設計範例報告

標題	***使用 LYTSwitchTM LYT4313E 的 12 W 可調光雙向閘流器 (TRIAC) 、高效率 (大於 88%) 功率因數修正升降壓式 LED 驅動器***
規格	90 VAC – 132 VAC 輸入； 72 $V_{TYPICAL}$，170 mA 輸出
應用	BR40 替換燈泡
作者	應用工程部門
文件編號	DER-357
日期	2013 年 4 月
修訂	1.0

摘要與功能

- Single-stage 功率因數修正 (PFC) 與精準定電流 (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 88%
- 快速啓動 (<250 ms) – 無可感延遲
- 整合式保護與可靠性功能
    - 無負載保護 / 堅固的短路保護
    - 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
    - 在線電壓欠壓輸入和電壓啓動情況下，不會發生任何損壞
- 120 VAC 時 PF 超過 0.9
- 120 VAC 時 %A THD 小於 25%
- 可選用輸出電流過熱保護，以擴展工作溫度範圍
- 符合 IEC 2.5 kV 振盪波、500 V 線電壓差動電壓突波和 EN55015 傳導性 EMI 規範

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重要附註：
雖然此電路板的設計符合非隔離式 LED 驅動器的安規要求，但工程原型尚未取得安規機構之認證。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

本工程報告文件說明採用 LYTSwitch 系列的 LYT4313E 的非隔離升降壓式 LED 驅動器 (電源供應器)。

DER-357 提供一個 12 W 可調光雙向閘流器 (TRIAC) 定電流輸出。

關鍵的設計目標是提升到最高效率和完成最小尺寸。這使得驅動器會安裝在 BR40 燈泡內，並盡可能接近量產產品設計。

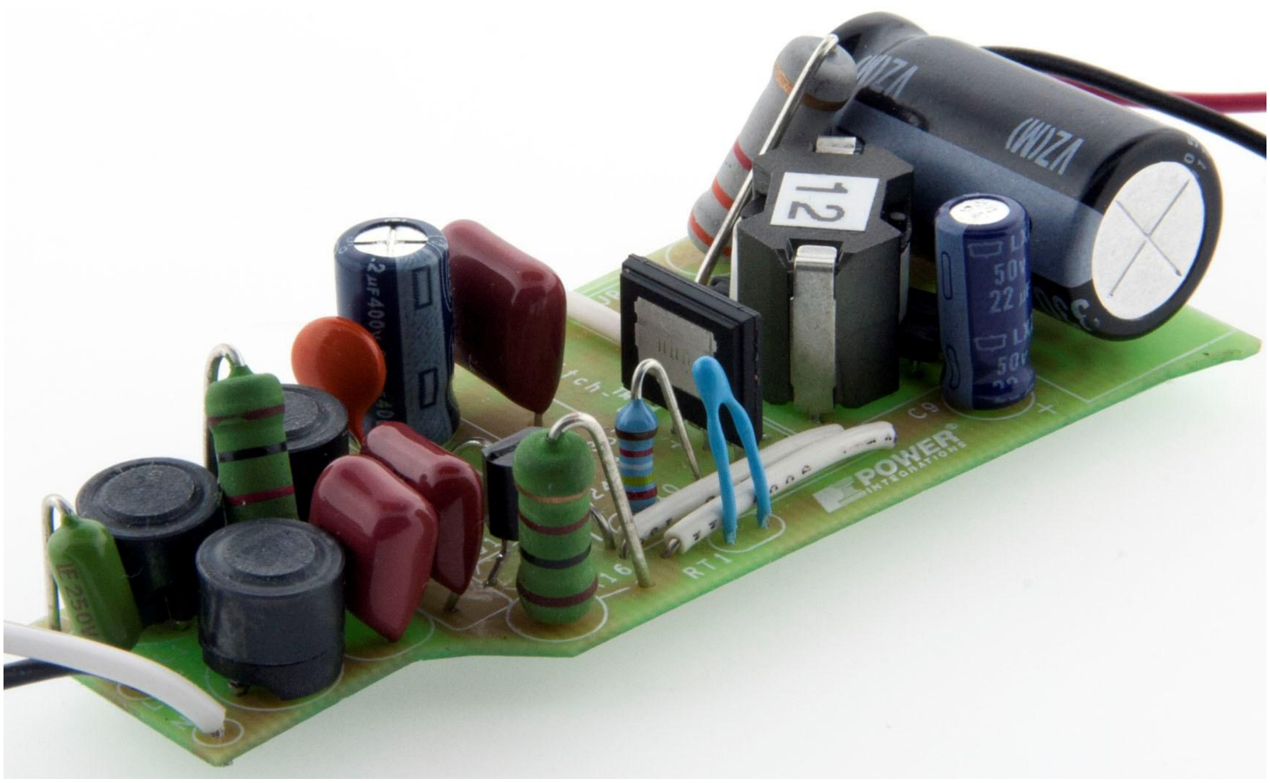

Figure 1 – PCB Assembly.

本電路板已完成最佳化，能夠在低壓 AC 輸入電壓範圍 (90 VAC 至 135 VAC，47 Hz 至 63 Hz) 上操作，採用 LYTSwitch IC 爲基礎的設計提供高功率因數 (>0.95)，符合所有現行國際安規要求。

電路板則選擇可裝入標準 BR40 LED 替換燈泡的尺寸。輸出爲非隔離式，並且需要機械設計的外殼才能將供應器輸出及 LED 負載與使用者隔離開來。

本文件內容涵蓋電源供應器的規格、電路圖、物料清單、變壓器文件、印刷電路板佈局、設計試算表和效能資料。

2 電源供應器規格

下表展示設計低可接受的最低效能。實際效能列在結果部分。

說明	符號	最小值	類型	最大值	單位	註解
輸入						
電壓	V_{IN}	90	120	132	VAC	雙線 – 無 P.E.
頻率	f_{LINE}	47	50/60	63	Hz	
功率因數		0.9				在 230 VAC
%ATHD				25		
輸出						
輸出電壓	V_{OUT}	69	72	75	V	
輸出電流	I_{OUT}	161.5	170	178.5	mA	在 230 VAC
總輸出功率						
連續輸出功率	P_{OUT}		12		W	
效率						
標準	η		88		%	於 P_{OUT} 25 °C、230 VAC 條件下測量
環境						
傳導性 EMI		符合 CISPR22B / EN55015 標準				
線電壓突波						1.2/50 µs 突波，IEC 1000-4-5，串聯阻抗：差模： 2 Ω
差模 (L1-L2)			500		V	
振盪波 (100 kHz)						2 Ω 短路串聯阻抗
差模 (L1-L2)			2.5		kV	

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3 電路圖

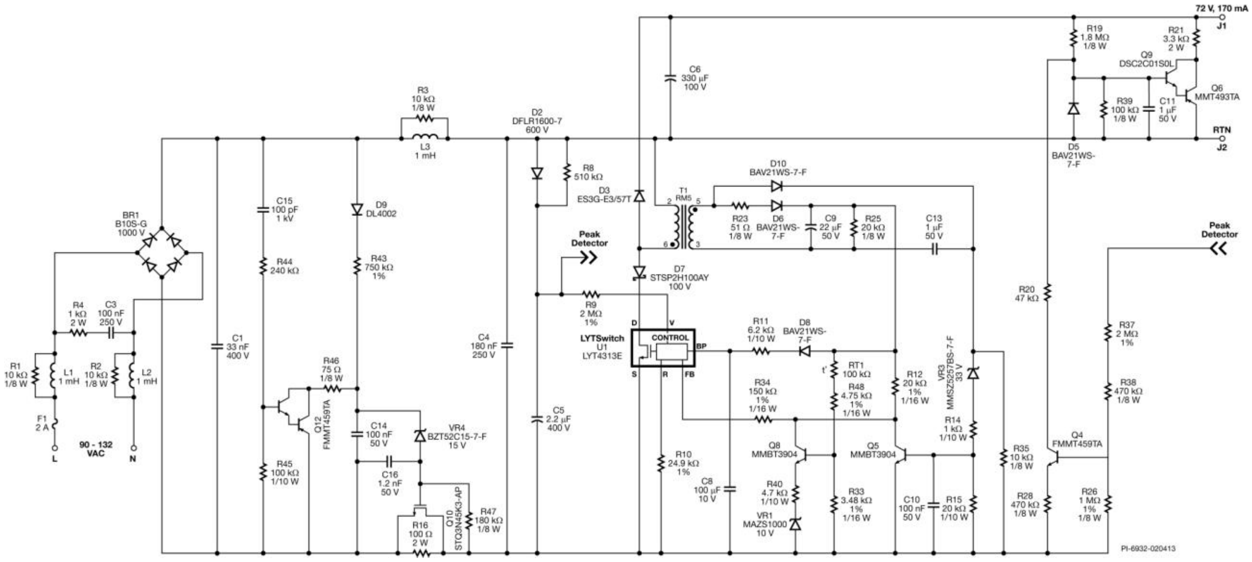

Figure 2 – Schematic for 72 V, 170 mA Replacement Lamp.

附註：將 R33 變更爲 11 k□ 以啓動過熱限流保護。請參考結論以瞭解溫度反應資訊。電阻器 R33 可以調整，以微調到所需的限流保護(foldback)特性。

4 電路說明

LYTSwitch (U1) 系列是高度整合功率 IC ，主要應用於 LED 驅動器。LYTSwitch IC 可在 Single-stage 轉換架構中提供高功率因數，同時還能跨輸入範圍 (90 VAC 至 132 VAC) 調節輸出電流和 LED 驅動器應用環境中常見的典型輸出電壓變化。所有負責這些功能的控制電路，加上高壓功率 MOSFET 都會整合在 IC 內。

4.1 輸入級

保險絲 F1 可防止元件發生故障。為了避免保險絲在線電壓突波期間發生開路，所以需要相當高且快速的 2 A 額定值。為了降低較低效率的成本，保險絲可換成可熔電阻器 (2 W、3.3 □)。

AC 輸入是 BR1 整流後的全波，以達到良好的功率因數和 THD。

差模電感器 L1 和 L2 是前端 EMI 濾波器，可抑制雜訊，包括橋式整流器切換雜訊在內。RC 洩放器 R4 和 C3 會安置於橋式整流器前面，以輔助 TRIAC 進行正常運作。電容器 C3 和 R4 可以安置在 L1 和 L2 之前，以進一步增強調光相容性，同時降低 EMI 電感器因磁致伸縮所可能產生的噪音。在必要時，電阻器 R1 和 R2 會抑制 EMI 濾波器的諧振。如果輻射性 EMI 頻再系統層級應用中有明顯的餘裕，則移除 R1 和 R2。

電容器 C1、C4 和差模電感器 L3 會形成橋式整流器後方的 EMI 濾波器。濾波器電容會受到限制，以維持高功率因數。這會輸入 π 濾波器網路，加上 LYTSwitch 的頻率抖動功能，就能符合 B 級輻射量限值。必要時，電阻器 R3 會抑制 EMI 濾波器的諧振，以防止系統中測量時 (驅動器加上機殼) EMI 頻中產生峰值。電容器 C1 的最小電容 33 nF 會經過最佳化，以避免 BR1 在線電壓突波期間產生電壓應力。

4.2 阻尼器階段

本設計使用 PI 專利主動阻尼器電路，來達成高效率、良好的調光器相容性、線電壓突波保護和散熱管理。RC 切斷頻率濾波器 C15 和 R44 已調到超過 140 Hz 時反應，以便在調光操作期間施加偏壓於 Q12。一旦調光操作，電晶體 Q12 在線電壓半週期時，會釋放 C14 中的電位。

在非調光操作期間，電晶體 Q10 通常開啓，以維持高效率。Q10 的閘極會透過 R43、VR4 和 R47 的分壓器施加偏壓，並準時由 C14 和 C16 進行濾波。在非調光操作時，C14 中的電位不會放電，藉此得以保持 Q10 閘極的連續偏壓。

調光期間，Q10 會在達到輸入電流的初始突波時關閉，以抑制輸入大電容和 EMI 濾波器所引入的浪湧電流(inrush current)。Q10 接著排定在 R47 和等級電容 C14 和 C16 的調光操作期間，進行線性操作。

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在線電壓差動電壓突波和線電壓波動期間，Q12 會關閉 Q10，以限制線電壓突波期間 U1 的元件應力。

4.3 使用 LYTSwitch 裝置的升降壓式架構

升降壓式傳動元件包含 U1 (電源開關 + 控制器)、D3 (飛輪二極體)、C6 (輸出電容器) 和 T1 (電感器)。二極體 D7 是用於防止 U1 汲源極間，特別是接近輸入電壓過零處出現負電壓，這可進而防止電流從來源接腳回流。BYPASS 電容器 C8 會內部供電給 U1，在啓動期間於 MOSFET 關閉期間透過汲極充電，以改善效率。進行調光操作時，於透過 D6 整流和 C9 濾波進行能量放電操作期間，會透過電感器的額外輔助繞組供電。IC 的內部限電流和自動重新啓動可防止發生輸出過載和短路。

4.4 輸出回授

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 (由偏壓繞組和主繞組之間的圈數比設定)。電阻 R12 和 R34 會將偏壓電壓轉換成電流，再將該電流饋送至 U1 的回授接腳 (FB)。U1 的內部引擎會結合 FB 接腳電流、電壓監測器 (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。電阻器 R23 的功能是限制整流期間的電壓振盪，以協助進行線電壓和負載調節。

4.5 負載中斷保護

當供電給電路板，輸出端卻沒有連接負載時，輸出電容器將提供過壓保護。這情況常發生在生產測試線。一旦因爲零負載情況而發生過壓，偏壓繞組電壓將上升，而 VR3 將會觸發 Q5 將 FB 接腳電流拉至低於 $I_{FB(AR)}$ 臨界值點。設備將進入自動重新啓動模式，以限制輸出電壓升至超出輸出電容器電壓額定值，藉此防止其因爲過壓而排放。

4.6 主動式準相位偵測負載

爲了使用主動式準相位偵測負載達到良好的調光和高調光比，可以對應調光特性。在非調光操作期間，PI 專利主動式準相位負載電路 (R21、R19、R39、R20、R28、R37、R38、D5、Q9、Q6 和 Q4) 不是主動模式 (非耗散)，以維持高效率。從峰值偵測電路進行調光期間，以及切換模式轉換器的有效操作期間，它會線性啓用在低於 70º 導通角。會線性施加偏壓於電晶體 Q9 和 Q6，以透過 R21 將功率損失共用至輸出電流補償量。最大補償是完全施加偏壓於 Q9 和 Q6 時，以及電阻器 R21 限制電流時。

4.7 熱輸出電流回疊

此參考設計採用選用電路，來啓動過熱限流保護，以擴大環境工作溫度，防止到達過熱保護臨界值。此電路由熱敏電阻 RT1、R48、R33、R40、Q8 和 VR1 組成。Q8 的集極會減弱來自 U1 的 FB 接腳的部分電流，以降低 LED 驅動器的輸出電流。降低電流量與 LED 驅動器的內部環境溫度成正比。當內部溫度升高，降低電流量會增加，藉此減少輸出電流。如果 R33 是 11 k□，則此電流共用會在 U1 約 110°C 時啓動。請根據最終系統設計所需的臨界值，調整此值。

5 PCB 佈局和外形

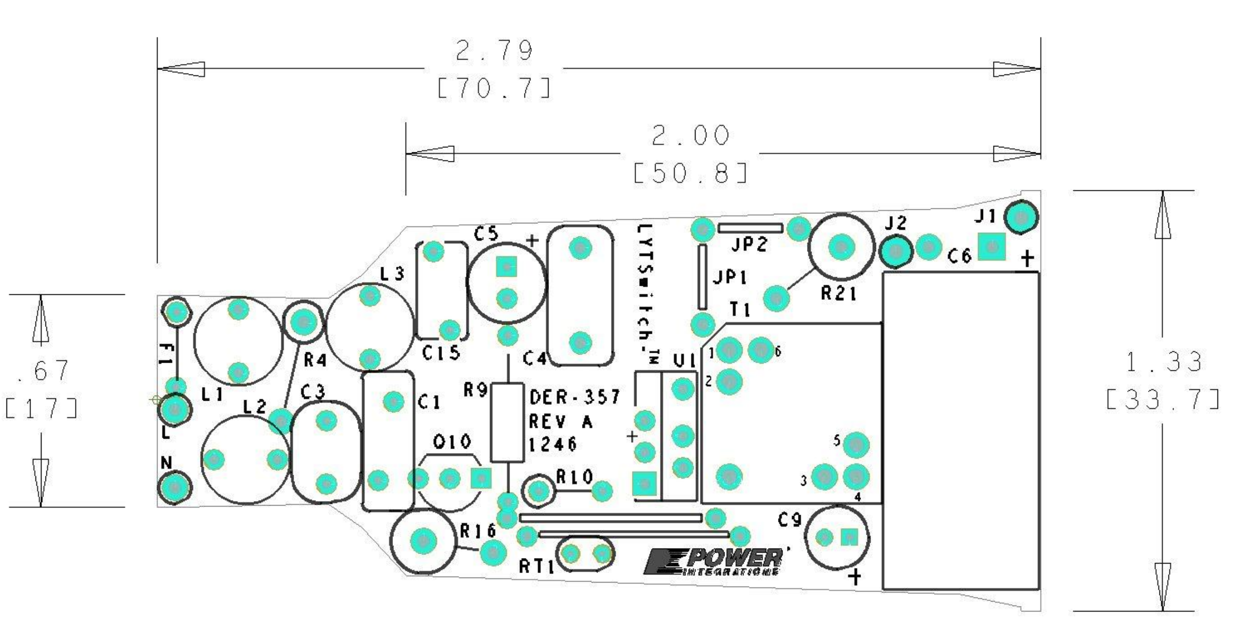

Figure 3 – Top Printed Circuit Layout.

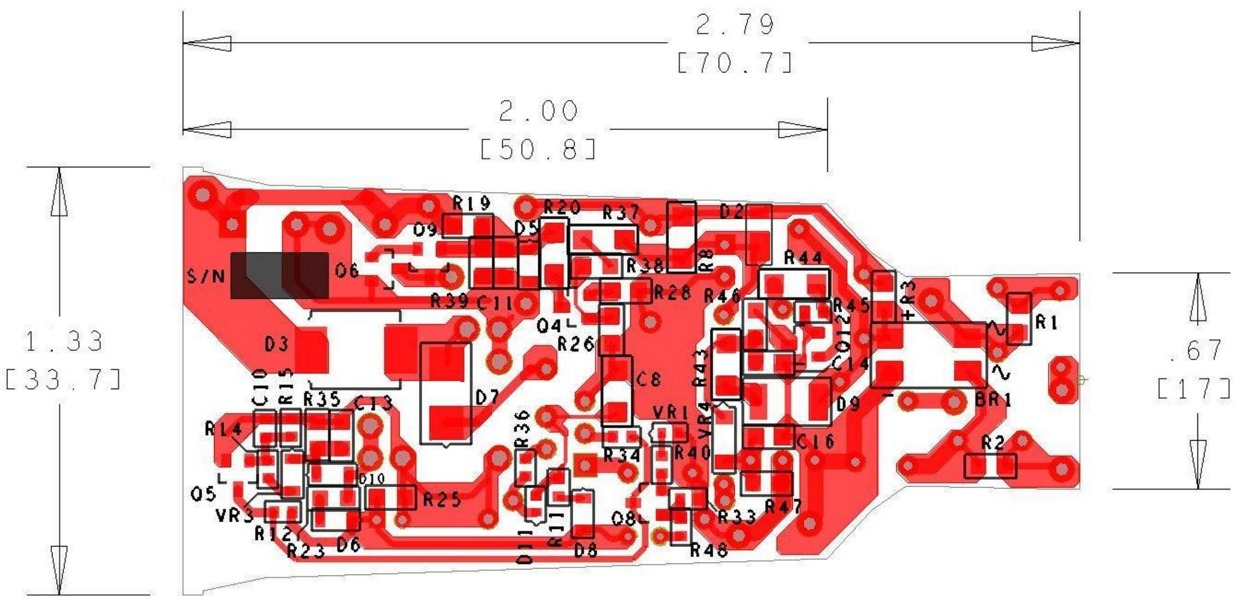

Figure 4 – Bottom Printed Circuit Layout.

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6 植入的 PCB

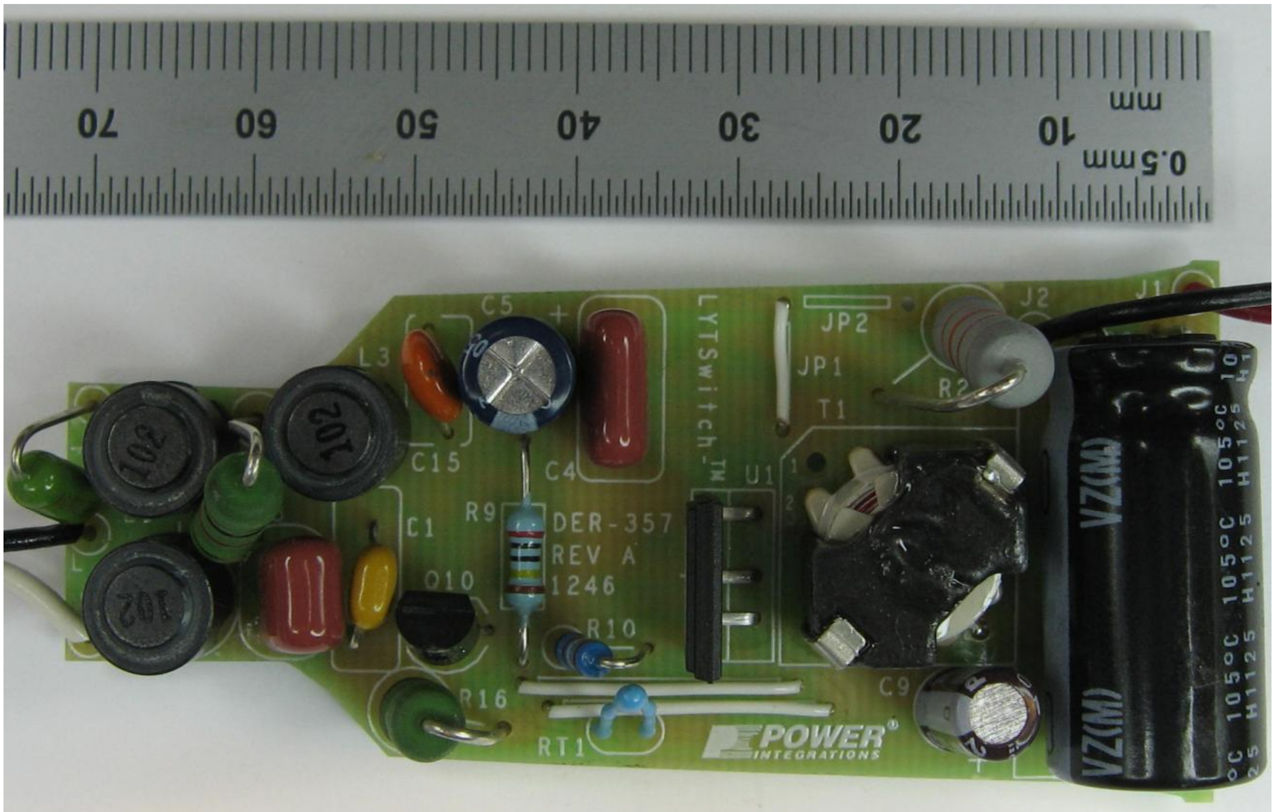

Figure 5 – Populated Circuit Board (Top Side) Board Height: 20 mm.

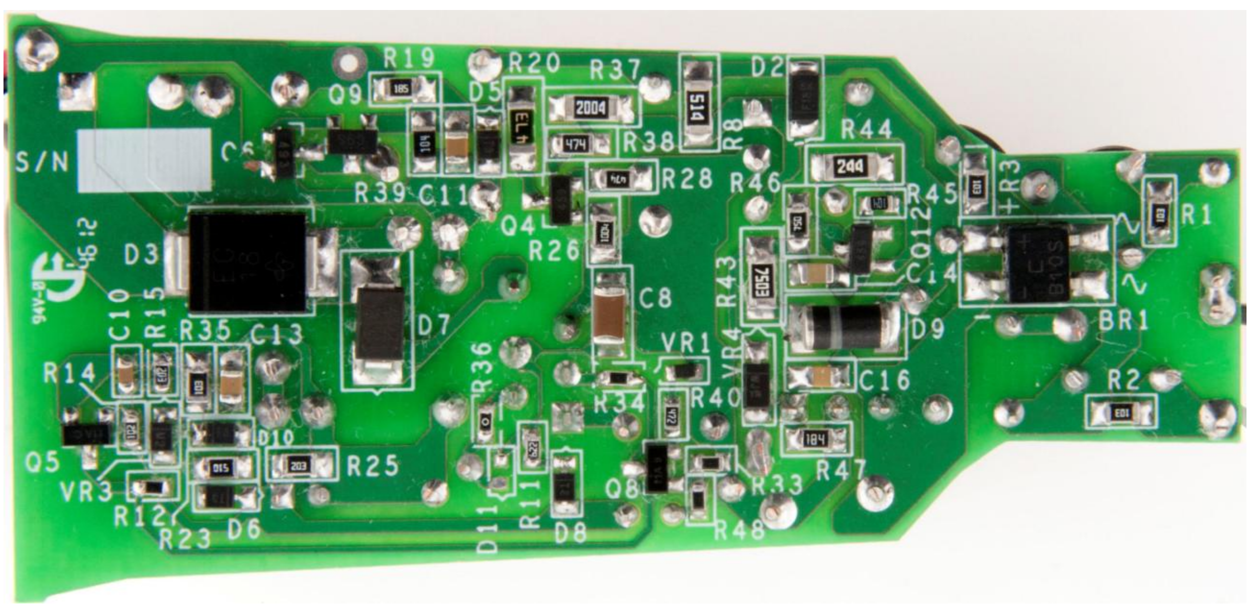

Figure 6 – Populated Circuit Board (Bottom Side).

7 物料清單

The table below is the reference design BOM.

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	1	C1	33 nF, 400 V, film	ECQ-E4333KF	Panasonic
3	1	C3	100 nF, 250 V, Film	ECQ-E2104KB	Panasonic
4	1	C4	180 nF, 250 V, Film	ECQ-E2184KB	Panasonic
5	1	C5	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
6	1	C6	3300 μF, 100 V, Electrolytic, (12.5 x 25)	UVZ2A331MHD	Nichicon
7	1	C8	100 μF, 10 V, Ceramic, X5R, 1206	C3216X5R1A107M	TDK
8	1	C9	22 μF, 50 V, Electrolytic, (5 x 11)	UPW1H220MDD	Nichicon
9	1	C10	100 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H104K	TDK
10	2	C11 C13	1 μF, 50 V, Ceramic, X5R, 0805	08055D105KAT2A	AVX
11	1	C14	100 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB104	Yageo
12	1	C15	100 pF, 1 kV, Disc Ceramic	562R5GAT10	Vishay
13	1	C16	1.2 nF, 50 V, Ceramic, X7R, 0805	08055C122KAT2A	AVX
14	1	D2	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
15	1	D3	DIODE ULTRA FAST 400 V 3 A, DO-214AB	ES3G-E3/57T	Vishay
16	4	D5 D6 D8 D10	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
17	1	D7	100 V, 2 A, Schottky, SMA	STPS2H100AY	ST Micro
18	1	D9	100 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)	DL4002-13-F	Diodes Inc
19	1	F1	Fuse, Pico, 2 A, 250V,Fast, Axial	0263002.MXL	Littlefuse Inc.
20	3	L1 L2 L3	1 mH, 0.23 A, Ferrite Core	CTSCH875DF-102K	CT Parts
21	2	Q4 Q12	NPN, Small Signal BJT, 450 V, 0.5 A, 150 MA, SOT-23	FMMT459TA	Diodes, Inc.
22	2	Q5 Q8	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semi
23	1	Q6	NPN, 100 V, 1000 Ma, SOT23-3	FMMT493TA	Diodes, Inc.
24	1	Q9	NPN, 100 V, 20 Ma, SOT23-3	DSC2C01S0L	Panasonic
25	1	Q10	450 V, 0.6 A, 3.8 Ω, N-Channel, TO-92	STQ3N45K3-AP	ST Micro
26	4	R1 R2 R3 R35	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
27	1	R4	1.0 kΩ, 5%, 2 W, Metal Oxide	RSMF2JT1K00	Stackpole
28	1	R8	510 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ514V	Panasonic
29	1	R9	2.00 MΩ, 1%, 1/4 W, Metal Film	RNF14FTD2M00	Stackpole
30	1	R10	24.9 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-24K9	Yageo
31	1	R11	6.2 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ622V	Panasonic
32	1	R12	20 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2002V	Panasonic
33	1	R14	1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
34	1	R15	20 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ203V	Panasonic
35	1	R16	100 Ω, 5%, 2 W, Metal Oxide	RSMF2JT100R	Stackpole
36	1	R19	1.8 M, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ185V	Panasonic
37	1	R20	47 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ473V	Panasonic
38	1	R21	3.3 kΩ, 5%, 2 W, Metal Oxide	RSF200JB-3K3	Yageo
39	1	R23	51 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ510V	Panasonic
40	1	R25	20 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ203V	Panasonic
41	1	R26	1 MΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1004V	Panasonic
42	2	R28 R38	470 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ474V	Panasonic
43	1	R33	3.48 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3481V	Panasonic

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Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
44	1	R34	150 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1503V	Panasonic
45	1	R37	2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
46	1	R39	100 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ104V	Panasonic
47	1	R40	4.7 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ472V	Panasonic
48	1	R43	750 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF7503V	Panasonic
49	1	R44	240 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ244V	Panasonic
50	1	R45	100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
51	1	R46	75 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ750V	Panasonic
52	1	R47	180 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ184V	Panasonic
53	1	R48	4.75 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF4751V	Panasonic
54	1	RT1	NTC Thermistor, 100 k Ohms, 0.00046 A	NTSD0WF104EE1B0	Murata
55	1	T1	Bobbin, RM5, Vertical, 4 pins	Custom made	Custom
56	1	U1	LYTSwitch, eSIP-7C	LYT4313E	Power Integrations
57	1	VR1	10.0 V, 5%, 150 mW, SOD-323	DZ2S100ML	Panasonic
58	1	VR3	33 V, 5%, 200 mW, SOD-323	MMSZ5257BS-7-F	Diodes, Inc.
59	1	VR4	15 V, 5%, 500 mW, SOD-123	BZT52C15-7-F	ON Semi

8 電感器規格

8.1 電氣圖

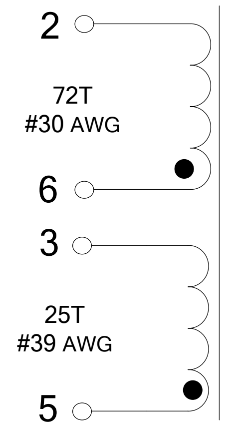

Figure 7 – Transformer Electrical Diagram.

8.2 電氣規格

Primary Inductance	Pins 2-6, all other windings open, measured at 100 kHz, 0.4 V_{RMS}	450 µH ±7%

8.3 材料

Item	Description
[1]	Core: RM5.
[2]	Bobbin: RM-5; 2/2 Pin Vertical.
[3]	Magnet Wire: #30 AWG.
[4]	Magnet Wire: #39 AWG.
[5]	Transformer Tape 4.8 mm.
[6]	Core Clip.

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8.4 電感器建構圖

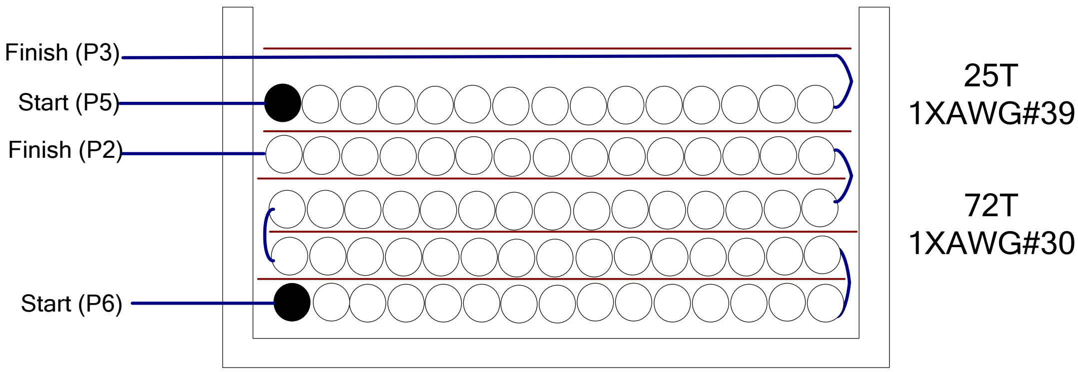

Figure 8 – Transformer Build Diagram.

8.5 電感器結構

Bobbin Preparation	For the purpose of these instructions, the bobbin is oriented on a winder such that pin 1 side is on the left. Winding direction is counter-clockwise. For 2/2 bobbin, follow the pin number assignment in the specification.
WDG 1	Start at pin 6. Wind 72 turns of item [3] and terminate at pin 1. Note that there is one turn of transformer tape item [5] per layer.
Insulation	Add 1 layer of tape of item [5].
WDG 2	Start at pin 5. Wind 25 turns of item [4] and terminate at pin 3.
Taping	Add 1 layer of tape to secure the winding.
Final Assembly	Grind the core to get the specified inductance. Secure the core with a clip item [6].

9 電感器設計試算表

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		90	V	Minimum AC Input Voltage
VACMAX	132		132	V	Maximum AC input voltage
fL	60		60	Hz	AC Mains Frequency
VO	72.00		72	V	Typical output voltage of LED string at full load
VO_MAX			79.20	V	Maximum expected LED string Voltage.
VO_MIN			64.80	V	Minimum expected LED string Voltage.
V_OVP			87.12	V	Over-voltage protection setpoint
IO	0.17		0.17	A	Typical full load LED current
PO			12.2	W	Output Power
n	0.85		0.85		Estimated efficiency of operation
VB			25	V	Bias Voltage
ENTER LYTSwitch VARIABLES					
LYTSwitch	**LYT4313**		**LYT4313**		Selected LYTSwitch
Current Limit Mode	**RED**		**RED**		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			1.00	A	Minimum current limit
ILIMITMAX			1.16	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	2.00		2	M-ohms	Upper V pin resistor
RV2			1E+012	M-ohms	Lower V pin resistor
IFB	144.00		144.0	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1			152.8	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	0.95		0.95		Ripple to Peak Current Ratio (For PF > 0.9, 0.4 < KP < 0.9)
LP			448	uH	Primary Inductance
VOR	72.00		72	V	Reflected Output Voltage.
Expected IO (average)			0.16	A	Expected Average Output Current
KP_VACMAX			1.04		Expected ripple current ratio at VACMAX
TON_MIN			1.54	us	Minimum on time at maximum AC input voltage
PCLAMP			0.10	W	Estimated dissipation in primary clamp
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**RM5**		**RM5**		
Bobbin			RM5S_BOBBIN	P/N:	
AE	0.2400		0.24	cm^2	Core Effective Cross Sectional Area
LE	2.3200		2.32	cm	Core Effective Path Length

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AL	1700.0	1700	nH/T^2	Ungapped Core Effective Inductance
BW	4.8	4.8	mm	Bobbin Physical Winding Width
M	0.0	0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	4.00	4		Number of Primary Layers
NS	73	73		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		0.38		Minimum duty cycle at peak of VACMIN
IAVG		0.15	A	Average Primary Current
IP		0.92	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS		0.26	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS				
LP		448	uH	Primary Inductance
LP_TOL	10	10		Tolerance of primary inductance
NP		72		Primary Winding Number of Turns
NB		26		Bias Winding Number of Turns
ALG		85	nH/T^2	Gapped Core Effective Inductance
BM		2376	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP		2875	Gauss	Peak Flux Density (BP<3700)
BAC		1129	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur		1308		Relative Permeability of Ungapped Core
LG		0.34	mm	Gap Length (Lg > 0.1 mm)
BWE		19.2	mm	Effective Bobbin Width
OD		0.26	mm	Maximum Primary Wire Diameter including insulation
INS		0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA		0.22	mm	Bare conductor diameter
AWG		32	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM		64	Cmils	Bare conductor effective area in circular mils
CMA		248	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 600)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)				
Lumped parameters				
ISP		0.92	A	Peak Secondary Current
ISRMS		0.30	A	Secondary RMS Current
IRIPPLE		0.25	A	Output Capacitor RMS Ripple Current
CMS		60	Cmils	Secondary Bare Conductor minimum circular mils
AWGS		32	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS		0.20	mm	Secondary Minimum Bare Conductor Diameter
ODS		0.07	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
VOLTAGE STRESS PARAMETERS				
VDRAIN		341	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance)
PIVS		275	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
PIVB		97	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	0.17	A	Measured Output Current at VAC1
IO_VAC2	0.17	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	153	k-ohms	Upper FB Pin Resistor Value
RFB2	1E+012	k-ohms	Lower FB Pin Resistor Value
VB1	22.4	V	Test Bias Voltage Condition1
VB2	27.6	V	Test Bias Voltage Condition2
IO1	0.17	A	Measured Output Current at Vb1
IO2	0.17	A	Measured Output Current at Vb2
RFB1 (new)	152.8	k-ohms	New RFB1
RFB2(new)	1.00E+12	k-ohms	New RFB2
Input Current Harmonic Analysis			
Harmonic	Max Current (mA)	Limit (mA)	
1st Harmonic			
3rd Harmonic	22.25	533.12	PASS. 3rd Harmonic current content is lower than the limit
5th Harmonic	20.4	297.92	PASS. 5th Harmonic current content is lower than the limit
7th Harmonic	19.3	156.80	PASS. 7th Harmonic current content is lower than the limit
9th Harmonic	15.18	78.40	PASS. 9th Harmonic current content is lower than the limit
11th Harmonic	9.43	54.88	PASS. 11th Harmonic current content is lower than the limit
13th Harmonic	4.48	46.43	PASS. 13th Harmonic current content is lower than the limit
15th Harmonic	2.75	40.23	PASS. 15th Harmonic current content is lower than the limit
THD	38.3	%	Estimated total Harmonic Distortion (THD)

Table 1 – Sample Spreadsheet Calculation.

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10 效能資料

All measurements performed at 25 ºC room temperature, 60 Hz input frequency unless otherwise specified.

Input		Input Measurement					LED Load Measurement			% Reg	Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)		
90	60	90.10	150.17	13.262	0.980	19.35	68.88	166.60	11.49	-2.00	86.60
100	60	100.13	135.81	13.268	0.976	21.17	68.90	167.96	11.58	-1.20	87.30
110	60	110.15	124.88	13.330	0.969	23.64	68.94	169.93	11.73	-0.04	87.96
120	60	120.15	115.31	13.371	0.965	24.61	68.97	171.39	11.83	0.82	88.48
132	60	132.17	105.68	13.425	0.961	25.07	69.00	172.58	11.92	1.52	88.77
90	60	90.10	157.34	13.899	0.980	19.28	72.00	166.04	11.97	-2.33	86.09
100	60	100.12	142.06	13.893	0.977	20.77	72.04	167.73	12.09	-1.34	87.04
110	60	110.15	130.66	13.957	0.970	23.49	72.08	169.86	12.25	-0.08	87.79
120	60	120.16	120.71	14.008	0.966	24.56	72.11	171.17	12.35	0.69	88.19
132	60	132.18	110.65	14.075	0.962	24.87	72.15	173.14	12.50	1.85	88.82
90	60	90.10	164.53	14.540	0.981	19.15	75.00	165.93	12.46	-2.39	85.66
100	60	100.12	148.26	14.509	0.977	20.5	75.03	167.29	12.56	-1.59	86.57
110	60	110.15	136.27	14.568	0.971	23.34	75.08	169.47	12.73	-0.31	87.40
120	60	120.16	125.99	14.630	0.966	24.51	75.13	171.56	12.90	0.92	88.16
132	60	132.18	115.53	14.711	0.963	24.73	75.17	173.37	13.04	1.98	88.65

Table 2 – Test Result Summary for this Design.

10.1 工作模式效率

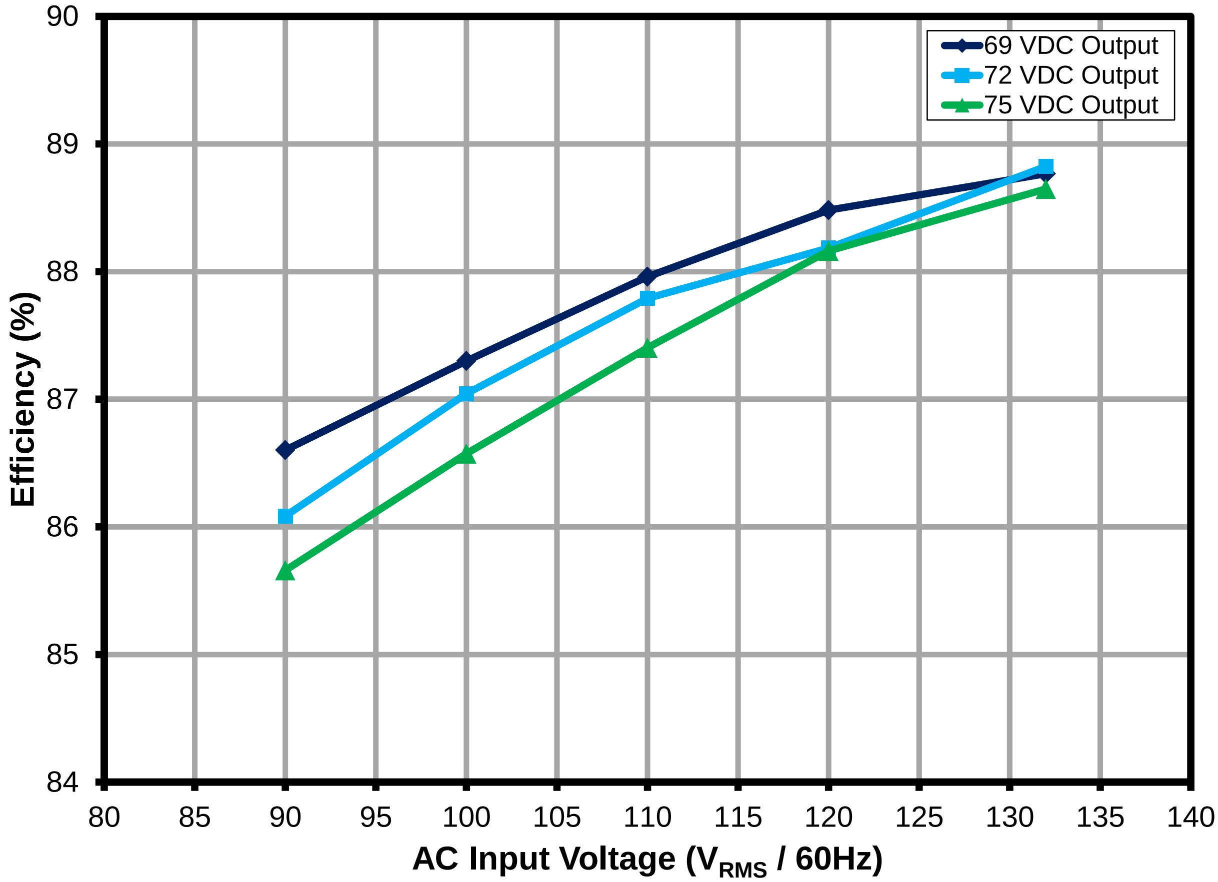

Figure 9 – Efficiency with Respect to AC Input Voltage.

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10.2 線電壓調節

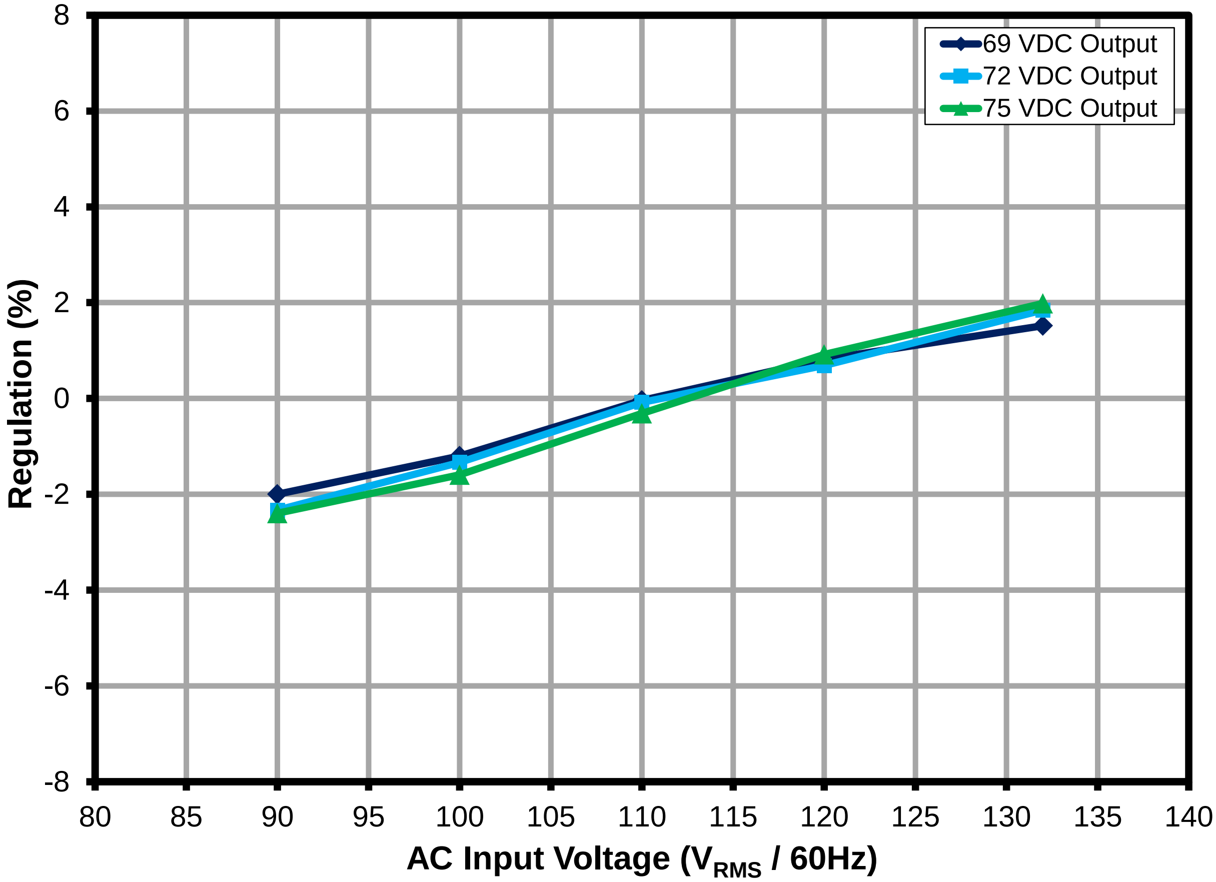

Figure 10 – Line Regulation, Room Temperature.

10.3 功率因數

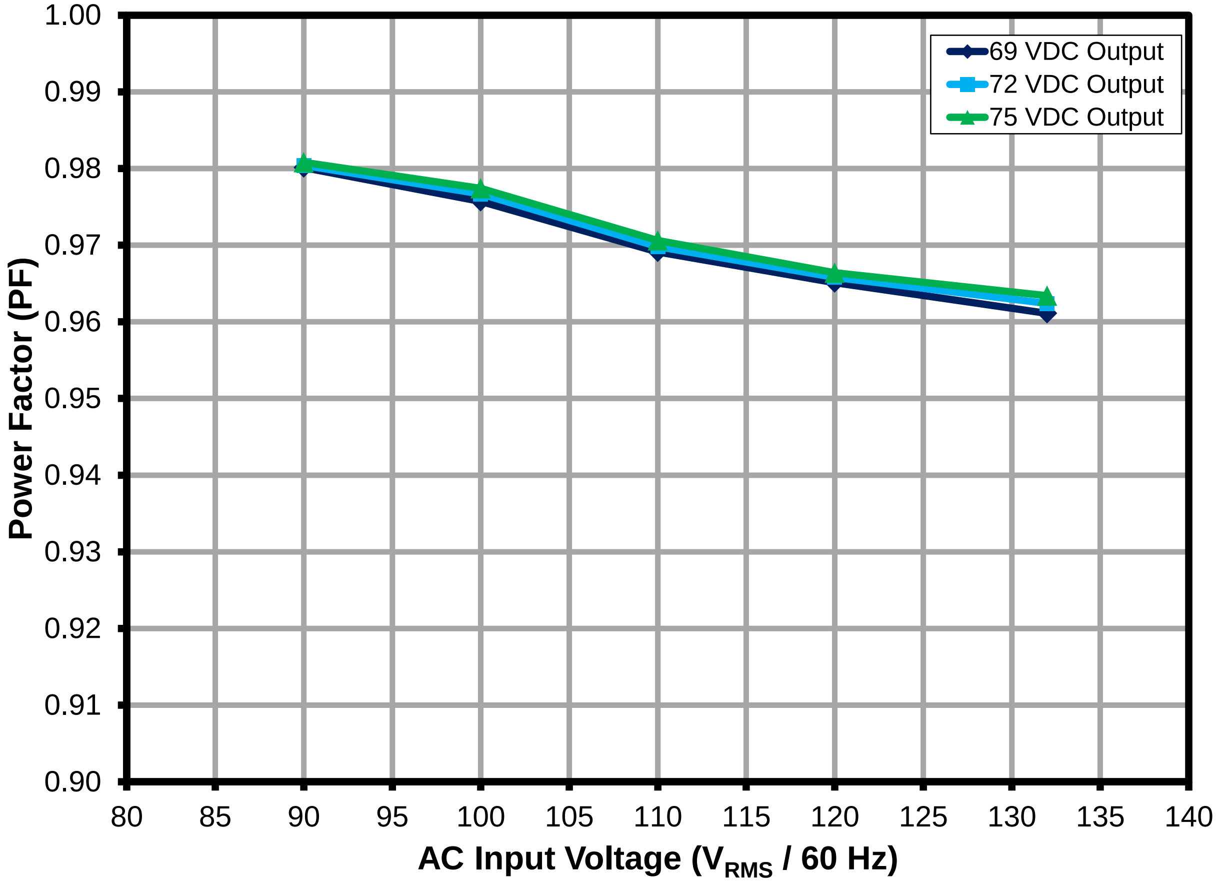

Figure 11 – High Power Factor within the Operating Range.

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10.4 %THD

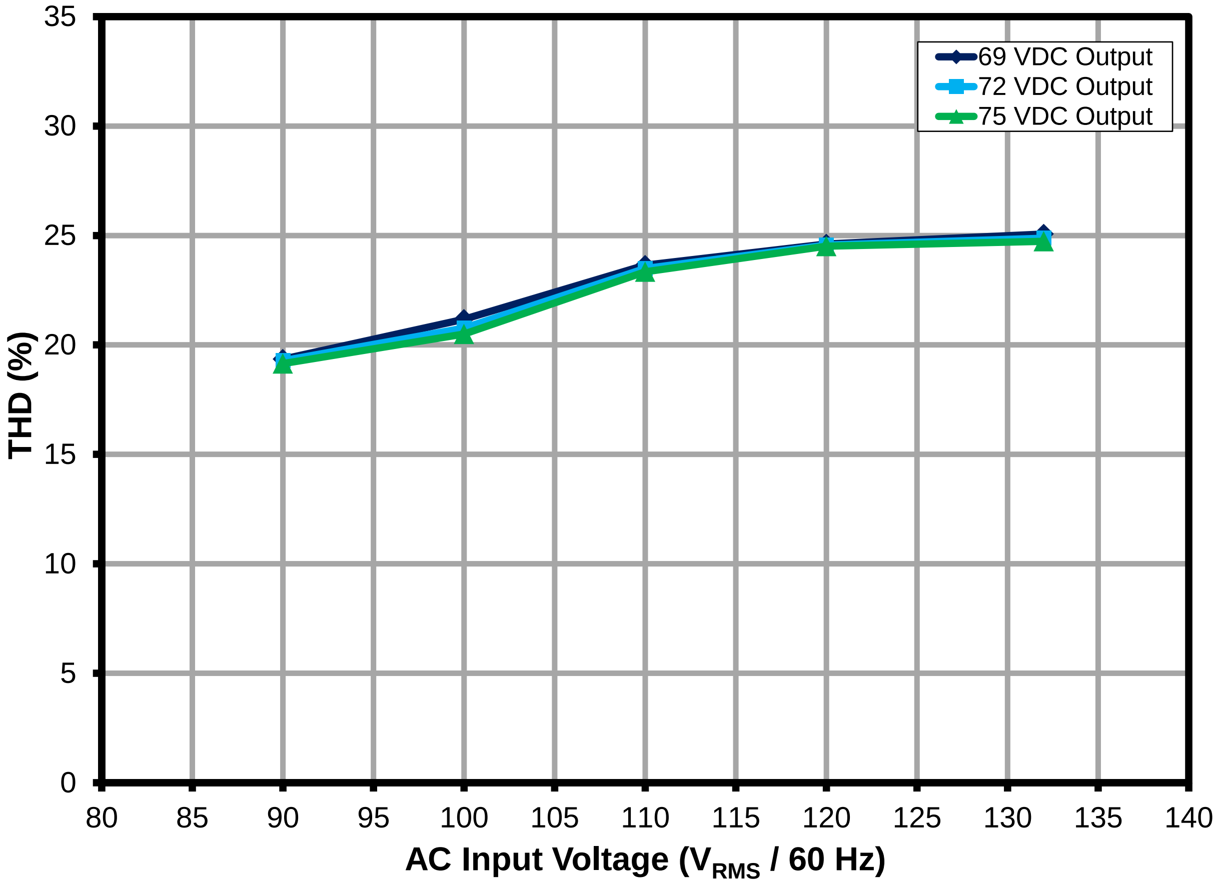

Figure 12 – Very Low %THD at 120 VAC.

10.5 諧波含量

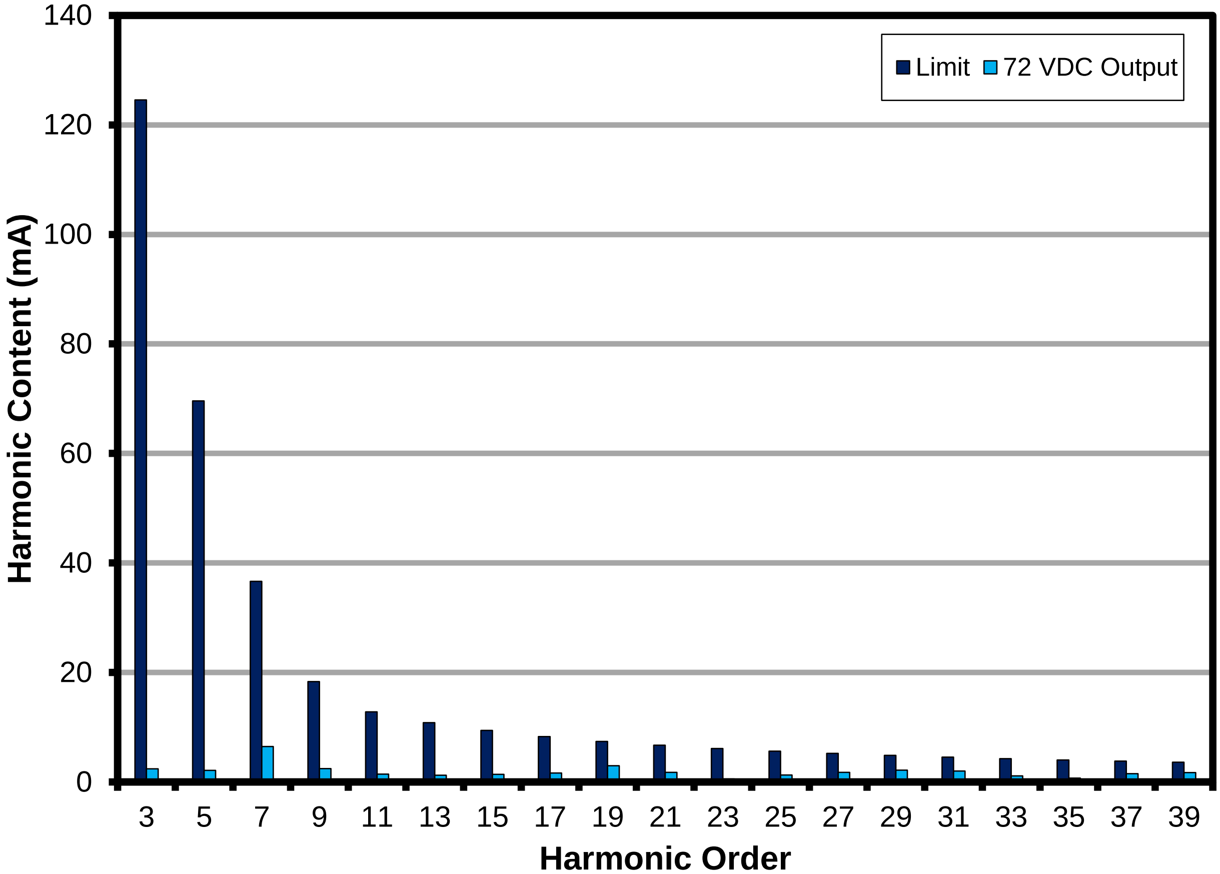

Figure 13 – Meets EN61000-3-2 Harmonics Contents Standards for <25 W Rating for 72 V LED Output.

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10.6 諧波測量

VAC (V_{RMS})	Freq (Hz)	I (mA)	P	PF
120	60.00	45.91	9.6660	0.9139
nth Order	**mA Content**	**% Content**	**Limit (mA) <25 W**	**Remarks**
1	151.10			
2	0.19	0.13%		
3	2.42	1.60%	124.5692	**Pass**
5	2.14	1.42%	69.6122	**Pass**
7	6.49	4.30%	36.6380	**Pass**
9	2.46	1.63%	18.3190	**Pass**
11	1.43	0.95%	12.8233	**Pass**
13	1.24	0.82%	10.8505	**Pass**
15	1.40	0.93%	9.4038	**Pass**
17	1.65	1.09%	8.2974	**Pass**
19	2.99	1.98%	7.4240	**Pass**
21	1.75	1.16%	6.7170	**Pass**
23	0.57	0.38%	6.1329	**Pass**
25	1.28	0.85%	5.6423	**Pass**
27	1.77	1.17%	5.2243	**Pass**
29	2.17	1.44%	4.8640	**Pass**
31	2.01	1.33%	4.5502	**Pass**
33	1.13	0.75%	4.2744	**Pass**
35	0.71	0.47%	4.0302	**Pass**
37	1.51	1.00%	3.8123	**Pass**
39	1.74	1.15%	3.6168	**Pass**
41	1.61	1.07%		
43	1.15	0.76%		
45	1.07	0.71%		
47	1.43	0.95%		
49	1.24	0.82%		

Table 3 – 120 VAC Input Current Harmonic Measurement for 72 V LED.

10.7 調光特性

Dimming characteristic from a controlled AC supply to emulate the TRIAC conduction pattern. The reference design meets the dimming requirement as set by National Electrical Manufacturers Association (NEMA) Standards Publication SSL 1-2010 (Electronic Drivers for LED Devices, Arrays or Systems) and SSL 6-2010 (Solid Light Lighting for Incandescent Replacement-Dimming).

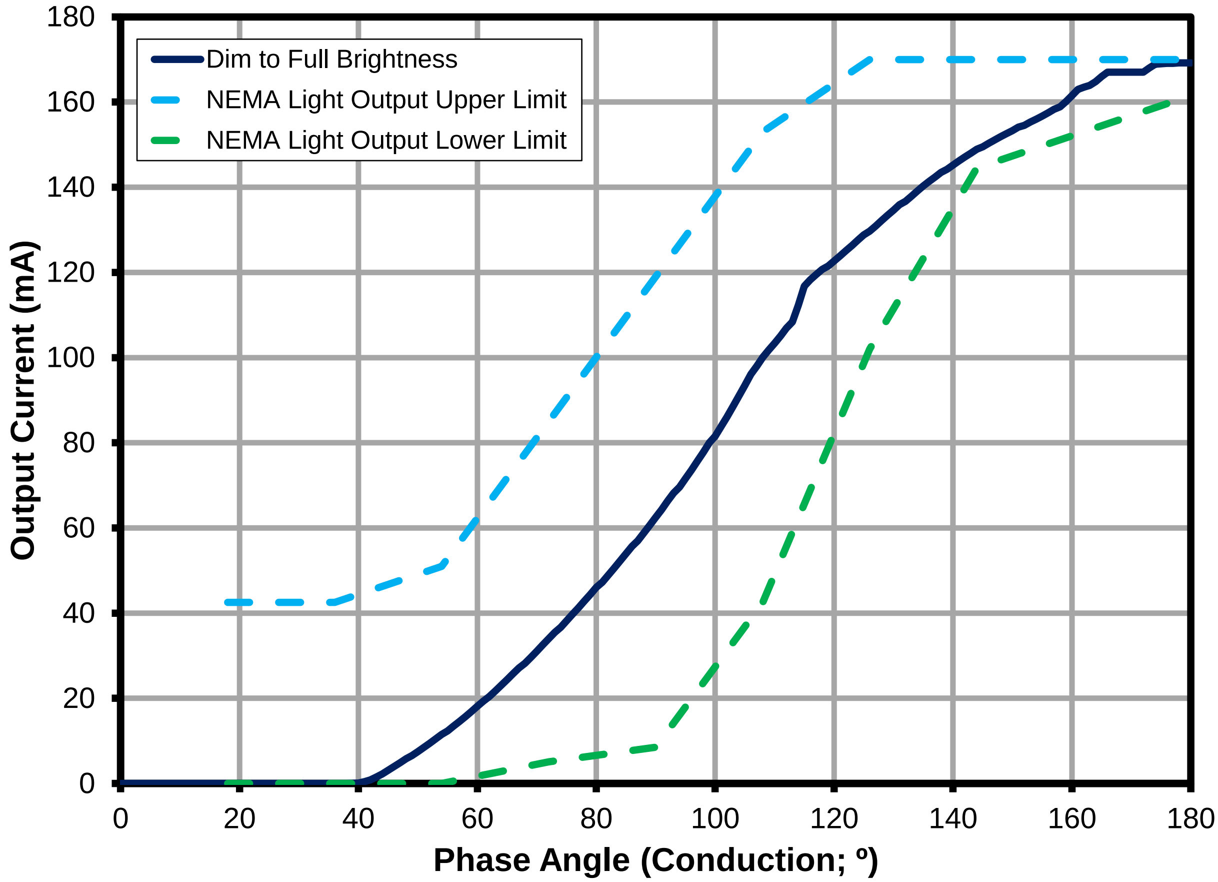

Figure 14 – Dimming Curve Characteristic from Full Dimming to Full Brightness. Meets NEMA SSL 6-2010.

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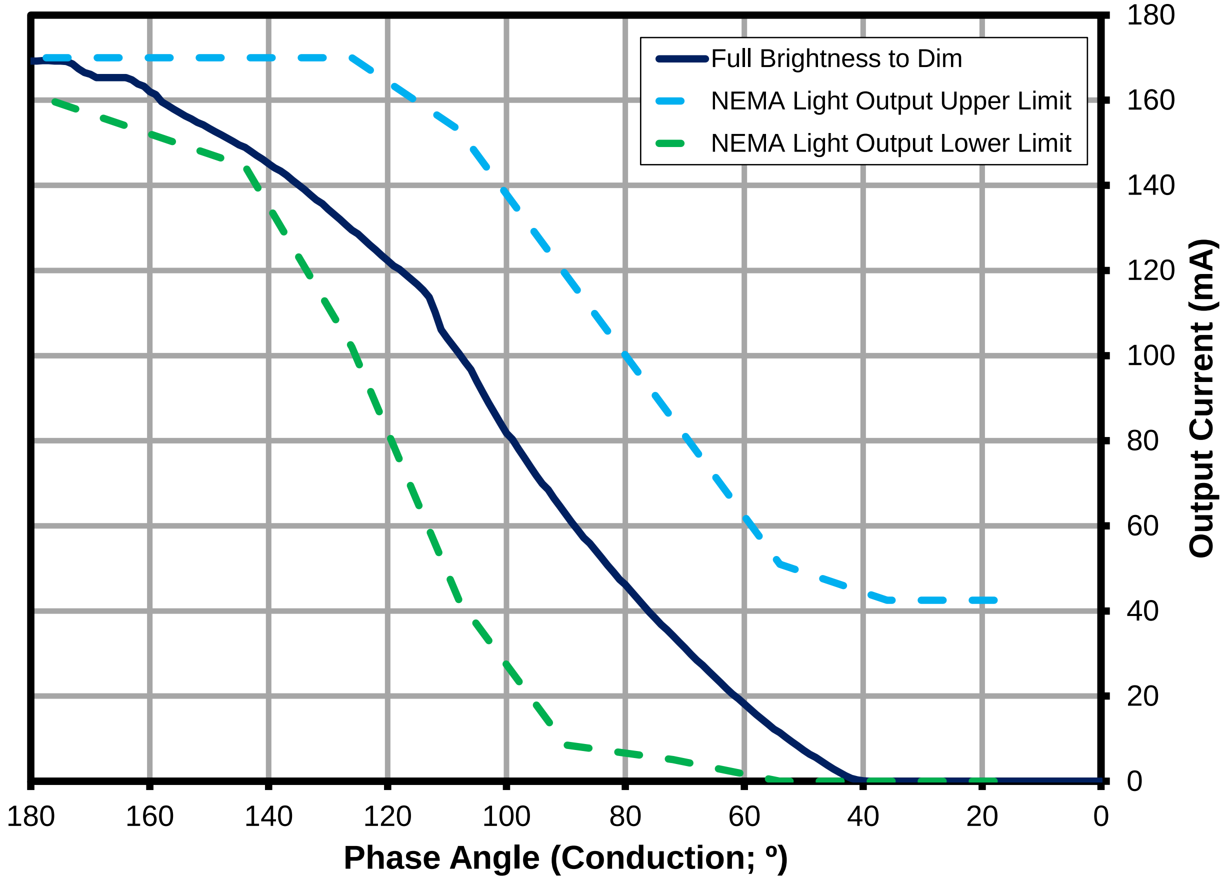

Figure 15 – Dimming Characteristic from Full Brightness to Full Dimming. Meets NEMA SSL 6-2010.

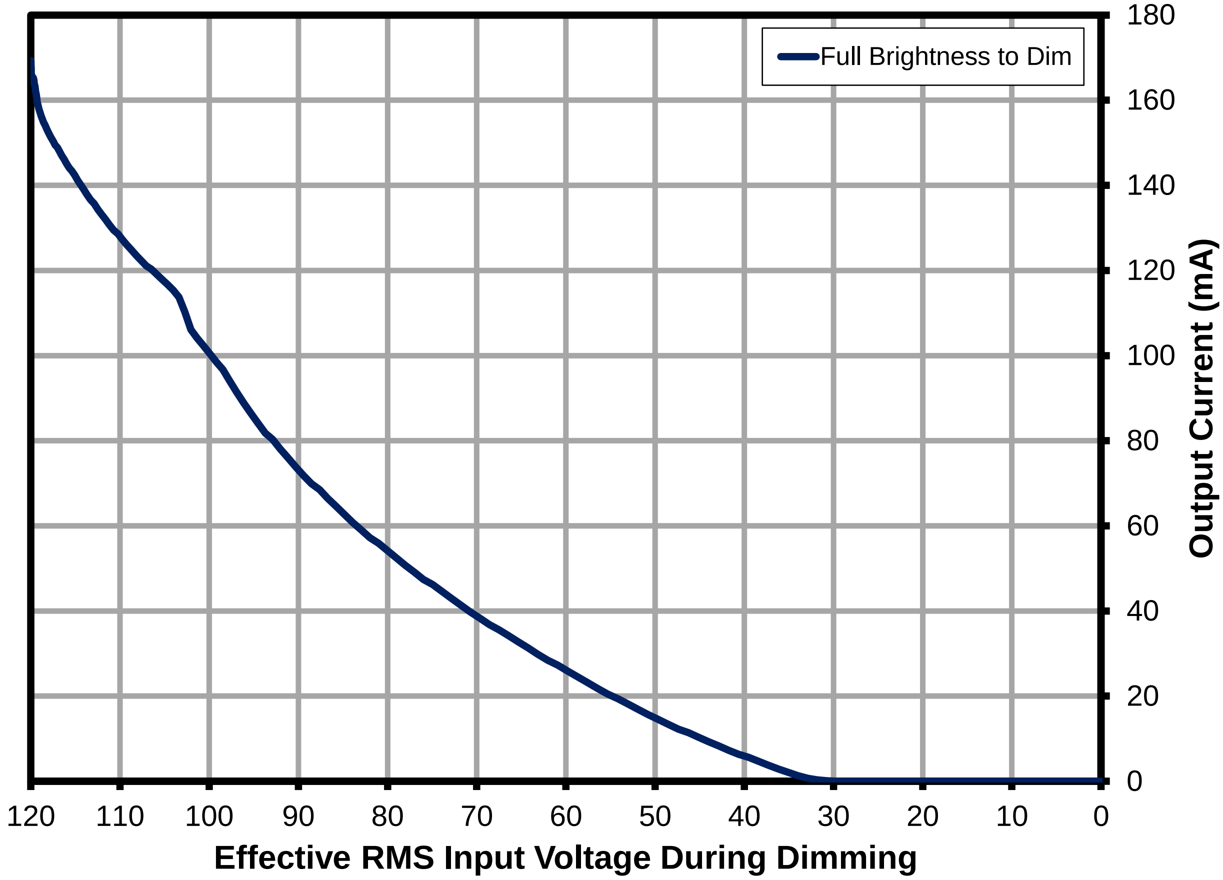

Figure 16 – Dimming Characteristic with Respect to RMS Input Voltage During Dimming.

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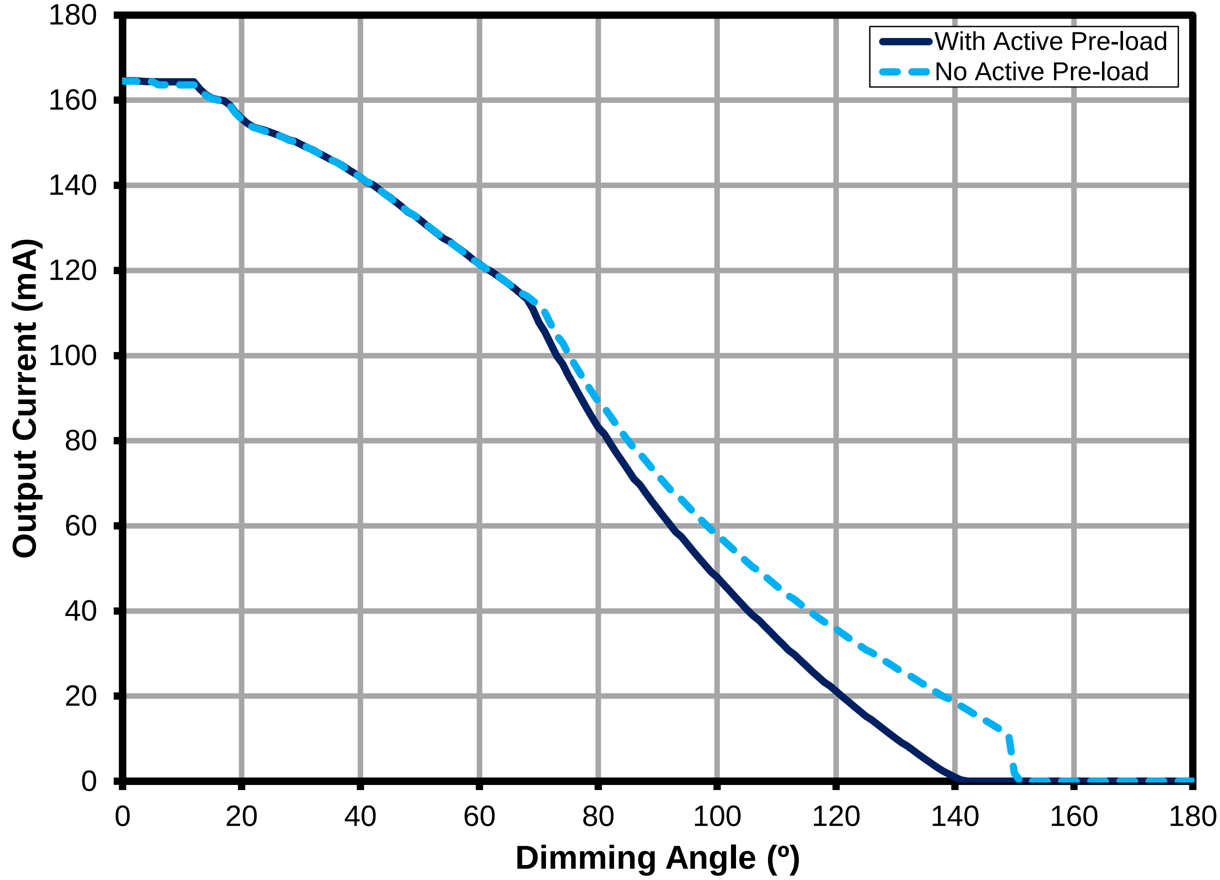

Figure 17 – Dimming Curve Comparison with and without Preload with Respect to Dimming Angle.

10.8 設備與調光器之間的相容性

These are the list of dimmers verified for this reference design. Users are not limited on the following list. Make sure to test the dimmers according to its recommended operating line input frequency to avoid flicker.

Dimmer	Dimmer Brand	Power	Part Number	I_{MIN} (mA)	I_{MAX} (mA)	Dim Ratio
1	LUTRON	600W	LG-600PH-WH	0	145	1450
2	LUTRON	600W	S-603P-WH	0	146	1460
3	LUTRON	600W	SLV600P-WH	0	148	1480
4	LUTRON	600W	S-600-WH	0	157	1570
5	LUTRON	600W	S-600PH-WH	0	146	1460
6	LUTRON	600W	DVWCL-153-PLH-WH	2	141	71
7	LUTRON	600W	DV-603P-WH	0	145	1450
8	LUTRON	600W	DV-600P-WH	0	145	1450
9	LUTRON	600W	TG-600PH-WH	2	150	75
10	LUTRON	600W	Q-600P-WH aka FA-600	0	147	1470
11	LUTRON	600W	AY-600P-WH	3	148	49
12	LUTRON	600W	GL-600P-WH	0	146	1460
13	LEVITON	600W	R62-06633-1LW	0	167	1670
14	LEVITON	600W	R62-06631-1LW	0	152	1520
15	LEVITON	600W	R60-IPI06-1LM	5	163	33
16	LEVITON	500W	R52-06161-00W	0	147	1470
17	LEVITON	600W	R52-RPI06-1LW	0	168	1680
18	LEVITON	600W	R60-06681-0IW	0	150	1500
19	LEVITON	1KVA	TGM10-1LW	0	143	1430
20	LEVITON	600W	R60-06684-1IW	0	167	1670
21	LEVITON	600W	6683	0	168	1680
22	LEVITON	450W	R02-06613-PLW	0	167	1670
23	COOPER		SLC03P-W-K-L	0	150	1500
24	LUTRON	600W	GL-600-WH	0	157	1570
25	LUTRON	200W	DVPDC-203P-WH	32	154	5
26	LUTRON	500W	LX-600PL-wh	0	153	1530
27	LUTRON	600W	D-600P-WH	0	141	1410
28	LUTRON	600W	CTCL-153PDH	0	142	1420
29	LUTRON	600W	S-600P	0	146	1460
30	LUTRON		TGLV-600P	0	151	1510
31	LUTRON	450W	TGLV-600PR	0	148	1480
32	LUTRON	300W	TT-300NLH-WH	0	160	1600
33	LUTRON	300W	TT-300H-WH	0	160	1600
34	LUTRON	800W	NLV-1000-WH	0	150	1500
35	LUTRON		MAELV -600	2	164	82
36	LUTRON		S-600P	0	154	1540
37	LUTRON		S-600P	0	166	1660
38	COOPER		S106P	0	164	1640
39	LUTRON	1000	S-103P-WH	4	156	39
40	LUTRON	1000	S-10P-WH	0	153	1530

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Dimmer	Dimmer Brand	Power	Part Number	I_{MIN} (mA)	I_{MAX} (mA)	Dim Ratio
41	LUTRON	600	S-600PNLH-WH	0	157	1570
42	LUTRON	600	S-603PNL-WH	0	157	1570
43	LUTRON	600	SLV-603P-WH	0	156	1560
44	LUTRON	600	S-603PGH-WH	0	130	1300
45	LUTRON	600	AYLV-600P-WH	0	157	1570
46	LUTRON	600	AYLV-603P-WH	0	154	1540
47	LUTRON	1000	AY-103PNL-WH	2	162	81
48	LUTRON	1000	AY-103P-WH	1	163	163
49	LUTRON	1000	AY-10PNL-WH	0	174	1740
50	LUTRON	1000	AY-10P-WH	0	163	1630
51	LUTRON	600	AY-603PNL-WH	0	149	1490
52	LUTRON	600	AY-603PG-WH	1	123	123
53	LUTRON	600	AY-603P-WH	4	153	38
54	LUTRON	600	AY-600PNL-WH	0	156	1560
55	LUTRON	300	DVELV-300P-WH	0	153	1530
56	LUTRON	1000	DVLV-10P-WH	0	144	1440
57	LUTRON	1000	DVLV-103P-WH	0	145	1450
58	LUTRON	600	DVLV-603P-WH	0	146	1460
59	LUTRON	1000	S-1000-WH	0	156	1560
60	LUTRON	300	SELV-300P-WH	0	149	1490
61	LUTRON	600	S-600P-WH	0	145	1450
62	LUTRON	1000	S-103PNL-WH	2	144	72
63	LUTRON		SPSELV-600-WH	1	153	153
64	LUTRON	600	GLV-600-WH	0	156	1560
65	LUTRON		LG-603PGH-WH	0	130	1300
66	LUTRON		DVW-603PGH-WH	0	129	1290
67	LEVITON		VPI06	0	158	1580
68	LUTRON		TG-10PR-WH	8	163	20
69	LUTRON		NT-600	0	166	1660
70	LUTRON		NT-1000	0	167	1670
71	LUTRON		LGCL-153PLH-WH	14	150	11
72	LUTRON		CTCL-153PDH-WH	4	151	38
73	LUTRON		TGCL-153PH-WH	5	148	30
74	LUTRON		DVWCL-153PH-LA	6	152	25
75	LEVITON		81000-W	0	167	1670
76	LUTRON		TTCL-100LH-WH	5	150	30
			Average	1	153	1161

11 散熱效能

11.1 使用設備

Chamber:	Tenney Environmental Chamber Model No: TJR-17 942
AC Source:	Chroma Programmable AC Source Model No: 6415
Wattmeter:	Yokogawa Power Meter Model No: WT2000
Data Logger:	Yokogawa MV2000

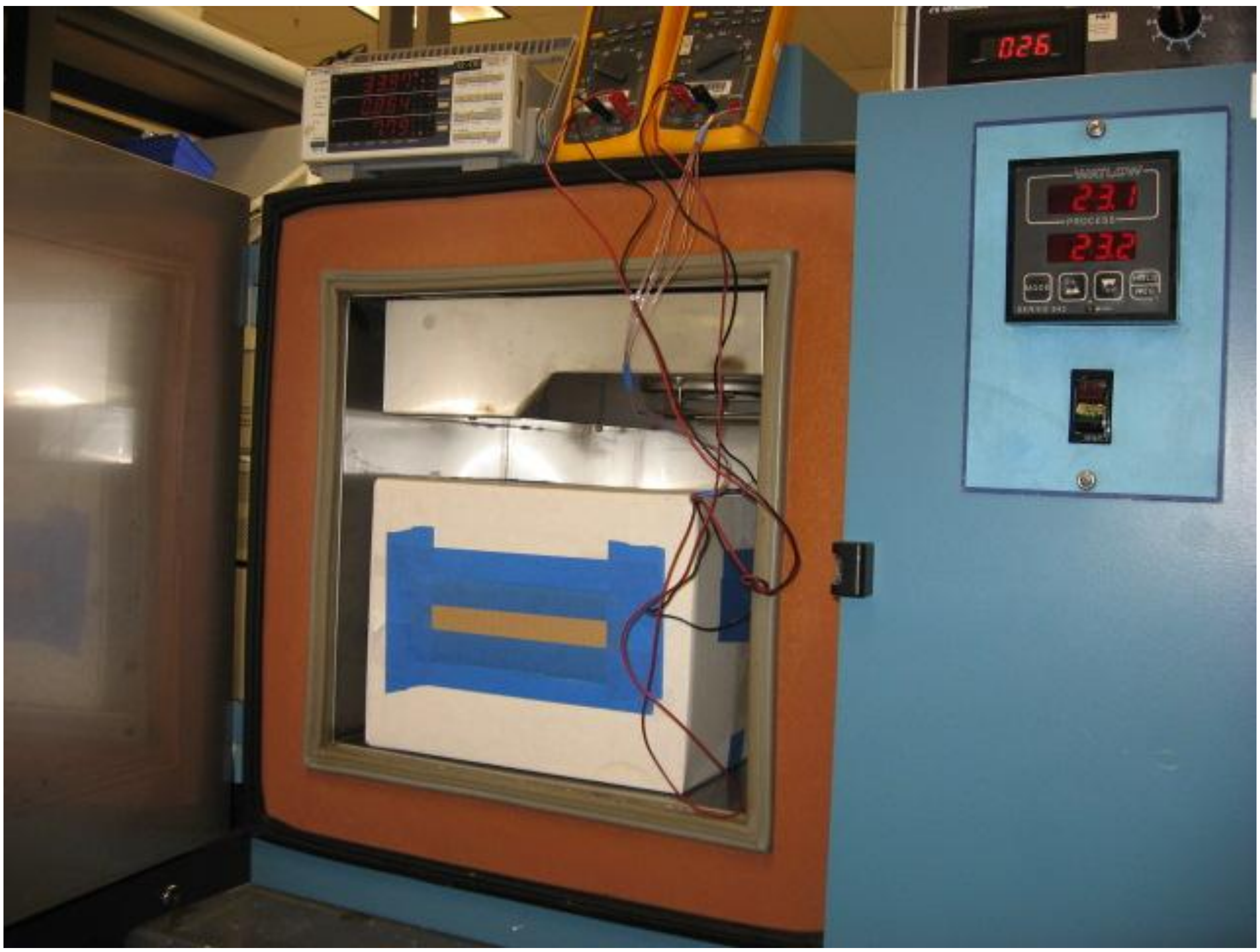

Figure 18 – Thermal Chamber Set-up Showing Box Used to Prevent Airflow Over UUT.

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11.2 散熱成效

The unit was verified inside an enclosure box to avoid the effect of the circulating air in the chamber (LED load was outside the chamber).

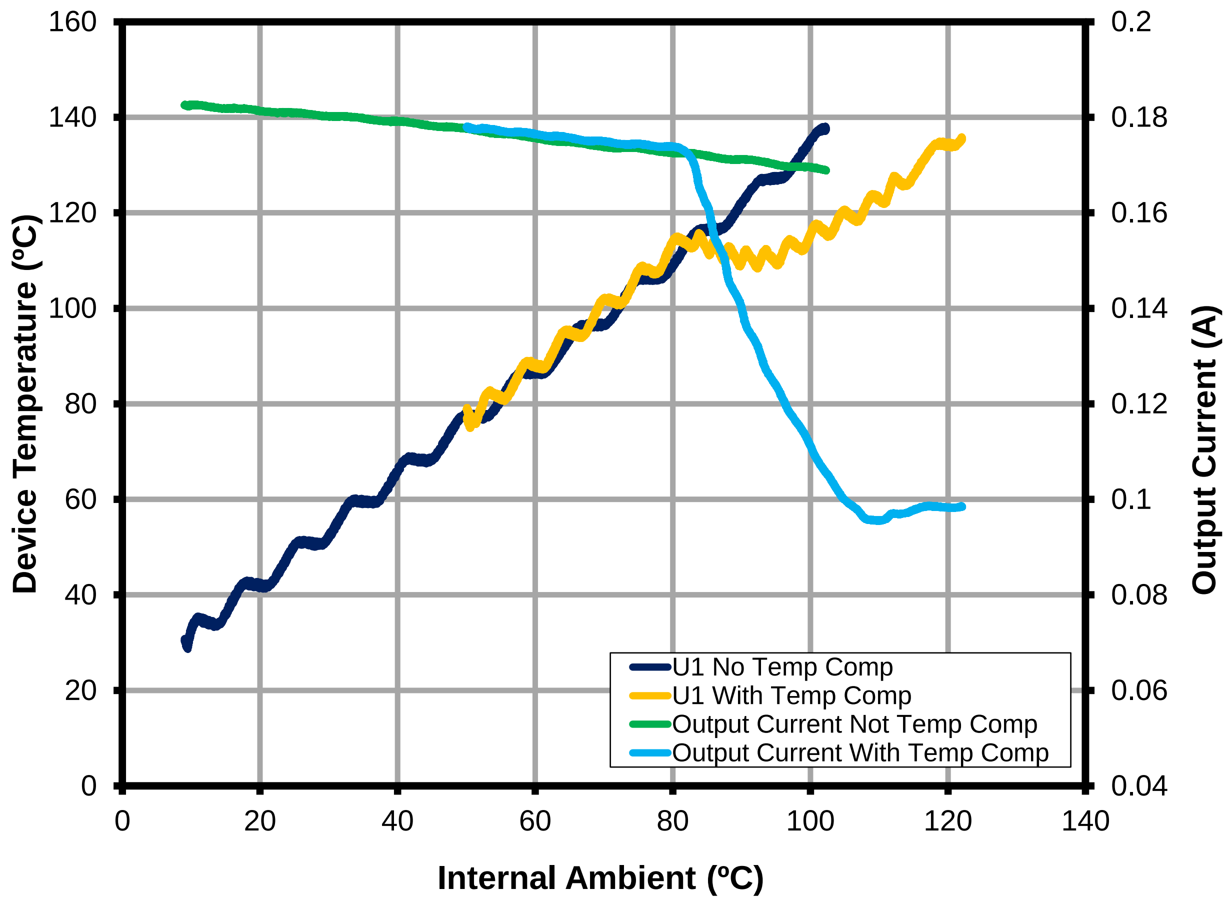

Figure 19 – Temperature Characteristic with and without Temperature Compensation at 90 V / 60 Hz Line Input. LED Driver is Potted.

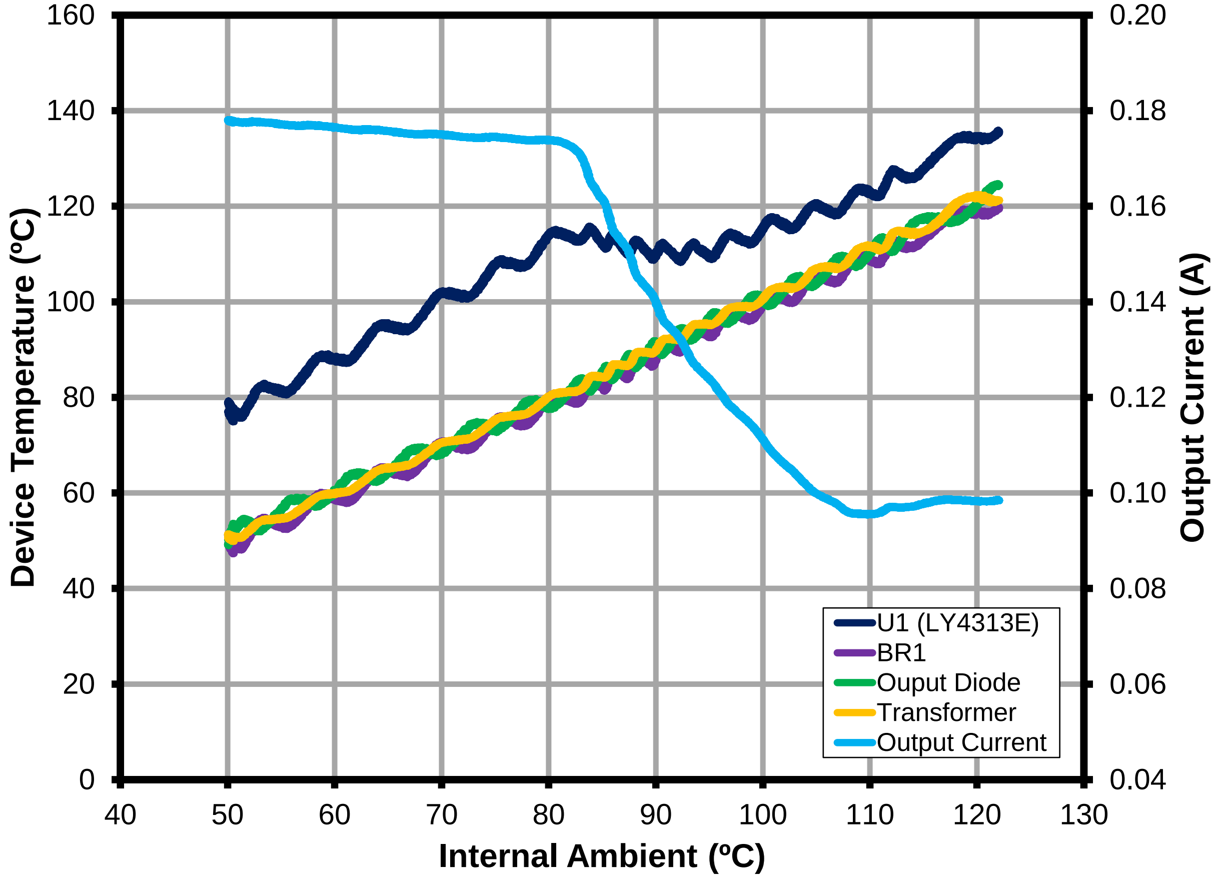

Figure 20 – Temperature characteristic of the LED Driver When Potted and with Thermal Compensation. Unit Can Be Designed to the Desired Characteristic for the Actual System.

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11.3 感熱掃描

The scan is conducted at ambient temperature of 25 ºC open frame, 90 VAC / 60 Hz input.

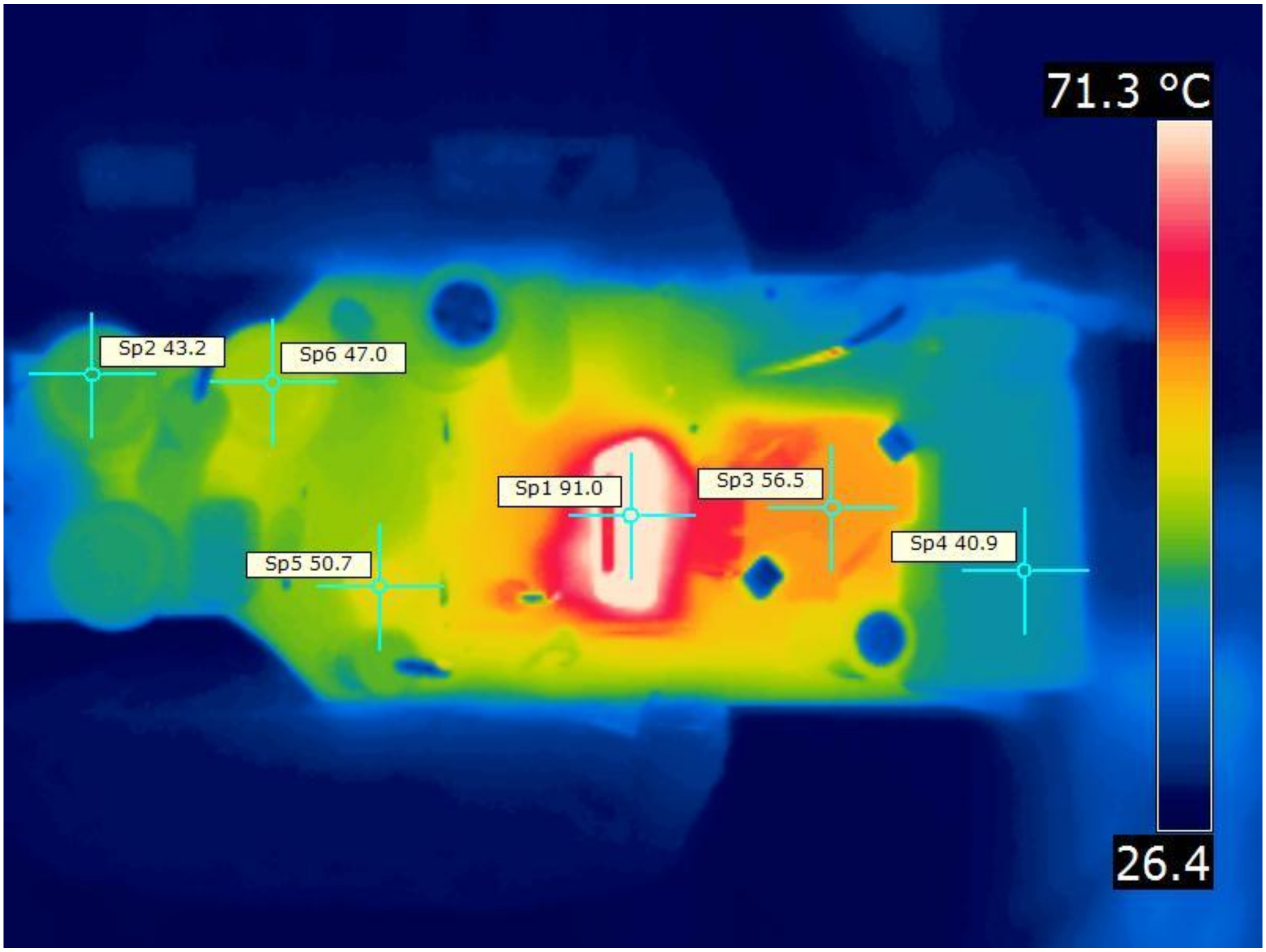

Figure 21 – Open Frame Thermal Scan. U1 without Heat Sink.

Legend:

- Sp1 – LTY4313E U1
- Sp2 – EMI Choke L1
- Sp3 – Power Transformer T1
- Sp4 – Output Capacitor C6
- Sp5 – Damper MOSFET Q10
- Sp6 – EMI Choke L3

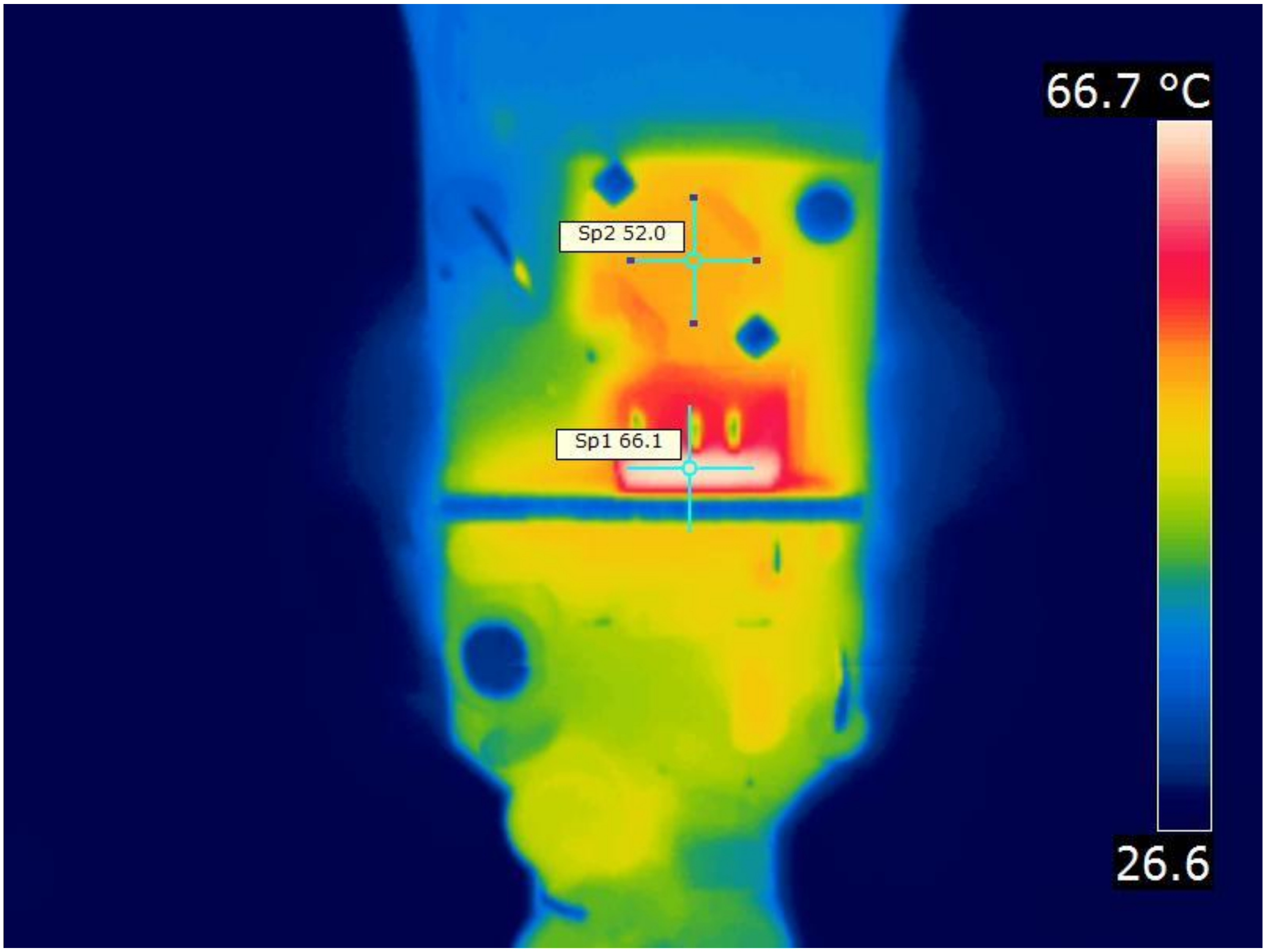

Figure 22 – Device (U1) Temperature Drops to 66 ºC Once Attached with 15 mm x 25 mm Aluminum Heat Sink.

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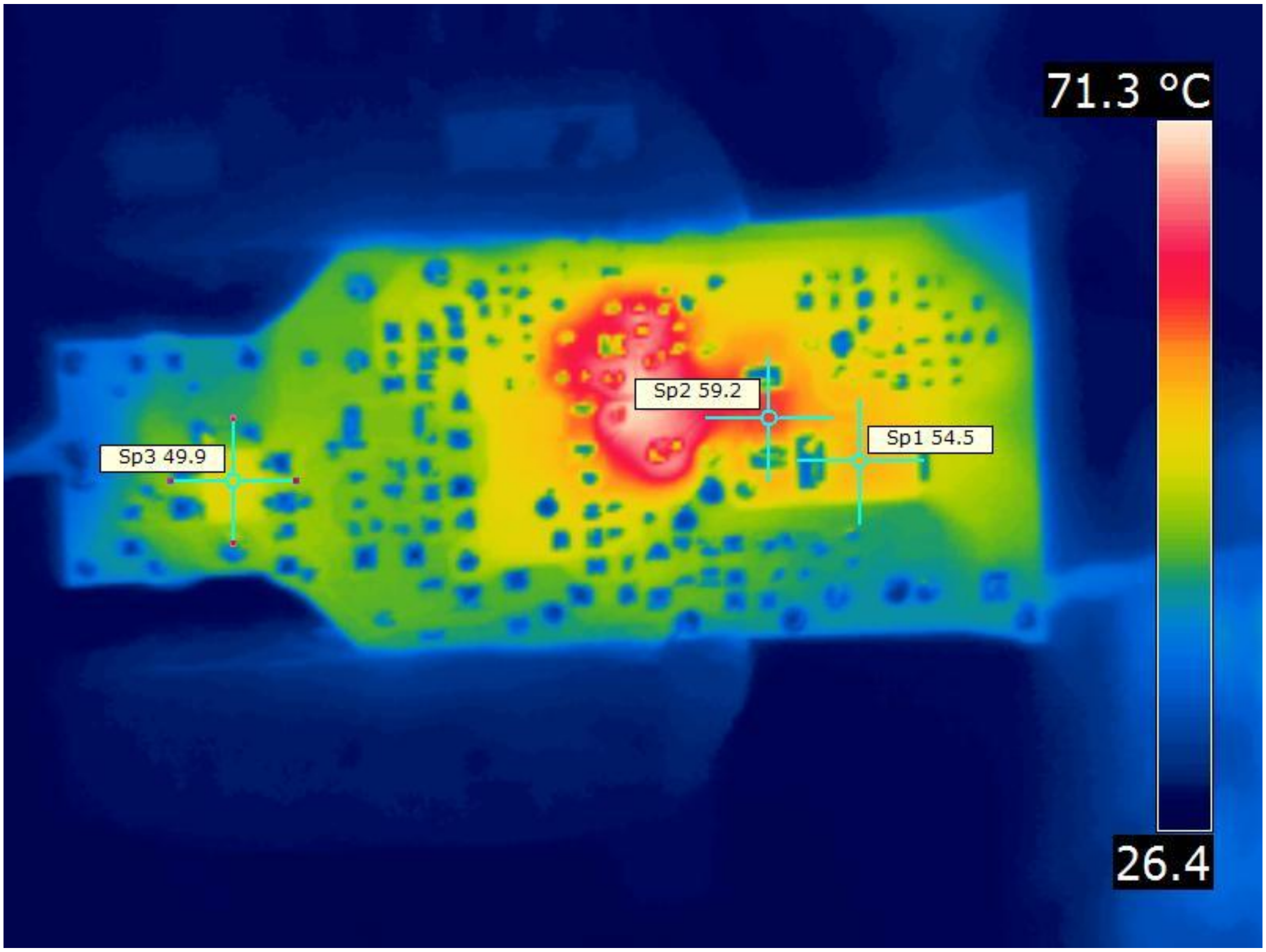

Figure 23 – Bottom Side Board Temperature at Open Frame.

Legend:

Sp1 – Output Diode D3
Sp2 – Blocking Diode D7
Sp3 – Bridge Rectifier BR1

12 波形

12.1 汲極電壓和電流，正常操作

No saturation in the inductor and guaranteed to work in continuous mode within the operating input voltage.

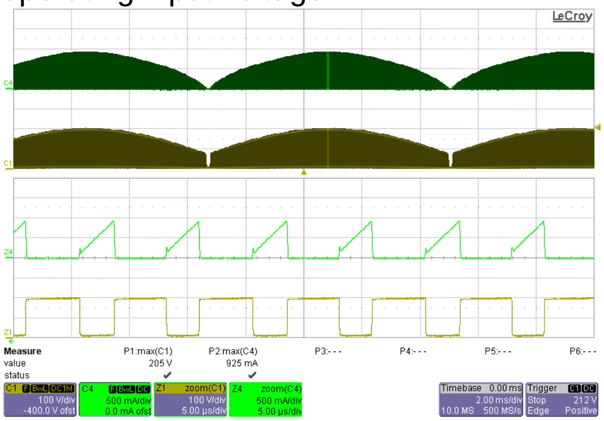

Figure 24 – 90 VAC / 60 Hz, 72 V LED String.
Ch1: V_{DRAIN}, 100 V / div.
Ch4: I_{DRAIN}, 0.5 A / div.
Time Scale: 2 ms / div.
Zoom Time Scale: 5 □s / div.

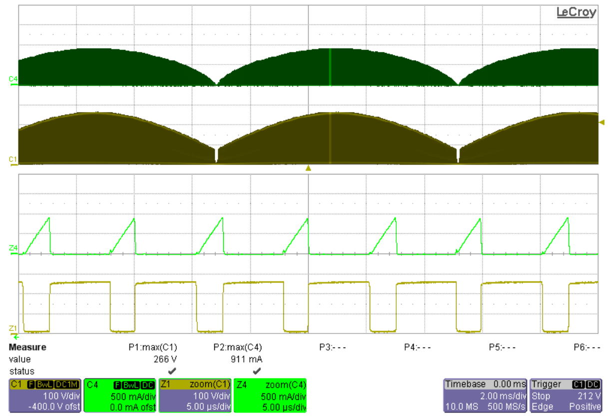

Figure 25 – 132 VAC / 60 Hz, 72 V LED String.
Ch1: V_{DRAIN}, 100 V / div.
Ch4: I_{DRAIN}, 0.5 A / div.
Time Scale: 2 ms / div.
Zoom Time Scale: 5 □s / div.

12.2 汲極電壓和電流啓動輪廓

The device has a built in soft start thereby reducing the stress in the device, transformer and output diode.

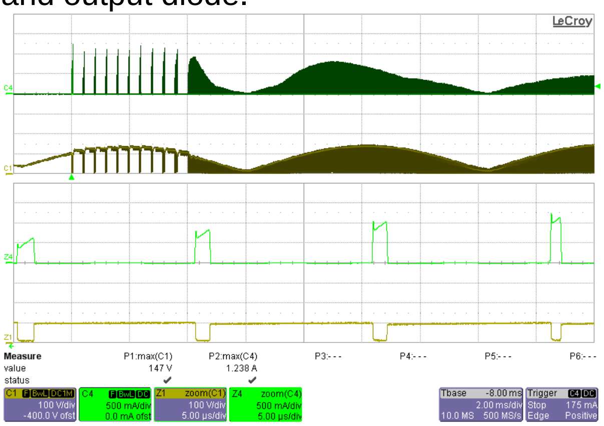

Figure 26 – 90 VAC / 60 Hz, 72 V LED String.
Ch1: V_{DRAIN}, 100 V / div.
Ch4: I_{DRAIN}, 0.5 A / div.
Time Scale: 2 ms / div.
Zoom Time Scale: 5 □s / div.

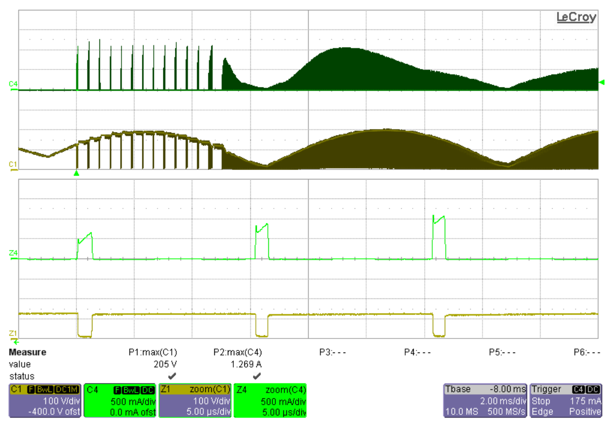

Figure 27 – 132 VAC / 60 Hz, 72 V LED String.
Ch1: V_{DRAIN}, 100 V / div.
Ch4: I_{DRAIN}, 0.5 A / div.
Time Scale: 2 ms / div.
Zoom Time Scale: 5 □s / div.

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12.3 輸出電壓啓動輪廓

Start-up time <250 ms; the reference design will emit light within 250 ms at non-dimming operation.

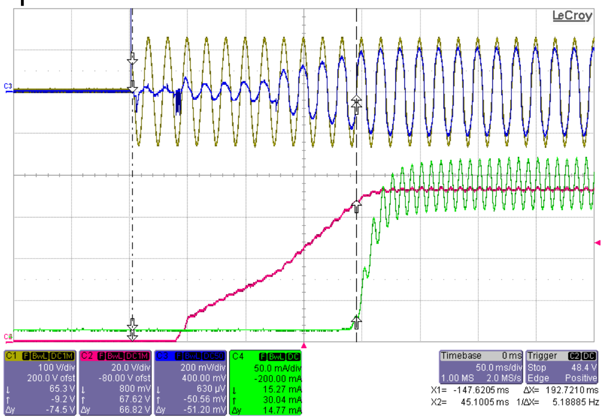

Figure 28 – 90 VAC / 60 Hz, 72 V LED.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{IN}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 50 mA / div., 50 ms / div.

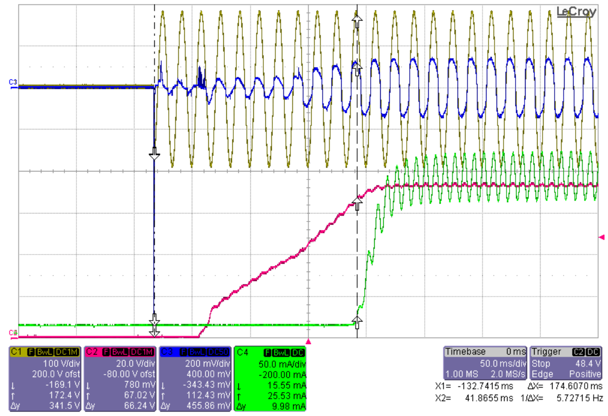

Figure 29 – 132 VAC / 60 Hz, 72 V LED.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{IN}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 50 mA / div., 50 ms / div.

12.4 輸入和輸出電壓與電流分析

Output current ripple is inversely proportional to the impedance of the LED. Verify the actual current ripple on the actual LED to be used in the system. Increase output capacitance for lesser output current ripple is intended.

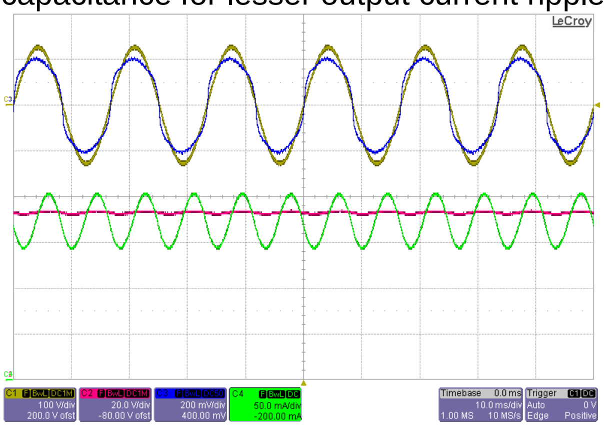

Figure 30 – 90 VAC / 60 Hz, 72 V LED String.
C_{OUT} = 330 □F.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 50 mA / div., 10 ms / div.

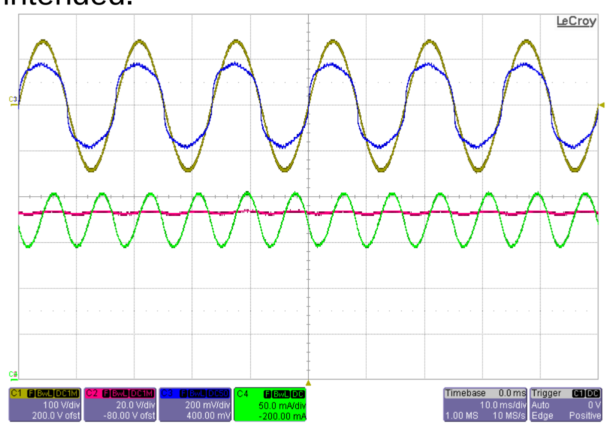

Figure 31 – 100 VAC / 60 Hz, 72 V LED String.
C_{OUT} = 330 □F.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 50 mA / div., 10 ms / div.

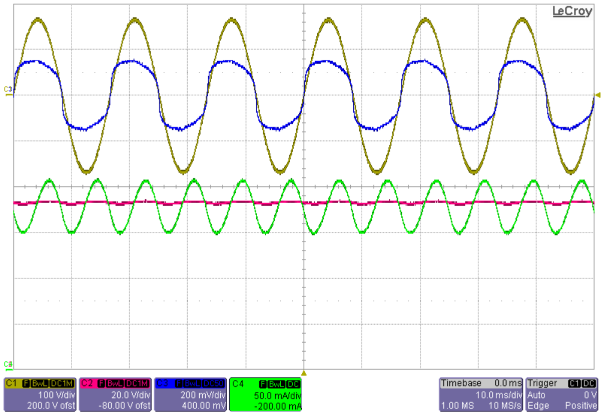

Figure 32 – 115 VAC / 60 Hz, 72 V LED String.
C_{OUT} = 330 □F.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 50 mA / div., 10 ms / div.

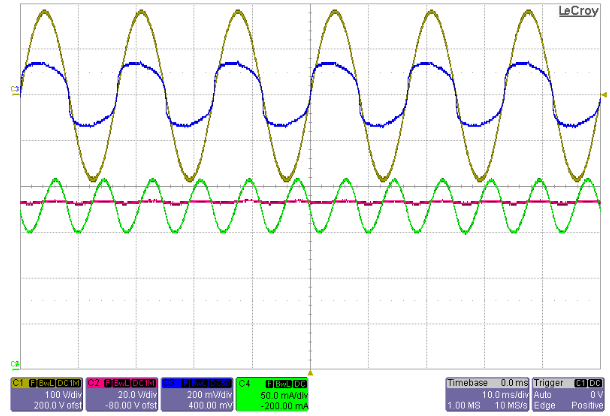

Figure 33 – 132 VAC / 60 Hz, 72 V LED String.
C_{OUT} = 330 □F.
Ch1: V_{IN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 50 mA / div., 10 ms / div..

12.5 汲極電壓和電流分析：正常操作到輸出短路

No saturation in the inductor during short circuit, inductor current is limited by the I_{LIM}.

Figure 34 – 90 VAC / 60 Hz, Normal Operation then Output Short.
Ch1: V_{DRAIN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{DRAIN}, 0.5 A / div., 10 ms / div.
Z4: I_{DRAIN}, 0.5A / div., 100 □s / div.

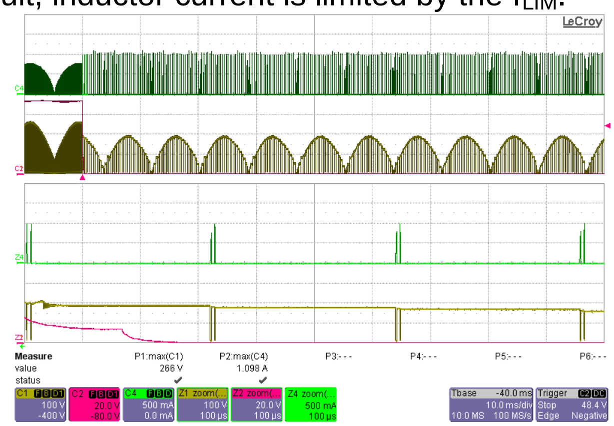

Figure 35 – 132 VAC / 60 Hz, Normal Operation then Output Short.
Ch1: V_{DRAIN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{DRAIN}, 0.5 A / div., 10 ms / div.
Z4: I_{DRAIN}, 0.5A / div., 100 □s / div.

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12.6 汲極電壓和電流分析：啓動但發生輸出短路

No saturation in the inductor during start-up short-circuit due to the built-in soft-start.

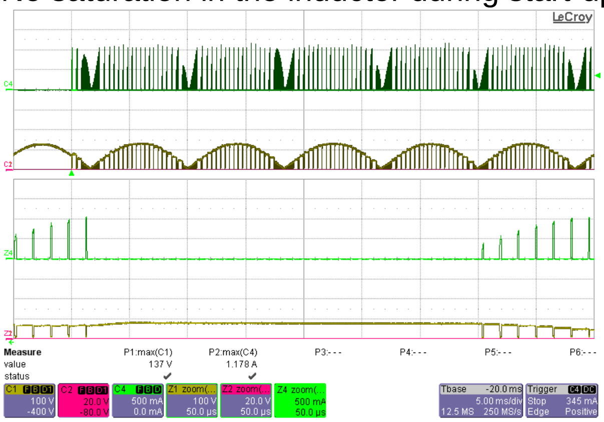

Figure 36 – 90 VAC / 50 Hz, Output Shorted.
Ch1: V_{DRAIN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{DRAIN}, 0.5 A / div., 5 ms / div.
Z4: I_{DRAIN}, 0.5A / div., 50 □s / div.

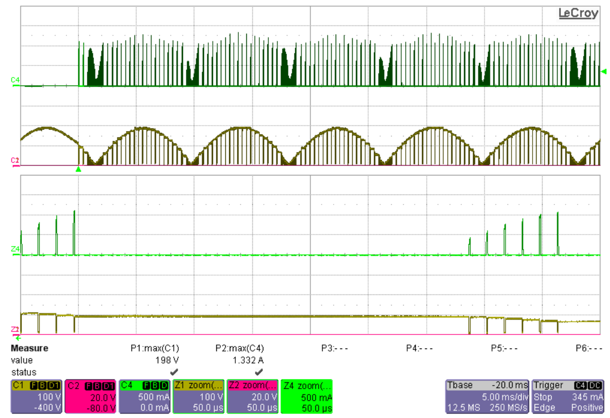

Figure 37 – 132 VAC / 50 Hz, Output Shorted.
Ch1: V_{DRAIN}, 100 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{DRAIN}, 0.5 A / div., 5 ms / div.
Z4: I_{DRAIN}, 0.5A / div., 50 □s / div.

12.7 零負載操作

The driver is protected during no-load operation, U1 operating is cycle skipping mode.

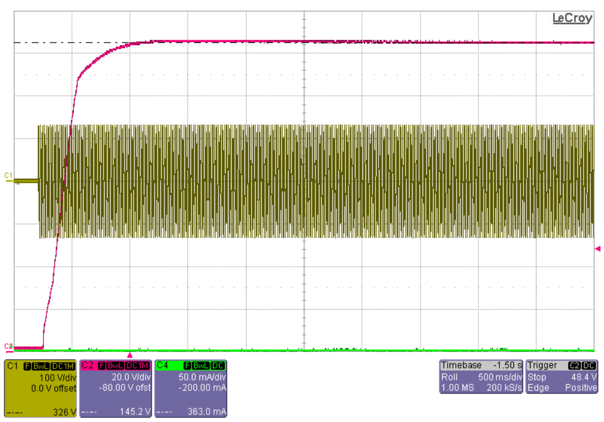

Figure 38 – 90 VAC / 60 Hz, Start-up No-load.
Ch2: V_{OUT}, 100 V / div.
Ch1: V_{IN}, 20 V / div.
Time Scale: 500 ms / div.

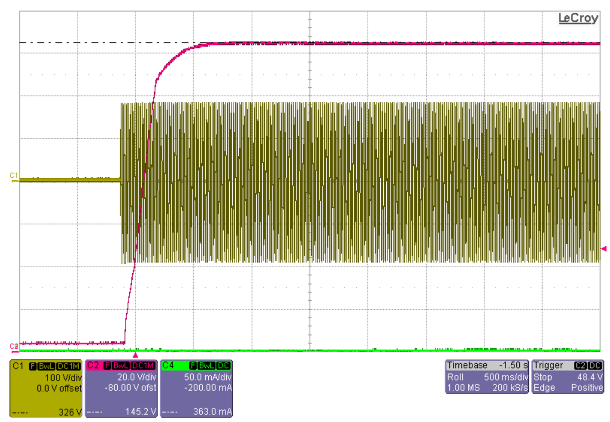

Figure 39 – 132 VAC / 60 Hz, Start-up No-load.
Ch2: V_{OUT}, 100 V / div.
Ch1: V_{IN}, 20 V / div.
Time Scale: 500 ms / div.

12.8 AC 週期

The reference design has no perceptible delay.

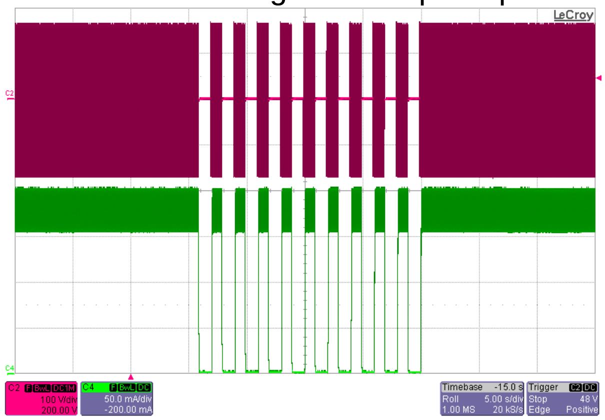

Figure 40 – 120 VAC / 60 Hz,
1 s On – 1 s Off.
Load: 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch4: I_{OUT}, 50 mA / div.
Time Scale: 5 s / div.

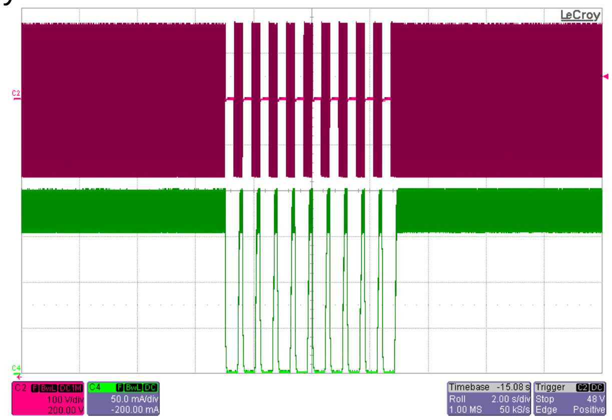

Figure 41 – 120 VAC / 60 Hz,
300 ms On – 300 ms Off.
Load: 72 V LED String.
Ch1: V_{IN}, 100 V / div.
Ch4: I_{OUT}, 50 mA / div.
Time Scale: 5 s / div.

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12.9 調光波形範例

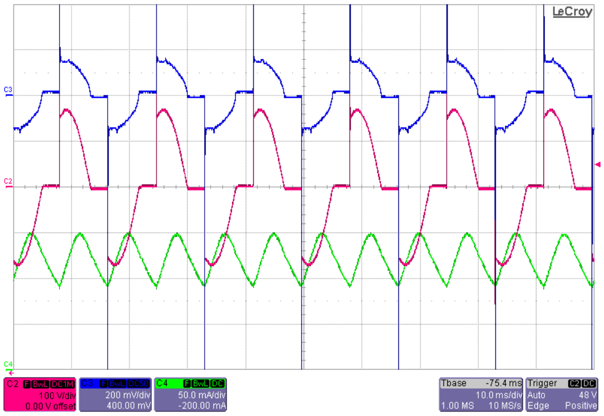

Figure 42 – 120 VAC / 60 Hz, LG-603PGH-Dimmer at Full TRIAC Conduction.
Load: 72 V LED String.
Ch2: V_{OUT}, 100 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 50 mA / div.
Time Scale: 10 ms / div.

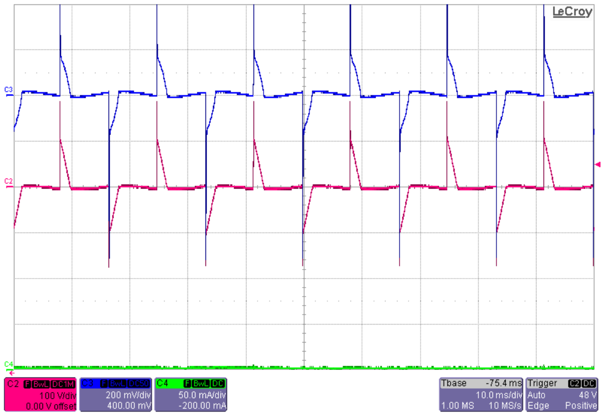

Figure 43 – 120 VAC / 60 Hz, LG-603PGH-Dimmer at Minimum TRIAC Conduction.
Load: 72 V LED String.
Ch2: V_{OUT}, 100 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 50 mA / div.
Time Scale: 10 ms / div.

Refer to the unit to dimmer compatibility section for the dimmers evaluated for this LED driver.

12.9.1 線電壓突波波形

12.9.2 線電壓差動電壓突波

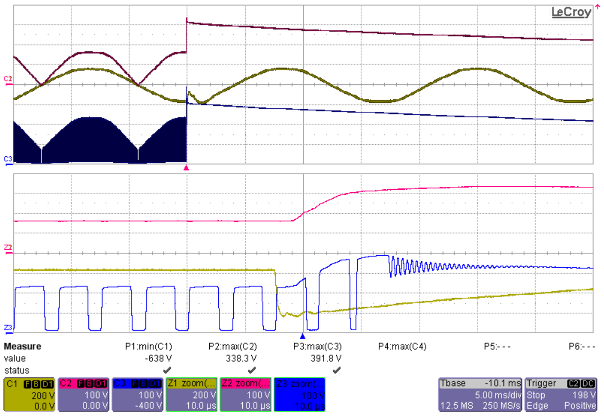

Figure 44 – 120 VAC / 60 Hz, 72 V Load,
V_{DS} = 391.8 $V_{PK.}$
(+) 500 V Differential Line Surge at 90º.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{BULK}, 100 V / div.
Ch4: V_{DS}, 100 V / div.,5 ms / div.
Zoom Time Scale: 10 µs / div.

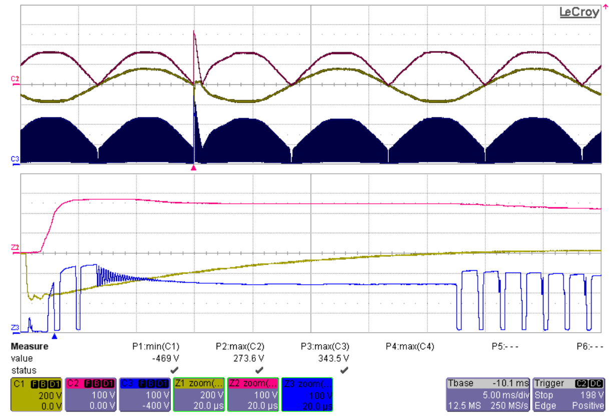

Figure 45 – 120 VAC / 60 Hz, 72 V Load,
V_{DS} = 343.5 $V_{PK.}$
(+) 500 V Differential Line Surge at 0º.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{BULK}, 100 V / div.
Ch4: V_{DS}, 100 V / div.,5 ms / div.
Zoom Time Scale: 20 µs / div.

12.9.3 差動振盪突波

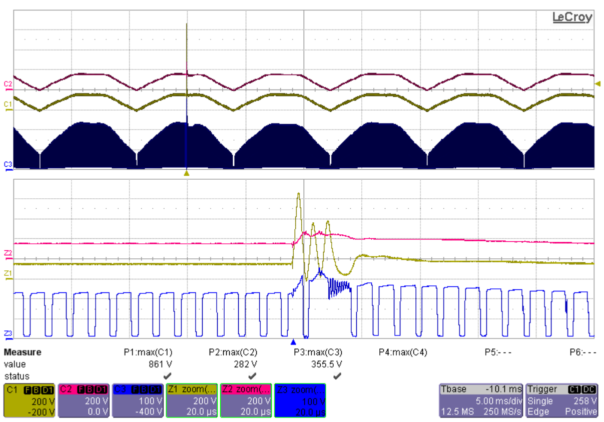

Figure 46 – 120 VAC / 60 Hz, 72 V Load,
V_{DS} = 391.8 $V_{PK.}$
(+) 500 V Differential Ring Surge at 90º.
Ch1: V_{BRIDGE}, 200 V / div.
Ch2: V_{BULK}, 200 V / div.
Ch4: V_{DS}, 100 V / div.,5 ms / div.
Zoom Time Scale: 20 µs / div.

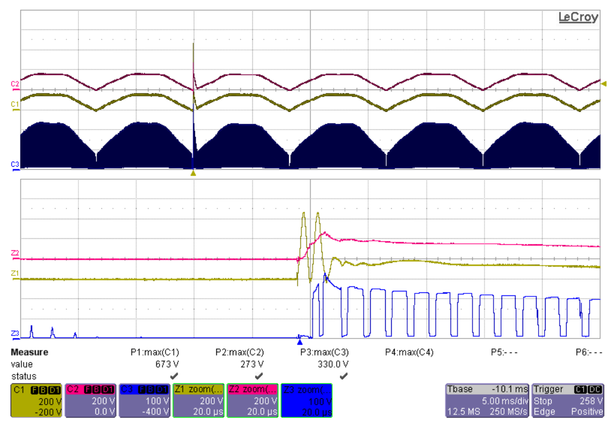

Figure 47 – 120 VAC / 60 Hz, 72 V Load,
V_{DS} = 343.5 $V_{PK.}$
(+) 500 V Differential Ring Surge at 0º.
Ch1: V_{BRIDGE}, 200 V / div.
Ch2: V_{BULK}, 200 V / div.
Ch4: V_{DS}, 100 V / div., 5 ms / div.
Zoom Time Scale: 20 µs / div.

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13 線電壓突波

Input voltage was set at 120 VAC / 60 Hz. Output was loaded with a 72 V LED string and operation was verified following each surge event. Two units were verified in the following conditions.

Differential input line 1.2 / 50 s surge testing was completed on one test unit to IEC61000-4-5.

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+500	120	L to N	0	Pass
-500	120	L to N	270	Pass
+500	120	L to N	90	Pass
-500	120	L to N	180	Pass

Differential input line ring surge testing was completed on one test unit to IEC61000-4-5.

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2500	120	L to N	0	Pass
-2500	120	L to N	270	Pass
+2500	120	L to N	90	Pass
-2500	120	L to N	180	Pass

The unit passes under all test conditions.

14 傳導性 EMI

14.1 設備

Receiver:

Rohde & Schwartz
ESPI - Test Receiver (9 kHz – 3 GHz)
Model No: ESPI3

LISN:

Rohde & Schwartz
Two-Line-V-Network
Model No: ENV216

14.2 EMI 測試裝置

Usually, the LED driver is placed in a conical metal housing (for self-ballasted lamps; CISPR15 Edition 7.2) but since the lamp housing was not available during UUT testing it was evaluated as shown in the figure below.

Figure 48 – Conducted Emissions Measurement Set-up.

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14.3 EMI 測試結果

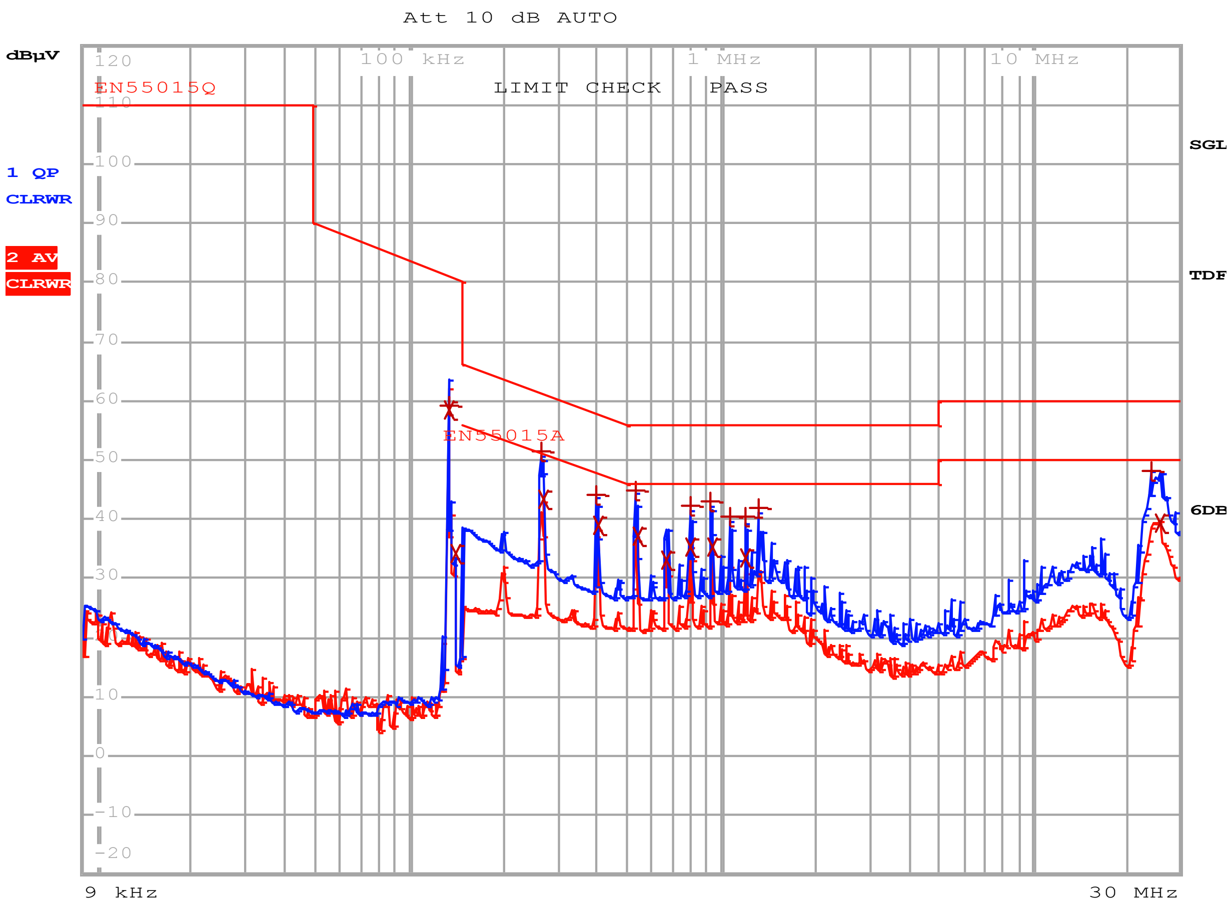

Figure 49 – Conducted EMI, 72 V Output / 170 mA Steady-State Load, 120 VAC, 60 Hz, and EN55015 Limits.

EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
1	Quasi Peak	133.454986145 kHz	59.23	N gnd	-21.83
2	Average	133.454986145 kHz	58.28	L1 gnd	
2	Average	140.262531674 kHz	34.24	L1 gnd	
1	Quasi Peak	264.49018761 kHz	51.33	N gnd	-9.95
2	Average	267.135089486 kHz	43.45	N gnd	-7.75
1	Quasi Peak	397.727746704 kHz	44.12	N gnd	-13.77
2	Average	401.705024172 kHz	39.02	N gnd	-8.79
1	Quasi Peak	530.769219795 kHz	44.94	N gnd	-11.05
2	Average	536.076911993 kHz	37.24	N gnd	-8.75
2	Average	667.263434405 kHz	33.13	N gnd	-12.86
1	Quasi Peak	798.145472681 kHz	42.15	N gnd	-13.84
2	Average	798.145472681 kHz	35.34	N gnd	-10.65
1	Quasi Peak	926.622115652 kHz	43.07	N gnd	-12.92
2	Average	935.888336808 kHz	35.13	N gnd	-10.86
1	Quasi Peak	1.06512822736 MHz	40.39	N gnd	-15.60
1	Quasi Peak	1.20021314689 MHz	40.43	N gnd	-15.56
2	Average	1.20021314689 MHz	33.33	N gnd	-12.66
1	Quasi Peak	1.32578199726 MHz	41.85	N gnd	-14.14
1	Quasi Peak	23.9878811379 MHz	48.01	L1 gnd	-11.98
2	Average	25.4636191981 MHz	39.24	L1 gnd	-10.75

Figure 50 – Conducted EMI, 72 V / 170 mA Steady-State Load Steady-State Load, 120 VAC, 60 Hz, and EN55015 Limits. Line and Neutral Scan Design Margin Measurement.

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15 修訂記錄

Date	Author	Revision	Description and Changes	Reviewed
09-Apr-13	JDC	1.0	Initial Release	Apps & Mktg

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