设计范例报告

标题	**使用*LinkSwitch™-PH LNK407EG*设计的*14.5 W*功率因数校正*(>0.98)*、可控硅调光的非隔离降压式*A19 LED*替换灯驱动器**
规格	90 VAC – 132 VAC输入； 30 V_{TYP}，480 mA输出 40 V_{TYP}，350 mA输出
应用	用于A19替换灯的可调光LED驱动器
作者	应用工程部
文档编号	DER-341
日期	2012年9月14日
修订版本	2.0

特色概述

- 单级功率因数校正(PFC)及精确恒流(CC)输出
- 低成本、元件数量少、印刷电路板(PCB)占用面积小
- 极高能效，在115 VAC输入下效率>89%
- 快速启动时间(<100 ms) – 无可见延迟
- 集成的保护及可靠性能
  - 短路保护
  - 更大迟滞的自动恢复热关断可同时保护元件和印刷电路板
  - 在输入电压跌落或缓升期间不会造成损坏
- 在115 VAC下，PF >0.98
- 在115 VAC下，%A-THD <15%
- 满足IEC 2.5 kV振铃波、500 V差模输入浪涌和EN55015传导EMI要求

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重要说明：虽然本电路板的设计满足安全隔离要求，但工程原型尚未获得机构认证。因此，必须使用隔离变压器向原型板提供AC输入，以执行所有测试。

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1 简介

本文档介绍的是一款非隔离、高功率因数(PF)、可控硅调光的LED驱动器。该驱动器可在90 VAC至132 VAC（典型值为60 Hz）的输入电压范围内为LED灯串提供额定电压30 V、额定电流480 A的驱动。该LED驱动器采用了LinkSwitch-PH系列IC中的LNK407EG器件。

所采用的拓扑结构是单级、非隔离、降压式拓扑结构，可满足本设计的高功率因数、良好的电流调整和调光要求。基于LinkSwitch-PH的设计可提供高功率因数(>0.9)，这有助于满足所有国际标准的要求。

本文档包含LED驱动器规格、电路原理图、PCB设计细节、物料清单、变压器规格文件和典型性能特征。

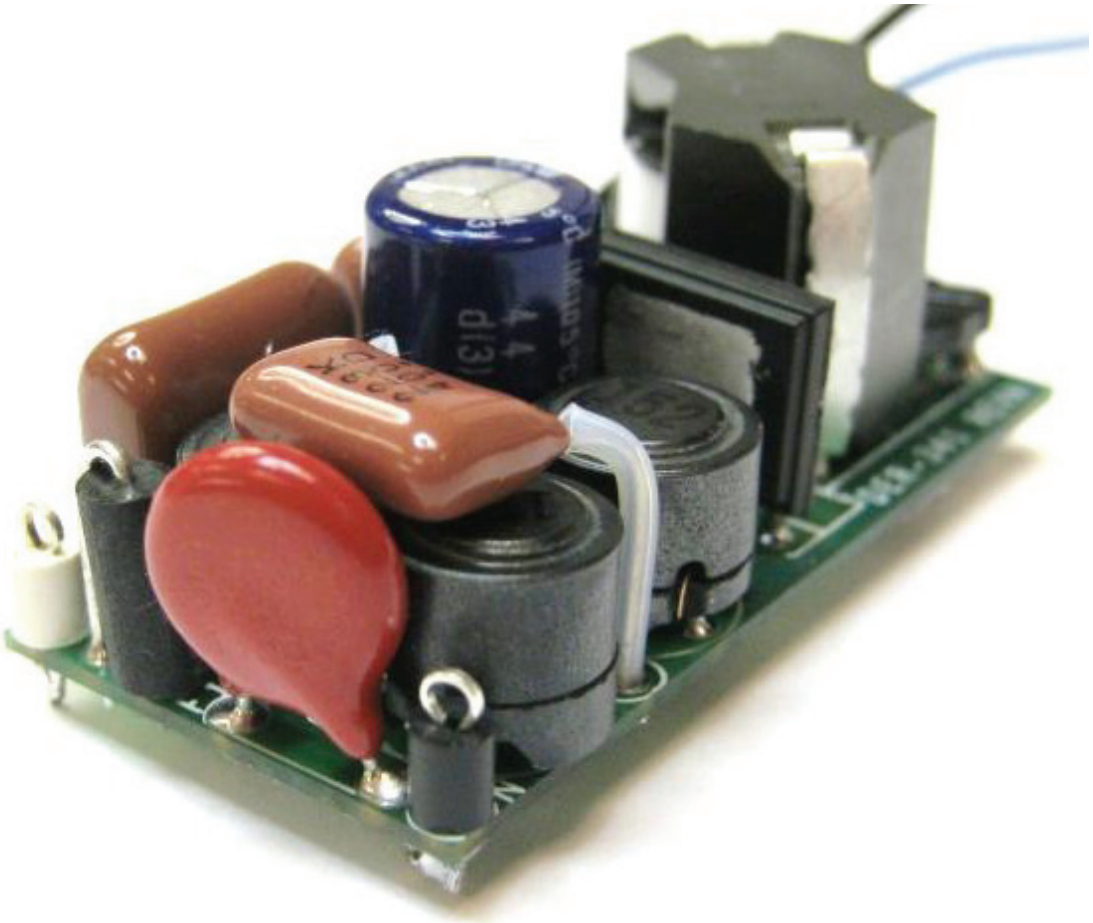

Figure 1 – Populated Circuit Board.

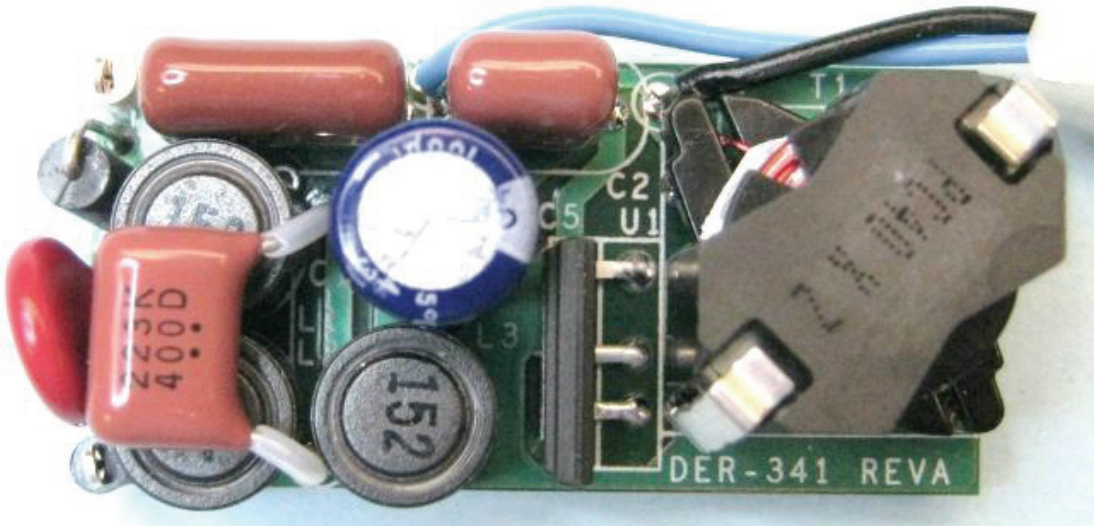

Figure 2 – Populated Circuit Board, Top View.

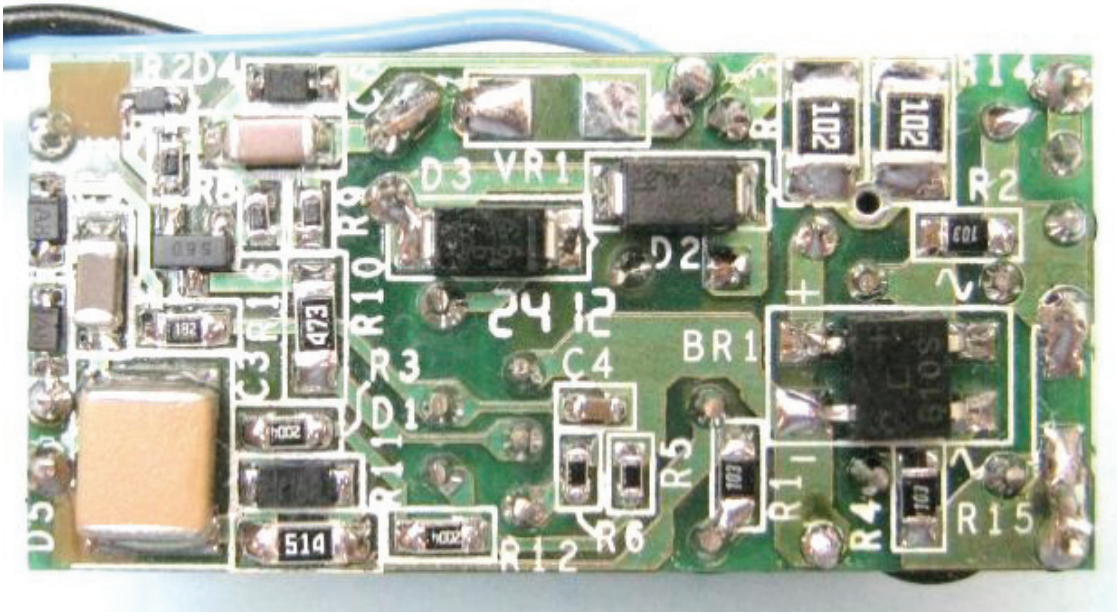

Figure 3 – Populated Circuit Board, Bottom View.

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2 电源规格

下表所列为设计的最低可接受性能。实际性能可参考测量结果部分。

说明	符号	最小值	典型值	最大值	单位	备注
输入						
电压	V_{IN}	90	120	132	VAC	双导线 – 无P.E.
频率	f_{LINE}	47	50/60	63	Hz	
输出						
输出电压	V_{OUT}	29	30	31	V	
输出电流	I_{OUT}		480		mA	在115 VAC下
总输出功率						
连续输出功率	P_{OUT}		14.5		W	
效率						
额定	η	88	89		%	在P_{OUT} 25 °C及115 VAC条件下测得
环境						
传导EMI		满足CISPR22B/EN55015要求				
输入浪涌 差模(L1-L2)			500		V	1.2/50 μs浪涌，IEC 1000-4-5，串联电阻： 差模：2 Ω
振铃波(100 kHz) 差模(L1-L2)			2.5		kV	2 Ω 短路 串联电阻
功率因数		0.9	0.98			在115 VAC下
A-THD				15	%	在115 VAC下
谐波电流		EN 61000-3-2 Class C				Class C限值 （对于P_{IN} >25 W限值）
环境温度	T_{AMB}		40		°C	自然对流，海平面

3 电路原理图

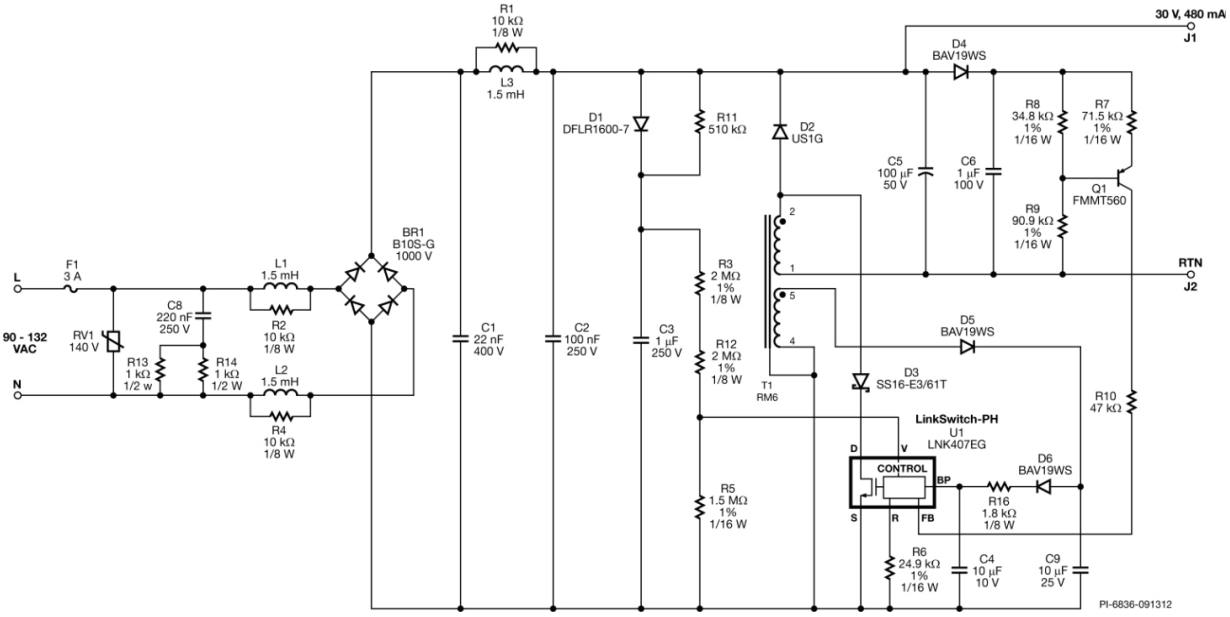

Figure 4 – Schematic Diagram for 30 V / 480 mA.

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%.*

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4 电路描述

LinkSwitch-PH (U1)是一款适用于LED驱动器应用的高集成度初级侧芯片控制器。LinkSwitch-PH能够在单级转换拓扑结构中提供高功率因数，同时对输出电流进行调节。所有提供这些功能的控制电路以及高压功率MOSFET都集成在该器件中。

电容C1和C2、差模扼流圈L1、L2和L3用于执行EMI滤波，同时维持高功率因数。该输入滤波器网络与LinkSwitch-PH的频率调制特性相结合，可使设计满足Class B干扰限值。电阻R1、R2和R4用于抑制电感滤波器的谐振，避免在EMI测量中出现意外峰值。

采用浮动输出连接的降压式功率电路由U1（功率开关 + 控制）、D2（续流二极管）、C5和C7（输出电容）以及T1（输出电感）构成。二极管D3用来防止U1的漏-源极出现负电压，特别是在接近输入电压的过零点时。二极管D1和C3检测峰值AC线电压。C3以及R3、R12和R5上的电压可设置馈入V引脚的电流。U1使用该电流来控制输入欠压(UV)、过压(OV)和前馈电流，前馈电流与反馈(FB)引脚电流共同为LED负载提供恒流。

本设计还采用了与T1耦合的偏置绕组，来为U1的旁路(BP)引脚供电。这样可在可控硅调光器对输入电压严重切角时，使U1在深度调光条件下工作。二极管D5对偏置电压进行整流，电容C9对D5进行滤波。电阻R16可限制提供给旁路引脚的电流，二极管D5在启动期间为C9提供与C4的隔离。

U1用于输出电压反馈的反馈引脚电流由电压-电流转换器网络（由R7、R8、R9、R10、Q1、C6和D4构成）提供。输出电压转换为反馈电流的表达式如下：

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

其中：

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

对R8电压取足够大的值以消除或降低温度和V_{CE}（与Q1的V_{BE}电压相关）的影响。

4.1 可控硅相位调光控制兼容性

对于用低成本的可控硅前沿及后沿相控调光器提供输出调光的要求，我们需要在设计时进行一些权衡。

由于LED照明的功耗非常低，整灯吸收的电流要小于许多应用中可控硅的维持电流。这样会因为可控硅触发不一致而产生某些不良情况，比如调光范围受限和/或闪烁。由于LED灯的阻抗相对较大，因此在可控硅导通时，浪涌电流会对输入电容进行充电，产生很严重的振铃。这种效应会造成类似不良情况，因为振荡会使可控硅电流降至零并关断。

为克服这些问题，我们在电源的输入端添加了由电容C8以及电阻R13和R14构成的无源泄放电路。

4.2 设计注释

驱动器的输出未配备过压保护。
请勿在未连接LED负载的情况下对驱动器上电。

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5 PCB布局

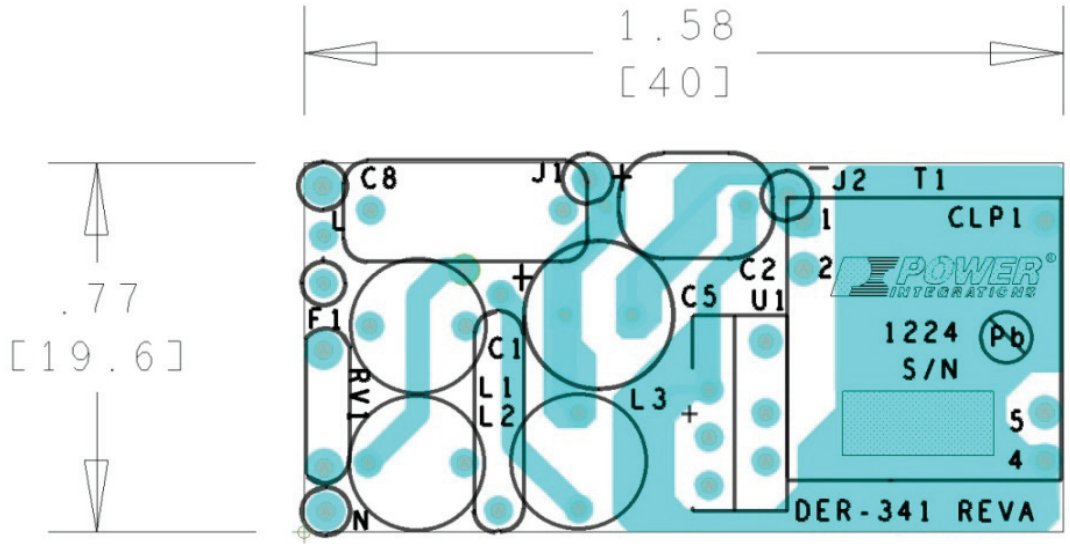

Figure 5 – Top Side.

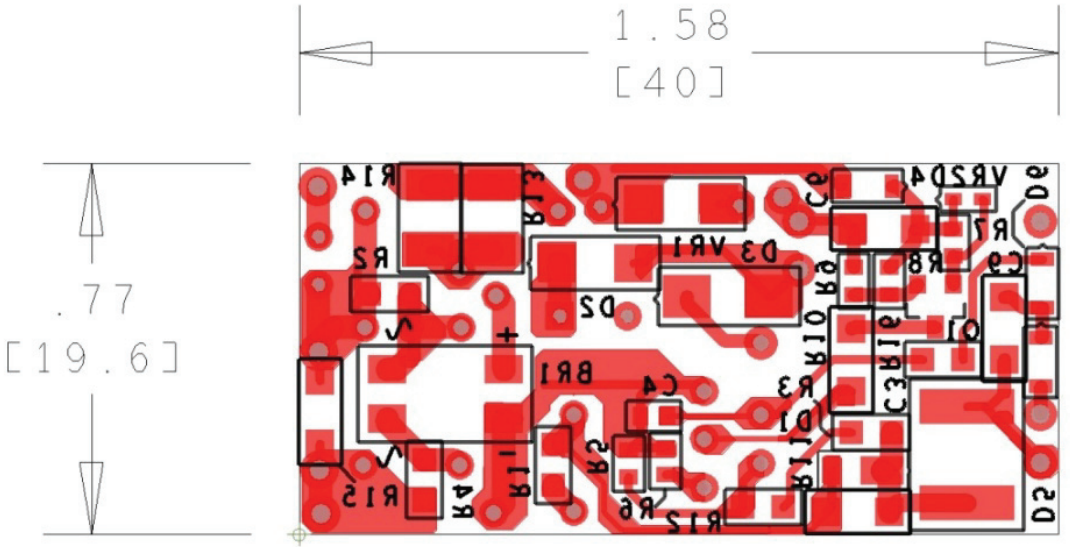

Figure 6 – Bottom Side.

6 物料清单(BOM)

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)	ELXZ500ELL101MH 12D	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

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7 电感规格

7.1 电气原理图

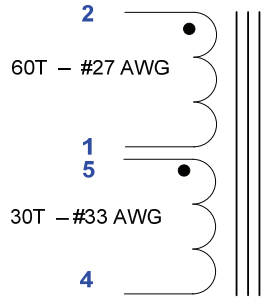

Figure 7 – Inductor Electrical Diagram.

7.2 电气规格

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 材料

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.

7.4 电感结构图

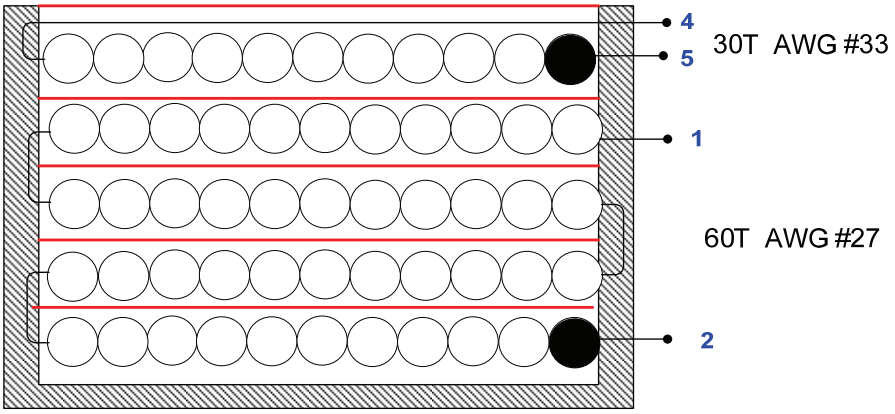

Figure 8 – Inductor Build Diagram.

7.5 电感构造

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.

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8 电感设计表格

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
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)

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9 性能数据

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

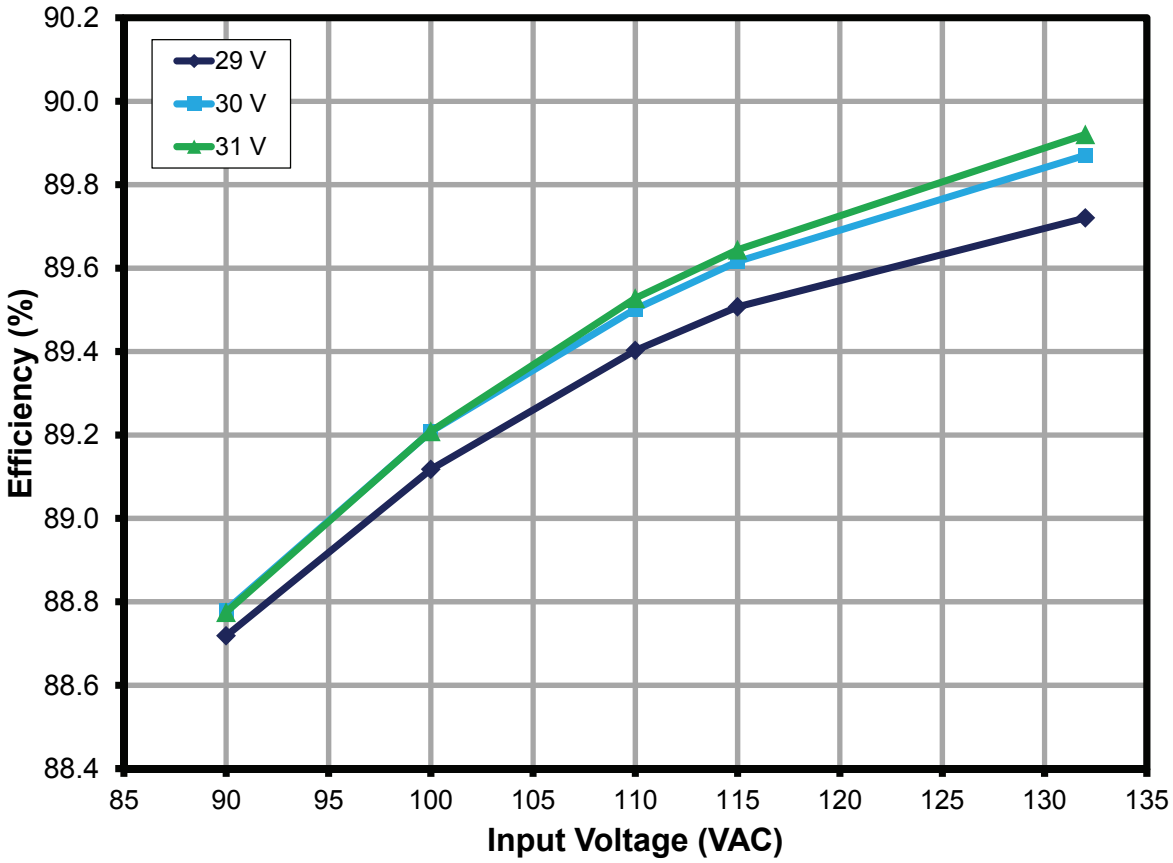

Figure 9 – Efficiency vs. Line and Load.

9.2 输入电压调整率和负载调整率

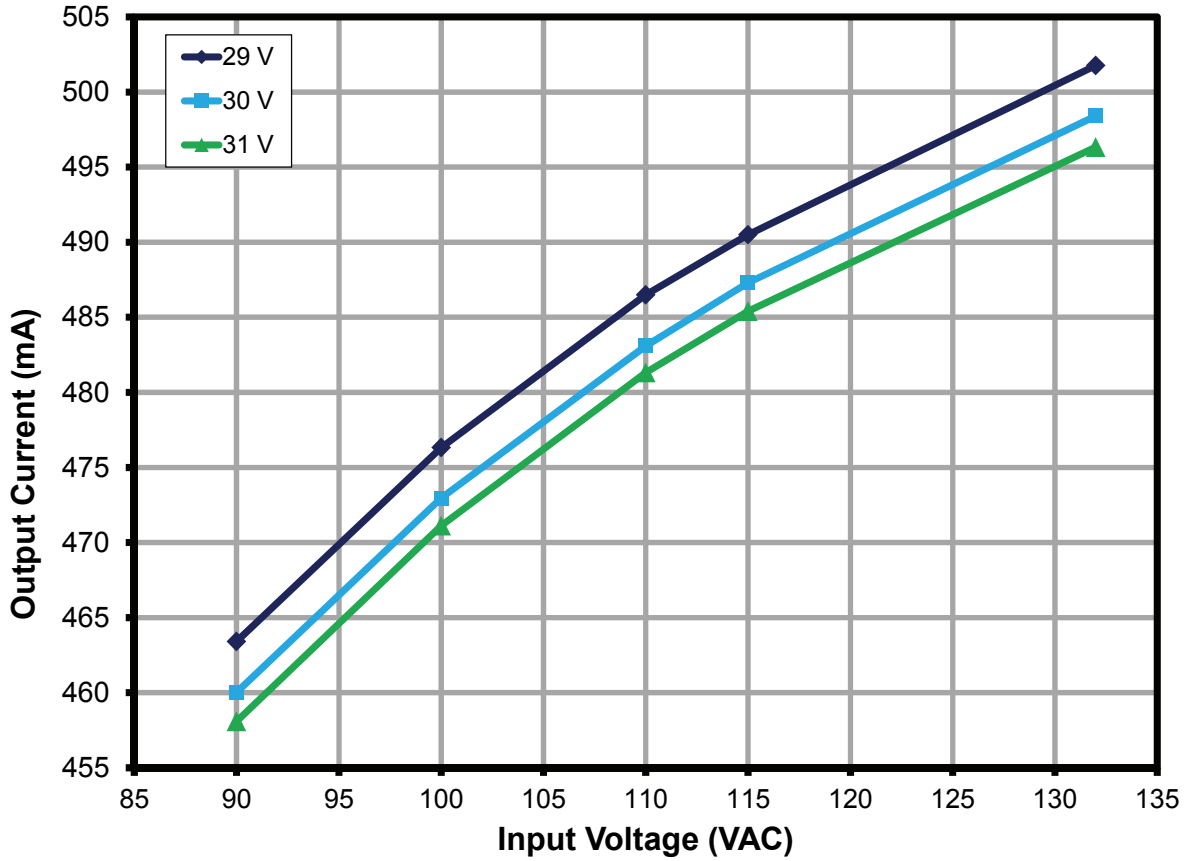

Figure 10 – Regulation vs. Line and Load.

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9.3 功率因数

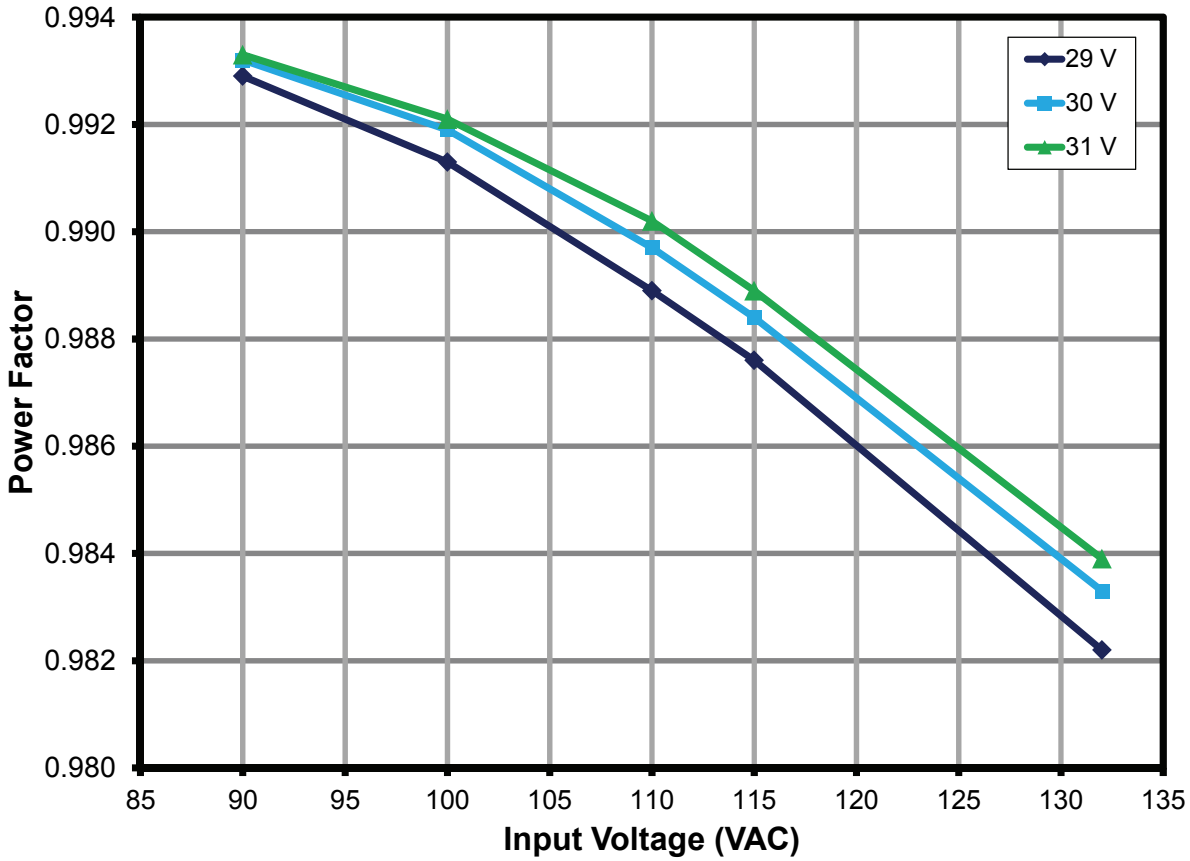

Figure 11 – Power Factor vs. Line and Load.

9.4 A-THD

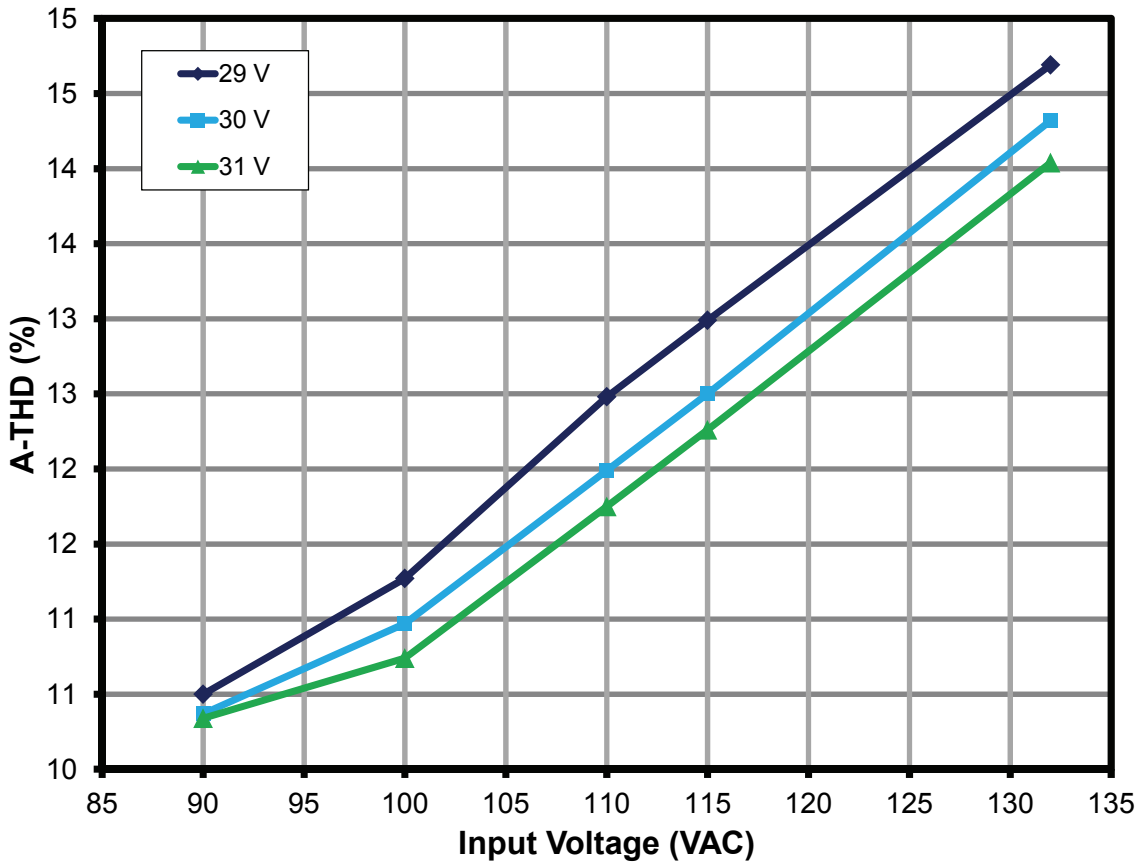

Figure 12 – A-THD vs. Line and Load.

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9.5 谐波

9.5.1 29 V LED负载

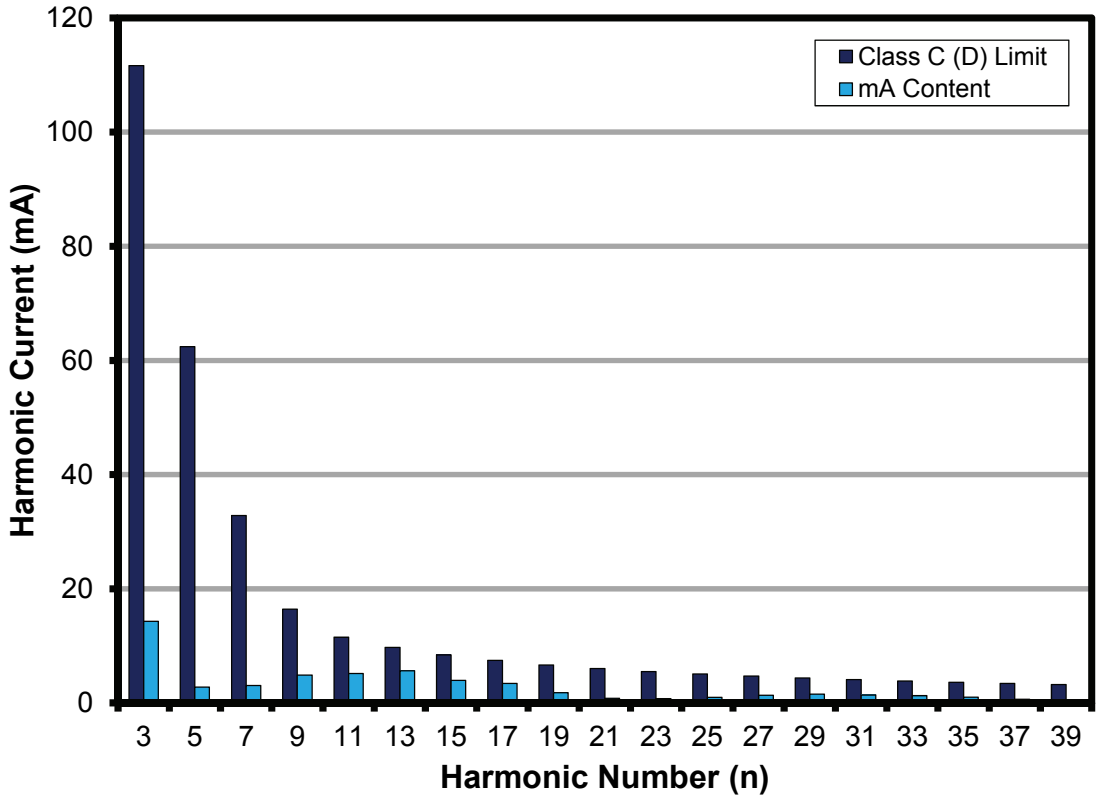

Figure 13 – 29 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

9.5.2 30 V LED负载

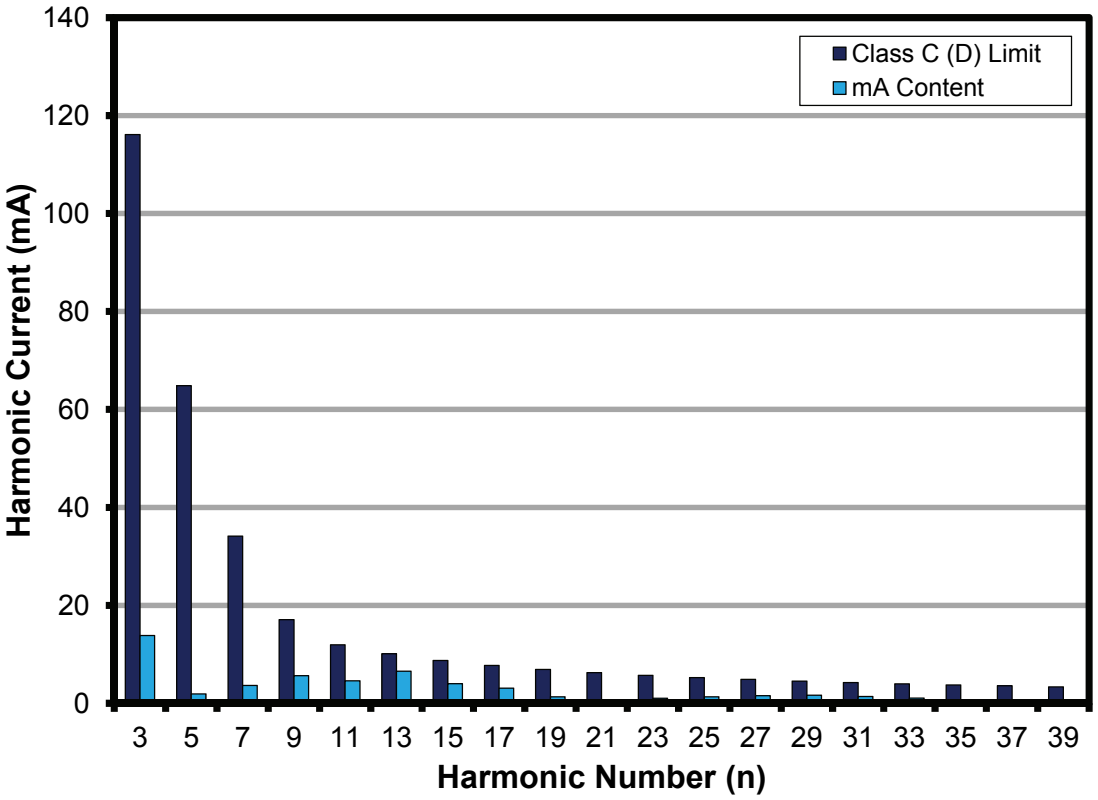

Figure 14 – 30 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

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9.5.3 31 V LED负载

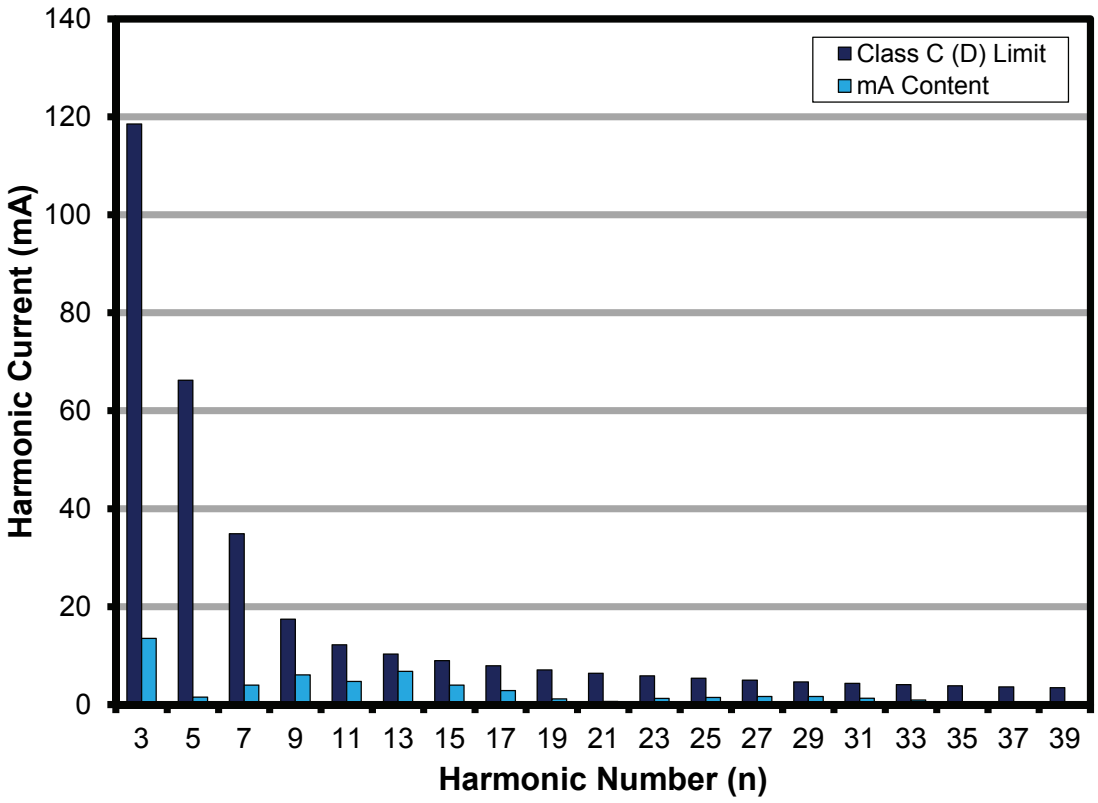

Figure 15 – 31 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

9.6 测试数据

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

9.6.1 测试数据，29 V LED负载

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 测试数据，30 V LED负载

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 测试数据，31 V LED负载

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

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10 调光性能数据

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 前沿调光器的典型调光曲线

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

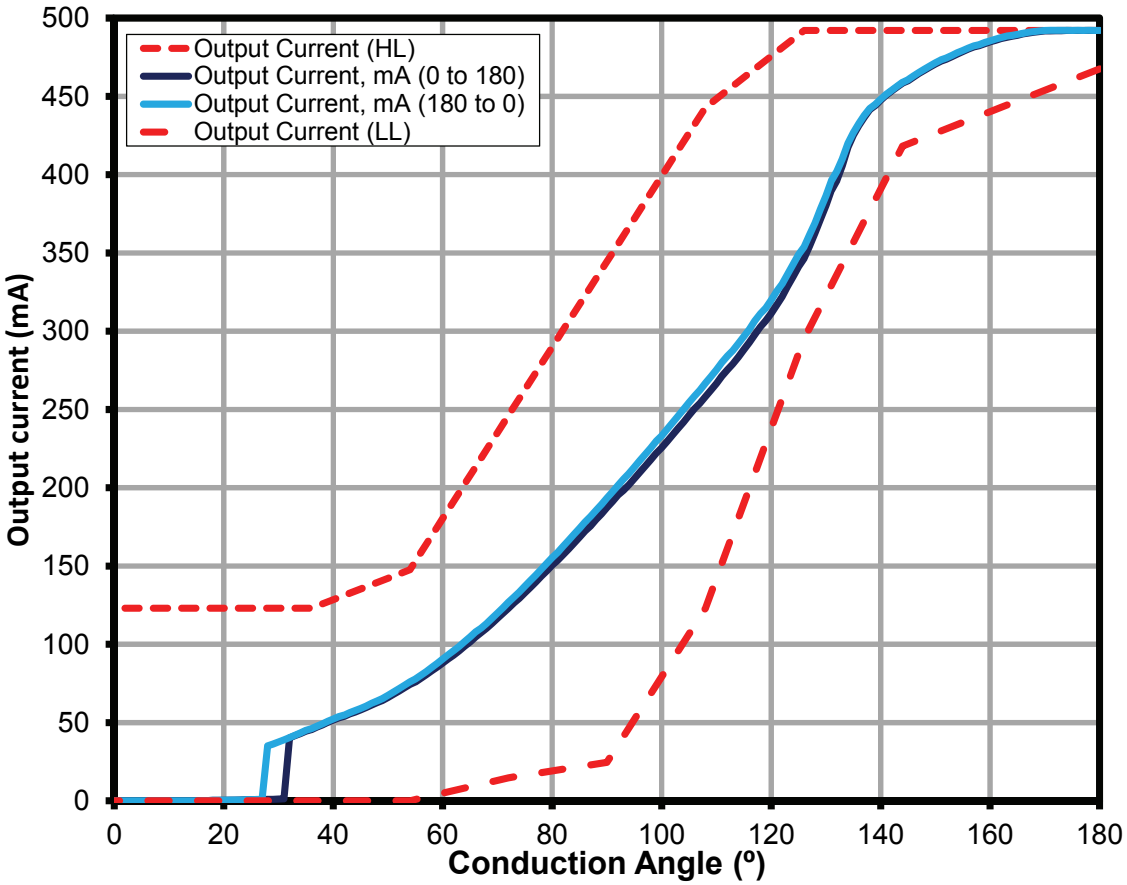

Figure 16 – Leading Edge Dimming Characteristics.

10.2 调光器兼容性列表

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.

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11 热性能

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

11.1 非调光V_{IN} = 90 VAC，60 Hz，30 V LED负载

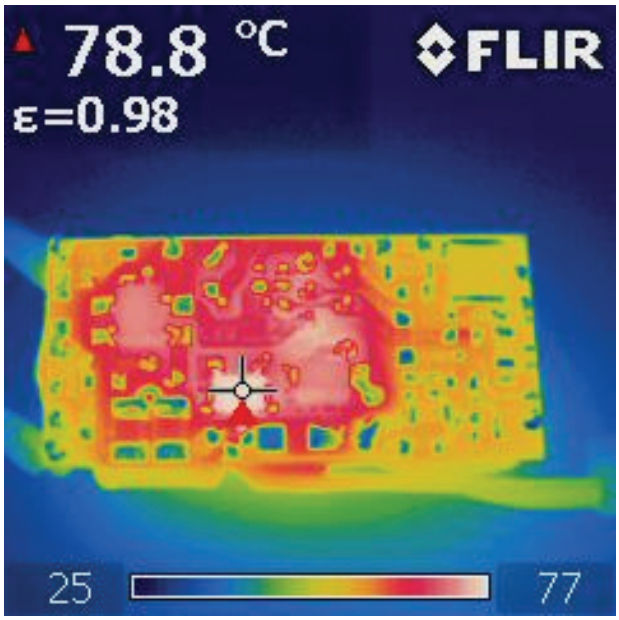

Figure 18 – Bottom Side.
D2-US1G: 78.8 ºC

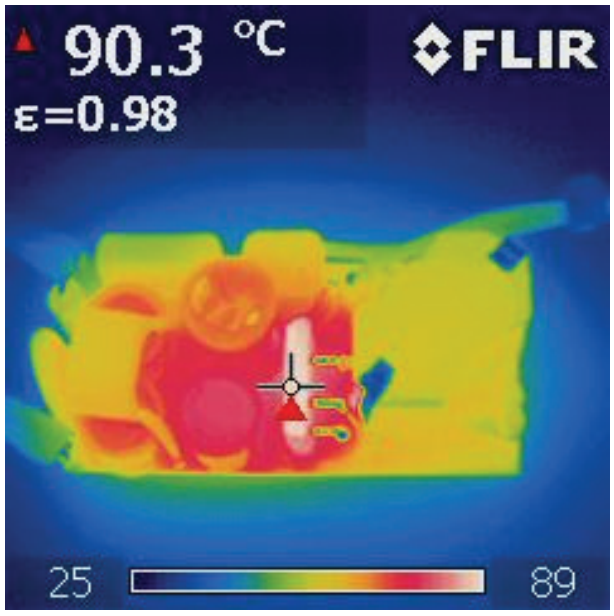

Figure 19 – Top Side.
U1-LNK407EG: 90.3 ºC

11.2 非调光V_{IN} = 132 VAC，60 Hz，30 V LED负载

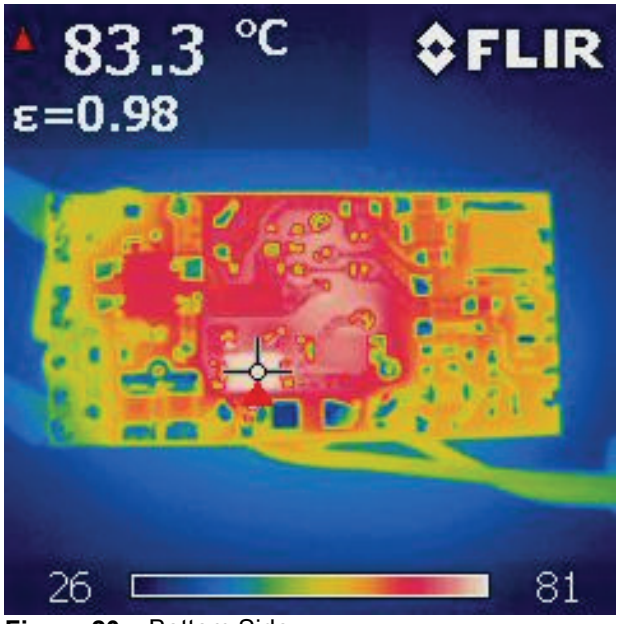

Figure 20 – Bottom Side.
D2-US1G: 83.3ºC

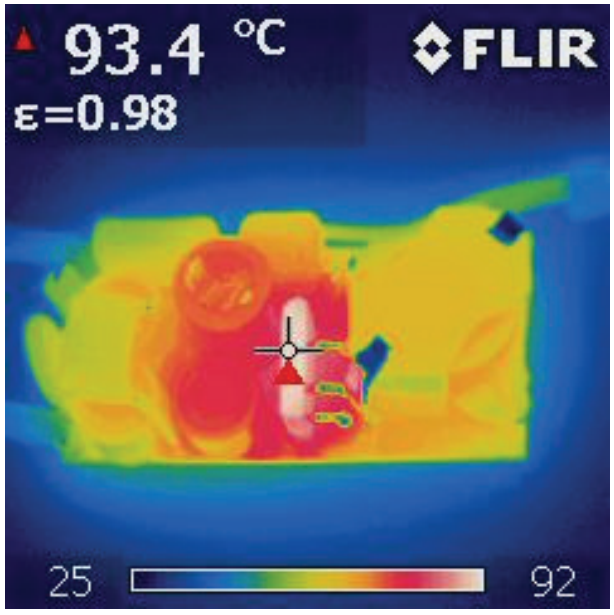

Figure 21 – Top Side.
U1-LNK407EG: 93.4 ºC

11.3 调光V_{IN} = 120 VAC 60 Hz，90º导通角，30 V LED负载

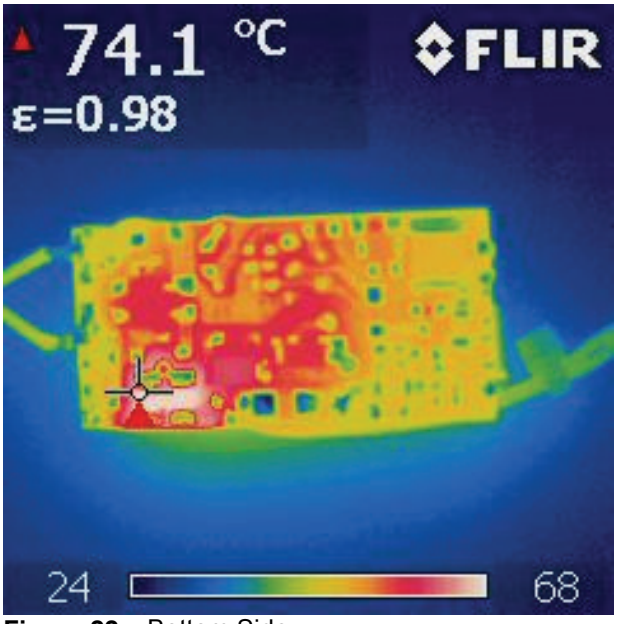

Figure 22 – Bottom Side.
R14-Bleeder Resistor: 74.1 ºC

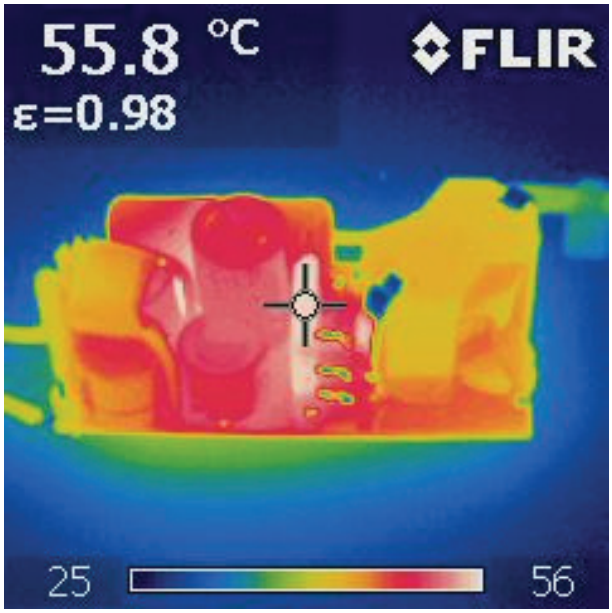

Figure 23 – Top Side.
U1-LNK407EG: 55.8 ºC

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12 非调光波形

12.1 输入电压和输入电流波形

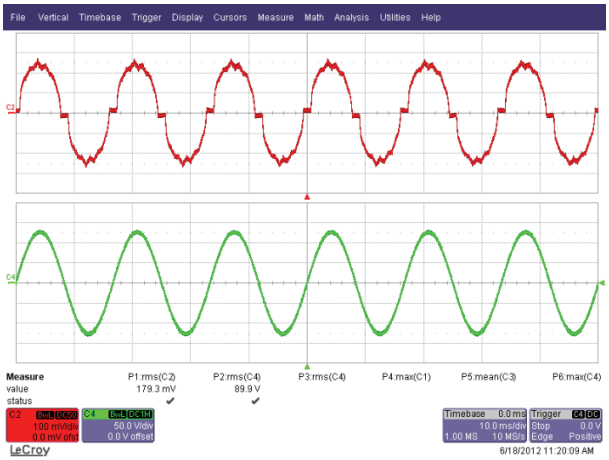

Figure 24 – 90 VAC, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 10 ms / div.

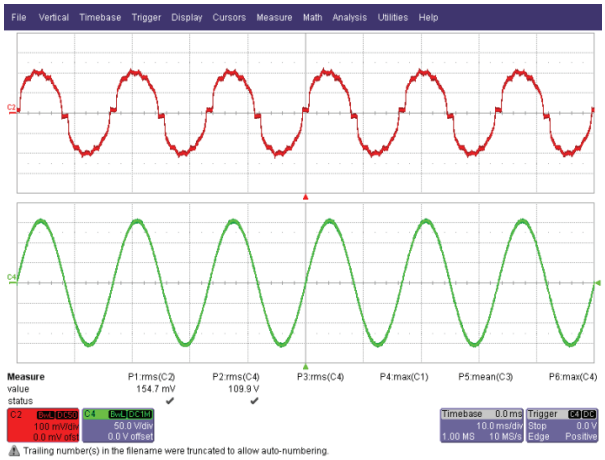

Figure 25 – 110 VAC, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 10 ms / div.

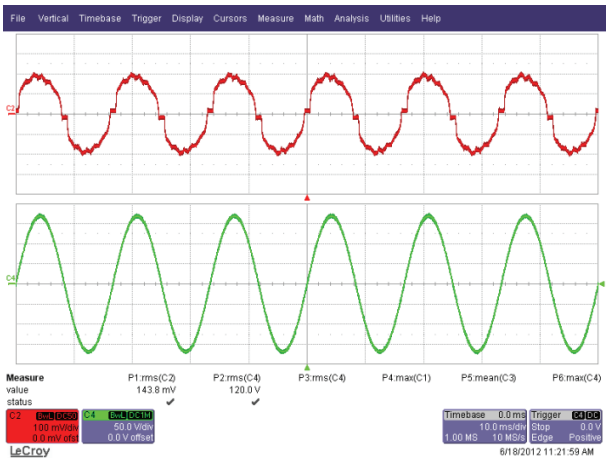

Figure 26 – 120 VAC, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 10 ms / div.

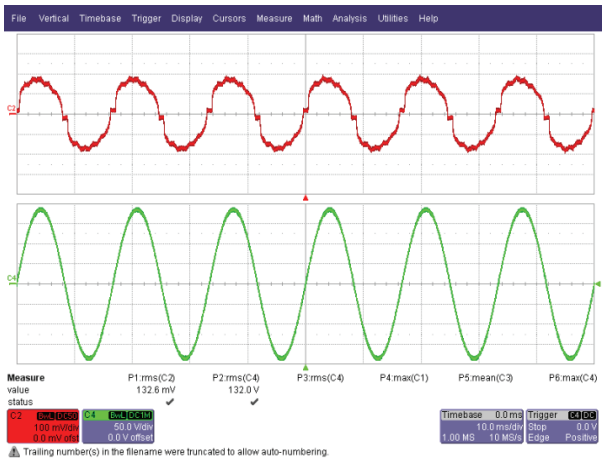

Figure 27 – 132 VAC, Full Load.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 10 ms / div.

12.2 正常工作时的输出电流和输出电压

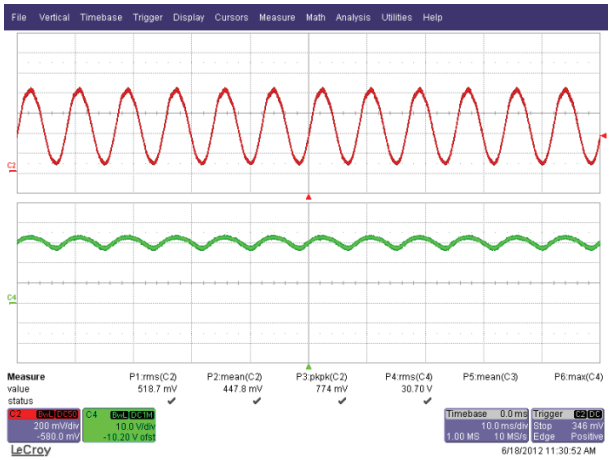

Figure 28 – 90 VAC, 60 Hz Full Load.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

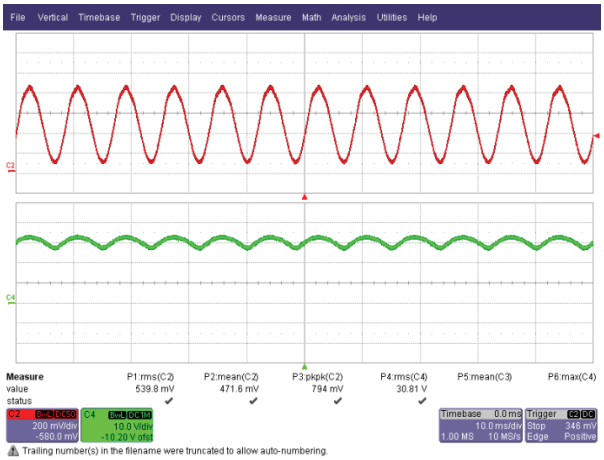

Figure 29 – 110 VAC, 60 Hz Full Load.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

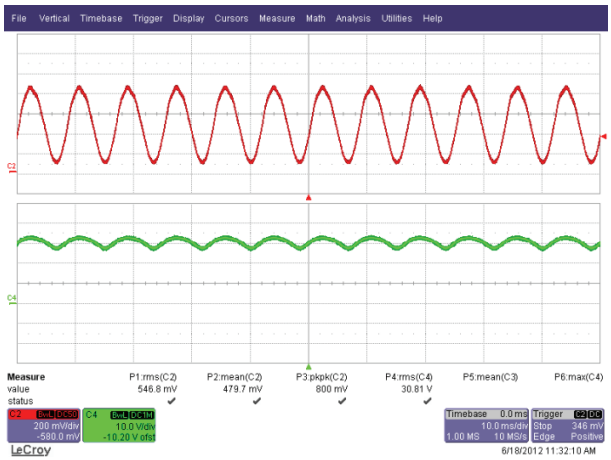

Figure 30 – 120 VAC, 60 Hz Full Load.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

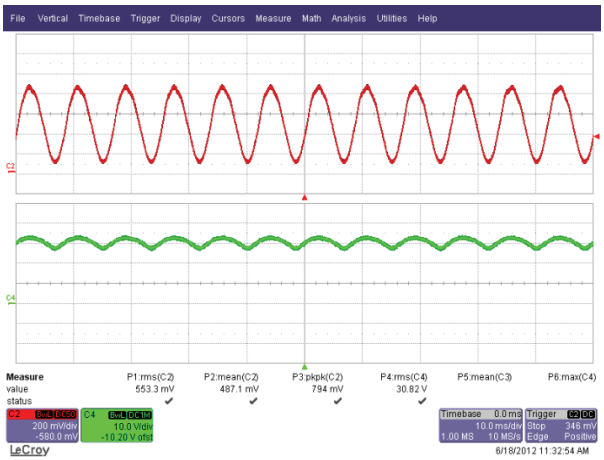

Figure 31 – 132 VAC, 60 Hz Full Load.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

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12.3 输出电流/电压的升降

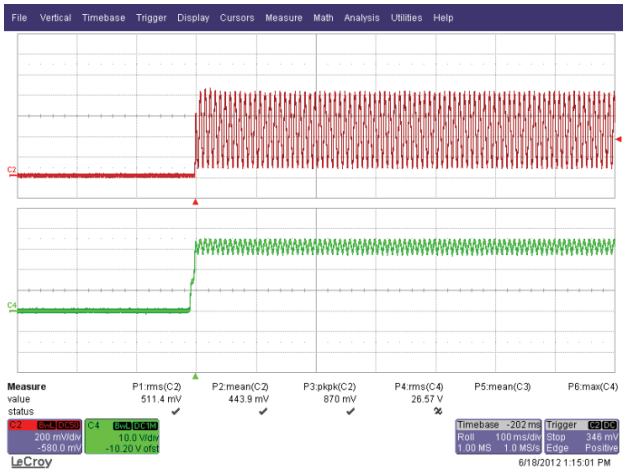

Figure 32 – 90 VAC Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 100 ms / div.

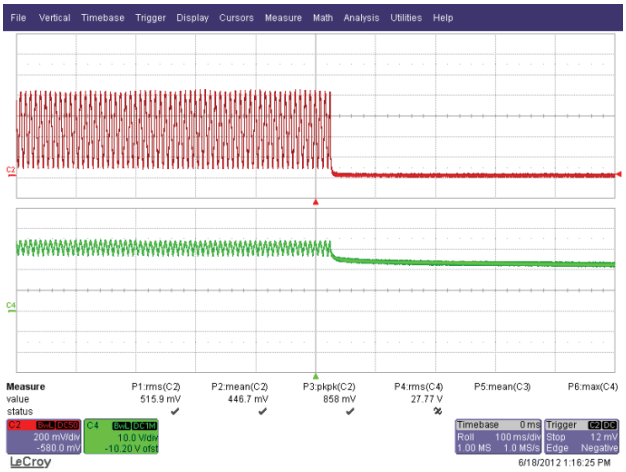

Figure 33 – 90 VAC Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 100 ms / div.

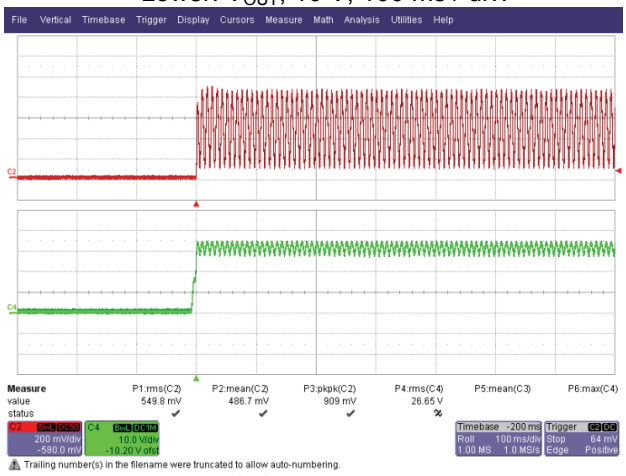

Figure 34 – 132 VAC Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 100 ms / div.

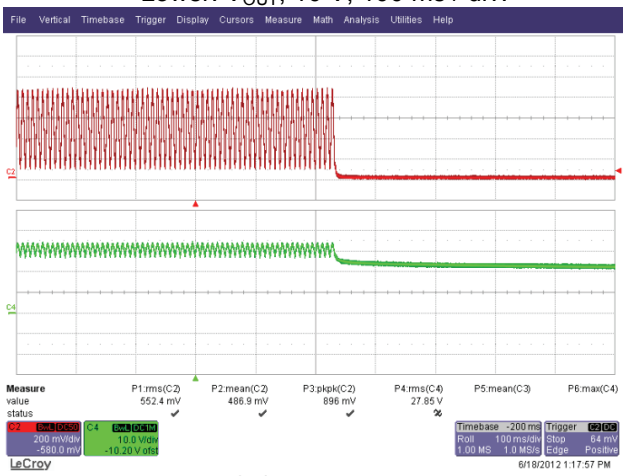

Figure 35 – 132 VAC Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{OUT}, 10 V, 100 ms / div.

12.4 启动时的输入电压和输出电流波形

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.

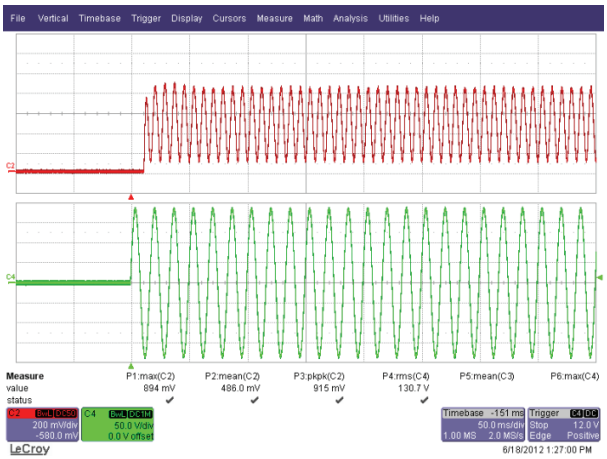

Figure 39 – 132 VAC, 60 Hz.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 50 V, 50 ms / div.

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12.5 正常工作时的漏极电压和漏极电流

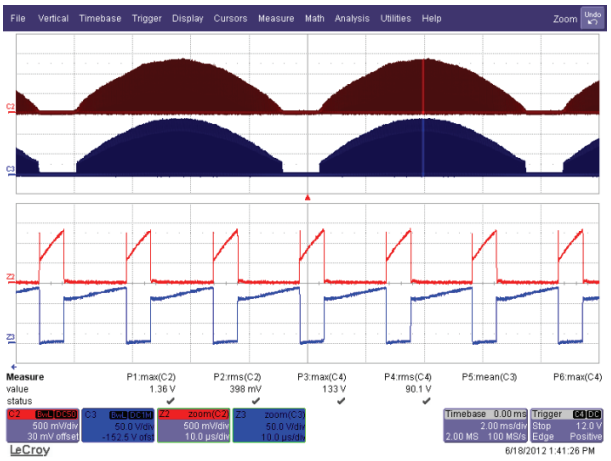

Figure 40 – 90 VAC, 60 Hz.
C2: I_{DRAIN}, 0.5 A, 2 ms / div.
C3: V_{DRAIN}, 50 V, 2 ms / div.
Z2: I_{DRAIN}, 0.5 A, 10 µs / div.
Z3: V_{DRAIN}, 50 V, 10 µs / div.

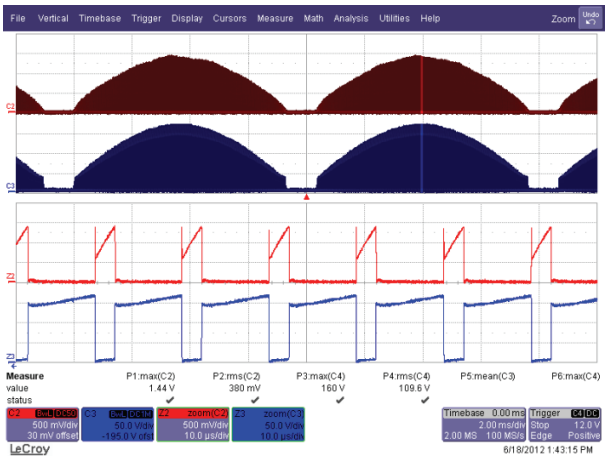

Figure 41 – 110 VAC, 60 Hz.
C2: I_{DRAIN}, 0.5 A, 2 ms / div.
C3: V_{DRAIN}, 50 V, 2 ms / div.
Z2: I_{DRAIN}, 0.5 A, 10 µs / div.
Z3: V_{DRAIN}, 50 V, 10 µs / div.

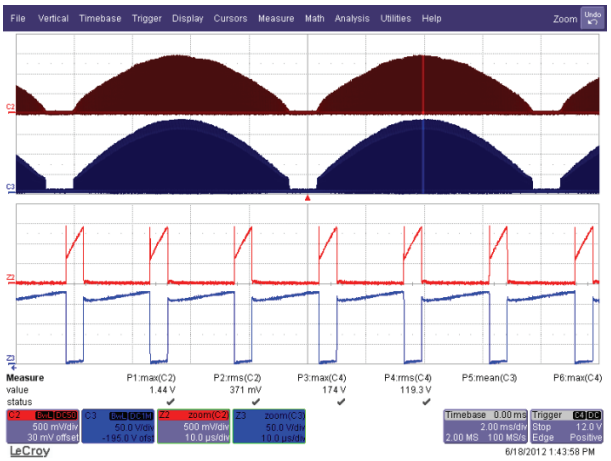

Figure 42 – 120 VAC, 60 Hz.
C2: I_{DRAIN}, 0.5 A, 2 ms / div.
C3: V_{DRAIN}, 50 V, 2 ms / div.
Z2: I_{DRAIN}, 0.5 A, 10 µs / div.
Z3: V_{DRAIN}, 50 V, 10 µs / div.

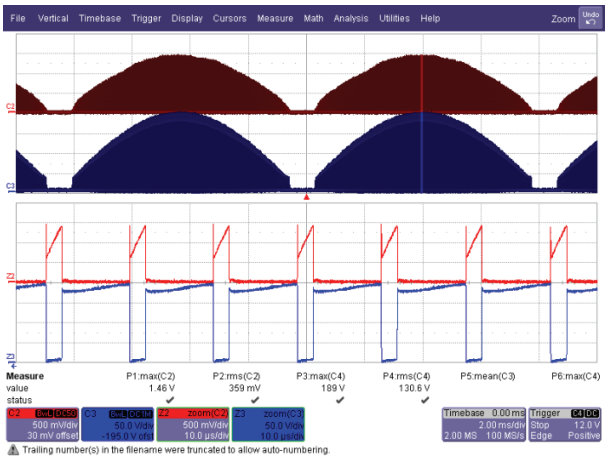

Figure 43 – 132 VAC, 60 Hz.
C2: I_{DRAIN}, 0.5 A, 2 ms / div.
C3: V_{DRAIN}, 50 V, 2 ms / div.
Z2: I_{DRAIN}, 0.5 A, 10 µs / div.
Z3: V_{DRAIN}, 50 V, 10 µs / div.

12.6 启动时的漏极电压和电流

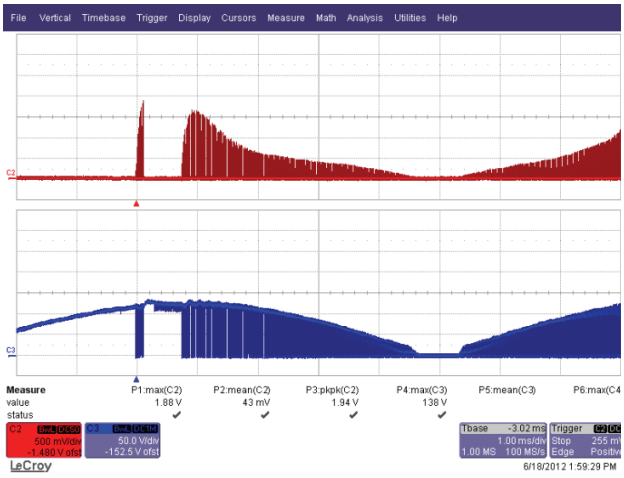

Figure 44 – 90 VAC, 60 Hz Start-up
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V, 1 ms / div.

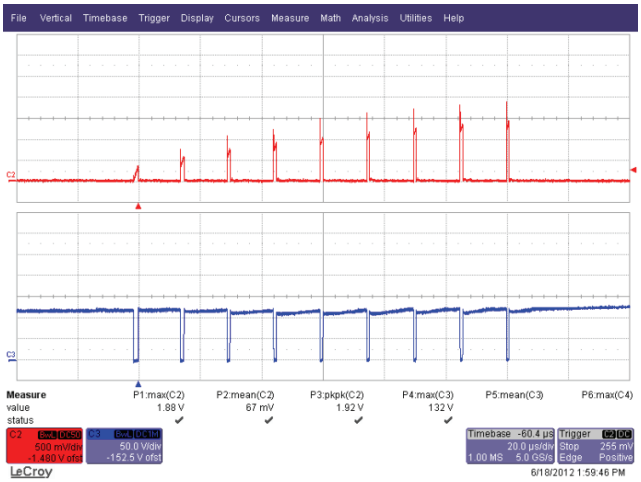

Figure 45 – 90 VAC, 60 Hz Start-up
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V, 20 µs / div.

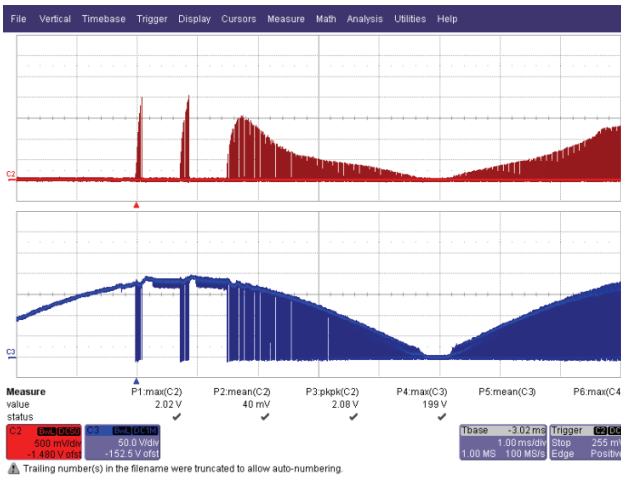

Figure 46 – 132 VAC, 60 Hz Start-up
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V, 1 ms / div.

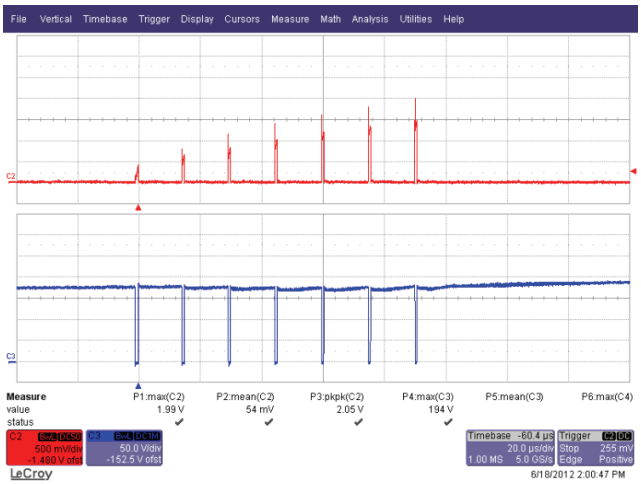

Figure 47 – 132 VAC, 60 Hz Start-up
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V, 20 µs / div.

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12.7 输出短路时的漏极电流和漏极电压

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

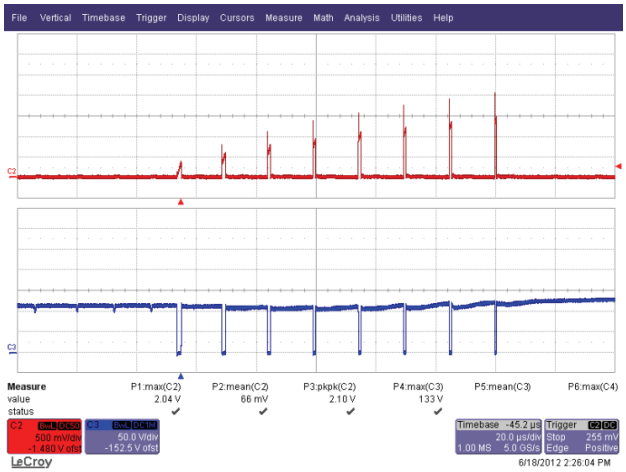

Figure 49 – 90 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V, 20 µs / div.

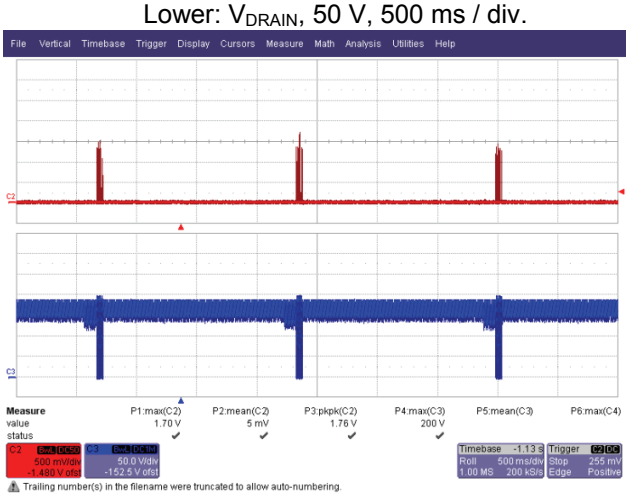

Figure 50 – 132 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V, 500 ms / div.

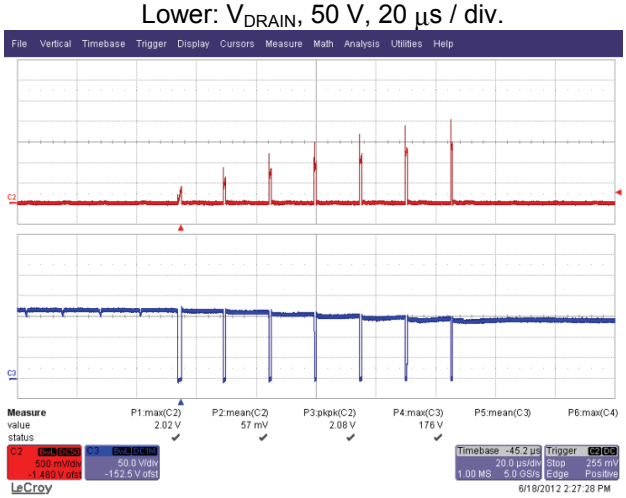

Figure 51 – 132 VAC, 60 Hz Output Short Condition.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V, 20 µs / div.

13 调光波形

13.1 输入电压和输入电流波形

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

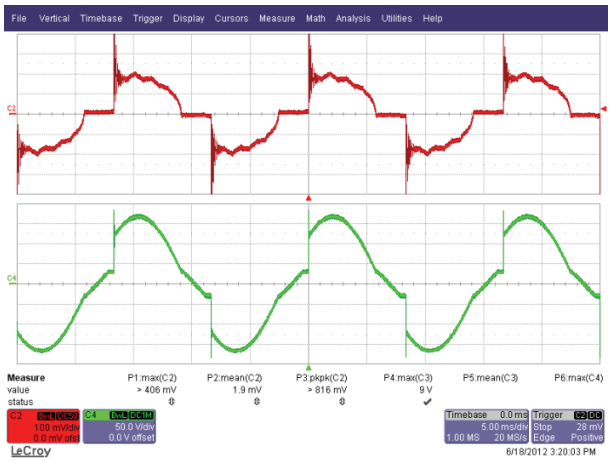

Figure 52 – 125º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

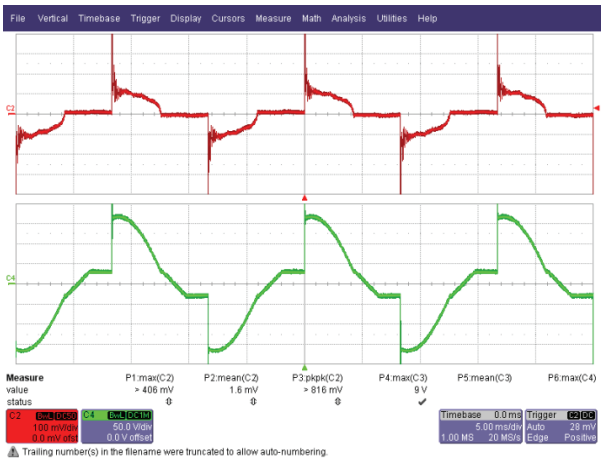

Figure 53 – 92º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

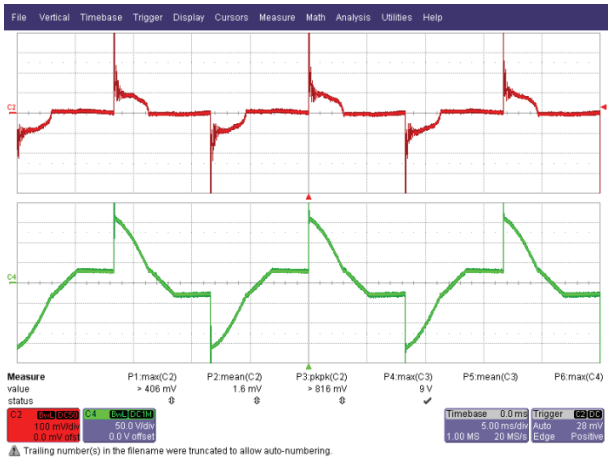

Figure 54 – 65º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

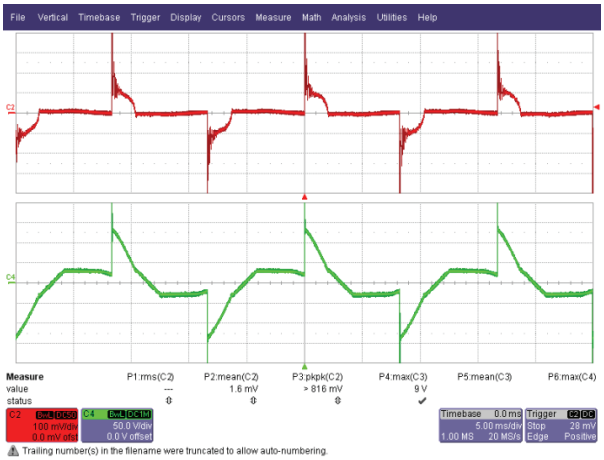

Figure 55 – 45º Conduction Angle.
Upper: I_{IN}, 100 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

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13.2 输出电流波形

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

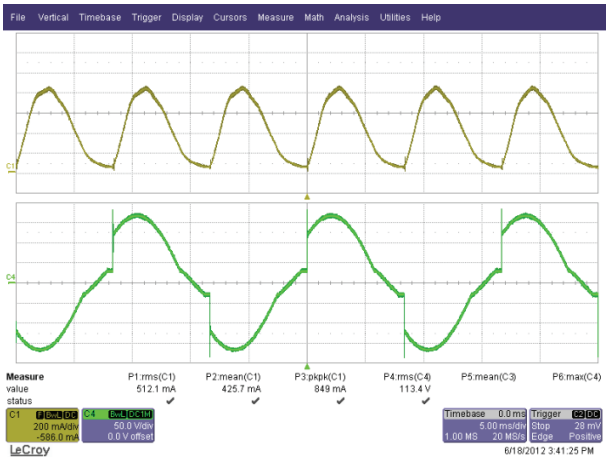

Figure 56 – 125º Conduction Angle.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

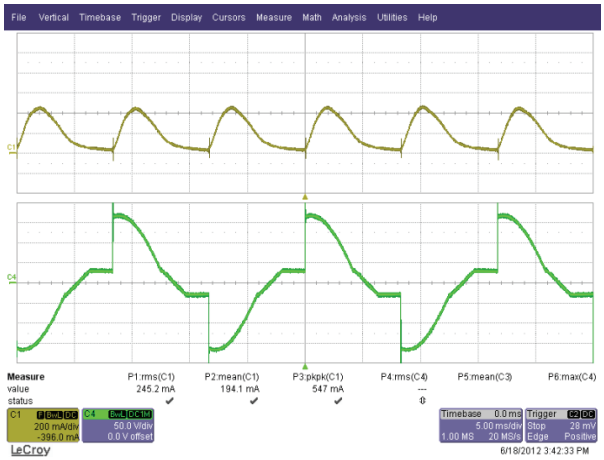

Figure 57 – 92º Conduction Angle.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

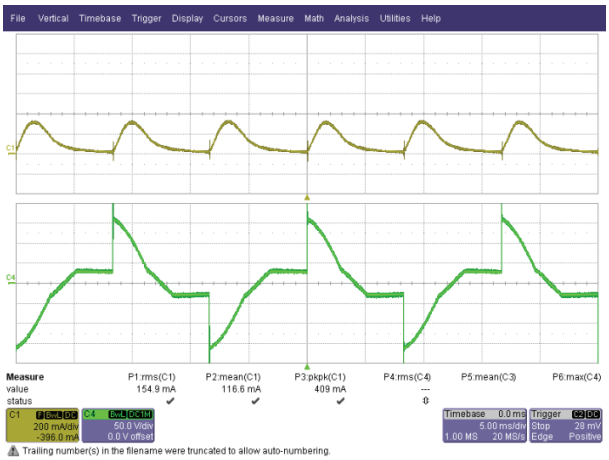

Figure 58 – 65º Conduction Angle.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

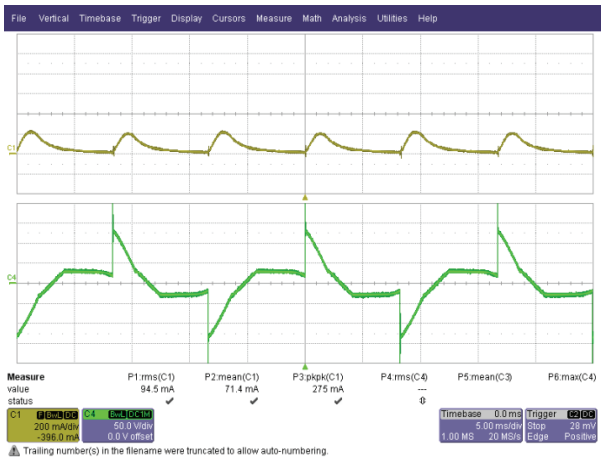

Figure 59 – 45º Conduction Angle.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 50 V, 5 ms / div.

14 传导EMI

14.1 测试设置

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

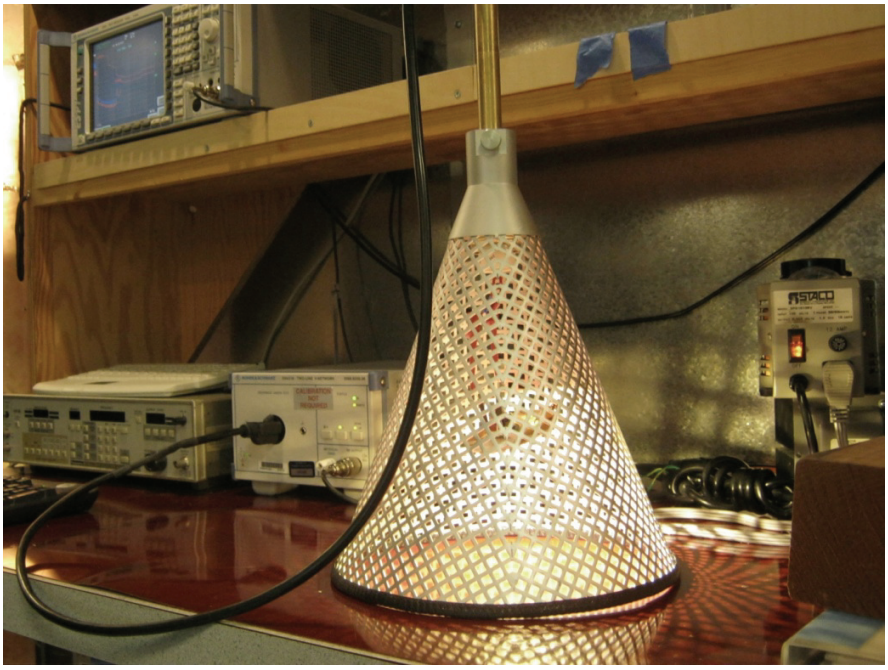

Figure 60 – EMI Test Set-up with the Unit and LED Load Placed Inside the Cone.

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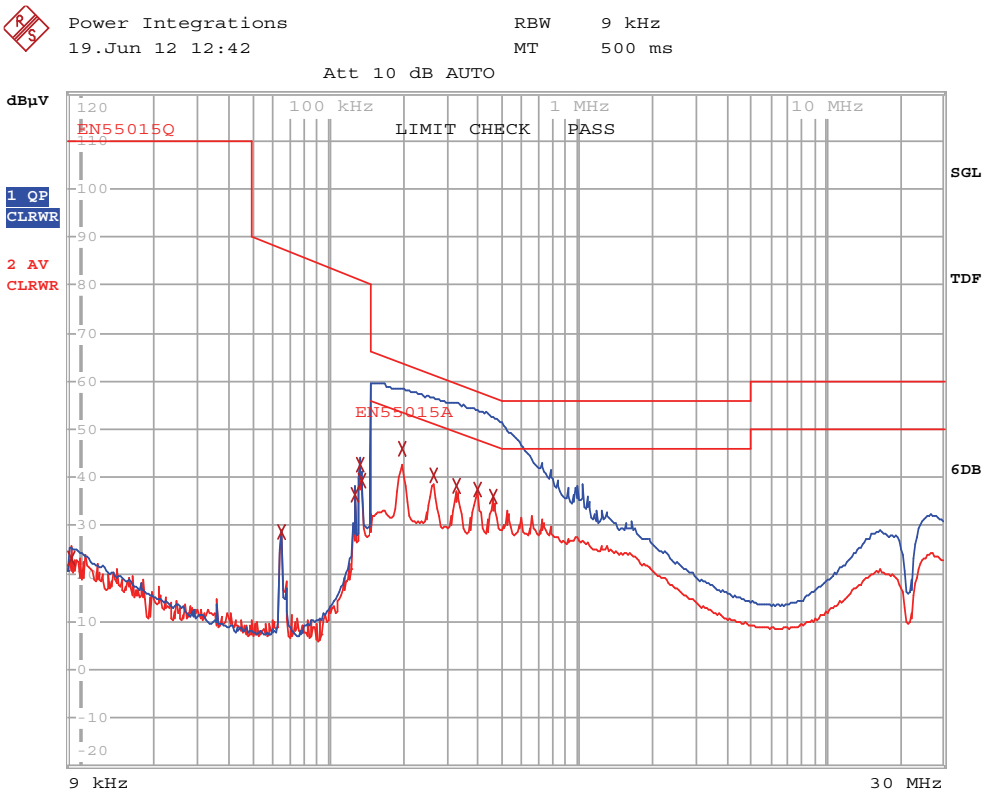
14.2 测试结果



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.

15 输入浪涌

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

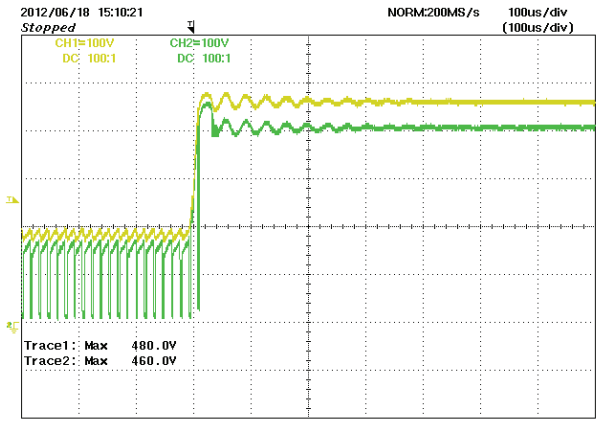


Figure 62 – +500 V (90º Injection Phase) Differential Surge VDS Waveforms.
C1: Input Rectified Voltage (Voltage Across C2)
C2: U1 Drain Voltage Reference to Source.

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16 40 V / 350 mA输出设计补充信息

16.1 电源规格

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.

16.2 电感规格(40 V / 350 mA)

16.2.1 电气原理图

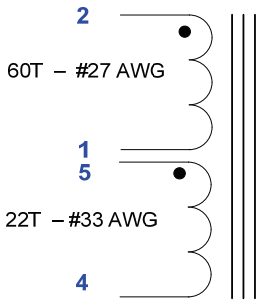

Figure 63 – Inductor Electrical Diagram.

16.2.2 电气规格

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 材料

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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16.2.4 电感结构图

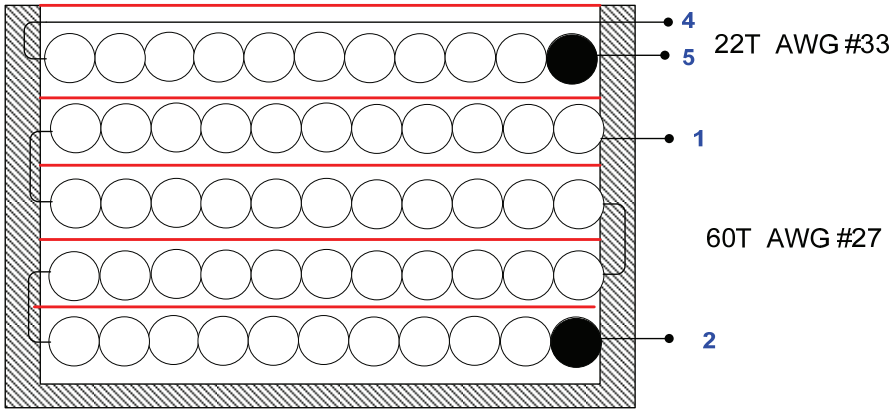

Figure 64 – Inductor Build Diagram.

16.2.5 电感构造

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.

16.3 性能数据

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 调光器兼容性列表

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	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	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	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

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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

16.4.1 效率

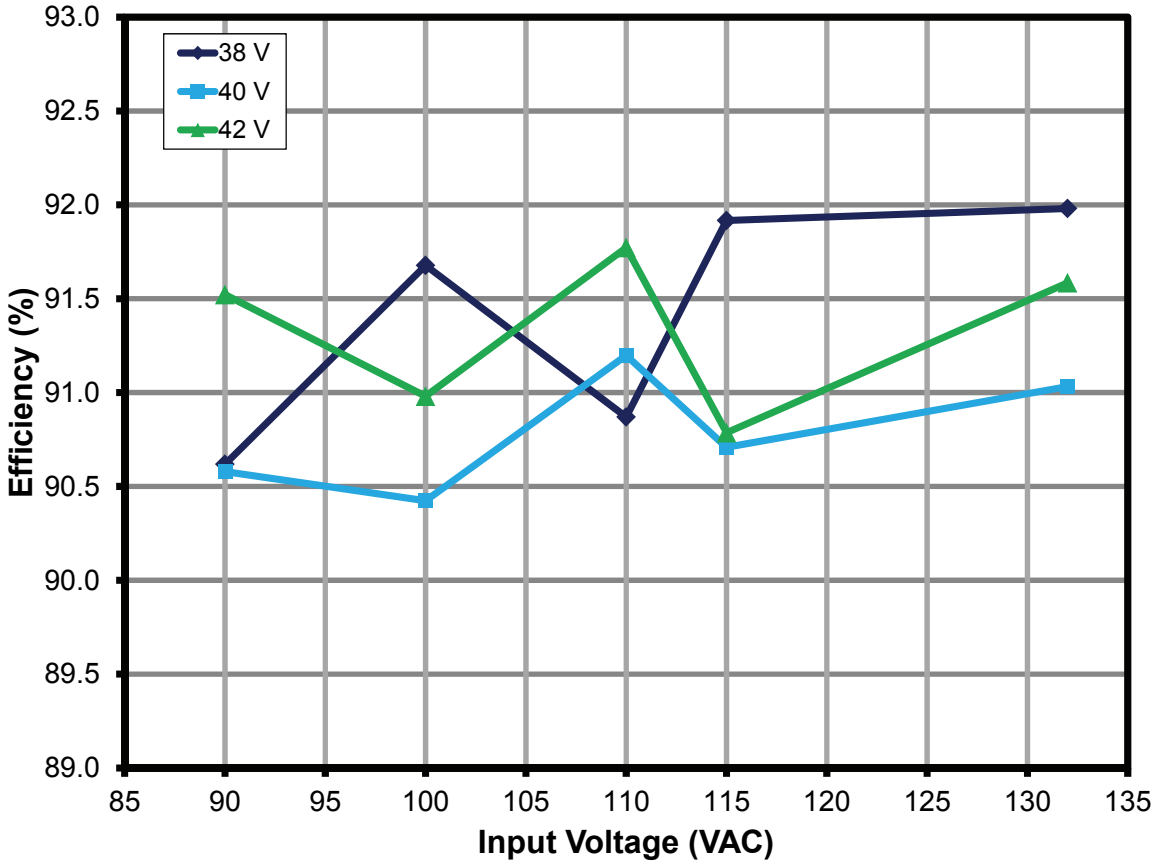

Figure 65 – Efficiency vs. Line and Load. 40 V / 350 mA.

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16.4.2 输入电压调整率和负载调整率

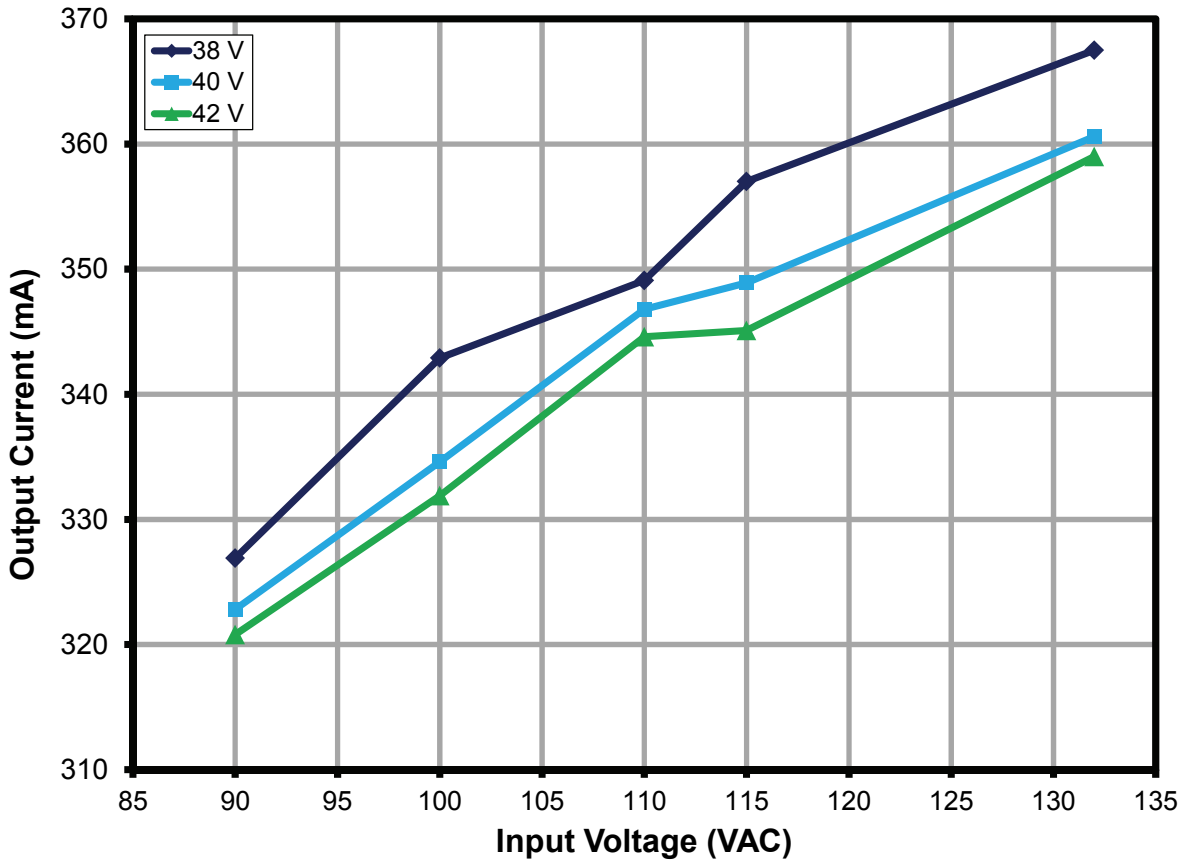

Figure 66 – Regulation vs. Line and Load.

16.4.3 功率因数

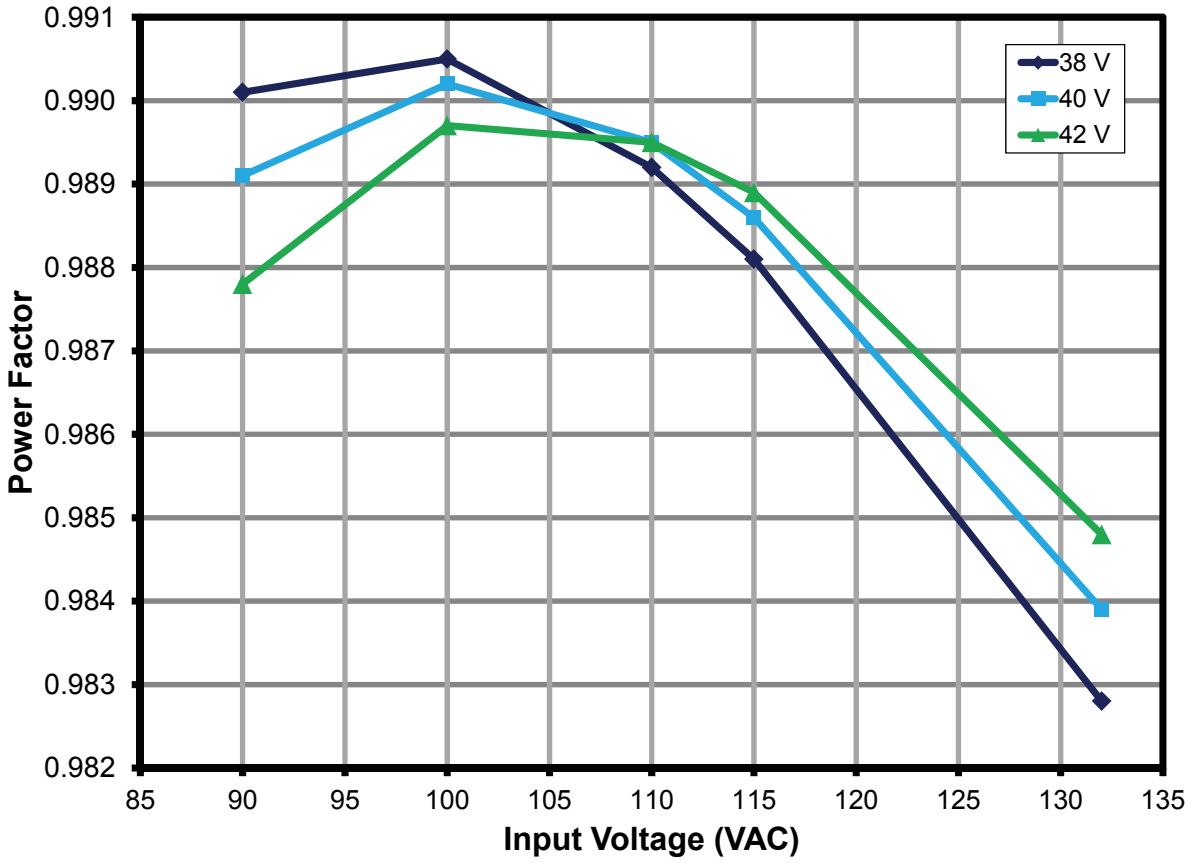

Figure 67 – Power Factor vs. Line and Load.

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16.4.4 A-THD

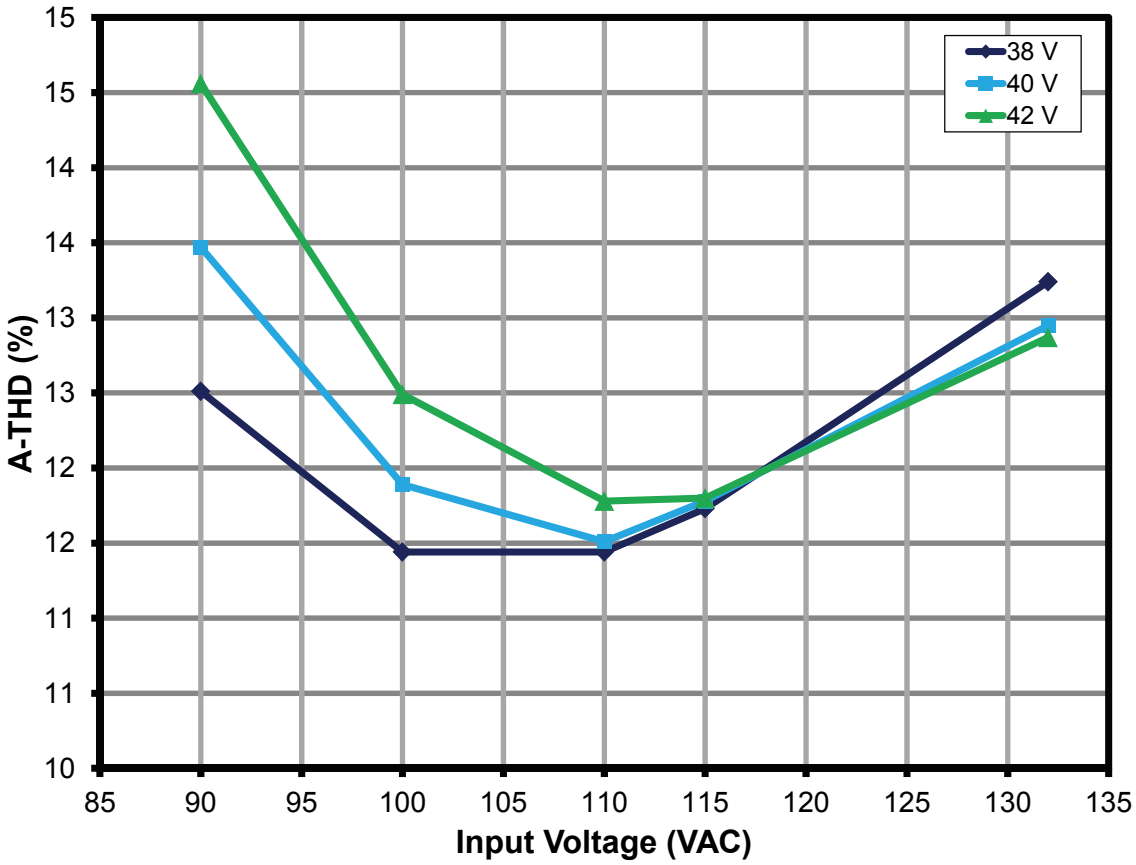

Figure 68 – A-THD vs. Line and Load.

16.4.5 40 V谐波

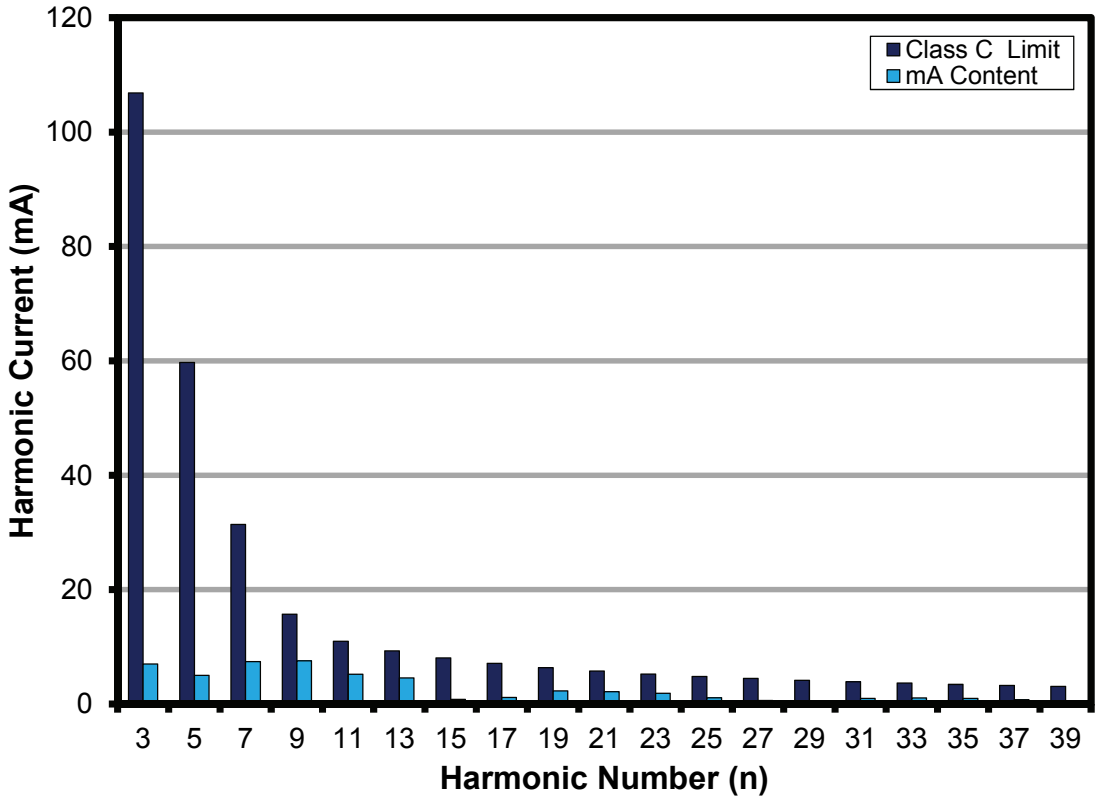

Figure 69 – 40 V / 350 mA LED Load Input Current Harmonics at 115 VAC, 60 Hz.

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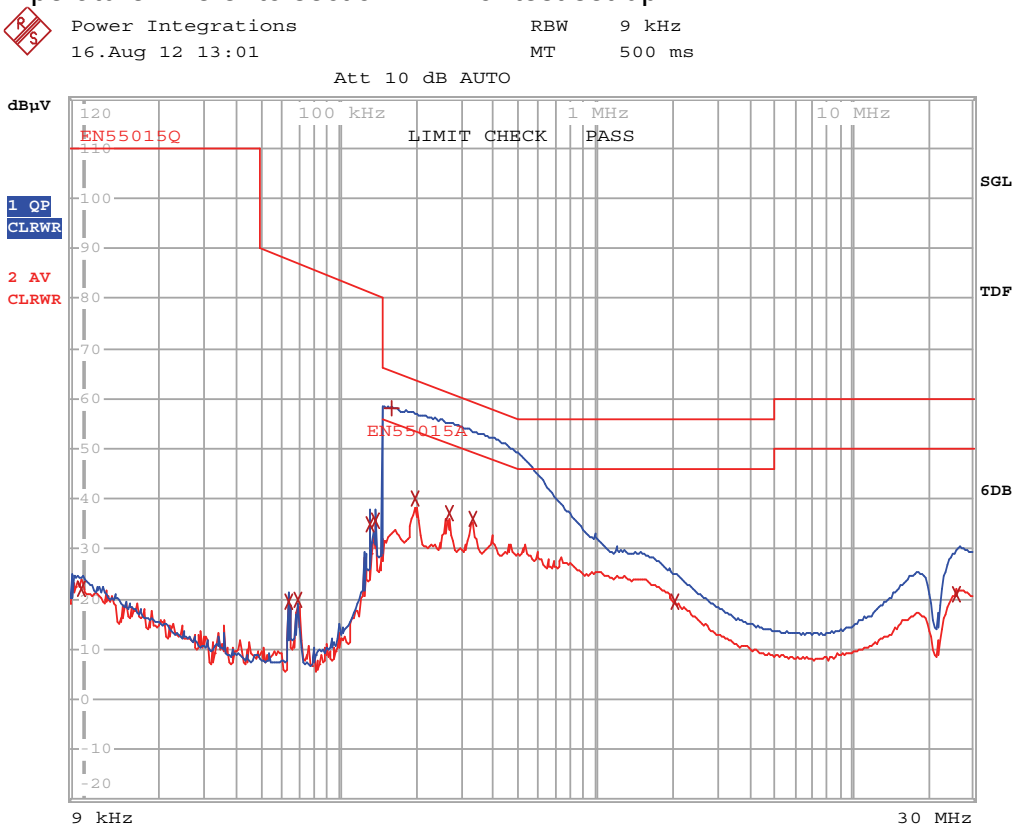
16.4.6 传导EMI测试结果

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.

17 版本历史

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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