设计范例报告

标题	***使用LYTSwitch™-4 LYT4322E设计的14.35 W高效率(>86%)．高功率因数(>0.95)．可控硅调光的非隔离抽头降压式LED驱动器***
规格	195 VAC – 265 VAC输入； 41 V_{TYP}，350 mA输出
应用	PAR30 LED驱动器
作者	应用工程部
文档编号	DER-395
日期	2014年2月27日
修订版本	1.0

特色概述

- 单级功率因数校正(PFC)与精确恒流(CC)输出相结合
- 在230 VAC输入下，效率>86%
- 可控硅调光
  - 可兼容各种可控硅调光器
- 低成本、元件数量少、印刷电路板(PCB)占用面积小
- 快速启动时间(<200 ms) – 无可见延迟
- 集成的保护及可靠性能
  - 输出短路保护，带自动恢复功能
  - 带更大迟滞的自动恢复热关断
  - 在AC电压跌落期间不会造成任何损坏
  - 输入过压保护
- 在230 VAC下，PF > 0.95
- 满足EN55015传导EMI要求

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

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1 简介

本文档介绍的是一款非隔离、高功率因数(PF)、高效率、可控硅调光的LED驱动器，它可以在195 VAC至265 VAC（典型值为50 Hz）的输入电压范围内为LED灯串提供额定电压41 V、额定电流350 mA的驱动。

所采用的拓扑结构是单级、非隔离、抽头降压式拓扑结构，可满足本设计的高功率因数、恒流调整和调光要求。

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

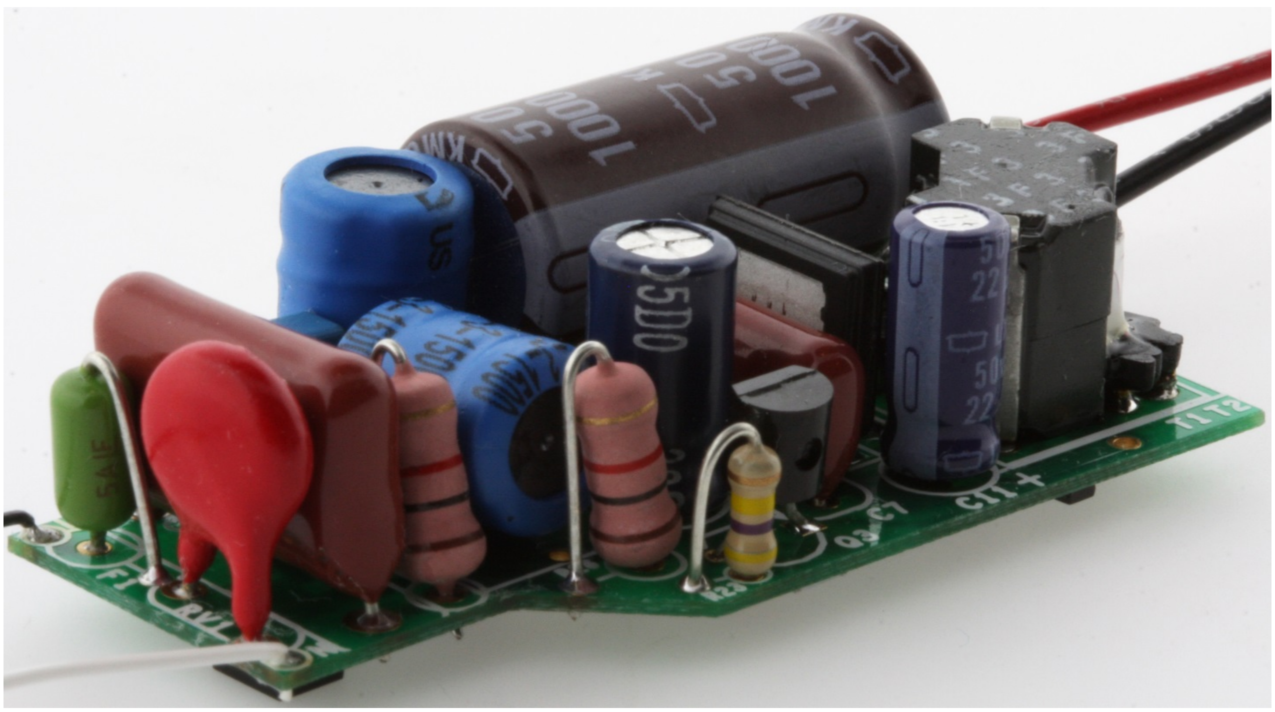

Figure 1 – Populated Circuit Board, Angle View.

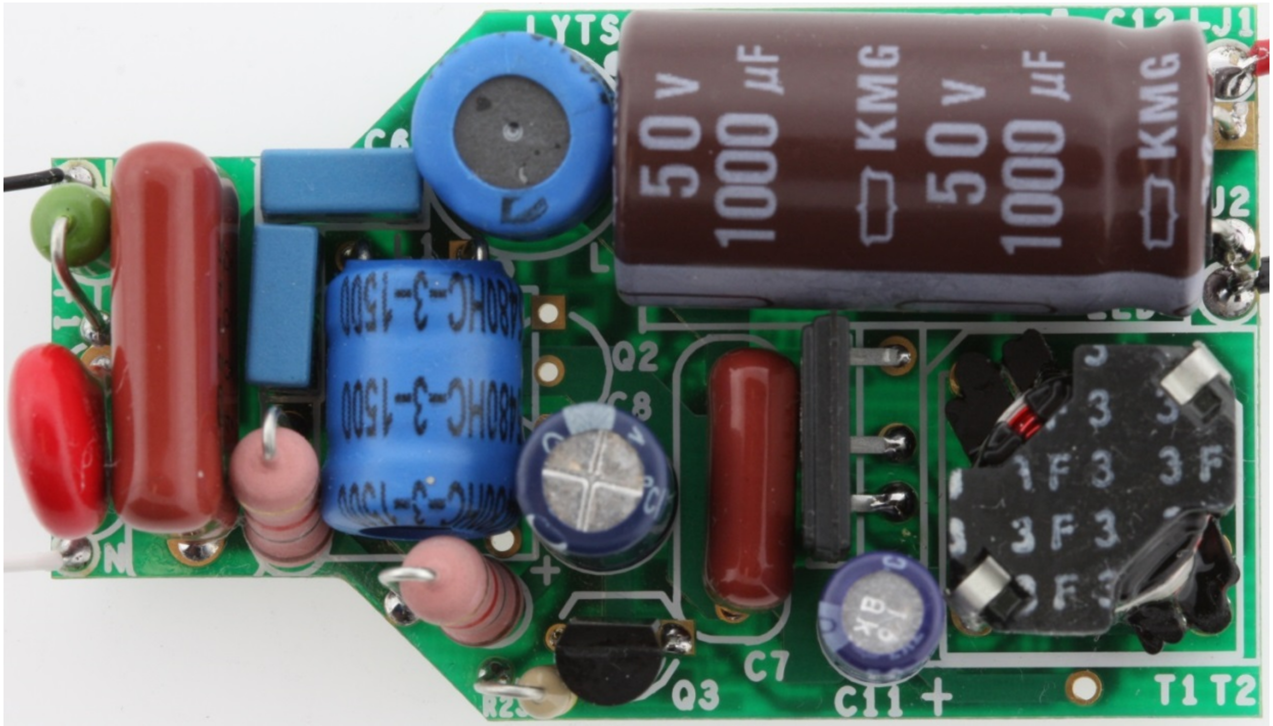

Figure 2 – Populated Circuit Board, Top View.

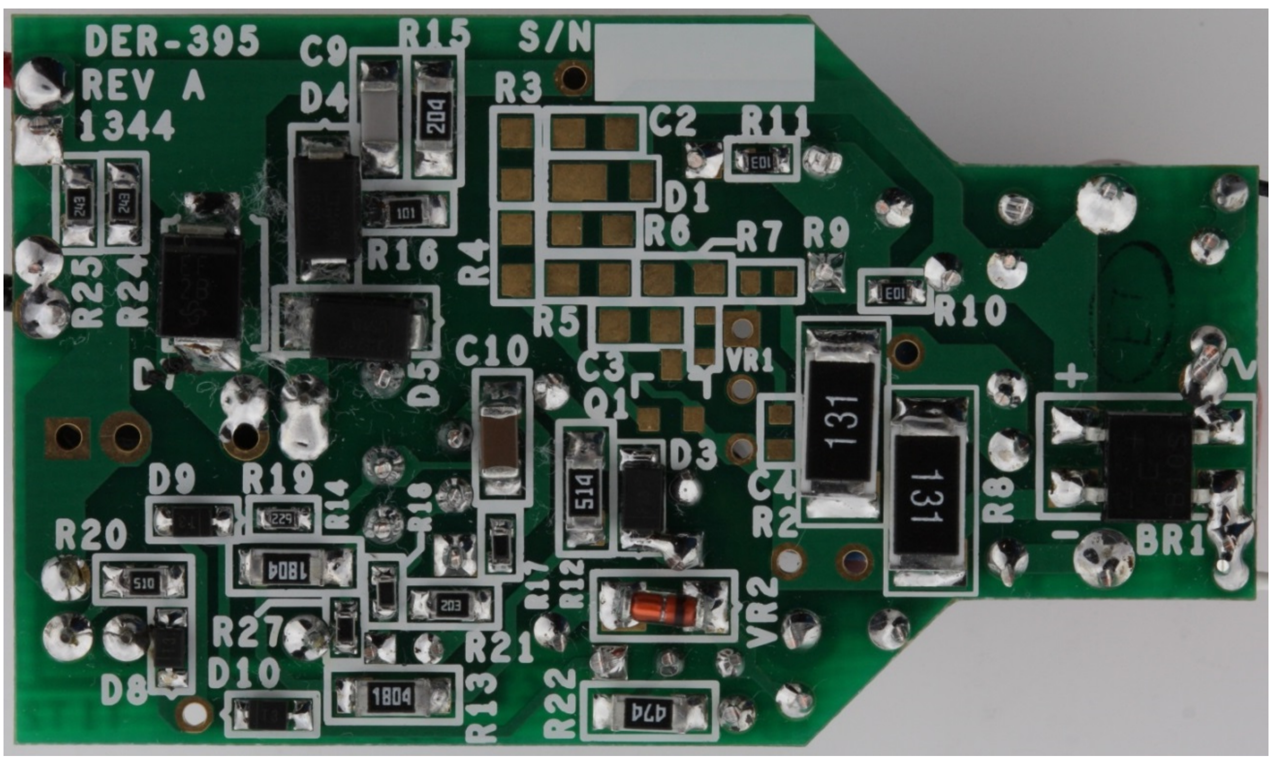

Figure 3 – Populated Circuit Board, Bottom View.

注：请参阅附录了解未装配元件的详细信息。

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2 电源规格

下表所列为设计的最低可接受性能。实际性能可参考测量结果部分。

说明	符号	最小值	典型值	最大值	单位	备注
输入						
电压	V_{IN}	195	230	265	VAC	双导线 – 无P.E.
频率	f_{LINE}		50/60		Hz	
输出						
输出电压	V_{OUT}	38	41	44	V	
输出电流	I_{OUT}		350		mA	V_{OUT} = 41 V, V_{IN} = 230 VAC, 25 ^{0}C
总输出功率						
连续输出功率	P_{OUT}		14.35		W	
效率						
满载	η		86		%	在P_{OUT} 25 °C条件下测得
环境						
传导EMI		CISPR 15B / EN55015B				
安全		非隔离				
振铃波(100 kHz)						
差模(L1-L2)			2.5		kV	
共模(L1/L2-PE)						
差模浪涌			500		V	
功率因数		0.9				在$V_{OUT(TYP)}$、$I_{OUT(TYP)}$ 以及230 VAC、50 Hz条件下测得
谐波电流		EN 61000-3-2 Class C				
环境温度	T_{AMB}		40		°C	

3 电路原理图

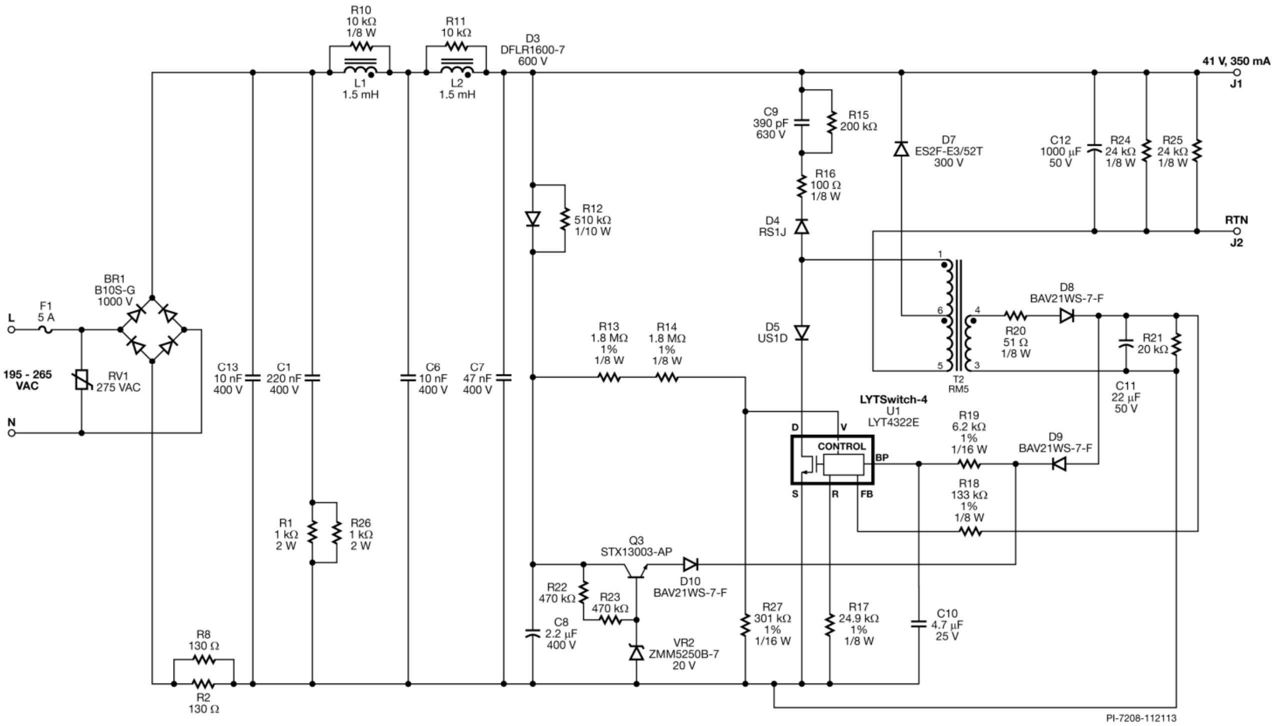

Figure 4 – Schematic.

4 电路描述

LYT4322E (U1)是一款适用于LED驱动器应用的高集成度初级侧芯片控制器。它能够在单级转换级中提供高功率因数，同时对特定输入电压(195 VAC - 265 VAC)电压条件下的输出电流进行调节。所有提供这些功能的控制电路以及高压功率MOSFET都集成在IC中。

4.1 输入EMI滤波

保险丝F1在元件发生故障时提供保护，而RV1用来对浪涌测试期间可能产生的最大电压进行箝位。桥式整流器BR1对AC输入电压进行整流。

EMI滤波由电感L1、L2以及电容C6、C7和C13提供。L1和L2上的电阻R10和R11可抑制电感的自谐振，避免以其谐振频率在传导EMI图上出现噪声峰值。

所选的电感未采用磁屏蔽设计，它们串联在一起且彼此相邻；L1与L2之间的磁耦合效应在布局时经过认真考虑，以便提供一致的EMI性能。在本设计中，L1垂直于L2安装，绕组的起始端和结束端受到控制，在电路原理图和PCB上用点表示。（请参阅电感厂商的数据手册，了解起始绕组和结束绕组的信息。）

4.2 功率电路

本设计所采用的拓扑结构为低压端抽头降压式配置，可在195 VAC至265 VAC的输入电压范围内提供高功率因数和恒流输出。

抽头降压式转换器具有诸多优势，包括可减小磁芯元件的尺寸、降低主开关U1上的电流应力以及降低输出二极管D7上的电压应力。主开关上的电流应力降低后，可使用较小的开关器件，从而实现具有成本效益的设计。

电感T2是降压转换器的主电感，它由初级绕组、次级绕组和偏置绕组这三个绕组组成。将匝数比选定为3:1（初级绕组与次级绕组匝数比）后，可使用一个300 V输出二极管，同时仍使U1 LYT4322E的最大电压远低于其最大值。

输出二极管D7每当U1关断时就会导通，将能量传输至负载。在C7上的电压（整流后的输入AC）降到输出电压以下时，需要使用二极管D5来防止反向电流流经U1。此外，还添加了一个电压箝位电路来限制由T2的漏感所产生的电压尖峰。电压箝位网络由二极管D4、电容C9以及电阻R15和R16组成。

选用电容C12来降低输出纹波(<30%)。当AC断电并确保灯完全熄灭时（而不是在AC断电后微弱发光数秒钟），假负载电阻R24和R25可使输出快速放电至LED灯串电压以下。

为向U1提供峰值输入电压信息，经整流AC的输入峰值经由D3对C8充电。然后电流经过R13和R14，注入U1的电压监测(V)引脚。添加R27用来提高输入电压/负载调整率。电阻R12提供放电通路，以使C8的电压跟踪AC输入的变化。

输入过压关断功能（通过V引脚电流检测）可使整流后的线电压承受能力（在浪涌和线电压陡升期间）达到内部功率MOSFET的额定725 BV_{DSS}。

电容C10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，C10从与U1的漏极(D)引脚相连的内部高压电流源被充电至约6 V。电容C10的选取值为4.7 μF，以使器件能够在完全模式下工作。

U1的参考(R)引脚通过电阻R17接地（源极）。24.9 kΩ值用来提供精确的恒流调整。

4.3 偏置电源和输出反馈

T2上的偏置绕组用于为IC提供反馈和供电。偏置绕组的反馈电压由D8进行整流并由C11进行滤波，以平滑电压和R20，从而降低耦合自漏感能量的过高电压。反馈电流然后经由电阻R18馈入反馈(FB)引脚。二极管D9和R19将BP引脚链路至偏置绕组。有必要采用二极管D9在启动时将C10与C11隔离，电阻R19用于限制从偏置绕组提供给BP引脚的电流。电阻R21对偏置电源提供负载，以加快C11在AC周期内的放电，同时有助于提高调光比。

4.4 可控硅相位调光控制兼容性

对于用低成本的可控硅前及后沿沿相控调光器提供输出调光的要求，我们需要在设计时进行全面权衡。

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）。

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本设计中所采用的衰减电路、泄放电路和线性稳压电路能够克服这些问题，并且对驱动器效率的影响保持在最小限度。

电阻R2和R8提供无源衰减。

无源泄放网络由电容C1和电阻R1/R26构成。该网络可以抑制输入网络，同时为可控硅调光器提供要求的锁存和维持电流。

本设计增加了线性稳压电路R22、R23、VR2、Q3和D10，以使IC的供电（BP引脚）保持恒定 – 使它能够在极低导通角下或以极低输入电压进行正常工作，并且使IC充当一个负载（这对具有高漏电流的可控硅特别重要）。大多数具有高功率额定值(>600 W)的可控硅调光器都有一个LC输入滤波器。如果RC的电容足够大，能够提供能量来为LED驱动器的输入级进行充电，那么LED可能会在LED负载加电时导通，直到输入放电为止。然后该周期重复发生，即使在可控硅关断时也会导致LED负载闪烁。

当偏置电压高于Vz_{VR2} +Vt_{Q3} + Vf_{D10}时，线性稳压器不会激活。本设计选择使用电压稳压器VR2，以便线性稳压器仅在偏置电压足够低时的深度调光期间工作，从而降低Q3的功耗。Q3采用低成本BJT (400 V)，电阻R22和R23提供足够的驱动，即使在深度调光期间输入电压较低时也可提高足够的驱动。

5 PCB布局

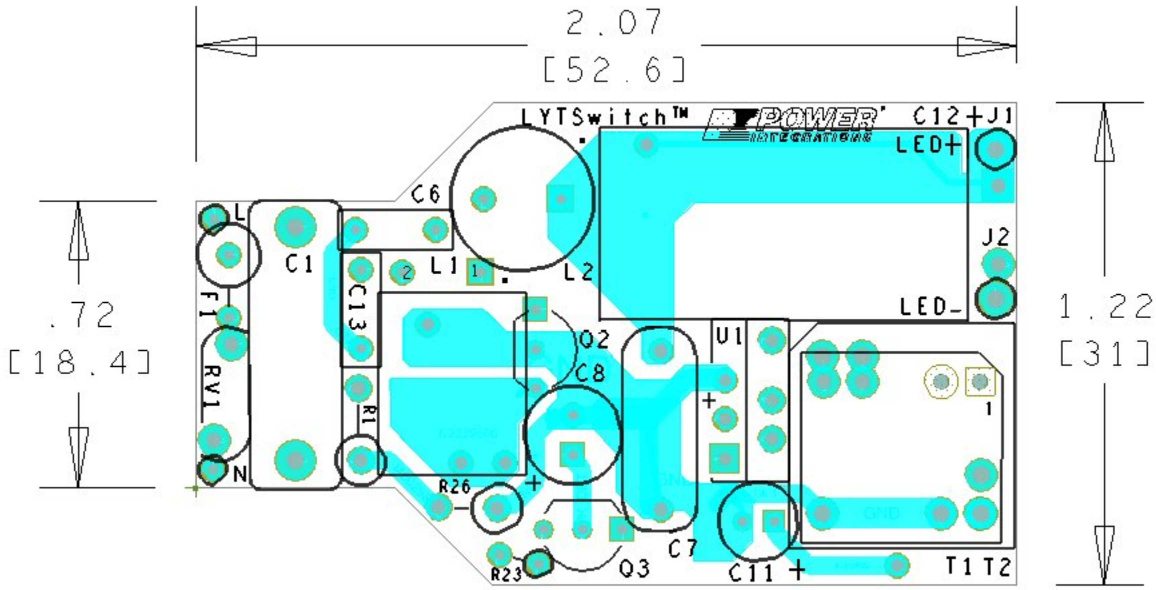

Figure 5 – Top Side.

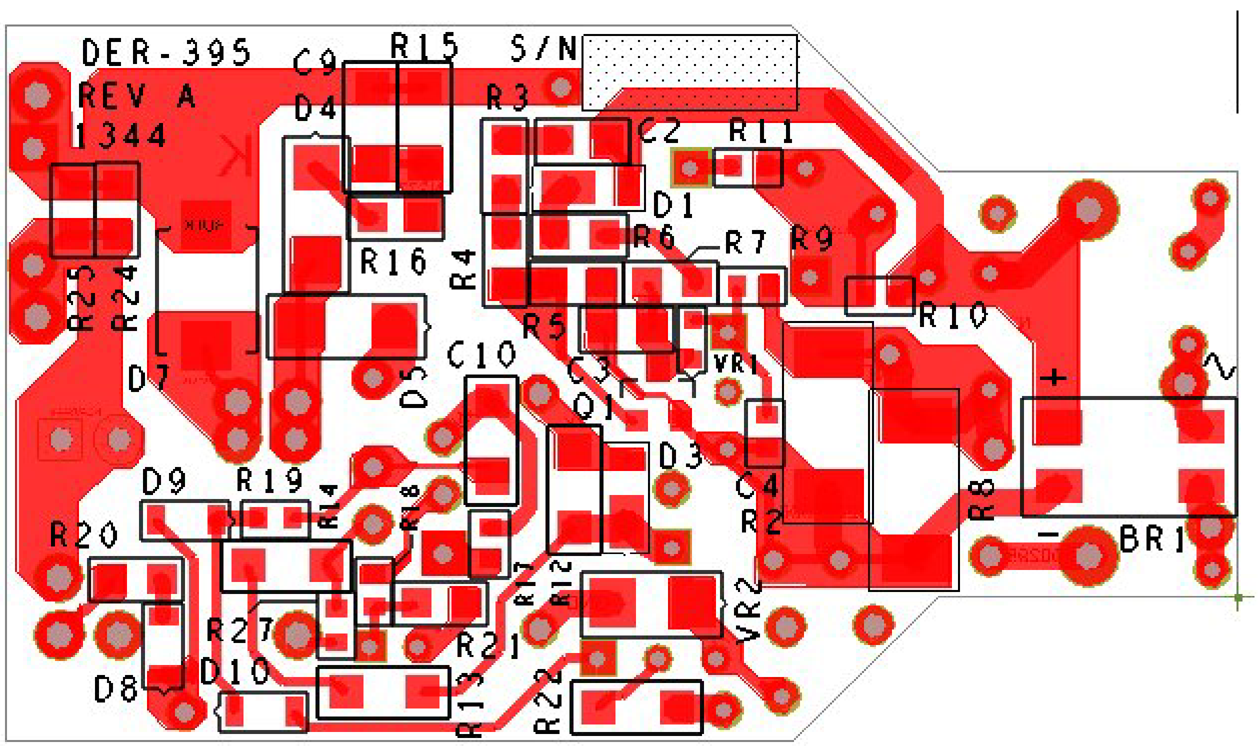

Figure 6 – Bottom Side.

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6 物料清单(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, 400 V, Film	ECQ-E4224KF	Panasonic
3	2	C6 C13	10 nF, 400 VDC, Metallized Polyester	B32529C6103K189	Epcos
4	1	C7	47 nF, 400 V, Film	ECQ-E4473KF	Panasonic
5	1	C8	2.2 μF, 400 V, Electrolytic, (6.3 x 11)	TAB2GM2R2E110	Ltec
6	1	C9	390 pF, 630 V, Ceramic, NPO, 1206	C3216C0G2J391J	TDK
7	1	C10	4.7 μF, 25 V, Ceramic, X7R, 1206	C3216X7R1E475K160AC	TDK
8	1	C11	22 μF, 50 V, Electrolytic, (5 x 11)	UPW1H220MDD	Nichicon
9	1	C12	1000 μF, 50 V, Electrolytic, Gen. Purpose, (12.5 x 25)	EKMG500ELL102MK25S	Nippon Chemi-Con
10	1	D3	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
11	1	D4	600 V, 1 A, Fast Recovery, 250 ns, SMA	RS1J-13-F	Diodes, Inc.
12	1	D5	DIODE ULTRA FAST, SW, 200 V, 1 A, SMA	US1D-13-F	Diodes, Inc.
13	1	D7	300 V, 2 A, Ultrafast Recovery, 50 ns, SMB Case	ES2F-E3/52T	Vishay
14	3	D8 D9 D10	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diode Inc.
15	1	F1	5 A, 250 V, Fast, Microfuse, Axial	0263005.MXL	Littlefuse
16	2	L1 L2	1.5 mH, 0.250 A, 10%	RL-5480HC-3-1500	Renco
17	1	Q3	NPN, Power BJT, 400 V, 1 A, TO-92	STX13003-AP	ST Micro
18	2	R1 R26	1 kΩ, 5%, 2 W, Metal Film	FMP200JR-52-1K	Yageo
19	2	R2 R8	130 Ω, 5%, 1 W, Thick Film, 2512	ERJ-1TYJ131U	Panasonic
20	2	R10 R11	10 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ103V	Panasonic
21	1	R12	510 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ514V	Panasonic
22	2	R13 R14	1.80 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1804V	Panasonic
23	1	R15	200 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ204V	Panasonic
24	1	R16	100 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ101V	Panasonic
25	1	R17	24.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2492V	Panasonic
26	1	R18	133 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1333V	Panasonic
27	1	R19	6.2 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ622V	Panasonic
28	1	R20	51 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ510V	Panasonic
29	1	R21	20 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ203V	Panasonic
30	1	R22	470 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ474V	Panasonic
31	1	R23	470 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-470K	Yageo
32	2	R24 R25	24 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ243V	Panasonic
33	1	R27	301 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3013V	Panasonic
34	1	RV1	275 V, 23 J, 7 mm, RADIAL	V275LA4P	Littlefuse
35	1	T2	Bobbin, RM5, Vertical, 6 pins	P-501	Pin Shine
36	1	U1	LYTSwitch-4, eSIP-7C	LYT4322E	Power Integrations
37	1	VR2	20 V, 5%, 500 mW, DO-213AA (MELF)	ZMM5250B-7	Diodes, Inc.

7 电感规格

7.1 电气原理图

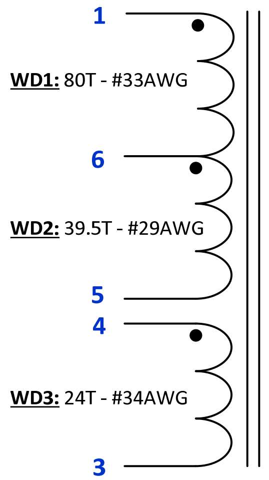

Figure 7 – Inductor Electrical Diagram.

7.2 电气规格

Primary Inductance	Pins 1-5, all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	1 mH ±3%
Resonant Frequency	Pins 1-5, all other windings open.	>1 MHz

7.3 材料

Item	Description
[1]	Core: RM5/I-3F3 Ferrox Cube.
[2]	Bobbin: RM5-Vertical, 6 pins (3/3). AllStar Magnetics P/N: CPV-RM5-1S-6P-G.
[3]	Clip: AllStar Magnetics P/N: CLI/P-RM4/5/I.
[4]	Magnet wire: #33 AWG - Double coated.
[5]	Magnet wire: #29 AWG - Double coated.
[6]	Magnet wire: #34 AWG - Double coated.
[7]	Tape: 3M 1298 Polyester Film, 4.5 mm wide, 2.0 mils thick, or equivalent.
[8]	Varnish: Dolph BC-359 or equivalent.

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7.4 电感结构图

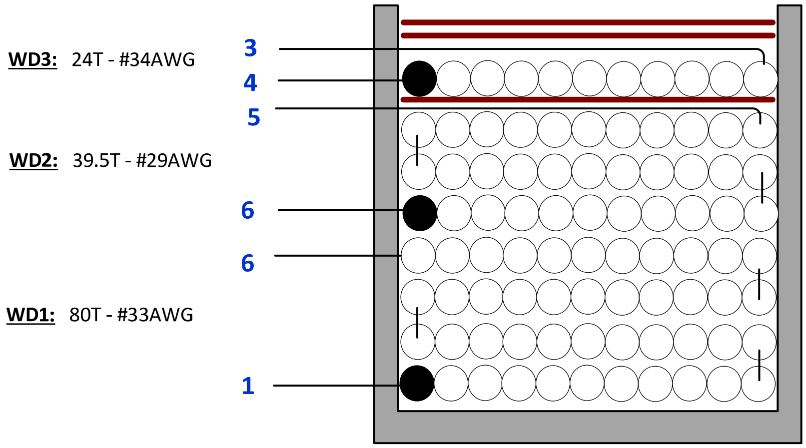

Figure 8 – Inductor Build Diagram.

7.5 电感构造

Winding Preparation	Place the bobbin on the mandrel with the pin side is on the left side. Winding direction is clockwise direction.
WD1	Start at pin 1, wind 80 turns of wire item [4] and end at pin 6. Do not put tape in-between layer.
WD2	Start at pin 6, wind 39.5 turns of wire item [5] and end at pin 5.
Insulation	Place 1 layer of tape item [7].
WD3	Start at pin 4, wind 24 turns of wire item [6] from left to right in 1 layer. At the last turn bring the wire back to the left and end at pin 3.
Insulation	Place 2 layers of tape item [7].
Final Assembly	Grind, assemble, and secure core halves with clip item [3]. Varnish with item [7].
Cutting of extra pins	Cut pin 2 of the bobbin as well as the core clip which is closer to pin 5 and pin 6. Do not cut the other clip as this will be soldered onto PCB.

8 电感设计表格

ACDC_LYTSwitch-4_Buck_102413; Rev.1.0; Copyright Power Integrations 2013	INPUT	INFO	OUTPUT	UNIT	ACDC_LYTSwitch_102413: LYTSwitch-4 Buck / Tapped Buck Design Spreadsheet
ENTER APPLICATION VARIABLES					
Topology Selection	**Tapped-Buck**				
Dimming required	**YES**		**YES**		Select "YES" option if dimming is required. Otherwise select "NO".
VACMIN	195.00		195	V	Minimum AC Input Voltage
VACNOM			230	V	Nominal AC Input Voltage
VACMAX			265	V	Maximum AC input voltage
fL			50	Hz	AC Mains Frequency
VO	41.00		41	V	Typical output voltage of LED string at full load
VO_MAX			44	V	Maximum LED string Voltage
VO_MIN			38	V	Minimum LED string Voltage
IO	0.35		0.35	A	Typical full load LED current
PO			14.35	Watts	Output Power
n	0.86		0.86		Estimated efficiency of operation
Feedback System	BIAS		BIAS		BIAS Supply
Bias Voltage			25	V	Bias Voltage
ENTER LYTSwitch VARIABLES					
LYTSwitch	**LYT4xx2**		LYT4322		Selected LYTSwitch device.
Current Limit Mode	**FULL**		FULL		Select "RED" for reduced Current Limit mode or "FULL" for Full current limit mode
ILIMITMIN			0.790	A	Minimum current limit
ILIMITMAX			0.920	A	Maximum current limit
fS			132000	Hz	Switching Frequency
fSmin			124000	Hz	Minimum Switching Frequency
fSmax			140000	Hz	Maximum Switching Frequency
IV			80.57	uA	V pin current
Rv			4	M-ohms	Voltage sense resistor
Rref			24.9	k-ohms	Reference Resistor Value
IFB			165	uA	FB pin current (90 uA < IFB < 210 uA)
RFB			133	k-ohms	IFB setting resistor
VDS			10	V	LYTSwitch on-state Drain to Source Voltage
VD			0.5	V	Output Winding Diode Forward Voltage Drop
VDB			0.7	V	Bias Winding Diode Forward Voltage Drop
CBP			4.7	uF	BP pin capacitor
Key Design Parameters					
L_TOTAL	1000.00		1000	uH	Total Inductance
N_RATIO	3.00		3.00		Turns Ratio (Np/Ns). For Buck Topology, N_RATIO=1
KP_VNOM			1.14		Ripple to Peak Current Ratio VACMIN peak)
KP_VMIN			1.11		Ripple to Peak Current Ratio VACMIN peak)
T_ON_MIN			1.91	us	Minimum T_ON at Maximum Input Voltage

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Duty_Expected			0.33		Minimum duty cycle at peak of VACMIN
Expected IO (average)			0.35	A	Expected Average Output Current
IFB_VO_MAX			179	uA	FB pin current at VO_MAX
IFB_VO_MIN			152	uA	FB pin current at VO_MIN
STRESS PARAMETERS					
VDRAIN			562.77		Peak voltage at the Drain of LYTSwitch (assuming 100V leakage spike)
VDIODE			187.59		Peak voltage across freewheeling diode
IP			0.57	A	Peak Primary Current (calculated at minimum input voltage VACMIN)
ISP			1.71	A	Peak Secondary Current (calculated at minimum input voltage VACMIN)
PIVB			94.06	V	Bias Rectifier Maximum Peak Inverse Voltage (calculated at VO_MAX, excludes leakage inductance spike)
INPUT CURRENT PARAMETERS					
IAVG			0.07	A	Average Primary Current at VACMIN
IRMS			0.15	A	Primary RMS Current (calculated at minimum input voltage VACMIN)
DC INPUT VOLTAGE PARAMETERS					
VMIN			276	V	Peak input voltage at VACMIN
VMAX			375	V	Peak input voltage at VACMAX
VIN_OVP			495	V	Typical Line Overvoltage Protection Threshold
TRANSFORMER CORE/CONSTRUCTION VARIABLES					
Core Type	**RM5/I**		RM5/I		Selected Core for inductor
Core		RM5/I		*P/N:*	RM5/I-3F3
Bobbin		RM5/I_BOBBIN		*P/N:*	CSV-RM5-1S-6P-G
AE			0.248	cm^2	Core Effective Cross Sectional Area
LE			2.32	cm	Core Effective Path Length
AL			1700	nH/T^2	Ungapped Core Effective Inductance
BW			4.68	mm	Bobbin Physical Winding Width
M			0	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
NLAYER_PRI	4.00		4		Number of Primary Layers
NLAYER_SEC	3.00		3		Number of Secondary Layers
TRANSFORMER PRIMARY DESIGN PARAMETERS					
L_TOTAL			1000	uH	Total Inductance
N_RATIO			3		Turns Ratio (Np/Ns). For Buck Topology, N_RATIO=1
N_TOTAL	120.00		120		Total Number of Turns (primary + secondary)
NS			40		Secondary winding turns
NB			24		Bias number of turns
ALG			69	nH/T^2	Gapped Core Effective Inductance
BM			2047	Gauss	Maximum Flux Density at PO, VMIN (BM<3000)
BP			3091	Gauss	Peak Flux Density (BP<4200)
BAC			1024	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
ur			1266		Relative Permeability of Ungapped Core

LG			0.43	mm	Gap Length (Lg > 0.1 mm)
BWE			18.72	mm	Effective Bobbin Width
OD			0.23	mm	Maximum Primary Wire Diameter including insulation
INS			0.05	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.19	mm	Bare conductor diameter
AWG			33	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			51	Cmils	Bare conductor effective area in circular mils
CMA			347	Cmils/Amp	Primary Winding Current Capacity (200 < CMA < 500)
TRANSFORMER SECONDARY DESIGN PARAMETERS Lumped parameters					
ISP			1.71	A	Peak Secondary Current
ISRMS			0.59	A	Secondary RMS Current
BWES			14.04	mm	Effective Bobbin Width
ODS			0.35	mm	Secondary Maximum Outside Diameter
INSS			0.06	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIAS			0.29	mm	Secondary Minimum Bare Conductor Diameter
AWGS			29.00	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
CMS			128.00	Cmils	Secondary Bare Conductor minimum circular mils
CMAS			210.68	Cmils/Amp	Secondary Winding Current Capacity (200 < CMAS < 500)
Estimated Input Current Harmonic Analysis					
Harmonic			Max Current (mA)	Limit (mA)	
1st Harmonic			69.64	N/A	Fundamental (mA)
3rd Harmonic			12.34	56.73	PASS. 3rd Harmonic current content is lower than the limit
5th Harmonic			2.57	31.70	PASS. 5th Harmonic current content is lower than the limit
7th Harmonic			0.90	16.69	PASS. 7th Harmonic current content is lower than the limit
9th Harmonic			2.28	8.34	PASS. 9th Harmonic current content is lower than the limit
11th Harmonic			2.70	5.84	PASS. 11th Harmonic current content is lower than the limit
13th Harmonic			2.61	4.94	PASS. 13th Harmonic current content is lower than the limit
15th Harmonic			2.24	4.28	PASS. 15th Harmonic current content is lower than the limit
THD			19.5	%	Estimated total Harmonic Distortion (THD)

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9 性能数据

All measurements performed at room temperature using an LED load. The following data was taken measured using 3 sets of loads representing a load range of 38 V to 44 V (output voltage). Refer to the table in Section 9.6 for complete test data values.

9.1 效率

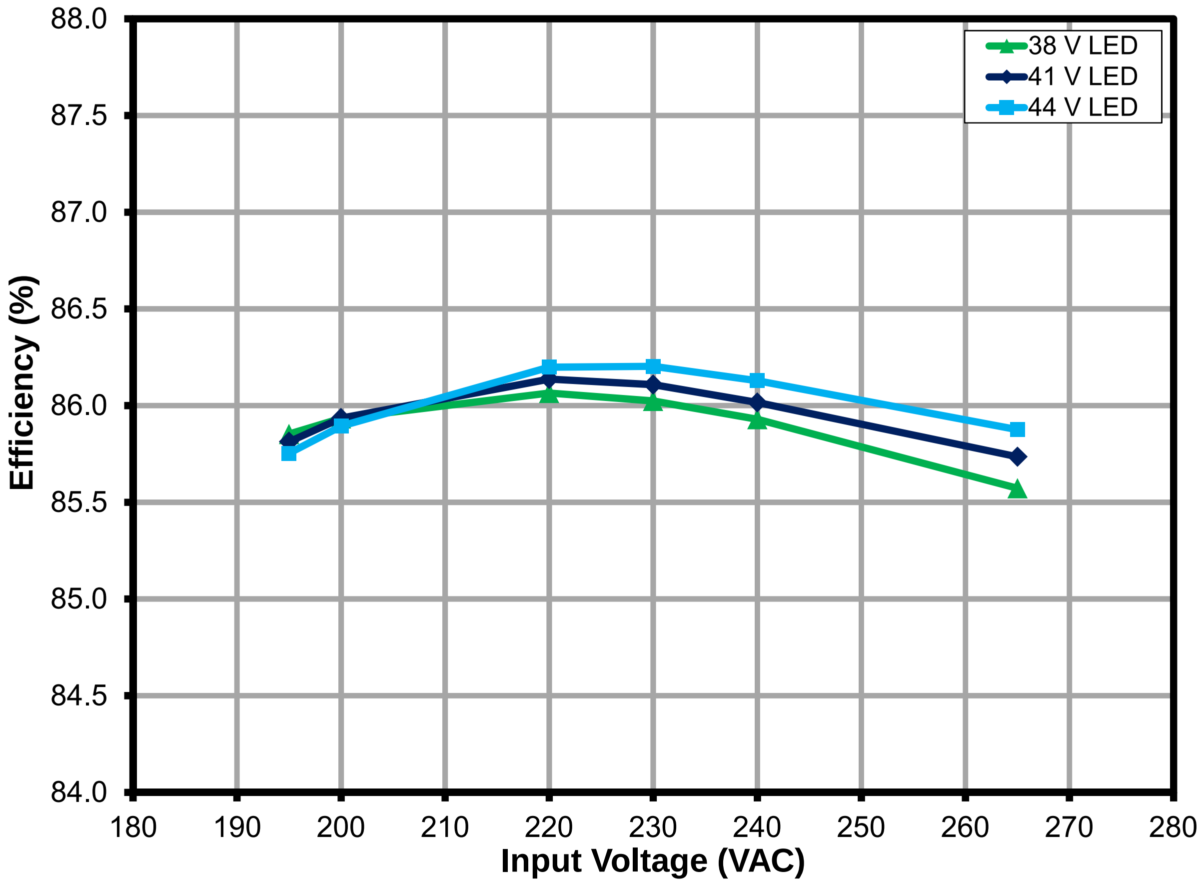

Figure 9 – Efficiency vs. Line and Load

9.2 输入电压调整率和负载调整率

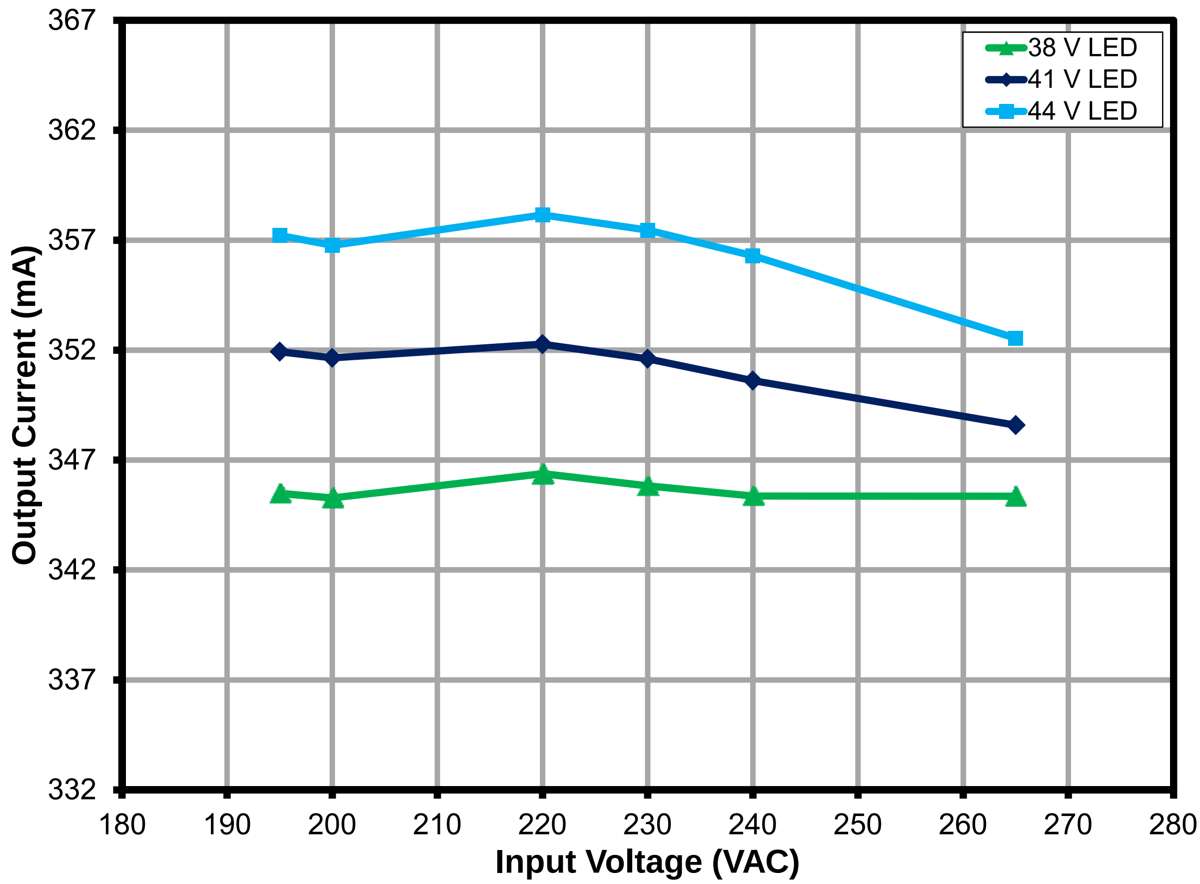

Figure 10 – Regulation vs. Line and Load

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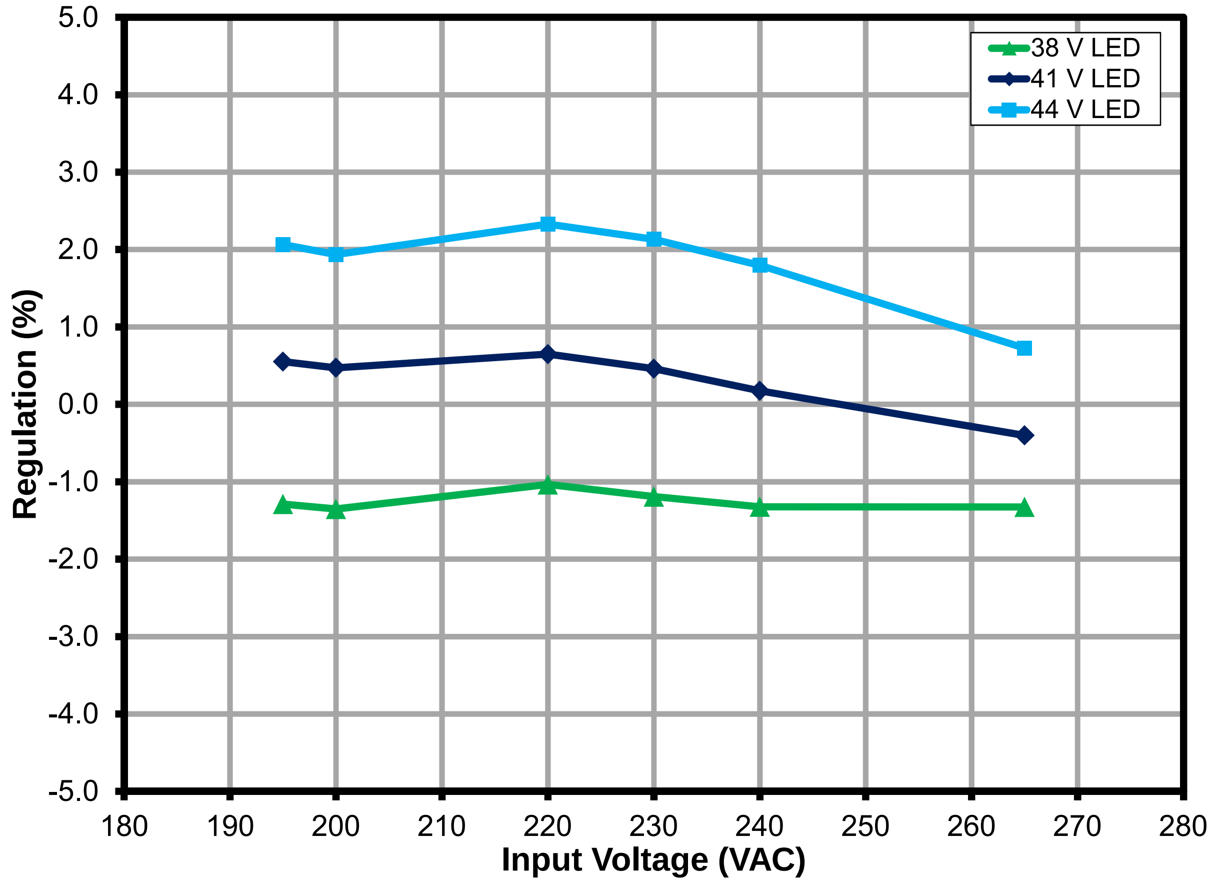

Figure 11 – % Regulation vs. Line and Load.

9.3 功率因数

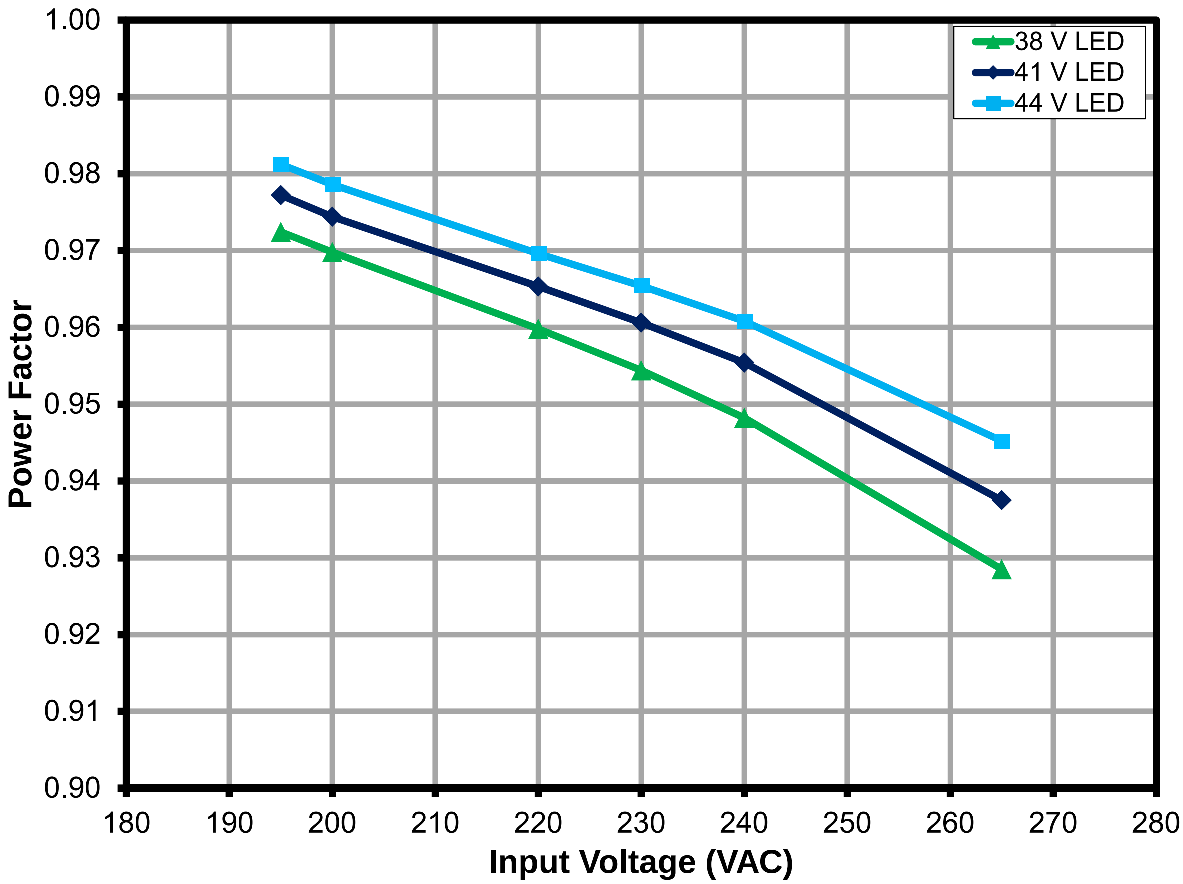

Figure 12 – Power Factor vs. Line and Load.

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9.4 A-THD

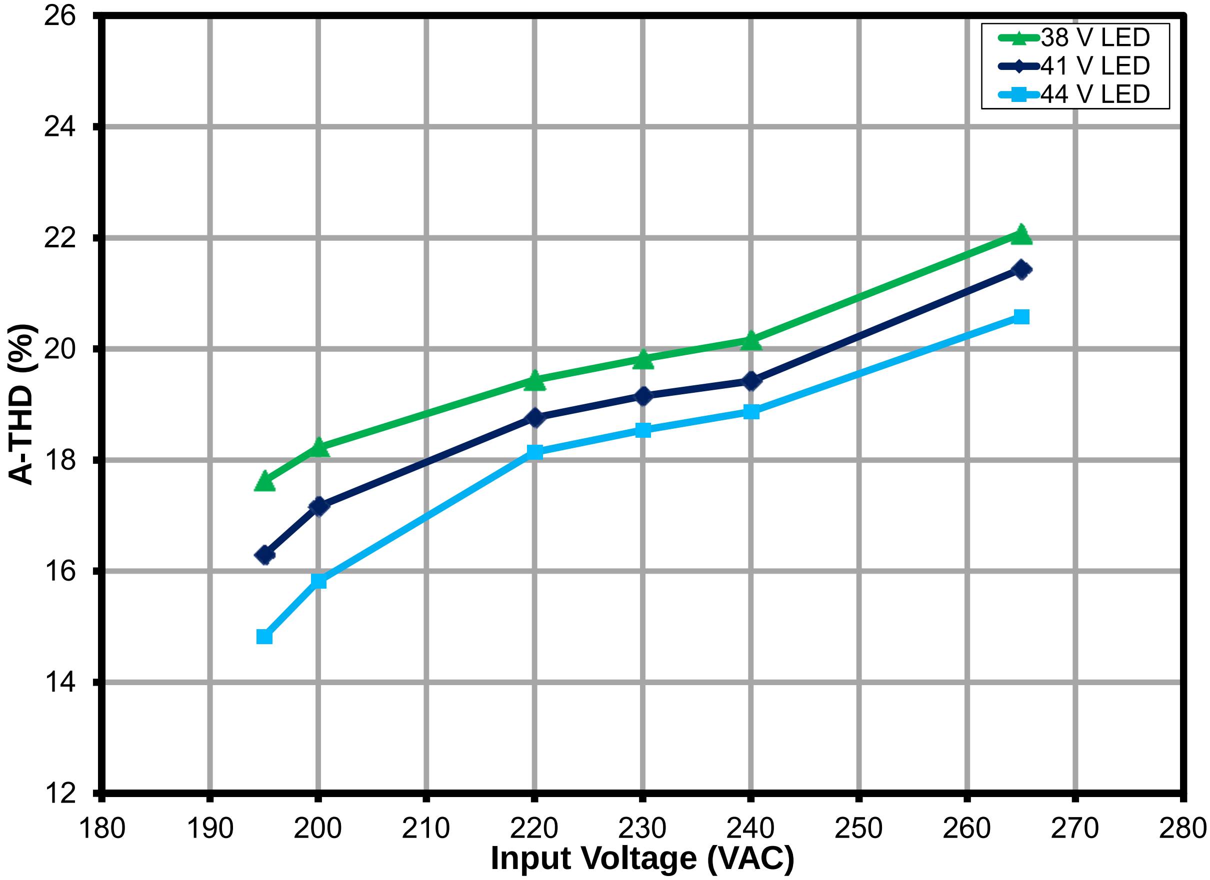

Figure 13 – A-THD vs. Line and Load.

9.5 谐波

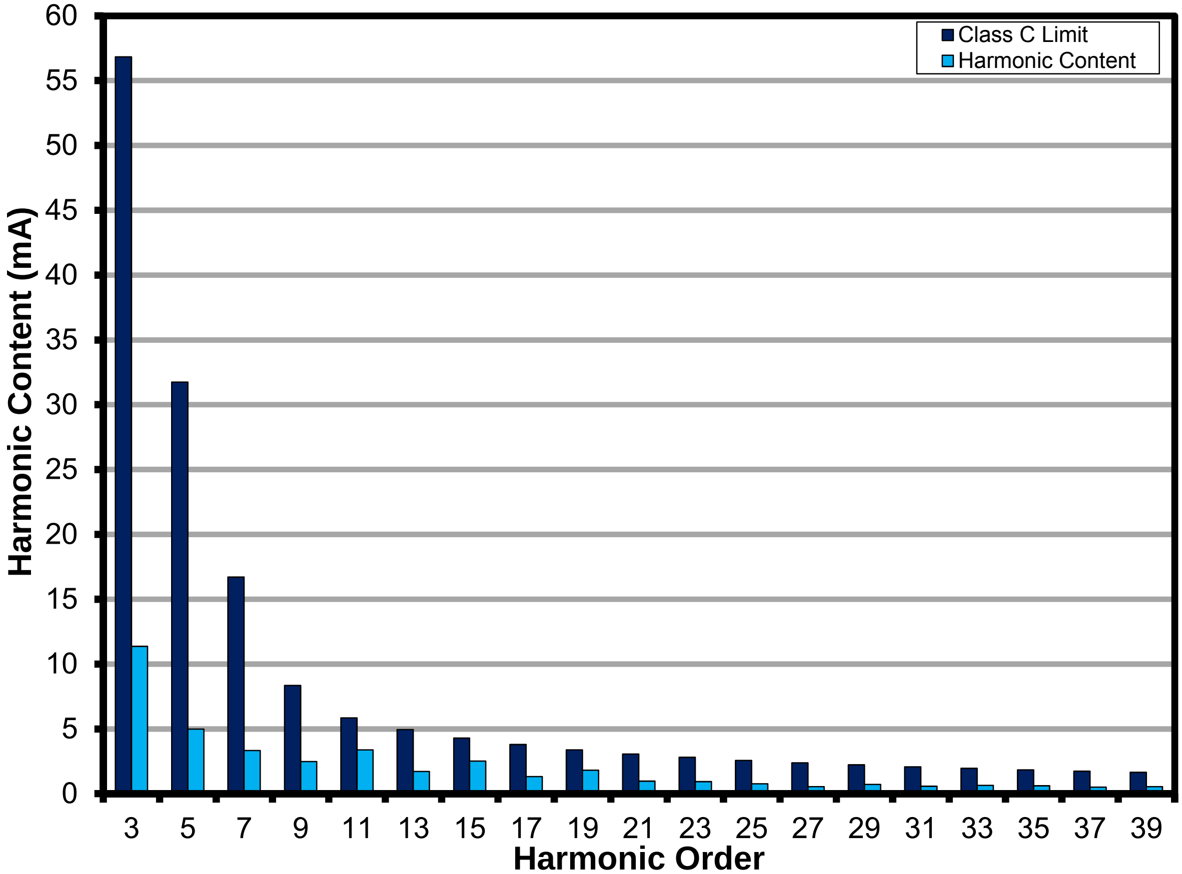

Figure 14 – 41 V LED Load Input Current Harmonics at 230 VAC, 50 Hz.

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9.6 测试数据

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

9.6.1 测试数据，38 V LED负载

Input		Input Measurement					Load Measurement				
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)	Efficiency (%)	% Reg
195	50	194.94	80.88	15.332	0.972	17.62	38.0540	345.490	13.163	85.85	-1.29
200	50	199.92	78.92	15.300	0.970	18.22	38.0350	345.270	13.148	85.93	-1.35
220	50	219.98	72.56	15.322	0.960	19.44	38.0270	346.380	13.187	86.07	-1.03
230	50	229.93	69.71	15.298	0.954	19.82	38.0100	345.830	13.160	86.02	-1.19
240	50	239.97	67.19	15.288	0.948	20.16	37.9940	345.370	13.137	85.93	-1.32
265	50	264.94	62.38	15.346	0.929	22.0800	37.9820	345.360	13.132	85.57	-1.33

9.6.2 测试数据，41 V LED负载

Input		Input Measurement					Load Measurement				
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)	Efficiency (%)	% Reg
195	50	194.94	88.26	16.812	0.977	16.29	40.9500	351.930	14.427	85.81	0.55
200	50	199.92	86.06	16.766	0.974	17.16	40.9270	351.650	14.408	85.94	0.47
220	50	219.98	78.88	16.750	0.965	18.76	40.9130	352.270	14.428	86.14	0.65
230	50	229.93	75.68	16.715	0.961	19.15	40.8920	351.610	14.393	86.11	0.46
240	50	239.96	72.74	16.676	0.955	19.42	40.8690	350.610	14.344	86.02	0.17
265	50	264.94	66.92	16.622	0.938	21.4400	40.8400	348.590	14.251	85.74	-0.40

9.6.3 测试数据，44 V LED负载

Input		Input Measurement					Load Measurement				
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)	Efficiency (%)	% Reg
195	50	194.94	95.20	18.209	0.981	14.82	43.6670	357.220	15.615	85.75	2.06
200	50	199.92	92.76	18.148	0.979	15.82	43.6470	356.770	15.588	85.89	1.93
220	50	219.98	85.10	18.151	0.970	18.14	43.6410	358.150	15.646	86.20	2.33
230	50	229.93	81.57	18.106	0.965	18.54	43.6210	357.460	15.608	86.20	2.13
240	50	239.96	78.30	18.052	0.961	18.87	43.5980	356.290	15.548	86.13	1.80
265	50	264.94	71.47	17.898	0.945	20.5800	43.5590	352.540	15.370	85.88	0.73

10 调光性能数据

TRIAC dimming results were taken with input voltage of 230 VAC, 50 Hz line frequency, room temperature, and nominal 41 V LED load.

10.1 前沿调光器的调光曲线

Taken using programmable AC source providing leading edge chopped AC input

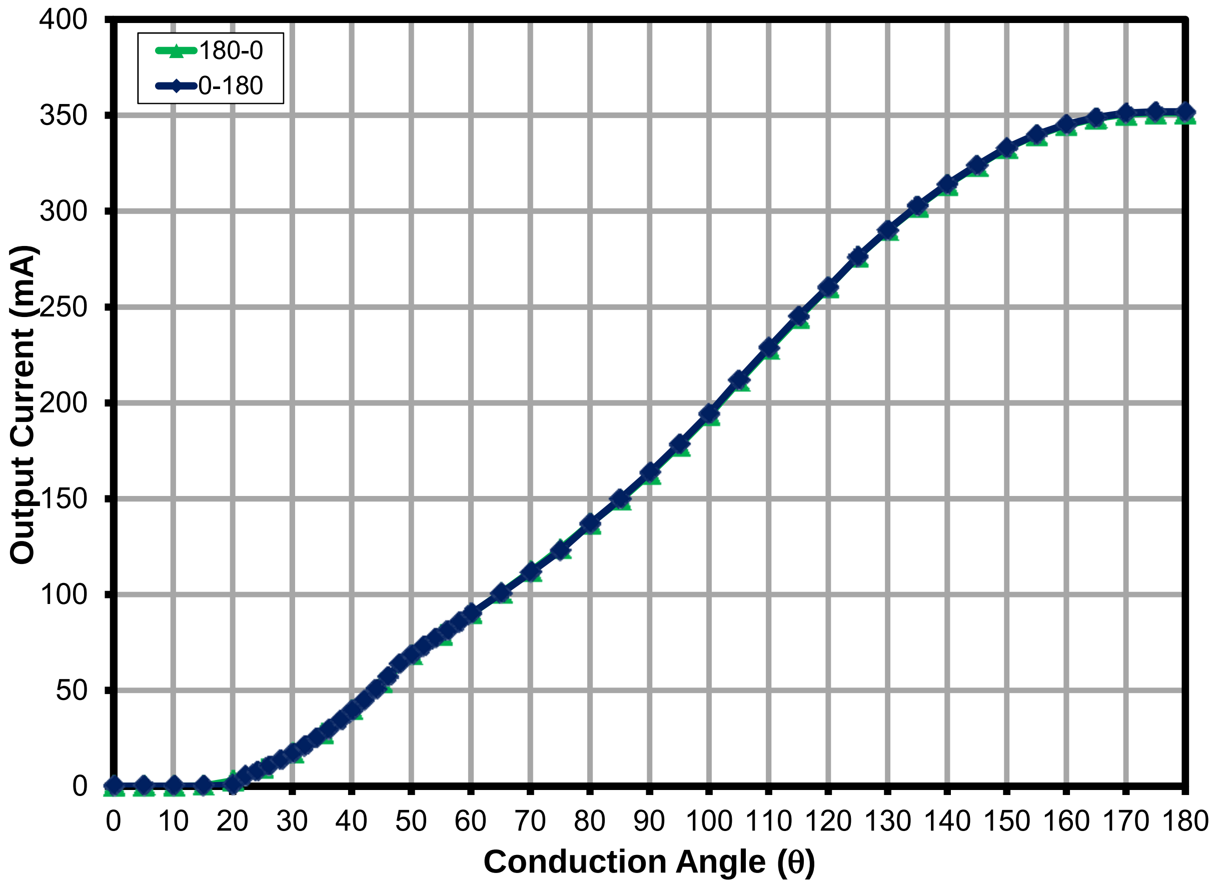

Figure 15 – Leading Edge Dimming Characteristics.

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10.2 调光器兼容性列表

The unit was tested with the following high-line dimmers at 230 VAC, 50 Hz input and 41 V LED load and using Agilent 6812B AC source.

Chinese Dimmers	Type	Maximum Setting I_{OUT} (mA)	Minimum Setting I_{OUT} (mA)	Dim Ratio
TCL 630 W	L	345	15	23
SEN BO LANG 300W	L	345	55	6
EBA HUANG	L	345	3	115
SB ELECT 600 W	L	334	3	115
MYONGBO	L	346	49	7
KBE 650W	L	345	4	86
CLIPMEI	L	345	3	115
MANK 200 W	L	346	63	5
Italian Dimmers				
RELCO RM34DMA 160W	L	341	38	9
RELCO RTM34LED DAXS 500W	L	276	25	11
RELCO RM34DMA 500W	L	346	48	7
RELCO RTS34.43 RLI 300W	L	346	9	38
RELCO RT34DSL 500W	L	347	45	8
MATIX AM5702 500W	L	277	58	5
Korean Dimmers				
SHIN SUNG 500W	L	343	71	5
FANTASIA 500W	L	340	84	4
SHIN SUNG	L	345	53	7
EU Dimmers				
NIKO 310-013	L	338	40	8
NIKO 310-014	L	338	62	5
NIKO-310-016	L	335	55	6
BERKER 2830 10	L	323	46	7
JUNG 225 NV DE	L	319	21	15
JUNG 266 G DE	L	323	35	9
BUSCH 2200 UJ-212	L	321	52	6
BUSCH 2250 U	L	330	23	14
BUSCH 2247 U	L	323	47	7
GIRA 2262 00 / IO1	L	325	14	23
GIRA 0300 00 / IO1	L	320	57	6
GIRA 0302 00 / IO1	L	324	37	9
BUSCH 2250	L	330	27	12
MERTEN 572499	L	339	12	28
BERKER 2875 600 W	L	324	34	10
KOPP 8033	L	301	33	9
Australian Dimmers				
32E450LM	L	306	4	77
32E450TM	T	311	34	9
32E2CFLDM	T	307	32	10
32E450UDM	T	326	45	7

Trailing Edge Dimmers				
PEHA 433HAB	T	316	90	4
PEHA 433HAB oA	T	285	50	6
BUSCH 6513	T	341	99	3
BUSCH 6591U-101	T	330	93	4
GIRA 1176	T	330	109	3
NIKO 310-017	T	307	76	4

Figure 16 – Compatibility List.

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11 热性能

11.1 开放式测量

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

11.1.1 非调光V_{IN} = 195 VAC，50 Hz，41 V LED负载

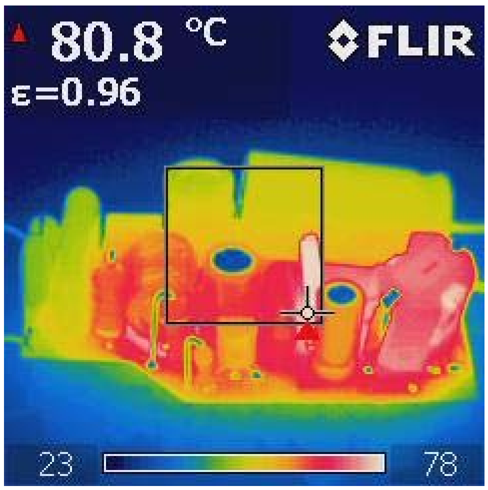

Figure 17 – Top Side.
U1-LYT4322E: 80.8 ºC.

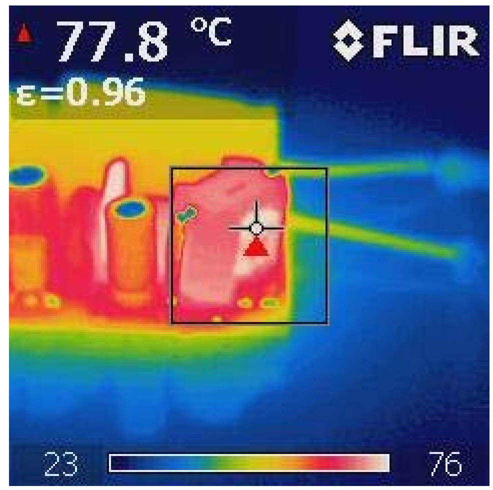

Figure 18 – Top Side.
T2: 77.8 ºC.

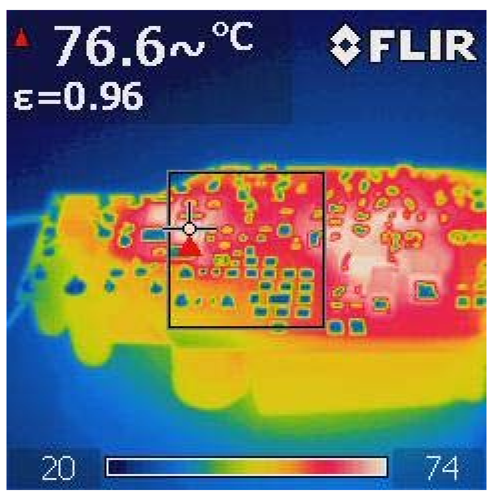

Figure 19 – Bottom Side.
PCB: 76.6 ºC.

11.1.2 非调光V_{IN} = 265 VAC，50 Hz，41 V LED负载

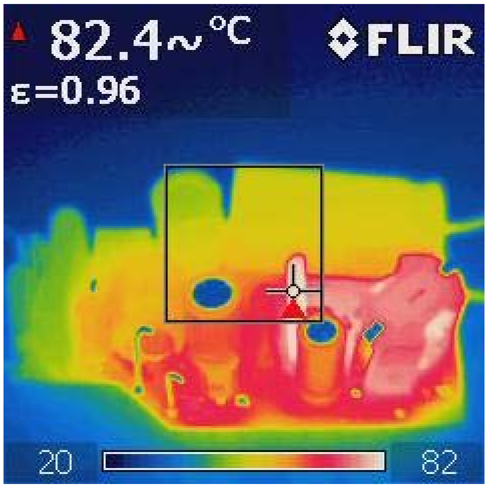

Figure 20 – Top Side.
U1-LYT4322E: 82.4 ºC.

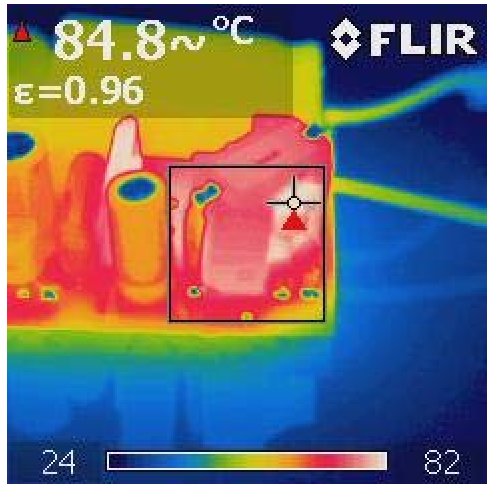

Figure 21 – Top Side, Inductor.
T2: 84.8 ºC.

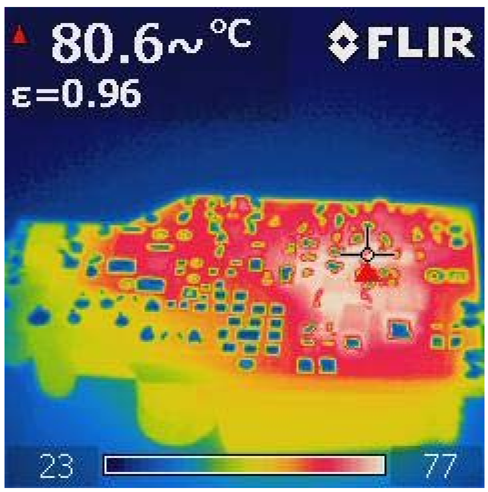

Figure 22 – Bottom Side.
PCB: 80.6 ºC.

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11.2 实际LED灯壳内的热测量

Figure 23 – Actual LED Enclosure Used in Thermal Verification.

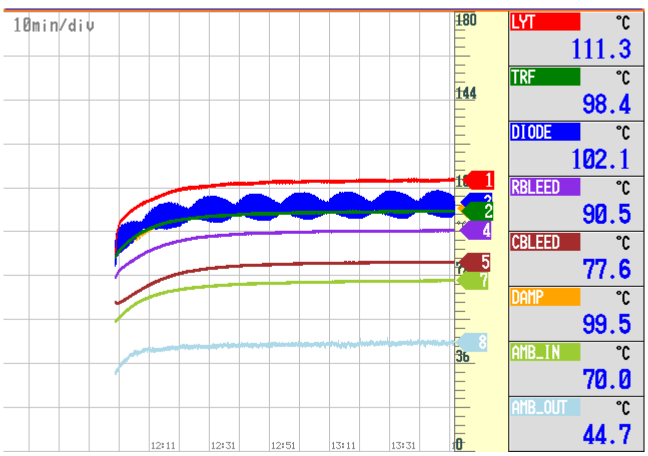

Figure 24 – V_{IN} = 195 VAC, Non-Dimming.

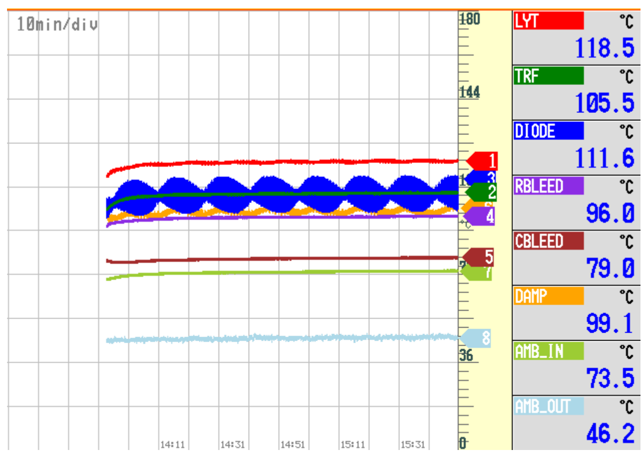

Figure 25 – V_{IN} = 265 VAC, Non-Dimming.

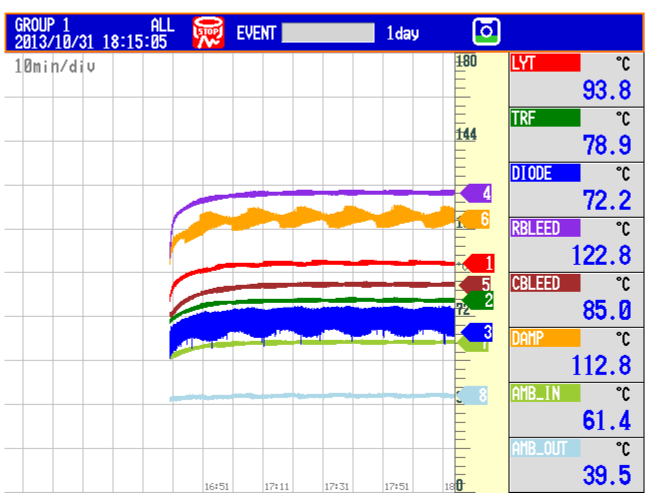

Figure 26 – V_{IN} = 230 VAC, Dimming at 90° Conduction Angle.

12 非调光波形

12.1 输入电压和输入电流波形

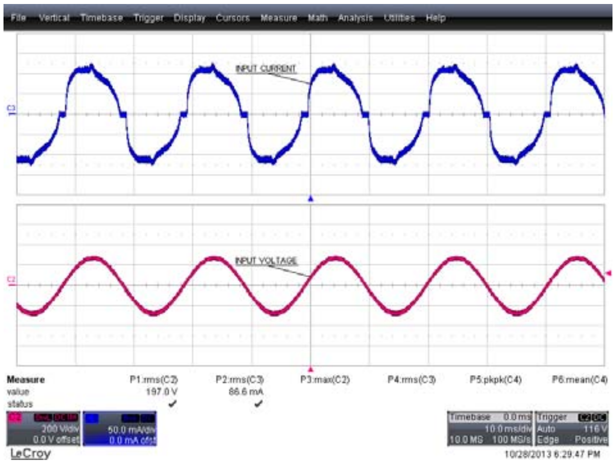

Figure 27 – 195 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 10 ms / div.

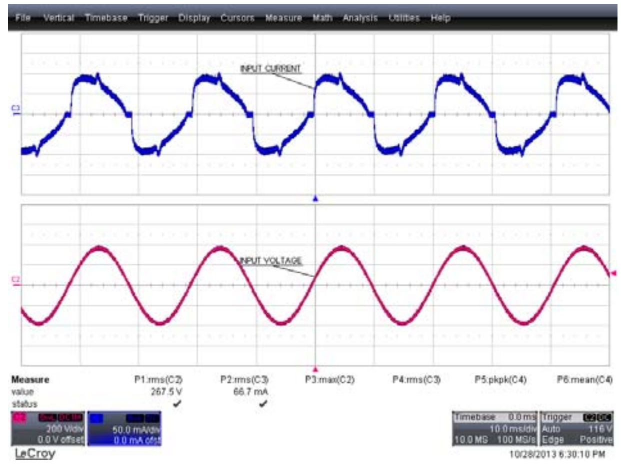

Figure 28 – 265 VAC, Full Load.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 10 ms / div.

12.2 正常工作时的输出电流和输出电压

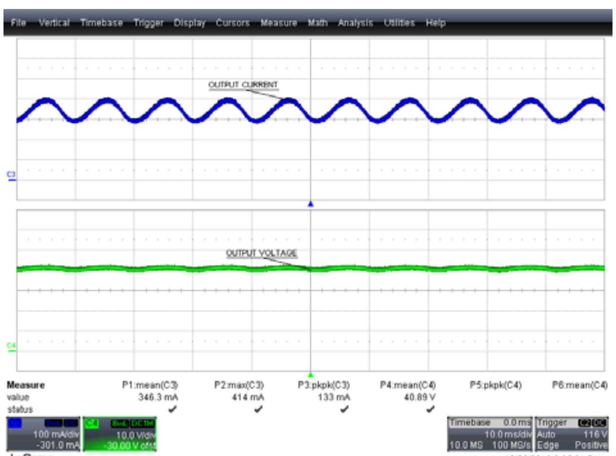

Figure 29 – 195 VAC, 50 Hz Full Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

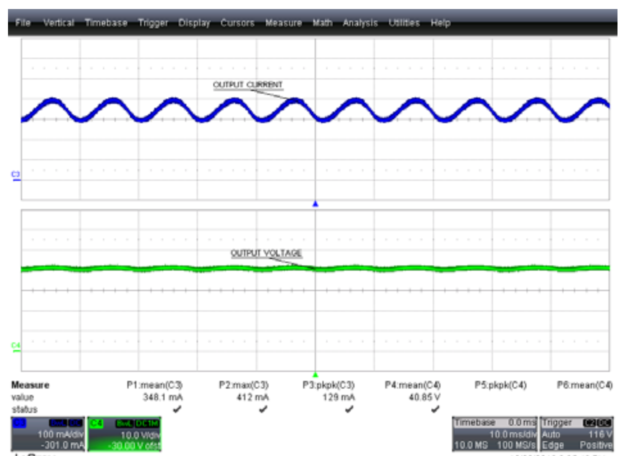

Figure 30 – 265 VAC, 50 Hz Full Load.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{OUT}, 10 V, 10 ms / div.

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12.3 启动时的输入电压和输出电流波形

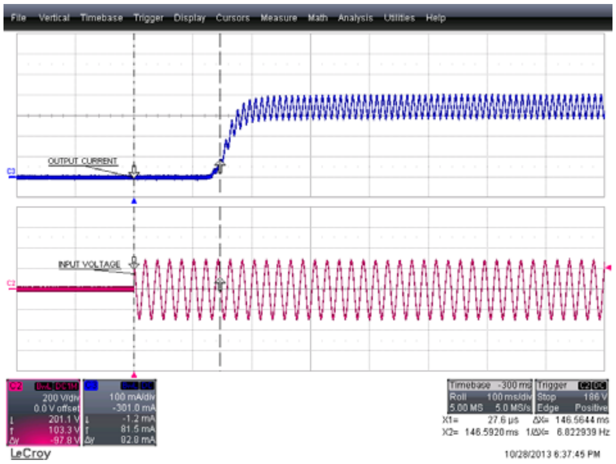

Figure 31 – 195 VAC, 50 Hz.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 200 V, 100 ms / div.
Start-up Time: 146 ms

Figure 32 – 265 VAC, 50 Hz.
Upper: I_{OUT}, 100m A / div.
Lower: V_{IN}, 200 V, 100 ms / div.
Start-up Time: 133 ms

12.4 正常工作时的漏极电压和电流

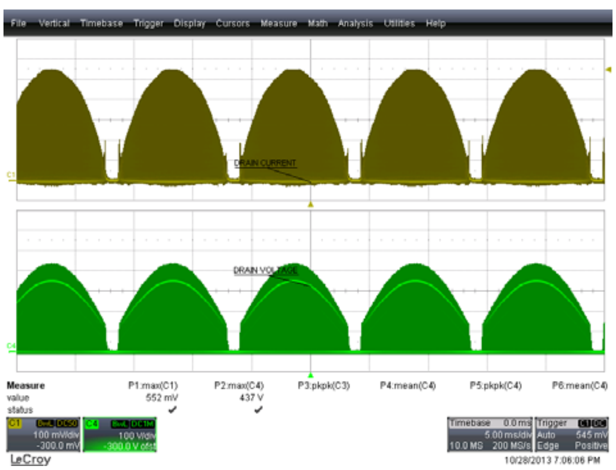

Figure 33 – 195 VAC, 50 Hz.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.

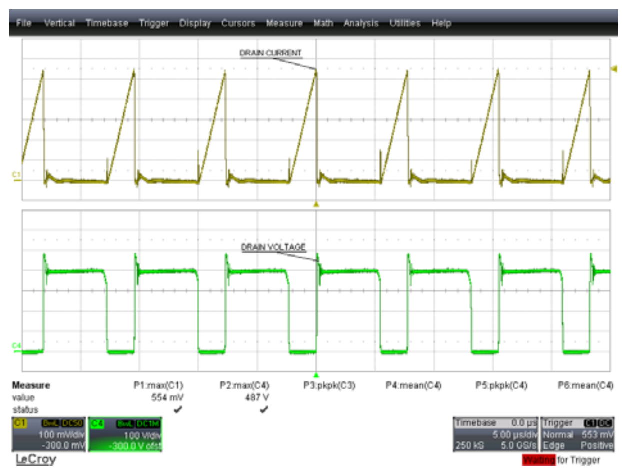

Figure 34 – 195 VAC, 50 Hz.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 µs / div.

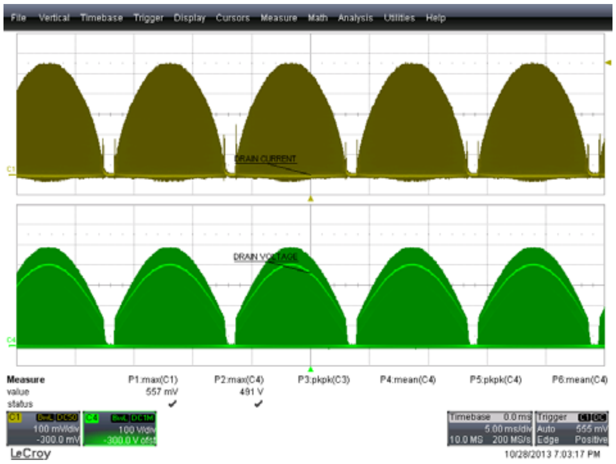

Figure 35 – 230 VAC, 50 Hz.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.

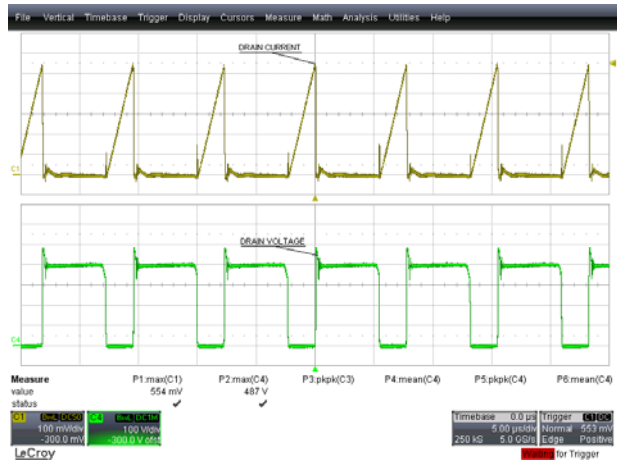

Figure 36 – 230 VAC, 50 Hz.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

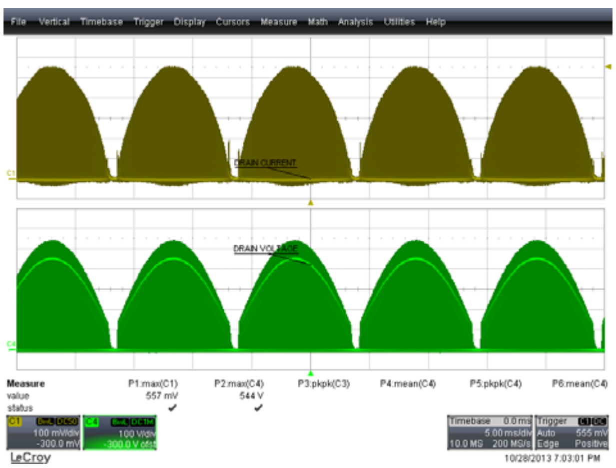

Figure 37 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 100 V, 5 ms / div.

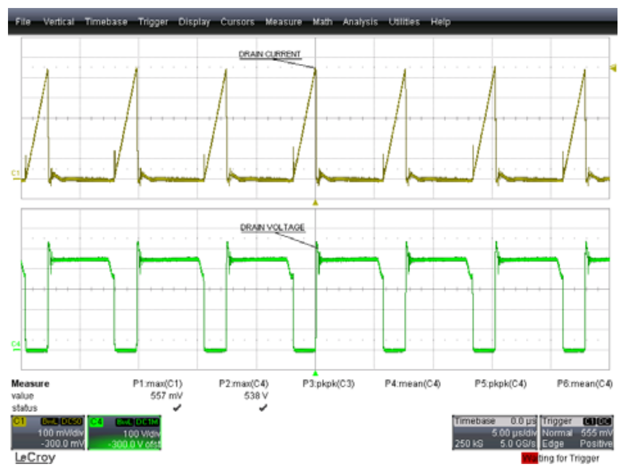

Figure 38 – 265 VAC, 50 Hz.
Upper: I_{DRAIN}, 100 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

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12.5 启动时的漏极电压和电流

Figure 39 – 195 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

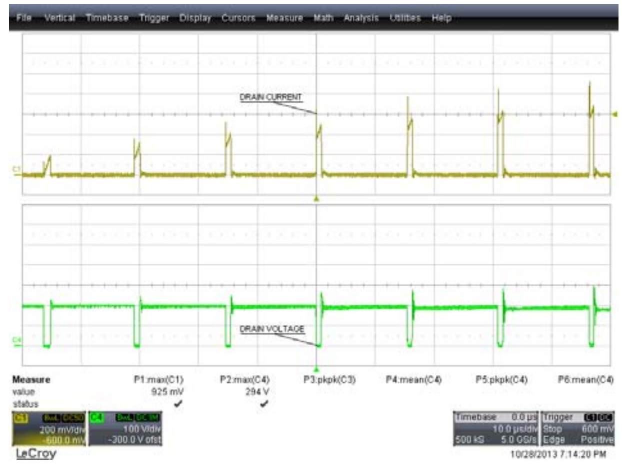

Figure 40 – 195 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 µs / div.

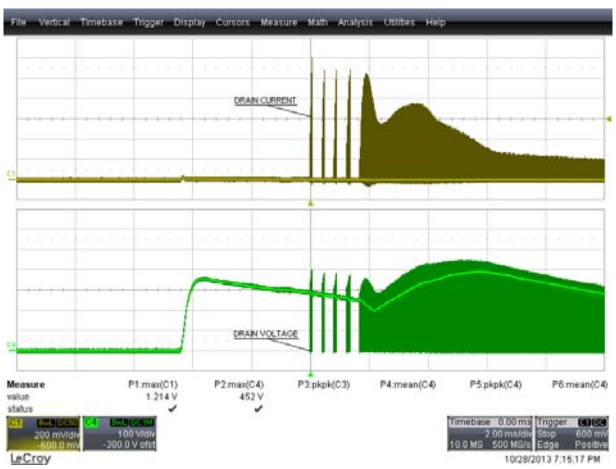

Figure 41 – 265 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 2 ms / div.

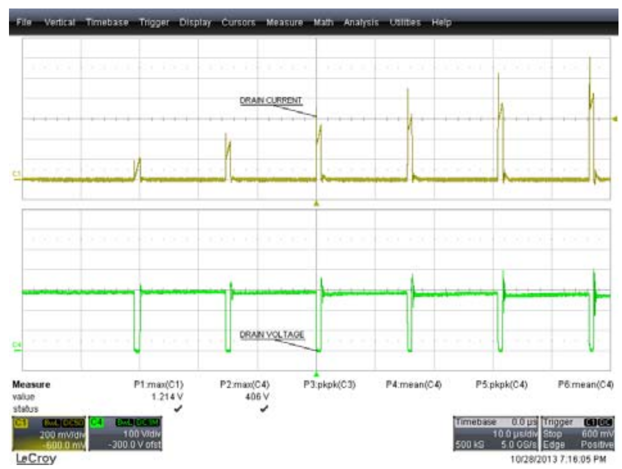

Figure 42 – 265 VAC, 50 Hz Start-up.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 µs / div.

12.6 输出短路时的漏极电流和漏极电压

Figure 43 – 195 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 200 ms / div.

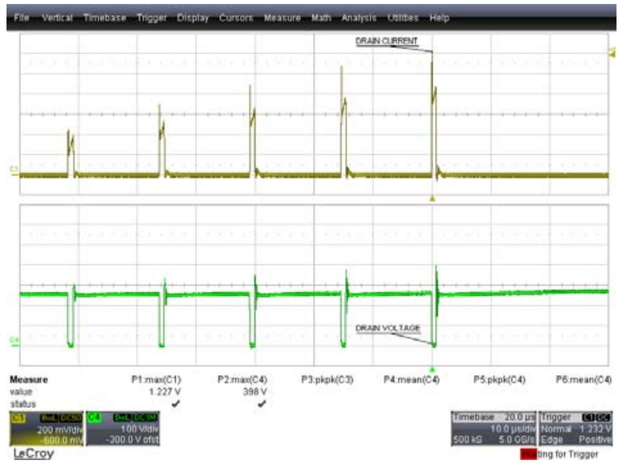

Figure 44 – 195 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V, 10 μs / div.

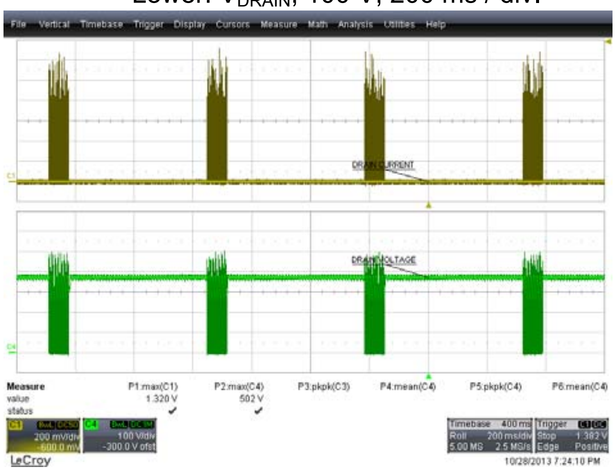

Figure 45 – 265 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: $V_{DRAIN,}$ 100 V, 200 ms / div.

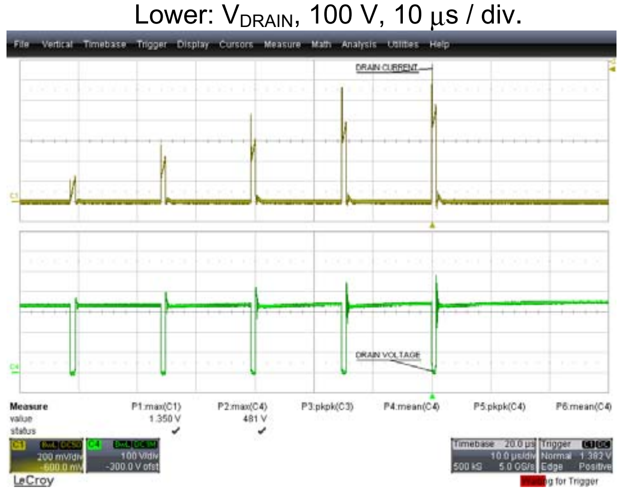

Figure 46 – 265 VAC, 50 Hz Output Short Condition.
Upper: I_{DRAIN}, 200 mA / div.
Lower: $V_{DRAIN,}$ 100 V, 10 μs / div.

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12.7 输出二极管电流和电压波形

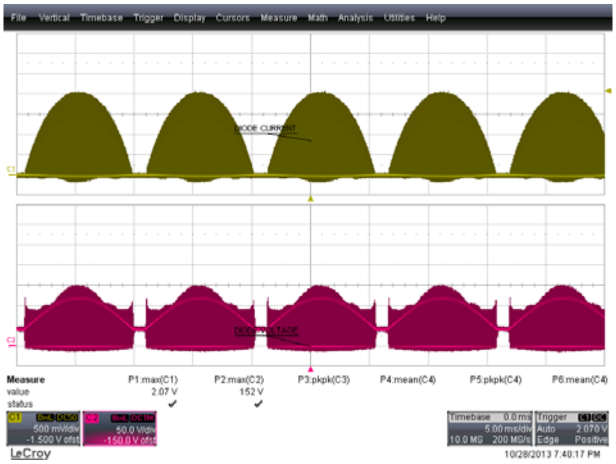

Figure 47 – 195 VAC, 50 Hz.
Upper: I_{D7}, 0.5 A / div.
Lower: V_{D7}, 50 V, 5 ms / div.

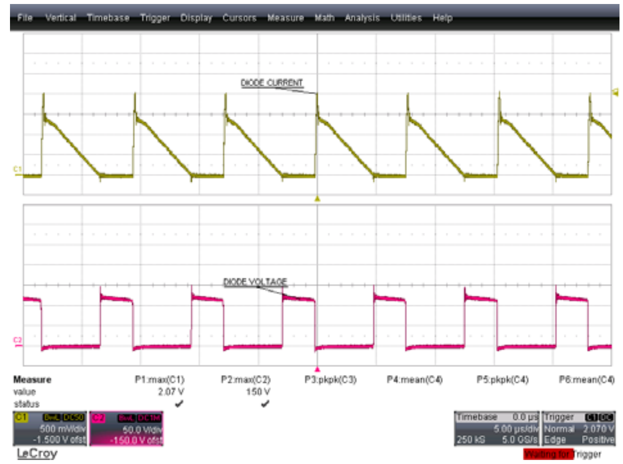

Figure 48 – 195 VAC, 50 Hz.
Upper: I_{D7}, 0.5 A / div.
Lower: V_{D7}, 50 V / div., 5 µs / div.

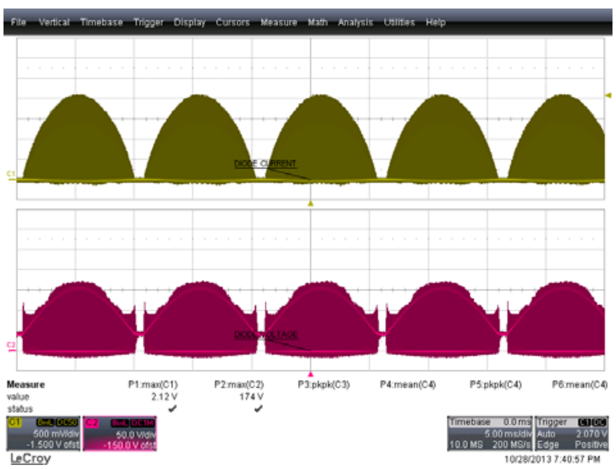

Figure 49 – 265 VAC, 50 Hz.
Upper: I_{D7}, 0.5 A / div.
Lower: V_{D7}, 50 V, 5 ms / div.

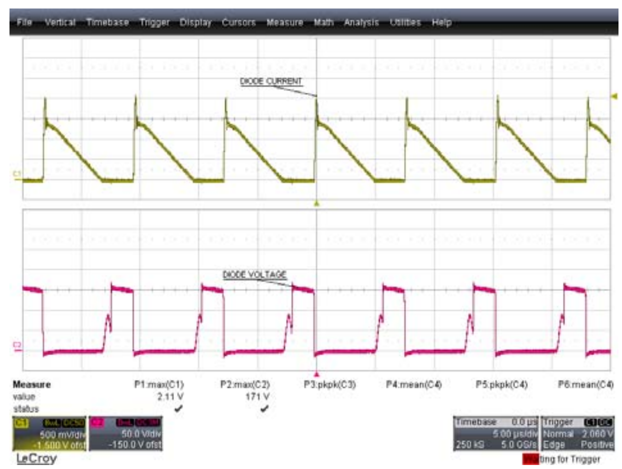

Figure 50 – 265 VAC, 50 Hz.
Upper: I_{D7}, 0.5 A / div.
Lower: V_{D7}, 50 V / div., 5 µs / div.

12.8 输出二极管电流和电压启动波形

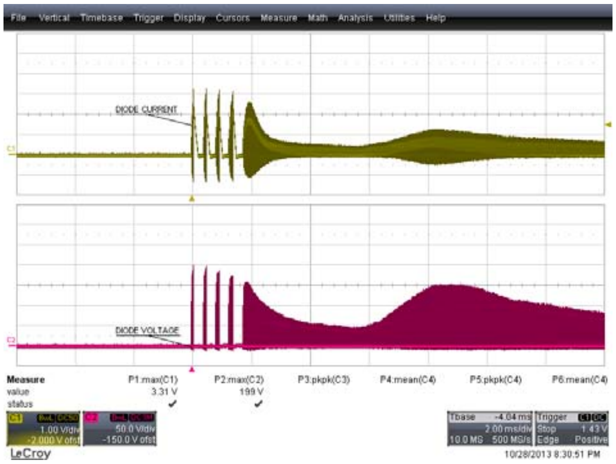

Figure 51 – 195 VAC, 50 Hz.
Upper: I_{D7}, 1 A / div.
Lower: V_{D7}, 50 V, 2 ms / div.

Figure 52 – 265 VAC, 50 Hz.
Upper: I_{D7}, 1 A / div.
Lower: V_{D7}, 50 V / div., 2 ms / div.

12.9 输出二极管电流和电压短路波形

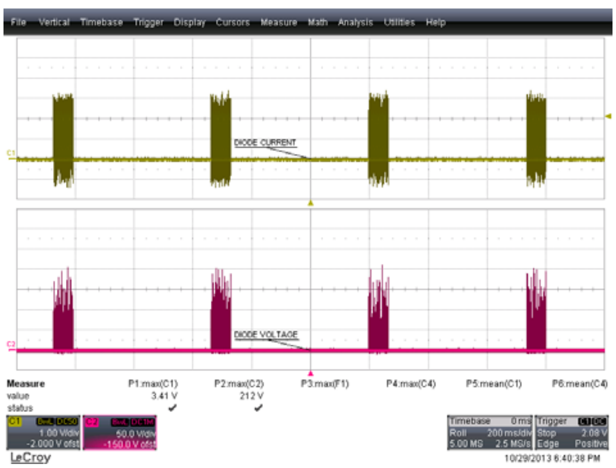

Figure 53 – 195 VAC, 50 Hz.
Upper: I_{D7}, 1 A / div.
Lower: V_{D7}, 50 V, 200 ms / div.

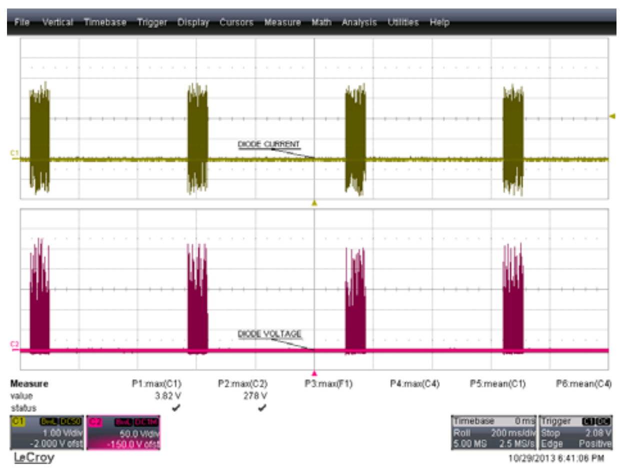

Figure 54 – 265 VAC, 50 Hz.
Upper: I_{D7}, 1 A / div.
Lower: V_{D7}, 50 V / div., 200 ms / div.

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12.10 电压跌落

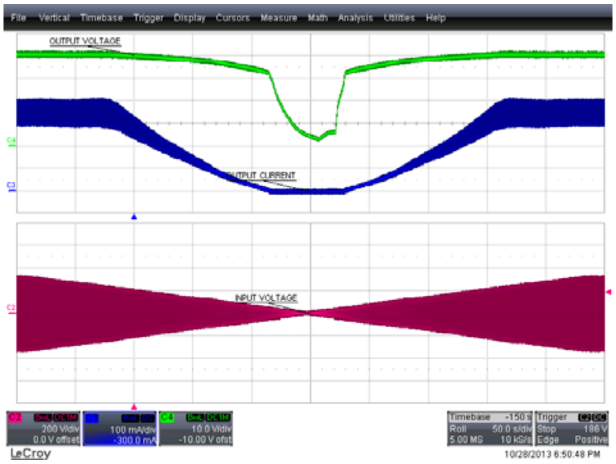

Figure 55 – 230 VAC, 50 Hz.
CH4: V_{OUT}, 10 V / div.
CH3: I_{OUT}, 100 mA / div.
CH2: V_{IN}, 200 V / div.

12.11 输入瞬态

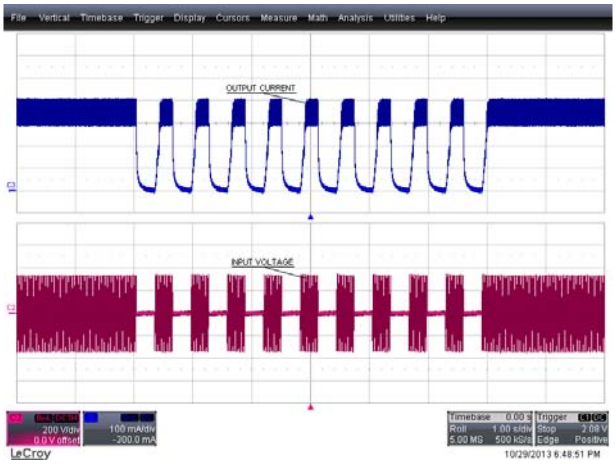

Figure 56 – 230 VAC, 50 Hz.
300 ms ON, 300 ms OFF.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 200 V /div, 1 s / div.

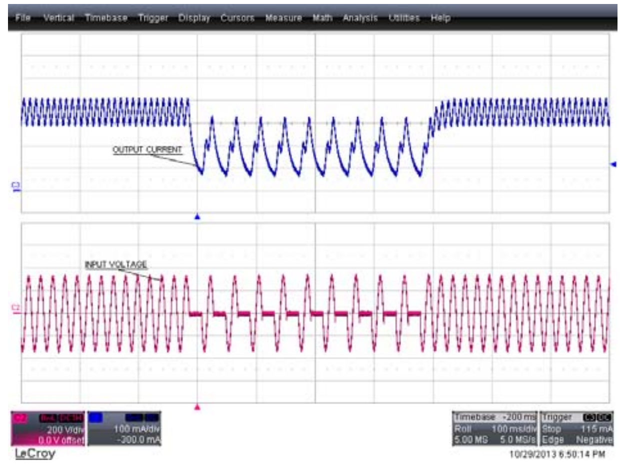

Figure 57 – 230 VAC, 50 Hz.
20 ms ON, 20 ms OFF.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 200 V /div, 100 ms / div.

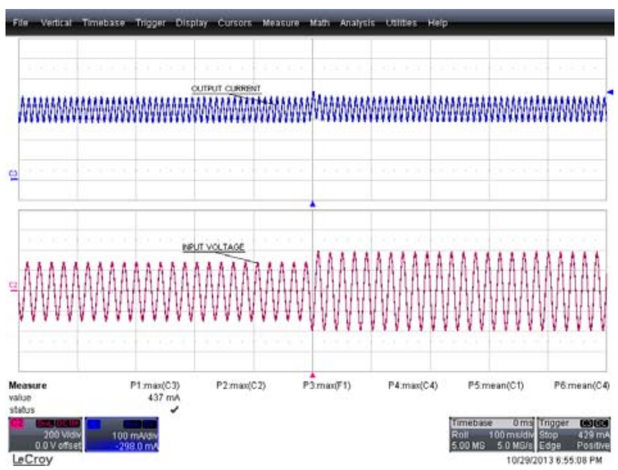

Figure 58 – 195 V to 265 V Step.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 200 V, 100 ms / div.

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13 调光波形

13.1 输入电压和输入电流波形

Input: 230 VAC, 50 Hz
Output: 41 V LED Load
Dimmer: BUSCH 2250 600 W

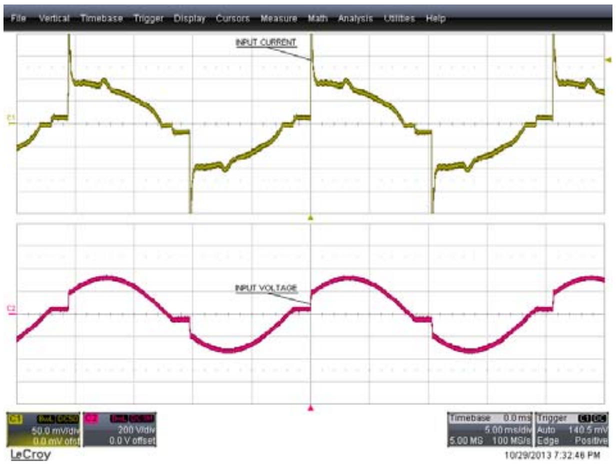

Figure 59 – 160º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

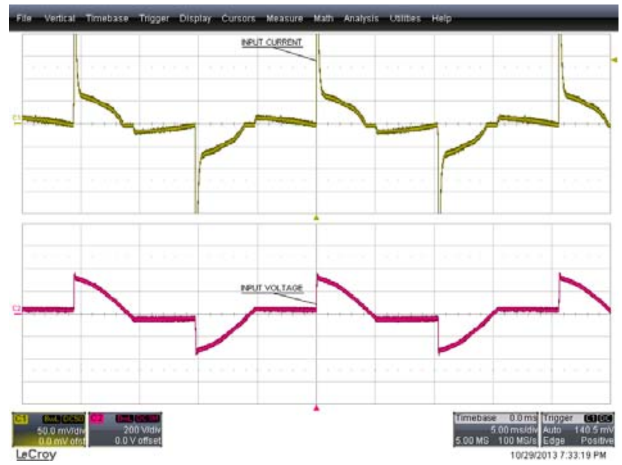

Figure 60 – 90º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

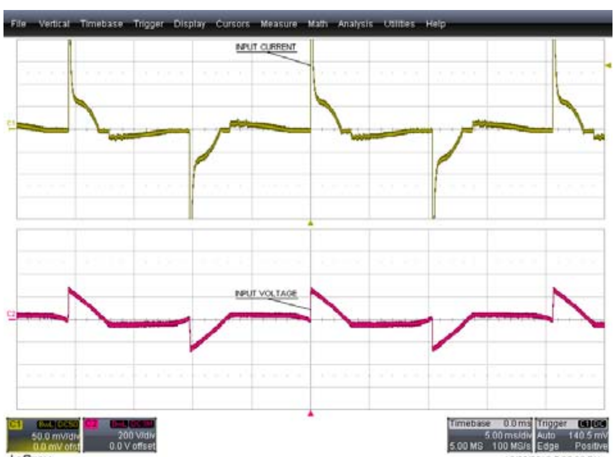

Figure 61 – 60º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

Figure 62 – 45º Conduction Angle.
Upper: I_{IN}, 50 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

13.2 输出电流波形

Input: 230 VAC, 50 Hz
Output: 41 V LED Load
Dimmer: BUSCH 2250 600 W

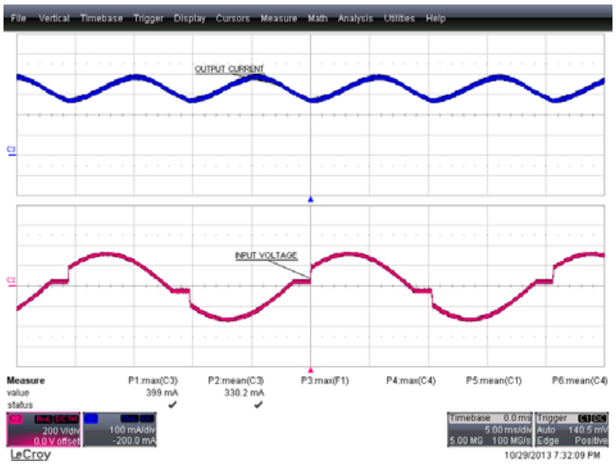

Figure 63 – 160º Conduction Angle.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

Figure 64 – 90º Conduction Angle.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

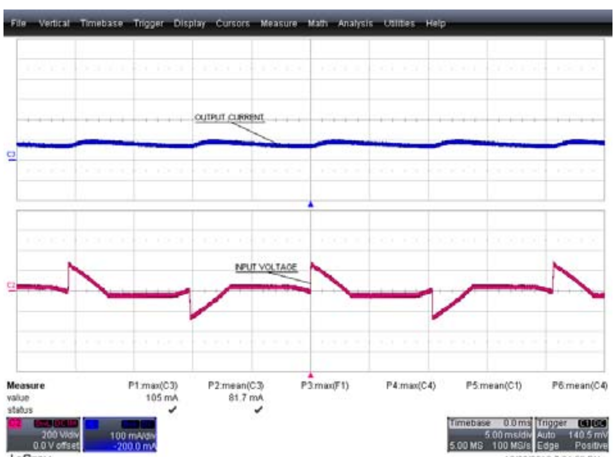

Figure 65 – 60º Conduction Angle.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

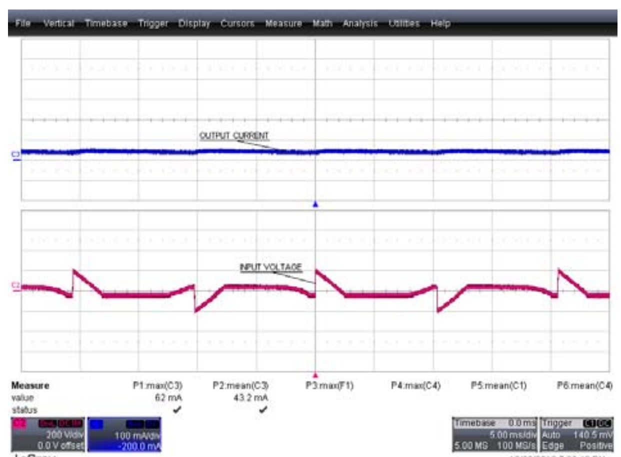

Figure 66 – 45º Conduction Angle.
Upper: I_{OUT}, 100 mA / div.
Lower: V_{IN}, 200 V, 5 ms / div.

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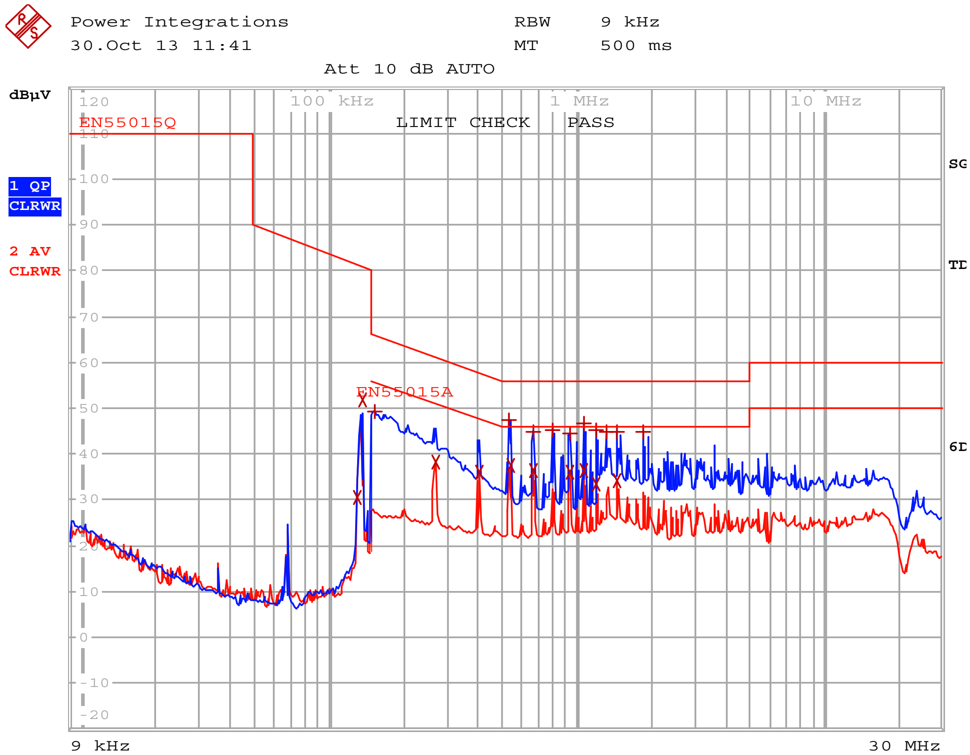
14 传导EMI

14.1 测试设置

The unit was tested using LED load (~41 V V_{OUT}) with input voltage of 230 VAC, 60 Hz at room temperature.

Figure 67 – EMI Test Set-up with the Unit and LED Load Placed Inside the Cone.

13.2 测试结果



EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q

Trace2: EN55015A

Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	129.530094744 kHz	30.68	N gnd	
2	Average	136.137431366 kHz	51.84	L1 gnd	
1	Quasi Peak	153.015 kHz	49.36	L1 gnd	-16.46
2	Average	267.135089486 kHz	38.32	L1 gnd	-12.88
2	Average	401.705024172 kHz	35.94	L1 gnd	-11.87
1	Quasi Peak	530.769219795 kHz	47.46	L1 gnd	-8.53
2	Average	536.076911993 kHz	37.63	L1 gnd	-8.36
1	Quasi Peak	667.263434405 kHz	45.00	L1 gnd	-10.99
2	Average	667.263434405 kHz	36.42	L1 gnd	-9.57
1	Quasi Peak	798.145472681 kHz	45.40	L1 gnd	-10.59
1	Quasi Peak	935.888336808 kHz	44.48	L1 gnd	-11.51
2	Average	935.888336808 kHz	35.96	L1 gnd	-10.03
1	Quasi Peak	1.06512822736 MHz	46.53	L1 gnd	-9.46
2	Average	1.06512822736 MHz	36.28	L1 gnd	-9.71
1	Quasi Peak	1.20021314689 MHz	45.12	L1 gnd	-10.88
2	Average	1.20021314689 MHz	33.28	L1 gnd	-12.71
1	Quasi Peak	1.32578199726 MHz	44.71	L1 gnd	-11.28
1	Quasi Peak	1.46448812765 MHz	44.81	L1 gnd	-11.18
2	Average	1.46448812765 MHz	34.07	L1 gnd	-11.92
1	Quasi Peak	1.85951131803 MHz	45.00	L1 gnd	-11.00

Figure 68 – Conducted EMI, 41 V LED Load, 230 VAC, 60 Hz, and EN55015 B Limits.

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15 输入浪涌测试

The unit was subjected to ±2500 V, 100 kHz ring wave and ±500 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)
+500	230	L1, L2	0	Surge (2Ω)	Pass
-500	230	L1, L2	90	Surge (2Ω)	Pass
+500	230	L1, L2	0	Surge (2Ω)	Pass
-500	230	L1, L2	90	Surge (2Ω)	Pass

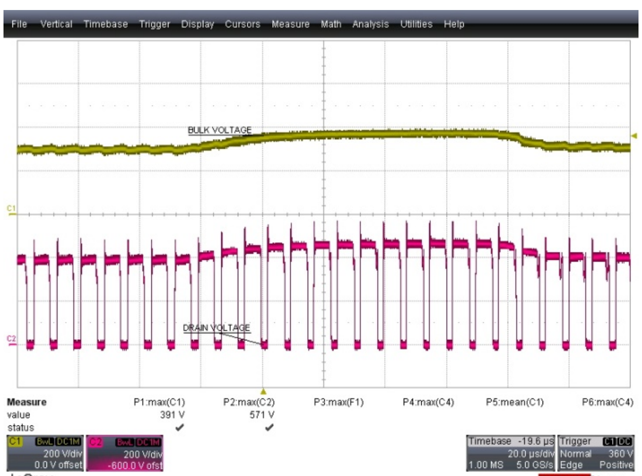

Figure 69 – (+)500 V Differential Surge, 90º.
Upper: V_{BULK}, 200 V / div.
Lower: V_{DRAIN}, 200 V, 20 μs / div.

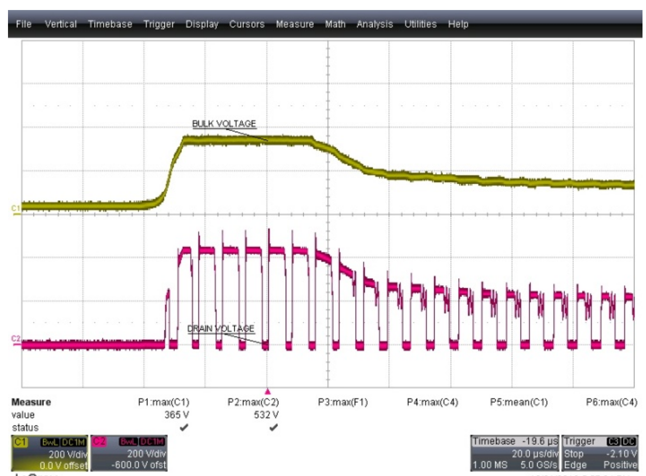

Figure 70 – (+)500 V Differential Surge, 0º.
Upper: V_{BULK}, 200 V / div.
Lower: V_{DRAIN}, 200 V, 20 μs / div.

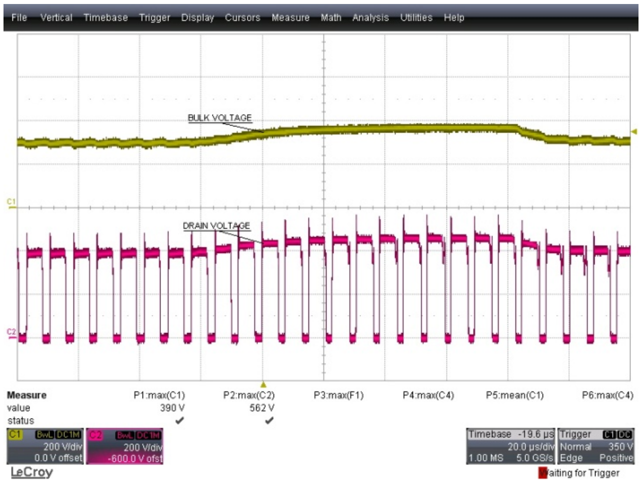

Figure 71 – (-)500 V Differential Surge, 270º.
Upper: V_{BULK}, 200 V / div.
Lower: V_{DRAIN}, 200 V, 20 µs / div.

Figure 72 – (-)500 V Differential Surge, 0º.
Upper: V_{BULK}, 200 V / div.
Lower: V_{DRAIN}, 200 V, 20 µs / div.

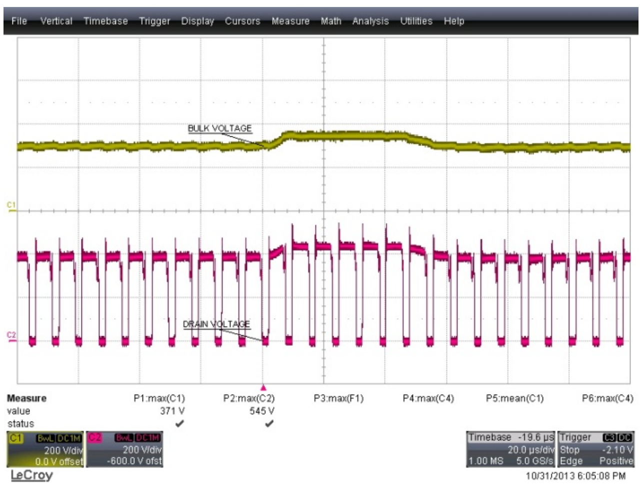

Figure 73 – (+)2.5 kV Ring Wave, 90º.
Upper: V_{BULK}, 200 V / div.
Lower: V_{DRAIN}, 200 V, 20 µs / div.

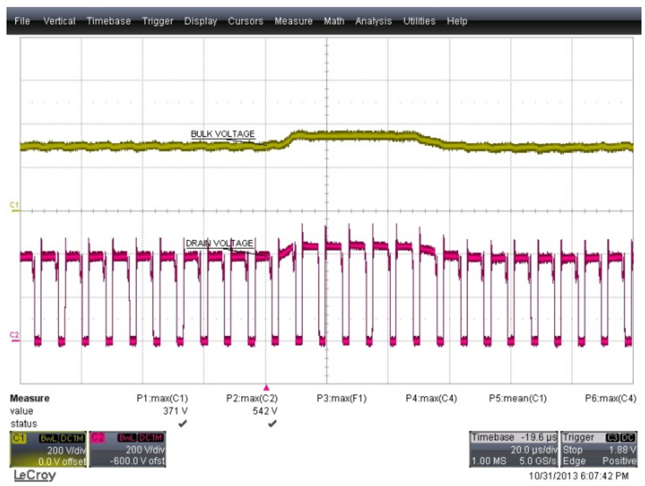

Figure 74 – (-)2.5 kV Ring Wave, 90º.
Upper: V_{BULK}, 200 V / div.
Lower: V_{DRAIN}, 200 V, 20 µs / div.

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16 附录

This section describes the operation of the optional active damper circuit that is incorporated in the pcb layout.

16.1 有源衰减电路的电路原理图

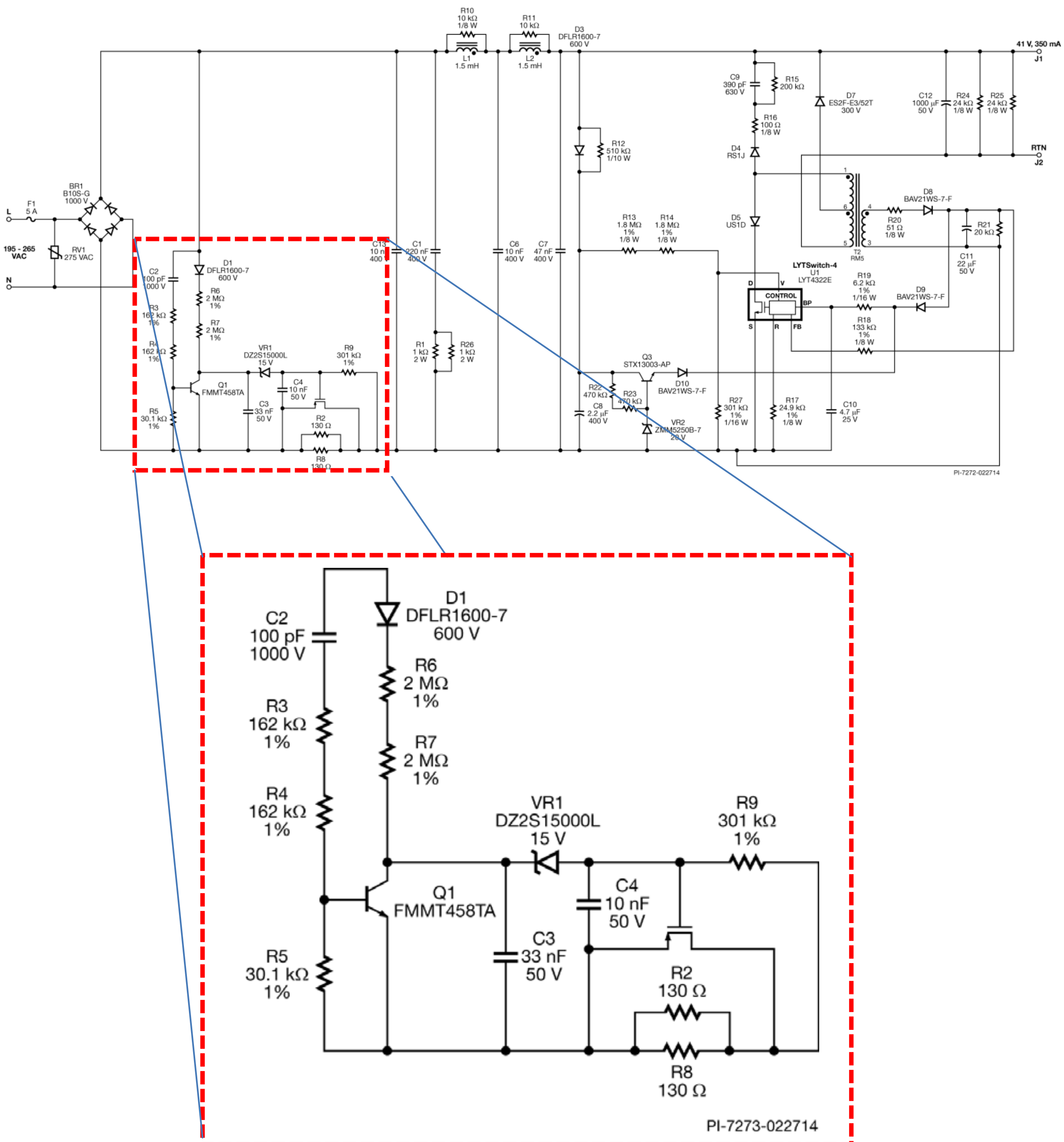

Figure 75 – Active Damper Schematic.

16.2 电路描述

Resistors R2 and R8 provide passive damping and the surrounding circuit comprised of D1, R6, R7, C3, VR1, C4, Q2, and R9 minimize power dissipation of R2 and R8 by operating Q2 in linear mode approximately 2 ms after the TRIAC turns ON. Capacitor C2, R3, R4, R5 and Q1 provide a discharge path so that Q2 is initially turned OFF when the next TRIAC switching cycle begins. The values were also selected such that when there is no TRIAC connected, Q2 will be permanently ON which helps improve efficiency in non-dimming operation.

With this circuit, the values of R2 and R8 can be increased further for better dimmer compatibility but with less impact on the thermal performance of these resistors during dimming.

16.3 效率数据

With the active damper circuit, efficiency improves by as much as +2% over the one without the optional circuit.

16.3.1 无衰减电路

Input		Input Measurement					Load Measurement			
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)	Efficiency (%)
195	50	194.95	87.09	16.600	0.978	15.86	42.0250	339.840	14.294	86.11
210	50	209.96	81.96	16.717	0.972	17.19	42.0210	342.990	14.425	86.29
220	50	220.00	79.41	16.901	0.967	17.79	42.0320	346.830	14.590	86.33
230	50	229.95	76.75	16.995	0.963	18.27	42.0280	348.660	14.666	86.30
240	50	239.98	74.05	17.021	0.958	18.75	42.0110	348.910	14.671	86.19
265	50	264.95	68.30	17.029	0.941	20.7200	41.9870	347.950	14.621	85.86

16.3.2 带有源衰减电路

Input		Input Measurement					Load Measurement				
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mArms)	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	Efficiency (%)	Effiency Improvement (%)
195	50	194.95	85.87	16.314	0.975	16.77	42.1030	342.590	14.436	88.49	2.38
210	50	209.96	81.25	16.517	0.968	17.96	42.1070	346.400	14.598	88.38	2.09
220	50	219.99	78.59	16.672	0.964	18.32	42.1070	349.130	14.713	88.25	1.92
230	50	229.94	75.91	16.749	0.960	18.79	42.0950	350.030	14.747	88.05	1.75
240	50	239.98	73.25	16.773	0.954	19.25	42.0730	349.740	14.727	87.80	1.61
265	50	264.95	67.81	16.825	0.937	21.3300	42.0480	348.750	14.676	87.23	1.37

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16.4 物料清单（有源衰减电路）

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	C2	100 pF, 1000 V, Ceramic, NPO, 0805	C0805C101MDGACTU	Kemet
2	1	C3	33 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB333	Yageo
3	1	C4	10 nF 50 V, Ceramic, X7R, 0603	C0603C103K5RACTU	Kemet
4	1	D1	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
5	1	Q1	NPN, HP, 400 V, 225 mA, SOT23-3	FMMT458TA	Diodes, Inc.
6	1	Q2	600 V, 0.4 A, 8 Ω, N-Channel, TO-92	STQ2NK60ZR-AP	ST Micro
7	2	R2 R8	130 Ω, 5%, 1 W, Thick Film, 2512	ERJ-1TYJ131U	Panasonic
8	2	R3 R4	162 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1623V	Panasonic
9	1	R5	30.1 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF3012V	Panasonic
10	2	R6 R7	2 MΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2004V	Panasonic
11	1	R9	301 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3013V	Panasonic
12	1	VR1	15 V, 5%, 150 mW, SSMINI-2	DZ2S15000L	Panasonic

17 版本历史

Date	Author	Revision	Description and Changes	Reviewed
27-Feb-14	DS	1.0	Initial Release	Apps & Mktg

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