设计范例报告

标题	***使用LYTSwitch™ -4 LYT4324E设计的20 W高效率(>86%)，可控硅调光，带功率因数校正的隔离反激式LED驱动器***
规格	185 VAC – 265 VAC输入； 36 $V_{TYPICAL}$，550 mA输出
应用	PAR38替换灯
作者	应用工程部
文档编号	DER-396
日期	2013年9月25日
修订版本	1.0

特色概述

- 单级功率因数校正(PFC)及精确恒流(CC)输出(+5%)
- 在230 VAC下，PF > 0.9
- 在230 VAC下，%A THD <20%
- 在不同生产环境下和过热范围内具有一致的调光性能
- 低成本、元件数量少、印刷电路板(PCB)占板面积小的设计
- 极高能效，在230 VAC输入下效率>86 %
- 快速启动时间(<250 ms) – 无可见延迟
- 干净的单向启动 – 无输出闪烁
- 集成的保护及可靠性能
  - 空载保护，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AC电压缓降期间不会造成任何损坏
- 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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5245 Hellyer Avenue, San Jose, CA 95138 USA.
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目录

重要说明：
虽然本电路板的设计满足非隔离LED驱动器安全要求，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

本文档是一份工程报告，介绍使用LYTSwitch-4高压系列器件LYT4324E设计的一款隔离式、高功率因数、可调光LED驱动器（电源）。

DER-396能够在185至265 VAC的输入电压范围内提供一路20 W (36 $V_{TYPICAL}$)、可调光的550 mA恒流输出。

主要设计目标是实现高效率，以提升发光效率并减小尺寸。这样可使驱动器装入BR38灯并尽可能接近可投产设计。

LYTSwitch-4 IC可用来实现具有成本效益的低元件数LED驱动器，同时使设计满足功率因数和谐波失真限值。LYTSwitch-4驱动器IC将PFC功能和次级输出恒流控制电路同时集成到一个开关级中。

所使用的拓扑结构是运行于连续导通模式下的隔离反激。输出电流调整完全从初级侧实现，因此无需使用次级反馈元件。在初级侧也无需检测外部电流，而是在IC内部进行，可进一步降低元件成本并提高效率。内部控制器调整功率MOSFET占空比以保持输入电流为正弦交流电，同时确保高功率因数和低谐波电流控制。

LYT4324E也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。输入过压可提供增强的抗输入故障和浪涌能力，输出过压可保护负载应当断开的电源，精确的迟滞热关断可确保在所有条件下平均PCB温度都处于安全范围内。

在任何LED照明装置中，驱动器的性能直接决定了最终用户对照明的感受，包括启动时间、调光性能和驱动器之间的一致性。该设计经过优化，可确保兼容各种调光器和更宽的调光范围。

本文档包括电源规格、电路原理图、物料清单、变压器规格文件、印刷电路板布局、设计表格及性能数据。

2 装配后的PCB板

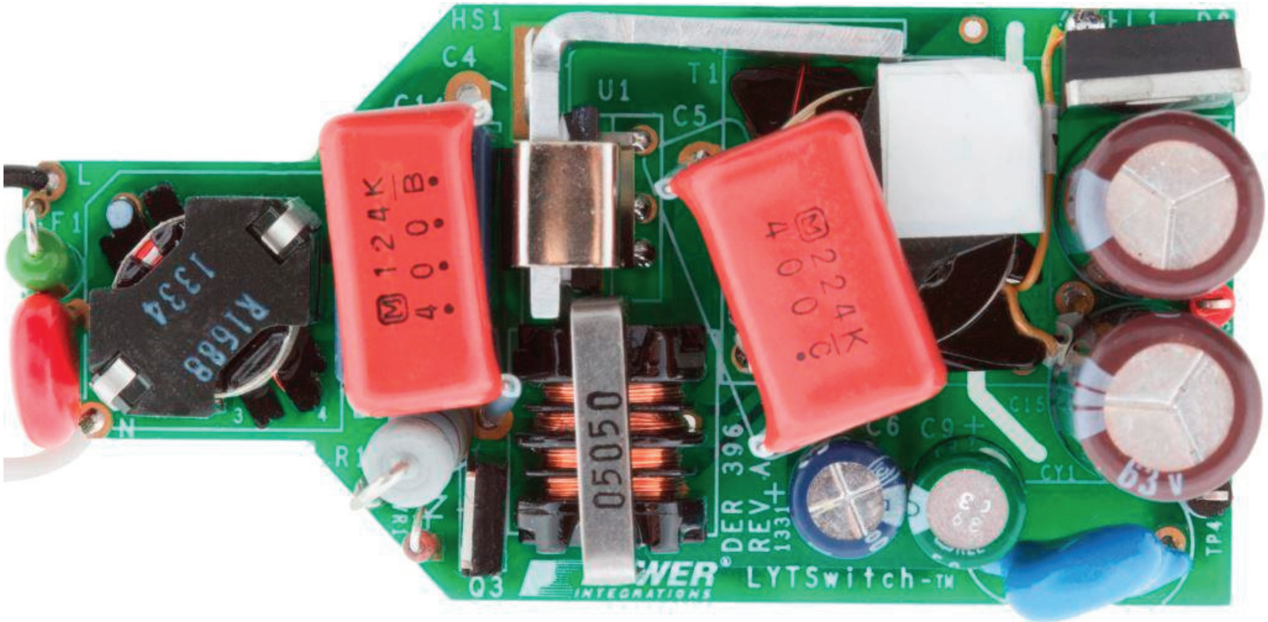

Figure 1 – Populated Circuit Board (Top Side).

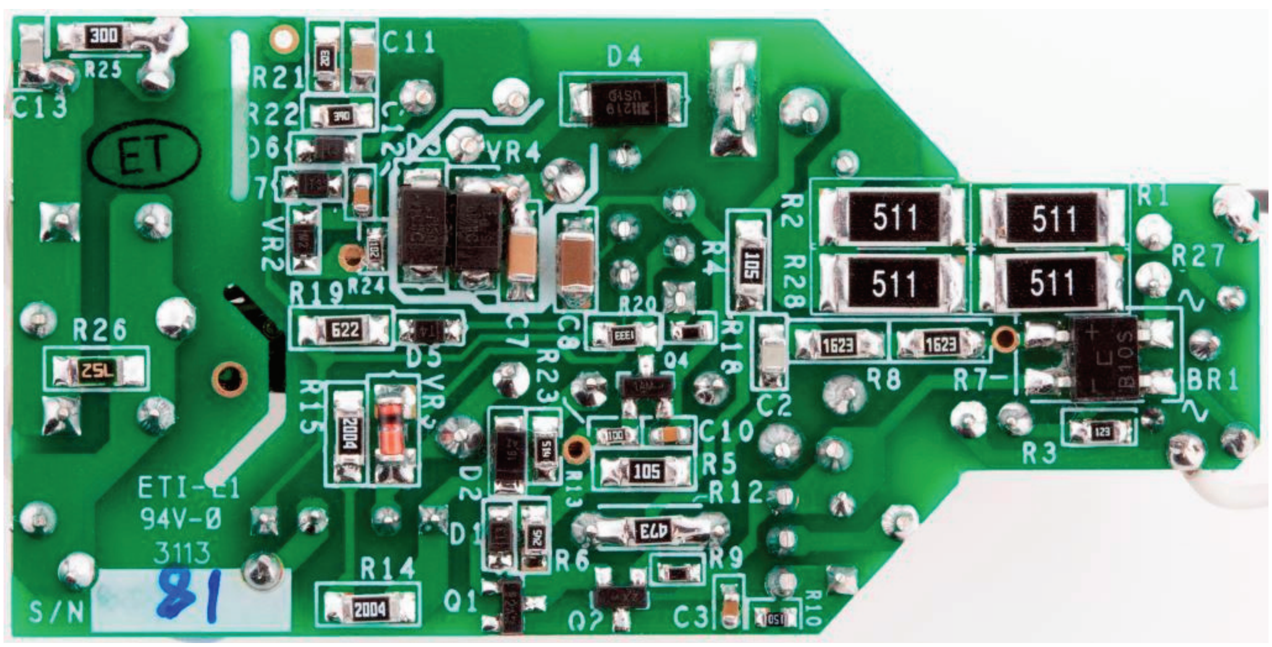

Figure 2 – Populated Circuit Board (Bottom Side).

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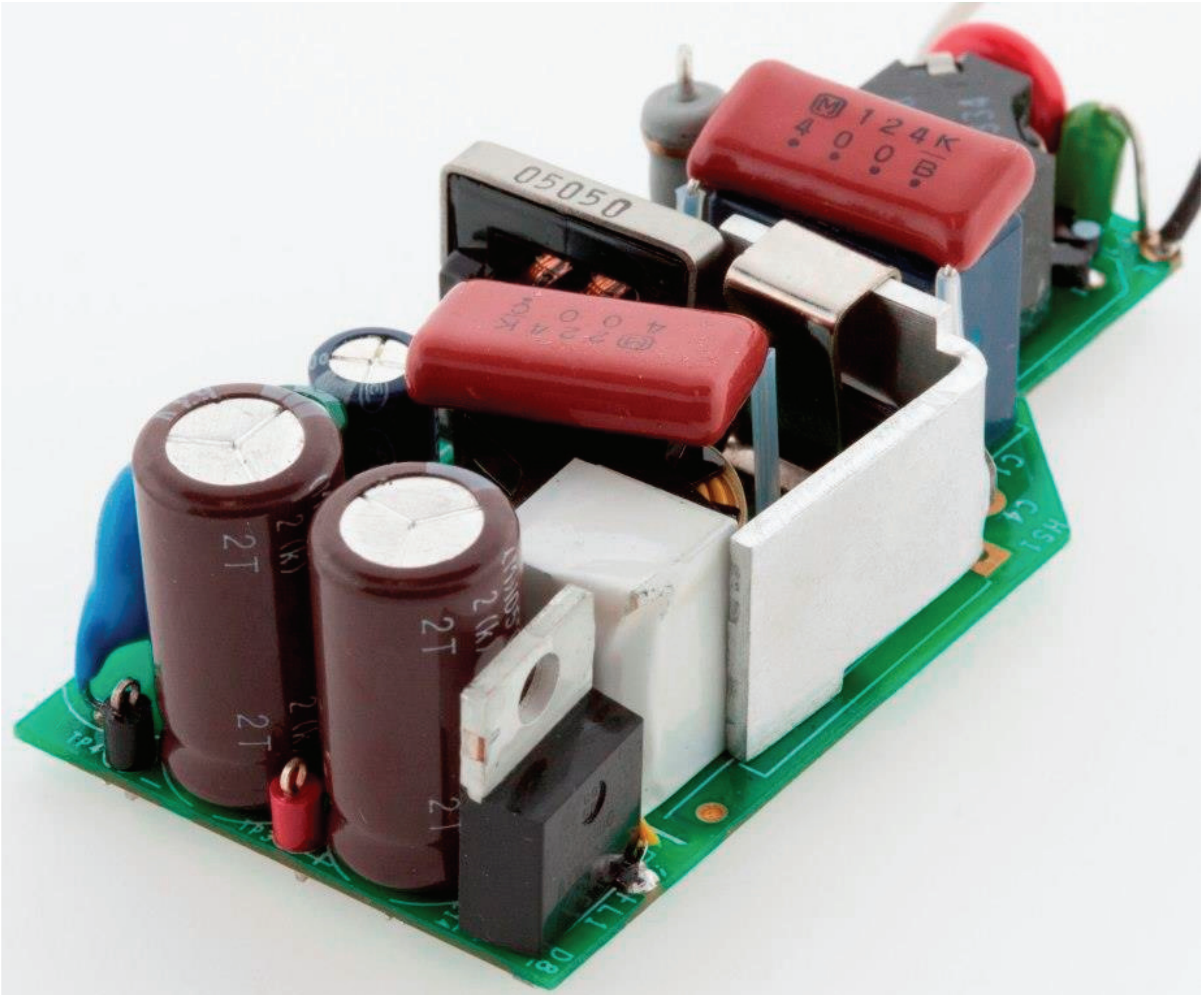

Figure 3 – Populated Circuit Board.
Dimensions: 2.68 in [68.1 mm] L x 1.32 in [33.6 mm] W x 1 in [25.4 mm] H.

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}	185	230	265	VAC	双导线 – 无P.E.
频率	f_{LINE}	47	50/60	63	Hz	
功率因数			0.9			在230 VAC下
%ATHD				17		
输出						
输出电压	V_{OUT}	33	36	39	V	
输出电流	I_{OUT}	522	550	577	mA	在230 VAC下
总输出功率						
连续输出功率	P_{OUT}		20		W	
效率						
额定	η		86		%	在P_{OUT} 25 ºC及230 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

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3.1 电路原理图

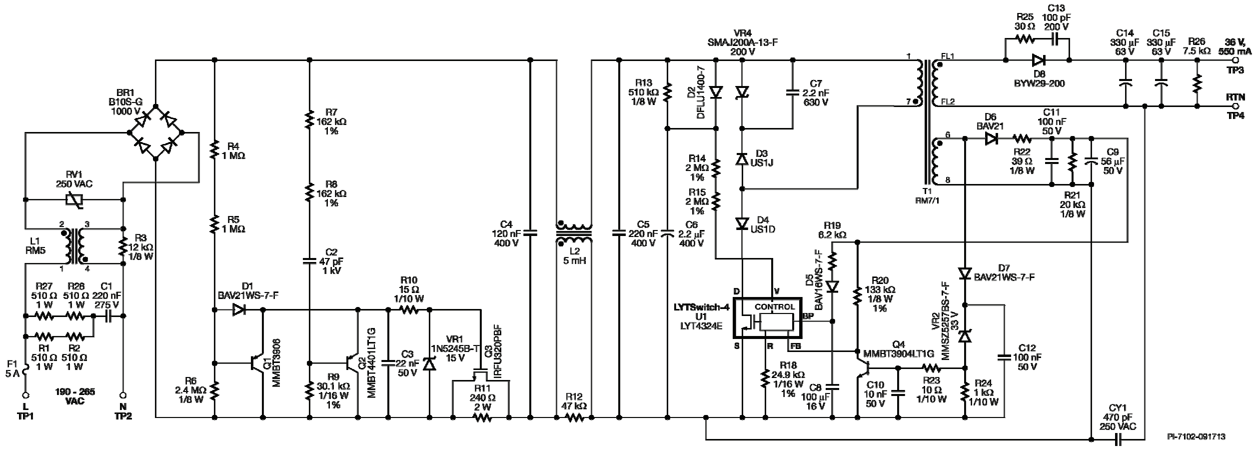

Figure 4 – Schematic for 36 V, 550 mA Replacement Lamp.

4 电路描述

LYTSwitch-4 (U1)系列器件是一系列适用于LED驱动器应用的高集成度电源IC。LYTSwitch-4能够在单级转换拓扑结构中提供高功率因数，同时特别对LED驱动器应用中常见的各种输入(185 VAC-265 VAC)和输出电压条件下的输出电流进行调节。

4.1 输入级

保险丝F1提供元件故障保护。需要使用一个额定值5 A的快速恢复二极管来防止在输入浪涌下误开路。压敏电阻RV1提供箝位功能，用以限制在差模输入电压浪涌期间的最大电压。RV1的额定电压为275 VAC，略高于最大指定工作电压(265 VAC)。LYTSwitch-4的快速反应输入过压检测与D2和C6峰值检测电容一起提供箝位功能，用以限制在IC的功率MOSFET上出现最大电压应力。此外，在差模输入浪涌期间（通过RC高通滤波器 - R7、R8和C2 - 检测到高dv/dt），Q2将关断Q3，与输入电流（在阻尼电阻R11中将增大）成正比的电压将从输入端减去。这有助于限制出现在U1漏极的电压应力。电阻R9从C2泄放电荷，并确保Q2在正常工作期间处于关断状态。

差模扼流圈L1是用来抑制噪声的前端EMI滤波器。电阻R3可在必要时衰减EMI滤波器的谐振。

BR1对AC输入进行全波整流以获得良好的功率因数和低THD。

电容C4、C5和共模扼流圈L2形成位于桥式整流管后面的EMI滤波器。滤波电容受到限制，可维持较高的功率因数。该输入π滤波器网络与LYTSwitch-4的频率调制特性相结合，可使设计满足Class B干扰限值。电阻R12可在必要时衰减EMI滤波器的谐振，从而防止当在系统（驱动器加外壳）中测量时EMI频谱中出现峰值。

4.2 衰减电路级

为了用低成本的可控硅前沿相控调光器提供输出调光，我们需要在设计时进行全面权衡。由于LED照明的功耗非常低（相对于传统的白炽灯泡），灯所吸收的电流要小于调光器内可控硅的维持电流。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，产生很严重的振荡。这同样会造成类似不良情况，因为振荡会使可控硅电流降至零（并关断可控硅）。要克服这些问题，需增加两个电路 – 有源衰减电路和无源泄放电路。这些电路的缺点是会增大功耗，进而降低电源的效率。对于非调光应用，可以省略这些元件。

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有源衰减电路由元件R4、R5、R6、R10、D1、Q1、C3、VR1和Q3以及R11共同组成。该电路可以限制可控硅导通时流入C3并对其充电的浪涌电流，实现方式是在导通前1 ms内将R11串联。在大约1 ms后，Q3导通并将R11短路。这样可使R11的功耗保持在低水平，在限流时可以使用更大的值。电阻R4、R5、R6和C3在可控硅导通后提供1 ms延迟。晶体管Q1在可控硅不导通时对C3进行放电，VR1将Q3的栅极电压箝位在15 V，R10用于防止MOSFET发生振荡。当无可控硅连接时，Q3将保持导通，从而旁通R11以提高效率。

无源RC泄放电路（C1、R1、R2、R27和R28）就位于保险丝后面，用来通过EMI电感降低调光期间的浪涌电流，进而降低音频噪声。使用了四个泄放电阻来分割功耗（特别是调光器处在90º导通角时），以便获得紧凑外形。这样可以使输入电流始终大于可控硅的维持电流，而与驱动器相应的输入电流将在每个AC半周期内增大，防止每个导通角期间的起始阶段出现可控硅的开关振荡。

4.3 LYTSwitch-4初级

变压器(T1)一端连接到DC总线，另一端连接到LYTSwitch-4 IC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。本设计选用RM7磁芯，因为它在板上占用的面积很小。由于骨架达不到230 VAC工作条件下的6.2 mm的安全爬电距离要求，因此使用飞线将次级绕组端接到PCB板中。

为向U1提供峰值输入电压信息，经整流AC的输入峰值经由D2对C6充电。然后电流经过R14和R15，注入U1的电压监测(V)引脚。电阻容差将会导致不同电源之间的V引脚电流有所差异，因此选择1%误差的电阻可以将这种变化降至最低。器件也会利用V引脚电流来设定输入过压阈值。电阻R13为C6提供放电通路，时间常数远大于经整流AC的放电时间，以防止V引脚电流被线电压频率所调制。

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。可在R引脚(R18)和V引脚上分别使用24.9 kΩ电阻和4 MΩ (R14+R15)电阻，使输入电压和输出电流保持线性关系，从而获得最大调光范围。

在功率MOSFET导通期间，在C5上的电压降到反射输出电压(V_{OR})以下时，需要使用二极管D4来防止反向电流流经U1。在瞬态工作期间，由于漏感会带来影响，VRCD缓冲电路二极管D3、VR4和C7将漏极电压箝位到一个安全水平。

二极管D6、C9、C11、R21和R22构成初级偏置供电，能量来自变压器的辅助绕组。电容C8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，C8从与漏极引脚相连的内部高压电流源被充电至约6 V。此时器件开始开关，器件的供电电流再由偏置供电经过R19提供。二极管D5隔离BP引脚和C8，以防止启动时间由于对C9和C11的充电而延长。

建议使用外部偏置供电（通过D5和R19），以实现最低的器件功耗、最高的效率和更佳的调光性能。

电容C8同时用来选择输出功率模式，选择100 μF用于减功率模式，可以将器件功耗减至最低，降低对散热片的要求。虽然47 μF是最小建议旁路电容值，但在使用SMD陶瓷电容时，建议采用68 μF – 100 μF / X5R的值以留出电容容差。

4.4 输出反馈

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R20将偏置电压转换为电流，馈入U1的FB引脚。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。

4.5 负载断开保护

本参考设计可获得防止出现意外LED负载断开（如在生产过程中）的保护。控制器将在自动重启动模式下工作，通过限定输出电压（通过来自电感辅助绕组的反射电压、D7整流和C12峰值滤波进行检测）防止电路板上的输出电容被损坏。驱动器会在Q4导通（从FB引脚吸入电流）时进入自动重启动模式，同时齐纳二极管VR2设置过压限值。

4.6 过载和短路保护

样品可通过初级流限获得过载和短路保护。在短路时，初级电流开始增大，直到达到限流点。请参见短路波形以获得详细信息。

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5 PCB布局轮廓

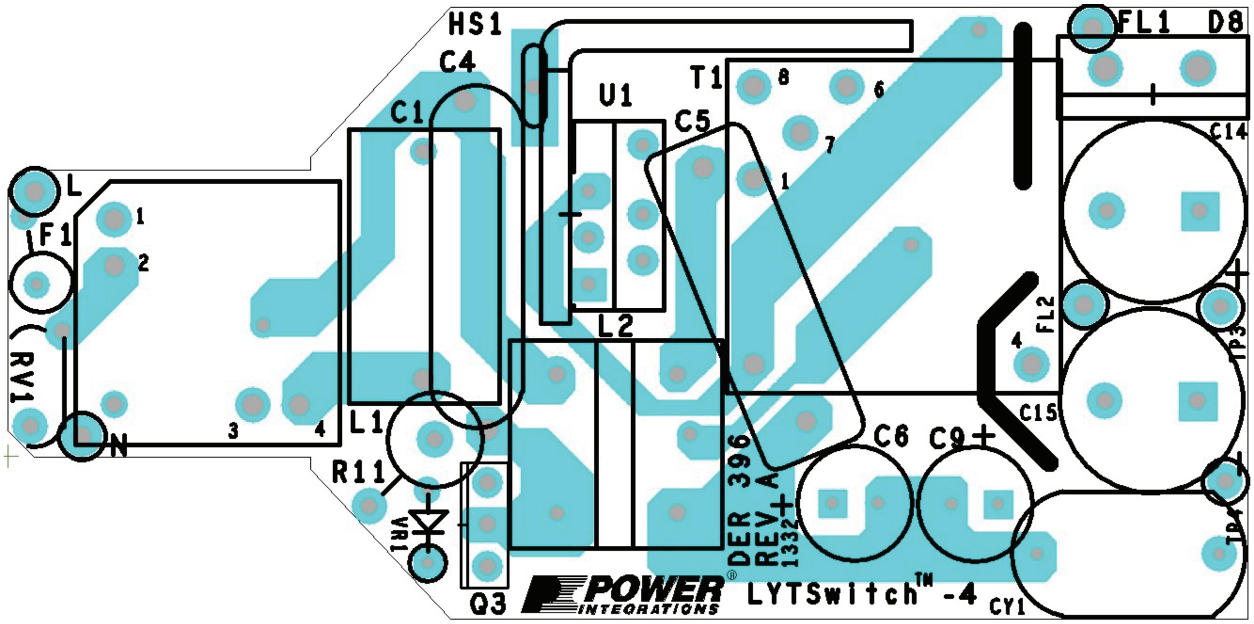

Figure 5 – Top Printed Circuit Layout.

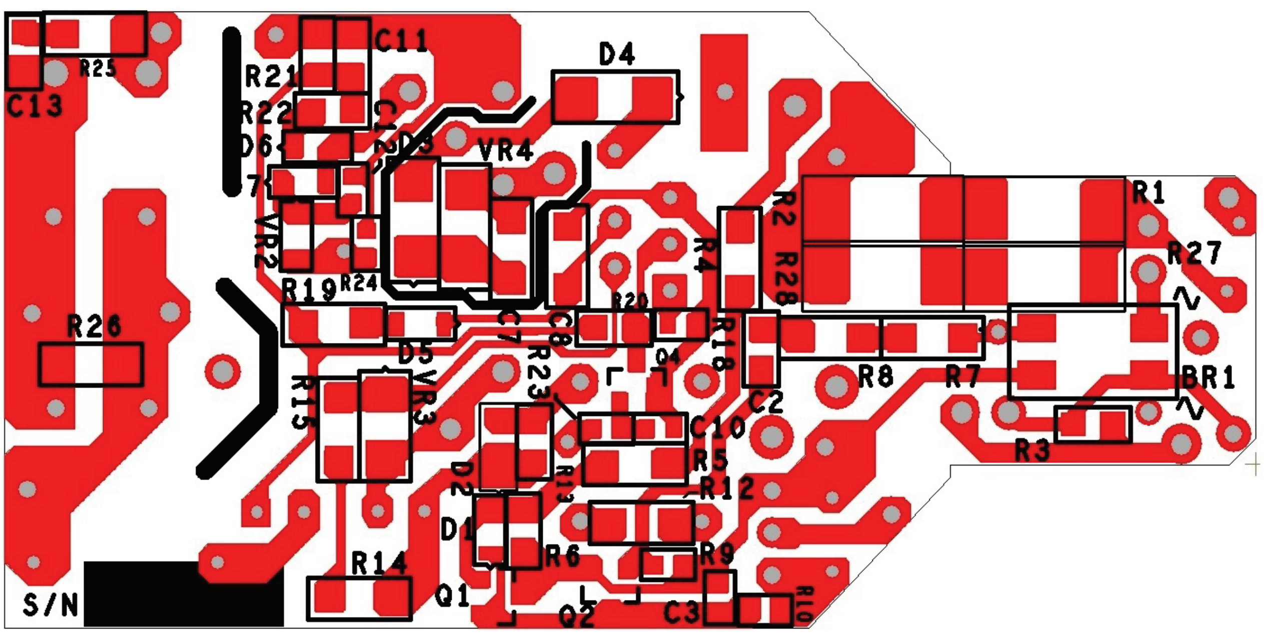

Figure 6 – Bottom Printed Circuit Layout.

6 物料清单(BOM)

The table below is the reference design BOM.

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip
2	1	C1	220 nF, 275 VAC, Film, X2	LE224-M	OKAYA
3	1	C2	47 pF, 1000 V, Ceramic, NPO, 0805	VJ0805A470JXGAT5Z	Vishay
3	1	C3	22 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H223K	TDK
4	1	C4	120 nF, 400 V, Film	ECQ-E4124KF	Panasonic
5	1	C5	220 nF, 400 V, Film	ECQ-E4224KF	Panasonic
6	1	C6	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
7	1	C7	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K	TDK
8	1	C8	100 μF, 16 V, X5R, 1206	3216X5R1C105M	TDK
9	1	C9	56 μF, 50 V, Electrolytic, Very Low ESR, 140 mΩ, (6.3 x 11)	EKZE500ELL560MF11D	Nippon Chemi-Con
10	1	C10	10 nF 50 V, Ceramic, X7R, 0603	C0603C103K5RACTU	Kemet
11	1	C11	100 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB104	Yageo
12	1	C12	100 nF 50 V, Ceramic, X7R, 0603	C1608X7R1H104K	TDK
13	1	C13	100 pF, 200 V, Ceramic, COG, 0805	08052A101JAT2A	AVX
14	2	C14 C15	330 μF, 63 V, Electrolytic, (10 x 20)	EKMG630ELL331MJ20S	United Chemi-con
15	1	CY1	470 pF, 250 VAC, Film, X1Y1	CD95-B2GA471KYNS	TDK
16	3	D1 D6 D7	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
17	1	D2	400 V, 1 A, DIODE SUP FAST 1A PWRDI 123	DFLU1400-7	Diodes, Inc.
18	1	D3	DIODE ULTRA FAST, SW 600 V, 1 A, SMA	US1J-13-F	Diodes, Inc.
19	1	D4	DIODE ULTRA FAST, SW, 200 V, 1 A, SMA	US1D-13-F	Diodes, Inc.
20	1	D5	75 V, 0.15 A, Switching, SOD-323	BAV16WS-7-F	Diodes, Inc.
21	1	D8	200 V, 8 A, Ultrafast Recovery, 25 ns, TO-220AC	BYW29-200G	On Semi
22	1	F1	5 A, 250 V, Fast, Microfuse, Axial	0263005.MXL	Littlefuse
23	1	L1	Custom, RM5, Vertical, 6 pins	SNX-R1688	Santronics USA
24	1	L2	5 mH, 0.5 A, Common Mode Choke Vertical	SU9VF-05050	Tokin
25	1	Q1	PNP, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3906LT1G	On Semi
36	1	Q2	NPN, Small Signal BJT, GP SS, 40 V, 0.6 A, SOT-23	MMBT4401LT1G	Diodes, Inc.
26	1	Q3	400 V, 3.1 A,N-Channel, TO-251AA	IRFU320PBF	Vishay
27	1	Q4	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3904LT1G	On Semi
28	4	R1 R2 R27 R28	510 Ω, 5%, 1 W, Thick Film, 2512	ERJ-1TYJ511U	Panasonic
29	1	R3	12 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ123V	Panasonic
30	2	R4 R5	1 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
31	1	R6	2.4 MΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ245V	Panasonic
32	1	R7	162 k, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1623V	Panasonic
33	1	R8	162 k, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1623V	Panasonic
34	1	R9	30.1 k, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3012V	Panasonic
35	1	R10	15 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ150V	Panasonic
36	1	R11	240 Ω, 5%, 2 W, Metal Oxide	RSF200JB-240R	Yageo
37	1	R12	47 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ473V	Panasonic
38	1	R13	510 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ514V	Panasonic
39	2	R14 R15	2.0 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
40	1	R17	200 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ204V	Panasonic

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Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
41	1	R18	24.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2492V	Panasonic
42	1	R19	6.2 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ622V	Panasonic
43	1	R20	133 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1333V	Panasonic
44	1	R21	20 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ203V	Panasonic
45	1	R22	39 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ390V	Panasonic
46	1	R23	10 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ100V	Panasonic
47	1	R24	1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
48	1	R25	30 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ300V	Panasonic
49	1	R26	7.5 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ752V	Panasonic
50	1	RV1	250 V, 21 J, 7 mm, RADIAL LA	V130LA20AP	Littlefuse
51	1	T1	Custom, RM7/I, Vertical, 8 pins with mtg clip CLI/P-RM7	SNX-R1689	Santronics USA
52	1	U1	LYTSwitch-4, eSIP-7C	LYT4324E	Power Integrations
53	1	VR1	15 V, 5%, 500 mW, DO-35	1N5245B-T	Diodes, Inc.
54	1	VR2	33 V, 5%, 200 mW, SOD-323	MMSZ5257BS-7-F	Diodes, Inc.
55	1	VR4	200 V, 400 W, SMA	SMAJ200A-13-F	Diodes, Inc.
Mechanical BOM					
1	1	HS1	Heat sink, Custom, Al, 3003, 0.062" Thk	Custom	Custom
2	1	POWER CLIP1	Heat sink Hardware, Edge Clip 21N (4.7 lbs) 10 mm L x 7 mm W x 0.5 mm H	CLP212SG	Aavid Thermalloy
3	6	Insulation Tubing	15 mm; PTTFE AWG #20 TW Tubing	TFT20-NT	Custom Cut

7 变压器(T1)规格

7.1 电气原理图

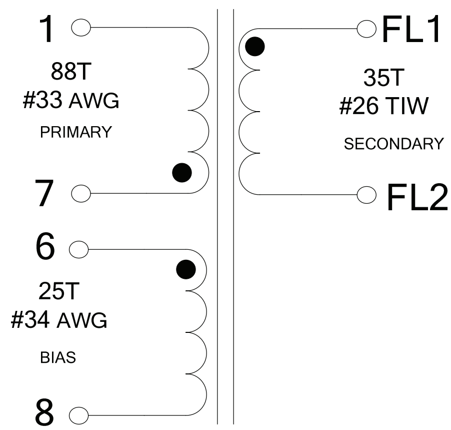

Figure 7 – Transformer Electrical Diagram.

7.2 电气规格

Primary Inductance	Pins 1-7, all other windings open, measured at 100 kHz, 0.4 $V_{RMS.}$	1 mH ±7%
Resonant Frequency	Pins 1-7, all other windings open.	1000 kHz (Min.)

7.3 材料

Item	Description
[1]	Core: RM7; 3F3.
[2]	Bobbin: Rm-7; 4/4 pin vertical.
[3]	Clip: EPCOS, KlammerRM7, Manufacture P/N: B65820B2001X.
[4]	Magnet Wire: #33 AWG, double coated.
[5]	Magnet Wire: #26 TIW, triple insulated.
[6]	Magnet Wire: #34 AWG, double coated.
[7]	Tape: 3M 1298 Polyester Film, 7.0.mm wide, 2.0 mil thick or equivalent.
[8]	Tape: 3M 1298 Polyester Film, 18.0.mm x 30.0.mm, 2.0.mil thick or equivalent.
[9]	Varnish: Dolph BC-359, or equivalent.

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7.4 结构图

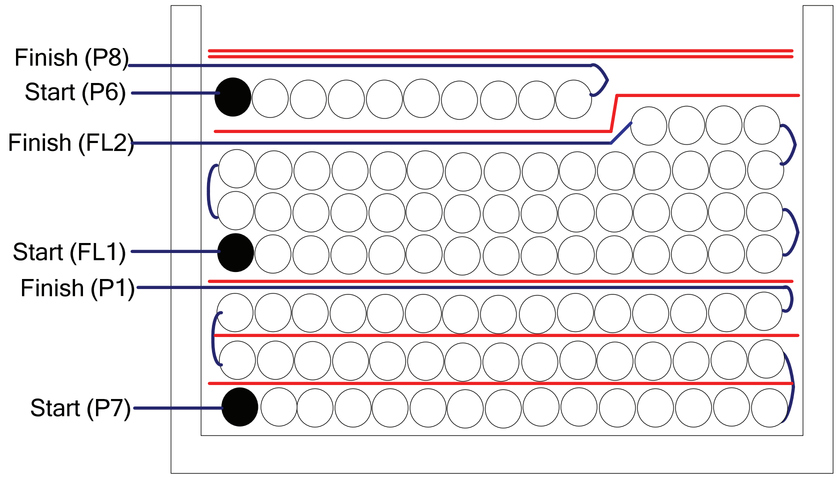

Figure 8 – Transformer Build Diagram.

7.5 绕制

Winding Preparation	Note: pin-out of bobbin is designated as in picture below. Place the bobbin item [1] on the mandrel with the pin side is on the left. Winding direction is clockwise direction.
Winding 1	Start at pin 7, wind 31 turns of wire item [4] from left to right for the 1st layer and place 1 layer of tape item [6]. Continue winding another 31 turns for the 2nd layer, from right to left and also place 1 layer of tape item [7]. Then wind 26 turns for the 3rd layer from left to right, at the last turn bring the wire back to the left and terminate at pin 1.
Insulation	Place 1 layer of tape item [7].
Winding 2	Use wire item [5], leave ~ 25 mm floating and place a piece of small tape to mark it as start lead FL1. Wind 32 turns of wire in 3 layers and 3 turns on the 4th layer on the right side of bobbin, at the last turn bring the wire back to the left and also leave ~ 25 mm floating as end lead FL2.
Insulation	Place 1 layer of tape item [7].
Winding 3	Now wind 25 turns of wire item [6] on the left section of 4th layer from winding 2, start at pin 6 and end with pin 8.
Insulation	Place 2 layers of tape item [7] to secure windings.
Final Assembly	Grind core halves item [2] to get 1 mH and secure with clips item [3] Cut short FL1 to 24 mm and FL2 to 12 mm. Cut ground lead of clip item [3] on the left side of core halves, see picture below. Prepare tape item [8]. Wrap 2 layers of tape item [8] on the left side of core halves for insulation. Varnish with item [9]. Cut pin number 2, 3 and 5.

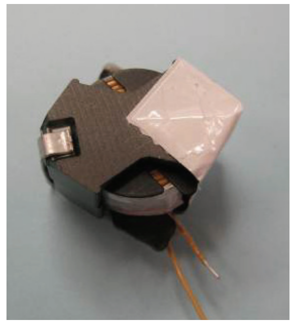

Figure 9 – Transformer Assembly Illustration.

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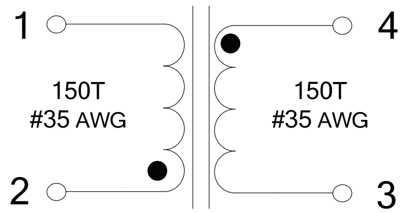
8 差模电感(L1)规格

8.1 结构图



Follow the transformer pin
according to its data sheet

Figure 10 – Inductor Electrical Diagram.

8.2 电气规格

Primary Inductance	Pins 1-2, all other windings open, measured at 100 kHz, 0.4 $V_{RMS.}$	240 µH ±10%

8.3 材料

Item	Description
[1]	Core: RM5 (3/3); N87.
[2]	Bobbin: RM-5; 3/3 pin vertical.
[3]	Magnet Wire: #35 AWG.
[4]	Tape: 3M 1298 Polyester Film, 4.8 mm wide, 2.0 mil thick or equivalent.
[5]	Varnish: Dolph BC-359, or equivalent.

8.4 结构图

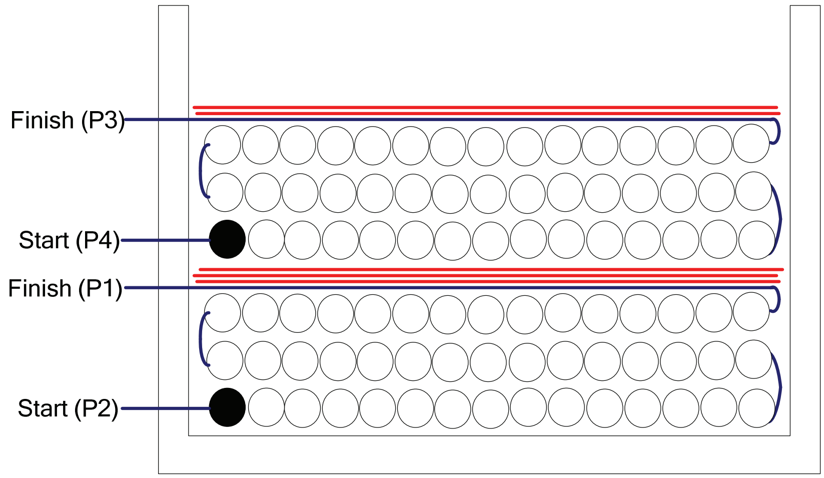


Figure 11 – Inductor Build Diagram.

8.5 绕制

Winding Preparation	Note: pin-out of bobbin is designated as in picture below. Place the bobbin item [1] on the mandrel with the pin side is on the left. Winding direction is clockwise direction.
Winding 1	Start at pin 2, wind 150 turns of wire item [3] continuously then terminate at pin 1.
Insulation	Place 3 layer of tape item [4].
Winding 2	Start at pin 4, wind 150 turns of wire item [3] continuously then terminate at pin 3.
Insulation	Place 2 layers of tape item [4] to secure windings.
Final Assembly	Grind core halves item [2] to get 1 mH and secure with clips. Varnish with item [5]. Cut pin 5 and 6.

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9 U1散热片

9.1 U1散热片加工图

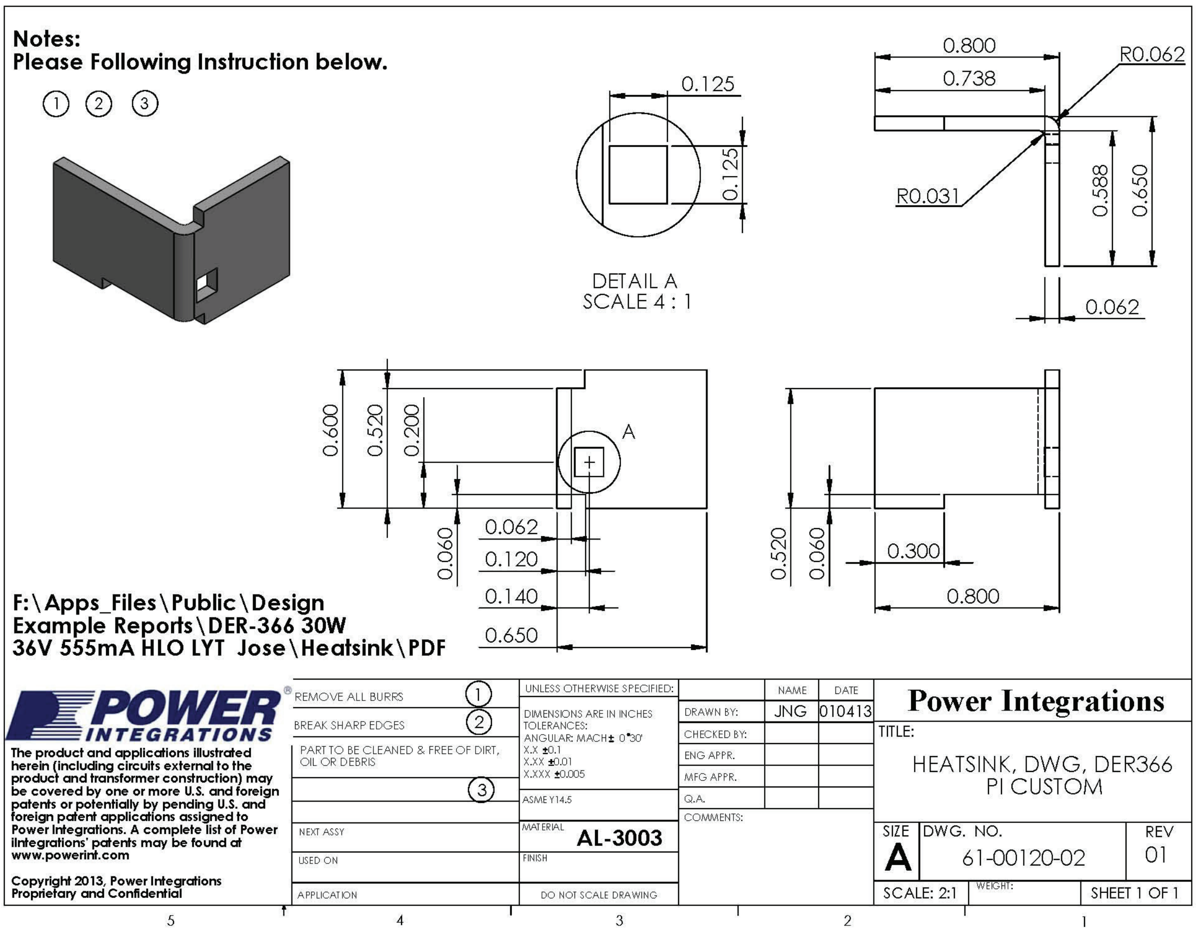

Figure 12 – U1 Heat Sink Fabrication Drawing.

9.2 *U1散热片装配图*

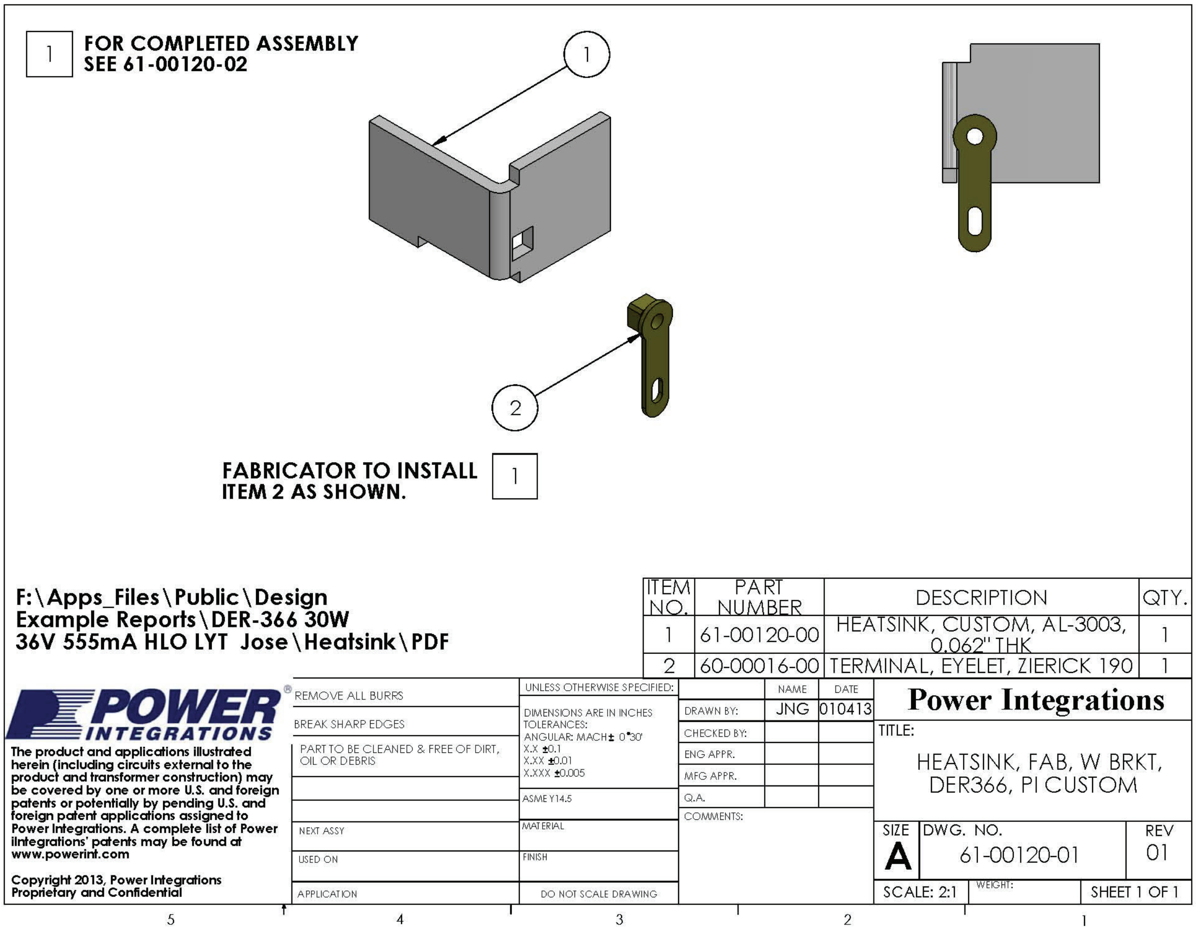

Figure 13 – U1 Heat Sink Assembly Drawing.

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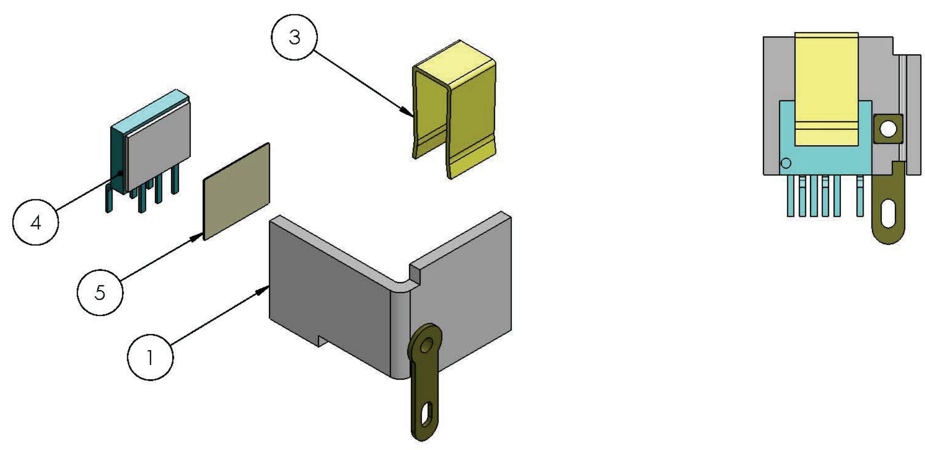
9.3 散热片和U1装配图



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	61-00120-00	HEATSINK, AL-3003, 0.062" THK	1
3	60-00031-00	HEATSINK HARDWARE, EDGE CLIP 16.5 L x 7.5 W x 0.5 H mm	1
4	10-00641-00	LYTSwitch, LYT4314E, eSIP-7C	1
5	60-00035-00	THERMAL GREASE-SILICONE, 5 OZ TUBE	1

F:\Apps_Files\Public\Design Example Reports\DER-366 30W 36V 555mA HLO LYT Jose\Heatsink\PDF

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REMOVE ALL BURRS
BREAK SHARP EDGES
PART TO BE CLEANED & FREE OF DIRT, OIL OR DEBRIS
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	010413
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Power Integrations

TITLE:
HEATSINK, ASSY, ESIP, DER366, PI CUSTOM

SIZE A | DWG. NO. 61-00120-02 | REV 01
SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1

Figure 14 – Heat Sink and U1 Assembly Drawing.

10 变压器设计表格

ACDC_LYTSwitch-4_HL_062013; Rev.1.0; Copyright Power Integrations 2013	INPUT	INFO	OUTPUT	UNIT	LYTSwitch-4_HL_062013: Flyback Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					**DER-396**
Dimming required	YES		YES		Select 'YES' option if dimming is required. Otherwise select 'NO'.
VACMIN	185		185	V	Minimum AC Input Voltage
VACMAX			265	V	Maximum AC input voltage
fL			50	Hz	AC Mains Frequency
VO	36		36	V	Typical output voltage of LED string at full load
VO_MAX			39.6	V	Maximum expected LED string Voltage.
VO_MIN			32.4	V	Minimum expected LED string Voltage.
V_OVP			42.47	V	Over-voltage protection setpoint
IO	0.55		0.55	A	Typical full load LED current
PO			19.8	W	Output Power
n			0.8		Estimated efficiency of operation
VB			25	V	Bias Voltage
ENTER LYTSwitch VARIABLES					
LYTSwitch	Auto		LYT4324		Selected LYTSwitch
Current Limit Mode	RED		RED		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			0.95	A	Minimum current limit
ILIMITMAX			1.11	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			80.56727984	uA	V pin current
RV			4	M-ohms	Upper V pin resistor
RV2			1E+12	M-ohms	Lower V pin resistor
IFB	178		178	uA	FB pin current (85 uA < IFB < 210 uA)
RFB1			123.5955056	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	0.7		0.7		Ripple to Peak Current Ratio (For PF > 0.9, 0.4 < KP < 0.9)
LP			998.2376383	uH	Primary Inductance
VOR	92		92	V	Reflected Output Voltage.
Expected IO (average)			0.547777905	A	Expected Average Output Current
KP_VNOM			0.666138709		Expected ripple current ratio at VACNOM
TON_MIN			1.493186757	us	Minimum on time at maximum AC input voltage
PCLAMP			0.159394306	W	Estimated dissipation in primary clamp
ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	RM7		RM7		Select Core Size
Custom Core	RM7				Enter Custom core part number (if applicable)
AE	0.45		0.45	cm^2	Core Effective Cross Sectional Area
LE	3		3	cm	Core Effective Path Length
AL	2500		2500	nH/T^2	Ungapped Core Effective Inductance
BW	6.9		6.9	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)

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L	4		4		Number of Primary Layers
NS	35		35		Number of Secondary Turns
DC INPUT VOLTAGE PARAMETERS					
VMIN			261.629509	V	Peak input voltage at VACMIN
VMAX			374.766594	V	Peak input voltage at VACMAX
CURRENT WAVEFORM SHAPE PARAMETERS					
DMAX			0.267730208		Minimum duty cycle at peak of VACMIN
IAVG			0.119116476	A	Average Primary Current
IP			0.826177997	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
IRMS			0.231970815	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			998.2376383	uH	Primary Inductance
LP_TOL	10		10		Tolerance of primary inductance
NP			88.21917808		Primary Winding Number of Turns
NB			24.64383562		Bias Winding Number of Turns
ALG			128.2649294	nH/T^2	Gapped Core Effective Inductance
BM			2077.457006	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
BP			2791.138572	Gauss	Peak Flux Density (BP<3700)
BAC			727.109952	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1326.288091		Relative Permeability of Ungapped Core
LG			0.418255474	mm	Gap Length (Lg > 0.1 mm)
BWE			27.6	mm	Effective Bobbin Width
OD			0.312857143	mm	Maximum Primary Wire Diameter including insulation
INS			0.053423557	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.259433586	mm	Bare conductor diameter
AWG			30	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			101.5936673	Cmils	Bare conductor effective area in circular mils
CMA			437.9588334	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 600)
TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
Lumped parameters					
ISP			2.082421254	A	Peak Secondary Current
ISRMS			0.884132667	A	Secondary RMS Current
IRIPPLE			0.692235923	A	Output Capacitor RMS Ripple Current
CMS			176.8265334	Cmils	Secondary Bare Conductor minimum circular mils
AWGS			27	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
DIAS			0.362522298	mm	Secondary Minimum Bare Conductor Diameter
ODS			0.197142857	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
VOLTAGE STRESS PARAMETERS					
VDRAIN			566.5923475	V	Estimated Maximum Drain Voltage assuming maximum LED string voltage (Includes Effect of Leakage Inductance)
PIVS			191.1564827	V	Output Rectifier Maximum Peak Inverse Voltage (calculated at VOVP, excludes leakage inductance spike)
PIVB			134.1846154	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	M-ohms	Upper V Pin Resistor Value

RV2			1E+12	M-ohms	Lower V Pin Resistor Value
VAC1			115	V	Test Input Voltage Condition1
VAC2			230	V	Test Input Voltage Condition2
IO_VAC1			0.55	A	Measured Output Current at VAC1
IO_VAC2			0.55	A	Measured Output Current at VAC2
RV1 (new)			4.000604137	M-ohms	New RV1
RV2 (new)			20911.63067	M-ohms	New RV2
V_OV			319.5673531	V	Typical AC input voltage at which OV shutdown will be triggered
V_UV			66.34665276	V	Typical AC input voltage beyond which power supply can startup
FB pin resistor Fine Tuning					
RFB1	133		133	k-ohms	Upper FB Pin Resistor Value
RFB2			1E+12	k-ohms	Lower FB Pin Resistor Value
VB1			22.46520548	V	Test Bias Voltage Condition1
VB2			27.53479452	V	Test Bias Voltage Condition2
IO1			0.55	A	Measured Output Current at Vb1
IO2			0.55	A	Measured Output Current at Vb2
RFB1 (new)			133	k-ohms	New RFB1
RFB2(new)			1E+12	k-ohms	New RFB2
Input Current Harmonic Analysis					
Harmonic			Max Current (mA)	Limit (mA)	
1st Harmonic					
3rd Harmonic			20.69736113	1666.17	PASS. 3rd Harmonic current content is lower than the limit
5th Harmonic			9.233940611	931.095	PASS. 5th Harmonic current content is lower than the limit
7th Harmonic			5.592928806	490.05	PASS. 7th Harmonic current content is lower than the limit
9th Harmonic			3.956638292	245.025	PASS. 9th Harmonic current content is lower than the limit
11th Harmonic			2.979917621	171.5175	PASS. 11th Harmonic current content is lower than the limit
13th Harmonic			2.264929473	145.103805	PASS. 13th Harmonic current content is lower than the limit
15th Harmonic			1.69769565	125.74683	PASS. 15th Harmonic current content is lower than the limit
THD			23.53869833	%	Estimated total Harmonic Distortion (THD)

Table 1 – Sample Spreadsheet Calculation.

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11 性能数据

All measurements performed at 25 ºC room temperature, 60 Hz input frequency unless otherwise specified.

Input		Input Measurement					LED Load Measurement			Efficiency (%)
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)	
185	50	184.85	140.39	24.969	0.962	15.62	39.1500	547.700	21.540	86.27
200	50	199.85	131.37	24.997	0.952	16.49	39.1100	549.800	21.610	86.45
220	50	219.90	121.59	25.016	0.936	17.59	39.0800	551.000	21.620	86.42
230	50	229.85	117.51	25.020	0.926	17.91	39.0500	551.000	21.610	86.37
240	50	239.88	113.83	25.028	0.917	18.01	39.0300	551.000	21.590	86.26
265	50	264.92	106.00	24.935	0.888	18.04	38.9900	547.000	21.410	85.86
185	50	184.84	130.63	23.130	0.958	15.76	35.9000	552.000	19.910	86.08
200	50	199.85	122.72	23.227	0.947	16.46	35.8900	555.000	20.030	86.24
220	50	219.91	114.31	23.363	0.929	17.27	35.8900	558.000	20.150	86.25
230	50	229.85	110.76	23.412	0.920	17.44	35.8900	559.000	20.170	86.15
240	50	239.88	107.35	23.399	0.909	17.55	35.8800	558.000	20.130	86.03
265	50	264.92	100.60	23.399	0.878	17.49	35.8600	556.000	20.030	85.60
185	50	184.85	122.49	21.580	0.953	16.09	33.2300	555.000	18.570	86.05
200	50	199.86	115.48	21.724	0.941	16.6	33.2100	560.000	18.720	86.17
220	50	219.91	107.91	21.887	0.922	17.17	33.1900	564.000	18.850	86.12
230	50	229.85	104.54	21.898	0.911	17.31	33.1700	564.000	18.840	86.04
240	50	239.89	101.58	21.922	0.900	17.27	33.1400	565.000	18.830	85.90
265	50	264.93	95.77	21.991	0.867	17.11	33.1200	564.000	18.790	85.44

Table 2 – Test Result Summary for this Design.

11.1 带载模式效率

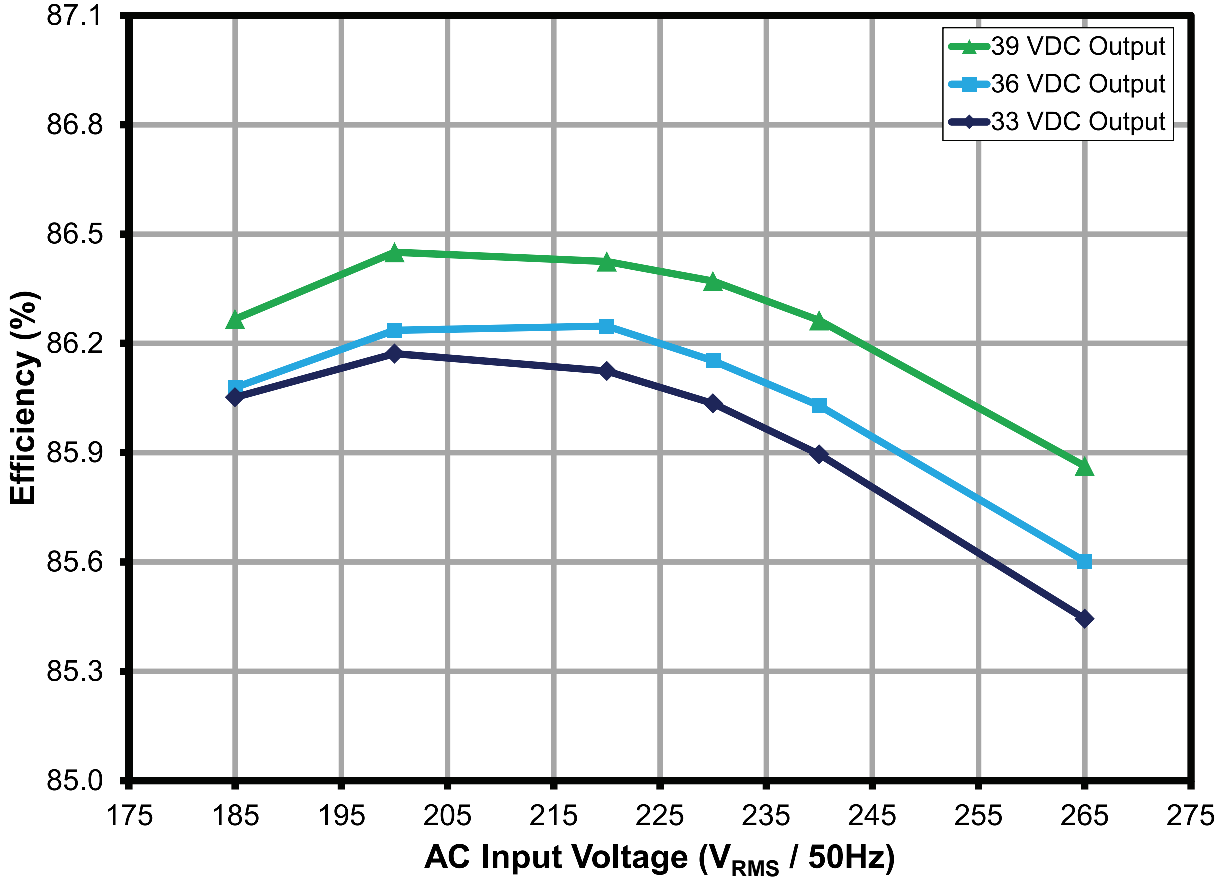

Figure 15 – Efficiency with Respect to AC Input Voltage.

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11.2 线电压调整

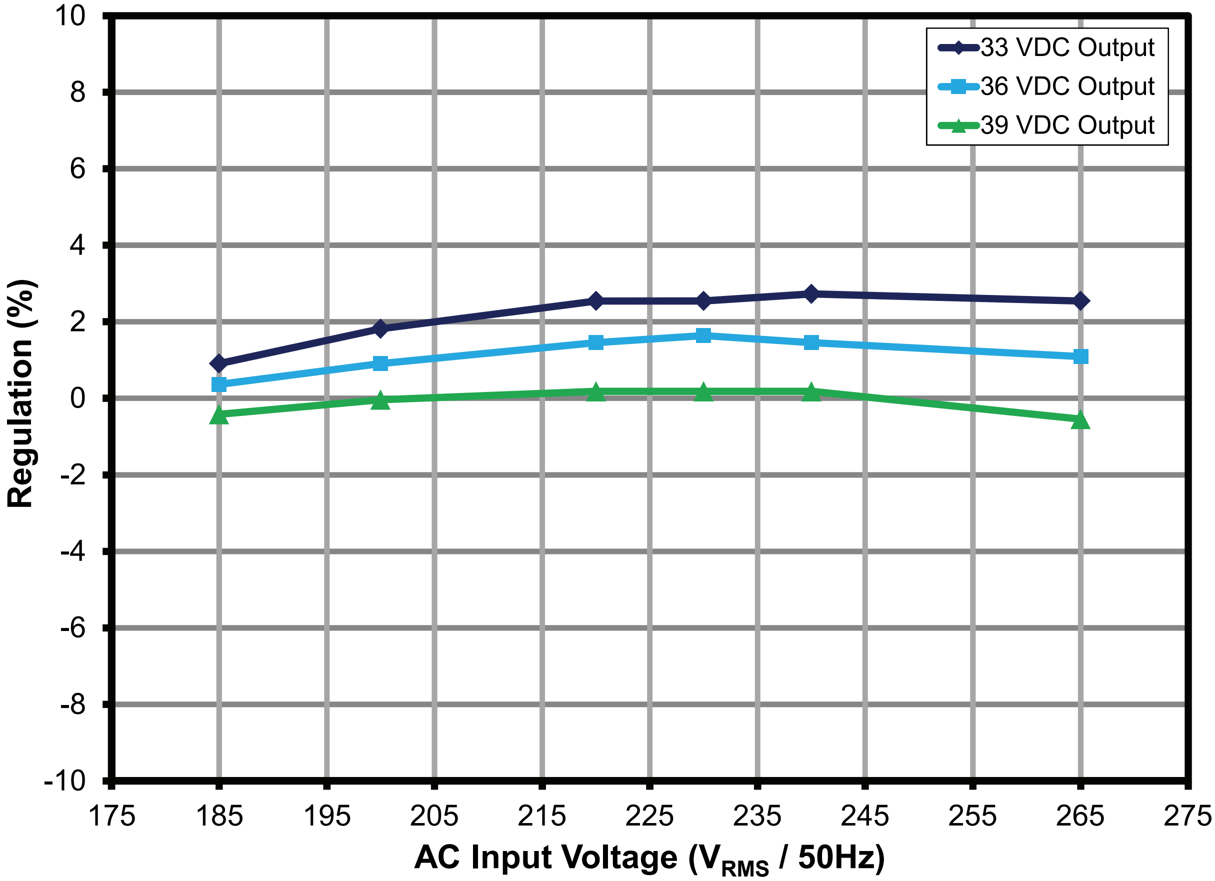

Figure 16 – Line Regulation, Room Temperature.

11.3 功率因数

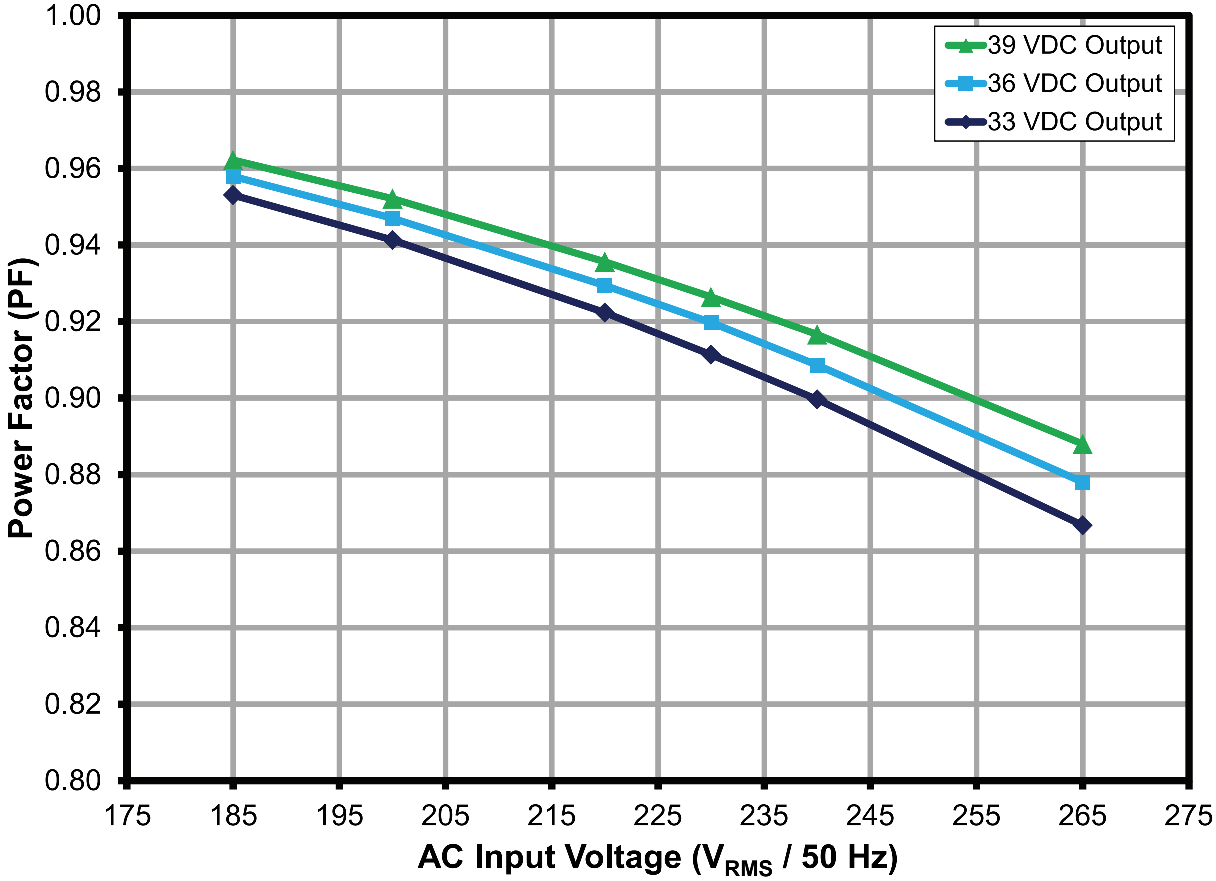

Figure 17 – High Power Factor within the Operating Range.

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11.4 %THD

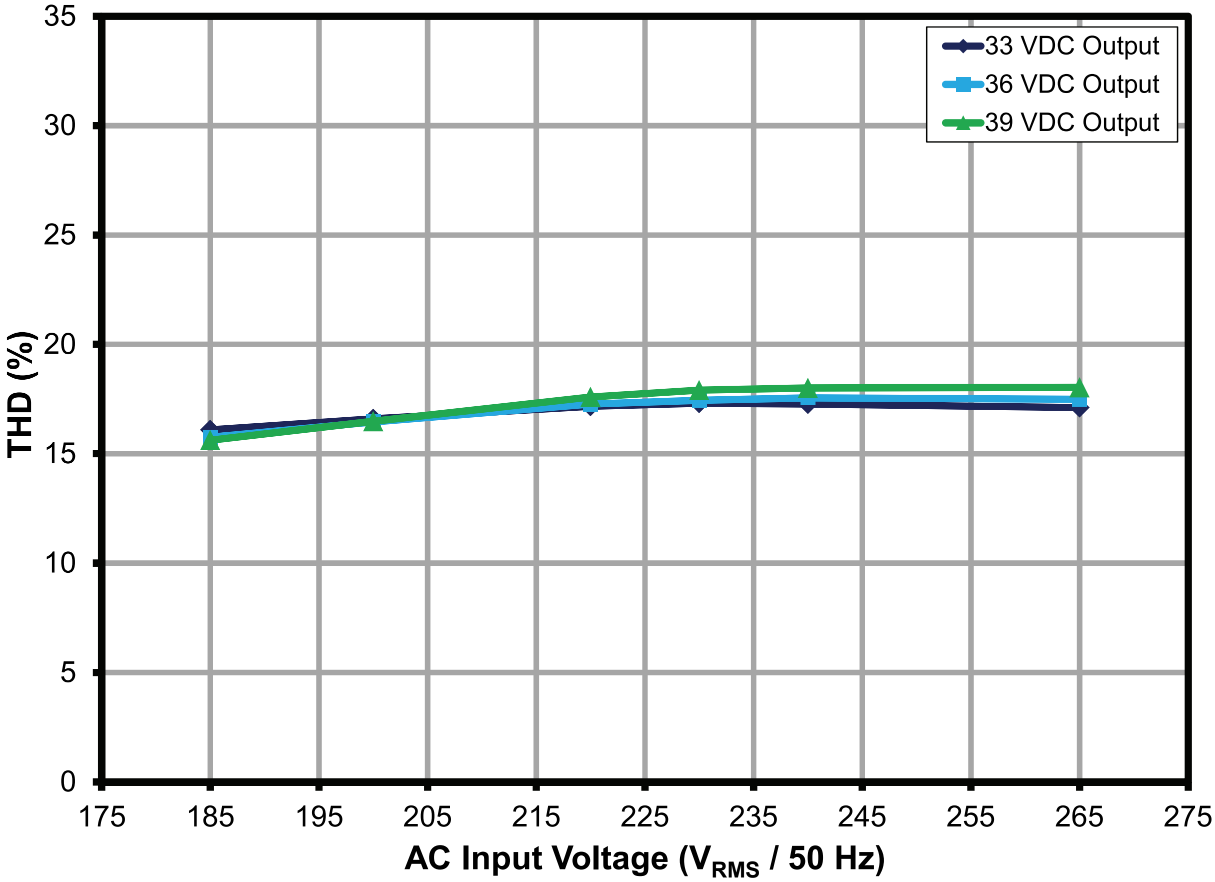

Figure 18 – Very Low %ATHD.

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11.5 谐波含量

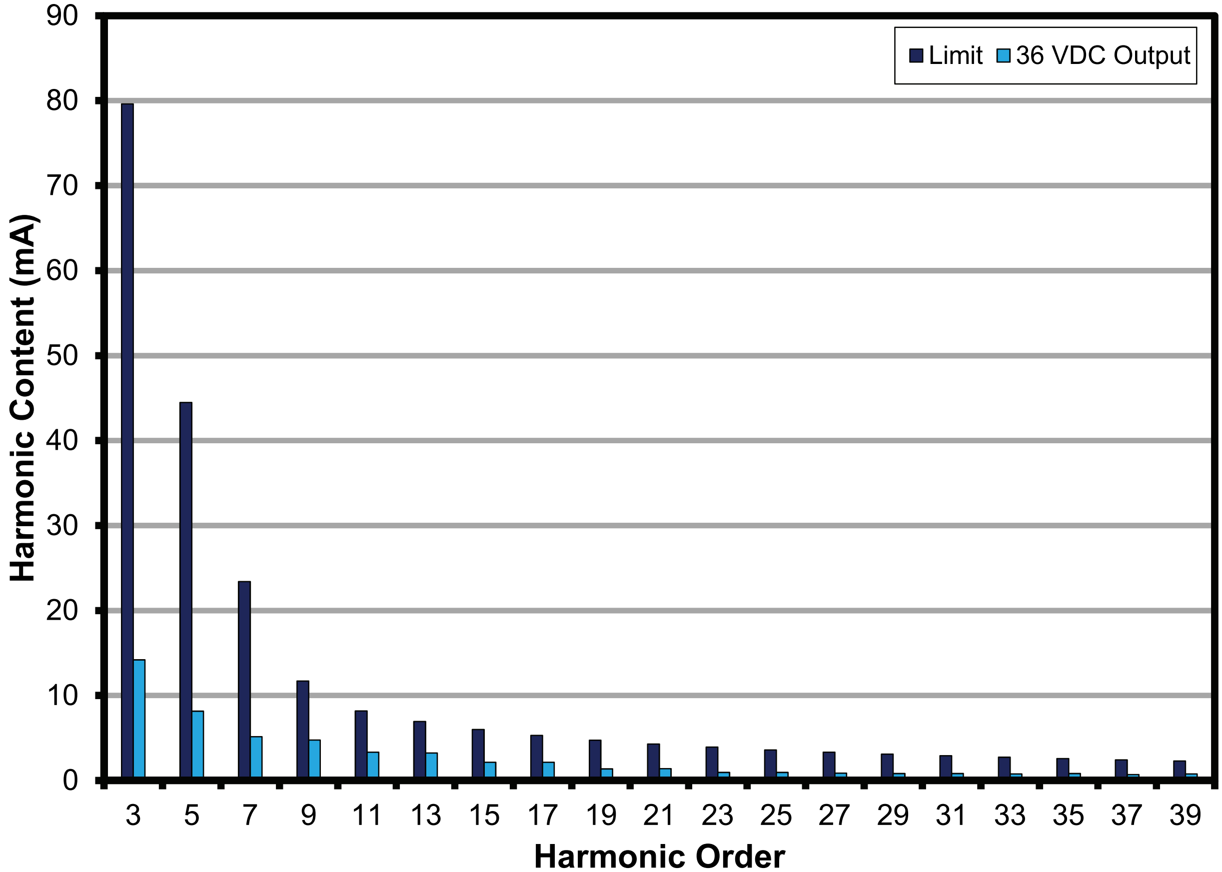

Figure 19 – Meets EN61000-3-2 Harmonics Contents Standards for <25 W Rating for 36 V LED Output.

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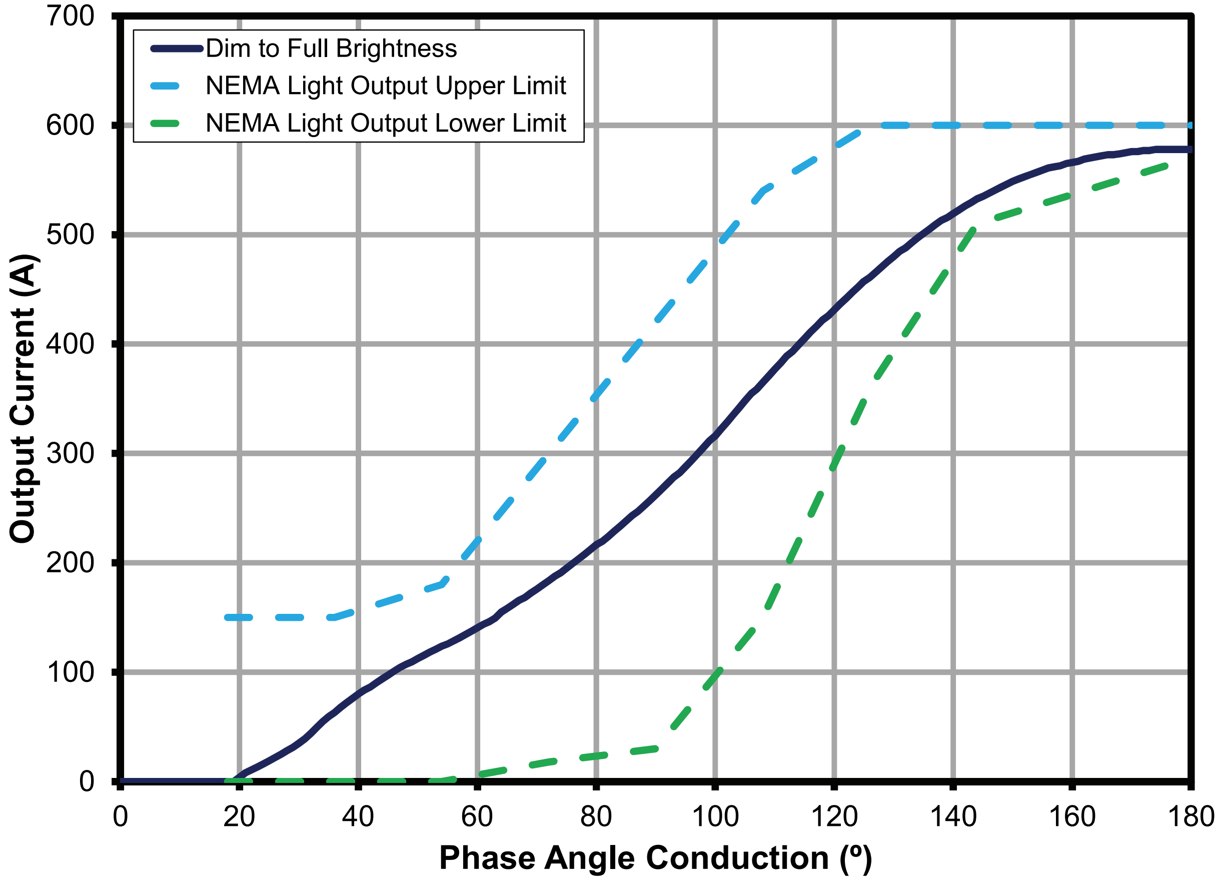
11.6 谐波测量

VAC (V_{RMS})	Freq (Hz)	I (mA)	P	PF
230	50.00	110.76	23.4120	0.9197
nth Order	**mA Content**	**% Content**	**Limit (mA) <25 W**	**Remarks**
1	109.04			
2	0.02	0.02%		
3	14.21	13.03%	79.6008	27.59%
5	8.15	7.47%	44.4828	10.00%
7	5.16	4.73%	23.4120	7.00%
9	4.75	4.36%	11.7060	5.00%
11	3.34	3.06%	8.1942	3.00%
13	3.24	2.97%	6.9336	3.00%
15	2.14	1.96%	6.0091	3.00%
17	2.15	1.97%	5.3021	3.00%
19	1.36	1.25%	4.7440	3.00%
21	1.39	1.27%	4.2922	3.00%
23	0.96	0.88%	3.9190	3.00%
25	0.96	0.88%	3.6054	3.00%
27	0.87	0.80%	3.3384	3.00%
29	0.81	0.74%	3.1081	3.00%
31	0.83	0.76%	2.9076	3.00%
33	0.76	0.70%	2.7314	3.00%
35	0.83	0.76%	2.5753	3.00%
37	0.70	0.64%	2.4361	3.00%
39	0.78	0.72%	2.3112	3.00%
41	0.59	0.54%		
43	0.68	0.62%		
45	0.50	0.46%		
47	0.64	0.59%		
49	0.44	0.40%		

Table 3 – 230 VAC Input Current Harmonic Measurement for 36 V LED.

11.7 调光特性

The dimming characteristic was taken from a controlled AC supply to emulate the TRIAC conduction pattern. The reference design meets the dimming requirement as set by National Electrical Manufacturers Association (NEMA) Standards Publication SSL 1-2010 (Electronic Drivers for LED Devices, Arrays or Systems) and SSL 6-2010(Solid Light Lighting for Incandescent Replacement-Dimming).



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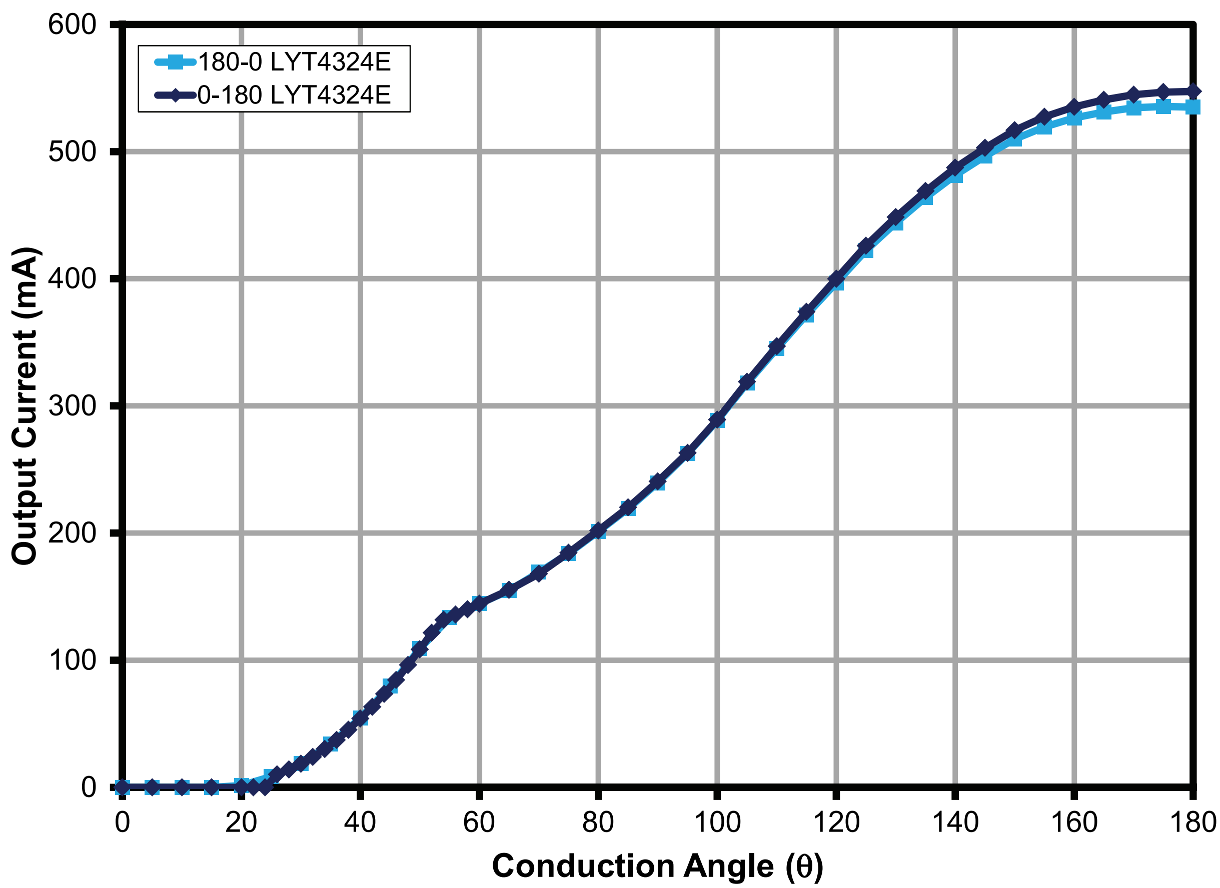

Figure 20 – Dimming Curve Characteristic From Full Dim to Full Brightness. Meets NEMA SSL 6-2010.

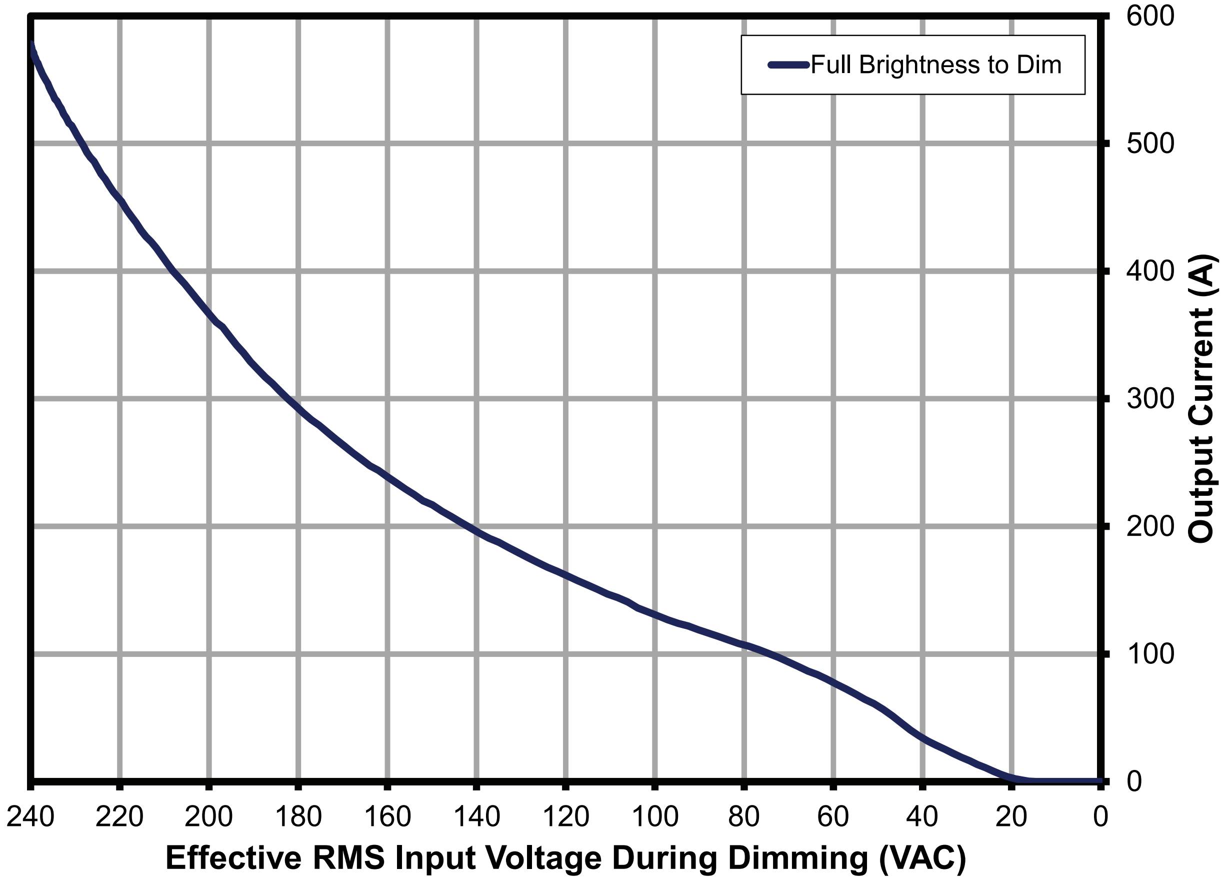

Figure 21 – Dimming Characteristic with Respect to RMS Input Voltage During Dimming.

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11.8 参考设计与调光器的兼容性

These are the list of dimmers verified for this reference design. Users are not limited on the following list. Make sure to test the dimmers according to its recommended operating line input frequency to avoid flicker.

Dimmer Origin	Part Number	I_{MIN} (mA)	I_{MAX} (mA)	Dim Ratio
China	TCL 630 W	147.4	556.0	4
China	Sen Bo Lang	189.4	555.0	3
China	Eba Huang	35.9	556.0	15
China	SB elect 600 W	1.3	545.5	420
China	Myongbo	191.4	558.0	3
China	KBE 650 W	0.6	555.5	926
China	Clipmei	147.2	556.0	4
China	Mank 200 W	202.8	557.0	3
Korea	Anam 500 W	191.0	551.0	3
Korea	Shin Sung	177.6	552.0	3
Korea	Fantasia 500 W	185.0	549.4	3
Korea	Shin Sung 2	158.2	552.0	3
Germany	Rev 300 W	0.1	537.6	5376
Germany	Busch 2250 600 W	107.1	542.4	5
Germany	PEHA 400 W	1.5	505.2	337
Germany	Merten 572499 400 W	77.5	550.0	7
Germany	Busch 6513 420 W	109.7	546.5	5
Germany	Berker 2875 600 W	123.5	532.9	4
Germany	Ove	113.4	503.9	4
Germany	Busch 691 U-101	106.4	529.2	5
Germany	Busch 6513 U-102	107.8	546.0	5
Germany	Peha 433AB	174.1	534.5	3

12 热性能

The scan is conducted at ambient temperature of 25 ºC open frame, 185 VAC / 50 Hz input.

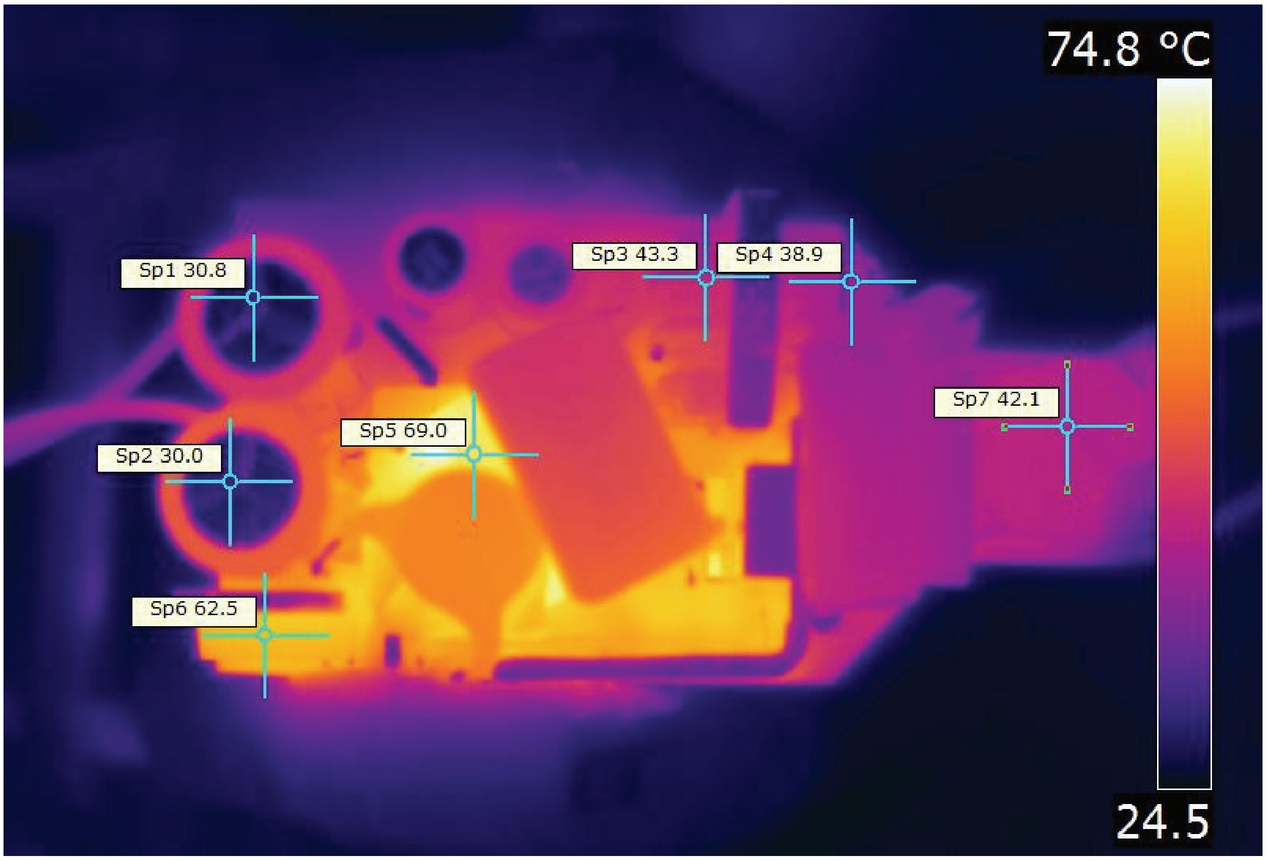

Figure 22 – Open Frame Thermal Scan

Legend:

- Sp1 – Output Capacitor C14
- Sp2 – Output Capacitor C15
- Sp3 – Common Mode Inductor L2
- Sp4 – Damper MOSFET Q3
- Sp5 – Transformer T1.
- Sp6 – Output Diode D8
- Sp7 – Differential Inductor L1

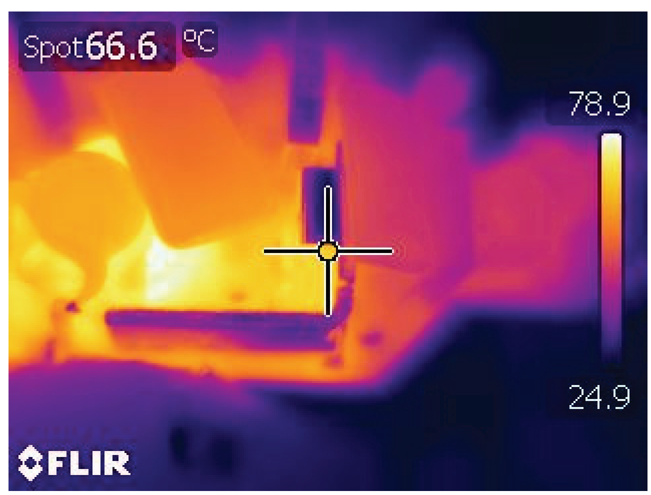

Figure 23 – U1 LNK4314E Device Temperature.

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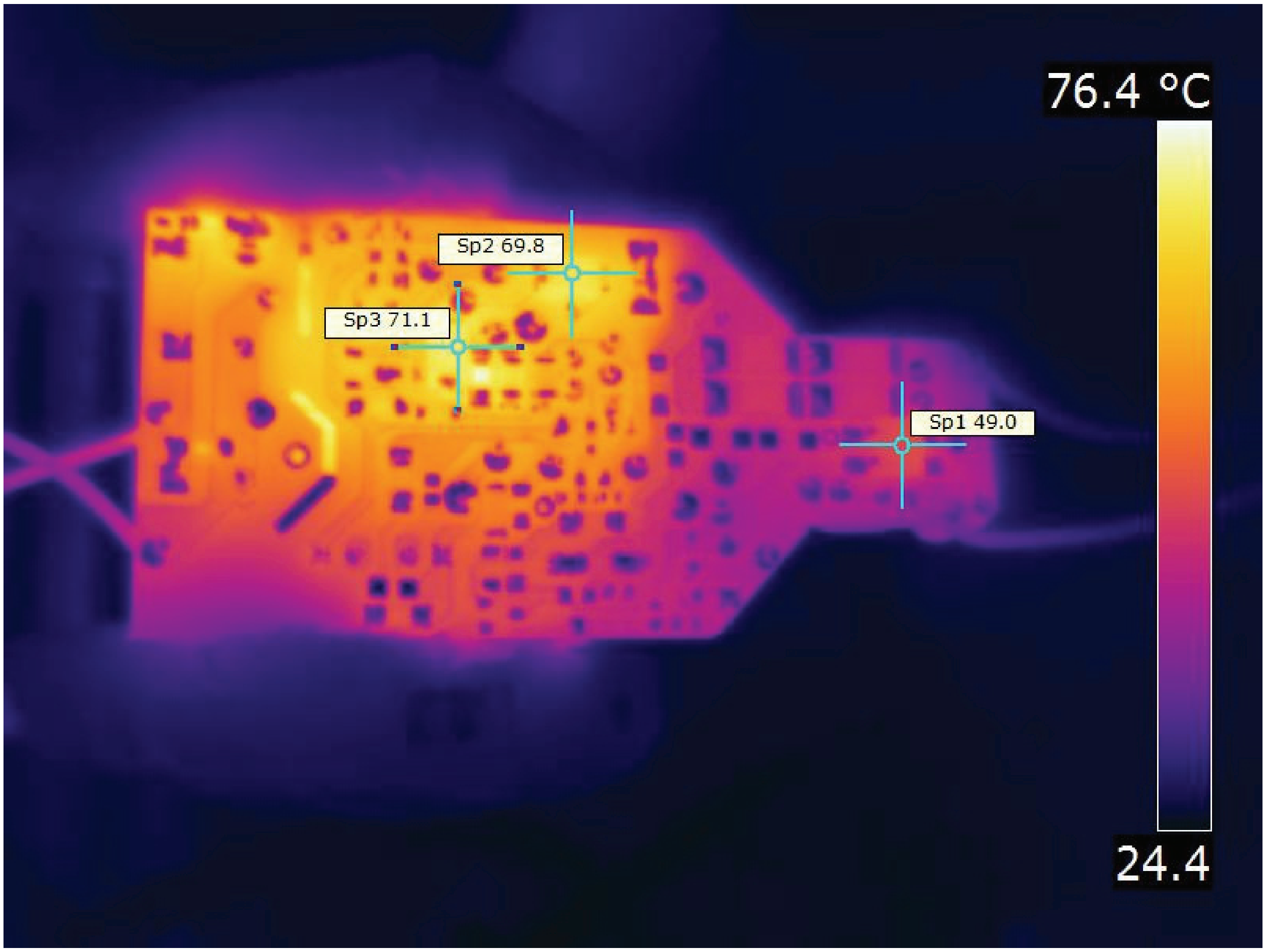

Figure 24 – Bottom Side Board Temperature at Open Frame.

Legend:

Sp1 – Bridge Rectifier BR1
Sp2 – Blocking Diode D4
Sp3 – Snubber Diode D3

13 波形

13.1 漏极电压和电流，正常工作

No saturation in the inductor and designed guaranteed to work in continuous mode within the operating input voltage.

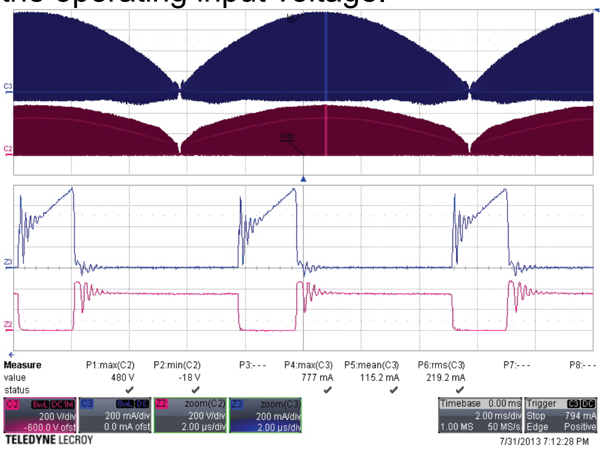

Figure 25 – 185 VAC / 50 Hz, 36 V LED String.
Ch2: V_{DRAIN}, 200 V / div.
Ch3: I_{DRAIN}, 0.2 A / div.
Time Scale: 2 ms / div.
Zoom Time Scale: 2 μs / div.

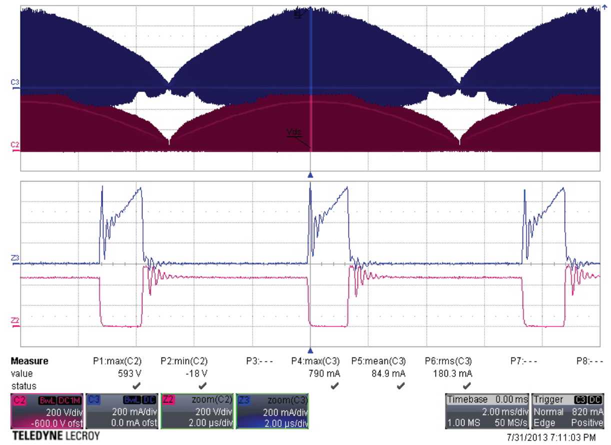

Figure 26 – 265 VAC / 50 Hz, 36 V LED String.
Ch2: V_{DRAIN}, 200 V / div.
Ch3: I_{DRAIN}, 0.2 A / div.
Time Scale: 2 ms / div.
Zoom Time Scale: 2 μs / div.

13.2 漏极电压和电流启动特征

Device has a built in soft start thereby reducing the stress in the device, transformer and output diode .

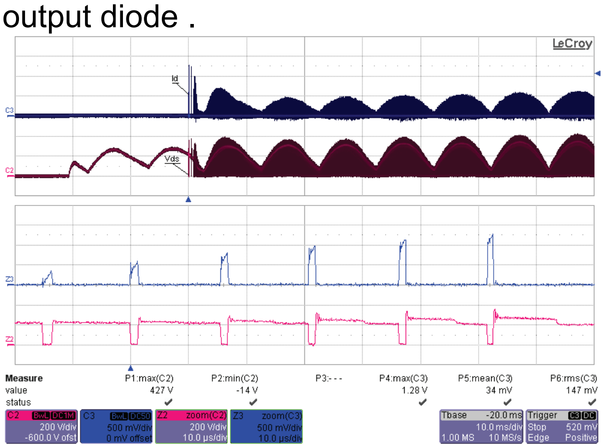

Figure 27 – 185 VAC / 50 Hz, 36 V LED String.
Ch2: V_{DRAIN}, 200 V / div.
Ch4: I_{DRAIN}, 0.2 A / div.
Time Scale: 10 ms / div.
Zoom Time Scale: 10 μs / div.

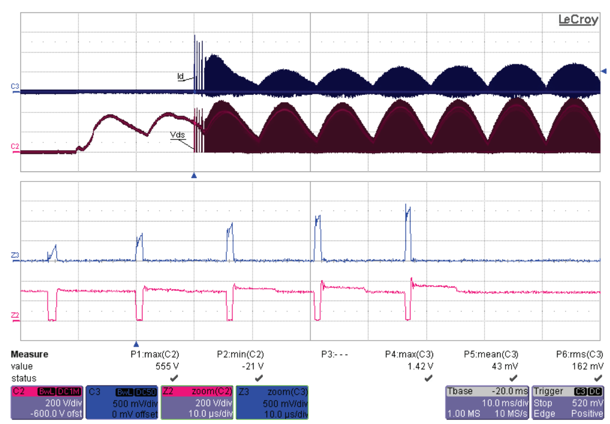

Figure 28 – 265 VAC / 50 Hz, 36 V LED String.
Ch2: V_{DRAIN}, 200 V / div.
Ch4: I_{DRAIN}, 0.2 A / div.
Time Scale: 10 ms / div.
Zoom Time Scale: 10 μs / div.

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13.3 输出电压启动特征

Start-up time <250 ms; the reference design will emit light within 250 ms at non-dimming operation.

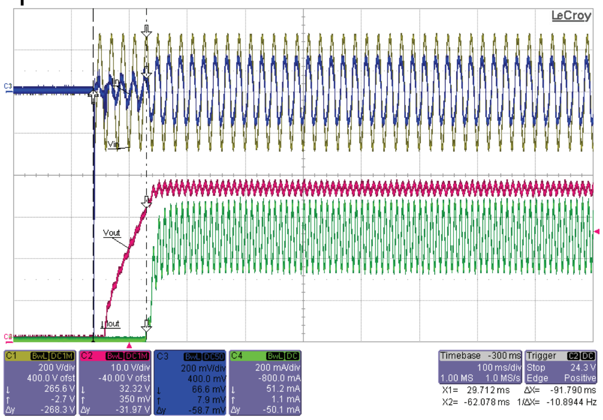

Figure 29 – 185 VAC / 50 Hz, 36 V LED
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 200 mA / div., 100 ms / div.

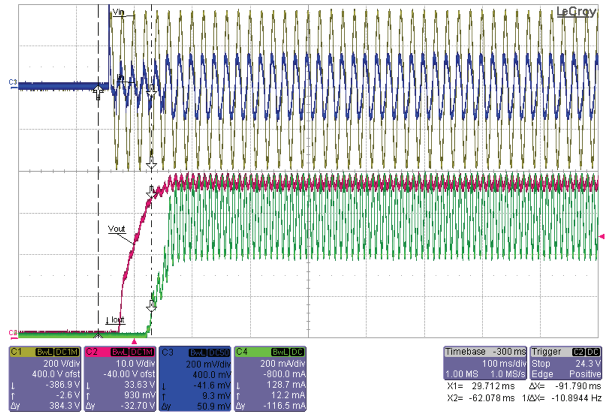

Figure 30 – 265 VAC / 50 Hz, 36 V LED
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 200 mA / div., 100 ms / div.

13.4 输入与输出电压和电流的波形

Output current ripple is inversely proportional to the impedance of the LED. Verify the actual current ripple on the actual LED to be used in the system. Increase output capacitance for lesser output current ripple is intended.

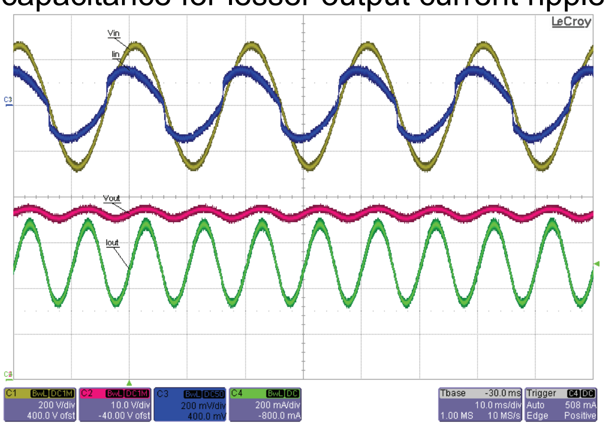

Figure 31 – 185 VAC / 50 Hz, 36 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 200 mA / div., 10 ms / div.

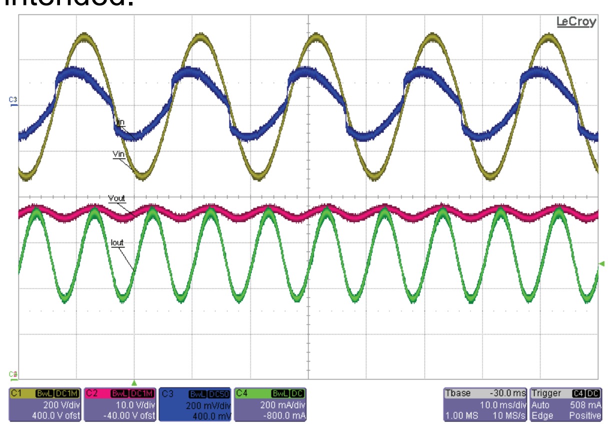

Figure 32 – 220 VAC / 50 Hz, 36 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 200 mA / div., 10 ms / div.

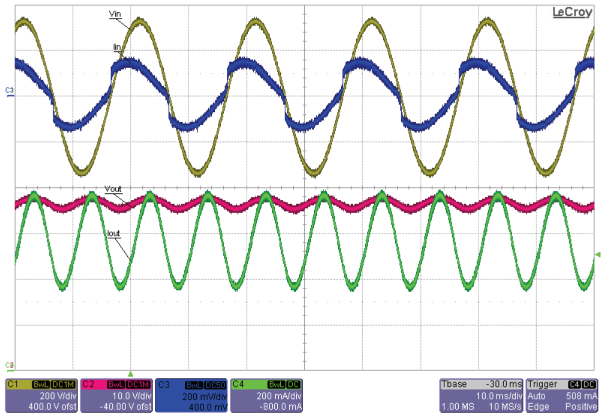

Figure 33 – 240 VAC / 50 Hz, 36 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 200 mA / div., 10 ms / div.

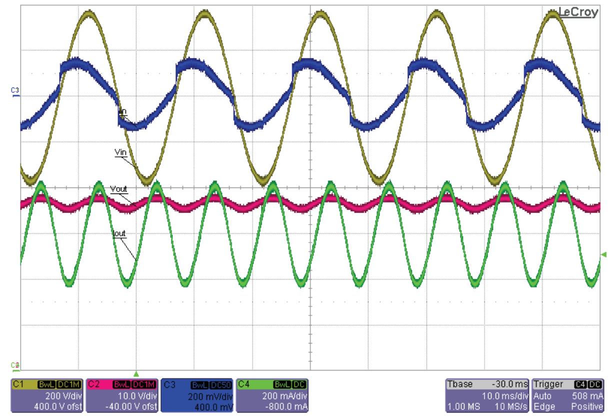

Figure 34 – 265 VAC / 50 Hz, 36 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 10 V / div.
Ch3: I_{IN}, 200 mA / div.
Ch4: I_{OUT}, 200 mA / div., 10 ms / div.

13.5 漏极电压和电流波形：正常工作到输出短路

No saturation in the inductor during short-circuit, inductor current is limited by the I_{LIM}.

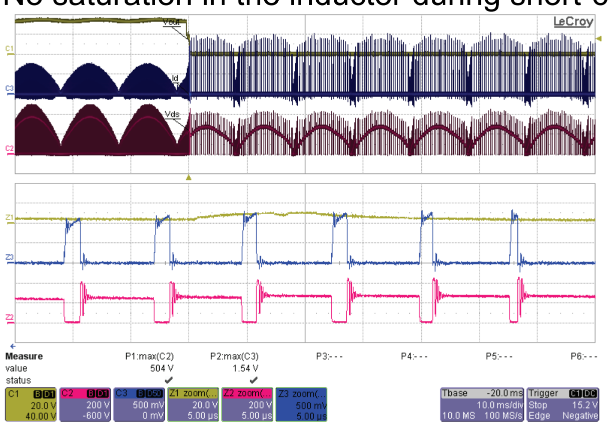

Figure 35 – 185 VAC / 50 Hz, Normal Operation then Output Short.
Ch1: V_{OUT}, 20 V / div.
Ch2: V_{DS}, 200 V / div.
Ch4: I_{DRAIN}, 0.5 A / div., 10 ms / div.
Z3: I_{DRAIN}, 0.2 A / div., 5 μs / div.

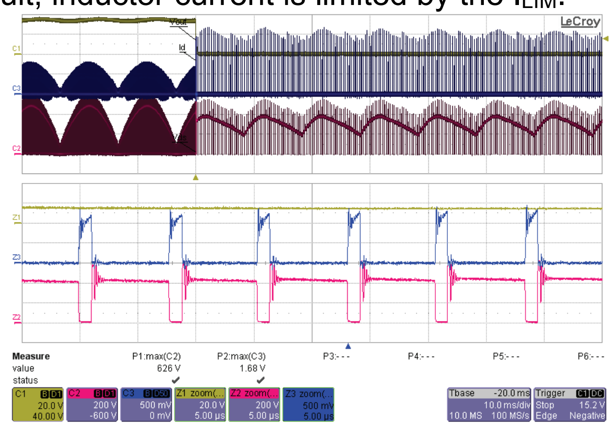

Figure 36 – 265 VAC / 50 Hz, Normal Operation then Output Short.
Ch1: V_{OUT}, 20 V / div.
Ch2: V_{DS}, 200 V / div.
Ch4: I_{DRAIN}, 0.5 A / div., 10 ms / div.
Z3: I_{DRAIN}, 0.2 A / div., 5 μs / div.

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13.6 漏极电压和电流波形：输出短路时启动

No saturation in the inductor during start-up short-circuit due to the built-in soft-start.

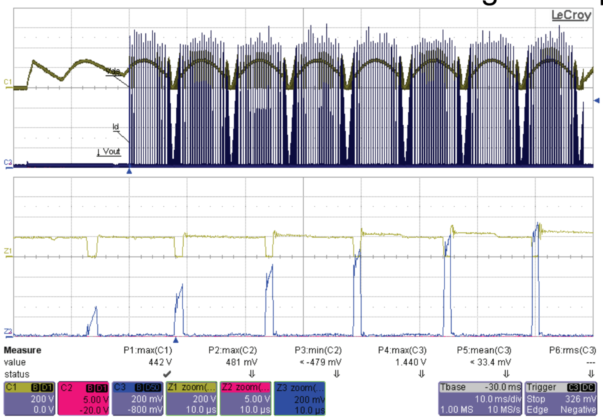

Figure 37 – 185 VAC / 50 Hz, Output Shorted.
Ch1: V_{DS}, 20 V / div.
Ch3: I_{DRAIN}, 0.2 A / div., 10 ms / div.
Z3: I_{DRAIN}, 0.2 A / div., 10 µs / div.

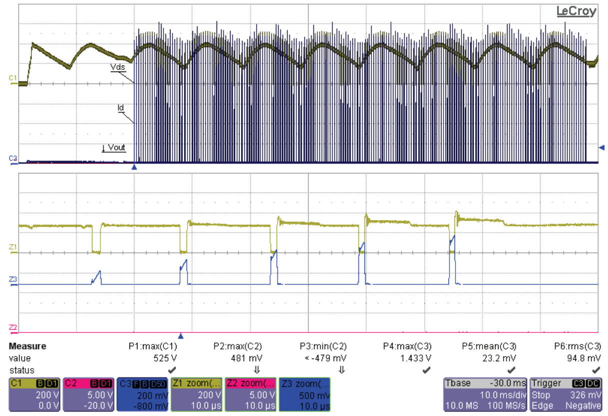

Figure 38 – 265 VAC / 50 Hz, Output Shorted.
Ch1: V_{DS}, 20 V / div.
Ch3: I_{DRAIN}, 0.2 A / div., 10 ms / div.
Z3: I_{DRAIN}, 0.2 A / div., 10 µs / div..

13.7 空载工作

The driver is protected during no-load operation, U1 operating is cycle skipping mode.

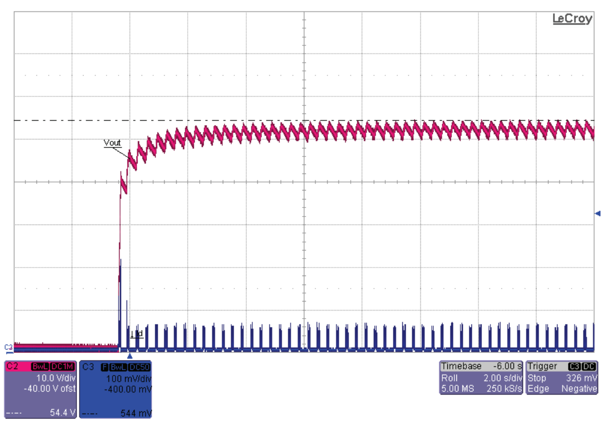

Figure 39 – 185 VAC / 50 Hz, Start-up No-load.
Ch2: V_{OUT}, 10 V / div.
Ch3: I_{DS}, 0.1 A / div.
Time Scale: 2 s / div.

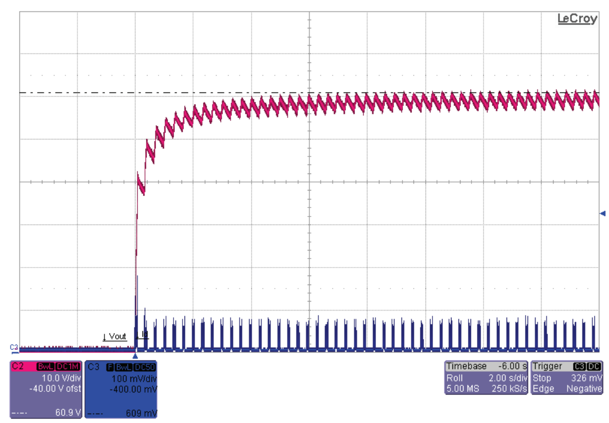

Figure 40 – 265 VAC / 50 Hz, Start-up No-load.
Ch2: V_{OUT}, 10 V / div.
Ch3: I_{DS}, 0.1 A / div.
Time Scale: 2 s / div.

13.8 交流电循环上电

The reference design has no perceptible delay.

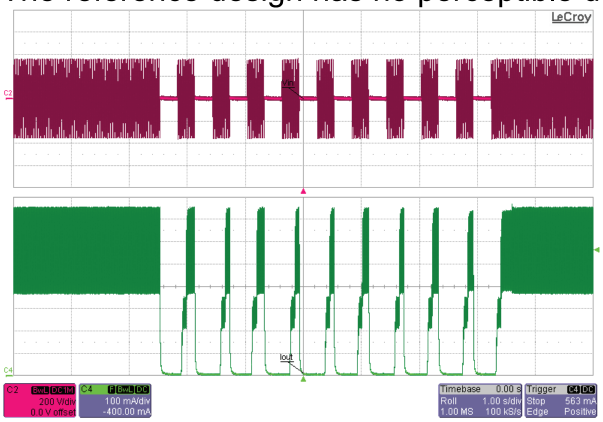

Figure 41 – 240 VAC / 50 Hz,
300 ms On – 300 ms Off.
Load: 36 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 1 s / div.

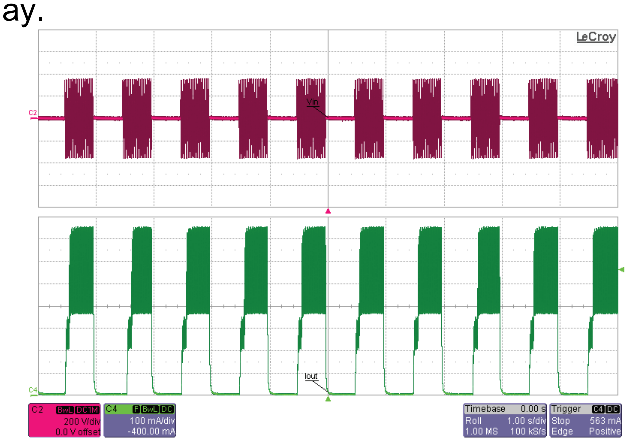

Figure 42 – 240 VAC / 50 Hz,
500 ms On – 500 ms Off.
Load: 36 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 1 s / div.

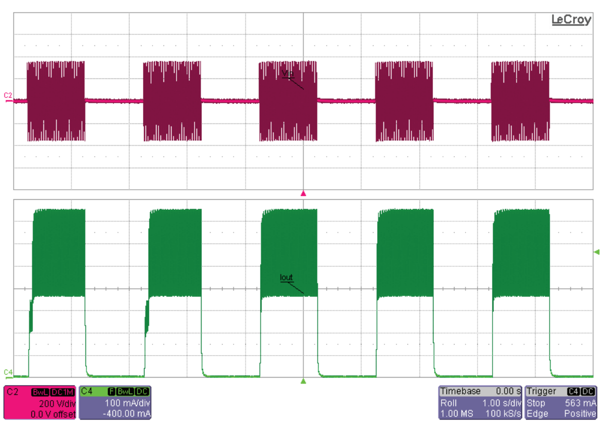

Figure 43 – 240 VAC / 50 Hz,
1s On – 1s Off.
Load: 36 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 1 s / div.

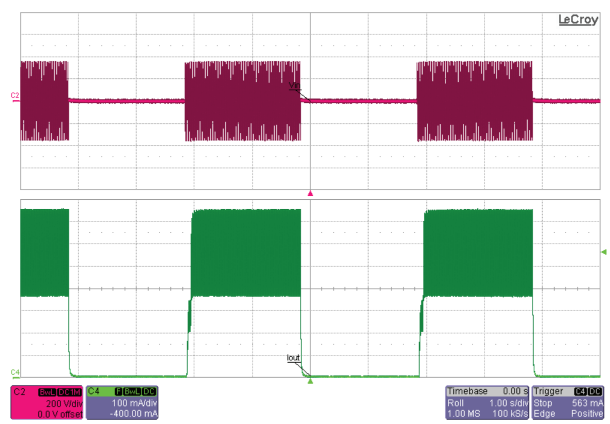

Figure 44 – 240 VAC / 50 Hz,
2s On – 2s Off.
Load: 36 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 1 s / div.

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13.9 调光波形

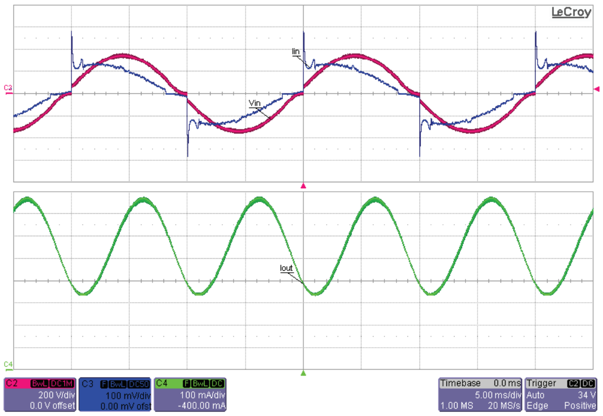

Figure 45 – 240 VAC / 50 Hz, (China) TCL 630 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

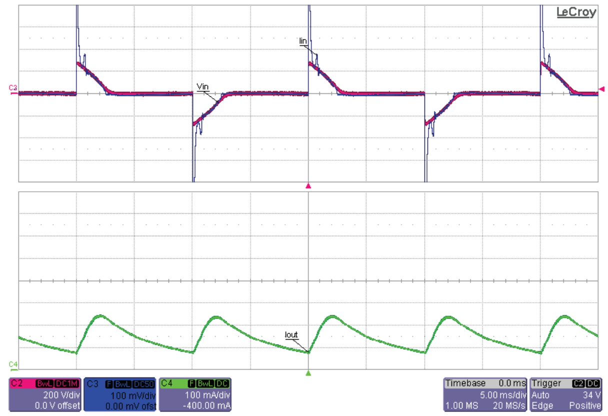

Figure 46 – 240 VAC / 50 Hz, (China) TCL 630 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

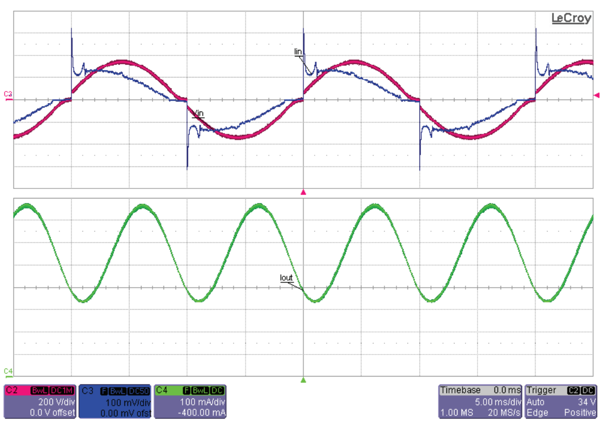

Figure 47 – 240 VAC / 50 Hz, (China) Sen Bo Lang 300 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

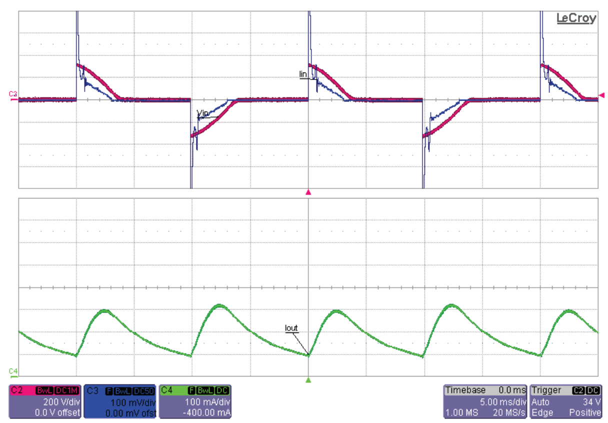

Figure 48 – 240 VAC / 50 Hz, (China) Sen Bo Lang 300 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

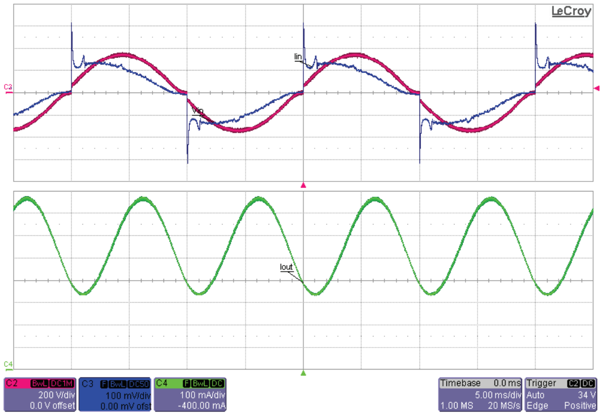

Figure 49 – 240 VAC / 50 Hz, (China) Eba Huang Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

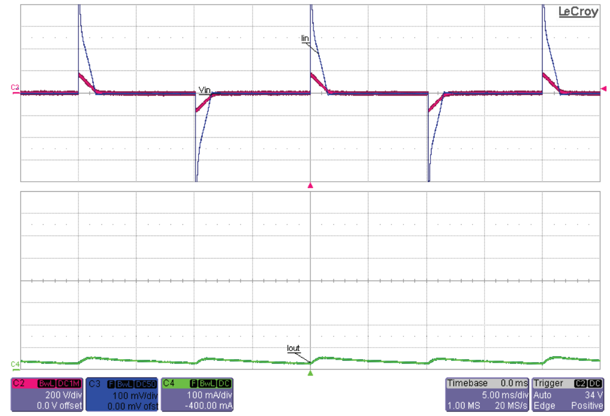

Figure 50 – 240 VAC / 50 Hz, (China) Eba Huang Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

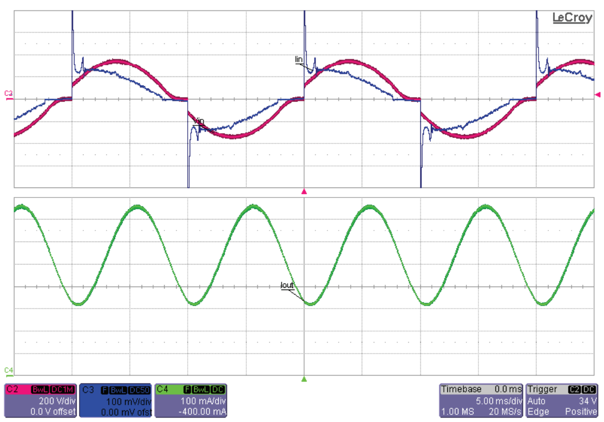

Figure 51 – 240 VAC / 50 Hz, (China) SB elect 600 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

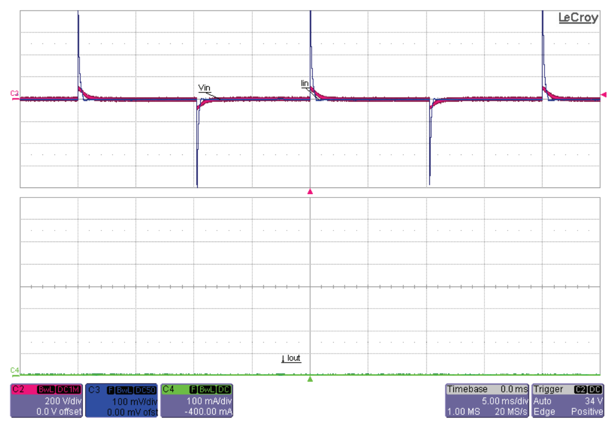

Figure 52 – 240 VAC / 50 Hz, (China) SB elect 600 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

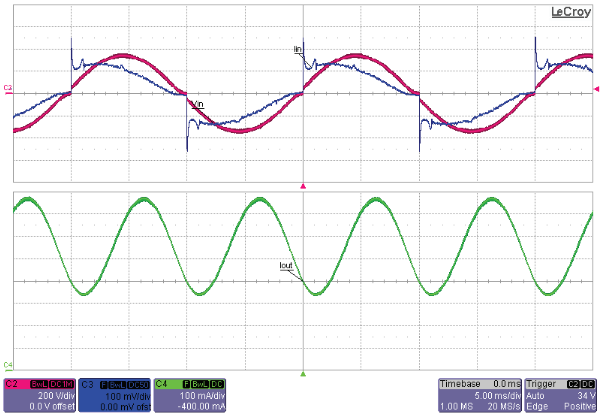

Figure 53 – 240 VAC / 50 Hz, (China) Myongbo Dimmer at Full TRIAC conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

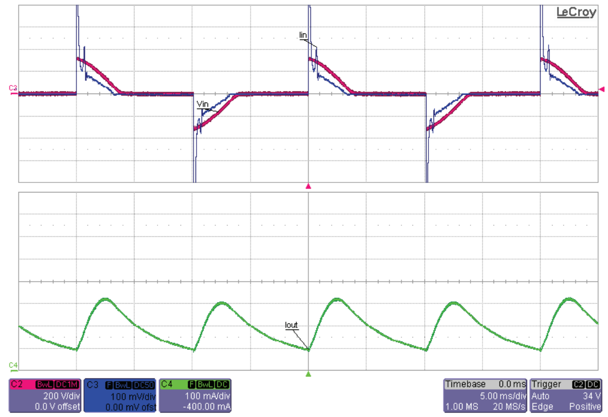

Figure 54 – 240 VAC / 50 Hz, (China) Myongbo Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

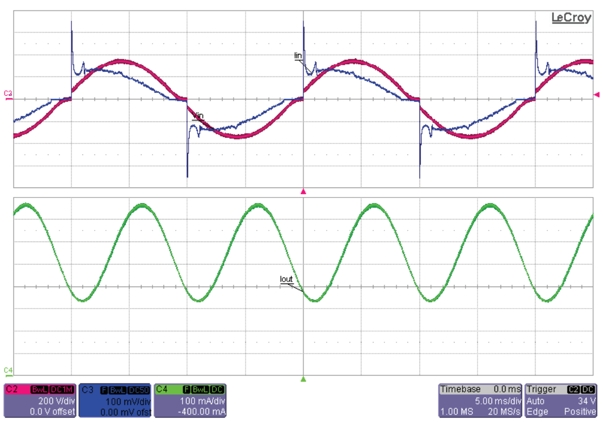

Figure 55 – 240 VAC / 50 Hz, (China) KBE, 650 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

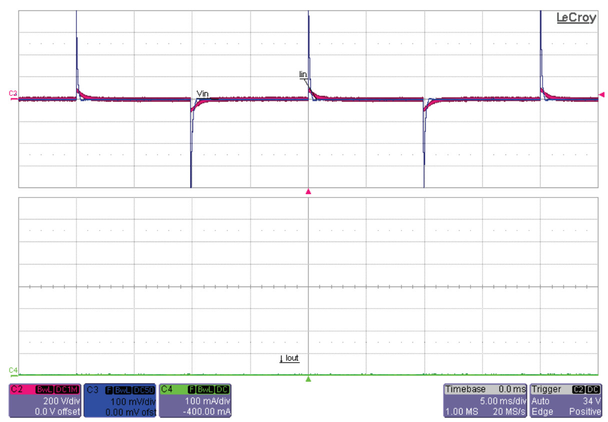

Figure 56 – 240 VAC / 50 Hz, (China) KBE, 650 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

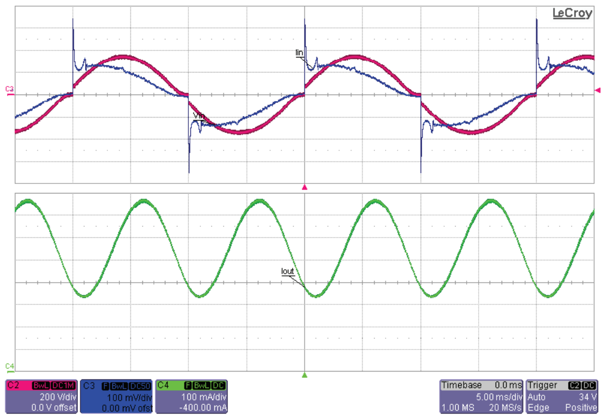

Figure 57 – 240 VAC / 50 Hz, (China) Clipmei Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

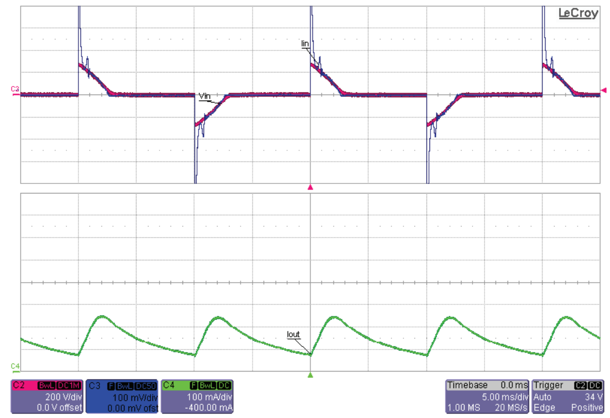

Figure 58 – 240 VAC / 50 Hz, (China) Clipmei Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

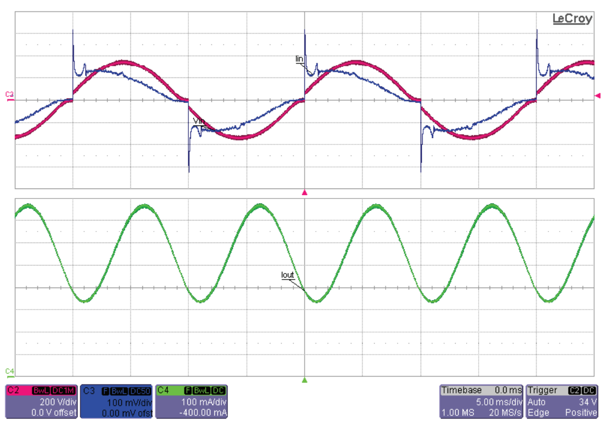

Figure 59 – 240 VAC / 50 Hz, (China) Mank 200 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

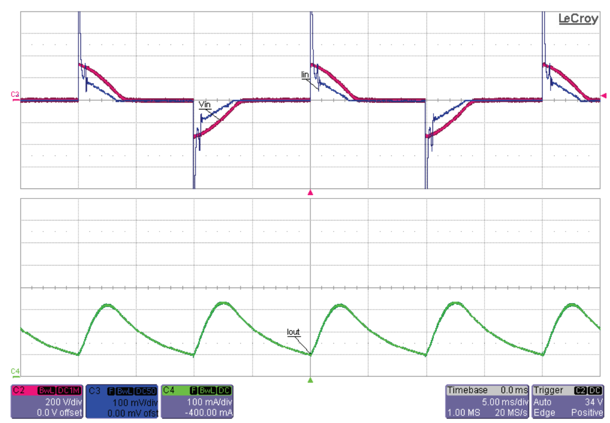

Figure 60 – 240 VAC / 50 Hz, (China) Mank 200 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

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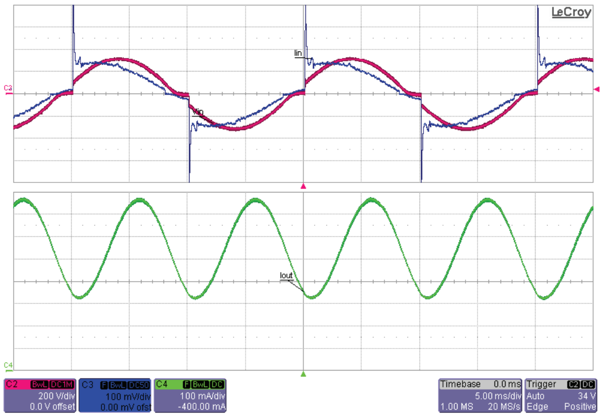

Figure 61 – 240 VAC / 50 Hz, (Korea) Anam, 500 W Dimmer at full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

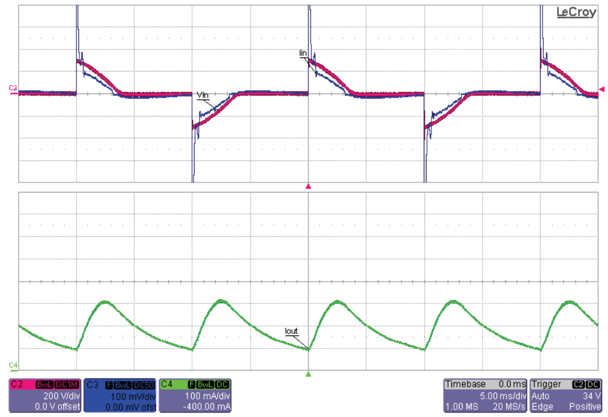

Figure 62 – 240 VAC / 50 Hz, (Korea) Anam, 500 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

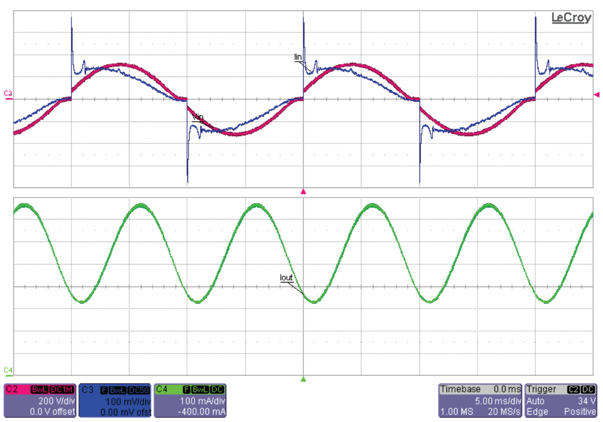

Figure 63 – 240 VAC / 50 Hz, (Korea) Shin Sung Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

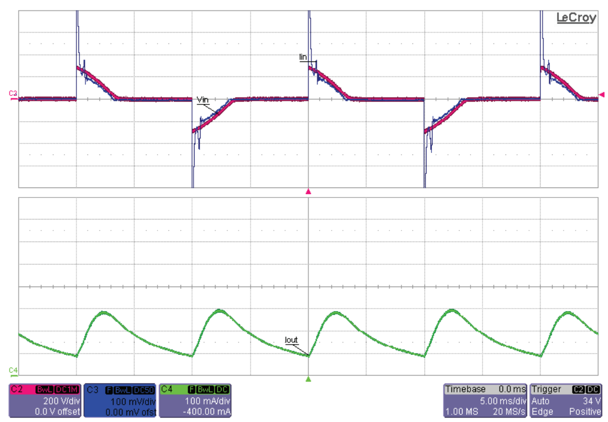

Figure 64 – 240 VAC / 50 Hz, (Korea) Shin Sung Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

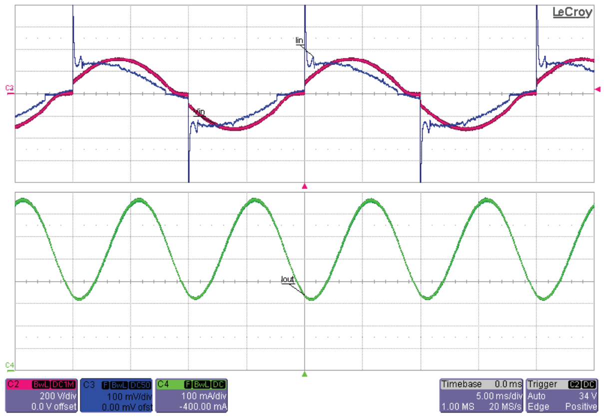

Figure 65 – 240 VAC / 50 Hz, (Korea) Fantasia 500 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

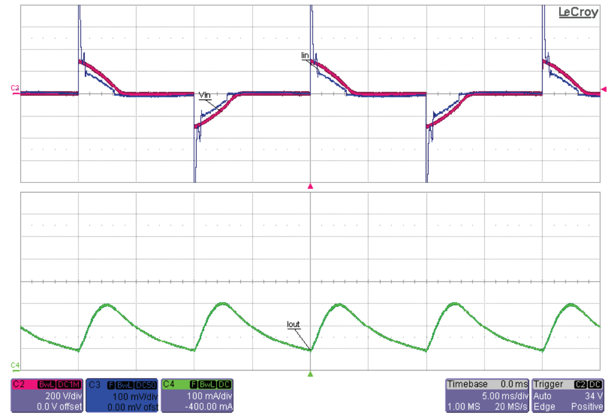

Figure 66 – 240 VAC / 50 Hz, (Korea) Fantasia 500 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

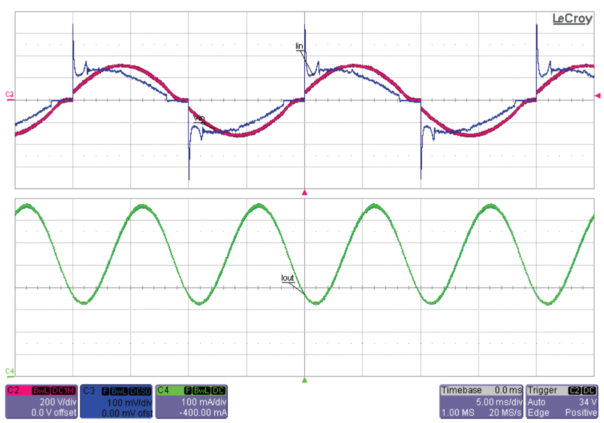

Figure 67 – 240 VAC / 50 Hz, (Korea) Shin Sung 2 Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

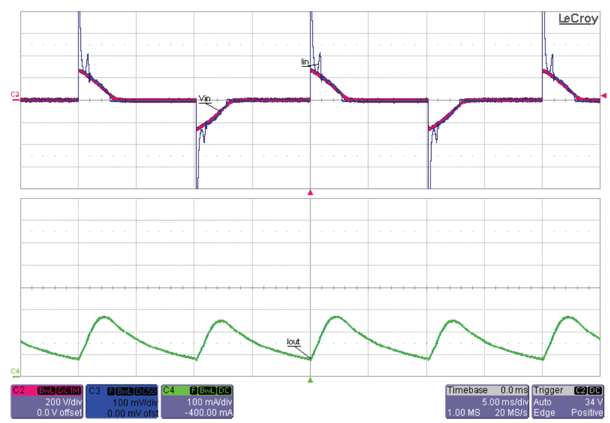

Figure 68 – 240 VAC / 50 Hz, (Korea) Shin Sung 2 Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

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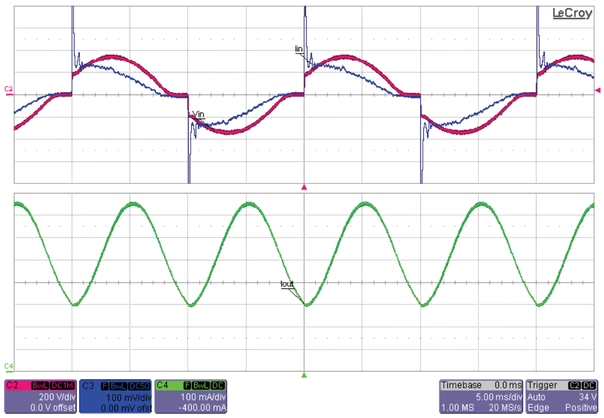

Figure 69 – 240 VAC / 50 Hz, (Germany) Rev 300 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

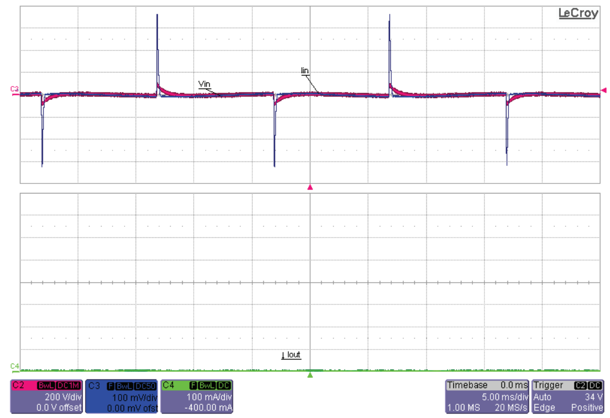

Figure 70 – 240 VAC / 50 Hz, (Germany) Rev 300 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

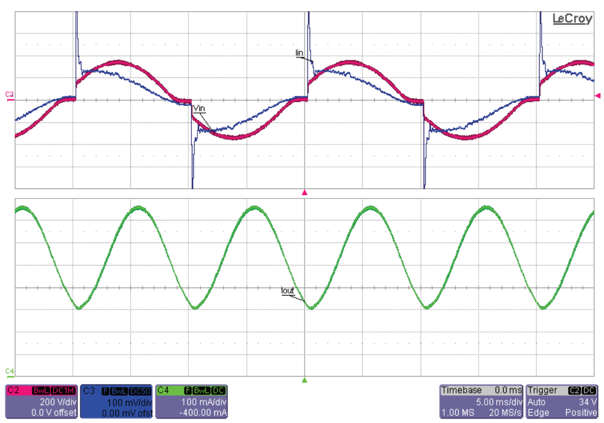

Figure 71 – 240 VAC / 50 Hz, (Germany) Busch 2250 600 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

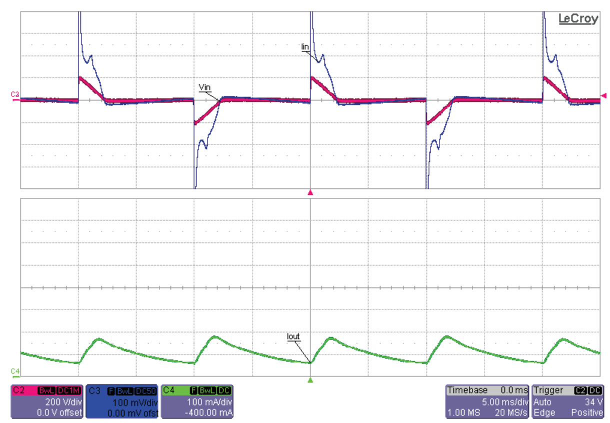

Figure 72 – 240 VAC / 50 Hz, (Germany) Busch 2250 600 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

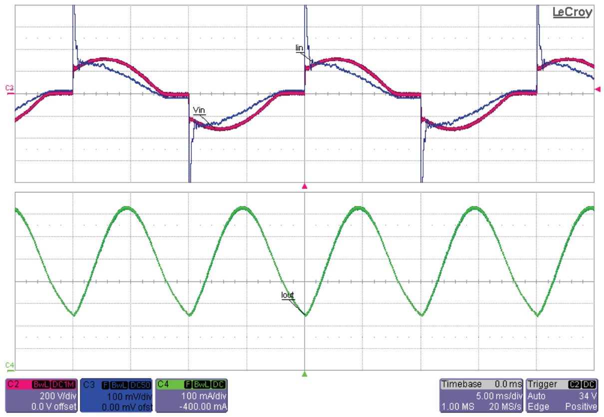

Figure 73 – 240 VAC / 50 Hz, (Germany) PEHA 400 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

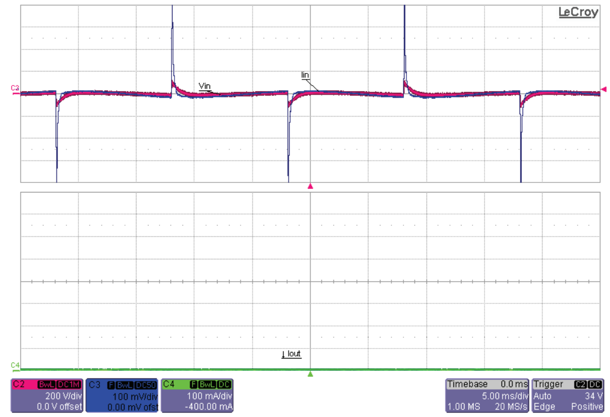

Figure 74 – 240 VAC / 50 Hz, (Germany) PEHA 400 W Dimmer at Minimum TRIAC conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

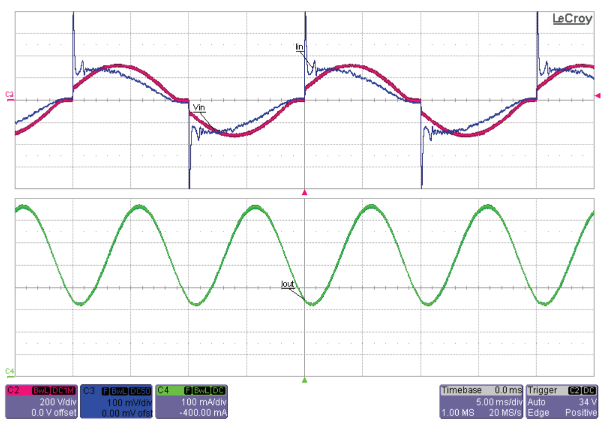

Figure 75 – 240 VAC / 50 Hz, (Germany) Merten 572499, 400 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

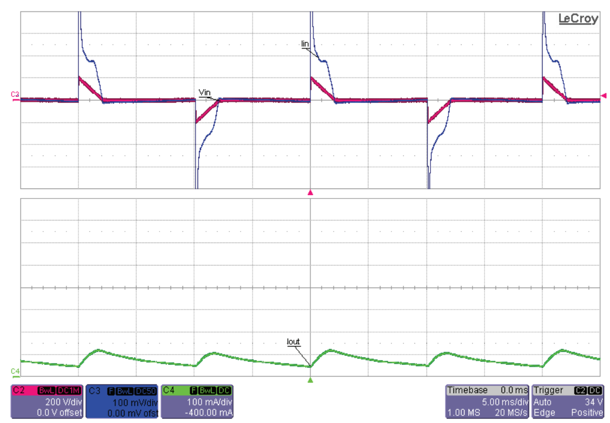

Figure 76 – 240 VAC / 50 Hz, (Germany) Merten 572499, 400 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

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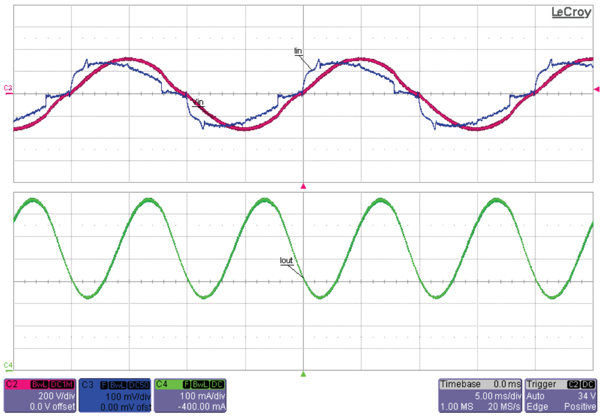

Figure 77 – 240 VAC / 50 Hz, (Germany) Busch 6513, 420 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

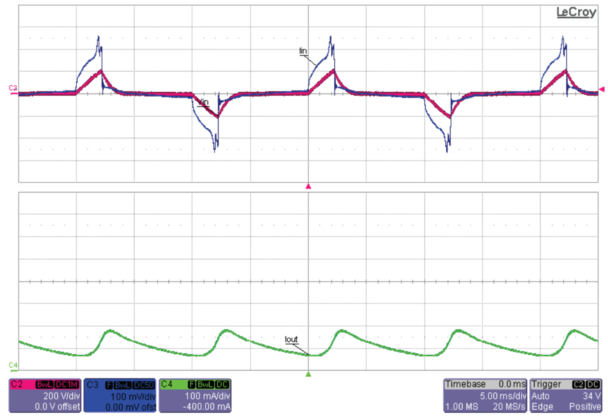

Figure 78 – 240 VAC / 50 Hz, (Germany) Busch 6513, 420 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

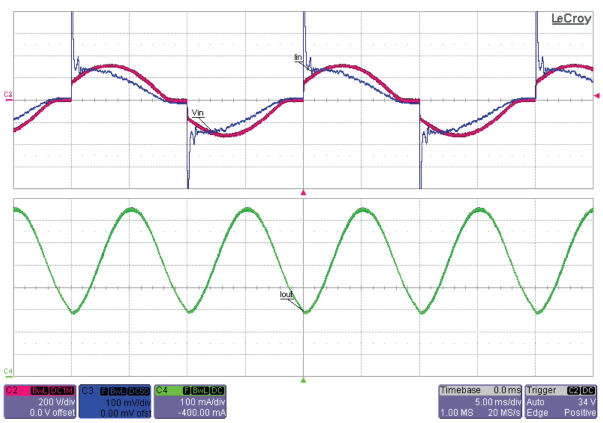

Figure 79 – 240 VAC / 50 Hz, (Germany) Berker 2875, 600 W Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

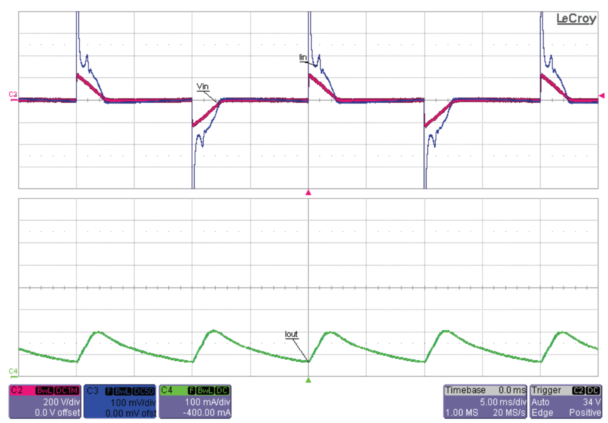

Figure 80 – 240 VAC / 50 Hz, (Germany) Berker 2875, 600 W Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

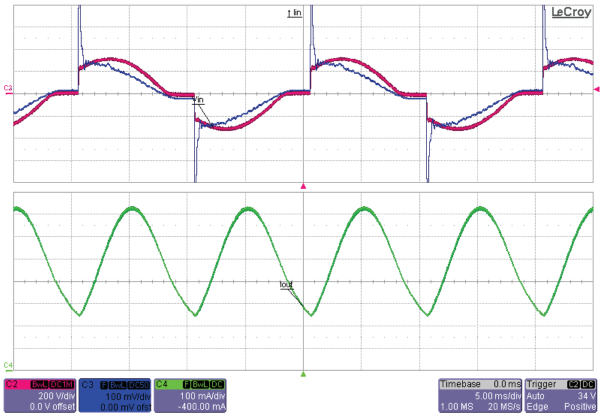

Figure 81 – 240 VAC / 50 Hz, (Germany) Ove Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

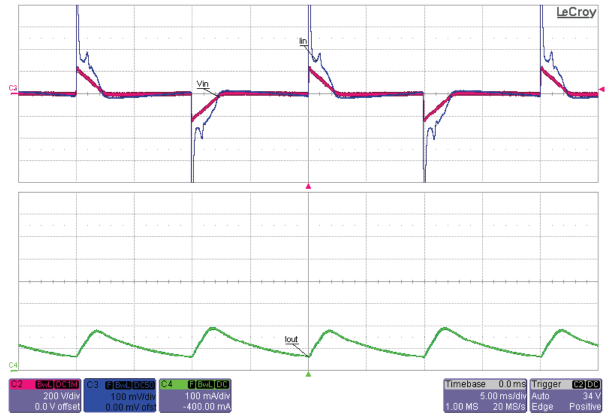

Figure 82 – 240 VAC / 50 Hz, (Germany) Ove Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

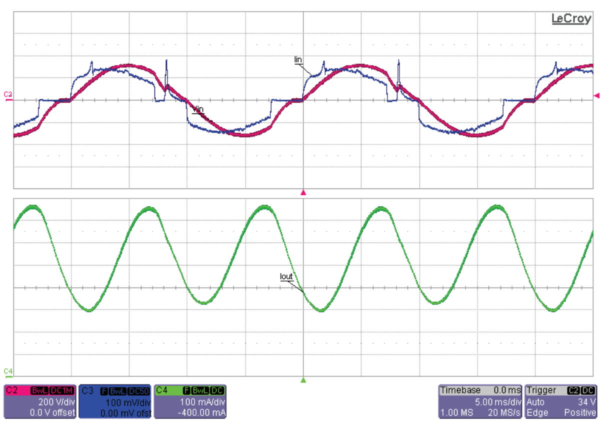

Figure 83 – 240 VAC / 50 Hz, (Germany) Busch 691 U-101 Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

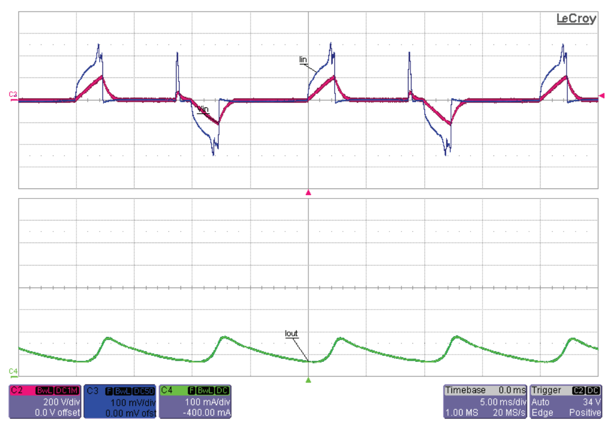

Figure 84 – 240 VAC / 50 Hz, (Germany) Busch 691 U-101 Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

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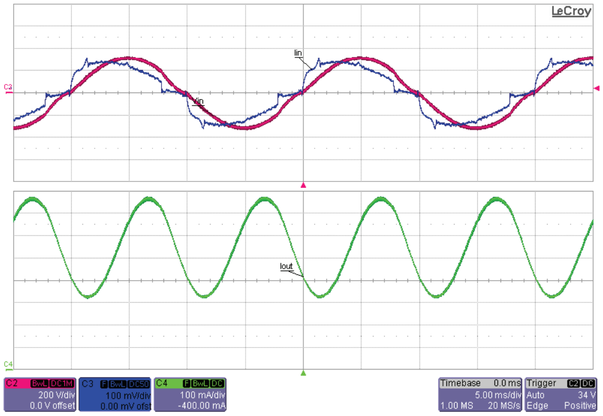

Figure 85 – 240 VAC / 50 Hz, (Germany) Busch 6513 U102 Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

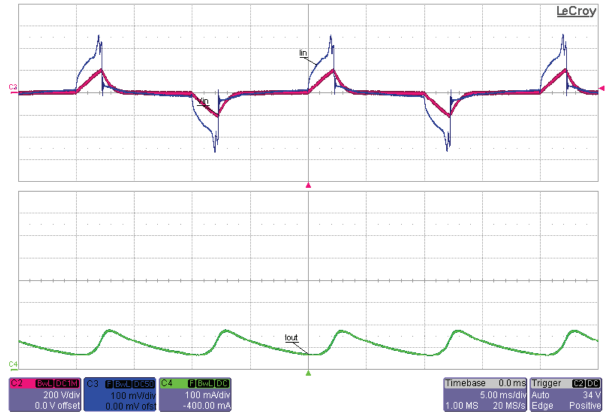

Figure 86 – 240 VAC / 50 Hz, (Germany) Busch 6513 U102 Dimmer at minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

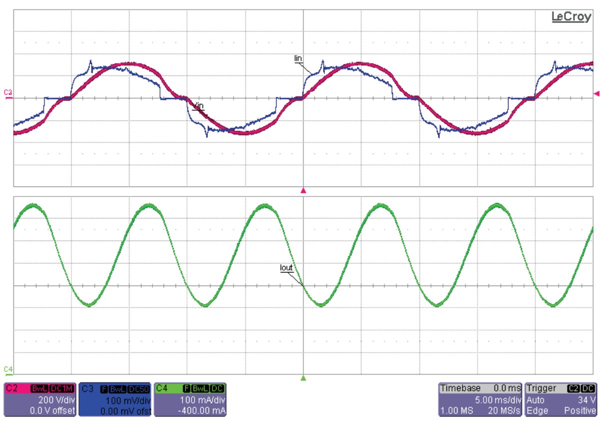

Figure 87 – 240 VAC / 50 Hz, (Germany) PEHA 433AB Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

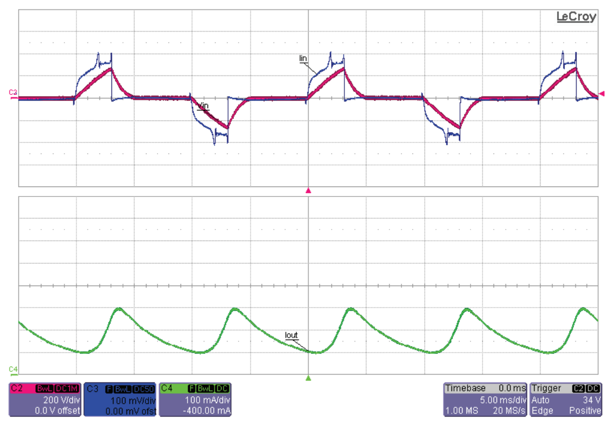

Figure 88 – 240 VAC / 50 Hz, (Germany) PEHA 433AB Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

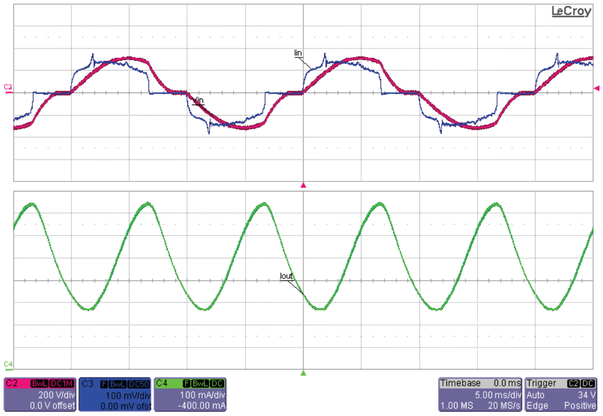

Figure 89 – 240 VAC / 50 Hz, (Germany) PEHA 433AB oA Dimmer at Full TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

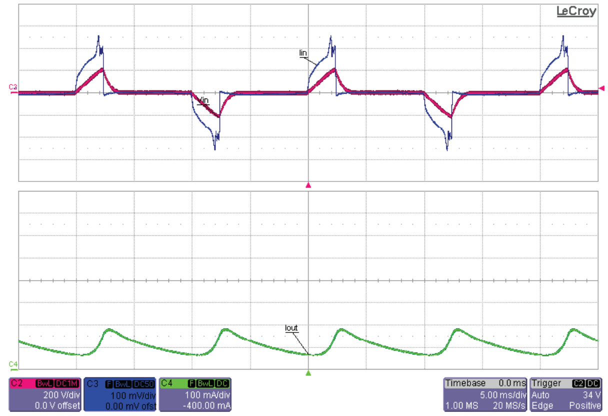

Figure 90 – 240 VAC / 50 Hz, (Germany) PEHA 433AB oA Dimmer at Minimum TRIAC Conduction.
Load: 36 V LED String.
Ch2: V_{IN}, 200 V / div.
Ch3: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 100 mA / div.
Time Scale: 5 ms / div.

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13.10 输入浪涌波形

13.10.1 差模输入浪涌

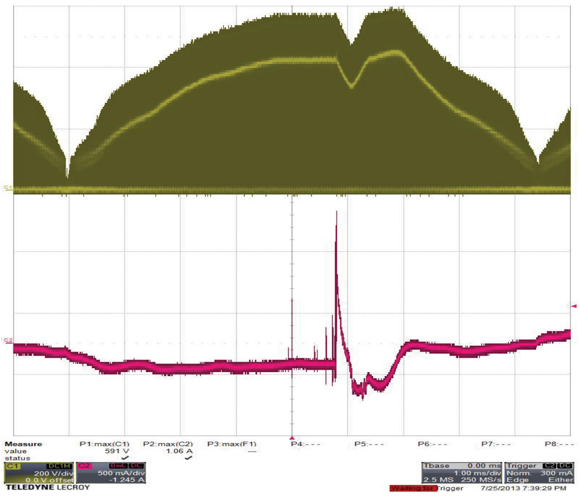

Figure 91 – 265 VAC / 60 Hz, 36 V Load,
V_{DS} = 591 V_{PK}
(+) 500 V Diff. Line Surge at 90º.
Ch1: V_{DS}, 200 V / div.
Ch2: I_{IN}, 500 mA / div.
Time Scale: 1 µs / div.

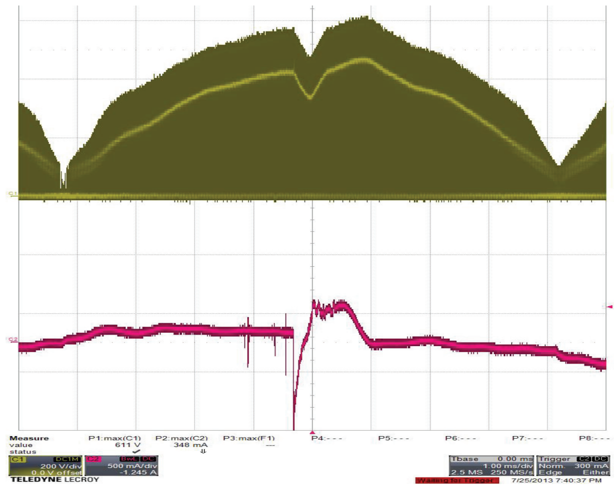

Figure 92 – 265 VAC / 50 Hz, 36 V Load,
V_{DS} = 611 V_{PK}
(+) 500 V Diff. Line Surge at 270º.
Ch1: V_{BULK}, 100 V / div.
Ch2: V_{DS}, 200 V / div.
Time Scale: 200 µs / div.
Zoom Time Scale: 20 µs / div.

13.10.2 差模振铃浪涌

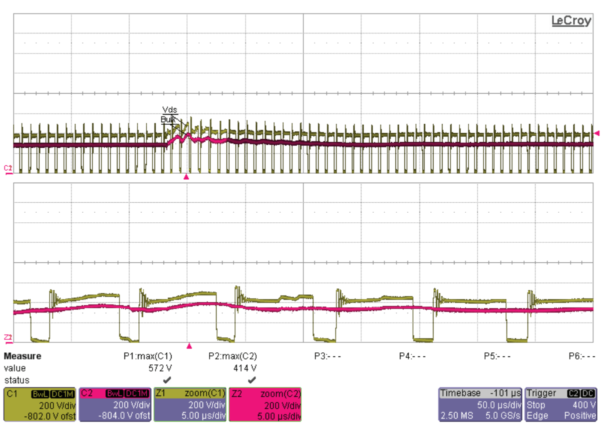

Figure 93 – 230 VAC / 60 Hz, 36 V Load,
V_{DS} = 572 V_{PK}
(+) 500 V Differential Ring Surge at 90º.
Ch1: V_{DS}, 200 V / div.
Ch2: V_{BULK}, 200 V / div.
Zoom Time Scale: 5 µs / div.

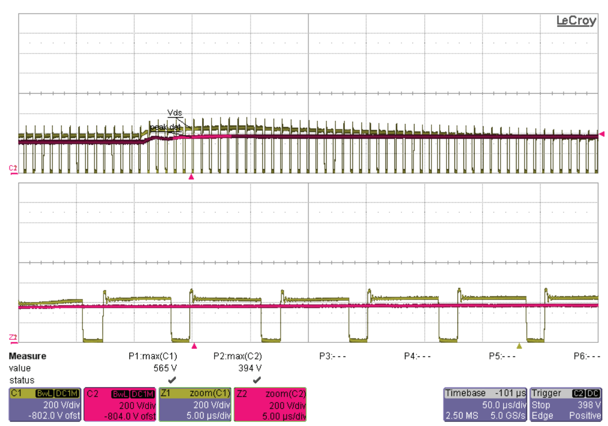

Figure 94 – 230 VAC / 60 Hz, 36 V Load,
V_{DS} = 565 V_{PK}
(+) 500 V Differential Ring Surge at 0º.
Ch1: V_{DS}, 200 V / div.
Ch2: V_{BULK}, 200 V / div.
Zoom Time Scale: 5 µs / div.

14 输入浪涌

Input voltage was set at 230 VAC / 60 Hz. Output was loaded with 36 V LED string and operation was verified following each surge event. Two units were verified in the following conditions.

Differential input line 1.2 / 50 μs surge testing was completed on one test unit to IEC61000-4-5.

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+500	120	L to N	0	Pass
-500	120	L to N	270	Pass
+500	120	L to N	90	Pass
-500	120	L to N	180	Pass

Differential input line ring surge testing was completed on one test unit to IEC61000-4-5.

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2500	120	L to N	0	Pass
-2500	120	L to N	270	Pass
+2500	120	L to N	90	Pass
-2500	120	L to N	180	Pass

Unit passes under all test conditions.

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15 传导EMI

15.1 设备

Receiver:
- Rohde & Schwartz
- ESPI - Test Receiver (9 kHz – 3 GHz)
- Model No: ESPI3

LISN:
- Rohde & Schwartz
- Two-Line-V-Network
- Model No: ENV216

15.2 EMI测试设置

Usually LED driver is placed in a conical metal housing (for self-ballasted lamps; CISPR15 Edition 7.2) but since lamp housing is not available during the UUT was tested then it was evaluated as shown in the figure below.

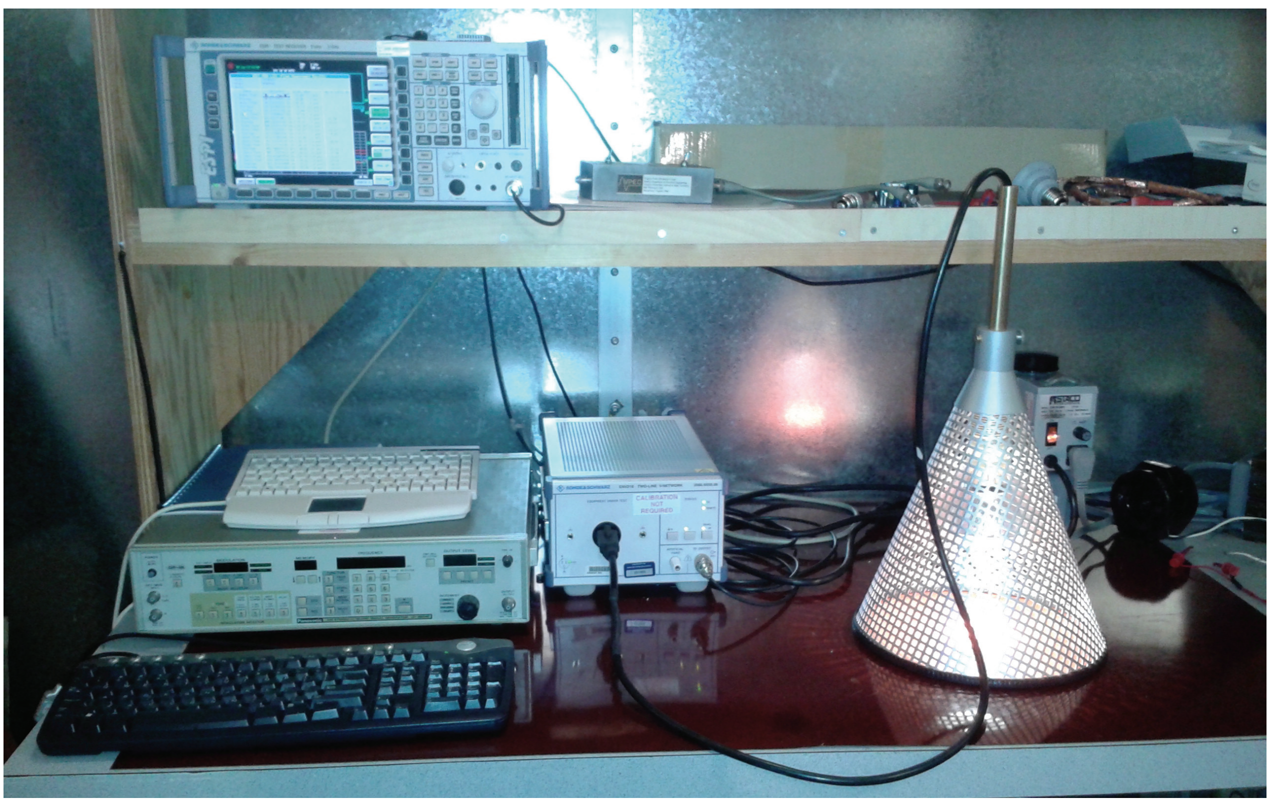

Figure 95 – Conducted Emissions Measurement Set-up.

15.3 EMI测试结果

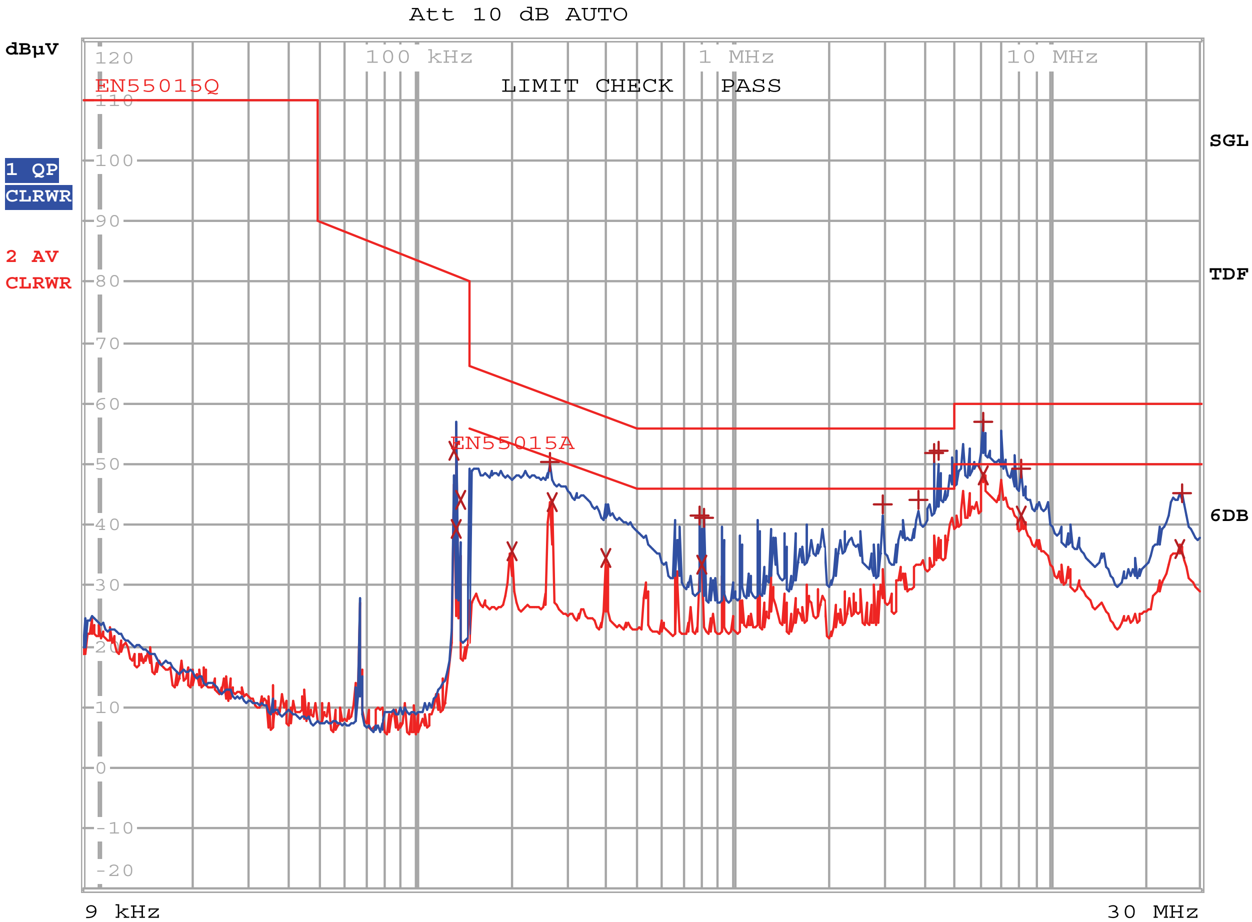

Figure 96 – Conducted EMI, 36 V output / 550 mA Steady-State Load, 230 VAC, 60 Hz, and EN55015 Limits.

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EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	130.825395691 kHz	38.20	L1 gnd	
1	Quasi Peak	133.454986145 kHz	64.55	L1 gnd	-16.50
2	Average	133.454986145 kHz	64.29	N gnd	
2	Average	136.137431366 kHz	24.88	L1 gnd	
1	Quasi Peak	174.145343305 kHz	52.73	L1 gnd	-12.02
2	Average	200.175581485 kHz	35.00	N gnd	-18.60
1	Quasi Peak	208.303512797 kHz	50.42	L1 gnd	-12.85
1	Quasi Peak	227.818484195 kHz	50.65	N gnd	-11.87
1	Quasi Peak	246.694773277 kHz	50.50	L1 gnd	-11.36
1	Quasi Peak	254.169871602 kHz	51.18	N gnd	-10.43
2	Average	267.135089486 kHz	44.12	N gnd	-7.07
2	Average	401.705024172 kHz	36.36	N gnd	-11.45
1	Quasi Peak	434.988979109 kHz	45.29	L1 gnd	-11.86
2	Average	667.263434405 kHz	34.06	N gnd	-11.93
2	Average	798.145472681 kHz	35.73	N gnd	-10.26
1	Quasi Peak	3.76891518811 MHz	42.16	L1 gnd	-13.83
2	Average	3.76891518811 MHz	33.46	L1 gnd	-12.53
1	Quasi Peak	4.16322710559 MHz	45.25	L1 gnd	-10.74
2	Average	5.28619370567 MHz	41.89	N gnd	-8.10
1	Quasi Peak	5.55584271143 MHz	46.93	N gnd	-13.06

Figure 97 – Conducted EMI, 36 V / 550 mA Steady-State Load Steady-State Load, 230 VAC, 60 Hz, and EN55015 Limits / Line and Neutral Scan Design Margin Measurement.

16 版本历史

Date	Author	Revision	Description and Changes	Reviewed
25-Sep-13	ME	1.0	Initial Release	Apps & Mktg

Power Integrations
电话：+1 408 414 9200 传真：+1 408 414 9201
www.powerint.com

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Power Integrations全球销售支持网络

全球总部
5245 Hellyer Avenue
San Jose, CA 95138, USA.
Main: +1-408-414-9200
Customer Service:
Phone: +1-408-414-9665
Fax: +1-408-414-9765
e-mail: usasales@powerint.com

德国
Lindwurmstrasse 114
80337, Munich
Germany
Phone: +49-895-527-39110
Fax: +49-895-527-39200
e-mail: eurosales@powerint.com

日本
Kosei Dai-3 Building
2-12-11, Shin-Yokohama,
Kohoku-ku, Yokohama-shi,
Kanagawa 222-0033
Japan
Phone: +81-45-471-1021
Fax: +81-45-471-3717
e-mail: japansales@powerint.com

台湾
5F, No. 318, Nei Hu Rd.,
Sec. 1
Nei Hu District
Taipei 114, Taiwan R.O.C.
Phone: +886-2-2659-4570
Fax: +886-2-2659-4550
e-mail: taiwansales@powerint.com

中国（上海）
Rm 1601/1610, Tower 1
Kerry Everbright City
No. 218 Tianmu Road West
Shanghai, P.R.C. 200070
Phone: +86-021-6354-6323
Fax: +86-021-6354-6325
e-mail: chinasales@powerint.com

印度
#1, 14th Main Road
Vasanthanagar
Bangalore-560052
India
Phone: +91-80-4113-8020
Fax: +91-80-4113-8023
e-mail: indiasales@powerint.com

韩国
RM 602, 6FL
Korea City Air Terminal B/D,
159-6
Samsung-Dong, Kangnam-Gu,
Seoul, 135-728 Korea
Phone: +82-2-2016-6610
Fax: +82-2-2016-6630
e-mail: koreasales@powerint.com

欧洲总部
1st Floor, St. James's House
East Street, Farnham
Surrey GU9 7TJ
United Kingdom
Phone: +44 (0) 1252-730-141
Fax: +44 (0) 1252-727-689
e-mail: eurosales@powerint.com

中国（深圳）
3rd Floor, Block A, Zhongtou
International Business Center, No.
1061, Xiang Mei Road, FuTian District,
ShenZhen, China, 518040
Phone: +86-755-8379-3243
Fax: +86-755-8379-5828
e-mail: chinasales@powerint.com

意大利
Via Milanese 20, 3rd. Fl.
20099 Sesto San Giovanni
(MI) Italy
Phone: +39-024-550-8701
Fax: +39-028-928-6009
e-mail: eurosales@powerint.com

新加坡
51 Newton Road,
#19-01/05 Goldhill Plaza
Singapore, 308900
Phone: +65-6358-2160
Fax: +65-6358-2015
e-mail: singaporesales@powerint.com

技术支持热线
World Wide +1-408-414-9660

技术支持传真
World Wide +1-408-414-9760