Design Example Report

Title	**40 W, 36 V Dimmable Flicker-Free Isolated Flyback LED Driver with Switched Valley-Fill PFC Using TinySwitch-5 (TNY5075E)**
Specification	120 – 277 VAC Input; 36 V / 1.12 A Output
Application	LED Driver
Author	Applications Engineering Department
Document Number	DER-1102
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Revision	A

Summary and Features

- > 87% full load efficiency at 230 VAC
- < 10% full load THD at 230 VAC
- > 0.92 power factor from 120 V – 277 VAC
- < 4% flicker
- 36 V – 25 V constant current output range
- 3-in-1 Dimmable (0-10 V, 10 V PWM, Resistor)
- Slim form factor: 134 mm (L) × 38 mm (W) × 15 mm (H)
- Comprehensive protection features:
    - Output short circuit, overload and overvoltage
    - Over temperature (OTP)
    - Line undervoltage and overvoltage
- Meets 2 kV combination wave differential mode surge

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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.

1 Introduction

This engineering report describes a 40 W 3-in-1 dimmable isolated CVCC flyback LED driver that employs the TinySwitch™-5 integrated switcher IC in combination with a cost-effective switched valley-fill PFC circuit to achieve high power factor and flicker-free operation.

The integration of the switched valley-fill PFC topology with the TinySwitch-5 variable-frequency, variable-current control algorithm delivers near-unity power factor without the use of an active PFC stage.

The power supply delivers constant voltage and dimmable constant-current down to 1% for LED loads in the 25 V to 36 V LED voltage range and supports an extended wide-range input voltage of 120 VAC to 277 VAC. The design is optimized for high efficiency, high power factor, low total harmonic distortion (THD), and low flicker.

This document includes the power supply specification, schematic, bill of materials, transformer documentation, printed circuit board layout, and performance data.

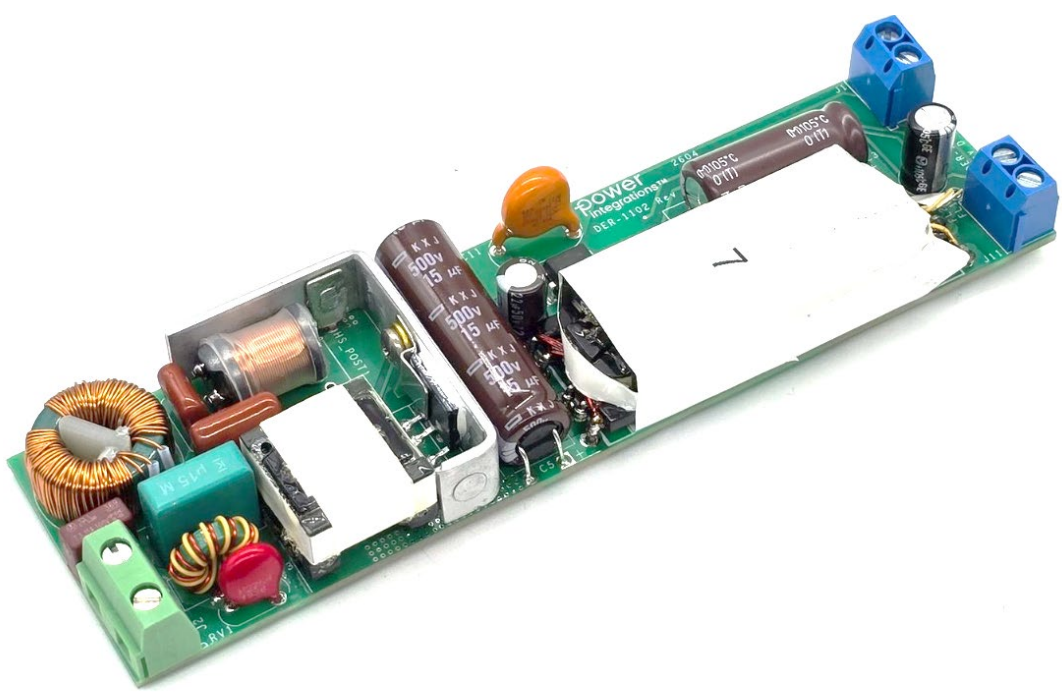


Figure 1 – Populated Circuit Board.

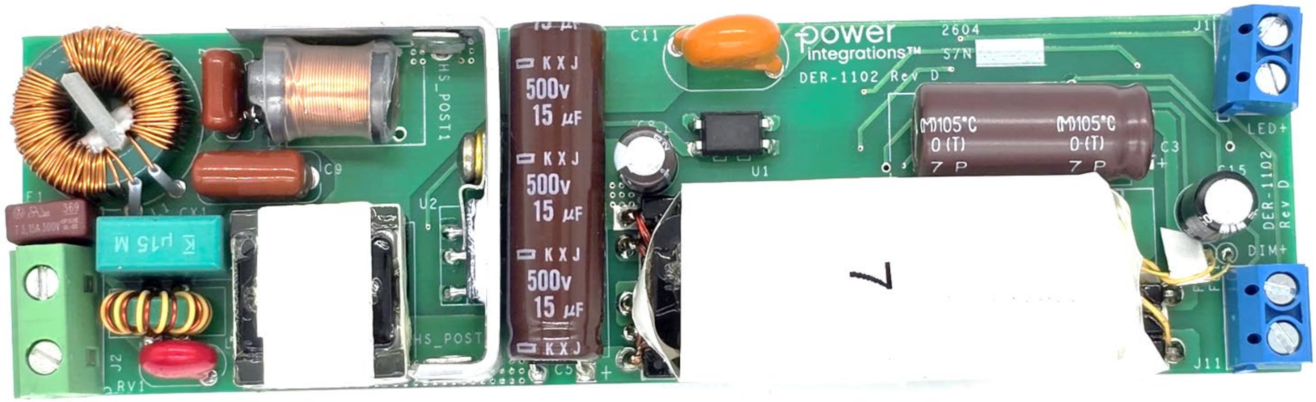


Figure 2 – Populated Circuit Board, Top Side.

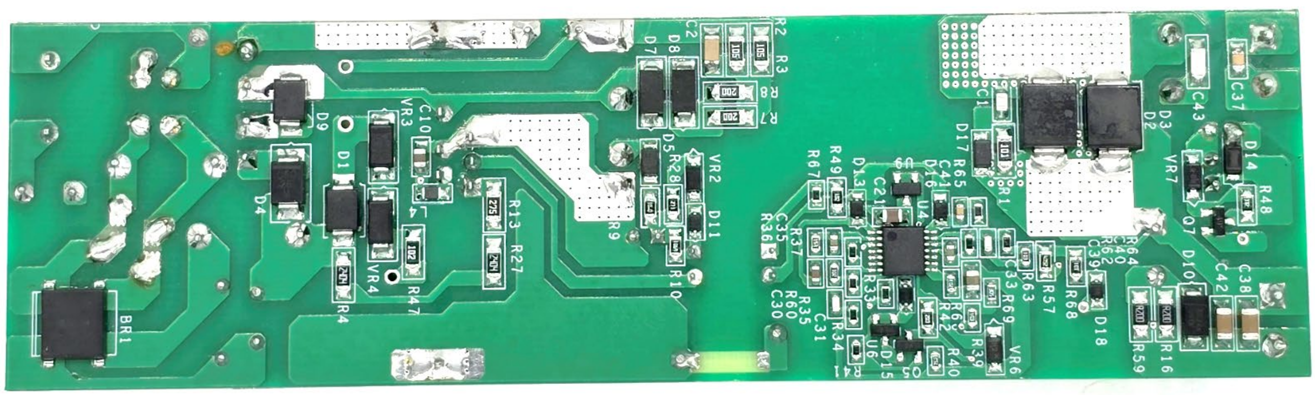


Figure 3 – Populated Circuit Board, Bottom Side.

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	**V_{IN}**	120		277	VAC	2 wire – no P.E.
Frequency	**f_{LINE}**	47	50/60	63	Hz	
Power Factor	**PF**	0.94				@ 230 VAC, 25-36 V LED, 1.12 A
Total Harmonic Distortion	**THD**			10	%	@ 230 VAC full load, 36 V LED
Output						
Output Voltage (CV)	**V_{OUT}**		36.5		V	±5%
Constant Current Region	**V_{LED}**	25		36	V	
Output Current	**I_{LED}**		1.12		A	±5%
Output Power	**P_{OUT}**		40		W	
Output Ripple Current	**I_{RIPPLE}**			100	mA	Peak to peak
Output Current Flicker				5	%	@ 25 – 35 V LED string
Output Ripple Voltage (CV)	**V_{Ripple}**			300	mV	Peak to peak
Efficiency						
Full Load	**$\eta_{230\ VAC}$**	87			%	Measured at output terminal, 36 V LED
Environmental						
Conducted EMI		CISPR22B / EN55022B				36 V LED load, floating
Combination Wave Surge (L/N)				±2	kV	Source impedance: 2 Ω
Ring Wave (L/N & L,N/PE)				±2.5	kV	Source impedance: 12 Ω
Ambient Temperature	**T_{AMB}**	0		55	°C	Free convection, sea level

Table 1 – Power Supply Specification.

3 Schematic

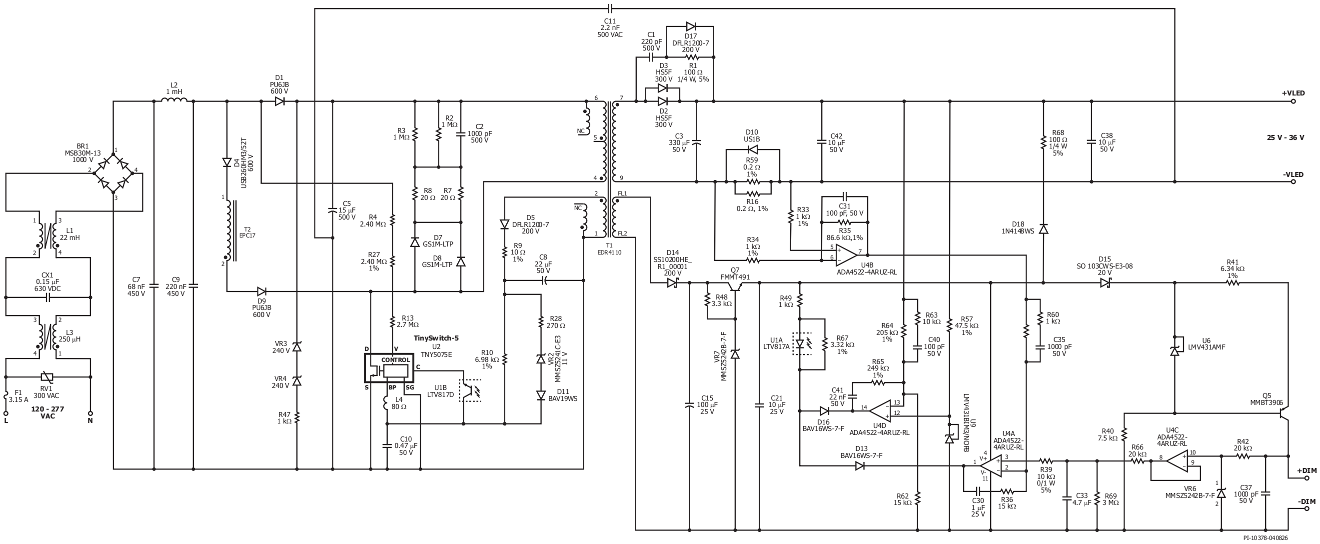


Figure 4 – Schematic.

4 Circuit Description

4.1 Input Rectification and EMI Filtering

Fuse F1 isolates the PSU circuitry and provides protection against component failures. RV1 protects the circuit from high-voltage surge events. The common-mode choke (CMC) L1, together with X-capacitor CX1, attenuates both common-mode and differential-mode noise in the <1 MHz conducted EMI frequency band. L1 also provides input current filtering to improve power factor and reduce THD. The common-mode choke L3 provides additional common-mode noise attenuation in the >1 MHz conducted EMI frequency band.

Bridge diode BR1 provides full-wave AC rectification. C7, L2, and C9 form a pi-filter that attenuates differential-mode noise caused by the flyback switching action. The capacitance and inductance values of these components are optimized to achieve high power factor and low THD while maintaining compliance with conducted EMI limits. Additionally, the TinySwitch-5 frequency jitter feature reduces conducted EMI.

4.2 Switched Valley-Fill PFC Circuit

The switched valley-fill (SVF) PFC circuit is a cost effective, passive-assisted power factor correction topology designed to improve input power factor and reduce THD. The input stage consists of low-capacitance film capacitors C7 and C9 together with differential choke L2 to form a pi-filter. The SVF network consists of blocking diodes D4 and D9 with the series inductor T2 placed between them. Diode D4 connects the SVF path to the film capacitor C9, while diode D9 connects the path to the primary MOSFET drain. Both the flyback transformer (T1) and the SVF inductor (T2) are designed to operate in discontinuous conduction mode (DCM), enabling improved input current shaping which enhances power factor.

At start-up, the rectified input voltage across capacitors C7 and C9 initially charges the bulk capacitor C5 through diode D1, providing the start-up supply for the TinySwitch-5 flyback controller via a tap on the drain pin of U2. Once switching begins, the SVF inductor (T2) and the flyback transformer (T1) magnetizing inductance are energized when the primary switching MOSFET in U2 turns on. The SVF inductor is charged directly from the rectified AC input via film capacitors C7 and C9. The flyback magnetizing inductance is energized from charge on the bulk capacitor C5. During this interval, the MOSFET drain current is the sum of the currents flowing through the SVF inductor and the flyback transformer.

When the MOSFET turns off, the energy stored in the SVF inductor is released by driving current in the reverse direction through the primary winding, transferring energy to the bulk capacitor C5. At the same time, the energy stored in the flyback transformer magnetizing inductance is delivered to the load through the secondary winding by flyback action. Because not all the SVF inductor energy is transferred directly to the load, the excess energy charges the bulk capacitor C5, raising its voltage above the rectified voltage across C9. Diode D1 prevents this elevated bulk voltage from feeding back into C7 and C9, maintaining proper current shaping and power factor performance.

The input current supplying the power supply flows through T2, with its peak current proportional to the rectified AC input voltage across C9 and the inductance value of T2. This interaction produces an input current that closely follows the input voltage waveform, resulting in near-sinusoidal current, high-power factor, and low THD.

4.3 Flyback Converter Circuit Using TinySwitch-5

The line undervoltage and overvoltage thresholds are established by the current injected into the V pin through the line-sense resistors R4, R13, and R27. These resistors are connected to film capacitor C9 to accurately sense the peak rectified AC input voltage. The primary RCD snubber, formed by D7, D8, R2, R3, R7, R8, and C2, minimizes the primary drain voltage spike induced by the energy built up in the transformer's leakage inductance commutating when the power switch turns off.

The TinySwitch-5 IC is self-powered at start-up through an internal high-voltage current source connected to the Drain of the integrated power switch, which supplies current to the internal primary bypass regulator to charge the BYPASS pin capacitor (C10) when AC input is first applied. A ferrite bead (L4) is added in series with the drain to improve noise immunity from events such as ring wave or EFT. During normal operation, the controller is powered from the bias winding of transformer T1. The bias winding output is rectified by diode D5 and filtered by R9 and C8. Resistor R10 limits the current supplied to the BYPASS pin of the TinySwitch-5 IC (U2), disabling the internal high-voltage current source once sufficient bias voltage is established.

Primary-side sensed overvoltage protection (OVP) is implemented using Zener diode VR2, current-limiting resistor R28, and blocking diode D11 connected from the bias supply to the BYPASS pin. If an output overvoltage occurs, the increased bias winding voltage causes VR2 to conduct, injecting additional current into the BYPASS pin. When this current exceeds the shutdown threshold (ISD), the TinySwitch-5 stops switching and enters auto-restart mode where it remains until the output voltage returns to within regulation.

During the primary switch off time, rectifier diodes D2 and D3 conduct the transformer flyback current from the secondary winding, delivering energy to the output. Output capacitor C3 filters the rectified waveform to produce a stable DC voltage, while capacitors C38 and C42 further attenuate high-frequency ripple.

The RC snubber network, composed of C1 and R1, limits voltage stress across D2 and D3, suppresses high-frequency ringing, and improves both conducted and radiated EMI performance. Diode D7 provides a discharge path for the snubber capacitor, thereby reducing power dissipation in R1 during snubber operation.

Diode D10 protects the current-sense resistors R59 and R16 from excessive inrush current during output short-circuit conditions. Components D18 and R68 prevent output overcurrent during an output short circuit by discharging the bias.

4.4 Secondary Feedback Circuit

The feedback circuit is powered by the dedicated secondary bias supply. Freewheeling diode D14 rectifies the voltage from the auxiliary bias winding during the primary MOSFET's on-time, producing a pulsating DC waveform. This rectified voltage is then smoothed by capacitor C15, which filters the ripple and provides a stable DC rail for downstream circuitry. A linear regulator formed by transistor Q7, Zener diode VR7, resistor R48, and smoothing capacitor C21 further conditions this rail, producing a regulated 11.3 V supply that feeds the secondary-side control components. This regulated bias voltage ensures stable operating conditions for the feedback comparators, references, and the optocoupler drive circuitry, resulting in accurate output-voltage and LED-current sensing across load and line.

Optocoupler U1 provides the isolated feedback path that delivers the regulation signal to the primary-side control IC. The current flowing through the optocoupler's LED (U1A) is limited by resistor R49, which protects the diode and sets the maximum feedback drive strength. OR-ing diodes D16 and D13 isolate the CV and CC comparator outputs from each other, ensuring that only the dominant loop—either constant-voltage protection or constant-current regulation controls the optocoupler. This prevents loop interaction and guarantees clean, non-interfering transitions between CV and CC modes.

The constant-voltage regulation loop is controlled by comparator U4D, which monitors the output voltage through the divider formed by R62 and R69 and compares the scaled voltage to the 2.5 V reference generated by the shunt regulator U9, with R57 providing the required bias and current limiting for the reference. Capacitor C39 filters the reference node to ensure a stable and noise-free comparison. The RC network composed of R63 and C40 introduces a phase-boost that improves loop stability and reduces output ripple during constant-voltage mode operation. To prevent oscillation and suppress voltage overshoot during input and load transients, the compensation network formed by C41 and R65 was added to slow the response of comparator U4D. Additionally, resistor R67 limits the surge current through the optocoupler diode in U1A during full-load cold-start conditions while the system is operating in CV mode, preventing overstressing the optocoupler and avoiding partial-power delivery during startup.

Constant-current regulation is controlled by comparator U4A. The reference voltage applied to the inverting input of U4A is derived from the dimming input signal through resistor R39, allowing the commanded LED current to follow the selected dimming method. The actual LED current is sensed across resistors R59 and R16, producing a voltage proportional to output current. This sense voltage is then amplified by the non-inverting amplifier stage formed by U4B together with resistors R33, R34, R35, and R37, generating a scaled feedback signal suitable for comparison. Comparator U4A evaluates the amplified LED-current signal against the dimming-derived reference voltage and adjusts its output accordingly. The resulting comparator output drives the optocoupler LED U1, which transmits output information the isolation barrier to the primary-side controller, which adjusts power delivery to regulate the LED output current.

The variable-resistor dimming input is converted into a 0–10 V analog dimming signal by a constant-current source formed by PNP transistor Q5, the 1.24 V shunt reference U6, and the current-setting resistor R41. The shunt regulator U6 maintains a fixed 1.24 V across its reference node, forcing a constant current through R41 and into the emitter-base junction of Q5. As a result, the collector current of Q5 is approximately (1.24 V−VBE)/R41, establishing a nearly temperature-independent current source. When an external dimmer resistor is connected to the dim-input terminal J11, this constant current flows through the dimmer resistance. The dim-input voltage delivered to the buffer amplifier U4C therefore becomes:

$$V_{DIM} = \frac{1.24\,V - V_{BE}}{R41} \times R_{DIM}$$

The 0-10 V analog control signal is proportional to the connected dimmer resistance. This ensures a linear and predictable mapping between the external 0–100 kΩ dimmer and the LED current-control reference.

During CV-mode operation, the buffer amplifier U4C provides a stable dim-reference voltage to the inverting input of comparator U4A, preventing the comparator output from pulling low during full-load startup conditions[1]. During CC-mode, U4C prevents LED-current overshoot at startup when a 0–10 V analog dimming input is already connected. Because U4C is initially off at startup, it isolates the dim-input node and prevents an abrupt application of the dimming voltage. When U4C turns on, the low-pass filter formed by R66 and C33 introduces a controlled delay to the dim-reference voltage applied to the inverting input of U4A. This delayed transition eliminates sudden reference steps, resulting in a smooth, well-controlled increasing LED-current with no overshoot during startup.

The 10 V PWM dimming input signal is also converted into a 0–10 V analog control voltage through the low-pass RC network formed by R66 and C33, which filters the incoming PWM waveform and produces an averaged voltage proportional to its duty cycle. Resistor R69 further conditions this dimming signal at the inverting input of comparator U4A by damping residual switching noise, thereby reducing LED-current ripple, especially at low LED output voltages where the control loop is more sensitive. An additional RC low-pass filter consisting of R42 and C37 suppresses noise originating from the external dimming source. This ensures stable, flicker free operation even when the dimming leads are long or exposed to electrically noisy environments. The Zener clamp VR6 limits the dim-input voltage to below 12 V, protecting U4 and its associated signal-conditioning circuitry from accidental overvoltage or mis-wire conditions.

[1] Without this buffering, the dim-reference node would briefly collapse at startup, which would momentarily increase the optocoupler drive and cause under-power delivery as the system transitions from CV mode into normal regulation.

5 PCB Layout

The PCB uses FR4 material with a thickness of 1.6 mm and a double-sided copper layer with a thickness of 2.0 oz.

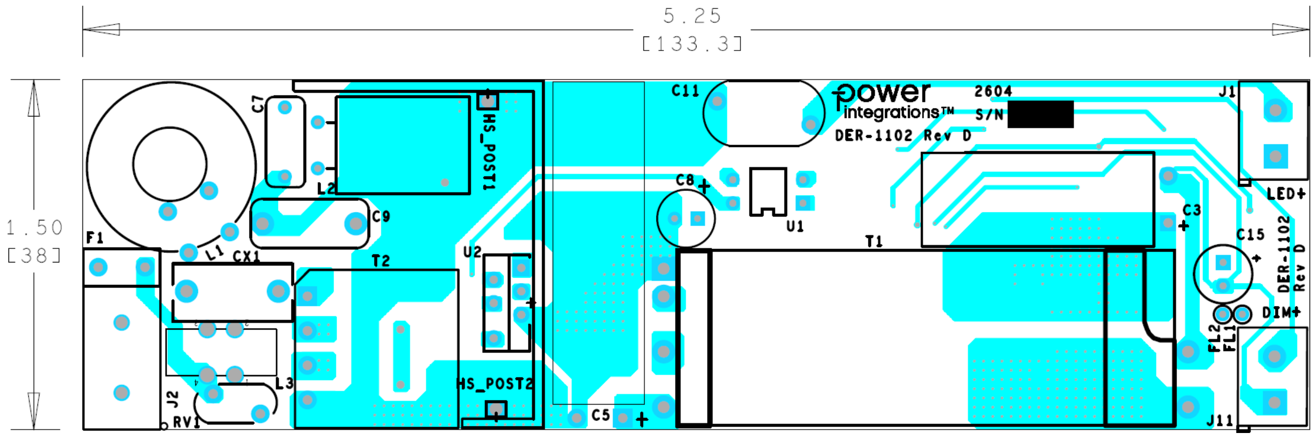


Figure 5 – Printed Circuit Layout, Top.

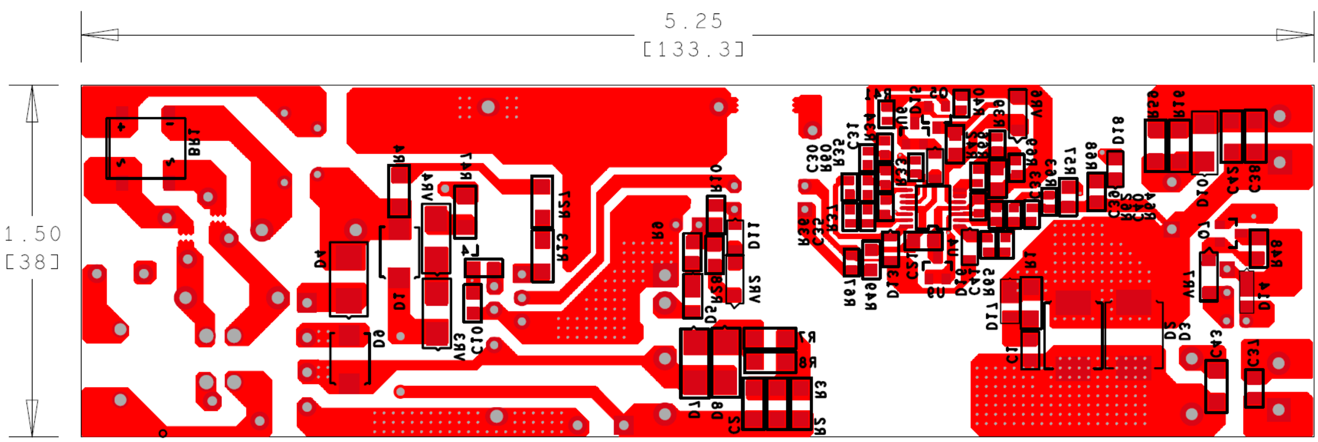


Figure 6 – Printed Circuit Layout, Bottom.

6 Bill of Materials

Item No.	Part Reference	Qty.	Description	Manufacturer	Mfr. Part Number
1	BR1	1	Bridge Rectifier, Single Phase, Standard, 1 kV, 3 A, Surface Mount, 4-MSBL, 4-SMD, Flat Leads	Diodes Incorporated	MSB30M-13
2	C1	1	220 pF, ±5%, 500 V, Ceramic Capacitor, X7R, 0805 (2012 Metric)	Kemet	C0805C221JCRAC7800
3	C2	1	1000 pF, ±10%, 500 V, Ceramic Capacitor X7R, 1206 (3216 Metric)	Samsung Electro-Mechanics	CL31B102KGFNNNE
4	C3	1	330 μF, 50 V, Electrolytic, Very Low ESR, 28 mOhm, (10 x 25)	Nippon Chemi-Con	EKZE500ELL331MJ25S
5	C5	1	15 μF, ±20%, 500 V, Aluminum Electrolytic Capacitors, Radial, Can, 8000 Hrs @ 105 °C, (10 x 35)	Chemi-Con	EKXJ501ELL150MJ35S
6	C7	1	68 nF, 450 VDC, 5%, Film	Duratech	MEXXD26804JJ
7	C8	1	22 μF, 50 V, Electrolytic, Gen. Purpose, (6.3 x 9)	Nichicon	UTT1H220MDD
8	C9	1	220 nF, 450 V, Film	Duratech	MEXXF32204JJ
9	C10	1	0.47 μF, ±10%, 50 V, Ceramic, X7R, 0805 (2012 Metric), -55 °C ~ 125 °C	TDK Corp	CGA4J3X7R1H474K125AB
10	C11	1	2200 pF, ±20%, 500 VAC (Y1), 760 VAC (X1), Ceramic, Y5U (E), RADIAL	Vishay	440LD22-R
11	C15	1	100 μF, 25 V, Electrolytic, Gen Purpose, (6.3 x 11.2)	Panasonic	ECA-1EHG101
12	C21	1	10 μF, ±10%, 25 V, Ceramic Capacitor, X7R, 0805 (2012 Metric)	Murata Electronics	GRT21BC71E106KE13L
13	C30	1	1 μF, ±10%, 25 V, Ceramic, X7R, 0603 (1608 Metric)	TDK Corp	CGA3E1X7R1E105K080AE
14	C31 C40	2	100 pF 50 V, Ceramic, NP0, 0603	Yageo	CC0603JRNPO9BN101
15	C33	1	4.7 μF, ±10%, 25 V, X7R, 0805 (2012 Metric), -55 °C ~ 125 °C	Taiyo Yuden	TMK212AB7475KG-T
16	C35	1	1000 pF, ±10%, 50 V, Ceramic Capacitor, X7R, 0603 (1608 Metric)	Samsung Electro-Mechanic	CL10B102KB8WPNC
17	C37	1	1000 pF, ±10% , 50 V, Ceramic Capacitor, X7R, 0805 (2012 Metric)	Kemet	C0805C102K5RECAUTO
18	C38 C42	2	10 μF, 10%, 50 V, Ceramic, X7R, -55 °C ~ 125 °C, 1206 (3216 Metric), 0.126" L x 0.063" W (3.20 mm x 1.60 mm)	Samsung Electro-Mechanics America, Inc.	CL31B106KBHNNNE
19	C39	1	1 μF, ±10%, 10 V, Ceramic Capacitor X7R, 0603 (1608 Metric)	YAGEO	AC0603KRX7R6BB105
20	C41	1	0.022 μF, ±10%, 50 V, Ceramic Capacitor, X7R, 0603 (1608 Metric)	AVX Corp	06035C223KAT2A
21	C43	1	100 pF, ±10%, 500 V, Ceramic, X7R, 1206 (3216 Metric)	Kemet	C1206C101KCRACTU
22	CX1	1	CAP, 0.15 μF, ±20%, 630 VDC, 310 VAC, FILM, POLYPROP, RAD, X2, 13 mm (L), 6 mm (W), 12 mm (H), 10 mm LS	KEMET	F861AP154M310L
23	D1 D9	2	Diode, 600 V, 6 A, Surface Mount DO-214AA (SMB)	Taiwan Semiconductor Corporation	PU6JB
24	D2 D3	2	Diode, 300 V, 5 A Surface Mount DO-214AB (SMC)	Taiwan Semiconductor Corporation	HS5F
25	D4	1	Diode, Ultrafast Recovery, 600 V, 2 A, Surface Mount, DO-214AA (SMB), DO214AA (SMB)(SMBJ)	Vishay General Semiconductor - Diodes Division	USB260HM3/52T
26	D5 D17	2	200 V, 1 A, Rectifier, Glass Passivated, POWERDI123	Diodes Inc	DFLR1200-7
27	D7 D8	2	1000 V, 1 A, DO-214AC	Micro Commercial Co	GS1M-LTP

28	D10	1	DIODE ULTRA FAST, 1 A, 100 V, SMA	Diodes, Inc	US1B-13-F
29	D11	1	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	Diode Inc.	BAV19WS-7-F
30	D13 D16	2	75 V, 0.15 A, Switching, SOD-323	Diode Inc.	BAV16WS-7-F
31	D14	1	Diode, Schottky, 200 V, 1 A, Surface Mount SOD-123HE	Panjit International Inc.	SS10200HE_R1_00001
32	D15	1	Diode, Schottky, 20 V, 350 mA (DC), Surface Mount, SOD-323 SC-76, SOD-323	Vishay Semiconductor Diodes Division	SD103CWS-E3-08
33	D18	1	DIODE, GEN PURP, 75 V, 150 mA, SOD323	Diodes Inc	1N4148WS-7-F
34	F1	1	3.15 A, 300 V, Slow, Long Time Lag, RST	Littelfuse Inc	36913150000
35	L1	1	22 mH +/- 40% @10KHz 0.4 V, 35 mH (typ) @ 100 KHz 0.4 V, 1 A, 0.3 ohm max DCR, Toroidal Common Mode Choke, Vert	Sumida	04291-T247
36	L2	1	1 mH, Unshielded Drum Core, Wirewound Inductor, 800 mA ,1.15 Ohm Max, Radial, Vertical Cylinder (Open) 10.5 mm x 14.5 mm height	Wurth	7447480102
37	L3	1	250 μH, Toroidal Common Mode Choke, custom, DER-1094, wound on 32-00330-00 core	Power Integrations	32-00485-00
38	L4	1	FERRITE Bead, 80 Ohms @ 100 MHz, 1 Signal Line, Ferrite Bead 0805 (2012 Metric), 300 mA, 300 mOhm	Max Echo	EBMS201209K800
39	Q5	1	PNP, Small Signal BJT, 40 V, 0.2 A, SOT-23	On Semiconductor	MMBT3906LT1G
40	Q7	1	NPN, 60 V 1000 MA, SOT-23	Zetex Inc	FMMT491TA
41	R1	1	100 Ohms ±5% 0.25 W, 1/4 W Chip Resistor 1206 (3216 Metric)	YAGEO	RC1206JR-07100RL
42	R2 R3	2	RES, 1.0 M, 5%, 2/3 W, Thick Film, 1206	Panasonic	ERJ-P08J105V
43	R4 R27	2	RES, 2.4 M, 1%, 1/4 W, Thick Film, 1206	Yageo	RC1206FR-072M4L
44	R7 R8	2	RES, 20 R, 5%, 2/3 W, Thick Film, 1206	Panasonic	ERJ-P08J200V
45	R9	1	RES, 10 R, 1%, 1/8 W, Thick Film, 0805	Panasonic	ERJ-6ENF10R0V
46	R10	1	RES, 6.98 k, 1%, 1/8 W, Thick Film, 0805	Panasonic	ERJ-6ENF6981V
47	R13	1	RES, 2.7 M, 5%, 1/4 W, Thick Film, 1206	YAGEO	RC1206FR-072M7L
48	R16 R59	2	RES, 0.2 R, 1%, 1/4 W, Thick Film 1206 (3216 Metric), ±600 ppm/°C, -55 °C ~ 155 °C	Yageo	RL1206FR-070R2L
49	R28	1	RES, 270 R, 5%, 1/8 W, Thick Film, 0805	Panasonic	ERJ-6GEYJ271V
50	R33 R34	2	RES, 1 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF1001V
51	R35	1	RES, 86.6 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF8662V
52	R36	1	RES, 15 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ153V
53	R37	1	RES, 12.1 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF1212V
54	R39	1	RES, 10 kOhms, ±5%, 0.1 W, 1/10 W, Chip Resistor 0603 (1608 Metric)	YAGEO	AC0603JR-0710KL
55	R40	1	RES, 7.5 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ752V
56	R41	1	RES, 6.34 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF6341V
57	R42	1	RES, 20 k, 5%, 1/8 W, Thick Film, 0805	Panasonic	ERJ-6GEYJ203V
58	R47	1	RES, 1 k, 5%, 2/3 W, Thick Film, 1206	Panasonic	ERJ-P08J102V
59	R48	1	RES, 3.3 k, 5%, 1/8 W, Thick Film, 0805	Panasonic	ERJ-6GEYJ332V
60	R49	1	RES, 1 k, 5%, 1/8 W, Thick Film, 0805	Panasonic	ERJ-6GEYJ102V
61	R57	1	RES, 47.5 k, 1%, 1/8 W, Thick Film, 0805	Panasonic	ERJ-6ENF4752V
62	R60	1	RES, 1 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ102V
63	R62	1	RES, 15 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF1502V
64	R63	1	RES, 10 kOhms, ±5%, 0.1 W, 1/10 W, Chip Resistor 0603 (1608 Metric)	Yageo	RC0603JR-0710KL
65	R64	1	RES, 205 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF2053V
66	R65	1	RES, 249 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF2493V
67	R66	1	RES, 20 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ203V
68	R67	1	RES, 3.32 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF3321V
69	R68	1	RES, 100 Ohms ±5% 0.125 W, 1/8 W, Chip Resistor 0805 (2012 Metric)	Stackpole Electronics Inc	RMCF0805JT100R
70	R69	1	RES, 3 M, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ305V

71	RV1	1	275 VAC, 23 J, 7 mm, RADIAL	Littelfuse	V275LA4P
72	T1	1	Bobbin, Vertical, EDR4110, 9 pins, 6 pri, 3sec	Changshu Xinli Magnetic Industrial CO LTD	FP9-EDR41/11
73	T2	1	Bobbin, EPC17, Horizontal, 10 pins	Pinshine	BEPC-17-1110CPH-P
74	U1	1	Optocoupler, 35 V, CTR 80-160%, 4-DIP	Liteon	LTV-817A
75	U2	1	TinySwitch-5, TNY5075E, eSIP-7C	Power Integrations	TNY5075E
76	U4	1	IC, Zero-Drift Amplifier, 4 Circuit, Rail-to-Rail, 14-TSSOP (0.173", 4.40 mm Width)	Analog Devices Inc.	ADA4522-4ARUZ-RL
77	U6	1	1.24 V Shunt Regulator IC, 1%, -40 to 85 °C, SOT23-3	Texas Instruments	LMV431AIMF/NOPB
78	U9	1	IC, REG ZENER SHUNT ADJ SOT-23	National Semiconductor	LM431BIM3/NOPB
79	VR2	1	Zener Diode, 11 V, ±2%, 500 mW, Surface Mount, SOD-123	Vishay General Semiconductor - Diodes Division	MMSZ5241C-E3-08
80	VR3 VR4	2	Zener Diode, 240 V, 1.25 W, - Surface Mount DO-214AC (SMA) Replaces 15-01293-00	Vishay Semiconductors	BZG04-200-HM3-08
81	VR6 VR7	2	DIODE ZENER 12 V 500 MW SOD123	Diodes, Inc	MMSZ5242B-7-F

Table 2 – Electrical Parts.

Item No.	Part Reference	Qty.	Description	Manufacturer	Mfr. Part Number
1	FL1 FL2	2	Flying Lead, Hole size 30 mils	N/A	N/A
2	HS_POST1 HS_POST2	2	Post, Heatsink, SS, Nickel Plated, 5 mm (W) x 9.1 mm (T)	Custom	Custom
3	J1 J11	2	CONN TERM BLOCK, 2 POS, 5 mm, PCB	On Shore Technology Inc	ED500/2DS
4	J2	1	2 Position Wire to Board Terminal Block Horizontal with Board 0.300" (7.62 mm) Through Hole	Phoenix Contact	1707027

Table 3 – Miscellaneous Parts.

7 SVF Inductor and Flyback Transformer Design Spreadsheet

1	ACDC_Flyback_PF_TinySwitch-5_012026; Rev.1.0; Copyright Power Integrations 2026	INPUT	INFO	OUTPUT	UNITS	Switched Valley-Fill Single Stage PFC (SVF S^2PFC)
2	**Application Variables**					
3	VACMIN	120		120	V	Minimum Input AC Voltage
4	VACNOM			230	V	Nominal Input AC Voltage
5	VACMAX	277		277	V	Maximum Input AC Voltage
6	VACRANGE			CUSTOM		Input Voltage Range
7	FL			50	Hz	Line Frequency
8	CIN	15.00		15.00	μF	Minimum Input Capacitance
9	V_CIN			500	V	Input Capacitance Recommended Voltage Rating
10	VO	36.00		36.00	V	Output Voltage
11	IO	1.12		1.12	A	Output Current
12	PO			40.32	W	Total Output Power
13	N	87.00		87.00	%	Estimated Efficiency
14	Z			0.50		Loss Allocation Factor
15	**Calculations Basis**					
16	PARcalcBASIS	VACNOM		VACNOM		Calculated Results Based on Selected VAC - VACNOM, VACMAX, VACMIN or Worst Case only
17	Flyback_Ind_Basis	Nom		Nom		Calculated Results Based on Selected LP - Min = LP_MIN, Nom = LP_NOM, Max = LP_MAX
18	Boost_Ind_Basis	Nom		Nom		Calculated Results Based on Selected LBOOST - Min = LBOOSTMIN,Nom = LBOOSTNOM,Max = LBOOSTMAX
19	**Primary Controller Section**					
20	PACKAGE	E		E		Device Package. Available options are eSOP(K), eDIP(V), eSIP(E)
21	DEVICE_MODE	Standard		Standard		Device Current Limit Mode
22	DEVNAME	TNY5075E		TNY5075E		PI Device Name
23	RDSON			3.35	Ohm	Device RDSON at 100 °C
24	ILIMITMIN			1.794	A	Minimum Current Limit
25	ILIMITTYP			1.930	A	Typical Current Limit
26	ILIMITMAX			2.066	A	Maximum Current Limit
27	POUT_MAX			70.000	W	Power Capability of the Device based on Thermal Performance
28	BVDSS	Auto		725	V	Peak Drain to Source Breakdown Voltage
29	VDS			0.01	V	On state Drain to Source Voltage
30	VDRAIN			561.74	V	Peak Drain to Source Voltage during Fet turn off
31	**Calculated Electrical Parameters Based on Specified Basis**					
32	Boost Converter					
33	IBOOSTRMS			326.96	mA	Boost RMS current
34	IBOOSTMAX			1115.77	mA	Boost PEAK current
35	IBOOSTAVG			161.73	mA	Boost AVG current

36	IINRMS			185.78	mA	Input RMS current
37	PF_est			0.9960		Estimated Power Factor
38	Flyback Converter					
39	FSMIN	39500		39500	Hz	Minimum Switching Frequency in a Line Period
40	FSMAX			96219.66	Hz	Maximum Switching Frequency in a Line Period
41	KPmin			1.1189		Minimum KP in a Line Period for VAC specified by PARcalcBASIS
42	IFETRMS			450.89	mA	Fet RMS current
43	IFETMAX			1923.38	mA	Fet PEAK current
44	IPRIRMS			0.3562	A	Primary Winding RMS current
45	IPRIMAX			1.6467	A	Primary Winding PEAK current
46	IPRIAVG			0.0019	A	Primary Winding AVG current
47	IPRIMIN			800.16	mA	Primary Winding Minimum current
48	ISECRMS			1.74	A	Secondary RMS current
49	ISECMAX			5.01	A	Secondary PEAK current
50	ISECRIPPLE			1.33	A	Secondary RIPPLE current
51	**Boost Choke Construction Parameters**					
52	RATIO_LBST_LFB	0.6200		0.6200		Boost Inductance and Flyback Primary Inductance Ratio
53	LBOOSTMIN			465.90	μH	Minimum Boost Inductance
54	LBOOSTNOM			500.97	μH	Nominal Boost Inductance
55	LBOOSTMAX			536.04	μH	Maximum Boost Inductance
56	LBOOSTTOL	7.00		7.00	%	Boost Inductance Tolerance
57	**Boost Core and Bobbin Selection**					
58	CR_TYPE_BOOST	EPC17		EPC17		Boost Core
59	CR_PN_BOOST			PC47EPC17-Z		Boost Core Code
60	AE_BOOST			22.80	mm^2	Boost Core Cross Sectional Area
61	LE_BOOST			40.20	mm	Boost Core Magnetic Path Length
62	AL_BOOST			1150.00	nH/turns^2	Boost Core Ungapped Core Effective Inductance
63	VE_BOOST			917.00	mm^3	Boost Core Volume
64	BOBBINID_BOOST			EPC17/8/6 5+5		Bobbin
65	AW_BOOST			26.70	mm^2	Window Area of Bobbin
66	BW_BOOST			8.90	mm	Bobbin Width
67	MARGIN_BOOST			0.00	mm	Safety Margin Width
68	BOBFILLFACTOR_Boost			39.50	%	Boost Bobbin Fill Factor
69	**Boost Winding Details**					
70	NBOOST	75.00		75.00		Boost Choke Turns
71	BP_BOOST			3653.75	Gauss	Boost Peak Flux Density
72	ALG_BOOST			89.06	nH/turns^2	Boost Core Ungapped Core Effective Inductance
73	LG_BOOST			0.30	mm	Boost Core Gap Length
74	L_BOOST			3.16		Number of Boost Layers
75	AWG_BOOST	28		28		Boost Winding Wire AWG
76	OD_BOOST_INSULATED			0.375	mm	Boost Winding Wire Output Diameter with Insulation

77	OD_BOOST_BARE			0.321	mm	Boost Winding Wire Output Diameter without Insulation
78	CMA_BOOST			342.61	Circular Mils/A	Boost Winding Wire CMA
79	**Flyback Transformer Construction Parameters**					
80	VOR	100.00		100.00	V	Secondary Voltage Reflected in the Primary Winding
81	LP_MIN			751.46	µH	Minimum Flyback Inductance
82	LP_NOM			808.02	µH	Nominal Flyback Inductance
83	LP_MAX			864.58	µH	Maximum Flyback Inductance
84	LP_TOL	7.00		7.00	%	Flyback Inductance Tolerance
85	**Flyback Core and Bobbin Selection**					
86	CR_TYPE	Custom		Custom		Flyback Core
87	CR_PN	EDR4110		EDR4110		Flyback Core Code
88	AE	170.00		170.00	mm^2	Flyback Core Cross Sectional Area
89	LE	28.42		28.42	mm	Flyback Core Magnetic Path Length
90	AL	8850.00		8850.00	nH/turns^2	Flyback Core Ungapped Core Effective Inductance
91	VE	4832.00		4832.00	mm^3	Flyback Core Volume
92	BOBBINID	EDR4110		EDR4110		Flyback Bobbin
93	AW	31.80		31.80	mm^2	Flyback Window Area of Bobbin
94	BW	3.80		3.80	mm	Flyback Bobbin Width
95	MARGIN			0.00	mm	Safety Margin Width
96	**Flyback Winding Details**					
97	NP			28.00		Primary Turns
98	BP			3873.48	Gauss	Flyback Peak Flux Density
99	BM			3705.88	Gauss	Flyback Maximum Flux Density
100	BAC			1397.67	Gauss	Flyback AC Flux Density
101	ALG			1030.64	nH/turns^2	Flyback Core Ungapped Core Effective Inductance
102	LG			0.18	mm	Flyback Core Gap Length
103	NB			4.00		Bias Turns
104	NS	10.00		10.00		Secondary Turns
105	**Primary Components Selection**					
106	Line Undervoltage					
107	BROWN_IN_REQUIRED			76.08	V	Required AC RMS line voltage brown-in threshold
108	RLS			4.00	MOhm	Two Resistors of this Value in Series to the V-pin
109	BROWN_IN_ACTUAL			62.3V - 77.2V	V	Actual AC RMS brown-in threshold
110	BROWN_OUT_ACTUAL			53.8V - 66.9V	V	Actual AC RMS brown-out threshold
111	**Line Overvoltage**					
112	OVERVOLTAGE_LINE		Info	282.9V - 352.6V	V	Line overvoltage level is more than 90% of device rating
113	**Bias Voltage**					
114	VBIAS			12.00	V	Rectified Bias Voltage
115	VF_BIASDIODE			0.70	V	Bias Winding Diode Forward Drop
116	VRRM_BIASDIODE			70.16	V	Bias diode reverse voltage
117	CBIAS			47.00	µF	Bias winding rectification capacitor

118	CBPP			0.47	μF	BPP pin capacitor
119	**Bulk Capacitor Zener Clamp**					
120	Use Clamp	Yes		Yes		Bulk Capacitor Clamp Needed? Yes, No or N/A
121	VZ1_V			240.00	V	Zener 1 Voltage Rating (In Series with Zener 2)
122	PZ1_W			1.25	W	Zener 1 Minimum Power Rating
123	VZ2_V			240.00	V	Zener 2 Voltage Rating
124	PZ2_W			1.25	W	Zener 2 Minimum Power Rating
125	RZ			1000.00	Ohm	Resistor in series with Zener 1 and Zener 2
126	**Secondary Components Selection**					
127	Feedback Components					
128	VREF_REG			2.50	V	Reference voltage of the feedback
129	RFB_UPPER			200.00	kOhm	Upper feedback 1% resistor
130	RFB_LOWER			15.00	kOhm	Lower feedback 1% resistor
131	**Secondary Bias Section - For VO > 25V ONLY**					
132	Sec Sec Bias Diode					
133	Use Secondary Bias	Yes		Yes		Secondary bias needed? Yes, No or N/A
134	VBIAS_SEC	16.00		16.00	V	Rectified secondary bias winding voltage
135	VF_SECBIASDIODE			0.70	V	Secondary bias winding diode forward drop
136	VRRM_SECBIASDIODE			81.95	V	Secondary bias winding diode reverse voltage
137	CSECBIAS	100.00		100.00	μF	Secondary bias winding rectification capacitor
138	NB_SEC			5.00		Secondary bias winding turns
140	**Output Components**					
141	VF			0.70	V	Output diode forward drop
142	VRRM			210.49	V	Output diode reverse voltage
143	COUT			315.05	μF	Output Capacitor - Capacitance
144	COUT_VOpercentRip			2.50	%	Output Capacitor Ripple % of VOUT
145	ICOUTrms			1.33	A	Output Capacitor Estimated Ripple Current
146	ESRmax			179.62	mOhm	Output Capacitor Maximum Recommended ESR
147	Total Harmonic Distortion					
148	THD			12.87	%	Estimated total harmonic distortion

Table 4 – TinySwitch-5 Flyback Transformer and SVF Boost Inductor Design Spreadsheet.

8 Flyback Transformer Specification

8.1 Electrical Diagram

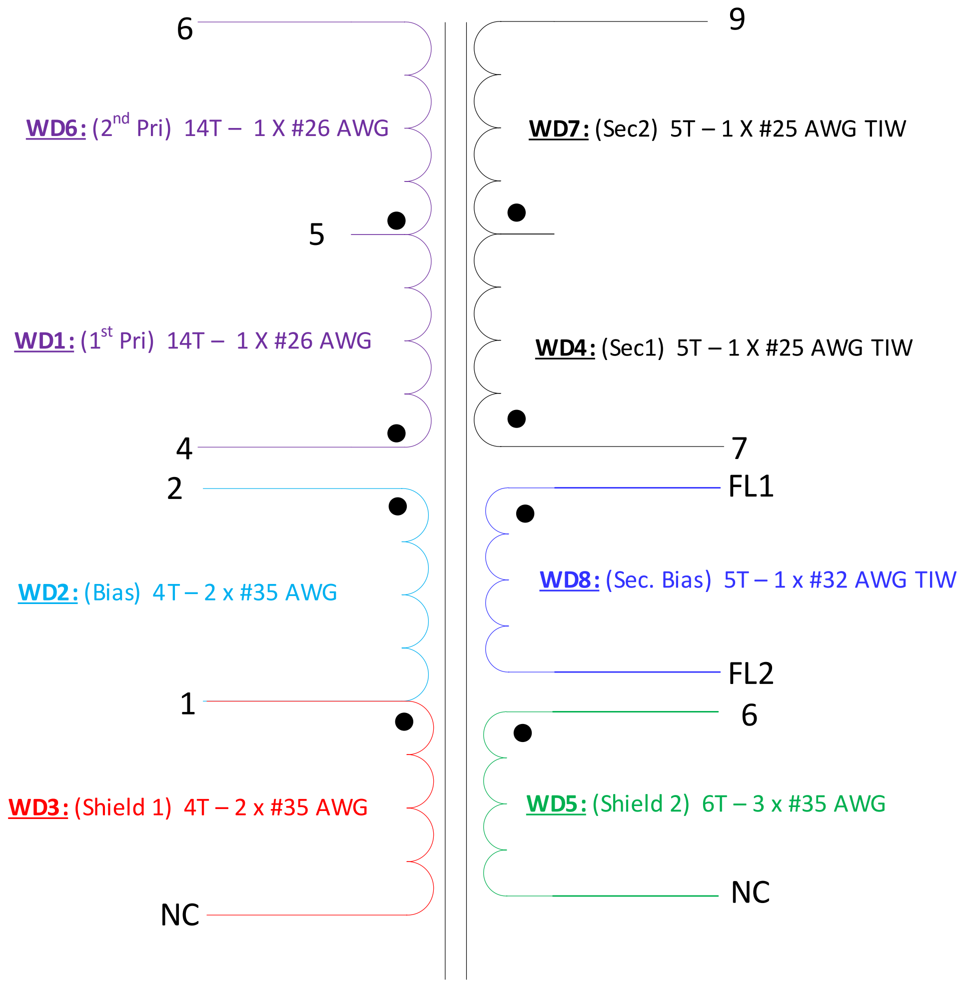


Figure 7 – Transformer Schematic.

8.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 4 and 6, with all other windings open.	800 µH ±5%
Primary Leakage Inductance	Measure inductance across Pin 4 and Pin 6 with all other windings shorted.	10 µH ±5%

Table 5 – Transformer Electrical Specification.

8.3 Materials

Item	Description
[1]	Core: EDR4110
[2]	Bobbin: Vertical, EDR4110, 9 pins, 6 pri, 3 sec, PI#: 25-01139-00
[3]	Magnet wire: #26 AWG, double coated
[4]	Magnet wire: #35 AWG, double coated
[5]	TIW: #32 AWG Tripple Insulated Wire
[6]	TIW: #25 AWG Tripple Insulated Wire
[7]	Tape: 36 mm, 3M 13450-F, Polyester Film
[8]	Tape: 18.6 mm, 3M 13450-F, Polyester Film
[9]	Tape: 4 mm, 3M 13450-F, Polyester Film
[10]	Varnish: Dolph BC-359

Table 6 – Transformer Materials.

8.4 Transformer Build Diagram

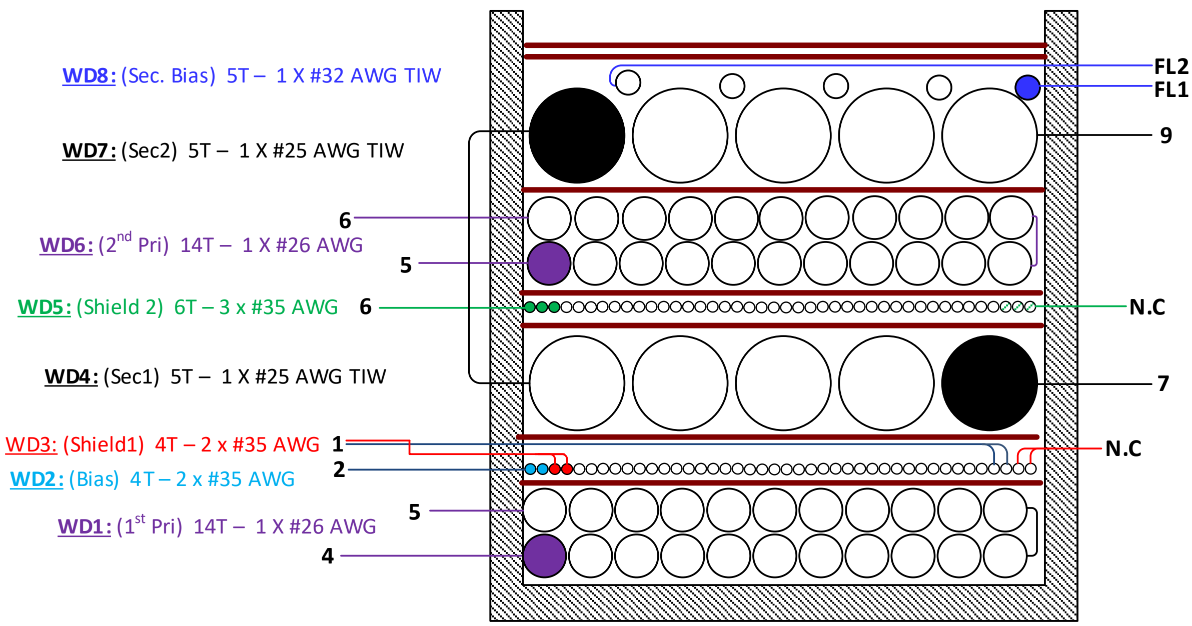
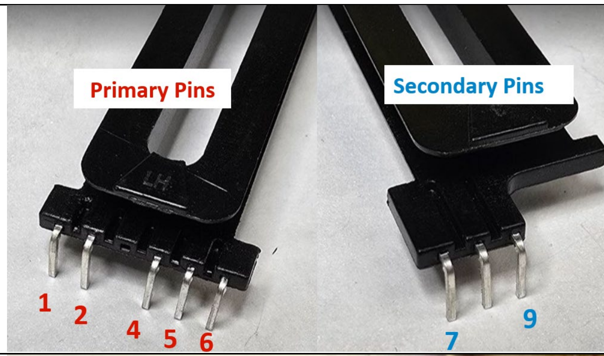
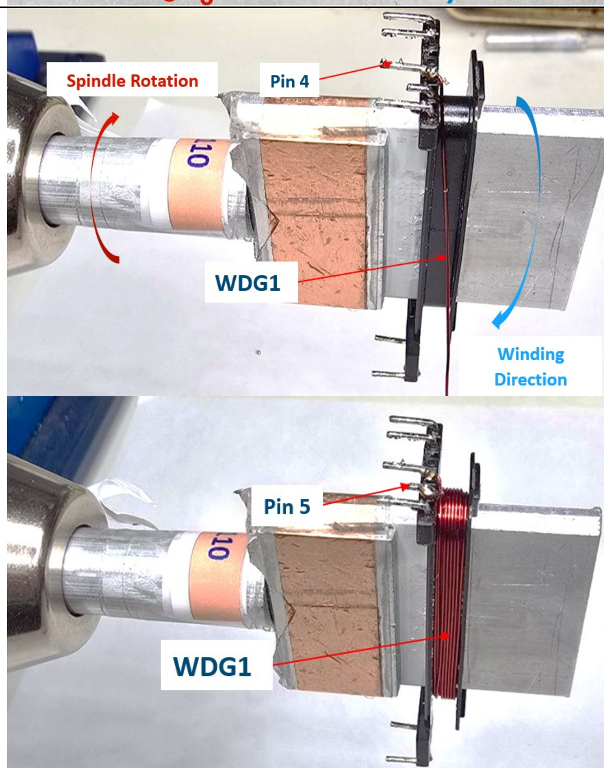
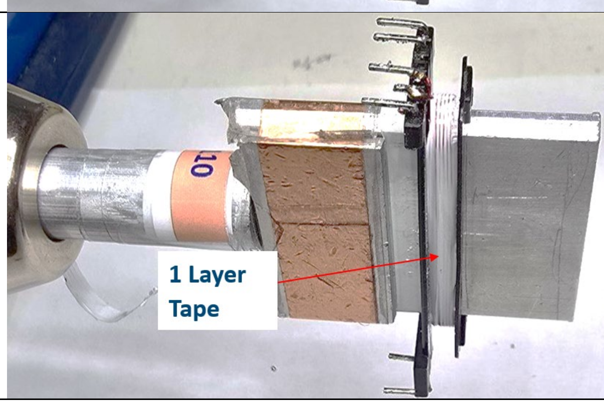
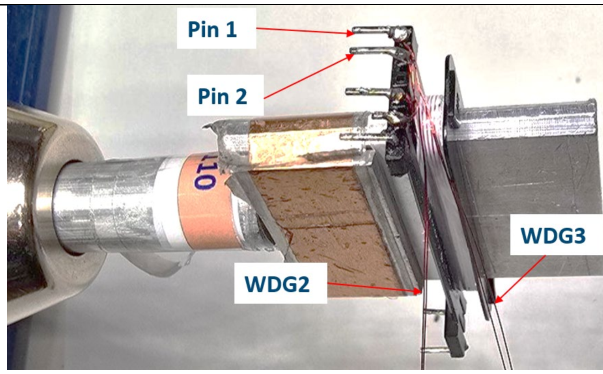
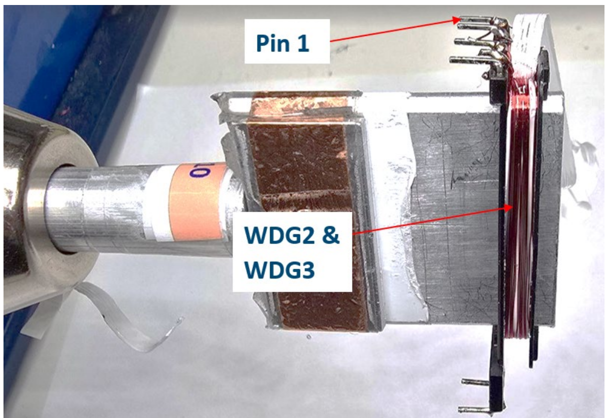


Figure 8 – Transformer Build Diagram.

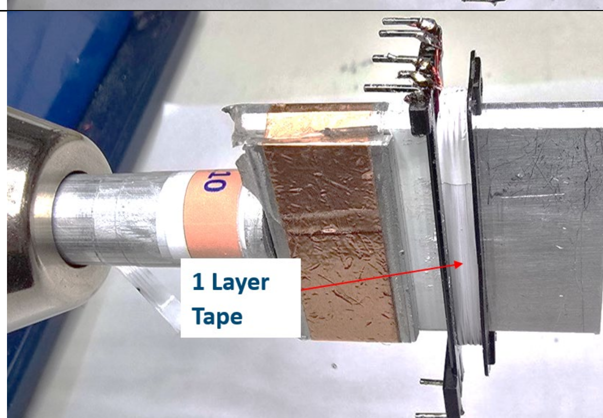
8.5 Winding Illustrations

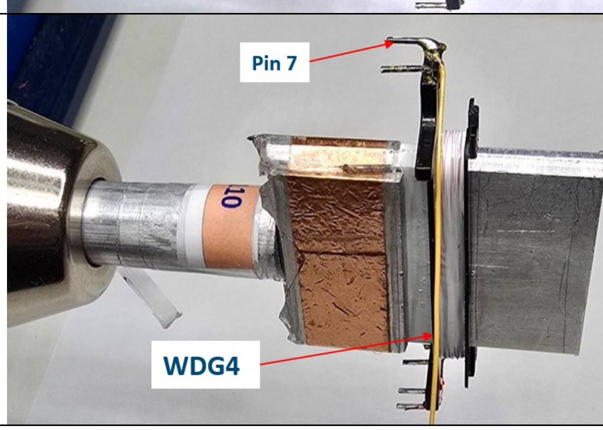
EDR4110 Vertical Bobbin		Bobbin terminal pin assignments
WDG1 1st Primary		The winding direction and spindle rotation are indicated in the figure on the left. **WDG1:** Using bifilar AWG #26 magnet wire (Item [3]), start at pin 2 and wind 14 turns from left to right, evenly distributed in two layers. Terminate the finish leads at pin 5.
Insulation Tape		Apply one layer of tape insulation (Item [10]) over the winding.

<table>
<tr>
<td>WDG2 (Pri. Bias) &
WDG3 (Shield 1)</td>
<td>


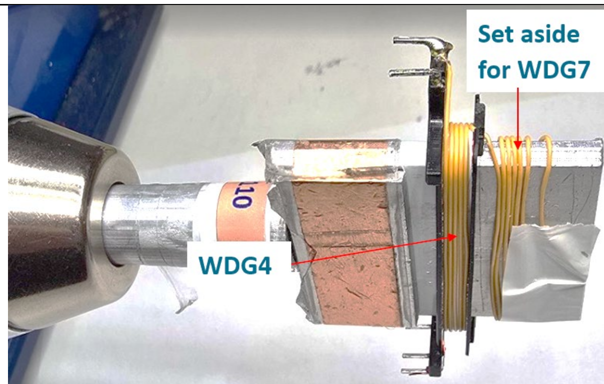
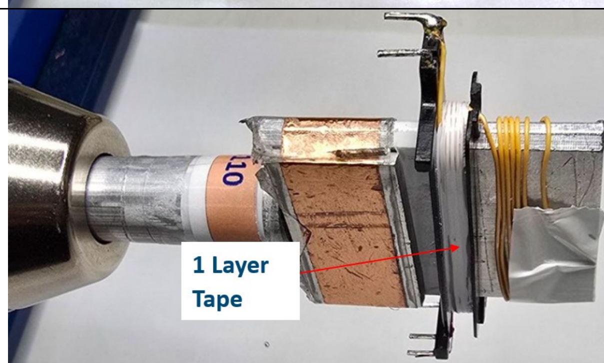
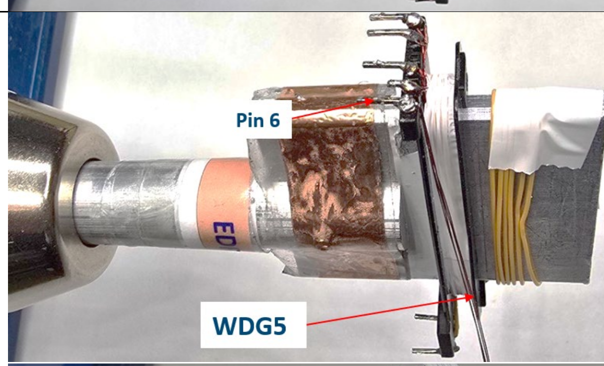
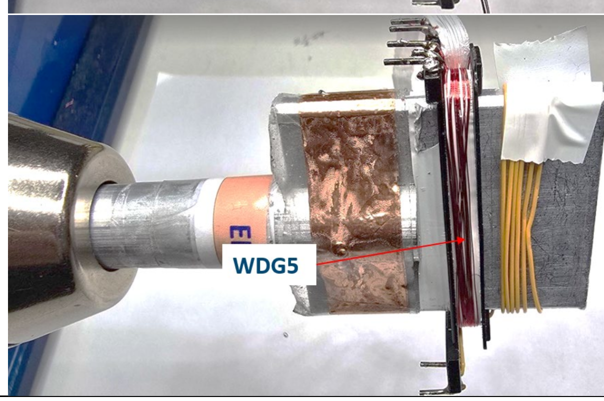


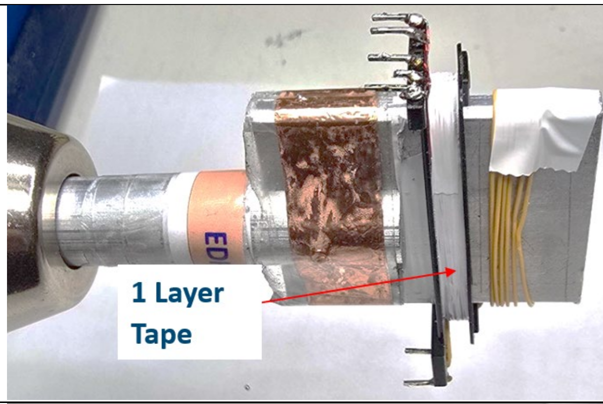
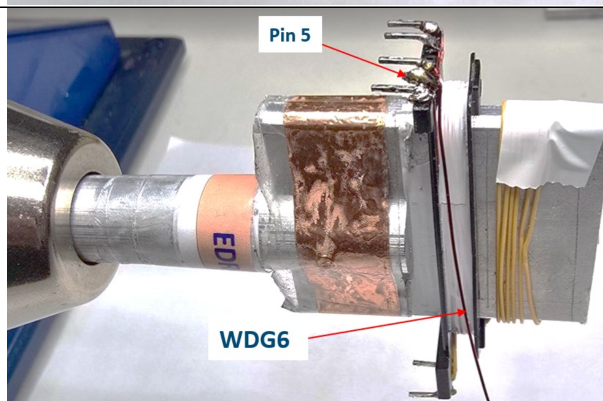
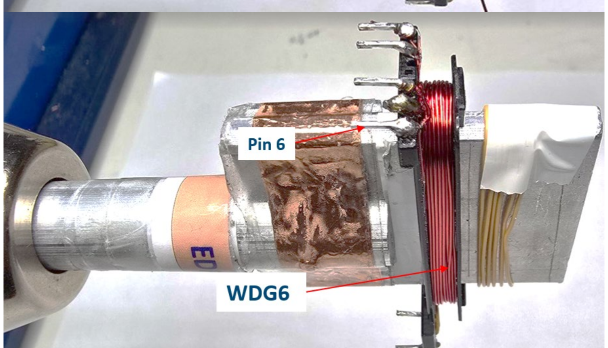
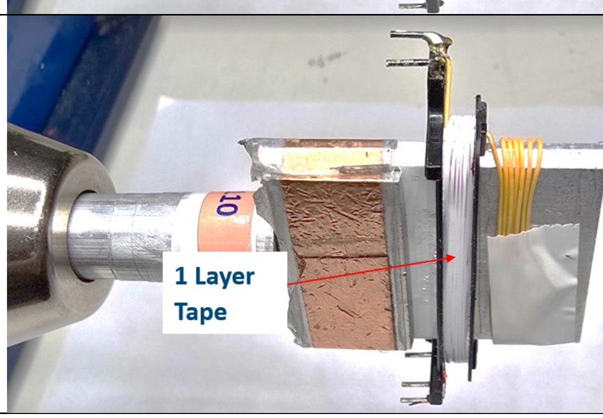
</td>
<td>WDG2 & WDG3: Using bifilar AWG #35 magnet wire (Item [4]), start Winding 2 (WDG2) at pin 2 and Winding 3 (WDG3) at pin 1. Wind 4 turns of both wires together from left to right, distributed evenly.

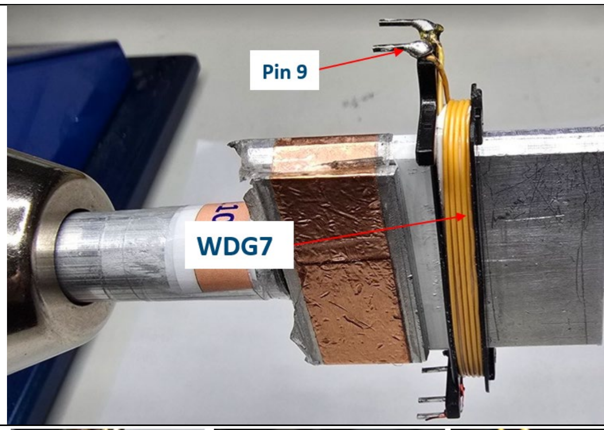
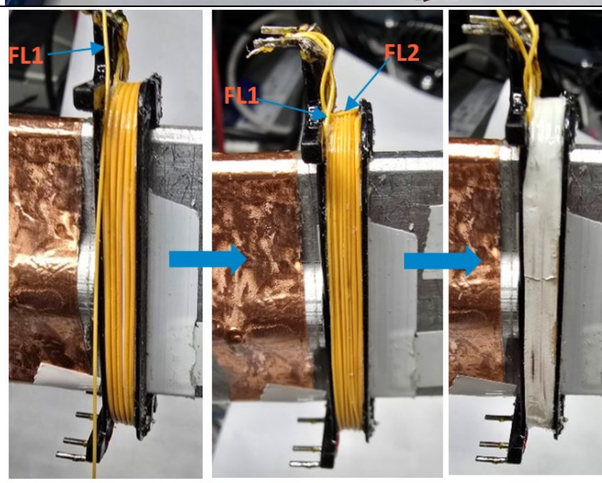
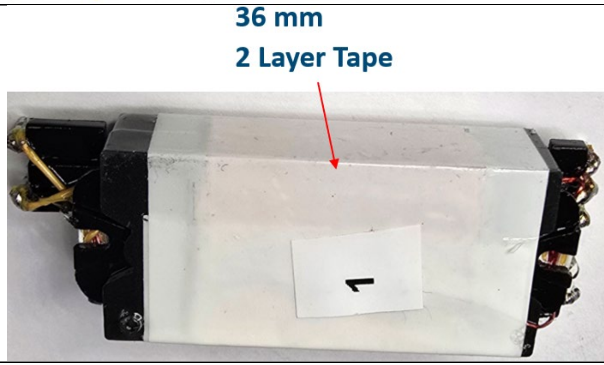
Terminate the WDG2 finish lead at pin 1 and leave the WDG3 finish lead cut and floating.</td>
</tr>
<tr>
<td>Insulation Tape</td>
<td>


</td>
<td>Apply one layer of tape insulation (Item [10]) over the winding.</td>
</tr>
<tr>
<td>WDG4
1st Secondary</td>
<td>


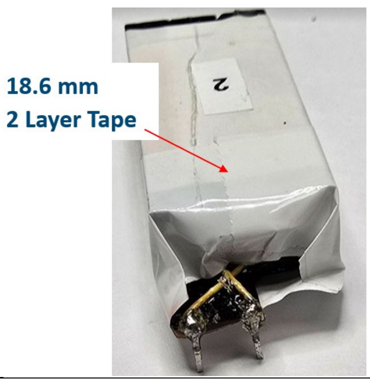
</td>
<td>WDG4: Position the bobbin with secondary pins (7–9) oriented at the top. Using AWG #25 triple-insulated wire (Item [7]), start WDG4 at pin 7 and wind 5 turns from left to right, distributed evenly.</td>
</tr>
</table>

		Place the finish lead of WDG4 into the secondary-side bobbin slot, leaving sufficient wire length reserved for WDG7 (5 turns) on the right.
Insulation Tape		Apply one layer of tape insulation (Item [9]) over the winding.
WDG5 Shield 2		**WDG5:** Position the bobbin back with primary pins (1–6) oriented at the top. Using trifilar AWG #35 magnet wire (Item [4]), start at pin 6 and wind 6 turns from left to right, distributed evenly. Cut and leave the finish leads floating.

Insulation Tape		Apply one layer of tape insulation (Item [9]) over the winding.
WDG6 2nd Primary		**WDG6:** Using bifilar AWG #26 magnet wire (Item [3]), start at pin 5 and wind 14 turns from left to right, evenly distributed in two layers. Terminate the finish leads at pin 6.
Insulation Tape		Apply one layer of tape insulation (Item [9]) over the winding.

WDG7 2nd Secondary		**WDG7:** Position the bobbin one last time with secondary pins (7–9) oriented at the top. Using the AWG #25 triple-insulated wire (Item [6]) previously set aside for WDG7, wind 5 turns from right to left, distributed evenly. Terminate the finish lead at pin 9.
WDG8 Secondary Bias + **Insulation Tape**		**WDG8:** After winding WDG7, use AWG #32 triple-insulated wire (Item [5]). Begin with a floating start lead labeled FL1 and wind 5 evenly distributed turns from left to right. Label the floating finish lead as FL2. Apply one layer of tape insulation (Item [9]) over the winding
Core Fixing		Wrap two layers of 36 mm polyester tape (Item [7]) to secure the cores to the bobbin. Ensure there is no excessive core overlap so that the gapped inductance value is maintained.

<table>
<tr>
<td>Secondary Safety Insulation Tape</td>
<td>

</td>
<td>Starting near the secondary terminals, wrap two layers of 18.6 mm-wide 3M polyester tape (Item [8]) to cover the exposed transformer core on the secondary side. Apply an additional 4 mm fixing tape (Item [9]) around the transformer, as shown in the figure, to secure the secondary safety-isolation tape.

Finish: Dip-varnish the completed transformer in Dolph BC-359 (Item [10]) for 1 hour.</td>
</tr>
</table>

Table 7 – Transformer Winding Illustrations.

9 SVF Inductor Specification

9.1 Electrical Diagram

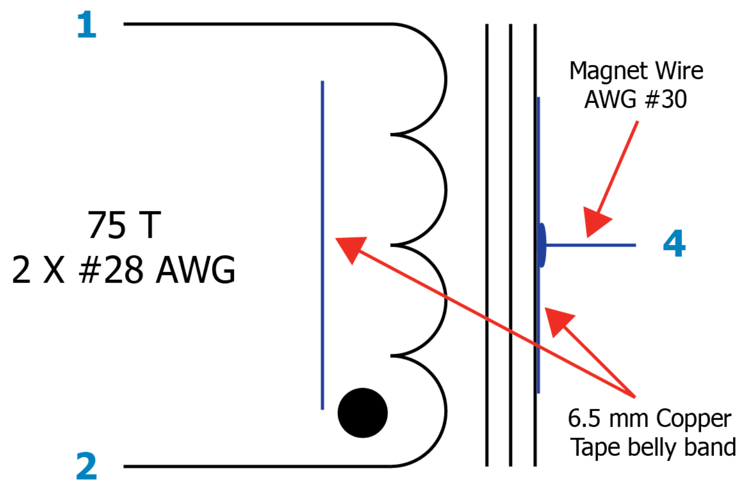


Figure 9 – SVF Inductor Electrical Diagram.

9.2 Electrical Specification

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 1 and pin 2.	500 μH
Tolerance	Tolerance of Primary Inductance.	± 7%

Table 8 – SVF Inductor Electrical Specification.

9.3 Materials

Item	Description
[1]	Core: EPC17
[2]	Bobbin: EPC17, Horizontal, 10 pins: 25-00976-00
[3]	Magnet Wire: #28 AWG
[4]	Magnet Wire: #30 AWG
[5]	Tape: 6 mm, 3M 13450-F, Polyester Film
[6]	Tape: 9 mm, 3M 13450-F, Polyester Film
[7]	Tape: 9.5 mm, 3M 13450-F, Polyester Film
[8]	6.5 mm, 3M 1194 Copper Foil Tape
[9]	Varnish: Dolph BC-359

Table 9 – SVF Inductor Materials.

9.4 Build Diagram

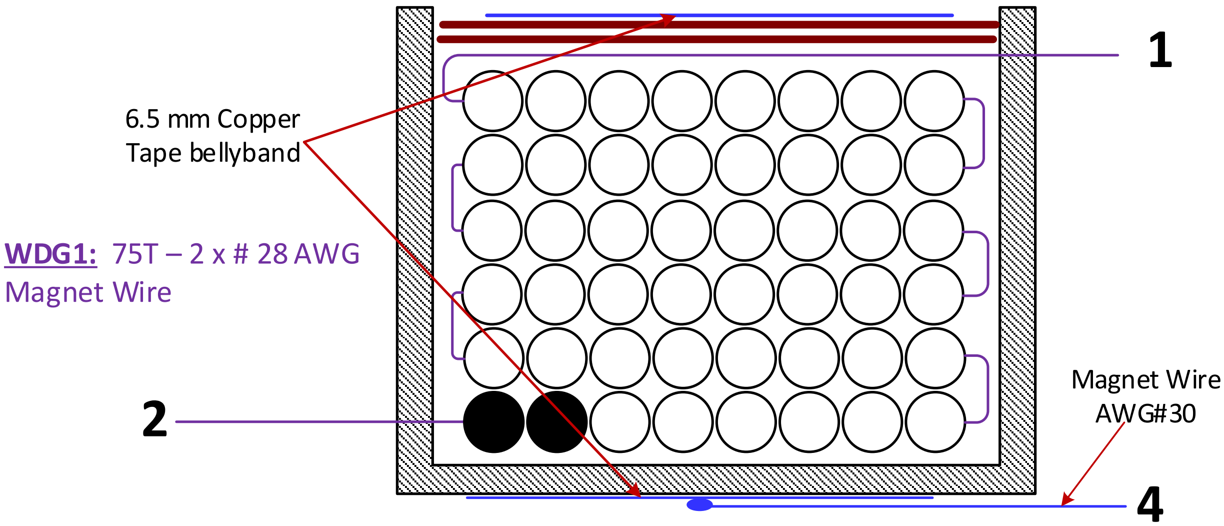
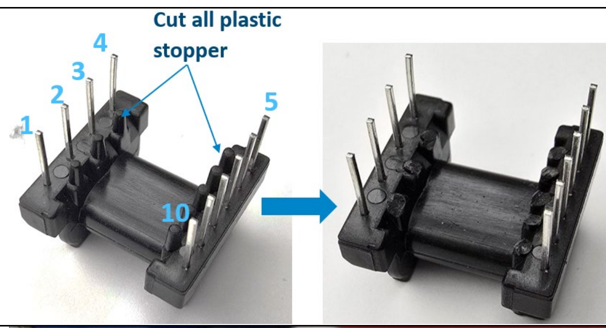
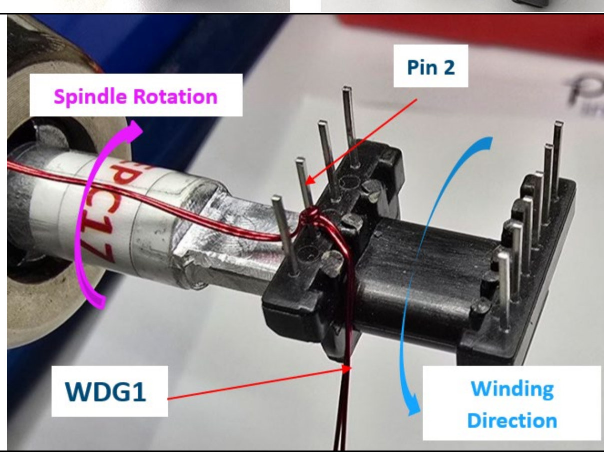


Figure 10 – SVF Inductor Build Diagram.

9.5 Winding Illustrations

Core Fixing		Cut all plastic wire stoppers to reduce the height of the inductor.
WDG1 and Insulation Tape		**WDG1:** Using bifilar AWG #28 magnet wire (Item [3]), start at pin 2 and wind 75 turns evenly distributed across the bobbin, then terminate the finish lead at pin 3. Apply one layer of 9.5 mm insulation tape insulation (Item [7]) over the winding

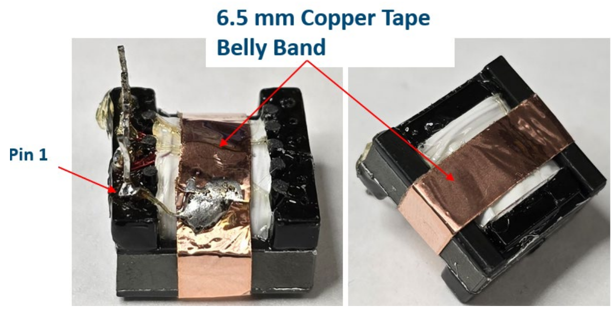
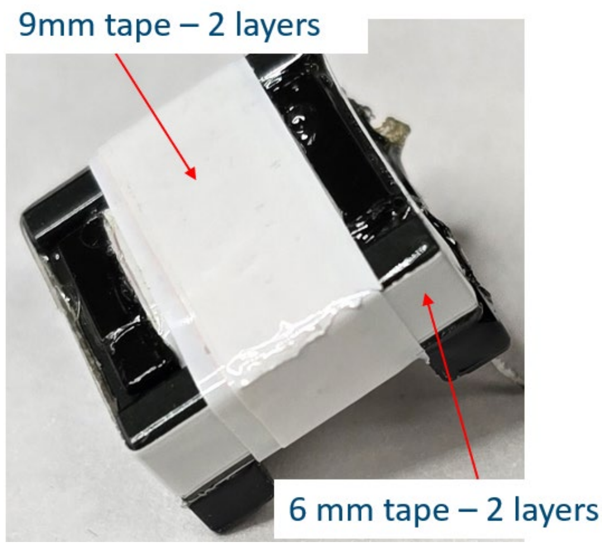
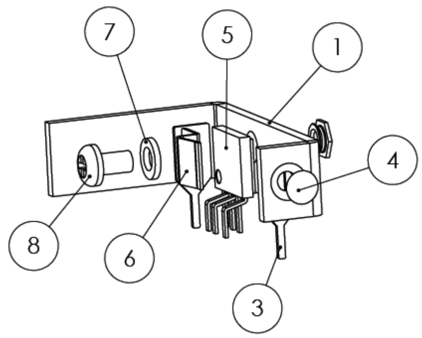
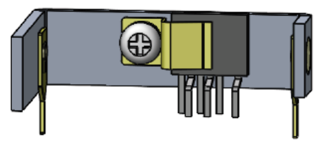
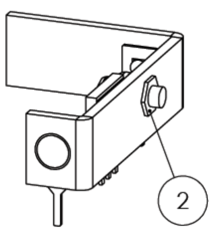
Copper Belly Band		Use one pair of EPC17 ferrite cores (Item [1]) and introduce a center-leg gap on one core to achieve the required inductance, measured between pins 2 and 3. Before applying the core-fixing tape, wrap the 6.5 mm copper tape belly band around the inductor as shown in the figure. Connect the belly band to pin 1 using AWG #30 magnet wire (Item [4]).
Core Fixing Tape and Insulation Tape		Apply two layers of 6 mm fixing tape (Item [5]) tightly around the core, ensuring no overlap or misalignment between the core halves so that the designed gap spacing — and thus the gapped inductance — is maintained. Apply 2 layers of 9 mm insulation tape (Item [6]) as shown in the figure. **Finish:** Dip-varnish the completed transformer in Dolph BC-359 (Item [9]) for 1 hour.

Table 10 – SVF Inductor Winding Illustrations.

10 TinySwitch-5 Heatsink







ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	61-00418-00	HEATSINK FOR DER-1102 REV.B	1
2	77-00005-00	CAPTIVE NUT,FLUSH,SS,440,PNL THK_061	1
3	60-00051-00	POST-HEATSINK-5mmWx9.1mmT	2
4	75-00083-00	RIVET,.093 DIA x 0.125-100 DEGREE CSK,SOFT,1100,F AL	2
5	10-01627-00	TinySwitch-5, TNY5075E, eSIP-7C	1
6	60-00037-00	EDGE CLIP 14.3mm L x 6.35mm W	1
7	75-00033-00	WASHER FLAT #6, SS	1
8	75-00002-00	SCREW MACHINE PHIL 4-40 X 5/16 SS	1

Figure 11 – TinySwitch-5 Heatsink Assembly and BOM.

11 Performance Data

Performance data was collected at room temperature, with voltages taken on the input and output terminals of the PCB unless noted otherwise.

11.1 Efficiency vs Input Voltage

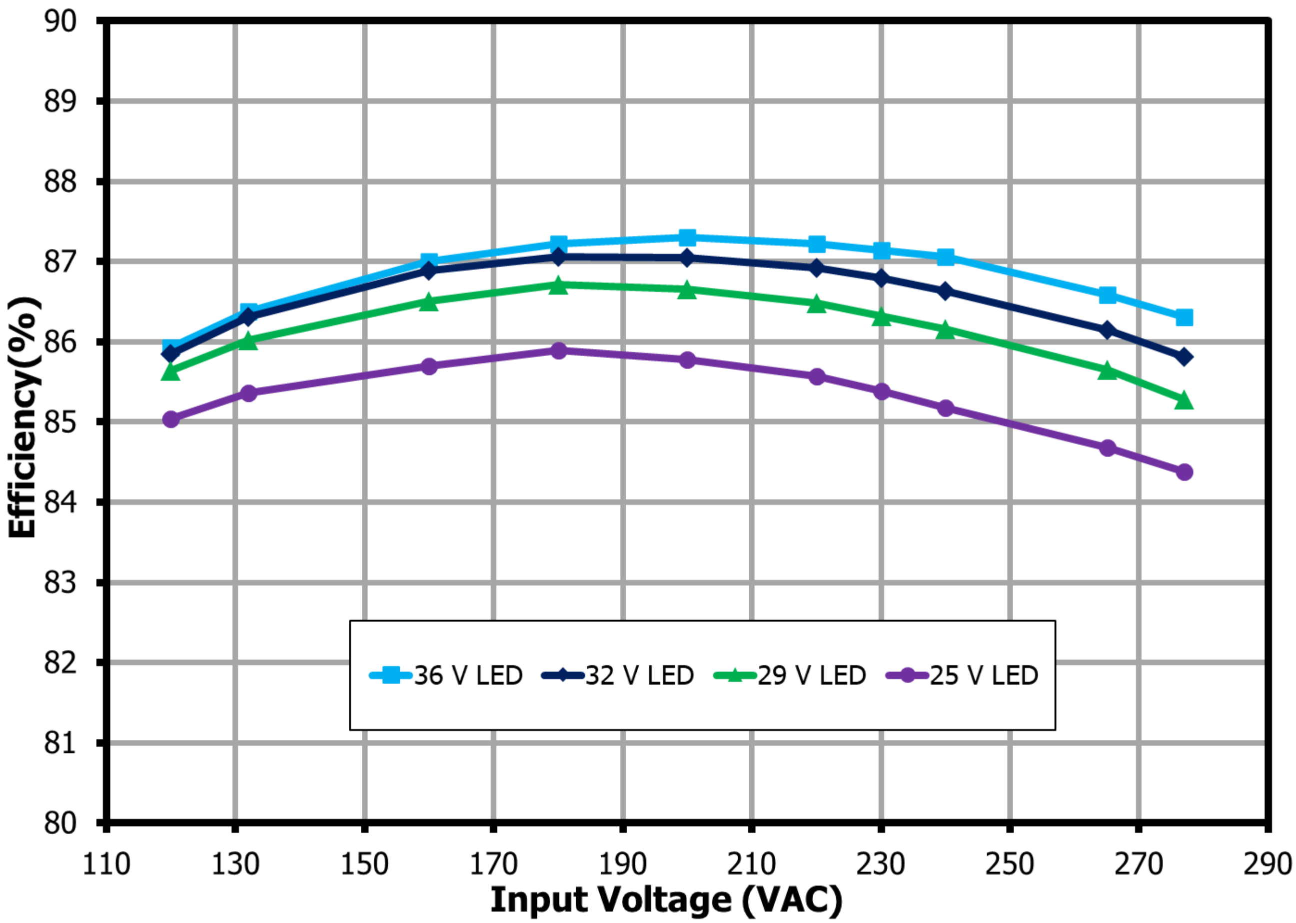


Figure 12 – Efficiency vs. Input Line Voltage at Different LED Voltage Load.

11.2 Power Factor vs Input Line Voltage

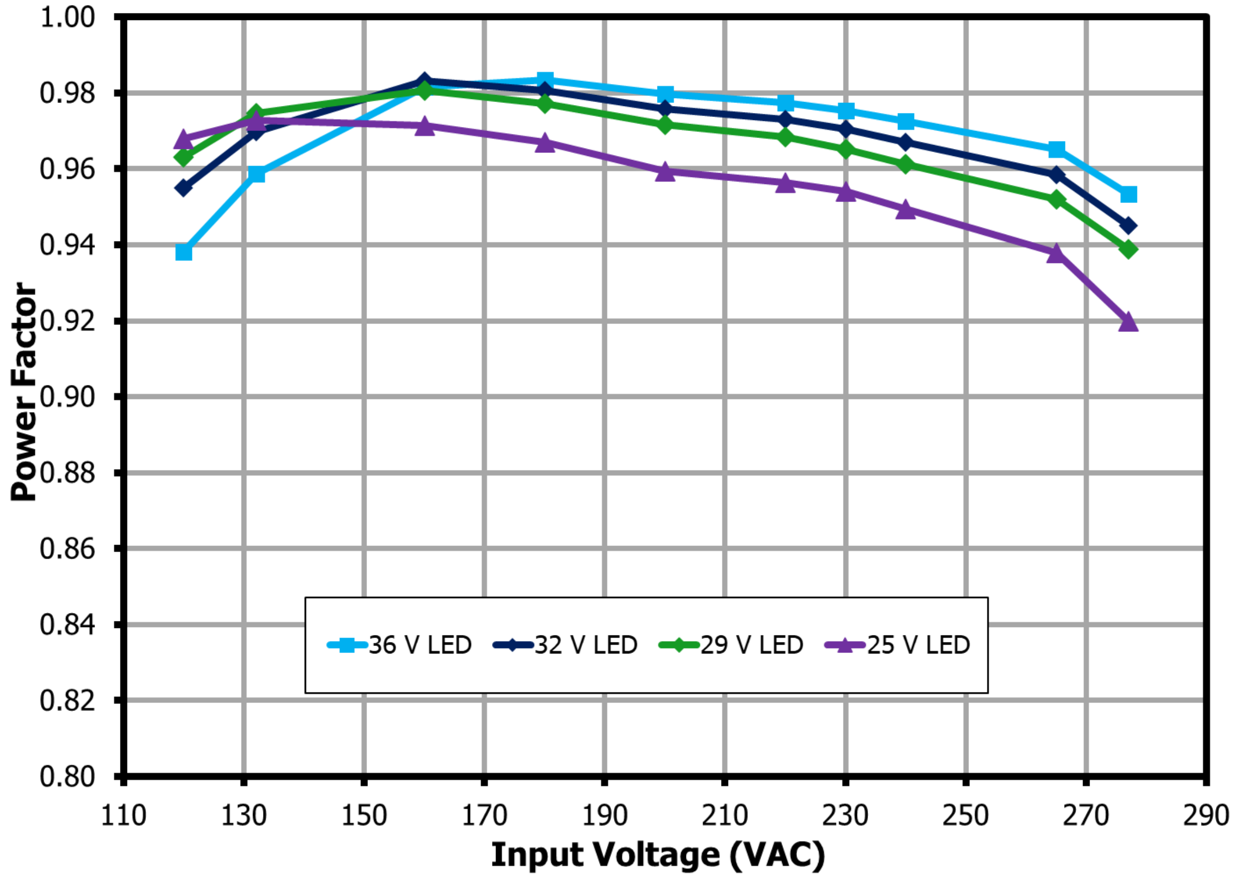


Figure 13 – Power Factor vs Input Line at Different LED Voltage Load.

11.3 Total Harmonic Distortion (THD) vs Input Line Voltage

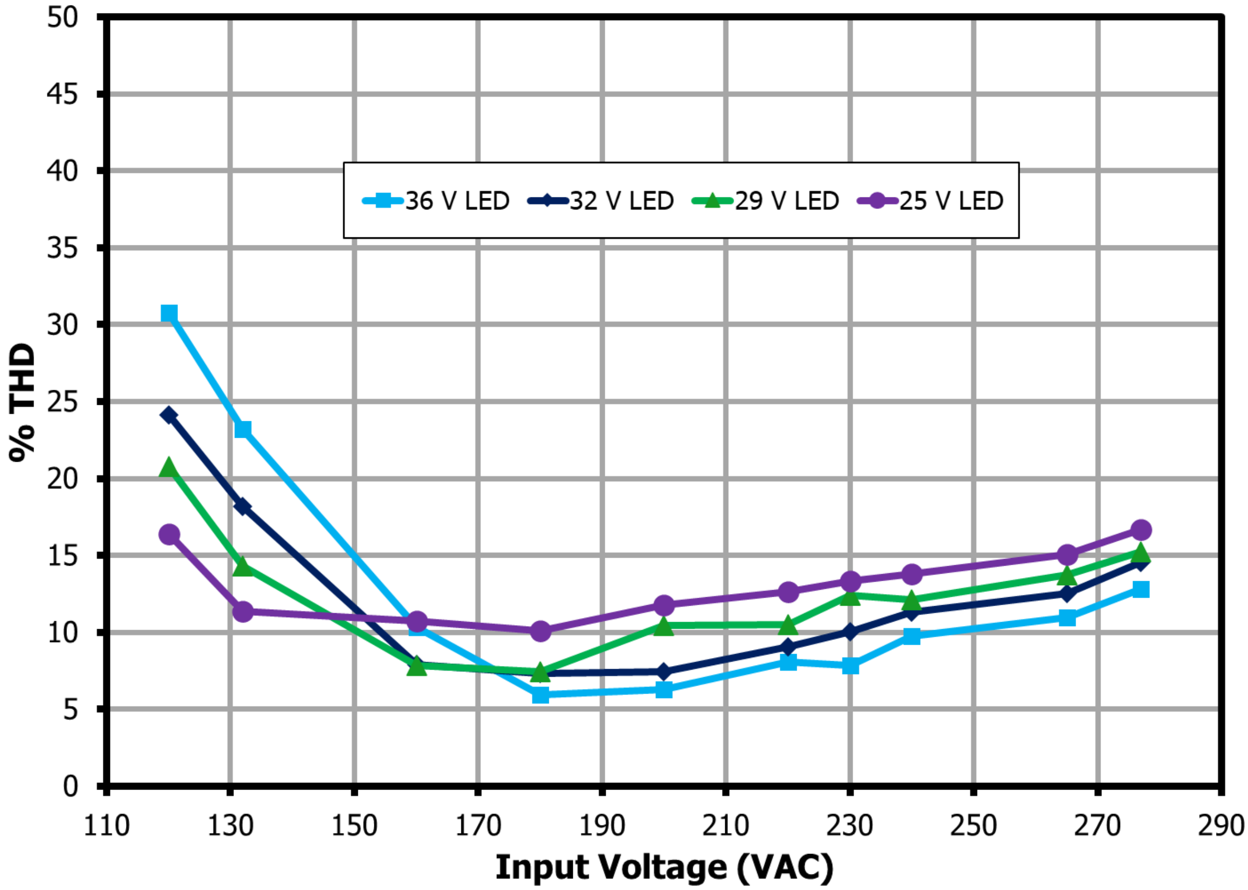


Figure 14 – THD vs Input Line at Different LED Voltage Load.

11.4 Output Current Regulation vs Input Line

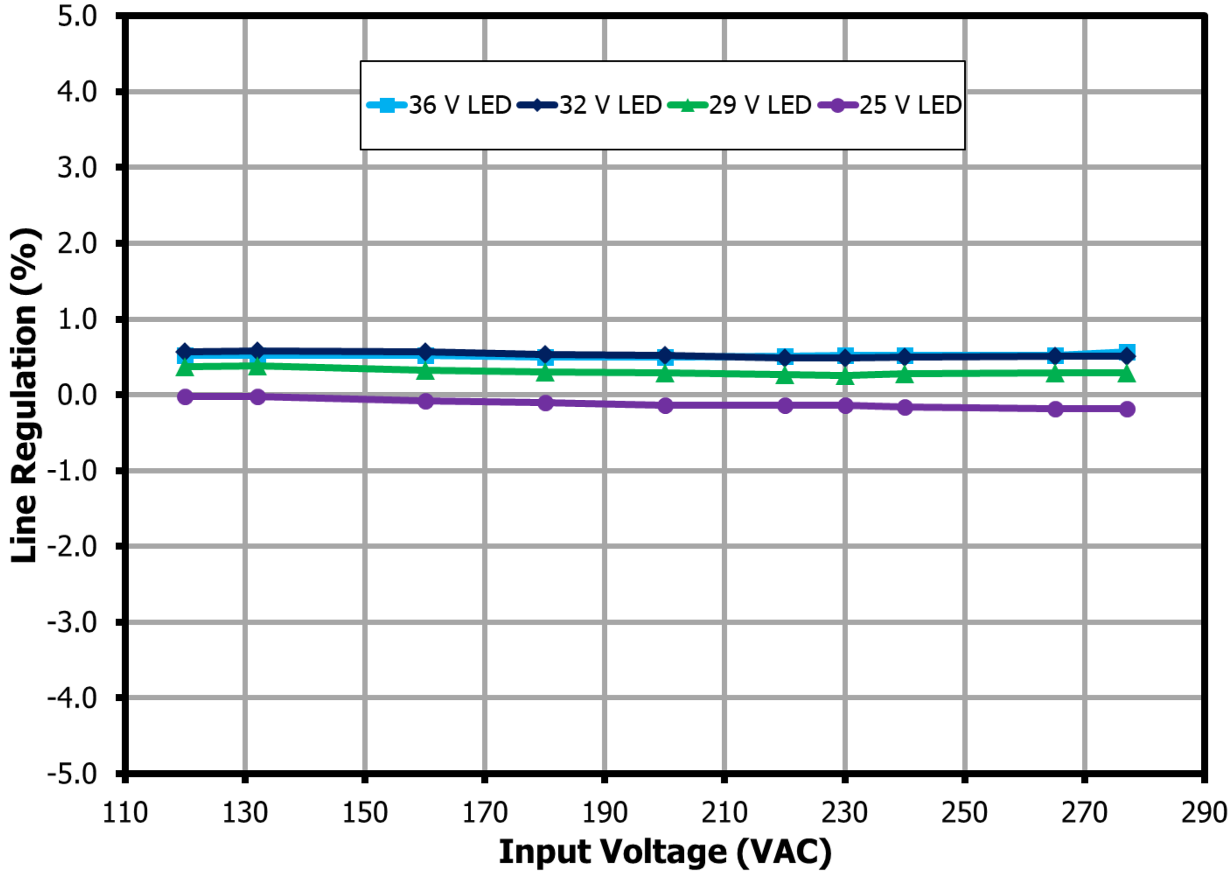


Figure 15 – Output Current Regulation vs Input Line at Different LED Voltage Load.

11.5 Electrical Test Data

11.5.1 CC Operation using LED Load

	Input		Input Measurement					Output 1 Measurement				
	VAC (RMS)	Freq (Hz)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	PF	% THD	V_O (V)	I_O (A)	P_O (W)	% I Reg	Eff
36 V LED	120	60	120	417	46.9	0.94	30.8	35.8	1.13	40.3	0.52	85.9
	132	60	132	369	46.7	0.96	23.2	35.8	1.13	40.3	0.53	86.4
	160	60	160	295	46.4	0.98	10.3	35.8	1.13	40.3	0.52	87.0
	180	60	180	261	46.2	0.98	5.97	35.8	1.13	40.3	0.50	87.2
	200	60	200	236	46.2	0.98	6.29	35.8	1.13	40.3	0.50	87.3
	220	50	220	215	46.2	0.98	8.06	35.8	1.13	40.3	0.51	87.2
	230	50	230	206	46.3	0.98	7.87	35.8	1.13	40.3	0.52	87.1
	240	50	240	199	46.3	0.97	9.75	35.8	1.13	40.3	0.53	87.1
	265	50	265	182	46.6	0.97	11.0	35.8	1.13	40.3	0.53	86.6
	277	60	277	177	46.8	0.95	12.8	35.8	1.13	40.4	0.56	86.3
	Input		**Input Measurement**					**Output 1 Measurement**				
	VAC (RMS)	**Freq (Hz)**	**V_{IN} (RMS)**	**I_{IN} (mA)**	**P_{IN} (W)**	**PF**	**% THD**	**V_O (V)**	**I_O (A)**	**P_O (W)**	**% I Reg**	**Eff**
32 V LED	120	60	120	367	42.0	0.96	24.1	32.1	1.13	36.1	0.56	85.9
	132	60	132	327	41.8	0.97	18.2	32.1	1.13	36.1	0.58	86.3
	160	60	160	264	41.5	0.98	7.9	32.0	1.13	36.1	0.56	86.9
	180	60	180	235	41.5	0.98	7.35	32.1	1.13	36.1	0.54	87.1
	200	60	200	212	41.5	0.98	7.42	32.1	1.13	36.1	0.52	87.0
	220	50	220	194	41.5	0.97	9.08	32.1	1.13	36.1	0.49	86.9
	230	50	230	186	41.6	0.97	10.1	32.1	1.13	36.1	0.48	86.8
	240	50	240	179	41.6	0.97	11.3	32.1	1.13	36.1	0.50	86.6
	265	50	265	165	41.9	0.96	12.6	32.1	1.13	36.1	0.51	86.1
	277	60	277	161	42.0	0.95	14.6	32.1	1.13	36.1	0.51	85.8
	Input		**Input Measurement**					**Output 1 Measurement**				
	VAC (RMS)	**Freq (Hz)**	**V_{IN} (RMS)**	**I_{IN} (mA)**	**P_{IN} (W)**	**PF**	**% THD**	**V_O (V)**	**I_O (A)**	**P_O (W)**	**% I Reg**	**Eff**
29 V LED	120	60	120	331	38.3	0.96	20.8	29.2	1.12	32.8	0.38	85.6
	132	60	132	296	38.1	0.97	14.3	29.2	1.12	32.8	0.38	86.0
	160	60	160	241	37.9	0.98	7.8	29.2	1.12	32.8	0.32	86.5
	180	60	180	215	37.8	0.98	7.42	29.2	1.12	32.8	0.30	86.7
	200	60	200	194	37.8	0.97	10.5	29.2	1.12	32.8	0.29	86.7
	220	50	220	178	37.9	0.97	10.5	29.2	1.12	32.8	0.27	86.5
	230	50	230	171	37.9	0.97	12.4	29.2	1.12	32.8	0.26	86.3
	240	50	240	165	38.0	0.96	12.1	29.2	1.12	32.8	0.28	86.2
	265	50	265	152	38.3	0.95	13.8	29.2	1.12	32.8	0.29	85.7
	277	60	277	148	38.4	0.94	15.3	29.2	1.12	32.8	0.29	85.3
	Input		**Input Measurement**					**Output Measurement**				
	VAC (RMS)	**Freq (Hz)**	**V_{IN} (RMS)**	**I_{IN} (mA)**	**P_{IN} (W)**	**PF**	**% THD**	**V_O (V)**	**I_O (A)**	**P_O (W)**	**% I Reg**	**Eff**
25 V LED	120	60	120	283	32.9	0.97	16.4	25.0	1.12	27.9	-0.02	85.0
	132	60	132	255	32.7	0.97	11.4	25.0	1.12	27.9	-0.03	85.4
	160	60	160	210	32.6	0.97	10.7	24.9	1.12	27.9	-0.08	85.7
	180	60	180	187	32.5	0.97	10.1	24.9	1.12	27.9	-0.11	85.9
	200	60	200	169	32.5	0.96	11.8	24.9	1.12	27.9	-0.13	85.8
	220	50	220	155	32.6	0.96	12.6	24.9	1.12	27.9	-0.14	85.6
	230	50	230	149	32.7	0.95	13.3	24.9	1.12	27.9	-0.13	85.4
	240	50	240	144	32.7	0.95	13.8	24.9	1.12	27.9	-0.16	85.2
	265	50	265	132	32.9	0.94	15.1	24.9	1.12	27.9	-0.18	84.7
	277	60	277	130	33.0	0.92	16.7	24.9	1.12	27.9	-0.19	84.4

Table 11 – Electrical Test Data.

11.5.2 CV Operation using an E-Load

Input		Input Measurement					Output 1 Measurement				Efficiency
VAC (RMS)	Freq (Hz)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	PF	% THD	V_O (V)	I_O (A)	P_O (W)	% I Reg	
120	60	120	374	42.5	0.95	26.3	36.7	1.00	36.7	-0.06	86.3
132	60	132	334	42.3	0.96	22.0	36.7	1.00	36.7	-0.06	86.8
160	60	160	270	41.9	0.97	14.8	36.7	1.00	36.7	-0.06	87.5
180	60	180	238	41.9	0.98	9.09	36.7	1.00	36.7	-0.06	87.5
200	60	200	215	42.0	0.97	6.29	36.7	1.00	36.7	-0.07	87.4
220	50	220	196	42.0	0.98	7.29	36.7	1.00	36.7	-0.07	87.3
230	50	230	188	42.1	0.97	7.62	36.7	1.00	36.7	-0.07	87.2
240	50	240	181	42.1	0.97	8.58	36.7	1.00	36.7	-0.07	87.2
265	50	265	165	42.2	0.96	9.52	36.7	1.00	36.7	-0.07	86.9
277	60	277	160	42.3	0.95	11.6	36.7	1.00	36.7	-0.07	86.8

Table 12 – Electrical Test Data at CV Operation.

11.6 Individual Harmonics Content

Individual current harmonics were measured and shown to be below the Class C limit.

Load: LED Load.
V$_{IN}$: 230 V 60 Hz.
Ambient Temperature: 25 °C.
Soak Time: 5 minutes.

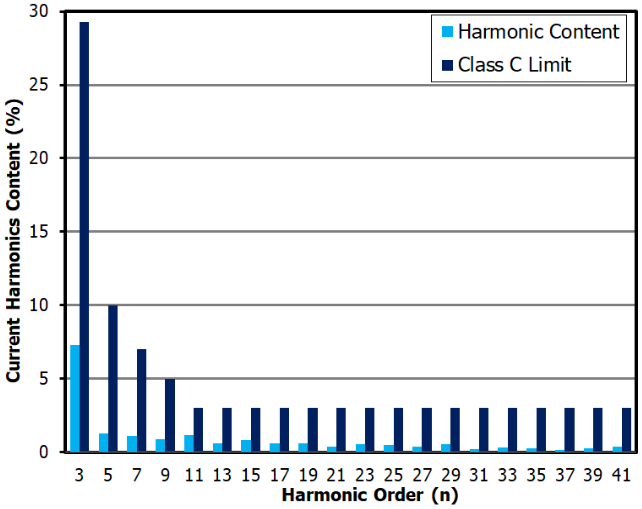


Figure 16 – Individual Harmonics Content, 36 V LED.

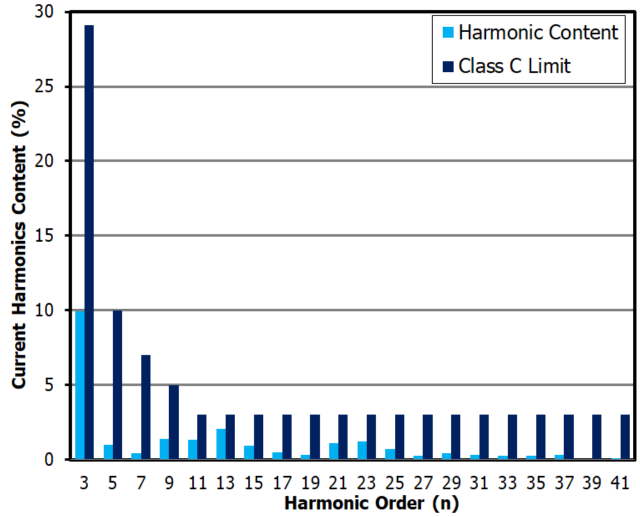


Figure 17 – Individual Harmonics Content, 32 V LED.

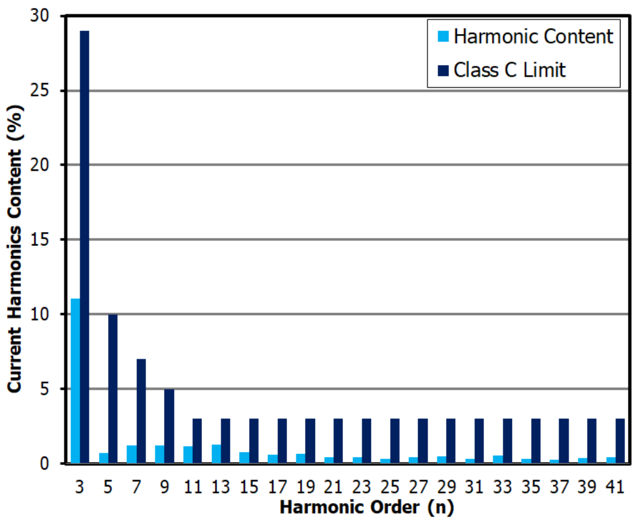


Figure 18 – Individual Harmonics Content, 29 V LED.

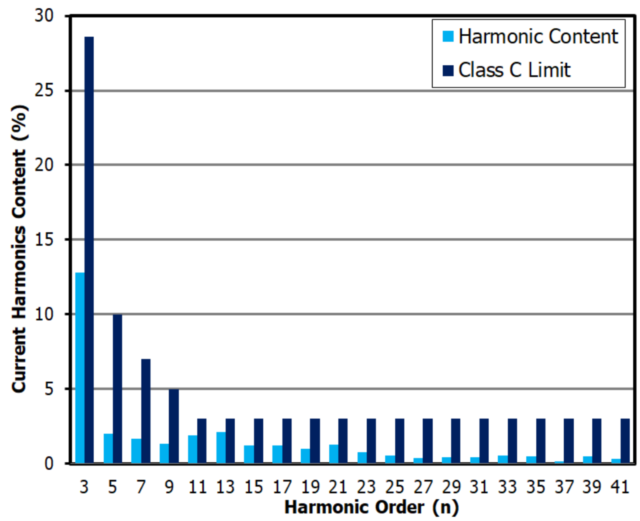


Figure 19 – Individual Harmonics Content, 25 V LED.

11.7 Flicker Performance

% Flicker data was measured through output ripple current using:

$$\% \, Flicker = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \times 100\%$$

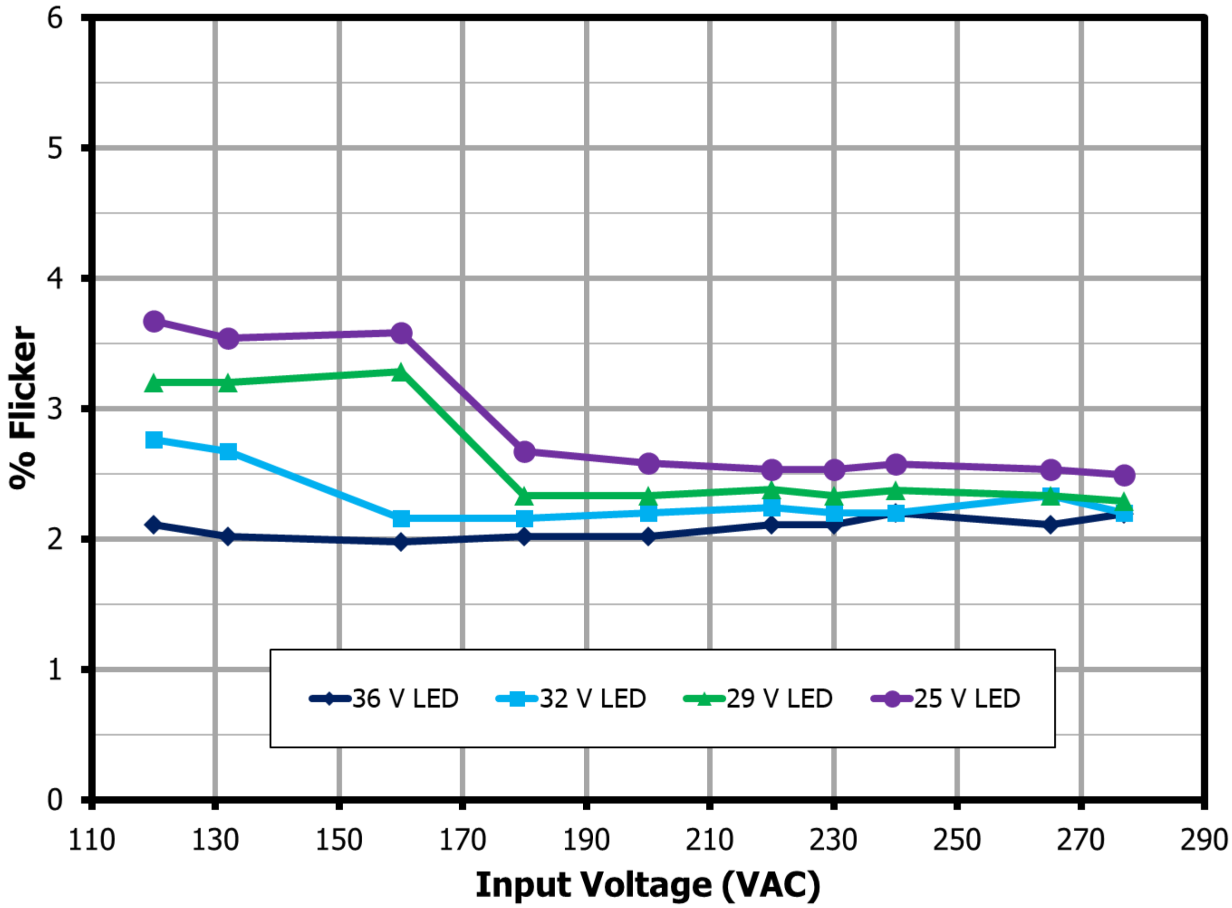


Figure 20 – % Flicker vs Input line at Different LED Voltage Load.

11.8 Output Ripple Current

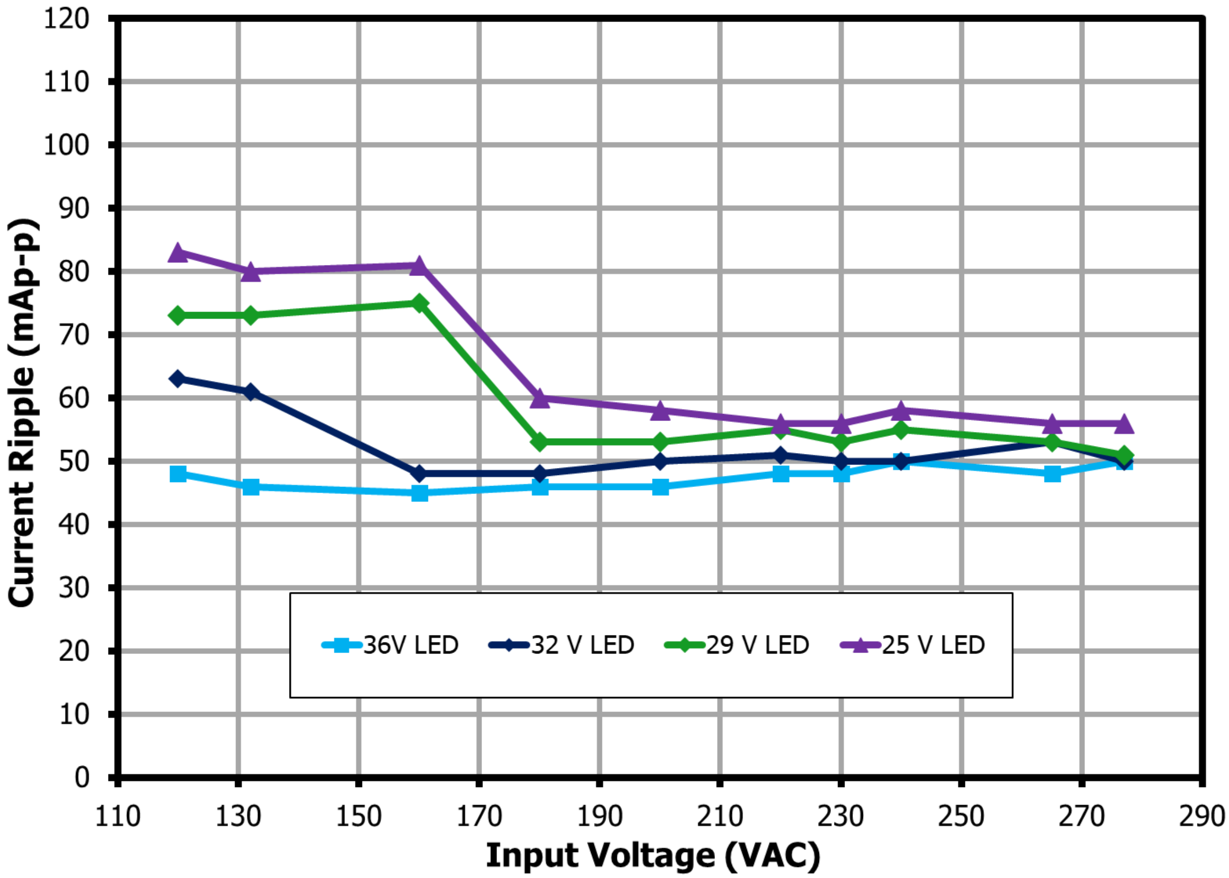


Figure 21 – Ripple Current at Different LED Voltage Load.

11.9 Output Ripple Voltage at Constant Voltage Mode

Note: C33 (4.7 µF) should be removed for constant-voltage (CV) applications.

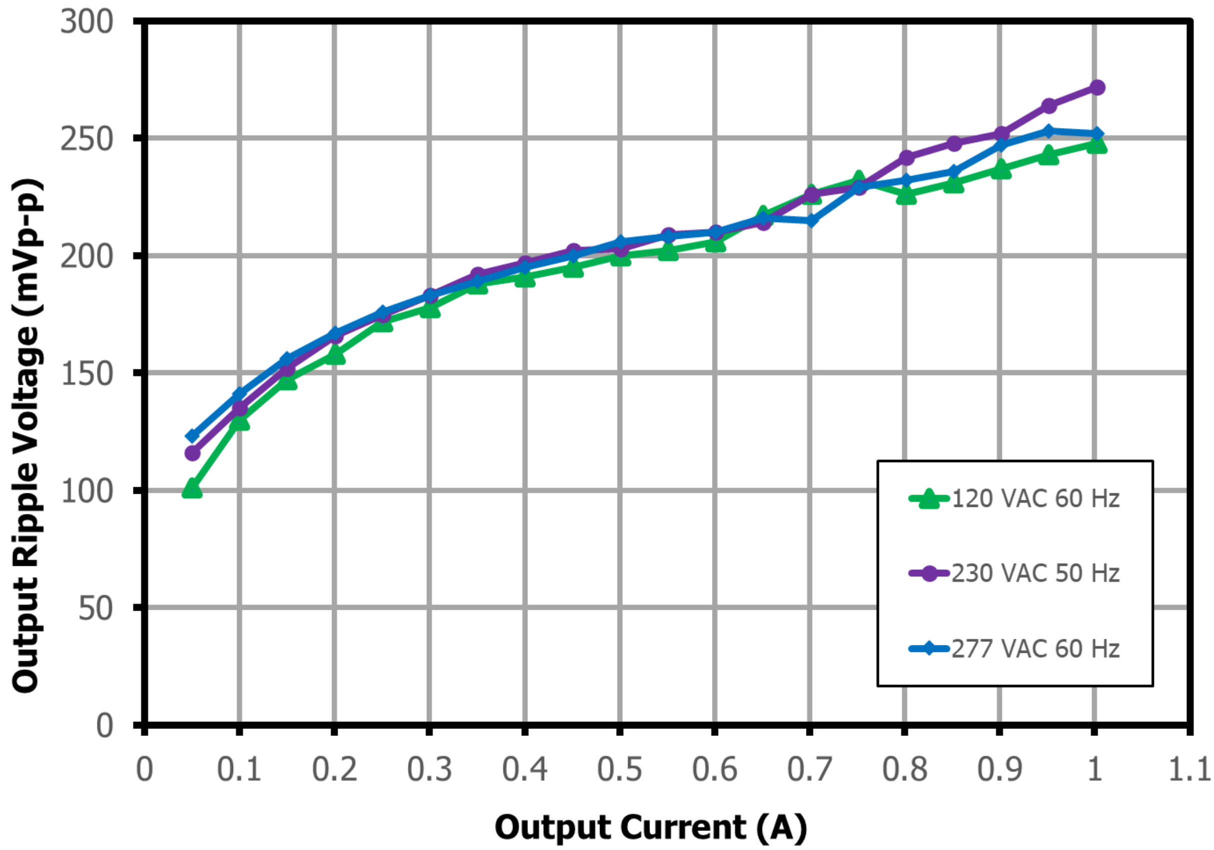


Figure 22 – Output Ripple Voltage vs Load at Different Input Line Voltage.

11.10 Output CVCC Characteristic Curve

Note: Less than 5% flicker is achieved across the 36 V to 25 V output voltage range.

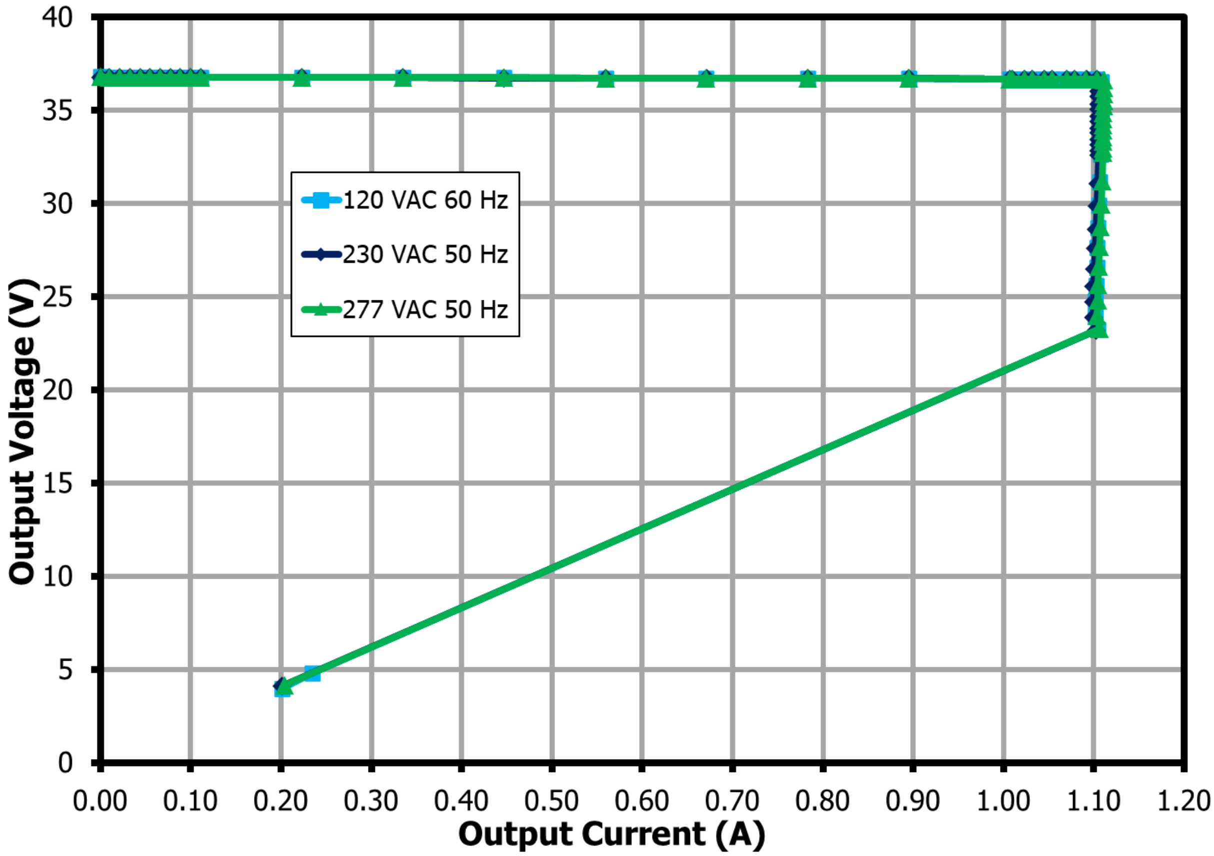


Figure 23 – CVCC Curve at Different Input Line.

11.11 Dimming Curves

11.11.1 Dimming Set-up

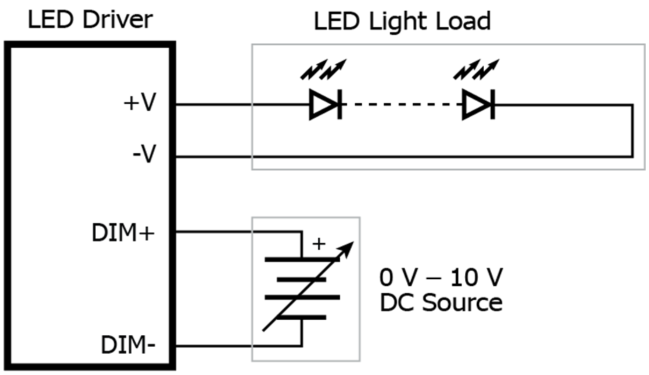


Figure 24 – 0 - 10 V Analog Dimming.

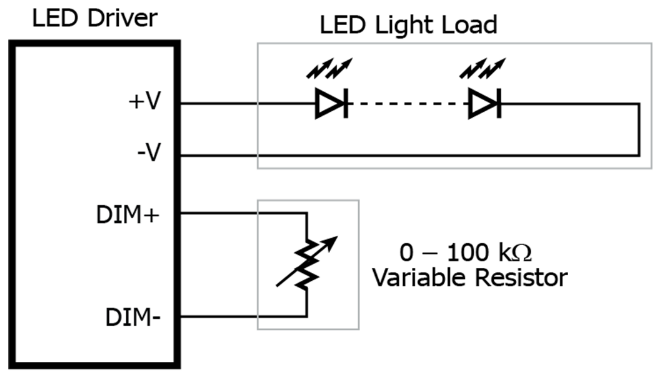


Figure 25 – Variable Resistor Dimming.

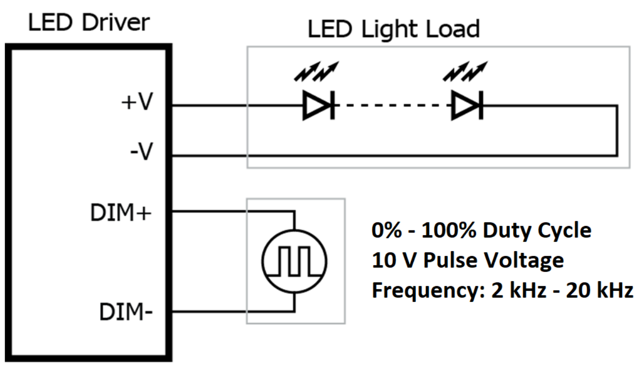


Figure 26 – PWM Dimming.

11.11.2 0-10 V Analog Dimming Curve

Tested using a DC source as the analog dimming input, supplied to terminal J11.

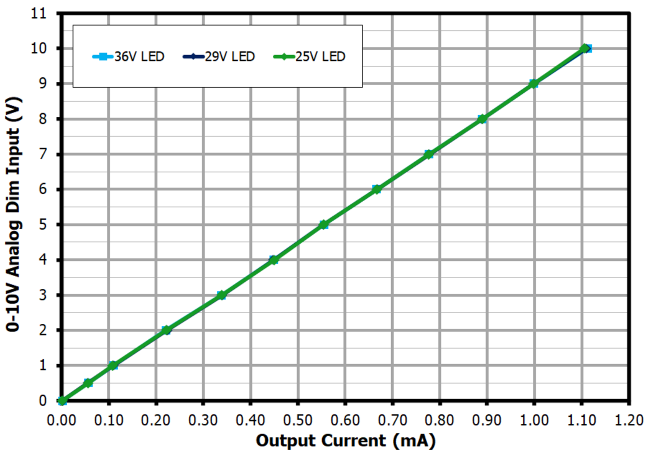


Figure 27 – 120 VAC, 60 Hz. 0 - 10 V Dim Input.

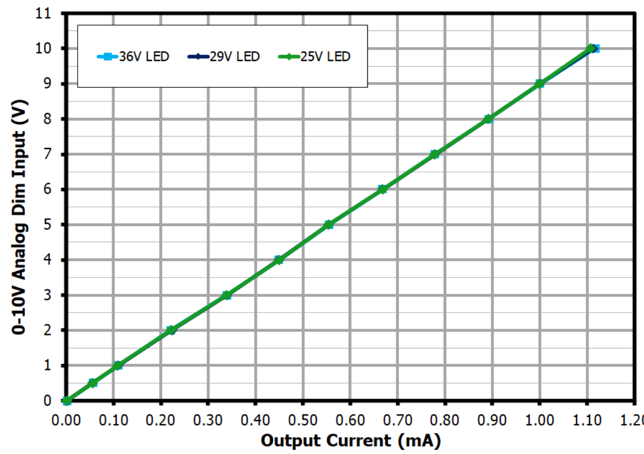


Figure 28 – 230 VAC, 60 Hz. 0 - 10 V Dim Input.

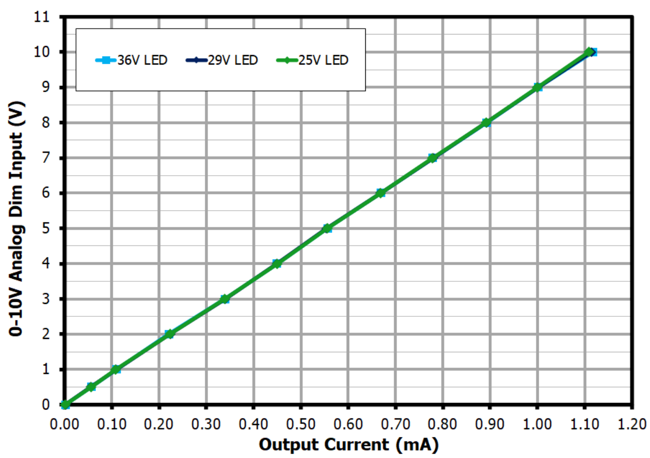


Figure 29 – 277 VAC, 60 Hz. 0 - 10 V Dim Input.

11.11.3 0-100 kΩ Resistor Dimming Curve

Tested using a variable resistor (0 Ω to 100 kΩ) as the dimming input, connected to terminal J11.

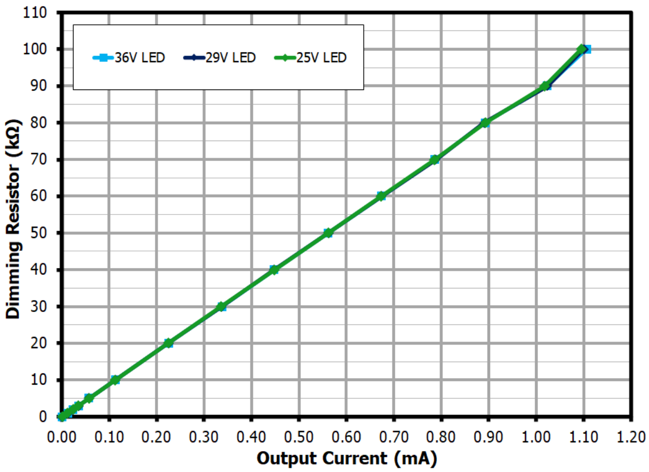


Figure 30 – 120 VAC, 60 Hz. Resistor Dim Input.

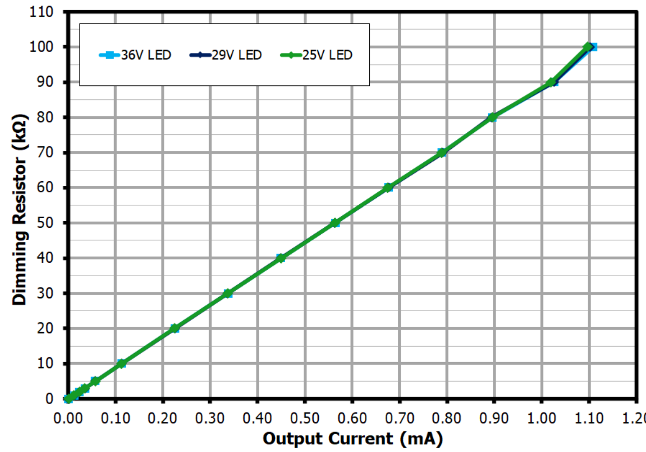


Figure 31 – 230 VAC, 60 Hz. Resistor Dim Input.

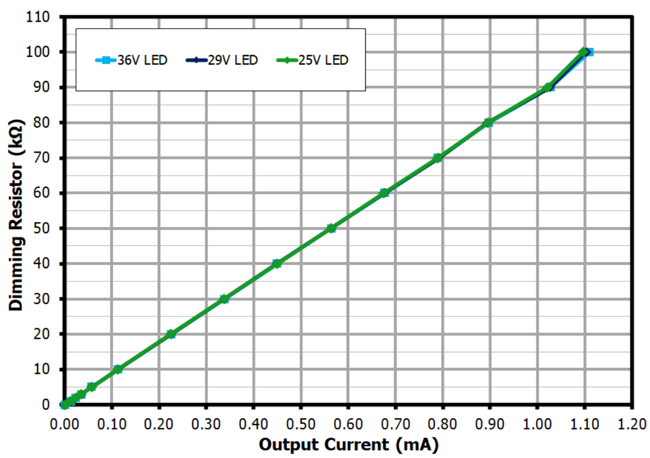


Figure 32 – 277 VAC, 60 Hz. Resistor Dim Input.

11.11.4 PWM Dimming Curve

Testing was performed using a 10 V PWM signal connected to the dimming input terminal J11 (see Fig. 26). The PWM duty cycle was varied from 0 % to 100%, with the PWM frequency set to 2 kHz.

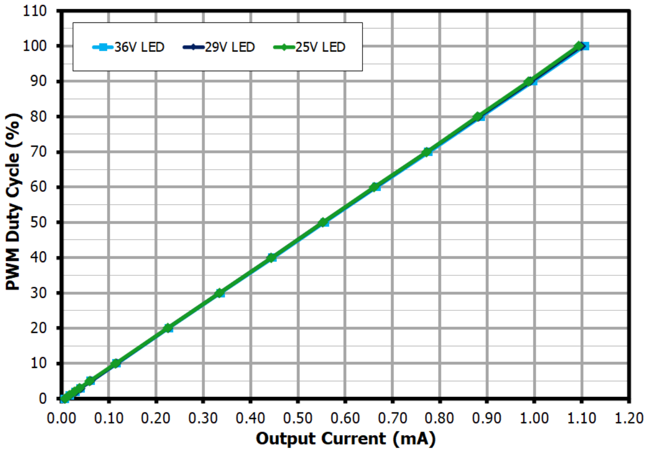


Figure 33 – 120 VAC, 60 Hz. PWM Dim Input.

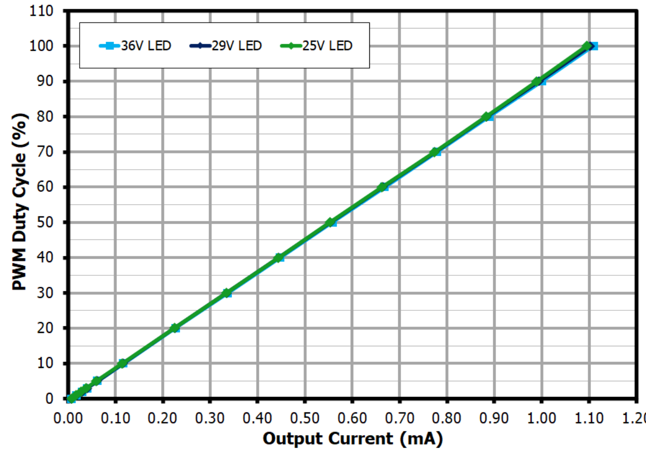


Figure 34 – 230 VAC, 60 Hz. PWM Dim Input.

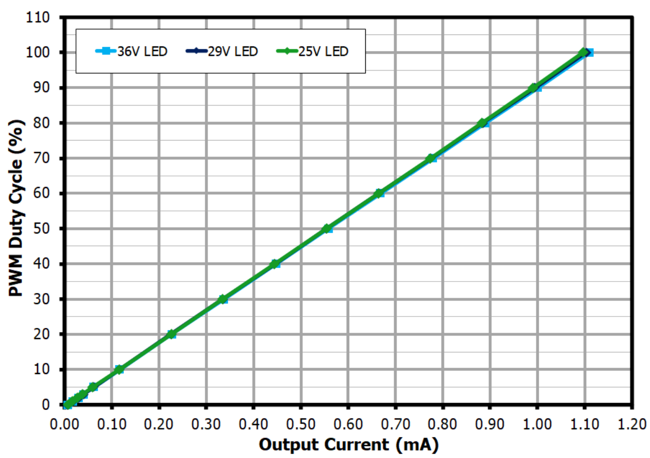


Figure 35 – 277 VAC, 60 Hz. PWM Dim Input.

11.12 Thermal Test

11.12.1 Thermal Test at Room Temperature

The open-frame PSU was soaked for at least one hour at room ambient temperature (25 °C) before capturing a thermal scan using a FLIR camera.

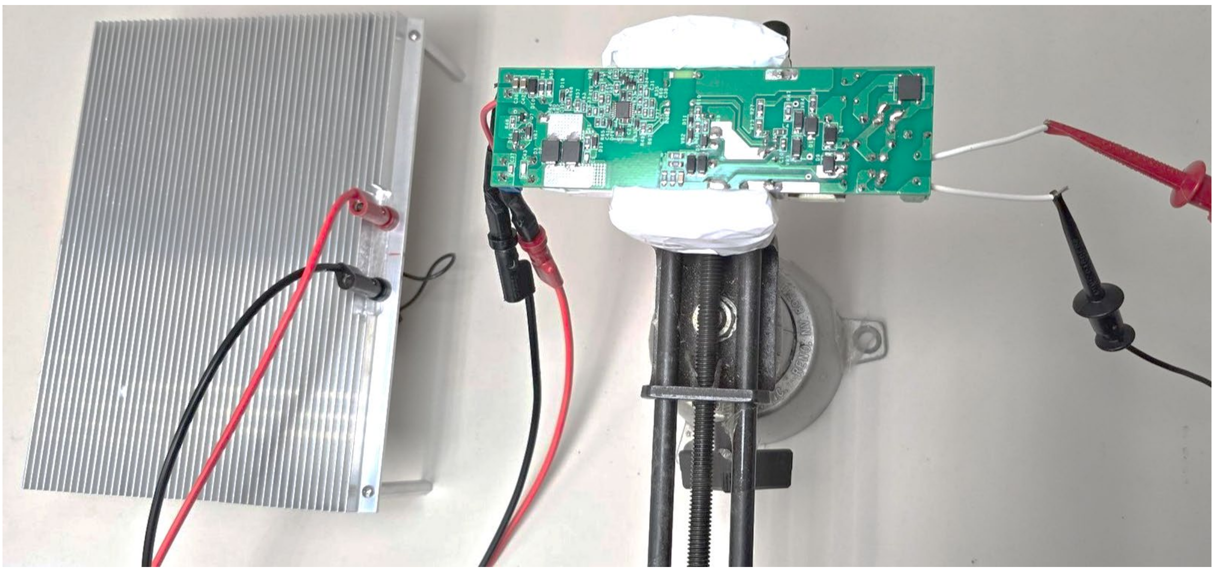


Figure 36 – Room Temperature Thermal Scan Test Set-up.

11.12.1.1 Thermal Scan Test Data (Summary)

The following thermal scan data showed that the heating components remained well below their maximum temperature ratings across the entire input voltage range.

Reference Designation	Part Description	Temperature °C		
		120 VAC	230 VAC	277 VAC
U2	TNY5075E	81.1	71.5	80.7
T2	SVF Inductor	70.3	70.6	74.2
T1	Flyback TRF	65.6	67.1	70.5
D9	SVF Boost Diode 1	77.6	68.9	71.3
D4	SVF Boost Diode 2	73.1	63.2	65.4
BR1	Bridge Rectifier	70.8	52.9	51.1
D3	Output Diode 1	68.7	68.5	69.3
D2	Output Diode 2	68.9	69.4	70.4

Table 13 – Room Temperature Thermal Scan Test Data.

11.12.1.2 Thermal Scan at 120 VAC 36 V LED String

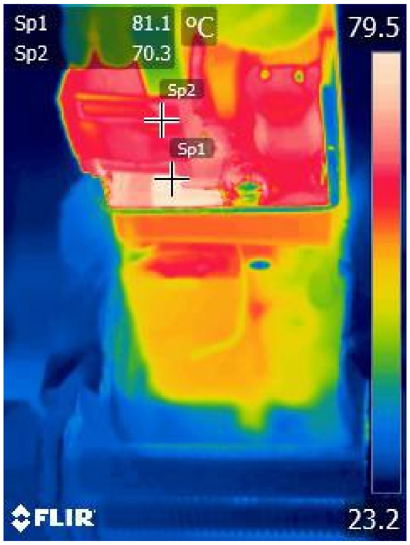


Figure 37 – Thermal Scan 120 V 36 V / 1.12 A
Sp1: U2-(TNY5075E): **81.1 °C**
Sp2: T2-(SVF Inductor): **70.3 °C**

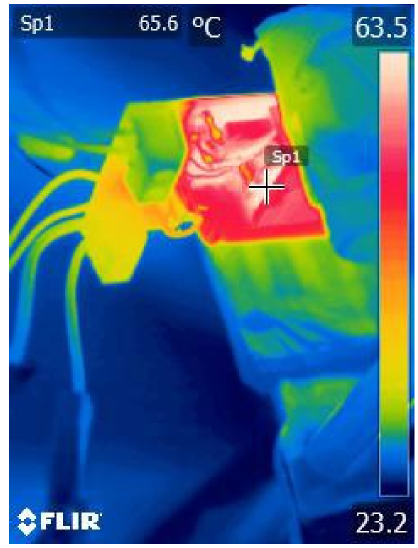


Figure 38 – Thermal Scan 100 V 36 V / 1.12 A
Sp1: T1-(Flyback TRF): **65.6 °C**

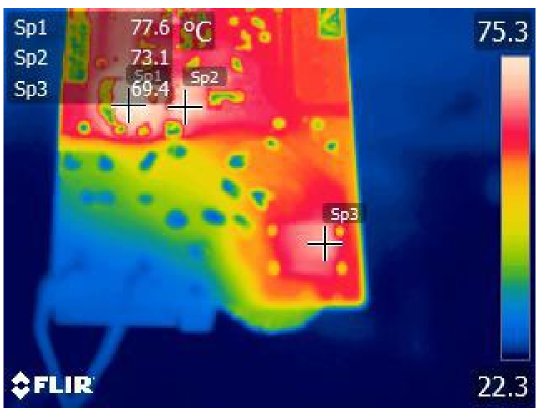


Figure 39 – Thermal Scan 120 V 36 V / 1.12 A
Sp1: D9-(SVF Boost Diode1): **77.6 °C**
Sp2: D4-(SVF Boost Diode2): **73.1 °C**
Sp3: BR1-(Bridge Diode): **70.8 °C**

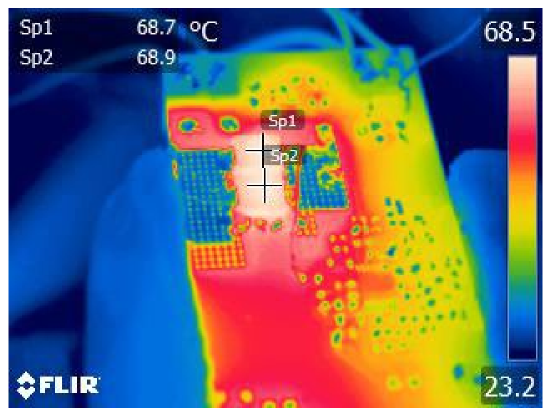


Figure 40 – Thermal Scan 120 V 36 V / 1.12 A
Sp1: D3-(Output Diode1): **68.7 °C**
Sp2: D2-(Output Diode1): **68.9 °C**

11.12.1.3Thermal Scan at 230 VAC 36 V LED String

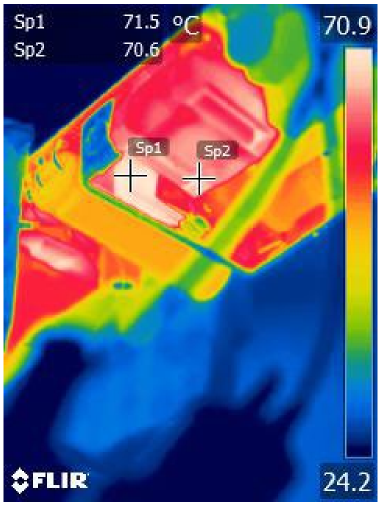


Figure 41 – Thermal Scan 230 V 36 V / 1.12 A
Sp1: U2-(TNY5075E): **71.5 °C**
Sp2: T2-(SVF Inductor): **70.6 °C**

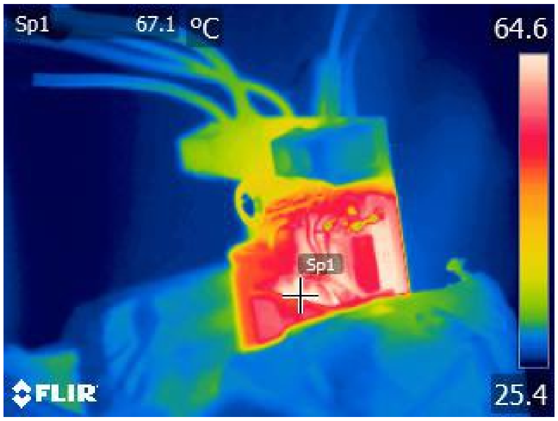


Figure 42 – Thermal Scan 230 V 36 V / 1.12 A
Sp1: T1-(Flyback TRF): **67.1 °C**

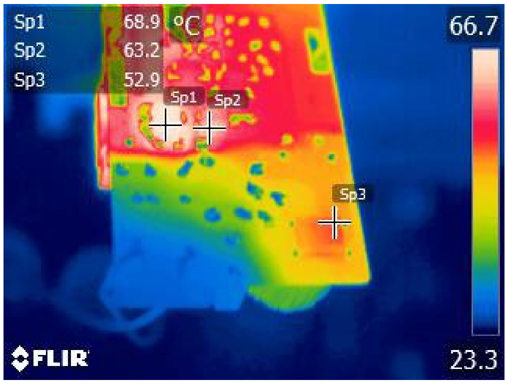


Figure 43 – Thermal Scan 230 V 36 V / 1.12 A
Sp1: D9-(SVF Boost Diode1): **68.9 °C**
Sp2: D4-(SVF Boost Diode2): **63.2 °C**
Sp3: BR1-(Bridge Diode): **52.9 °C**

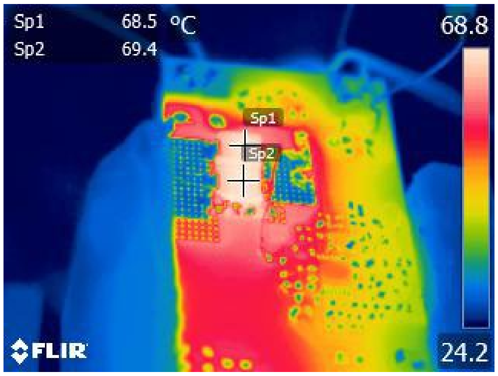


Figure 44 – Thermal Scan 230 V 36 V / 1.12 A
Sp1: D3-(Output Diode1): **68.5 °C**
Sp2: D2-(Output Diode1): **69.4 °C**

11.12.1.4 Thermal Scan at 230 VAC 36 V LED String

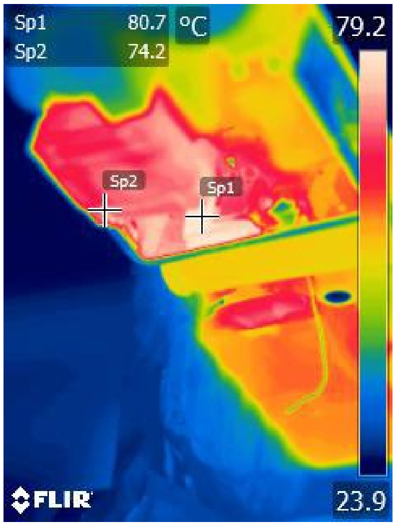


Figure 45 – Thermal Scan 277 V 36 V / 1.12 A
Sp1: U2-(TNY5075E): **80.7 °C**
Sp2: T2-(SVF Inductor): **74.2 °C**

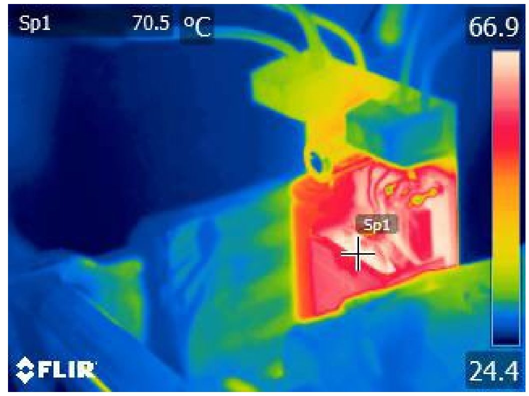


Figure 46 – Thermal Scan 277 V 36 V / 1.12 A
Sp1: T1-(Flyback TRF): **70.5 °C**

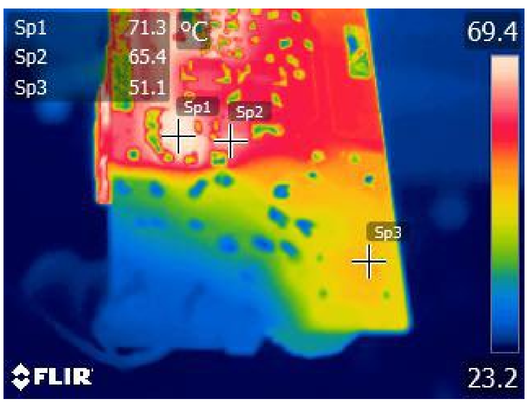


Figure 47 – Thermal Scan 277 V 36 V / 1.12 A
Sp1: D9-(SVF Boost Diode1): **71.3 °C**
Sp2: D4-(SVF Boost Diode2): **65.4 °C**
Sp3: BR1-(Bridge Diode): **51.1 °C**

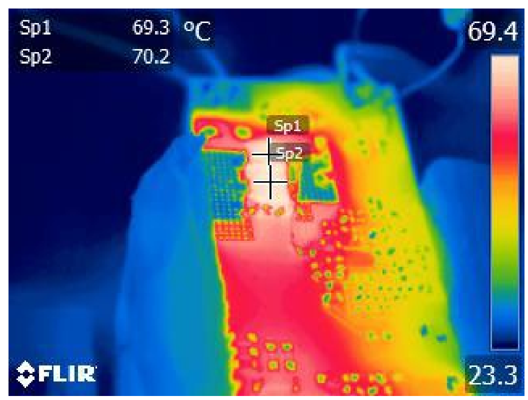


Figure 48 – Thermal Scan 277 V 36 V / 1.12 A
Sp1: D3-(Output Diode1): **69.3 °C**
Sp2: D2-(Output Diode1): **70.2 °C**

11.12.2 Thermal Test at 55 °C Ambient

Type K thermocouples were used to measure component temperatures. The open frame power supply unit (PSU) was placed inside an enclosed housing and then positioned in an environmental chamber set to a static temperature of 55 °C. The unit was loaded using a 36 V LED string loading the PSU to 40 W power. The thermal profile was recorded after a 2 hour soak time.

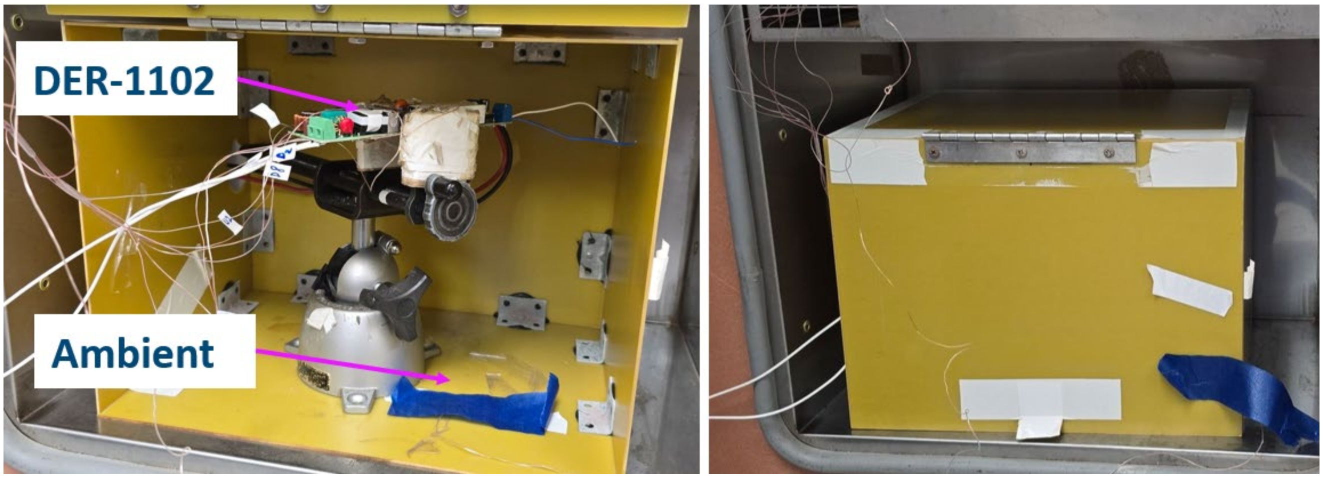


Figure 49 – Thermal Scan Test Set-up at 55 °C Ambient.

11.12.2.1 Thermal Test Data Summary at 55 °C Ambient

The following thermal scan data showed that the heating components remained well below their maximum temperature ratings across the entire input voltage range.

Item	CKT Code	Description	Temperature (°C)		
			100 VAC	230 VAC	277 VAC
1	D9	SVF Boost Diode 1	110	96.1	99.5
2	D4	SVF Boost Diode 2	110	92.6	95.0
3	T1	Flyback TRF	98.0	95.0	97.5
4	T2	SVF Boost Inductor	107	103	110
5	U2	TNY5075E	122	104	112
6	D8	Primary Snubber Diode	101	90.6	93.7
7	D2	Output Diode 1	102	99.6	103
8	Ambient		55.4	55.7	55.8

Table 14 – Thermal Test Data at 55 °C Ambient Temperature.

11.12.2.2 Component Thermal Profile at 55 °C Ambient

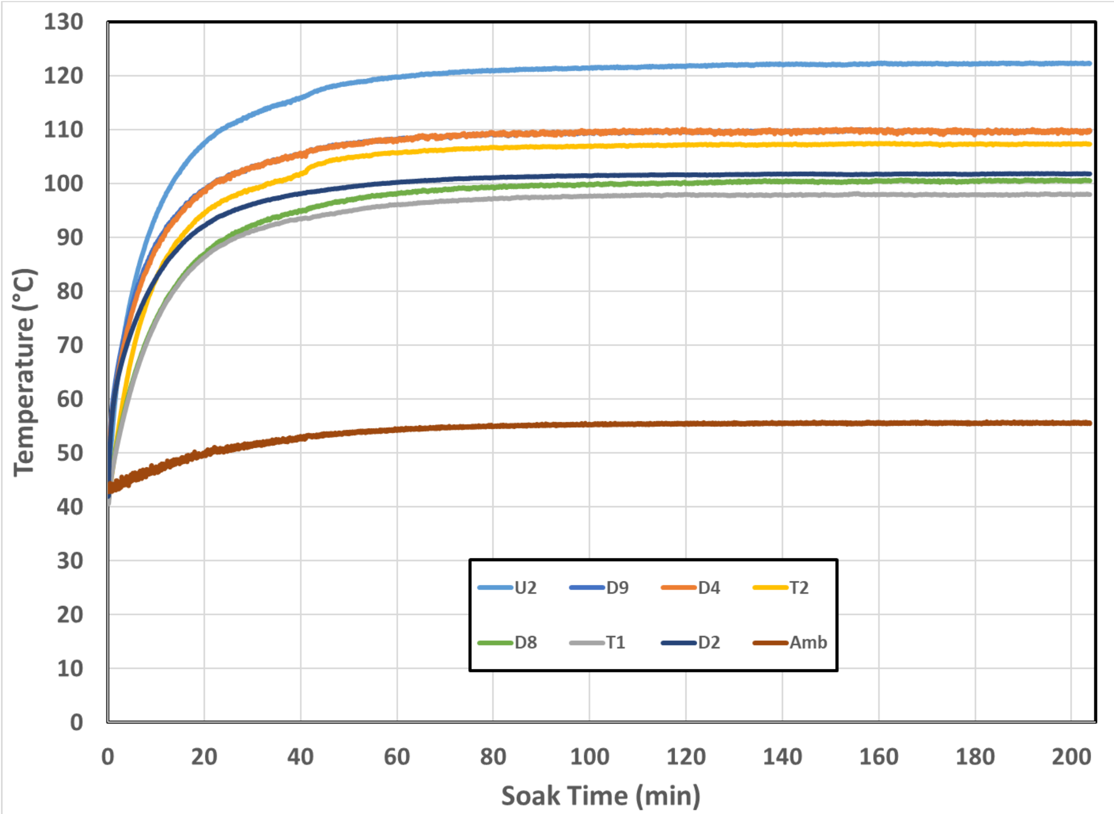


Figure 50 – Thermal Profile at 120 VAC, 36 V Full Load.

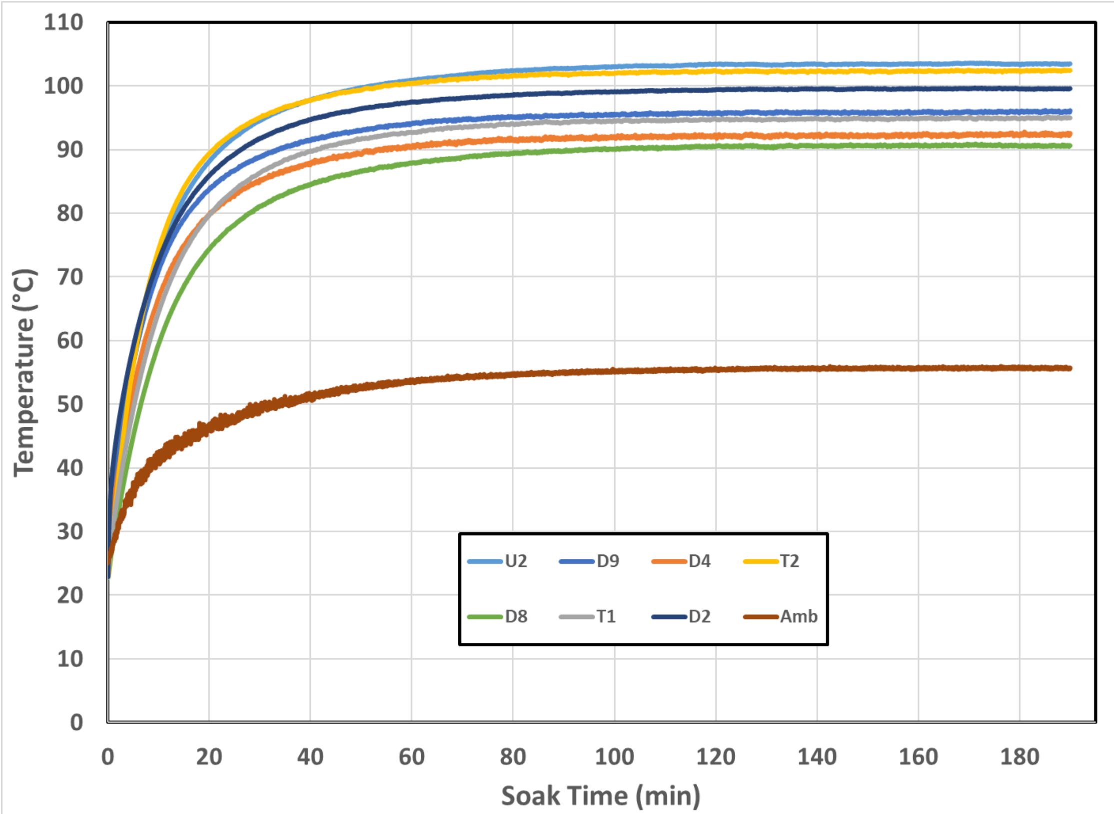


Figure 51 – Thermal Profile at 230 VAC, 36 V Full Load.

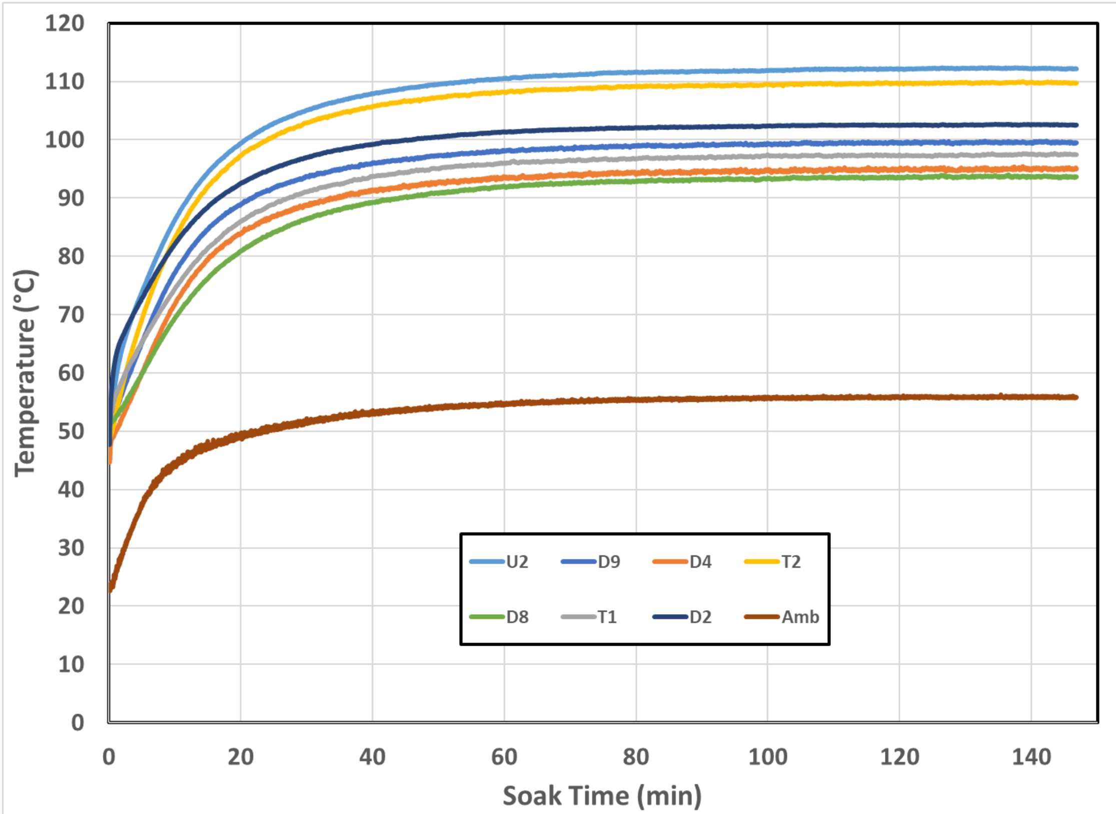


Figure 52 – Thermal Profile at 277 VAC, 36 V Full Load.

12 Waveforms

12.1 Start-up Profile in CC (Constant Current) Operation

12.1.1 Start-up Profile for 36 V LED String

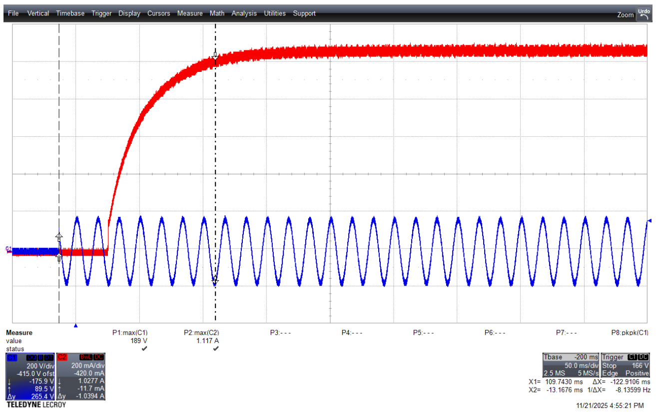


Figure 53 – 120 VAC, 60 Hz. 36 V LED String.
CH1: V_{IN}, 200 V / div., 50 ms / div.
CH2: I_{OUT}, 200 mA / div., ms / div.
$t_{ON\ Delay}$ = 123 ms
$I_{OUT\ Max}$ = 1.12 A

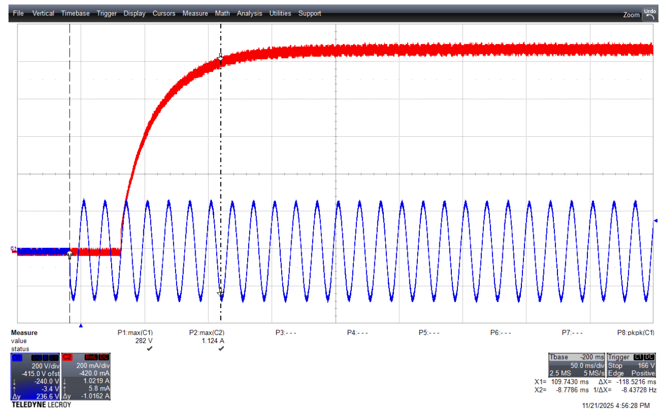


Figure 54 – 180 VAC, 50 Hz. 36 V LED String.
CH1: V_{IN}, 200 V / div., 50 ms / div.
CH2: I_{OUT}, 200 mA / div., ms / div.
$t_{ON\ Delay}$ = 118 ms
$I_{OUT\ Max}$ = 1.12 A

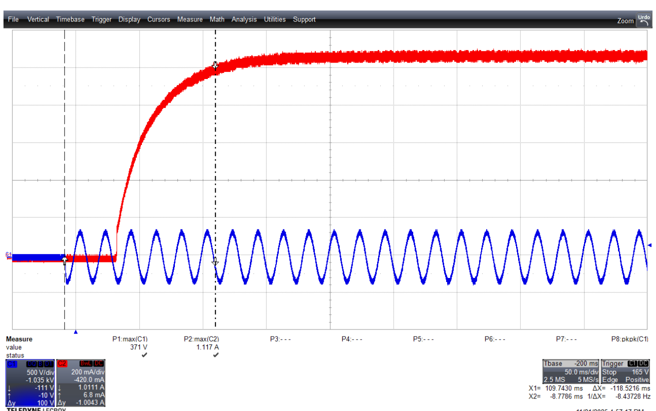


Figure 55 – 230 VAC, 50 Hz. 36 V LED String.
CH1: V_{IN}, 500 V / div., 50 ms / div.
CH2: I_{OUT}, 200 mA / div., 50 ms / div.
$t_{ON\ Delay}$ = 119 ms
$I_{OUT\ Max}$ = 1.12 A

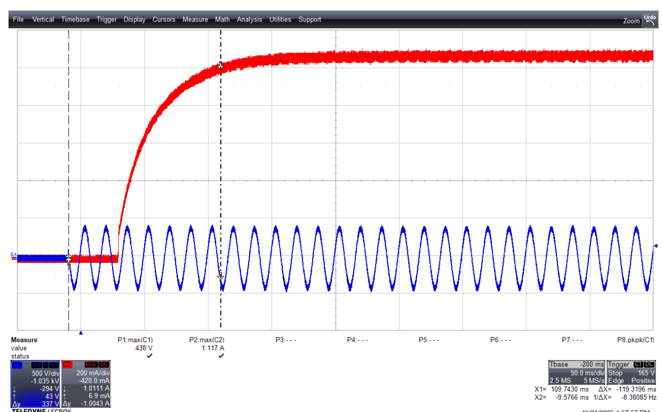


Figure 56 – 277 VAC, 50 Hz. 36 V LED String.
CH1: V_{IN}, 500 V / div., 50 ms / div.
CH2: I_{OUT}, 200 mA / div., 50 ms / div.
$t_{ON\ Delay}$ = 119 ms
$I_{OUT\ Max}$ = 1.12 A

12.1.2 Start-up Profile for 25 V LED String

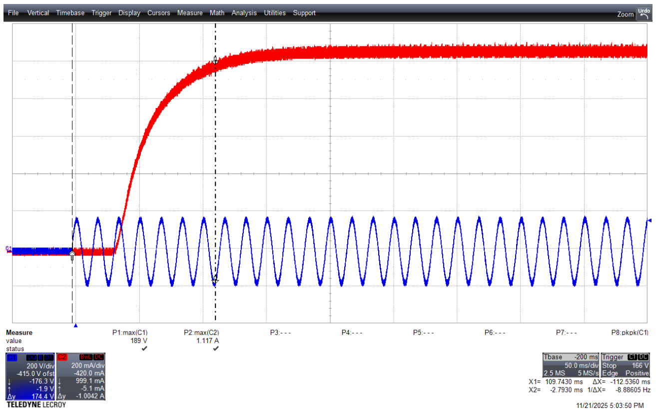


Figure 57 – 120 VAC, 60 Hz. 25 V LED String.
CH1: V_{IN}, 200 V / div., 50 ms / div.
CH2: I_{OUT}, 200 mA / div., 50 ms / div.
$t_{ON\ Delay}$ = 113 ms
$I_{OUT\ Max}$ = 1.12 A

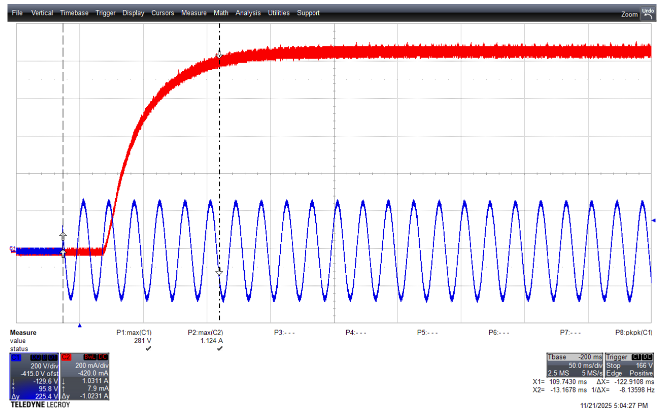


Figure 58 – 180 VAC, 50 Hz. 25 V LED String.
CH1: V_{IN}, 200 V / div., 50 ms / div.
CH2: I_{OUT}, 200 mA / div., 50 ms / div.
$t_{ON\ Delay}$ = 123 ms
$I_{OUT\ Max}$ = 1.12 A

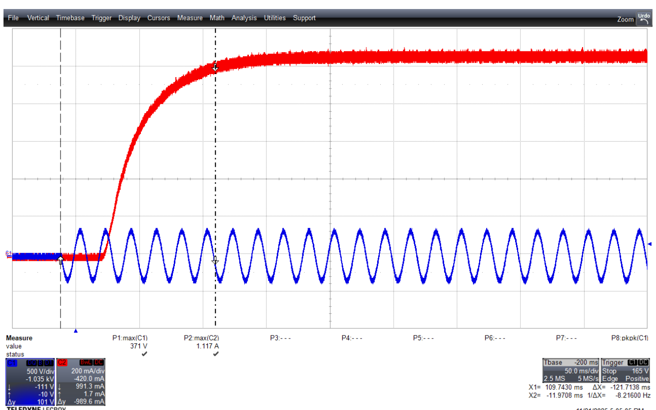


Figure 59 – 230 VAC, 50 Hz. 25 V LED String.
CH1: V_{IN}, 500 V / div., 50 ms / div.
CH2: I_{OUT}, 200 mA / div., 50 ms / div.
$t_{ON\ Delay}$ = 122 ms
$I_{OUT\ Max}$ = 1.12 A

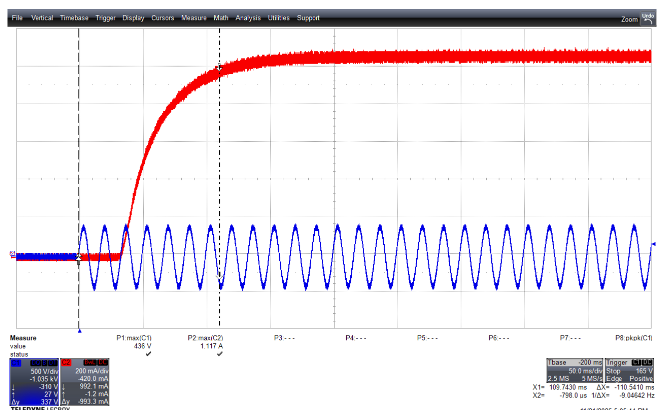


Figure 60 – 277 VAC, 50 Hz. 25 V LED String.
CH1: V_{IN}, 500 V / div., 50 ms / div.
CH2: I_{OUT}, 200 mA / div., 50 ms / div.
$t_{ON\ Delay}$ = 111 ms
$I_{OUT\ Max}$ = 1.12 A

12.2 Start-up Profile in CV Operation

Note: C33 (4.7 μF) should be removed for constant-voltage (CV) applications.

12.2.1 Start-Up Profile at 1 A Load

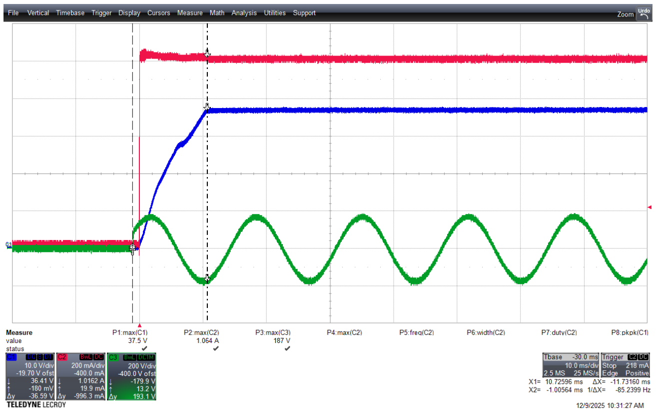


Figure 61 – 120 VAC, 60 Hz. 1 A CC Load
CH1: V_{OUT}, 10 V / div., 10 ms / div.
CH2: I_{OUT}, 200 mA / div., 10 ms / div.
CH3: V_{IN}, 200 V / div., 10 ms / div.
$t_{ON\ Delay}$ = 12 ms
$V_{OUT\ Max}$ = 37.5 V

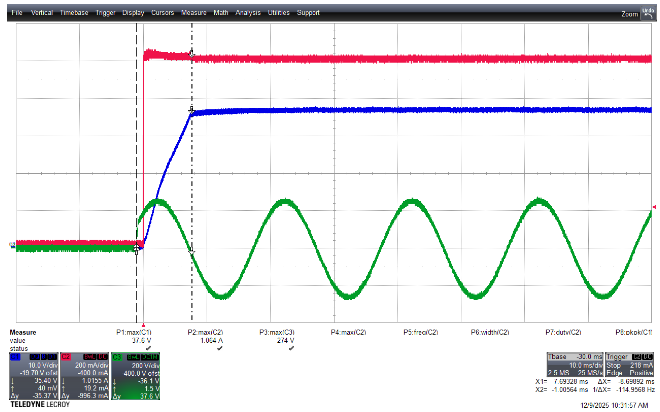


Figure 62 – 180 VAC, 50 Hz. 1 A CC Load
CH1: V_{OUT}, 10 V / div., 10 ms / div.
CH2: I_{OUT}, 200 mA / div., 10 ms / div.
CH3: V_{IN}, 200 V / div., 10 ms / div.
$t_{ON\ Delay}$ = 8.7 ms
$V_{OUT\ Max}$ = 37.6 V

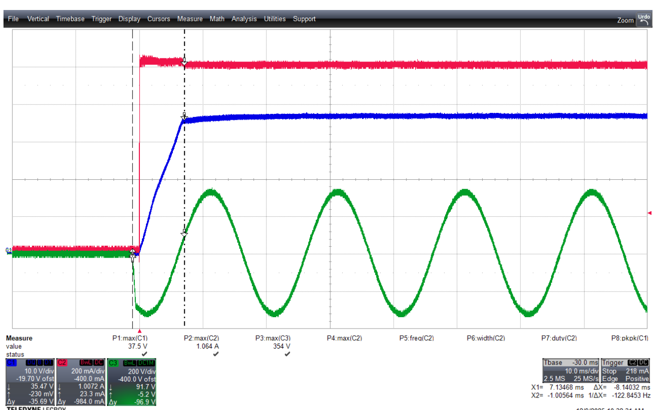


Figure 63 – 230 VAC, 50 Hz. 1 A CC Load
CH1: V_{OUT}, 10 V / div., 10 ms / div.
CH2: I_{OUT}, 200 mA / div., 10 ms / div.
CH3: V_{IN}, 500 V / div., 10 ms / div.
$t_{ON\ Delay}$ = 8.14 ms
$V_{OUT\ Max}$ = 37.5 V

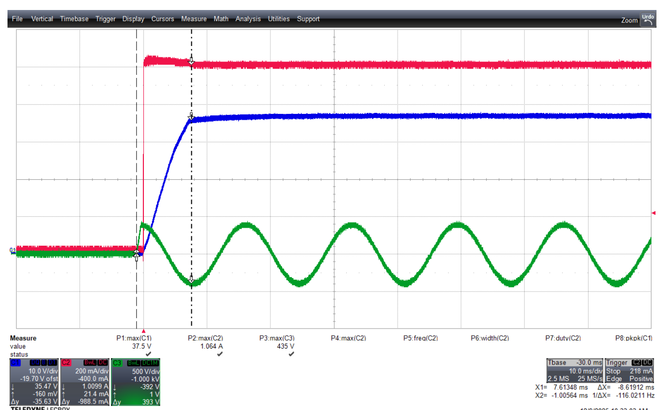


Figure 64 – 277 VAC, 50 Hz. 1 A CC Load
CH1: V_{OUT}, 10 V / div., 10 ms / div.
CH2: I_{OUT}, 200 mA / div., 10 ms / div.
CH3: V_{IN}, 500 V / div., 10 ms / div.
$t_{ON\ Delay}$ = 8.62 ms
$V_{OUT\ Max}$ = 37.5 V

12.3 Primary Drain Voltage and Current

12.3.1 Steady State Operation with 36 V LED String

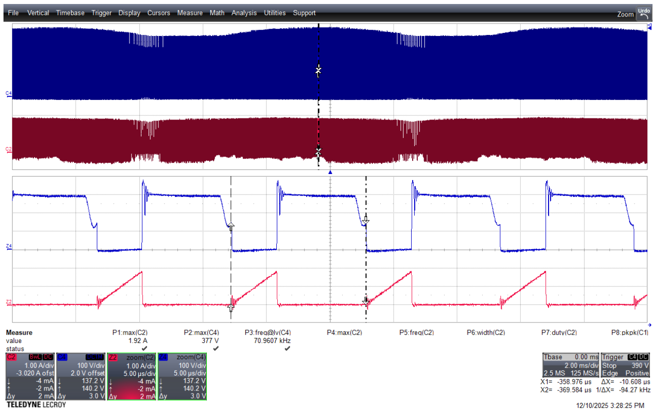


Figure 65 – 120 VAC, 60 Hz. 36 V LED String.
CH2: I_{DS}, 1 A / div., 2 ms / div.
CH4: V_{DS}, 100 V / div., 2 ms / div.
Zoom in: 7 µs / div.
$V_{DS\ Max}$ = 377 V
$I_{DS\ Max}$ = 1.92 A

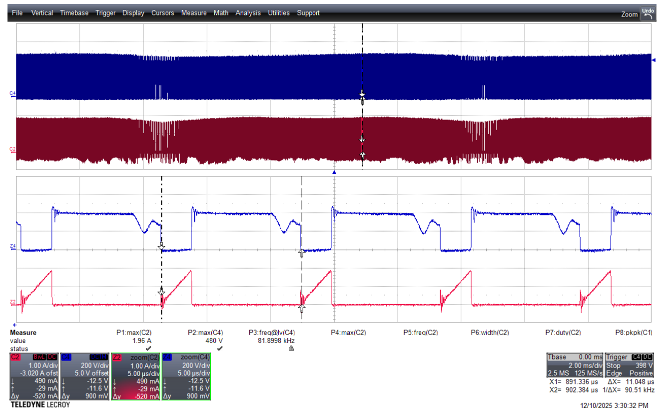


Figure 66 – 180 VAC, 60 Hz. 36 V LED String.
CH2: I_{DS}, 1 A / div., 2 ms / div.
CH4: V_{DS}, 100 V / div., 2 ms / div.
Zoom in: 5 µs / div.
$V_{DS\ Max}$ = 480 V
$I_{DS\ Max}$ = 1.96 A

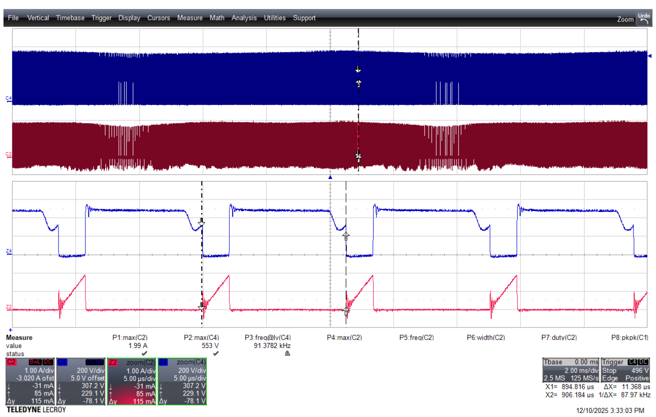


Figure 67 – 230 VAC, 50 Hz. 36 V LED String.
CH2: I_{DS}, 1 A / div., 2 ms / div.
CH4: V_{DS}, 200 V / div., 2 ms / div.
Zoom in: 5 µs / div.
$V_{DS\ Max}$ = 553 V
$I_{DS\ Max}$ = 1.99 A

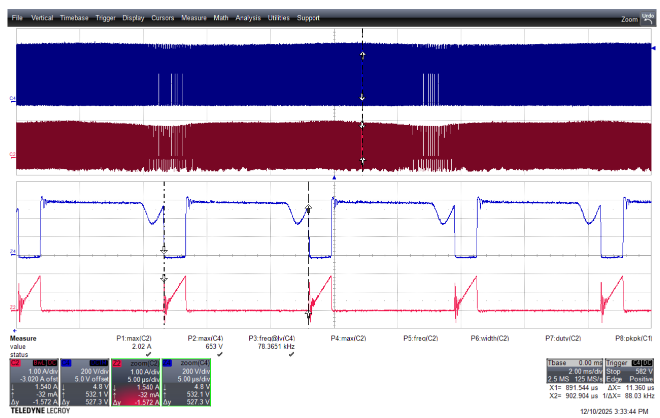


Figure 68 – 277 VAC, 60 Hz. 36 V LED String.
CH2: I_{DS}, 1 A / div., 2 ms / div.
CH4: V_{DS}, 200 V / div., 2 ms / div.
Zoom in: 5 µs / div.
$V_{DS\ Max}$ = 653 V
$I_{DS\ Max}$ = 2.02 A

12.3.2 Steady State Operation with 25 V LED String

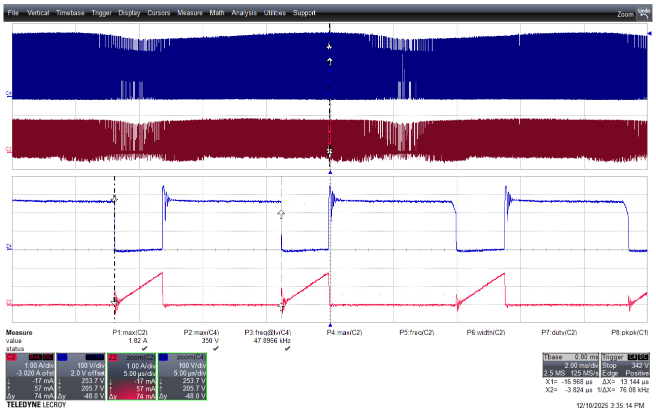


Figure 69 – 120 VAC, 60 Hz. 25 V LED String.
CH2: I_{DS}, 1 A / div., 2 ms / div.
CH4: V_{DS}, 100 V / div., 2 ms / div.
Zoom in: 5 µs / div.
$V_{DS\ Max}$ = 350 V
$I_{DS\ Max}$ = 1.82 A

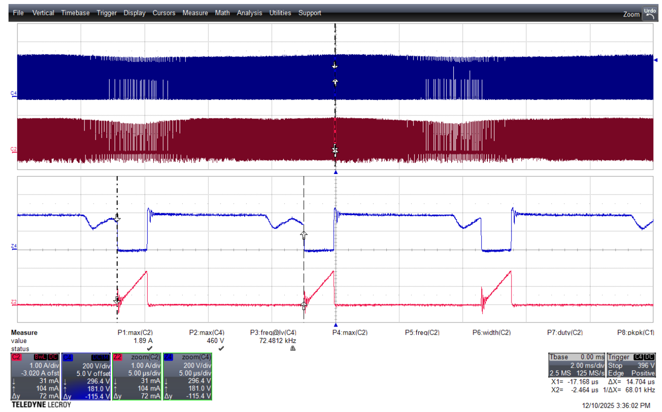


Figure 70 – 180 VAC, 60 Hz. 25 V LED String.
CH2: I_{DS}, 1 A / div., 2 ms / div.
CH4: V_{DS}, 200 V / div., 2 ms / div.
Zoom in: 5 µs / div.
$V_{DS\ Max}$ = 460 V
$I_{DS\ Max}$ = 1.89 A

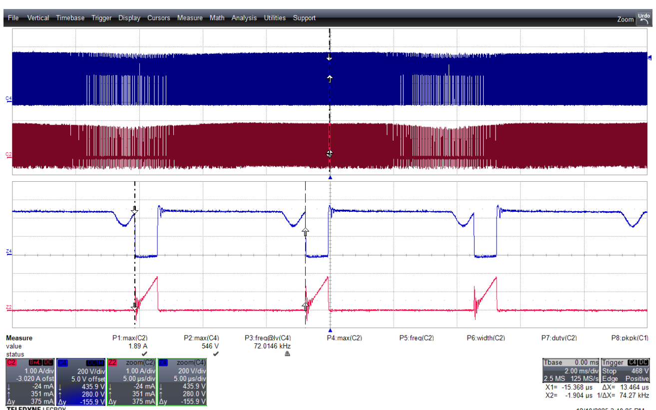


Figure 71 – 230 VAC, 50 Hz. 25 V LED String.
CH2: I_{DS}, 1 A / div., 2 ms / div.
CH4: V_{DS}, 200 V / div., 2 ms / div.
Zoom in: 5 µs / div.
$V_{DS\ Max}$ = 546 V
$I_{DS\ Max}$ = 1.89 A

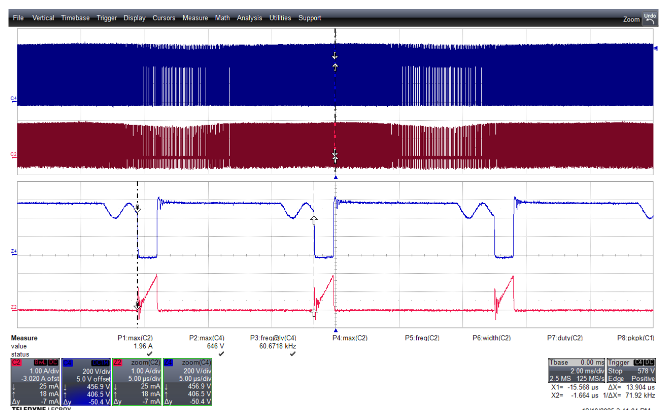


Figure 72 – 277 VAC, 60 Hz. 25 V LED String.
CH2: I_{DS}, 1 A / div., 2 ms / div.
CH4: V_{DS}, 200 V / div., 2 ms / div.
Zoom in: 5 µs / div.
$V_{DS\ Max}$ = 646 V
$I_{DS\ Max}$ = 1.96 A

12.3.3 Start-up Operation with 36 V LED String

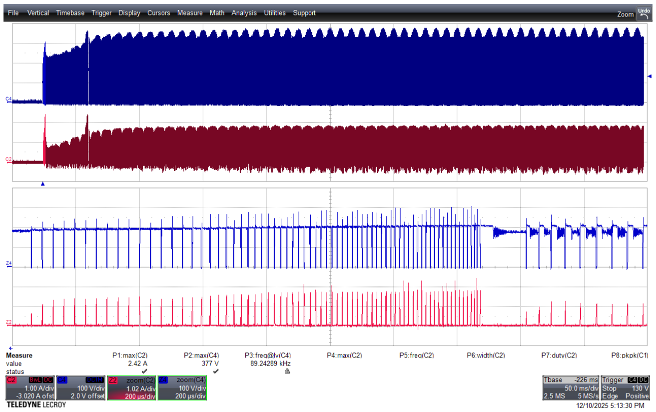


Figure 73 – 120 VAC, 60 Hz. 36 V LED String.
CH2: I_{DS}, 1 A / div., 50 ms / div.
CH4: V_{DS}, 100 V / div., 50 ms / div.
Zoom in: 200 µs / div.
$V_{DS\ Max}$ = 377 V
$I_{DS\ Max}$ = 2.42 A

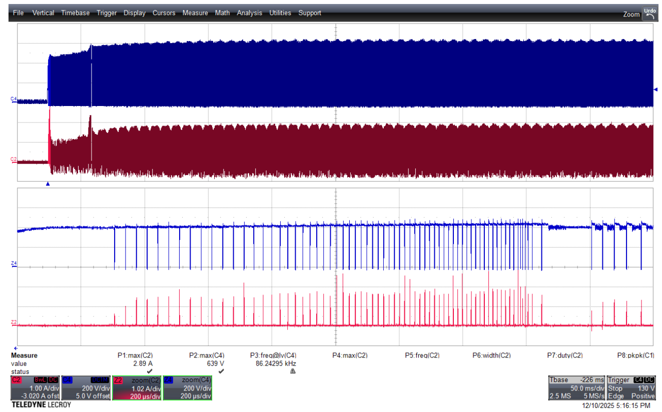


Figure 74 – 277 VAC, 60 Hz. 36 V LED String.
CH2: I_{DS}, 1 A / div., 50 ms / div.
CH4: V_{DS}, 200 V / div., 50 ms / div.
Zoom in: 200 µs / div.
$V_{DS\ Max}$ = 639 V
$I_{DS\ Max}$ = 2.89 A

12.3.4 Start-up Operation with 25 V LED String

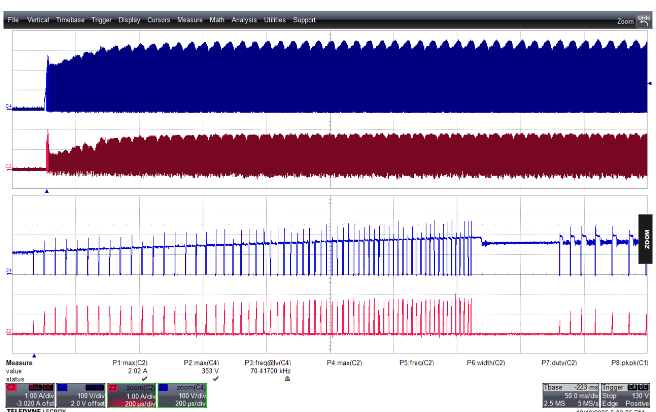


Figure 75 – 120 VAC, 60 Hz. 25 V LED String.
CH2: I_{DS}, 1 A / div., 50 ms / div.
CH4: V_{DS}, 100 V / div., 50 ms / div.
Zoom in: 200 µs / div.
$V_{DS\ Max}$ = 353 V
$I_{DS\ Max}$ = 2.02 A

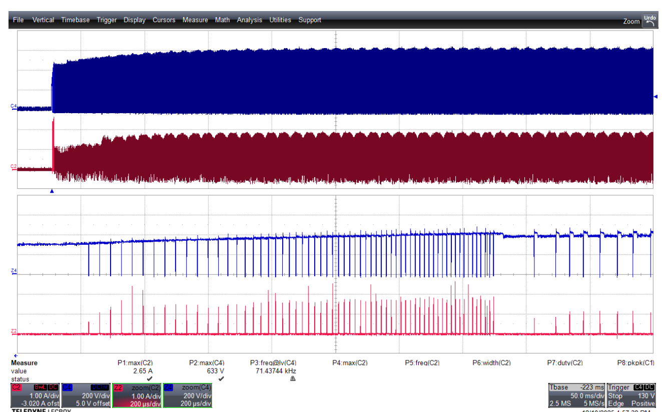


Figure 76 – 277 VAC, 60 Hz. 25 V LED String.
CH2: I_{DS}, 1 A / div., 50 ms / div.
CH4: V_{DS}, 200 V / div., 50 ms / div.
Zoom in: 200 µs / div.
$V_{DS\ Max}$ = 633 V
$I_{DS\ Max}$ = 2.65 A

12.3.5 Output Short Circuit at No Load

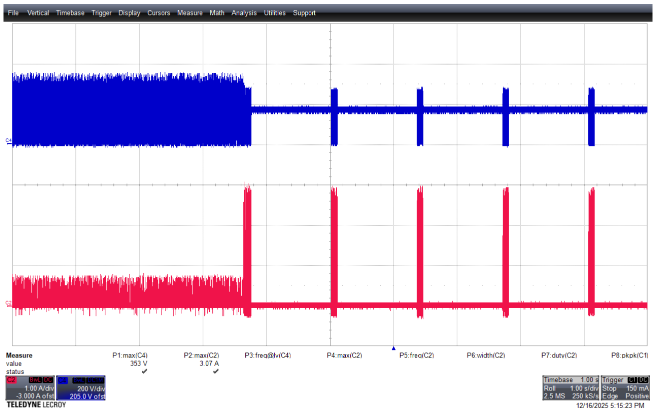


Figure 77 – 120 VAC, 60 Hz. Shorted at No Load.
CH2: I_{DS}, 1 A / div., 1 s / div.
CH4: V_{DS}, 200 V / div., 1 s / div.
$V_{DS\ Max}$ = 353 V
$I_{DS\ Max}$ = 3.07 A

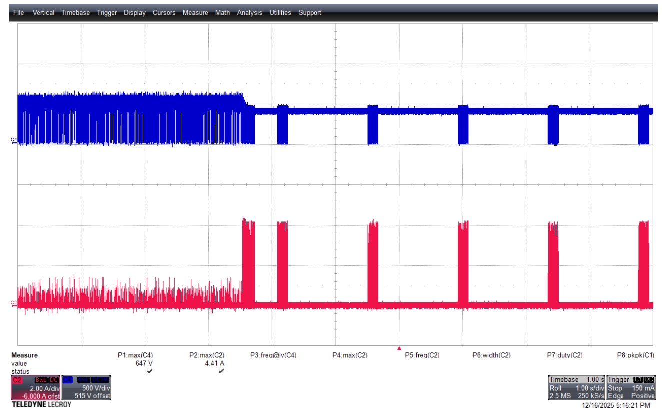


Figure 78 – 277 VAC, 60 Hz. Shorted at No Load.
CH2: I_{DS}, 2 A / div., 1 s / div.
CH4: V_{DS}, 500 V / div., 1 s / div.
$V_{DS\ Max}$ = 647 V
$I_{DS\ Max}$ = 4.41 A

12.3.6 Start-Up into Short-Circuit Condition

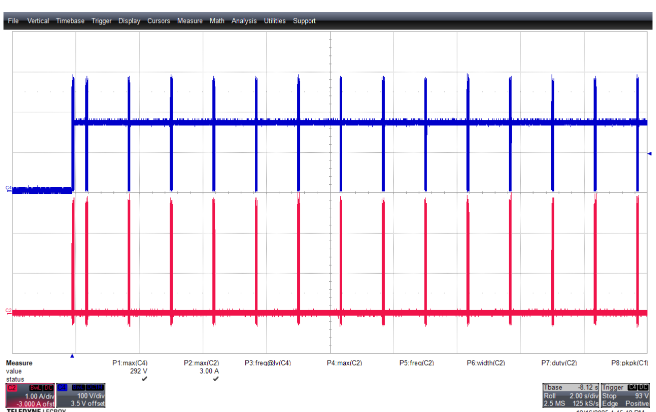


Figure 79 – 120 VAC, 60 Hz. Start up into Short Circuit.
CH2: I_{DS}, 1 A / div., 2 s / div.
CH4: V_{DS}, 100 V / div., 2 s / div.
$V_{DS\ Max}$ = 292 V
$I_{DS\ Max}$ = 3.00 A

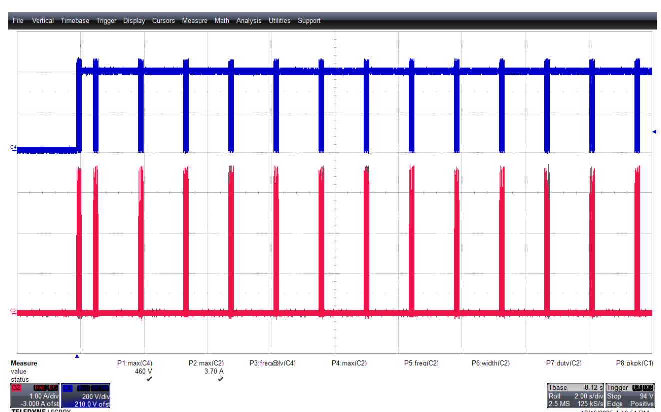


Figure 80 – 277 VAC, 60 Hz. Start up into Short Circuit.
CH2: I_{DS}, 1 A / div., 2 s / div.
CH4: V_{DS}, 200 V / div., 2 s / div.
$V_{DS\ Max}$ = 460 V
$I_{DS\ Max}$ = 3.70 A

12.3.7 36 V LED Short applied During Full-Load Operation

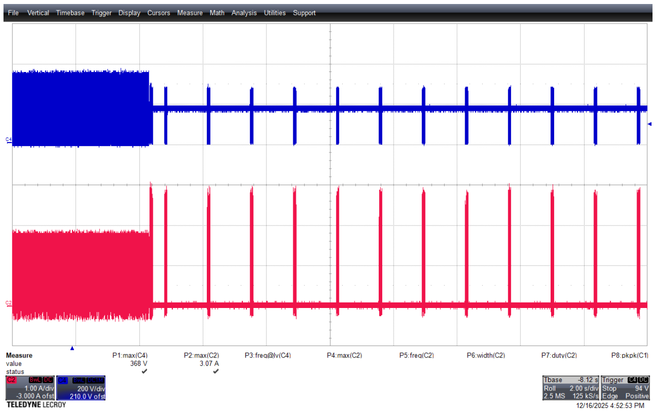


Figure 81 – 120 VAC, 60 Hz. 36 V LED - Shorted.
CH2: I_{DS}, 1 A / div., 2 s / div.
CH4: V_{DS}, 200 V / div., 2 s / div.
$V_{DS\ Max}$ = 368 V
$I_{DS\ Max}$ = 3.07 A

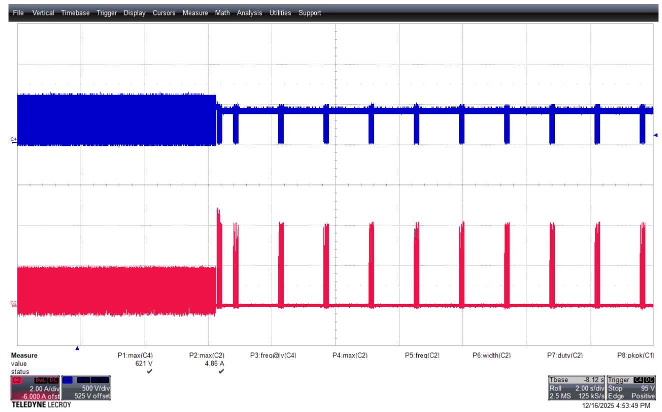


Figure 82 – 277 VAC, 60 Hz. 36 V LED - Shorted.
CH2: I_{DS}, 2 A / div., 2 s / div.
CH4: V_{DS}, 500 V / div., 2 s / div.
$V_{DS\ Max}$ = 621 V
$I_{DS\ Max}$ = 4.86 A

12.3.8 Short Circuit Applied when Operating with a 25 V LED Load

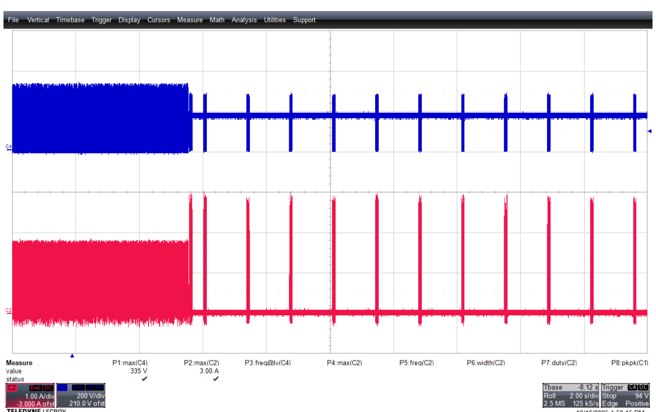


Figure 83 – 120 VAC, 60 Hz. Short Circuit Applied when Operating with 25 V LED Load.
CH2: I_{DS}, 1 A / div., 2 s / div.
CH4: V_{DS}, 200 V / div., 2 s / div.
$V_{DS\ Max}$ = 335 V
$I_{DS\ Max}$ = 3.00 A

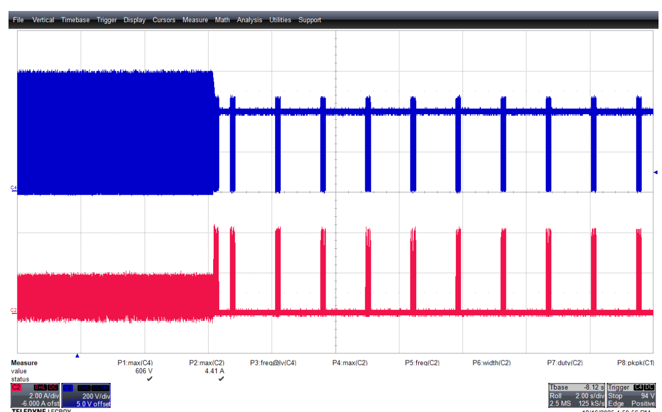


Figure 84 – 277 VAC, 60 Hz. Short Circuit Applied when Operating with 25 V LED Load.
CH2: I_{DS}, 2 A / div., 2 s / div.
CH4: V_{DS}, 200 V / div., 2 s / div.
$V_{DS\ Max}$ = 606 V
$I_{DS\ Max}$ = 4.41 A

12.3.9 Output Short Circuit Recovery with 36 V LED Load

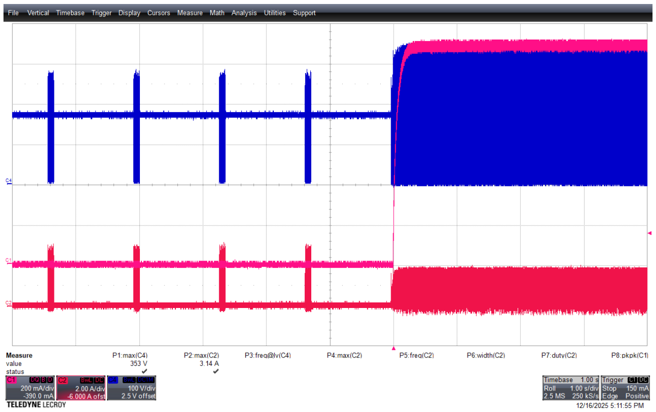


Figure 85 – 120 VAC, 60 Hz. 36 V LED.
CH1: I_{OUT}, 200 mA / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
CH4: V_{DS}, 100 V / div., 1 s / div.
$V_{DS\ Max}$ = 353 V
$I_{DS\ Max}$ = 3.14 A

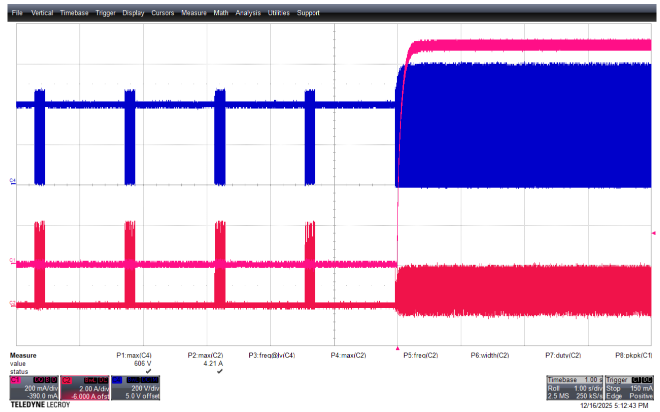


Figure 86 – 277 VAC, 60 Hz. 36 V LED.
CH1: I_{OUT}, 200 mA / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
CH4: V_{DS}, 200 V / div., 1 s / div.
$V_{DS\ Max}$ = 606 V
$I_{DS\ Max}$ = 4.21 A

12.3.10 Output Short Circuit Recovery with 25 V LED Load

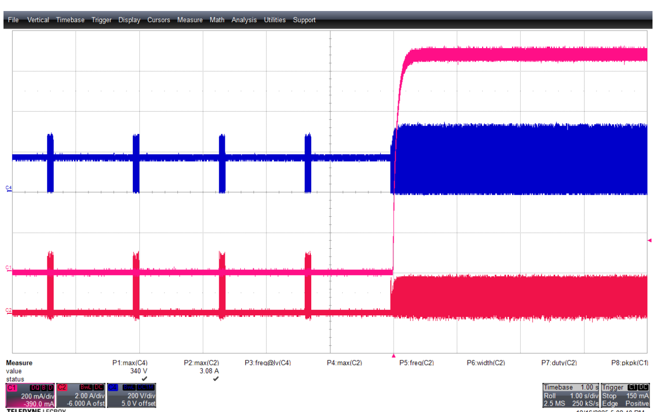


Figure 87 – 120 VAC, 60 Hz. 25 V LED.
CH1: I_{OUT}, 200 mA / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
CH4: V_{DS}, 100 V / div., 1 s / div.
$V_{DS\ Max}$ = 340 V
$I_{DS\ Max}$ = 3.08 A

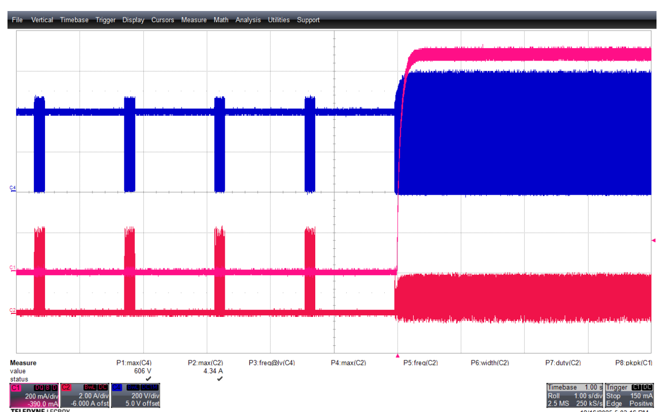


Figure 88 – 277 VAC, 60 Hz. 25 V LED.
CH1: I_{OUT}, 200 mA / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
CH4: V_{DS}, 200 V / div., 1 s / div.
$V_{DS\ Max}$ = 606 V
$I_{DS\ Max}$ = 4.34 A

12.4 Voltage Stress on Output Diode

12.4.1 Voltage Stress on Output Diode at Steady State

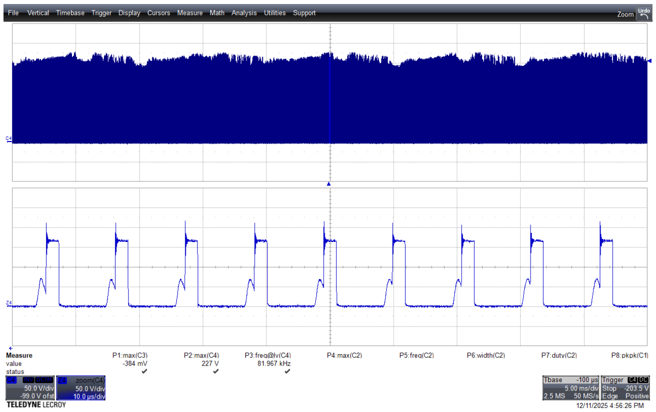


Figure 89 – 230 VAC, 50 Hz. 36 V LED.
CH4: V_{DIODE}, 50 V / div., 5 ms / div.
$V_{DIODE\ Max}$ = 227 V
Voltage Stress: 75.7%

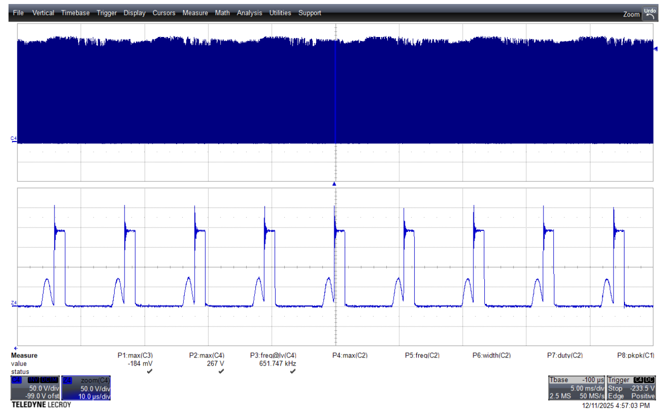


Figure 90 – 277 VAC, 60 Hz. 36 V LED.
CH4: V_{DIODE}, 50 V / div., 5 ms / div.
$V_{DIODE\ Max}$ = 267 V
Voltage Stress: 89%

12.4.2 Voltage Stress on Output Diode During Start-up Full Load

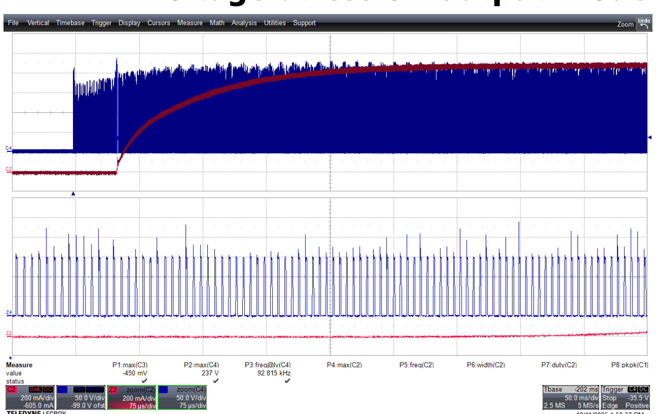


Figure 91 – 230 VAC, 50 Hz. 36 V LED.
CH2: I_{OUT}, 200 mA / div., 50 ms / div.
CH4: V_{DIODE}, 50 V / div., 50 ms / div.
Zoom In: 75 µs / div
$V_{DIODE\ Max}$ = 237 V
Voltage Stress: 79%

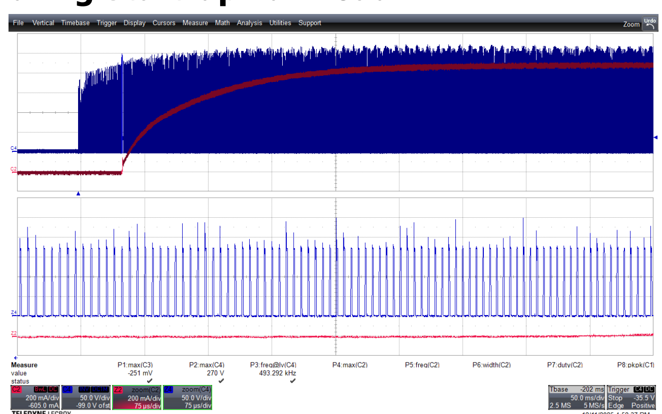


Figure 92 – 277 VAC, 50 Hz. 36 V LED.
CH2: I_{OUT}, 200 mA / div., 50 ms / div.
CH4: V_{DIODE}, 50 V / div., 50 ms / div.
Zoom In: 75 µs / div
$V_{DIODE\ Max}$ = 270 V
Voltage Stress: 90%

12.5 AC On/Off Cycling with 36 V LED String

12.5.1 On/Off Cycling with 36 V LED String

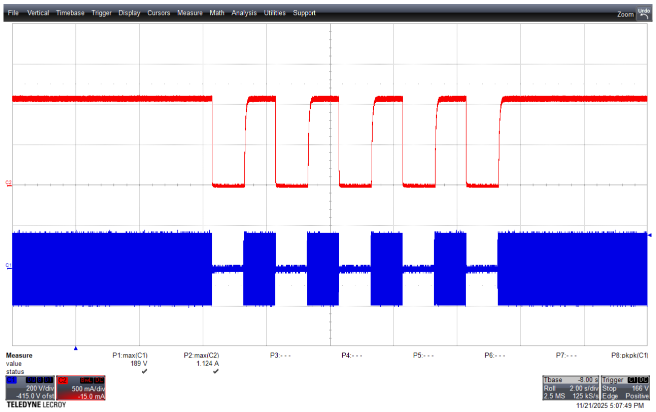


Figure 93 – 120 VAC, 60 Hz 1 s On/Off, 36 V LED.
CH1: V_{IN}, 200 V / div., 2 s / div.
CH2: I_{DS}, 500 mA / div., 2 s / div.
$I_{OUT\ Max}$ = 1.12 A

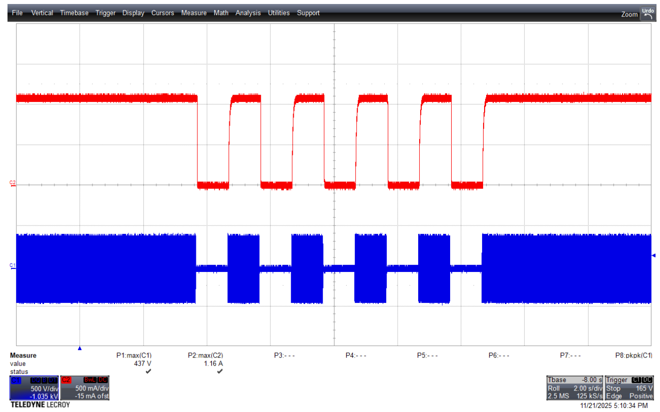


Figure 94 – 277 VAC, 60 Hz 1 s On/Off, 36 V LED.
CH1: V_{IN}, 500 V / div., 2 s / div.
CH2: I_{DS}, 500 mA / div., 2 s / div.
$I_{OUT\ Max}$ = 1.16 A

12.5.2 AC On/Off Cycling with 25 V LED String

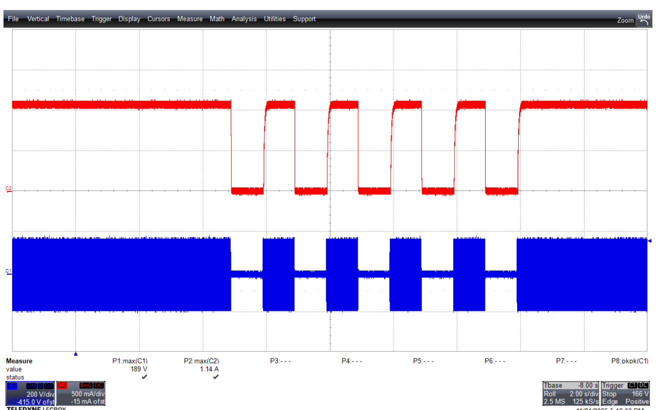


Figure 95 – 120 VAC, 60 Hz 1 s On/Off, 25 V LED.
CH1: V_{IN}, 200 V / div., 2 s / div.
CH2: I_{DS}, 500 mA / div., 2 s / div.
$I_{OUT\ Max}$ = 1.14 A

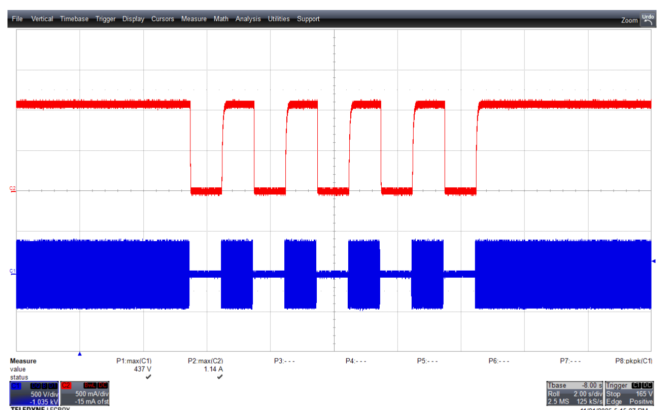


Figure 96 – 277 VAC, 60 Hz 1 s On/Off, 25 V LED.
CH1: V_{IN}, 500 V / div., 2 s / div.
CH2: I_{DS}, 500 mA / div., 2 s / div.
$I_{OUT\ Max}$ = 1.14 A

12.6 Input Voltage and Current

12.6.1 Input Voltage and Current with 36 V LED Load in Steady-State

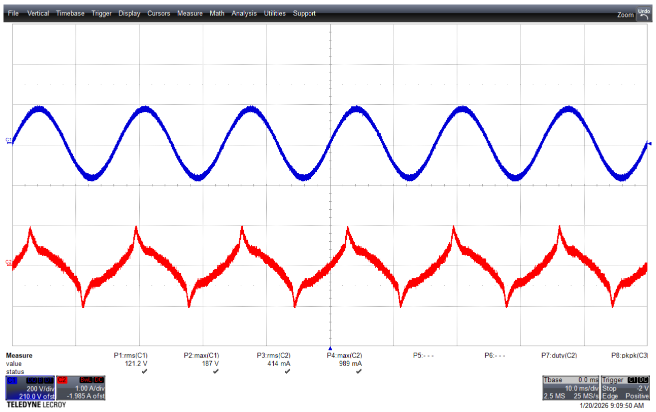


Figure 97 – 120 VAC, 60 Hz. 36 V LED String.
CH1: V_{IN}, 200 V / div., 10 ms / div.
CH2: I_{IN}, 1 A / div., 10 ms / div.
$I_{IN\ RMS}$ = 414 mA
$V_{IN\ MAX}$ = 187 V

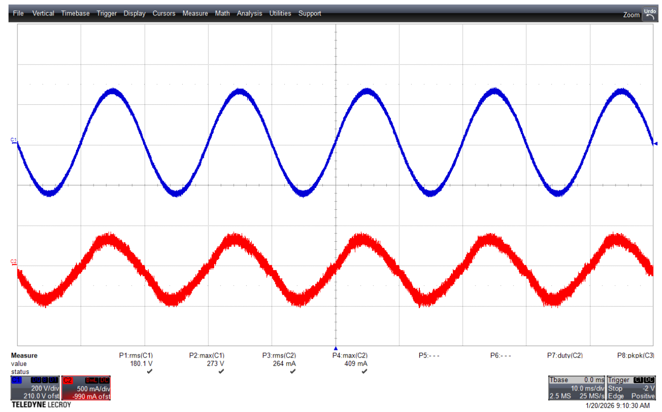


Figure 98 – 120 VAC, 60 Hz. 36 V LED String.
CH1: V_{IN}, 200 V / div., 10 ms / div.
CH2: I_{IN}, 500 mA / div., 10 ms / div.
$I_{IN\ RMS}$ = 264 mA
$V_{IN\ MAX}$ = 273 V

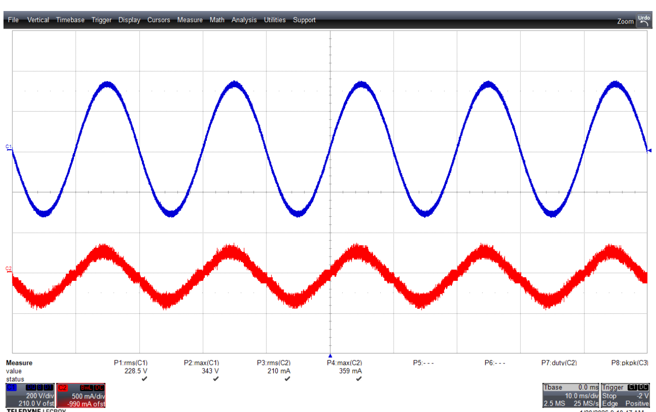


Figure 99 – 230 VAC, 50 Hz. 36 V LED String.
CH1: V_{IN}, 200 V / div., 10 ms / div.
CH2: I_{IN}, 500 mA / div., 10 ms / div.
$I_{IN\ RMS}$ = 210 mA
$V_{IN\ MAX}$ = 343 V

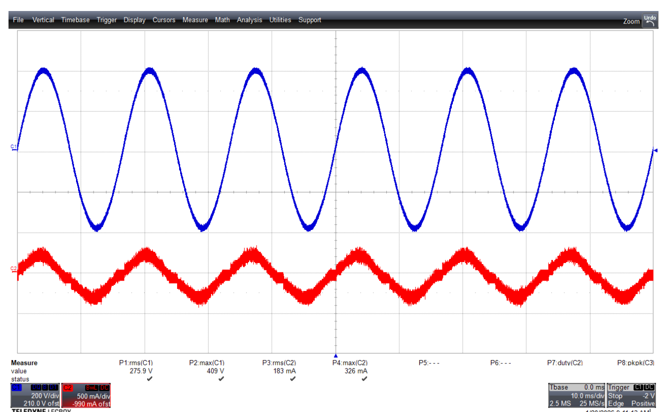


Figure 100 – 277 VAC, 60 Hz. 36 V LED String.
CH1: V_{IN}, 200 V / div., 10 ms / div.
CH2: I_{IN}, 500 mA / div., 10 ms / div.
$I_{IN\ RMS}$ = 183 mA
$V_{IN\ MAX}$ = 409 V

12.6.2 Input Voltage and Current with 25 V LED Load in Steady State

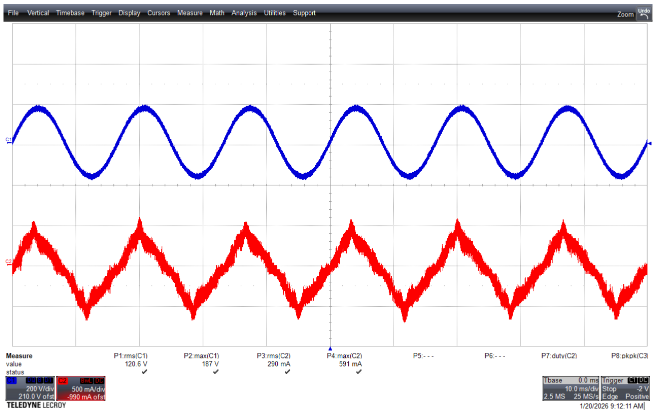


Figure 101 – 120 VAC, 60 Hz. 25 V LED String.
CH1: V_{IN}, 200 V / div., 10 ms / div.
CH2: I_{IN}, 500 mA / div., 10 ms / div.
$I_{IN\ RMS}$ = 290 mA
$V_{IN\ MAX}$ = 187 V

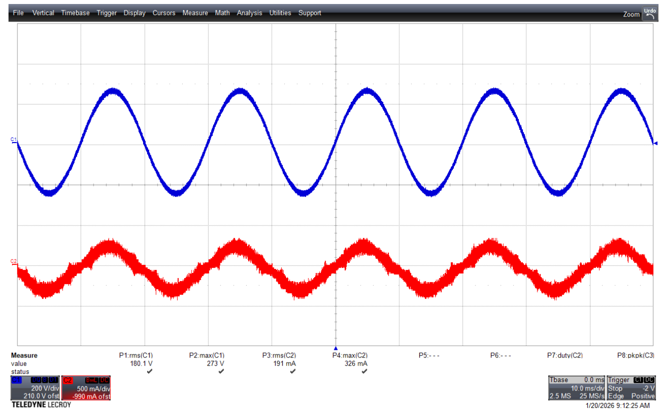


Figure 102 – 120 VAC, 60 Hz. 25 V LED String.
CH1: V_{IN}, 200 V / div., 10 ms / div.
CH2: I_{IN}, 500 mA / div., 10 ms / div.
$I_{IN\ RMS}$ = 191 mA
$V_{IN\ MAX}$ = 273 V

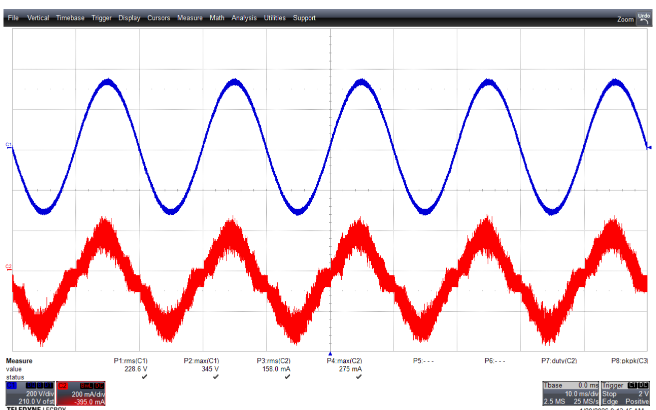


Figure 103 – 230 VAC, 50 Hz. 25 V LED String.
CH1: V_{IN}, 200 V / div., 10 ms / div.
CH2: I_{IN}, 200 mA / div., 10 ms / div.
$I_{IN\ RMS}$ = 158 mA
$V_{IN\ MAX}$ = 345 V

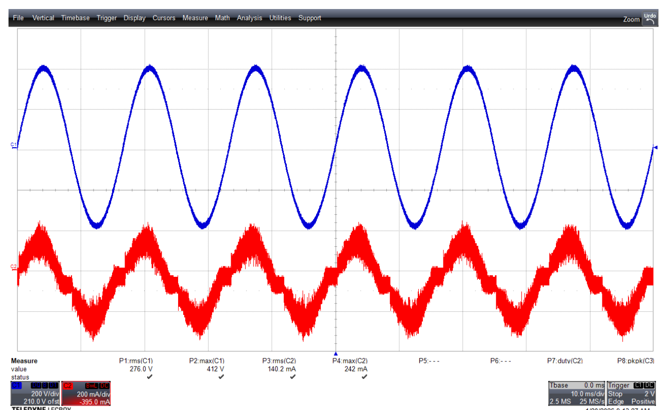


Figure 104 – 277 VAC, 60 Hz. 25 V LED String.
CH1: V_{IN}, 200 V / div., 10 ms / div.
CH2: I_{IN}, 200 mA / div., 10 ms / div.
$I_{IN\ RMS}$ = 140 mA
$V_{IN\ MAX}$ = 412 V

12.7 Output Ripple Current at 36 V LED String

12.7.1 Output Ripple Current at 36 V LED String

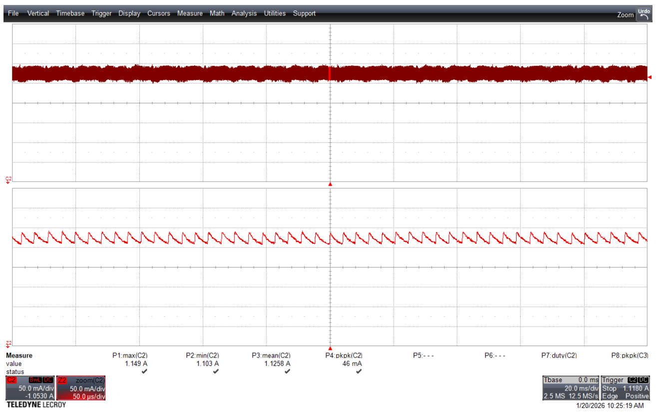


Figure 105 – 120 VAC, 60 Hz. 36 V LED String.
CH1: I_{OUT}, 50 mA / div., 20 ms / div.
Zoom In: 50 µs / div.
I_{RIPPLE} = 46 mA pk-pk

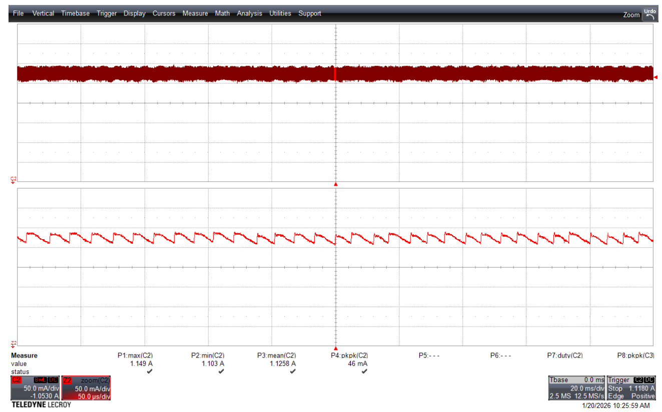


Figure 106 – 180 VAC, 60 Hz. 36 V LED String.
CH2: I_{OUT}, 50 mA / div., 20 ms / div.
Zoom In: 50 µs / div.
I_{RIPPLE} = 46 mA pk-pk

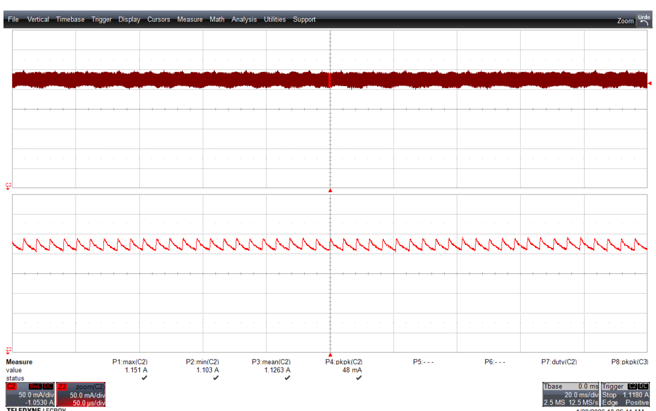


Figure 107 – 230 VAC, 50 Hz. 36 V LED String.
CH2: I_{OUT}, 50 mA / div., 20 ms / div.
Zoom In: 50 µs / div.
I_{RIPPLE} = 48 mA pk-pk

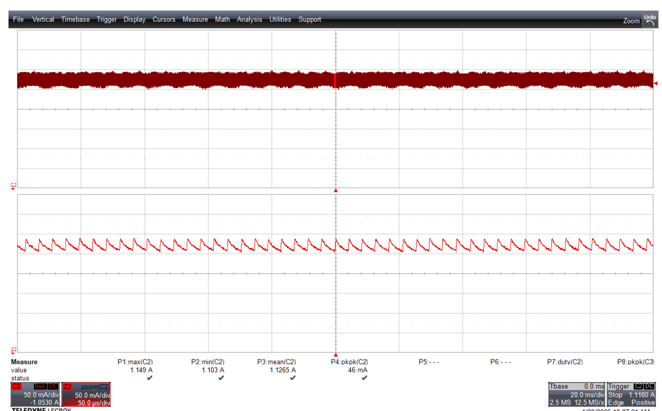


Figure 108 – 277 VAC, 60 Hz. 36 V LED String.
CH2: I_{OUT}, 50 mA / div., 20 ms / div.
Zoom In: 50 µs / div.
I_{RIPPLE} = 46 mA pk-pk

12.7.2 Output Ripple Current at 25 V LED String

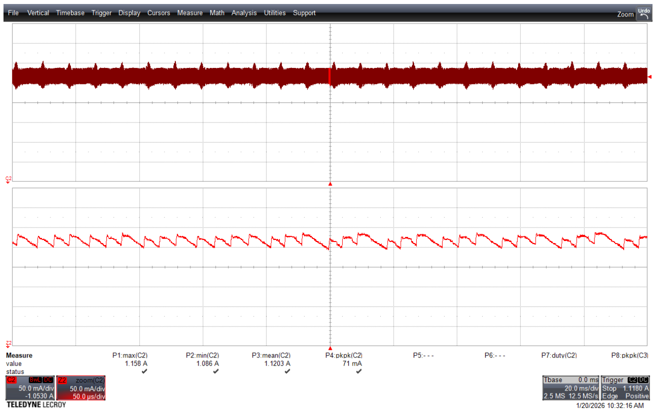


Figure 109 – 120 VAC, 60 Hz. 36 V LED String.
CH1: I_{OUT}, 50 mA / div., 20 ms / div.
Zoom In: 50 µs / div.
I_{RIPPLE} = 46 mA pk-pk

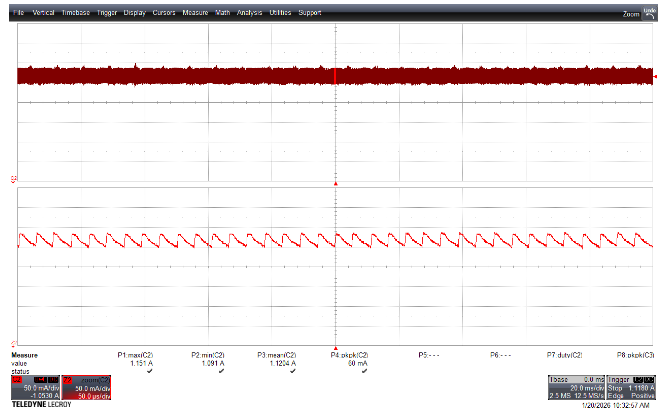


Figure 110 – 180 VAC, 60 Hz. 36 V LED String.
CH2: I_{OUT}, 50 mA / div., 20 ms / div.
Zoom In: 50 µs / div.
I_{RIPPLE} = 46 mA pk-pk

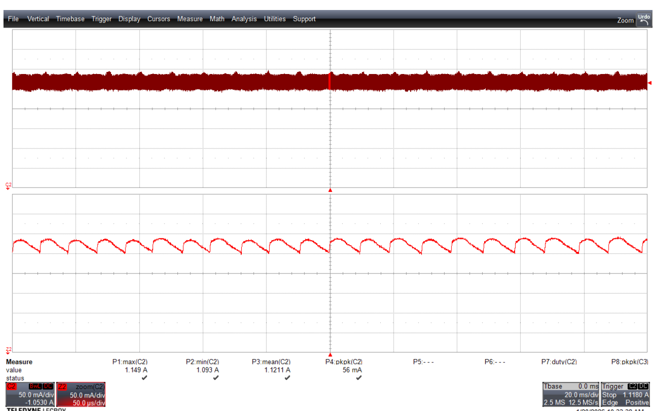


Figure 111 – 230 VAC, 50 Hz. 36 V LED String.
CH2: I_{OUT}, 50 mA / div., 20 ms / div.
Zoom In: 50 µs / div.
I_{RIPPLE} = 48 mA pk-pk

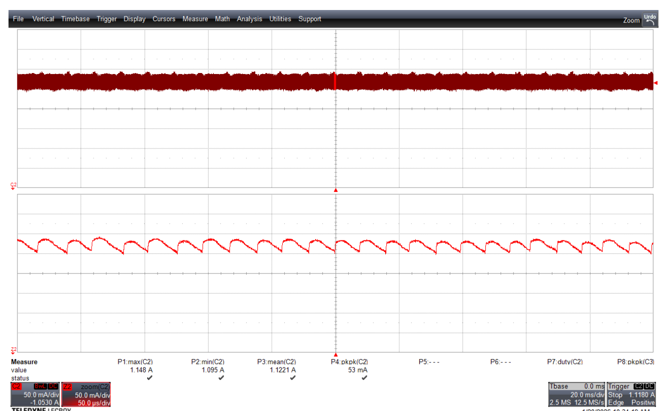


Figure 112 – 277 VAC, 60 Hz. 36 V LED String.
CH2: I_{OUT}, 50 mA / div., 20 ms / div.
Zoom In: 50 µs / div.
I_{RIPPLE} = 46 mA pk-pk

12.8 Output Ripple Voltage

12.8.1 Measurement Set-up

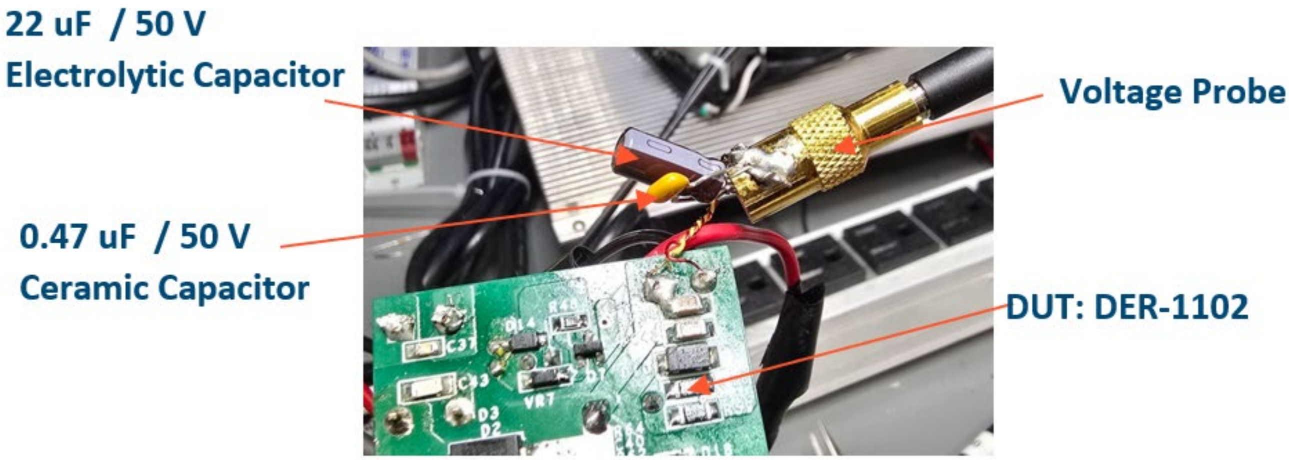


Figure 113 – Ripple Voltage Measurement Set-up Picture.

12.8.2 Output Ripple Current with 36 V LED String

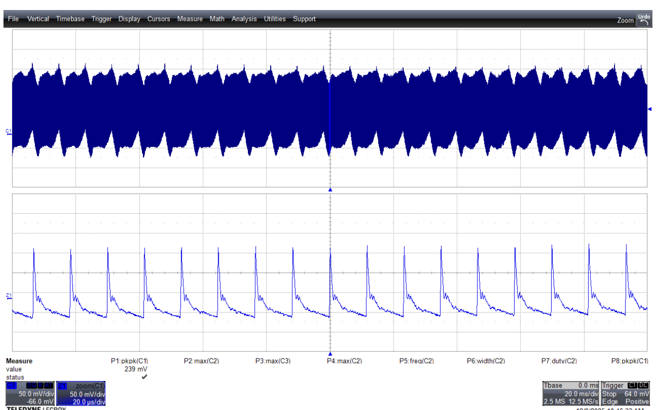


Figure 114 – 120 VAC, 60 Hz. 1 A Load
CH1: V_{RIPPLE}, 50 mV / div., 20 ms / div.
Zoom In: 20 µs / div.
V_{RIPPLE} = 239 mV pk-pk

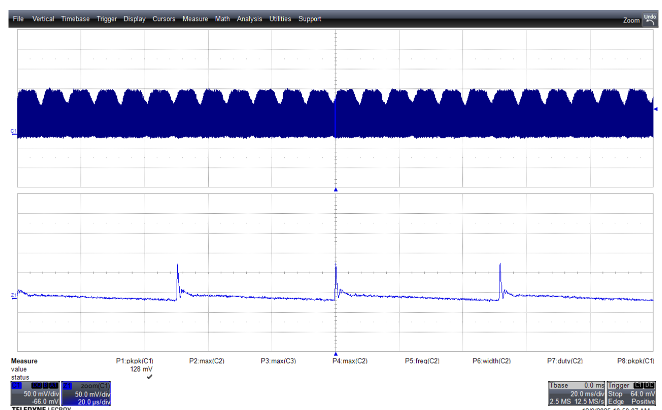


Figure 115 – 120 VAC, 60 Hz. 0.1 A Load
CH1: V_{RIPPLE}, 50 mV / div., 20 ms / div.
Zoom In: 20 µs / div.
V_{RIPPLE} = 128 mV pk-pk

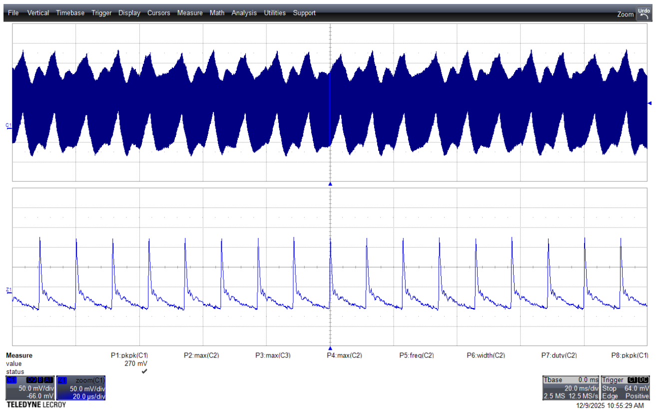


Figure 116 – 230 VAC, 50 Hz. 1 A Load
CH1: V_{RIPPLE}, 50 mV / div., 20 ms / div.
Zoom In: 20 μs / div.
V_{RIPPLE} = 270 mV pk-pk

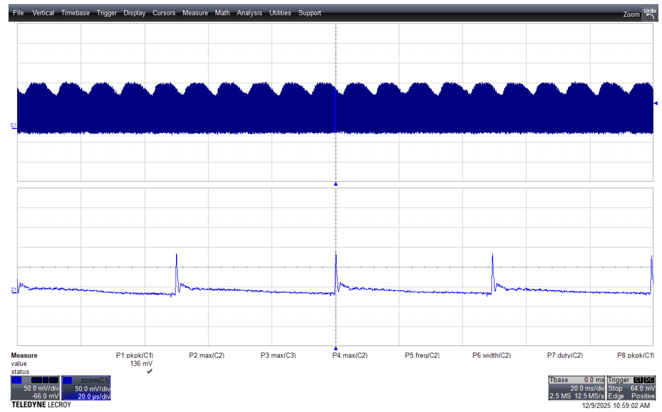


Figure 117 – 230 VAC, 50 Hz. 0.1 A Load
CH1: V_{RIPPLE}, 50 mV / div., 20 ms / div.
Zoom In: 20 μs / div.
V_{RIPPLE} = 136 mV pk-pk

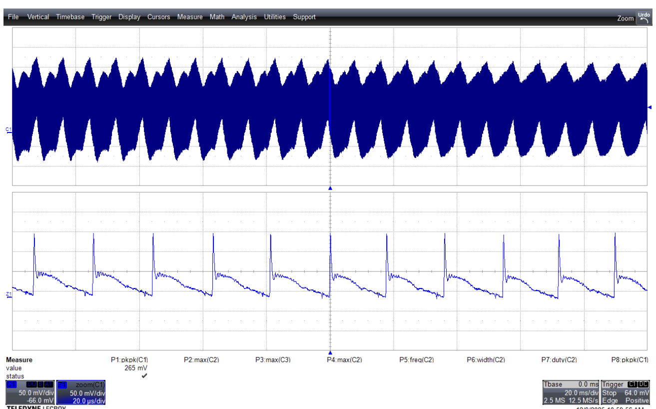


Figure 118 – 277 VAC, 60 Hz. 1 A Load
CH1: V_{RIPPLE}, 50 mV / div., 20 ms / div.
Zoom In: 20 μs / div.
V_{RIPPLE} = 265 mV pk-pk

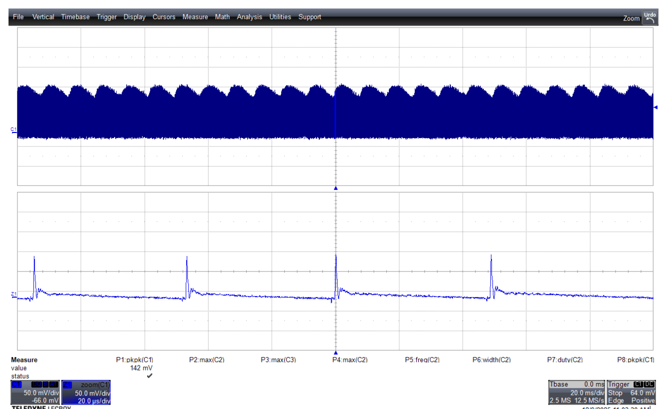


Figure 119 – 277 VAC, 60 Hz. 0.1 A Load
CH1: V_{RIPPLE}, 50 mV / div., 20 ms / div.
Zoom In: 20 μs / div.
V_{RIPPLE} = 142 mV pk-pk

12.9 Transient Load Response in CV Operation

Note: C33 (4.7 μF) should be removed for constant-voltage (CV) applications.

12.10 200 Hz, 50 % Duty Cycle

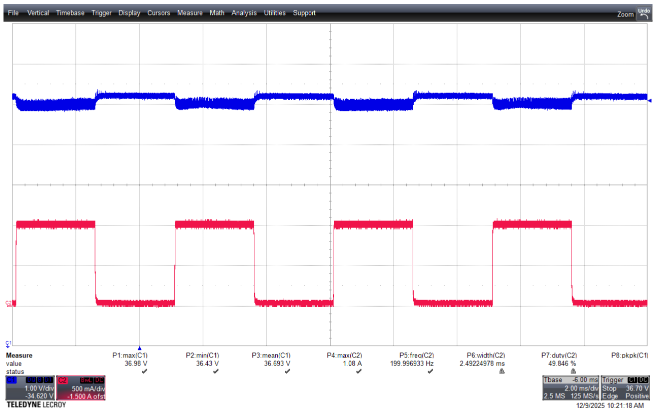


Figure 120 – 120 VAC, 60 Hz. 0 – 1 A Dynamic Load
CH1: V_{OUT}, 1 V / div., 2 ms / div.
CH2: I_{OUT}, 500 mA / div., 2 s / div.
$V_{OUT\ Max}$ = 36.9 V
$V_{OUT\ Min}$ = 36.4 V

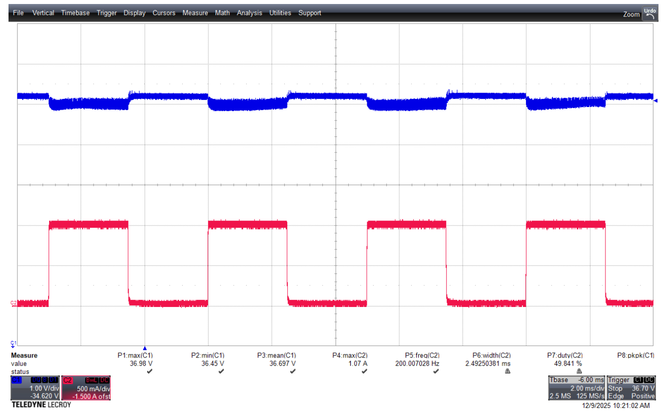


Figure 121 – 277 VAC, 60 Hz. 0 – 1 A Dynamic Load
CH1: V_{OUT}, 1 V / div., 2 ms / div.
CH2: I_{OUT}, 500 mA / div., 2 s / div.
$V_{OUT\ Max}$ = 36.9 V
$V_{OUT\ Min}$ = 36.5 V

12.11 10 Hz, 50 % Duty Cycle

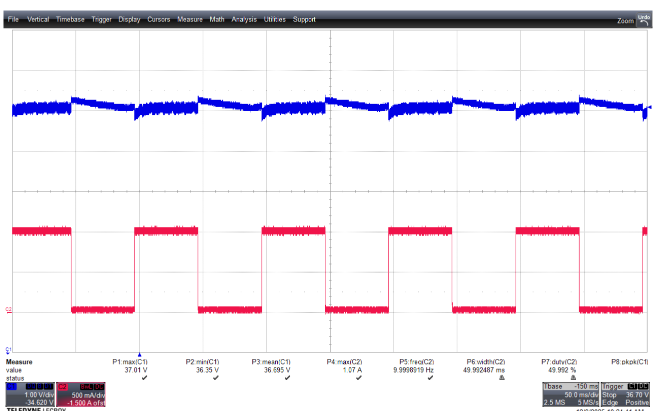


Figure 122 – 120 VAC, 60 Hz. 0 – 1 A Dynamic Load
CH1: V_{OUT}, 1 V / div., 2 ms / div.
CH2: I_{OUT}, 500 mA / div., 2 s / div.
$V_{OUT\ Max}$ = 37 V
$V_{OUT\ Min}$ = 36.4 V

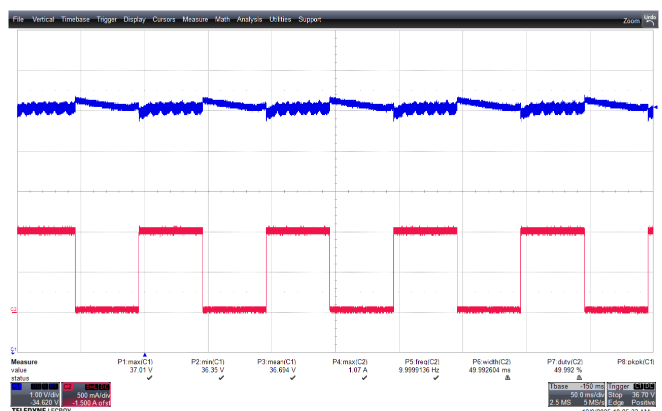


Figure 123 – 277 VAC, 60 Hz. 0 – 1 A Dynamic Load
CH1: V_{OUT}, 1 V / div., 2 ms / div.
CH2: I_{OUT}, 500 mA / div., 2 s / div.
$V_{OUT\ Max}$ = 37 V
$V_{OUT\ Min}$ = 36.4 V

12.12 1 kHz, 50 % Duty Cycle

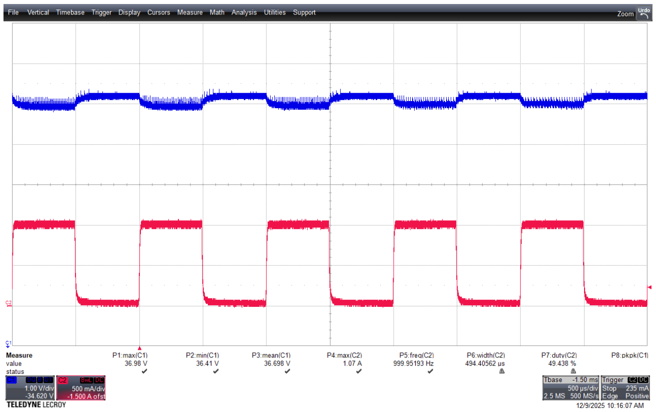


Figure 124 – 120 VAC, 60 Hz. 0 – 1 A Dynamic Load
CH1: V_{OUT}, 1 V / div., 2 ms / div.
CH2: I_{OUT}, 500 mA / div., 2 s / div.
$V_{OUT\ Max}$ = 36.9 V
$V_{OUT\ Min}$ = 36.4 V

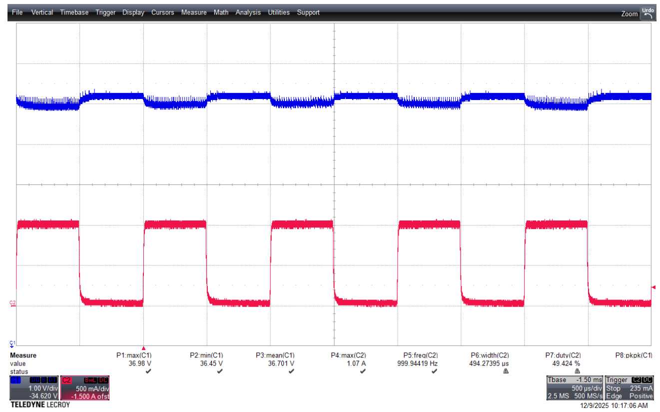


Figure 125 – 277 VAC, 60 Hz. 0 – 1 A Dynamic Load
CH1: V_{OUT}, 1 V / div., 2 ms / div.
CH2: I_{OUT}, 500 mA / div., 2 s / div.
$V_{OUT\ Max}$ = 36.9 V
$V_{OUT\ Min}$ = 36.5 V

12.13 2 kHz, 50 % Duty Cycle

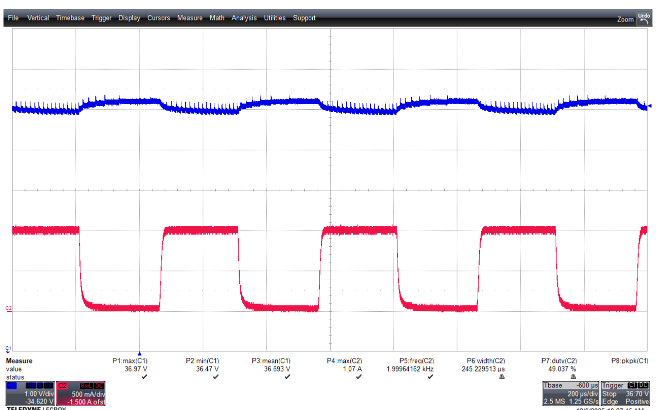


Figure 126 – 120 VAC, 60 Hz. 0 – 1 A Dynamic Load
CH1: V_{OUT}, 1 V / div., 2 ms / div.
CH2: I_{OUT}, 500 mA / div., 2 s / div.
$V_{OUT\ Max}$ = 37.9 V
$V_{OUT\ Min}$ = 36.5 V

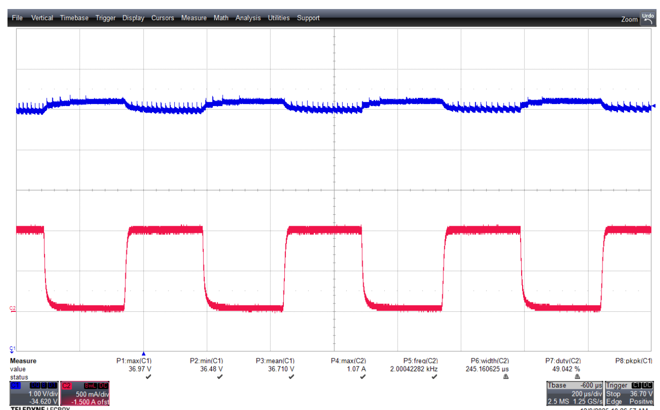


Figure 127 – 277 VAC, 60 Hz. 0 – 1 A Dynamic Load
CH1: V_{OUT}, 1 V / div., 2 ms / div.
CH2: I_{OUT}, 500 mA / div., 2 s / div.
$V_{OUT\ Max}$ = 37.9 V
$V_{OUT\ Min}$ = 36.5 V

12.14 Input Line Overvoltage and Overvoltage Recovery Test

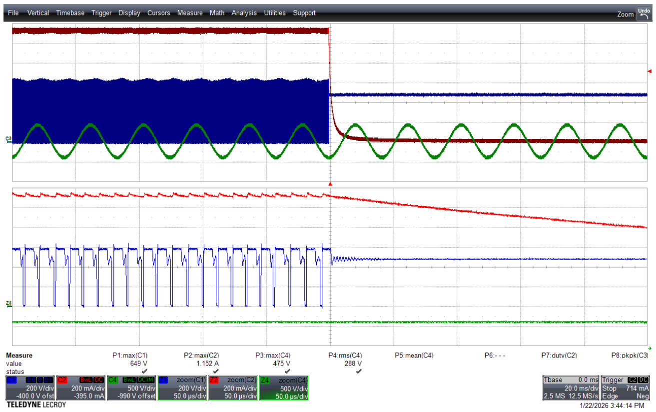


Figure 128 – Line Overvoltage at 36 V LED
CH2: I_{OUT}, 200 mA / div., 10 ms / div.
CH3: V_{IN}, 500 V / div., 10 ms / div.
CH4: V_{DS}, 200 V / div., 10 ms / div.
Zoom In: 50 μs / div.
$V_{IN\text{-}OVP\ RMS}$ = 294 V
V_{DS} = 649 V

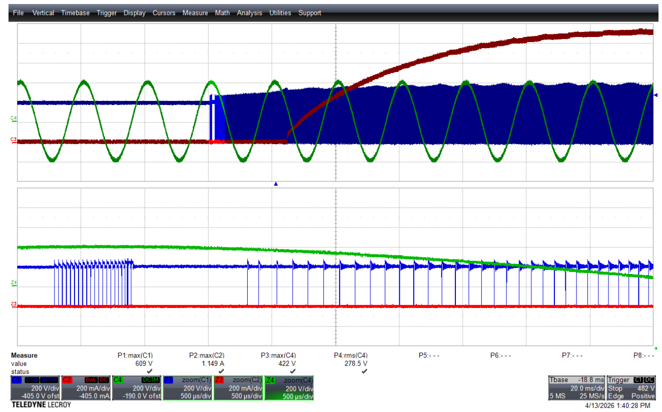


Figure 129 – Line Overvoltage Recovery at 36 V LED
CH2: I_{OUT}, 200 mA / div., 10 ms / div.
CH3: V_{IN}, 500 V / div., 10 ms / div.
CH4: V_{DS}, 200 V / div., 10 ms / div.
Zoom In: 50 μs / div.
$V_{IN\text{-}OVP\text{-}Recovery\ RMS}$ = 278.5 V
V_{DS} = 609 V

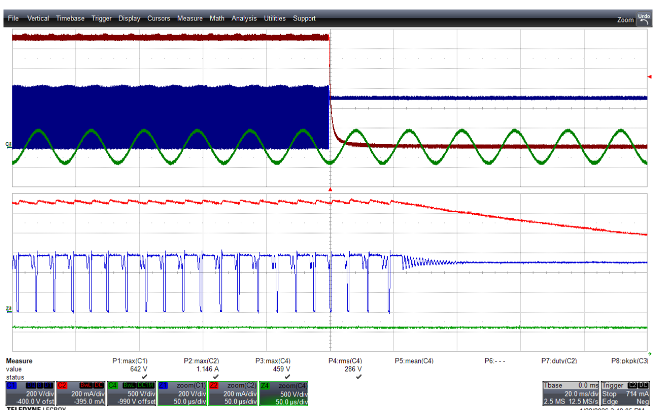


Figure 130 – Line Overvoltage at 25 V LED
CH2: I_{OUT}, 200 mA / div., 10 ms / div.
CH3: V_{IN}, 500 V / div., 10 ms / div.
CH4: V_{DS}, 200 V / div., 10 ms / div.
Zoom In: 50 μs / div.
$V_{IN\text{-}OVP\ RMS}$ = 292 V
V_{DS} = 642 V

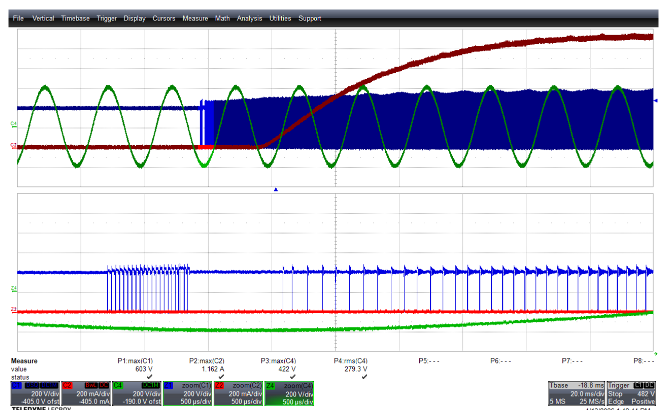


Figure 131 – Line Overvoltage Recovery at 25 V LED
CH2: I_{OUT}, 200 mA / div., 10 ms / div.
CH3: V_{IN}, 500 V / div., 10 ms / div.
CH4: V_{DS}, 200 V / div., 10 ms / div.
Zoom In: 50 μs / div.
$V_{IN\text{-}OVP\text{-}Recovery\ RMS}$ = 279.3 V
V_{DS} = 603 V

12.15 Input Step Transient Response

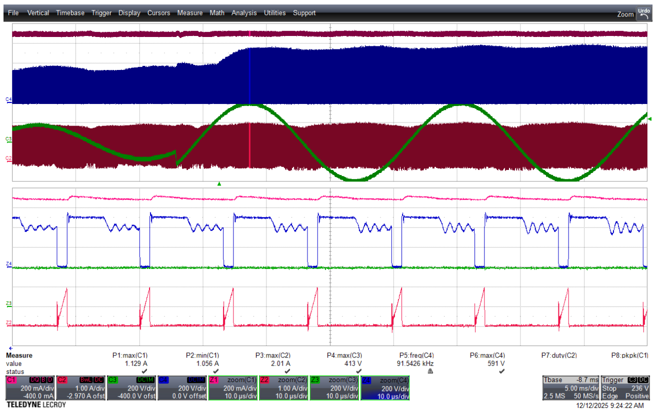


Figure 132 – Step Line 100 V -277 V with 36 V LED load
CH1: I_{OUT}, 200 mA / div., 5 ms / div.
CH2: I_{DS}, 1 A / div., 5 ms / div.
CH3: V_{IN}, 200 V / div., 5 ms / div.
CH4: V_{DS}, 200 V / div., 5 ms / div.
$I_{OUT\ Max}$ = 1.29 A
$I_{OUT\ Min}$ = 1.07 A

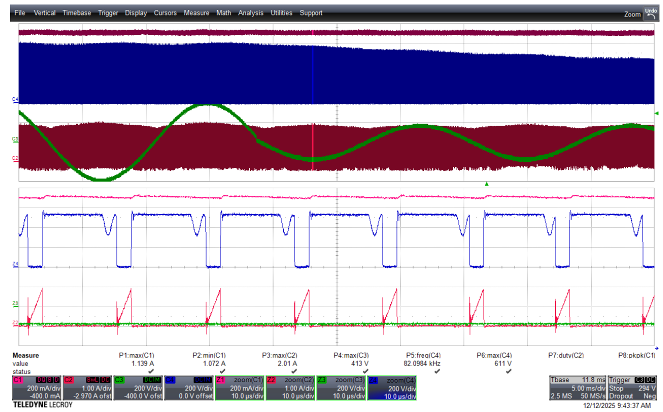


Figure 133 – Step Line 277 V -100 V with 36 V LED load
CH1: I_{OUT}, 200 mA / div., 5 ms / div.
CH2: I_{DS}, 1 A / div., 5 ms / div.
CH3: V_{IN}, 200 V / div., 5 ms / div.
CH4: V_{DS}, 200 V / div., 5 ms / div.
$I_{OUT\ Max}$ = 1.14 A
$V_{DS\ Max}$ = 1.07 A

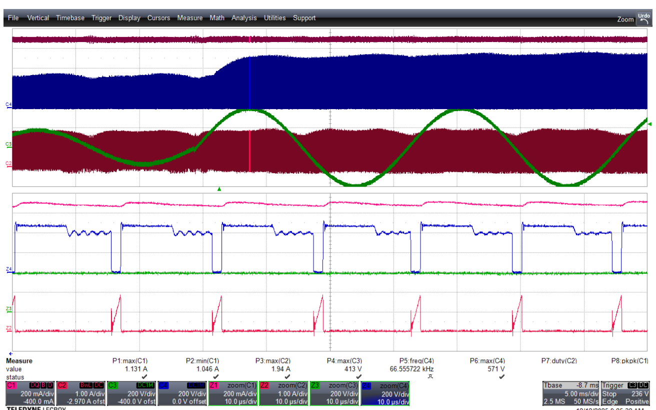


Figure 134 – Step Line 100 V -277 V with 25 VLED load
CH1: I_{OUT}, 200 mA / div., 5 ms / div.
CH2: I_{DS}, 1 A / div., 5 ms / div.
CH3: V_{IN}, 200 V / div., 5 ms / div.
CH4: V_{DS}, 200 V / div., 5 ms / div.
$I_{OUT\ Max}$ = 1.13 A
$I_{OUT\ Min}$ = 1.05 A

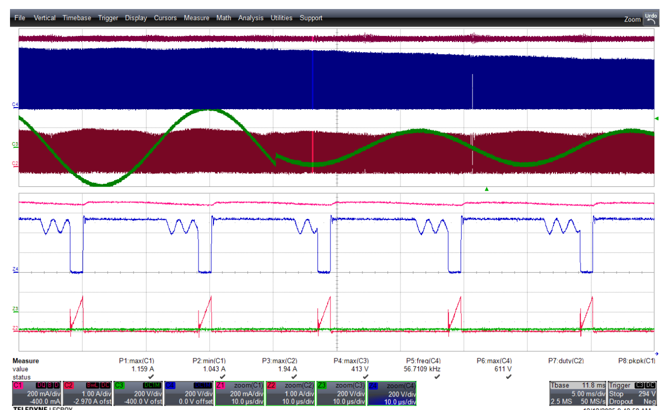


Figure 135 – Step Line 277 V -100 V at 25 VLED load
CH1: I_{OUT}, 200 mA / div., 5 ms / div.
CH2: I_{DS}, 1 A / div., 5 ms / div.
CH3: V_{IN}, 200 V / div., 5 ms / div.
CH4: V_{DS}, 200 V / div., 5 ms / div.
$I_{OUT\ Max}$ = 1.16 A
$I_{OUT\ Min}$ = 1.04 A

12.16 Brown-in/Brown-out Test with 36 V LED Load

12.16.1 Brown-in/Brown-out Test with 36 V LED Load

Remark: No overheating or component damage was observed during brown-in and brown-out testing.

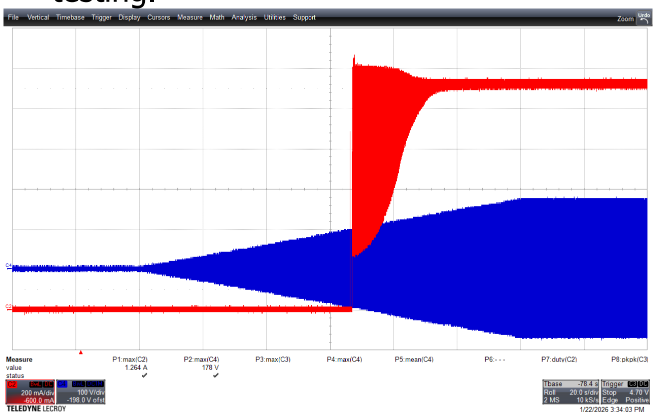


Figure 136 – Brown in, 0 - 100 V, 1 V / s, at 36 VLED
CH2: I_{OUT}, 200 mA / div., 20 s / div.
CH4: V_{IN}, 100 V / div., 20 s / div.

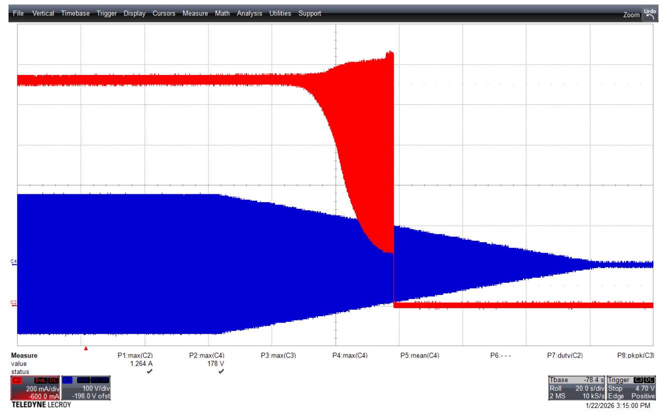


Figure 137 – Brown in, 100 - 0 V, 1 V / s, at 36 VLED
CH2: I_{OUT}, 200 mA / div., 20 s / div.
CH4: V_{IN}, 100 V / div., 20 s / div.

12.16.2 Brown-in/Brown-out Test with 25 V LED Load

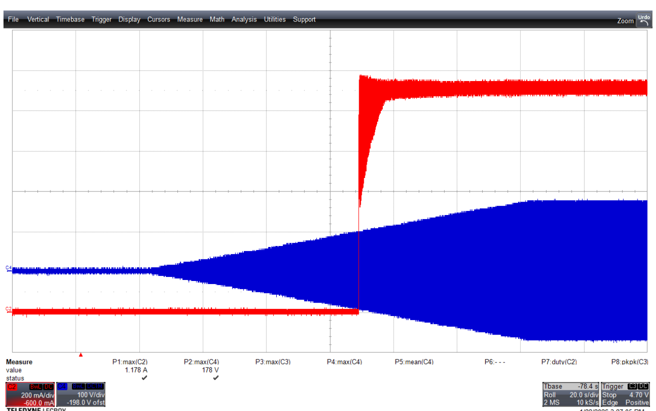


Figure 138 – Brown in, 0 - 100 V, 1 V / s, for 25 V LED Load
CH2: I_{OUT}, 200 mA / div., 20 s / div.
CH4: V_{IN}, 100 V / div., 20 s / div.

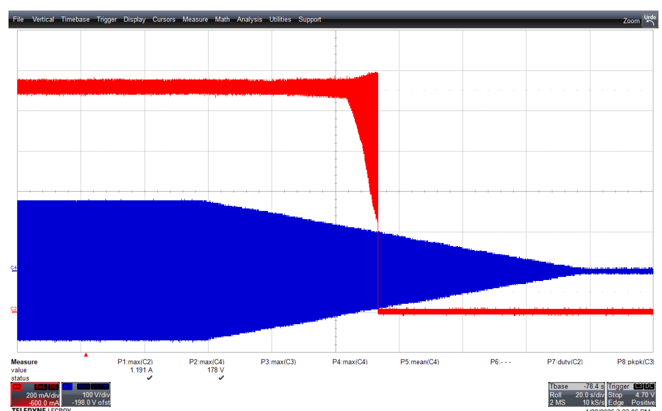


Figure 139 – Brown in, 100 - 0 V, 1 V / s, for 25 V LED Load
CH2: I_{OUT}, 200 mA / div., 20 s / div.
CH4: V_{IN}, 100 V / div., 20 s / div.

13 Conducted EMI

EMI scans were performed at 230 VAC using a 36 V LED Load.

13.1 Test Set-up

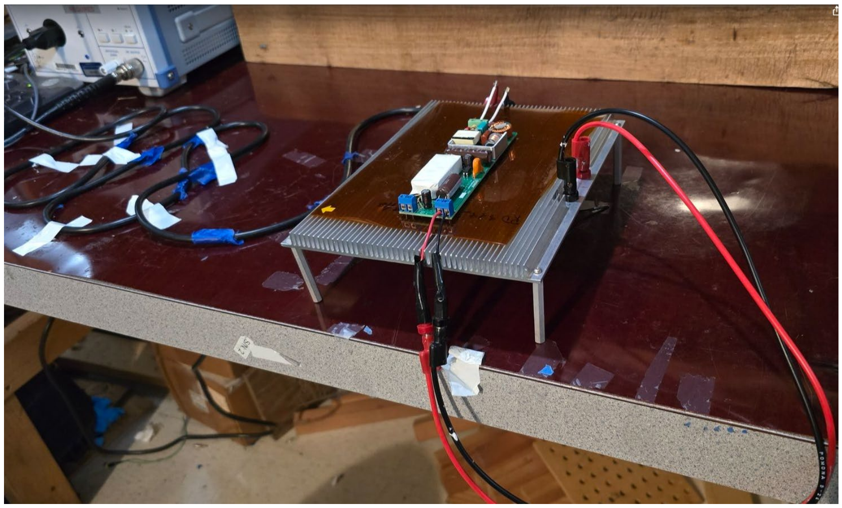


Figure 140 – Conducted EMI Test Set-up.

13.2 Conducted EMI Scan

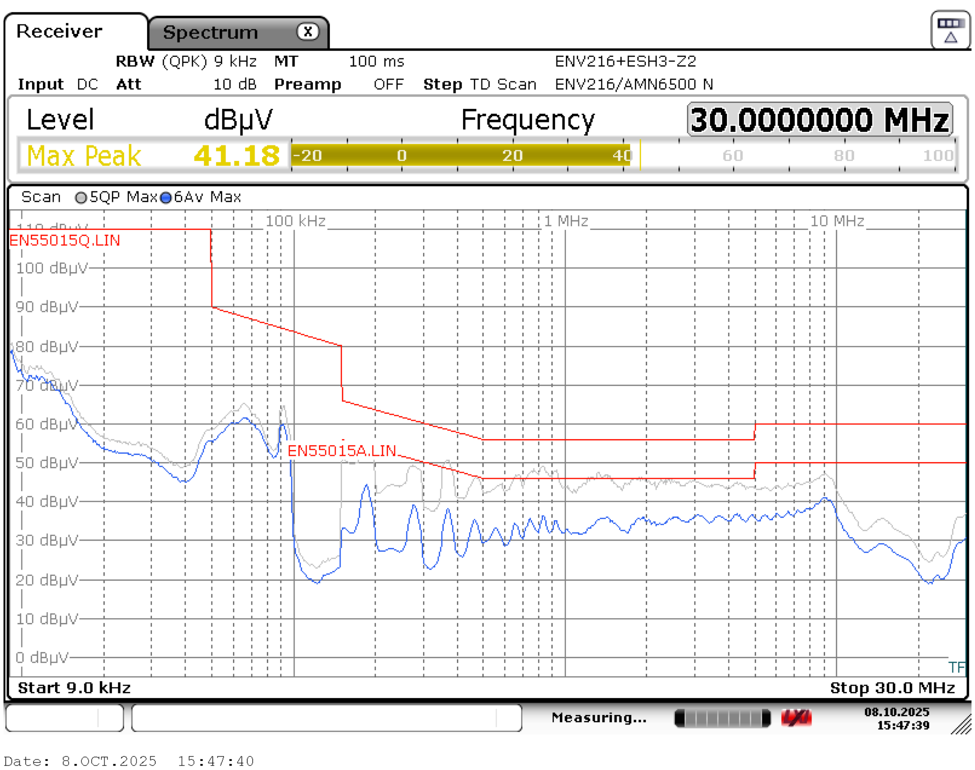


Figure 141 – Conducted EMI with 36 V LED Load (Floating), 230 VAC.

14 Line Surge

The unit was subjected to ±2500 V ring wave and ±2000 V combination wave surge with 10 strikes for each condition. The unit is considered to have failed if the result of a test is non-recoverable interruption of output that requires either repair or AC cycling.

14.1 Combination Wave Differential Mode Surge

AC Input Voltage (VAC)	Surge Voltage (kV)	Injection Location	Phase Angle (°)	Generator Impedance (Ω)	Number of Strikes	Test Result
230	+2000	L to N	0	2	10	PASS
230	-2000	L to N	0	2	10	PASS
230	+2000	L to N	90	2	10	PASS
230	-2000	L to N	90	2	10	PASS
230	+2000	L to N	180	2	10	PASS
230	-2000	L to N	180	2	10	PASS
230	+2000	L to N	270	2	10	PASS
230	-2000	L to N	270	2	10	PASS

Note: output recovered after AR

Table 15 – Combination Wave Differential Mode Surge.

14.2 Ring Wave Surge

14.2.1 Ring Wave Differential Mode Surge

AC Input Voltage (VAC)	Surge Voltage (kV)	Injection Location	Phase Angle (°)	Generator Impedance (Ω)	Number of Strikes	Test Result
230	+2500	L to N	0	12	10	PASS
230	-2500	L to N	0	12	10	PASS
230	+2500	L to N	90	12	10	PASS
230	-2500	L to N	90	12	10	PASS
230	+2500	L to N	180	12	10	PASS
230	-2500	L to N	180	12	10	PASS
230	+2500	L to N	270	12	10	PASS
230	-2500	L to N	270	12	10	PASS

Table 16 – Ring Wave Differential Mode Surge.

15 Appendix

15.1 Thermal Foldback Circuit

The following schematic shows a recommended circuit for implementing a thermal foldback function. The circuit consists of NTC thermistor RT2, NPN transistor Q4, and resistors R5 and R11. The thermistor was placed close to the body of TinySwitch-5 to monitor the IC temperature. As the TinySwitch-5 temperature increased and approached the threshold of approximately 135 °C, the resistance of RT2 decreased, which raised the base-emitter voltage (V_BE) of Q4. As Q4 turns on, it biases feedback current into the TinySwitch-5 feedback pin (C), thereby reducing the converter's output current.

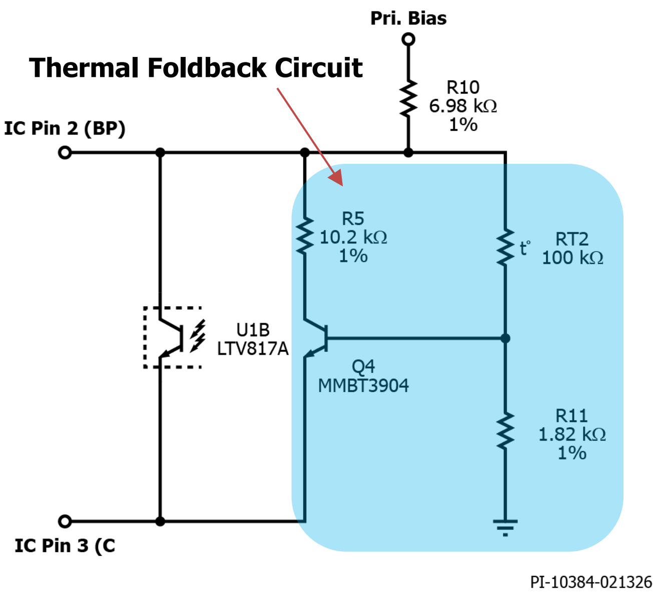


Figure 142 – Thermal Foldback Circuit.

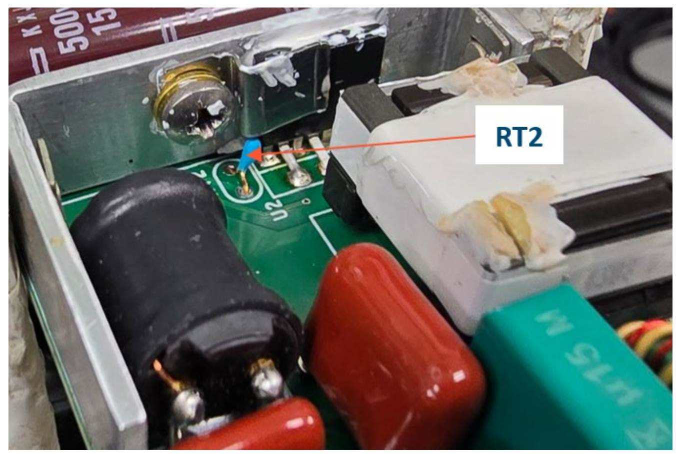


Figure 143 – Thermistor Location – Close to the IC.

Component	Parameters	Min	Nom	Max	Unit
TinySwitch-5	V_{BP}	5.15	5.4	5.65	V
	V_C	2	2.1	2.2	V
Q4- MMBT3904	$V_{BE(SAT)}$	0.65	0.8	0.85	V

Table 17 – Datasheet Parameters for $RT2_{FOLDBACK}$ Calculation.

Using the above parameters, the thermistor foldback threshold resistance RT2 $RT2_{FOLDBACK}$, was calculated using the equation shown below. The corresponding foldback temperature threshold was determined using the thermistor datasheet.

$$RT2_{Foldback} = \frac{V_{BP} \times R11}{V_{BE(SAT)} + V_C} - R11$$

The following IC temperature versus output-current characteristic curve demonstrates the effectiveness of the thermal foldback circuit, which maintained the IC temperature within safe limits as the ambient temperature increased.

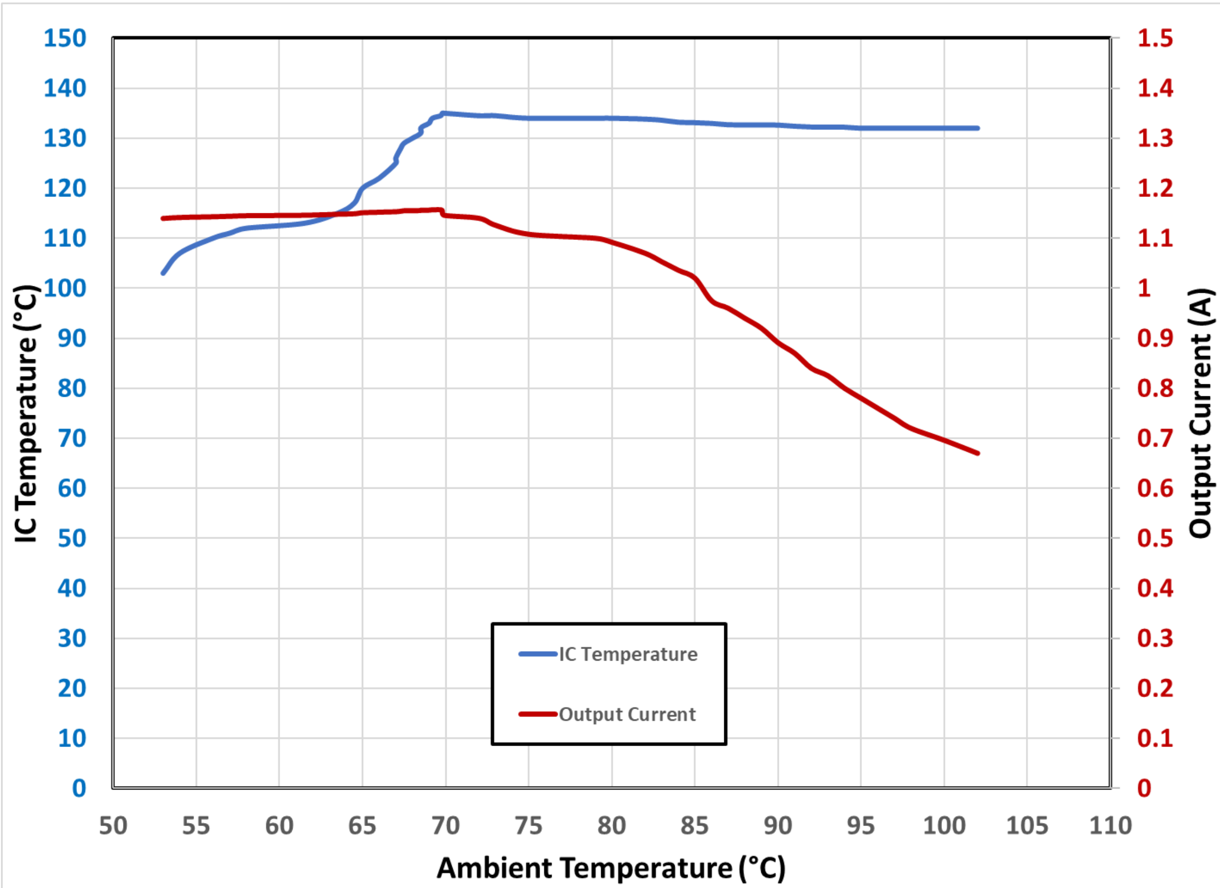


Figure 144 – IC Temperature and Output Current Curve vs Ambient Temperature.

15.2 Constant Current LED Driver using Dual Operation Amplifier

The following feedback circuit recommendation uses two operational amplifiers for a constant-current (CC) 3-in-1 dimmable LED driver implementation. This feedback circuit is not intended for constant-voltage (CV) LED driver applications.

The circuit functional description is the same as DER-1102. Components Q6, R38, and C32 provide a delay at the comparator's inverting input to prevent output current overshoot during start-up conditions when PWM or 0-10 V dimming are already connected to J11.

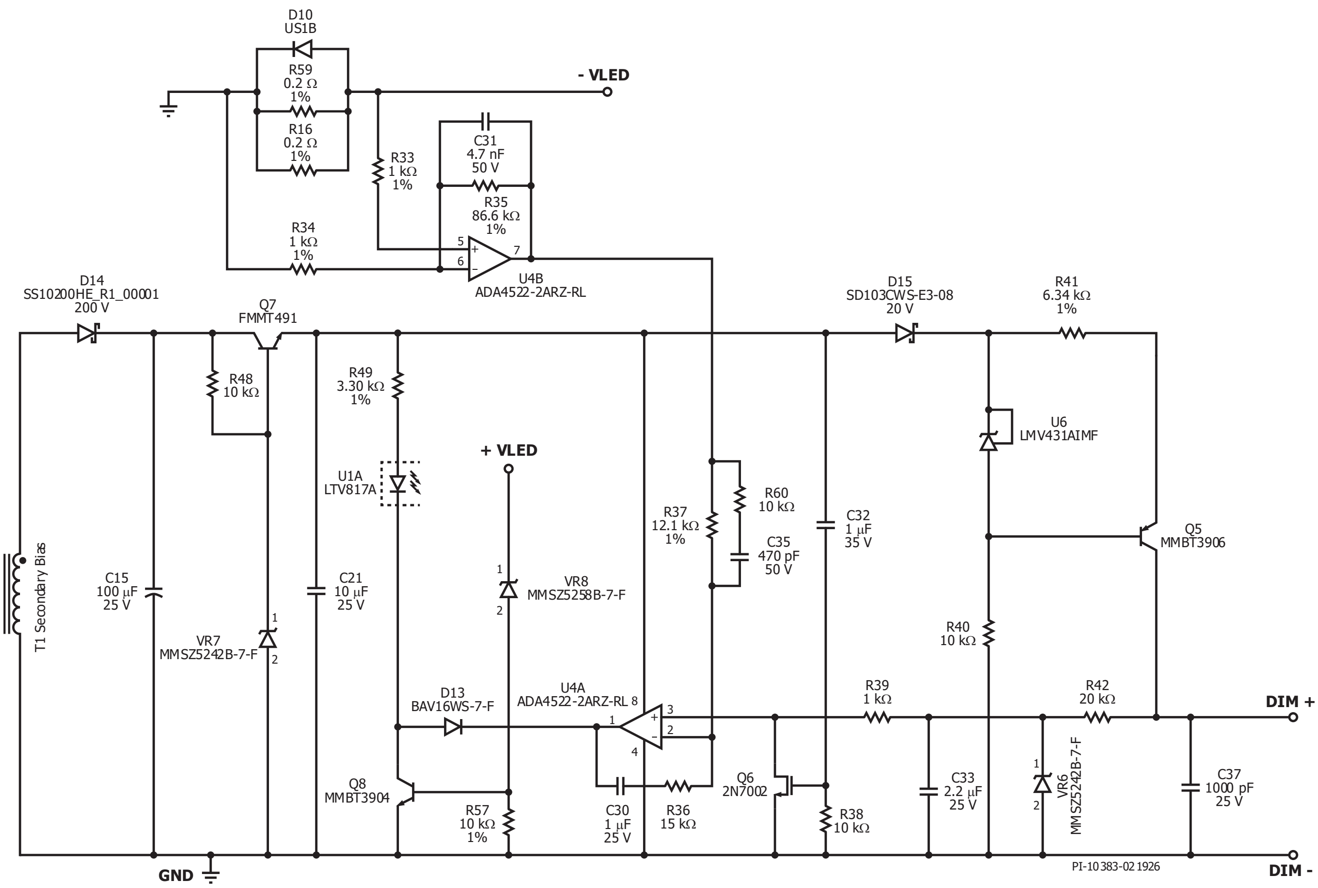


Figure 145 – 3-in-1 Feedback Circuit Using Dual Operation Amplifier.

Item No.	Part Reference	Qty.	Description	Manufacturer	Mfr. Part Number
1	C15	1	100 μF, 25 V, Electrolytic, Gen Purpose, (6.3 x 11.2)	Panasonic	ECA-1EHG101
2	C21	1	10 μF, ±10%, 25 V, Ceramic Capacitor, X7R, 0805 (2012 Metric)	Murata Electronics	GRT21BC71E106KE13L
3	C30	1	1 μF, ±10%, 25 V, Ceramic, X7R, 0603 (1608 Metric)	TDK Corp	CGA3E1X7R1E105K080AE
4	C31	1	4.7 nF 50 V, Ceramic, X7R, 0603	Samsung	CL10B472KB8NNNC
5	C32	1	1 μF, ±10%, 35 V, Ceramic, X7R, 0603 (1608 Metric)	TDK Corp	CGA3E1X7R1V105K080AC
6	C33	1	3.3 μF, 25 V, Ceramic, X7R, 0805	TDK Corp	C2012X7R1E335K
7	C35	1	470 pF, ±10%, 50 V, Ceramic Capacitor X7R, 0603 (1608 Metric)	KEMET	C0603C471K5RACAUTO
8	C37	1	OPS|CAP| 1000 pF ±10% 25 V Ceramic X7R 0805	YAGEO	AC0805KRX7R8BB102
9	D10	1	DIODE ULTRA FAST, 1 A, 100 V, SMA	Diodes, Inc	US1B-13-F
10	D13	1	75 V, 0.15 A, Switching, SOD-323	Diode Inc.	BAV16WS-7-F
11	D14	1	Diode, Schottky, 200 V, 1 A, Surface Mount SOD-123HE	Panjit International Inc.	SS10200HE_R1_00001
12	D15	1	Diode, Schottky, 20 V, 350 mA (DC), Surface Mount, SOD-323	Vishay	SD103CWS-E3-08
13	Q5	1	PNP, Small Signal BJT, 40 V, 0.2 A, SOT-23	On Semiconductor	MMBT3906LT1G
14	Q6	1	60 V, 115 MA, SOT23-3	Diodes Inc	2N7002-7-F
15	Q7	1	NPN, 60 V 1000 MA, SOT-23	Zetex Inc	FMMT491TA
16	Q8	1	NPN, Small Signal BJT, 40 V, 0.2 A, SOT-23	On Semiconductor	MMBT3904LT1G
17	R16 R59	2	RES, 0.2 R, 1%, 1/4 W, Thick Film 1206 (3216 Metric)	Yageo	RL1206FR-070R2L
18	R33 R34	2	RES, 1 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF1001V
19	R35	1	RES, 86.6 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF8662V
20	R36	1	RES, 15 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ153V
21	R37	1	RES, 12.1 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF1212V
22	R38 R40	2	RES, 10 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ103V
23	R39	1	RES, 1 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ102V
24	R41	1	RES, 6.34 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF6341V
25	R42	1	RES, 20 k, 5%, 1/8 W, Thick Film, 0805	Panasonic	ERJ-6GEYJ203V
26	R48	1	RES, 36 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ363V
27	R49	1	RES, 3.30 k, 1%, 1/8 W, Thick Film, 0805	Panasonic ECG	ERJ-6ENF3301V
28	R57	1	RES, 10 kOhms, ±1%, 0.1 W, 1/10 W, Chip Resistor 0603 (1608 Metric)	TE Connectivity	CRGCQ0603F10K
29	R60	1	RES, 10 kOhms, ±5%, 0.1 W, 1/10 W, Chip Resistor 0603 (1608 Metric)	Yageo	RC0603JR-0710KL
30	U1	1	Optocoupler, 35 V, CTR 80-160%, 4-DIP	Liteon	LTV-817A
31	U4	1	IC, Zero-Drift Amplifier, Dual, 2 Circuit, Rail-to-Rail, 8-SOIC	Analog Devices Inc.	ADA4522-2ARZ-RL
32	U6	1	1.24 V Shunt Regulator IC, 1%, -40 to 85 °C, SOT23-3	Texas Instruments	LMV431AIMF/NOPB
33	VR6 VR7	2	DIODE ZENER 12 V 500 MW SOD123	Diodes, Inc	MMSZ5242B-7-F
34	VR8	1	DIODE ZENER 36 V 500 MW SOD123	Diodes, Inc	MMSZ5258B-7-F

Table 18 – Bill of Materials for Dual Op-Amp Feedback Circuit.

16 Revision History

Date	Author	Revision	Description & Changes	Reviewed
29-Apr-26	MGM	A	Initial Release.	Apps & Mktg

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