设计范例报告

标题	*使用**LinkSwitch™-PH LNK420EG** 设计的高效率 **(>91%)**、两通道**150 W**、带功率因数校正的固态照明**(SSL)LED** 驱动器*
规格	184 VAC – 277 VAC输入；30 V – 36 V， 4.2 A_{TOTAL}（每个通道2.1 A）输出
应用	路灯LED驱动器
作者	应用工程部
文档编号	DER-291
日期	2012年10月19日
修订版本	2.0

特色概述

- 150 W两通道LED驱动器；每个通道75 W
- 可极大简化离线式功率因数校正LED驱动器的设计
  - 单级、带功率因数校正的隔离式LED驱动器
  - 元件数量极少，外形紧凑
  - 在整个输入电压和负载范围内具有高功率因数（PF >0.95）
  - 在不同输入电压和负载下的效率均>91%
  - 在不同输入电压和负载下均具有低THD (<22%)
  - 满足IEC61000-3-2 CLASS C标准，且具有出色的裕量
  - 满足IEC 61000-4-5振铃波 >2.5 kV和差模浪涌 >2 kV的耐受电压要求
  - 省去所有控制环路补偿电路
  - 无需输出电流检测
  - 频率调制技术极大降低了EMI滤波元件的成本
  - 集成的保护及可靠性能

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- 锁存输出过开路负载(OVP)电路
- 输出短路保护，带自动恢复功能
- 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

专利信息

此处介绍的产品和应用（包括产品之外的变压器结构和电路）可能包含一项或多项美国及国外专利，或正在申请的美国或国外专利。有关Power Integrations专利的完整列表，请参见www.powerint.com。Power Integrations按照在<http://www.powerint.com/ip.htm>中所述规定，向客户授予特定专利权利的许可。

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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高效率(>92%)、两通道150 W (2 x 75 W)、隔离式、带功率因数校正的、低THD、低谐波电流含量LED驱动器，它可以在184 VAC至277 VAC的输入电压范围内为LED灯串提供30 V - 36 V、2.1 A的驱动。

LinkSwitch-PH能够以高成本效益的方式提供带初级侧恒流控制的高效率单级功率因数校正LED驱动器。LinkSwitch-PH控制器非常适合外围元件极少的LED驱动器应用。它无需使用光耦器即可对LED负载中的输出电流提供控制。

LinkSwitch-PH在一个芯片中集成了725 V功率MOSFET和控制器。该控制器包括一个振荡器、PWM（脉宽调制）、6 V稳压器、旁路(BP)引脚设定功能、过热保护、频率抖动、逐周期限流、前沿消隐以及一个用于输出恒流控制和功率因数校正的充电控制器。

LinkSwitch-PH还可提供一系列复杂的保护功能，包括控制环路开环/短路和输出短路条件下自动重启动。精确的迟滞热关断可确保PCB板平均温度在所有条件下均处于安全范围内。

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

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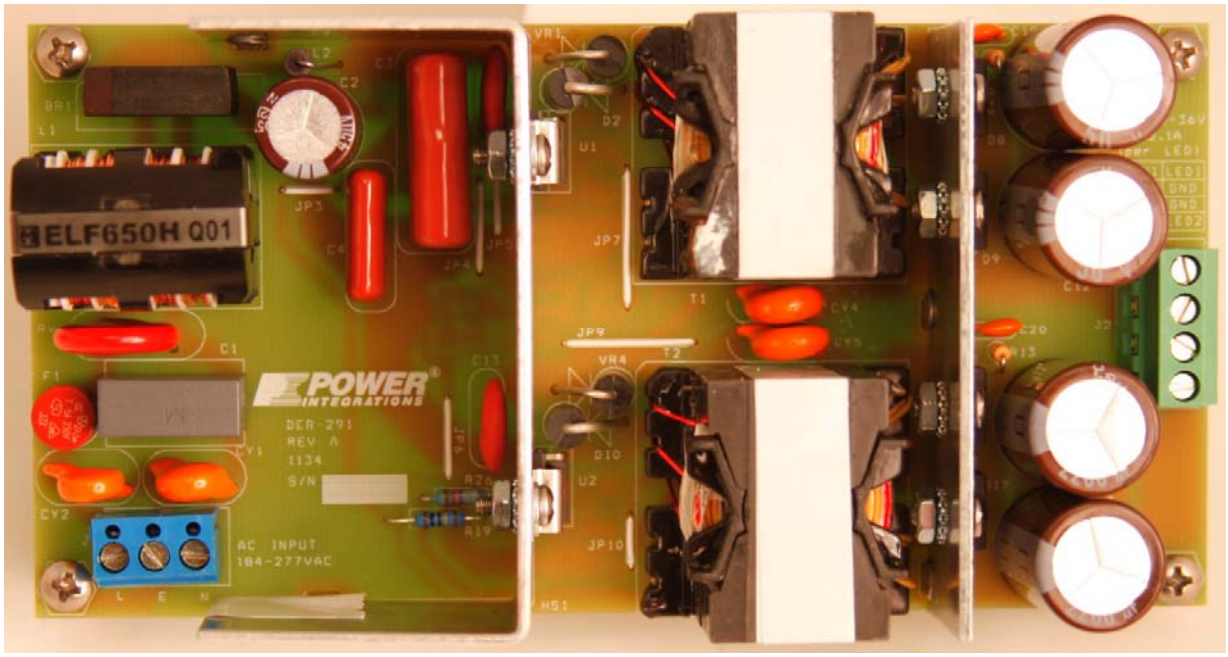

Figure 1 – Populated Circuit Board Photograph, Top (3” x 6”).

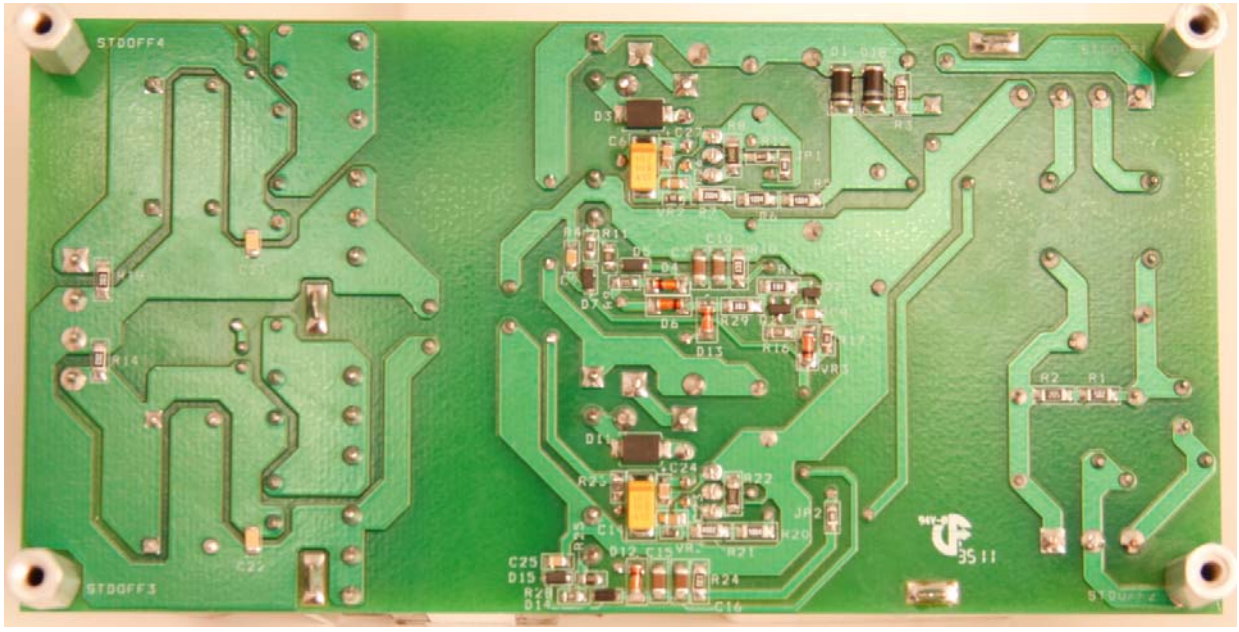

Figure 2 – Populated Circuit Board Photograph, Bottom.

2 设计要点

- 高效率
  - 使用较大的PQ3230以降低铜损耗，使用高质量铁氧体磁芯材料（如PC44或4F4）以降低磁芯损耗。
  - 由于利用偏置电源为LinkSwitch-PH供电，与通过其内部稳压器从总线电源吸收的功率相比，器件从低压偏置电源吸收的功率更少。
  - 使用2个并联肖特基二极管用于输出整流管
  - 使用肖特基二极管用于漏极阻断
- 耐2 kV浪涌
  - V引脚峰值检测电容C3使用较小值，以提高过压检测速度
  - 使用无源10 μF电解电容C2来吸收浪涌能量，从而限制整流总线电压的峰值电压。
- 满足EN61000-3-2 Class C标准
  - 使用反激式拓扑结构时KP <0.65。
  - 尽量减小输入电容的值（如X电容）。

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3 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}	184		277	VAC	3线 – 输出浮动
频率	f_{LINE}		50/60		Hz	
输出						
LED电压	V_{OUT}	30	33	36	V	
LED1电流		1.950	2.10	2.250	mA	
LED2电流		1.950	2.10	2.250	mA	
总输出功率						
连续输出功率	P_{OUT}		150		W	两个通道总和
环境						
传导EMI		满足EN55015B标准				
安全		隔离式				
效率		91	92			
谐波电流		Class C				IEC 61000-3-2
功率因数		0.95				
环境温度	T_{AMB}		65		°C	
保护						
开路负载锁存				50	V	AC复位 <1秒

4 电路原理图

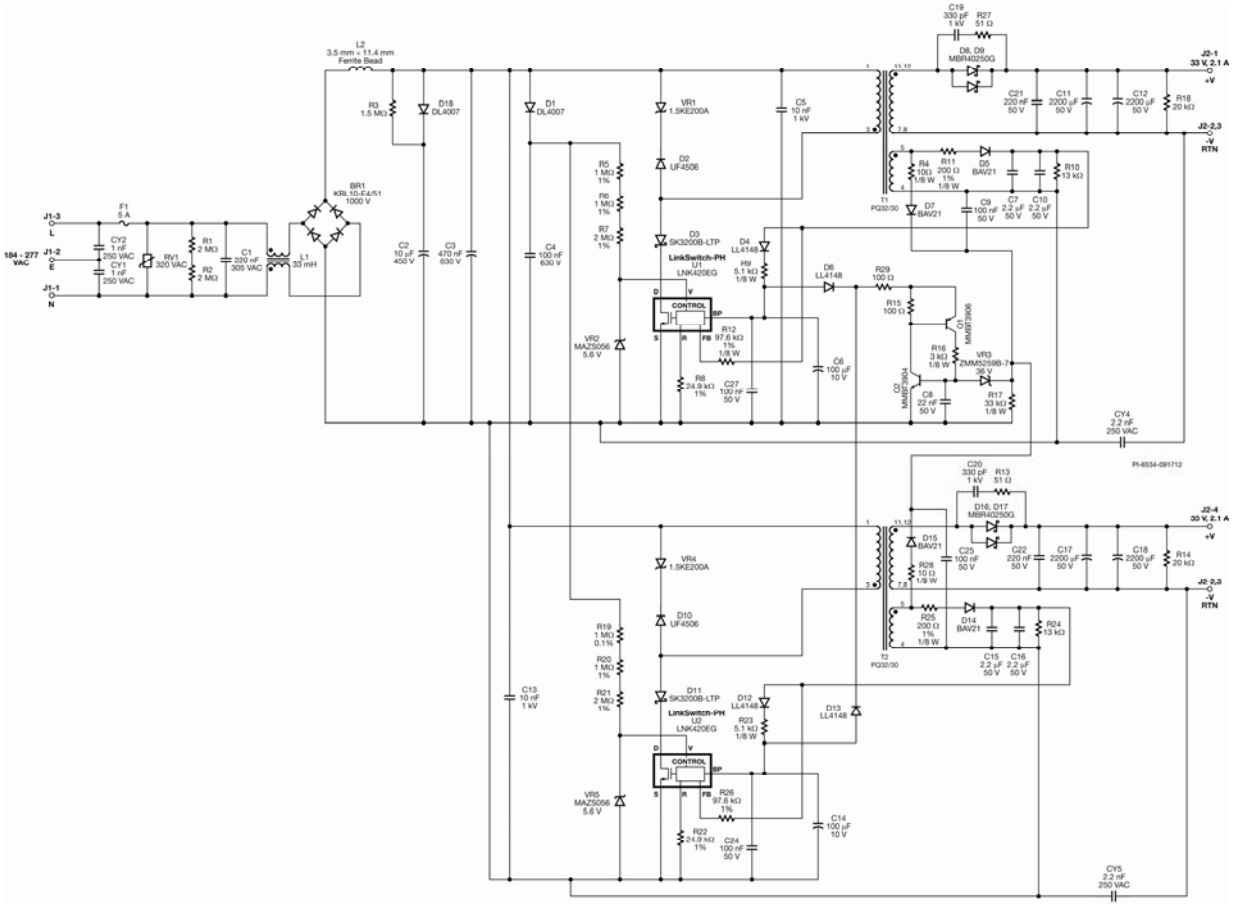

Figure 3 – Schematic.

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5 说明

LinkSwitch-PH器件是一种将控制器和725 V MOSFET集成在一起的器件，用于LED驱动器应用。LinkSwitch-PH可用于单级连续导通模式反激式拓扑结构，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和谐波含量。

5.1 输入滤波

保险丝F1保护输入，BR1对AC线电压进行整流。电感L1、L2和C1构成EMI滤波器，再加上CY1、CY2、CY4和CY5（Y1安全）电容，可使设计符合EN55015B传导EMI限值。电容C3为初级侧开关电流提供低阻抗通道，为使功率因数保持在0.9以上，需要确保较低的电容值。高压旁路电容C13和C5可缩小每个转换器的输入的环路面积，从而减少EMI的产生。

5.2 LinkSwitch-PH初级

二极管D1和高压电容C4检测峰值AC线电压。电容C4取较小值(100 nF)，以提高输入过压的检测速度，特别是在差模浪涌条件下。此电压通过连接到U1和U2的V引脚的串联电阻转换为电流并注入电压监测(V)引脚。器件也会利用检测到的电流来设置输入过压/欠压保护阈值。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。非调光设计要求在参考(R)引脚(R8, R22)和V引脚上分别使用24.9 kΩ电阻和4 MΩ电阻。齐纳二极管VR2和VR5在启动期间为V引脚提供保护。

二极管D2、D10、VR1和VR4对漏极电压进行箝位，使其低于U1和U2内部功率MOSFET的BV_{DSS}额定值(725 V)。二极管D3和D11可阻止反向电流流经LinkSwitch-PH器件（即最小输入电容导致的结果）。

为了耐受2 kV的差模输入浪涌，本设计使用压敏电阻RV1和C10 (10 μF)在浪涌期间吸收大部分的能量，从而限制最大总线电压。二极管D18在正常工作条件下将C2与AC输入隔离，R3在出现浪涌后充当C2的放电路径。

5.3 偏置电源和输出过压检测

二极管D5、D14、C7、C10、C15和C16构成初级偏置电源。在正常工作时，该电源通过D4、D12以及R9、R23 将IC工作电流馈入旁路(BP)引脚。电阻R11和R25提供滤波以改善输出稳压，R10和R24则充当最小负载。

电容C6和C14是LinkSwitch-PH的电源去耦。在启动期间，这些电容从与器件漏极(D)引脚相连的内部高压电流源被充电至约6 V。充电后，这些电容中储存的能量为器件供电，直到输出和偏置绕组电压在调整中上升。电容C24和C27提供局部高频率去耦。这些电容必须放置于U1和U2的器件引脚。

开路负载/过压关断功能由晶体管Q1和Q2提供。当通过VR3检测到过压时，Q2将经由D6和D13同时将U1和U2的BP引脚电压拉低至其BP-UVLO（欠压锁存）阈值，并在AC输入重新上电前保持关断。本设计采用了单独的偏置供电（R4、D7和C9），以便使用更低值的滤波电容(C9)，因而在输出过压条件下实现更短的响应时间。

5.4 输出反馈

与来自初级偏置绕组的输出电压成比例的电流通过R12和R26注入到FB引脚。此信息与输入线电压和漏极电流一起用于维持恒定的输出电流。

5.5 输出整流和滤波

二极管D8、D9、D16和D17对次级绕组进行整流，电容C11、C12、C17和C18对输出进行滤波。为实现高效率，对每个输出使用了两个20 A、250 V肖特基二极管。电阻R18和R14提供最小负载，以便在AC断电时对输出电容中剩余的电荷进行放电。

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6 PCB布局

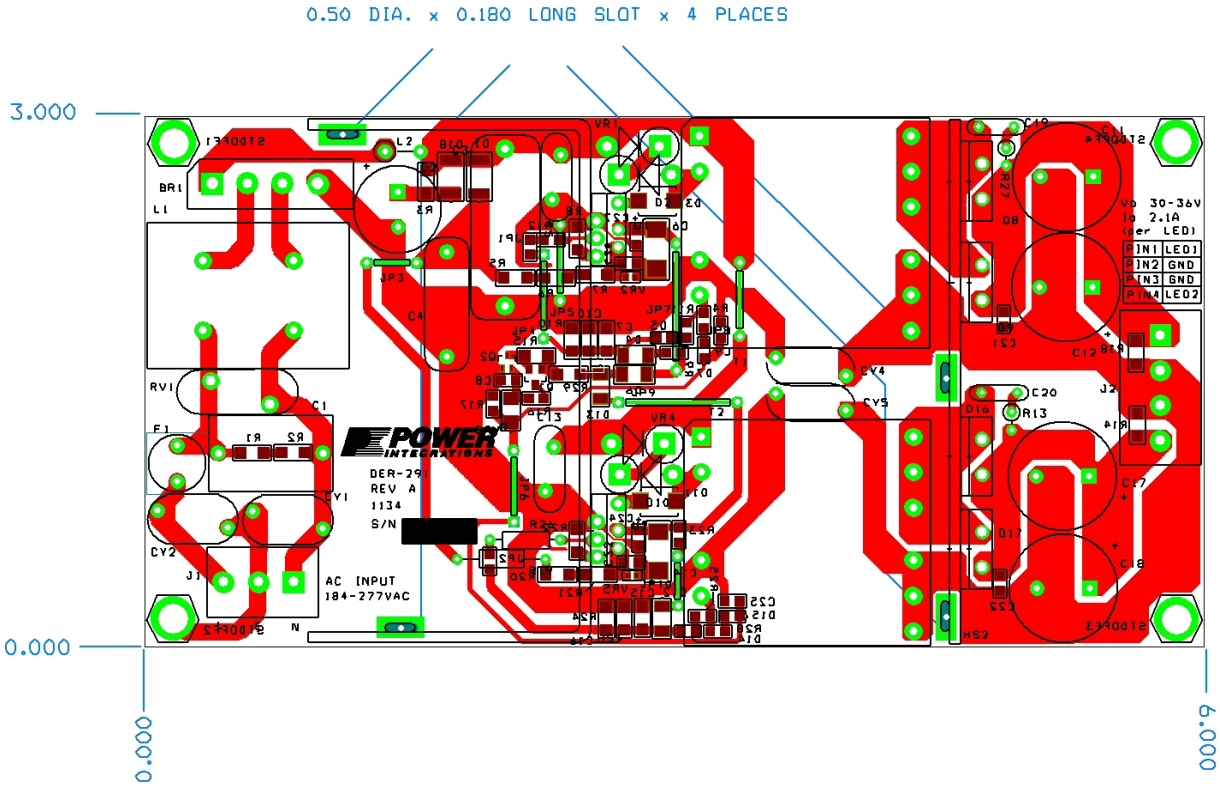

Figure 4 – Printed Circuit Layout, Top and Bottom (3” x 6”).

7 物料清单(BOM)

7.1 电气BOM

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	1000 V, 4 A, Bridge Rectifier	KBL10-E4/51	Vishay
2	1	C1	220 nF, 305 VAC, Film, X2	R463I322000M2M	Kemet
3	1	C2	10 μF, 450 V, Electrolytic, (12.5 x 20)	EKMG451ELL100MK20S	United Chemi-Com
4	1	C3	470 nF, 630 V, Film	ECQ-E6474KF	Panasonic
5	1	C4	100 nF, 630 V, Film	ECQ-E6104KF	Panasonic
6	2	C5 C13	10 nF, 1 kV, Disc Ceramic	562R5HKMS10	Vishay
7	2	C6 C14	100 μF, 10 V, Tant Electrolytic, C Case, SMD	T491C107K010AS	Kemet
8	4	C7 C10 C15 C16	2.2 μF, 50 V, Ceramic, Y5V, 1206	GRM31MF51H225ZA01L	Murata
9	1	C8	22 nF, 50 V, Ceramic, X7R, 0805	ECJ-2VB1H223K	Panasonic
10	4	C9 C24 C25 C27	100 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB104	Yageo
11	4	C11 C12 C17 C18	2200 μF, 50 V, Electrolytic, Gen. Purpose, (16 x 35.5)	EKMG500ELL222MLP1S	Nippon Chemi-Con
12	2	C19 C20	330 pF, 1 kV, Disc Ceramic	562R5GAT33	Vishay
13	1	C21	220 nF, 50 V, Ceramic, X7R, 1206	ECJ-3YB1H224K	Panasonic
14	1	C22	220 nF, 50 V, Ceramic, X7R, 1206	12065C224KAT2A	AVX
15	2	CY1 CY2	1 nF, Ceramic, Y1	440LD10-R	Vishay
16	2	CY4 CY5	2.2 nF, Ceramic, Y1	440LD22-R	Vishay
17	2	D1 D18	1000 V, 1 A, Rectifier, Glass Passivated, DO-213AA (MELF)	DL4007-13-F	Diodes, Inc.
18	2	D2 D10	600 V, 3 A, Ultrafast Recovery, 75 ns, DO-201AD	UF5406-E3/54	Vishay
19	2	D3 D11	200 V, 3 A, Diode Schottky 1 A 200 V, SMB	SK3200B-LTP	Micro Commercial
20	4	D4 D6 D12 D13	75 V, 0.15 A, Fast Switching, 4 ns, MELF	LL4148-13	Diodes, Inc.
21	4	D5 D7 D14 D15	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
22	4	D8 D9 D16 D17	250 V, 40 A, Schottky, TO-220AC	MBR40250G	On Semi
23	1	F1	5 A, 250 V, Slow, TR5	37215000411	Wickman
24	1	L1	33 mH, 0.8 A, Common Mode Choke	ELF-18D650H	Panasonic
25	1	L2	3.5 mm x 11.4 mm, 144 Ohms at 100 MHz, #22 AWG hole, Ferrite Bead	2761008112	Fair-Rite
26	1	Q1	PNP, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3906LT1G	On Semi
27	1	Q2	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-323	MMST3904-7-F	Diodes, Inc.
28	2	R1 R2	2 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ205V	Panasonic
29	1	R3	1.5 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ155V	Panasonic
30	2	R4 R28	10 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ100V	Panasonic
31	3	R5 R6 R20	1.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1004V	Panasonic
32	2	R7 R21	2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
33	2	R8 R22	24.9 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2492V	Panasonic
34	2	R9 R23	5.1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ512V	Panasonic
35	2	R10 R24	13 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ133V	Panasonic
36	2	R11 R25	200 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2000V	Panasonic

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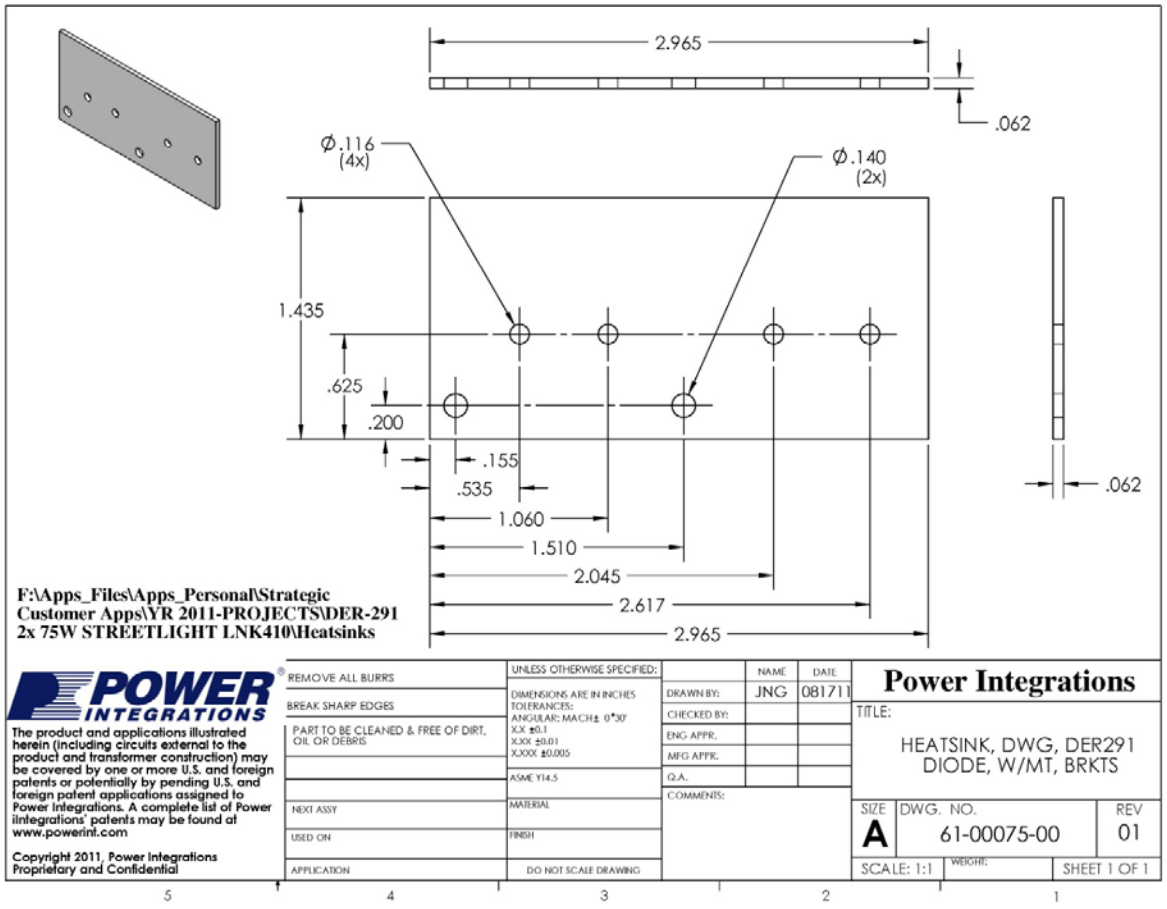
37	1	R12	97.6 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF9762V	Panasonic
38	2	R13 R27	51 Ω, 5%, 1/4 W, Carbon Film	CFR-25JB-51R	Yageo
39	2	R14 R18	20 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ203V	Panasonic
40	2	R15 R29	100 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ101V	Panasonic
41	1	R16	3 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ302V	Panasonic
42	1	R17	33 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ333V	Panasonic
43	1	R19	1 MΩ, 0.1%, 1/4 W, Metal Film	RC55Y-1M0BI	Welwyn Comp
44	1	R26	97.6 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-97K6	Yageo
45	1	RV1	320 V, 80 J, 14 mm, RADIAL	V320LA20AP	Littlefuse
46	2	U1 U2	LinkSwitch-PH, eSIP	LNK420EG	Power Integrations
47	2	VR1 VR4	200 V, 1500 W, TVS, GP-20	1.5KE200A-E3/54	Vishay
48	2	VR2 VR5	5.6 V, 5%, 150 mW, SOD-323	MAZS0560ML	Panasonic
49	1	VR3	39 V, 5%, 500 mW, DO-213AA (MELF)	ZMM5259B-7	Diodes, Inc.

8 散热片组件

8.1 输出二极管散热片

8.1.1 输出二极管散热片工程图



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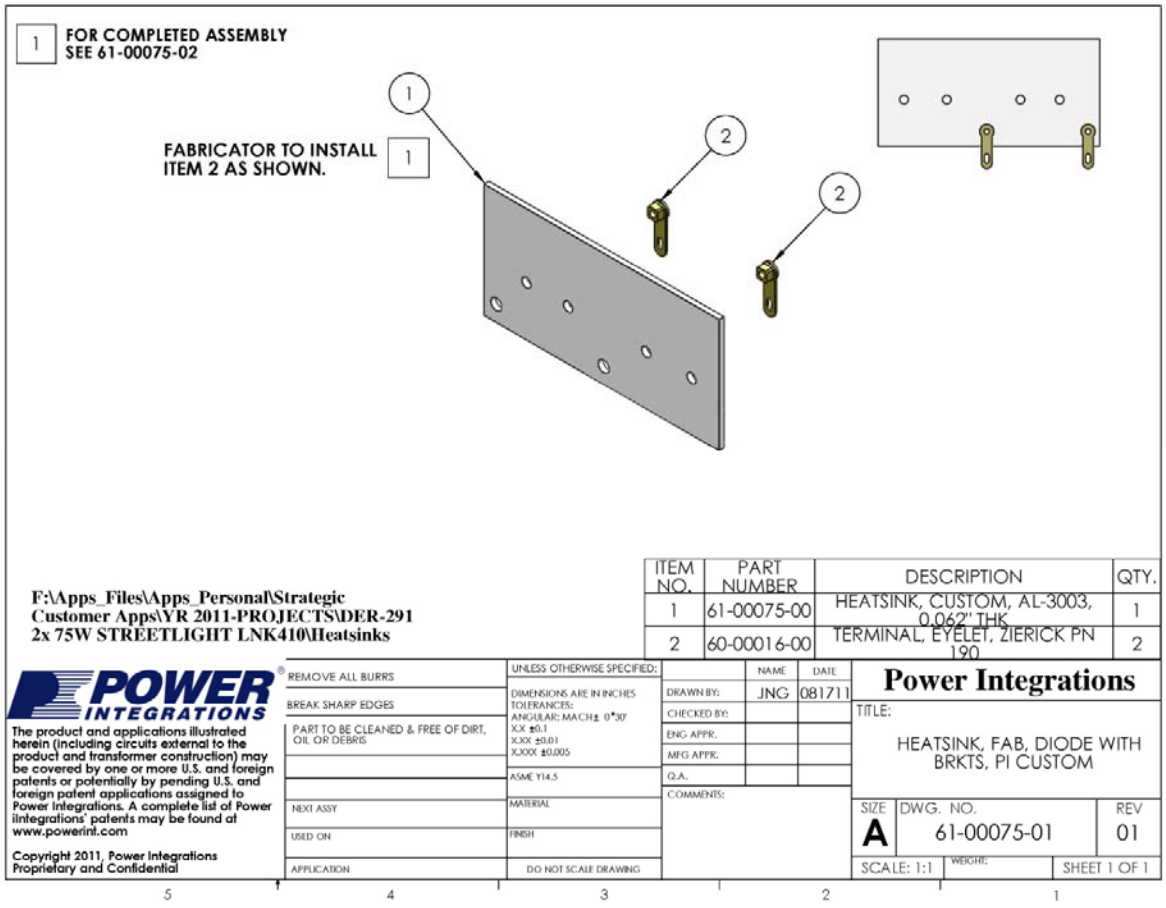
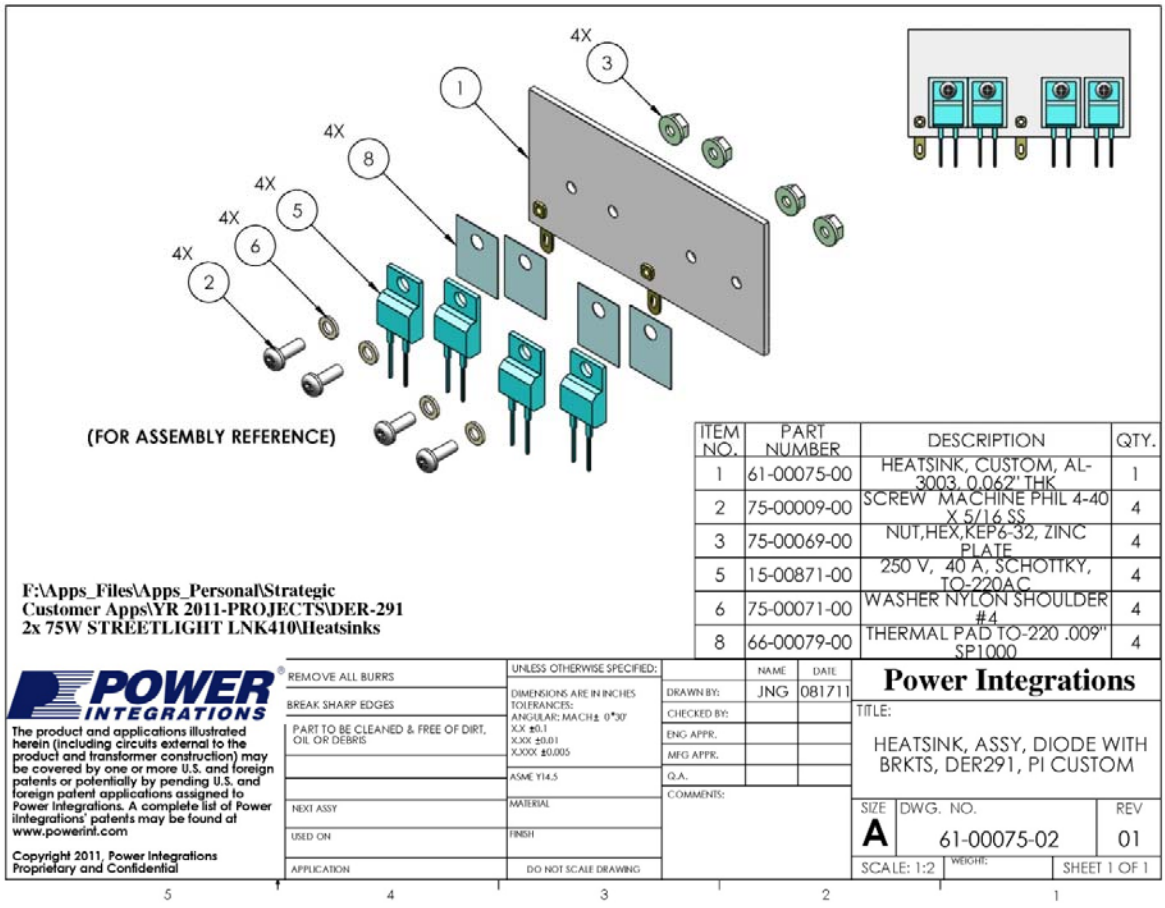
8.1.2 输出二极管散热片加工图



8.1.3 输出二极管和散热片装配图



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	61-00075-00	HEATSINK, CUSTOM, AL-3003, 0.062" THK	1
2	75-00009-00	SCREW MACHINE PHIL 4-40 X 5/16 SS	4
3	75-00069-00	NUT,HEX,KEP6-32, ZINC PLATE	4
5	15-00871-00	250 V, 40 A, SCHOTTKY, TO-220AC	4
6	75-00071-00	WASHER NYLON SHOULDER #4	4
8	66-00079-00	THERMAL PAD TO-220 .009" SP1000	4

F:\Apps_Files\Apps_Personal\Strategic Customer Apps\YR 2011-PROJECTS\DER-291 2x 75W STREETLIGHT LNK410\Heatsinks

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NEXT ASSY
USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 0°30'
X.X ±0.1
X.XX ±0.01
X.XXX ±0.005
ASME Y14.5
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	JNG	081711
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

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TITLE: HEATSINK, ASSY, DIODE WITH BRKTS, DER291, PI CUSTOM

SIZE	DWG. NO.	REV
A	61-00075-02	01
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1

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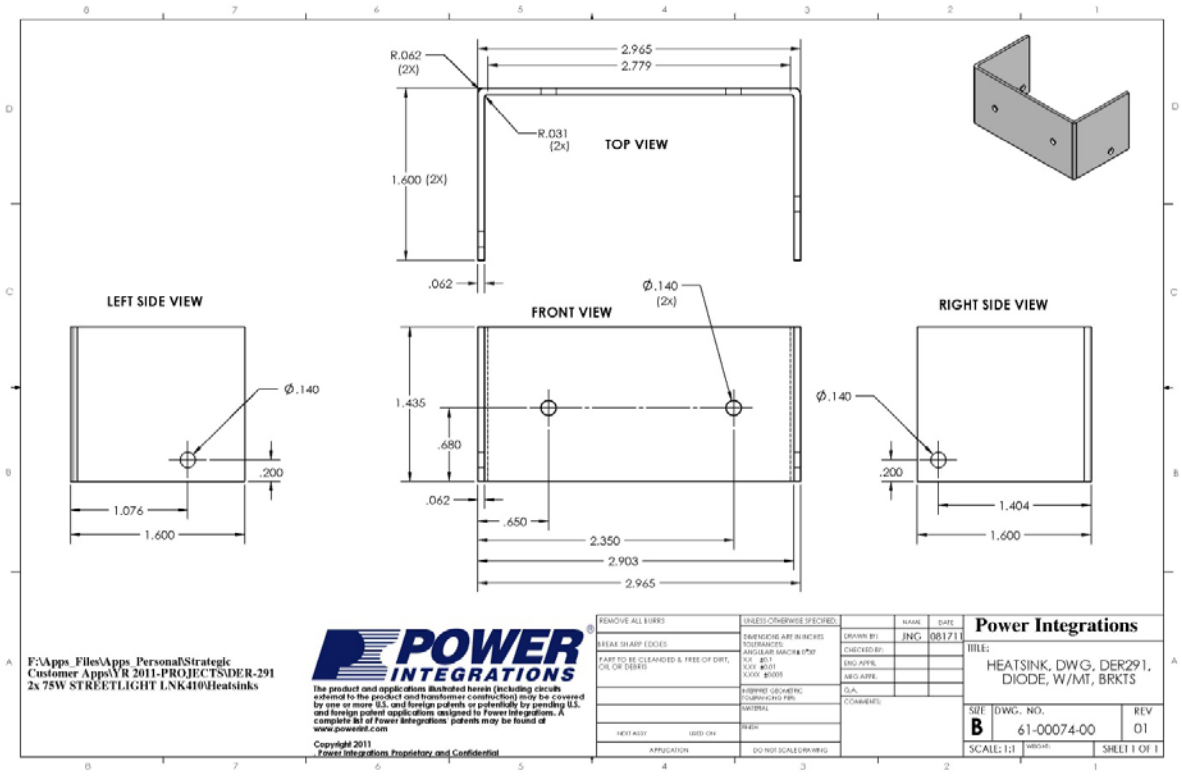
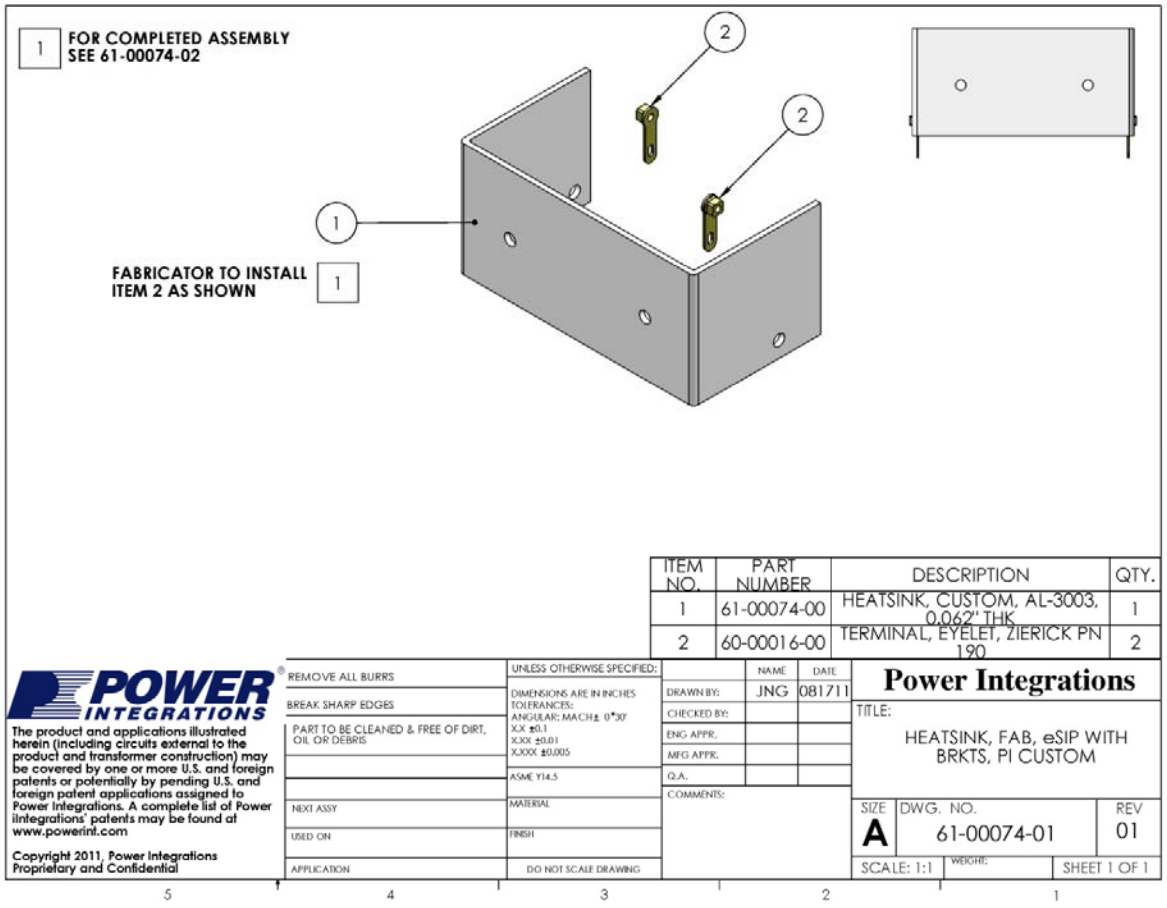
8.2 eSIP散热片

8.2.1 eSIP散热片工程图



8.2.2 eSIP散热片加工图



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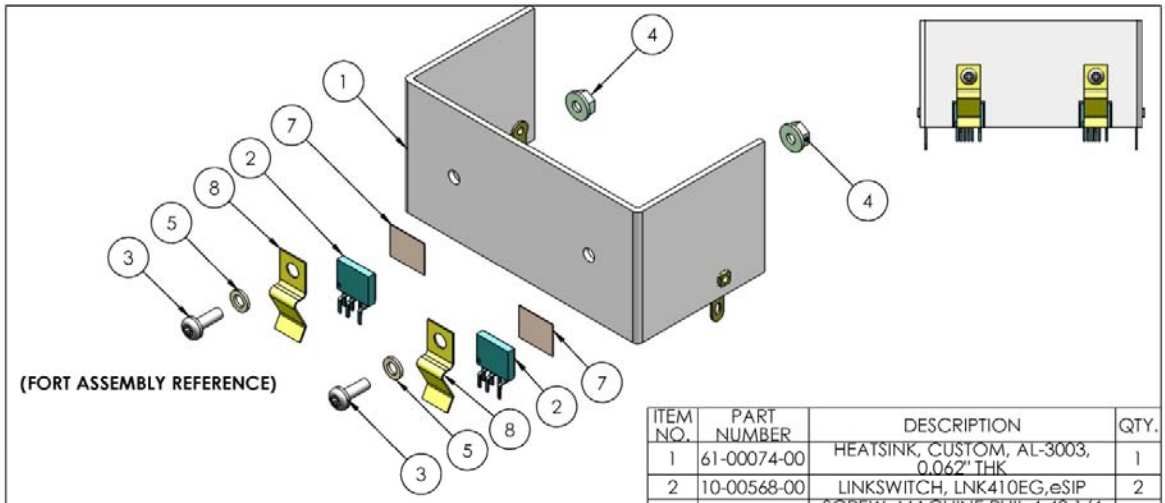
8.2.3 eSIP和散热片装配图



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	61-00074-00	HEATSINK, CUSTOM, AL-3003, 0.062" THK	1
2	10-00568-00	LINKSWITCH, LNK410EG,eSIP	2
3	75-00001-00	SCREW MACHINE PHIL 4-40 1/4 SS	2
4	75-00069-00	NUT,HEX,KEP6-32, ZINC PLATE	2
5	75-00165-00	WASHER FLAT, # 6, SS ,	2
7	66-00024-00	THERMAL TAPE DOUBLE SIDED .008"	2
8	60-00042-00	EDGE CLIP, 20.76mm L x 8 mm WX 0.015mm THK	2

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 0°30'
X.X ±0.1
X.XX ±0.01
X.XXX ±0.005
ASME Y14.5
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	JNG	081611
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Power Integrations

TITLE: HEATSINK, ASSY,eSIP WITH BRKTS DER291, PI CUSTOM

SIZE A | DWG. NO. 61-00074-02 | REV 01

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1

9 变压器规格

9.1 电气原理图

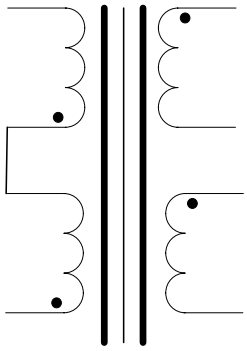

Figure 5 – Transformer Electrical Diagram.

9.2 电气规格

Electrical Strength	1 second, 60 Hz, from pins 1-6 to pins 7-12	3000 VAC
Primary Inductance	Pins 1-2, all other windings open, measured at 100 kHz, 0.4 V_{RMS}	1186 μH, +/-10%
Resonant Frequency	Pins 1-2, all other windings open	1700 kHz (Min.)
Primary Leakage Inductance	Pins 1-2, with pins 7-12 shorted, measured at 100 kHz, 0.4 V_{RMS}	70 μH (Max.)

9.3 材料

Item	Description
[1]	Core: PC444; PQ3230.
[2]	Bobbin: RPQ3230 Vertical, 6+6 Pins.
[3]	Magnet Wire: #24 AWG.
[4]	Magnet Wire: #33 AWG.
[5]	Magnet Wire: #22 AWG Triple-insulated Wire.
[6]	Tape: 3M 1298 Polyester Film, 17.7 mm Width.
[7]	Tape: 3M 1298 Polyester Film, 36 mm Width.
[7]	Tape: 3M 1298 Polyester Film, 10 mm Width.
[8]	Varnish.

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9.4 变压器结构图

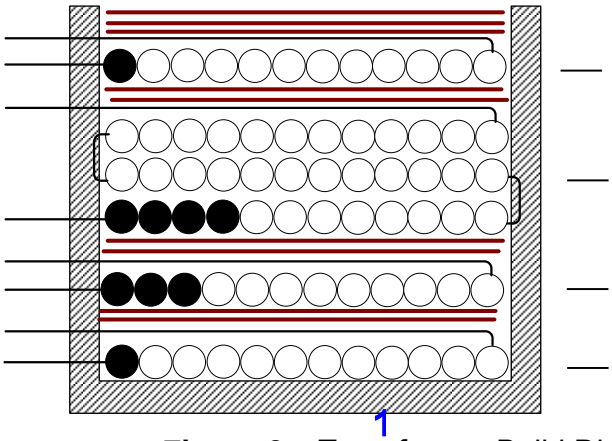
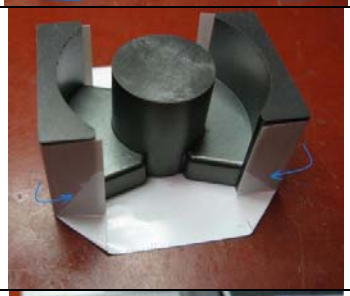
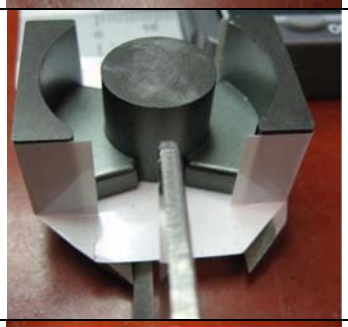
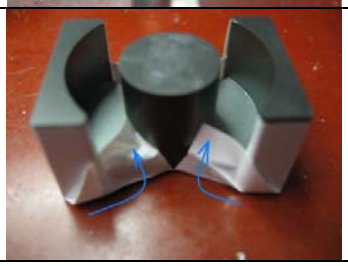


Figure 6 – Transformer Build Diagram.

9.5 变压器构造

Bobbin Preparation	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 2; wind with firm tension 28 turns of item [3] from left to right. Finish at pin 3.
Insulation	2 layers of tape [6] for insulation.
WDG2 Bias	Start at pin 5; wind with firm tension 9 trifilar turns of item [4] from left to right. Finish at pin 4.
Insulation	2 layers of tape [6] for insulation.
WDG3 Secondary	Start at pin 11 and 12; wind with firm tension 14 quadfilar turns of item [5] in continuously in three layers. Finish at pin 7 and 8. Termination is 2 wires per pin.
Insulation	2 layers of tape [6] for insulation.
WDG4 Primary 2	Start at pin 3; wind with firm tension 28 turns of item [3] from left to right. Finish at pin 1.
Insulation	3 layers of tape [6] for insulation.
Taping	Add 1 layer of tape [7] on the bottom side of the transformer to isolate the core to secondary and primary pins. Refer to the figures below.
Assemble core	Assemble and secure the cores with 3 layers of tape [7].
Finish	Varnish transformer assembly.

9.6 变压器磁芯缠绕流程

Step 1. Position the core at the center of 60 mm X 36 mm polyester film tape [7]	
Step 2. Fold both ends of the tape into the sides of the core as shown in the illustration. Make sure that no excess tape higher than the core.	
Step 3. Fold the tape in the 4 corners of the core. Extend the folding down to the bottom of the tape until it locks.	
Step 4. Cut the center of the bottom tape on its 2 sides.	
Step 5. Fold the tape into the legs of the core as shown in the illustration. Same procedure is applied to the other side of the core.	

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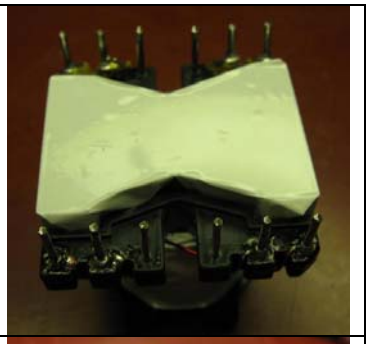
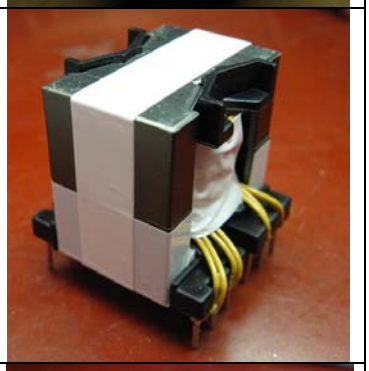
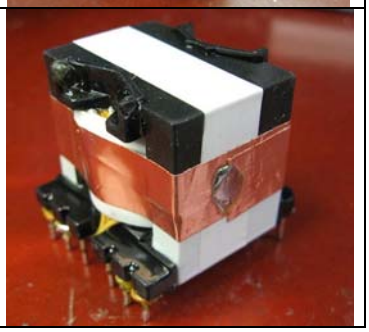
Step 6. Insert the wrapped core into the bottom side of the bobbin. Make sure that the tape is inserted between the core and the bobbin as shown in the figure.	
Step 7. Grind the top portion of the core to set the inductance as required. Assemble and fix the cores as shown in the illustration. Varnish.	
Step 8. Add 1 turn of copper shield as shown in the illustration. Solder the end of the copper shield. Varnish.	

Figure 7 – Core Wrapping Illustration.

10 变压器设计表格

ACDC_LinkSwitch-PH_040312; Rev.1.8; Copyright Power Integrations 2012	INPUT	INFO	OUTPUT	UNIT	LinkSwitch-PH_040312: Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
Dimming required	**NO**		**NO**		Select 'YES' option if dimming is required. Otherwise select 'NO'.
VACMIN	184		184	V	Minimum AC Input Voltage
VACMAX	277		277	V	Maximum AC input voltage
fL			50	Hz	AC Mains Frequency
VO	33.00		33	V	Typical output voltage of LED string at full load
VO_MAX			36.30	V	Maximum expected LED string Voltage.
VO_MIN			29.70	V	Minimum expected LED string Voltage.
V_OVP			38.50	V	Over-voltage protection setpoint
IO	2.10		2.10	A	Typical full load LED current
PO			69.3	W	Output Power
n			0.8		Estimated efficiency of operation
VB			20	V	Bias Voltage
ENTER LinkSwitch-PH VARIABLES					
LinkSwitch-PH	**LNK420**			Universal	115 Doubled/230V
Chosen Device		LNK420	Power Out	79W	74W
Current Limit Mode	**FULL**		FULL		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			4.90	A	Minimum current limit
ILIMITMAX			5.70	A	Maximum current limit
fS			66000	Hz	Switching Frequency
fSmin			62000	Hz	Minimum Switching Frequency
fSmax			70000	Hz	Maximum Switching Frequency
IV			78.4	uA	V pin current
RV	4.00		4	M-ohms	Upper V pin resistor
RV2			1.402	M-ohms	Lower V pin resistor
IFB	180.00		180.0	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1			94.4	k-ohms	FB pin resistor
VDS			10	V	LinkSwitch-PH on-state Drain to Source Voltage
VD			0.50	V	Output Winding Diode Forward Voltage Drop (0.5 V for Schottky and 0.8 V for PN diode)
VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
Key Design Parameters					
KP	0.53		0.53		Ripple to Peak Current Ratio (For PF > 0.9, 0.4 < KP < 0.9)
LP			1186	uH	Primary Inductance
VOR	133.00		133	V	Reflected Output Voltage.
Expected IO (average)		Info	1.90	A	Expected Average Output current is outside 5% tolerance band. Change IFB to 206 for better current regulation set-point
KP_VACMAX			0.65		Expected ripple current ratio at VACMAX
TON_MIN			3.84	us	Minimum on time at maximum AC input voltage
PCLAMP			0.78	W	Estimated dissipation in primary clamp
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**PQ3230**		**PQ3230**		
Bobbin		*PQ3230/ 12pins*			
AE	1.6700		1.67	cm^2	Core Effective Cross Sectional Area
LE	7.5000		7.5	cm	Core Effective Path Length
AL	4500.0		4500	nH/T^2	Ungapped Core Effective Inductance

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BW	17.0		17	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
L	2.00		2		Number of Primary Layers
NS	14		14		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			260	V	Peak input voltage at VACMIN
VMAX			392	V	Peak input voltage at VACMAX
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.35		Minimum duty cycle at peak of VACMIN
IAVG			0.48	A	Average Primary Current
IP			2.42	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS			0.83	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			1186	uH	Primary Inductance
NP			56		Primary Winding Number of Turns
NB			9		Bias Winding Number of Turns
ALG			384	nH/T^2	Gapped Core Effective Inductance
BM			3089	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP			3603	Gauss	Peak Flux Density (BP<3700)
BAC			818	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
Ur			1608		Relative Permeability of Ungapped Core
LG			0.50	mm	Gap Length (Lg > 0.1 mm)
BWE			34	mm	Effective Bobbin Width
OD			0.61	mm	Maximum Primary Wire Diameter including insulation
INS			0.07	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.54	mm	Bare conductor diameter
AWG			24	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			406	Cmils	Bare conductor effective area in circular mils
CMA			490	Cmils/Amp	!!! DECREASE CMA (200 < CMA < 600) Decrease L(primary layers),increase NS,smaller Core
LP_TOL	10		10		Tolerance of primary inductance
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			9.60	A	Peak Secondary Current
ISRMS			4.16	A	Secondary RMS Current
IRIPPLE			3.60	A	Output Capacitor RMS Ripple Current
CMS			833	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			20	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.81	mm	Secondary Minimum Bare Conductor Diameter
ODS			1.21	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
VOLTAGE STRESS PARAMETERS					
VDRAIN			660	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance)
PIVS			137	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
PIVB			84	V	Bias Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
FINE TUNING (Enter measured values from prototype)					

V pin Resistor Fine Tuning					
RV1			4.00	M-ohms	Upper V Pin Resistor Value
RV2			1.40	M-ohms	Lower V Pin Resistor Value
VAC1			115.0	V	Test Input Voltage Condition1
VAC2			230.0	V	Test Input Voltage Condition2
IO_VAC1			2.10	A	Measured Output Current at VAC1
IO_VAC2			2.10	A	Measured Output Current at VAC2
RV1 (new)			4.00	M-ohms	New RV1
RV2 (new)			1.40	M-ohms	New RV2
V_OV			325.6	V	Typical AC input voltage at which OV shutdown will be triggered
V_UV			72.4	V	Typical AC input voltage beyond which power supply can startup
FB pin resistor Fine Tuning					
RFB1	97.6		98	k-ohms	Upper FB Pin Resistor Value
RFB2			1E+012	k-ohms	Lower FB Pin Resistor Value
VB1			18.0	V	Test Bias Voltage Condition1
VB2			22.0	V	Test Bias Voltage Condition2
IO1	2.1		2.10	A	Measured Output Current at Vb1
IO2			2.10	A	Measured Output Current at Vb2
RFB1 (new)			97.6	k-ohms	New RFB1
RFB2(new)			1.00E+12	k-ohms	New RFB2

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11 性能数据

The following data was measured using 3 sets of loads (30 V, 33 V, and 36 V). Refer to the table on Section 12.6 for the complete set of data values. All measurements were performed open frame at room temperature.

11.1 效率

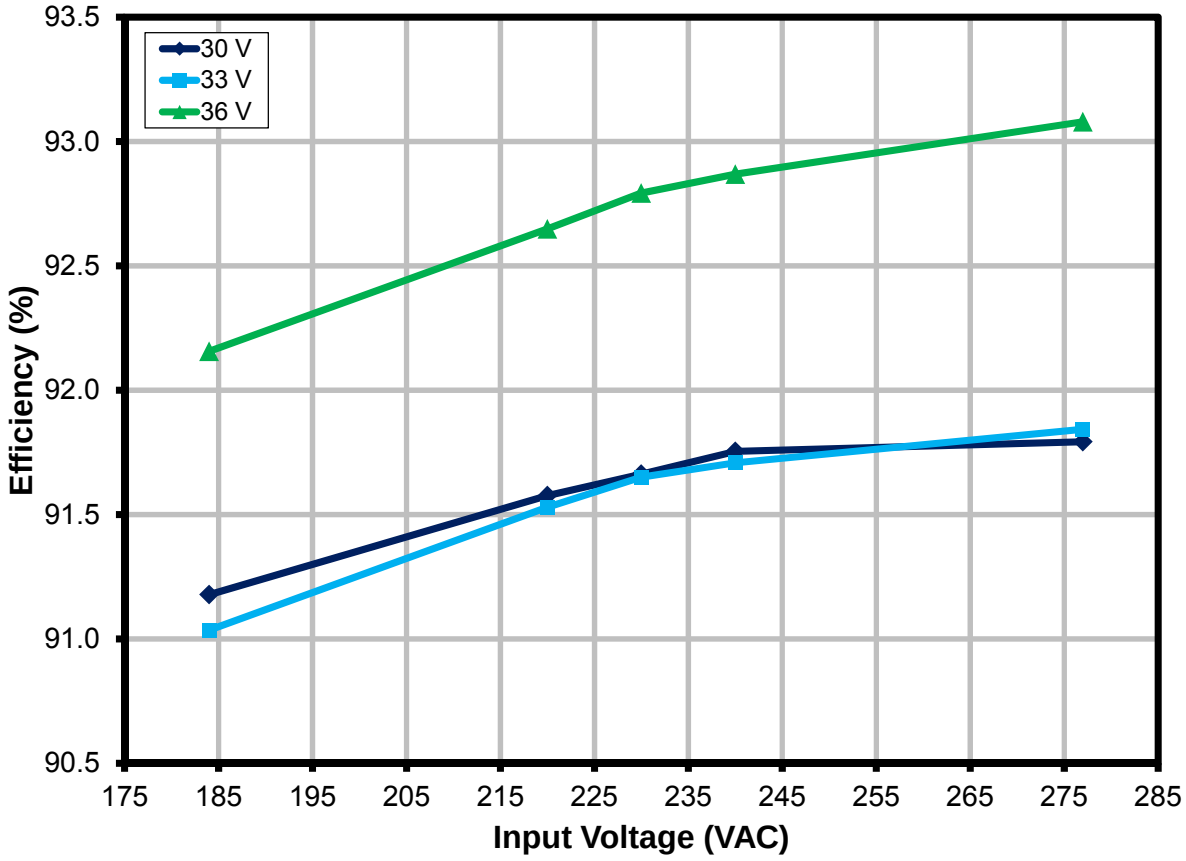

Figure 8 – Efficiency vs. Line and Load.

11.2 输入电压调整率和负载调整率

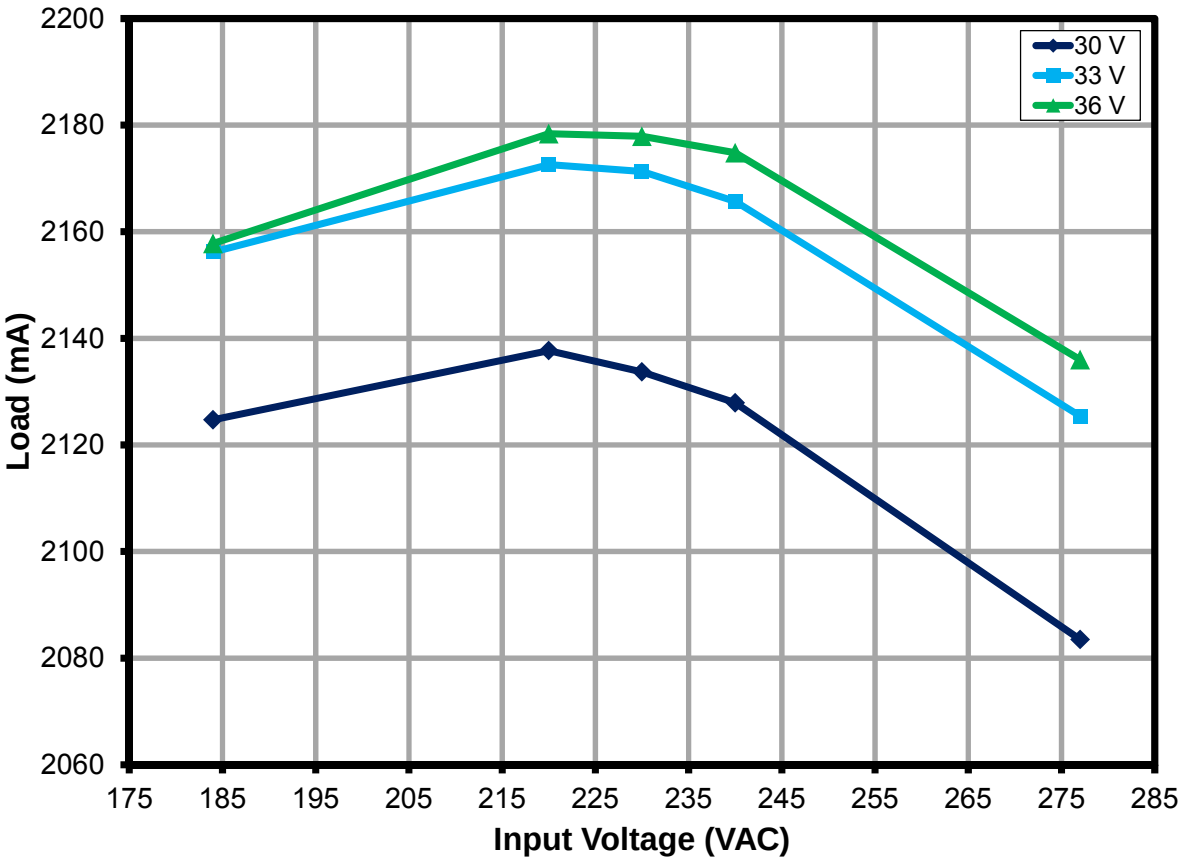

Figure 9 – Regulation vs. Line and Load.

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11.3 功率因数

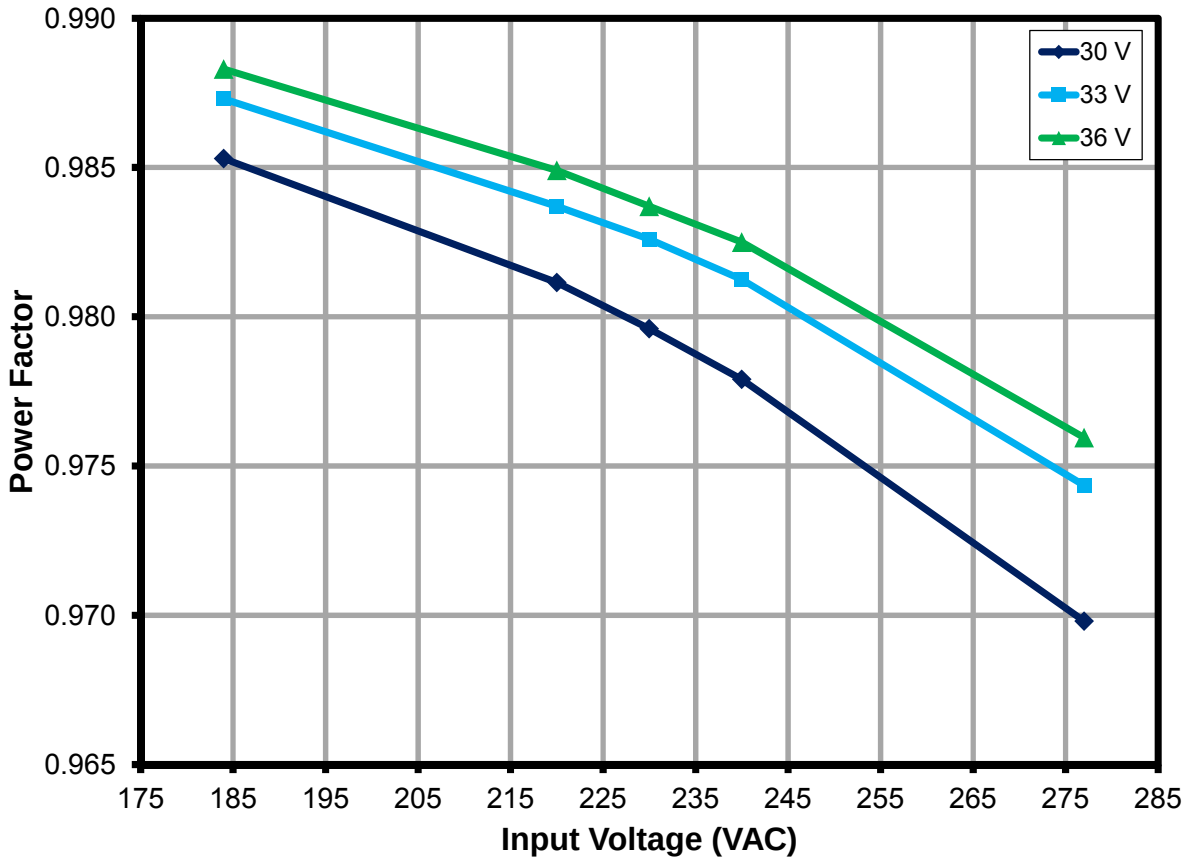

Figure 10 – Power Factor vs. Line and Load.

11.4 A-THD

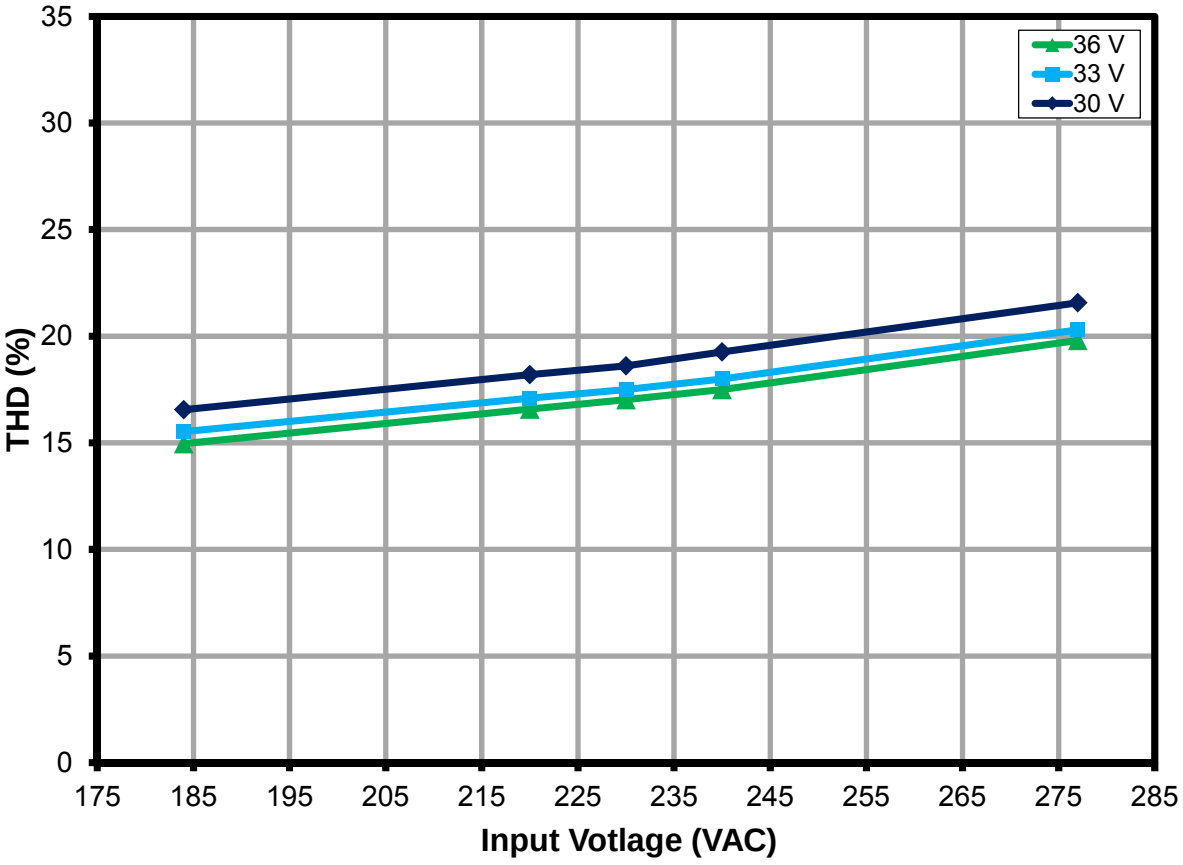

Figure 11 – A-THD vs. Line and Load.

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11.5 谐波电流

11.5.1 30 V LED负载

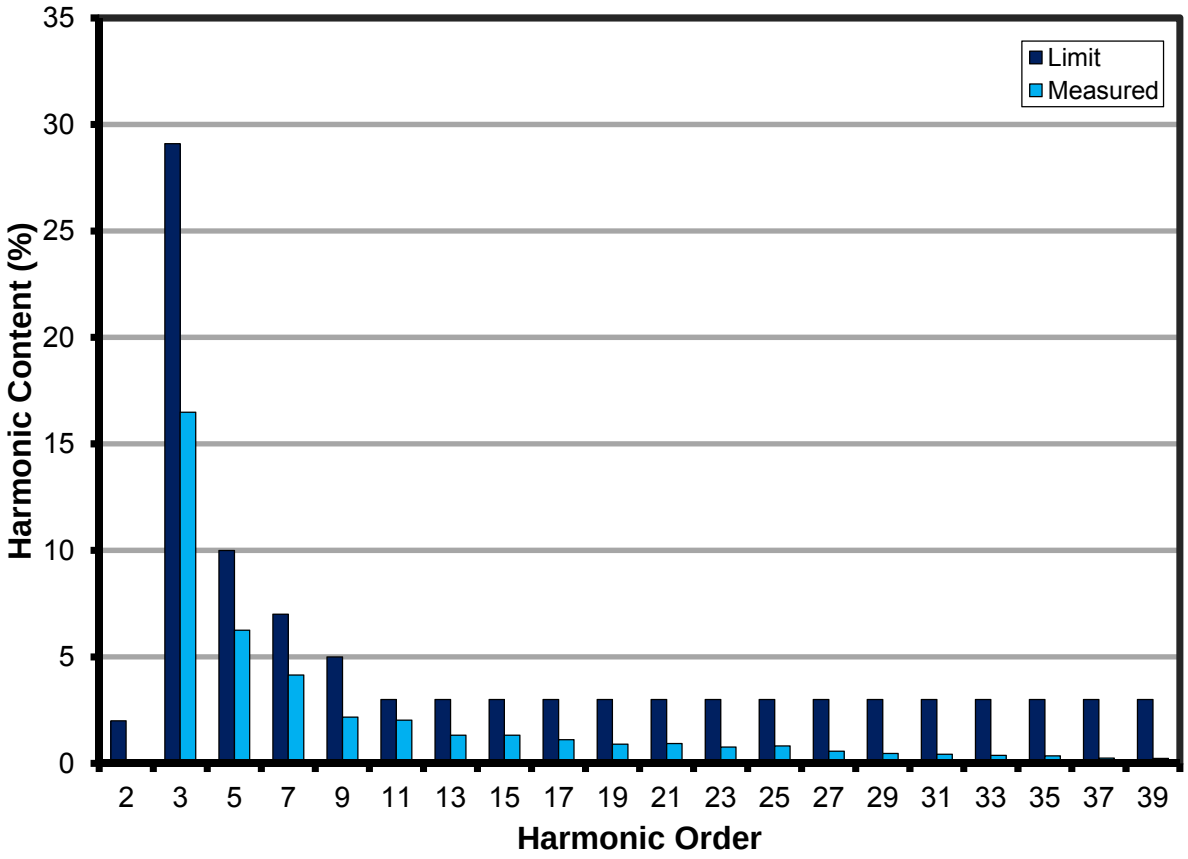

Figure 12 – Input Current Harmonics. Class C EN61000-3-2.

11.5.2 33 V LED负载

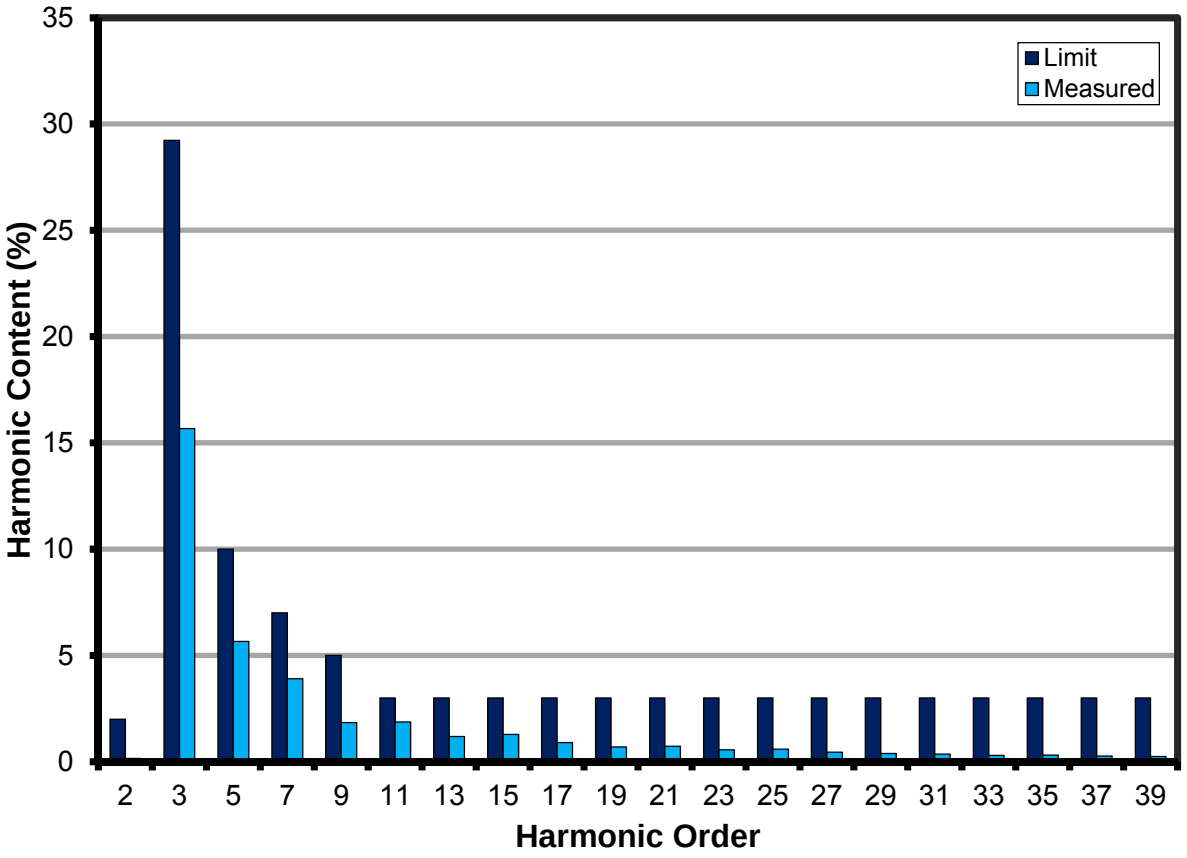

Figure 13 – Input Current Harmonics. Class C EN61000-3-2.

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11.5.3 36 V LED负载

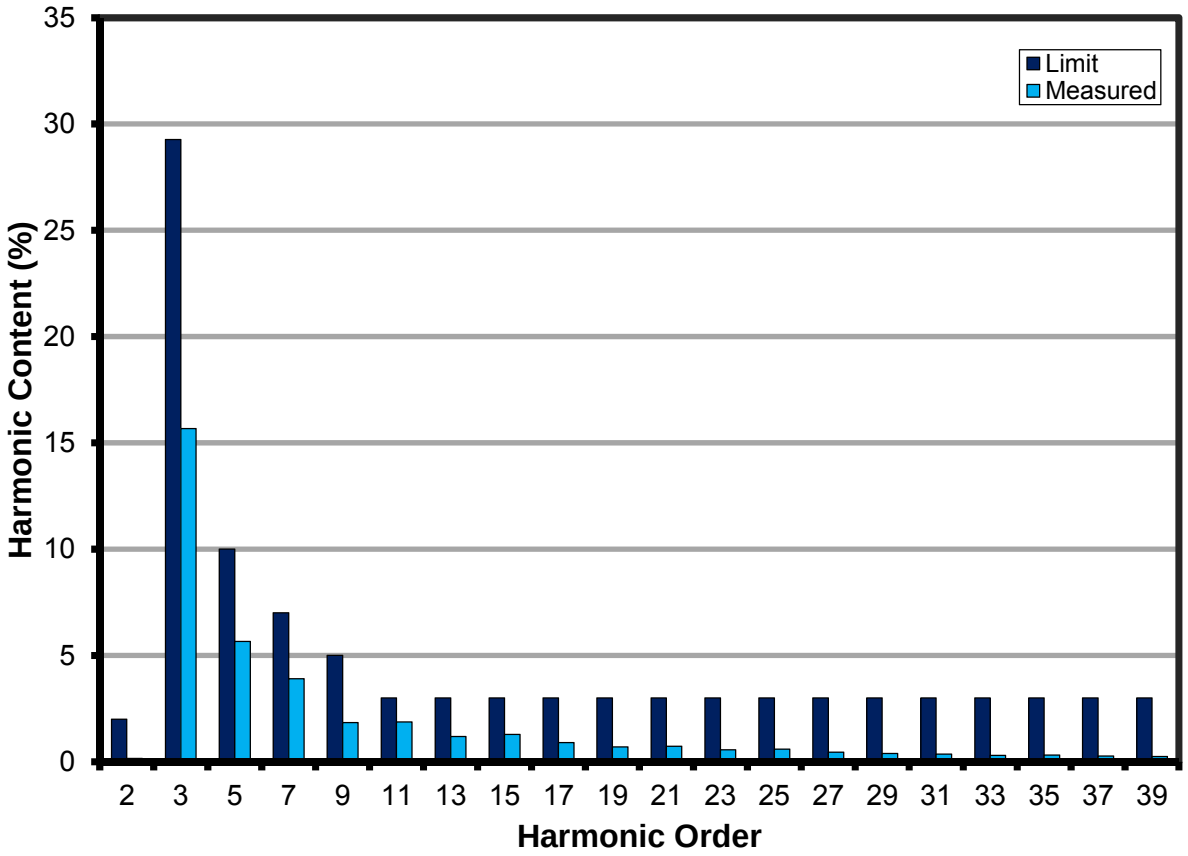

Figure 14 – Input Current Harmonics. Class C EN61000-3-2.

11.6 测试数据

All measurements were taken with the board at open frame, 25 °C ambient, and 50 Hz line frequency

11.6.1 测试数据，30 V LED负载

Input		Input Measurement					Load Measurement CH1			Load Measurement CH2			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)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	$P_{TOTAL(CAL)}$ (W)	Efficiency (%)
184	50	184.66	742.70	135.13	0.985	16.56	29.56	2124.70	62.95	28.91	2087.90	60.51	123.46	91.18
220	50	220.83	623.30	135.05	0.981	18.20	29.47	2137.70	63.14	28.86	2099.60	60.75	123.88	91.58
230	50	230.93	594.45	134.47	0.980	18.61	29.39	2133.70	62.84	28.82	2097.10	60.58	123.42	91.66
240	50	240.97	567.80	133.80	0.978	19.26	29.33	2127.90	62.54	28.78	2092.40	60.36	122.90	91.75
277	50	278.19	484.35	130.68	0.970	21.57	29.24	2083.50	61.04	28.71	2051.40	59.03	120.07	91.79

11.6.2 测试数据，33 V LED负载

Input		Input Measurement					Load Measurement CH1			Load Measurement CH2			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)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	$P_{TOTAL(CAL)}$ (W)	Efficiency (%)
184	50	184.63	861.55	157.05	0.987	15.52	33.32	2156.20	71.97	33.36	2120.60	70.86	142.84	91.04
220	50	220.91	723.05	157.13	0.984	17.10	33.31	2172.60	72.48	33.32	2135.20	71.26	143.75	91.53
230	50	230.90	690.20	156.59	0.983	17.50	33.28	2171.30	72.38	33.27	2133.50	71.10	143.48	91.65
240	50	240.99	659.25	155.90	0.981	17.99	33.25	2165.70	72.13	33.23	2128.10	70.83	142.96	91.71
277	50	278.27	562.10	152.42	0.974	20.30	33.18	2125.40	70.62	33.15	2089.20	69.37	139.99	91.84

11.6.3 测试数据，36 V LED负载

Input		Input Measurement					Load Measurement CH1			Load Measurement CH2			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)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	$P_{TOTAL(CAL)}$ (W)	Efficiency (%)
184	50	184.70	915.95	167.19	0.988	14.96	36.02	2157.80	77.84	35.87	2125.50	76.35	154.187	92.16
220	50	220.92	767.10	166.90	0.985	16.59	35.82	2178.40	78.14	35.70	2143.60	76.65	154.787	92.65
230	50	230.97	730.15	165.90	0.984	17.03	35.65	2177.90	77.75	35.55	2143.20	76.30	154.054	92.79
240	50	241.06	696.30	164.91	0.983	17.50	35.51	2174.80	77.35	35.44	2138.20	75.88	153.233	92.87
277	50	278.34	592.65	160.99	0.976	19.81	35.36	2136.00	75.64	35.30	2101.30	74.27	149.914	93.08

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11.6.4 277 VAC 50 Hz，30 V LED负载谐波数据

V	Freq	I (mA)	P	PF	%THD
277	50.00	483.90	130.5400	0.9698	21.59

nth Order	mA Content	% Content	Limit >25 W	Remarks
1	556.00			
2	0.50	0.09%	2.00%	Pass
3	91.70	16.49%	29.09%	Pass
5	34.80	6.26%	10.00%	Pass
7	23.10	4.15%	7.00%	Pass
9	12.10	2.18%	5.00%	Pass
11	11.30	2.03%	3.00%	Pass
13	7.40	1.33%	3.00%	Pass
15	7.40	1.33%	3.00%	Pass
17	6.20	1.12%	3.00%	Pass
19	5.00	0.90%	3.00%	Pass
21	5.20	0.94%	3.00%	Pass
23	4.30	0.77%	3.00%	Pass
25	4.60	0.83%	3.00%	Pass
27	3.20	0.58%	3.00%	Pass
29	2.60	0.47%	3.00%	Pass
31	2.40	0.43%	3.00%	Pass
33	2.10	0.38%	3.00%	Pass
35	2.00	0.36%	3.00%	Pass
37	1.40	0.25%	3.00%	Pass
39	1.30	0.23%	3.00%	Pass
41	1.60	0.29%		
43	1.20	0.22%		
45	2.80	0.50%		
47	17.00	3.06%		
49	16.50	2.97%		

11.6.5 230 VAC 50 Hz，33 V LED负载谐波数据

V	Freq	I (mA)	P	PF	%THD
277	50.00	562.10	152.4200	0.9744	20.32

nth Order	mA Content	% Content	Limit >25 W	Remarks
1	648.50			
2	1.00	0.15%	2.00%	Pass
3	101.60	15.67%	29.23%	Pass
5	36.70	5.66%	10.00%	Pass
7	25.30	3.90%	7.00%	Pass
9	11.90	1.84%	5.00%	Pass
11	12.10	1.87%	3.00%	Pass
13	7.70	1.19%	3.00%	Pass
15	8.30	1.28%	3.00%	Pass
17	5.80	0.89%	3.00%	Pass
19	4.50	0.69%	3.00%	Pass
21	4.70	0.72%	3.00%	Pass
23	3.60	0.56%	3.00%	Pass
25	3.80	0.59%	3.00%	Pass
27	2.90	0.45%	3.00%	Pass
29	2.50	0.39%	3.00%	Pass
31	2.30	0.35%	3.00%	Pass
33	1.90	0.29%	3.00%	Pass
35	2.00	0.31%	3.00%	Pass
37	1.70	0.26%	3.00%	Pass
39	1.60	0.25%	3.00%	Pass
41	1.50	0.23%		
43	1.70	0.26%		
45	3.70	0.57%		
47	17.70	2.73%		
49	16.00	2.47%		

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11.6.6 230 VAC 50 Hz，36 V LED负载谐波数据

V	Freq	I (mA)	P	PF	%THD
277	50.00	592.90	161.0600	0.9759	19.83

nth Order	mA Content	% Content	Limit >25 W	Remarks
1	684.70			
2	0.80	0.12%	2.00%	Pass
3	104.80	15.31%	29.28%	Pass
5	37.30	5.45%	10.00%	Pass
7	26.00	3.80%	7.00%	Pass
9	12.20	1.78%	5.00%	Pass
11	12.20	1.78%	3.00%	Pass
13	11.50	1.68%	3.00%	Pass
15	6.00	0.88%	3.00%	Pass
17	6.00	0.88%	3.00%	Pass
19	4.20	0.61%	3.00%	Pass
21	4.70	0.69%	3.00%	Pass
23	3.80	0.55%	3.00%	Pass
25	3.80	0.55%	3.00%	Pass
27	3.00	0.44%	3.00%	Pass
29	2.70	0.39%	3.00%	Pass
31	2.40	0.35%	3.00%	Pass
33	2.20	0.32%	3.00%	Pass
35	2.00	0.29%	3.00%	Pass
37	1.90	0.28%	3.00%	Pass
39	1.70	0.25%	3.00%	Pass
41	1.80	0.26%		
43	1.50	0.22%		
45	3.80	0.55%		
47	16.90	2.47%		
49	17.40	2.54%		

12 波形

12.1 输入线电流

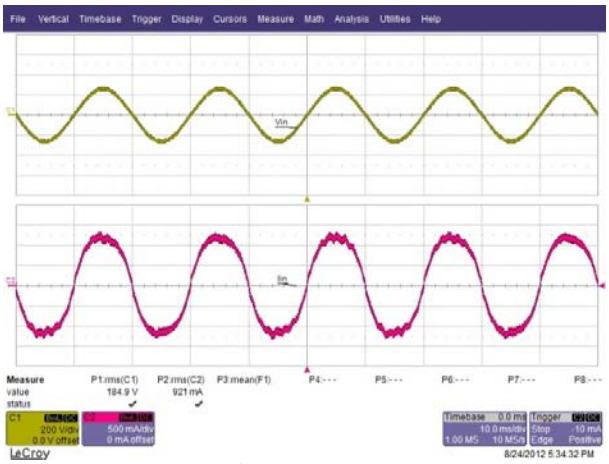

Figure 15 – 184 VAC 50 Hz, Full Load.
Upper: V_{IN}, 200 V
Lower: I_{IN}, 0.5 A / div.,10 ms / div.

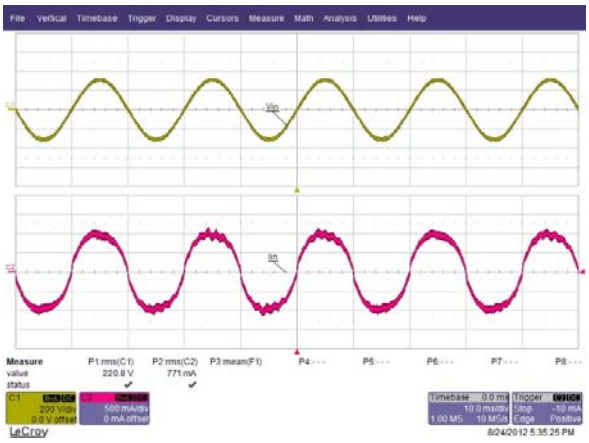

Figure 16 – 220 VAC 50 Hz, Full Load.
Upper: V_{IN}, 200 V
Lower: I_{IN}, 0.5 A / div.,10 ms / div.

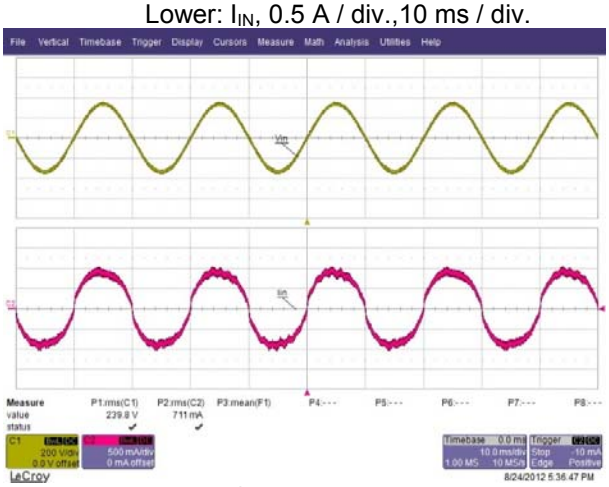

Figure 17 – 240 VAC 50 Hz, Full Load.
Upper: V_{IN}, 200 V
Lower: I_{IN}, 0.5 A / div.,10 ms / div.

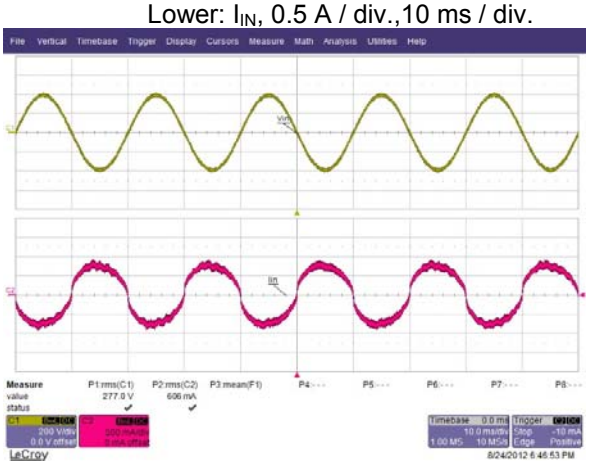

Figure 18 – 277 VAC 50 Hz, Full Load.
Upper: V_{IN}, 200 V
Lower: I_{IN}, 0.5 A / div.,10 ms / div.

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12.2 漏极电压和电流正常工作

Figure 19 – 184 VAC 50 Hz, Full Load.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 200 V, 2 ms / div.

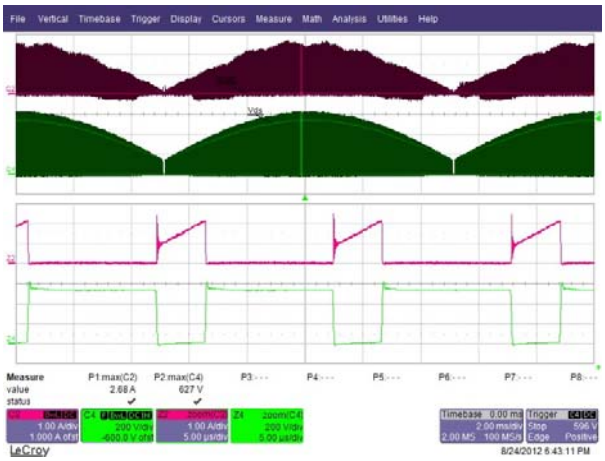

Figure 20 – 277 VAC 50 Hz, Full Load.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 200 V, 2 ms / div.

12.3 漏极电压和电流启动工作

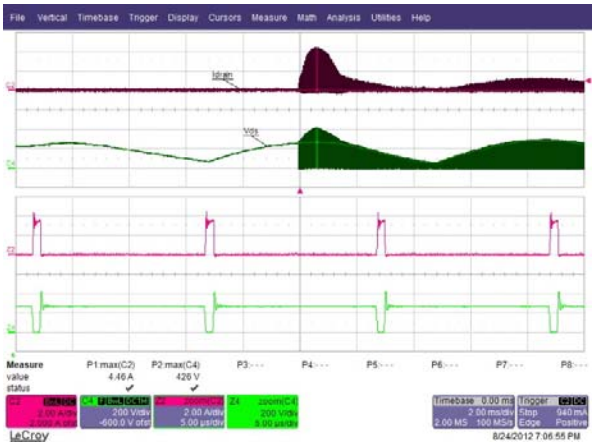

Figure 21 – 184 VAC 50 Hz., Full Load Start-up.
Upper: I_{DRAIN}, 2 A / div.
Lower: V_{DRAIN}, 200 V, 2 ms / div.

Figure 22 – 277 VAC 50 Hz., Full Load Start-up.
Upper: I_{DRAIN}, 2 A / div.
Lower: V_{DRAIN}, 200 V, 2 ms / div.

12.4 输出电流和输出电压

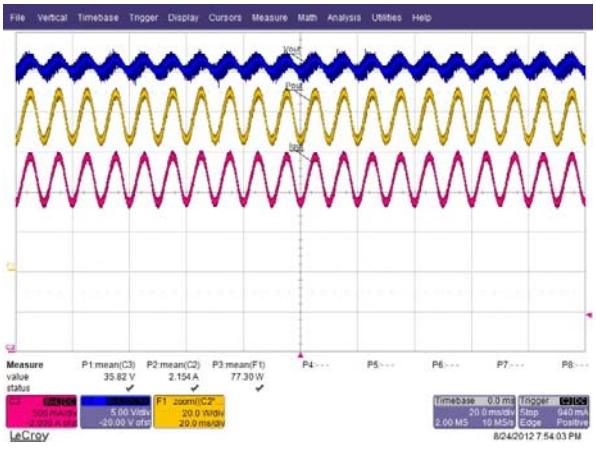

Figure 23 – 184 VAC 50 Hz., Max Load.
Upper: V_{OUT}, 5V / div.
Middle: P_{OUT}, 20W / div.
Lower: I_{OUT}, 500 mA / div.

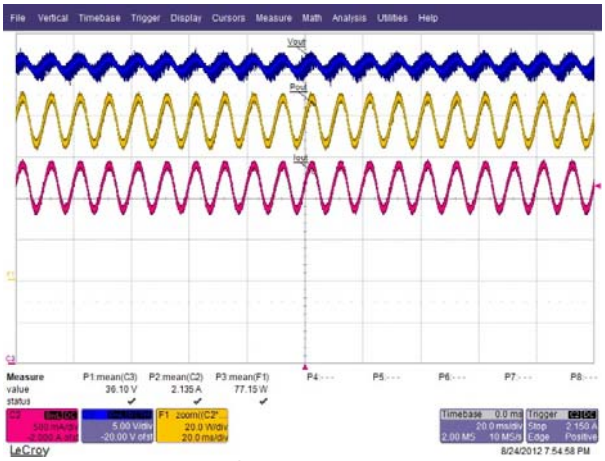

Figure 24 – 277 VAC 50 Hz., Max Load.
Upper: V_{OUT}, 5V / div.
Middle: P_{OUT}, 20W / div.
Lower: I_{OUT}, 500 mA / div.

12.5 启动时的输出电流和电压

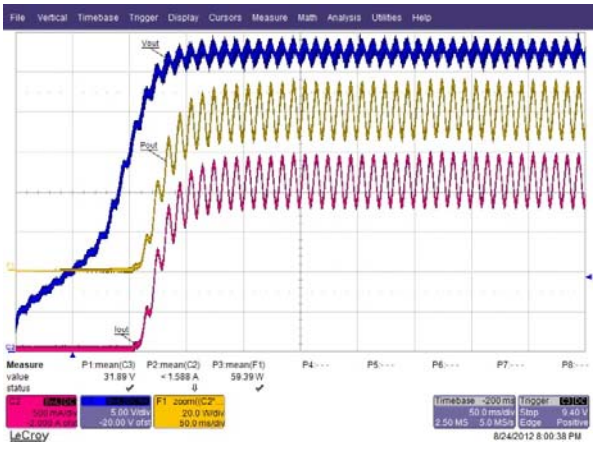

Figure 25 – 184 VAC 50 Hz, Output Rise.
Upper: V_{OUT}, 5V / div.
Middle: P_{OUT}, 20W / div.
Lower: I_{OUT}, 500 mA / div.

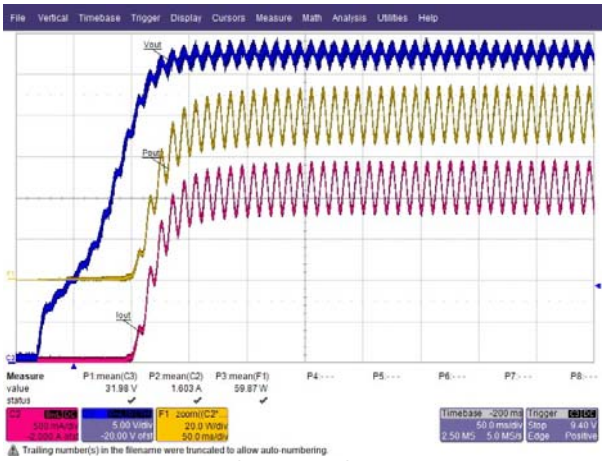

Figure 26 – 277 VAC 50 Hz, Output Rise.
Upper: V_{OUT}, 5V / div.
Middle: P_{OUT}, 20W / div.
Lower: I_{OUT}, 500 mA / div.

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12.6 上电和断电时的输出跟踪

Figure 27 – 184 VAC 50 Hz, Power-up.
Upper: $V_{OUT-LED1}$, 5 V / div.
Lower: $V_{OUT-LED2}$, 5 V / div., 50ms / div.

Figure 28 – 277 VAC 50 Hz, Power-down.
Upper: $V_{OUT-LED1}$, 5 V / div.
Lower: $V_{OUT-LED2}$, 5 V / div., 50ms / div.

12.7 开路负载测试

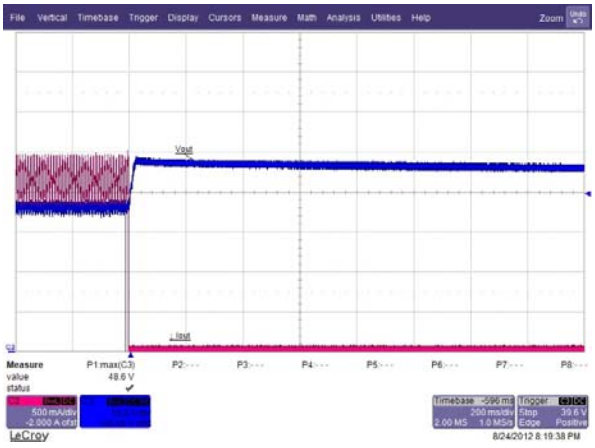

Figure 29 – 277 VAC 50 Hz, Output 1 Open.
Upper: $V_{OUT-LED1}$, 10 V / div.
Lower: $I_{OUT-LED1}$, 500 mA, 200 ms / div.

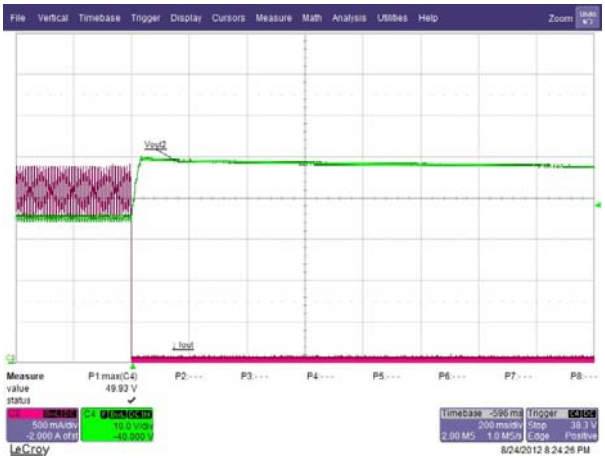

Figure 30 – 277 VAC 50 Hz, Output 2 Open.
Upper: $V_{OUT-LED1}$, 10 V / div.
Lower: $I_{OUT-LED1}$, 500 mA, 200 ms / div.

12.8 输出整流管反向峰值电压

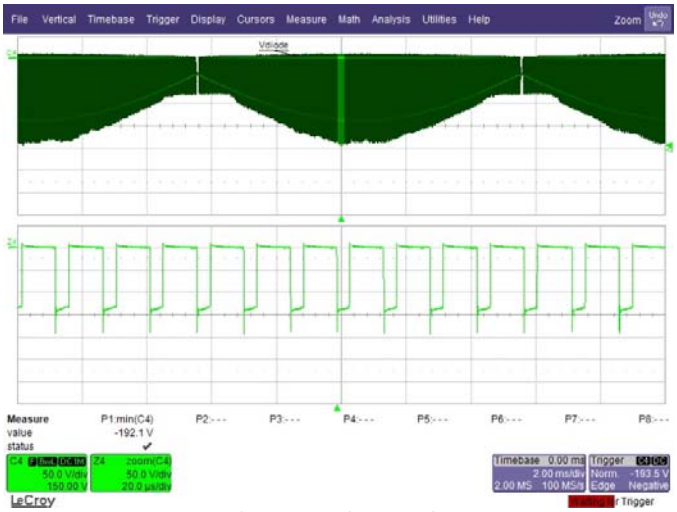

Figure 31 – 277 VAC 50 Hz, Output Short.
Lower: V_{PIV}, 50 V, 5 ms / div.

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13 电源瞬态测试

The unit was subjected to ±2500 V, 100 kHz ring wave and ±2000 V differential surge at 230 VAC using 10 strikes at each condition. A test failure was defined as a non-recoverable interruption of output requiring supply repair or recycling of input voltage.

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

Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Type	Test Result (Pass/Fail)
+2000	230	L1, L2	0	Surge (2Ω)	Pass
-2000	230	L1, L2	90	Surge (2Ω)	Pass
+2000	230	L1, L2	0	Surge (2Ω)	Pass
-2000	230	L1, L2	90	Surge (2Ω)	Pass

14 热测量

Thermal performance was measured inside an enclosure with two 36 V LED loads with no airflow. The thermocouple was attached to the body of the components. Temperature stabilized after 2 hour.

DESCRIPTION	184 VAC / 50 Hz. (ºC)	230 VAC / 50 Hz. (ºC)	277 VAC / 50 Hz. (ºC)
Ambient Temperature	65	65	65
Input Bridge (BR1)	110.5	103.5	95.5
Transformer (T1)	78.6	81.3	82.6
Transformer (T2)	77.3	79.6	81.9
LNK-PH (U1)	119.7	116.3	114.2
LNK-PH (U2)	120.5	117.9	115.5
Output Diode (D17)	99.9	98.5	98
Output Diode (D9)	99.6	99.9	99.5
Output Diode (D16)	97.3	97.8	97.3
Output Diode (D8)	99.1	99	98.3
TVS (VR1)	110.9	105.2	102.7
TVS (VR4)	112.3	107.6	104
Block Diode (D3)	114.6	108.9	105.5
Block Diode (D11)	116.6	111.3	106.6

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15 传导EMI测量

15.1 传导EMI测试设置

The UUT is placed on a ground plane as shown below together with the LED load.

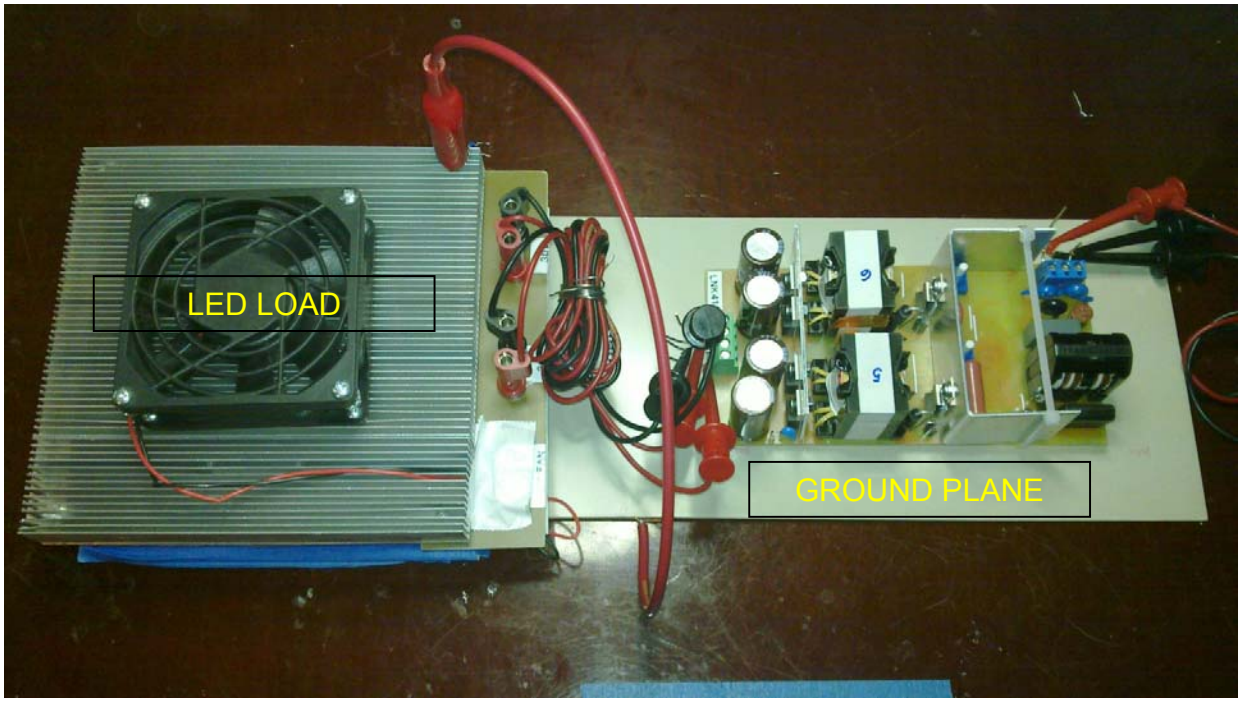

Figure 32 – EMI Measurement Set-up.

15.2 传导EMI测试结果

Figure 33 – 30 V LED Load, 230 VAC, 60 Hz, and EN55015 Limits.

EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	64.5467705779 kHz	38.64	N gnd	
2	Average	67.8393045788 kHz	40.85	N gnd	
2	Average	126.977840157 kHz	48.68	L1 gnd	
2	Average	130.825395691 kHz	50.77	L1 gnd	
2	Average	133.454986145 kHz	55.87	N gnd	
2	Average	137.49880568 kHz	53.71	N gnd	
1	Quasi Peak	164.052790903 kHz	47.12	N gnd	-18.12
2	Average	165.693318812 kHz	40.45	L1 gnd	-14.71
2	Average	196.231331718 kHz	48.41	L1 gnd	-5.35
1	Quasi Peak	198.193645035 kHz	56.59	L1 gnd	-7.09
1	Quasi Peak	264.49018761 kHz	48.32	L1 gnd	-12.96
2	Average	264.49018761 kHz	39.23	L1 gnd	-12.05
1	Quasi Peak	332.507282579 kHz	45.25	L1 gnd	-14.13
1	Quasi Peak	397.727746704 kHz	40.49	L1 gnd	-17.40
1	Quasi Peak	598.084042089 kHz	39.43	L1 gnd	-16.56
1	Quasi Peak	7.71534368894 MHz	40.79	L1 gnd	-19.21
1	Quasi Peak	20.6619488204 MHz	52.62	N gnd	-7.37
2	Average	20.6619488204 MHz	44.60	N gnd	-5.39
1	Quasi Peak	28.9799739049 MHz	46.37	N gnd	-13.62

Figure 34 – Scan Summary at 30 V LED Load, 230 VAC, 60 Hz, and EN55015 Limits.

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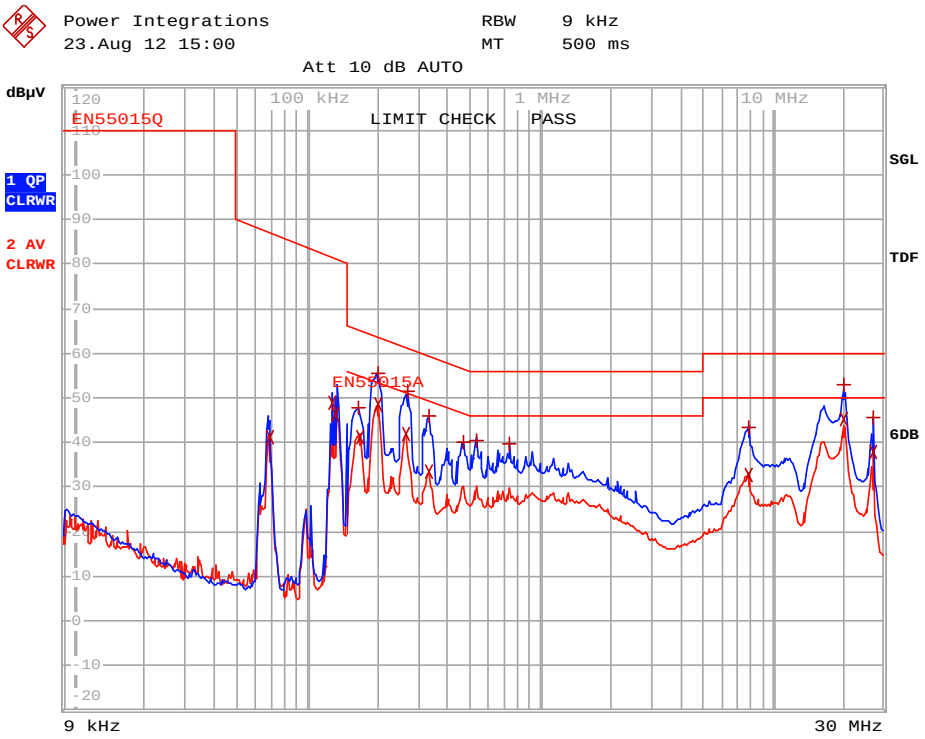

Figure 35 – Line Conducted EMI, 36 V LED Load, 230 VAC, 60 Hz, and EN55015 Limits

EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	68.5176976246 kHz	41.29	L1 gnd	
2	Average	126.977840157 kHz	48.93	N gnd	
2	Average	132.133649648 kHz	46.48	N gnd	
1	Quasi Peak	164.052790903 kHz	47.91	L1 gnd	-17.34
2	Average	167.350252 kHz	41.25	L1 gnd	-13.83
1	Quasi Peak	200.175581485 kHz	55.59	N gnd	-8.00
2	Average	200.175581485 kHz	48.52	L1 gnd	-5.07
2	Average	264.49018761 kHz	41.74	L1 gnd	-9.54
1	Quasi Peak	267.135089486 kHz	51.30	L1 gnd	-9.90
1	Quasi Peak	332.507282579 kHz	46.06	L1 gnd	-13.32
2	Average	332.507282579 kHz	33.55	L1 gnd	-15.83
1	Quasi Peak	466.367062279 kHz	40.20	L1 gnd	-16.37
1	Quasi Peak	530.769219795 kHz	40.56	L1 gnd	-15.43
1	Quasi Peak	729.776191209 kHz	39.79	L1 gnd	-16.20
1	Quasi Peak	7.79249712583 MHz	43.47	L1 gnd	-16.52
2	Average	7.79249712583 MHz	32.54	L1 gnd	-17.45
1	Quasi Peak	20.2548268017 MHz	52.99	N gnd	-7.00
2	Average	20.2548268017 MHz	45.25	N gnd	-4.74
1	Quasi Peak	26.7625196891 MHz	45.70	N gnd	-14.29
2	Average	26.7625196891 MHz	37.87	N gnd	-12.12

Figure 36 – Scan Summary at 36 V LED Load, 230 VAC, 60 Hz, and EN55015 Limits.

16 版本历史

Date	Author	Revision	Description and Changes	Reviewed
11-Nov-11	ME	1.0	Initial Release	Apps & Mktg
19-Oct-12	JDC	2.0	Updated Test Results for LNK420EG	Apps & Mktg

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