設計範例報告

標題	*採用 **LYTSwitch™-4 LYT4311E** 的 **5.8 W** 高功率因數非隔離升降壓式，可透過雙向閘流器 **(TRIAC)** 調光 **LED** 驅動器*
規格	90 VAC – 132 VAC 輸入； 48 V_{TYP}，120 mA 輸出
應用	A19 LED 驅動器
作者	應用工程部門
文件編號	DER-407
日期	2014 年 5 月 16 日
修訂	1.0

摘要與功能

- 結合 Single-stage 功率因數修正與定電流 (CC) 輸出
- 所需元件少、極輕薄小巧型設計
- 可調光雙向閘流器 (TRIAC)
  - 可選擇使用廣泛的雙向閘流器 (TRIAC) 調光器 (300 W 至 1200 W)
  - 快速啓動 (小於 200 ms) – 無可感延遲
- 整合式保護與信賴度特性
  - 藉由自動恢復功能提供輸出短路保護
  - 具有高磁滯時間的自動恢復回復過溫保護
  - 在電壓關閉情況下，不會發生任何損壞
- 120 VAC 時功率因數 (PF) 大於 0.9
- 符合振盪波、線差動電壓突波和 EN55015 傳導性 EMI 規定

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5245 Hellyer Avenue, San Jose, CA 95138 USA.
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目錄

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

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1 簡介

本文件說明非隔離式高功率因數 (PF)、可調光雙向閘流器 (TRIAC) LED 驅動器，其設計爲輸入電壓範圍爲 90 VAC 至 132 VAC (典型值 60 Hz) 時，於 120 mA 下驅動 48 V 的標準 LED 串電壓。此 LED 驅動器採用 LYTSwitch-4 IC 系列中的 LYT4311E。

此設計使用 Single-stage 非隔離升降壓式架構，以符合此設計的高功率因數、定電流調節和調光要求。

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

2 植入的 PCB

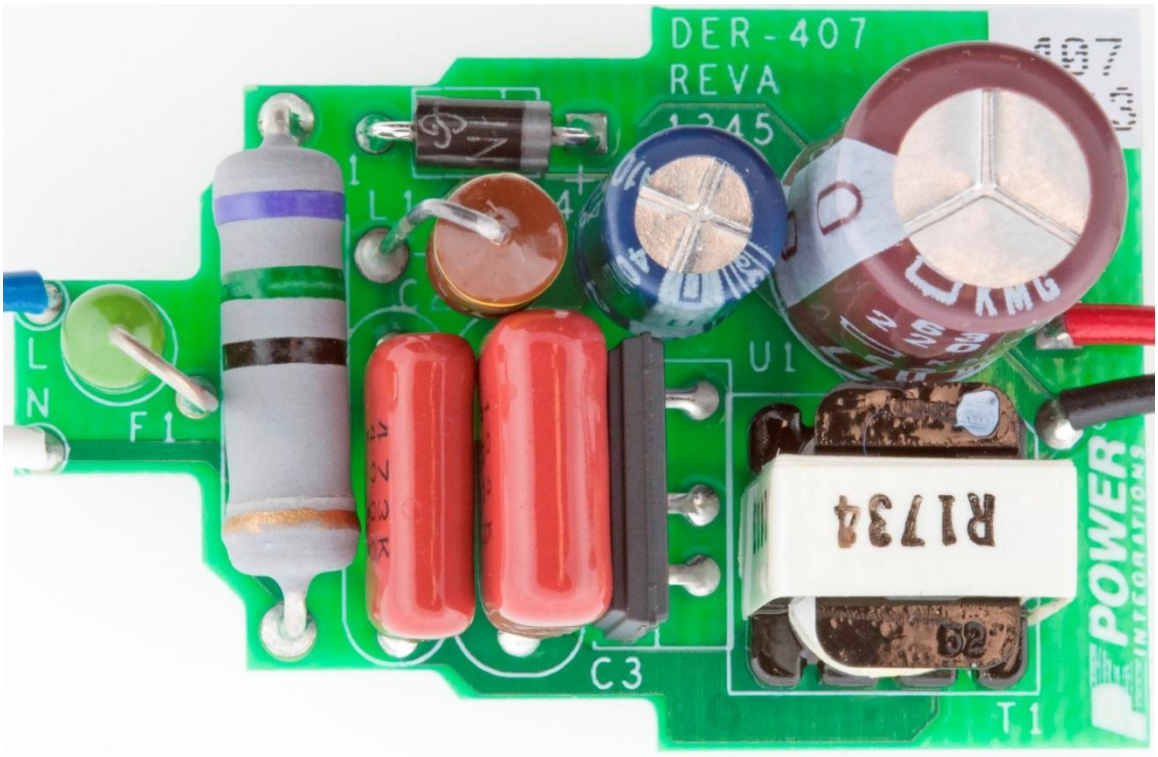

Figure 1 – Populated Circuit Board, Top View.

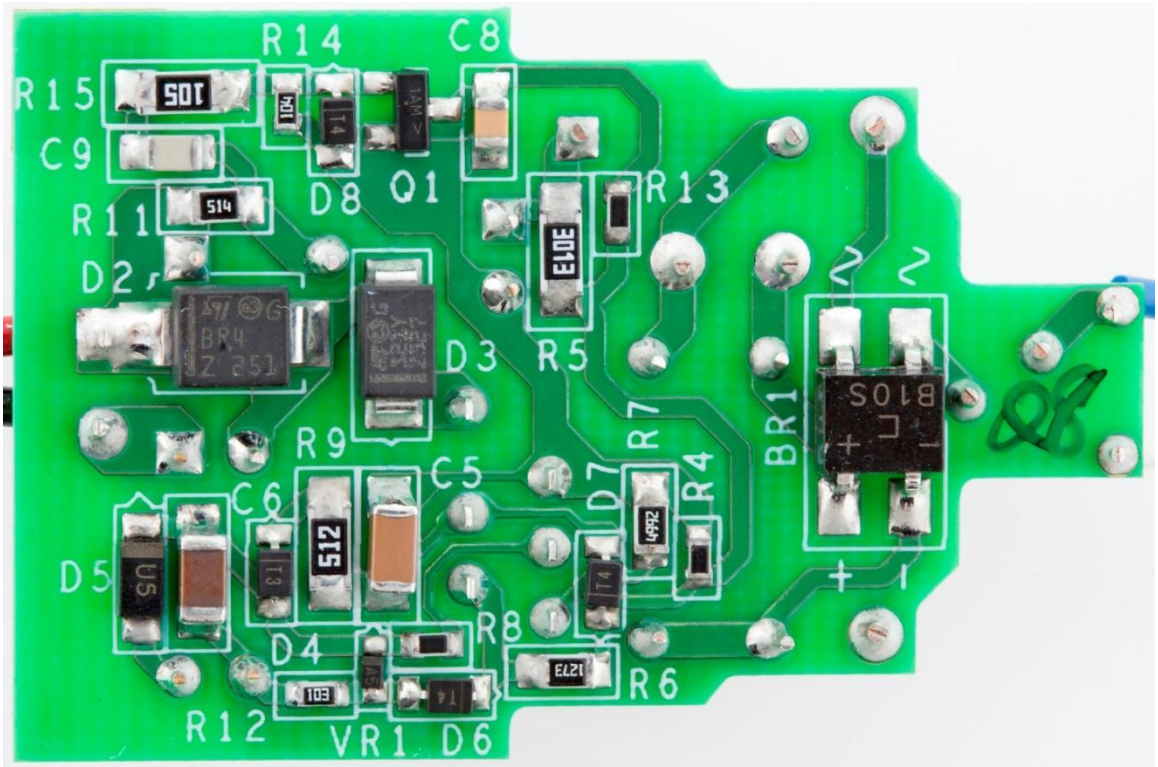

Figure 2 – Populated Circuit Board, Bottom View.

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3 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}	90	120	132	VAC	雙線 – 無 P.E.
頻率	f_{LINE}		60		Hz	
輸出						
輸出電壓	V_{OUT}		48		V	V_{OUT} = 48 V，V_{IN} = 120 VAC, 25 °C
輸出電流	I_{OUT}		120		mA	
總輸出功率						
連續輸出功率	P_{OUT}		5.76		W	
效率						
滿載	η		83		%	在 P_{OUT} 25°C、無調光、120VAC 時測量
環境						
傳導性 EMI		CISPR 15B / EN55015B				
安全		非隔離式				
振盪波 (100 kHz)						
差模 (L1-L2)			2.5		kV	
差模突波			500		V	
功率因數 (PF)			0.9			於 $V_{OUT(TYP)}$、$I_{OUT(TYP)}$ 及 120 VAC、50 Hz 條件下測量
環境溫度	T_{AMB}		50		°C	開放式架構，120 VAC

4 電路圖

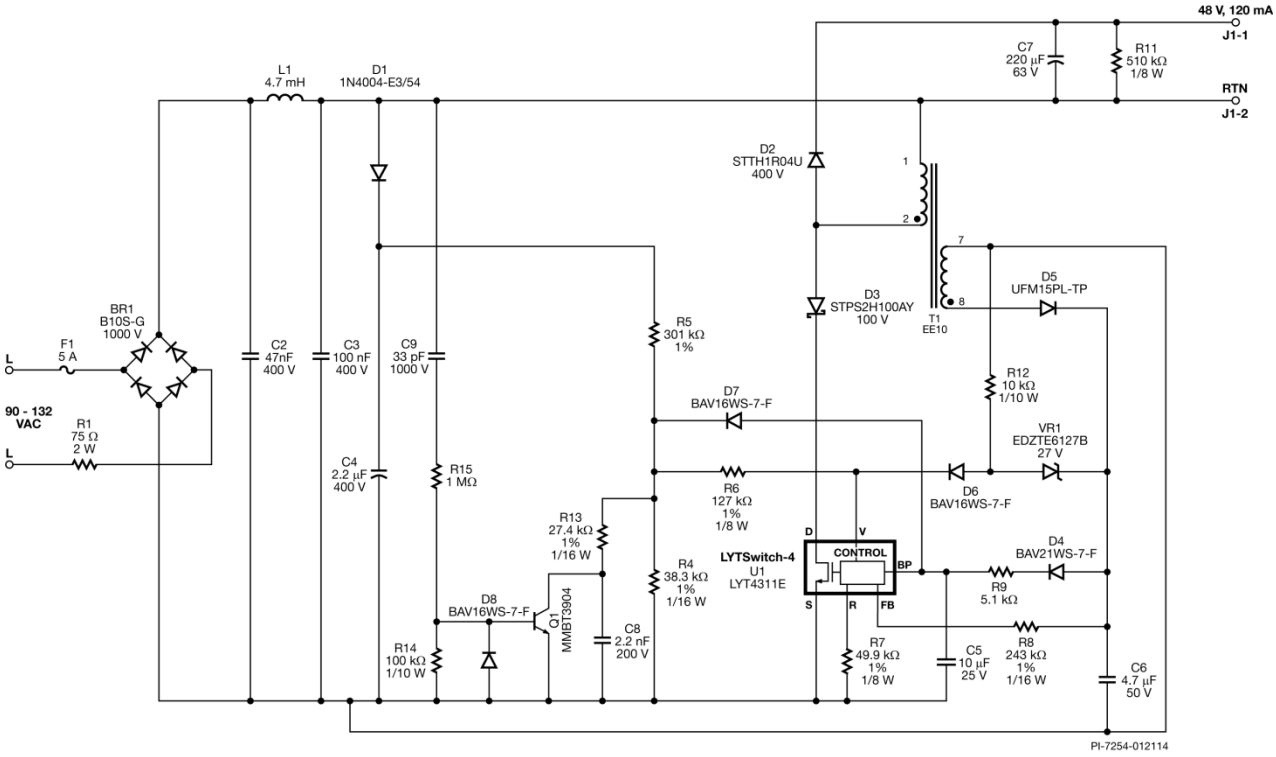

Figure 3 – Schematic Diagram.

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5 電路說明

LYTSwitch-4 LYT4311E 裝置是採用整合式 725 V 功率 MOSFET的控制器，適用於 LED 驅動器。LYTSwitch-4 family 設定用於Single-stage 升降壓式架構，可提供已調整的定電流輸出，同時保持高功率因數 (PF)。

5.1 輸入 EMI 濾波

保險絲 F1 可在異常狀況下防止元件發生故障。橋式整流器 BR1 可對 AC 線電壓和電容器 C3 進行整流，來爲一次側切換電流提供低阻抗路徑 (去耦合)。爲保持功率因數 (PF) 大於 0.9，需要使用小輸入電容值 (C2 與 C3 之和)。EMI 濾波由電感器 L1，以及電容器 C2 和 C3 提供。

5.2 電源電路

此設計中所選擇的架構是升降壓式架構，具有低側切換，設定爲在 90 VAC 至 132 VAC 輸入電壓範圍內提供高功率因數及定電流輸出。

每當 U1 關閉時，輸出二極體 D2 就會傳導，並將能量輸送到負載。需要使用二極體 D3，才能在 C3 上的電壓 (整流後的輸入 AC) 降到低於輸出電壓時防止反向電流流經 U1。

爲了提供峰值線電壓資訊給 U1，輸入整流 AC 峰值電壓會透過 D1 爲 C4 充電。然後該資料將以透過 R5 和 R6 的電流形式饋送至 U1 的電壓監測器 (V) 接腳。選擇電阻器 R4、R5 和 R6，可在 120 VAC 輸入時提供大約 100 µA 的 I_V (請見 PIXls 試算表)。

線電壓過壓關機功能 (透過 V 接腳電流感測) 可讓整流後的線電壓耐受度 (在突波和線間陡昇期間) 提高至內部功率 MOSFET 的 725 BV_{DSS} 額定值。

電容器 C5 會爲 U1 的 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 的 D 接腳連接的內部高壓電流源將 C10 充電至約 6 V。

U1 的參考接腳透過 49.9 kΩ 電阻器 R7 接地 (源極)。

5.3 輸出回授

從偏壓繞組衍生的回授訊號，會由二極體 D5 和電容器 C6 組成的網路進行整流和濾波。電容器 C6 產生的輸出電壓資訊會由電阻器 R8 轉換爲回授電流。LYT4311E 會使用此電流來調節轉換器的輸出電流。

5.4 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 的前緣觸發和後緣觸發相位調光器需要在設計時有些取捨。

由於 LED 照明所消耗的功率小得多，因此燈泡所汲取的電流會低於大多數 TRIAC 調光器的保持電流 (holding current)。這會導致不良狀況，例如調光範圍受限和/或閃爍。開啓 TRIAC 時，LED 燈相對較大的阻抗會因對輸入電容充電的突波電流 (inrush current) 而導致大幅振盪。這個效應也會導致發生上述的不良情況，因爲振盪可能導致 TRIAC 電流降至零並關閉。

爲了解決這些問題，採用了被動阻尼器和無功損主動洩放器。

電阻器 R1 用於抑制連接 TRIAC 時產生的輸入網路振盪。

透過增加在 AC 輸入週期的上升邊緣部分期間處理的功率，提供額外的阻尼。此方法可模擬被動 RC 洩放器 的行爲，但在調光時不會有相關的功損及其他的缺點。

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6 PCB 佈局

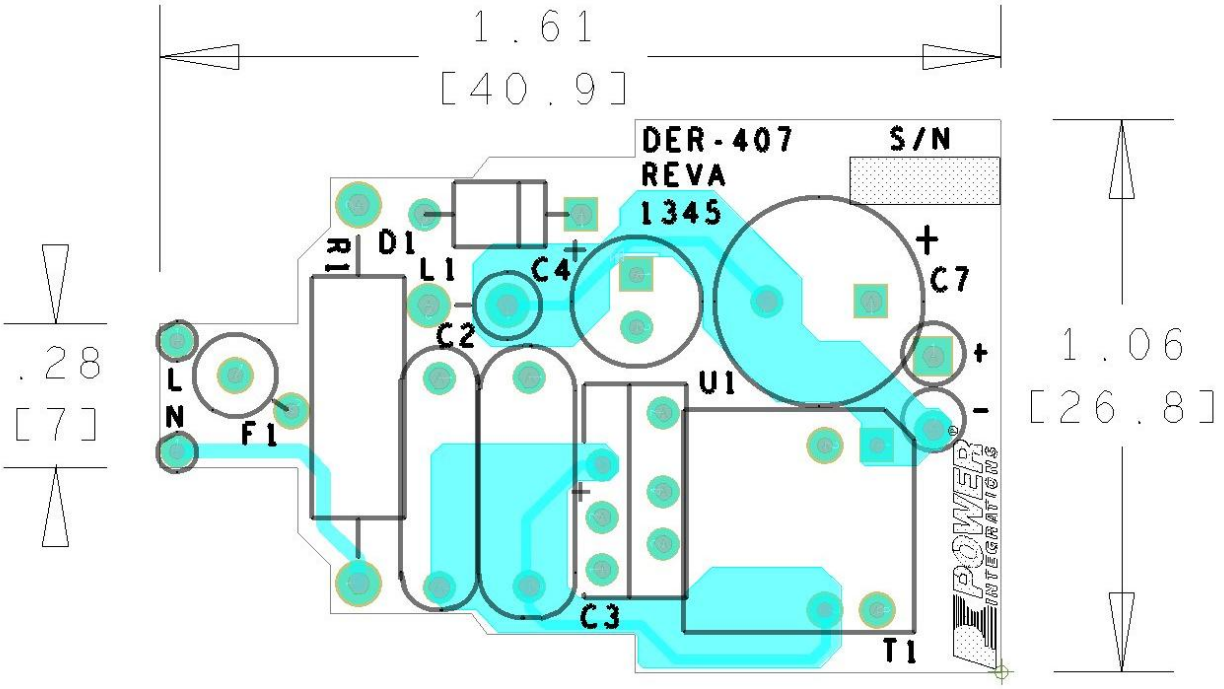

Figure 4 – Top Side.

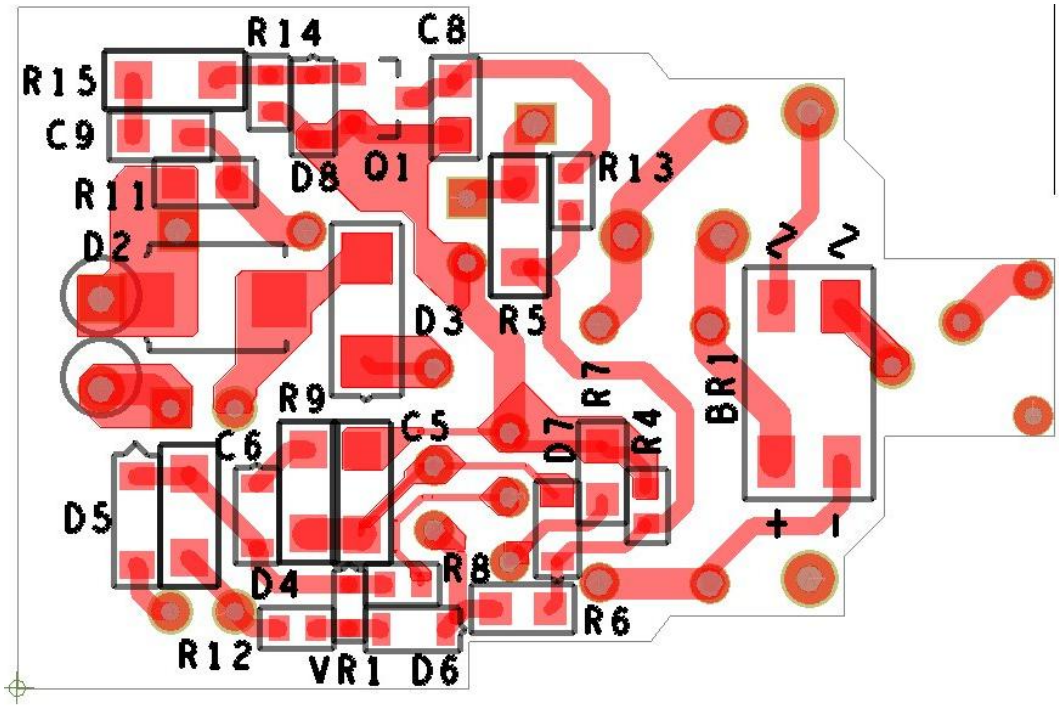

Figure 5 – Bottom Side.

7 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	C2	47 nF, 400 V, Film	ECQ-E4473KF	Panasonic
3	1	C3	100 nF, 400 V, Film	ECQ-E4104KF	Panasonic
4	1	C4	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
5	1	C5	10 μF, 25 V, Ceramic, X7R, 1206	C3216X7R1E106M	TDK Corp
6	1	C6	4.7 μF, 50 V, Ceramic, X7R, 1206	UMK316AB7475KL-T	Taiyo Yuden
7	1	C7	220 μF, 63 V, Electrolytic, (10 x 16)	EKMG630ELL221MJ16S	United Chemi-con
8	1	C8	2.2 nF, 200 V, Ceramic, X7R, 0805	08052C222KAT2A	AVX
9	1	C9	33 pF, 1000 V, Ceramic, COG, 0805	0805AA330KAT1A	AVX
10	1	D1	400 V, 1 A, Rectifier, DO-41	1N4004-E3/54	Vishay
11	1	D2	400 V, 1 A, Ultrafast Recovery, 500 ns, DO-214AA, SMB	STTH1R04U	ST Micro
12	1	D3	100 V, 2 A, Schottky, SMA	STPS2H100AY	ST Micro
13	1	D4	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
14	1	D5	600 V, 1 A, Ultrafast Recovery, 75 ns, SOD-123	UFM15PL-TP	MCC
15	1	D6	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diodes, Inc.
16	1	D7	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diodes, Inc.
17	1	D8	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diodes, Inc.
18	1	F1	5 A, 250 V, Fast, Microfuse, Axial	0263005.MXL	Littlefuse
19	1	L1	4.7 mH, 90 mA, 20 Ohm, RF Inductor	B82144A2475J	Epcos
20	1	Q1	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semi
21	1	R1	75 Ω, 5%, 2 W, Metal Oxide	RSF200JB-75R	Yageo
22	1	R4	38.3 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3832V	Panasonic
23	1	R5	301 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF3013V	Panasonic
24	1	R6	127 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1273V	Panasonic
25	1	R7	49.9 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF4992V	Panasonic
26	1	R8	243 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2433V	Panasonic
27	1	R9	5.1 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ512V	Panasonic
28	1	R11	510 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ514V	Panasonic
29	1	R12	10 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ103V	Panasonic
30	1	R13	27.4 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2742V	Panasonic
31	1	R14	100 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ104V	Panasonic
32	1	R15	1 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
33	1	T1	Bobbin, EE10, Vertical, 8 pins Transformer	101 SNX-R1734	Hical Magnetics Santronics
34	1	U1	LYTSwitch-4, eSIP-7C	LYT4311E	Power Integrations
35	1	VR1	27 V, 5%, 150 mW, SOD 523	EDZTE6127B	Rohm Semi

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8 電感器設計試算表

ACDC_LYTSwitch-4_101813; Rev.1.3; Copyright Power Integrations 2013	INPUT	INFO	OUTPUT	UNIT	LYTSwitch-4_101813: 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		50	Hz	AC Mains Frequency
VO	48.00		48	V	Typical output voltage of LED string at full load
VO_MAX			52.80	V	Maximum expected LED string Voltage.
VO_MIN			43.20	V	Minimum expected LED string Voltage.
V_OVP			58.08	V	Over-voltage protection setpoint
IO	0.12		0.12	A	Typical full load LED current
PO			5.8	W	Output Power
n	0.82		0.82		Estimated efficiency of operation
VB	23		23	V	Bias Voltage
ENTER LYTSwitch-4 VARIABLES					
LYTSwitch-4	**Auto**		**LYT4311**		Selected LYTSwitch-4
Current Limit Mode	**RED**		**RED**		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			0.75	A	Minimum current limit
ILIMITMAX			0.85	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			96.7	uA	V pin current
RV	1.65		1.65	M-ohms	Upper V pin resistor
RV2			1000000000000	M-ohms	Lower V pin resistor
IFB	100.00		100.0	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1			200.0	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	1.00		1.00		Ripple to Peak Current Ratio (For PF0.9，0.4 < KP < 0.9)/>
LP			468	uH	Primary Inductance
VOR	48.50		48.5	V	Reflected Output Voltage.
Expected IO (average)			0.12	A	Expected Average Output Current
KP_VACMAX			1.09		Expected ripple current ratio at VACMAX
TON_MIN			1.08	us	Minimum on time at maximum AC input voltage
PCLAMP			0.05	W	Estimated dissipation in primary clamp
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**EE13**		**EE13**		Core Size

Custom Core					Enter custom core part number
AE			0.171	cm^2	Core Effective Cross Sectional Area
LE			3.02	cm	Core Effective Path Length
AL			1130	nH/T^2	Ungapped Core Effective Inductance
BW			7.4	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L			3		Number of Primary Layers
NS	93		93		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			0.29		Minimum duty cycle at peak of VACMIN
IAVG			0.08	A	Average Primary Current
IP			0.63	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS			0.16	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			468	uH	Primary Inductance
LP_TOL			10		Tolerance of primary inductance
NP			93		Primary Winding Number of Turns
NB			45		Bias Winding Number of Turns
ALG			54	nH/T^2	Gapped Core Effective Inductance
BM			1844	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP			2504	Gauss	Peak Flux Density (BP<3700)
BAC			922	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1588		Relative Permeability of Ungapped Core
LG			0.38	mm	Gap Length (Lg0.1 mm)/>
BWE			22.2	mm	Effective Bobbin Width
OD			0.24	mm	Maximum Primary Wire Diameter including insulation
INS			0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.19	mm	Bare conductor diameter
AWG			33	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			51	Cmils	Bare conductor effective area in circular mils
CMA			317	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 600)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			0.63	A	Peak Secondary Current
ISRMS			0.23	A	Secondary RMS Current
IRIPPLE			0.20	A	Output Capacitor RMS Ripple Current
CMS			47	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			33	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG

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					value)
DIAS			0.18	mm	Secondary Minimum Bare Conductor Diameter
ODS			0.08	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
VOLTAGE STRESS PARAMETERS					
VDRAIN			297	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance)
PIVS			245	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
PIVB			119	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			1.65	M-ohms	Upper V Pin Resistor Value
RV2			1000000000000	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			0.12	A	Measured Output Current at VAC1
IO_VAC2			0.12	A	Measured Output Current at VAC2
RV1 (new)			1.65	M-ohms	New RV1
RV2 (new)			8626.05	M-ohms	New RV2
V_OV			133.4	V	Typical AC input voltage at which OV shutdown will be triggered
V_UV			28.9	V	Typical AC input voltage beyond which power supply can startup
FB pin resistor Fine Tuning					
RFB1			200	k-ohms	Upper FB Pin Resistor Value
RFB2			1000000000000	k-ohms	Lower FB Pin Resistor Value
VB1			20.7	V	Test Bias Voltage Condition1
VB2			25.3	V	Test Bias Voltage Condition2
IO1			0.12	A	Measured Output Current at Vb1
IO2			0.12	A	Measured Output Current at Vb2
RFB1 (new)			200.0	k-ohms	New RFB1
RFB2(new)			1000000000000.0000	k-ohms	New RFB2
Input Current Harmonic Analysis					
Harmonic		Max Current	Limit		
1st Harmonic		65.10	N/A	mA	
3rd Harmonic		16.30	N/A	mA	N/A
5th Harmonic		8.47	N/A	mA	N/A
7th Harmonic		5.09	N/A	mA	N/A
9th Harmonic		3.54	N/A	mA	N/A
11th Harmonic		2.63	N/A	mA	N/A
13th Harmonic		1.97	N/A	mA	N/A
15th Harmonic		1.58	N/A	mA	N/A
THD		29.2	%		Estimated total Harmonic Distortion (THD)

9 電感器規格

9.1 電氣圖

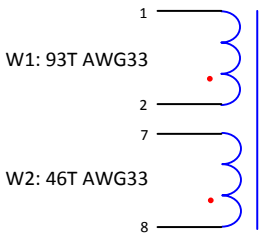

Figure 6 – Inductor Electrical Diagram.

9.2 電氣規格

Primary Inductance	Pins 1-2, all other windings open, measured at 100 kHz, 0.4 RMS. AL= 54.432 nH/n^2	470 µH ±5%
Resonant Frequency	Pins 1-2, all other windings open.	1 MHz (Min.)

9.3 材料

Item	Description
[1]	Core: TDK PC40EE10/11-Z.
[2]	Bobbin: B-EE10-V-8pins-(4/4)
[3]	Magnet Wire: #33 AWG.
[4]	Tape: 3M 1298 Polyester Film, 6.5 mm wide.
[5]	Dolph BC-359 or equivalent

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9.4 電感構建圖

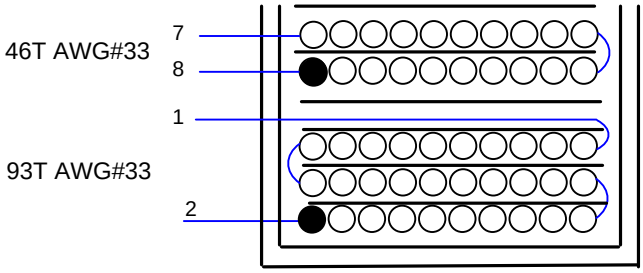

Figure 7 – Inductor Build Diagram.

9.5 電感器結構

Bobbin Preparation	Place the bobbin item [2] on the mandrel with pin side on the left and winding direction is clockwise direction.
Winding 1	Use wire item [3], start at pin 2 wind 93 turns in ~ 3 layers and at the last turn terminate the wire at pin 1. Apply 1 layer of tape item [4] between layers
Winding 2	Use wire item [3], start at pin 8 wind 46 turns in ~ 2 layers, and at the last turn terminate the wire at pin 7. Apply 1 layer of tape item [4] between layers
Finish	Grind core to get 470 μH inductance, secure the core with tape. Dip impregnate using varnish item[5]
Pins	Cut pins 3, 4, 5, 6.

10 效能資料

All measurements were performed at room temperature using an LED load. The following data was taken using a custom LED load of ~48 V output voltage. Refer to the table in Section 9.4 for the complete data set.

10.1 效率

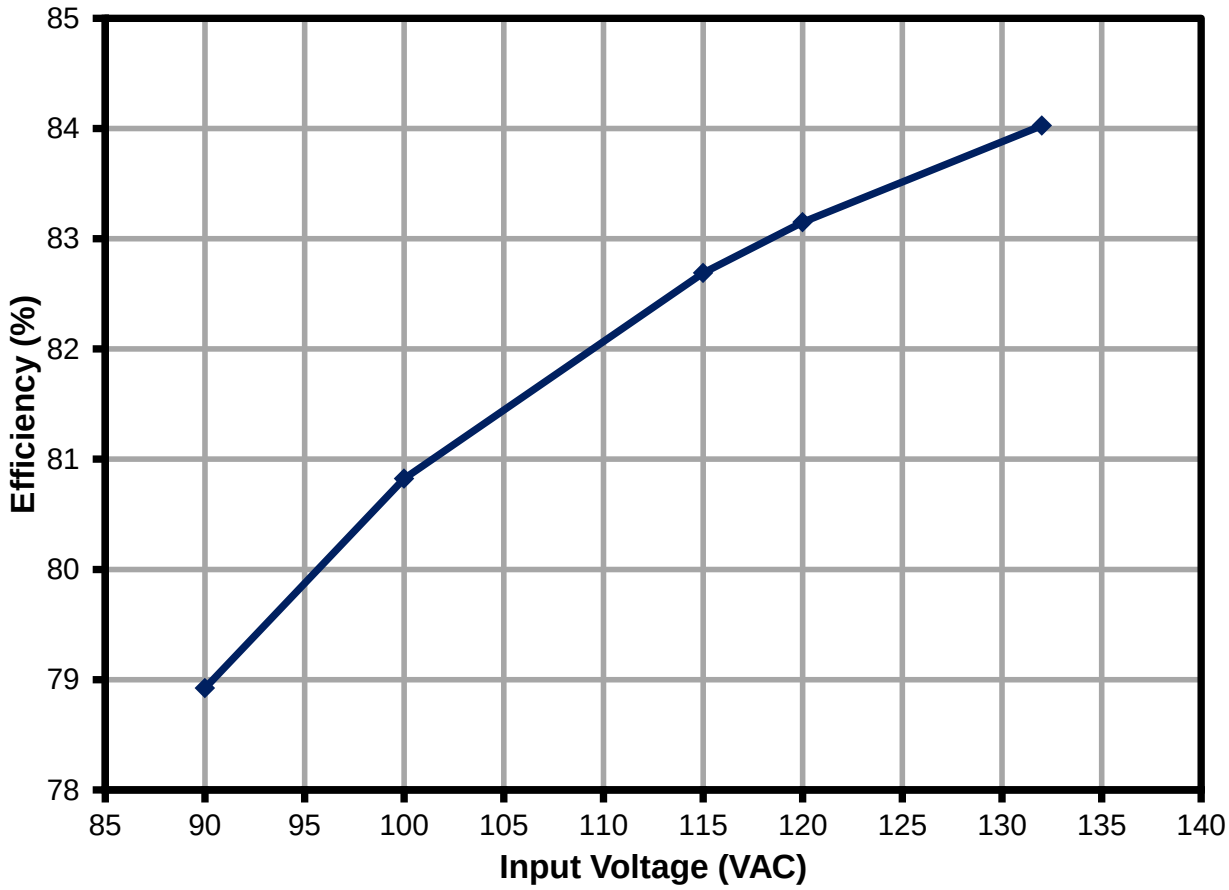

Figure 8 – Efficiency vs. Line.

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10.2 線電壓調節

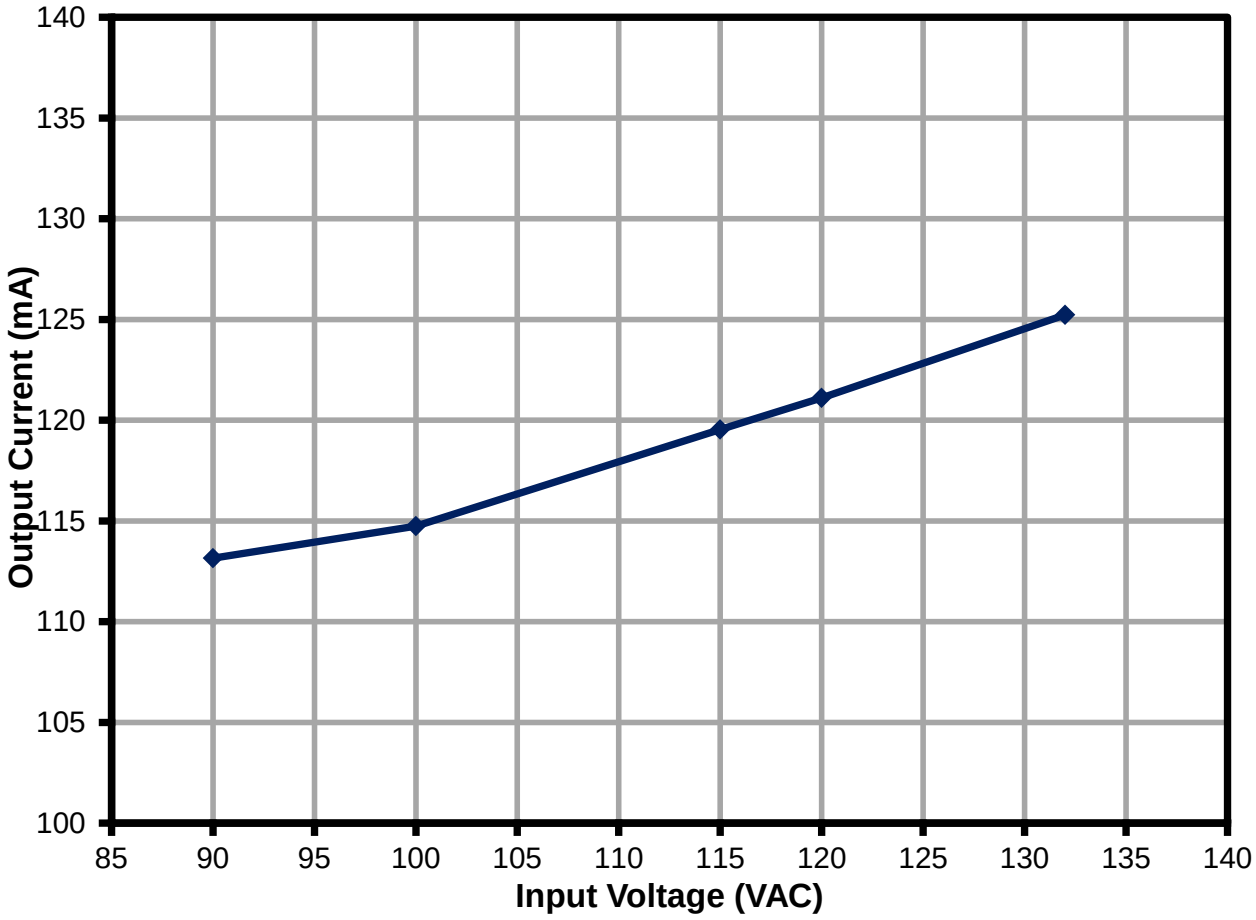

Figure 9 – Regulation vs. Line.

10.3 功率因數 (PF)

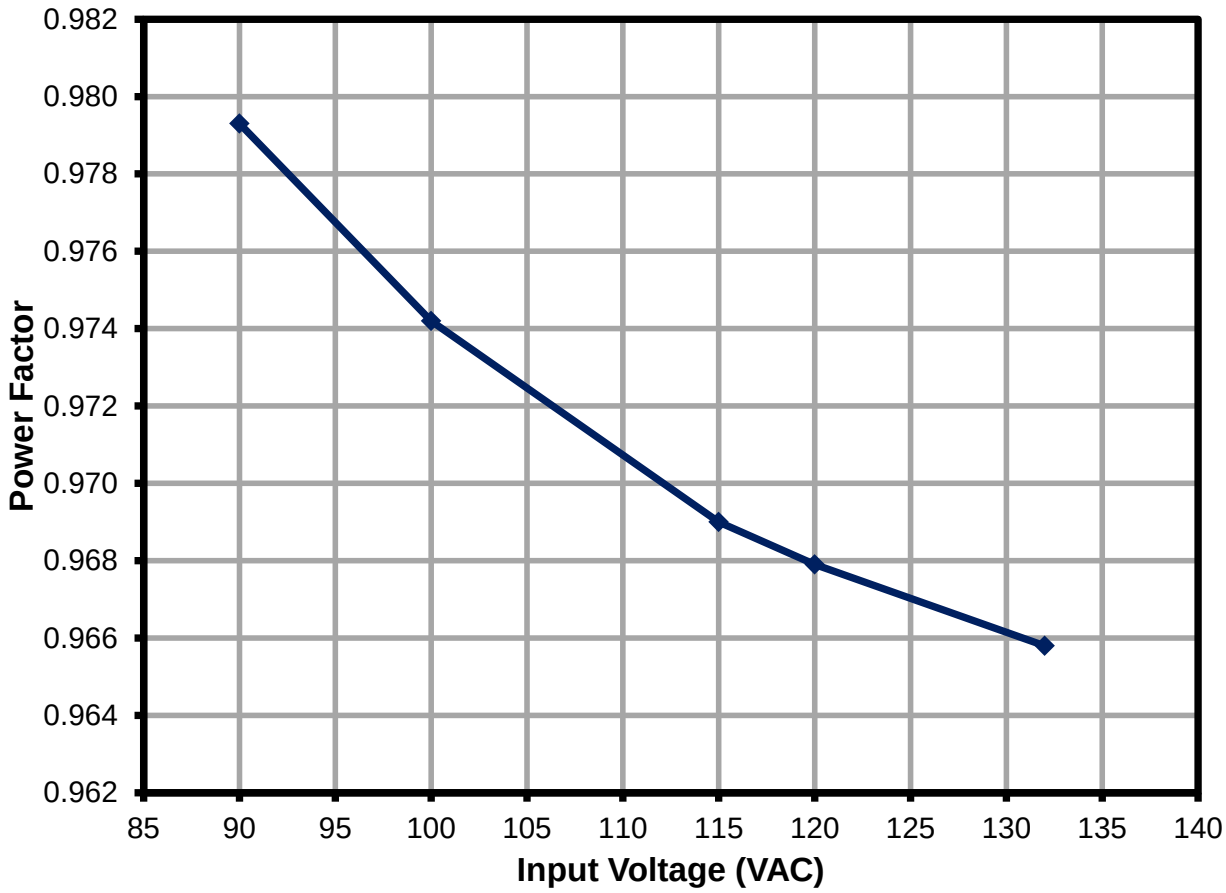

Figure 10 – Power Factor vs. Line.

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10.4 測試資料

All measurements were taken with the board mounted open frame, 25 ºC ambient, 60 Hz line frequency, and with an LED load.

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)
90.06	80.76	7.123	0.979	20.09	49.5970	113.150	5.622	5.61	78.92	1.50
100.03	72.39	7.055	0.974	22.24	49.6110	114.740	5.702	5.69	80.82	1.35
115.07	64.51	7.193	0.969	24	49.6730	119.540	5.948	5.94	82.69	1.25
120.06	62.38	7.249	0.968	24.18	49.6840	121.110	6.028	6.02	83.15	1.22
132.09	58.20	7.425	0.966	24.29	49.7320	125.230	6.239	6.23	84.03	1.19

11 調光效能資料

TRIAC dimming results were taken with input voltage of 120 VAC, 60 Hz line frequency, room temperature, and nominal ~48 V LED load.

11.1 調光曲線

Taken using a programmable AC source providing the leading edge chopped AC input.

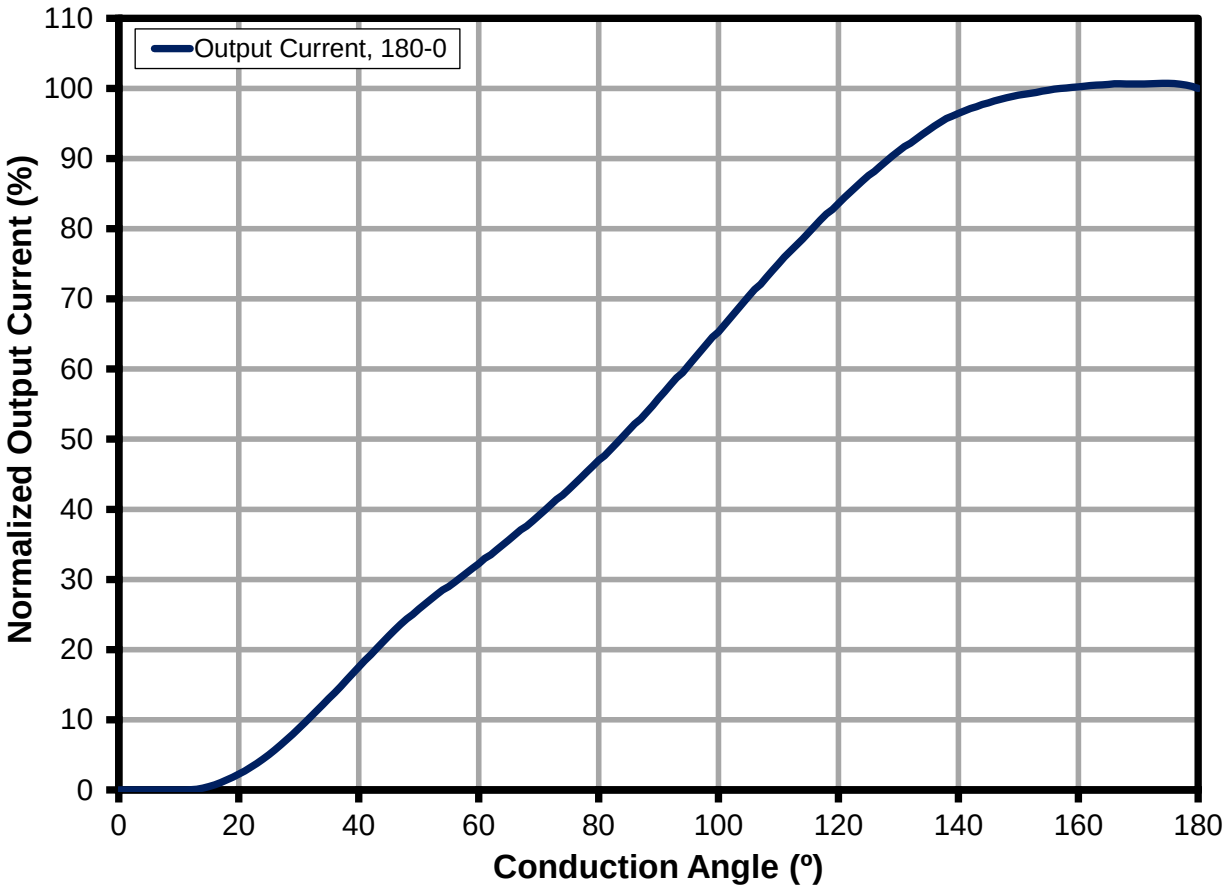

Figure 11 – Leading Edge Dimming Characteristics.

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11.2 調光效率

Measured using a programmable AC source providing the leading edge chopped AC input.

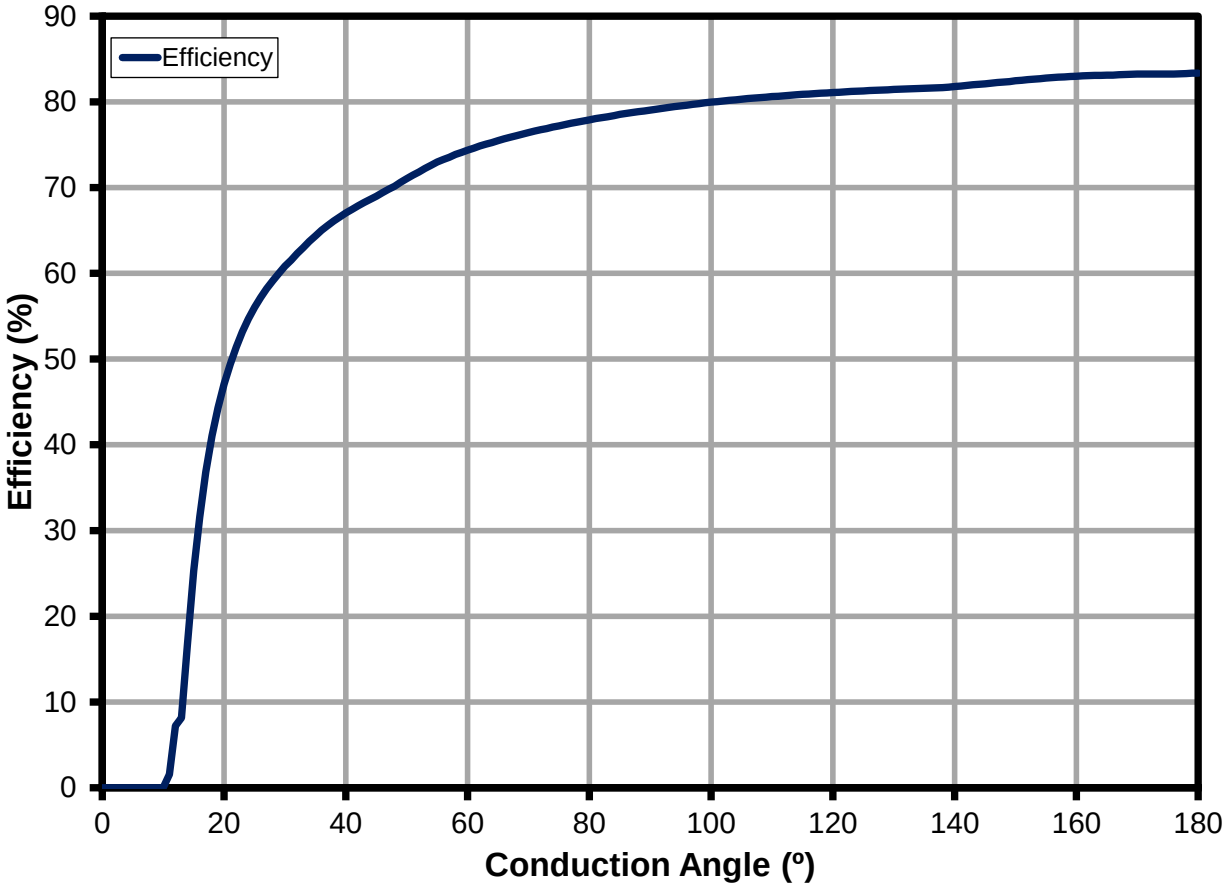

Figure 12 – Driver Efficiency as a Function of Conduction Angle.

11.3 調光時的驅動器功率損失

Measured using a programmable AC source providing the trailing edge chopped AC input.

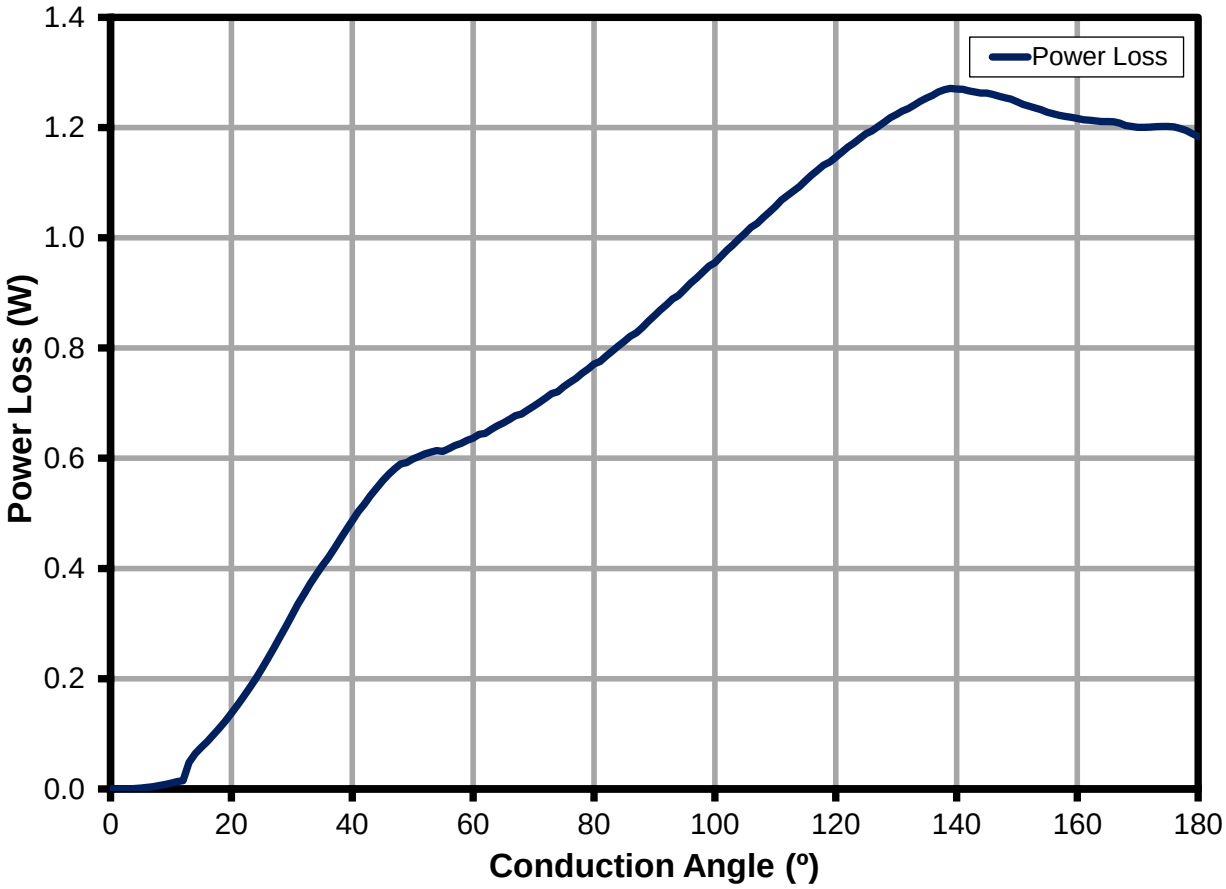

Figure 13 – Driver Power Loss as a Function of Conduction Angle.

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11.4 調光器相容性清單

The unit was tested with the following high-line dimmers at 120 VAC, 60 Hz input and ~48 V LED load.

List of Dimmers	Type	Part Number	Min, mA	Max, mA	DR
LUTRON LG600PH-LA	L	LG-600PH-WH	14	115	8.21
LUTRON S603P	L	S-603P-WH	12	116	9.67
LUTRON SLV600P	T	SLV600P-WH	20	116	5.80
LUTRON S600	L	S-600-WH	18	118	6.56
LUTRON S-600PH-WH	L	S-600PH-WH	11	115	10.45
LUTRON DVCL153P	L	DVWCL-153-PLH-WH	13	114	8.77
LUTRON DV603P	L	DV-603P-WH	14	115	8.21
LUTRON DV600P	L	DV-600P-WH	13	115	8.85
LUTRON TG600PH-IV	L	TG-600PH-WH	29	117	4.03
LUTRON AY600P	T	AY-600P-WH	31	95	3.06
LUTRON GL600P-WH	L	GL-600P-WH	17	116	6.82
LEVITON 6633PLI	L	R62-06633-1LW	13	119	9.15
LEVITON 6631-LI	L	R62-06631-1LW	5	117	23.40
LEVITON IPI06	L	R60-IPI06-1LM	31	118	3.81
LEVITON 6161-I	E	R52-06161-00W	24	116	4.83
LEVITON RP106	L	R52-RPI06-1LW	17	119	7.00
LEVITON 6681	L	R60-06681-0IW	10	119	11.90
LEVITON 6684	L	R60-06684-1IW	3	118	39.33
LEVITON 6683	L	6683	5	119	23.80
LEVITON 6613	L	R02-06613-PLW	10	119	11.90
COOPER SLC03	L	SLC03P-W-K-L	7	117	16.71
LUTRON GL600-WH	L	GL-600-WH	19	119	6.26
LUTRON DVPDC-203P-WH	L	DVPDC-203P-WH	50	118	2.36
LUTRON LX600PL	L	LX-600PL-wh	21	118	5.62
LUTRON D600P	L	D-600P-WH	10	113	11.30
LUTRON CTCL-153PDH	L		10	115	11.50
LUTRON S-600P	L	S-600P	10	115	11.50
LUTRON TGLV-600P	L	TGLV-600P	25	117	4.68
LUTRON TGLV-600PR	L	TGLV-600PR	23	116	5.04
LUTRON TT-300NLH-WH	L	TT-300NLH-WH	18	118	6.56
LUTRON TT-300H-WH	L	TT-300H-WH	12	118	9.83
LUTRON NLV-1000-WH	L	NLV-1000-WH	14	117	8.36
Lutron	E	MAELV-600	20	106	5.30
Lutron	L	S-600P-WH	14	115	8.21
Lutron	E	MIR-600	12	110	9.17
Lutron	L	S-600-WH	11	119	10.82
Cooper	L	S106P	22	119	5.41
Lutron	L	S-103P-WH	23	116	5.04
Lutron	L	S-10P-WH	18	115	6.39
Lutron	L	S-600PNLH-WH	18.5	117	6.32
Lutron	L	S-603PNL-WH	21	116	5.52
Lutron	L	SLV-603P-WH	25	116	4.64
Lutron	L	S-603PGH-WH	12	100	8.33
Lutron	L	AYLV-600P-WH	25	116	4.64
Lutron	L	AYLV-603P-WH	26	116	4.46

Lutron	L	AY-103PNL-WH	20	117	5.85
Lutron	L	AY-10PNL-WH	17	119	7.00
Lutron	L	AY-10P-WH	14	116	8.29
Lutron	L	AY-603PNL-WH	25	115	4.60
Lutron	L	AY-603PG-WH	25	97	3.88
Lutron	L	AY-603P-WH	31	115	3.71
Lutron	L	AY-600PNL-WH	26	117	4.50
Lutron	T	DVELV-300P-WH	16	102	6.38
Lutron	L	DVLV-10P-WH	27	115	4.26
Lutron	L	DVLV-103P-WH	25	115	4.60
Lutron	L	DVLV-603P-WH	24	115	4.79
Lutron	L	S-1000-WH	19	118	6.21
Lutron	T	SELV-300P-WH	15	100	6.67
Lutron	L	S-600P-WH	11	115	10.45
Lutron	L	S-103PNL-WH	24	115	4.79
Lutron	E	SPSLV-1000-WH	23	119	5.17
Lutron	E	SPSLV-600-WH	23	119	5.17
Lutron	E	SPSELV-600-WH	20	106	5.30
Lutron	L	GLV-600-WH	13	119	9.15
Lutron	L	LG-603PGH-WH	16	96.5	6.03
Lutron	L	DVW-603PGH-WH	17	96	5.65
Lutron	L	TG-10PR-WH	25	116	4.64
Lutron	L	NT-600	13	117	9.00
Lutron	L	NT-1000	13	117	9.00
Lutron	L	LGCL-153PLH-WH	18	111	6.17
Lutron	L	CTCL-153PDH-WH	24	111	4.63
Lutron	L	TGCL-153PH-WH	18	113	6.28
Lutron	L	DVWCL-153PH-LA	26	112	4.31
Leviton	L	81000-W	27	117	4.33
Lutron	L	TTCL-100LH-WH	26	111	4.27

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12 散熱效能

The following readings were taken with the power supply configured for open frame and room temperature ambient conditions.

12.1 120 VAC、60 Hz 調光器未連接

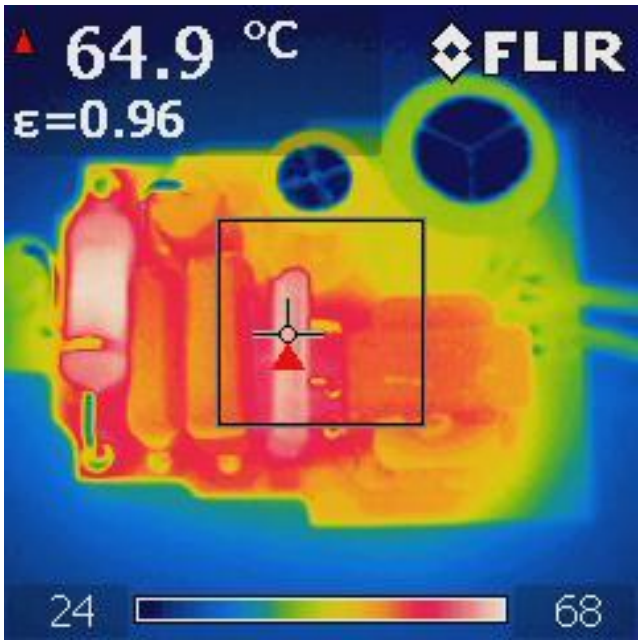

Figure 14 – U1: LYT4311E.

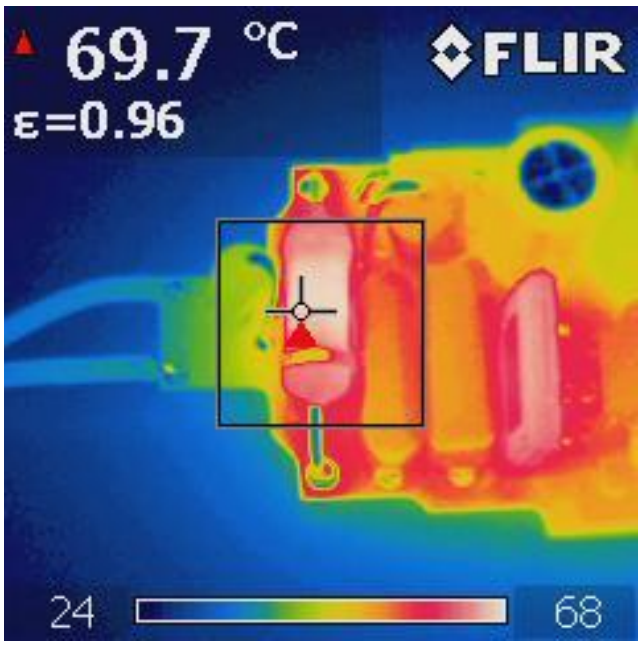

Figure 15 – R1: Damper Resistor.

12.2 120 VAC、60 Hz 調光器已連接，90⁰ 導通角

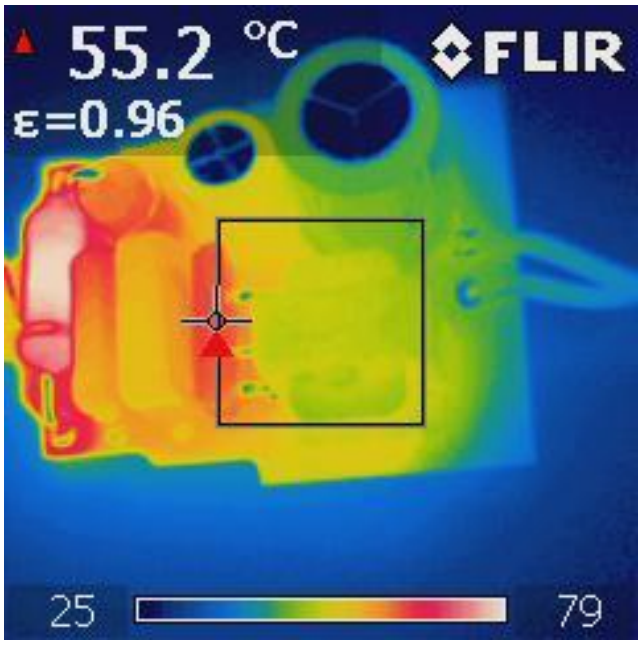

Figure 16 – U1: LYT4311E**.**

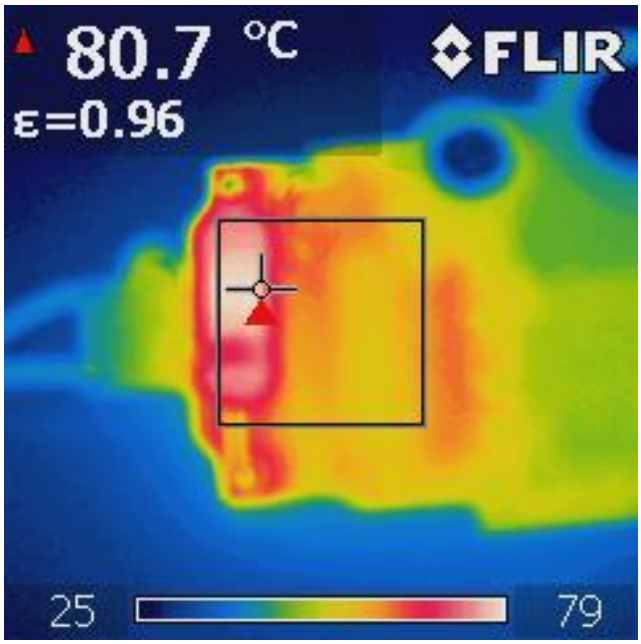

Figure 17 – R1: Damper Resistor.

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13 非調光 (調光器未連接) 波形

13.1 輸入電壓和輸入電流波形

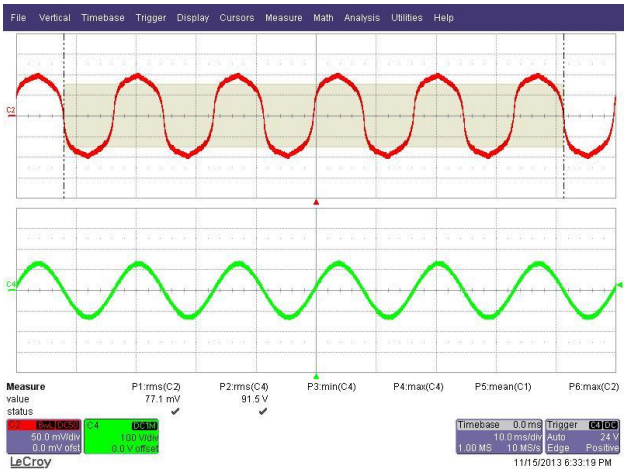

Figure 18 – 90 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

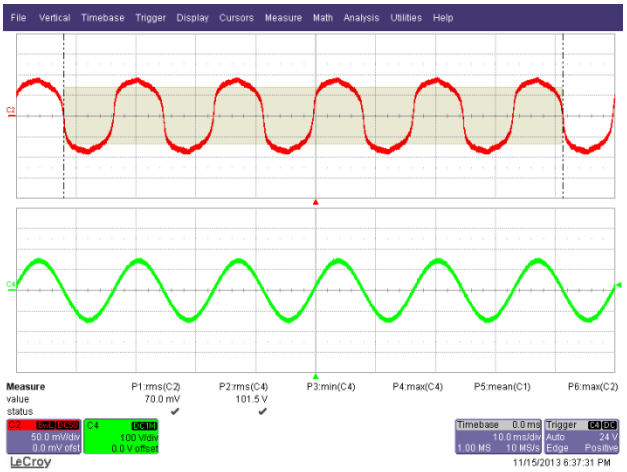

Figure 19 – 100 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

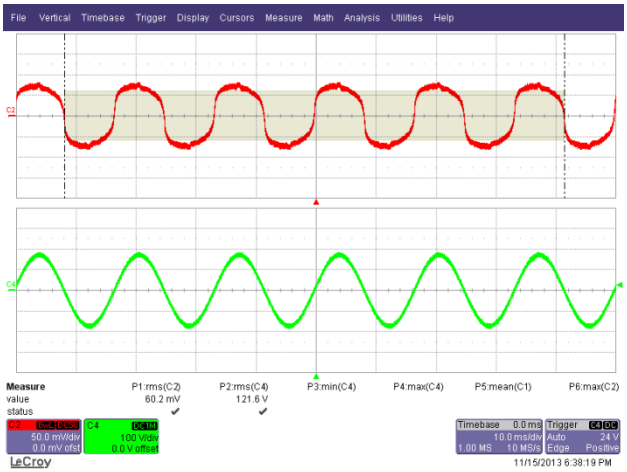

Figure 20 – 120 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

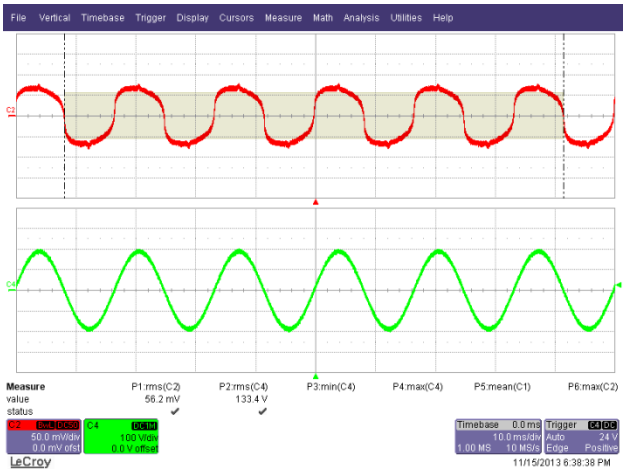

Figure 21 – 132 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 100 V, 10 ms / div.

13.2 正常運作下的輸出電流和輸出電壓

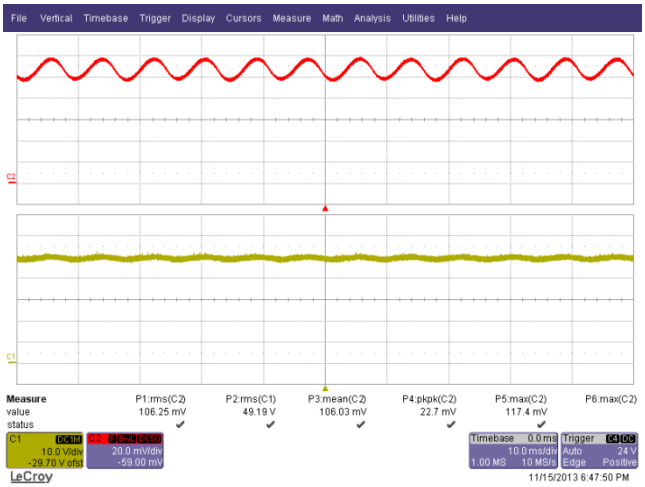

Figure 22 – 90 VAC, 60 Hz Full Load.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

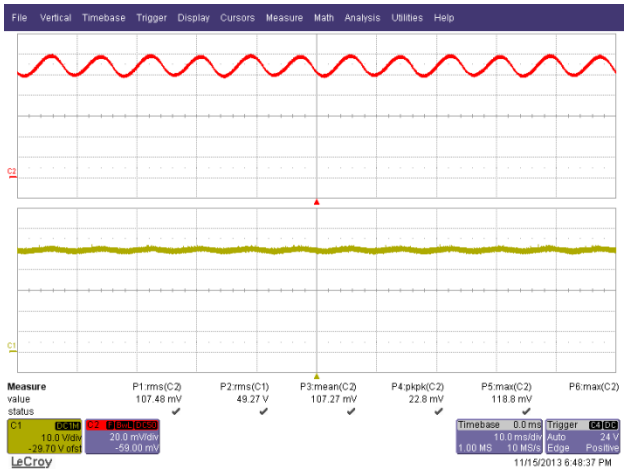

Figure 23 – 100 VAC, 60 Hz Full Load.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

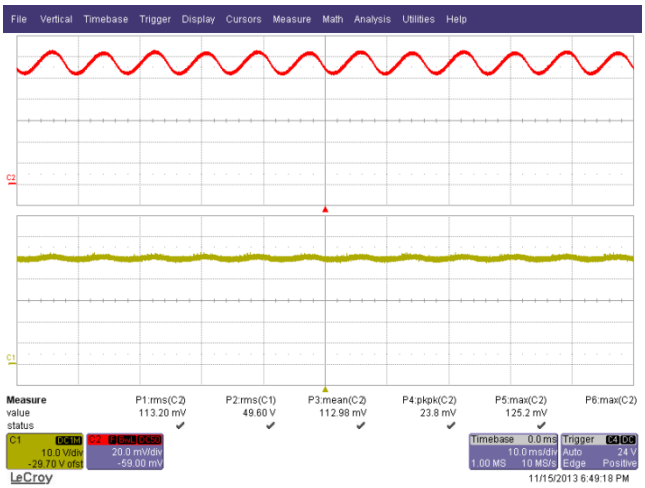

Figure 24 – 120 VAC, 60 Hz Full Load.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

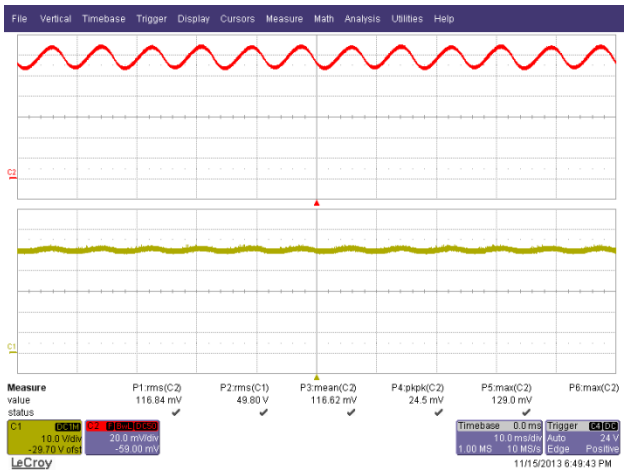

Figure 25 – 132 VAC, 60 Hz Full Load.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

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13.3 輸出電流上升及下降

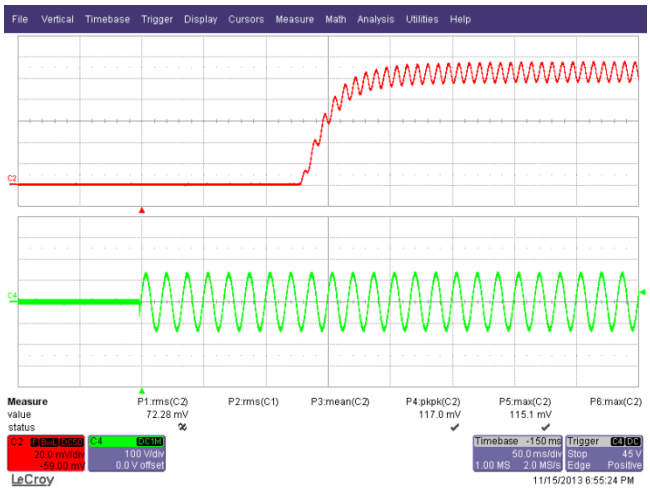

Figure 26 – 90 VAC Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 200 V, 100 ms / div.

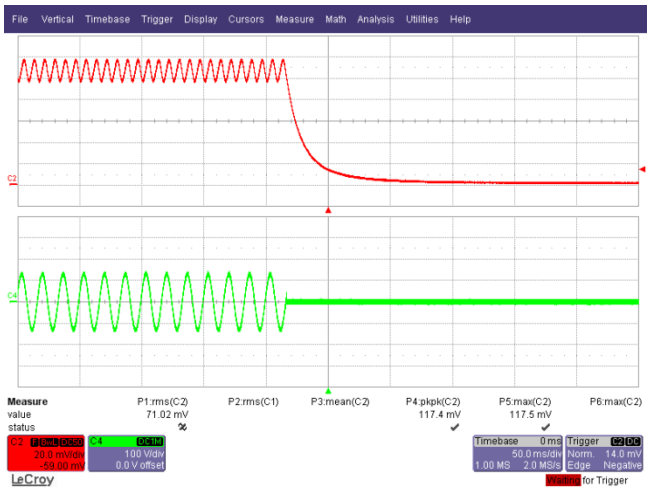

Figure 27 – 90 VAC Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 200 V, 100 ms / div.

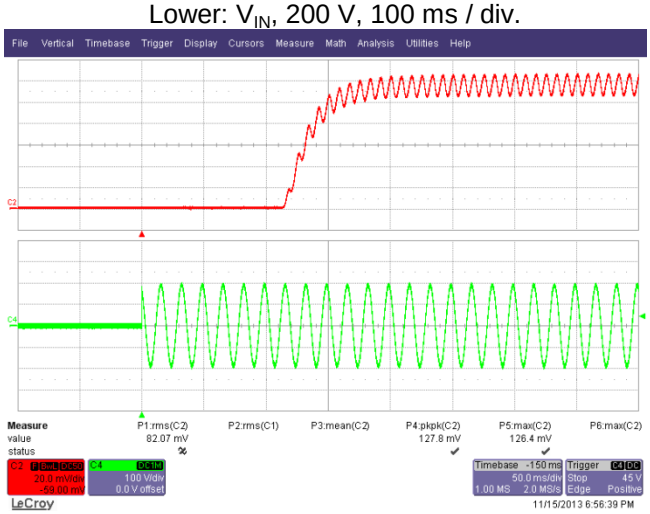

Figure 28 – 132 VAC Output Rise.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 200 V, 100 ms / div.

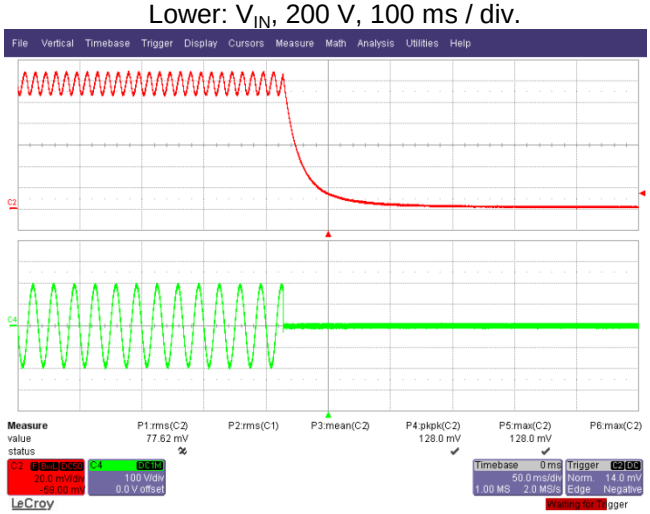

Figure 29 – 132 VAC Output Fall.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 200 V, 100 ms / div.

13.4 正常運作下的汲極電壓和電流

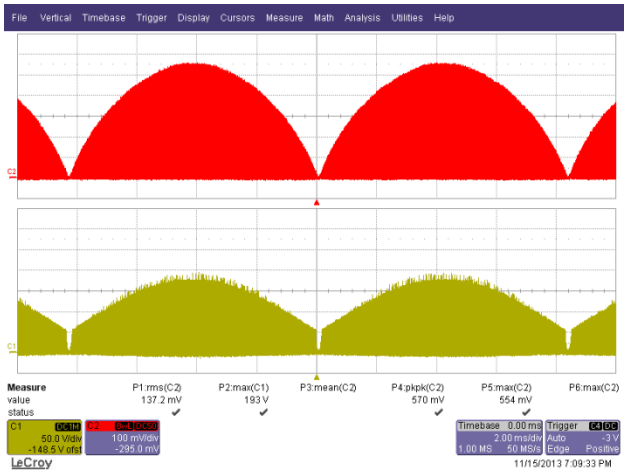

Figure 30 – 90 VAC, 60 Hz.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 50 V, 2 ms / div.

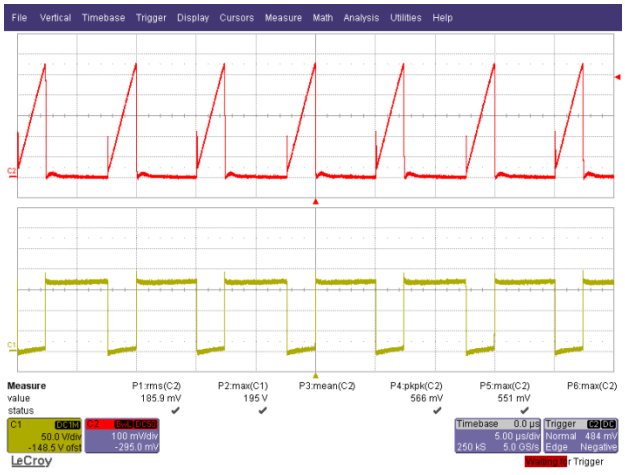

Figure 31 – 90 VAC, 60 Hz.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 50 V / div., 5 µs / div.

Figure 32 – 132 VAC, 60 Hz.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 50 V, 2 ms / div.

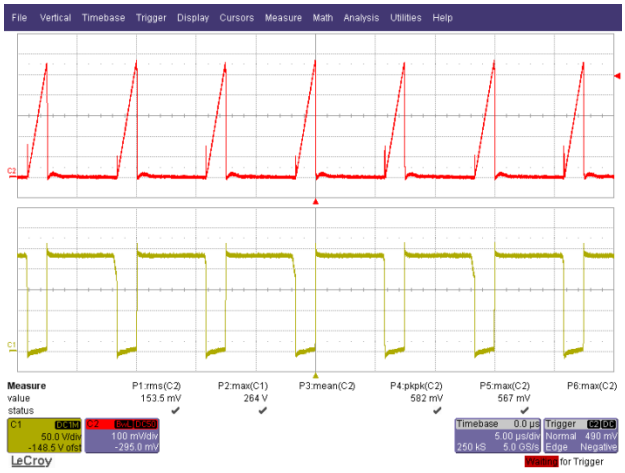

Figure 33 – 132 VAC, 600 Hz.
Upper: I_{DRAIN}, 0.1 A / div.
Lower: V_{DRAIN}, 50 V / div., 5 µs / div.

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13.5 啓動汲極電壓和電流

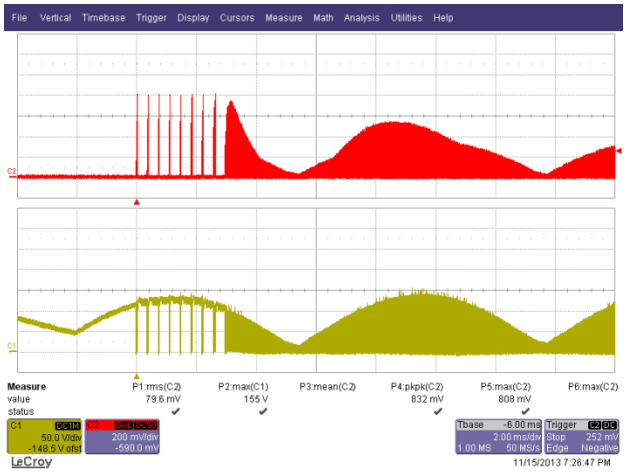

Figure 34 – 90 VAC, 60 Hz Start-up.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

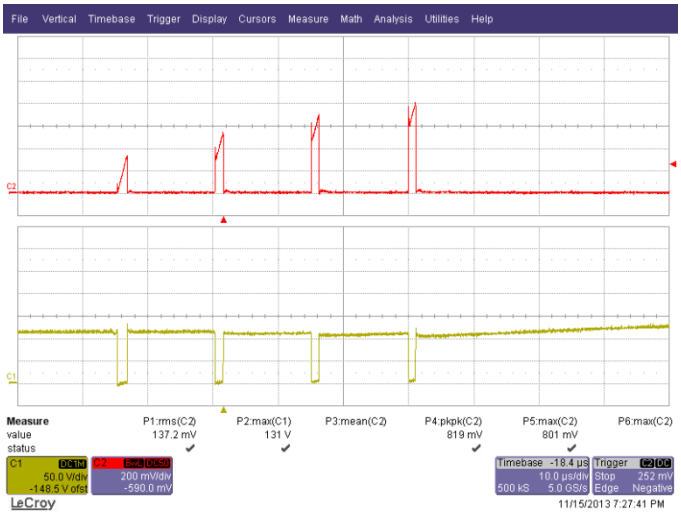

Figure 35 – 90 VAC, 60 Hz Start-up.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V, 5 µs / div.

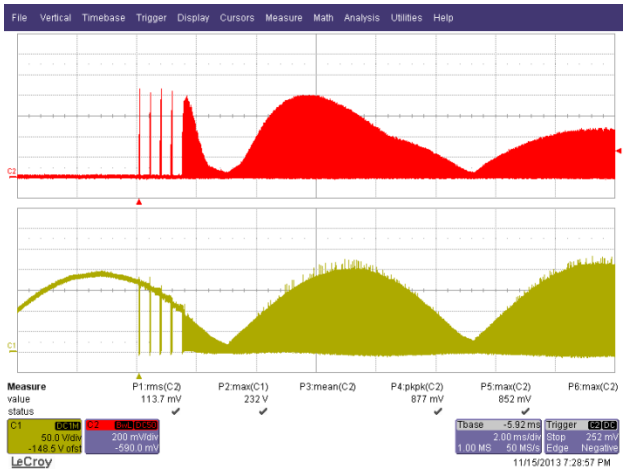

Figure 36 – 132 VAC, 60 Hz Start-up.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

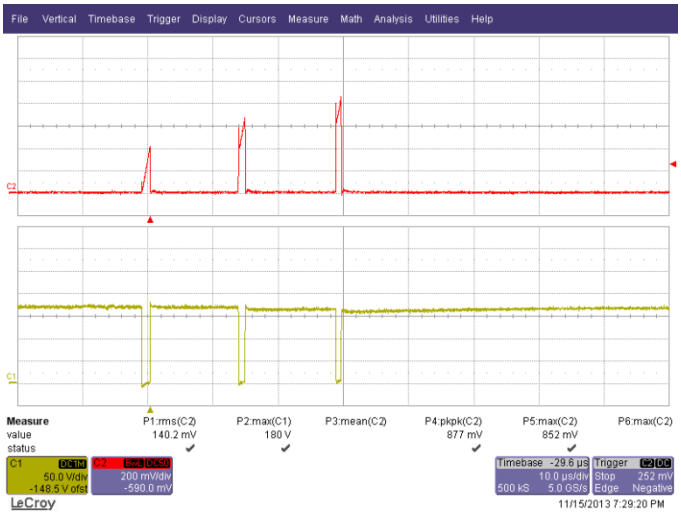

Figure 37 – 132 VAC, 60 Hz Start-up.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V, 5 µs / div.

13.6 輸出短路情況下的汲極電流和汲極電壓

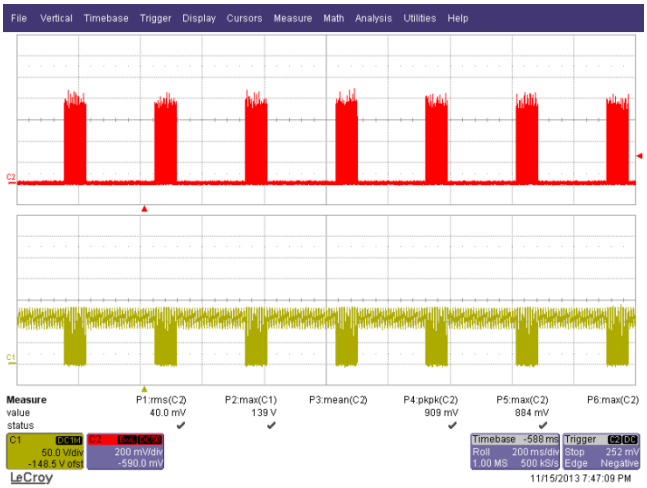

Figure 38 – 90 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V, 200 ms / div.

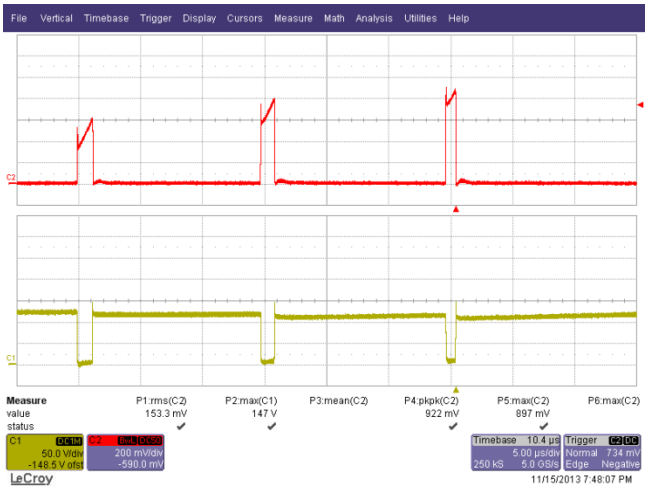

Figure 39 – 90 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V, 0.5 µs / div.

Figure 40 – 132 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 500 mA / div.
Lower: $V_{DRAIN,}$ 100 V, 5 ms / div.

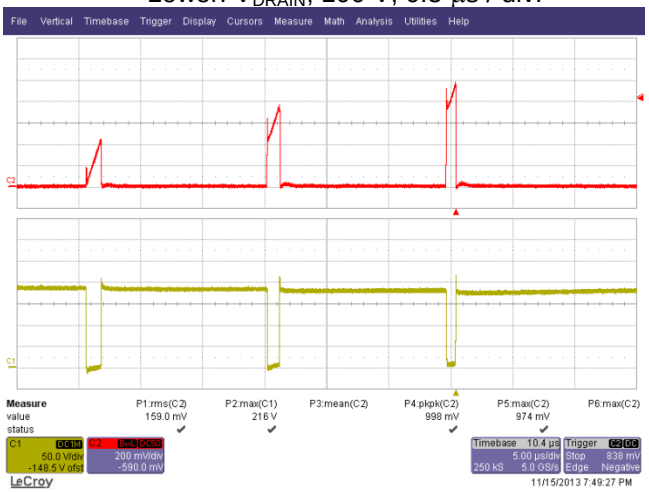

Figure 41 – 132 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 500 mA / div.
Lower: $V_{DRAIN,}$ 100 V, 1 µs / div.

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13.7 開路負載特性

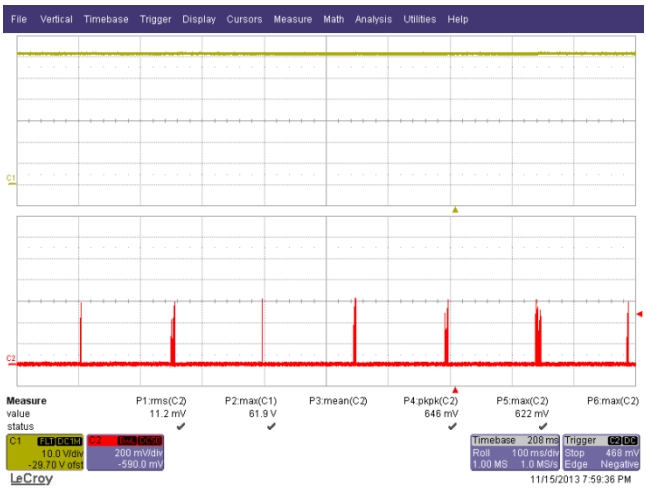

Figure 42 – 90 VAC, 60 Hz Output Short Condition.
Upper: V_{OUT}, 10 V / div.
Lower: I_{DRAIN}, 200 mA, 200 ms / div.

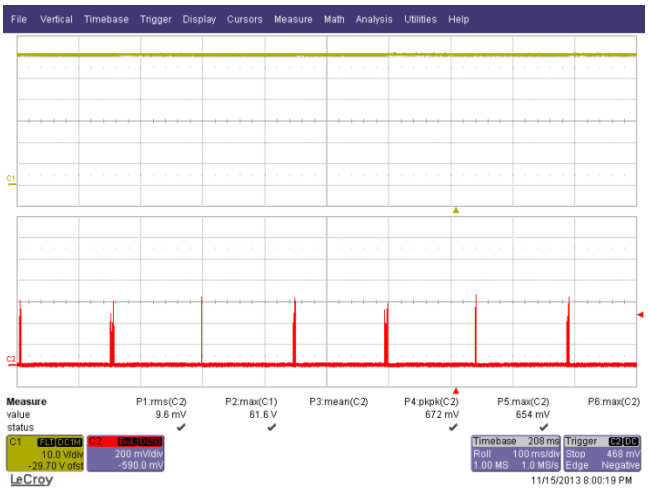

Figure 43 – 132 VAC, 60 Hz Output Short Condition.
Upper: V_{OUT}, 10 V / div.
Lower: I_{DRAIN}, 200 mA, 200 ms / div.

13.8 電壓關閉/電壓啓動

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

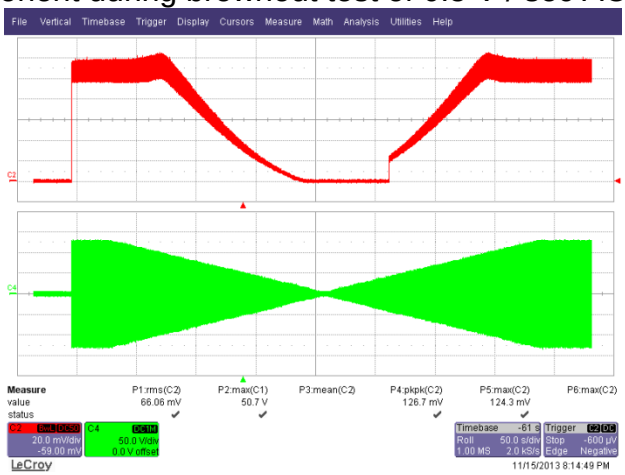

Figure 44 – Brown-out Test at 0.5 V / s. The Unit is Able to Operate Normally Without Any Failure and Without Flicker.
Ch4: V_{IN}; 50 V / div.
Ch2: I_{OUT}; 20 mA / div.
Time Scale: 50 s / div.

14 調光波形

14.1 輸入電壓和輸入電流波形 – 前緣調光器

Input: 120 VAC, 60 Hz
Output: 48 V LED Load
Dimmer: S-600-WH

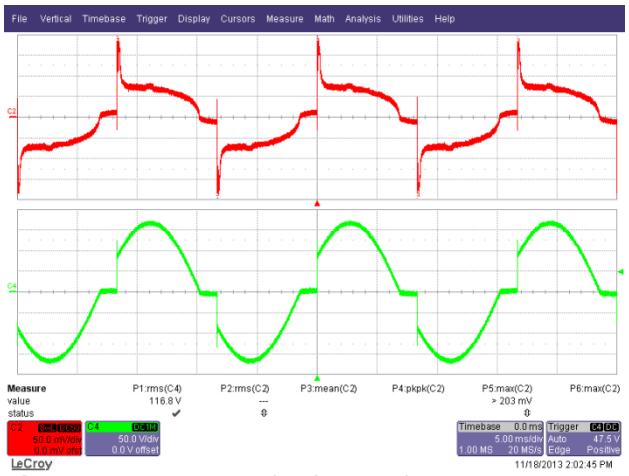

Figure 45 – 147º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

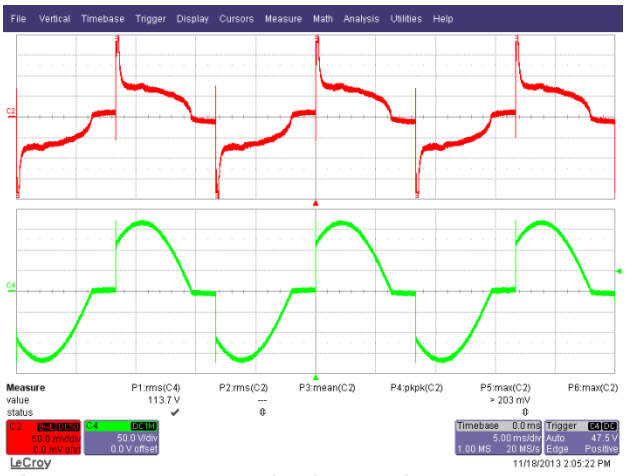

Figure 46 – 135º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

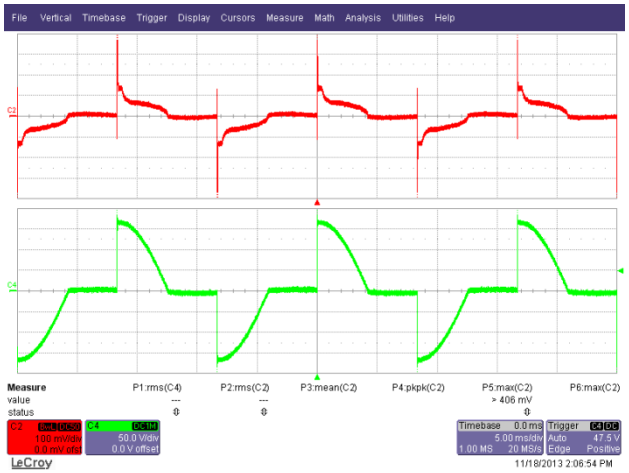

Figure 47 – 90º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

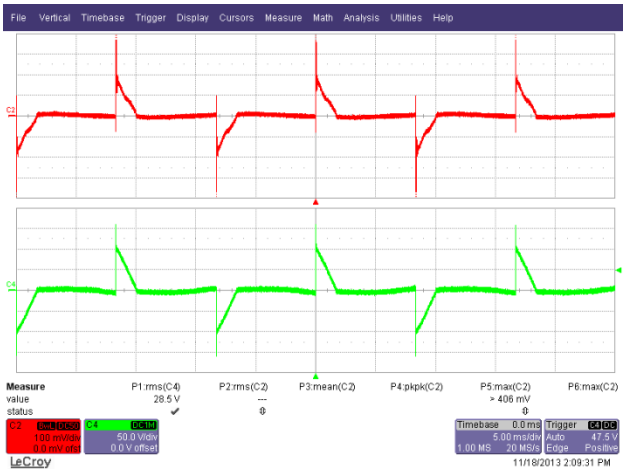

Figure 48 – 36º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

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14.2 輸出電流波形 – 前緣調光器

Input: 120 VAC, 60 Hz
Output: 48 V LED Load
Dimmer: S-600-WH

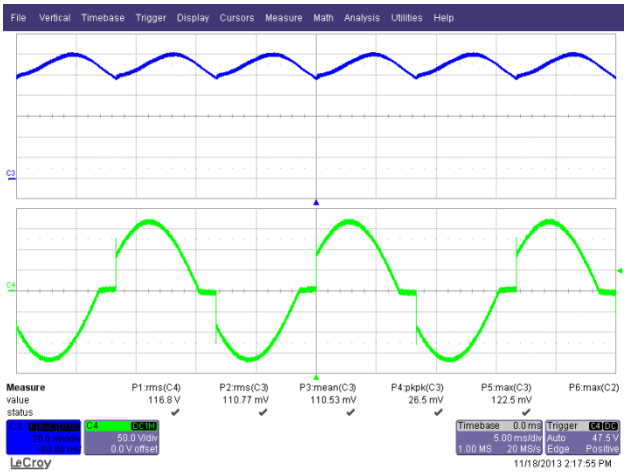

Figure 49 – 147º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

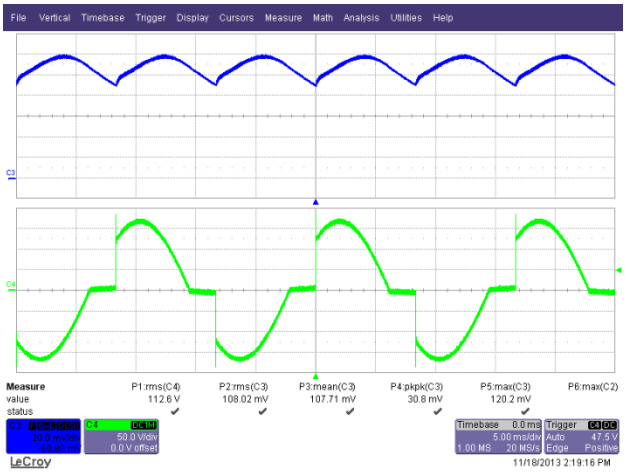

Figure 50 – 135º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

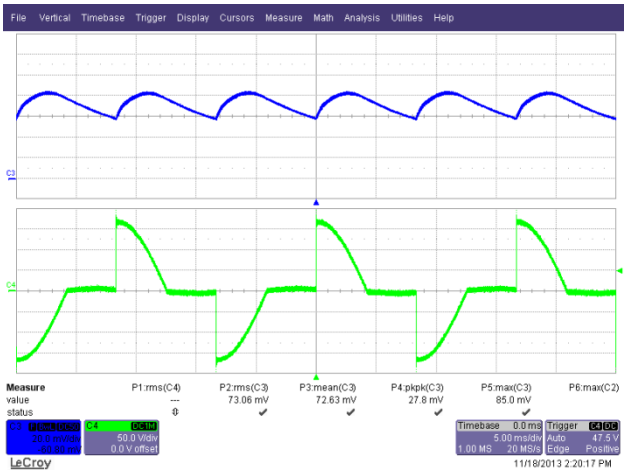

Figure 51 – 90º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

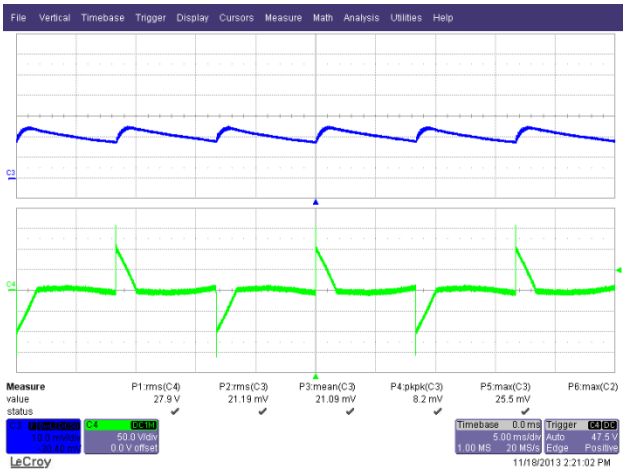

Figure 52 – 36º Conduction Angle.
Upper: I_{OUT}, 10 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

14.3 輸入電壓和輸入電流波形 – 後緣調光器

Input: 120 VAC, 60 Hz
Output: 48 V LED Load
Dimmer: DVELV-300P-WH

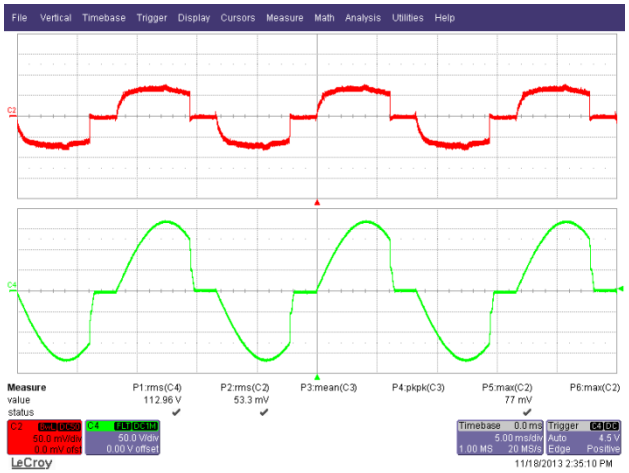

Figure 53 – 131º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

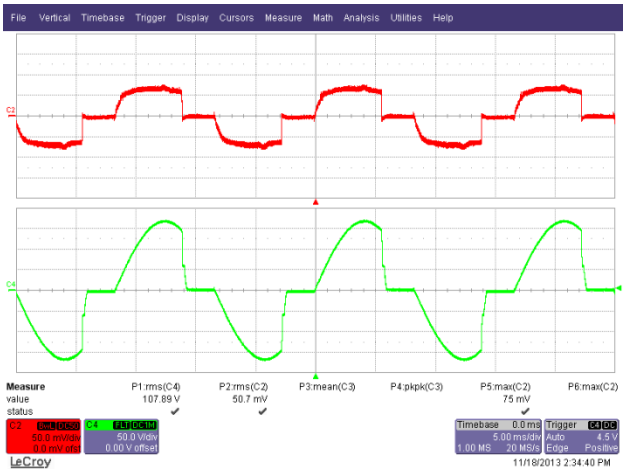

Figure 54 – 120º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

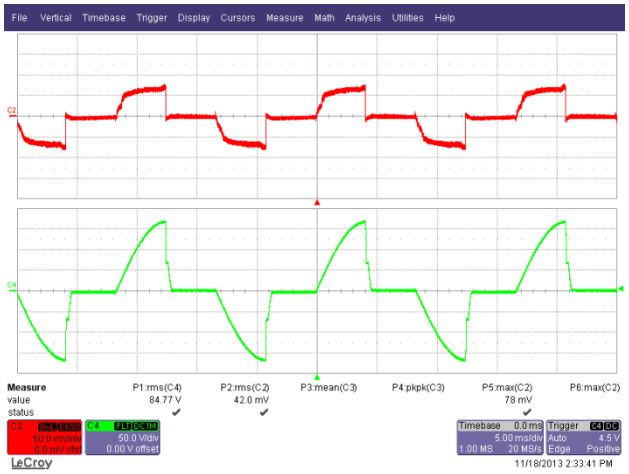

Figure 55 – 90º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

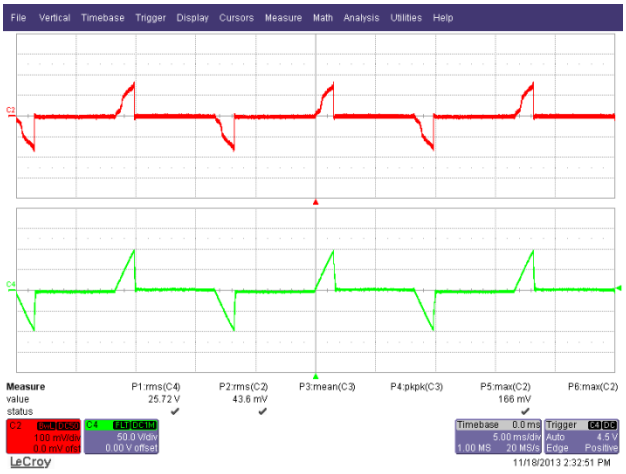

Figure 56 – 40º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

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14.4 輸出電流波形 – 後緣調光器

Input: 120 VAC, 60 Hz
Output: 48 V LED Load
Dimmer: DVELV-300P-WH

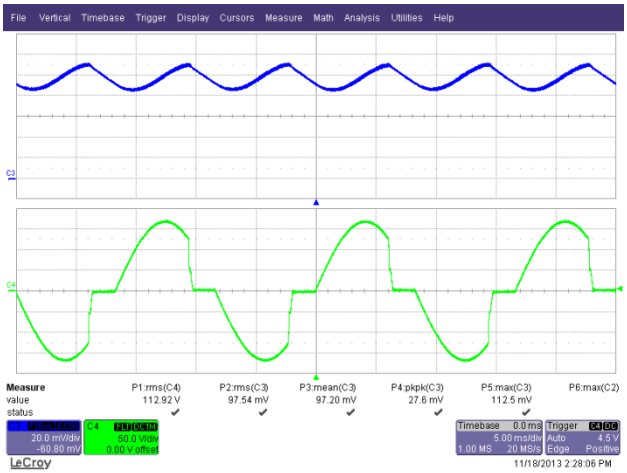

Figure 57 – 131º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

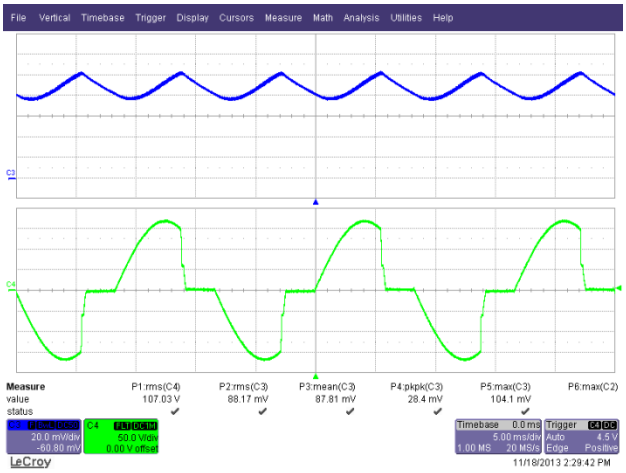

Figure 58 – 120º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

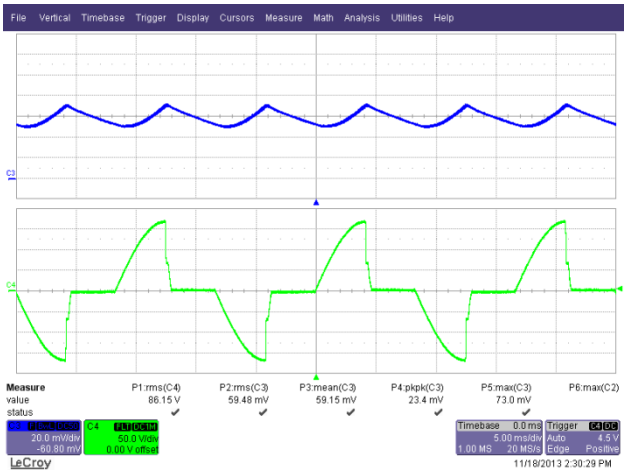

Figure 59 – 90º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

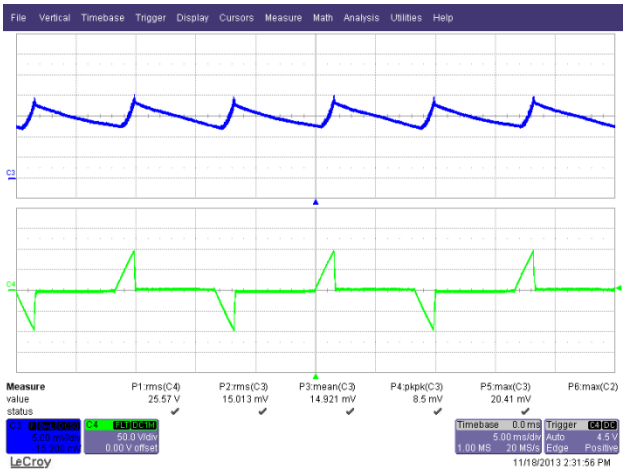

Figure 60 – 40º Conduction Angle.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

14.5 汲極電流波形 – 前緣調光器

Input: 120V, 60 Hz
Output: 48 V LED Load
Dimmer: S-1000-WH

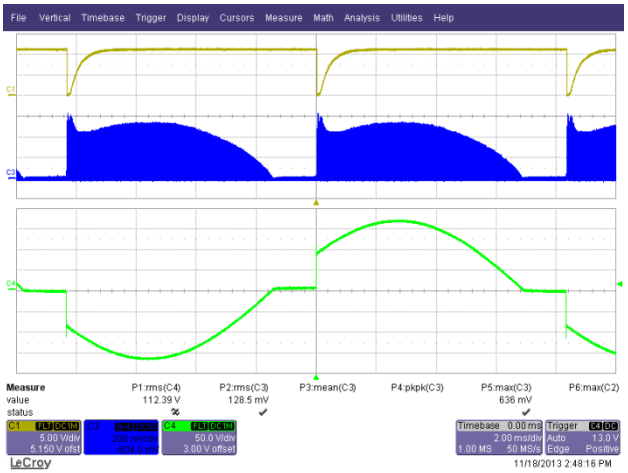

Figure 61 – 150º Conduction Angle.
Upper: U1 I_{DS}, 200 mA / div.
Q1 V_{CE}, 5 V / div.
Lower: V_{IN}, 50 V, 2 ms / div.

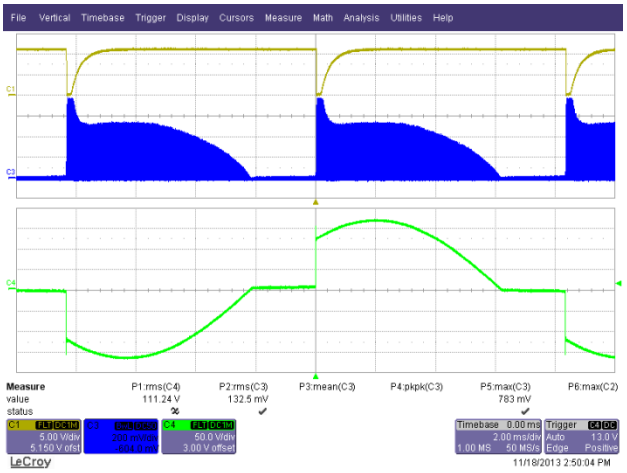

Figure 62 – 135º Conduction Angle.
Upper: U1 I_{DS}, 200 mA / div.
Q1 V_{CE}, 5 V / div.
Lower: V_{IN}, 50 V, 2 ms / div.

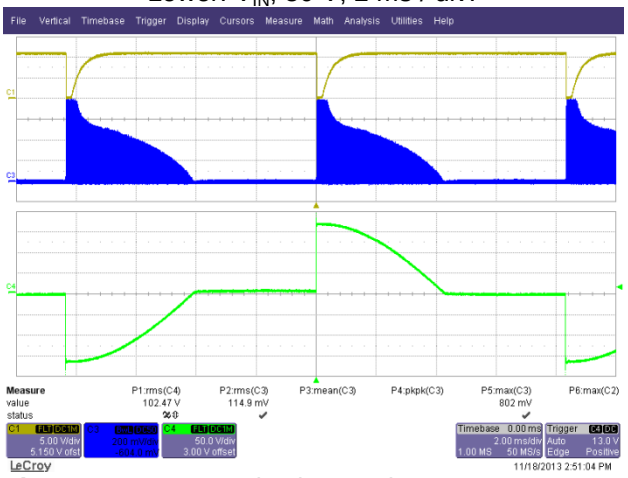

Figure 63 – 90º Conduction Angle.
Upper: U1 I_{DS}, 200 mA / div.
Q1 V_{CE}, 5 V / div.
Lower: V_{IN}, 50 V, 2 ms / div.

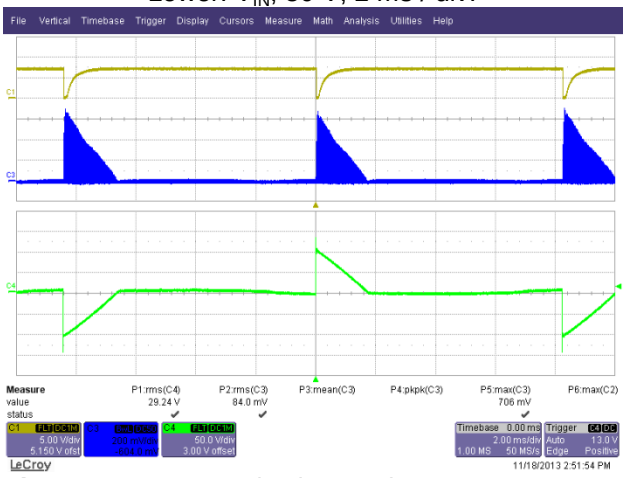

Figure 64 – 40º Conduction Angle.
Upper: U1 I_{DS}, 200 mA / div.
Q1 V_{CE}, 5 V / div.
Lower: V_{IN}, 50 V, 2 ms / div.

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15 傳導性 EMI

15.1 測試裝置

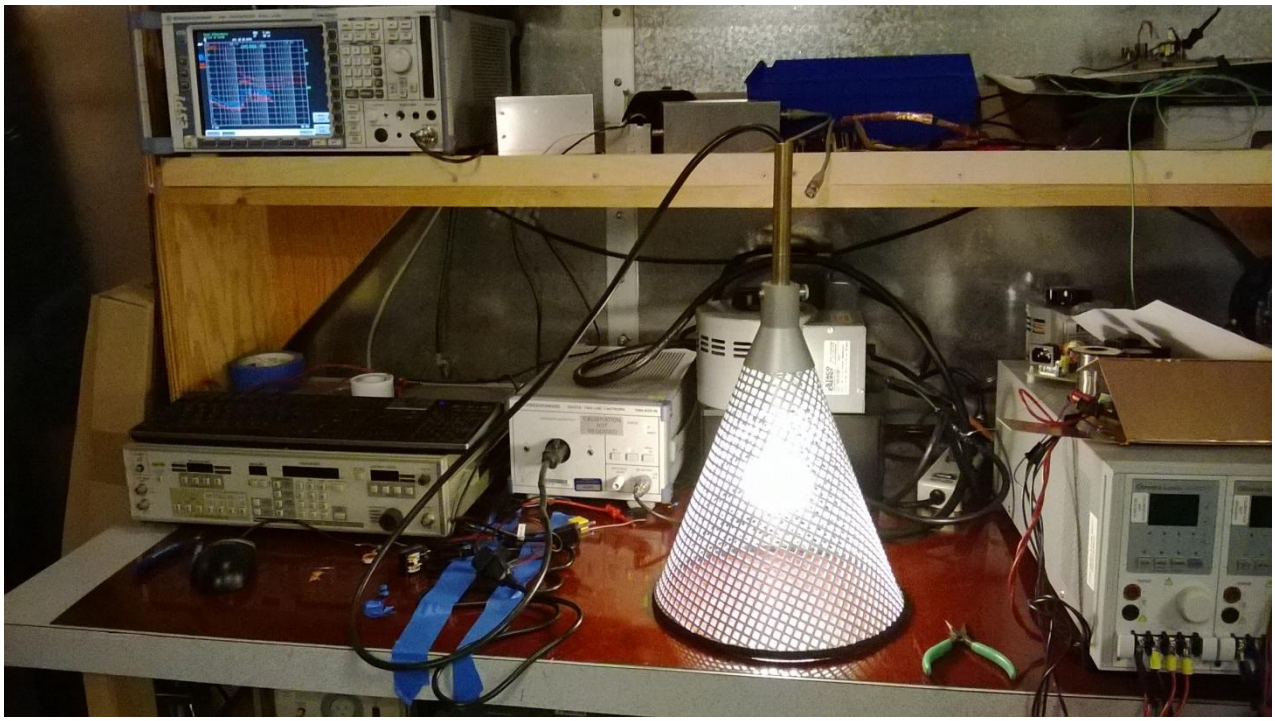

Figure 65 – Conducted EMI Test Set-up.

15.2 測試結果

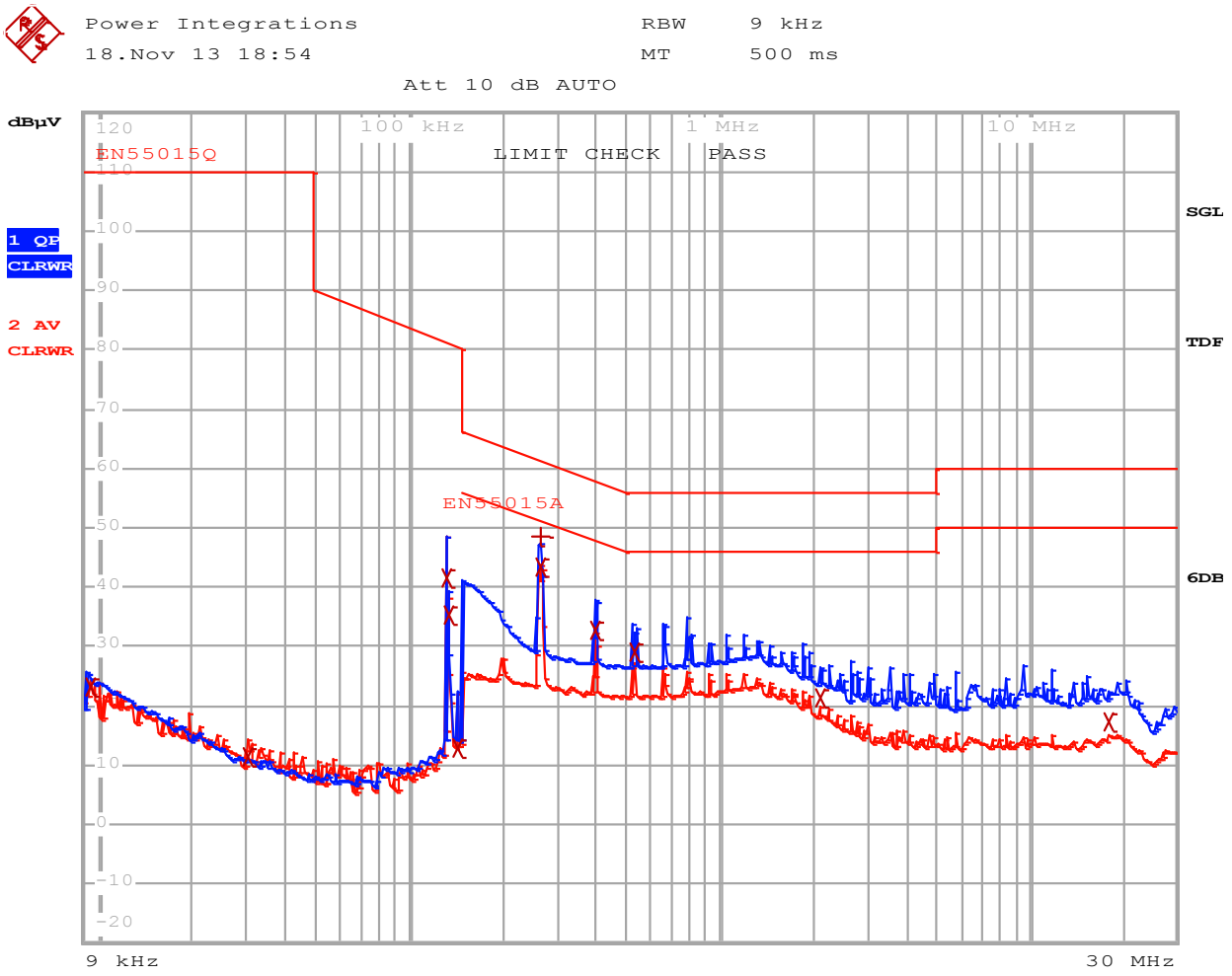

Figure 66 – Conducted EMI, ~48 V LED Load, 115 VAC, 60 Hz, and EN55015 B Limits.

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EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

	TRACE	FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	9.36543609 kHz	23.00	L1 gnd	
2	Average	30.0005168717 kHz	11.39	N gnd	
2	Average	130.825395691 kHz	41.59	L1 gnd	
2	Average	133.454986145 kHz	35.44	N gnd	
2	Average	141.665156991 kHz	12.79	N gnd	
1	Quasi Peak	264.49018761 kHz	48.51	N gnd	-12.77
2	Average	264.49018761 kHz	43.33	N gnd	-7.95
2	Average	397.727746704 kHz	32.58	N gnd	-15.31
2	Average	530.769219795 kHz	29.10	N gnd	-16.90
2	Average	2.11629733595 MHz	21.43	N gnd	-24.57
2	Average	17.975130353 MHz	17.28	N gnd	-32.71

Figure 67 – Conducted EMI, Final Measurement Results.

16 線電壓突波

Differential input line 500 V surge testing was completed on a single test unit to IEC61000-4-5. Input voltage was set at 120 VAC / 60 Hz.

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

Unit passed under all test conditions.

Differential ring input line surge testing was completed on a single test unit to IEC61000-4-5. Input voltage was set at 120 VAC / 60 Hz. Output was loaded at full load and operation was verified following each surge event.

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

Unit passed under all test conditions.

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17 修訂記錄

Date	Author	Revision	Description and Changes	Reviewed
16-May-14	CA	1.0	Initial Release	Mktg & Apps

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本處所述的產品和應用 (包括 PI 裝置 IC 之外的變壓器結構和電路) 可能包含 Power Integrations 的一項或多項美國及國外專利，或是正在申請的美國及國外專利。www.powerint.com 上提供了 Power Integrations 專利的完整清單。Power Integrations 授予其客戶某些特定專利權的授權，詳情請參閱 <http://www.powerint.com/ip.htm>。

Power Integrations 全球銷售支援地點

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

中國 (上海)
Rm 2410, Charity Plaza, No. 88,
North Caoxi Road,
Shanghai, PRC 200030
電話： +86-21-6354-6323
傳真： +86-21-6354-6325
電子郵件：
chinasales@powerint.com

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

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

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

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

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

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

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

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

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

應用服務專線
全球 +1-408-414-9660

應用服務傳真
全球 +1-408-414-9760

Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.powerint.com