Design Example Report

Title	*72 W Isolated Flyback Power Supply Using InnoSwitch™4-QR PowiGaN™ INN4275C-H186*
Specification	90 VAC – 265 VAC Input; 12 V / 6 A Output
Application	Appliance Application
Author	Applications Engineering Department
Document Number	DER-993
Date	May 19, 2024
Revision	1.0

Summary and Features

- Off-line CV/CC QR flyback integrated switcher IC with 750 V PowiGaN and synchronous rectification for higher efficiency
- <70 mW no-load input power at 230 VAC input
- Very high average efficiency
  - >91.5 % at 115 VAC and >92% at 230 VAC
- Very high full-load efficiency
  - 90.5 % at 115 VAC and 92 % at 230 VAC
- No optocoupler increases reliability
- Input voltage monitor with accurate brown-in/brown-out protection
- Meets EN550022 and CISPR-22 Class B conducted EMI with >6db margin
- Very low component count: 44 components

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www.power.com

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Important Note:
Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

1 Introduction

This engineering report describes a 12 V / 6 A power supply using the InnoSwitch4-QR INN4275C-H186 IC. This design shows a high-power density and efficiency that is possible due to the high level of integration of the InnoSwitch4-QR controller and PowiGaN providing exceptional performance.

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

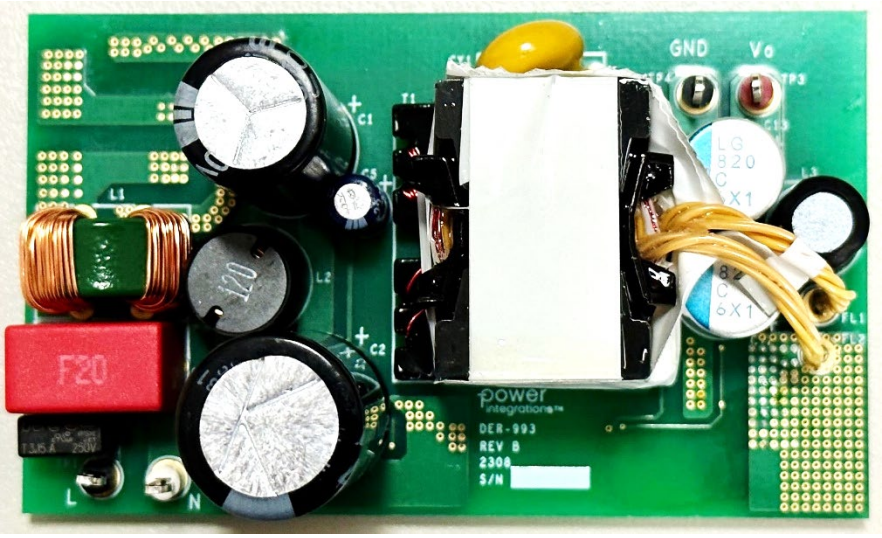


Figure 1 – Populated Circuit Board Photograph, Top.

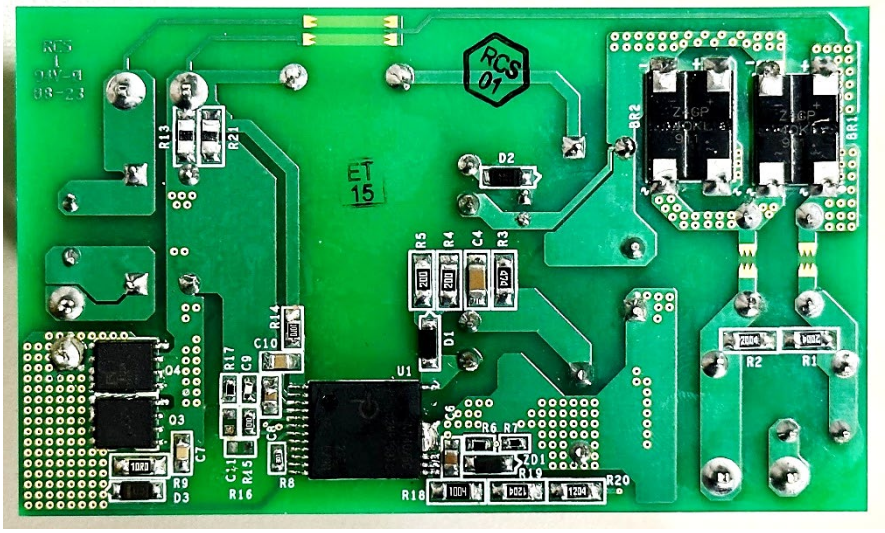


Figure 2 – Populated Circuit Board Photograph, Bottom.

2 Power Supply Specification

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

Description	Symbol	Min	Nom	Max	Units	Comment
Input						
Voltage	V_{IN}	90	115/230	265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)				<70	mW	
Output						
Output Voltage	V_{OUT}	11.4	12	12.6	V	± 5%
Output Ripple Voltage	V_{RIPPLE}			120	mV	20 MHz Bandwidth, at 25 Deg°C Ambient
Output Current	I_{OUT}		6		A	
Total Output Power						
Continuous Output Power	P_{OUT}		72		W	
Efficiency						
	η		90.5		%	Full Load @ 115 VAC
			92			Full Load @ 230 VAC
			91.5			Average @ 115 VAC
			92.5			Average @ 230 VAC
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Surge (Differential)				2	kV	1.2/50 μs Surge, IEC 61000-4-5, Impedance: 2 Ω Class A
Combination Wave Surge Test				6	kV	
EFT				4	kV	IEC 61000-4-4
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

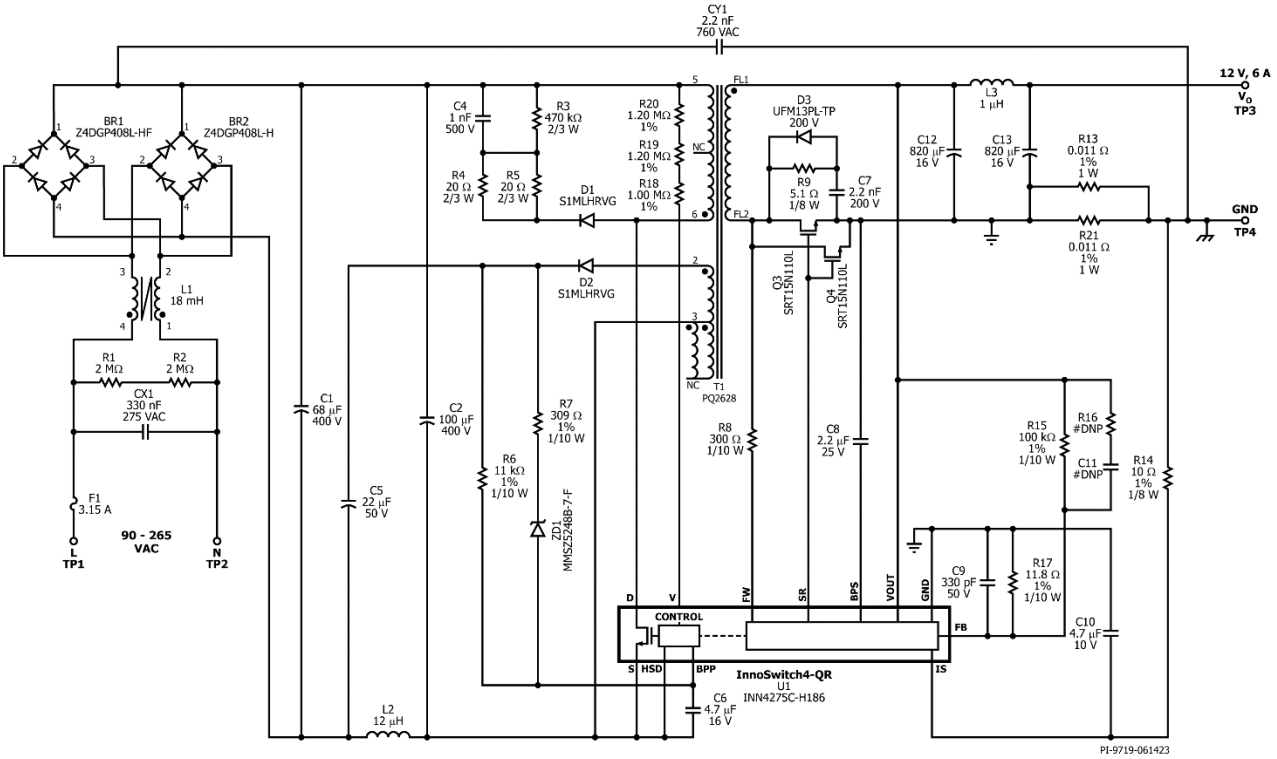


Figure 3 – Power Stage Schematic.

4 Circuit Description

The InnoSwitch4-QR IC combines primary, secondary and feedback circuits in a single surface mounted off-line flyback switcher IC. The IC incorporates PowiGaN primary switch, primary-side controller, secondary-side controller for synchronous rectification and Fluxlink™ technology that eliminates the need for an optocoupler needed on a secondary sensed feedback system. InnoSwitch4-QR operates in Quasi-Resonant to achieve high efficiency.

4.1 Input EMI Filtering

Fuse F1 isolates the circuit and provides protection from component failure, X capacitor CX1 and common mode choke L1 forms a filter to attenuate common mode noise. Bridge rectifier BR1 and BR2 rectifies the AC line voltage and provides a full wave rectified DC across the filter capacitor C1 and C2. Capacitors C1, C2 along with L2 forms pi filter circuit. It attenuates both common and differential mode noise. Capacitor CY1 is used to mitigate the common mode EMI.

4.2 InnoSwitch4-QR IC Primary

One end of the transformer (T1) primary is connected to the rectified DC bus; the other is connected to the drain terminal of the switch inside the InnoSwitc4-QR IC (U1). Resistors R18, R19 and R20 provide input voltage sense protection for undervoltage and overvoltage conditions.

A low-cost RCD clamp formed by diode D1, resistors R3, R4, R5 and capacitor C4 limits the peak drain voltage of U1 at the instant of turn off of the switch inside U1. The clamp helps to dissipate the energy stored in the leakage reactance of transformer T1.

The IC is self-starting, using an internal high-voltage current source to charge the BPP pin capacitor (C6) when AC is first applied. During normal operation, the primary-side block is powered from an auxiliary winding on the transformer T1. Output of the auxiliary (or bias) winding is rectified using diode D2 and filtered using capacitor C5. Resistor R6 limits the current being supplied to the BPP pin of the InnoSwitch4-QR (U1).

Zener diode ZD1 along with R7 offers primary sensed output overvoltage protection. In a flyback converter, output of the auxiliary winding tracks the output voltage of the converter. In case of overvoltage at output of the converter, the auxiliary winding voltage increases and causes breakdown of VR1 which then causes a current to flow into the BPP pin of InnoSwitch4-QR IC U1. If the current flowing into the BPP pin increases above the I_{SD} threshold, the InnoSwitch4-QR controller will undergo auto-restart to protect itself from any damage.

4.3 InnoSwitch4-QR IC Secondary

The secondary-side of the InnoSwitch4-QR IC provides output voltage, output current sensing and drive to the SR FET providing synchronous rectification. The secondary of the transformer is rectified by SR FET Q3, Q4 and filtered by output capacitor. High frequency ringing during switching transients that would otherwise create radiated EMI is reduced via an RCD snubber R9, C7 and D3. Diode D3 was used to minimize the dissipation in resistor R6.

The gate of Q3 and Q4 are turned on by secondary-side controller inside IC U1, based on the winding voltage sensed via resistor R8 and fed into the FWD pin of the IC. The FWD pin is also used to supply the secondary-side of IC U1 when the VOUT pin is below the threshold value.

The secondary-side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. Capacitor C8 connected to the BPS pin of InnoSwitch4-QR IC U1 provides decoupling for the internal circuitry.

Output current is sensed by monitoring the voltage drop across resistor R14 between the IS and GND pins with a threshold of approximately 35 mV to reduce losses. Capacitor C10 provides filtering on the IS pin from external noise.

The device operates in constant voltage mode before reaching the current limit set by resistor R14. During constant voltage mode operation, output voltage regulation is achieved through sensing the output voltage via divider resistors R15 and R17. The voltage across R17 is fed into the FB pin with an internal reference voltage threshold of 1.265 V. Output voltage is regulated to achieve a voltage of 1.265 V on the FB pin. Capacitor C9 provides noise filtering of the signal at the FB pin.

The capacitors C15, C16 and inductor L3 form a pi filter that is used to reduce the high frequency output voltage ripple.

5 PCB Layout

PCB copper thickness is 2.0 oz.
PCB material thickness is 1.6 mm.
PCB material is FR4.

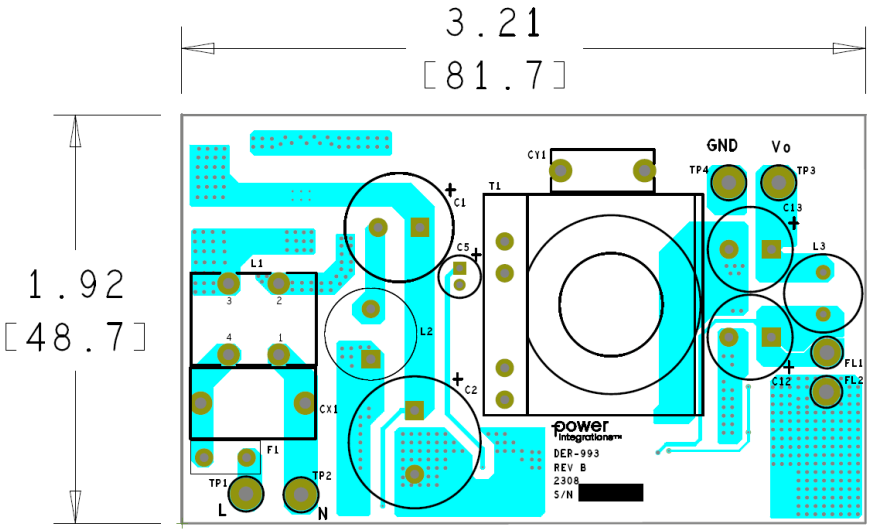


Figure 4 – Printed Circuit Layout, Top.

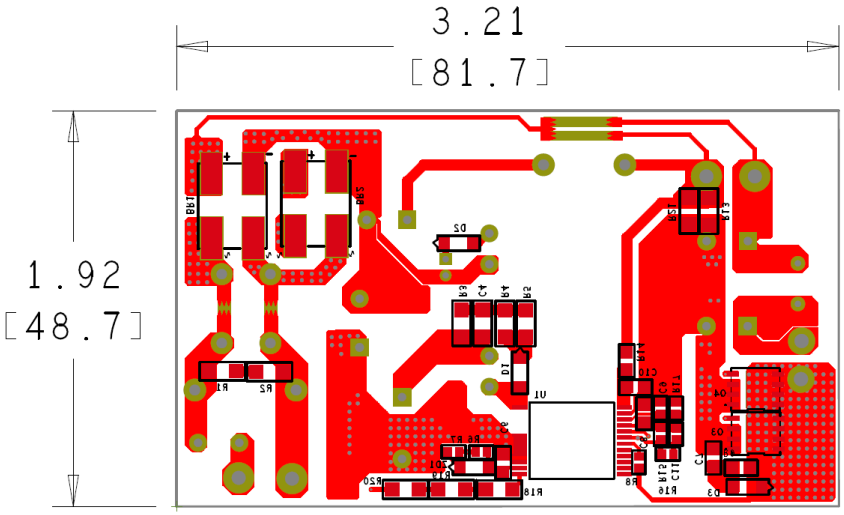


Figure 5 – Printed Circuit Layout, Bottom.

6 Bill of Materials

6.1 Bill of Material: Electrical Components

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	2	BR1 BR2	RECT BRIDGE, GP, 800 V, 4 A, Z4-D	Z4DGP408L-HF	Comchip
2	1	C1	68 μF, ±20%, 400 V, Electrolytic, (13 x 30)	ERK2GM680K30OT	AiSHi
3	1	C2	Electrolytic, 100 μF, 400 V, Aluminum, Radial, Can, -40 °C ~ 105 °C, 12000 Hrs @ 105°C ,(16 x 32)	400BXW100MEFR16X30	Rubycon
4	1	C4	1000 pF, 1 nF, ±10%, 500 V, Ceramic X7R, 1206	CC1206KKX7RBBB102	Yageo
5	1	C5	22 μF, 50 V, Electrolytic, (5 x 11)	UPW1H220MDD	Nichicon
6	1	C6	4.7 μF, 16 V, Ceramic, X7R, 0805	CL21B475KOFNNNE	Samsung
7	1	C7	2.2 nF, 200 V, Ceramic, X7R, 0805	08052C222KAT2A	AVX
8	1	C8	2.2 μF, ±10%, 25 V, Ceramic, X7R, 0805	C2012X7R1E225K125AB	TDK
9	1	C9	330 pF, ±5%, 50 V, Ceramic, C0G, NP0, 0603	C0603C331J5GACAUTO	KEMET
10	1	C10	4.7 μF ±10% 10 V Ceramic X7R 0805	LMK212B7475KGHT	Taiyo Yuden
11	2	C12 C13	820 μF, ±20%,16 V, Aluminum Polymer, Gen. Purpose, -55°C ~ 105°C, 2000 Hrs @ 105 °C	PLG1C821MDO1	Nichicon
12	1	CX1	330 nF, ±10%, 275 VAC, Polypropylene Film, X2, 15.00 mm x 8.5 0mm	890324024003CS	Wurth
13	1	CY1	2200 pF, ±20% ,760 VAC, Ceramic Y5U (E) Radial, Disc	AY1222M47Y5UC63L0	Vishay
14	2	D1 D2	Diode, Standard, 1000 V, 1 A, SMT, Sub SMA	S1MLHRVG	TAIWAN SEMI
15	1	D3	Diode, GEN PURP, 200 V, 1 A, SOD-123F, SOD123FL	UFM13PL-TP	Micro Commercial
16	1	F1	3.15 A, 250 V, Slow, RST	RST 3.15-BULK	Belfuse
17	1	L1	Custom, CMC, 18 mH @ 10 kHz, Toroidal, 17.5 mm OD x 11.0 mm thick. 40 turns x 2, 0.40 mm wire 190 mΩ max	04291-T231	Sumida
18	1	L2	Fixed Inductor, 12 μH @100 kHz, ± 10%, 5.1 A, 0.035 ohm, AEC-Q200, Unshielded, Ferrite, Radial, -40°C ~ 85°C, 11 x 11.5mm	RFB1010-120L	Coilcraft
19	1	L3	FIXED IND 1 μH 10 A 13 mΩ TH	6000-1R0M-RC	Bourns
20	2	Q3 Q4	MOSFET, N-CH, 150 V 80 A, 153 W (Tc=25C), SMT 8-DFN (5x6), 8DFN	SRT15N110L	sanrise-tech.com
21	2	R1 R2	RES, 2.0 MΩ, 5%, 1/4 W, Thick Film, 1206	RC1206JR-072ML	YAGEO
22	1	R3	RES, 470 kΩ, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J474V	Panasonic
23	2	R4 R5	RES, 20 Ω, 5%, 2/3 W, Thick Film, 1206	ERJ-P08J200V	Panasonic
24	1	R6	RES, 11 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF1102V	Panasonic
25	1	R7	RES, 309 Ω, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF3090V	Panasonic
26	1	R8	RES, 300 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ301V	Panasonic
27	1	R9	RES, 5.1 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ5R1V	Panasonic
28	2	R13 R21	0.011 Ω, ±1%, ±75ppm/°C, 1 W, 1206, Automotive AEC-Q200, Current Sense, -55°C ~ 155°C	ERJ-8CWFR011V	Panasonic
29	1	R14	RES, 10 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF10R0V	Panasonic
30	1	R15	RES, 100 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF1003V	Panasonic
31	1	R17	RES, 11.8 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF1182V	Panasonic
32	1	R18	RES, 1.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1004V	Panasonic
33	2	R19 R20	RES, 1.20 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1204V	Panasonic
34	1	T1	Bobbin, PQ-2628, 6 pins, 6pri, 0sec	PQ-2628	Golden Bamboo Electronics Zhuhai
35	1	U1	InnoSwitch4-QR, 230 VDC,90 W, insop-24D	INN4275C-H186	Power Integrations
36	1	ZD1	Diode ZENER 18 V 500 mW SOD123	MMSZ5248B-7-F	Diodes, Inc.

6.2 Bill of Material: Mechanical Components

Item	Qty	Ref Des	Description	Mfg	Mfg Part Number
1	2	TP1 TP4	Test Point, BLK, THRU-HOLE MOUNT	Keystone	5011
2	1	TP2	Test Point, WHT, THRU-HOLE MOUNT	Keystone	5012
3	1	TP3	Test Point, RED, THRU-HOLE MOUNT	Keystone	5010

7 Transformer Specification

7.1 Electrical Diagram

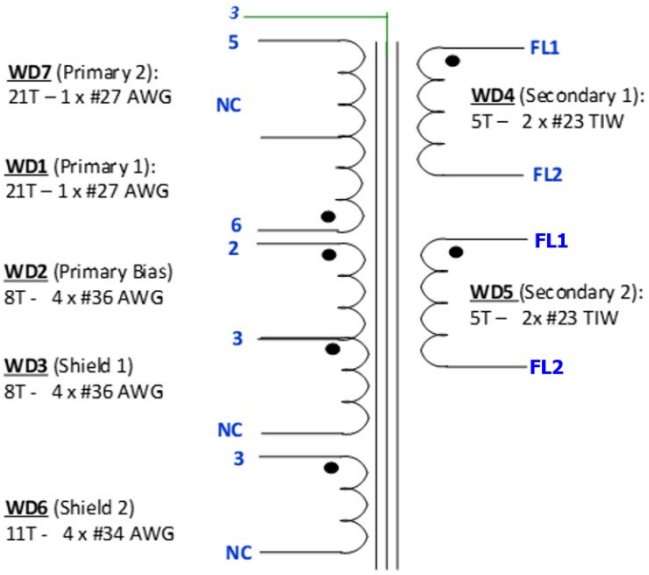


Figure 6 – Electrical Diagram.

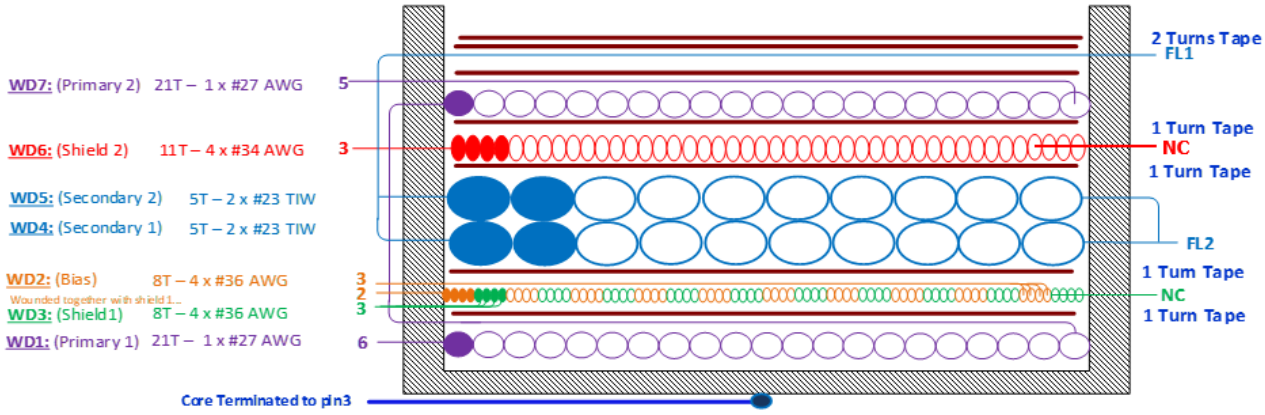
7.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, typical switching frequency, between pin 6 to pin 5, with all other Windings open.	519 µH ±5.0%
Resonant Frequency	Measured between pin 6 to pin 5.	1808 kHz (Nominal)
Primary Leakage Inductance	Measured between pin 6 to pin 5, with all other windings shorted.	5.5 µH (Max).

7.3 Materials List

Item	Description
[1]	Core: PQ2620, (use PC cores).
[2]	Bobbin: PQ2628, 25-01137-00.
[3]	Thin Copper Tape 0.5 mm.
[4]	Varnish; Dolph BC 359 or Equivalent.
[5]	Single Core Wire: #27 AWG (0.41 mm), insulation Heavy Build.
[6]	Separation Tape: Polyester Film [1 mil (25.4 Micrometers) Base Thickness], 9.5 mm Wide.
[7]	Single Core Wire: #36 AWG (0.15 mm), Insulation Heavy Build.
[8]	Triple Insulated Wire: #23 AWG.
[9]	Single Core Wire: #34 AWG (0.19 mm), Insulation Heavy Build.
[10]	Separation Tape: 3M 1298 Polyester Film, 1 mil Thick, 33.0 mm Wide.
[11]	Bus Wire: Uninsulated #26 AWG.

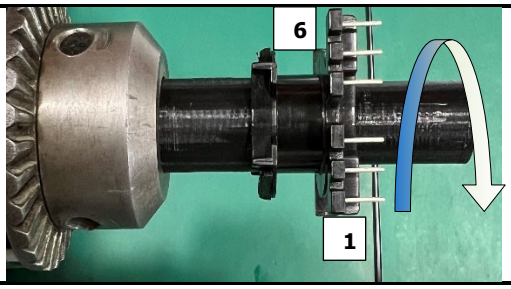
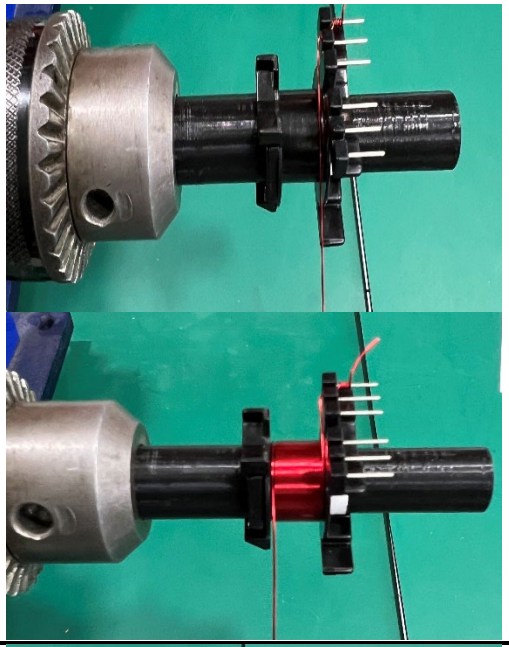
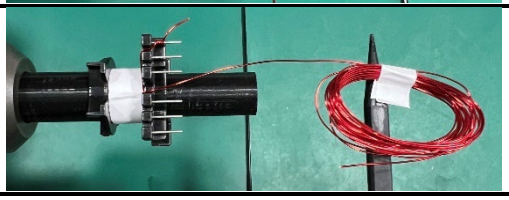
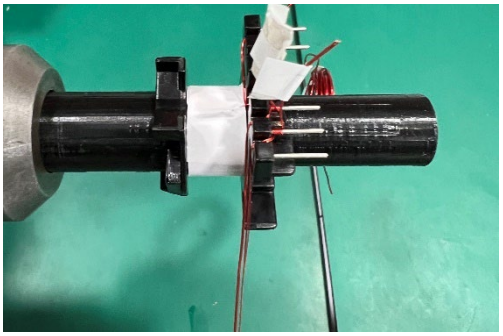
7.4 Transformer Build Diagram

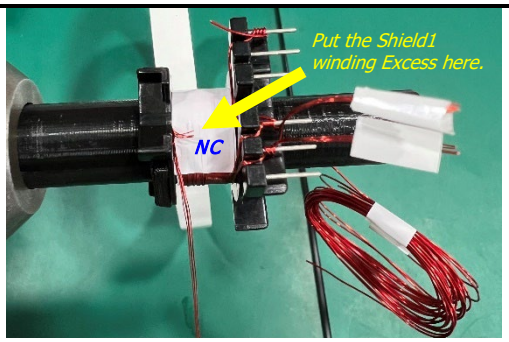
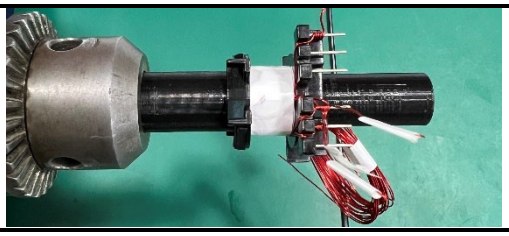
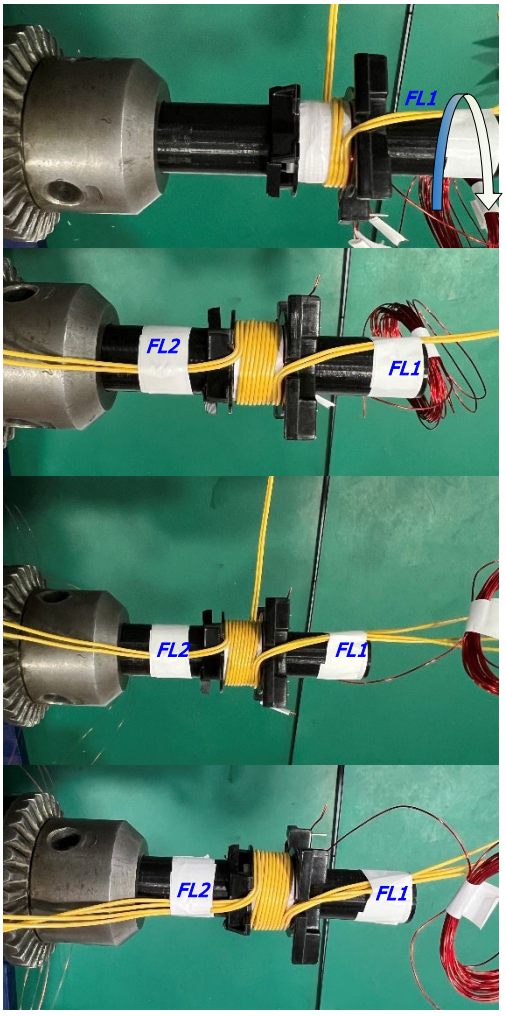


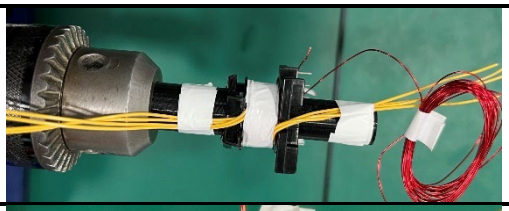
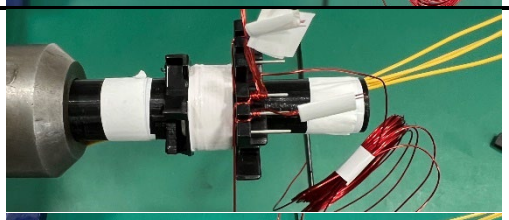
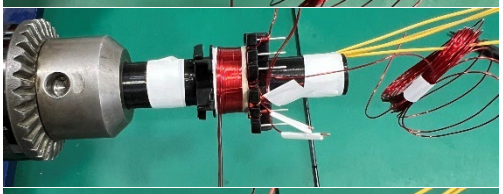
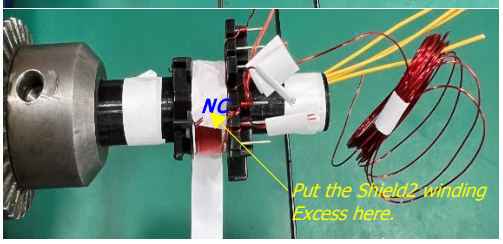
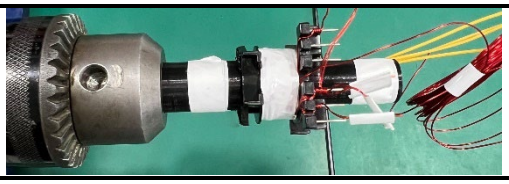
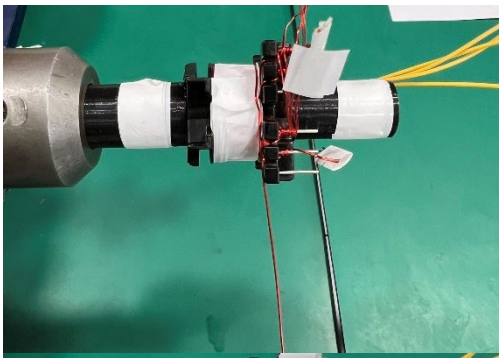
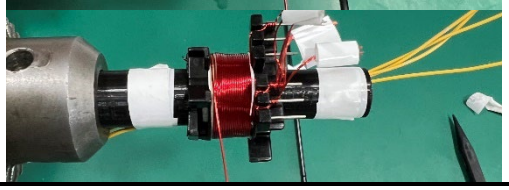
7.5 Transformer Instruction

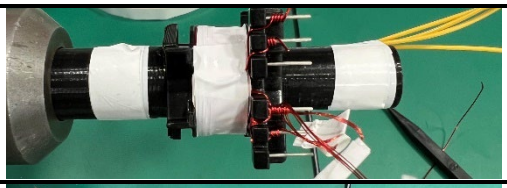
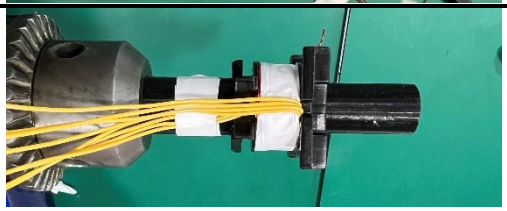
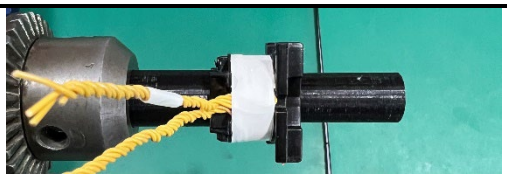
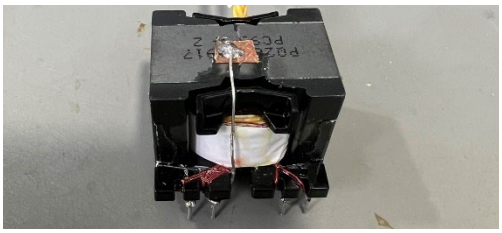
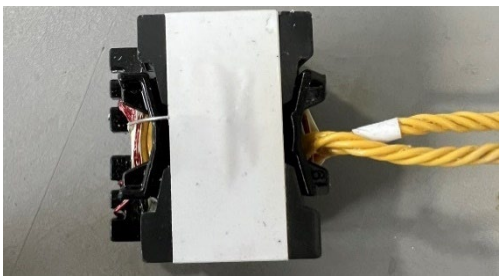
Winding Preparation	Position the bobbin Item [2] on the mandrel, pins facing the opposite direction of the winding machine, pin 1 on the lower side and pin 6 on the upper side. Winding direction is clockwise.
WD1: Primary 1	Start at pin 6, wind 21 turns of wire Item [5], from right to left in 1 layer. At the last turn, bring the wire where you started, and leave enough length of wire-floating for WD7-2nd Primary.
Insulation	1 layer of tape Item [6].
WD2: Bias & WD3: Shield1	Use 4 wires Item [7] start at pin 2 for Bias winding, also use 4 wires same Item [7] for WD3-Shield1 winding start at pin 3, winding right to left direction, wind all 8 wires in parallel for 8 turns, at the last turn terminate Bias winding at pin 3. For Shield1 winding cut the wire at the last turn, leave at least 3mm of excess to tuck it in the layer of tape.
Insulation	1 layer of tape Item [6].
WD4 & WD5: Secondary	Switch to the other side of bobbin, WD4 Start from FL1 wind 2 wires of Item [8] for 5 turns, from right to left. Secure FL2 with tape. Repeat the process 1 more time for WD5. WD5 wires winding should be on top of WD4.
Insulation	1 layer of tape Item [6].
WD6: Shield2	For WD6 Shield2 winding use 4 wires of Item [9] start at pin 3 from right to left. At the last turn cut the leave a floating wire with at least 3 mm, to tuck it in the layer of tape.
Insulation	1 layer of tape Item [6].
WD7: Primary 2	Use the floating wire from WD1-Primary 1, wind 21 turns from right to left. Terminate the wire at pin 5.
Insulation	1 layer of tape Item [6].
FL1 Wire	Route FL1 wire to the top of the bobbin towards FL2.
Insulation	2 layers of tape Item [6] to secure all windings.
Finish	Use a tape Item [6] to Indicate FL1. Use Item [1], Gap Cores to get 519 μH. Put thin copper tape item [3] onto the upper half of the core, solder a bus wire Item [11] then terminate at pin 3. Use 3 layers of tape Item [6] to secure the upper and lower part of the core. Remove pins: 1, 4. Use a wide tape Item [10] to envelop bottom and secondary-side part of the bobbin. Use 2 layers of tape Item [6] horizontally to secure the cores. FL1 and FL2 should be at least 3.5 cm long. Varnish Item [4] the transformer.

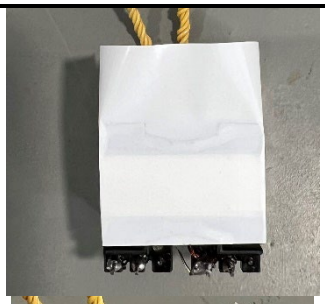
7.6 Winding Illustrations

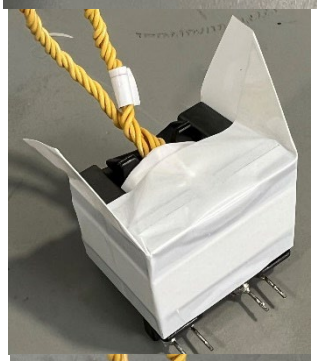
Winding Preparation		Position the bobbin Item [2] on the mandrel, pins facing the opposite direction of the winding machine, pin 1 on the lower side and pin 6 on the upper side. Winding direction is clockzwise.
WD1 **Primary 1**		Start at pin 6, wind 21 turns of wire Item [5], from right to left in 1 layer. At the last turn, bring the wire where you started, and leave enough length of wire-floating for WD7-2nd Primary.
Insulation		1 layer of tape Item [6].
WD2: Bias **&** **WD3: Shield1**		Use 4 wires Item [7] start at pin 2 for Bias winding, also use 4 wires same Item [7] for WD3-Shield1 winding start at pin 3, winding right to left direction, Wind all 8 wires in parallel for 8 turns, at the last turn terminate Bias winding at pin 3. For Shield1 winding cut the wire at the last turn, leave at least 3mm of excess to tuck it in the layer of tape.

		
Insulation		1 layer of tape Item [6].
WD4 & WD5 Secondary		Switch to the other side of bobbin, WD4 Start from FL1 wind 2 wires of Item [8] for 5 turns, from right to left. Secure FL2 with tape. Repeat the process 1 more time for WD5. WD5 wires winding should be on top of WD4.

Insulation		1 layer of tape Item [6].
WD6 Shield2	  	For WD6 Shield2 winding use 4 wires of item [9] start at Pin 3 from right to left. At the last turn cut the leave a floating wire with at least 3mm, to tuck it in the layer of tape.
Insulation		1 layer of tape Item [6].
WD7 Primary 2	 	Use the floating wire from WD1-Primary 1, wind 21 turns from right to left. Terminate the wire at pin 5.

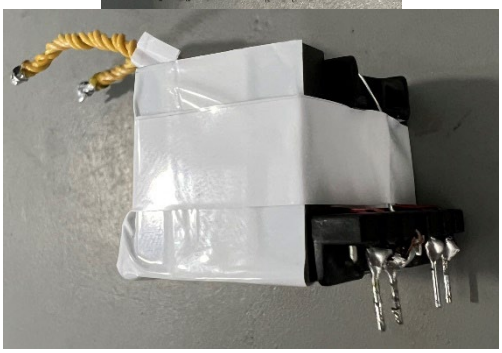
Insulation		1 layer of tape Item [6].
FL1 Wire		Route FL1 Wire to the top of the bobbin towards FL2.
Insulation		2 layers of tape Item [6] to secure all windings.
Finish	  	Use a tape Item [6] to Indicate FL1 Use Item [1], Gap Cores to get 519 µH. Put thin copper tape Item [3] onto the upper half of the core, solder a bus wire Item [11] then terminate at pin 3. Use 3 layers of tape Item [6] to secure the upper and lower part of the core. Remove pins: 1, 4.





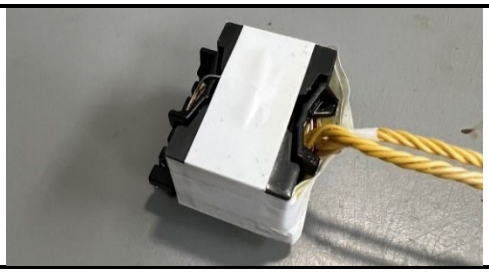
Use a wide tape Item [10] to envelop bottom and secondary-side part of the bobbin.

Use 2 layers of tape Item [6] horizontally to secure the cores.



FL1 and FL2 should be at least 3.5cm long

Varnish Item [4] the transformer.

Finished Transformer		

8 Transformer Design Spreadsheet

1	ACDC_InnoSwitch4-QR_Flyback_033123; Rev.0.1; Copyright Power Integrations 2023	INPUT	INFO	OUTPUT	UNITS	InnoSwitch4 QR Single/Multi Output Flyback Design Spreadsheet
2	**APPLICATION VARIABLES**					
3	INPUT_TYPE	AC		AC		Input Type
4	VIN_MIN	90		90	V	Minimum AC input voltage
5	VIN_MAX			265	V	Maximum AC input voltage
6	VIN_RANGE			UNIVERSAL		Range of AC input voltage
7	LINEFREQ			60	Hz	AC Input voltage frequency
8	CAP_INPUT	168.0		168.0	uF	Input capacitor
9	VOUT	12.00		12.00	V	Output voltage at the board
10	CDC			0	mV	Cable drop compensation desired at full load
11	IOUT	6.000		6.000	A	Output current
12	POUT			72.00	W	Output power
13	EFFICIENCY	0.90		0.90		AC-DC efficiency estimate at full load given that the converter is switching at the valley of the rectified minimum input AC voltage
14	FACTOR_Z			0.60		Z-factor estimate
15	ENCLOSURE	ADAPTER		ADAPTER		Power supply enclosure
19	**PRIMARY CONTROLLER SELECTION**					
20	ILIMIT_MODE	INCREASED		INCREASED		Device current limit mode
21	DEVICE_GENERIC	AUTO		INN4275		Generic device code
22	DEVICE_CODE			INN4275C		Actual device code
23	POUT_MAX			75	W	Power capability of the device based on thermal performance
24	RDSON_100DEG			0.54	Ω	Primary switch on time drain resistance at 100 degC
25	ILIMIT_MIN			2.374	A	Minimum current limit of the primary switch
26	ILIMIT_TYP			2.580	A	Typical current limit of the primary switch
27	ILIMIT_MAX			2.786	A	Maximum current limit of the primary switch
28	VDRAIN_BREAKDOWN			750	V	Device breakdown voltage
29	VDRAIN_ON_PRSW			0.42	V	Primary switch on time drain voltage
30	VDRAIN_OFF_PRSW			583.4	V	Peak drain voltage on the primary switch during turn-off
34	**WORST CASE ELECTRICAL PARAMETERS**					
35	FSWITCHING_MAX	69000		69000	Hz	Maximum switching frequency at full load and valley of the rectified minimum AC input voltage
36	VOR	100.0		100.0	V	Secondary voltage reflected to the primary when the primary switch turns off
37	VMIN			99.95	V	Valley of the minimum input AC voltage at full load
38	KP			0.63		Measure of continuous/discontinuous mode of operation
39	MODE_OPERATION			CCM		Mode of operation
40	DUTYCYCLE			0.501		Primary switch duty cycle
41	TIME_ON		Info	12.34	us	Primary switch on-time is greater than 10.5us: Increase the controller switching frequency or increase the VOR NOTE: Actual operation limits TIME_ON

						to ton(max) and FSWITCHING will increase. Meausured maximum FSW on board is around 80 kHz less than fOVL.
42	TIME_OFF			7.23	us	Primary switch off-time
43	LPRIMARY_MIN			493.3	uH	Minimum primary inductance
44	LPRIMARY_TYP			519.3	uH	Typical primary inductance
45	LPRIMARY_TOL			5.0	%	Primary inductance tolerance
46	LPRIMARY_MAX			545.2	uH	Maximum primary inductance
48	**PRIMARY CURRENT**					
49	IPEAK_PRIMARY			2.531	A	Primary switch peak current
50	IPEDESTAL_PRIMARY			0.830	A	Primary switch current pedestal
51	IAVG_PRIMARY			0.772	A	Primary switch average current
52	IRIPPLE_PRIMARY			1.983	A	Primary switch ripple current
53	IRMS_PRIMARY			1.163	A	Primary switch RMS current
55	**SECONDARY CURRENT**					
56	IPEAK_SECONDARY			21.261	A	Secondary winding peak current
57	IPEDESTAL_SECONDARY			6.971	A	Secondary winding current pedestal
58	IRMS_SECONDARY			9.745	A	Secondary winding RMS current
62	**TRANSFORMER CONSTRUCTION PARAMETERS**					
63	**CORE SELECTION**					
64	CORE	PQ26/20		PQ26/20		Core selection. Refer to the 'Transformer Construction' tab to see the detailed report
65	CORE CODE			B65877B0000R095		Core code
66	AE			122.30	mm^2	Core cross sectional area
67	LE			44.40	mm	Core magnetic path length
68	AL			6300	nH/turns^2	Ungapped core effective inductance
69	VE			5435.0	mm^3	Core volume
70	BOBBIN			B65878E0012D001		Bobbin
71	AW			33.00	mm^2	Window area of the bobbin
72	BW			9.00	mm	Bobbin width
73	MARGIN			0.0	mm	Safety margin width (Half the primary to secondary creepage distance)
75	**PRIMARY WINDING**					
76	NPRIMARY			42		Primary turns
77	BPEAK			3084	Gauss	Peak flux density
78	BMAX			2650	Gauss	Maximum flux density
79	BAC			1016	Gauss	AC flux density (0.5 x Peak to Peak)
80	ALG			294	nH/turns^2	Typical gapped core effective inductance
81	LG			0.498	mm	Core gap length
83	**PRIMARY BIAS WINDING**					
84	NBIAS_PRIMARY			7		Primary bias winding number of turns
86	**SECONDARY WINDING**					
87	NSECONDARY	5		5		Secondary winding number of turns
89	**SECONDARY BIAS WINDING**					
90	NBIAS_SECONDARY			NA		Secondary bias winding number of turns
94	**PRIMARY COMPONENTS SELECTION**					
95	**CLAMPZERO**					
96	LLEAK			5.19	uH	Primary winding leakage inductance
97	CCLAMP			3.12	nF	Primary clamp capacitor
98	RCLAMP			46.47	kΩ	Primary clamp resistor
100	**LINE UNDERVOLTAGE**					
101	BROWN-IN REQURED			70.20	V	Required AC RMS/DC line voltage brown-in threshold
102	RLS			3.56	MΩ	Connect two 1.78 MOhm resistors to the V-pin for the required UV/OV threshold

103	BROWN-IN ACTUAL			59V - 71.4V	V	Actual AC RMS/DC brown-in range
104	BROWN-OUT ACTUAL			52.5V - 65V	V	Actual AC RMS/DC brown-out range
106	**LINE OVERVOLTAGE**					
107	OVERVOLTAGE_LINE			265.6V - 301.5V	V	Actual AC RMS/DC line over-voltage range
109	**PRIMARY BIAS DIODE**					
110	VBIAS_PRIMARY	16.0		16.0	V	Rectified primary bias voltage
111	VF_BIAS_PRIMARY			0.70	V	Bias winding diode forward drop
112	VREVERSE_BIASDIODE_PRIMARY			79.03	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
113	CBIAS_PRIMARY			22	uF	Bias winding rectification capacitor
114	CBPP			4.70	uF	BPP pin capacitor
118	**SECONDARY COMPONENTS**					
119	RFB_UPPER			100.00	kΩ	Upper feedback resistor (connected to the first output voltage)
120	RFB_LOWER			11.80	kΩ	Lower feedback resistor
121	CFB_LOWER			330	pF	Lower feedback resistor decoupling capacitor
123	**SECONDARY BIAS DIODE**					
124	USE_SECONDARY_BIAS	AUTO		NO		Use secondary bias winding for the design
125	VBIAS_SECONDARY			NA	V	Rectified secondary bias voltage
126	VF_BIAS_SECONDARY			NA	V	Bias winding diode forward drop
127	VREVERSE_BIASDIODE_SECONDARY			NA	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
128	CBIAS_SECONDARY			NA	uF	Bias winding rectification capacitor
129	CBPS			NA	uF	BPP pin capacitor
132	**MULTIPLE OUTPUT PARAMETERS**					
133	OUTPUT 1					
134	VOUT1			12.00	V	Output 1 voltage
135	IOUT1			6.00	A	Output 1 current
136	POUT1			72.00	W	Output 1 power
137	IRMS_SECONDARY1			9.745	A	Root mean squared value of the secondary current for output 1
138	IRIPPLE_CAP_OUTPUT1			7.679	A	Current ripple on the secondary waveform for output 1
139	NSECONDARY1			5		Number of turns for output 1
140	VREVERSE_RECTIFIER1			56.45	V	SR FET reverse voltage (not accounting parasitic voltage ring) for output 1
141	SR FET1	Auto		AON6280		Secondary rectifier (Logic MOSFET) for output 1
142	VF_SR FET1			0.030	V	SR FET on-time drain voltage for output 1
143	VBREAKDOWN_SR FET1			80	V	SR FET breakdown voltage for output 1
144	RDSON_SR FET1			5.0	mΩ	SR FET on-time drain resistance at 25degC and VGS=4.4V for output 1
172	PO_TOTAL			72.00	W	Total power of all outputs
173	NEGATIVE OUTPUT	N/A		N/A		If negative output exists, enter the output number; e.g. If VO2 is negative output, select 2

9 Performance Data

All the performance data has been taken on the board unless otherwise specifically mentioned.

9.1 Full-load Efficiency vs. Line

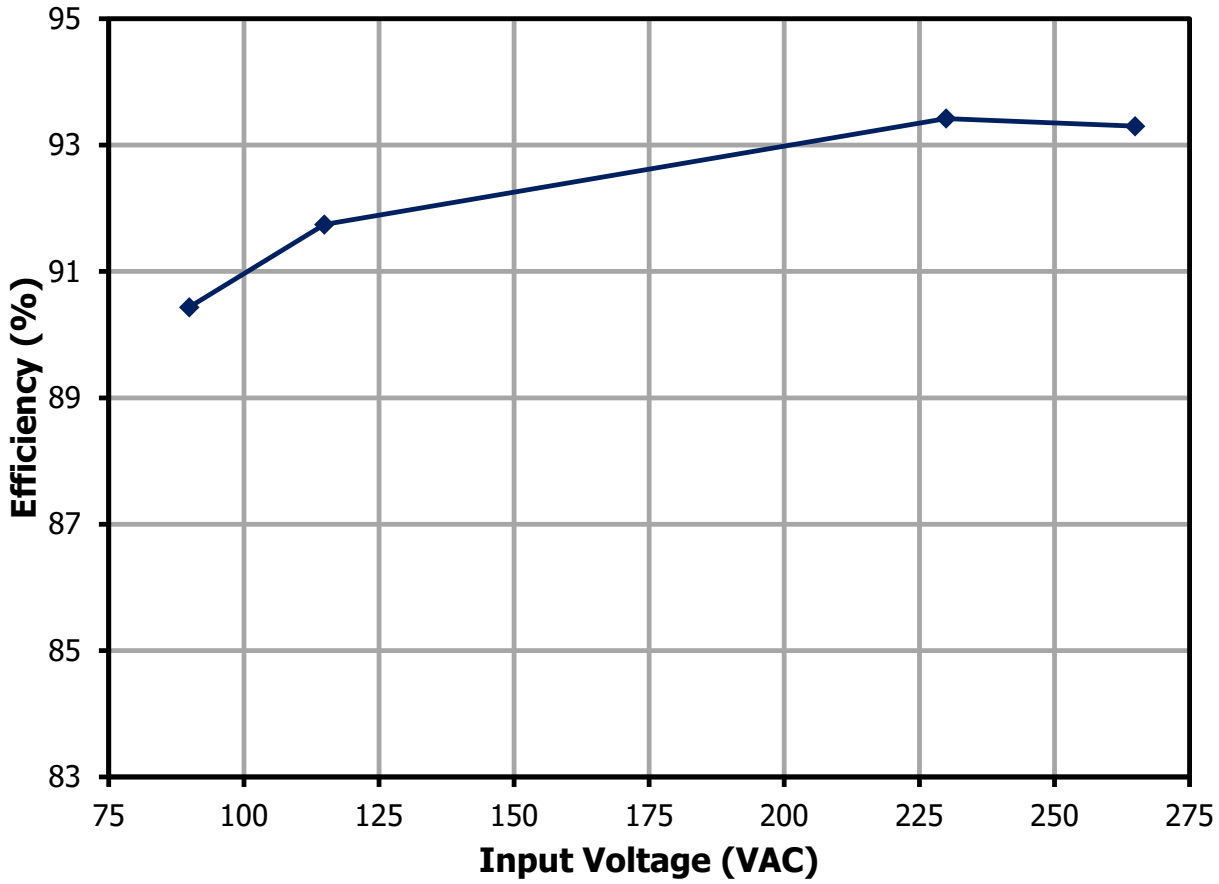


Figure 7 – Full-load Efficiency vs. Line, Room Ambient.

9.2 Efficiency vs. Load

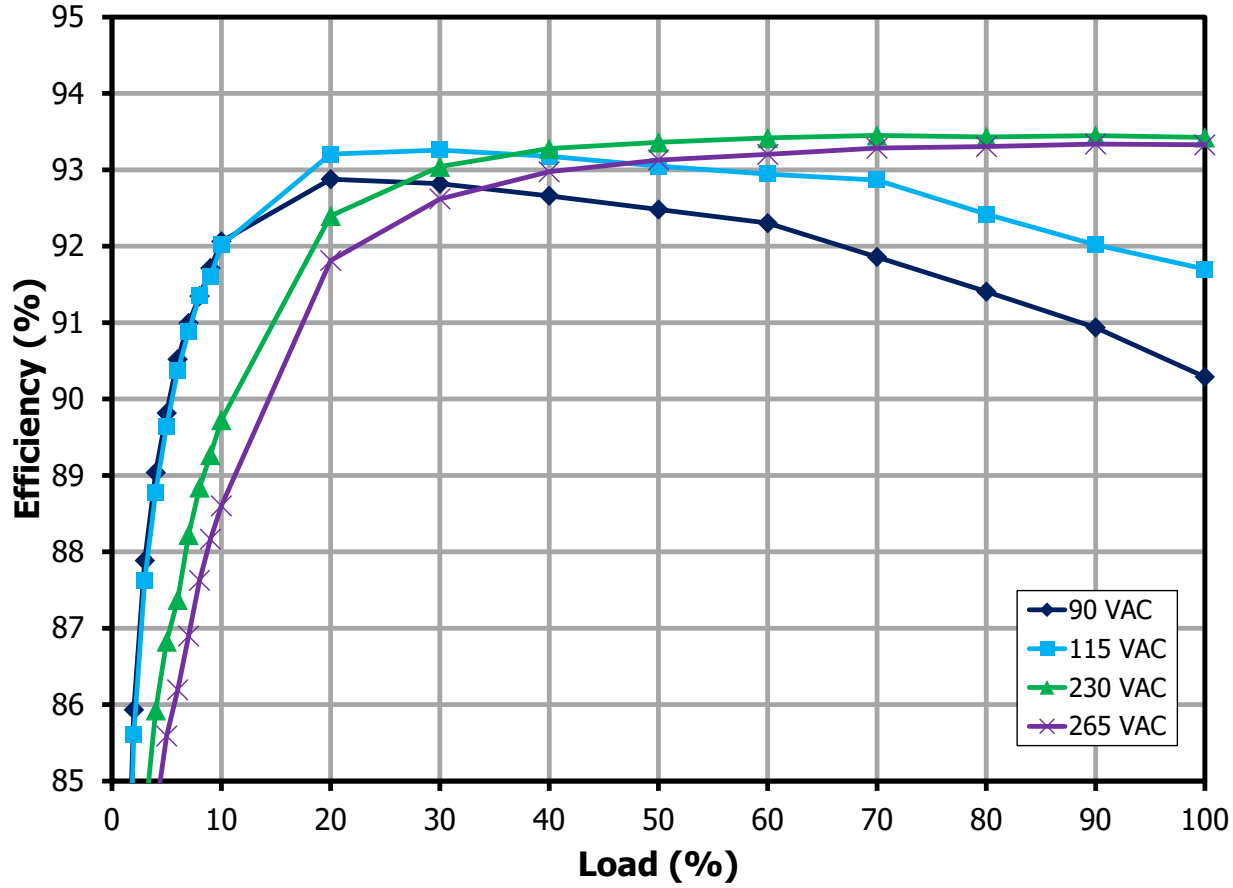


Figure 8 – Efficiency vs. Load, Room Ambient.

9.3 Average Efficiency

	Test	Average	Average	10% Load
Output Voltage (V)	Power [W]	DOE6 Limit (%)	CoC v5 Tier 2 (%)	CoC v5 Tier 2 (%)
12	72	88.00	89.00	79.00

9.4 Average and 10% Efficiency at 90 VAC Input

% Load	POUT (W)	Efficiency (%)	Average Efficiency (%)
100	70.96	90.59	91.85
75	53.35	91.61	
50	35.69	92.43	
25	17.91	92.77	
10	7.17	92.00	

9.5 Average and 10% Efficiency at 115 VAC Input

% Load	POUT (W)	Efficiency (%)	Average Efficiency (%)
100	71.00	91.88	92.65
75	53.57	92.45	
50	35.71	93.05	
25	17.91	93.24	
10	7.16	92.07	

9.6 Average and 10% Efficiency at 230 VAC Input

% Load	POUT (W)	Efficiency (%)	Average Efficiency (%)
100	71.35	92.89	93.23
75	53.51	93.54	
50	35.77	93.48	
25	17.92	92.99	
10	7.17	90.24	

9.7 Average and 10% Efficiency at 265 VAC Input

% Load	POUT (W)	Efficiency (%)	Average Efficiency (%)
100	71.34	92.88	93.03
75	53.51	93.38	
50	35.77	93.28	
25	17.92	92.56	
10	7.17	89.23	

9.8 No-Load Input Power

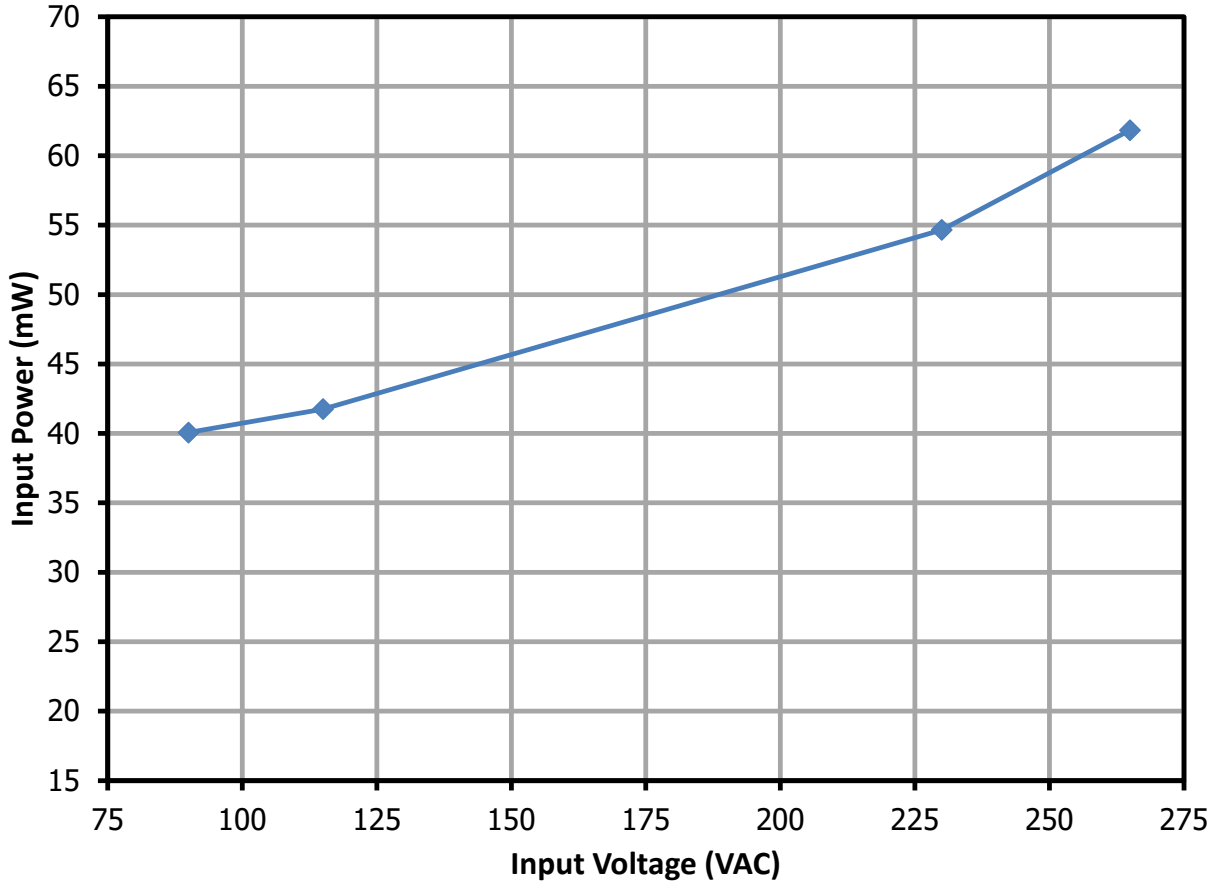


Figure 9 – No-Load Input Power vs. Input Line Voltage, Room Temperature.

9.9 Line Regulation

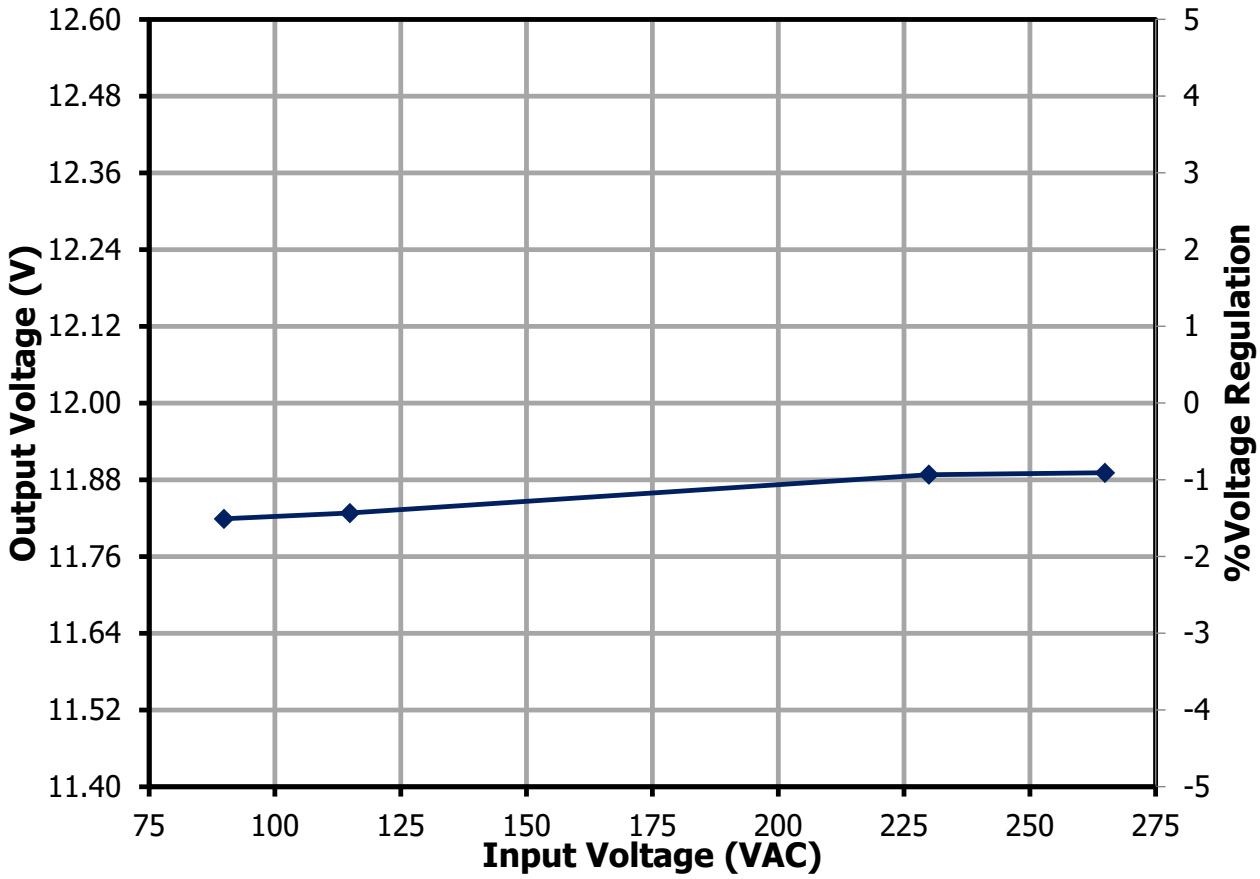


Figure 10 – Line Regulation.

9.10 Load Regulation

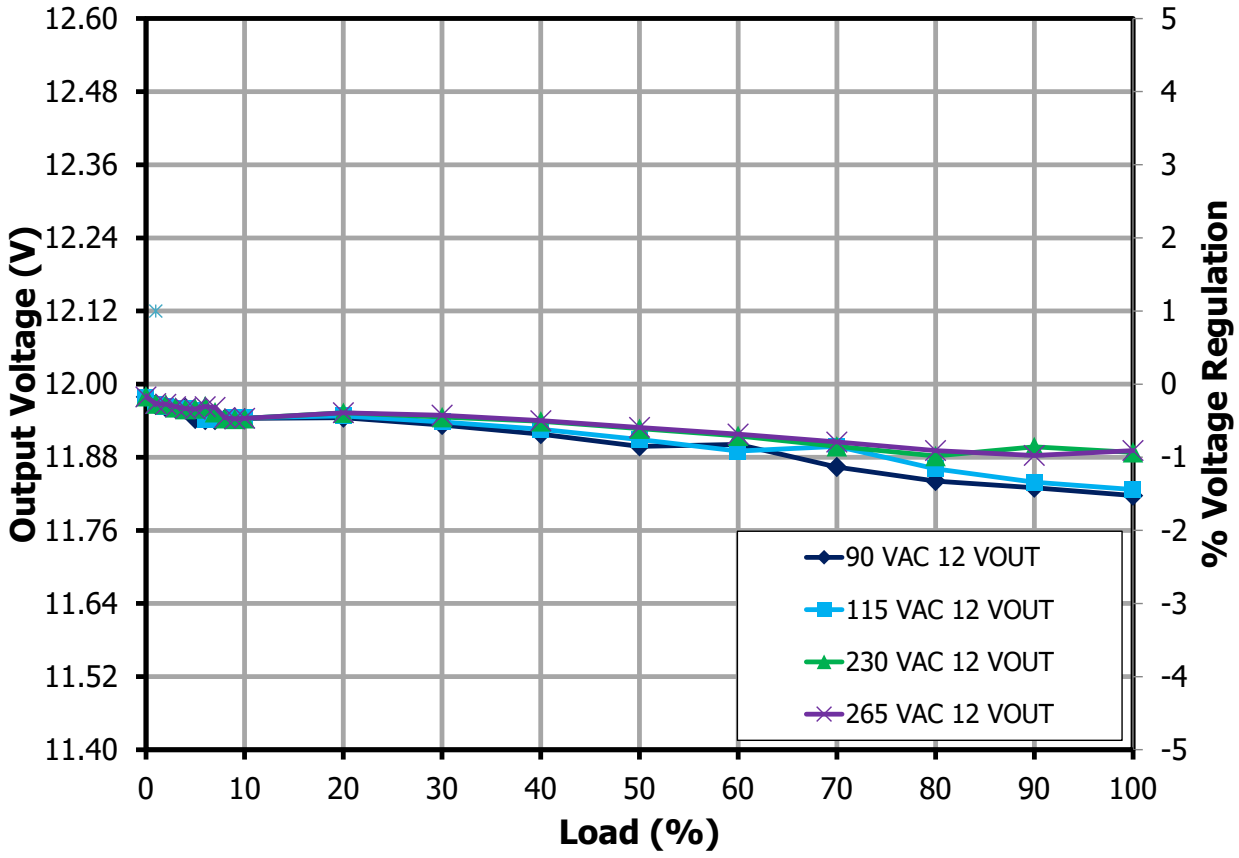


Figure 11 – Load Regulation.

10 Thermal Performance

Thermal performance is measured inside a thermal chamber at ambient temp of 25 ºC and 40 ºC using a data logger with 1s interval for 1 hour.

10.1 90 VAC, 72 W at 25 ºC Ambient

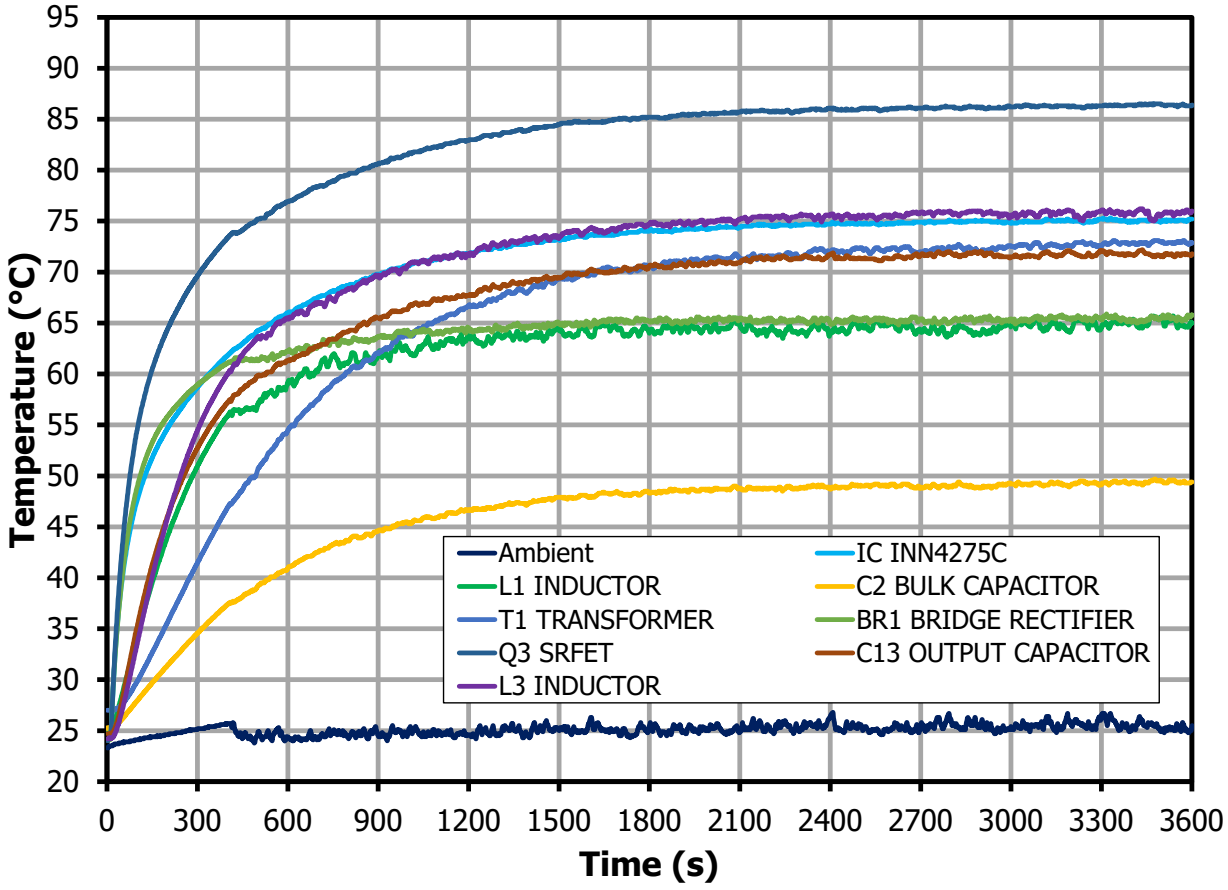


Figure 12 – Thermal Performance at 90 VAC Input.

Component	Max Temperature (ºC)
INN4275C (U1)	75
INDUCTOR (L1)	64.7
BULK CAPACITOR (C2)	49.4
TRANSFORMER (T1)	73
Bridge Rectifier (BR1)	65.4
SR FET (Q3)	86.4
OUTPUT CAPACITOR C13)	72.8
INDUCTOR (L3)	75.8
Ambient	25.2

10.2 265 VAC, 72 W at 25 ºC Ambient

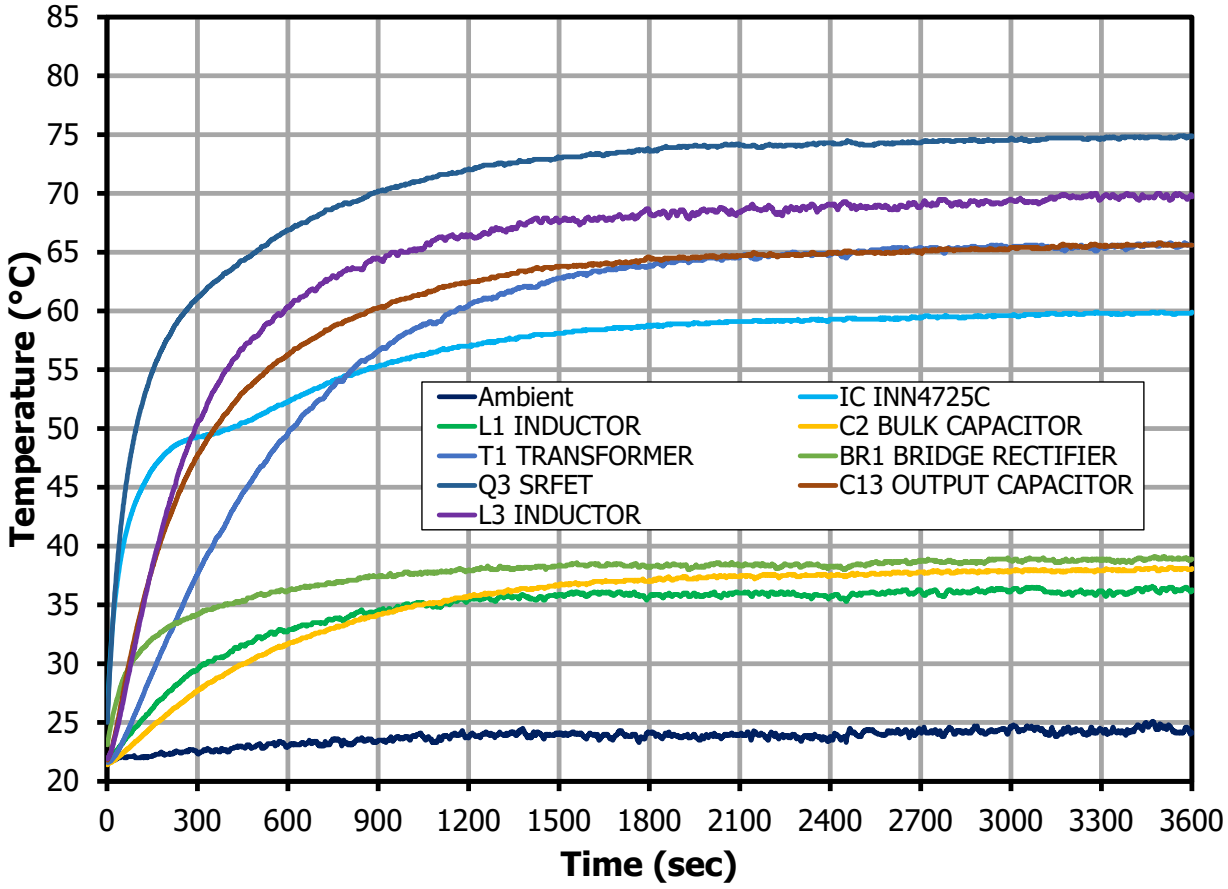


Figure 13 – Thermal Performance at 265 VAC Input.

Component	Max Temperature (ºC)
INN4275C (U1)	59.9
INDUCTOR (L1)	36.2
BULK CAPACITOR (C2)	38.1
TRANSFORMER (T1)	65.6
Bridge Rectifier (BR1)	38.9
SR FET (Q3)	74.8
OUTPUT CAPACITOR C13)	65.6
INDUCTOR (L3)	69.8
Ambient	24.1

10.3 90 VAC, 72 W at 40 ºC Ambient

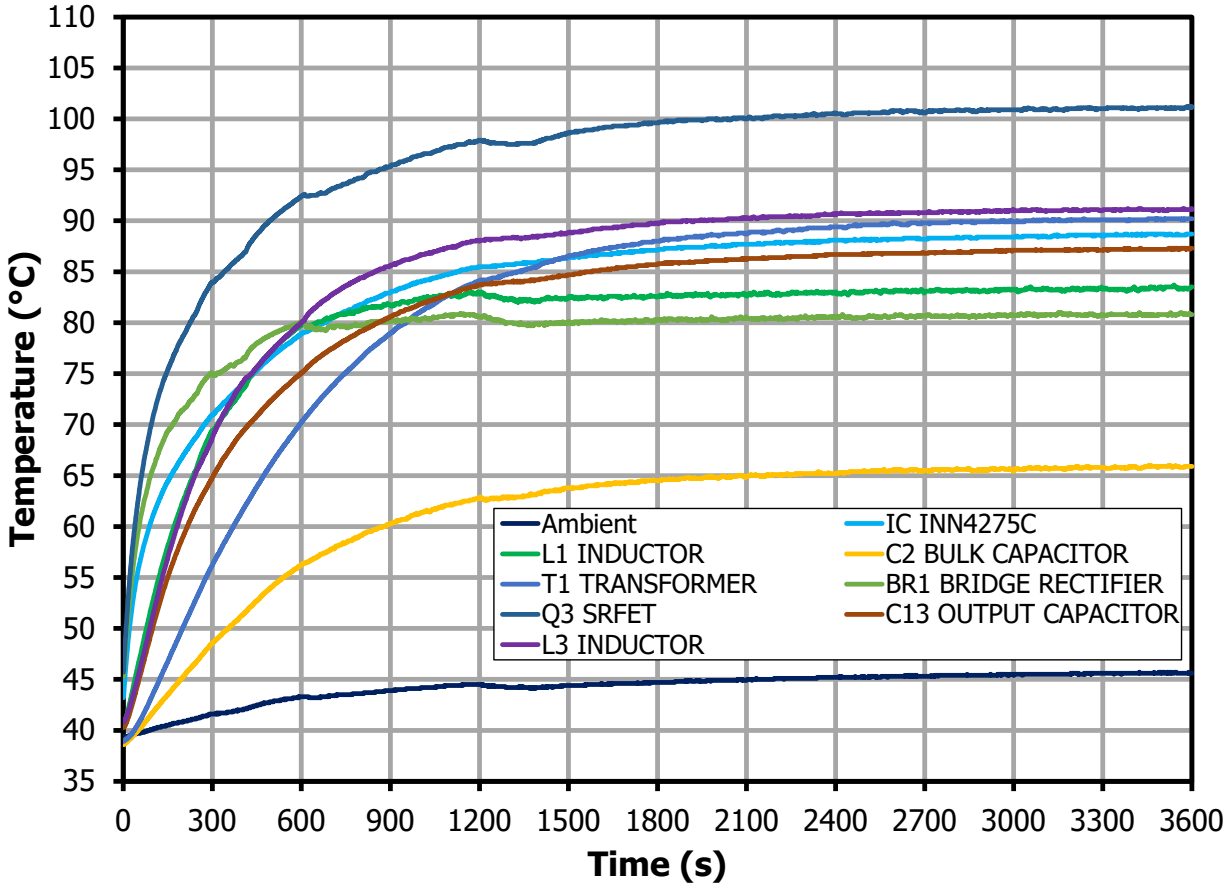


Figure 14 – Thermal Performance at 90 VAC Input.

Component	Max Temperature (ºC)
INN4275C (U1)	88.7
INDUCTOR (L1)	83.5
BULK CAPACITOR (C2)	65.9
TRANSFORMER (T1)	90.2
Bridge Rectifier (BR1)	80.8
SR FET (Q3)	101.2
OUTPUT CAPACITOR C13)	87.3
INDUCTOR (L3)	91.2
Ambient	45.6

10.4 265 VAC Input, 72 W at 40 ºC Ambient

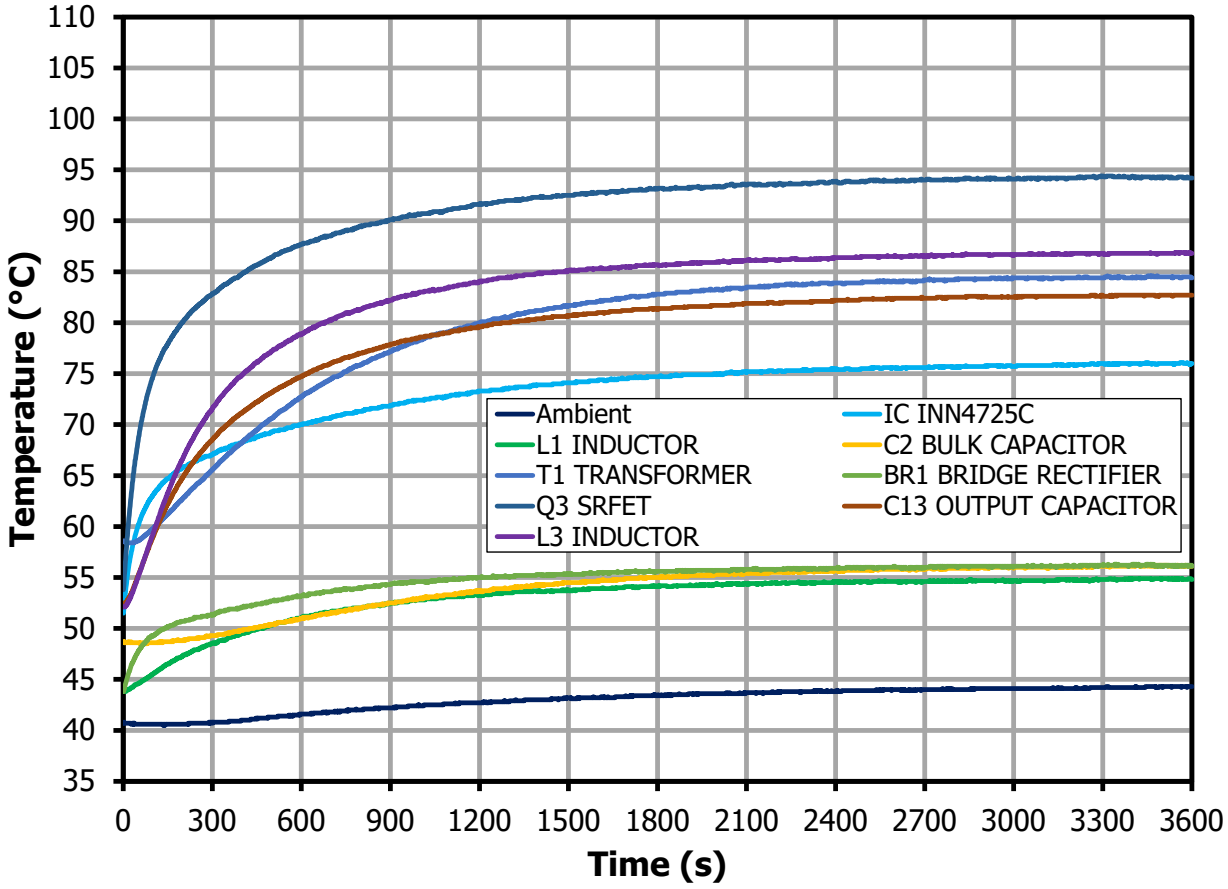


Figure 15 – Thermal Performance at 265 VAC Input.

Component	Max Temperature (ºC)
INN4275C (U1)	76
INDUCTOR (L1)	54.8
BULK CAPACITOR (C2)	56.1
TRANSFORMER (T1)	84.4
Bridge Rectifier (BR1)	56.1
SR FET (Q3)	94.2
OUTPUT CAPACITOR C13)	82.7
INDUCTOR (L3)	86.8
Ambient	44.3

11 Waveforms

11.1 Output Voltage Start-up Waveforms at Room Temperature

11.1.1 CC Load

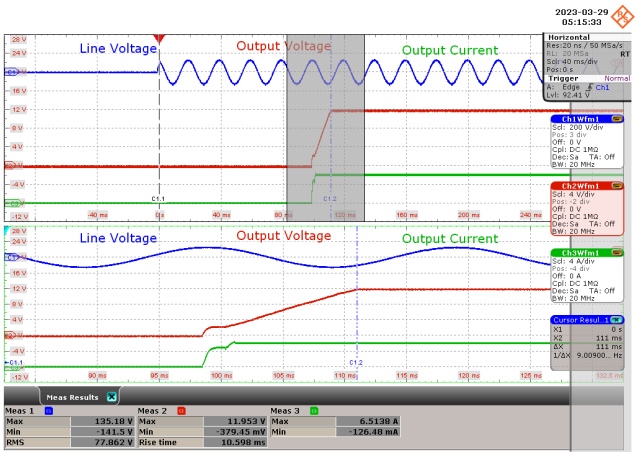


Figure 16 – 90 VAC 60 Hz, Io = 6 A (Full-Load, CC)
CH1: Input Voltage: 200 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 11.953 V.
Output Voltage, Rise Time = 10.598 ms.
Start-up Time = 111 ms.

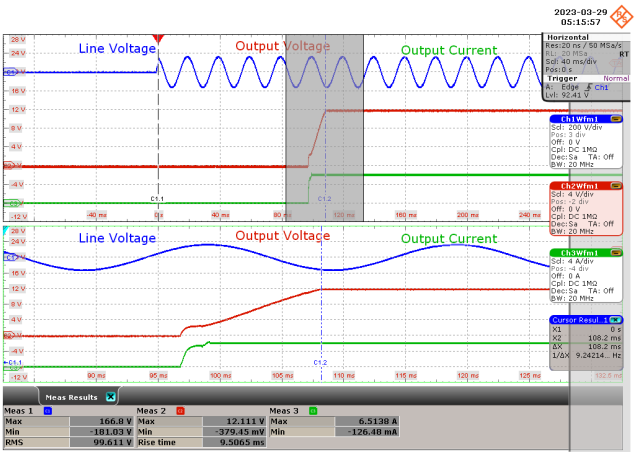


Figure 17 – 115 VAC 60 Hz, Io = 6 A (Full-Load, CC).
CH1: Input Voltage: 200 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max = 12.111 V.
Output Voltage, Rise Time = 9.5065 ms.
Start-up Time = 108.2 ms.

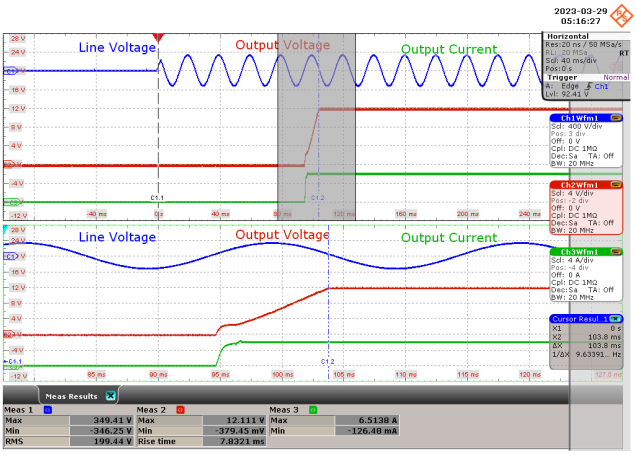


Figure 18 – 230 VAC 60 Hz, Io = 6 A (Full-Load, CC).
CH1: Input Voltage: 400 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 12.111 V.
Output Voltage, Rise Time = 7.8321 ms.
Start-up Time = 103.8 ms.

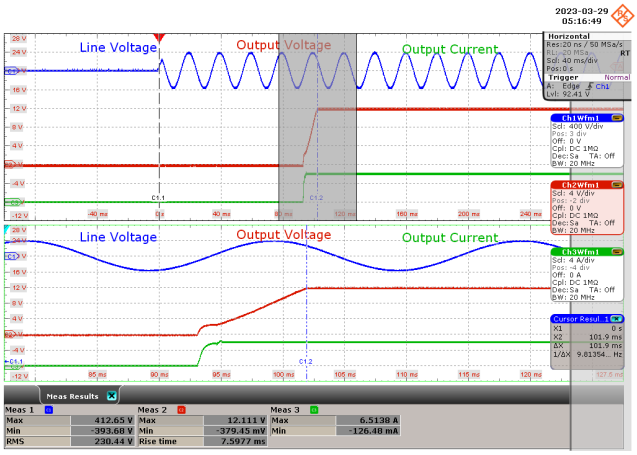


Figure 19 – 265 VAC 60 Hz, Io = 6 A (Full-Load, CC).
CH1: Input Voltage: 400 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 12.111 V.
Output Voltage, Rise Time = 7.5977 ms.
Start-up Time = 101.9 ms.

11.1.2 CR Load

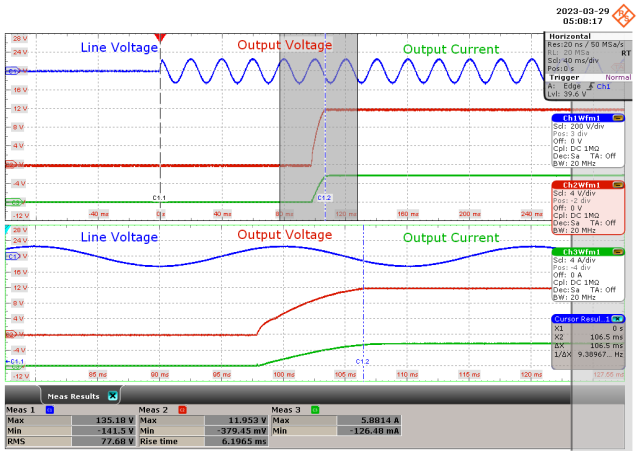


Figure 20 – 90 VAC 60 Hz, Ro= 2 Ω (Full-Load, CR).
CH1: Input Voltage: 200 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 11.953 V.
Output Voltage, Rise Time = 6.1965 ms.
Start-up Time = 106.5 ms.

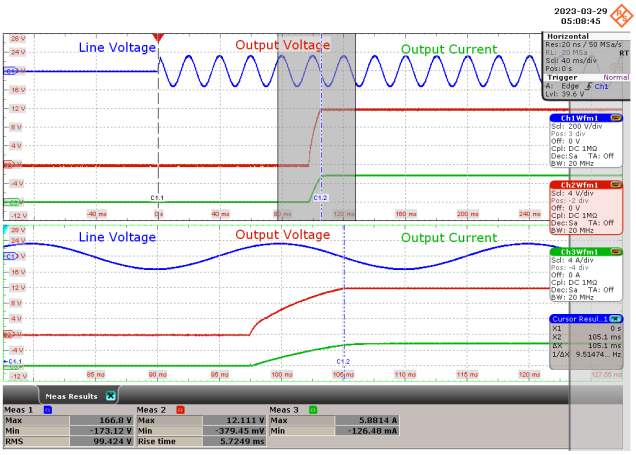


Figure 21 – 115 VAC 60 Hz, Ro= 2 Ω (Full-Load, CR).
CH1: Input Voltage: 200 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 12.111 V.
Output Voltage, Rise Time = 5.7249 ms.
Start-up Time = 105.1 ms.

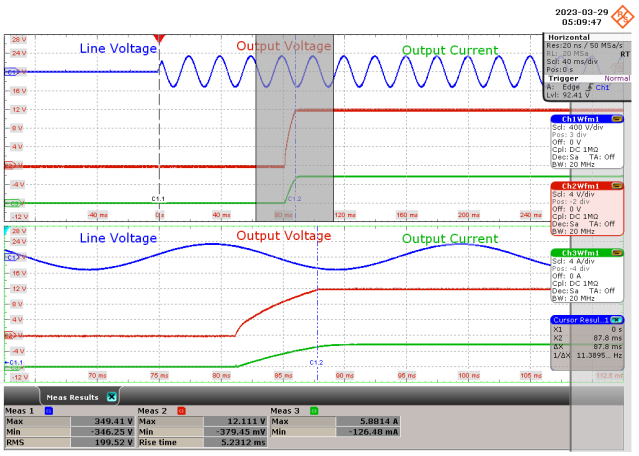


Figure 22 – 230 VAC 60 Hz, Ro= 2 Ω (Full-Load, CR).
CH1: Input Voltage: 400 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 12.111 V.
Output Voltage, Rise Time = 5.2312 ms.
Start-up Time = 87.8 ms.

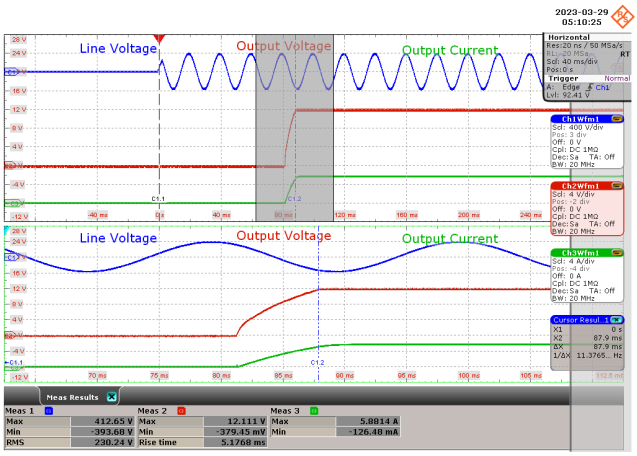


Figure 23 – 265 VAC 60 Hz, Ro= 2 Ω (Full-Load, CR).
CH1: Input Voltage: 400 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 12.111 V.
Output Voltage, Rise Time = 5.1768 ms.
Start-up Time = 87.9 ms.

11.1.3 No-Load

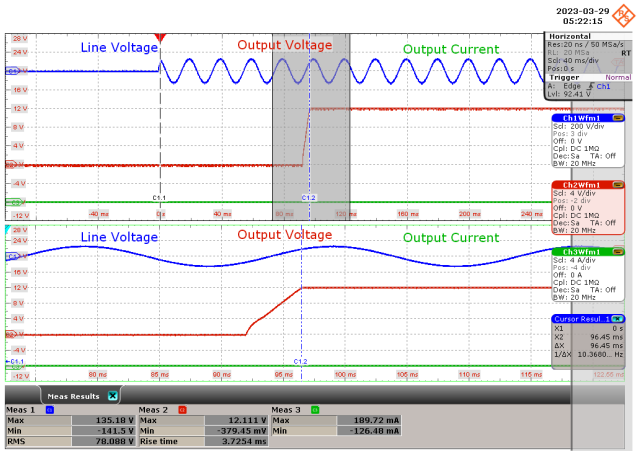


Figure 24 – 90 VAC 60 Hz, Io = 0 A (No- Load).
CH1: Input Voltage: 200 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 12.111 V.
Output Voltage, Rise Time = 3.7254 ms.
Start-up Time = 96.45 ms.

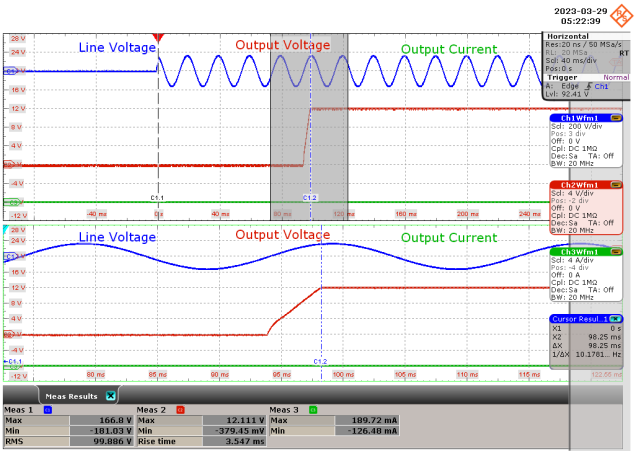


Figure 25 – 115 VAC 60 Hz, Io = 0 A (No- Load).
CH1: Input Voltage: 200 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 12.111 V.
Output Voltage, Rise Time = 3.547 ms.
Start-up Time = 98.25 ms.

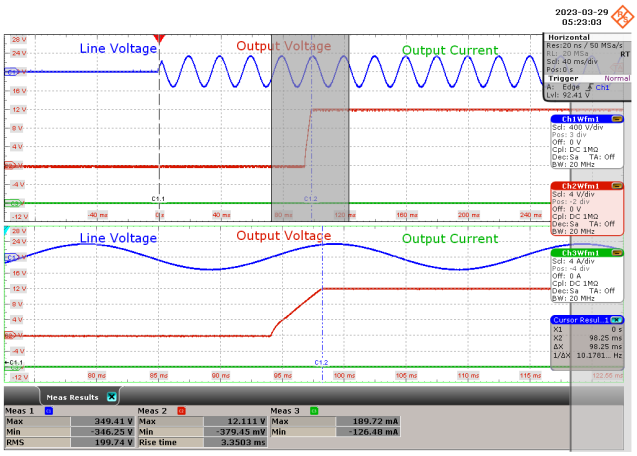


Figure 26 – 230 VAC 60 Hz, Io = 0 A (No- Load).
CH1: Input Voltage: 400 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 12.111 V.
Output Voltage, Rise Time = 3.3503 ms.
Start-up Time = 98.25 ms.

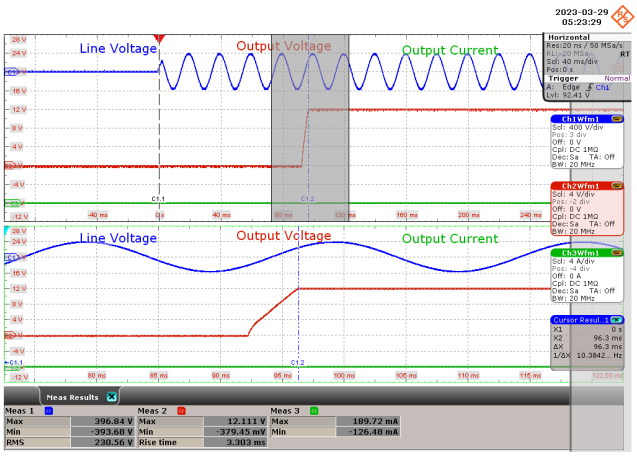


Figure 27 – 265 VAC 60 Hz, Io = 0 A (No- Load).
CH1: Input Voltage: 400 V / div., 40 ms / div.
CH2: Output Voltage: 4 V / div., 40 ms / div.
CH3: Output Current: 4 A / div., 40 ms / div.
Zoom: 5 ms / div.
Output Voltage, Max. = 12.111 V.
Output Voltage, Rise Time = 3.303 ms.
Start-up Time = 96.3 ms.

11.2 Load Transient Response (On Board)

11.2.1 0 – 100 % Load Step

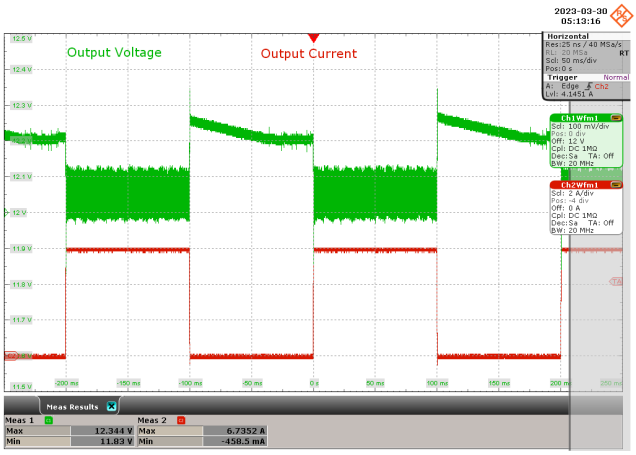


Figure 28 – 90 VAC 60 Hz. Io = 0 A – 6 A (0 - 100%) Load Step.
CH1: Output Voltage: 100 mV / div., 50 ms / div.
CH2: Output Current: 2 A / div., 50 ms / div.
$V_{O1,MAX}$: 12.344 V.
$V_{O1,MIN}$: 11.83 V.

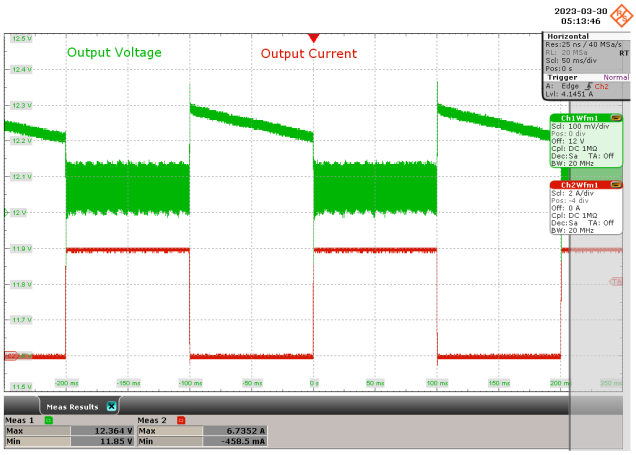


Figure 29 – 115 VAC 60 Hz. Io = 0 A – 6 A (0 - 100%) Load Step.
CH1: Output Voltage: 100 mV / div., 50 ms / div.
CH2: Output Current: 2 A / div., 50 ms / div.
$V_{O1,MAX}$: 12.364 V.
$V_{O1,MIN}$: 11.85 V.

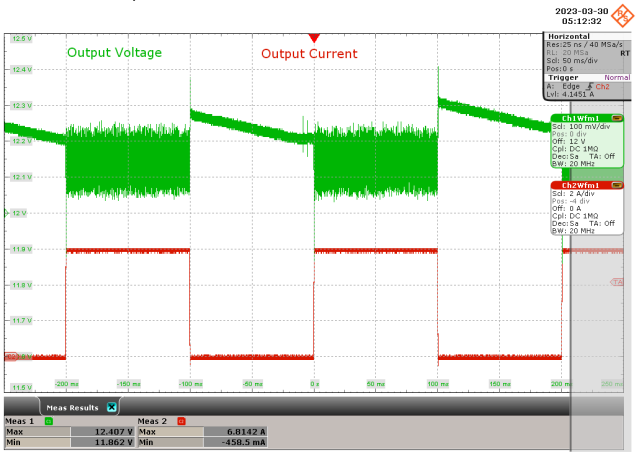


Figure 30 – 230 VAC 50 Hz. Io = 0 A – 6 A (0 - 100%) Load Step.
CH1: Output Voltage: 100 mV / div., 50 ms / div.
CH2: Output Current: 2 A / div., 50 ms / div.
$V_{O1,MAX}$: 12.407 V.
$V_{O1,MIN}$: 11.862 V.

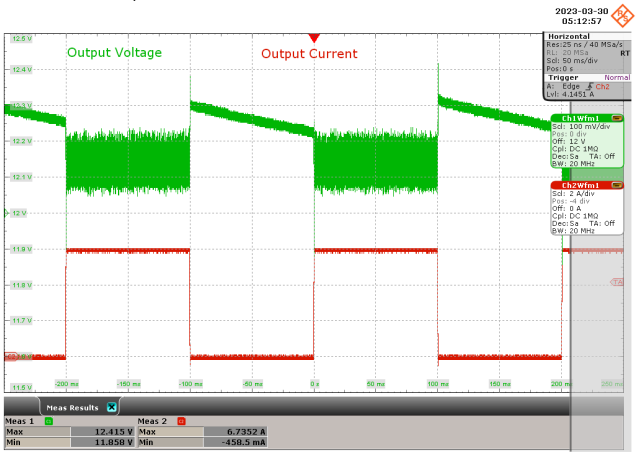


Figure 31 – 265 VAC 50 Hz. Io = 0 A – 6 A (0 - 100%) Load Step.
CH1: Output Voltage: 100 mV / div., 50 ms / div.
CH2: Output Current: 2 A / div., 50 ms / div.
$V_{O1,MAX}$: 12.415 V.
$V_{O1,MIN}$: 11.858 V.

11.2.2 50 % – 100 % Load Step

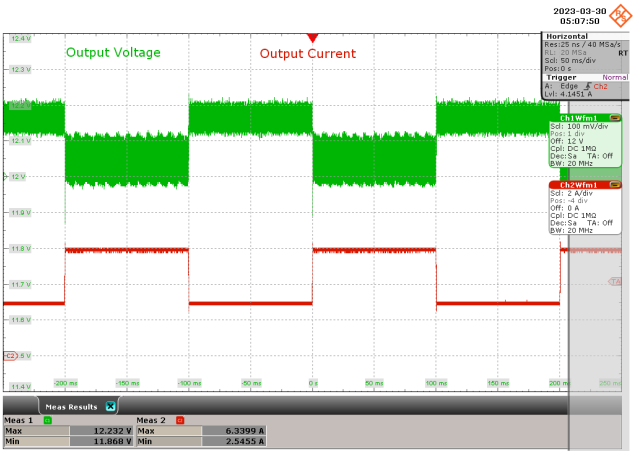


Figure 32 – 90 VAC 60 Hz. Io = 3 A – 6 A (50 - 100%) Load Step.
CH1: Output Voltage: 100 mV / div., 50 ms / div.
CH2: Output Current: 2 A / div., 50 ms / div.
$V_{O1,MAX}$: 12.232 V.
$V_{O1,MIN}$: 11.868 V.

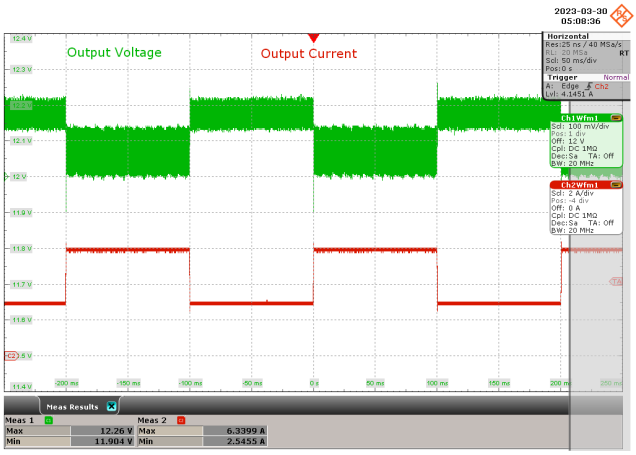


Figure 33 – 115 VAC 60 Hz. Io = 3 A – 6 A (50 -100%) Load Step.
CH1: Output Voltage: 100 mV / div., 50 ms / div.
CH2: Output Current: 2 A / div., 50 ms / div.
$V_{O1,MAX}$: 12.26 V.
$V_{O1,MIN}$: 11.904 V.

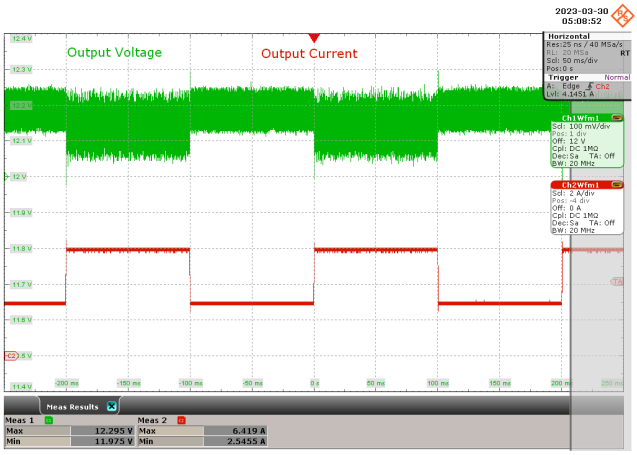


Figure 34 – 230 VAC 50 Hz. Io = 3 A – 6 A (50 -100%) Load Step.
CH1: Output Voltage: 100 mV / div., 50 ms / div.
CH2: Output Current: 2 A / div., 50 ms / div.
$V_{O1,MAX}$: 12.295 V.
$V_{O1,MIN}$: 11.975 V.

Figure 35 – 265 VAC 60 Hz. Io = 3 A – 6 A (50 -100%) Load Step.
CH1: Output Voltage: 100 mV / div., 50 ms / div.
CH2: Output Current: 2 A / div., 50 ms / div.
$V_{O1,MAX}$: 12.315 V.
$V_{O1,MIN}$: 11.975 V.

11.3 Switching Waveforms

11.3.1 Drain Voltage and Current at Start-up Operation

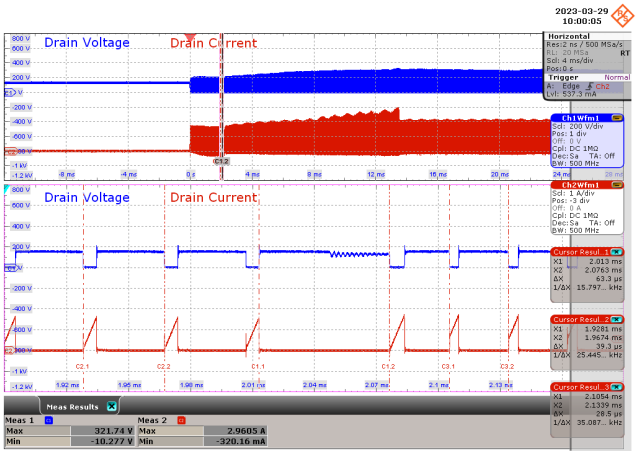


Figure 36 – 90 VAC, Io = 6 A (Full-Load).
CH 1: Drain Voltage: 200 V / div., 4 ms / div.
CH 2: Drain Current: 1 A / div., 4 ms / div.
Zoom: 30 µs / div.
Drain voltage, Max. = 321.74 V.
Drain current, Max. = 2.9605 A.

Figure 37 – 265 VAC, Io = 6 A (Full-Load).
CH 1: Drain Voltage: 200 V / div., 4 ms / div.
CH 2: Drain Current: 1 A / div., 4 ms / div.
Zoom: 30 µs / div.
Drain voltage, Max. = 535.18 V.
Drain current, Max. = 2.6047 A.

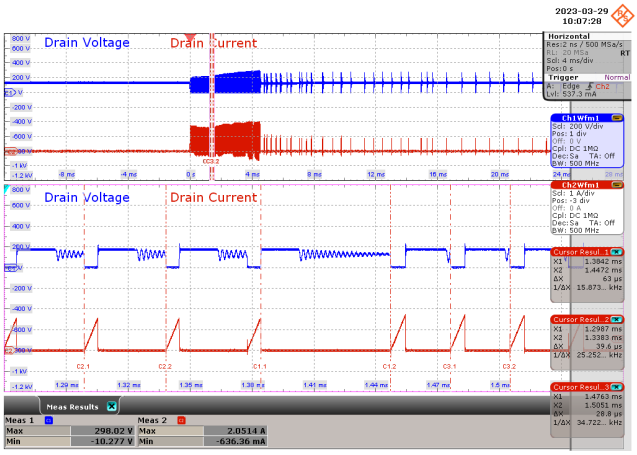


Figure 38 – 90 VAC, Io = 0 A (No-Load).
CH 1: Drain Voltage: 200 V / div., 4 ms / div.
CH 2: Drain Current: 1 A / div., 4 ms / div.
Zoom: 30 µs / div.
Drain Voltage, Max. = 298.02 V.
Drain Current, Max. = 2.0514 A.

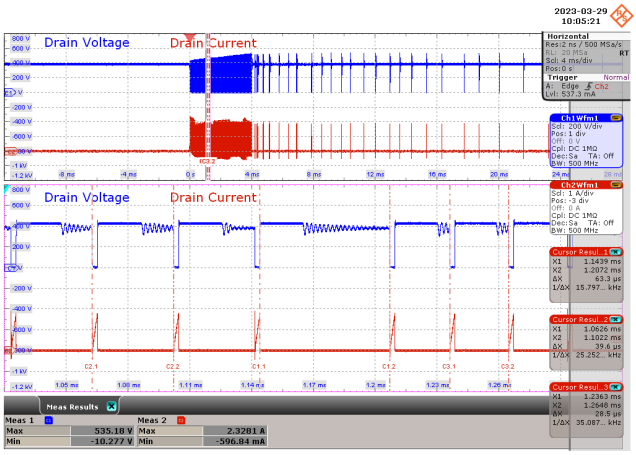


Figure 39 – 265 VAC, Io = 0 A (No-Load).
CH 1: Drain Voltage: 200 V / div., 4 ms / div.
CH 2: Drain Current: 1 A / div., 4 ms / div.
Zoom: 30 µs / div.
Drain Voltage, Max. = 535.18 V.
Drain Current, Max. = 2.3281 A.

11.3.2 Drain Voltage and Current at Normal Operation

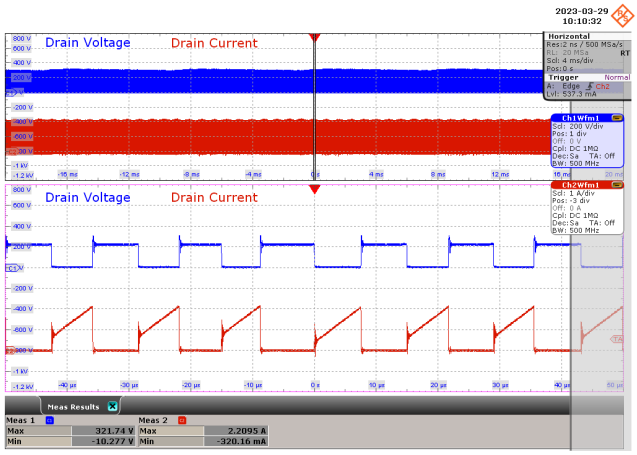


Figure 40 – 90 VAC, Io = 6 A (Full-Load).
CH 1: Drain Voltage: 200 V / div., 4 ms / div.
CH 2: Drain Current: 1 A / div., 4 ms / div.
Zoom: 10 µs / div.
Drain voltage, Max. = 321.74 V.
Drain current, Max. = 2.2095 A.

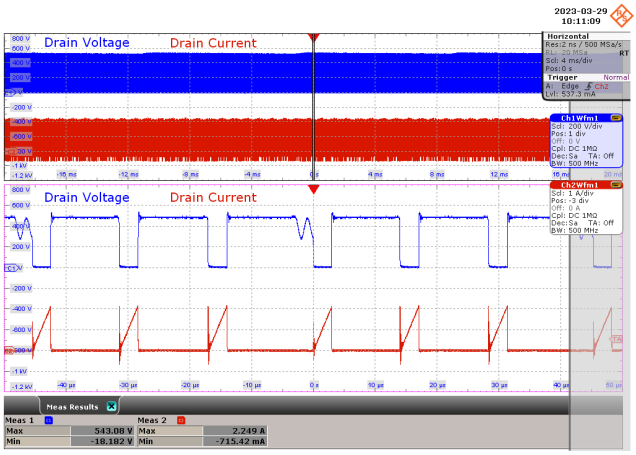


Figure 41 – 265 VAC, Io = 6 A (Full-Load).
CH 1: Drain Voltage: 200 V / div., 4 ms / div.
CH 2: Drain Current: 1 A / div., 4 ms / div.
Zoom: 10 µs / div.
Drain voltage, Max. = 543.08 V.
Drain current, Max. = 2.249 A.

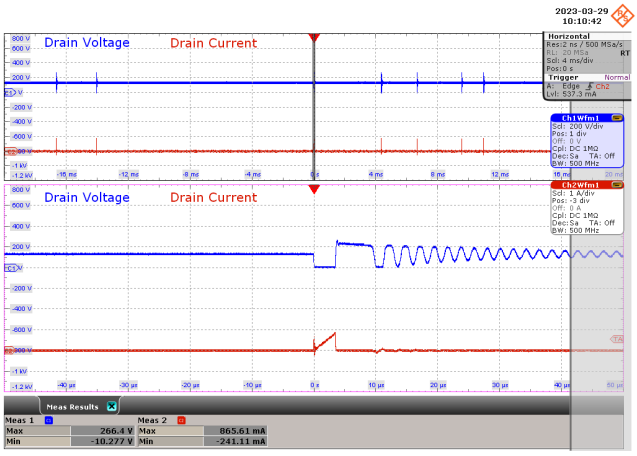


Figure 42 – 90 VAC, Io = 0 A (No-Load).
CH 1: Drain Voltage: 200 V / div., 4 ms / div.
CH 2: Drain Current: 1 A / div., 4 ms / div.
Zoom: 10 µs / div.
Drain voltage, Max. = 266.4 V.
Drain current, Max. = 865.61 mA.

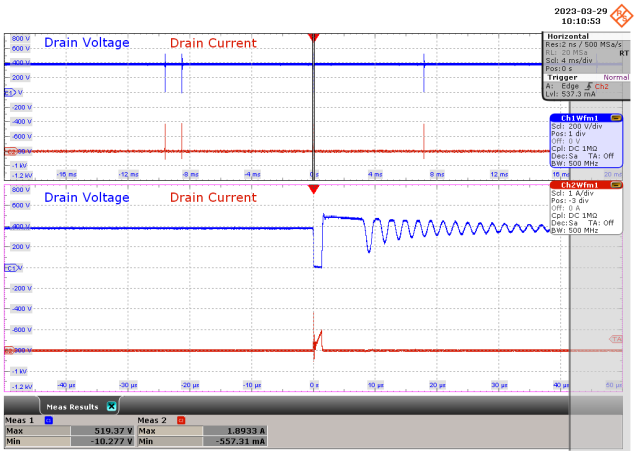


Figure 43 – 265 VAC, Io = 0 A (No-Load).
CH 1: Drain Voltage: 200 V / div., 4 ms / div.
CH 2: Drain Current: 1 A / div., 4 ms / div.
Zoom: 10 µs / div.
Drain voltage, Max. = 519.37 V.
Drain current, Max. = 1.8933 A.

11.3.3 SR FET Voltage and Current at Start-up

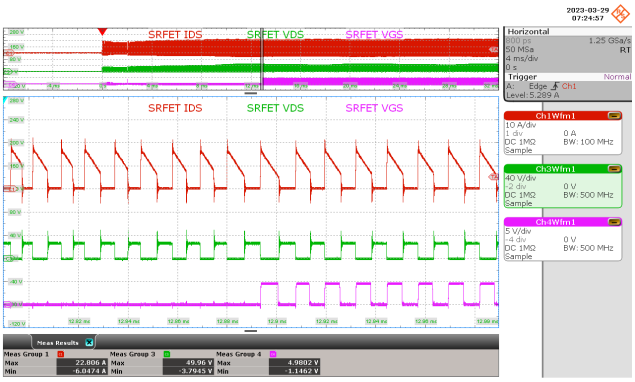


Figure 44 – 90 VAC, Io = 6 A (Full-Load).
CH 1: SR FET Drain Current: 10 A / div., 4 ms / div.
CH 2: SR FET Drain Voltage: 40 V / div., 4 ms / div.
CH 3: SR FET Gate Voltage: 5 V / div., 4 ms / div.
Zoom: 20 µs.
SR FET Drain Voltage, Max. = 49.96 V.
SR FET Drain Current, Max. = 22.806 A.

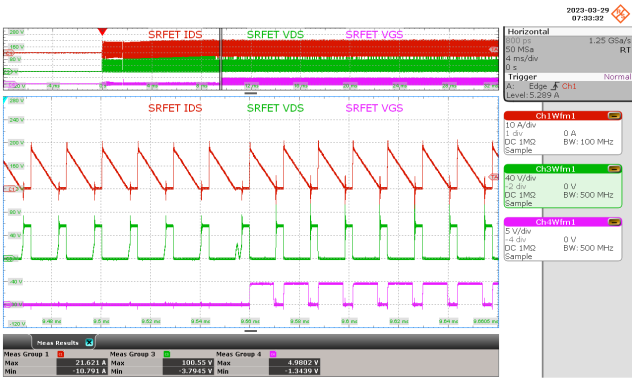


Figure 45 – 265 VAC, Io = 6 A (Full-Load).
CH 1: SR FET Drain Current: 10 A / div., 4 ms / div.
CH 2: SR FET Drain Voltage: 40 V / div., 4 ms / div.
CH 3: SR FET Gate Voltage: 5 V / div., 4 ms / div.
Zoom: 20 µs
SR FET Drain Voltage, Max. = 100.55 V.
SR FET Drain Current, Max. = 21.621 A.

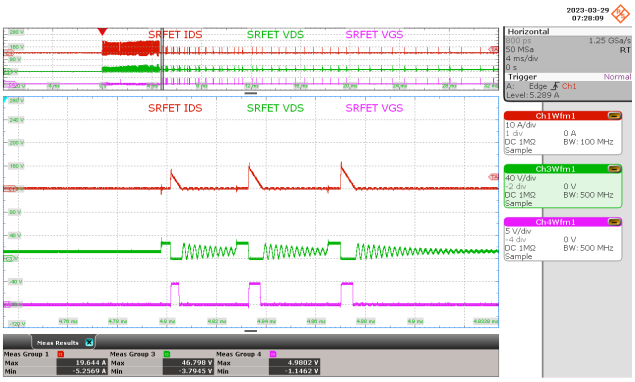


Figure 46 – 90 VAC, Io = 0 A (No-Load).
CH 1: SR FET Drain Current: 10 A / div., 4 ms / div.
CH 2: SR FET Drain Voltage: 40 V / div., 4 ms / div.
CH 3: SR FET Gate Voltage: 5 V / div., 4 ms / div.
Zoom: 20 µs.
SR FET Drain Voltage, Max. = 46.798 V.
SR FET Drain Current, Max. = 19.644 A

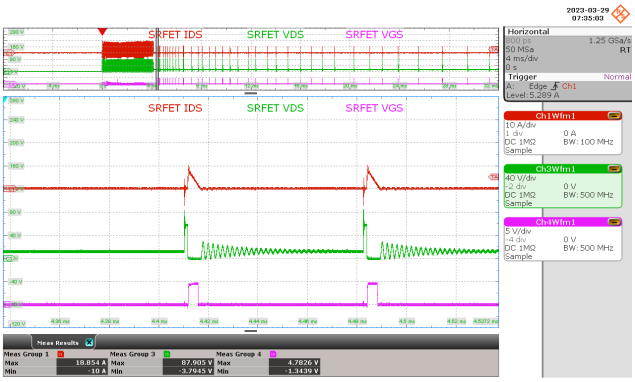


Figure 47 – 265 VAC, Io = 0 A (No-Load).
CH 1: SR FET Drain Current: 10 A / div., 4 ms / div.
CH 2: SR FET Drain Voltage: 40 V / div., 4 ms / div.
CH 3: SR FET Gate Voltage: 5 V / div., 4 ms / div.
Zoom: 20 µs.
SR FET Drain Voltage, Max. = 87.905 V.
SR FET Drain Current, Max. = 18.854 A.

11.3.4 SR FET Voltage and Current at Normal Operations

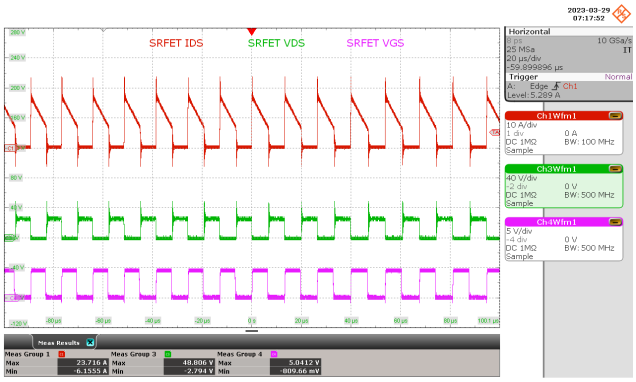


Figure 48 – 90 VAC, Io = 6 A (Full-Load).
CH 1: SR FET Drain Current: 10 A / div., 20 µs / div.
CH 2: SR FET Drain Voltage: 40 V / div., 20 µs / div.
CH 3: SR FET Gate Voltage: 5 V / div., 20 µs / div.
SR FET Drain Voltage, Max. = 48.806 V.
SR FET Drain Current, Max. = 23.716. A.

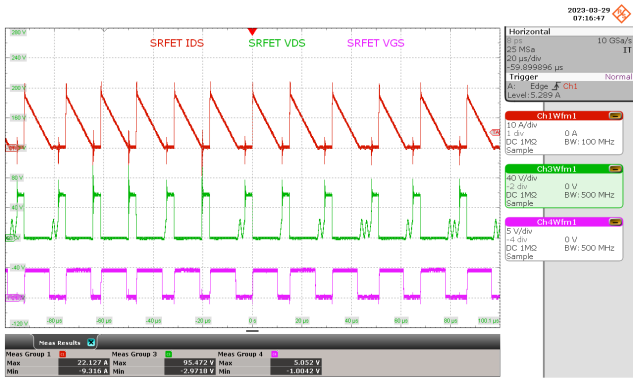


Figure 49 – 265 VAC, Io = 6 A (Full-Load).
CH 1: SR FET Drain Current: 10 A / div., 20 µs / div.
CH 2: SR FET Drain Voltage: 40 V / div., 20 µs / div.
CH 3: SR FET Gate Voltage: 5 V / div., 20 µs / div.
SR FET Drain Voltage, Max. = 95.472 V.
SR FET Drain Current, Max. = 22.127 A.

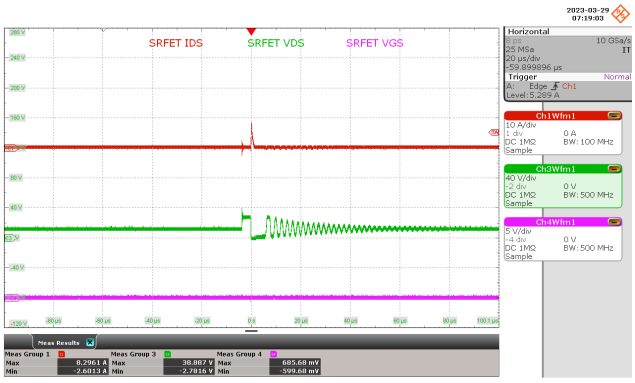


Figure 50 – 90 VAC, Io = 0 A (No-Load).
CH 1: SR FET Drain Current: 10 A / div., 4 ms / div.
CH 2: SR FET Drain Voltage: 40 V / div., 4 ms / div.
CH 3: SR FET Gate Voltage: 5 V / div., 4 ms / div.
SR FET Drain Voltage, Max. = 38.887 V.
SR FET Drain Current, Max. = 8.2961 A.

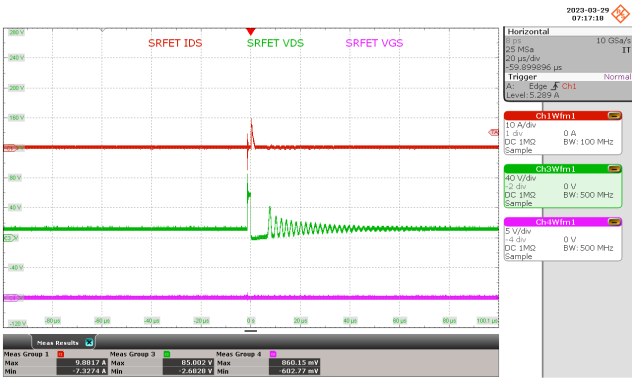


Figure 51 – 265 VAC, Io = 0 A (No-Load).
CH 1: SR FET Drain Current: 10 A / div., 4 ms / div.
CH 2: SR FET Drain Voltage: 40 V / div., 4 ms / div.
CH 3: SR FET Gate Voltage: 5 V / div., 4 ms / div.
SR FET Drain Voltage, Max. = 85.002 V.
SR FET Drain Current, Max. = 9.8817 A.

11.4 Output Ripple Measurements

11.4.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized in order 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).

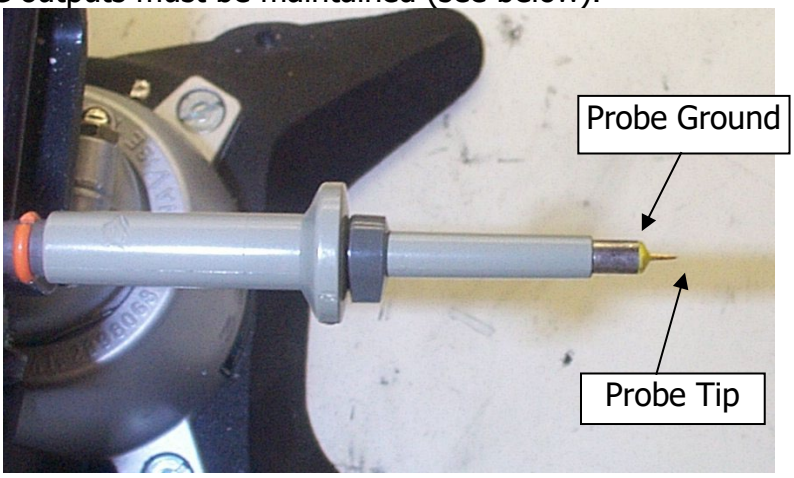


Figure 52 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

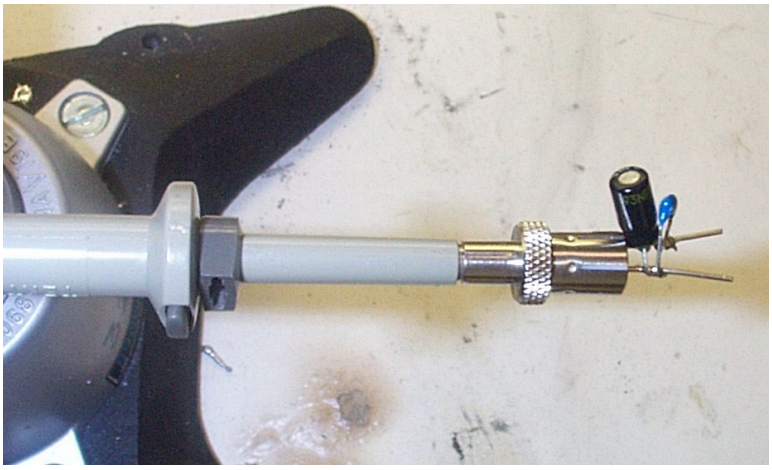


Figure 53 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

11.4.2 Ripple Waveforms (Measured on Board)

11.4.2.1 100% Load

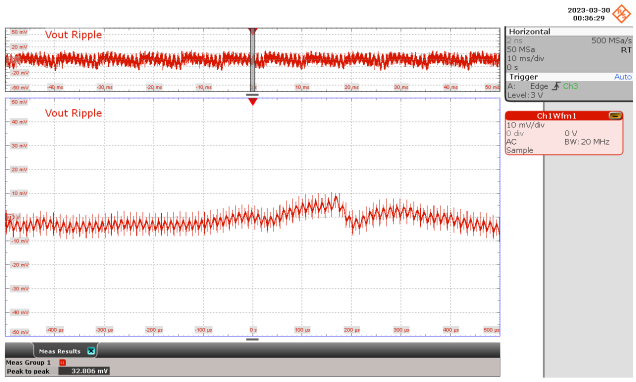


Figure 54 – Output Ripple. (PK-PK – 32.806 mV).
90 VAC Input, 100% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

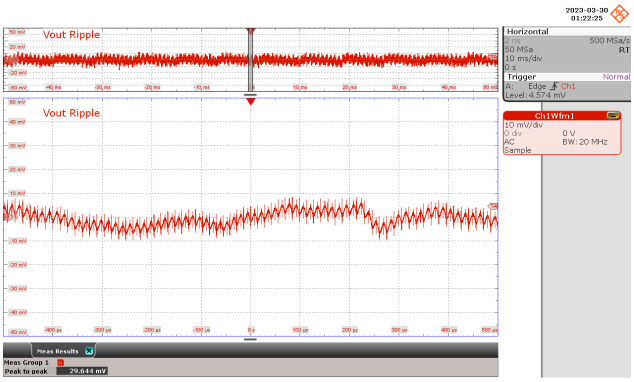


Figure 55 – Output Ripple. (PK-PK – 29.644 mV).
115 VAC Input, 100% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

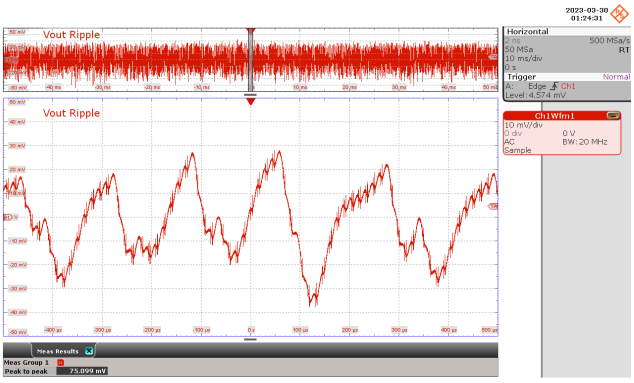


Figure 56 – Output Ripple.(PK-PK – 75.099 mV).
230 VAC Input, 100% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

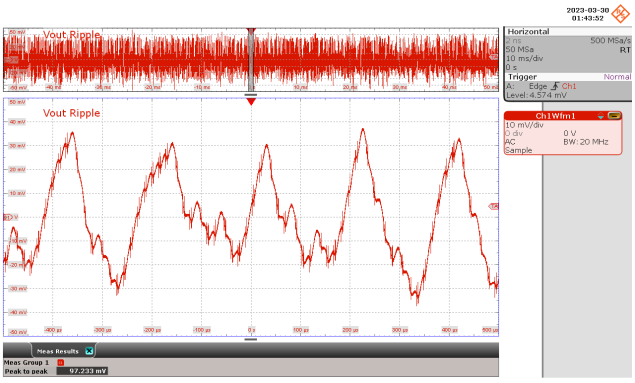


Figure 57 – Output Ripple. (PK-PK – 97.233 mV).
265 VAC Input, 100% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

11.4.2.2 75% Load

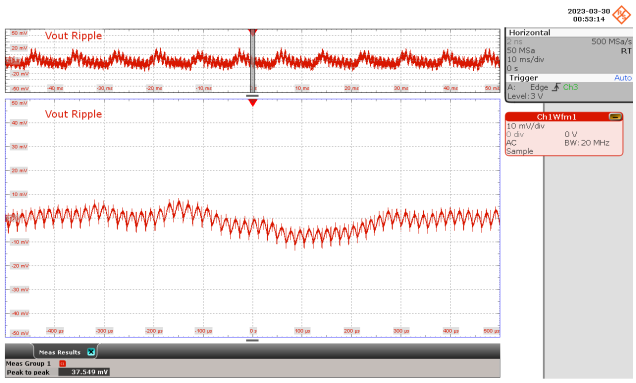


Figure 58 – Output Ripple. (PK-PK – 37.549 mV).
90 VAC Input, 75% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 µs.

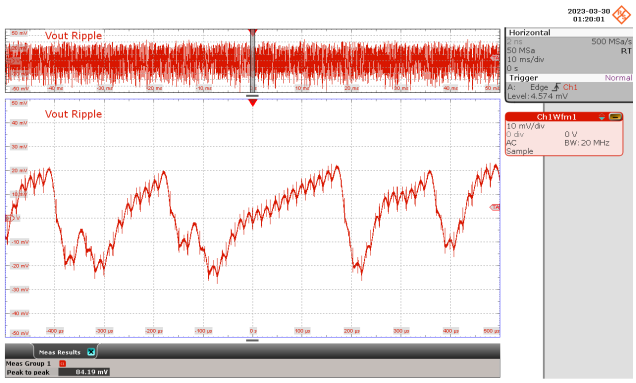


Figure 59 – Output Ripple. (PK-PK – 84.19 mV).
115 VAC Input, 75% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 µs.

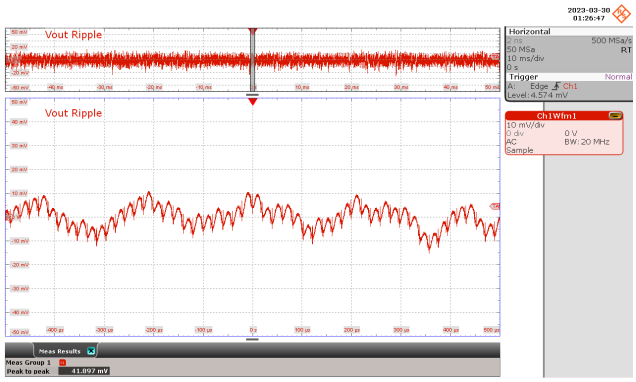


Figure 60 – Output Ripple. (PK-PK – 41.897 mV).
230 VAC Input, 75% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 µs.

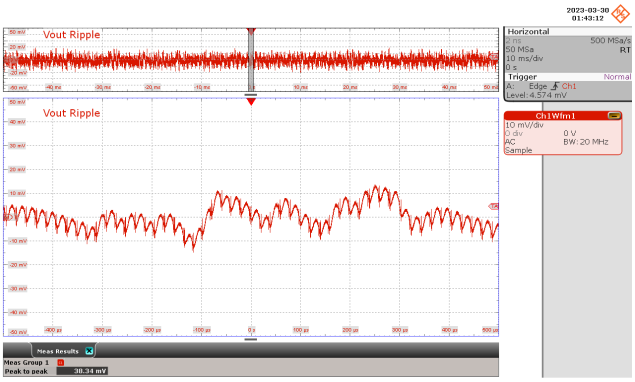


Figure 61 – Output Ripple. (PK-PK – 38.34 mV).
265 VAC Input, 75% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 µs.

11.4.2.3 50% Load

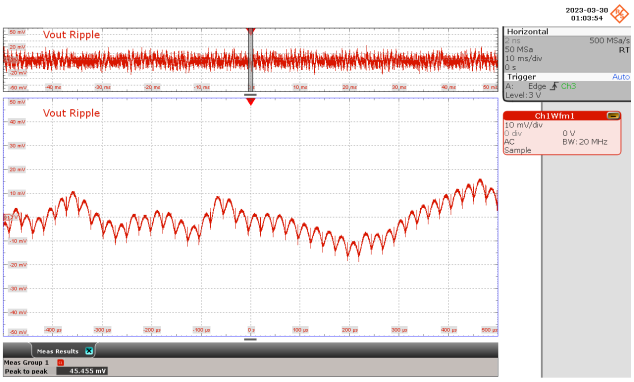


Figure 62 – Output Ripple. (PK-PK – 45.455 mV).
90 VAC Input, 50% Load.
VOUT, 10 mV / div., 10 ms / div.
Zoom: 100 µs.

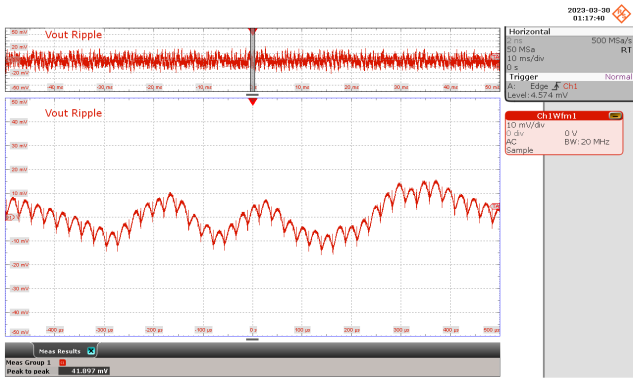


Figure 63 – Output Ripple. (PK-PK – 41.897 mV).
115 VAC Input, 50% Load.
VOUT, 10 mV / div., 10 ms / div.
Zoom: 100 µs.

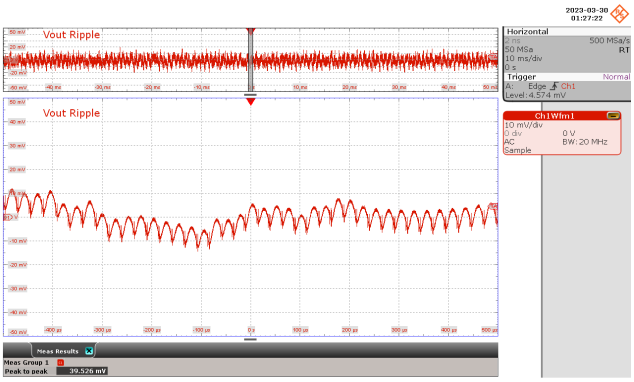


Figure 64 – Output Ripple. (PK-PK – 39.526 mV).
230 VAC Input, 50% Load.
VOUT, 10 mV / div., 10 ms / div.
Zoom: 100 µs.

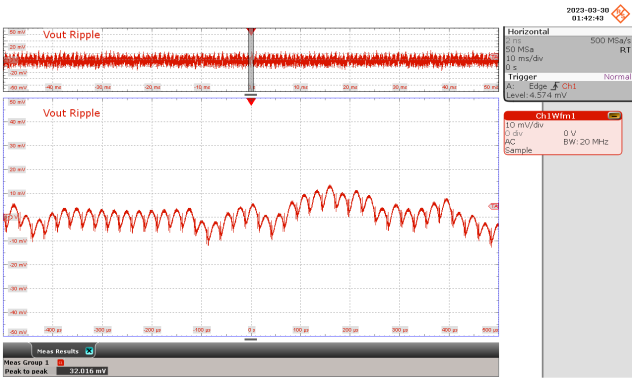


Figure 65 – Output Ripple. (PK-PK – 32.816 mV).
265 VAC Input, 50% Load.
VOUT, 10 mV / div., 10 ms / div.
Zoom: 100 µs.

11.4.2.4 25% Load

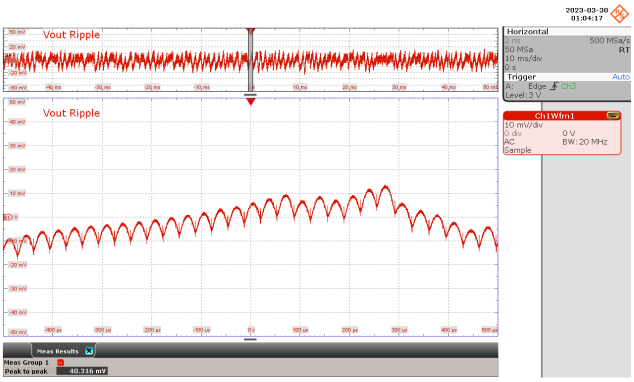


Figure 66 – Output Ripple. (PK-PK – 40.316 mV).
90 VAC Input, 25% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

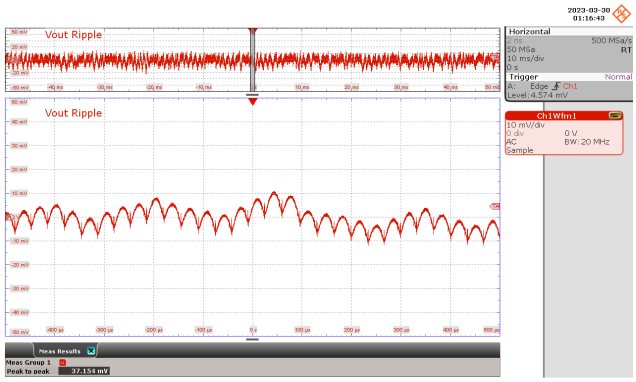


Figure 67 – Output Ripple. (PK-PK – 37.154 mV).
115 VAC Input, 25% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

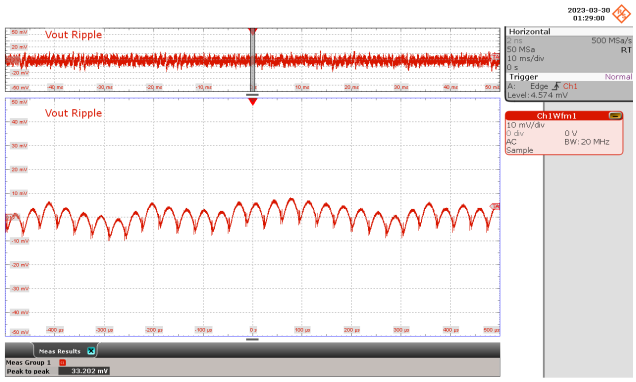


Figure 68 – Output Ripple. (PK-PK – 33.202 mV).
230 VAC Input, 25% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

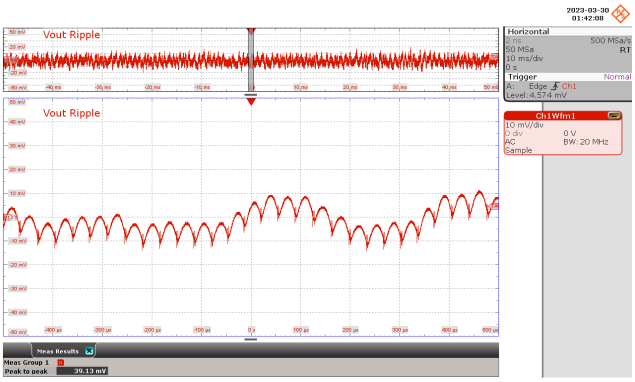


Figure 69 – Output Ripple. (PK-PK – 39.13 mV).
265 VAC Input, 25% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

11.4.2.5 10% Load

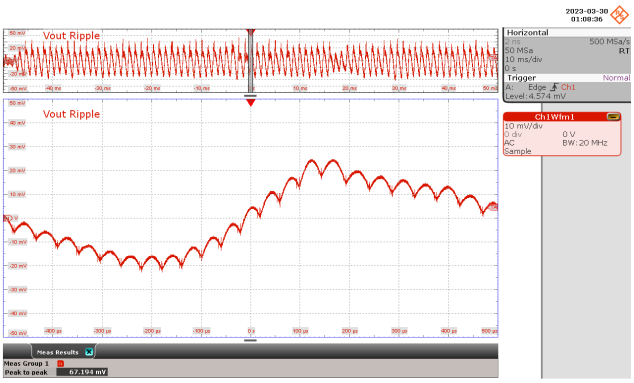


Figure 70 – Output Ripple. (PK-PK – 67.194 mV).
90 VAC Input, 10% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

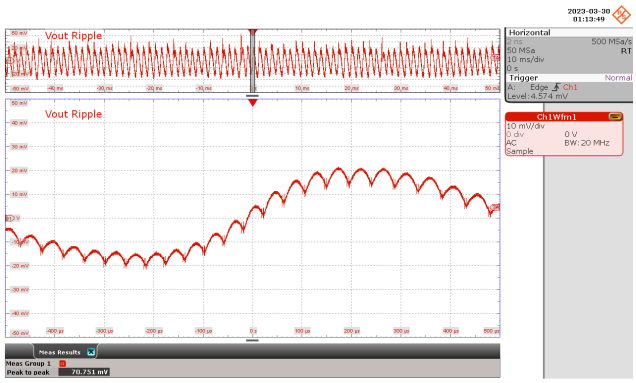


Figure 71 – Output Ripple. (PK-PK – 70.751 mV).
115 VAC Input, 10% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

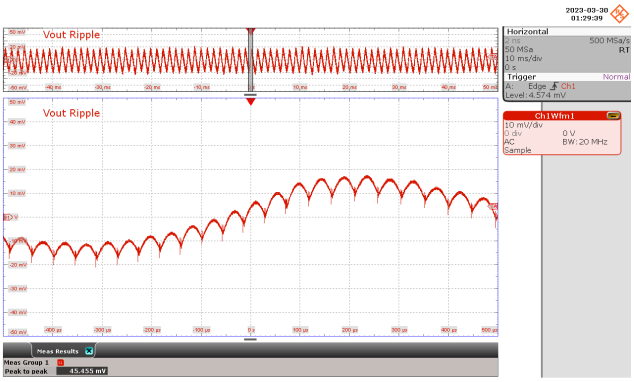


Figure 72 – Output Ripple. (PK-PK – 45.455 mV).
230 VAC Input, 10% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

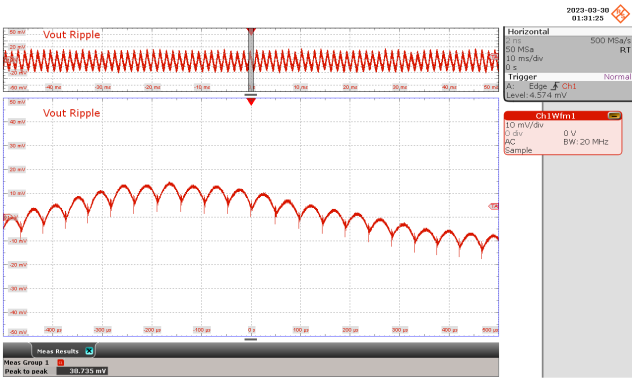


Figure 73 – Output Ripple. (PK-PK – 38.735mV).
265 VAC Input, 10% Load.
V_{OUT}, 10 mV / div., 10 ms / div.
Zoom: 100 μs.

11.4.3 Output Voltage Ripple

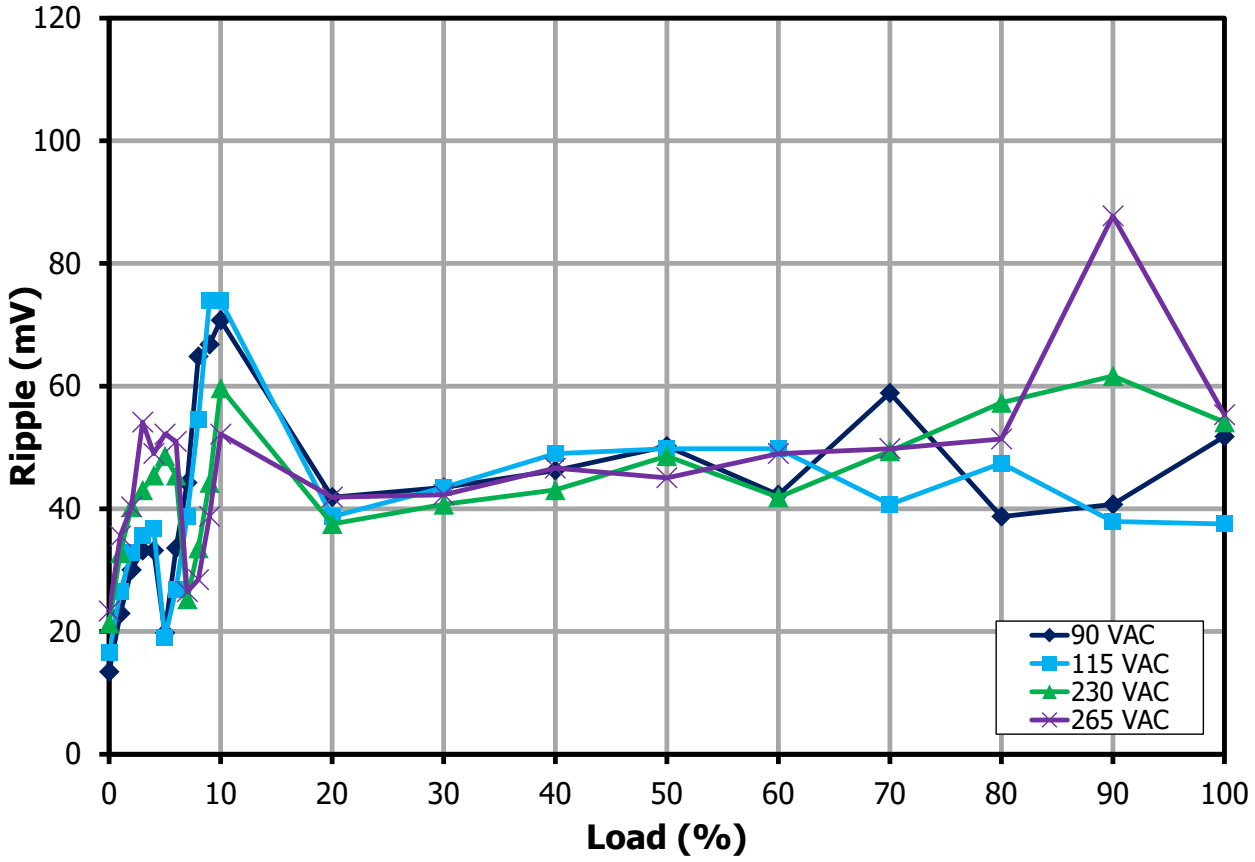


Figure 74 – Output Ripple**.**

11.5 Brown-In and Brown-Out

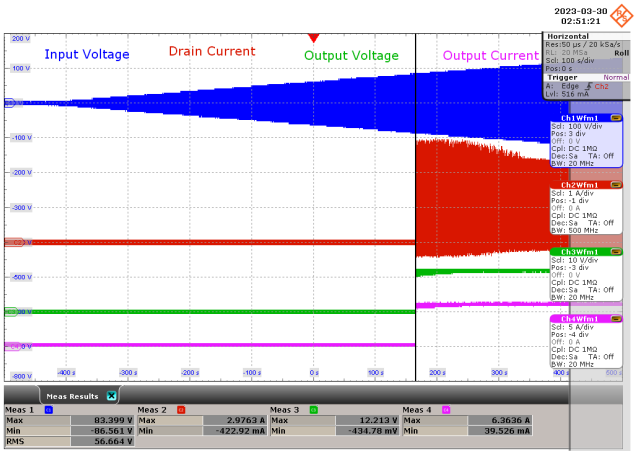


Figure 75 – 0-90 VAC Brown-In (0.1 V / s) Ro = 2 Ω (Full-Load, CR).
CH 1: Input Voltage: 100 V / div., 100 s / div.
CH 2: Drain Current: 1 A / div., 100 s / div.
CH 3: Output Voltage: 10 V / div., 100 s / div.
CH 4: Output Current: 5 A / div., 100 s / div.
Drain Current, Max. = 2.9763 A.
Brown-In Voltage, RMS = 56.664 V.

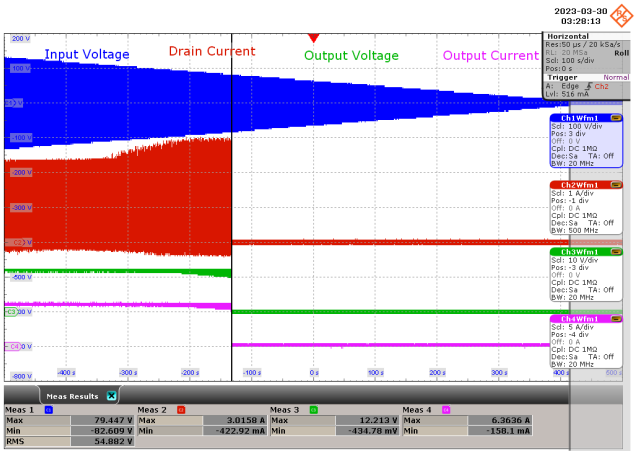


Figure 76 – 90-0 VAC Brown-Out (0.1 V / s) Ro = 2 Ω (Full-Load, CR).
CH 1: Input Voltage: 100 V / div., 100 s / div.
CH 2: Drain Current: 1 A / div., 100 s / div.
CH 3: Output Voltage: 10 V / div., 100 s / div.
CH 4: Output Current: 5 A / div., 100 s / div.
Drain Current, Max. = 3.0158 A.
Brown-Out Voltage, RMS = 54.882 V.

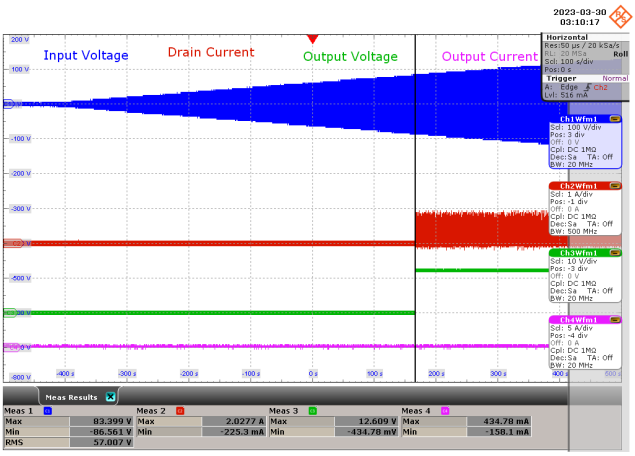


Figure 77 – 0-90 VAC brown-in (0.1 V / s) No-Load.
CH 1: Input Voltage: 100 V / div., 100 s / div.
CH 2: Drain Current: 1 A / div., 100 s / div.
CH 3: Output Voltage: 10 V / div., 100 s / div.
CH 4: Output Current: 5 A / div., 100 s / div.
Drain current, Max. = 2.0277 A.
Brown-In Voltage, RMS = 57.007 V.

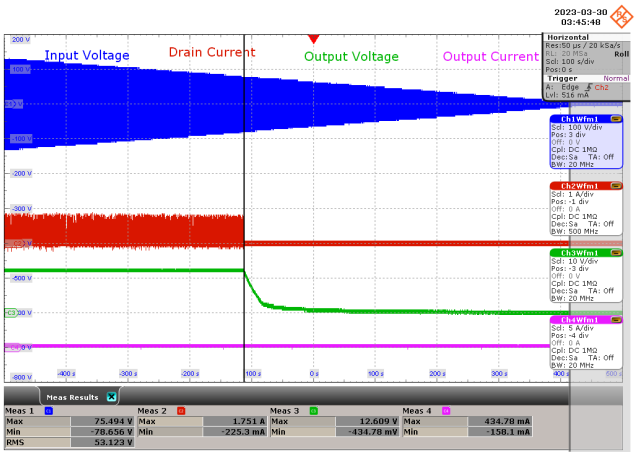


Figure 78 –90-0 VAC brown-out (0.1 V / s) No-Load.
CH 1: Input Voltage: 100 V / div., 100 s / div.
CH 2: Drain Current: 1 A / div., 100 s / div.
CH 3: Output Voltage: 10 V / div., 100 s / div.
CH 4: Output Current: 5 A / div., 100 s / div.
Drain Current, Max. = 1.751 A.
Brown-In Voltage, RMS = 53.123 V.

11.6 Auto-Restart with Output Short-Circuit

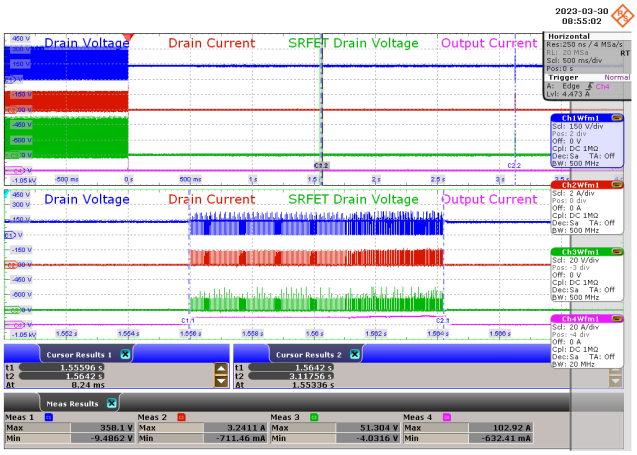


Figure 79 – 90 VAC, Output Shorted at PCB End.
CH 1: Drain Voltage: 150 V / div., 500 ms /div.
CH 2: Drain Current: 2 A / div., 500 ms / div.
CH 3: SR FET Drain Voltage: 20 V / div., 500 ms / div.
CH 4: Output Current: 20 A / div., 500 ms / div.
Zoom: 2 ms / div.
$V_{DS\ max\ during\ auto\text{-}restart}$ = 358.1 V, 47.75% Derating.
SR FET $V_{DS\ max\ during\ AR}$ = 51.304 V, 34.2% Derating.
$t_{AR(ON)}$ = 8.24 ms.
$t_{AR(OFF)}$ = 1.55336 s.

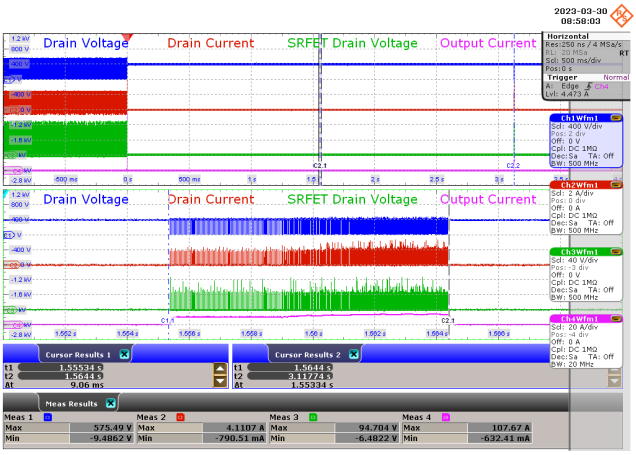


Figure 80 – 265 VAC, Output Shorted at PCB End.
CH 1: Drain Voltage: 400 V / div., 500 ms / div.
CH 2: Drain Current: 2 A / div., 500 ms / div.
CH 3: SR FET Drain Voltage: 40 V / div., 500 ms / div.
CH 4: Output Current: 20 A / div., 500 ms / div.
Zoom: 2 ms / div.
$V_{DS\ max\ during\ auto\text{-}restart}$ = 575.49 V, 76.73% Derating.
SR FET $V_{DS\ max\ during\ AR}$ = 94.704 V, 63.14% Derating.
$t_{AR(ON)}$ = 9.06 ms.
$t_{AR(OFF)}$ = 1.55334 s.

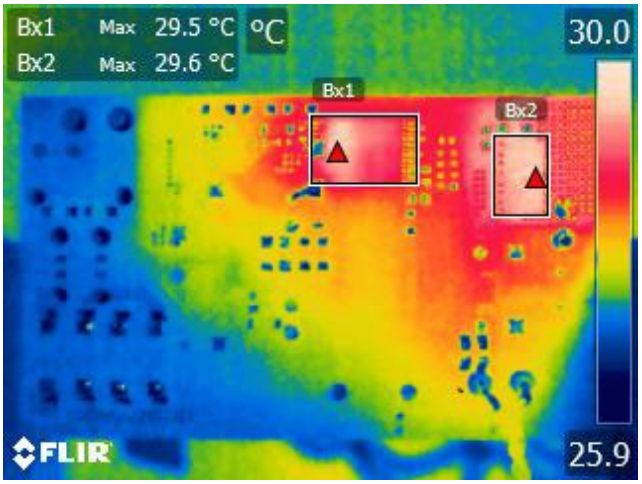


Figure 81 – 90 VAC, Output Shorted at PCB End.
Bx1: INN4275C: 29.5 ºC
Bx2: SR FET: 29.6 ºC

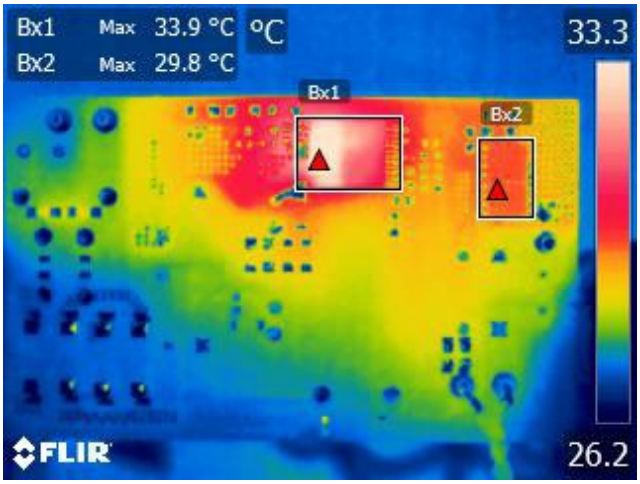


Figure 82 – 265 VAC, Output Shorted at PCB End.
Bx1: INN4275C: 33.9 ºC
Bx2: SR FET: 29.8 ºC

12 Conducted EMI

12.1 Floating Output

12.1.1 Line

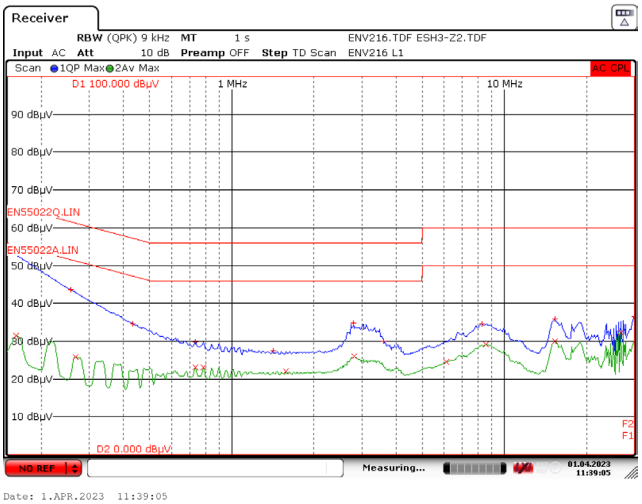


Figure 83 – Floating Output EMI, 12 V / 100% Load for 115 VAC.

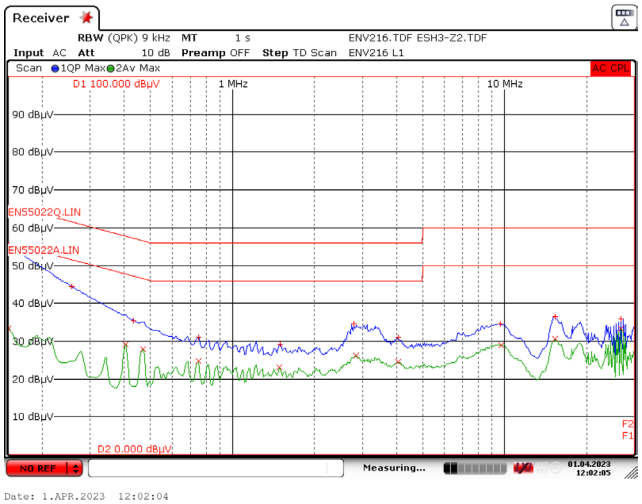


Figure 84 – Floating Output EMI, 12 V / 100% Load for 230 VAC.

12.1.2 Neutral

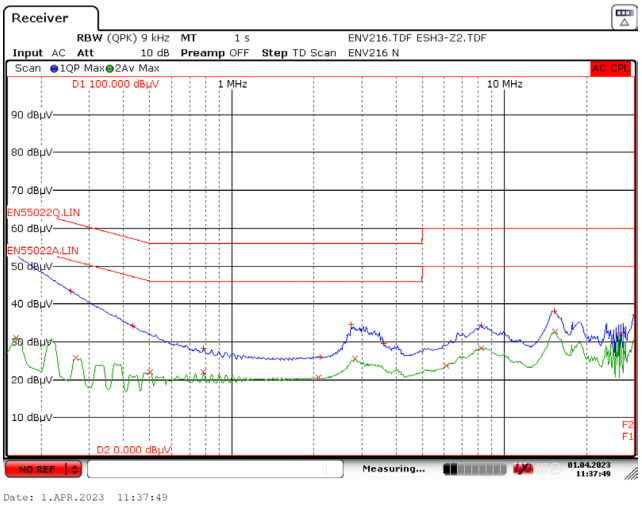


Figure 85 – Floating Output EMI, 12 V / 100% Load for 115 VAC.

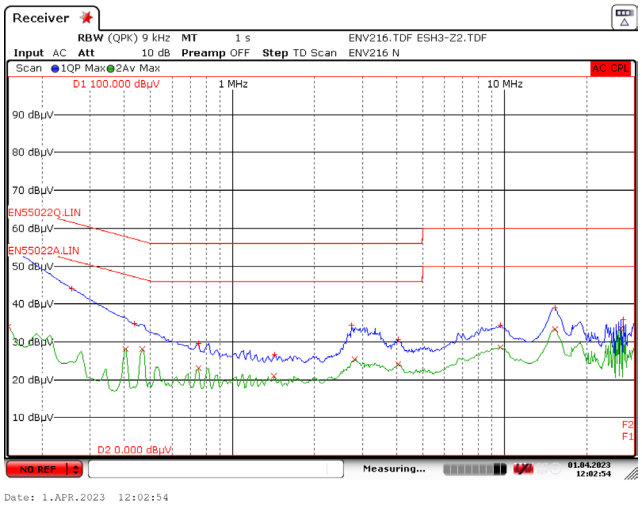


Figure 86 – Floating Output EMI, 12 V / 100% Load for 230 VAC.

12.2 Artificial Hand Output

12.2.1 Line

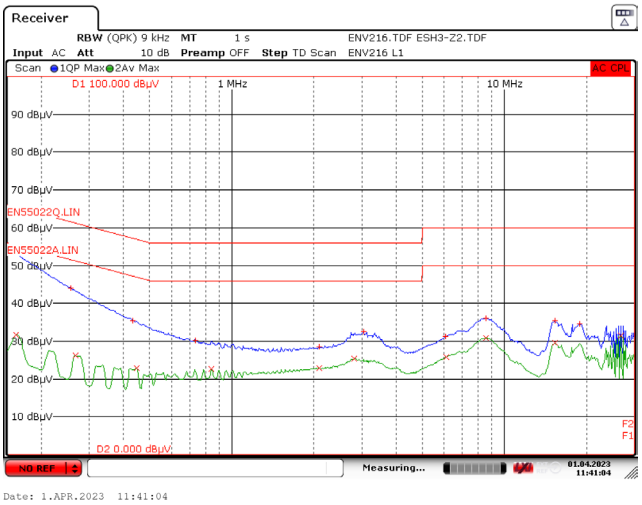


Figure 87 – Artificial hand Output EMI, 12 V / 100% Load for 115 VAC.

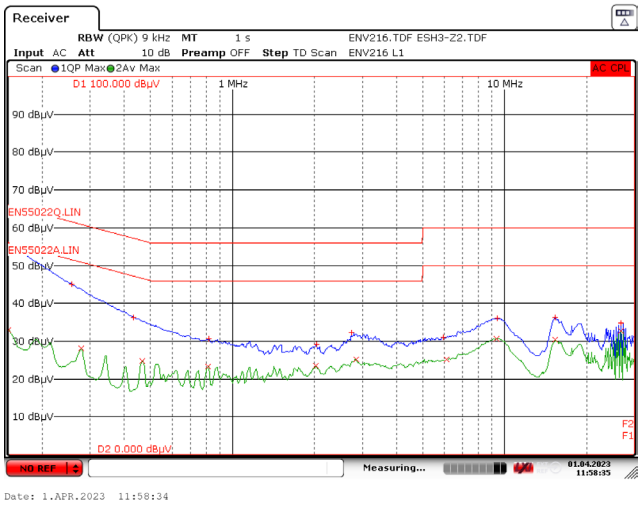


Figure 88 – Artificial hand Output EMI, 12 V / 100% Load for 230 VAC.

12.2.2 Neutral

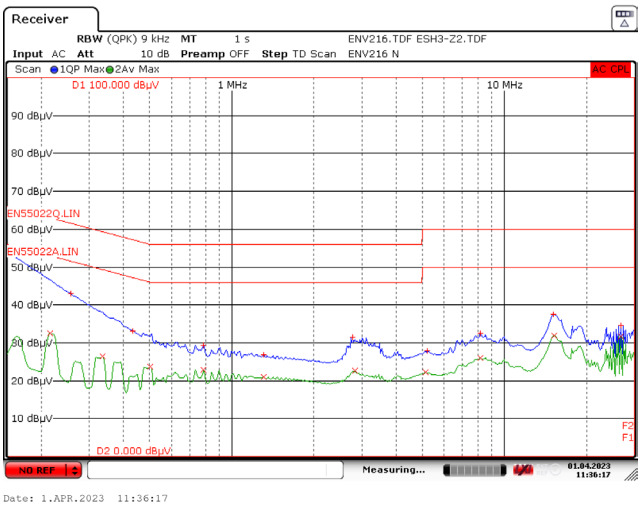


Figure 89 – Artificial hand Output EMI, 12 V / 100% Load for 115 VAC.

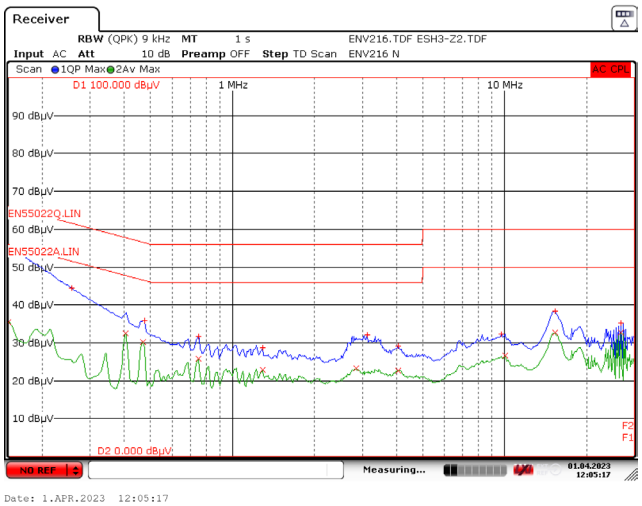


Figure 90 – Artificial Hand Output EMI, 12 V / 100% Load for 230 VAC.

12.3 Grounded Output

12.3.1 Line

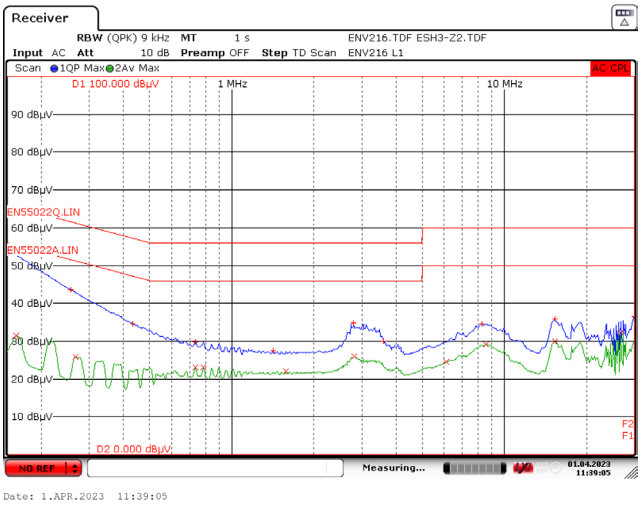


Figure 91 – Grounded Output EMI, 12 V / 100% Load for 115 VAC.

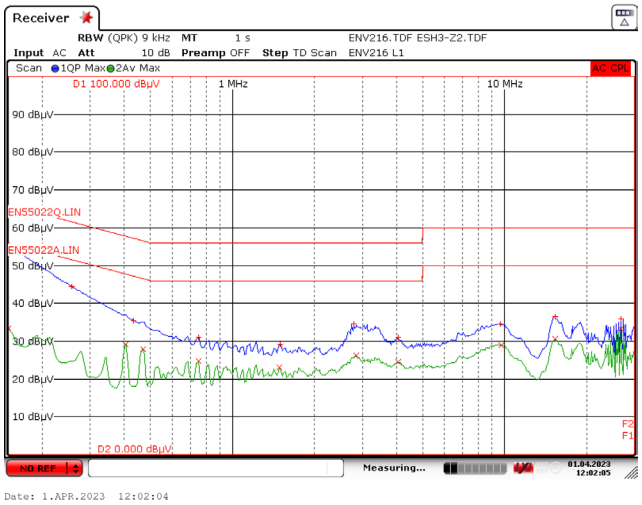


Figure 92 – Grounded Output EMI, 12 V / 100% Load for 230 VAC.

12.3.2 Neutral

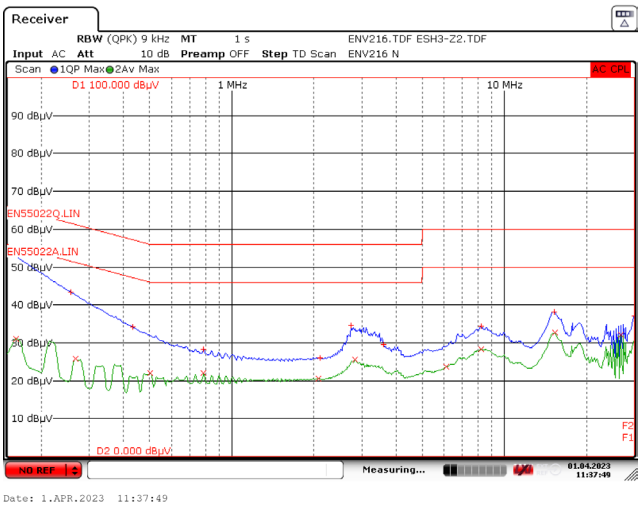


Figure 93 – Grounded Output EMI, 12 V / 100% Load for 115 VAC.

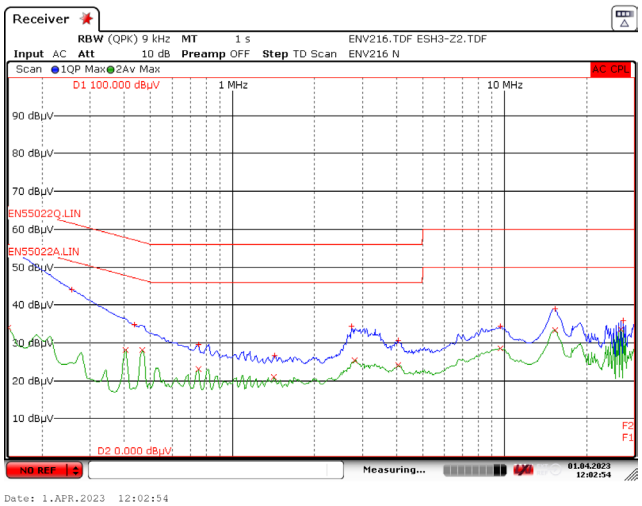


Figure 94 – Grounded Output EMI, 12 V / 100% Load for 230 VAC.

13 Line Surge

13.1 Differential Mode Test

13.1.1 115 VAC Input

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
+2000	0	L, N	2	10	Pass
–2000	0	L, N	2	10	Pass
+2000	90	L, N	2	10	Pass
–2000	90	L, N	2	10	Pass
+2000	180	L, N	2	10	Pass
–2000	180	L, N	2	10	Pass
+2000	270	L, N	2	10	Pass
–2000	270	L, N	2	10	Pass

13.1.2 230 VAC Input

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
+2000	0	L, N	2	10	Pass
–2000	0	L, N	2	10	Pass
+2000	90	L, N	2	10	Pass
–2000	90	L, N	2	10	Pass
+2000	180	L, N	2	10	Pass
–2000	180	L, N	2	10	Pass
+2000	270	L, N	2	10	Pass
–2000	270	L, N	2	10	Pass

13.2 Ring Wave Surge

13.2.1 115 VAC Input

Surge Voltage (V)	Phase Angle (°)	IEC Coupling	Generator Impedance (Ω)	Number Strikes	Result
+6000	0	L, N → PE	12	10	Pass
–6000	0	L, N → PE	12	10	Pass
+6000	90	L, N → PE	12	10	Pass
–6000	90	L, N → PE	12	10	Pass
+6000	180	L, N → PE	12	10	Pass
–6000	180	L, N → PE	12	10	Pass
+6000	270	L, N → PE	12	10	Pass
–6000	270	L, N → PE	12	10	Pass

13.2.2 230 VAC Input

Surge Voltage (V)	Phase Angle (°)	IEC Coupling	Generator Impedance (Ω)	Number Strikes	Result
+6000	0	L, N → PE	12	10	Pass
–6000	0	L, N → PE	12	10	Pass
+6000	90	L, N → PE	12	10	Pass
–6000	90	L, N → PE	12	10	Pass
+6000	180	L, N → PE	12	10	Pass
–6000	180	L, N → PE	12	10	Pass
+6000	270	L, N → PE	12	10	Pass
–6000	270	L, N → PE	12	10	Pass

14 EFT

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

15 ESD

Passed ±16.5 kV air discharge and ±8.8 kV contact discharge at both output positive and negative terminals, under full load condition for both 115 VAC and 230 VAC.

Air Discharge (kV)	Number of Strikes	Test Result
+16.5	10	PASS
-16.5	10	PASS

Contact Discharge (kV)	Number of Strikes	Test Result
+8.8	10	PASS
-8.8	10	PASS

16 Revision History

Date	Author	Revision	Description & Changes	Reviewed
19-May-24	JMR/RN	1.0	Initial Release.	Apps & Mktg

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

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