設計範例報告

標題	***採用 LYTSwitch TM-4 LYT4225E 的 25 W 高效率 (高於 90%)、高功率因數 (大於 0.97)、非隔離升降壓式 T10 燈管 LED 驅動器***
規格	195 VAC – 300 VAC 輸入； 144 V – 175 mA 輸出
應用	T10 燈管 LED 驅動器
作者	應用工程部門
文件編號	DER-405
日期	2013 年 12 月 5 日
修訂	1.0

摘要與功能

- Single-stage 結合功率因數修正 (PFC)、低 THD 與定電流 (CC) 輸出，非隔離式 LED 驅動器
- 不需要輸出電流感測
- 免除所有控制迴路電路
- 進階效能特色
  - 可補償電感公差
  - 可補償輸入電壓變異
  - 可補償輸出電壓變異
  - 頻率抖動功能可大幅降低 EMI 濾波器成本
- 進階保護和安全功能
  - 自動重新啓動可提供短路保護
  - 磁滯回復過溫保護
  - 開路負載保護
- 體積小巧，採用所需元件極少的單面 PCB
- 負載和線電壓範圍內超過 90% 的高效率
- 230 VAC 時大於 0.9 的高功率因數 (PF)
- 總諧波失真 (THD) 低，230 VAC 時小於 15%
- 符合 IEC61000-3-2 C 級標準

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目錄

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

1 簡介

本文件說明非隔離式、功率因數修正且低 THD 的高效率 LED 驅動器。此設計能在 90 VAC 至 265 VAC 的輸入電壓範圍內，以 180 mA 驅動 144 V LED 燈串。

本公司所開發的 LYTSwitch-4，能以符合成本效益的方式實作 Single-stage 功率因數修正 LED 驅動器，並結合一次側定電流控制。LYTSwitch-4 控制器經過最佳化，最適合 LED 驅動器應用，且所需的外部零件極少。這個裝置不需借助光耦合器，即可控制輸出電流。

LYTSwitch-4 將 725 V 功率 MOSFET 和控制器整合到單一晶片上。這個控制器功能包含振盪器、PWM、6 V 調整器、過溫保護、頻率抖動、逐週期限電流(cycle-by-cycle current limit)以及其他保護功能，加上充電控制器，用於輸出 CC (定電流) 控制。

LYTSwitch-4 另外還提供精密的多種保護功能，其中包括控制迴路開路/短路故障和輸出短路狀況時的自動重新啓動。精確的磁滯回復過溫保護功能可確保 PCB 在所有情況下皆可保持在安全的溫度。

本報告所呈現的非隔離式功率因數修正升降壓式設計，顯示 LYTSwitch-4 如何大幅簡化離線式高效率、且具功率因數修正的 LED 驅動器設計，並實現符合 EN 61000-3-2 C 級標準的優越效能、高輸出電壓 LED 驅動器實作。

本文件包含 LED 驅動器規格、電路圖、PCB 資訊、物料清單、傳導性 EMI 和散熱測量、電感器文件以及典型的效能特性。

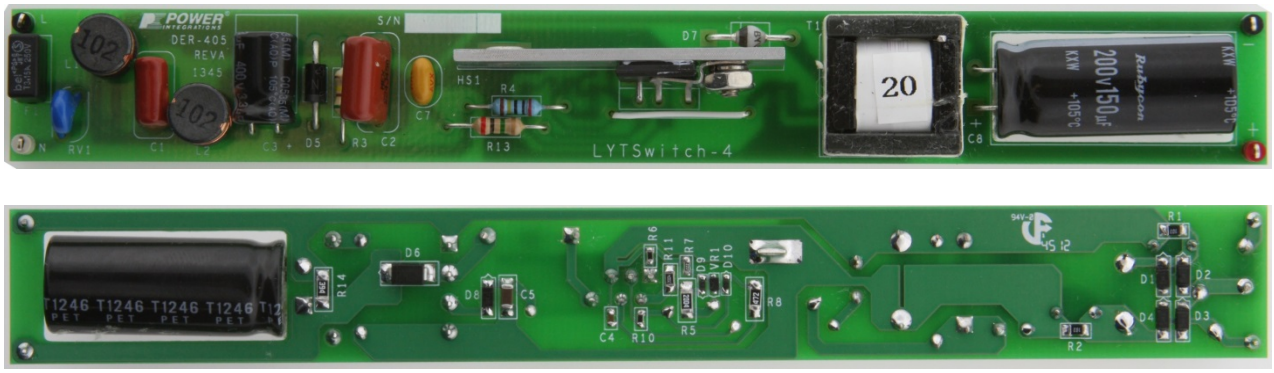

Figure 1 – Populated Circuit Board Showing Top and Bottom Views

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2 電源供應器規格

下表列出此設計可接受的最低效能。實際效能列在結果部分。

說明	符號	最小值	典型值	最大值	單位	註解
輸入						
電壓	V_{IN}	195		300	VAC	雙線 – 無 P.E.
頻率	f_{LINE}		50/60		Hz	
輸出						
LED 電壓	V_{OUT}	141	144	147	V	
LED 電流			175		mA	±5%
總輸出功率						
連續輸出功率	P_{OUT}		25		W	
環境						
傳導性 EMI		符合 EN55015B 標準				
安全		非隔離式				
振盪波 (100 kHz)						
差模 (L1-L2)			2.5		kV	
差動突波 (1.2 / 50 μs)			1		kV	
效率		90			%	於 230 VAC， 25 °C 條件下測量
諧波電流		EN 61000-3-2 C 級				
功率因數 (PF)		0.9				於 $V_{OUT(TYP)}$、$I_{OUT(TYP)}$ 及 230 VAC、50 Hz 條件下測量
環境溫度	T_{AMB}		45		°C	

3 電路圖

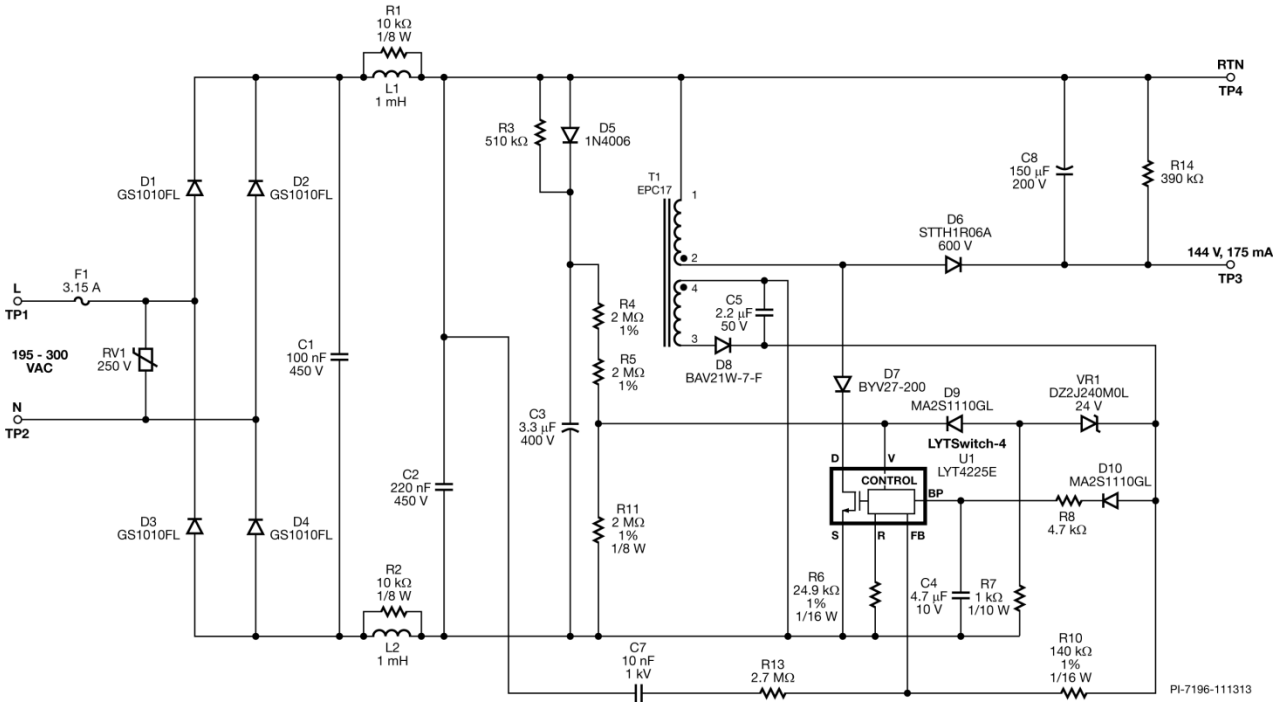

Figure 2 – Schematic.

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4 電路說明

LYTSwitch-4 (U1) 是一個高度整合的一次側控制器，主要用於 LED 驅動器應用。LYTSwitch-4 以 Single-stage 轉換架構提供高功率因數，同時會在典型 LED 驅動器環境中所預期的輸入和輸出電壓範圍內，調整輸出電流。所有負責這些功能的控制電路，加上高電壓功率 MOSFET 都會整合到裝置內。

電容器 C1、C2 和差模電感器 L1、L2 會一起執行 EMI 濾波網路，且大小可以維持高功率因數。電阻器 R1 和 R2 則用於箝制 L1 和 L2 的 Q，以降低諧振峰值來避免 EMI 增加。

浮接輸出升降壓式功率電路是由 U1 (電源開關 + 控制)、輸出二極體 D6、輸出電容器 C8 以及輸出電感器 T1 所組成。電感器 T1 在返馳式配置中配置有第二個繞組，用於提供偏壓電源給 U1，以降低裝置的功耗並提高效率。二極體 D7 是用於防止 U1 汲源極間，接近正弦曲線輸入電壓過零處出現負電壓。二極體 D5 和 C3 會偵測峰值 AC 線電壓。在 C3 上的電壓以及 R4 和 R5 會設定饋入電壓監測器 (V) 接腳的輸入電流。電阻器 R11 可進一步改善線電壓的定電流調節。此電流會由 U1 用於控制線電壓欠壓 (UV)、過壓 (OV) 及前饋電流，並與回授 (FB) 接腳電流一起，將定電流提供給 LED 負載。U1 用於調節輸出電流的 FB 接腳電流則是透過整流後的偏壓電源供應器提供，並且由 R10 限制電流。

電容器 C4 會爲 U1 的 BYPASS (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 U1 汲極 (D) 接腳連接的內部高電壓電流源將 C4 充電至約 6 V。選擇的電容器 C4 爲 4.7 µF，可讓裝置在縮減模式下操作。採用外部偏壓供電 (透過 D10 和 R8)，可提供最低的裝置功耗。輸出過壓 (開路) 保護透過 V 接腳和 VR1、R7 及 D9 提供。一旦偏壓供電的電容器 C5 上的電壓因爲開路負載狀況而超過 VR1 臨界值，電流將會流入 V 接腳，直到到達線電壓過壓臨界值 (I_{OV}) 爲止。然後 IC 會立即終止切換，藉此防止輸出電壓再次升高。

採用前饋 RC 網路 C7 和 R13，將 ATHD 降低至小於 10%。

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5 PCB 佈局

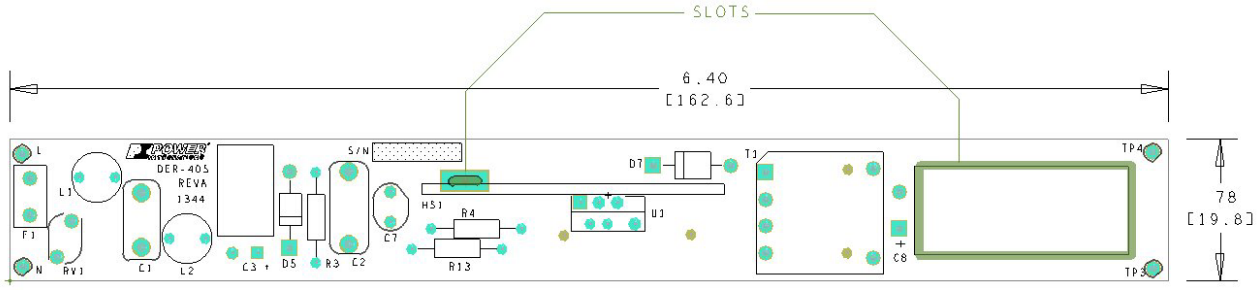

Figure 3 – Printed Circuit Layout, Top.

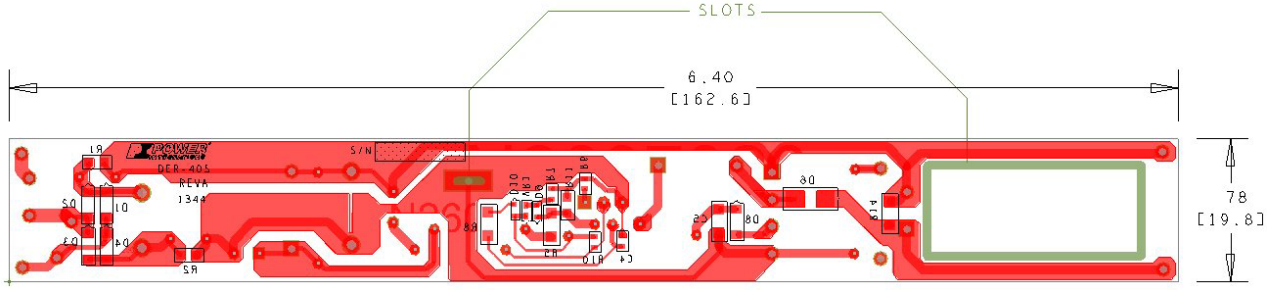

Figure 4 – Printed Circuit Layout, Bottom.

6 物料清單

6.1 電氣物料清單

Item	Qty	Ref Des	說明	Mfg Part Number	Mfg
1	1	C1	100 nF, 450 V, Film	MEXXD31004JJ1	Duratech
2	1	C2	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
3	1	C3	3.3 µF, 400 V, Electrolytic, (8 x 11.5)	TAQ2G3R3MK0811MLL3	Taicon
4	1	C4	4.7 µF, 10 V, Ceramic, X5R, 0603	C1608X5R1A475M/0.50	TDK
5	1	C5	2.2 µF, 50 V, Ceramic, Y5V, 1206	GRM31MF51H225ZA01L	Murata
6	1	C7	10 nF, 1 kV, Disc Ceramic, X7R	SV01AC103KAR	AVX
7	1	C8	150 µF, 200 V, Electrolytic (12.5 x 30)	200KXW150MEFC12.5X30	Rubycon
8	1	D1	1000 V, 1 A, Standard Recovery, SOD-123FL	GS1010FL	PANJIT Micro Commercial
9	1	D2	1000 V, 1 A, Standard Recovery, SOD-123FL	GS1010FL	PANJIT Micro Commercial
10	1	D3	1000 V, 1 A, Standard Recovery, SOD-123FL	GS1010FL	PANJIT Micro Commercial
11	1	D4	1000 V, 1 A, Standard Recovery, SOD-123FL	GS1010FL	PANJIT Micro Commercial
12	1	D5	800 V, 1 A, GP, Rectifier, DO-41	1N4006-E3/54	Vishay
13	1	D6	600 V, 1 A, Ultrafast Recovery, 45 ns, SMA	STTH1R06A	ST Micro
14	1	D7	200 V, 2 A, Ultrafast Recovery, 25 ns, SOD57	BYV27-200-TR	Vishay
15	1	D8	250 V, 0.2 A, Fast Switching, 50 ns, SOD-123	BAV21W-7-F	Diodes, Inc.
16	1	D9	80 V, 0.10 A, Fast Switching, 3 ns, SS Mini 2P	MA2S1110GL	Panasonic
17	1	D10	80 V, 0.10 A, Fast Switching, 3 ns, SS Mini 2P	MA2S1110GL	Panasonic
18	1	F1	3.15 A, 250 V, Slow, RST	507-1181	Belfuse
19	1	L1	1 mH, 0.30 A, Ferrite Core	CTCH895F-102K	CT Parts
20	1	L2	1 mH, 0.30 A, Ferrite Core	CTCH895F-102K	CT Parts
21	1	R1	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
22	1	R2	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
23	1	R3	510 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-510K	Yageo
24	1	R4	2.00 MΩ, 1%, 1/4 W, Metal Film	RNF14FTD2M00	Stackpole Elect
25	1	R5	2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
26	1	R6	24.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2492V	Panasonic
27	1	R7	1.0 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
28	1	R8	4.7 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ472V	Panasonic
29	1	R10	140 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1403V	Panasonic
30	1	R11	2 MΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ205V	Panasonic
31	1	R13	2.7 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-2M7	Yageo
32	1	R14	390 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ394V	Panasonic
33	1	RV1	390 V, 8.2 J, 5 mm, RADIAL	S05K250	Epcos
34	1	T1	Bobbin, EPC17, Horizontal, 10 pins	BEPC-17-1110CPHFR	TDK
35	1	U1	LYTSwitch-4, eSIP-7C	LYT4225E	Power Integrations
36	1	VR1	24 V, 5%, 200 mW, SMINI-2	DZ2J240M0L	Panasonic

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7 T1 變壓器規格

7.1 電氣圖

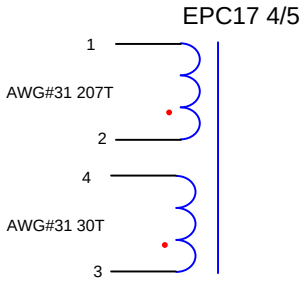

Figure 5 – Electrical Diagram.

7.2 電氣規格

Primary Inductance	Pins 1-2, all other windings open, measured at 10 kHz, 0.4 V_{RMS}.	1.0 mH ±2%
Resonant Frequency	Pins 1-2, all other windings open.	1 MHz (Max.)

7.3 材料

Item	說明
[1]	Core: EPC17.
[2]	Bobbin:BEPC-17-1110CPHFR, Horizontal, 9 pins, 4/6.
[3]	Magnet Wire: #31 AWG.
[4]	Magnet Wire: #31 AWG.
[5]	Tape: 3M 1298 Polyester Film, 4.5 mm wide.
[6]	Non-insulated wire: #31.

7.4 變壓器建構圖

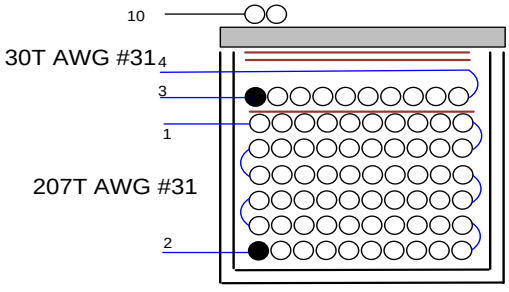

Figure 6 – Transformer Build Diagram.

7.5 變壓器結構

Bobbin Preparation	Pull-out pin number 6-9.
General Note	For the purpose of these instructions, Bobbin is oriented on winder such that pin 1 side is on the left side (see illustration). Winding direction as shown is clockwise.
WDG1 Primary	Start at pin 2; wind with firm tension 207 turns of item [3] from left to right and right to left in 6 layers and finish this winding on pin(s) 1.
Insulation	1 layer of tape [5] for insulation.
WDG2 Bias	Start on pin 3 and wind 30 turns of item [4], wind in same rotational direction as primary winding with tight tension. Finish this winding on pin(s) 4.
Insulation	2 layers of tape [5] for insulation.
Assemble Core	Assemble and secure the cores with glue item [7], (see pictures below).
Flux Wire Band	Wrap a two shorted turns of item [6] around the outside of windings and core halves with tight tension. Terminate to pin 10 with this wire and wrap core halves with tape.
Finish	Varnish transformer assembly with item [8].

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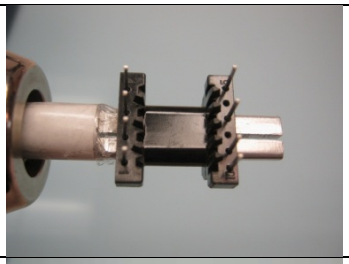
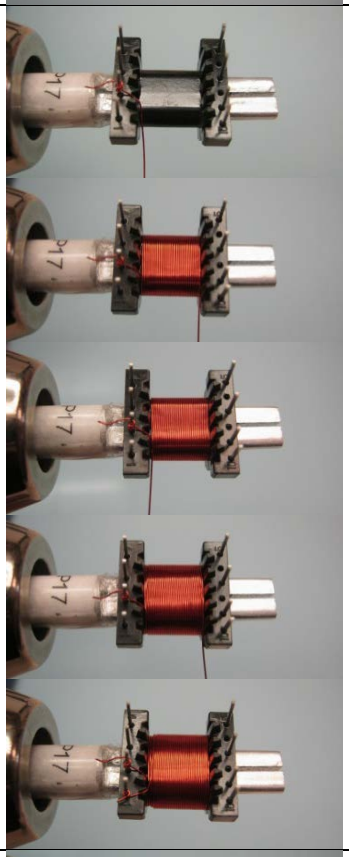
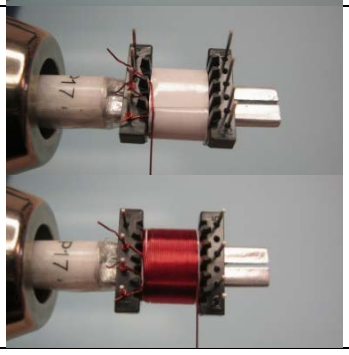
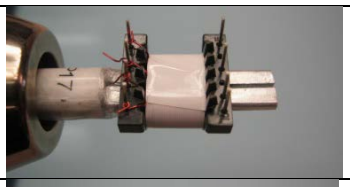
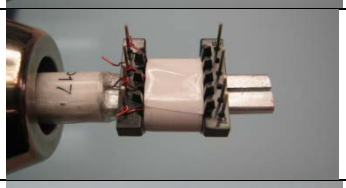
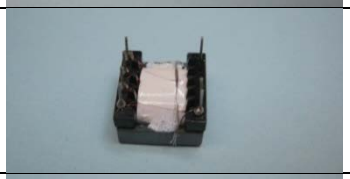
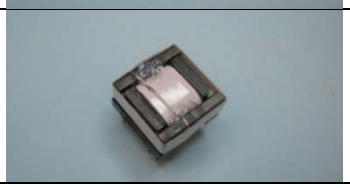
7.6 變壓器繞組示意圖

General Note		For the purpose of these instructions, bobbin is oriented on winder such that pin 1 side is on the left side (see illustration). Winding direction as shown is clockwise.
WDG1 Primary		Start at pin 2; wind with firm tension 207 turns of item [3] from left to right and right to left in 6 layers and finish this winding on pin(s) 1.
Insulation		1 layer of tape [5] for insulation.
WDG2 Bias		Start on pin 3 and wind 30 turns of item [4], wind in same rotational direction as primary winding with tight tension. Finish this winding on pin(s) 4.

		
Insulation		2 layers of tape [5] for insulation.
Assemble Core		Assemble and secure the cores with glue item [7]. (see pictures below)
Flux Wire Band		Wrap a two shorted turns of item [6] around the outside of windings and core halves with tight tension. Terminate to pin 10 with this wire and wrap core halves with tape.
Finish		Varnish transformer assembly with item [8].

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8 電感器設計試算表

Buck-boost inductor parameters can be calculated using LYTSwitch-4 PIXIs spreadsheet using VO ≡ VOR.

ACDC_LYTSwitch-4_HL_092313; Rev.1.1; Copyright Power Integrations 2013	INPUT	INFO	OUTPUT	UNIT	LYTSwitch-4_HL_092313: Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
Dimming required	**NO**		**NO**		Select 'YES' option if dimming is required. Otherwise select 'NO'.
VACMIN			195	V	Minimum AC Input Voltage
VACMAX	300.00		300	V	Maximum AC input voltage
fL			50	Hz	AC Mains Frequency
VO	144.00		144.00	V	Typical output voltage of LED string at full load
VO_MAX			158.40	V	Maximum expected LED string Voltage.
VO_MIN			129.60	V	Minimum expected LED string Voltage.
V_OVP			174.24	V	Over-voltage protection setpoint
IO	0.18		0.18	A	Typical full load LED current
PO			25.2	W	Output Power
n	0.88		0.88		Estimated efficiency of operation
VB			20	V	Bias Voltage
ENTER LYTSwitch VARIABLES					
LYTSwitch	**LYT4225**		**LYT4225**		Selected LYTSwitch
Current Limit Mode	**full**		**full**		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			1.41	A	Minimum current limit
ILIMITMAX			1.63	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			80.6	uA	V pin current
RV			4	M-ohms	Upper V pin resistor
RV2			1E+12	M-ohms	Lower V pin resistor
IFB	170.00		170.0	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1			100.0	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			1005	uH	Primary Inductance
VOR	144.00		144	V	Reflected Output Voltage.
Expected IO (average)			0.166	A	Expected Average Output Current
KP_VNOM			0.91		Expected ripple current ratio at VACNOM
TON_MIN			1.92	us	Minimum on time at maximum AC input voltage
PCLAMP			0.16	W	Estimated dissipation in primary clamp
			23.96828385		
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**EPC17**		**EPC17**		Select Core Size
Custom Core					Enter Custom core part number (if applicable)
AE			0.228	cm^2	Core Effective Cross Sectional Area

LE			4.02	cm	Core Effective Path Length
AL			1150	nH/T^2	Ungapped Core Effective Inductance
BW			9.55	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	6.00		6		Number of Primary Layers
NS			207		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			276	V	Peak input voltage at VACMIN
VMAX			424	V	Peak input voltage at VACMAX
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.35		Minimum duty cycle at peak of VACMIN
IAVG			0.13	A	Average Primary Current
IP			0.82	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS			0.23	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			1005	uH	Primary Inductance
LP_TOL			10		Tolerance of primary inductance
NP			206		Primary Winding Number of Turns
NB			30		Bias Winding Number of Turns
ALG			24	nH/T^2	Gapped Core Effective Inductance
BM			1745	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP			3484	Gauss	Peak Flux Density (BP<3700)
BAC			829	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1614		Relative Permeability of Ungapped Core
LG			1.19	mm	Gap Length (Lg > 0.1 mm)
BWE			57.3	mm	Effective Bobbin Width
OD			0.28	mm	Maximum Primary Wire Diameter including insulation
INS			0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.23	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			276	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 600)
Lumped parameters					
ISP			0.81	A	Peak Secondary Current
ISRMS			0.29	A	Secondary RMS Current
IRIPPLE			0.23	A	Output Capacitor RMS Ripple Current
CMS			57	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			0.05	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
VOLTAGE STRESS PARAMETERS					
VDRAIN			713	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance)
PIVS			600	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
PIVB			85	V	Bias Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage

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					inductance spike)
FINE TUNING (Enter measured values from prototype)					
V pin Resistor Fine Tuning					
RV1			4.00	M-ohms	Upper V Pin Resistor Value
RV2			1E+12	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			0.18	A	Measured Output Current at VAC1
IO_VAC2			0.18	A	Measured Output Current at VAC2
RV1 (new)			4.00	M-ohms	New RV1
RV2 (new)			20911.63	M-ohms	New RV2
V_OV			319.6	V	Typical AC input voltage at which OV shutdown will be triggered
V_UV			66.3	V	Typical AC input voltage beyond which power supply can startup
FB pin resistor Fine Tuning					
RFB1			100	k-ohms	Upper FB Pin Resistor Value
RFB2			1E+12	k-ohms	Lower FB Pin Resistor Value
VB1			17.9	V	Test Bias Voltage Condition1
VB2			22.1	V	Test Bias Voltage Condition2
IO1			0.18	A	Measured Output Current at Vb1
IO2			0.18	A	Measured Output Current at Vb2
RFB1 (new)			100.0	k-ohms	New RFB1
RFB2(new)			1.00E+12	k-ohms	New RFB2
Input Current Harmonic Analysis					
Harmonic			% of Fund	Limit (%)	
1st Harmonic			113.28	N/A	Fundamental (mA)
3rd Harmonic			21.20	27.00	PASS. Percentage of 3rd Harmonic is lower than the limit
5th Harmonic			10.65	10.00	FAIL. %age of 5th Harmonic exceeds the limit
7th Harmonic			6.10	7.00	PASS. Percentage of 7th Harmonic is lower than the limit
9th Harmonic			3.78	5.00	PASS. Percentage of 9th Harmonic is lower than the limit
11th Harmonic			2.75	3.00	PASS. Percentage of 11th Harmonic is lower than the limit
13th Harmonic			2.08	3.00	PASS. Percentage of 13th Harmonic is lower than the limit
15th Harmonic			1.51	3.00	PASS. Percentage of 15th Harmonic is lower than the limit
THD			24.4	%	Estimated total Harmonic Distortion (THD)

9 U1 散熱片組裝

9.1 散熱片製造圖

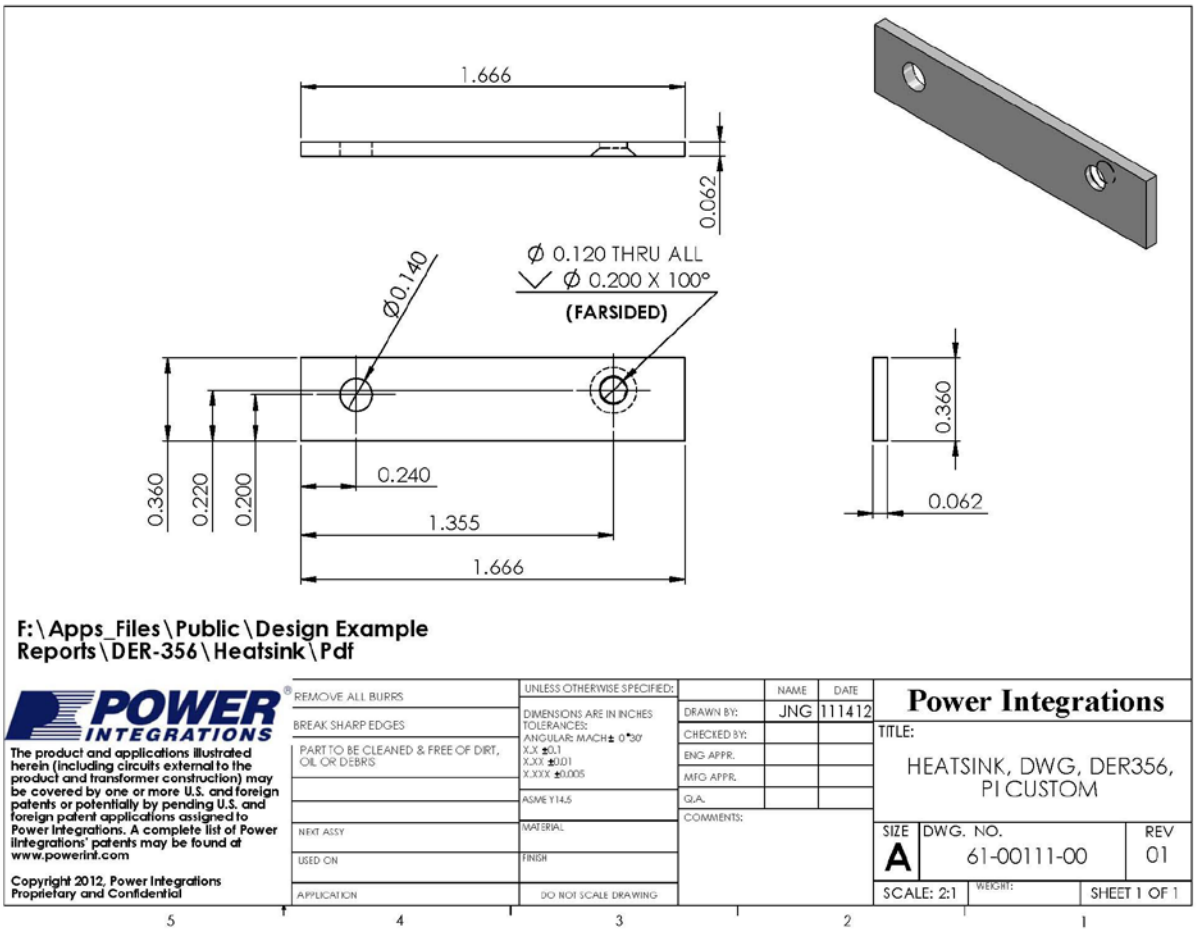

Figure 7 – U1 Heat Sink Dimensions.

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9.2 散熱片組裝圖

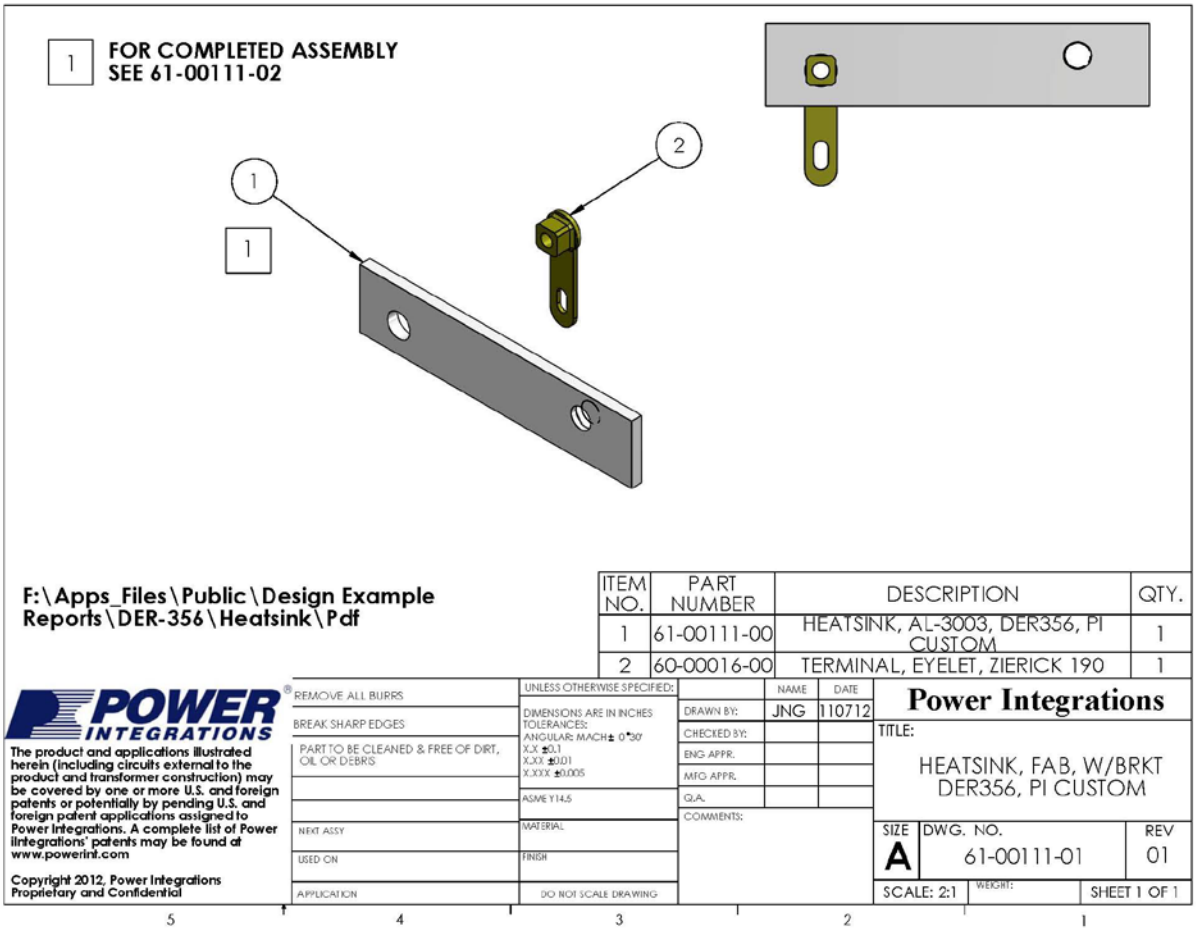

Figure 8 – U1 Heat Sink Fabrication Drawing.

9.3 散熱片和 U1 組裝圖

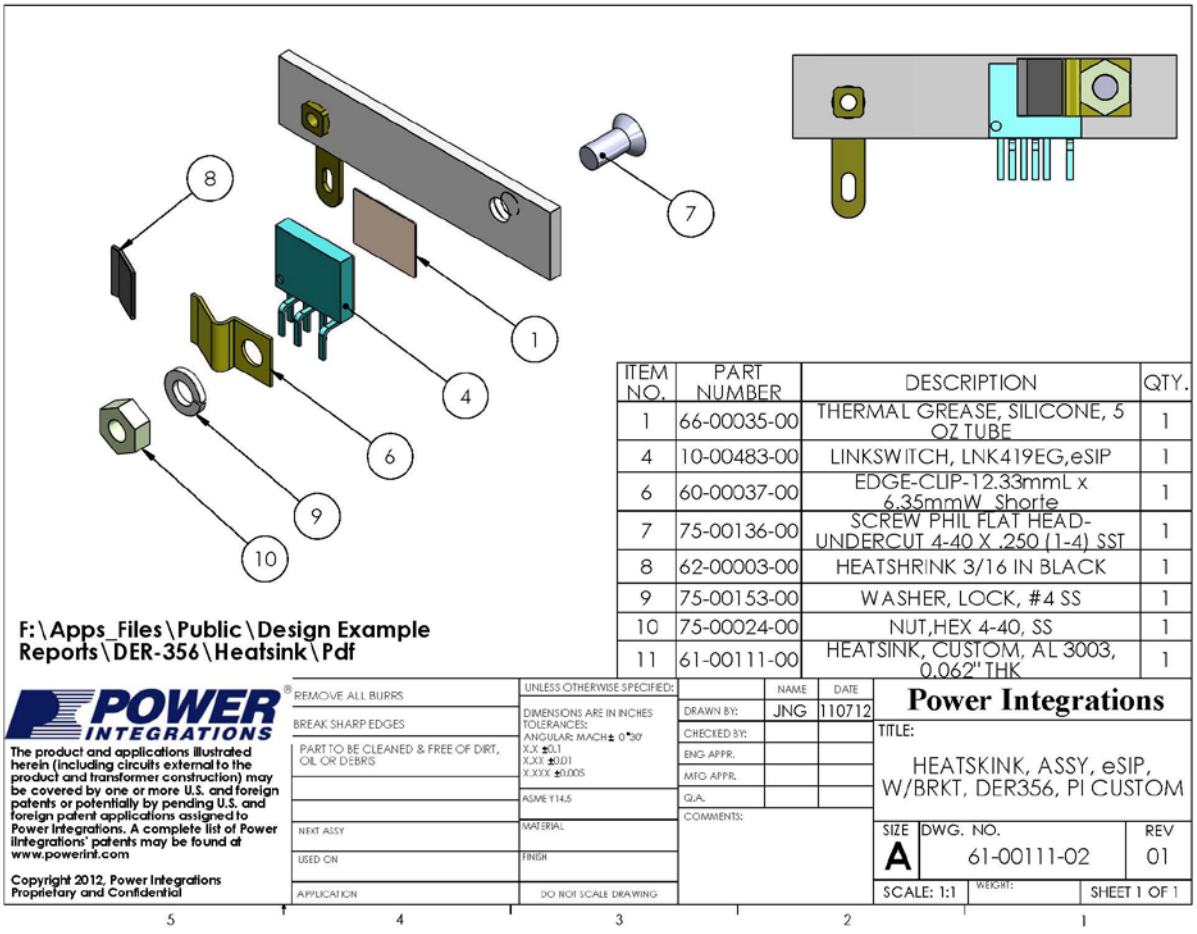

Figure 9 – U1 Heat Sink Assembly Drawing.

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10 效能資料

The following data was compiled using 3 sets of load (144 V, 141 V, 138 V and 147 V LED strings). All measurements were performed at room temperature.

10.1 效率

Efficiency is greater than 90% across line and load.

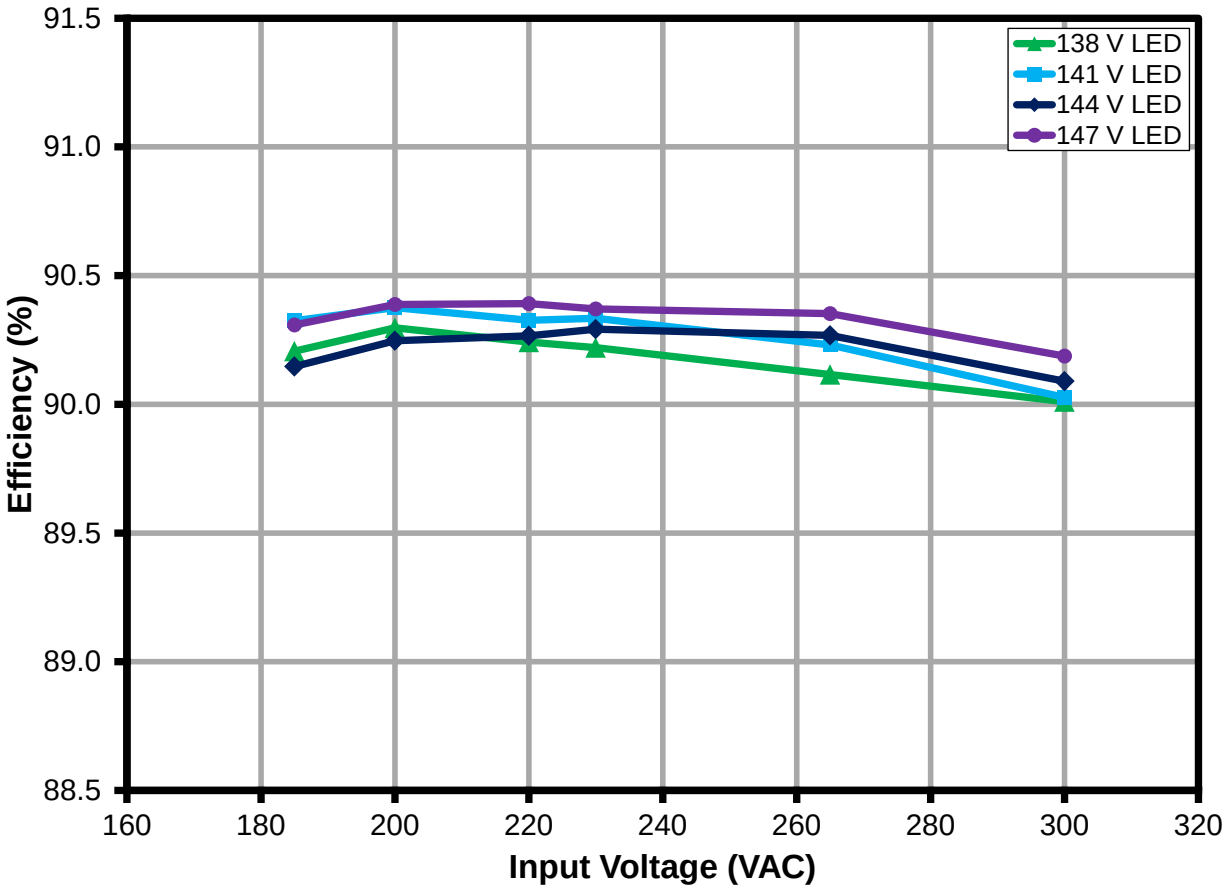

Figure 10 – Efficiency vs. Line and Load.

10.2 線電壓與負載穩定度關係圖

Regulation is well within ±5% across line and load.

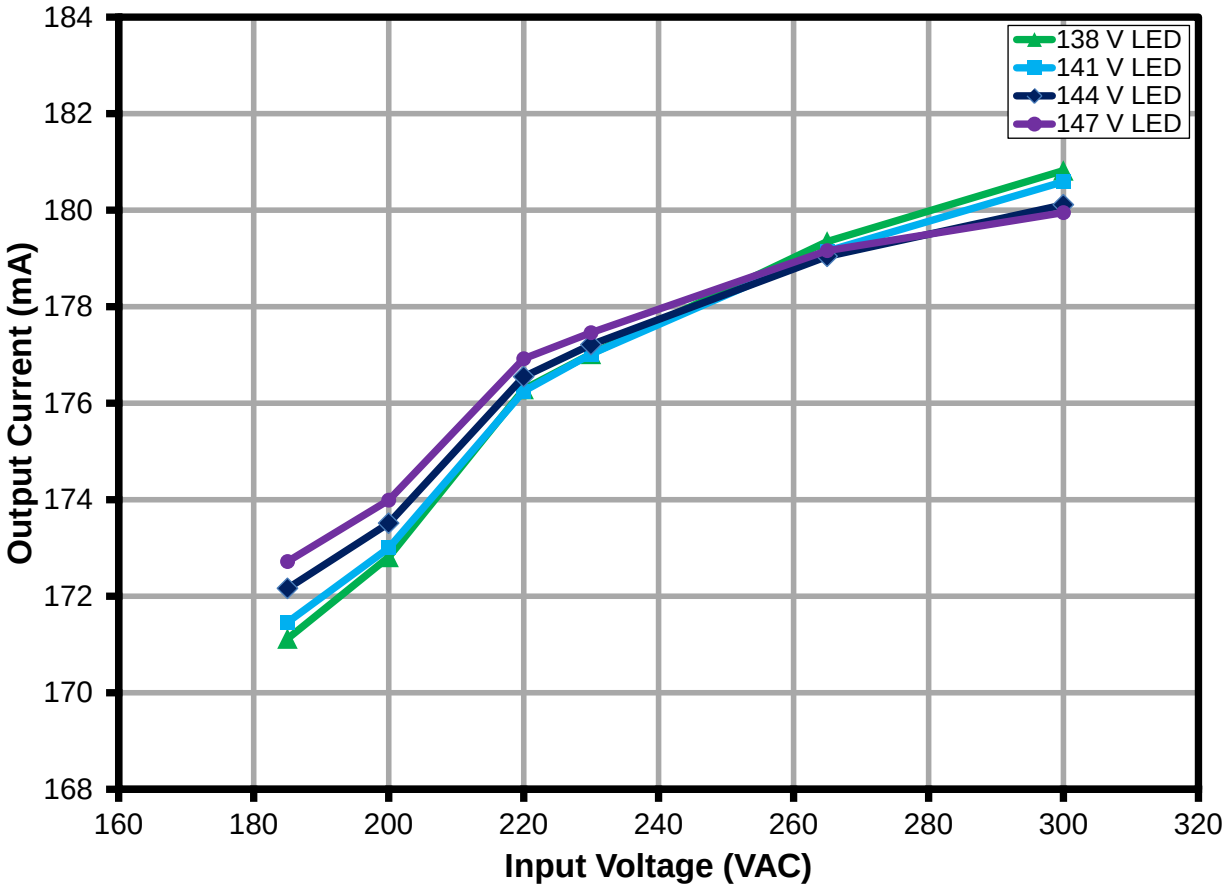

Figure 11 – Regulation vs. Line and Load.

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10.3 線電壓與負載穩定度關係圖

Regulation is well within ±5% across line and load.

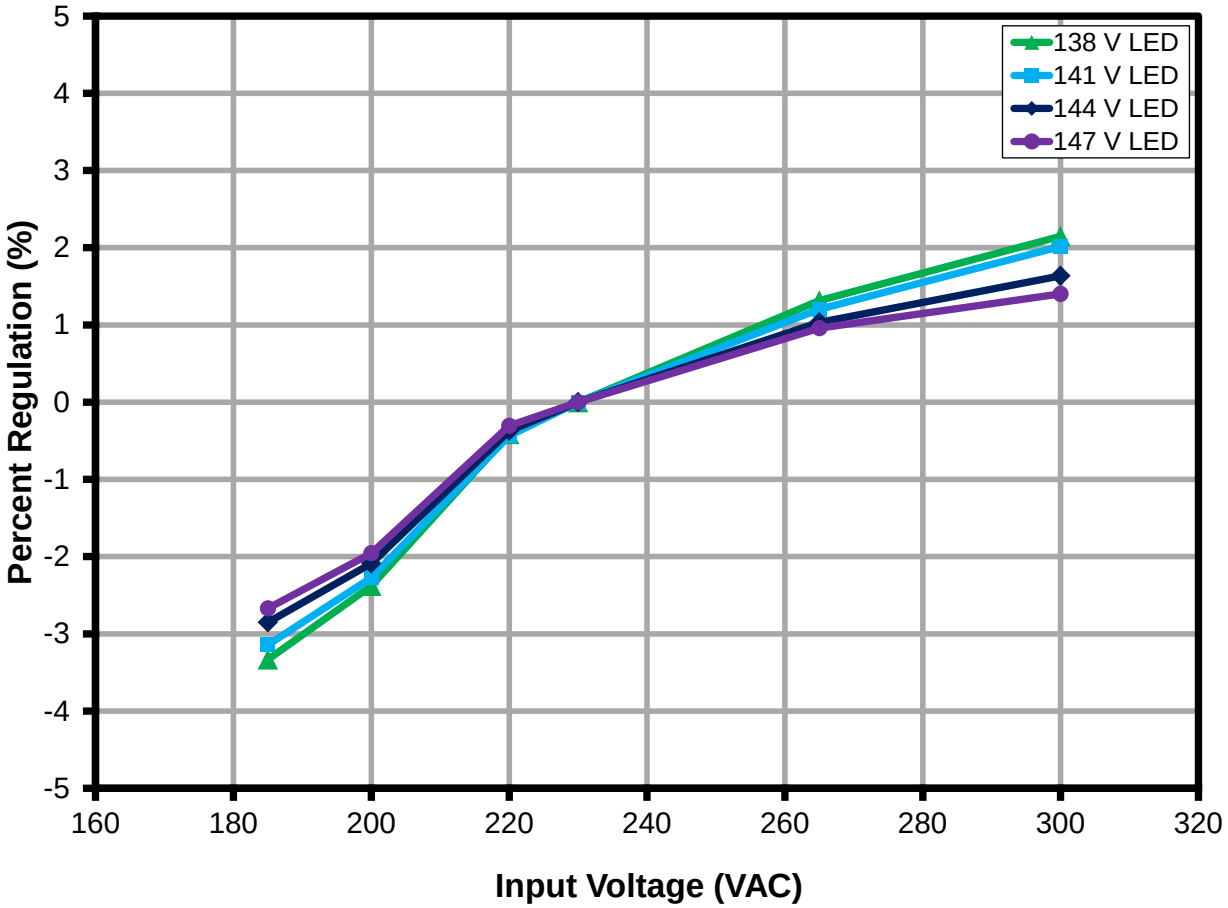

Figure 12 – Percent Line/Load Regulation.

10.4 功率因數 (PF)

PF is greater than 0.94 across line and load.

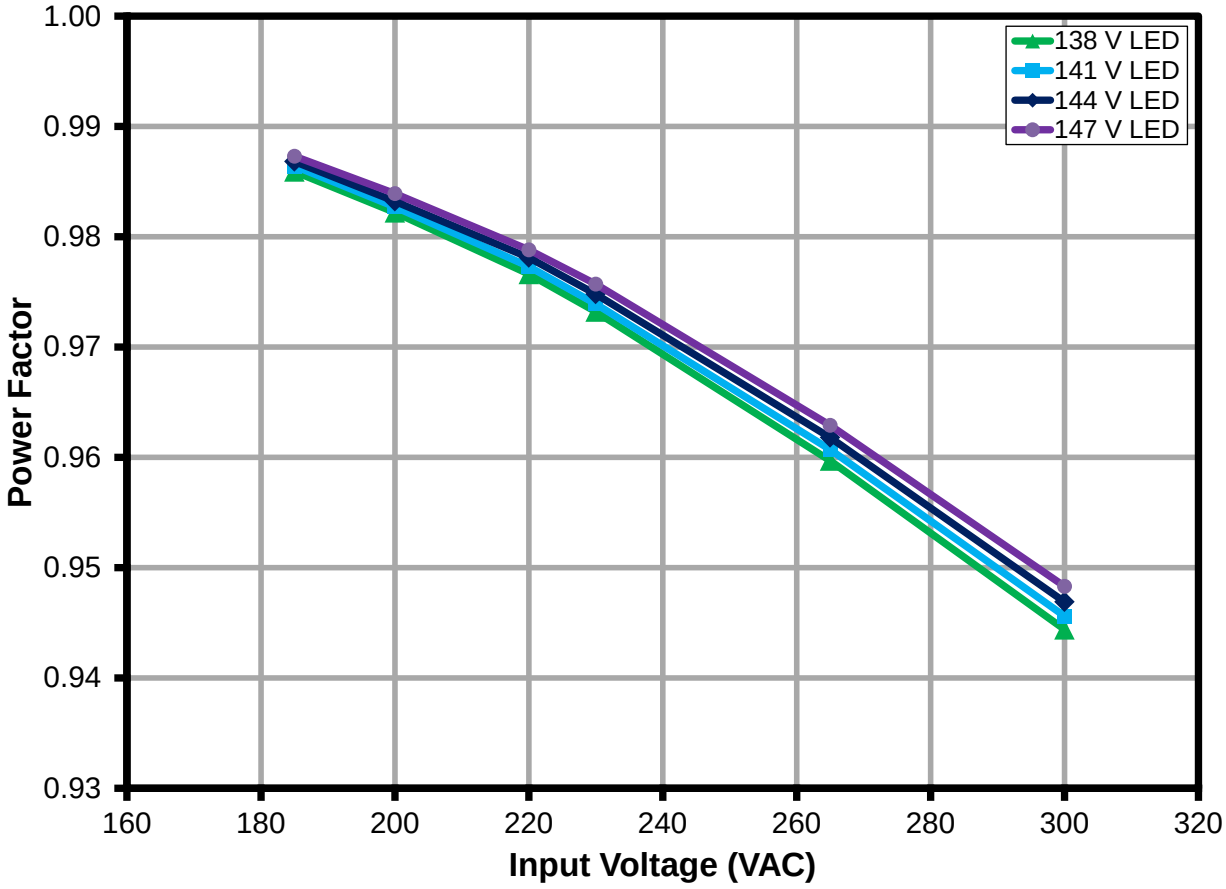

Figure 13 – Power Factor vs. Line and Load.

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10.5 A-THD

Current Total Harmonic Distortion (ATHD) is below 10% at 240 V and less than 14% across line and load.

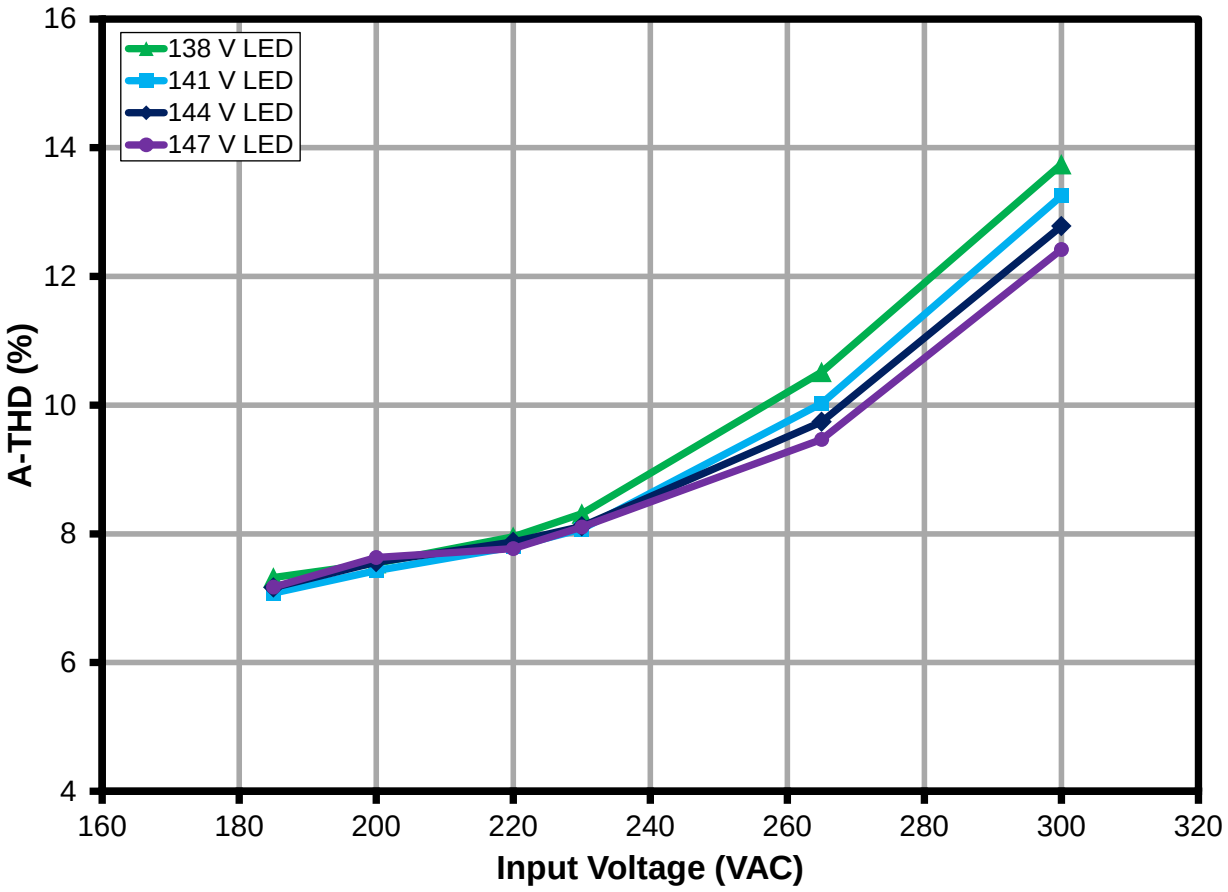

Figure 14 – A-THD vs. Line and Load.

10.6 諧波

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.

10.6.1 230 V，50 Hz 輸入條件下的 144 V LED 負載

All Odd Harmonic Current contents are well below the mandated Class C Limit.

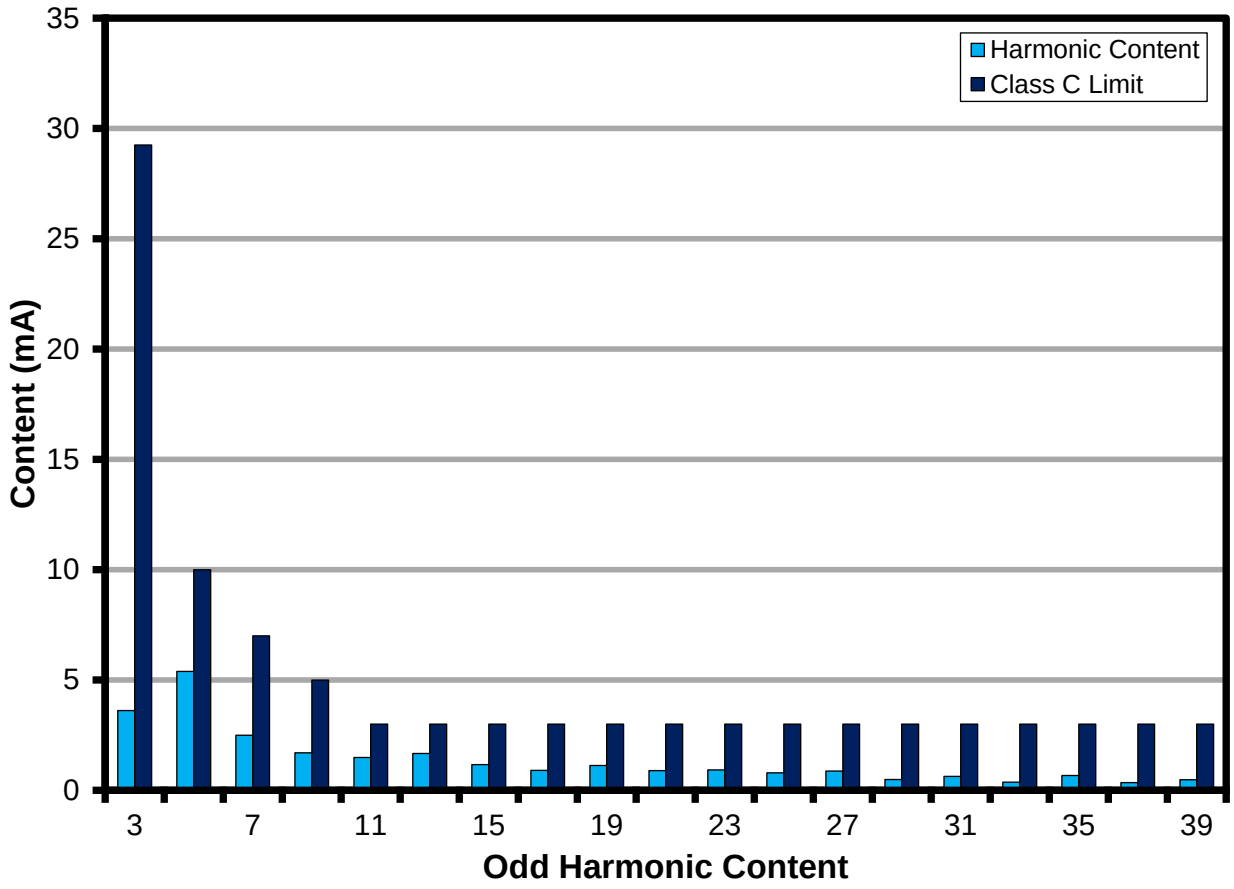

Figure 15 – 144 V LED Load Input Current Harmonics at 230 VAC, 50 Hz.

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10.6.3 230 V，50 Hz 輸入條件下的 138 V LED 負載

All Odd Harmonic Current contents are well below the mandated Class C Limit.

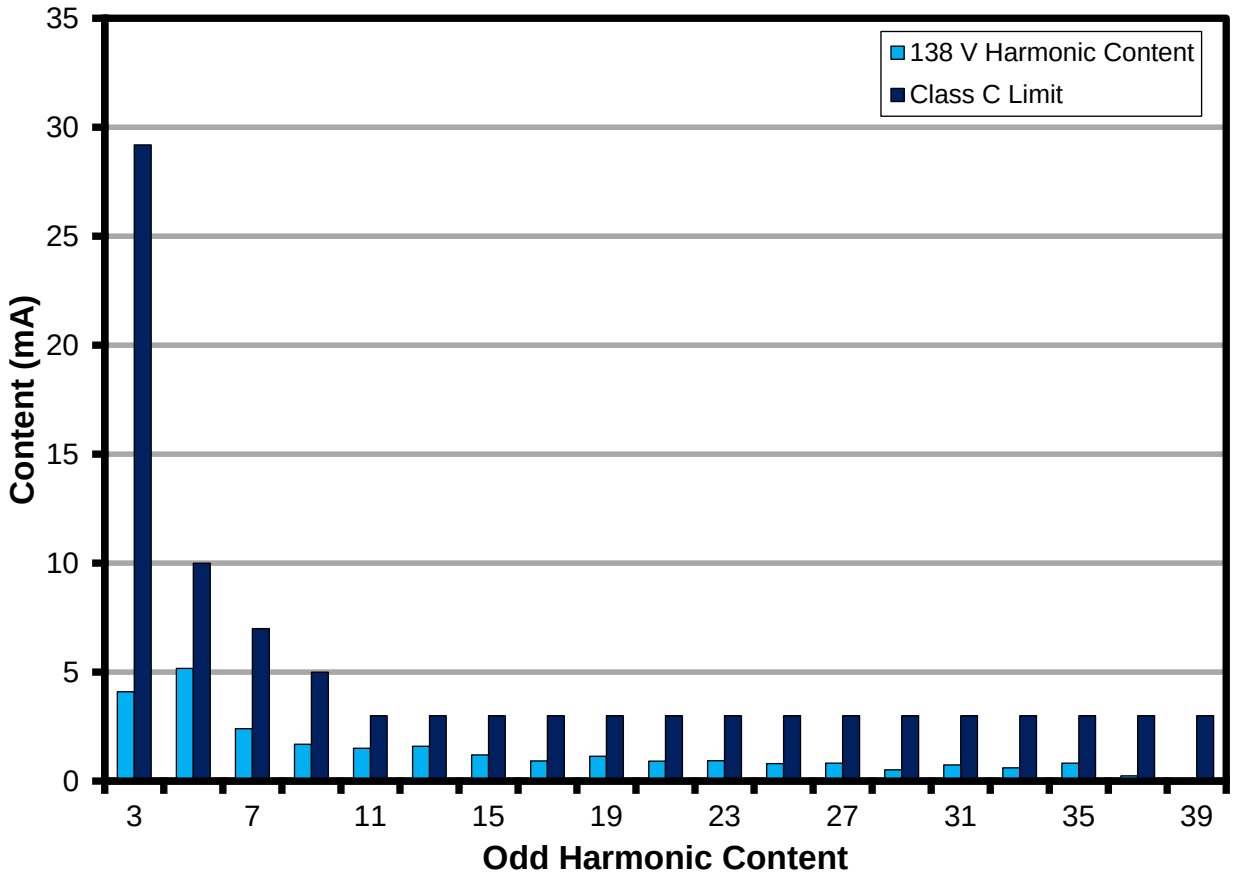

Figure 16 – 138 V LED Load Input Current Harmonics at 230 VAC, 50 Hz.

10.7 測試資料

All measurements were taken with the board in open frame configuration, and 25 °C ambient.

10.7.1 測試資料，144 V LED 負載

輸入		Input Measurement					LED Load Measurement				
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)	%Reg	Efficiency (%)
185	50	184.85	151.01	27.5	0.987	7.166	143.93	172	24.8	-2.85%	90.15
200	50	199.86	141.13	27.7	0.983	7.559	143.9	173	25.0	-2.09%	90.25
220	50	219.84	131.28	28.2	0.978	7.874	144.0	176	25.5	-0.37%	90.27
230	**50**	**229.87**	**126.42**	**28.3**	**0.975**	**8.115**	**144.0**	**177**	**25.6**	**0%**	**90.29**
265	50	264.88	112.41	28.6	0.962	9.74	144.0	179	25.9	1.03%	90.27
300	50	299.96	101.64	28.9	0.947	12.782	144.0	180	26.0	1.64%	90.09

10.7.2 測試資料，141 V LED 負載

輸入		Input Measurement					LED Load Measurement				
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)	%Reg	Efficiency (%)
185	50	184.85	146.82	26.770	0.986	7.08	140.7	171	24.2	-3.14%	90.32
200	50	199.86	137.44	26.994	0.983	7.427	140.7	173	24.4	-2.27%	90.38
220	50	219.84	128.13	27.530	0.977	7.797	140.7	176	24.9	-0.43%	90.33
230	**50**	**229.87**	**123.48**	**27.645**	**0.974**	**8.076**	**140.7**	**177**	**25.0**	**0%**	**90.33**
265	50	264.88	110.09	28.015	0.961	10.028	140.7	179	25.3	1.20%	90.23
300	50	299.96	99.79	28.306	0.946	13.251	140.7	180	25.5	2.02%	90.03

10.7.3 測試資料，138 V LED 負載

輸入		Input Measurement					LED Load Measurement				
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)	%Reg	Efficiency (%)
185	50	184.9	143.8	26.2	0.99	7.3	137.9	171.1	23.6	-3.33%	90.21
200	50	199.9	134.7	26.4	0.98	7.5	137.9	172.8	23.9	-2.38%	90.30
220	50	219.8	125.8	27.0	0.98	8.0	137.9	176.3	24.4	-0.41%	90.24
230	**50**	**229.9**	**121.3**	**27.1**	**0.97**	**8.3**	**137.9**	**177.0**	**24.5**	**0%**	**90.22**
265	50	264.9	108.3	27.5	0.96	10.5	138.0	179.4	24.8	1.32%	90.12
300	50	300.0	98.2	27.8	0.94	13.7	138.0	180.8	25.1	2.15%	90.01

10.7.4 測試資料，147 V LED 負載

輸入		Input Measurement					LED Load Measurement				
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)	%Reg	Efficiency (%)
185	50	184.9	154.3	28.2	0.99	7.2	146.9	173	25.4	-2.67%	90.31
200	50	199.9	144.1	28.3	0.98	7.6	146.9	174	25.6	-1.96%	90.39
220	50	219.8	134.0	28.8	0.98	7.8	147.0	177	26.1	-0.30%	90.39
230	**50**	**229.9**	**129.0**	**28.9**	**0.98**	**8.1**	**147.0**	**177**	**26.1**	**0%**	**90.37**
265	50	264.9	114.5	29.2	0.96	9.5	147.0	179	26.4	0.96%	90.35
300	50	300.0	103.5	29.4	0.95	12.4	147.2	180	26.6	1.40%	90.19

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10.7.5 230 VAC、50 Hz 輸入條件下的 144 V LED 負載諧波資料

V	Freq	I (mA)	P	PF	%THD
230	50.00	126.42	28.3280	0.9748	8.115
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	125.45				
2	0.03	0.02%		2.00%	Pass
3	4.53	3.61%	96.3152	29.24%	Pass
5	6.76	5.39%	53.8232	10.00%	Pass
7	3.13	2.50%	28.3280	7.00%	Pass
9	2.13	1.70%	14.1640	5.00%	Pass
11	1.87	1.49%	9.9148	3.00%	Pass
13	2.10	1.67%	8.3894	3.00%	Pass
15	1.46	1.16%	7.2709	3.00%	Pass
17	1.14	0.91%	6.4155	3.00%	Pass
19	1.41	1.12%	5.7401	3.00%	Pass
21	1.12	0.89%	5.1935	3.00%	Pass
23	1.16	0.92%	4.7419	3.00%	Pass
25	0.99	0.79%	4.3625	3.00%	Pass
27	1.09	0.87%	4.0394	3.00%	Pass
29	0.62	0.49%	3.7608	3.00%	Pass
31	0.79	0.63%	3.5182	3.00%	Pass
33	0.46	0.37%	3.3049	3.00%	Pass
35	0.84	0.67%	3.1161	3.00%	Pass
37	0.44	0.35%	2.9476	3.00%	Pass
39	0.60	0.48%	2.7965	3.00%	Pass
41	0.49	0.39%			

10.7.6 230 VAC、50 Hz 輸入條件下的 141 V LED 負載諧波資料

V	Freq	I (mA)	P	PF	%THD
230	50.00	123.48	27.6450	0.9739	8.076
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	122.50				
2	0.03	0.02%		2.00%	Pass
3	4.61	3.76%	93.9930	29.22%	Pass
5	6.44	5.26%	52.5255	10.00%	Pass
7	2.95	2.41%	27.6450	7.00%	Pass
9	2.10	1.71%	13.8225	5.00%	Pass
11	1.81	1.48%	9.6758	3.00%	Pass
13	1.96	1.60%	8.1872	3.00%	Pass
15	1.45	1.18%	7.0956	3.00%	Pass
17	1.13	0.92%	6.2608	3.00%	Pass
19	1.42	1.16%	5.6018	3.00%	Pass
21	1.12	0.91%	5.0683	3.00%	Pass
23	1.09	0.89%	4.6275	3.00%	Pass
25	0.95	0.78%	4.2573	3.00%	Pass
27	1.03	0.84%	3.9420	3.00%	Pass
29	0.61	0.50%	3.6701	3.00%	Pass
31	0.80	0.65%	3.4333	3.00%	Pass
33	0.43	0.35%	3.2253	3.00%	Pass
35	0.81	0.66%	3.0410	3.00%	Pass
37	0.48	0.39%	2.8766	3.00%	Pass
39	0.60	0.49%	2.7291	3.00%	Pass
41	0.41	0.33%			

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10.7.7 230 VAC、50 Hz 輸入條件下的 138 V LED 負載諧波資料

V	Freq	I (mA)	P	PF	%THD
230	50.00	121.27	27.1280	0.9732	8.315
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25 W**	**Remarks**
1	120.27				
2	0.03	0.02%		2.00%	Pass
3	4.93	4.10%	92.2352	29.20%	Pass
5	6.22	5.17%	51.5432	10.00%	Pass
7	2.89	2.40%	27.1280	7.00%	Pass
9	2.04	1.70%	13.5640	5.00%	Pass
11	1.81	1.50%	9.4948	3.00%	Pass
13	1.93	1.60%	8.0341	3.00%	Pass
15	1.45	1.21%	6.9629	3.00%	Pass
17	1.12	0.93%	6.1437	3.00%	Pass
19	1.37	1.14%	5.4970	3.00%	Pass
21	1.11	0.92%	4.9735	3.00%	Pass
23	1.13	0.94%	4.5410	3.00%	Pass
25	0.97	0.81%	4.1777	3.00%	Pass
27	0.99	0.82%	3.8683	3.00%	Pass
29	0.63	0.52%	3.6015	3.00%	Pass
31	0.90	0.75%	3.3691	3.00%	Pass
33	0.74	0.62%	3.1649	3.00%	Pass
35	0.99	0.82%	2.9841	3.00%	Pass
37	0.29	0.24%	2.8228	3.00%	Pass
39	0.68	0.57%	2.6780	3.00%	Pass
41	0.39	0.32%			

10.7.8 230 VAC、50 Hz 輸入條件下的 147 V LED 負載諧波資料

V	Freq	I (mA)	P	PF	%THD
230	50.00	128.95	28.9220	0.9757	8.106
nth Order	**mA Content**	**% Content**	**Limit <25 W**	**Limit >25W**	**Remarks**
1	128.00				
2	0.02	0.02%		2.00%	Pass
3	4.19	3.27%	98.3348	29.27%	Pass
5	6.99	5.46%	54.9518	10.00%	Pass
7	3.19	2.49%	28.9220	7.00%	Pass
9	2.17	1.70%	14.4610	5.00%	Pass
11	1.88	1.47%	10.1227	3.00%	Pass
13	2.16	1.69%	8.5654	3.00%	Pass
15	1.45	1.13%	7.4233	3.00%	Pass
17	1.14	0.89%	6.5500	3.00%	Pass
19	1.37	1.07%	5.8605	3.00%	Pass
21	1.14	0.89%	5.3024	3.00%	Pass
23	1.12	0.88%	4.8413	3.00%	Pass
25	0.94	0.73%	4.4540	3.00%	Pass
27	0.98	0.77%	4.1241	3.00%	Pass
29	0.58	0.45%	3.8396	3.00%	Pass
31	0.91	0.71%	3.5919	3.00%	Pass
33	0.81	0.63%	3.3742	3.00%	Pass
35	1.13	0.88%	3.1814	3.00%	Pass
37	0.18	0.14%	3.0095	3.00%	Pass
39	0.71	0.55%	2.8551	3.00%	Pass
41	0.31	0.24%			

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11 波形

11.1 輸入線電流

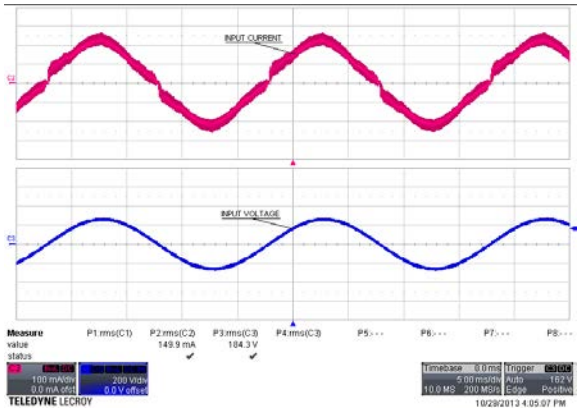

Figure 17 – 185 VAC 50 Hz, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

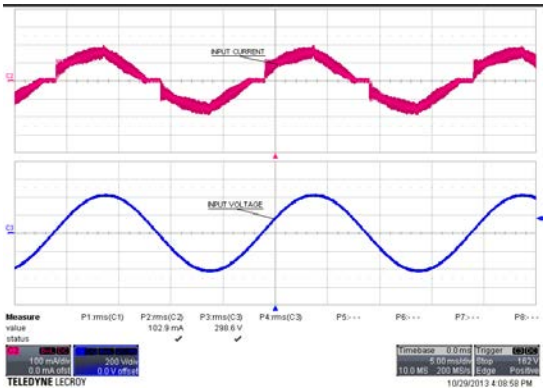

Figure 18 – 300 VAC 50 Hz, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

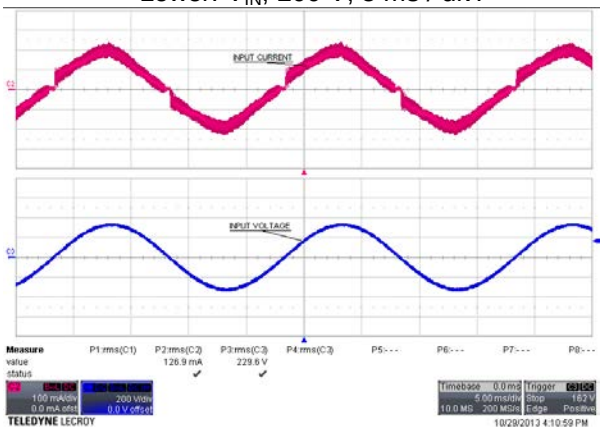

Figure 19 – 230 VAC 50 Hz, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

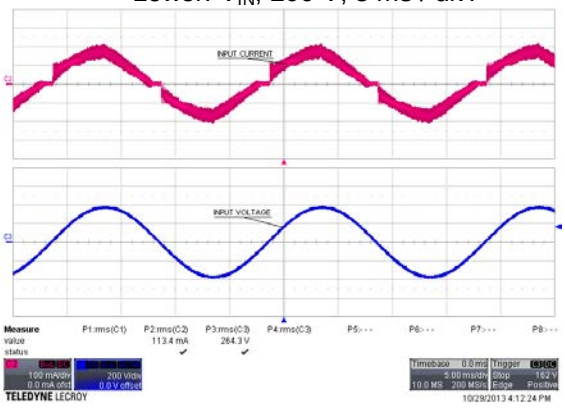

Figure 20 – 265 VAC 50 Hz, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

11.2 汲極電壓和電流與正常操作

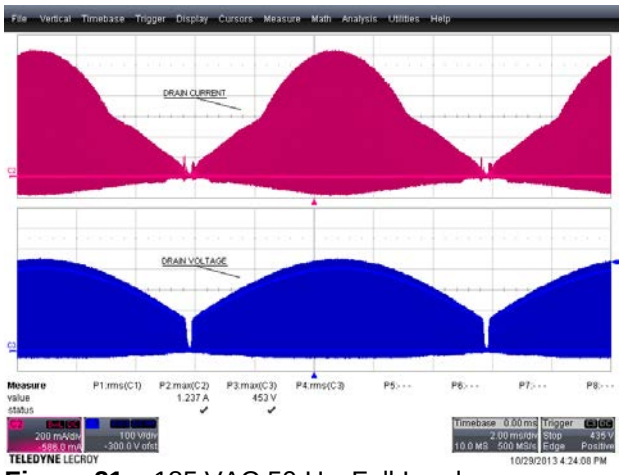

Figure 21 – 185 VAC 50 Hz, Full Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

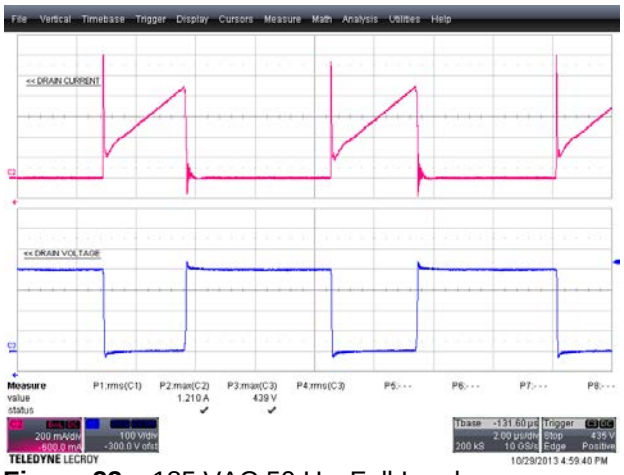

Figure 22 – 185 VAC 50 Hz, Full Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 2 µs / div.

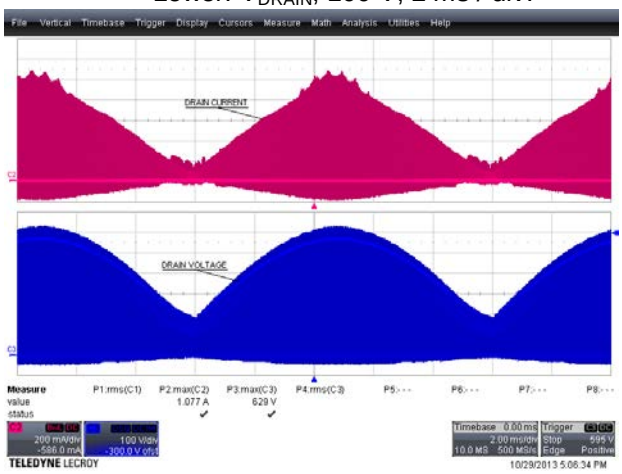

Figure 23 – 300 VAC 50 Hz, Full Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

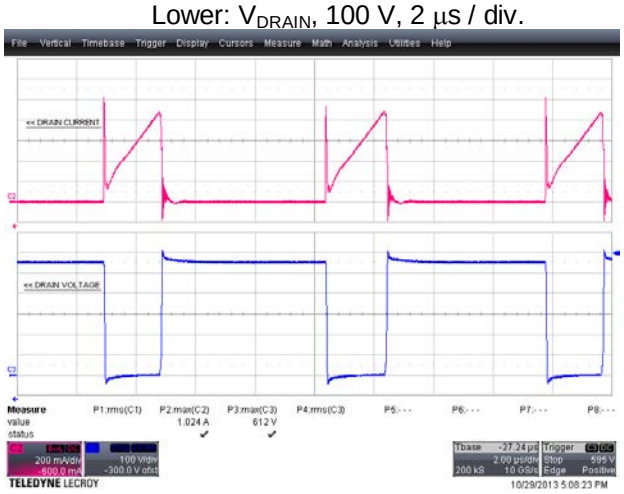

Figure 24 – 300 VAC 50 Hz, Full Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 2 µs / div.

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11.3 汲極電壓和電流啓動操作

Figure 25 – 185 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 20 ms / div.

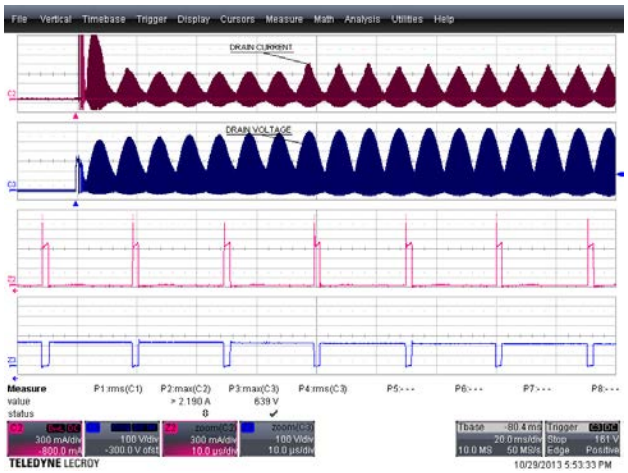

Figure 26 – 300 VAC 50 Hz, Full Load Start-up.
Upper: I_{DRAIN}, 300 mA / div.
Lower: V_{DRAIN}, 100 V, 20 ms / div.

11.4 輸出電流與輸出電壓

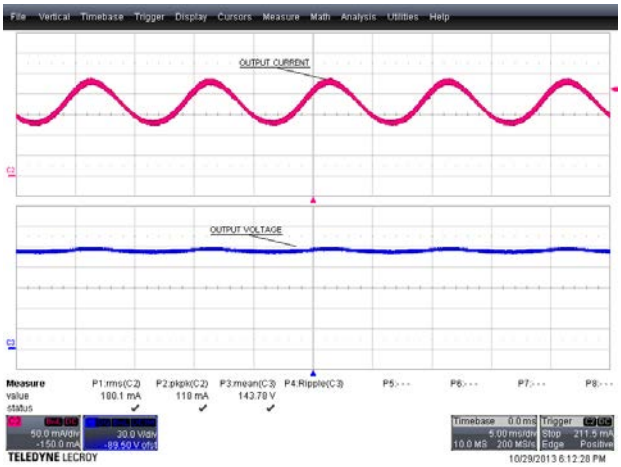

Figure 27 – 185 VAC 50 Hz, Full Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 30 V, 5 ms / div.

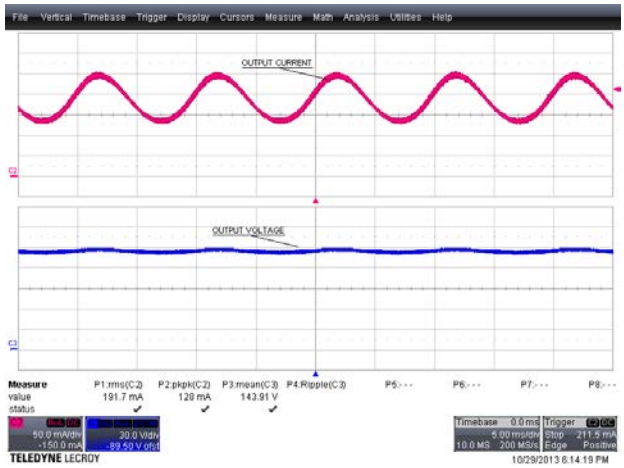

Figure 28 – 300 VAC 50 Hz, Full Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 30 V, 5 ms / div.

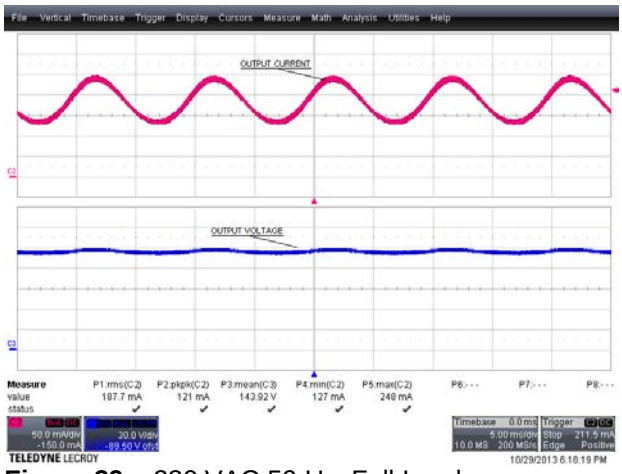

Figure 29 – 230 VAC 50 Hz, Full Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 30 V, 5 ms / div.

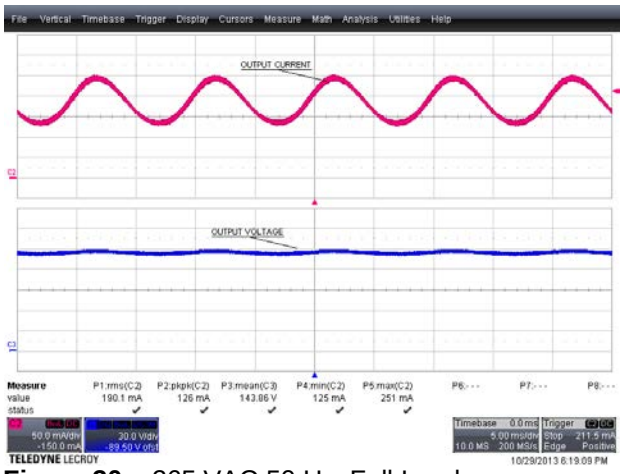

Figure 30 – 265 VAC 50 Hz, Full Load.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 30 V, 5 ms / div.

11.5 開機、關機時的輸出電流與電壓

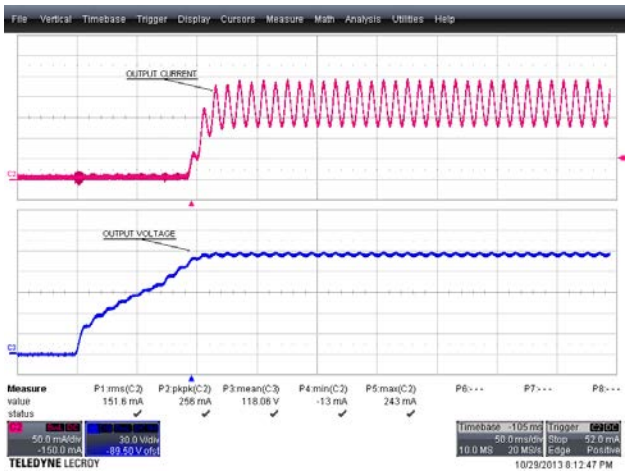

Figure 31 – 230 VAC 50 Hz, Output Rise.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 30 V, 50 ms / div.

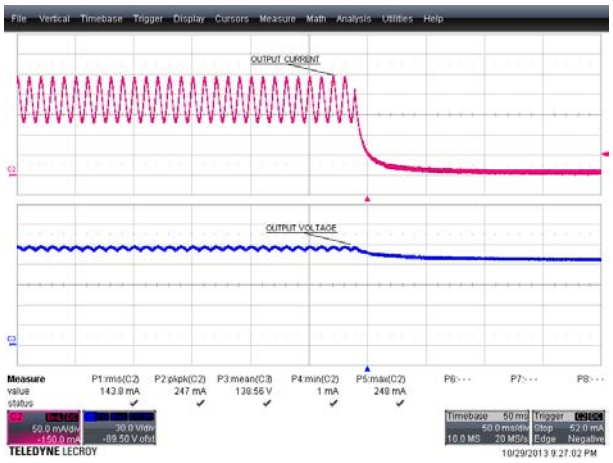

Figure 32 – 230 VAC 50 Hz, Output Fall.
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 30 V, 50 ms / div.

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11.6 輸出短路

Figure 33 – 185 VAC 50 Hz, Output Short.
Upper: I_{DRAIN}, 0.5 A / div.
Lower: V_{DRAIN}, 100 V, 100 ms / div.

Figure 34 – 300 VAC 50 Hz, Output Short.
Upper: I_{DRAIN}, 0.5 A / div.
Lower: V_{DRAIN}, 100 V, 100 ms / div.

11.7 開路負載

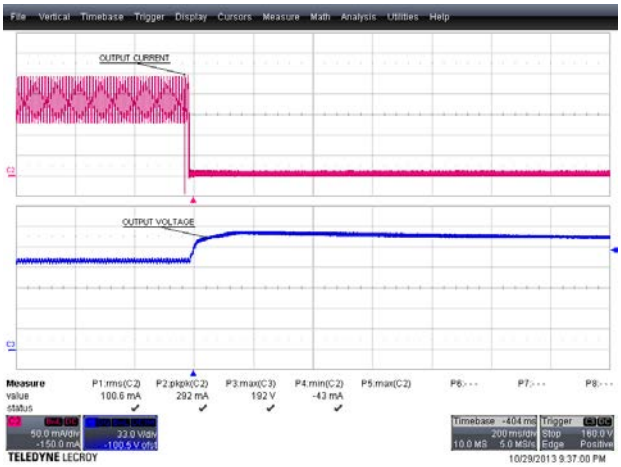

Figure 35 – 230 VAC 50 Hz, Running Open Load
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 30 V, 200 ms / div.

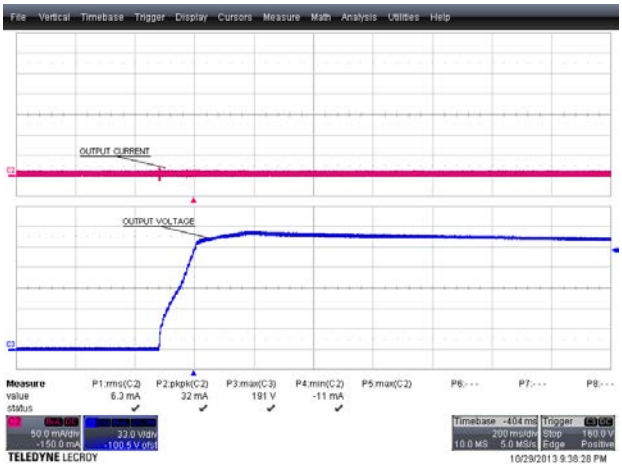

Figure 36 – 230 VAC 50 Hz, Open Load Start-up
Upper: I_{OUT}, 50 mA / div.
Lower: V_{OUT}, 50 V, 200 ms / div.

12 散熱測量

Thermal measurements were done with the UUT operated at room temperature (25 °C) with 144 V LED Load

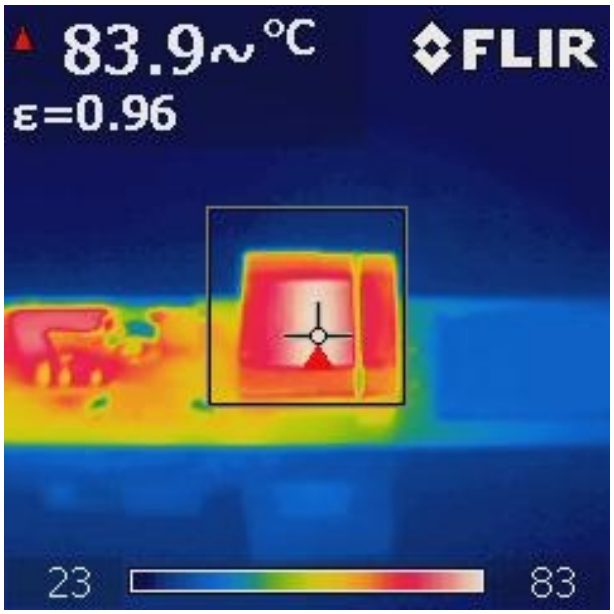

Figure 37 – Transformer (T1), 185 VAC, 50 Hz.

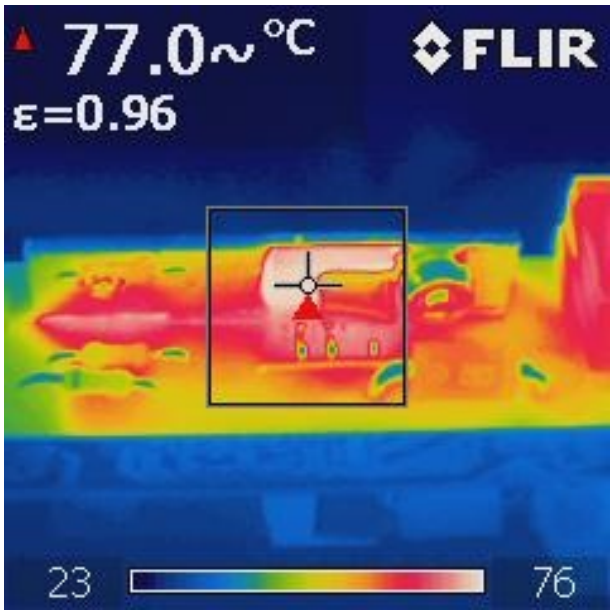

Figure 38 – LYT4225E (U1), 185 VAC, 50 Hz.

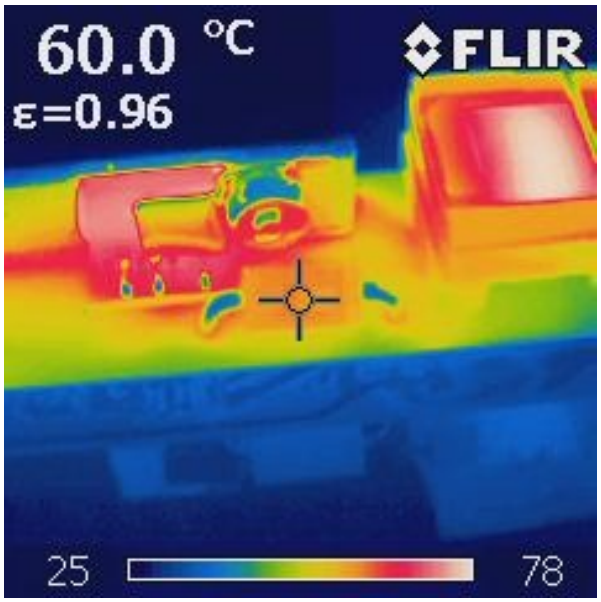

Figure 39 – Output Diode (D6), 185VAC, 50 Hz

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13 傳導性 EMI 測量

The unit was tested using ~144 V LED strings as load with an input voltage of 230 VAC, 60 Hz at room temperature. The UUT was mounted on the heatsink of the LED load, it served as ground plane which shunted RFI emanating from the board.

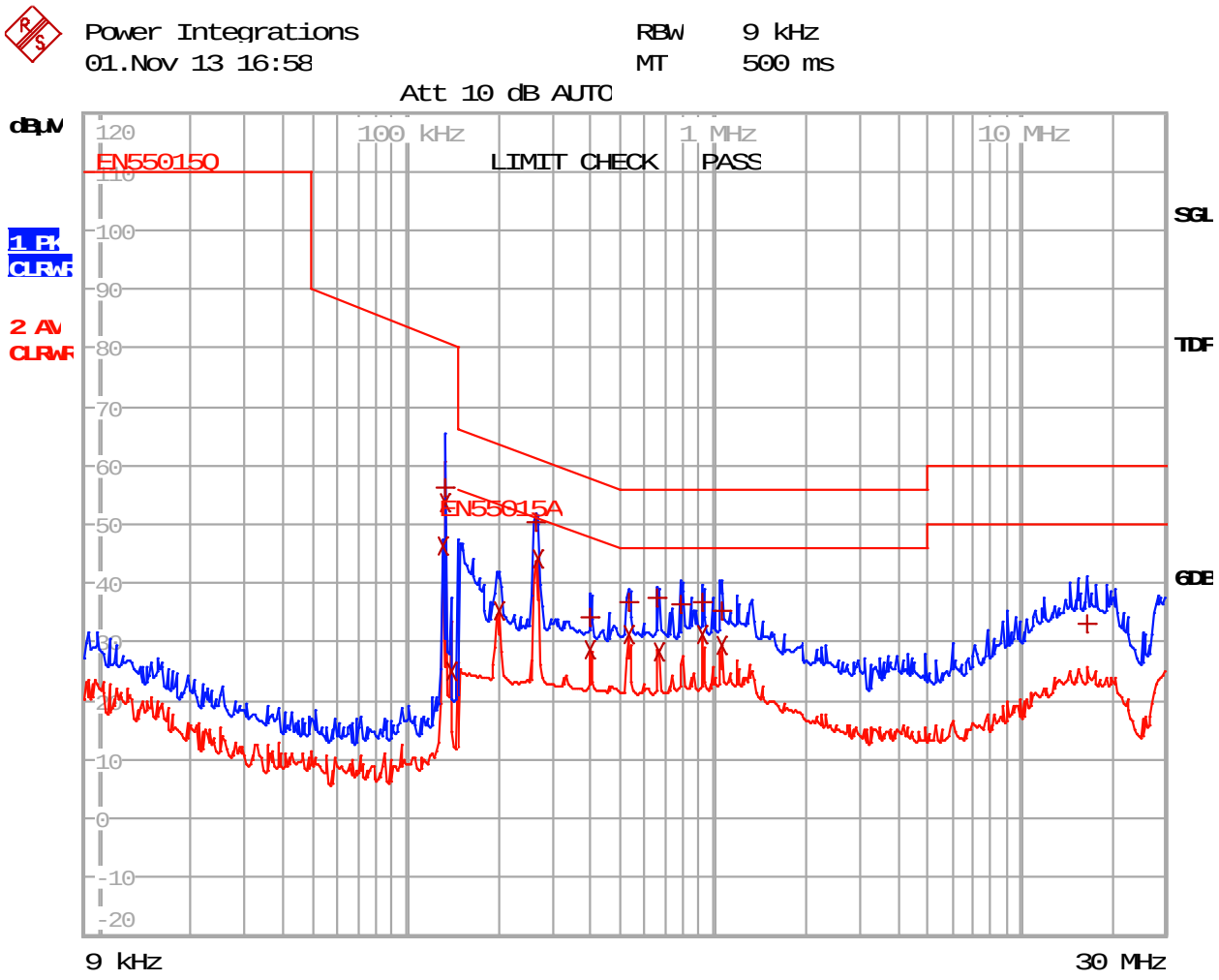

Figure 40 – Conducted EMI, 144 V LED Load, 230 VAC, 60 Hz, EN55015B Limits.

EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

	TRACE	FREQUENCY	LEVEL dBµV			DELTA LIMIT dB
2	Average	130.825395691 kHz	46.22	L1	gnd	
1	Quasi Peak	133.454986145 kHz	56.17	N	gnd	-24.88
2	Average	133.454986145 kHz	53.73	N	gnd	
2	Average	140.262531674 kHz	25.16	L1	gnd	
2	Average	200.175581485 kHz	35.43	L1	gnd	-18.16
1	Quasi Peak	264.49018761 kHz	50.32	L1	gnd	-10.96
2	Average	267.135089486 kHz	44.12	L1	gnd	-7.08
1	Quasi Peak	397.727746704 kHz	34.21	L1	gnd	-23.68
2	Average	397.727746704 kHz	28.83	L1	gnd	-19.07
1	Quasi Peak	530.769219795 kHz	36.65	L1	gnd	-19.34
2	Average	530.769219795 kHz	31.22	N	gnd	-14.77
1	Quasi Peak	660.656865747 kHz	37.38	N	gnd	-18.61
2	Average	667.263434405 kHz	28.33	N	gnd	-17.66
1	Quasi Peak	790.243042258 kHz	36.24	N	gnd	-19.75
1	Quasi Peak	926.622115652 kHz	36.75	N	gnd	-19.24
2	Average	926.622115652 kHz	31.13	N	gnd	-14.86
1	Quasi Peak	1.06512822736 MHz	35.46	N	gnd	-20.53
2	Average	1.06512822736 MHz	29.24	N	gnd	-16.76
1	Quasi Peak	16.4353775277 MHz	32.93	N	gnd	-27.06

Figure 41 – Conducted EMI, 144 V LED Load, 230 VAC, 60 Hz, EN55015B Limits.

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14 線電壓突波測試

The unit was subjected to ±2500 V, 100 kHz ring wave and ±1000 V differential surge at 230 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.

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+2500	230	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
-2500	230	L1, L2	90	100 kHz Ring Wave (500 A)	Pass
+2500	230	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
-2500	230	L1, L2	90	100 kHz Ring Wave (500 A)	Pass

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+1000	230	L1, L2	0	Surge (2Ω)	Pass
-1000	230	L1, L2	90	Surge (2Ω)	Pass
+1000	230	L1, L2	0	Surge (2Ω)	Pass
-1000	230	L1, L2	90	Surge (2Ω)	Pass

15 修訂記錄

日期	作者	修訂	**Description and Changes**	**Reviewed**
05-Dec-13	ME	1.0	Initial Release	Apps and Mktg

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