Design Example 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	DER-1040
Date	February 6, 2025
Revision	A

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 Under Voltage Protection
    - Line Over Voltage Protection
    - Over Temperature Protection (OTP)
    - Short Circuit Protection
    - Over Power Protection.
- Class B Conducted EMI with > 6 dB margin.

Power Integrations
5245 Hellyer Avenue, San Jose, CA 95138 USA.
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www.power.com

Table of Contents

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.

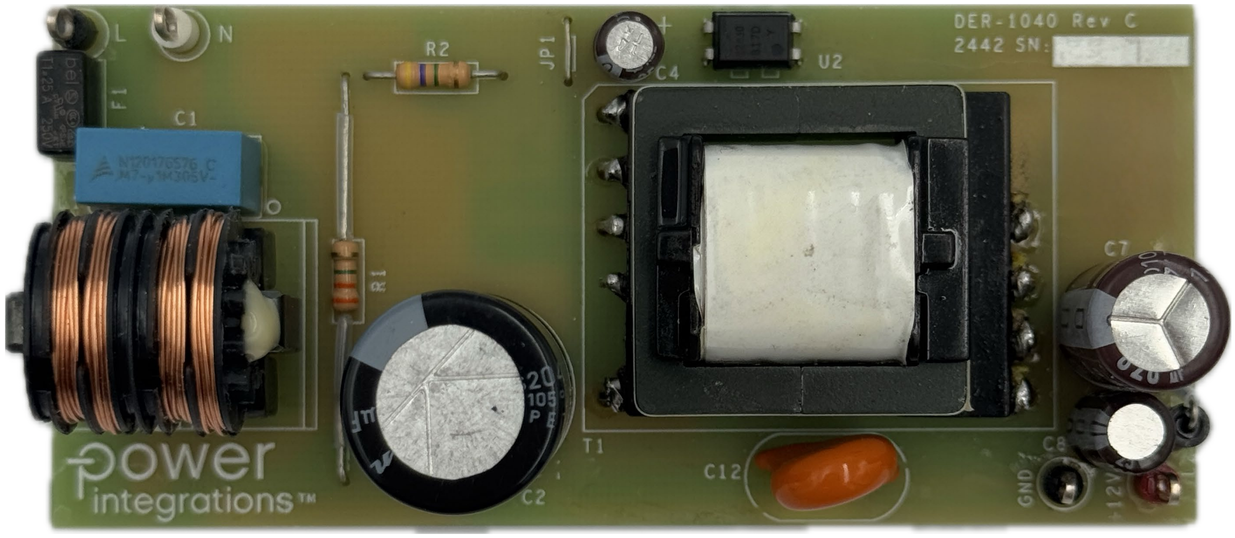


Figure 2 – Photograph, Top View.

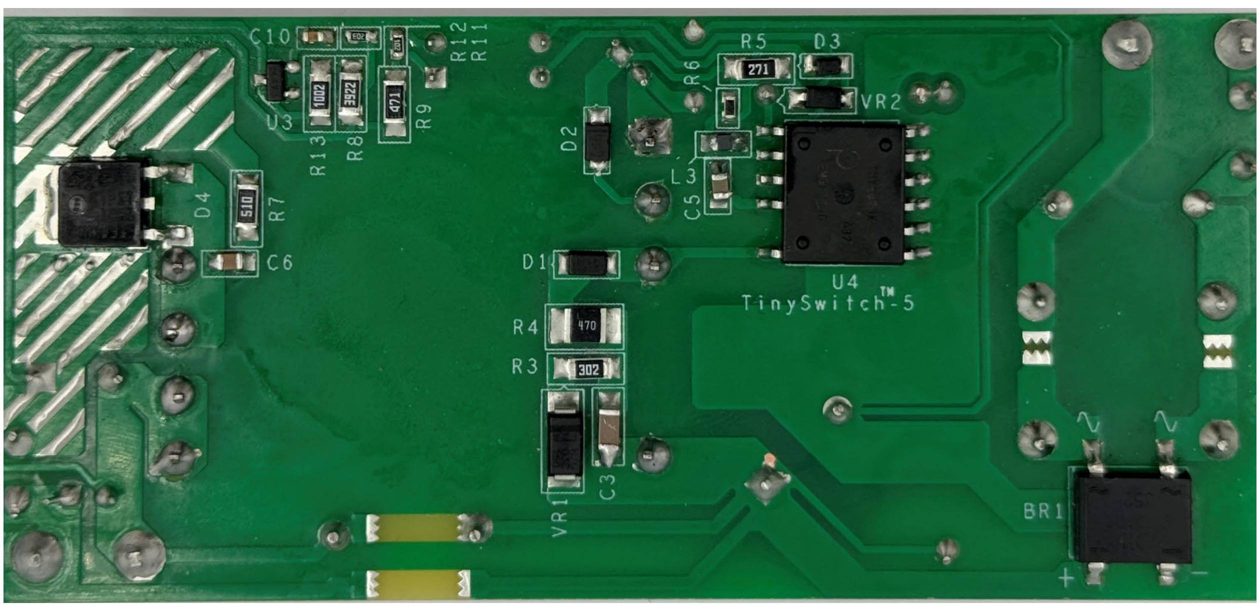


Figure 3 – Photograph, Bottom View.

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%
Output Ripple Voltage	$V_{RIPPLE1}$			150	mV	20 MHz Bandwidth.
Output Current	I_{OUT1}	0		3	A	
Total Output Power						
Continuous Output Power	P_{OUT}		36		W	
Efficiency						
Full Load 115Vac	$\eta_{115\ VAC}$	87			%	Measured at P_{OUT} 25 °C.
Full Load 230Vac	$\eta_{230\ VAC}$	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 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.

3 Schematic

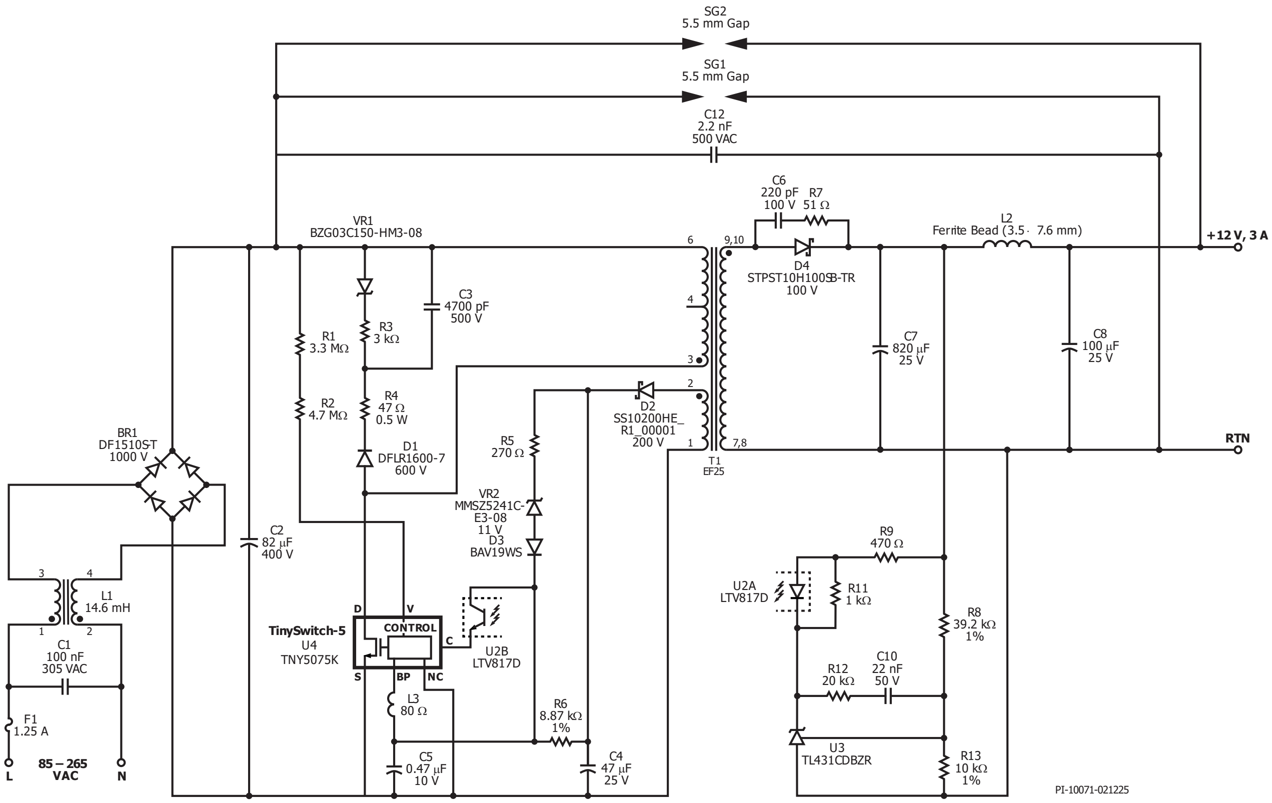


Figure 4 – Schematic

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. It regulates the output by adjusting the MOSFET off time duration, which is 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 monolithic 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 minimizing 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 shut down and enter auto-restart.

Bypass capacitor C5 serves as the selector for the maximum drain current (either standard or reduced) and is placed as close as possible to U4. C5 was used to select standard current limit of the IC. 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 diodes D4 rectify 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 or TL431CDBZR, is used to set the output voltage 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, ±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

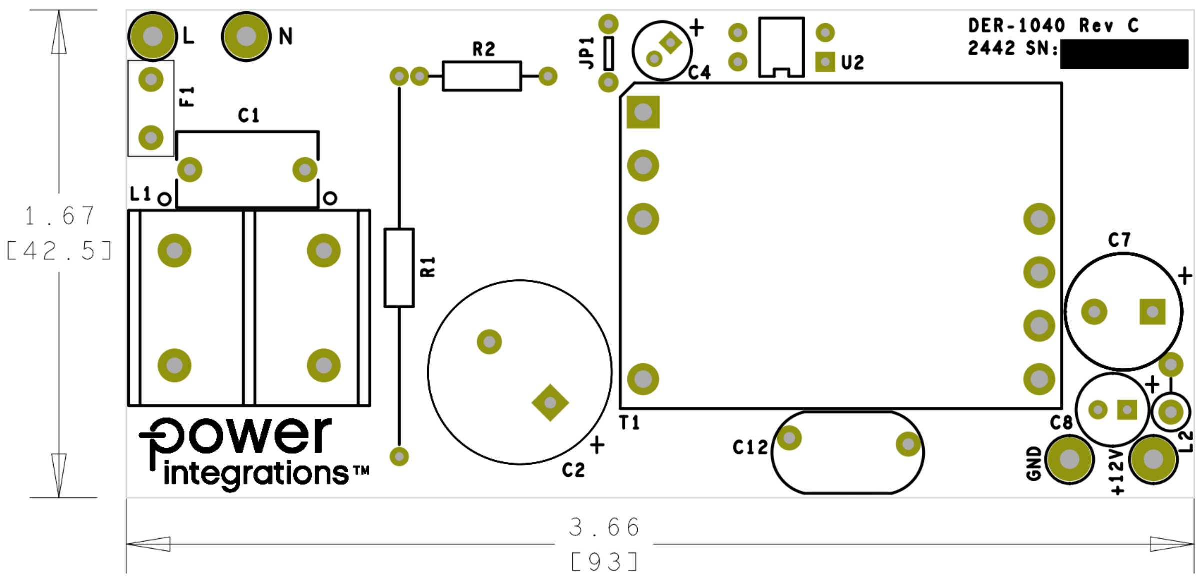


Figure 5 – Printed Circuit Board, Top View.

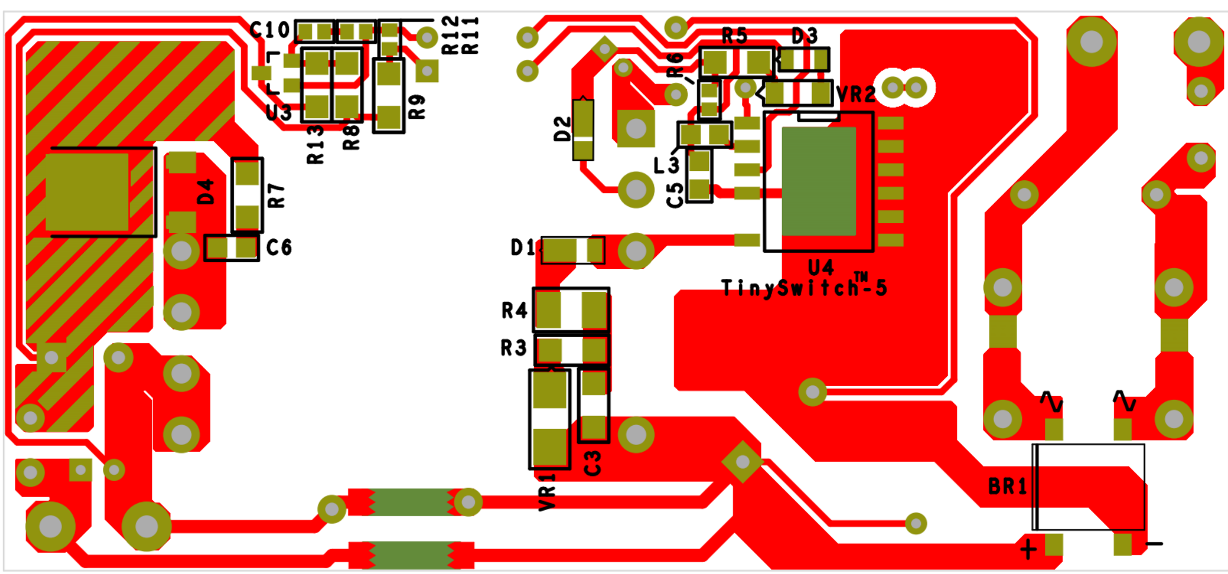


Figure 6 – Printed Circuit Board, Bottom View.

6 Bill of Materials

6.1 Electrical BOM

Item	Qty.	Ref Des	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 C0G, 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	STMicroelectro nics
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, ±5%, 0.75 W, 1210 (3225 Metric), Pulse Withstanding, Thick Film	CRCW121047R0JNEAHP	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, 39.2 k, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF3922V	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,±6%, Surface Mount, DO-214AC (SMA)	BZG03C150-HM3-08	Vishay Semiconductors
37	VR2	1	Zener Diode, 11 V, ±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

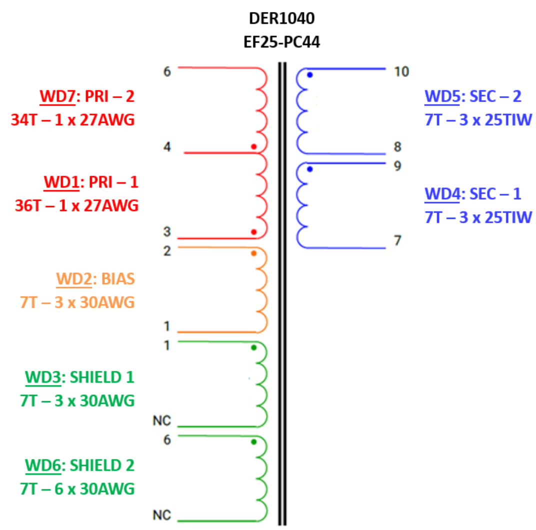


Figure 7 – Transformer Electrical Diagram.

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 µH
Tolerance	Tolerance of Primary Inductance.	±5%
Leakage Inductance	Measured across primary winding with all other windings shorted.	< 9.70 µH

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

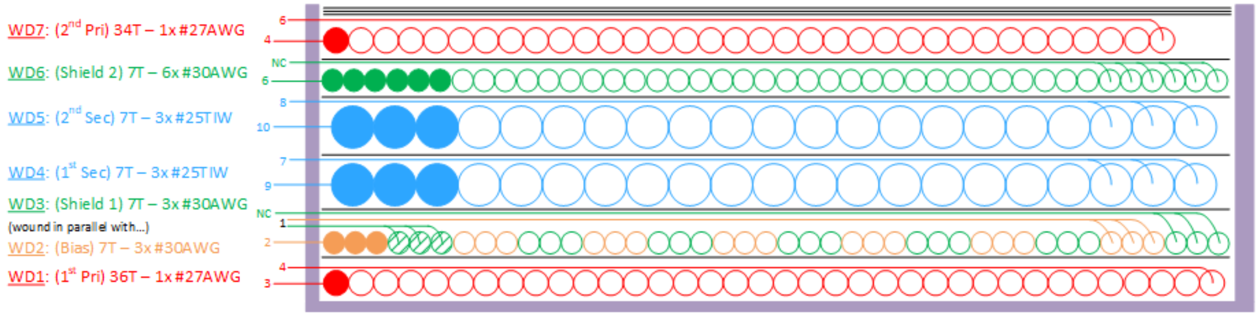


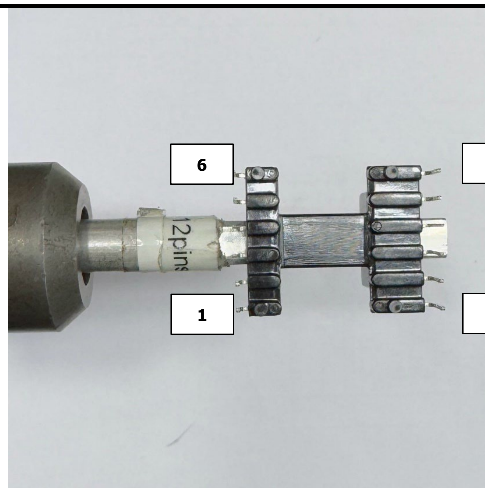
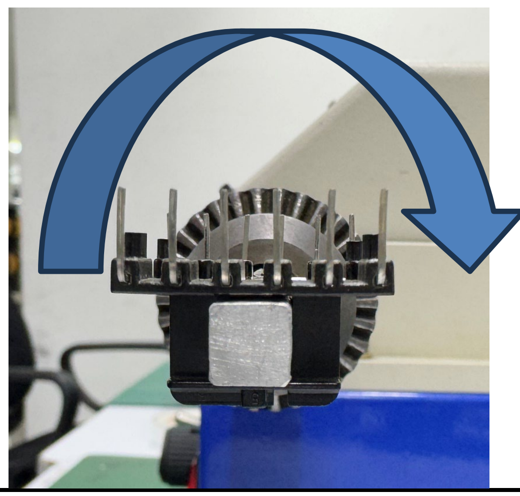
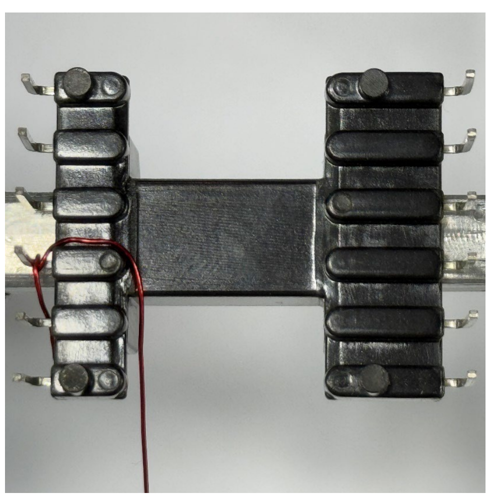
Figure 8 – Transformer Build Diagram.

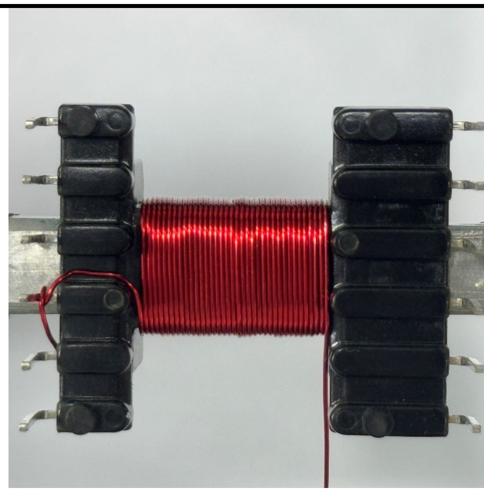
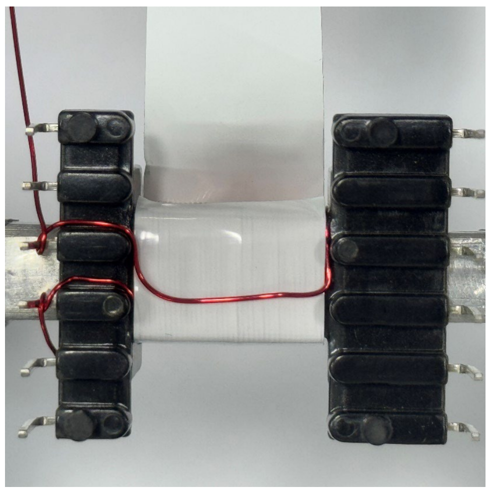
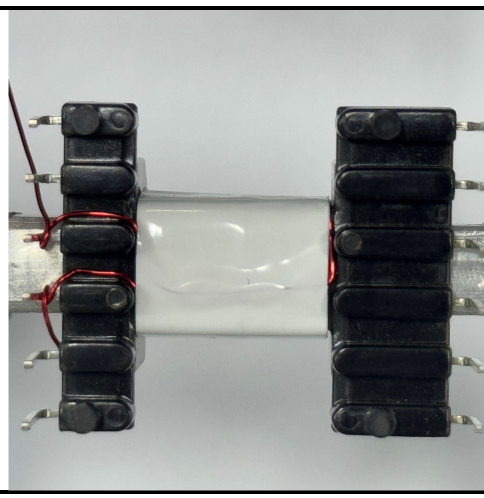
7.5 Transformer Instructions

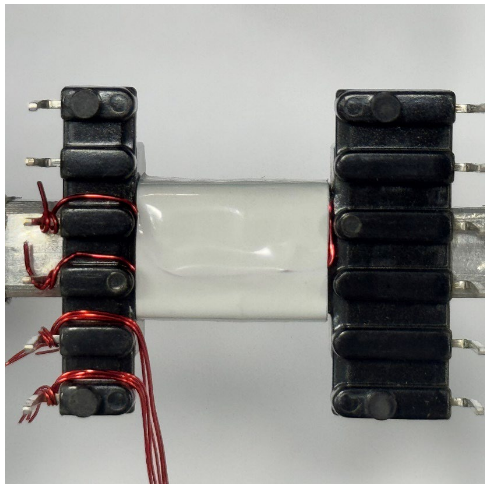
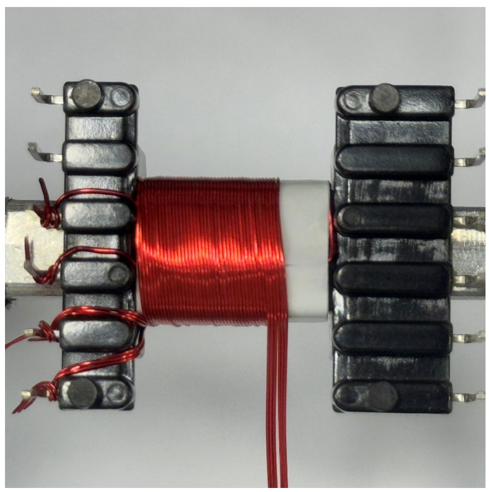
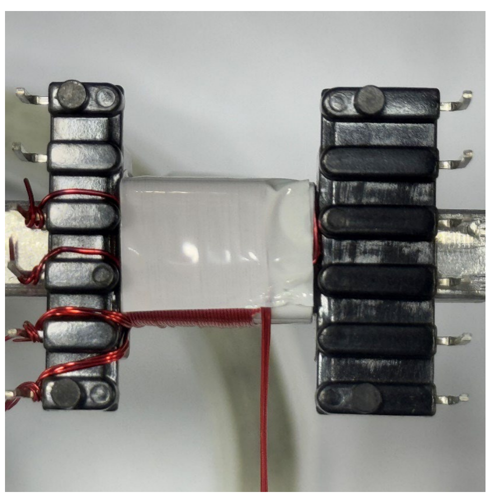
Preparation	Place the bobbin Item [2] such that pins 1-6 are on the left side while 7-12 are on right side. The shorter side signifies the side of Pin 1. Winding direction is clockwise as shown.
WD1 1st Primary	Prepare 1 strand of wire Item [5]. Start WD1 at pin 3. Wind 36 turns of wire Item [5] for 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 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.

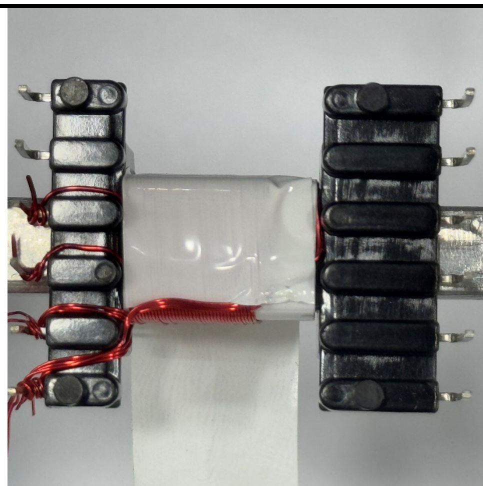
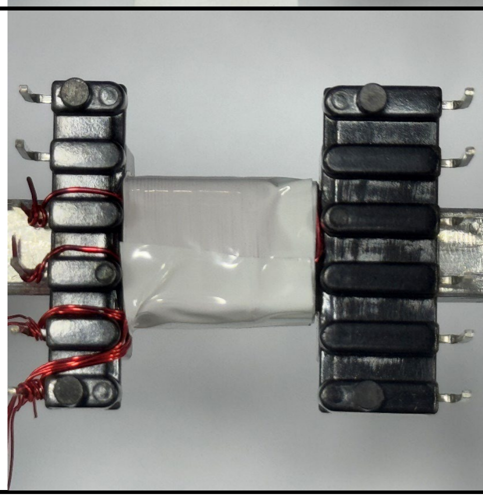
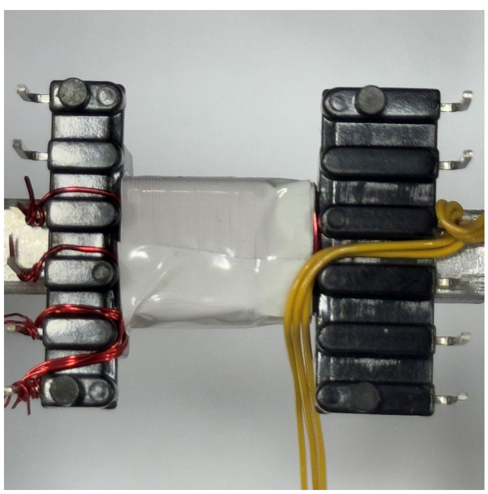
Finish	Varnish using Item [4]. Check Primary Inductance and Leakage Inductance to confirm that the varnished transformer is within specification.

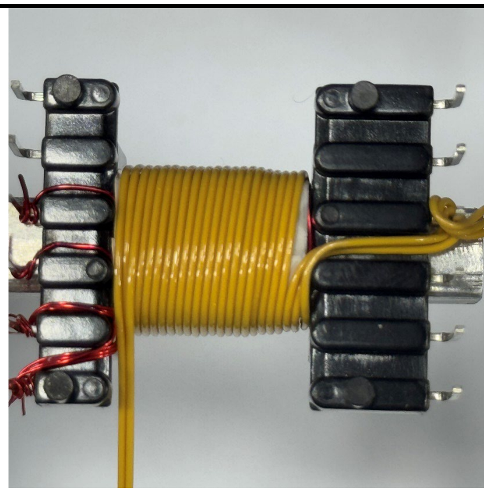
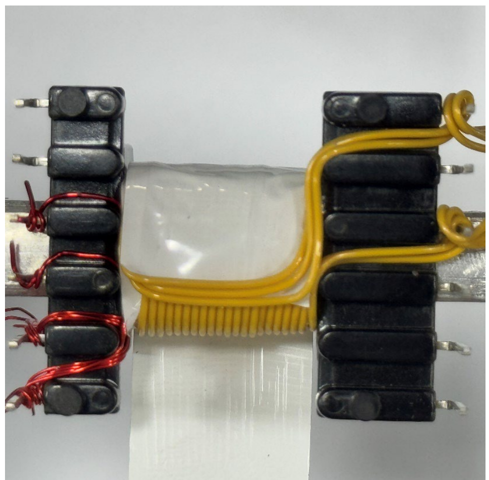
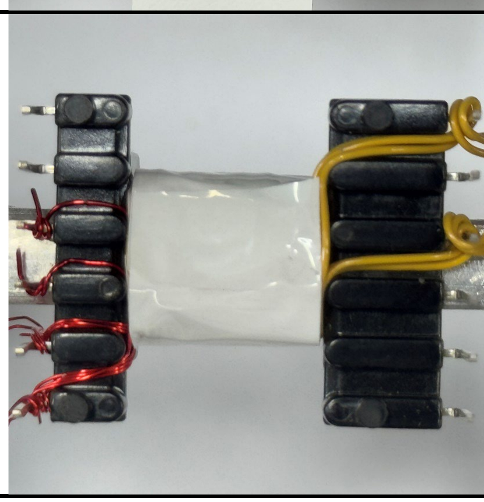
7.6 Transformer Winding Illustrations

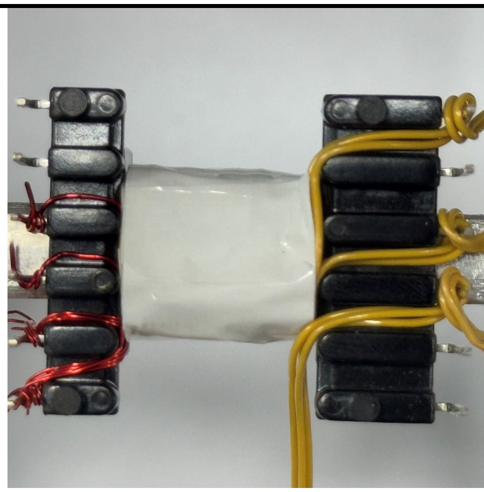
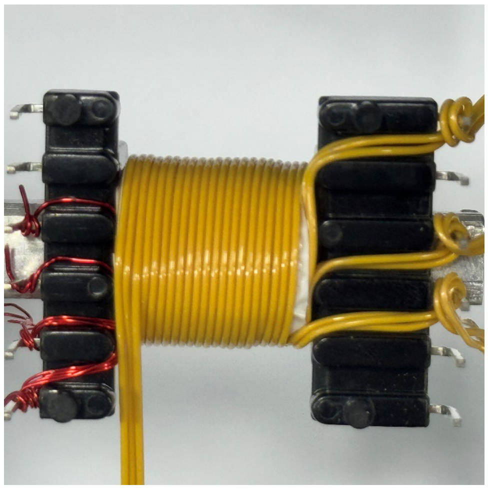
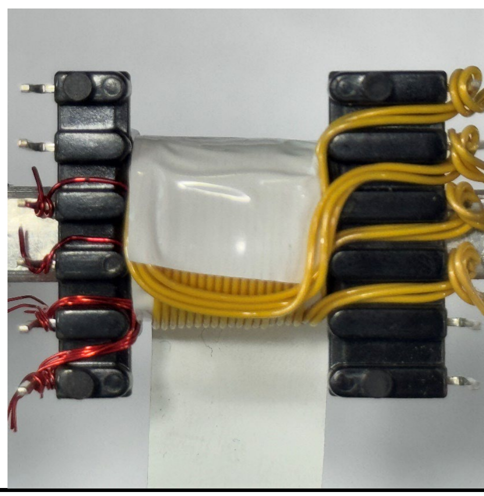
<table>
<tr><td rowspan="2">Preparation</td><td>
</td><td>Place the bobbin Item [2] such that pins 1-6 are on the left side while 7-12 are on right side. The shorter side signifies the side of Pin 1.</td></tr>
<tr><td></td><td>Winding direction is clockwise as shown.</td></tr>
<tr><td>WD1
1st Primary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

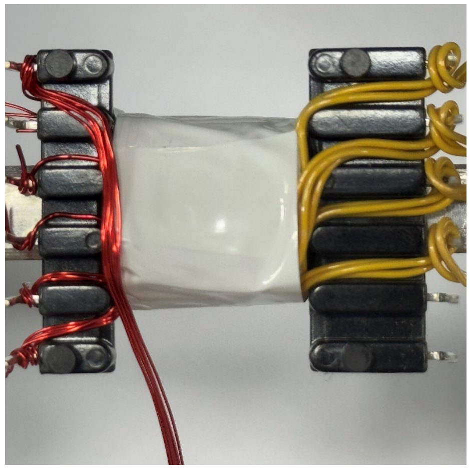
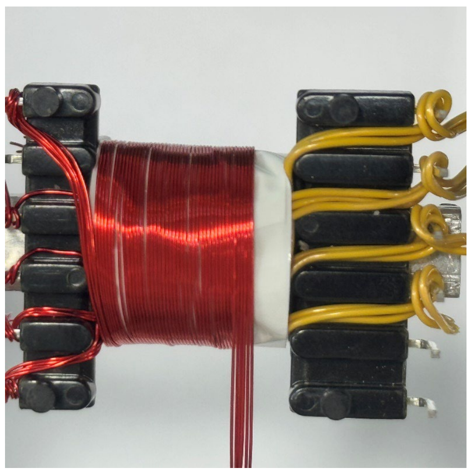
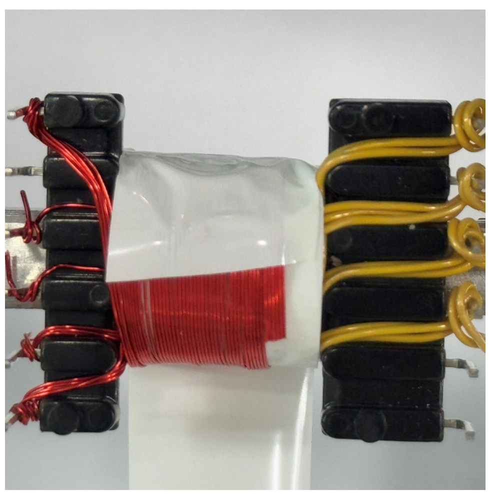
		Wind 36 turns of wire Item [5] for the first layer from left to right.
		Apply tape Item [6] to hold the winding. Finish WD1 on pin 4.
Insulation		Finish wrapping the tape for insulation and to cover WD1.

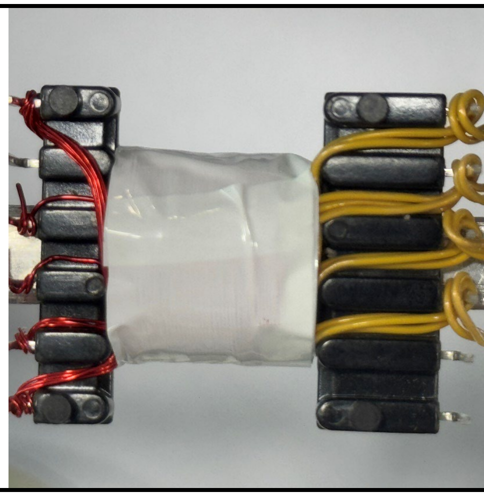
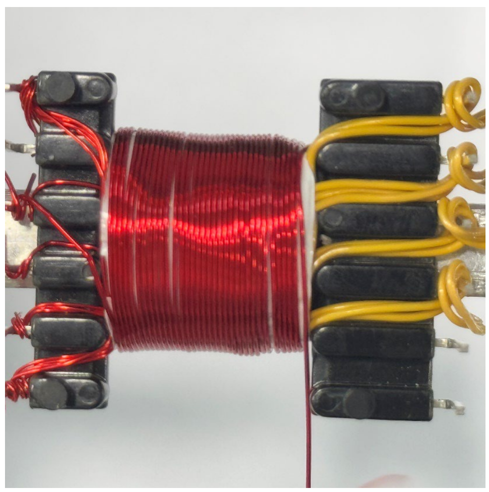
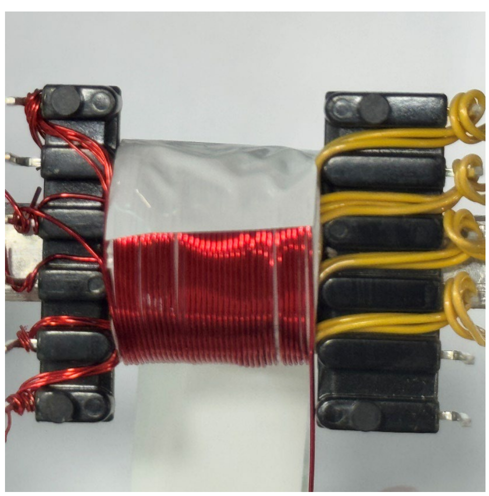
<table>
<tr><td rowspan="3">WD2 and WD3
Bias and 1st Shield</td><td></td><td>Prepare 3 strands of wire Item [7] for WD2 and another 3 strands of wire Item [7] for WD3.</td></tr>
<tr><td></td><td>Start WD2 at pin 2 and WD3 at pin 1, then wind them together for 7 turns from left to right.</td></tr>
<tr><td></td><td>Cut the excess wire from WD3 and leave it not connected. Use tape Item [6] to hold the wires in place.</td></tr>
</table>

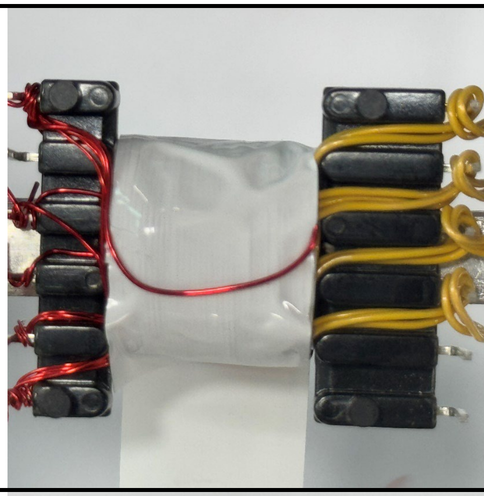
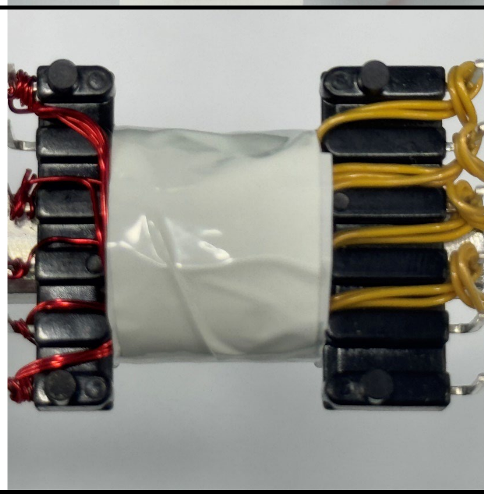
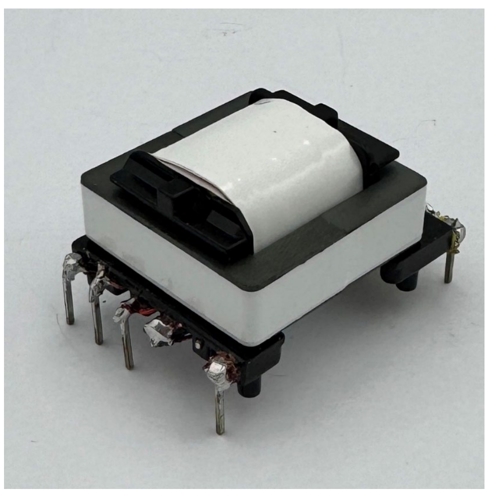
		Bend the end of WD2 by 90 degrees to finish it on pin 1.
Insulation		Finish wrapping the tape for insulation and to cover WD2 and WD3.
WD4 **1st Secondary**		Prepare 3 strands of wire Item [8] for WD4.

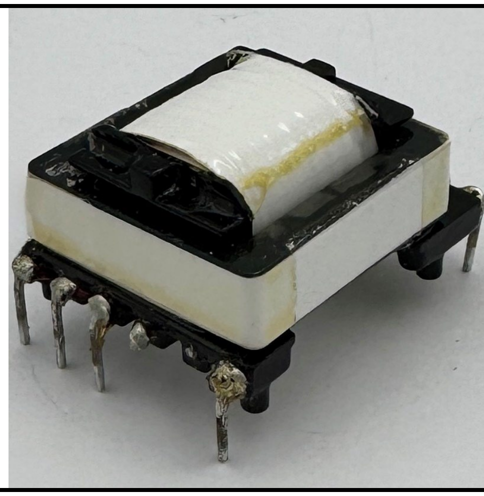
		Start WD4 at pin 9, and wind 7 turns from right to left.
		Apply 1 layer of tape Item [6] for insulation and to hold wires in place. Bend the end of WD4 90 degrees then finish WD2 on pin 7.
Insulation		Finish wrapping the tape to cover and insulate WD4.

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.

<table>
<tr><td rowspan="3">WD6
2nd Shield</td><td></td><td>Prepare 6 strands of wire Item [7]. Start WD6 at pin 6.</td></tr>
<tr><td></td><td>Wind 7 turns from left to right to finish WD6.</td></tr>
<tr><td></td><td>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.</td></tr>
</table>

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.

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	ILIMIT_MODE	STANDARD		STANDARD		Device current limit mode
21	PACKAGE_DEVICE	eSOP		eSOP		Device Package
22	DEVICE_CODE			TNY5075K		Actual device code
23	POUT_MAX			45	W	Power capability of the device based on thermal performance
24	RDSON_100DEG			3.10	Ω	Primary switch on time drain resistance at 100 degC
25	ILIMIT_MIN			1.104	A	Minimum current limit of the primary switch
26	ILIMIT_TYP			1.200	A	Typical current limit of the primary switch
27	ILIMIT_MAX			1.296	A	Maximum current limit of the primary switch
28	VDRAIN_BREAKDOWN			725	V	Device breakdown voltage
29	VDRAIN_ON_PRSW			1.37	V	Primary switch on time drain voltage
30	VDRAIN_OFF_PRSW			528.4	V	Peak drain voltage on the primary switch during turn-off. A 30V leakage spike voltage is assumed
31						
32						
33						
34	WORST CASE ELECTRICAL PARAMETERS					
35	FSWITCHING_MAX	84700		84700	Hz	Maximum switching frequency at full load and valley of the rectified minimum AC input voltage.
36	VOR	125.0		125.0	V	Secondary voltage reflected to the primary when the primary switch turns off
37	VMIN			89.19	V	Valley of the minimum input AC voltage at full load

38	KP			0.60		Measure of continuous/discontinuous mode of operation
39	MODE_OPERATION			CCM		Mode of operation
40	DUTYCYCLE			0.587		Primary switch duty cycle
41	TIME_ON			13.50	us	Primary switch on-time
42	TIME_ON_AT_FSWITCHING_MAX			6.93	us	Primary switch on-time at FSWITCHING_MAX
43	TIME_OFF			4.87	us	Primary switch off-time at 85VAC, 36W, and 84700Hz.
44	LPRIMARY_MIN			921.2	uH	Minimum primary inductance
45	LPRIMARY_TYP			969.7	uH	Typical primary inductance
46	LPRIMARY_TOL	5.0		5.0	%	Primary inductance tolerance
47	LPRIMARY_MAX			1018.2	uH	Maximum primary inductance
48						
49	PRIMARY CURRENT					
50	IPEAK_PRIMARY			1.216	A	Primary switch peak current
51	IPEDESTAL_PRIMARY			0.434	A	Primary switch current pedestal
52	IAVG_PRIMARY			0.443	A	Primary switch average current
53	IRIPPLE_PRIMARY			0.923	A	Primary switch ripple current
54	IRMS_PRIMARY			0.613	A	Primary switch RMS current
55						
56	SECONDARY CURRENT					
57	IPEAK_SECONDARY			12.161	A	Secondary winding peak current
58	IPEDESTAL_SECONDARY			4.335	A	Secondary winding current pedestal
59	IRMS_SECONDARY			5.141	A	Secondary winding RMS current
60						
61						
62						
63	TRANSFORMER CONSTRUCTION PARAMETERS					
64	CORE SELECTION					
65	CORE	Custom		Custom		Core selection. Refer to the 'Transformer Construction' tab to see the detailed report
66	CORE CODE	PC44EF25-Z		PC44EF25-Z		Core code
67	AE	51.80		51.80	mm^2	Core cross sectional area
68	LE	57.80		57.80	mm	Core magnetic path length
69	AL	2000		2000	nH/turns^2	Ungapped core effective inductance
70	VE	290.0		290.0	mm^3	Core volume
71	BOBBIN	EF25 Vertical		EF25 Vertical		Bobbin
72	AW	61.00		61.00	mm^2	Window area of the bobbin
73	BW	15.90		15.90	mm	Bobbin width
74	MARGIN			0.0	mm	Safety margin width (Half the primary to secondary creepage distance)
75						
76	PRIMARY WINDING					
77	NPRIMARY			70		Primary turns
78	BPEAK			3757	Gauss	Peak flux density
79	BMAX			3374	Gauss	Maximum flux density

80	BAC			1255	Gauss	AC flux density (0.5 x Peak to Peak)
81	ALG			198	nH/turns^2	Typical gapped core effective inductance
82	LG			0.296	mm	Core gap length
83						
84	PRIMARY BIAS WINDING					
85	NBIAS_PRIMARY			7	turns	Primary bias winding number of turns
86						
87	SECONDARY WINDING					
88	NSECONDARY	7		7	turns	Secondary winding number of turns
89						
90	SECONDARY BIAS WINDING					
91	NBIAS_SECONDARY			NA	turns	Secondary bias winding number of turns
92						
93						
94						
95	PRIMARY COMPONENTS SELECTION					
96	LINE UNDERVOLTAGE					
97	BROWN-IN REQURED			76.08	V	Required AC RMS/DC line voltage brown-in threshold
98	RLS			8.04	MΩ	Connect two 4.02 MOhm resistors to the V-pin for the required UV/OV threshold
99	BROWN-IN ACTUAL			63.5 - 78.6	V	Actual AC RMS/DC brown-in range
100	BROWN-OUT ACTUAL			55 - 67.9	V	Actual AC RMS/DC brown-out range
101						
102	LINE OVERVOLTAGE					
103	OVERVOLTAGE_LINE			285.4 - 355.2	V	Actual AC RMS/DC line over-voltage range
104						
105	PRIMARY BIAS DIODE					
106	VBIAS_PRIMARY	11.0		11.0	V	Rectified primary bias voltage
107	VF_BIAS_PRIMARY			0.70	V	Bias winding diode forward drop
108	VREVERSE_BIASDIODE_PRIMARY			49.34	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
109	CBIAS_PRIMARY			47	uF	Bias winding rectification capacitor
110	CBP			0.47	uF	BP pin capacitor
111						
112						
113						
114	SECONDARY COMPONENTS					
115	VREF_REG	2.50		2.50	V	Reference voltage of the feedback
116	RFB_UPPER			38.30	kΩ	Upper feedback resistor (connected to the first output voltage)
117	RFB_LOWER			10.00	kΩ	Lower feedback resistor
118						
119	SECONDARY BIAS DIODE					
120	USE_SECONDARY_BIAS	AUTO		NO		Use secondary bias winding for the design
121	VBIAS_SECONDARY			NA	V	Rectified secondary bias voltage
122	VF_BIAS_SECONDARY			NA	V	Bias winding diode forward drop

123	VREVERSE_BIASDIODE_SECONDARY			NA	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
124	CBIAS_SECONDARY			NA	uF	Bias winding rectification capacitor
125						
126						
127	MULTIPLE OUTPUT PARAMETERS					
128	OUTPUT 1					
129	VOUT1			12.00	V	Output 1 voltage
130	IOUT1			3.00	A	Output 1 current
131	POUT1			36.00	W	Output 1 power
132	VD1	0.55		0.55	V	Forward voltage drop of diode for output 1
133	NS1			7.00	turns	Number of turns for output 1
134	ISPEAK1			12.16	A	Instantaneous peak value of the secondary current for output 1
135	ISRMS1			5.141	A	Root-mean-squared value of the secondary current for output 1
136	ISRIPPLE1			4.175	A	Current ripple on the secondary waveform for output 1
137	PIV1_CALCULATED			59.04	V	Computed peak inverse voltage stress on the diode for output 1
138	OUTPUT_RECTIFIER1	AUTO		MBR1060		Recommended diode for output 1.
139	PIV1_RATING			60.00	V	Peak inverse voltage rating on the diode for output 1
140	TRR1			0.00	ns	Reverse recovery time of the diode for output 1
141	IFM1			10.00	A	Maximum forward continuous current of the diode for output 1
142	PLOSS_DIODE1			1.89	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.

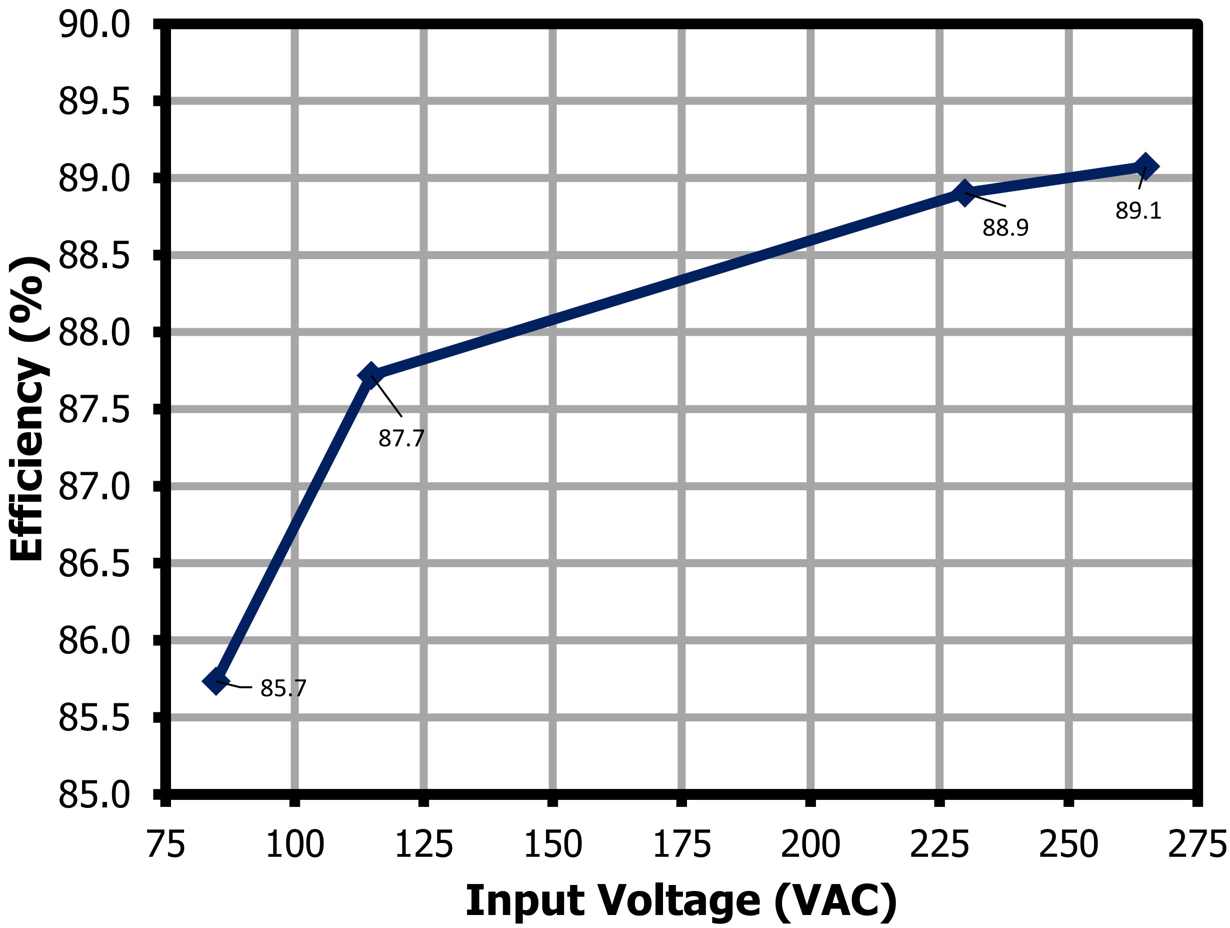


Figure 9 – Efficiency vs. Input Voltage.

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	84.7	873	43.1	12.3	3000	37	2.73	85.7
115	60	115	702	42.2	12.3	3000	37	2.74	87.7
230	50	230	462	41.6	12.3	3000	37	2.73	88.9
265	50	265	428	41.5	12.3	3000	37	2.73	89.1

9.2 Efficiency vs. Load

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

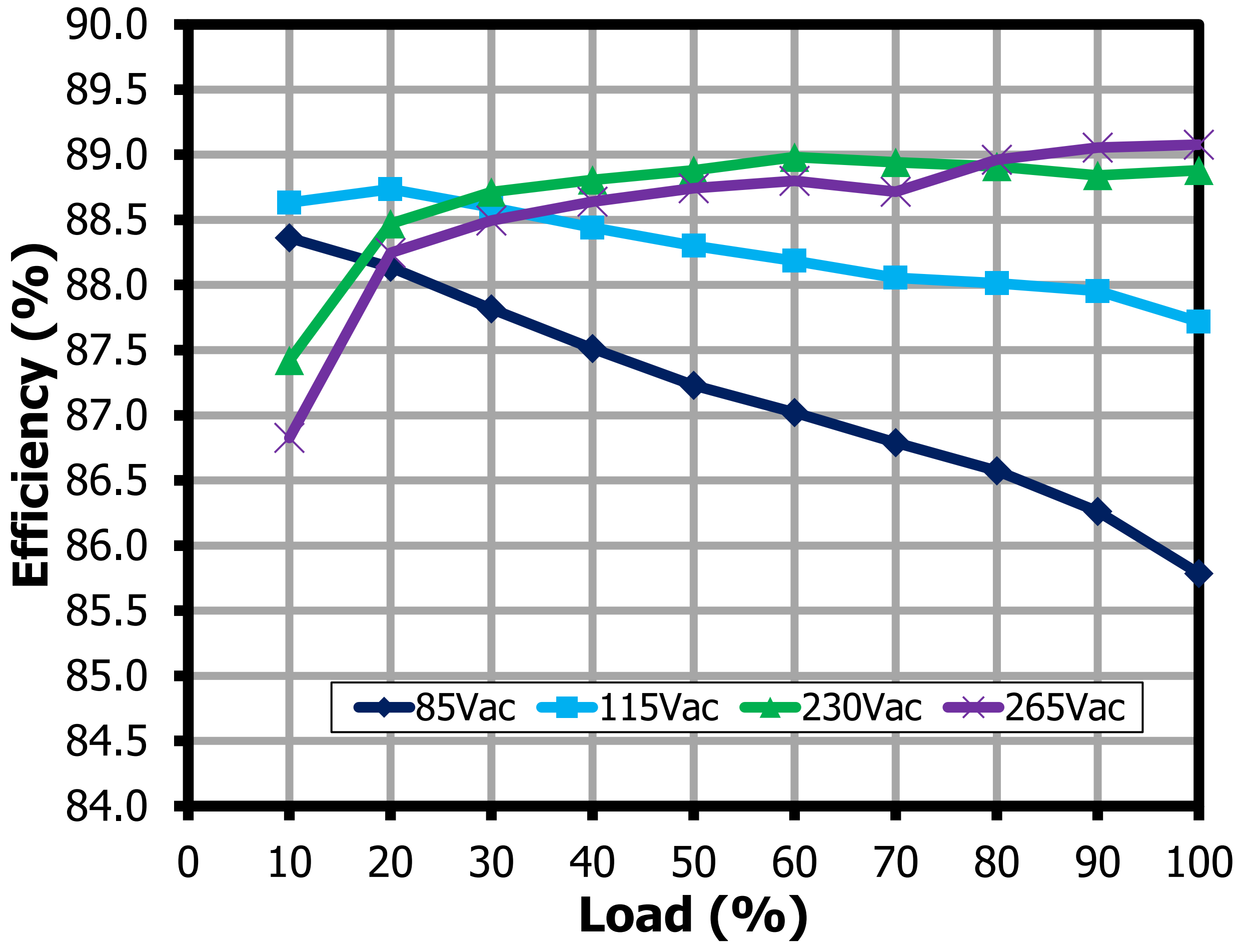


Figure 10 – Efficiency vs. Percentage Load.

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	84.7	872	43.1	12.3	3000	37	2.74	85.8
85	60	84.8	793	38.6	12.3	2700	33.3	2.77	86.3
85	60	84.8	716	34.2	12.3	2400	29.6	2.79	86.6
85	60	84.8	640	29.9	12.3	2100	25.9	2.81	86.8
85	60	84.8	563	25.5	12.3	1800	22.2	2.82	87.0
85	60	84.8	486	21.2	12.3	1500	18.5	2.83	87.2
85	60	84.9	406	16.9	12.3	1200	14.8	2.84	87.5
85	60	84.9	324	12.7	12.3	900	11.1	2.85	87.8
85	60	84.9	236	8.40	12.3	600	7.41	2.87	88.1
85	60	84.9	138	4.19	12.3	300	3.71	2.87	88.4
85	60	84.9	51.9	0.04	12.3		0.00	2.85	

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	702	42.2	12.3	3000	37	2.74	87.7
115	60	115	644	37.9	12.3	2700	33.3	2.77	88.0
115	60	115	587	33.6	12.3	2400	29.6	2.78	88.0
115	60	115	528	29.4	12.3	2100	25.9	2.80	88.1
115	60	115	468	25.2	12.3	1800	22.2	2.81	88.2
115	60	115	406	21.0	12.3	1500	18.5	2.83	88.3
115	60	115	341	16.7	12.3	1200	14.8	2.83	88.4
115	60	115	273	12.5	12.3	900	11.1	2.84	88.6
115	60	115	199	8.35	12.3	600	7.41	2.86	88.7
115	60	115	122	4.18	12.3	300	3.70	2.87	88.6
115	60	115	69.5	0.04	12.34		0.00	2.83	

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	462	41.6	12.3	3000	37.0	2.73	88.9
230	50	230	427	37.5	12.3	2700	33.3	2.73	88.8
230	50	230	391	33.3	12.3	2400	29.6	2.76	88.9
230	50	230	353	29.1	12.3	2100	25.9	2.77	88.9
230	50	230	314	25.0	12.3	1800	22.2	2.79	89.0
230	50	230	274	20.8	12.3	1500	18.5	2.81	88.9
230	50	230	233	16.7	12.3	1200	14.8	2.83	88.8
230	50	230	191	12.5	12.3	900	11.1	2.84	88.7
230	50	230	153	8.37	12.3	600	7.41	2.85	88.5
230	50	230	114	4.24	12.3	300	3.70	2.86	87.4
230	50	230	105	0.08	12.3		0.00	2.83	

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	428	41.5	12.3	3000	37.0	2.73	89.1
265	50	265	394	37.4	12.3	2700	33.3	2.74	89.1
265	50	265	360	33.3	12.3	2400	29.6	2.75	89.0
265	50	265	324	29.2	12.3	2100	25.9	2.77	88.7
265	50	265	288	25.0	12.3	1800	22.2	2.78	88.8
265	50	265	251	20.9	12.3	1500	18.5	2.80	88.7
265	50	265	214	16.7	12.3	1200	14.8	2.82	88.6
265	50	265	177	12.6	12.3	900	11.1	2.83	88.5
265	50	265	143	8.39	12.3	600	7.40	2.85	88.3
265	50	265	109	4.27	12.34	300	3.70	2.87	86.8
265	50	265	93.3	0.08	12.34		0.00	2.83	

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%	42.2	12.3	3000	37.0	87.7	**88.0**	**87.4**
75%	31.6	12.3	2250	27.8	87.9		
50%	21.0	12.3	1500	18.5	88.2		
25%	10.5	12.3	750	9.26	88.5		
10%	4.19	12.3	300	3.70	88.3	---	---

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%	41.6	12.3	3000	37.0	88.9	**88.7**	**87.4**
75%	31.3	12.3	2250	27.8	88.8		
50%	20.8	12.3	1500	18.5	88.8		
25%	10.5	12.3	750	9.26	88.5		
10%	4.25	12.3	300	3.70	87.2	---	---

9.4 No-Load Input Power

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

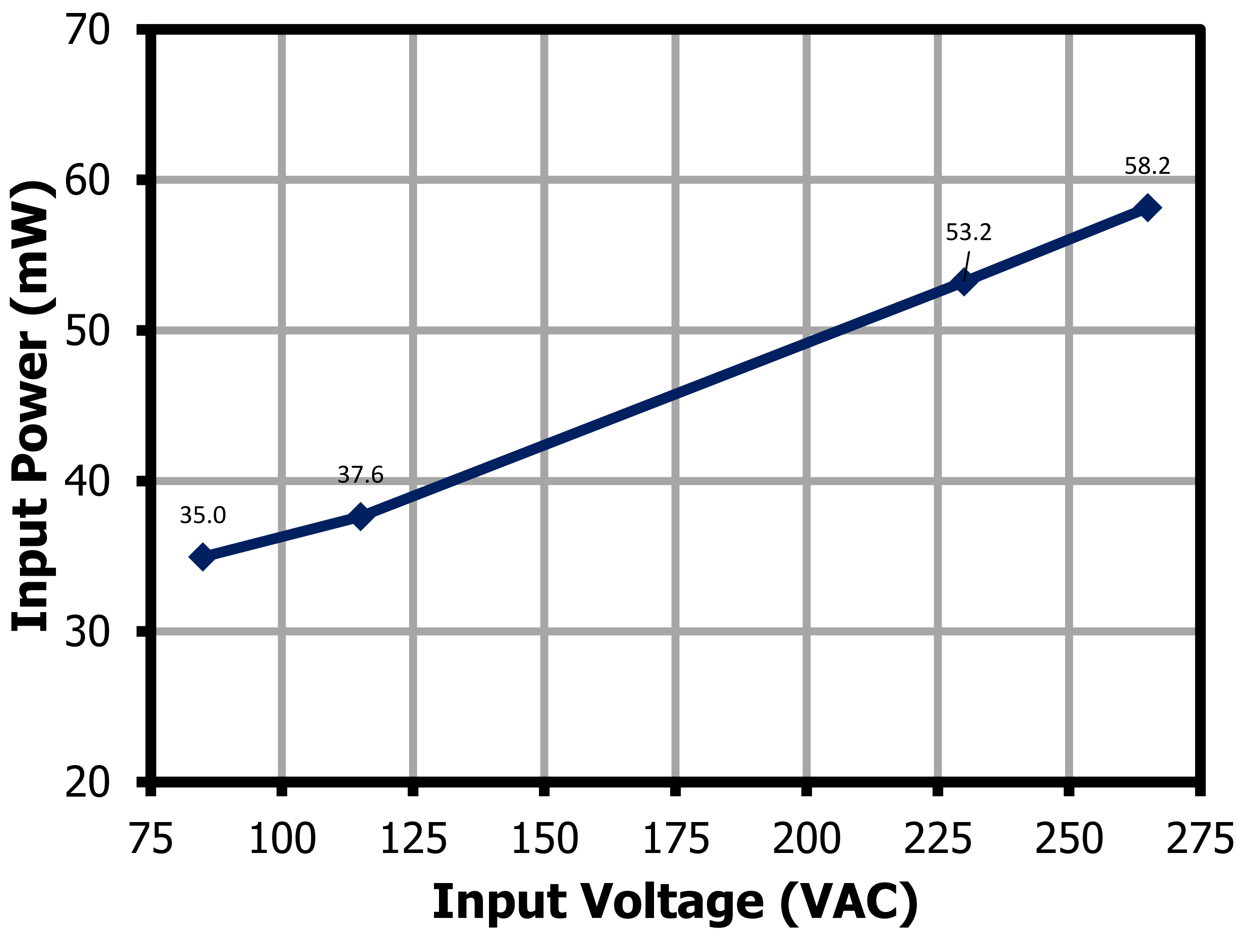


Figure 11 – No-Load Input Power vs. Line at Room Temperature.

VAC	**No Load P_{IN}**
(RMS)	**(mW)**
85	35.0
115	37.6
230	53.2
265	58.2

9.5 Line Regulation

Test Condition: Soak for 15 minutes for each line.

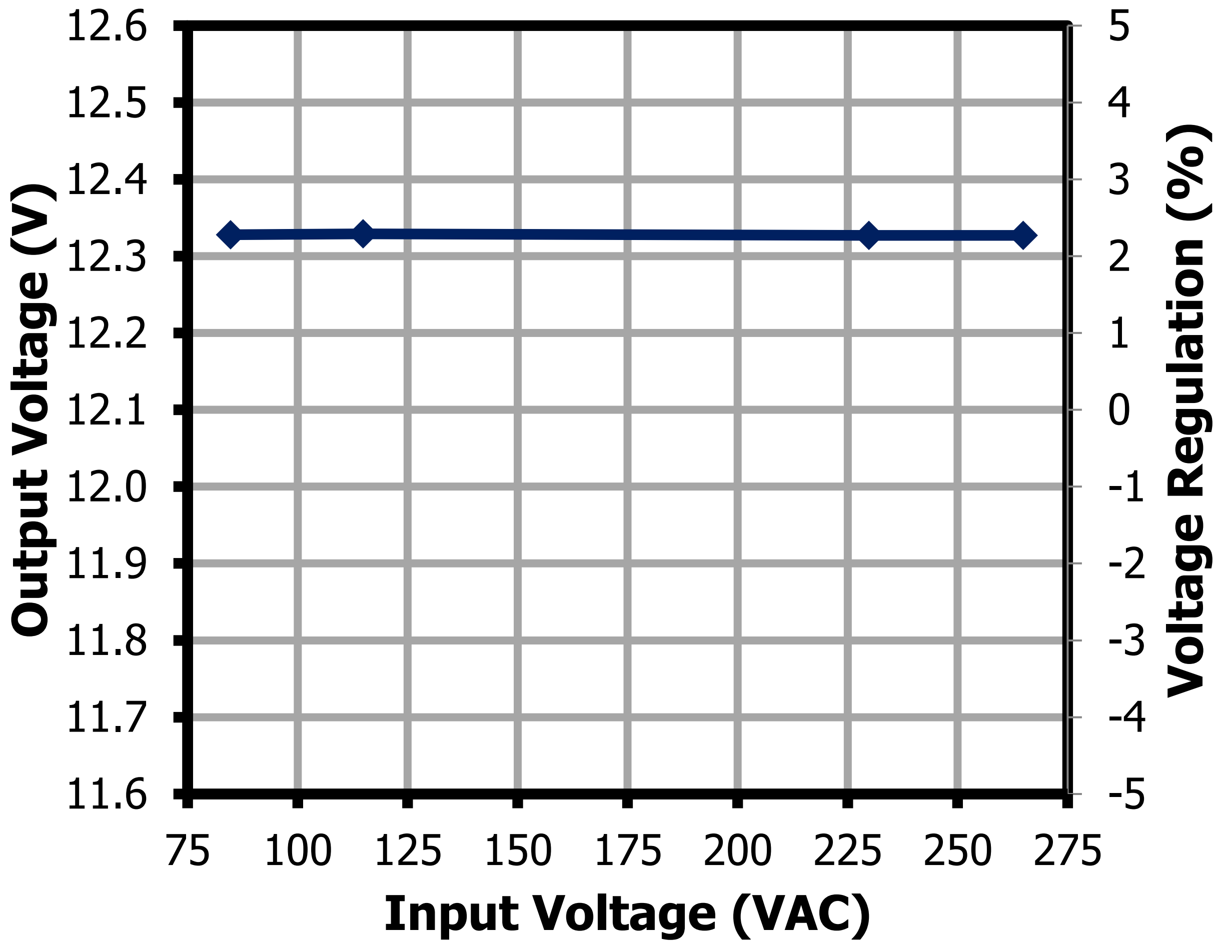


Figure 12 – Output Voltage vs. Line Voltage.

9.6 Load Regulation

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

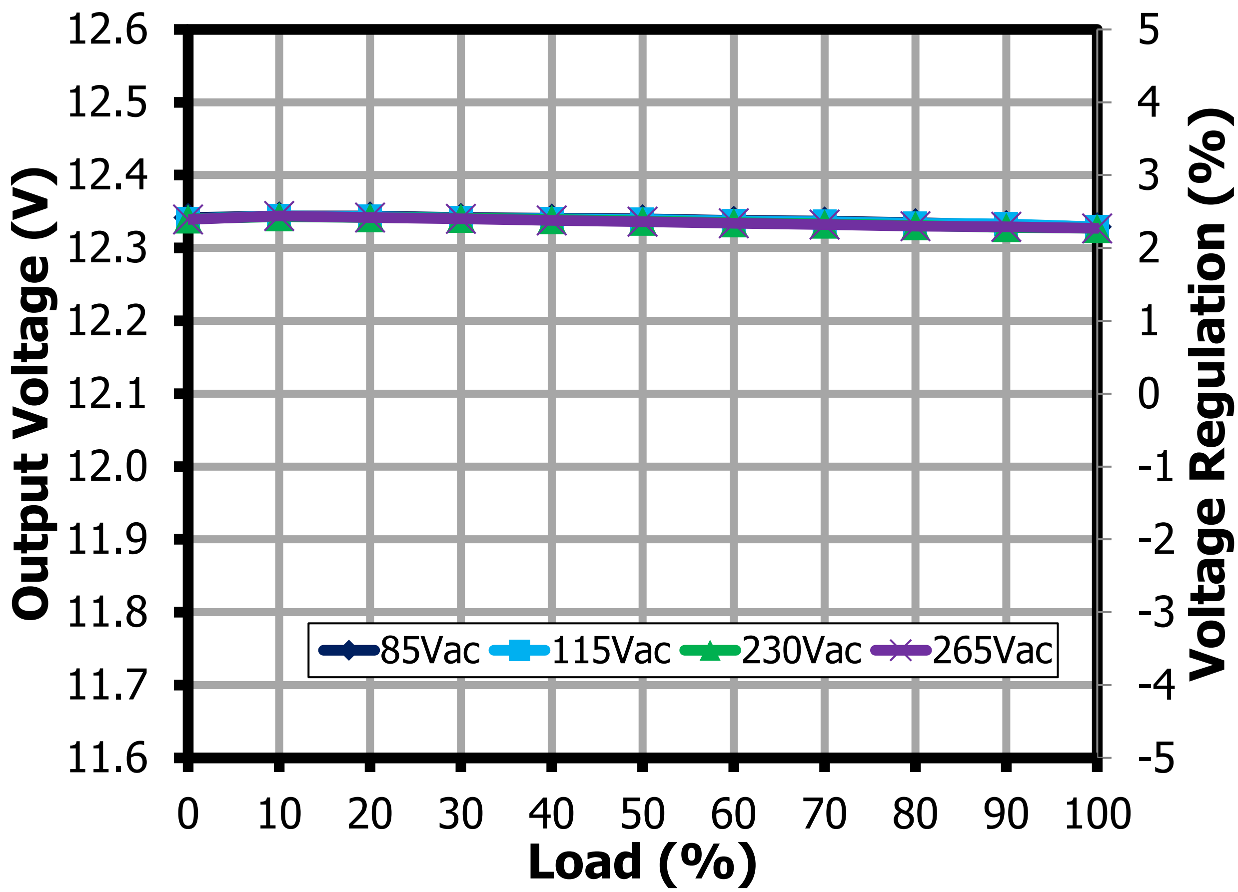


Figure 13 – Output Voltage vs. Percent Load.

9.7 Standby Efficiency

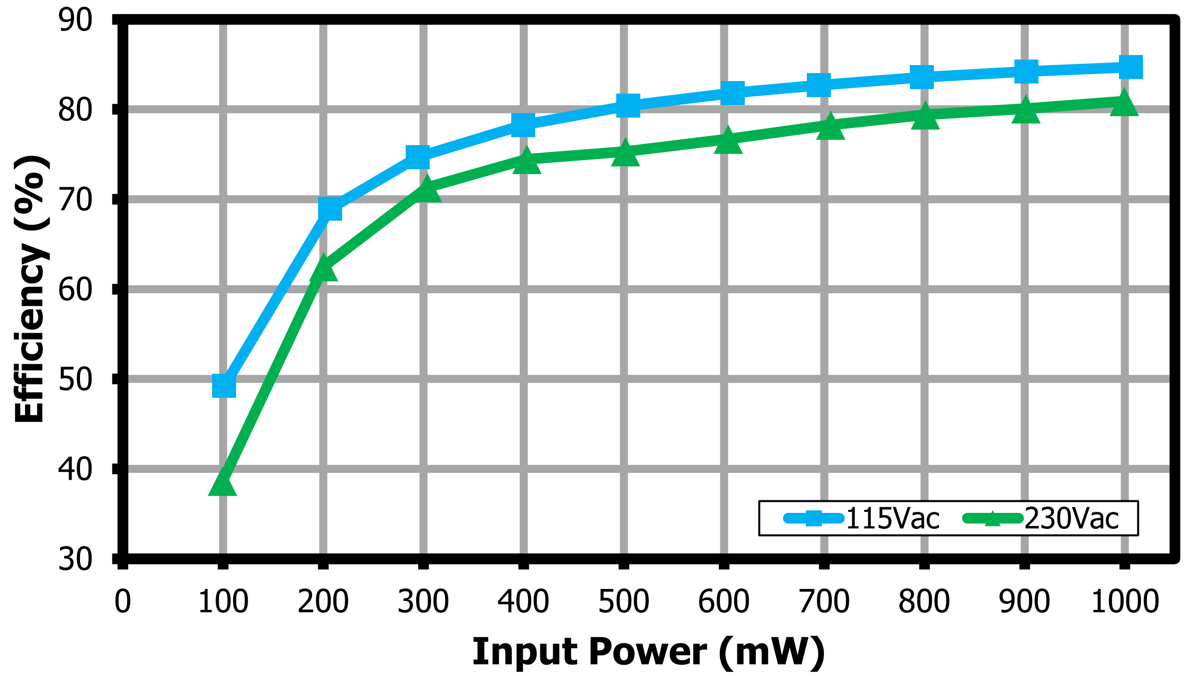


Figure 14 – Efficiency vs Input Power

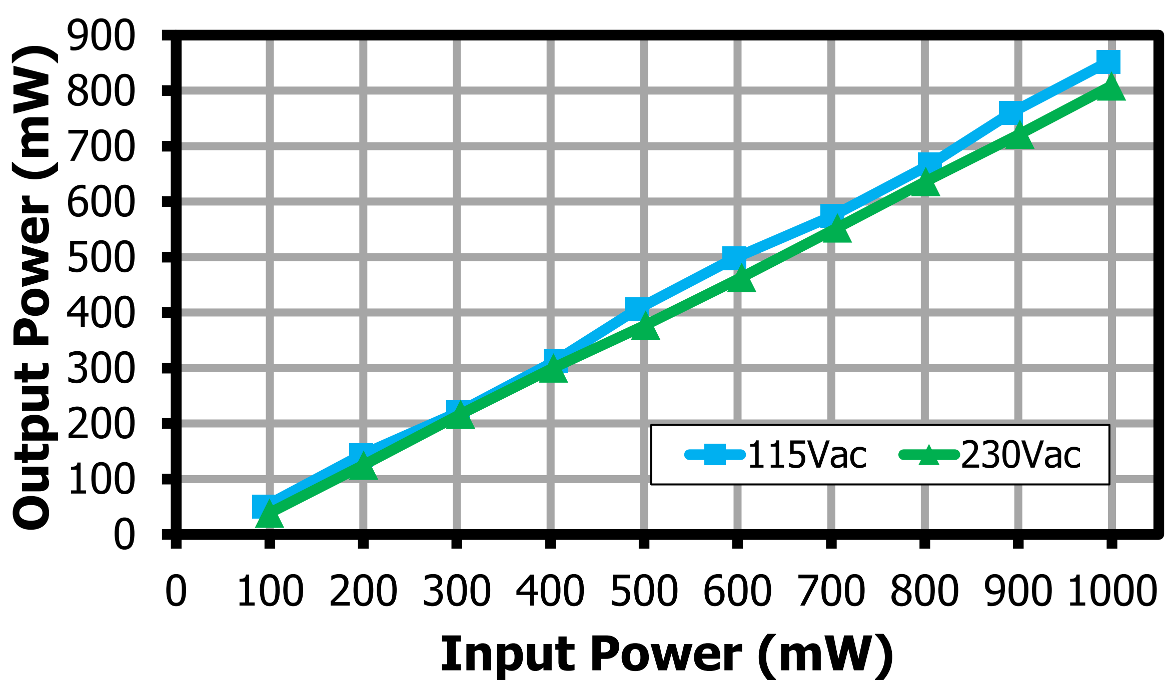


Figure 15 – Output Power vs Input Power.

10 Waveforms

10.1 Load Transient Response

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

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}: 12.4 V
V_{MIN}: 12.1 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}: 12.4 V
V_{MIN}: 12.1 V

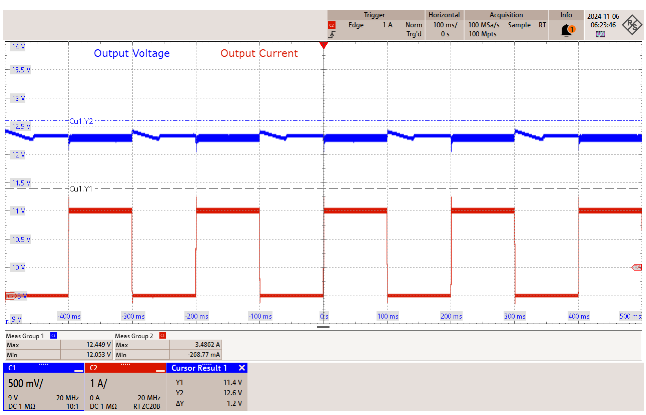


Figure 18 – 230 VAC 50 Hz.
CH1: V_{OUT}, 500 mV / div., 100 ms / div.
CH2: I_{OUT}, 1 A / div., 100 ms / div.
V_{OUT}: V_{MAX}: 12.4 V
V_{MIN}: 12.1 V

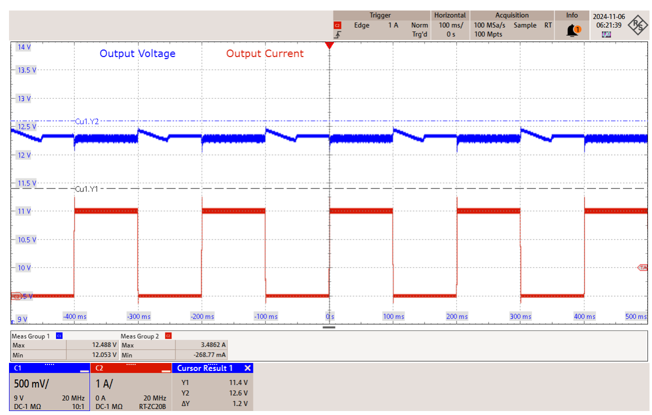


Figure 19 – 265 VAC 50 Hz.
CH1: V_{OUT}, 500 mV / div., 100 ms / div.
CH2: I_{OUT}, 1 A / div., 100 ms / div.
V_{OUT}: V_{MAX}: 12.5 V
V_{MIN}: 12.1 V

10.2 **Output Start-up**

10.2.1 Full Load CC Mode

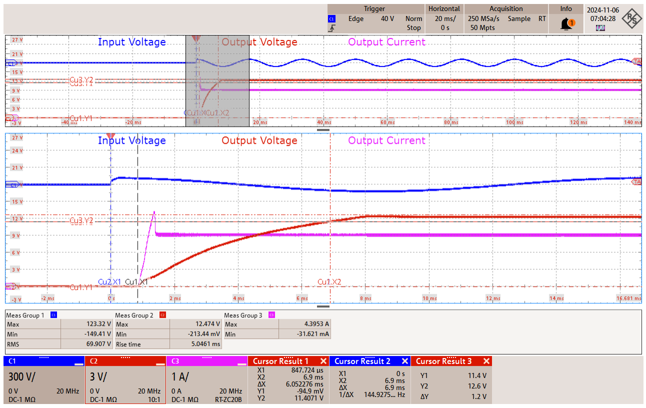


Figure 20 – 85 VAC 60 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_o Rise Time = 6.05 ms
Startup Time = 6.9 ms
V_{MAX} = 12.5 V

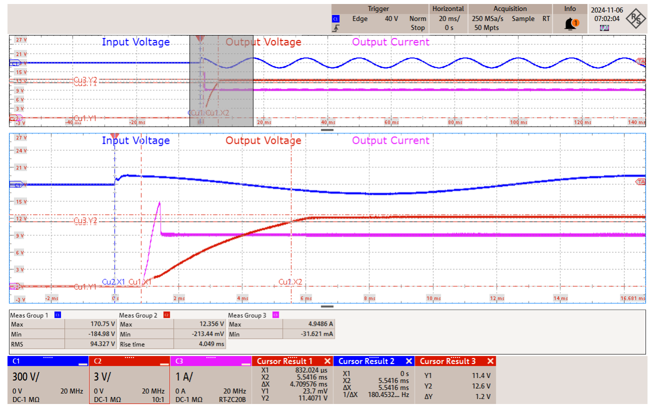


Figure 21 – 115 VAC 60 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_o Rise Time = 4.71 ms
Startup Time = 5.54 ms
V_{MAX} = 12.4 V

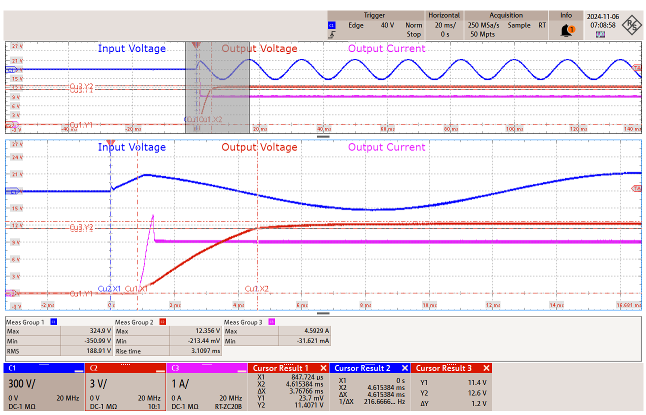


Figure 22 – 230 VAC 50 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_o Rise Time = 3.77 ms
Startup Time = 4.62 ms
V_{MAX} = 12.4 V

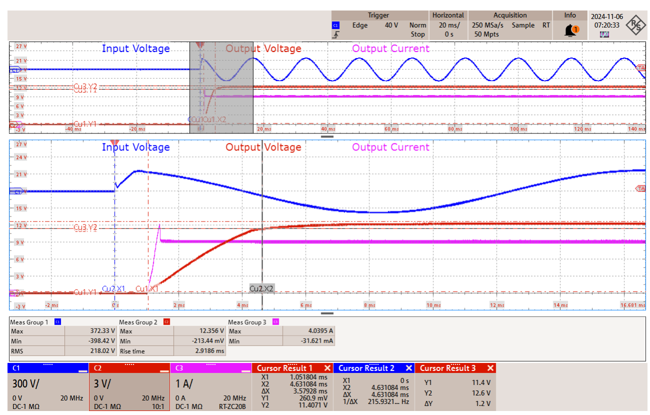


Figure 23 – 265 VAC 50 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_o Rise Time = 3.58 ms
Startup Time = 4.63 ms
V_{MAX} = 12.4 V

10.2.2 Full Load CR Mode

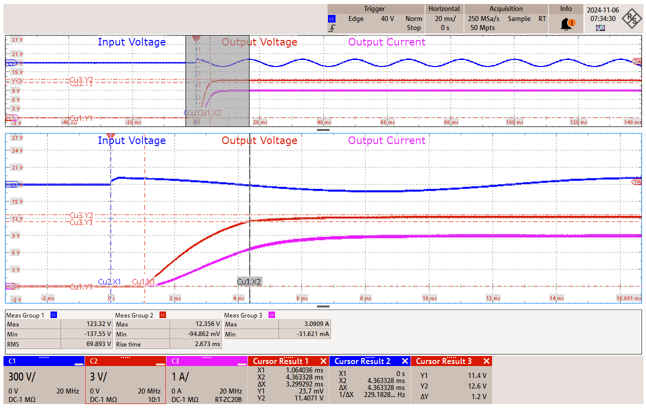


Figure 24 – 85 VAC 60 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_O Rise Time = 3.30 ms
Startup Time = 4.36 ms
V_{MAX} = 12.4 V

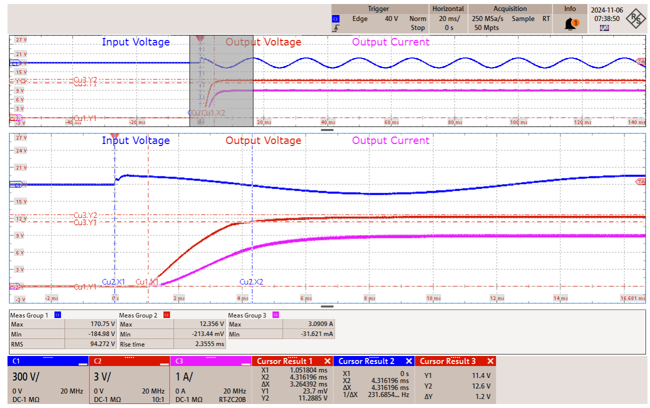


Figure 25 – 115 VAC 60 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_O Rise Time = 3.26 ms
Startup Time = 4.32 ms
V_{MAX} = 12.4 V

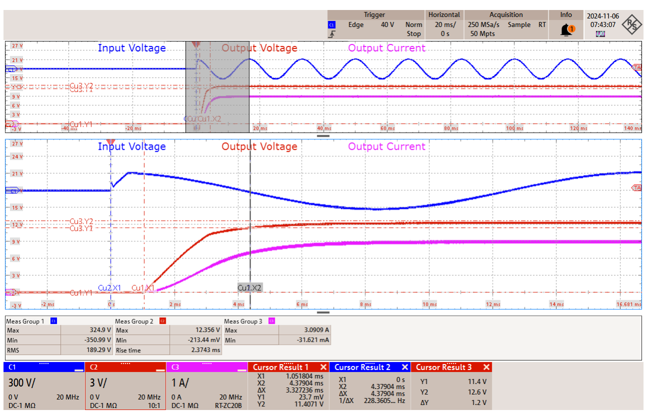


Figure 26 – 230 VAC 50 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_O Rise Time = 3.33 ms
Startup Time = 4.38 ms
V_{MAX} = 12.4 V

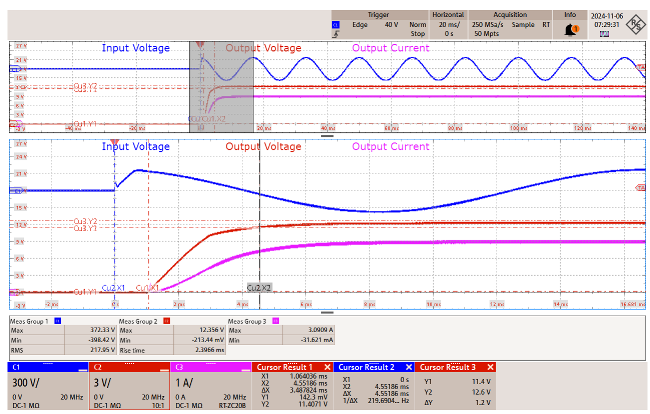


Figure 27 – 265 VAC 50 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_O Rise Time = 3.49 ms
Startup Time = 4.55 ms
V_{MAX} = 12.4 V

10.2.3 No Load

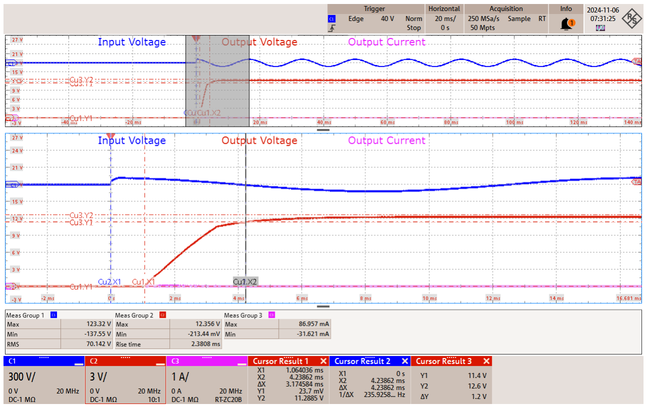


Figure 28 – 85 VAC 60 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_O Rise Time = 3.17 ms
Startup Time = 4.24 ms
V_{MAX} = 12.4 V

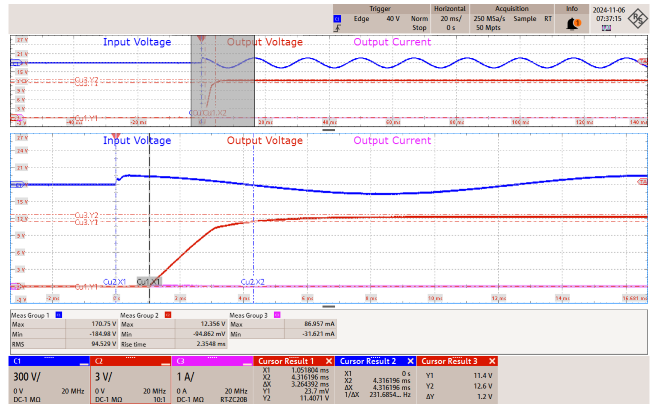


Figure 29 – 115 VAC 60 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_O Rise Time = 3.26 ms
Startup Time = 4.32 ms
V_{MAX} = 12.4 V

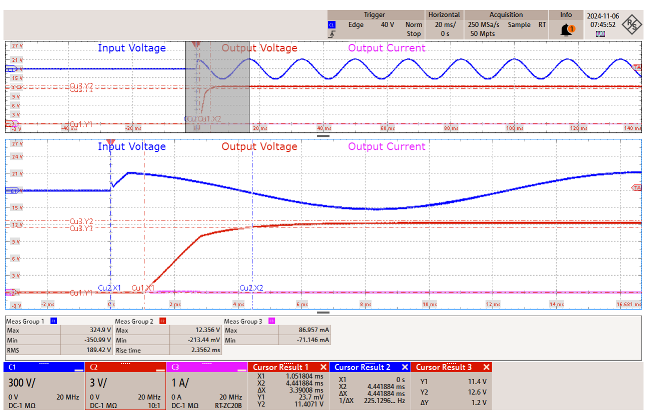


Figure 30 – 230 VAC 50 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_O Rise Time = 3.39 ms
Startup Time = 4.44 ms
V_{MAX} = 12.4 V

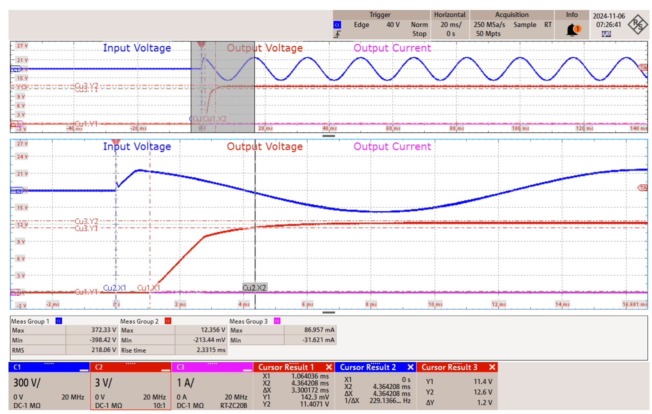


Figure 31 – 265 VAC 50 Hz.
CH1: Input Voltage, 300 V / div., 20 ms / div.
CH2: Output Voltage, 3 V / div., 20 ms / div.
CH3: Output Current, 1 A / div., 20 ms / div.
Zoom: 2 ms / div.
V_O Rise Time = 3.30 ms
Startup Time = 4.36 ms
V_{MAX} = 12.4 V

10.3 **Switching Waveforms**

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

10.3.1.1 Full Load

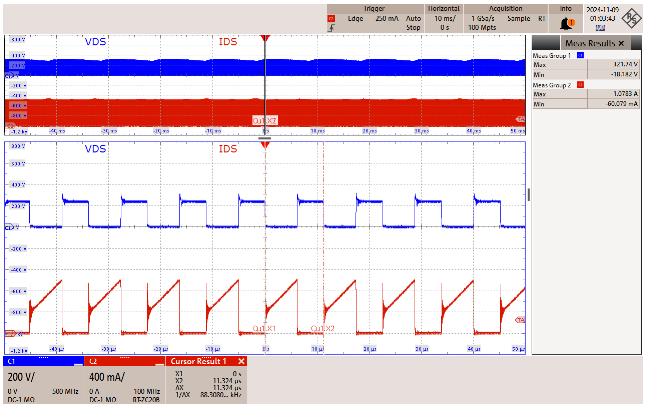


Figure 32 – 85 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 322 V
$I_{DS(MAX))}$ = 1.08 A

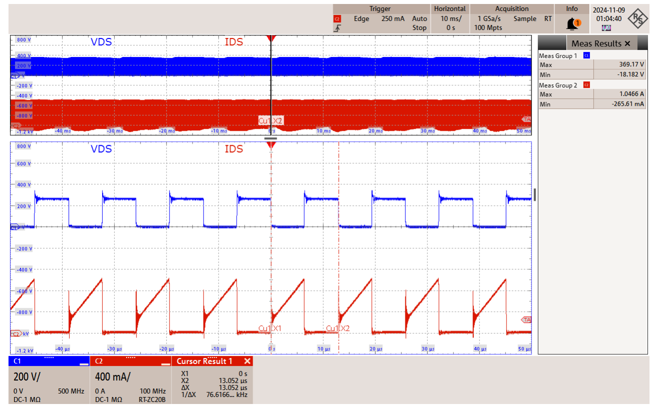


Figure 33 – 115 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 369 V
$I_{DS(MAX)}$ = 1.05 A

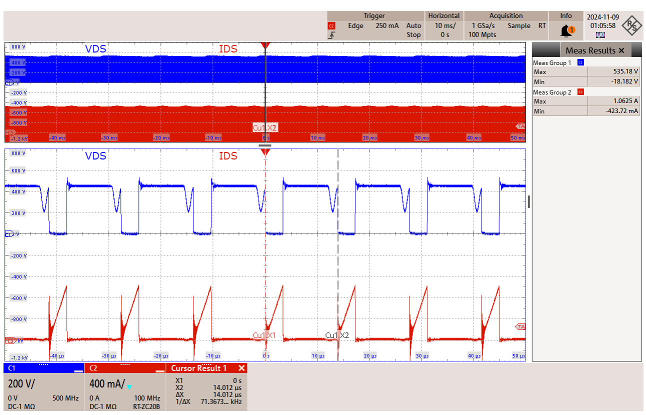


Figure 34 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 535 V
$I_{DS(MAX)}$ = 1.06 A

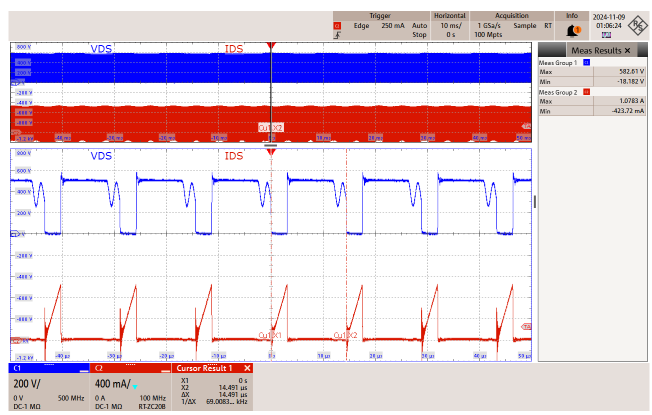


Figure 35 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 583 V
$I_{DS(MAX)}$ = 1.08 A

10.3.1.2 No Load

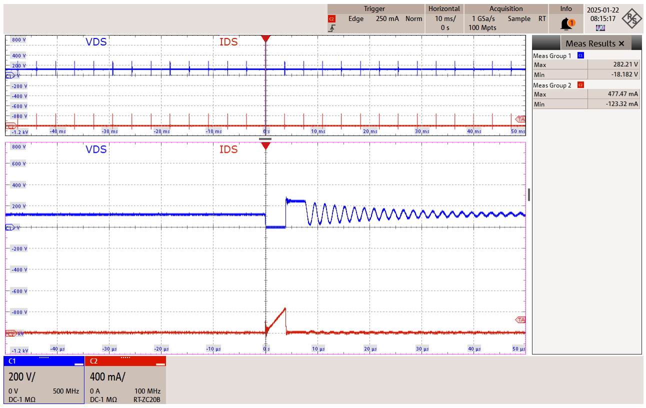


Figure 36 – 85 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 282 V
$I_{DS(MAX)}$ = 477 mA

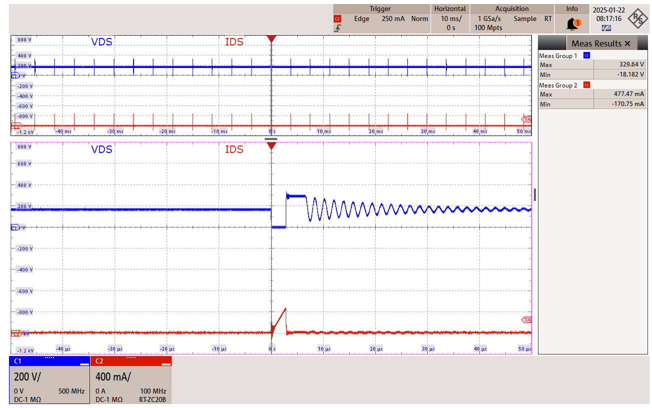


Figure 37 – 115 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 330 V
$I_{DS(MAX)}$ = 477 mA

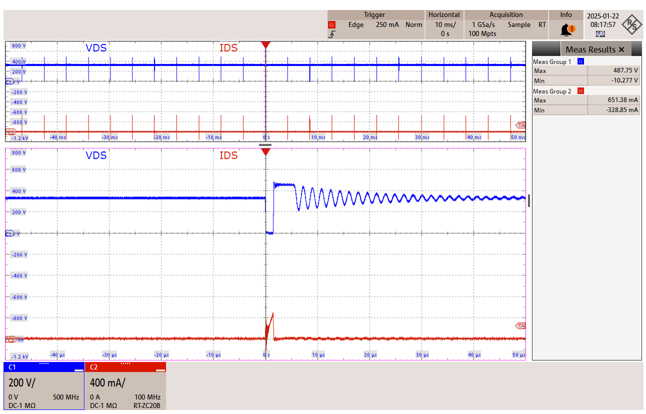


Figure 38 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 488 V
$I_{DS(MAX)}$ = 651 mA

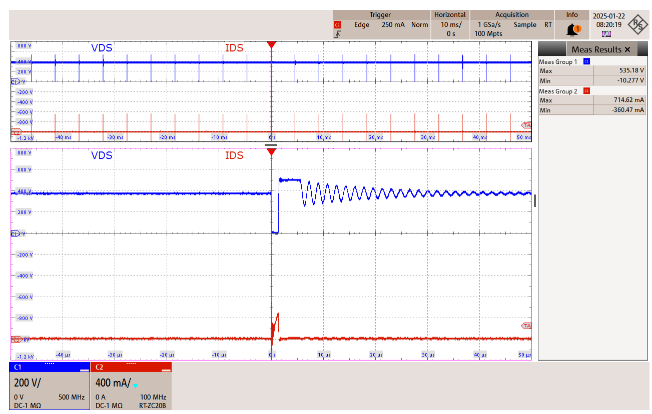


Figure 39 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 10 µs / div.
$V_{DS(MAX)}$ = 535 V
$I_{DS(MAX)}$ = 714 mA

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

10.3.2.1 Full Load

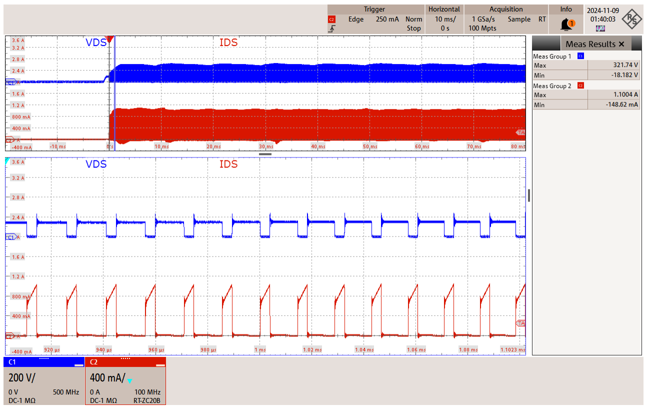


Figure 40 – 85 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 20 µs / div.
$V_{DS(MAX)}$ = 322 V
$I_{DS(MAX)}$ = 1.10 A

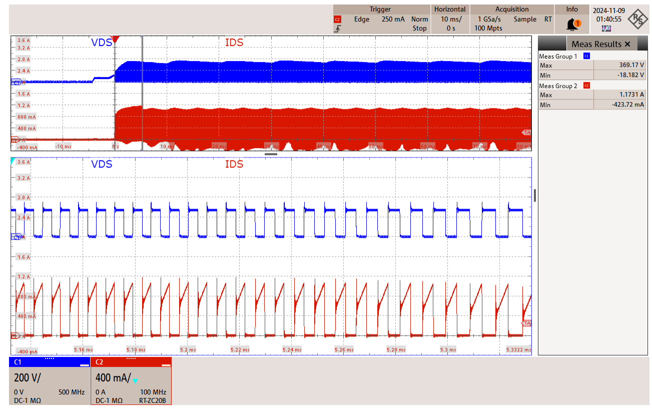


Figure 41 – 115 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 20 µs / div.
$V_{DS(MAX)}$ = 369 V
$I_{DS(MAX)}$ = 1.17 A

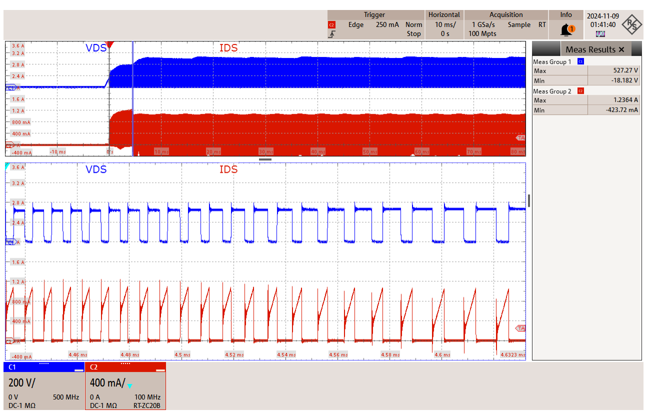


Figure 42 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 20 µs / div.
$V_{DS(MAX)}$ = 527 V
$I_{DS(MAX)}$ = 1.24 A

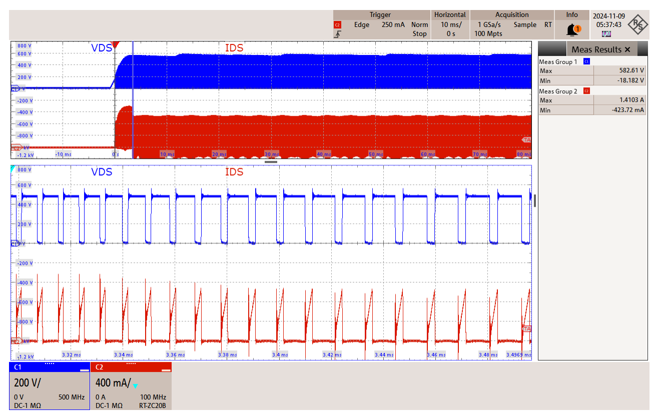


Figure 43 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 20 µs / div.
$V_{DS(MAX)}$ = 583 V
$I_{DS(MAX)}$ = 1.41 A

10.3.2.2 No Load

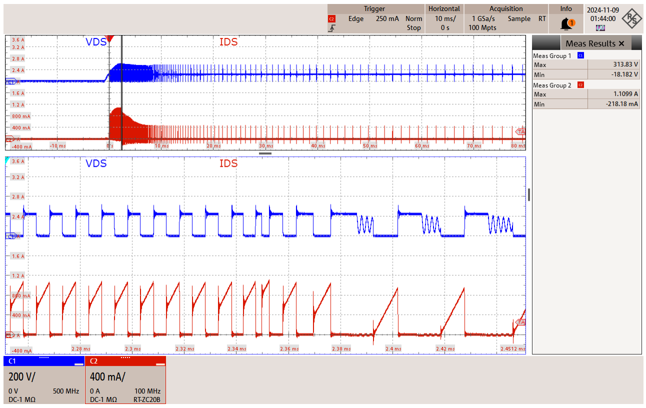


Figure 44 – 85 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 20 µs / div.
$V_{DS(MAX)}$ = 314 V
$I_{DS(MAX)}$ = 1.11 A

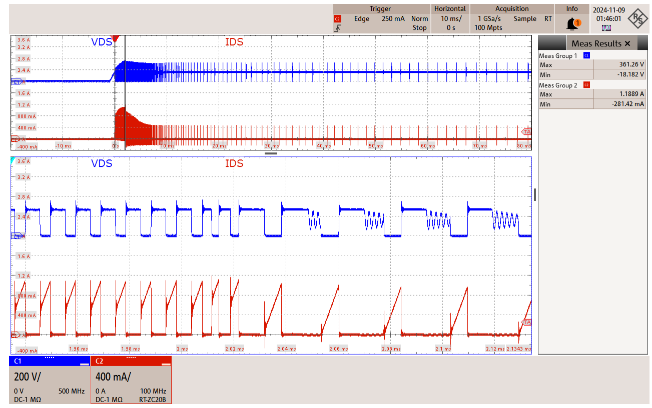


Figure 45 – 115 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 20 µs / div.
$V_{DS(MAX)}$ = 361 V
$I_{DS(MAX)}$ = 1.19 A

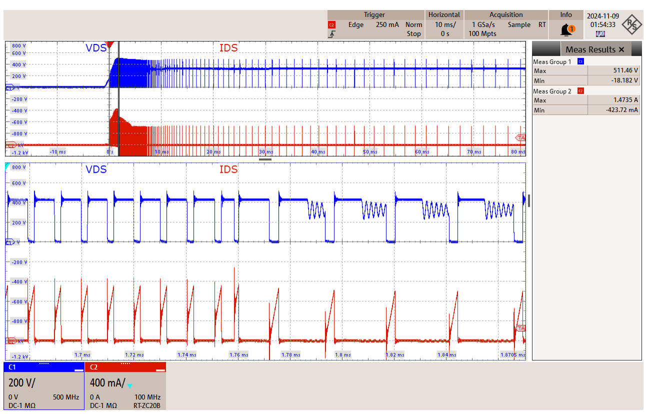


Figure 46 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 20 µs / div.
$V_{DS(MAX)}$ = 511 V
$I_{DS(MAX)}$ = 1.47 A

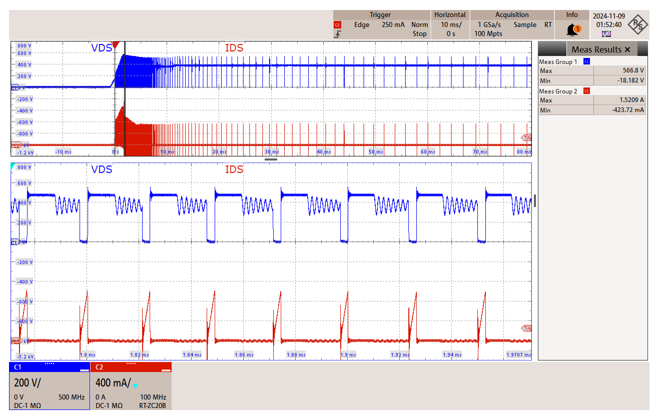


Figure 47 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 10 ms / div.
CH2: I_{DS}, 400 mA / div., 10 ms / div.
Zoom: 20 µs / div.
$V_{DS(MAX)}$ = 567 V
$I_{DS(MAX)}$ = 1.52 A

10.3.3 Freewheeling Diode Voltage at Normal Operation

10.3.3.1 Full Load

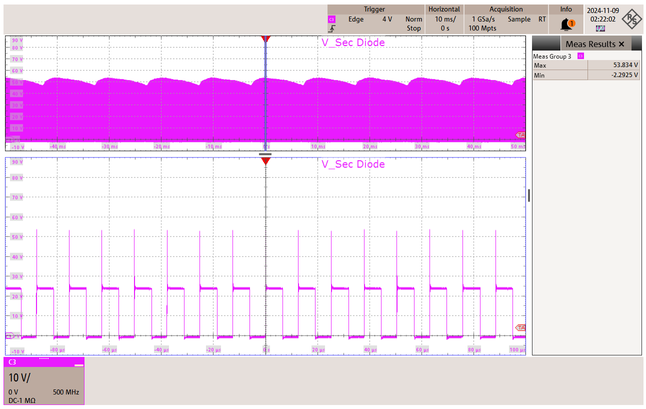


Figure 48 – 85 VAC 60 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 53.8 V

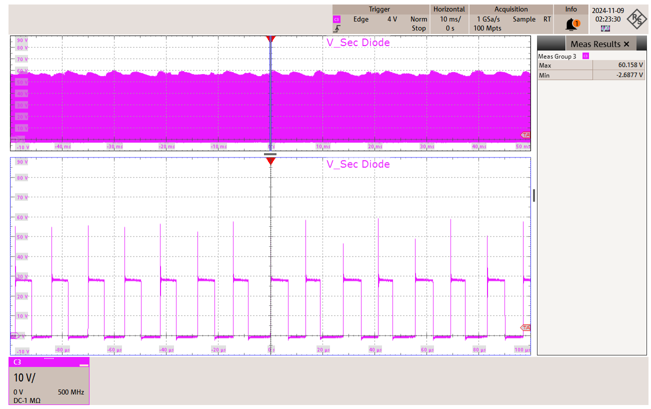


Figure 49 – 115 VAC 60 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 60.2 V

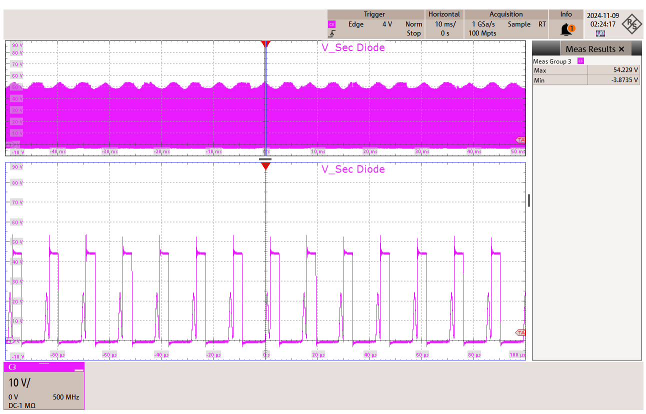


Figure 50 – 230 VAC 50 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 54.2 V

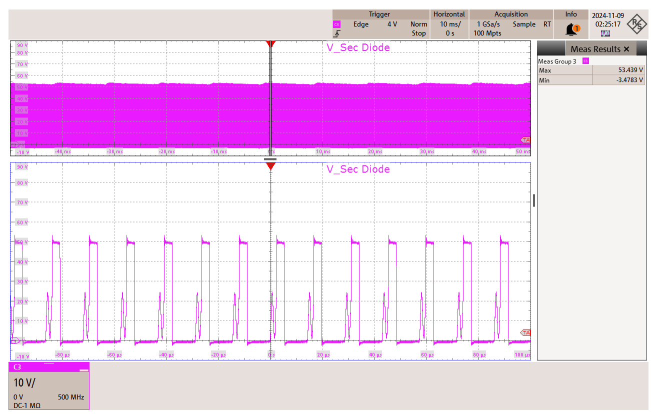


Figure 51 – 265 VAC 50 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 53.4 V

10.3.3.2 No Load

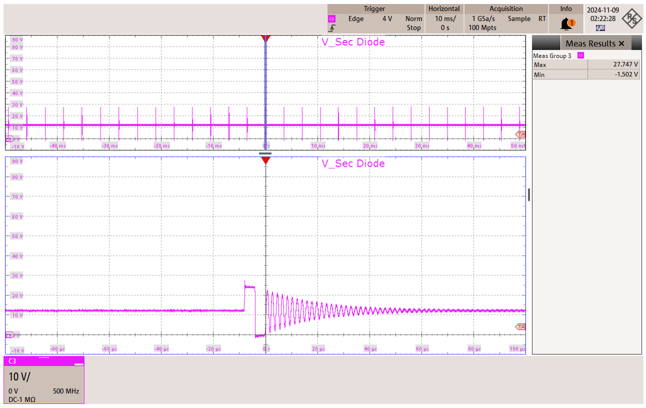


Figure 52 – 85 VAC 60 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 27.7 V

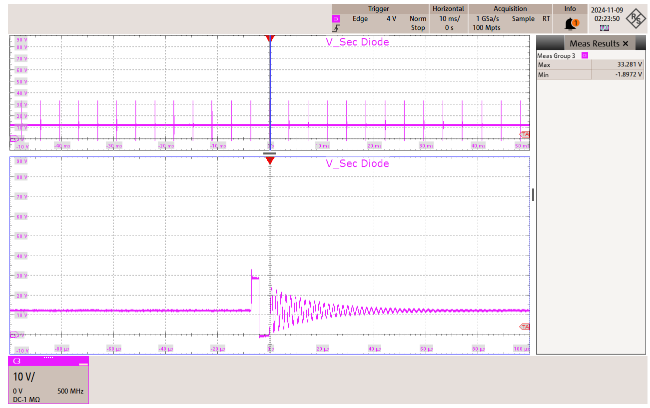


Figure 53 – 115 VAC 60 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 33.3 V

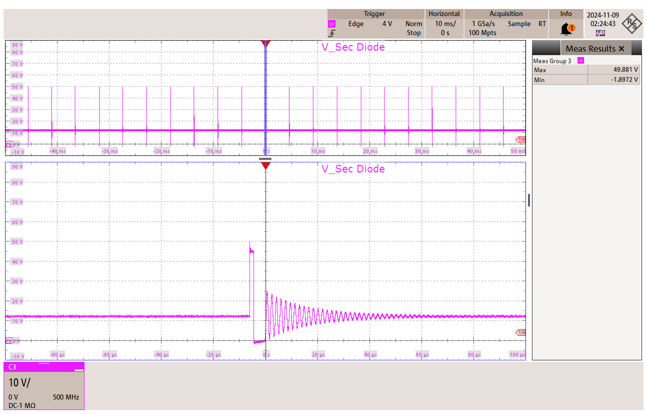


Figure 54 – 230 VAC 50 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 49.9 V

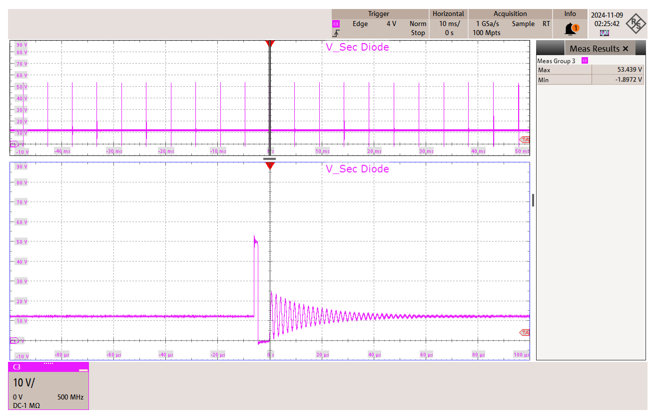


Figure 55 – 265 VAC 50 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 53.4 V

10.3.4 Freewheeling Diode Voltage at Start-Up

10.3.4.1 Full Load

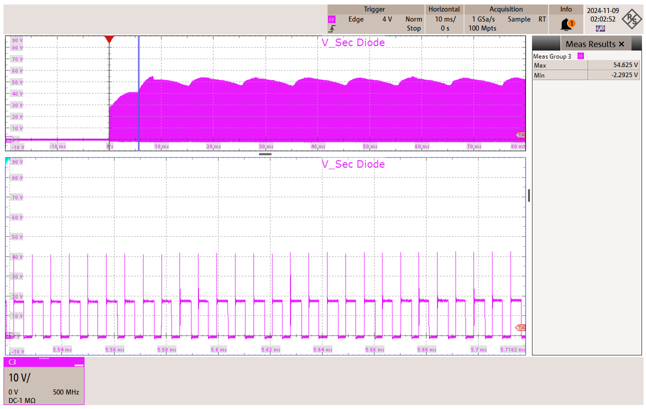


Figure 56 – 85 VAC 60 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 54.6 V

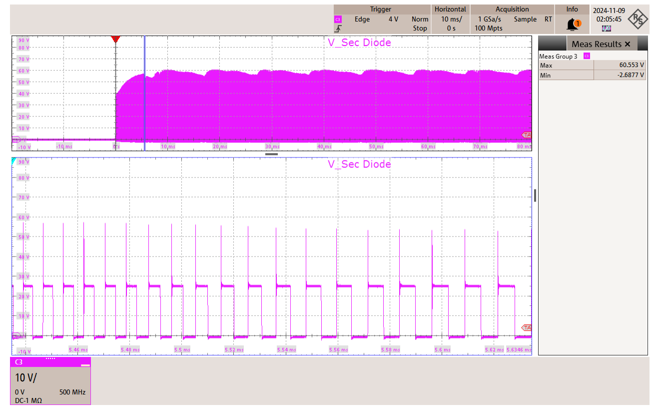


Figure 57 – 115 VAC 60 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 60.6 V

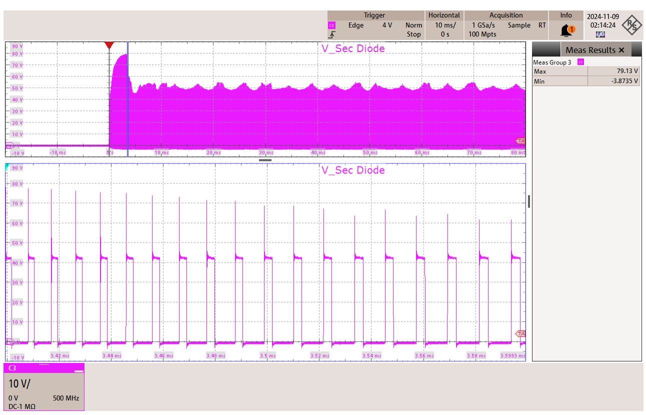


Figure 58 – 230 VAC 50 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 79.1 V

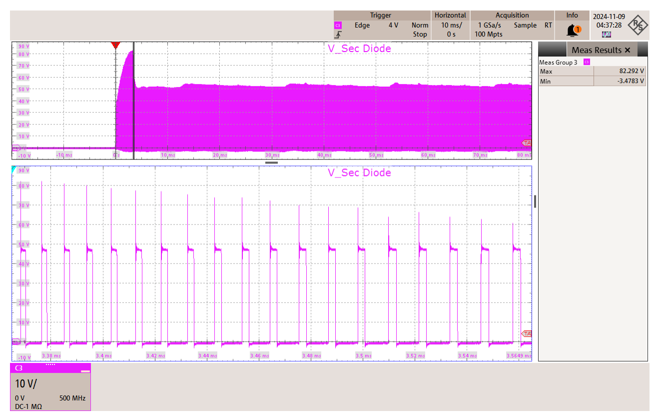


Figure 59 – 265 VAC 50 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 82.3 V

10.3.4.2 No Load

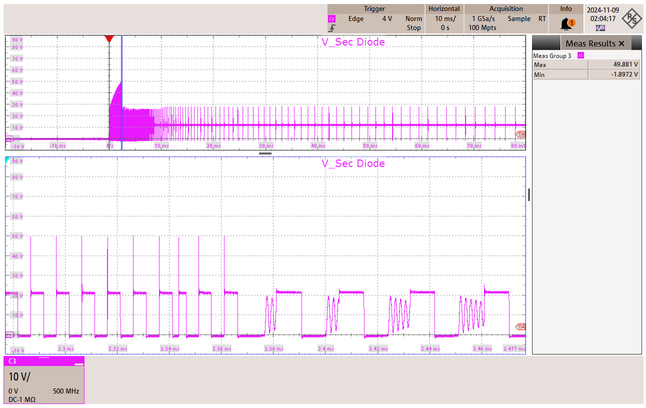


Figure 60 – 85 VAC 60 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 49.9 V

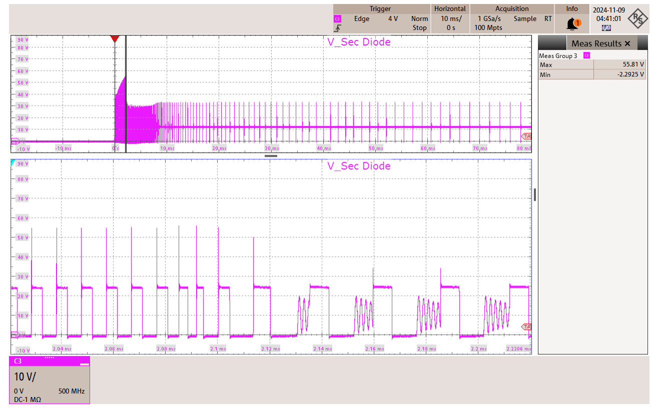


Figure 61 – 115 VAC 60 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 55.8 V

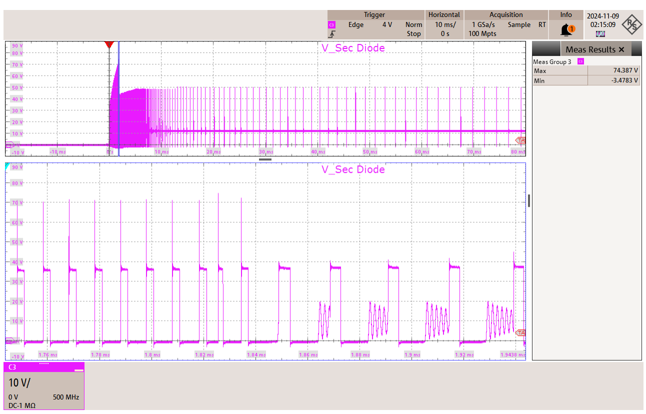


Figure 62 – 230 VAC 50 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 74.4 V

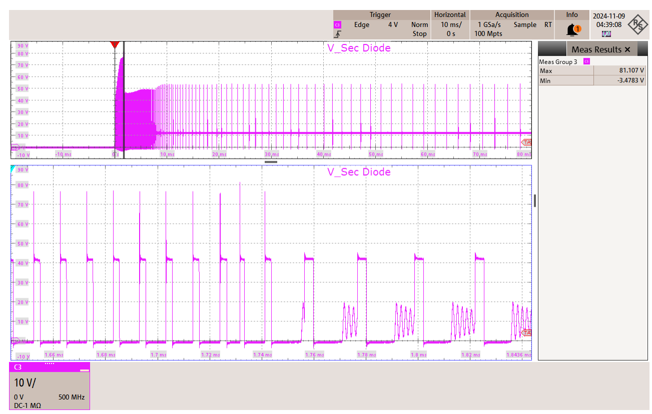


Figure 63 – 265 VAC 50 Hz.
CH3: V_Sec Diode, 10 V / div., 10 ms / div.
Zoom: 20 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 81.1 V

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).

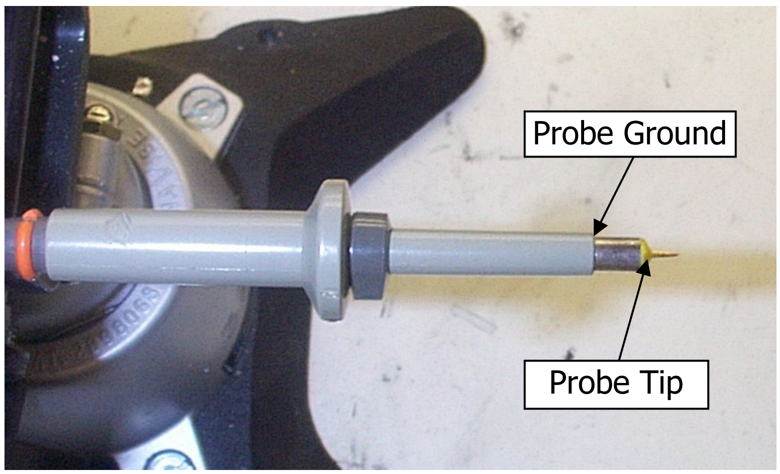


Figure 64 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed.)

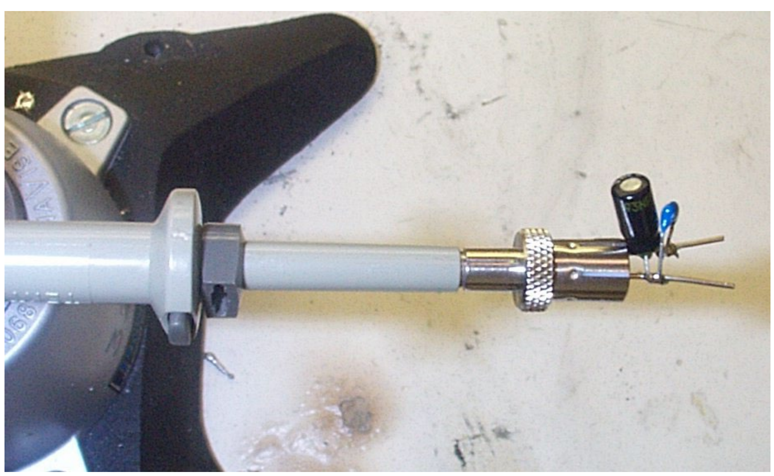


Figure 65 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added.)

10.4.2 Measurement Results

Note: All ripple measurements were taken at PCB end.

10.4.2.1 100% Load Condition

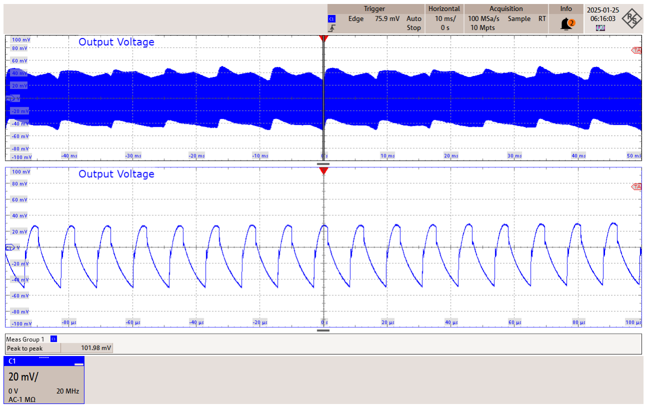


Figure 66 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 102 mV

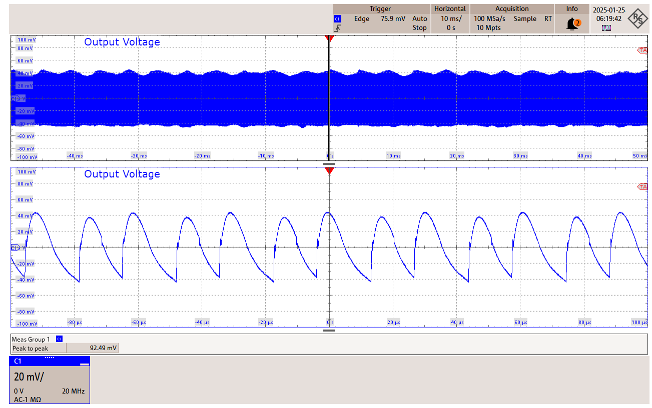


Figure 67 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 92.5 mV

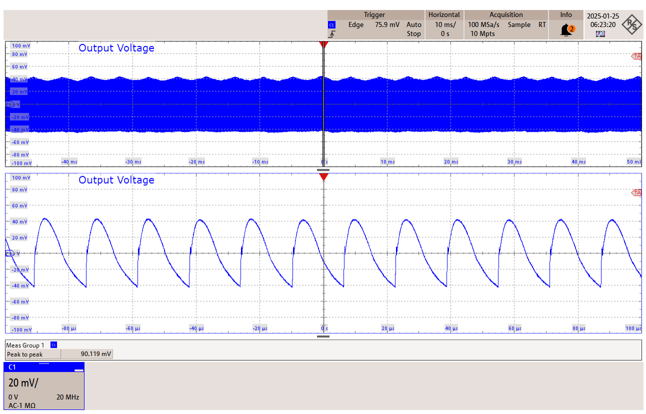


Figure 68 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 90.1 mV

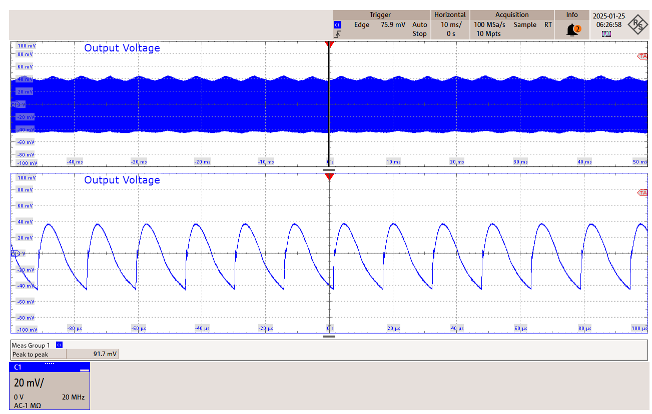


Figure 69 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 91.7 mV

10.4.2.2 75% Load Condition

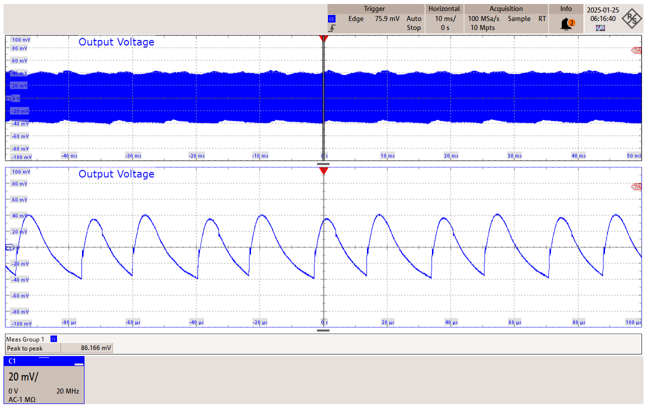


Figure 70 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 86.2 mV

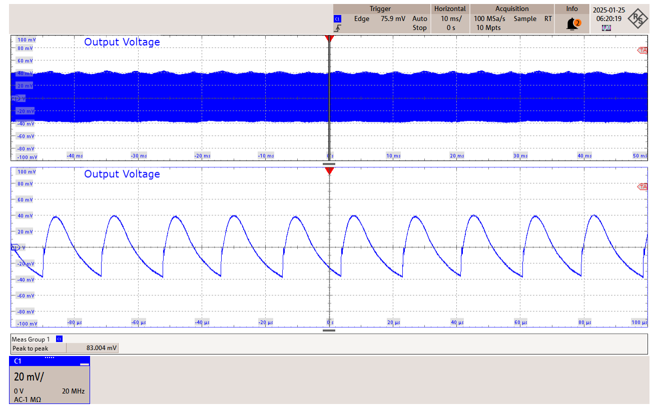


Figure 71 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 83.0 mV

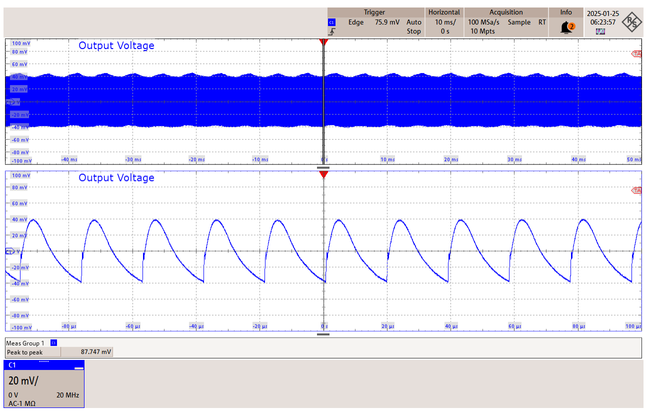


Figure 72 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 87.7 mV

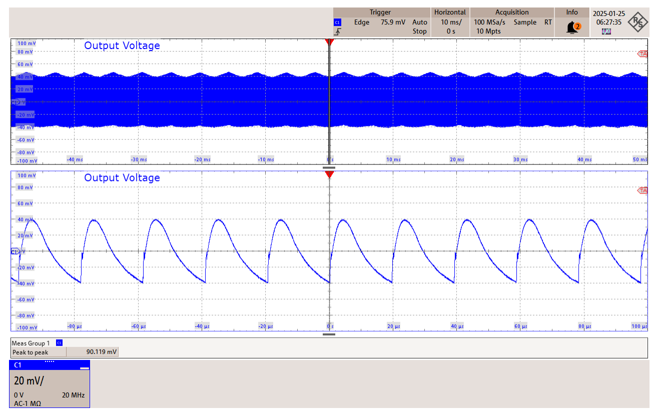


Figure 73 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 90.1 mV

10.4.2.3 50% Load Condition

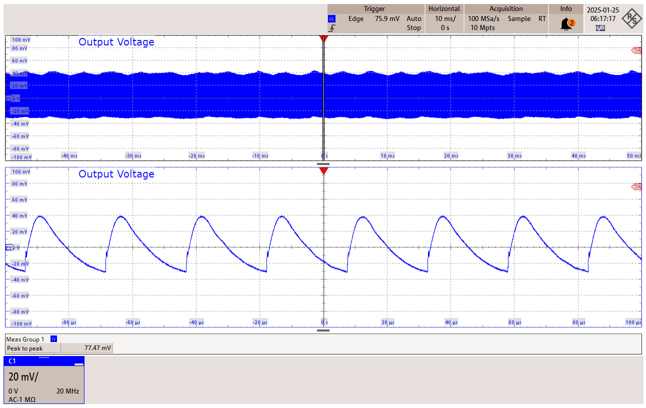


Figure 74 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 77.5 mV

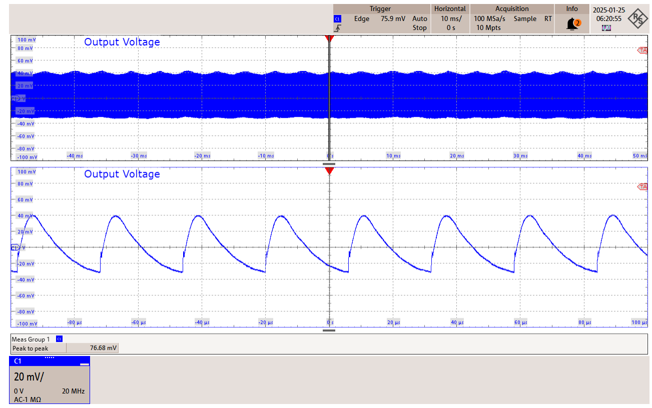


Figure 75 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 76.7 mV

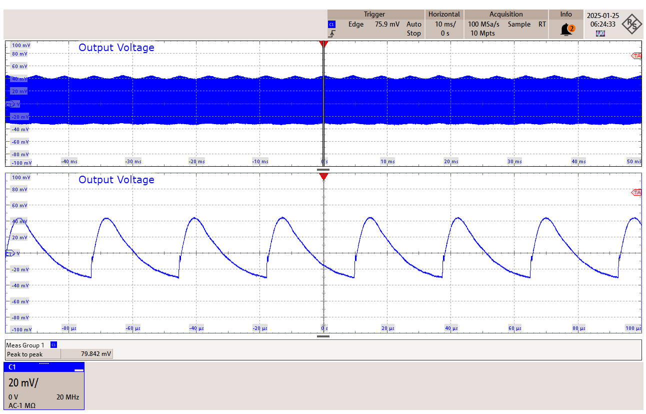


Figure 76 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 79.8 mV

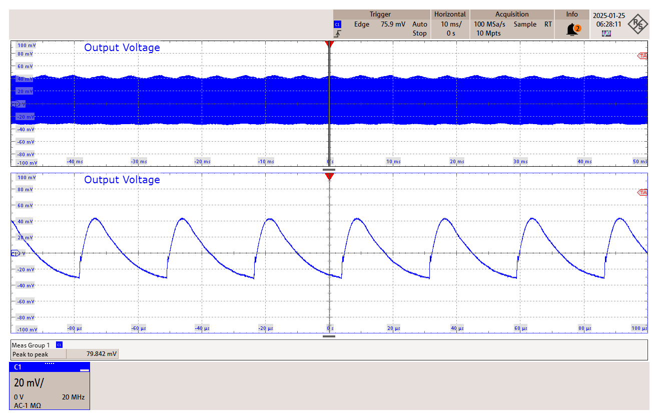


Figure 77 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 79.8 mV

10.4.2.4 25% Load Condition

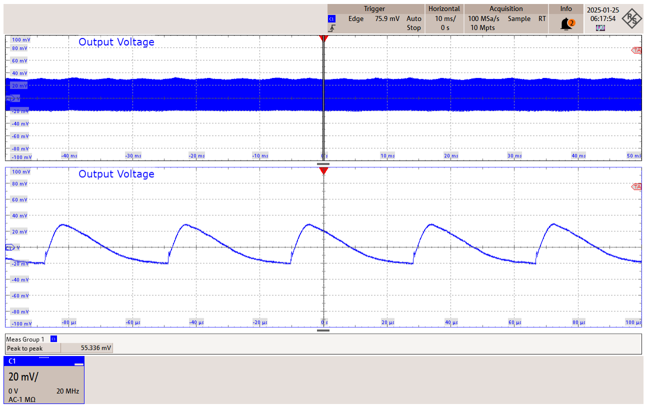


Figure 78 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 55.3 mV

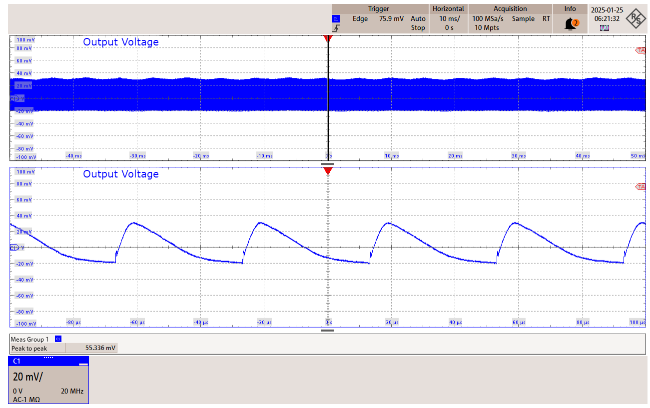


Figure 79 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 55.3 mV

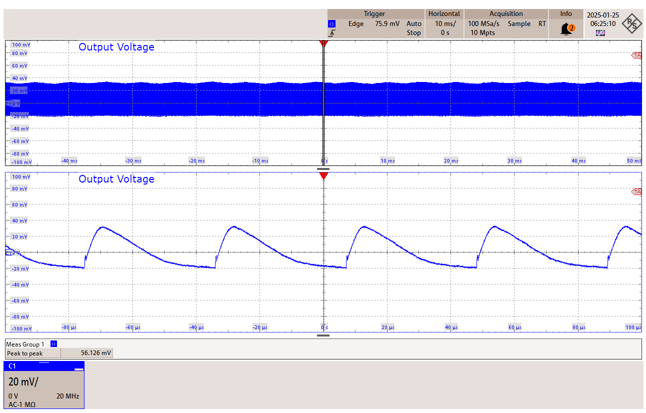


Figure 80 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 56.1 mV

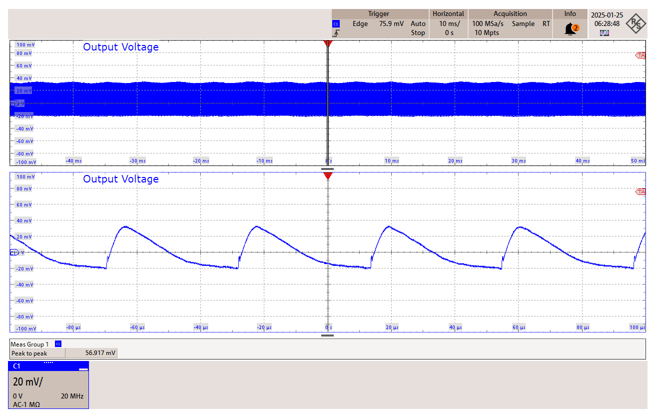


Figure 81 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 56.9 mV

10.4.2.5 0% Load Condition

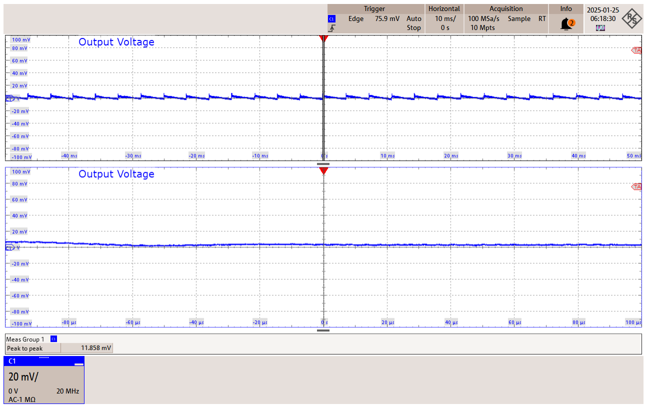


Figure 82 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 11.9 mV

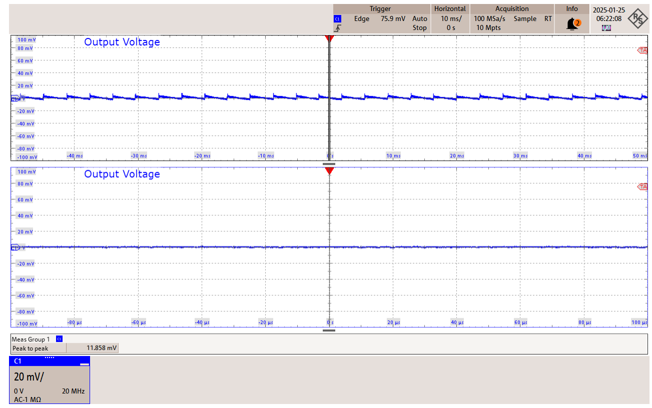


Figure 83 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 11.9 mV

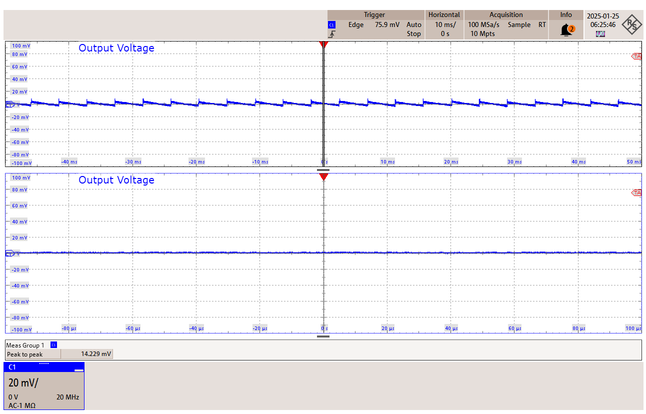


Figure 84 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 14.2 mV

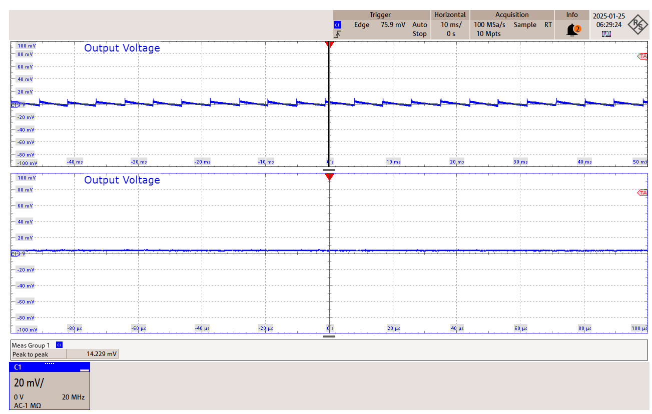


Figure 85 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 µs / div.
Output Ripple = 14.2 mV

10.4.3 Output Ripple Voltage Graph

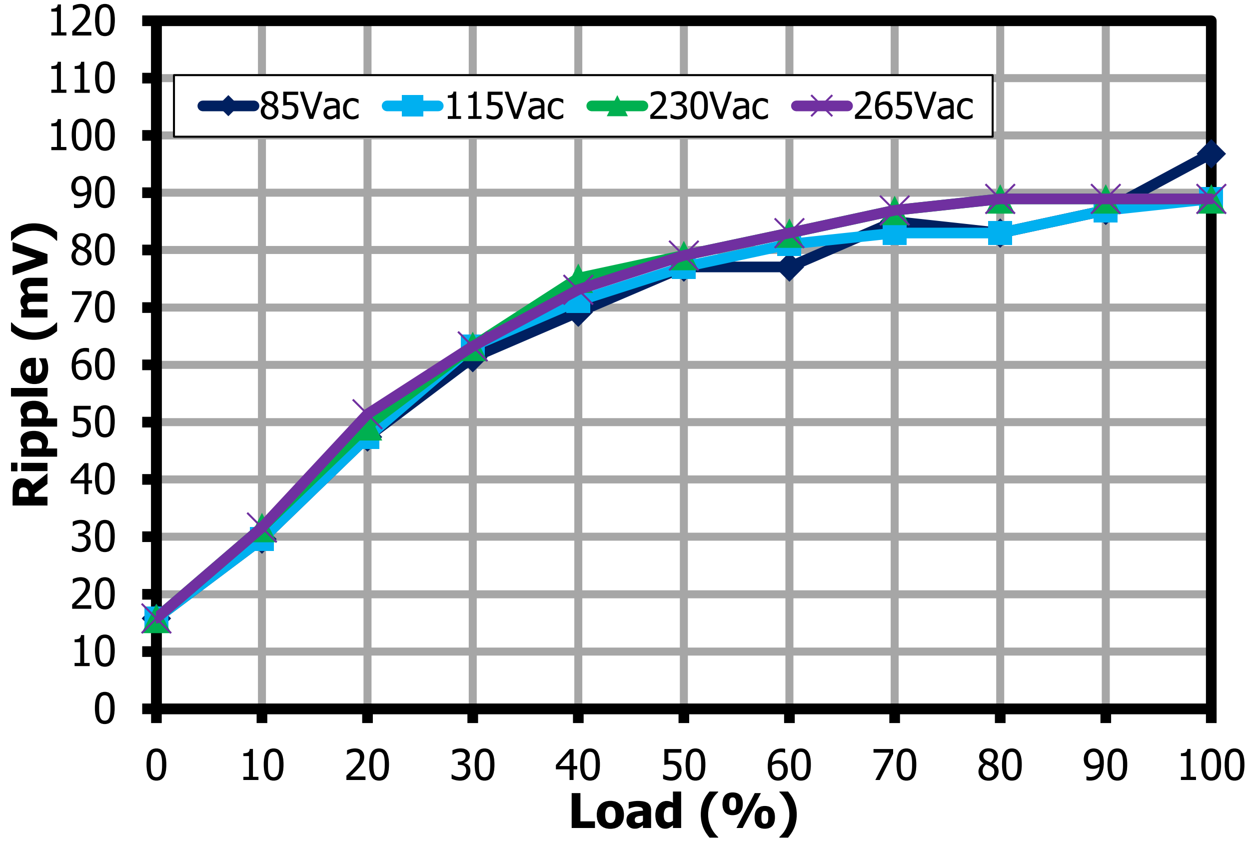


Figure 86 – Voltage Ripple (Measured at PCB End at Room Temperature).

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.

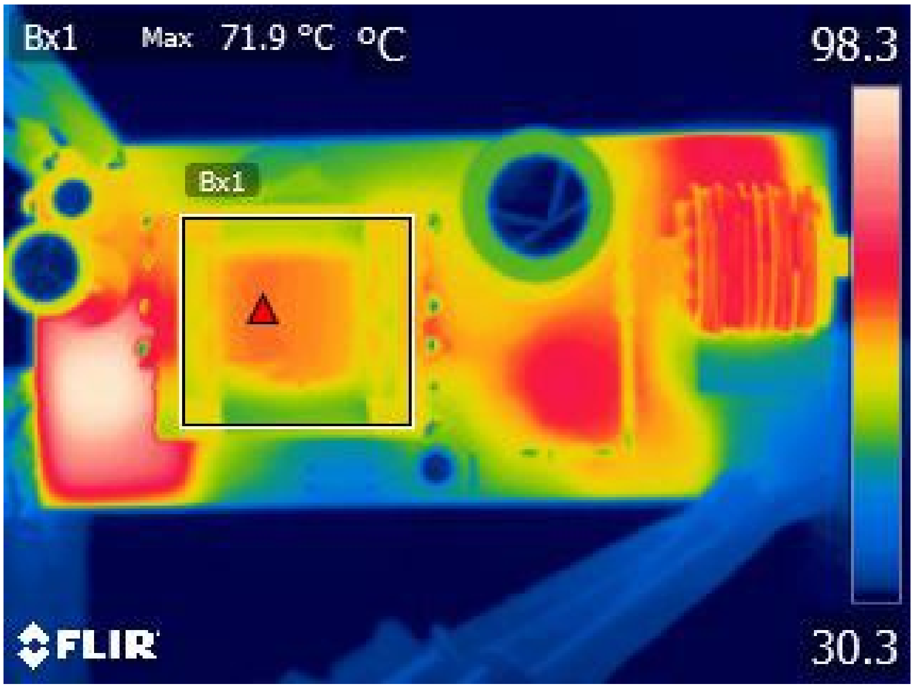


Figure 87 – 85 VAC 60 Hz. Top Side Discrete Component Thermals.

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

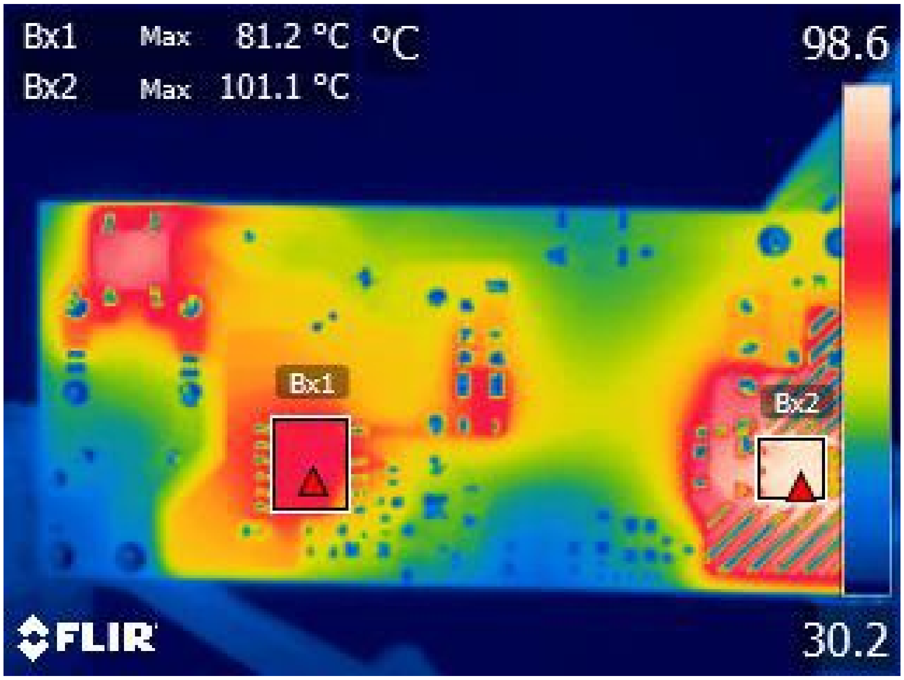


Figure 88 – 85 VAC 60 Hz. Bottom Side Thermals.

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.

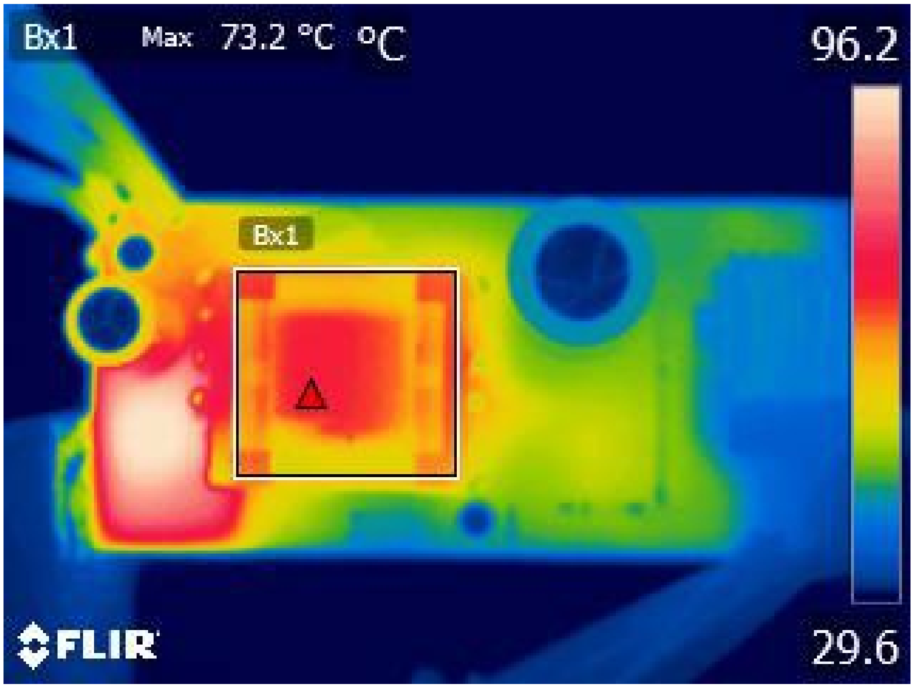


Figure 89 – 265 VAC 50 Hz. Top Side Discrete Component Thermals.

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

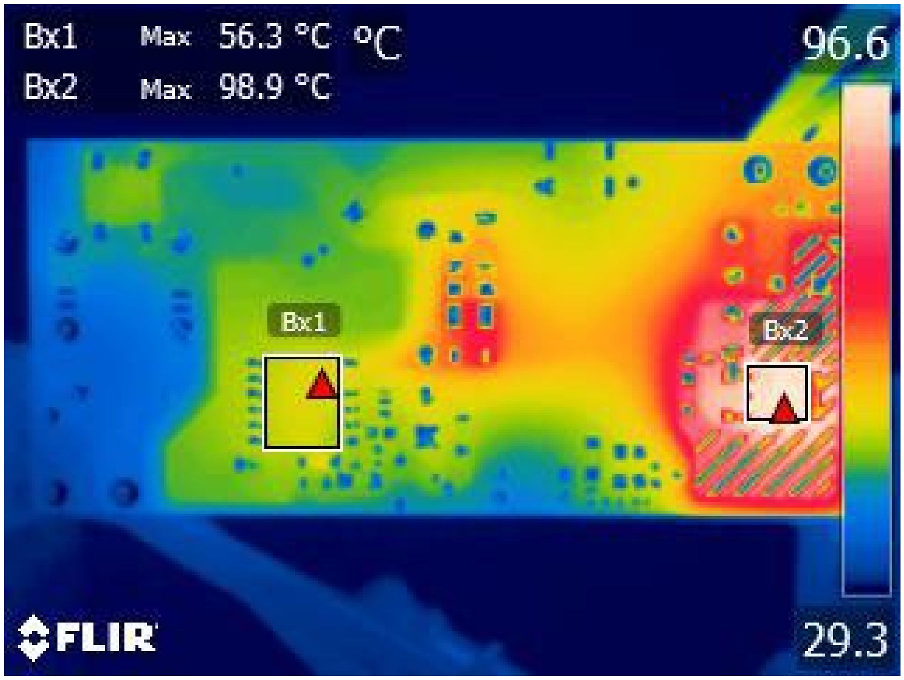


Figure 90 – 265 VAC 50 Hz. Bottom Side Thermals.

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.
CH2: 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.
CH2: 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 Running Short

12.1.1.1 Full Load

S

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 V
$I_{DS(MAX)}$ = 1.34 A
$t_{AR\_(OFF)1}$ = 339 ms
$t_{AR\_(OFF)2}$ = 1.20 s
$t_{AR(ON)}$ = 76.8 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 V
$I_{DS(MAX)}$ = 1.51 A
$t_{AR\_(OFF)1}$ = 339 ms
$t_{AR\_(OFF)2}$ = 1.20 s
$t_{AR(ON)}$ = 150 ms

12.2 Overpower Protection

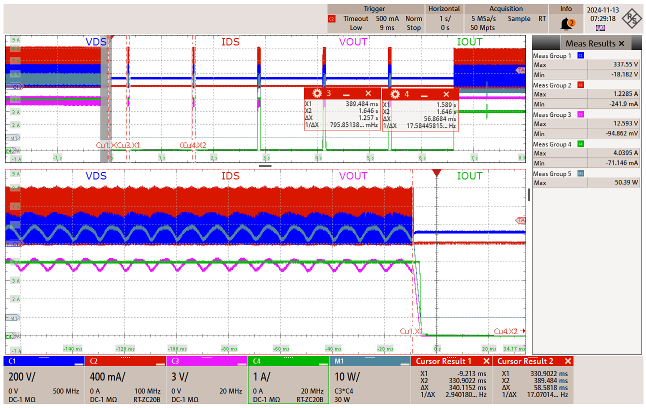


Figure 95 – 85 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 1 s / div.
CH2: I_{DS}, 400 mA / div., 1 s / div.
CH3: V_{OUT}, 3 V / div., 1 s / div.
CH2: I_{OUT}, 1 A / div., 1 s / div.
M1: P_{OUT}, 10 W / div., 1 s / div.
Zoom: 20 ms / div.
$P_{OUT(MAX)}$ = 50.4 W
$t_{AR\_(OFF)1}$ = 340 ms
$t_{AR\_(OFF)2}$ = 1.26 s
$t_{AR(ON)}$ = 58.6 ms

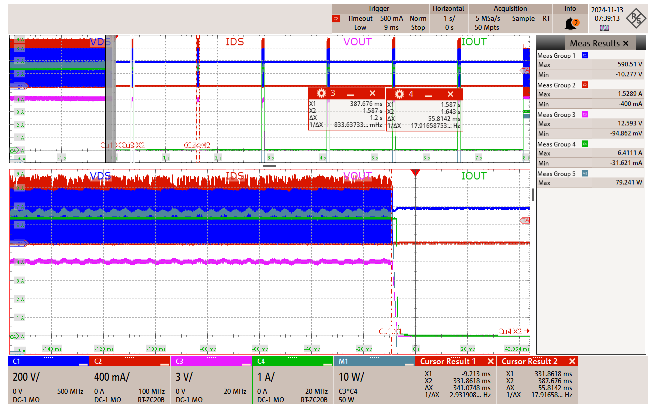


Figure 96 – 265 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 1 s / div.
CH2: I_{DS}, 400 mA / div., 1 s / div.
CH3: V_{OUT}, 3 V / div., 1 s / div.
CH2: I_{OUT}, 1 A / div., 1 s / div.
M1: P_{OUT}, 10 W / div., 1 s / div.
Zoom: 20 ms / div.
$P_{OUT(MAX)}$ = 79.2 W
$t_{AR\_(OFF)1}$ = 341 ms
$t_{AR\_(OFF)2}$ = 1.2 s
$t_{AR(ON)}$ = 55.8 ms

12.3 Overtemperature Protection

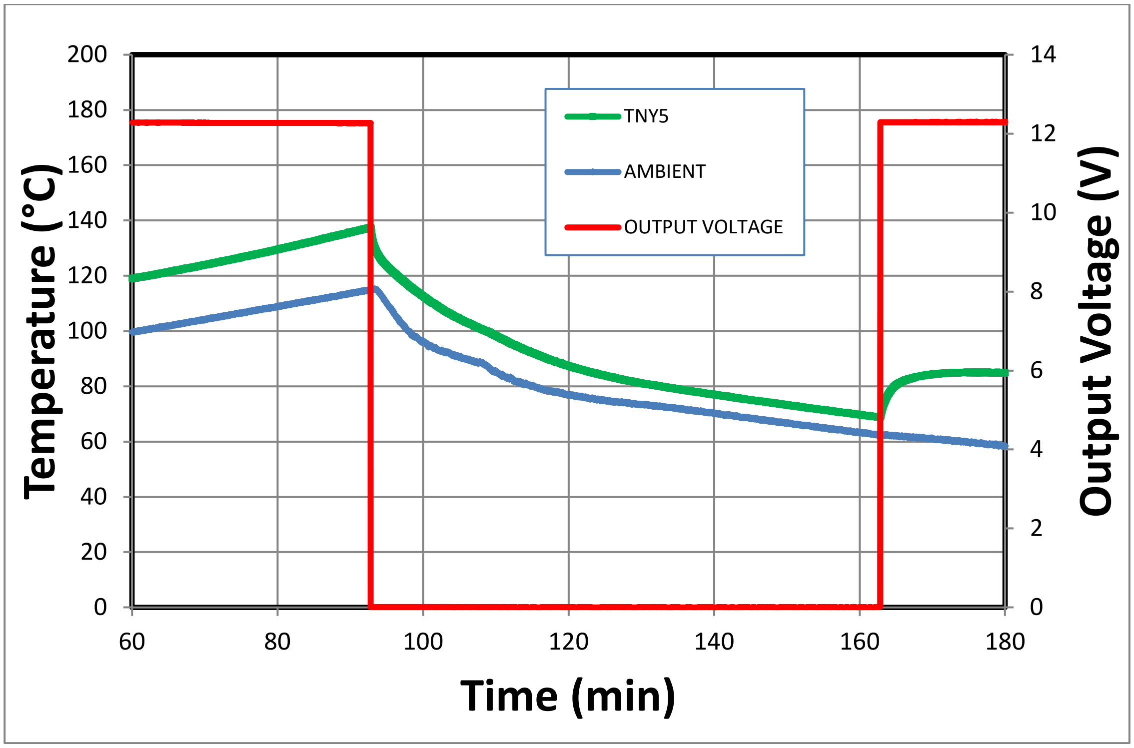


Figure 97 – 265 VAC Full Load OTP

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

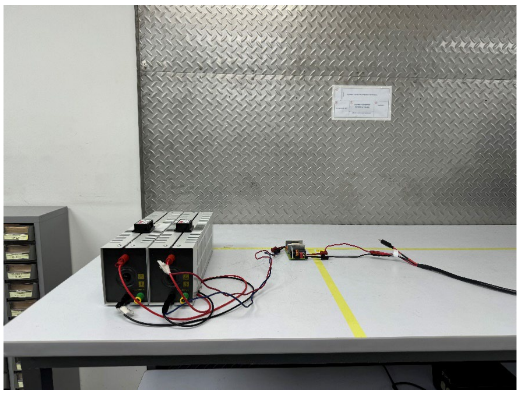
13 Conducted EMI

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.



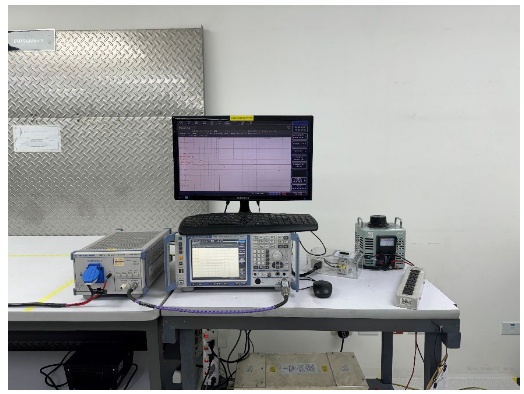


Figure 98 – EMI Test Set-up.

13.2 Output Float

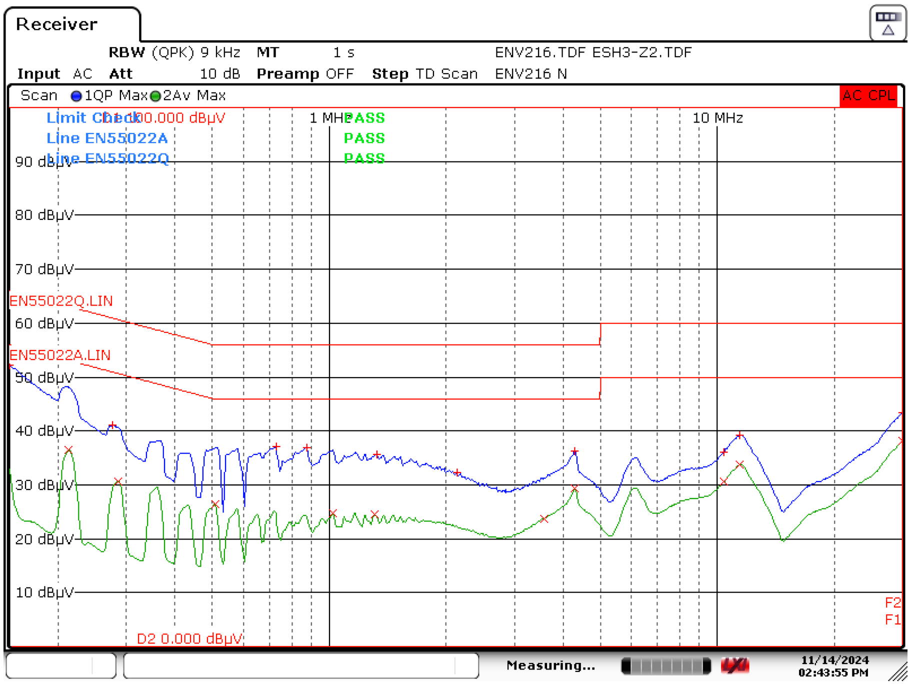


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Figure 99 – 115 VAC 60 Hz.
Line / Neutral - Floating

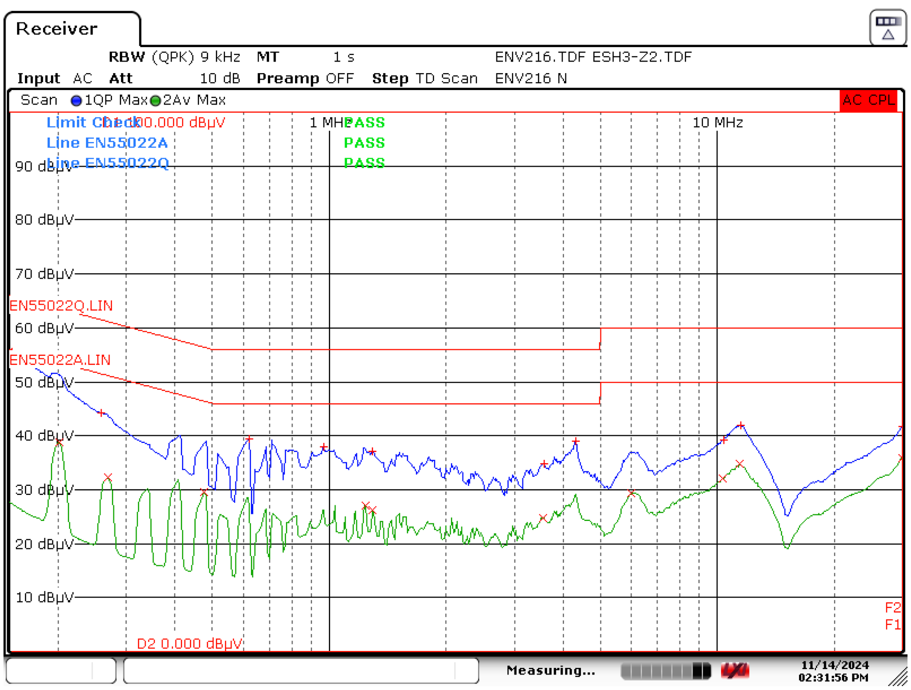

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Figure 100 – 230 VAC 50 Hz.
Line / Neutral - Floating

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
-8.8	12 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.

Passed ±16.5 kV air discharge

Air Discharge Voltage (kV)	Applied to	Number of Strikes	Test Result
+16.5	12 V	10	PASS
-16.5	12 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.

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
–1000 V	0°	L, N	2Ω	10	PASS
+1000 V	90°	L, N	2Ω	10	PASS
–1000 V	90°	L, N	2Ω	10	PASS
+1000 V	180°	L, N	2Ω	10	PASS
–1000 V	180°	L, N	2Ω	10	PASS
+1000 V	270°	L, N	2Ω	10	PASS
–1000 V	270°	L, N	2Ω	10	PASS

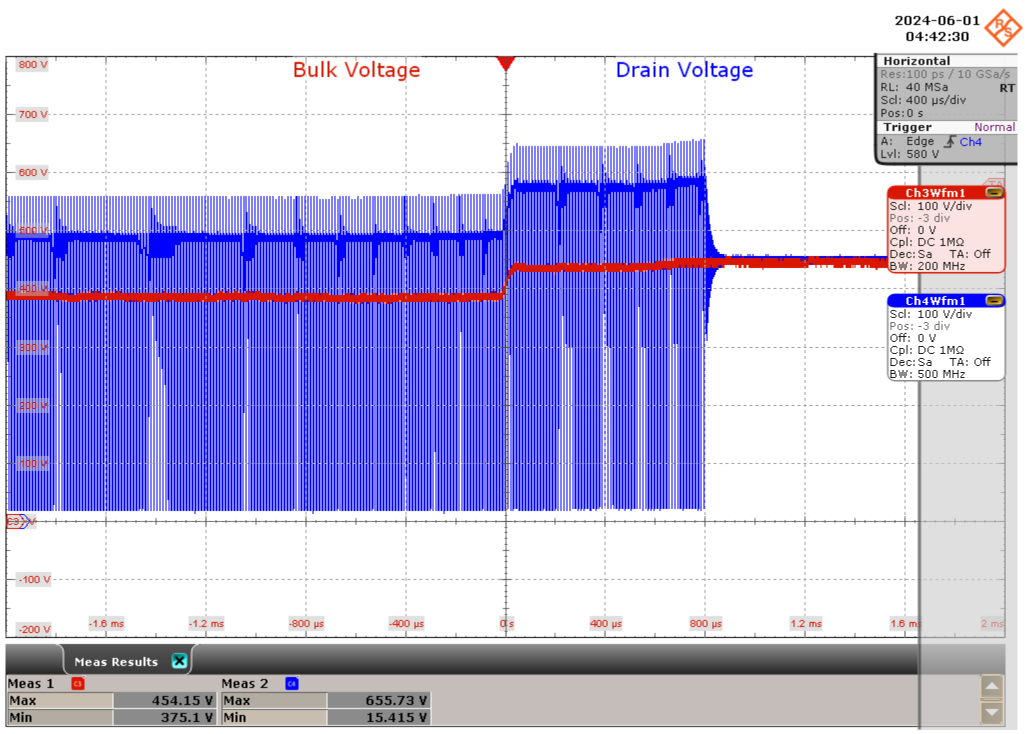

Figure 101 – 230 VAC 50 Hz., -1 kV 270° surge event
CH3: Input Voltage, 100 V / div., 400 µs / div.
CH4: Output Voltage, 100 V / div., 400 µs / div.
Drain Voltage$_{(MAX)}$ = 656 V
Bulk Voltage$_{(MAX)}$ = 454 V

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
–4000 V	0°	L/N - PE	12	10	PASS
+4000 V	90°	L/N - PE	12	10	PASS
–4000 V	90°	L/N - PE	12	10	PASS
+4000 V	180°	L/N - PE	12	10	PASS
–4000 V	180°	L/N - PE	12	10	PASS
+4000 V	270°	L/N - PE	12	10	PASS
–4000 V	270°	L/N - PE	12	10	PASS

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
–4000 V	0°	L/N - PE	12	10	PASS
+4000 V	90°	L/N - PE	12	10	PASS
–4000 V	90°	L/N - PE	12	10	PASS
+4000 V	180°	L/N - PE	12	10	PASS
–4000 V	180°	L/N - PE	12	10	PASS
+4000 V	270°	L/N - PE	12	10	PASS
–4000 V	270°	L/N - PE	12	10	PASS

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
–4000 V	0°	5 kHz	15 ms	300 ms	120 s	L1/L2	Pass
+4000 V	0°	100 kHz	750 µs	300 ms	120 s	L1/L2	Pass
–4000 V	0°	100 kHz	750 µs	300 ms	120 s	L1/L2	Pass
+4000 V	90°	5 kHz	15 ms	300 ms	120 s	L1/L2	Pass
–4000 V	90°	5 kHz	15 ms	300 ms	120 s	L1/L2	Pass
+4000 V	90°	100 kHz	750 µs	300 ms	120 s	L1/L2	Pass
–4000 V	90°	100 kHz	750 µs	300 ms	120 s	L1/L2	Pass
+4000 V	180°	5 kHz	15 ms	300 ms	120 s	L1/L2	Pass
–4000 V	180°	5 kHz	15 ms	300 ms	120 s	L1/L2	Pass
+4000 V	180°	100 kHz	750 µs	300 ms	120 s	L1/L2	Pass
–4000 V	180°	100 kHz	750 µs	300 ms	120 s	L1/L2	Pass
+4000 V	270°	5 kHz	15 ms	300 ms	120 s	L1/L2	Pass
–4000 V	270°	5 kHz	15 ms	300 ms	120 s	L1/L2	Pass
+4000 V	270°	100 kHz	750 µs	300 ms	120 s	L1/L2	Pass
–4000 V	270°	100 kHz	750 µs	300 ms	120 s	L1/L2	Pass

18 Revision History

Date	Author	Revision	Description and Changes	Reviewed
06-Feb-25	JPM, JKB	A	Initial Release	Apps & Mktg.

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