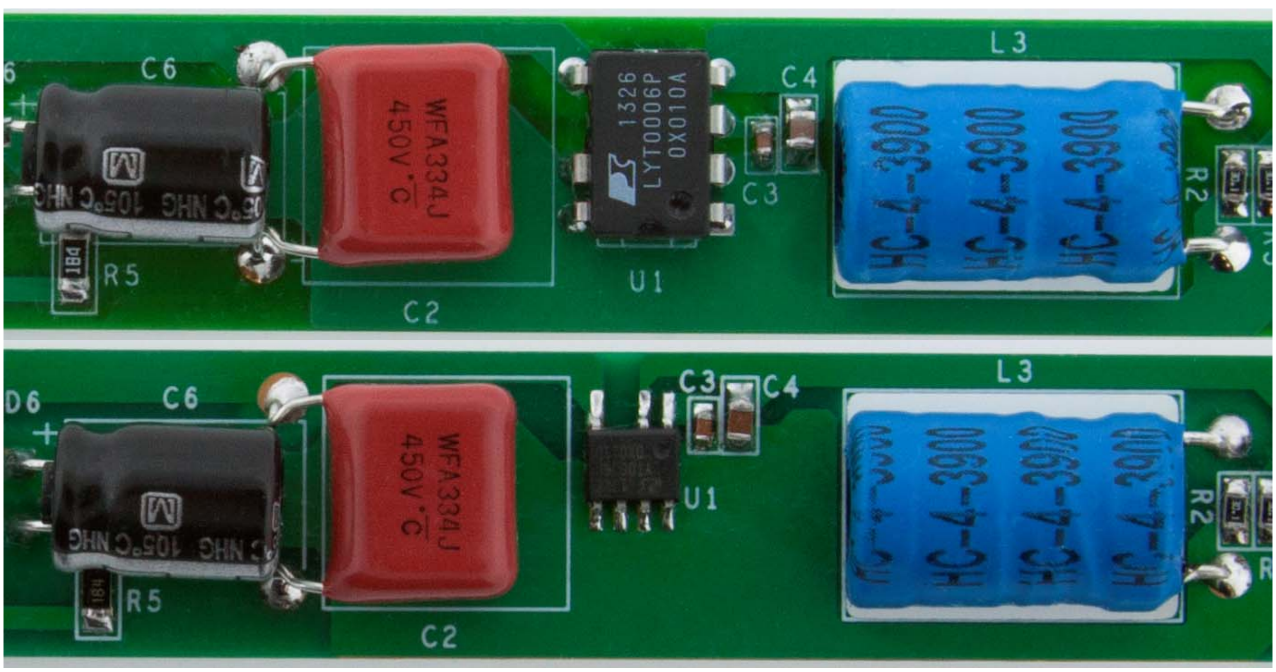

Figure 6 – There are 2 Possible LYTSwitch-0 Package Options for this Application - Only Difference is the Temperature Rise, P Package being Lower by 5 °C.

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2 電源供應器規格

下表列出此設計可接受的最低效能。實際效能列在結果部分。

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}	190		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}	83	85	88	V	在 200 VAC - 240 VAC 條件下 ±4%
輸出電流	I_{OUT}		82		mA	
總輸出功率						
連續輸出功率	P_{OUT}			12	W	
效率						
240 VAC；85 V LED	η	90			%	於 P_{OUT}、25 °C 條件下測量
功率因數 (PF)						
240 VAC；85 V LED	功率因數 (PF)	0.7				在 P_{OUT} ,25 °C 時測量
環境						
傳導性 EMI		符合 CISPR22B / EN55015B 標準				
線電壓突波 差模 (L1-L2)			1		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

3 電路圖

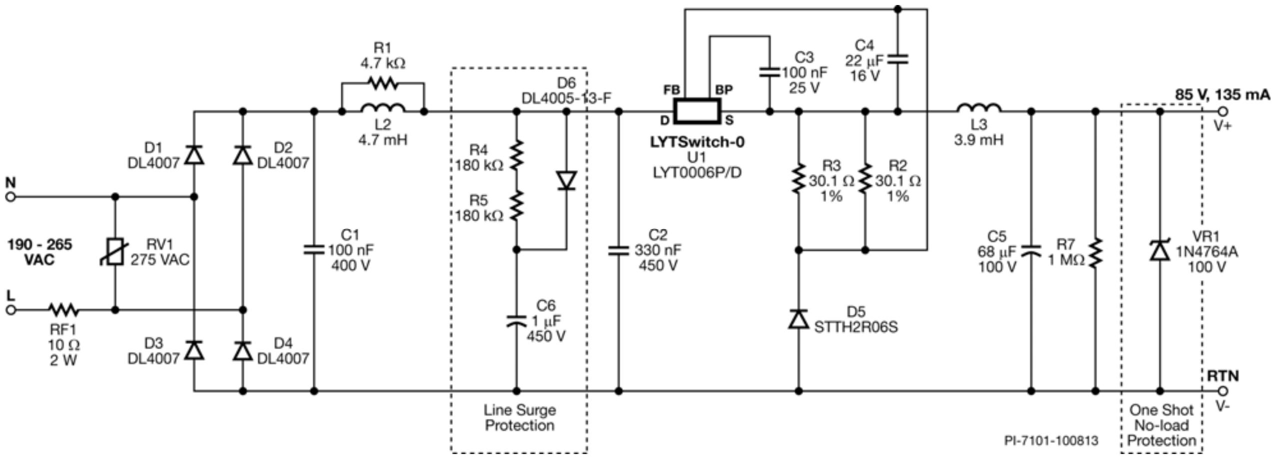

Figure 7 – Schematic.

附註：可選用積納二極體 VR1，其提供一次性無負載保護。請參閱 AN-60 以瞭解其他的 OVP 選項。

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4 電路說明

圖 7 中所示的電源供應器採用高壓降壓式結構的 LYT0006P (U1)，可在 85 VDC 輸出電壓下提供恆定的 135 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) 電源供應器驅動。

4.1 輸入 EMI 濾波

保險絲 RF1 提供短路保護。二極體 D1、D2、D3 和 D4 構成全橋整流器，用於進行全波整流以實現良好的功率因數 (PF)。佈局中使用四個單一二極體而非單一封裝，以便平均分配功率損失 (熱量) 並降低成本。電容器 C1 和 C2 及差模電感器 L2 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。還可在電路板上佈建額外的共模電感器 (L1)，以免需要更多電感才能符合系統 EMI 要求。

對於 1 kV 及更高的線電壓高壓突波，裝置使用 RCD (C6、D6、R4 和 R5) 電路及 MOV (RV1) 來箝制線間突波能量。對於 2 kV 及更高的突波要求，將 RF1 換成具有高 I^2t 額定值的普通保險絲。對於 500 V 的線電壓高壓突波，移除 RCD 電路。2.5 kV 的線電壓高壓突波僅需要 RV1 來保護 AC 整流器。

參考設計濾波器已經過最佳化，可實現高功率因數 (PF)。透過適當組合並最佳化 π 濾波器和輸出電壓，在標準輸入條件下功率因數 (PF) 達到 0.7。

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 ºC (LYTSwitch-0 外殼溫度) 內提供嚴格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。透過儘量減少輸入電流失真並擴展整個 AC 週期內的輸入電流，總輸入電容得到最佳化，以儘可能提供最高功率因數 (PF)。

LYTSwitch-0 系列具有內建過熱限制，可在燈管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 LYT0006D (U1) 內的整合式功率 MOSFET 切換開關、飛輪二極體 D5、感測電阻器 (R2 和 R3)、功率電感器 L3 和輸出電容器 C5 組成。該轉換器通常在連續模式 (CM) 下運作，以提供所需的輸出電流。選用了快速飛輪二極體以將切換損失降至最低。

電源轉換器中使用現成的標準電感器，以降低設計成本。

降低輸出電容器 (C5) 的電容不會限制驅動器運作。事實上，在需要低輸出電流漣波的直接驅動應用中可移除 C5。

4.3 輸出整流

對於此功率等級，功率電感器通常在連續模式下運作，快速輸出二極體 (D5) 用於將反向電流降至最低 (建議 t_{RR} 小於 35 nS)，以實現高效率和低散熱運作。

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，流入回授 (FB) 接腳的電壓也會上升。如果此電壓超過 V_{FB}，則將跳離後續切換週期，直到電壓降至低於 V_{FB}。輸出電流從 R2 和 R3 進行感測並由 C4 進行濾波，然後饋送至 FB 接腳並與內部參考相比較，以進行精確調節。實現良好線間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。這可透過 PIXIs 設計試算表完成。

BYPASS 電容器 (C4) 連接 FB 接腳和源極 (S) 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，因為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。請參閱 AN-60 以瞭解其他的 OVP 選項。

在實際運作中 (LED 改良式燈具)，負載始終是接通的，因此可移除不必要的 VR1 以節省成本。如果負載意外中斷，尤其是在製造中的電路板等級測試期間，首先可對輸入端施加 70 VAC，然後測量輸出電流以確定負載是否已接通。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

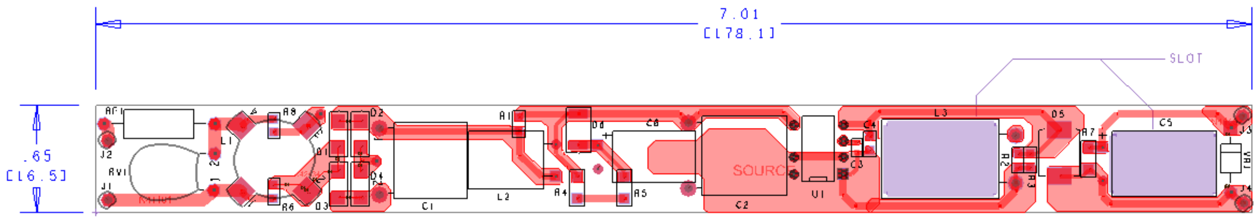

Figure 8 – Printed Circuit Layout for DIP-8 P Package.Top View.

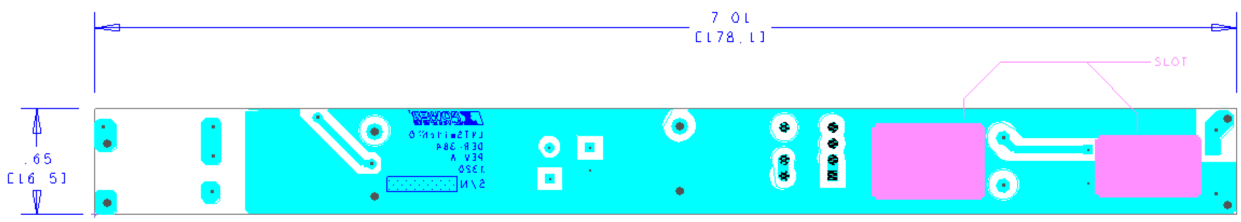

Figure 9 – Printed Circuit Layout for P Package.Bottom View.

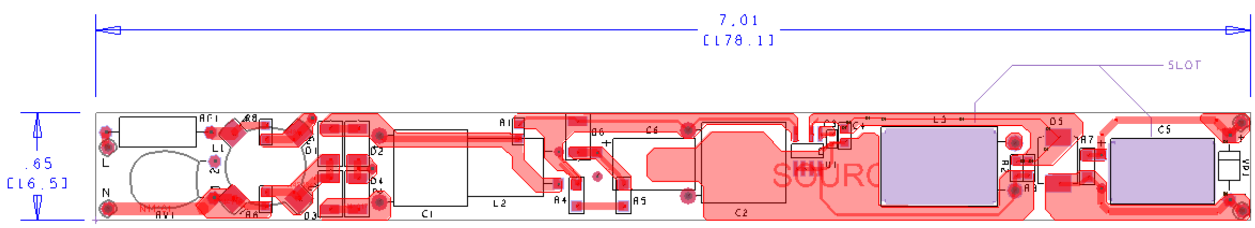

Figure 10 – Printed Circuit Layout for SO-8 D Package.Top View.

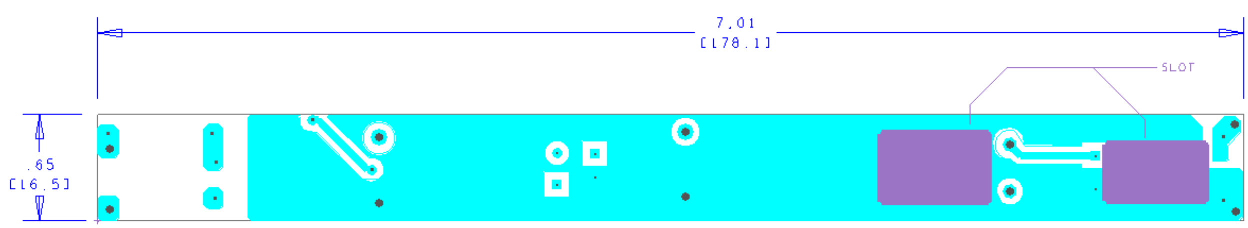

Figure 11 – Printed Circuit Layout for D Package.Bottom View.

6 物料清單

Item	Qty	Ref Des	說明	Manufacturer P/N	Manufacturer
Electrical					
1	1	C1	100 nF, 400 V, Film	ECQ-E4104KF	Panasonic
2	1	C2	330 nF, 450 V, METALPOLYPRO	ECW-F2W334JAQ	Panasonic
3	1	C3	100 nF, 25 V, Ceramic, X7R, 0603	VJ0603Y104KNXAO	Vishay
4	1	C4	22 μF, 16 V, Ceramic, X7R, 0805	C2012X5R1C226K	TDK
5	1	C5	68 μF, 100 V, Electrolytic, Gen. Purpose, (10 x 16)	UHE2A680MPD	Nichicon
6	1	C6	1.0 μF, 450 V, Electrolytic, NHG, (8 x 11.5)	ECA-2WHG010	Panasonic
7	4	D1 D2 D3 D4	1000 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)	DL4007-13-F	Diodes, Inc.
8	1	D5	DIODE ULTRA FAST 600 V 2 A HE SMC, DO-214AB	STTH2R06S	ST Micro
9	1	D6	600 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)	DL4005-13-F	Diodes, Inc.
10	1	L2	4.7 mH, 0.150 A, 20%	RL-5480-3-4700	Renco Elect
11	1	L3	3.9 mH, 0.250 A, 20%	RL-5480HC-4-3900	Renco Elect
12	1	R1	4.7 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ472V	Panasonic
13	2	R2 R3	31/8 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF30R1V	Panasonic
14	2	R4 R5	180 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ184V	Panasonic
15	1	R7	1 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
16	1	RF1	10 Ω, 5%, 2 W, Wirewound, Fusible	FW20A10R0JA	Bourns
17	1	RV1	275 V, 23 J, 7 mm, RADIAL	V275LA4P	Littlefuse
18	1	U1	LYTSwitch-0, DIP-8B	LYT0006P/D	Power Integrations
19	1	VR1	100 V, 5%, 1 W, DO-41	1N4764A-TAP	Vishay
Mechanical					
16	1	WIRE (V-)	Wire, UL1007, #24 AWG, Blk, PVC, 4"	1007-24/7-0	Anixter
17	1	WIRE (L)	Wire, UL1007, #24 AWG, Blu, PVC, 4"	1007-24/7-6	Anixter
18	1	WIRE (V+)	Wire, UL1007, #24 AWG, Red, PVC, 4"	1007-24/7-2	Anixter
19	1	WIRE (N)	Wire, UL1007, #24 AWG, Wht, PVC, 4"	1007-24/7-9	Anixter
20	1	PCB	FR4, 0.31, 1 Oz Cu (0.65" X 7.0")		

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7 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	190		190	Volts	Minimum AC Input Voltage
VACNOM	230		230		
VACMAX	265		265	Volts	Maximum AC Input Voltage
FL	50		50	Hertz	Line Frequency
VO	85		85	Volts	輸出電壓
IO	135		135	mA	輸出電流
Pout			11.5	W	
EFFICIENCY	0.90		0.90		Overall Efficiency Estimate (Adjust to match Calculated, or enter Measured Efficiency)
CIN	0.43		0.43	uF	Input Filter Capacitor
DC INPUT VARIABLES					
VMIN			85.70624	Volts	Minimum DC Bus Voltage
VMAX			374.7666	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
IRMS			110.4053	mA	Expected RMS current through LYTSwitch
VDS			4.8375	Volts	Maximum On-State Drain To Source Voltage drop
DIODE					
VD			0.7	Volts	Freewheeling Diode Forward Voltage Drop
VRR			400	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	Off-the-Shelf		Off-the-Shelf		Select core type between Ferrite and Off-the-Shelf
Core size					Select core size
Custom Core					Enter custom core description (if used)
AE			N/A	mm^2	Core Effective Cross Sectional Area
LE			N/A	mm	Core Effective Path Length
AL			N/A	nH/T^2	Ungapped Core Effective Inductance
BW			N/A	mm	Bobbin Physical Winding Width
NL			N/A		Number of turns on inductor
BP			N/A	Gauss	Peak flux density
LG			N/A	mm	Gap length
OD			N/A		Maximum Primary Wire Diameter including insulation
INS			N/A		Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			N/A		Bare conductor diameter
AWG			N/A		Primary Wire Gauge (Rounded to next

					smaller standard AWG value)
CM			N/A		Bare conductor effective area in circular mils
CMA			N/A		!!! INCREASE CMA > 200 (increase L(primary layers),decrease NS, use larger Core)
L			N/A		
LP	3510		3510	uH	Output Inductor, Recommended Standard Value
IO_Average			135.7396	mA	Average output current
ILRMS			174.5175	mA	Estimated RMS inductor current (at VMAX)
FEEDBACK COMPONENTS					
RFB	15.05		15.05	Ohms	Feedback Resistor.Use closest standard 1% value
CFB			22	uF	Feedback Capacitor
OUTPUT REGULATION					
IO_VACMIN			135.7396	mA	Output Current at VACMIN
IO_VACNOM			136.7358	mA	Output Current at VACNOM
IO_VACMAX			135.3795	mA	Output Current at VACMAX

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8 效能資料

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

輸入		Input Measurement				LED Load Measurement			Regulation (%)	Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	功率因數 (PF)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)		
V_{OUT} Minimum										
190	50	189.93	83.76	12.377	0.778	82.0	136.2	11.190	0.89	90.41
200	50	199.89	81.65	12.432	0.762	82.0	136.6	11.230	1.19	90.33
220	50	219.95	78.22	12.460	0.724	82.0	136.6	11.220	1.19	90.05
240	50	239.93	75.75	12.459	0.686	82.0	136.2	11.180	0.89	89.73
265	50	264.97	73.32	12.464	0.642	81.9	135.8	11.140	0.59	89.38
V_{OUT} Nominal										
190	50	189.95	84.98	12.777	0.792	85.0	135.7	11.580	0.52	90.63
200	50	199.89	82.94	12.818	0.773	85.0	136.1	11.600	0.81	90.50
220	50	219.95	79.45	12.924	0.740	85.1	136.9	11.670	1.41	90.30
240	50	239.93	76.78	12.922	0.701	85.1	136.5	11.630	1.11	90.00
265	50	264.97	74.40	12.930	0.656	85.1	136.1	11.590	0.81	89.64
V_{OUT} Maximum										
190	50	189.95	86.14	13.173	0.805	88.1	135.4	11.970	0.30	90.87
200	50	199.89	84.04	13.230	0.788	88.1	135.8	12.000	0.59	90.70
220	50	219.95	80.51	13.307	0.752	88.2	136.3	12.050	0.96	90.55
240	50	239.93	77.84	13.391	0.717	88.2	136.7	12.080	1.26	90.21
265	50	264.97	75.55	13.417	0.670	88.2	136.4	12.050	1.04	89.81

Table 1 – Test Data from the UUT.

8.1 工作模式效率

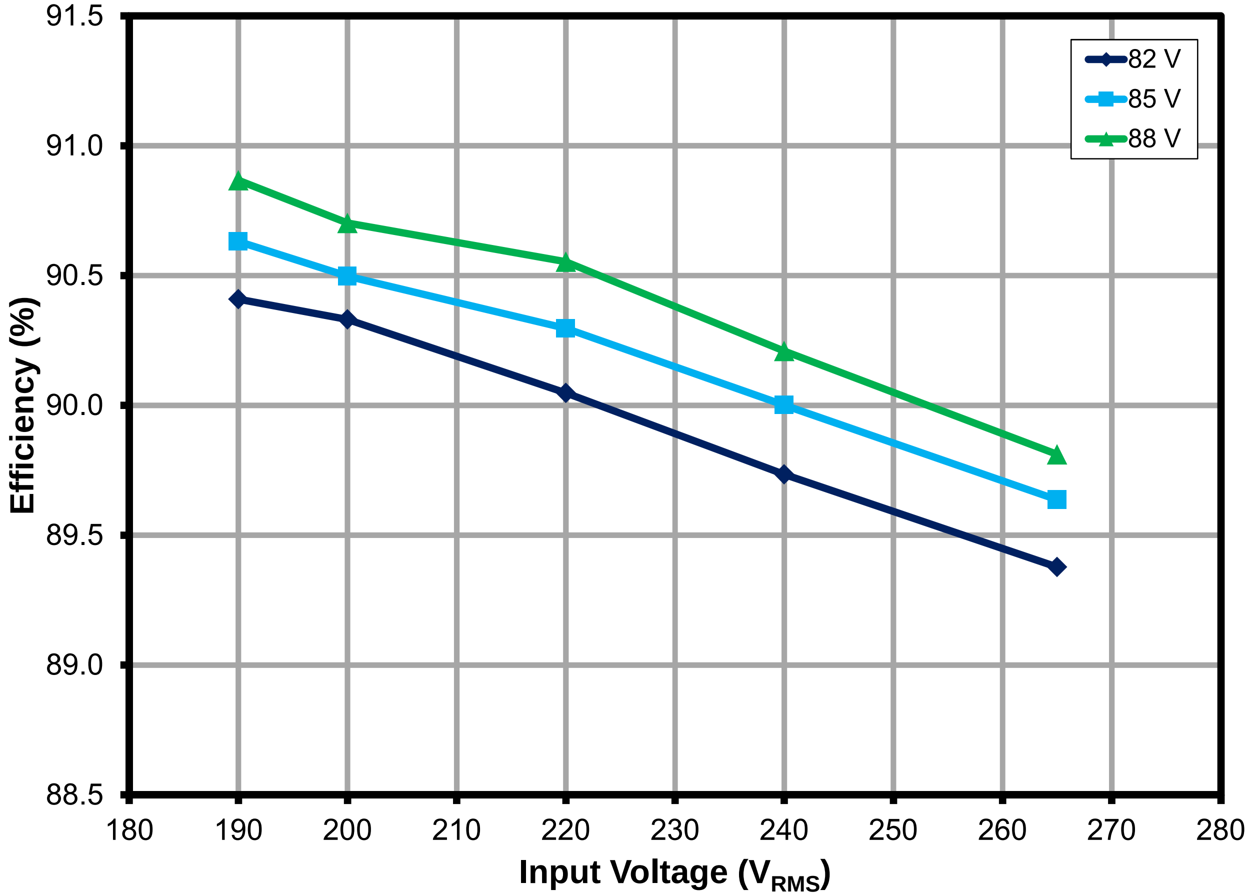

Figure 12 – Efficiency with Respect to AC Input Voltage 190-265 VAC (60 Hz) Input.

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8.2 輸出電流調節

8.2.1 線間電壓與負載範圍內的輸出電流調節

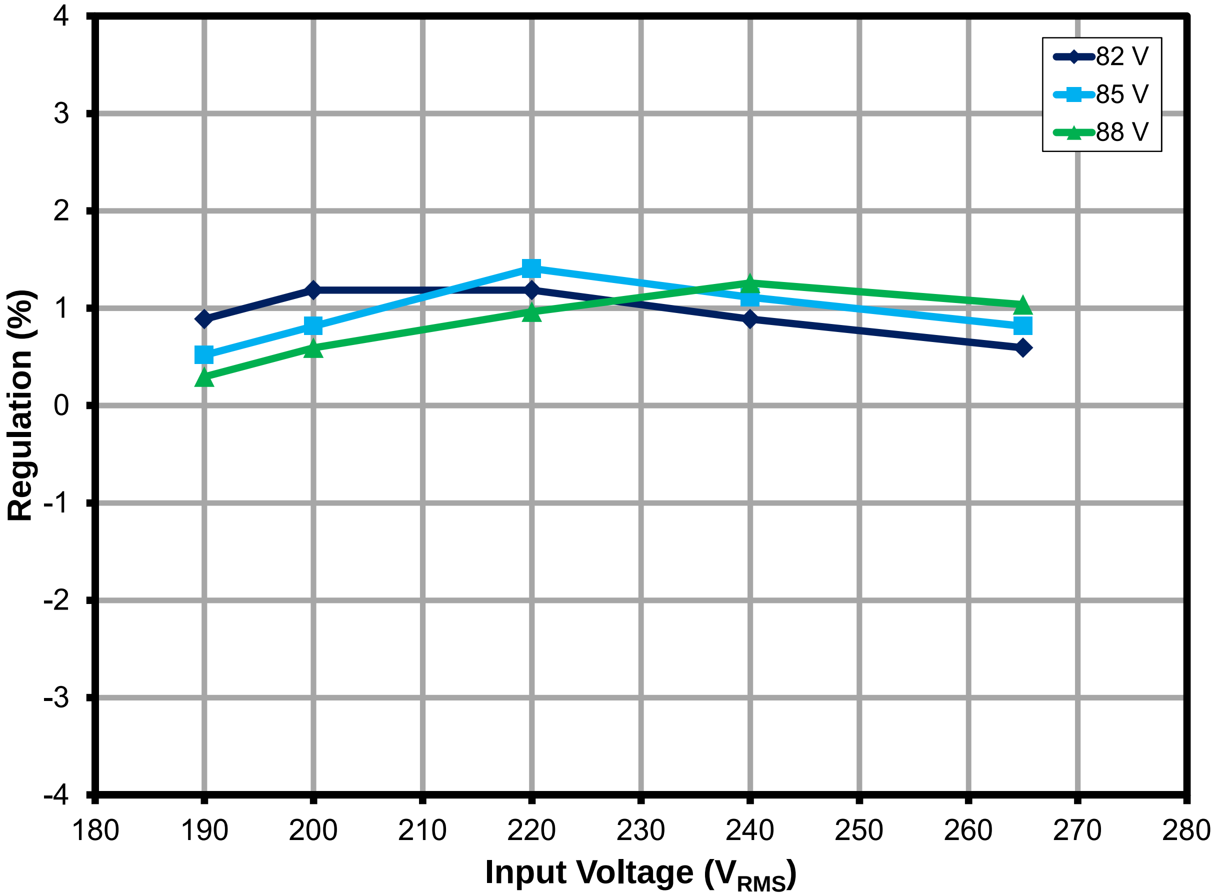

Figure 13 – Load Regulation, Room Temperature.

8.3 負載調節

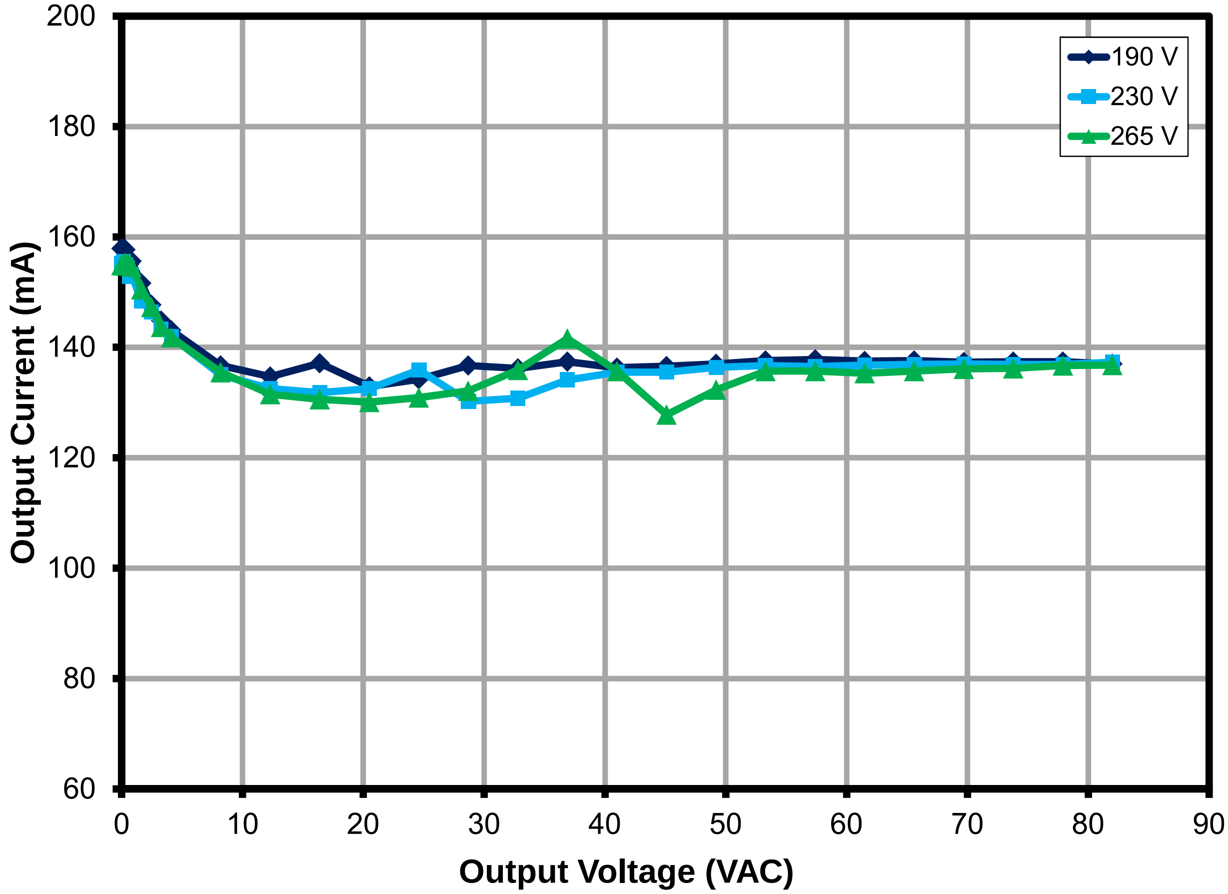

Figure 14 – Load Regulation at 190 V, 230 V and 265 V. The Design Can Operate in a Wide Operating Output Voltage.

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8.4 功率因數 (PF)

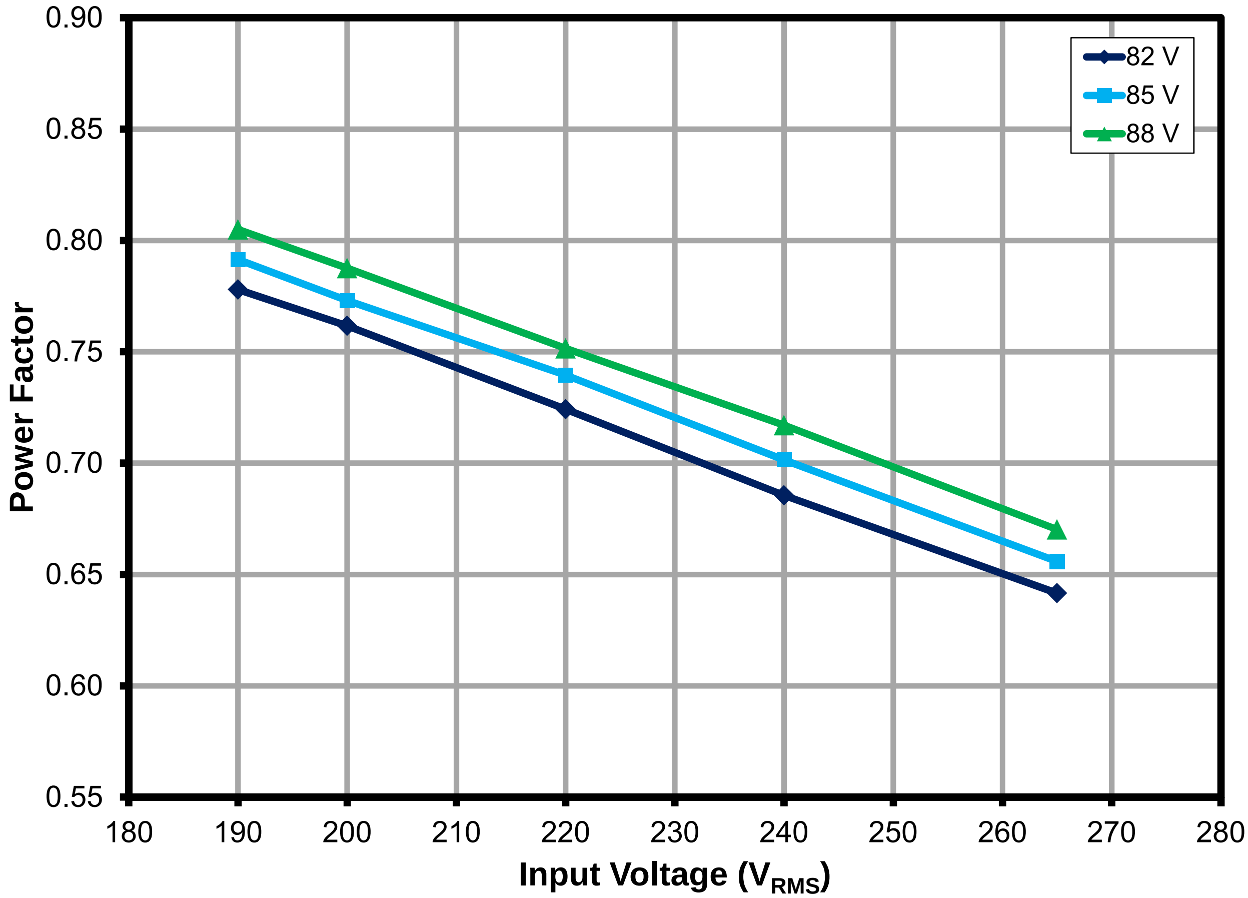

Figure 15 – Power Factor Performance at Different LED Voltage.

9 散熱效能

9.1 使用設備

AC Source:	Chroma Programmable AC Source Model No: 6415	Wattmeter:	Yokogawa Power Meter Model No:WT2000
		Data Logger:	Agilent

Figure 16 – LED Driver Inserted in a T8, 2 ft. Tube for Thermal Evaluation.

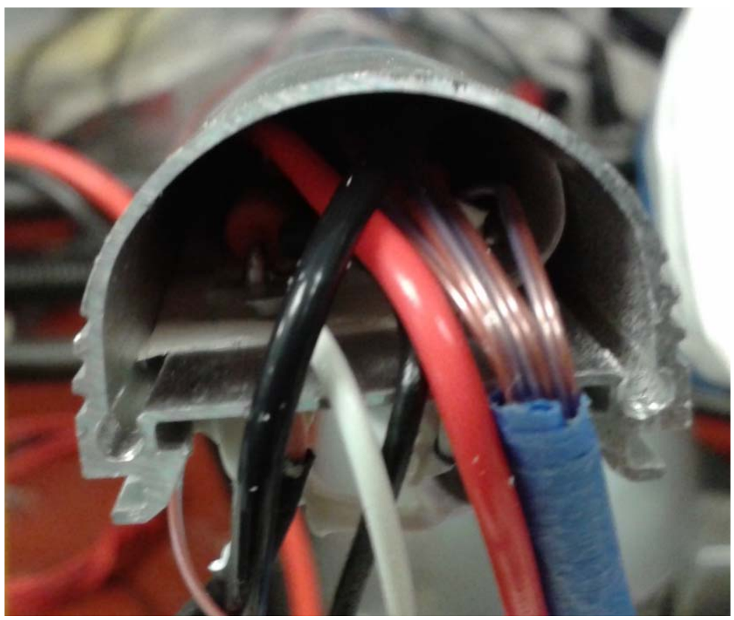

Figure 17 – LED Driver Thermal Unit Fitted Inside a T8 Tube Housing.

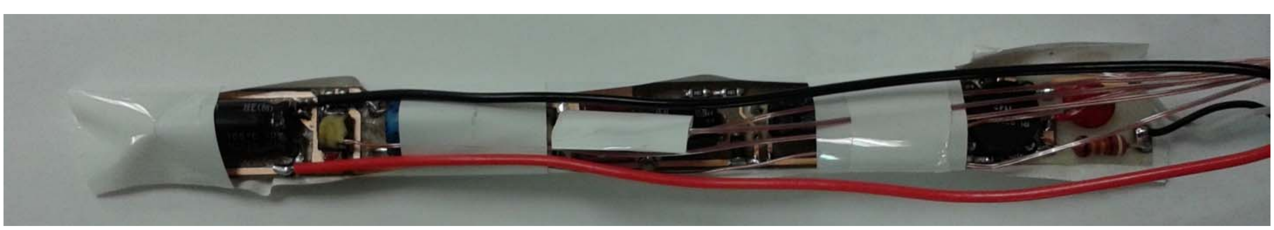

Figure 18 – Thermal Unit with Thermocouple Set-up.

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9.2 散熱成效

Input:190 V / 50 Hz
負載：85 V / 135 m A LED load.

Device Location	Unit	Measurement
External Ambient	°C	36.8
Internal Ambient	°C	42.7
Bridge (D2)	°C	50.0
LYT0006P/D (U1)	°C	49.0
Power Inductor (L2)	°C	44.0
Output Diode (D5)	°C	50.0

Table 2 – Thermal Measurement.

9.3 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.

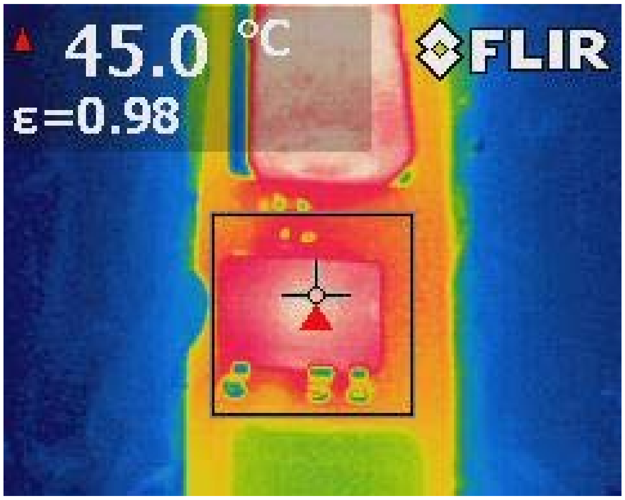

Figure 19 – LYT0006P Device Temperature (°C).

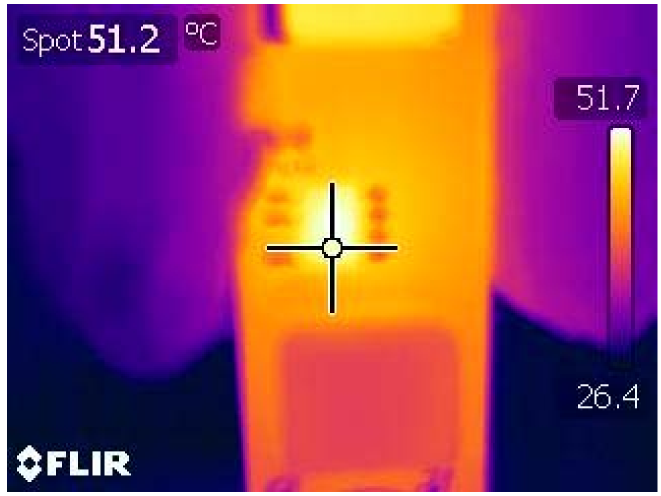

Figure 20 – LYT0006D Device Temperature (°C).

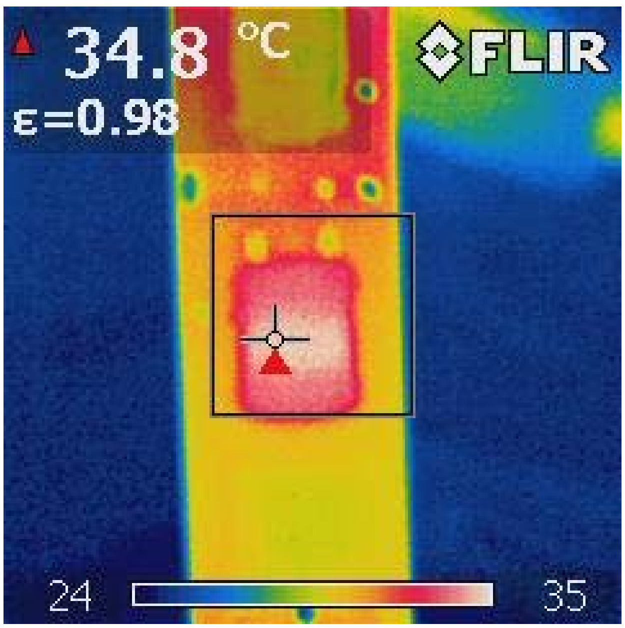

Figure 21 – EMI Choke; L1 Temperature (°C).

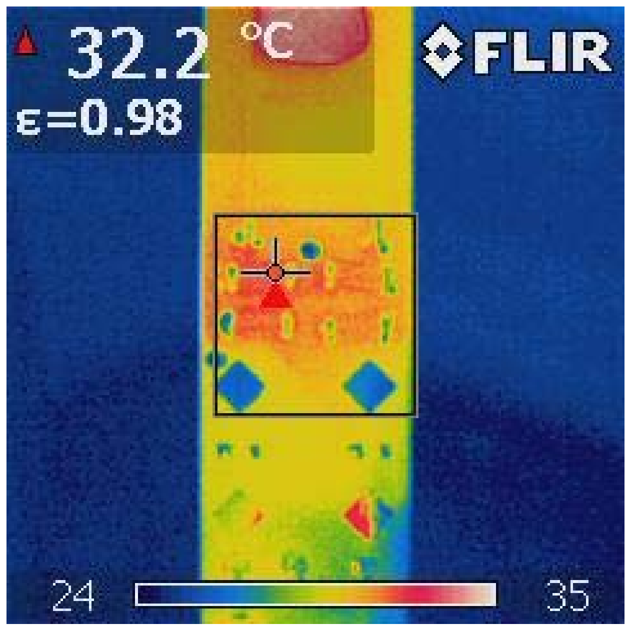

Figure 22 – D1 Temperature (°C).

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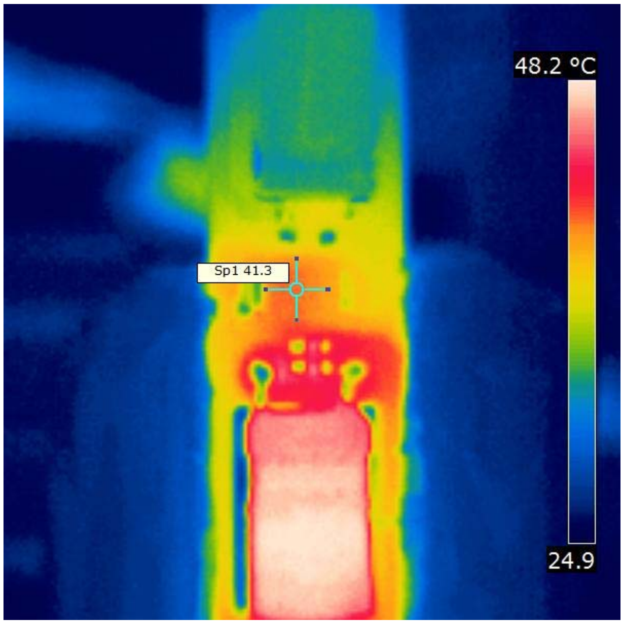

Figure 23 – D5 Freewheeling Diode Temperature (°C)

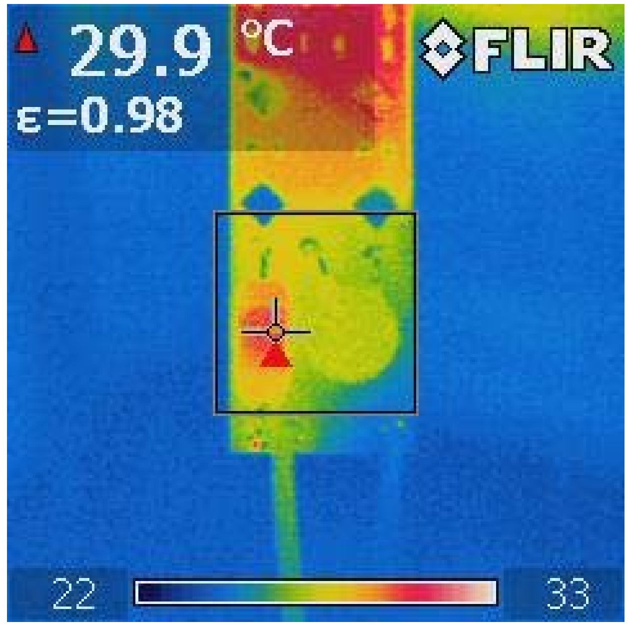

Figure 24 – Temperature (°C) at Bottom Side of PCB.

10 波形

10.1 正常運作下的汲極電壓和電流

Skipped cycles are normal as they are the mode used to regulate the output current.These skipped cycles will occur every time the voltage drop on sense resistor (R2, R3) reaches 1.65 V. The unit will enter into auto-restart if there is not at least one missing pulse within 50 ms.

In some designs with high power inductance and operating mostly in CCM, a reverse current may be present.This can be avoided by increasing the device size, increasing the input capacitance, or adding a drain blocking diode.See AN-60 for more additional information.

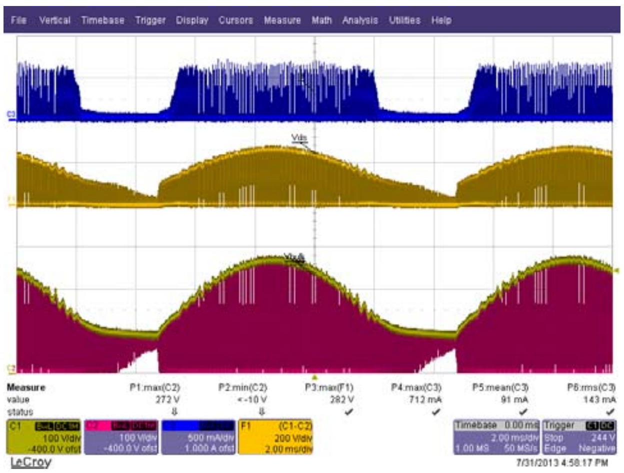

Figure 25 – 190 VAC, 50 Hz, Nominal V_{LED} Load.
F1 (Orange):V_{D-S}, 200 V / div.
Ch1 (Yellow):$V_{BULK-GROUND}$, 100 V / div.
Ch2 (Yellow):V_{S-G}, 100 V / div.
Ch3 (Blue):I_{DRAIN}, 500 mA / div.
Time Scale:2 ms / div.

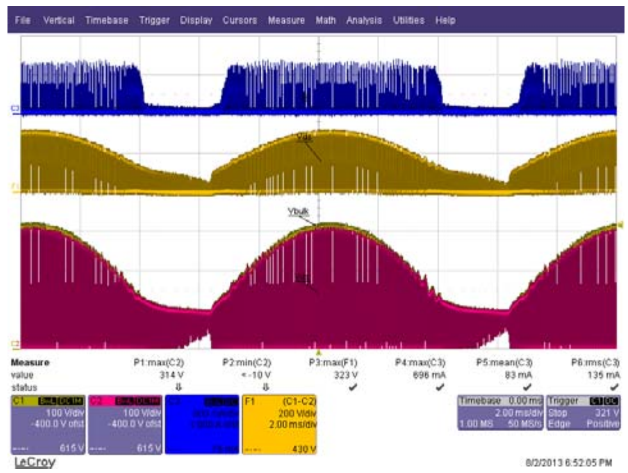

Figure 26 – 220 VAC, 50 Hz, Nominal V_{LED} Load.
F1 (Orange):V_{D-S}, 200 V / div.
Ch1 (Yellow):$V_{BULK-GROUND}$, 100 V / div.
Ch2 (Yellow):V_{S-G}, 100 V / div.
Ch3 (Blue):I_{DRAIN}, 500 mA / div.
Time Scale:2 ms / div.

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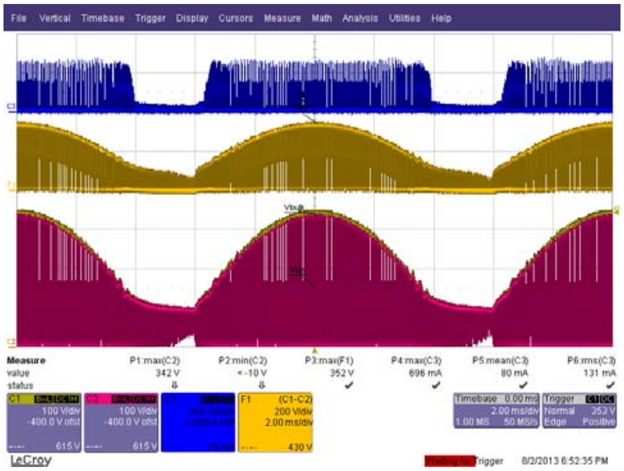

Figure 27 – 240 VAC, 50 Hz, Nominal V_{LED} Load.
F1 (Orange):V_{D-S}, 200 V / div.
Ch1 (Yellow):$V_{BULK-GROUND}$, 100 V / div.
Ch2 (Yellow):V_{S-G}, 100 V / div.
Ch3 (Blue):I_{DRAIN}, 500 mA / div.
Time Scale:2 ms / div.

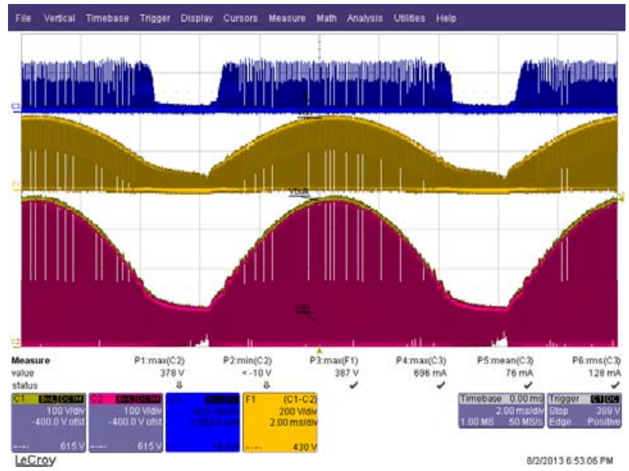

Figure 28 – 265 VAC, 50 Hz, Nominal V_{LED} Load.
F1 (Orange):V_{D-S}, 200 V / div.
Ch1 (Yellow):$V_{BULK-GROUND}$, 100 V / div.
Ch2 (Yellow):V_{S-G}, 100 V / div.
Ch3 (Blue):I_{DRAIN}, 500 mA / div.
Time Scale:2 ms / div.

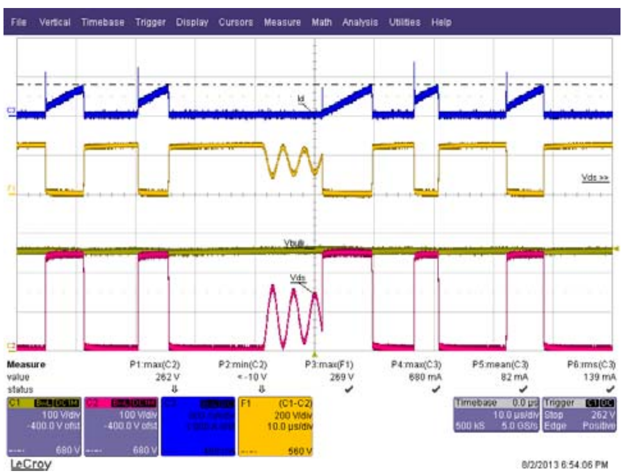

Figure 29 – 190 VAC, 50 Hz, Nominal V_{LED} Load.
F1 (Orange):V_{D-S}, 200 V / div.
Ch1 (Yellow):$V_{BULK-GROUND}$, 100 V / div.
Ch2 (Yellow):V_{S-G}, 100 V / div.
Ch3 (Blue):I_{DRAIN}, 500 mA / div.
Time Scale:10 μs / div.

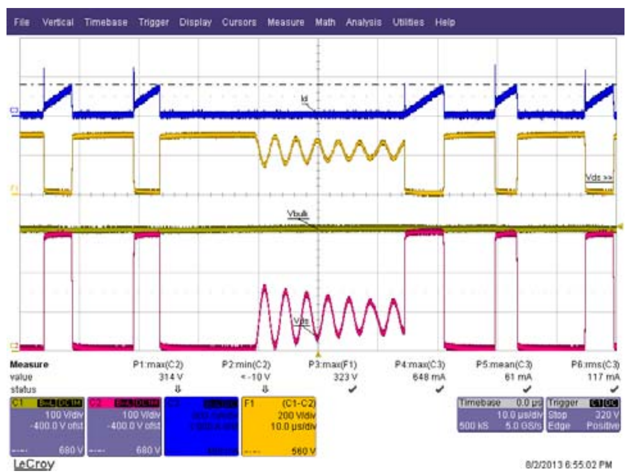

Figure 30 – 220 VAC, 50 Hz, Nominal V_{LED} Load.
F1 (Orange):V_{D-S}, 200 V / div.
Ch1 (Yellow):$V_{BULK-GROUND}$, 100 V / div.
Ch2 (Yellow):V_{S-G}, 100 V / div.
Ch3 (Blue):I_{DRAIN}, 500 mA / div.
Time Scale:10 μs / div.

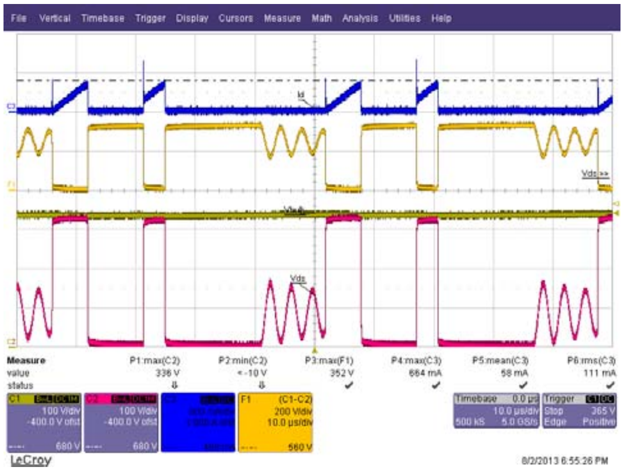

Figure 31 – 240 VAC, 50 Hz, Nominal V_{LED} Load.
F1 (Orange):V_{D-S}, 200 V / div.
Ch1 (Yellow):$V_{BULK-GROUND}$, 100 V / div.
Ch2 (Yellow):V_{S-G}, 100 V / div.
Ch3 (Blue):I_{DRAIN}, 500 mA / div.
Time Scale:10 μs / div.

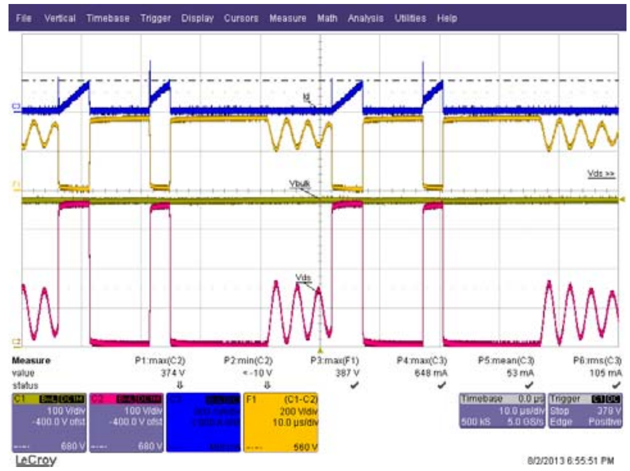

Figure 32 – 265 VAC, 50 Hz, Nominal V_{LED} Load.
F1 (Orange):V_{D-S}, 200 V / div.
Ch1 (Yellow):$V_{BULK-GROUND}$, 100 V / div.
Ch2 (Yellow):V_{S-G}, 100 V / div.
Ch3 (Blue):I_{DRAIN}, 500 mA / div.
Time Scale:10 μs / div.

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10.2 輸出短路時的汲極電壓和電流

Device is operating within range, no inductor saturation was observed.

Figure 33 – LYT0006D Output Short.190 VAC.
Ch1:V_{BULK}, 100 V / div.
Ch2:V_{S-G}, 100 V / div.
Ch3:I_{DRAIN}, 0.5 A / div.
Time Scale:2 ms / div.

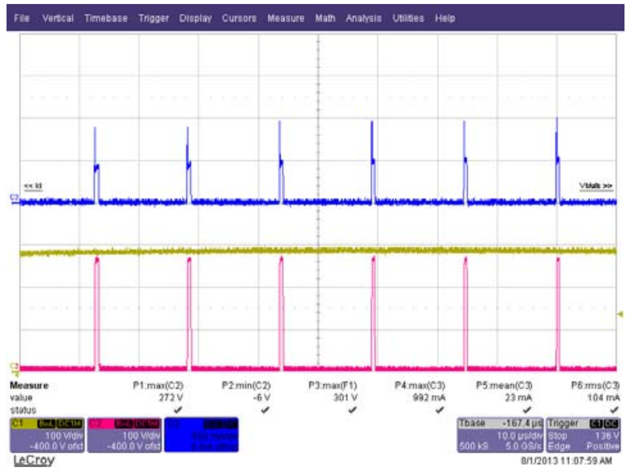

Figure 34 – LYT0006D Output Short.190 VAC.
Ch1:V_{BULK}, 100 V / div.
Ch2:V_{S-G}, 100 V / div.
Ch3:I_{DRAIN}, 0.5 A / div.
Time Scale:10 μs / div.

Figure 35 – LYT0006D Output Short.265 VAC.
Ch1:V_{BULK}, 100 V / div.
Ch2:V_{S-G}, 100 V / div.
Ch3:I_{DRAIN}, 0.5 A / div.
Time Scale:2 ms / div.

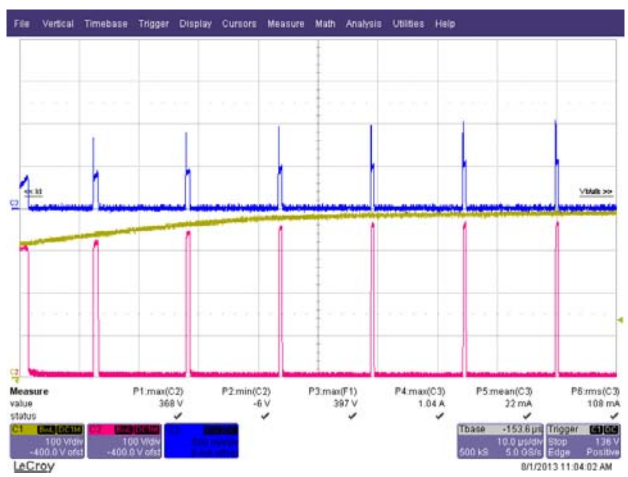

Figure 36 – LYT0006D Output Short.265 VAC.
Ch1:V_{BULK}, 100 V / div.
Ch2:V_{S-G}, 100 V / div.
Ch3:I_{DRAIN}, 0.5 A / div.
Time Scale:10 μs / div.

10.3 汲極電壓和電流啟動輪廓

Device is operating within range, no inductor saturation was observed.

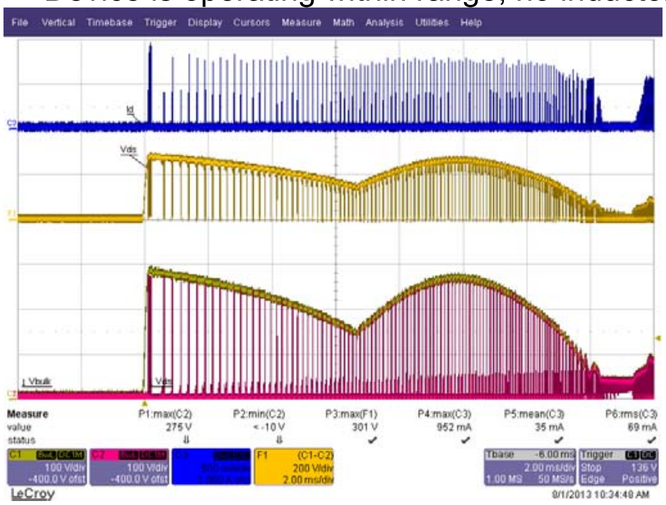

Figure 37 – 190 VAC / 50 Hz Start-up.
Ch1:V_{BULK}, 100 V / div.
Ch2:$V_{S\text{-}G}$, 100 V / div.
Ch3:I_{DRAIN}, 0.5 A / div.
F1:$V_{D\text{-}S}$, 200 V / div.
Time Scale:2 ms / div.

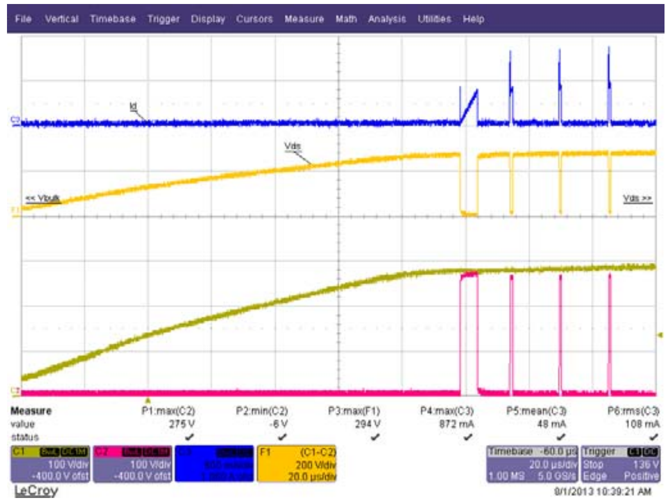

Figure 38 – 190 VAC / 50 Hz Start-up.
Ch1:V_{BULK}, 100 V / div.
Ch2:$V_{S\text{-}G}$, 100 V / div.
Ch3:I_{DRAIN}, 0.5 A / div.
F1:$V_{D\text{-}S}$, 200 V / div.
Time Scale:20 μs / div.

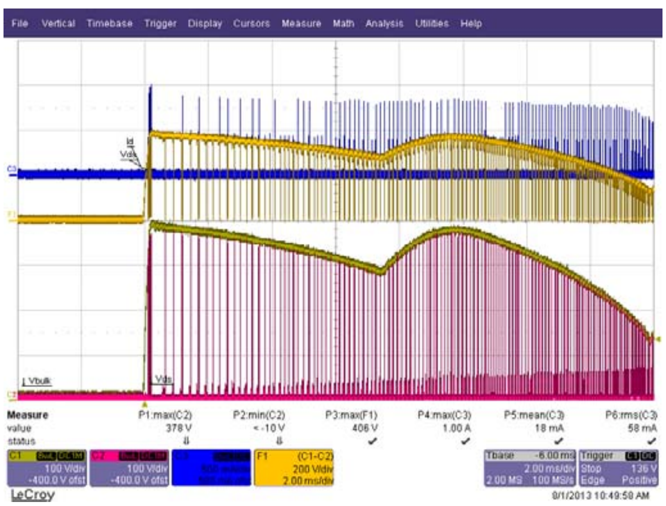

Figure 39 – 265 VAC / 50 Hz Start-up.
Ch1:V_{BULK}, 100 V / div.
Ch2:$V_{S\text{-}G}$, 100 V / div.
Ch3:I_{DRAIN}, 0.5 A / div.
F1:$V_{D\text{-}S}$, 200 V / div.
Time Scale:2 ms / div.

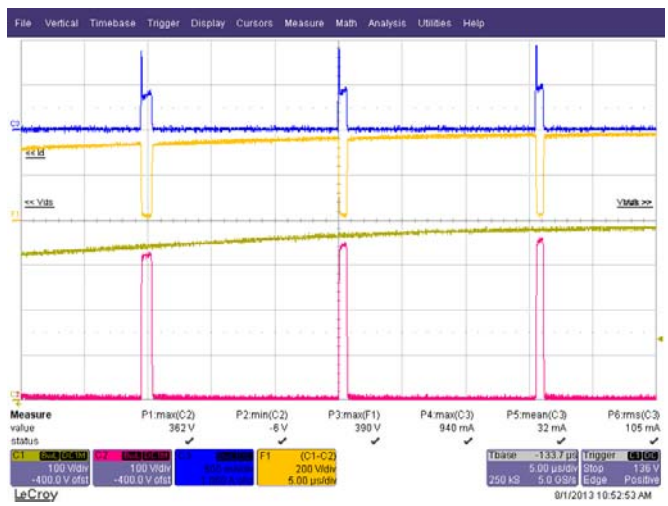

Figure 40 – 265 VAC / 50 Hz Start-up.
Ch1:V_{BULK}, 100 V / div.
Ch2:$V_{S\text{-}G}$, 100 V / div.
Ch3:I_{DRAIN}, 0.5 A / div.
F1:$V_{D\text{-}S}$, 200 V / div.
Time Scale:5 μs / div.

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10.4 輸出電流啟動分析

Output current/light is present in just one AC cycle, 100 ms.

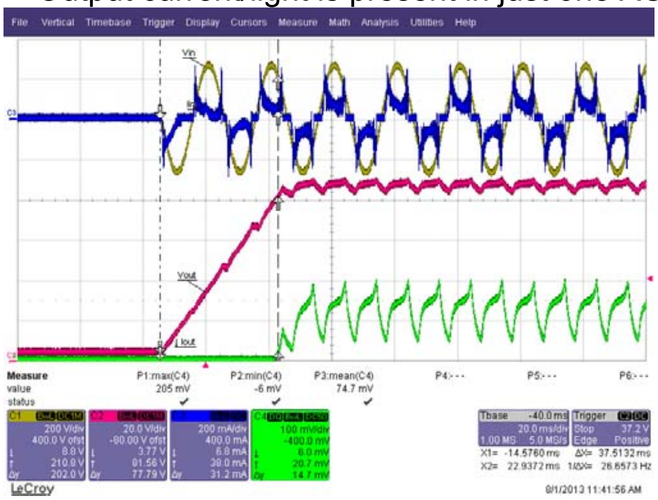

Figure 41 – 190 VAC, 5 0Hz, Nominal V_{LED} Load.
Ch1 (Yellow):V_{IN}, 200 V / div.
Ch2 (Red):V_{OUT}, 20 V.
Ch3 (Blue):I_{IN}, 200 mA / div.
Ch4 (Green):I_{OUT}, 100 mA / div.
Time Scale:20 ms / div.

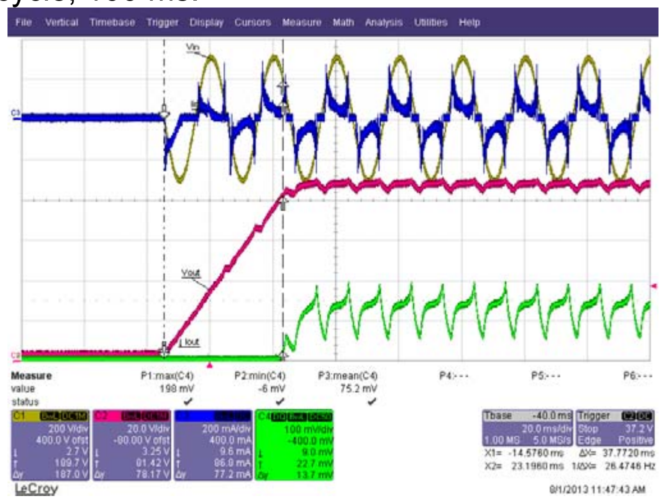

Figure 42 – 220 VAC, 50 Hz, Nominal V_{LED} Load.
Ch1 (Yellow):V_{IN}, 200 V / div.
Ch2 (Red):V_{OUT}, 20 V.
Ch3 (Blue):I_{IN}, 200 mA / div.
Ch4 (Green):I_{OUT}, 100 mA / div.
Time Scale:20 ms / div.

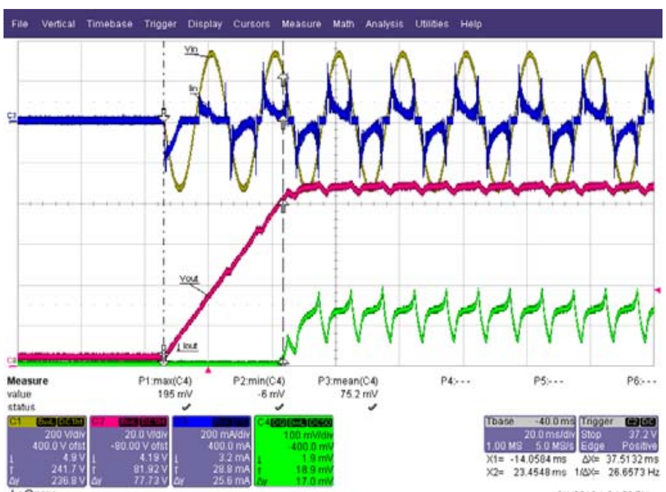

Figure 43 – 240 VAC, 50 Hz, Nominal V_{LED} Load.
Ch1 (Yellow):V_{IN}, 200 V / div.
Ch2 (Red):V_{OUT}, 20 V.
Ch3 (Blue):I_{IN}, 200 mA / div.
Ch4 (Green):I_{OUT}, 100 mA / div.
Time Scale:20 ms / div.

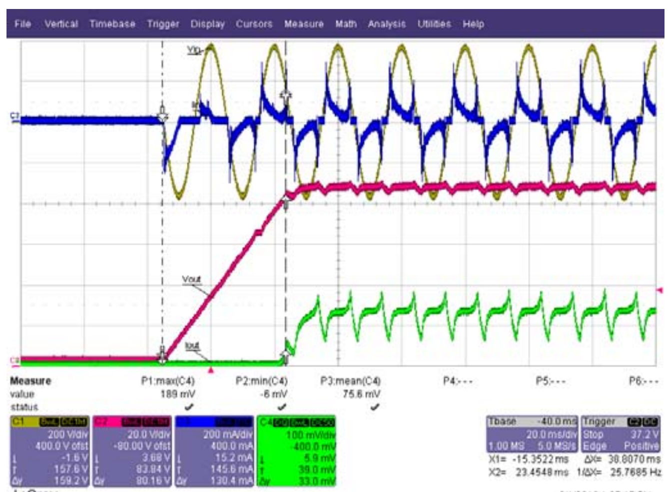

Figure 44 – 265 VAC, 50 Hz, Nominal V_{LED} Load.
Ch1 (Yellow):V_{IN}, 200 V / div.
Ch2 (Red):V_{OUT}, 20 V.
Ch3 (Blue):I_{IN}, 200 mA / div.
Ch4 (Green):I_{OUT}, 100 mA / div.
Time Scale:20 ms / div.

10.5 輸入-輸出分析

There is no limitation to the amount of output capacitance that can be added.If the application requires low output current ripple then increase the output capacitor value until the desired level is achieved.Note that the output current waveform below will change depending on LED load impedance which also varies according to LED type.An LED with high bulk resistance (low current rated LED) will tend to have lower ripple than high current LED with low bulk resistance for the same current impressed.

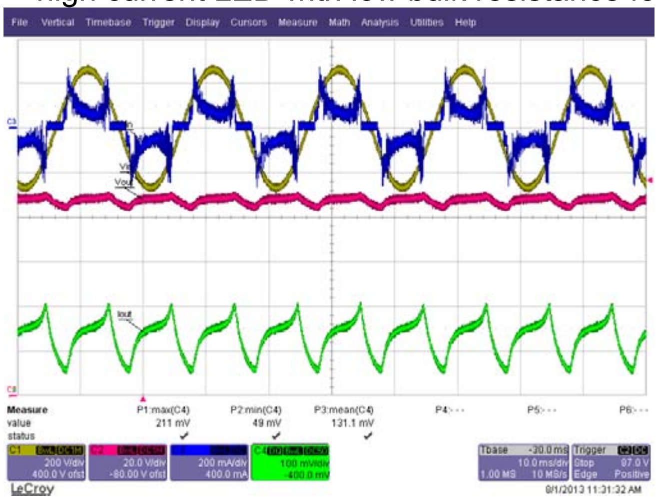

Figure 45 – 190 VAC / 50 Hz, Nominal V_{LED} Load.
Ch1 (Yellow):V_{IN}, 200 V / div.
Ch2 (Red):V_{OUT}, 20 V.
Ch3 (Blue):I_{IN}, 200 mA / div.
Ch4 (Green):I_{OUT}, 100 mA / div. Time Scale:10 ms / div.

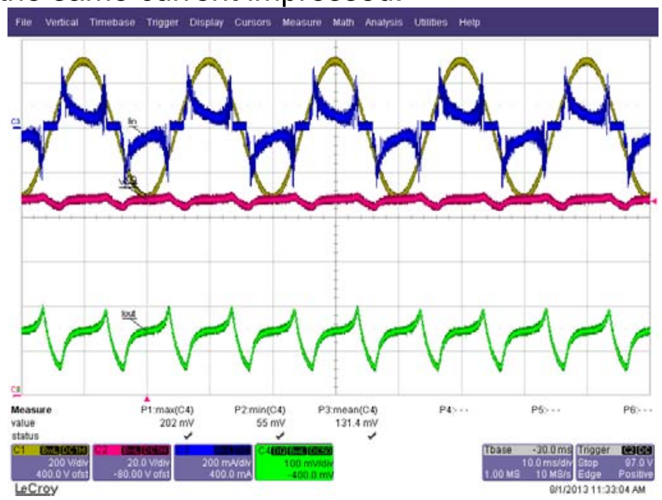

Figure 46 – 220 VAC / 50 Hz, Nominal V_{LED} Load.
Ch1 (Yellow):V_{IN}, 200 V / div.
Ch2 (Red):V_{OUT}, 20 V.
Ch3 (Blue):I_{IN}, 200 mA / div.
Ch4 (Green):I_{OUT}, 100 mA / div. Time Scale:10 ms / div.

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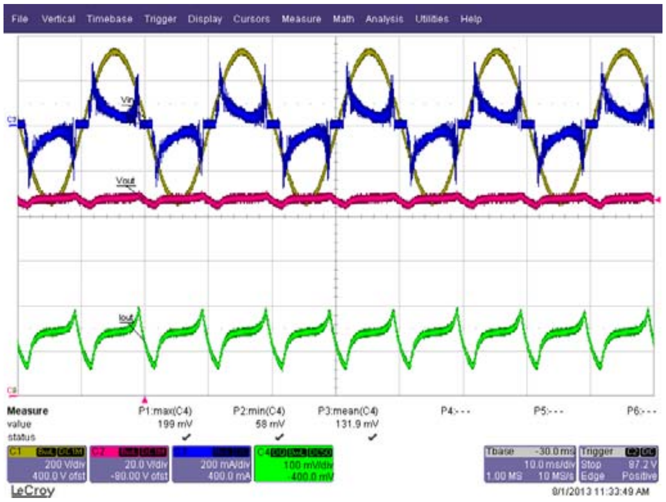

Figure 47 – 240 VAC / 50 Hz, Nominal V_{LED} Load.
Ch1 (Yellow):V_{IN}, 200 V / div.
Ch2 (Red):V_{OUT}, 20 V.
Ch3 (Blue):I_{IN}, 200 mA / div.
Ch4 (Green):I_{OUT}, 100 mA / div. Time Scale:10 ms / div.

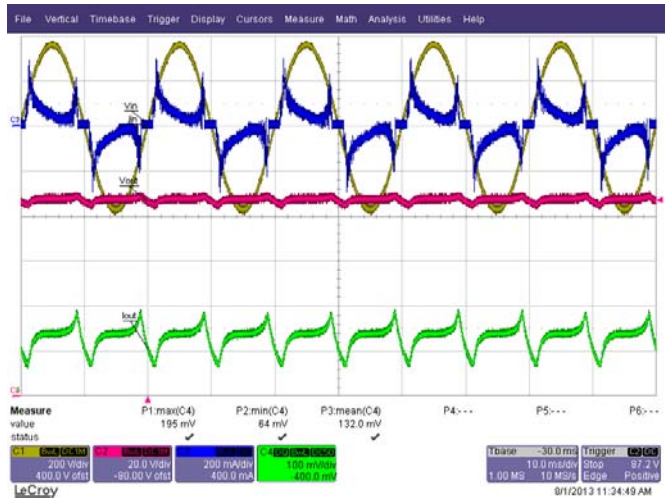

Figure 48 – 265 VAC / 50 Hz, Nominal V_{LED} Load.
Ch1 (Yellow):V_{IN}, 200 V / div.
Ch2 (Red):V_{OUT}, 20 V.
Ch3 (Blue):I_{IN}, 200 mA / div.
Ch4 (Green):I_{OUT}, 100 mA / div.
Time Scale:10 ms / div.

10.6 線電壓弛波和突波

An inherent advantage of the buck converter implemented within LYTSwitch-0 is the imperceptible start-up delay, the driver will turn-on within 100 ms as shown below.No failure of any component occurred during line fluctuation tests.

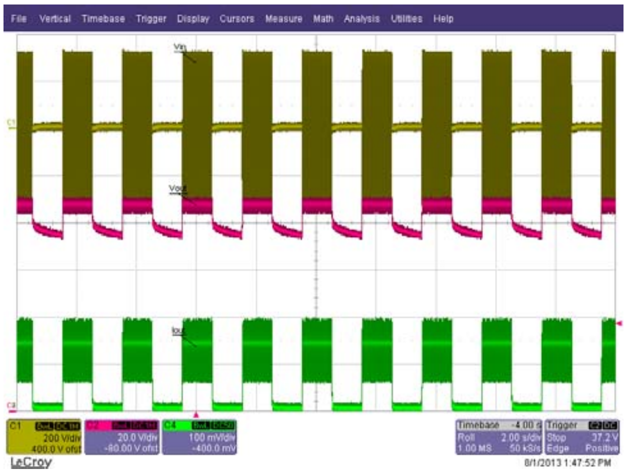

Figure 49 – Line Sag Test at 230 - 0 V at 1 s Interval.
Ch1:V_{IN}, 200 V / div.
Ch2:V_{OUT}, 20 V / div.
Ch4:I_{OUT}, 100 mA / div.
Time Scale:2 s / div.

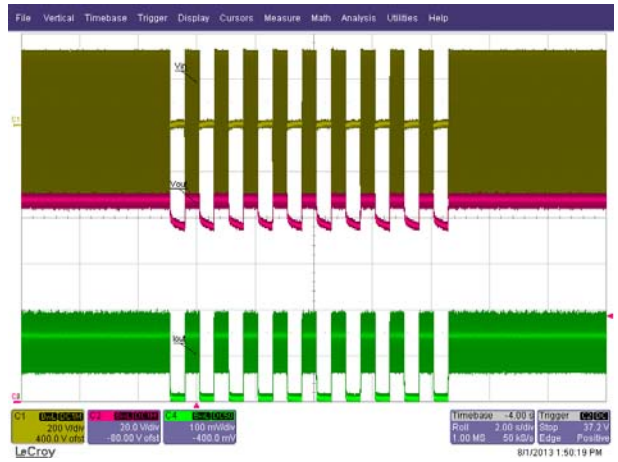

Figure 50 – Line Sag Test at 230 - 0 V at 0.5 s Interval.
Ch1:V_{IN}, 200 V / div.
Ch2:V_{OUT}, 20 V / div.
Ch4:I_{OUT}, 100 mA / div.
Time Scale:2 s / div.

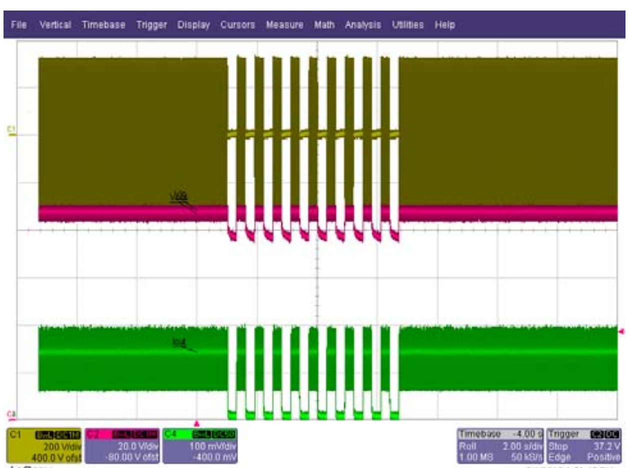

Figure 51 – Line Sag Test at 230 - 0 V at 0.3 s Interval.
Ch1:V_{IN}, 200 V / div.
Ch2:V_{OUT}, 20 V / div.
Ch4:I_{OUT}, 100 mA / div.
Time Scale:2 s / div.

Figure 52 – Line Sag Test at 230 - 0 V at 0.1 s Interval.
Ch1:V_{IN}, 200 V / div.
Ch2:V_{OUT}, 20 V / div.
Ch4:I_{OUT}, 100 mA / div.
Time Scale:2 s / div.

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10.7 單擊無負載保護

The reference design is protected with one shot no-load protection.Replace VR1 after fault.It's been observed that the SMD Zener tends to short out when it fails.Use of a SMD diode (500 mW) is recommended.

Figure 53 – No-Load Protection when Load is Disconnected.265 V / 50 Hz.Ch2:V_{IN}, 200 V / div.
Ch2:V_{OUT}, 20 V / div.
Ch3:I_{OUT}, 100 mA / div.
Time Scale:100 ms / div.

Figure 54 – No-Load Start-Up.265 V / 50 Hz.Ch2:V_{IN}, 200 V / div.
Ch2:V_{OUT}, 20 V / div.
Ch3:I_{OUT}, 100 mA / div.
Time Scale:100 ms / div.

10.8 電壓關閉/電壓啟動

No failure of any component during brown-out test of 1 V / sec and 10 V / sec AC cut-in and cut-off.

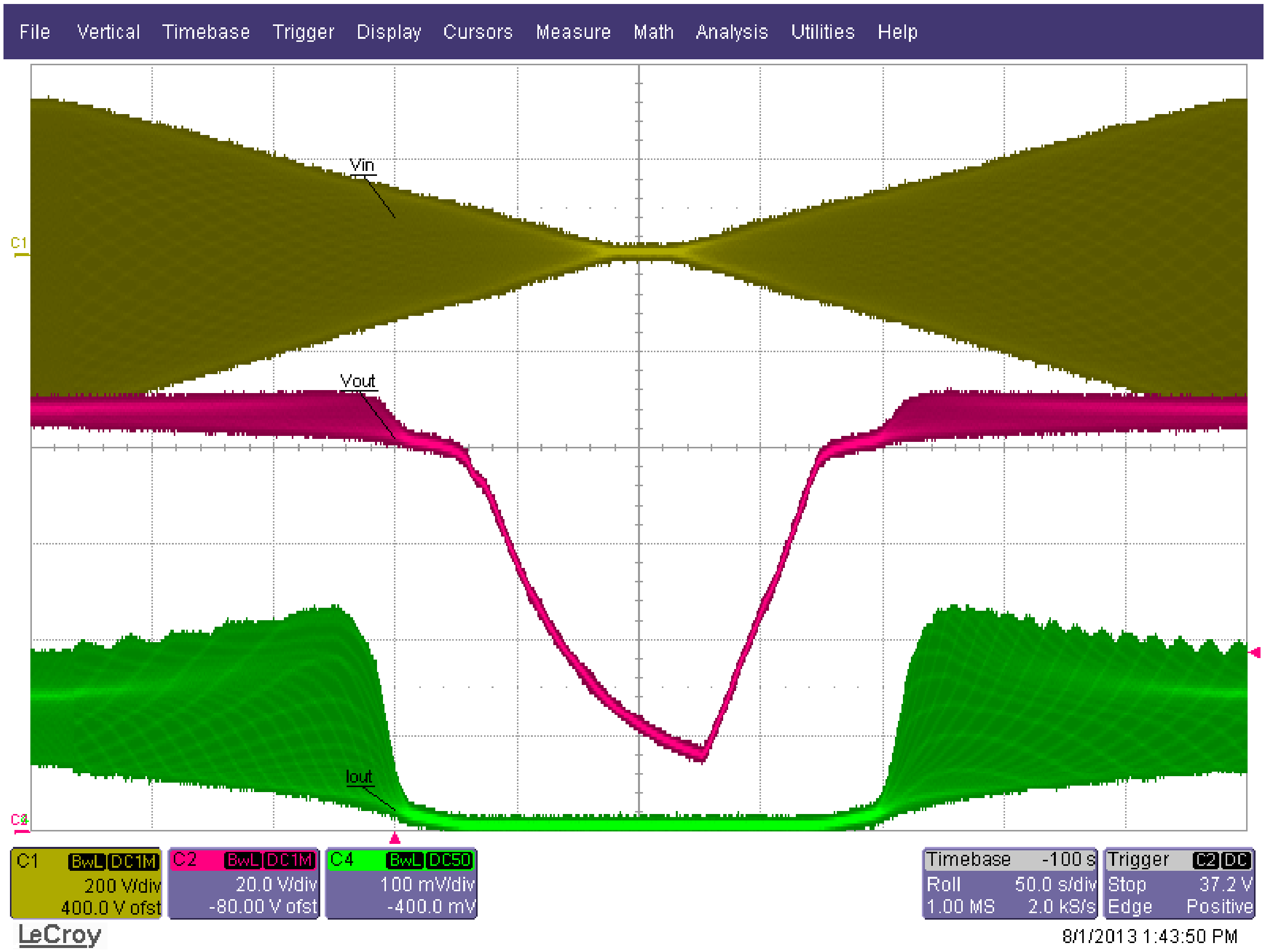

Figure 55 – Brown-out Test at 1 V / s.
The Unit is Able to Operate Normally Without Any Failure and Without Flicker.
230 V - 0 - 230 V.
Ch1:V_{IN}, 200 V / div.
Ch2:V_{OUT}, 20 V / div.
Ch3:I_{OUT}, 100 mA / div.
Time Scale:50 s / div.

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11 線電壓突波

Differential input line 1 kV / 50 μs surge testing was completed on a single test unit following the test method described in 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 (kV)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+1	230	L to N	90	Pass
-1	230	L to N	90	Pass
+1	230	L to N	270	Pass
-1	230	L to N	270	Pass
+1	230	L to N	0	Pass
-1	230	L to N	0	Pass

Unit passed under all test conditions.Tested up to 30% more voltage and no failure was observed.

Differential ring input line surge testing was completed on a single test unit following the test method described in 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.Tested up to 30% more voltage and no failure was observed.

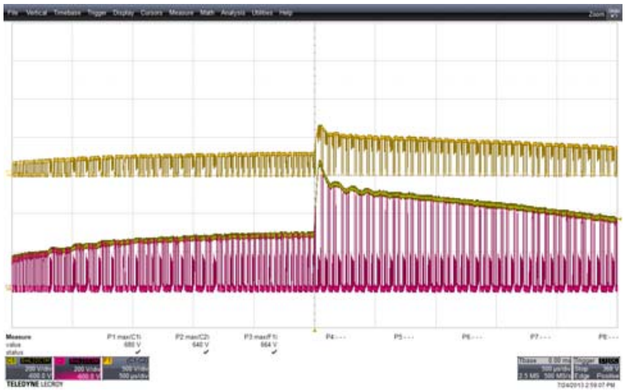

Figure 56 – Differential Line Surge at 1 kV / 90°.Peak Drain Voltage Recorded is 664 V.
Ch1:$V_{BULK\text{-}GROUND}$, 200 V / div.
Ch2:$V_{S\text{-}G}$, 200 V / div.
F1:V_{DRAIN}, 500 V / div.
Time Scale:500 µs / div.

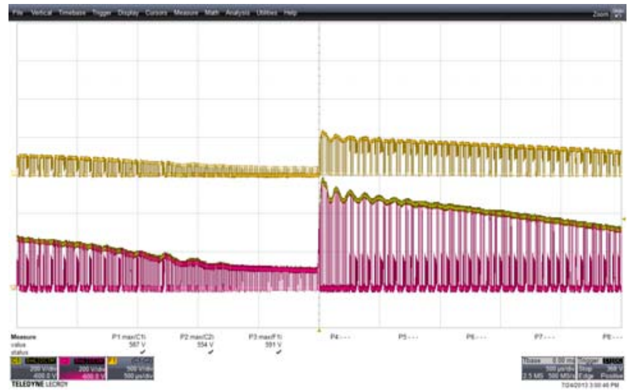

Figure 57 – Differential Line Surge at 1 kV / 0°.Peak Drain Voltage Recorded is 591 V.
Ch1:$V_{BULK\text{-}GROUND}$, 200 V / div.
Ch2:$V_{S\text{-}G}$, 200 V / div.
F1:V_{DRAIN}, 500 V / div.
Time Scale:500 µs / div.

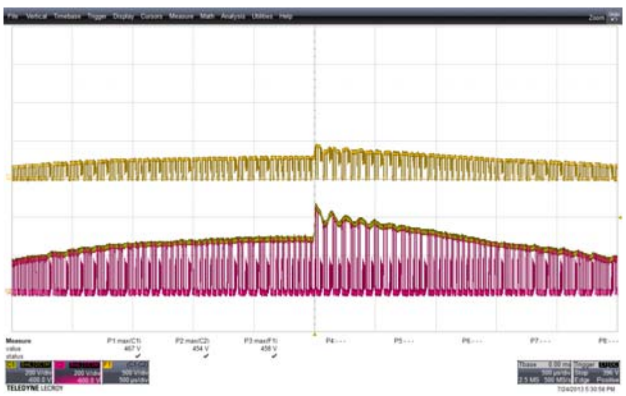

Figure 58 – Differential Ring Surge at 2500 V / 90°.Peak Drain Voltage Recorded is 458 V.
Ch1:$V_{BULK\text{-}GROUND}$, 200 V / div.
Ch2:$V_{S\text{-}G}$, 200 V / div.
F1:V_{DRAIN}, 500 V / div.
Time Scale:500 µs / div.

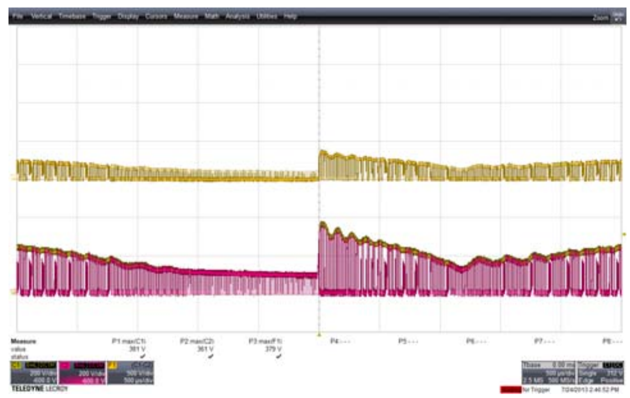

Figure 59 – Differential Ring Surge at 2500 V / 0°.Peak Drain Voltage Recorded is 380 V.
Ch1:$V_{BULK\text{-}GROUND}$, 200 V / div.
Ch2:$V_{S\text{-}G}$, 200 V / div.
F1:V_{DRAIN}, 500 V / div.
Time Scale:500 µs / div.

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12 傳導性 EMI

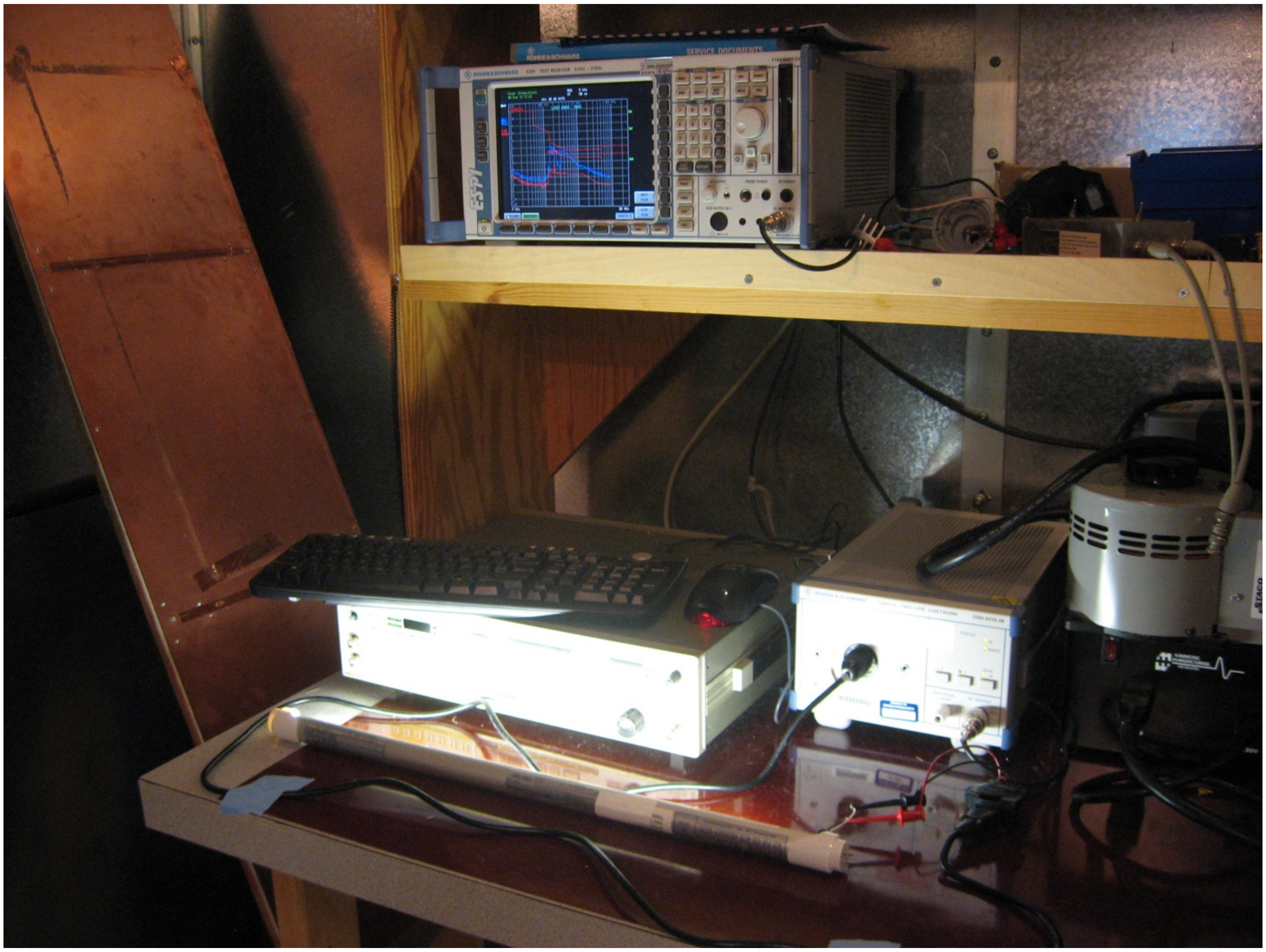

Figure 60 – The Driver was Tested in a Tube Lamp.Position the AC Inlet as Close as Possible to the End for Best EMI Performance.Let the DC Output Wire Cross the Driver.

Figure 26 – Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55015 B Limits.UUT was Fitted Inside a T8 Tube Enclosure.

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EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q

Trace2: EN55015A

Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	9.4590904509 kHz	22.77	N gnd	
2	Average	64.5467705779 kHz	11.79	N gnd	
2	Average	125.720633819 kHz	20.27	L1 gnd	
2	Average	130.825395691 kHz	21.01	N gnd	
2	Average	148.891503746 kHz	22.87	L1 gnd	
1	Quasi Peak	151.5 kHz	50.87	N gnd	-15.04
2	Average	175.886796739 kHz	34.50	L1 gnd	-20.17
2	Average	256.711570318 kHz	35.64	L1 gnd	-15.89
1	Quasi Peak	2.50634031306 MHz	37.58	N gnd	-18.41
2	Average	3.15087835298 MHz	28.85	L1 gnd	-17.15
2	Average	16.4353775277 MHz	27.83	L1 gnd	-22.16
2	Average	30 MHz	16.88	L1 gnd	-33.11

Table 3 – Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55015 B Limits.UUT was Fitted Inside a T8 Tube Enclosure.

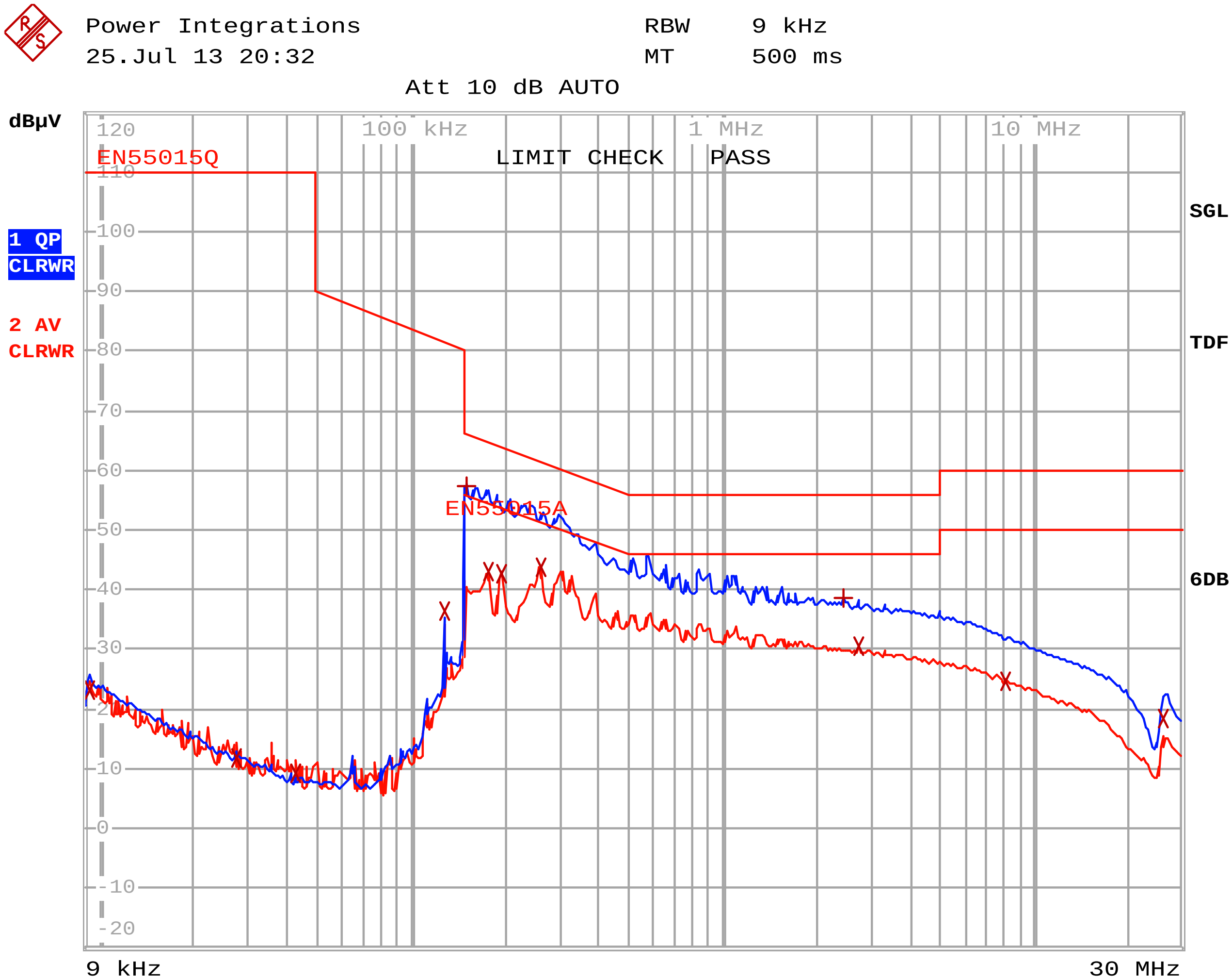

Figure 61 – Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55015 B Limits.UUT Without Enclosure.

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EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	9.1809 kHz	23.11	L1 gnd	
2	Average	27.159076558 kHz	11.76	L1 gnd	
2	Average	42.0780345374 kHz	9.26	N gnd	
2	Average	128.247618558 kHz	36.48	L1 gnd	
1	Quasi Peak	151.5 kHz	57.33	N gnd	-8.57
2	Average	175.886796739 kHz	42.89	L1 gnd	-11.78
2	Average	194.288447245 kHz	42.76	L1 gnd	-11.08
2	Average	259.278686021 kHz	43.74	L1 gnd	-7.70
1	Quasi Peak	2.45695550736 MHz	38.72	L1 gnd	-17.27
2	Average	2.71400741459 MHz	30.37	L1 gnd	-15.62
2	Average	8.10890375706 MHz	24.58	L1 gnd	-25.41
2	Average	26.2351923234 MHz	18.47	N gnd	-31.52

Table 4 – Conducted EMI, Maximum Steady State Load, 230 VAC, 60 Hz, and EN55015 B Limits.UUT without Enclosure.

13 修訂記錄

日期	作者	修訂	Description & changes	Reviewed
08-Oct-13	JDC	1.0	Initial Release	Apps & Mktg

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