設計範例報告

標題	***使用 LinkSwitchTM-PH LNK407EG 的 14.5 W 功率因數修正 (大於 0.98)，非隔離降壓式，可調光雙向閘流器 (TRIAC)，LED 驅動器，適用於*** A19 替換燈泡
規格	90 VAC ～ 132 VAC 輸入； 30 V_{TYP}，480 mA 輸出或 40 V_{TYP}，350 mA 輸出
應用	適用於 A19 替換燈泡
作者	應用工程部門
文件編號	DER-341
日期	2012 年 9 月 14 日
修訂	2.0

摘要與功能

- Single-stage 功率因數修正 (PFC) 與精準定電流 (CC) 輸出
- 成本低、所需元件極少且 PCB 佔位面積小
- 高度節能，在 115 VAC 輸入條件下效率大於 89%
- 快速啓動 (小於 100 ms) – 無可感延遲
- 整合式保護與可靠性功能
  - 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
  - 在電壓關閉和電壓啓動情況下，不會發生任何損壞
- 115 VAC 時 PF 超過 0.98
- 115 VAC 時 %A THD 小於 15%
- 符合 IEC 2.5 kV 振盪波、500 V 線差動電壓突波和 EN55015 傳導性 EMI 規範

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重要事項：雖然此電路板的設計滿足安全隔離需求，但其工程原型未經相關機構核准。因此，執行所有測試應使用隔離變壓器才能提供 AC 輸入給原型板。

1 簡介

本文件說明非隔離式、高功率因數 (PF)、雙向閘流器 (TRIAC) 調光 LED 驅動器。此驅動器旨在驅動標準 LED 串，當輸入電壓範圍是 90 VAC 至 132 VAC (典型值 60 Hz) 時，使 LED 的電壓和電流爲 30 V/480 mA。此 LED 驅動器使用 LinkSwitch-PH 系列 IC 中的 LNK407EG。

此設計使用 Single-stage 非隔離降壓式架構，以符合此設計的高功率因數、良好電流調節和調光要求。採用 LinkSwitch-PH 爲基礎的設計提供高功率因數 (>0.9)，符合國際安規要求。

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

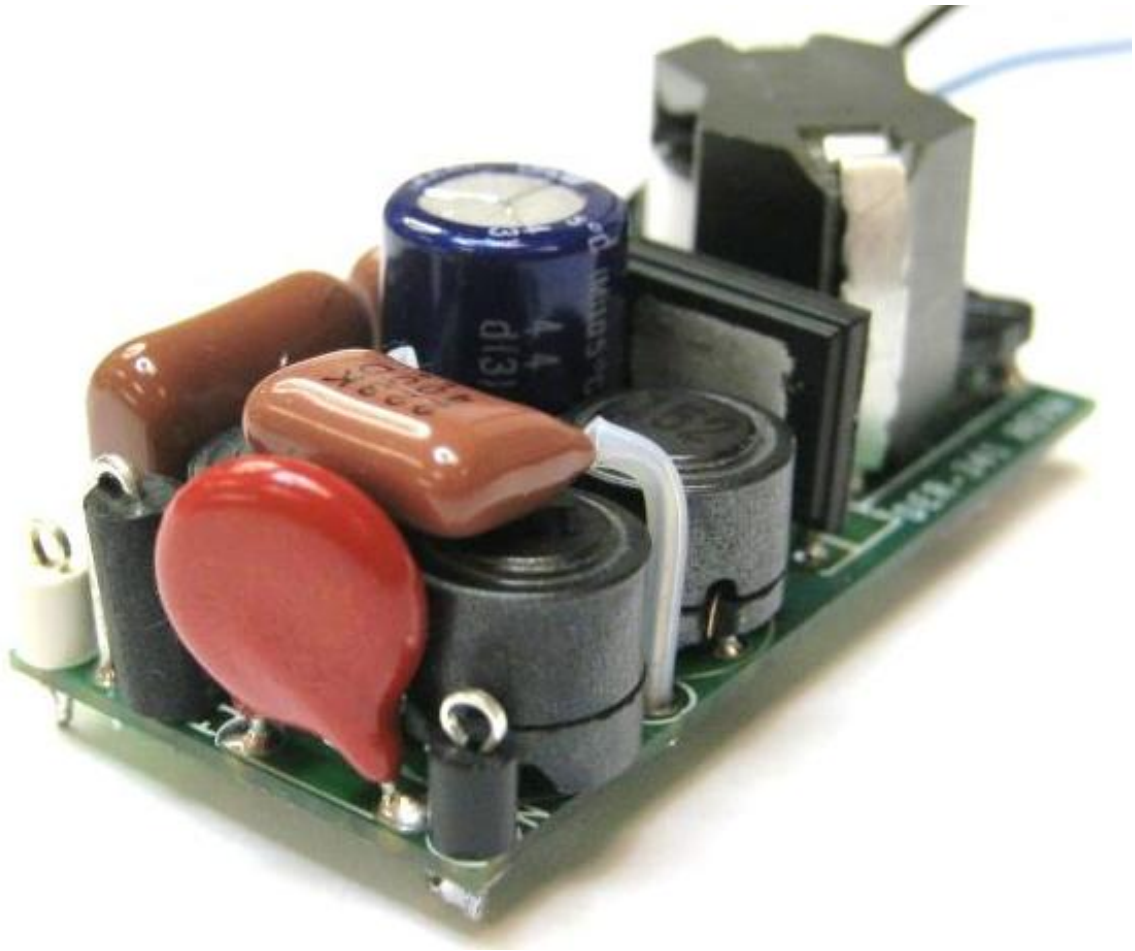

Figure 1 – Populated Circuit Board.

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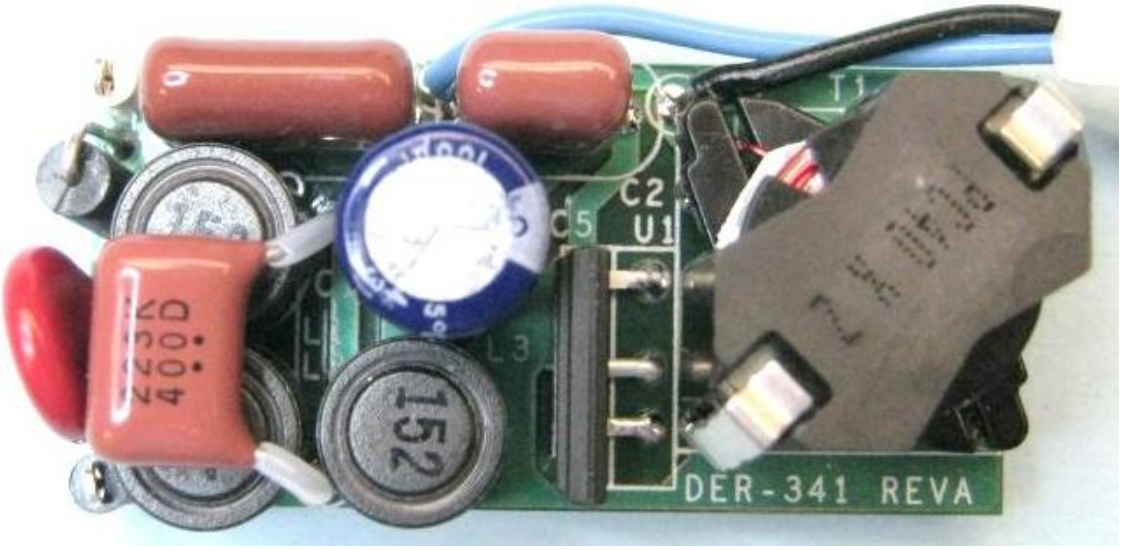

Figure 2 – Populated Circuit Board, Top View.

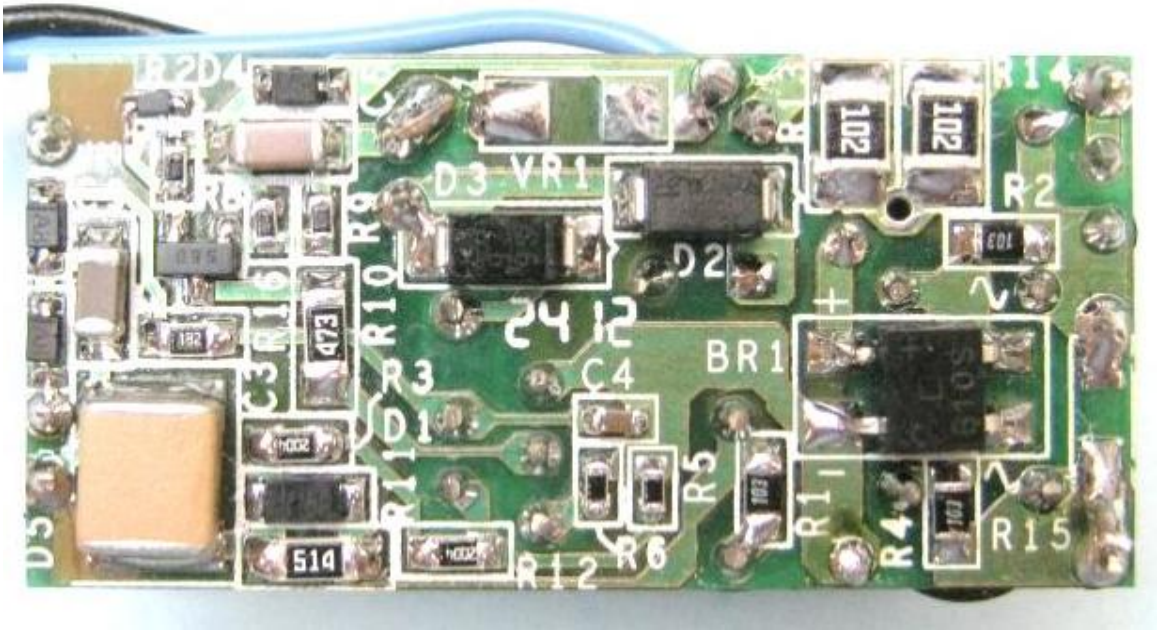

Figure 3 – Populated Circuit Board, Bottom View.

2 電源供應器規格

下表列出可接受此設計的最低效能。實際效能列在結果部分。

說明	符號	最小值	類型	最大值	單位	註解
輸入						
電壓	V_{IN}	90	120	132	VAC	雙線 – 無 P.E.
頻率	f_{LINE}	47	50/60	63	Hz	
輸出						
輸出電壓	V_{OUT}	29	30	31	V	
輸出電流	I_{OUT}		480		mA	在 115 VAC
總輸出功率						
連續輸出功率	P_{OUT}		14.5		W	
效率						
標準	η	88	89		%	於 P_{OUT} 25 °C、115 VAC 條件下測量
環境						
傳導性 EMI		符合 CISPR22B / EN55015 標準				
線間突波 差模 (L1-L2)			500		V	1.2/50 μs 突波，IEC 1000-4-5，串聯阻抗： 差模： 2 Ω
振盪波 (100 kHz) 差模 (L1-L2)			2.5		kV	2 Ω 短路 串聯阻抗
功率因數		0.9	0.98			在 115 VAC
A-THD				15	%	在 115 VAC
諧波電流		EN 61000-3-2 C 級				C 級限值 (針對 P_{IN} >25 W 限值)
環境溫度	T_{AMB}		40		°C	自然對流，海平面

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3 電路圖

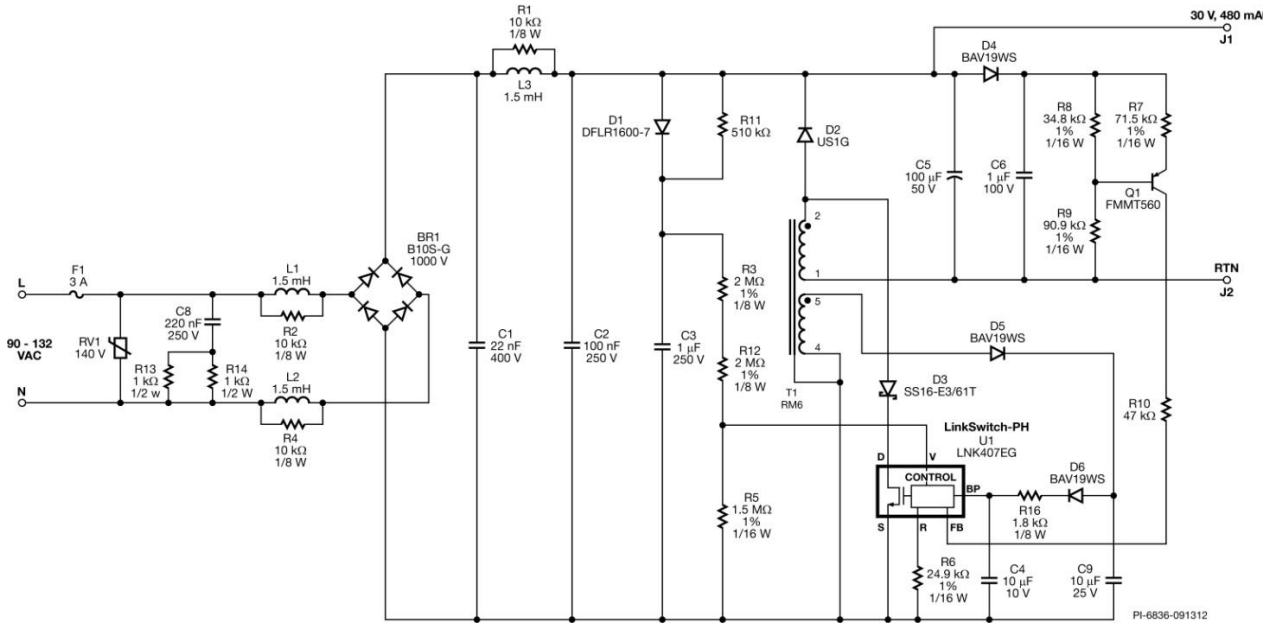

Figure 4 – Schematic Diagram for 30 V / 480 mA.

Notes for 40 V / 350 mA:

1. *Replace transformer T1 (620 µH inductance and bias winding of 22 turns).Refer to addendum section for more details.*
2. *Change R7 to 90.9 kΩ / 1%.*

4 電路說明

LinkSwitch-PH (U1) 是一個高度整合的一次側控制器，主要應用於 LED 驅動器。LinkSwitch-PH 以 Single-stage 轉換架構提供高功率因數，同時調整輸出電流。所有負責這些功能的控制電路，加上高電壓功率 MOSFET 都會被整合在裝置內。

電容器 C1、C2 和差模電感器 L1、L2 和 L3 會執行 EMI 濾波功能，同時維持高功率因數。此輸入濾波器網路，加上 LinkSwitch-PH 的頻率抖動功能，可符合 B 級輻射量限值。電阻器 R1、R2 和 R4 則用於箝制濾波器的諧振，防止 EMI 測量時產生不需要的峰值。

連接浮接輸出的升壓式功率電路包含 U1 (電源開關 + 控制器)、D2 (飛輪二極體)、C5 (輸出電容器) 和 T1 (輸出電感器)。二極體 D3 是用於防止 U1 汲源極間，尤其接近輸入電壓過零處出現負電壓。二極體 D1 和 C3 會偵測峰值 AC 線電壓。在 C3 上的電壓以及 R3、R12 和 R5 會設定饋入 V 接腳的電流。此電流會由 U1 用於控制線間電壓欠壓 (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。

耦合至 T1 的偏壓繞組也會用於供電給 U1 的旁路 (BP) 接腳。TRIAC 調光器銳減輸入電壓時，這會讓 U1 可以在深度調光情況下運作。二極體 D5 會調節偏壓電壓，而電容器 C9 則進行濾波。電阻器 R16 會限制供應給旁路接腳的電流，二極體 D5 則在啓動條件下，使 C9 與 C4 隔離。

U1 用於輸出電壓回授的回授接腳電流則由電壓至電流轉換器網路提供，這個網路是使用 R7、R8、R9、R10、Q1、C6 和 D4 構成。輸出電壓會轉換成回授電流，其關係如下：

$$I_{FB} \approx k \times V_{OUT}$$

其中：

$$k = \frac{1}{R7} * \frac{R8}{R8 + R9}$$

爲消除或盡量降低溫度效應，以及 Q1 之 V_{BE} 電壓的 V_{CE} 相依性，選用了夠高的 R8 上電壓。

4.1 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在設計時有些取捨。

由於 LED 照明所消耗的功率小得多，因此整體燈泡所汲取的電流會低於許多調光器內 TRIAC 的保持電流(holding current)。這會導致發生不良情況，例如調光範圍受限及 (或) 在 TRIAC 啓動時不一致地閃爍。開啓 TRIAC 時，LED 燈相對較大的阻抗會因對輸入電容

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充電的突波電流(inrush current)而導致大幅振盪。這個效應會導致發生類似的不良情況，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，採用了由電容器 C8 和電阻器 R13 與 R14 構成的被動洩放器，並將其新增到電源供應器的輸入端。

4.2 設計附註

此驅動器的輸出沒有安裝過壓保護功能。
請勿在沒有 LED 負載的情況下啓動此裝置。

5 PCB 佈局

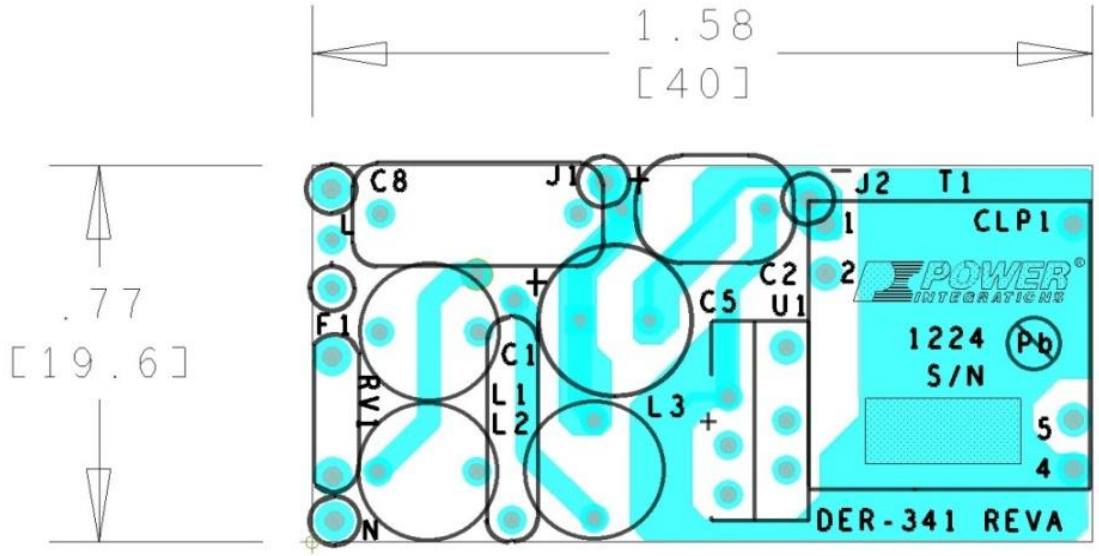

Figure 5 – Top Side.

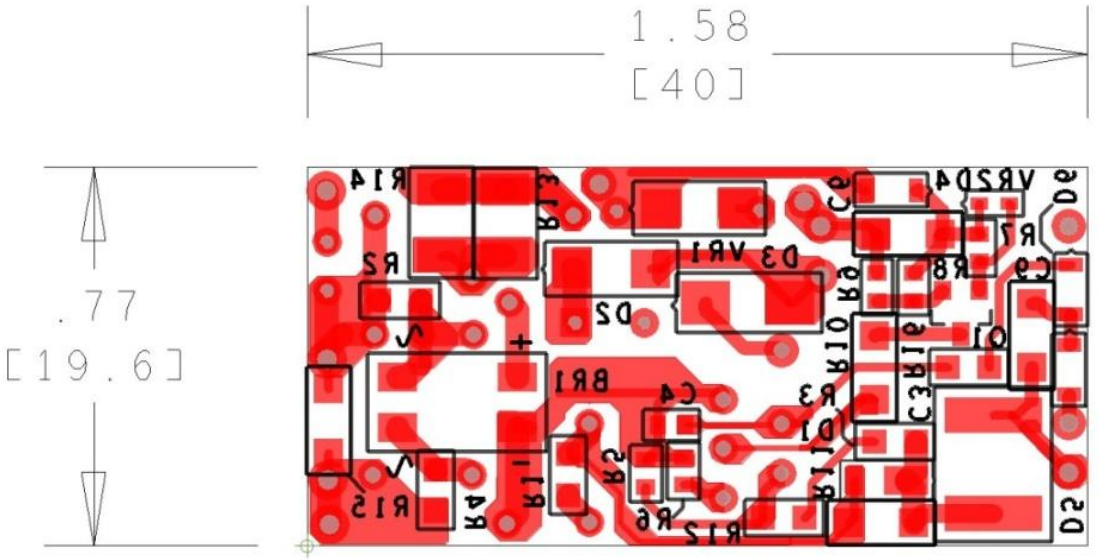

Figure 6 – Bottom Side.

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6 物料清單

Item	Qty	Part Ref	Description	Mfg Part Number	Mfg
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip Technology
2	1	C1	22 nF, 400 V, Film	ECQ-E4223KF	Panasonic
3	1	C2	100 nF, 250 V, Film	ECQ-E2104KB	Panasonic
4	1	C3	1.0 μF, 250 V, Ceramic, X7R, 2220	C5750X7R2E105K	TDK
5	1	C4	10 μF, 10 V, Ceramic, X5R, 0603	C1608X5R1A106M	TDK
6	1	C5	100 μF, 50 V, Electrolytic, Low ESR, 220 mΩ, (8 x 12)	ELXZ500ELL101MH12D	Nippon Chemi-Con
7	1	C6	1 μF, 100 V, Ceramic, X7R, 1206	C3216X7R2A105K	TDK
8	1	C8	220 nF, 250 V, Film	ECQ-E2224KF	Panasonic
9	1	C9	10 μF, 25 V, Ceramic, X5R, 1206	ECJ-3YB1E106M	Panasonic
10	1	D1	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
11	1	D2	DIODE ULTRA FAST, GPP, 400 V, 1A SMA	US1G-13-F	Diodes, Inc.
12	1	D3	60 V, 1 A, Schottky, DO-214AC	SS16-E3/61T	Vishay
13	3	D4 D5 D6	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diode Inc.
14	1	F1	3 A, 125 V, Fast, Microfuse, Axial	MQ3	Bel Fuse
15	2	J1 J2	PCB Terminal Hole, 22 AWG	N/A	N/A
16	2	L N	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
17	3	L1 L2 L3	1.5 mH, 0.19 A, Ferrite Core	CTSCH875DF-152K	CT Parts
18	1	Q1	PNP, Small Signal BJT, 500 V, 0.15 A, SOT23	FMMT560TA	Zetex
19	3	R1 R2 R4	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
20	2	R3 R12	2 MΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2004V	Panasonic
21	1	R5	1.50 MΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1504V	Panasonic
22	1	R6	24.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2492V	Panasonic
23	1	R7	71.5 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF7152V	Panasonic
24	1	R8	34.8 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3482V	Panasonic
25	1	R9	90.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF9092V	Panasonic
26	1	R10	47 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ473V	Panasonic
27	1	R11	510 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ514V	Panasonic
28	2	R13 R14	1 kΩ, 5%, 1/2 W, Thick Film, 1210	ERJ-14YJ102U	Panasonic
29	1	R16	1.8 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ182V	Panasonic
30	1	RV1	140 V, 12 J, 7 mm, RADIAL	V140LA2P	Littlefuse
31	1	T1	Bobbin, RM6, Vertical, 6 pins	B65808-N1006-D1	Epcos
32	1	U1	LinkSwitch-PH, eSIP	LNK407EG	Power Integrations

Note for 40V/350mA version:

23	1	R7	90.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF9092V	Panasonic
31	1	T1	Bobbin, RM6, Vertical, 6 pins	Custom for 40V/350mA	Epcos

7 電感器規格

7.1 電氣圖

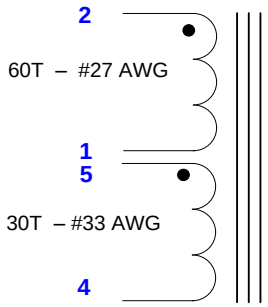

Figure 7 – Inductor Electrical Diagram.

7.2 電氣規格

Primary Inductance	Pins 1-2 all other windings open, measured at 66 kHz, 0.4 V_{RMS}	470 µH ±7%
Resonant Frequency	Pins 1-2, all other windings open	1.8 MHz (Min.)

7.3 物料

Item	Description
[1]	Core:RM6S PC40 or equivalent.
[2]	Bobbin:B-RM6-V 6pins 3/3.
[3]	Magnet Wire, #27 AWG, solderable double coated.
[4]	Magnet Wire, #33 AWG, solderable double coated.

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7.4 電感器建構圖

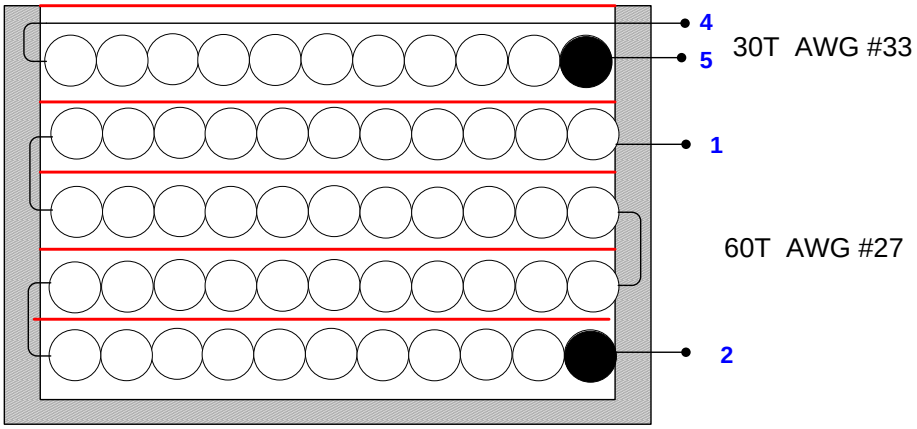

Figure 8 – Inductor Build Diagram.

7.5 電感器結構

General Note	For the purpose of these instructions, bobbin is oriented on winder such that pin 1 side is on the right.
WD1	Start at pin 2. Wind 60 turns of item [3] as shown in Figure 2. Terminate at pin 1.
WD2	Start at pin 5. Wind 30 turns of item [4] and terminate the other end at pin 4.
Finish	Grind the core to get the specified inductance.Place the clip to secure both cores.Cut pins 3 and 6.

8 電感器設計試算表

ACDC_LNK-PH_Buck_032811; Rev.1.0; Copyright Power Integrations 2011	INPUT	OUTPUT	UNIT	LNK-PH_032811:LinkSwitch-PH Buck Design Spreadsheet
ENTER APPLICATION VARIABLES				
Dimming required	**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	69	69	Hz	AC Mains Frequency
VO	30.00		V	Typical output voltage of LED string at full load
VO_MAX		37.50	V	Maximum LED string Voltage.Ensure that the maximum LED string voltage is below VO_MAX
VO_MIN		23.68	V	Minimum LED string Voltage.Ensure that the minimum LED string voltage is above VO_MIN
V_OVP		41.25	V	Over-voltage setpoint
IO	0.48			Typical full load LED current
PO		14.4	Watts	Output Power
n	0.90	0.90		Estimated efficiency of operation
ENTER LinkSwitch-PH VARIABLES				
LNK-PH	**LNK407**			Selected Linkswitch-PH device.If Dimming is required, select device from LNK40X family, Otherwise select device from LNK41X family
Current Limit Mode	**RED**			Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN		1.420	A	Minimum current limit
ILIMITMAX		1.660	A	Maximum current limit
fS		66000	Hz	Switching Frequency
fSmin		62000	Hz	Minimum Switching Frequency
fSmax		70000	Hz	Maximum Switching Frequency
IV		39.91	uA	V pin current
Rv		4	M-ohms	Upper V pin resistor
RV2		1.402	M-ohms	Lower V pin resistor
IFB	95.00	95.00	uA	!!! Warning.IFB is too low.Use larger device
R7		88.42	k-ohms	IFB setting resistor (See RDR254 schematic)
R8		35.35	k-ohms	Upper resistor in base divider (See RDR254 schematic)
R9		90.90	k-ohms	Lower resistor in base divider (See RDR254 schematic)
VDS		10	V	LinkSwitch-PH on-state Drain to Source Voltage
VD	0.60		V	Output Winding Diode Forward Voltage Drop
VDB	0.70		V	Bias Winding Diode Forward Voltage Drop
Key Design Parameters				
KP	0.75	0.75		Ripple to Peak Current Ratio (0.4 < KRP < 1.3)
LP		470	uH	Primary Inductance
KP Expected		0.62		Ripple to Peak Current Ratio (0.4 < KRP < 1.3)
Expected IO (average)		0.48	A	Expected Average Output Current
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES				
Core Type	**RM6**			Selected Core for inductor
Core			*P/N:*	*
Bobbin			*P/N:*	CSV-RM6/R-1S-4P
AE		0.32	cm^2	Core Effective Cross Sectional Area
LE		2.56	cm	Core Effective Path Length
AL		1420	nH/T^2	Ungapped Core Effective Inductance
BW		6.4	mm	Bobbin Physical Winding Width
M		0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	4.00	4		Number of Primary Layers

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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		0.24		Minimum duty cycle at peak of VACMIN
IAVG		0.48	A	Average Primary Current
IP		1.18	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS		0.48	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS				
LP		470	uH	Primary Inductance
NP		60		Primary Winding Number of Turns
ALG		131	nH/T^2	Gapped Core Effective Inductance
BM		2899	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP		3987	Gauss	Peak Flux Density (BP<4200)
BAC		1081	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur		904		Relative Permeability of Ungapped Core
LG		0.28	mm	Gap Length (Lg > 0.1 mm)
BWE		25.6	mm	Effective Bobbin Width
OD		0.43	mm	Maximum Primary Wire Diameter including insulation
INS		0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA		0.37	mm	Bare conductor diameter
AWG		27	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM		203	Cmils	Bare conductor effective area in circular mils
CMA		420	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)

9 效能資料

All measurements performed at room temperature using an LED load.The following data were measured using 3 sets of loads to represent the load range of 29 V to 31 V. Refer to the table on Section 9.6 for complete test data.

9.1 效率

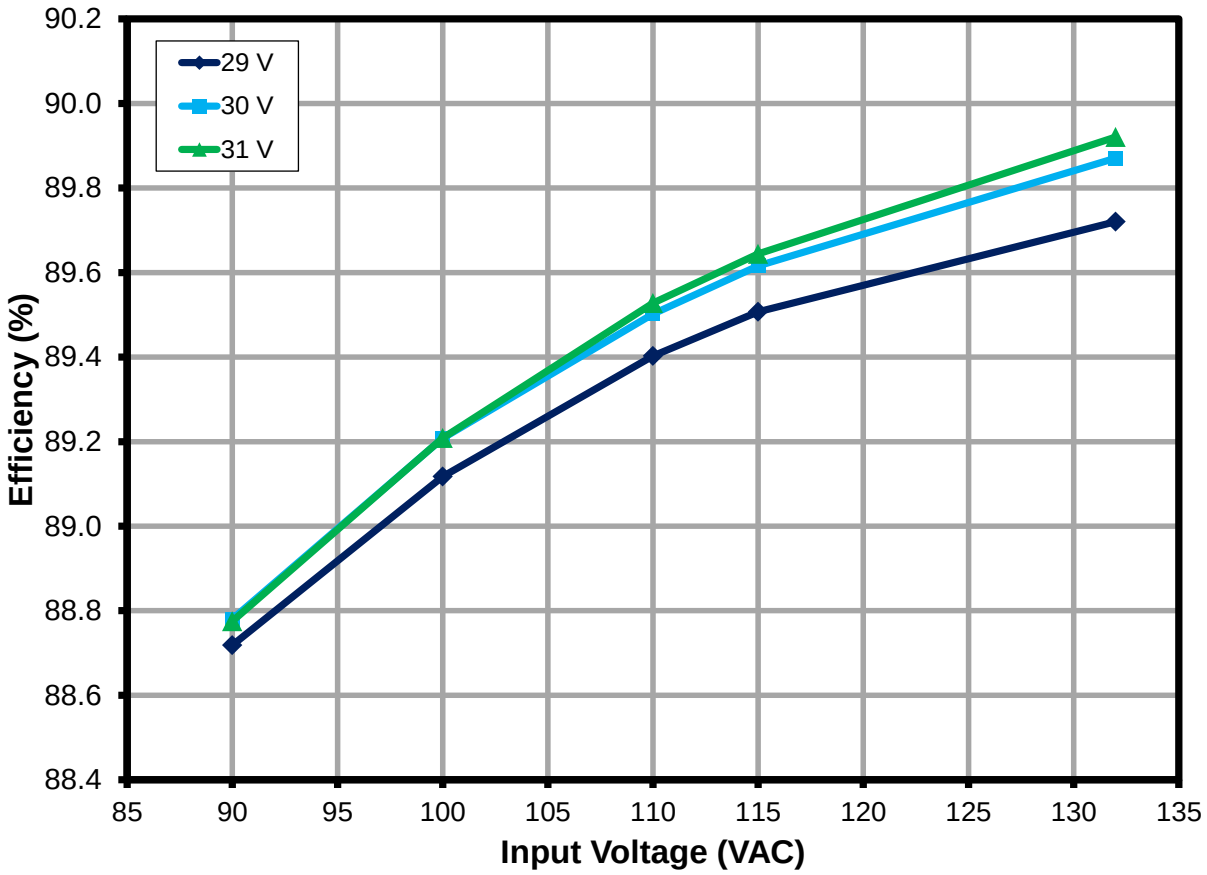

Figure 9 – Efficiency vs. Line and Load.

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9.2 線電壓與負載穩定度關係圖

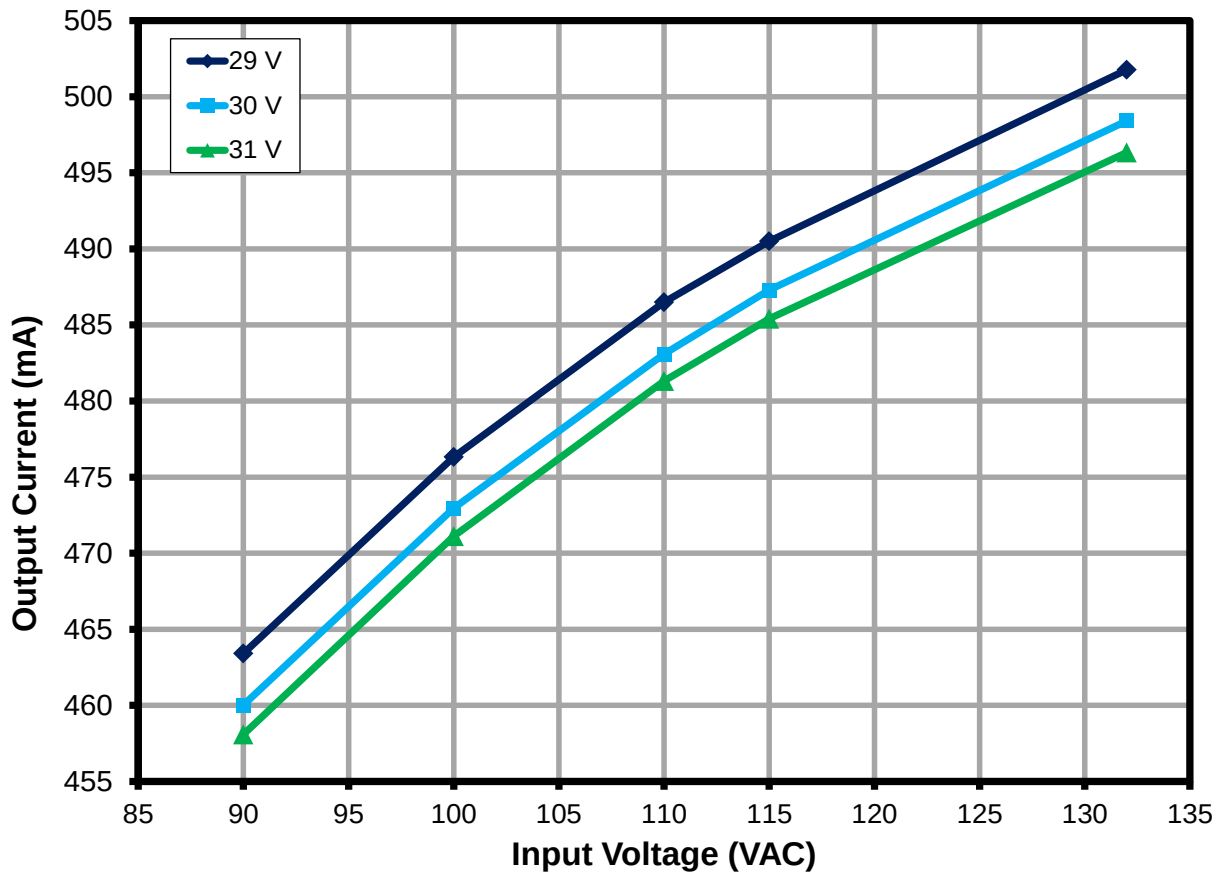

Figure 10 – Regulation vs. Line and Load.

9.3 功率因數

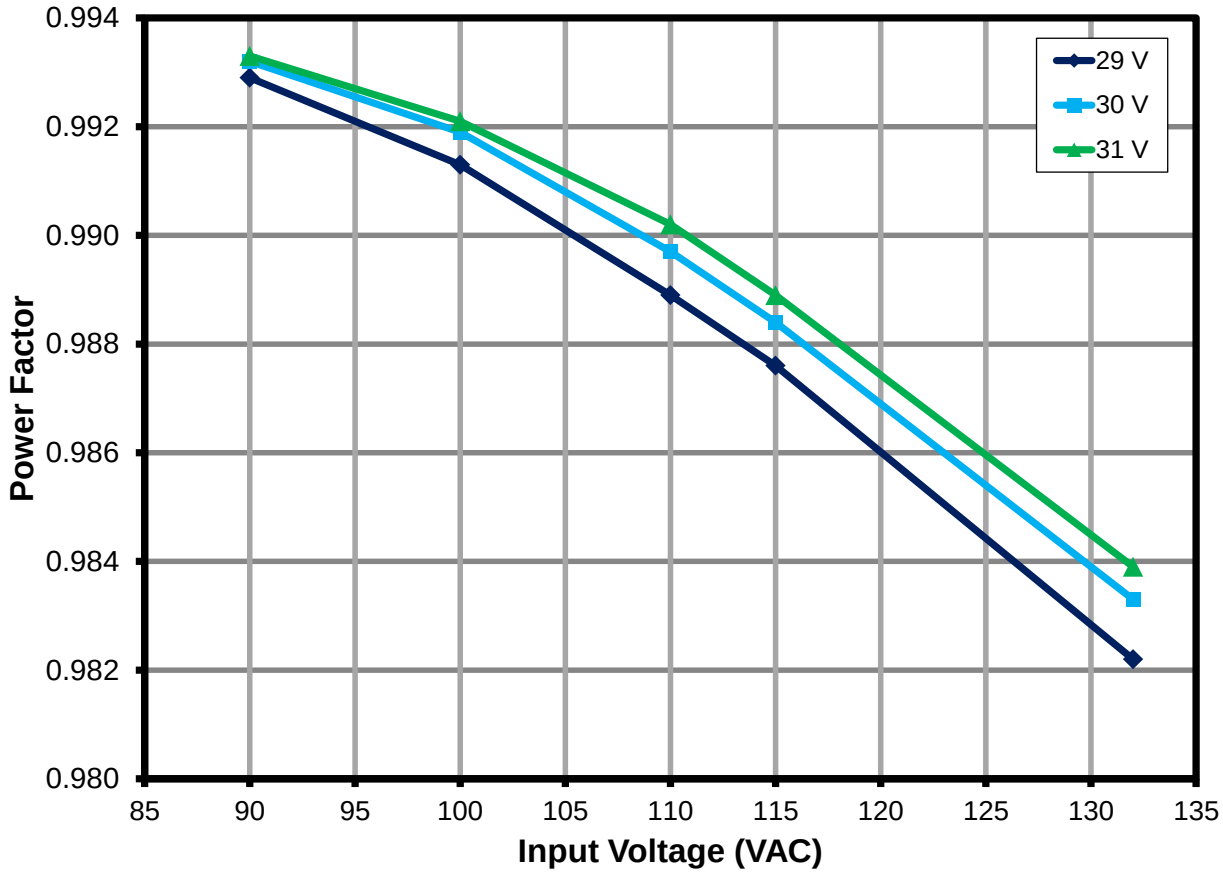

Figure 11 – Power Factor vs. Line and Load.

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9.4 A-THD

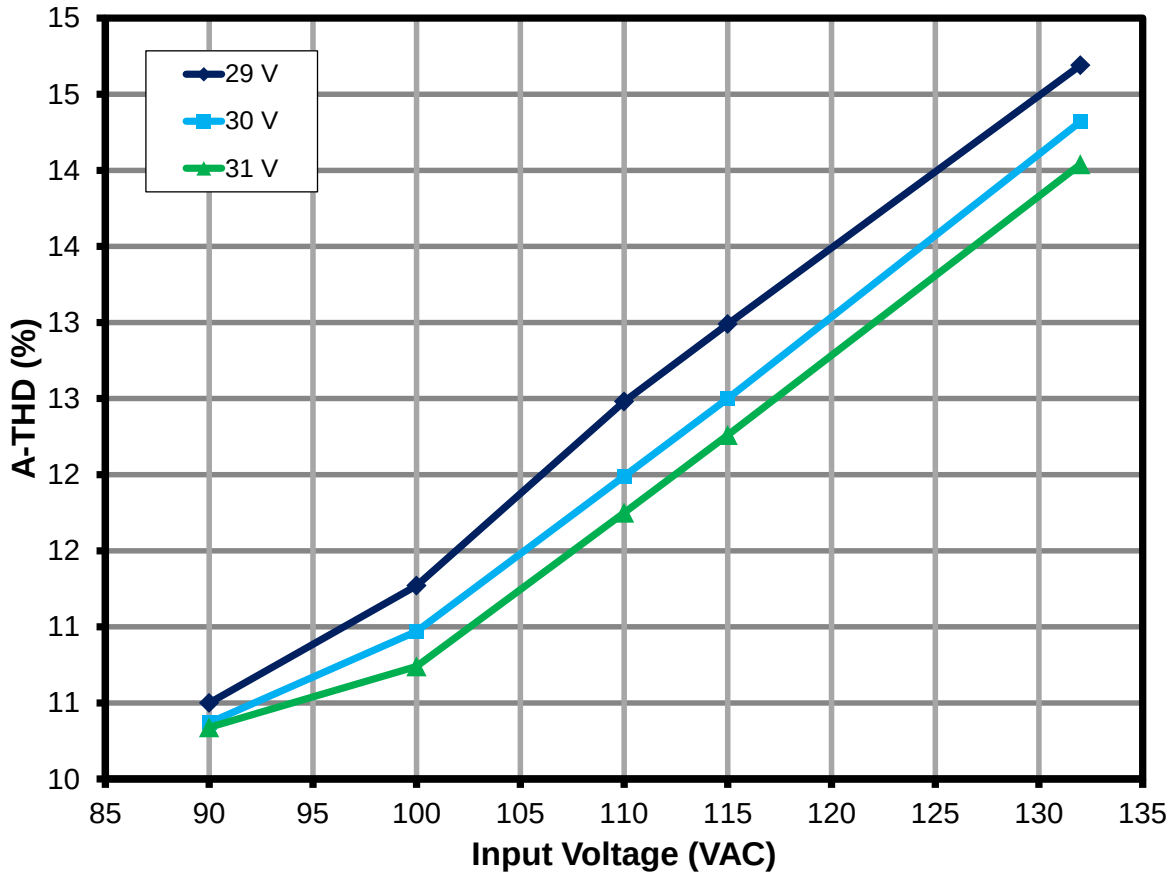

Figure 12 – A-THD vs. Line and Load.

9.5 諧波

9.5.1 29 V LED 負載

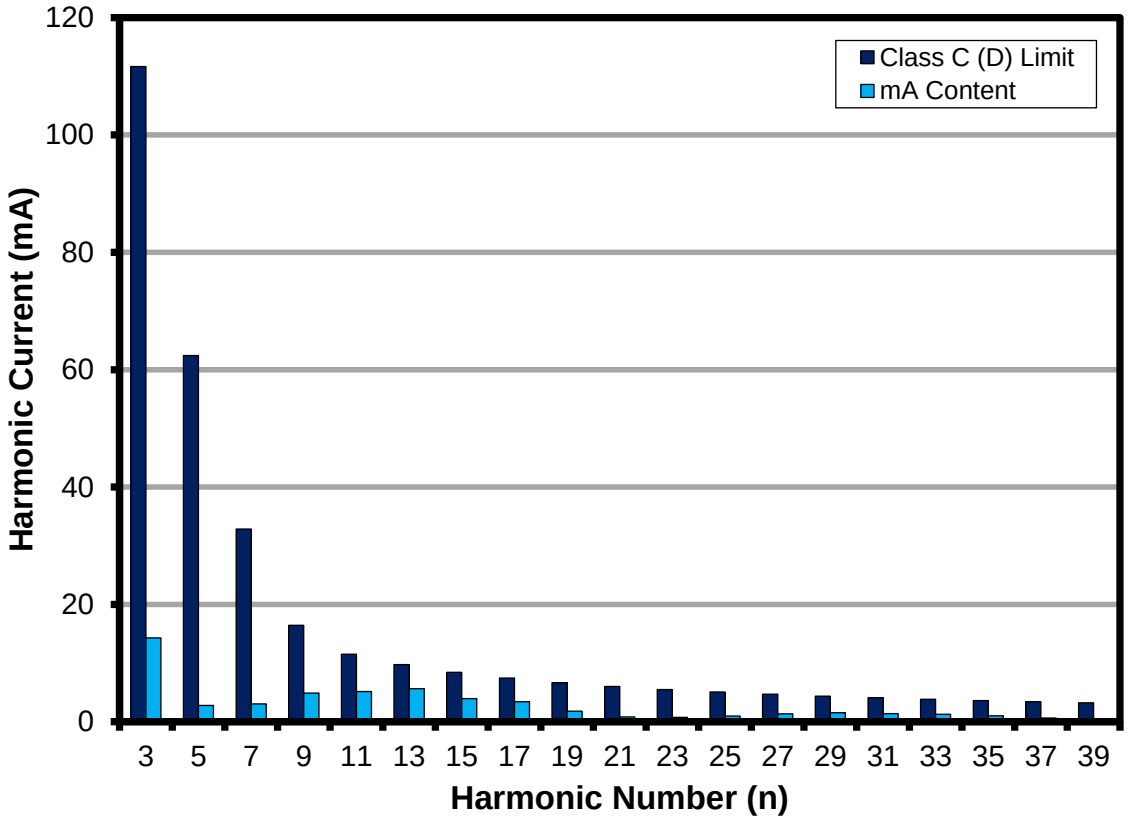

Figure 13 – 29 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

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9.5.2 30 V LED 負載

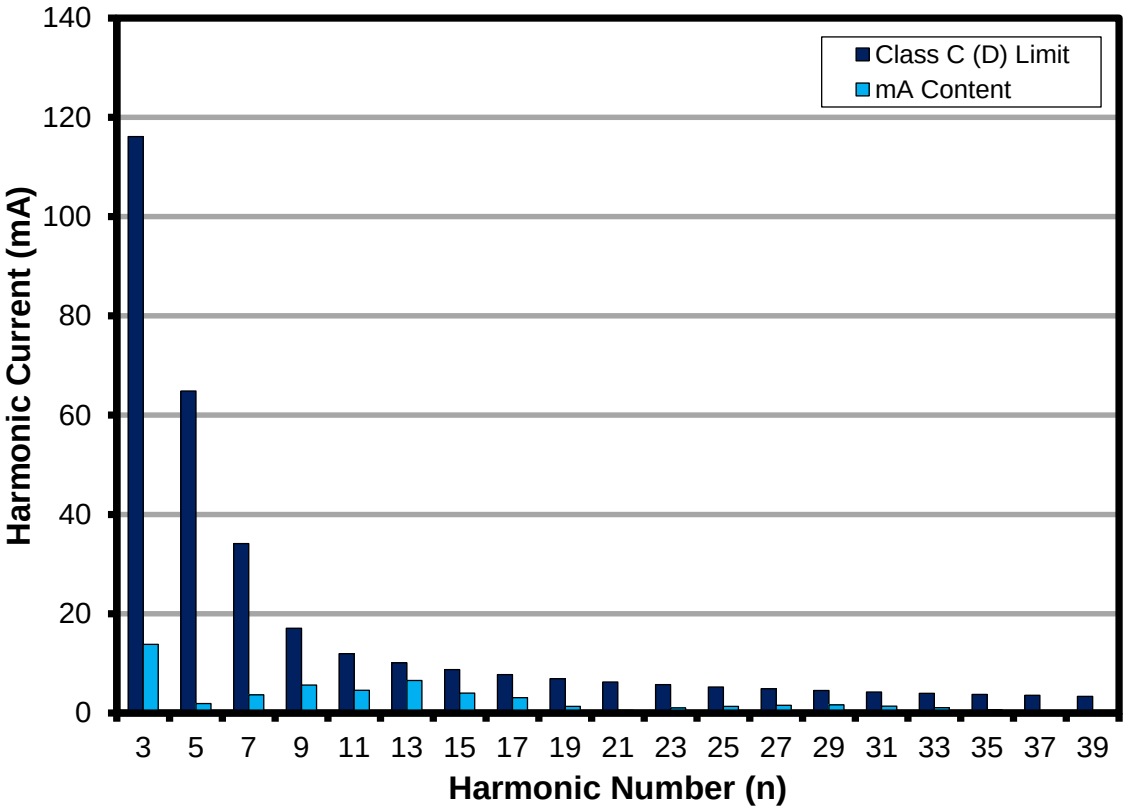

Figure 14 – 30 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

9.5.3 31 V LED 負載

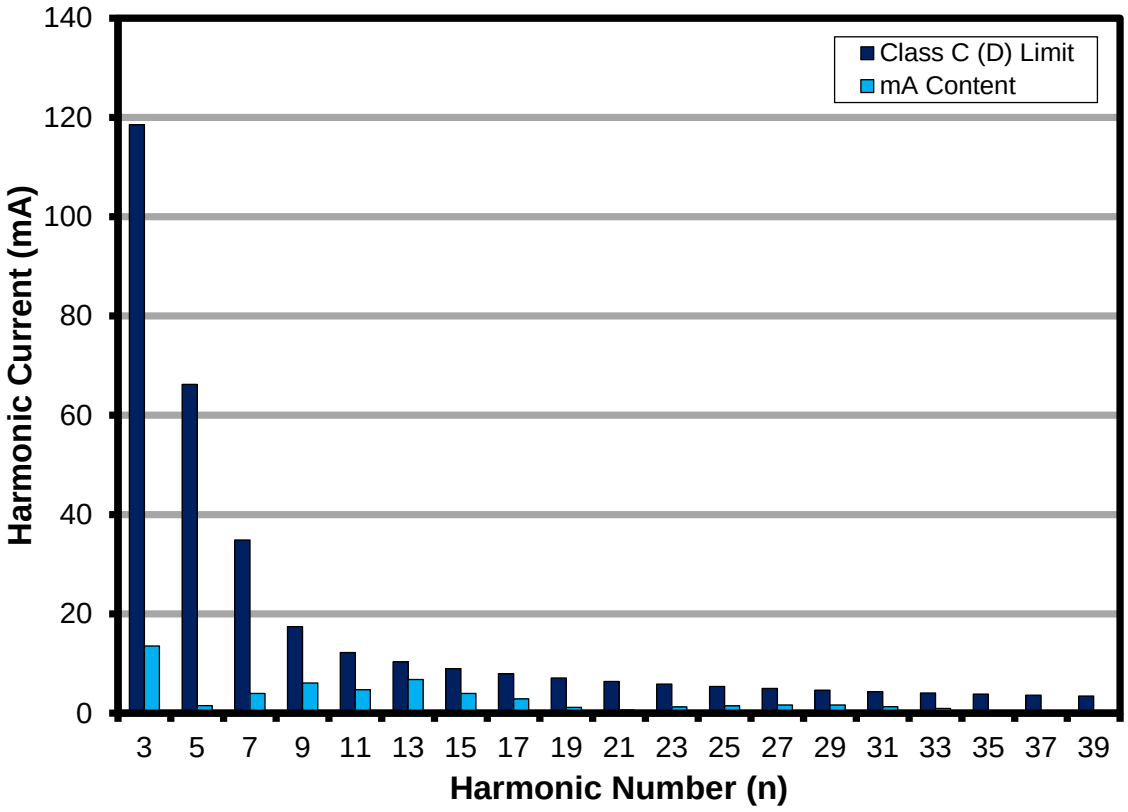

Figure 15 – 31 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

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9.6 測試資料

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

9.6.1 測試資料，29 V LED 負載

Input		Input Measurement					Load Measurement			Calculation		
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)	P_{CAL} (W)	Efficiency (%)	Loss (W)
90	60	89.99	174.90	15.627	0.993	10.50	28.93	463.41	13.86	13.41	88.72	1.76
100	60	99.95	161.55	16.007	0.991	11.27	29.00	476.32	14.27	13.81	89.12	1.74
110	60	110.01	149.88	16.306	0.989	12.48	29.05	486.50	14.58	14.13	89.40	1.73
115	60	114.99	144.60	16.421	0.988	12.99	29.06	490.50	14.70	14.25	89.51	1.72
132	60	132.01	129.36	16.771	0.982	14.69	29.11	501.77	15.05	14.61	89.72	1.72

9.6.2 測試資料，30 V LED 負載

Input		Input Measurement					Load Measurement			Calculation		
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)	P_{CAL} (W)	Efficiency (%)	Loss (W)
90	60	90.00	181.68	16.239	0.993	10.37	30.31	460.02	14.42	13.94	88.78	1.82
100	60	99.97	167.76	16.633	0.992	10.97	30.39	472.96	14.84	14.37	89.21	1.80
110	60	110.02	155.62	16.946	0.990	11.99	30.44	483.09	15.17	14.71	89.50	1.78
115	60	115.00	150.20	17.074	0.988	12.5	30.46	487.29	15.30	14.84	89.62	1.77
132	60	132.02	134.23	17.425	0.983	14.32	30.52	498.41	15.66	15.21	89.87	1.77

9.6.3 測試資料，31 V LED 負載

Input		Input Measurement					Load Measurement			Calculation		
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)	P_{CAL} (W)	Efficiency (%)	Loss (W)
90	60	90.00	185.45	16.579	0.993	10.34	31.08	458.08	14.72	14.24	88.77	1.86
100	60	99.97	171.26	16.986	0.992	10.74	31.16	471.12	15.15	14.68	89.21	1.83
110	60	110.03	158.83	17.303	0.990	11.75	31.21	481.31	15.49	15.02	89.53	1.81
115	60	115.01	153.25	17.430	0.989	12.26	31.23	485.41	15.63	15.16	89.64	1.81
132	60	132.02	136.87	17.779	0.984	14.04	31.29	496.34	15.99	15.53	89.92	1.79

10 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 30 V LED load.

10.1 使用前緣調光器的典型調光曲線

Data taken using programmable AC source (Agilent 6812B) providing leading edge chopped AC input.

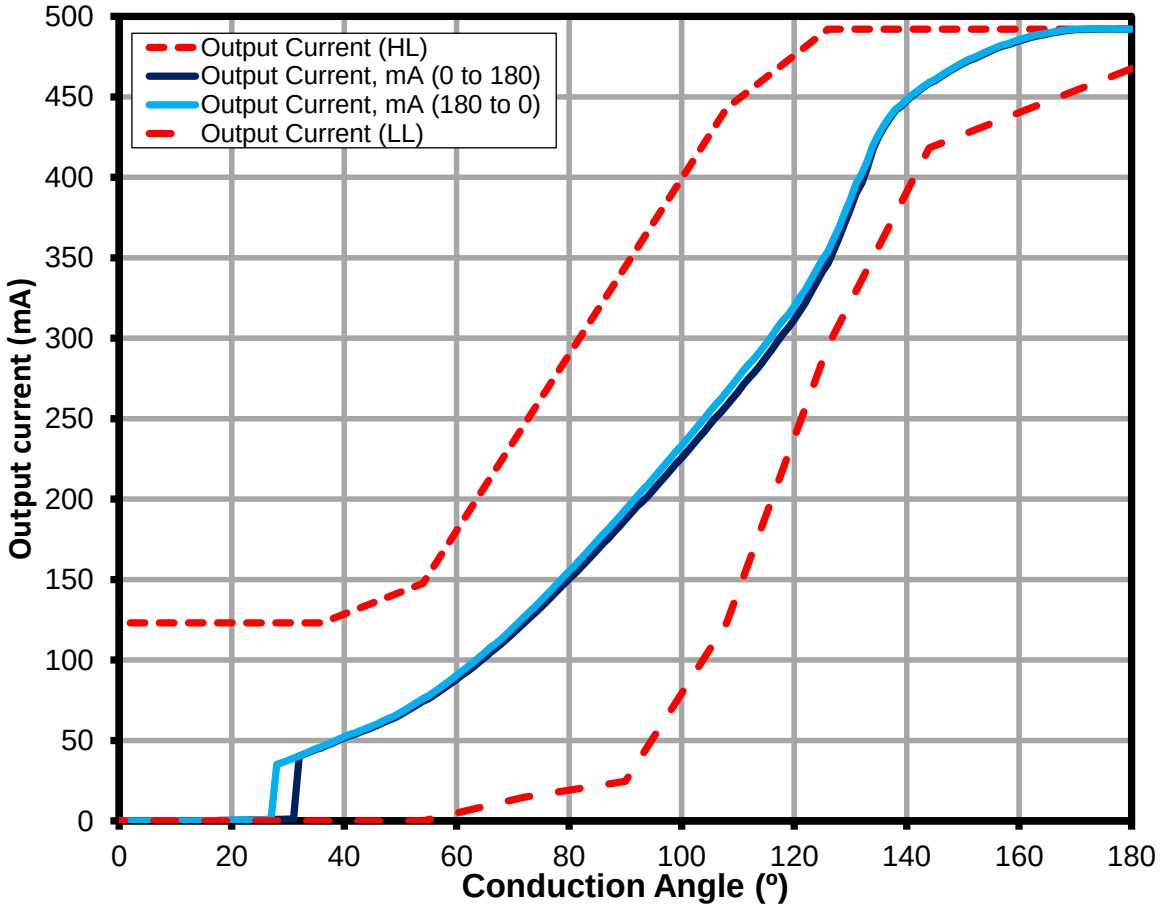

Figure 16 – Leading Edge Dimming Characteristics.

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10.2 調光器相容性清單

The unit was tested with the following high-line dimmers at 120 VAC, 60 Hz (direct from utility line) input and 30 V LED load.

	List of Dimmers	Type	Part Number	Max Iout, mA	Min Iout, mA	Dim Ratio
1	LUTRON LG600PH-LA	L	LG-600PH-WH	436	1.07	407
2	LUTRON S603P	L	S-603P-WH	457	1.05	435
3	LUTRON SLV600P	L	SLV600P-WH	453	1.1	412
4	LUTRON S600	L	S-600-WH	485	1.05	462
5	LUTRON S-600PH-WH	L	S-600PH-WH	458	1.05	436
6	LUTRON DVCL153P	L	DVWCL-153-PLH-WH	461	46	10
7	LUTRON DV603P	L	DV-603P-WH	436	1.1	396
8	LUTRON DV600P	L	DV-600P-WH	435	1.1	395
9	LUTRON TG600PH-IV	L	TG-600PH-WH	450	1.07	421
10	LUTRON AY600P	L	AY-600P-WH	448	1.1	407
11	LUTRON GL600P-WH	L	GL-600P-WH	457	1.05	435
12	LEVITON 6633PLI	L	R62-06633-1LW	496	1.03	482
13	LEVITON 6631-LI	L	R62-06631-1LW	473	1.06	446
14	LEVITON IPI06	L	R60-IPI06-1LM	493	83	6
15	LEVITON RP106	L	R52-RPI06-1LW	499	1	499
16	LEVITON 6681	L	R60-06681-0IW	499	35	14
17	LEVITON 6684	L	R60-06684-1IW	499	1	499
18	LEVITON 6613	L	R02-06613-PLW	492	1.11	443
19	COOPER SLC03		SLC03P-W-K-L	469	127	4
20	LUTRON GL600-WH	L	GL-600-WH	484	1.05	461
21	LUTRON DVPDC-203P-WH	L	DVPDC-203P-WH	487	139	4
22	LUTRON LX600PL	L	LX-600PL-wh	480	66	7
23	LUTRON S-600P	L	S-600P	460	1.05	438
24	LUTRON TGLV-600P	L	TGLV-600P	463	1.1	421
25	LUTRON TGLV-600PR	L	TGLV-600PR	445	1.11	401
26	LUTRON TT-300NLH-WH	L	TT-300NLH-WH	488	1.01	483
27	LUTRON TT-300H-WH	L	TT-300H-WH	488	1	488
28	LUTRON NLV-1000-WH	L	NLV-1000-WH	468	40	12

Figure 17 – TRIAC Dimmer Compatibility Table.

11 散熱效能

Images captured after running for >30 minutes at room temperature (25 °C), open frame for the conditions specified.

11.1 非調光 V_{IN} = 90 VAC，60 Hz，30 V LED 負載

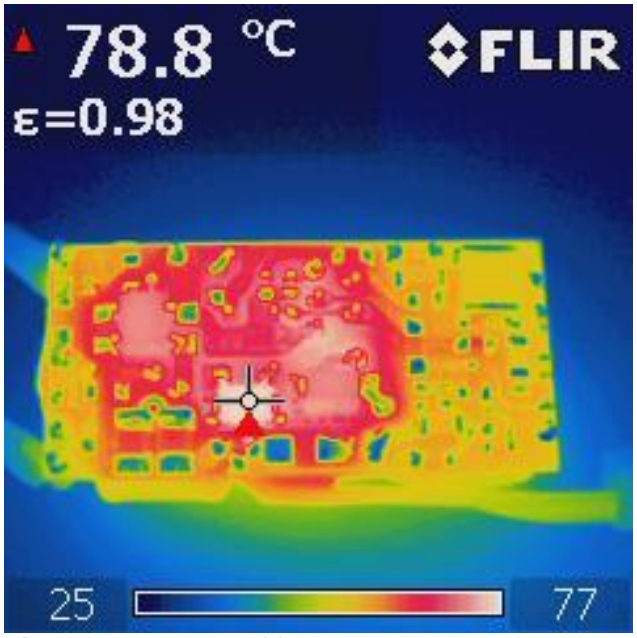

Figure 18 – Bottom Side.
D2-US1G:78.8 ºC

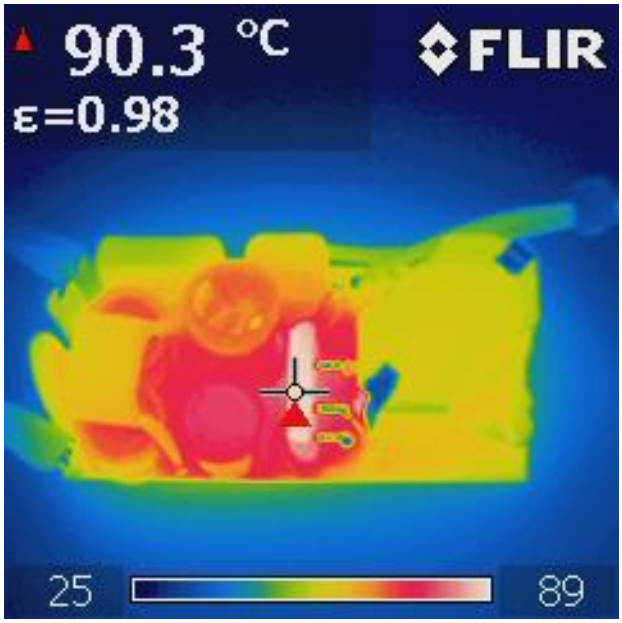

Figure 19 – Top Side.
U1-LNK407EG:90.3 ºC

11.2 非調光 V_{IN} = 132 VAC，60 Hz，30 V LED 負載

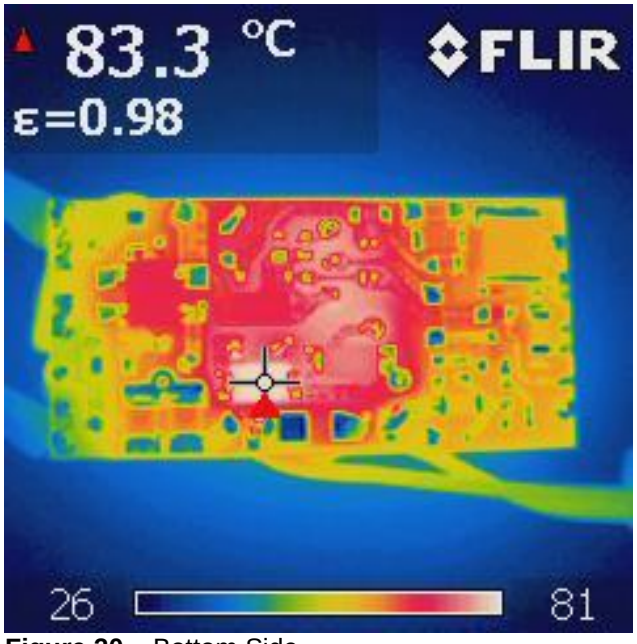

Figure 20 – Bottom Side.
D2-US1G:83.3ºC

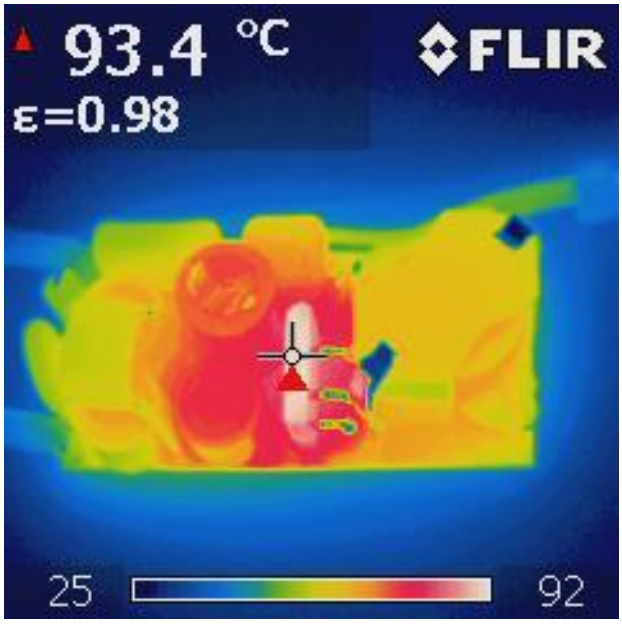

Figure 21 – Top Side.
U1-LNK407EG:93.4 ºC

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11.3 調光 V_{IN} = 120 VAC 60 Hz，90º 導通角，30 V LED 負載

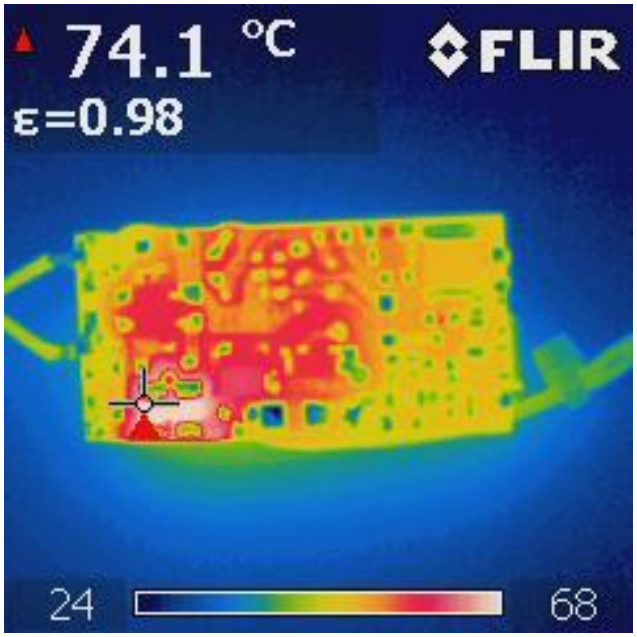

Figure 22 – Bottom Side.
R14-Bleeder Resistor:74.1 ºC

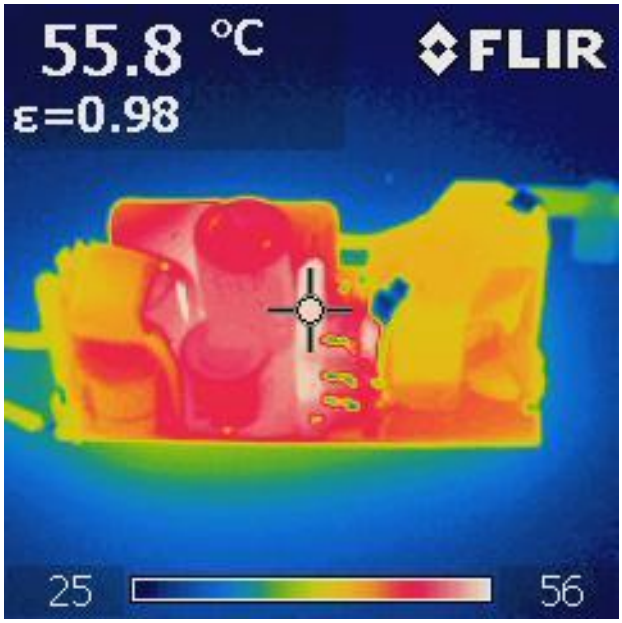

Figure 23 – Top Side.
U1-LNK407EG:55.8 ºC

12 非調光波形

12.1 輸入電壓和輸入電流波形

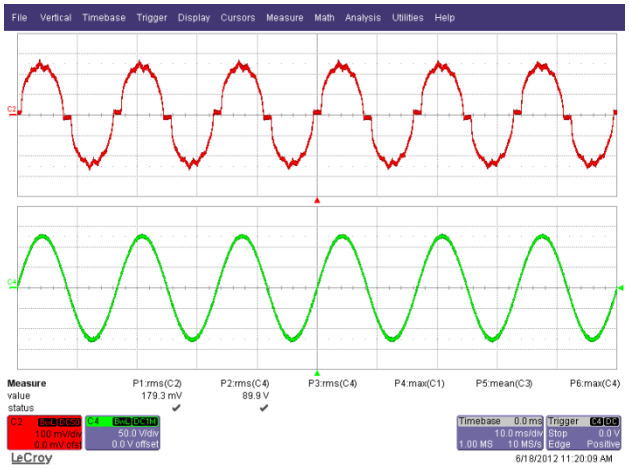

Figure 24 – 90 VAC, Full Load.
Upper:I_{IN}, 100 mA / div.
Lower:V_{IN}, 50 V, 10 ms / div.

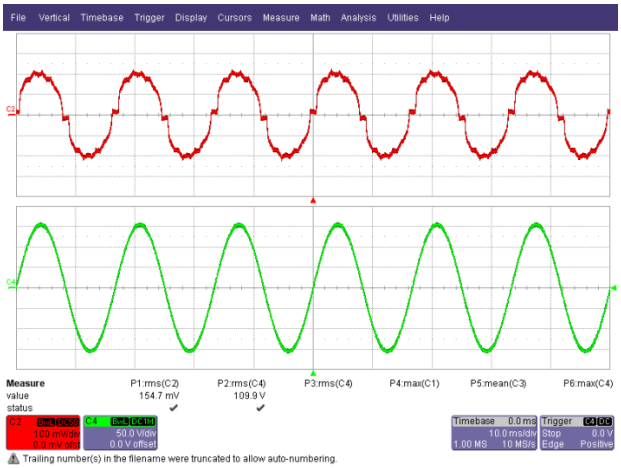

Figure 25 – 110 VAC, Full Load.
Upper:I_{IN}, 100 mA / div.
Lower:V_{IN}, 50 V, 10 ms / div.

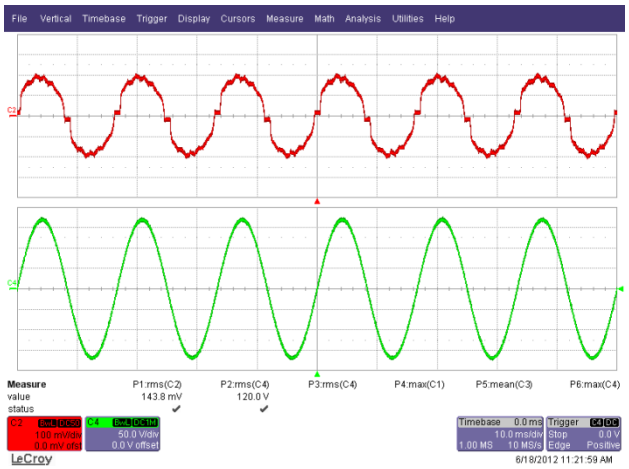

Figure 26 – 120 VAC, Full Load.
Upper:I_{IN}, 100 mA / div.
Lower:V_{IN}, 50 V, 10 ms / div.

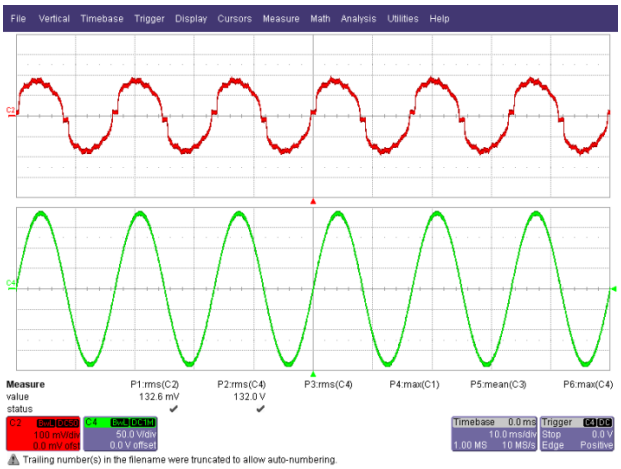

Figure 27 – 132 VAC, Full Load.
Upper:I_{IN}, 100 mA / div.
Lower:V_{IN}, 50 V, 10 ms / div.

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12.2 正常運作下的輸出電流和輸出電壓

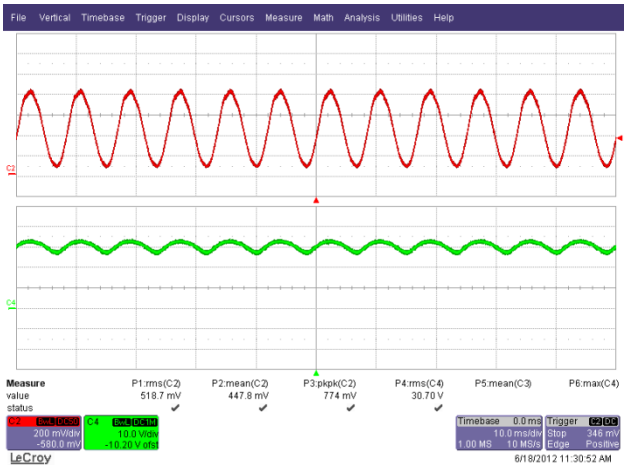

Figure 28 – 90 VAC, 60 Hz Full Load.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{OUT}, 10 V, 10 ms / div.

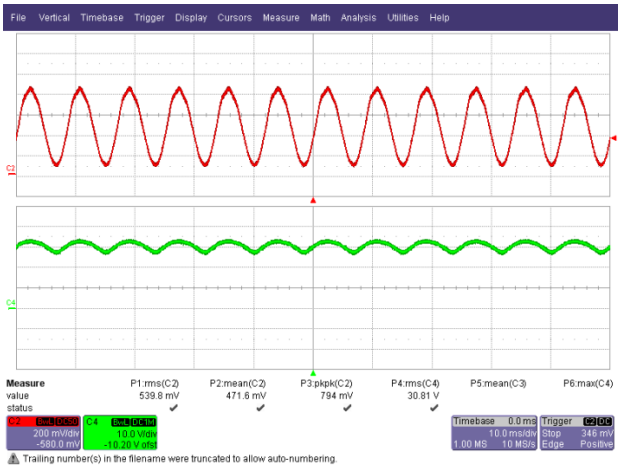

Figure 29 – 110 VAC, 60 Hz Full Load.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{OUT}, 10 V, 10 ms / div.

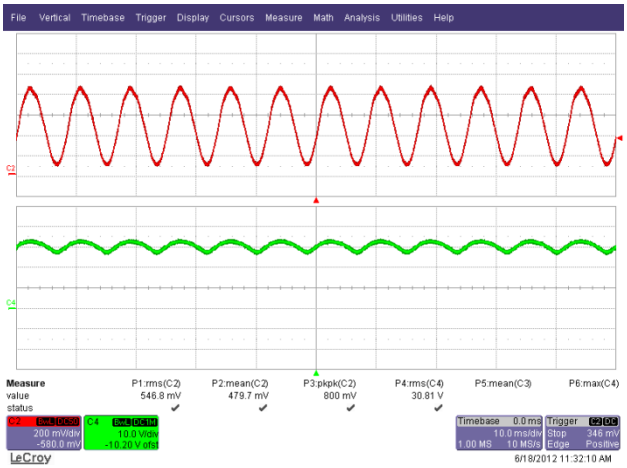

Figure 30 – 120 VAC, 60 Hz Full Load.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{OUT}, 10 V, 10 ms / div.

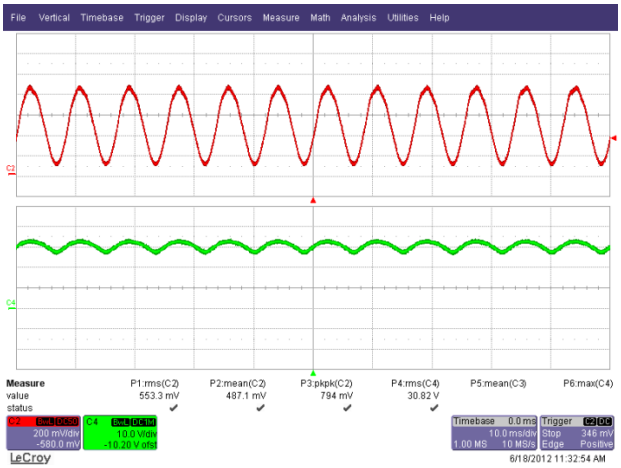

Figure 31 – 132 VAC, 60 Hz Full Load.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{OUT}, 10 V, 10 ms / div.

12.3 輸出電流/電壓上升及下降

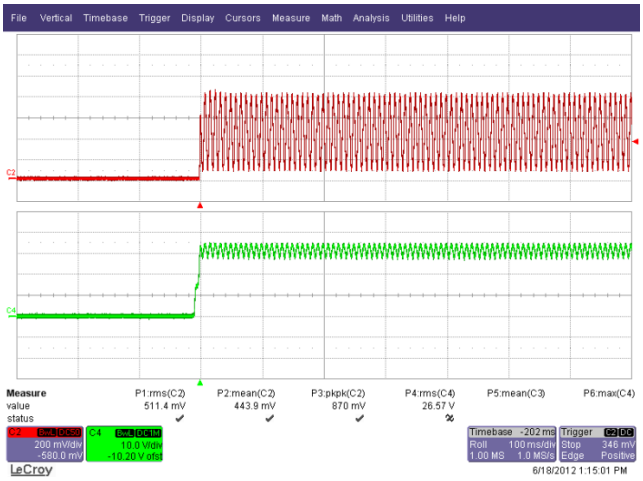

Figure 32 –90 VAC Output Rise.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{OUT}, 10 V, 100 ms / div.

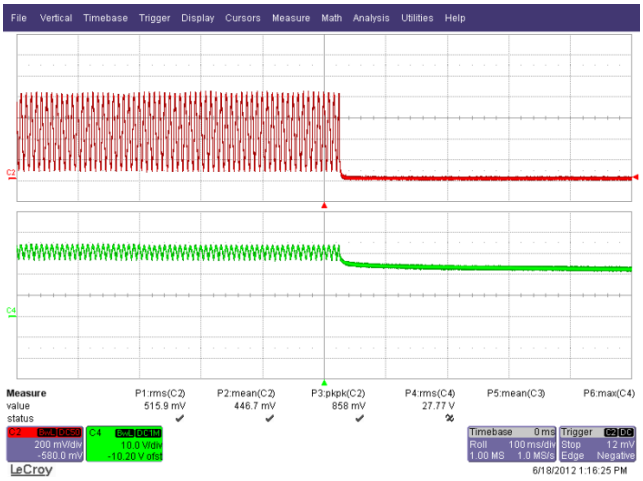

Figure 33 – 90 VAC Output Fall.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{OUT}, 10 V, 100 ms / div.

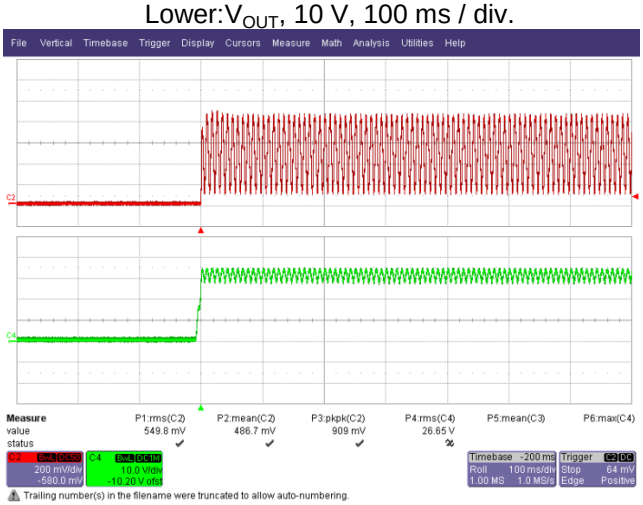

Figure 34 – 132 VAC Output Rise.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{OUT}, 10 V, 100 ms / div.

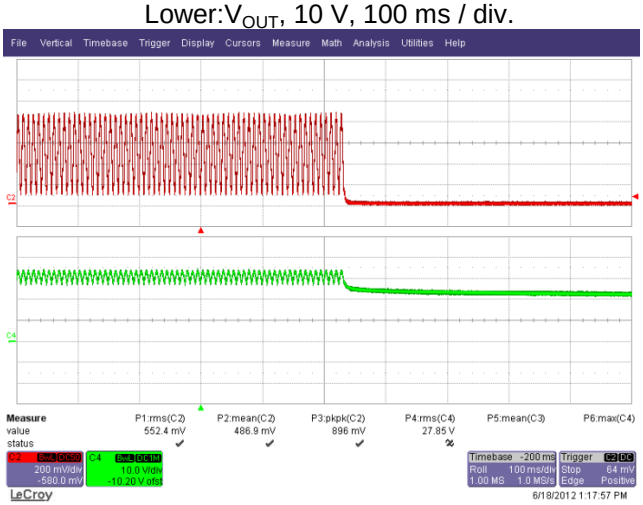

Figure 35 – 132 VAC Output Fall.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{OUT}, 10 V, 100 ms / div.

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12.4 啓動時的輸入電壓和輸出電流波形

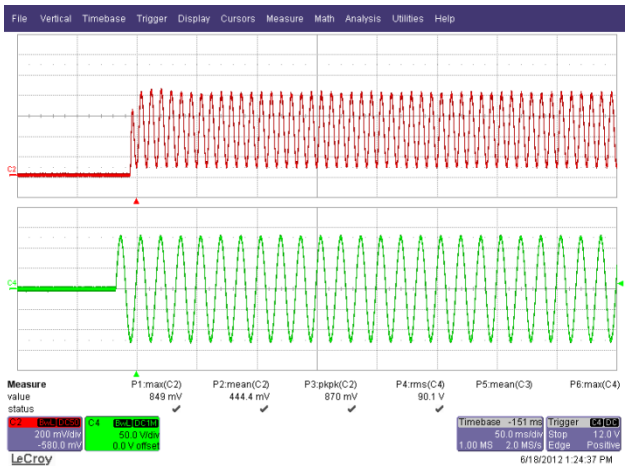

Figure 36 – 90 VAC, 60 Hz.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{IN}, 50 V, 50 ms / div.

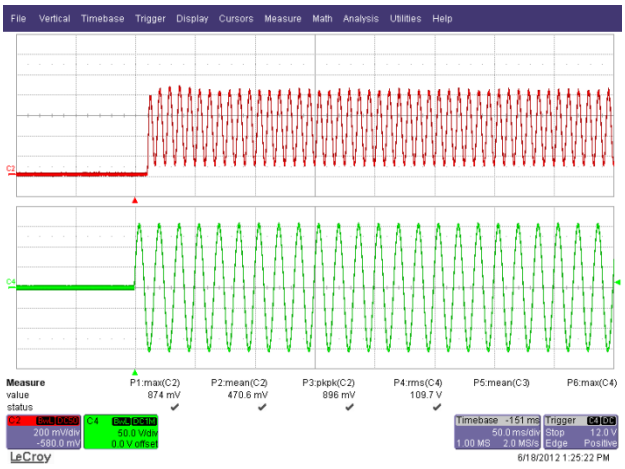

Figure 37 – 110 VAC, 60 Hz.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{IN}, 50 V, 50 ms / div.

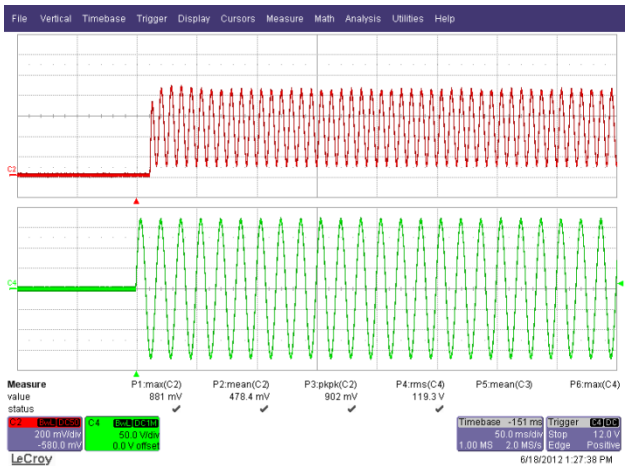

Figure 38 – 120 VAC, 60 Hz.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{IN}, 50 V, 50 ms / div.

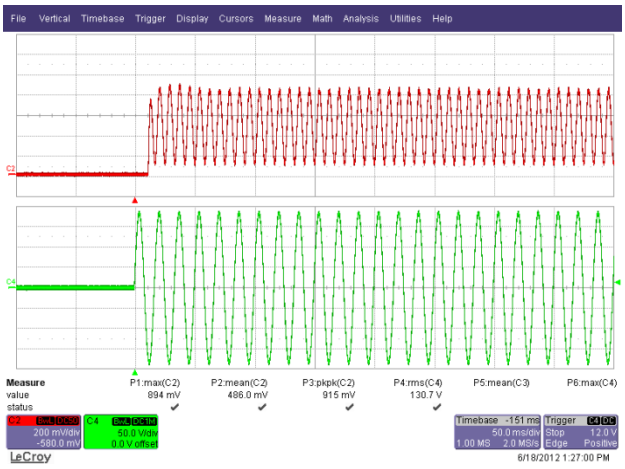

Figure 39 – 132 VAC, 60 Hz.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{IN}, 50 V, 50 ms / div.

12.5 正常運作下的汲極電壓和汲極電流

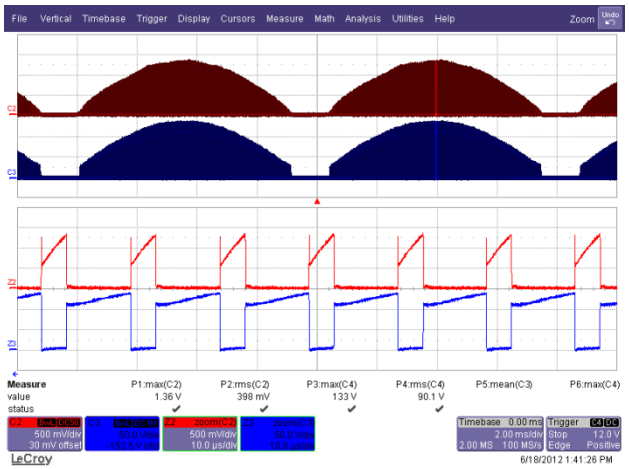

Figure 40 – 90 VAC, 60 Hz.
C2:I_{DRAIN}, 0.5 A, 2 ms / div.
C3:V_{DRAIN}, 50 V, 2 ms / div.
Z2:I_{DRAIN}, 0.5 A, 10 µs / div.
Z3:V_{DRAIN}, 50 V, 10 µs / div.

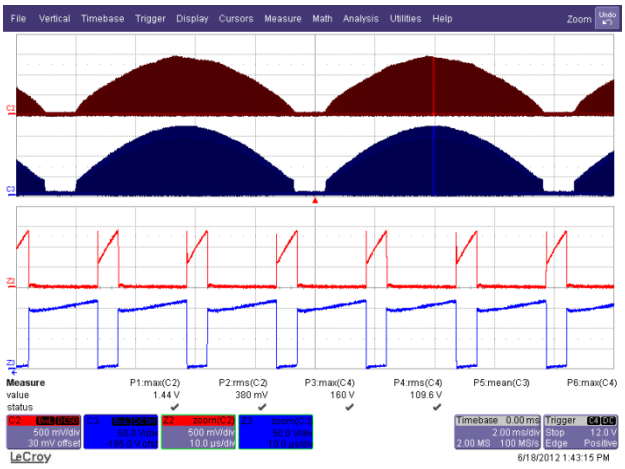

Figure 41 – 110 VAC, 60 Hz.
C2:I_{DRAIN}, 0.5 A, 2 ms / div.
C3:V_{DRAIN}, 50 V, 2 ms / div.
Z2:I_{DRAIN}, 0.5 A, 10 µs / div.
Z3:V_{DRAIN}, 50 V, 10 µs / div.

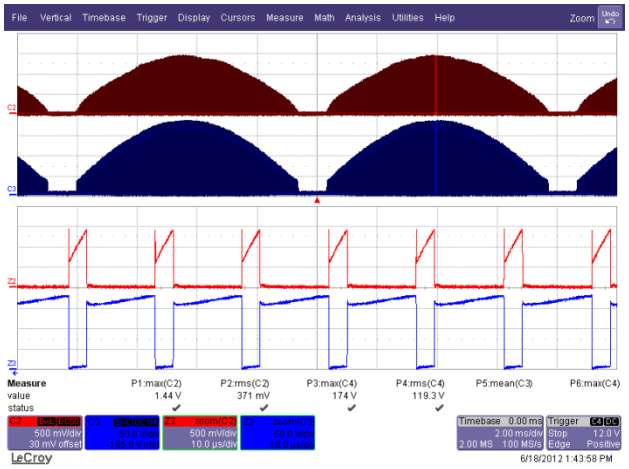

Figure 42 – 120 VAC, 60 Hz.
C2:I_{DRAIN}, 0.5 A, 2 ms / div.
C3:V_{DRAIN}, 50 V, 2 ms / div.
Z2:I_{DRAIN}, 0.5 A, 10 µs / div.
Z3:V_{DRAIN}, 50 V, 10 µs / div.

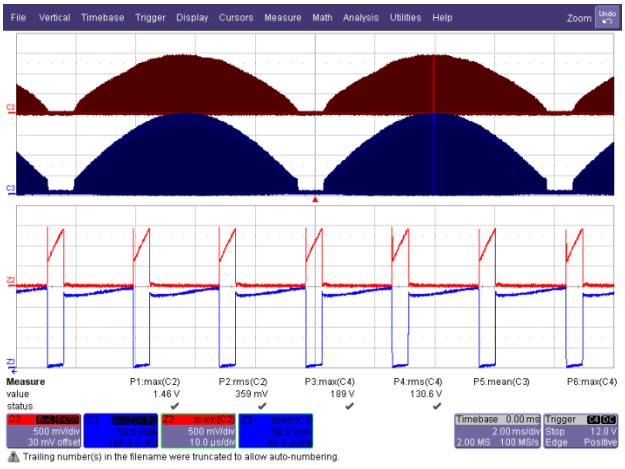

Figure 43 – 132 VAC, 60 Hz.
C2:I_{DRAIN}, 0.5 A, 2 ms / div.
C3:V_{DRAIN}, 50 V, 2 ms / div.
Z2:I_{DRAIN}, 0.5 A, 10 µs / div.
Z3:V_{DRAIN}, 50 V, 10 µs / div.

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12.6 啓動汲極電壓和電流

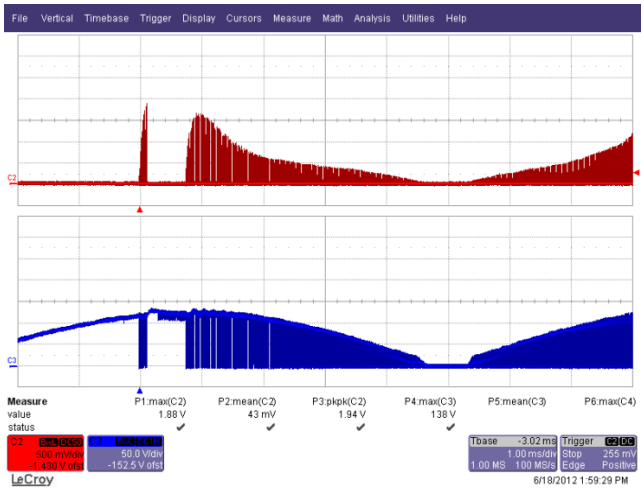

Figure 44 – 90 VAC, 60 Hz Start-up
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 50 V, 1 ms / div.

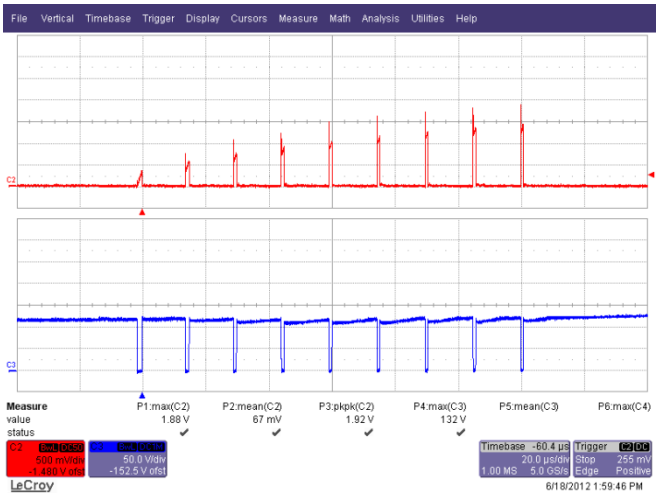

Figure 45 – 90 VAC, 60 Hz Start-up
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 50 V, 20 µs / div.

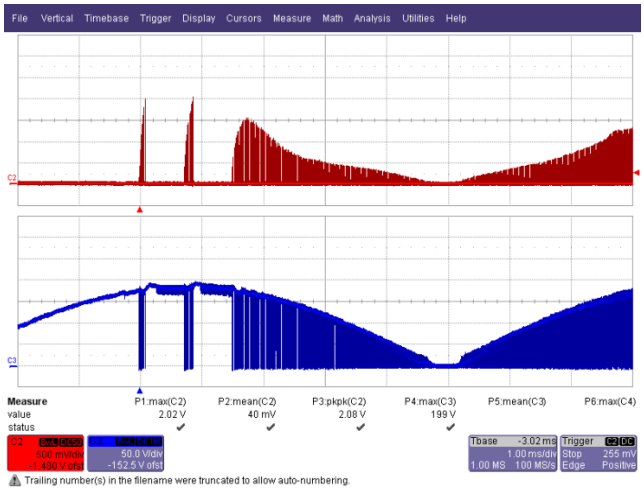

Figure 46 – 132 VAC, 60 Hz Start-up
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 50 V, 1 ms / div.

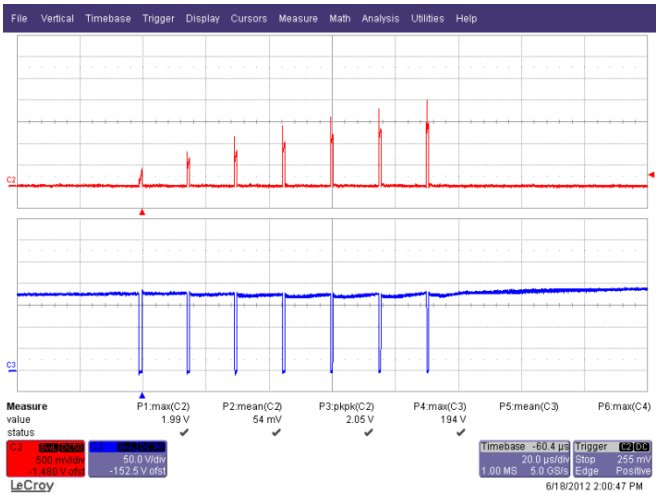

Figure 47 – 132 VAC, 60 Hz Start-up
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 50 V, 20 µs / div.

12.7 輸出短路時的汲極電流和汲極電壓

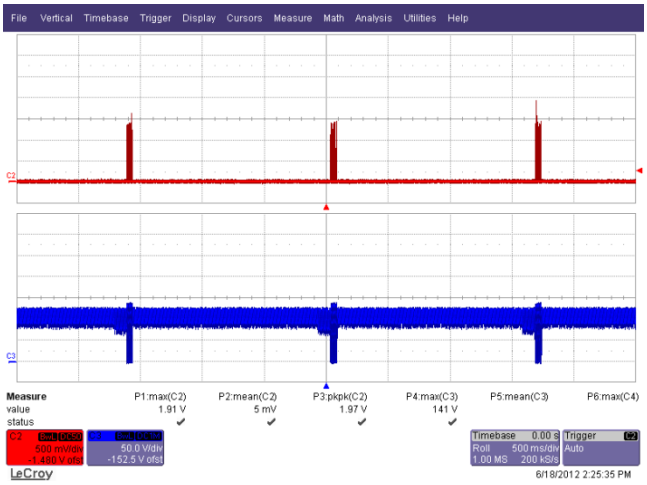

Figure 48 – 90 VAC, 60 Hz Output Short Condition.
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 50 V, 500 ms / div.

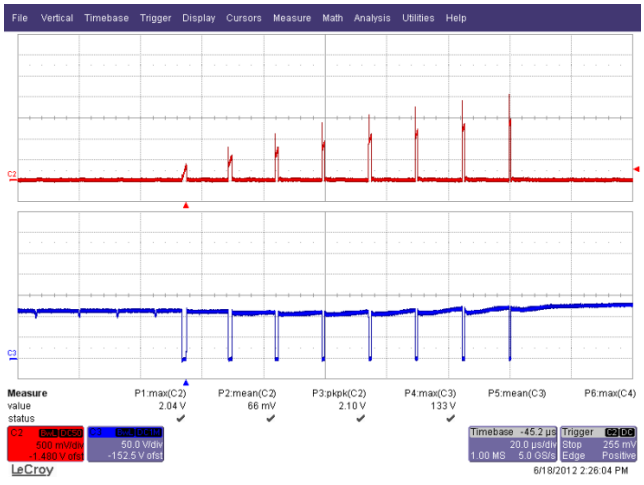

Figure 49 – 90 VAC, 60 Hz Output Short Condition.
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 50 V, 20 µs / div.

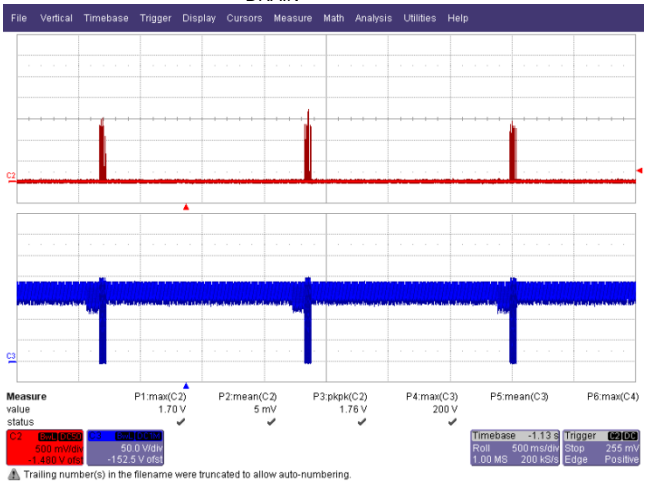

Figure 50 – 132 VAC, 60 Hz Output Short Condition.
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 50 V, 500 ms / div.

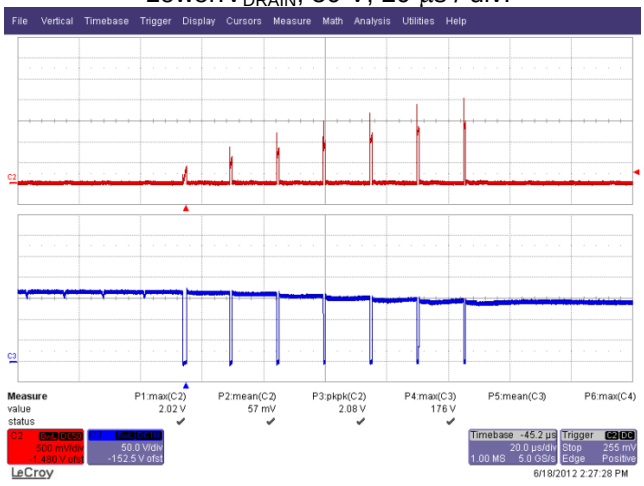

Figure 51 – 132 VAC, 60 Hz Output Short Condition.
Upper:I_{DRAIN}, 500 mA / div.
Lower:V_{DRAIN}, 50 V, 20 µs / div.

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13 調光波形

13.1 輸入電壓和輸入電流波形

Input:120 VAC, 60 Hz
Output:30 V LED Load
Dimmer:LUTRON LG-600PH-WH

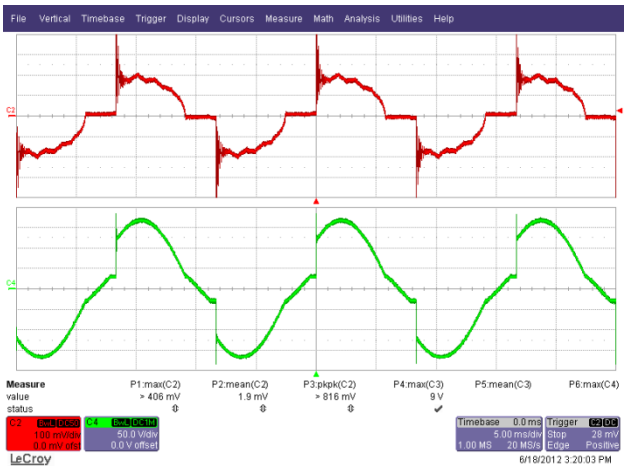

Figure 52 – 125º Conduction Angle.
Upper:I_{IN}, 100 mA / div.
Lower:V_{IN}, 50 V, 5 ms / div.

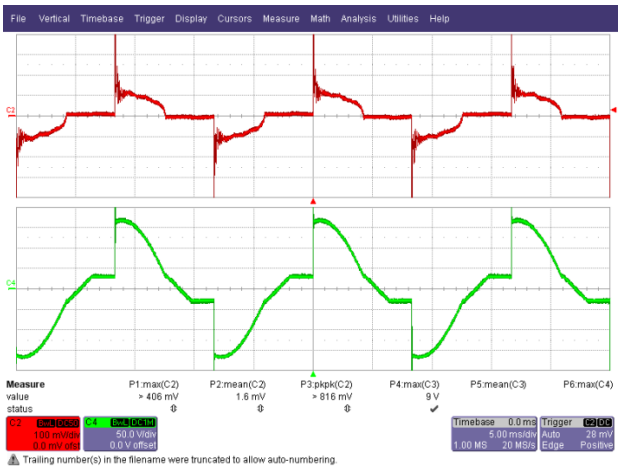

Figure 53 – 92º Conduction Angle.
Upper:I_{IN}, 100 mA / div.
Lower:V_{IN}, 50 V, 5 ms / div.

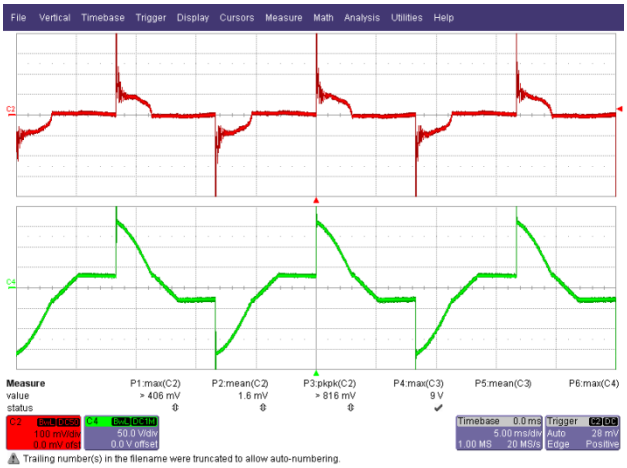

Figure 54 – 65º Conduction Angle.
Upper:I_{IN}, 100 mA / div.
Lower:V_{IN}, 50 V, 5 ms / div.

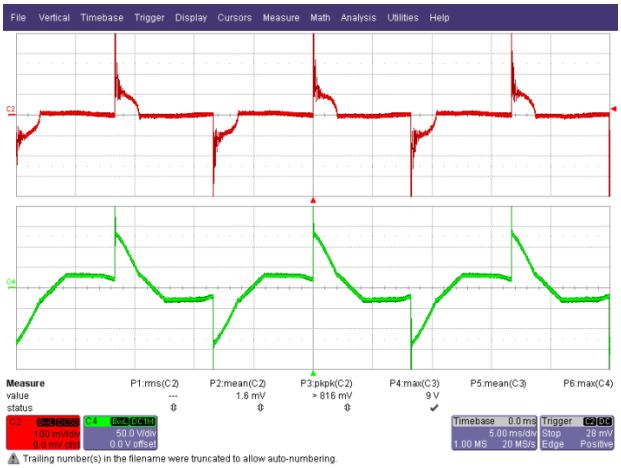

Figure 55 – 45º Conduction Angle.
Upper:I_{IN}, 100 mA / div.
Lower:V_{IN}, 50 V, 5 ms / div.

13.2 輸出電流波形

Input:120 VAC, 60 Hz
Output:30 V LED Load
Dimmer:LUTRON LG-600PH-WH

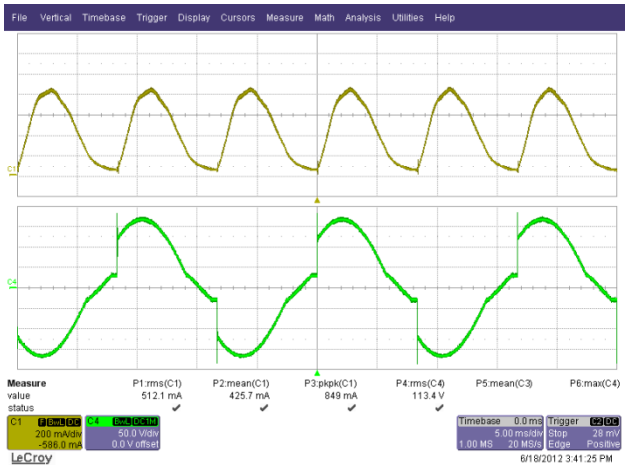

Figure 56 – 125º Conduction Angle.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{IN}, 50 V, 5 ms / div.

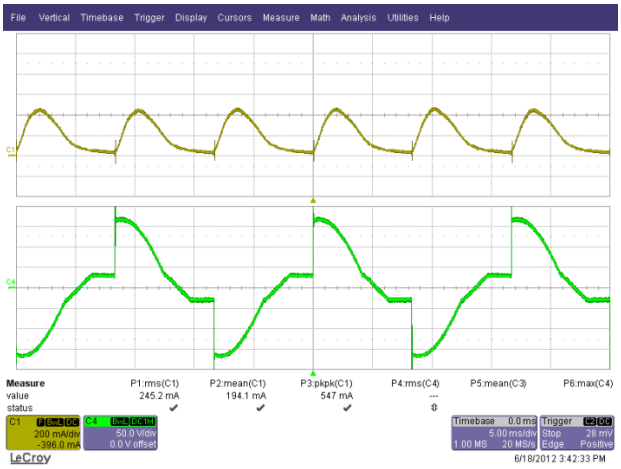

Figure 57 – 92º Conduction Angle.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{IN}, 50 V, 5 ms / div.

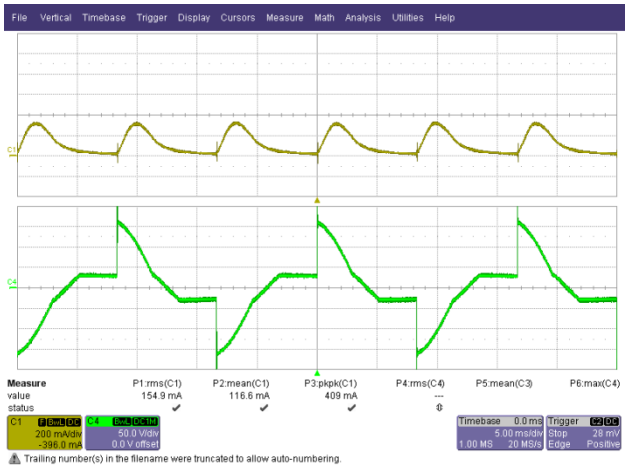

Figure 58 – 65º Conduction Angle.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{IN}, 50 V, 5 ms / div.

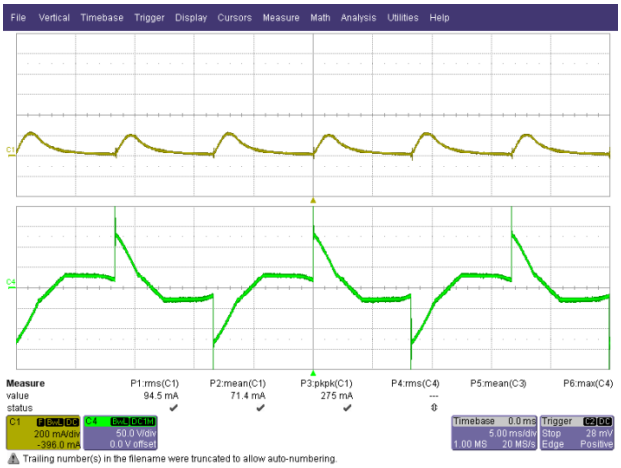

Figure 59 – 45º Conduction Angle.
Upper:I_{OUT}, 200 mA / div.
Lower:V_{IN}, 50 V, 5 ms / div.

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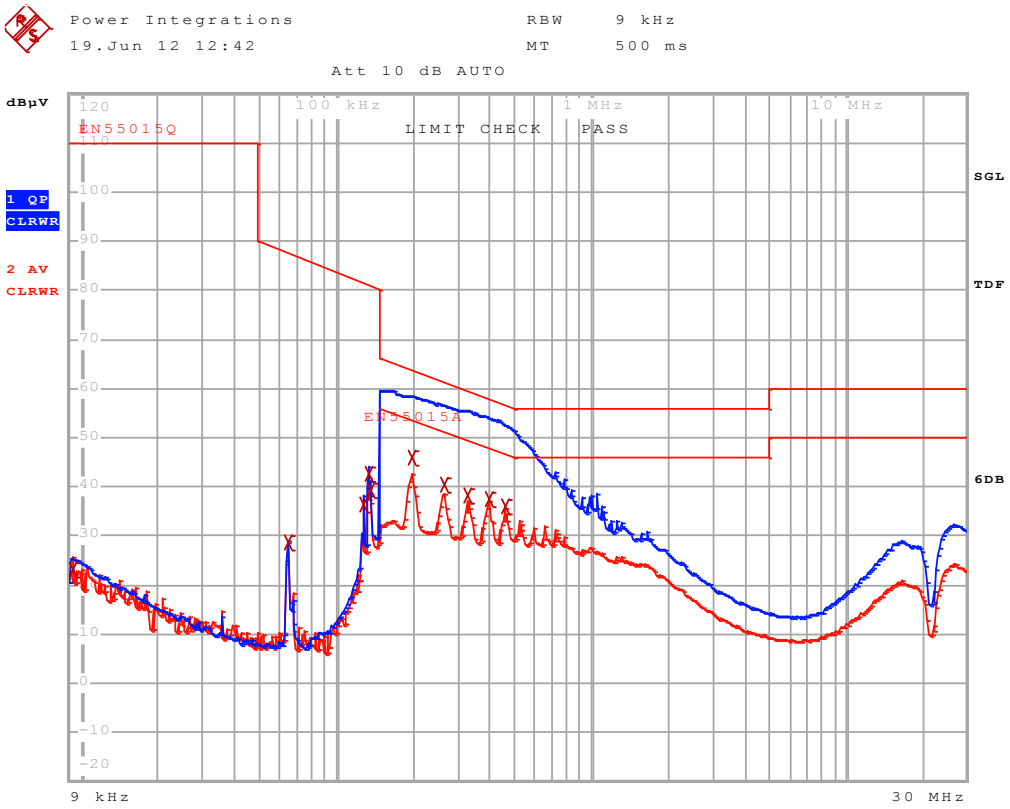
14 傳導性 EMI

14.1 測試裝置

The unit was tested using LED load (~30 V V_{OUT}) with input voltage of 115 VAC, 60 Hz at room temperature.

Figure 60 – EMI Test Set-up with the Unit and LED Load Placed Inside the Cone.

14.2 測試結果



EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	9.272709 kHz	23.09	N gnd	
2	Average	64.5467705779 kHz	28.77	L1 gnd	
2	Average	126.977840157 kHz	36.54	N gnd	
2	Average	133.454986145 kHz	42.75	N gnd	
2	Average	136.137431366 kHz	39.51	N gnd	
2	Average	198.193645035 kHz	45.85	N gnd	-7.82
2	Average	264.49018761 kHz	40.32	N gnd	-10.96
2	Average	329.215131266 kHz	38.16	N gnd	-11.30
2	Average	397.727746704 kHz	37.62	N gnd	-10.27
2	Average	461.749566613 kHz	36.08	N gnd	-10.57

Figure 61 – Conducted EMI, 30 V LED Load, 115 VAC, 60 Hz, and EN55015 B Limits.

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15 電壓突波

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

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+2500	120	L1, L2	0	100kHz Ring Wave (200 A)	Pass
-2500	120	L1, L2	0	100kHz Ring Wave (200 A)	Pass
+2500	120	L1, L2	90	100kHz Ring Wave (200 A)	Pass
-2500	120	L1, L2	90	100kHz Ring Wave (200 A)	Pass

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

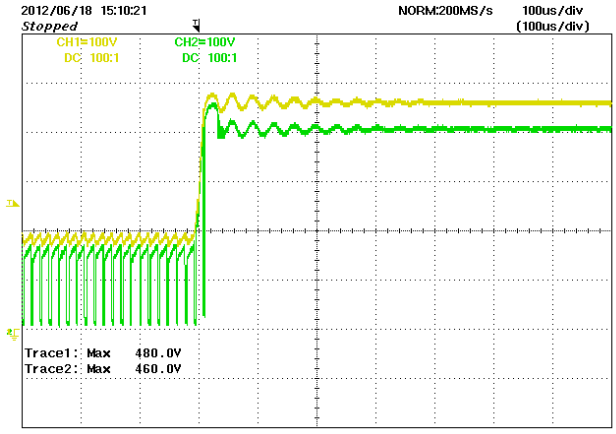

Figure 62 – +500 V (90º Injection Phase) Differential Surge VDS Waveforms.
C1: Input Rectified Voltage (Voltage Across C2)
C2: U1 Drain Voltage Reference to Source.

16 40 V / 350 mA 輸出設計附錄

16.1 電源供應器規格

The table below represents the minimum acceptable performance of the design.Actual performance is listed in the results section.Compliance characteristic is same as the original version.

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90	120	132	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	63	Hz	
Output						
Output Voltage	V_{OUT}	39	40	41	V	
Output Current	I_{OUT}		350		mA	At 115 VAC
Total Output Power						
Continuous Output Power	P_{OUT}		14.0		W	
Efficiency						
Nominal	η	87	90		%	Measured at P_{OUT} 25 °C at 115 VAC
Power Factor		0.9	0.98			At 115 VAC
A-THD				15	%	At 115 VAC
Harmonic Currents		EN 61000-3-2 Class C				Class C Limits

Note:

Refer to the schematic section 3 for the component updates for 40 V / 350 mA version.

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16.2 電感器規格 (40 V / 350 mA)

16.2.1 電氣圖

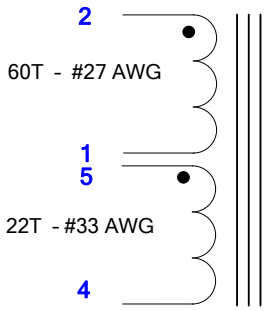

Figure 63 – Inductor Electrical Diagram.

16.2.2 電氣規格

Primary Inductance	Pins 1-2 all other windings open, measured at 66 kHz, 0.4 $V_{RMS.}$	620 µH ±7%
Resonant Frequency	Pins 1-2, all other windings open.	1.8 MHz (Min.)

16.2.3 物料

Item	Description
[1]	Core:RM6S PC40 or equivalent.
[2]	Bobbin:B-RM6-V 6pins 3/3.
[3]	Magnet Wire, #27 AWG, solderable double coated.
[4]	Magnet Wire, #33 AWG, solderable double coated.

16.2.4 電感器建構圖

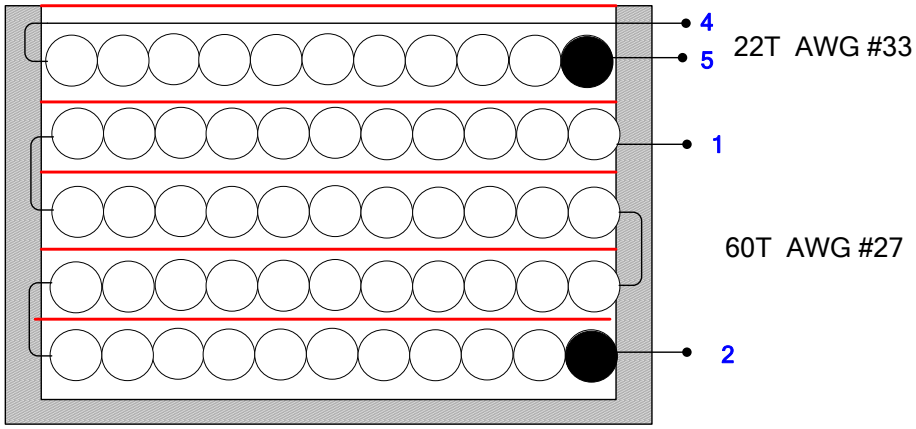

Figure 64 – Inductor Build Diagram.

16.2.5 電感器結構

General Note	For the purpose of these instructions, bobbin is oriented on winder such that pin 1 side is on the right.
WD1	Start at pin 2. Wind 60 turns of item [3] as shown in Figure 2. Terminate at pin 1.
WD2	Start at pin 5. Wind 22 turns of item [4] and terminate the other end at pin 4.
Finish	Grind the core to get the specified inductance.Place the clip to secure both cores.Cut pins 3 and 6.

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16.3 效能資料

All measurements performed at room temperature using an LED load.The following data were measured using 3 sets of loads to represent the load range of 38 V to 42 V output voltage.

16.4 調光器相容性清單

The unit was tested with the following U.S. dimmers at 120 VAC, 60 Hz (supplied from programmable AC source) input and 40 V LED load.

List of Dimmers	Type	Remarks	Power	Part Number	I_{MIN} (mA)	I_{MAX} (mA)	Dim Ratio
LUTRON LG600PH-LA	L	17 Lutron 600-Watt Slide Dimmer LG-600PH-LA	600W	LG-600PH-WH	26	283	11
LUTRON S603P	L	Lutron Skylark Incandescent 600W 3-Way Preset Dimmer with On/Off	600W	S-603P-WH	23	291	13
LUTRON SLV600P	T	Lutron SLV-600P-WH 600-Watt Skylark Magnetic Low-Voltage Single-Pole Dimmer	600W	SLV600P-WH	35	288	8
LUTRON S600	L	Slide-to-Off Single Pole Skylark Dimmer Switch (RFI suppression)	600W	S-600-WH	28	305	11
LUTRON S-600PH-WH	L	18 Lutron Skylark 5-Amp White Gloss Dimmer	600W	S-600PH-WH	25	291	12
LUTRON DVCL153P	L	Cfl&led Dimmer, Paddle/slide, 120V, 600W	600W	DVWCL-153-PLH-WH	38	291	8
LUTRON DV603P	L	600W Diva Dimmer, 3-Way - Ivory	600W	DV-603P-WH	26	282	11
LUTRON DV600P	L	Lutron Diva DV-600P-WH Incand 600 Watt Single Pole Light Dimmer in White	600W	DV-600P-WH	26	282	11
LUTRON TG600PH-IV	L	Ivry Toggle Dimmer 1p Preset	600W	TG-600PH-WH	25	288	12
LUTRON AY600P	T	Lutron Ariadni AY-600P-WH Incand Preset 600 Watt Single Pole Light Dimmer in White	600W	AY-600P-WH	23	284	12
LUTRON GL600P-WH	L	Glyder Incandescent Single Pole 600 Watts Preset Dimmer, White	600W	GL-600P-WH	26	290	11
LEVITON 6633PLI	L	SureSlide 600W Incandescent Dimmer	600W	R62-06633-1LW	26	308	12
LEVITON 6631-LI	L	SureSlide 600W Incandescent Slide Dimmer, Single-Pol	600W	R62-06631-1LW	21	297	14
LEVITON IPI06	L	IllumaTech Incandescent Preset Slide Dimmer	600W	R60-IPI06-1LM	62	307	5
LEVITON RP106	L	IllumaTech Rotary Controls 120V AC 60Hz	600W	R52-RPI06-1LW	28	307	11
LEVITON 6681	L	A Push On and Push Off Dimmer	600W	R60-06681-0IW	25	298	12
LEVITON 6684	L	Leviton 600-Watt 3-Way Lighted White/Ivory Push Dimmer	600W	R60-06684-1IW	26	307	12
LEVITON 6683			600W	6683	40	308	8
LEVITON 6613	L	SURESLIDE" MAGNETIC LOW VOLTAGE DIMMER *600VA, 120V AC, 60Hz	450W	R02-06613-PLW	26	307	12
COOPER SLC03				SLC03P-W-K-L	39	295	8
LUTRON GL600-WH	L	Lutron 15-Amp White Slide Dimmer	600W	GL-600-WH	2	303	152
LUTRON DVPDC-203P-WH	L	Diva, Screw Base Compact Fluorescent Dimming with Philips® DIMMABLE Energy Saver CFL, Single Pole/3-Way, 200W, White	200W	DVPDC-203P-WH	98	304	3
LUTRON LX600PL	L	19 Lyneo Lx Single Pole Dimmer 600W	500W	LX-600PL-wh	52	301	6
LUTRON D600P	L	Single Pole - Incandescent - Push On/Off - 600 Watt - White	600W	D-600P-WH	29	288	10
LUTRON CTCL-153PDH			600W		38	292	8
LUTRON S-600P			600W	S-600P	25	291	12
LUTRON TGLV-600P				TGLV-600P	28	292	10
LUTRON TGLV-600PR			450W	TGLV-600PR	31	287	9
LUTRON TT-300NLH-WH	L	Lutron Diva Satin 5-Amp Desert Stone Preset Dimmer	300W	TT-300NLH-WH	31	306	10

LUTRON TT-300H-WH	L	Lutron Credenza 300-Watt White Lamp Dimmer	300W	TT-300H-WH	25	306	12
Lutron		S-600P			24	288	12
Lutron		S-600P			26	303	12
Cooper		S106P			288	297	1
Lutron		S-103P-WH			57	290	5
Lutron		S1-10P-WH			42	295	7
Lutron		S-600PNLH-WH			25	293	12
Lutron		S-603PNL-WH			28	292	10
Lutron		SLV-603P-WH			26	285	11
Lutron		S-603PGH-WH			27	198	7

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16.4.1 效率

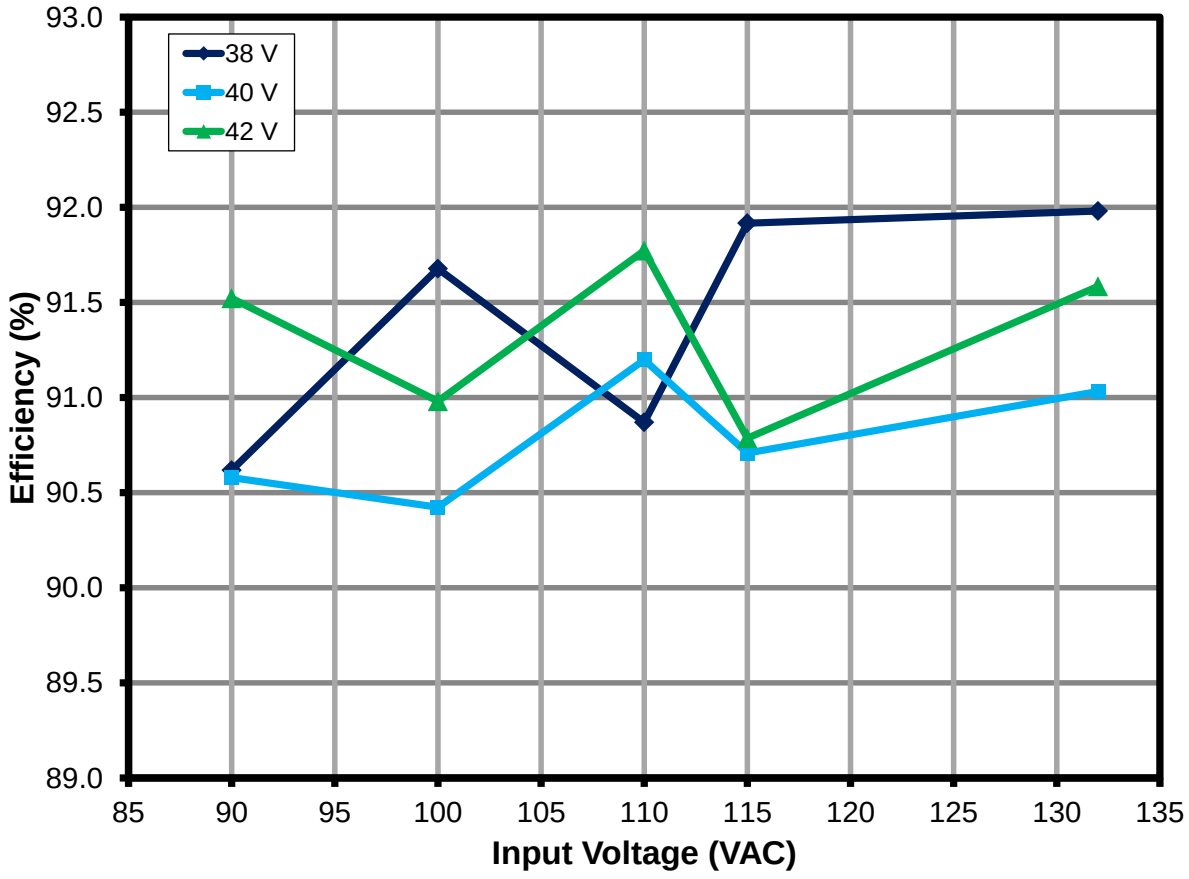

Figure 65 – Efficiency vs. Line and Load.40 V / 350 mA.

16.4.2 線電壓與負載穩定度關係圖

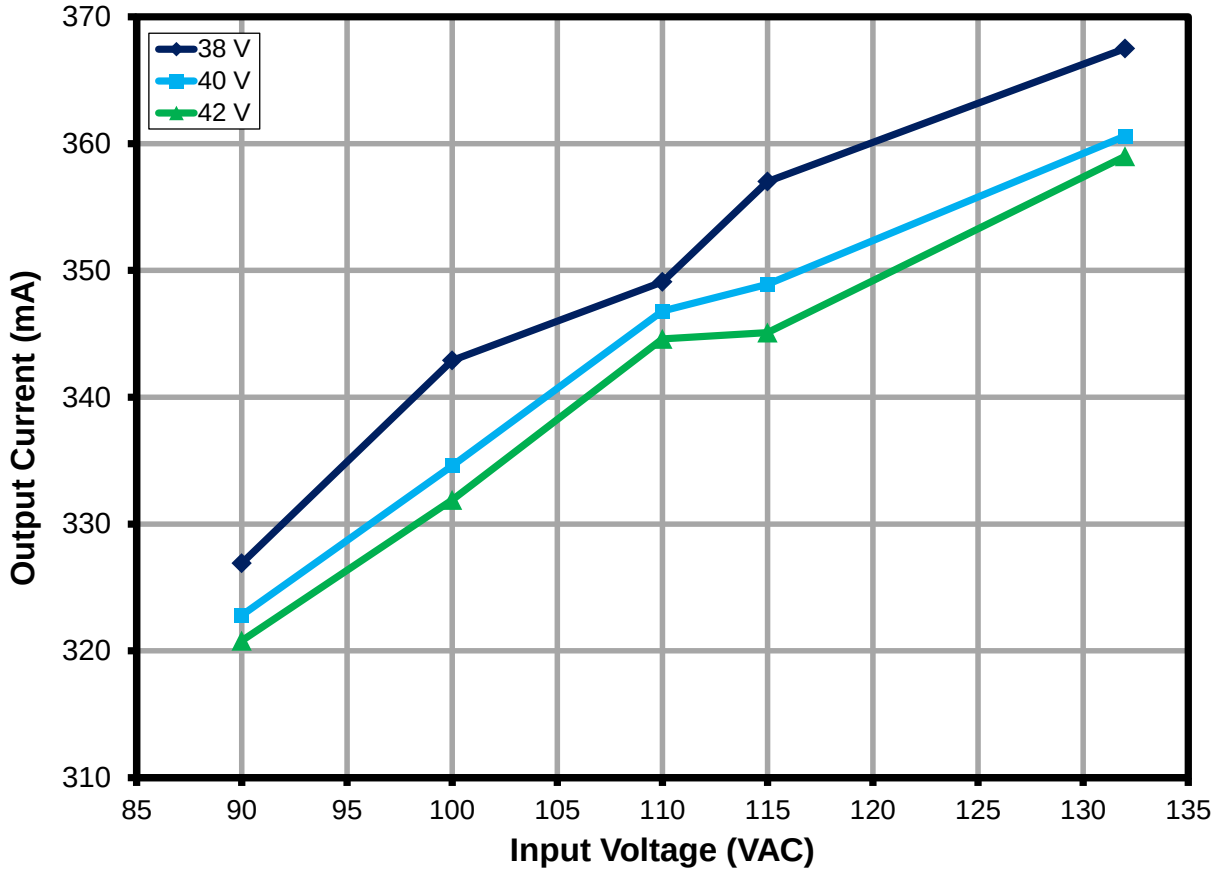

Figure 66 – Regulation vs. Line and Load.

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16.4.3 功率因數

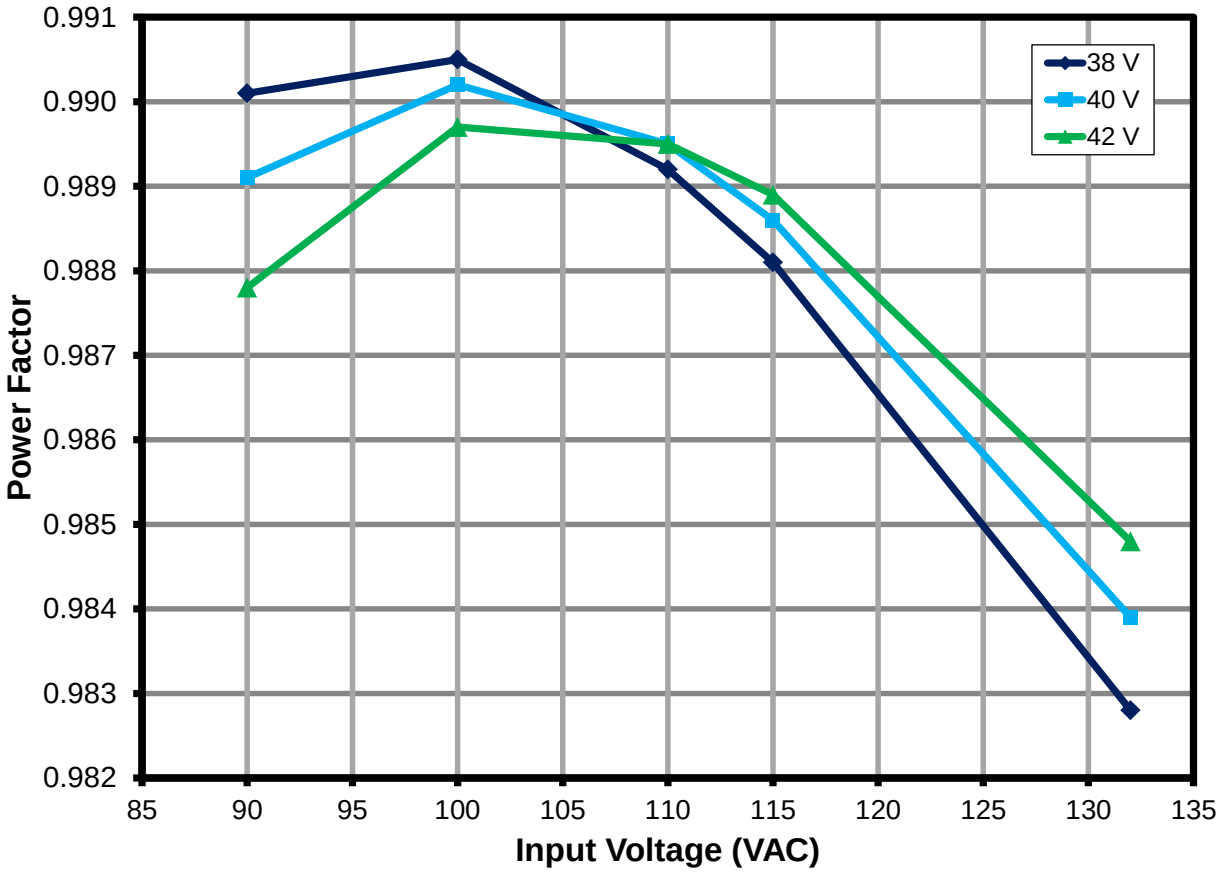

Figure 67 – Power Factor vs. Line and Load.

16.4.4A-THD

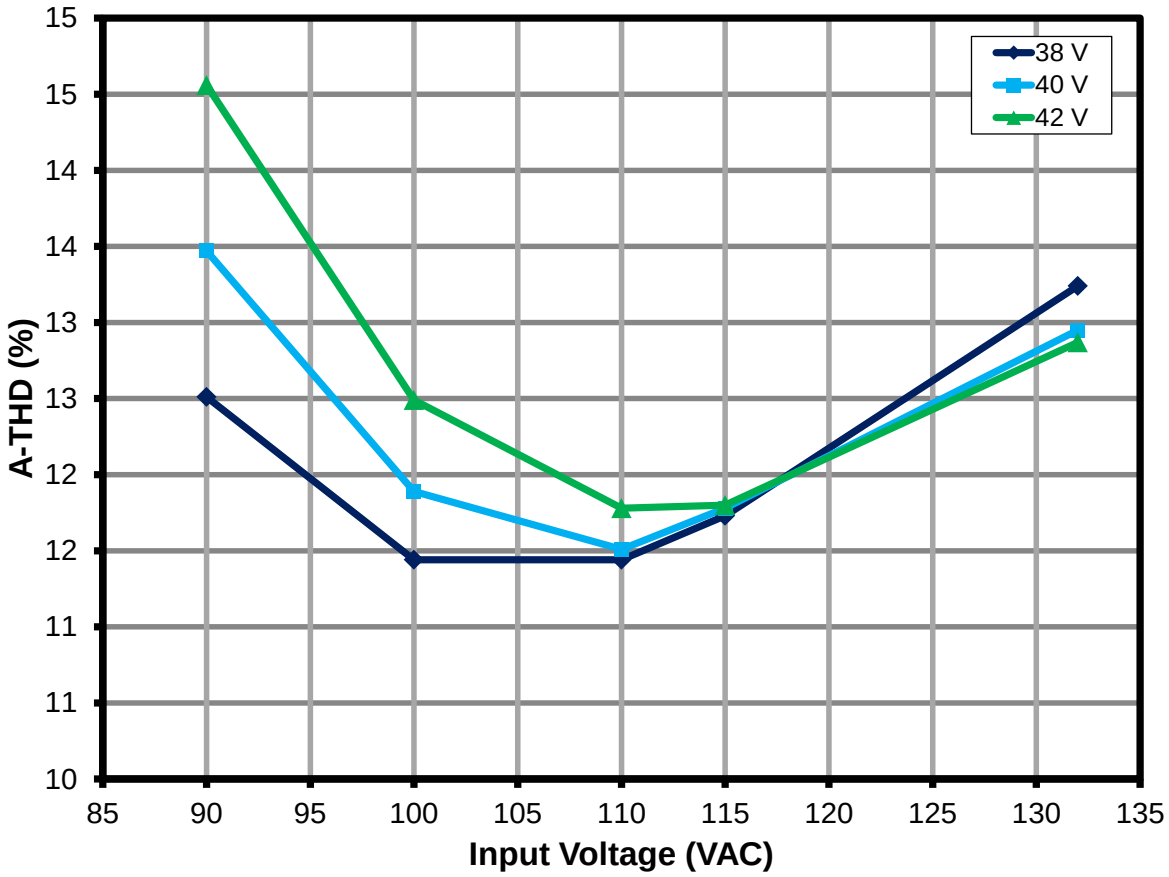

Figure 68 – A-THD vs. Line and Load.

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16.4.540 V 諧波

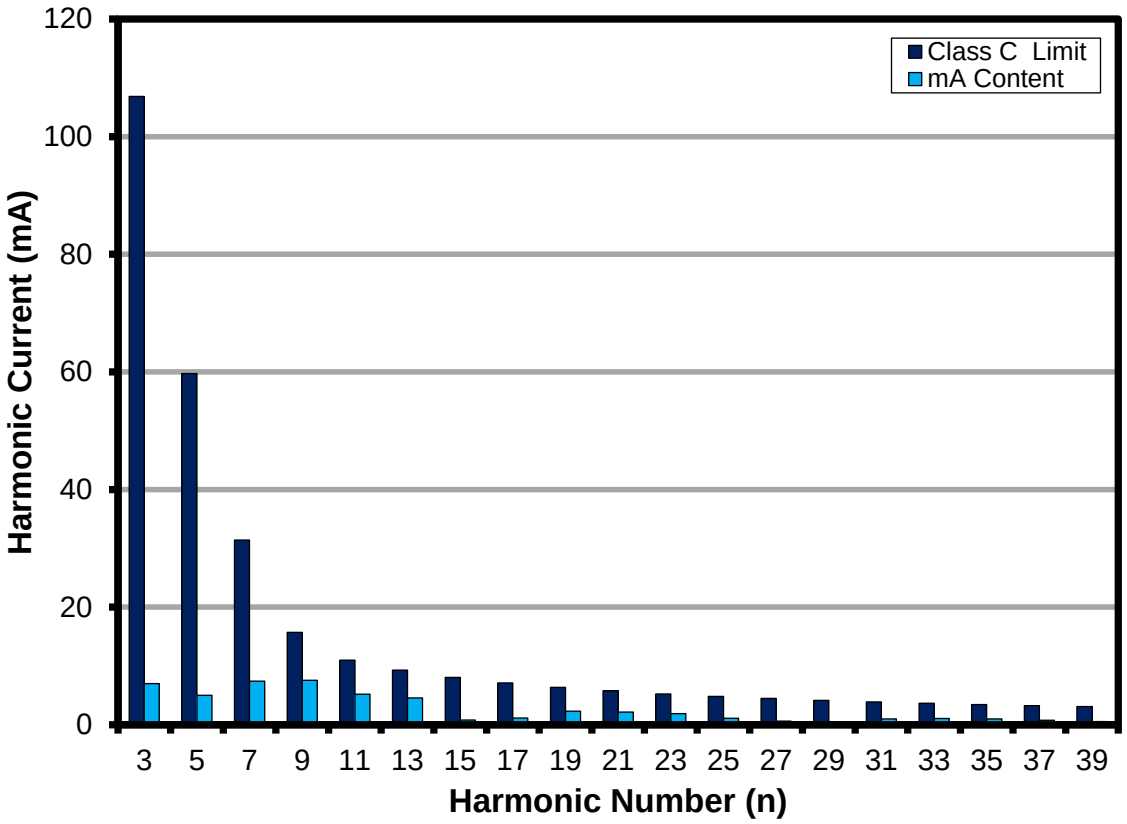
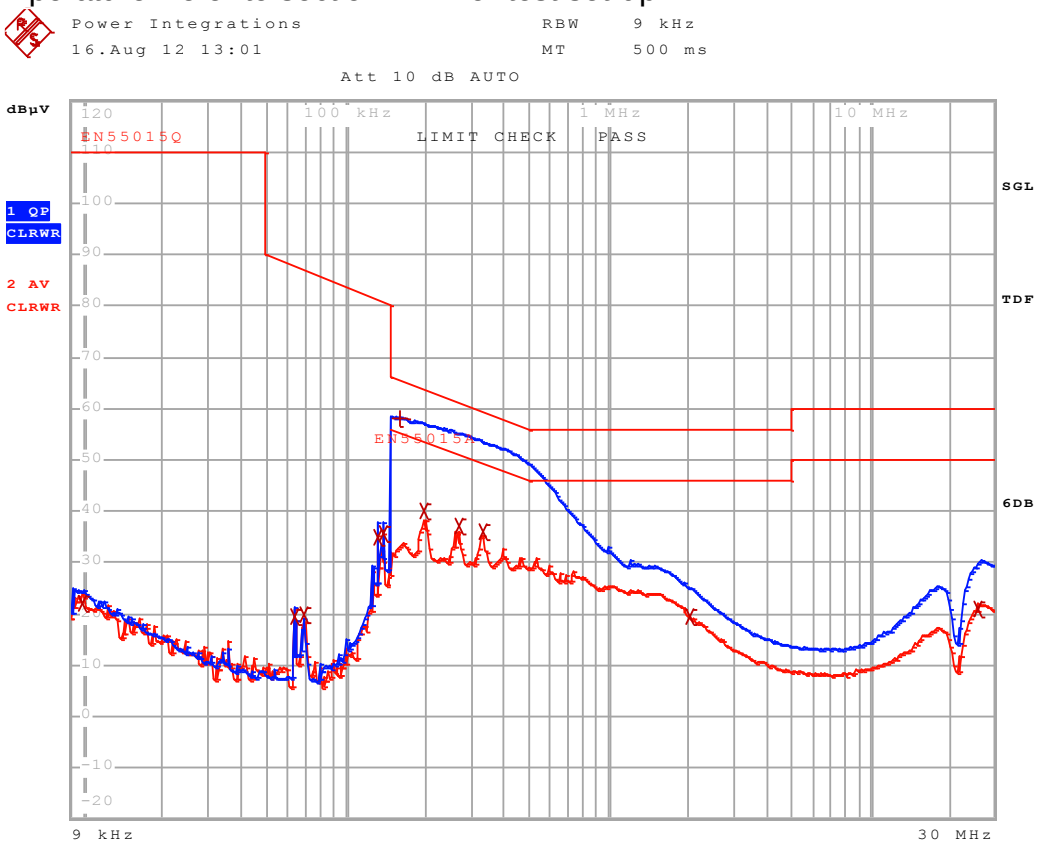


Figure 69 – 40 V / 350 mA LED Load Input Current Harmonics at 115 VAC, 60 Hz.

16.4.6 傳導性 EMI 測試結果

The unit was tested using LED load (~40 V V_{OUT}) with input voltage of 115 VAC, 60 Hz at room temperature.Refer to section 14.1 for test set-up.



EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV			DELTA LIMIT dB
2	Average	9.84316745416 kHz	22.15	L1	gnd	
2	Average	63.9076936414 kHz	19.47	N	gnd	
2	Average	69.2028746009 kHz	19.74	L1	gnd	
2	Average	130.825395691 kHz	35.05	N	gnd	
2	Average	137.49880568 kHz	35.69	N	gnd	
1	Quasi Peak	159.22802259 kHz	58.24	N	gnd	-7.25
2	Average	198.193645035 kHz	40.22	N	gnd	-13.46
2	Average	267.135089486 kHz	37.13	N	gnd	-14.06
2	Average	332.507282579 kHz	35.99	N	gnd	-13.39
2	Average	2.05405734435 MHz	19.34	L1	gnd	-26.65
2	Average	25.4636191981 MHz	20.92	L1	gnd	-29.07

Figure 70 – Conducted EMI, 40 V/350mA LED Load, 115 VAC, 60 Hz, and EN55015 B Limits.

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17 修訂記錄

Date	Author	Revision	Description and Changes	Reviewed
17-Aug-12	CA	1.0	Initial Release	Apps & Mktg
14-Sep-12	JDC	2.0	Added simple modification to convert to 40 V / 350 mA version	

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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 1601/1610, Tower 1,
Kerry Everbright City
No. 218 Tianmu Road West,
Shanghai, P.R.C. 200070
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
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