

Reference Design Report

Title	36 W Isolated Flyback Power Supply Using TinySwitch-5 (TNY5075K)
Specification	85–265 VAC Input; 12 V / 3 A Output
Application	Appliance
Author	Applications Engineering Department
Document Number	RDR-1040
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Revision	B

Summary and Features

- Up to 150 kHz switching frequency for small transformer.
- >87% full load efficiency at 115 VAC and >88% full load efficiency at 230 VAC
- >87.4% average efficiency at 115 VAC and 230 VAC
- >70% efficient at 230 VAC and 300 mW input power
- <60 mW no-load input power at 230 VAC
- Delivers 36 W output from 85 VAC to 265 VAC
- Extensive protection features including:
 - Line Undervoltage Protection
 - Line Overvoltage Protection
 - Over Temperature Protection (OTP)
 - Short Circuit Protection
 - Over Power Protection.
- Class B Conducted EMI with > 6 dB margin.

PATENT INFORMATION

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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 flyback converter that provides an isolated nominal output voltage of 12 V at 3 A from a wide input voltage range of 85 VAC to 265 VAC. This power supply utilizes the TNY5075K from the TinySwitch™-5 family of ICs.

This document contains the complete power supply specification, bill of materials, transformer construction, circuit schematic and printed circuit board layout, along with performance data and electrical waveforms.



Figure 1 – Photograph, Side View.



Figure 2 – Photograph, Top View.

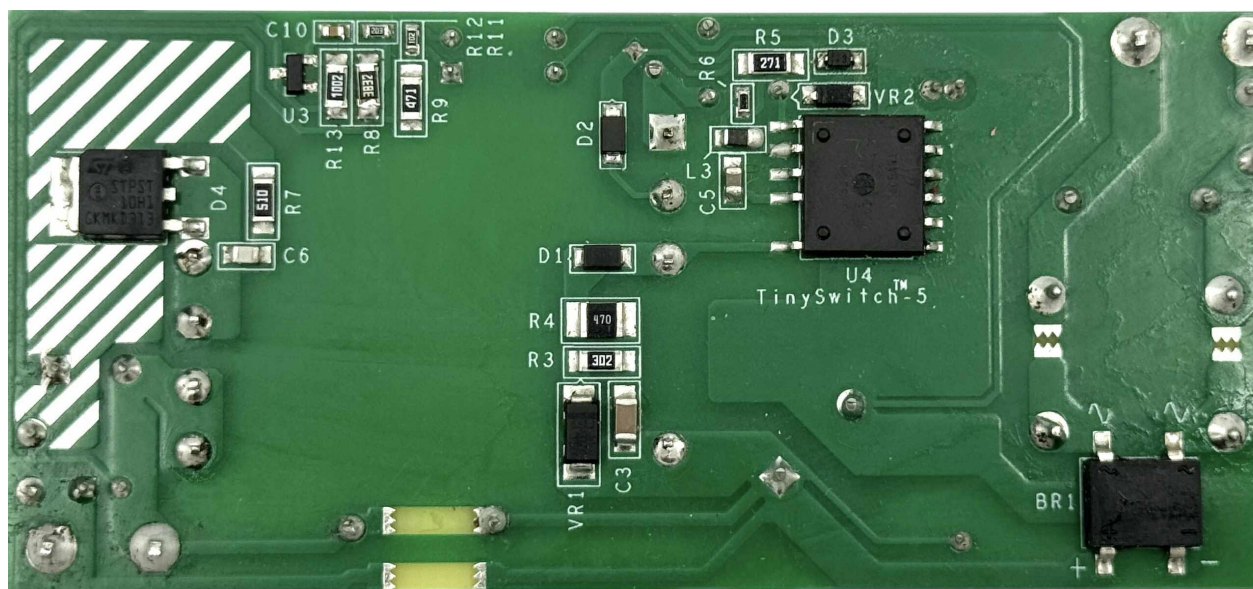


Figure 3 – Photograph, Bottom View.

2 Power Supply Specification

The table 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}	85	115/230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50 / 60	64	Hz	
No-load Input Power (230 VAC)				60	mW	
Output1						
Output Voltage	V_{OUT1}	11.4	12	12.6	V	± 5% 20 MHz Bandwidth.
Output Ripple Voltage	$V_{RIPPLE1}$			150	mV	
Output Current	I_{OUT1}	0		3	A	
Total Output Power						
Continuous Output Power	P_{OUT}		36		W	
Efficiency						
Full Load 115Vac	$\eta_{115\text{ VAC}}$	87			%	Measured at P_{OUT} 25 °C.
Full Load 230Vac	$\eta_{230\text{ VAC}}$	88			%	
Average efficiency at 25, 50, 75 and 100 % of P_{OUT}	η_{DOE}	87.4			%	Measured at Nominal Input 115 VAC and 230 VAC.
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Surge (Differential)				±1	kV	1.2/50 μ s 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.

4 Circuit Description

This power supply employs a TNY5075K off-line switcher, (U4), in a flyback configuration. IC U4 has an integrated 725 V power MOSFET. The TinySwitch-5 IC regulates the output by adjusting the MOSFET off time duration and ILIM, which are inversely proportional to the current fed into its CONTROL pin.

4.1 Input EMI Filtering and Rectification

Fuse F1 isolates the circuit and provides protection from component failure. X Capacitor C1 together with common mode choke L1 forms an EMI filter that attenuates both common mode and differential mode conducted EMI. BR1 converts the AC line voltage into the DC voltage seen across bulk capacitor C2.

4.2 TinySwitch-5 Primary

The TNY5075K device (U4) integrates an oscillator, a switch controller, start-up and protection circuitry, and a power MOSFET, all on one IC. One side of the power transformer (T1) primary winding is connected to the positive side of the bulk capacitor C2, and the other side is connected to the DRAIN pin of U4. When the MOSFET turns off, the leakage inductance of the transformer induces a voltage spike on the drain node. The spike amplitude is limited by an RCDZ clamp network that consists of D1, R3, R4, C3 and VR1. The RZCD arrangement prevents the voltage across the capacitor C3 discharging below a minimum value (defined by the voltage rating of VR1 and resistor R3) and therefore minimizes clamp dissipation under light and no-load conditions. Resistor R4 is used together with capacitor C3 to damp high frequency ringing and improve EMI. This arrangement was selected to reduce clamp losses under light and no-load conditions. Y capacitor CY1, connected between the primary and secondary side helps improve EMI.

The TNY5075K regulates the output by adjusting the power MOSFET off-time duration in proportion to the current into its CONTROL pin. The power supply output voltage is sensed on the secondary side by shunt regulator U3 and provides a feedback signal to the primary side through optocoupler U2.

The line undervoltage and overvoltage is determined by the current supplied from resistors R1 and R2 to the V pin. R5, D3, and VR2 are used for output overvoltage protection. An increase in output voltage causes an increase in the bias winding voltage, sensed by VR2. Once VR2 is activated, it will inject current to the BP pin causing the IC U4 to interrupt switch and enter auto-restart.

Bypass capacitor C5 should be placed as physically as close possible to U4. At start-up, this capacitor is charged through the DRAIN (D) pin. Once it is charged, U4 begins to switch. Capacitor C4 stores enough energy to ensure the TinySwitch-5 IC is powered until the output reaches regulation. After start-up, the bias winding delivers current via diode D2 and R6 to charge capacitor C4 which in turn powers the controller. Resistor R6 is used to

set the typical bias current of the IC U4. Ferrite bead L3 minimizes the noise coming to the BP Pin and should be placed close as possible to the IC.

4.3 Output Rectification

Schottky diode D4 rectifies the secondary winding output of T1. The output voltage is filtered by C7, C8, and L2. Resistor R7 and capacitor C6 snubs the voltage spike caused by the commutation of D4. Low ESR capacitor C7 and C8 help in minimizing output voltage ripple.

4.4 Output Feedback

The reference IC, U3 (TL431CDBZR), is used to set the output voltage and is programmed via the feedback resistor divider R8 and R13. The TL431CDBZR varies its cathode voltage to keep its input voltage constant (equal to 2.5 V, $\pm 2.2\%$). As the cathode voltage changes, the current through the optocoupler LED and transistor within U2 changes. R9, R12 and C10 ensure stable operation, while resistor R11 maintains minimum bias to U3.

5 PCB Layout

5.1 PCB Specification

- Layer: 1
- Board Thickness: 1.6 mm.
- Copper Thickness: 2 oz.
- Finishing: LF HASL
- Material: FR4
- Solder mask: Green
- Silkscreen: White

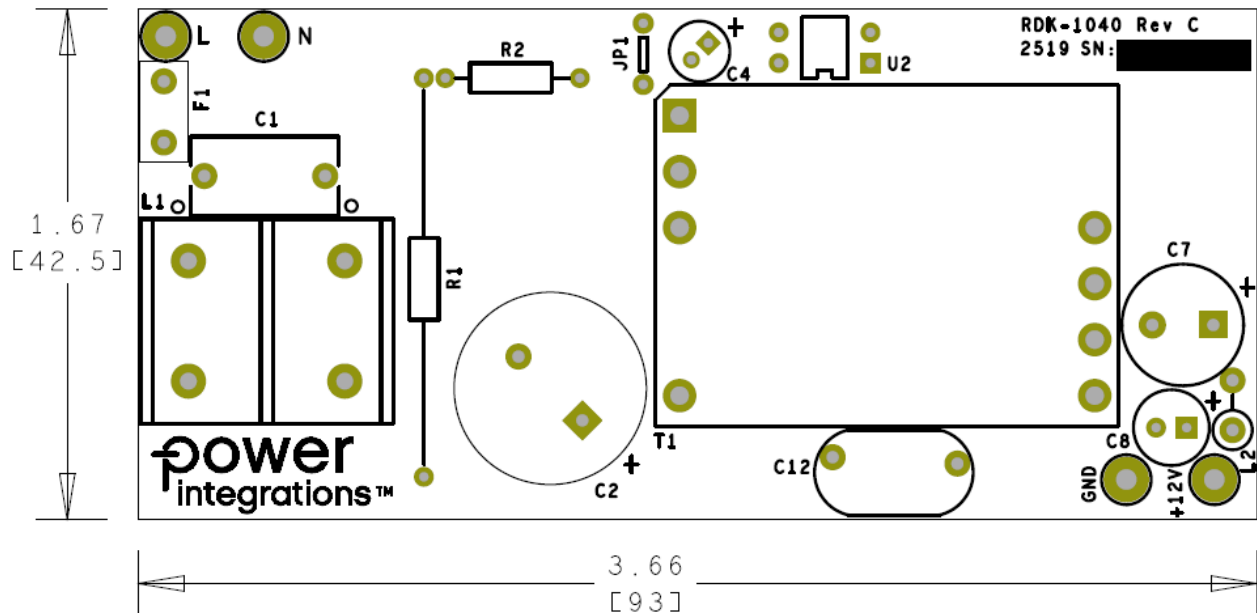
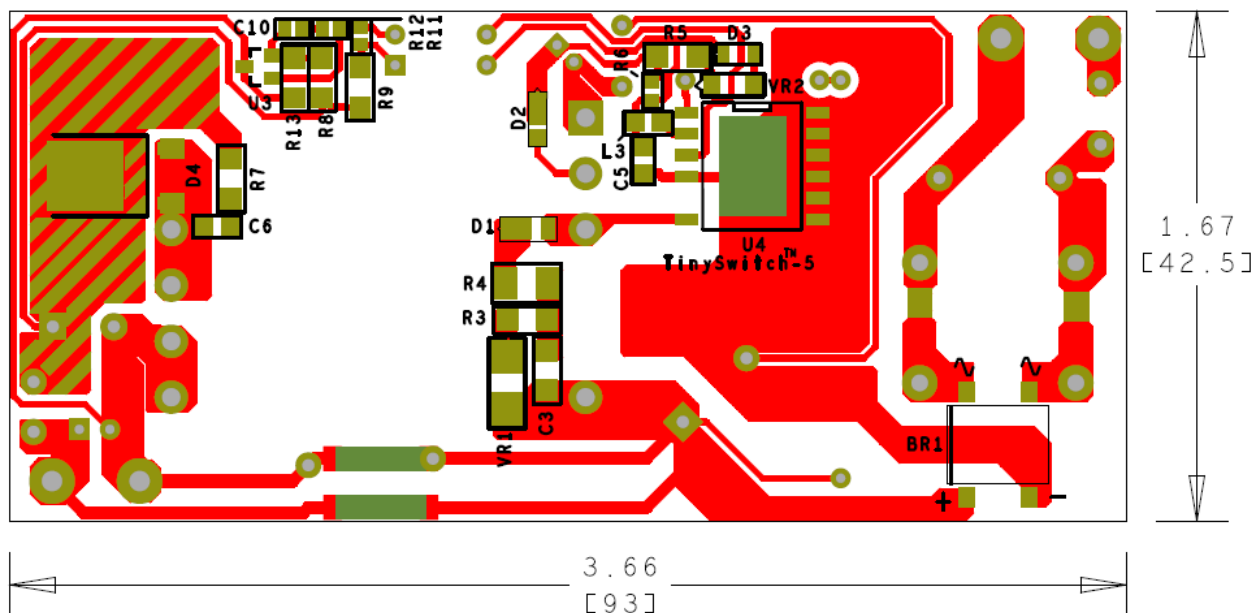


Figure 5 – Printed Circuit Board, Top View.

**Figure 6** – Printed Circuit Board, Bottom View.

6 Bill of Materials

6.1 Electrical BOM

Item	Ref Des	Qty.	Description	Mfr. Part Number	Manufacturer
1	BR1	1	Bridge Rectifier, Single Phase, Standard, 1 kV, Surface Mount DF-S), DF-S,4-SMD	DF1510S-T	Diodes Incorporated
2	C1	1	100 nF, 305 VAC, Film, X2	B32921C3104M	Epcos
3	C2	1	82 uF, 400 V, General Purpose,Electrolytic, (16 x 25)	400LXW82MEFR16 X25	Rubycon
4	C3	1	4700pF ±5% 500 V Ceramic Capacitor COG, NP0 1206 (3216 Metric)	C1206C472JCGAC AUTO	Kemet
5	C4	1	47 uF, 25 V, Electrolytic, Very Low ESR, 300 mOhm, (5 x 11)	EKZE250ELL470ME 11D	Nippon Chemi-Con
6	C5	1	0.47 µF, ±5%, 10 V, Ceramic Capacitor X7R, 0805 (2012 Metric)	VJ0805Y474JXQT W1BC	Vishay Vitramon
7	C6	1	220 pF, 100 V, Ceramic, X7R, 0805	08051C221KAT2A	AVX
8	C7	1	820 uF, 25 V, Electrolytic, Very Low ESR, 22 mOhm, (10 x 25)	EKZE250ELL821MJ 25S	Nippon Chemi-Con
9	C8	1	100 uF, 25 V, Electrolytic, Very Low ESR, 130 mOhm, (6.3 x 11)	EKZE250ELL101MF 11D	Nippon Chemi-Con
10	C10	1	0.022µF, ±10%, 50 V, Ceramic Capacitor, X7R, 0603 (1608 Metric)	06035C223KAT2A	AVX Corp
11	C12	1	2200 PF, ±20%, 500 VAC (Y1),760VAC (X1), Ceramic, Y5U (E), RADIAL	440LD22-R	Vishay
12	D1	1	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes Inc
13	D2	1	Diode, Schottky, 200 V, 1A, Surface Mount SOD-123HE	SS10200HE_R1_00 001	Panjit International Inc.
14	D3	1	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diode Inc.
15	D4	1	DIODE, SCHOTTKY, 10 A, 100 V, TO-252-3, DPak (2 Leads + Tab), SC-63	STPST10H100SB-TR	STMicroelectronics
16	F1	1	FUSE, 1.25 A 250 VAC, Slow, 8.35 mm x 4.0 mm x 7.7 mm	RST 1.25-BULK	Bel Fuse Inc
17	L1	1	14.6 mH, 1 A, Common Mode Choke	SS21V-R100146	KEMET
18	L2	1	3.5 mm x 7.6 mm, 75 Ohms at 25 MHz, 22 AWG hole, Ferrite Bead	2743004112	Fair-Rite
19	L3	1	FERRITE Bead, 80 Ohms @ 100 MHz, 1 Signal Line, Ferrite Bead 0805 (2012 Metric), 300 mA, 300 mOhm	EBMS201209K800	Max Echo
20	R1	1	RES, 3.3 M, 5%, 1/4 W, Carbon Film	CFR-25JB-3M3	Yageo
21	R2	1	RES, 4.7 M, 5%, 1/4 W, Carbon Film	CFR-25JB-4M7	Yageo
22	R3	1	RES, 3.0 k, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J302V	Panasonic

23	R4	1	RES, 47 Ohm, $\pm 5\%$, 0.75 W, 1210 (3225 Metric), Pulse Withstanding, Thick Film	CRCW121047R0JN EAHP	Vishay Dale
24	R5	1	RES, 270 R, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J271V	Panasonic
25	R6	1	RES, 8.87 k, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF8871V	Panasonic
26	R7	1	RES, 51 R, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J510V	Panasonic
27	R8	1	RES, 38.3 k, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF3832V	Panasonic
28	R9	1	RES, 470 R, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J471V	Panasonic
29	R11	1	RES, 1 k, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
30	R12	1	RES, 20 k, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ203V	Panasonic
31	R13	1	RES, 10.0 k, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1002V	Panasonic
32	T1	1	Bobbin, EF25, Horizontal, 12 pins	YC2504	Ying Chin
33	U2	1	Opto coupler, 35 V, CTR 300-600%, 4-DIP	LTV-817D	Liteon
34	U3	1	IC, Shunt Regulator Adj., 2.495 V, 2.2%, 100mA, 0 °C ~ 70 °C (TA), SOT23-3, TO-236-3, SC-59, SOT-23-3	TL431CDBZR	Texas Instruments
35	U4	1	TinySwitch-5, TNY5075K, eSOP-12P	TNY5075K	Power Integrations
36	VR1	1	Zener Diode, 150 V, 1.25 W, $\pm 6\%$, Surface Mount, DO-214AC (SMA)	BZG03C150-HM3-08	Vishay Semiconductors
37	VR2	1	Zener Diode, 11 V, $\pm 2\%$, 500 mW, Surface Mount, SOD-123	MMSZ5241C-E3-08	Vishay General Semiconductor - Diodes Division

6.2 Mechanical BOM

Item	Qty.	Ref Des	Description	Mfr. Part Number	Manufacturer
1	1	+12 V	Test Point, RED, THRU-HOLE MOUNT	5010	Keystone
2	2	GND L	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
3	1	JP1	Wire Jumper, Non insulated, 26 AWG, 0.2 in	299/1 SV001	Alpha Wire
4	1	N	Test Point, WHT, THRU-HOLE MOUNT	5012	Keystone



7 Transformer Specification

7.1 Electrical Diagram

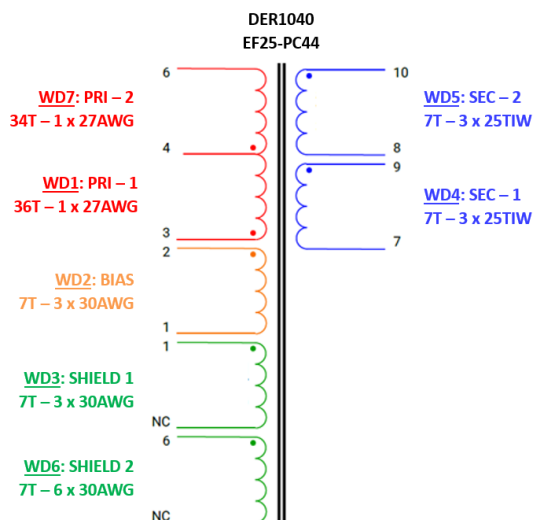


Figure 7 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V pk-pk and 100 kHz frequency, between pin 3 to pin 6, with all other Windings open.	970 μ H
Tolerance	Tolerance of Primary Inductance.	$\pm 5\%$
Leakage Inductance	Measured across primary winding with all other windings shorted.	< 9.70 μ H

7.3 Material List

Item	Description
[1]	Core: EF25 PC44
[2]	Bobbin: EF25, Vertical, 12 pins (Mfg PN:YC2504, Mfg: Ying Chin)
[3]	Polyester tape: 6 mm.
[4]	Varnish
[5]	Magnet Wire: #27 AWG.
[6]	Polyester Tape: 15.9 mm.
[7]	Magnet Wire: #30 AWG.
[8]	Triple Insulated Wire: #25 AWG.

7.4 Transformer Build Diagram

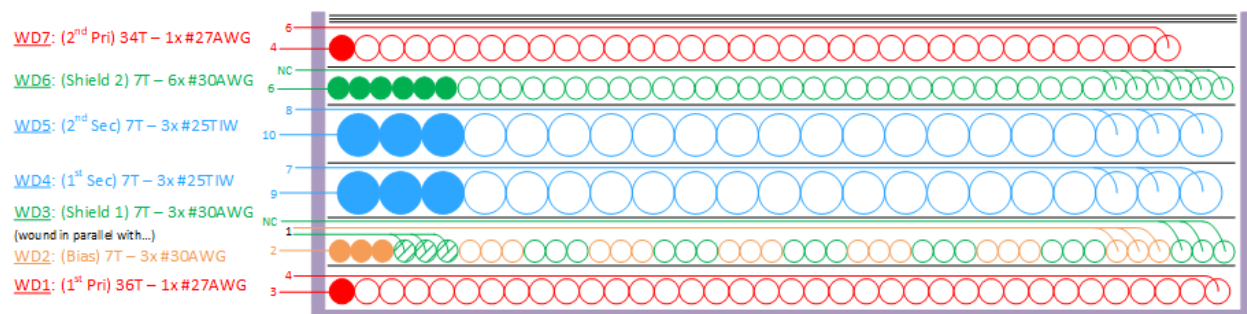


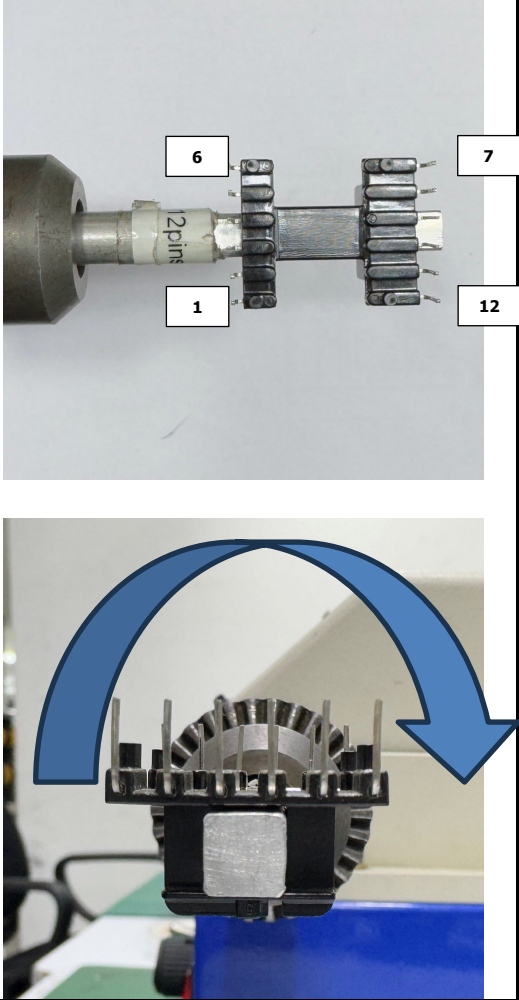
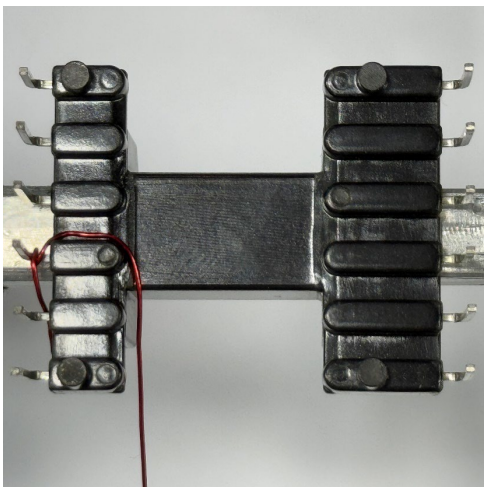
Figure 8 – Transformer Build Diagram.

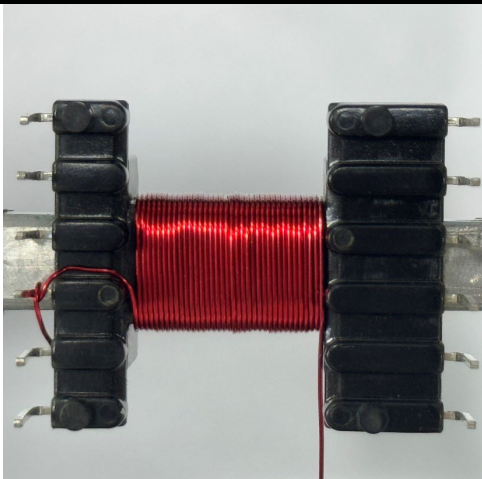
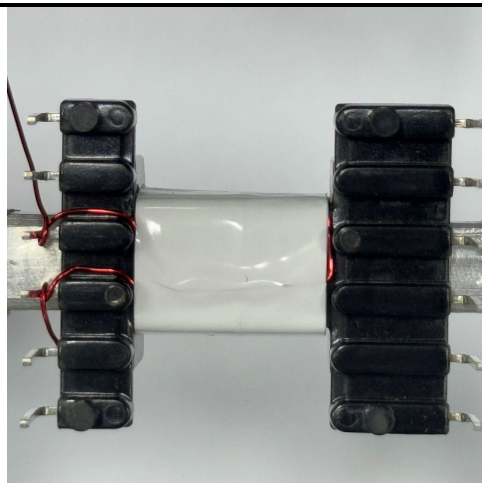
7.5 Transformer Instructions

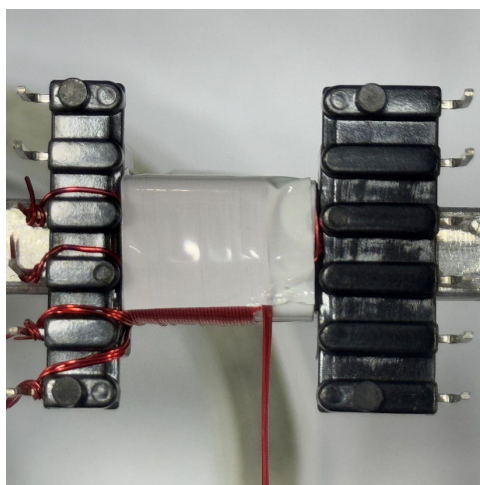
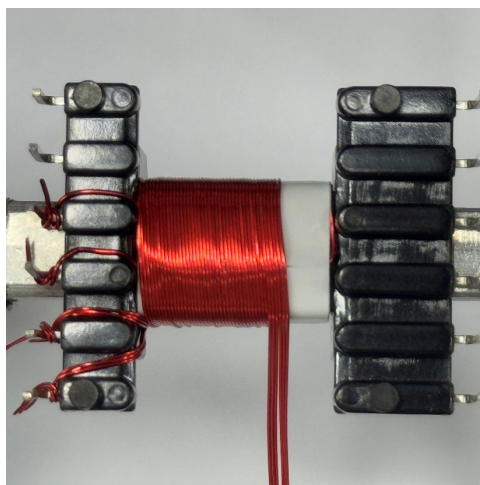
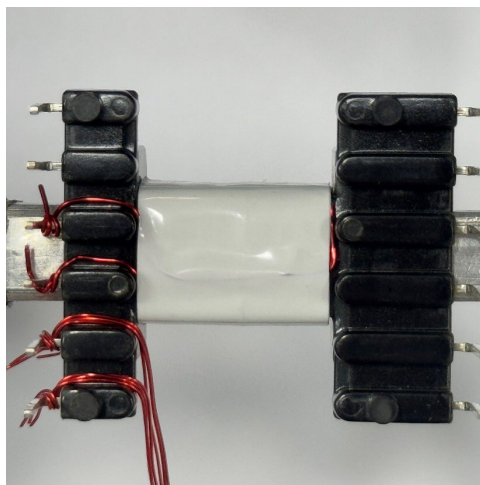
Preparation	Place the bobbin Item [2] such that pins 1-6 are on the left side while 7-12 are on right side. The shorter side signifies the side of Pin 1. Winding direction is clockwise as shown.
WD1 1st Primary	Prepare 1 strand of wire Item [5]. Start WD1 at pin 3. Wind 36 turns of wire Item [5] for the first layer from left to right. Apply tape Item [6] to hold the winding. Finish WD1 on pin 4.
Insulation	Finish wrapping the tape for insulation and to cover WD1.
WD2 and WD3 Bias and 1st Shield	Prepare 3 strands of wire Item [7] for WD2 and another 3 strands of wire Item [7] for WD3. Start WD2 at pin 2 and WD3 at pin 1, then wind them together for 7 turns from left to right. Cut the excess wire from WD3 and leave it not connected. Use tape Item [6] to hold the wires in place. Bend the end of WD2 by 90 degrees to finish it on pin 1.
Insulation	Finish wrapping the tape for insulation and to cover WD2 and WD3.
WD4 1st Secondary	Prepare 3 strands of wire Item [8] for WD4. Start WD4 at pin 9, and wind 7 turns from right to left. Apply 1 layer of tape Item [6] for insulation and to hold wires in place. Bend the end of WD4 90 degrees then finish WD2 on pin 7.
Insulation	Finish wrapping the tape to cover and insulate WD4.
WD5 2nd Secondary	Prepare 3 strands of wire Item [8] for WD5. Start at pin 10, and wind 7 turns from right to left. Apply 1 layer of tape Item [6] for insulation and to hold wires in place. Bend the end of WD5 90 degrees and finish WD5 on pin 8.
Insulation	Finish wrapping the tape to cover and insulate WD5.
WD6 2nd Shield	Prepare 6 strands of wire Item [7]. Start WD6 at pin 6. Wind 7 turns from left to right to finish WD6. Apply 1 layer of tape Item [6] for insulation and to hold wires in place, then cut the excess wires of WD6 and leave it not connected.
Insulation	Finish wrapping the tape to cover and insulate WD6.
WD7 2nd Primary	Prepare 1 strand of wire Item [7]. Start WD7 at pin 4 and wind 34 turns from left to right. Apply 1 layer of tape Item [6] for insulation and to hold wires in place. Bend the end of WD7 and finish WD7 on pin 6.
Insulation	Finishing wrapping the tape to cover WD7 and apply 2 additional layers of tape item [6].
Assembly	Cut the excess wires and solder them to the transformer pins. Remove pins 4, 5, 11, and 12. Grind the center leg of the upper half of Item [1] to get 970 μ H measured between Pin 3 and Pin 6 with all other pins open. Wrap the body of transformer with 2 layers of tape Item [3]. Measure Primary Inductance between Pin 3 and Pin 6 with all other pins open, then Leakage Inductance between Pin 3 and Pin 6 with all other pins shorted together.

Finish	Varnish using Item [4]. Check Primary Inductance and Leakage Inductance to confirm that the varnished transformer is within specification.
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7.6 Transformer Winding Illustrations

Preparation		Place the bobbin Item [2] such that pins 1-6 are on the left side while 7-12 are on right side. The shorter side signifies the side of Pin 1. Winding direction is clockwise as shown.
WD1 1st Primary		Prepare 1 strand of wire Item [5]. Start WD1 at pin 3.

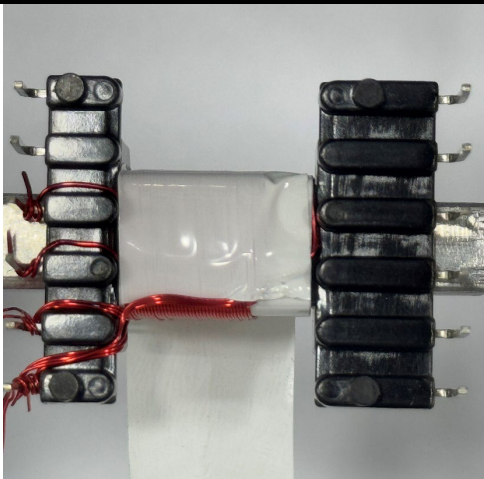
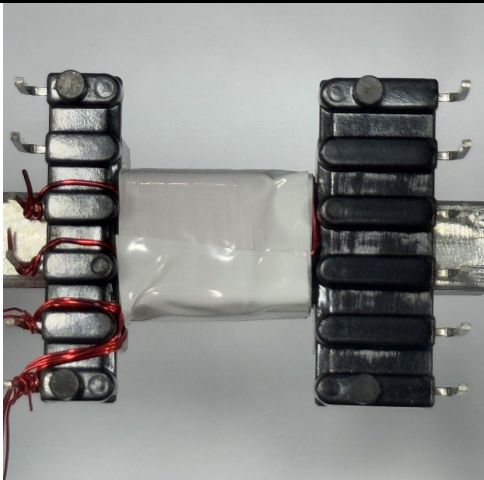
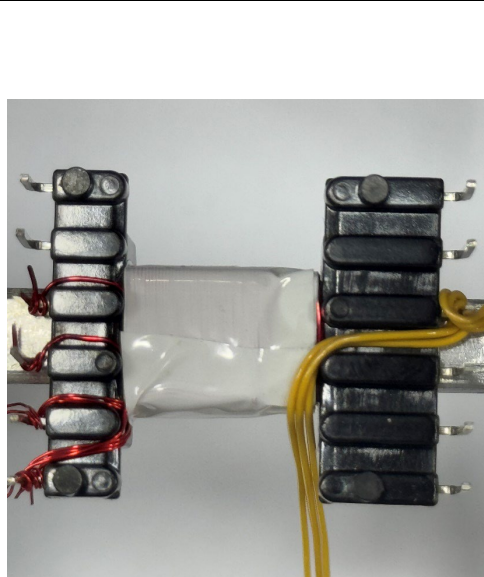
		Wind 36 turns of wire Item [5] for the first layer from left to right.
		Apply tape Item [6] to hold the winding. Finish WD1 on pin 4.
Insulation		Finish wrapping the tape for insulation and to cover WD1.

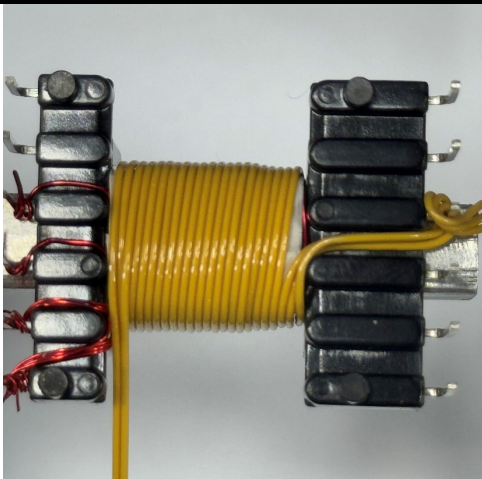
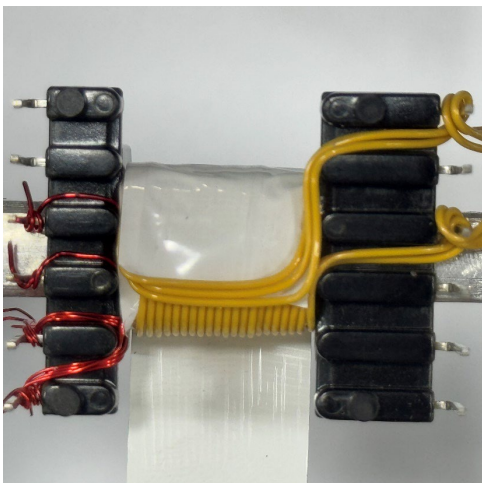
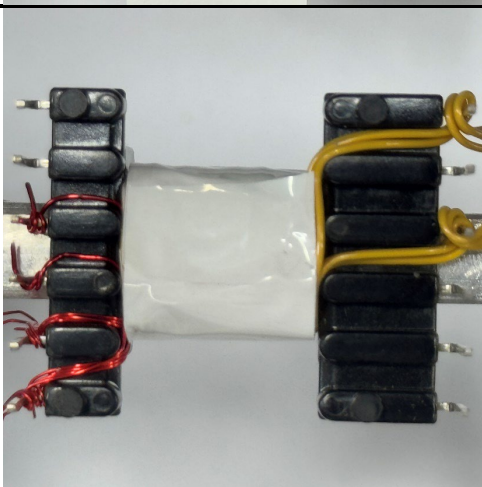
**WD2 and WD3
Bias and 1st Shield**

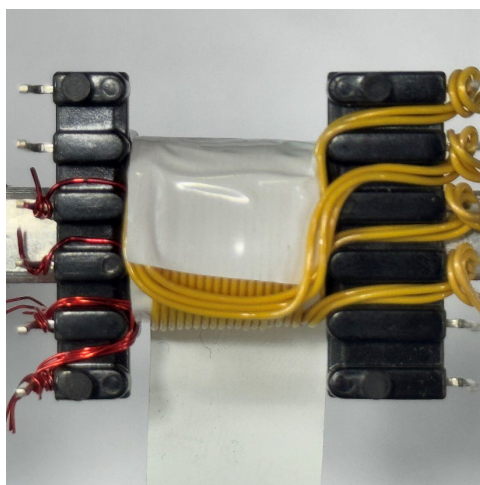
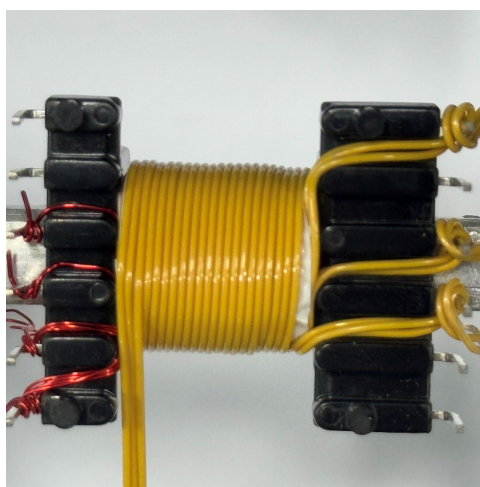
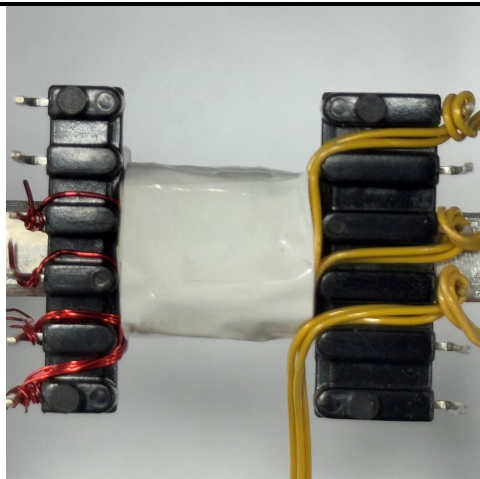
Prepare 3 strands of wire Item [7] for WD2 and another 3 strands of wire Item [7] for WD3.

Start WD2 at pin 2 and WD3 at pin 1, then wind them together for 7 turns from left to right.

Cut the excess wire from WD3 and leave it not connected. Use tape Item [6] to hold the wires in place.

		Bend the end of WD2 by 90 degrees to finish it on pin 1.
Insulation		Finish wrapping the tape for insulation and to cover WD2 and WD3.
WD4 1st Secondary		Prepare 3 strands of wire Item [8] for WD4.

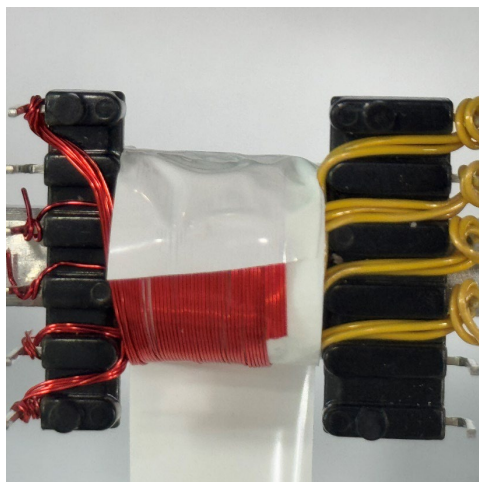
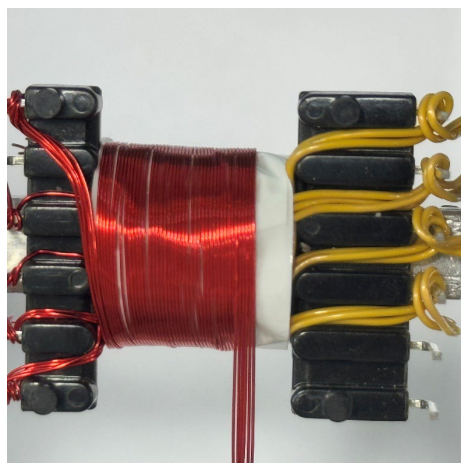
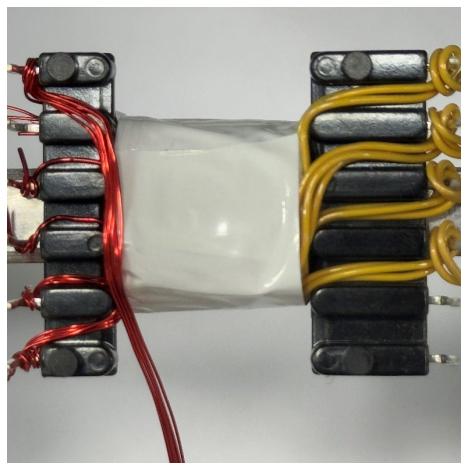
	 	Start WD4 at pin 9, and wind 7 turns from right to left. Apply 1 layer of tape Item [6] for insulation and to hold wires in place. Bend the end of WD4 90 degrees then finish WD2 on pin 7.
Insulation		Finish wrapping the tape to cover and insulate WD4.

WD5
2nd Secondary

Prepare 3 strands of wire Item [8] for WD5.

Start at pin 10, and wind 7 turns from right to left.

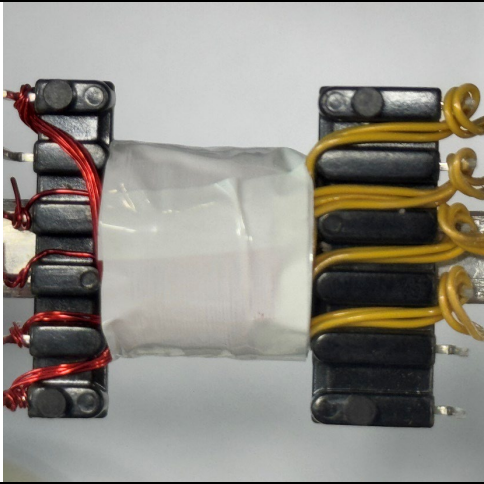
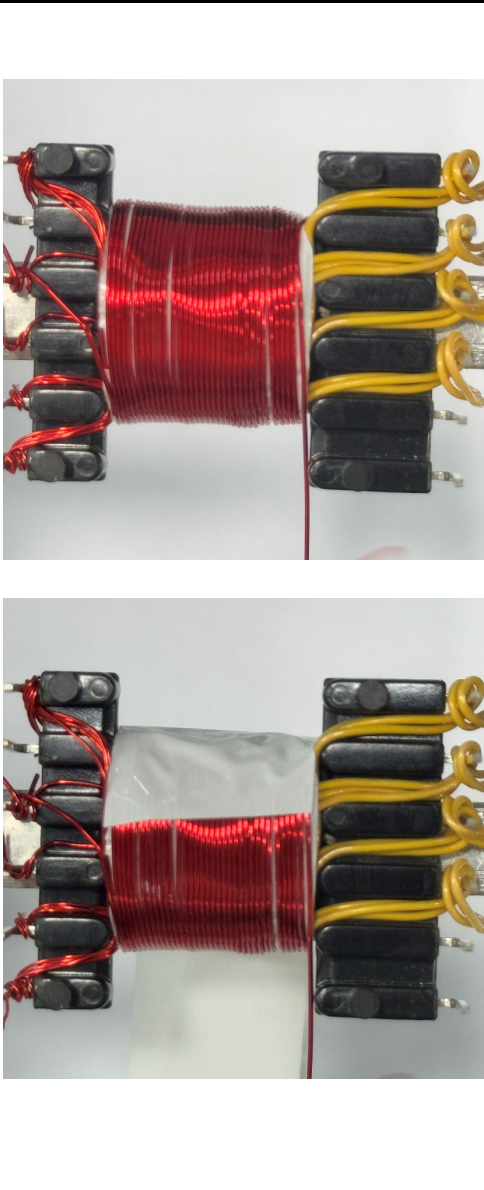
Apply 1 layer of tape Item [6] for insulation and to hold wires in place. Bend the end of WD5 90 degrees and finish WD5 on pin 8.

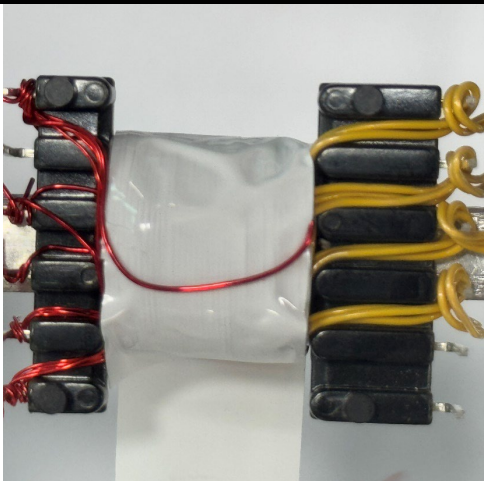
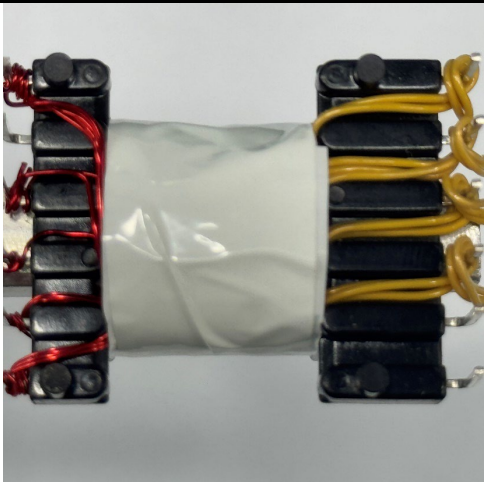
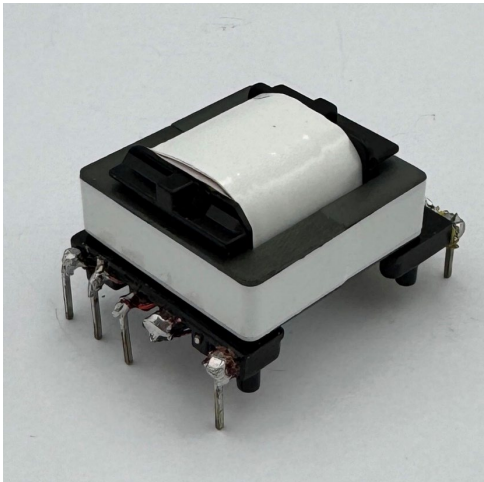
**WD6
2nd Shield**

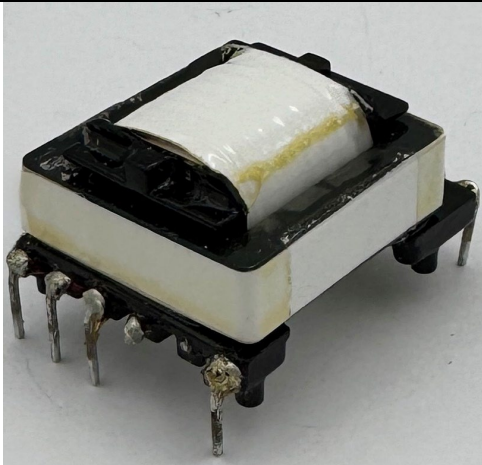
Prepare 6 strands of wire Item [7]. Start WD6 at pin 6.

Wind 7 turns from left to right to finish WD6.

Apply 1 layer of tape Item [6] for insulation and to hold wires in place, then cut the excess wires of WD6 and leave it not connected.

Insulation		Finish wrapping the tape to cover and insulate WD6.
WD7 2nd Primary		Prepare 1 strand of wire Item [7]. Start WD7 at pin 4 and wind 34 turns from left to right. Apply 1 layer of tape Item [6] for insulation and to hold wires in place.

		Bend the end of WD7 and finish WD7 on pin 6.
Insulation		Finishing wrapping the tape to cover WD7 and apply 2 additional layers of tape item [6].
Assembly		Cut the excess wires and solder them to the transformer pins. Remove pins 4, 5, 11, and 12. Grind the center leg of the upper half of Item [1] to get 970 μH measured between Pin 3 and Pin 6 with all other pins open. Wrap the body of transformer with 2 layers of tape Item [3]. Measure Primary Inductance between Pin 3 and Pin 6 with all other pins open, then Leakage Inductance between Pin 3 and Pin 6 with all other pins shorted together.

Finish		Varnish using Item [4]. Check Primary Inductance and Leakage Inductance to confirm that the varnished transformer is within specification.
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8 Design Spreadsheet

1	ACDC_TinySwitch5_Flyback_021825; Rev.0.2; Copyright Power Integrations 2025	INPUT	INFO	OUTPUT	UNITS	TinySwitch5 Single/Multi Output Flyback Design Spreadsheet
2	APPLICATION VARIABLES					Design Title
3	INPUT_TYPE	AC		AC		Input Type
4	VIN_MIN			85	V	Minimum AC input voltage
5	VIN_MAX			265	V	Maximum AC input voltage
6	VIN_RANGE			85-265	VAC	Range of AC input voltage
7	LINEFREQ			60	Hz	AC Input voltage frequency
8	CAP_INPUT	82.0		82.0	uF	Input capacitor
9	VOUT			12.00	V	Output voltage at the board
10	IOUT	3.000		3.000	A	Output current
11	POUT			36.00	W	Output power
12	EFFICIENCY	0.86		0.86		AC-DC efficiency estimate at full load given that the converter is switching at the valley of the rectified minimum input AC voltage
13	FACTOR_Z			0.50		Z-factor estimate
14	ENCLOSURE	OPEN FRAME		OPEN FRAME		Power supply enclosure
15						
16						
17						
18	PRIMARY CONTROLLER SELECTION					
19	DEVICE_SERIES	TNY5075		TNY5075		Generic device code
20	PACKAGE_DEVICE	eSOP		eSOP		Device Package
21	DEVICE_CODE			TNY5075K		Actual device code
22	POUT_MAX			45	W	Power capability of the device based on thermal performance
23	RDSON_100DEG			3.10	Ω	Primary switch on time drain resistance at 100 degC
24	ILIMIT_MIN			1.125	A	Minimum current limit of the primary switch
25	ILIMIT_TYP			1.210	A	Typical current limit of the primary switch
26	ILIMIT_MAX			1.295	A	Maximum current limit of the primary switch
27	VDRAIN_BREAKDOWN			725	V	Device breakdown voltage
28	VDRAIN_ON_PRSW			1.37	V	Primary switch on time drain voltage
29	VDRAIN_OFF_PRSW			573.4	V	Peak drain voltage on the primary switch during turn-off. A 30V leakage spike voltage is assumed
30						
31						
32						
33	WORST CASE ELECTRICAL PARAMETERS					
34	FSWITCHING_MAX	81050		81050	Hz	Maximum switching frequency at full load and valley of the rectified minimum AC input voltage.
35	VOR	125.0		125.0	V	Secondary voltage reflected to the primary when the primary switch turns off
36	VMIN			89.19	V	Valley of the minimum input AC voltage at full load



37	KP			0.62		Measure of continuous/discontinuous mode of operation
38	MODE_OPERATION			CCM		Mode of operation
39	DUTYCYCLE			0.587		Primary switch duty cycle
40	TIME_ON			13.50	us	Primary switch on-time
41	TIME_ON_AT_FSWITCHING_MAX			7.25	us	Primary switch on-time at FSWITCHING_MAX
42	TIME_OFF			5.09	us	Primary switch off-time at 85VAC, 36W, and 84700Hz.
43	LPRIMARY_MIN			921.1	uH	Minimum primary inductance
44	LPRIMARY_TYP			969.9	uH	Typical primary inductance
45	LPRIMARY_TOL	5.0		5.0	%	Primary inductance tolerance
46	LPRIMARY_MAX			1018.1	uH	Maximum primary inductance
47						
48	PRIMARY CURRENT					
49	IPEAK_PRIMARY			1.215	A	Primary switch peak current
50	IPEDESTAL_PRIMARY			0.419	A	Primary switch current pedestal
51	IAVG_PRIMARY			0.443	A	Primary switch average current
52	IRIPPLE_PRIMARY			0.921	A	Primary switch ripple current
53	IRMS_PRIMARY			0.613	A	Primary switch RMS current
54						
55	SECONDARY CURRENT					
56	IPEAK_SECONDARY			12.155	A	Secondary winding peak current
57	IPEDESTAL_SECONDARY			4.192	A	Secondary winding current pedestal
58	IRMS_SECONDARY			5.141	A	Secondary winding RMS current
59						
60						
61						
62	TRANSFORMER CONSTRUCTION PARAMETERS					
63	CORE SELECTION					
64	CORE	Custom		Custom		Core selection. Refer to the 'Transformer Construction' tab to see the detailed report
65	CORE CODE	PC44EF25-Z		PC44EF25-Z		Core code
66	AE	51.80		51.80	mm^2	Core cross sectional area
67	LE	57.80		57.80	mm	Core magnetic path length
68	AL	2000		2000	nH/turns^2	Ungapped core effective inductance
69	VE	290.0		290.0	mm^3	Core volume
70	BOBBIN	EF25 Vertical		EF25 Vertical		Bobbin
71	AW	61.00		61.00	mm^2	Window area of the bobbin
72	BW	15.90		15.90	mm	Bobbin width
73	MARGIN			0.0	mm	Safety margin width (Half the primary to secondary creepage distance)
74						
75	PRIMARY WINDING					
76	NPRIMARY			70		Primary turns
77	BPEAK			3753	Gauss	Peak flux density
78	BMAX			3372	Gauss	Maximum flux density



79	BAC			1253	Gauss	AC flux density (0.5 x Peak to Peak)
80	ALG			198	nH/turns^2	Typical gapped core effective inductance
81	LG			0.296	mm	Core gap length
82						
83	PRIMARY BIAS WINDING					
84	NBIAS_PRIMARY			7	turns	Primary bias winding number of turns
85						
86	SECONDARY WINDING					
87	NSECONDARY	7		7	turns	Secondary winding number of turns
88						
89	SECONDARY BIAS WINDING					
90	NBIAS_SECONDARY			NA	turns	Secondary bias winding number of turns
91						
92						
93						
94	PRIMARY COMPONENTS SELECTION					
95	LINE UNDERVOLTAGE					
96	BROWN-IN REQUIRED			76.08	V	Required AC RMS/DC line voltage brown-in threshold
97	RLS			8.04	MΩ	Connect two 4.02 MOhm resistors to the V-pin for the required UV/OV threshold
98	BROWN-IN ACTUAL			63.5 - 78.6	V	Actual AC RMS/DC brown-in range
99	BROWN-OUT ACTUAL			55 - 67.9	V	Actual AC RMS/DC brown-out range
100						
101	LINE OVERVOLTAGE					
102	OVERVOLTAGE_LINE			285.4 - 355.2	V	Actual AC RMS/DC line over-voltage range
103						
104	PRIMARY BIAS DIODE					
105	VBIAS_PRIMARY	11.0		11.0	V	Rectified primary bias voltage
106	VF_BIAS_PRIMARY			0.70	V	Bias winding diode forward drop
107	VREVERSE_BIASDIODE_PRIMARY			49.34	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
108	CBIAS_PRIMARY			47	uF	Bias winding rectification capacitor
109	CBP			0.47	uF	BP pin capacitor
110						
111						
112						
113	SECONDARY COMPONENTS					
114	VREF_REG	2.50		2.50	V	Reference voltage of the feedback
115	RFB_UPPER			38.30	kΩ	Upper feedback resistor (connected to the first output voltage)
116	RFB_LOWER			10.00	kΩ	Lower feedback resistor
117						
118	SECONDARY BIAS DIODE					
119	USE_SECONDARY_BIAS	AUTO		NO		Use secondary bias winding for the design
120	VBIAS_SECONDARY			NA	V	Rectified secondary bias voltage
121	VF_BIAS_SECONDARY			NA	V	Bias winding diode forward drop

122	VREVERSE_BIASDIODE_SECONDARY			NA	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
123	CBIAS_SECONDARY			NA	uF	Bias winding rectification capacitor
124						
125						
126	MULTIPLE OUTPUT PARAMETERS					
127	OUTPUT 1					
128	VOUT1			12.00	V	Output 1 voltage
129	IOUT1			3.00	A	Output 1 current
130	POUT1			36.00	W	Output 1 power
131	VD1	0.55		0.55	V	Forward voltage drop of diode for output 1
132	NS1			7.00	turns	Number of turns for output 1
133	ISP1			12.15	A	Instantaneous peak value of the secondary current for output 1
134	IS1			5.141	A	Root-mean-squared value of the secondary current for output 1
135	IS1RIPPLE			4.174	A	Current ripple on the secondary waveform for output 1
136	PIV1_CALCULATED			59.04	V	Computed peak inverse voltage stress on the diode for output 1
137	OUTPUT_RECTIFIER1	AUTO		MBR1060		Recommended diode for output 1.
138	PIV1_RATING			60.00	V	Peak inverse voltage rating on the diode for output 1
139	TRR1			0.00	ns	Reverse recovery time of the diode for output 1
140	IFM1			10.00	A	Maximum forward continuous current of the diode for output 1
141	PLOSS_DIODE1			1.81	W	Maximum diode power loss for output 1

9 Performance Data

9.1 Full Load Efficiency vs. Line

Test Condition: Soak for 15 minutes for each line.

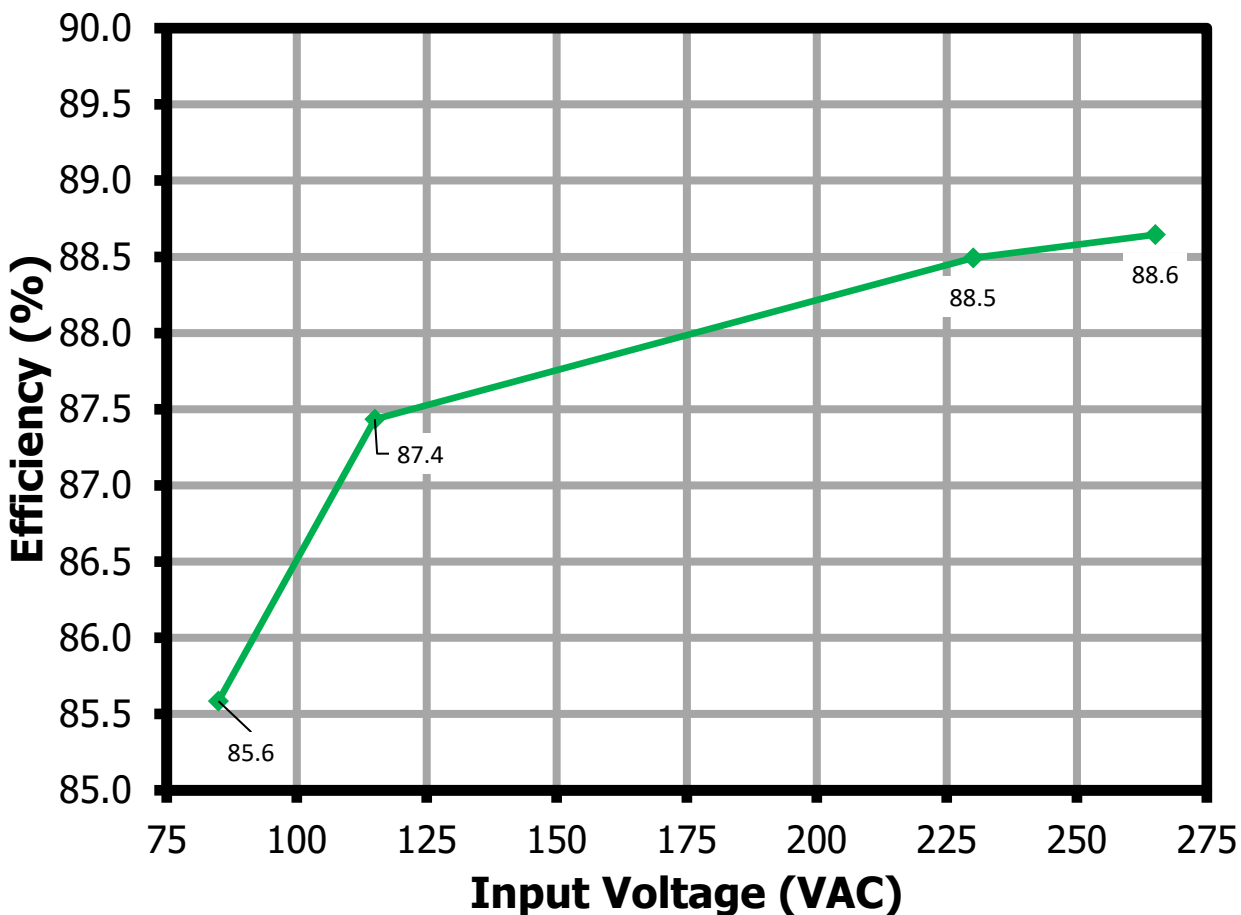


Figure 9 – Efficiency vs. Input Voltage.

VAC	Freq	V _{IN}	I _{IN}	P _{IN}	V _{OUT}	I _{OUT}	P _{OUT}	V _{REG}	Efficiency
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(mA)	(W)	(%)	(%)
85	60	84.9	863	42.2	12.0	3007	36.1	0.15	85.6
115	60	115	699	41.3	12.0	3007	36.1	0.16	87.4
230	50	230	458	40.8	12.0	3007	36.1	0.12	88.5
265	50	265	423	40.8	12.0	3007	36.1	0.12	88.6

9.2 Efficiency vs. Load

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

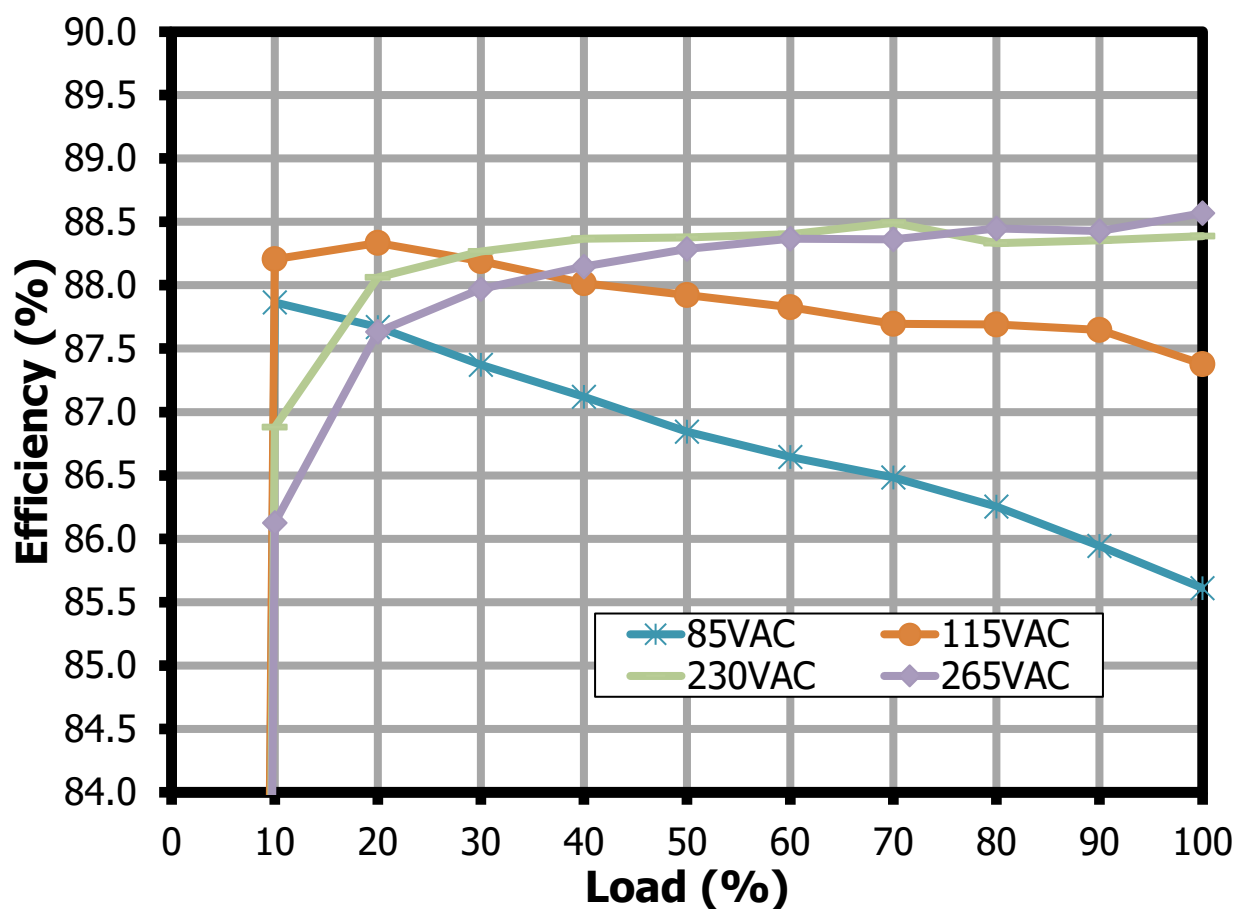


Figure 10 – Efficiency vs. Percentage Load.

VAC	Freq	V _{IN}	I _{IN}	P _{IN}	V _{OUT}	I _{OUT}	P _{OUT}	V _{REG}	Efficiency
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(mA)	(W)	(%)	(%)
85	60	84.9	863	42.2	12.0	3007	36.1	0.16	85.6
85	60	84.9	786	37.9	12.0	2706	32.5	0.18	85.9
85	60	85.0	711	33.5	12.0	2405	28.9	0.22	86.3
85	60	85.0	635	29.3	12.0	2104	25.3	0.23	86.5
85	60	85.0	560	25.0	12.0	1804	21.7	0.24	86.7
85	60	85.0	483	20.8	12.0	1503	18.1	0.26	86.8
85	60	85.0	403	16.6	12.0	1202	14.5	0.27	87.1
85	60	85.0	321	12.4	12.0	901	10.8	0.28	87.4
85	60	85.0	233	8.24	12.0	600	7.22	0.29	87.7
85	60	85.0	130	4.11	12.0	300	3.61	0.30	87.9
85	60	85.0	17.5	0.04	12.0		0.00	0.32	

VAC	Freq	V _{IN}	I _{IN}	P _{IN}	V _{OUT}	I _{OUT}	P _{OUT}	V _{REG}	Efficiency
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(mA)	(W)	(%)	(%)
115	60	115	699	41.4	12.0	3007	36.1	0.17	87.4
115	60	115	641	37.1	12.0	2706	32.5	0.20	87.7
115	60	115	584	33.0	12.0	2405	28.9	0.22	87.7
115	60	115	526	28.9	12.0	2104	25.3	0.22	87.7
115	60	115	466	24.7	12.0	1804	21.7	0.23	87.8
115	60	115	404	20.6	12.0	1503	18.1	0.24	87.9
115	60	115	339	16.4	12.0	1202	14.5	0.26	88.0
115	60	115	269	12.3	12.0	901	10.8	0.28	88.2
115	60	115	190	8.18	12.0	600	7.22	0.28	88.3
115	60	115	101	4.09	12.0	300	3.61	0.29	88.2
115	60	115	17.7	0.04	12.0		0.00	0.32	

VAC	Freq	V _{IN}	I _{IN}	P _{IN}	V _{OUT}	I _{OUT}	P _{OUT}	V _{REG}	Efficiency
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(mA)	(W)	(%)	(%)
230	50	230	458	40.9	12.0	3007	36.1	0.12	88.4
230	50	230	422	36.8	12.0	2706	32.5	0.13	88.4
230	50	230	385	32.7	12.0	2405	28.9	0.16	88.3
230	50	230	344	28.6	12.0	2104	25.3	0.18	88.5
230	50	230	302	24.5	12.0	1804	21.7	0.19	88.4
230	50	230	259	20.5	12.0	1503	18.1	0.22	88.4
230	50	230	213	16.4	12.0	1202	14.5	0.23	88.4
230	50	230	166	12.3	12.0	901	10.8	0.25	88.3
230	50	230	116	8.20	12.0	600	7.22	0.27	88.1
230	50	230	63.4	4.15	12.0	300	3.61	0.28	86.9
230	50	230	16.9	0.07	12.0		0.00	0.32	

VAC	Freq	V _{IN}	I _{IN}	P _{IN}	V _{OUT}	I _{OUT}	P _{OUT}	V _{REG}	Efficiency
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(mA)	(W)	(%)	(%)
265	50	265	422	40.8	12.0	3007	36.1	0.13	88.6
265	50	265	387	36.8	12.0	2706	32.5	0.14	88.4
265	50	265	350	32.7	12.0	2405	28.9	0.16	88.5
265	50	265	312	28.6	12.0	2105	25.3	0.18	88.4
265	50	265	273	24.5	12.0	1804	21.7	0.19	88.4
265	50	265	233	20.5	12.0	1503	18.1	0.21	88.3
265	50	265	192	16.4	12.0	1202	14.5	0.22	88.2
265	50	265	149	12.3	12.0	901	10.8	0.25	88.0
265	50	265	105	8.24	12.0	600	7.22	0.27	87.6
265	50	265	57.9	4.19	12.0	300	3.61	0.28	86.1
265	50	265	17.2	0.09	12.0		0.00	0.32	

9.3 Average and 10% Efficiency

9.3.1 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)	(V _{DC})	(mA _{DC})	(W)	(%)	(%)	(%)
100%	41.5	12.0	3000	36.1	87.2	87.6	87.4
75%	31.0	12.0	2250	27.1	87.5		
50%	20.6	12.0	1500	18.1	87.8		
25%	10.3	12.0	750	9.03	88.0		
10%	4.11	12.0	300	3.61	87.9	---	---

9.3.2 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)	(V _{DC})	(mA _{DC})	(W)	(%)	(%)	(%)
100%	40.9	12.0	3000	36.1	88.3	88.3	87.4
75%	30.7	12.0	2250	27.1	88.5		
50%	20.5	12.0	1500	18.1	88.3		
25%	10.3	12.0	750	9.03	88.0		
10%	4.17	12.0	300	3.61	86.6	---	---

9.4 No-Load Input Power

Test Condition: Soak for 15 minutes each line and 1 minute integration time.

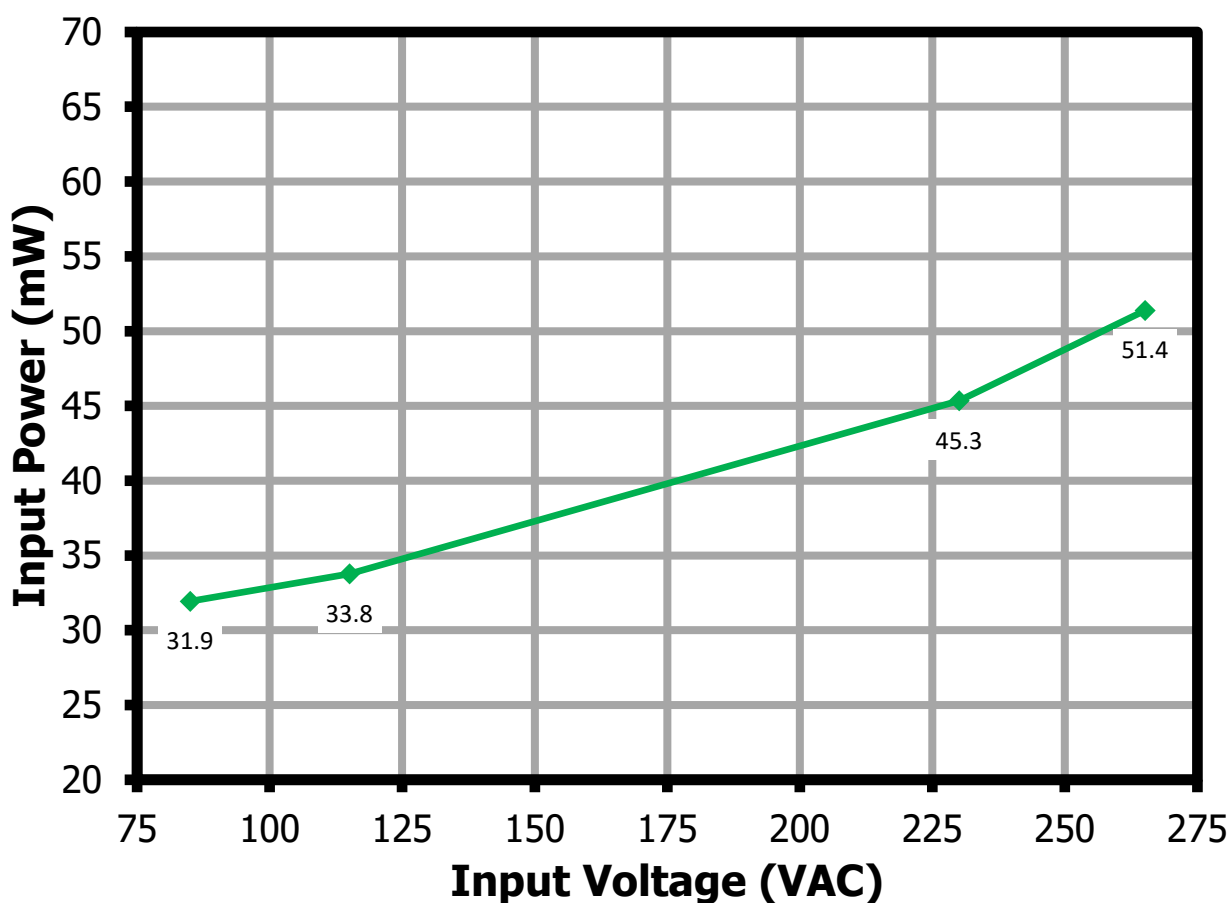


Figure 11 – No-Load Input Power vs. Line at Room Temperature.

VAC	No Load P _{IN}
(RMS)	(mW)
85	31.9
115	33.8
230	45.3
265	51.4

9.5 Line Regulation

Test Condition: Soak for 15 minutes for each line.

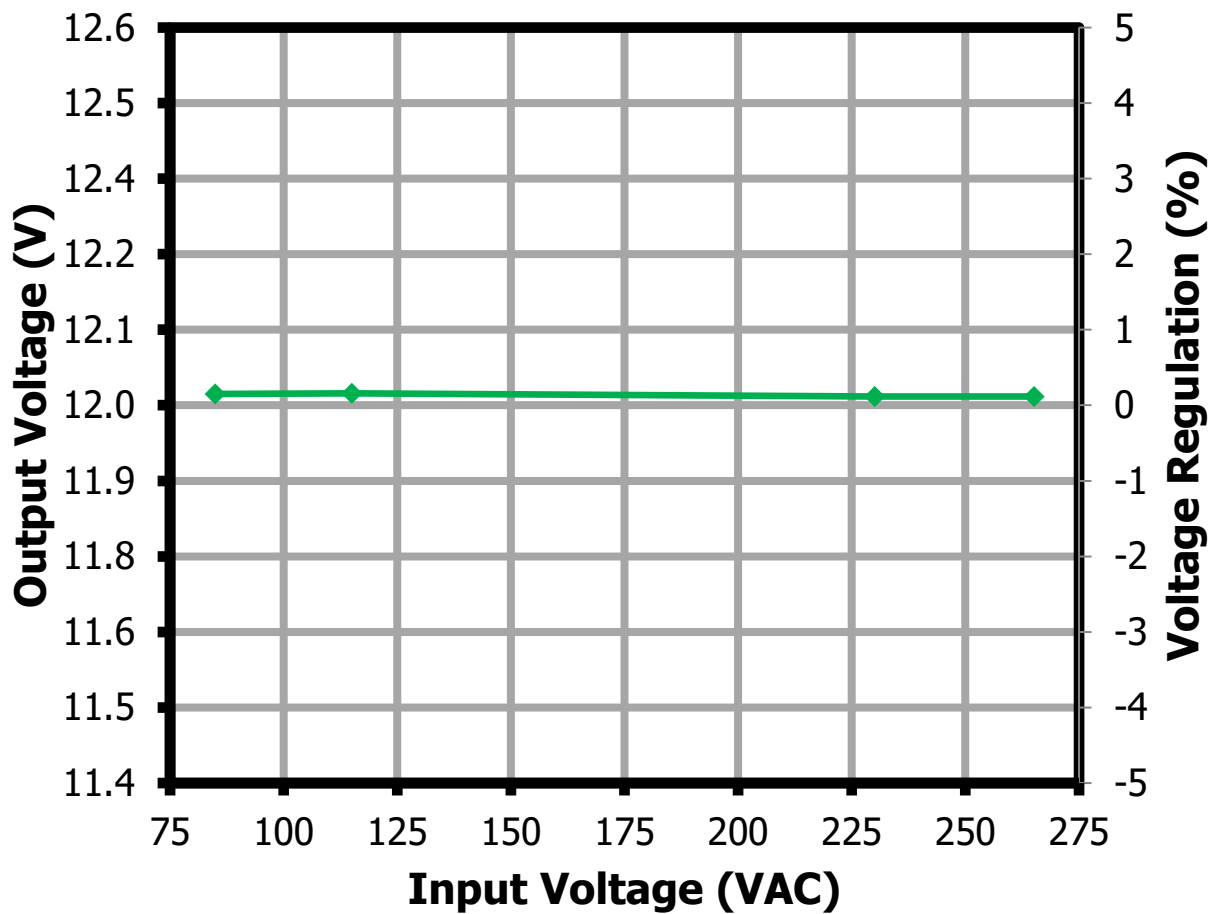


Figure 12 – Output Voltage vs. Line Voltage.

9.6 Load Regulation

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

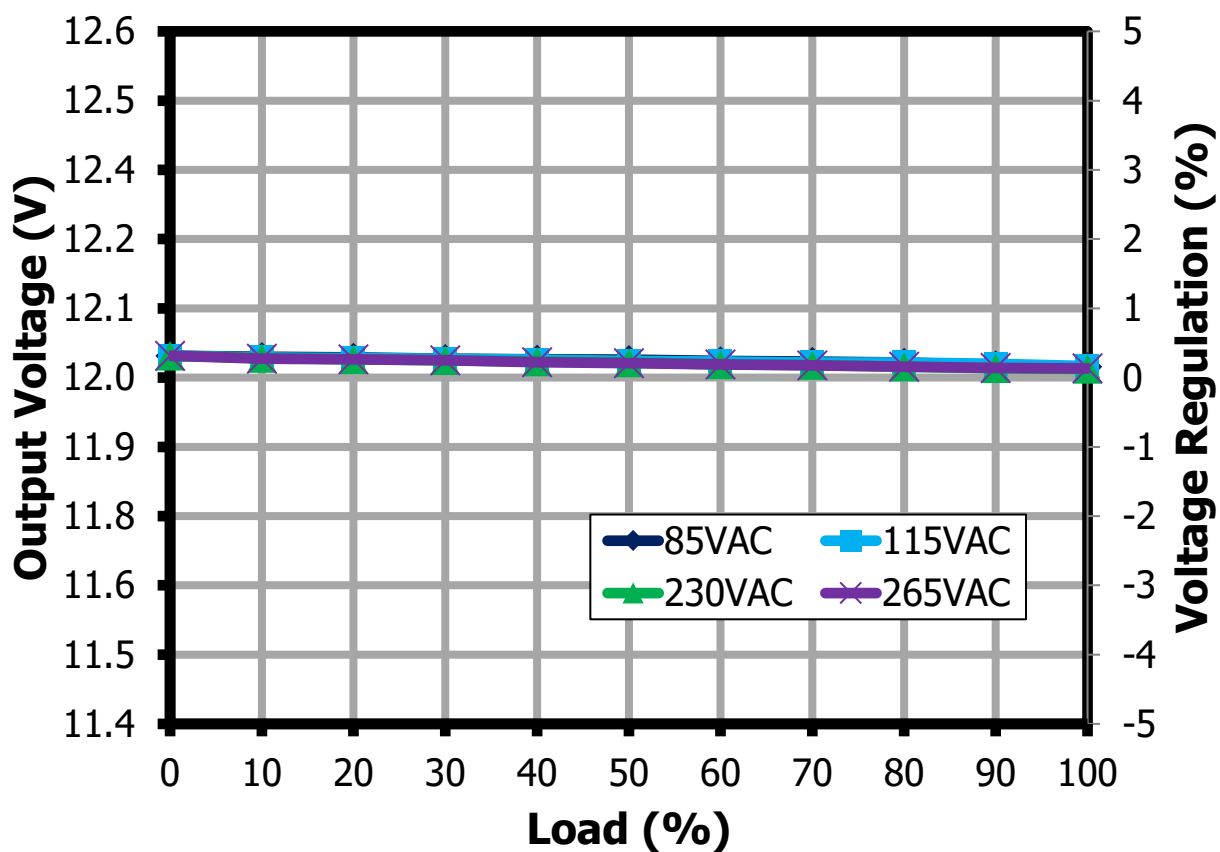


Figure 13 – Output Voltage vs. Percent Load.

9.7 Standby Efficiency

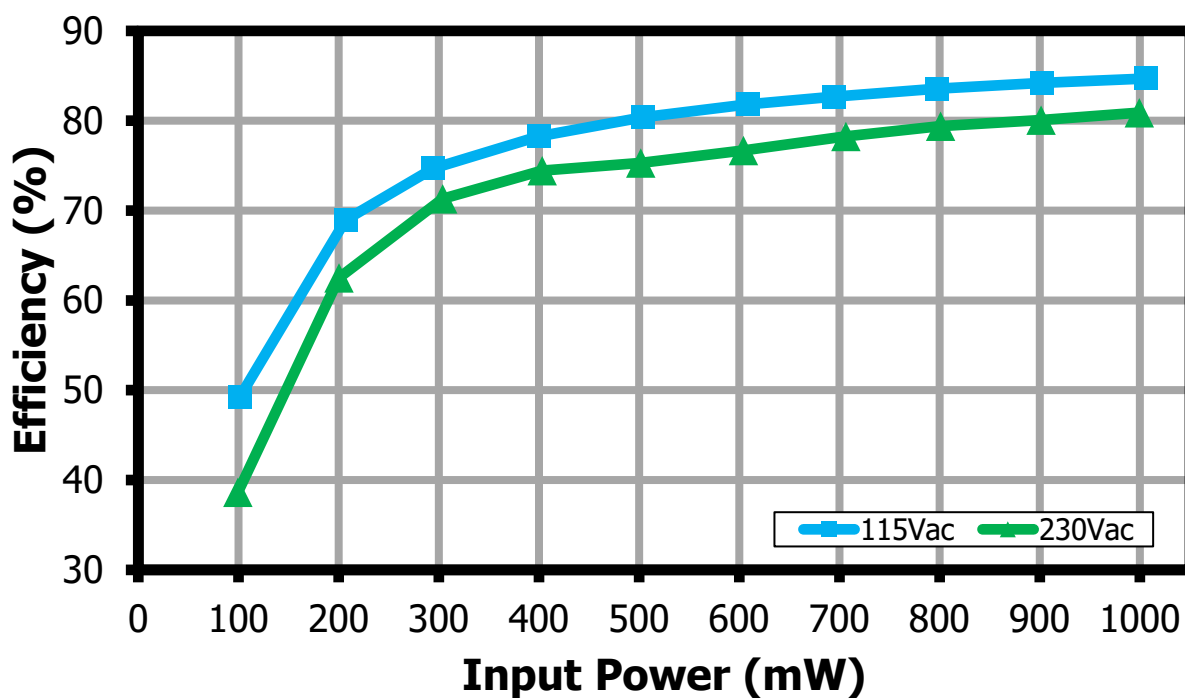


Figure 14 – Efficiency vs Input Power

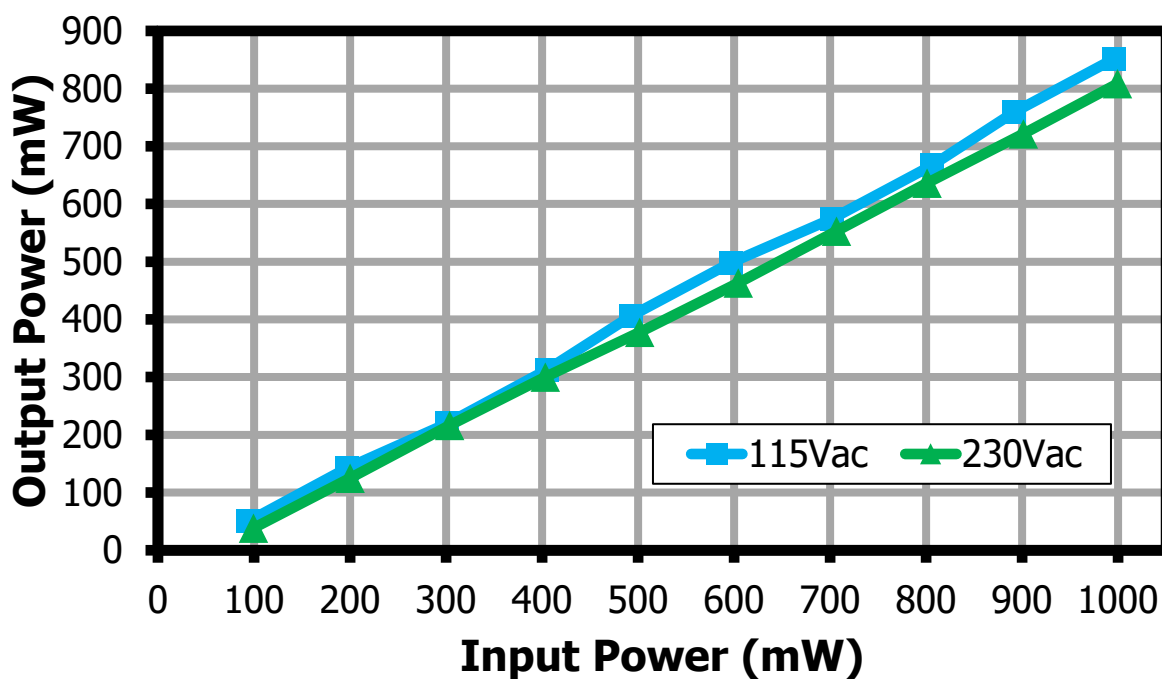


Figure 15 – Output Power vs Input Power.

10 Waveforms

10.1 Load Transient Response

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

10.1.1 Transient 0% - 100% Load Change



Figure 16 – 85 VAC 60 Hz.

CH1: V_{OUT} , 500 mV / div., 100 ms / div.

CH2: I_{OUT} , 1 A / div., 100 ms / div.

V_{OUT} : V_{MAX} : 12.1 V

V_{MIN} : 11.7 V

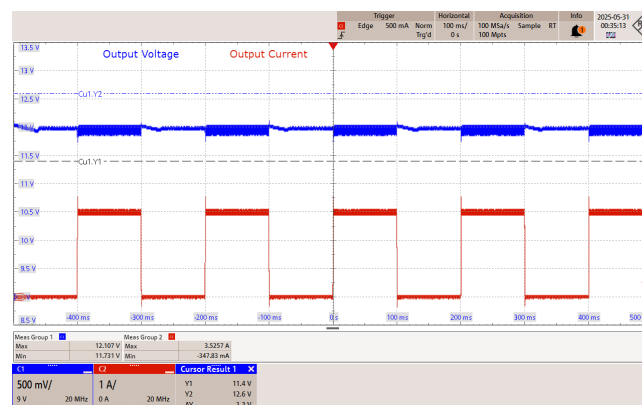


Figure 17 – 115 VAC 60 Hz.

CH1: V_{OUT} , 500 mV / div., 100 ms / div.

CH2: I_{OUT} , 1 A / div., 100 ms / div.

V_{OUT} : V_{MAX} : 12.1 V

V_{MIN} : 11.7 V



Figure 18 – 230 VAC 50 Hz.

CH1: V_{OUT} , 500 mV / div., 100 ms / div.

CH2: I_{OUT} , 1 A / div., 100 ms / div.

V_{OUT} : V_{MAX} : 12.1 V

V_{MIN} : 11.7 V

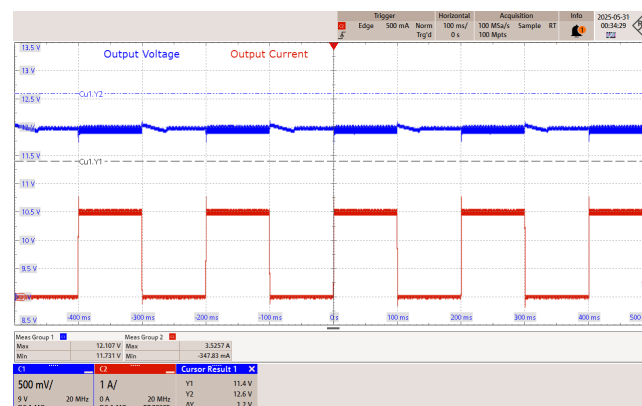


Figure 19 – 265 VAC 50 Hz.

CH1: V_{OUT} , 500 mV / div., 100 ms / div.

CH2: I_{OUT} , 1 A / div., 100 ms / div.

V_{OUT} : V_{MAX} : 12.1 V

V_{MIN} : 11.7 V

10.2 Output Start-up

10.2.1 Full Load CC Mode

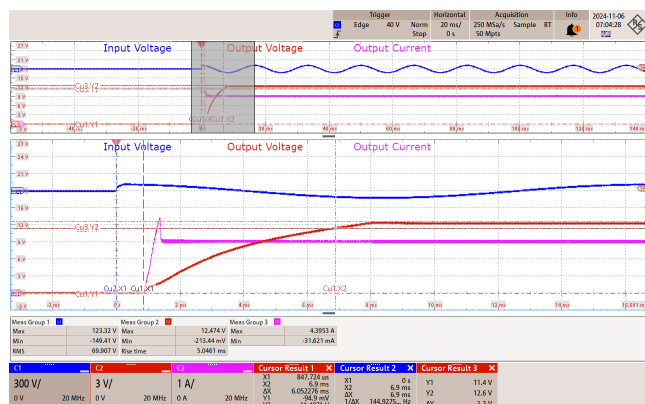


Figure 20 – 85 VAC 60 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 6.05 ms
 Startup Time = 6.9 ms
 V_{MAX} = 12.5 V

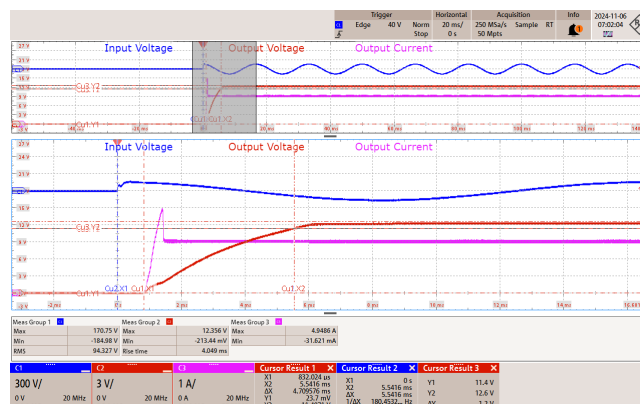


Figure 21 – 115 VAC 60 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 4.71 ms
 Startup Time = 5.54 ms
 V_{MAX} = 12.4 V

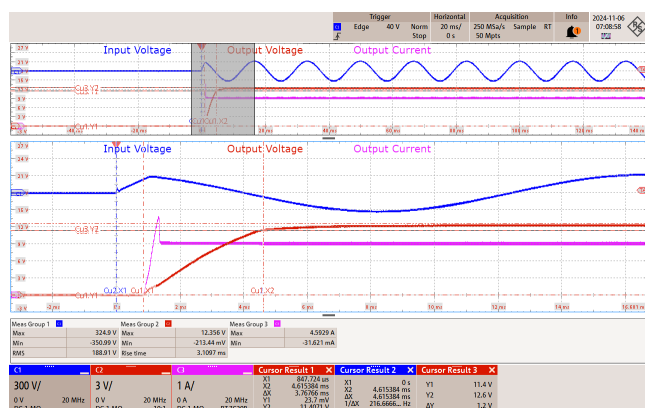


Figure 22 – 230 VAC 50 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.77 ms
 Startup Time = 4.62 ms
 V_{MAX} = 12.4 V

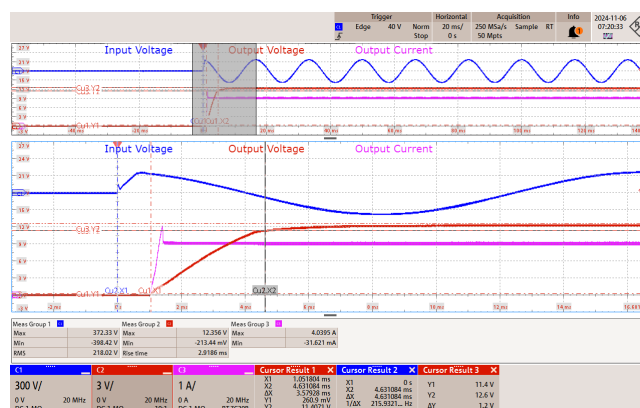
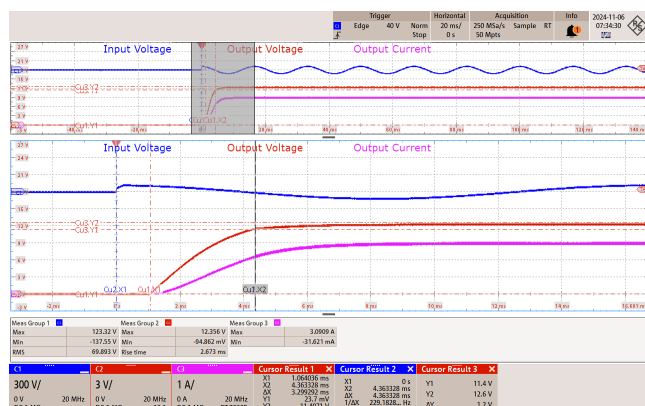


Figure 23 – 265 VAC 50 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.58 ms
 Startup Time = 4.63 ms
 V_{MAX} = 12.4 V

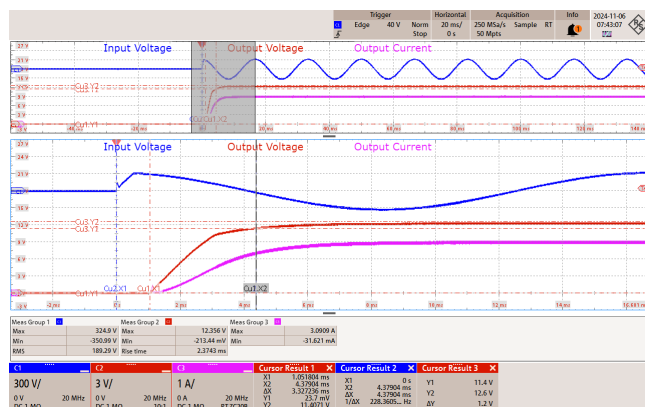
10.2.2 Full Load CR Mode

**Figure 24** – 85 VAC 60 Hz.

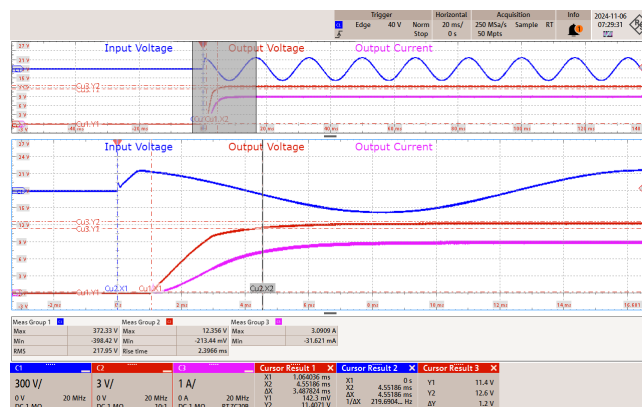
CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.30 ms
 Startup Time = 4.36 ms
 V_{MAX} = 12.4 V

**Figure 25** – 115 VAC 60 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.26 ms
 Startup Time = 4.32 ms
 V_{MAX} = 12.4 V

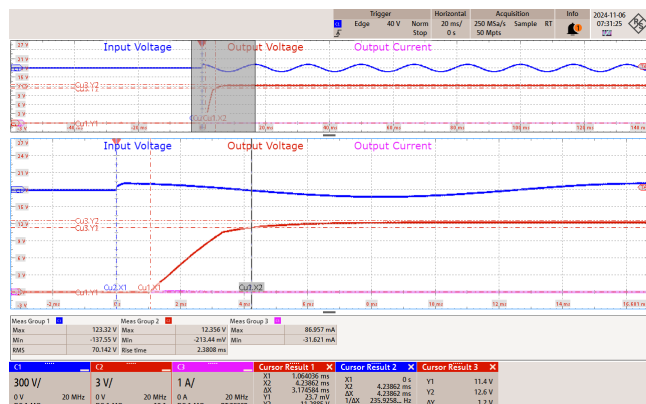
**Figure 26** – 230 VAC 50 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.33 ms
 Startup Time = 4.38 ms
 V_{MAX} = 12.4 V

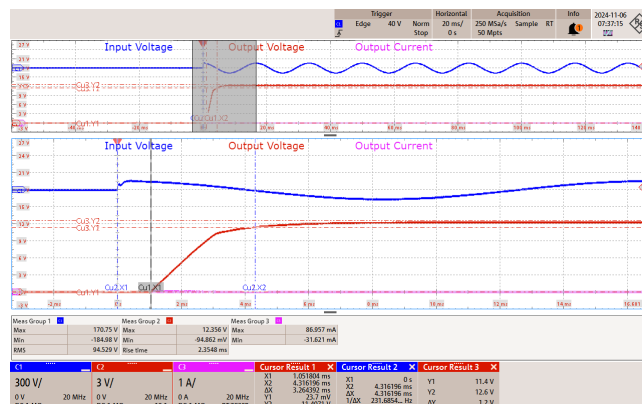
**Figure 27** – 265 VAC 50 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.49 ms
 Startup Time = 4.55 ms
 V_{MAX} = 12.4 V

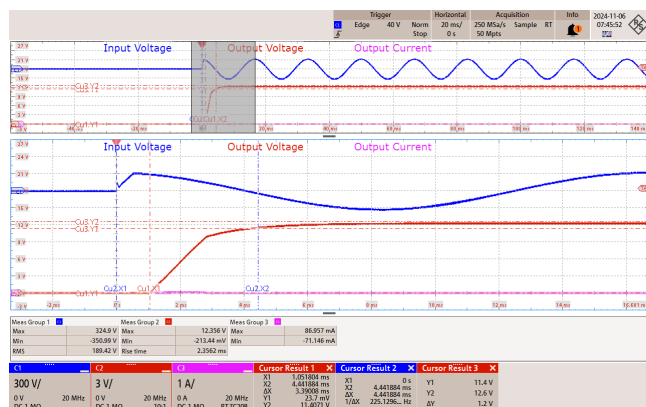
10.2.3 No Load

**Figure 28** – 85 VAC 60 Hz.

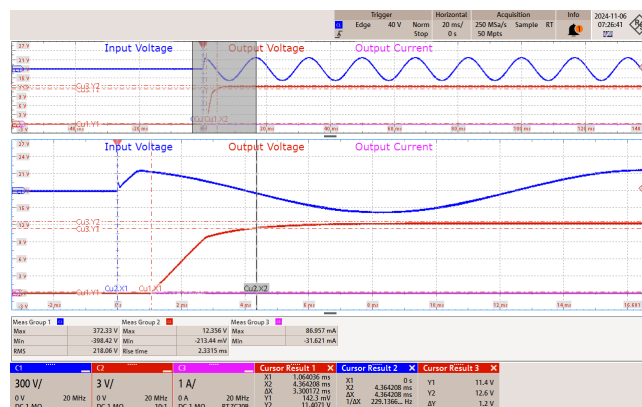
CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.17 ms
 Startup Time = 4.24 ms
 V_{MAX} = 12.4 V

**Figure 29** – 115 VAC 60 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.26 ms
 Startup Time = 4.32 ms
 V_{MAX} = 12.4 V

**Figure 30** – 230 VAC 50 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.39 ms
 Startup Time = 4.44 ms
 V_{MAX} = 12.4 V

**Figure 31** – 265 VAC 50 Hz.

CH1: Input Voltage, 300 V / div., 20 ms / div.
 CH2: Output Voltage, 3 V / div., 20 ms / div.
 CH3: Output Current, 1 A / div., 20 ms / div.
 Zoom: 2 ms / div.
 V_o Rise Time = 3.30 ms
 Startup Time = 4.36 ms
 V_{MAX} = 12.4 V

10.3 Switching Waveforms

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

10.3.1.1 Full Load

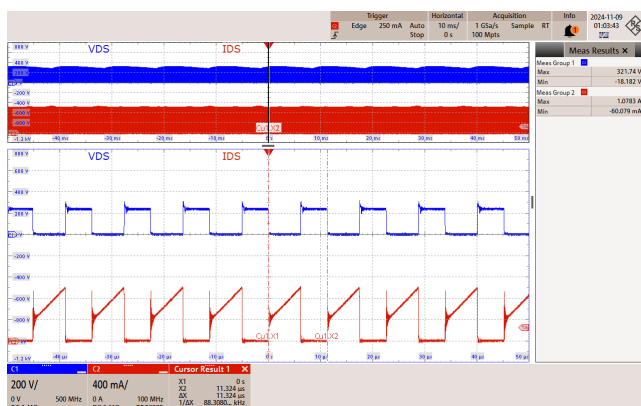


Figure 32 – 85 VAC 60 Hz.

CH1: V_{DS}, 200 V / div., 10 ms / div.
 CH2: I_{DS}, 400 mA / div., 10 ms / div.
 Zoom: 10 μs / div.
 V_{DS}(MAX) = 322 V
 I_{DS}(MAX) = 1.08 A

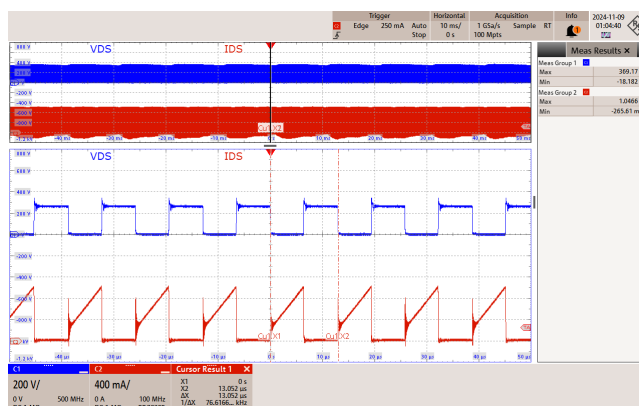


Figure 33 – 115 VAC 60 Hz.

CH1: V_{DS}, 200 V / div., 10 ms / div.
 CH2: I_{DS}, 400 mA / div., 10 ms / div.
 Zoom: 10 μs / div.
 V_{DS}(MAX) = 369 V
 I_{DS}(MAX) = 1.05 A

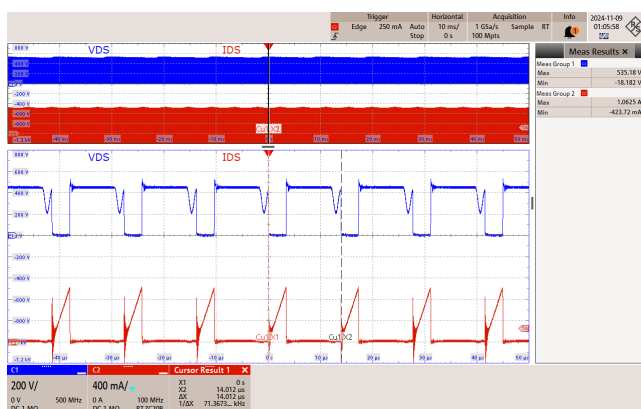


Figure 34 – 230 VAC 50 Hz.

CH1: V_{DS}, 200 V / div., 10 ms / div.
 CH2: I_{DS}, 400 mA / div., 10 ms / div.
 Zoom: 10 μs / div.
 V_{DS}(MAX) = 535 V
 I_{DS}(MAX) = 1.06 A

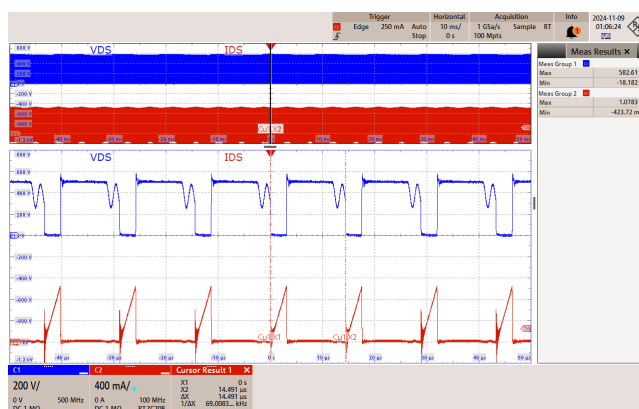
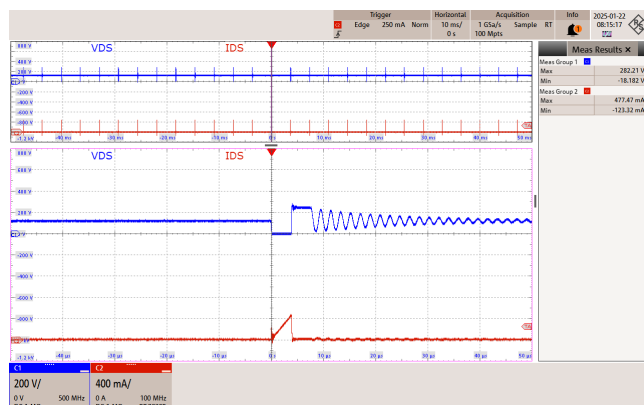


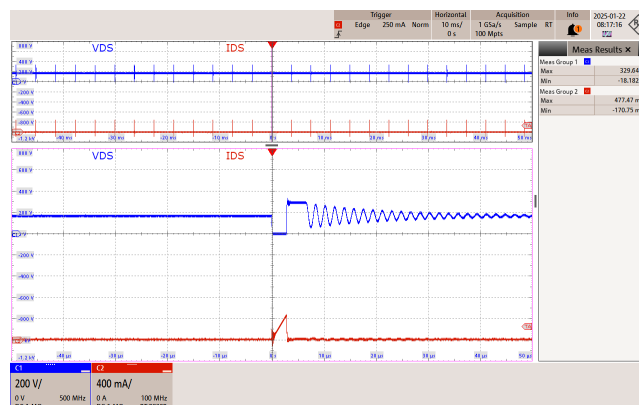
Figure 35 – 265 VAC 50 Hz.

CH1: V_{DS}, 200 V / div., 10 ms / div.
 CH2: I_{DS}, 400 mA / div., 10 ms / div.
 Zoom: 10 μs / div.
 V_{DS}(MAX) = 583 V
 I_{DS}(MAX) = 1.08 A

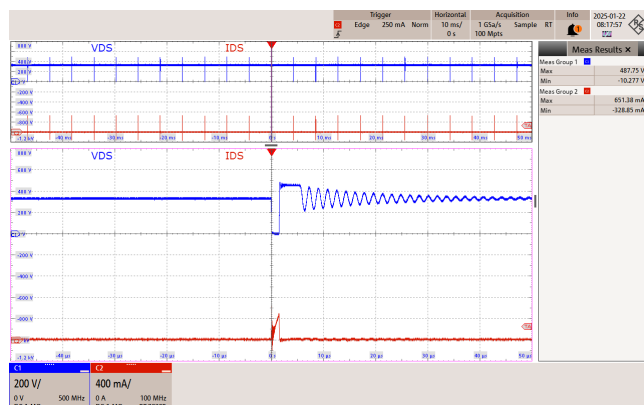
10.3.1.2 No Load

**Figure 36** – 85 VAC 60 Hz.

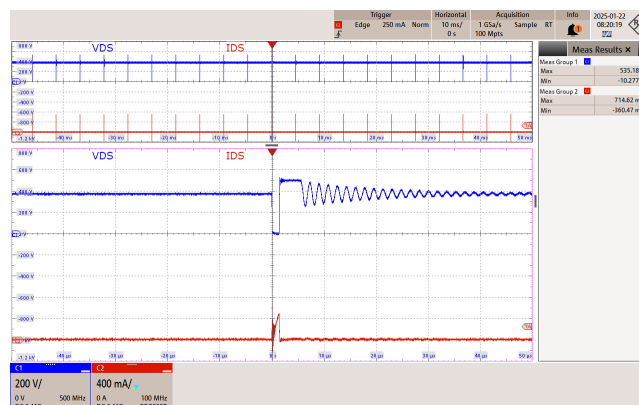
CH1: V_{DS} , 200 V / div., 10 ms / div.
 CH2: I_{DS} , 400 mA / div., 10 ms / div.
 Zoom: 10 μs / div.
 $V_{DS(MAX)} = 282$ V
 $I_{DS(MAX)} = 477$ mA

**Figure 37** – 115 VAC 60 Hz.

CH1: V_{DS} , 200 V / div., 10 ms / div.
 CH2: I_{DS} , 400 mA / div., 10 ms / div.
 Zoom: 10 μs / div.
 $V_{DS(MAX)} = 330$ V
 $I_{DS(MAX)} = 477$ mA

**Figure 38** – 230 VAC 50 Hz.

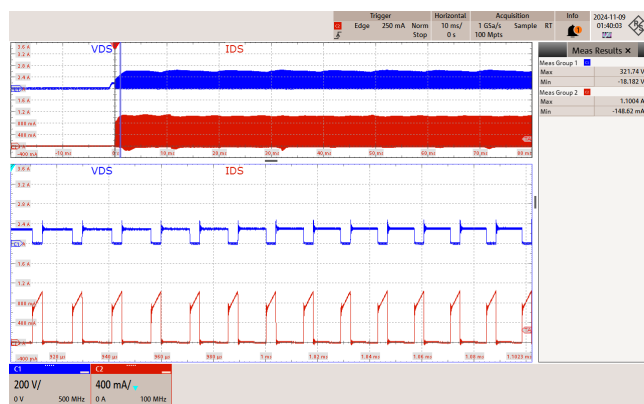
CH1: V_{DS} , 200 V / div., 10 ms / div.
 CH2: I_{DS} , 400 mA / div., 10 ms / div.
 Zoom: 10 μs / div.
 $V_{DS(MAX)} = 488$ V
 $I_{DS(MAX)} = 651$ mA

**Figure 39** – 265 VAC 50 Hz.

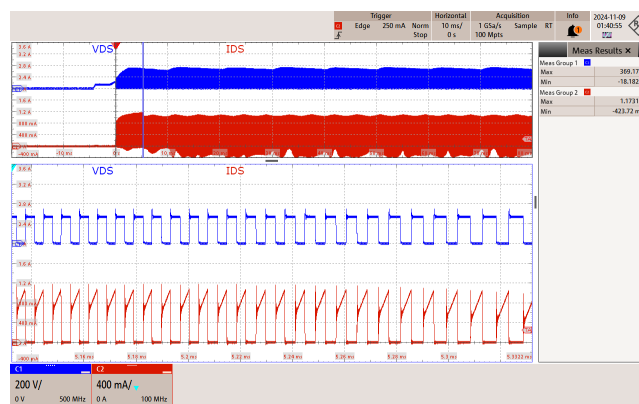
CH1: V_{DS} , 200 V / div., 10 ms / div.
 CH2: I_{DS} , 400 mA / div., 10 ms / div.
 Zoom: 10 μs / div.
 $V_{DS(MAX)} = 535$ V
 $I_{DS(MAX)} = 714$ mA

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

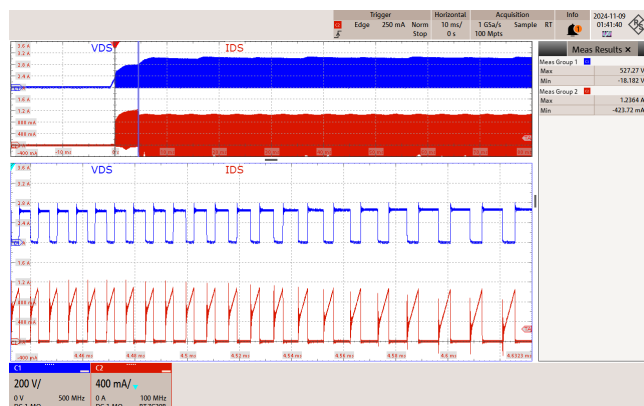
10.3.2.1 Full Load

**Figure 40** – 85 VAC 60 Hz.

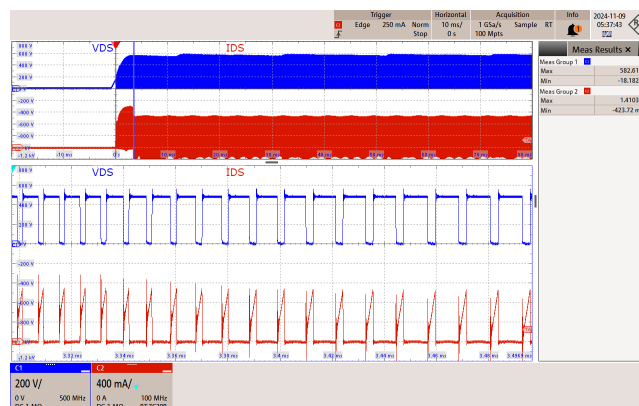
CH1: V_{DS}, 200 V / div., 10 ms / div.
 CH2: I_{DS}, 400 mA / div., 10 ms / div.
 Zoom: 20 μs / div.
 V_{DS(MAX)} = 322 V
 I_{DS(MAX)} = 1.10 A

**Figure 41** – 115 VAC 60 Hz.

CH1: V_{DS}, 200 V / div., 10 ms / div.
 CH2: I_{DS}, 400 mA / div., 10 ms / div.
 Zoom: 20 μs / div.
 V_{DS(MAX)} = 369 V
 I_{DS(MAX)} = 1.17 A

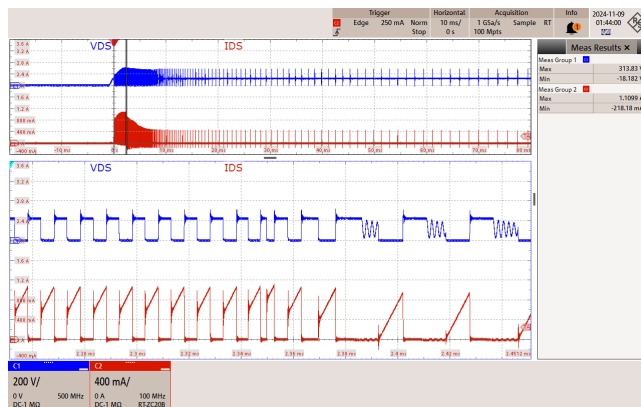
**Figure 42** – 230 VAC 50 Hz.

CH1: V_{DS}, 200 V / div., 10 ms / div.
 CH2: I_{DS}, 400 mA / div., 10 ms / div.
 Zoom: 20 μs / div.
 V_{DS(MAX)} = 527 V
 I_{DS(MAX)} = 1.24 A

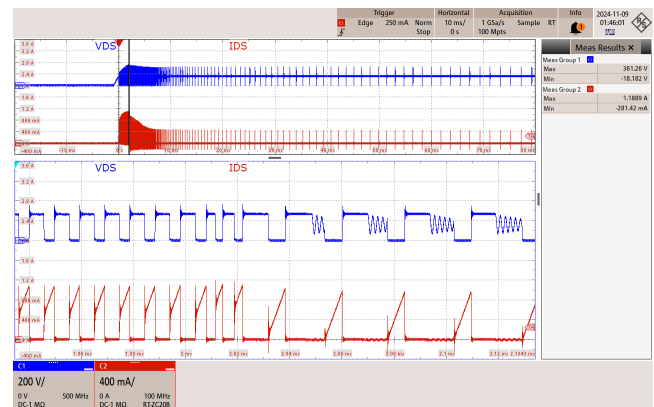
**Figure 43** – 265 VAC 50 Hz.

CH1: V_{DS}, 200 V / div., 10 ms / div.
 CH2: I_{DS}, 400 mA / div., 10 ms / div.
 Zoom: 20 μs / div.
 V_{DS(MAX)} = 583 V
 I_{DS(MAX)} = 1.41 A

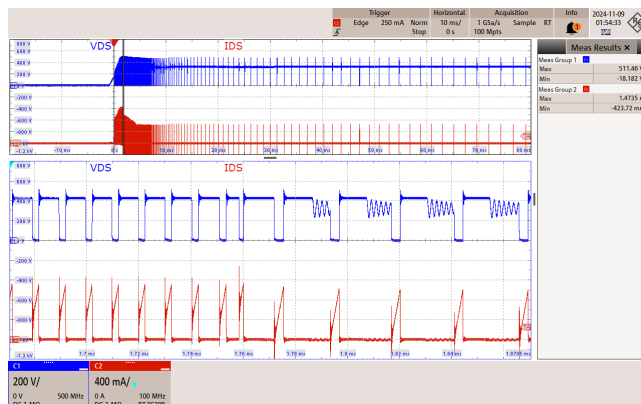
10.3.2.2 No Load

**Figure 44 – 85 VAC 60 Hz.**

CH1: V_{DS} , 200 V / div., 10 ms / div.
 CH2: I_{DS} , 400 mA / div., 10 ms / div.
 Zoom: 20 μs / div.
 $V_{DS(MAX)} = 314$ V
 $I_{DS(MAX)} = 1.11$ A

**Figure 45 – 115 VAC 60 Hz.**

CH1: V_{DS} , 200 V / div., 10 ms / div.
 CH2: I_{DS} , 400 mA / div., 10 ms / div.
 Zoom: 20 μs / div.
 $V_{DS(MAX)} = 361$ V
 $I_{DS(MAX)} = 1.19$ A

**Figure 46 – 230 VAC 50 Hz.**

CH1: V_{DS} , 200 V / div., 10 ms / div.
 CH2: I_{DS} , 400 mA / div., 10 ms / div.
 Zoom: 20 μs / div.
 $V_{DS(MAX)} = 511$ V
 $I_{DS(MAX)} = 1.47$ A

**Figure 47 – 265 VAC 50 Hz.**

CH1: V_{DS} , 200 V / div., 10 ms / div.
 CH2: I_{DS} , 400 mA / div., 10 ms / div.
 Zoom: 20 μs / div.
 $V_{DS(MAX)} = 567$ V
 $I_{DS(MAX)} = 1.52$ A

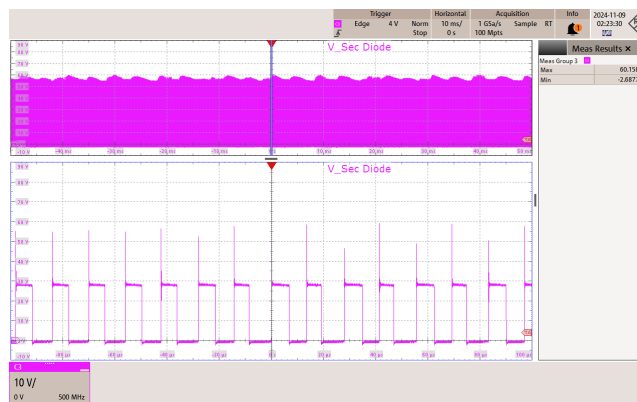
10.3.3 Freewheeling Diode Voltage at Normal Operation

10.3.3.1 Full Load

**Figure 48** – 85 VAC 60 Hz.

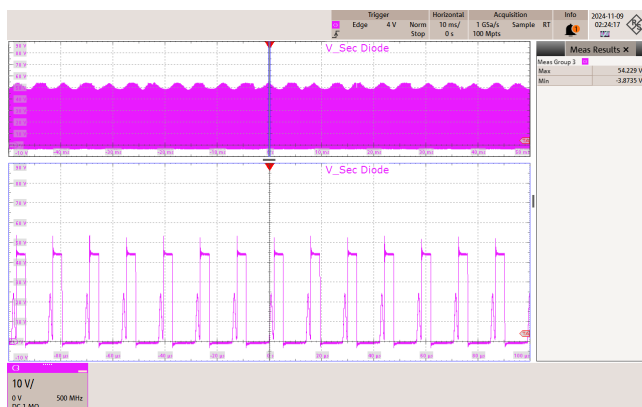
CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μs / div.

Freewheel Diode Voltage_(MAX) = 53.8 V**Figure 49** – 115 VAC 60 Hz.

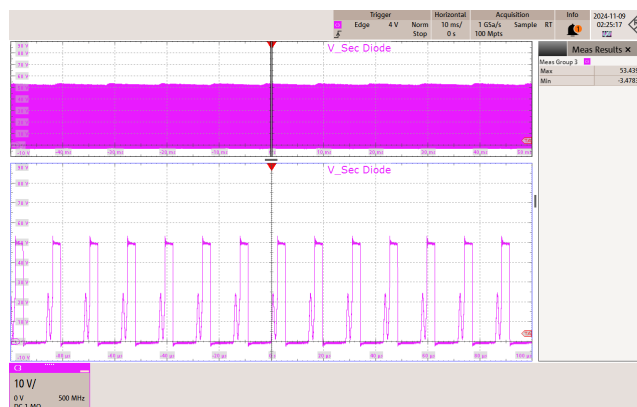
CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μs / div.

Freewheel Diode Voltage_(MAX) = 60.2 V**Figure 50** – 230 VAC 50 Hz.

CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μs / div.

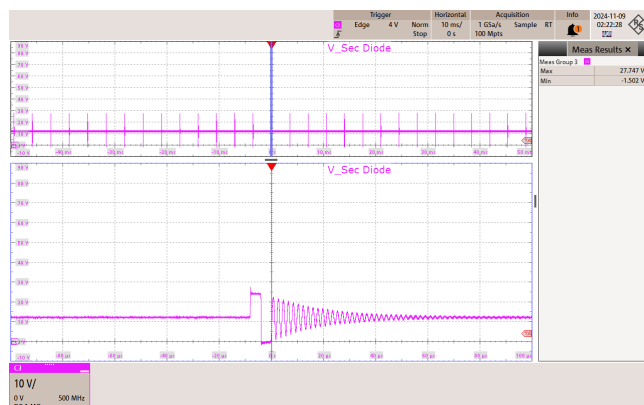
Freewheel Diode Voltage_(MAX) = 54.2 V**Figure 51** – 265 VAC 50 Hz.

CH3: V_Sec Diode, 10 V / div., 10 ms / div.

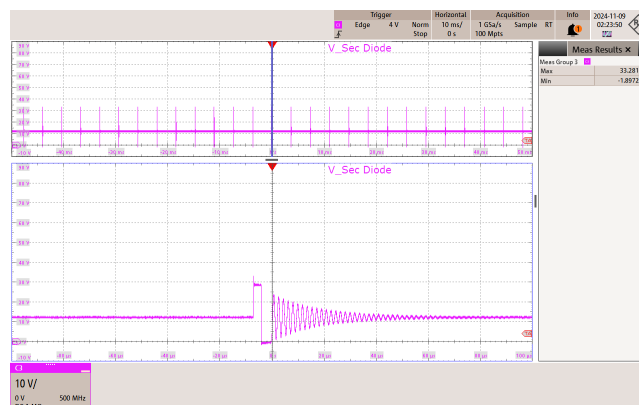
Zoom: 20 μs / div.

Freewheel Diode Voltage_(MAX) = 53.4 V

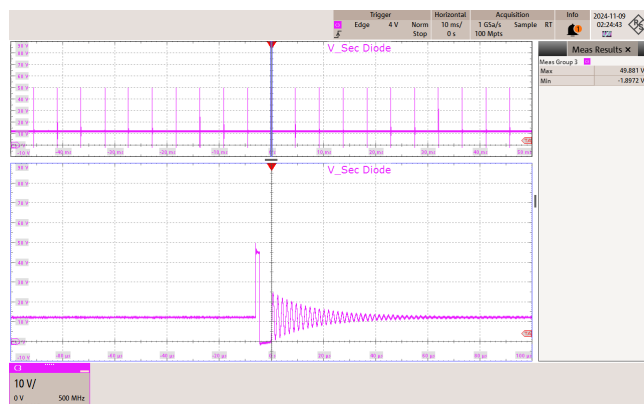
10.3.3.2 No Load

**Figure 52** – 85 VAC 60 Hz.

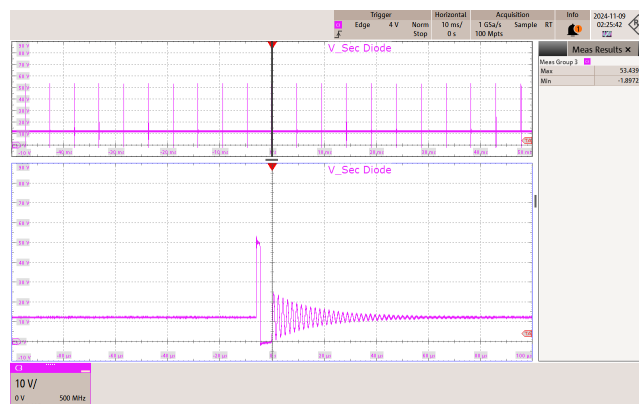
CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μ s / div.Freewheel Diode Voltage_(MAX) = 27.7 V**Figure 53** – 115 VAC 60 Hz.

CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μ s / div.Freewheel Diode Voltage_(MAX) = 33.3 V**Figure 54** – 230 VAC 50 Hz.

CH3: V_Sec Diode, 10 V / div., 10 ms / div.

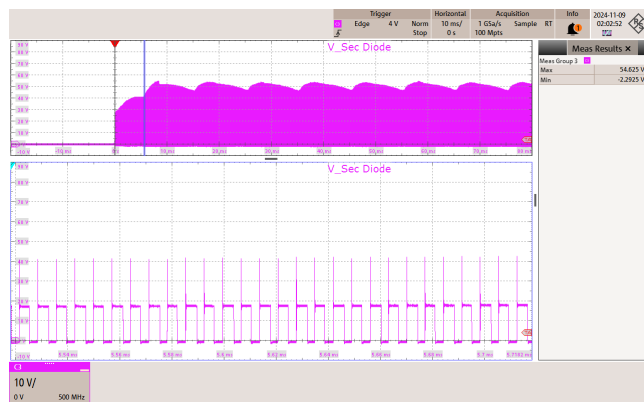
Zoom: 20 μ s / div.Freewheel Diode Voltage_(MAX) = 49.9 V**Figure 55** – 265 VAC 50 Hz.

CH3: V_Sec Diode, 10 V / div., 10 ms / div.

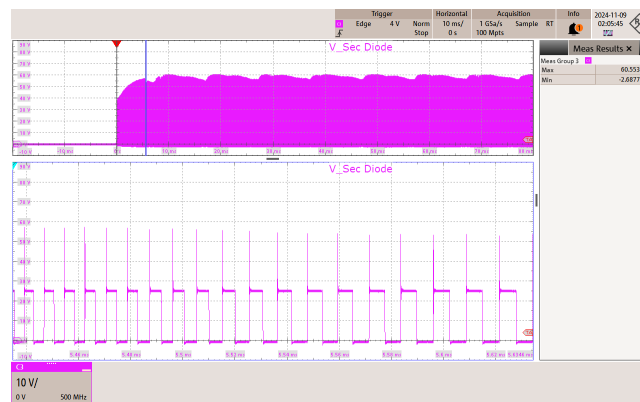
Zoom: 20 μ s / div.Freewheel Diode Voltage_(MAX) = 53.4 V

10.3.4 Freewheeling Diode Voltage at Start-Up

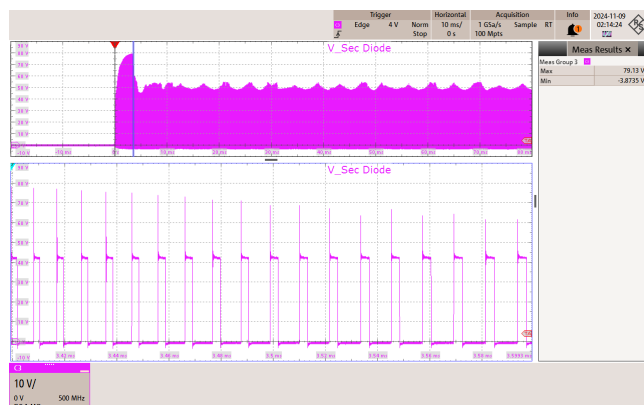
10.3.4.1 Full Load

**Figure 56** – 85 VAC 60 Hz.

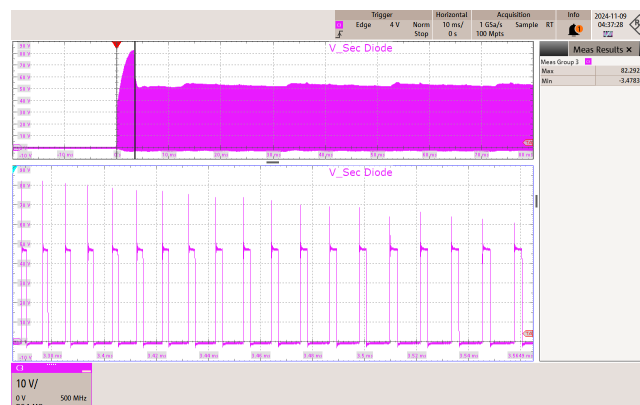
CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μ s / div.Freewheel Diode Voltage_(MAX) = 54.6 V**Figure 57** – 115 VAC 60 Hz.

CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μ s / div.Freewheel Diode Voltage_(MAX) = 60.6 V**Figure 58** – 230 VAC 50 Hz.

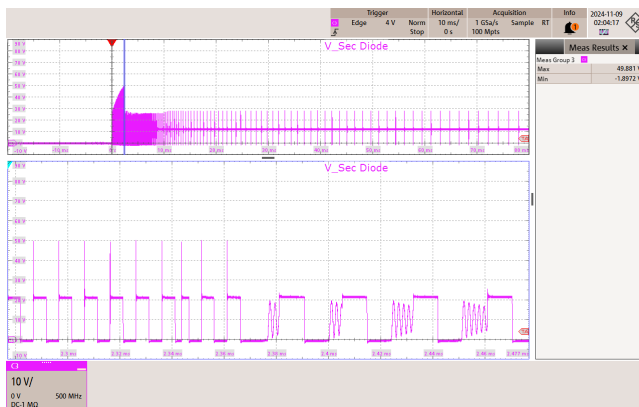
CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μ s / div.Freewheel Diode Voltage_(MAX) = 79.1 V**Figure 59** – 265 VAC 50 Hz.

CH3: V_Sec Diode, 10 V / div., 10 ms / div.

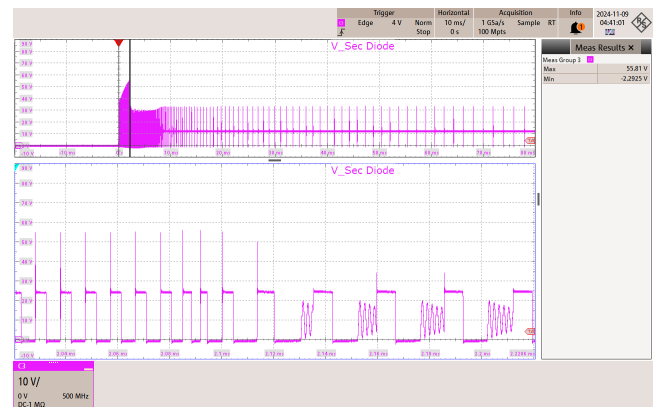
Zoom: 20 μ s / div.Freewheel Diode Voltage_(MAX) = 82.3 V

10.3.4.2 No Load

**Figure 60** – 85 VAC 60 Hz.

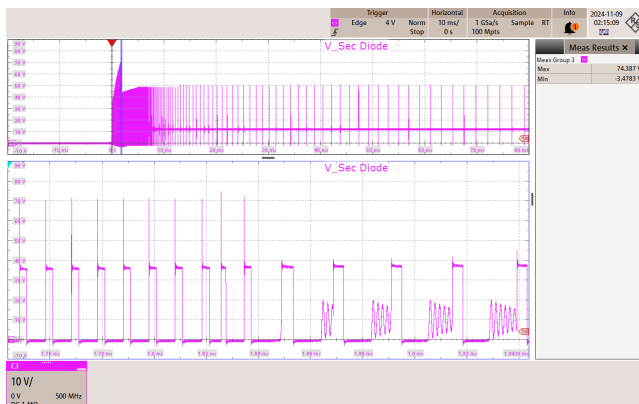
CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μs / div.

Freewheel Diode Voltage_(MAX) = 49.9 V**Figure 61** – 115 VAC 60 Hz.

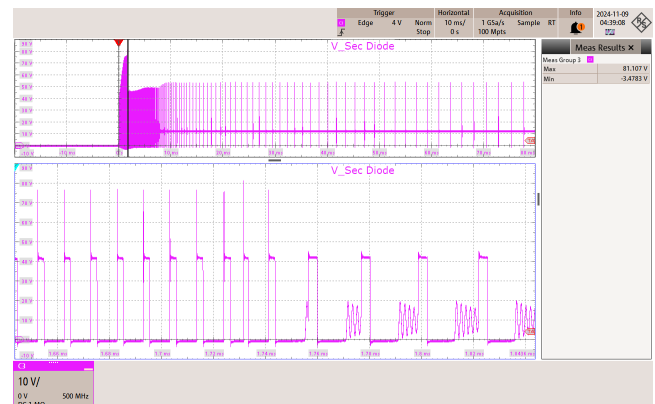
CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μs / div.

Freewheel Diode Voltage_(MAX) = 55.8 V**Figure 62** – 230 VAC 50 Hz.

CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μs / div.

Freewheel Diode Voltage_(MAX) = 74.4 V**Figure 63** – 265 VAC 50 Hz.

CH3: V_Sec Diode, 10 V / div., 10 ms / div.

Zoom: 20 μs / div.

Freewheel Diode Voltage_(MAX) = 81.1 V

10.4 Output Voltage Ripple

10.4.1 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).

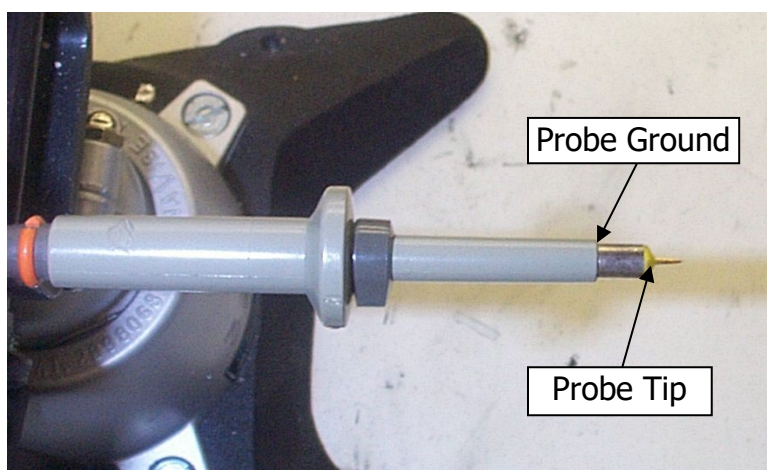


Figure 64 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed.)

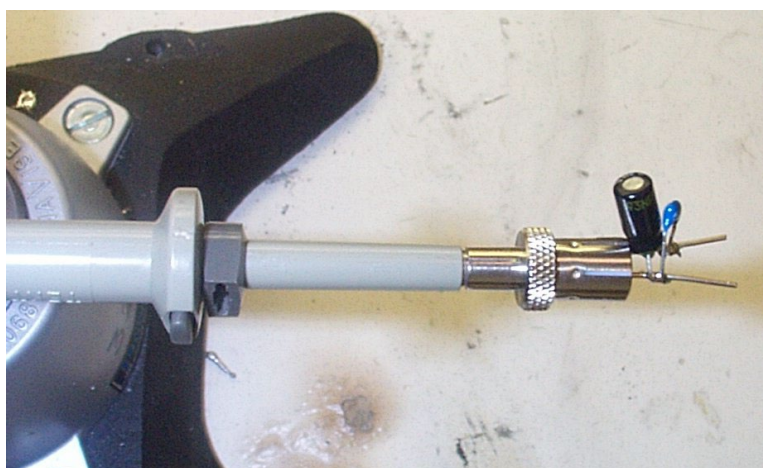


Figure 65 – Oscilloscope Probe with Probe Master (www.probemaster.com) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added.)

10.4.2 Measurement Results

Note: All ripple measurements were taken at PCB end.

10.4.2.1 100% Load Condition

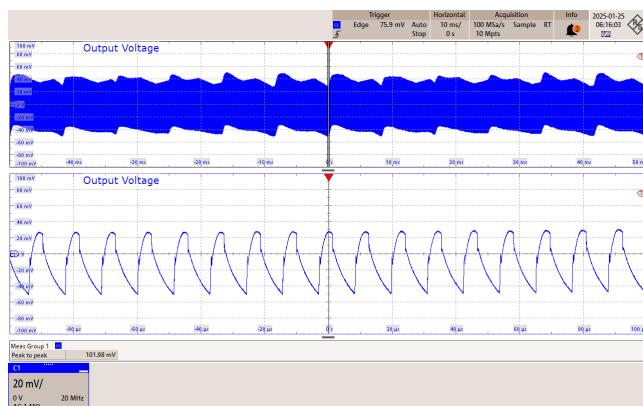


Figure 66 – 85 VAC 60 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 102 mV

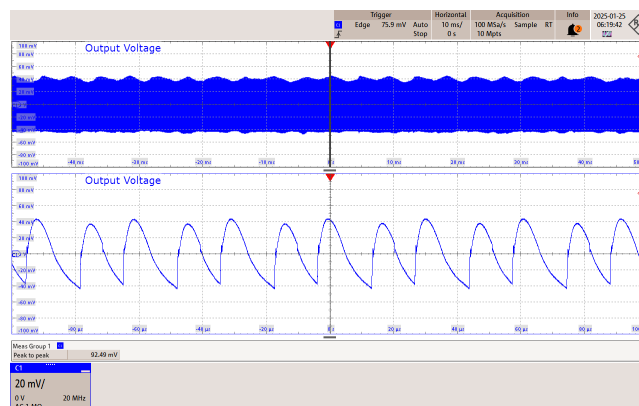


Figure 67 – 115 VAC 60 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 92.5 mV

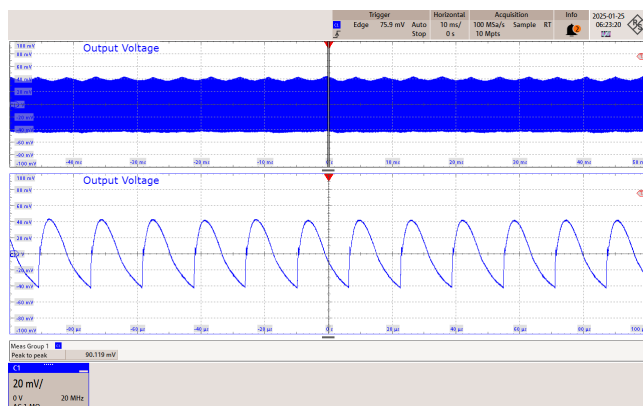


Figure 68 – 230 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 90.1 mV

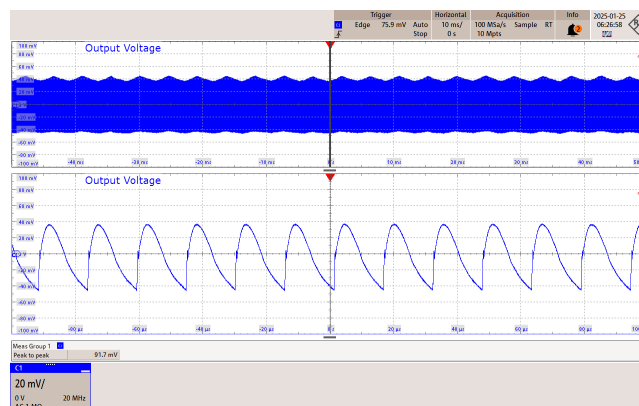
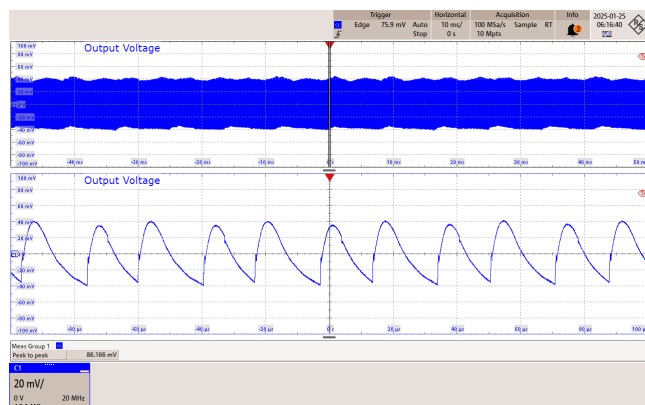


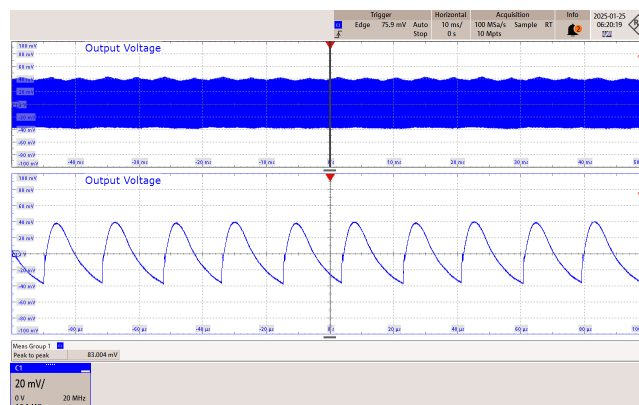
Figure 69 – 265 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 91.7 mV

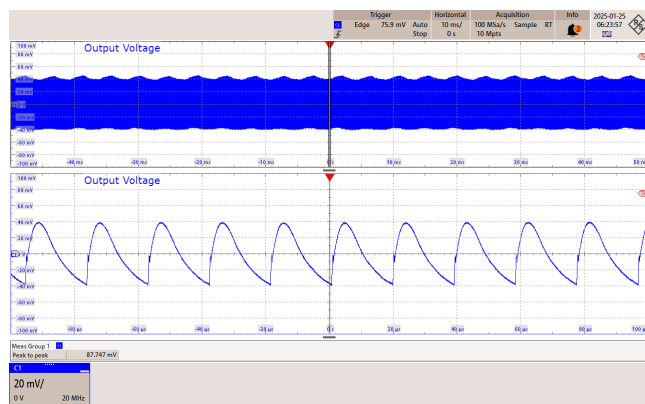
10.4.2.2 75% Load Condition

**Figure 70** – 85 VAC 60 Hz.

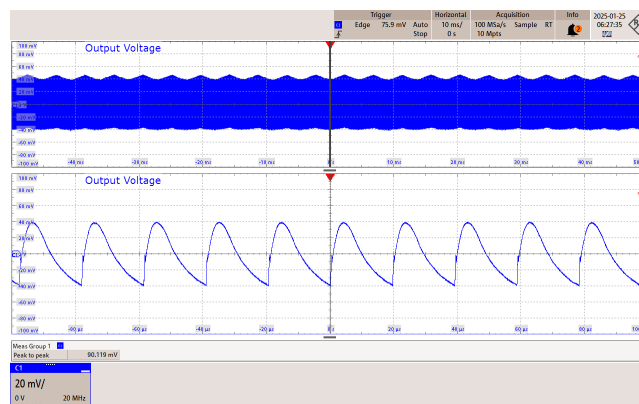
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 86.2 mV

**Figure 71** – 115 VAC 60 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 83.0 mV

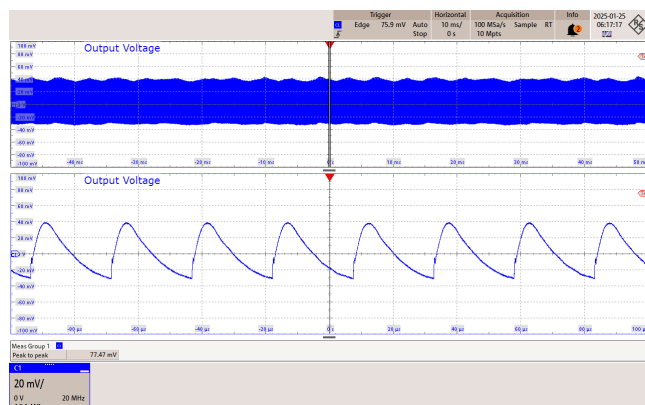
**Figure 72** – 230 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 87.7 mV

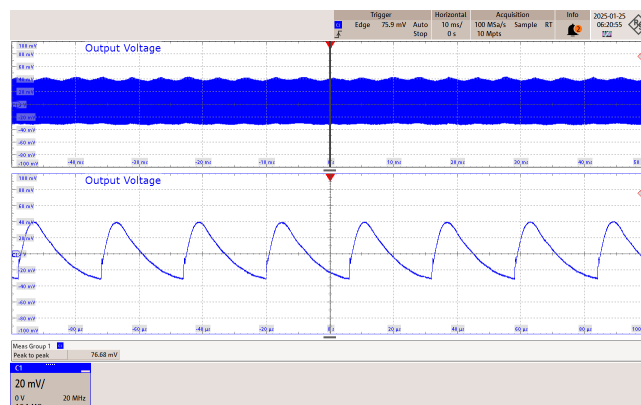
**Figure 73** – 265 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 90.1 mV

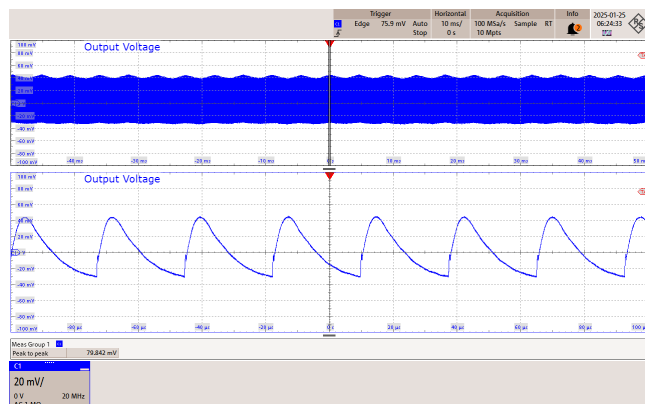
10.4.2.3 50% Load Condition

**Figure 74** – 85 VAC 60 Hz.

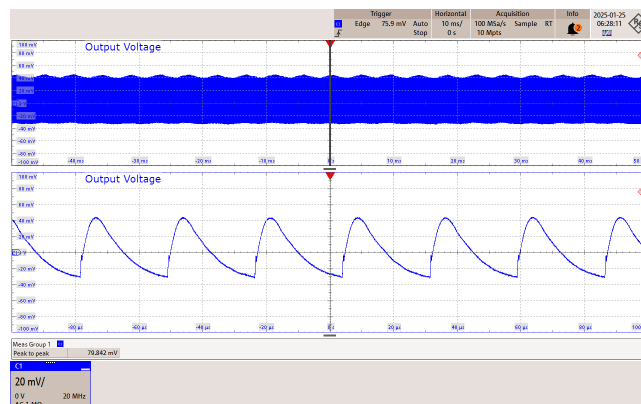
CH1: Output Ripple, 20 mV / div., 10 ms / div.
 Zoom: 20 μs / div.
 Output Ripple = 77.5 mV

**Figure 75** – 115 VAC 60 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
 Zoom: 20 μs / div.
 Output Ripple = 76.7 mV

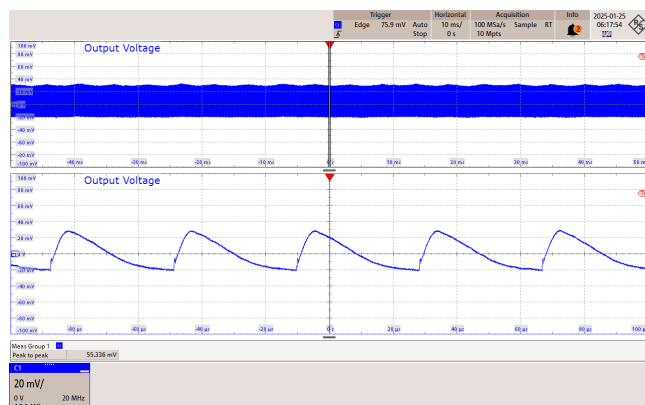
**Figure 76** – 230 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
 Zoom: 20 μs / div.
 Output Ripple = 79.8 mV

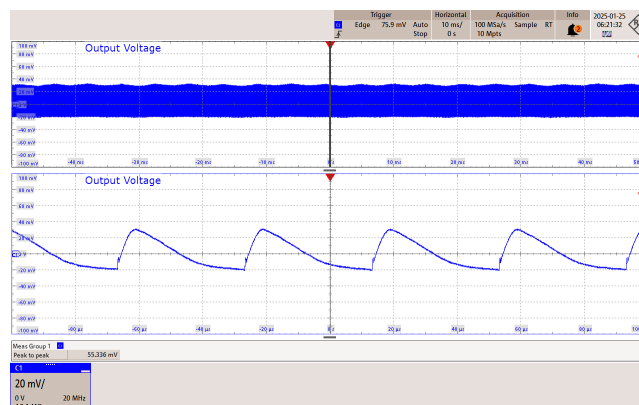
**Figure 77** – 265 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
 Zoom: 20 μs / div.
 Output Ripple = 79.8 mV

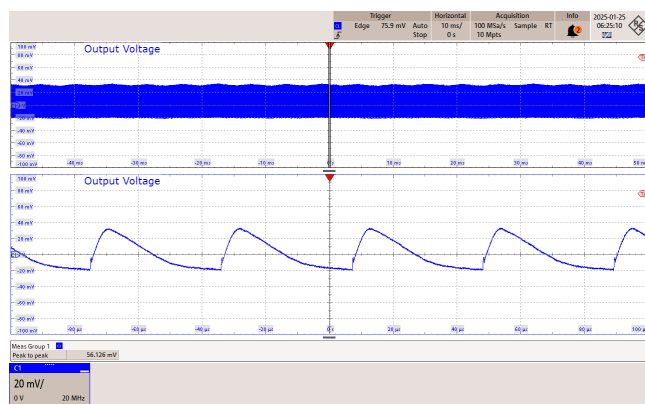
10.4.2.4 25% Load Condition

**Figure 78** – 85 VAC 60 Hz.

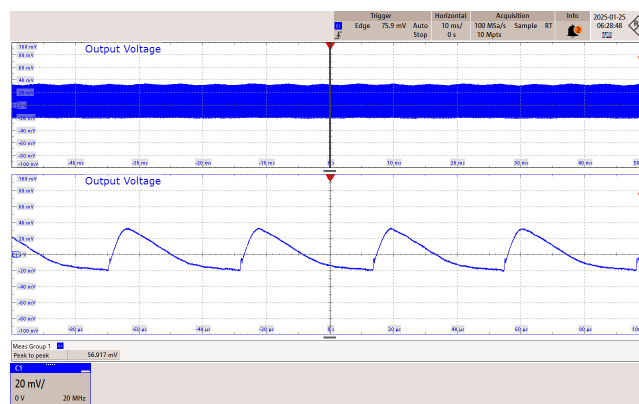
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 55.3 mV

**Figure 79** – 115 VAC 60 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 55.3 mV

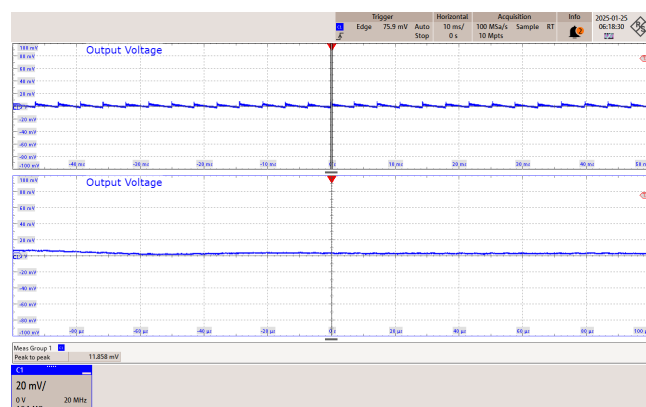
**Figure 80** – 230 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 56.1 mV

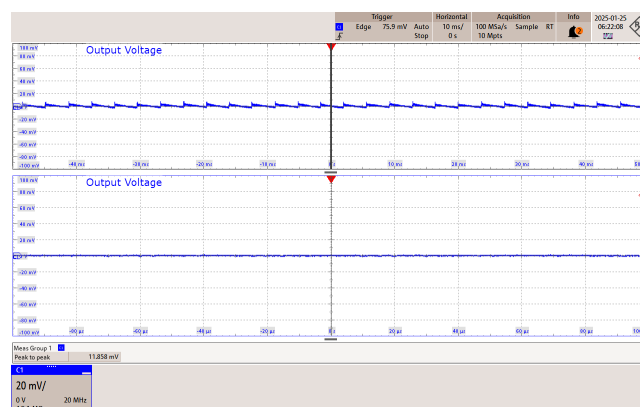
**Figure 81** – 265 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 56.9 mV

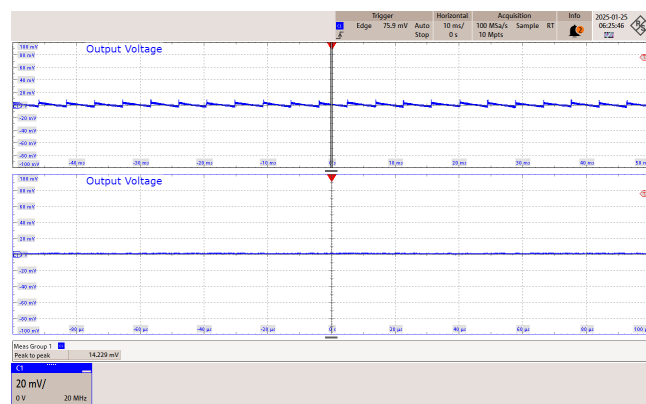
10.4.2.5 0% Load Condition

**Figure 82** – 85 VAC 60 Hz.

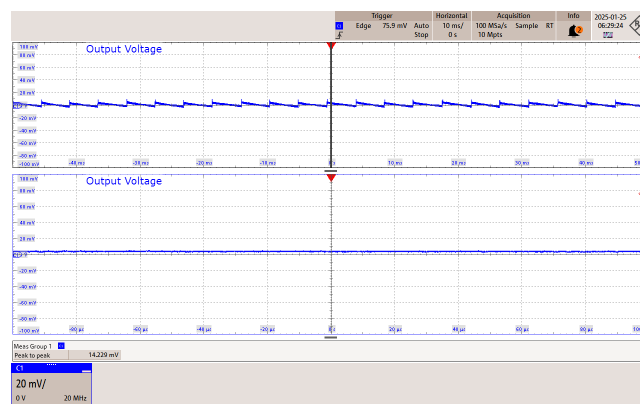
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 11.9 mV

**Figure 83** – 115 VAC 60 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 11.9 mV

**Figure 84** – 230 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 14.2 mV

**Figure 85** – 265 VAC 50 Hz.

CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μ s / div.
Output Ripple = 14.2 mV

10.4.3 Output Ripple Voltage

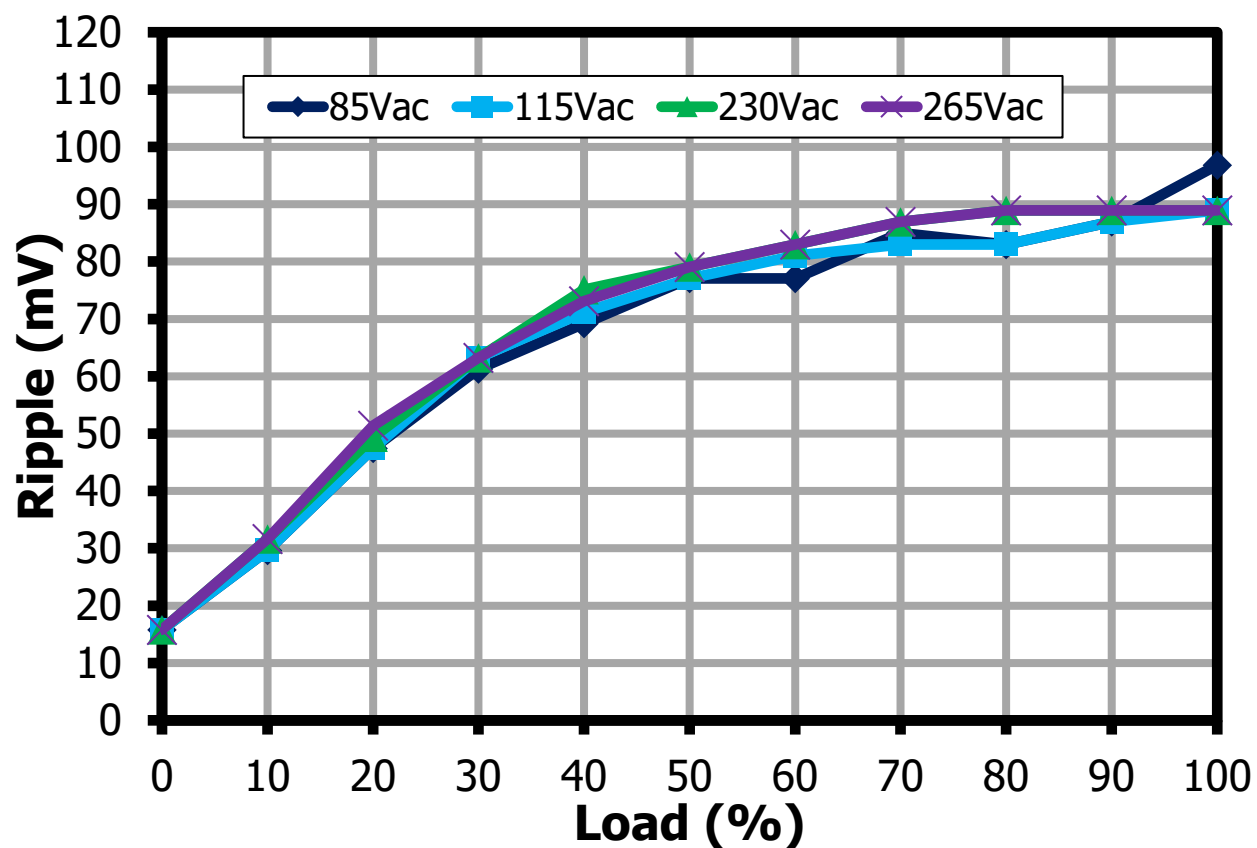


Figure 86 – Voltage Ripple (Measured at PCB End at Room Temperature).

11 Thermal Performance

11.1 25 °C Ambient Thermals

11.1.1 85 VAC Full Load at 25 °C Ambient

Test result after 60 mins running continuously at 85 VAC full load.



Figure 87 – 85 VAC 60 Hz. Top Side Discrete Component Thermals.

Component	Temperature (°C)
Ambient	30.3
Transformer (T1)	71.9

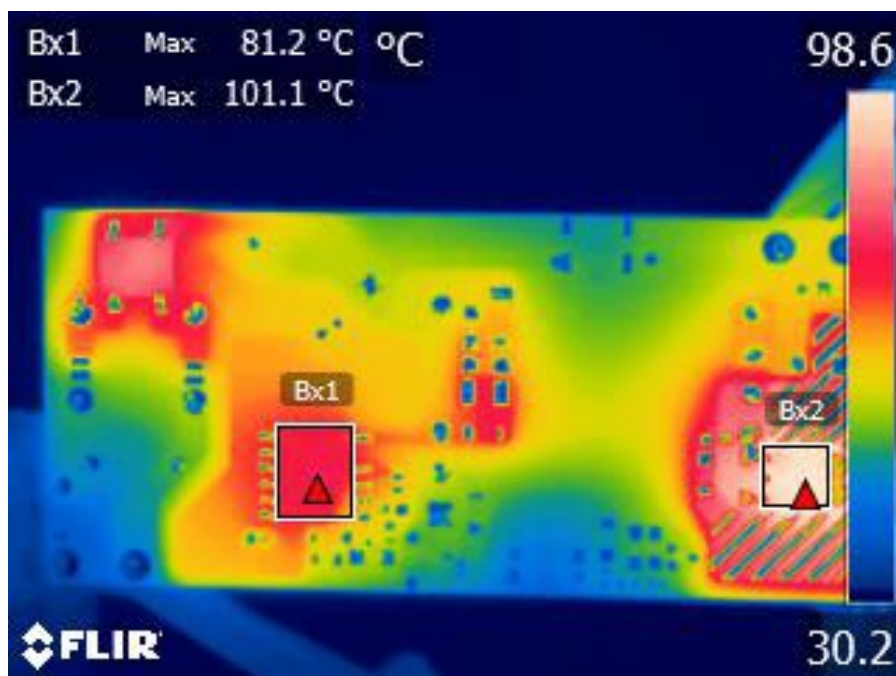


Figure 88 – 85 VAC 60 Hz. Bottom Side Thermals.

Component	Temperature (°C)
Ambient	30.2
TNY5075K (U4)	81.2
Secondary Diode (D4)	101.1

11.1.2 265 VAC Full Load at 25 °C Ambient

Test result after 60 mins running continuously at 265 VAC full load.



Figure 89 – 265 VAC 50 Hz. Top Side Discrete Component Thermals.

Component	Temperature (°C)
Ambient	29.6
Transformer (T1)	73.2

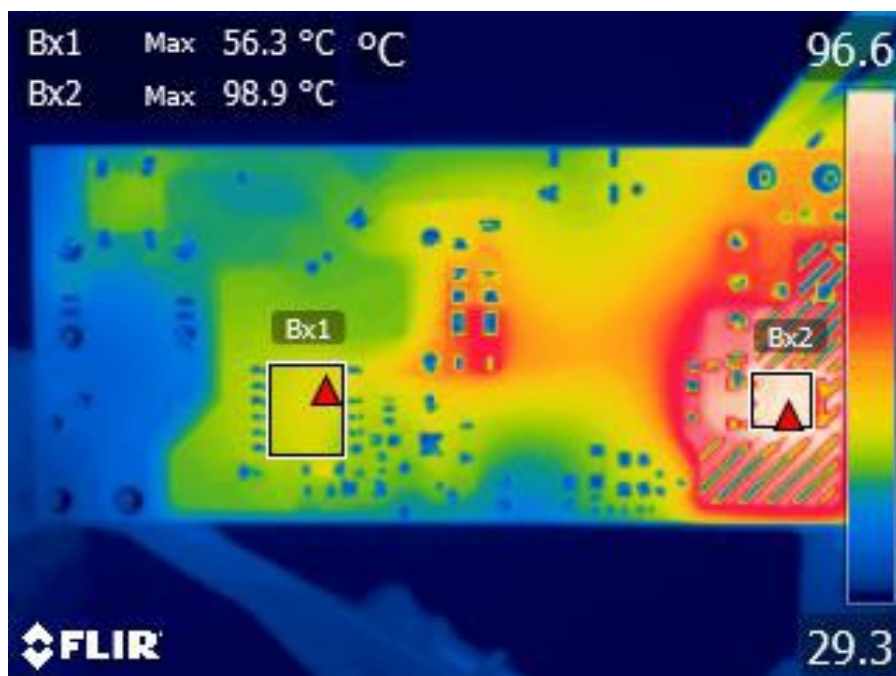


Figure 90 – 265 VAC 50 Hz. Bottom Side Thermals.

Component	Temperature (°C)
Ambient	29.3
TNY5075K (U4)	56.3
Secondary Diode (D4)	98.9

12 Fault Condition

12.1 Output Short-Circuit Protection

12.1.1 Start-Up Short



Figure 91 – 85 VAC 60 Hz. Output Short.

CH1: V_{DS}, 200 V / div., 1 s / div.

CH2: I_{DS}, 400 mA / div., 1 s / div.

CH3: V_{OUT}, 3 V / div., 1 s / div.

CH4: I_{OUT}, 1 A / div., 1 s / div.

V_{DS}(MAX) = 306 V

I_{DS}(MAX) = 1.34 A

t_{AR(OFF)1} = 342 ms

t_{AR(OFF)2} = 1.20 s

t_{AR(ON)} = 77.5 ms



Figure 92 – 265 VAC 50 Hz Output Short.

CH1: V_{DS}, 200 V / div., 1 s / div.

CH2: I_{DS}, 400 mA / div., 1 s / div.

CH3: V_{OUT}, 3 V / div., 1 s / div.

CH4: I_{OUT}, 1 A / div., 1 s / div.

V_{DS}(MAX) = 559 V

I_{DS}(MAX) = 1.48 A

t_{AR(OFF)1} = 340 ms

t_{AR(OFF)2} = 1.20 s

t_{AR(ON)} = 144 ms

12.1.1.1 Running Short

12.1.1.1.1 Full Load



Figure 93 – 85 VAC 60 Hz. Output Short.

CH1: V_{DS} , 200 V / div., 1 s / div.
 CH2: I_{DS} , 400 mA / div., 1 s / div.
 CH3: V_{OUT} , 3 V / div., 1 s / div.
 CH2: I_{OUT} , 1 A / div., 1 s / div.
 $V_{DS(MAX)} = 338 \text{ V}$
 $I_{DS(MAX)} = 1.34 \text{ A}$
 $t_{AR(OFF)1} = 339 \text{ ms}$
 $t_{AR(OFF)2} = 1.20 \text{ s}$
 $t_{AR(ON)} = 76.8 \text{ ms}$

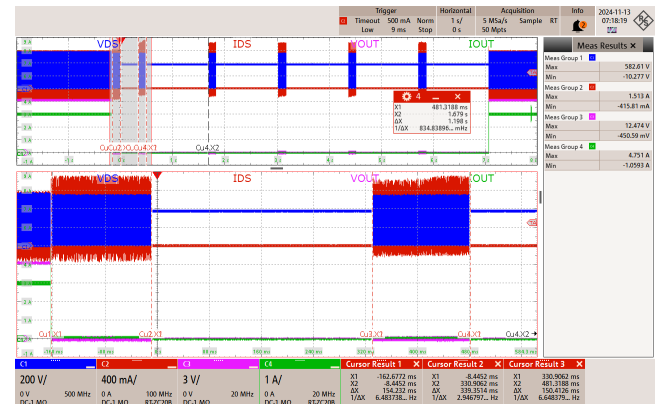


Figure 94 – 265 VAC 50 Hz Output Short.

CH1: V_{DS} , 200 V / div., 1 s / div.
 CH2: I_{DS} , 400 mA / div., 1 s / div.
 CH3: V_{OUT} , 3 V / div., 1 s / div.
 CH2: I_{OUT} , 1 A / div., 1 s / div.
 $V_{DS(MAX)} = 583 \text{ V}$
 $I_{DS(MAX)} = 1.51 \text{ A}$
 $t_{AR(OFF)1} = 339 \text{ ms}$
 $t_{AR(OFF)2} = 1.20 \text{ s}$
 $t_{AR(ON)} = 150 \text{ ms}$

12.2 Overpower Protection

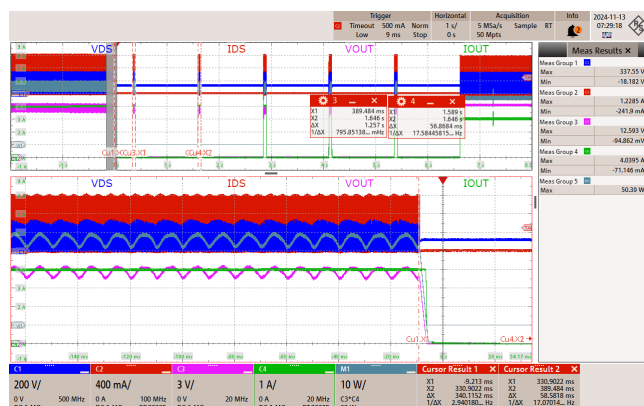


Figure 95 – 85 VAC 60 Hz.

CH1: V_{DS}, 200 V / div., 1 s / div.
 CH2: I_{DS}, 400 mA / div., 1 s / div.
 CH3: V_{OUT}, 3 V / div., 1 s / div.
 CH2: I_{OUT}, 1 A / div., 1 s / div.
 M1: P_{OUT}, 10 W / div., 1 s / div.
 Zoom: 20 ms / div.
 P_{OUT}(MAX) = 50.4 W
 t_{AR}(OFF)1 = 340 ms
 t_{AR}(OFF)2 = 1.26 s
 t_{AR}(ON) = 58.6 ms

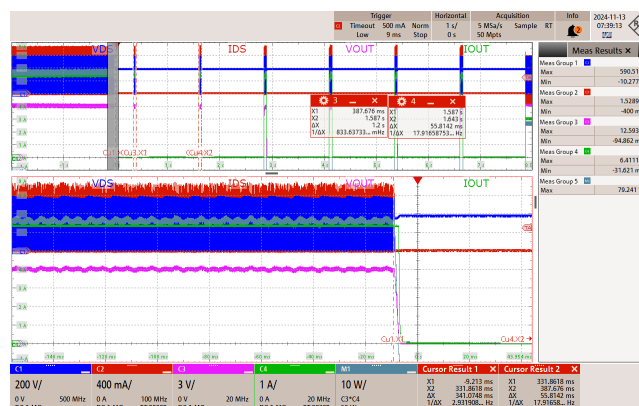


Figure 96 – 265 VAC 60 Hz.

CH1: V_{DS}, 200 V / div., 1 s / div.
 CH2: I_{DS}, 400 mA / div., 1 s / div.
 CH3: V_{OUT}, 3 V / div., 1 s / div.
 CH2: I_{OUT}, 1 A / div., 1 s / div.
 M1: P_{OUT}, 10 W / div., 1 s / div.
 Zoom: 20 ms / div.
 P_{OUT}(MAX) = 79.2 W
 t_{AR}(OFF)1 = 341 ms
 t_{AR}(OFF)2 = 1.2 s
 t_{AR}(ON) = 55.8 ms

12.3 Overtemperature Protection

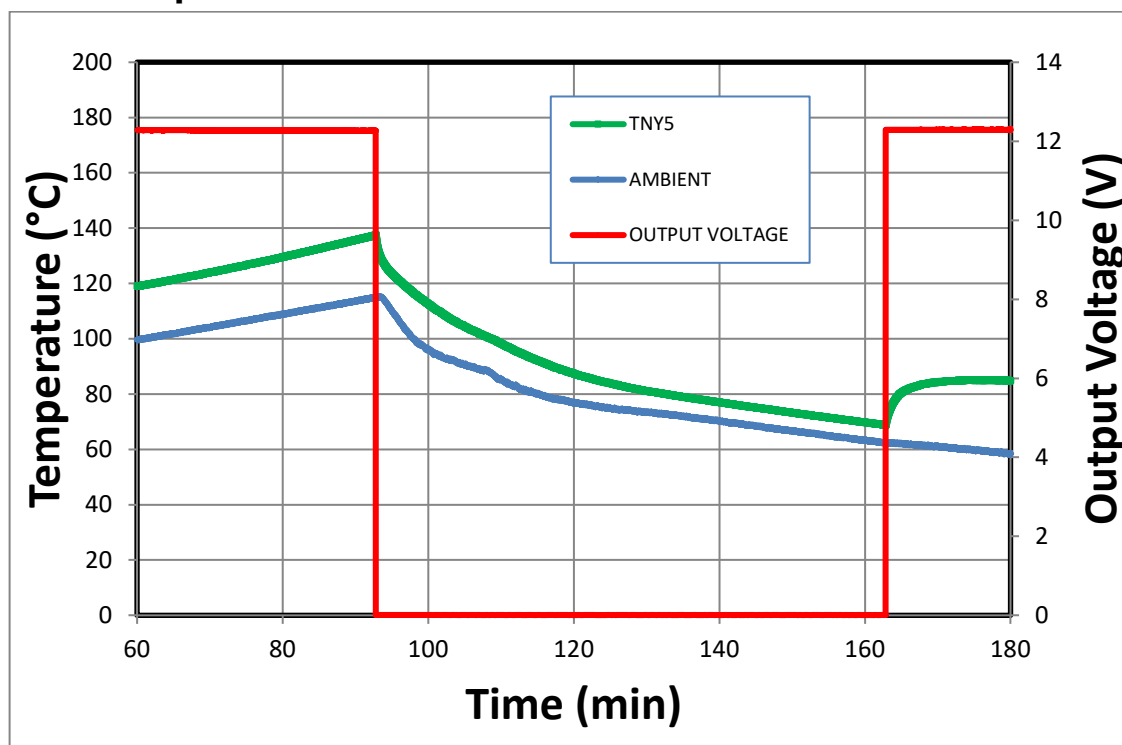


Figure 97 – 265 VAC Full Load OTP

OTP Temperature	137 °C
Recovery Temperature	68.8 °C
Hysteresis	68.7 °C

13 Conducted EMI

Conducted emissions tests were performed at 115 VAC and 230 VAC at full load (12 V, 3 A). Measurements were taken with floating ground.

13.1 Test Set-up Equipment

13.1.1 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. 12 V R_{LOAD} resistance is 4 Ohms.

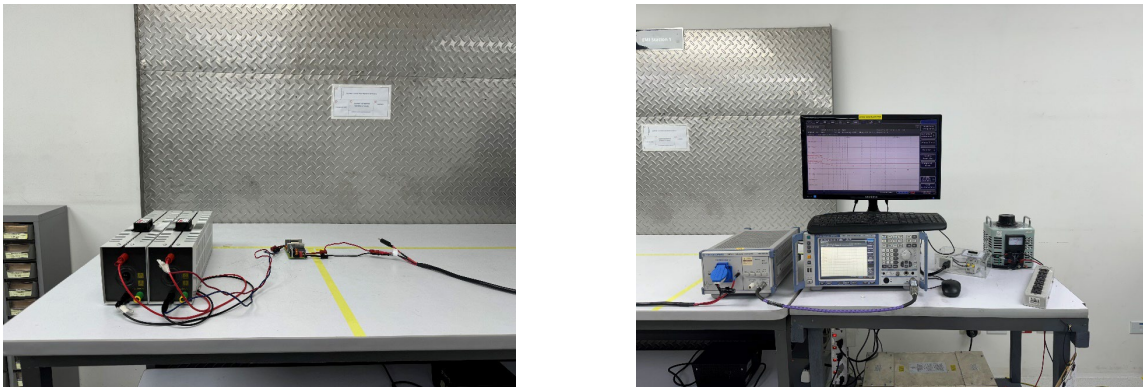


Figure 98 – EMI Test Set-up.

13.2 Output Float

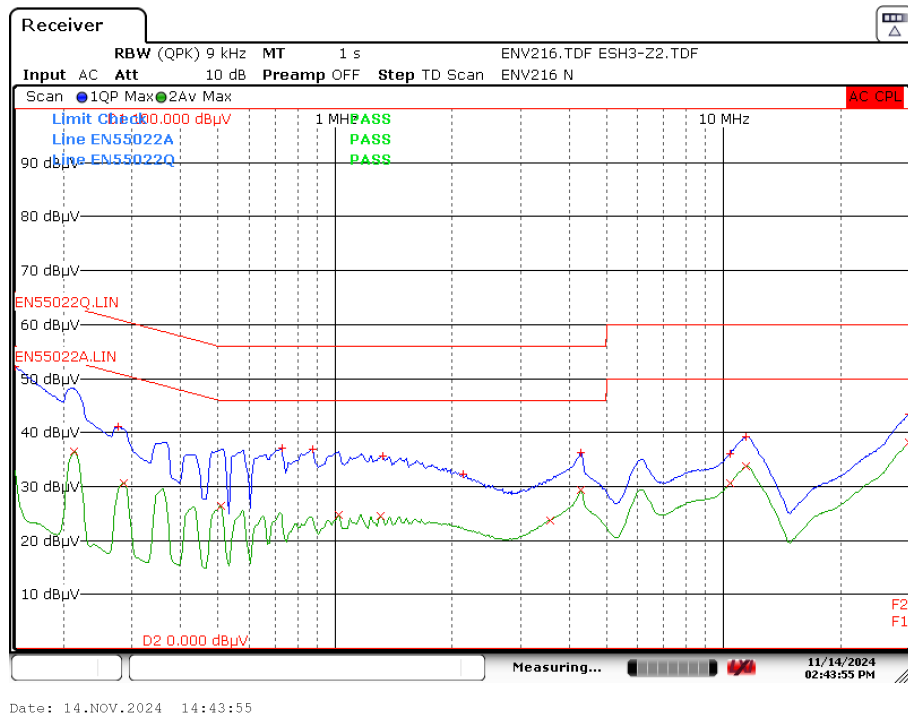


Figure 99 – 115 VAC 60 Hz.
Line / Neutral - Floating

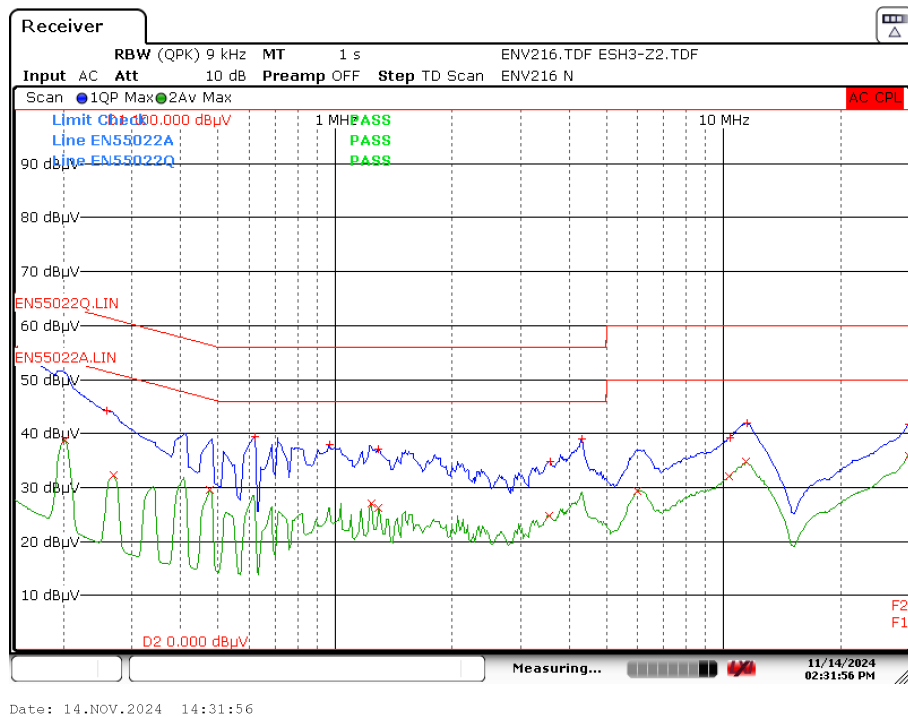


Figure 100 – 230 VAC 50 Hz.
Line / Neutral - Floating

14 ESD

All ESD strikes were applied at PCB end 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	12 V	10	PASS – No AR
-8.8	12 V	10	PASS – No AR
+8.8	GND	10	PASS – No AR
-8.8	GND	10	PASS – No AR

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

Passed ± 16.5 kV air discharge

Air Discharge Voltage (kV)	Applied to	Number of Strikes	Test Result
+16.5	12 V	10	PASS – No AR
-16.5	12 V	10	PASS – No AR
+16.5	GND	10	PASS – No AR
-16.5	GND	10	PASS – No AR

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

15 Combination Wave (Differential Mode)

Tested at 230 VAC input voltage and full load

15.1 230 VAC

Passed 1kV Surge voltage

Surge Voltage	Phase Angle	IEC Coupling	Generator Impedance	Number of Strikes	Results
+1000 V	0°	L, N	2Ω	10	PASS – No AR
-1000 V	0°	L, N	2Ω	10	PASS – No AR
+1000 V	90°	L, N	2Ω	10	PASS – No AR
-1000 V	90°	L, N	2Ω	10	PASS – No AR
+1000 V	180°	L, N	2Ω	10	PASS – No AR
-1000 V	180°	L, N	2Ω	10	PASS – No AR
+1000 V	270°	L, N	2Ω	10	PASS – No AR
-1000 V	270°	L, N	2Ω	10	PASS – with AR and recovers

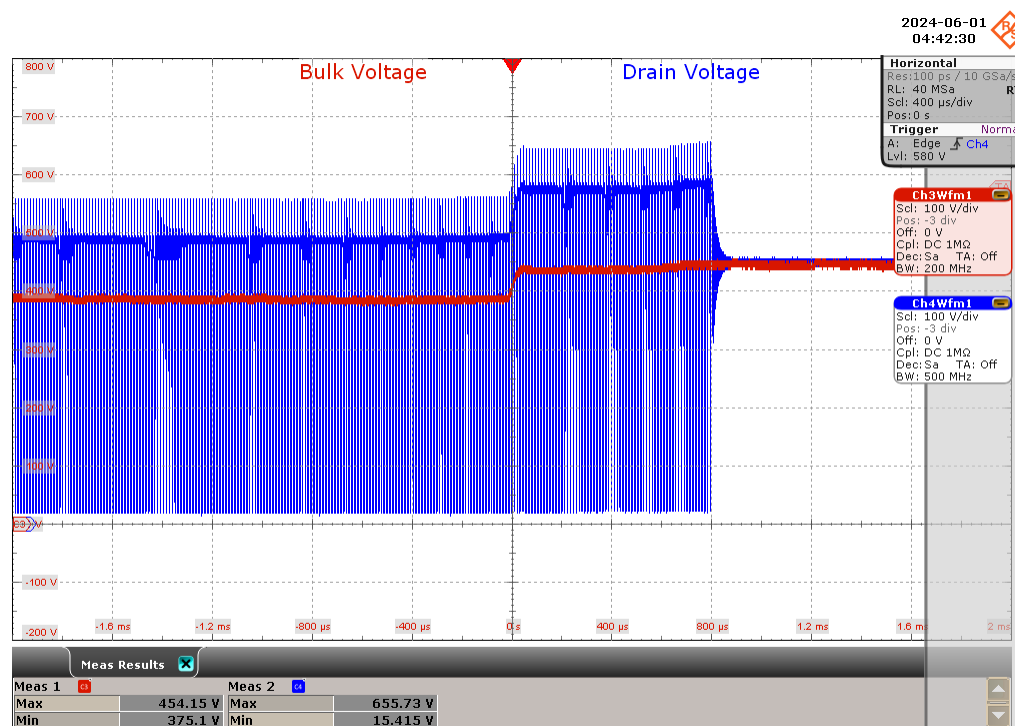


Figure 101 – 230 VAC 50 Hz, -1 kV 270° surge event

CH3: Input Voltage, 100 V / div., 400 μs / div.

CH4: Output Voltage, 100 V / div., 400 μs / div.

Drain Voltage_(MAX) = 656 V

Bulk Voltage_(MAX) = 454 V

16 Ring Wave (Common Mode)

Tested at 115 VAC and 230 VAC input voltage and full load

16.1 115 VAC

115 VAC: 4 kV Surge Event

Surge Voltage	Phase Angle	IEC Coupling	Generator Impedance	Number of Strikes	Results
+4000 V	0°	L/N - PE	12	10	PASS – No AR
–4000 V	0°	L/N - PE	12	10	PASS – No AR
+4000 V	90°	L/N - PE	12	10	PASS – No AR
–4000 V	90°	L/N - PE	12	10	PASS – No AR
+4000 V	180°	L/N - PE	12	10	PASS – No AR
–4000 V	180°	L/N - PE	12	10	PASS – No AR
+4000 V	270°	L/N - PE	12	10	PASS – No AR
–4000 V	270°	L/N - PE	12	10	PASS – No AR

16.2 230 VAC

230 VAC: 4 kV Surge Event

Surge Voltage	Phase Angle	IEC Coupling	Generator Impedance	Number of Strikes	Results
+4000 V	0°	L/N - PE	12	10	PASS – No AR
–4000 V	0°	L/N - PE	12	10	PASS – No AR
+4000 V	90°	L/N - PE	12	10	PASS – No AR
–4000 V	90°	L/N - PE	12	10	PASS – No AR
+4000 V	180°	L/N - PE	12	10	PASS – No AR
–4000 V	180°	L/N - PE	12	10	PASS – No AR
+4000 V	270°	L/N - PE	12	10	PASS – No AR
–4000 V	270°	L/N - PE	12	10	PASS – No AR

17 EFT

Tested at 230 VAC Input Voltage and Full Load

17.1 230 VAC

Surge Voltage	Injection Phase	Frequency	T-Burst	T-Rep	Test Duration	Injection Location	Remarks
+4000 V	0°	5 kHz	15 ms	300 ms	120 s	L1/L2	PASS – No AR
–4000 V	0°	5 kHz	15 ms	300 ms	120 s	L1/L2	PASS – No AR
+4000 V	0°	100 kHz	750 µs	300 ms	120 s	L1/L2	PASS – No AR
–4000 V	0°	100 kHz	750 µs	300 ms	120 s	L1/L2	PASS – No AR
+4000 V	90°	5 kHz	15 ms	300 ms	120 s	L1/L2	PASS – No AR
–4000 V	90°	5 kHz	15 ms	300 ms	120 s	L1/L2	PASS – No AR
+4000 V	90°	100 kHz	750 µs	300 ms	120 s	L1/L2	PASS – No AR
–4000 V	90°	100 kHz	750 µs	300 ms	120 s	L1/L2	PASS – No AR
+4000 V	180°	5 kHz	15 ms	300 ms	120 s	L1/L2	PASS – No AR
–4000 V	180°	5 kHz	15 ms	300 ms	120 s	L1/L2	PASS – No AR
+4000 V	180°	100 kHz	750 µs	300 ms	120 s	L1/L2	PASS – No AR
–4000 V	180°	100 kHz	750 µs	300 ms	120 s	L1/L2	PASS – No AR
+4000 V	270°	5 kHz	15 ms	300 ms	120 s	L1/L2	PASS – No AR
–4000 V	270°	5 kHz	15 ms	300 ms	120 s	L1/L2	PASS – No AR
+4000 V	270°	100 kHz	750 µs	300 ms	120 s	L1/L2	PASS – No AR
–4000 V	270°	100 kHz	750 µs	300 ms	120 s	L1/L2	PASS – No AR

18 Bode Plot

Tested at 115 VAC and 230 VAC input voltage and full load

18.1 115 VAC

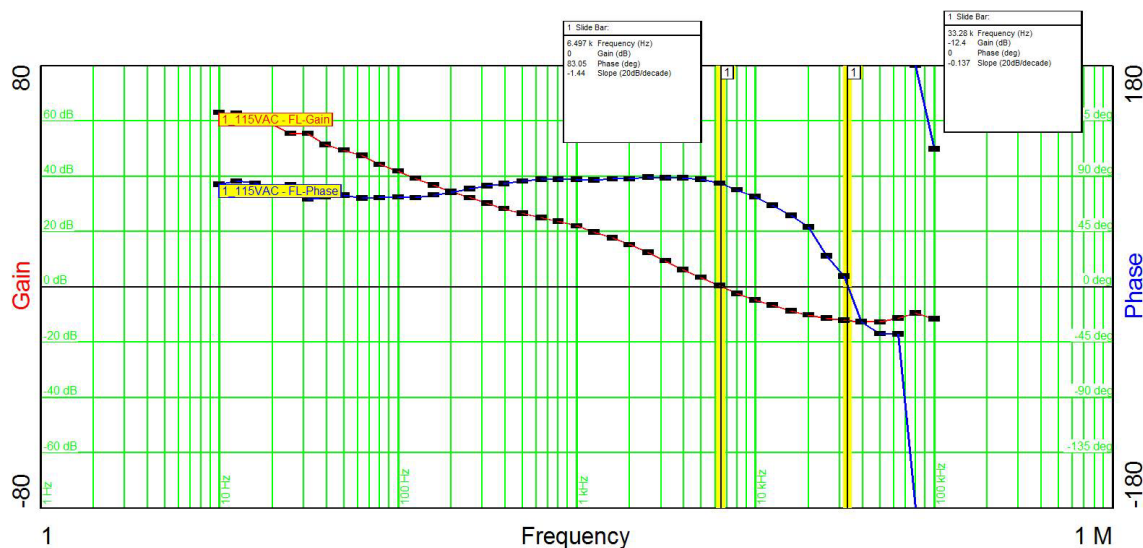


Figure 102 – 115 VAC 60 Hz, Full Load

$f_{\text{crossover}} = 6.50 \text{ kHz}$

Phase Margin = 83.1°

Gain Margin = 12.4 dB

18.2 230 VAC

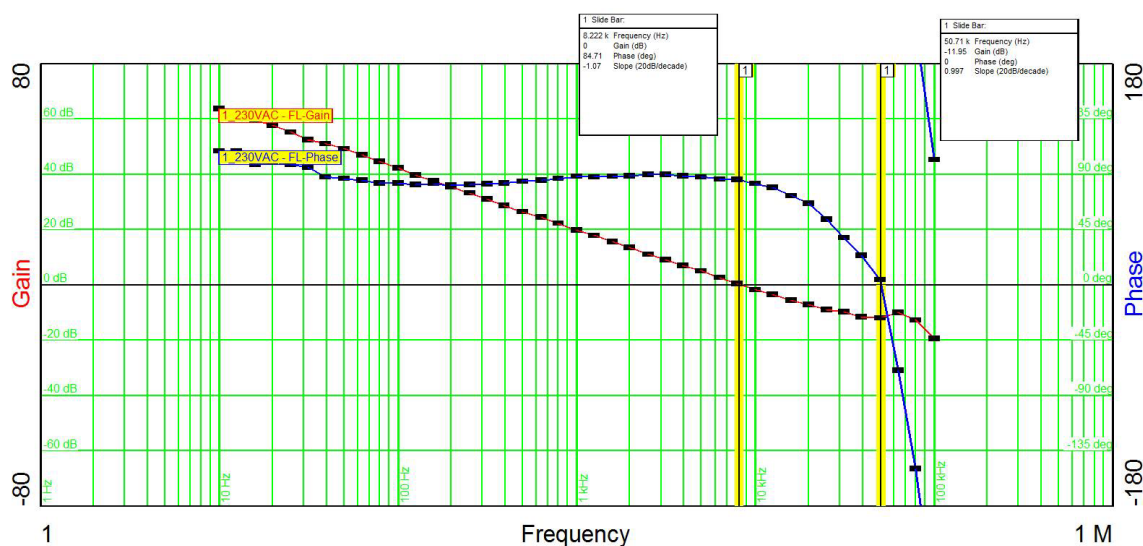


Figure 103 – 230 VAC 50 Hz, Full Load

$f_{\text{crossover}} = 8.22 \text{ kHz}$

Phase Margin = 84.7°

Gain Margin = 12.0 dB

19 Revision History

Date	Author	Revision	Description and Changes	Reviewed
4-June-25	JPM, JKB	A	Initial Release	Apps & Mktg.
12-Dec-25	JPM, JKB	B	Removed all ILIM selection as per PCN-25481.	Apps & Mktg.



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