Design Example Report

Title	**120 W Isolated Flyback Power Supply Using LinkSwitch™-HP LNK6779E**
Specification	85 VAC – 265 VAC Input; 24.0 V / 5 A Outputs
Application	Appliance
Author	Applications Engineering Department
Document Number	DER-762
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Revision	A

Summary and Features

- Primary-side regulated isolated flyback converter with ±5% regulation
- 132 kHz switching frequency for small transformer and output filter size
- Full load Continuous Conduction Mode (CCM) operation for improved efficiency and reduced output capacitor ripple current
- <70 mW no-load input power at 230 VAC
- Multimode operation maximizes efficiency across load range
- Extensive protection including OVP, OTP, brown-in/out, line overvoltage, and lost-regulation (auto-restart)
- 88% full load efficiency @ 115 VAC and 90% full load efficiency @ 230 VAC
- Easily meets DoE 6 efficiency requirements of 88% average efficiency (end of cable)
- Class B Conducted EMI with > 6 db margin

Power Integrations

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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 report describes a universal input, 12 V, 120 W, isolated flyback using LNK6779E from the LinkSwitch-HP family of ICs. It contains the complete power supply specifications, bill of materials, transformer construction information, schematic and printed circuit board layout, along with performance data and electrical waveforms.

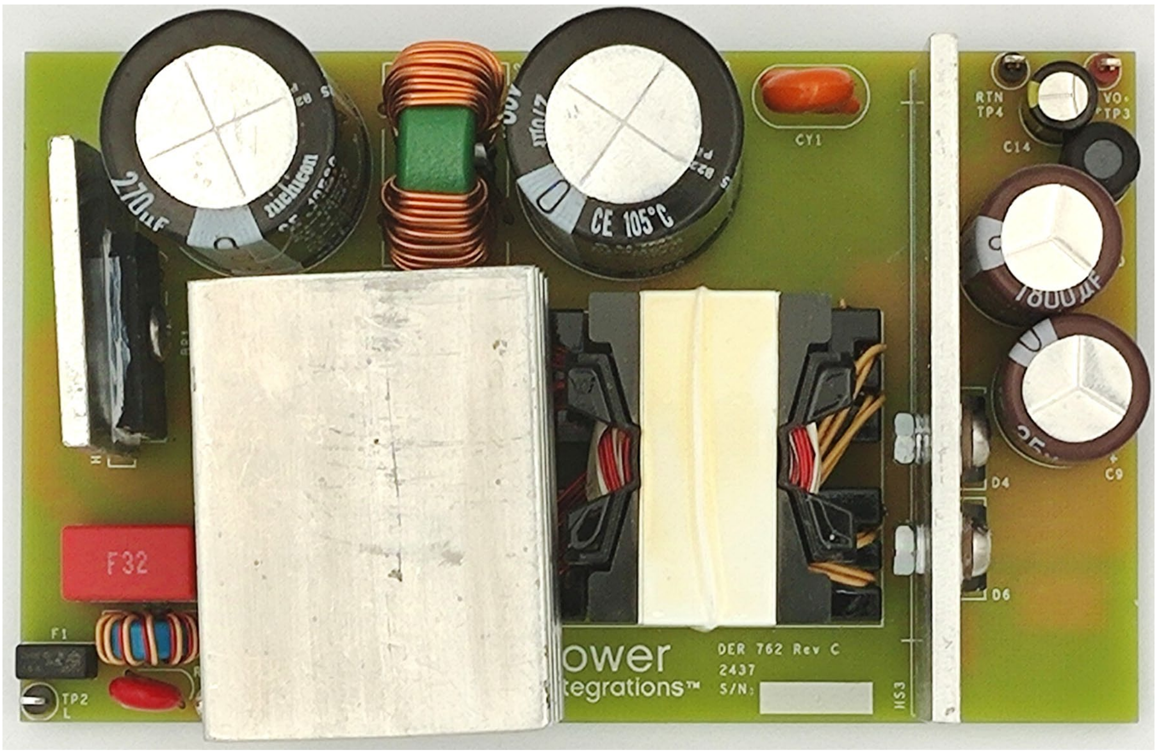


Figure 1 – Populated Circuit Board, Top View.

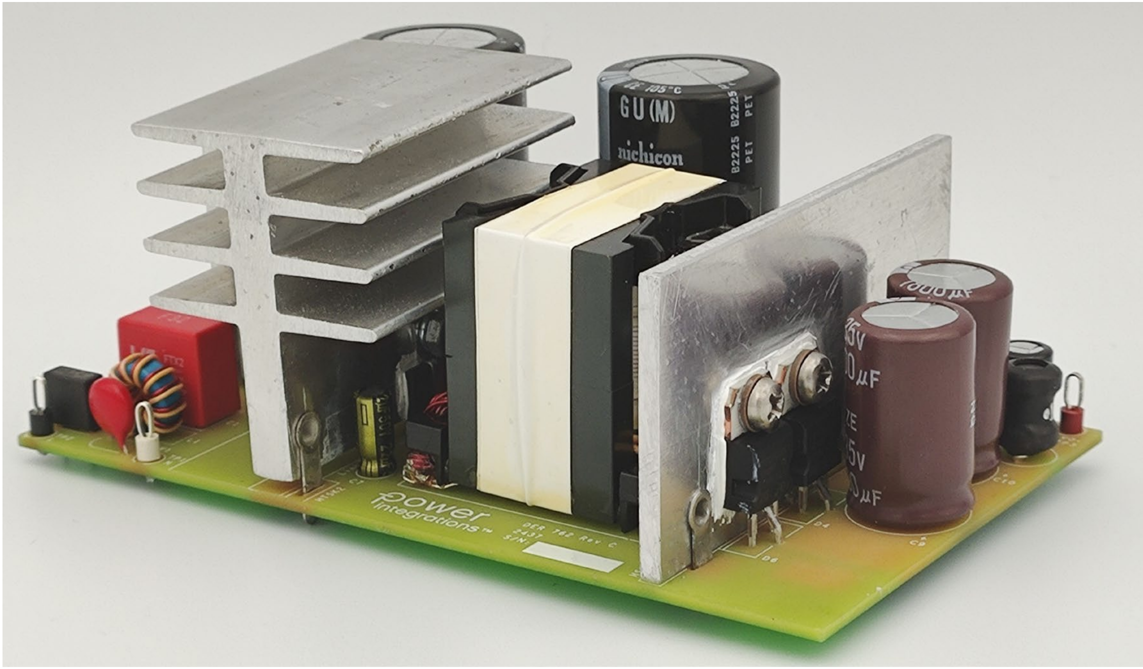


Figure 2 – Populated Circuit Board, Side View.

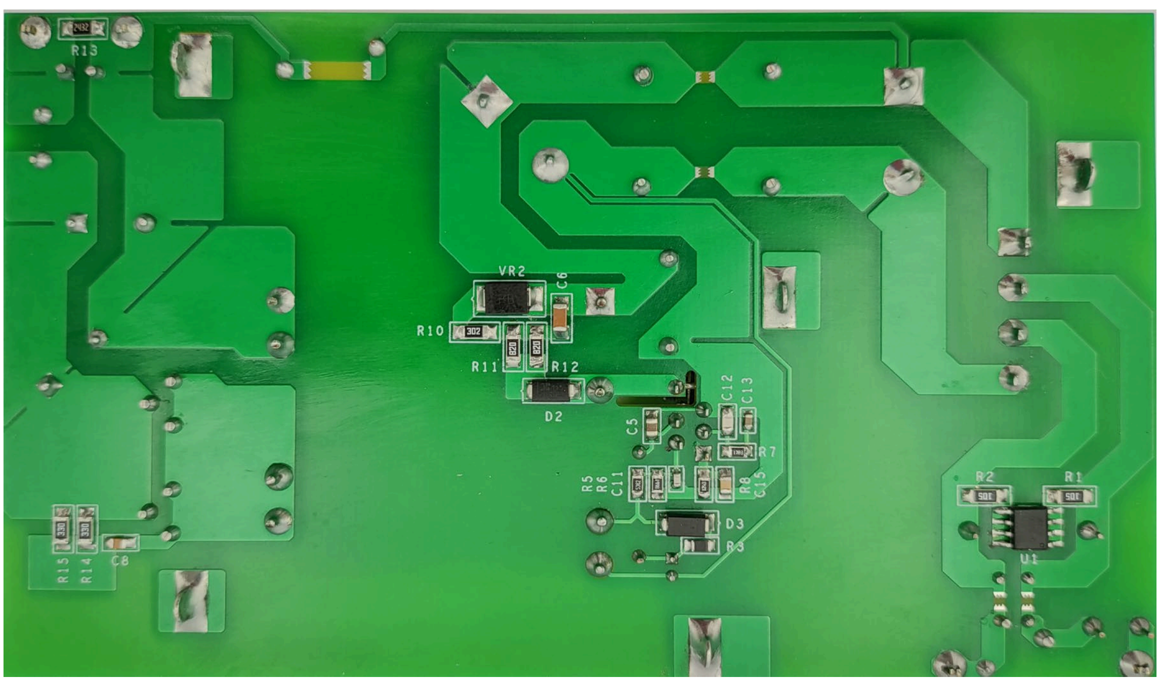


Figure 3 – Populated Circuit Board, Bottom View.

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	85	115/230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50 / 60	64	Hz	
No-load Input Power (230 VAC)				70	mW	
Output1						
Output Voltage	V_{OUT1}	22.8	24	25.2	V	± 5%
Output Ripple Voltage	$V_{RIPPLE1}$			150	mV	20 MHz Bandwidth.
Output Current	I_{OUT1}	0		5	A	
Total Output Power						
Continuous Output Power	P_{OUT}	0		120	W	
Efficiency						
Full Load 115 VAC	$\eta_{115\ VAC}$	88			%	Measured at P_{OUT} 25 °C.
Full Load 230 VAC	$\eta_{230\ VAC}$	90			%	
Average efficiency at 25, 50, 75 and 100 % of P_{OUT}	η_{DOE}	88			%	Measured at Nominal Input 115 VAC and 230 VAC.
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Surge (Differential)				±2	kV	1.2/50 µs Surge, IEC 61000-4-5
Ring Wave (Common Mode)				±4	kV	
Electrical Fast Transient				±4	kV	
ESD – Air Discharge				±16.5	kV	
ESD – Contact Discharge				±8.8	kV	
Ambient Temperature	T_{AMB}	0		40	°C	Free Convection, Sea Level. At an ambient temperature of 40 °C, the maximum power that can be supported is 120 W with a minimum input voltage of 95 VAC, and 113 W with a minimum input voltage of 85 VAC.

Table 1 – Power Supply Specifications.

3 Schematic

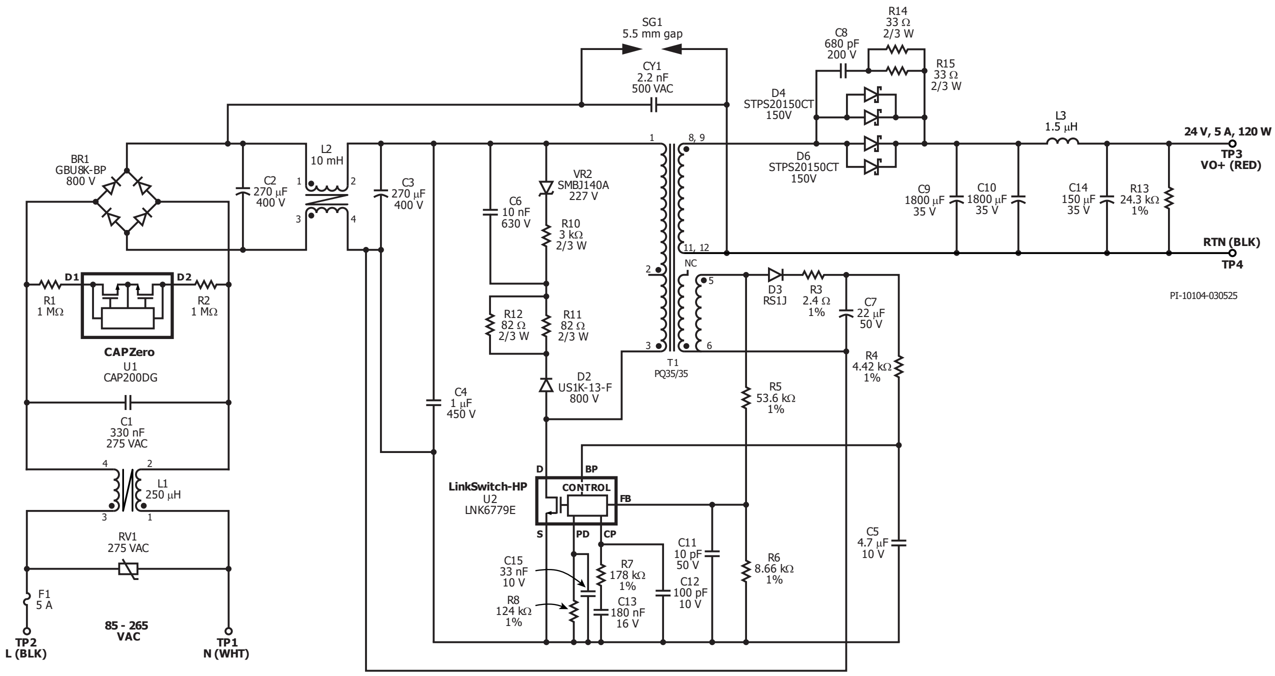


Figure 4 – Schematic.

4 Circuit Description

The circuit shown in Figure 4 utilizes the LNK6779E IC in a 24 V, 120 W isolated flyback power supply.

4.1 Input EMI Filtering and Rectification

Fuse F1 isolates the circuit and provides protection from component failure. Varistor RV1 suppresses any line transient voltage or surge seen by the power supply. X capacitor C1 and common mode choke L1 form an EMI filter supplemented a pi-filter formed by capacitors C2 and C3 together with a common mode choke L2. The input filter attenuates both common mode and differential mode conducted EMI. Resistors R1 and R2 together with the CAP200DG (U1) discharge C1 when AC power is removed. BR1 converts the AC line voltage into the DC voltage seen across bulk capacitors.

4.2 LinkSwitch-HP Primary

The LNK6779E IC (U2) integrates a driver, an oscillator, an error amplifier and multi-mode control circuit, start-up and protection circuitry and a high-voltage power MOSFET all in one monolithic IC.

When AC is first applied, an internal current source connected to the DRAIN (D) pin charges C5 to power the controller inside the IC. During steady-state, the controller will be powered via a bias winding to minimize losses through the current limiting resistor R4.

At the start of a switching cycle, the internal power MOSFET turns on, allowing current to ramp in the primary winding up to a threshold set by the voltage output of the internal error amplifier pin (CP). Due to the phase orientation of the transformer windings, the output rectifier diodes, D4 and D6, are reverse biased at this point in the cycle. D4 and D6 conduct when the power MOSFET turns off, allowing the energy stored in the core of the transformer to be delivered to the output.

The value of capacitor C5 connected to the BYPASS (BP) pin sets over-temperature protection (OTP) to hysteretic mode, and overvoltage protection (OVP) as well as lost-regulation-protection to automatic-restart (AR), with a long off-period (typically 1.5 s).

4.3 Primary RCDZ Snubber

Diode D2, VR2, C6 and R10 form a Resistor-Zener-Capacitor-Diode (RZCD) snubber that is used to limit the voltage stress across the primary switch in the LinkSwitch-HP IC. Peak drain voltage is limited to less than 600 V providing significant margin to the 725 V drain voltage limit (BVDSS). Zener diode VR2 prevents capacitor C6 from fully discharging during each switching cycle to reduce power consumption during standby. Resistors R11 and R12 damp drain oscillations for better output voltage regulation and EMI response.

4.4 Output Rectification

Schottky diodes D4 and D6 rectify the output of T1. The output voltage is filtered by C9, C10, L3, and C14. Resistors R14 and R15 and capacitor C8 snubs the voltage spike caused by the commutation of D4 and D6. Low Equivalent Series Resistance (ESR) capacitors C9 and C10 minimize output voltage ripple, while post filter L3 and C14 adds further attenuation. Resistor R13 serves as a preload which helps regulation during light to no-load operation.

4.5 External Current Limit Setting

The maximum cycle-by-cycle current limit is set by resistor R8 connected to the PROGRAM (PD) pin. A 124 kΩ resistor sets the maximum current limit to 100% of the LNK6779E's default current limit.

4.6 Output Feedback

The output voltage is indirectly sensed through the bias winding via a resistor divider (R5 and R6). The sensed voltage is then applied to the to the FEEDBACK (FB) pin. This network is also used to indirectly monitor the bus voltage during start-up and enables output power delivery only when the input voltage reaches the brown-in threshold and also stops below brown-out condition. The voltage sensed at the FB pin produces a control voltage at the CP pin. Resistor R7 and capacitor C12, C13 are used for control loop compensation. The operating peak primary current and the operating switching frequency are determined by the CP pin voltage.

If the bus voltage becomes excessive (e.g. during operation by line surge) U2 stops switching. Additionally, the cycle-by-cycle current limit is compensated over line to limit the overload power. See device data sheet for more information.

5 PCB Layout

Layers	:	1 layer
Board Thickness	:	1.6 mm
Copper Thickness	:	2 oz
Material	:	FR-4

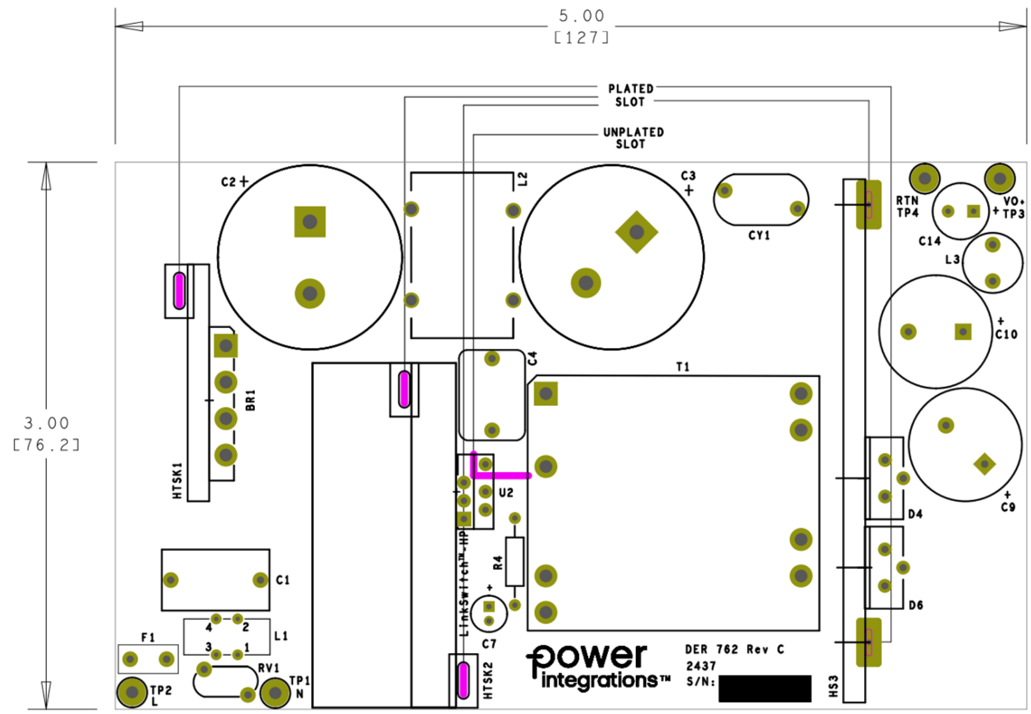


Figure 5 – Printed Circuit Board, Top View.

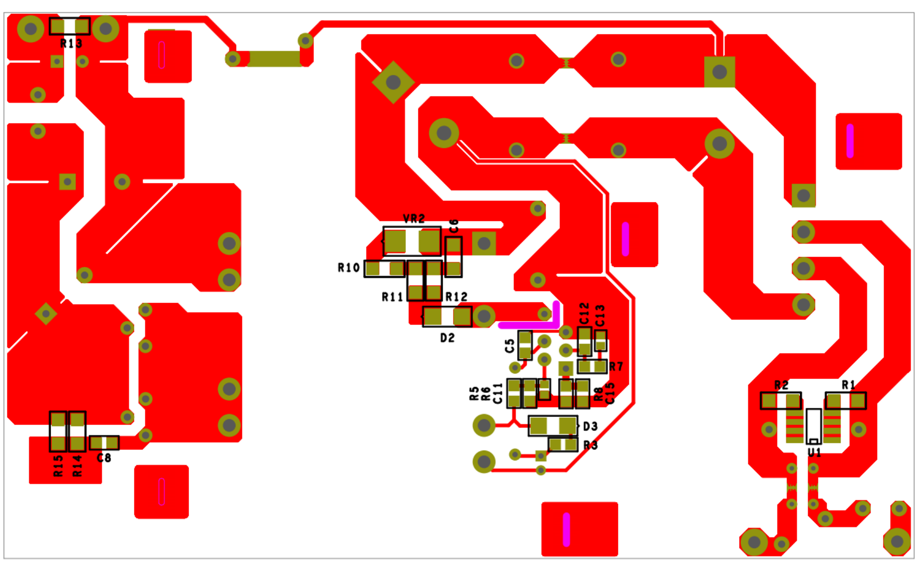


Figure 6 – Printed Circuit Board, Bottom View.

6 Bill of Materials

6.1 Electrical BOM

Item	Qty.	Ref Des.	Description	Mfr. Part Number	Manufacturer
1	1	BR1	800 V, 8 A, Bridge Rectifier, GBU Case	GBU8K-BP	Micro Commercial Co.
2	1	C1	330 nF, ±10%, 275 VAC, Polypropylene Film, X2, 15.00 mm x 8.50 mm	890324024003CS	Wurth Electronics Inc.
3	2	C2 C3	270 μF, 400 V, Electrolytic, (25.4 x 35)	EKMR401VSN271MQ35S	UCC
4	1	C4	CAP, FILM, 1.0 μF, 10%, 450 VDC, RADIAL	ECW-FD2W105Q1	Panasonic
5	1	C5	4.7 μF ±10% 10 V Ceramic Capacitor X7R 0805 (2012 Metric)	LMK212B7475KGHT	Taiyo Yuden
6	1	C6	10 nF, 630 V, Ceramic, X7R, 1206	C1206C103KBRACTU	Kemet
7	1	C7	22 μF, 50 V, Aluminum Electrolytic Capacitors, Radial, Can 2000 Hrs @ 85 °C, (5 x 11), LS 2 mm	EEU-FM1H220H	Panasonic
8	1	C8	680 pF 200V X7R MULTI-LAYER CERAMIC +/- 10%	C0805C681K2RACAUTO	Kemet
9	2	C9 C10	1800 μF, 35 V, Electrolytic, Very Low ESR, 16 mOhm, (16 x 25)	EKZE350ELL182ML25S	Nippon Chemi-Con
10	1	C11	10 pF, ±0.25 pF, 50 V, Ceramic Capacitor, C0G, NP0, 0603 (1608 Metric)	CC0603CRNPO9BN100	Yageo
11	1	C12	100 pF, ±10%, 10 V, Ceramic, X7R, 0805 (2012 Metric)	C0805C101K8RACAUTO	Kemet
12	1	C13	180 nF, 16 V, Ceramic, X7R, 0603	GRM188R71C184KA01D	Murata
13	1	C14	150 μF, 35 V, Electrolytic, Gen. Purpose, (8 x 11.5)	EEU-FM1V151	Panasonic
14	1	C15	33 nF, 0.033 μF, 10 V, Ceramic, X7R, 0805	0805ZC333KAT2A	AVX Corporation
15	1	CY1	2200 PF, ± 20%, 500 VAC (Y1), 760 VAC (X1), Ceramic, Y5U (E), RADIAL	440LD22-R	Vishay
16	1	D2	800 V, 1 A, Fast Recovery, 500 ns, SMA	US1K-13-F	Diodes, Inc
17	1	D3	600 V, 1 A, Fast Recovery, 250 ns, SMA	RS1J-13-F	Diodes, Inc
18	2	D4 D6	Diode Array, 1 Pair, Common Cathode, 150 V, 10 A, Through Hole TO-220-3	STPS20150CT	ST Microelectronics
19	1	F1	5 A, 250 V, Slow, Long Time Lag, RST	RST 5	Belfuse
20	1	L1	250 μH, Toroidal Common Mode Choke, custom, DER-538, wound on 32-00275-00 core.	32-00367-00	Power Integrations
21	1	L2	Common Mode Choke Toroidal	XF0093PI-VOCMC	XFMRS, LTD
22	1	L3	1.5 μH, 8.5 A, Hi Current, Radial (See 30-00623-00 for alternate)	6000-1R5M-RC	JW Miller
23	2	R1 R2	RES, 1.0 M, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J105V	Panasonic
24	1	R3	RES, SMD, 2.4 R, 1%, 1/8 W, 0805	CRCW08052R40FKEA	Vishay-Dale
25	1	R4	RES, 4.42 k, 1%, 1/4 W, Metal Film	MFR-25FBF-4K42	Yageo
26	1	R5	RES, 53.6 k, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF5362V	Panasonic
27	1	R6	RES, 8.66 k, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF8661V	Panasonic
28	1	R7	RES, 178 k, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1783V	Panasonic
29	1	R8	RES, 124 k, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1243V	Panasonic
30	1	R10	RES, 3.0 k, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J302V	Panasonic
31	2	R11 R12	RES, 82 R, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J820V	Panasonic
32	1	R13	RES, 24.3 k, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2432V	Panasonic

33	2	R14 R15	RES, 33 R, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J330V	Panasonic
34	1	RV1	275 VAC, 23 J, 7 mm, RADIAL	V275LA4P	Littlefuse
35	1	T1	Bobbin, PQ35/35, Vertical, 12 pins	BQ35/35-1112CPFR	TDK
				CPV-PQ35/35-1S-12P-Z	Ferroxcube
36	1	U1	CAPZero-2, CAP200DG, SO-8C	CAP200DG	Power Integrations
38	1	U2	LinkSwitch-HP, LNK6779E, Esip-7C	LNK6779E	Power Integrations
37	1	VR2	227V Clamp, 5%, 2.65 A Ipp, Tvs Diode, Surface Mount SMB, DO-214AA, (SMBJ)	SMBJ140A	KYOCERA AVX

Table 2 – Bill of Materials, Electrical parts.

6.2 Mechanical BOM

Item	Qty.	Ref Des.	Description	Mfr. Part Number	Manufacturer
1	1	ESIP CLIP1	Heatsink Hardware, Edge Clip, 12.40 mm x 6.50 mm	TRK-24	Kang Tang Hardware Enterprise Co. Ltd.
2	1	HS1	SHTM, Heat Sink, DER-762_Bridge_Heatsink	61-00368-00	Custom
3	1	HS2	SHTM, Heat Sink, DER-762_LinkSwitch_Heatsink_4 FINS	61-00367-00	Custom
4	1	HS3	SHTM, Heat Sink, DER-762_Sec_Diode_Heatsink	61-00369-00	Custom
5	3	NUT1 NUT3 NUT4	Nut, Hex, Metric, M3 SS	68024082	Import
6	1	NUT2	Nut, Hex 6-32, SS	HNSS 632	Building Fasteners
7	4	RTV1 RTV2 RTV3 RTV4	Thermally conductive Silicone Grease	120-SA	Wakefield
8	1	SCREW1	SCR, Phillips, M3 X 12 mm, Panhead Mach, Metric SS with rubber O-ring.	SM3X12MM-2701	APM HEXSEAL
9	1	SCREW2	SCREW MACHINE PHIL 6-32 X 3/8 SS	PMSSS 632 0038 PH	Building Fasteners
10	2	SCREW3 SCREW4	SCR, Phillips, M3 X 8 mm, Panhead Mach, Metric SS with rubber O-ring.	RM3X8MM 2701	APM HEXSEAL
11	5	TE1 TE2 TE3 TE4 TE5	Terminal, Eyelet, Tin Plated Brass, Zierick PN 190	190	Zierick
12	1	TP1	Test Point, WHT, THRU-HOLE MOUNT	5012	Keystone
13	2	TP2 TP4	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
14	1	TP3	Test Point, RED, THRU-HOLE MOUNT	5010	Keystone
15	3	WASHER1 WASHER3 WASHER4	Washer, Lk, M 3 Zinc, Metric	MLWZ 003	Building Fasteners
16	1	WASHER2	Washer Flat #6, SS	FWSS 006	Building Fasteners
17	2	WASHER5 WASHER6	Washer, Shoulder, #4, 0.125 Shoulder x 0.140 Dia, Polyphenylene Sulfide PPS	7721-3PPSG	Aavid Thermalloy

Table 3 – Bill of Materials, Mechanical parts.

7 Transformer Specification

7.1 Electrical Diagram

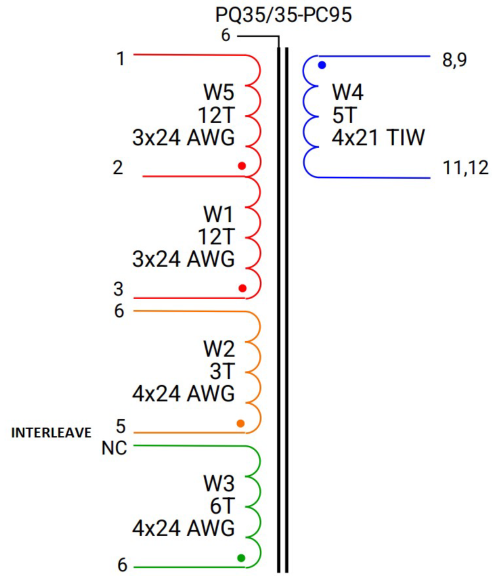


Figure 7 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	**Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 1 and pin 3 with all other windings open.**	**364 µH**
Tolerance	**Tolerance of Primary Inductance.**	**±5 %**
Leakage Inductance	**Measured across primary winding with all other windings shorted.**	**< 7.29 µH**

Table 4 – Transformer Electrical Specifications.

7.3 List of Materials

Item	Description
[1]	Core: PQ35/35, PC44, gapped for ALG of 630 nH/T^2.
[2]	Bobbin: Phenolic BQ35/35-1112CPFR (TDK) or CPV-PQ35/35-1S-12P-Z (Ferroxcube) or equivalent.
[3]	Magnet Wire: #24 AWG.
[4]	TIW Wire: #21 AWG.
[5]	Polyester Tape: 21 mm.
[6]	Polyester Tape: 13 mm.
[7]	Polyester Tape: 14.5 mm.
[8]	Varnish: Dolph BC 359; or Equivalent.
[9]	Bus Wire: #28 AWG, Alpha Wire, Tinned Copper; or Equivalent.

Table 5 – Transformer Materials List.

7.4 Transformer Build Diagram

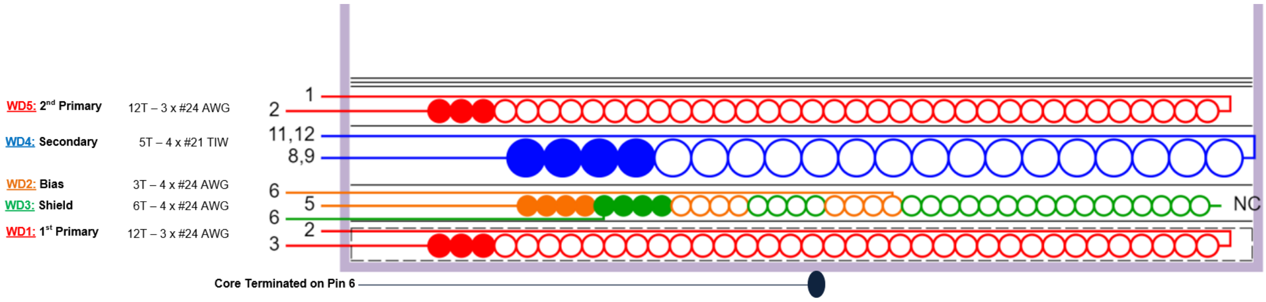


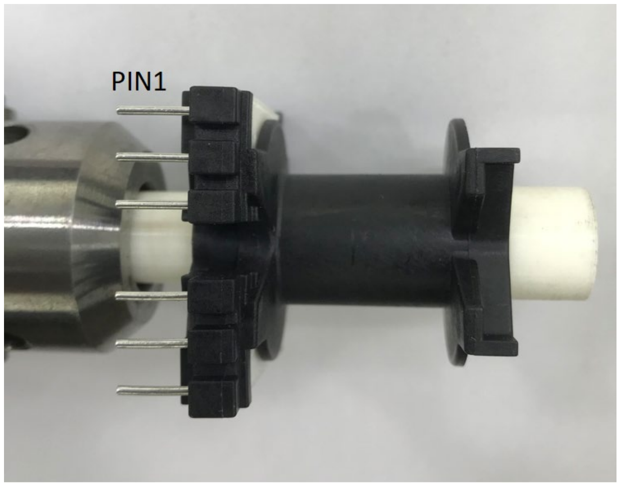
Figure 8 – Transformer Build Diagram.

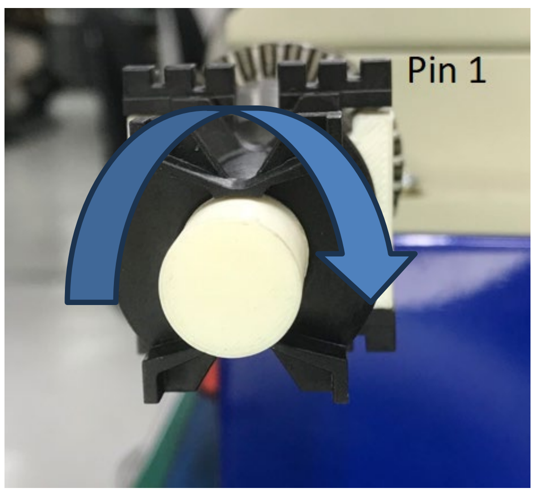
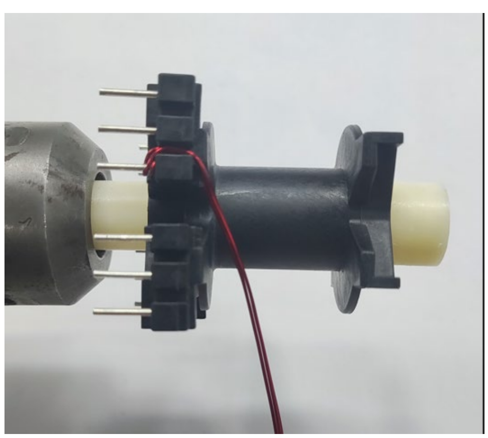
7.5 Transformer Instructions

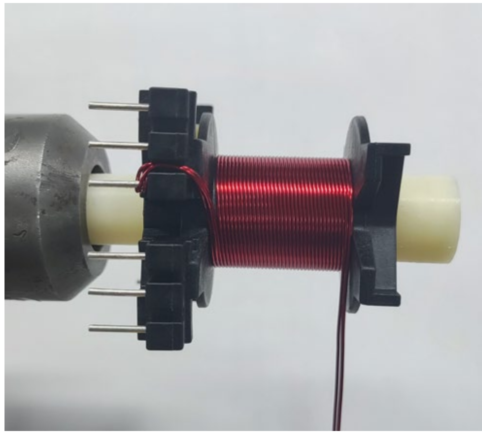
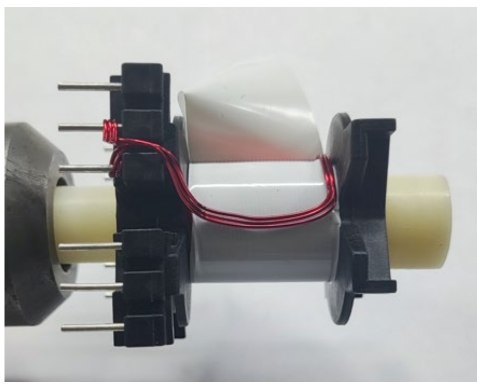
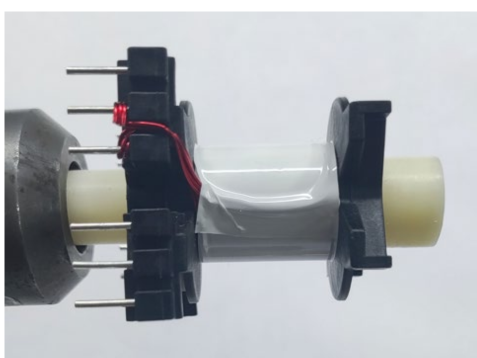
Winding Preparation	Position the bobbin Item [2] on the mandrel, pins facing the direction of the winding machine, pin 1 on the upper side and pin 6 on the lower side. Winding direction is clockwise.
WD1 1st Primary	Prepare 3 strands of wire Item [3]. Start at pin 3, wind 12 turns of wire Item [3] in 1 layer from left to right.
Insulation	Apply 1 layer of tape Item [5] for insulation and leave enough to cover the wire going back to the pin side. Finish WD1 at pin 2. Wrap the tape to cover WD1.
WD2 & WD3 Bias and Shield	Prepare 8 strands of wire Item [3]. Start WD2 at pin 5 with 4 strands. Mark the end of WD2 to avoid confusion. Start WD3 at pin 6 with 4 strands. Wind all the wires together for 3 turns from left to right. Apply 1 layer of tape Item [6] to hold wires in place and leave enough to cover the wire going back to the pin side. Exit WD2 to the left, and finish WD2 at pin 6. Wrap the tape to cover WD2. Wind the remaining 3 turns for WD3.
Insulation	Apply 1 layer of tape Item [5] for insulation and leave enough to cover the wire going back to the pin side. Bend the end of WD3 90 degrees, cut as shown and leave it floating. Wrap the tape to cover WD3 and WD2.
WD4 Secondary	Prepare 4 strands of wire Item [4]. Start 4 strands of wire Item [4] at pin 8 and 9, wind 4 wires 5 turns in parallel in 1 layer. Spread out the winding evenly.
Insulation	Apply 1 layer of tape Item [5] for insulation and leave enough to cover the wire going back to the pin side. Finish WD4 at pin 11 and 12. Wrap the tape to cover WD4.
WD5 2nd Primary	Prepare 3 strands of wire Item [3]. Start at pin 2, wind 12 turns of wire Item [3] in 1 layer from left to right.
Insulation	Apply 1 layer of tape Item [5] for insulation. Finish WD5 at pin 1. Wrap the tape to cover WD5 and apply 2 additional layers of tape Item [5].
Assembly	Grind the center leg of the upper half of Item [1] to get 364 μH measured between Pin 1 and Pin 3 with all other pins open. Use Item [9] and wrap it around Item [1], then solder to Pin 6. Wrap the body of transformer with 3 layers of tape Item [7]. Measure Primary Inductance between Pin 1 and Pin 3 with all other pins open, then Leakage Inductance between Pin 1 and Pin 3 with all other pins shorted together.
Finish	Varnish using Item [8]. Check again Primary and Leakage Inductance if within specifications.

Table 6 – Transformer Build Instructions.

7.6 Transformer Winding Illustrations

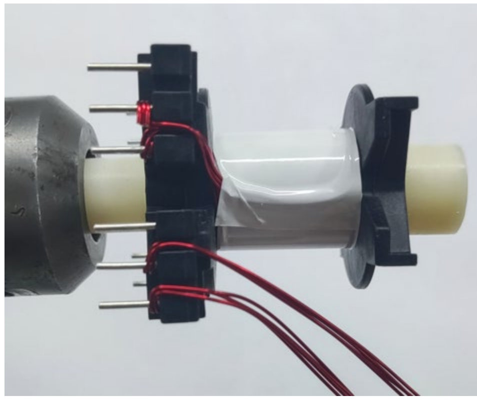
<table>
<tr><td>Winding Preparation</td><td>


</td><td>Position the bobbin Item [2] on the mandrel, pins facing the direction of the winding machine, pin 1 on the upper side and pin 6 on the lower side. Winding direction is clockwise.</td></tr>
<tr><td>WD1
1st Primary</td><td></td><td>Prepare 3 strands of wire Item [3].</td></tr>
</table>

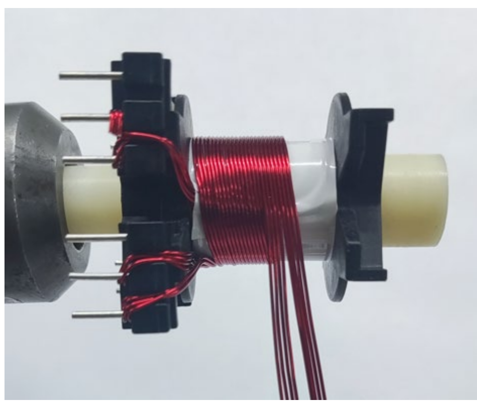
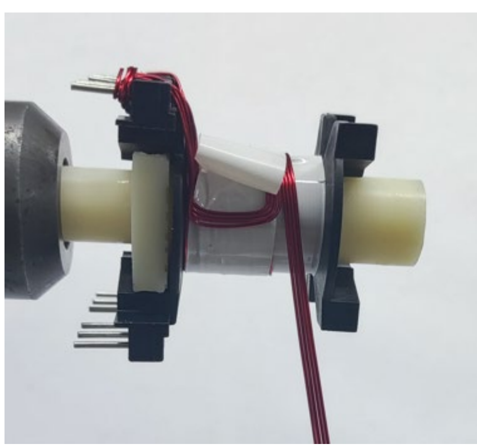
<table>
<tr><td></td><td></td><td>Start at pin 3, wind 12 turns of wire Item [3] in 1 layer from left to right.</td></tr>
<tr><td>Insulation</td><td>
</td><td>Apply 1 layer of tape Item [5] for insulation and leave enough to cover the wire going back to the pin side.

Finish WD1 at pin 2.

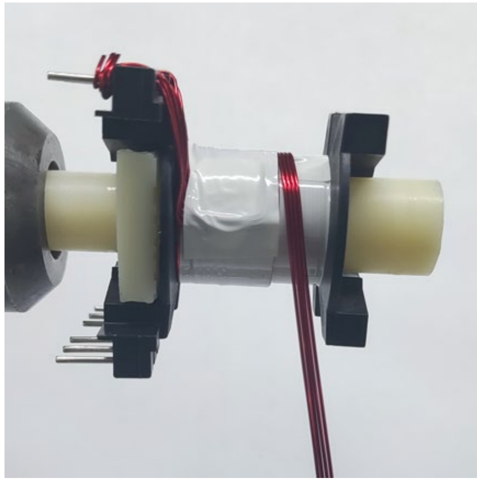
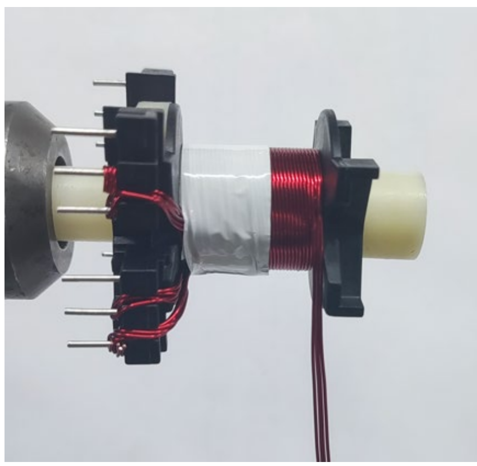
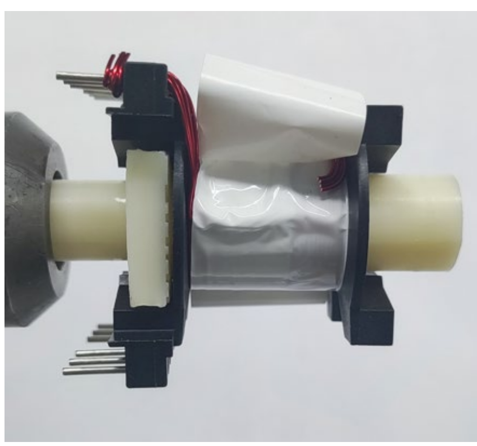
Wrap the tape to cover WD1.</td></tr>
</table>

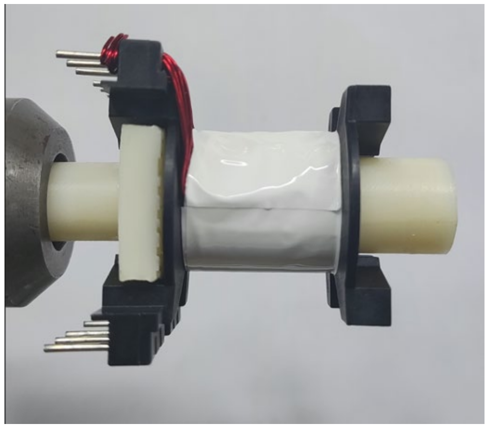
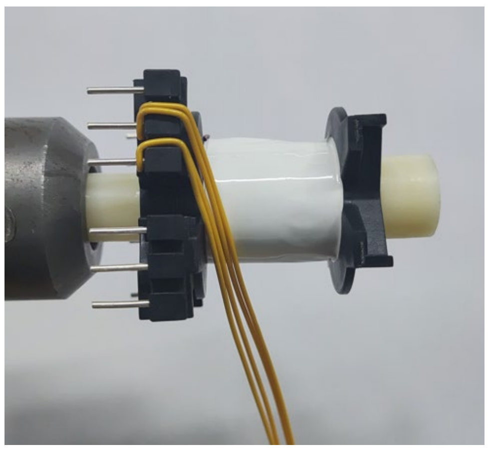
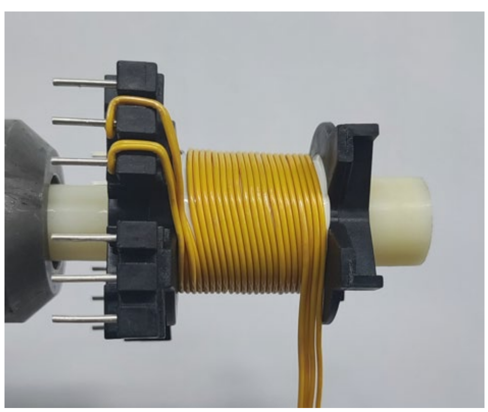
<table>
<tr>
<td rowspan="3">WD2 & WD3 Bias and Shield</td>
<td></td>
<td>Prepare 8 strands of wire Item [3].

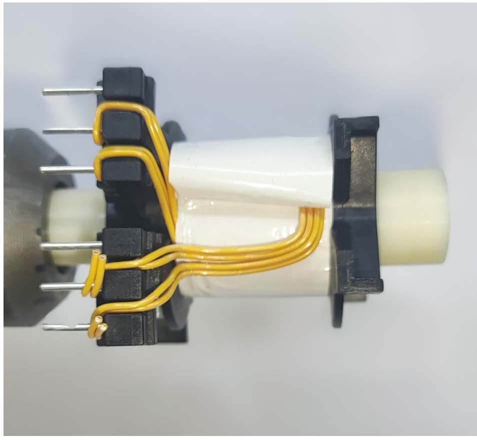
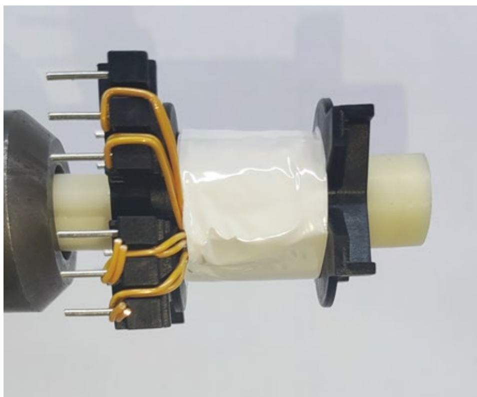
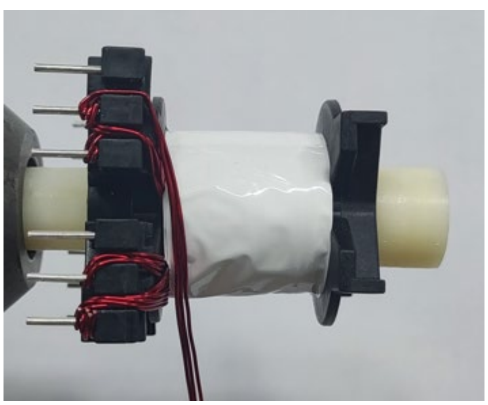
Start WD2 at pin 5 with 4 strands. Mark the end of WD2 to avoid confusion.

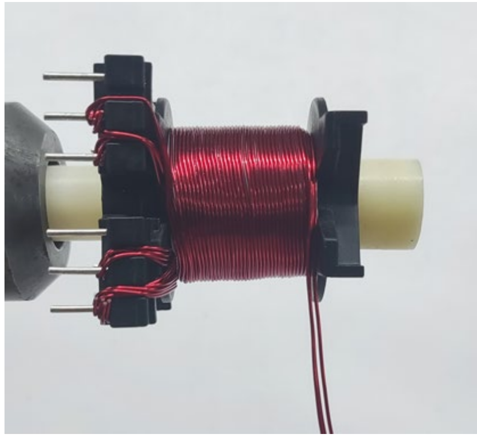
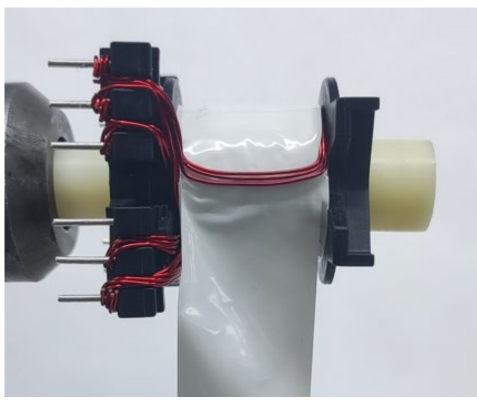
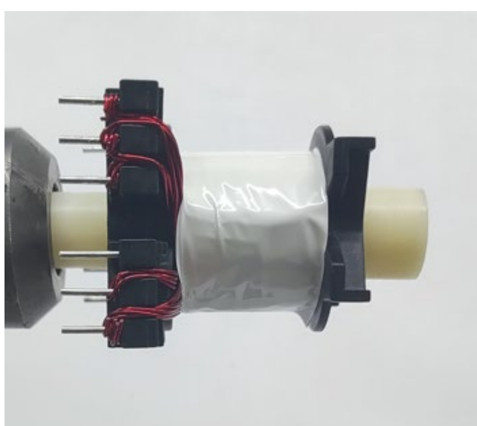
Start WD3 at pin 6 with 4 strands.</td>
</tr>
<tr>
<td></td>
<td>Wind all the wires together for 3 turns from left to right.</td>
</tr>
<tr>
<td></td>
<td>Apply 1 layer of tape Item [6] to hold wires in place and leave enough to cover the wire going back to the pin side.

Exit WD2 to the left, and finish WD2 at pin 6.</td>
</tr>
</table>

	 	Wrap the tape to cover WD2. Wind the remaining 3 turns for WD3.
Insulation		Apply 1 layer of tape Item [5] for insulation and leave enough to cover the wire going back to the pin side. Bend the end of WD3 90 degrees, cut as shown and leave it floating.

		Wrap the tape to cover WD3 and WD2.
WD4 Secondary		Prepare 4 strands of wire Item [4]. Start 4 strands of wire Item [4] at pin 8 and 9, wind 4 wires 5 turns in parallel in 1 layer.
		Spread out the winding evenly.

Insulation	 	Apply 1 layer of tape Item [5] for insulation and leave enough to cover the wire going back to the pin side. Finish WD4 at pin 11 and 12. Wrap the tape to cover WD4.
WD5 **2nd Primary**		Prepare 3 strands of wire Item [3].

		Start at pin 2, wind 12 turns of wire Item [3] in 1 layer from left to right.
Insulation	 	Apply 1 layer of tape Item [5] for insulation. Finish WD5 at pin 1. Wrap the tape to cover WD5 and apply 2 additional layers of tape Item [5].

Assembly		Grind the center leg of the upper half of Item [1] to get 364 μH measured between Pin 1 and Pin 3 with all other pins open. Use Item [9] and wrap it around Item [1], then solder to Pin 5.
		Wrap the body of transformer with 3 layers of tape Item [7]. Measure Primary Inductance between Pin 1 and Pin 3 with all other pins open, then Leakage Inductance between Pin 1 and Pin 3 with all other pins shorted together.
Finish		Varnish using Item [8]. Check Primary and Leakage Inductance to ensure that they meet specifications.

Table 7 – Transformer Winding Illustrations.

8 Common Mode Choke L1 Specification

8.1 Electrical Diagram

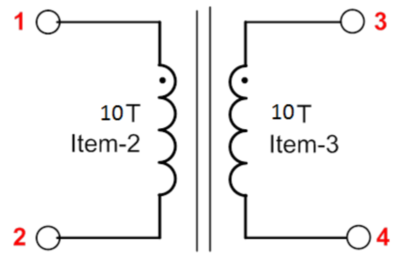


Figure 9 – Choke Electrical Diagram.

8.2 Electrical Specifications

Parameter	Condition	Spec.
Winding Inductance	Pin 1 – Pin 2 (or Pin 3 – Pin 4), all other windings open, measured at 100 kHz, 1 V_{RMS}.	**250 µH ± 20%**

Table 8 – Common Mode Choke Electrical Specifications.

8.3 List of Materials

Item	Description
[1]	Toroid Core: 32-00376-00 (Blue), Mfr. Part Number: B64290L0038X046
[2]	Triple Insulated Wire: #24 AWG, Triple Coated.
[3]	Magnet Wire: #24 AWG, Double Coated.

Table 9 – Common Mode Choke Materials List.

8.4 Common Mode Choke Construction

Figure 10 – Finished Choke.

Winding & Termination	Using 1 Strand each of items [2] and [3], wind 10 bifilar turns on core [1]. Trim leads to within 5mm of core, tin last 4mm of leads. Finished choke should look like the example shown above.

Table 10 – Common Mode Choke Build Instructions.

9 Design Spreadsheet

1	ACDC_LinkSwitch-HP_060623; Rev.2.2; Copyright Power Integrations 2023	INPUT	INFO	OUTPUT	UNIT	ACDC_LinkSwitchHP_060623 Rev 2-2.xls: LinkSwitch-HP Flyback Continuous/Discontinuous Transformer Design Spreadsheet
2	ENTER APPLICATION VARIABLES					Customer
3	VACMIN	85		85	V	Minimum AC Input Voltage
4	VACMAX	265		265	V	Maximum AC Input Voltage
5	fL			50	Hz	AC Mains Frequency
6	VO	24.00		24.00	V	Output Voltage (main)
7	PO	120.00	Info	120.00	W	Maximum power limit for selected enclosure reached
8	n	0.86		0.86		Efficiency Estimate
9	Z			0.50		Loss Allocation Factor
10	VB	12.00		12.00	V	Bias Voltage
11	tC			3.00	ms	Bridge Rectifier Conduction Time Estimate
12	CIN	540		540	μF	Input Filter Capacitor
13	Package	E/V		E/V		E and V Package Selected
14	Enclosure	Open Frame		Open Frame		Open Frame type enclosure
15	Heatsink	Metal		Metal		Metallic heatsink thermally connected to the exposed metal on the E-package
16						
17						
18	ENTER LinkSwitch-HP VARIABLES					
19	LinkSwitch-HP	LNK6779E		LNK6779E		Manual Device Selection
20	ILIMITMIN			3.162	A	Minimum Current limit
21	ILIMITMAX			3.638	A	Maximum current limit
22	ILIMITMIN_EXT			3.162	A	External Minimum Current limit
23	ILIMITMAX_EXT			3.638	A	External Maximum current limit
24	KI	1		1		Current limit reduction factor
25	Rpd			124.00	k-ohm	Program delay Resistor
26	Cpd			33.0	nF	Program delay Capacitor
27	Total programmed delay			0.86	sec	Total program delay
28	fS			132	kHz	LinkSwitch-HP Switching Frequency
29	fSmin			120	kHz	LinkSwitch-HP Minimum Switching Frequency
30	fSmax			136	kHz	LinkSwitch-HP Maximum Switching Frequency
31	KP	0.40		0.40		Ripple to Peak Current Ratio (0.4 < KP < 6.0)
32	VOR	114.00		114.00	V	Reflected Output Voltage
33	Voltage Sense					
34	VUVON			114.49	V	Undervoltage turn on
35	VUVOFF			48.24	V	Undervoltage turn off
36	VOV			520.32	V	Overvoltage threshold
37	FMAX_FULL_LOAD			133.21	kHz	Maximum switching frequency at full load
38	FMIN_FULL_LOAD			117.54	kHz	Minimum switching frequency at full load
39	TSAMPLE_FULL_LOAD			3.45	μs	Minimum available Diode conduction time at full load. This should be greater than 2.5 μs
40	TSAMPLE_LIGHT_LOAD			2.40	μs	Minimum available Diode conduction time at light load. This should be greater than 1.4 μs
41	VDS			3.28	V	LinkSwitch-HP on-state Drain to Source Voltage.
42	VD			0.50	V	Output Winding Diode Forward Voltage Drop
43	VDB			0.70	V	Bias Winding Diode Forward Voltage Drop
44						
45						
46						
47	FEEDBACK SENSING SECTION					

48	RFB1			56.20	k-ohms	Feedback divider upper resistor
49	RFB2			8.66	k-ohms	Feedback divider lower resistor
50						
51						
52	ENTER TRANSFORMER CORE/CONSTRUCTION VARIABLES					
53	Select Core Size	Custom	Info	Custom		Manual Core Selected
54	Core			Custom		Selected Core
55	Custom Core	PQ35/35-PC95				Enter name of custom core is applicable
56	AE	1.96		1.96	cm^2	Core Effective Cross Sectional Area
57	LE	8.79		8.79	cm	Core Effective Path Length
58	AL	7320		7320	nH/T^2	Ungapped Core Effective Inductance
59	BW	20.80		20.80	mm	Bobbin Physical Winding Width
60	M			0.00	mm	Safety Margin Width (Half the Primary to Secondary Creepage Distance)
61	L			2		Number of Primary Layers
62	NS			5		Number of Secondary Turns
63						
64						
65	DC INPUT VOLTAGE PARAMETERS					
66	VMIN			104	V	Minimum DC Input Voltage
67	VMAX			375	V	Maximum DC Input Voltage
68						
69						
70	CURRENT WAVEFORM SHAPE PARAMETERS					
71	DMAX			0.53		Maximum Duty Cycle
72	IAVG			1.34	A	Average Primary Current
73	IP			3.16	A	Peak Primary Current
74	IR			1.26	A	Primary Ripple Current
75	IRMS			1.86	A	Primary RMS Current
76						
77						
78	TRANSFORMER PRIMARY DESIGN PARAMETERS					
79	LP_TYP			364	μH	Typical Primary Inductance
80	LP_TOL	5		5	%	Primary inductance Tolerance
81	NP			24		Primary Winding Number of Turns
82	NB			3		Bias Winding Number of Turns
83	ALG			632	nH/T^2	Gapped Core Effective Inductance
84	BM			2445	Gauss	Maximum Flux Density at PO, VMIN (BM<3100)
85	BP			2958	Gauss	Peak Flux Density (BP<3700)
86	BAC			489	Gauss	AC Flux Density for Core Loss Curves (0.5 X Peak to Peak)
87	ur			2612		Relative Permeability of Ungapped Core
88	LG			0.36	mm	Gap Length (Lg > 0.1 mm)
89	BWE			41.6	mm	Effective Bobbin Width
90	OD			1.73	mm	Maximum Primary Wire Diameter including insulation
91	INS			0.10	mm	Estimated Total Insulation Thickness (= 2 * film thickness)
92	DIA			1.64	mm	Bare conductor diameter
93	AWG			14	AWG	Primary Wire Gauge (Rounded to next smaller standard AWG value)
94	CM			4096	Cmils	Bare conductor effective area in circular mils
95	CMA		Warning	2203	Cmils/Amp	!!! Info. This is an overdesign. You can decrease CMA (200 < CMA < 500) Decrease L (primary layers), increase NS, smaller Core

96						
97						
98						
99	TRANSFORMER SECONDARY DESIGN PARAMETERS (SINGLE OUTPUT EQUIVALENT)					
100	Lumped parameters					
101	ISP			15.16	A	Peak Secondary Current
102	ISRMS			8.39	A	Secondary RMS Current
103	IO			5.00	A	Power Supply Output Current
104	IRIPPLE			6.74	A	Output Capacitor RMS Ripple Current
105	CMS			1678	Cmils	Secondary Bare Conductor minimum circular mils
106	AWGS			17	AWG	Secondary Wire Gauge (Rounded up to next larger standard AWG value)
107	DIAS			1.15	mm	Secondary Minimum Bare Conductor Diameter
108	ODS			4.16	mm	Secondary Maximum Outside Diameter for Triple Insulated Wire
109	INSS			1.50	mm	Maximum Secondary Insulation Wall Thickness
110						
111						
112	VOLTAGE STRESS PARAMETERS					
113	VDRAIN			634	V	Peak voltage across drain to source of LinkSwitch-HP
114	PIVS			102	V	Output Rectifier Maximum Peak Inverse Voltage
115	PIVB			59	V	Bias Rectifier Maximum Peak Inverse Voltage
116						
117						
118	TRANSFORMER SECONDARY DESIGN PARAMETERS (MULTIPLE OUTPUTS)					
119	1st output					
120	VO1			24.00	V	Output Voltage
121	IO1			5.00	A	Output DC Current
122	PO1			120	W	Output Power
123	VD1			0.50	V	Output Diode Forward Voltage Drop
124	NS1			5.00		Output Winding Number of Turns
125	ISRMS1			8.392	A	Output Winding RMS Current
126	IRIPPLE1			6.74	A	Output Capacitor RMS Ripple Current
127	PIVS1			102	V	Output Rectifier Maximum Peak Inverse Voltage
128	CMS1			1678	Cmils	Output Winding Bare Conductor minimum circular mils
129	AWGS1			17	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
130	DIAS1			1.15	mm	Minimum Bare Conductor Diameter
131	ODS1			4.16	mm	Maximum Outside Diameter for Triple Insulated Wire
132						
133						
134	2nd output					
135	VO2			0.00	V	Output Voltage
136	IO2			0.00	A	Output DC Current
137	PO2			0	W	Output Power
138	VD2			0.70	V	Output Diode Forward Voltage Drop
139	NS2			1.00		Output Winding Number of Turns
140	ISRMS2			0	A	Output Winding RMS Current
141	IRIPPLE2			0.00	A	Output Capacitor RMS Ripple Current
142	PIVS2			16	V	Output Rectifier Maximum Peak Inverse Voltage

143	CMS2			0	Cmils	Output Winding Bare Conductor minimum circular mils
144	AWGS2			N/A	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
145	DIAS2			N/A	mm	Minimum Bare Conductor Diameter
146	ODS2			N/A	mm	Maximum Outside Diameter for Triple Insulated Wire
147						
148						
149	3rd output					
150	VO3			0.00	V	Output Voltage
151	IO3			0.00	A	Output DC Current
152	PO3			0	W	Output Power
153	VD3			0.70	V	Output Diode Forward Voltage Drop
154	NS3			1.00		Output Winding Number of Turns
155	ISRMS3			0	A	Output Winding RMS Current
156	IRIPPLE3			0.00	A	Output Capacitor RMS Ripple Current
157	PIVS3			16	V	Output Rectifier Maximum Peak Inverse Voltage
158	CMS3			0	Cmils	Output Winding Bare Conductor minimum circular mils
159	AWGS3			N/A	AWG	Wire Gauge (Rounded up to next larger standard AWG value)
160	DIAS3			N/A	mm	Minimum Bare Conductor Diameter
162						
161	ODS3			N/A	mm	Maximum Outside Diameter for Triple Insulated Wire
162						
163	Total power			120	W	Total Power for Multi-output section
164						
165	Negative Output	N/A		N/A		If negative output exists enter Output number; e.g. If VO2 is negative output, select 2
166						

* Note: Actual RFB1 used is 53.6 kΩ, RFB1 is adjusted based on the actual line UV turn on voltage and output voltage regulation.

10 Heat Sinks

10.1 LinkSwitch-HP Heat Sink

10.1.1 LinkSwitch-HP Heat Sink Metal Drawing

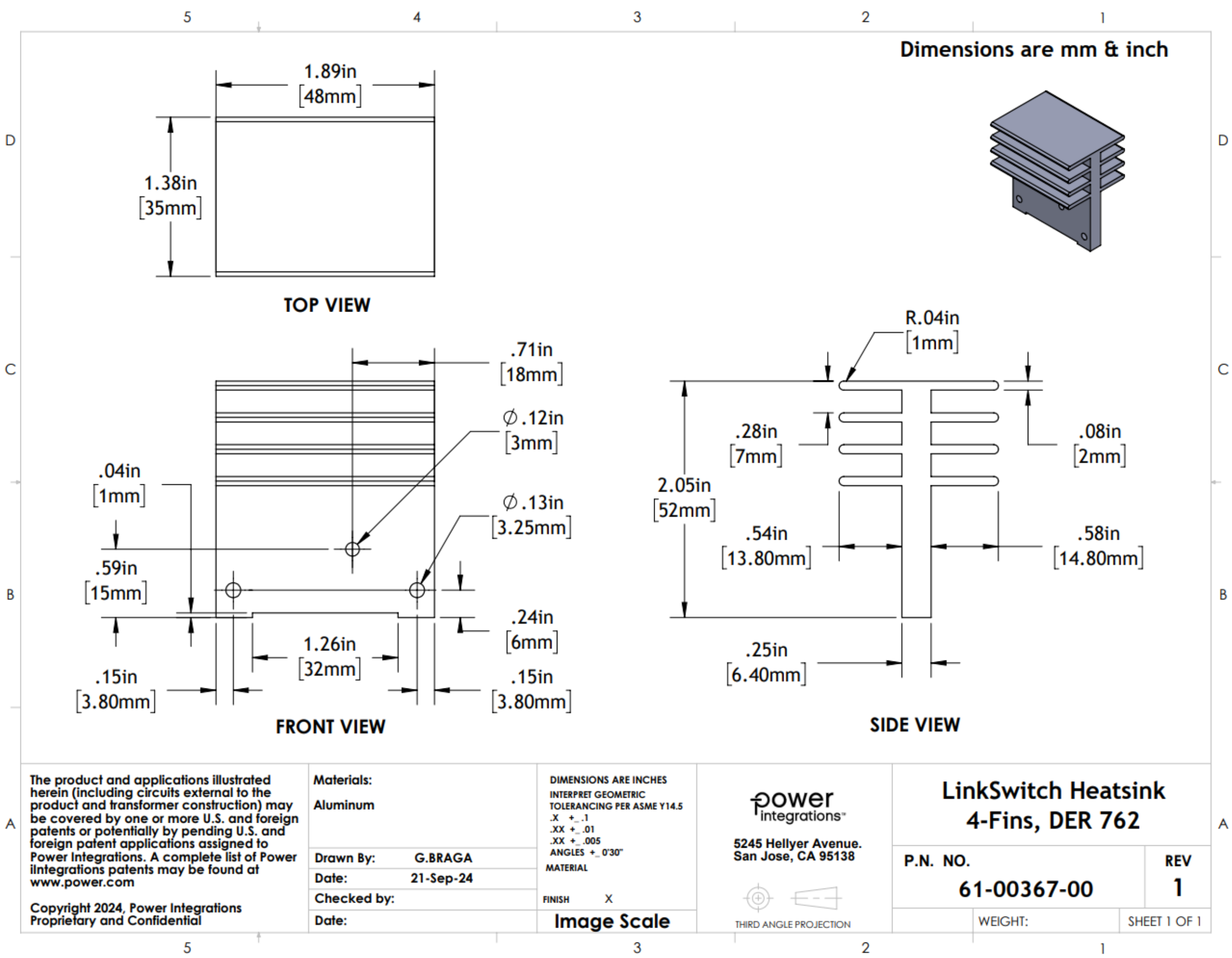
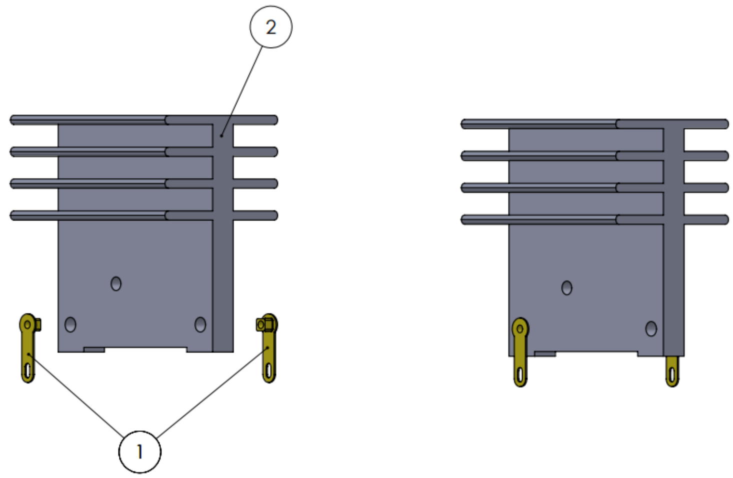


Figure 11 – DER-762 LinkSwitch-HP Heat Sink Metal Drawing.

10.1.2 Finished LinkSwitch-HP Heat Sink with Hardware

Dimensions are mm & inch



ITEM	PART NUMBER	DESCRIPTION	QUANTITY
1	60-00016-00	TERMINAL, EYELET, TIN PLATED BRASS, ZIERICK	2
2	61-00367-00	LinkSwitch Heatsink 4-Fins, Aluminum 6.4mm Thickness	1

The product and applications illustrated herein (including circuits external to the product and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations patents may be found at www.power.com

Drawn By: G.BRAGA
Date: 21-Sep-24
Checked by:
Date:

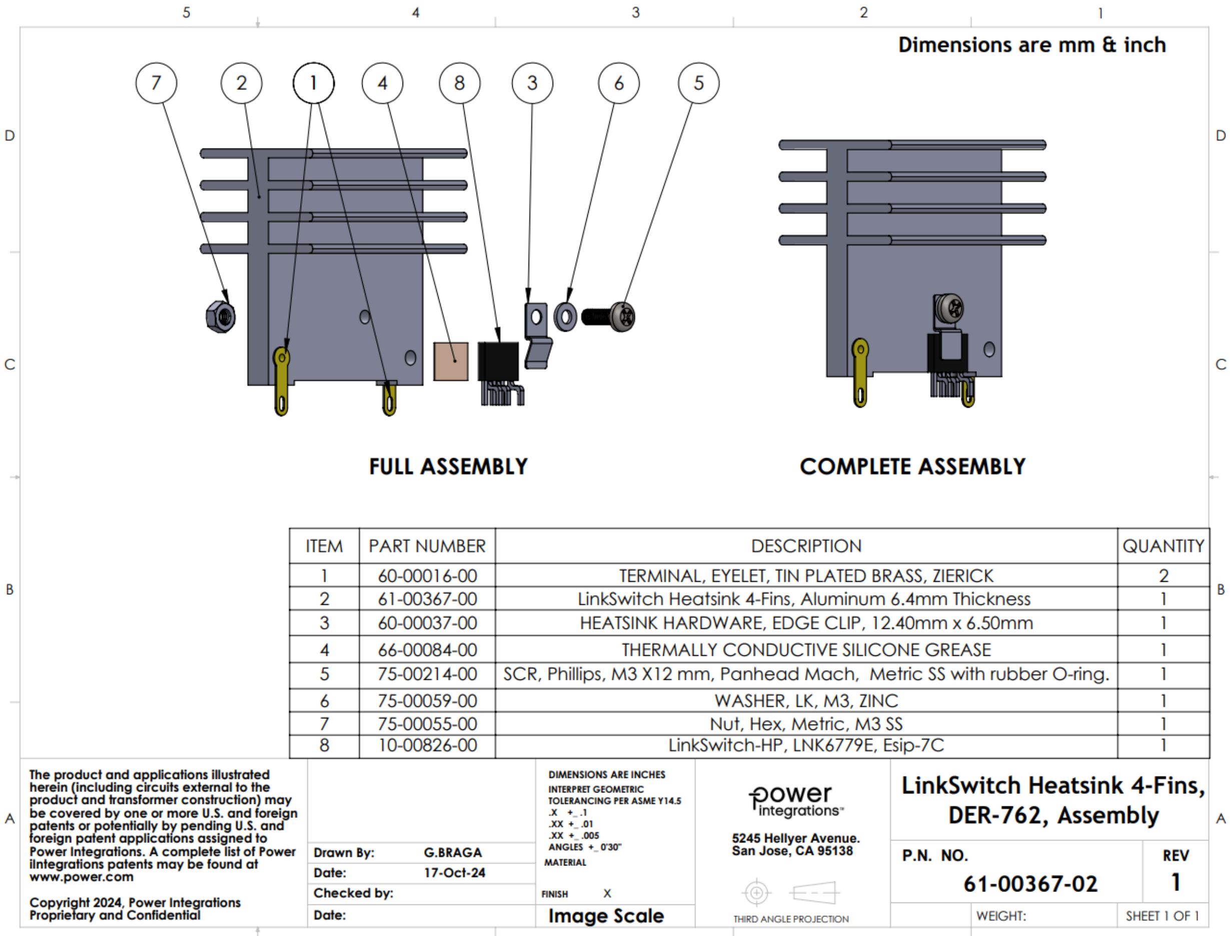
DIMENSIONS ARE INCHES
INTERPRET GEOMETRIC TOLERANCING PER ASME Y14.5
.X +_ .1
.XX +_ .01
.XX +_ .005
ANGLES +_ 0'30"
MATERIAL
FINISH X
Image Scale

power integrations
5245 Hellyer Avenue.
San Jose, CA 95138
THIRD ANGLE PROJECTION

LinkSwitch Heatsink 4-Fins, DER 762, Fab
P.N. NO. 61-00367-01
REV 1
WEIGHT:
SHEET 1 OF 1

Figure 12 – DER-762 Finished LinkSwitch-HP Heat Sink with Hardware.

10.1.3 LinkSwitch-HP Heat Sink Assembly



ITEM	PART NUMBER	DESCRIPTION	QUANTITY
1	60-00016-00	TERMINAL, EYELET, TIN PLATED BRASS, ZIERICK	2
2	61-00367-00	LinkSwitch Heatsink 4-Fins, Aluminum 6.4mm Thickness	1
3	60-00037-00	HEATSINK HARDWARE, EDGE CLIP, 12.40mm x 6.50mm	1
4	66-00084-00	THERMALLY CONDUCTIVE SILICONE GREASE	1
5	75-00214-00	SCR, Phillips, M3 X12 mm, Panhead Mach, Metric SS with rubber O-ring.	1
6	75-00059-00	WASHER, LK, M3, ZINC	1
7	75-00055-00	Nut, Hex, Metric, M3 SS	1
8	10-00826-00	LinkSwitch-HP, LNK6779E, Esip-7C	1

Figure 13 – DER-762 LinkSwitch-HP Heat Sink Assembly.

10.2 Bridge Rectifier Heat Sink

10.2.1 Bridge Rectifier Heat Sink Metal Drawing

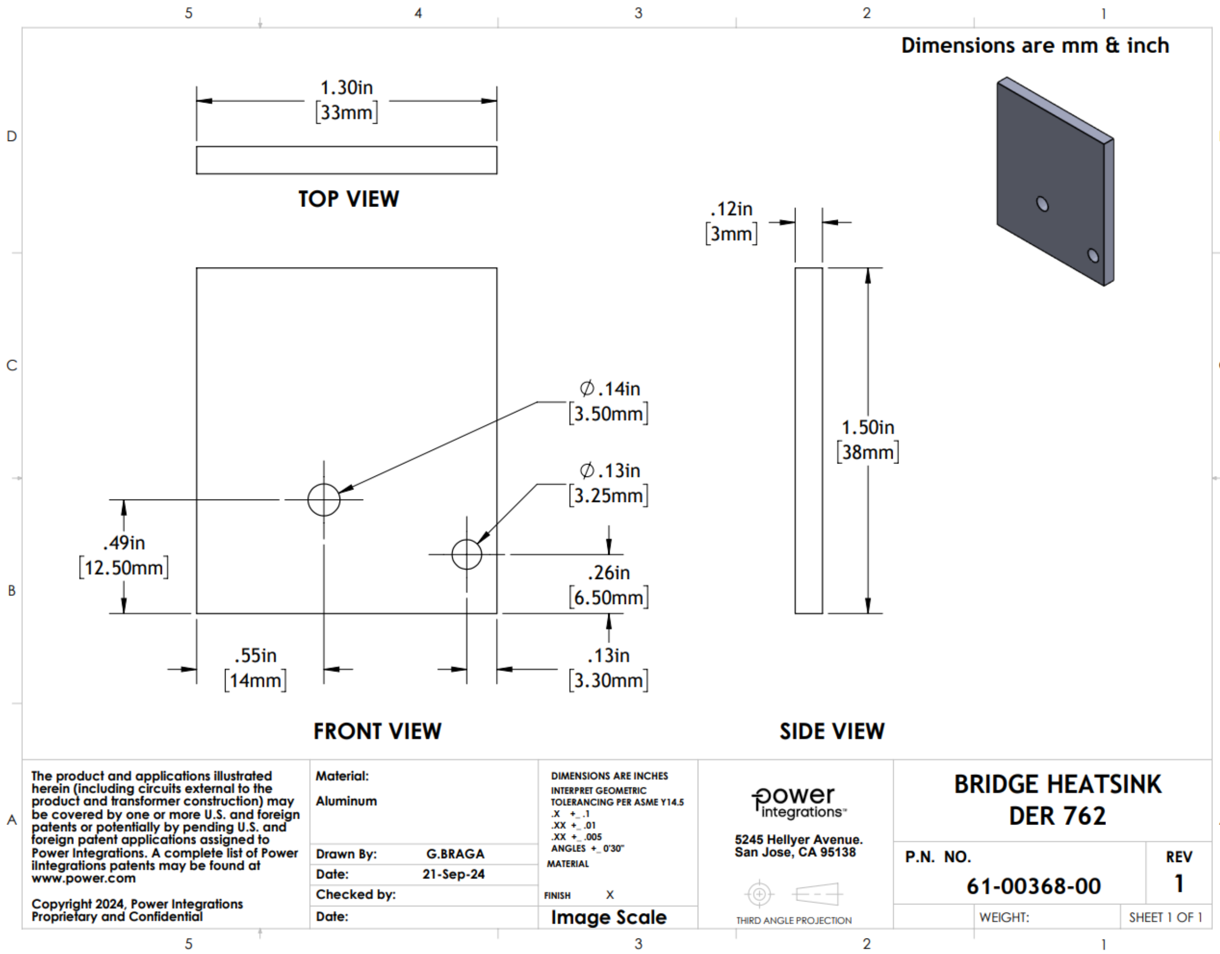
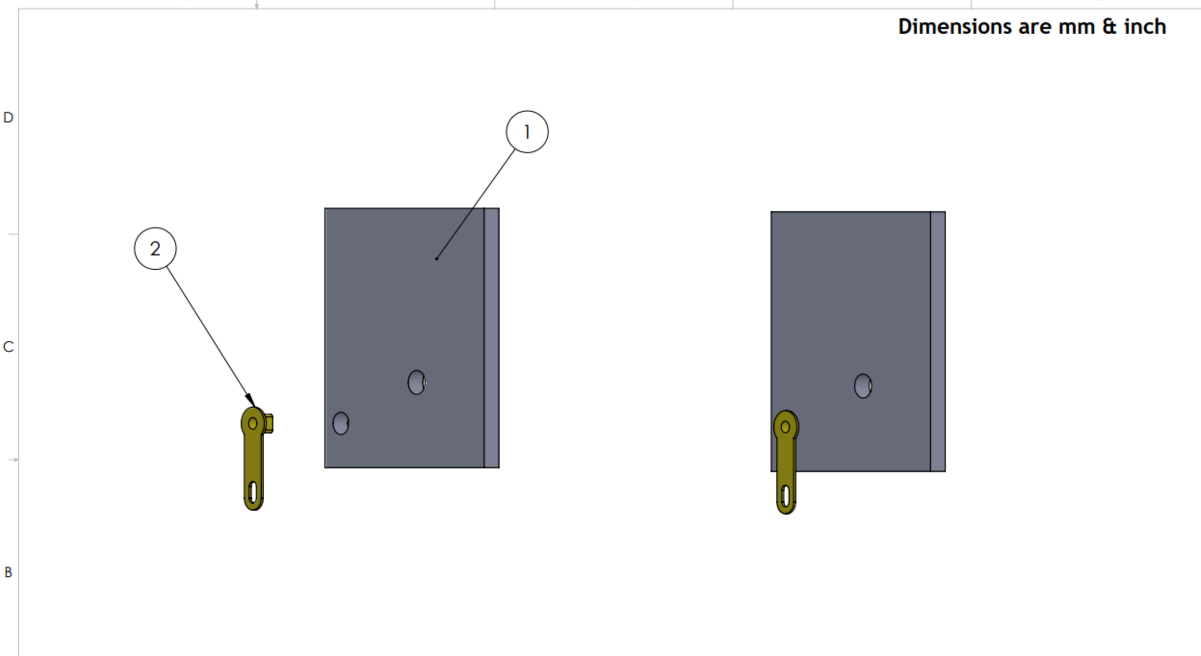


Figure 14 – DER-762 Bridge Rectifier Heat Sink Metal Drawing.

10.2.2 Finished Bridge Rectifier Heat Sink with Hardware



ITEM	PART NUMBER	DESCRIPTION	QUANTITY
1	61-00368-00	Bridge Heatsink, Aluminum 3.0mm Thickness	1
2	60-00016-00	TERMINAL, EYELET, TIN PLATED BRASS, ZIERICK	1

The product and applications illustrated herein (including circuits external to the product and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations patents may be found at www.power.com

Drawn By: G.BRAGA
Date: 21-Sep-24
Checked by:
Date:

DIMENSIONS ARE INCHES
INTERPRET GEOMETRIC TOLERANCING PER ASME Y14.5
.X +_ .1
.XX +_ .01
.XXX +_ .005
ANGLES +_ 0°30"
MATERIAL
FINISH X
Image Scale

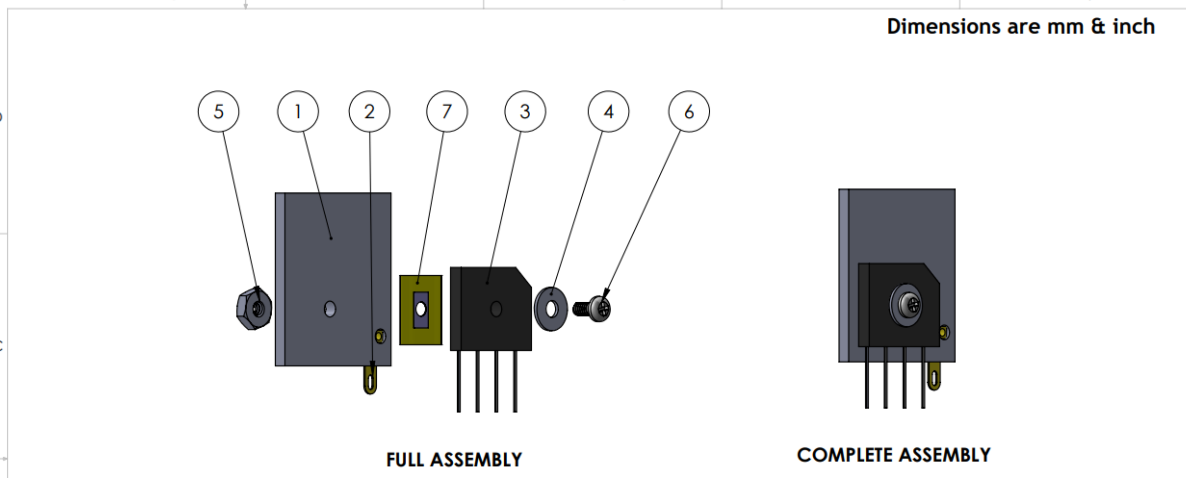
power integrations
5245 Hellyer Avenue.
San Jose, CA 95138
THIRD ANGLE PROJECTION

Bridge Heatsink
DER 762, FAB

P.N. NO. 61-00368-01
REV 1
WEIGHT:
SHEET 1 OF 1

Figure 15 – DER-762 Bridge Rectifier Heat Sink with Hardware.

10.2.3 Bridge Rectifier Heat Sink Assembly



ITEM	PART NUMBER	DESCRIPTION	QUANTITY
1	61-00368-00	Bridge Heatsink, Aluminum 3.0mm Thickness	1
2	60-00016-00	TERMINAL, EYELET, TIN PLATED BRASS, ZIERICK	1
3	15-00347-00	800 V, 8 A, Bridge Rectifier, GBU Case	1
4	75-00033-00	Washer Flat #6, SS	1
5	75-00025-00	Nut, Hex 6-32, SS	1
6	75-00009-00	SCREW MACHINE PHIL 6-32 X 3/8 SS	1
7	66-00084-00	Thermally Conductive Silicon Grease	1

The product and applications illustrated herein (including circuits external to the product and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power iIntegrations patents may be found at www.power.com

Drawn By: G.BRAGA
Date: 17-Oct-24
Checked by:
Date:

DIMENSIONS ARE INCHES
INTERPRET GEOMETRIC TOLERANCING PER ASME Y14.5
.X +_ .1
.XX +_ .01
.XX +_ .005
ANGLES +_ 0'30"
MATERIAL
FINISH X
Image Scale

power integrations
5245 Hellyer Avenue.
San Jose, CA 95138
THIRD ANGLE PROJECTION

BRIDGE HEATSINK, DER-762, ASSEMBLY
P.N. NO. 61-00368-02
REV 1
WEIGHT:
SHEET 1 OF 1

Figure 16 – DER-762 Bridge Rectifier Heat Sink Assembly.

10.3 Secondary Diode Heat Sink

10.3.1 Secondary Diode Heat Sink Metal Drawing

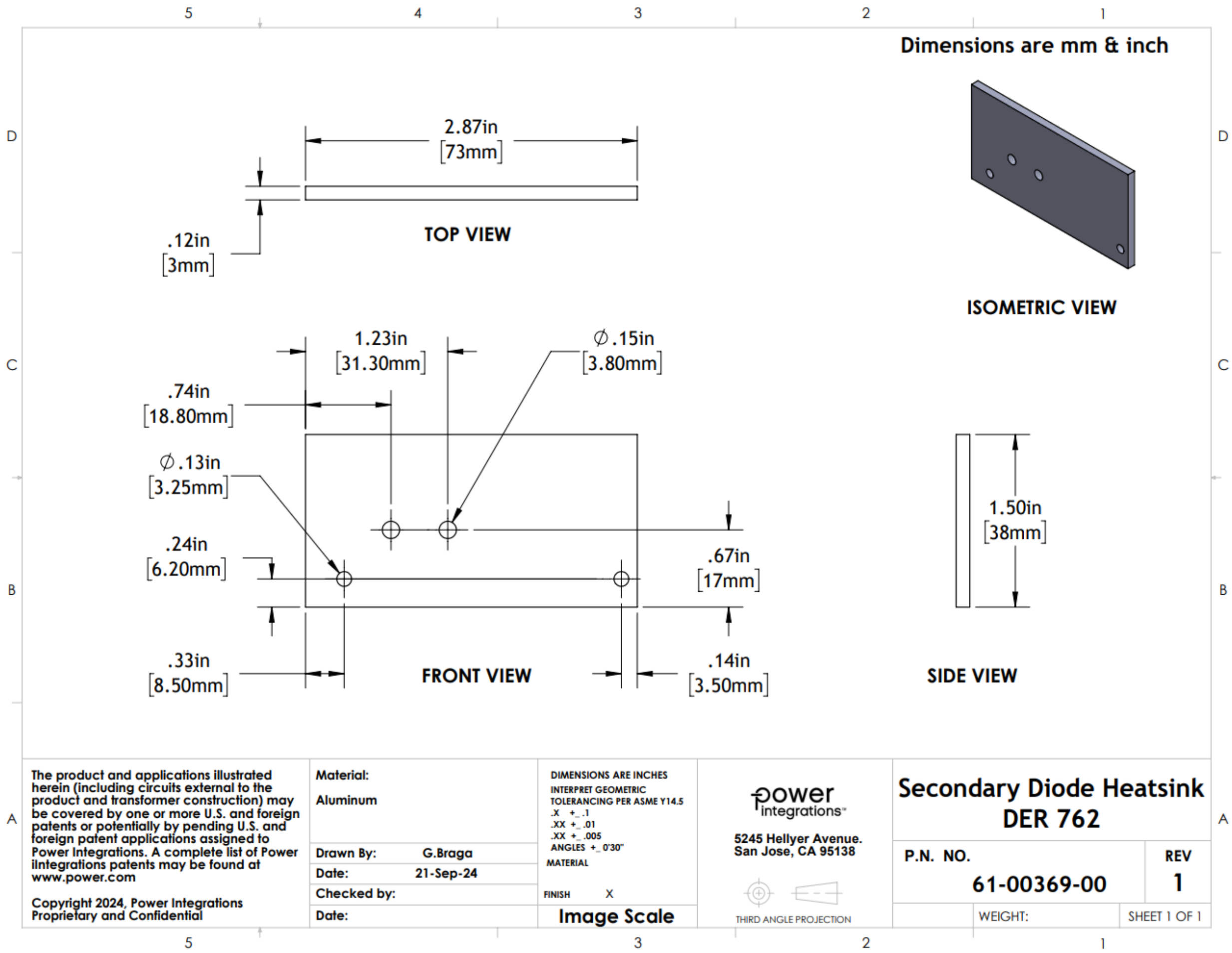


Figure 17 – DER-762 Secondary Diode Heat Sink Metal Drawing.

10.3.2 Finished Secondary Diode Heat Sink with Hardware

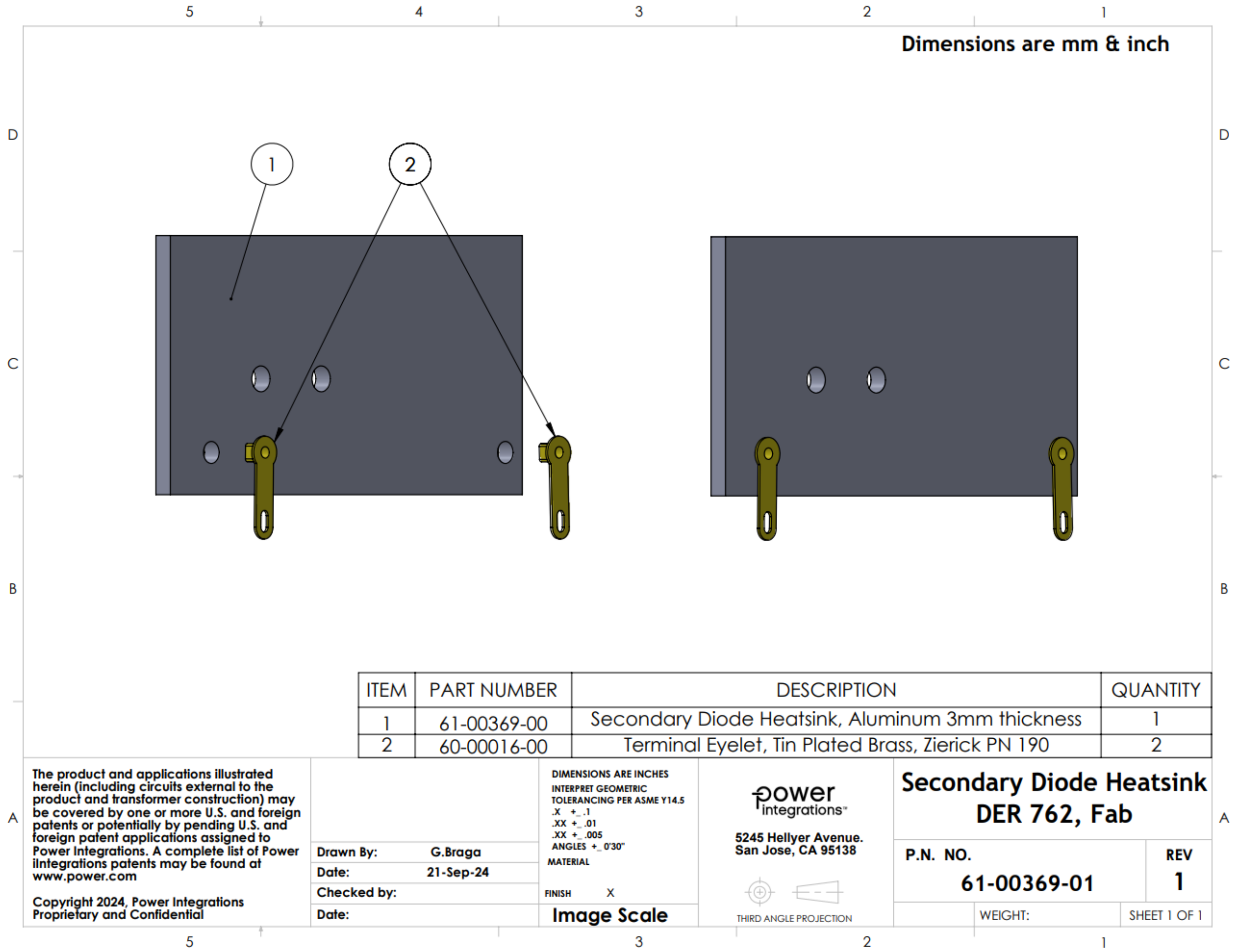
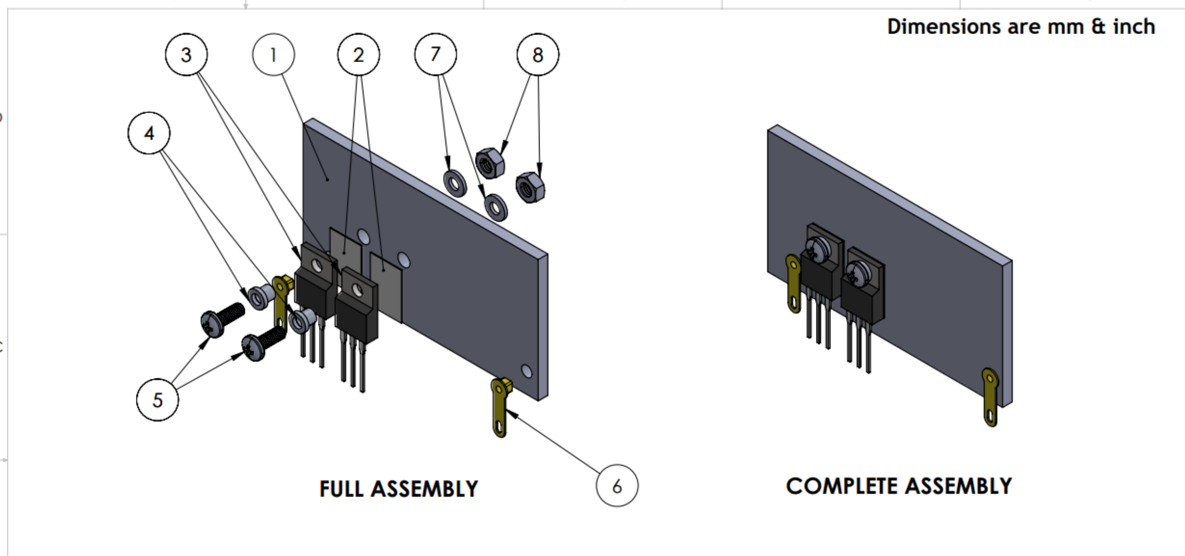


Figure 18 – DER-762 Secondary Diode Heat Sink with Hardware.

10.3.3 Secondary Diode Heat Sink Assembly



ITEM	PART NUMBER	DESCRIPTION	QUANTITY
1	61-00369-00	Secondary Diode Heatsink, Aluminum 3mm Thickness	1
2	60-00099-00	Thermal Silicone Compound, 2 OZ Jar	2
3	15-02102-00	Diode Array, 1 Pair, Common Cathode, 150 V, 10A, Through Hole TO-220-3	2
4	75-00154-00	WASHER, Shoulder, #4, 0.125 Shoulder x 0.140Dia	2
5	75-00215-00	SCR, Phillips, M3x8mm, Panhead Mach, O ring	2
6	60-00016-00	Terminal Eyelet, Tin Plated Brass, Zierick PN 190	2
7	75-00059-00	Washer, Lk, M3 Zinc, Metric	2
8	75-00055-00	Nut Hex, Metric M3 SS	2

The product and applications illustrated herein (including circuits external to the product and transformer construction) may be covered by one or more U.S. and foreign patents or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power iIntegrations patents may be found at www.power.com

Material:

Drawn By: G.Braga
Date: 21-Sep-24
Checked by:
Date:

DIMENSIONS ARE INCHES
INTERPRET GEOMETRIC TOLERANCING PER ASME Y14.5
.X +_ .1
.XX +_ .01
.XX +_ .005
ANGLES +_ 0'30"
MATERIAL
FINISH X
Image Scale

power integrations
5245 Hellyer Avenue.
San Jose, CA 95138
THIRD ANGLE PROJECTION

Secondary Diode Heatsink DER 762, Assembly

P.N. NO. 61-00369-02 REV 1
WEIGHT: SHEET 1 OF 1

Figure 19 – DER-762 Secondary Diode Heat Sink Assembly.

11 Performance Data

11.1 Full Load Efficiency vs. Line

Test Condition: Soak for 15 minutes for each line.

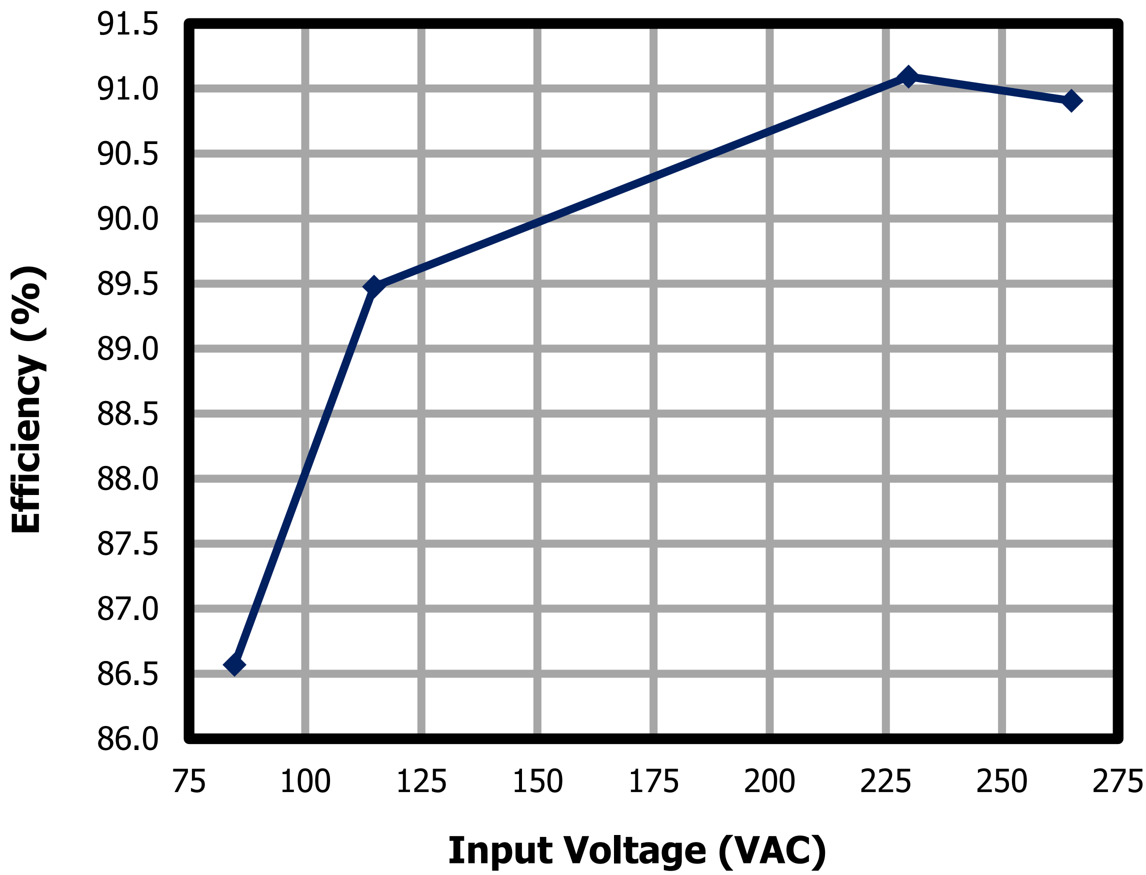


Figure 20 – Efficiency vs. Input Voltage.

11.2 Efficiency vs. Load

Test Condition: Soak for 15 minutes each line at full load, and 10 seconds for each load.

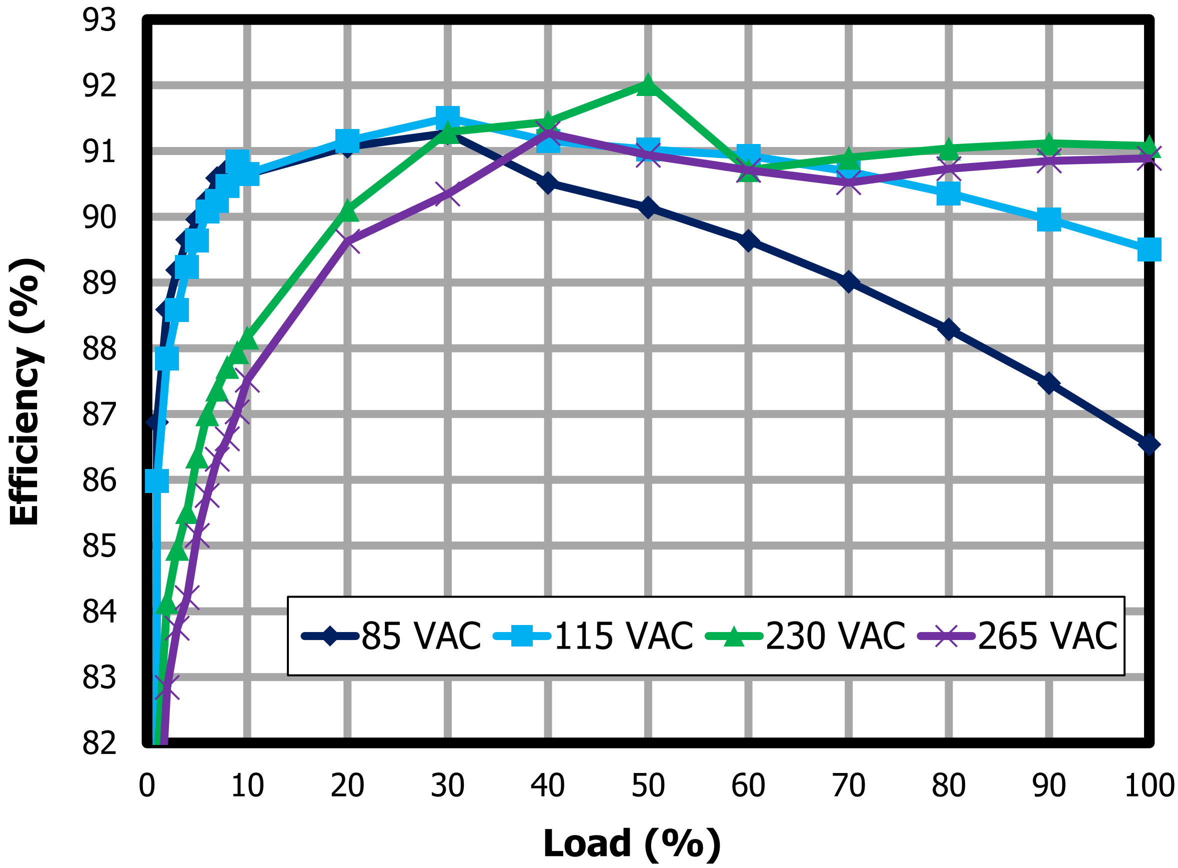


Figure 21 – Efficiency vs. Percentage Load.

11.3 Average and 10% Efficiency

11.3.1 Average and 10% Efficiency at 115 VAC

Load	P_{IN}	V_{OUT} at PCB	I_{OUT}	P_{OUT}	Efficiency at PCB	Average Efficiency	DOE6 Limit
(A)	(W)	(VDC)	(mA_{DC})	(W)	(%)	(%)	(%)
100%	133	23.8	5000	119	89.7	**90.6**	88
75%	98.6	23.8	3750	89.3	90.7		
50%	65.5	23.9	2500	59.7	91.1		
25%	32.9	24.0	1250	30.0	91.1		
10%	13.3	24.1	501	12.0	90.7	---	79

11.3.2 Average and 10% Efficiency at 230 VAC

Load	P_{IN}	V_{OUT} at PCB	I_{OUT}	P_{OUT}	Efficiency at PCB	Average Efficiency	DOE6 Limit
(A)	(W)	(VDC)	(mA_{DC})	(W)	(%)	(%)	(%)
100%	130	23.8	5000	119	91.2	**91.2**	88
75%	98	23.8	3750	89.2	91.0		
50%	64.8	23.9	2500	59.7	92.0		
25%	33.2	24	1250	30.0	90.4		
10%	13.6	24.1	501	12.0	88.4	---	79

11.4 Standby, Input Power and Efficiency

Test Condition: Soak for 15 minutes at each line voltage with 1 minute integration time.

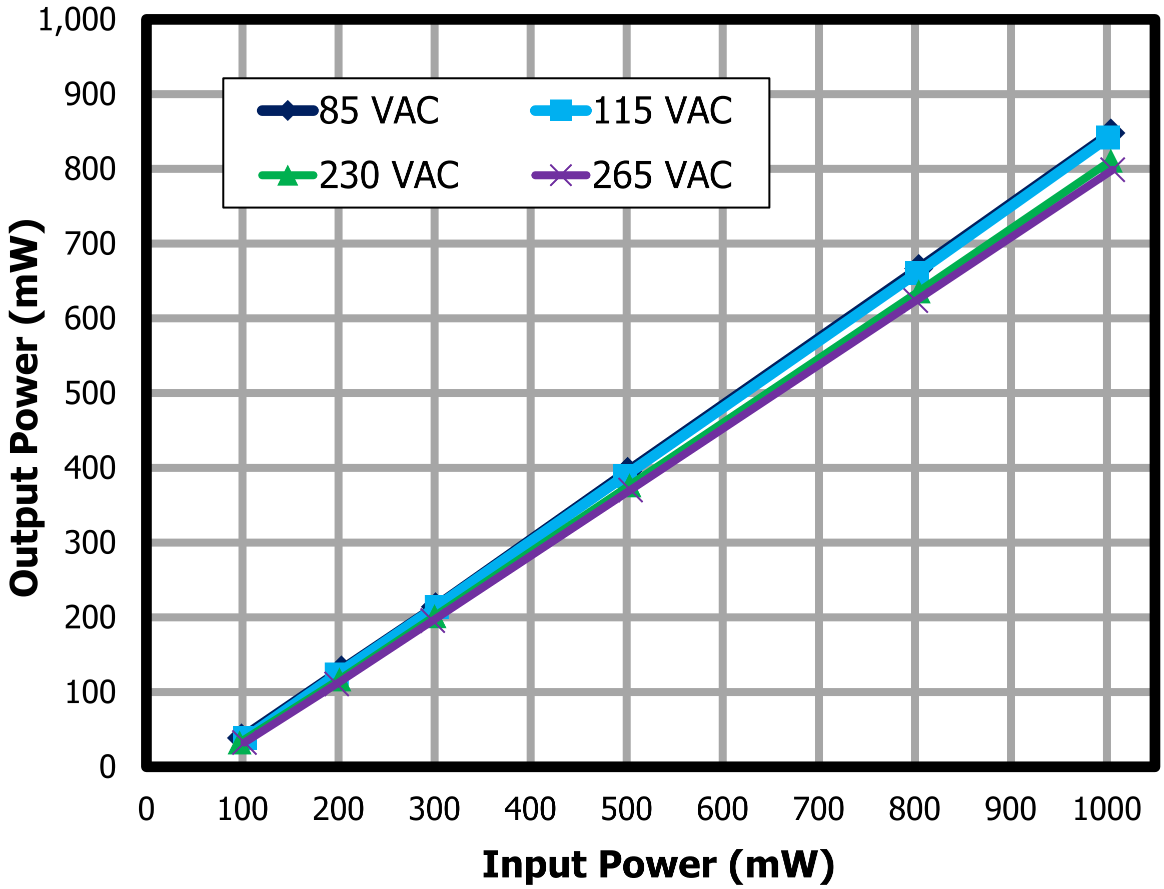


Figure 22 – Output Power vs. Input Power at Room Temperature.

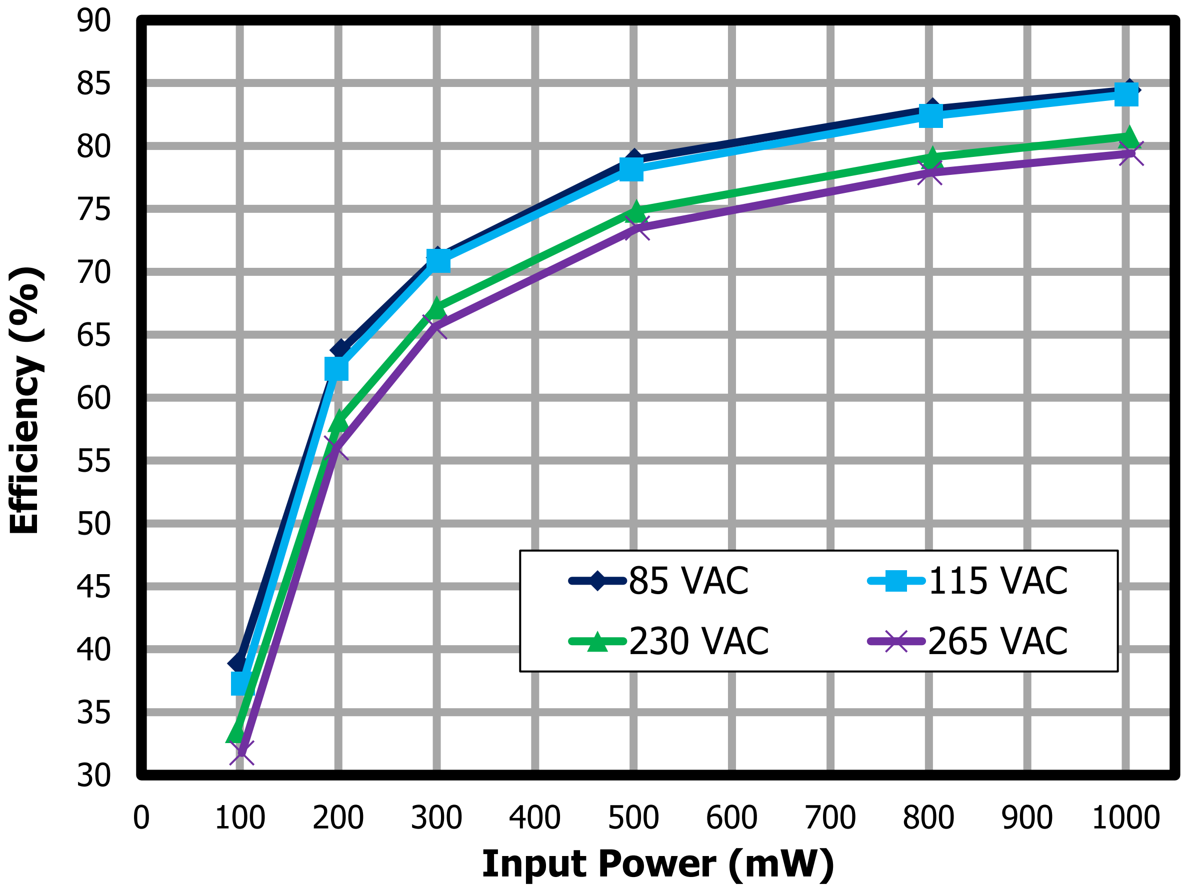


Figure 23 – Efficiency vs. Input Power at Room Temperature.

11.5 No-Load Input Power

Test Condition: Soak for 15 minutes at each line voltage with 1 minute integration time.

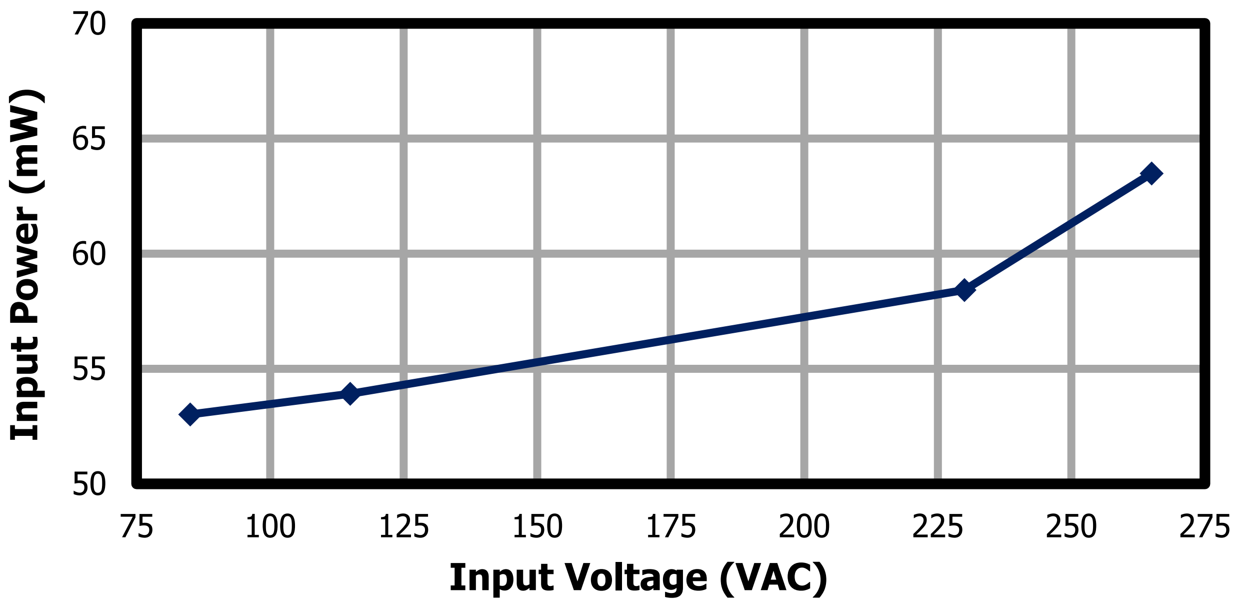


Figure 24 – No-Load Input Power vs. Line at Room Temperature.

11.6 Line Regulation

Test Condition: Soak for 15 minutes for each line voltage.

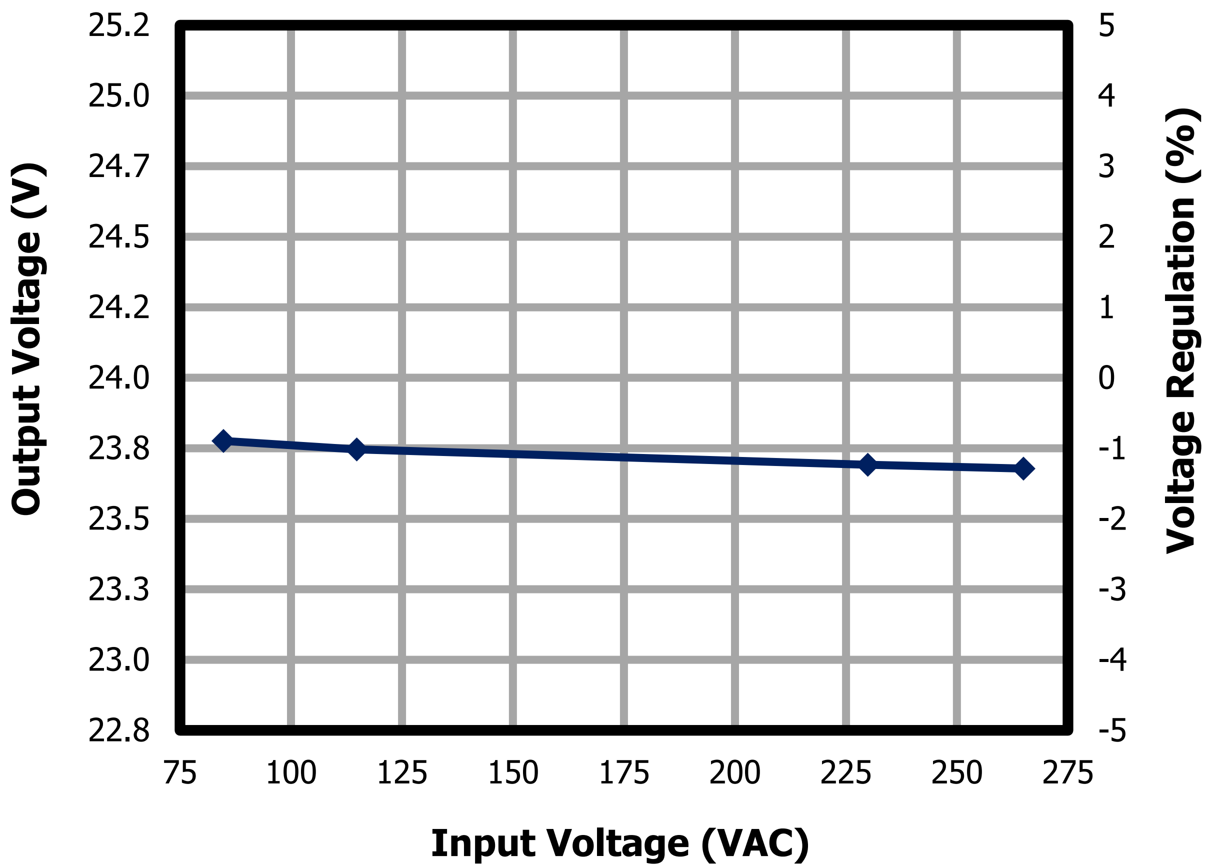


Figure 25 – Output Voltage vs. Line Voltage.

11.7 Load Regulation

Test Condition: Soak for 15 minutes each line at full load, and 10 seconds for each load.

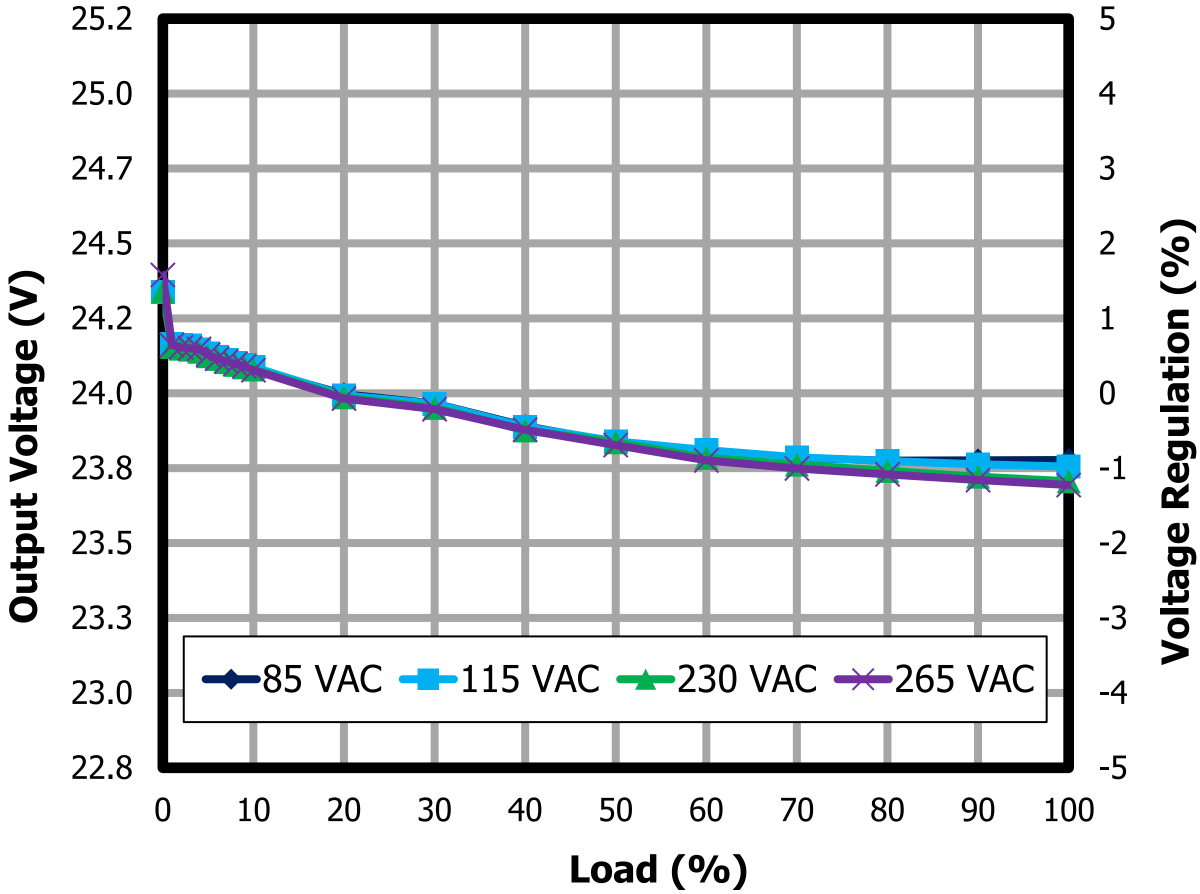


Figure 26 – Output Voltage vs. Percent Load.

12 Waveforms

12.1 Load Transient Response

Test Condition: Dynamic load frequency = 5 Hz, Duty cycle = 50%
Slew Rate = 0.8 A / µs

12.1.1 Transient 10% - 100% Load Change

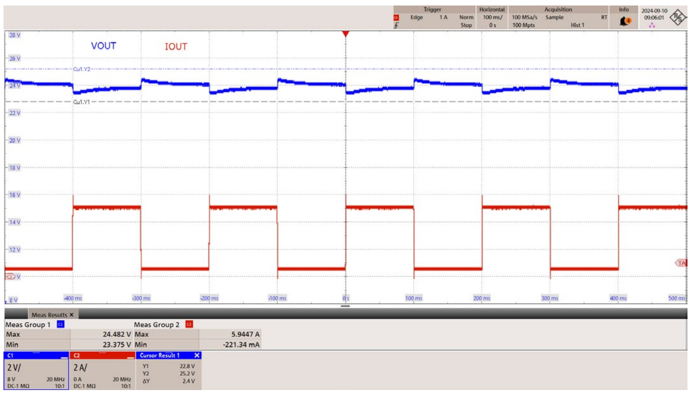


Figure 27 – 85 VAC 60 Hz.
CH1: V_{OUT}, 2 V / div., 100 ms / div.
CH2: I_{OUT}, 2 A / div., 100 ms / div.
$V_{OUT(MAX)}$: 24.5 V
$V_{OUT(MIN)}$: 23.4 V

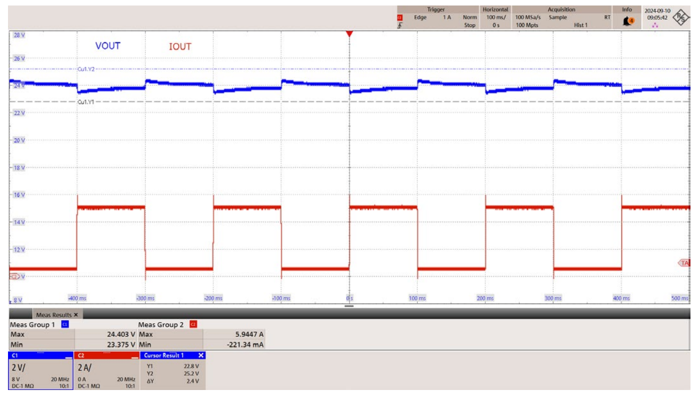


Figure 28 – 115 VAC 60 Hz.
CH1: V_{OUT}, 2 V / div., 100 ms / div.
CH2: I_{OUT}, 2 A / div., 100 ms / div.
$V_{OUT(MAX)}$: 24.4 V
$V_{OUT(MIN)}$: 23.4 V

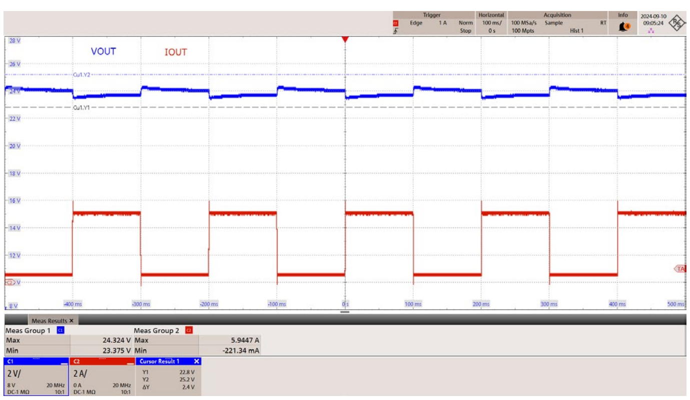


Figure 29 – 230 VAC 50 Hz.
CH1: V_{OUT}, 2 V / div., 100 ms / div.
CH2: I_{OUT}, 2 A / div., 100 ms / div.
$V_{OUT(MAX)}$: 24.3 V
$V_{OUT(MIN)}$: 23.4 V

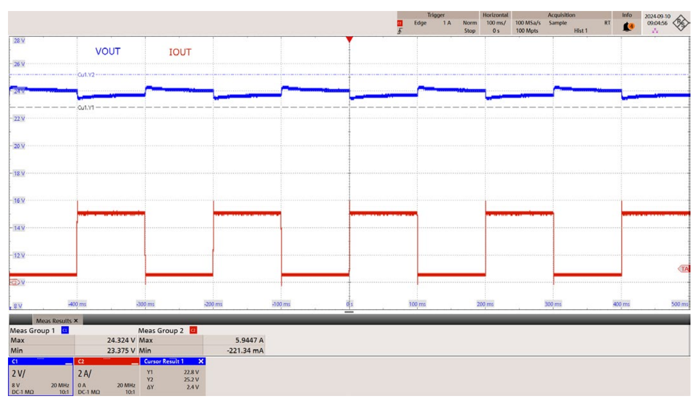


Figure 30 – 265 VAC 50 Hz.
CH1: V_{OUT}, 2 V / div., 100 ms / div.
CH2: I_{OUT}, 2 A / div., 100 ms / div.
$V_{OUT(MAX)}$: 24.3 V
$V_{OUT(MIN)}$: 23.4 V

12.2 Output Start-up

12.2.1 Full Load CC Mode

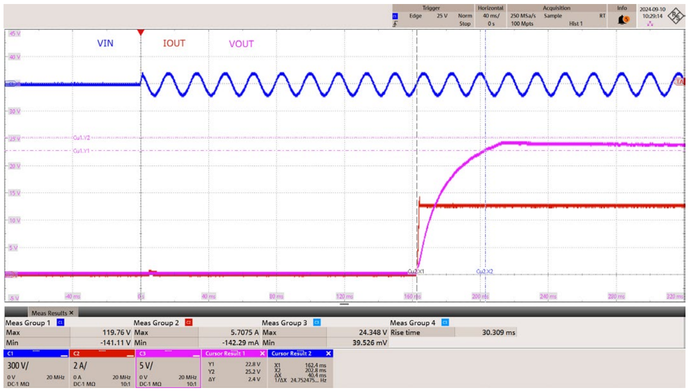


Figure 31 – 85 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 40.4 ms
V_{MAX} = 24.3 V

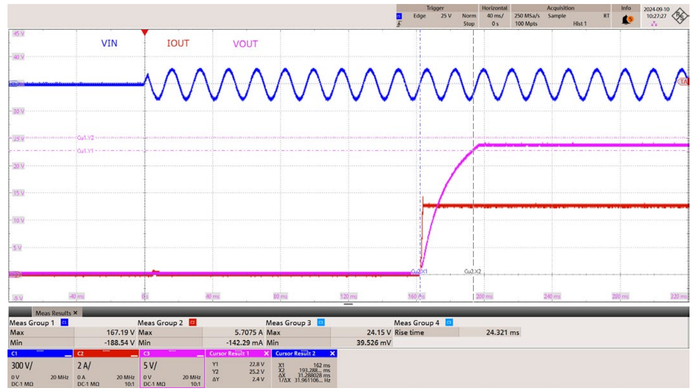


Figure 32 – 115 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 31.3 ms
V_{MAX} = 24.2 V

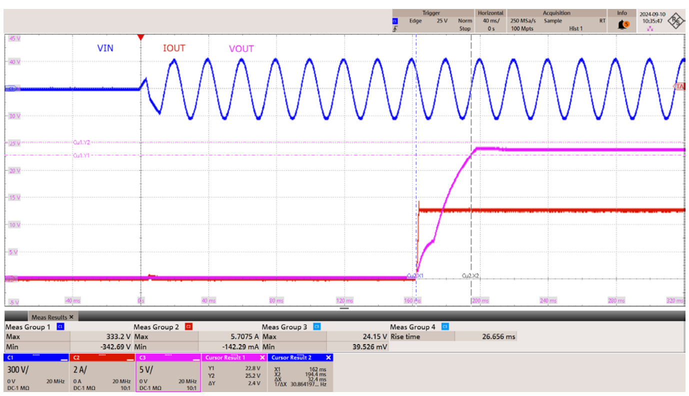


Figure 33 – 230 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 32.4 ms
V_{MAX} = 24.2 V

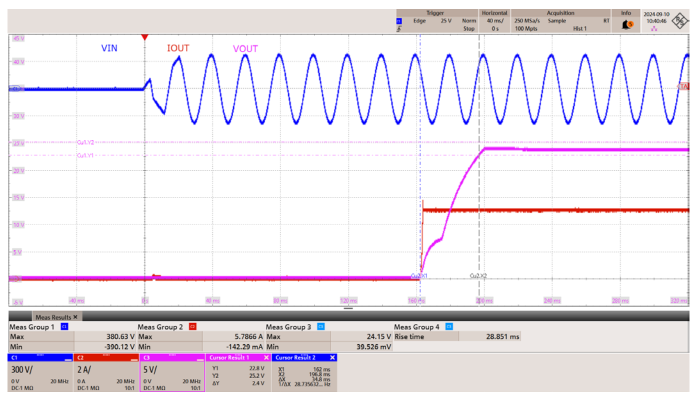


Figure 34 – 265 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 34.8 ms
V_{MAX} = 24.2 V

12.2.2 Full Load CR Mode

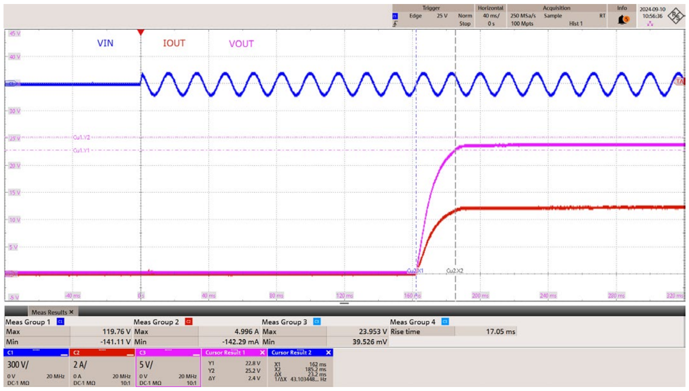


Figure 35 – 85 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 23.2 ms
V_{MAX} = 24.0 V

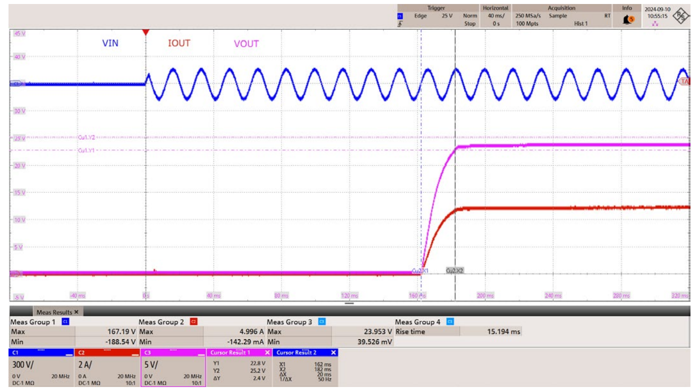


Figure 36 – 115 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 20 ms
V_{MAX} = 24.0 V

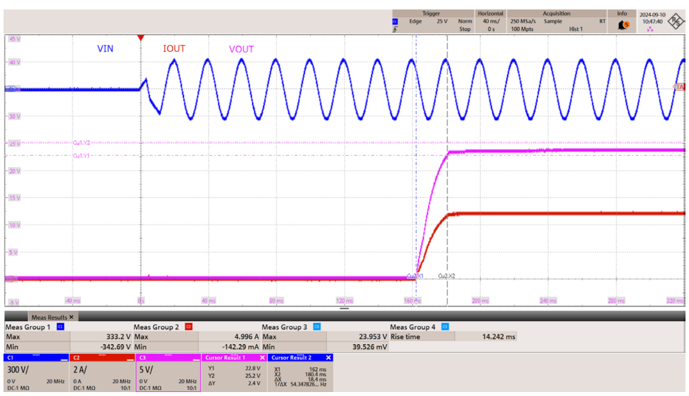


Figure 37 – 230 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 18.4 ms
V_{MAX} = 24.0 V

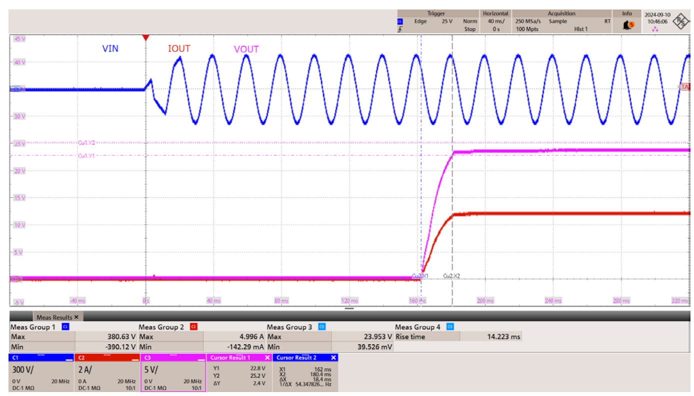


Figure 38 – 265 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 18.4 ms
V_{MAX} = 24.0 V

12.2.3 No Load

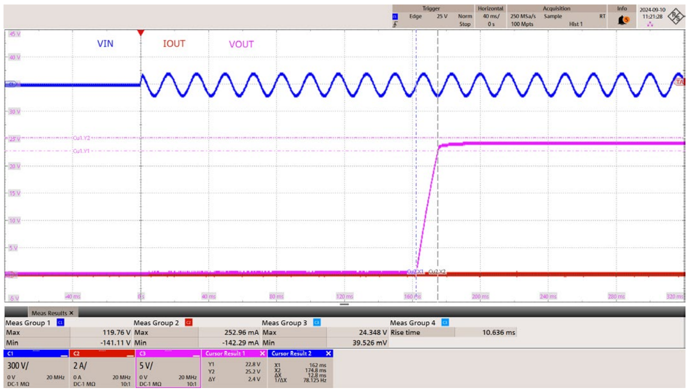


Figure 39 – 85 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 12.8 ms
V_{MAX} = 24.3 V

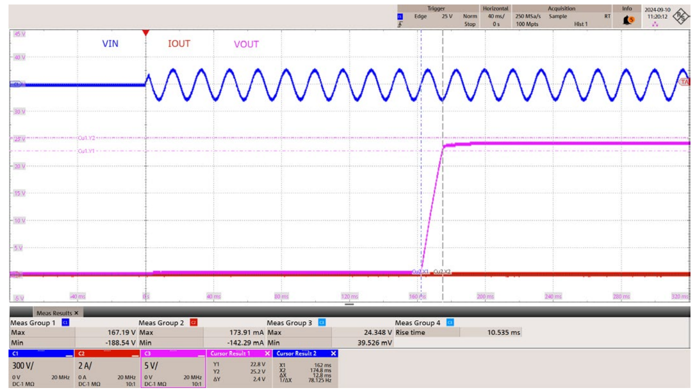


Figure 40 – 115 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 12.8 ms
V_{MAX} = 24.3 V

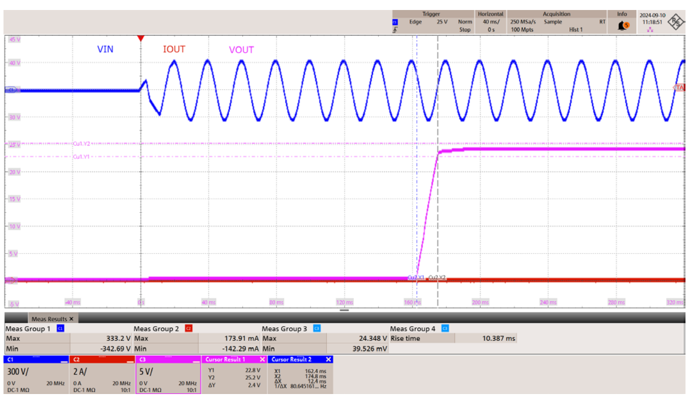


Figure 41 – 230 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 12.4 ms
V_{MAX} = 24.3 V

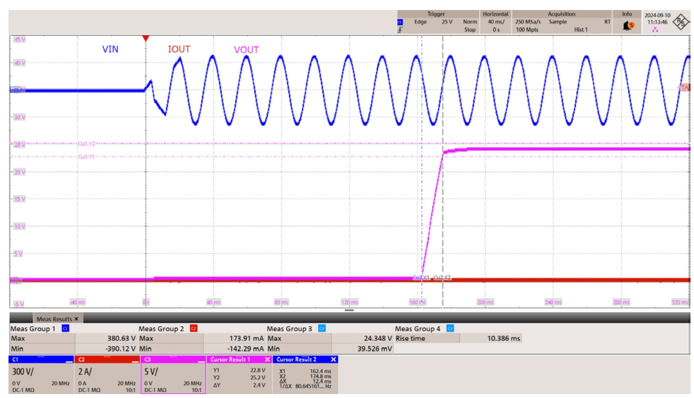


Figure 42 – 265 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 40 ms / div.
CH2: I_{OUT}, 2 A / div., 40 ms / div.
CH3: V_{OUT}, 5 V / div., 40 ms / div.
Rise Time = 12.4 ms
V_{MAX} = 24.3 V

12.3 Switching Waveforms

12.3.1 Primary MOSFET Drain-Source Voltage and Current at Normal Operation

12.3.1.1 Full Load

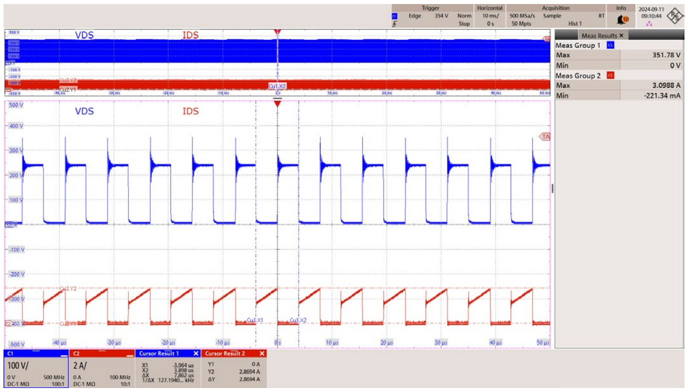


Figure 43 – 85 VAC 60 Hz.
CH1: V_{DS}, 100 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
Zoom: 10 μs / div.
$V_{DS(MAX)}$ = 352 V
$I_{DS(MAX)}$ = 3.1 A

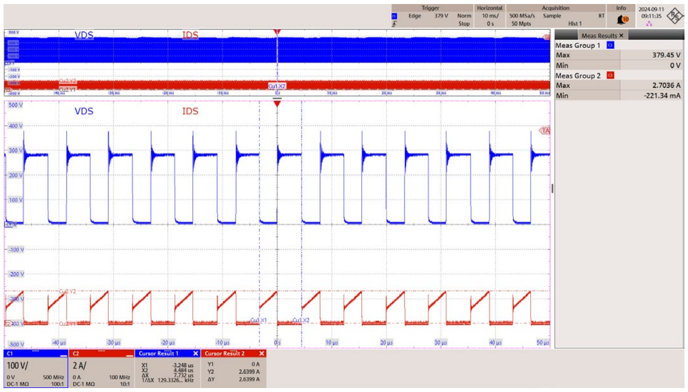


Figure 44 – 115 VAC 60 Hz.
CH1: V_{DS}, 100 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
Zoom: 10 μs / div.
$V_{DS(MAX)}$ = 379 V
$I_{DS(MAX)}$ = 2.70 A

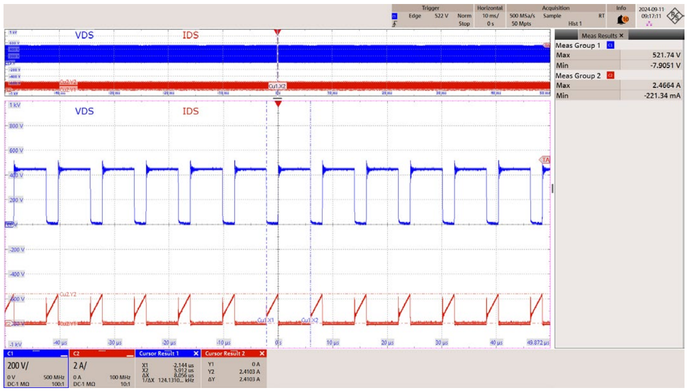


Figure 45 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
Zoom: 10 μs / div.
$V_{DS(MAX)}$ = 522 V
$I_{DS(MAX)}$ = 2.47 A

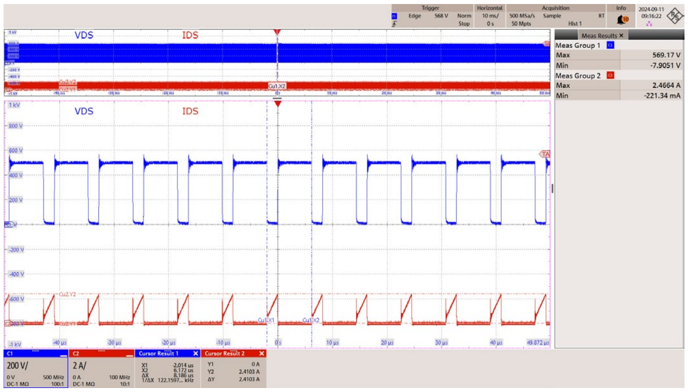


Figure 46 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
Zoom: 10 μs / div.
$V_{DS(MAX)}$ = 569 V
$I_{DS(MAX)}$ = 2.47 A

12.3.1.2 No Load

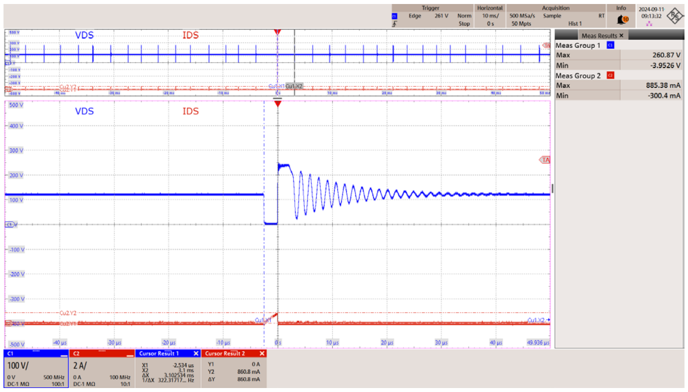


Figure 47 – 85 VAC 60 Hz.
CH1: V_{DS}, 100 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
Zoom: 10 μs / div.
$V_{DS(MAX)}$ = 261 V
$I_{DS(MAX)}$ = 885 mA

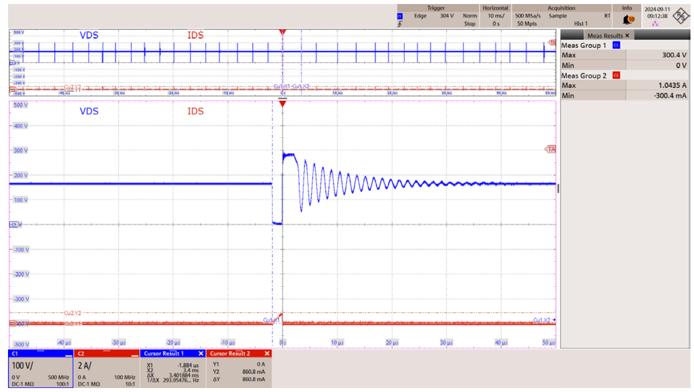


Figure 48 – 115 VAC 60 Hz.
CH1: V_{DS}, 100 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
Zoom: 10 μs / div.
$V_{DS(MAX)}$ = 300 V
$I_{DS(MAX)}$ = 1.04 A

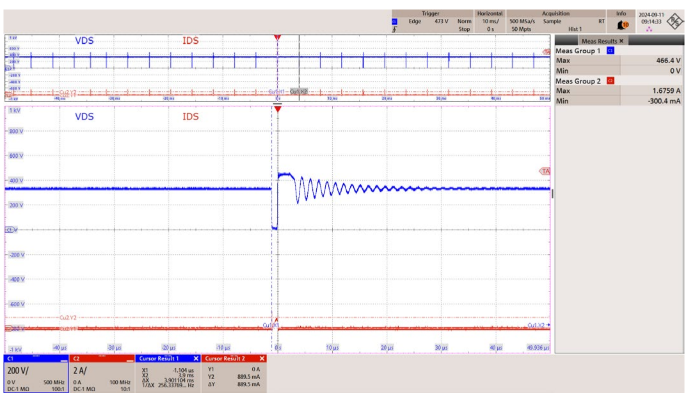


Figure 49 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
Zoom: 10 μs / div.
$V_{DS(MAX)}$ = 466 V
$I_{DS(MAX)}$ = 1.68 A

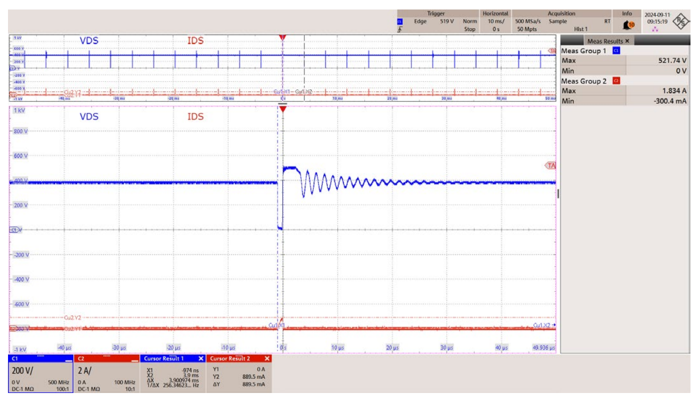


Figure 50 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
Zoom: 10 μs / div.
$V_{DS(MAX)}$ = 522 V
$I_{DS(MAX)}$ = 1.83 A

12.3.2 Primary MOSFET Drain-Source Voltage and Current at Start-up Operation

12.3.2.1 Full Load

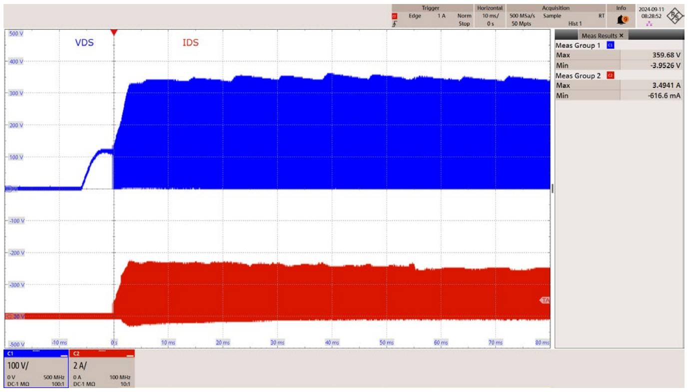


Figure 51 – 85 VAC 60 Hz.
CH1: V_{DS}, 100 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
$V_{DS(MAX)}$ = 360 V
$I_{DS(MAX)}$ = 3.49 A

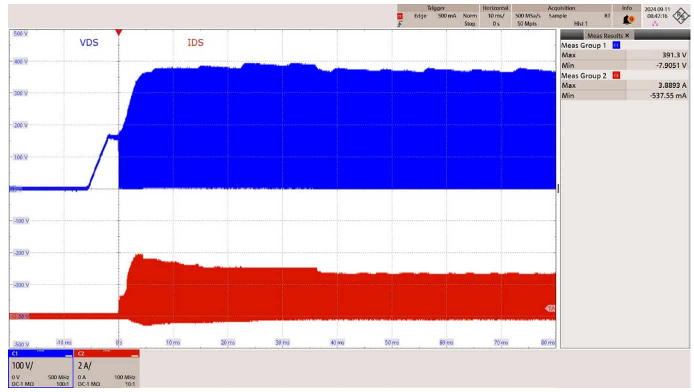


Figure 52 – 115 VAC 60 Hz.
CH1: V_{DS}, 100 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
$V_{DS(MAX)}$ = 391 V
$I_{DS(MAX)}$ = 3.89 A

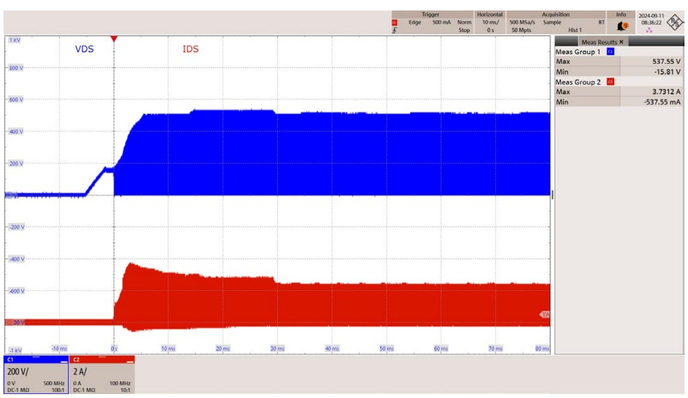


Figure 53 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
$V_{DS(MAX)}$ = 538 V
$I_{DS(MAX)}$ =3.73 A

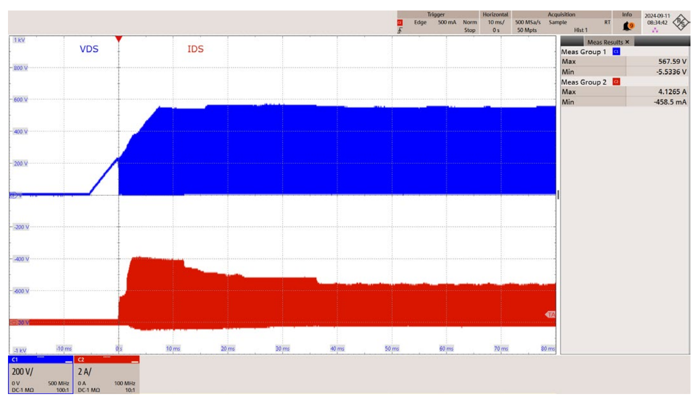


Figure 54 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
$V_{DS(MAX)}$ = 568 V
$I_{DS(MAX)}$ = 4.13 A

12.3.2.2 No Load

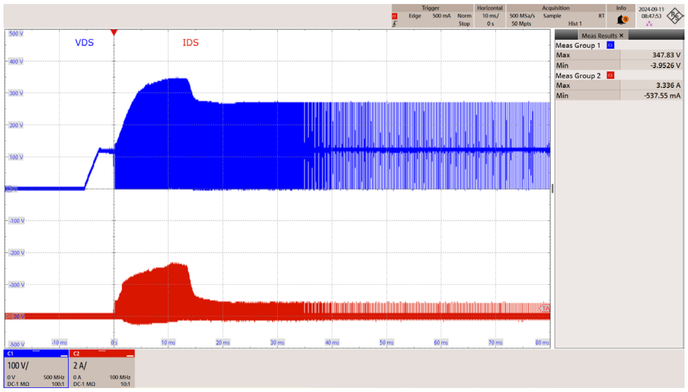


Figure 55 – 85 VAC 60 Hz.
CH1: V_{DS}, 100 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
$V_{DS(MAX)}$ = 348 V
$I_{DS(MAX)}$ = 3.34 A

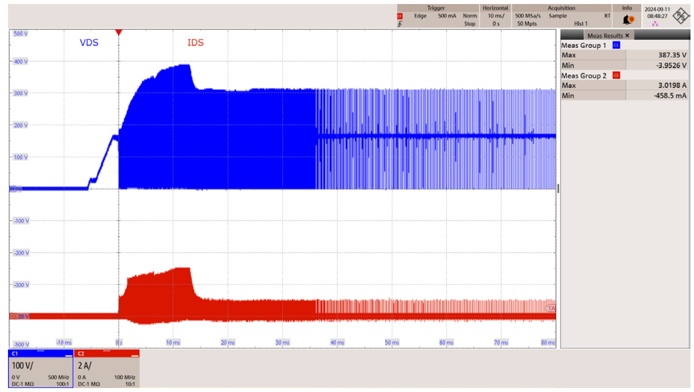


Figure 56 – 115 VAC 60 Hz.
CH1: V_{DS}, 100 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
$V_{DS(MAX)}$ = 387 V
$I_{DS(MAX)}$ = 3.02 A

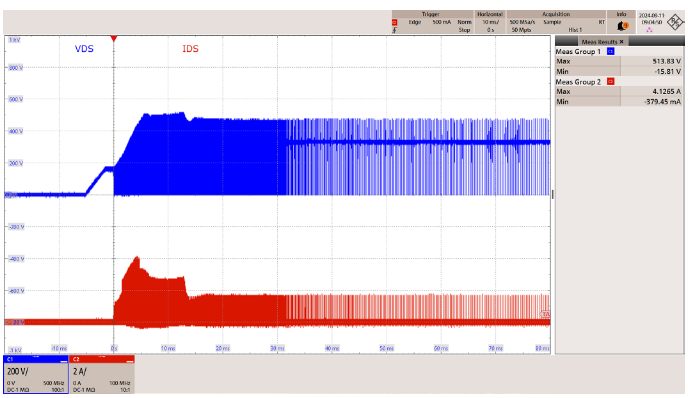


Figure 57 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
$V_{DS(MAX)}$ = 514 V
$I_{DS(MAX)}$ = 4.13 A

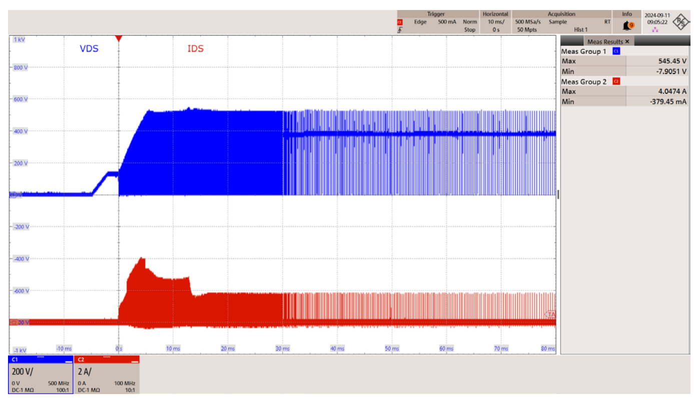


Figure 58 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 2 A / div., 10 ms / div.
$V_{DS(MAX)}$ = 545 V
$I_{DS(MAX)}$ = 4.05 A

12.3.3 Output Rectifier Diode Voltage and Current at Normal Operation

12.3.3.1 Full Load

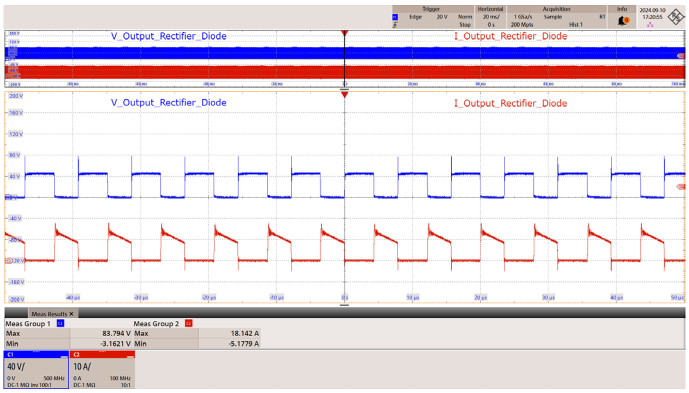


Figure 59 – 85 VAC 60 Hz.
CH1: $V_{OutputRectifierDiode}$, 40 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
Zoom = 10 µs /div.
$V_{OutputRectifierDiode\_MAX}$ = 83.8 V
$I_{OutputRectifierDiode\_MAX}$ = 18.1 A

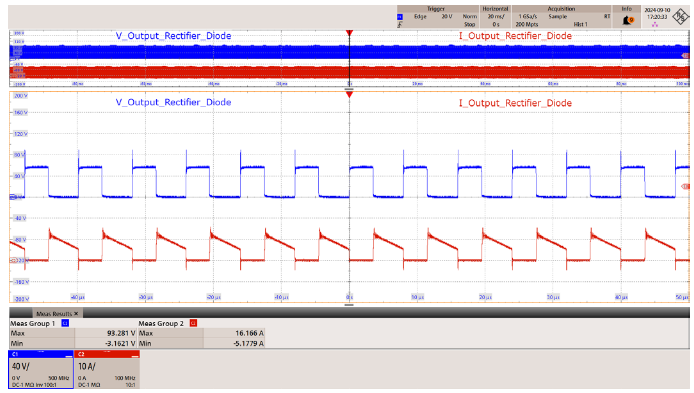


Figure 60 – 115 VAC 60 Hz.
CH1: $V_{OutputRectifierDiode}$, 40 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
Zoom = 10 µs /div.
$V_{OutputRectifierDiode\_MAX}$ = 93.3 V
$I_{OutputRectifierDiode\_MAX}$ = 16.2 A

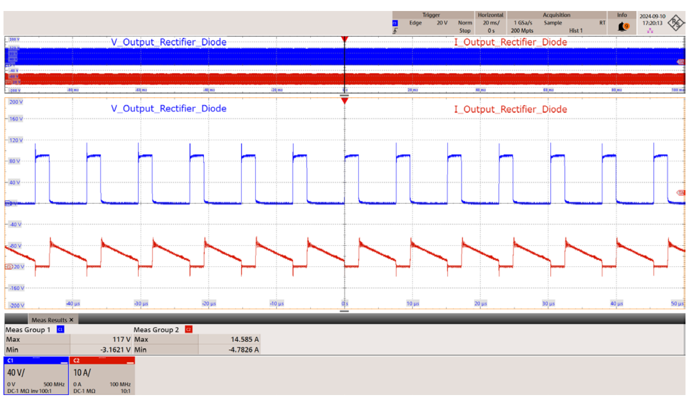


Figure 61 – 230 VAC 50 Hz.
CH1: $V_{OutputRectifierDiode}$, 40 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
Zoom = 10 µs /div.
$V_{OutputRectifierDiode\_MAX}$ = 117 V
$I_{OutputRectifierDiode\_MAX}$ = 14.6 A

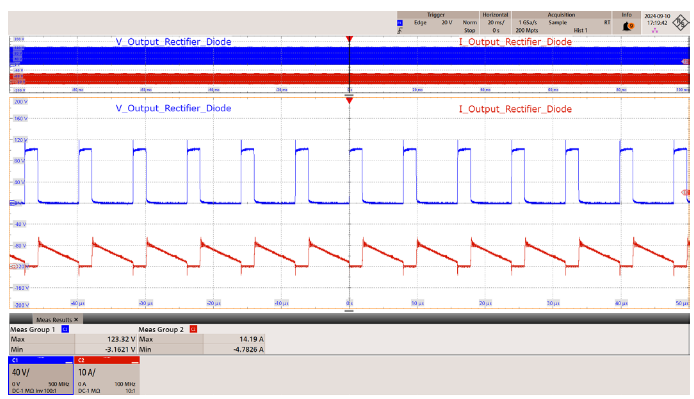


Figure 62 – 265 VAC 50 Hz.
CH1: $V_{OutputRectifierDiode}$, 40 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
Zoom = 10 µs /div.
$V_{OutputRectifierDiode\_MAX}$ = 123 V
$I_{OutputRectifierDiode\_MAX}$ = 14.2 A

12.3.3.2 No Load

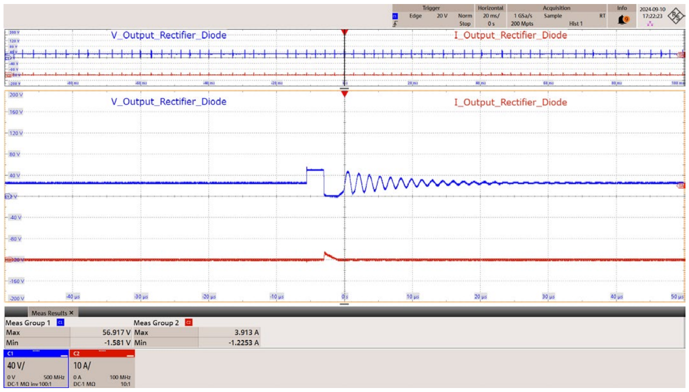


Figure 63 – 85 VAC 60 Hz.
CH1: $V_{OutputRectifierDiode}$, 40 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
Zoom = 10 µs /div.
$V_{OutputRectifierDiode\_MAX}$ = 56.9 V
$I_{OutputRectifierDiode\_MAX}$ = 3.91 A

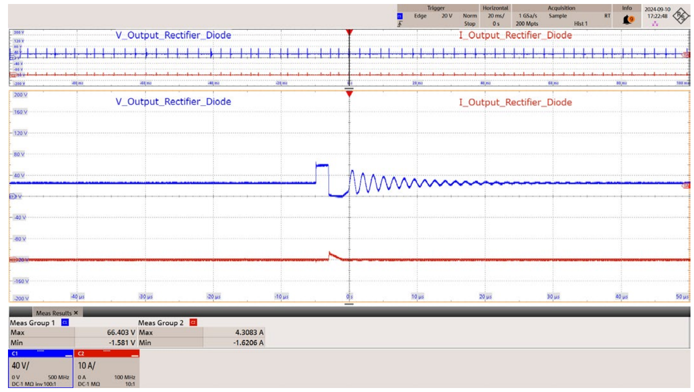


Figure 64 – 115 VAC 60 Hz.
CH1: $V_{OutputRectifierDiode}$, 40 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
Zoom = 10 µs /div.
$V_{OutputRectifierDiode\_MAX}$ = 66.4 V
$I_{OutputRectifierDiode\_MAX}$ = 4.31 A

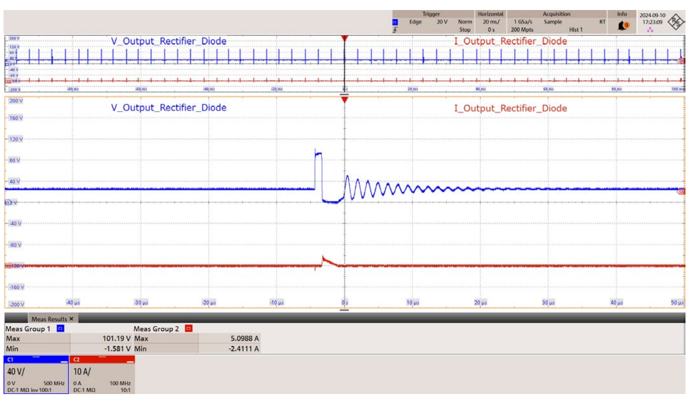


Figure 65 – 230 VAC 50 Hz.
CH1: $V_{OutputRectifierDiode}$, 40 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
Zoom = 10 µs /div.
$V_{OutputRectifierDiode\_MAX}$ = 101 V
$I_{OutputRectifierDiode\_MAX}$ = 5.1 A

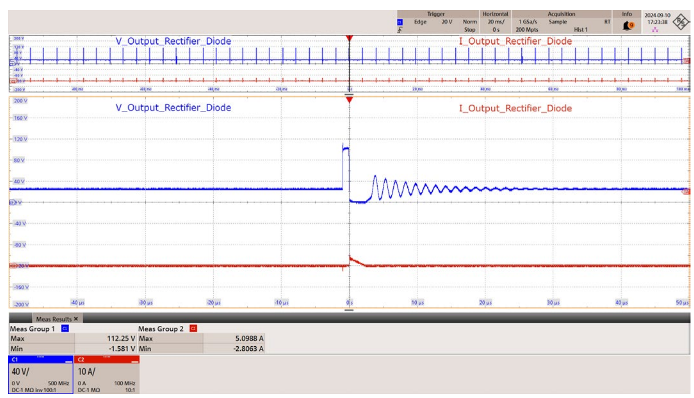


Figure 66 – 265 VAC 50 Hz.
CH1: $V_{OutputRectifierDiode}$, 40 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
Zoom = 10 µs /div.
$V_{OutputRectifierDiode\_MAX}$ = 112 V
$I_{OutputRectifierDiode\_MAX}$ = 5.1 A

12.3.4 Output Rectifier Diode Voltage and Current at Start-Up

12.3.4.1 Full Load

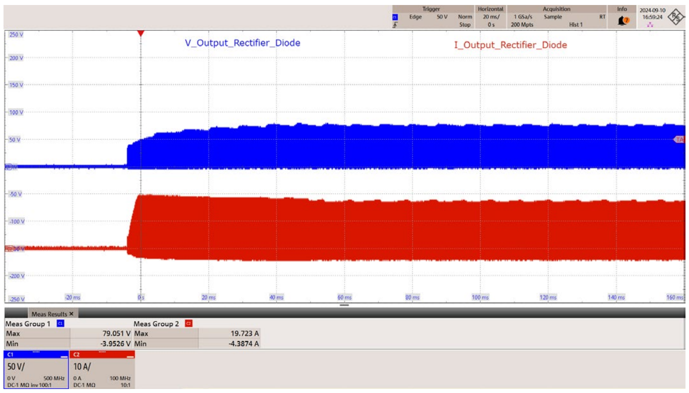


Figure 67 – 85 VAC 60 Hz.
CH1: $V_{OutputRectifierDiode,}$ 50 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode,}$ 10 A / div., 20 ms / div.
$V_{OutputRectifierDiode\_MAX}$ = 79.1 V
$I_{OutputRectifierDiode\_MAX}$ = 19.7 A

Figure 68 – 115 VAC 60 Hz.
CH1: $V_{OutputRectifierDiode,}$ 50 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode,}$ 10 A / div., 20 ms / div.
$V_{OutputRectifierDiode\_MAX}$ = 90.9 V
$I_{OutputRectifierDiode\_MAX}$ = 18.9 A

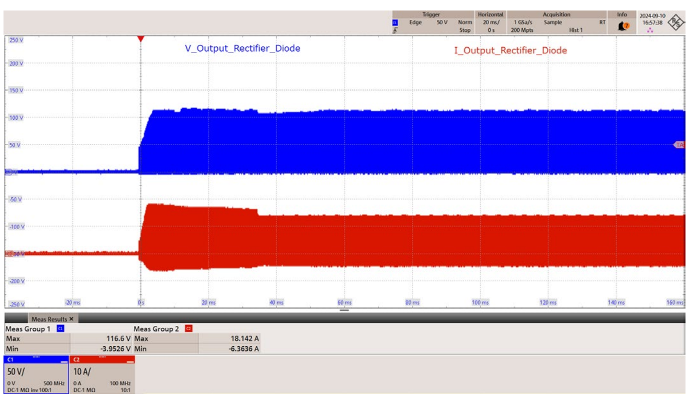


Figure 69 – 230 VAC 50 Hz.
CH1: $V_{OutputRectifierDiode,}$ 50 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode,}$ 10 A / div., 20 ms / div.
$V_{OutputRectifierDiode\_MAX}$ = 117 V
$I_{OutputRectifierDiode\_MAX}$ = 18.1 A

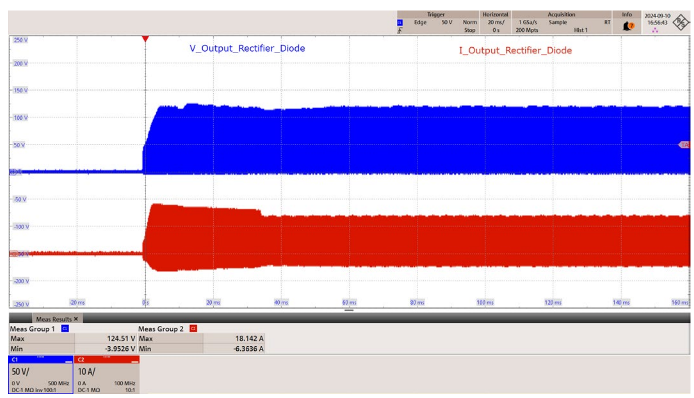


Figure 70 – 265 VAC 50 Hz.
CH1: $V_{OutputRectifierDiode,}$ 50 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode,}$ 10 A / div., 20 ms / div.
$V_{OutputRectifierDiode\_MAX}$ = 125 V
$I_{OutputRectifierDiode\_MAX}$ = 18.1 A

12.3.4.2 No Load

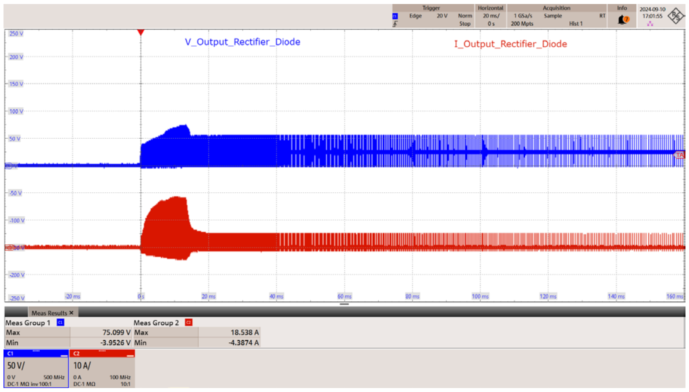


Figure 71 – 85 VAC 60 Hz.
CH1: $V_{OutputRectifierDiode}$, 50 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
$V_{OutputRectifierDiode\_MAX}$ = 75.1 V
$I_{OutputRectifierDiode\_MAX}$ = 18.5 A

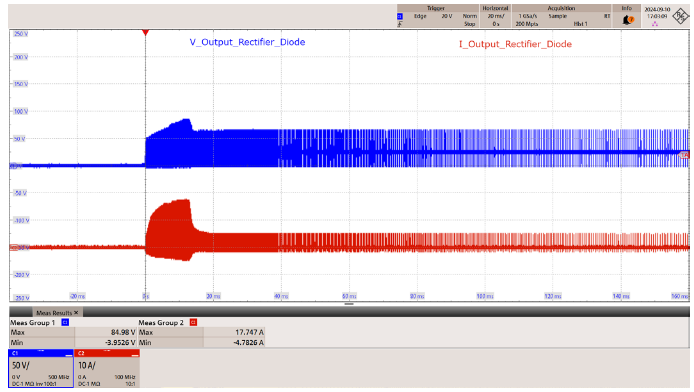


Figure 72 – 115 VAC 60 Hz.
CH1: $V_{OutputRectifierDiode}$, 50 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
$V_{OutputRectifierDiode\_MAX}$ = 85 V
$I_{OutputRectifierDiode\_MAX}$ = 17.7 A

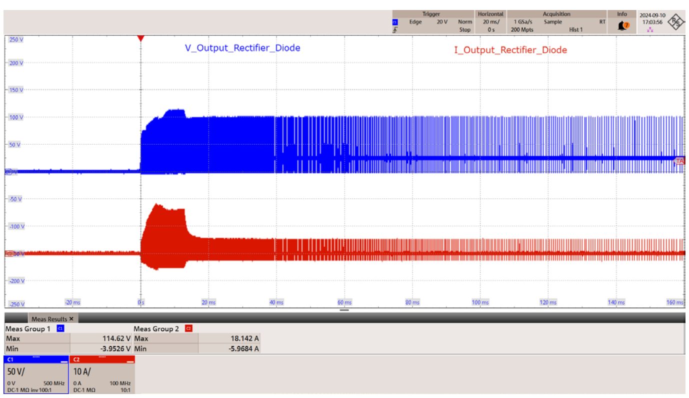


Figure 73 – 230 VAC 50 Hz.
CH1: $V_{OutputRectifierDiode}$, 50 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
$V_{OutputRectifierDiode\_MAX}$ = 115 V
$I_{OutputRectifierDiode\_MAX}$ = 18.1 A

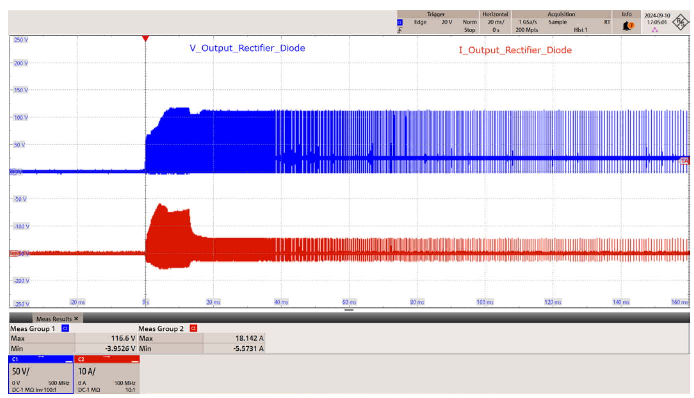


Figure 74 – 265 VAC 50 Hz.
CH1: $V_{OutputRectifierDiode}$, 50 V / div., 20 ms / div.
CH2: $I_{OutputRectifierDiode}$, 10 A / div., 20 ms / div.
$V_{OutputRectifierDiode\_MAX}$ = 117 V
$I_{OutputRectifierDiode\_MAX}$ = 18.1 A

12.4 Brown-In and Brown-Out

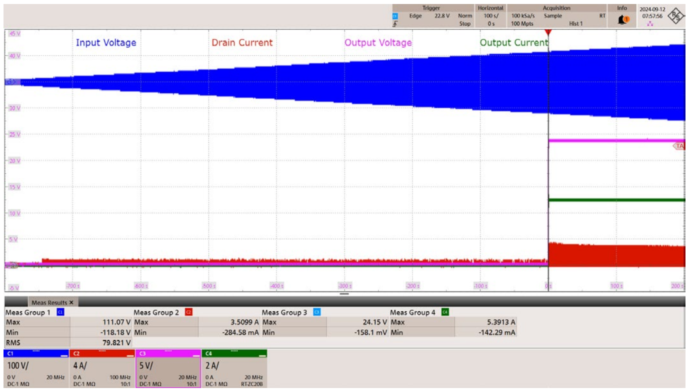


Figure 75 – Brown-In Full Load.
CH1: V_{IN}, 100 V / div., 100 s / div.
CH2: I_{DS}, 4 A / div., 100 s / div.
CH3: V_{OUT}, 5 V / div., 100 s / div.
CH4: I_{OUT}, 2 A / div., 100 s / div.
$V_{BROWN\text{-}IN}$ = 79.8 V_{RMS}

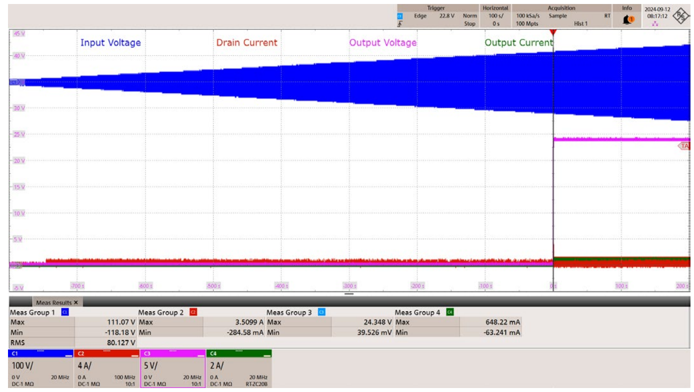


Figure 76 – Brown-In 10% Load.
CH1: V_{IN}, 100 V / div., 100 s / div.
CH2: I_{DS}, 4 A / div., 100 s / div.
CH3: V_{OUT}, 5 V / div., 100 s / div.
CH4: I_{OUT}, 2 A / div., 100 s / div.
$V_{BROWN\text{-}IN}$ = 80.1 V_{RMS}.

Figure 77 – Brown-Out Full Load.
CH1: V_{IN}, 300 V / div., 100 s / div.
CH2: I_{DS}, 4 A / div., 100 s / div.
CH3: V_{OUT}, 5 V / div., 100 s / div.
CH4: I_{OUT}, 2 A / div., 100 s / div.
$V_{BROWN\text{-}OUT}$ = 68.6 V_{RMS}

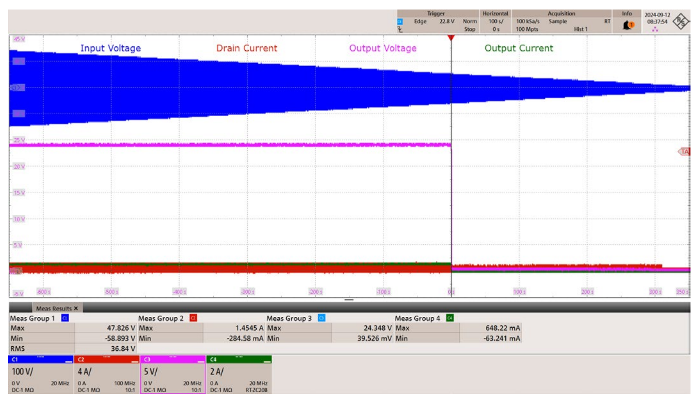


Figure 78 – Brown-Out 10% Load.
CH1: V_{IN}, 300 V / div., 100 s / div.
CH2: I_{DS}, 4 A / div., 100 s / div.
CH3: V_{OUT}, 5 V / div., 100 s / div.
CH4: I_{OUT}, 2 A / div., 100 s / div.
$V_{BROWN\text{-}OUT}$ = 36.8 V_{RMS}

12.5 Output Voltage Ripple

12.5.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized to reduce spurious signals due to pick-up. Details of the probe modification are provided in the Figures below.

The 4987BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 μF / 50 V ceramic type and one (1) 47 μF / 50 V aluminum electrolytic. The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).

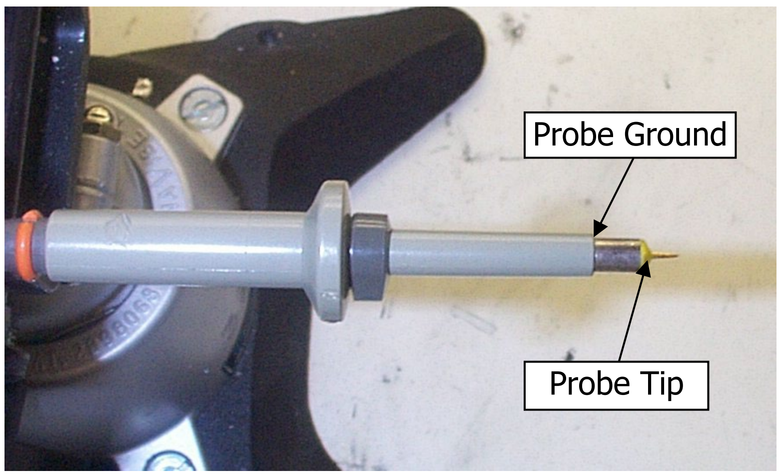


Figure 79 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed.)

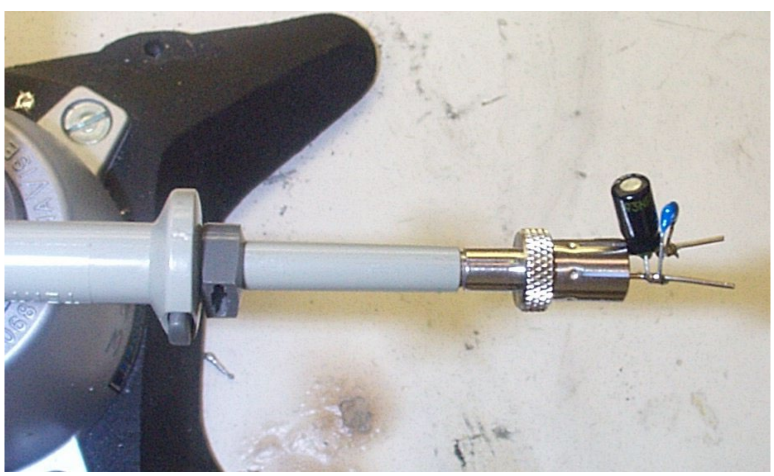


Figure 80 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987BA BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added.)

12.5.2 Measurement Results

Note: All ripple measurements were taken at PCB end.

12.5.2.1 100% Load Condition

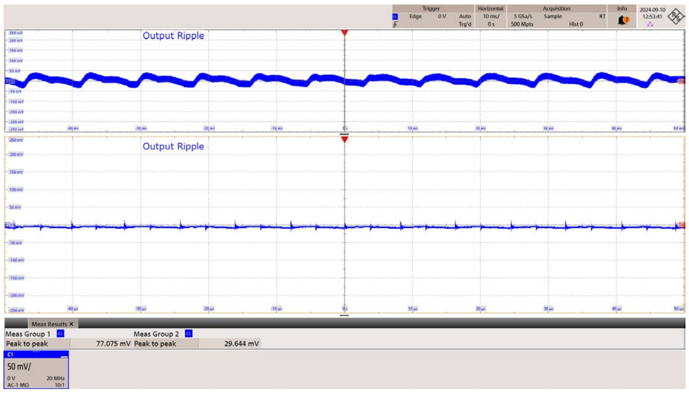


Figure 81 – 85 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 77.1 mV

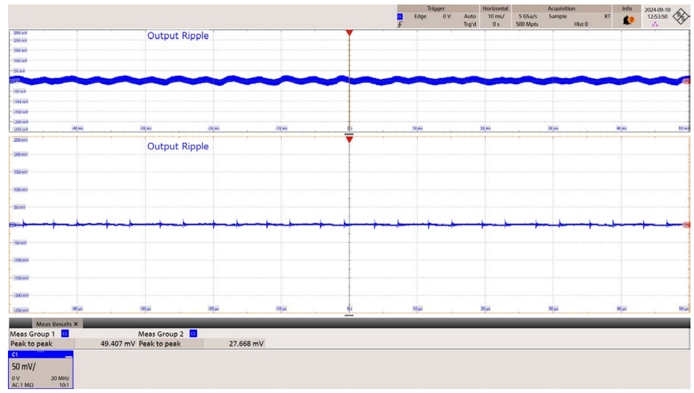


Figure 82 – 115 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 49.4 mV

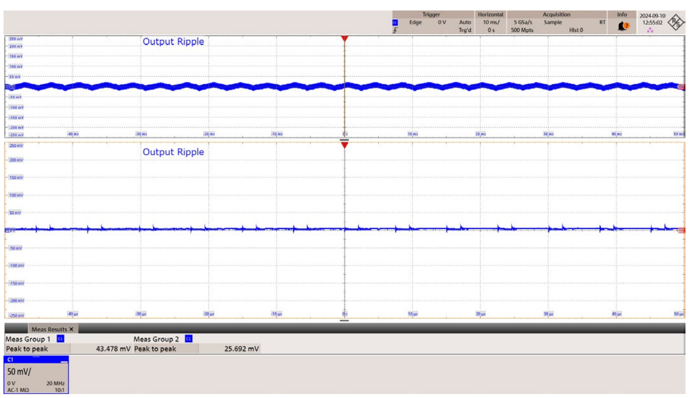


Figure 83 – 230 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 43.5 mV

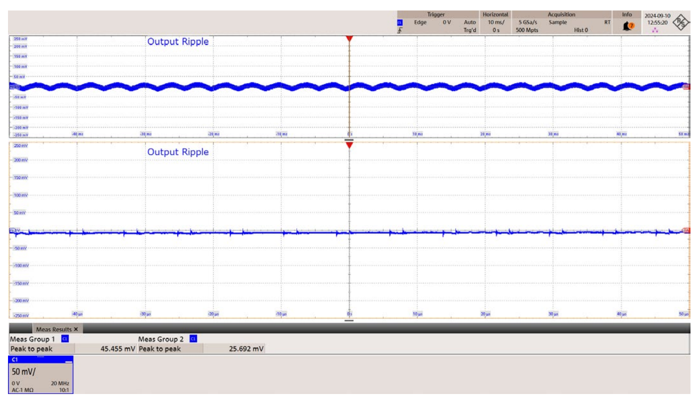


Figure 84 – 265 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 45.5 mV

12.5.2.2 75% Load Condition

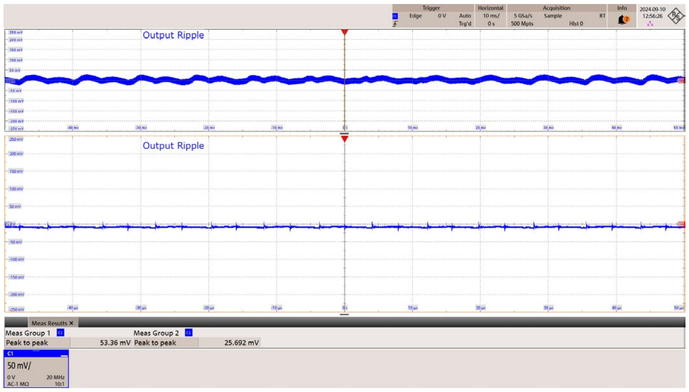


Figure 85 – 85 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 53.4 mV

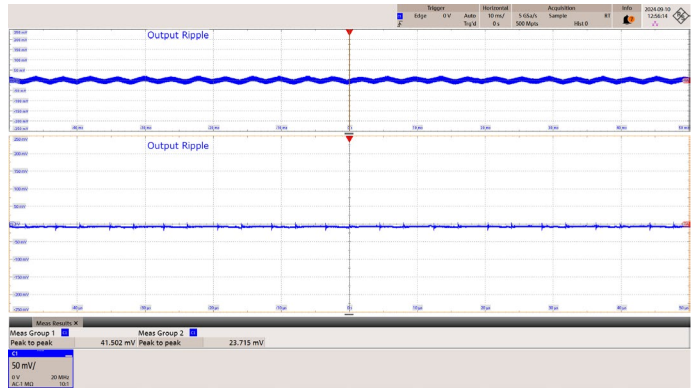


Figure 86 – 115 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 41.5 mV

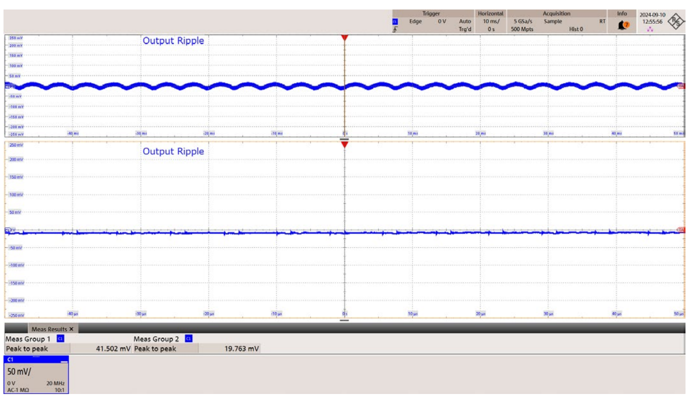


Figure 87 – 230 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 41.5 mV

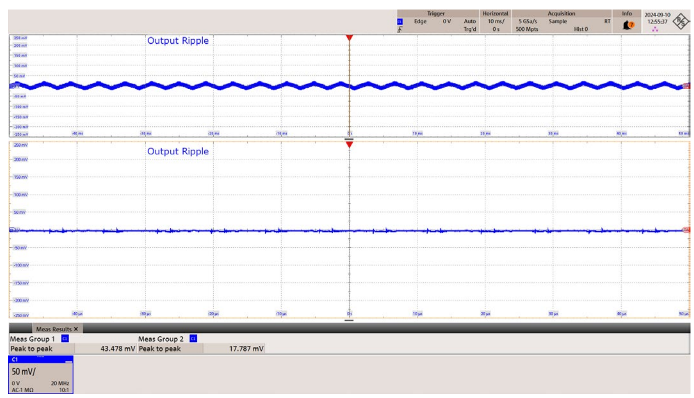


Figure 88 – 265 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 43.5 mV

12.5.2.3 50% Load Condition

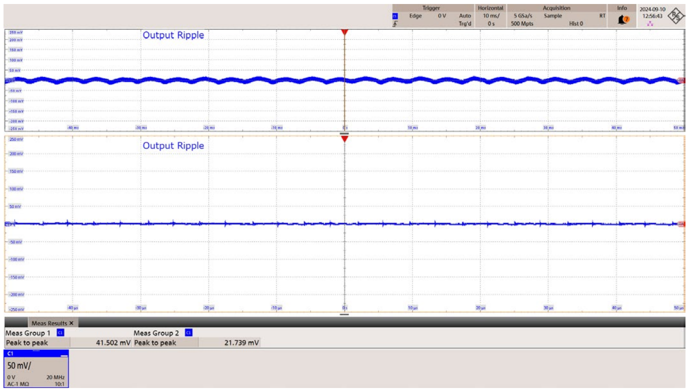


Figure 89 – 85 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 41.5 mV

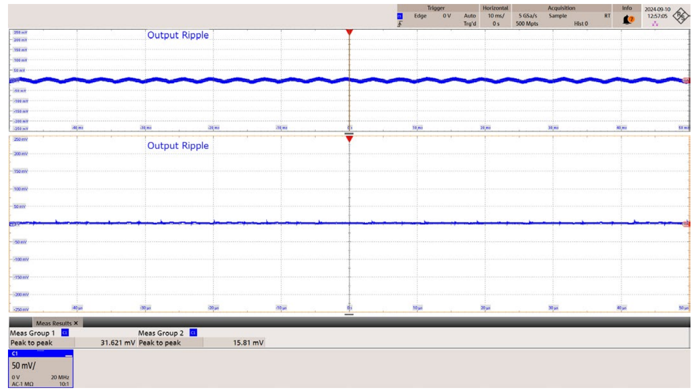


Figure 90 – 115 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 31.6 mV

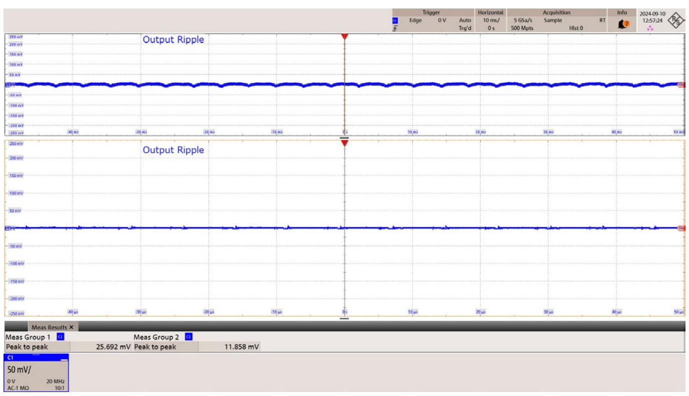


Figure 91 – 230 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 25.7 mV

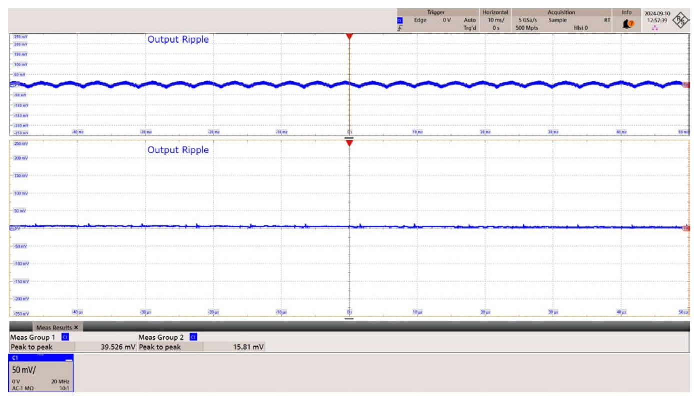


Figure 92 – 265 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 39.5 mV

12.5.2.4 25% Load Condition

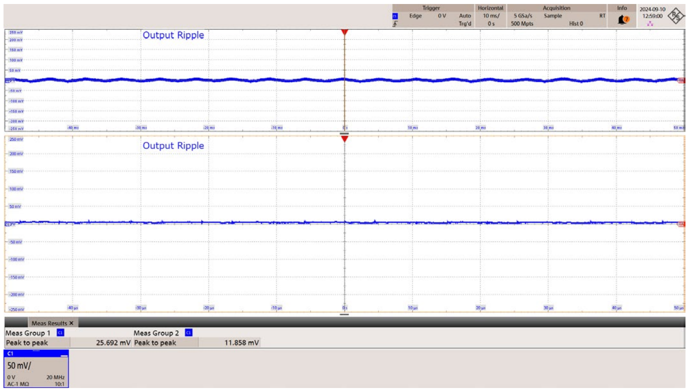


Figure 93 – 85 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 μs / div.
Output Ripple = 25.7 mV

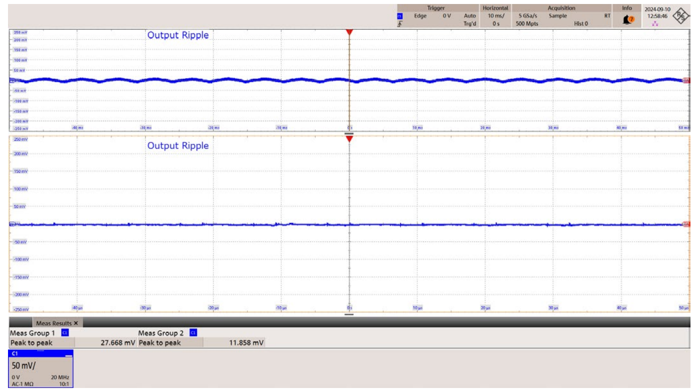


Figure 94 – 115 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 μs / div.
Output Ripple = 27.7 mV

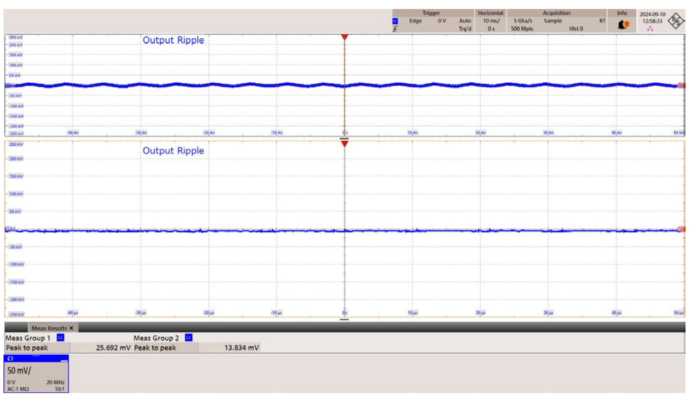


Figure 95 – 230 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 μs / div.
Output Ripple = 25.7 mV

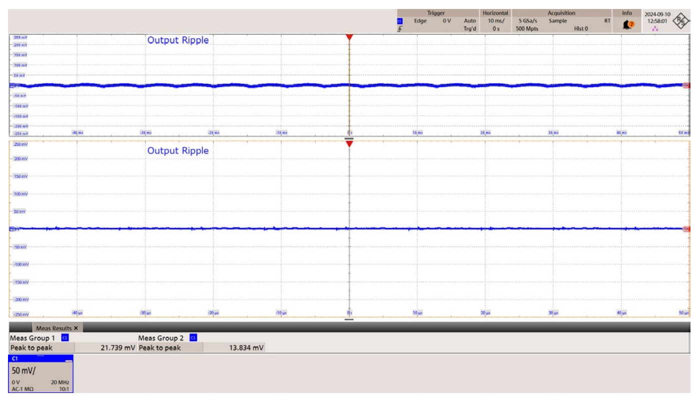


Figure 96 – 265 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 μs / div.
Output Ripple = 21.7 mV

12.5.2.5 10% Load Condition

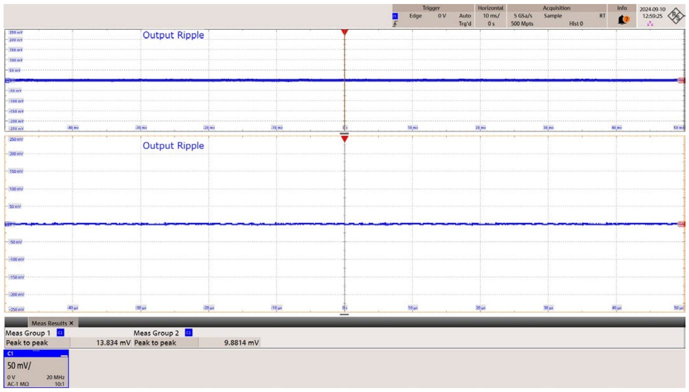


Figure 97 – 85 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 μs / div.
Output Ripple = 13.8 mV

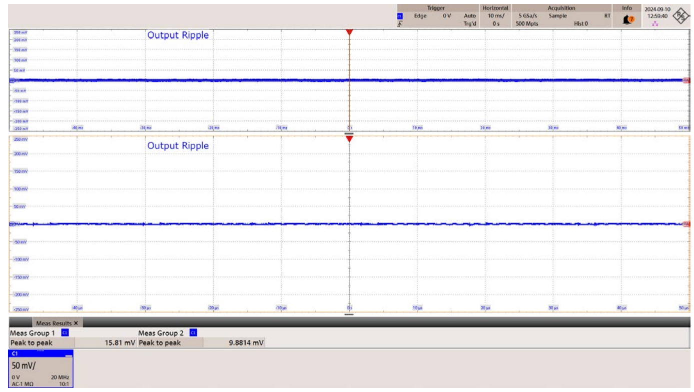


Figure 98 – 115 VAC 60 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 μs / div.
Output Ripple = 15.8 mV

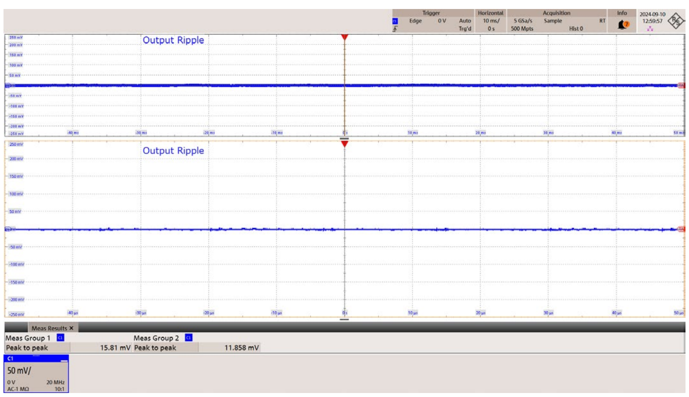


Figure 99 – 230 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 μs / div.
Output Ripple = 15.8 mV

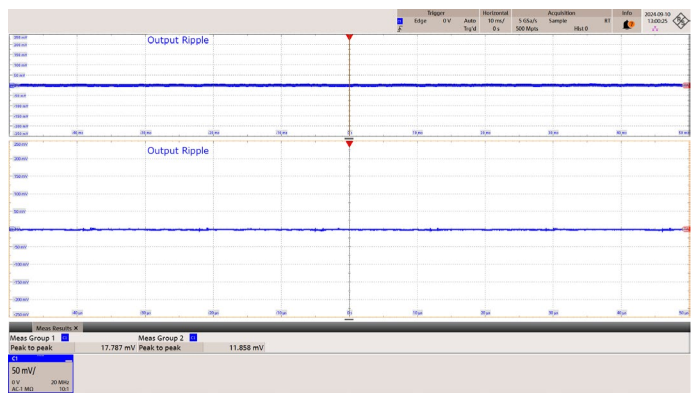


Figure 100 – 265 VAC 50 Hz.
CH1: V_{Ripple}, 50 mV / div., 10 ms / div.
Zoom: 10 μs / div.
Output Ripple = 17.8 mV

12.5.3 Output Ripple Voltage

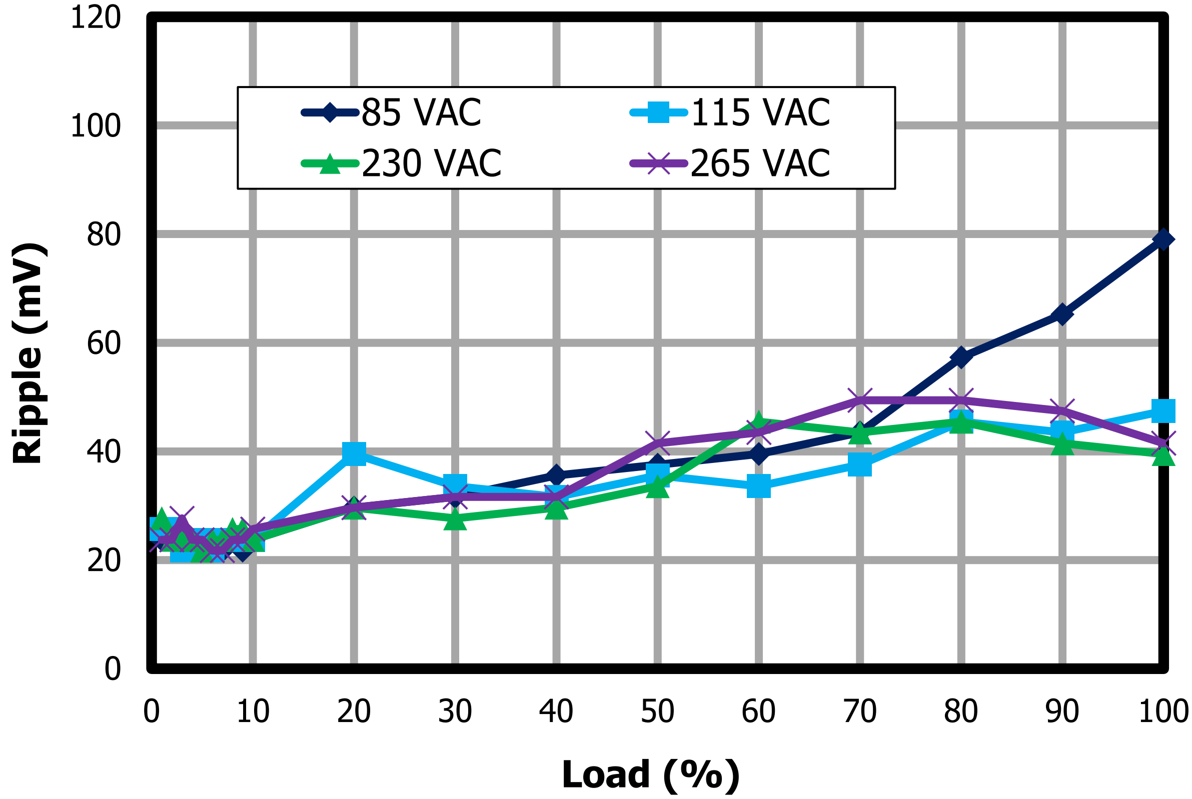


Figure 101 – Voltage Ripple (Measured at PCB Edge, Room Temperature).

13 Thermal Performance

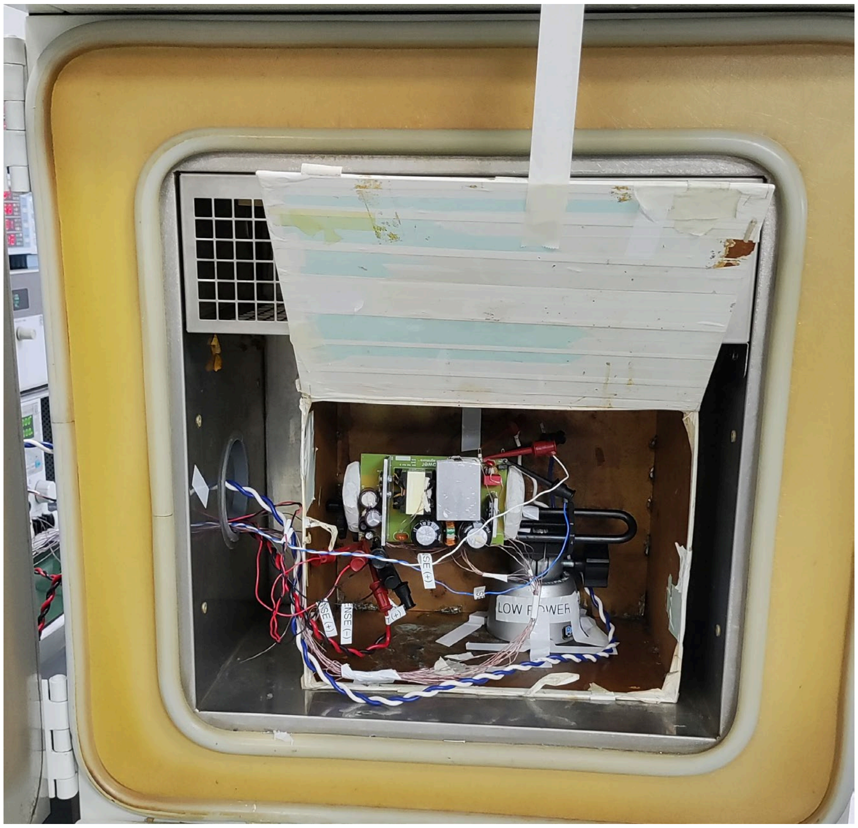


Figure 102 – Setup for Thermal Performance Measured in a Thermal Test Chamber.

13.1 25 °C Ambient Thermals

To measure the temperature of U2, T1, BR1, D4, D6, C9, C2, and L2, a T-type thermocouple was attached to each component. A thermal chamber was utilized to maintain a constant ambient temperature of 25 °C.

13.1.1 85 VAC Full Load at 25 °C Ambient

Test result after 2 hours running continuously at 85 VAC full load.

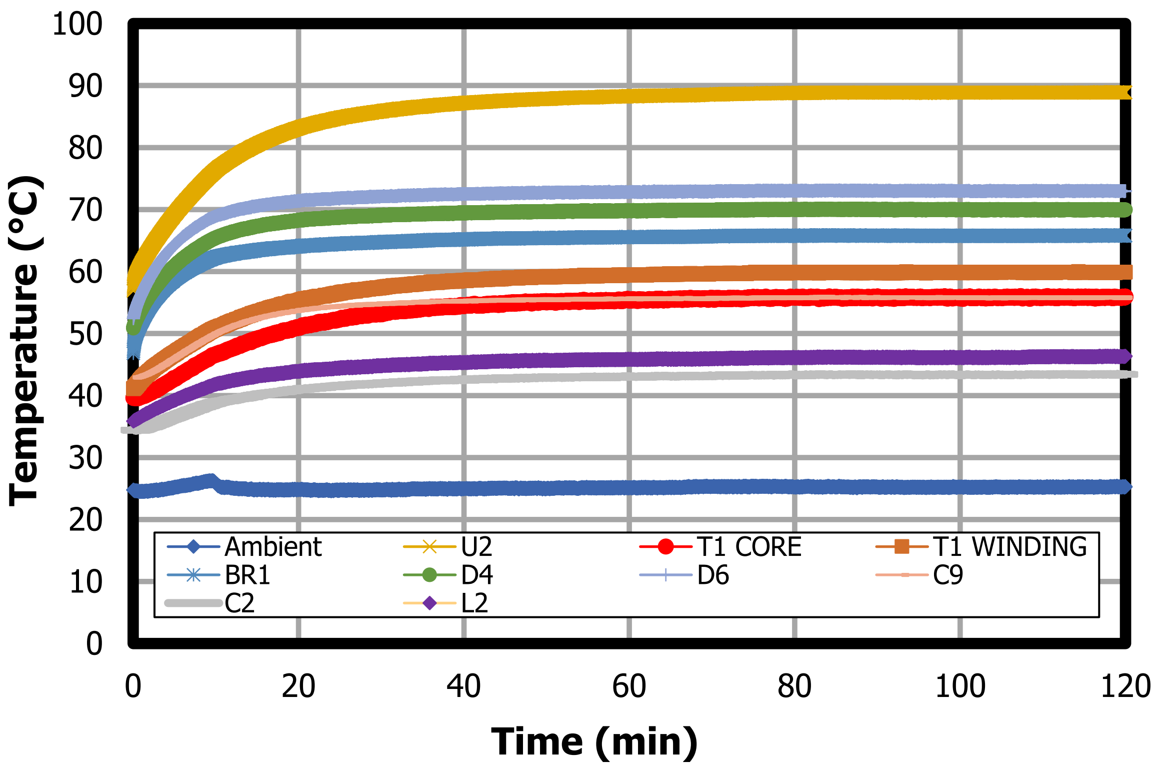


Figure 103 – 85 VAC 60 Hz. Top Side Discrete Component Thermals.

Component	Temperature (°C)
Ambient	25.4
LNK3779E (U2)	89.0
Transformer Core (T1)	56.1
Transformer Winding (T1)	60
Bridge (BR1)	65.9
Output Rectifier Diode (D4)	70.1
Output Rectifier Diode (D6)	73.2
Output Capacitor (C9)	55.9
Bulk Capacitor (C2)	43.5
CMC (L2)	46.4

Table 11 – Thermal Readings at 85 VAC Full Load at 25 °C Ambient.

13.1.2 265 VAC Full Load at 25 °C Ambient

Test result after 2 hours running continuously at 265 VAC full load.

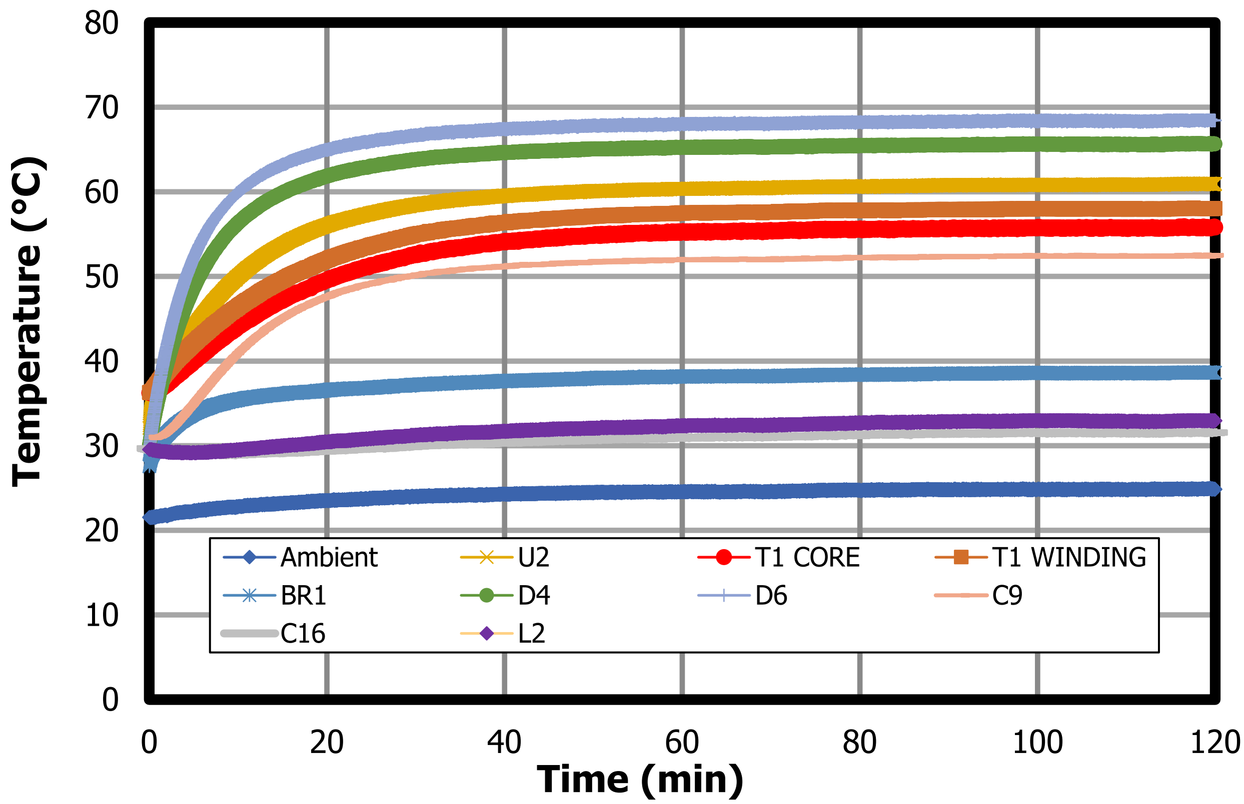


Figure 104 – 265 VAC 50 Hz. Top Side Discrete Component Thermals.

Component	Temperature (°C)
Ambient	25
LNK3779E (U2)	61
Transformer Core (T1)	56.0
Transformer Winding (T1)	58.1
Bridge (BR1)	38.7
Output Rectifier Diode (D4)	65.8
Output Rectifier Diode (D6)	68.6
Output Capacitor (C9)	52.6
Bulk Capacitor (C2)	31.7
CMC (L2)	33.1

Table 12 – Thermal Readings at 265 VAC Full Load at 25 °C Ambient.

13.2 40 °C Ambient Thermals

A thermal chamber was utilized to maintain a constant ambient temperature of 40 °C. To measure the temperature of the top side discrete components U2, T1, BR1, D4, D6, C9, C16, and L2, a T-type thermocouple was attached to each component.

13.2.1 95 VAC Full Load at 40 °C Ambient (Thermal Chamber)

Test result after 2 hours running continuously at 95 VAC full load.

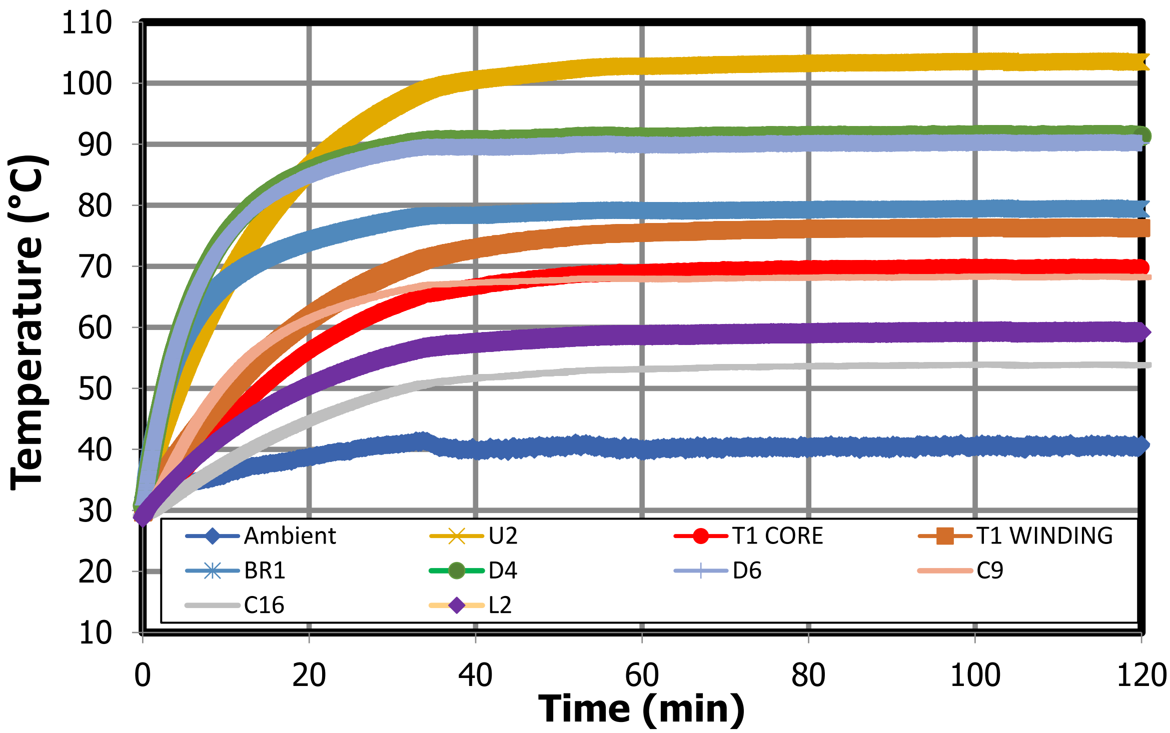


Figure 105 – 95 VAC 60 Hz. Thermals at 40 °C Ambient.

Component	Temperature (°C)
Ambient	41.0
LNK3779E (U2)	103
Transformer Core (T1)	69.9
Transformer Winding (T1)	76.4
Bridge (BR1)	79.6
Output Rectifier Diode (D4)	91.5
Output Rectifier Diode (D6)	90.4
Output Capacitor (C9)	68.4
Bulk Capacitor (C2)	53.9
CMC (L2)	59.4

Table 13 – Thermal Readings at 95 VAC Full Load at 40 °C Ambient.

13.2.2 265 VAC Full Load at 40 °C Ambient (Thermal Chamber)

Test result after 2 hours running continuously at 265 VAC full load.

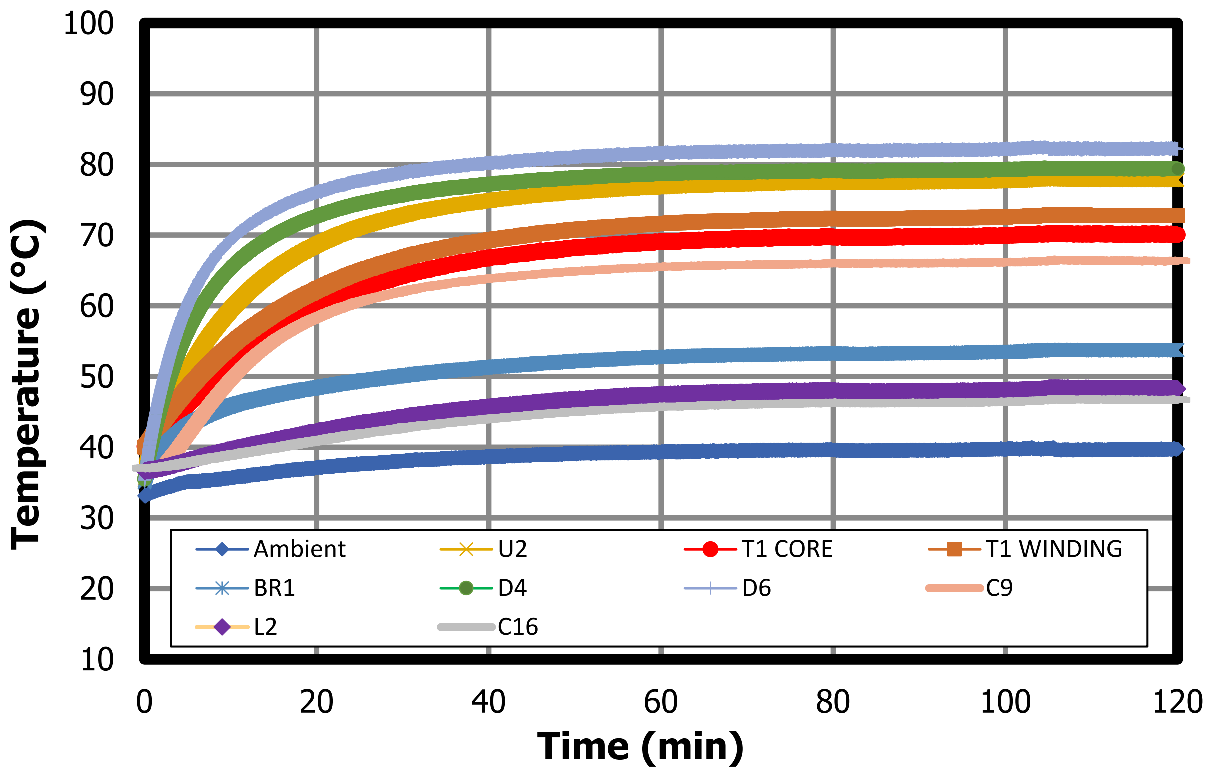


Figure 106 – 265 VAC 50 Hz. Thermals at 40 °C Ambient.

Component	Temperature (°C)
Ambient	40.0
LNK3779E (U2)	78.0
Transformer Core (T1)	70.3
Transformer Winding (T1)	72.9
Bridge (BR1)	53.8
Output Rectifier Diode (D4)	79.5
Output Rectifier Diode (D6)	82.5
Output Capacitor (C9)	66.6
Bulk Capacitor (C2)	46.8
CMC (L2)	48.4

Table 14 – Thermal Readings at 265 VAC Full Load at 40 °C Ambient.

14 Fault Condition

14.1 Output Short-Circuit Protection

14.1.1 Start-Up

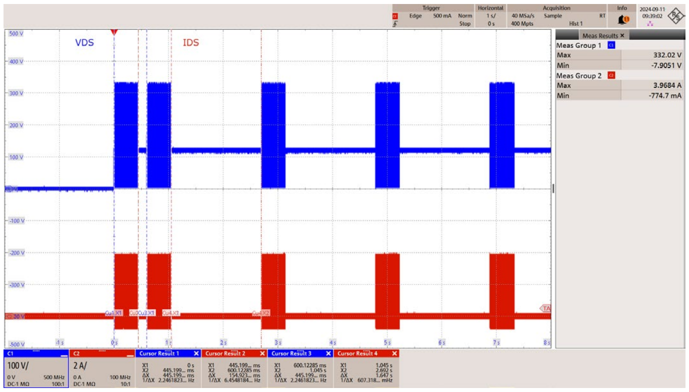


Figure 107 – 85 VAC 60 Hz. Output Short.
CH1: V_{DS}, 100 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 332 V
$I_{DS(MAX)}$ = 3.97 A
t_{AR_ON} = 445 ms
$t_{AR\_OFF\_INITIAL}$ = 155 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

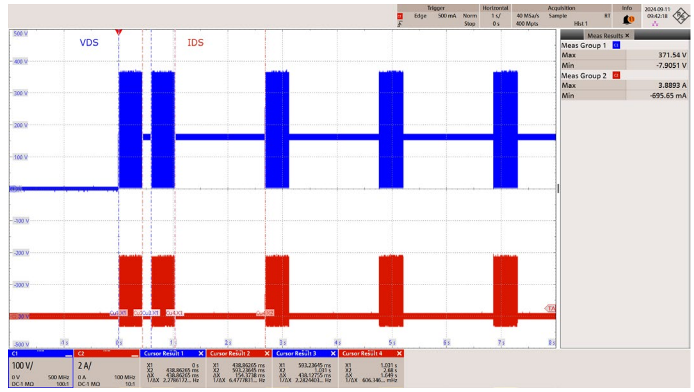


Figure 108 – 115 VAC 60 Hz. Output Short.
CH1: V_{DS}, 100 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 371 V
$I_{DS(MAX)}$ = 3.89 A
t_{AR_ON} = 439 ms
$t_{AR\_OFF\_INITIAL}$ = 154 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

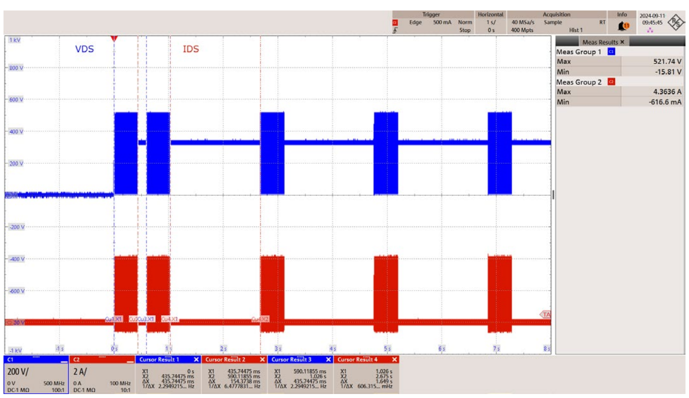


Figure 109 – 230 VAC 50 Hz. Output Short.
CH1: V_{DS}, 200 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 522 V
$I_{DS(MAX)}$ = 4.36 A
t_{AR_ON} = 436 ms
$t_{AR\_OFF\_INITIAL}$ = 154 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

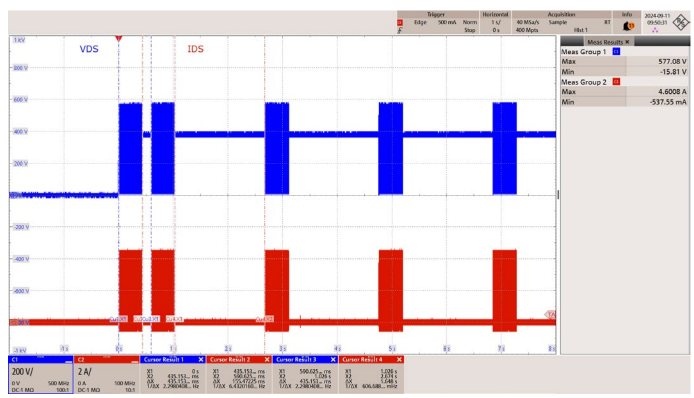


Figure 110 –265 VAC 50 Hz. Output Short.
CH1: V_{DS}, 200 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 577 V
$I_{DS(MAX)}$ = 4.60 A
t_{AR_ON} = 435 ms
$t_{AR\_OFF\_INITIAL}$ = 155 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

14.1.2 Running Short

14.1.2.1 Full Load

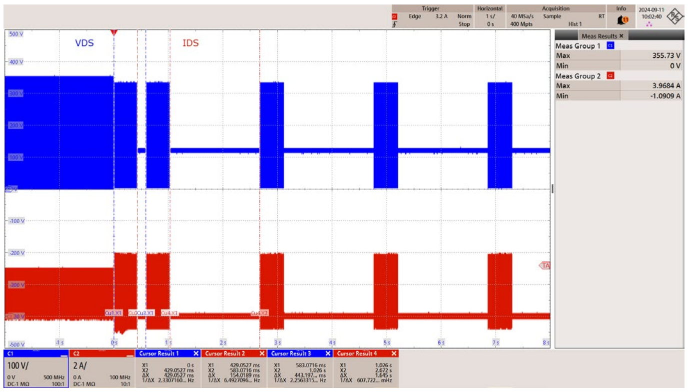


Figure 111 – 85 VAC 60 Hz. Output Short.
CH1: V_{DS}, 100 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 366 V
$I_{DS(MAX)}$ = 3.97 A
t_{AR_ON} = 443 ms
$t_{AR\_OFF\_INITIAL}$ = 154 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

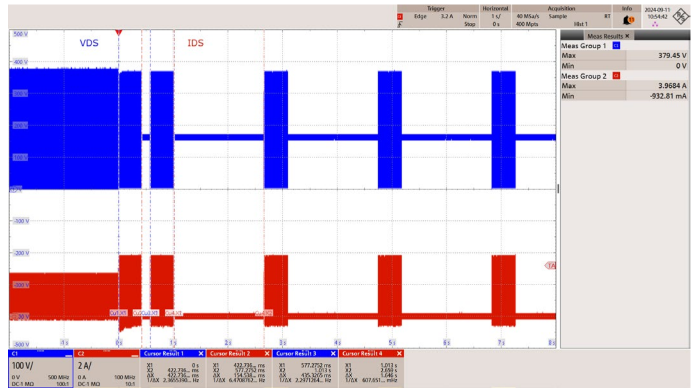


Figure 112 – 115 VAC 60 Hz. Output Short.
CH1: V_{DS}, 100 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 379 V
$I_{DS(MAX)}$ = 3.97 A
t_{AR_ON} = 435 ms
$t_{AR\_OFF\_INITIAL}$ = 155 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

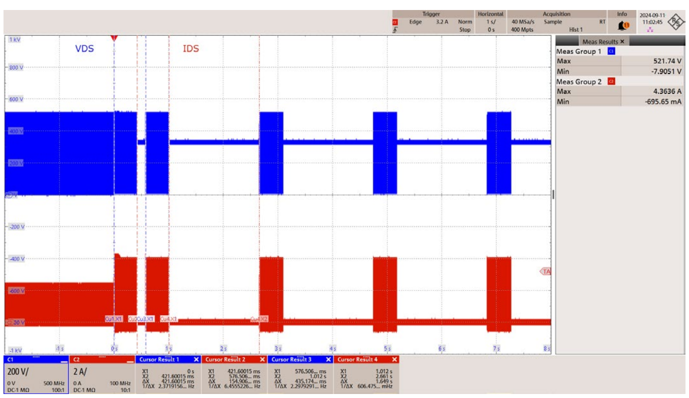


Figure 113 – 230 VAC 50 Hz. Output Short.
CH1: V_{DS}, 200 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 522 V
$I_{DS(MAX)}$ = 4.36 A
t_{AR_ON} = 435 ms
$t_{AR\_OFF\_INITIAL}$ = 155 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

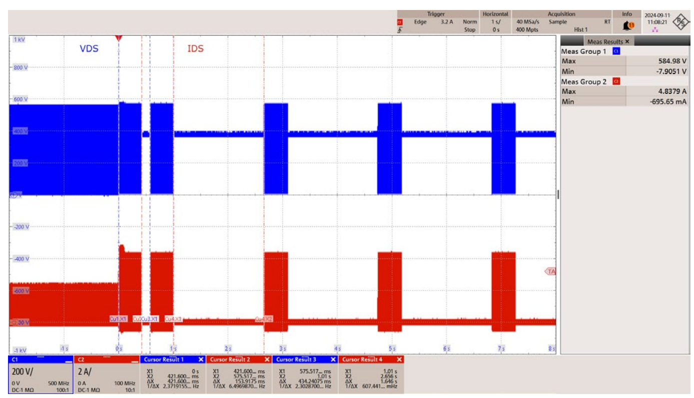


Figure 114 –265 VAC 50 Hz. Output Short.
CH1: V_{DS}, 200 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 585 V
$I_{DS(MAX)}$ = 4.84 A
t_{AR_ON} = 434 ms
$t_{AR\_OFF\_INITIAL}$ = 154 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

14.1.2.2 No Load

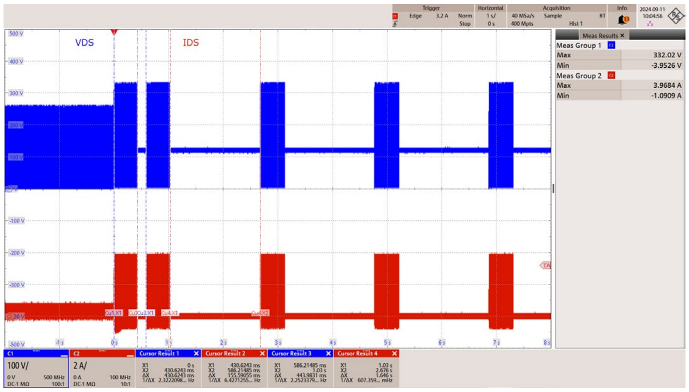


Figure 115 – 85 VAC 60 Hz. Output Short.
CH1: V_{DS}, 100 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 332 V
$I_{DS(MAX)}$ = 3.97 A
t_{AR_ON} = 444 ms
$t_{AR\_OFF\_INITIAL}$ = 156 s
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

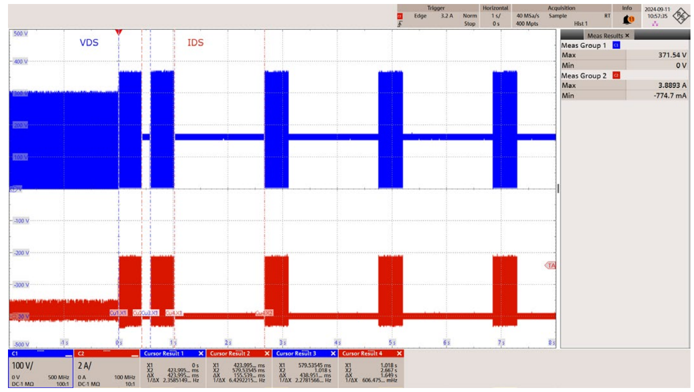


Figure 116 – 115 VAC 60 Hz. Output Short.
CH1: V_{DS}, 100 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 372 V
$I_{DS(MAX)}$ = 3.89 A
t_{AR_ON} = 439 ms
$t_{AR\_OFF\_INITIAL}$ = 156 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

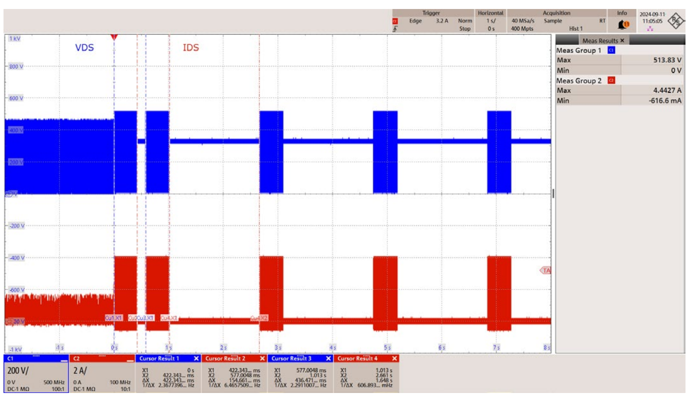


Figure 117 – 230 VAC 50 Hz. Output Short.
CH1: V_{DS}, 200 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 514 V
$I_{DS(MAX)}$ = 4.44 A
t_{AR_ON} = 436 ms
$t_{AR\_OFF\_INITIAL}$ = 155 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

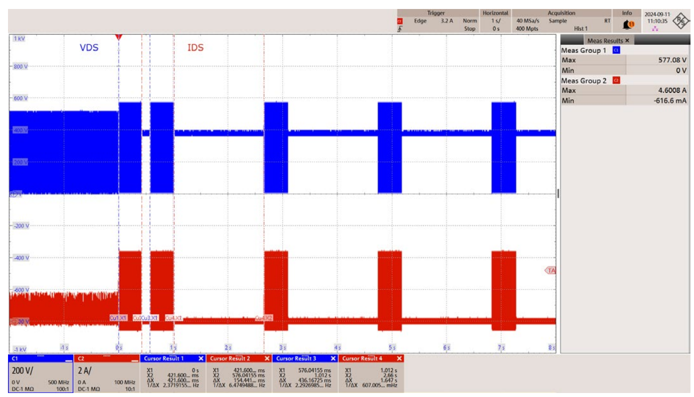


Figure 118 – 265 VAC 50 Hz. Output Short.
CH1: V_{DS}, 200 V / div., 1 s / div.
CH2: I_{DS}, 2 A / div., 1 s / div.
$V_{DS(MAX)}$ = 577 V
$I_{DS(MAX)}$ = 4.60 A
t_{AR_ON} = 436 ms
$t_{AR\_OFF\_INITIAL}$ = 154 ms
$t_{AR\_OFF\_SUBSEQUENT}$ = 1.65 s

14.1.2.3 Thermals

Component	Temperature (°C)
Ambient	25.8
LNK3779E (U2)	33.1
Transformer Core (T1)	37.3
Transformer Winding (T1)	39.2
Bridge (BR1)	28.2
Output Rectifier Diode (D4)	63.8
Output Rectifier Diode (D6)	66.9
Output Capacitor (C9)	49.7
Bulk Capacitor (C2)	27.3
CMC (L2)	28.2

Table 15 – 85 VAC 60 Hz. Discrete Component Thermals Output Short (1 hr. Soak).

Component	Temperature (°C)
Ambient	25
LNK3779E (U2)	31.3
Transformer Core (T1)	32.9
Transformer Winding (T1)	34
Bridge (BR1)	25.9
Output Rectifier Diode (D4)	51.7
Output Rectifier Diode (D6)	53.9
Output Capacitor (C9)	41.7
Bulk Capacitor (C2)	25.8
CMC (L2)	26.5

Table 16 – 265 VAC 50 Hz. Discrete Component Thermals Output Short (1 hr. Soak).

14.2 Over Temperature Protection

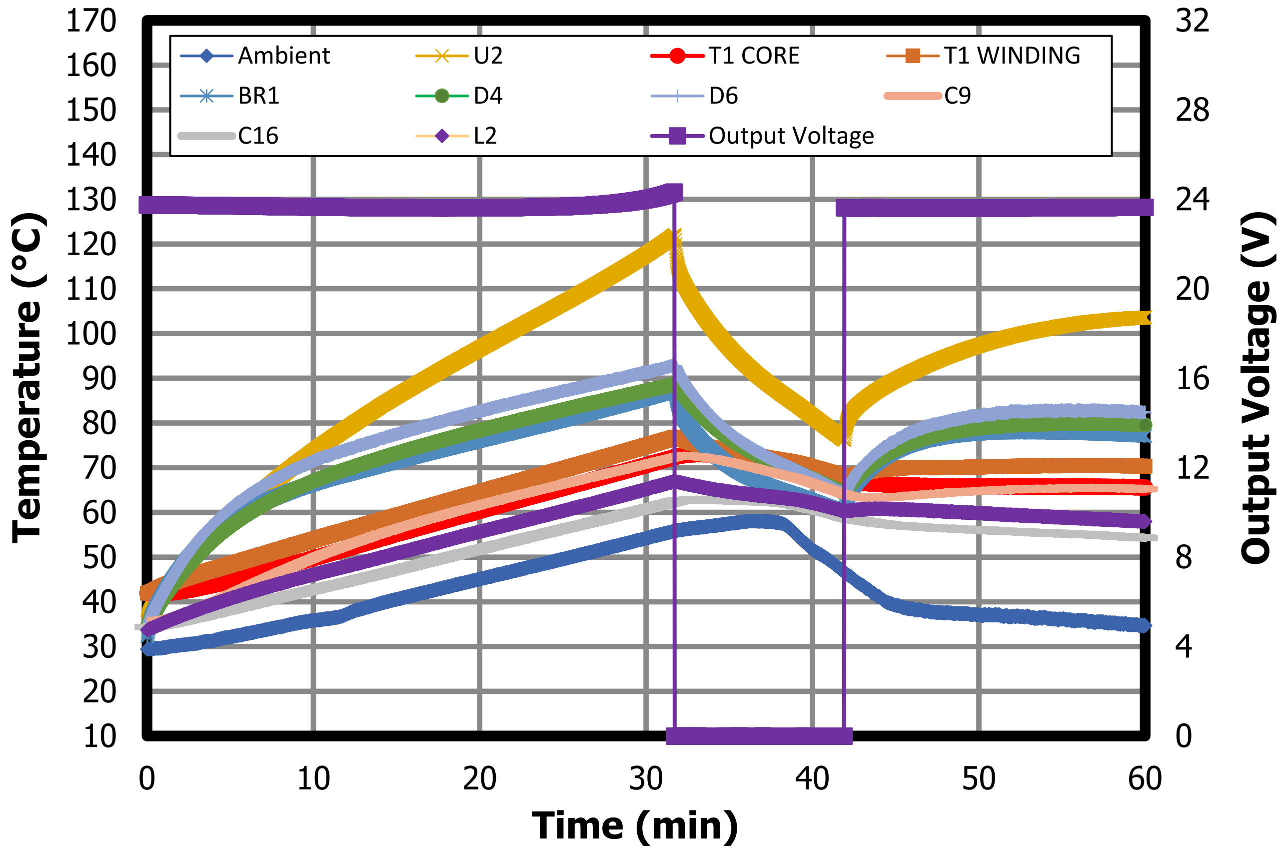


Figure 119 – 85 VAC 60 Hz. Full Load OTP.

Component	At OTP Trigger Temperature (°C)	At Recovery Temperature (°C)
Ambient	55.8	46.7
LNK3779E (U2)	122	76.2
Transformer Core (T1)	72.4	67.6
Transformer Winding (T1)	76.8	68
Bridge (BR1)	87.4	60.0
Output Rectifier Diode (D4)	88.7	64.4
Output Rectifier Diode (D6)	92.8	64.2
Output Capacitor (C9)	72.5	64.0
Bulk Capacitor (C2)	62.4	58.9
CMC (L2)	67.0	60.3

Table 17 – Thermal Readings at 85 VAC Input during OTP and Output Recovery.

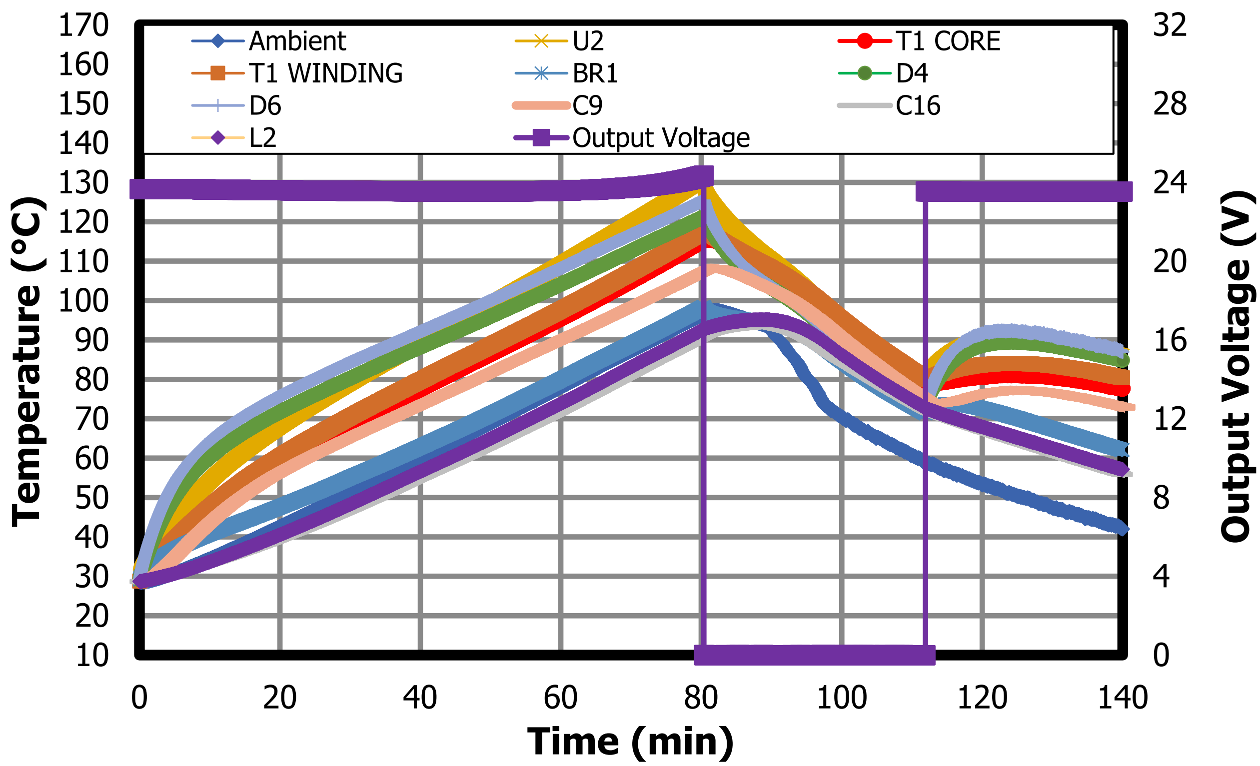


Figure 120 – 265 VAC 50 Hz. Full Load OTP.

Component	At OTP Trigger Temperature (°C)	At Recovery Temperature (°C)
Ambient	96.6	59
LNK3779E (U2)	131	783
Transformer Core (T1)	115	796
Transformer Winding (T1)	188	80
Bridge (BR1)	98.4	71.3
Output Rectifier Diode (D4)	121	73.5
Output Rectifier Diode (D6)	125	73
Output Capacitor (C9)	108	74.4
Bulk Capacitor (C2)	91.0	72.3
CMC (L2)	928	72.7

Table 18 – Thermal Readings at 265Vac Input during OTP and Output Recovery.

Input (VAC)	IC Temperature (°C)	
	OTP Shutdown	Recover
85	122	76.2
265	131	78.3

Table 19 – Thermal Readings of LNK6779E IC during OTP and Output Recovery.

15 Conducted EMI

Conducted emissions tests were performed at 115 VAC and 230 VAC at full load (24 V 5 A). Measurements were taken with floating ground.

15.1 Test Set-up Equipment

15.1.1 Equipment and Load Used

1. Rohde and Schwarz ENV216 two line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Input voltage set at 115 VAC and 230 VAC.
4. 24 V RLOAD resistance is 4.8 ohms.

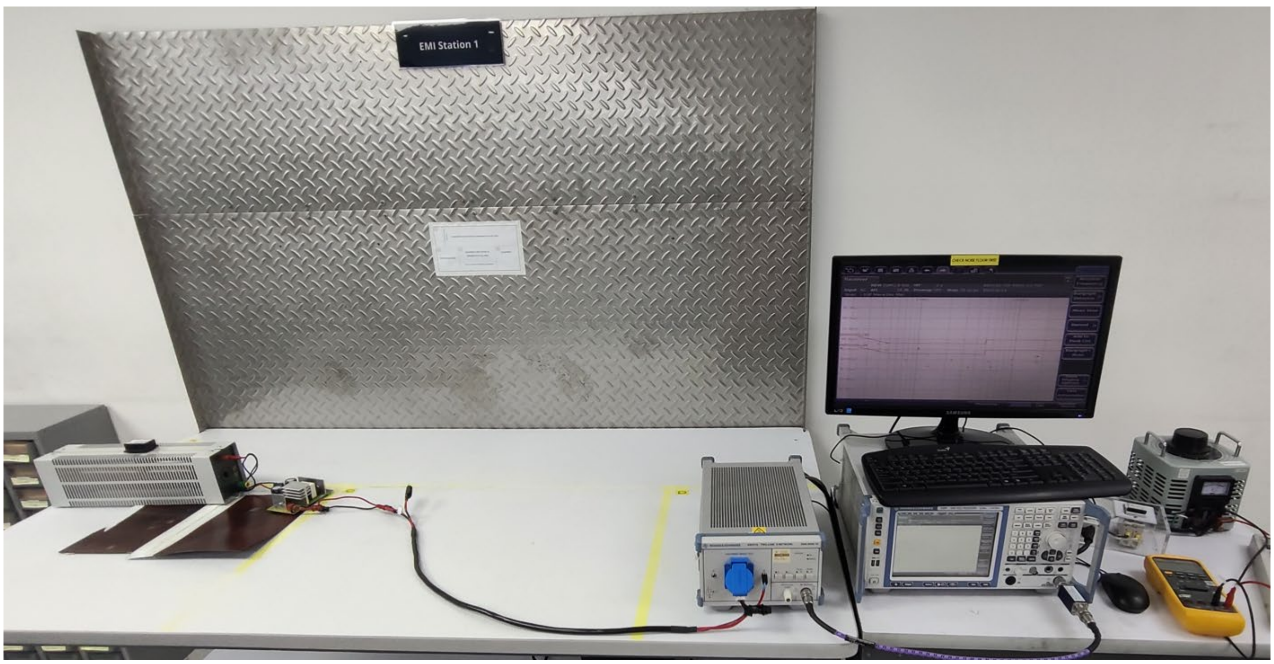


Figure 121 – EMI Test Set-up.

15.2 Output Float

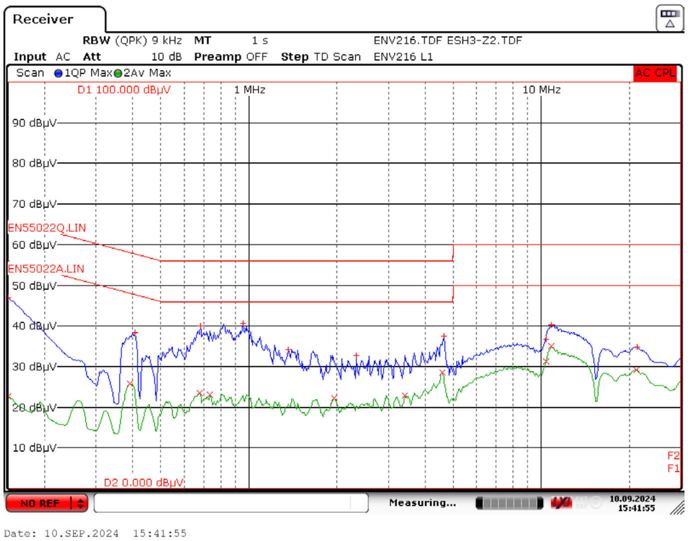


Figure 122 – 115 VAC 60 Hz.
Line with Floating

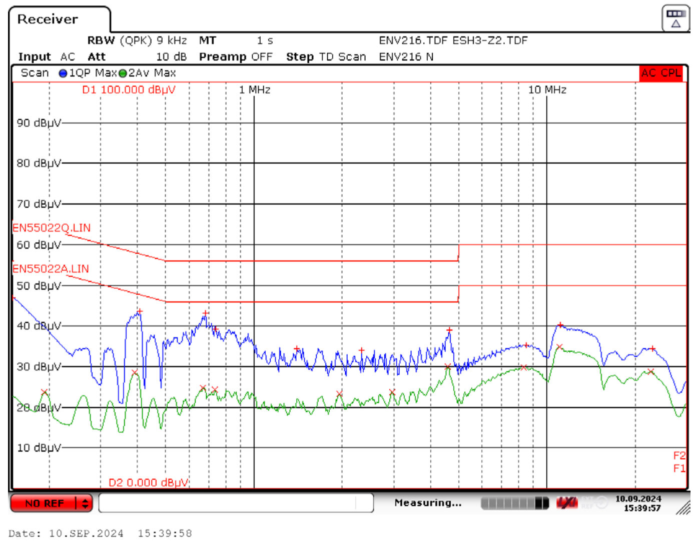


Figure 123 – 115 VAC 60 Hz.
Neutral with Floating

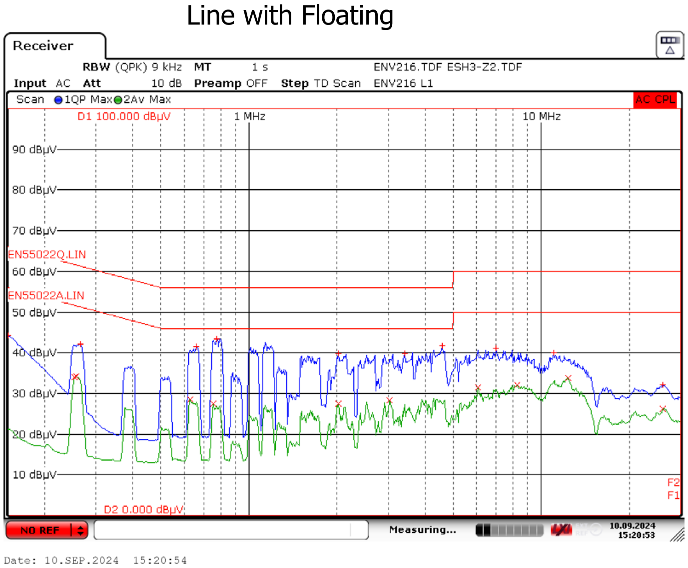


Figure 124 – 230 VAC 60 Hz.
Line with Floating

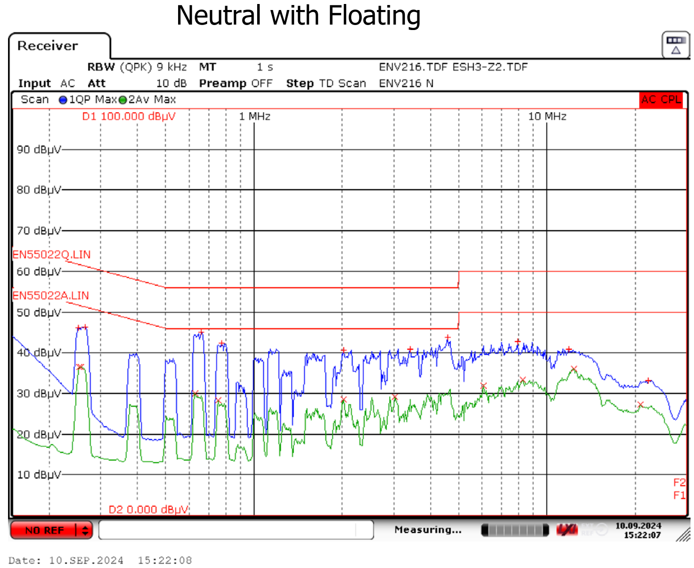


Figure 125 – 230 VAC 60 Hz.
Neutral with Floating

16 Line Surge

IEC61000-4-5 differential mode and common mode input line surge testing was completed on a single test unit. Input voltage was set at 230 VAC / 60 Hz. Output was loaded at full load and operation was verified following each surge event.

16.1 Differential Mode Surge

DM Surge Level (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2000 V	230	L to N	0	Pass
–2000 V	230	L to N	0	Pass
+2000 V	230	L to N	90	Pass
–2000 V	230	L to N	90	Pass
+2000 V	230	L to N	180	Pass
–2000 V	230	L to N	180	Pass
+2000 V	230	L to N	270	Pass
–2000 V	230	L to N	270	Pass

Note: In all PASS results, power supply is still functional after the test.

Table 20 – Differential Mode Surge Test Results.

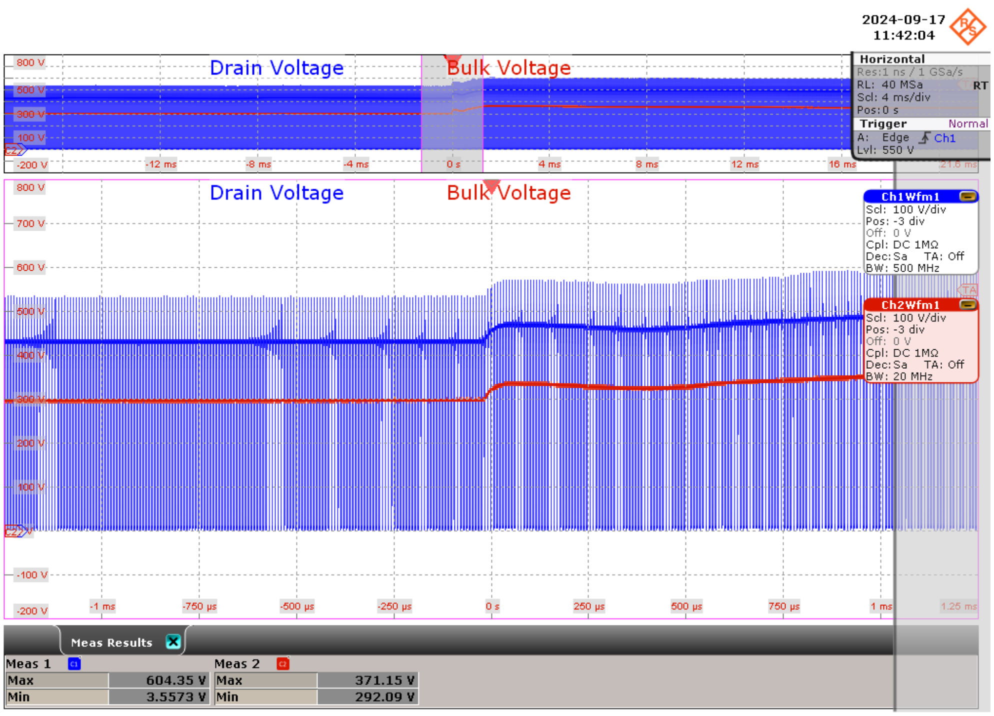


Figure 126 – Differential Mode Surge Input AC and V_{DS} Waveform.
Ch1: V_{DS} 100 V / div., 4 ms / div.
Ch2: Bulk Voltage 100 V / div., 4 ms /div.
Zoom: 250 μs / div.
$V_{DS(MAX)}$: 604 V.

16.2 Common Mode Ring Wave Surge

Surge Voltage	Phase Angle	IEC Coupling	Generator Impedance	Number Strikes	Result
+4000 V	0°	L, N → PE	12 Ω	10	Pass
–4000 V	0°	L, N → PE	12 Ω	10	Pass
+4000 V	90°	L, N → PE	12 Ω	10	Pass
–4000 V	90°	L, N → PE	12 Ω	10	Pass
+4000 V	270°	L, N → PE	12 Ω	10	Pass
–4000 V	270°	L, N → PE	12 Ω	10	Pass

Note: In all PASS results, power supply is still functional after the test.

Table 21 – Common Mode Ring Wave Surge Test Results.

17 Electrical Fast Transient (EFT)

Input voltage was set at 230 VAC / 60 Hz. Output was loaded at full load and operation was verified following each surge event.

Surge Voltage	Phase Angle	IEC Coupling	Frequency	Burst Time	Reception Time	Step Duration	Result
+4000 V	0°	L to N	5 kHz	15 ms	300 ms	120 s	Pass
–4000 V	0°	L to N	5 kHz	15 ms	300 ms	120 s	Pass
+4000 V	0°	L to N	100 kHz	750 µs	300 ms	120 s	Pass
–4000 V	0°	L to N	100 kHz	750 µs	300 ms	120 s	Pass
+4000 V	90°	L to N	5 kHz	15 ms	300 ms	120 s	Pass
–4000 V	90°	L to N	5 kHz	15 ms	300 ms	120 s	Pass
+4000 V	90°	L to N	100 kHz	750 µs	300 ms	120 s	Pass
–4000 V	90°	L to N	100 kHz	750 µs	300 ms	120 s	Pass
+4000 V	180°	L to N	5 kHz	15 ms	300 ms	120 s	Pass
–4000 V	180°	L to N	5 kHz	15 ms	300 ms	120 s	Pass
+4000 V	180°	L to N	100 kHz	750 µs	300 ms	120 s	Pass
–4000 V	180°	L to N	100 kHz	750 µs	300 ms	120 s	Pass
+4000 V	270°	L to N	5 kHz	15 ms	300 ms	120 s	Pass
–4000 V	270°	L to N	5 kHz	15 ms	300 ms	120 s	Pass
+4000 V	270°	L to N	100 kHz	750 µs	300 ms	120 s	Pass
–4000 V	270°	L to N	100 kHz	750 µs	300 ms	120 s	Pass

Note: In all PASS results, power supply is still functional after the test.

Table 22 – EFT Test Results.

18 Electrostatic Discharge (ESD)

All ESD strikes were applied at end of cable with 230 VAC input voltage and full load.

Passed ±8.8 kV contact discharge

Contact Discharge Voltage (kV)	Applied to	Number of Strikes	Test Result
+8.8	24 V	10	PASS
-8.8	24 V	10	PASS
+8.8	GND	10	PASS
-8.8	GND	10	PASS

Note: In all PASS results, power supply is still functional after the test.

Table 23 – ESD Contact Discharge Test Results.

Passed ±16.5 kV air discharge

Air Discharge Voltage (kV)	Applied to	Number of Strikes	Test Result
+16.5	24 V	10	PASS
-16.5	24 V	10	PASS
+16.5	GND	10	PASS
-16.5	GND	10	PASS

Note: In all PASS results, power supply is still functional after the test.

Table 24 – ESD Air Discharge Test Results.

19 Revision History

Date	Author	Revision	Description and Changes	Reviewed
11 Aug 2025	RMD/RPA/AJF/JPM/KP	A	Initial Release.	RPA

For the latest updates, visit our website: www.power.com

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