CRD1616-8W
8 Watt Reference Design

Features

- Quasi-resonant Flyback with Constant-current Output
- Flicker-free Dimming
- Line Voltage 207VAC - 253VAC
- Rated Output Power: 7W
- Efficiency: 82.5% at 250mA for 10×LEDs in Series
- Supports Cirrus Logic CS1616

General Description

The CRD1616-8W reference design demonstrates the performance of the CS1616 single stage dimmable AC/DC LED driver IC with a 250mA output driving 10×LEDs in series. It offers best-in-class dimmer compatibility with leading-edge, trailing-edge, and digital dimmers. The form factor is targeted to fit into many LED bulb applications (GU10, A19, PAR, BR).

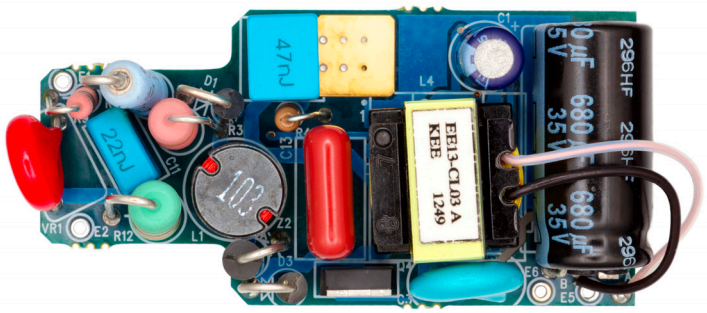
DIMENSIONS (OVERALL)

Length	Width	Height
2.028″(51.5*mm*) ×	1.004″(25.5*mm*) ×	0.65″(16.5*mm*)

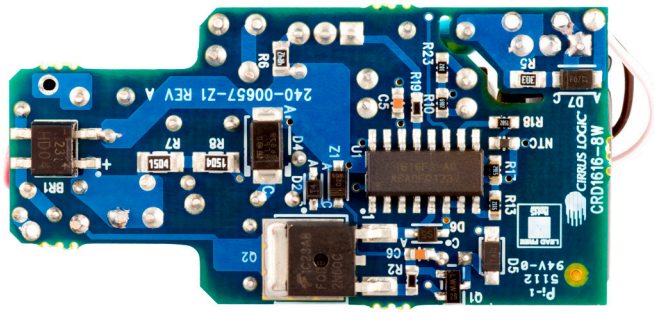
For more information, see Figure 3 on page 6.

ORDERING INFORMATION

CRD1616-8W-Z	8 Watt Reference Design Supports CS1616



Top



Bottom

IMPORTANT SAFETY INSTRUCTIONS

Read and follow all safety instructions prior to using this demonstration board.

This Engineering Evaluation Unit or Demonstration Board must only be used for assessing IC performance in a laboratory setting. This product is not intended for any other use or incorporation into products for sale.

This product must only be used by qualified technicians or professionals who are trained in the safety procedures associated with the use of demonstration boards.

DANGER Risk of Electric Shock

- The direct connection to the AC power line and the open and unprotected boards present a serious risk of electric shock and can cause serious injury or death. Extreme caution needs to be exercised while handling this board.
- Avoid contact with the exposed conductor or terminals of components on the board. High voltage is present on exposed conductor and it may be present on terminals of any components directly or indirectly connected to the AC line.
- Dangerous voltages and/or currents may be internally generated and accessible at various points across the board.
- Charged capacitors store high voltage, even after the circuit has been disconnected from the AC line.
- Make sure that the power source is off before wiring any connection. Make sure that all connectors are well connected before the power source is on.
- Follow all laboratory safety procedures established by your employer and relevant safety regulations and guidelines, such as the ones listed under, OSHA General Industry Regulations - Subpart S and NFPA 70E.

WARNING Suitable eye protection must be worn when working with or around demonstration boards. Always comply with your employer's policies regarding the use of personal protective equipment.

WARNING All components and metallic parts may be extremely hot to touch when electrically active.

Contacting Cirrus Logic Support

For all product questions and inquiries contact a Cirrus Logic Sales Representative. To find the one nearest to you go to www.cirrus.com

1. INTRODUCTION

The CS1616 is a 230VAC quasi-resonant flyback mode dimmable LED controller IC. The CS1616 uses a digital control algorithm that is optimized for high efficiency and >0.9 power factor over a wide input voltage range (207VAC to 253VAC). The CS1616 integrates a dimmer compatibility circuit with a constant output current, quasi-resonant flyback stage. An adaptive dimmer compatibility algorithm controls the dimmer compatibility operation mode to enable flicker-free operation from 0% to 100% output current with leading-edge, trailing-edge, and digital dimmers.

The CRD1616-8W board is optimized to deliver low system cost in a high-efficiency, flicker-free, phase-dimmable, solid-state lighting (SSL) solution for incandescent lamp replacement applications. The feedback loop is closed through an integrated digital control system within the IC. Protection algorithms such as output open/short, current-sense resistor open/short, and overtemperature thermistors protect the system during abnormal conditions. When using the CS1616 for a design that does not require active clamp circuitry, the CLAMP pin should be left floating. Details of these features are provided in the CS1616/16 data sheet DS961 *Single Stage Dimmable Offline AC/DC Controller for LED Lamps*.

The CRD1616-8W board demonstrates the performance of the CS1616. This reference board has been designed for an output load of 10×LEDs in series at 250mA (~28V typical).

This document provides the schematic for the board. It includes oscilloscope screen shots that indicate various operating waveforms. Graphs are also provided that document the performance of the board in terms of Efficiency vs. Line Voltage, Output Current vs. Line Voltage, and Output Current vs. Dim Angle for the CS1616 dimmable LED controller IC.

Extreme caution needs to be exercised while handling this board. This board is to be used by trained professionals only.

2. SCHEMATIC

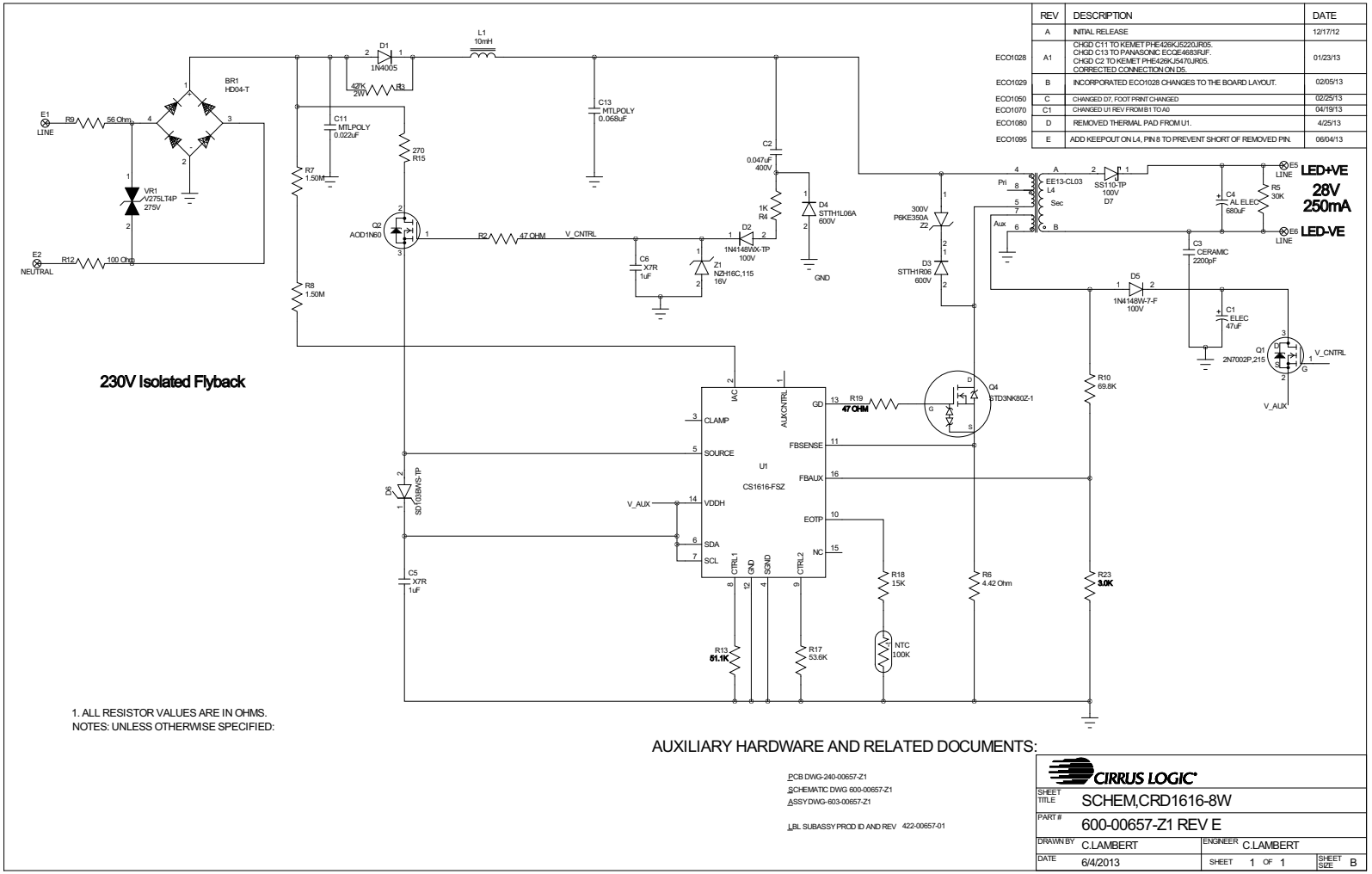


Figure 1. Schematic

3. BILL OF MATERIALS

Item	Rev	Description	Qty	Reference Designator	MFG	MFG P/N
1		DIODE RECT 400V 0.8A NPB MINIDIP	1	BR1	DIODES INC	HD04-T
2		CAP 47uF ±20% 35V AL ELEC NPb RAD	1	C1	KEMET	ESK476M035AC3AA
3		CAP 0.047uF ±5%LS 400V MTL NPb RAD	1	C2	KEMET	PHE426KJ5470JR05
4	A	CAP 2200pF ±10% 2KV CERAMIC NPb TH	1	C3	MURATA	DEBB33D222KA2B
5		CAP 680uF ±20% 35V AL ELEC NPb RAD	1	C4	PANASONIC	EEUFR1V681
6		CAP 1uF ±10% 25V X7R CER NPb 0603	2	C5 C6	TDK	CGA3E1X7R1E105K
7		CAP 0.022uF ±5%LS 400V MTL NPb RAD	1	C11	KEMET	PHE426KJ5220JR05
8		CAP 0.068uF ±5%LS 400V MTL NPb RAD	1	C13	PANASONIC	ECQE4683RJF
9		DIODE RECT 600V 1A 50mA NPb DO-41	1	D1	DIODES INC	1N4005
10		DIODE HS SWT 100V 300mA NPb SOD323	1	D2	MICRO COMMERCIAL	1N4148WX-TP
11		DIODE FAST 600V 1A NPb DO-41	1	D3	ST	STTH1R06
12		DIODE ULT FAST 600V 1A NPb SMA	1	D4	ST MICROELECTRONICS	STTH1L06A
13		DIODE FAST SW 100V 400mW NPb SOD123	1	D5	DIODES INC	1N4148W-7-F
14		DIODE SCHOTTKY 350mA 30V NPb SOD323	1	D6	MICRO COMMERCIAL	SD103BWS-TP
15		DIODE SKY RECT 100V 1A NPb DO-214AC	1	D7	MCC	SS110-TP
16		NO POP PAD H40 P64 NPb TH	4	E1 E2 E5 E6	NO POP	NP-PAD-H40P64
17		IND 10mH ±10% 34OHM NPb 350DIA TH	1	L1	COILCRAFT	RFB0807-103L
18		XFMR 4.0mH ±10% 10KHz NPb TH	1	L4	KUNSHAN EAGERNESS	EE13-CL03
19		THERM 100K OHM ±5% 0.10mA NPb 0603	1	NTC	MURATA	NCP18WF104J03RB
20		TRAN MSFET nCH 60V 360mA NPb SOT-23	1	Q1	NXP	2N7002P,215
21		TRAN MOSFET nCH 1.3A 600V NPb DPAK	1	Q2	ALPHA & OMEGA	AOD1N60
22		TRAN MOSFET nCH 2.5A 800V NPb IPAK	1	Q4	ST MICROELECTRONICS	STD3NK80Z-1
23		RES 47 OHM 1/10W ±1% NPb 0603	2	R2 R19	PANASONIC	ERJ3EKF47R0V
24		RES 4.7K OHM 2W 5% MTL FILM NPb AXL	1	R3	YAGEO	FMP200JR-52-4K7
25		RES 1k OHM 1/2W ±5% CARFL NPb AXL	1	R4	STACKPOLE ELECTRONICS	CFM12JT1K00
26		RES 30K OHM 1/8W ±0.1% NPb 0805	1	R5	PANASONIC	ERA-6YEB303V
27		RES 4.42 OHM 1/8W ±1% NPb 0805 FLM	1	R6	YAGEO	RC0805FR-074R42L
28		RES 1.50M OHM 1/4W ±1% NPb 1206	2	R7 R8	PANASONIC	ERJ8ENF1504V
29		RES 56 OHM 1W 5% MTL FILM NPb AXL	1	R9	YAGEO	FMP100JR-52-56R
30		RES 69.8k OHM 1/10W ±1% NPb 0603	1	R10	DALE	CRCW060369K8FKEA
31		RES 100 OHM 2W 5% FUSIBLE WW NPb AX	1	R12	YAGEO	FKN2WSJR-73-100R
32		RES 51.1k OHM 1/10W±1% NPb 0603 FLM	1	R13	DALE	CRCW060351K1FKEA
33		RES 270 OHM 2W ±5% MTL FLM NPb AXL	1	R15	PANASONIC	ERG2SJ271
34		RES 53.6k OHM 1/10W±1% NPb0603 FILM	1	R17	DALE	CRCW060353K6FKEA
35		RES 15k OHM 1/10W ±1% 0603 FILM	1	R18	DALE	CRCW060315K0FKEA
36		RES 3k OHM 1/10W ±5% NPb 0603 FILM	1	R23	DALE	CRCW06033K00JNEA
37	A0	IC CRUS TRIAC DIM PFC 230V NPb SO16	1	U1	CIRRUS LOGIC	CS1616-FSZ/A0
38		VARISTOR 275V 80pF 23J 7mm NPb RAD	1	VR1	LITTELFUSE	V275LT4P
39		DIODE ZENER 500mW 16V NPb SOD123F	1	Z1	NXP	NZH16C,115
40		DIODE TVS 300V 600W NPb DO-204AC	1	Z2	LITTELFUSE	P6KE350A

Figure 2. Bill of Materials

4. BOARD LAYOUT

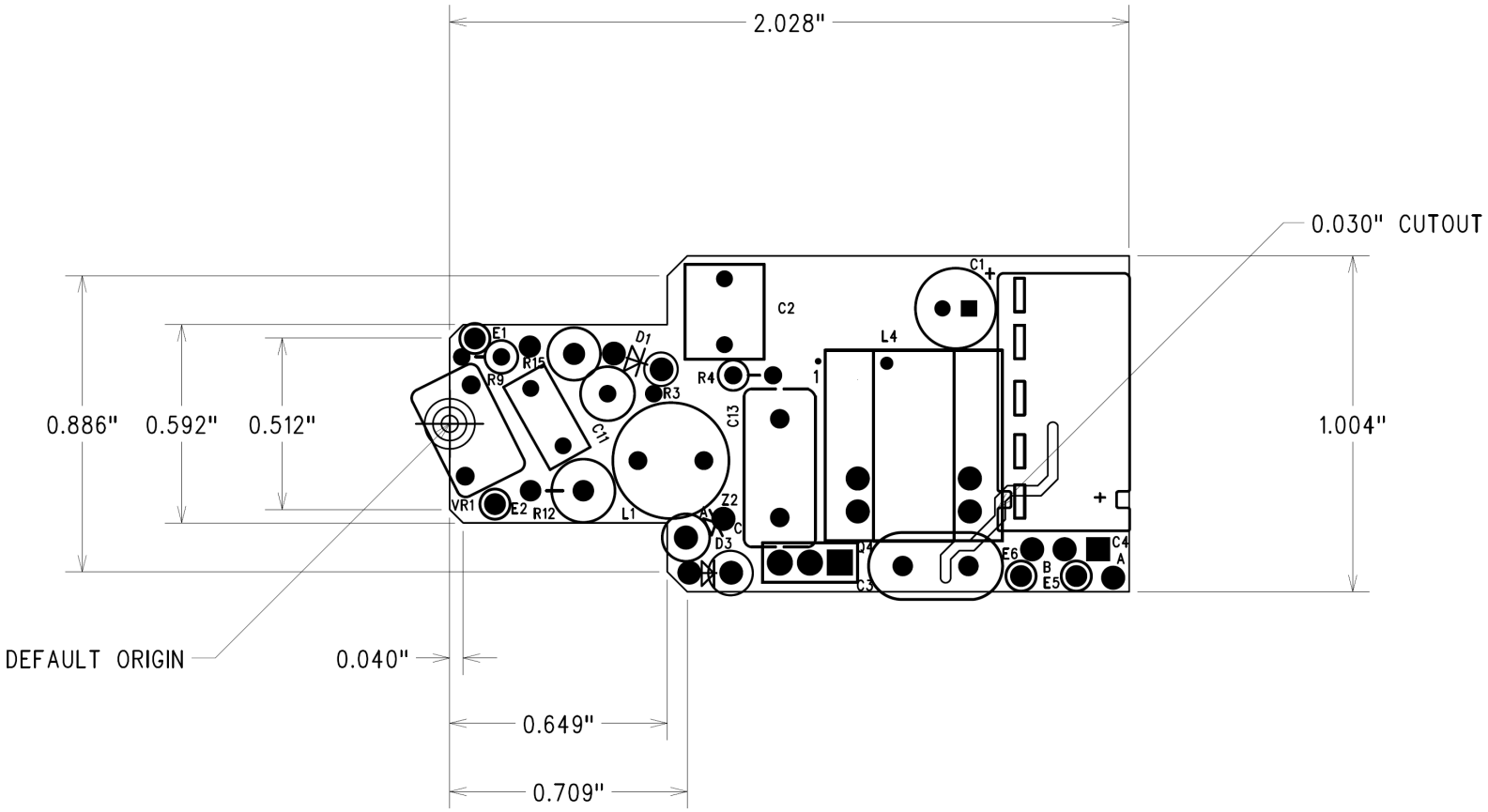


Figure 3. PCB Dimensions

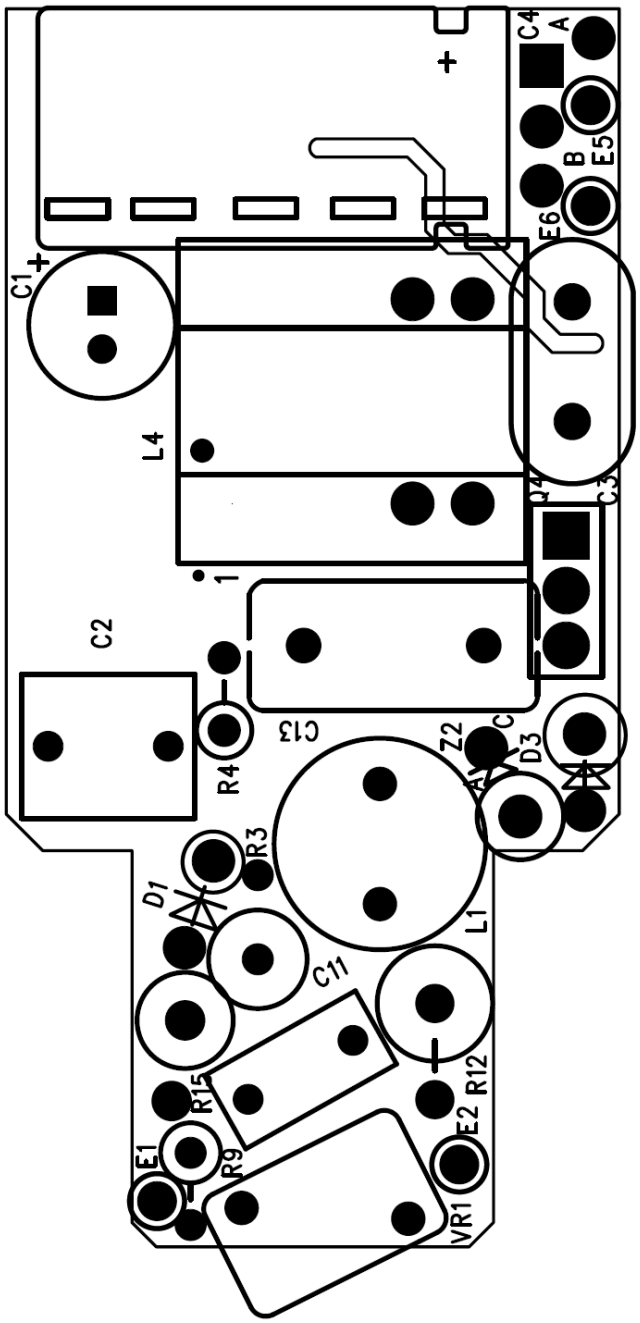


Figure 4. Top Silkscreen

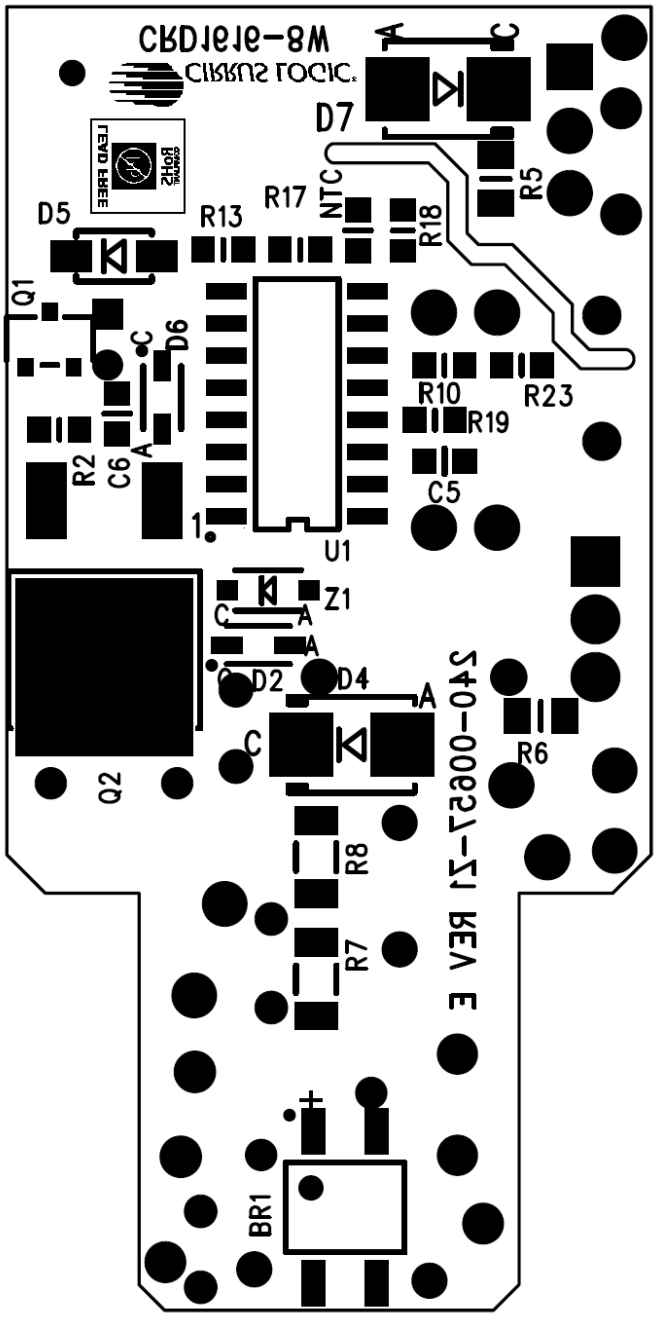


Figure 5. Bottom Silkscreen

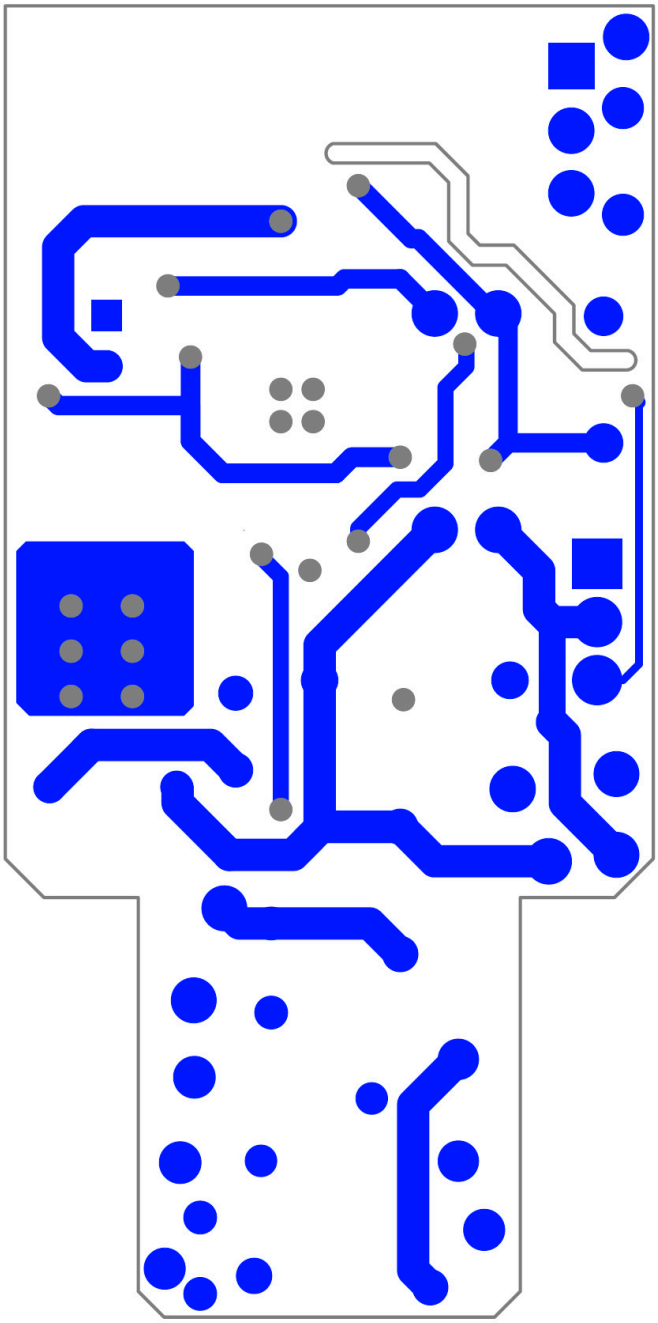


Figure 6. Top Routing

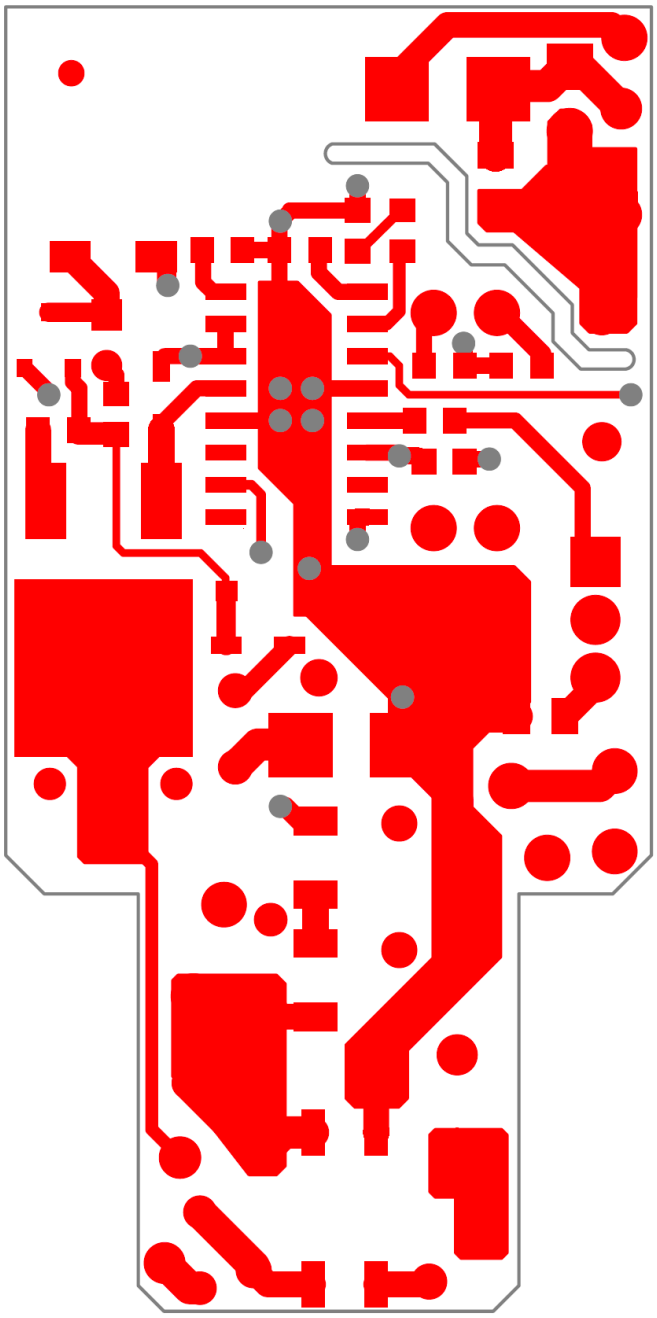


Figure 7. Bottom Routing

5. THERMAL IMAGING

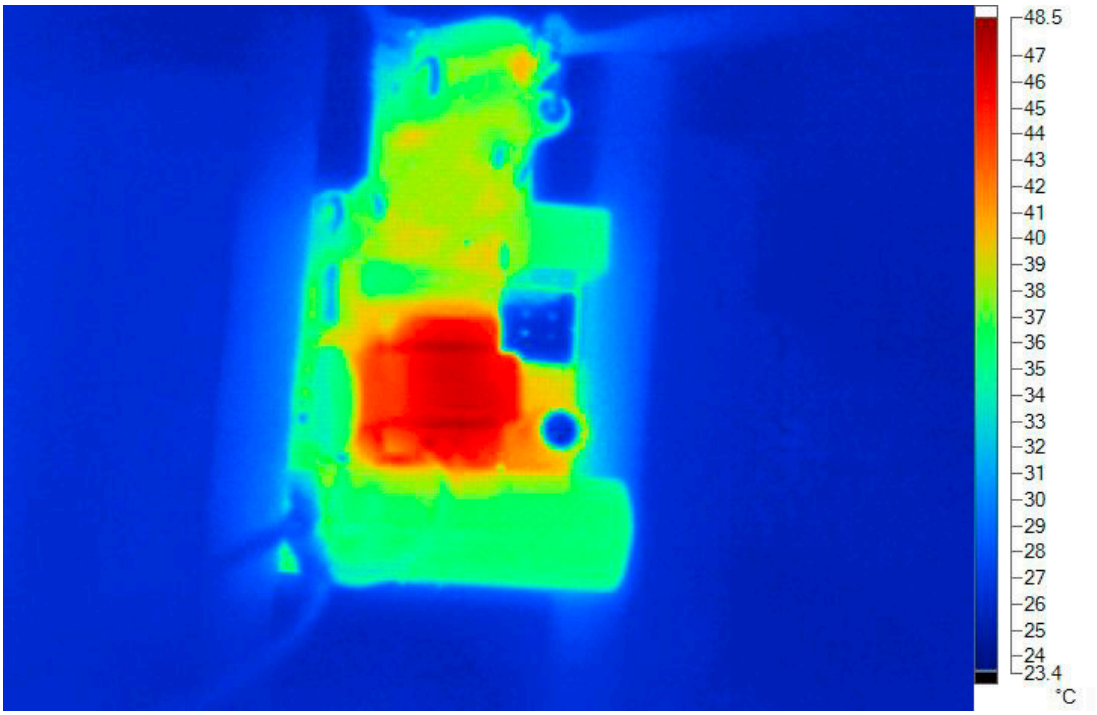


Figure 8. Top Thermal

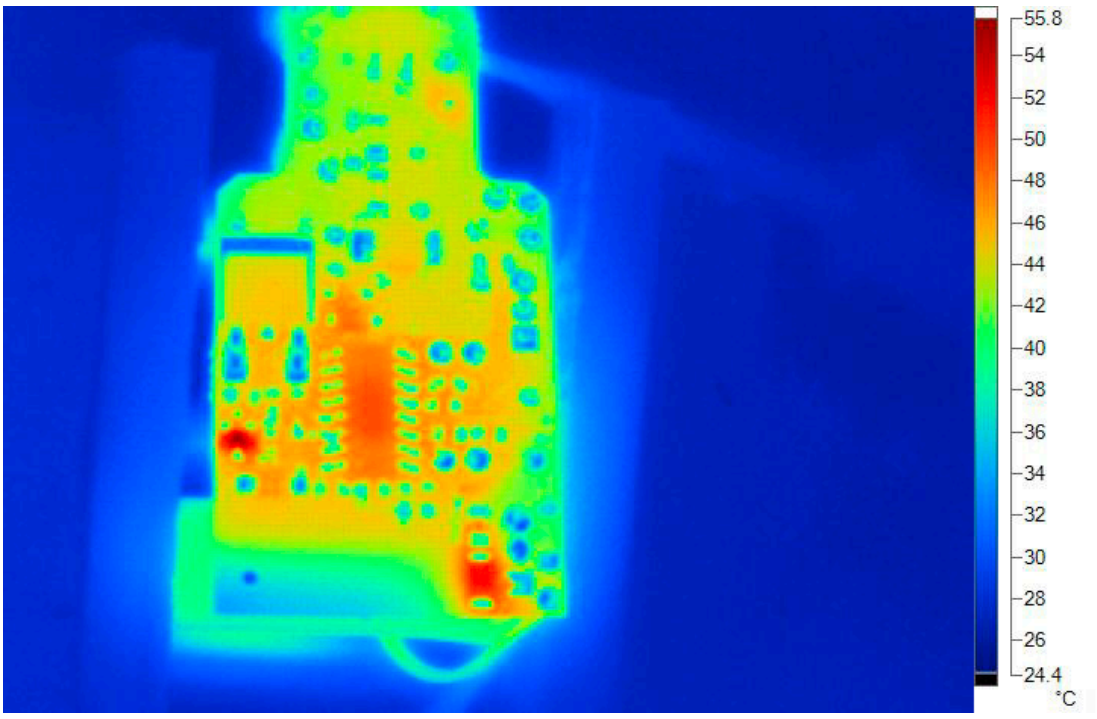


Figure 9. Bottom Thermal

6. DIMMER COMPATIBILITY - A19 WITH CS1616 (230V/50HZ)

Input Power	8.34W	Dimmer Compatibility	718/864	Efficiency	81.7%

Date	1/14/2013	**Power Factor[1,5]**	0.95
Vendor	Cirrus Logic	**EN55015 Compliant (Y/N)**	Y
Input Voltage	230V/50Hz	**Nominal Input Power (W)[1,5]**	8.34
Form Factor	A19	**Maximum Input Power (W)[1,5]**	8.5
Model #	CRD1616-8W	**Output Voltage (V)[1,3]**	27.51
IC	CS1616	**Output Current (mA)[1,3]**	248
Topology	Flyback	**Output Current Ripple ≤ 120Hz (mA_{p-p})[1,4]**	200
Isolation (Y/N)	Y	**Output Power (W)[1,5]**	6.82
Compatibility Spec.	1.0	**Efficiency (%)**	81.3

Dimmer Type	Flicker Free Steady-state			Monotonic Dimming			Max I_{OUT} (mA)			Min I_{OUT} (mA)			Total
	# of Lamps			# of Lamps			# of Lamps			# of Lamps			
	1	5	10	1	5	10	1	5	10	1	5	10	
Berker - Leading Edge	N	Y	N	Y	Y	Y	-	249	-	8	2	7	12
Bticino - Trailing Edge	N	Y	Y	Y	Y	Y	120	113	110	3	3	3	16
Bull - Leading Edge	Y	N	N	Y	Y	Y	251	248	249	3	3	3	14
Busch - Leading Edge	Y	Y	Y	Y	Y	Y	250	249	249	3	3	3	24
Busch - Trailing Edge	Y	Y	Y	N	Y	Y	249	247	248	2	2	2	23
Busch - Trailing Edge	Y	Y	Y	N	Y	Y	249	248	248	2	2	2	23
Chint - Leading Edge	N	Y	Y	Y	Y	N	-	245	246	3	3	3	17
Chisen - Leading Edge	Y	Y	Y	Y	Y	Y	249	248	249	3	3	3	24
Chisen - Leading Edge	Y	Y	Y	Y	Y	Y	248	248	248	3	3	3	24
Clipsal - Trailing Edge	N	Y	Y	Y	Y	Y	-	249	248	2	2	2	18
Clipsal - Trailing Edge	Y	Y	Y	Y	Y	Y	248	246	248	2	2	2	24
Clipsal - Leading Edge	Y	Y	Y	Y	Y	Y	250	249	249	3	3	3	24
CLSEN - Leading Edge	Y	Y	Y	Y	Y	Y	247	247	250	3	3	3	24
Cshyh - Leading Edge	Y	Y	N	Y	Y	Y	249	247	250	4	3	3	19
Dbang - Leading Edge	Y	Y	Y	Y	Y	Y	248	246	249	3	3	3	24
Elro - Twilight Sensor	Y	Y	Y	Y	Y	Y	243	245	246	0	0	0	24
Elro - Motion Detector	Y	Y	Y	Y	Y	Y	243	245	246	0	0	0	24
Futina - Leading Edge	Y	Y	Y	Y	Y	Y	244	248	247	3	3	3	24
Gira - Leading Edge	N	N	N	Y	Y	Y	249	250	248	3	3	3	9
HPM - Trailing Edge	Y	Y	Y	N	Y	N	220	216	211	2	2	2	19
Jung - Leading Edge	Y	N	Y	Y	Y	Y	249	249	249	2	10	2	19
Legrand - Trailing Edge	Y	Y	Y	Y	Y	Y	75	73	73	2	2	2	21
Leiben - Leading Edge	Y	Y	Y	Y	Y	Y	249	247	248	3	3	3	24

Dimmer Type	Flicker Free Steady-state			Monotonic Dimming			Max I_{OUT} (mA)			Min I_{OUT} (mA)			Total
	# of Lamps			# of Lamps			# of Lamps			# of Lamps			
	1	5	10	1	5	10	1	5	10	1	5	10	
Lonon - Leading Edge	Y	Y	Y	Y	Y	Y	248	248	251	3	3	3	24
Lutron - Leading Edge	Y	N	N	Y	Y	Y	249	248	249	3	3	3	14
Lutron - Leading Edge	Y	Y	N	Y	Y	Y	244	245	246	3	3	3	19
MK - Leading Edge	Y	N	N	Y	Y	Y	250	251	250	3	3	3	14
N&L - Trailing Edge	N	Y	Y	N	N	N	213	209	202	2	3	2	13
Opus - Leading Edge	Y	Y	N	Y	Y	Y	249	248	249	3	3	3	19
Siemens - Leading Edge	Y	Y	N	Y	Y	Y	247	247	249	3	3	2	19
Songri - Leading Edge	Y	Y	Y	Y	Y	Y	248	248	249	3	3	3	24
T&J - Leading Edge	Y	Y	N	Y	Y	Y	248	248	249	3	3	3	19
T&J - Leading Edge	Y	Y	Y	Y	Y	Y	250	248	250	3	3	3	24
TCL - Leading Edge	N	Y	N	Y	N	Y	-	243	246	3	3	3	12
TNC - Leading Edge	Y	Y	N	Y	Y	Y	247	247	248	3	3	3	19
Wuyun - Trailing Edge	Y	Y	Y	Y	Y	Y	249	250	247	3	2	2	24
												Overall Total	718

Notes:
1. Tested at nominal input voltage, nominal input frequency, and without a dimmer, after soaking for 15 minutes
2. Compliant with IEC 61000-3-2 Class C < 25W
3. Average
4. Peak-to-peak
5. Measured with Chroma 66202 Power Analyzer

7. INDUCTOR CONSTRUCTION

The CRD1616-8W provides power factor correction and dimmer compatibility with a constant output current, quasi-resonant flyback stage. The following sections describe the flyback transformer installed on the CRD1616-8W.

7.1 Flyback Transformer

The flyback transformer stage is a quasi-resonant peak current-regulated DC-DC converter capable of delivering the highest possible efficiency with constant current output while minimizing line frequency ripple. The auxiliary winding is used for zero-current detection and overvoltage protection.

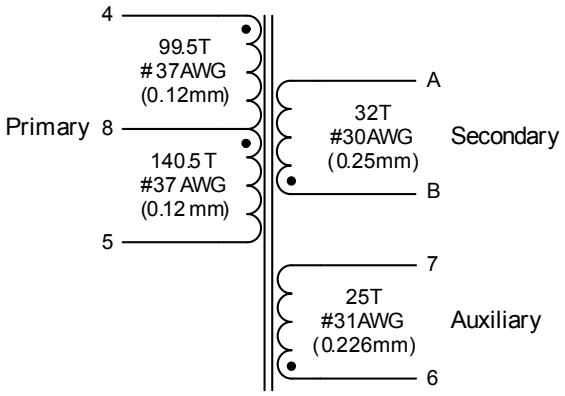


Figure 10. Flyback Transformer Schematic

7.1.1 Electrical Specifications

Characteristics conditions:

- Operating temperature range: -25 °C to +120 °C (including coil heat)

Parameter		Condition	Sym	Min	Typ	Max	Unit
Flyback Transformer							
Electrical Strength	(Note 1)	$f_{operate}$=50/60Hz		-	1200	-	V_{RMS}
Primary Inductance	(Note 2)	$f_{resonant}$=10kHz, 0.3V at 20°C	L_P	3.6	4.0	4.4	mH
Primary Leakage Inductance	(Note 2)	$f_{resonant}$=10kHz, 0.3V at 20°C	L_K	-	-	80	µH
Primary DC Resistance	(Note 2)	t_{DCR}=20°C		8.8	11	13.2	Ω
Secondary DC Resistance	(Note 3)	t_{DCR}=20°C		-	-	0.372	Ω
Auxiliary DC Resistance	(Note 4)	t_{DCR}=20°C		0.304	0.38	0.456	Ω

Notes:
1. Time = 2sec.
2. Measured across pins 4 and 5.
3. Measured across pins B and A.
4. Measured across pins 6 and 7.

8. PERFORMANCE PLOTS

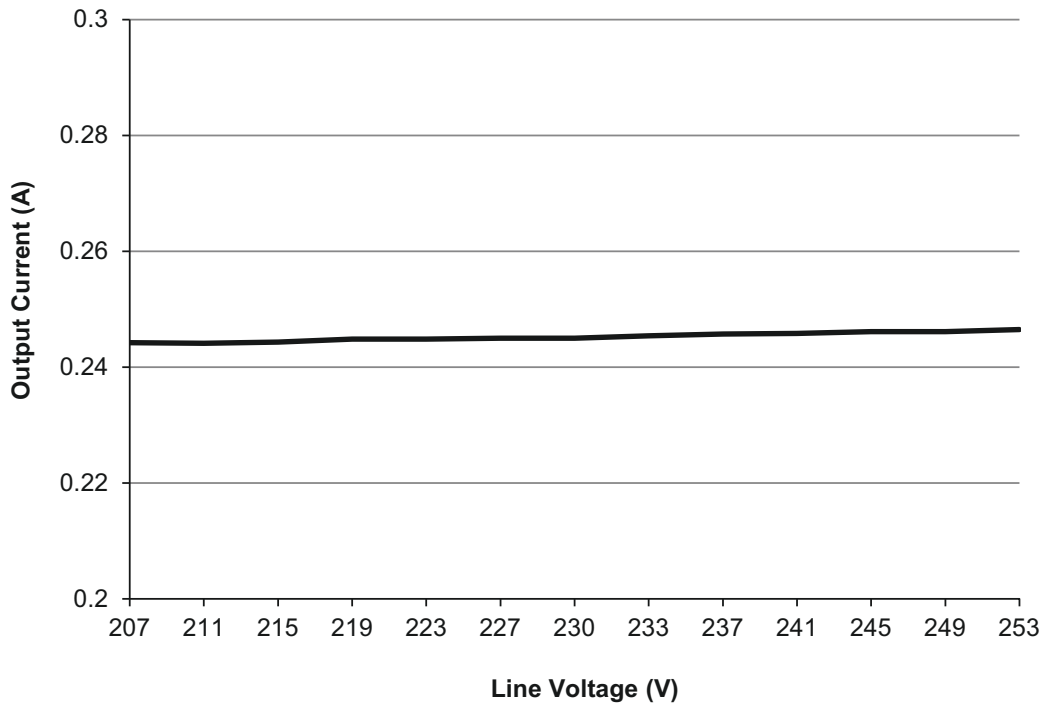


Figure 11. Output Current vs Line Voltage

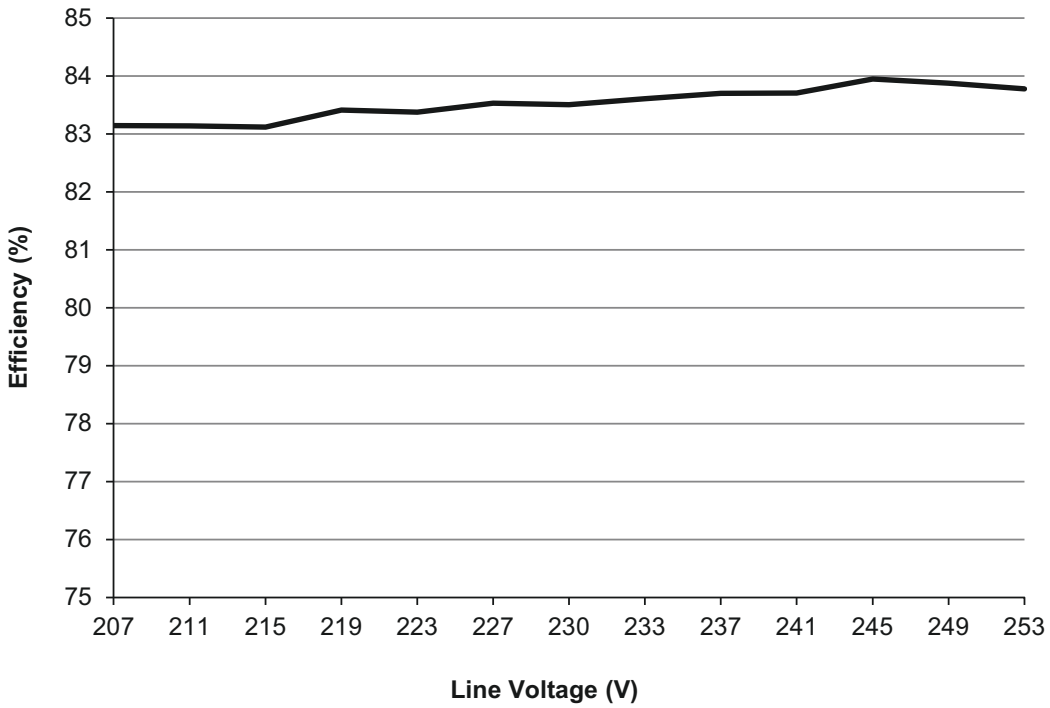


Figure 12. Typical Efficiency vs Line Voltage

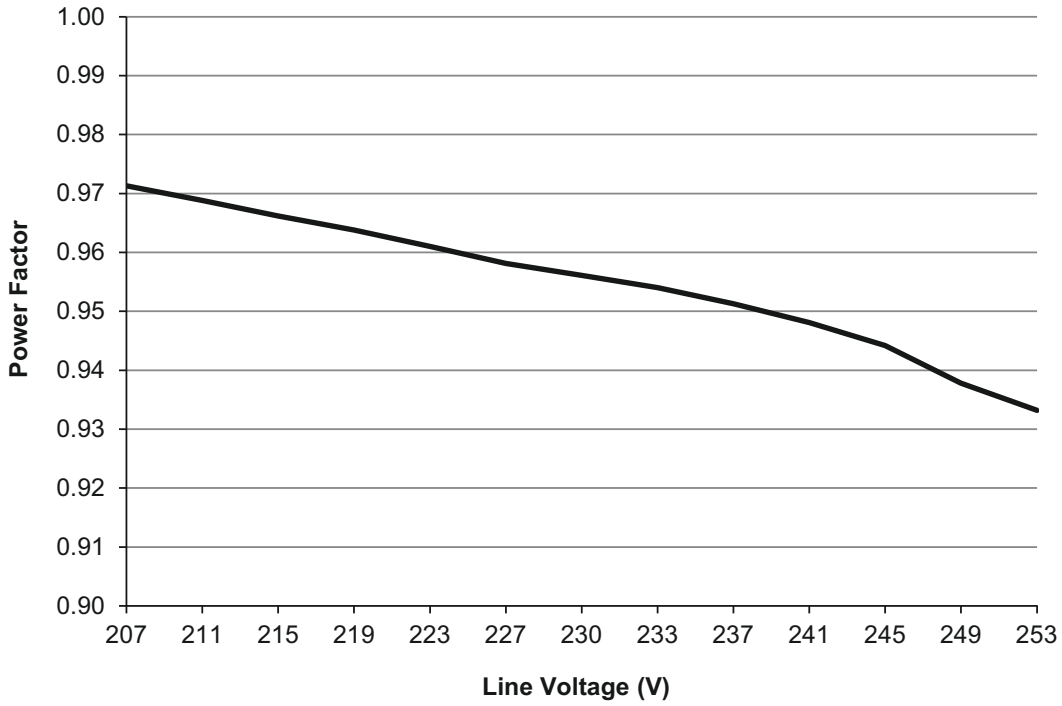


Figure 13. Power Factor vs Line Voltage

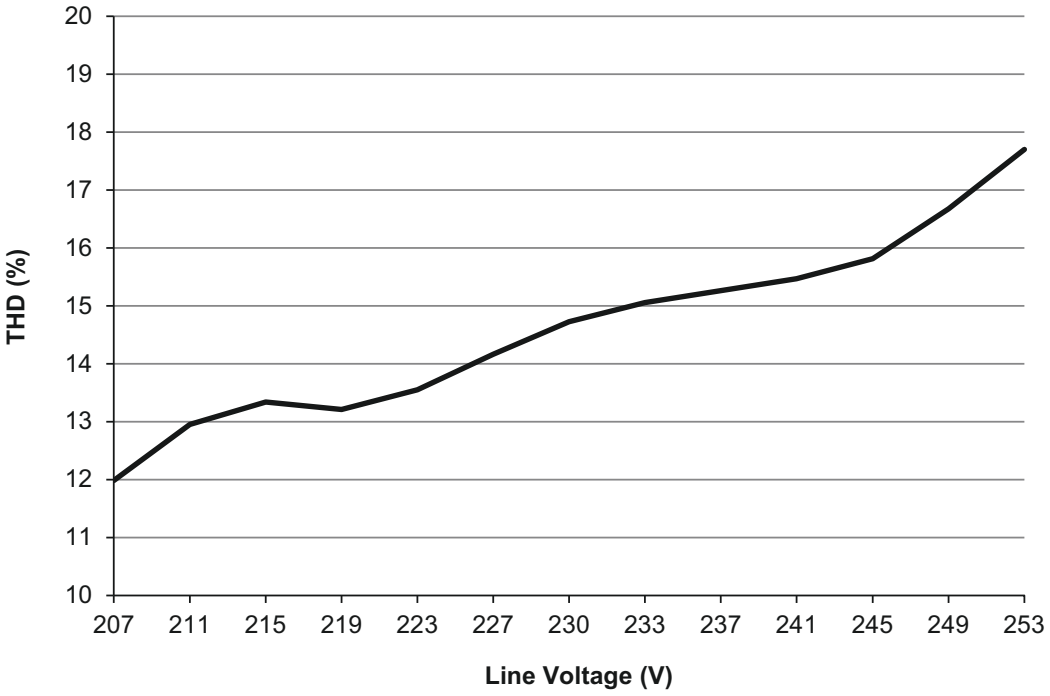


Figure 14. THD vs Line Voltage

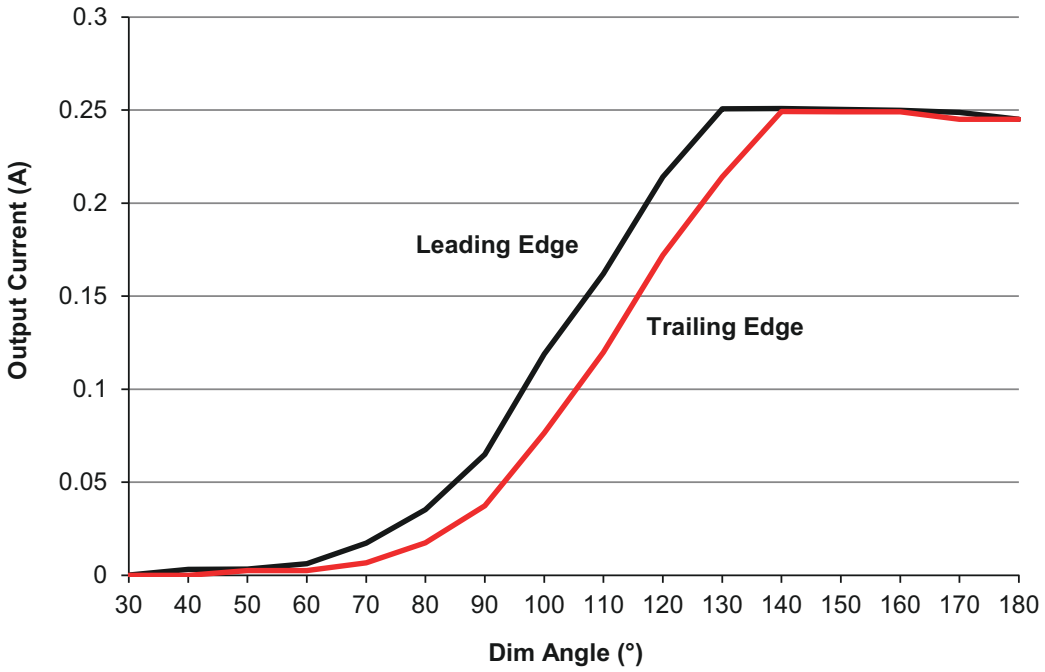


Figure 15. Typical Output Current vs Dim Angle

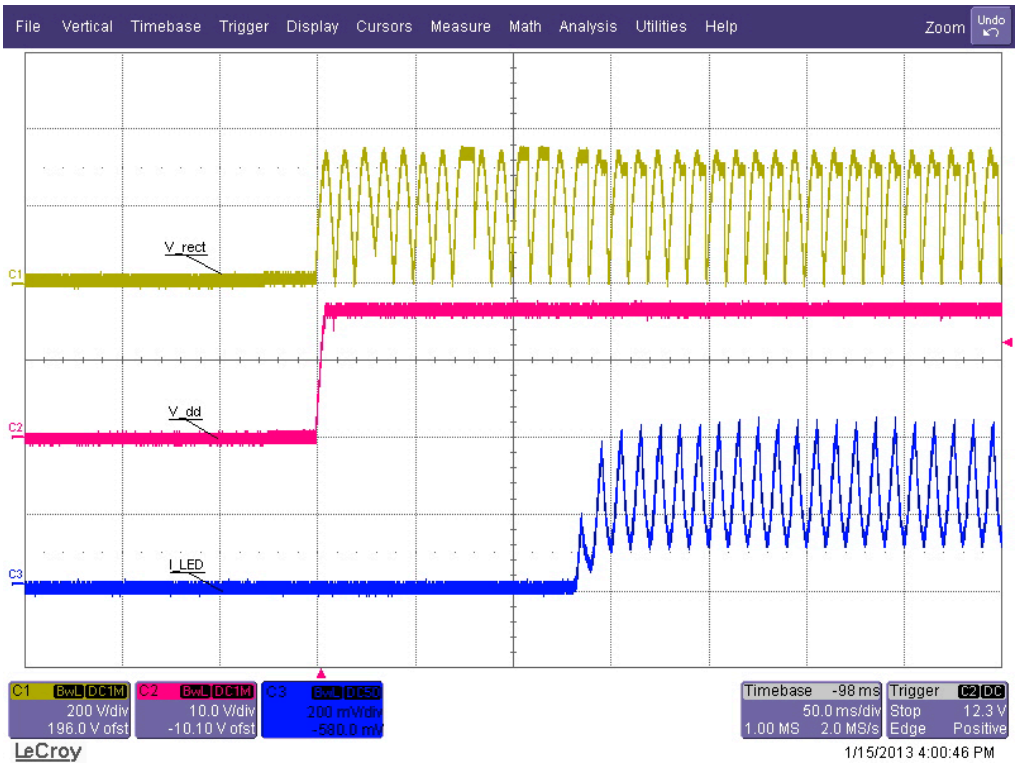


Figure 16. No-dimmer Mode, Startup, 230 VAC

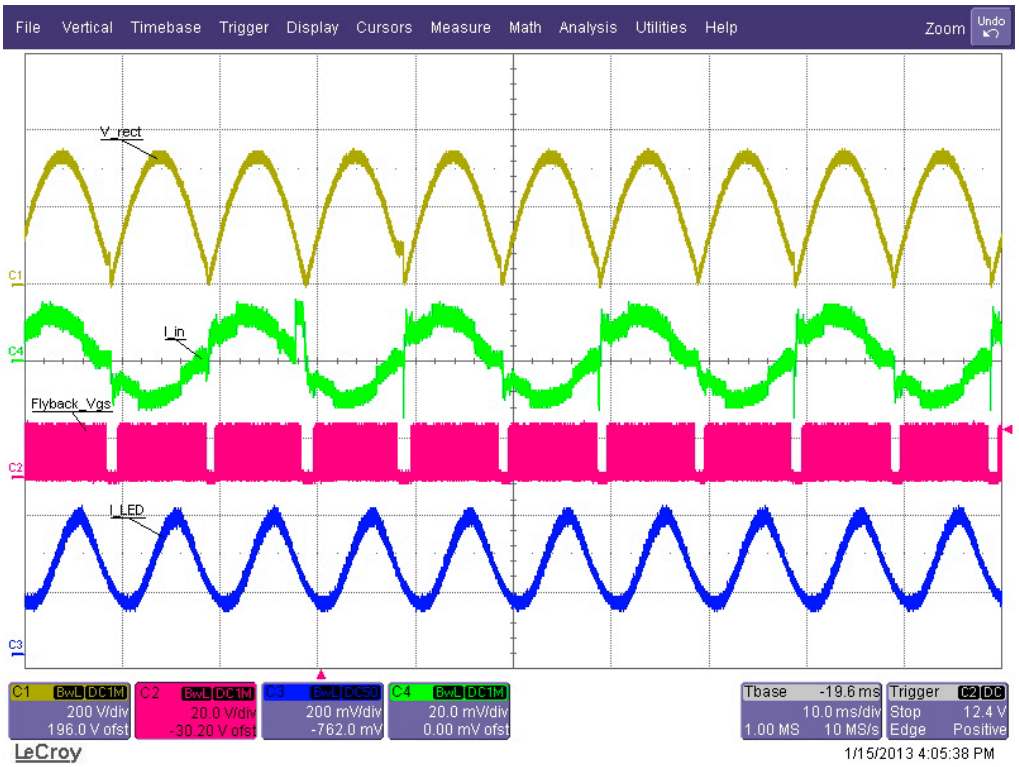


Figure 17. No-dimmer Mode, Steady-state, 230 VAC

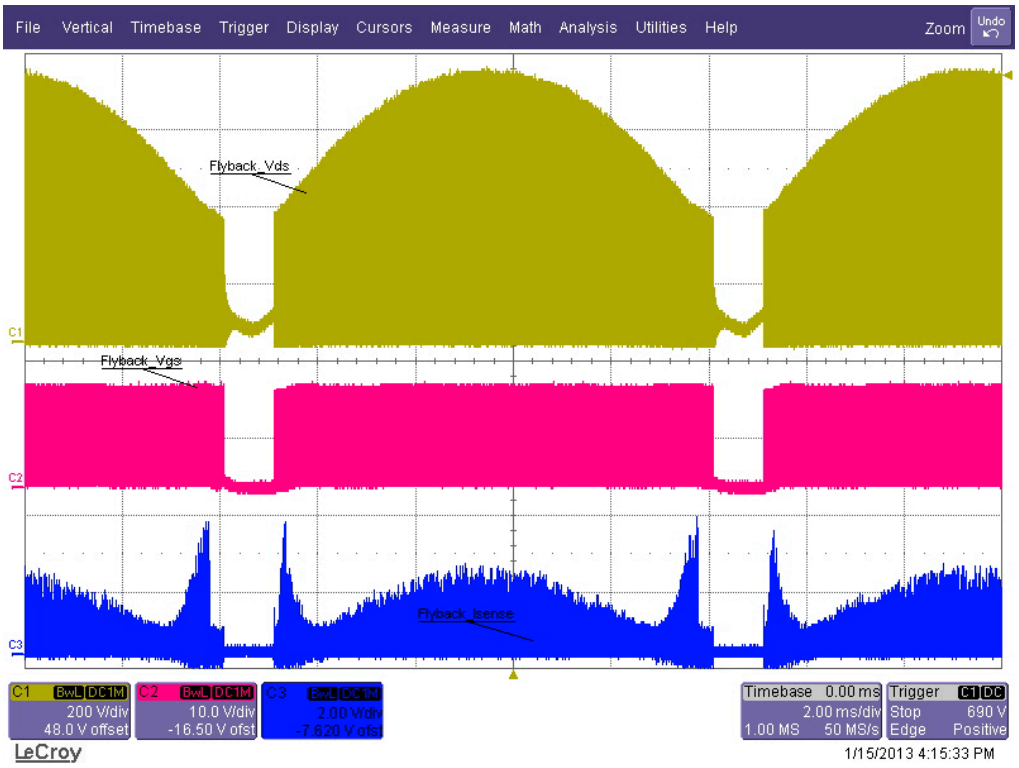


Figure 18. Flyback FET Q3, 230VAC

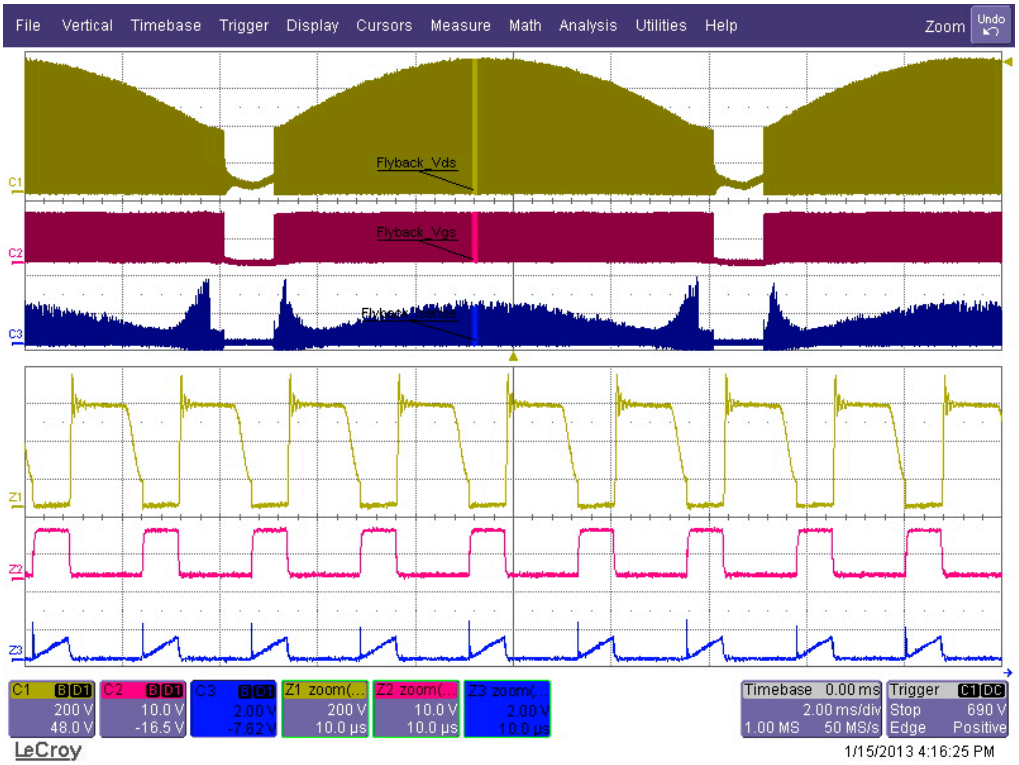


Figure 19. Flyback FET Q3, 230VAC (with Zoom In)

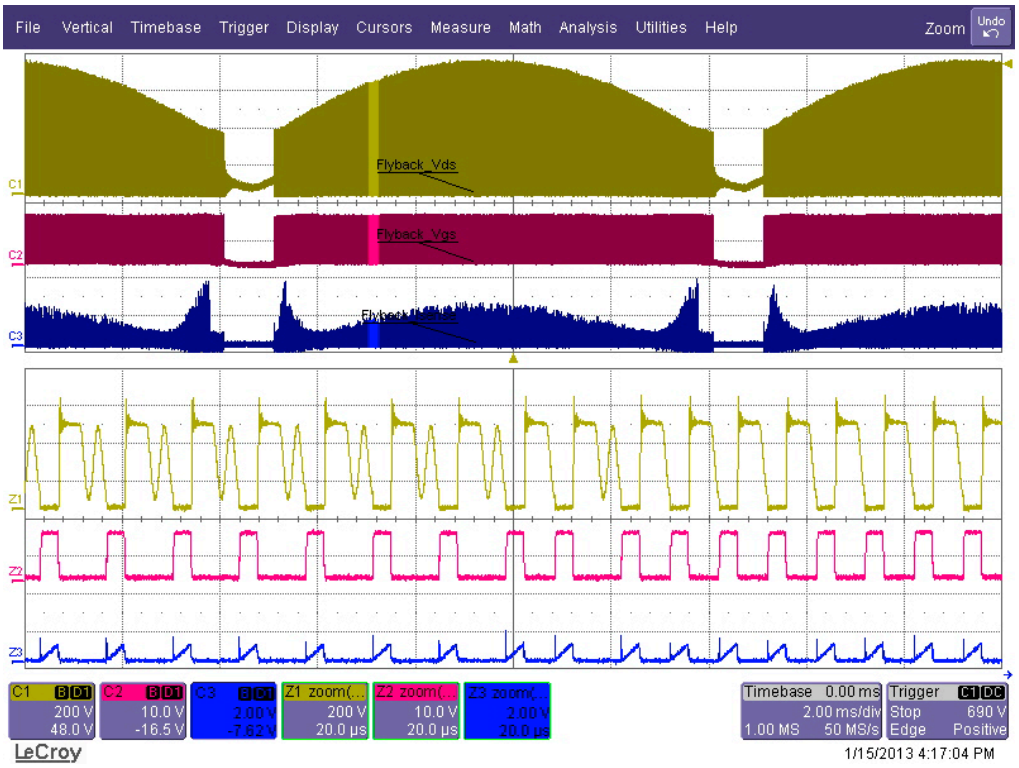


Figure 20. Flyback FET Q3, 230VAC (with Zoom In)

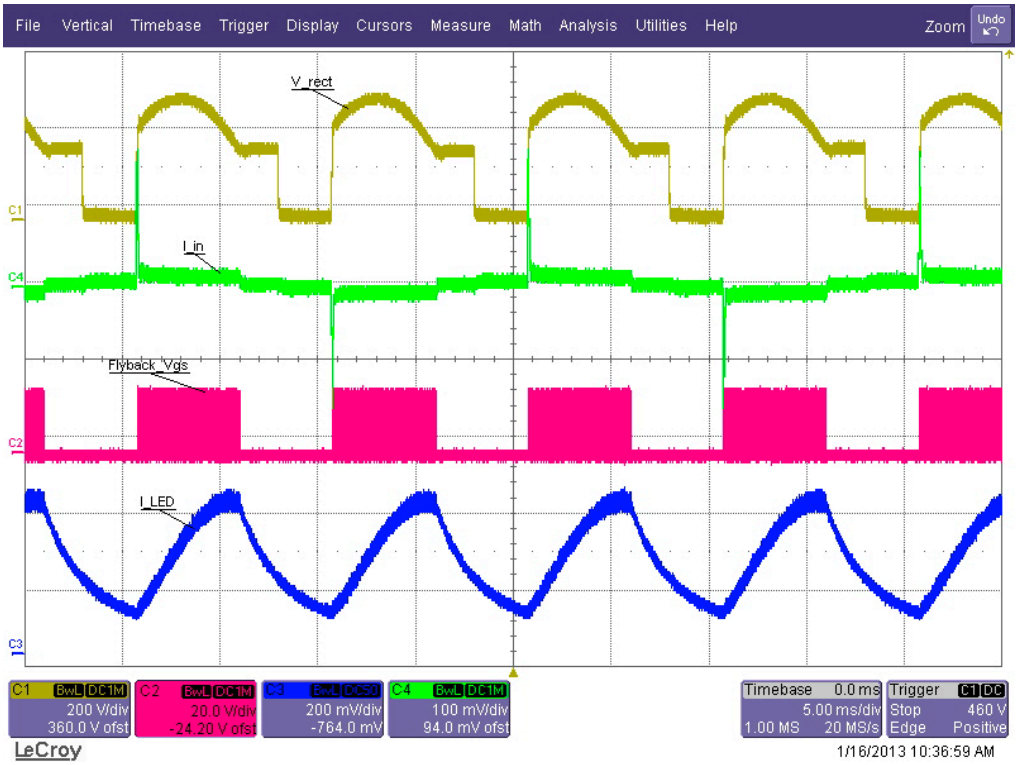


Figure 21. Leading-edge Dimmer Mode, Steady-state, 230VAC

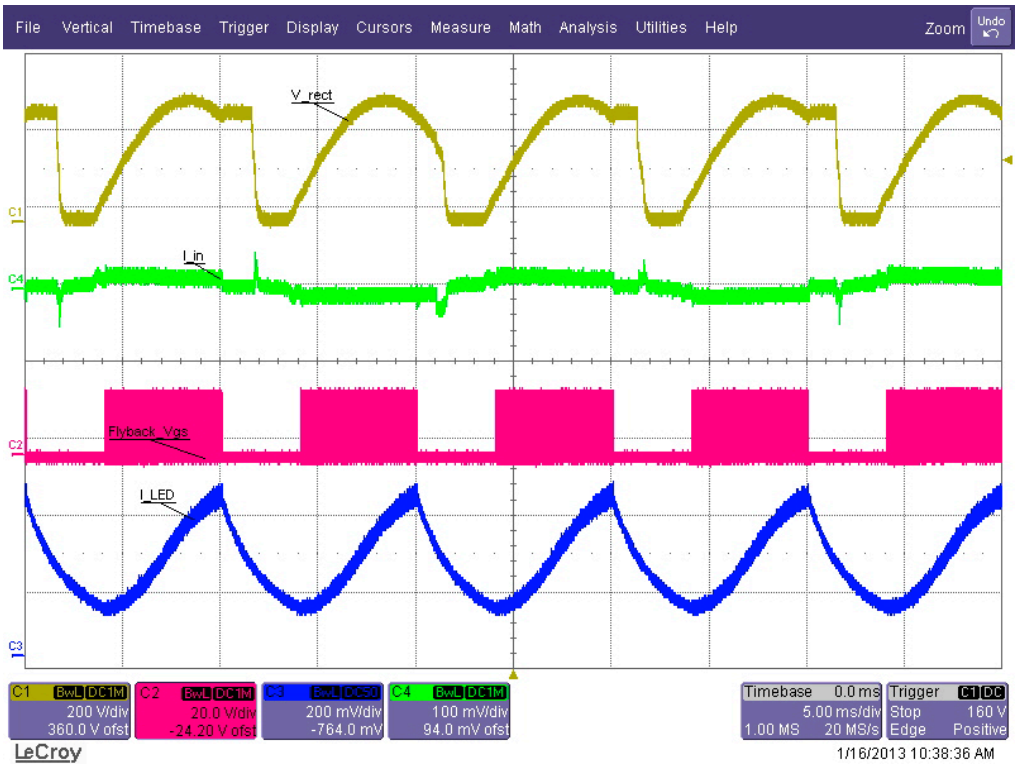


Figure 22. Trailing-edge Dimmer Mode, Steady-state, 230VAC

9. CONDUCTED EMI

Device Under Test: CRD1616-8W-Z
Operating Conditions: NOMINAL
Test Specification: EN55022:2010
Operator Name: CAL

Scan Settings (1 Range)

Frequencies			Receiver Settings			
Start	***Stop***	***Step***	***Res BW***	***M-Time***	***Atten***	***Preamp***
150kHz	30MHz	4.5kHz	9kHz (6dB)	50ms	Auto	Off

Final Measurement

Detectors: QP, AV **Peaks:** 25 **Meas Time:** See scan settings **Acc. Margin:** 12dB

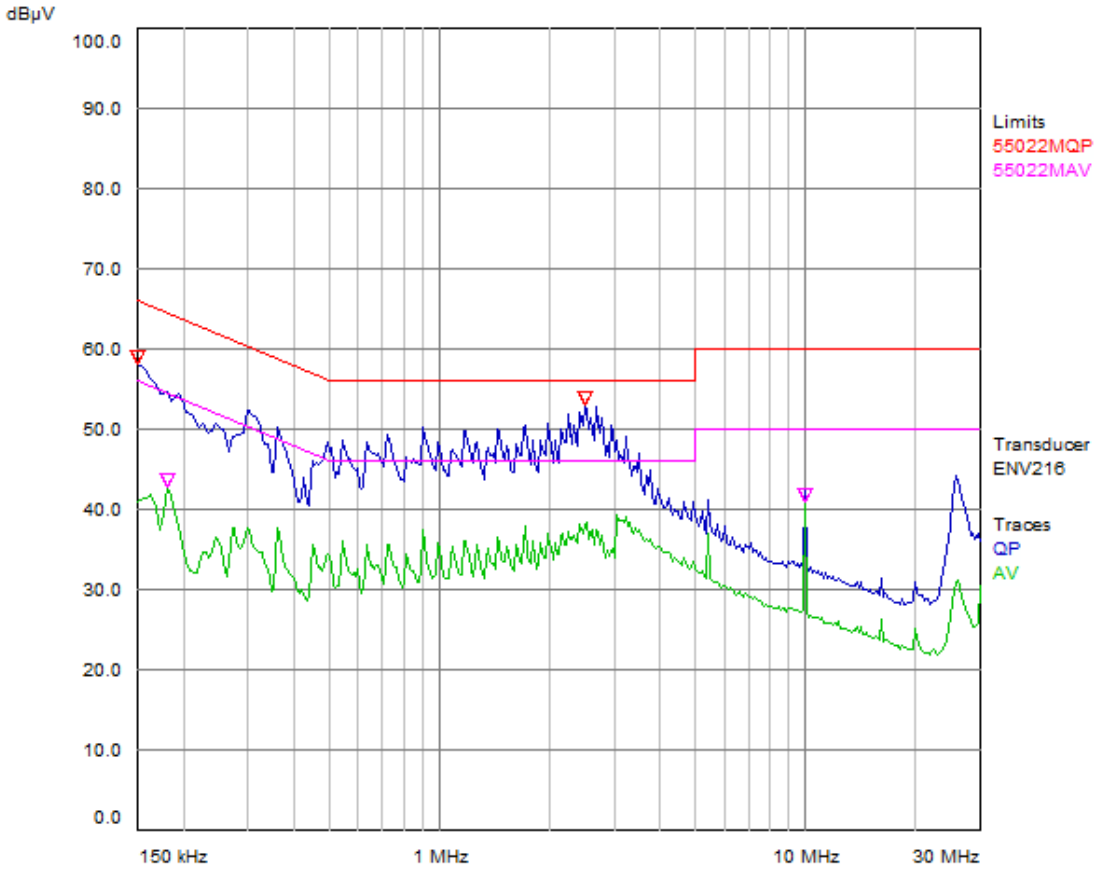


Figure 23. Conducted EMI

Final Measurement Results

Trace	Frequency (MHz)	Level (dBµV)	Limit (dBµV)	Delta Limit (dB)	Delta Ref (dB)	Comment
1 QP	0.15	58.20	66.00	-7.80		N / on
2 AV	0.1815	42.87	54.42	-11.55		N / on
1 QP	2.5125	52.99	56.00	-3.01		N / on
2 AV	10.0005	40.93	50.00	-9.07		N / on

* = Limit Exceeded

10. REVISION HISTORY

Revision	Date	Changes
RD1	FEB 2013	Final release
RD2	APR 2013	Context clarification
RD3	JUL 2013	Content updated using PCBA Rev C
RD4	DEC 2013	Corrected typographical errors