Design Example Report

Title	***40 W 2-Stage Buck-Boost and Isolated Flyback Dimmable LED Ballast Using LinkSwitchTM-PH LNK419EG and LYTSwitchTM-6 LYT6068C***
Specification	90 VAC – 305 VAC Input; 42 V, 960 mA Output
Application	3-Way Dimming LED Ballast
Author	Applications Engineering Department
Document Number	DER-597
Date	February 16, 2018
Revision	1.1

Summary and Features

- With integrated PFC function, PF >0.9
- Accurate output voltage and current regulation, ±5%
- Very low ripple current, <10% of I_{OUT}
- Highly energy efficient, >88 % at 230 V
- Low cost and low component count for compact PCB solution
- 3-way dimming functions
  - 0 VDC - 10 VDC analog dimming
  - 10 V PWM signal (frequency range: 100 Hz to 3 kHz)
  - Variable resistance (0 to 100 kΩ)
- Integrated protection and reliability features
  - Output short-circuit
  - Line and output OVP
  - Line surge or line overvoltage
  - Thermal foldback and over temperature shutdown with hysteretic automatic power recovery
- No damage during line brown-out or brown-in conditions
- Meets IEC 2.5 kV ring wave, 2 kV differential surge
- Meets EN55015 conducted EMI

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PATENT INFORMATION

The products and applications illustrated herein (including transformer construction and circuits external to the products) may be covered by one or more U.S. and foreign patents, or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at www.powerint.com. Power Integrations grants its customers a license under certain patent rights as set forth at <http://www.powerint.com/ip.htm>.

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Important Note: Although this board is designed to satisfy safety isolation requirements, 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.

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1 Introduction

This engineering report describes a constant voltage (CV) and constant current (CC) output 40 W LED ballast with 3-way dimming functions. At constant voltage application, the LED ballast is designed to provide a 42 V output voltage across 0 mA to 960 mA output current load while at constant current mode operation, it can provide 960 mA (3-way dimmable) constant current at 42 V – 30 V LED voltage string. The design is optimized to operate from an input voltage range of 90 VAC to 305 VAC.

The LED ballast employs a two-stage design with a buck-boost PFC at first stage and an isolated flyback DC-DC for the secondary stage. The buck-boost PFC utilizes LNK419EG from the LinkSwitch-PH family of device while the second stage flyback uses LYTSwitch-6 controller.

LinkSwitch-PH is a highly integrated controller that eliminates passive circuitry for power factor correction. LinkSwitch-PH ICs incorporate a 725 V power MOSFET, a continuous mode PWM controller, a high-voltage switched current source for self-biasing, frequency jittering, protection circuitry including cycle-by-cycle current limit and hysteretic thermal shutdown.

LYTSwitch-6 ICs combine primary, secondary and feedback circuits in a single surface mounted off-line flyback switcher IC. The LYTSwitch-6 IC incorporates the primary FET, the primary-side controller and a secondary-side synchronous rectification controller. The new IC also includes an innovative new technology, FluxLink™, which safely bridges the isolation barrier and eliminates the need for an optocoupler.

DER-597 offers high power factor, wide input and output voltage ranges, 3-way dimmable and low component count solution for 40 W LED ballast. The key design goals were low component count, high power factor, high efficiency and low component count.

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

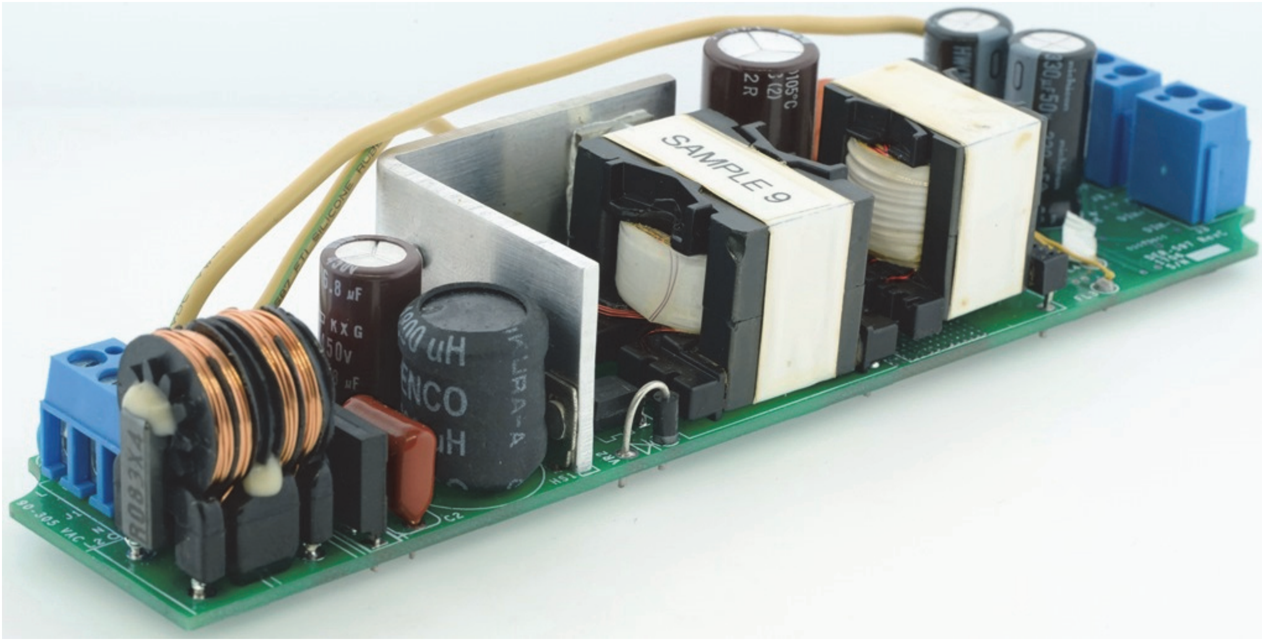

Figure 1 – Populated Circuit Board

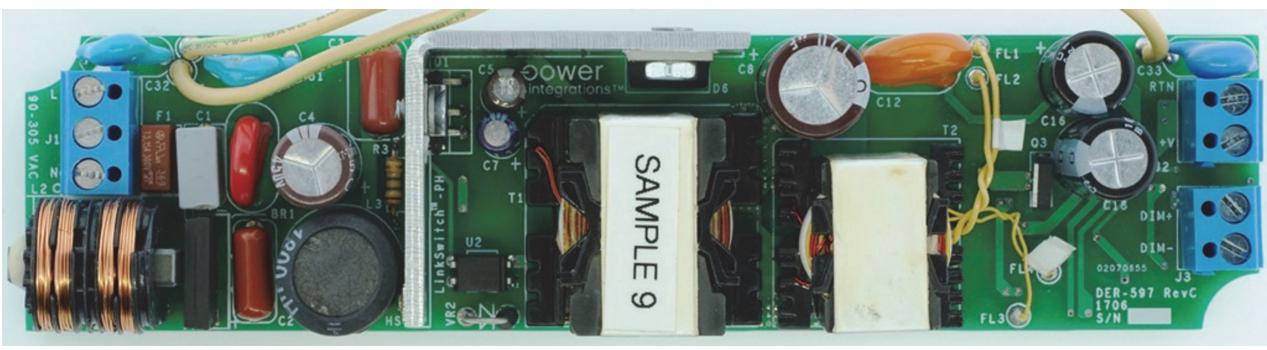

Figure 2 – Populated Circuit Board, Top View.

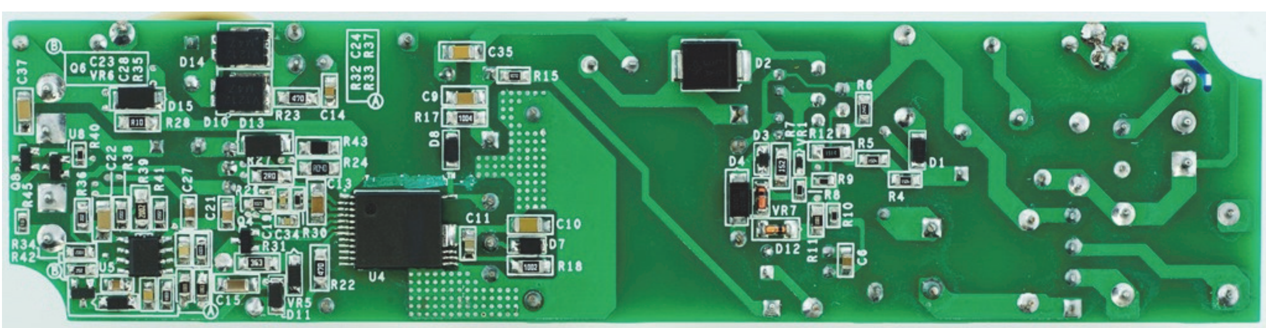

Figure 3 – Populated Circuit Board, Bottom View.

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2 Power Supply Specification

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}	90	115 / 60	305	VAC / Hz	2-wire floating output or 3-wire with P.E.
Frequency	f_{LINE}		230 / 50 277 / 50			
Output						
Output Voltage	V_{OUT}		42		V	
Output Current	I_{OUT}	912	960	1008	mA	±5%
Total Output Power						
Continuous Output Power	P_{OUT}		40.32		W	
Efficiency						
Full Load	η		88		%	230 V / 50 Hz at 25 ºC.
Environmental						
Conducted EMI		CISPR 15B / EN55015B				
Safety		Isolated				
Ring Wave (100 kHz)			2.5		kV	
Differential Mode (L1-L2)			2.0		kV	
Power Factor			0.9			Measured at 115 V / 60 Hz, 230 VAC / 50 Hz and 277 V / 50 Hz.
Ambient Temperature	T_{AMB}			60	ºC	Free Air Convection, Sea Level.

3 Schematic

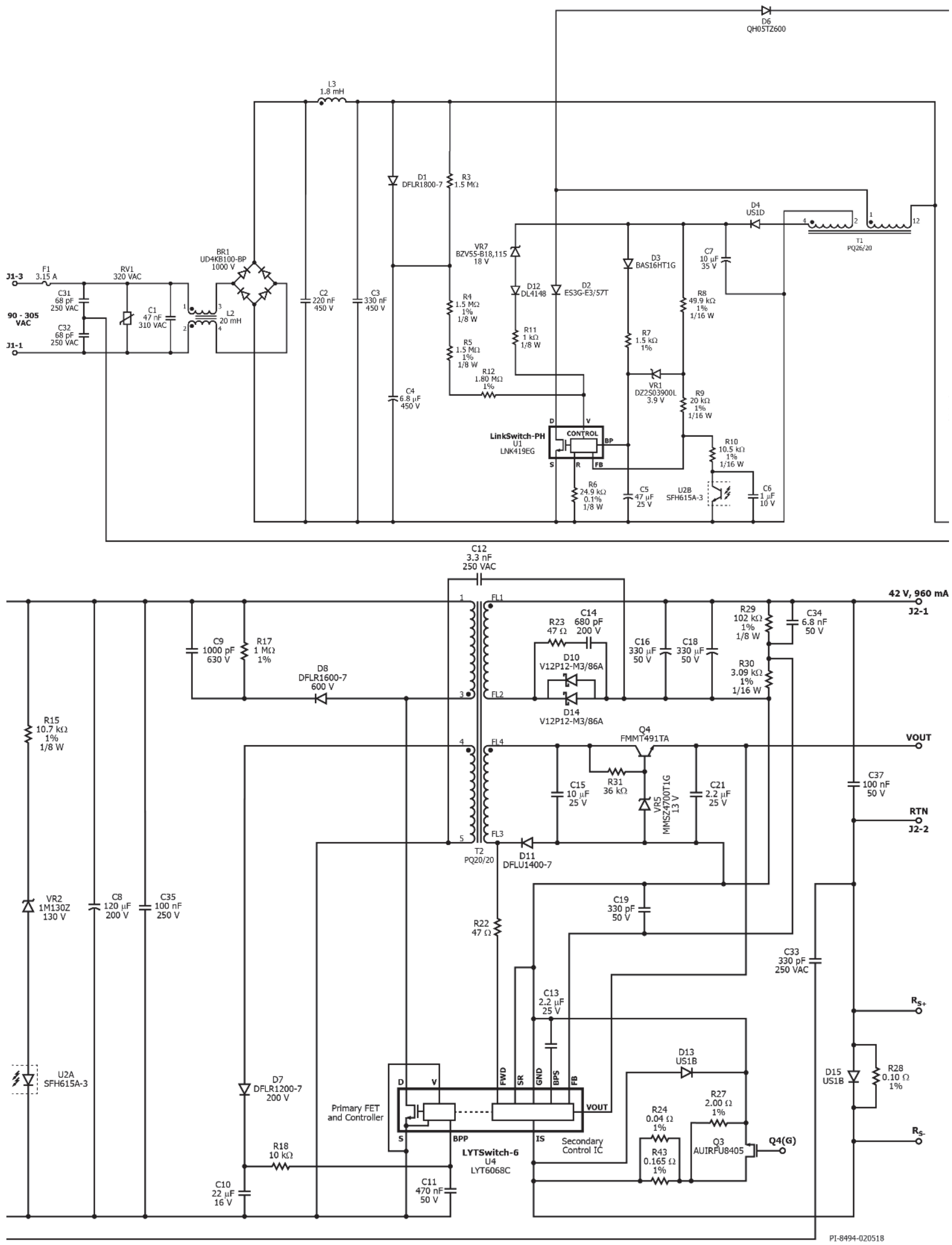

Figure 4 – Schematic.

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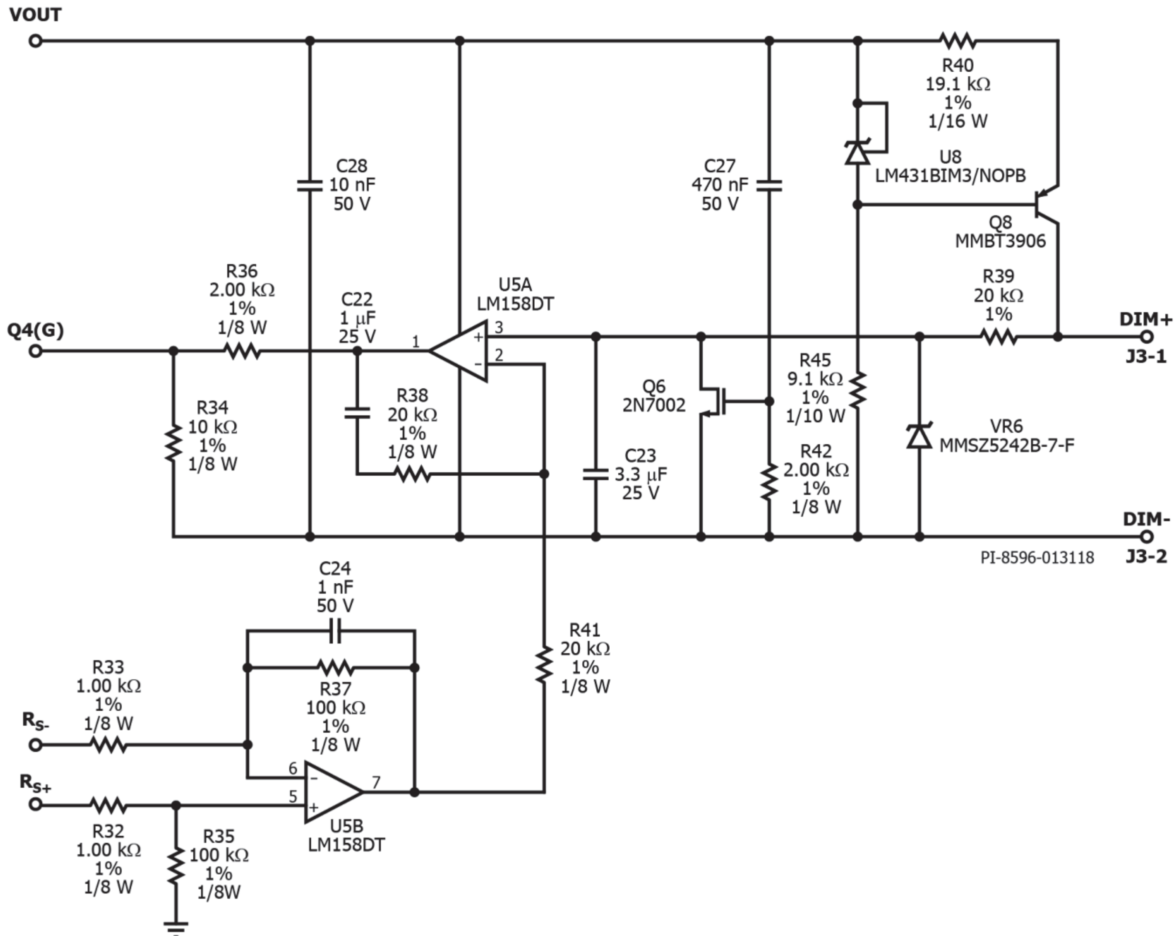

Figure 5 – Schematic.

4 Circuit Description

The LED ballast circuit employs two-stage PFC with 3-way dimming circuit functions. The first stage is a buck-boost PFC using LNK419EG from LinkSwitch-PH family of devices. The second stage is an isolated flyback DC-DC power supply using a LYTSwitch-6 IC.

LinkSwitch-PH is a highly integrated LED constant current controller which is configured to provide a highly efficient single-stage power factor correction stage with very low external passive components.

LYTSwitch-6 incorporates the primary FET, the primary-side controller and a secondary-side synchronous rectification controller. This IC also includes an innovative new technology, FluxLink™, which safely bridges the isolation barrier and eliminates the need for an optocoupler.

The figure below shows the LED ballast block diagram.

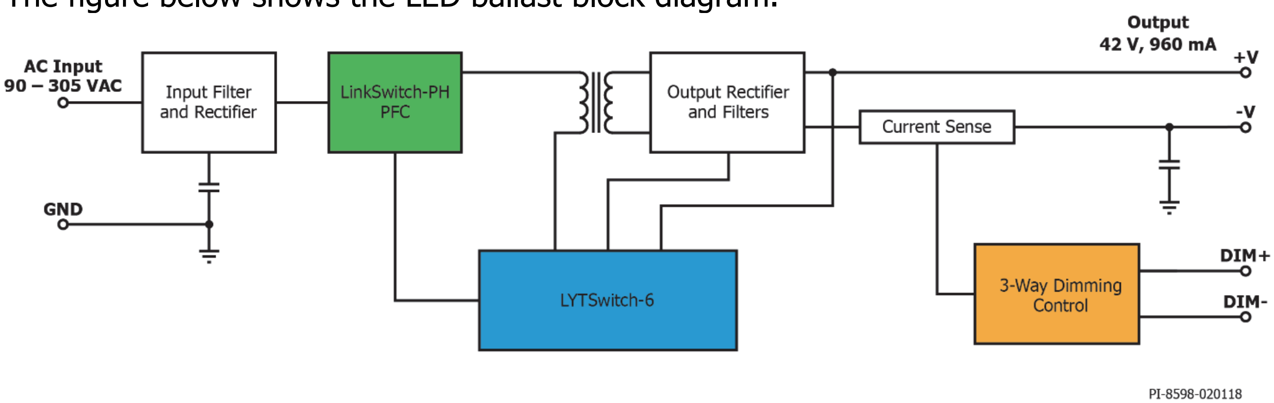

Figure 6 – Ballast Circuit Block Diagram.

4.1 *Input EMI Filter and Rectifier*

The input fuse F1 provides safety protection. Varistor RV1 acts as a voltage clamp that limits the voltage spike on the primary during line transient voltage surge events. A 320 V rated part was selected, being slightly above the maximum specified operating input voltage (320 V). The AC input voltage is full wave rectified by BR1 to achieve good power factor and low THD. Capacitor C2, C3 and L3 form a pi filter which together with C1 suppress differential mode noise. Common mode noise is suppressed by common mode choke L2 together with Y capacitor C12. Additional Y capacitors C31, C32 and C33 were added for earth wire connection to suppress common mode noise.

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4.2 *First Stage: Buck-Boost PFC Using LinkSwitch-PH*

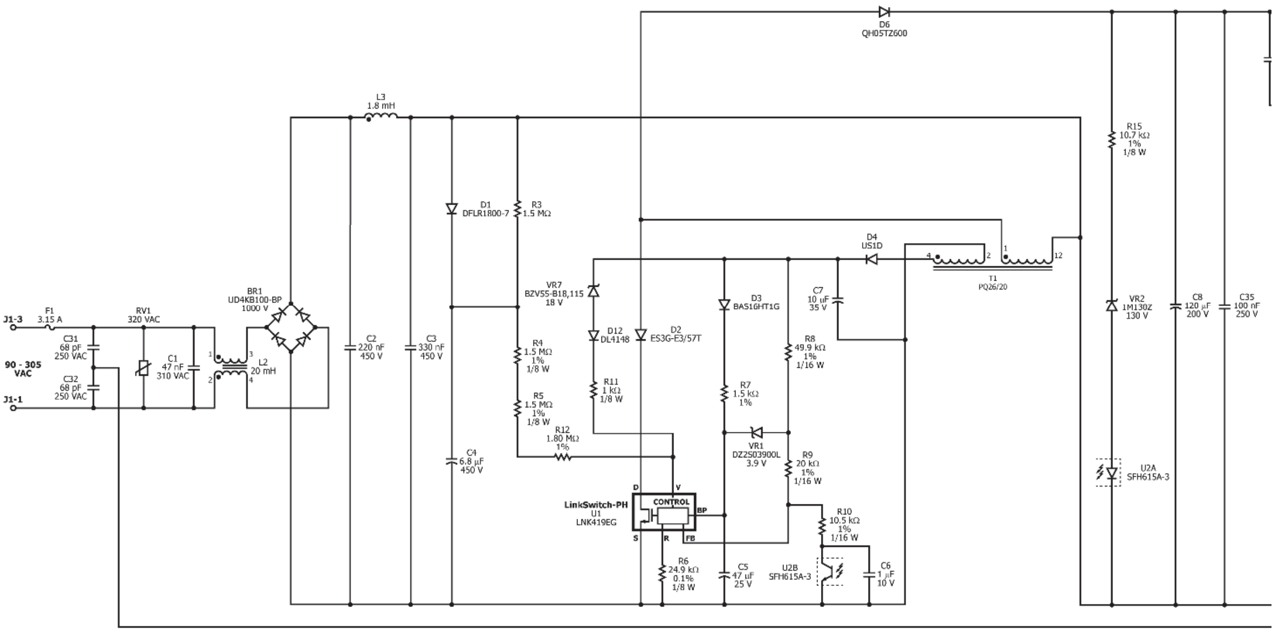

Figure 7 – PFC Circuit Diagram.

The PFC circuit topology is a low side buck-boost configuration, where the FET of U1 is connected to the ground rail. It was configured to operate at CV mode operation to power the second stage flyback DC-DC. During the FET on-time, current ramps through the inductor (T1) winding storing energy in the form of magnetic field which is then delivered to the output load via boost diode D6 during the FET off-time. The output voltage of the PFC was set to 130 VDC which was optimized based on the boost diode (D6) voltage stress (600 V).

PFC Output Voltage: $V_{OPFC} < (V_{RRM} – 1.41 \times V_{ACMAX})/1.2$
V_{RRM}: Boost diode peak repetitive reverse voltage

For higher efficiency at CCM operation, QH05TZ600 from the Qspeed™ family was selected. Diode QH05TZ600 has the lowest Q_{RR} and t_{RR} of any 600 V rated silicon diode. The inductance of the inductor T1 was optimized to keep the operation in CCM. This is done to ensure high power factor and Low THD (<15%). CCM operation also reduces the primary RMS current that results to lower EMI and higher efficiency.

Diode D2 is necessary to prevent reverse current from flowing through U1 during the period when the AC input voltage is lower than the reflected output voltage.

Diode D1 and C4 detect the peak AC line voltage. This voltage is converted to a current into the VOLTAGE MONITOR (V) pin via R4, R5 and R12. This current is also used by the device to set the input over/undervoltage protection thresholds and to provide a linear relationship between input voltage and the output current. The V pin current and the FEEDBACK (FB) pin current are used internally to control the average output LED current. Resistor R3 provides a discharge path for C3 with a time constant much longer than that of the rectified AC to prevent generation of line frequency ripple.

Constant current (CC) non-dimming applications require 24.9 kΩ ±1% resistance value for (R6) on the REFERENCE (R) pin.

Capacitor C5 provides local decoupling for the BP pin of U1. The BP pin also serves as the supply pin for the internal controller. During start-up, C5 is charged to ~6 V from an internal high-voltage current source connected to the (D) pin of U1. Once charged, U1 starts switching at which point the operating supply current is provided from the bias supply via R7. Diode D3 isolates the BP pin from the bias capacitance C7 to prevent the start-up time increasing due to charging of both C7 and C5.

Diode D12, VR7 and R11 provide OVP protection. The output OVP is set through the (V) pin line OVP threshold (I_{OV}). Diode D12 blocks current going to C7 during start-up to prevent triggering the undervoltage protection (I_{UV-}). Once the bias voltage exceeded its Zener voltage threshold, VR7 conducts current increasing the I_V. Once I_{OV} is reached, the IC will terminate the switching immediately preventing the output voltage from rising further

At CV mode operation, the bias supply is very slow to ramp up during full load start-up. Zener diode VR1 is needed to provide feedback current from BP pin to FB pin to prevent I_{FB} current from going down to auto-restart threshold.

To maintain the output voltage across the load, a closed loop negative feedback circuit is used comprising of Zener diode VR2 and an optocoupler U2. Zener diode VR2 senses the output voltage and conducts current I_Z with respect to its V_Z threshold. The Zener diode current I_Z drives the optocoupler U2 to control the U1-LNK419EG FB current.

Output capacitor C8 and C35 provides PFC output filtering for a low ripple voltage supply to the DC-DC circuit.

The thermal shutdown circuitry senses the controller die temperature. The threshold is set at 142 °C typical with a 75 °C hysteresis. When the die temperature rises above this threshold (142 °C) the power FET is disabled and remains disabled until the die temperature falls by 75 °C, at which point the power FET is re-enabled.

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4.3 *Second Stage: Isolated Flyback DC-DC Using LYTSwitch-6*

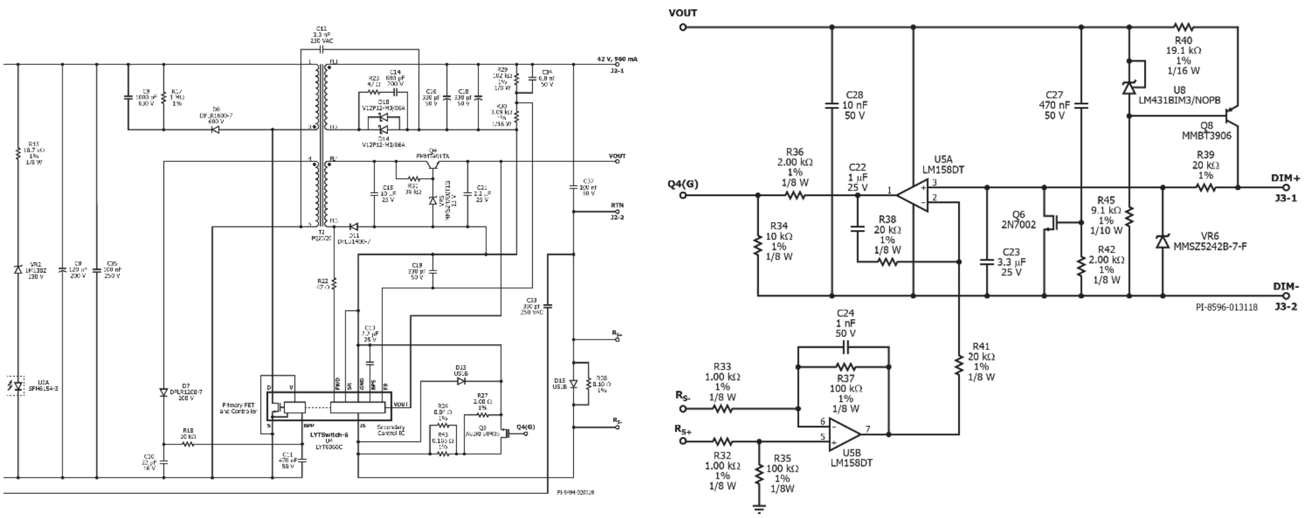

Figure 8 – Isolated Flyback DC-DC Circuit Block Diagram.

The second stage circuit topology is a flyback DC-DC power supply controlled by the LYTSwitch-6 IC. One side of the transformer (T2) primary is connected to the positive output terminal of the PFC while the other side is connected to the integrated 650 V power MOSFET inside the LYTSwitch-6 IC (U4). A low cost RCD clamp formed by D8, R17 and C9 limits the peak drain leakage voltage spike due to the effects of transformer leakage inductance.

The VOLTAGE MONITOR (V) pin of LYTSwitch-6 IC is connected to ground to disable the input line detection time during start-up that could extend the ballast turn on delay.

During start-up when PFC output voltage is first applied, an internal high-voltage current source charges the BPP pin capacitor (C11). During normal operation the primary side block is powered by the auxiliary winding of the transformer. The auxiliary winding is configured as a flyback, rectified and filtered (D7 and C10) and fed to the BPP pin via a current limiting resistor R18. Output regulation is achieved by controlling the switching duty cycle.

The secondary-side control of the LYTSwitch-6 provides output voltage and output current sensing. The secondary of the transformer is rectified by low V_F Schottky diodes D10 and D14 and then filtered by C16 and C18. High frequency ringing during switching transients that would otherwise create high-voltage across output diode D10 and D14 is reduced via snubber components R22 and C14.

SYNCHRONOUS RECTIFIER DRIVE (SR) pin is connected to secondary ground to allow the use of cheaper Schottky output diode instead of using an SR FET.

Secondary bias supply provides a regulated voltage supply to the 3-way dimming circuit. The secondary bias winding is rectified by D11 and filtered by C15. A series regulator comprising of VR5, R31, Q4 and C21 provides a 13 V regulated supply to the dimming circuit and the secondary side block of LYTSwitch-6 IC. For lower voltage stress, the FORWARD (FWD) pin supply is connected to the lower voltage secondary bias winding instead of connecting to secondary winding.

The secondary side of the IC is self-powered from either the secondary bias winding forward voltage or the secondary bias 13 V regulated output. During CV operation the regulated secondary bias supply voltage powers the device which is fed into the VO pin. During CC operation, when the output voltage falls the device will power itself from the secondary bias winding directly. During the on-time of the primary side MOSFET the forward voltage that appears across the secondary winding is used to charge the C13 via R22 and an internal regulator.

Output current is sensed externally via sense resistors R43, R24 together with dimming resistor R27 between the IS and GND pins with a threshold of 35 mV to minimize losses. Once the internal current sense threshold is exceeded, the device adjusts the switching frequency to maintain a fixed output current. Diode D13 serves as a clamp during output short-circuit condition to protect the IS pin from overvoltage stress.

Above the CC threshold the device operates in constant voltage mode. The output voltage is sensed via resistor divider R29 and R30 operation with a reference voltage of 1.265 V on the FB pin when at the regulation output voltage. Filter capacitor C19 and C34 are added across feedback resistors to filter unwanted noise and prevent mis-trigerring the OVP function. The unit enters auto-restart when the sensed output voltage is lower than 3 V.

The thermal shutdown circuitry senses the primary MOSFET die temperature. The threshold (T_{SD}) is typically set to 142 °C with 70 °C hysteresis $T_{SD(H)}$. When the die temperature rises above this threshold the power MOSFET is disabled and remains disabled until the die temperature falls by $T_{SD(H)}$ at which point it is re-enabled. A large hysteresis of 70 °C is provided to prevent over-heating of the PCB due to continuous fault condition.

The thermal foldback is activated when the secondary controller die temperature reaches 124 °C, the output power is reduced by reducing the constant current reference threshold.

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4.4 ***3-Way Dimming Control Circuit***

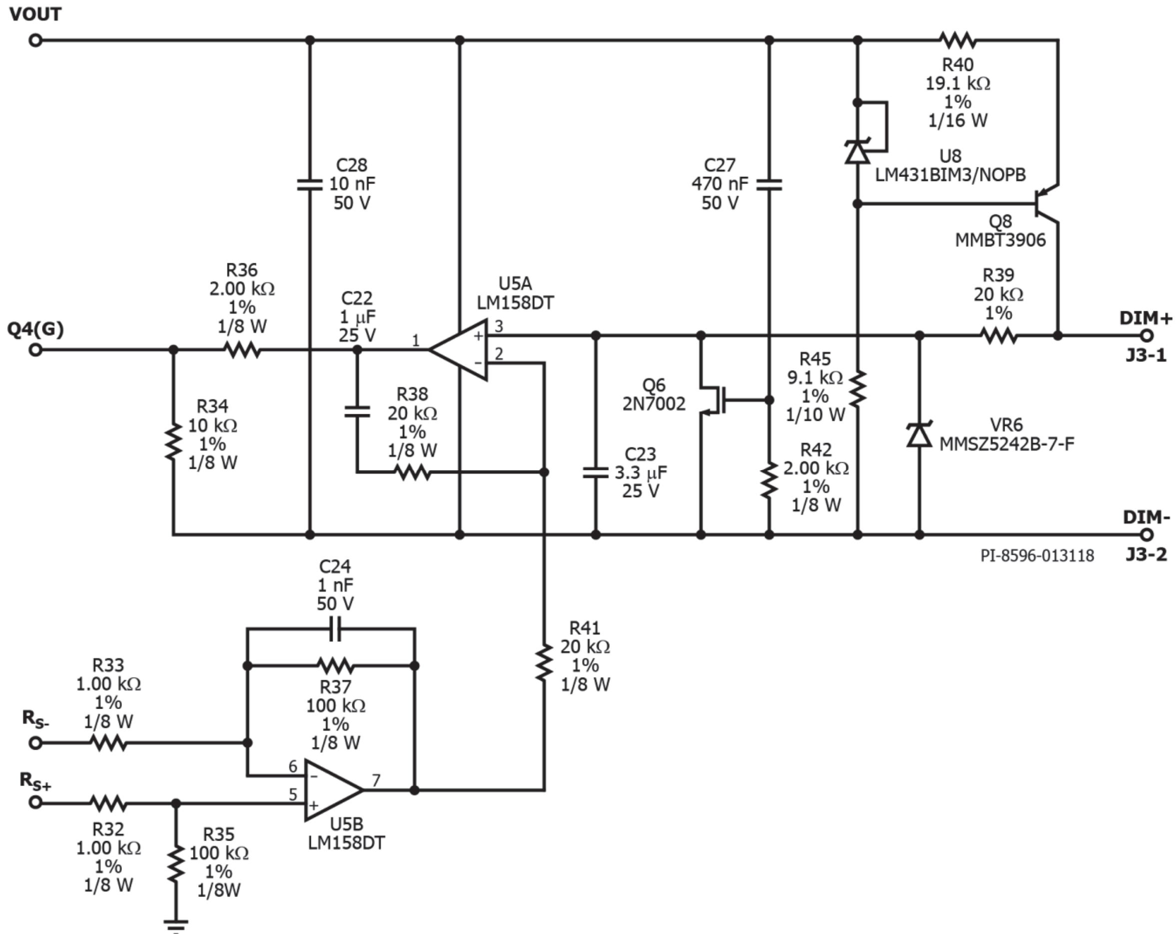

Figure 9 – 3 Way Dimming Circuit Diagram.

The simplified 3-way dimming control circuit with series MOSFET is shown in Figure 9. The idea is to vary the constant current (CC) point of the DCDC output section by varying the total sense resistance seen across IS (pin 1) and GND (pin 2) of U4 (LYTSwitch-6 IC). This is done by varying the ohmic resistance across drain-to-source of Q3 depending on the set voltage, PWM duty cycle, or resistance across the dimming input terminals, DIM+ and DIM-. IC U5 is a dual op-amp. The first op-amp, U5A, monitors the voltage from the dimming input and compares it with the voltage coming from the second op-amp, U5B, which serves as reference by providing output current information. IC U5B is configured as a differential amplifier which monitors the level of the output current I_{OUT}. The following considerations are made to simplify the voltage equation at pin 7 of U5B (V1):

If $\boldsymbol{R32 = R33} \quad \boldsymbol{and} \quad \boldsymbol{R35 = R37}$
Then $\boldsymbol{V_1} = (\boldsymbol{I_{OUT}} * \boldsymbol{R28})\ \frac{\boldsymbol{R37}}{\boldsymbol{R33}}$

The output of U5A drives the gate of Q3 to maintain the output current to a level that corresponds to a zero difference in voltage between its inverting (pin 2) and non-inverting (pin 3) terminals. For example, if the voltage at its non-inverting pin increases, its output also increases to drive Q3 harder (decreasing the drain-to-source resistance), resulting to larger I_{OUT} and, thereby, increasing V1 to the level equal to the voltage at non-inverting pin of U5A. Since the voltage at the non-inverting pin of U5A is proportional to the voltage (or duty cycle, in case of PWM input) across DIM+ to DIM-, the output current could be controlled via these terminals. If no input is applied to DIM+ and DIM-, the capacitor C23 will charge to the level of V_{OUT} which is also the voltage at the non-inverting (pin 3) of U5A. This will result to maximum output voltage at pin 1 driving Q3 at its minimum $R_{DS(ON)}$. The minimum $R_{DS(ON)}$ of Q3 is chosen to be very small compared to R24 such that at this condition, the maximum output current will be dictated by R24.

The supply voltage of the dimming circuit comes from an auxiliary winding (FL3 and FL4) which is rectified and filtered by D11 and C15, respectively. Transistor Q4, R31, and VR5 form a linear regulator which maintains the voltage at V_{OUT} to around 11.5 V that serves as the supply of the dimming circuit and the VOUT pin (pin 6) of U4. Capacitor C21 serves as a bypass filter to the VOUT pin (pin 6) of U4 while C28 is the bypass filter for the op-amp IC supply pin – these are especially helpful in filtering unwanted noise when the regulator and the ICs have to be quite far in the PCB layout and there are high dv/dt or di/dt traces (critical loops) nearby.

MOSFET Q6, C27, and R42 form a one shot, blanking circuit to discharge whatever voltage there is at C23 during start-up and ensure it will start charging from around 0 V. This avoids non-monotonic, output current overshoot during start-up especially when there’s already a voltage applied across DIM+ to DIM- before powering-up the unit.

Zener diode VR6 serves as protection in case the DIM+ terminal is accidentally connected to the output terminal by preventing excessive voltage at the non-inverting pin of U5A. It also protects against negative input to the non-inverting pin of U5A in case the DIM+ and DIM- are accidentally interchanged.

Resistor R41 is necessary to cancel the effect of input bias current. Thus, its value is set to be equal to R39. C22 and R38 form the frequency compensation for U5A, adding a pole and a zero to the frequency response characteristics of the circuit.

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4.4.1 0 VDC - 10 VDC Dimming

When a voltage is applied across DIM+ to DIM-, C23 will be charged up to this voltage level via R39. Essentially, the voltage at the dimming input terminals will also be the voltage at the non-inverting pin of U5A. U5A will respond to this input by increasing/decreasing its output, driving Q3 to adjust the output current to a level that will result to a voltage level at V1 equal to the dimming input voltage. The dimming input range is from 0 V to 10 V – applying 0 V will result to minimum output current while applying 10 V will result to maximum output current.

4.4.2 Variable Duty PWM Input (10 V Peak)

When a PWM signal is applied across DIM+ to DIM-, the averaging filter composed of R39 and C23 will result to a voltage at the non-inverting (pin 3) terminal of U5A proportional to the PWM duty cycle.

That is,

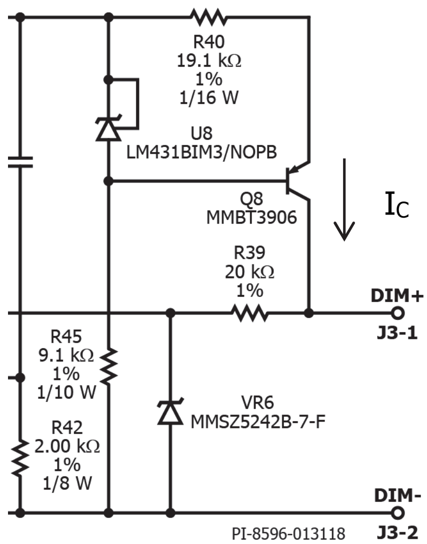
$$V_{+\ of\ U5A} = D * V_{PEAK}$$

Where:

$V_{+\ of\ U5A}$ – voltage at the non-inverting pin of U5A
D – PWM duty cycle
V_{PEAK} – max. voltage of the PWM signal

The maximum voltage of the PWM input should be 10 V and the minimum frequency should be 300 Hz. The value of R39 and C23 are chosen such that the resulting time constant (RC product) is much larger than the period of the minimum PWM frequency to ensure effective filtering.

4.4.3 Variable Resistance (0 Ω – 100 kΩ)



A voltage divider bias PNP transistor circuit is used to convert the resistance dimming input into dimming voltage input. It uses a 2.5 V constant reference voltage from LM431 U8 to accurately regulate the collector current.

$I_C = (2.5 - V_{BE}) / R_{40}$

The Q8 collector current (I_C) drives the dimming input resistor to come up with dimming input voltage from 0 V - 10 V which basically same dimming profile with 0 V - 10 V dimming.

$V_{DIM} = I_C * R_{DIM} = 0\ V - 10\ V$

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5 PCB Layout

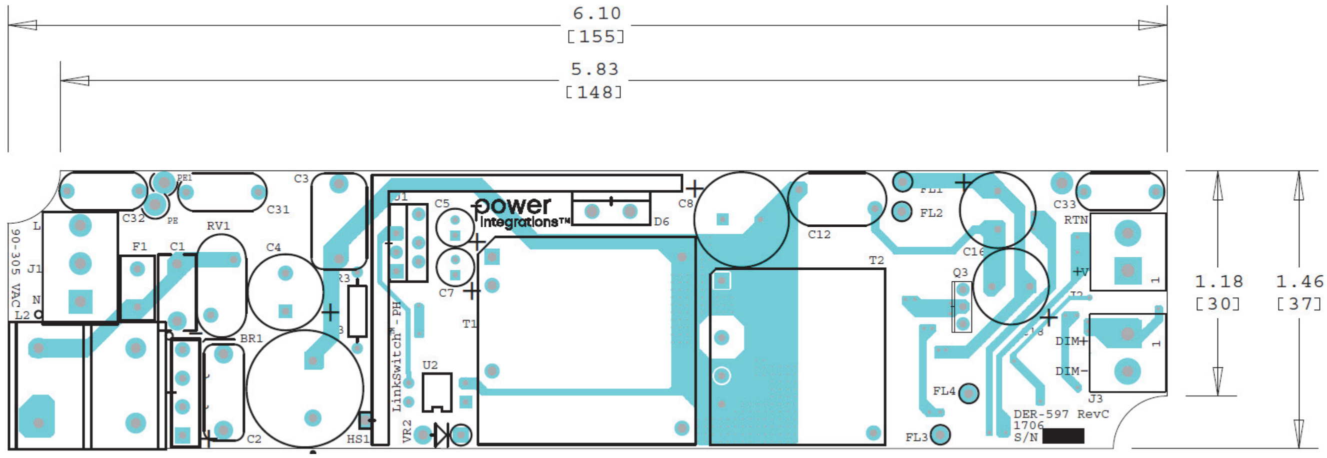

Figure 10 – Top Side.

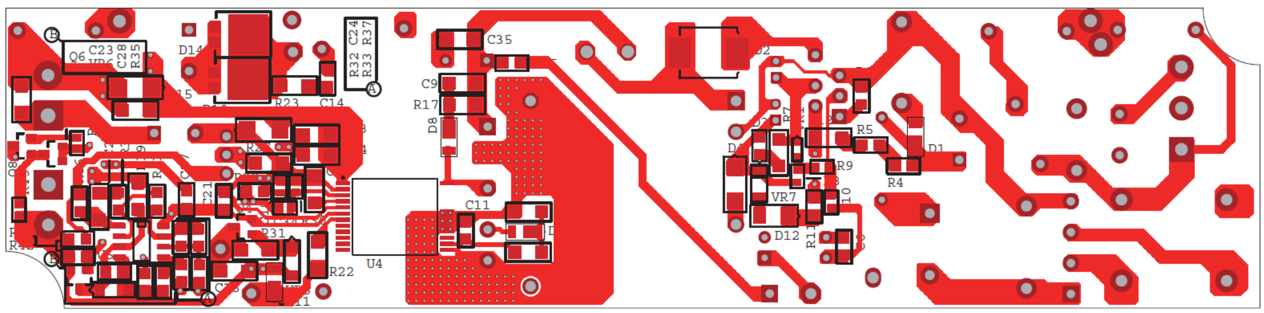

Figure 11 – Bottom Side.

6 Bill of Materials

6.1 *Main BOM*

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	Bridge Rectifier, 1000 V, 4 A, 4-ESIP	UD4KB100-BP	Micro Commercial
2	1	C1	47 nF, 310 VAC, Polyester Film, X2	BFC233920473	Vishay
3	1	C2	220 nF, 450 V, Film	MEXXF32204JJ	Duratech
4	1	C3	330 nF, 450 V, METALPOLYPRO	ECW-F2W334JAQ	Panasonic
5	1	C4	6.8 μF, 450 V, Electrolytic, (10 x 20),	EKXG451ELL6R8MJ20S	Nippon Chemi-Con
6	1	C5	47 μF, 25 V, Electrolytic, Very Low ESR, 300 mΩ, (5 x 11)	EKZE250ELL470ME11D	Nippon Chemi-Con
7	1	C6	CAP, CER, 1UF, 10V, X7R, 0805	CL21B105KPFNNNE	Samsung
8	1	C7	10 μF, 35 V, Electrolytic, Gen. Purpose, (5 x 11)	ECA-1VM100	Panasonic
9	1	C8	120 μF, 200 V, Electrolytic, (12.5 x 25)	EKMQ201ELL121MK25S	Nippon Chemi-Con
10	1	C9	1000 pF, 630 V, Ceramic, X7R, 1206	C1206C102KBRACTU	Kemet
11	1	C10	22 μF, 16 V, Ceramic, X5R, 1206	EMK316BJ226ML-T	Taiyo Yuden
12	2	C11 C27	470 nF, 50 V, Ceramic, X7R, 0805	GRM21BR71H474KA88L	Murata
13	1	C12	3.3 nF, Ceramic, Y1	440LD33-R	Vishay
14	1	C13	2.2 μF, 25 V, Ceramic, X7R, 1206	TMK316B7225KL-T	Taiyo Yuden
15	1	C14	680 pF 200V X7R MULTI-LAYER CERAMIC ± 10 %	C0805C681K2RACAUTO	Kemet
16	1	C15	10 μF, 25 V, Ceramic, X7R, 1206	C3216X7R1E106M	TDK
17	2	C16 C18	CAP, ALUM, 330 uF, 20%, 50 V, RADIAL, 10000 Hrs @ 105°C, 0.394"	UHW1H331MPD493-6975-ND	Nichicon
18	1	C19	330 pF 50 V, Ceramic, X7R, 0603	CC0603KRX7R9BB331	Yageo
19	1	C21	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
20	1	C22	1 μF, 25 V, Ceramic, X7R, 1206	C3216X7R1E105K	TDK
21	1	C23	3.3 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E335K	TDK
22	1	C24	1 nF, 50 V, Ceramic, X7R, 0805	08055C102KAT2A	AVX
23	1	C28	10 nF, 50 V, Ceramic, X7R, 0805	C0805C103K5RACTU	Kemet
24	2	C31 C32	68 pF, Ceramic, Y1	440LQ68-R	Vishay
25	1	C33	330 pF, Ceramic Y1	440LT33-R	Vishay
26	1	C34	6.8 nF 50 V, Ceramic, X7R, 0603	CC0603KRX7R9BB682	Yageo
27	1	C35	100 nF, 250 V, Ceramic, X7R, 1206	C3216X7R2E104M	TDK
28	1	C37	100 nF, 50 V, Ceramic, X7R, 1206	CC1206KRX7R9BB104	Yageo
29	1	D1	800 V, 1 A, Rectifier, POWERDI123	DFLR1800-7	Diodes, Inc.
30	1	D2	DIODE ULTRA FAST 400V 3A, DO-214AB	ES3G-E3/57T	Vishay
31	1	D3	75 V, 200 mA, Rectifier, SOD323	BAS16HT1G	ON Semi
32	1	D4	DIODE ULTRA FAST, SW, 200V, 1A, SMA	US1D-13-F	Diodes, Inc.
33	1	D6	600 V, 5 A, TO-220AC	QH05TZ600	Power Integrations
34	1	D7	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1200-7	Diodes, Inc.
35	1	D8	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes, Inc.
36	2	D10 D14	Diode, Schottky, 120 V, 12 A, Surface Mount, TO-277A (SMPC)	V12P12-M3/86A	Vishay
37	1	D11	400 V, 1 A, DIODE SUP FAST 1A PWRDI 123	DFLU1400-7	Diodes, Inc.
38	1	D12	75 V, 0.15 A, Fast Switching, 4 ns, MELF, SOD80C	DL4148-TP	Micro Commercial
39	2	D13 D15	DIODE ULTRA FAST, 1A, 100V, SMA	US1B-13-F	Diodes, Inc.
40	1	F1	3.15 A, 300 V, Slow, Long Time Lag, RST	36913150000	Littlefuse
41	1	L2	20 mH, 0.8 A, Common Mode Choke	SS21V-R080200	KEMET
42	1	L3	1.8 mH, 1.0 A, 20%	RL-5480-5-1800	Renco
43	1	Q3	MOSFET, N-Channel, 40 V, 100 A (Tc,) 163 W (Tc,)	AUIRFU8405	Infineon
44	1	Q4	NPN, 60 V 1000MA, SOT-23	FMMT491TA	Zetex
45	1	Q6	60 V, 115 mA, SOT23-3	2N7002-7-F	Diodes, Inc.
46	1	Q8	PNP, Small Signal BJT, 40 V, 0.2 A, SOT-23	MMBT3906LT1G	On Semi
47	1	R3	RES, 1.5 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-1M5	Yageo

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48	2	R4 R5	RES, 1.5 MΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1504V	Panasonic
49	1	R6	RES, 24.9 kΩ, 0.1%, 1/8 W, Thick Film, 0805	TNPW080524K9BEEA	Vishay
50	1	R7	RES, 1.5 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1501V	Panasonic
51	1	R8	RES, 49.9 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF4992V	Panasonic
52	1	R9	RES, 20 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2002V	Panasonic
53	1	R10	RES, 10.5 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1052V	Panasonic
54	1	R11	RES, 1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ102V	Panasonic
55	1	R12	RES, 1.80 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1804V	Panasonic
56	1	R15	RES, 10.7 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1072V	Panasonic
57	1	R17	RES, 1.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1004V	Panasonic
58	1	R18	RES, 10 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ103V	Panasonic
59	2	R22 R23	RES, 47 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ470V	Panasonic
60	1	R24	0.04 Ω, ±1%, ±1200 ppm / °C, -55°C ~ 155°C	RL1206FR-070R04L	Yageo
61	1	R27	RES, 2.00 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8RQF2R0V	Panasonic
62	1	R28	RES, SMD, 0.10 Ω, 1%, 1/4 W, Thick Film	CRL1206-FW-R100ELF	Bourns
63	1	R29	RES, 102 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1023V	Panasonic
64	1	R30	RES, 3.09 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF3091V	Panasonic
65	1	R31	RES, 36 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ363V	Panasonic
66	2	R32 R33	RES, 1.00 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1001V	Panasonic
67	1	R34	RES, 10 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1002V	Panasonic
68	2	R35 R37	RES, 100 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1003V	Panasonic
69	2	R36 R42	RES, 2.00 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2001V	Panasonic
70	2	R38 R41	RES, 20 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2002V	Panasonic
71	1	R39	RES, 20.0 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2002V	Panasonic
72	1	R40	RES, 19.1 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1912V	Panasonic
73	1	R43	0.165 Ω, ±1%, ±75ppm/°C, 0.25W, 1/4W, 1206	PT1206FR-070R165L	Yageo
74	1	R45	RES, 9.1 kΩ, 1%, 1/0 W, Thick Film, 0603	ERJ-3EKF9101V	Panasonic
75	1	RV1	320 VAC, 23 J, 10 mm, RADIAL	V320LA10P	Littlefuse
76	1	T1	Bobbin, PQ26/20, Vertical, 12 pins	BPQ26/20-1112CPFR	TDK
77	1	T2	Bobbin, PQ20/20, Vertical, 14 pins	CPV-PQ20/20-1S14PZ	Ferroxcube
78	1	U1	LinkSwitch-PH, LNK419EG, eSIP	LNK419EG	Power Integrations
79	1	U2	Opto coupler, 70 V, CTR 100-200%, 4-DIP	SFH615A-3	
80	1	U4	LYTSwitch-6 Integrated Circuit, InSOP24D	LYT6068C	Power Integrations
81	1	U5	IC, OpAmp, Dual, R2R, 8-SOIC	LM158DT	ST Micro
82	1	U8	IC, REG ZENER SHUNT ADJ SOT-23	LM431BIM3/NOPB	National Semi
83	1	VR1	3.9 V, 5%, 150 mW, SSMINI-2	DZ2S03900L	Panasonic
84	1	VR2	130 V, 5%, 1 W, DO-41	1M130Z	Taiwan Semi
85	1	VR5	13 V, 5%, 500 Mw, SOD-123	MMSZ4700T1G	Taiwan Semi
86	1	VR6	DIODE ZENER 12 V 500 mW SOD123	MMSZ5242B-7-F	Diodes, Inc.
87	1	VR7	Diode, Zener, 18 V 500 mW, ±2%, SOD-80C	BZV55-B18,115	NXP Semi

6.2 *Miscellaneous Parts*

Item	Qty	Ref	Description	Mfg Part Number	Mfg
1	1	ESIP CLIP1	Heat sink Hardware, Edge Clip, 12.40 mm x 6.50 mm	TRK-24	Kang Tang Hardware
2	4	FL1 FL2 FL3 FL4	Flying Lead, Hole size 50mils	N/A	N/A
3	1	HS_POST1	Post, Heat sink, SS, Nickel Plated ,5 mm W x 9.1mm T	Custom	Custom
4	1	HTSKDWG1	SHTM, HEAT SINK, DER597		Custom
5	1	J1	CONN TERM BLOCK 5.08 mm 3 POS, Screw - Leaf Spring, Wire Guard	ED120/3DS	On Shore Tech
6	2	J2 J3	2 Position (1 x 2) header, 5 mm (0.196) pitch, Vertical, Screw - Rising Cage Clamp	1715022	Phoenix Contact
7	1	RIVET1	Rivet, Al, .093 Dia x 0.187 (3/16) L, 100 Deg Countersunk, soft, 1100-F Aluminum		Any RoHS Compliant Mfg.
8	1	SCREW1	SCREW MACHINE PHIL 4-40X 3/16 SS	67413609	MSC Industrial Supply
9	1	SCREW2	SCREW MACHINE PHIL Flat head 4-40 X 1/4 SS		Any RoHS Compliant Mfg.
10	2	WASHER1 WASHER2	WASHER FLAT #4 Zinc, OD 0.219, ID 0.125, Thk 0.032,Yellow Chromate Finish	5205820-2	Tyco
11	1	NUT1	Nut, Hex 4-40, SS		

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7 PFC Inductor (T1) Specifications

7.1 *Electrical Diagram*

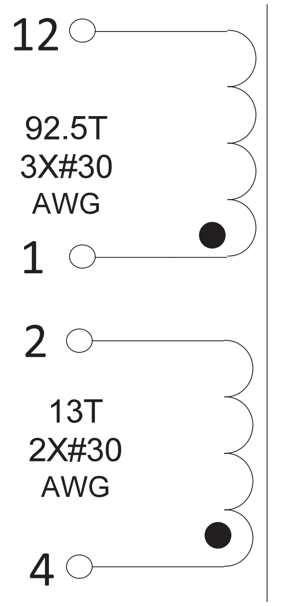

Figure 12 – Inductor Electrical Diagram.

7.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 1 and pin 12, with all other windings open.	1900 μH
Tolerance	Tolerance of Primary Inductance.	±5%

7.3 *Material List*

Item	Description
[1]	Core: PQ26/20 PC95 or Equivalent.
[2]	Bobbin, PQ26/20, Vertical, 12 pins, Part No.: 25-00025-00.
[3]	Magnet Wire: #30 AWG.
[4]	Polyester Tape: 8.7 mm.
[5]	Polyester Tape: 11 mm.

7.4 *Inductor Build Diagram*

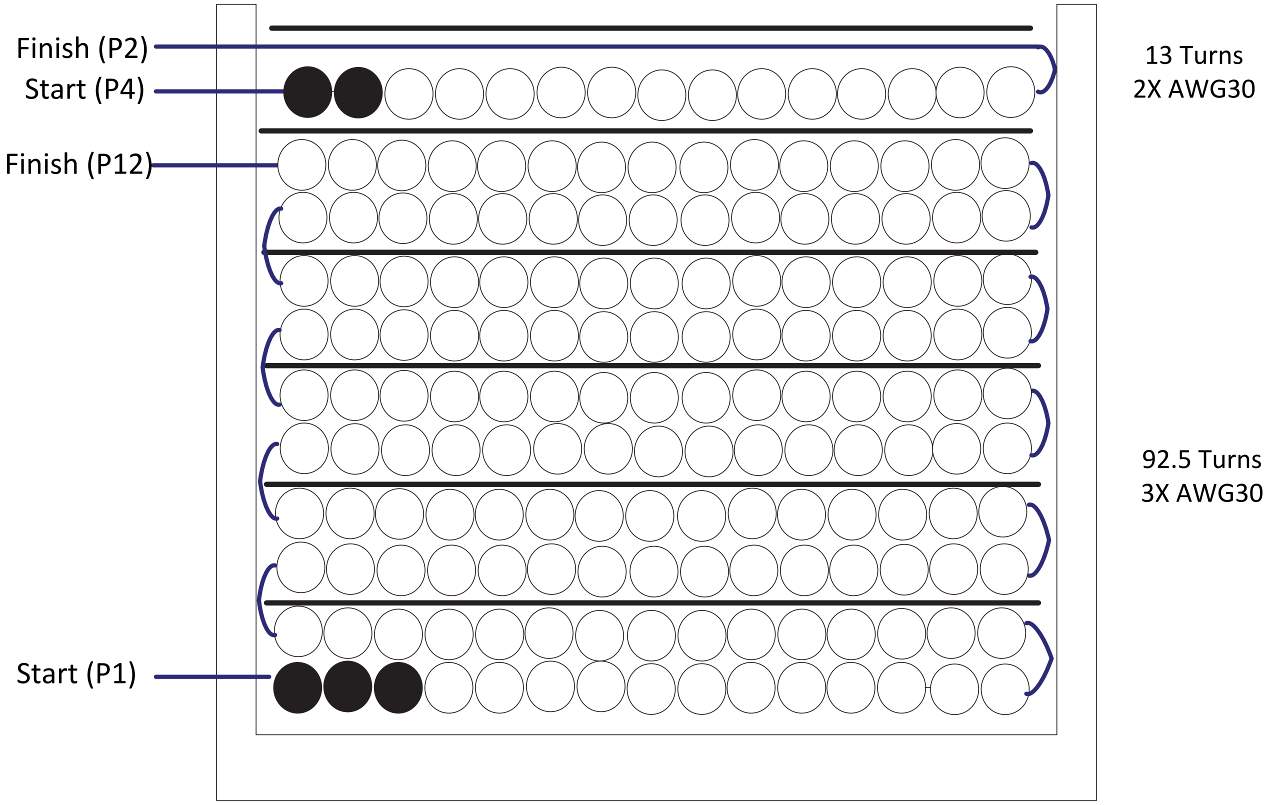

Figure 13 – Transformer Build Diagram.

7.5 *Inductor Construction*

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 1-6 is on the left side. The winding direction is clockwise.
Winding 1	Use magnetic wire Item [3]. Prepare magnetic wire for trifilar wound. Start at pin 1 and wind 92.5 turns in trifilar wound then finish the winding on pin 12.
Insulation	Apply 1 layer of polyester tape Item [4] every 2 winding layers. Added tape every 2 layers help windings distributed evenly.
Winding 2	Use magnetic wire Item [3]. Prepare magnetic wire for bifilar wound. Start at pin 4 and wind 13 turns in bifilar wound then finish the winding on pin 2.
Insulation	Apply 1 layer of polyester tape, Item [5] for insulation.
Core Grinding	Grind the center leg of 1 core to meet the nominal inductance specification 1900 μH.
Assemble Core	Assemble the 2 cores into the bobbin
Bobbin Tape	Add 2 layers of polyester tape Item [5] around the bobbin together with the core to fix the 2 cores.
Pins	Cut terminal pins 3, 5, 6, 8, 9, 10 and 11.
Finish	Apply 2:1 varnish and thinner solution.

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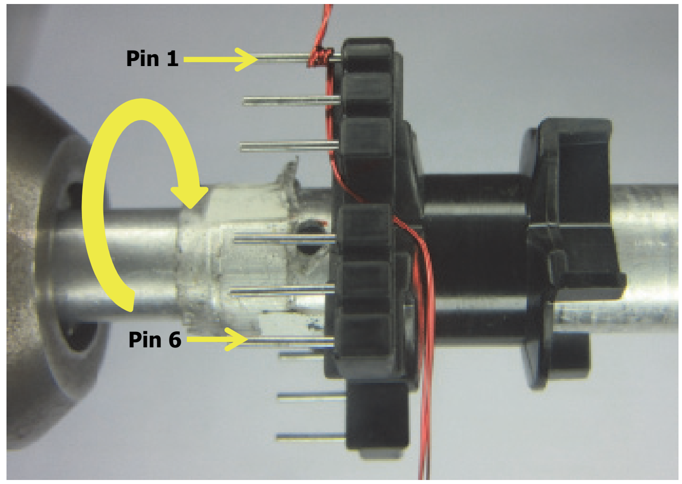
7.6 *Winding Illustrations*

Winding Directions

Bobbin is oriented on winder jig such that terminal pin 1-6 is on the left side. The winding direction is clockwise.

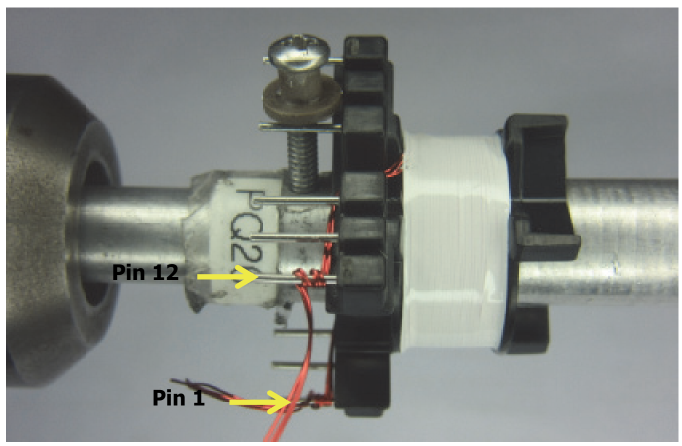
Winding 1

Use magnetic wire Item [3]. Prepare magnetics wire for trifilar wound. Start at pin 1 and wind 93 turns in trifilar wound then finish the winding on pin 12.



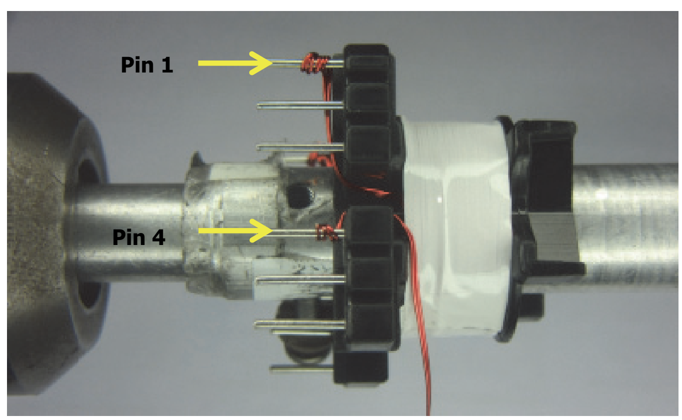
Insulation

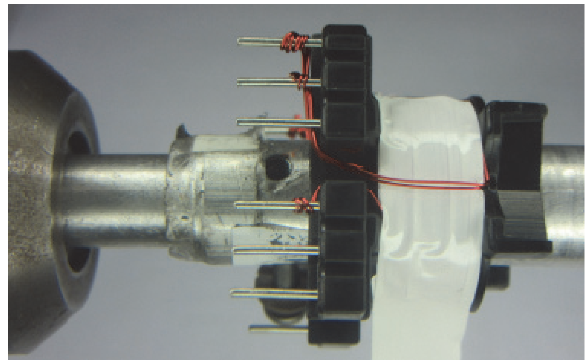
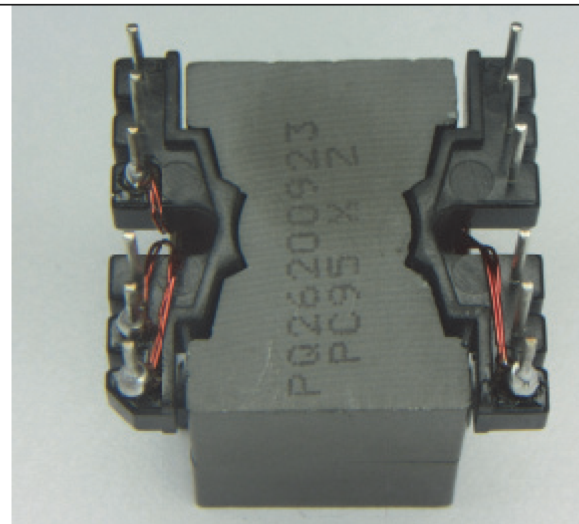
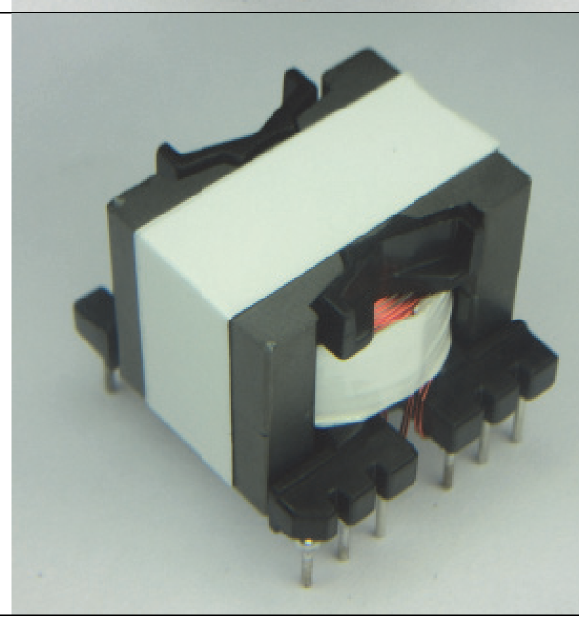
Apply 1 layer of polyester tape Item [4] every 2 winding layers. Added tape every 2 layers help windings to be distributed evenly.



Winding 2

Use magnetic wire Item [3]. Prepare magnetic wire for bifilar wound. Start at pin 4 and wind 13 turns in bifilar wound then finish the winding on pin 2.



Insulation Apply 1 layer of polyester tape, Item [5] for insulation	
Assemble Core Assemble the 2 cores into the bobbin.	
Bobbin Tape Add 2 Layers of polyester tape Item [5] around the bobbin together with the core to fix the 2 cores.	

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8 Flyback Transformer (T2) Specifications

8.1 *Electrical Diagram*

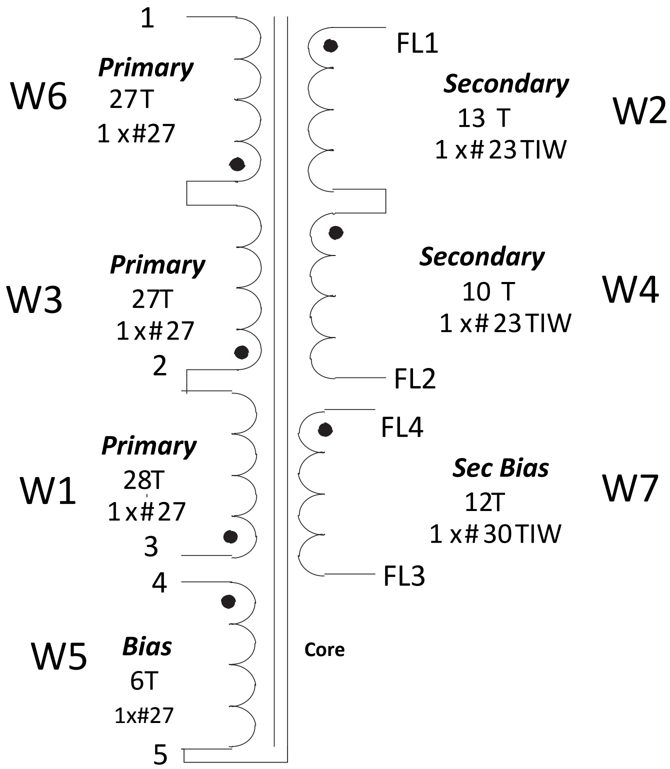

Figure 14 – Transformer Electrical Diagram.

8.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, across pin 1 and pin 3, with all other windings open.	960 μH
Tolerance	Tolerance of Primary Inductance.	±5%
Leakage Inductance	Short all bias windings and secondary windings. Measured at 1 V_{PK-PK}, 100 kHz switching frequency, across pin 1 and pin 3.	<5 μH

8.3 *Material List*

Item	Description
[1]	Core: PQ20/20 PC44 or Equivalent.
[2]	Bobbin: PQ20/20, Vertical, 14 pins, Part No. : 25-00948-00.
[3]	Magnet Wire: #27 AWG.
[4]	TIW: # 23 AWG.
[5]	TIW: # 30 AWG.
[6]	Polyester Tape: 12 mm.

8.4 *Transformer Build Diagram*

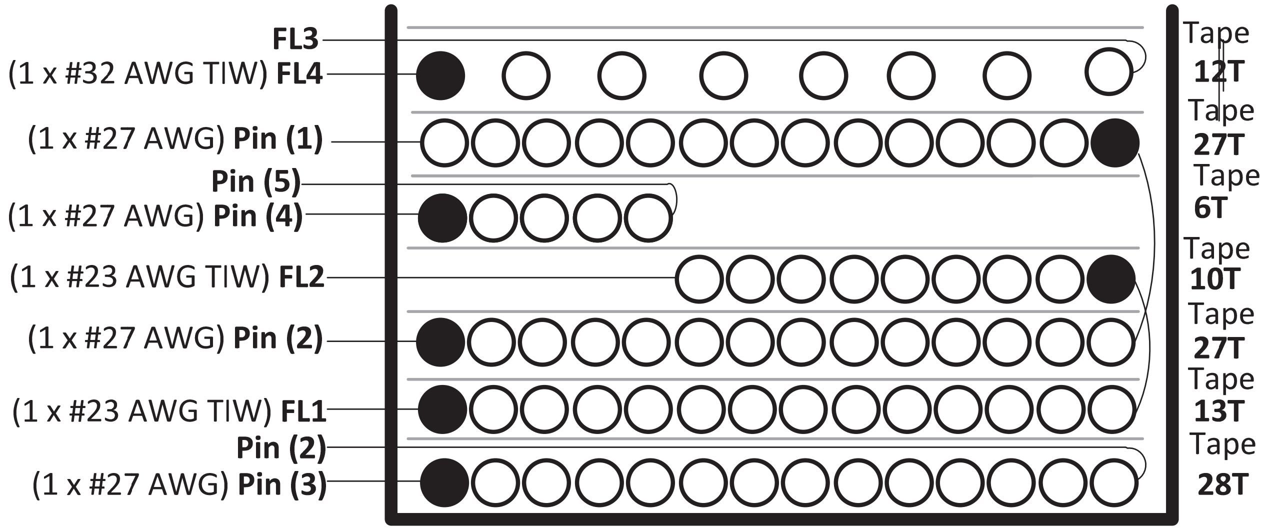

Figure 15 – Inductor Build Diagram.

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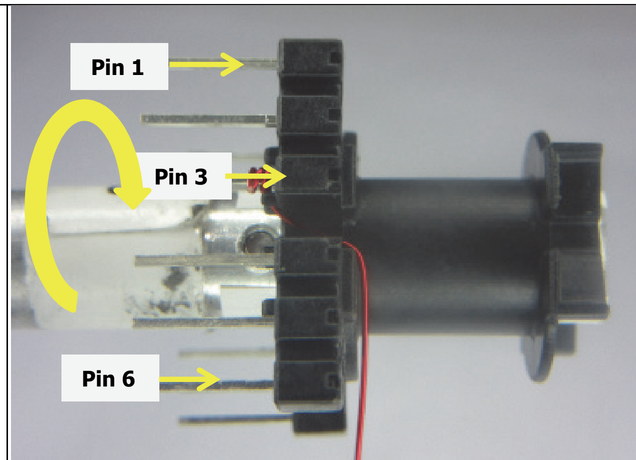
8.5 *Transformer Construction*

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 1-6 is on the left side. The winding direction is clockwise.
Winding 1	Use magnetic wire Item 3. Start at pin 3 and wind 28 turns evenly. Finish the winding on pin 2.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation.
Winding 2	Use triple insulated wire Item [4] with enough length (1.2 m) for W2 (13T) and W4 (10T). Mark the Start terminal as (FL1). Start at FL1 and wind 13 turns in 1 layer as shown in the figure. Do not cut the excess wire and reserve it for W 4.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation.
Winding 3	Use magnetic wire Item 3 with length (2.7 m) enough for W3 (27T) and W5 (27T). Start at pin 2 and wind 27 turns evenly. Don not cut the excess wire and reserve for W5.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation.
Winding 4	Use excess wire from Winding 2. Wind 10 turns evenly. The finished terminal will be a fly wire mark as FL2.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation.
Winding 5	Use magnetic wire Item 3. Start at pin 4 and wind 6 turns evenly. Finish the winding on pin 5.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation.
Winding 6	Use excess wire from Winding 3. Wind 27 turns evenly from right to left and finish the winding on pin 1.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation.
Winding 7	Use triple insulated wire Item [5]. Mark the start terminal as (FL4). Start at FL4 and wind 12 turns evenly distributed in one layer as shown in the figure. Mark the finish terminal as FL3
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation.
Core Grinding	Grind the center leg of 1 core to meet the nominal inductance specification of 960 μH.
Core Termination	Apply copper strip on bottom core and solder an AWG #30 magnetic wire. Terminate the wire on pin 5.
Assemble Core	Assemble the 2 cores into the bobbin.
Bobbin Tape	Add 2 Layers of polyester tape, Item [6] around the bobbin together with the core to fix the 2 cores.
Pins	Cut terminal pins 2, 6 and pins 8-14.
Apply Varnish	Apply 2:1 varnish and thinner solution.
Trim Extended Bobbin Plastic Rib	Cut bobbin extended plastic rib on pin 1 to prevent interference with nearby component (C8).

8.6 *Winding Illustrations*

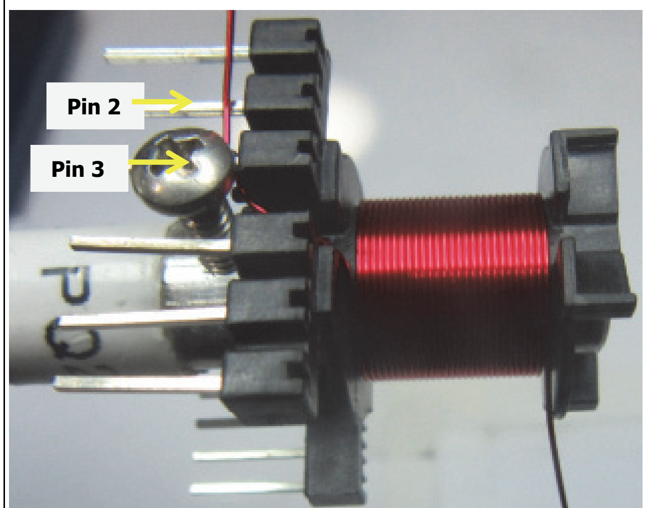
Winding Directions

Bobbin is oriented on winder jig such that terminal Pin 1-6 is on the left side. The winding direction is clockwise.



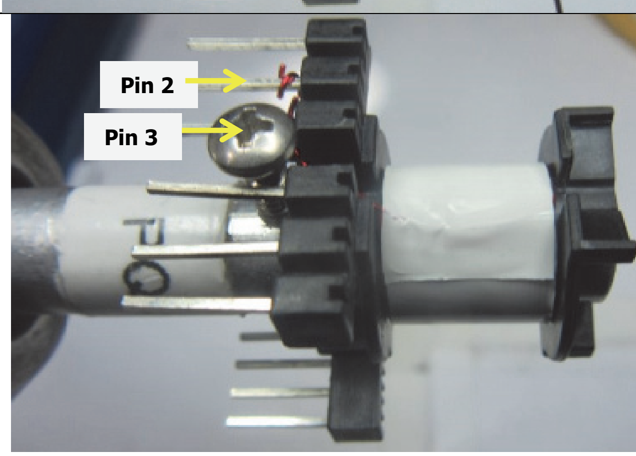
Winding 1

Use magnetic wire Item 3. Start at pin 3 and wind 28 turns evenly. Finish the winding on pin 2.



Insulation

Apply 1 layer of polyester tape, Item [6] for insulation



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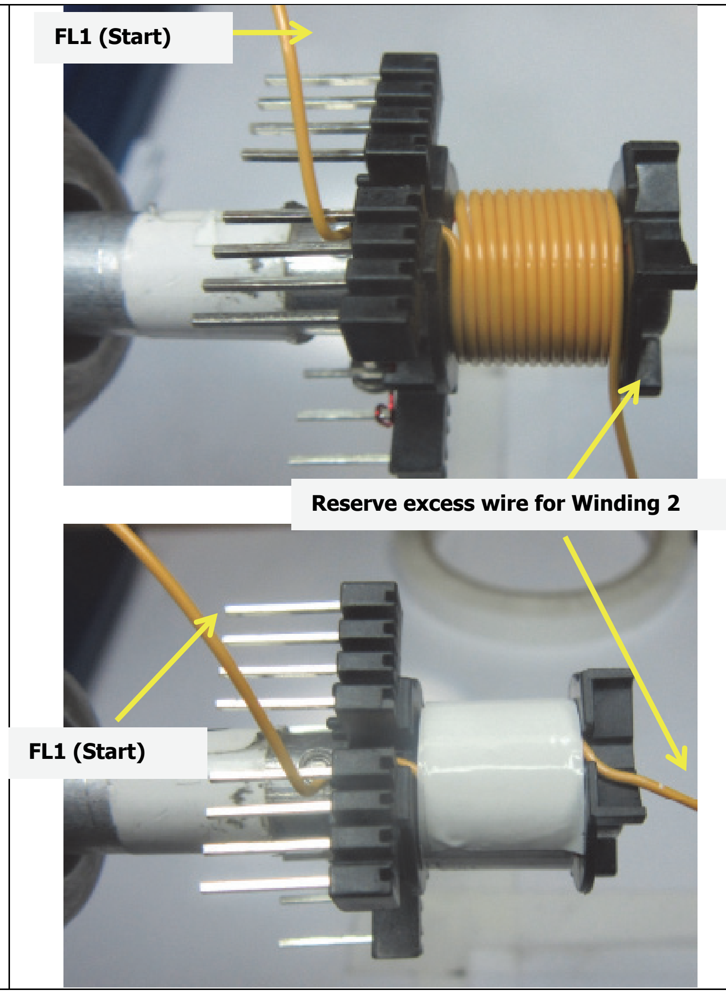
Winding 2

Use triple insulated wire Item [4] with enough length (1.2m) for W2 (13T) and W4 (10T). Mark the Start terminal as (FL1). Start at FL1 and wind 13 turns in 1 layer as shown in the figure. Do not cut the excess wire and reserve it for W 4.

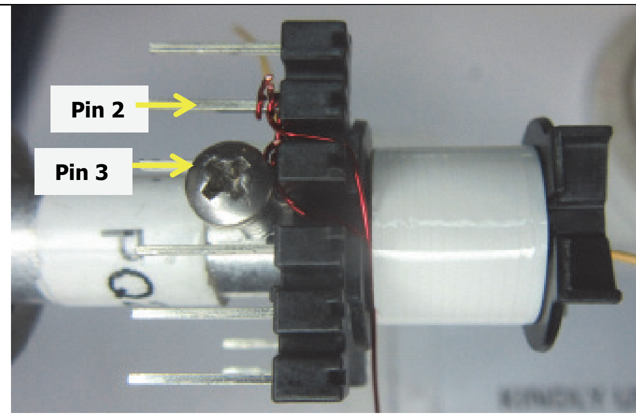


Insulation

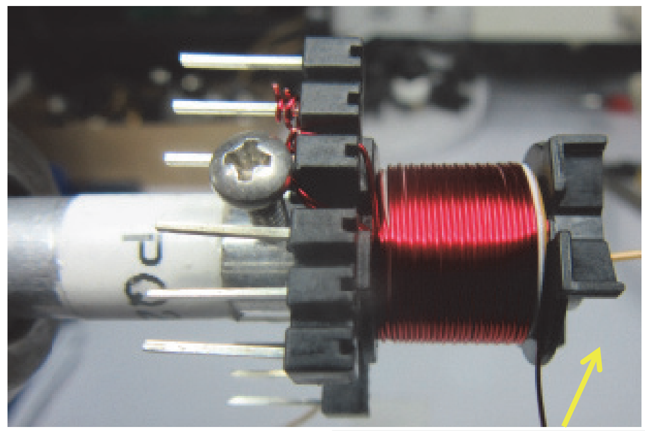
Apply 1 layer of polyester tape, Item [6] for insulation

Winding 3

Use magnetic wire Item 3 with length (2.7m) enough for W3 (27T) and W5 (27T). Start at pin 2 and wind 27 turns evenly.

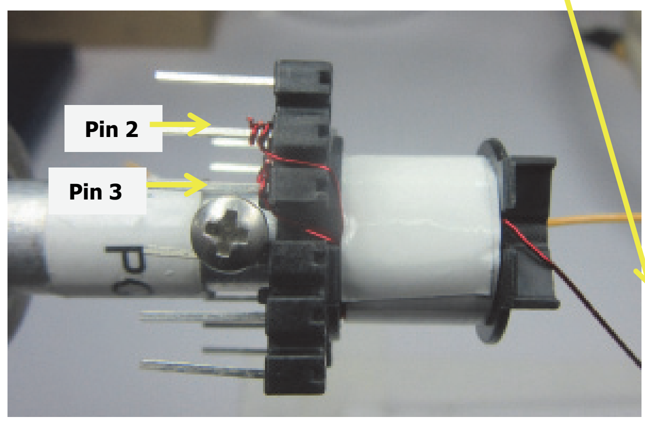


Do not cut the excess wire and reserve for W5.



Insulation

Apply 1 layer of polyester tape, Item [6] for insulation



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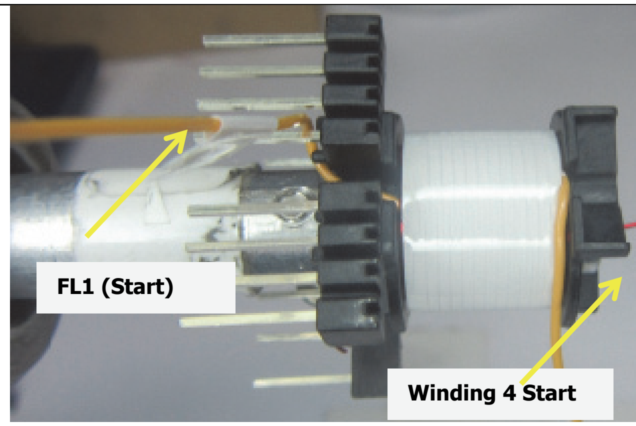
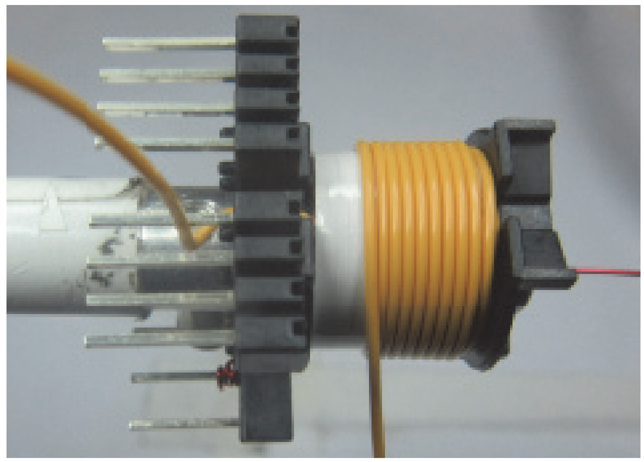
Winding 4

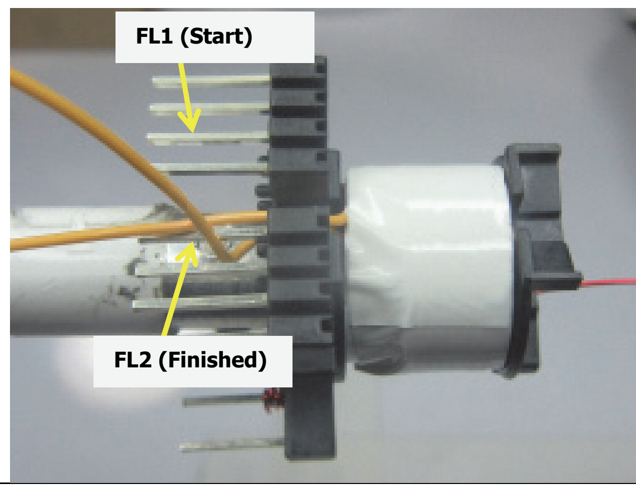
Use excess wire from Winding 2. Wind 10 turns evenly. The finished terminal will be a fly wire mark as FL2





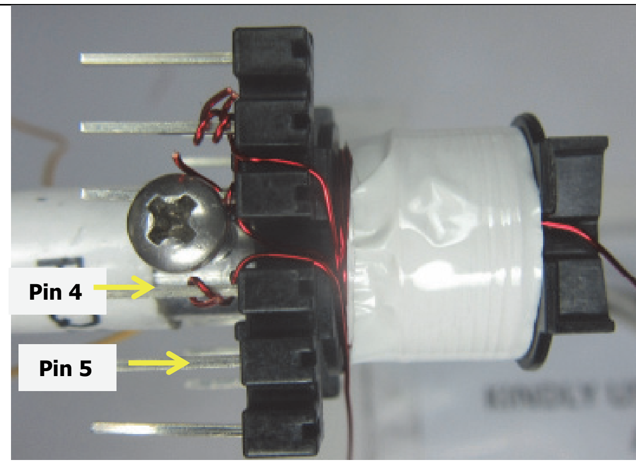
Insulation

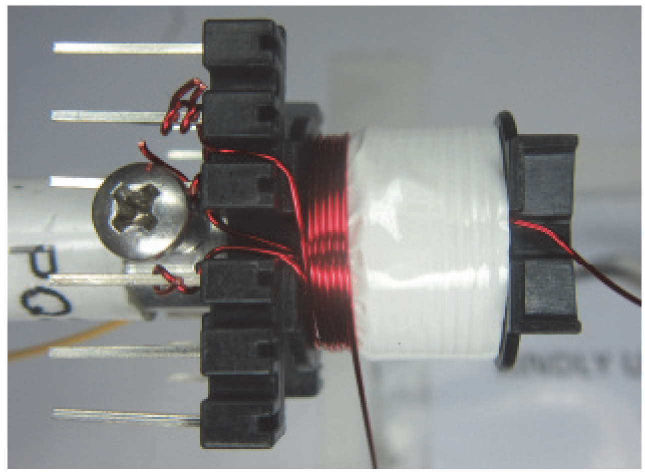
Apply 1 layer of polyester tape, Item [6] for insulation



Winding 5

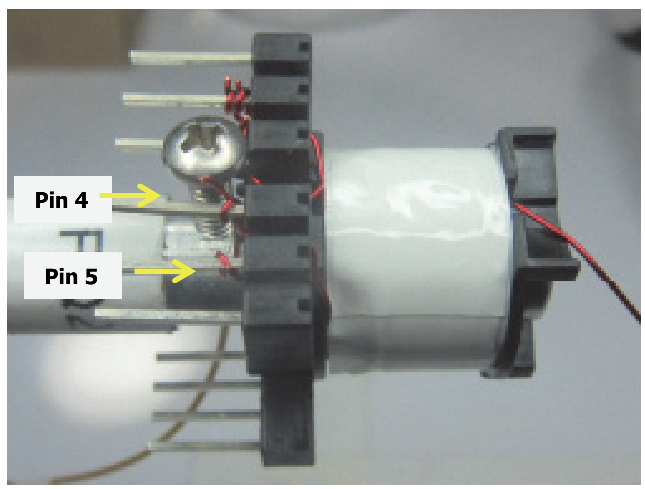
Use magnetic wire Item 3. Start at pin 4 and wind 6 turns evenly. Finish the winding on pin 5.





Insulation

Apply 1 layer of polyester tape, Item [6] for insulation



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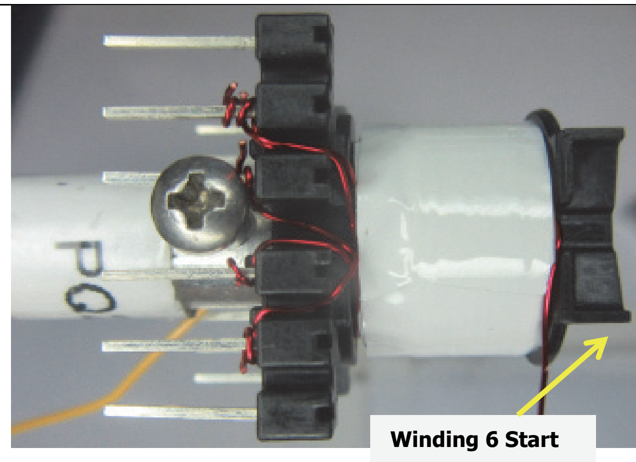
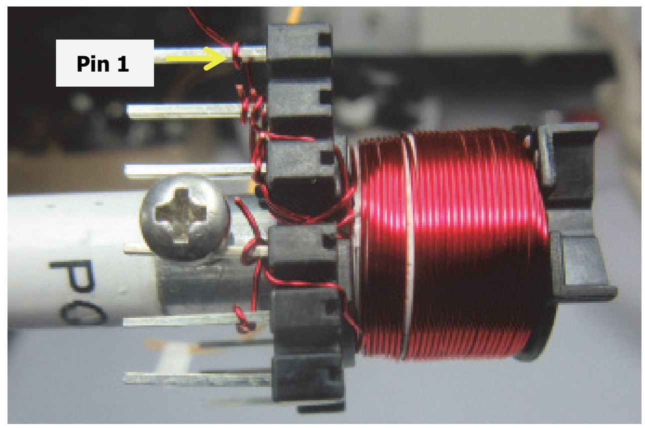
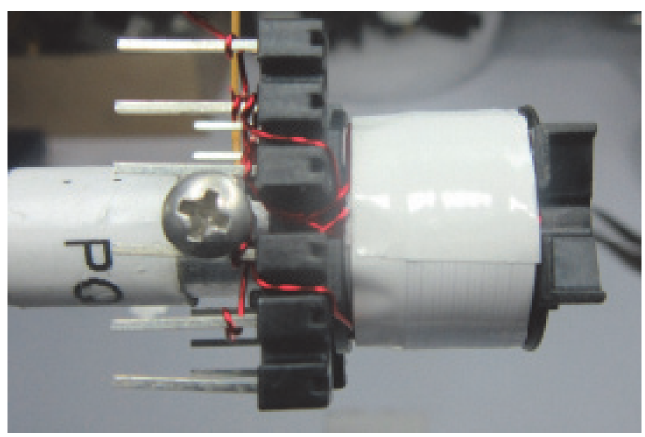
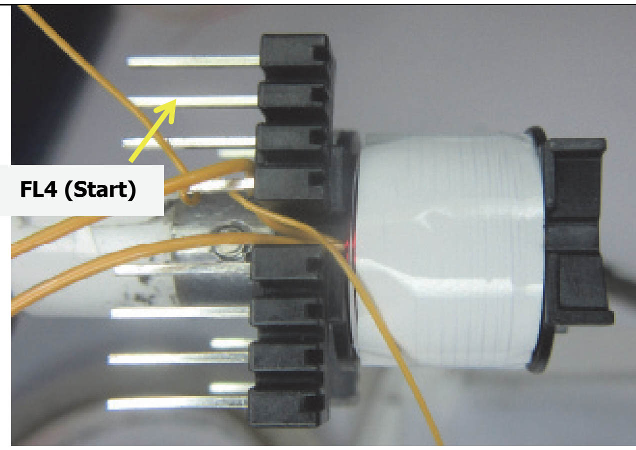
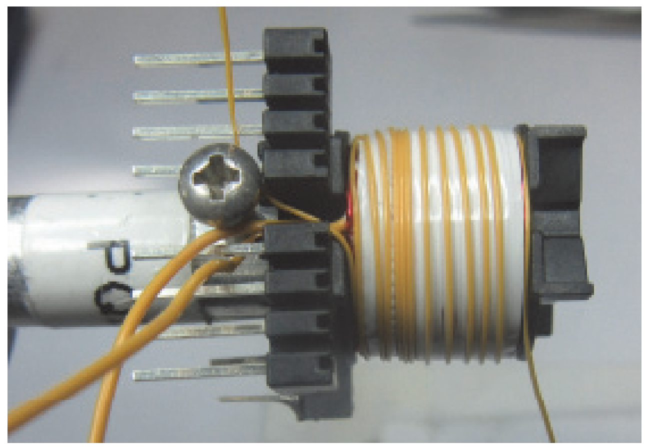
Winding 6 Use excess wire from Winding 3. Wind 27 turns evenly from right to left and finish the winding on Pin 1.	 
Insulation Apply 1 layer of polyester tape, Item [6] for insulation	

Winding 7

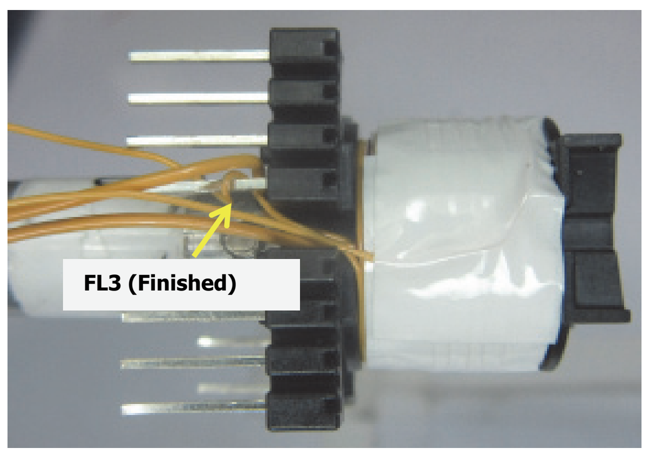
Use triple insulated wire Item [5]. Mark the Start terminal as (FL4). Start at FL4 and wind 12 turns evenly distributed in one layer as shown in the figure. Mark the finish terminal as FL3.





Insulation

Apply 1 layer of polyester tape, Item [6] for insulation



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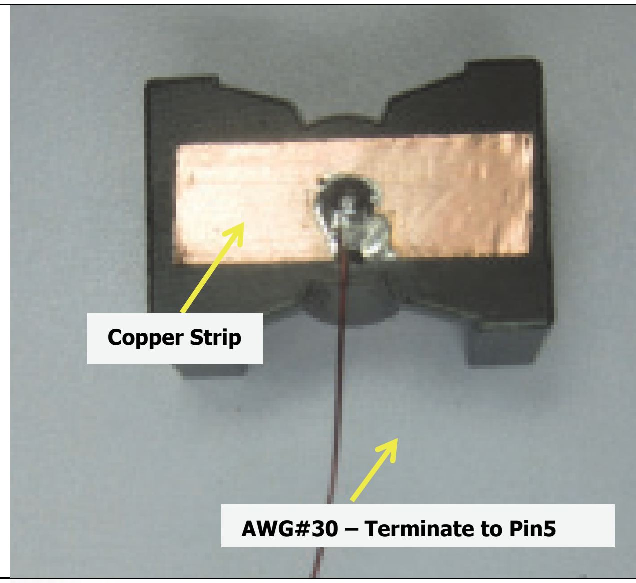
<table>
<tr><td>

Core Termination

Apply copper strip on bottom core and solder an AWG #30 magnetic wire. Terminate the wire on Pin 5.

</td><td>



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Assemble Core

Assemble the 2 cores into the bobbin

Bobbin Tape

Add 2 Layers of polyester tape, Item [8] around the bobbin together with the core to fix the 2 cores.

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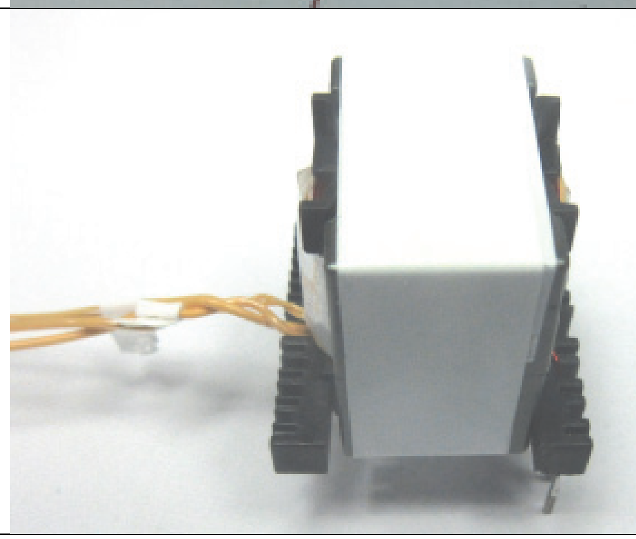

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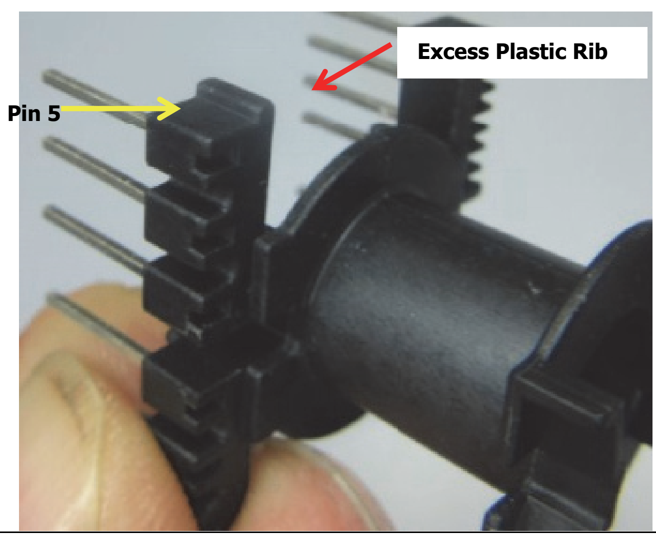
Trim Extended Bobbin Plastic Rib

Cut bobbin extended plastic rib on pin 1 to prevent interference with nearby component (C8).

</td><td>



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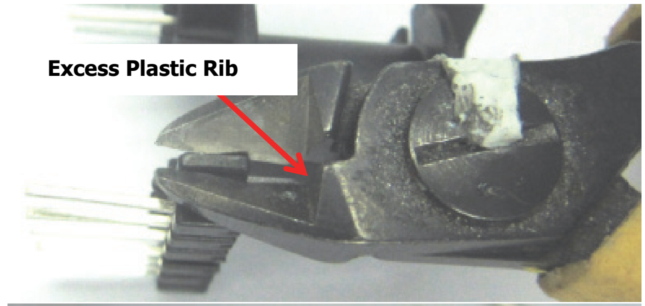

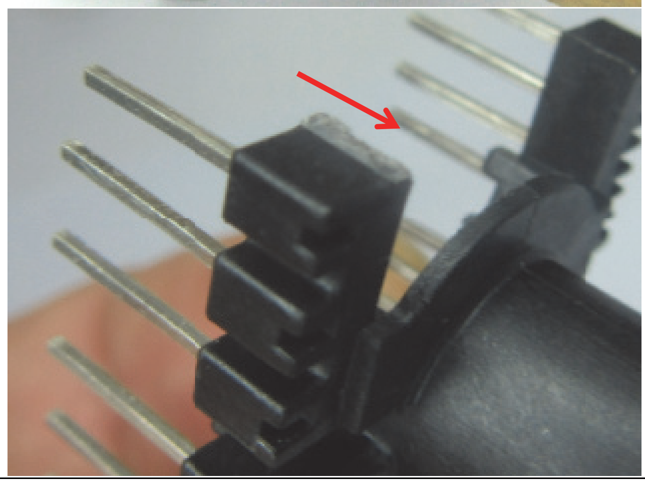

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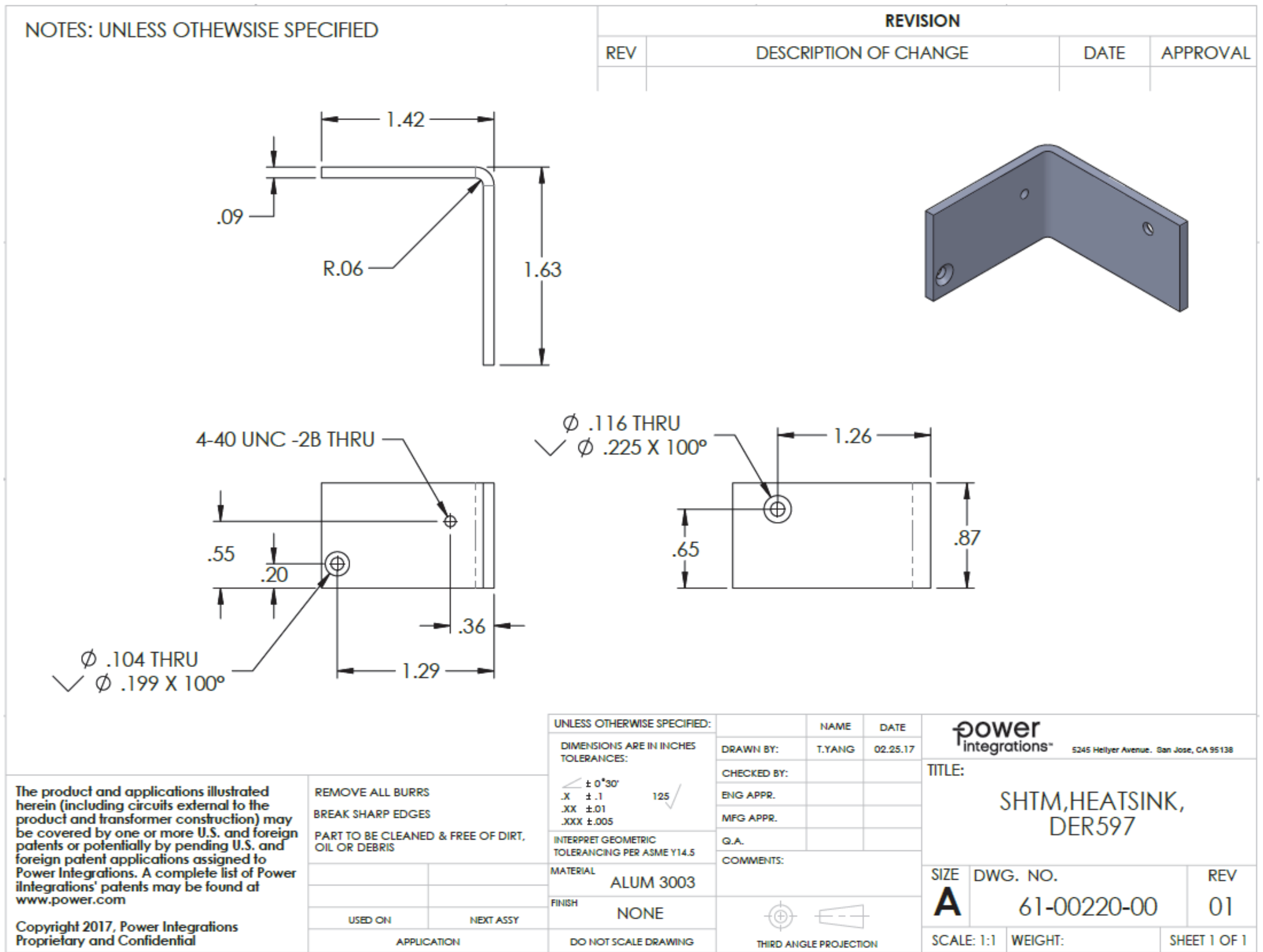
9 Heat Sink Assembly

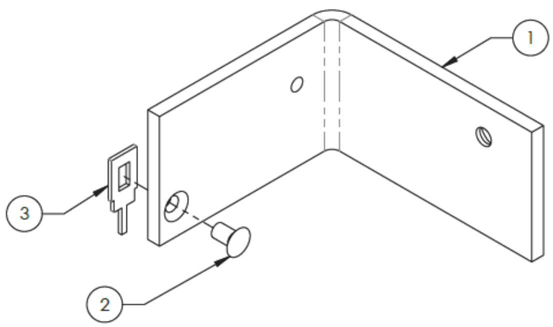
9.1 *Heat Sink Fabrication Drawing*

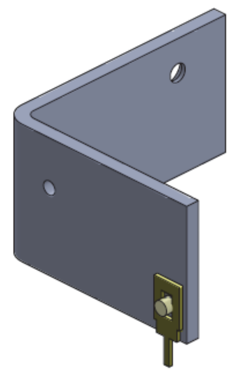


9.2 *Heat Sink Fabrication Drawing*

NOTES: UNLESS OTHERWISE SPECIFIED

REVISION			
REV	DESCRIPTION OF CHANGE	DATE	APPROVAL





ITEM	PART NUMBER	DESCRIPTION	QTY
3	60-00051-00	POST,HEATSINK,SS,NICKEL PLATED,5mmwX9.1mmT	1
2	75-00084-00	RIVET,AL,.093DIAX.187L,100DEG CSK	1
1	61-00220-00	SHTM,HEATSINK,DER597	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
∠ ± 0°30'
.X ± .1
.XX ± .01
.XXX ± .005
125 √
INTERPRET GEOMETRIC TOLERANCING PER ASME Y14.5

	NAME	DATE
DRAWN BY:	T.YANG	02.25.17
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

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TITLE: FAB,HEATSINK, DER597

MATERIAL: SEE BOM
FINISH: NONE
DO NOT SCALE DRAWING
THIRD ANGLE PROJECTION

SIZE	DWG. NO.	REV
A	61-00220-01	01
SCALE: 3:2	WEIGHT:	SHEET 1 OF 1

REMOVE ALL BURRS
BREAK SHARP EDGES
PART TO BE CLEANED & FREE OF DIRT, OIL OR DEBRIS

USED ON	NEXT ASSY
APPLICATION	

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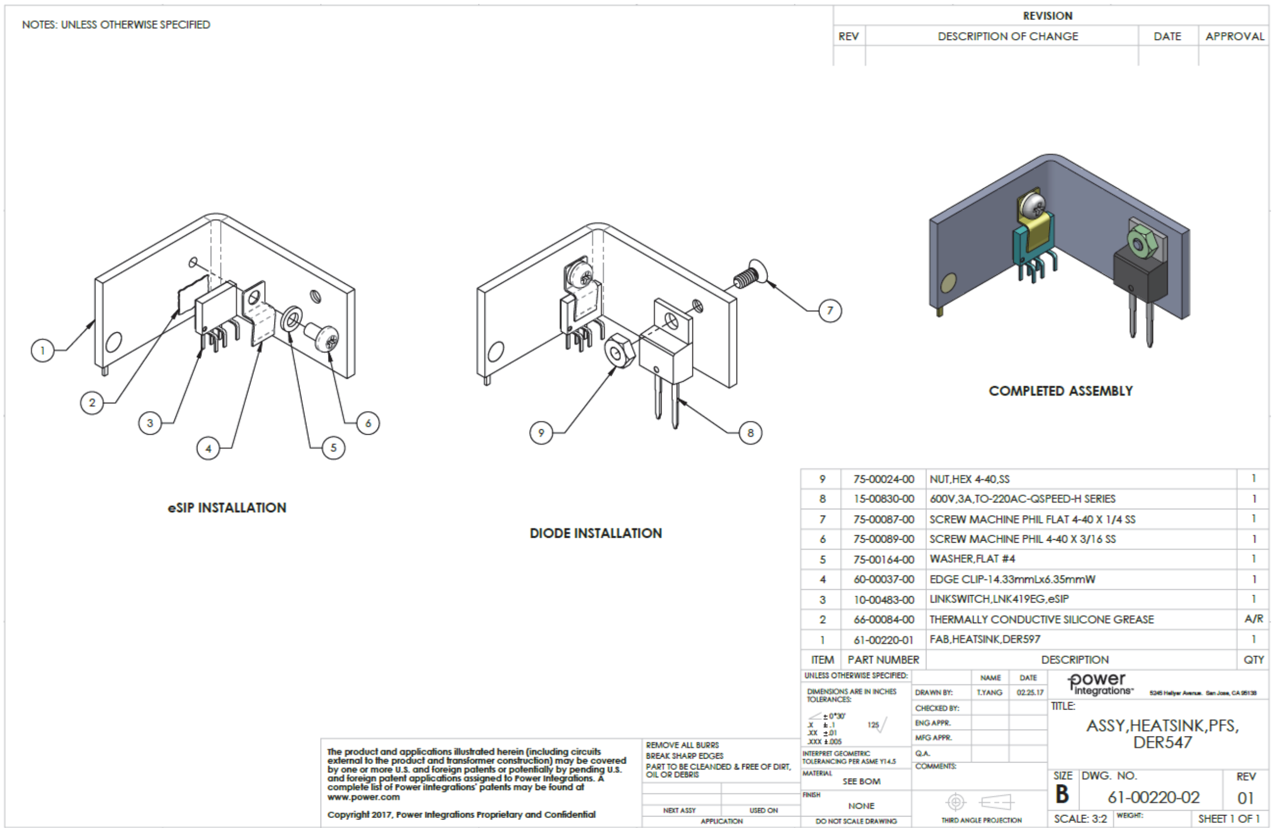
9.3 *Heat Sink and Assembly Drawing*



ITEM	PART NUMBER	DESCRIPTION	QTY
9	75-00024-00	NUT,HEX 4-40,SS	1
8	15-00830-00	600V,3A,TO-220AC-QSPEED-H SERIES	1
7	75-00087-00	SCREW MACHINE PHIL FLAT 4-40 X 1/4 SS	1
6	75-00089-00	SCREW MACHINE PHIL 4-40 X 3/16 SS	1
5	75-00164-00	WASHER,FLAT #4	1
4	60-00037-00	EDGE CLIP-14.33mmLx6.35mmW	1
3	10-00483-00	LINKSWITCH,LNK419EG,eSIP	1
2	66-00084-00	THERMALLY CONDUCTIVE SILICONE GREASE	A/R
1	61-00220-01	FAB,HEATSINK,DER597	1

10 Performance Data

All measurements were performed at room temperature.

10.1 *CV/CC Output Characteristic Curve*

CC regulation was measured using LED Load

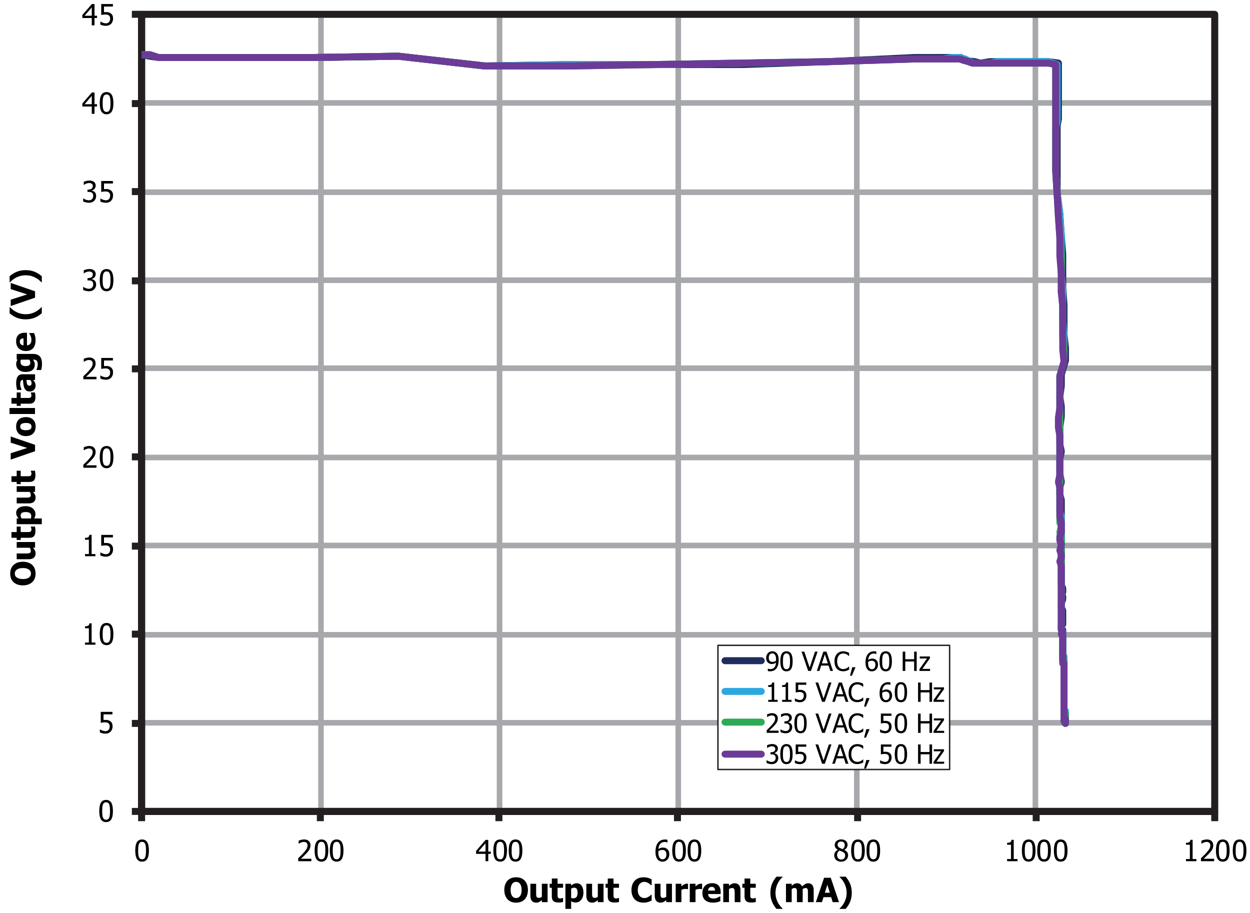


Figure 16 – CV/CC Curve.

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10.2 *System Efficiency*

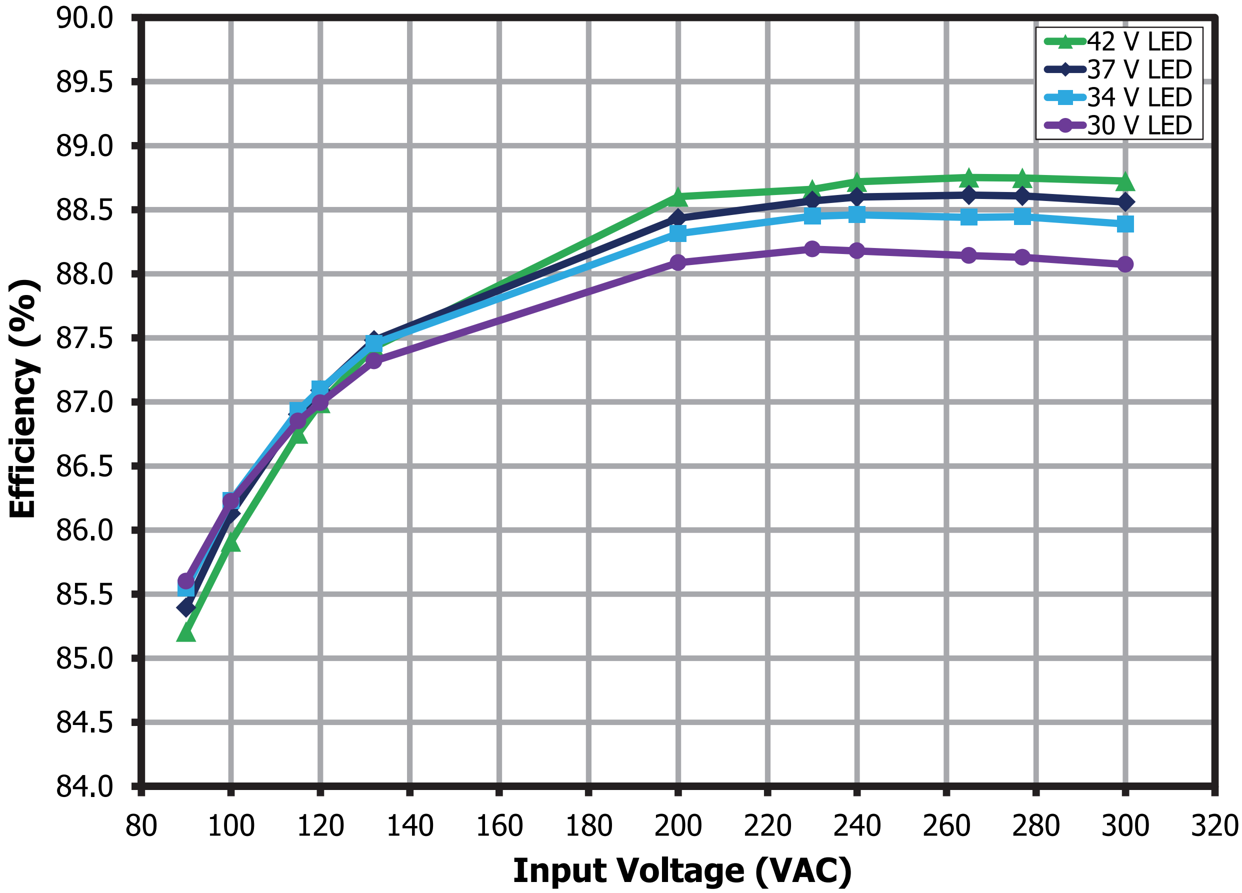

Figure 17 – Efficiency vs. Line and LED Load.

10.3 *Output Current Regulation*

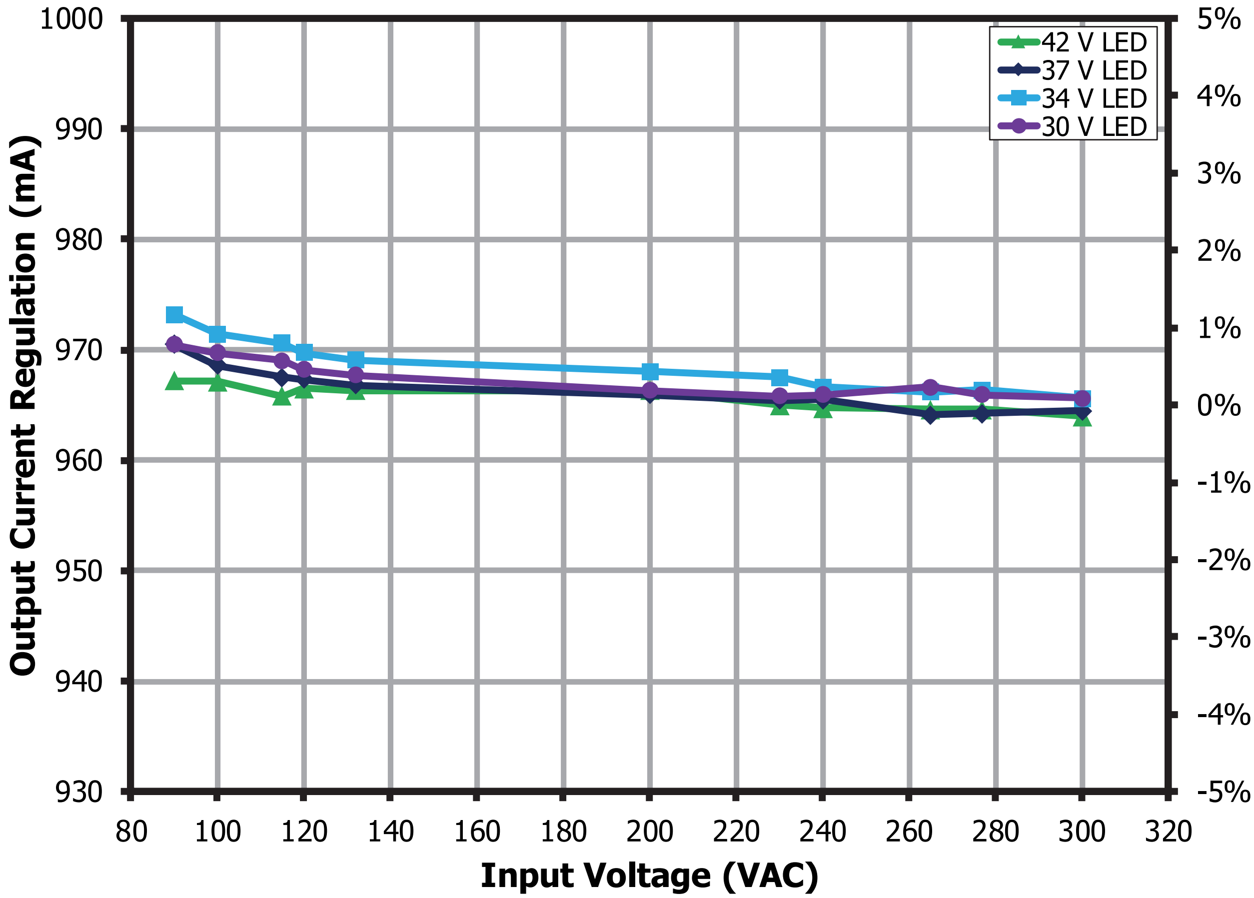

Figure 18 – Current Regulation vs. Line and LED Load.

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10.4 ***Power Factor***

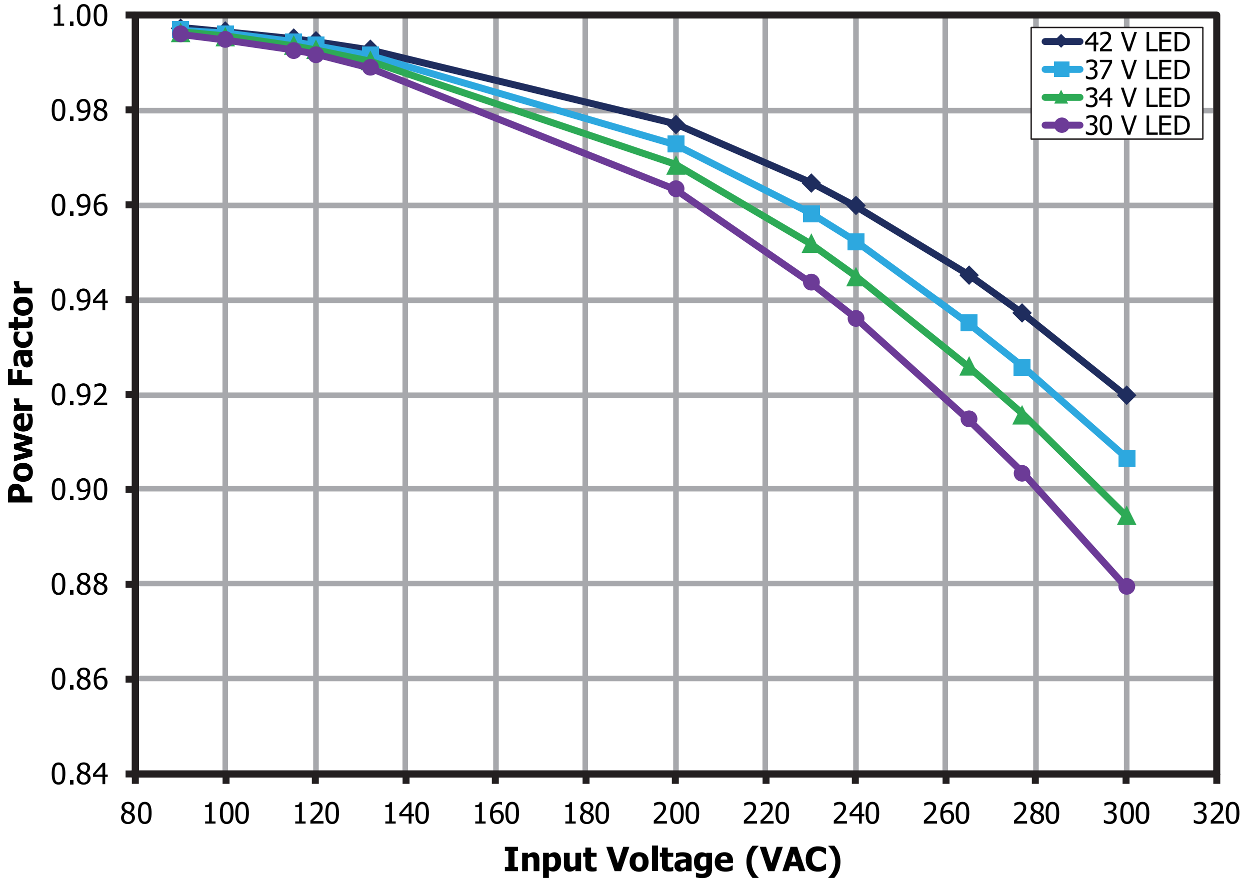

Figure 19 – Power Factor vs. Line and LED Load.

10.5 *%ATHD*

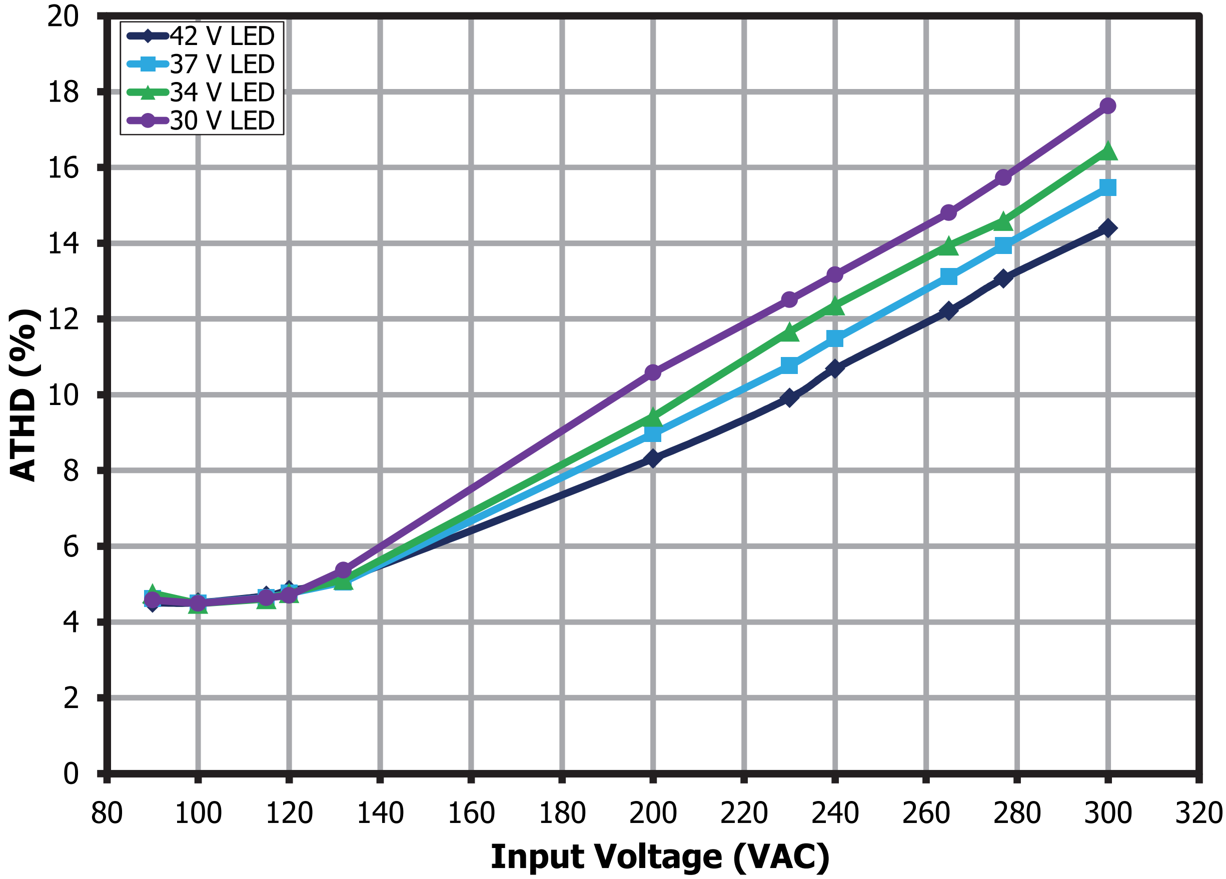

Figure 20 – %ATHD vs. Line and LED Load.

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10.6 *Individual Harmonic Content at 42 V LED Load*

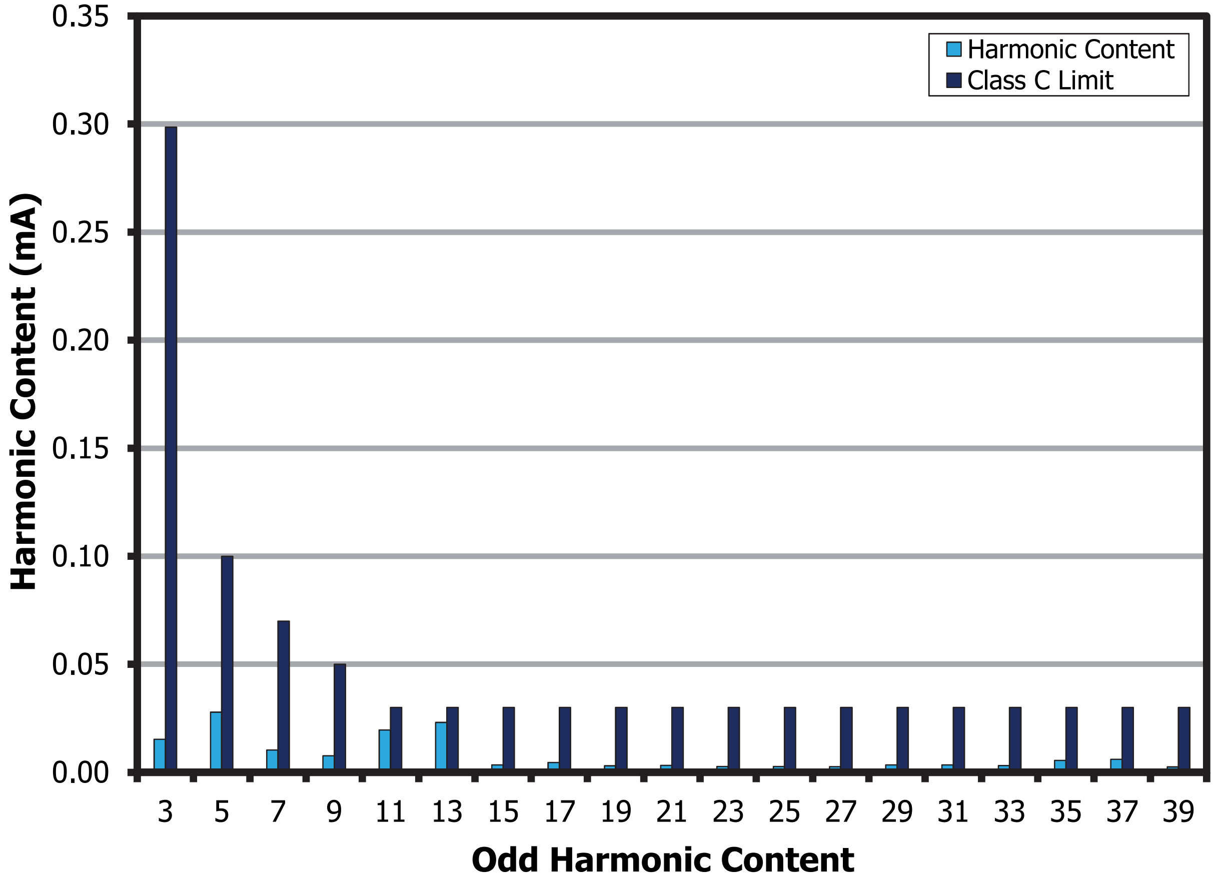

Figure 21 – 42 V LED Load Input Current Harmonics at 115 VAC, 60 Hz.

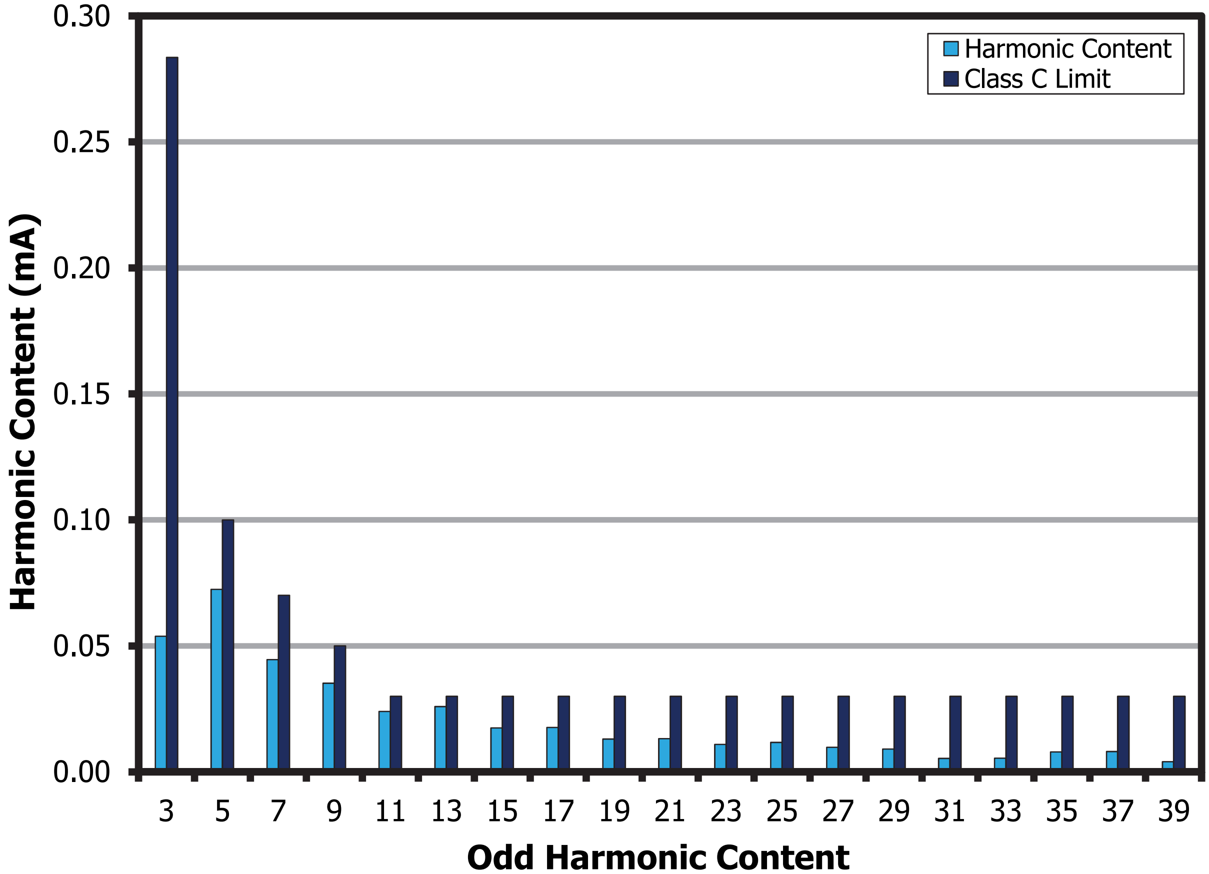

Figure 22 – 42 V LED Load Input Current Harmonics at 277 VAC, 50 Hz.

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10.7 ***No-Load Input Power***

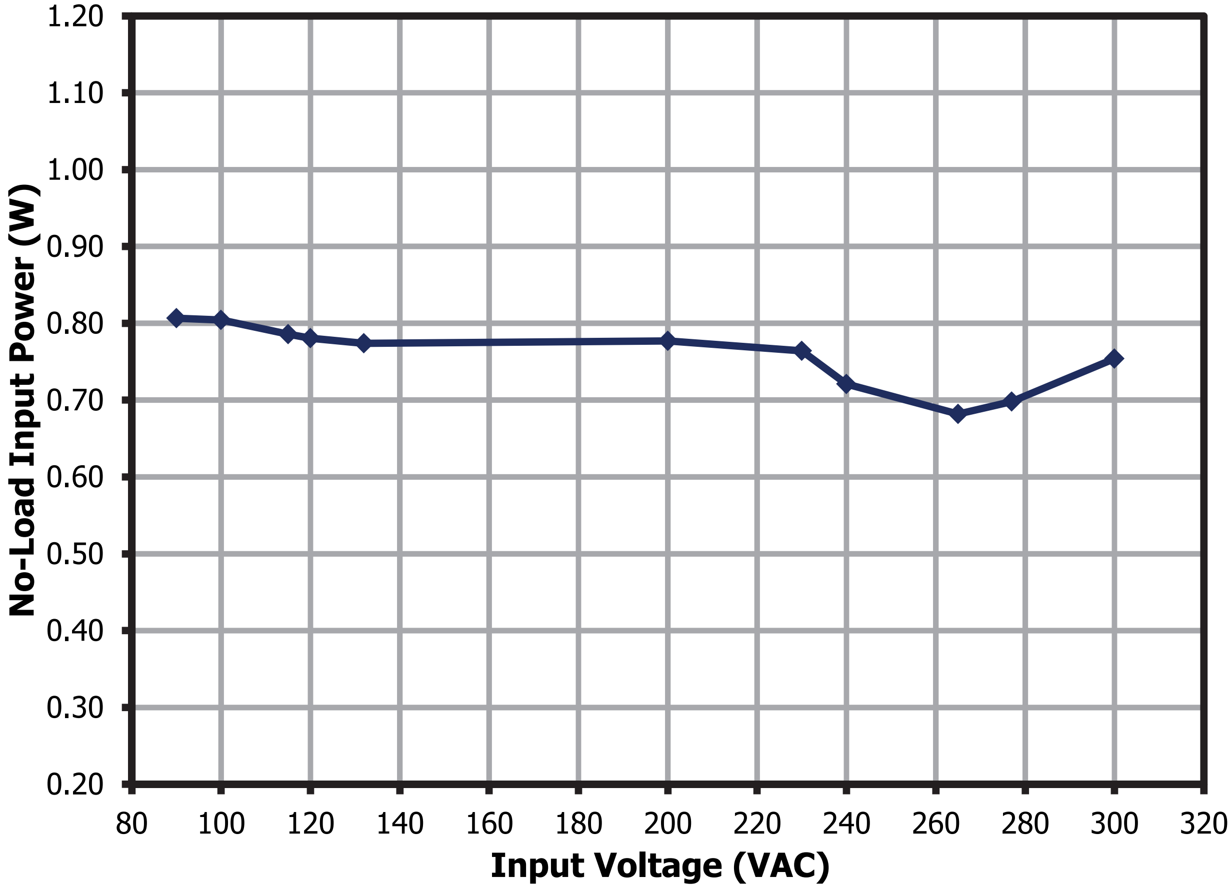

Figure 23 – No-Load Input Power vs. Line.

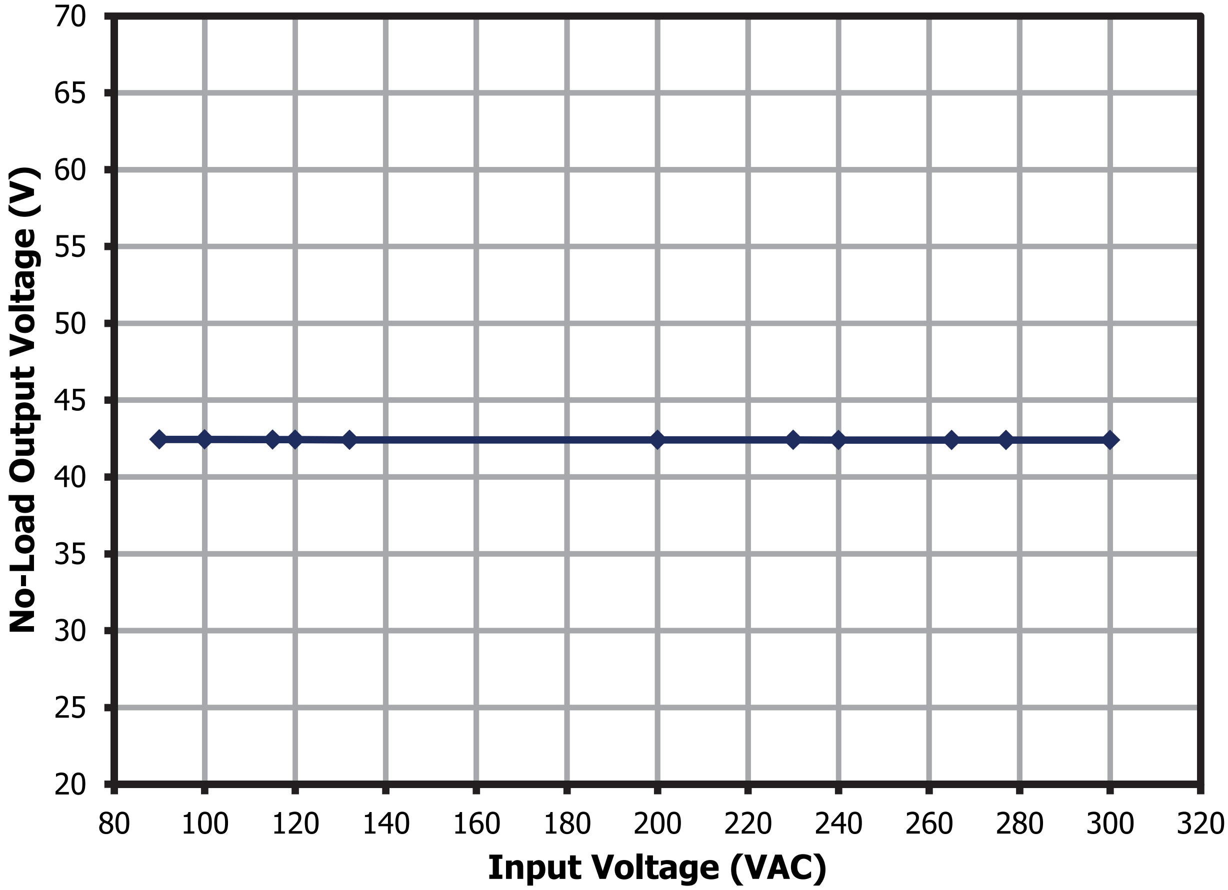

Figure 24 – No-Load Voltage vs. Line.

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11 Test Data

11.1 *42 V LED Load*

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	89.85	520.41	46.79	0.997	4.51	41.22	967.20	39.87	85.49
100	60	99.88	464.12	46.35	0.997	4.51	41.17	967.10	39.82	86.19
115	60	114.87	399.53	45.79	0.995	4.69	41.14	965.80	39.73	86.98
120	60	119.93	382.07	45.68	0.995	4.84	41.12	966.50	39.74	87.19
132	60	131.92	346.18	45.42	0.993	5.13	41.10	966.30	39.71	87.59
200	50	199.91	229.02	44.81	0.977	8.31	41.09	966.30	39.70	88.76
230	50	229.97	201.19	44.70	0.965	9.92	41.07	965.00	39.63	88.80
240	50	239.98	193.61	44.65	0.960	10.68	41.06	964.70	39.61	88.81
265	50	265.01	177.94	44.62	0.945	12.21	41.06	964.60	39.61	88.86
277	50	276.99	171.69	44.62	0.937	13.06	41.05	964.60	39.60	88.85
300	50	299.94	161.43	44.59	0.920	14.40	41.05	964.00	39.57	88.83

11.2 *37 V LED Load*

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	89.86	473.87	42.52	0.997	4.62	37.41	970.50	36.31	85.54
100	60	99.89	421.39	41.98	0.996	4.50	37.33	968.60	36.16	86.24
115	60	114.88	362.95	41.50	0.994	4.64	37.27	967.50	36.06	86.97
120	60	119.94	346.70	41.35	0.994	4.76	37.23	967.30	36.01	87.16
132	60	131.93	314.11	41.11	0.992	5.06	37.20	966.80	35.97	87.53
200	50	199.91	208.76	40.61	0.973	8.97	37.18	965.90	35.91	88.47
230	50	229.97	183.75	40.50	0.958	10.76	37.16	965.40	35.87	88.59
240	50	239.99	177.09	40.48	0.952	11.47	37.15	965.50	35.87	88.62
265	50	265.01	163.00	40.40	0.935	13.12	37.13	964.10	35.80	88.63
277	50	277.00	157.49	40.40	0.926	13.93	37.12	964.20	35.80	88.63
300	50	299.95	148.59	40.42	0.907	15.46	37.12	964.50	35.80	88.59

11.3 *34 V LED Load*

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	89.87	434.70	39.10	0.997	4.76	34.37	973.20	33.45	85.92
100	60	99.89	387.90	38.62	0.996	4.49	34.28	971.40	33.30	86.31
115	60	114.89	334.50	38.21	0.994	4.61	34.22	970.60	33.22	86.99
120	60	119.94	319.30	38.05	0.993	4.77	34.18	969.70	33.14	87.14
132	60	131.93	289.50	37.85	0.990	5.12	34.15	969.10	33.10	87.50
200	50	199.92	193.10	37.40	0.969	9.42	34.13	968.00	33.03	88.36
230	50	229.97	170.50	37.31	0.952	11.67	34.11	967.50	33.00	88.45
240	50	239.99	164.30	37.26	0.945	12.36	34.09	966.60	32.96	88.48
265	50	265.01	151.70	37.23	0.926	13.94	34.08	966.20	32.93	88.45
277	50	277.00	146.80	37.23	0.916	14.59	34.08	966.40	32.93	88.45
300	50	299.95	138.70	37.21	0.895	16.45	34.07	965.60	32.89	88.39

11.4 *30 V LED Load*

Input		Input Measurement					LED Load Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	89.87	393.00	35.22	0.996	4.58	31.06	970.50	30.15	85.69
100	60	99.90	350.90	34.91	0.995	4.49	31.04	969.70	30.10	86.29
115	60	114.90	303.30	34.61	0.993	4.64	31.02	969.00	30.06	86.91
120	60	119.95	289.90	34.52	0.992	4.70	31.01	968.20	30.03	87.06
132	60	131.94	263.20	34.36	0.989	5.37	31.01	967.70	30.01	87.38
200	50	199.92	176.50	34.01	0.963	10.58	31.00	966.30	29.96	88.16
230	50	229.98	156.40	33.94	0.944	12.51	31.00	965.80	29.94	88.20
240	50	240.00	151.00	33.95	0.936	13.16	30.99	965.90	29.94	88.24
265	50	265.02	140.10	33.99	0.915	14.80	30.99	966.60	29.96	88.22
277	50	277.00	135.60	33.97	0.903	15.73	30.99	965.90	29.93	88.20
300	50	299.96	128.70	33.98	0.880	17.62	30.99	965.60	29.92	88.14

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11.5 ***No-Load***

Input		Input Measurement					V_{OUT}
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%ATHD	V (V_{DC})
90	60	89.93	25.17	0.81	0.36	58.64	42.45
100	60	99.95	24.82	0.80	0.32	62.89	42.45
115	60	114.93	24.19	0.79	0.28	66.86	42.43
120	60	119.99	24.04	0.78	0.27	68.16	42.43
132	60	131.97	23.74	0.77	0.25	70.38	42.42
200	50	199.93	21.75	0.78	0.18	76.00	42.42
230	50	229.97	20.89	0.76	0.16	71.38	42.41
240	50	239.99	20.67	0.72	0.15	69.53	42.41
265	50	265.00	20.01	0.68	0.13	65.91	42.40
277	50	276.99	19.78	0.70	0.13	67.34	42.40
300	50	299.93	20.46	0.75	0.12	56.48	42.40

11.6 *Individual Harmonic Content at 115 VAC and 42 V LED Load*

V_{IN} (V_{RMS})	Freq	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%THD
115	60	414.20	46.96	0.987	6.94
Harmonic Content			**Class C Limit**		
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**mA Limit >25 W**	**Remarks**
1	381.70				
2	0.36	0.00		0.02	
3	5.85	0.02	310.59	0.30	Pass
5	10.61	0.03	173.57	0.10	Pass
7	3.94	0.01	91.35	0.07	Pass
9	2.91	0.01	45.68	0.05	Pass
11	7.49	0.02	31.97	0.03	Pass
13	8.81	0.02	27.05	0.03	Pass
15	1.32	0.00	23.45	0.03	Pass
17	1.73	0.00	20.69	0.03	Pass
19	1.17	0.00	18.51	0.03	Pass
21	1.24	0.00	16.75	0.03	Pass
23	1.03	0.00	15.29	0.03	Pass
25	1.03	0.00	14.07	0.03	Pass
27	0.98	0.00	13.03	0.03	Pass
29	1.31	0.00	12.13	0.03	Pass
31	1.31	0.00	11.35	0.03	Pass
33	1.18	0.00	10.66	0.03	Pass
35	2.10	0.01	10.05	0.03	Pass
37	2.30	0.01	9.51	0.03	Pass
39	0.94	0.00	9.02	0.03	Pass

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11.7 *Individual Harmonic Content at 277 VAC and 42 V LED Load*

V_{IN} (V_{RMS})	Freq	I_{IN} (mA_{RMS})	P_{IN} (W)	PF	%THD
277	50	177.94	44.57	0.945	12.212
Harmonic Content			**Class C Limit**		
nth Order	**mA Content**	**% Content**	**mA Limit <25 W**	**mA Limit >25 W**	**Remarks**
1	175.97				
2	0.19	0.00		0.02	Pass
3	9.46	0.05	151.54	0.28	Pass
5	12.75	0.07	84.68	0.10	Pass
7	7.83	0.04	44.57	0.07	Pass
9	6.19	0.04	22.29	0.05	Pass
11	4.22	0.02	15.60	0.03	Pass
13	4.55	0.03	13.20	0.03	Pass
15	3.07	0.02	11.44	0.03	Pass
17	3.10	0.02	10.09	0.03	Pass
19	2.29	0.01	9.03	0.03	Pass
21	2.32	0.01	8.17	0.03	Pass
23	1.91	0.01	7.46	0.03	Pass
25	2.06	0.01	6.86	0.03	Pass
27	1.71	0.01	6.36	0.03	Pass
29	1.59	0.01	5.92	0.03	Pass
31	0.93	0.01	5.54	0.03	Pass
33	0.96	0.01	5.20	0.03	Pass
35	1.39	0.01	4.90	0.03	Pass
37	1.42	0.01	4.64	0.03	Pass
39	0.70	0.00	4.40	0.03	Pass

12 Dimming Performance

Dimming performance data were taken at room temperature.

12.1 *Dimming Curve*

12.1.1 0 V - 10 V Dimming Curve

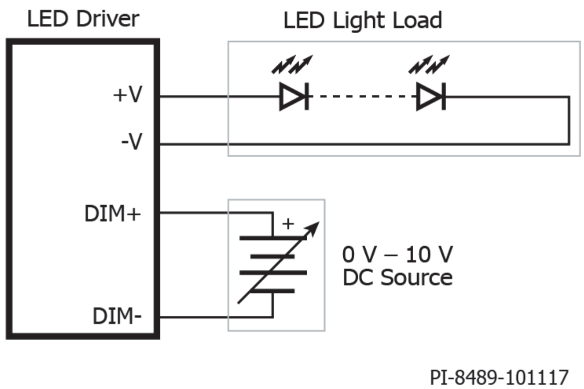

Figure 25 – 0 V- 10 V Dimming Set-up.

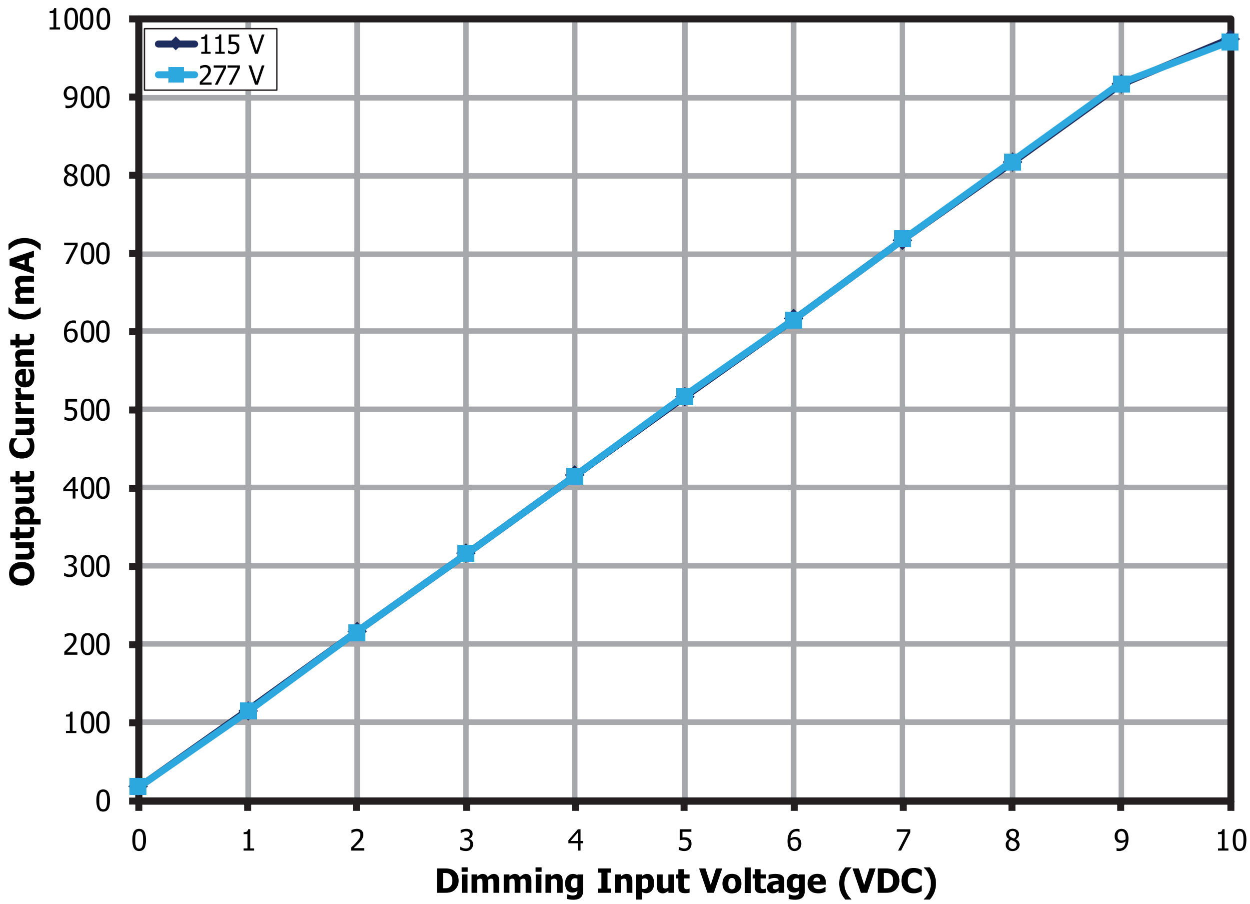

Figure 26 – 0 V – 10 V Dimming Curve at 42 V LED Load.

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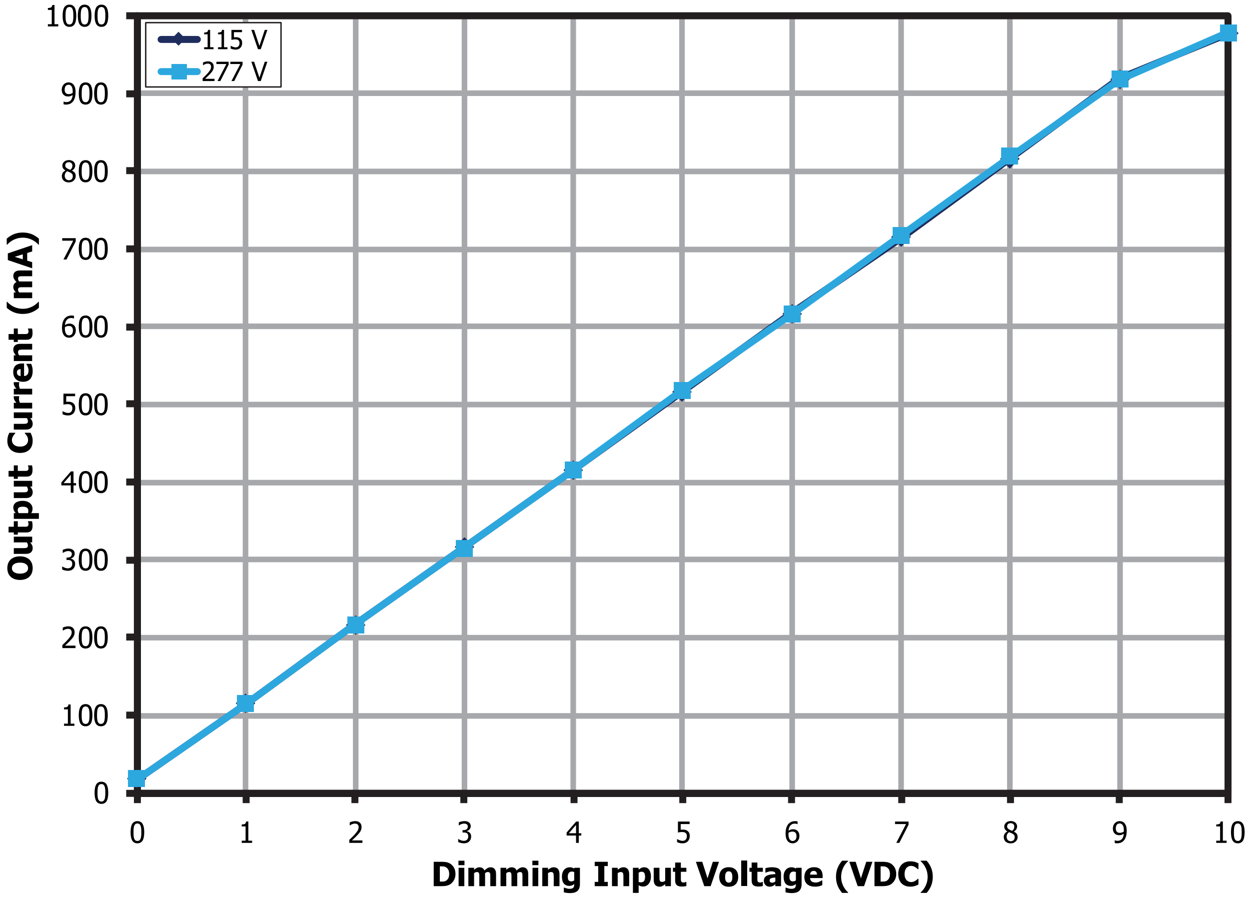

Figure 27 – 0 V - 10 V Dimming Curve at 35 V LED Load.

12.1.2 10 V 1 kHz PWM Dimming Curve

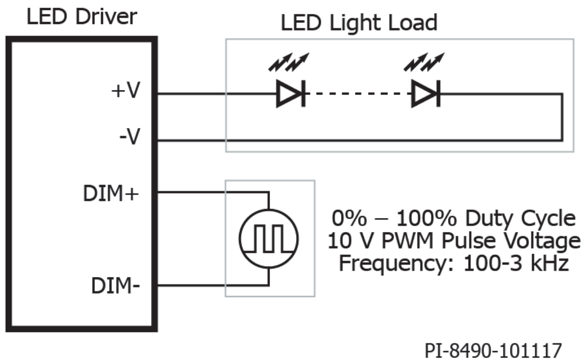

Figure 28 – 10 V, 1 KHz PWM Dimming Set-up.

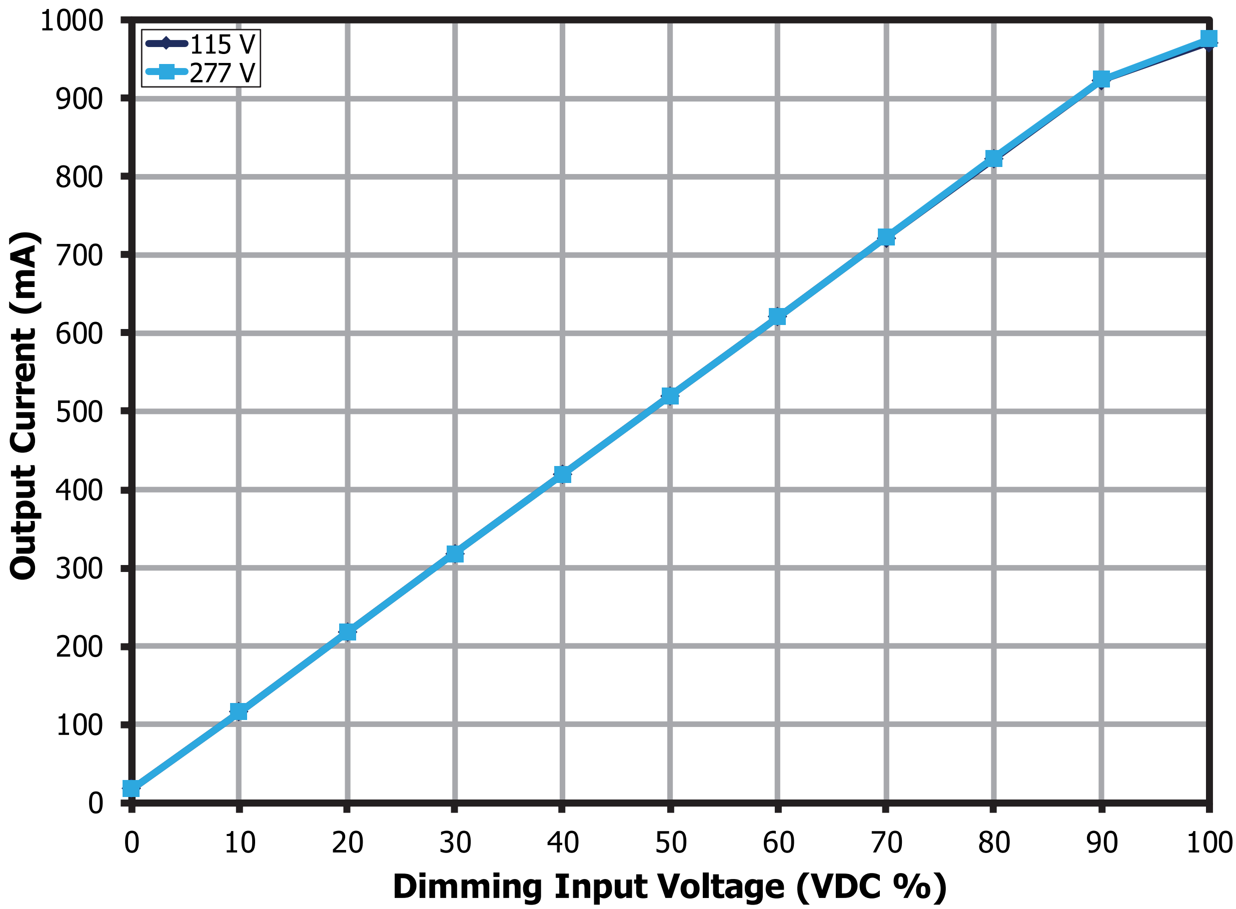

Figure 29 – 1 kHz, 10 V PWM Dimming Curve at 42 V LED Load.

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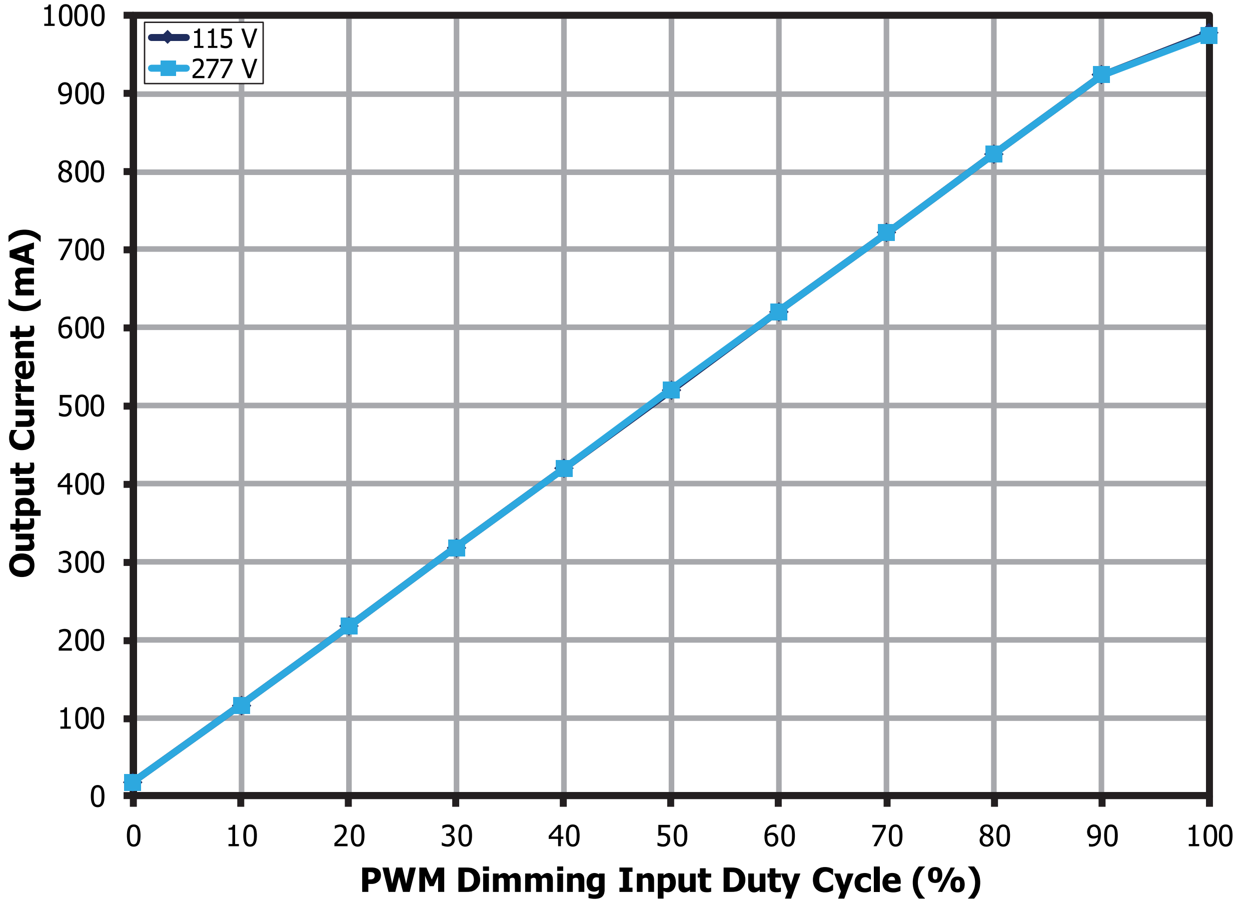

Figure 30 – 1 kHz, 10 V PWM Dimming Curve at 35 V LED Load.

12.1.3 Variable Resistor Dimming Curve

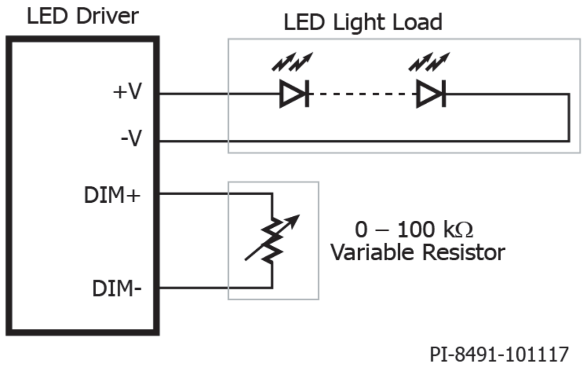

Figure 31 – 0-100 kΩ Variable Resistor Dimming Set-up.

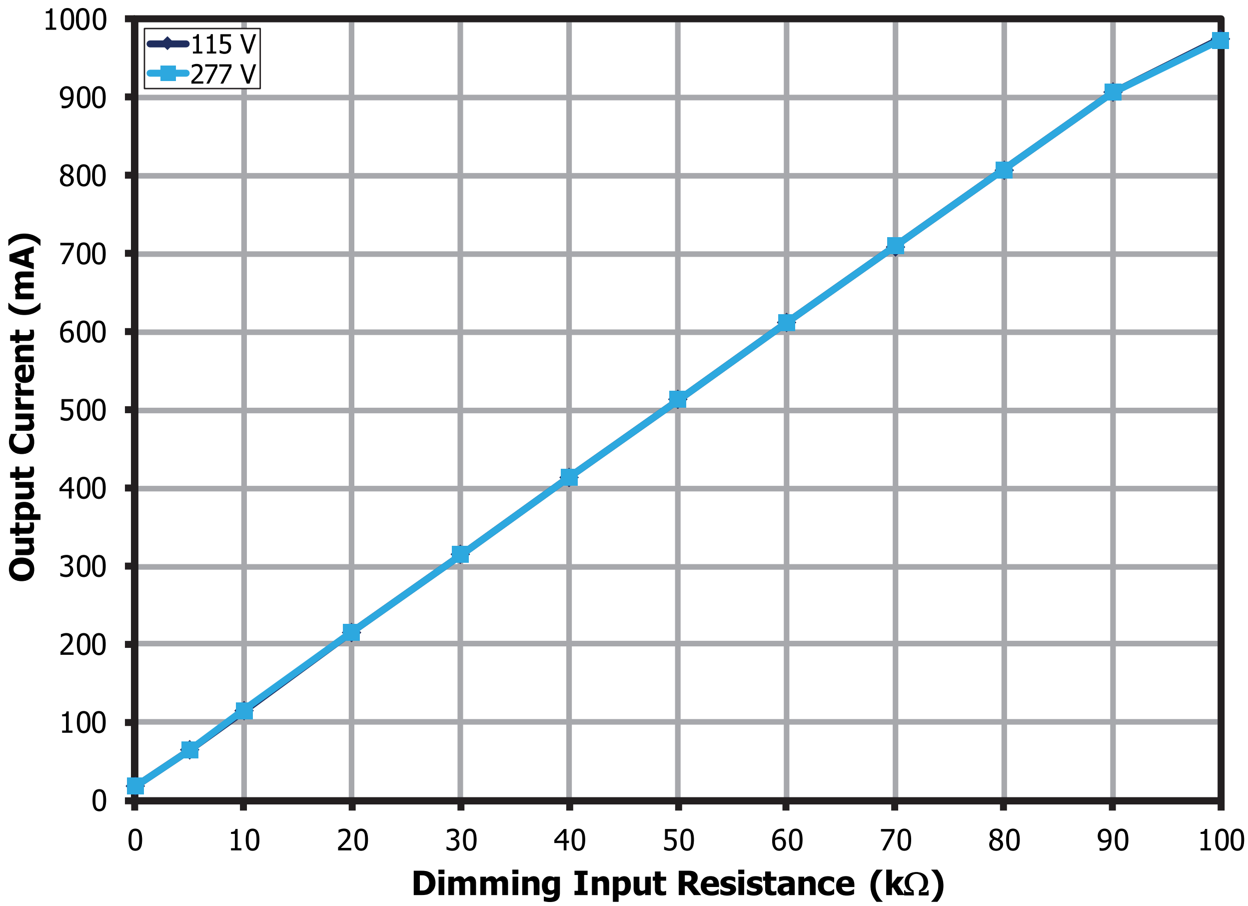

Figure 32 – 0-100 kΩ Variable Resistor Dimming Curve at 42 V LED Load.

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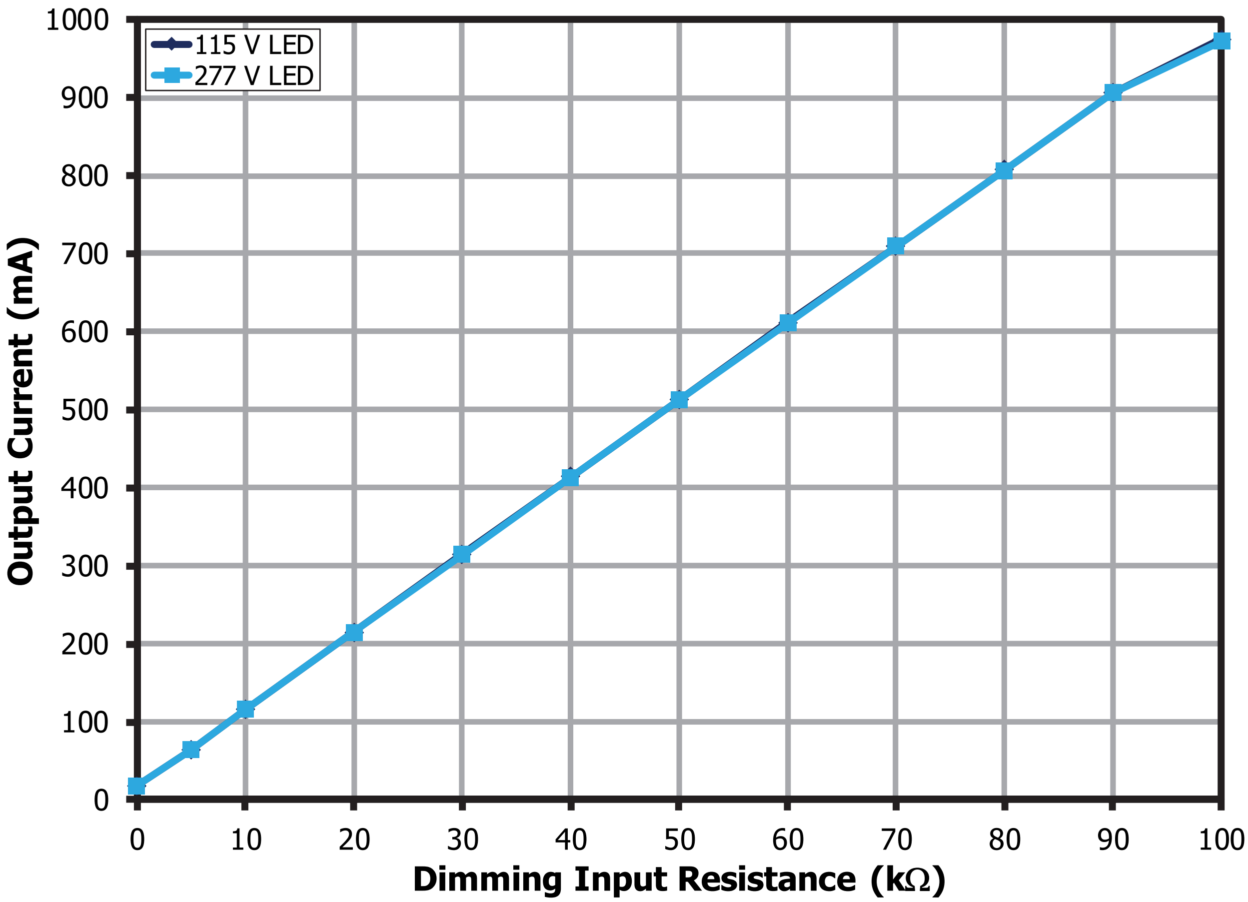

Figure 33 – 0-100 kΩ Variable Resistor Dimming Curve at 35 V LED Load.

12.2 *Dimming Efficiency*

Dimming efficiency was measured during 0 V – 10 V dimming. The 0 V - 10 V dimming efficiency curve has the same profile with PWM and variable resistor dimming.

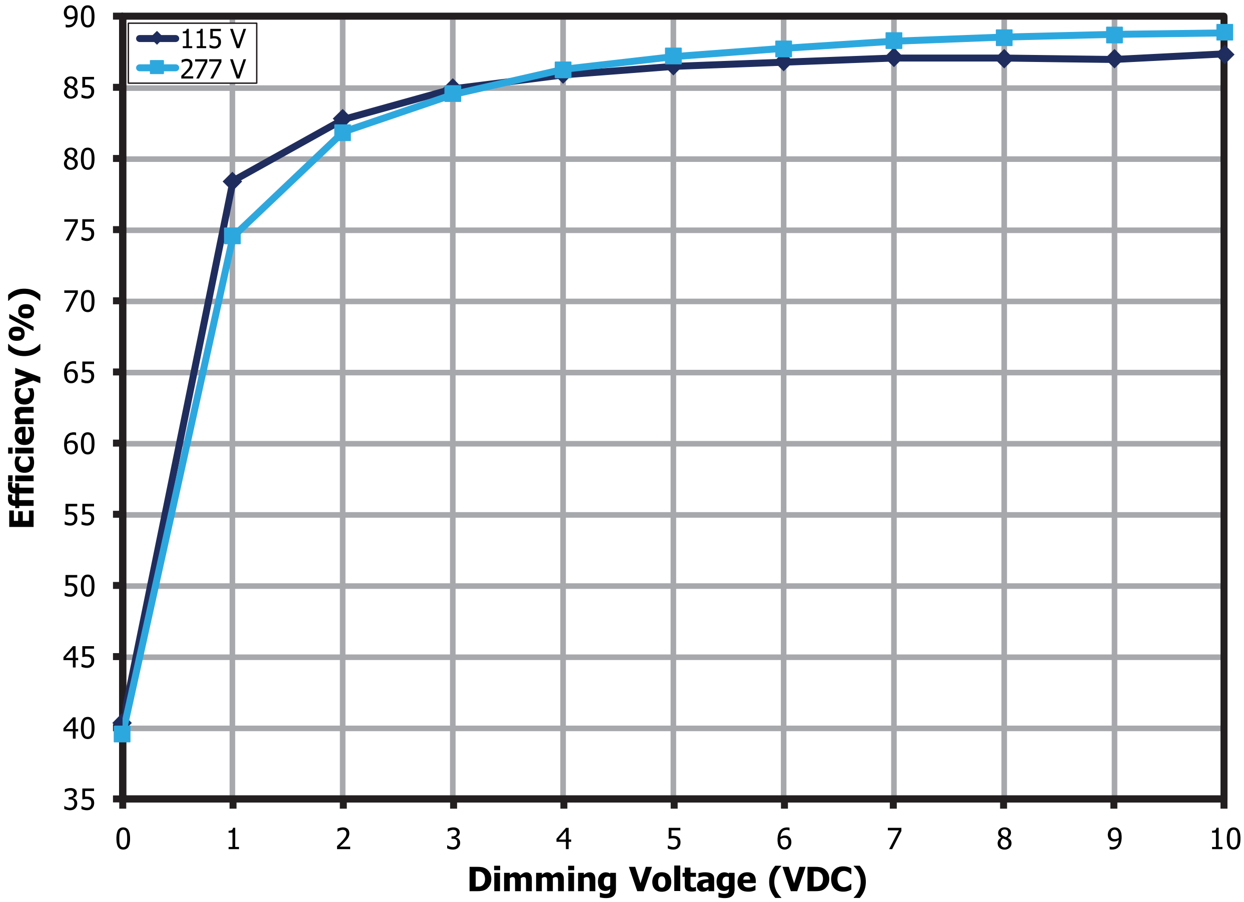

Figure 34 – Driver Efficiency at 42 V LED Load.

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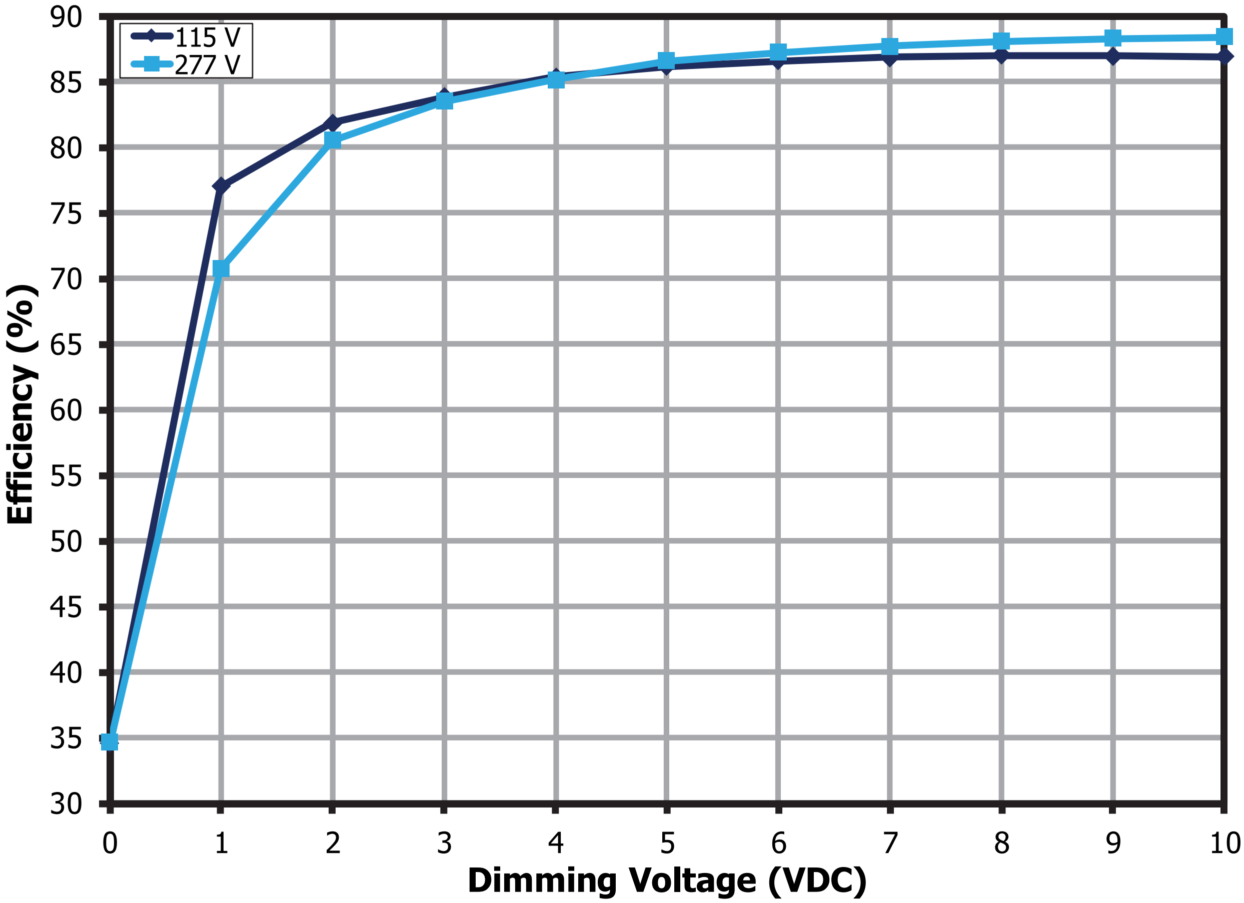

Figure 35 – Driver Efficiency at 35 V LED Load.

13 Thermal Performance

13.1 *Thermal Scan at 25 ºC Ambient*

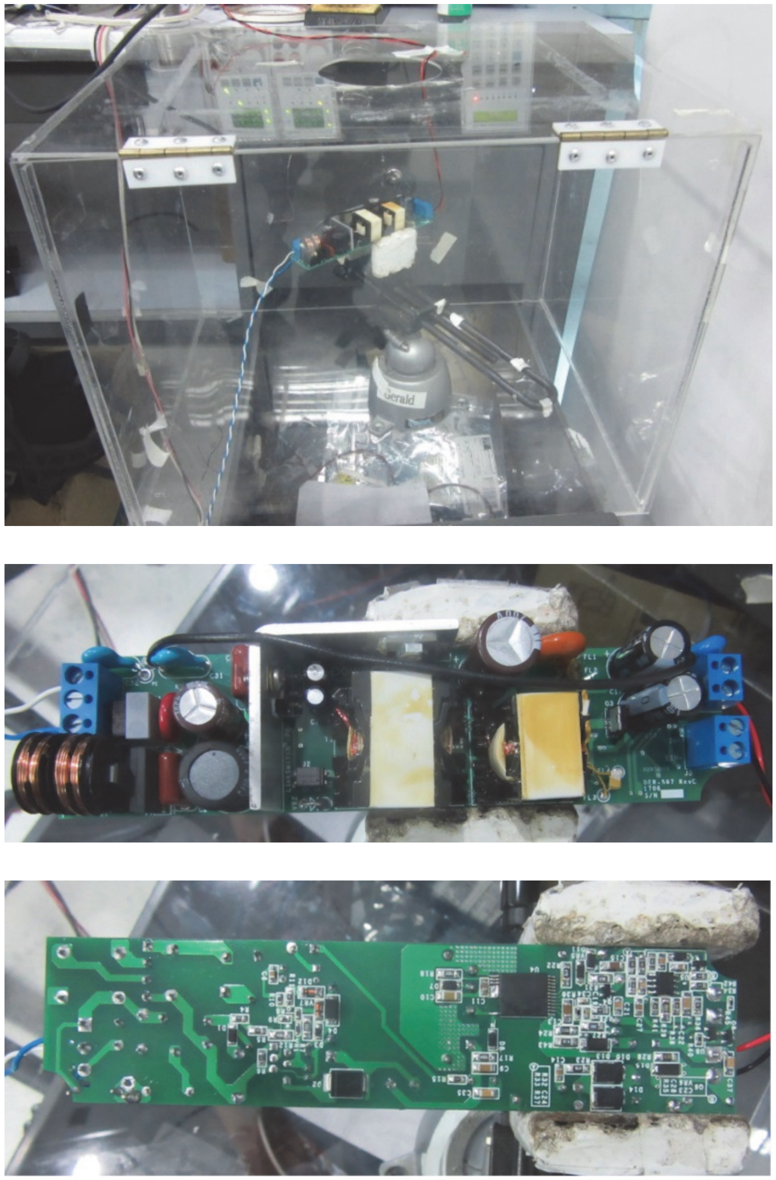

Figure 36 – Test Set-up Picture - Open Frame

Unit in open frame was placed inside an acrylic enclosure to prevent airflow that might affect the thermal measurements. Temperature was measured using FLIR Thermal Camera.

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13.1.1 Thermal Scan at 90 VAC Full Load

Thermal scan was performed at worst case input voltage of 90 VAC at room ambient temperature.

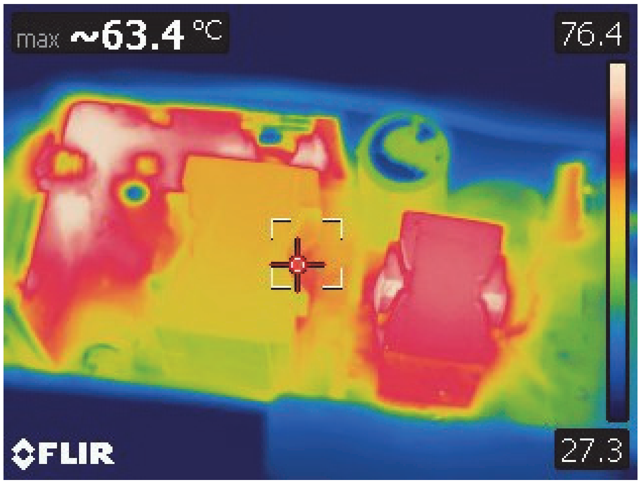

Figure 37 – 90 VAC, 42 V LED Load.
Spot 1: PFC Inductor (T1): 63.4 ºC.

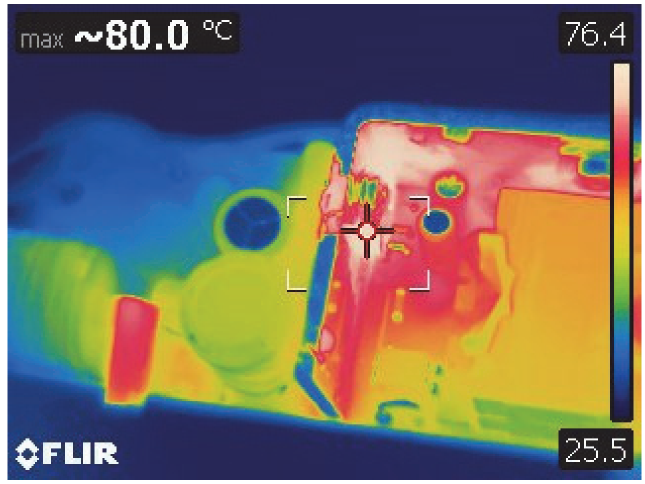

Figure 38 – 90 VAC, 42 V LED Load.
Spot 1: LNK419EG (U1): 80 ºC.

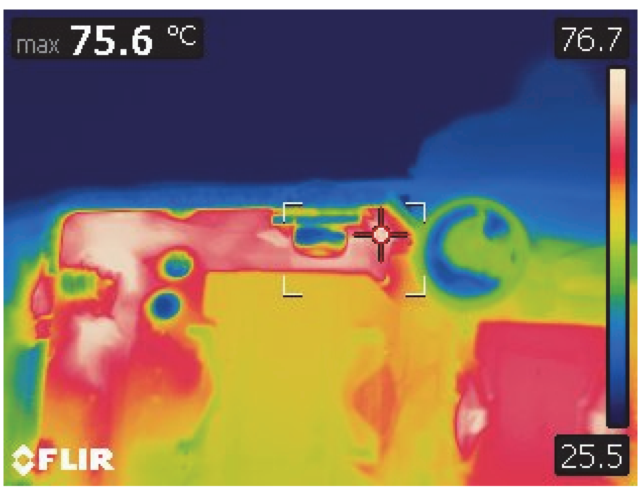

Figure 39 – 90 VAC, 42 V LED Load.
Spot 1: Boost Diode (D6): 75.6 ºC.

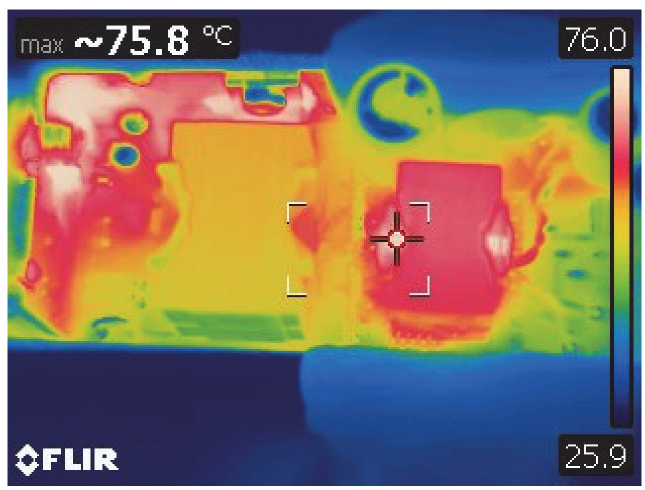

Figure 40 – 90 VAC, 42 V LED Load.
Spot 1: DC-DC Transformer: 75.8 ºC.

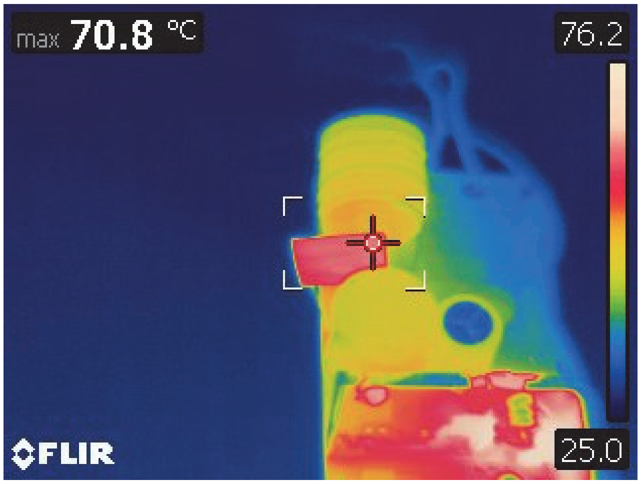

Figure 41 – 90 VAC, 42 V LED Load.
Spot 1: Bridge Diode (BR1): 70.8 ºC.

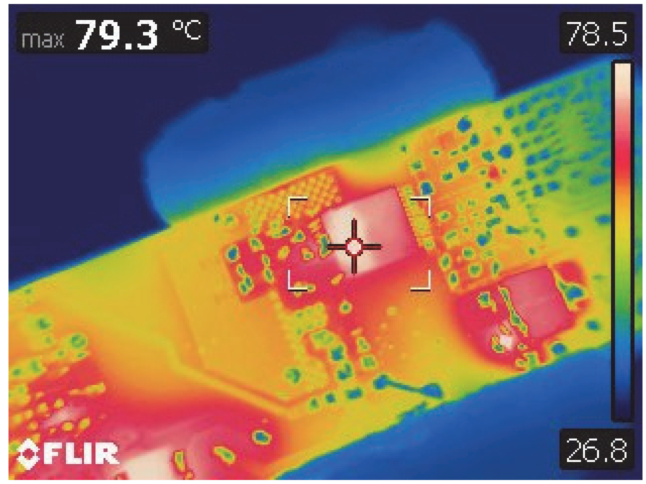

Figure 42 – 230 VAC, 42 V LED Load.
Spot 1: LYTSwitch-6 (U4): 79.4 ºC.

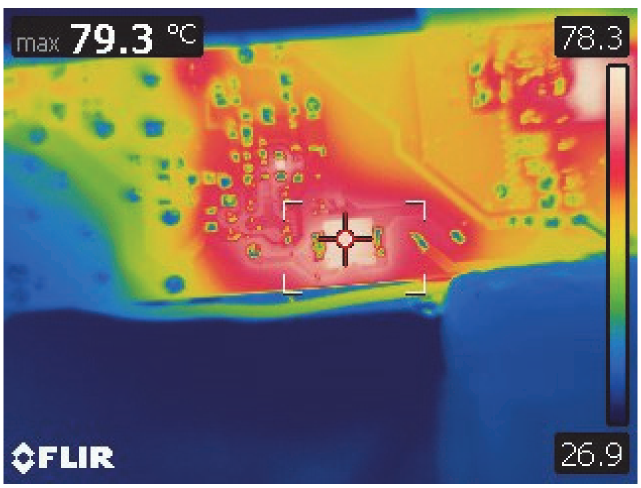

Figure 43 – 90 VAC, 42 V LED Load.
Spot 1: PFC Blocking Diode (D2): 79.3 ºC.

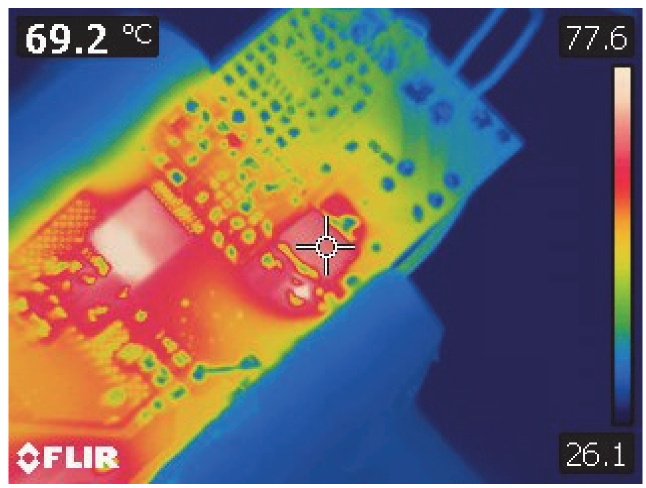

Figure 44 – 90 VAC, 42 V LED Load.
Spot 1: Output Diode (D10): 69.2 ºC.

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13.2 *Thermal Performance at 60 ºC Ambient*

Figure 45 – Test Set-up Picture Thermal at 60 ºC Ambient - Open Frame.

Unit in open frame was placed inside an enclosure to prevent airflow that might affect the thermal measurements. Ambient temperature inside enclosure is 60 ºC. Temperature was measured using type T thermocouple.

No.	Components	Temperature (°C)	
		90 VAC	305 VAC
1	Ambient Temperature	60.3	60.1
2	BR1-Bridge Diode	89.1	59.8
2	C16-Output Capacitor	85	88.1
3	C8-PFC Output Capacitor	92.2	89.5
4	U1-LinkSwitch-PH	108	89.7
5	T2-Flyback Transformer	100.5	97.9
6	L3-Differential Choke	86	49.6
7	U4-LYTSwitch-6	101.4	97.4
8	D10-Output Rectifier	99.6	97.5
9	T1-PFC Inductor	96.8	87.7
10	D6-PFC Boost Diode	106.3	91.6
11	L2-Input CMC	89.1	70.4
12	D2-Blocking Diode	99.9	81.2

14 Waveforms.

14.1 *Input Voltage and Input Current at 42 V LED Load*

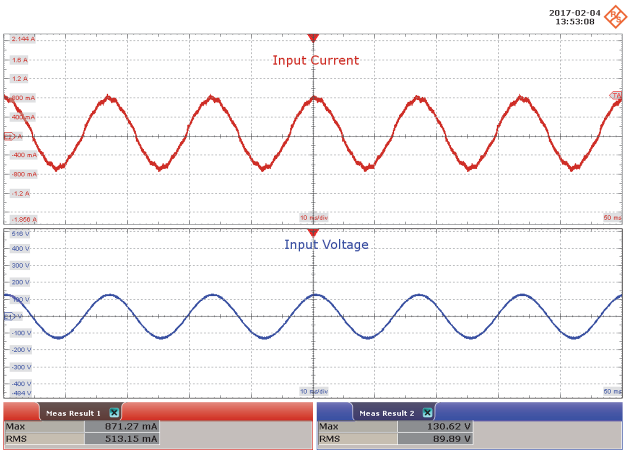

Figure 46 –90 VAC, 42 V LED Load.
Upper: I_{IN}, 400 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

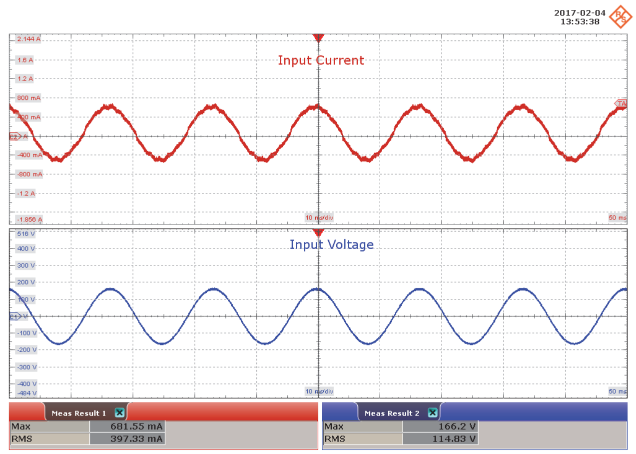

Figure 47 – 115 VAC, 42 V LED Load.
Upper: I_{IN}, 400 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

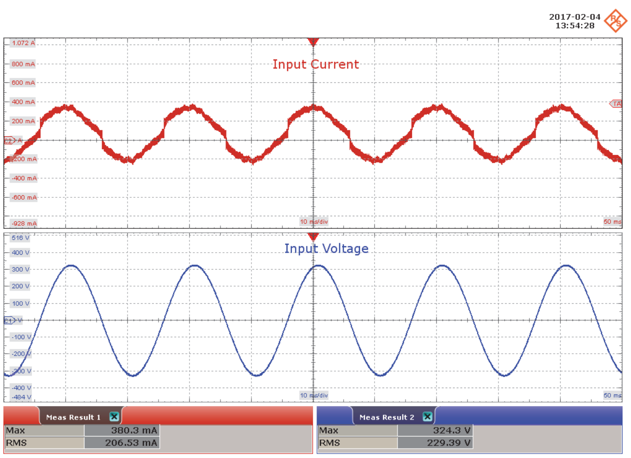

Figure 48 – 230 VAC, 42 V LED Load.
Upper: I_{IN}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

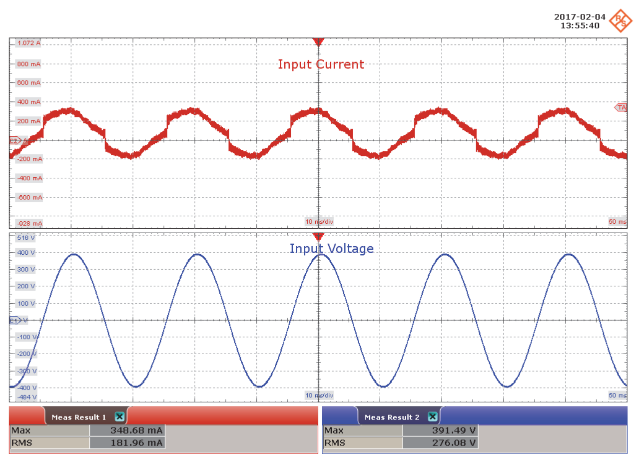

Figure 49 – 277 VAC, 42 V LED Load.
Upper: I_{IN}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 10 ms / div.

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14.2 *Start-up Profile at 42 V LED Load*

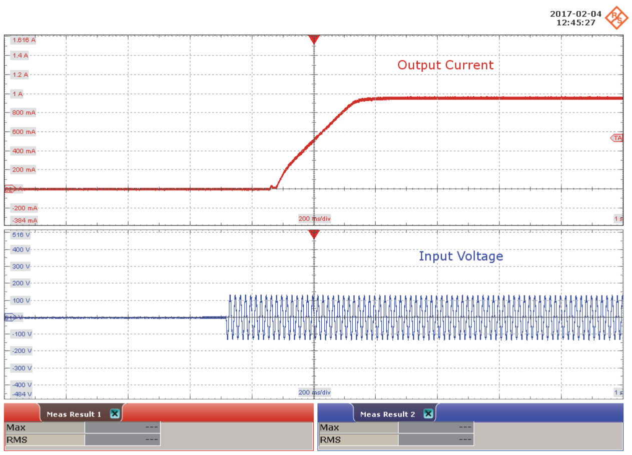

Figure 50 – 90 VAC, 42 V LED, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.
Turn-on Time: 402 ms.

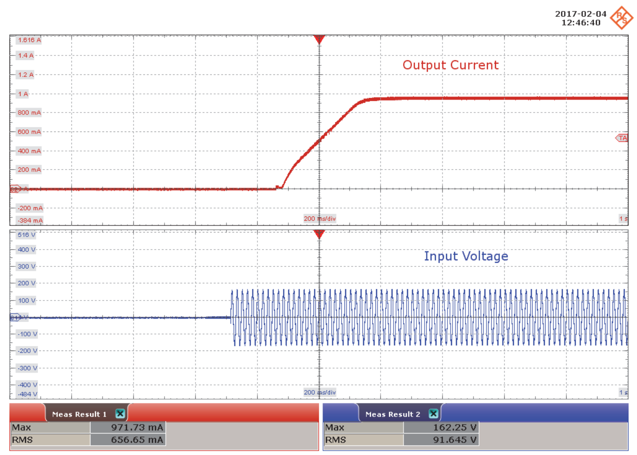

Figure 51 – 115 VAC, 42 V LED, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.
Turn-on Time: 408 ms.

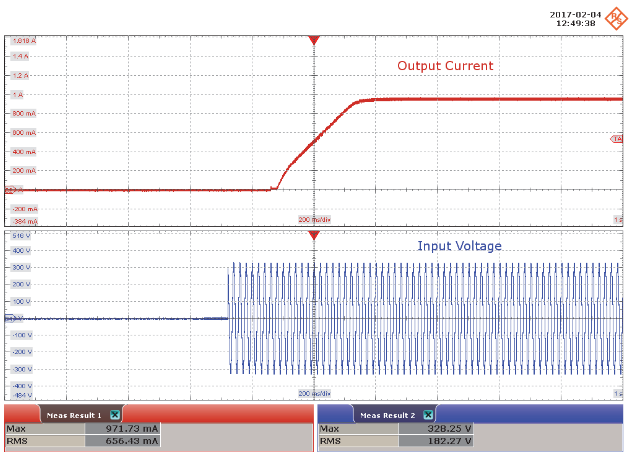

Figure 52 – 230 VAC, 42 V LED, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.
Turn-on Time: 400 ms.

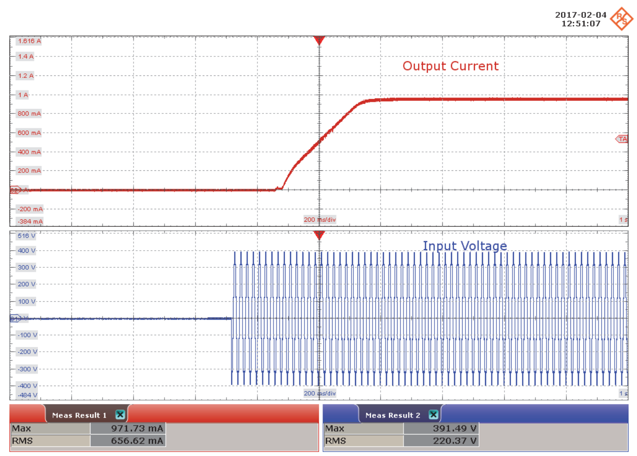

Figure 53 – 277 VAC, 42 V LED, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.
Turn-on Time: 404 ms.

14.3 *Start-up Profile at 30 V LED Load*

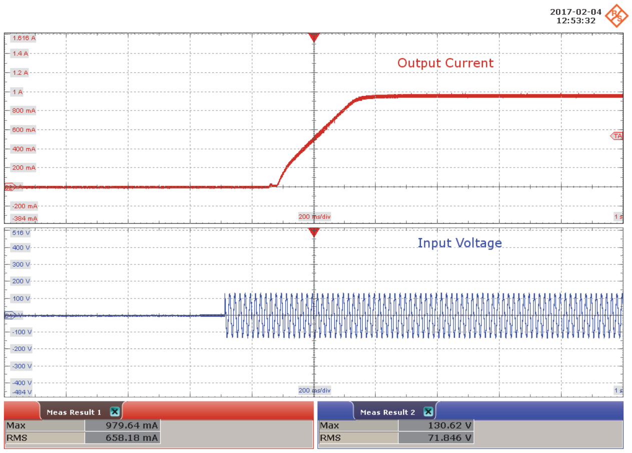

Figure 54 – 90 VAC, 30 V LED, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.
Turn-on Time: 408 ms.

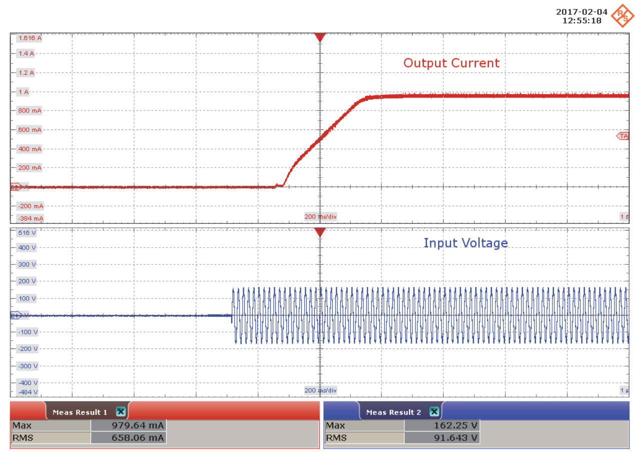

Figure 55 – 115 VAC, 30 V LED, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.
Turn-on Time: 402 ms.

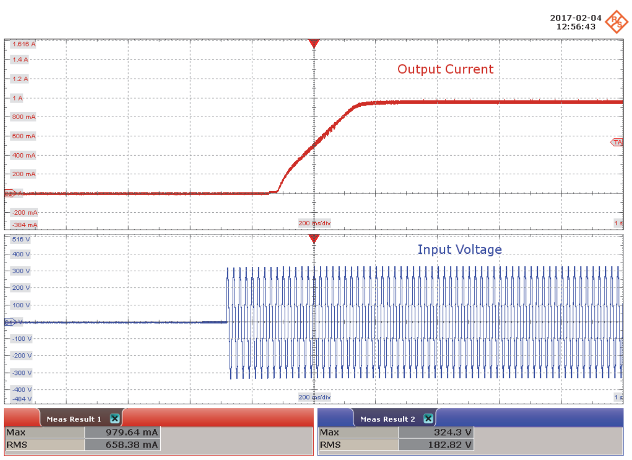

Figure 56 – 230 VAC, 30 V LED, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.
Turn-on Time: 404 ms.

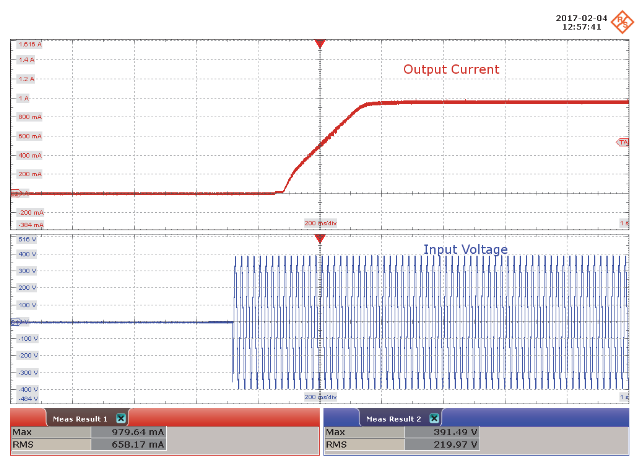

Figure 57 – 277 VAC, 30 V LED, Output Rise.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 200 ms / div.
Turn-on Time: 402 ms.

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14.4 ***Output Current Fall at 42 V LED Load***

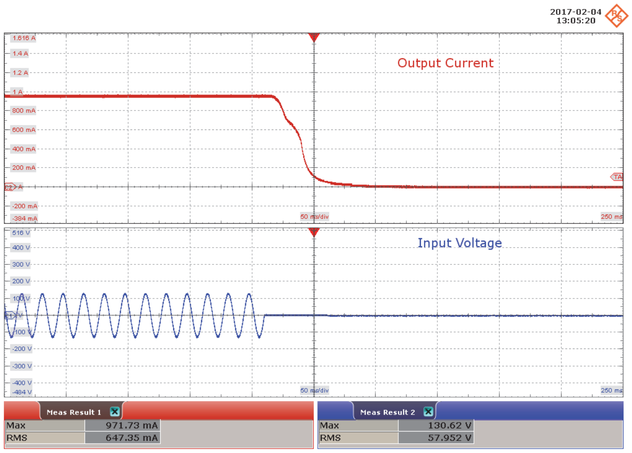

Figure 58 – 90 VAC, 42 V LED, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 16.5 ms.

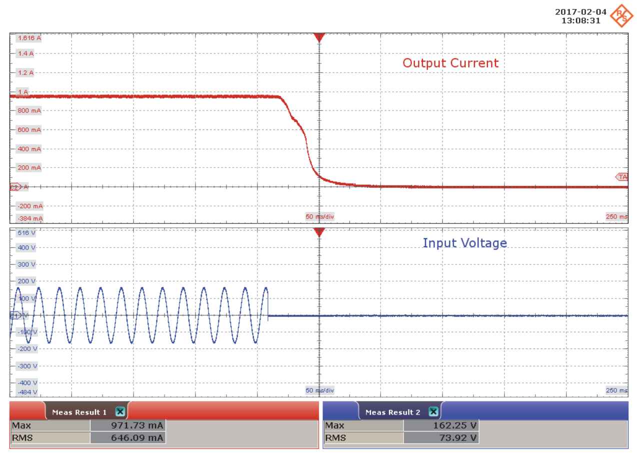

Figure 59 – 115 VAC, 42 V LED, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 17.5 ms.

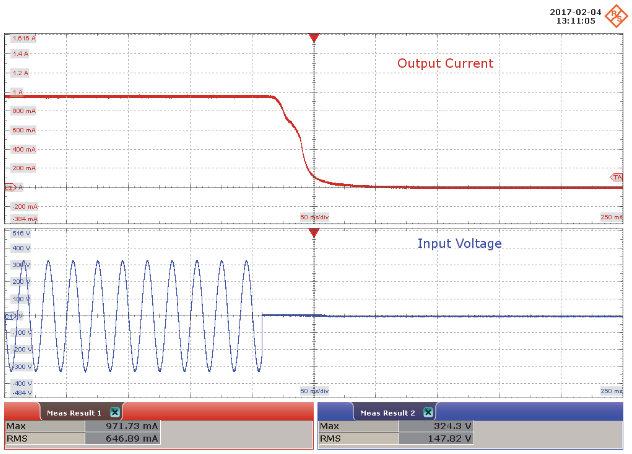

Figure 60 – 230 VAC, 42 V LED, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 17.5 ms.

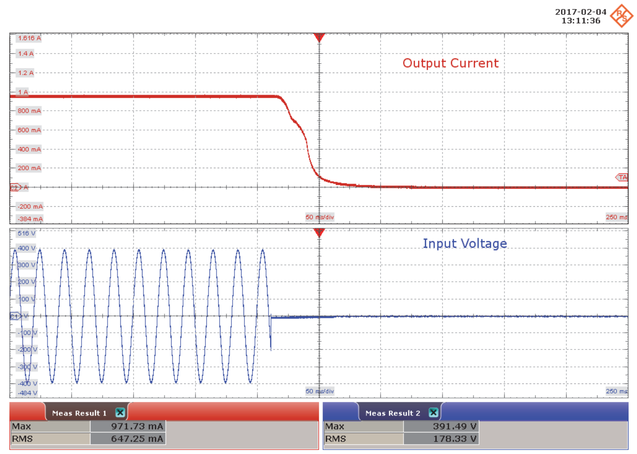

Figure 61 – 277 VAC, 42 V LED, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 15 ms.

14.5 *Output Current Fall at 30 V LED Load*

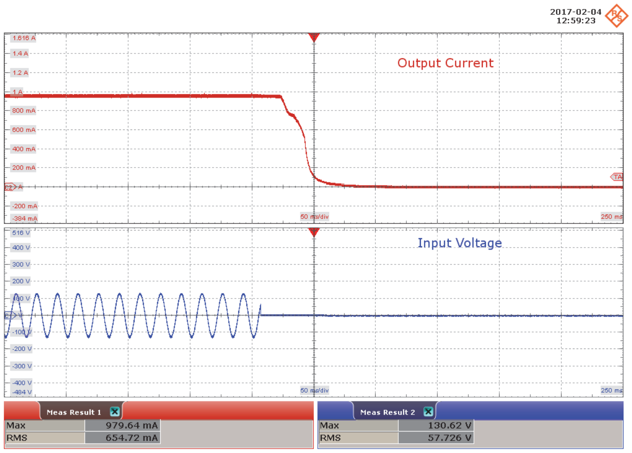

Figure 62 – 90 VAC, 30 V LED, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 20 ms.

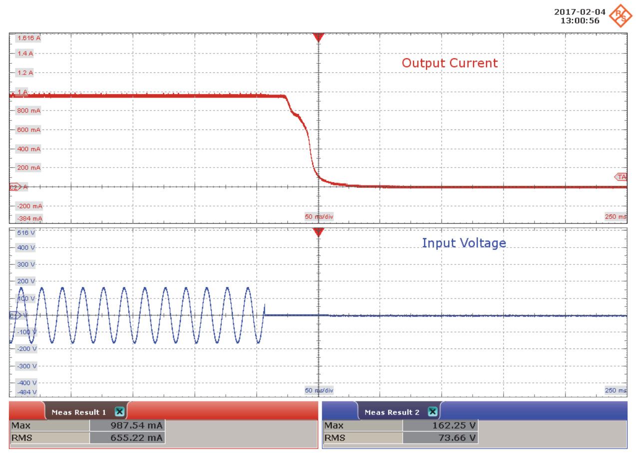

Figure 63 – 115 VAC, 30 V LED, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 20 ms.

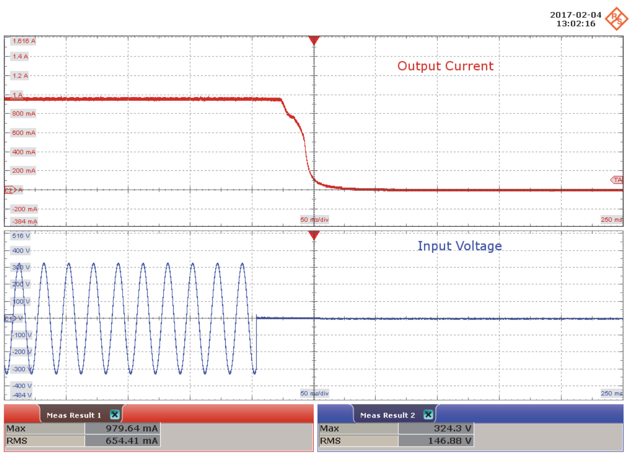

Figure 64 – 230 VAC, 30 V LED, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 26 ms.

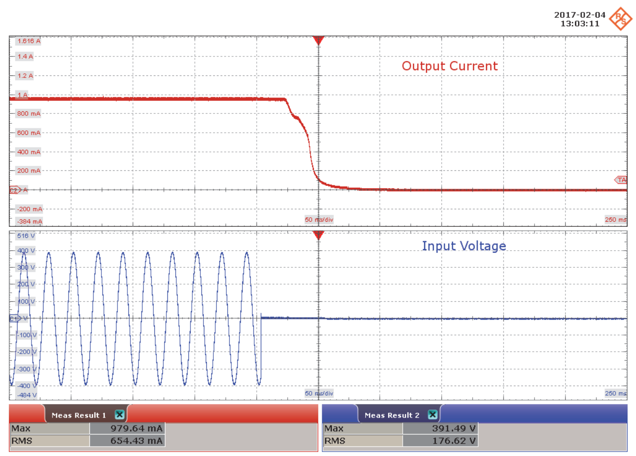

Figure 65 – 277 VAC, 30 V LED, Output Fall.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 50 ms / div.
Hold-up Time: 26 ms.

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14.6 *LNK419EG (U1) Drain Voltage and Current at Normal Operation*

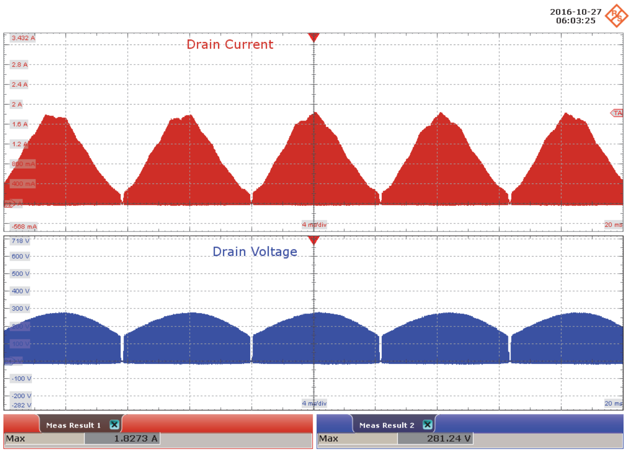

Figure 66 – 90 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

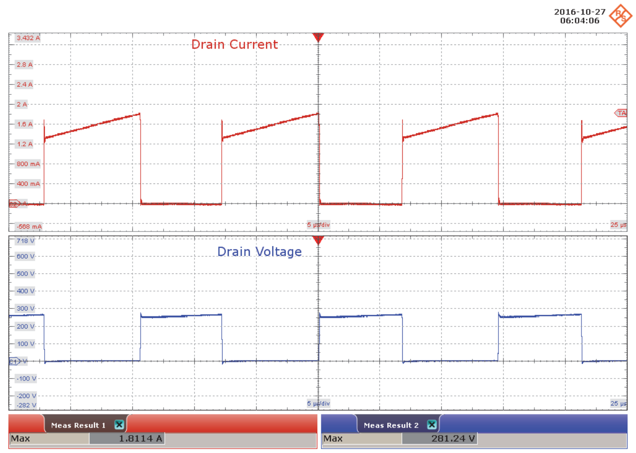

Figure 67 – 90 VAC, 42V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

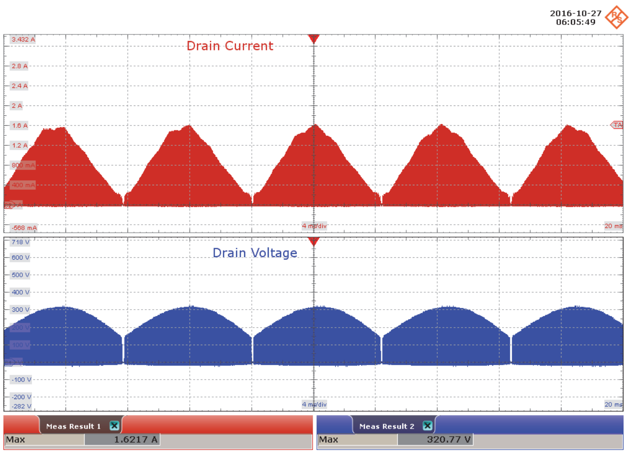

Figure 68 – 115 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

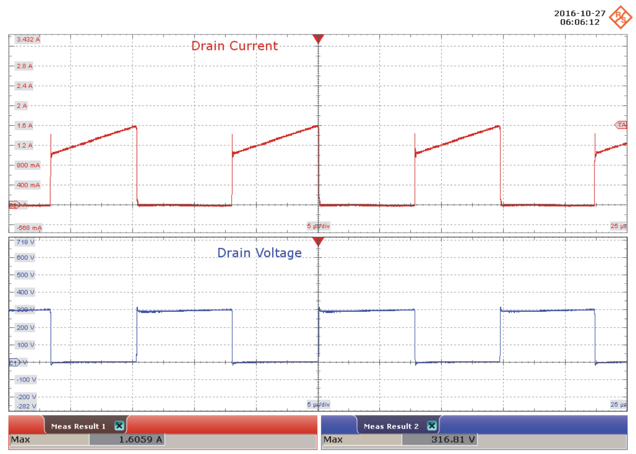

Figure 69 – 115 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

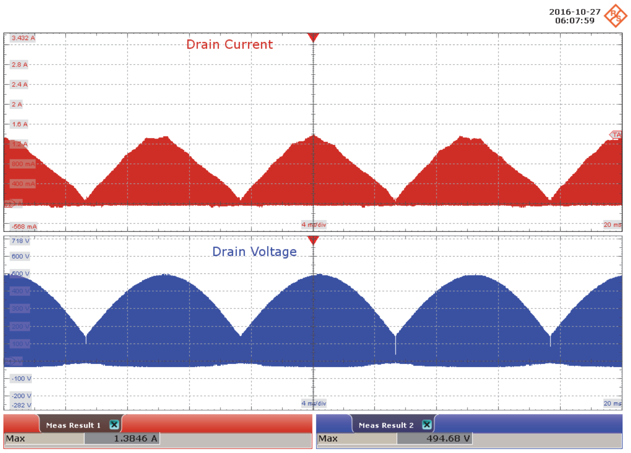

Figure 70 – 230 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

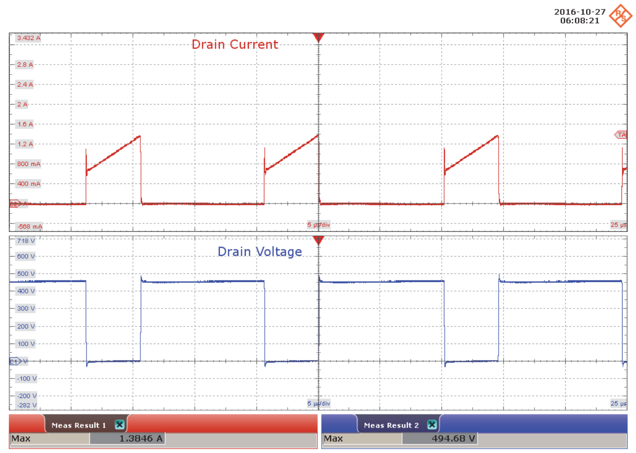

Figure 71 – 230 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

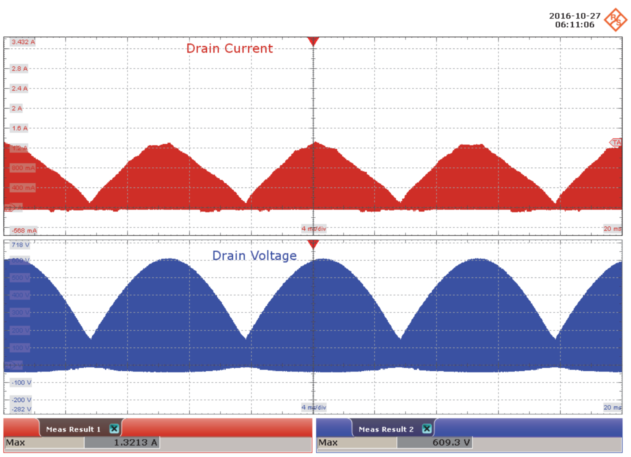

Figure 72 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

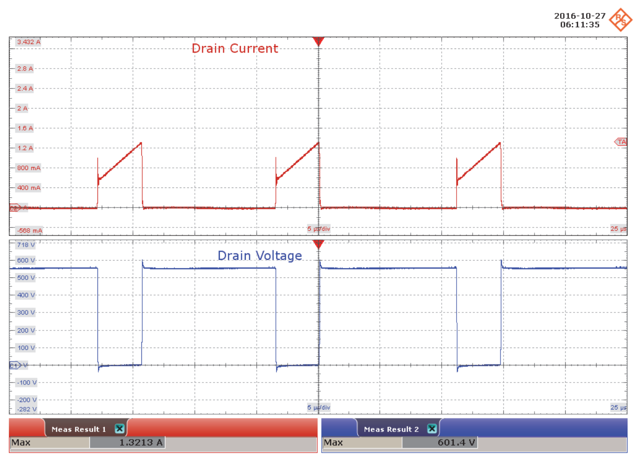

Figure 73 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 μs / div.

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14.7 *LNK419EG (U1) Drain Voltage and Current at Start-up*

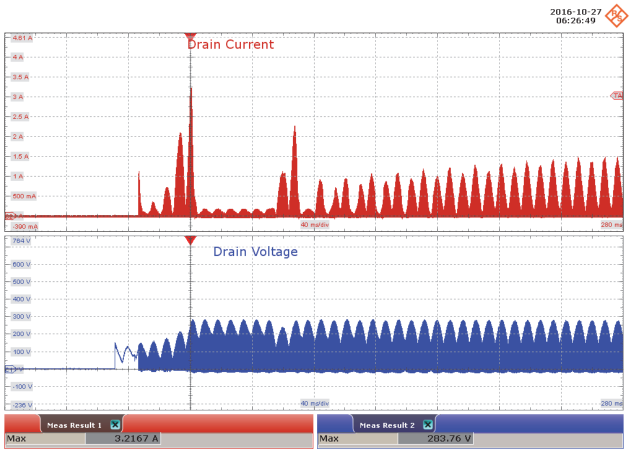

Figure 74 – 90 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 40 ms / div.

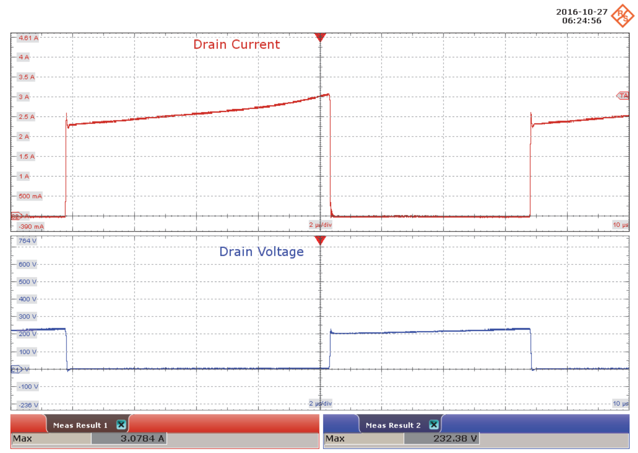

Figure 75 – 90 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

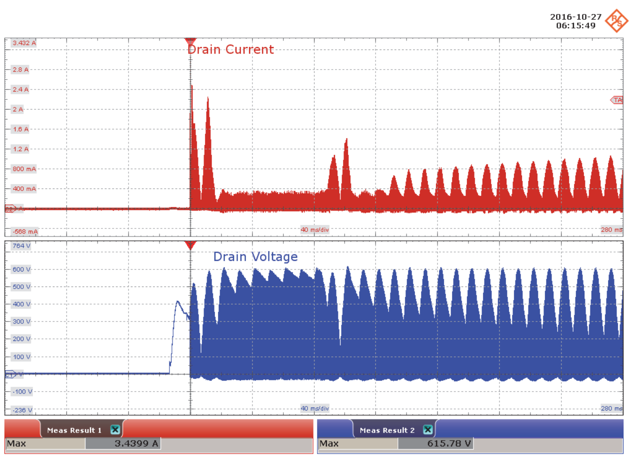

Figure 76 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 40 ms / div.

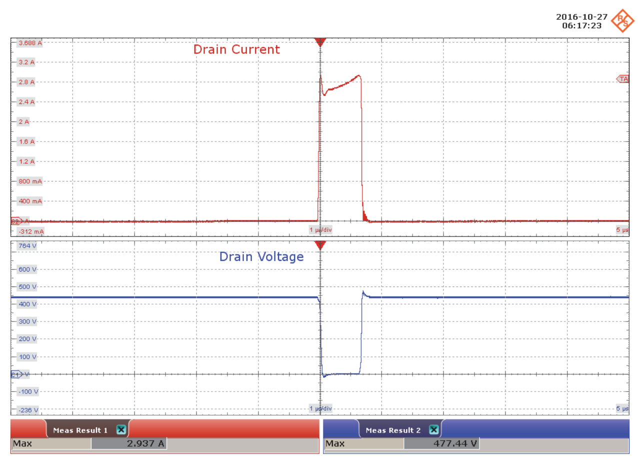

Figure 77 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 μs / div.

14.8 *LNK419EG (U1) Drain Voltage and Current during Output Short-Circuit*

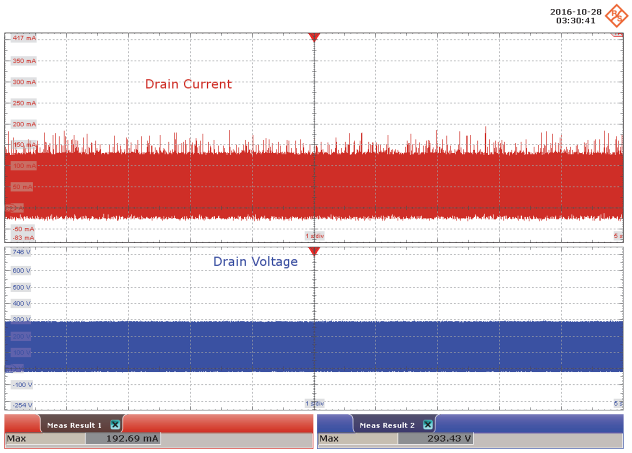

Figure 78 – 90 VAC, Output Short Circuit.
Upper: I_{DRAIN}, 50 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.

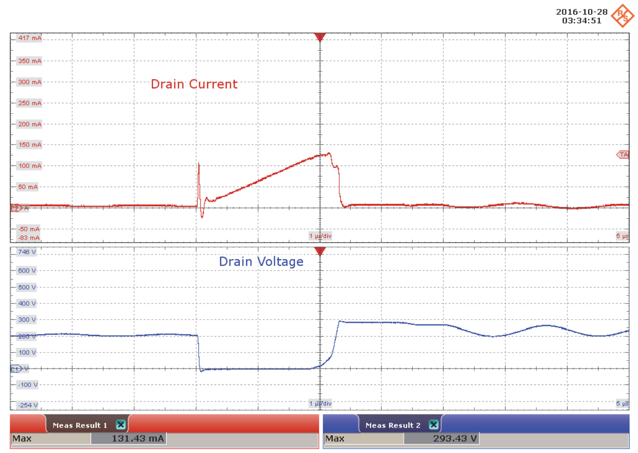

Figure 79 – 90 VAC, Output Short Circuit.
Upper: I_{DRAIN}, 50 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 µs / div.

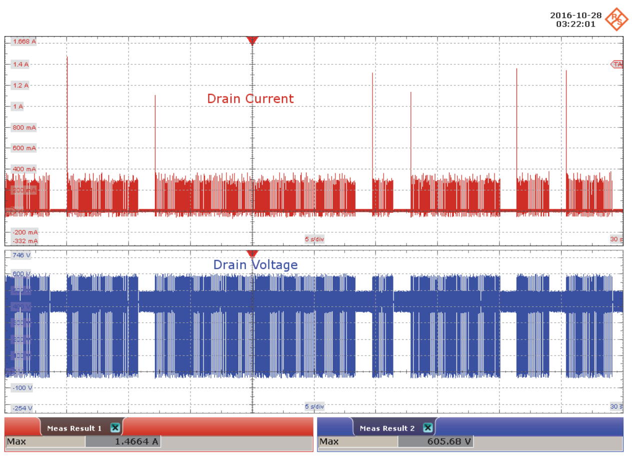

Figure 80 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 5 s / div.

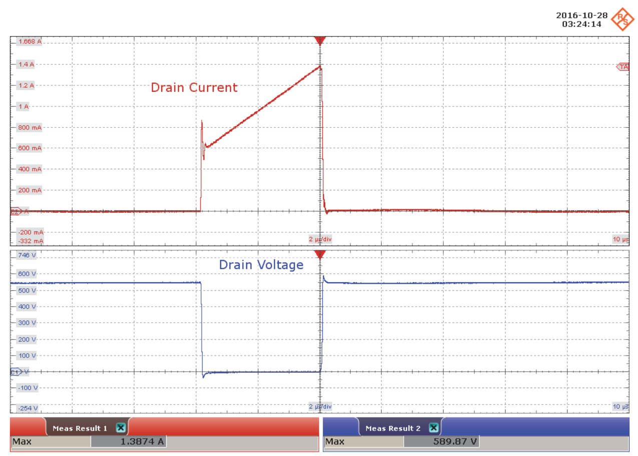

Figure 81 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 200 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 µs / div.

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14.9 ***LYTSwitch-6 (U4) Drain Voltage and Current at Normal Operation***

14.9.1 LED Load

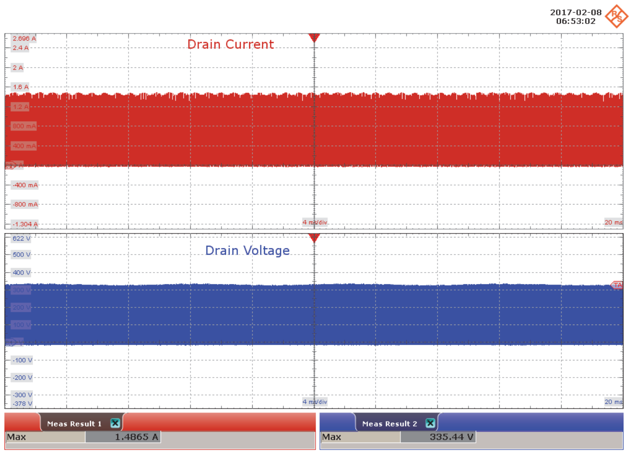

Figure 82 – 90 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

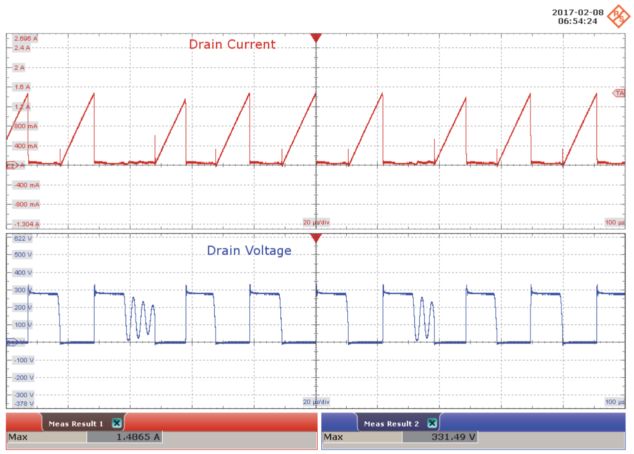

Figure 83 – 90 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 µs / div.

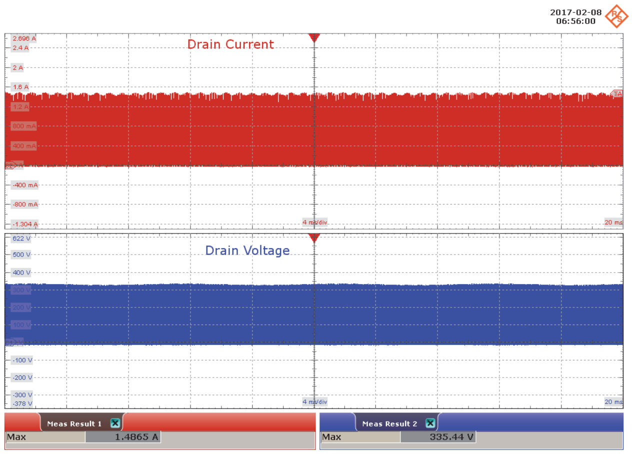

Figure 84 – 120 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

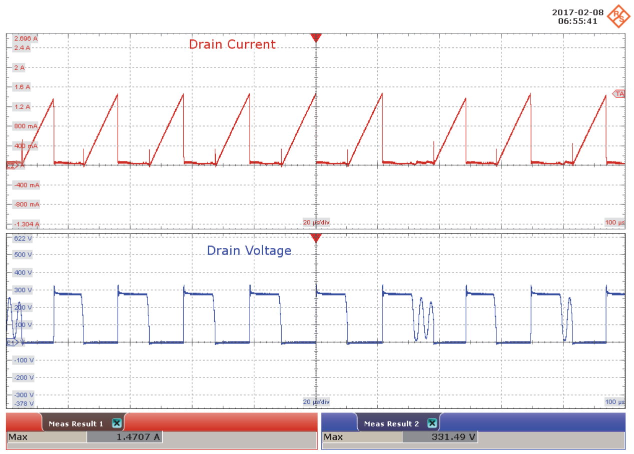

Figure 85 – 120 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 µs / div.

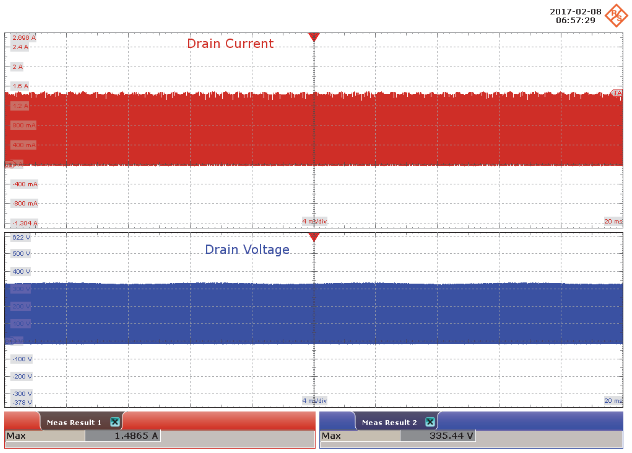

Figure 86 – 265 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

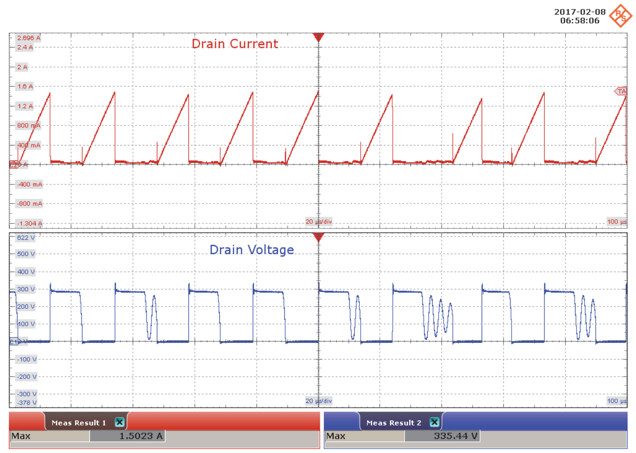

Figure 87 – 265 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 µs / div.

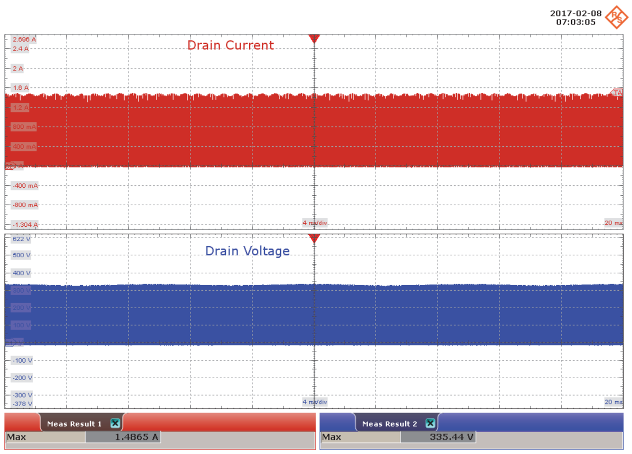

Figure 88 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

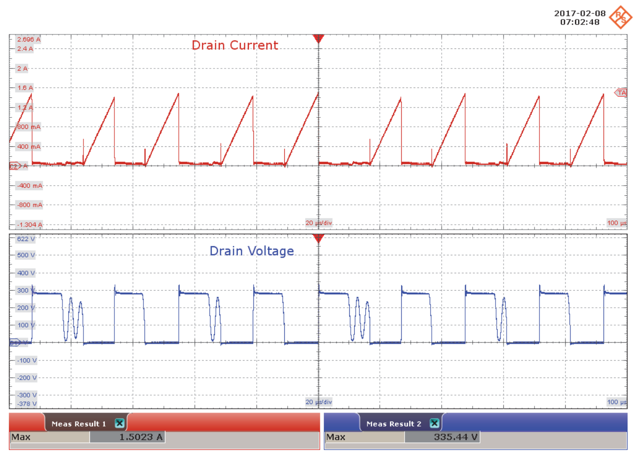

Figure 89 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 µs / div.

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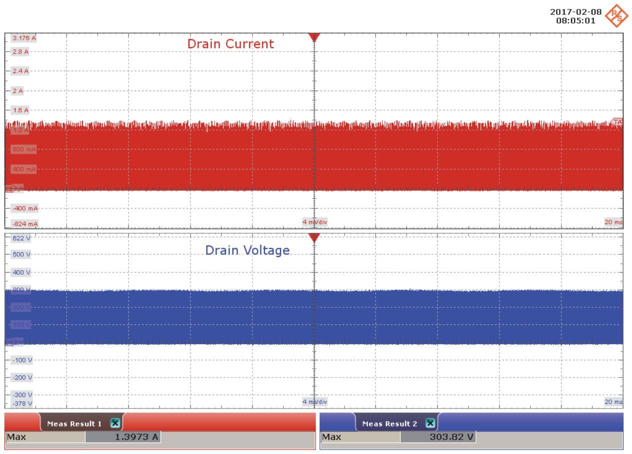

Figure 90 – 90 VAC, 30 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 ms / div.

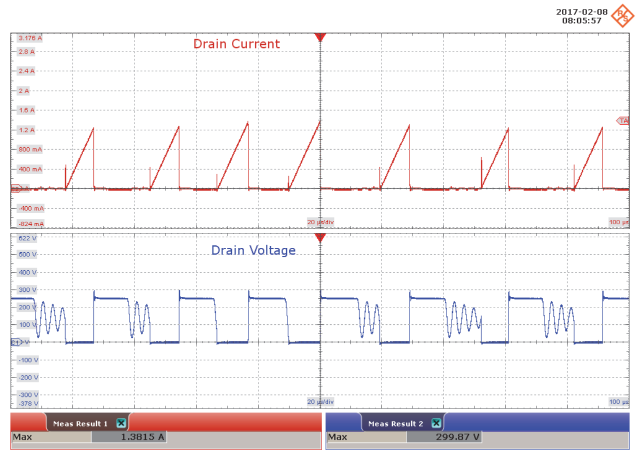

Figure 91 – 90 VAC, 30V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 µs / div.

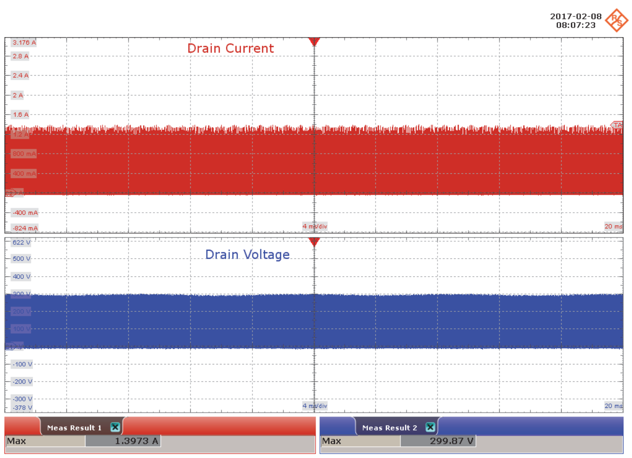

Figure 92 – 305 VAC, 30 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 ms / div.

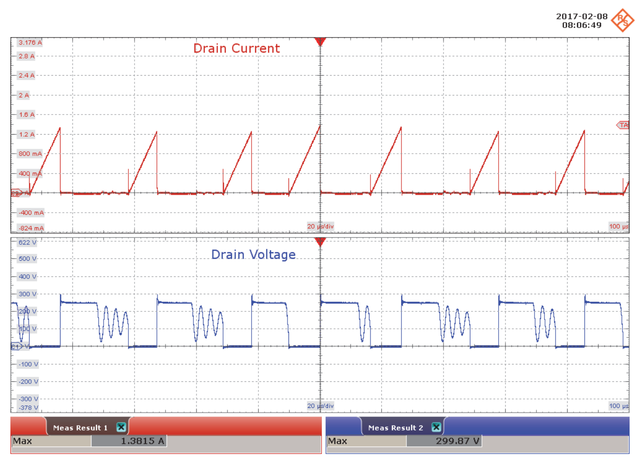

Figure 93 – 305 VAC, 30 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 µs / div.

14.9.2 E-Load at 960 mA CC Load

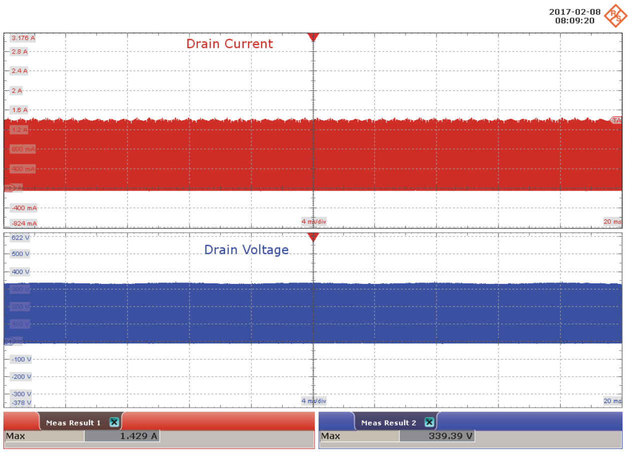

Figure 94 – 90 VAC, 0.96 A Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

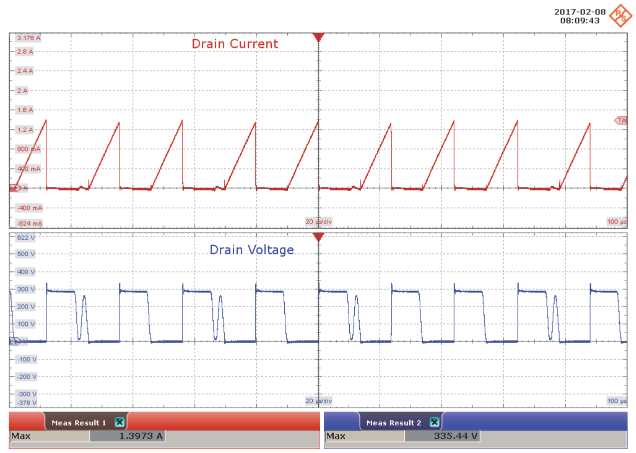

Figure 95 – 90 VAC, 0.96 A Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 μs / div.

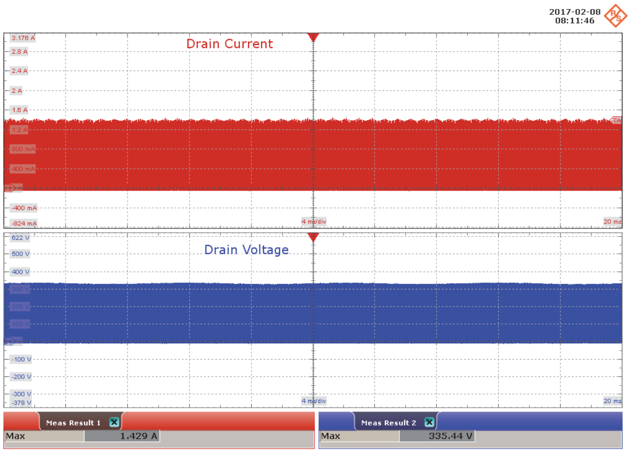

Figure 96 – 305 VAC, 0.96 A Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 4 ms / div.

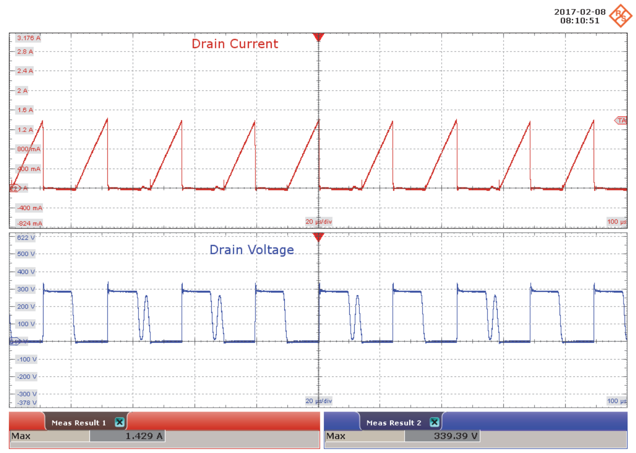

Figure 97 – 305 VAC, 0.96 A Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 μs / div.

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14.10 *LYTSwitch-6 (U4) Drain Voltage and Current at Start-up*

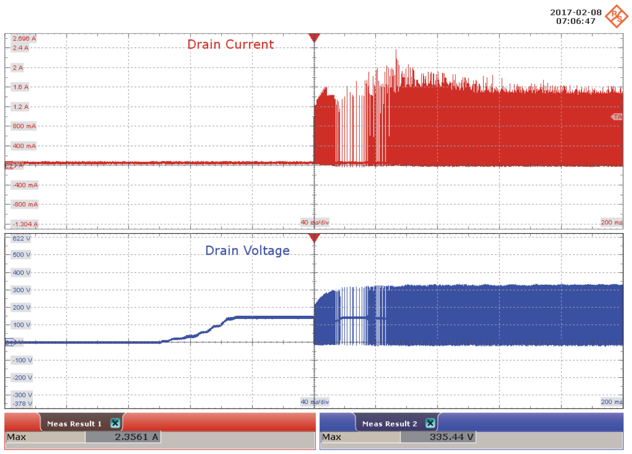

Figure 98 – 90 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 40 ms / div.

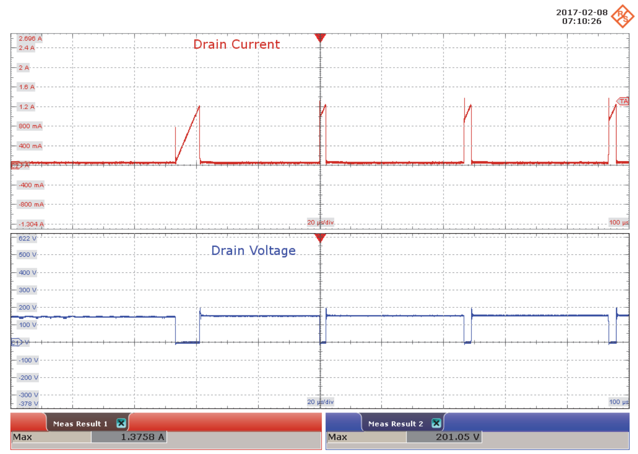

Figure 99 – 90 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 μs / div.

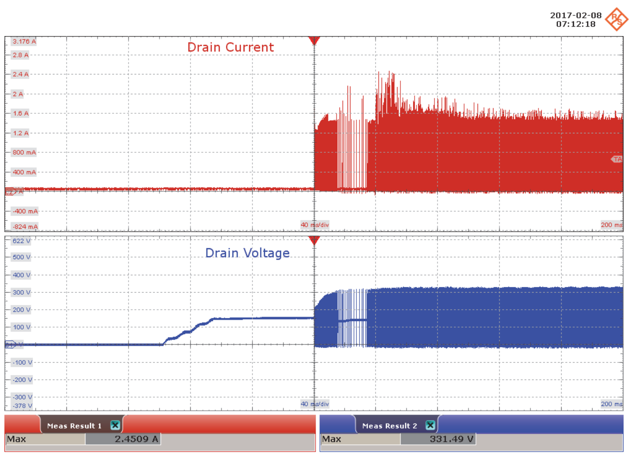

Figure 100 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 40 ms / div.

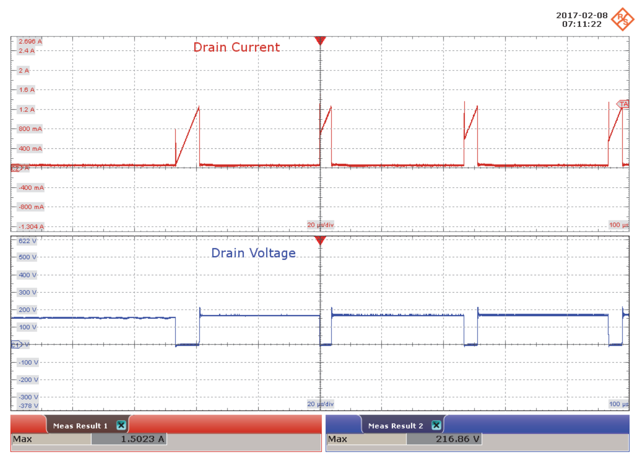

Figure 101 – 305 VAC, 42 V LED Load.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 100 V / div., 20 μs / div.

14.11 *LYTSwitch-6 (U4) Drain Voltage and Current during Output Short Circuit*

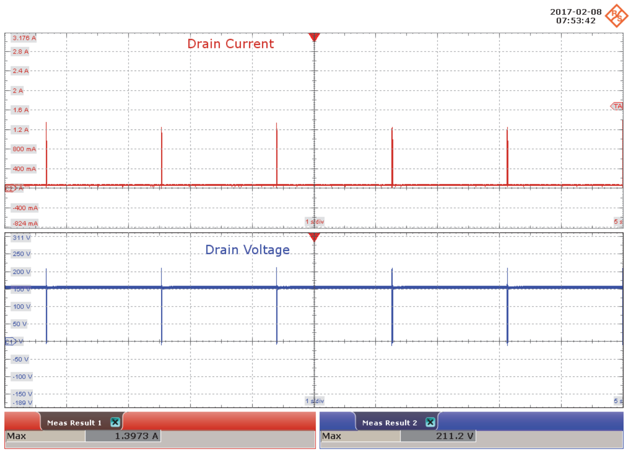

Figure 102 – 90 VAC, Output Shorted.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 s / div.

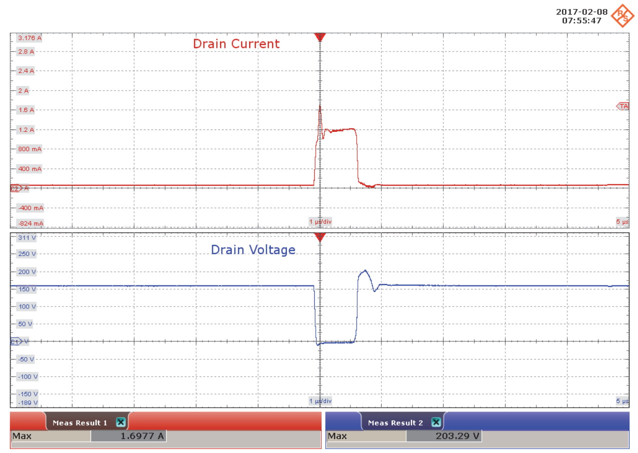

Figure 103 – 90 VAC, Output Shorted.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 μs / div.

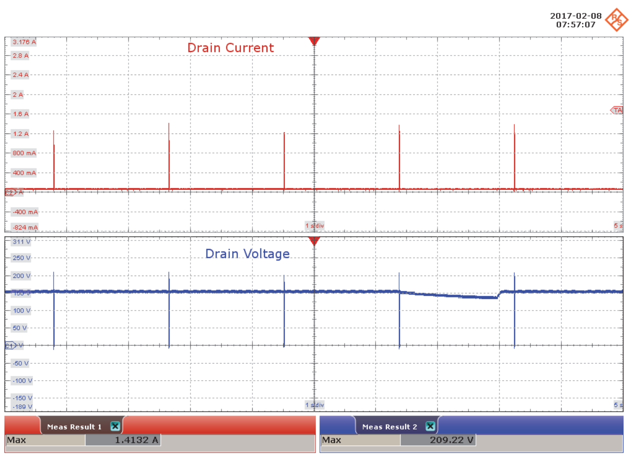

Figure 104 – 305 VAC, Output Shorted.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 s / div.

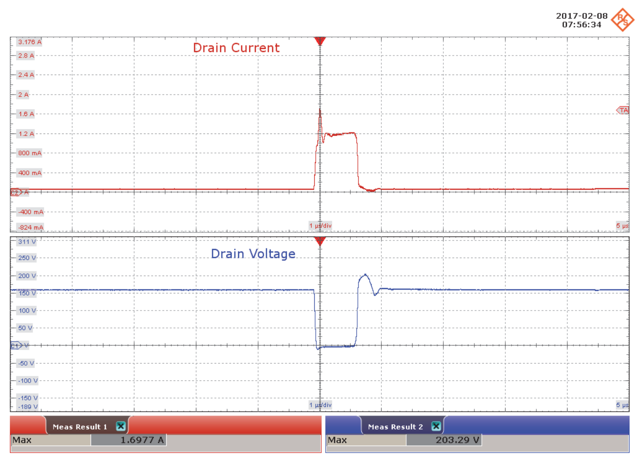

Figure 105 – 305 VAC, Output Shorted.
Upper: I_{DRAIN}, 400 mA / div.
Lower: V_{DRAIN}, 50 V / div., 1 μs / div.

14.12 *Input Power during Output Short Circuit*

Input		Input Measurement		
VAC (V_{RMS})	Freq (Hz)	V (V_{RMS})	I (mA_{RMS})	P (W)
90	60	89.94	25.29	0.764
120	60	120.00	24.39	0.735
230	50	229.99	21.28	0.604
277	50	277.01	19.91	0.644
300	50	299.96	19.28	0.658

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14.13 *Output Voltage and Current at Open Output LED Load*

Maximum measured no load output voltage is below the rated voltage of the output capacitor

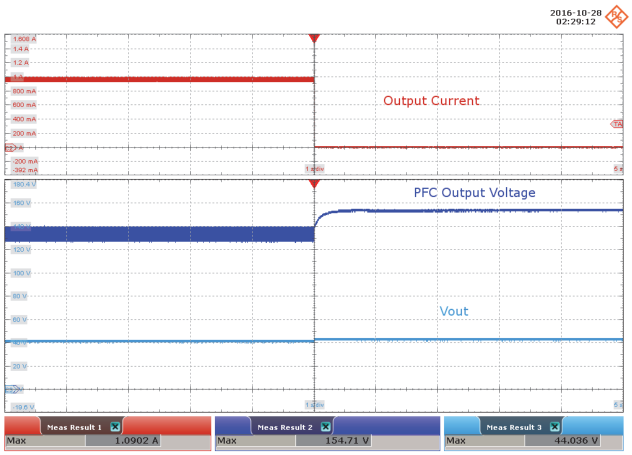

Figure 106 – 90 VAC, 42 V LED Load,
Running Open Load.
I_{OUT}, 200 mA / div.
V_{OUT}, 20 V / div., 1 s / div.
PFC V_{OUT}, 20 V / div.

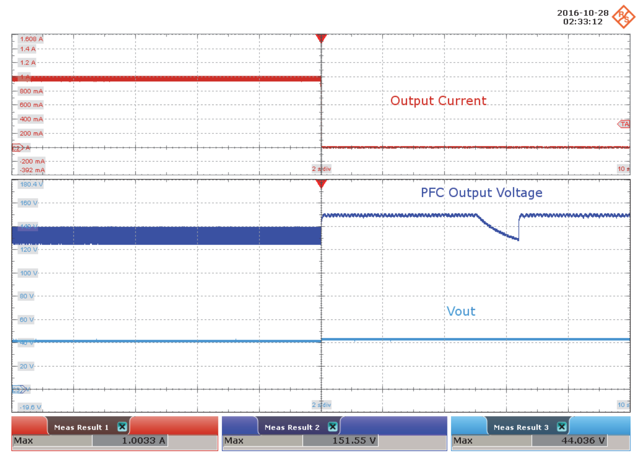

Figure 107 – 305 VAC, 42 V LED Load,
Running Open Load.
I_{OUT}, 200 mA / div.
V_{OUT}, 20 V / div., 2 s / div.
PFC V_{OUT}, 20 V / div.

14.14 *Output Voltage and Current – Start-up at Open Output Load*

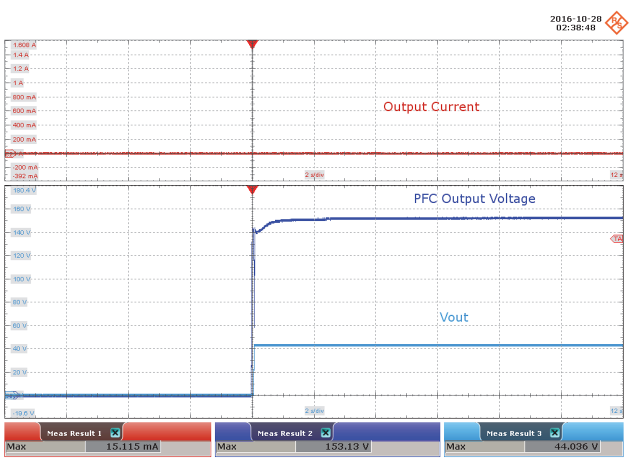

Figure 108 – 90 VAC, Open Load,
Open Load Start-up.
I_{OUT}, 200 mA / div.
V_{OUT}, 20 V / div., 2 s / div.
PFC V_{OUT}, 20 V / div.

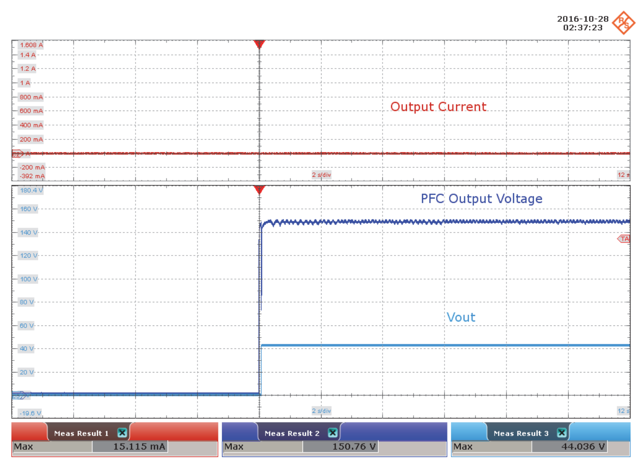

Figure 109 – 305 VAC, Open Load
Open Load Start-up.
Upper: I_{OUT}, 20 mA / div.
Lower: V_{OUT}, 20 V / div., 2 s / div.

14.15 *Output Ripple Current at Full load*

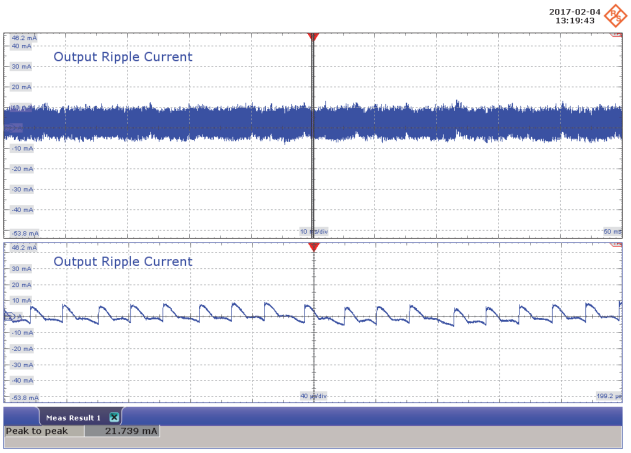

Figure 110 – 90 VAC, 60 Hz, 42 V LED Load.
Upper: I_{OUT}, 10 mA / div., 10 ms / div.

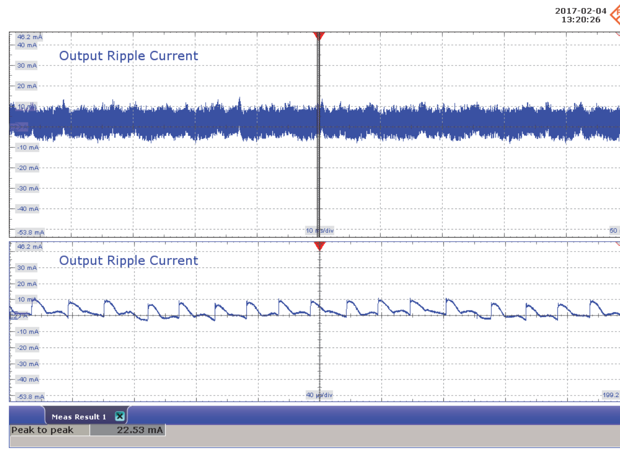

Figure 111 – 115 VAC, 60 Hz, 42 V LED Load.
Upper: I_{OUT}, 10 mA / div., 10 ms / div.

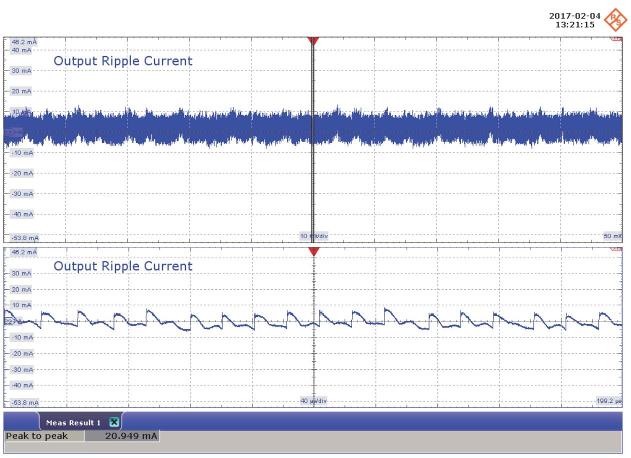

Figure 112 – 230 VAC, 50 Hz, 42 V LED Load.
Upper: I_{OUT}, 10 mA / div., 10 ms / div.

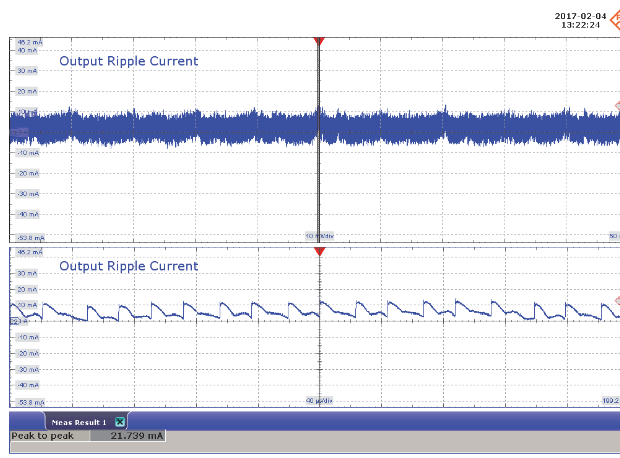

Figure 113 – 305 VAC, 50 Hz, 42 V LED Load.
Upper: I_{OUT}, 10 mA / div., 10 ms / div.

V_{IN} (VAC)	I_{PK-PK} (mA)	I_{MEAN} (mA)	% Ripple 100 x (I_{RP-P})/ (I_{OUT})	% Flicker 100 x (I_{RP-P})/ (2*I_{OUT})
90	21.74	960	2.26	1.13
115	22.53		2.35	1.17
230	21		2.19	1.09
305	22		2.29	1.15

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14.16 ***Output Ripple Current at 30 V LED Load***

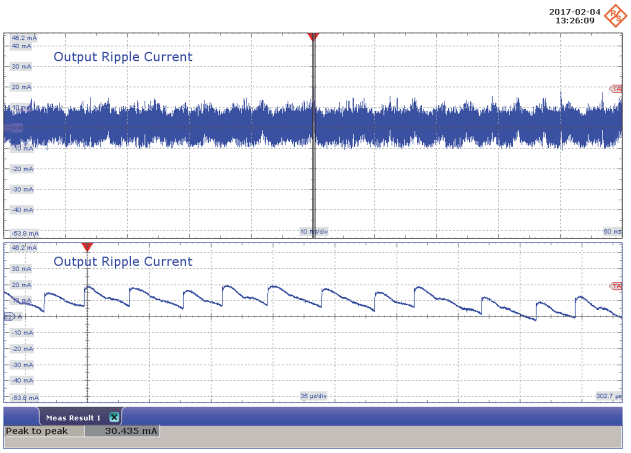

Figure 114 – 90 VAC, 50 Hz, 30 V LED Load.
Upper: I_{OUT}, 20 mA / div., 10 ms / div.

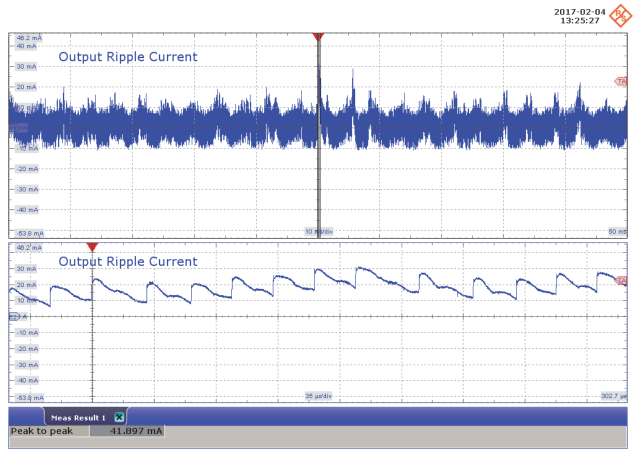

Figure 115 – 115 VAC, 50 Hz, 30 V LED Load.
Upper: I_{OUT}, 20 mA / div., 10 ms / div.

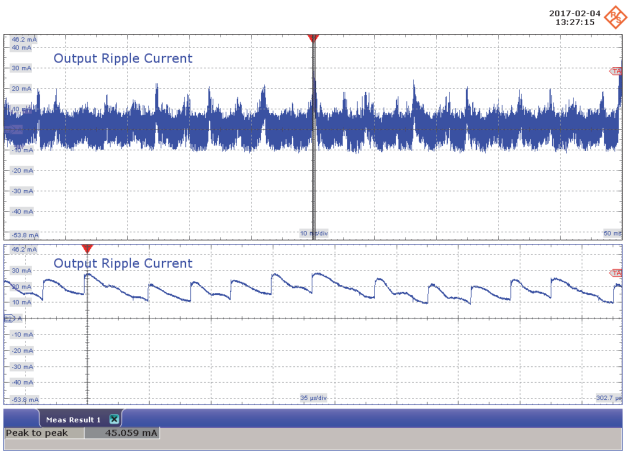

Figure 116 – 230 VAC, 50 Hz, 30 V LED Load.
Upper: I_{OUT}, 20 mA / div., 10 ms / div.

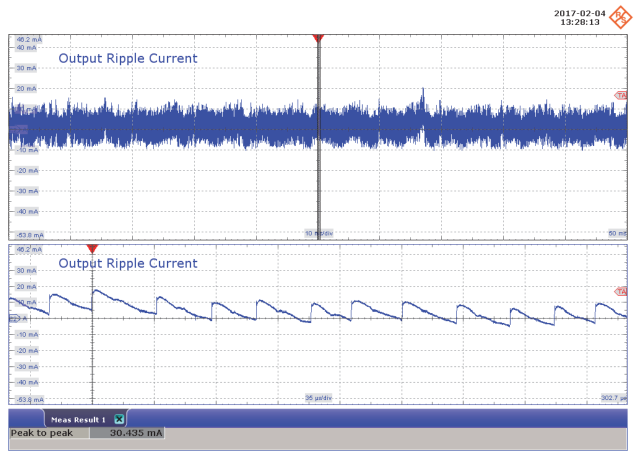

Figure 117 – 305 VAC, 50 Hz, 30 V LED Load.
Upper: I_{OUT}, 20 mA / div., 10 ms / div.

V_{IN} (VAC)	I_{P-P} (mA)	I_{MEAN} (mA)	% Ripple 100 x (I_{RP-P})/ (I_{OUT})	% Flicker 100 x (I_{RP-P})/ (2*I_{OUT})
90	30.4	960	3.17	1.58
115	42		4.38	2.19
230	45		4.69	2.34
305	31		3.23	1.61

15 AC Cycling Test at 42 V LED Load

No output current overshoot or undershoot was observed during on/off cycling.

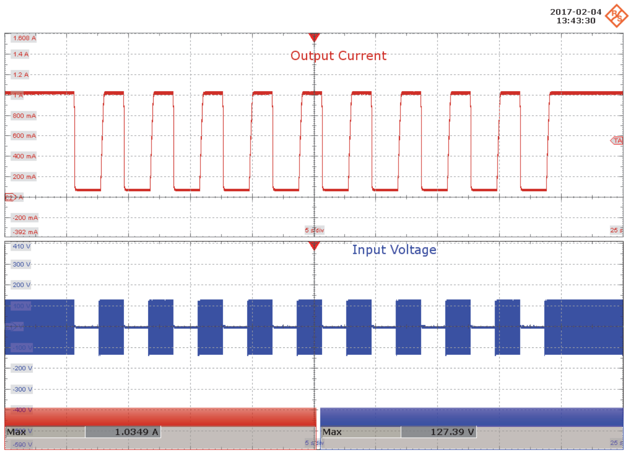

Figure 118 – 90 VAC, 42 V LED Load.
2 s On – 2 s Off.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 5 s / div.

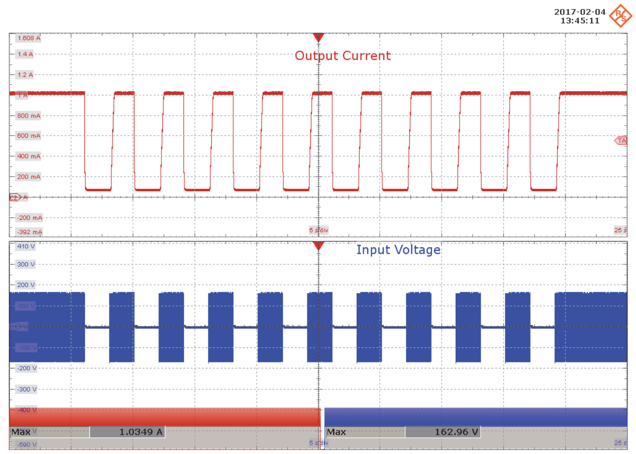

Figure 119 – 115 VAC, 42 V LED Load.
2 s On – 2 s Off.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 5 s / div.

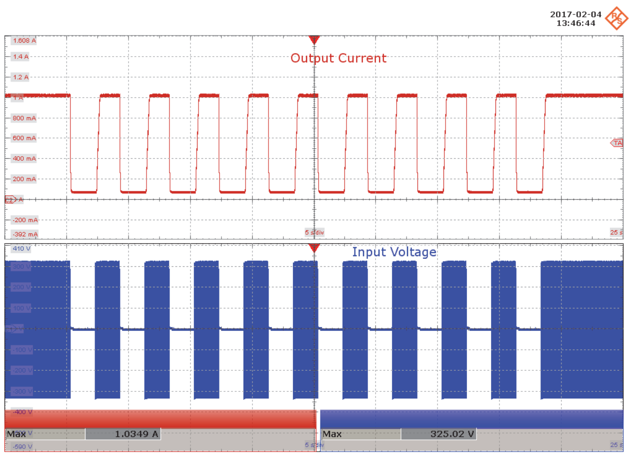

Figure 120 – 230 VAC, 42 V LED Load.
2 s On – 2 s Off.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 5 s / div.

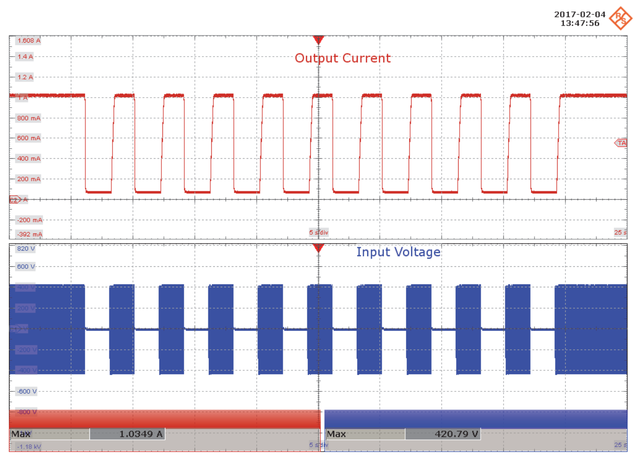

Figure 121 – 300 VAC, 42 V LED Load.
2 s On – 2 s Off.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 200 V / div., 5 s / div.

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16 AC Cycling Test at 30 V LED Load

No output current overshoot or undershoot was observed during on/off cycling.

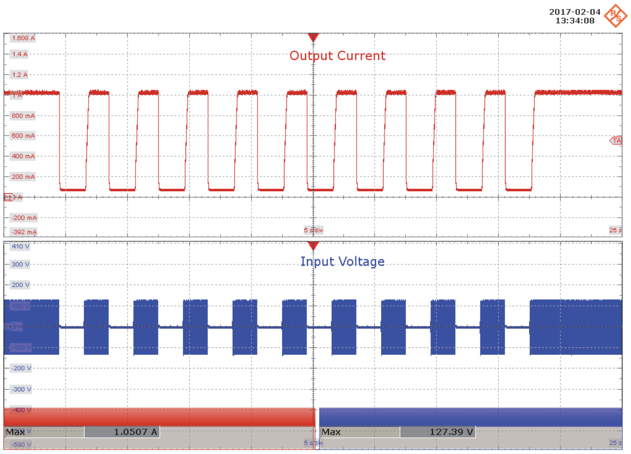

Figure 122 – 90 VAC, 30 V LED Load.
2 s On – 2 s Off.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 5 s / div.

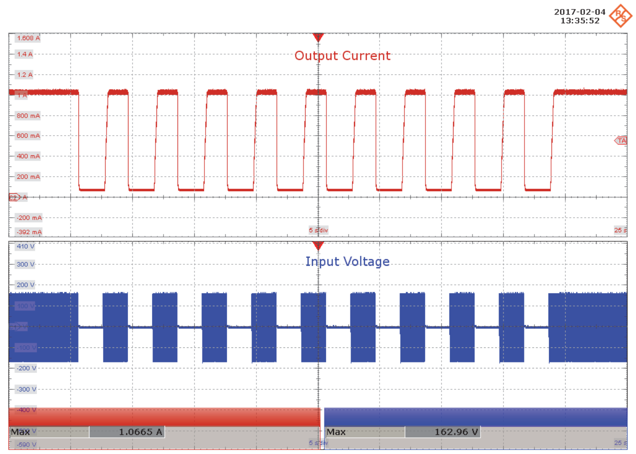

Figure 123 – 115 VAC, 30 V LED Load.
2 s On – 2 s Off.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 5 s / div.

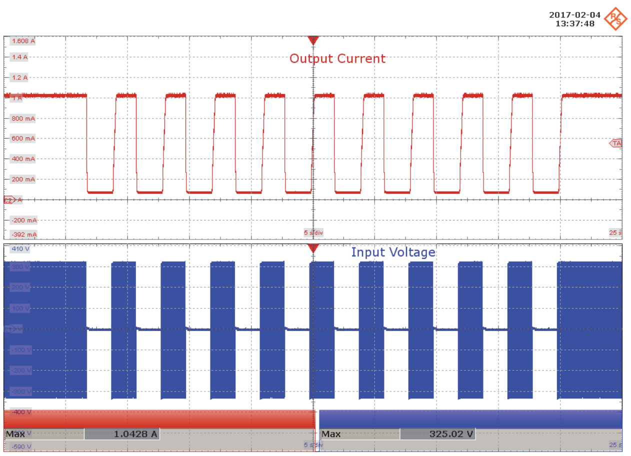

Figure 124 – 230 VAC, 30 V LED Load.
2 s On – 2 s Off.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 100 V / div., 5 s / div.

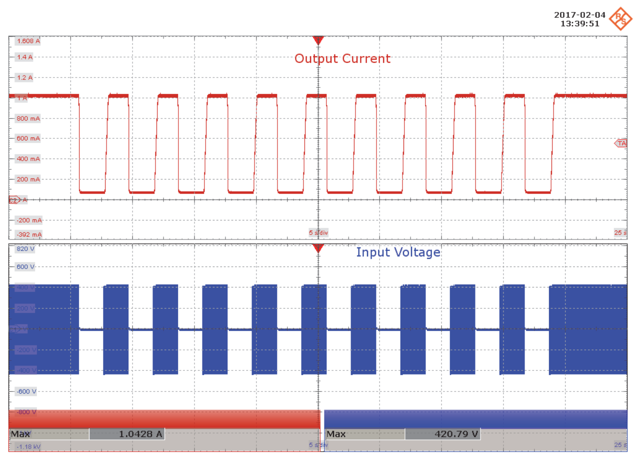

Figure 125 – 305 VAC, 30 V LED Load.
2 S On – 2 s Off.
Upper: I_{OUT}, 200 mA / div.
Lower: V_{IN}, 200 V / div., 5 s / div.

17 Conducted EMI

17.1 *Test Set-up 1*

LED metal heat sink is connected to ground. Unit with input ground wire connection is placed on top of LED metal heat sink. See below set-up picture.

17.2 *Equipment and Load Used*

1. Rohde and Schwarz ENV216 two line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Hioki 3322 power hitester.
4. Chroma measurement test fixture.
5. 42 V LED load with input voltage set at 230 VAC and 115 VAC.

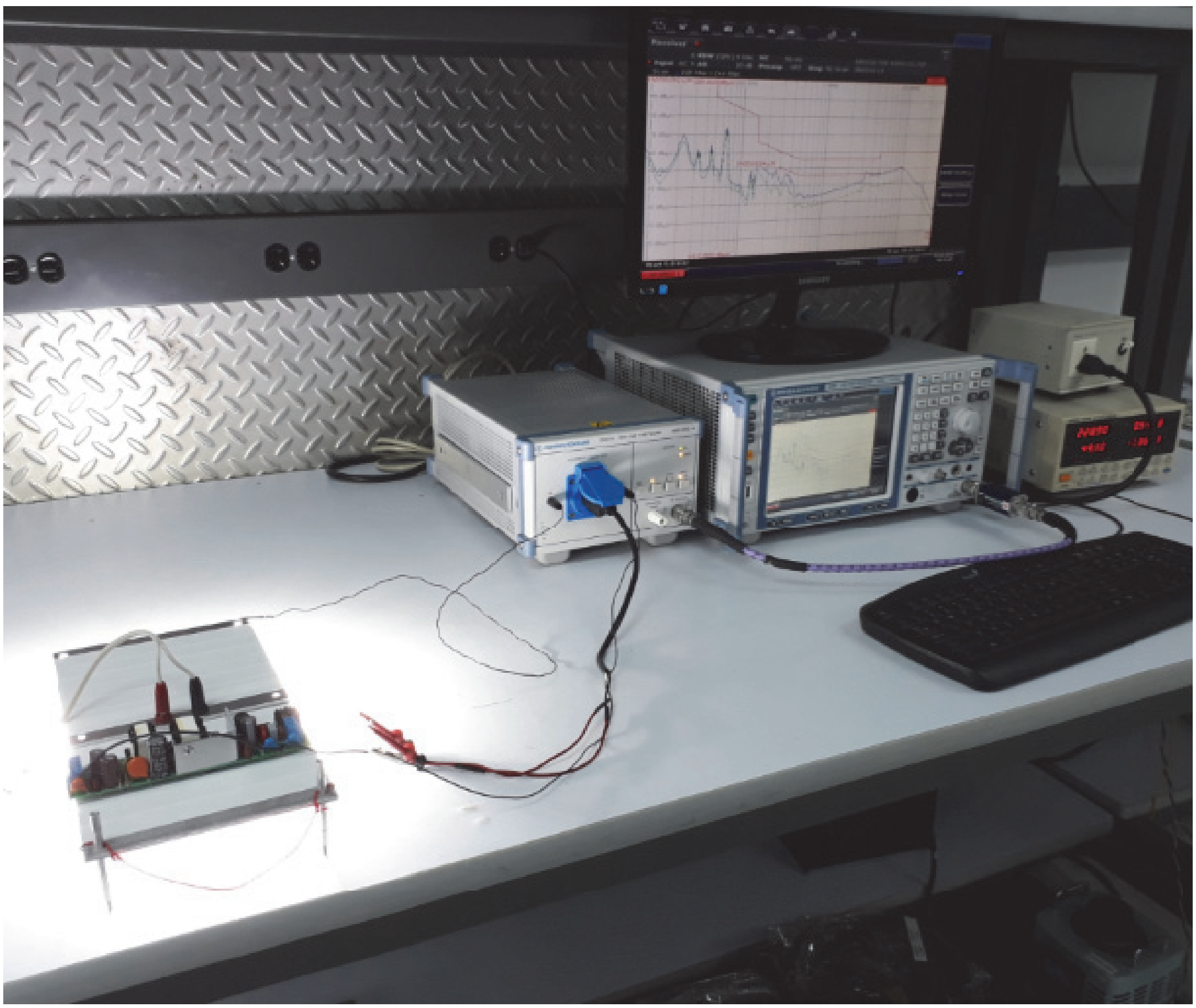

Figure 126 – Conducted EMI Test Set-up.

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17.2.1 EMI Test Results: Set-up 1

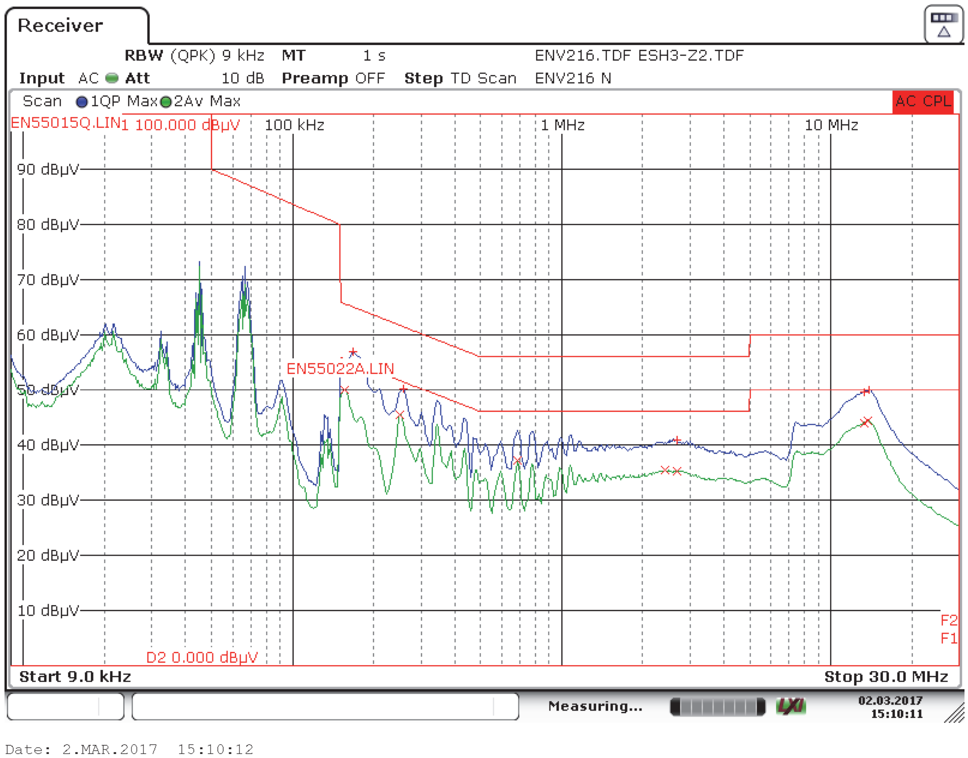

Figure 127 – Conducted EMI QP Scan at 42 V LED Load, 230 VAC, 50 Hz, and EN55015 B Limits.

Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
2 Average	156.7500 kHz	50.05 L1	-5.58 dB
2 Average	13.7220 MHz	44.28 L1	-5.72 dB
2 Average	13.3283 MHz	44.00 L1	-6.00 dB
2 Average	251.2500 kHz	45.42 L1	-6.30 dB
1 Quasi Peak	168.0000 kHz	56.92 N	-8.14 dB
2 Average	687.7500 kHz	37.10 L1	-8.90 dB
1 Quasi Peak	13.9043 MHz	49.93 L1	-10.07 dB
1 Quasi Peak	13.3125 MHz	49.56 L1	-10.44 dB
2 Average	2.4248 MHz	35.39 L1	-10.61 dB
2 Average	2.6925 MHz	35.28 N	-10.72 dB
1 Quasi Peak	258.0000 kHz	50.32 L1	-11.18 dB
1 Quasi Peak	2.6902 MHz	40.87 N	-15.13 dB

Figure 128 – Conducted EMI Data at 230 VAC, 42 V LED Load.

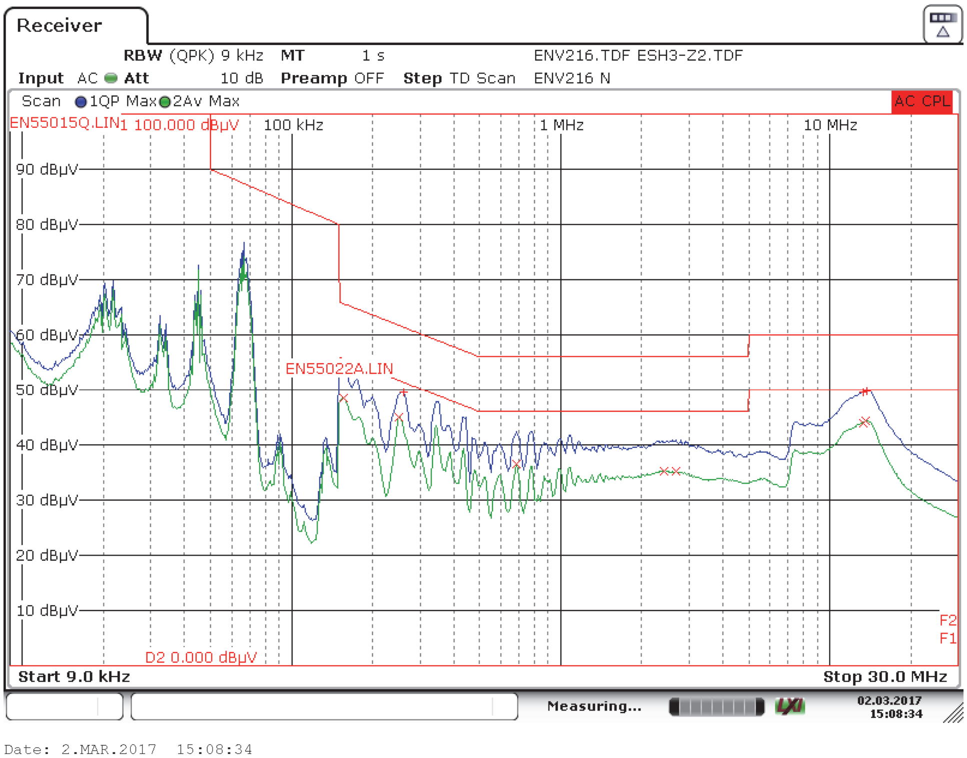

Figure 129 – Conducted EMI QP Scan at 42 V LED Load, 115 VAC, 60 Hz, and EN55015 B Limits.

Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
2 Average	13.6725 MHz	44.32 L1	-5.68 dB
2 Average	13.2675 MHz	44.00 L1	-6.00 dB
2 Average	251.2500 kHz	44.96 L1	-6.76 dB
2 Average	156.7500 kHz	48.40 L1	-7.23 dB
2 Average	687.7500 kHz	36.60 N	-9.40 dB
1 Quasi Peak	13.8098 MHz	49.87 L1	-10.13 dB
1 Quasi Peak	13.2675 MHz	49.61 L1	-10.39 dB
2 Average	2.4293 MHz	35.24 N	-10.76 dB
2 Average	2.6858 MHz	35.15 N	-10.85 dB
1 Quasi Peak	260.2500 kHz	49.56 L1	-11.86 dB
1 Quasi Peak	150.0000 kHz	53.63 L1	-12.37 dB

Figure 130 – Conducted EMI Data at 115 VAC, 42 V LED Load.

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17.3 ***EMI Test Set-up 2***

Unit is placed on top of the LED load chassis without earth ground connection.

17.3.1 Equipment and Load Used

6. Rohde and Schwarz ENV216 two line V-network.
7. Rohde and Schwarz ESRP EMI test receiver.
8. Hioki 3322 power hitester.
9. Chroma measurement test fixture.
10. 42 V LED load with input voltage set at 230 VAC and 115 VAC.

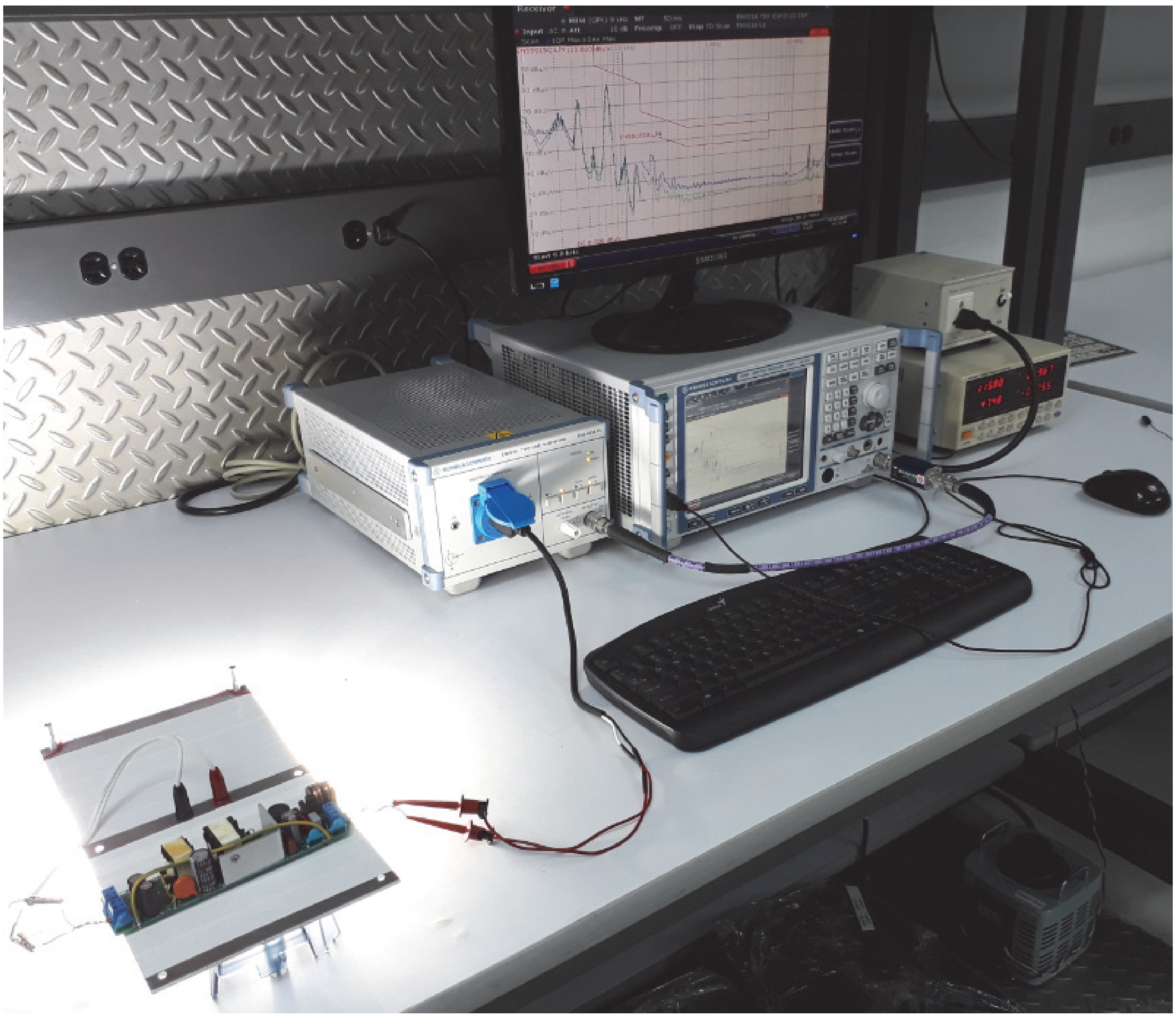

Figure 131 – Conducted EMI Test Set-up.

17.3.2 EMI Test Results: Set-up 2

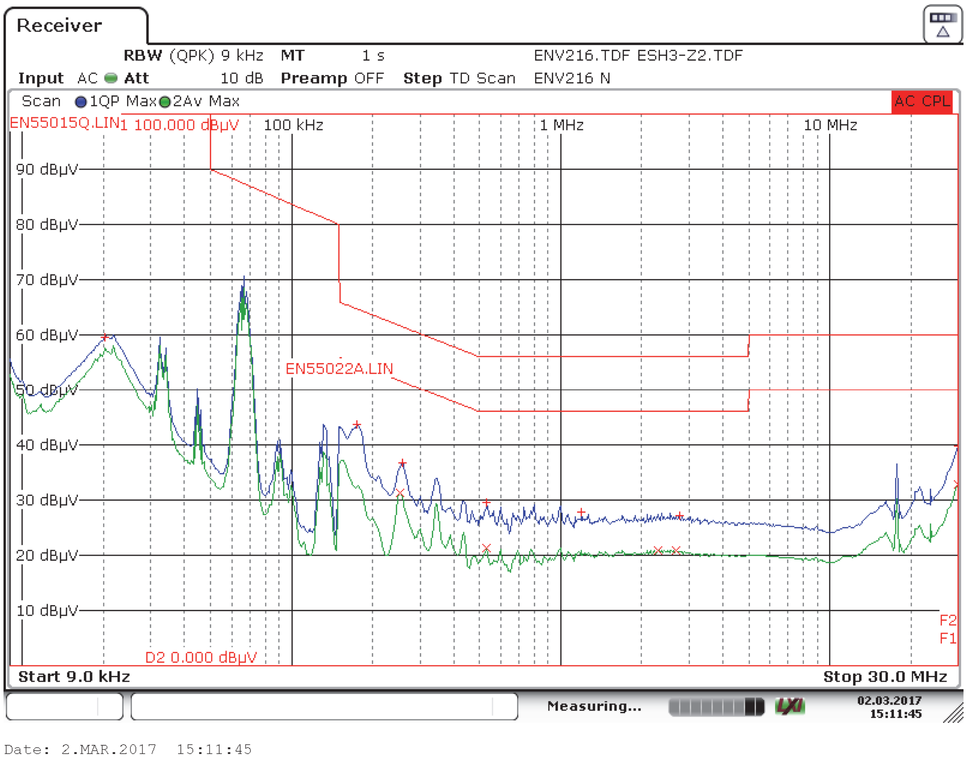

Figure 132 – Conducted EMI QP Scan at 42 V LED Load, 230 VAC, 50 Hz, and EN55015 B Limits.

Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
2 Average	30.0000 MHz	32.72 L1	-17.28 dB
1 Quasi Peak	30.0000 MHz	39.69 L1	-20.31 dB
2 Average	253.5000 kHz	31.33 L1	-20.31 dB
1 Quasi Peak	174.7500 kHz	43.74 L1	-20.99 dB
2 Average	532.5000 kHz	21.32 N	-24.68 dB
1 Quasi Peak	258.0000 kHz	36.76 L1	-24.74 dB
2 Average	2.2965 MHz	20.97 N	-25.03 dB
2 Average	2.6993 MHz	20.80 N	-25.20 dB
1 Quasi Peak	532.5000 kHz	29.51 N	-26.49 dB
1 Quasi Peak	1.1985 MHz	27.84 N	-28.16 dB
1 Quasi Peak	2.7622 MHz	27.09 N	-28.91 dB
1 Quasi Peak	20.2000 kHz	59.64 N	-50.36 dB

Figure 133 – Conducted EMI Data at 230 VAC, 42 V LED Load.

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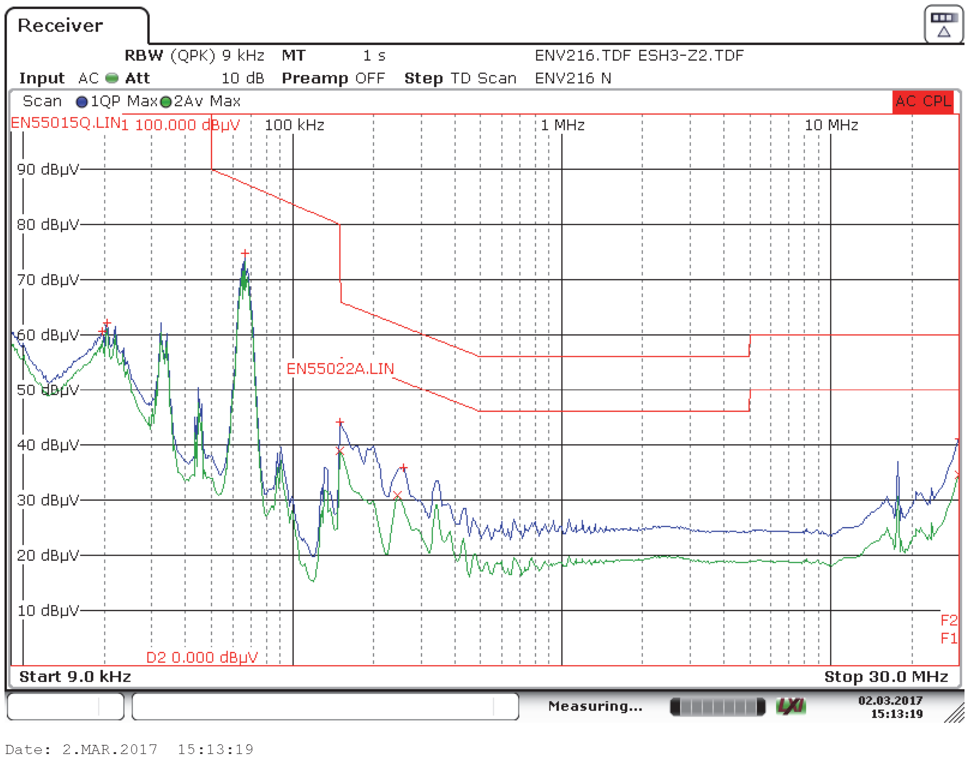

Figure 134 – Conducted EMI QP Scan at 42 V LED Load, 115 VAC, 60 Hz, and EN55015 B Limits.

Trace1: EN55015Q.LIN Trace2: EN55022A.LIN

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	66.6500 kHz	74.86 N	-12.52 dB
2 Average	29.9625 MHz	34.55 L1	-15.45 dB
2 Average	150.0000 kHz	38.86 L1	-17.14 dB
1 Quasi Peak	29.9940 MHz	41.17 L1	-18.83 dB
2 Average	246.7500 kHz	30.95 L1	-20.92 dB
1 Quasi Peak	150.0000 kHz	44.16 L1	-21.84 dB
1 Quasi Peak	258.0000 kHz	35.81 L1	-25.69 dB
1 Quasi Peak	20.4500 kHz	62.16 N	-47.84 dB
1 Quasi Peak	19.6500 kHz	60.65 L1	-49.35 dB

Figure 135 – Conducted EMI Data at 115 VAC, 42 V LED Load.

18 Line Surge

The unit was subjected to ±2500 V, 100 kHz ring wave and ±2000 V differential surge with 10 strikes at each condition. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

18.1 *Differential Surge Test Results*

Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2000	230	L to N	0	Pass
-2000	230	L to N	0	Pass
+2000	230	L to N	90	Pass
-2000	230	L to N	90	Pass

18.2 *Ring Wave Surge Test Results*

Surge Level (V)	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

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18.3 *2 kV Differential Surge Test*

The Drain voltage of PFC driver U1-LINK419EG was measured during 2 kV differential surge test.

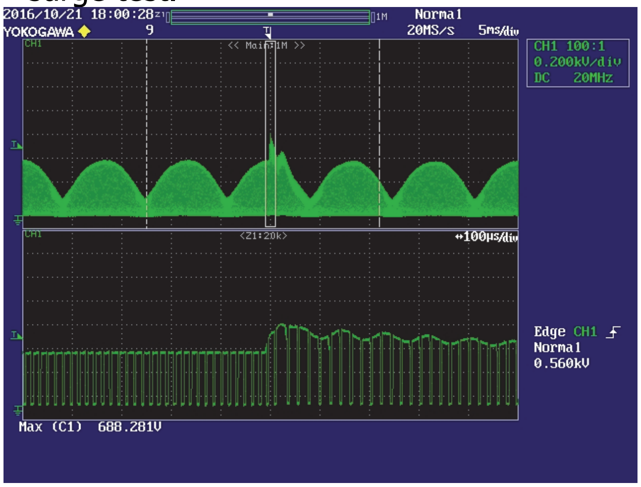

Figure 136 – (+)2 kV Differential Surge, 90º Phase Angle. Lower: V_{DRAIN}, 200 V / div., 5 ms / div. Peak V_{DRAIN}: 688.28 V.

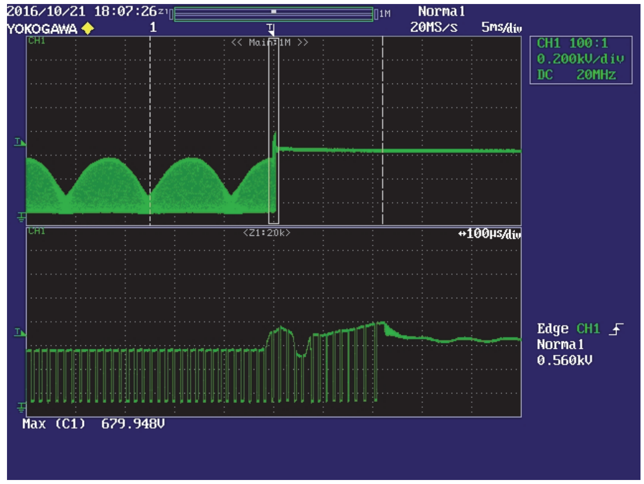

Figure 137 – (-)2 kV Differential Surge, 90º Phase Angle. Lower: V_{DRAIN}, 200 V / div., 5 ms / div. Peak V_{DRAIN}: 679.95 V.

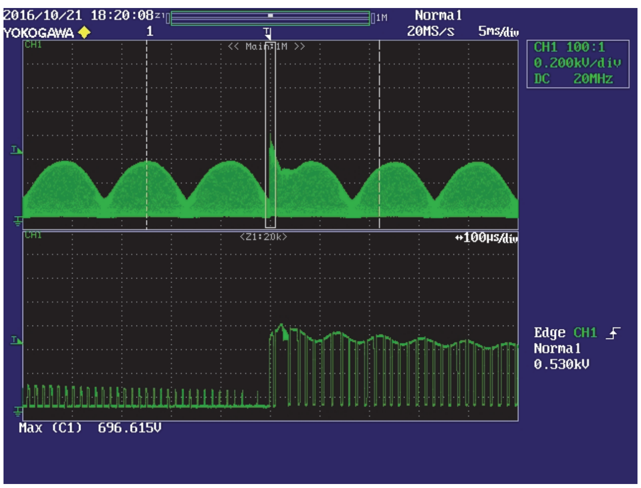

Figure 138 – (+)2 kV Differential Surge, 0º Phase Angle. Lower: V_{DRAIN}, 200 V / div., 5 ms / div. Peak V_{DRAIN}: 696.6 V.

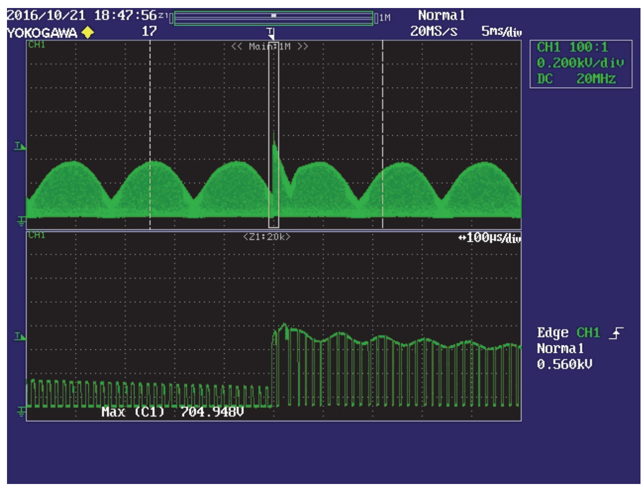

Figure 139 – (-)2 kV Differential Surge, 0º Phase Angle. Lower: V_{DRAIN}, 200 V / div., 5 ms / div. Peak V_{DRAIN}: 679.95 V.

18.4 ***2.5 kV Ring Wave Surge Test***

The Drain voltage of PFC driver U1-LINK419EG was measured during 2 kV ring wave surge test.

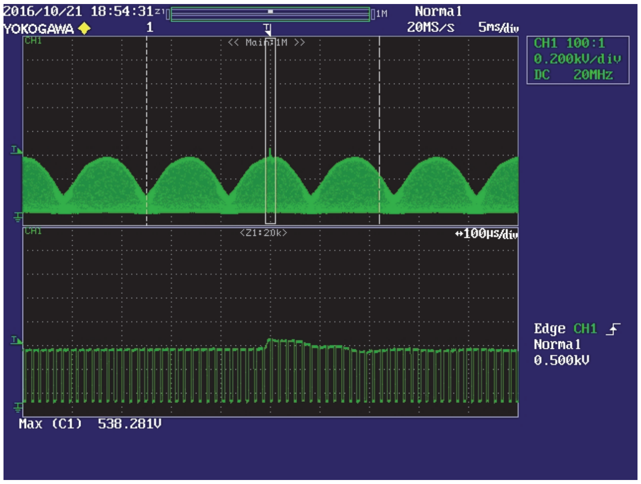

Figure 140 – (+) 2.5 kV Ring Wave Surge, 90º Phase Angle. Lower: V_{DRAIN}, 200 V / div., 5 ms / div. Peak V_{DRAIN}: 538.28 V.

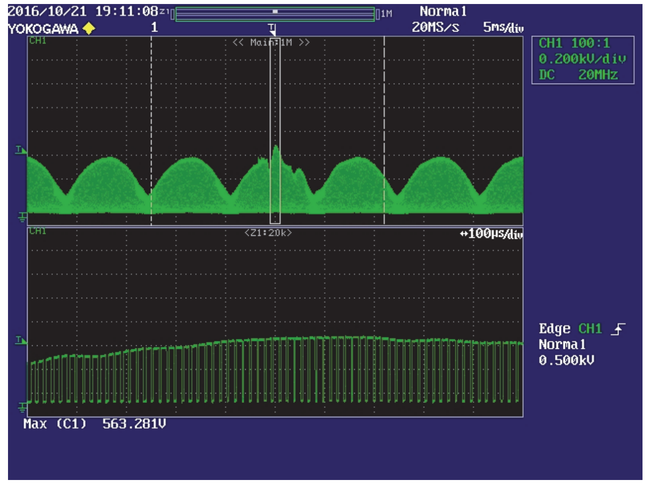

Figure 141 – (-) 2.5 kV Ringwave Surge, 90º Phase Angle. Lower: V_{DRAIN}, 200 V / div., 5 ms / div. Peak V_{DRAIN}: 563.28 V.

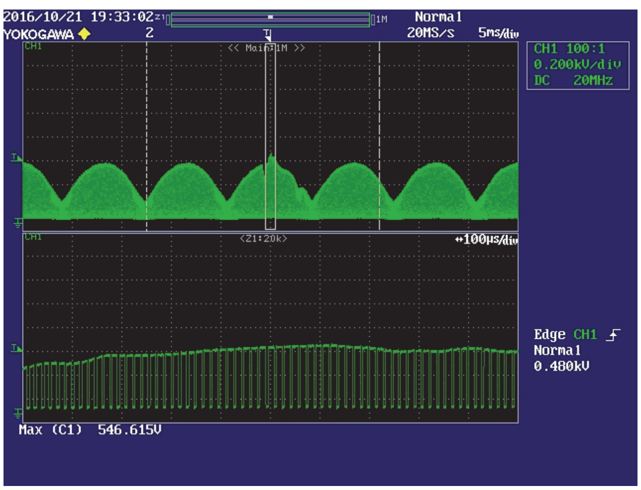

Figure 142 – (+) 2.5 kV Ring Wave Surge, 90º Phase Angle. Lower: V_{DRAIN}, 200 V / div., 5 ms / div. Peak V_{DRAIN}: 546.62 V.

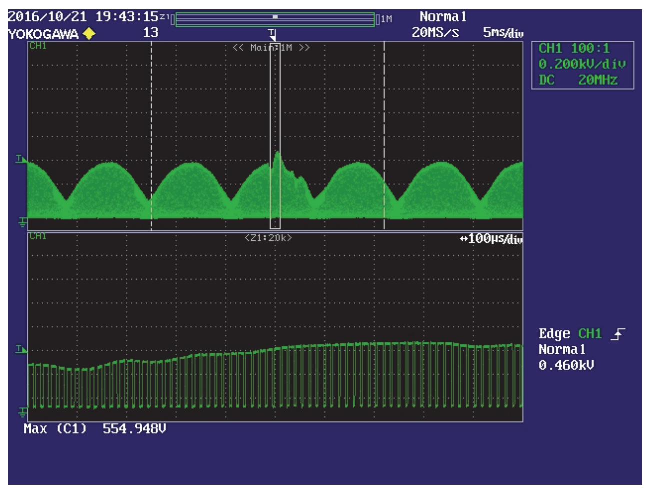

Figure 143 – (-) 2.5 kV Ringwave Surge, 90º Phase Angle. Lower: V_{DRAIN}, 200 V / div., 5 ms / div. Peak V_{DRAIN}: 554.9 V.

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19 Brown-in/Brown-out Test

No abnormal overheating, current overshoot/undershoot was observed during and after 0.5 V / s and 1 V / s brown in and brown out test.

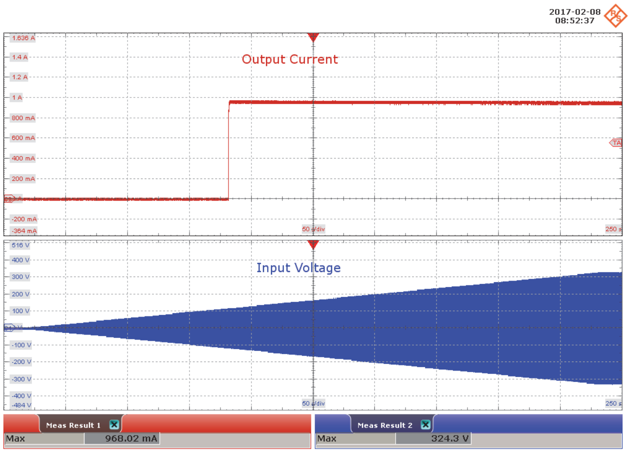

Figure 144 – Brown-in Test at 0.5 V / s.
Ch1: I_{OUT}, 200 mA / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

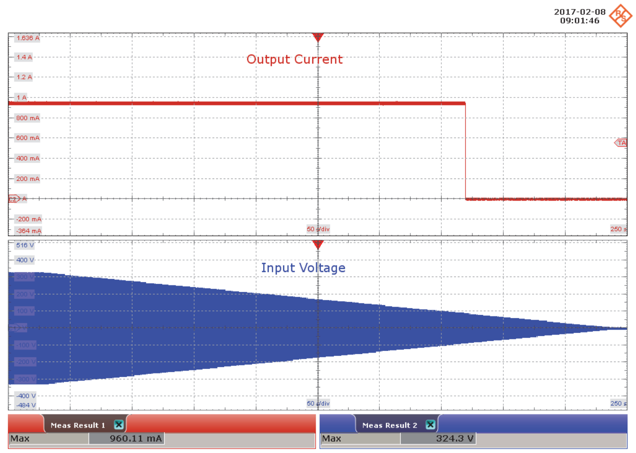

Figure 145 – Brown-out Test at 0.5 V / s
Ch1: I_{OUT}, 200 mA / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

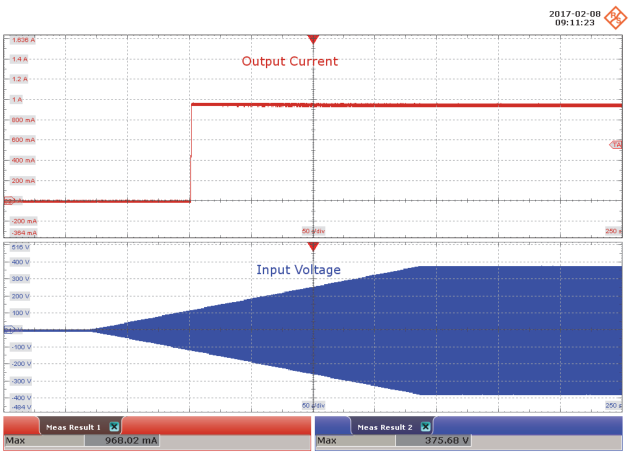

Figure 146 – Brown-in Test at 1 V / s.
Ch1: I_{OUT}, 200 mA / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

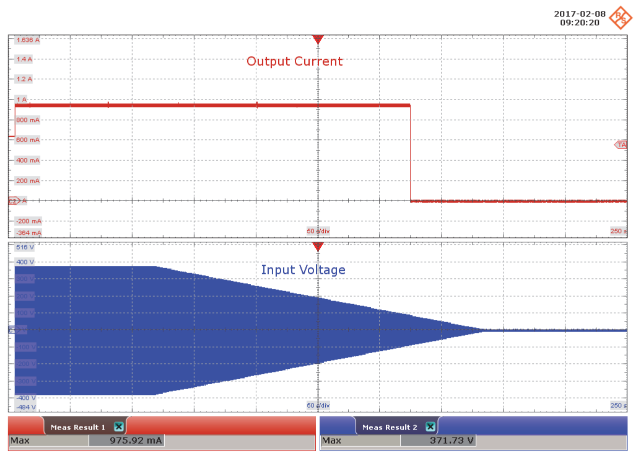

Figure 147 – Brown-out Test at 1 V / s.
Ch1: I_{OUT}, 200 mA / div.
Ch2: V_{IN}, 100 V / div.
Time Scale: 50 s / div.

20 Revision History

Date	Author	Revision	Description and Changes	Reviewed
05-Feb-18	MGM	1.0	Initial Release.	Apps & Mktg
16-Feb-18	MCE	1.1	Minor Edits. Updated PCB Images.	Apps & Mktg

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