設計範例報告

標題	***使用 LYTSwitch™-4 LYT4317E 的 20 W 隔離返馳式、可調光雙向閘流器 (TRIAC)、功率因數修正 (大於 0.98) LED 驅動器***
規格	90 VAC ～ 132 VAC 輸入；36 V、550 mA 輸出
應用	PAR38 LED 驅動器
作者	應用工程部門
文件編號	DER-350
日期	2013 年 5 月 20 日
修訂	2.1

<u>**摘要與功能**</u>

- 於 120 VAC 時可達 85% 以上的高效率
- 廣泛的調光器相容性 (在 NEMA SSL6 調光曲線內)，適用於各種以美國 TRIAC 為基礎的調光器
- 強化使用者體驗
  - 無閃爍、單向調光，
  - 快速單向啓動 (小於 200 ms) – 無可感延遲
- 調光時光源穩定或低導通角低成本
  - Single-stage 結合 PFC 與精準的一次側調節定電流 (CC) 輸出
  - 單面 PCB，所需元件極少
- 整合式保護與可靠性功能
  - 使用自動恢復功能以保護輸出開路/輸出短路
  - 快速線電壓輸入過壓關機，增強了線路故障時的耐壓程度
    - 無須 MOV，依然可承受 ±2500 V 的振盪波和 ±500 V 的差模突波
  - 透過高磁滯溫度提供自動恢復過溫保護功能，同時保護元件與印刷電路板

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- 符合 IEC 61000-4-5 振盪波、IEC 61000-3-2 C THD 和 IEC CISPR 15 / EN55015 B 傳導性 EMI 標準

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目錄

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重要事項：雖然此電路板的設計滿足安全隔離需求，但其工程原型未經相關機構核准。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。

1 簡介

本文件說明隔離式高功率因數 (PF) 且雙向閘流器 (TRIAC) 調光的 LED 驅動器，其設計爲輸入電壓範圍爲 90 VAC 至 132 VAC 時，用於驅動 36 V (典型值 550 mA) 的標準 LED 串電壓。此 LED 驅動器採用 LYTSwitch-4 IC 系列中的 LYT4317E。

所使用的架構是 Single-stage 功率因數修正返馳式轉換器，用於實現高絕緣效率、高功率因數、低 THD，以及低元件數。

高功率因數和低 THD 是透過採用 LYTSwitch-4 IC 來達成，此裝置也提供眾多精密的保護功能，包括開路控制迴路與輸出短路狀況的自動重新啓動。線電壓過壓可提高對線路故障與突波的承受度，而精確的磁滯回復過溫保護功能可確保 PCB 在各種狀況下皆可保持在安全的平均溫度。

本文件包含 LED 驅動器規格、電路圖、PCB 圖、物料清單、變壓器文件及典型效能特性。

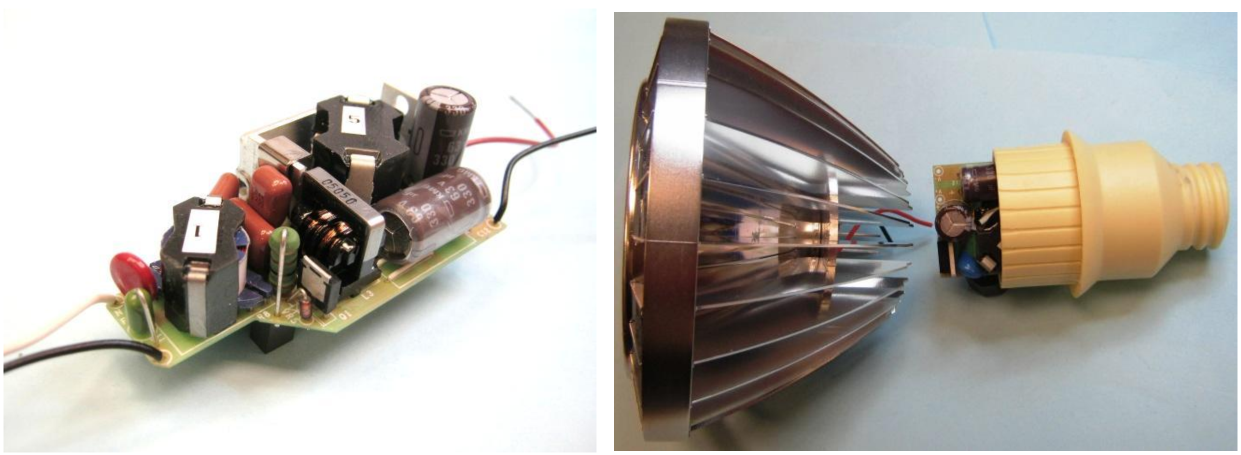

Figure 1 – Populated Circuit Board Photograph (Left) and Placed Inside a CREE PAR38 Lamp (Right).

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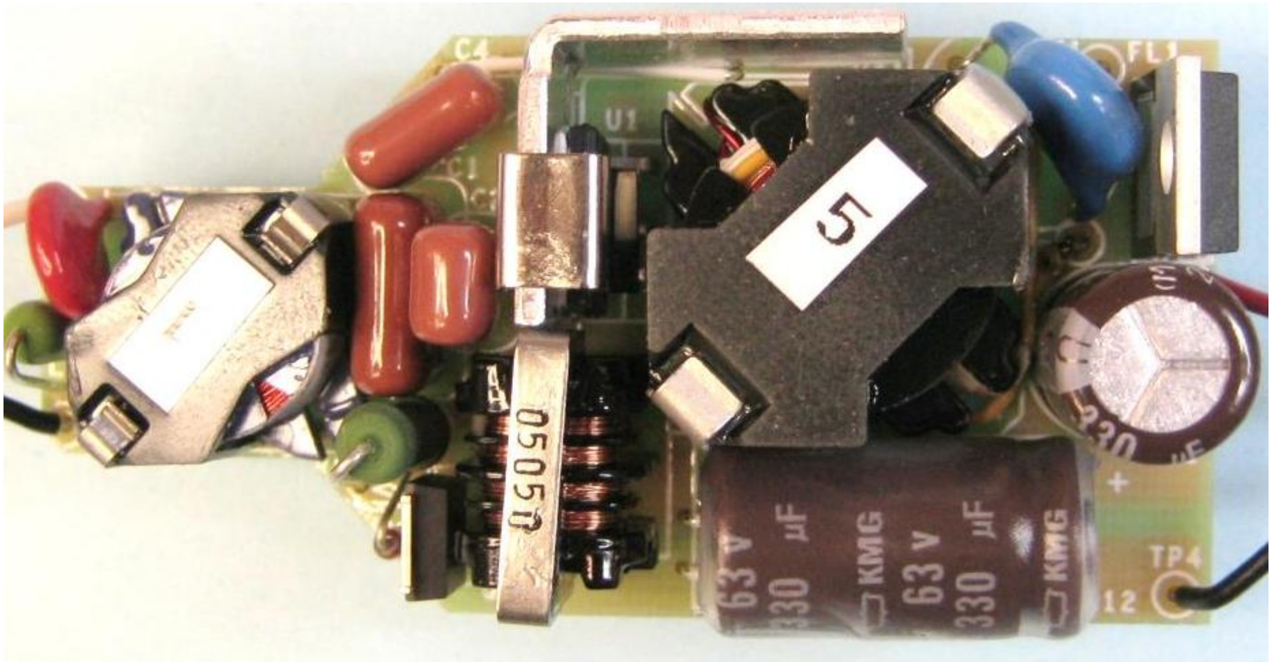

Figure 2 – Populated Circuit Board Photograph (Top View).

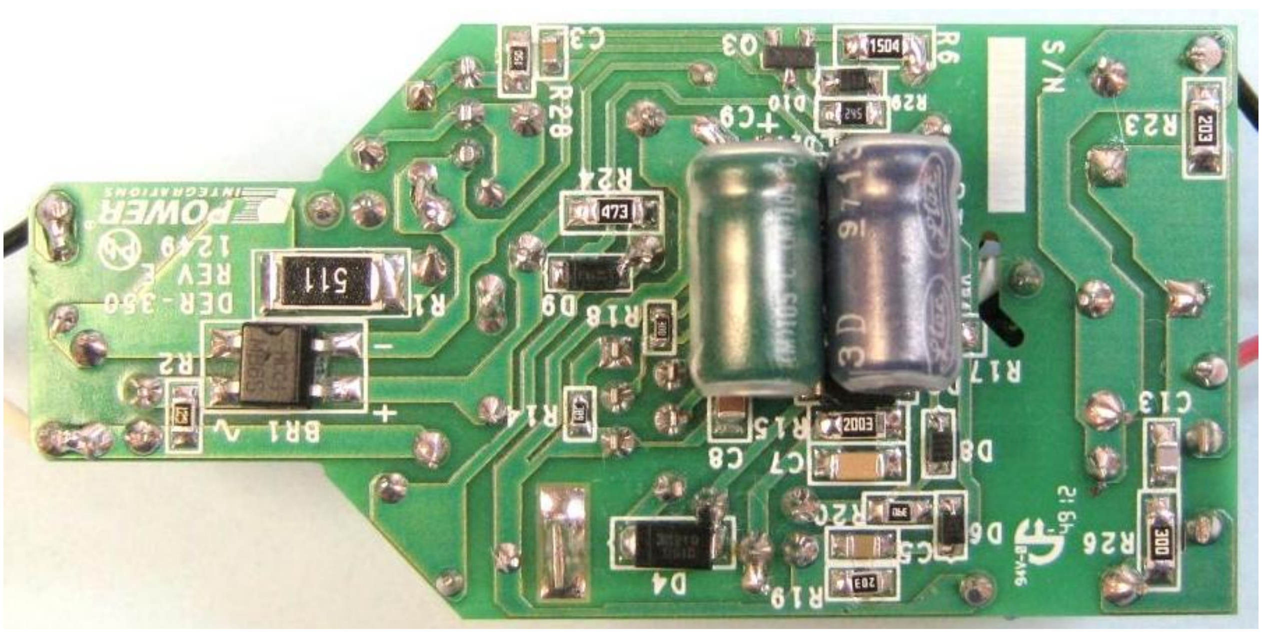

Figure 3 – Populated Circuit Board Photograph (Bottom View).

2 電源供應器規格

下表列出可接受此設計的最低效能。實際效能列在結果部分。

說明	符號	最小值	類型	最大值	單位	註解
輸入						
電壓	V_{IN}	90	120	132	VAC	
頻率	f_{LINE}		60		Hz	
輸出						
輸出電壓	V_{OUT}	33	36	39	V	
輸出電流	I_{OUT}		550		mA	
總輸出功率						
連續輸出功率	P_{OUT}		20		W	
效率						
滿載	η		85		%	V_{OUT} = 36, V_{IN} = 120 VAC，環境溫度爲 25 °C
環境						
傳導性 EMI		CISPR 15B / EN55015B				
安全		隔離式				
振盪波 (100 kHz)						
差模 (L1-L2)			2.5		kV	
共模 (L1/L2-PE)						
差動突波 (1.2 / 50 μs)			500		V	
功率因數			0.97			於 $V_{OUT(TYP)}$、$I_{OUT(TYP)}$ 及 120 VAC、60 Hz 條件下測量
諧波電流		EN 61000-3-2 D 級 (C)				C 級規範 P_{IN} 小於 25 W 時的 D 級限值
環境溫度	T_{AMB}		45		°C	自然對流，海平面

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3 電路圖

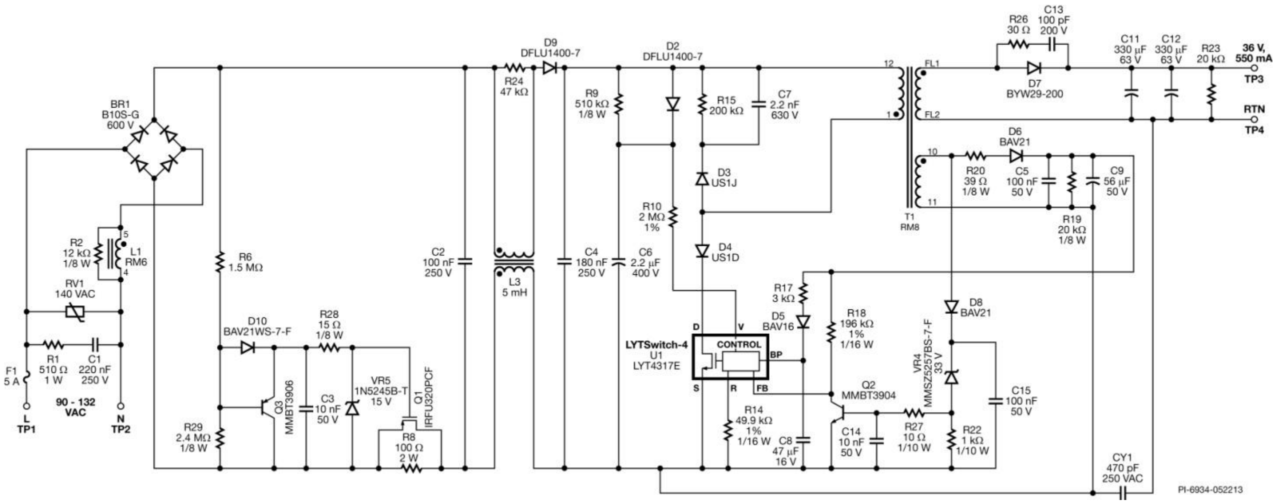

Figure 4 – Schematic.

4 電路說明

LYTSwitch-4 裝置是採用整合式 650 V 功率 MOSFET的控制器，適用於 LED 驅動器。LYTSwitch-4 設定用於Single-stage 返馳式架構，具備調整好的一次側定電流輸出，同時保持 AC 輸入端的高功率因數。

4.1 輸入濾波功能

保險絲 F1 可防止元件發生故障。為防止線電壓高壓 (1.2 µs / 50 µs) 突波，已選用極高的電流額定值。LYTSwitch-4 的快斷型線電壓過壓偵測加上搭配使用 D2 和 C6 峰值偵測器電容器，可提供箝位以限制 IC 的整合式功率 MOSFET 上的最大電壓應力。為了要大於 500 V 線差動電壓突波，使用選用 MOV (金屬氧化物可變電阻) RV1。選取 140 VAC 額定部分，其稍微高於指定的最大工作電壓 132 VAC。橋式整流器 BR1 可利用電容器 C4 對 AC 線電壓進行整流，來為一次側切換電流提供低阻抗路徑 (去耦合)。

EMI 濾波由電感器 L1，以及電容器 C2、C4 和 CY1 提供。L2 和 L3 上的電阻器 R2 和 R24 會分別抑制因濾波元件和 AC 線電壓阻抗而產生的 LC 任何 LC 諧振，否則會導致傳導性 EMI 測量增加。

4.2 LYTSwitch-4 一次側

變壓器 (T1) 的一端會連接到 DC 匯流排，而另一端會透過阻隔二極體 D4 連接到 LYTSwitch-4 裝置的汲極 (D) 接腳。電流會在功率 MOSFET 開啓期間逐漸增加一次側儲存能量，然後在功率 MOSFET 關閉期間傳輸至輸出。

為了提供峰值線電壓資訊給 U1，輸入整流 AC 峰值電壓會透過 D2 為 C6 充電。然後該電壓將以透過 R10 的電流形式饋送至 U1 的電壓監測器 (V) 接腳。電阻器 R9 為 C6 提供放電路徑，時間常數遠大於整流 AC 的時間常數，防止以線電壓頻率調變 V 接腳電流 (其會使功率因數降低)。

線電壓過壓關機功能可讓整流線電壓的承受度 (在突波和線電壓上升期間) 提高至內部功率 MOSFET 的 650 BV_{DSS} 額定值。

在內部使用 V 接腳電流和回授 (FB) 接腳電流，以控制平均輸出 LED 電流。對於相位角調光應用，在參考接腳 (R14) 上使用了 49.9 kΩ 電阻器，同時在 V 接腳上使用 2 MΩ (R10) 電阻，以便使輸入電壓和輸出電流之間形成線性關係。這可在與 TRIAC 調光器搭配使用時，使調光範圍最大。

在功率 MOSFET 關閉期間，由於漏電感的影響，D3、R15 及 C7 會將汲極電壓箝制在安全等級。需要使用二極體 D4，才能在 C4 上的電壓 (整流 AC 輸入) 低於輸出反射電壓 (設計試算表中的參數 V_{OR}) 時防止反向電流流經 U1。

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D6、C5、C9、R20 和 R19 會從變壓器上的輔助繞組產生 U1 的一次側偏壓供電。電阻器 R20 提供濾波功能，以讓偏壓電壓可密切追蹤輸出電壓，以便 LED 電壓變更時維持恆定的輸出電流。電阻器 R19 會在輸出短路情況下將 C9 放電。

電容器 C8 會爲 U1 的旁路 (BP) 接腳 (內部控制器的供電接腳) 提供本機去耦合。在啓動期間，會從 D 接腳連接的內部高電壓電流源將 C8 充電至約 6 V。完成充電之後，U1 就可以透過 R17 ，在偏壓供電元件提供工作電流時啓動切換。

建議使用外部偏壓供電 (透過 D5 和 R17) 以提供最低的裝置消耗功率，並在深度調光情況下，充分供電給 U1。

電容器 C8 也可選取輸出功率模式，選取 47 μF (降低的功率模式) 可讓裝置的消耗功率與散熱需求降至最低。

4.3 回授

使用偏壓繞組電壓可間接感測輸出電壓，而不再需要二次側回授元件。偏壓繞組電壓與輸出電壓成正比 (由偏壓繞組和二次側繞組之間的圈數比設定)。電阻器 R18 會將偏壓電壓轉換成電流，再將該電流饋送至 U1 的 FB 接腳。U1 的內部引擎會結合 FB 接腳電流、V 接腳電流及內部汲極電流資訊，以便提供恆定的輸出電流，同時維持高輸入功率因數。

4.4 負載中斷保護

在開路負載 (斷開) 故障情況下，積納二極體 VR4 將會在電晶體 Q2 上執行啓動。電晶體 Q2 接著會降低 FB 接腳，以強制 IC 進入自動重新啓動模式。在緩啓動期間後，一旦 FB 接腳電流降至低於 $I_{FB(AR)}$ 臨界值，控制器便會顯示出短路以及開迴路的情況。爲了在出現此類故障時將功率消耗降至最低，關機/自動重新啓動電路會開啓電源供應器 (與緩啓動期間相同) 並於自動啓動工作週期時關閉電源供應器，直到故障情況消失。如果在自動重新啓動的關閉時間內排除了故障，電源供應器將保持自動重新啓動模式，直到整個關閉期間結束爲止。

4.5 輸出整流

變壓器二次側繞組由 D7 進行整流，由電容器 C11 和 C12 進行濾波。對於需要更低漣波的設計，可以增大輸出電容值。

4.6 TRIAC 相位調光控制相容性

爲了提供低成本的輸出調光功能，採用 TRIAC 的上升邊緣相位調光器在設計時有許多取捨。

由於 LED 照明所消耗的功率小得多，因此燈具所汲取的電流會低於調光器內 TRIAC 的吸持電流。這會引起不良狀況，例如燈具在調光器控制範圍結束之前關閉及/或在 TRIAC 啓動時不一致地閃爍。開啓 TRIAC 時，LED 燈相對較大的阻抗會因對輸入電容充電的浪湧電流而導致大幅振盪。這同樣會引起不良狀況，因爲振盪可能導致 TRIAC 電流降至零。

爲了克服這些問題，加入了被動洩放器電路。這些電路的缺點是會增大功耗，進而降低電源供應器的效率。對於非調光應用，省略這些元件即可。

主動阻尼器包含元件 R6、R28、R29、D10、Q1、Q3、C3、VR5 以及搭配使用 R8。此電路透過串聯電阻器 R8，可在 TRIAC 開啓時，於導通期間約 0.5 ms 內限制對輸入電容器 C2 與 C4 充電的浪湧電流。約 0.5 ms 後，電晶體 Q1 會開啓，從而使電阻器 R8 短路。這樣可保持 R8 功耗較低，並允許電流限制期間使用較大的值。電阻 R6、R29 和電容器 C3 會在 TRIAC 導通後提供 0.5 ms 延遲時間。TRIAC 未導通時，電晶體 Q3 會將 C3 放電，VR5 將 Q1 的閘極電壓箝制在 15 V，而 R28 則同時防止 MOSFET 振盪。

被動洩放器電路由 C1 和 R1 構成。此電路可在每個 AC 半週期內驅動器的輸入電流增大時，保持輸入電流高於 TRIAC 的保持電流(holding current)，防止 TRIAC 切換在每個導通角期間開始 (和結束) 時震盪。

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5 PCB 布局

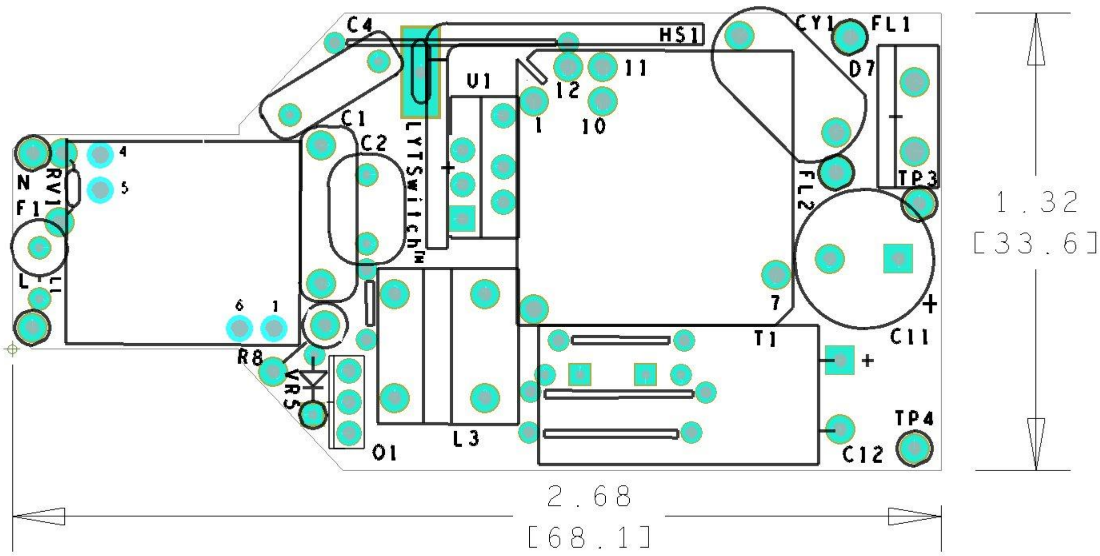

Figure 5 – Top Side.

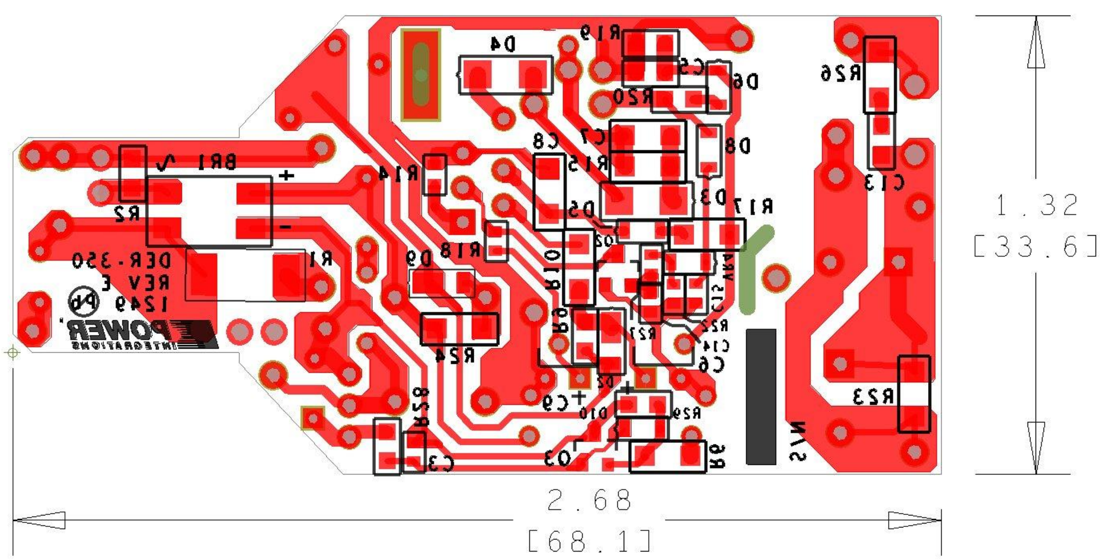

Figure 6 – Bottom Side.

6 物料清單

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	1	C1	220 nF, 250 V, Film	ECQ-E2224KF	Panasonic
3	1	C2	100 nF, 250 V, Film	ECQ-E2104KB	Panasonic
4	2	C3 C14	10 nF 50 V, Ceramic, X7R, 0603	C0603C103K5RACTU	Kemet
5	1	C4	180 nF, 250 V, Film	ECQ-E2184KB	Panasonic
6	1	C5	100 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB104	Yageo
7	1	C6	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
8	1	C7	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K	TDK
9	1	C8	47 μF, 16 V, X5R, 1206	3216X5R1C476M	TDK
10	1	C9	56 μF, 50 V, Electrolytic, Very Low ESR, 140 mΩ, (6.3 x 11)	EKZE500ELL560MF11D	Nippon Chemi-Con
11	2	C11 C12	330 μF, 63 V, Electrolytic, (10 x 20)	EKMG630ELL331MJ20S	United Chemi-con
12	1	C13	100 pF, 200 V, Ceramic, COG, 0805	08052A101JAT2A	AVX
13	1	C15	100 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H104K	TDK
14	1	CY1	470 pF, 250 VAC, Film, X1Y1	CD95-B2GA471KYNS	TDK
15	2	D2 D9	400 V, 1 A, DIODE SUP FAST 1 A PWRDI 123	DFLU1400-7	Diodes, Inc.
16	1	D3	DIODE ULTRA FAST, SW 600 V, 1 A, SMA	US1J-13-F	Diodes, Inc.
17	1	D4	DIODE ULTRA FAST, SW, 200 V, 1 A, SMA	US1D-13-F	Diodes, Inc.
18	1	D5	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diodes, Inc.
19	3	D6 D8 D10	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
20	1	D7	200 V, 8 A, Ultrafast Recovery, 25 ns, TO-220AC	BYW29-200G	On Semi
21	1	F1	7 5 A, 250 V, Fast, Microfuse, Axial	0263005.MXL	Littlefuse
22	1	L1	Bobbin, RM6, Vertical, 6 pins Inductor	B65808-N1006-D1 SNX-R1684	Epcos Santronics-USA
23	1	L3	5 mH, 0.5 A, Common Mode Choke Vertical	SU9VF-05050	Tokin
24	1	Q1	400 V, 3.1 A, N-Channel, TO-251AA	IRFU320PBF	Vishay/Siliconix
25	1	Q2	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semi
26	1	Q3	PNP, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3906LT1G	On Semi
27	1	R1	510 Ω, 5%, 1 W, Thick Film, 2512	ERJ-1TYJ511U	Panasonic
28	1	R2	12 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ123V	Panasonic
29	1	R6	1.5 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ155V	Panasonic
30	1	R8	100 Ω, 5%, 2 W, Metal Oxide	RSMF2JT100R	Stackpole
31	1	R9	510 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ514V	Panasonic
32	1	R10	2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
33	1	R14	49.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF4992V	Panasonic
34	1	R15	200 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ204V	Panasonic
35	1	R17	3 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ302V	Panasonic
36	1	R18	196 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1963V	Panasonic
37	1	R19	20 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ203V	Panasonic
38	1	R20	39 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ390V	Panasonic
39	1	R22	1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
40	1	R23	20 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ203V	Panasonic

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41	1	R24	47 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ473V	Panasonic
42	1	R26	30 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ300V	Panasonic
43	1	R27	10 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ100V	Panasonic
44	1	R28	15 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ150V	Panasonic
45	1	R29	2.4 MΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ245V	Panasonic
46	1	RV1	140 V, 12 J, 7 mm, RADIAL	V140LA2P	Littlefuse
47	1	T1	Bobbin, RM8, Vertical, 12 pins Transformer	RM8/12/1 SNX-R1670	Schwartzpunkt Santronics-USA
48	1	U1	LYTSwitch-4, eSIP-7C	LYT4317E	Power Integrations
49	1	VR4	33 V, 5%, 200 mW, SOD-323	MMSZ5257BS-7-F	Diodes, Inc.
50	1	VR5	15 V, 5%, 500 mW, DO-35	1N5245B-T	Diodes, Inc.

7 變壓器規格

7.1 電氣圖

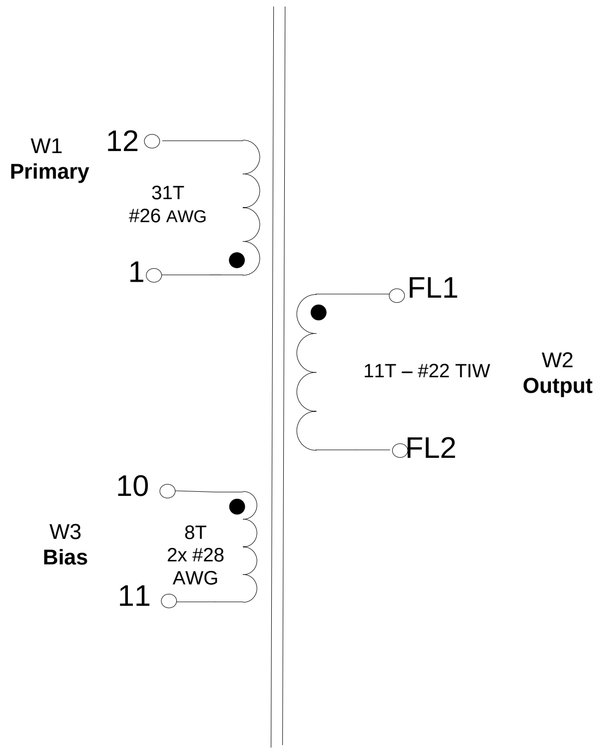

Figure 7 – Transformer Electrical Diagram.

7.2 電氣規格

Electrical Strength	1 second, 60 Hz, from pins 1, 10, 11, 12 to FL1, FL2.	3000 VAC
Primary Inductance	Pins 1 and 12, all other windings open, measured at 10 kHz, 0.4 V_{RMS}.	387 μH +7%
Resonant Frequency	Pins 1 -12, all other windings open.	750 kHz (Min.)
Primary Leakage Inductance	Pins 1-12, with FL1-FL2 shorted, measured at 132 kHz, 0.4 V_{RMS}.	<10 μH

7.3 物料

Item	Description
[1]	Core:RM8/I, 3F3.
[2]	Bobbin, 12 pin vertical, CSV-RM8-1S-12P from Philips or equivalent. With mounting clip, CLI/P-RM8.
[3]	Tape, Polyester film, 3M 1350F-1 or equivalent, 9 mm wide.
[4]	Wire:Magnet, #26 AWG, solderable double coated.
[5]	Wire:Magnet, #28 AWG, solderable double coated.
[6]	Wire, Triple Insulated, Furukawa TEX-E or Equivalent, #22 TIW.
[7]	Transformer Varnish, Dolph BC-359 or equivalent.

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7.4 變壓器建構圖

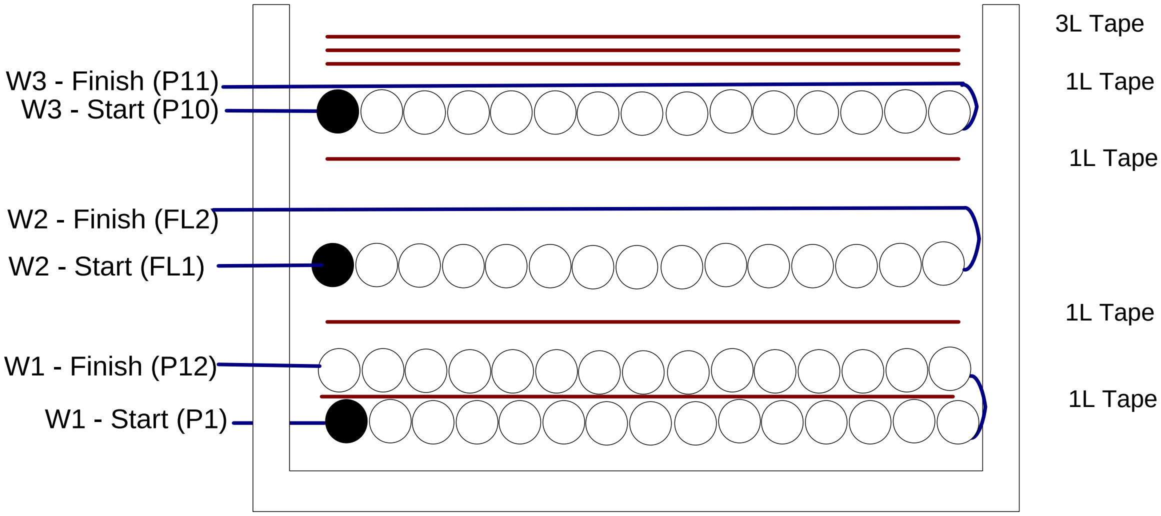

Figure 8 – Transformer Build Diagram.

7.5 變壓器結構

Bobbin Preparation	Place the bobbin item [2] on the mandrel such that pin side on the left side.Winding direction is the clockwise direction.
WDG 1 (Primary)	Starting at pin 1, wind 31 turns of wire item [4] in two layers.Apply one layer of tape item [3] between 1st and 2nd layer (spread the winding evenly).Finish at pin 12.
Insulation	Apply one layer of tape item [3].
WDG 2 (Secondary)	Leave about 1” of wire item [6], use small tape to mark as FL1, enter into slot of secondary side of bobbin, wind 11 turns in one layer.At the last turn exit the same slot, leave about 1”, and mark as FL2.
Insulation	Apply one layer of tape item [3].
WDG 3 (Bias)	Starting at pin 10, wind bifilar 8 turns of wire item [5], spreading the wire, and finish at pin 11.
Finish Wrap	Apply three layers of tape item [3] for finish wrap.
Final Assembly	Cut FL1 and FL2 to 0.75”.Grind core to get 387 μH inductance. Assemble and secure core halves.Dip impregnate using varnish item [7].

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8 變壓器設計試算表

ACDC_LYTSwitch_101712; Rev.1.0; Copyright Power Integrations 2012	INPUT	INFO	OUTPUT	UNIT	LYTSwitch_101712:Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
Dimming required	**YES**		**YES**		Select 'YES' option if dimming is required.Otherwise select 'NO'.
VACMIN			90	V	Minimum AC Input Voltage
VACMAX			132	V	Maximum AC input voltage
fL			60	Hz	AC Mains Frequency
VO	36.00		36	V	Typical output voltage of LED string at full load
VO_MAX	39.00		39.00	V	Maximum expected LED string Voltage.
VO_MIN	33.00		33.00	V	Minimum expected LED string Voltage.
V_OVP			42.90	V	Over-voltage protection setpoint
IO	0.55		0.55	A	Typical full load LED current
PO			19.8	W	Output Power
n	0.85		0.85		Estimated efficiency of operation
VB			25	V	Bias Voltage
ENTER LYTSwitch VARIABLES					
LYTSwitch	**LYT4317**		**LYT4317**		Selected LYTSwitch
Current Limit Mode	**RED**		**RED**		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			2.35	A	Minimum current limit
ILIMITMAX			2.73	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			79.8	uA	V pin current
RV			2	M-ohms	Upper V pin resistor
RV2			1E+012	M-ohms	Lower V pin resistor
IFB	133.00		133.0	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1			165.4	k-ohms	FB pin resistor
VDS			10	V	LYTSwitch on-state Drain to Source Voltage
VD			0.50	V	Output Winding Diode Forward Voltage Drop (0.5 V for Schottky and 0.8 V for PN diode)
VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
Key Design Parameters					
KP	0.97		0.97		Ripple to Peak Current Ratio (For PF > 0.9, 0.4 < KP < 0.9)
LP			389	uH	Primary Inductance
VOR	102.00		102	V	Reflected Output Voltage.
Expected IO (average)			0.55	A	Expected Average Output Current
KP_VACMAX			1.08		Expected ripple current ratio at VACMAX
TON_MIN			1.83	us	Minimum on time at maximum AC input voltage
PCLAMP			0.16	W	Estimated dissipation in primary clamp
9 ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**RM8/I**		**RM8/I**		
Bobbin		RM8/I_BOBBIN		P/N:	*
AE			0.63	cm^2	Core Effective Cross Sectional Area
LE			3.84	cm	Core Effective Path Length
AL			3000	nH/T^2	Ungapped Core Effective Inductance

BW		8.6	mm	Bobbin Physical Winding Width
M		0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	1.50	1.5		Number of Primary Layers
NS	11	11		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS				
VMIN		127	V	Peak input voltage at VACMIN
VMAX		187	V	Peak input voltage at VACMAX
CURRENT WAVEFORM SHAPE PARAMETERS				
DMAX		0.47		Minimum duty cycle at peak of VACMIN
IAVG		0.25	A	Average Primary Current
IP		1.29	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS		0.39	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS				
LP		389	uH	Primary Inductance
LP_TOL		10		Tolerance of primary inductance
NP		31		Primary Winding Number of Turns
NB		8		Bias Winding Number of Turns
ALG		412	nH/T^2	Gapped Core Effective Inductance
BM		2586	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP		3081	Gauss	Peak Flux Density (BP<3700)
BAC		1254	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur		1455		Relative Permeability of Ungapped Core
LG		0.17	mm	Gap Length (Lg > 0.1 mm)
BWE		12.9	mm	Effective Bobbin Width
OD		0.42	mm	Maximum Primary Wire Diameter including insulation
INS		0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA		0.36	mm	Bare conductor diameter
AWG		28	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM		161	Cmils	Bare conductor effective area in circular mils
CMA		416	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 600)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)				
Lumped parameters				
ISP		3.59	A	Peak Secondary Current
ISRMS		1.07	A	Secondary RMS Current
IRIPPLE		0.92	A	Output Capacitor RMS Ripple Current
CMS		214	Cmils	Secondary Bare Conductor minimum circular mils
AWGS		26	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS		0.41	mm	Secondary Minimum Bare Conductor Diameter
ODS		0.78	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
VOLTAGE STRESS PARAMETERS				
VDRAIN		394	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance)
PIVS		110	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)

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PIVB	77	V	Bias Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
FINE TUNING (Enter measured values from prototype)			
V pin Resistor Fine Tuning			
RV1	2.00	M-ohms	Upper V Pin Resistor Value
RV2	1E+012	M-ohms	Lower V Pin Resistor Value
VAC1	115.0	V	Test Input Voltage Condition1
VAC2	230.0	V	Test Input Voltage Condition2
IO_VAC1	0.55	A	Measured Output Current at VAC1
IO_VAC2	0.55	A	Measured Output Current at VAC2
RV1 (new)	2.00	M-ohms	New RV1
RV2 (new)	10455.82	M-ohms	New RV2
V_OV	161.1	V	Typical AC input voltage at which OV shutdown will be triggered
V_UV	34.5	V	Typical AC input voltage beyond which power supply can startup
FB pin resistor Fine Tuning			
RFB1	165	k-ohms	Upper FB Pin Resistor Value
RFB2	1E+012	k-ohms	Lower FB Pin Resistor Value
VB1	22.9	V	Test Bias Voltage Condition1
VB2	27.1	V	Test Bias Voltage Condition2
IO1	0.55	A	Measured Output Current at Vb1
IO2	0.55	A	Measured Output Current at Vb2
RFB1 (new)	165.4	k-ohms	New RFB1
RFB2(new)	1.00E+12	k-ohms	New RFB2

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9L1 電感器規格

9.1 電氣圖

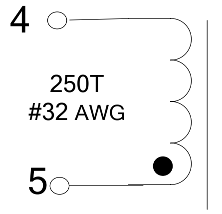

Figure 9 – Inductor Electrical Diagram.

9.2 電氣規格

Primary Inductance	Pins 4-5, all other windings open, measured at 100 kHz, 0.4 $V_{RMS.}$	2 mH ±5%
Resonant Frequency	Pins 4-5, all other windings open.	750 kHz (Min.)

9.3 物料

Item	Description
[1]	Core:RM6, TDK - PC40.ALG=32nH/n^2.
[2]	Bobbin:RM6-V 6 pins (3/3), PI#: 25-00039-00.
[3]	Clip:AllStar Magnetic, #:CLI-RM6/I; or equivalent.
[4]	Tape:Polyester film, 3M 1350F-1; or equivalent, 6.4 mm wide.
[5]	Wire:Magnet, #32 AWG, solderable double coated.
[6]	Varnish:Dolph BC-359 or equivalent.

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9.4 電感器建構圖

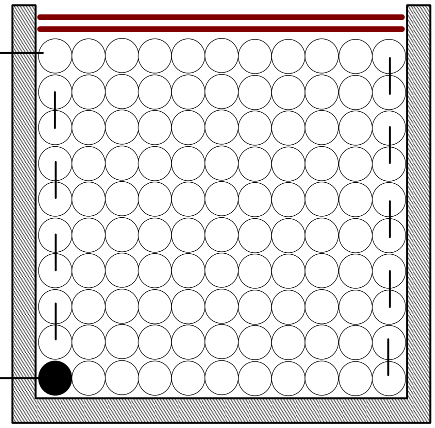

Figure 10 – Inductor Build Diagram.

9.5 電感器結構

Bobbin Preparation	Place bobbin item [2] on the mandrel such that pin side is on the left side. Winding direction is the clockwise direction. Note: pin 1 side has V notch on the top of bobbin.
Winding	Start pin 5, wind 250 turns of wire item [5] from left to right then form right to left in 10 layers, at the last turn finish at pin 4.
Finish	Apply 1 layer of tape item [4] to secure the winding. Grind both core halves to get 2.0 mH and assemble with clip item [3]. Cut pins:2 and 3. Varnish item [6].

10 U1 散熱片組裝

10.1 U1 散熱片製造圖

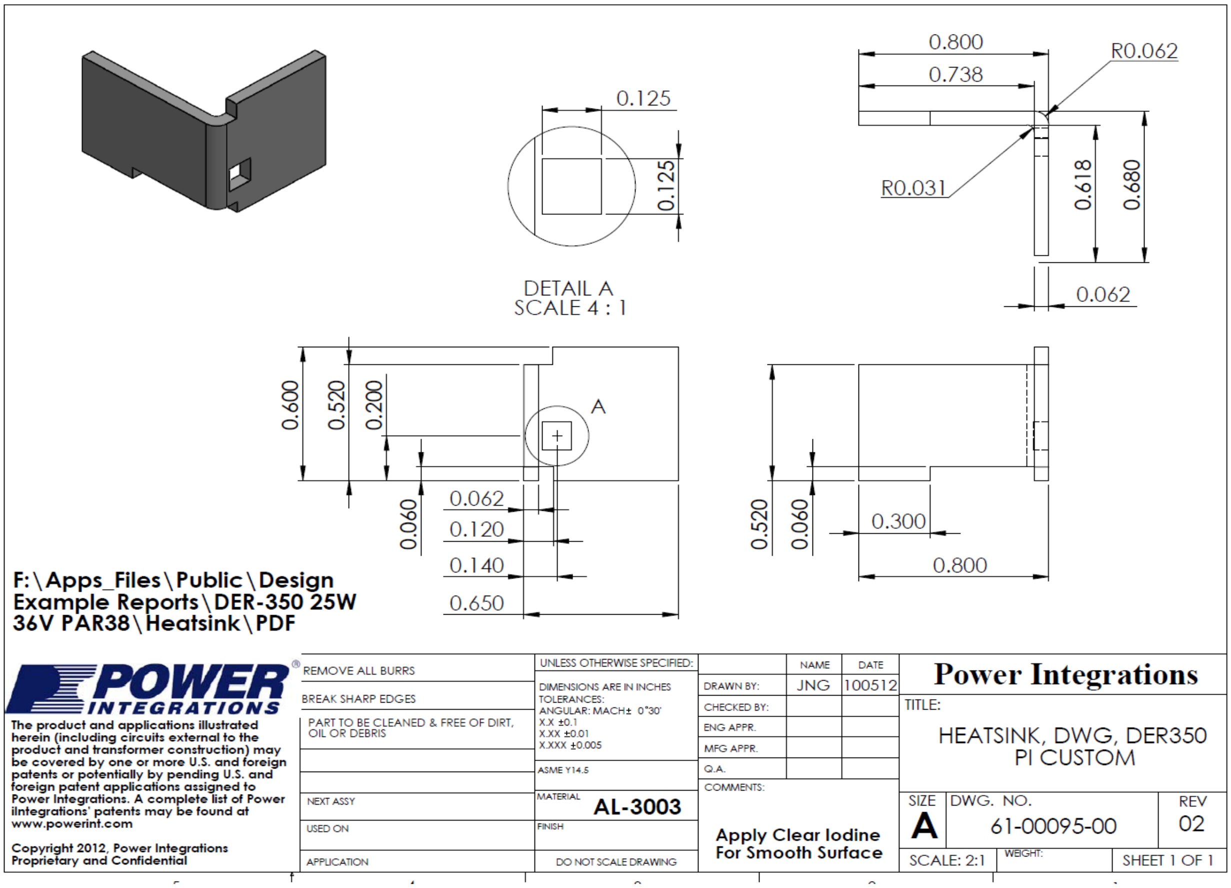

Figure 11 – Heat Sink Fabrication Drawing.

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10.2 U1 散熱片組裝圖

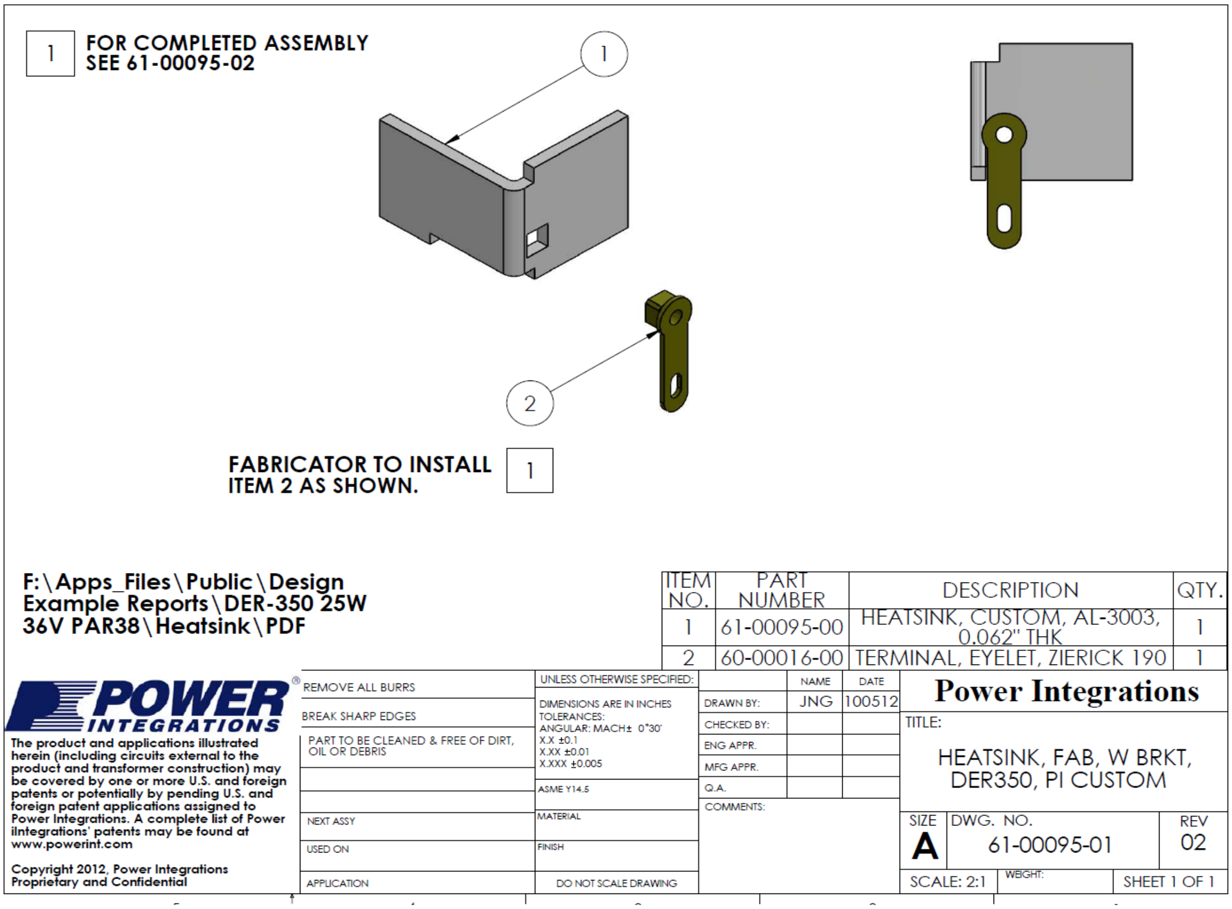

Figure 12 – U1 Heat Sink Assembly Drawing.

10.3 U1 和散熱片組裝圖

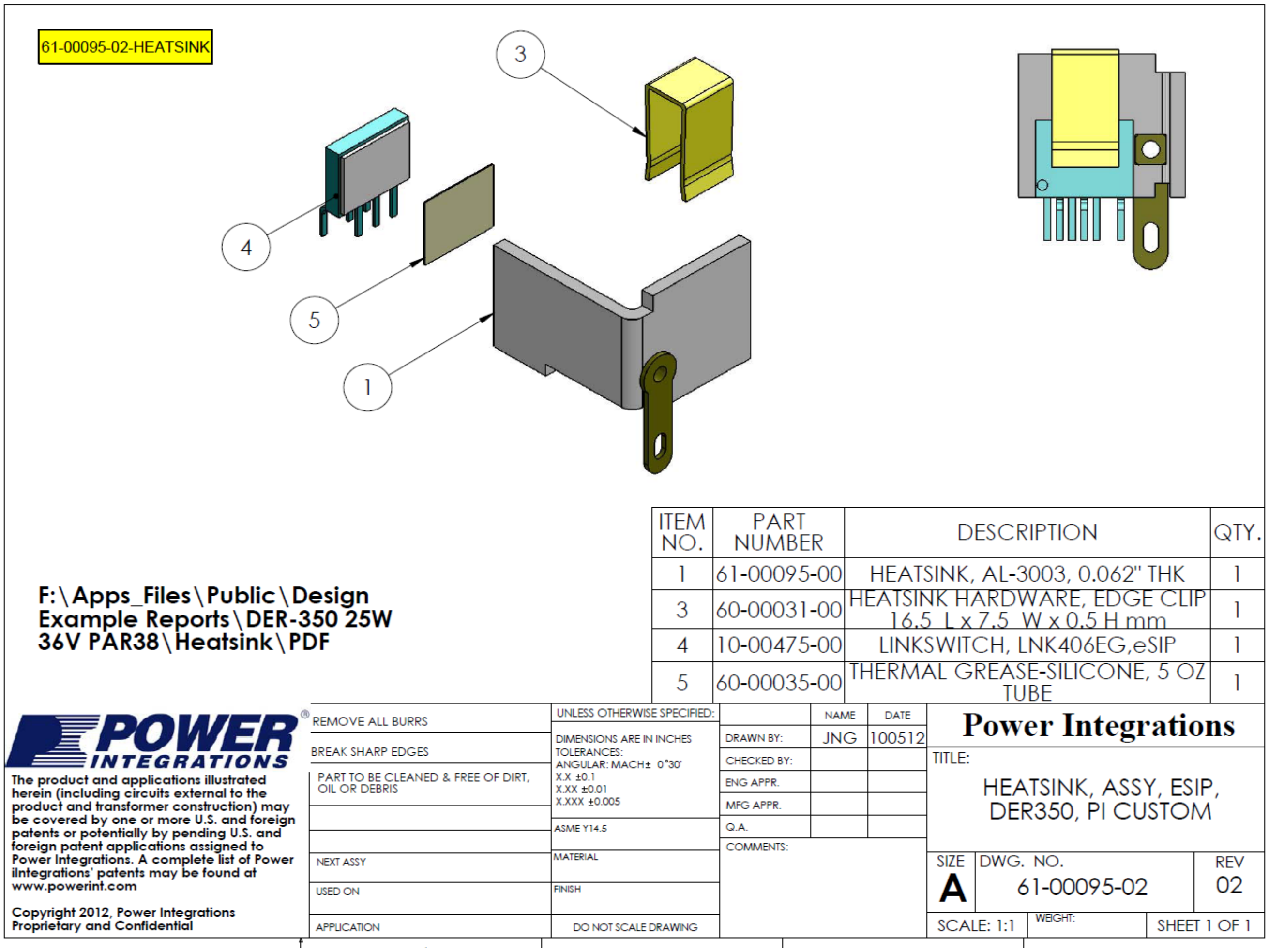

Figure 13 – U1 and Heat Sink Assembly Drawing.

11 效能資料

All measurements performed at room temperature using an LED load.The table in Section 11.6 shows complete test data values.

11.1 效率

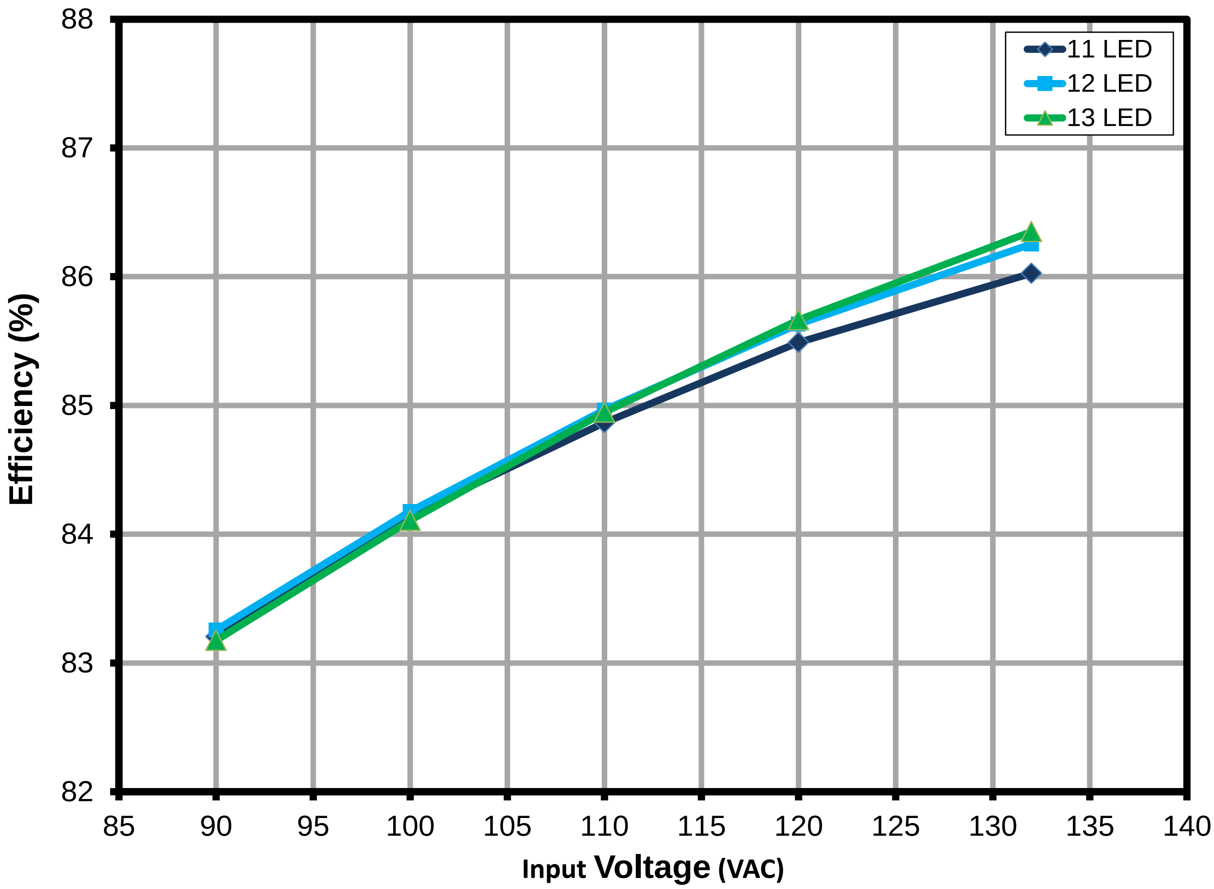

Figure 14 – Efficiency vs. Line.

11.2 線電壓與負載穩定度關係圖

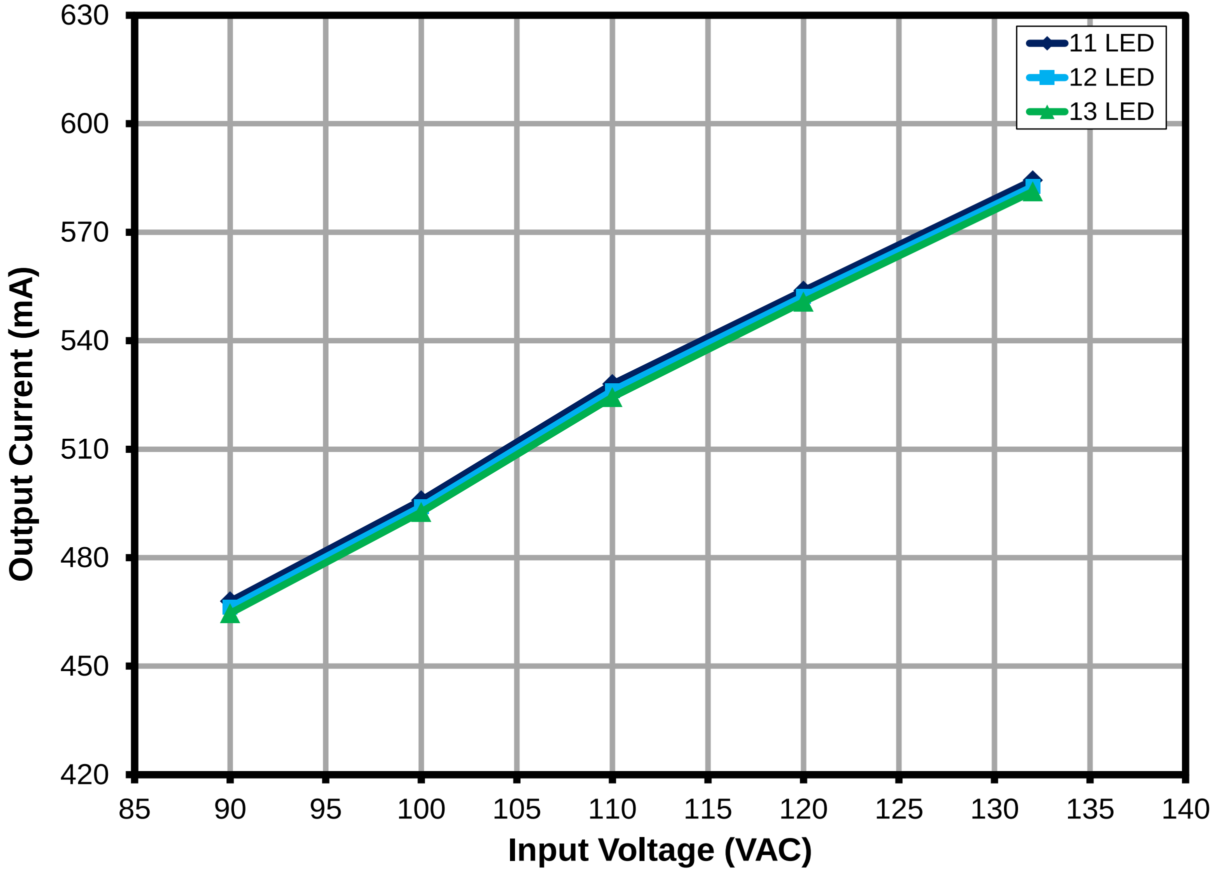

Figure 15 – Regulation vs. Line and Load.

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11.3 功率因數

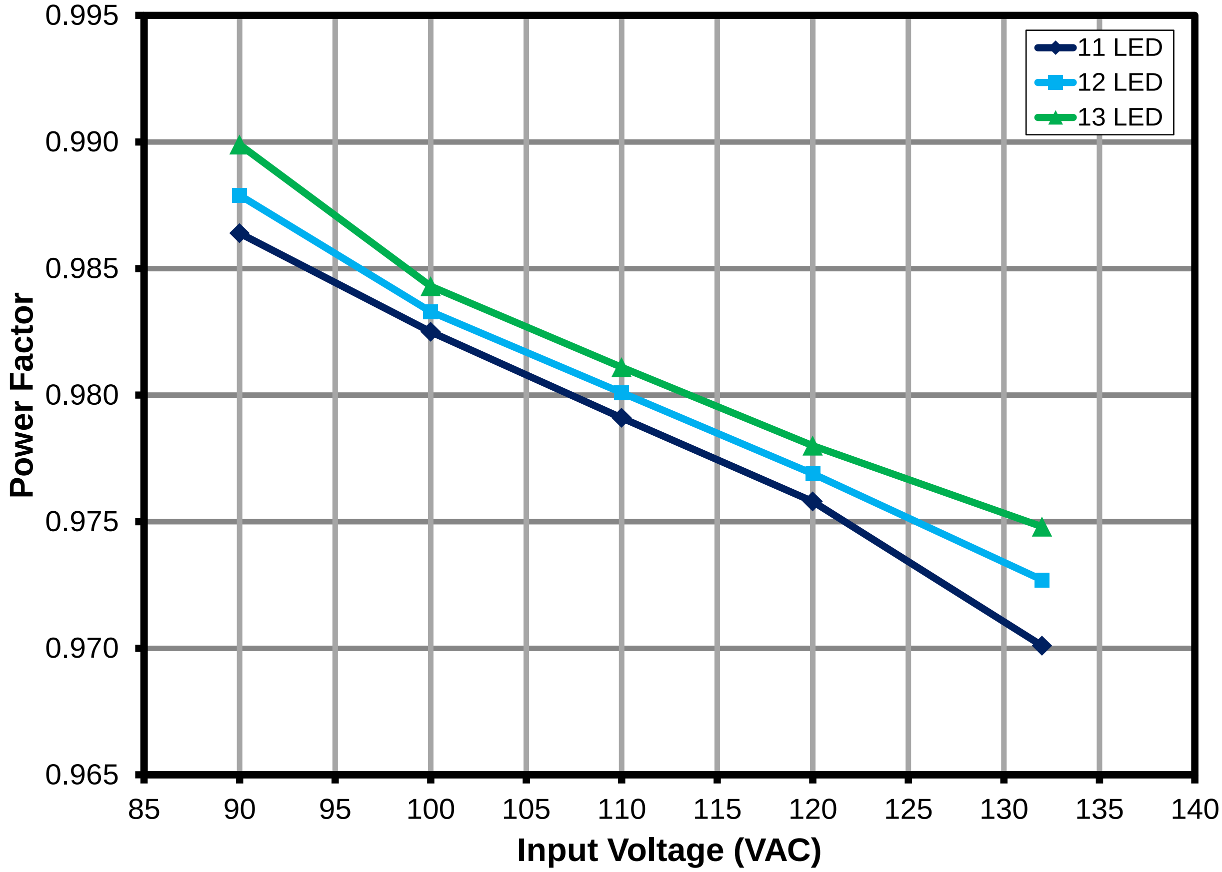

Figure 16 – Power Factor vs. Line and Load.

11.4 A-THD

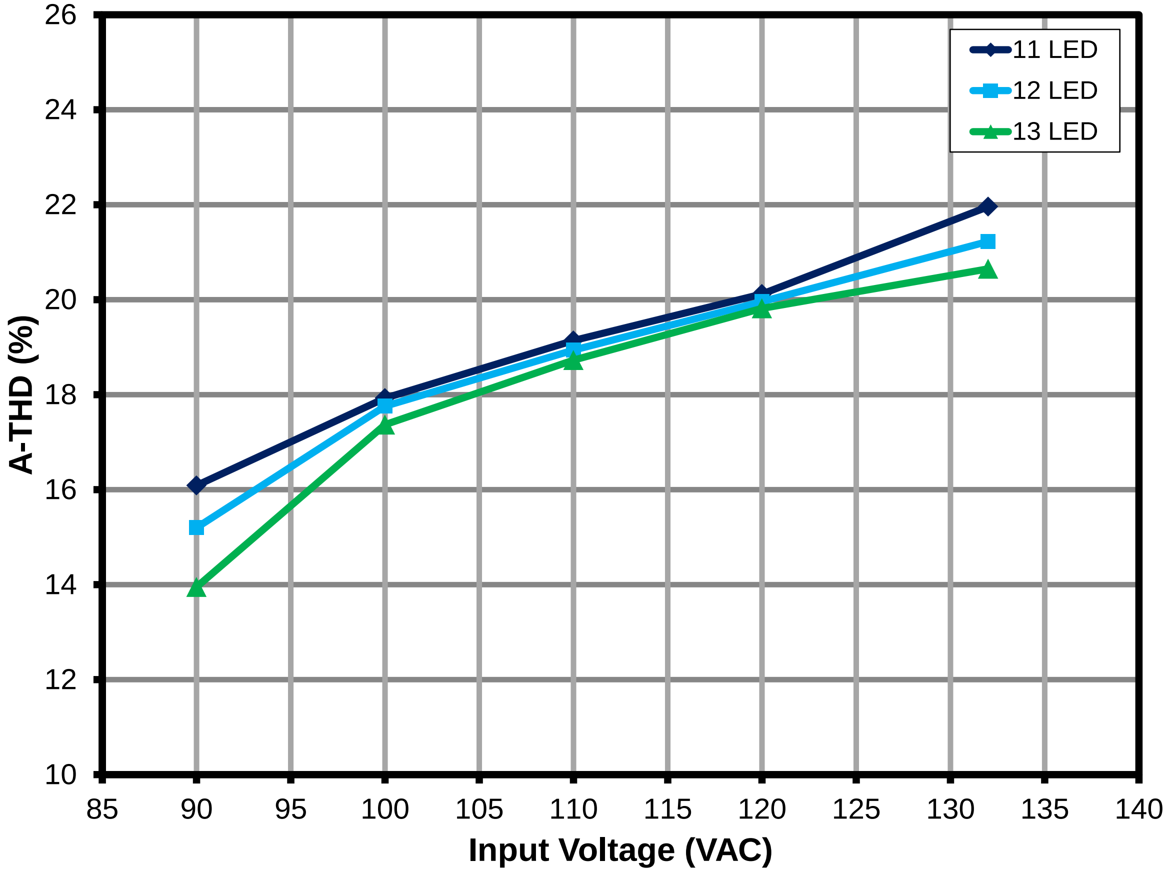

Figure 17 – A-THD vs. Line and Load.

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11.5 諧波電流

The design met the IEC61000-3-2 Limits for Class C equipment (section 7.3-a) for an Active input power of >25 W, which states that the harmonic currents shall not exceed the related limits given in Table 2 - Limits for Class C equipment.

11.5.1 11 LED 負載

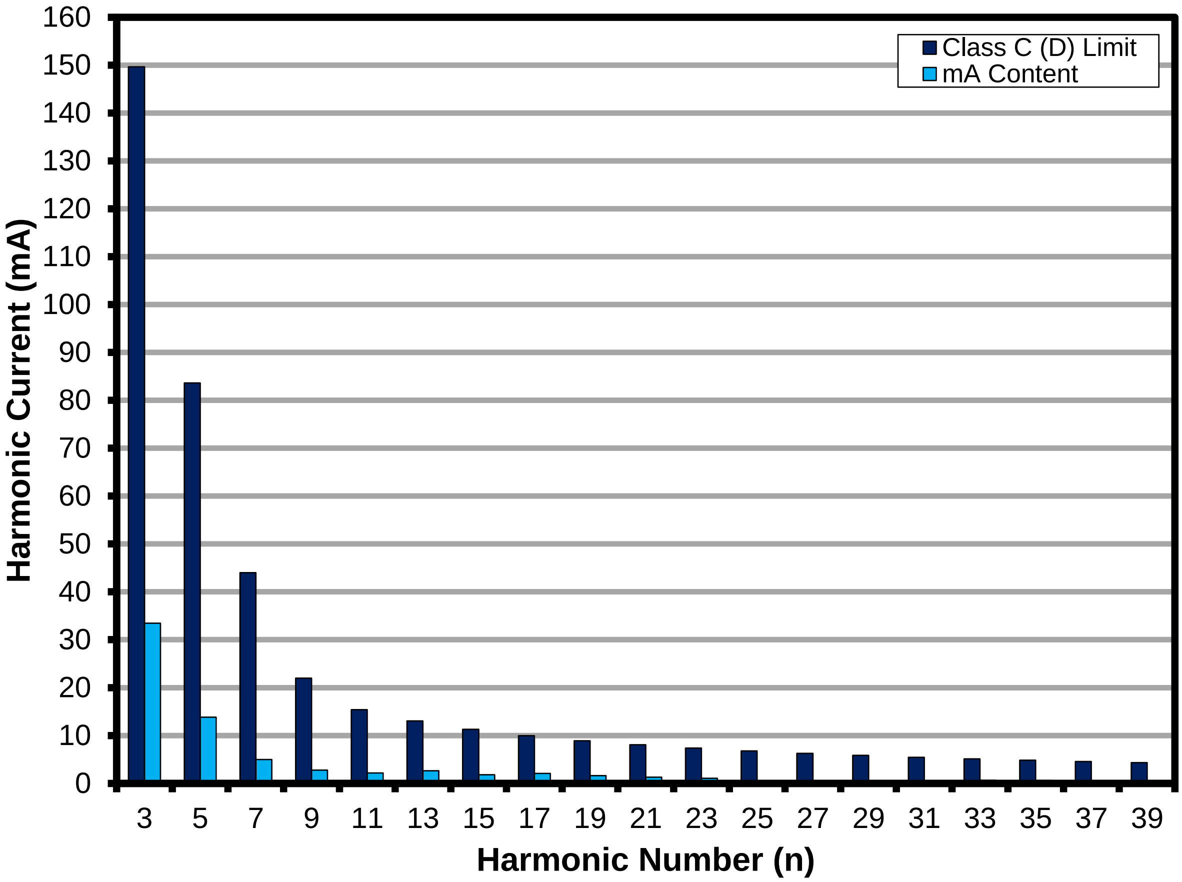

Figure 18 – 11 LED Load Input Current Harmonics (IEC61000-3-2) at 120 VAC, 60 Hz.

11.5.2 12 LED 負載

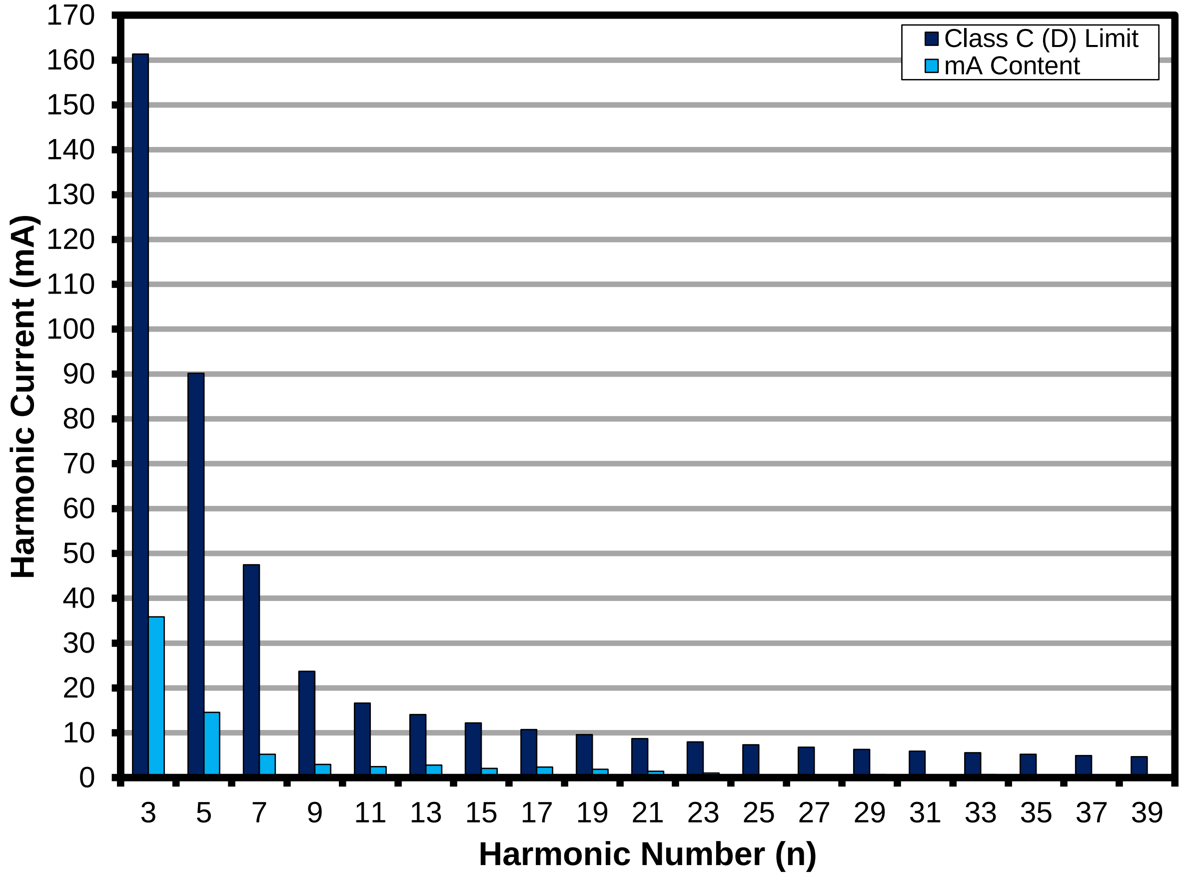

Figure 19 – 12 LED Load Input Current Harmonics case (IEC61000-3-2) at 120 VAC, 60 Hz.

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11.5.3 13 LED 負載

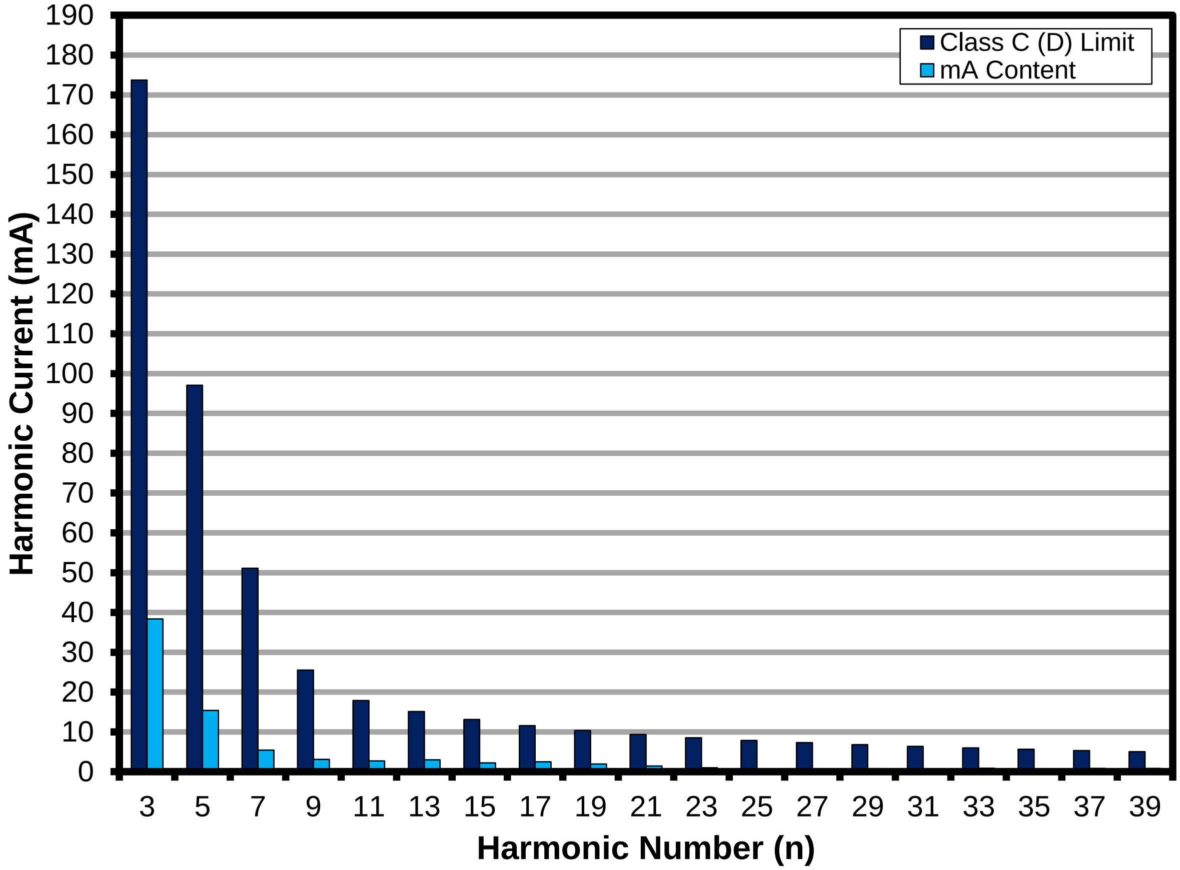

Figure 20 – 13 LED Load Input Current Harmonics (IEC61000-3-2) at 120 VAC, 60 Hz.

11.6 測試資料

All measurements were taken with the board at open frame, 25 °C ambient, and 60 Hz line frequency.

11.6.1 測試資料，11 LED 負載

Input Measurement					Load Measurement			Calculation		
V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	P_{CAL} (W)	Efficiency (%)	Loss (W)
90.04	213.30	18.944	0.986	16.09	33.56	467.90	15.76	15.70	83.20	3.18
100.01	202.56	19.904	0.983	17.93	33.65	495.89	16.75	16.69	84.15	3.16
110.07	195.64	21.086	0.979	19.14	33.76	528.03	17.90	17.82	84.87	3.19
120.05	187.84	22.004	0.976	20.12	33.83	553.86	18.81	18.74	85.49	3.19
132.08	180.56	23.136	0.970	21.96	33.92	584.33	19.90	19.82	86.03	3.23

11.6.2 測試資料，12 LED 負載

Input Measurement					Load Measurement			Calculation		
V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	P_{CAL} (W)	Efficiency (%)	Loss (W)
90.03	229.36	20.401	0.988	15.20	36.30	466.32	16.99	16.93	83.26	3.42
100.01	218.20	21.456	0.983	17.76	36.43	494.09	18.06	18.00	84.18	3.40
110.07	210.62	22.723	0.980	18.94	36.56	526.19	19.31	19.24	84.97	3.42
120.05	202.30	23.726	0.977	19.96	36.65	552.30	20.32	20.24	85.63	3.41
132.08	194.00	24.923	0.973	21.23	36.76	582.69	21.50	21.42	86.25	3.43

11.6.3 測試資料，13 LED 負載

Input Measurement					Load Measurement			Calculation		
V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	P_{CAL} (W)	Efficiency (%)	Loss (W)
90.03	246.50	21.967	0.990	13.95	39.21	464.64	18.27	18.22	83.17	3.70
100.00	234.86	23.117	0.984	17.37	39.36	492.59	19.44	19.39	84.11	3.67
110.06	226.53	24.460	0.981	18.73	39.50	524.39	20.78	20.72	84.95	3.68
120.04	217.61	25.547	0.978	19.82	39.61	550.75	21.89	21.82	85.67	3.66
132.07	208.34	26.822	0.975	20.65	39.72	581.26	23.16	23.09	86.35	3.66

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11.6.4 120 VAC 60 Hz，11 LED 負載諧波資料

Current Harmonics Limits for IEC61000-3-2

V	Freq	I (mA)	P	PF	%THD
120	60.00	187.84	22.0040	0.9758	20.12
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	183.99				
2	0.04	0.02%		2.00%	
3	33.44	18.17%	149.6272	29.27%	Pass
5	13.81	7.51%	83.6152	10.00%	Pass
7	4.99	2.71%	44.0080	7.00%	Pass
9	2.76	1.50%	22.0040	5.00%	Pass
11	2.19	1.19%	15.4028	3.00%	Pass
13	2.63	1.43%	13.0331	3.00%	Pass
15	1.82	0.99%	11.2954	3.00%	Pass
17	2.08	1.13%	9.9665	3.00%	Pass
19	1.62	0.88%	8.9174	3.00%	Pass
21	1.30	0.71%	8.0681	3.00%	Pass
23	1.06	0.58%	7.3666	3.00%	Pass
25	0.28	0.15%	6.7772	3.00%	Pass
27	0.12	0.07%	6.2752	3.00%	Pass
29	0.54	0.29%	5.8424	3.00%	Pass
31	0.56	0.30%	5.4655	3.00%	Pass
33	0.67	0.36%	5.1343	3.00%	Pass
35	0.61	0.33%	4.8409	3.00%	Pass
37	0.28	0.15%	4.5792	3.00%	Pass
39	0.28	0.15%	4.3444	3.00%	Pass
41	0.34	0.18%			
43	0.33	0.18%			
45	0.40	0.22%			
47	0.34	0.18%			
49	0.19	0.10%			

11.6.5 120 VAC 60 Hz，12 LED 負載諧波資料

Current Harmonics Limits for IEC61000-3-2

V	Freq	I (mA)	P	PF	%THD
120	60.00	202.30	23.7260	0.9769	19.96
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	198.22				
2	0.03	0.02%		2.00%	
3	35.84	18.08%	161.3368	29.31%	Pass
5	14.56	7.35%	90.1588	10.00%	Pass
7	5.20	2.62%	47.4520	7.00%	Pass
9	2.94	1.48%	23.7260	5.00%	Pass
11	2.44	1.23%	16.6082	3.00%	Pass
13	2.81	1.42%	14.0531	3.00%	Pass
15	2.06	1.04%	12.1793	3.00%	Pass
17	2.35	1.19%	10.7465	3.00%	Pass
19	1.86	0.94%	9.6153	3.00%	Pass
21	1.43	0.72%	8.6995	3.00%	Pass
23	1.03	0.52%	7.9431	3.00%	Pass
25	0.12	0.06%	7.3076	3.00%	Pass
27	0.14	0.07%	6.7663	3.00%	Pass
29	0.71	0.36%	6.2997	3.00%	Pass
31	0.62	0.31%	5.8932	3.00%	Pass
33	0.71	0.36%	5.5361	3.00%	Pass
35	0.62	0.31%	5.2197	3.00%	Pass
37	0.27	0.14%	4.9376	3.00%	Pass
39	0.28	0.14%	4.6844	3.00%	Pass
41	0.35	0.18%			
43	0.36	0.18%			
45	0.49	0.25%			
47	0.43	0.22%			
49	0.27	0.14%			

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11.6.6 120 VAC 60 Hz，13 LED 負載諧波資料

Current Harmonics Limits for IEC61000-3-2

V	Freq	I (mA)	P	PF	%THD
120	60.00	217.61	25.5470	0.9780	19.82
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	213.26				
2	0.05	0.02%		2.00%	
3	38.35	17.98%	173.7196	29.34%	Pass
5	15.40	7.22%	97.0786	10.00%	Pass
7	5.43	2.55%	51.0940	7.00%	Pass
9	3.09	1.45%	25.5470	5.00%	Pass
11	2.69	1.26%	17.8829	3.00%	Pass
13	3.00	1.41%	15.1317	3.00%	Pass
15	2.20	1.03%	13.1141	3.00%	Pass
17	2.49	1.17%	11.5713	3.00%	Pass
19	1.93	0.90%	10.3533	3.00%	Pass
21	1.45	0.68%	9.3672	3.00%	Pass
23	1.02	0.48%	8.5527	3.00%	Pass
25	0.19	0.09%	7.8685	3.00%	Pass
27	0.19	0.09%	7.2856	3.00%	Pass
29	0.78	0.37%	6.7832	3.00%	Pass
31	0.73	0.34%	6.3455	3.00%	Pass
33	0.86	0.40%	5.9610	3.00%	Pass
35	0.55	0.26%	5.6203	3.00%	Pass
37	0.83	0.39%	5.3165	3.00%	Pass
39	0.85	0.40%	5.0439	3.00%	Pass
41	0.52	0.24%			
43	0.61	0.29%			
45	0.68	0.32%			
47	0.68	0.32%			
49	0.42	0.20%			

12 調光效能資料

TRIAC dimming results were taken at an input voltage of 120 VAC, 60 Hz line frequency, room temperature, and a nominal 36 V LED load.

The output current High Limit I_{OUT} (Max) and Low Limit I_{OUT} (Min) were incorporated based on the USA NEMA publication SSL6-2010 section 4 page 9 for dimming performance system requirements for reference.The standard however refers to 120 VAC operating input voltage and pertains to the limits as relative light output.The limits incorporated on the succeeding graphs assumes that 100% relative light output falls on the maximum operating output current of 550 mA and 0 mA as 0% light output, and input line of 120 VAC, 60 Hz.

12.1 使用模擬 (使用 Agilent 6812B 交流電源) 前緣調光器的調光曲線

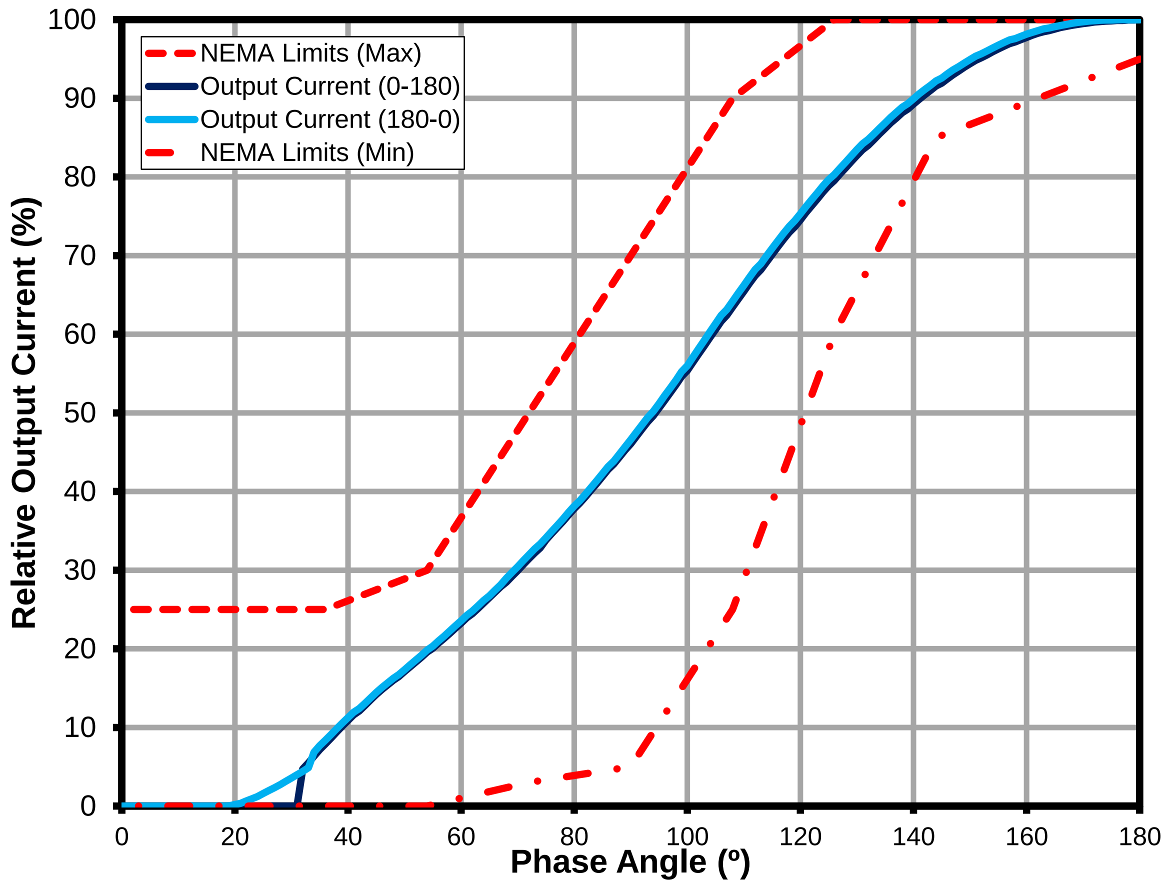

Figure 21 – Dimming Curve at 120 VAC, 60 Hz Input.

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12.2 使用以 TRIAC 調光器的快速啓動 (不到 200 ms)

Using a TRIAC-based U.S. dimmer model S-600P-WH (Lutron) with thumb-wheel adjust set to minimum turn-on (i.e. <30 degrees) which guarantees the LED driver is off when it is switched to ON position.The test was made by turning/sliding the dimmer knob as quickly as possible from minimum to maximum position then measuring the time from the point the dimmer started conducting to the point the output current started rising.

Input voltage:120 VAC / 60 Hz

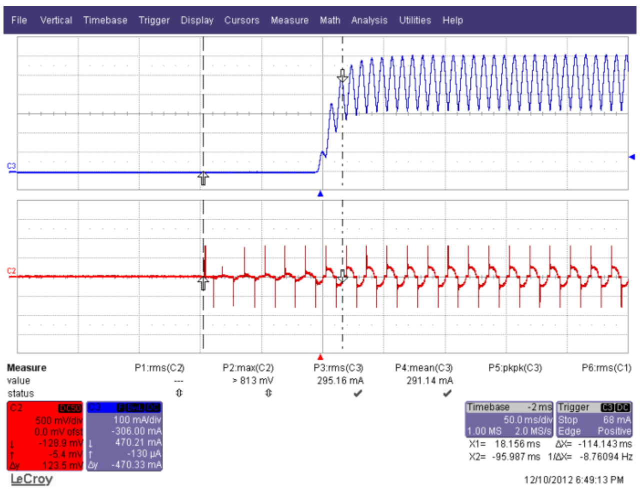

Figure 22 – Measured Start-up Time 114 ms. Flicking the Switch ON, Dimmer at Full Conduction.
Upper:I_{OUT}, 100 mA / div.
Lower:I_{IN}, 500 mA, 50 ms / div.

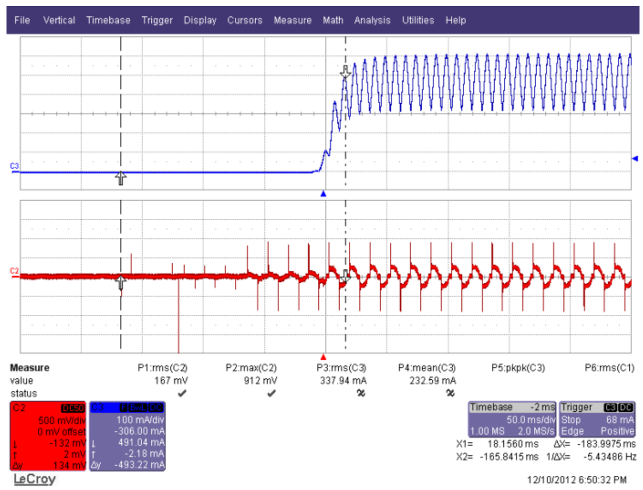

Figure 23 – Measured Start-up Time 184 ms. Quickly Sliding the Knob from Minimum to Full Conduction.
Upper:I_{OUT}, 100 mA / div.
Lower:I_{IN}, 500 mA, 50 ms / div.

12.3 使用以 TRIAC 調光器的光源穩定啓動狀態

Pop-on per NEMA SSL-6 definition is lowest dimmer setting above minimum at which the lamp transitions from off to dimmed.

This particular test was conducted using 120 V / 60 Hz TRIAC dimmer model S-600P-WH (Lutron U.S. dimmer).

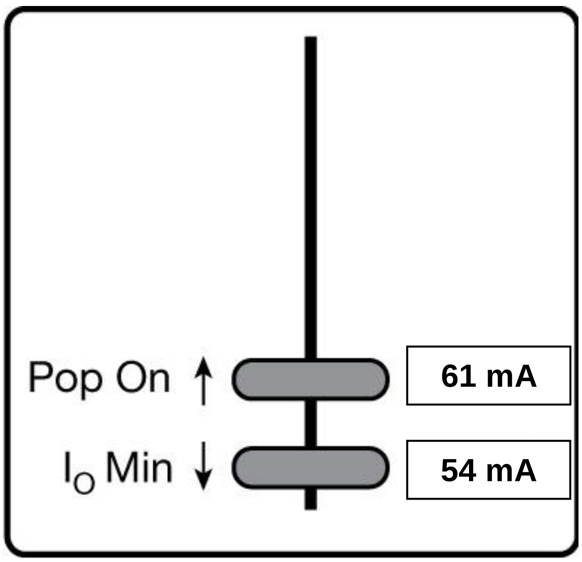

Figure 24 – 35º Conduction Angle was Measured at Pop-on Point.

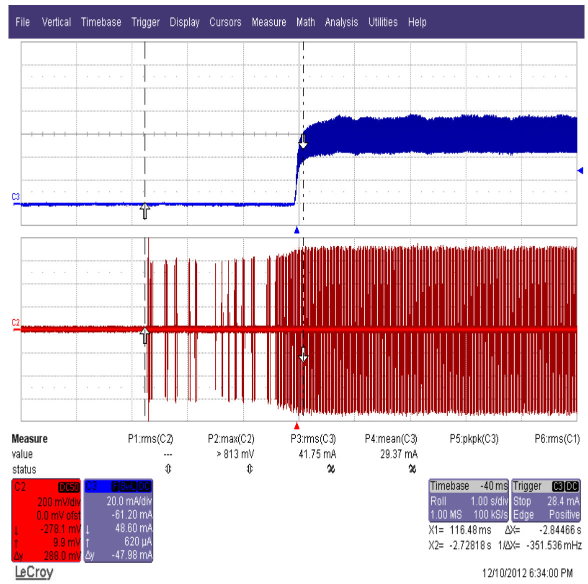

Figure 25 – 35º Conduction Angle at Pop-on Point.
Upper: I_{OUT}, 20 mA / div.
Middle: V_{OUT}, 200 V / div.
Lower: I_{IN}, 0.2 A / div., 1 s / div.

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12.4 使用調光器的輸出電流和輸入電流波形

Input:120 VAC, 60 Hz Utility Line
Output:36 V LED Load
Dimmer:LUTRON GL-600WH

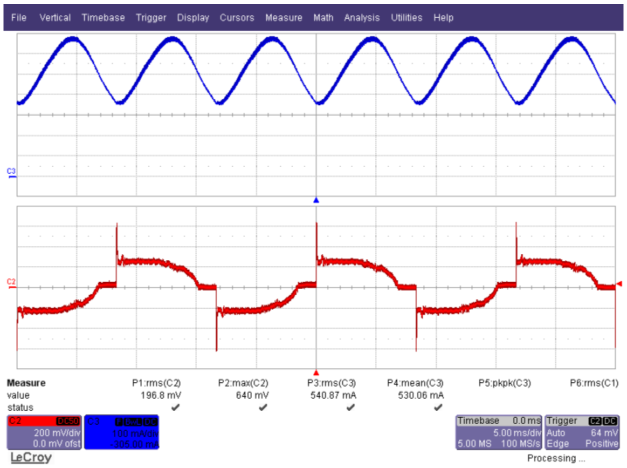

Figure 26 – 147º Conduction Angle.
Upper:I_{OUT}, 100 mA / div.
Lower:I_{IN}, 200 mA, 5 ms / div.

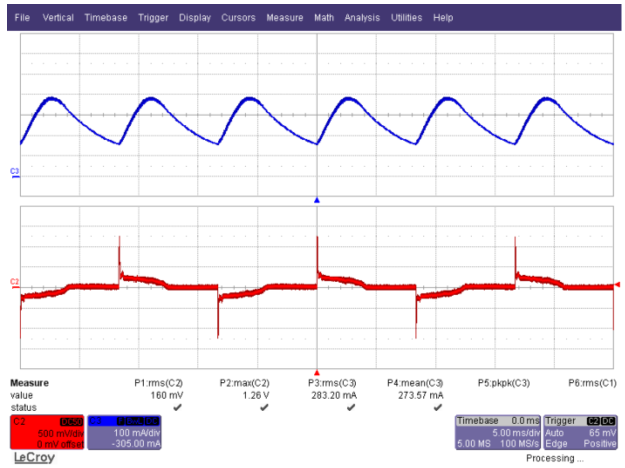

Figure 27 – 90º Conduction Angle.
Upper:I_{OUT}, 100 mA / div.
Lower:I_{IN}, 500 mA, 5 ms / div.

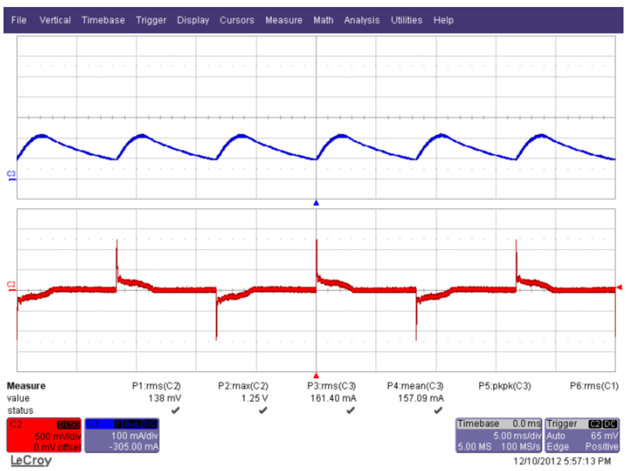

Figure 28 – 60º Conduction Angle.
Upper:I_{OUT}, 100 mA / div.
Lower:I_{IN}, 500 mA, 5 ms / div.

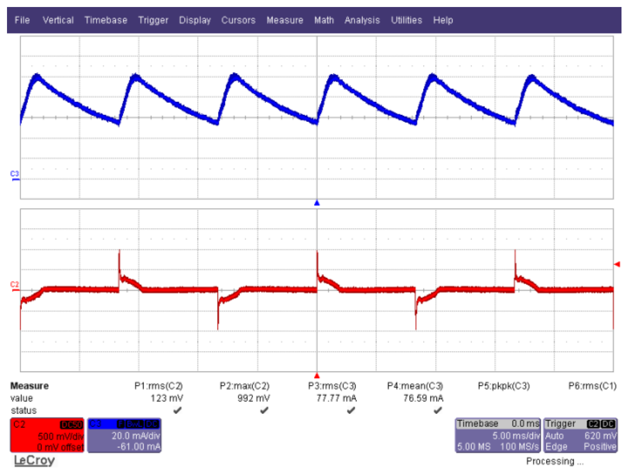

Figure 29 – 40º Conduction Angle.
Upper:I_{OUT}, 20 mA / div.
Lower:I_{IN}, 500 mA, 5 ms / div.

12.6 相容性清單

The following U.S. TRIAC-based dimmers were tested with utility line input (~120 VAC, 60 Hz) and 36 V LED load.

Dimmer Brand	Type	Part Number	$V_{RMS(MIN)}$	I_{MIN} (mA)	$V_{RMS(MAX)}$	I_{MAX} (mA)	Dim Ratio
Lutron	L	LG-600PH-WH	24	41	115.5	492	12
Lutron	L	S-603P-WH	24.5	43	116.0	497	12
Lutron	L	SLV600P-WH	29	62	116.7	505	8
Lutron	L	S-600-WH	27.5	57	118.5	530	9
Lutron	L	S-600PH-WH	23	40	116.1	501	13
Lutron	L	DVWCL-153-PLH-WH	21.8	32	114.0	484	15
Lutron	L	DV-603P-WH	25	48	115.6	498	10
Lutron	L	DV-600P-WH	24	42	115.8	498	12
Lutron	L	TG-600PH-WH	40	87	117.0	513	6
Lutron	L	Q-600P-WH aka FA-600	19.6	18	115.0	494	28
Lutron	L	AY-600P-WH	42.2	91	116.5	508	6
Lutron	L	GL-600P-WH	28.5	61	116.0	502	8
Leviton	L	R62-06633-1LW	24	42	119.8	549	13
Leviton	L	R62-06631-1LW	13	4	117.6	520	130
Leviton	L	R60-IPI06-1LM	43	95	119.2	542	6
Leviton	E	R52-06161-00W	33	60	116.3	507	8
Leviton	L	R52-RPI06-1LW	32	50	119.9	555	11
Leviton	L	TGM10-1LW	16.8	12	115.0	493	41
Leviton	L	R02-06613-PLW	21	28	120.0	550	20
Cooper	L	SLC03P-W-K-L	16	10	117.4	519	51
Lutron	L	GL-600-WH	31	66	118.4	533	8
Lutron	L	DVPDC-203P-WH	65	166	118.0	527	3
Lutron	L	LX-600PL-wh	29	60	118.0	525	9
Lutron	L	CTCL-153PDH	20	21	114.7	488	23
Lutron	L	S-600P	22	36	116.0	503	14
Lutron	L	TGLV-600P	33	70	117.0	517	7
Lutron	L	TGLV-600PR	32	67	117.0	512	8
Lutron	L	TT-300NLH-WH	40	84	119.0	540	6
Lutron	L	NLV-1000-WH	25	45	117.4	519	12
Lutron	T		30.7	52	115.5	495	10
Lutron	L		24	41	118.2	532	13
Cooper	L		32	70	118.0	528	8
Lutron	L	S-103P-WH	32	68	116.0	503	7
Lutron	L	S-10P-WH	27	56	115.0	496	9
Lutron	L	S-600PNLH-WH	29	63	116.2	511	8
Lutron	L	S-603PNL-WH	31	68	116.0	508	7
Lutron	L	SLV-603P-WH	33	71	116.0	506	7
Lutron	L	AYLV-600P-WH	33	71	117.0	514	7
Lutron	L	AYLV-603P-WH	33.5	73	115.0	497	7
Lutron	L	AY-103PNL-WH	31	65	117.6	523	8
Lutron	L	AY-103P-WH	31	60	118.0	526	9
Lutron	L	AY-10PNL-WH	29	63	119.8	551	9

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Lutron	L	AY-10P-WH	24.5	44	117.8	528	12
Lutron	L	AY-603PNL-WH	34	73	114.6	493	7
Lutron	L	AY-603PG-WH	37	77	103.7	395	5
Lutron	L	AY-603P-WH	41	90	115.1	497	6
Lutron	L	AY-600PNL-WH	37	76	116.6	512	7
Lutron	T	DVELV-300P-WH	25	33	112.3	458	14
Lutron	L	DVLV-10P-WH	34	72	115.8	493	7
Lutron	L	DVLV-103P-WH	33	70	115.9	498	7
Lutron	L	DVLV-603P-WH	32	68	116.0	500	7
Lutron	L	S-1000-WH	32	67	118.6	531	8
Lutron	T	SELV-300P-WH	25	34	111.0	452	13
Lutron	L	S-600P-WH	24	41	115.6	501	12
Lutron	L	S-103PNL-WH	33.5	66	115.3	498	8
Lutron		SPSLV-1000-WH	30	64	117.0	518	8
Lutron		SPSLV-600-WH	30	64	116.7	517	8
Lutron		SPSELV-600-WH	30	52	115.7	496	10
Lutron	L	GLV-600-WH	24	43	118.5	533	12
Lutron	L	LG-603PGH-WH	27	54.0	106.0	408.0	8
Lutron	L	DVW-603PGH-WH	29	61.0	106.1	409.0	7
Leviton	L	VPI06	26	51.0	116.9	510.0	10
Lutron	L	TG-10PR-WH	39.7	85.0	118.0	523.0	6
Lutron	L	NT-600	22.5	32.0	118.7	532.0	17
Lutron	L	NT-1000	23	38.0	118.7	534.0	14
Lutron	L	LGCL-153PLH-WH	27	56.0	114.2	486.0	9
Lutron	L	CTCL-153PDH-WH	37	75.0	115.0	491.0	7
Lutron	L	TGCL-153PH-WH	27	56.0	114.5	491.0	9
Lutron	L	DVWCL-153PH-LA	38.7	81.0	114.7	492.0	6
Leviton	L	81000-W	38	79.0	119.3	538.0	7
Lutron	L	TTCL-100LH-WH	37	76.0	114.4	486.0	6

Figure 30 – U.S. TRIAC-Based Dimmers Compatibility List.

13 散熱效能

13.1 使用 PAR38 燈泡的散熱測量

The UUT was placed inside a PAR38 with MT-G2 lamp provided by CREE and the lamp was screwed into a conical metal housing oriented in upside down position for worse case position.Type-T thermo-couple wire was attached on the body of each device under test.Temperature readings were recorded when it stabilizes after running more than one hour with 36 V LED (MT-G2) load at the specified input voltage and load current.The probe location for the ambient was shown on the figure below.

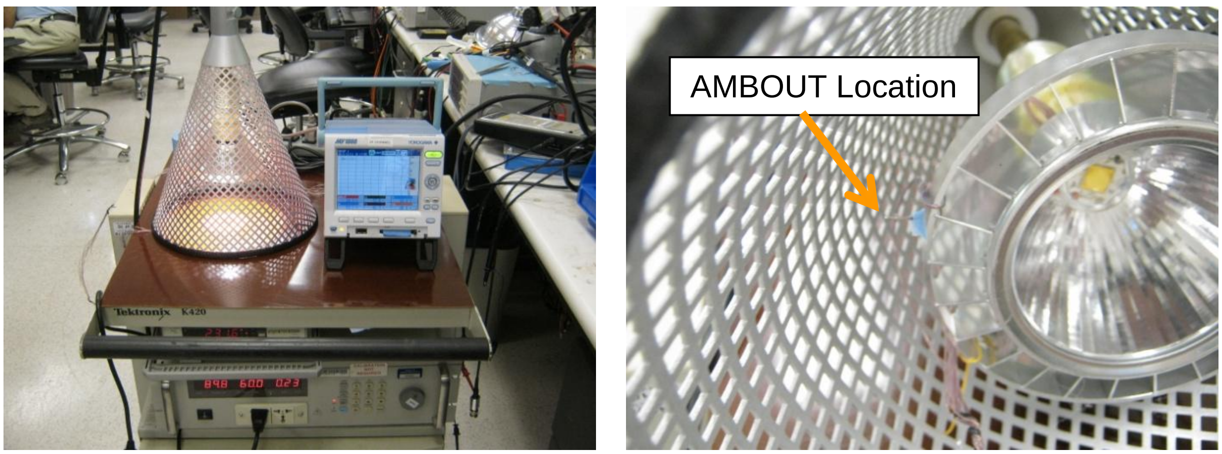

Figure 31 – Thermal Set-up.

13.2 90 VAC，非調光

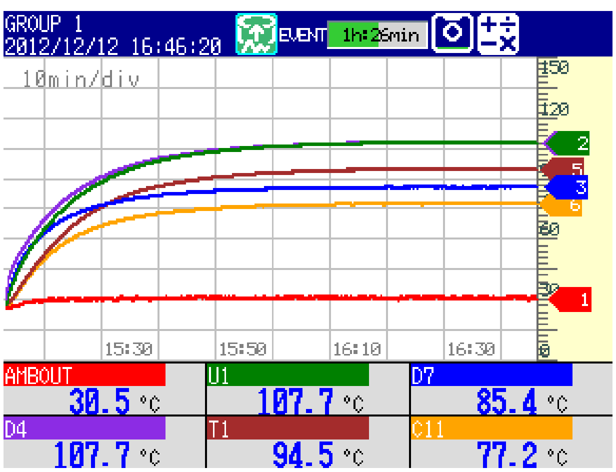

Figure 32 – 90 VAC.
AMBOUT, U1, D7, D4, T1, C11.

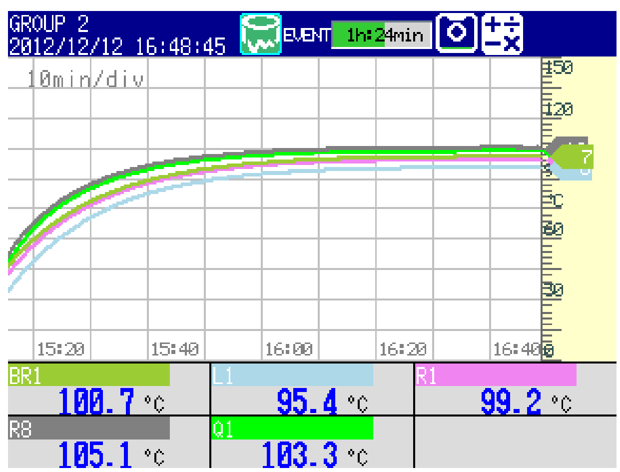

Figure 33 – 90 VAC Conduction Angle.
BR1, L1, R1, R8, Q1.

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13.3 132 VAC，非調光

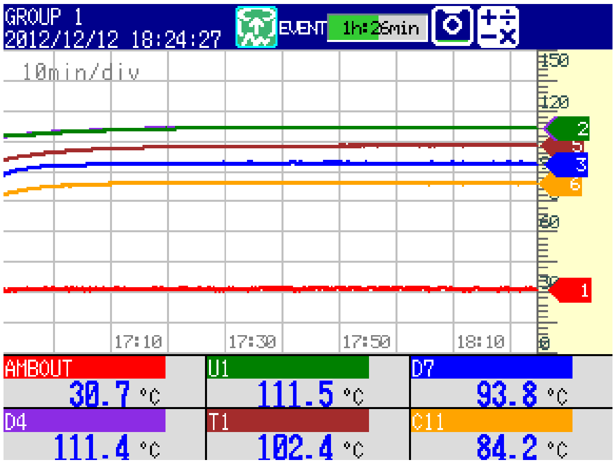

Figure 34 – 132 VAC.
AMBOUT, U1, D7, D4, T1, C11.

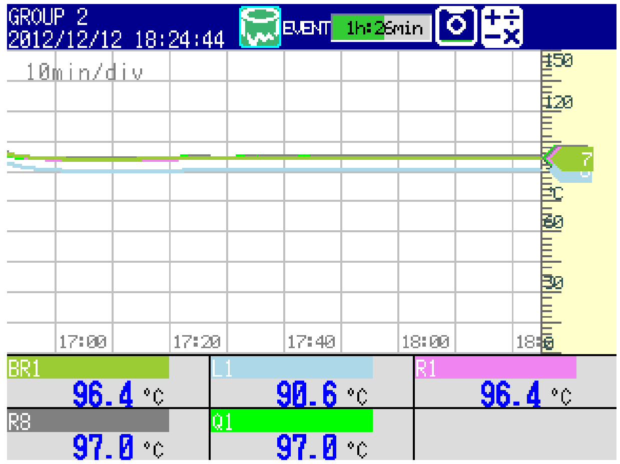

Figure 35 – 132 VAC.
BR1, L1, R1, R8, Q1.

13.4 120 VAC、90º 導通角

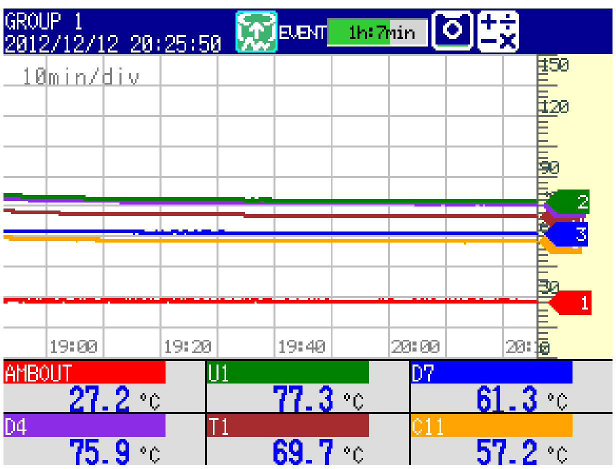

Figure 36 – 120 VAC, 90 º Conduction Angle.
AMBOUT, U1, D7, D4, T1, C11.

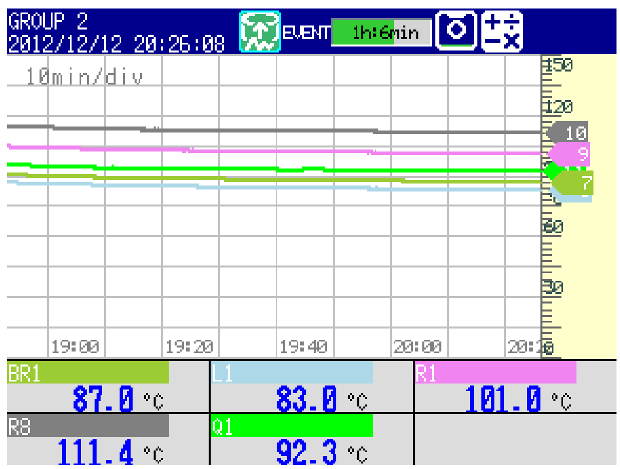

Figure 37 – 120 VAC, 90º Conduction Angle.
BR1, L1, R1, R8, Q1.

14 非調光波形

14.1 輸出電流和輸入電流波形

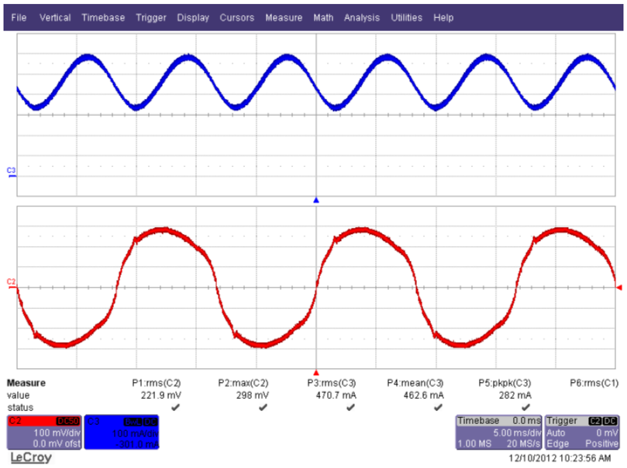

Figure 38 – 90 VAC, 36 V LED Load.
Upper:I_{OUT}, 100 mA / div.
Lower:I_{IN}, 100 mA, 5 ms / div.

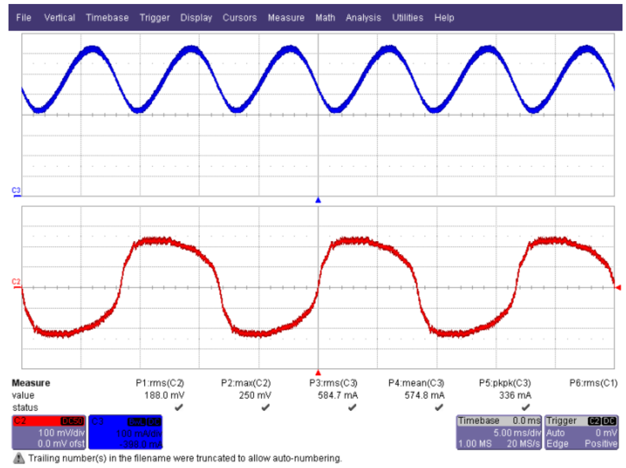

Figure 39 – 132 VAC, 36 V LED Load.
Upper:I_{OUT}, 100 mA / div.
Lower:I_{IN}, 100 mA, 5 ms / div.

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14.2 *正常運作下的輸出電流和輸出電壓波形*

Input Condition	I_{OUT}, Mean (mA)	I_{OUT}, Peak to Peak (mA)	I_{OUT} Ripple (%)
90 VAC, 60 Hz	457	256	±28
120 VAC, 60 Hz	540	291	±27
132 VAC, 60 Hz	572	315	±28

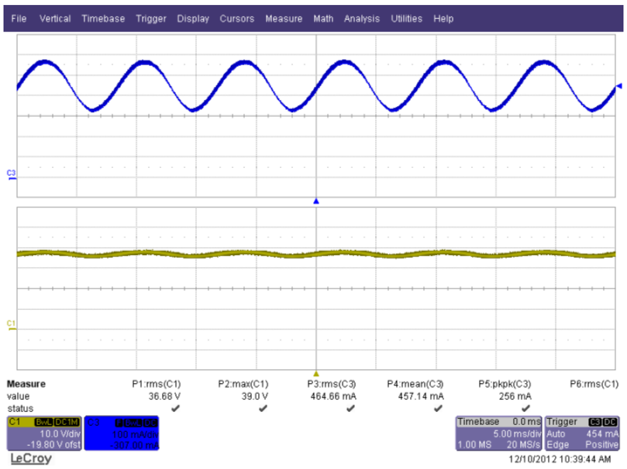

Figure 40 – 90 VAC, 60 Hz Full Load.
Upper:I_{OUT}, 100 mA / div.
Lower:V_{OUT}, 10 V, 5 ms / div.

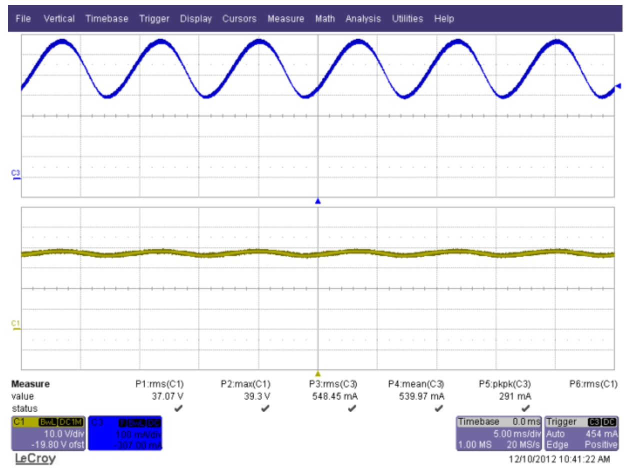

Figure 41 – 120 VAC, 60 Hz Full Load.
Upper:I_{OUT}, 100 mA / div.
Lower:V_{OUT}, 10 V, 5 ms / div.

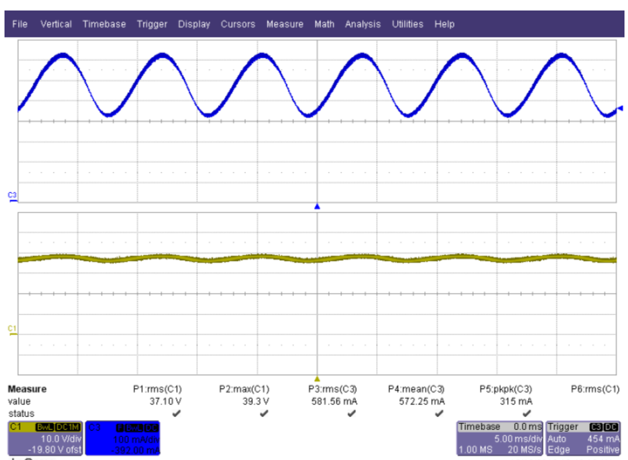

Figure 42 – 132 VAC, 60 Hz Full Load.
Upper:I_{OUT}, 100 mA / div.
Lower:V_{OUT}, 10 V, 5 ms / div.

14.3 啓動時的輸入電壓和輸出電流波形

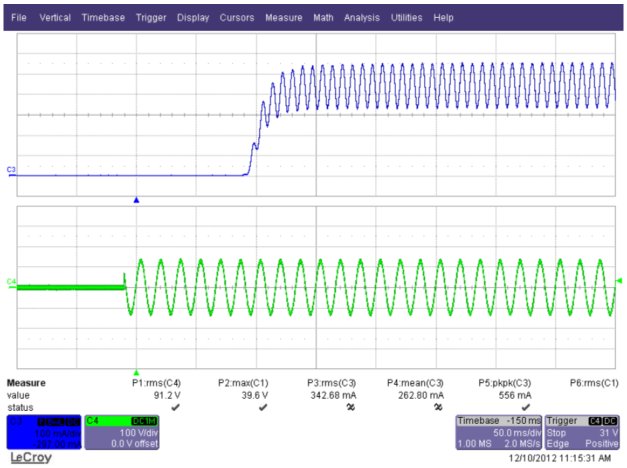

Figure 43 – 90 VAC, 60 Hz.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 100 V, 50 ms / div.

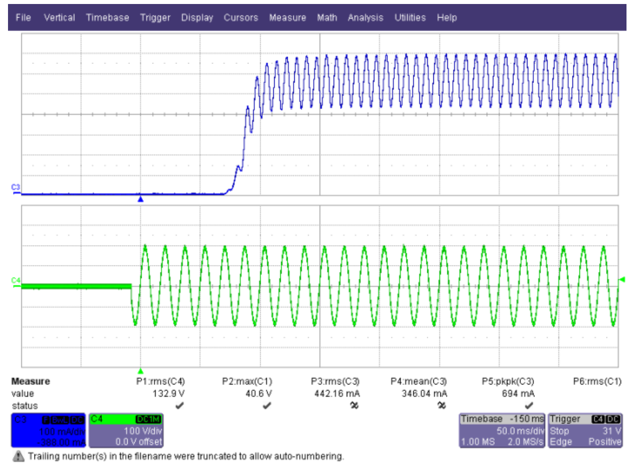

Figure 44 – 132 VAC, 60 Hz.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 100 V, 50 ms / div.

14.4 啓動時的輸出電壓和輸出電流波形

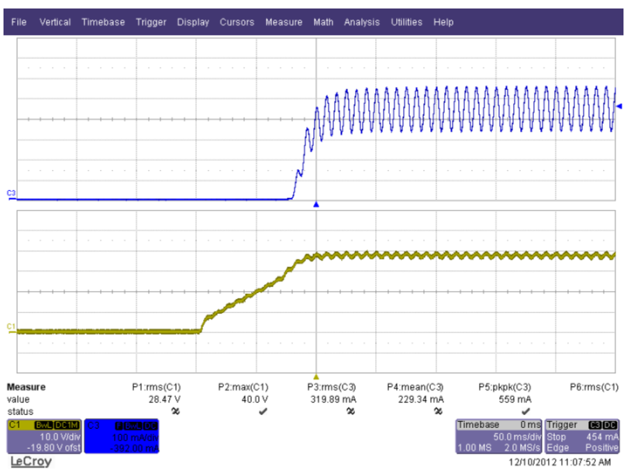

Figure 45 – 90 VAC, 60 Hz.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V, 50 ms / div.

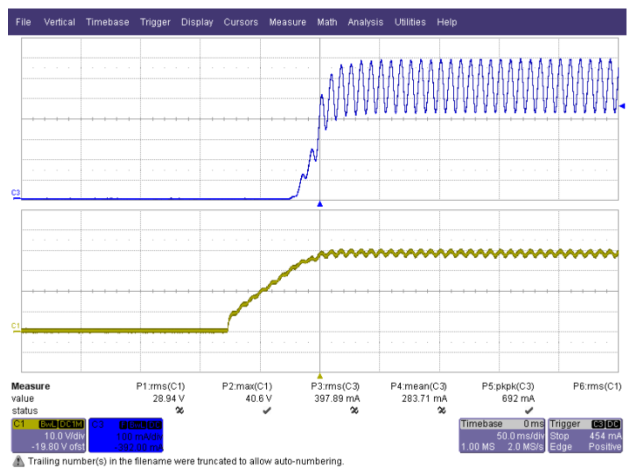

Figure 46 – 132 VAC, 60 Hz.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V, 50 ms / div.

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14.5 *正常運作下的汲極電壓和電流*

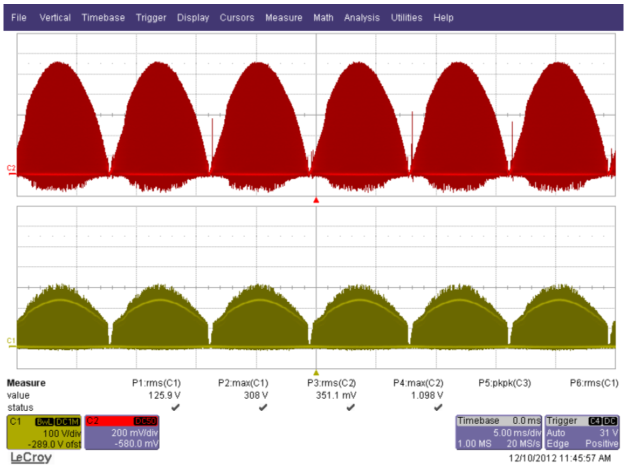

Figure 47 – 90 VAC, 60 Hz.
Upper:I_{DRAIN}, 0.2 A / div.
Lower:V_{DRAIN}, 100 V, 5 ms / div.

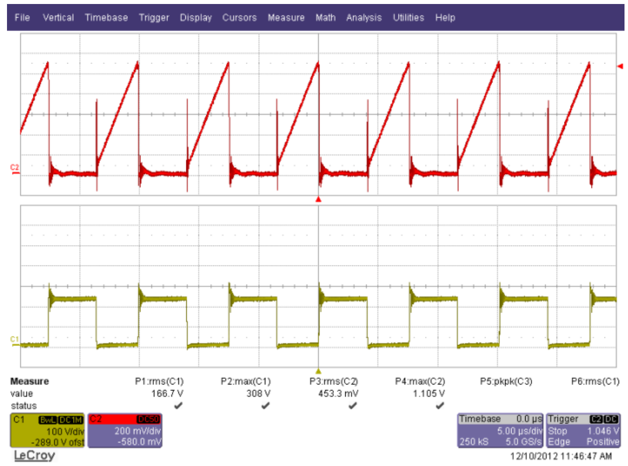

Figure 48 – 90 VAC, 60 Hz.
Upper:I_{DRAIN}, 0.2 A / div.
Lower:V_{DRAIN}, 100 V / div., 5 μs / div.

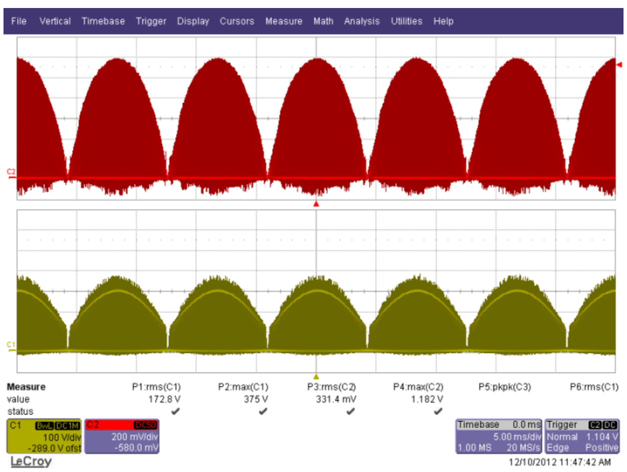

Figure 49 – 132 VAC, 60 Hz.
Upper:I_{DRAIN}, 0.2 A / div.
Lower:V_{DRAIN}, 100 V, 5 ms / div.

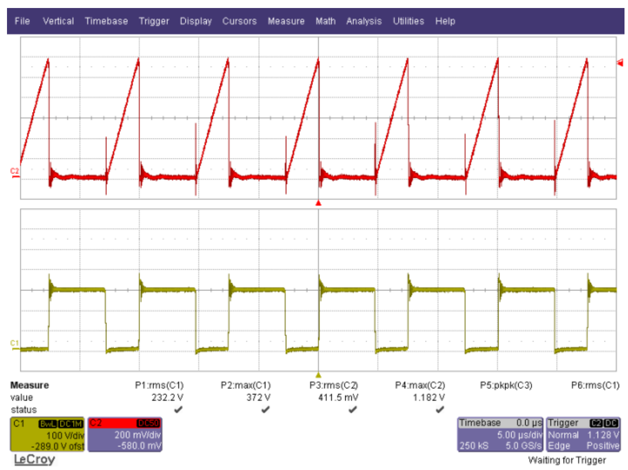

Figure 50 – 132 VAC, 60 Hz.
Upper:I_{DRAIN}, 0.2 A / div.
Lower:V_{DRAIN}, 100 V / div., 5 μs / div.

14.6 啓動時的汲極電壓和電流

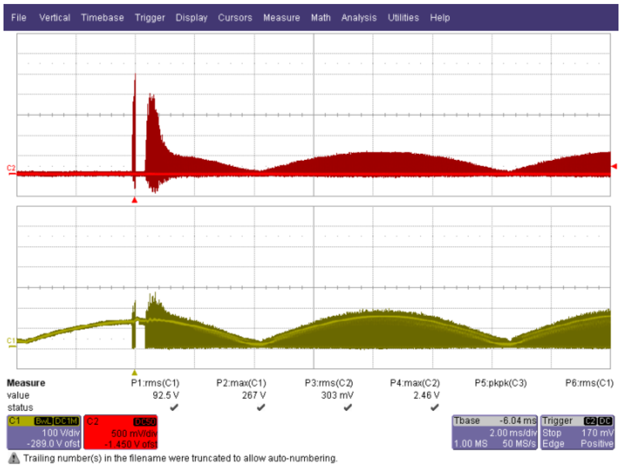

Figure 51 – 90 VAC, 60 Hz Start-up.
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 100 V, 2 ms / div.

Figure 52 – 90 VAC, 60 Hz Start-up.
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 100 V, 10 µs / div.

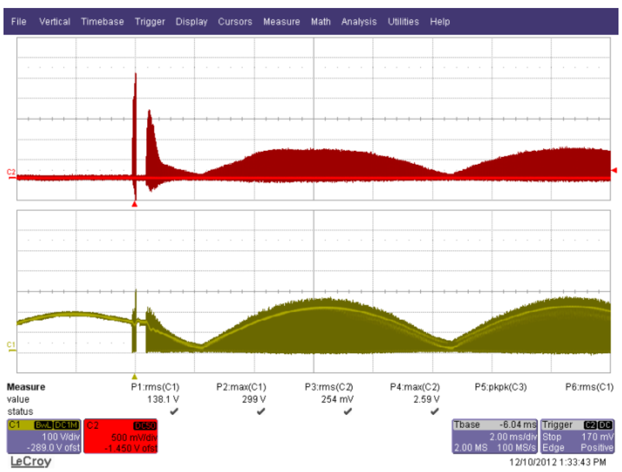

Figure 53 – 132 VAC, 60 Hz Start-up.
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 100 V, 2 ms / div.

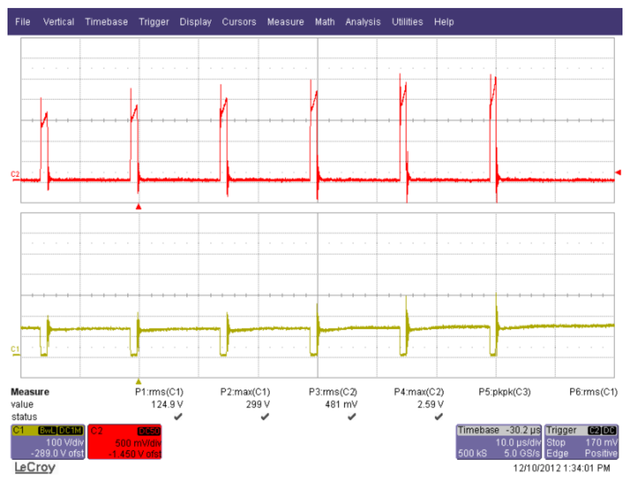

Figure 54 – 132 VAC, 60 Hz Start-up.
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 100 V, 10 µs / div.

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14.7 輸出短路情況下的汲極電壓和電流輸出

During output short condition, the I_{FB} current falls below the $I_{FB(AR)}$ threshold and enters the auto-restart condition.During this condition, to minimize power dissipation on the power components, the auto-restart circuit turns the power supply on and off at an auto-restart duty cycle of typically DC_{AR} for as long as the fault condition persists.

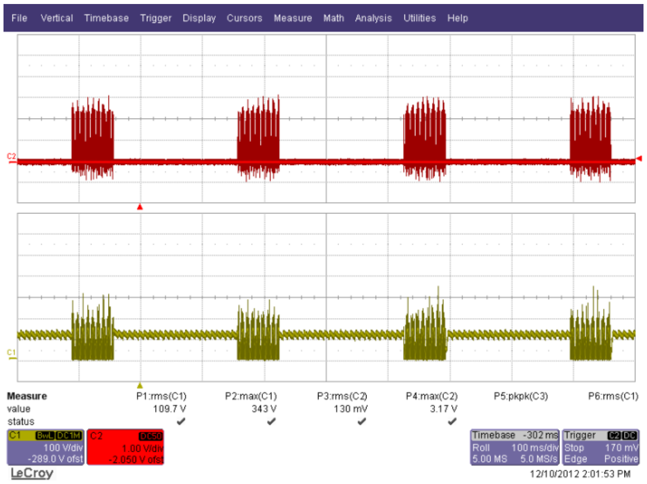

Figure 55 – 90 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V, 100 ms / div.

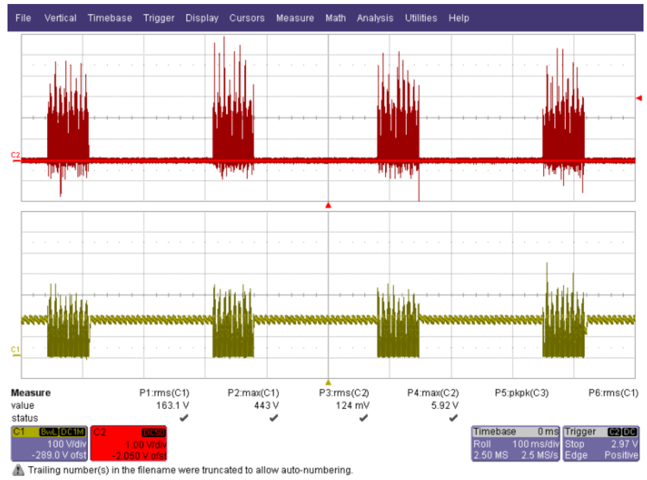

Figure 56 – 132 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V, 100 ms / div.

14.8 開路負載狀況

The LED load was disconnected from the driver.

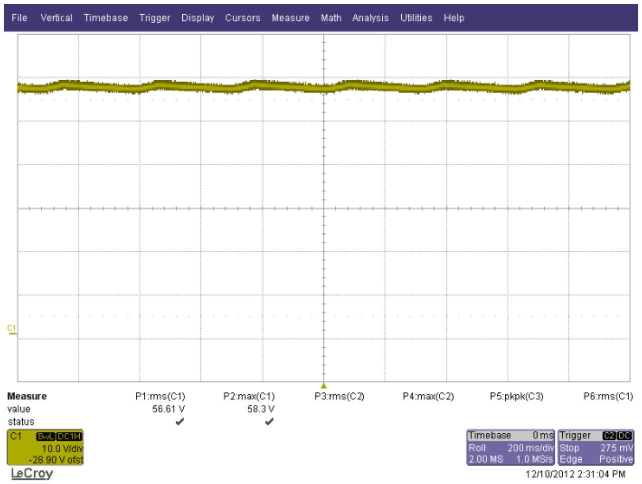

Figure 57 – 90 VAC, 60 Hz Output Open Load. CH4:V_{OUT}, 10 V, 200 ms / div.

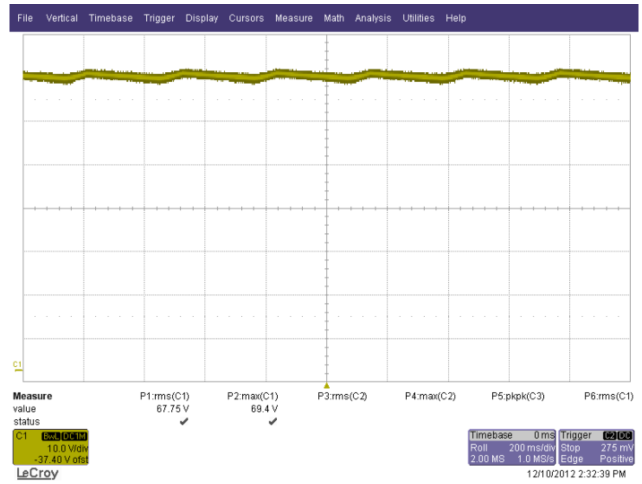

Figure 58 – 132 VAC, 60 Hz Output Open Load. CH4:V_{OUT}, 10 V, 200 ms / div.

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14.9 正常運作下的輸出二極體電壓和電流波形

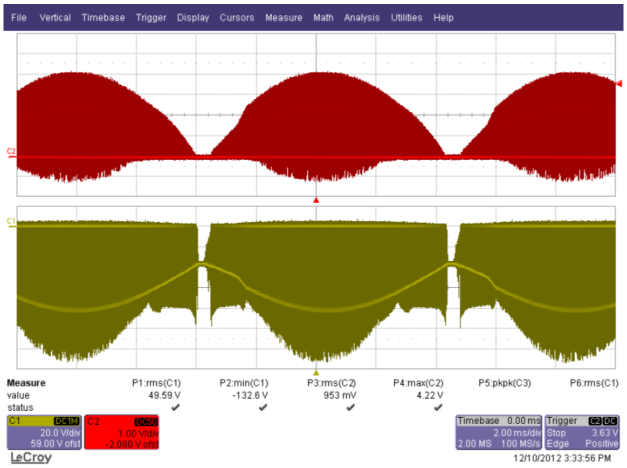

Figure 59 – 90 VAC, 60 Hz.
Upper:I_{D7}, 1A / div.
Lower:V_{D7}, 10 V, 2 ms / div.

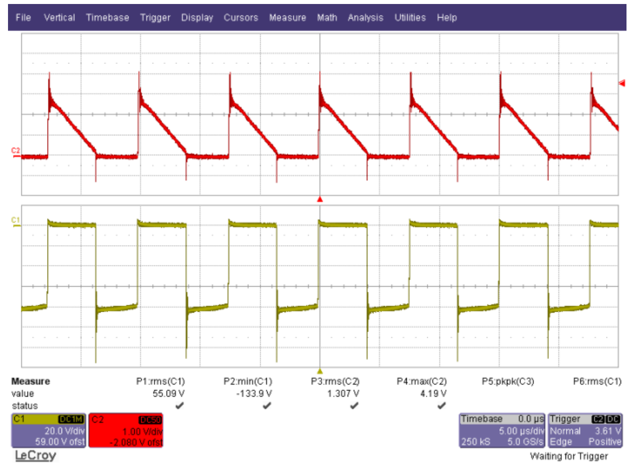

Figure 60 – 90 VAC, 60 Hz.
Upper:I_{D7}, 1 A / div.
Lower:V_{D7}, 20 V / div., 5 μs / div.

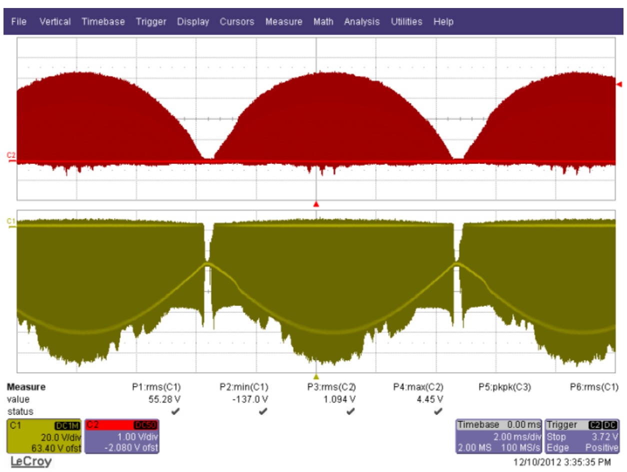

Figure 61 – 132 VAC, 60 Hz.
Upper:I_{D7}, 1 A / div.
Lower:V_{D7}, 20 V, 2 ms / div.

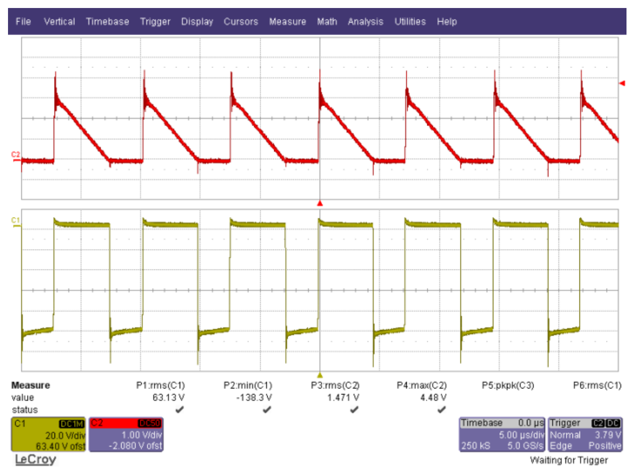

Figure 62 – 132 VAC, 60 Hz.
Upper:I_{D7}, 1 A / div.
Lower:V_{D7}, 20 V / div., 5 μs / div.

15 傳導性 EMI

The design met the limits for conducted electromagnetic emission (EMI) with frequency range of 9 kHz to 30 MHz as per described in the CISPR 15 / IEC:2005 Standard.

15.1 測試裝置

The UUT was placed inside a PAR38 with MT-G2 lamp provided by CREE at input voltage of 120 VAC, 60 Hz at room temperature.The unit was placed inside a conical metal housing as shown in Figure 63.

Figure 63 – EMI Test Set-up with the Unit and LED Load Placed Inside a Conical Metal Housing as Described in CISPR 15 / IEC:2005 Standard.

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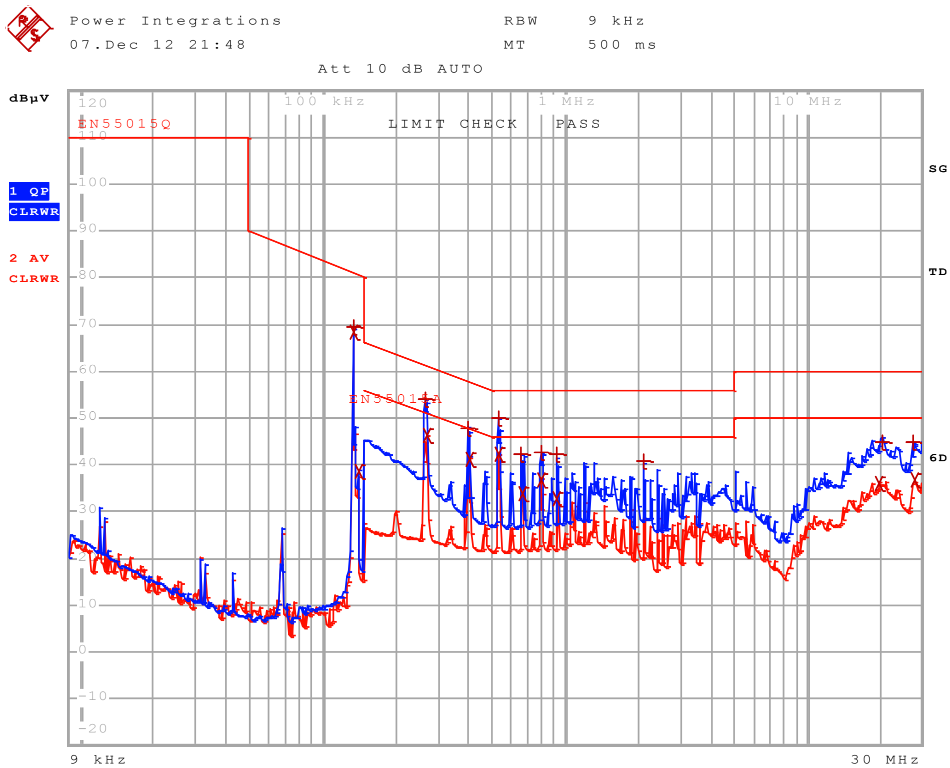
15.2 測試結果



EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

	TRACE	FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
1	Quasi Peak	133.454986145 kHz	69.43	L1 gnd	-11.62
2	Average	133.454986145 kHz	68.36	N gnd	
2	Average	140.262531674 kHz	38.70	L1 gnd	
1	Quasi Peak	264.49018761 kHz	54.05	L1 gnd	-7.23
2	Average	267.135089486 kHz	46.46	L1 gnd	-4.73
1	Quasi Peak	397.727746704 kHz	47.97	L1 gnd	-9.92
2	Average	401.705024172 kHz	41.31	L1 gnd	-6.50
1	Quasi Peak	530.769219795 kHz	49.87	L1 gnd	-6.12
2	Average	530.769219795 kHz	42.20	L1 gnd	-3.79
1	Quasi Peak	660.656865747 kHz	42.26	L1 gnd	-13.73
2	Average	667.263434405 kHz	33.72	L1 gnd	-12.27
1	Quasi Peak	798.145472681 kHz	42.47	L1 gnd	-13.52
2	Average	798.145472681 kHz	36.78	L1 gnd	-9.21
1	Quasi Peak	926.622115652 kHz	42.24	L1 gnd	-13.75
2	Average	926.622115652 kHz	32.58	L1 gnd	-13.41
1	Quasi Peak	2.11629733595 MHz	40.80	L1 gnd	-15.19
2	Average	19.8557266951 MHz	36.09	L1 gnd	-13.90
1	Quasi Peak	20.4573750697 MHz	44.92	L1 gnd	-15.07
1	Quasi Peak	27.5734507982 MHz	44.75	L1 gnd	-15.24
2	Average	27.8491853062 MHz	36.93	L1 gnd	-13.06

Figure 64 – Conducted EMI, 36 V LED Load, 120 VAC, 60 Hz, and EN55015 B Limits**.**

16 線電壓突波

The unit was subjected to ±2500 V 100 kHz ring wave and ±500 V differential surge at 120 VAC using 10 strikes at each condition.A test failure was defined as a non-recoverable interruption of output requiring supply repair or recycling of input voltage.

The unit tested passed both ±2500 V 100 kHz ring wave and ±500 V differential surge with and without MOV.

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+2500	120	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
-2500	120	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
+2500	120	L1, L2	90	100 kHz Ring Wave (500 A)	Pass
-2500	120	L1, L2	90	100 kHz Ring Wave (500 A)	Pass

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+500	120	L1, L2	0	Surge (2 Ω)	Pass
-500	120	L1, L2	0	Surge (2 Ω)	Pass
+500	120	L1, L2	90	Surge (2 Ω)	Pass
-500	120	L1, L2	90	Surge (2 Ω)	Pass

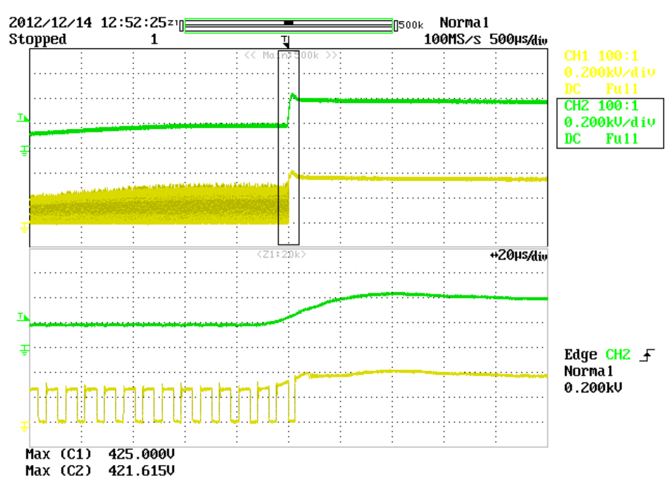


Figure 65 – CH1:90º 500 V Differential Surge (No MOV).
CH1:U1 VDS.
CH2:C2 Voltage.

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17 修訂記錄

Date	Author	Revision	Description and Changes	Reviewed
13-Nov-12	ME	1.0	Initial release	Apps & Mktg
15-Jan-13	CA	2.0	Design Updated with Inductor	Apps & Mktg
20-May-13	KM	2.1	Changed name to LYTSwitch-4	Apps & Mktg

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