设计范例报告

标题	***使用LYTSwitch™ LYT4215E设计的仅限输入低压．超薄．T8．隔离式．23 W．带功率因数校正(PF >0.98)的LED驱动器***
规格	90 VAC – 135 VAC输入；50 V，430 mA输出
应用	适用于超薄T8灯管的LED驱动器
作者	应用工程部
文档编号	DER-338
日期	2013年1月29日
修订版本	1.0

特色概述

- 成本低
  - 将PFC与PSR控制的CC同时集成到单个开关级
  - 单面PCB
  - 元件数量少
- 超薄设计（元件高度<10 mm）
- 极高能效
  - 在110 VAC下≥86%
- 在110 VAC下，PF >0.98，THD <15%
- 抗浪涌保护
  - 满足1 kV差模浪涌保护要求
  - 满足500 V浪涌保护要求，无金属氧化物压敏电阻(MOV)
  - 满足61000-4-5振铃波要求
- 集成的保护及可靠性能
  - 输出开路/输出短路保护，带自动恢复功能
  - 输入过压关断可扩展输入故障时的电压耐受范围
  - 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

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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。

1 简介

本文档介绍的是一款超薄T8（元件高度<10 mm）、隔离式、高功率因数(PF) LED驱动器设计，该驱动器可以在90 VAC到135 VAC的输入电压范围内为额定电压50 V的LED灯串提供430 mA的驱动。该LED驱动器采用了LYTSwitch系列IC中的LYT4215E器件。

本设计的主要目标是：

- 装入窄小(<20 mm)、低元件高度(<10 mm)的T8灯壳内
- 耐受1 kV差模浪涌

所采用的拓扑结构为单级、带功率因数校正的、连续导通模式反激式拓扑结构，可满足高效率、高功率因数、低THD、隔离、低元件数以及严格的空间要求。

LYTSwitch IC还可提供各种复杂的保护功能，包括环路开环或输出短路条件下自动重启动等，利用该器件可实现高功率因数和低THD。

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

Figure 1 – Populated Circuit Board Photograph (Top View).

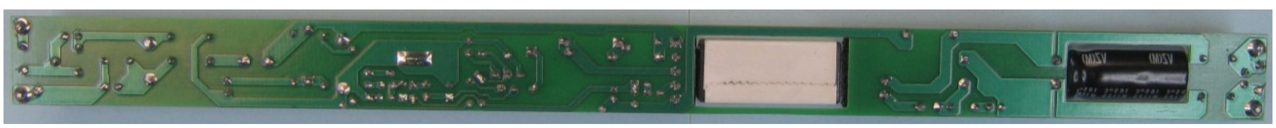

Figure 2 – Populated Circuit Board Photograph (Bottom View).

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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	115	135	VAC	双导线 – 无P.E.
频率	f_{LINE}		60		Hz	
输出						
输出电压	V_{OUT}	45	50	55	V	
输出电流	I_{OUT}		430		mA	V_{OUT} = 50, V_{IN} =115 VAC, 25 °C
总输出功率						
连续输出功率	P_{OUT}			23	W	
效率						
满载	η	86			%	在115 VAC、25 ºC条件下测得
环境						
传导EMI		CISPR 15B / EN55015B				
安全		隔离式				
浪涌(1.2 μ / 50 μ)						
差模(L1-L2)			1		kV	
功率因数		0.98				在$V_{OUT(TYP)}$、$I_{OUT(TYP)}$ 以及115 VAC、60 Hz条件下测得
谐波电流		EN 61000-3-2 Class C				
环境温度	T_{AMB}			40	ºC	壳体外部，自然对流，海平面

3 电路原理图

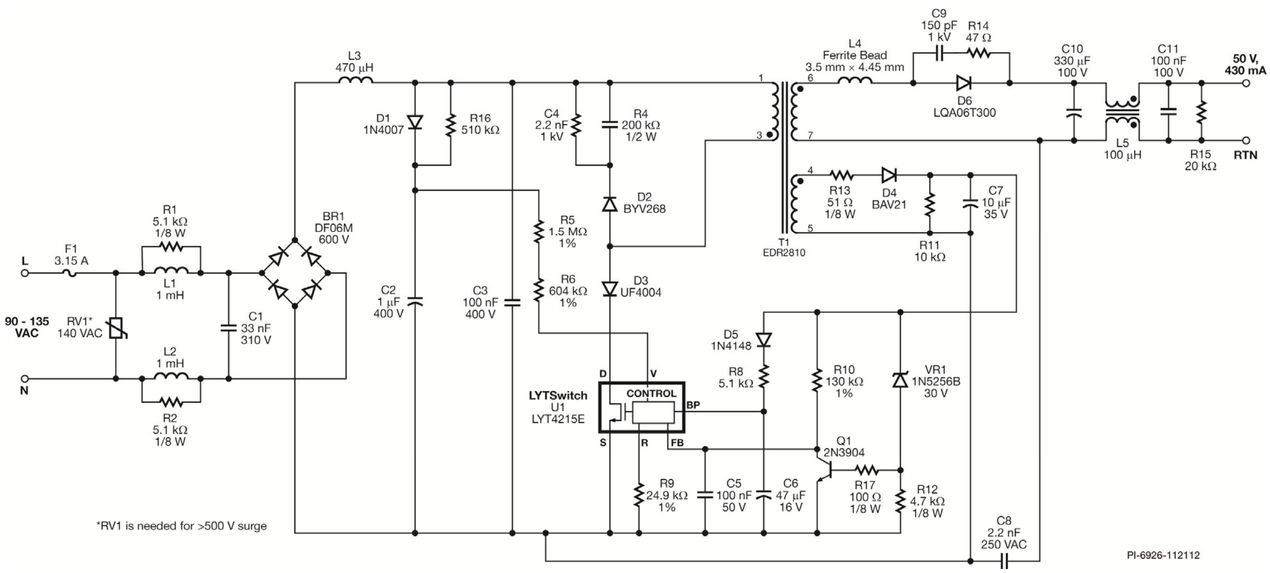

Figure 3 – Schematic.

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4 电路描述

LYTSwitch器件是一种将控制器和650 V功率MOSFET集成在一起的器件，用于LED驱动器应用。LYTSwitch可用于单级反激式拓扑结构，提供初级侧调节的恒流隔离输出，同时使AC输入保持高功率因数。

4.1 输入滤波

保险丝F1在元件发生故障时提供保护，而RV1用来对1 kV差模浪涌测试期间可能产生的最大电压进行箝位。RV1的额定电压为140 VAC，略高于最大指定工作电压135 VAC。二极管桥堆BR1对AC线电压进行整流，电容C3为初级开关电流提供低阻抗通路（去耦）。

输入EMI滤波由差模电感L1、L2和L3以及X电容C1和Y电容C8提供。L1和L2两端的电阻R1和R2可抑制在传导EMI测量中通常出现的、由滤波元件和AC输入阻抗引起的共振。

4.2 LYTSwitch初级

变压器(T1)一端连接到DC总线，另一端经过阻断二极管D3连接到LinkSwitch-PH器件的漏极(D)引脚。在功率MOSFET的导通时间内，初级绕组中的电流升高，存储的能量随后在功率MOSFET关断时间内传送到输出。本电路选用了EDR2810磁芯尺寸，以满足设计的功率处理和尺寸要求。

为向U1提供峰值输入电压信息，经整流AC的输入峰值经由D1对C2充电。然后电流经过R5和R6，注入U1的电压监测(V)引脚。

V引脚电流和反馈(FB)引脚电流在内部用来控制LED平均输出电流。对于非调光设计，需要在参考(R)引脚(R9)和V引脚上分别使用一个24.9 kΩ电阻和一个2.1 MΩ（R5和R6）电阻。

在功率MOSFET的关断时间内，由于漏感的影响，D2、R4和C4将漏极电压箝位到一个安全水平。

二极管D4、C7、R13和R11构成初级偏置供电，能量来自变压器的辅助绕组。电阻R13、R11和C7提供滤波，以使偏置电压密切跟踪输出电压（从而使输出电流在LED电压发生变化时保持恒定）。

电容C6对U1的旁路(BP)引脚进行局部去耦，该引脚是内部控制器的供电引脚。在启动期间，C6从与D引脚相连的内部高压电流源被充电至约6 V。充电完成后，U1开始开关，器件的供电电流再由偏置供电经过R8提供。电容C6同时用来选择输出功率模式，选择47 μF（低功率模式）可以将器件功耗减至最低，降低对散热片的要求。

4.3 反馈

偏置绕组电压用来间接地反映输出电压的高低，而无需使用次级侧反馈元件。偏置绕组上的电压与输出电压成比例（由偏置绕组与次级绕组之间的匝数比决定）的。电阻R10将偏置电压转换为电流，馈入U1的FB引脚。电容C5对U1的FB引脚进行局部去耦。

U1中的内部引擎综合FB引脚电流、V测引脚电流和内部漏极电流信息，提供恒定的输出电流，同时保持较高的输入功率因数。

在开路负载情况下，齐纳二极管VR1将限定输出电压。驱动器会在Q1导通时进入自动重启动模式，同时齐纳二极管VR1设置过压限值。

4.4 输出整流

变压器次级绕组由D6进行整流，由C10和C11进行滤波。对于可以接受较高纹波的设计，可降低输出电容值。

D6两端的电阻R14和电容C9降低输出整流管D6上的峰值反向电压应力。磁珠L4和输出共模扼流圈L5与电容C11一起降低>10 MHz的EMI噪声。

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5 PCB布局

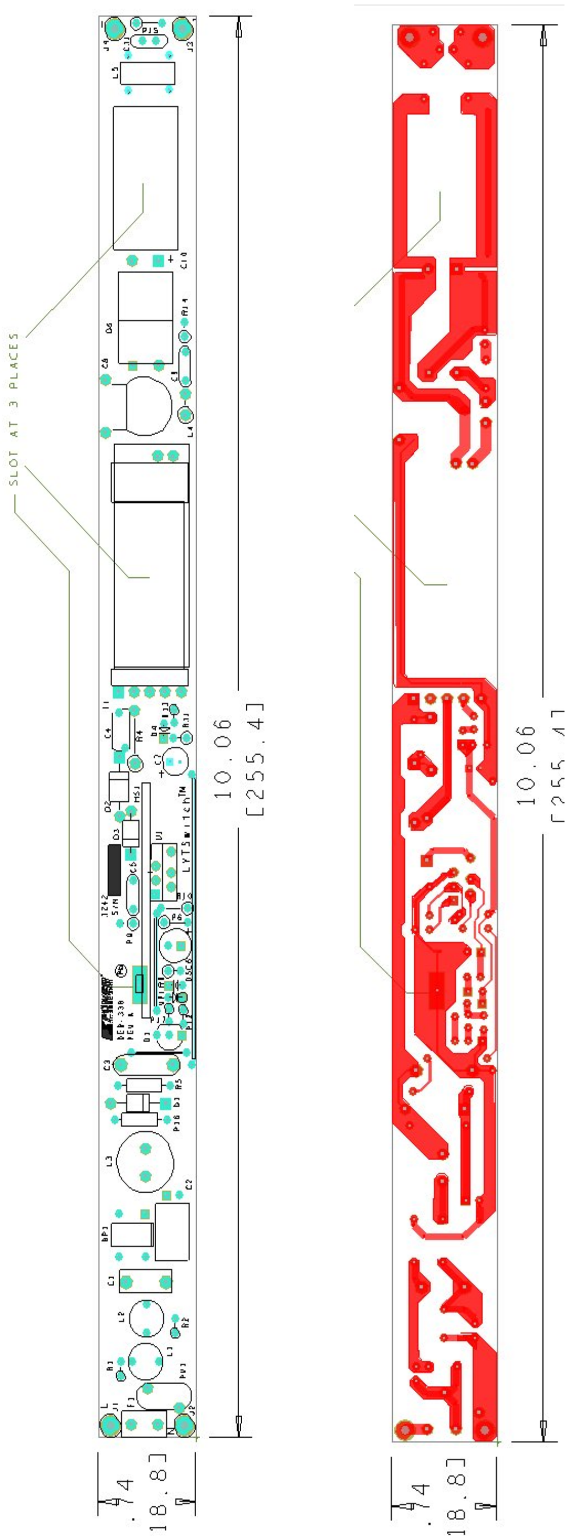

Figure 4 – PCB Layout, Outline and Silkscreen.

6 物料清单(BOM)

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	600 V, 1 A, Bridge Rectifier, DFM package	DF06M	Diodes, Inc.
2	1	C1	33 nF, 310 VAC, Polyester Film, X2	BFC233920333	Vishay
3	1	C2	1 μF, 400 V, Electrolytic, (6.3 x 11)	EKMG401ELL1R0MF11D	United Chemi-Con
4	1	C3	100 nF, 400 V, Film	ECQ-E4104KF	Panasonic
5	1	C4	2200 pF, 1 kV, Disc Ceramic	562R5GAD22	Vishay
6	1	C5	100 nF, 50 V, Ceramic, Z5U, .2Lead Space	C317C104M5U5TA	Kemet
7	1	C6	47 μF, 16 V, Electrolytic, Gen. Purpose, (6.3 x 7)	USA1C470MDD	Nichicon
8	1	C7	10 μF, 35 V, Electrolytic, Gen Purpose, (5 x 7)	UPW1V100MDD6	Nichicon
9	1	C8	2.2 nF, Ceramic, Y1	440LD22-R	Vishay
10	1	C9	150 pF, 1 kV, Disc Ceramic	NCD151K1KVY5F	NIC Components
11	1	C10	3300 μF, 100 V, Electrolytic, (12.5 x 25)	UVZ2A331MHD	Nichicon
12	1	C11	100 nF, 100 V, Ceramic, X7R	SR201C104KAR	AVX
13	1	D1	1000 V, 1 A, Rectifier, DO-41	1N4007-E3/54	Vishay
14	1	D2	400 V, 1 A, Ultrafast Recovery, 30 ns, SOD57	BYV26B	Philips
15	1	D3	400 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	UF4004-E3	Vishay
16	1	D4	250 V, 250 mA, Fast Switching, DO-35	BAV21	Vishay
17	1	D5	75 V, 300 mA, Fast Switching, DO-35	1N4148TR	Vishay
18	1	D6	300 V, 6 A, TO-220AC	LQA06T300	Power Integrations
19	1	F1	3.15 A, 250 V, Slow, RST	507-1181	Belfuse
20	1	HS1	Heat Sink, Custom, Al, 3003, 0.062" Thk		Custom
21	2	L1 L2	1 mH, 0.30 A, Ferrite Core	CTCH895F-102K	CT Parts
22	1	L3	470 μH, 0.38 A, Radial	TSL0808RA-471KR38-PF	TDK
23	1	L4	3.5 mm x 4.45 mm, 68 Ω at 100 MHz, #22 AWG hole, Ferrite Bead	2743001112	Fair-Rite
24	1	L5	Custom, 100 μH, constructed on Core# 35T0375-10H from PI# 32-00275-00		Power Integrations
25	1	Q1	NPN, Small Signal BJT, 40 V, 0.2 A, TO-92	2N3904RLRAG	On Semi
26	2	R1 R2	5.1 kΩ, 5%, 1/8 W, Carbon Film	CFR-12JB-5K1	Yageo
27	1	R4	200 kΩ, 5%, 1/2 W, Carbon Film	CFR-50JB-200K	Yageo
28	1	R5	1.5 MΩ, 1%, 1/4 W, Metal Film	RNF14FTD1M50	Stackpole
29	1	R6	604 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-604K	Yageo
30	1	R8	5.1 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-5K1	Yageo
31	1	R9	24.9 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-24K9	Yageo
32	1	R10	130 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-130K	Yageo
33	1	R11	10 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-10K	Yageo
34	1	R12	4.7 kΩ, 5%, 1/8 W, Carbon Film	CFR-12JB-4K7	Yageo
35	1	R13	51 Ω, 5%, 1/8 W, Carbon Film	CFR-12JB-51R	Yageo
36	1	R14	47 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-47R	Yageo
37	1	R15	20 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-20K	Yageo
38	1	R16	510 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-510K	Yageo
39	1	R17	100 Ω, 5%, 1/8 W, Carbon Film	CFR-12JB-100R	Yageo
40	1	RV1	140 V, 12 J, 7 mm, RADIAL	V140LA2P	Littlefuse
41	1	T1	Bobbin, EDR-2810, Horizontal, 9 pins		SBEF
42	1	U1	LYTSwitch, eSIP-7C	LYT4215E	Power Integrations
43	1	VR1	30 V, 5%, 500 mW, DO-35	1N5256B	Microsemi

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7 共模电感规格

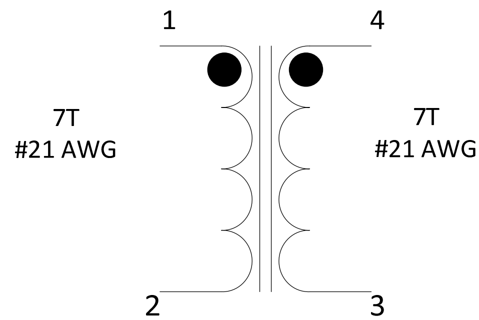

Figure 5 – CMC Electrical Diagram.

7.1 电气规格

Inductance (LCM)	Pins 1-2 or 3-4 measured at 100 kHz.	90 μH min.
Leakage (LL)	Pins 1-2 with pins 3-4 shorted or versa at 100 kHz.	1 μH

7.2 材料

Item	Description
[1]	Toroid Ferrite Core: 35T0375-10H Dimension: OD: 9.53 mm / ID: 4.75 mm / HT: 3.18 mm.
[2]	Magnet Wire: #24 AWG, Heavy Nyleze.

7.3 绕组说明

- Wind each winding individually and separated from each other.
- This will result in required leakage.
- Do not interleave both the windings.

8 变压器规格

8.1 电气原理图

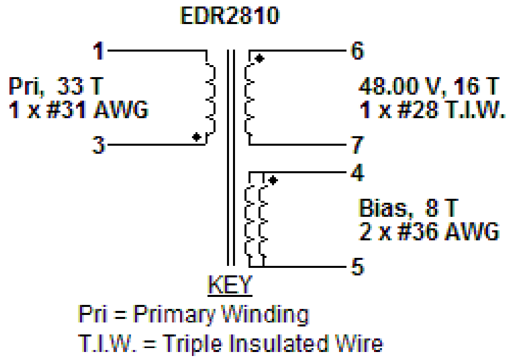

Figure 6 – Transformer Electrical Diagram.

8.2 电气规格

Electrical Strength	1 second, 60 Hz, from pins 1-3 to pins 6-7.	3000 VAC
Primary Inductance	Pins 1-3, all other windings open, measured at 100 kHz, 0.4 $V_{RMS.}$	925 µH, ±10%
Resonant Frequency	Pins 1-3, all other windings open.	800 kHz (Min.)
Primary Leakage Inductance	Pins 1-3, with pins 6-7 shorted, measured at 100 kHz, 0.4 $V_{RMS.}$	50 µH (Max.)

8.3 材料

Item	Description
[1]	Core: EDR2810, AL= 849 nH/N^2.
[2]	Bobbin: Vertical Generic, 5 pri. + 2 sec.
[3]	Barrier Tape: Polyester film [1 mil (25 µm) base thickness], 4.60 mm wide.
[4]	Copper Tape: 2 mil thick.
[5]	Magnet Wire: #31 AWG, Solderable Double Coated.
[6]	Magnet Wire: #36 AWG, Solderable Double Coated.
[8]	Triple Insulated Wire: #28 AWG.
[8]	Varish.

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8.4 变压器结构图

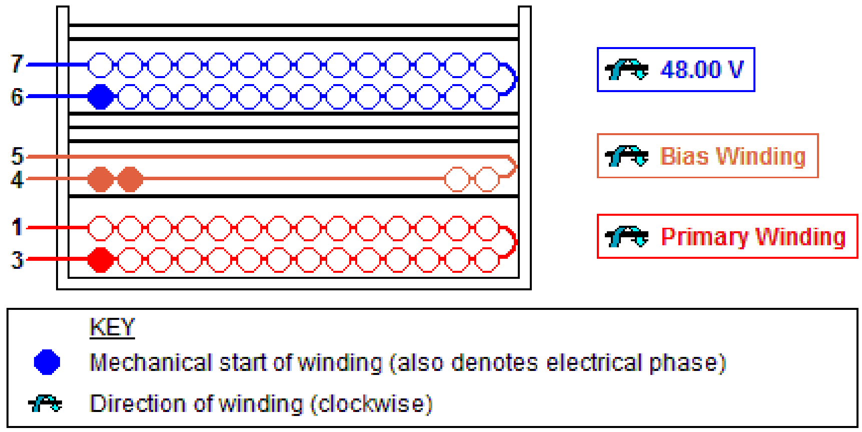

Figure 7 – Transformer Build Diagram.

8.5 变压器构造

Bobbin Preparation	Pull-out pin number 8. Position the bobbin such that the pins are on the left side of the bobbin chuck. Machine rotates in forward direction.
WDG1 Primary 1	Start at pin 3; wind with firm tension 33 turns of item [5] in 2 layers from left to right. At the end of 1st layer, continue to wind the next layer from right to left. On the final layer, spread the winding evenly across entire bobbin. Finish this winding on pin(s) 1
Insulation	1 layer of tape [3] for insulation.
WDG2 Bias	Start on pin(s) 4 and wind 8 turns (x 2 filar) of item [6]. Wind in same rotational direction as primary winding. Spread the winding evenly across entire bobbin. Finish this winding on pin(s) 5.
Insulation	3 layer of tape [3] for insulation.
WDG3 Secondary	Start on pin(s) 6 and wind 16 turns (x 1 filar) of item [7]. Spread the winding evenly across entire bobbin. Wind in same rotational direction as primary winding. Finish this winding on pin(s) 7.
Insulation	2 layers of tape [3] for insulation.
Assemble Core	Assemble and secure the cores.
Flux Band	Construct a flux band by wrapping a single shorted turn of item [4] around the outside of windings and core halves with tight tension. Make an electrical connection to pin(s) 5 using wire. Add 3 layers of tape, item [3], for insulation.
Finish	Varnish transformer assembly.

9 变压器设计表格

ACDC_LYTSwitch_101112; Rev.1.0; Copyright Power Integrations 2012	INPUT	OUTPUT	UNIT	LYTSwitch_101112: Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES				
Dimming required	No	NO		Select 'YES' option if dimming is required. Otherwise select 'NO'.
VACMIN		90	V	Minimum AC Input Voltage
VACMAX		132	V	Maximum AC input voltage
fL		60	Hz	AC Mains Frequency
VO	50	50	V	Typical output voltage of LED string at full load
VO_MAX		55	V	Maximum expected LED string Voltage.
VO_MIN		45	V	Minimum expected LED string Voltage.
V_OVP		58	V	Over-voltage protection setpoint
IO	0.43	0.43	A	Typical full load LED current
PO		21.5	W	Output Power
n	0.85	0.85		Estimated efficiency of operation
VB	20	20	V	Bias Voltage
ENTER LYTSwitch VARIABLES				
LYTSwitch	LYT4215	LYT4215	Universal	115 Doubled/230V
Current Limit Mode	RED	RED		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN		1.42	A	Minimum current limit
ILIMITMAX		1.66	A	Maximum current limit
fS		132000	Hz	Switching Frequency
fSmin		124000	Hz	Minimum Switching Frequency
fSmax		140000	Hz	Maximum Switching Frequency
IV		76.02	uA	V pin current
RV	2.1	2.1	M-ohms	Upper V pin resistor
RV2		1E+12	M-ohms	Lower V pin resistor
IFB	180	180	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1		94.44	k-ohms	FB pin resistor
VDS		10	V	LYTSwitch on-state Drain to Source Voltage
VD		0.5	V	Output Winding Diode Forward Voltage Drop (0.5 V for Schottky and 0.8 V for PN diode)
VDB		0.7	V	Bias Winding Diode Forward Voltage Drop
Key Design Parameters				
KP	0.6084	0.61		Ripple to Peak Current Ratio (For PF > 0.9, 0.4 < KP < 0.9)
LP		925.00	uH	Primary Inductance
VOR	105	105.00	V	Reflected Output Voltage.
Expected IO (average)		0.41	A	Expected Average Output Current
KP_VACMAX		0.64		Expected ripple current ratio at VACMAX
TON_MIN		2.73	us	Minimum on time at maximum AC input voltage
PCLAMP		0.19	W	Estimated dissipation in primary clamp
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES				
Core Type	EDR2810	EDR2810		
Bobbin			P/N:	#N/A
AE	0.84	0.84	cm^2	Core Effective Cross Sectional Area
LE	2.46	2.46	cm	Core Effective Path Length
AL	5700	5700	nH/T^2	Ungapped Core Effective Inductance
BW	4.6	4.6	mm	Bobbin Physical Winding Width
M		0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)

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L		3		Number of Primary Layers
NS	16	16		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS				
VMIN		127.28	V	Peak input voltage at VACMIN
VMAX		186.68	V	Peak input voltage at VACMAX
CURRENT WAVEFORM SHAPE PARAMETERS				
DMAX		0.47		Minimum duty cycle at peak of VACMIN
IAVG		0.23	A	Average Primary Current
IP		0.93	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS		0.33	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS				
LP		925.00	uH	Primary Inductance
LP_TOL		10.00		Tolerance of primary inductance
NP		33.27		Primary Winding Number of Turns
NB		6.56		Bias Winding Number of Turns
ALG		835.81	nH/T^2	Gapped Core Effective Inductance
BM		3062.70	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP		3573.15	Gauss	Peak Flux Density (BP<3700)
BAC		931.60	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur		1328.37		Relative Permeability of Ungapped Core
LG		0.11	mm	Gap Length (Lg > 0.1 mm)
BWE		13.80	mm	Effective Bobbin Width
OD		0.41	mm	Maximum Primary Wire Diameter including insulation
INS		0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA		0.35	mm	Bare conductor diameter
AWG		28.00	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM		161.27	Cmils	Bare conductor effective area in circular mils
CMA		485.20	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 600)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)				
Lumped parameters				
ISP		1.92	A	Peak Secondary Current
ISRMS		0.68	A	Secondary RMS Current
IRIPPLE		0.53	A	Output Capacitor RMS Ripple Current
CMS		136.19	Cmils	Secondary Bare Conductor minimum circular mils
AWGS		28	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS		0.32	mm	Secondary Minimum Bare Conductor Diameter
ODS		0.29	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
VOLTAGE STRESS PARAMETERS				
VDRAIN		402.85	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage
PIVS		148.12	V	Output Rectifier Maximum Peak Inverse Voltage
PIVB		60.14	V	Bias Rectifier Maximum Peak Inverse Voltage

10 散热片装配

10.1 散热片加工图

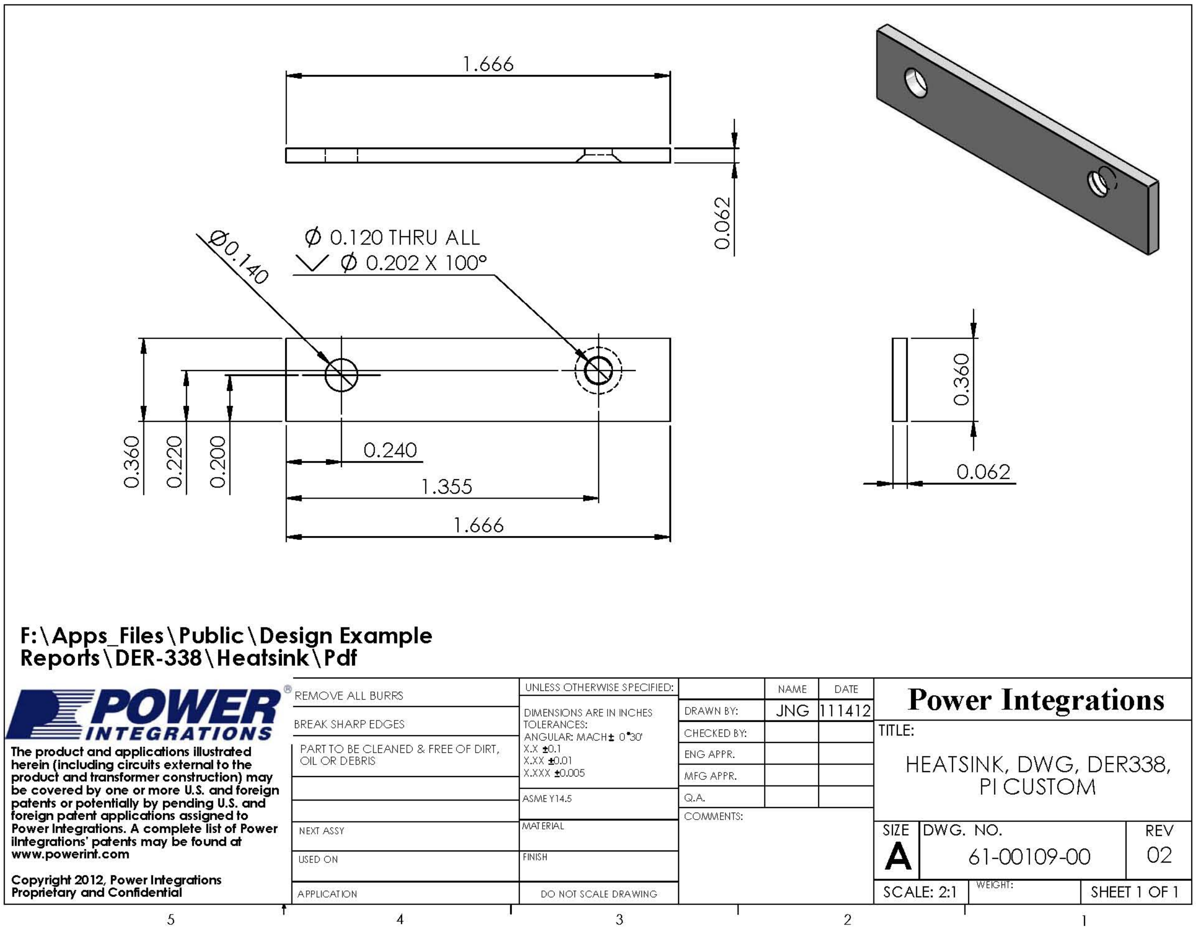

Figure 8 – Heat Sink Fabrication Drawing.

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10.2 散热片装配图

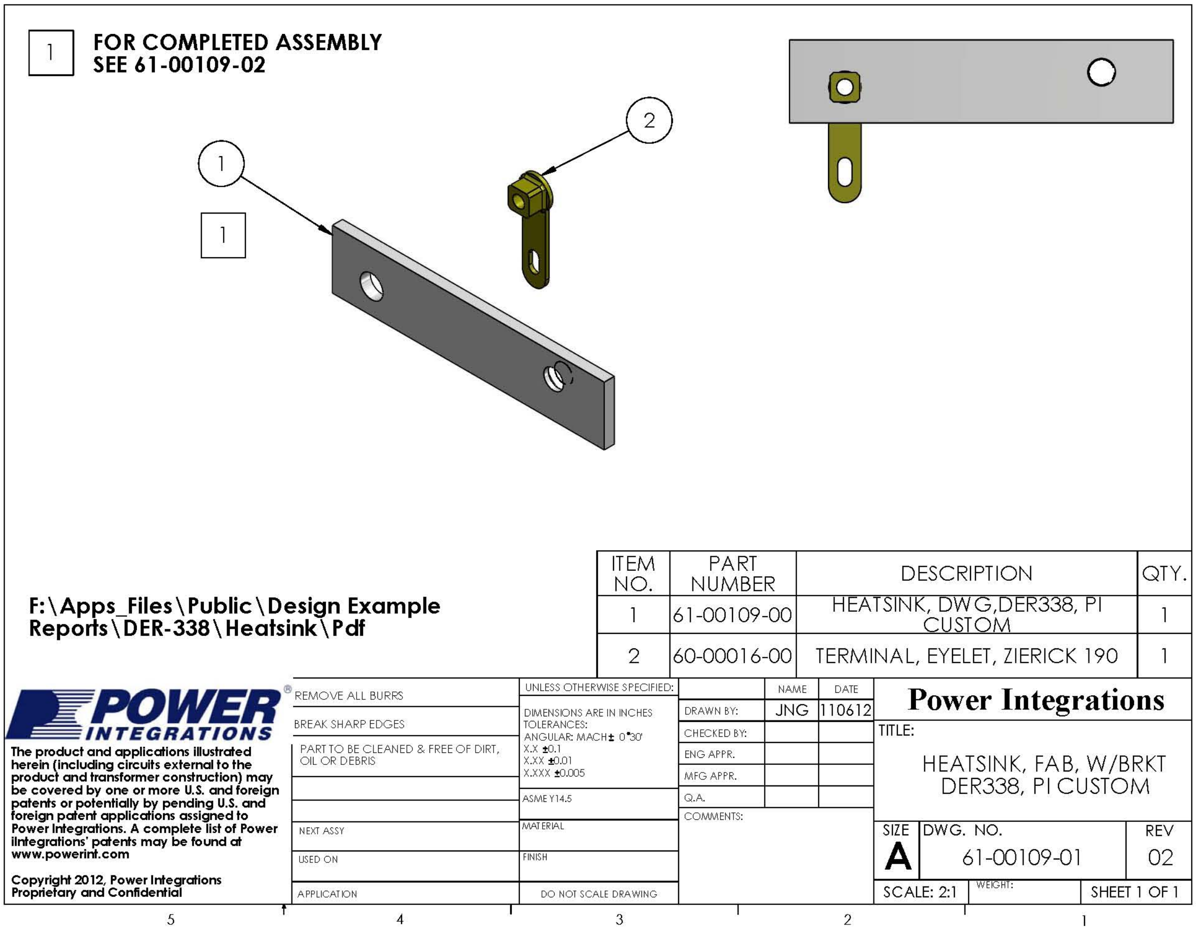
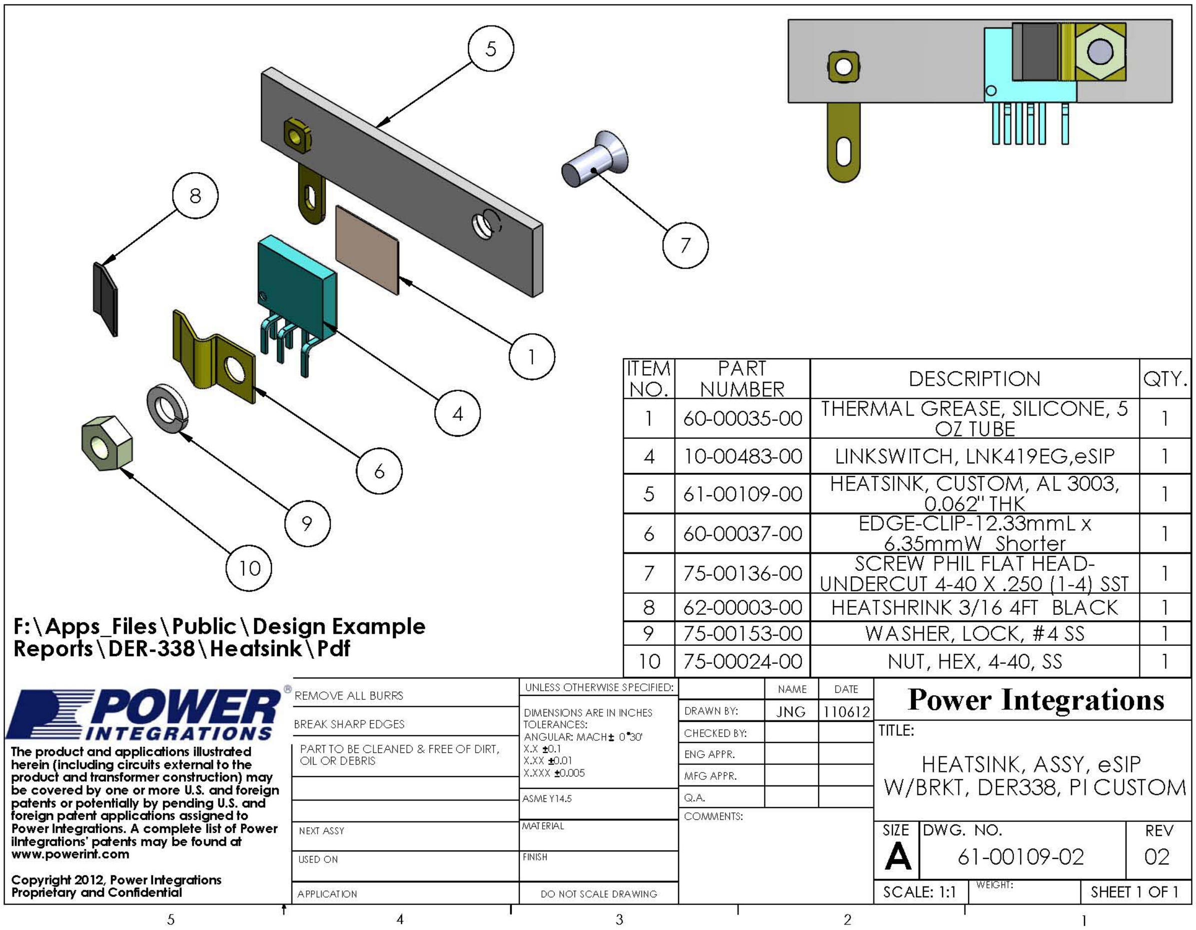


Figure 9 – Heat Sink Assembly Drawing.

10.3 散热片和LYTSwitch装配图



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	60-00035-00	THERMAL GREASE, SILICONE, 5 OZ TUBE	1
4	10-00483-00	LINKSWITCH, LNK419EG,eSIP	1
5	61-00109-00	HEATSINK, CUSTOM, AL 3003, 0.062" THK	1
6	60-00037-00	EDGE-CLIP-12.33mmL x 6.35mmW Shorter	1
7	75-00136-00	SCREW PHIL FLAT HEAD-UNDERCUT 4-40 X .250 (1-4) SST	1
8	62-00003-00	HEATSHRINK 3/16 4FT BLACK	1
9	75-00153-00	WASHER, LOCK, #4 SS	1
10	75-00024-00	NUT, HEX, 4-40, SS	1

Figure 10 – Heat Sink and LYTSwitch Assembly Drawing.

11 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 a voltage of 45 V ~ 55 V. The table in Section 11.6 shows complete test data values.

11.1 效率

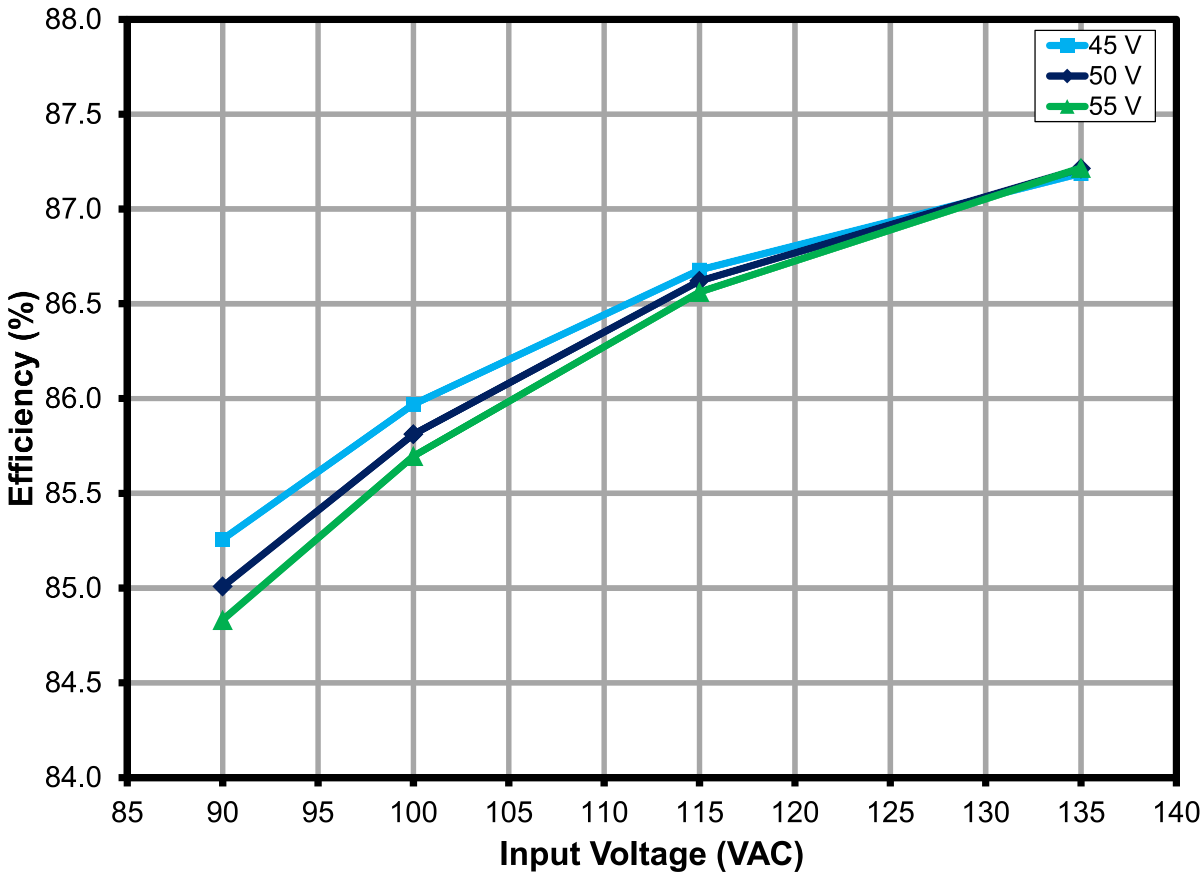


Figure 11 – Efficiency vs. Line and Load.

11.2 输入电压调整率和负载调整率

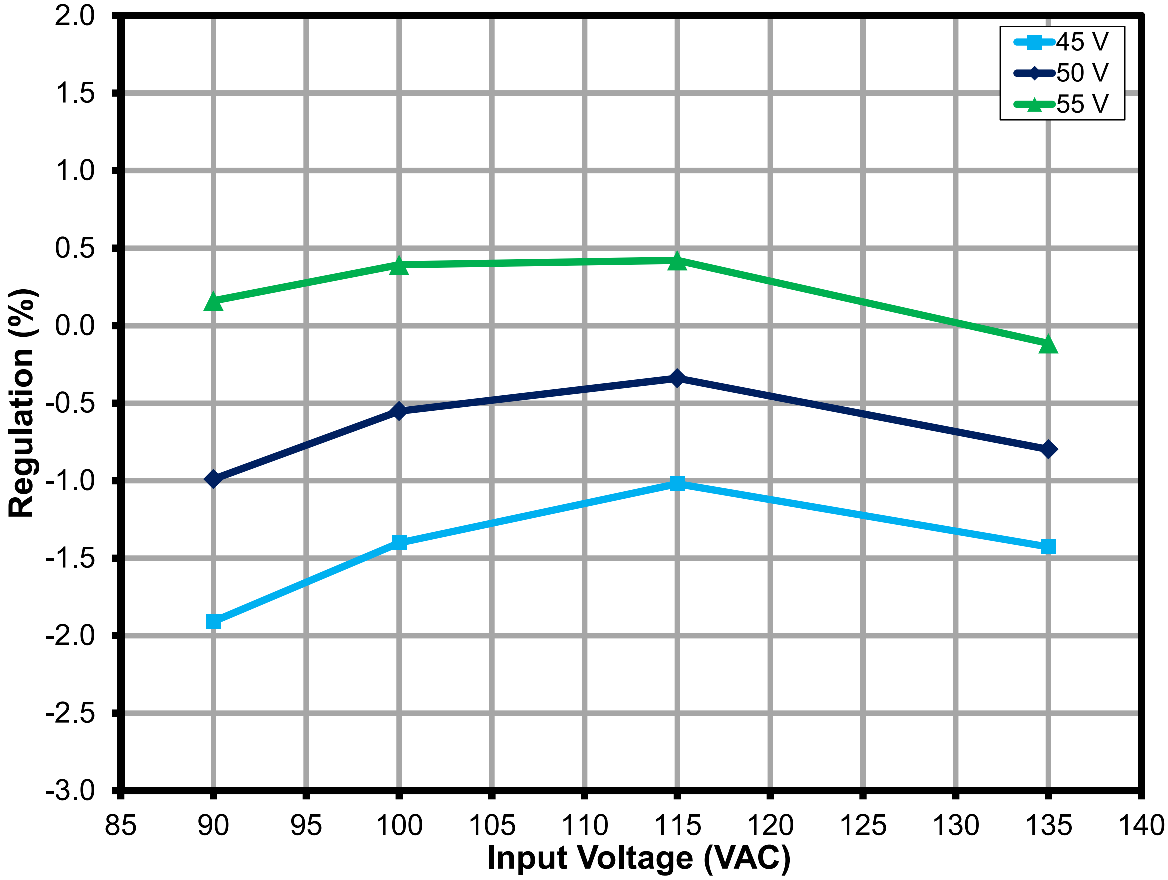


Figure 12– Regulation vs. Line and Load.

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11.3 功率因数

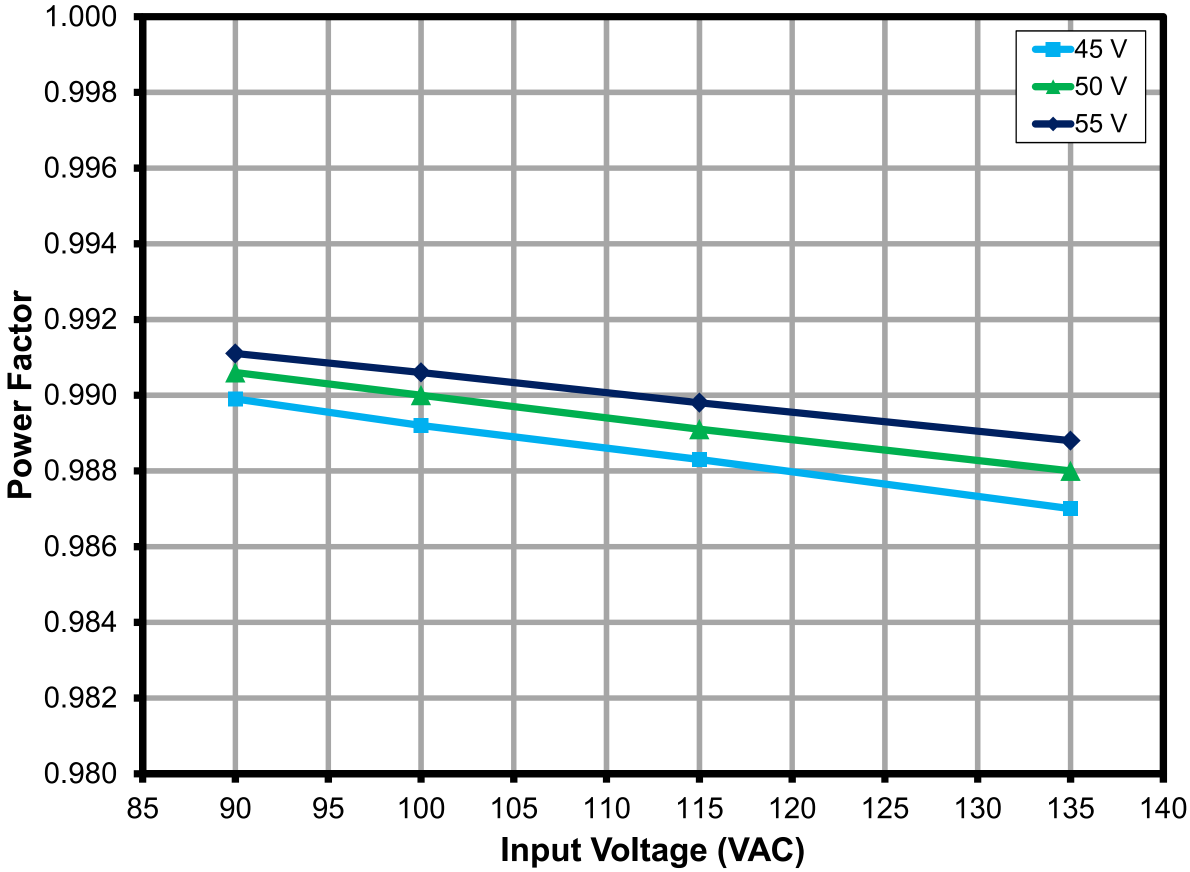

Figure 13 – Power Factor vs. Line and Load.

11.4 A-THD

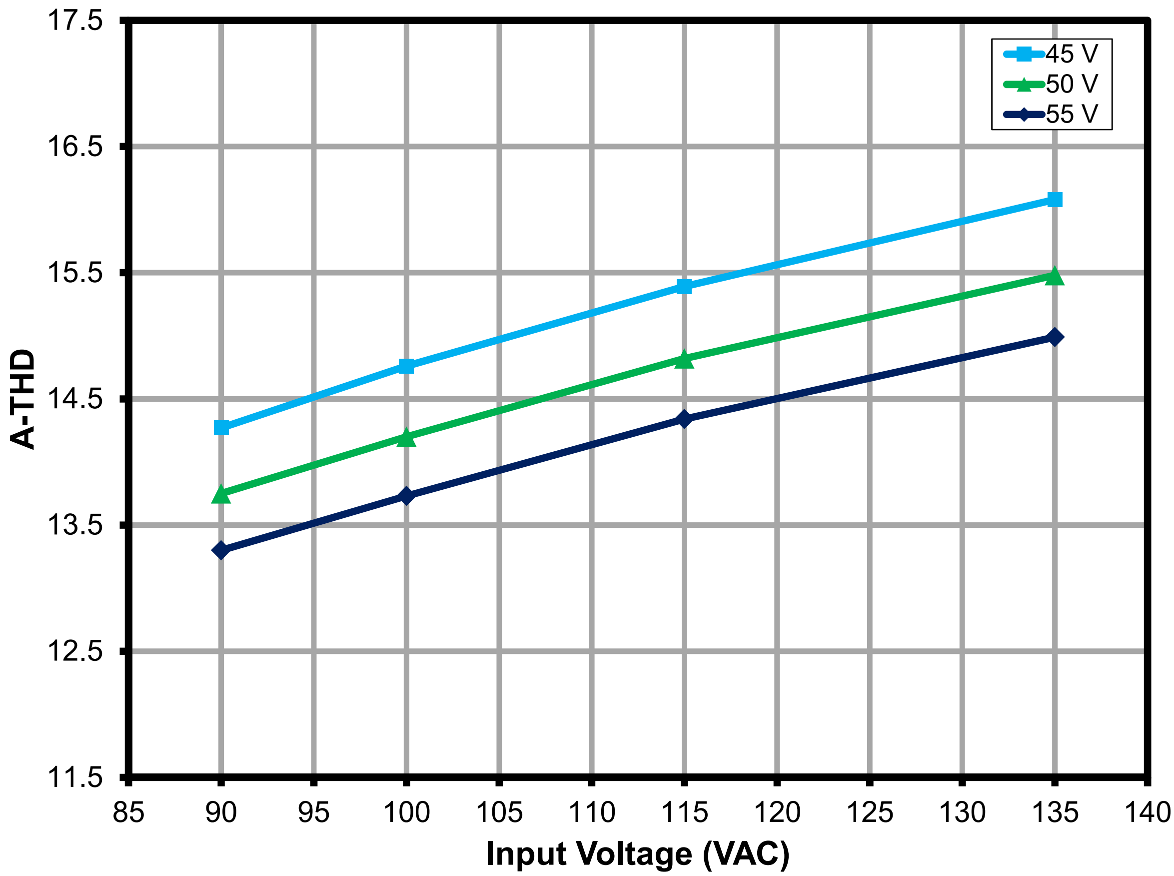

Figure 14 – A-THD vs. Line and Load.

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11.5 谐波电流

The design was made to meet the IEC61000-3-2 Limits for Class C equipment (section 7.3-a) for an Active input power of > 25 W, which states that the harmonic currents shall not exceed the related limits given in Table 2 - Limits for Class C equipment. For multiple units operating in parallel, all units can pass Class C limits as well.

11.5.1 45 V LED负载

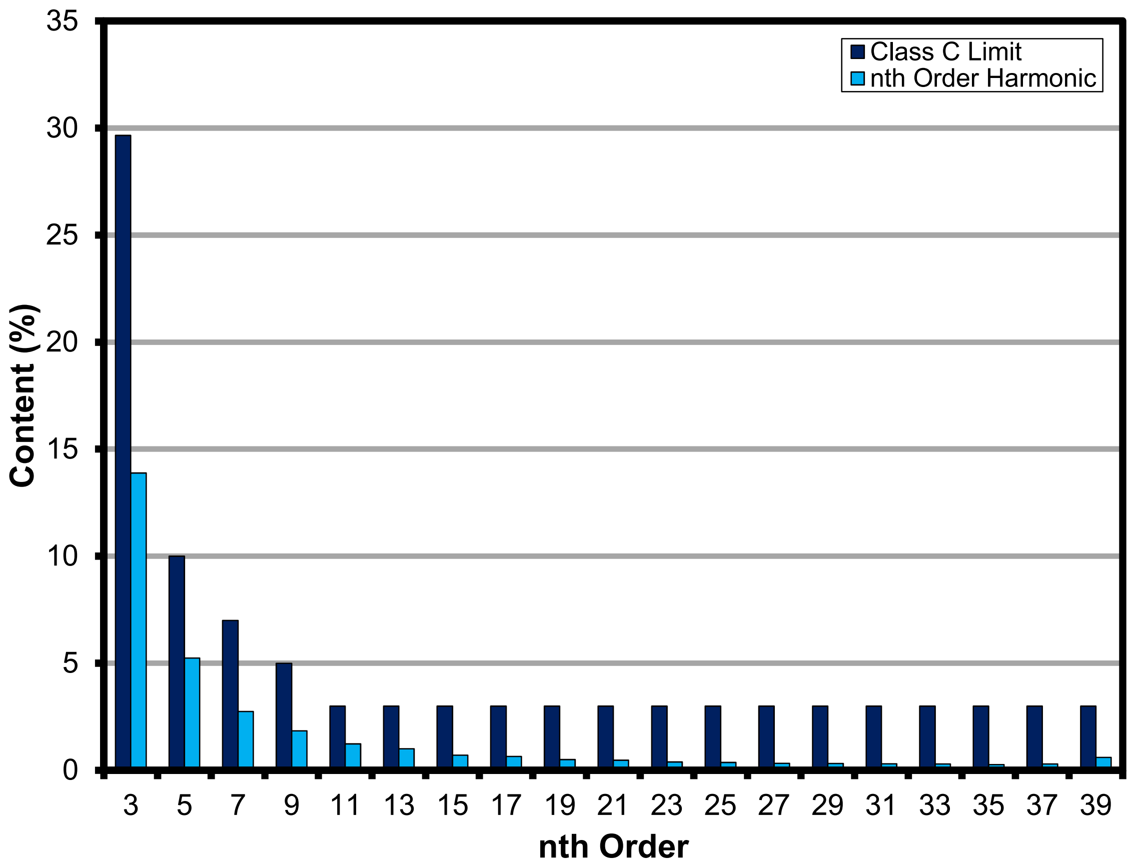

Figure 15 – 45 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

11.5.2 50 V LED负载

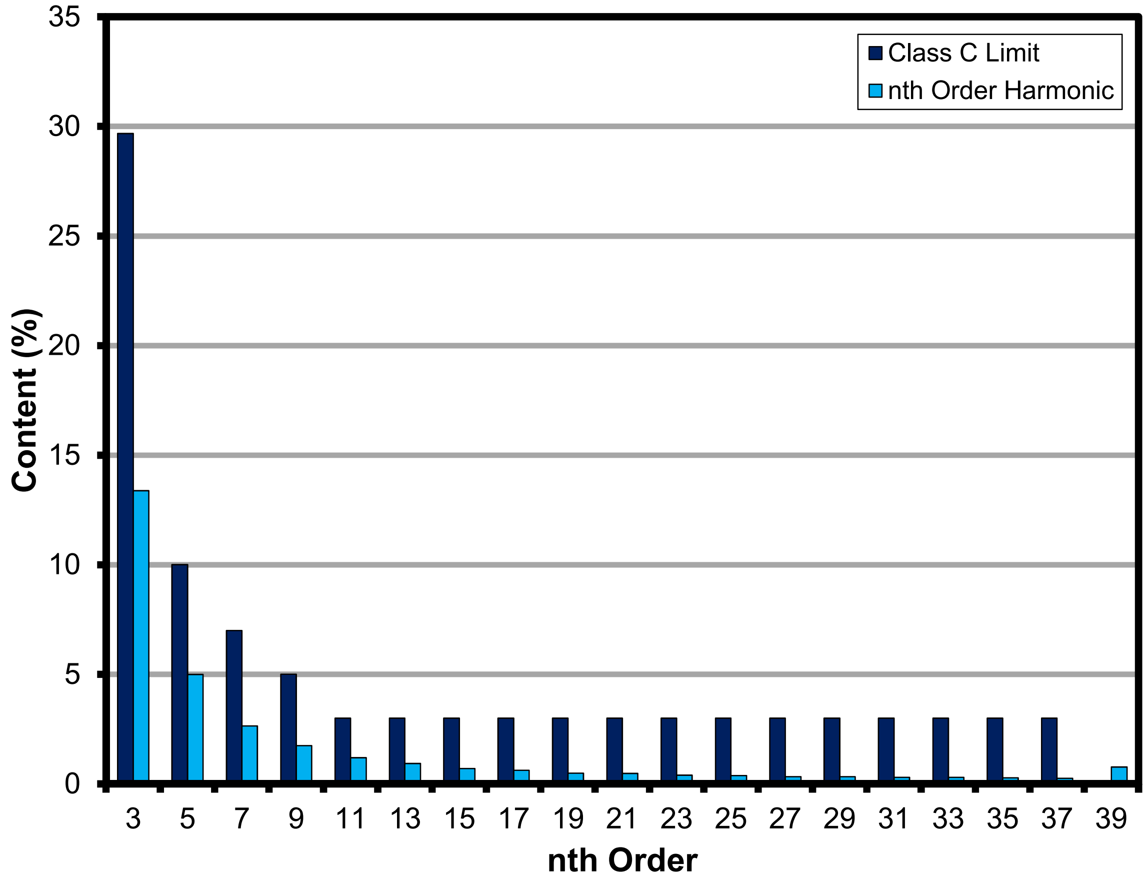

Figure 16 – 50 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

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11.5.3 55 V LED负载

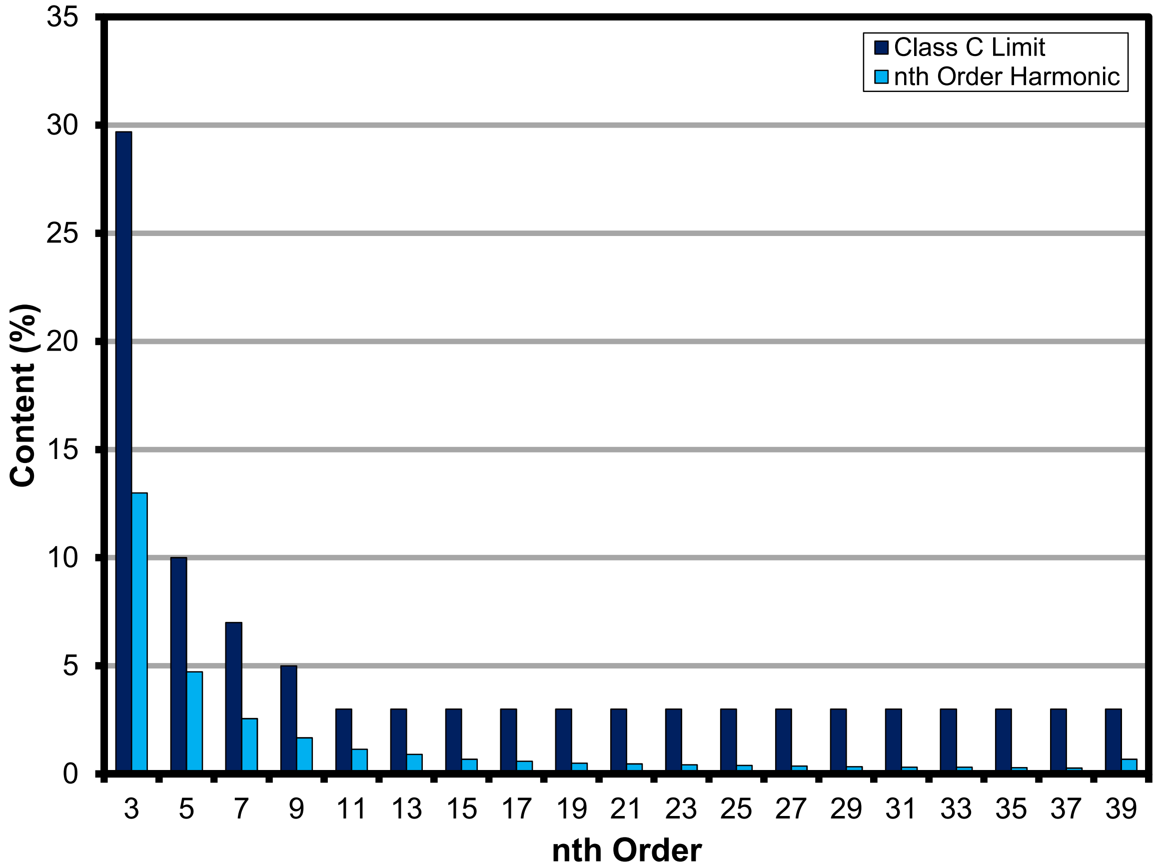

Figure 17 – 55 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

11.6 测试数据

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

11.6.1 测试数据，45 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	89.90	249.70	22.221	0.990	14.27	44.5730	421.790	18.945	18.80	85.26	3.28
100	60	99.94	224.01	22.146	0.989	14.76	44.5660	423.970	19.039	18.89	85.97	3.11
115	60	114.96	194.05	22.047	0.988	15.39	44.5620	425.610	19.110	18.97	86.68	2.94
135	60	134.96	163.78	21.816	0.987	16.08	44.5420	423.860	19.021	18.88	87.19	2.80

11.6.2 测试数据，50 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	89.90	280.67	24.994	0.991	13.75	49.5590	425.740	21.247	21.10	85.01	3.75
100	60	99.94	251.31	24.864	0.990	14.2	49.5470	427.630	21.336	21.19	85.81	3.53
115	60	114.96	217.04	24.679	0.989	14.82	49.5400	428.540	21.377	21.23	86.62	3.30
135	60	134.95	182.88	24.385	0.988	15.48	49.5190	426.570	21.267	21.12	87.21	3.12

11.6.3 测试数据，55 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	89.90	309.39	27.566	0.991	13.3	53.9570	430.690	23.385	23.24	84.83	4.18
100	60	99.94	276.17	27.341	0.991	13.73	53.9370	431.690	23.430	23.28	85.70	3.91
115	60	114.96	237.84	27.064	0.990	14.34	53.9210	431.810	23.427	23.28	86.56	3.64
135	60	134.95	200.08	26.700	0.989	14.99	53.8900	429.510	23.287	23.15	87.22	3.41

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11.6.4 115 VAC 60 Hz，45 V LED负载谐波数据

V	Freq	I (mA)	P	PF	%THD
115	60.00	194.05	22.0470	0.9883	15.39
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**% Limit >25 W**	**Remarks**
1	191.84				
2	0.07	0.04%		2.00%	Pass
3	26.64	13.89%	149.9196	29.65%	Pass
5	10.06	5.24%	83.7786	10.00%	Pass
7	5.28	2.75%	44.0940	7.00%	Pass
9	3.54	1.85%	22.0470	5.00%	Pass
11	2.37	1.24%	15.4329	3.00%	Pass
13	1.93	1.01%	13.0586	3.00%	Pass
15	1.36	0.71%	11.3175	3.00%	Pass
17	1.23	0.64%	9.9860	3.00%	Pass
19	0.96	0.50%	8.9348	3.00%	Pass
21	0.90	0.47%	8.0839	3.00%	Pass
23	0.75	0.39%	7.3810	3.00%	Pass
25	0.71	0.37%	6.7905	3.00%	Pass
27	0.62	0.32%	6.2875	3.00%	Pass
29	0.61	0.32%	5.8539	3.00%	Pass
31	0.58	0.30%	5.4762	3.00%	Pass
33	0.56	0.29%	5.1443	3.00%	Pass
35	0.51	0.27%	4.8503	3.00%	Pass
37	0.56	0.29%	4.5882	3.00%	Pass
39	1.16	0.60%	4.3529	3.00%	Pass

11.6.5 115 VAC 60 Hz，50 V LED负载谐波数据

V	Freq	I (mA)	P	PF	%THD
115	60.00	217.04	24.6790	0.9891	14.82
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**% Limit >25 W**	**Remarks**
1	214.72				
2	0.06	0.03%		2.00%	Pass
3	28.72	13.38%	167.8172	29.67%	Pass
5	10.73	5.00%	93.7802	10.00%	Pass
7	5.68	2.65%	49.3580	7.00%	Pass
9	3.75	1.75%	24.6790	5.00%	Pass
11	2.57	1.20%	17.2753	3.00%	Pass
13	2.00	0.93%	14.6176	3.00%	Pass
15	1.50	0.70%	12.6686	3.00%	Pass
17	1.33	0.62%	11.1781	3.00%	Pass
19	1.05	0.49%	10.0015	3.00%	Pass
21	1.03	0.48%	9.0490	3.00%	Pass
23	0.85	0.40%	8.2621	3.00%	Pass
25	0.81	0.38%	7.6011	3.00%	Pass
27	0.70	0.33%	7.0381	3.00%	Pass
29	0.70	0.33%	6.5527	3.00%	Pass
31	0.65	0.30%	6.1299	3.00%	Pass
33	0.64	0.30%	5.7584	3.00%	Pass
35	0.59	0.27%	5.4294	3.00%	Pass
37	0.55	0.26%	5.1359	3.00%	Pass
39	1.65	0.77%	4.8725	3.00%	Pass

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11.6.6 115 VAC 60 Hz，55 V LED负载谐波数据

V	Freq	I (mA)	P	PF	%THD
115	60.00	237.84	27.0640	0.9898	14.34
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**% Limit >25 W**	**Remarks**
1	235.40				
2	0.06	0.03%		2.00%	Pass
3	30.58	12.99%	184.0352	29.69%	Pass
5	11.11	4.72%	102.8432	10.00%	Pass
7	6.02	2.56%	54.1280	7.00%	Pass
9	3.94	1.67%	27.0640	5.00%	Pass
11	2.68	1.14%	18.9448	3.00%	Pass
13	2.13	0.90%	16.0302	3.00%	Pass
15	1.60	0.68%	13.8929	3.00%	Pass
17	1.38	0.59%	12.2584	3.00%	Pass
19	1.17	0.50%	10.9680	3.00%	Pass
21	1.10	0.47%	9.9235	3.00%	Pass
23	1.00	0.42%	9.0606	3.00%	Pass
25	0.93	0.40%	8.3357	3.00%	Pass
27	0.86	0.37%	7.7183	3.00%	Pass
29	0.78	0.33%	7.1860	3.00%	Pass
31	0.73	0.31%	6.7223	3.00%	Pass
33	0.73	0.31%	6.3149	3.00%	Pass
35	0.70	0.30%	5.9541	3.00%	Pass
37	0.63	0.27%	5.6322	3.00%	Pass
39	1.61	0.68%	5.3434	3.00%	Pass

12 热性能

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

12.1 V_{IN} = 115 VAC，60 Hz，50 V LED负载

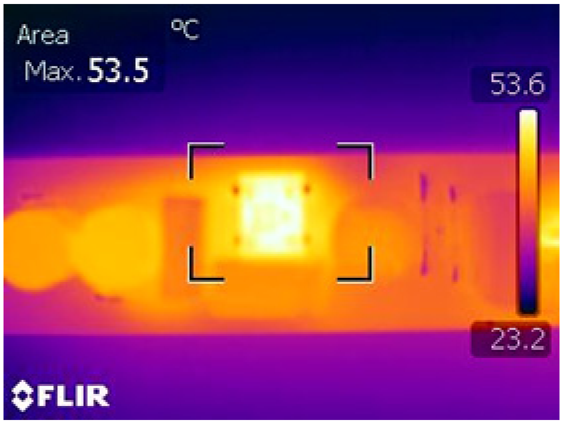

Figure 18 – Input Area. 115 VAC, 60 Hz.

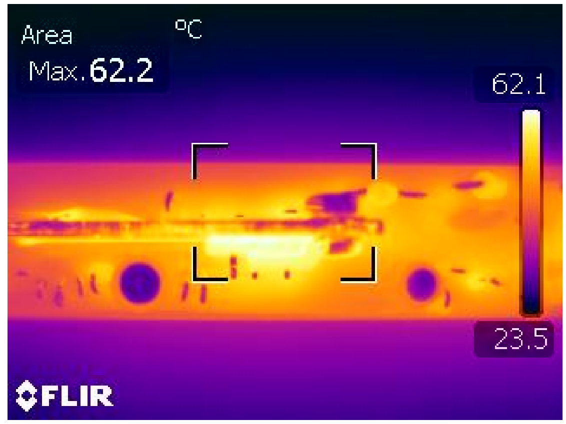

Figure 19 – LYT4215E Area. 115 VAC, 60 Hz.

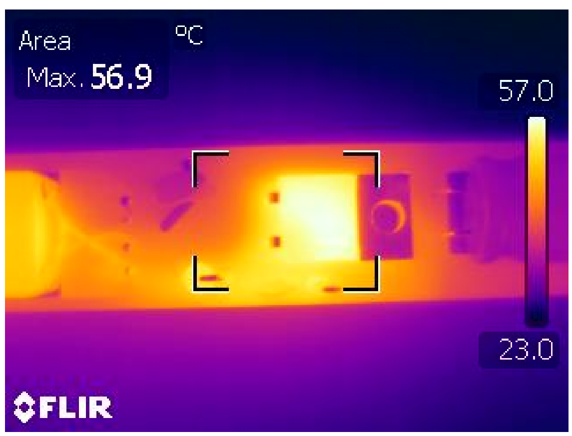

Figure 20 – Transformer and Output Area. 115 VAC, 60 Hz.

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13 波形

13.1 输入电压和输入电流波形

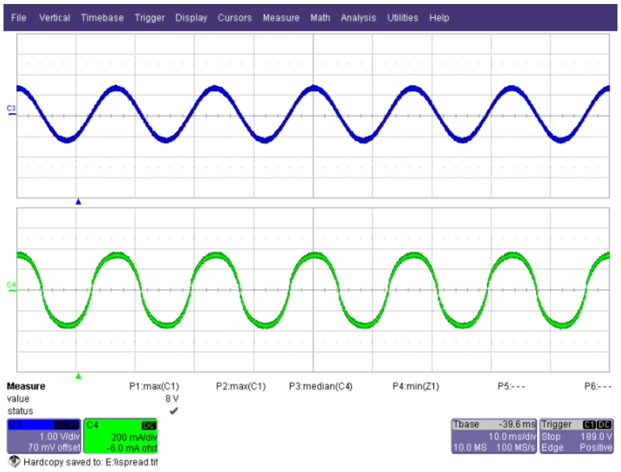

Figure 21 – 90 VAC, Full Load.
Upper: V_{IN}, 100 V / div.
Lower: I_{IN}, 200 mA, 10 ms / div.

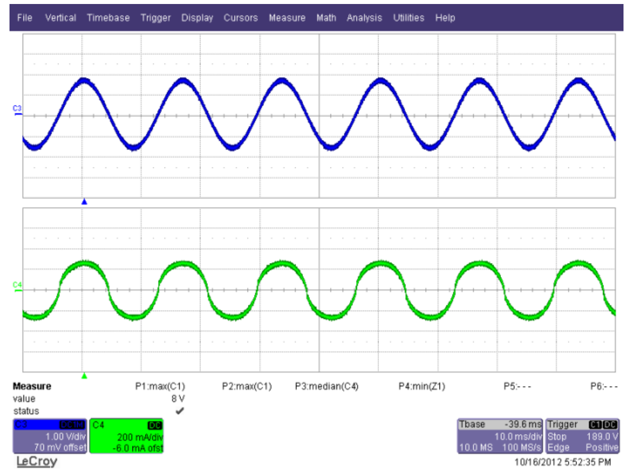

Figure 22 – 115 VAC, Full Load.
Upper: V_{IN}, 100 V / div.
Lower: I_{IN}, 200 mA, 10 ms / div.

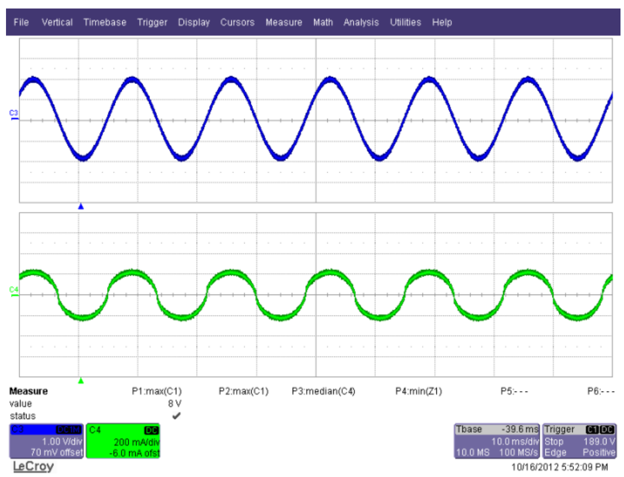

Figure 23 – 135 VAC, Full Load.
Upper: V_{IN}, 100 V / div.
Lower: I_{IN}, 200 mA, 10 ms / div.

13.2 输出电压和输出电流波形

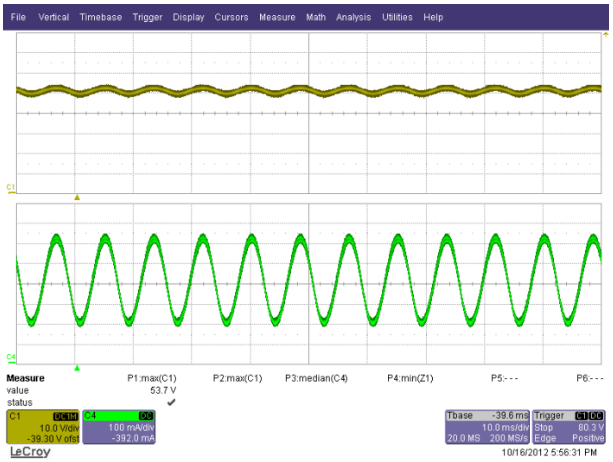

Figure 24 – 90 VAC, 60 Hz Full Load.
Upper: V_{OUT}, 10 V / div.
Lower: I_{OUT}, 100 mA, 10 ms / div.

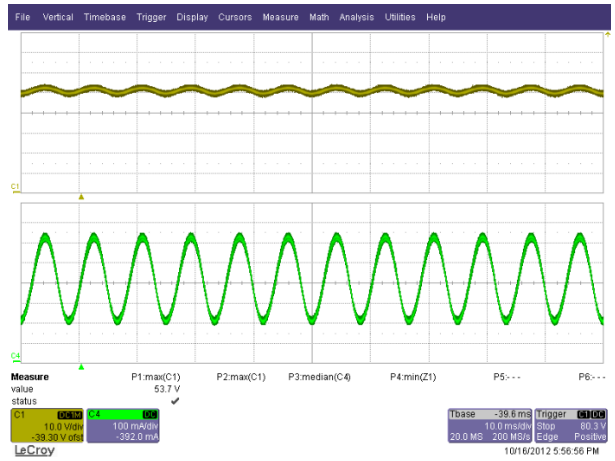

Figure 25 – 115 VAC, 60 Hz Full Load.
Upper: V_{OUT}, 10 V / div.
Lower: I_{OUT}, 100 mA, 10 ms / div.

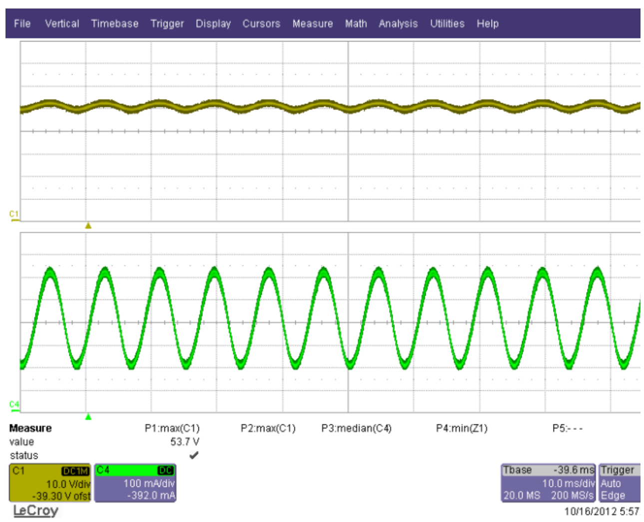

Figure 26 – 135 VAC, 60 Hz Full Load.
Upper: V_{OUT}, 10 V / div.
Lower: I_{OUT}, 100 mA, 10 ms / div.

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13.3 启动时的输出电压和输出电流波形

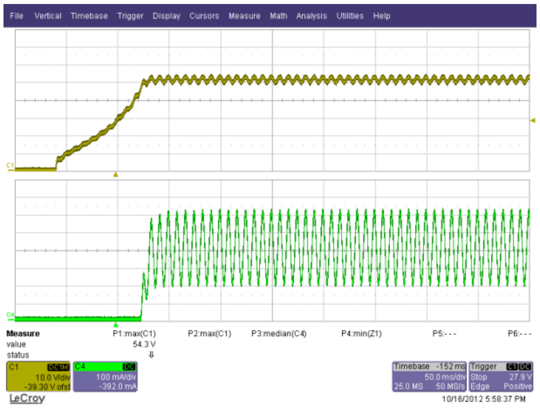

Figure 27 – 90 VAC Output Rise.
Upper: V_{OUT}, 10 V / div.
Lower: I_{OUT}, 100 mA, 50 ms / div.

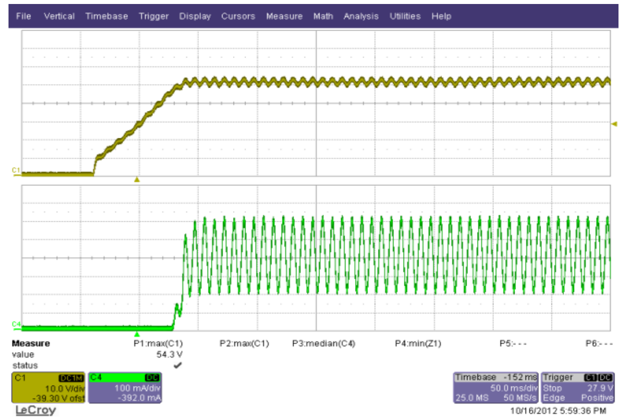

Figure 28 – 135 VAC Output Fall.
Upper: V_{OUT}, 10 V / div.
Lower: I_{OUT}, 100 mA, 100 ms / div.

13.4 启动时的漏极电压和电流波形

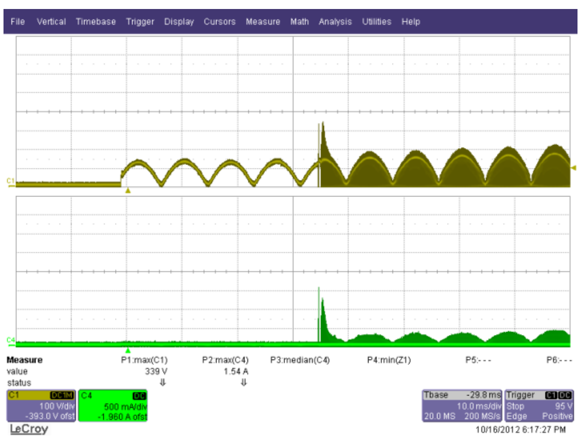

Figure 29 – 90 VAC, 60 Hz Start-up.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA, 10 ms / div.

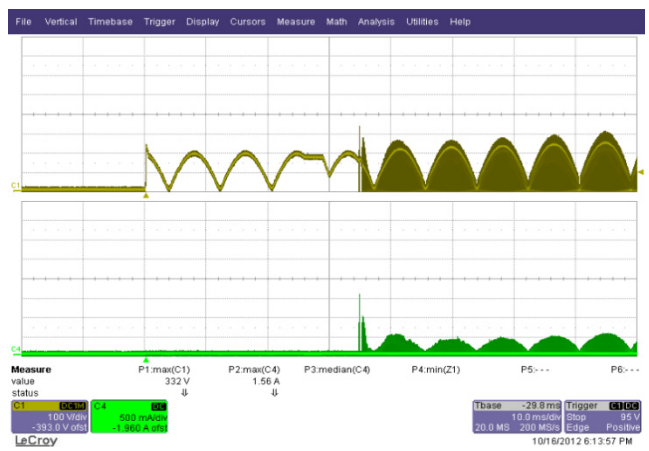

Figure 30 – 135 VAC, 60 Hz Start-up.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA, 10 ms / div.

13.5 启动时的输入电压和输出电流波形

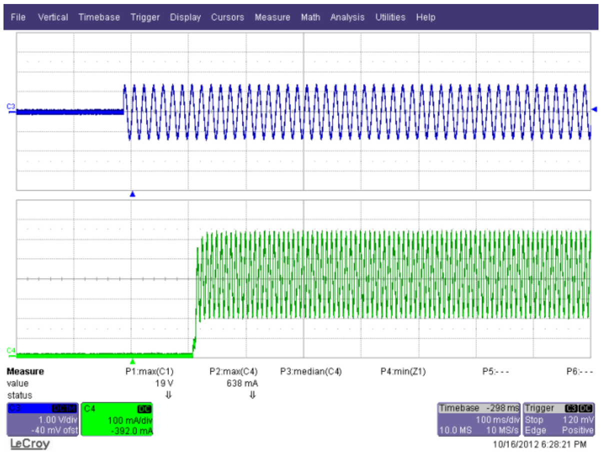

Figure 31 – 90 VAC, 60 Hz.
Upper: V_{IN}, 100 V / div.
Lower: I_{OUT}, 100 mA, 100 ms / div.

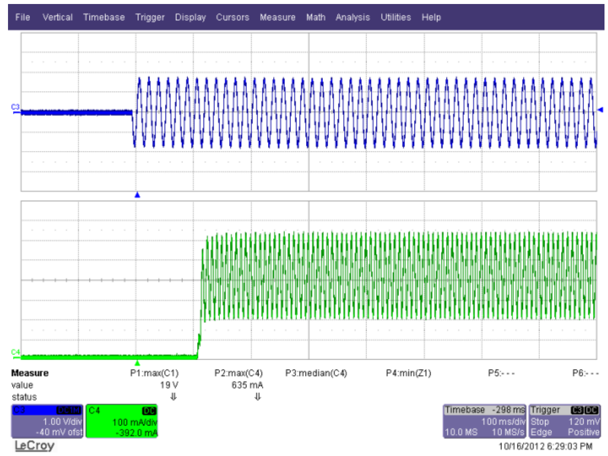

Figure 32 – 115 VAC, 60 Hz.
Upper: V_{IN}, 100 V / div.
Lower: I_{OUT}, 100 mA, 100 ms / div.

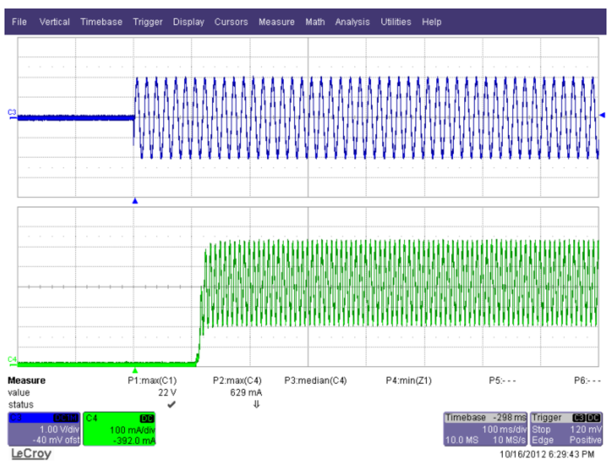

Figure 33 – 135 VAC, 60 Hz.
Upper: V_{IN}, 100 V / div.
Lower: I_{OUT}, 100 mA, 100 ms / div.

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13.6 漏极电压和电流波形

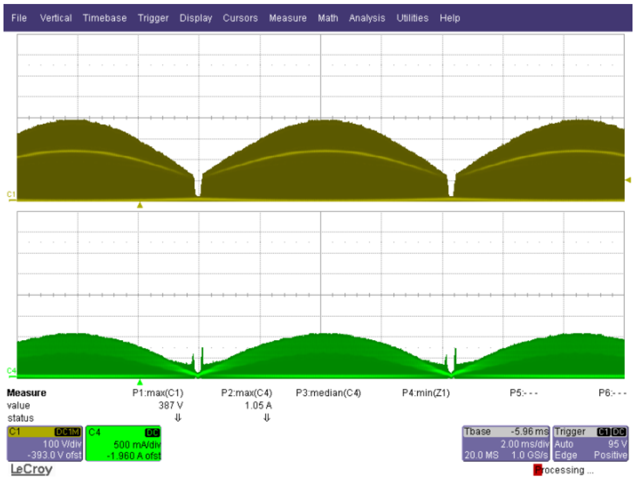

Figure 34 – 90 VAC, 60 Hz.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA, 2 ms / div.

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

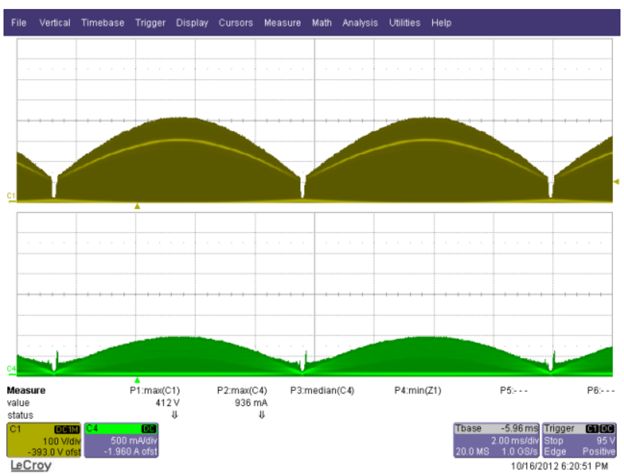

Figure 36 – 135 VAC, 60 Hz.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA, 2 ms / div.

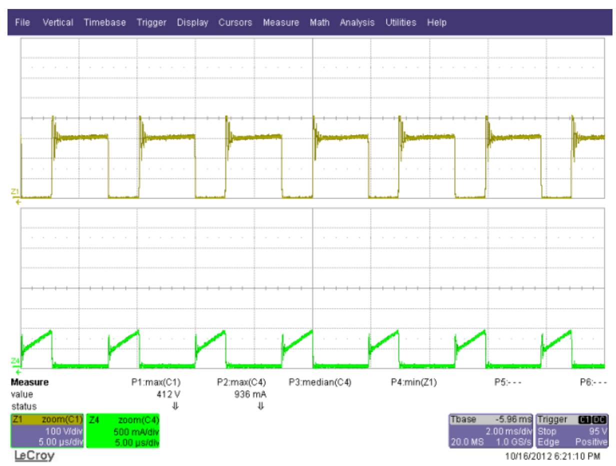

Figure 37 – 135 VAC, 60 Hz.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA, 5 µs / div.

13.7 输出短路

During output short condition, the I_{FB} current falls below the $I_{FB(AR)}$ threshold and enters the auto-restart condition. During this condition, to minimize power dissipation on the power components, the auto-restart circuit turns the power supply on and off at an auto-restart duty cycle of typically DC_{AR} for as long as the fault condition persists.

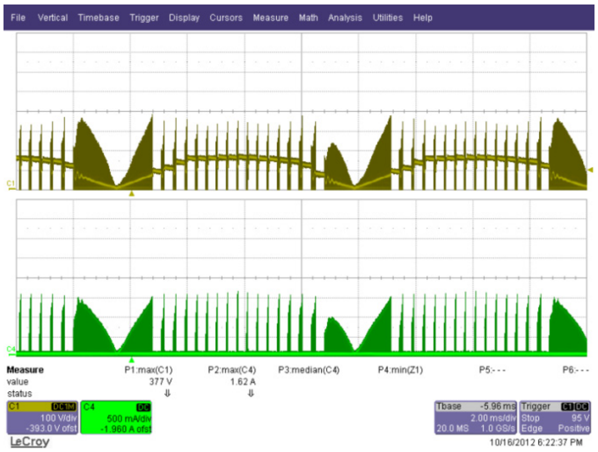

Figure 38 – 90 VAC, 60 Hz Output Short Condition.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA, 2 ms / div.

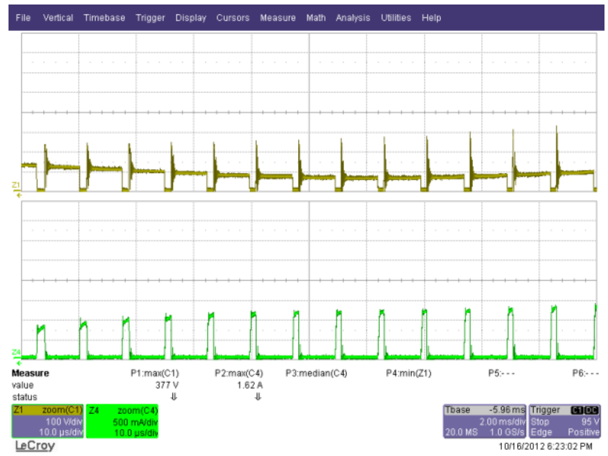

Figure 39 – 90 VAC, 60 Hz Output Short Condition.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA, 10 µs / div.

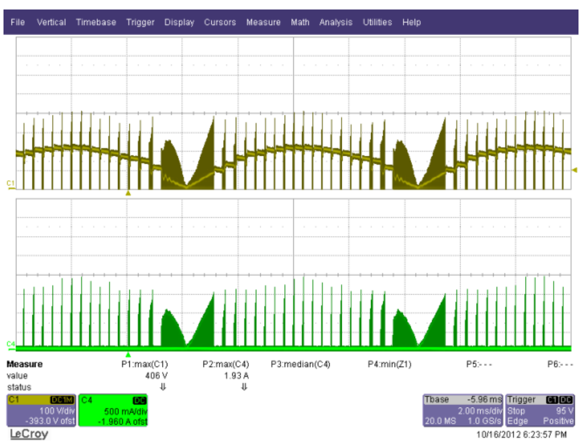

Figure 40 – 135 VAC, 60 Hz Output Short Condition.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA, 2 ms / div.

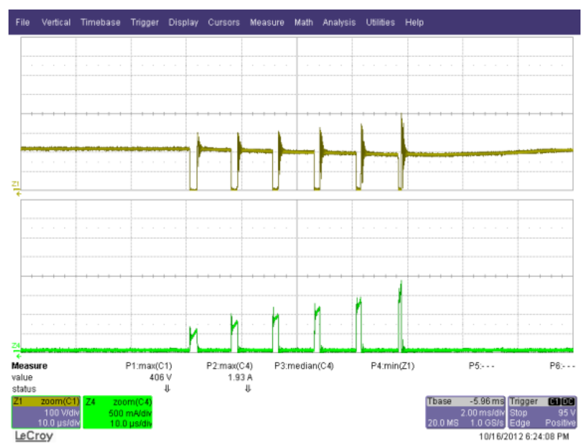

Figure 41 – 135 VAC, 60 Hz Output Short Condition.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 500 mA, 10 µs / div.

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13.8 输出二极管电压和电流波形

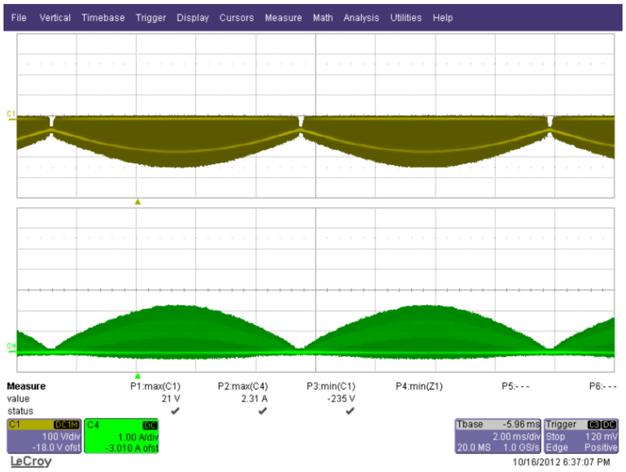


Figure 42 – 135 VAC, 60 Hz Normal Operation.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 1 A, 2 ms / div.

Figure 43– 135 VAC, 60 Hz Output Short.
Upper: V_{DRAIN}, 100 V / div.
Lower: I_{DRAIN}, 1 A, 10 µs / div.

13.9 开路负载时的输出电压波形

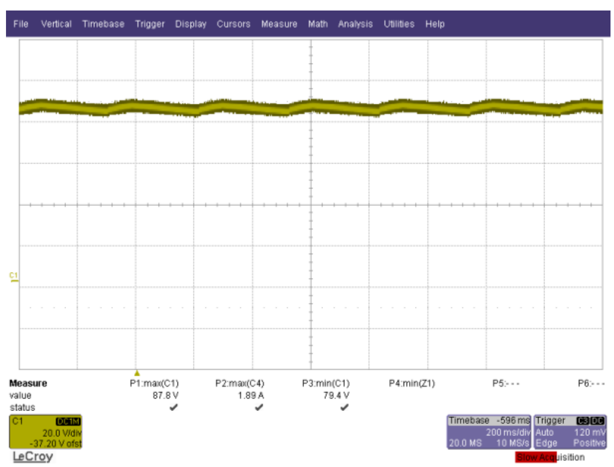
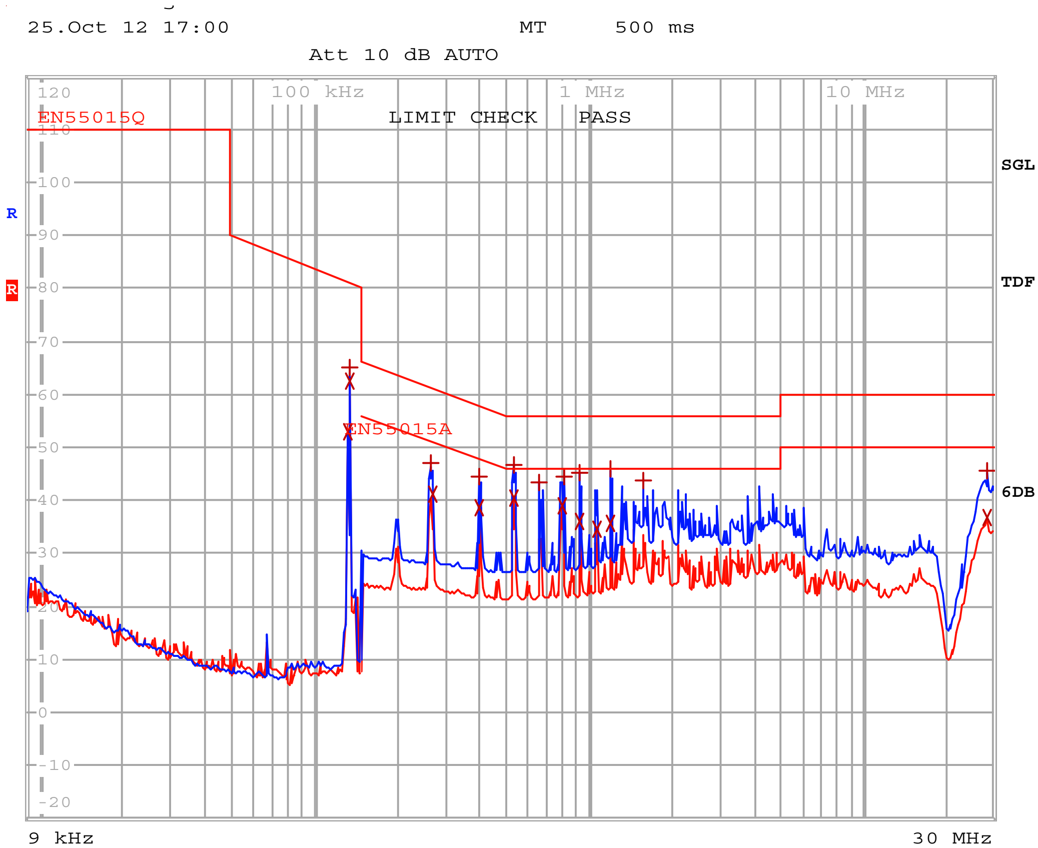


Figure 44 – 135 VAC, 60 Hz Output Open.
$V_{OUT,}$ 20 V / div., 200 ms/div.

14 传导EMI



EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	130.825395691 kHz	52.82	N gnd	
1	Quasi Peak	133.454986145 kHz	65.04	L1 gnd	-16.02
2	Average	133.454986145 kHz	62.52	N gnd	
1	Quasi Peak	264.49018761 kHz	46.89	N gnd	-14.39
2	Average	267.135089486 kHz	41.33	N gnd	-9.87
1	Quasi Peak	397.727746704 kHz	44.56	L1 gnd	-13.33
2	Average	397.727746704 kHz	38.71	L1 gnd	-9.18
1	Quasi Peak	530.769219795 kHz	46.74	L1 gnd	-9.25
2	Average	530.769219795 kHz	40.27	L1 gnd	-5.73
1	Quasi Peak	660.656865747 kHz	43.25	L1 gnd	-12.74
2	Average	798.145472681 kHz	39.12	L1 gnd	-6.87
1	Quasi Peak	806.126927408 kHz	44.44	L1 gnd	-11.56
1	Quasi Peak	926.622115652 kHz	45.15	L1 gnd	-10.84
2	Average	926.622115652 kHz	36.01	L1 gnd	-9.98
2	Average	1.06512822736 MHz	34.60	L1 gnd	-11.39
1	Quasi Peak	1.1883298484 MHz	45.90	L1 gnd	-10.09
2	Average	1.20021314689 MHz	35.59	L1 gnd	-10.40
1	Quasi Peak	1.58583078933 MHz	43.89	L1 gnd	-12.10
1	Quasi Peak	28.4089539309 MHz	45.60	N gnd	-14.39
2	Average	28.4089539309 MHz	36.59	L1 gnd	-13.40

Figure 45 – Conducted EMI, 50 V LED Load, 115 VAC, 60 Hz and EN55015 B Limits.

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15 输入浪涌

The unit was subjected to 2500 V ring wave and 1000 V differential surge at 115 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	115	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
-2500	115	L1, L2	0	100 kHz Ring Wave (500 A)	Pass
+2500	115	L1, L2	90	100 kHz Ring Wave (500 A)	Pass
-2500	115	L1, L2	90	100 kHz Ring Wave (500 A)	Pass

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+1000	115	L1, L2	0	Surge (2Ω)	Pass
-1000	115	L1, L2	0	Surge (2Ω)	Pass
+1000	115	L1, L2	90	Surge (2Ω)	Pass
-1000	115	L1, L2	90	Surge (2Ω)	Pass

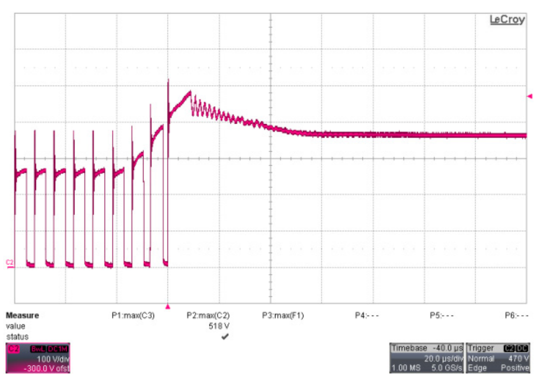

Figure 46 – +1 kV Differential Surge, 90º
V_{DRAIN}, 100 V / div., 20 μs / div.

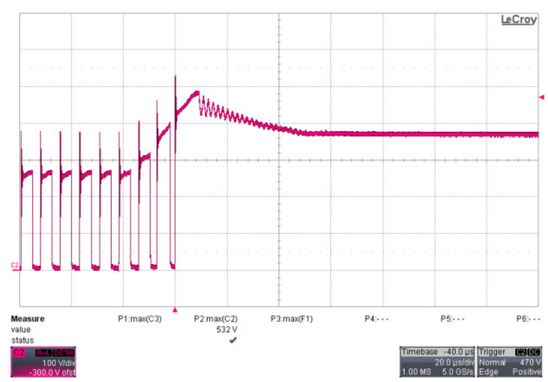

Figure 47 – -1 kV Differential Surge, 90º
V_{DRAIN}, 100 V / div., 20 μs / div.

16 版本历史

Date	Author	Revision	Description and Changes	Reviewed
29-Jan-13	DK	1.0	Initial Release	Apps & Mktg

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