设计范例报告

标题	***使用LinkSwitch™-PL LNK460KG设计的5.8 W 可控硅调光的高效率、高功率因数校正(PF > 0.9)、非隔离、降压-升压式LED驱动器***
规格	195 VAC – 265 VAC输入； 145 V_{TYP}，40 mA输出
应用	可调光GU10 LED驱动器
作者	应用工程部
文档编号	DER-336
日期	2013年6月10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
- 低成本，低元件数，高效率，且可轻松装入GU10 LED灯
- 快速启动时间(<300 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
  - 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
- 在230 VAC下，PF >0.9
- 兼容大多数前沿及后沿可控硅调光器

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目录

重要说明：虽然本电路板的设计满足安全要求，但工程原型尚未获得机构认证。此外，本设计不提供输出与AC输入的电气隔离。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可调光、非隔离、高效率、高功率因数(PF) LED驱动器，它可以在195 VAC至265 VAC的输入电压范围内为LED灯串提供额定电压145 V、额定电流40 mA的驱动。该LED驱动器采用了LinkSwitch-PL系列IC中的LNK460KG器件。

该驱动器采用的是单级、非隔离、降压-升压式拓扑结构，可装入GU10灯并满足本设计的高效率要求。基于LinkSwitch-PL的设计可提供高功率因数(>0.9)，这有助于满足现行国际标准的谐波要求。

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。

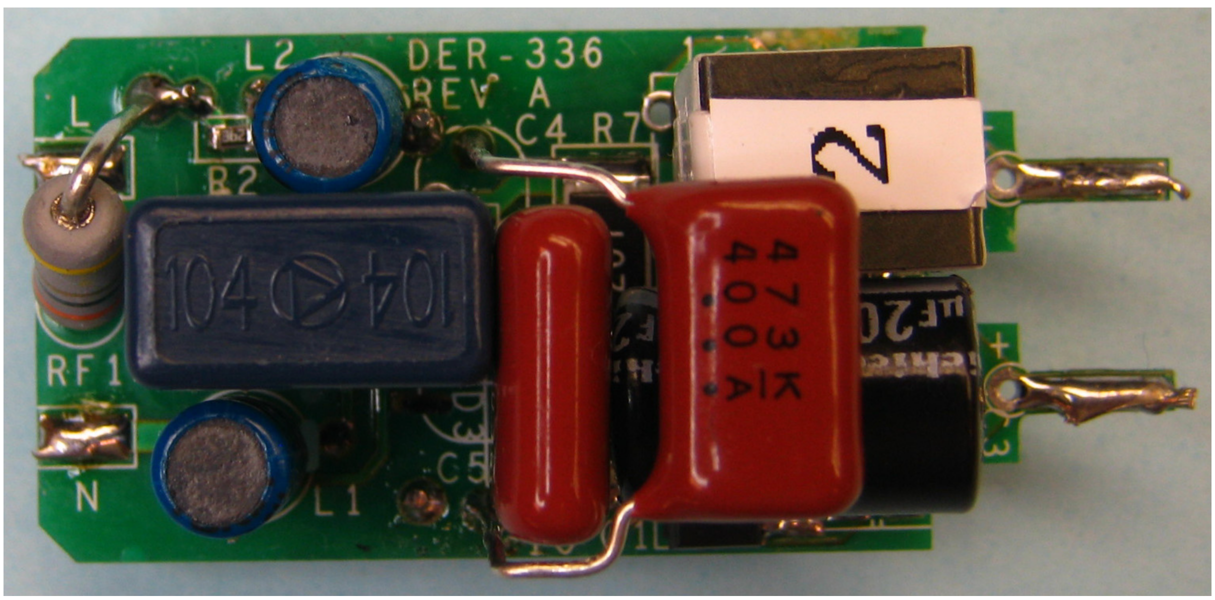

Figure 1 – Populated Circuit Board, Top View.

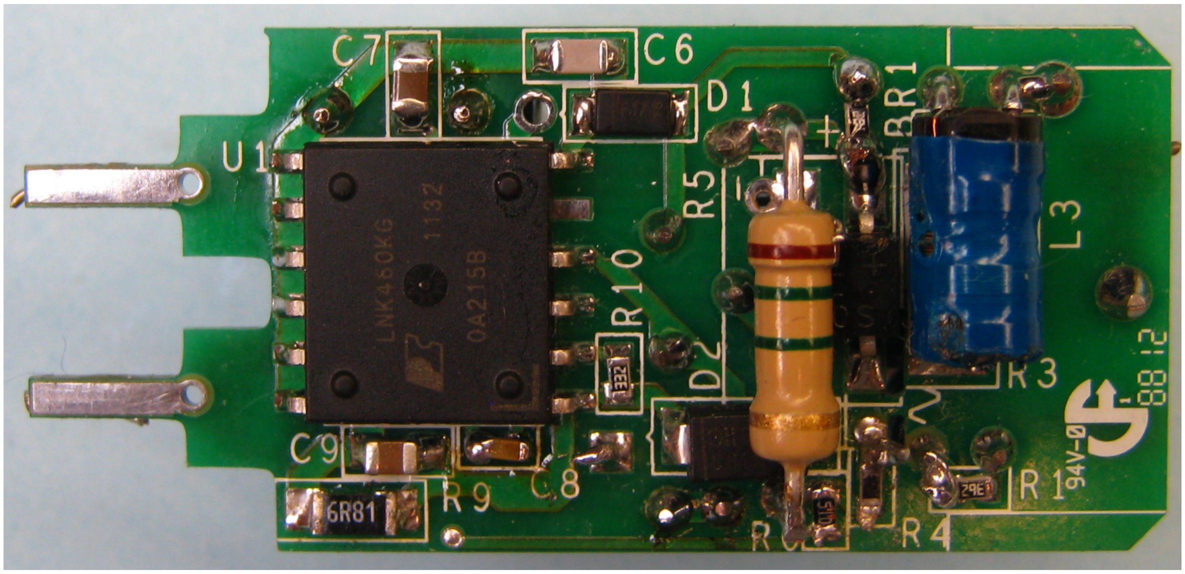

Figure 2 – Populated Circuit Board, Bottom View.

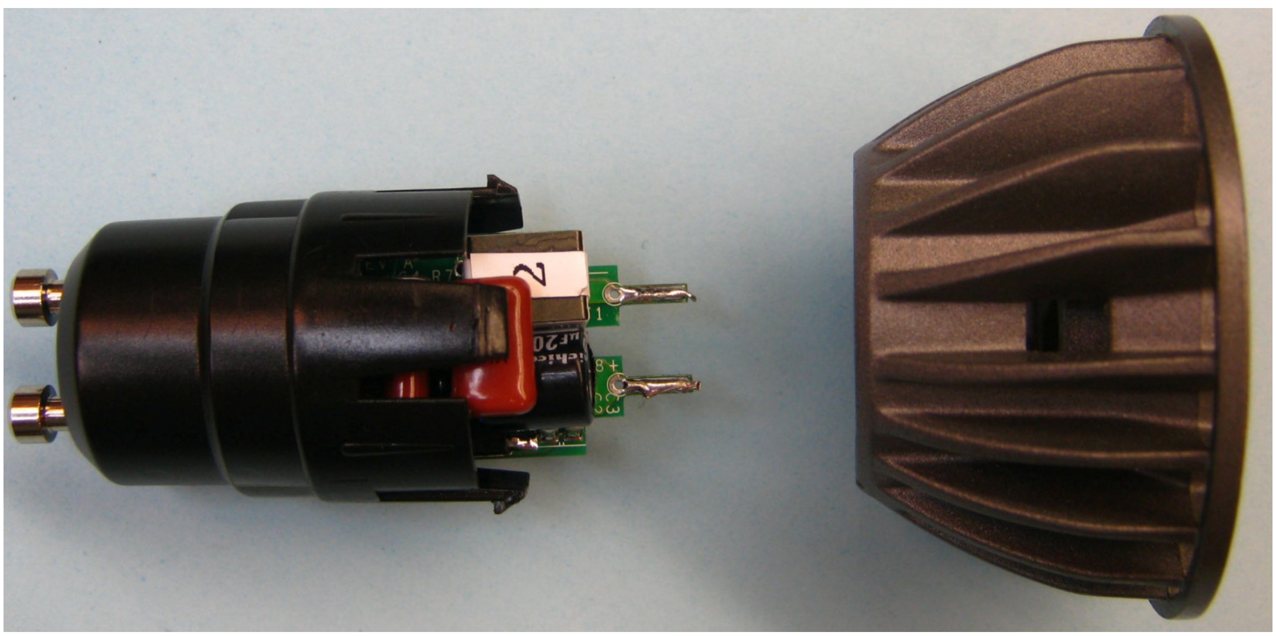

Figure 3 – Fitted into a GU10 Case.

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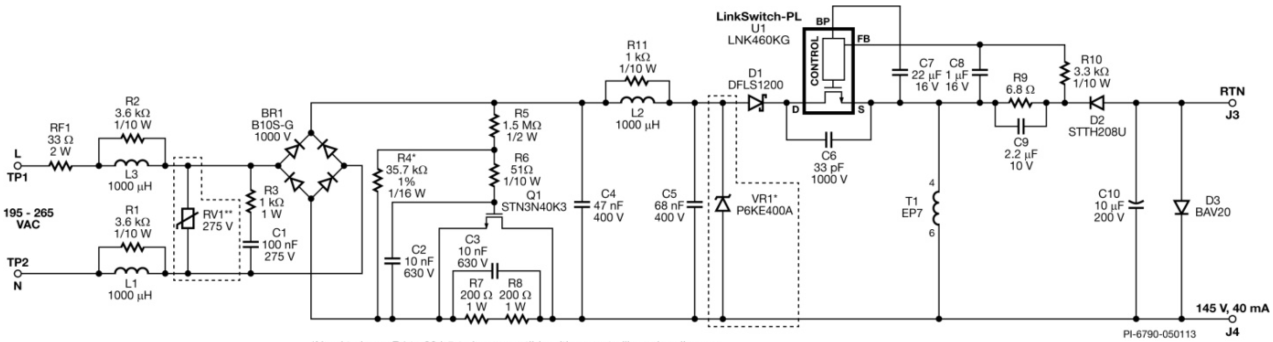
2 电源规格

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	235	265	VAC	双导线 – 无P.E.
频率	f_{LINE}		50		Hz	
输出						
输出电压	V_{OUT}		145		V	
输出电流	I_{OUT}		40		mA	
总输出功率						
连续输出功率	P_{OUT}		5.8		W	
效率						
满载	η		80		%	在P_{OUT} 25 ºC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)						未测试
差模浪涌(1.2 / 50 μs)						未测试
功率因数		0.9				在230 VAC、50 Hz下
谐波电流		EN 61000-3-2 Class D (C)				当P_{IN} <25 W， Class C指定Class D限值
环境温度	T_{AMB}		40		ºC	自然对流，海平面

3 电路原理图



*Need to lower R4 to 20 kΩ to be compatible with some trailing edge dimmers.
**Optional surge components, not on PCB.

Figure 4 – Schematic.

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4 电路描述

LinkSwitch-PL (U1)是一款适用于LED驱动器应用的高集成度初级侧控制器芯片。LinkSwitch-PL能够在单级转换拓扑结构中提供高功率因数，同时对输出电流进行调节。本设计还能补偿LED驱动器应用中常见的输出电压变化。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

电感L1-L3 和C4-C5将降压-升压式转换器所产生的输入开关电流滤波至线路。L1、L2和L3两端的电阻R1、R2和R3可抑制输入电感、电容和AC输入阻抗之间在传导EMI升高时通常会出现的任何共振。

桥式整流管BR1对AC线电压进行整流，电容C4为初级开关电流提供低阻抗通路（去耦）。为使功率因数保持在0.9以上，需要确保较低的电容（C4和C5之和）值。

4.2 电源及反馈电路

电路被配置为降压-升压式转换器，U1的源极(S)引脚经由一个电流检测电阻连接至续流二极管D2的阴极。电流检测电阻R9用来检测降压-升压式转换器的二极管电流。其值经调整后可在额定输入电压下使输出电流的中心值为40 mA。电容C8和R10充当低通滤波器，对二极管电流进行均分，二极管电流用作反馈信号，它与输出电流成正比。电容C9充当通过R9的高频率的旁路，从而提高总体效率。

连接至DC正极的漏极(D)引脚通过D1对输入进行了整流。二极管D1用于防止反向电流流经U1。EP7电感磁芯尺寸经过优化，可装入GU10壳体。

电容C7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，C7从与漏极引脚相连的内部高压电流源被充电至约6 V。

二极管D3提供断开负载保护，即在负载断开时表现为短路故障。

4.3 可控硅调光控制兼容性

有源衰减电路由元件R4、R5、R6、C2、Q1以及R7和R8共同组成。该电路可以限制可控硅导通时流入C4并对其充电的浪涌电流，实现方式是在每个半线周期内将R7和R8串联约2.5 ms。这样可使R7和R8的功耗保持在低水平，在限流时可以使用更大的值。电阻分压器R4和R5决定输入电压的导通阈值。

无源泄放电路由X电容C1和R3构成。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，防止每个导通期间的起始阶段出现可控硅的开关振荡。

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5 PCB布局

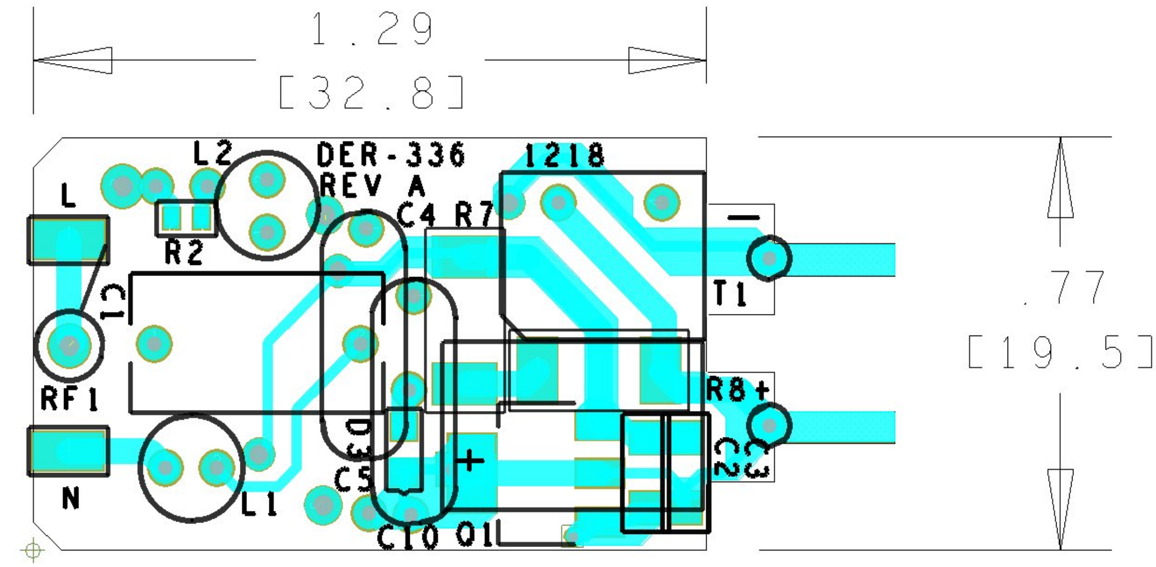

Figure 5 – Top Side.

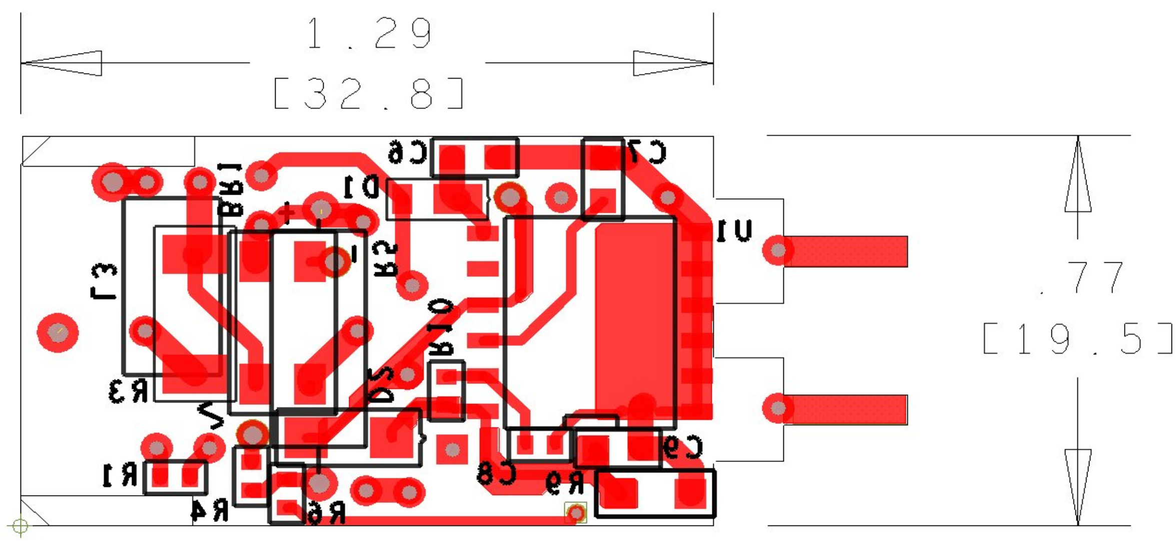

Figure 6 – Bottom Side.

6 物料清单(BOM)

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	1000 V, 0.8 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	B10S-G	Comchip Tech
2	1	C1	100 nF, 275 VAC, Film, X2	LE104-M	OKAY
3	2	C2 C3	10 nF, 630 V, Ceramic, X7R, 1206	C1206C103KBRACTU	Kemet
4	1	C4	47 nF, 400 V, Film	ECQ-E4473KF	Panasonic
5	1	C5	68 nF, 400 V, Film	ECQ-E4683KF	Panasonic
6	1	C6	33 pF, 1000 V, Ceramic, COG, 0805	0805AA330KAT1A	AVX
7	1	C7	22 μF, 16 V, Ceramic, X7R, 0805	C2012X5R1C226K	TDK
8	1	C8	1 μF, 16 V, Ceramic, X5R, 0603	GRM188R61C105KA93D	Murata
9	1	C9	2.2 μF, 10 V, Ceramic, X7R, 0805	GRM21BR71A225MA01L	Murata
10	1	C10	10 μF, 200 V, Electrolytic, (8 x 11)	SMQ200VB10RM8X11LL	Nippon Chemi-Con
11	1	D1	200 V, 1 A, Diode Schottky, PWRDI123	DFLS1200	Diodes, Inc.
12	1	D2	800 V, 2 A, Ultrafast Recovery, 75 ns, DO-214AA	STTH208U	ST Micro
13	1	D3	200 V, 200 mA, Fast Switching, 50 ns, DO-35	BAV20	Vishay
14	3	L1 L2 L3	1000 μH, 0.21 A, 5.5 x 10.5 mm	SBC1-102-211	Tokin
15	1	Q1	400 V, 1.8 A, N-Channel, SOT 223	STN3N40K3	ST Micro
16	2	R1 R2	3.6 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ362V	Panasonic
17	1	R3	1 kΩ, 5%, 1 W, Thick Film, 2512	ERJ-1TYJ102U	Panasonic
18	1	R4	35.7 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3572V	Panasonic
19	1	R5	1.5 MΩ, 5%, 1/2 W, Carbon Film	CFR-50JB-1M5	Yageo
20	1	R6	51 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ510V	Panasonic
21	2	R7 R8	200 Ω, 5%, 1 W, Thick Film, 2512	ERJ-1TYJ201U	Panasonic
22	1	R9	6.8 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ6R8V	Panasonic
23	1	R10	3.3 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ332V	Panasonic
24	1	R11	1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
25	1	RF1	33 Ω, 2 W, Fusible/Flame Proof Wire Wound	ULW2-33RJA25	TT Electronics-Welwyn
26	1	T1	Bobbin, EP7, 6 pins	CSH-EP7-1S-6P-E	Phillips
27	1	U1	LinkSwitch-PL, eSOP-12B	LNK460KG	Power Integrations

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7 电感规格

7.1 电气原理图

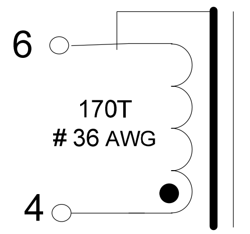

Figure 7 – Inductor Electrical Diagram.

7.2 电气规格

Primary Inductance	Pins 4-6, all other windings open, measured at 66 kHz, 0.4 $V_{RMS.}$	330 μH ±5%
Resonant Frequency	Pins 4-6, all other windings open.	1 MHz (Min.)

7.3 材料

Item	Description
[1]	Core: EP7.
[2]	Bobbin: B-EP7-V-6pins-(3/3).
[3]	Tape, Polyester film, 3M 1350F-1 or equivalent, 6.4 mm wide.
[4]	Wire: Magnet, #36 AWG, solderable double coated.
[5]	Copper Tape: 2 mil thick.

7.4 电感结构图

Pins Side

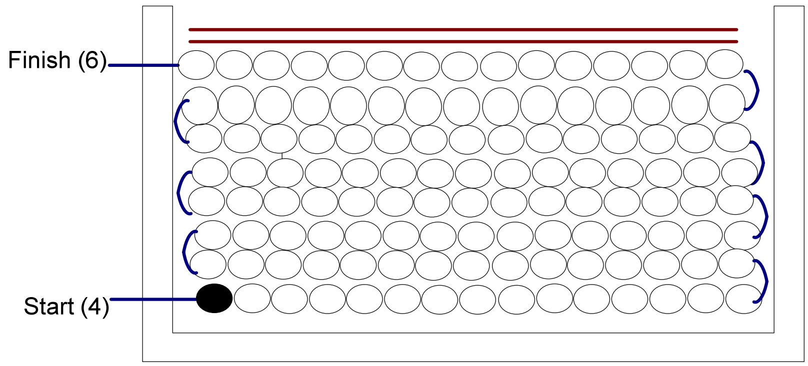

Figure 8 – Inductor Build Diagram.

7.5 电感说明

Bobbin Preparation	Place the bobbin item [2] on the mandrel such that pin side on the left side. Winding direction is the clockwise direction.
WDG	Starting at pin 4, wind 170 turns of wire item [4] in 8 layers. Finish at pin 6.
Core Assembly	Grind core to get 0.33 mH inductance. Assemble and secure core halves
Flux Band	Construct a flux band by wrapping a single shorted turn of item [5] around the output side of windings and core halves with tight tension. Make an electrical connection to pin (6) using wire. Add 3 layers of tape, item (3) for insulation
Varnish	Dip varnish uniformly.

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8 电感设计表格

ACDC_LinkSwitch-PL-Buck-Boost_121211; Rev.1.0; Copyright Power Integrations 2011	INPUT	INFO	OUTPUT	UNIT	ACDC_LinkSwitch-PL-Buck-Boost_121211; LinkSwitch-PL Buck-Boost Transformer Design Spreadsheet
ENTER APPLICATION VARIABLES					
VACMIN	195		195	V	Minimum AC input voltage
VACNOM	230		230	V	Nominal AC input voltage
VACMAX	265		265	V	Maximum AC input voltage
FL			50	Hz	Minimum line frequency
VO_MIN			136.8	V	Minimum output voltage tolerance
VO_NOM	144.00		144.00	V	Nominal Output Voltage
VO_MAX			151.20	V	Maximum output voltage tolerance
IO	0.040		0.040	A	Average output current specification
n	0.80		0.800	%/100	Total power supply efficiency
Z			0.5		Loss allocation factor
Enclosure	Retrofit Lamp		Retrofit Lamp		Enclosure selections determine thermal conditions and maximum power. Enter "Retrofit Lamp" or "Open frame"
PO			5.76	W	Total output power
VD			0.4	V	Output diode forward voltage drop
LinkSwitch-PL DESIGN VARIABLES					
Device	LNK460		LNK460		Chosen LinkSwitch-PL Device
TON			1.34	us	Expected on-time of MOSFET at low line and PO
FSW			45.4	kHz	Expected switching frequency at low line and PO
Duty Cycle			6.1	%	Expected operating duty cycle at low line and PO
VDRAIN			546	V	Estimated worst case drain voltage at VACMAX and VO_MAX
IRMS			0.133	A	Nominal RMS current through the switch
IPK			1.617	A	Worst Case Peak current
ILIM_MIN			1.637	A	Minimum device current limit
KDP			6.86		Ratio between off-time of switch and reset time of core at VACNOM
LinkSwitch-PL EXTERNAL COMPONENT CALCULATIONS					
RSENSE			7.250	Ohms	Output current sense resistor
Standard RSENSE			7.32	Ohms	Closest 1% value for RSENSE
PSENSE			11.6	mW	Power dissipated by RSENSE
ENTER INDUCTOR CORE/CONSTRUCTION VARIABLES					
Core Type	EP7		EE10		Core Type
AE	10.70		10.70	mm^2	Core Effective Cross Sectional Area
LE	15.50		15.50	mm	Core Effective Path Length
AL	1000		1000	nH/T^2	Ungapped Core Effective Inductance
BW	3.50		3.5	mm	Bobbin Physical Winding Width
L	8		8		Number of winding layers
TRANSFORMER PRIMARY DESIGN PARAMETERS					
LP			330.0	uH	Primary Inductance
LP Tolerance			10	%	Tolerance of Primary Inductance
N	170.00		170	Turns	Number of Turns
ALG			11	nH/T^2	Gapped Core Effective Inductance

BM			2934	Gauss	Operating Flux Density
BAC			1467	Gauss	Worst case AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
BP		Warning	4157	Gauss	!!! Reduce peak flux density (BP < 3600 G) by increasing NP, selecting a bigger core or decreasing KDP
LG			1.178	mm	Gap Length (Lg > 0.1 mm)
BWE			28	mm	Effective Bobbin Width
L_IRMS			0.258	A	RMS Current through the inductor
OD			0.16	mm	Maximum Primary Wire Diameter including insulation
INS			0.04	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
DIA			0.13	mm	Bare conductor diameter
AWG			36	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
CM			25	Cmils	Bare conductor effective area in circular mils
CMA		Warning	98	Cmils/Amp	!!! INCREASE CMA > 200 (increase L (primary layers) or choose a larger core)
Current Density (J)		Warning	20.37	A/mm^2	!!! Current density is above recommended value of 9.75 A/mm^2. Use larger wire diameter (OD), increase L or increase core size to decrease current density.
Output Parameters					
IO			0.040	A	Expected Output Current
PIVD			737.0	V	Peak Inverse Voltage at VO_MAX on output diode

Notes:

1. The peak flux density warning (BP) can be ignored for this design. The spreadsheet BP calculation assumes that the LNK460KG will operate at $I_{LIM(MAX)}$ during start-up. In practice, due to the internal soft-start function this current level is not reached and therefore no core saturation occurs. This was confirmed in both Figures 38 and 39 for normal start-up and Figures 41 and 43 for start-up with a shorted output (fault condition). In all cases, the peak drain current is below the absolute maximum data sheet specification
2. CMA <200 Cmils/Amp and J>9.75 A/mm^2 are acceptable in this design with low inductor temperature.

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9 性能数据

All measurements performed at room temperature using an LED load. The following data were measured using 3 sets of loads to represent the load range of 140 V to 150 V (output voltage). Refer to the table on Section 9.6 for the complete set of test data values.

9.1 效率

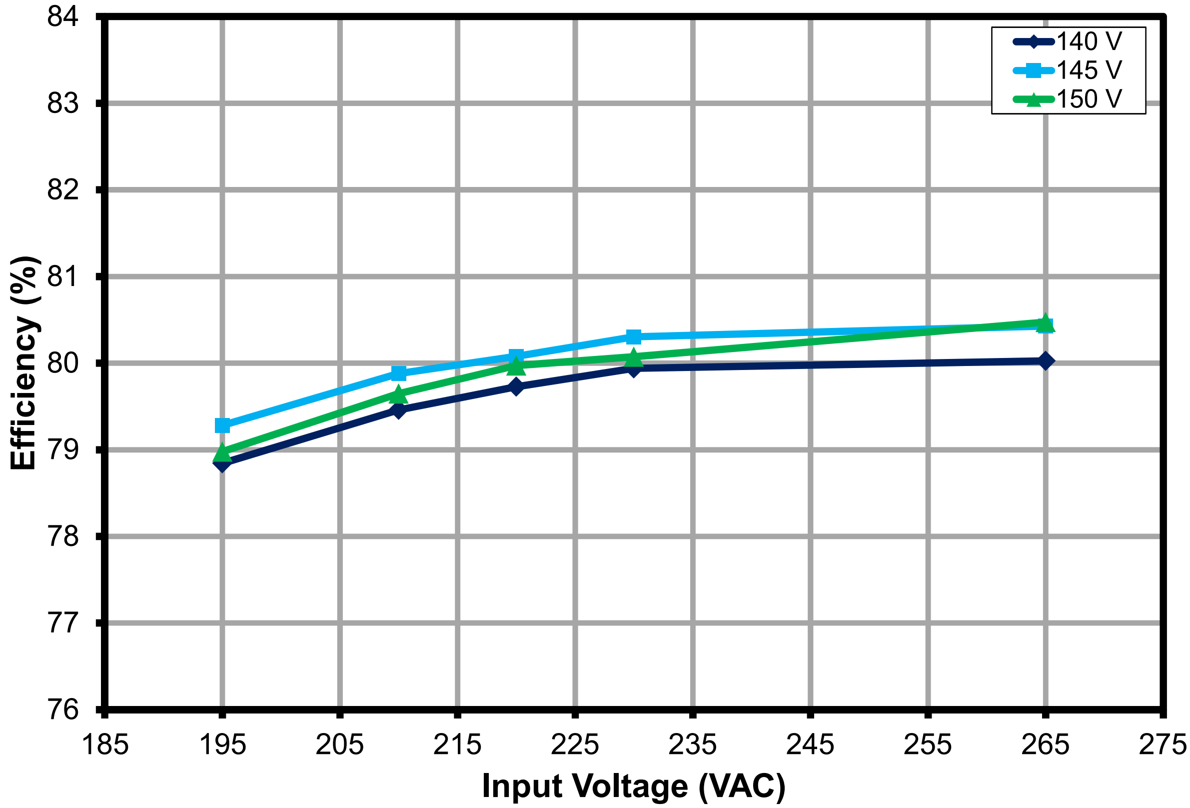

Figure 9 – Efficiency vs. Line and Load.

9.2 输入电压调整率和负载调整率

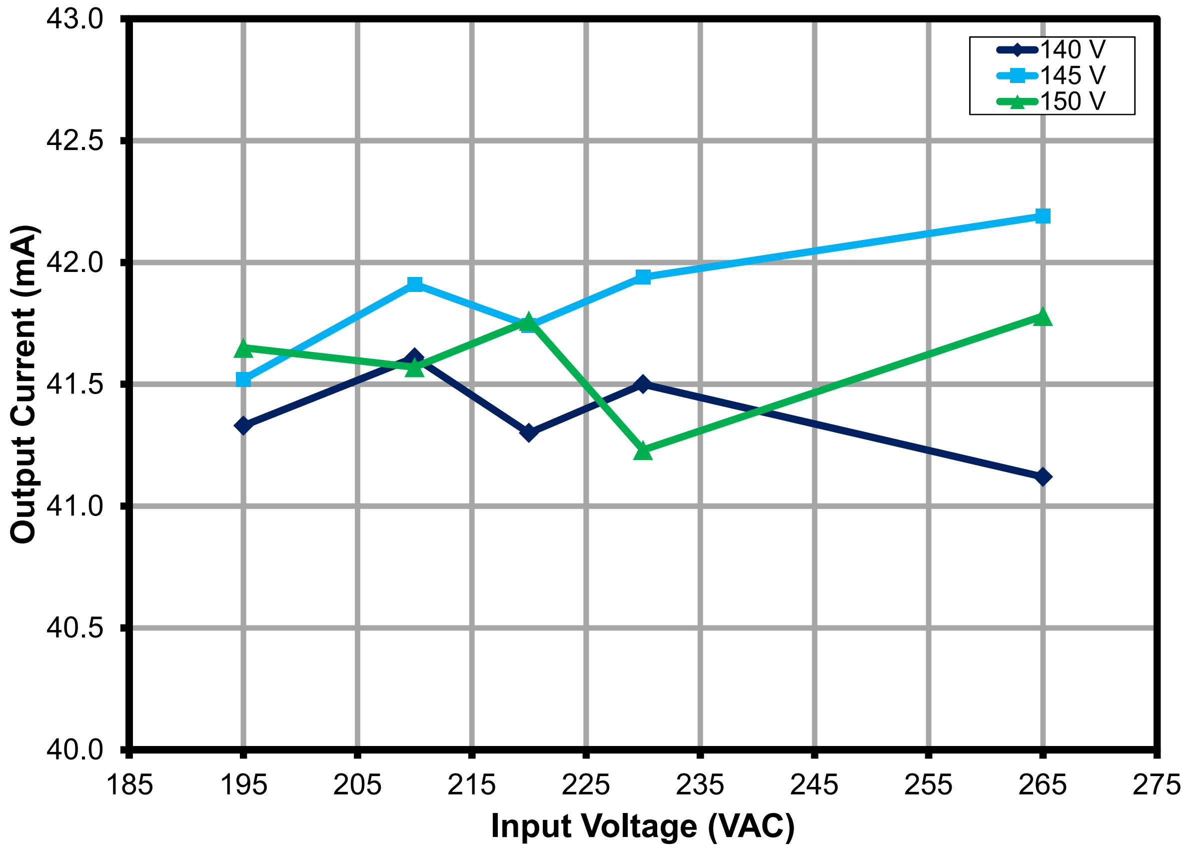

Figure 10 – Regulation vs. Line and Load.

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9.3 功率因数

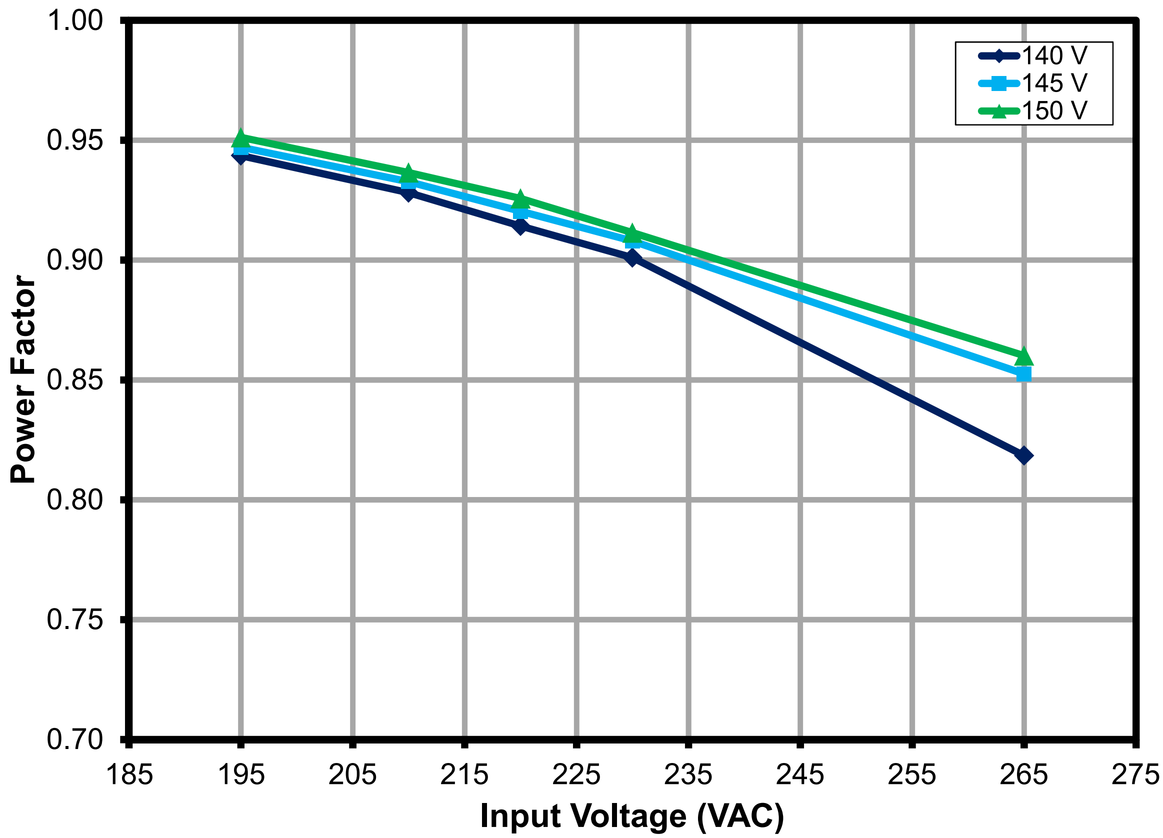

Figure 11 – Power Factor vs. Line and Load.

9.4 A-THD

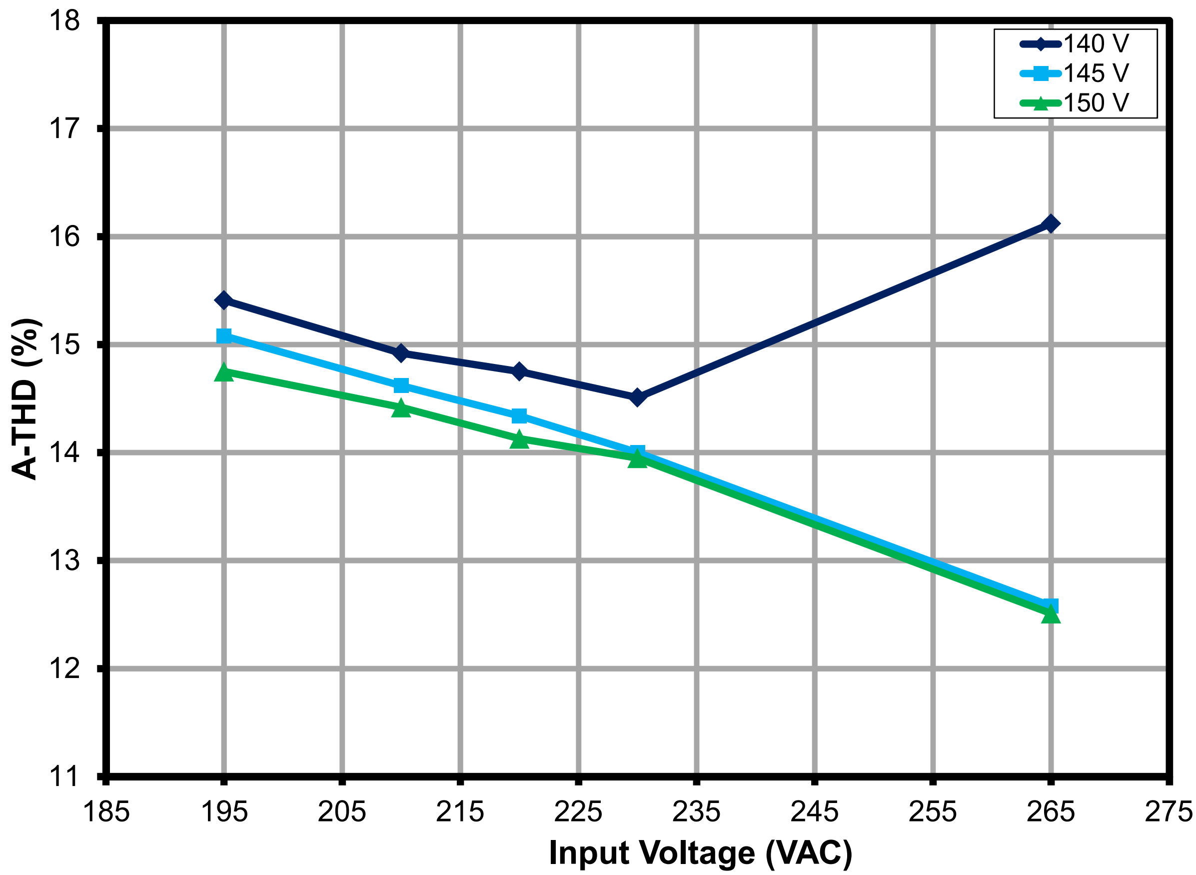

Figure 12 – A-THD vs. Line and Load.

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9.5 谐波

The design met the limits for Class C equipment for an active input power of <25 W. In this case IEC61000-3-2 specifies that harmonic currents shall not exceed the limits of Class D equipment[1]. Therefore the limits shown in the charts below are Class D limits which must not be exceeded to meet Class C compliance.

9.5.1 140 V LED负载

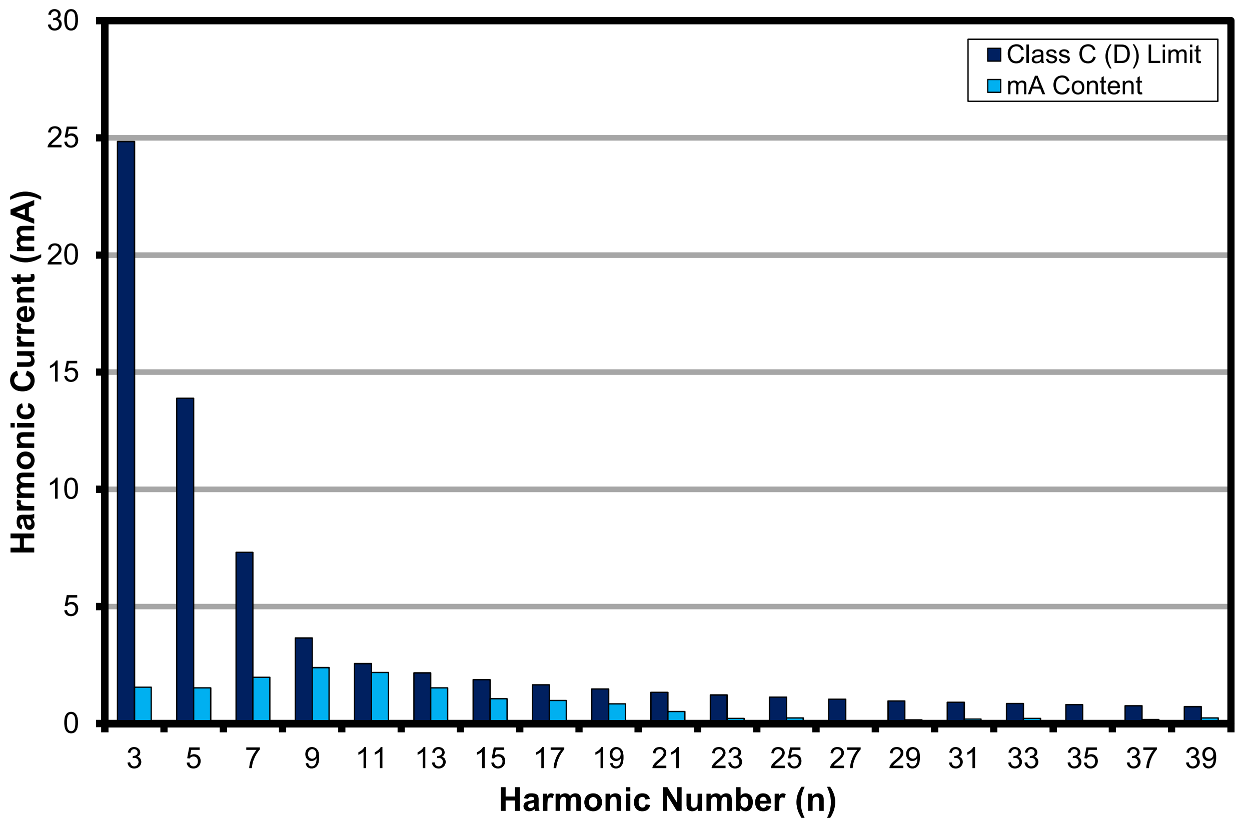

Figure 13 – 140 V LED Load Input Current Harmonics at 230 VAC, 50 Hz.

[1] IEC6000-3-2 Section 7.3, table 2, column 2.

9.5.2 145 V LED负载

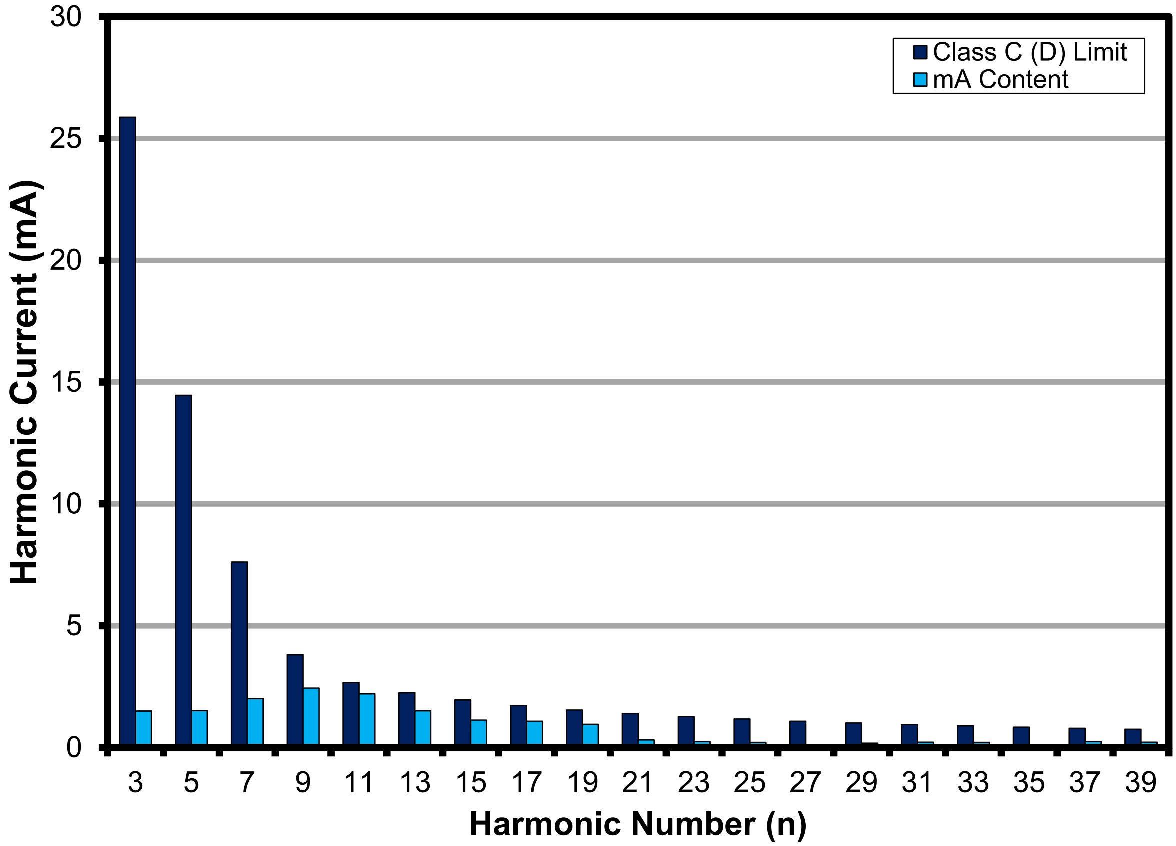

Figure 14 – 145 V LED Load Input Current Harmonics at 230 VAC, 50 Hz.

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9.5.3 150 V LED负载

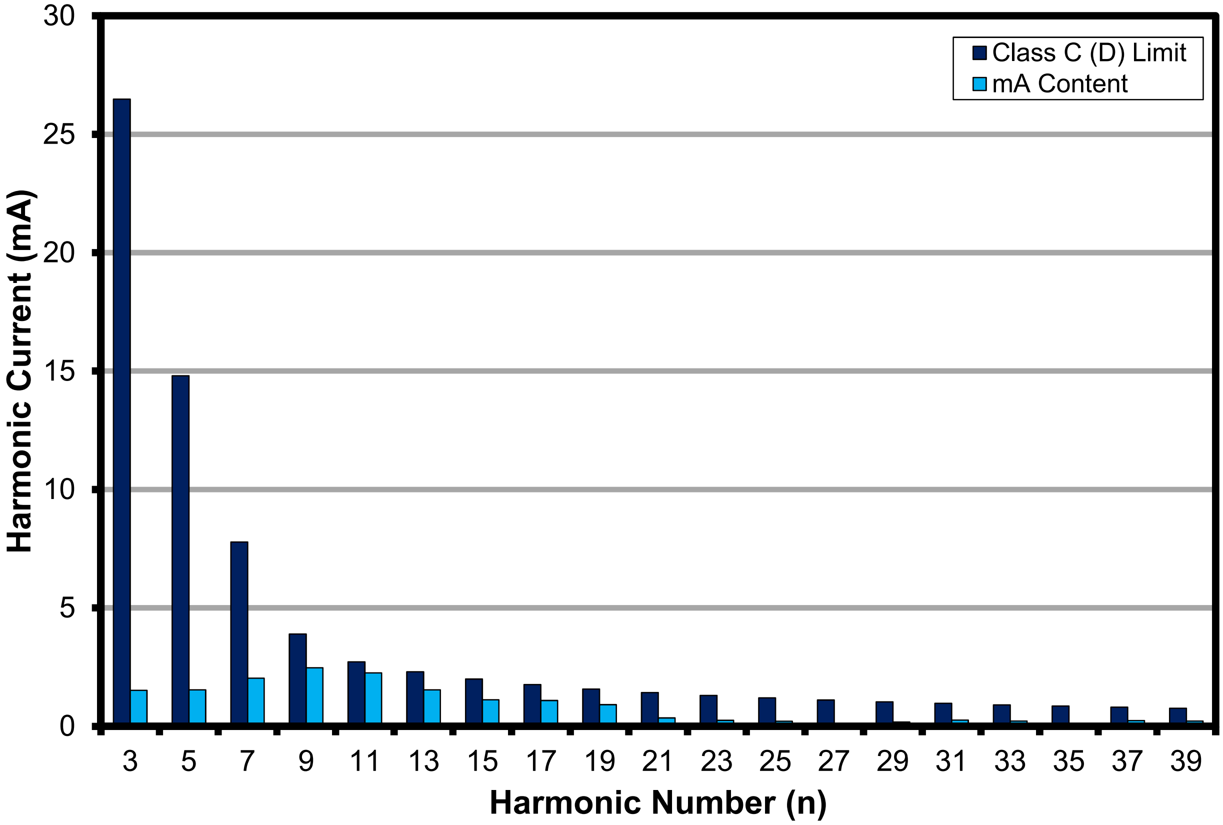

Figure 15 – 150 V LED Load Input Current Harmonics at 230 VAC, 50 Hz.

9.6 测试数据

All measurements were taken with the board at open frame, 25 ºC ambient.

9.6.1 测试数据，140 V LED负载

Input		Input Measurement					Load Measurement			Calculation		
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	P_{CAL} (W)	Efficiency (%)	Loss (W)
195	50	194.96	40.13	7.383	0.944	15.41	139.3000	41.330	5.821	5.76	78.84	1.56
210	50	209.90	37.87	7.376	0.928	14.92	139.3000	41.610	5.861	5.80	79.46	1.52
220	50	219.94	36.26	7.291	0.914	14.75	139.3000	41.300	5.813	5.75	79.73	1.48
230	50	229.98	35.27	7.308	0.901	14.51	139.3000	41.500	5.842	5.78	79.94	1.47
265	50	265.00	33.34	7.229	0.818	16.12	139.3000	41.120	5.785	5.73	80.02	1.44

9.6.2 测试数据，145 V LED负载

Input		Input Measurement					Load Measurement			Calculation		
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	P_{CAL} (W)	Efficiency (%)	Loss (W)
195	50	194.96	41.36	7.636	0.947	15.08	144.2000	41.520	6.054	5.99	79.28	1.58
210	50	209.89	39.07	7.649	0.933	14.62	144.3000	41.910	6.110	6.05	79.88	1.54
220	50	219.94	37.52	7.595	0.920	14.34	144.2000	41.740	6.082	6.02	80.08	1.51
230	50	229.98	36.45	7.610	0.908	14	144.2000	41.940	6.111	6.05	80.30	1.50
265	50	264.99	33.84	7.644	0.853	12.58	144.3000	42.190	6.148	6.09	80.43	1.50

9.6.3 测试数据，150 V LED负载

Input		Input Measurement					Load Measurement			Calculation		
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	P_{CAL} (W)	Efficiency (%)	Loss (W)
195	50	194.95	43.07	7.987	0.951	14.75	149.8000	41.650	6.308	6.24	78.98	1.68
210	50	209.88	40.20	7.901	0.937	14.42	149.8000	41.570	6.293	6.23	79.65	1.61
220	50	219.93	38.83	7.904	0.926	14.13	149.8000	41.760	6.321	6.26	79.97	1.58
230	50	229.97	37.16	7.789	0.911	13.95	149.8000	41.230	6.237	6.18	80.07	1.55
265	50	264.99	34.47	7.856	0.860	12.51	149.9000	41.780	6.322	6.26	80.47	1.53

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9.6.4 230 VAC 50 Hz，140 V LED负载谐波数据

nth Order	mA Content	% Content	Limit <25 W	Remarks
1	34.90			
2	0.20	0.58%		
3	1.55	4.45%	24.8472	Pass
5	1.52	4.36%	13.8852	Pass
7	1.97	5.65%	7.3080	Pass
9	2.39	6.85%	3.6540	Pass
11	2.19	6.27%	2.5578	Pass
13	1.52	4.36%	2.1643	Pass
15	1.07	3.05%	1.8757	Pass
17	0.99	2.84%	1.6550	Pass
19	0.84	2.41%	1.4808	Pass
21	0.52	1.49%	1.3398	Pass
23	0.22	0.63%	1.2233	Pass
25	0.24	0.69%	1.1254	Pass
27	0.09	0.26%	1.0421	Pass
29	0.16	0.45%	0.9702	Pass
31	0.19	0.56%	0.9076	Pass
33	0.22	0.64%	0.8526	Pass
35	0.09	0.24%	0.8039	Pass
37	0.18	0.50%	0.7604	Pass
39	0.24	0.69%	0.7214	Pass

9.6.5 230 VAC 50 Hz，145 V LED负载谐波数据

nth Order	mA Content	% Content	Limit <25 W	Remarks
1	36.09			
2	0.02	0.05%		
3	1.50	4.15%	25.8740	Pass
5	1.52	4.20%	14.4590	Pass
7	2.00	5.55%	7.6100	Pass
9	2.44	6.76%	3.8050	Pass
11	2.20	6.10%	2.6635	Pass
13	1.50	4.17%	2.2537	Pass
15	1.13	3.13%	1.9532	Pass
17	1.08	2.99%	1.7234	Pass
19	0.95	2.64%	1.5420	Pass
21	0.31	0.86%	1.3952	Pass
23	0.25	0.69%	1.2738	Pass
25	0.21	0.58%	1.1719	Pass
27	0.10	0.26%	1.0851	Pass
29	0.19	0.51%	1.0103	Pass
31	0.22	0.61%	0.9451	Pass
33	0.21	0.59%	0.8878	Pass
35	0.10	0.27%	0.8371	Pass
37	0.25	0.70%	0.7919	Pass
39	0.22	0.61%	0.7512	Pass

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9.6.6 230 VAC 50 Hz，150 V LED负载谐波数据

nth Order	mA Content	% Content	Limit <25 W	Remarks
1	36.73			
2	0.02	0.06%		
3	1.52	4.14%	26.4826	Pass
5	1.54	4.18%	14.7991	Pass
7	2.03	5.54%	7.7890	Pass
9	2.48	6.74%	3.8945	Pass
11	2.25	6.13%	2.7262	Pass
13	1.54	4.18%	2.3067	Pass
15	1.12	3.04%	1.9992	Pass
17	1.09	2.97%	1.7640	Pass
19	0.91	2.49%	1.5783	Pass
21	0.36	0.97%	1.4280	Pass
23	0.25	0.69%	1.3038	Pass
25	0.22	0.60%	1.1995	Pass
27	0.06	0.16%	1.1107	Pass
29	0.18	0.49%	1.0341	Pass
31	0.27	0.72%	0.9673	Pass
33	0.23	0.62%	0.9087	Pass
35	0.08	0.21%	0.8568	Pass
37	0.25	0.68%	0.8105	Pass
39	0.23	0.62%	0.7689	Pass

10 热性能

Images captured after running for more than 30 minutes at room temperature (25 °C), open frame.

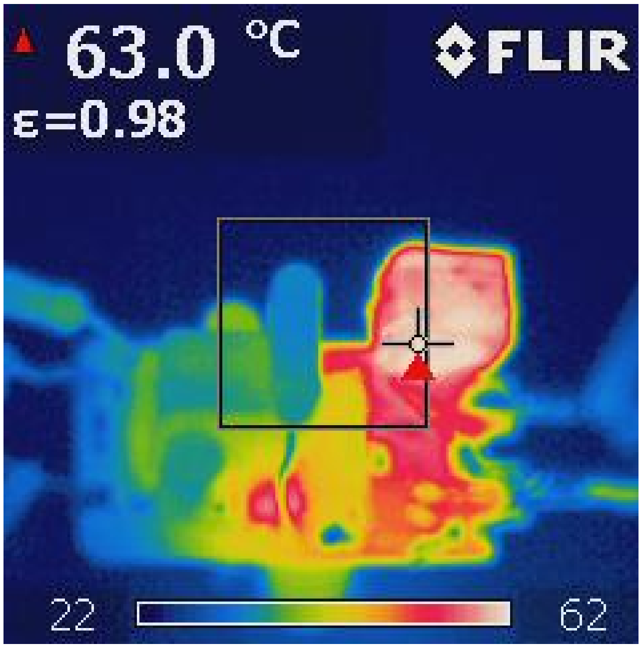

Figure 16 – 195 VAC, Full Load.
Transformer Temperature = 63 ºC.

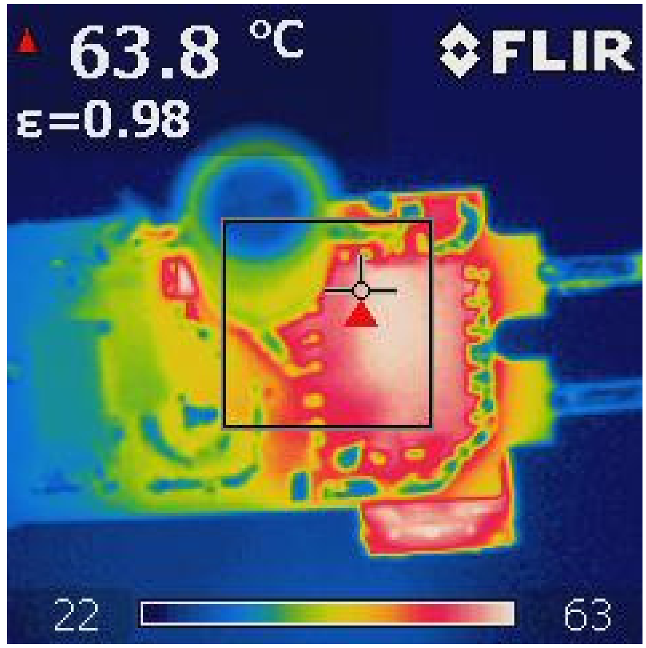

Figure 17 – 195 VAC, Full Load.
LNK460KG Temperature = 63 ºC.

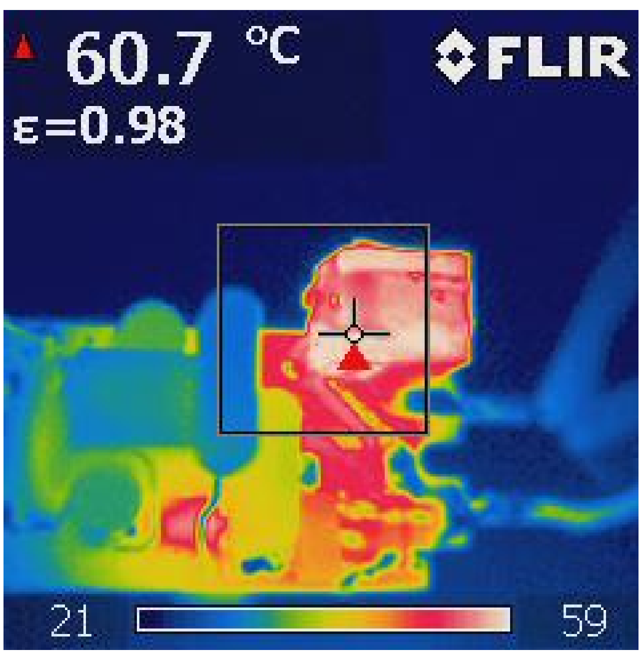

Figure 18 – 230 VAC, Full Load.
Transformer Temperature = 61 ºC.

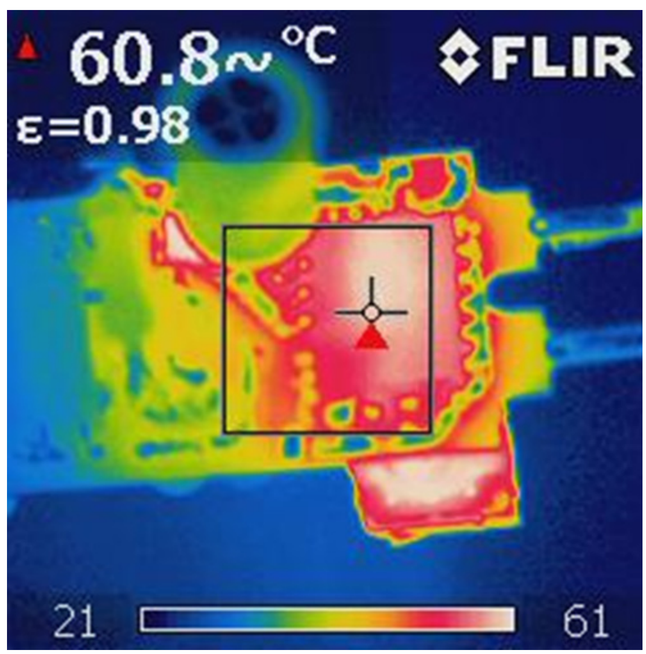

Figure 19 – 230 VAC, Full Load.
LNK460KG Temperature = 61 ºC.

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11 波形

11.1 输入电压和输入电流波形

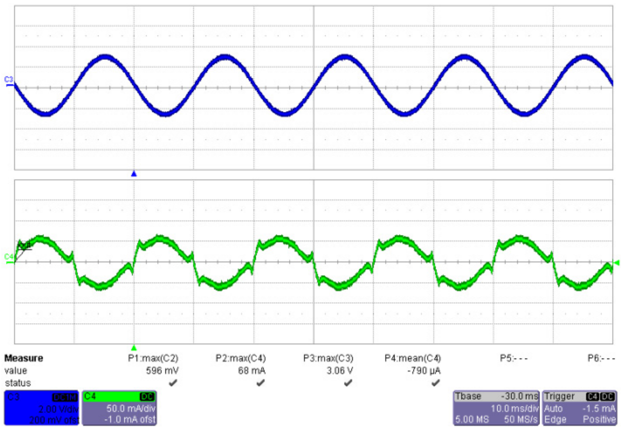

Figure 20 – 195 VAC, 50 Hz Full Load.
Upper: V_{IN}, 200 V / div.
Lower: I_{IN}, 50 mA, 10 ms / div.

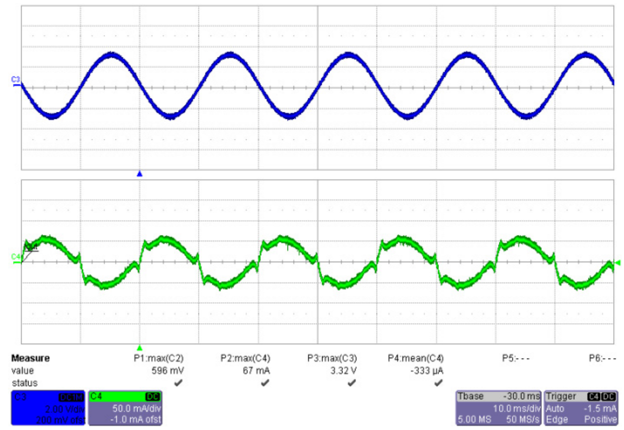

Figure 21 – 210 VAC, 50 Hz Full Load.
Upper: V_{IN}, 200 V / div.
Lower: I_{IN}, 50 mA, 10 ms / div.

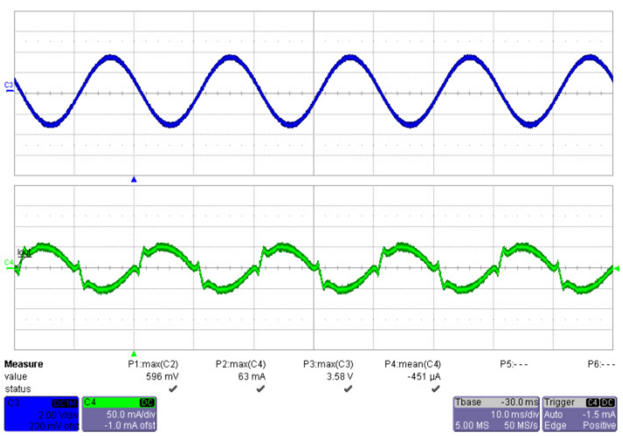

Figure 22 – 230 VAC, 50 Hz Full Load.
Upper: V_{IN}, 200 V / div.
Lower: I_{IN}, 50 mA, 10 ms / div.

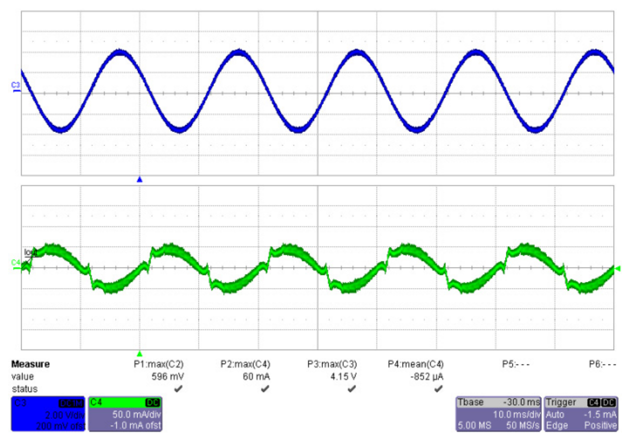

Figure 23 – 265 VAC, 50 Hz Full Load.
Upper: V_{IN}, 200 V / div.
Lower: I_{IN}, 50 mA, 10 ms / div.

11.2 正常工作时的输出电流和输出电压

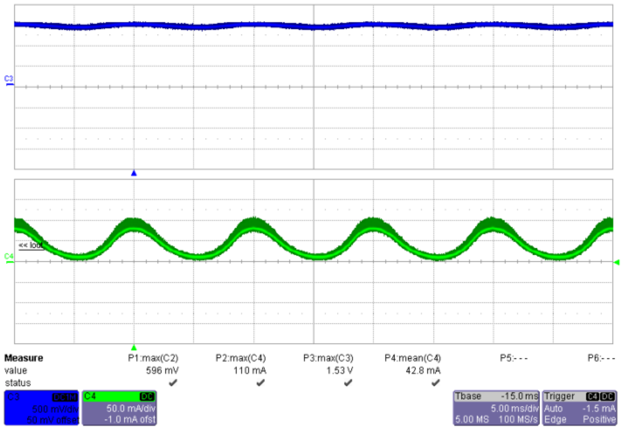

Figure 24 – 195 VAC, 50 Hz Full Load.
Upper: V_{OUT}, 50 V / div.
Lower: I_{OUT}, 50 mA, 5 ms / div.

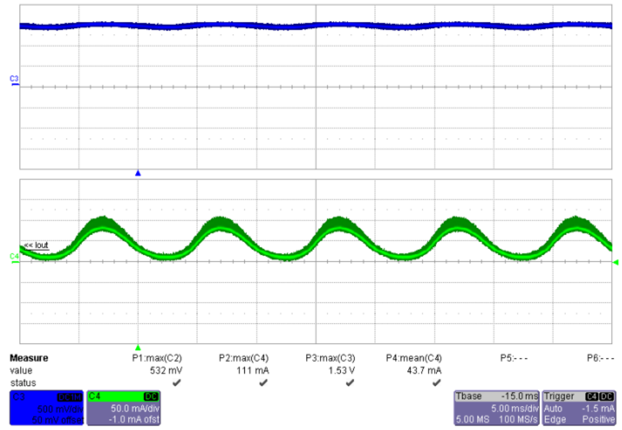

Figure 25 – 210 VAC, 50 Hz Full Load.
Upper: V_{OUT}, 50 V / div.
Lower: I_{OUT}, 50 mA, 5 ms / div.

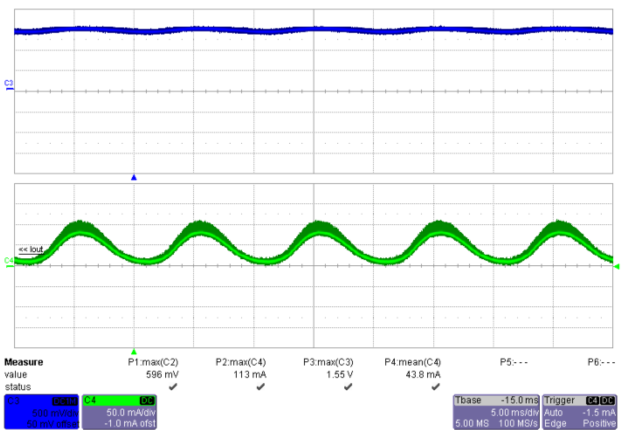

Figure 26 – 230 VAC, 50 Hz Full Load.
Upper: V_{OUT}, 50 V / div.
Lower: I_{OUT}, 50 mA, 5 ms / div.

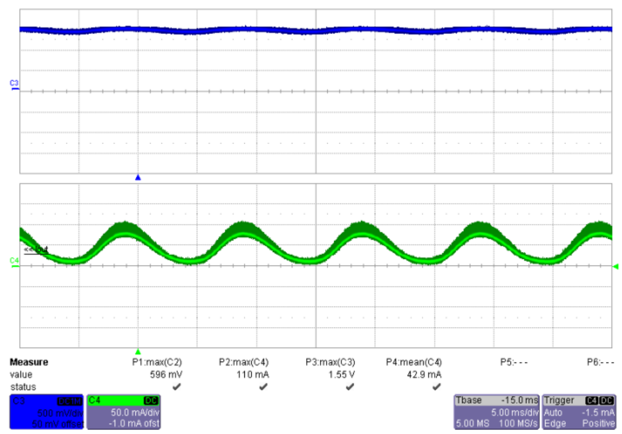

Figure 27 – 265 VAC, 50 Hz Full Load.
Upper: V_{OUT}, 50 V / div.
Lower: I_{OUT}, 50 mA, 5 ms / div.

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11.3 输出电流/电压的升降

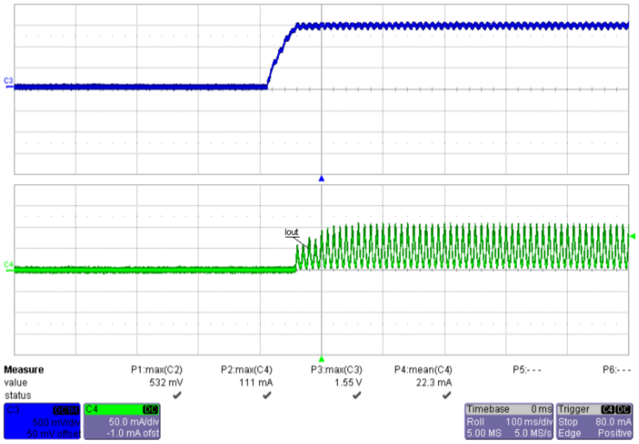

Figure 28 – 195 VAC, 50 Hz Output Rise.
Upper: V_{OUT}, 50 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

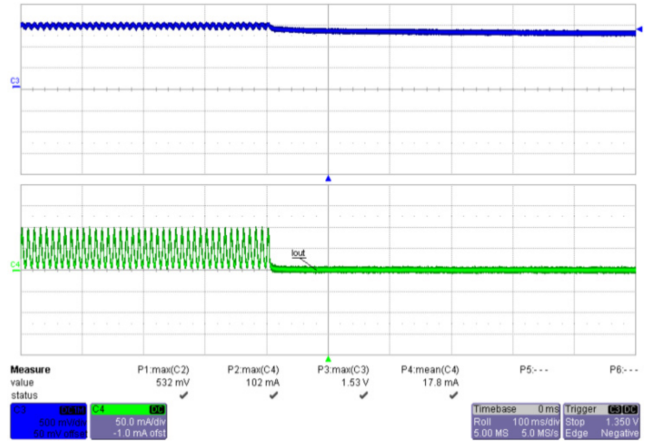

Figure 29 – 195 VAC, 50 Hz Output Fall.
Upper: V_{OUT}, 50 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

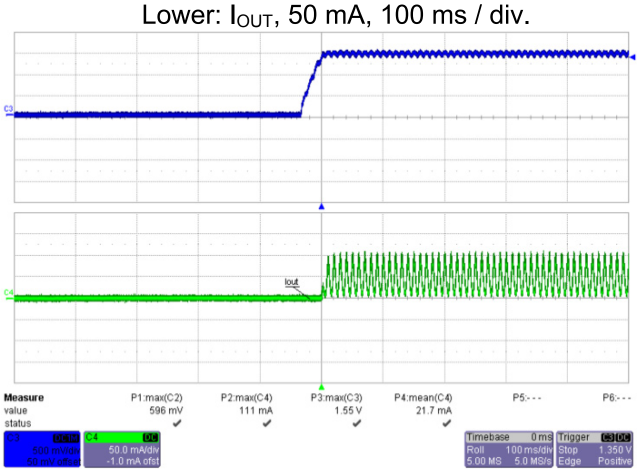

Figure 30 – 265 VAC, 50 Hz Output Rise.
Upper: V_{OUT}, 50 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

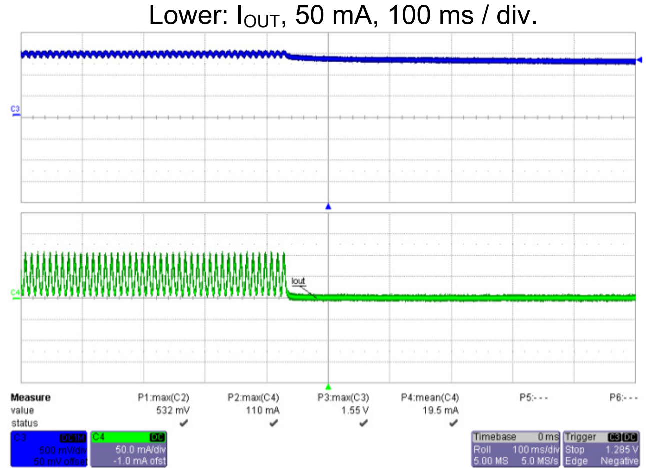

Figure 31 – 265 VAC, 50 Hz Output Fall.
Upper: V_{OUT}, 50 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

11.4 启动时的输入电压和输出电流波形

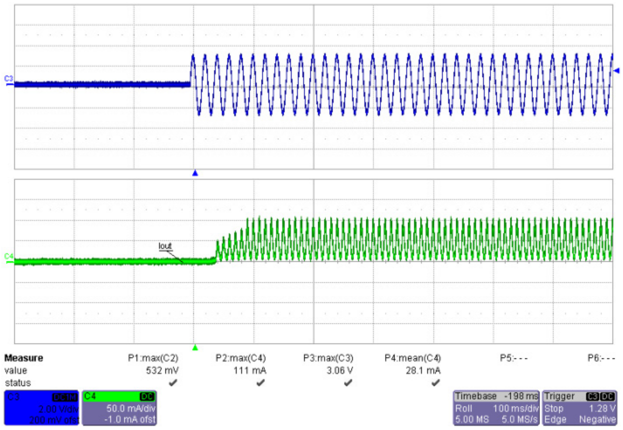

Figure 32 – 195 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

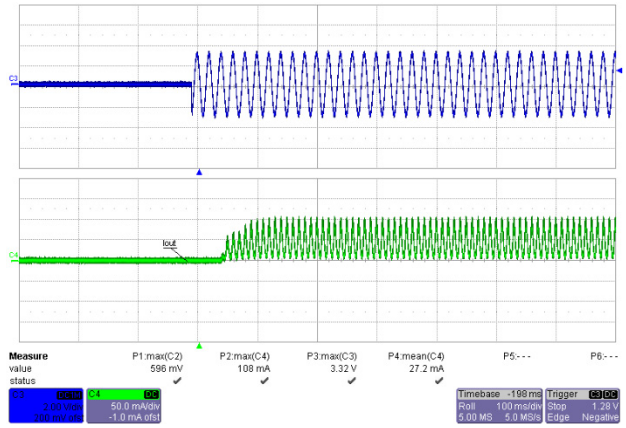

Figure 33 – 210 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

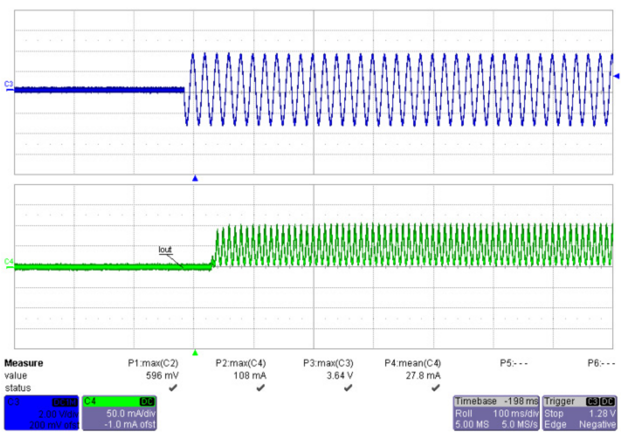

Figure 34 – 230 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

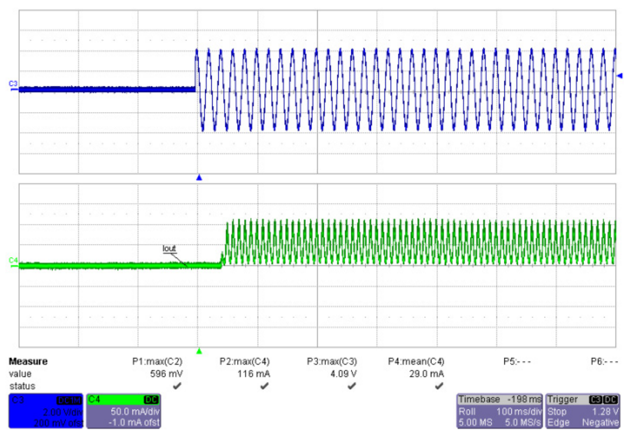

Figure 35 – 265 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

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11.5 正常工作时的漏极电压和电流

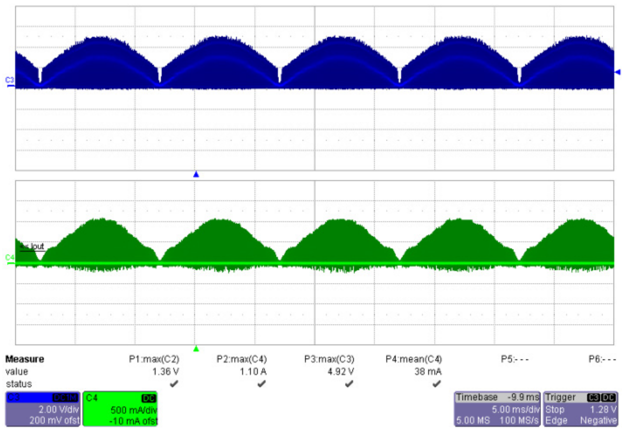

Figure 36 – 195 VAC, 50 Hz.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 500 mA, 5 ms / div.

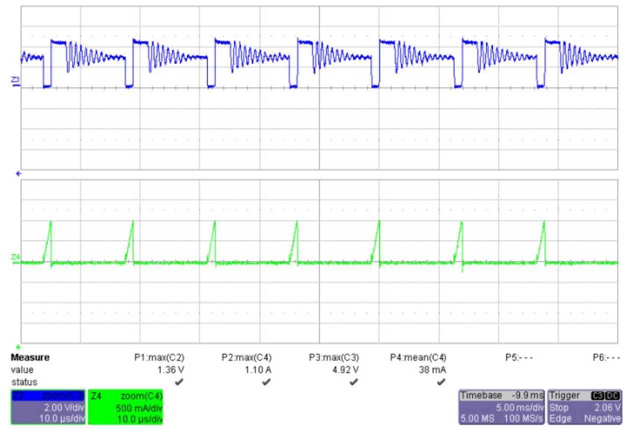

Figure 37 – 195 VAC, 50 Hz.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 500 mA, 5 µs / div.

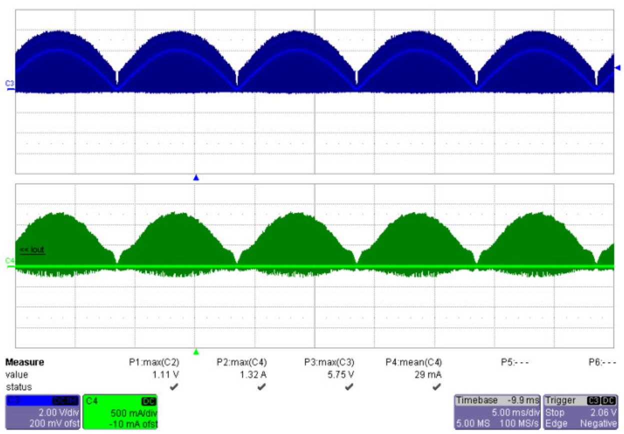

Figure 38 – 265 VAC, 50 Hz.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 500 mA, 5 ms / div.

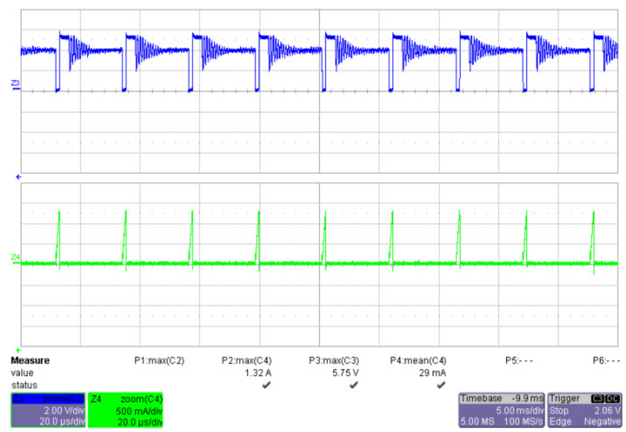

Figure 39 – 265 VAC, 50 Hz.
Upper: V_{DRAIN}, 200 V / div.
Lower: V_{DRAIN}, 500 mA, 5 µs / div.

11.6 启动时的漏极电压和电流

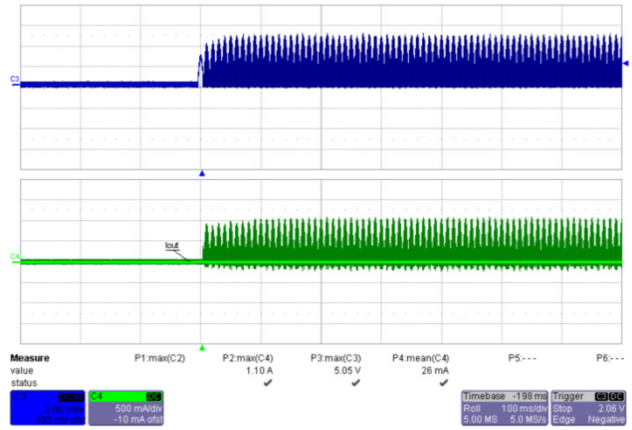

Figure 40 – 195 VAC, 50 Hz.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 500 mA, 100 ms / div.

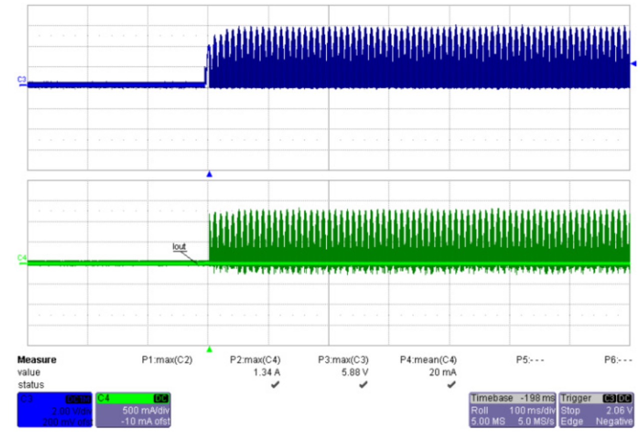

Figure 41 – 265 VAC, 50 Hz.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 500 mA, 100 ms / div.

11.7 输出短路时的漏极电流和漏极电压

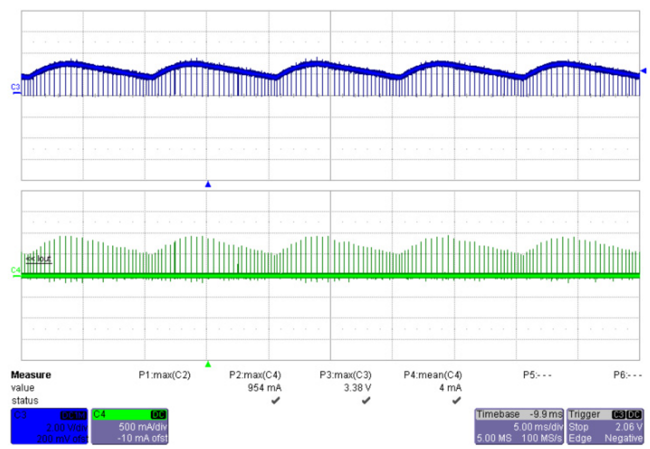

Figure 42 – 195 VAC, 50 Hz Output Short Condition.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 500 mA, 5 ms / div.

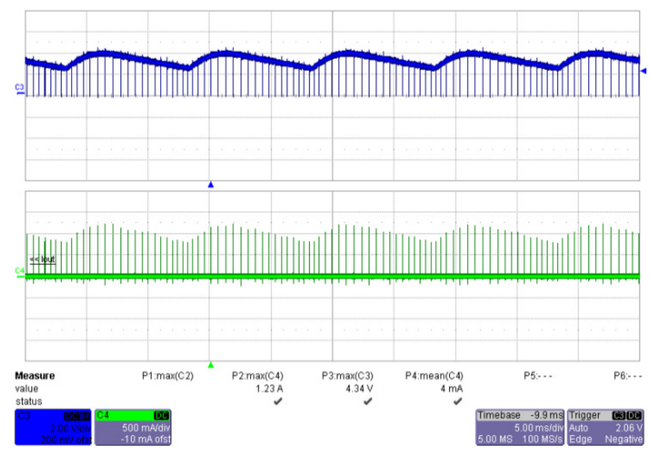

Figure 43 – 265 VAC, 50 Hz Output Short Condition.
Upper: V_{DRAIN}, 200 V / div.
Lower: I_{DRAIN}, 500 mA, 5 ms / div.

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11.8 续流二极管电压和输出电流波形

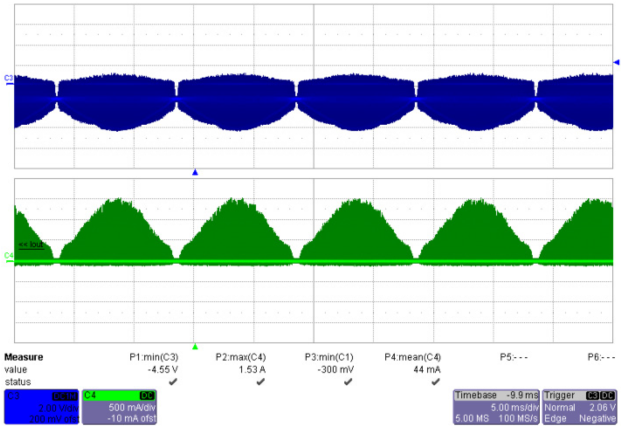

Figure 44 – 195 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

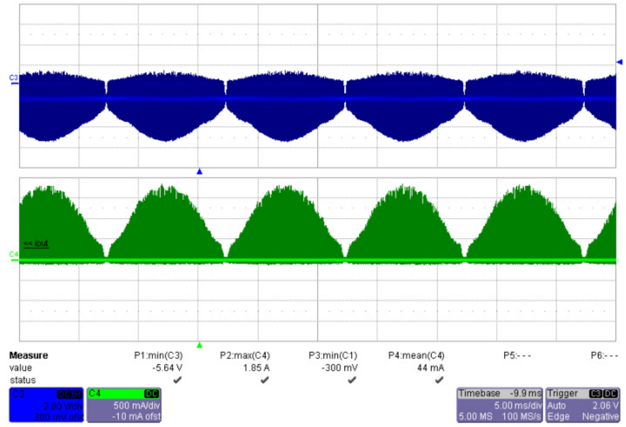

Figure 45 – 210 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

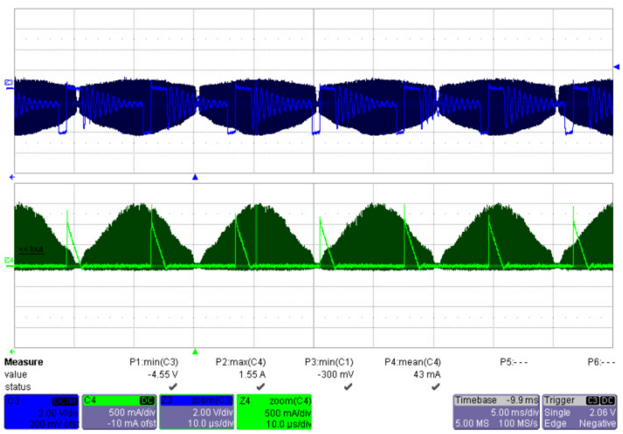

Figure 46 – 230 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

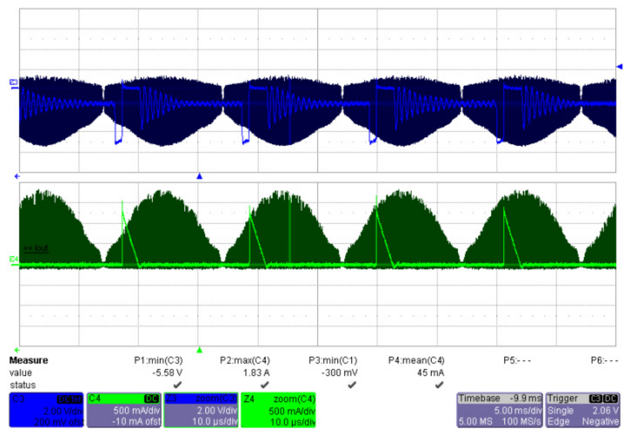

Figure 47 – 265 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

11.9 采用前沿调光器时的输入电压及输出电流波形

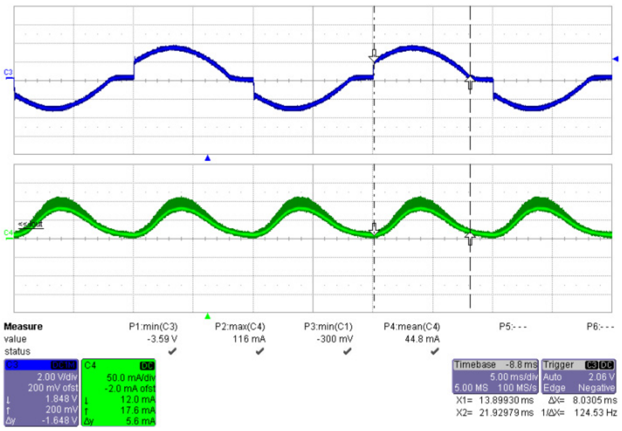

Figure 48 – 230 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

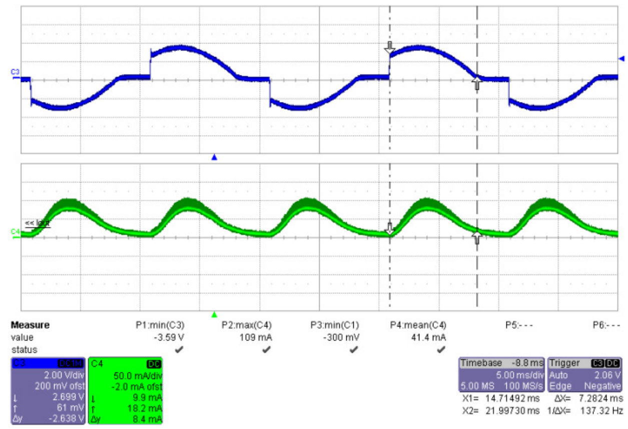

Figure 49 – 230 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

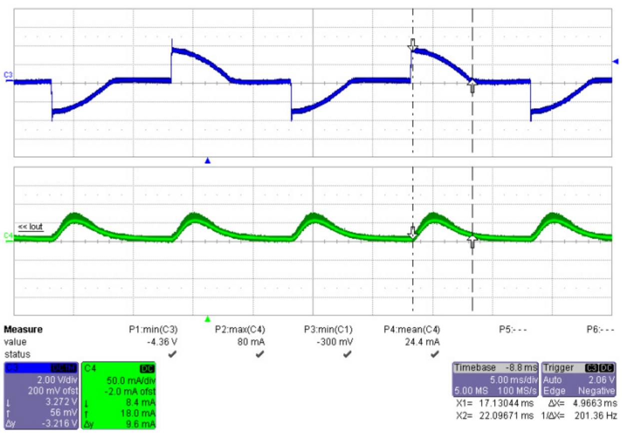

Figure 50 – 230 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

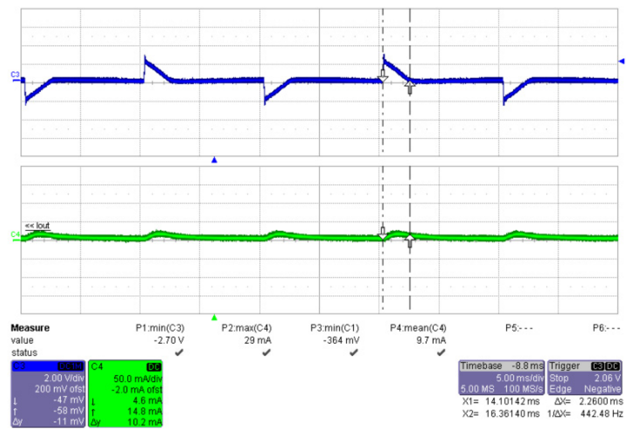

Figure 51 – 230 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

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11.10 采用后沿调光器时的输入电压及输出电流波形

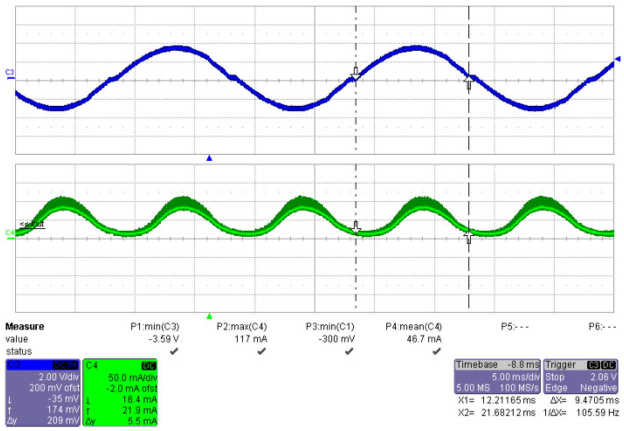

Figure 52 – 230 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

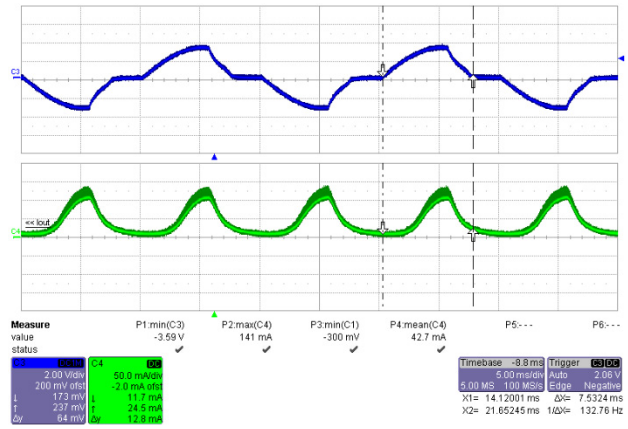

Figure 53 – 230 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

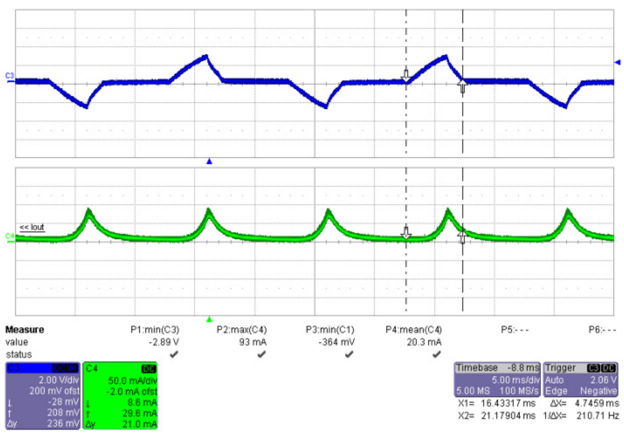

Figure 54 – 230 VAC, 50 Hz.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

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11.11 衰减电阻和泄放电阻上的电压波形

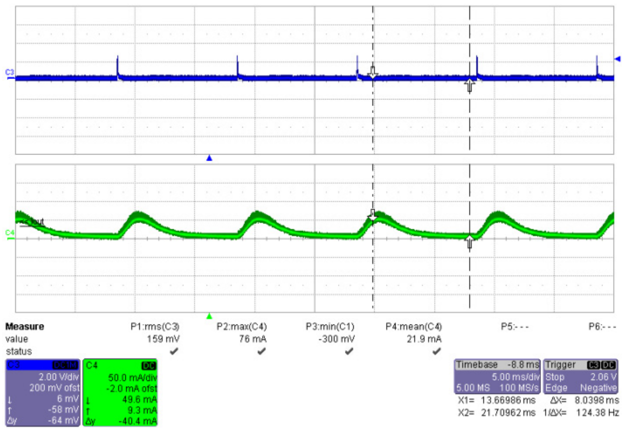

Figure 55 – 230 VAC, 50 Hz. at 90º Phase.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

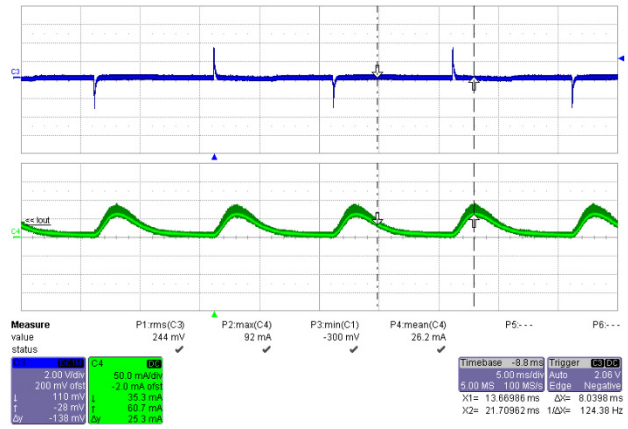

Figure 56 – 230 VAC, 50 Hz. at 90º Phase.
Upper: V_{IN}, 200 V / div.
Lower: I_{OUT}, 50 mA, 100 ms / div.

11.12 开路负载时的输出电压波形

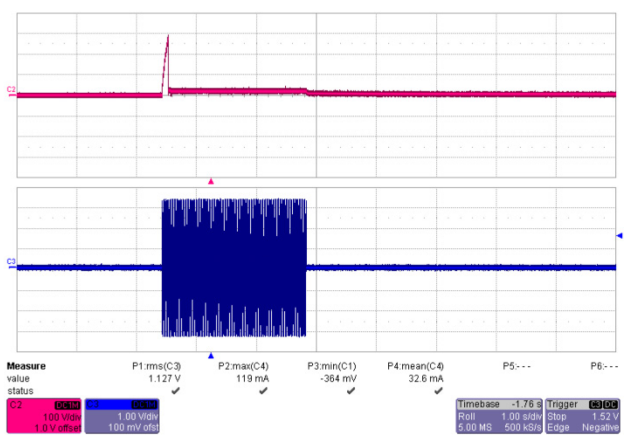

Figure 57 – 230 VAC, 50 Hz.
Upper: V_{OUT}, 100 V / div.
Lower: V_{IN}, 100 V, 1 s / div.

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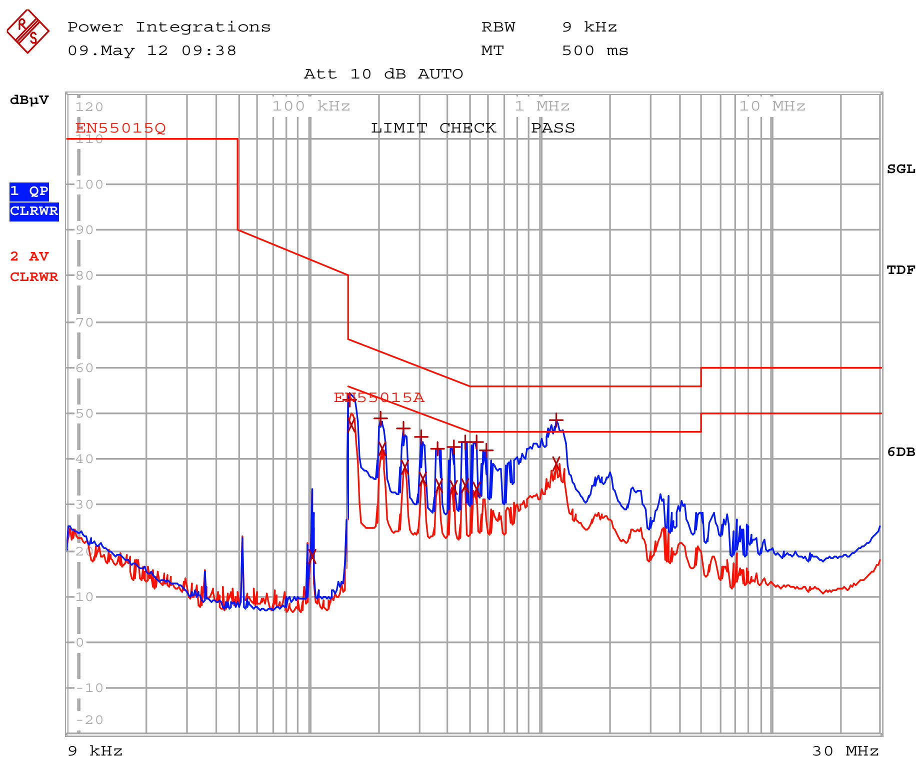
12 传导EMI


Power Integrations
09.May 12 09:38
RBW 9 kHz
MT 500 ms
Att 10 dB AUTO
dBµV
1 QP
CLRWR
2 AV
CLRWR
EN55015Q
LIMIT CHECK PASS
EN55015A
SGL
TDF
6DB
100 kHz
1 MHz
10 MHz
9 kHz
30 MHz

EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	104.063986756 kHz	18.68	L1 gnd	
1	Quasi Peak	151.5 kHz	53.02	L1 gnd	-12.89
2	Average	153.015 kHz	47.48	L1 gnd	-8.35
1	Quasi Peak	204.199110673 kHz	48.82	L1 gnd	-14.61
2	Average	208.303512797 kHz	42.37	N gnd	-10.89
1	Quasi Peak	256.711570318 kHz	46.55	N gnd	-14.98
2	Average	259.278686021 kHz	38.14	N gnd	-13.31
1	Quasi Peak	307.064896815 kHz	44.70	N gnd	-15.34
2	Average	310.135545783 kHz	35.71	N gnd	-14.25
1	Quasi Peak	360.057740611 kHz	42.33	N gnd	-16.39
2	Average	367.294901197 kHz	34.06	N gnd	-14.50
2	Average	422.19601758 kHz	33.88	N gnd	-13.52
1	Quasi Peak	426.417977756 kHz	42.72	N gnd	-14.60
1	Quasi Peak	475.741040231 kHz	43.81	N gnd	-12.59
2	Average	475.741040231 kHz	34.02	N gnd	-12.38
1	Quasi Peak	530.769219795 kHz	43.71	N gnd	-12.28
2	Average	530.769219795 kHz	33.30	N gnd	-12.69
1	Quasi Peak	586.299423673 kHz	41.93	N gnd	-14.06
1	Quasi Peak	1.17656420634 MHz	48.39	N gnd	-7.61
2	Average	1.17656420634 MHz	39.06	N gnd	-6.93

Figure 58 – Conducted EMI, 145 V LED Load, 230 VAC, 50 Hz, and EN55015 B Limits.

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13 版本历史

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

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