Design Example Report

Title	**12 W Isolated Flyback Power Supply Using TNY5072K**
Specification	85 – 265 VAC Input; 12 V / 1 A Output
Application	Appliance
Author	Applications Engineering Department
Document Number	DER-1017
Date	January 31, 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% average efficiency at 115 VAC and 230 VAC
- >70% efficiency at 230 VAC and 300 mW input power
- <50 mW no-load input power at 230 VAC
- Continuous 12 W output power 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

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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 designed to provide an isolated nominal output voltage of 12 V at 1 A load from a wide input voltage range of 85 VAC to 265 VAC. This power supply utilizes the TNY5072K from the TinySwitch-5 family of ICs.

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

Figure 1 – Photograph, Top View.

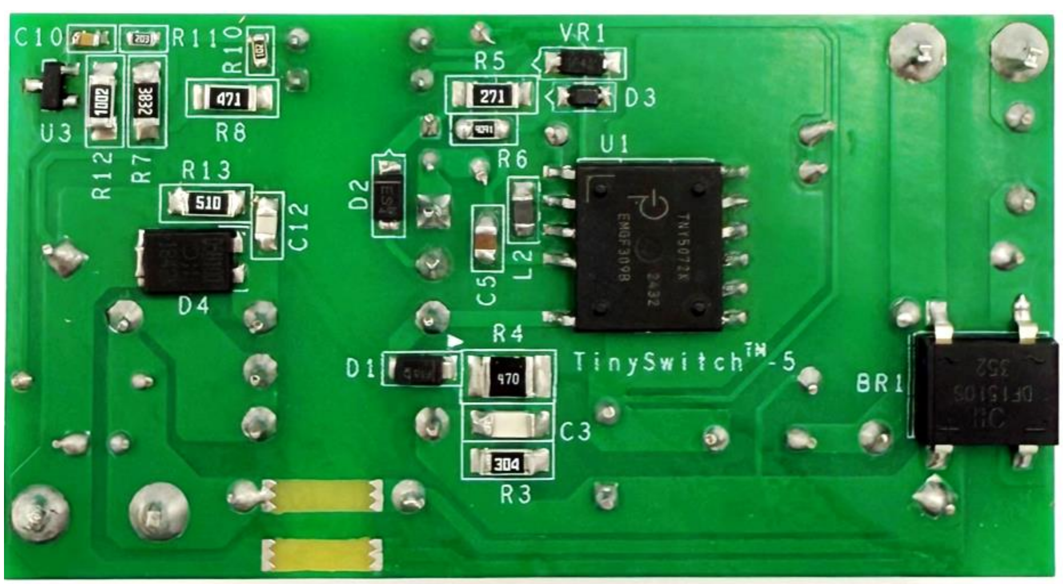


Figure 2 – Photograph, Bottom View.

Figure 3 – Photograph, Isometric View.

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	85	115/230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	63	Hz	
No-load Input Power (230 VAC)				50	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		1	A	
Total Output Power						
Continuous Output Power	P_{OUT}		12		W	
Efficiency						
Full Load 115 VAC	$\eta_{115\ VAC}$	87			%	Measured at P_{OUT} 25 °C
Full Load 230 VAC	$\eta_{230\ VAC}$	88			%	
Average efficiency at 25, 50, 75 and 100% of P_{OUT}	η_{DOE}	82.96			%	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

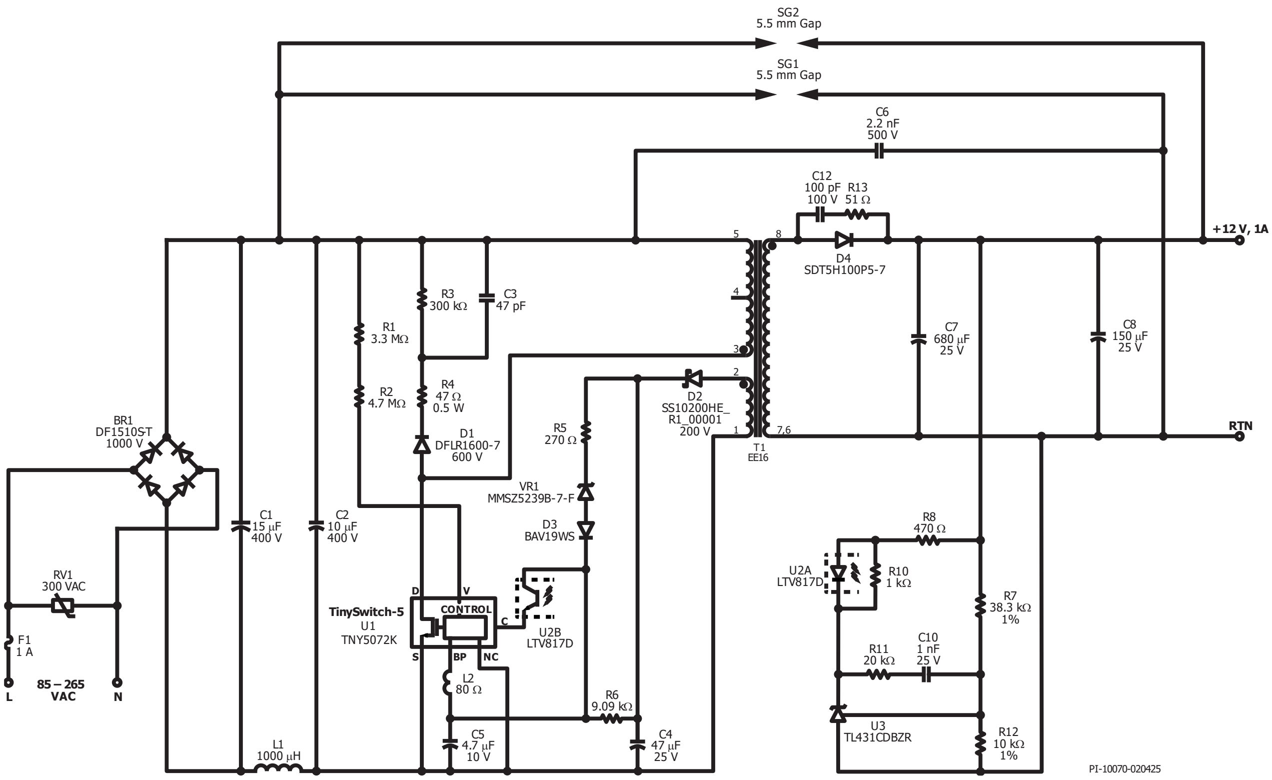


Figure 4 – Schematic.

4 Circuit Description

This power supply employs a TNY5072K off-line switcher, (U1), in a flyback configuration. IC U1 has an integrated 725 V power MOSFET. It regulates the output by adjusting the power 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. Varistor RV1 suppresses line transient voltage surge seen by the power supply. Bulk Capacitors C1 and C2 together with differential 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 capacitors C1 and C2.

4.2 TinySwitch-5 Primary

The TNY5072K device (U1) 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 capacitors C1 and C2, and the other side is connected to the DRAIN pin of U1. 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 a RCD clamp network that consists of D1, R3, R4, and C3. Resistor R4 are used together with capacitor C3 to damp out high frequency ringing and improve EMI. Y capacitor CY1, connected between the primary and secondary side helps improve EMI.

The TNY5072K regulates the output by adjusting the power MOSFET off time duration based on 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 VR1 are used for output overvoltage protection. An increase in output voltage causes an increase in the bias winding voltage, sensed by VR1. Once VR1 is activated, it will inject current to the BP pin causing the IC U1 to shut down and undergo auto-restart.

Bypass capacitor C5 serves as the current limit selection and is placed as physically close as possible to U1. C5 was used to select reduced current limit of the IC. At start-up, this capacitor is charged through the DRAIN (D) pin. Once it is charged, U1 begins to switch. Capacitor C4 stores enough energy to ensure the power supply output reaches regulation. After start-up, the bias winding via diode D2 and capacitor C4 powers the controller via the current through resistor R6. Resistor R6 was used to set the typical bias current of the IC U1. Ferrite bead L2 minimizes the noise coming to BP Pin and should be place 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 and C8. Resistor R13 and capacitor C12 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 R7 and R12. The TL431CDBZR varies its cathode voltage to keep its input voltage constant (equal to 2.50 V, ±2.2%). As the cathode voltage changes, the current through the optocoupler LED and transistor within U2 changes. R8, R11 and C10 provide stable operation throughout the range of operation, while resistor R10 ensures minimum bias to U3.

5 PCB Layout

5.1 PCB Specification

Layer: 1
Board Thickness: 1.6 mm
Copper Thickness: 2 oz.
Material: FR-4

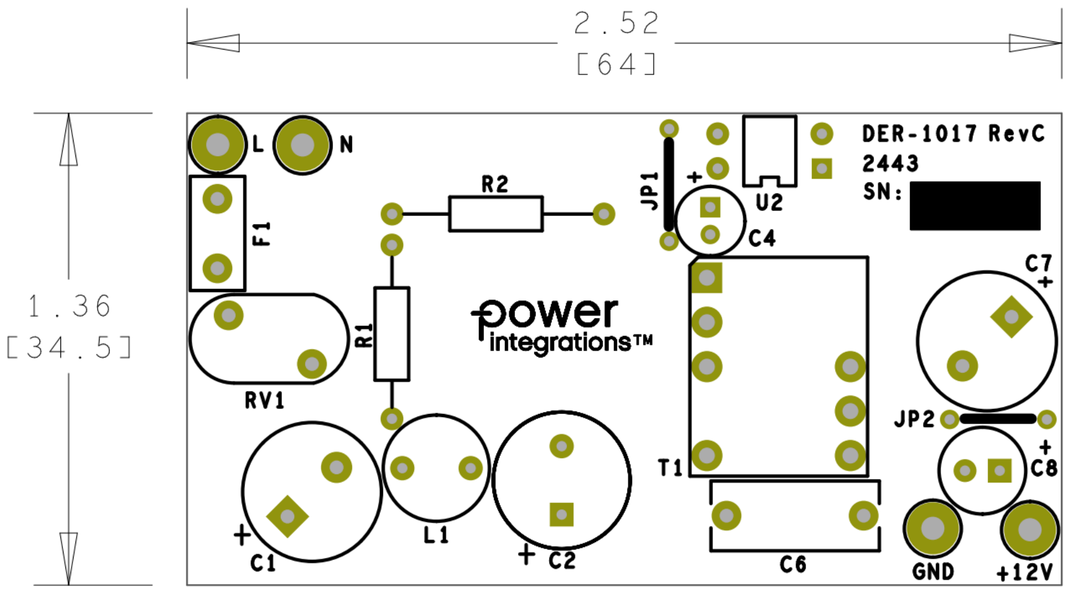


Figure 5 – Printed Circuit Board, Top View.

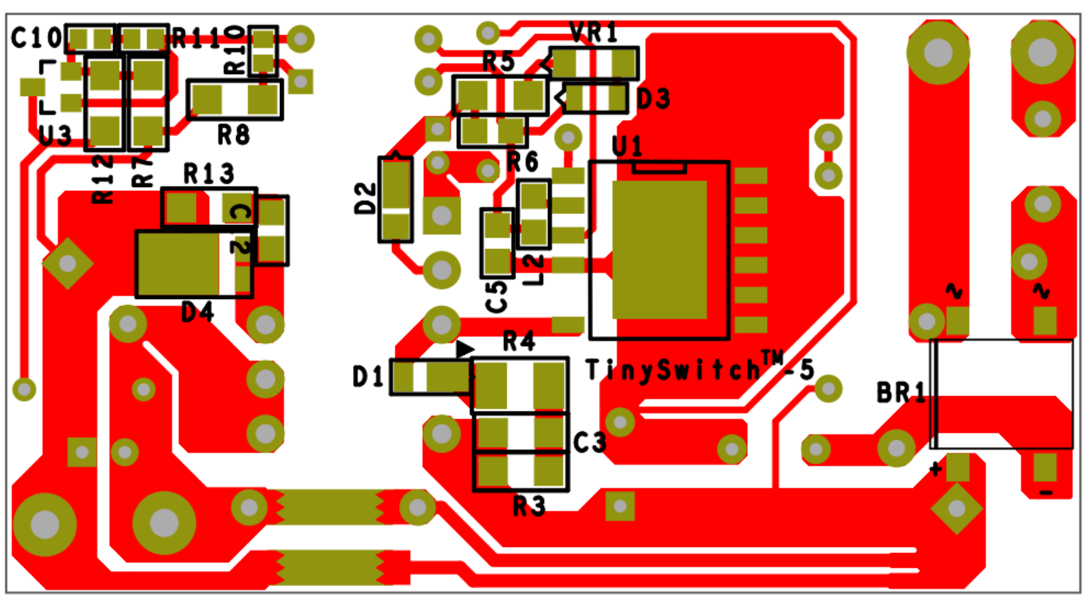


Figure 6 – Printed Circuit Board, Bottom View.

6 Bill of Materials

6.1 Electrical BOM

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	Bridge Rectifier, Single Phase, Standard, 1 kV, Surface Mount DF-S), DF-S,4-SMD	DF1510S-T	Diodes Incorporated
2	1	C1	15 uF, 400 V, Electrolytic, (10 x 16)	UVC2G150MPD	Nichicon
3	1	C2	10 uF,±20%, 400 V, Electrolytic, (10 x 12.5)	UVC2G100MPD	Nichicon
4	1	C3	47 pF, ±5%, 1000 V, Ceramic,C0G_NP0, 1206 (3216 Metric)	C1206C470JDGACAUTO	KEMET
5	1	C4	47 uF, 25 V, Electrolytic, Very Low ESR, 300 mOhm, (5 x 11)	EKZE250ELL470ME11D	Nippon Chemi-Con
6	1	C5	4.7 µF ±10% 10 V Ceramic Capacitor X7R 0805 (2012 Metric)	LMK212B7475KGHT	Taiyo Yuden
7	1	C6	2.2 nF, 500 VAC, Ceramic, Y1	VY1222M47Y5UG63V0	Vishay BC Components
8	1	C7	680 uF, 25 V, Electrolytic, Very Low ESR, 32 mOhm, (10 x 16)	EKZH250EC3681MJ16S	Nippon Chemi-Con
9	1	C8	150 uF, 25 V, Electrolytic, Low ESR, 180 mOhm, (6.3 x 15)	ELXZ250ELL151MF15D	Nippon Chemi-Con
10	1	C10	1 nF, ±10%,25 V, Ceramic, X7R, 0603 (1608 Metric)	GCM188R71E102KA37D	Murata
11	1	C12	100 pF 100 V 10 % X7R 0805	08051C101JAT2A	AVX Corp
12	1	D1	600 V, 1 A, Rectifier, Glass Passivated, POWERDI123	DFLR1600-7	Diodes Inc
13	1	D2	Diode, Schottky, 200 V, 1 A, Surface Mount SOD-123HE	SS10200HE_R1_00001	Panjit International Inc.
14	1	D3	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diode Inc.
15	1	D4	100 V, 5 A, Schottky, SMD, POWERD15,PowerDI™ 5	SDT5H100P5-7	Diode Inc.
16	1	F1	1 A, 250 V, Slow, Long Time Lag, RST 1	RST 1	Belfuse
17	1	L1	1000 uH, 0.3 A	RLB0914-102KL	Bourns
18	1	L2	FERRITE Bead, 80 Ohms at 100 MHz, 1 Signal Line, Ferrite Bead 0805 (2012 Metric), 300 mA , 300 mOhm		Max Echo
19	1	R1	RES, 3.3 M, 5%, 1/4 W, Carbon Film	CFR-25JB-3M3	Yageo
20	1	R2	RES, 4.7 M, 5%, 1/4 W, Carbon Film	CFR-25JB-4M7	Yageo
21	1	R3	RES, 300 k, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J304V	Panasonic
22	1	R4	RES, 47 Ohm, ±5%, 0.75 W, 1210 (3225 Metric), Pulse Withstanding, Thick Film	CRCW121047R0JNEAHP	Vishay Dale
23	1	R5	RES, 270 R, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J271V	Panasonic
24	1	R6	RES, 9.09 k, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF9091V	Panasonic
25	1	R7	RES, 38.3 k, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF3832V	Panasonic
26	1	R8	RES, 470 R, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J471V	Panasonic
27	1	R10	RES, 1 k, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
28	1	R11	RES, 20 k, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ203V	Panasonic
29	1	R12	RES,10 kOhms, ±1%, ±200ppm/°C, 0.5 W, ½ W Chip Resistor 1206 (3216 Metric), Moisture Resistant, Thick Film	RC1206FR-7W10KL	Yageo
30	1	R13	RES, 51 R, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J510V	Panasonic
31	1	RV1	300 Vac, 25 J, 7 mm, RADIAL	V300LA4P	Littlefuse
32	2	SG1 SG2	Spark Gap 5.5mm 2 pin		
33	1	T1	Bobbin, EE16 Vertical, 10 pins, DER-839	YW-527-00B	Yih-Hwa Enterprises
34	1	U1	TinySwitch-5, TNY5072K, eSOP-12P	TNY5072K	Power Integrations
35	1	U2	Opto coupler, 35 V, CTR 300-600%, 4-DIP	LTV-817D	Liteon
36	1	U3	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
37	1	VR1	DIODE ZENER 9.1 V 500MW SOD123	MMSZ5239B-7-F	Diodes, Inc

6.2 Mechanical BOM

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
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	2	JP1 JP2	Wire Jumper, Insulated, 24 AWG, 0.2 in	C2003A-12-02	Gen Cable
4	1	N	Test Point, WHT,THRU-HOLE MOUNT	5012	Keystone

7 Transformer Specification

7.1 Electrical Diagram

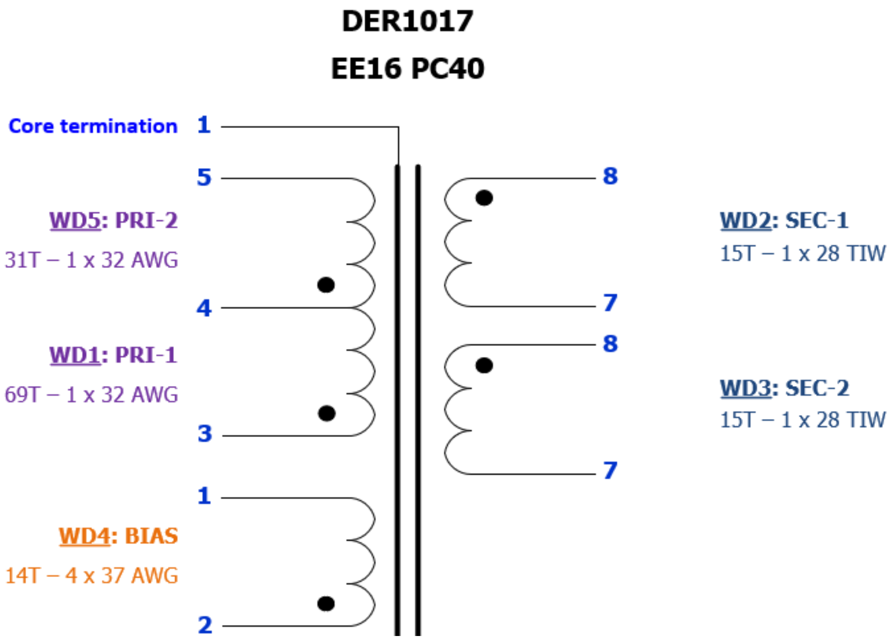


Figure 7 – Transformer Electrical Diagram.

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 5, with all other Windings open.	1219 μH
Tolerance	Tolerance of Primary Inductance.	±5%
Leakage Inductance	Measured across primary winding with all other windings shorted.	< 12.19 μH

7.3 Material List

Item	Description
[1]	Core: EE16 PC40, 3F3, gapped for ALG of 122 nH / T^2
[2]	Bobbin: YW-527-00B, EE16 Vertical, 10 pins, PI#25-00970-00.
[3]	Bus wire: #28AWG, Alpha Wire, Tinned Copper, 80mm Length.
[4]	Varnish: Dolph BC 359 or Equivalent.
[5]	Magnet Wire: 32 AWG
[6]	Polyester Tape: 8.5 mm
[7]	Triple Insulated Wire: 28 AWG
[8]	Magnet Wire: 37 AWG

7.4 Transformer Build Diagram

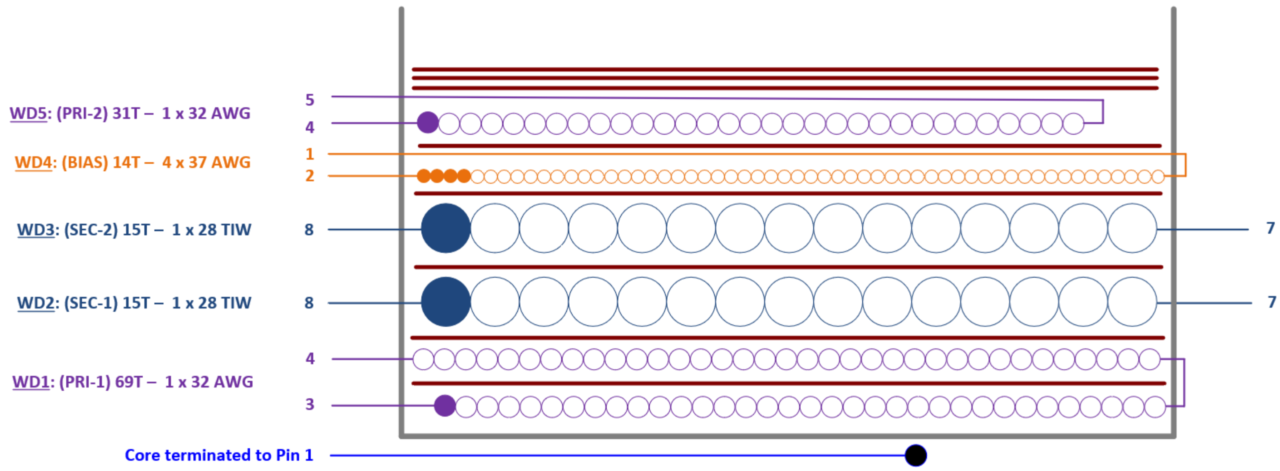


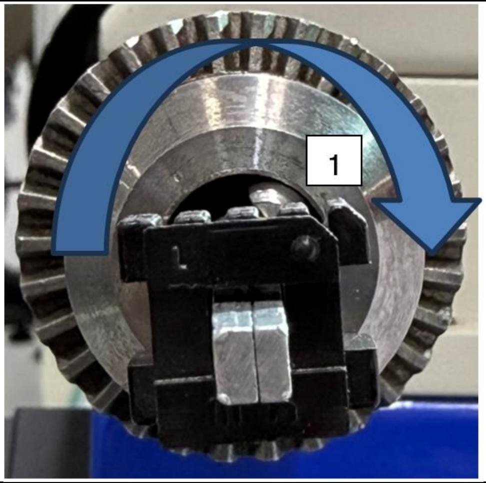
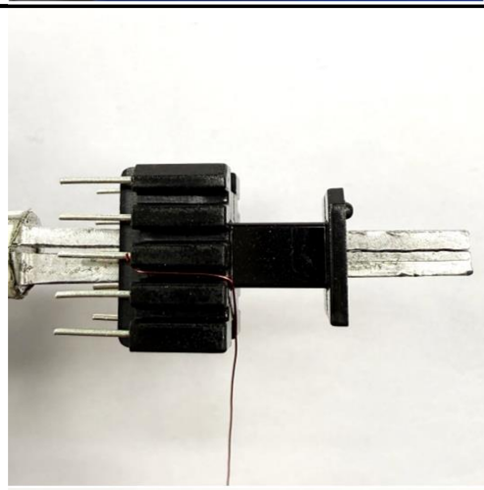
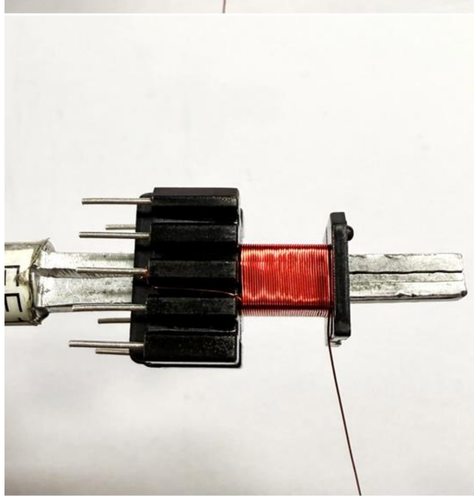
Figure 8 – Transformer Build Diagram.

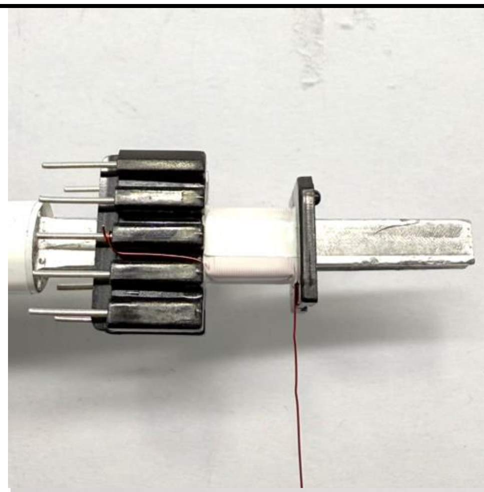
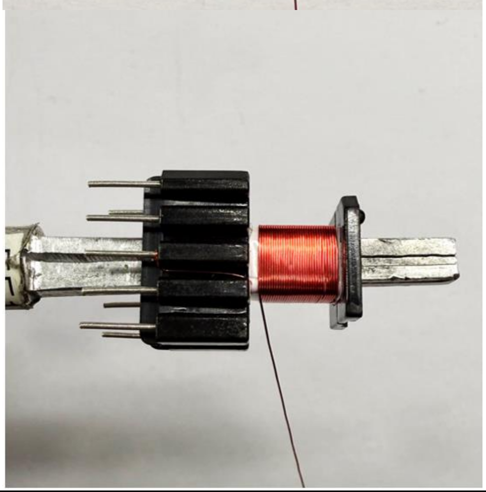
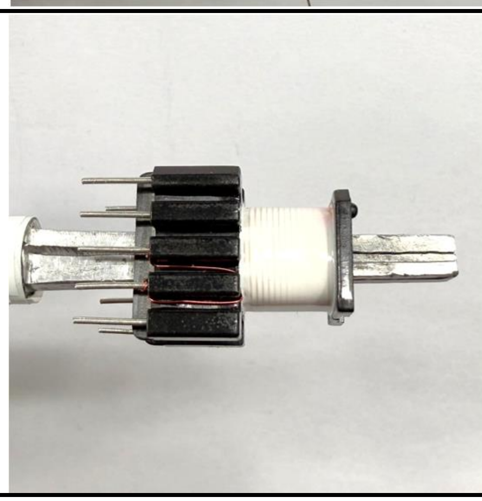
7.5 Transformer Instructions

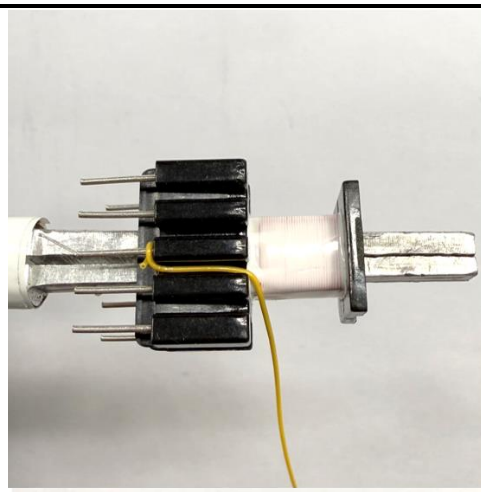
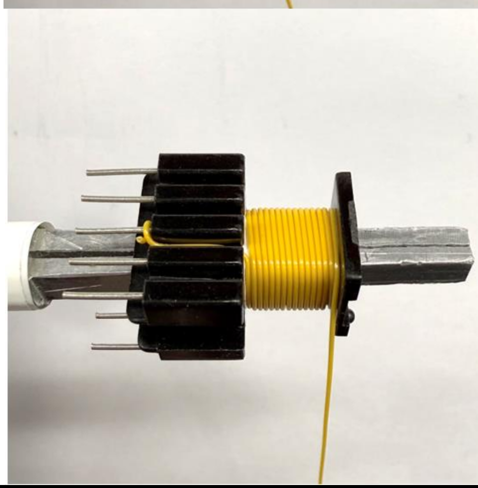
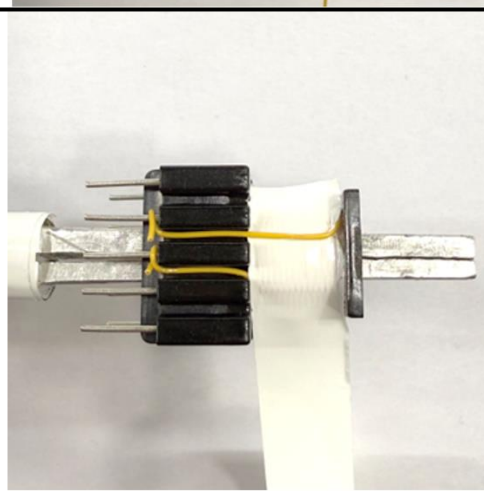
Preparation	Place the bobbin Item [2] such that pins 1-5 are on upper side while 6-10 are on lower side. The notch on the bobbin signifies Pin 1. Winding direction is clockwise as shown.
WD1 1st Primary	Start with 1 lead of Item [5] from Pin 3, and wind 69 turns in Clockwise direction in total of 2 layers. Wind one layer from left to right. Before each new layer, Apply 1 layer of tape, Item [6]. At the end of 1st layer, continue to wind the next layer towards the beginning of the previous layer. Finish this winding on Pin 4.
Insulation	Apply 1 layer of tape Item [6] for insulation.
WD2 1st Secondary	Start with 1 lead of Item [7] at pin 8, and wind 15 turns in Clockwise direction in total of 1 layer. Wind one layer from left to right.
Insulation	Apply 1 layer of tape, Item [6] for insulation and to hold wires in place. Bend the end of WD2 90 degrees then finish WD2 on pin 7. Finish wrapping the tape to cover WD2.
WD3 2nd Secondary	Start with 1 lead of Item [7] at pin 8, and wind 15 turns in Clockwise direction in total of 1 layer. Wind one layer from left to right.
Insulation	Apply 1 layer of tape, Item [6] for insulation and to hold wires in place. Bend the end of WD3 90 degrees then finish WD3 on pin 7. Finish wrapping the tape to cover WD3.
WD4 Primary Bias	Start with 4 leads of Item [8] at Pin 2, and wind 14 turns in Clockwise direction in total of 1 layer. Wind one layer from left to right.
Insulation	Apply 1 layer of tape Item [6] for insulation and to hold wires in place. Bend the end of WD4 90 degrees and finish WD4 on pin 1. Finish wrapping the tape to cover WD4.
WD5 2nd Primary	Start with 1 lead of Item [5] at Pin 4, and wind 31 turns in Clockwise direction in total of 1 layer. Wind one layer from left to right. Spread the winding evenly across the entire bobbin.
Insulation	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 5. Wrap the tape to cover WD5 and apply 2 additional layers of tape Item [6].

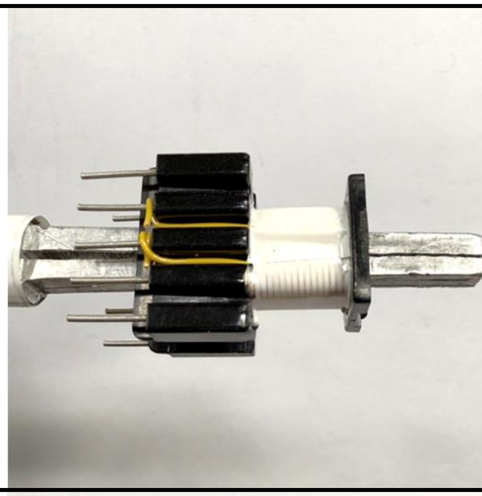
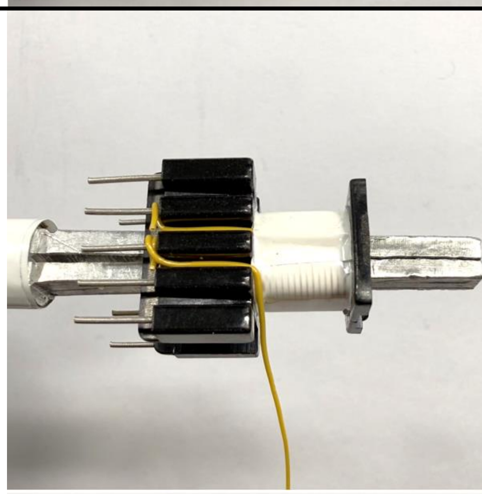
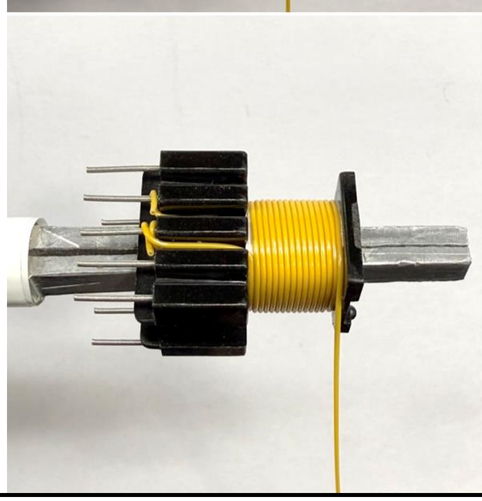
Assembly	Grind the center leg of the upper half of Item [1] to get 1219 μH measured between Pin 3 and Pin 5 with all other pins open. Use Item [3] and wrap it around Item [1], then solder to Pin 1. Wrap the body of the transformer with 2 layers of tape Item [6]. Measure Primary Inductance between Pin 3 and Pin 5 with all other pins open, then Leakage Inductance between Pin 3 and Pin 5 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.

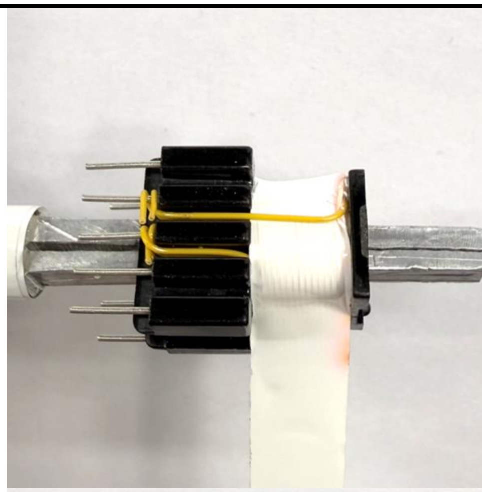
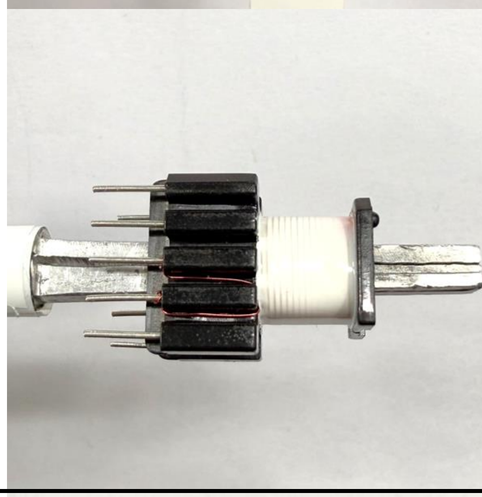
7.6 Transformer Winding Illustrations

Preparation		Place the bobbin Item [2] such that pins 1-5 are on upper side while 6-10 are on lower side. The notch on the bobbin signifies Pin 1. Winding direction is clockwise as shown.
WD1 **1st Primary**		Start with 1 lead of Item [5] from Pin 3, and wind 69 turns in Clockwise direction in total of 2 layers. Wind one layer from left to right.

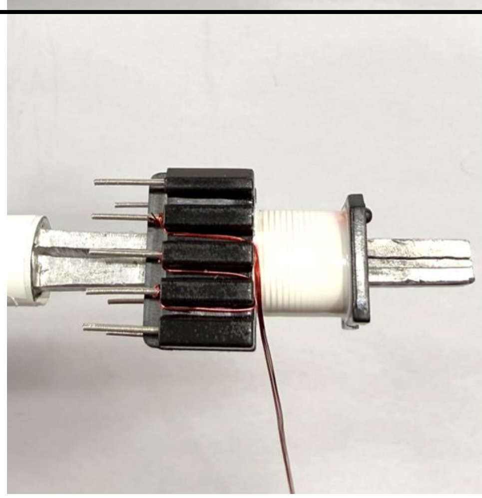
	 	Before each new layer, Apply 1 layer of tape, Item [6]. At the end of 1st layer, continue to wind the next layer towards the beginning of the previous layer. Finish this winding on Pin 4.
Insulation		Apply 1 layer of tape Item [6] for insulation.

WD2 **1st Secondary**	 	Start with 1 lead of Item [7] at pin 8, and wind 15 turns in Clockwise direction in total of 1 layer. Wind one layer from left to right.
Insulation		Apply 1 layer of tape Item [6] for insulation and to hold wires in place. Bend the end of WD2 90 degrees then finish WD2 on pin 7.

<table>
<tr><td></td><td></td><td>Finish wrapping the tape to cover WD2.</td></tr>
<tr><td rowspan="2">WD3
2nd Secondary</td><td></td><td>Start with 1 lead of Item [7] at pin 8, and wind 15 turns in Clockwise direction in total of 1 layer.</td></tr>
<tr><td></td><td>Wind one layer from left to right.</td></tr>
</table>

<table>
<tr><td>Insulation</td><td>
</td><td>Apply 1 layer of tape Item [6] for insulation and to hold wires in place.

Bend the end of WD3 90 degrees then finish WD3 on pin 7.

Finish wrapping the tape to cover WD3.</td></tr>
<tr><td>WD4
Primary Bias</td><td></td><td>Start with 4 leads of Item [8] at pin 2, and wind 14 turns in Clockwise direction in total of 1 layer.</td></tr>
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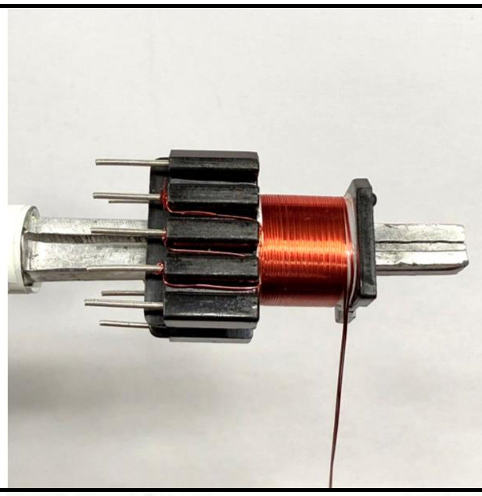
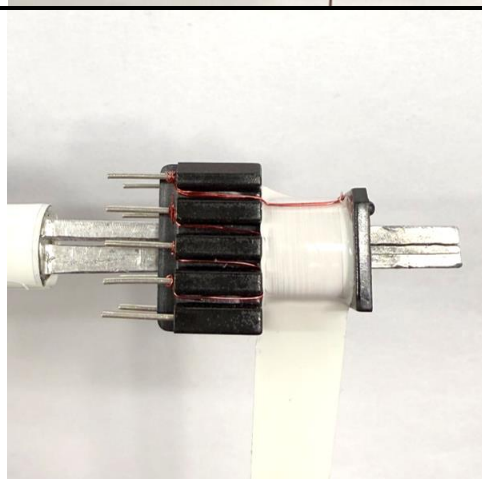
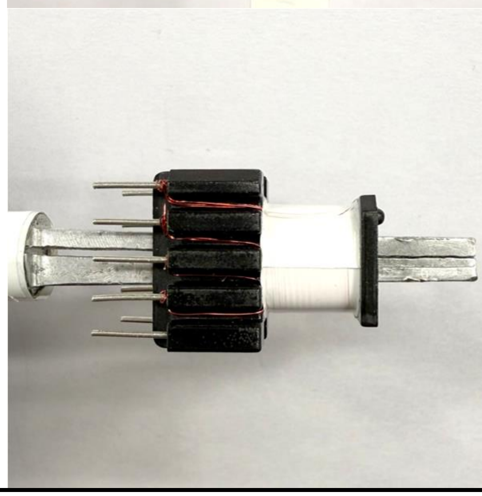
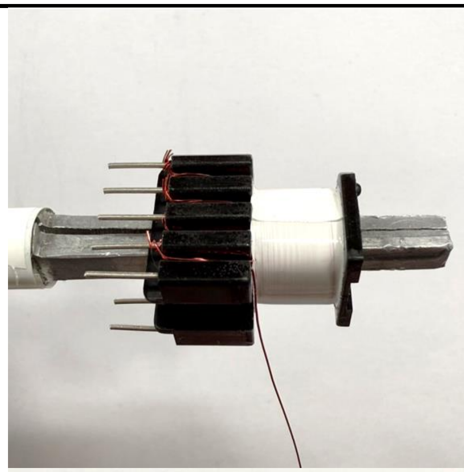
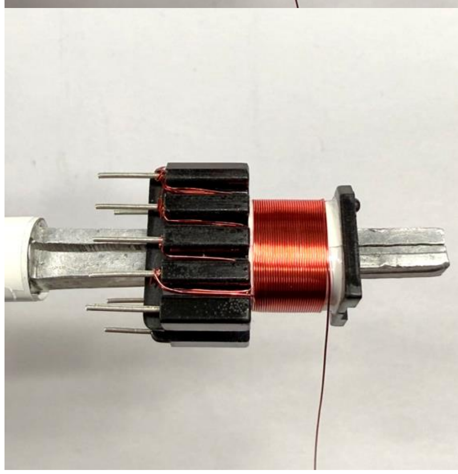
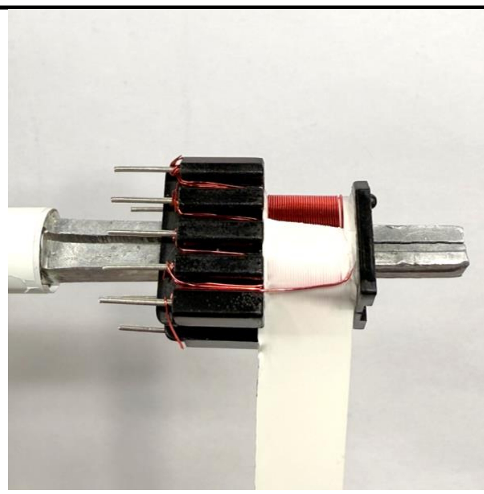
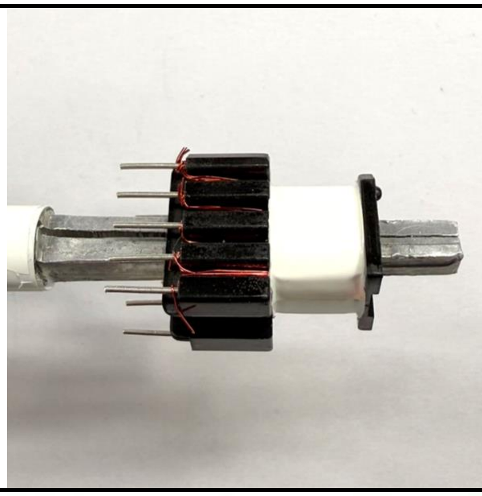
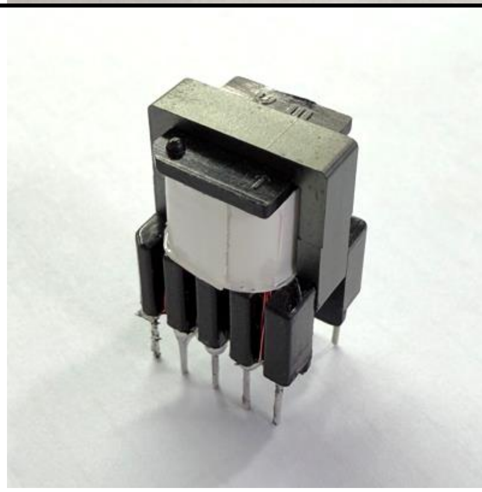
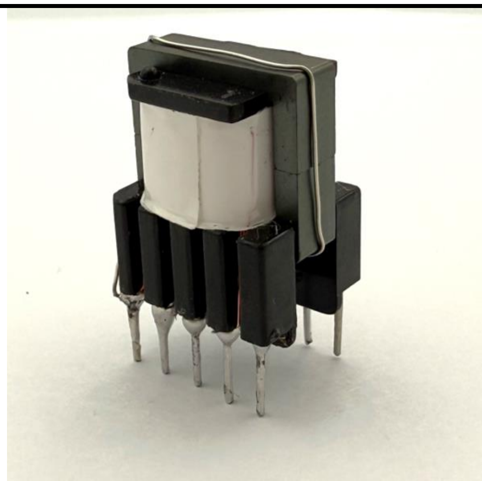
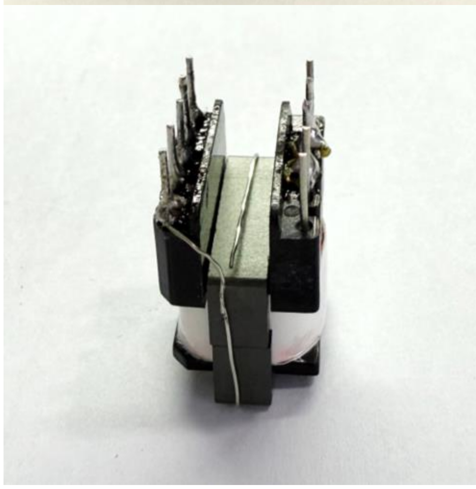
		Wind one layer from left to right.
Insulation		Apply 1 layer of tape Item [6] for insulation and to hold wires in place. Bend the end of WD4 90 degrees and finish WD4 on pin 1.
		Finish wrapping the tape to cover WD4.

WD5 **2nd Primary**	 	Start with 1 lead of Item [5] at pin 4, and wind 31 turns in Clockwise direction in total of 1 layer. Wind one layer from left to right. Spread the winding evenly across the entire bobbin.
Insulation		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 5.

		Wrap the tape to cover WD5 and apply 2 additional layers of tape Item [6].
Assembly		Grind the center leg of the upper half of Item [1] to get 1219 µH measured between Pin 3 and Pin 5 with all other pins open.

	 	Use Item [3] and wrap it around Item [1], then solder to Pin 1.
		Wrap the body of transformer with 2 layers of tape Item [6]. Measure Primary Inductance between Pin 3 and Pin 5 with all other pins open, then Leakage Inductance between Pin 3 and Pin 5 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_103124; Rev.0.1; Copyright Power Integrations 2024**	**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		85	V	Minimum AC input voltage
5	VIN_MAX	265		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	25.0		25.0	uF	Input capacitor
9	VOUT	12.00		12.00	V	Output voltage at the board
10	IOUT	1.000		1.000	A	Output current
11	POUT			12.00	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	PACKAGE_DEVICE	eSOP		eSOP		Device Package
20	ILIMIT_MODE	REDUCED		REDUCED		Device current limit mode
21	DEVICE_SERIES	TNY5072		TNY5072		Generic device code
22	DEVICE_CODE			TNY5072K		Actual device code
23	POUT_MAX			20	W	Power capability of the device based on thermal performance
24	RDSON_100DEG			9.70	Ω	Primary switch on time drain resistance at 100 °C
25	ILIMIT_MIN			0.442	A	Minimum current limit of the primary switch
26	ILIMIT_TYP			0.480	A	Typical current limit of the primary switch
27	ILIMIT_MAX			0.518	A	Maximum current limit of the primary switch
28	VDRAIN_BREAKDOWN			725	V	Device breakdown voltage
29	VDRAIN_ON_PRSW			1.48	V	Primary switch on time drain voltage
30	VDRAIN_OFF_PRSW			483.4	V	Peak drain voltage on the primary switch during turn-off. A 30 V leakage spike voltage is assumed
31						
32						
33						
34	WORST CASE ELECTRICAL PARAMETERS					
35	FSWITCHING_MAX			130000	Hz	Maximum switching frequency at full load and valley of the rectified minimum AC input voltage
36	VOR	80.0		80.0	V	Secondary voltage reflected to the primary when the primary switch turns off
37	VMIN			86.31	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			0.485		Primary switch duty cycle
41	TIME_ON			6.92	us	Primary switch on-time
42	TIME_OFF			3.96	us	Primary switch off-time
43	LPRIMARY_MIN			1158.3	uH	Minimum primary inductance
44	LPRIMARY_TYP			1219.2	uH	Typical primary inductance
45	LPRIMARY_TOL			5.0	%	Primary inductance tolerance
46	LPRIMARY_MAX			1280.2	uH	Maximum primary inductance
47						
48	PRIMARY CURRENT					
49	IPEAK_PRIMARY			0.513	A	Primary switch peak current
50	IPEDESTAL_PRIMARY			0.181	A	Primary switch current pedestal
51	IAVG_PRIMARY			0.153	A	Primary switch average current
52	IRIPPLE_PRIMARY			0.395	A	Primary switch ripple current
53	IRMS_PRIMARY			0.234	A	Primary switch RMS current
54						
55	SECONDARY CURRENT					
56	IPEAK_SECONDARY			3.418	A	Secondary winding peak current
57	IPEDESTAL_SECONDARY			1.208	A	Secondary winding current pedestal
58	IRMS_SECONDARY			1.603	A	Secondary winding RMS current
59						
60						
61						
62	TRANSFORMER CONSTRUCTION PARAMETERS					
63	CORE SELECTION					
64	CORE	EE16		EE16		Core selection. Refer to the 'Transformer Construction' tab to see the detailed report
65	CORE CODE			PC40EE16-Z		Core code
66	AE			19.00	mm^2	Core cross sectional area
67	LE			34.50	mm	Core magnetic path length
68	AL			1140	nH/turns ^2	Ungapped core effective inductance
69	VE			656.0	mm^3	Core volume
70	BOBBIN			BE16-116CPFR		Bobbin
71	AW			27.30	mm^2	Window area of the bobbin
72	BW			8.50	mm	Bobbin width
73	MARGIN			0.0	mm	Safety margin width (Half the primary to secondary creepage distance)
74						
75	PRIMARY WINDING					
76	NPRIMARY			100		Primary turns
77	BPEAK			3640	Gauss	Peak flux density
78	BMAX			3424	Gauss	Maximum flux density
79	BAC			1301	Gauss	AC flux density (0.5 x Peak to Peak)
80	ALG			122	nH/turns ^2	Typical gapped core effective inductance
81	LG			0.175	mm	Core gap length
82						
83	PRIMARY BIAS WINDING					
84	NBIAS_PRIMARY			14	turns	Primary bias winding number of turns
85						
86	SECONDARY WINDING					
87	NSECONDARY			15	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 REQURED			66.30	V	Required AC RMS/DC line voltage brown-in threshold
97	RLS			6.96	MΩ	Connect two 3.48 mOhm resistors to the V-pin for the required UV/OV threshold
98	BROWN-IN ACTUAL			54.1 - 67.1	V	Actual AC RMS/DC brown-in range
99	BROWN-OUT ACTUAL			46.7 - 57.9	V	Actual AC RMS/DC brown-out range
100						
101	LINE OVERVOLTAGE					
102	OVERVOLTAGE_LINE		Info	246.1- 306.5	V	The line over-voltage threshold is lower than the maximum input AC RMS/DC voltage
103						
104	PRIMARY BIAS DIODE					
105	VBIAS_PRIMARY	10.0		10.0	V	Rectified primary bias voltage
106	VF_BIAS_PRIMARY			0.70	V	Bias winding diode forward drop
107	VREVERSE_BIASDIODE_PRIMARY			63.47	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
108	CBIAS_PRIMARY			47	uF	Bias winding rectification capacitor
109	CBPP			4.70	uF	BPP pin capacitor
110						
111						
112						
113	SECONDARY COMPONENTS					
114	VREF_REG			2.5	V	Reference voltage of the feedback
115	RFB_UPPER			38.3	kΩ	Upper feedback resistor (connected to the first output voltage)
116	RFB_LOWER			10.00	kΩ	Lower feedback resistor
117	CFB_LOWER			330	pF	Lower feedback resistor decoupling capacitor
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	CBPS			NA	uF	BPP pin capacitor
126						
127						
128	MULTIPLE OUTPUT PARAMETERS					
129	OUTPUT 1					
130	VOUT1			12.00	V	Output 1 voltage
131	IOUT1			1.00	A	Output 1 current
132	POUT1			12.00	W	Output 1 power

133	VD1			0.70	V	Forward voltage drop of diode for output 1
134	NS1			15.00	turns	Number of turns for output 1
135	ISPEAK1			3.42	A	Instantaneous peak value of the secondary current for output 1
136	ISRMS1			1.603	A	Root-mean-squared value of the secondary current for output 1
137	ISRIPPLE1			1.253	A	Current ripple on the secondary waveform for output 1
138	PIV1_CALCULATED			81.34	V	Computed peak inverse voltage stress on the diode for output 1
139	OUTPUT_RECTIFIER1	AUTO		SB3100		Recommended diode for output 1.
140	PIV1_RATING			100.00	V	Peak inverse voltage rating on the diode for output 1
141	TRR1			0.00	ns	Reverse recovery time of the diode for output 1
142	IFM1			3.00	A	Maximum forward continuous current of the diode for output 1
143	PLOSS_DIODE1			0.63	W	Maximum diode power loss for output 1
144						
145	OUTPUT 2					
146	VOUT2			0.00	V	Output 2 voltage
147	IOUT2			0.000	A	Output 2 current
148	POUT2			0.00	W	Output 2 power
149	VD2			N/A	V	Forward voltage drop of diode for output 2
150	NS2			N/A	turns	Number of turns for output 2
151	ISPEAK2			N/A	A	Instantaneous peak value of the secondary current for output 1
152	ISRMS2			N/A	A	Root mean squared value of the secondary current for output 2
153	ISRIPPLE2			N/A	A	Current ripple on the secondary waveform for output 2
154	PIV2			N/A	V	Computed peak inverse voltage stress on the diode for output 2
155	OUTPUT_RECTIFIER2	AUTO		N/A		Recommended diode for output 2.
156	PIV2_RATING			N/A	V	Peak inverse voltage rating on the diode for output 2
157	TRR2			N/A	ns	Reverse recovery time of the diode for output 2
158	IFM2			N/A	A	Maximum forward continuous current of the diode for output 2
159	PLOSS_DIODE2			N/A	W	Maximum diode power loss for output 2
160						
161	OUTPUT 3					
162	VOUT3			0.00	V	Output 3 voltage
163	IOUT3			0.000	A	Output 3 current
164	POUT3			0.00	W	Output 3 power
165	VD3			N/A	V	Forward voltage drop of diode for output 3
166	NS3			N/A	turns	Number of turns for output 3
167	ISPEAK3			N/A	A	Instantaneous peak value of the secondary current for output 1

9 Performance Data

9.1 Full Load Efficiency vs. Line

Test Condition: Soak for 15 minutes for each line.

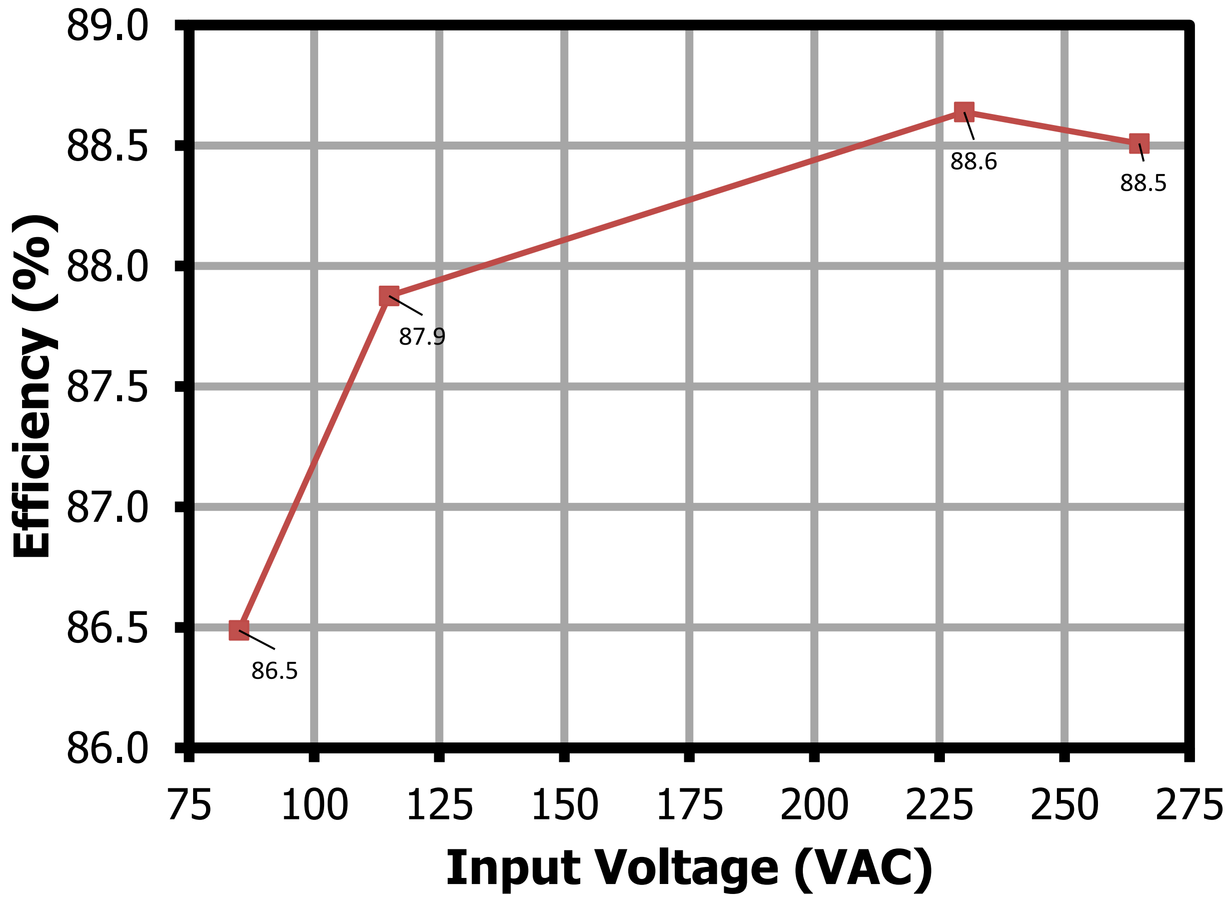


Figure 9 – Efficiency vs. Input Voltage.

VAC	Freq	V_{IN}	I_{IN}	P_{IN}	V_{OUT}	I_{OUT}	P_{OUT}	V_{REG}	Efficiency
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(A)	(W)	(%)	(%)
85	60.0	85	286	13.9	12.0	1	12.0	0.375	86.5
115	60.0	115	233	13.7	12.0	1	12.0	0.383	87.9
230	50.0	230	151	13.6	12.0	1	12.0	0.392	88.6
265	50.0	265	142	13.6	12.0	1	12.0	0.392	88.5

9.2 Line Regulation

Test Condition: Soak for 15 minutes for each line.

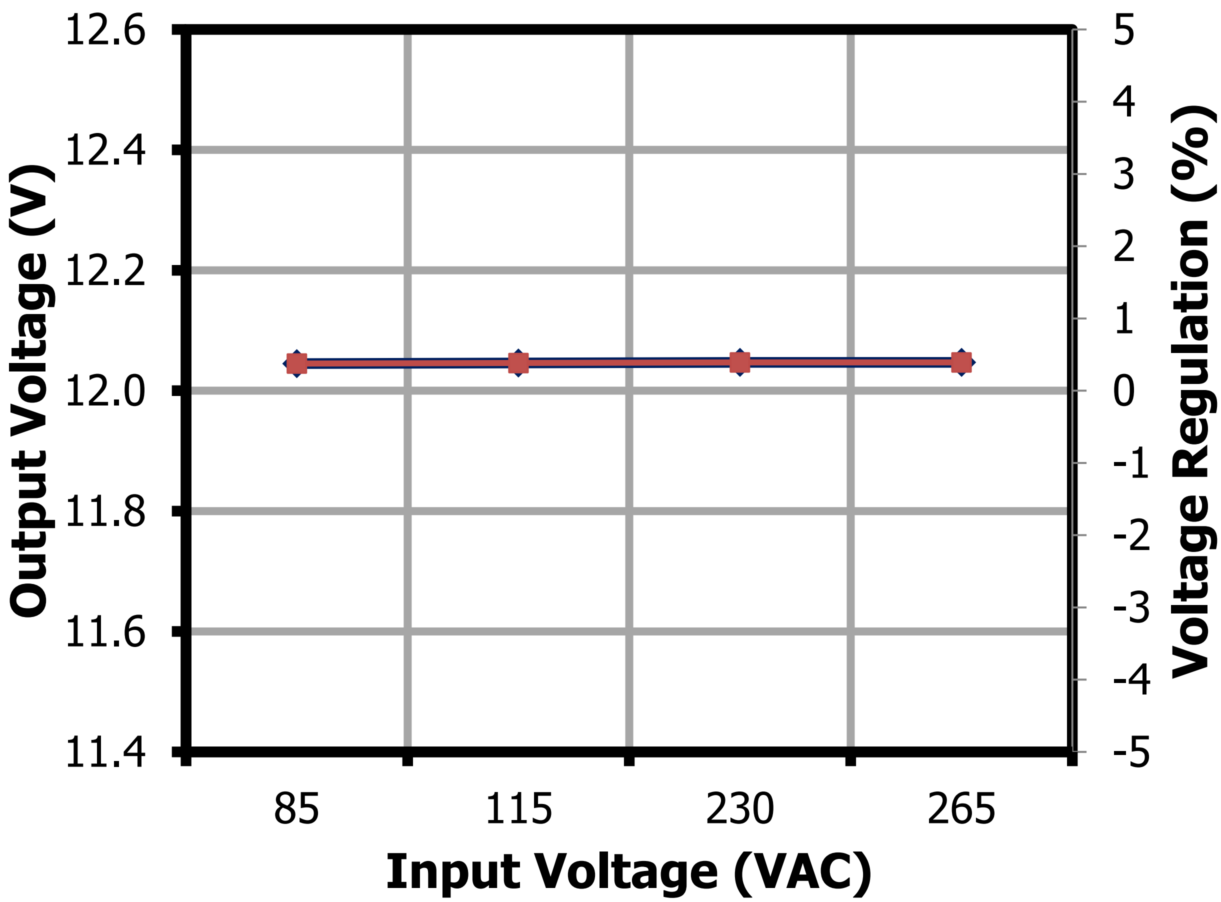


Figure 10 – Output Voltage vs. Line Voltage.

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	60.0	85	286	13.9	12.0	1000	12.0	0.375	86.5
115	60.0	115	233	13.7	12.0	1000	12.0	0.383	87.9
230	50.0	230	151	13.6	12.0	1000	12.0	0.392	88.6
265	50.0	265	142	13.6	12.0	1000	12.0	0.392	88.5

9.3 Efficiency vs. Load

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

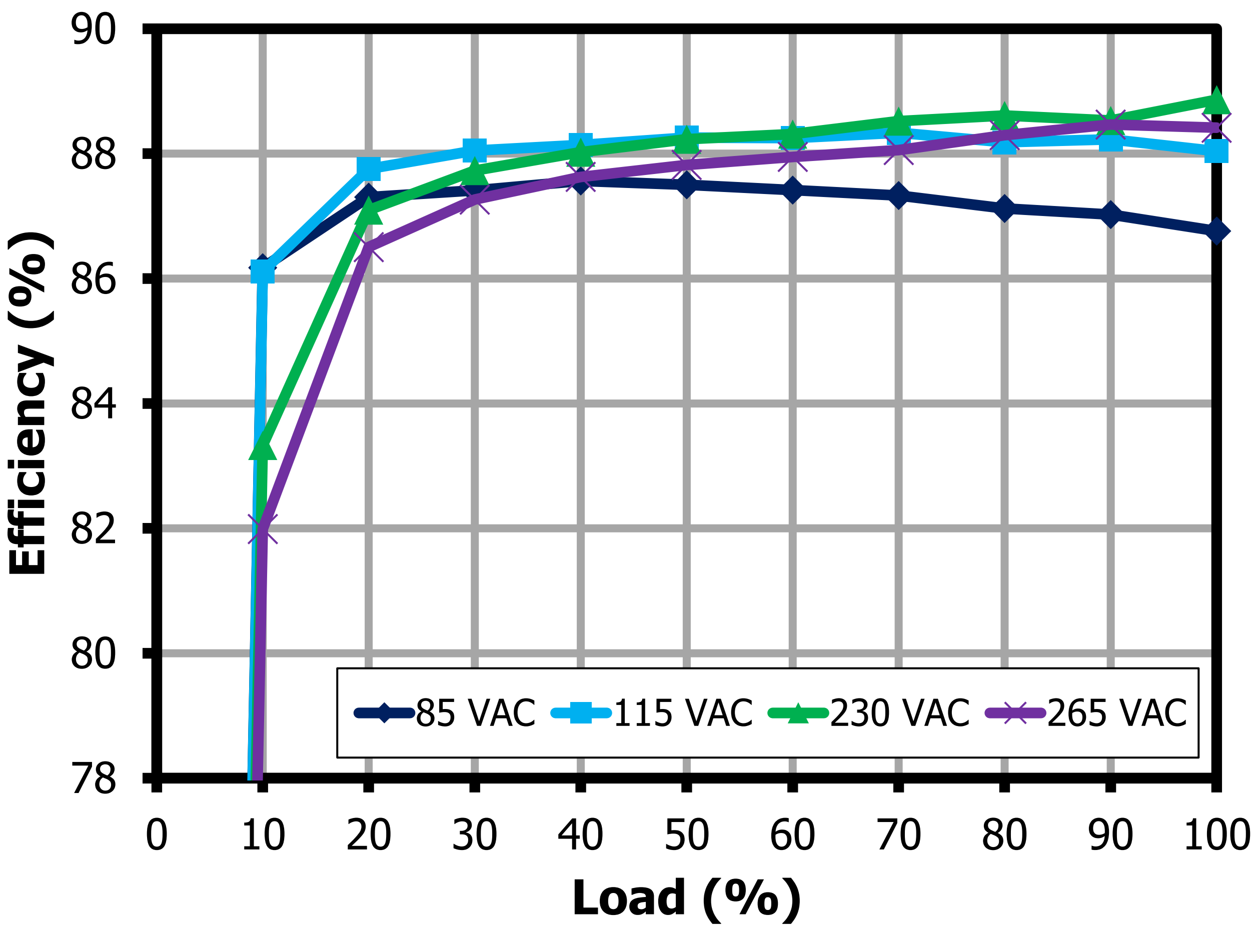


Figure 11 – Efficiency vs. Percentage Load.

9.4 Load Regulation

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

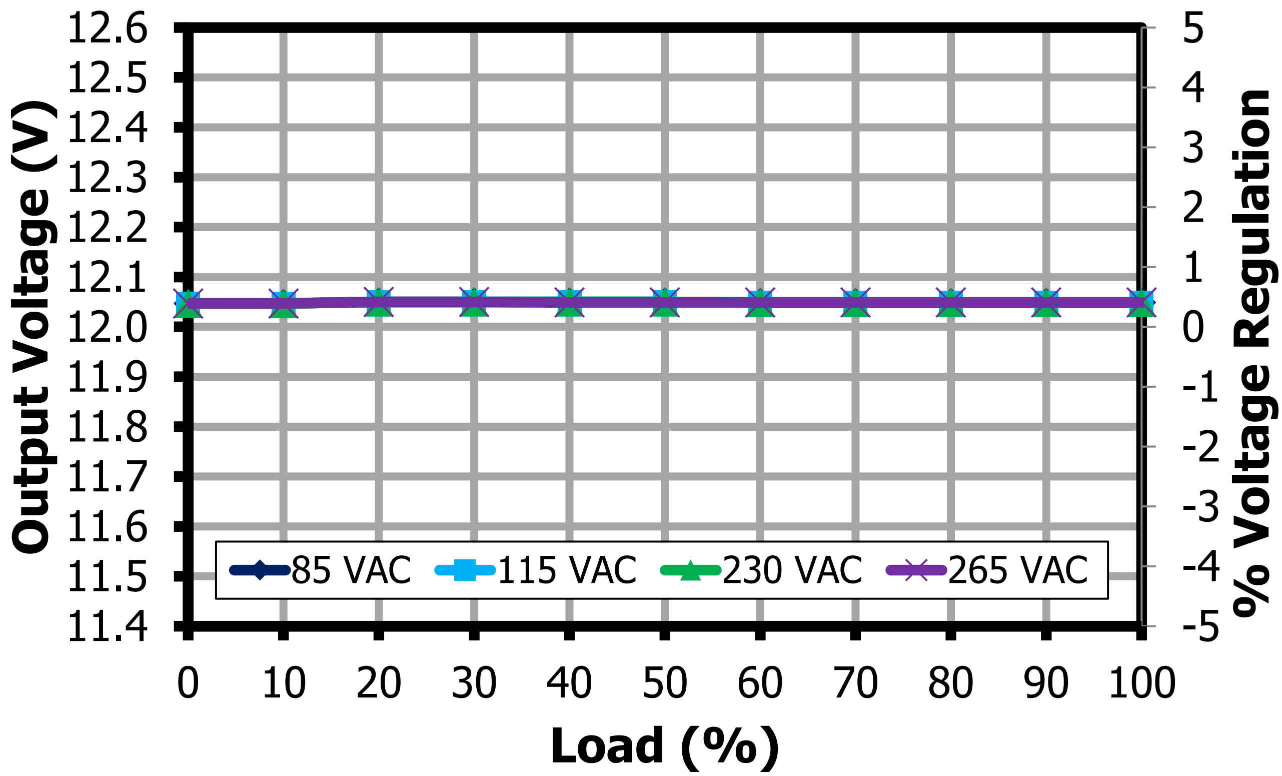


Figure 12 – Output Voltage vs. Percent Load.

VAC	Freq	V_{IN}	I_{IN}	P_{IN}	V_{OUT}	I_{OUT}	P_{OUT}	V_{REG}	Efficiency	V_{RIPPLE}
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(mA)	(W)	(%)	(%)	(mV)
85	60	85	286	13.9	12.0	1000	12.0	0.408	86.8	106
85	60	85	261	12.5	12.0	900	10.9	0.408	87.0	96.4
85	60	85	236	11.0	12.0	800	9.64	0.408	87.1	92.5
85	60	85	211	9.66	12.0	700	8.44	0.408	87.3	84.6
85	60	85	186	8.27	12.0	600	7.23	0.408	87.4	83.8
85	60	85	160	6.89	12.0	500	6.03	0.417	87.5	83.0
85	60	85	134	5.51	12.0	400	4.82	0.417	87.6	80.6
85	60	85	106	4.14	12.0	300	3.62	0.417	87.4	75.9
85	60	85	77.0	2.76	12.0	200	2.41	0.417	87.3	68.8
85	60	85	45.0	1.41	12.0	100	1.21	0.392	86.1	58.5

VAC	Freq	V_{IN}	I_{IN}	P_{IN}	V_{OUT}	I_{OUT}	P_{OUT}	V_{REG}	Efficiency	V_{RIPPLE}
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(mA)	(W)	(%)	(%)	(mV)
115	60	115	232	13.7	12.0	1000	12.0	0.408	88.0	90.1
115	60	115	213	12.3	12.0	900	10.9	0.408	88.0	87.7
115	60	115	194	10.9	12.0	800	9.64	0.408	88.1	83.8
115	60	115	174	9.55	12.0	700	8.44	0.408	88.1	83.0
115	60	115	154	8.20	12.0	600	7.23	0.408	88.2	81.4
115	60	115	136	6.83	12.0	500	6.03	0.417	88.2	81.4
115	60	115	111	5.47	12.0	400	4.82	0.417	88.2	79.1
115	60	115	89.1	4.11	12.0	300	3.62	0.417	88.1	77.5
115	60	115	65.3	2.75	12.0	200	2.41	0.417	87.9	73.5
115	60	115	36.5	1.41	12.0	100	1.21	0.392	86.2	63.2

VAC	Freq	V_{IN}	I_{IN}	P_{IN}	V_{OUT}	I_{OUT}	P_{OUT}	V_{REG}	Efficiency	V_{RIPPLE}
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(mA)	(W)	(%)	(%)	(mV)
230	50	230	150	13.6	12.0	1000	12.0	0.408	88.8	91.7
230	50	230	139	12.3	12.0	900	10.9	0.408	88.5	93.3
230	50	230	127	10.9	12.0	800	9.64	0.408	88.6	91.7
230	50	230	115	9.53	12.0	700	8.44	0.408	88.5	90.9
230	50	230	101	8.19	12.0	600	7.23	0.408	88.3	89.3
230	50	230	88.1	6.83	12.0	500	6.03	0.417	88.2	88.5
230	50	230	73.5	5.48	12.0	400	4.82	0.417	88.0	87.0
230	50	230	57.6	4.12	12.0	300	3.62	0.417	87.7	82.2
230	50	230	40.6	2.77	12.0	200	2.41	0.417	87.1	74.3
230	50	230	22.7	1.45	12.0	100	1.21	0.392	83.3	63.2

VAC	Freq	V_{IN}	I_{IN}	P_{IN}	V_{OUT}	I_{OUT}	P_{OUT}	V_{REG}	Efficiency	V_{RIPPLE}
(RMS)	(Hz)	(RMS)	(mA)	(W)	(V)	(mA)	(W)	(%)	(%)	(mV)
265	50	265	141	13.6	12.0	1000	12.0	0.408	88.4	94.9
265	50	265	130	12.3	12.0	900	10.9	0.408	88.5	94.1
265	50	265	120	10.9	12.0	800	9.64	0.408	88.3	92.5
265	50	265	109	9.58	12.0	700	8.44	0.408	88.1	91.7
265	50	265	94.3	8.22	12.0	600	7.23	0.408	88.0	90.9
265	50	265	81.0	6.86	12.0	500	6.03	0.408	87.8	89.3
265	50	265	66.9	5.50	12.0	400	4.82	0.408	87.6	87.7
265	50	265	52.2	4.15	12.0	300	3.62	0.417	87.3	83.8
265	50	265	36.8	2.79	12.0	200	2.41	0.417	86.5	76.7
265	50	265	20.7	1.48	12.0	100	1.21	0.392	82	65.6

9.5 Average and 10% Efficiency

9.5.1 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%	13.7	12.0	1000	12.0	88.0	**88.0**	83.0
75%	10.2	12.0	750.	9.03	88.2		
50%	6.84	12.0	500	6.02	88.0		
25%	3.43	12.0	250	3.01	87.8		
10%	1.40	12.0	100	1.21	86.3	---	---

9.5.2 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%	13.6	12.0	1000	12.0	88.6	**87.9**	83.0
75%	10.2	12.0	750	9.03	88.2		
50%	6.85	12.0	500	6.02	87.9		
25%	3.47	12.0	250	3.01	86.8		
10%	1.44	12.0	100	1.20	83.5	---	---

9.6 No-Load Input Power

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

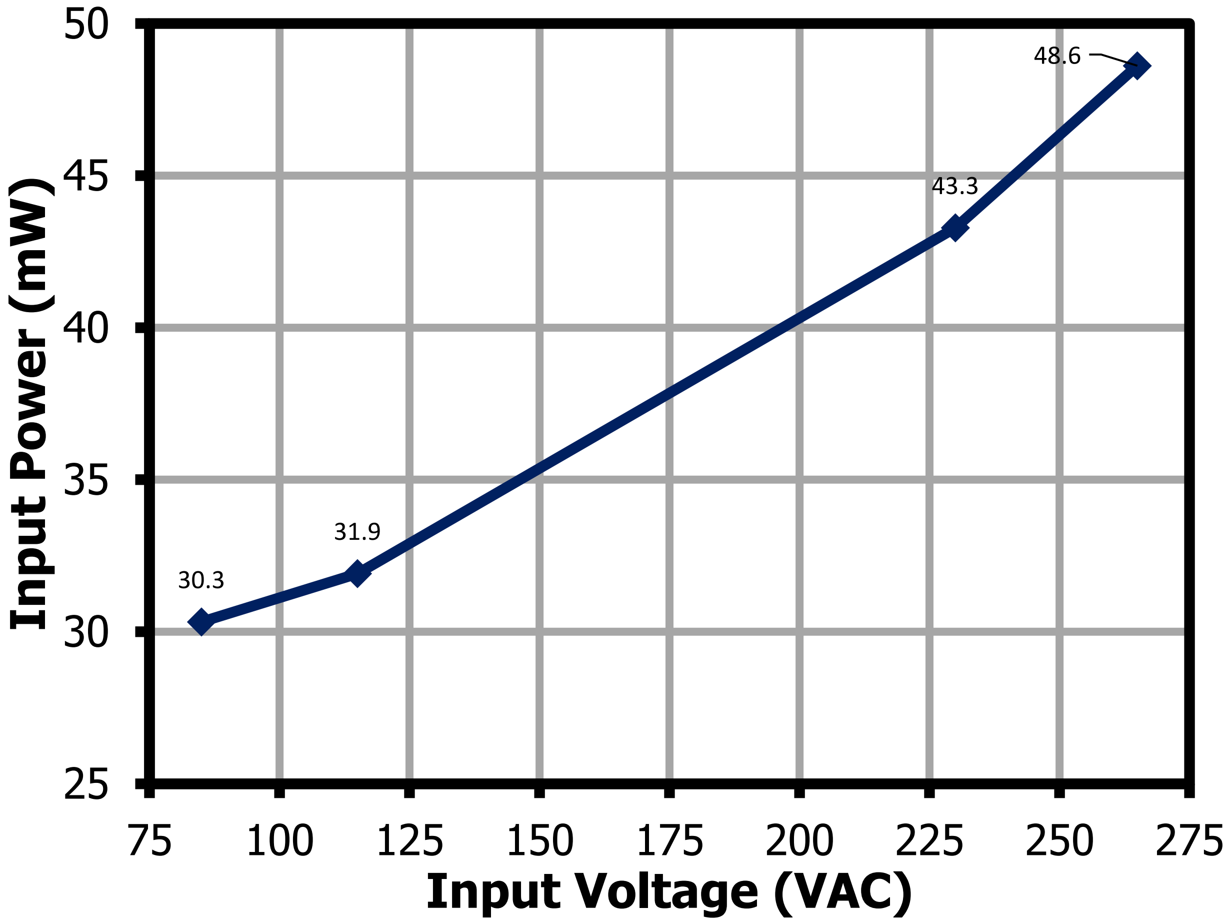


Figure 13 – No-Load Input Power vs. Line at Room Temperature.

VAC	Freq	V_{IN}	I_{IN}	P_{IN}
(RMS)	(Hz)	(RMS)	(mA)	(mW)
85.0	60.0	85.0	2.79	30.3
115	60.0	115	2.58	31.9
230	50.0	230	1.71	43.3
265	50.0	265	1.38	48.6

9.7 Standby Input Power

9.7.1 Standby Efficiency

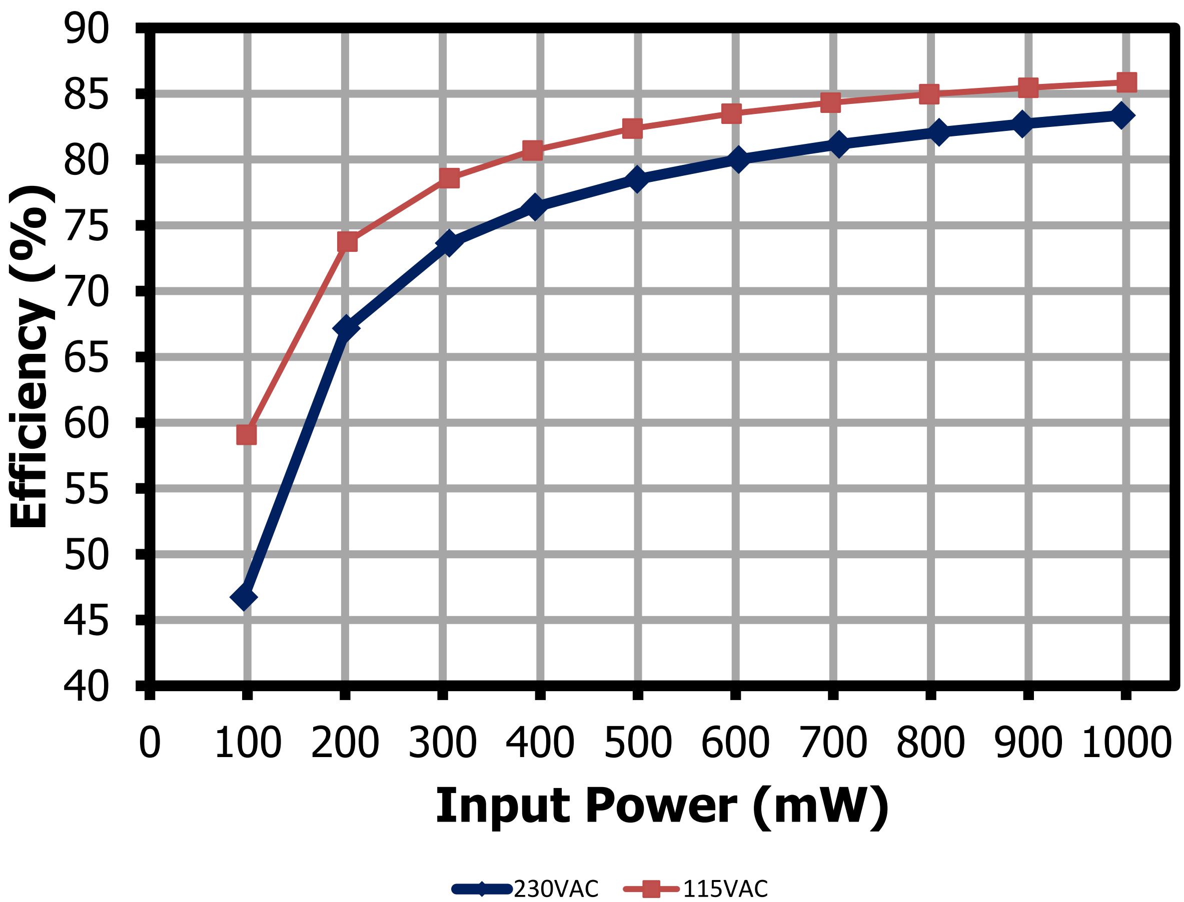


Figure 14 – Efficiency vs. Input Power

9.7.2 Standby Input Power

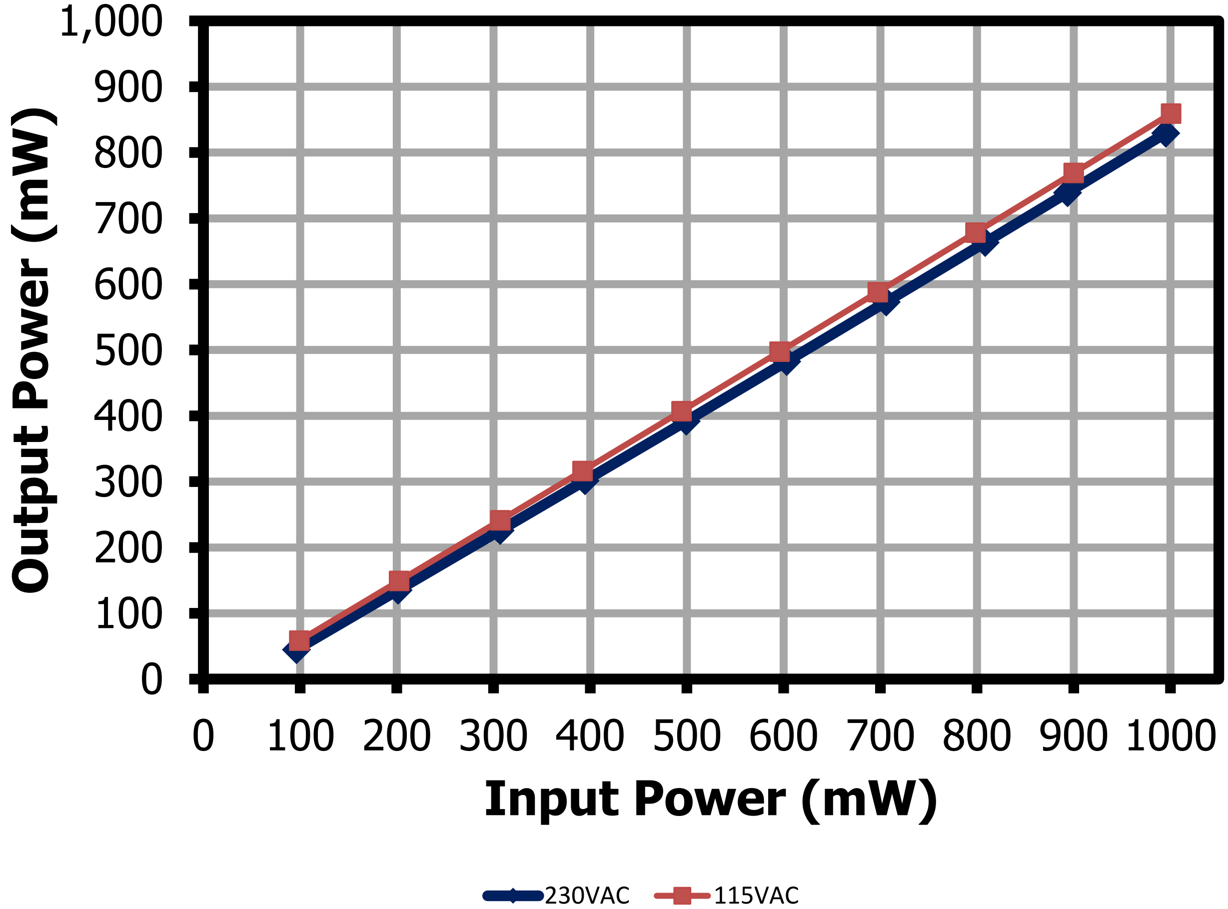


Figure 15 – Output Power vs. Input Power

10 Waveforms

10.1 Switching Waveforms

10.1.1 Primary MOSFET Vds and Ids at Normal Operation

10.1.1.1 Full Load

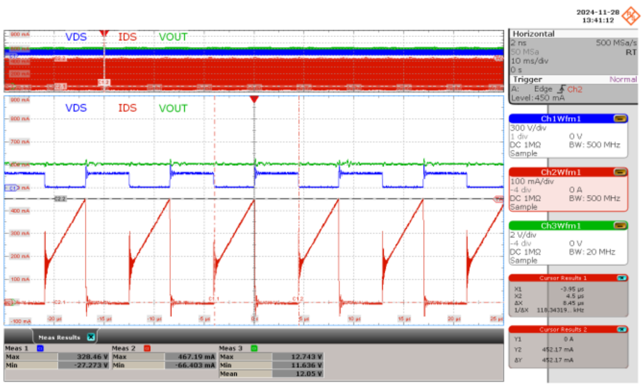


Figure 16 – 85 VAC 60 Hz.
CH1: V_{DS}, 300 V / div., 10 ms / div.
CH2: I_{DS}, 100 mA / div., 10 ms / div.
CH3: V_{OUT}, 2 V / div., 10 ms / div
Zoom: 5 μs / div.
Drain Voltage$_{(MAX)}$ = 328 V
Drain Current$_{(MAX)}$ = 467 mA

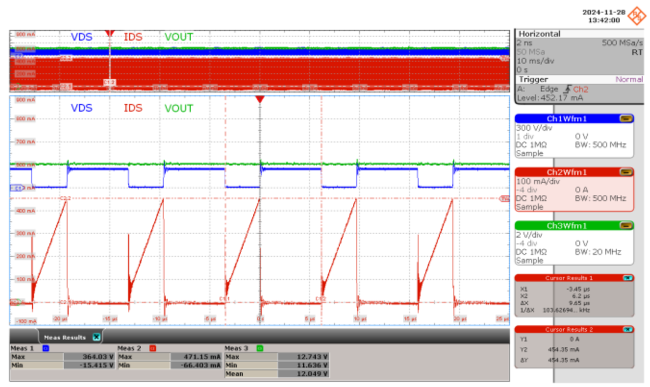


Figure 17 – 115 VAC 60 Hz.
CH1: V_{DS}, 300 V / div., 10 ms / div.
CH2: I_{DS}, 100 mA / div., 10 ms / div.
CH3: V_{OUT}, 2 V / div., 10 ms / div
Zoom: 5 μs / div.
Drain Voltage$_{(MAX)}$ = 364 V
Drain Current$_{(MAX)}$ = 471 mA

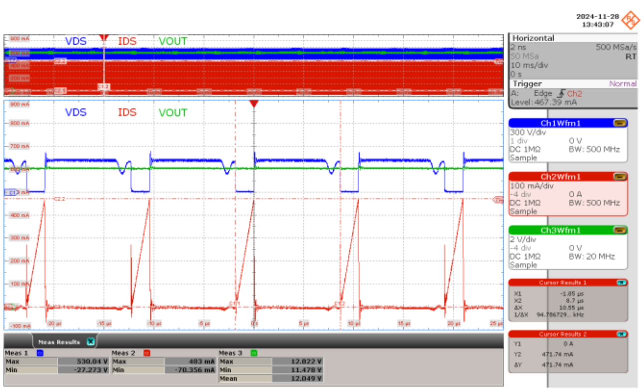


Figure 18 – 230 VAC 50 Hz.
CH1: V_{DS}, 300 V / div., 10 ms / div.
CH2: I_{DS}, 100 mA / div., 10 ms / div.
CH3: V_{OUT}, 2 V / div., 10 ms / div
Zoom: 5 μs / div.
Drain Voltage$_{(MAX)}$ = 530 V
Drain Current$_{(MAX)}$ = 483 mA

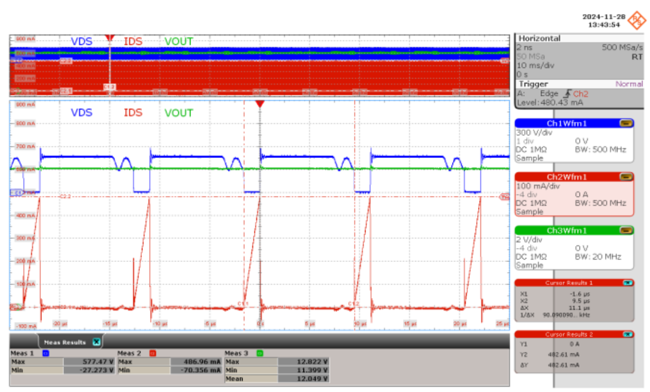


Figure 19 – 265 VAC 50 Hz.
CH1: V_{DS}, 300 V / div., 10 ms / div.
CH2: I_{DS}, 100 mA / div., 10 ms / div.
CH3: V_{OUT}, 2 V / div., 10 ms / div
Zoom: 5 μs / div.
Drain Voltage$_{(MAX)}$ = 577 V
Drain Current$_{(MAX)}$ = 487 mA

10.1.1.2 No Load

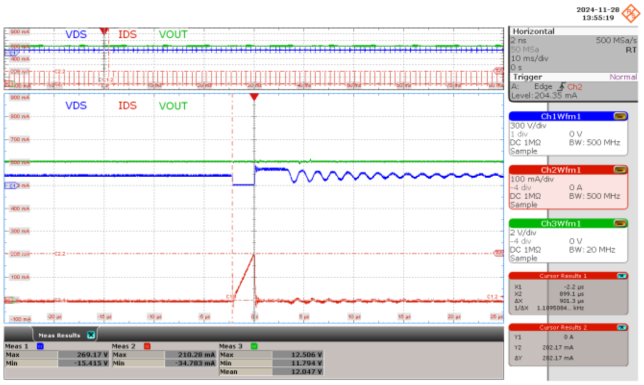


Figure 20 – 85 VAC 60 Hz.
CH1: V_{DS}, 300 V / div., 10 ms / div.
CH2: I_{DS}, 100 mA / div., 10 ms / div.
CH3: V_{OUT}, 2 V / div., 10 ms / div
Zoom: 5 µs / div.
Drain Voltage$_{(MAX)}$ = 269 V
Drain Current$_{(MAX)}$ = 210 mA

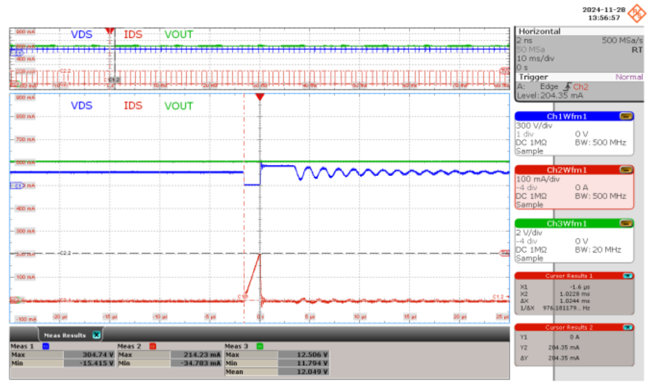


Figure 21 – 115 VAC 60 Hz.
CH1: V_{DS}, 300 V / div., 10 ms / div.
CH2: I_{DS}, 100 mA / div., 10 ms / div.
CH3: V_{OUT}, 2 V / div., 10 ms / div
Zoom: 5 µs / div.
Drain Voltage$_{(MAX)}$ = 305 V
Drain Current$_{(MAX)}$ = 214 mA

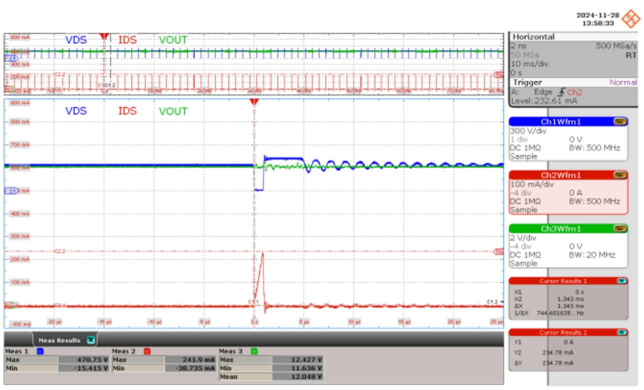


Figure 22 – 230 VAC 50 Hz.
CH1: V_{DS}, 300 V / div., 10 ms / div.
CH2: I_{DS}, 100 mA / div., 10 ms / div.
CH3: V_{OUT}, 2 V / div., 10 ms / div
Zoom: 5 µs / div.
Drain Voltage$_{(MAX)}$ = 471 V
Drain Current$_{(MAX)}$ = 242 mA

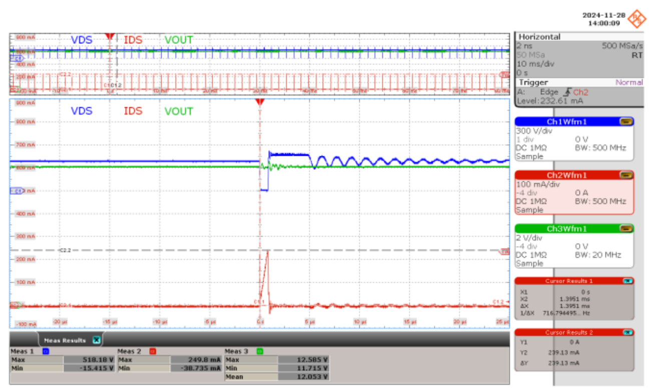


Figure 23 – 265 VAC 50 Hz.
CH1: V_{DS}, 300 V / div., 10 ms / div.
CH2: I_{DS}, 100 mA / div., 10 ms / div.
CH3: V_{OUT}, 2 V / div., 10 ms / div
Zoom: 5 µs / div.
Drain Voltage$_{(MAX)}$ = 518 V
Drain Current$_{(MAX)}$ = 250 mA

10.1.2 Primary MOSFET Vds and Ids at Start-up Operation

10.1.2.1 Full Load

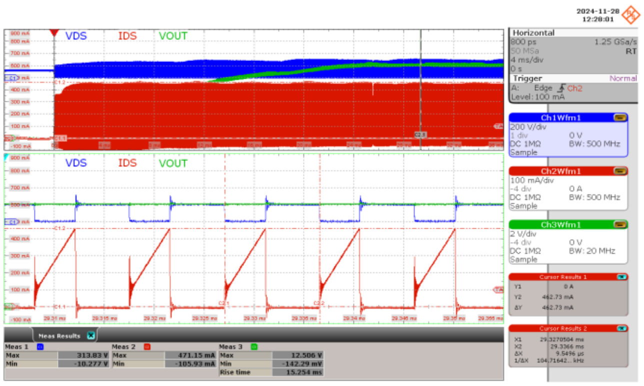


Figure 24 – 85 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 4 ms / div.
CH2: I_{DS}, 100 mA / div., 4 ms / div.
CH3: V_{OUT}, 2 V / div., 4 ms / div
Zoom: 5 µs / div.
Drain Voltage$_{(MAX)}$ = 314 V
Drain Current$_{(MAX)}$ = 471 mA

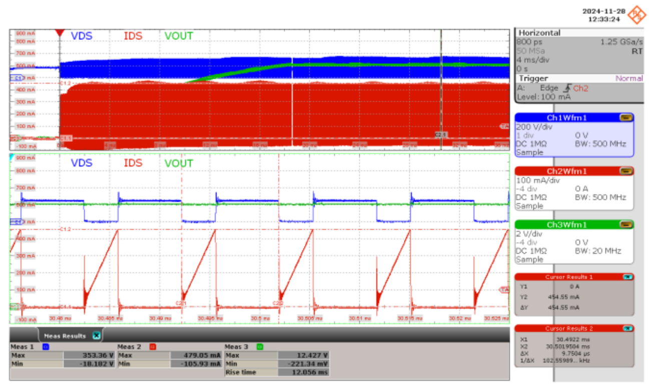


Figure 25 – 115 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 4 ms / div.
CH2: I_{DS}, 100 mA / div., 4 ms / div.
CH3: V_{OUT}, 2 V / div., 4 ms / div
Zoom: 5 µs / div.
Drain Voltage$_{(MAX)}$ = 353 V
Drain Current$_{(MAX)}$ = 479 mA

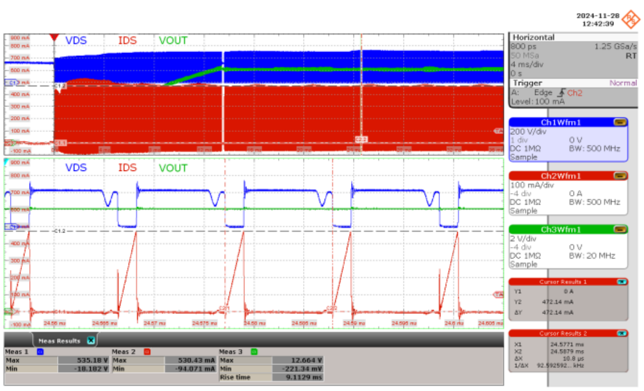


Figure 26 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 4 ms / div.
CH2: I_{DS}, 100 mA / div., 4 ms / div.
CH3: V_{OUT}, 2 V / div., 4 ms / div
Zoom: 5 µs / div.
Drain Voltage$_{(MAX)}$ = 535 V
Drain Current$_{(MAX)}$ = 530 mA

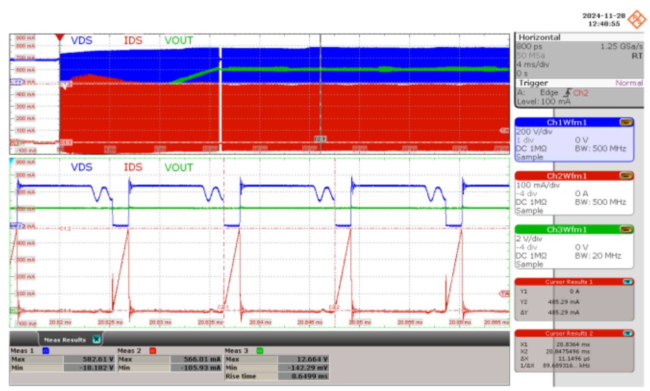


Figure 27 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 4 ms / div.
CH2: I_{DS}, 100 mA / div., 4 ms / div.
CH3: V_{OUT}, 2 V / div., 4 ms / div
Zoom: 5 µs / div.
Drain Voltage$_{(MAX)}$ = 583 V
Drain Current$_{(MAX)}$ = 566 mA

10.1.2.2 No Load

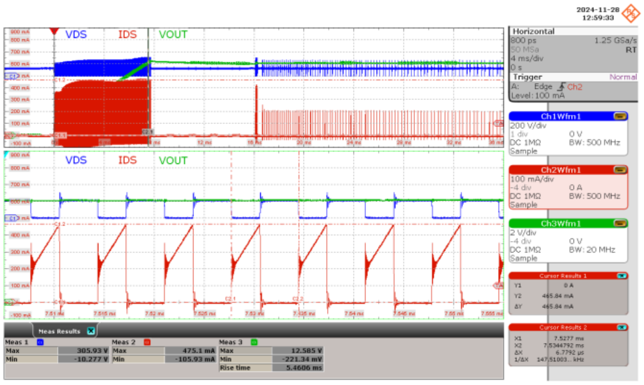


Figure 28 – 85 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 4 ms / div.
CH2: I_{DS}, 100 mA / div., 4 ms / div.
CH3: V_{OUT}, 2 V / div., 4 ms / div
Zoom: 5 µs / div.
Drain $Voltage_{(MAX)}$ = 306 V
Drain $Current_{(MAX)}$ = 475 mA

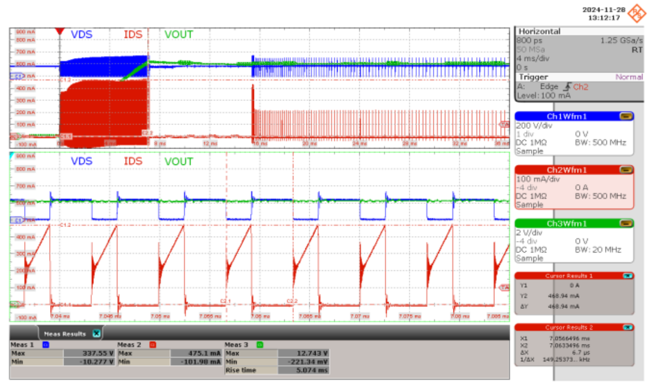


Figure 29 – 115 VAC 60 Hz.
CH1: V_{DS}, 200 V / div., 4 ms / div.
CH2: I_{DS}, 100 mA / div., 4 ms / div.
CH3: V_{OUT}, 2 V / div., 4 ms / div
Zoom: 5 µs / div.
Drain $Voltage_{(MAX)}$ = 338 V
Drain $Current_{(MAX)}$ = 475 mA

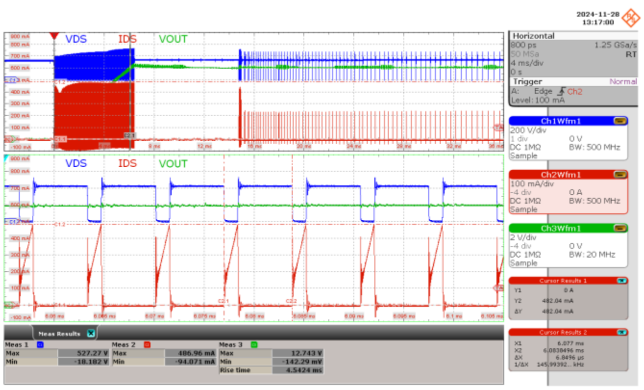


Figure 30 – 230 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 4 ms / div.
CH2: I_{DS}, 100 mA / div., 4 ms / div.
CH3: V_{OUT}, 2 V / div., 4 ms / div
Zoom: 5 µs / div.
Drain $Voltage_{(MAX)}$ = 527 V
Drain $Current_{(MAX)}$ = 487 mA

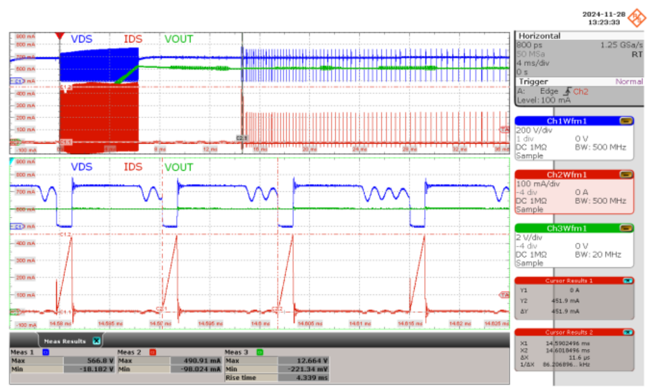


Figure 31 – 265 VAC 50 Hz.
CH1: V_{DS}, 200 V / div., 4 ms / div.
CH2: I_{DS}, 100 mA / div., 4 ms / div.
CH3: VOUT, 2 V / div., 4 ms / div
Zoom: 5 µs / div.
Drain $Voltage_{(MAX)}$ = 567 V
Drain $Current_{(MAX)}$ = 491 mA

10.1.3 Freewheeling Diode Voltage at Normal Operation

10.1.3.1 Full Load

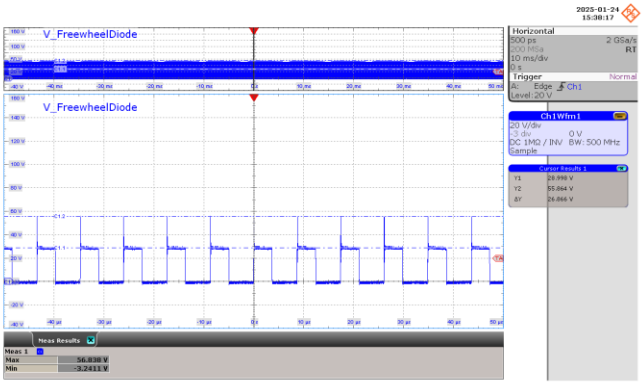


Figure 32 – 85 VAC 60 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 56.8 V

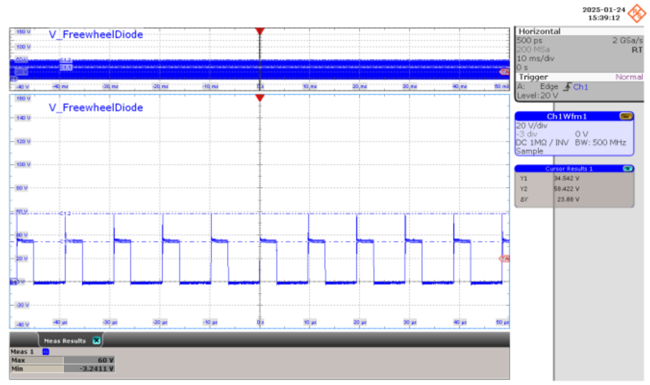


Figure 33 – 115 VAC 60 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 60 V

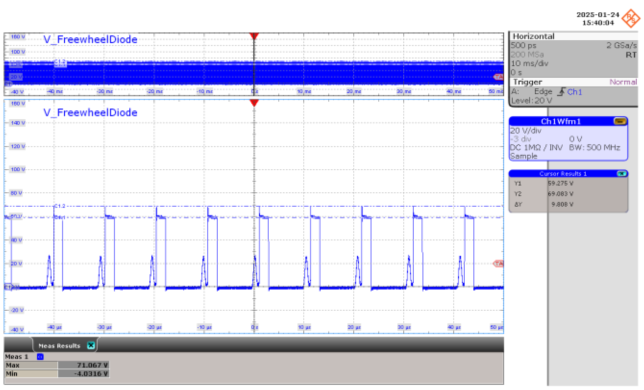


Figure 34 – 230 VAC 50 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 71.1 V

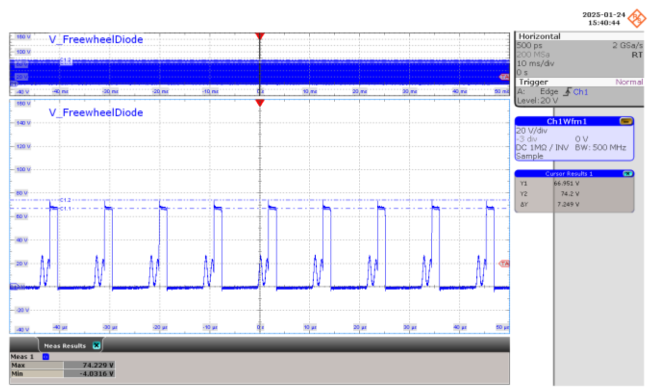


Figure 35 – 265 VAC 50 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 74.2 V

10.1.3.2 No Load

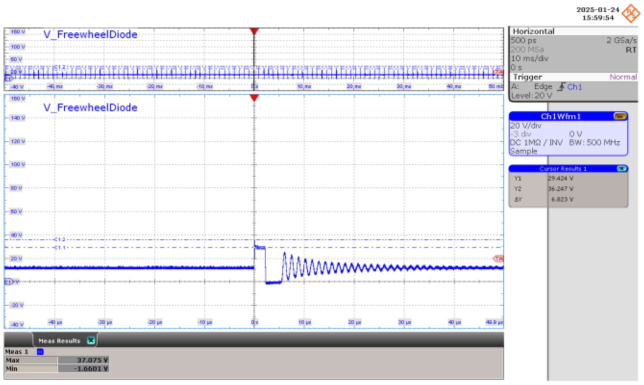


Figure 36 – 85 VAC 60 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 37.1 V

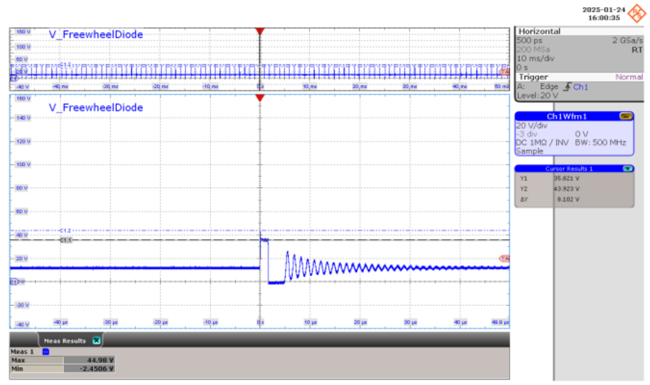


Figure 37 – 115 VAC 60 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 45 V

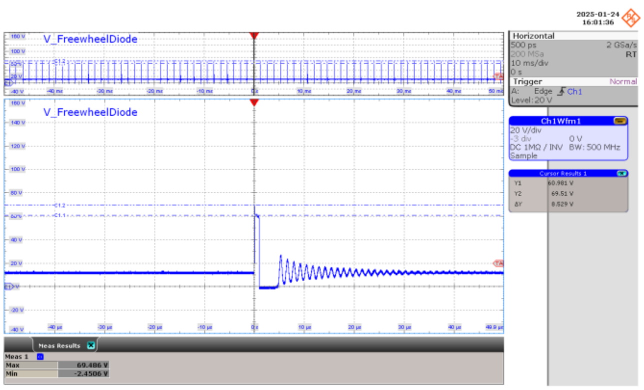


Figure 38 – 230 VAC 50 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 69.5 V

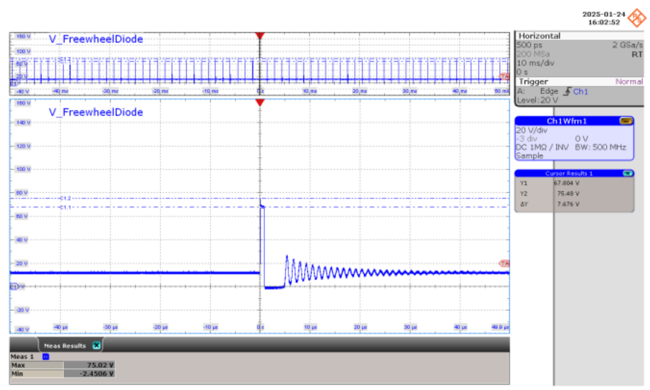


Figure 39 – 265 VAC 50 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 75 V

10.1.4 Freewheeling Diode Voltage at Start-Up

10.1.4.1 Full Load

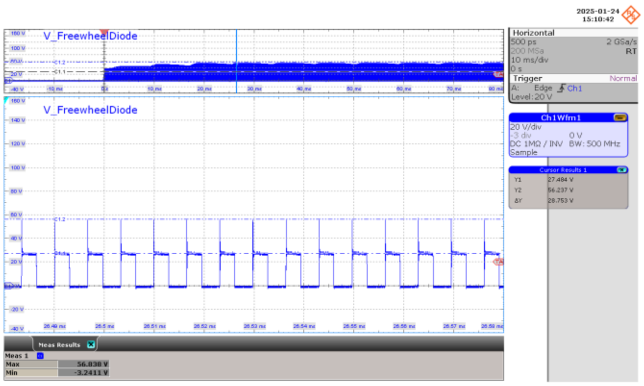


Figure 40 – 85 VAC 60 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 56.8 V

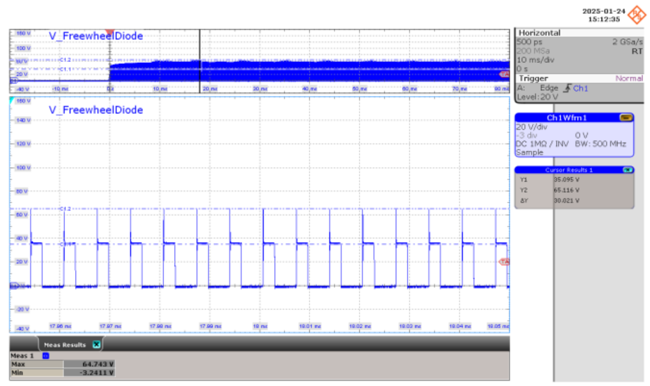


Figure 41 – 115 VAC 60 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 64.7 V

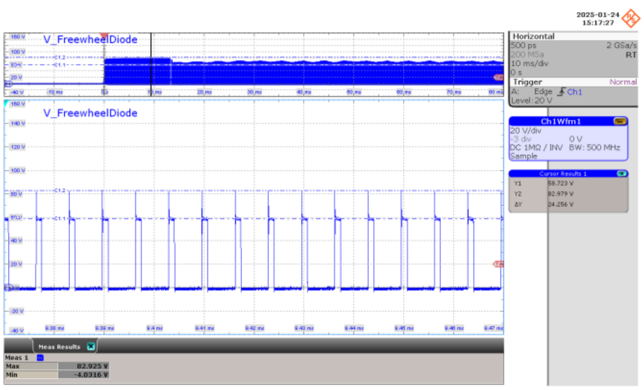


Figure 42 – 230 VAC 50 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 82.9 V

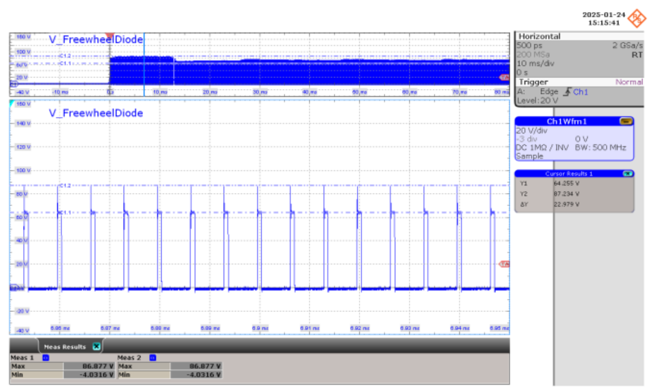


Figure 43 – 265 VAC 50 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 86.9 V

10.1.4.2 No Load

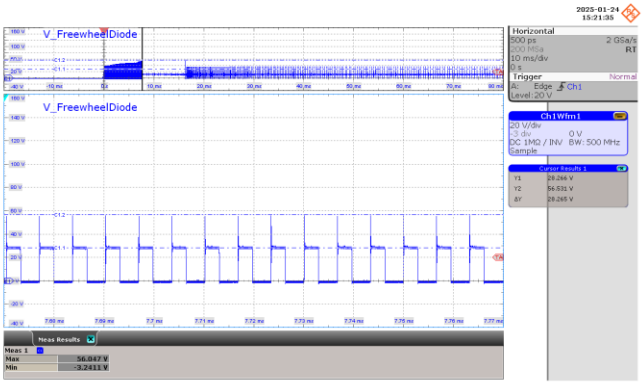


Figure 44 – 85 VAC 60 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 56 V

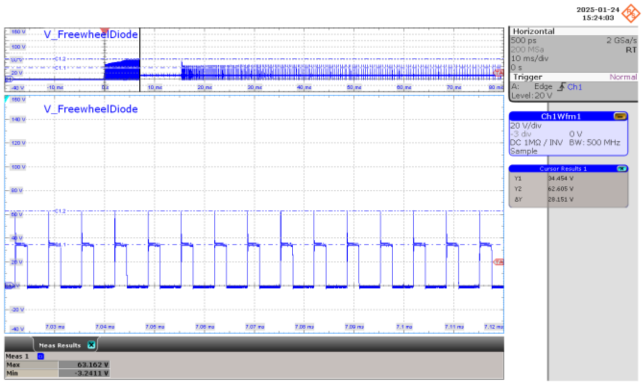


Figure 45 – 115 VAC 60 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 63.2 V

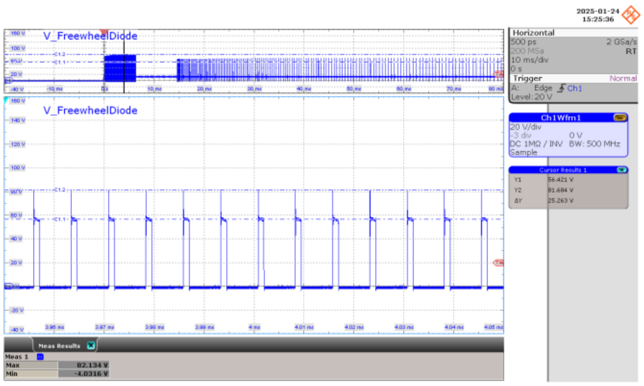


Figure 46 – 230 VAC 50 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 82.1 V

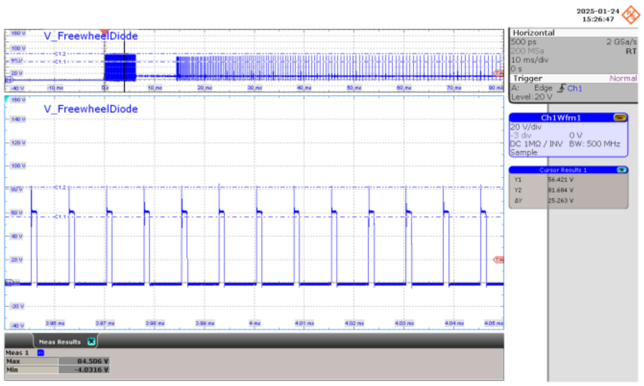


Figure 47 – 265 VAC 50 Hz.
CH1: Freewheel Diode Voltage, 20 V / div., 10 ms / div.
Zoom: 10 µs / div.
Freewheel Diode Voltage$_{(MAX)}$ = 84.5 V

10.1 Output Start-up

10.1.1 Full Load CC Mode

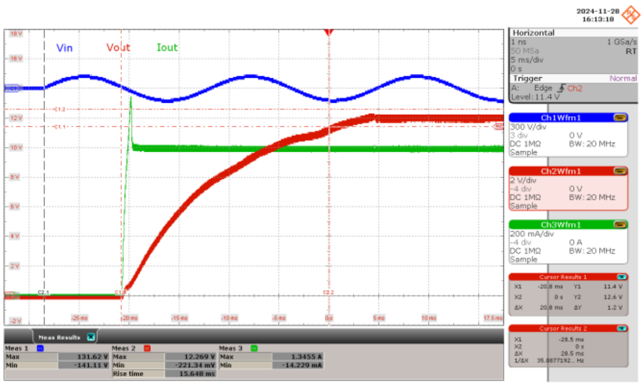


Figure 48 – 85 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 28.5 ms.
V_{MAX} = 12.3 V

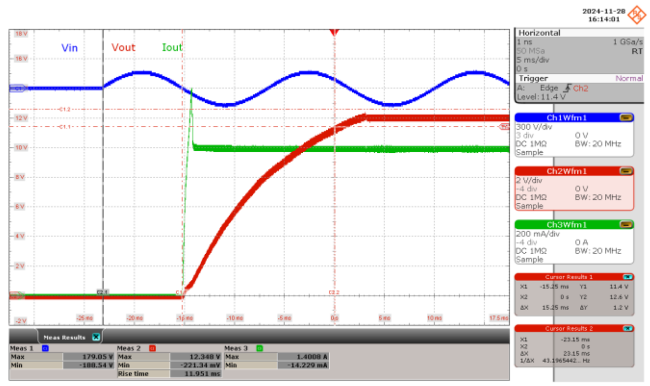


Figure 49 – 115 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 23.2 ms.
V_{MAX} = 12.3 V

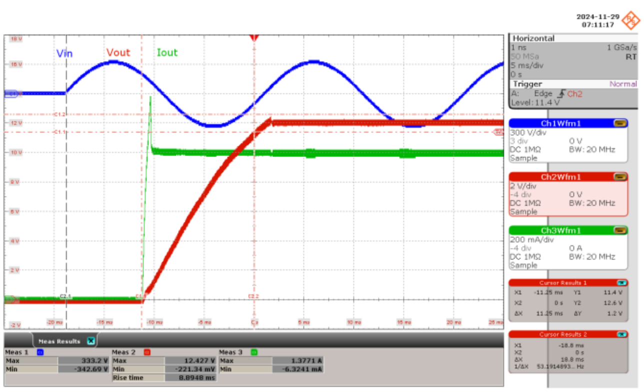


Figure 50 – 230 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 18.8 ms.
V_{MAX} = 12.4 V

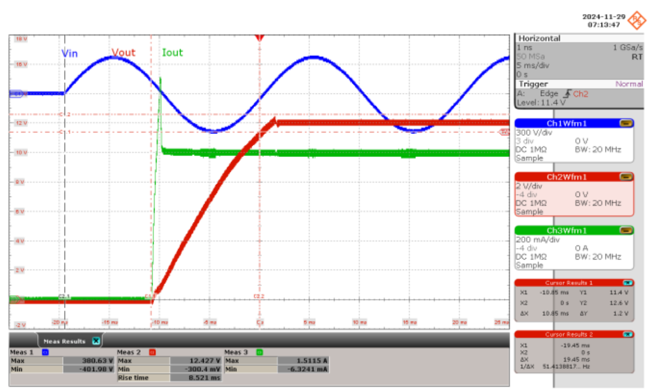


Figure 51 – 265 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 19.5 ms.
V_{MAX} = 12.4 V

10.1.2 Full Load CR Mode

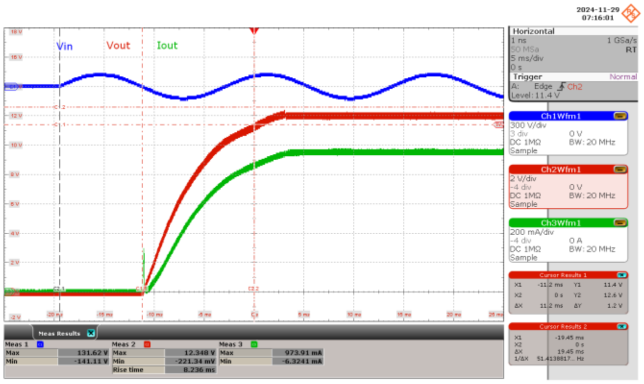


Figure 52 – 85 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 19.5 ms.
V_{MAX} = 12.3 V

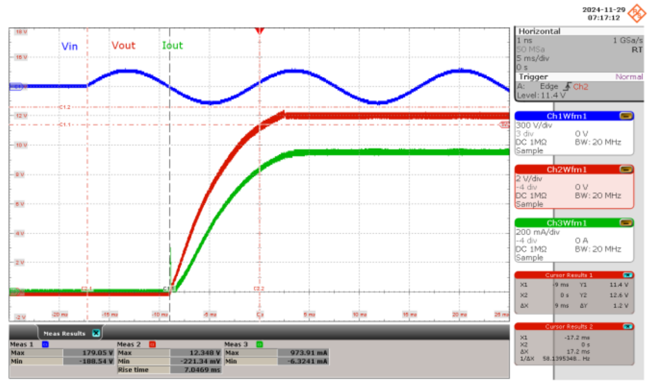


Figure 53 – 115 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 17.2 ms.
V_{MAX} = 12.3 V

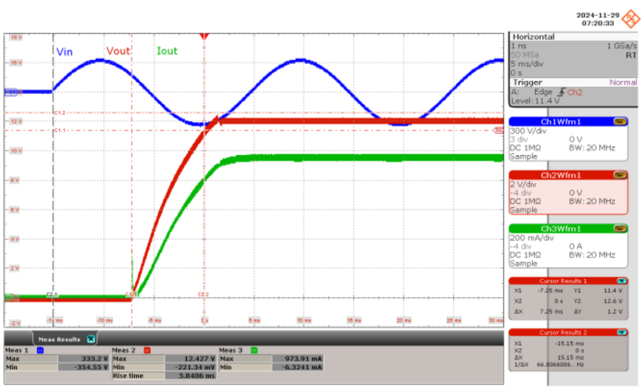


Figure 54 – 230 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 15.2 ms.
V_{MAX} = 12.4 V

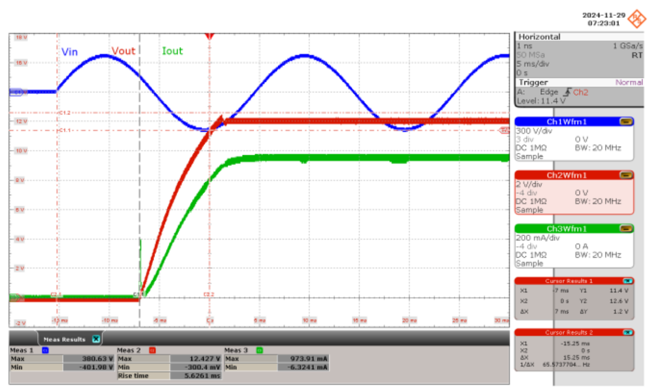


Figure 55 – 265 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 15.3 ms.
V_{MAX} = 12.4 V

10.1.3 No Load

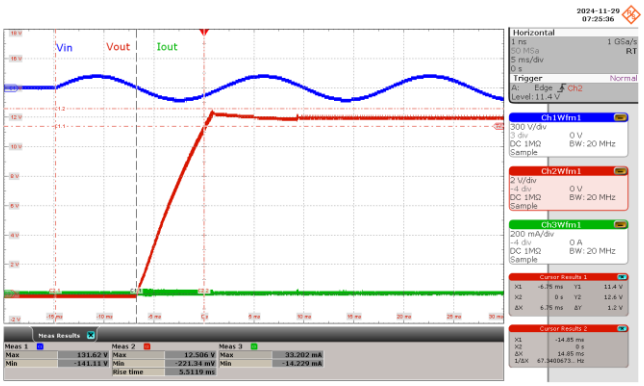


Figure 56 – 85 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 14.9 ms.
V_{MAX} = 12.5 V

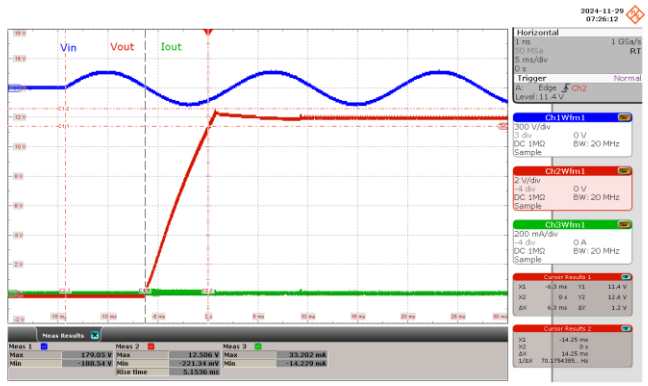


Figure 57 – 115 VAC 60 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 14.3 ms.
V_{MAX} = 12.5 V

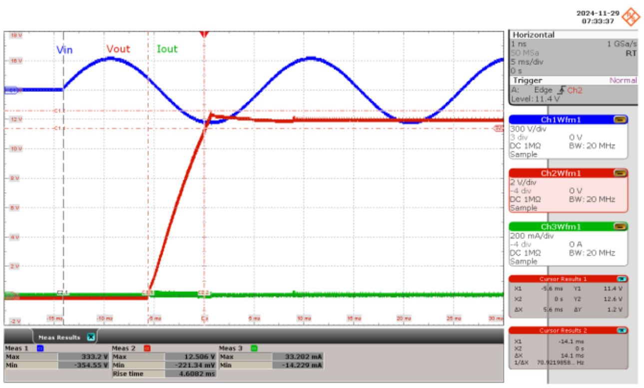


Figure 58 – 230 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 14.1 ms.
V_{MAX} = 12.5 V

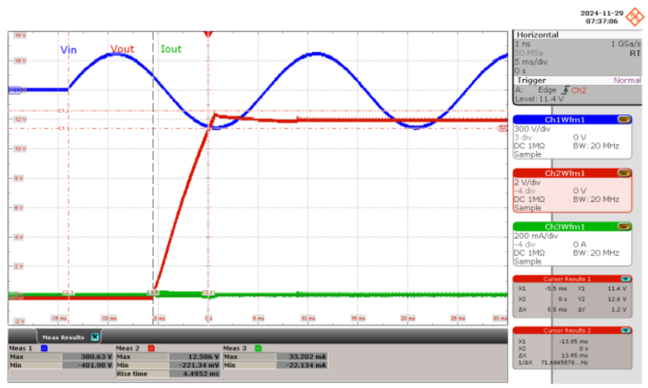


Figure 59 – 265 VAC 50 Hz.
CH1: V_{IN}, 300 V / div., 5 ms / div.
CH2: V_{OUT}, 2 V / div., 5 ms / div.
CH3: I_{OUT}, 200 mA / div., 5 ms / div.
Rise Time = 14 ms.
V_{MAX} = 12.5 V

10.2 Load Transient Response

Test Condition: Dynamic load frequency = 10 Hz, Duty cycle = 50 %
Slew Rate = 0.8 A / µs

10.2.1 Transient 0% - 100% Load Change

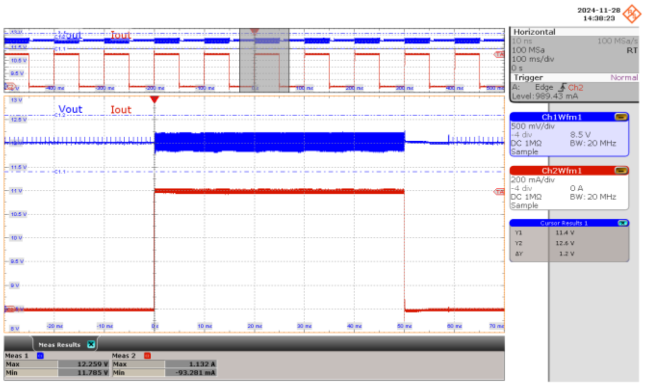


Figure 60 – 85 VAC 60 Hz.
CH1: V_{OUT}, 500 mV / div., 100 ms / div.
CH2: I_{OUT}, 200 mA / div., 100 ms / div.
V_{OUT}: V_{MAX}: 12.3 V
V_{MIN}: 11.8 V

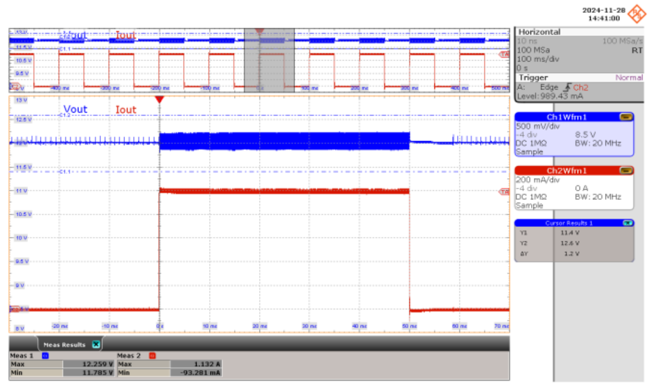


Figure 61 – 115 VAC 60 Hz.
CH1: V_{OUT}, 500 mV / div., 100 ms / div.
CH2: I_{OUT}, 200 mA / div., 100 ms / div..
V_{OUT}: V_{MAX}: 12.3 V
V_{MIN}: 11.8 V

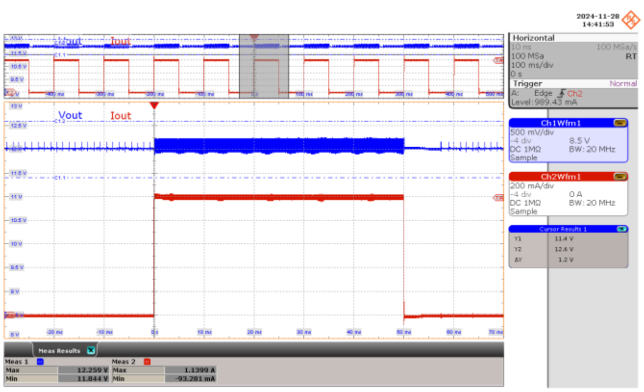


Figure 62 – 230 VAC 50 Hz.
CH1: V_{OUT}, 500 mV / div., 100 ms / div.
CH2: I_{OUT}, 200 mA / div., 100 ms / div.
V_{OUT}: V_{MAX}: 12.3 V
V_{MIN}: 11.8 V

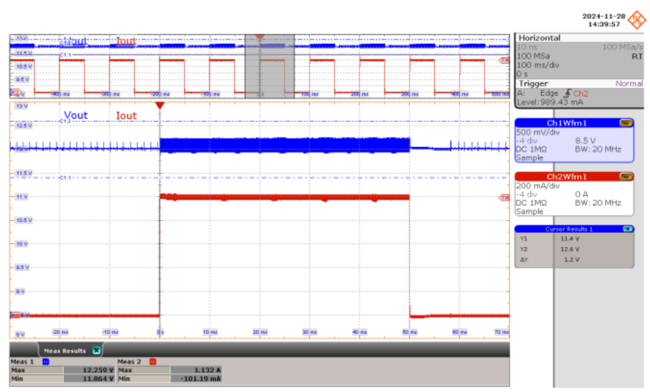


Figure 63 – 265 VAC 50 Hz.
CH1: V_{OUT}, 500 mV / div., 100 ms / div.
CH2: I_{OUT}, 200 mA / div., 100 ms / div.
V_{OUT}: V_{MAX}: 12.3 V
V_{MIN}: 11.9 V

10.3 Output Voltage Ripple

10.3.1 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).

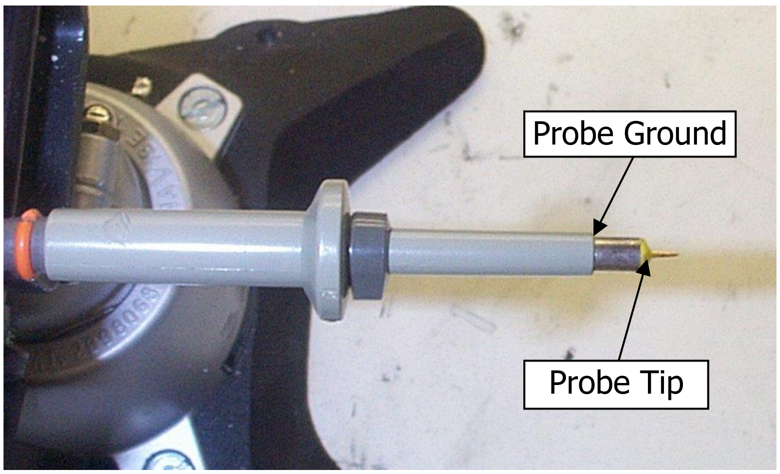


Figure 64 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

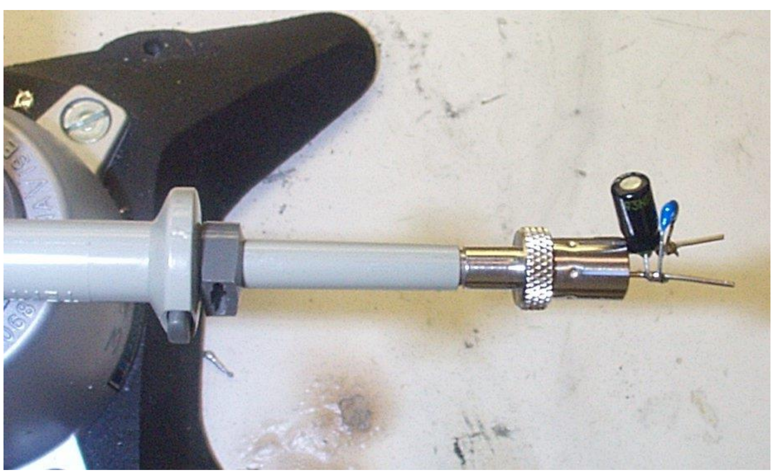


Figure 65 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added.)

10.3.2 Measurement Results

Note: All ripple measurements were taken at PCB end.

10.3.2.1 100% Load Condition

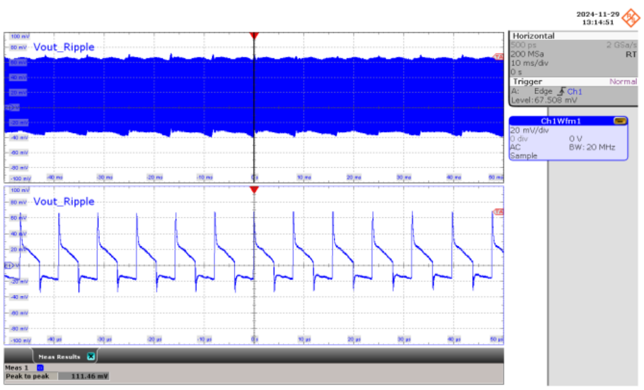


Figure 66 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 111 mV

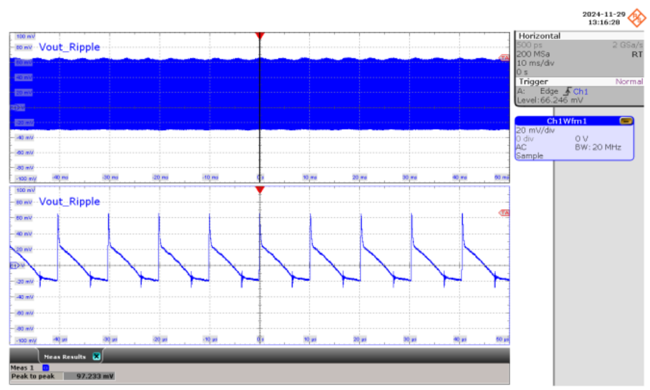


Figure 67 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 97.2 mV

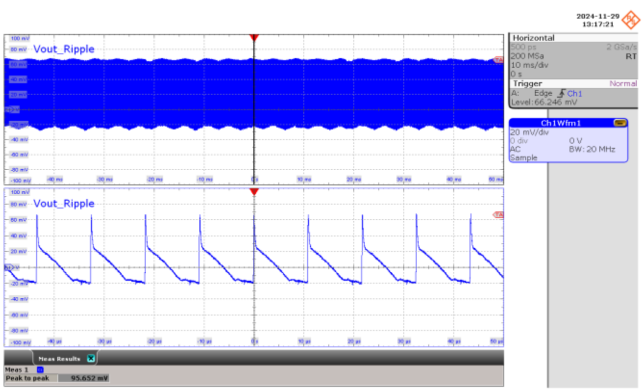


Figure 68 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 95.7 mV

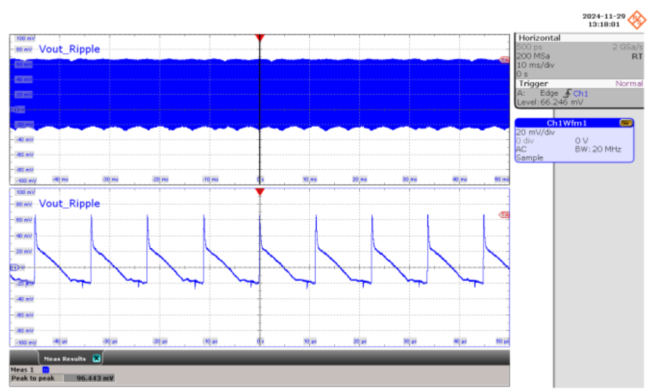


Figure 69 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 96.4 mV

10.3.2.2 75% Load Condition

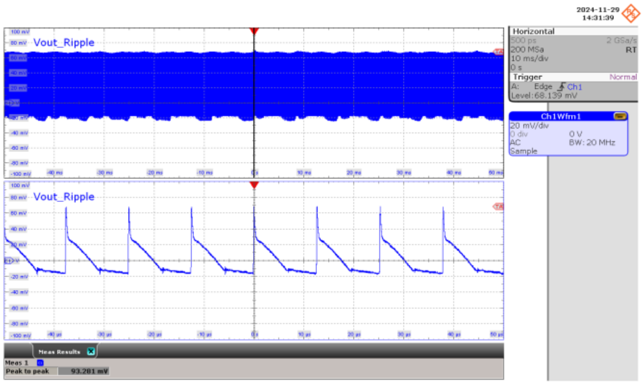


Figure 70 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 93.3 mV

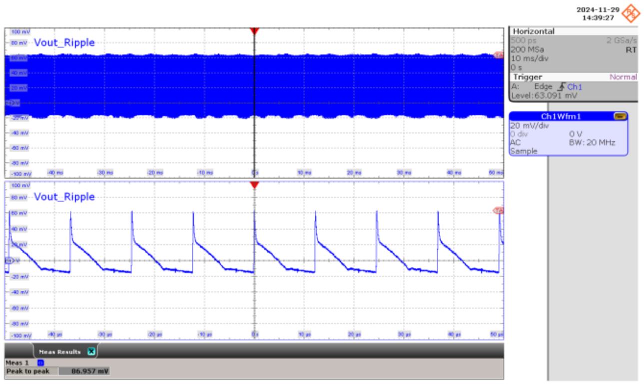


Figure 71 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 87 mV

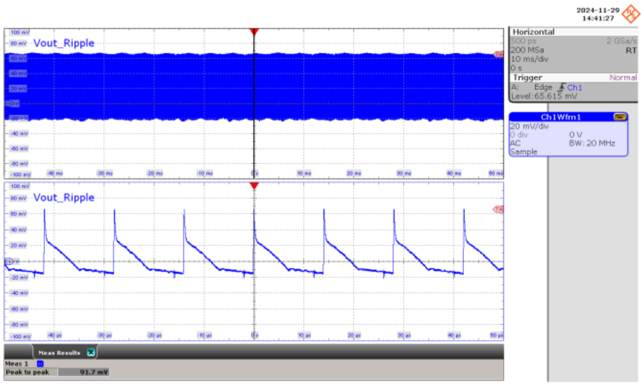


Figure 72 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 91.7 mV

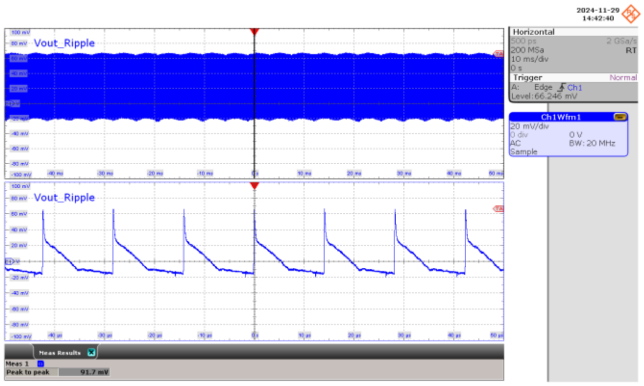


Figure 73 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 91.7 mV

10.3.2.3 50% Load Condition

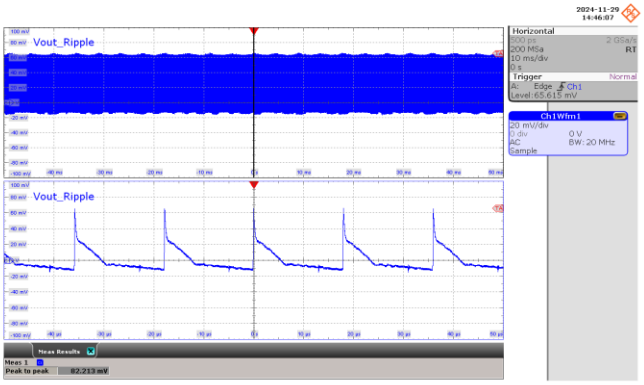


Figure 74 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 82.2 mV

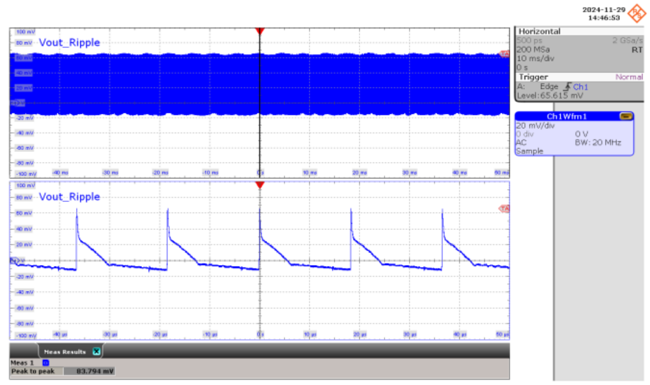


Figure 75 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 83.8 mV

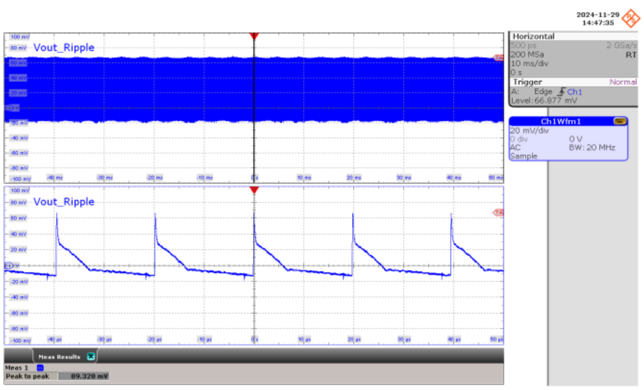


Figure 76 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 89.3 mV

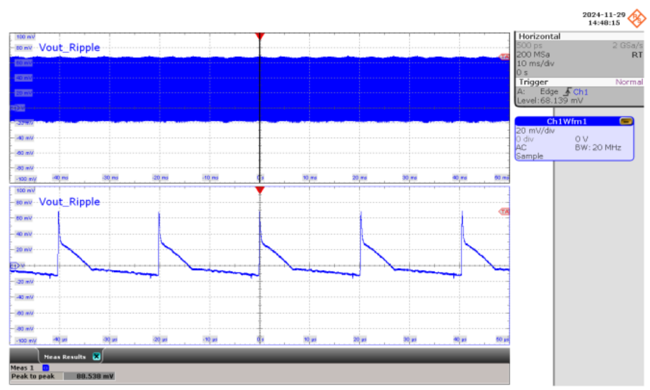


Figure 77 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 88.5 mV

10.3.2.4 25% Load Condition

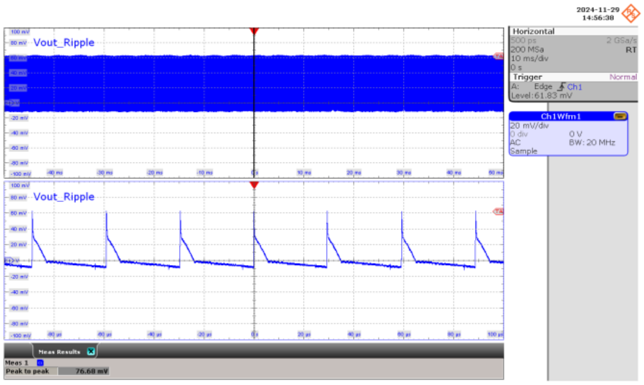


Figure 78 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 76.7 mV

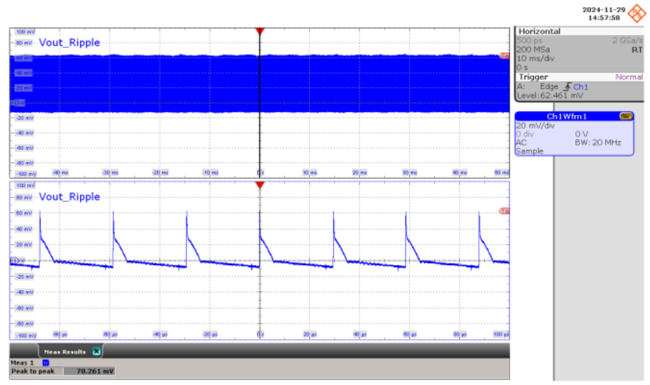


Figure 79 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 78.3 mV

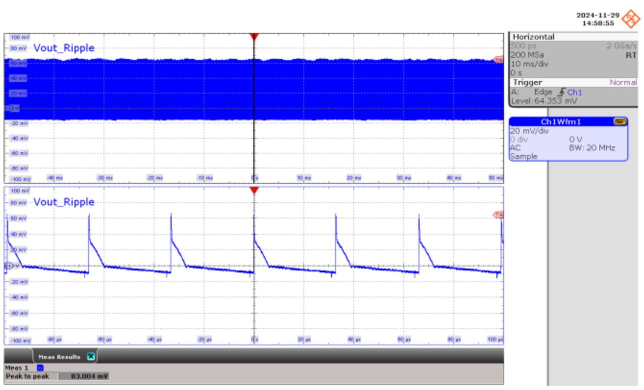


Figure 80 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 83 mV

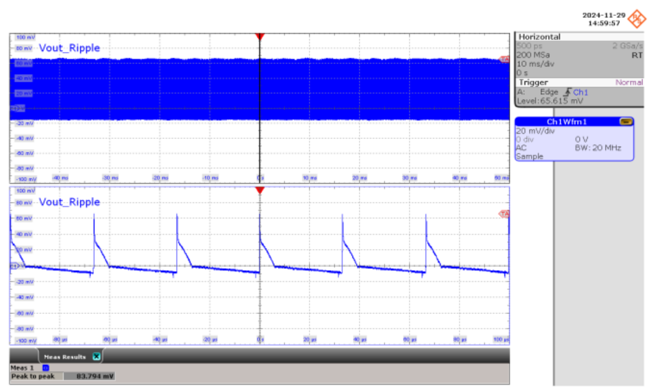


Figure 81 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 20 μs / div.
Output Ripple = 83.8 mV

10.3.2.5 0% Load Condition

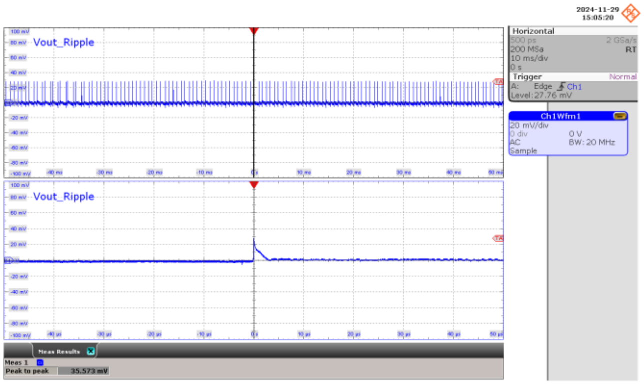


Figure 82 – 85 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 35.6 mV

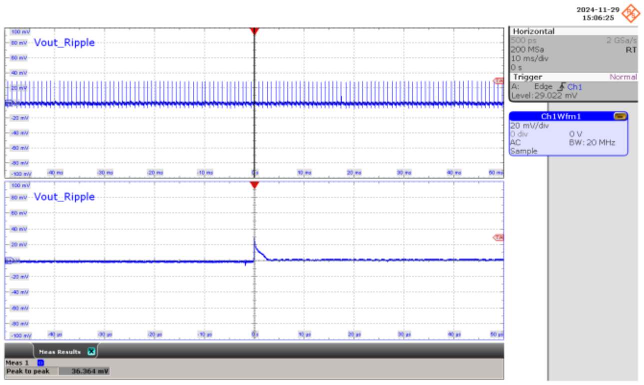


Figure 83 – 115 VAC 60 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 36.4 mV

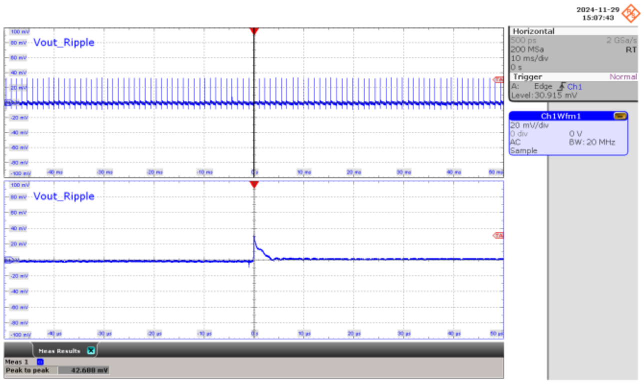


Figure 84 – 230 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 42.7 mV

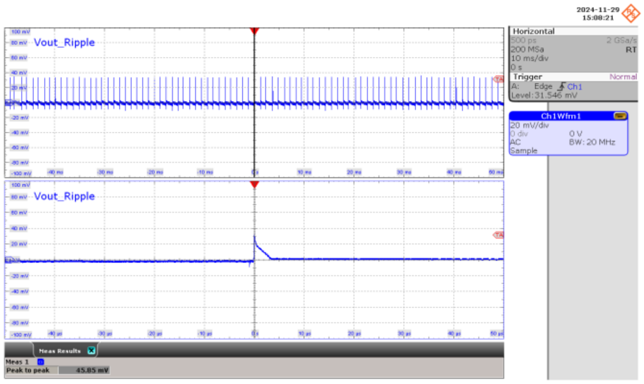


Figure 85 – 265 VAC 50 Hz.
CH1: Output Ripple, 20 mV / div., 10 ms / div.
Zoom: 10 µs / div.
Output Ripple = 45.9 mV

10.3.3 Output Ripple Voltage Graph

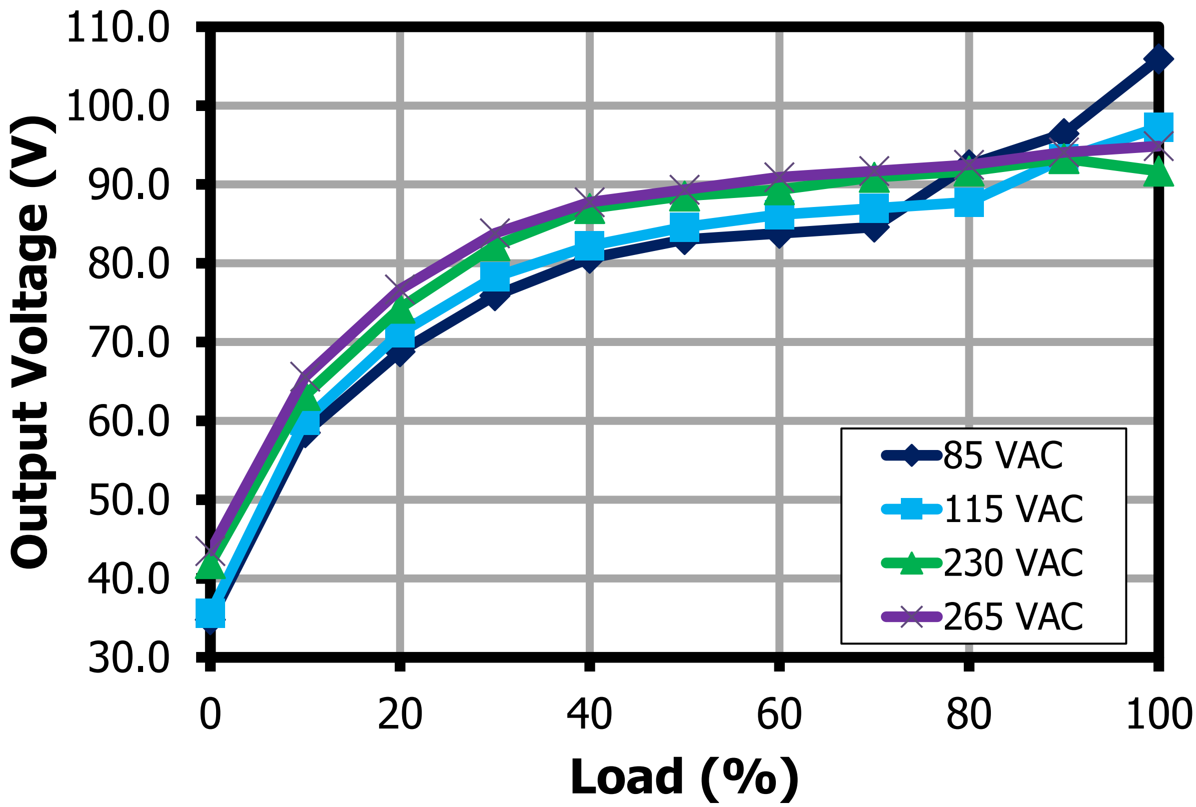


Figure 86 – Voltage Ripple (Measured at PCB End at Room Temperature).

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.

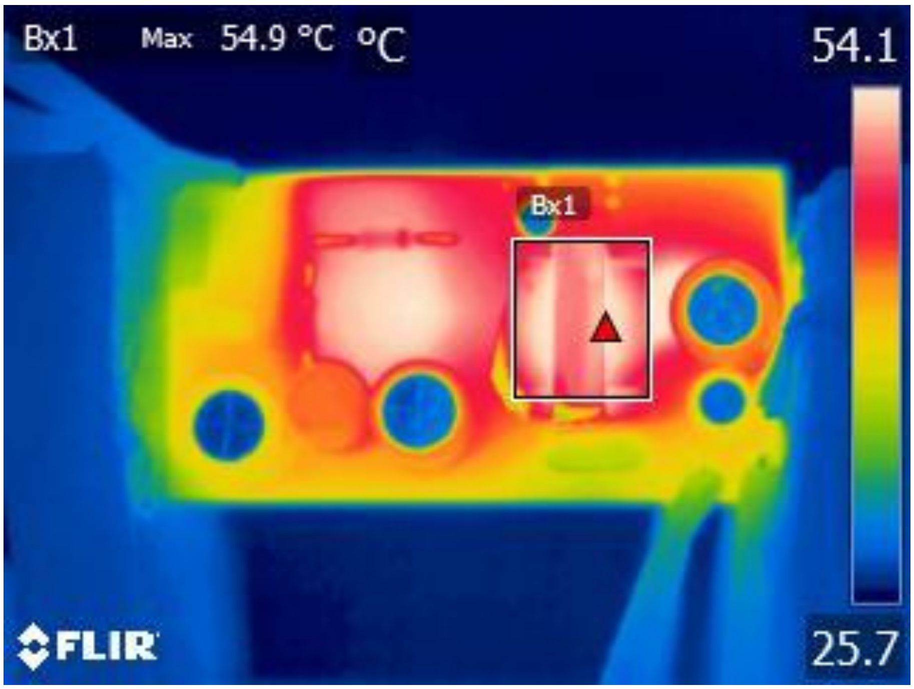


Figure 87 – 85 VAC 60 Hz. Top Side Discrete Component Thermals.

Component	Temperature (°C)
Ambient	25.7
Transformer Core (T1)	54.9

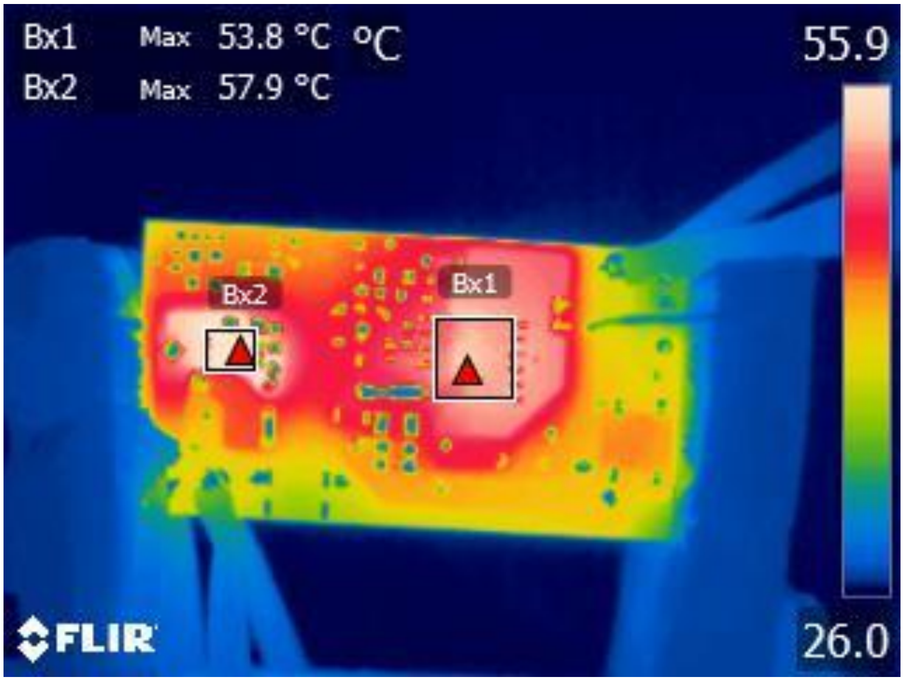


Figure 88 – 85 VAC 60 Hz. Bottom Side Thermals.

Component	Temperature (°C)
Ambient	26
TNY5072K (U1)	53.8
Secondary Diode (D4)	57.9

11.1.2 265 VAC Full Load at 25 °C Ambient

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

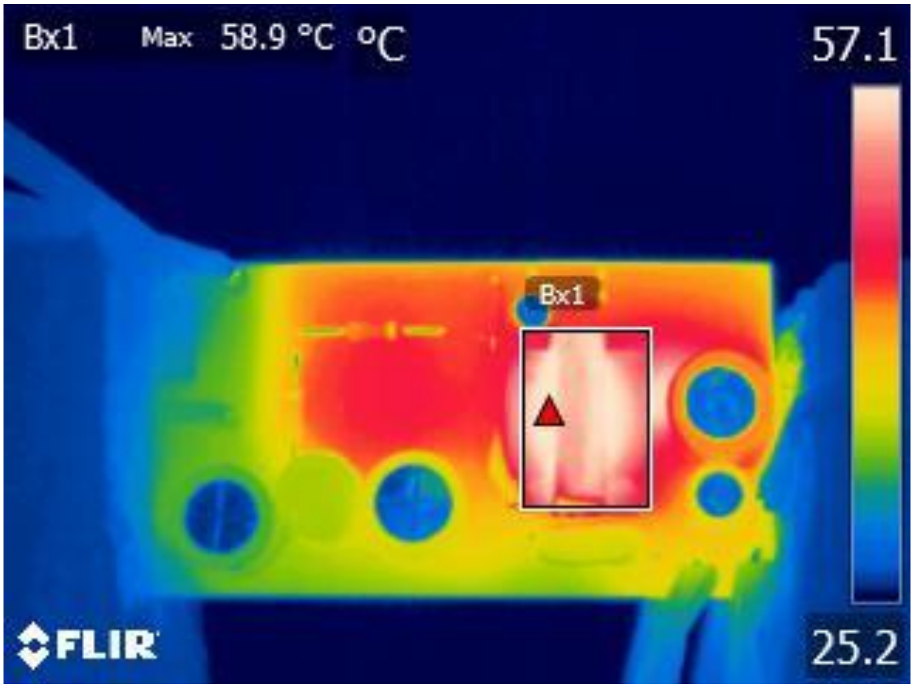


Figure 89 – 265 VAC 50 Hz. Top Side Discrete Component Thermals.

Component	Temperature (°C)
Ambient	25.2
Transformer Core (T1)	58.9

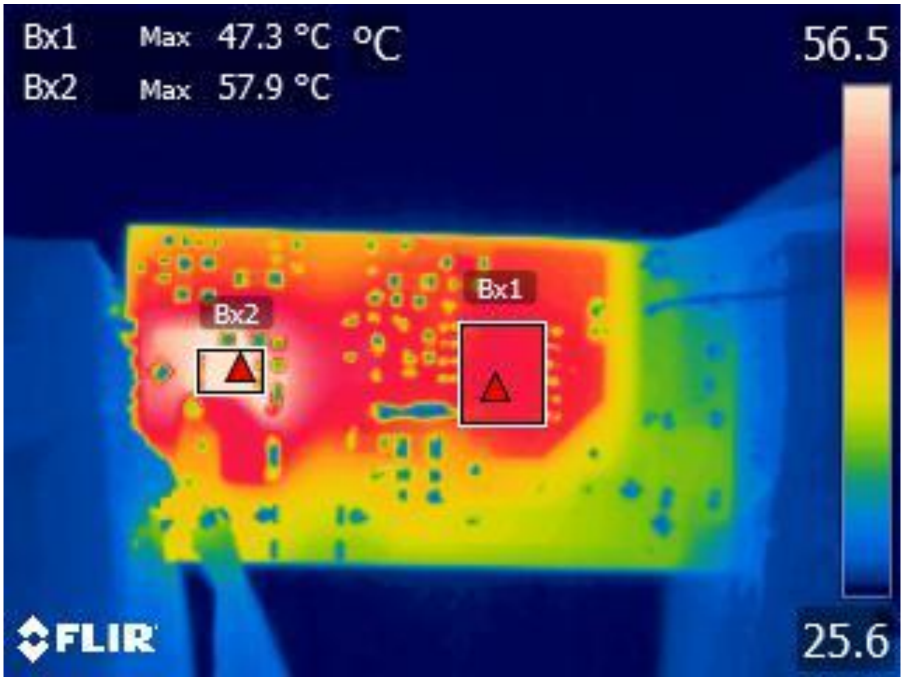


Figure 90 – 265 VAC 50 Hz. Bottom Side Thermals.

Component	Temperature (°C)
Ambient	25.6
TNY5072K (U1)	47.3
Secondary Diode (D4)	57.9

12 Fault Condition

12.1 Output Short-Circuit Protection

12.1.1 Start-Up Short

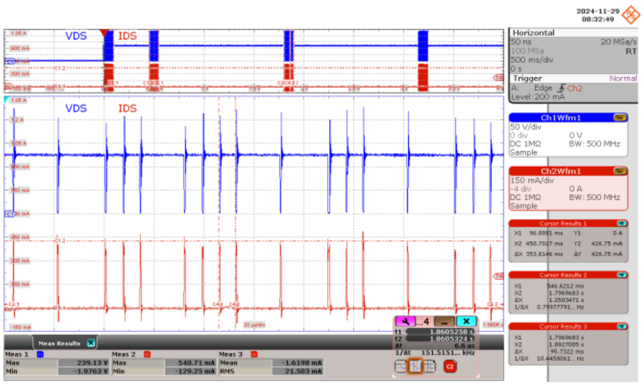


Figure 91 – 85 VAC 60 Hz. Output Short.
CH1: V_{DS}, 50 V / div., 500 ms / div.
CH2: I_{DS}, 150 mA / div., 500 ms / div.
Zoom: 20 µs / div.
Drain Voltage$_{(MAX)}$ = 239.1 V
Drain Current$_{(MAX)}$ = 541 mA
$t_{AR\_(OFF)1}$ = 354 ms
$t_{AR\_(OFF)2}$ = 1.25 s
$t_{AR(ON)}$ = 95.7 ms

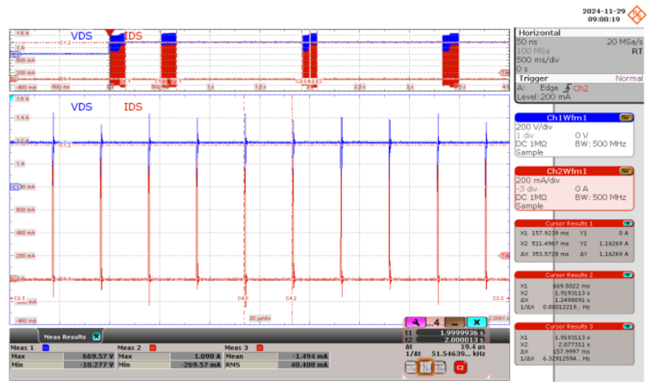


Figure 92 – 265 VAC 50 Hz Output Short.
CH1: V_{DS}, 200V / div., 500 ms / div.
CH2: I_{DS}, 150 mA / div., 500 ms / div.
Zoom: 20 µs / div.
Drain Voltage$_{(MAX)}$ = 669.6 V
Drain Current$_{(MAX)}$ = 1.10 A
$t_{AR\_(OFF)1}$ = 354 ms
$t_{AR\_(OFF)2}$ = 1.25 s
$t_{AR(ON)}$ = 158 ms

12.1.1 Running Short

12.1.1.1 Full Load

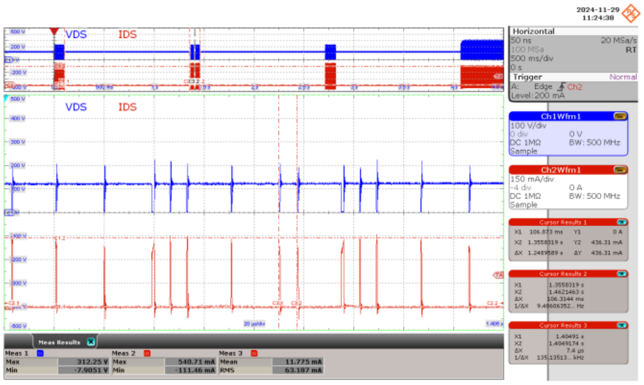


Figure 93 – 85 VAC 60 Hz. Output Short.
CH1: V_{DS}, 100 V / div., 500 ms / div.
CH2: I_{DS}, 150 mA / div., 500 ms / div.
Zoom: 20 µs / div.
Drain Voltage$_{(MAX)}$ = 312 V
Drain Current$_{(MAX)}$ = 541 mA
$t_{AR\_(OFF)}$ = 1.25 s
$t_{AR(ON)}$ = 106 ms

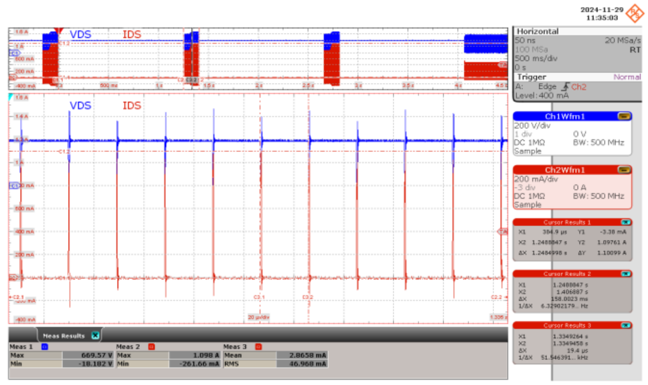


Figure 94 – 265 VAC 50 Hz Output Short.
CH1: V_{DS}, 200 V / div., 500 ms / div.
CH2: I_{DS}, 200 mA / div., 500 ms / div.
Zoom: 20 µs / div.
Drain Voltage$_{(MAX)}$ = 669.6 V
Drain Current$_{(MAX)}$ = 1.10 A
$t_{AR\_(OFF)}$ = 1.25 s
$t_{AR(ON)}$ = 158 ms

12.2 Over Temperature Protection

12.2.1 OTP at 85VAC

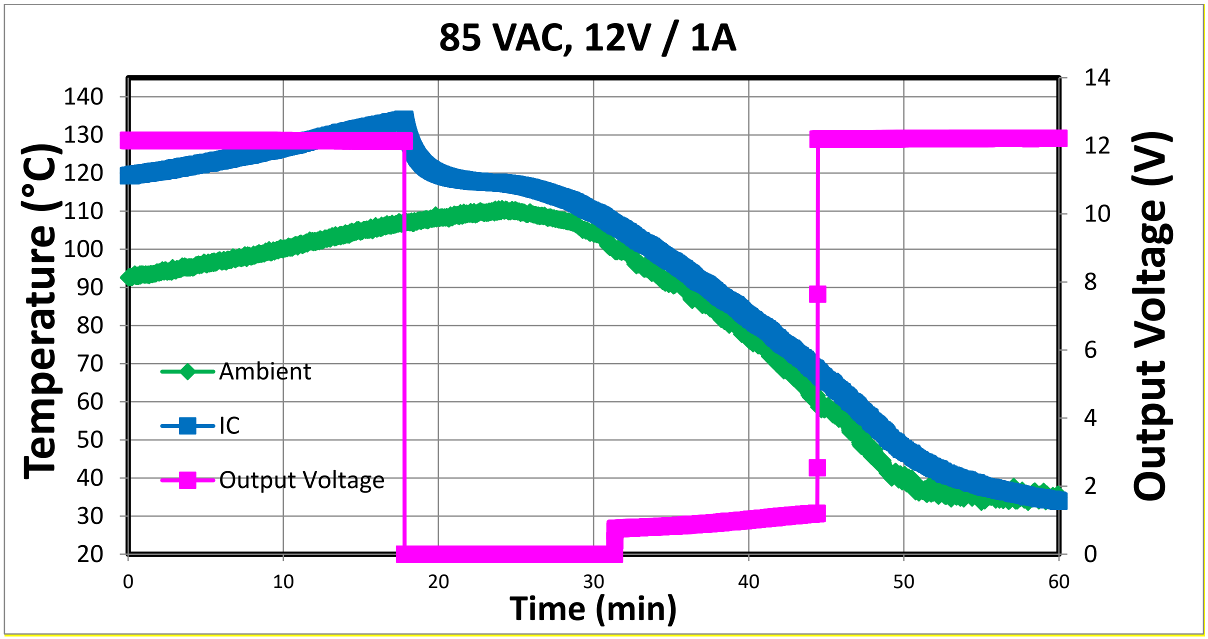


Figure 95 – 85 VAC, Io = 1 A (100% load)
OTP: 134.1 ºC
OTP recovery: 67.8 ºC
Hysteresis: 63.6 ºC

12.2.2 OTP at 265VAC

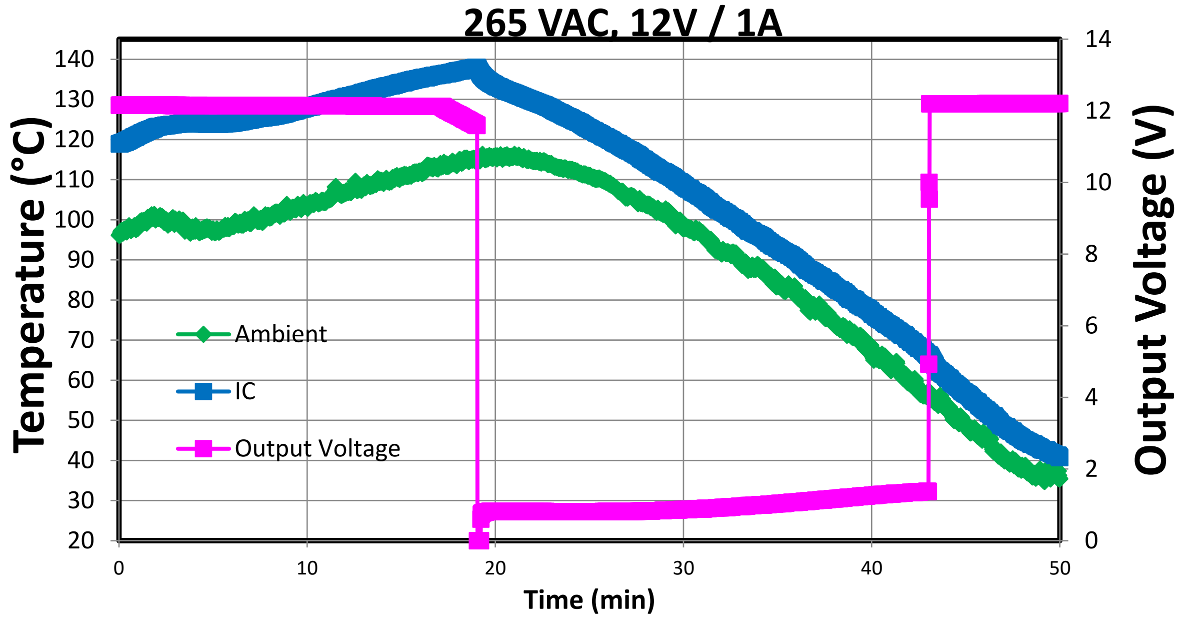


Figure 96 – 265 VAC, Io = 1 A (100% load)
OTP: 138 ºC
OTP recovery: 66.1 ºC
Hysteresis: 71.9 ºC

12.3 Overpower Protection

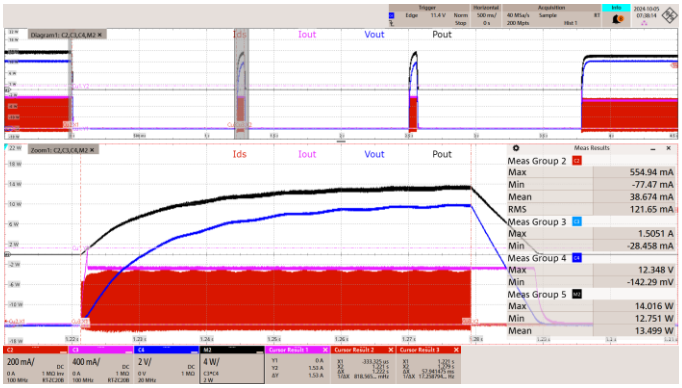


Figure 97 – 85 Vac, I_O = 1.16 A
CH 2: I_{DS}: 200 mA / div., 500 ms / div.
CH 3: I_{OUT}: 400 mA / div., 500 ms / div.
CH 4: V_{OUT}: 2 V / div., 500 ms / div.
Zoom: 10 ms / div.
$P_{OUT,max}$ = 13.5 W
$t_{AR(ON)}$ = 57.9 ms
$t_{AR(OFF)}$ = 1.22 s

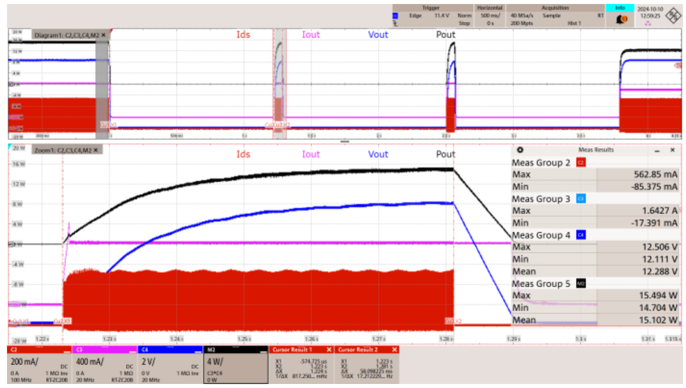


Figure 98 – 115 Vac, I_O = 1.27 A
CH 2: I_{DS}: 200 mA / div., 500 ms / div.
CH 3: I_{OUT}: 400 mA / div., 500 ms / div.
CH 4: V_{OUT}: 2 V/div., 500 ms/div.
Zoom: 10 ms / div.
$P_{OUT,max}$ = 15.1 W
$t_{AR(ON)}$ = 58.1 ms
$t_{AR(OFF)}$ = 1.22 s

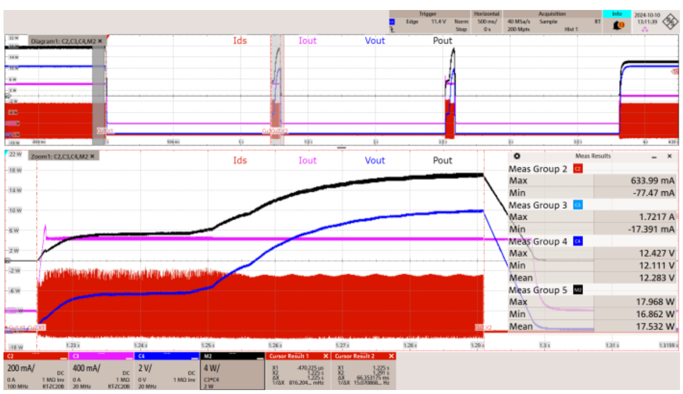


Figure 99 – 230 Vac, I_O = 1.43 A
CH 2: I_{DS}: 200 mA / div., 500 ms / div.
CH 3: I_{OUT}: 400 mA / div., 500 ms / div.
CH 4: V_{OUT}: 2 V / div., 500 ms / div.
Zoom: 10 ms / div.
$P_{OUT,max}$ = 17.5 W
$t_{AR(ON)}$ = 66.4 ms
$t_{AR(OFF)}$ = 1.23 s

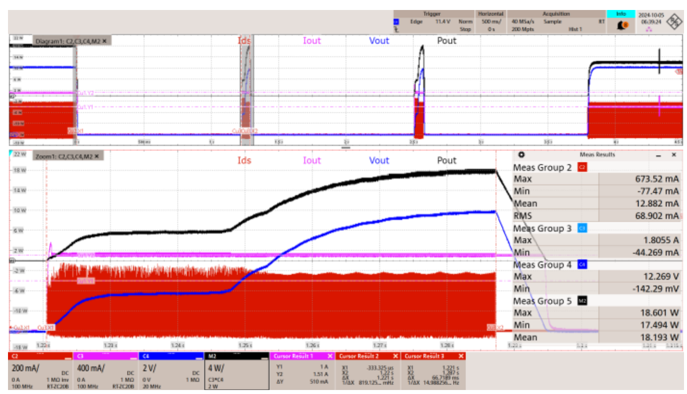


Figure 100 – 265 Vac, I_O = 1.51 A
CH 2: I_{DS}: 200 mA / div., 500 ms / div.
CH 3: I_{OUT}: 400 mA / div., 500 ms / div.
CH 4: V_{OUT}: 2 V / div., 500 ms / div.
Zoom: 10 ms / div.
$P_{OUT,max}$ = 18.2 W
$t_{AR(ON)}$ = 66.7 ms
$t_{AR(OFF)}$ = 1.22 s

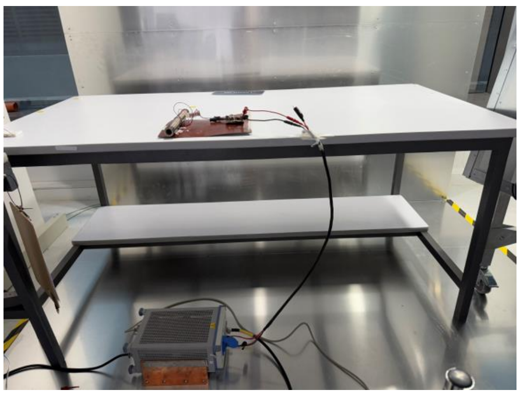
13 Conducted EMI

Conducted emissions tests were performed at 115 VAC and 230 VAC at full load (12 V, 6 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 12 Ohms.



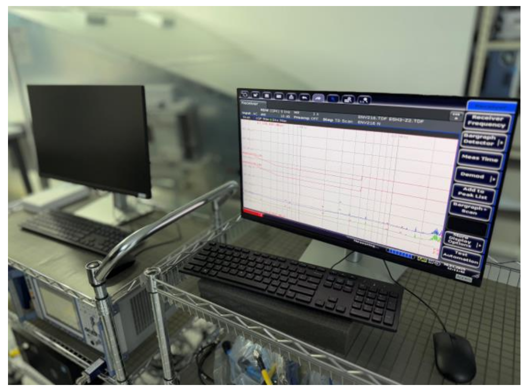


Figure 101 – EMI Test Set-up.

13.2 Output Float

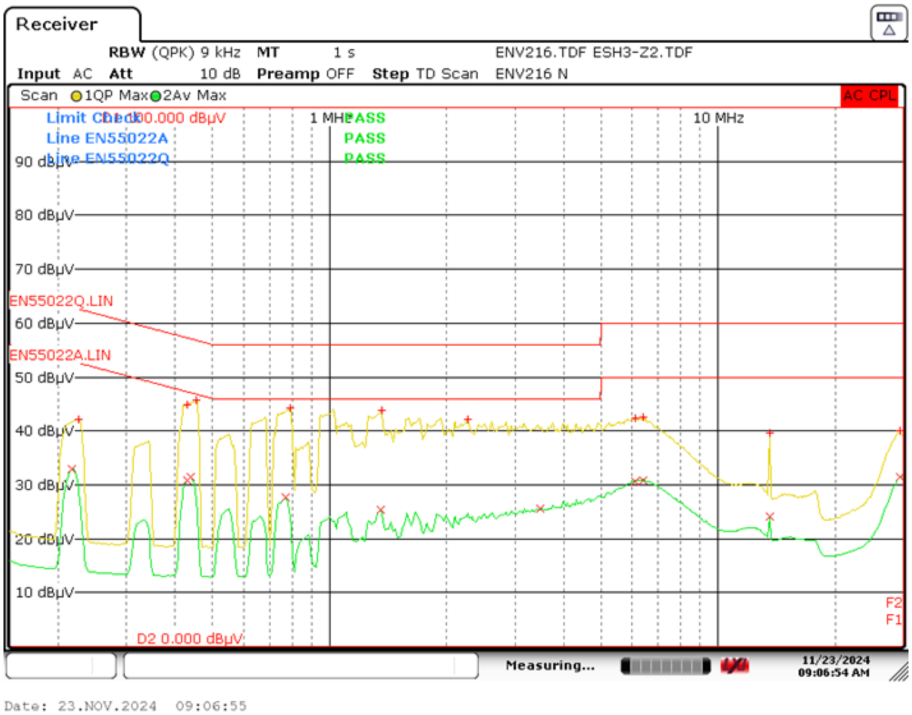


Figure 102 – 115 VAC 60 Hz.
Line / Neutral – Floating

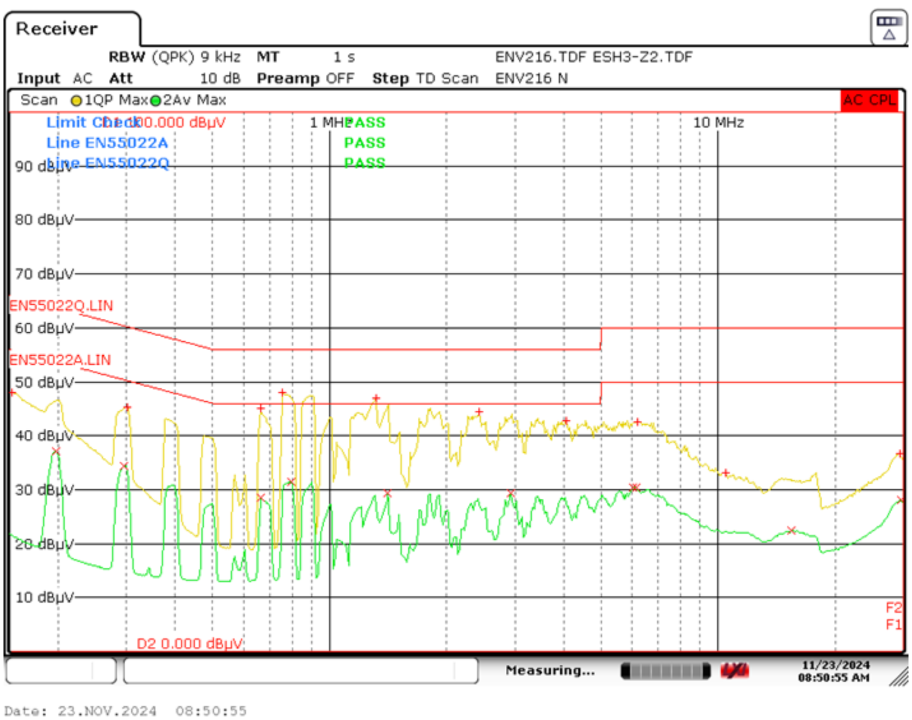


Figure 103 – 230 VAC 50 Hz.
Line / Neutral - Floating

14 Surge

14.1 Combinational Wave (Differential Mode)

14.1.1 230 VAC

Surge Voltage (V)	Phase Angle (°)	IEC Coupling	Generator Impedance (Ω)	Number Strikes	Result
+1000	0	L, N	2	10	Pass
−1000	0	L, N	2	10	Pass
+1000	90	L, N	2	10	Pass
−1000	90	L, N	2	10	Pass
+1000	180	L, N	2	10	Pass
−1000	180	L, N	2	10	Pass
+1000	270	L, N	2	10	Pass
−1000	270	L, N	2	10	Pass

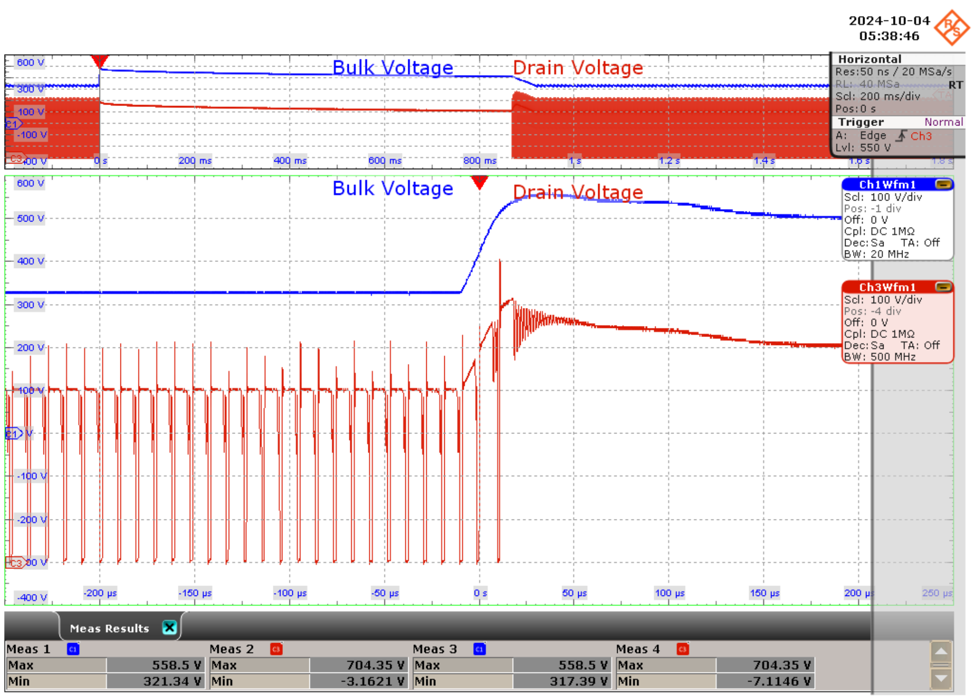


Figure 104 – 230 VAC, FL R_{Load}, -1 kV 180º surge event.
CH 1: Bulk Voltage: 100 V / div., 200 ms / div.
CH 2: Drain Voltage: 100 V / div., 200 ms / div.
Zoom: 50 µs
Drain Voltage, max = 704.4 V

14.2 Ring Wave (Common Mode)

14.2.1 115VAC

Ring Wave Voltage (kV)	Phase Angle (°)	IEC Coupling	Generator Impedance (Ω)	Number of Strikes	Test Result
4	0	L/N - PE	12	10	Pass
-4	0	L/N - PE	12	10	Pass
4	90	L/N - PE	12	10	Pass
-4	90	L/N - PE	12	10	Pass
4	180	L/N - PE	12	10	Pass
-4	180	L/N - PE	12	10	Pass
4	270	L/N - PE	12	10	Pass
-4	270	L/N - PE	12	10	Pass

14.2.2 230VAC

Ring Wave Voltage (kV)	Phase Angle (°)	IEC Coupling	Generator Impedance (Ω)	Number of Strikes	Test Result
4	0	L/N - PE	12	10	Pass
-4	0	L/N - PE	12	10	Pass
4	90	L/N - PE	12	10	Pass
-4	90	L/N - PE	12	10	Pass
4	180	L/N - PE	12	10	Pass
-4	180	L/N - PE	12	10	Pass
4	270	L/N - PE	12	10	Pass
-4	270	L/N - PE	12	10	Pass

14.3 EFT

14.3.1 115 VAC

EFT Voltage (kV)	Phase Angle (°)	Frequency (kHz)	T-Burst	T-Rep	T-Duration	Coupling	Test Result
4	0	5	15 ms	300 ms	120 s	L1/L2	Pass
-4	0	5	15 ms	300 ms	120 s	L1/L2	Pass
4	0	100	750 us	300 ms	120 s	L1/L2	Pass
-4	0	100	750 us	300 ms	120 s	L1/L2	Pass
4	90	5	15 ms	300 ms	120 s	L1/L2	Pass
-4	90	5	15 ms	300 ms	120 s	L1/L2	Pass
4	90	100	750 us	300 ms	120 s	L1/L2	Pass
-4	90	100	750 us	300 ms	120 s	L1/L2	Pass
4	180	5	15 ms	300 ms	120 s	L1/L2	Pass
-4	180	5	15 ms	300 ms	120 s	L1/L2	Pass
4	180	100	750 us	300 ms	120 s	L1/L2	Pass
-4	180	100	750 us	300 ms	120 s	L1/L2	Pass
4	270	5	15 ms	300 ms	120 s	L1/L2	Pass
-4	270	5	15 ms	300 ms	120 s	L1/L2	Pass
4	270	100	750 us	300 ms	120 s	L1/L2	Pass
-4	270	100	750 us	300 ms	120 s	L1/L2	Pass

14.3.2 230 VAC

EFT Voltage (kV)	Phase Angle (°)	Frequency (kHz)	T-Burst	T-Rep	T-Duration	Coupling	Test Result
4	0	5	15 ms	300 ms	120 s	L1/L2	Pass
-4	0	5	15 ms	300 ms	120 s	L1/L2	Pass
4	0	100	750 us	300 ms	120 s	L1/L2	Pass
-4	0	100	750 us	300 ms	120 s	L1/L2	Pass
4	90	5	15 ms	300 ms	120 s	L1/L2	Pass
-4	90	5	15 ms	300 ms	120 s	L1/L2	Pass
4	90	100	750 us	300 ms	120 s	L1/L2	Pass
-4	90	100	750 us	300 ms	120 s	L1/L2	Pass
4	180	5	15 ms	300 ms	120 s	L1/L2	Pass
-4	180	5	15 ms	300 ms	120 s	L1/L2	Pass
4	180	100	750 us	300 ms	120 s	L1/L2	Pass
-4	180	100	750 us	300 ms	120 s	L1/L2	Pass
4	270	5	15 ms	300 ms	120 s	L1/L2	Pass
-4	270	5	15 ms	300 ms	120 s	L1/L2	Pass
4	270	100	750 us	300 ms	120 s	L1/L2	Pass
-4	270	100	750 us	300 ms	120 s	L1/L2	Pass

15 ESD

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

Passed ±8.8 kV contact discharge

Contact Discharge Voltage (kV)	Applied to	Number of Strikes	Test Result
+8.8	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.

16 Revision History

Date	Author	Revision	Description and Changes	Reviewed
31-Jan-2025	JKB, KCP	A	Initial Release	Apps & Mktg

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