Design Example Report

Title	***High Efficiency 3.8 W Dimmable Power Factor Corrected LED Driver Using LinkSwitch™-PL LNK457DG in a Non-Isolated Buck Topology***
Specification	190 VAC – 265 VAC Input; 42 V – 54 V, 80 mA Output
Application	LED Driver for Candelabra Lamp Replacement
Author	Applications Engineering Department
Document Number	DER-301
Date	November 10, 2011
Revision	1.0

Summary and Features

- Single-stage power factor corrected and accurate constant current (CC) output
- Dimmable
- Low cost, low component count and small PCB footprint
- Highly energy efficient, >83.5% at 230 VAC input for 48 V
- Fast start-up time (<300 ms) – no perceptible delay
- Integrated protection and reliability features
  - Output short-circuit protected with auto-recovery
  - Disconnected load protection with auto-recovery
  - Auto-recovering thermal shutdown with large hysteresis protects both components and PCB
  - No damage during brown-out conditions
- PF >0.91 at 230 VAC
- % ATHD <25% at 230 VAC; 48 V LED
- Meets IEC ring wave, differential line surge and EN55015 conducted EMI

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Table of Contents

Important Note:
Although this board is designed to satisfy safety requirements for non-isolated LED drivers, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

1 Introduction

This document is an engineering report describing a non-isolated dimmable LED driver (power supply) utilizing a LNK457DG from the LinkSwitch-PL family of devices.

The DER-301 provides a single constant current output with an output power of 3.8 W output.

The key design goals were high efficiency, dimmable and compact size, enabling the driver to fit into candelabra and B10 sized lamps and maximize efficacy.

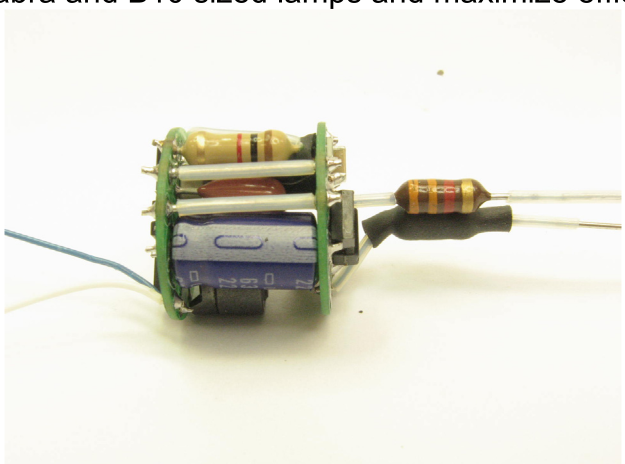

Figure 1 – Populated Circuit Board Photograph.

The board was optimized to operate over the high AC input voltage range (190 VAC to 265 VAC, 47 Hz to 63 Hz). LinkSwitch-PL based designs provide a high power factor (>0.91) meeting current international requirements.

The form factor of the board was chosen to meet the space limitations of standard Candelabra LED replacement lamps. The output is non-isolated and requires the mechanical design of the enclosure to isolate the output of the supply and the LED load from the user.

The document contains the power supply specification, schematic, bill of materials, printed circuit layout and performance data.

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Figure 2 – Populated Circuit Mounted in the B10 Casing.

2 Power Supply Specifications

The table below represents the minimum acceptable performance of the design. Actual performance is listed in the results section.

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	190		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	63	Hz	
Power Factor		0.92				
%ATHD				25		At 230 V; nominal load
Output						
Output Voltage	V_{OUT}		48		V	
Output Current	I_{OUT}	75	80	85	mA	230 VAC
		70		90	mA	190 VAC - 265 VAC
Total Output Power						
Continuous Nominal Output Power	P_{OUT}		3.8		W	
Efficiency						
Nominal	η		83		%	Measured at P_{OUT} 25 °C at 230 VAC
Environmental						
Conducted EMI		Meets CISPR22B / EN55015				
Line Surge Differential Mode (L1-L2)			1		kV	1.2/50 µs surge, IEC 1000-4-5, Series Impedance: Differential Mode: 2 Ω
Ring Wave (100 kHz) Differential Mode (L1-L2)			2.5		kV	2 Ω short-circuit Series Impedance
Harmonic Currents		EN 61000-3-2 Class D (C) Section 7.3.b - Second Clause				Class C specifies Class D Limits when P_{IN} <25 W See Section 9.4
Operating Ambient		0		70	ºC	

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3 Schematic

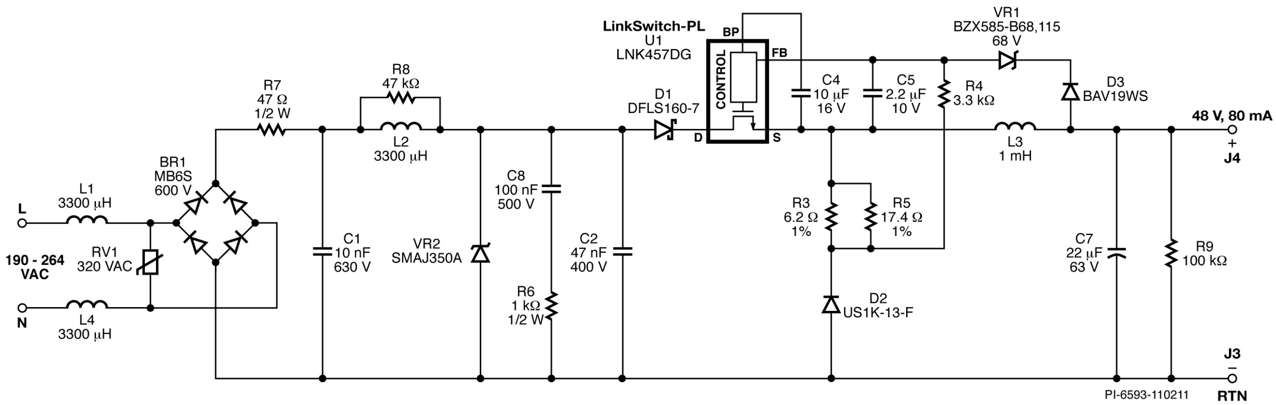

Figure 3 – Schematic.

4 Circuit Description

The LinkSwitch-PL (U1) is a highly integrated primary side controller intended for use in LED driver applications. The LinkSwitch-PL provides high power factor in a single-stage conversion topology while regulating the output current across a range of input (190 VAC to 265 VAC) and output voltage variations typically encountered in LED driver applications. All of the control circuitry responsible for these functions plus the high-voltage power MOSFET are incorporated into the IC.

4.1 Input EMI Filtering

The maximum input voltage is clamped by RV1 and by VR2 (TVS) during differential line surges. Varistor RV1 can be removed for a differential line surge requirement of ≤500 V.

The AC input is full wave rectified by BR1 (vs. half wave) to achieve good power factor and dimmability.

Inductor L1 and L4 are positioned before the bridge to avoid an imbalance in the EMI scan between line and neutral and filters the differential noise. Capacitor C1, C2, and differential choke L2 perform EMI filtering while the limited total capacitance maintains high power factor. This input π filter network plus the frequency jittering feature of LinkSwitch-PL allows compliance with Class B emission limits.

- EMI inductor L1 and L4 are also used as a protection against component failure (providing a fusing function).
- RC bleeder R6 and C8 are located near the switching node to reduce radiated and conducted noise.
- Shielded inductor L3 was selected to reduce conducted and radiated noise.

4.2 Dimmable Buck using LinkSwitch-PL

The buck power train is composed of U1 (power switch + control), D2 (free-wheeling diode), C7 (output capacitor), and L3 (inductor). Diode D1 was used to prevent negative voltage appearing across the drain-source of U1 especially near the zero-crossing of the input voltage. The bypass capacitor C4 provides the internal supply for the device when the power MOSFET is on.

The integrated device enables a very low component count and high efficiency that makes it ideal for candelabra B10 or other compact applications.

4.3 Output Feedback

The output current feedback is sensed on the voltage drop across R3 and R5 then filtered by a low pass filter (R4 and C5) to keep the LinkSwitch-PL operating point such that the average FEEDBACK (FB) pin voltage is 290 mV in steady-state operation. The output inductor is operated in DCM for better CC control and the current regulation is sampled during the discharge in the energy of the output inductor.

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4.4 Disconnected Load Protection

The LED driver is protected in the event of accidental open load operation by monitoring the voltage across the output inductor during energy decay. The threshold is limited by VR1 and the discharge resistor (R9) in the output.

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5 PCB Layout

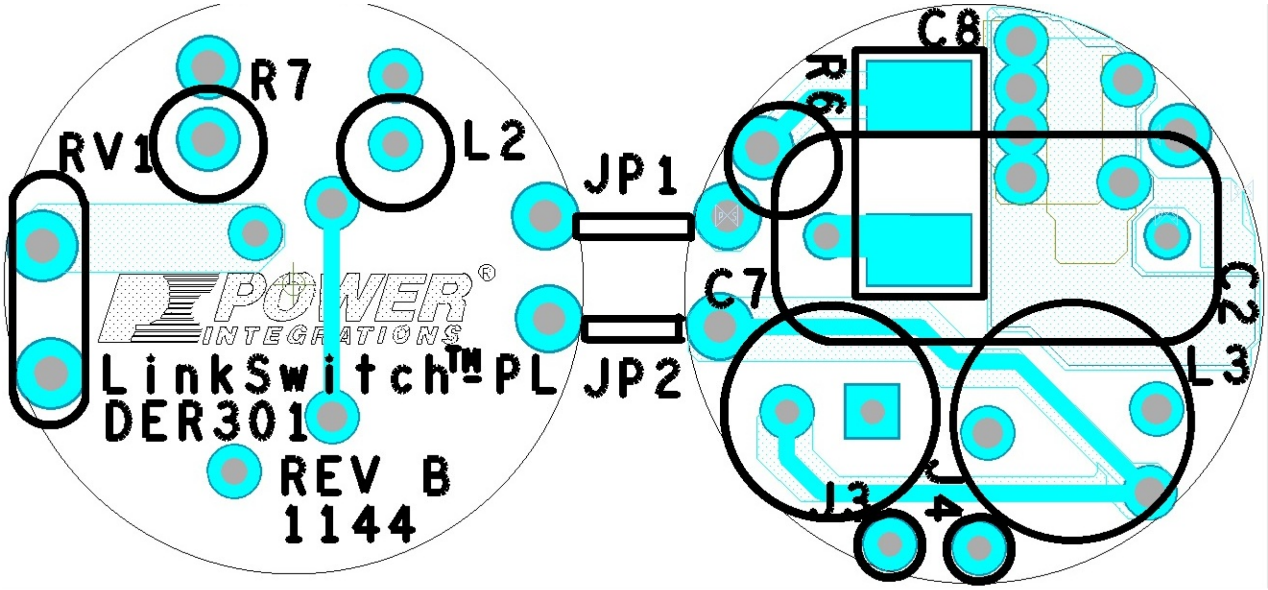

Figure 4 – Top Printed Circuit Layout (Diameter = .68” [17.3 mm]).

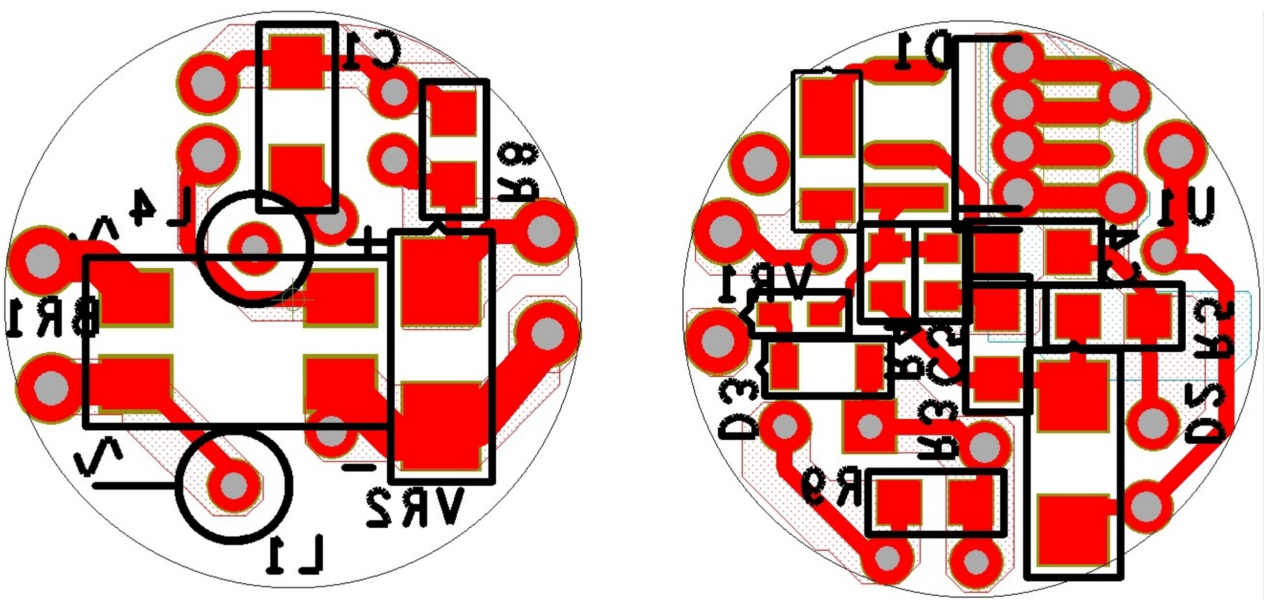

Figure 5 – Bottom Printed Circuit Layout.

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6 Bill of Materials

The table below is the reference design BOM.

Item	Qty	Ref Des	Description	Mfg Part Number	Manufacturer
1	1	BR1	600 V, 0.5 A, Bridge Rectifier, SMD, MBS-1, 4-SOIC	MB6S-TP	Micro Commercial
2	1	C1	10 nF, 630 V, Ceramic, X7R, 1206	C1206C103KBRACTU	Kemet
3	1	C2	47 nF, 400 V, Film	ECQ-E4473KF	Panasonic
4	1	C4	10 μF, 16 V, Ceramic, X5R, 0805	GRM21BR61C106KE15L	Murata
5	1	C5	2.2 μF, 10 V, Ceramic, X5R, 0603	GRM188R61A225KE34D	Murata
6	1	C7	22 μF, 63, Electrolytic, Low ESR, 1000 mΩ, (6.3 x 11.5)	ELXZ630ELL220MFB5D	Nippon Chemi-Con
7	1	C8	100 nF, 500 V, Ceramic, X7R, 1812	VJ1812Y104KXEAT	Vishay
8	1	D1	60 V, 1 A, Diode Schottky, PWRDI 123	DFLS160-7	Diodes, Inc.
9	1	D2	800 V, 1 A, Fast Recovery, 500 ns, SMA	US1K-13-F	Diodes, Inc.
10	1	D3	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diode Inc.
11	2	JP1 JP2	Wire Jumper, Insulated, TFE, #22 AWG, 0.6 in	C2004-12-02	Alpha
12	3	L1 L2 L4	3300 μH, 62 mA, 59.5 Ω, Axial Ferrite Inductor	B78108S1335J	Epcos
13	1	L3	1 mH, 0.23 A, Ferrite Core	CTSCH875DF-102K	CT Parts
14	1	R3	6.2 Ω, 1%, 1/8 W, Thick Film, 0805	RL1220S-6R2-F	Susumu
15	1	R4	3.3 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ332V	Panasonic
16	1	R5	17.4 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF17R4V	Panasonic
17	1	R6	1 kΩ, 5%, 1/2 W, Carbon Film	CFR-50JB-1K0	Yageo
18	1	R7	47 Ω, 5%, 1/2 W, Carbon Film	CFR-50JB-47R	Yageo
19	1	R8	47 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ473V	Panasonic
20	1	R9	100 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1003V	Panasonic
21	1	RV1	320 V, 26 J, 7 mm, RADIAL	V320LA7	Littlefuse
22	1	U1	LinkSwitch-PL, SO-8C	LNK457DG	Power Integrations
23	1	VR1	68 V, 2%, 300 mW, SSMINI-2	BZX585-B68,115	NXP Semi
24	1	VR2	350 V, 400 W, 5%, DO214AC (SMA)	SMAJ350A	LittleFuse

7 Performance Data

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

7.1 Active Mode Efficiency

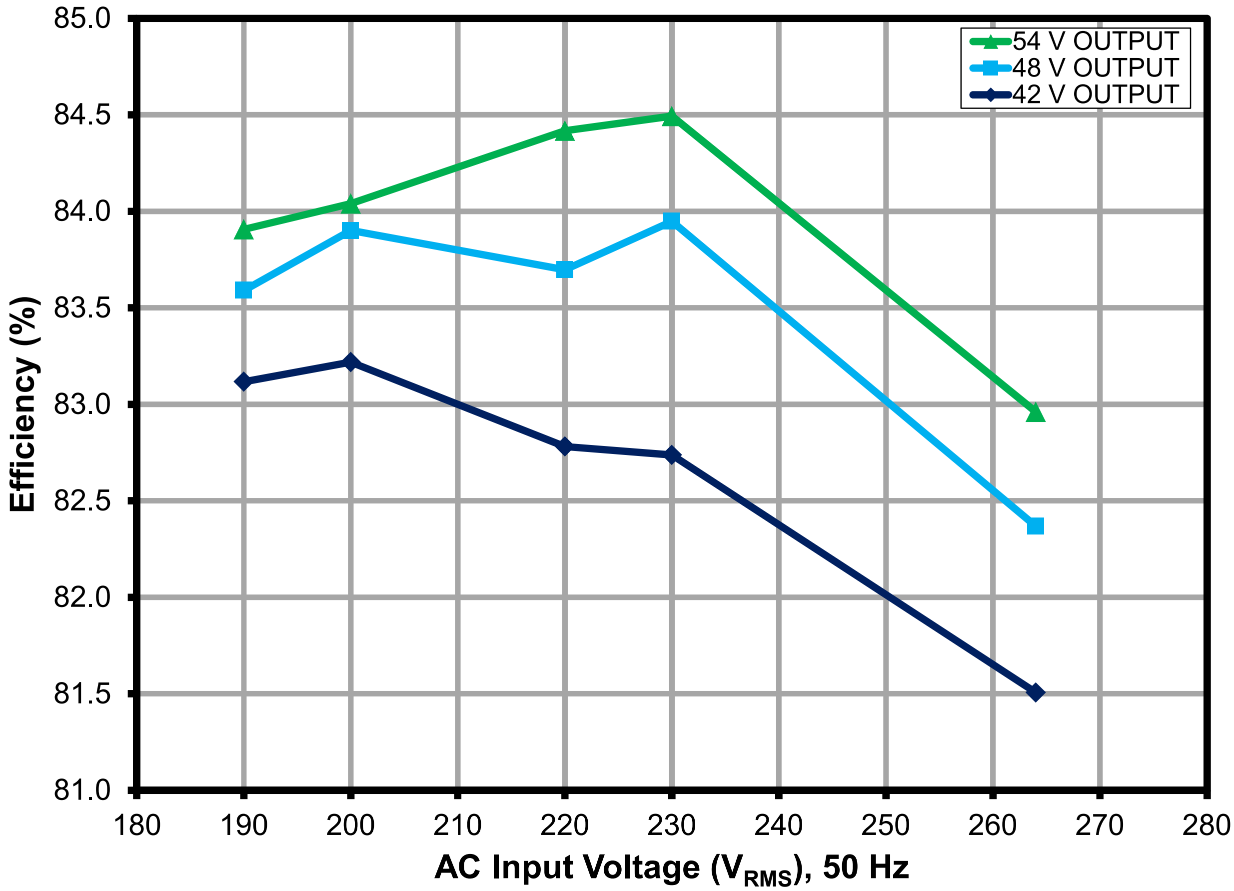

Figure 6 – Efficiency with Respect to AC Input Voltage.

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7.2 Line Regulation

The LinkSwitch-PL device regulates the output by controlling the power MOSFET on-time and switching frequency to maintain the average FB pin at its 0.29 V threshold. Slight changes in output current may be observed when input or output conditions are changed, or after AC cycling due to the device selecting a slightly different operating state (selection of on-time and frequency).

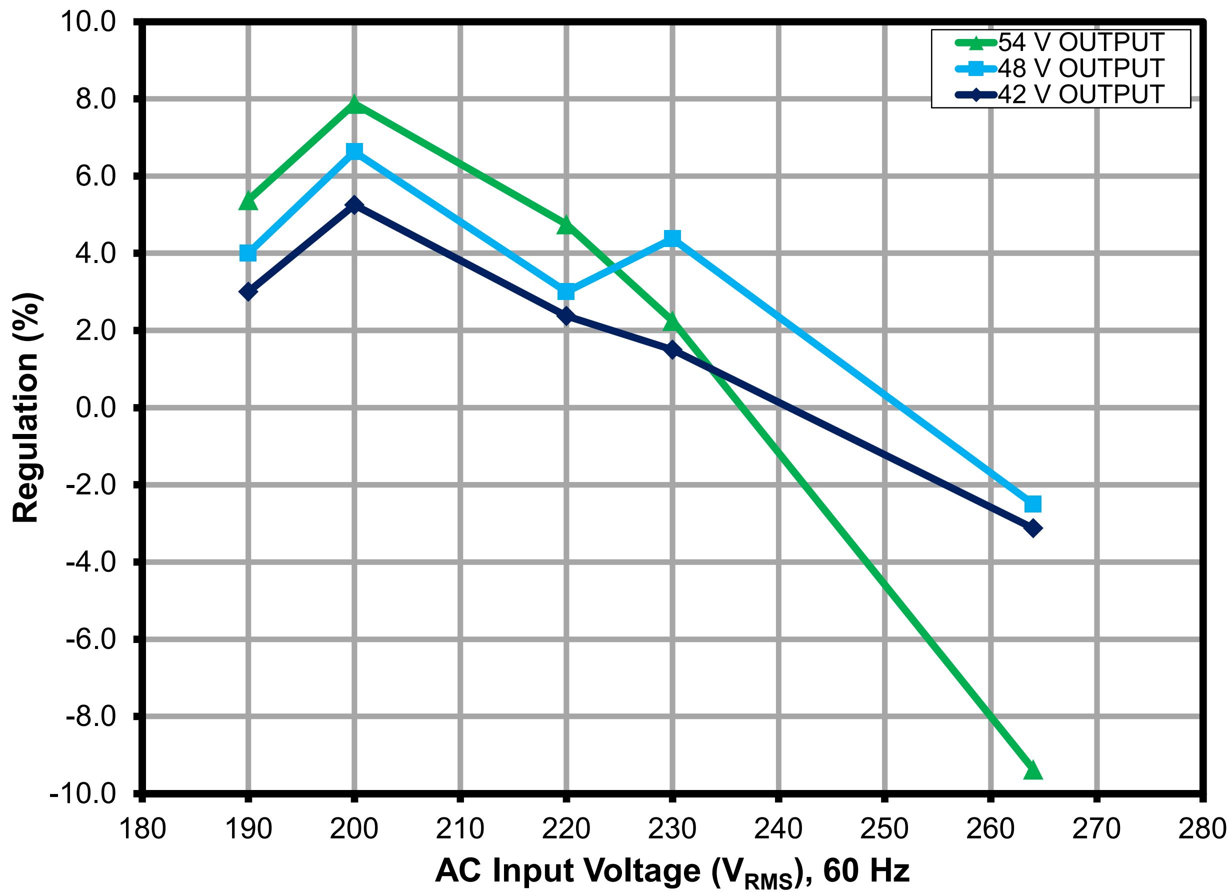

Figure 7 – Line Regulation, Room Temperature.

7.3 Power Factor

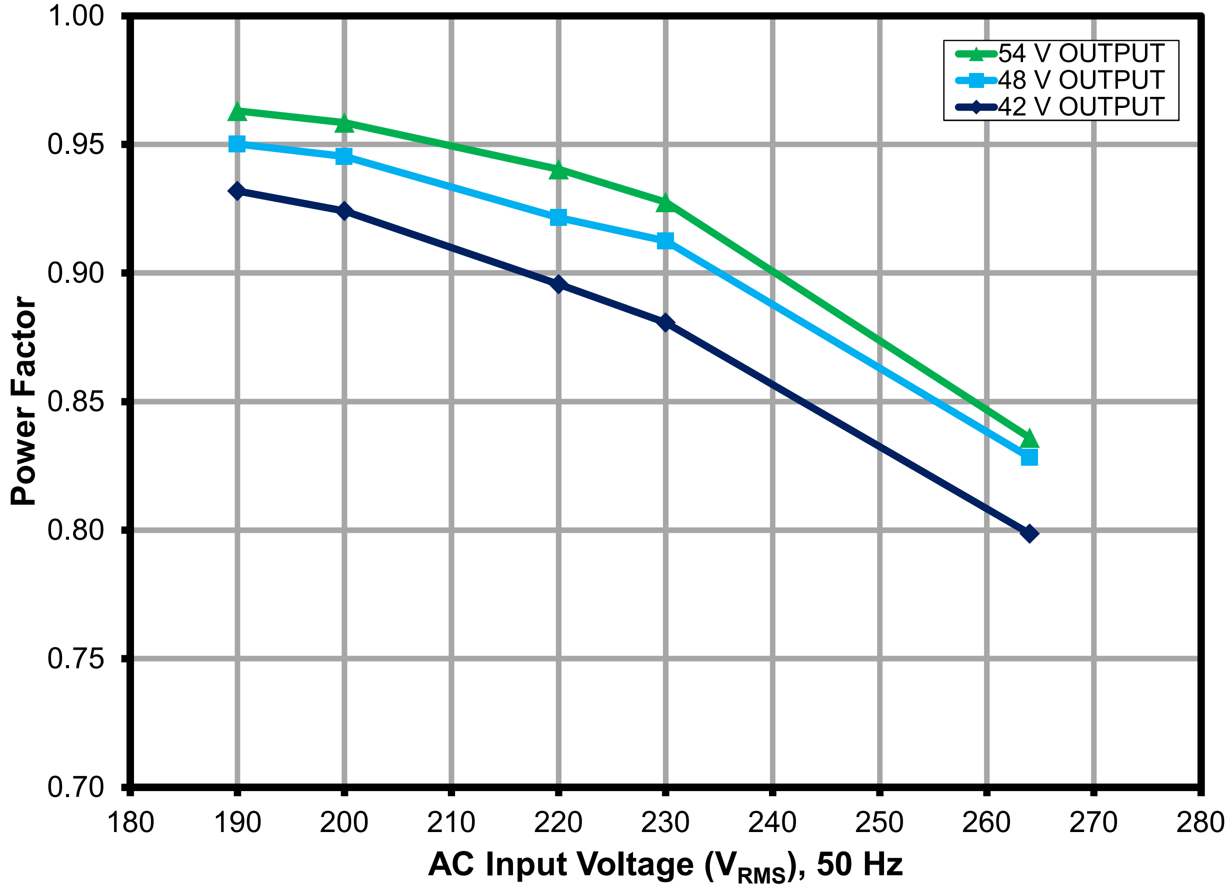

Figure 8 – High Power Factor within the Operating Range.

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7.4 %THD

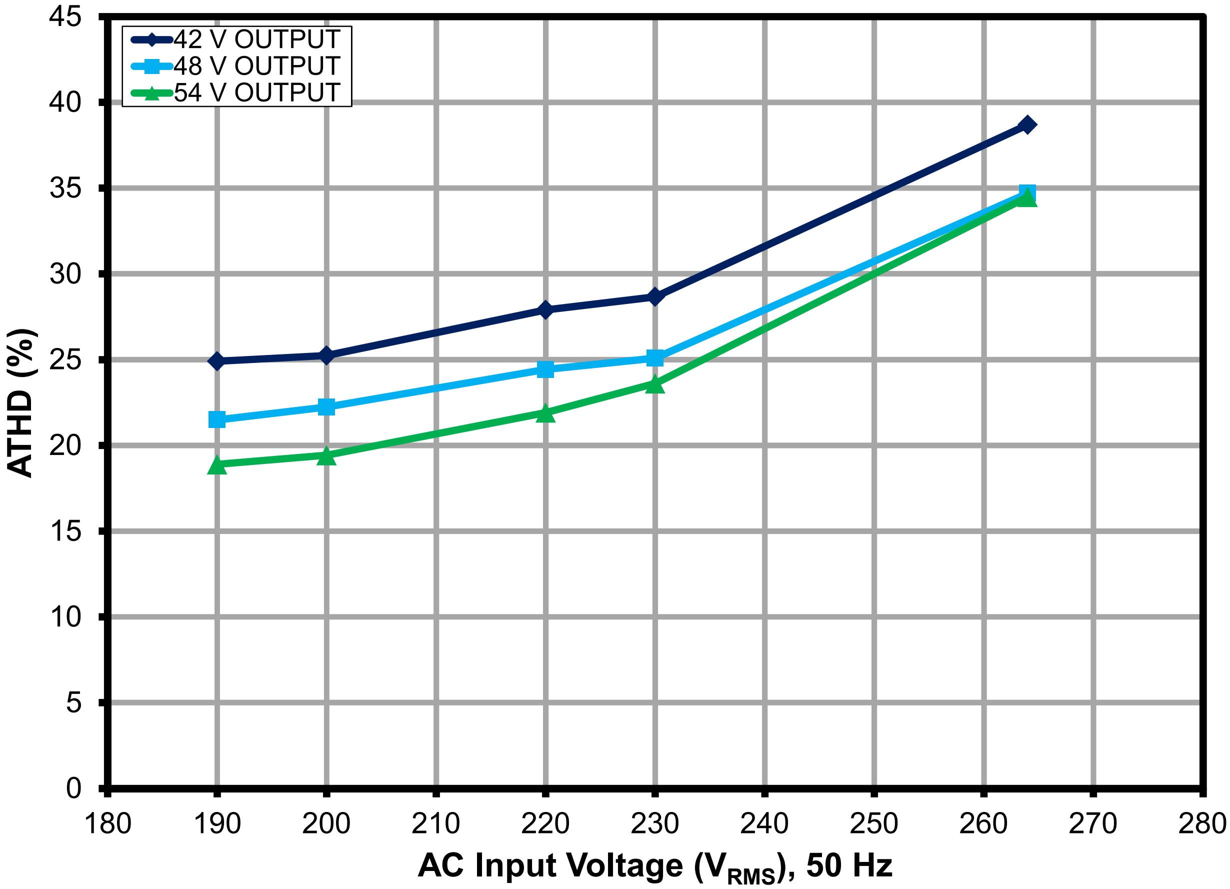

Figure 9 – Very Low %ATHD within the Operating Range.

8 Thermal Scans

The scan is conducted at ambient temperature of 25 ºC, 190 VAC / 50 Hz input and 48 V LED string voltage.

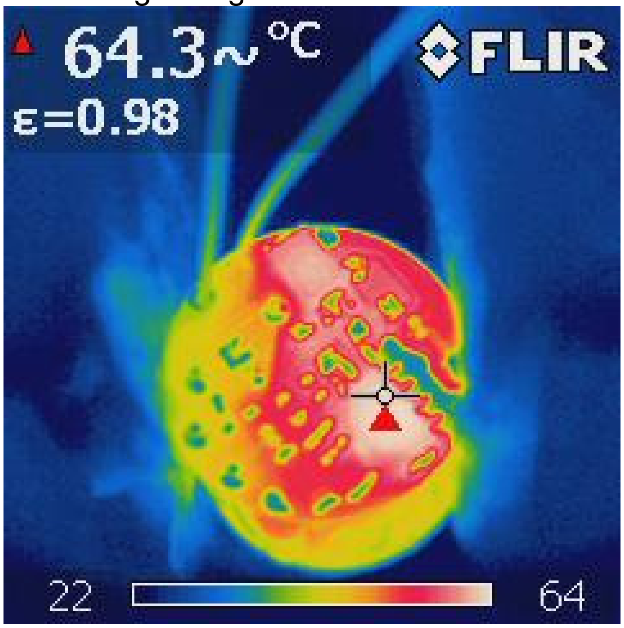

Figure 10 – LNK457DG (U1) Case Temperature.

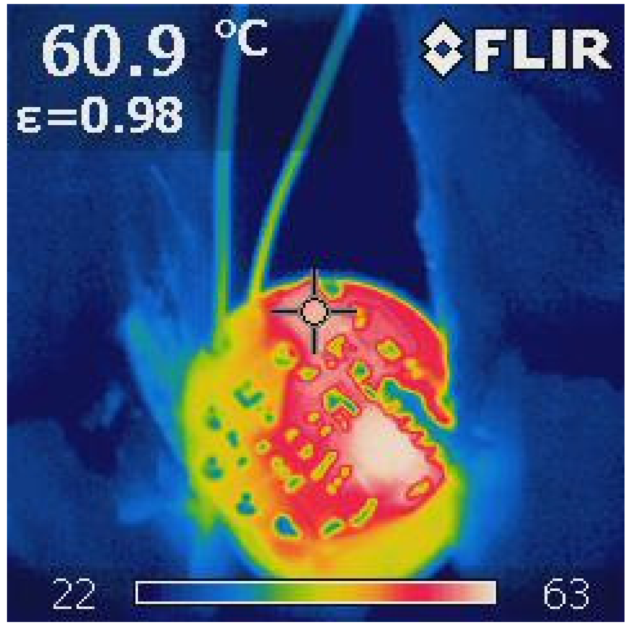

Figure 11 – Output Diode (D2) Case Temperature.

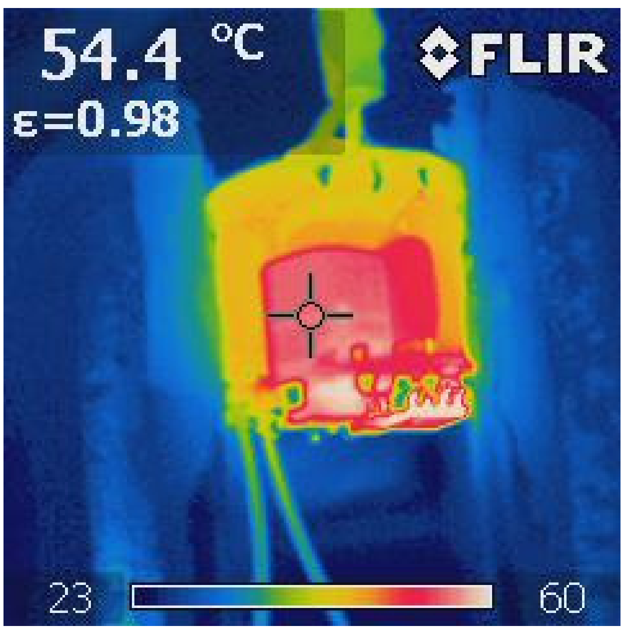

Figure 12 – L3 Output Inductor Temperature.

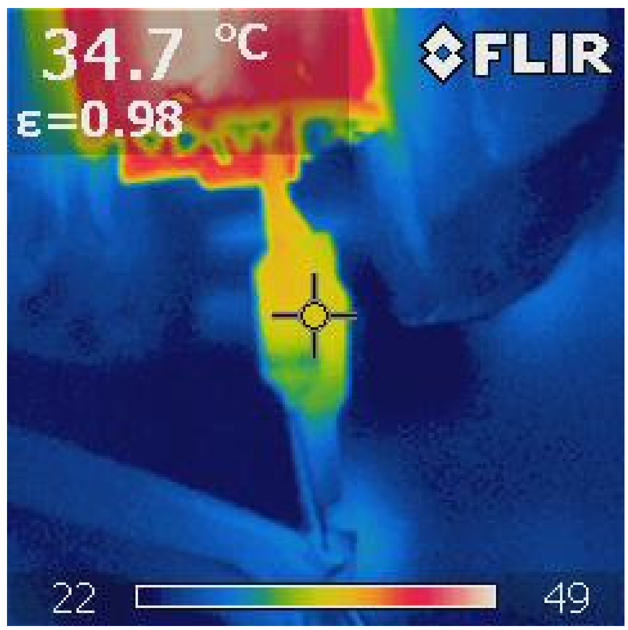

Figure 13 – L1 EMI Inductor Temperature.

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9 Waveforms

9.1 Drain Voltage and Current, Normal Operation

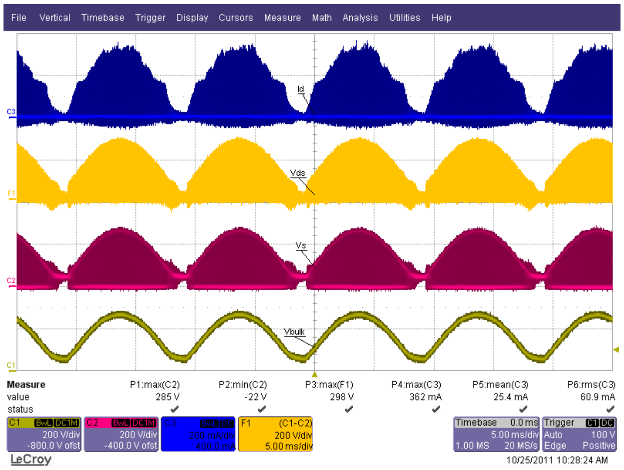

Figure 14 – 190 VAC / 50 Hz, 48 V LED String.
Ch1: V_{BULK}, 200 V / div.
Ch1: $V_{S\ PIN}$, 200 V / div.
Ch3: I_{DRAIN}, 0.2 A / div.
F1: V_{DS}, 200 V / div.
Time Scale: 5 ms / div.

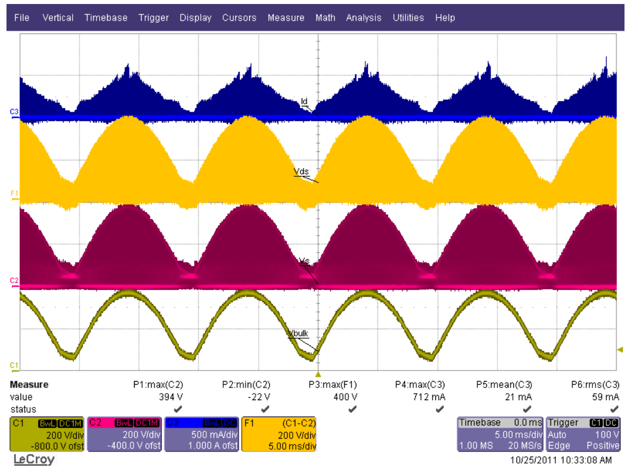

Figure 15 – 265 VAC / 50 Hz, 48 V LED String.
Ch1: V_{BULK}, 200 V / div.
Ch1: $V_{S\ PIN}$, 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div.
F1: V_{DS}, 200 V / div.
Time Scale: 5 ms / div.

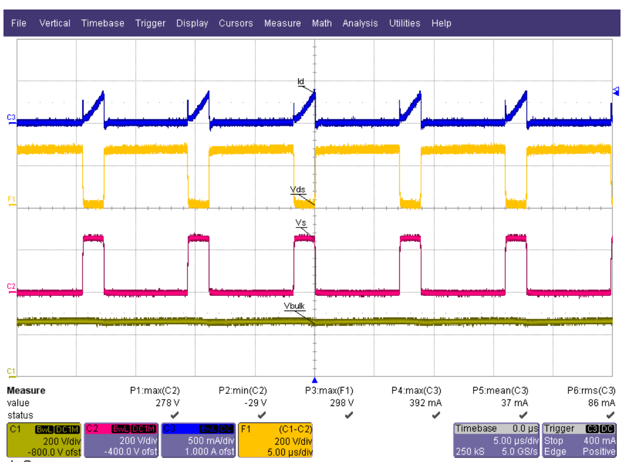

Figure 16 – 190 VAC / 50 Hz, 48 V LED String.
Ch1: V_{BULK}, 200 V / div.
Ch1: $V_{S\ PIN}$, 200 V / div.
Ch3: I_{DRAIN}, 0.2 A / div.
F1: V_{DS}, 200 V / div.
Time Scale: 5 µs / div.

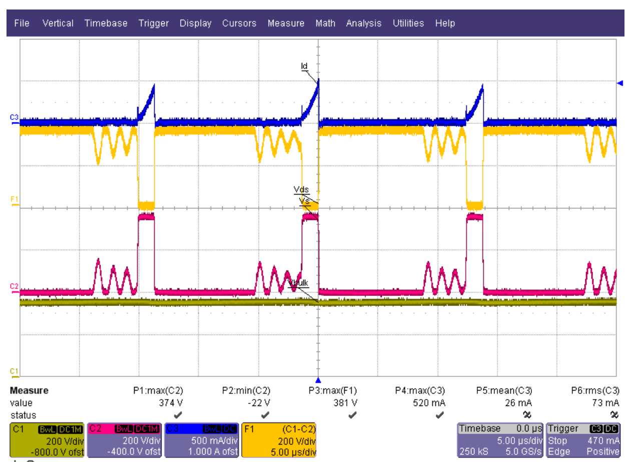

Figure 17 – 265 VAC / 50 Hz, 48 V LED String.
Ch1: V_{BULK}, 200 V / div.
Ch1: $V_{S\ PIN}$, 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div.
F1: V_{DS}, 200 V / div.
Time Scale: 5 µs / div.

9.2 *Drain Voltage and Current Start-up Profile*

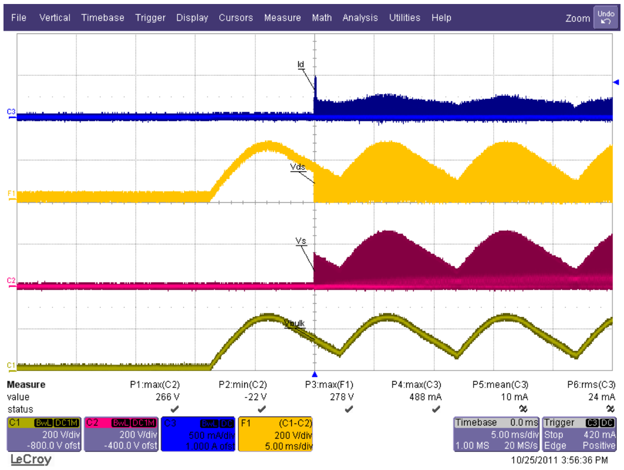

Figure 18 – 190 VAC / 50 Hz, 48 V LED String.
Ch1: V_{BULK}, 200 V / div.
Ch1: $V_{S\ PIN}$, 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div.
F1: V_{DS}, 200 V / div.
Time Scale: 5 ms / div.

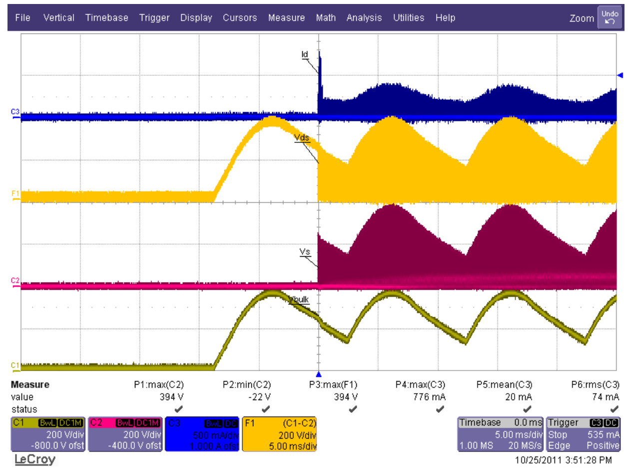

Figure 19 – 265 VAC / 50 Hz, 48 V LED String.
Ch1: V_{BULK}, 200 V / div.
Ch1: $V_{S\ PIN}$, 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div.
F1: V_{DS}, 200 V / div.
Time Scale: 5 ms / div.

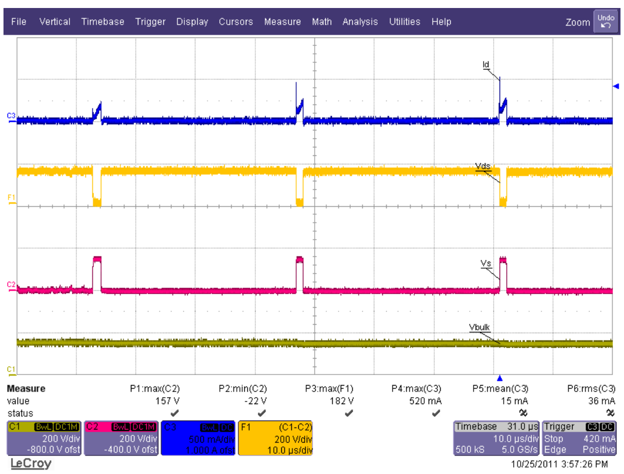

Figure 20 – 190 VAC / 50 Hz, 48 V LED String.
Ch1: V_{BULK}, 200 V / div.
Ch1: $V_{S\ PIN}$, 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div.
F1: V_{DS}, 200 V / div.
Time Scale: 10 μs / div.

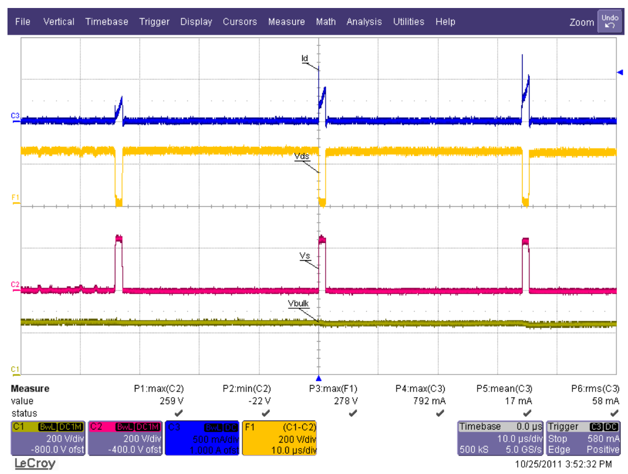

Figure 21 – 265 VAC / 50 Hz, 48 V LED String.
Ch1: V_{BULK}, 200 V / div.
Ch1: $V_{S\ PIN}$, 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div.
F1: V_{DS}, 200 V / div.
Time Scale: 10 μs / div.

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9.3 *Output Voltage Start-up Profile*

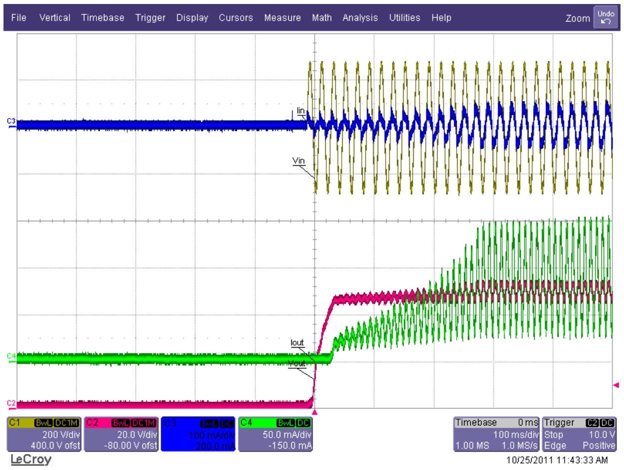

Figure 22 – 190 VAC / 50 Hz, 48 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch1: V_{OUT}, 200 V / div.
Ch3: I_{IN}, 0.5 A / div.
Ch4: I_{OUT}, 0.05 A / div.
Time Scale: 100 ms / div.

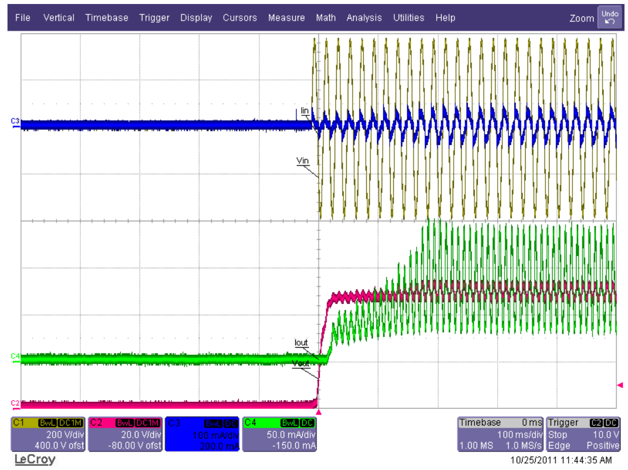

Figure 23 – 265 VAC / 50 Hz, 48 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch1: V_{OUT}, 200 V / div.
Ch3: I_{IN}, 0.5 A / div.
Ch4: I_{OUT}, 0.05 A / div.
Time Scale: 100 ms / div.

9.4 *Input and Output Voltage and Current Profiles*

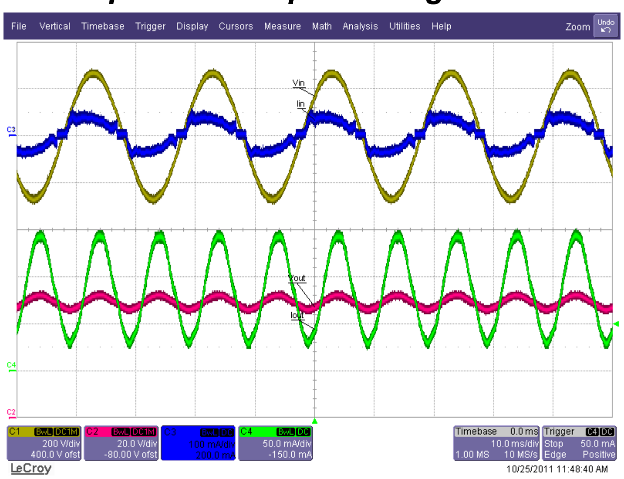

Figure 24 – 190 VAC / 50 Hz, 48 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch1: V_{OUT}, 200 V / div.
Ch3: I_{IN}, 0.1 A / div.
Ch4: I_{OUT}, 0.05 A / div.
Time Scale: 10 ms / div.

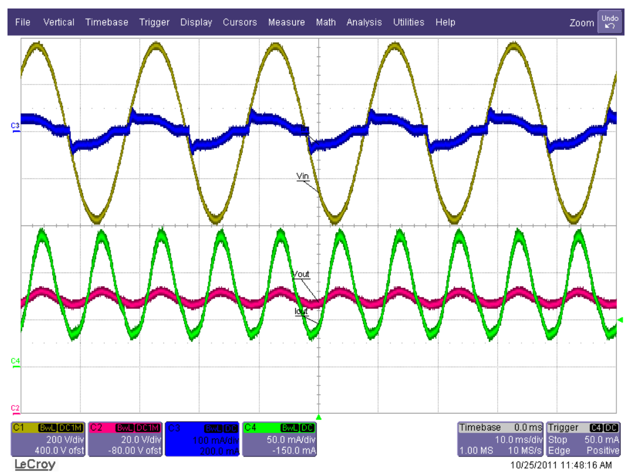

Figure 25 – 265 VAC / 50 Hz, 48 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch1: V_{OUT}, 200 V / div.
Ch3: I_{IN}, 0.1 A / div.
Ch4: I_{OUT}, 0.05 A / div.
Time Scale: 10 ms / div.

9.5 Drain Voltage and Current Profile with Output Shorted

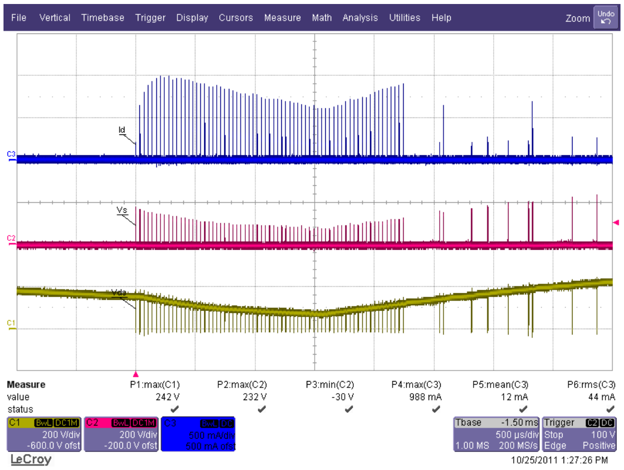

Figure 26 – 190 VAC / 50 Hz, Output Shorted.
Ch1: V_{DS}, 200 V / div.
Ch4: V_{SOURCE} , 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div., 500 μs / div.

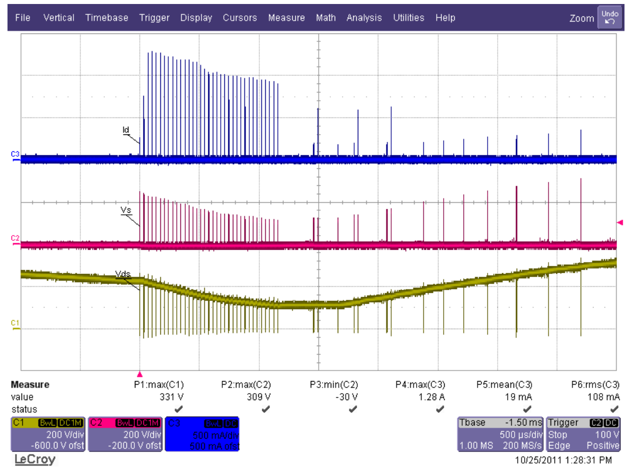

Figure 27 – 265 VAC / 50 Hz, Output Shorted.
Ch1: V_{DS}, 200 V / div.
Ch4: V_{SOURCE} , 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div., 500 μs / div.

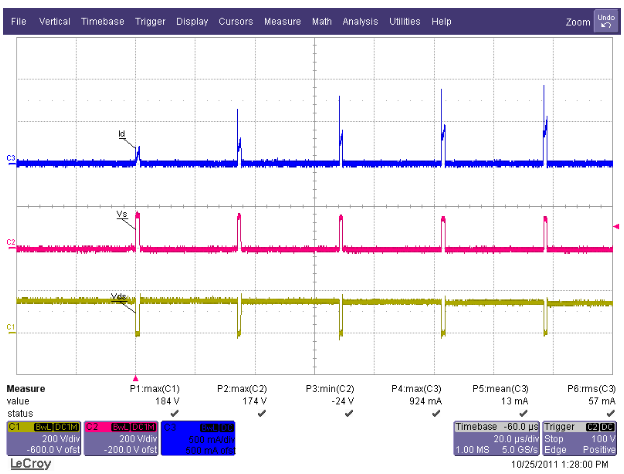

Figure 28 – 190 VAC / 50 Hz, Output Shorted.
Ch1: V_{DS}, 200 V / div.
Ch4: V_{SOURCE} , 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div., 20 μs / div.

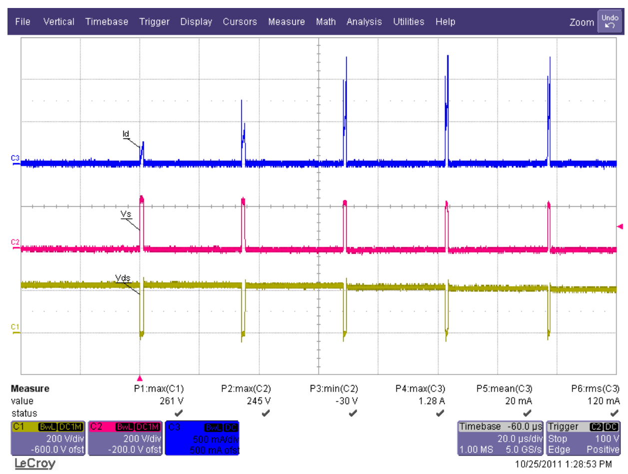

Figure 29 – 265 VAC / 50 Hz, Output Shorted.
Ch1: V_{DS}, 200 V / div.
Ch4: V_{SOURCE} , 200 V / div.
Ch3: I_{DRAIN}, 0.5 A / div., 20 μs / div.

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9.6 Line Transient Response

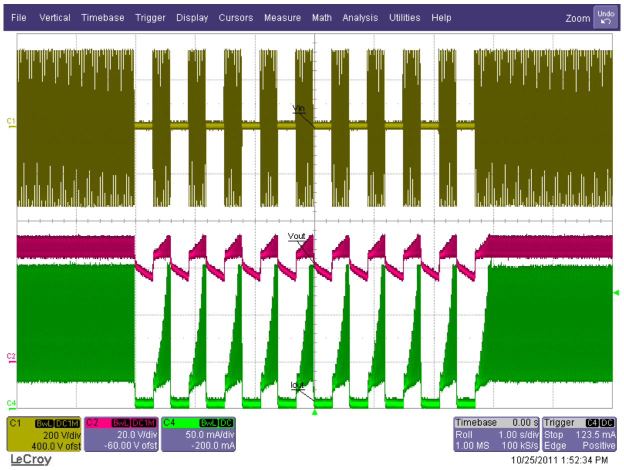

Figure 30 – 230 VAC / 50 Hz,
300 ms On – 300 ms Off.
Load: 48 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 50 mA / div., 1 s / div.

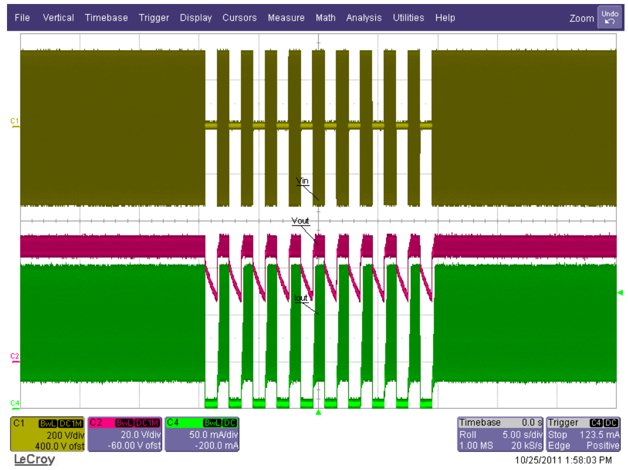

Figure 31 – 230 VAC / 50 Hz,
1 s On – 1 s Off.
Load: 48 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 50 mA / div., 5 s / div.

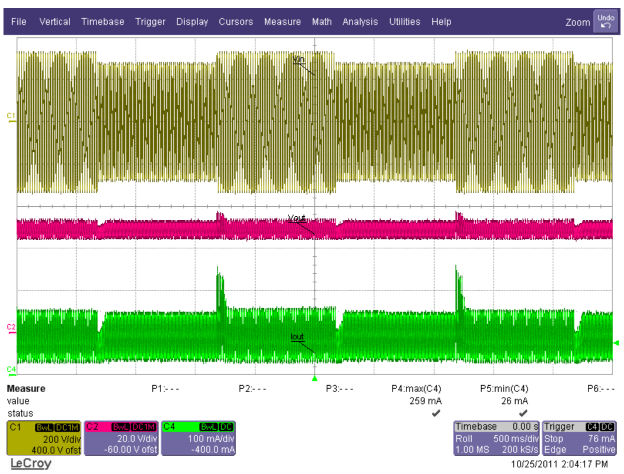

Figure 32 – 1 s at 230 VAC, 1 s at 190 VAC / 50 Hz,
Load: 48 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 50 mA / div., 500 ms / div.

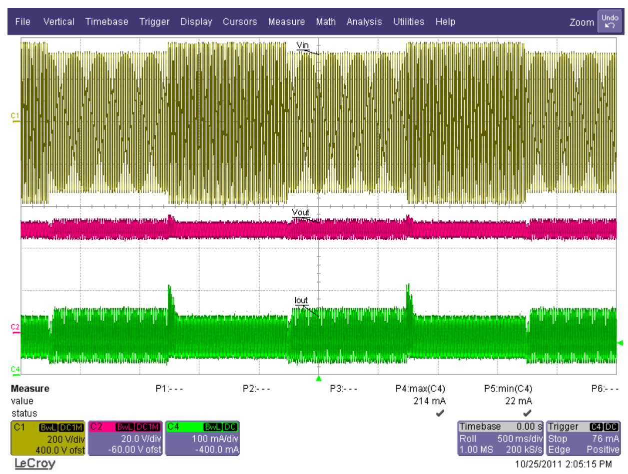

Figure 33 – 1 s at 230 VAC, 1 s at 265 VAC / 50 Hz,
Load: 48 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 50 mA / div., 500 ms / div.

9.7 Brown-out

Input voltage slew rate of 0.02 V / ms from 230 VAC / 50 Hz line input variation; no failure observed.

Figure 34 – 230 VAC / 50 Hz, 0.02 V / ms Slew Rate.
Load: 48 V LED String.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 50 mA / div., 1 s / div.

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9.8 *Start-up No-load*

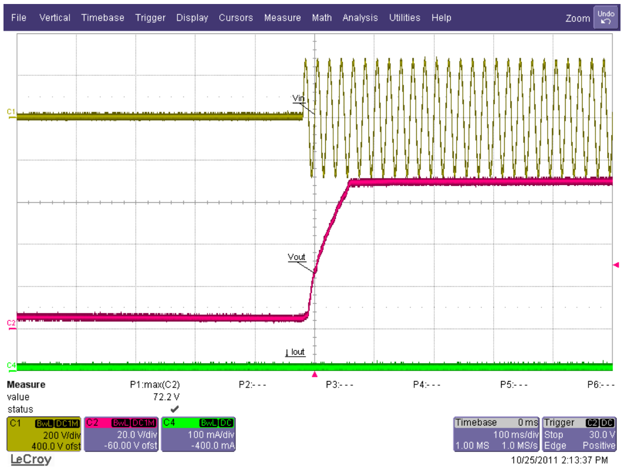

Figure 35 – 190 VAC / 50 Hz, Start-up No-load.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 100 mA / div., 100 ms / div.

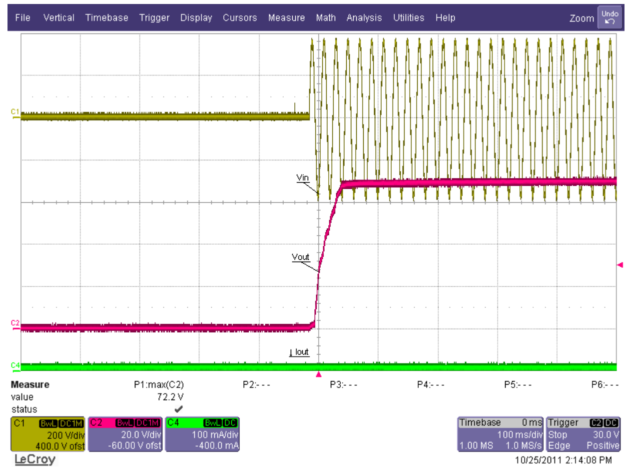

Figure 36 – 265 VAC / 50 Hz, Start-up No-load.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 100 mA / div., 100 ms / div.

9.9 *Normal Operation then No-load*

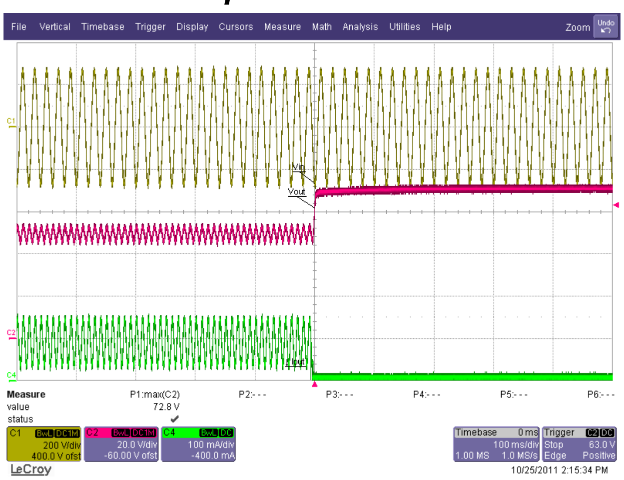

Figure 37 – 190 VAC / 50 Hz, Normal Operation then No-load.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 100 mA / div., 100 ms / div.

Figure 38 – 265 VAC / 50 Hz, Normal Operation then No-load.
Ch1: V_{IN}, 200 V / div.
Ch2: V_{OUT}, 20 V / div.
Ch4: I_{OUT}, 100 mA / div., 100 ms / div.

9.10 Line Surge Waveform

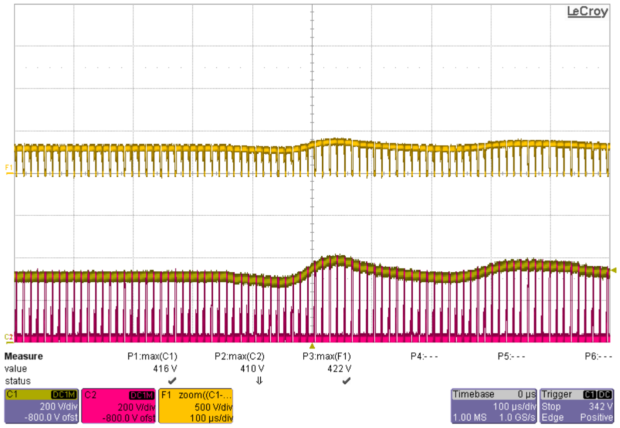

Figure 39 – 230 VAC / 60 Hz, 48 V Load,
V_{DS}=422 V_{PK}.
(+)2.5 kV Differential Ring Surge at 0º.
Ch1: V_{IN}, 200 V / div.
Ch2: $V_{S\ PIN}$, 200 V / div.
F1: V_{DS}, 500 V / div., 10 μs / div.

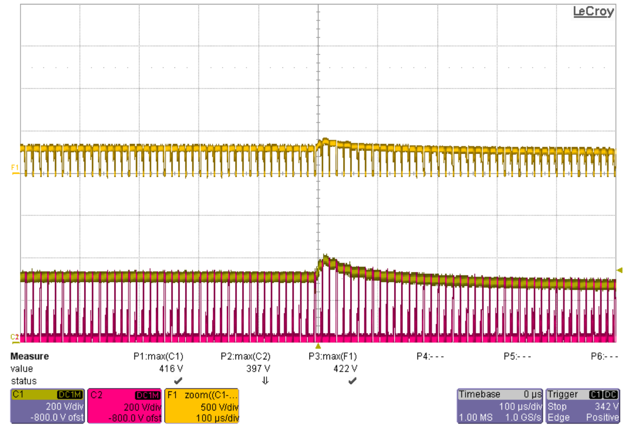

Figure 40 – 230 VAC / 60 Hz, 48 V Load,
V_{DS}=422 V_{PK}.
(+)2.5 kV Differential Ring Surge at 90º.
Ch1: V_{IN}, 200 V / div.
Ch2: $V_{S\ PIN}$, 200 V / div.
F1: V_{DS}, 500 V / div., 10 μs / div.

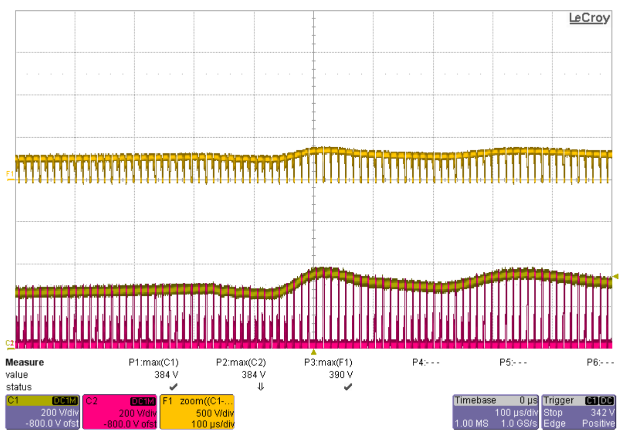

Figure 41 – 230 VAC / 60 Hz, 48 V Load,
V_{DS}=422 V_{PK}.
(-)2.5 kV Differential Ring Surge at 0º.
Ch1: V_{IN}, 200 V / div.
Ch2: $V_{S\ PIN}$, 200 V / div.
F1: V_{DS}, 500 V / div., 10 μs / div.

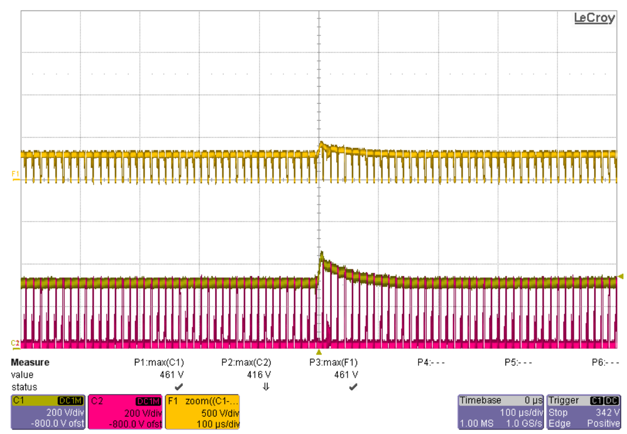

Figure 42 – 230 VAC / 60 Hz, 48 V Load,
V_{DS}=422 V_{PK}.
(-)2.5 kV Differential Ring Surge at 90º.
Ch1: V_{IN}, 200 V / div.
Ch2: $V_{S\ PIN}$, 200 V / div.
F1: V_{DS}, 500 V / div., 10 μs / div.

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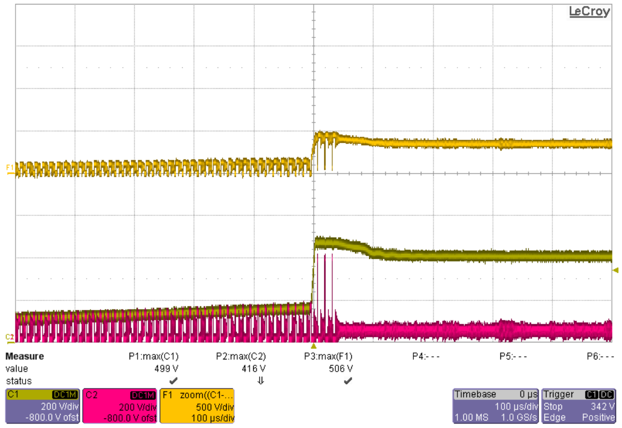

Figure 43 – 115 VAC / 60 Hz, 48 V load,
V_{DS}=506 V_{PK}.
(+)1 kV Differential Surge at 0º.
Ch1: V_{IN}, 200 V / div.
Ch2: $V_{S\ PIN}$, 200 V / div.
F1: V_{DS}, 500 V / div., 10 µs / div.

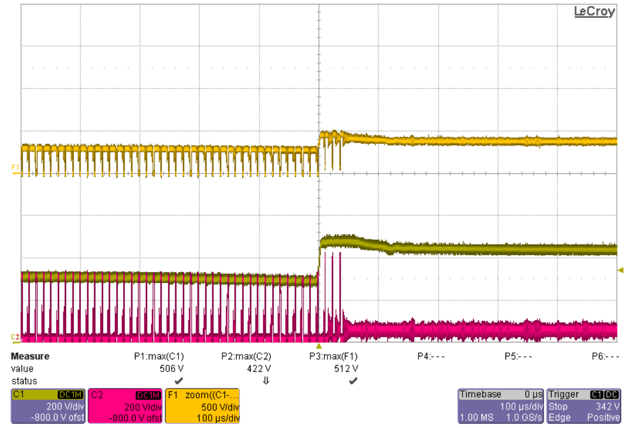

Figure 44 – 230 VAC / 60 Hz, 48 V Load,
V_{DS}=512 V_{PK}.
(+)1kV Differential Surge at 90º.
Ch1: V_{IN}, 200 V / div.
Ch2: $V_{S\ PIN}$, 200 V / div.
F1: V_{DS}, 500 V / div., 10 µs / div.

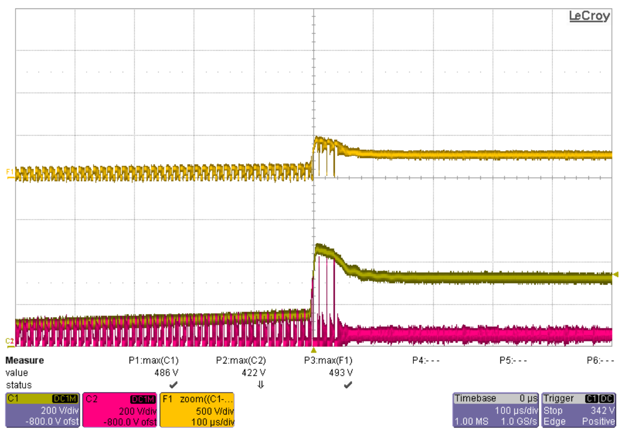

Figure 45 – 115 VAC / 60 Hz, 48 V Load,
V_{DS}=493 V_{PK}.
(-)1 kV Differential Surge at 0º.
Ch1: V_{IN}, 200 V / div.
Ch2: $V_{S\ PIN}$, 200 V / div.
F1: V_{DS}, 500 V / div., 10 µs / div.

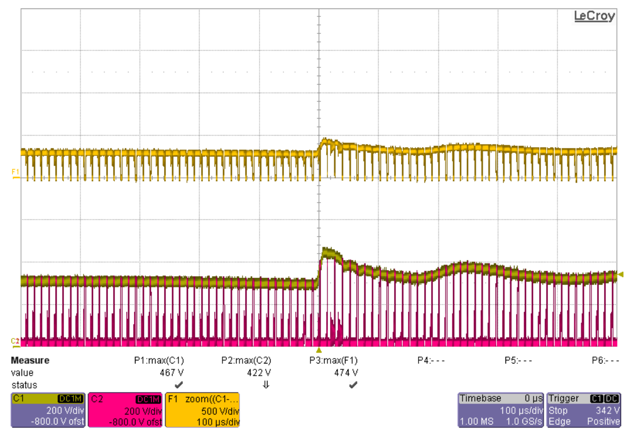

Figure 46 – 115 VAC / 60 Hz, 48 V Load,
V_{DS}=474 V_{PK}.
(-)1 kV Differential Surge at 90º.
Ch1: V_{IN}, 200 V / div.
Ch2: $V_{S\ PIN}$, 200 V / div.
F1: V_{DS}, 500 V / div., 10 µs / div.

10 Dimming Sample Waveform

The input voltage waveform varies depending on the internal circuitry and leakage of the dimmer especially at full dim.

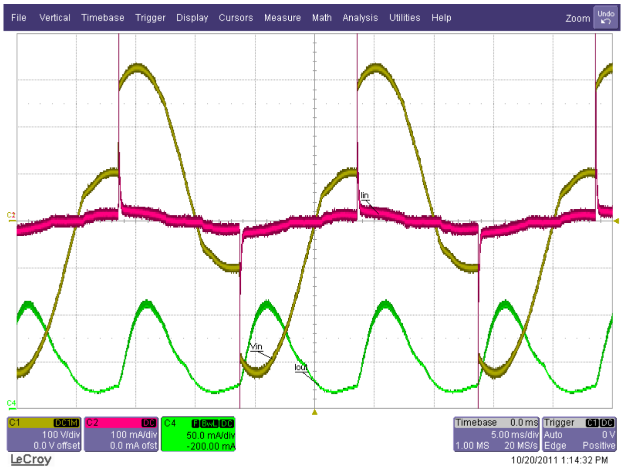

Figure 47 – 230 VAC / 50 Hz, Dimming at Full Conduction from Relco-RTM34LED DAXS Dimmer.
Ch1: V_{IN}, 100 V / div.
Ch2: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 50 mA / div., 5 ms / div.

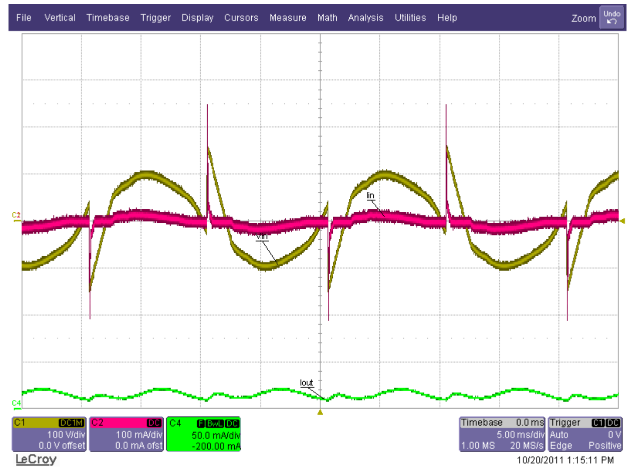

Figure 48 – 230 VAC / 50 Hz, Dimming at Full Dim from Relco-RTM34LED DAXS Dimmer.
Ch1: V_{IN}, 100 V / div.
Ch2: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 50 mA / div., 5 ms / div.

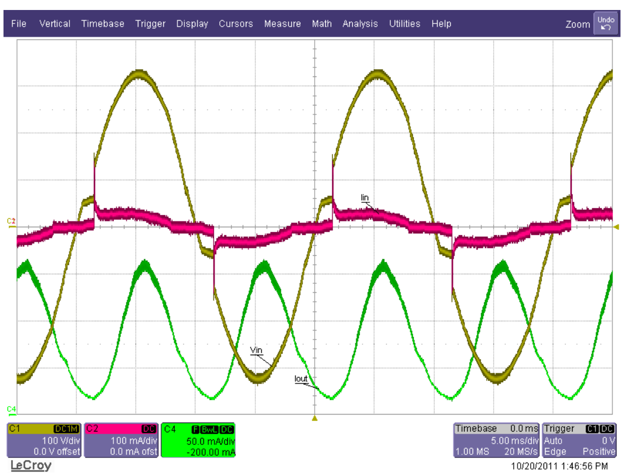

Figure 49 – 230 VAC / 50 Hz, Dimming at Full Conduction from Sen Bo Lang Dimmer.
Ch1: V_{IN}, 100 V / div.
Ch2: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 50 mA / div., 5 ms / div.

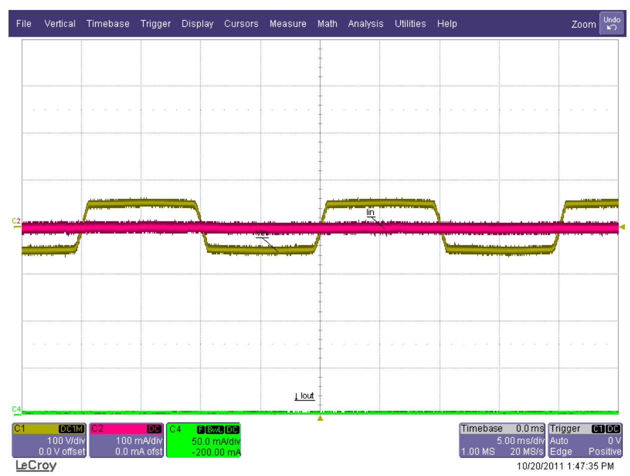

Figure 50 – 230 VAC / 50 Hz, Dimming at Full Dim from Sen Bo Lang Dimmer.
Ch1: V_{IN}, 100 V / div.
Ch2: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 50 mA / div., 5 ms / div.

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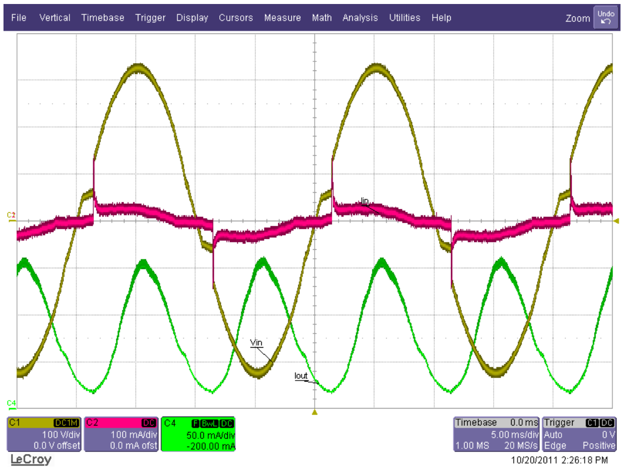

Figure 51 – 230 VAC / 50 Hz, Dimming at Full Conduction from Mank Dimmer.
Ch1: V_{IN}, 100 V / div.
Ch2: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 50 mA / div., 5 ms / div.

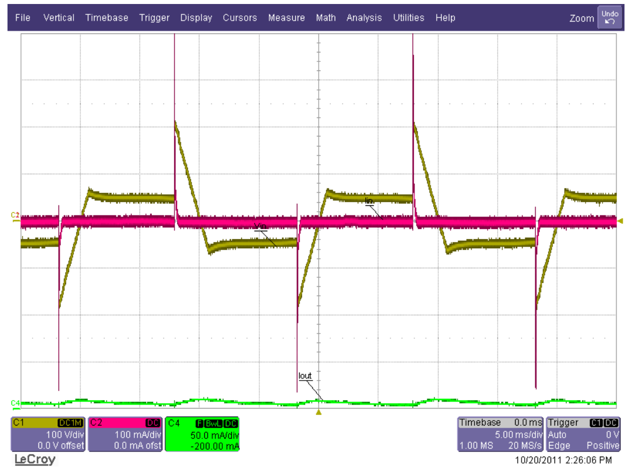

Figure 52 – 230 VAC / 50 Hz, Dimming at Full Dim from Mank Dimmer.
Ch1: V_{IN}, 100 V / div.
Ch2: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 50 mA / div., 5 ms / div.

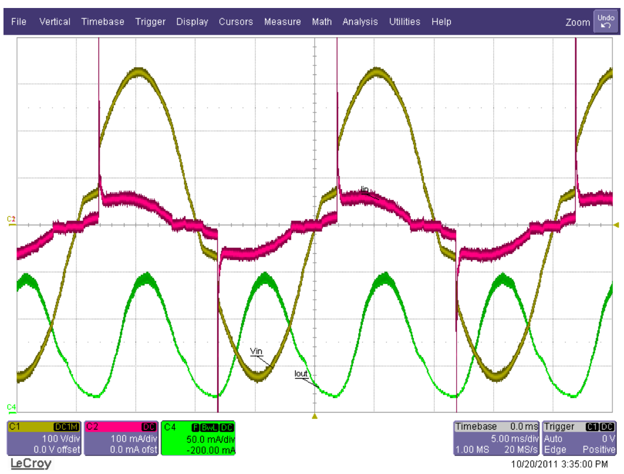

Figure 53 – 230 VAC / 50 Hz, Dimming at Full Conduction from Anam Dimmer.
Ch1: V_{IN}, 100 V / div.
Ch2: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 50 mA / div., 5 ms / div.

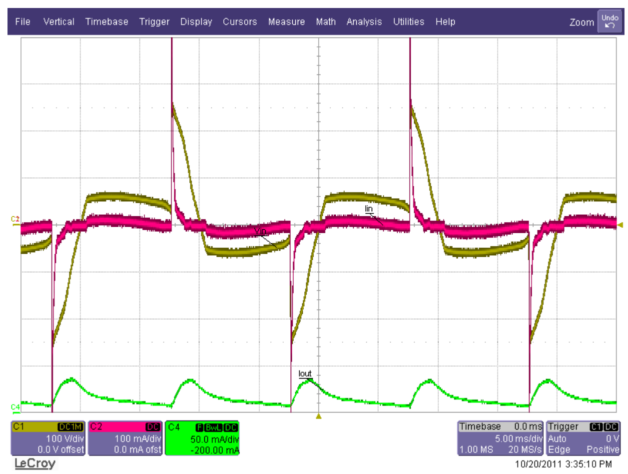

Figure 54 – 230 VAC / 50 Hz, Dimming at Full Dim from Anam Dimmer.
Ch1: V_{IN}, 100 V / div.
Ch2: I_{IN}, 100 mA / div.
Ch4: I_{OUT}, 50 mA / div., 5 ms / div.

11 Dimming Compatibility

The LED driver was verified to the following list of 230 V dimmers. This table does not limit the types and models of dimmers to be matched in the LED driver instead these are the only available dimmers in the laboratory by the time the UUT was evaluated.

Most of the dimmers are high power rated wherein the holding current is way above the instantaneous drawn current of the driver. For this reason and in some cases it will require for this application to parallel the UUT in order to reach the minimum holding current of the dimmers in order to avoid shimmer.

Brand	Model	Power (W)	Country	No. of Units to Satisfy Holding Current of TRIAC	I_{OUT} Max mA_{AVG}	I_{OUT} Min mA_{AVG}
Relco	RH34LEDPLT	300	Italian	3	70.60	2.80
Relco	RM34DMA	160	Italian	1	75.00	10.29
Relco	RTM34LED DAXS	500	Italian	1	53.73	13.19
Relco	RM34DMA	300	Italian	2	81.10	7.42
Relco	RTS34.43RLI	300	Italian	2	81.60	11.62
Relco	RT34DSL	500	Italian	2	80.90	5.56
TCL	TCL	630	China	3	81.20	0.81
Sen Bo Lang	SBL	300	China	1	80.70	0.41
Eba Huang	-	-	China	1	79.50	0.29
SB Elect	-	600	China	1	70.00	0.33
Myongbo	-	-	China	1	79.90	0.42
KBE	-	650	China	1	80.60	0.32
Clipmei	-	-	China	1	79.60	0.51
Mank	-	200	China	1	78.70	4.52
REV	-	300	Germany	3	67.00	0.80
Busch	2250	600	Germany	4	72.90	2.59
Merten	572499	400	Germany	5	79.50	0.57
Busch	3513	420	Germany	1	81.60	43.40
Berker	2875	600	Germany	1	67.20	5.60
Anam	-	500	Korea	2	775.70	14.45
Shin Sung	-	500	Korea	3	78.50	6.00
Fantasia	-	500	Korea	3	76.20	14.72
SS	-	700	Korea	3	78.70	3.37
Aurora	-	400	UK	5	65.60	0.47

Note: Shimmering can be observed if there is significant imbalance in the conduction of a dimmer.

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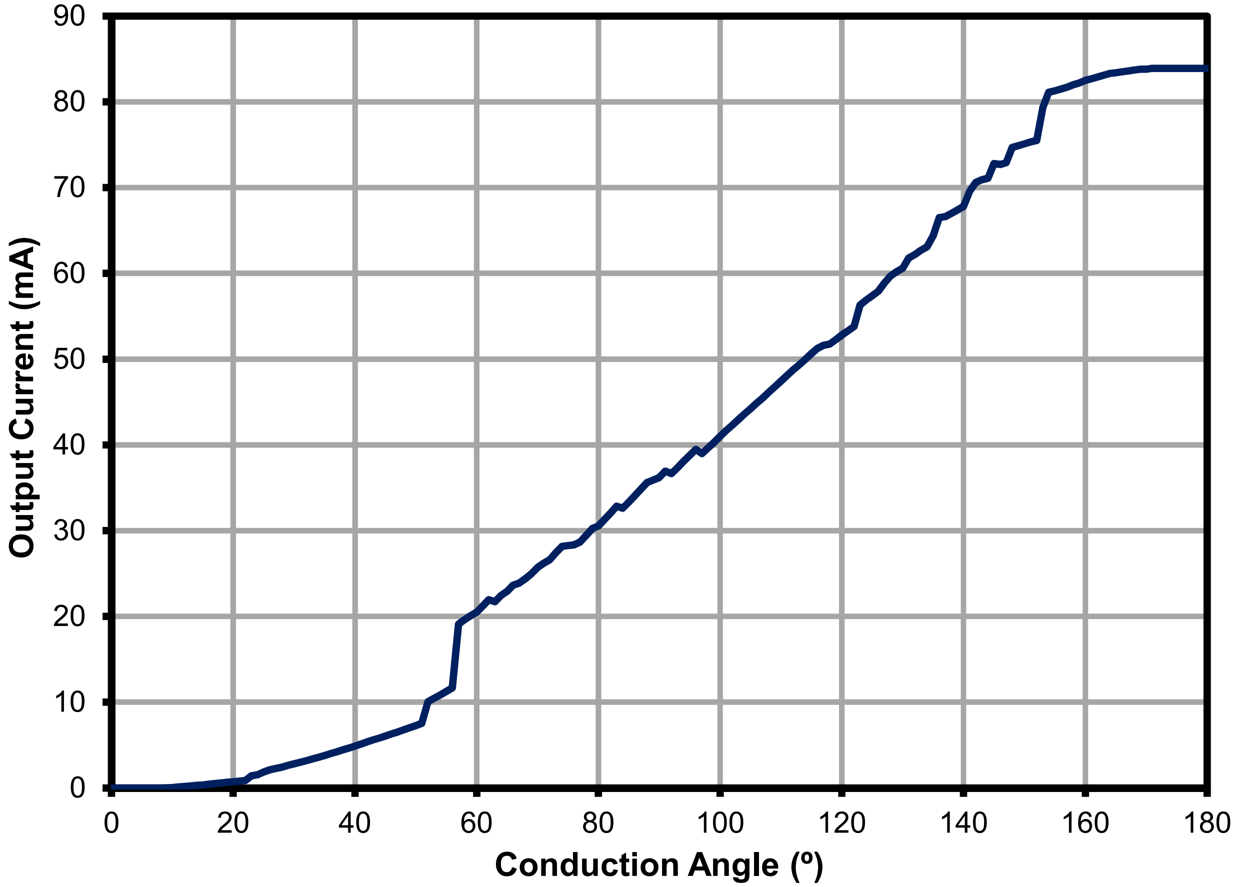

Figure 55 – Dimming Curve Characteristic; Measured from Controlled AC Source to Emulate the Dimmer Conduction Angle.

12 Line Surge

Input voltage was set at 230 VAC / 60 Hz. Output was loaded with 48 V LED string and operation was verified following each surge event.

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

Surge Level (V) 10strikes/condition	**Input Voltage (VAC)**	**Injection Location**	**Injection Phase (°)**	**Test Result (Pass/Fail)**
+1000	230	L to N	0	Pass
-1000	230	L to N	0	Pass
+1000	230	L to N	90	Pass
-1000	230	L to N	90	Pass

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

Surge Level (V) 10strikes/condition	**Input Voltage (VAC)**	**Injection Location**	**Injection Phase (°)**	**Test Result (Pass/Fail)**
+2500	230	L to N	0	Pass
-2500	230	L to N	0	Pass
+2500	230	L to N	90	Pass
-2500	230	L to N	90	Pass

Unit passes under all test conditions.

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13 Conducted EMI

13.1 Equipment

Receiver:

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

LISN:

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

13.2 EMI Test Set-up

LED driver is placed in a conical metal housing (for self-ballasted lamps; CISPR15 Edition 7.2).

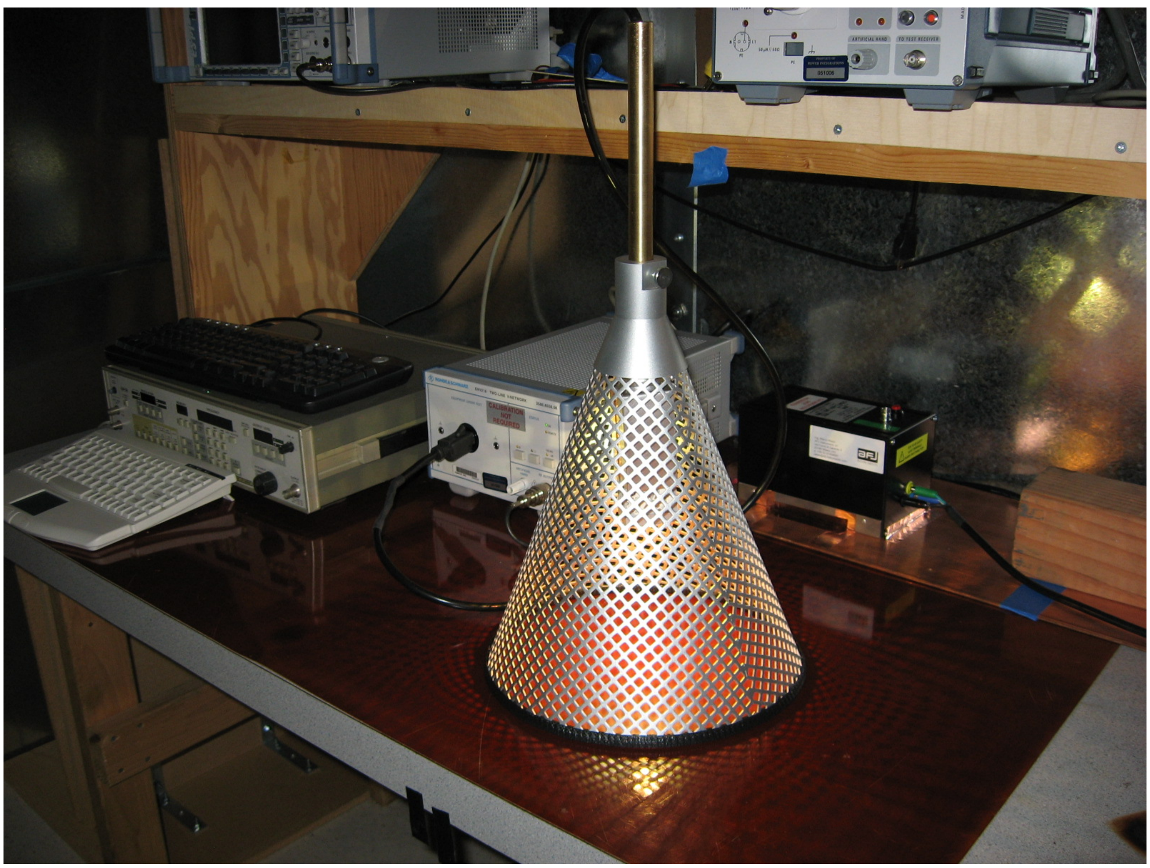

Figure 56 – Conducted Emissions Measurement Set-up
Showing Conical Ground Plane Inside which UUT was Mounted.

13.3 EMI Test Result

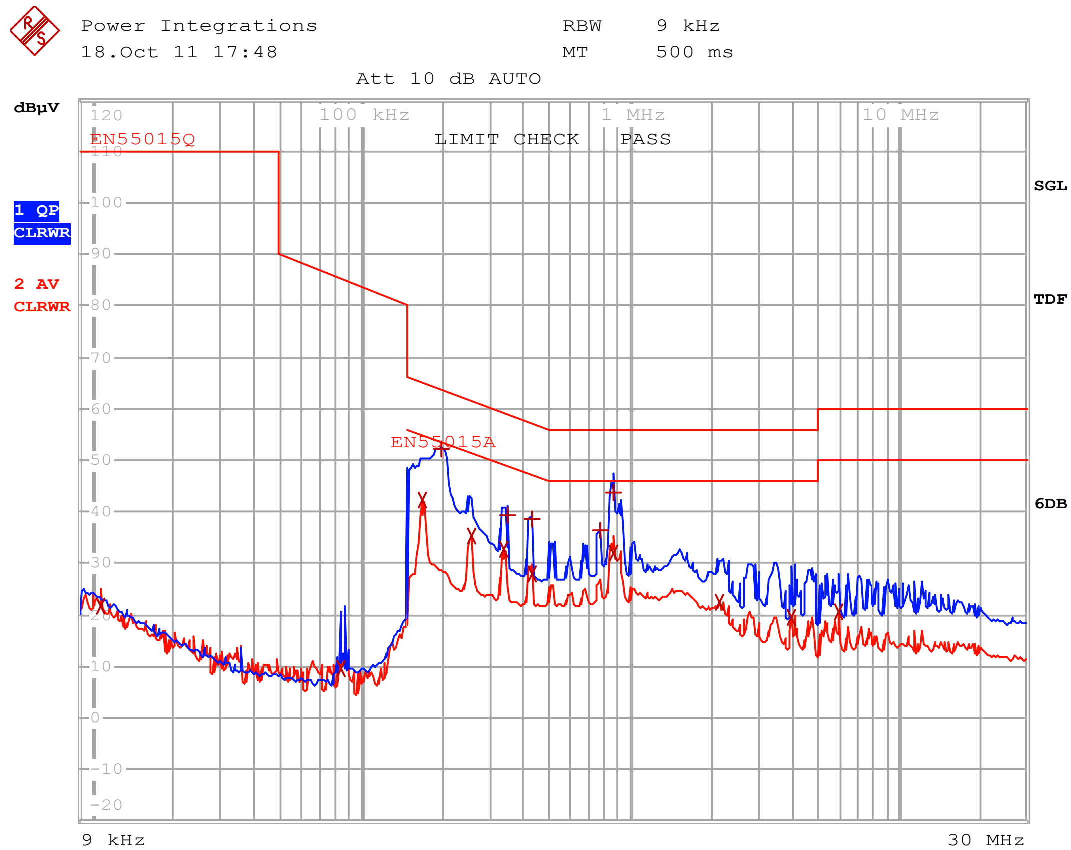

Figure 57 – Conducted EMI, 48 V / 80 mA Steady-State Load, 230 VAC, 60 Hz, and EN55015 Limits.

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EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55015Q
Trace2: EN55015A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV		DELTA LIMIT dB
2	Average	9.64921816896 kHz	22.51	L1 gnd	
3	Quasi Peak	90.5318149441 kHz	9.16	L1 gnd	
2	Average	133.454986145 kHz	34.00	N gnd	
1	Quasi Peak	151.5 kHz	45.23	L1 gnd	-20.68
3	Quasi Peak	177.645664706 kHz	46.59	N gnd	
2	Average	196.231331718 kHz	42.75	L1 gnd	-11.01
1	Quasi Peak	225.562855639 kHz	47.76	N gnd	-14.84
1	Quasi Peak	254.169871602 kHz	52.39	N gnd	-9.22
2	Average	261.871472881 kHz	41.28	L1 gnd	-10.09
3	Quasi Peak	267.135089486 kHz	51.59	N gnd	
2	Average	325.955575511 kHz	35.12	L1 gnd	-14.43
3	Quasi Peak	352.963180679 kHz	31.44	L1 gnd	
2	Average	389.890938834 kHz	31.30	L1 gnd	-16.76
1	Quasi Peak	401.705024172 kHz	39.76	L1 gnd	-18.05
3	Quasi Peak	448.169580165 kHz	34.81	L1 gnd	
2	Average	457.177788726 kHz	28.62	L1 gnd	-18.11
1	Quasi Peak	466.367062279 kHz	38.33	L1 gnd	-18.24
3	Quasi Peak	715.396717193 kHz	29.60	L1 gnd	
3	Quasi Peak	798.145472681 kHz	33.36	N gnd	
2	Average	864.277177159 kHz	29.94	N gnd	-16.05

Figure 58 – Conducted EMI, 48 V / 80 mA Steady-State Load Steady-State Load, 230 VAC, 60 Hz, and EN55015 Limits. Line and Neutral Scan Design Margin Measurement.

14 Revision History

Date	Author	Revision	Description and Changes	Reviewed
10-Nov-11	JDC	1.0	Initial Release	Apps and Mktg

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