Design Example Report

Title	***6 W Non-Isolated Buck Converter Using LinkSwitch™-TN2 LNK3209G***
Specification	85 VAC – 265 VAC Input; 6 V, 1 A Output
Application	Appliance
Author	Applications Engineering Department
Document Number	DER-972
Date	August 18, 2022
Revision	1.0

Summary and Features

- 725 V maximum drain voltage
- Highly integrated solution
- Lowest possible component count
- No optocoupler required for regulation
- Thermal overload protection with automatic recovery
- Start-up soft start function
- Capable to operate at full load up to 50 ºC ambient
- >71% efficiency at full load nominal line
- <±5% load regulation

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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 prototype report describes a non-isolated 6 V, 1 A power supply utilizing a LinkSwitch-TN2 LNK3209G IC from Power Integrations. The document contains the power supply specification, schematic, bill-of-materials, printed circuit layout, and performance data.

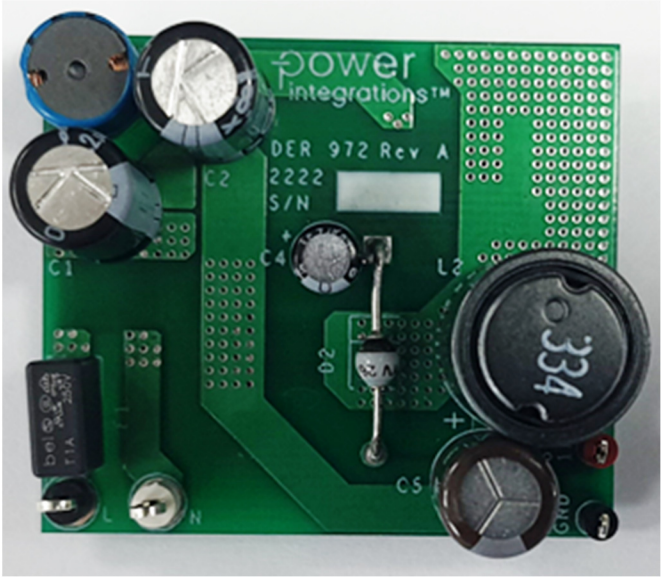

Figure 1– Populated Circuit Board Photograph, Top.

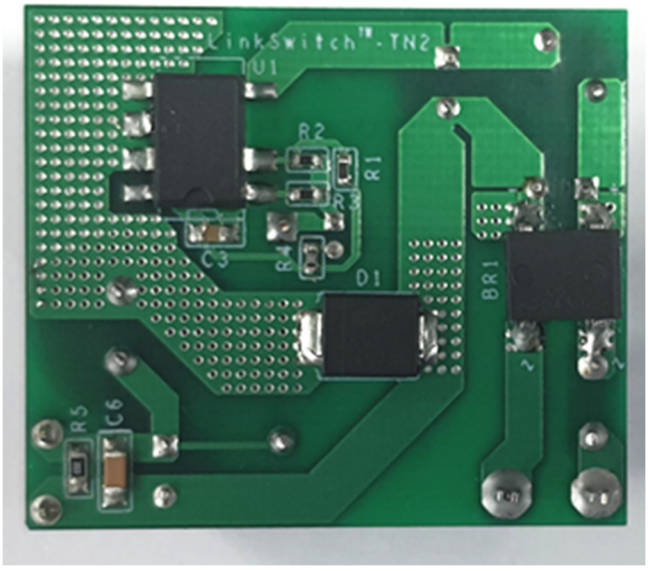

Figure 2 – Populated Circuit Board Photograph, Bottom.

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	85		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power (230 VAC)				<50	mW	
Output						
Output Voltage	V_{OUT}		6		V	±5% Steady-State, Transient ±8%.
Output Ripple Voltage	V_{RIPPLE}			150	mV	20 MHz Bandwidth.
Output Current	I_{OUT}		1		A	
Min. Output Current	$I_{OUT,MIN}$		0.1		A	System Load Upon Insertion.
Total Output Power						
Continuous Output Power	P_{OUT}		6		W	
Efficiency						
Full Load (115 VAC / 230 VAC)	η	71			%	Measured at the End of PCB. 25 ºC.
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Line Surge Differential Mode (L1-L2)			1		kV	1.2/50 μs Surge, IEC 61000-4-5, Series Impedance: Differential Mode: 2 Ω.
Ambient Temperature	T_{AMB}	0		40	ºC	Free Convection, Sea Level.

3 Schematic

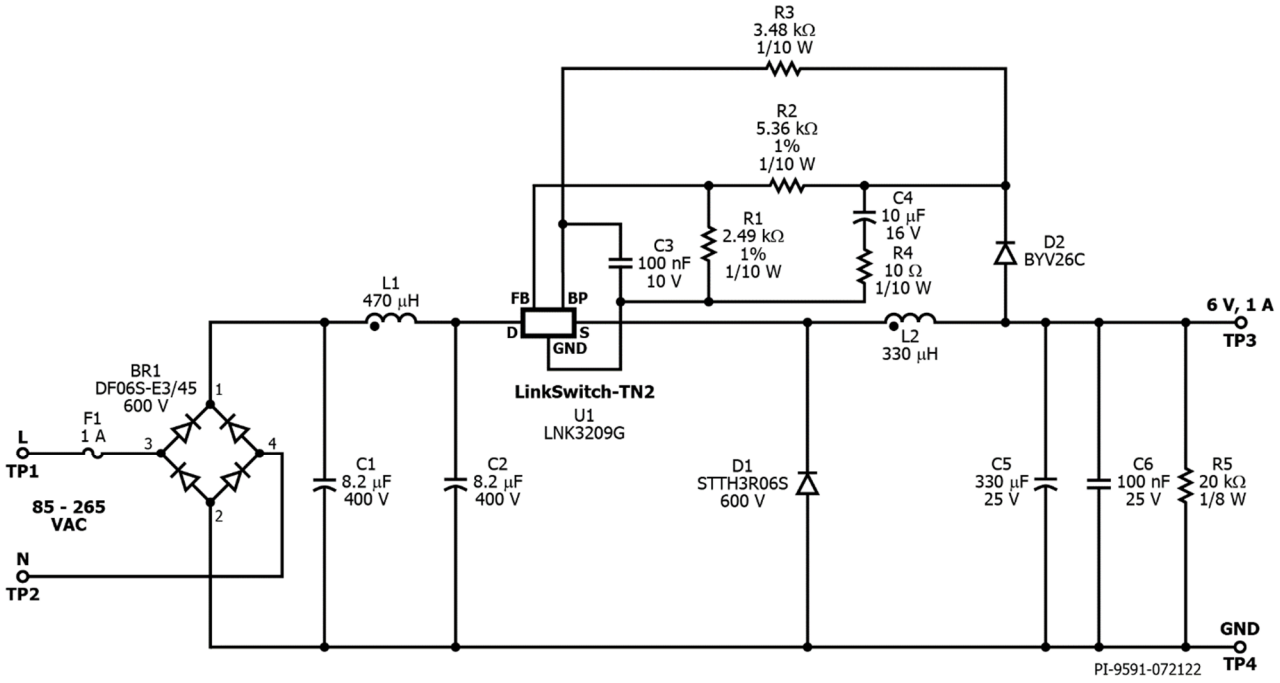

Figure 3 – Schematic.

4 Circuit Description

The schematic in Figure 3 shows an implementation of a buck converter using LNK3209G. The circuit provides a non-isolated 6 V, 1 A continuous output.

4.1 *Input EMI Filtering*

The input stage is comprised of fuse F1, bridge rectifier diode BR1, and an EMI suppression circuit in a pi filter configuration with C1, inductor L1, and C2.

4.2 *LinkSwitch-TN2*

The LinkSwitch-TN2 IC combines a high-voltage power MOSFET and the power supply controller into a low cost monolithic IC.

When AC is first applied, an internal current source connected to the DRAIN (D) pin charges C3 to power the controller inside the IC. When the output voltage is established, the device controller will now be powered from the output via a feedback diode D2 and current limiting resistor R3 to minimize losses.

The control scheme used is similar to the ON/OFF control used in TinySwitch™. The LNK3209G controller works on the principle of ON/OFF control in which output regulation is achieved by skipping cycles in response to a signal applied to the FEEDBACK (FB) pin. Current into the FB pin greater than 49 μA will inhibit the switching of the internal power MOSFET, while current below this allows switching cycles to occur. During full load operation, only a few switching cycles will be skipped (disabled), which results in a high effective switching frequency. As the load is reduced, some switching cycles are skipped reducing the effective switching frequency.

4.3 *Output Rectification*

When the internal power MOSFET is on, current ramps through L2 until the internal current limit is reached. This then turns off the internal power MOSFET and allows the inductor current to freewheel via diode D1 for the remainder of the switching cycle. For this design, an ultrafast diode (t_{RR} of 35 ns) is selected for D1 due to continuous operation at full load. Capacitor C5 should be selected to have an adequate ripple current rating (low ESR type). Capacitor C6 provides the filtering of the high frequency output voltage ripple.

4.4 *Output Feedback*

During the power MOSFET off-time, capacitor C4 is charged to the output voltage via D2. The voltage developed across C4 tracks the output voltage. This voltage is used to provide feedback to the IC via the resistor divider formed by resistors R1 and R2. The values of R1 and R2 are selected such that at the nominal output voltage, the voltage on the FB pin is 2 V. The FEEDBACK (FB) pin is then sampled by the controller inside U1 during each switching cycle. To improve output ripple, R4 is placed in series with sample and hold cap C4.

5 PCB Layout

Layers: Two (2)
Board Materials: FR4
Board Thickness: 1 mm
Copper Weight: 2 oz

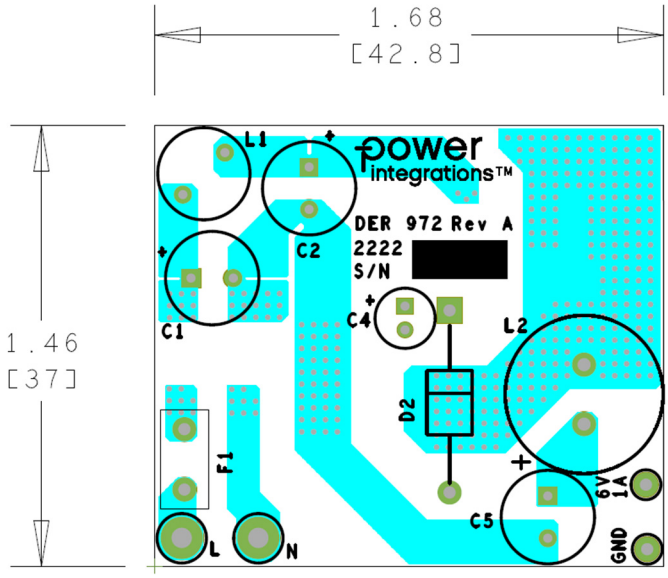

Figure 4 – Printed Circuit Layout, Top (1.00” [25.4 mm] L x 1.00” [25.4 mm] W).

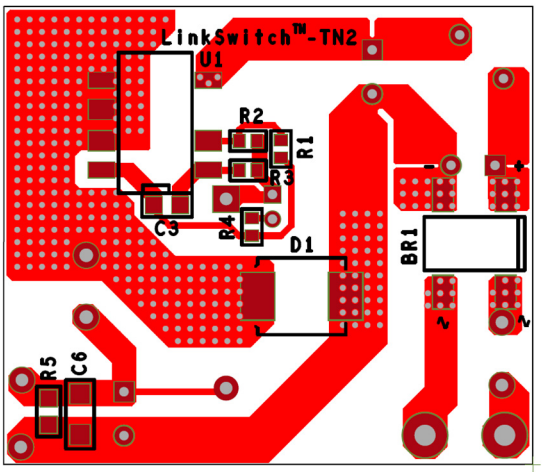

Figure 5 – Printed Circuit Layout, Bottom.

6 Bill of Materials

6.1 *Main BOM*

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	BR1	1	600 V, 1 A, Bridge Rectifier, SMD, DFS	DF06S-E3/45	Vishay
2	C1 C2	2	8.2 μF, 400 V, Electrolytic, (8 x 16), 20%	400AX8.2M8X16	Rubycon
3	C3	1	100 nF, 0.1 μF, 10 V, Ceramic, X7R, 0805	0805ZC104MAT2A	AVX
4	C4	1	10 μF, 16 V, Electrolytic, Gen. Purpose, (5 x 11)	UVR1C100MDD	Nichicon
5	C5	1	330 μF, 25 V, Electrolytic, Very Low ESR, 56 mΩ, (8 x 15)	EKZE250ELL331MH15D	Nippon Chemi-Con
6	C6	1	100 nF, 25 V, Ceramic, X7R, 1206	C1206F104K3RACTU	Kemet
7	D1	1	600 V, 3 A, SMC, DO-214AB	STTH3R06S	ST Micro
8	D2	1	600 V, 1 A, Ultrafast Recovery, 30 ns, SOD57	BYV26C-TAP	Vishay
9	F1	1	1 A, 250 V, Slow, Long Time Lag, RST 1	RST 1	Belfuse
10	L1	1	470 μH, 0.49 A	SBC3-471-491	Tokin
11	L2	1	Fixed Inductors, RFS1317, 330 μH, 10%, 0.286 Ω, Radial, 13.3 mm Diam, 16 mm Length	RFS1317-334KL	Coilcraft
12	R1	1	RES, 2.49 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF2491V	Panasonic
13	R2	1	RES, 5.36 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF5361V	Panasonic
14	R3	1	RES, 3.48 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF3481V	Panasonic
15	R4	1	RES, 10 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ100V	Panasonic
16	R5	1	RES, 20 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ203V	Panasonic
17	U1	1	LinkSwitch-TN2, SMD-8C	LNK3209G	Power Integrations

6.2 *Miscellaneous Parts*

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	N	1	Test Point, WHT, THRU-HOLE MOUNT	5012	Keystone
2	L	1	Test Point, BLK, THRU-HOLE MOUNT	5011	Keystone
3	6V	1	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone
4	GND	1	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone

7 Design Spreadsheet

1	ACDC_LinkSwitchTN2-Buck_060122; Rev.1.6; Copyright Power Integrations 2022	INPUT	INFO	OUTPUT	UNIT	ACDC_LinkSwitchTN2 Buck
2	**ENTER APPLICATION VARIABLES**					
3	LINE VOLTAGE RANGE			Universal		AC line voltage range
4	VACMIN			85.00	V	Minimum AC line voltage
5	VACTYP			115.00	V	Typical AC line voltage
6	VACMAX			265.00	V	Maximum AC line voltage
7	fL			60.00	Hz	AC mains frequency
8	LINE RECTIFICATION TYPE	F		F		Select 'F'ull wave rectification or 'H'alf wave rectification
9	VOUT	6.00		6.00	V	Output voltage
10	IOUT	1.000	Info	1.000	A	Device operation is too continuous, verify power delivery on the bench or select a larger device
11	EFFICIENCY_ESTIMATED			0.80		Efficiency estimate at output terminals
12	EFFICIENCY_CALCULATED			0.58		Calculated efficiency based on real components and operating point
13	POUT			6.00	W	Continuous Output Power
14	CIN	16.40		16.40	uF	Input capacitor
15	VMIN			93.5	V	Valley of the rectified input voltage
16	VMAX			374.8	V	Peak of the rectified maximum input AC voltage
17	T_AMBIENT			50	degC	Operating ambient temperature in degrees celcius
18	INPUT STAGE RESISTANCE			10	Ohms	Input stage resistance in ohms (includes fuse, thermistor, filtering components)
19	PLOSS_INPUTSTAGE			0.078	W	Input stage losses estimate
23	**ENTER LINKSWITCH-TN2 VARIABLES**					
24	OPERATION MODE			MCM		Mostly continuous mode of operation
25	CURRENT LIMIT MODE	STD		STD		Choose 'RED' for reduced current limit or 'STD' for standard current limit
26	PACKAGE	SMD-8C		SMD-8C		Select the device package
27	DEVICE SERIES	Auto		LNK32X9		Generic LinkSwitch-TN2 device
28	DEVICE CODE			LNK3209G		Required LinkSwitch-TN2 device
29	ILIMITMIN			1.200	A	Minimum current limit of the device
30	ILIMITTYP			1.300	A	Typical current limit of the device
31	ILIMITMAX			1.400	A	Maximum current limit of the device
32	RDSON			4.37	ohms	MOSFET's on-time drain to source resistance at 100degC
33	FSMIN			62000	Hz	Minimum switching frequency
34	FSTYP			66000	Hz	Typical switching frequency
35	FSMAX			70000	Hz	Maximum switching frequency
36	VDSON			2.00	V	MOSFET on-time drain to source voltage estimate
37	DUTY			0.07		Maximum duty cycle
38	TIME_ON			1.171	us	MOSFET conduction time at the minimum line voltage
39	TIME_ON_MIN			1.173	us	MOSFET conduction time at the maximum line voltage
40	KP_TRANSIENT		Info	0.070		Transient KP less than 0.2 may lead to a leading edge SOA trigger
41	IRMS_MOSFET			0.271	A	MOSFET RMS current
42	PLOSS_MOSFET			1.104	W	Primary MOSFET loss estimate
46	**BUCK INDUCTOR PARAMETERS**					
47	INDUCTANCE_MIN			297	uH	Minimum design inductance required for power delivery

48	INDUCTANCE_TYP			330	uH	Typical design inductance required for power delivery
49	INDUCTANCE_MAX			363	uH	Maximum design inductance required for power delivery
50	TOLERANCE_INDUCTANCE			10	%	Tolerance of the design inductance
51	DC RESISTANCE OF INDUCTOR			2.0	ohms	DC resistance of the buck inductor
52	FACTOR_LOSS			0.900		Factor that accounts for off-state power loss to be supplied by inductor
53	IRMS_INDUCTOR			1.007	A	Inductor RMS current
54	PLOSS_INDUCTOR			2.027	W	Inductor losses
58	**FREEWHEELING DIODE PARAMETERS**					
59	VF_FREEWHEELING			0.70	V	Forward voltage drop of the freewheeling diode
60	PIV			468	V	Peak inverse voltage of the freewheeling diode
61	IRMS_DIODE			0.969	A	Diode RMS current
62	TRR			30	ns	Required reverse recovery time of the selected diode
63	PLOSS_DIODE			1.107	W	Freewheeling diode losses
64	RECOMMENDED DIODE			BYV26C	W	Recommended freewheeling diode
68	**BIAS/FEEDBACK PARAMETERS**					
69	VF_BIAS			0.70	V	Forward voltage drop of the bias diode
70	RBIAS			2490	Ohms	Bias resistor
71	CBP			0.1	uF	BP pin capacitor
72	RFB			4640	Ohms	Feedback resistor
73	CFB			10	uF	Feedback capacitor
74	C_SOFTSTART				uF	No soft-start capacitor required
75	PLOSS_FEEDBACK			0.005	W	Feedback section losses
79	**OUTPUT CAPACITOR**					
80	OUTPUT VOLTAGE RIPPLE			120	mV	Desired output voltage ripple
81	IRIPPLE_COUT			0.400	A	Output capacitor ripple current
82	ESR_COUT			300	mOhms	Maximum ESR of the output capacitor

8 Assembly Instructions

Solder fill all PCB vias before soldering electrical and mechanical parts to the PCB.

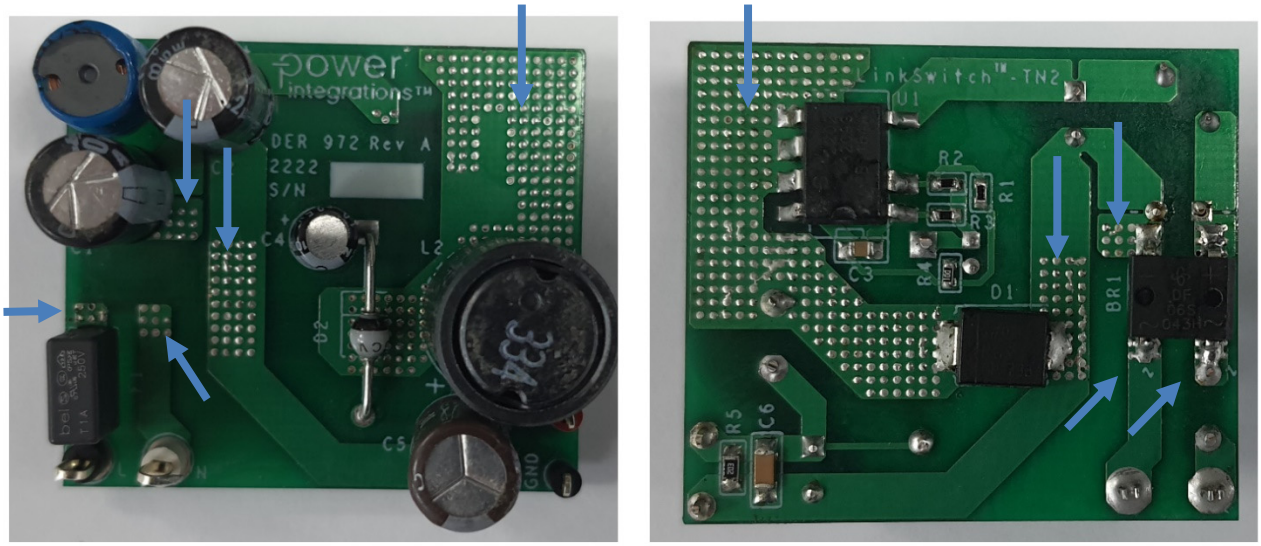

Figure 6 – Solder Fill Via Locations.

9 Performance Data

All measurements performed at room temperature.

9.1 *Efficiency vs. Line*

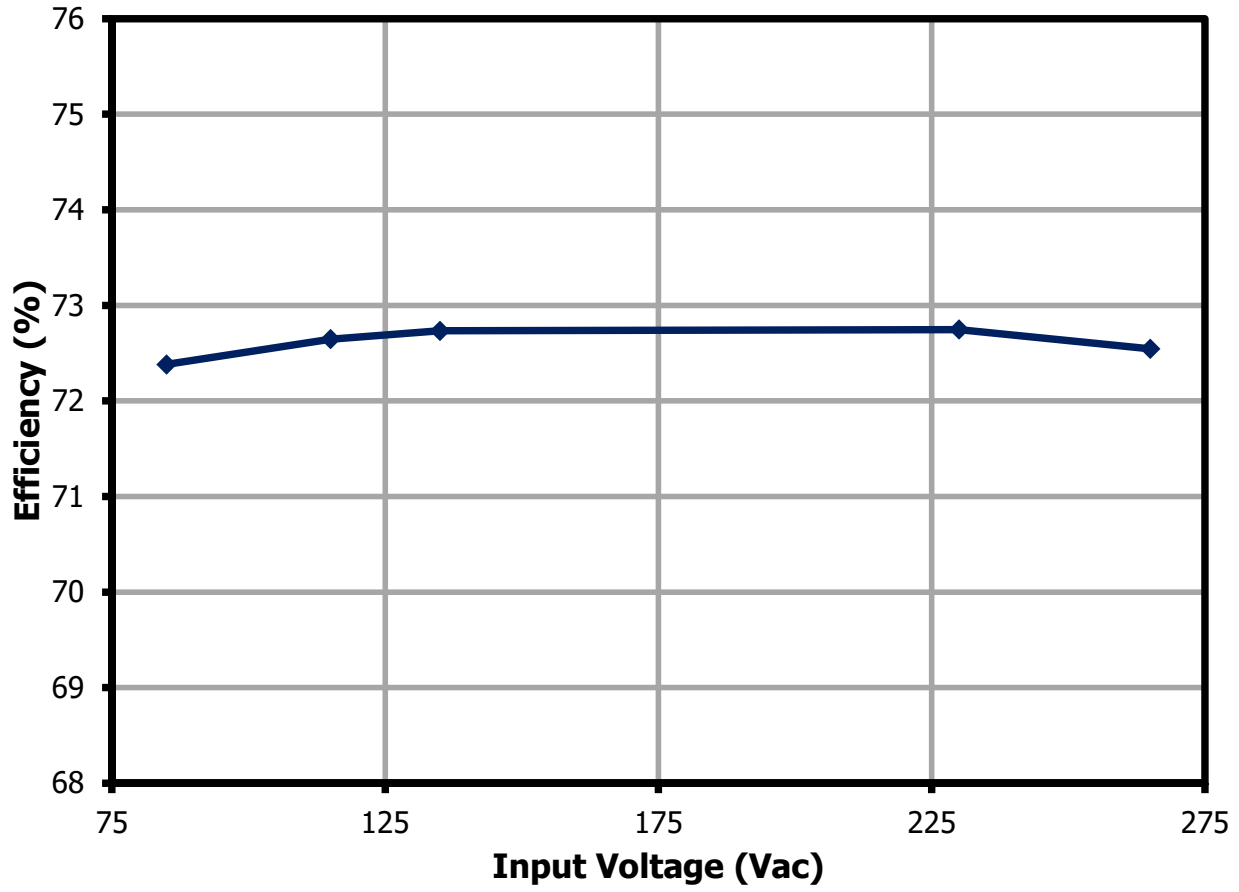

Figure 7 – Full Load Efficiency vs. Line Voltage, Room Temperature.

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
85	239.50	8.27	5.99	999.90	5.99	72.38
115	194.80	8.24	5.99	1000.00	5.99	72.65
135	175.30	8.23	5.99	999.90	5.99	72.73
230	106.60	8.23	5.99	1000.00	5.99	72.75
265	93.11	8.25	5.99	1000.10	5.99	72.55

9.2 *Efficiency vs. Load*

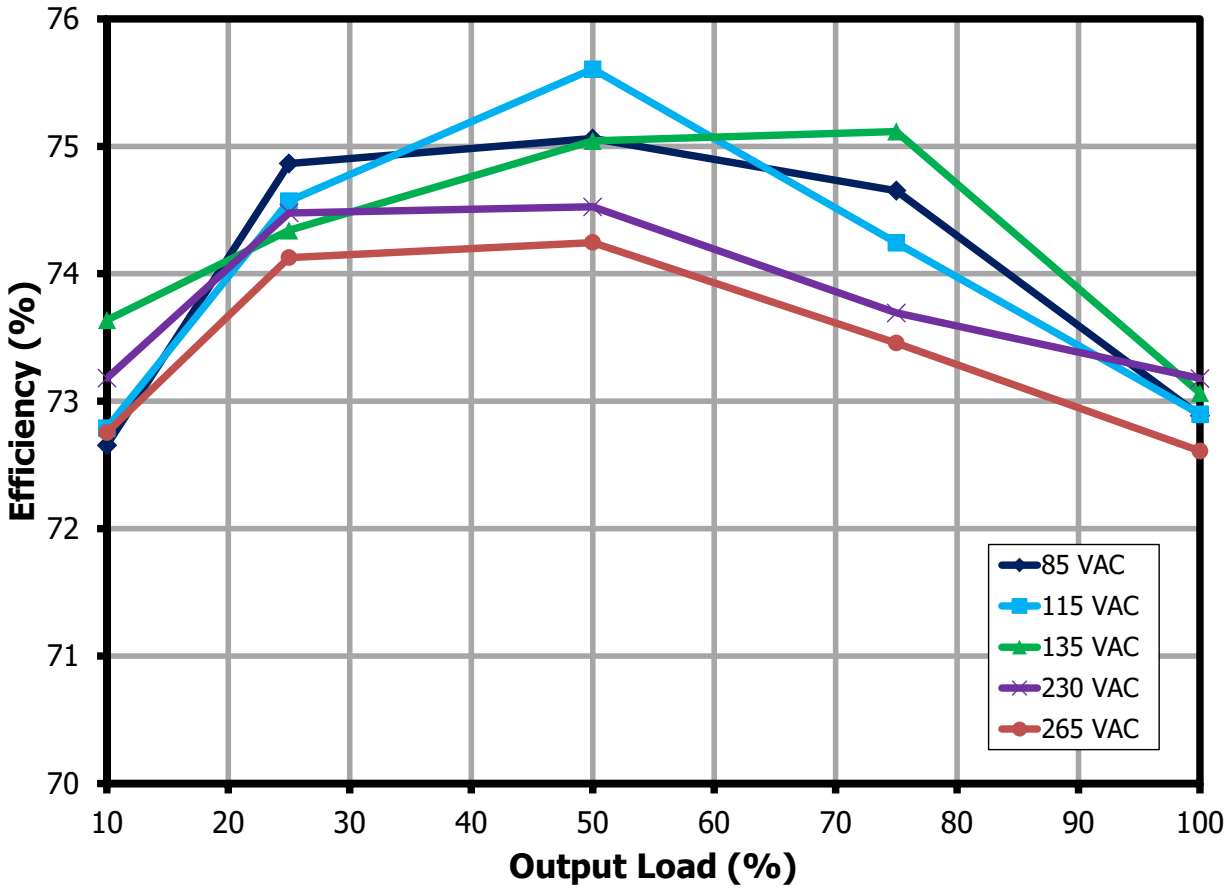

Figure 8 – Efficiency vs. Load, Room Temperature.

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
85	233.00	8.21	5.98	1000.00	5.98	72.89
85	198.90	6.04	6.01	750.10	4.51	74.65
85	163.50	4.03	6.05	500.10	3.03	75.06
85	133.34	2.04	6.12	250.12	1.53	74.87
85	88.90	0.86	6.22	100.33	0.62	72.65

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
115	190.50	8.21	5.99	1000.00	5.99	72.90
115	163.70	6.08	6.02	750.10	4.51	74.24
115	134.84	4.00	6.05	500.10	3.03	75.61
115	109.00	2.05	6.11	250.14	1.53	74.57
115	73.10	0.86	6.22	100.33	0.62	72.79

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
135	169.68	8.19	5.98	1000.00	5.98	73.06
135	145.29	6.00	6.01	750.10	4.51	75.12
135	122.10	4.04	6.06	500.10	3.03	75.04
135	106.63	2.06	6.11	250.10	1.53	74.34
135	66.36	0.85	6.22	100.33	0.62	73.64

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
230	104.41	8.18	5.99	1000.00	5.99	73.18
230	86.94	6.12	6.01	750.10	4.51	73.69
230	64.87	4.06	6.05	500.10	3.03	74.53
230	44.26	2.05	6.10	250.12	1.53	74.48
230	28.27	0.85	6.22	100.34	0.62	73.18

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
265	92.61	8.24	5.98	1000.00	5.98	72.61
265	73.70	6.14	6.02	750.10	4.51	73.46
265	55.77	4.08	6.05	500.10	3.03	74.25
265	35.20	2.06	6.10	250.13	1.52	74.13
265	21.48	0.86	6.22	100.34	0.62	72.75

9.4 *Available Standby Output Power*

Test Condition: Soak at full load for 5 minutes and decrease load to standby mode for 5 minutes for each line step.

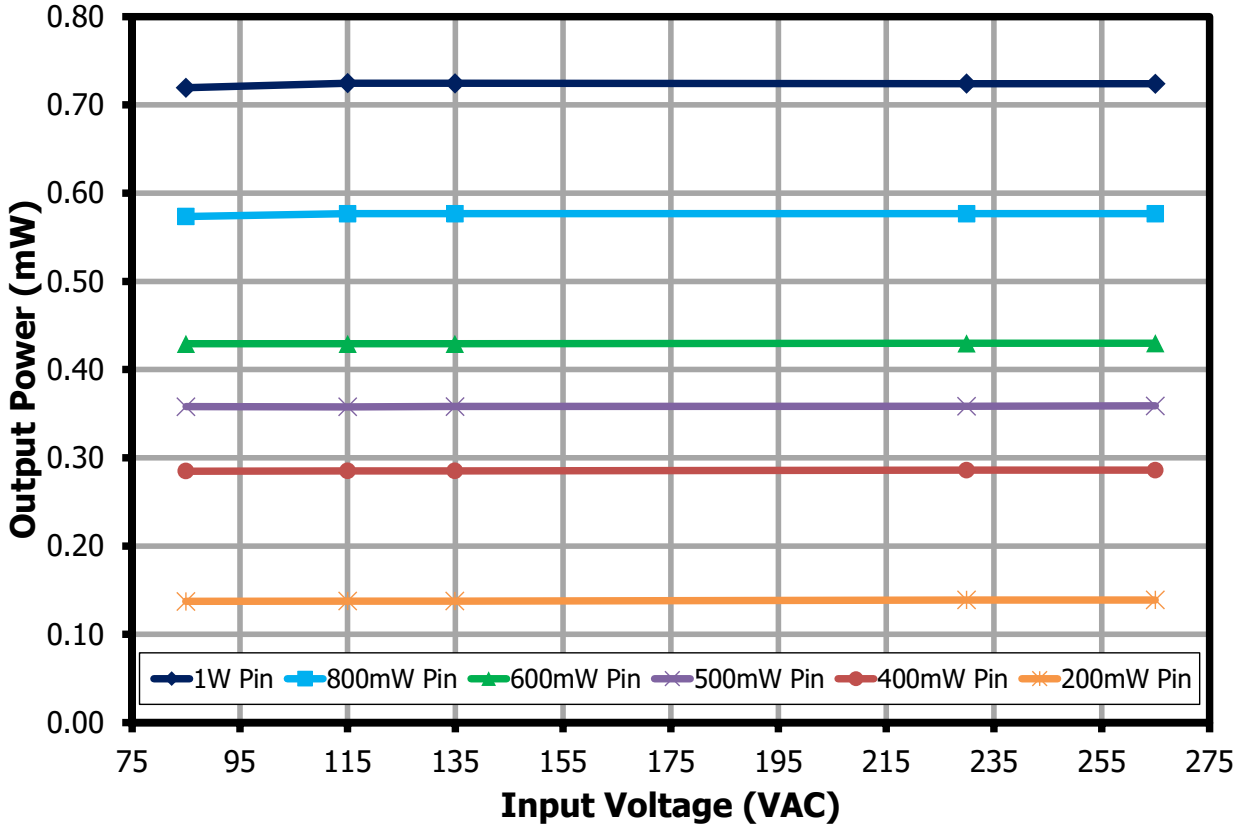

Figure 9 – Available Output Power per Input Power.

9.4.1 200 mW Input Power

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
84.98	34.62	0.202	6.71	20.53	0.14	68.04
115.00	30.44	0.201	6.73	20.53	0.14	68.40
134.93	29.41	0.201	6.73	20.53	0.14	68.52
229.92	16.23	0.205	6.79	20.54	0.14	67.87
264.94	9.35	0.205	6.79	20.53	0.14	67.60

9.4.2 400 mW Input Power

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
84.98	54.92	0.404	6.40	44.57	0.28	70.55
115.00	44.51	0.401	6.41	44.57	0.29	71.19
134.93	43.67	0.400	6.41	44.57	0.29	71.36
229.92	23.36	0.402	6.43	44.57	0.29	71.19
264.94	14.04	0.403	6.43	44.57	0.29	71.02

9.4.3 500 mW Input Power

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
84.99	61.53	0.503	6.34	56.49	0.36	71.08
115.01	52.92	0.499	6.34	56.49	0.36	71.69
134.94	48.12	0.499	6.34	56.49	0.36	71.79
229.92	25.67	0.499	6.35	56.49	0.36	71.76
264.95	15.76	0.501	6.36	56.49	0.36	71.70

9.4.4 600 mW Input Power

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
84.99	66.11	0.600	6.30	68.23	0.43	71.58
115.01	57.33	0.596	6.30	68.23	0.43	72.04
134.93	52.85	0.595	6.30	68.23	0.43	72.19
229.92	24.63	0.594	6.30	68.23	0.43	72.36
264.95	17.21	0.596	6.30	68.24	0.43	72.15

9.4.5 800 mW Input Power

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
84.99	78.55	0.80	6.24	91.99	0.57	71.61
115.01	64.12	0.80	6.24	92.55	0.58	72.55
134.94	59.51	0.80	6.24	92.55	0.58	72.18
229.92	25.85	0.79	6.24	92.55	0.58	72.72
264.94	19.85	0.80	6.24	92.55	0.58	72.46

9.4.6 1 W Input Power

Input Measurement			Output Measurement			Efficiency (%)
V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
84.99	88.19	1.00	6.20	116.04	0.72	71.94
115.01	75.38	1.00	6.20	116.97	0.72	72.39
134.94	68.85	1.00	6.20	116.97	0.72	72.67
229.92	28.82	0.99	6.19	116.97	0.72	73.07
264.94	22.19	1.00	6.19	116.97	0.72	72.76

9.5 *No-Load Input Power*

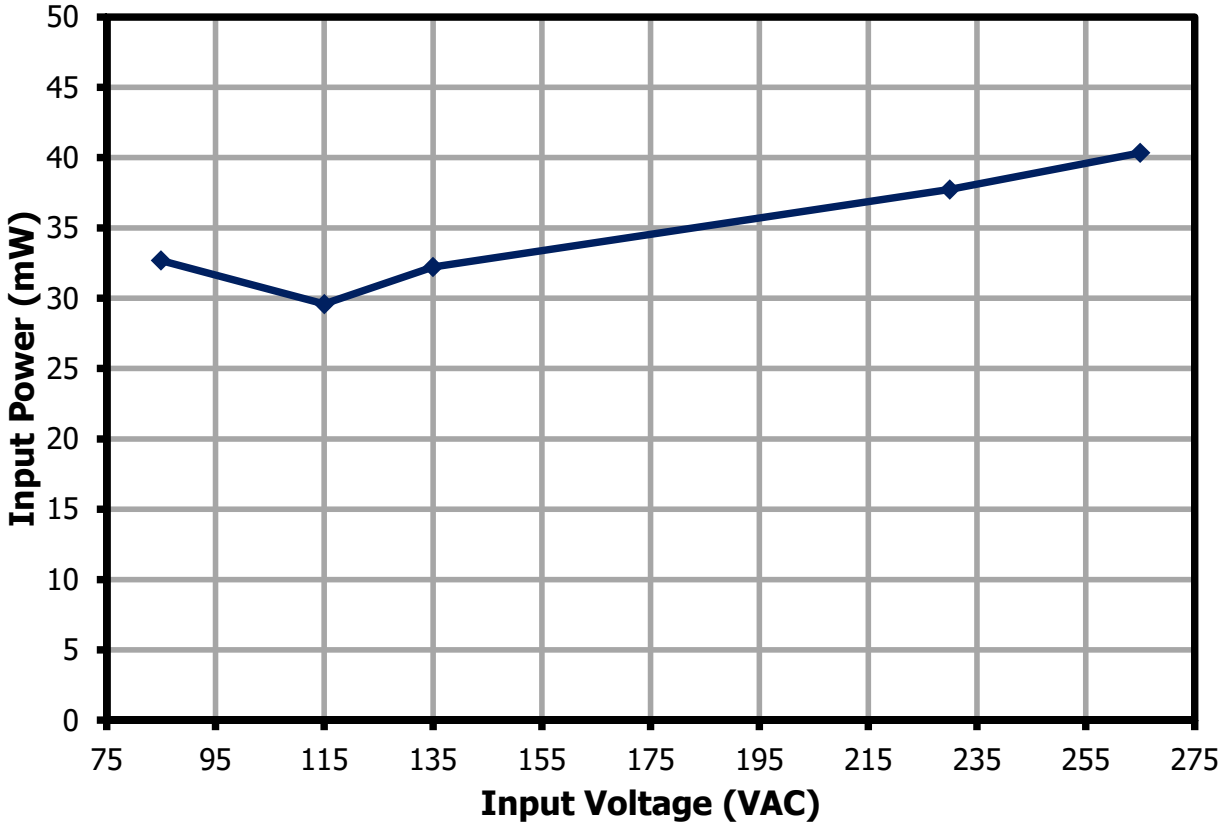

Figure 10 – No-Load Input Power vs. Input Line Voltage, Room Temperature.

9.6 *Load Regulation*

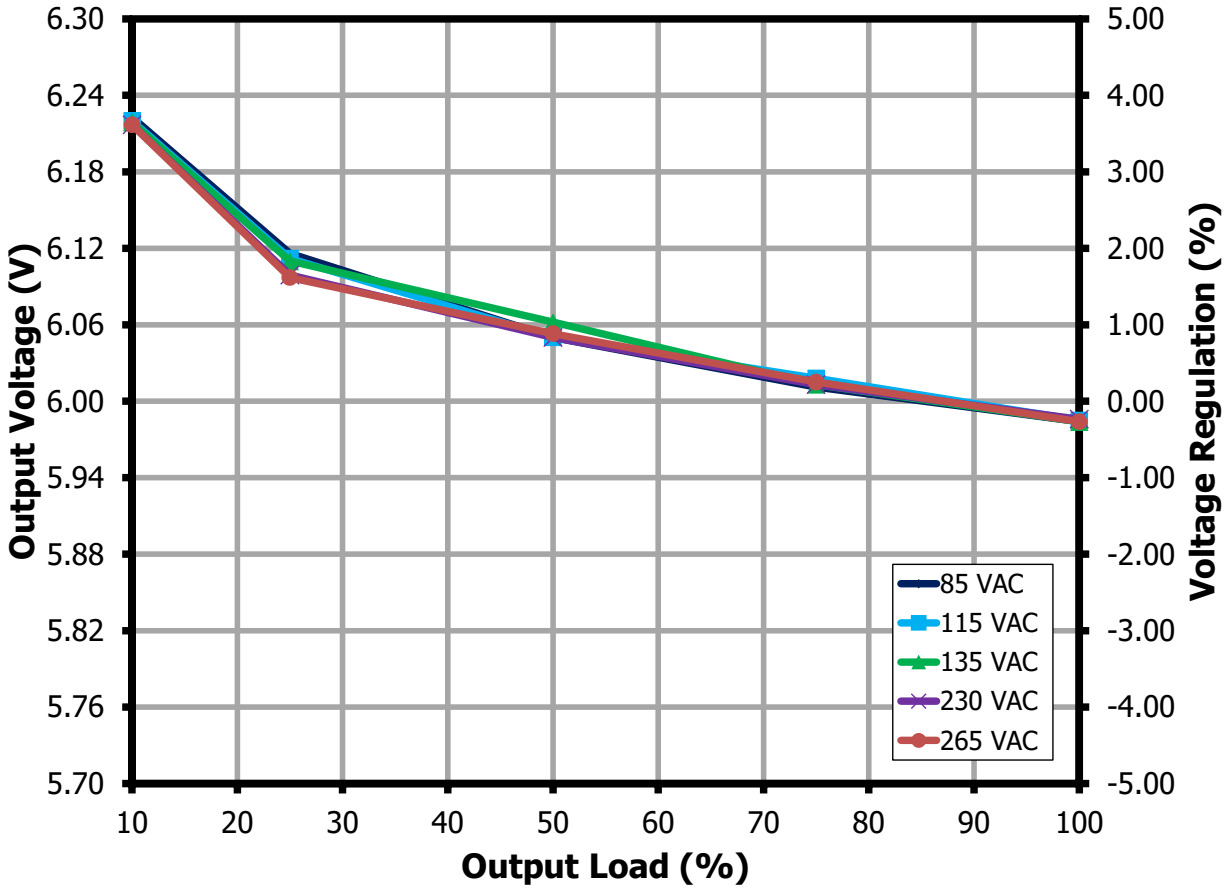

Figure 11 – Output Voltage vs. Output Current, Room Temperature.

9.7 *Line Regulation at Full Load*

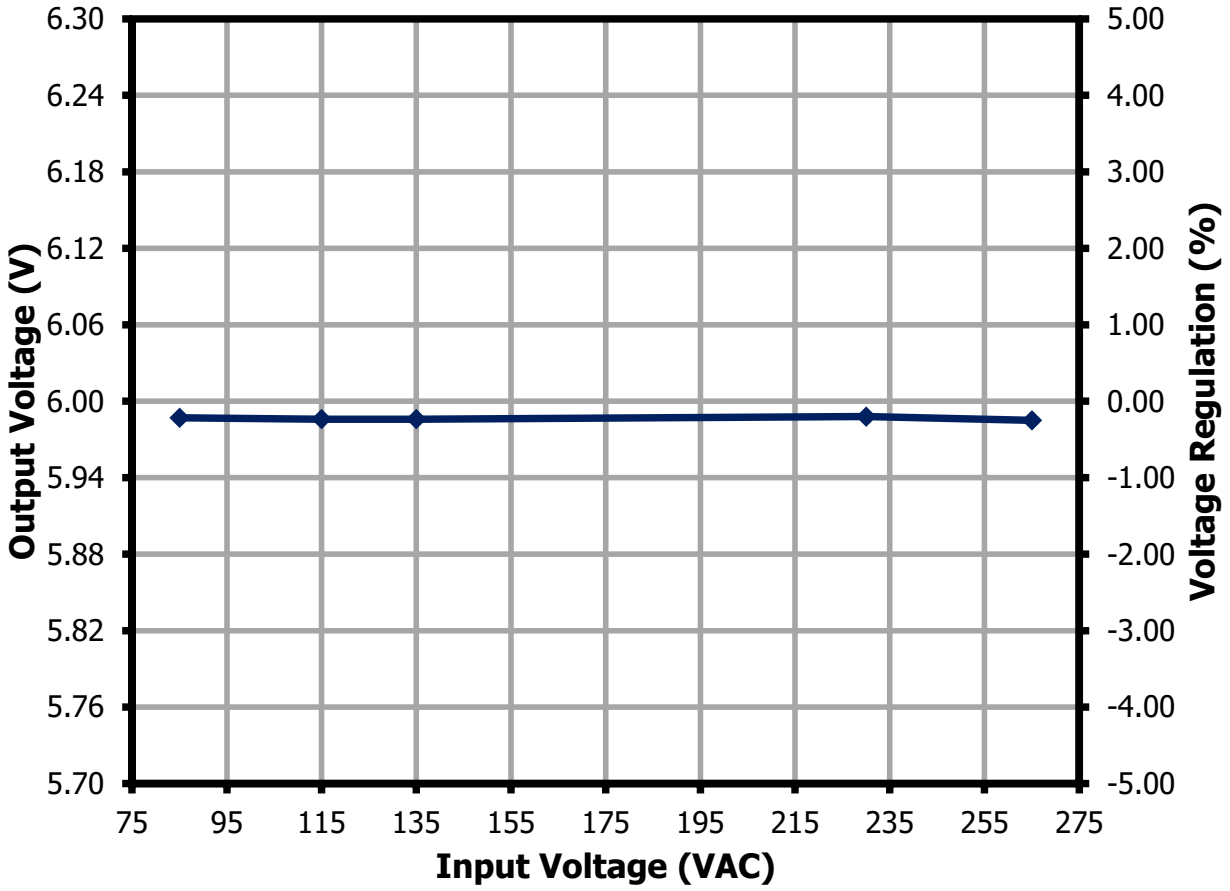

Figure 12 – Full Load Output Voltage vs. Input Voltage, Room Temperature.

10 Thermal Performance

10.1 *Ambient Thermal Performance*

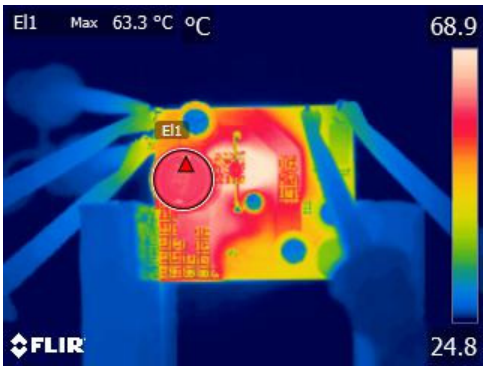

Figure 13 – Output Choke (El1), 63.3 ºC.
85 VAC, 1 A Output.

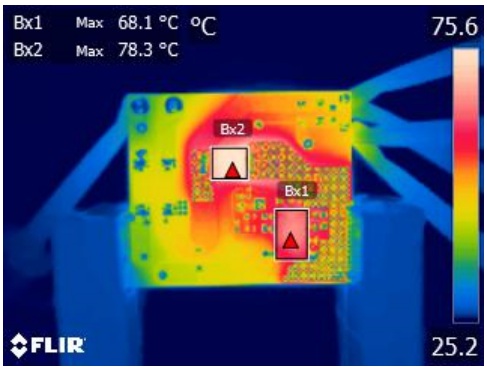

Figure 14 – LNK3209G (Bx1), 68.1 ºC.
Buck Diode (Bx2), 78.3 ºC.
85 VAC, 1 A Output.

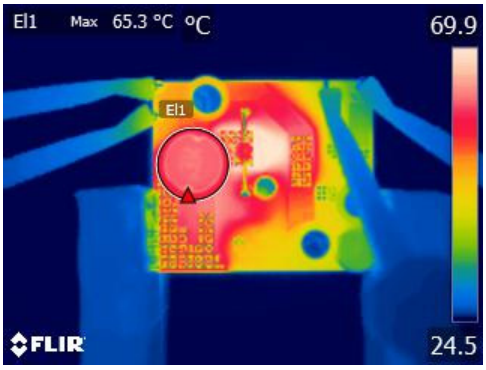

Figure 15 – Output Choke (El1), 65.3 ºC.
135 VAC, 1 A Output.

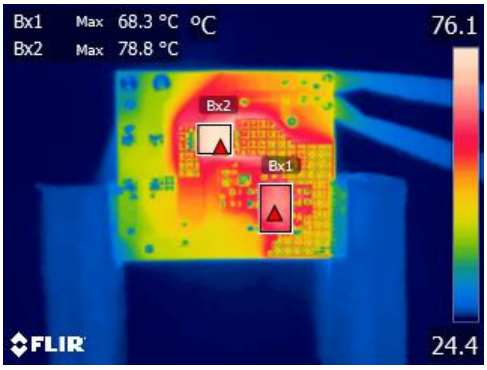

Figure 16 – LNK3209G (Bx1), 68.3 ºC.
Buck Diode (Bx2), 78.8 ºC.
135 VAC, 1 A Output.

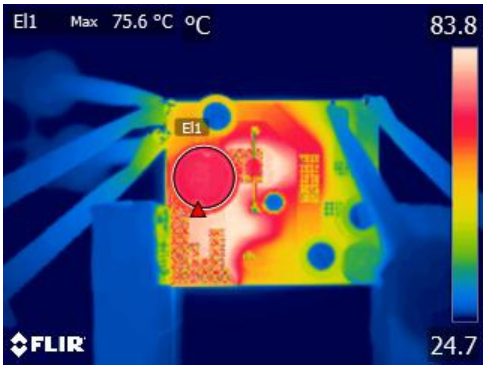

Figure 17 – Output Choke (El1), 75.6 ºC.
265 VAC, 1 A Output.

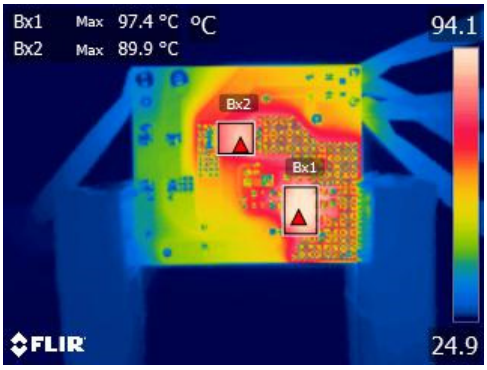

Figure 18 – LNK3209G (Bx1), 97.4 ºC.
Buck Diode (Bx2), 89.9 ºC.
265 VAC, 1 A Output.

10.2 *40 ºC Thermal Performance*

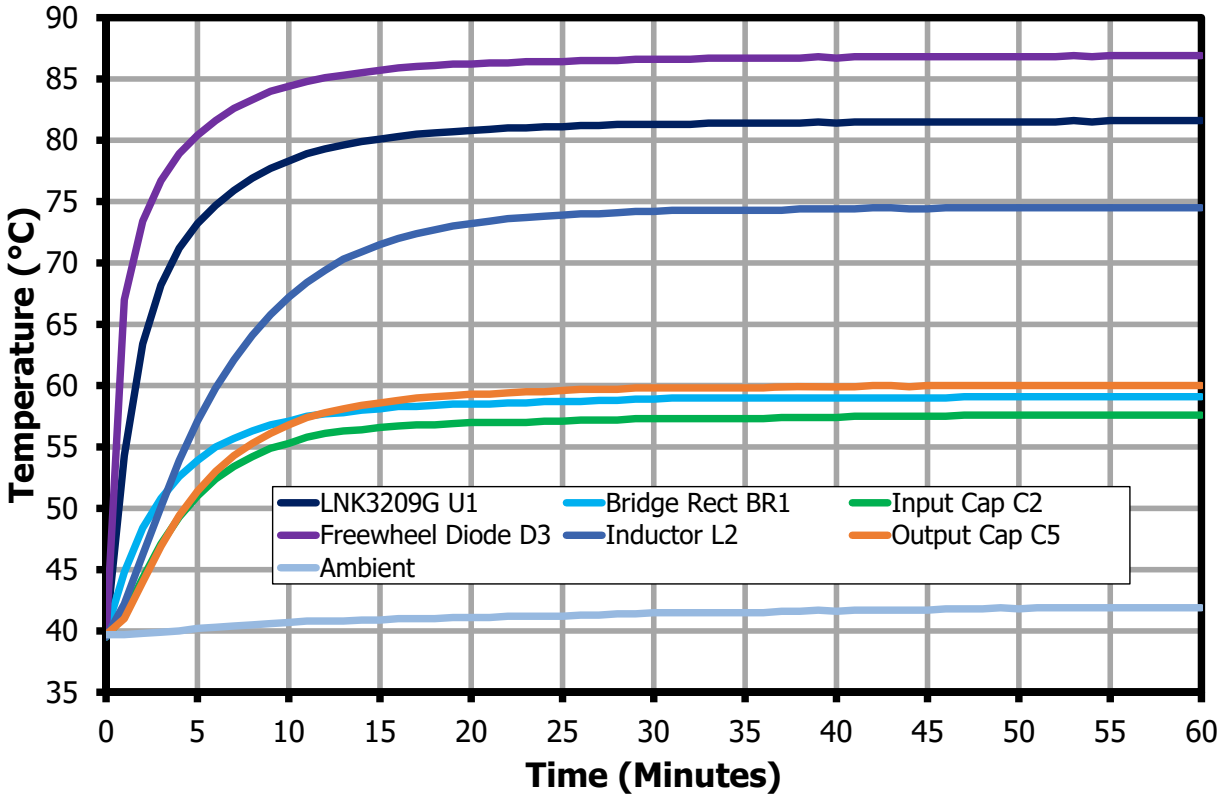

Figure 19 – 85 VAC Thermal Performance at Full Load.

Component	Temperature (°C)
LNK3209G U1	81.6
Bridge Rectifier BR1	59.1
Input Capacitor C2	57.6
Freewheel Diode D3	86.9
Inductor L2	74.5
Output Capacitor C5	60
Ambient Temperature	41.9

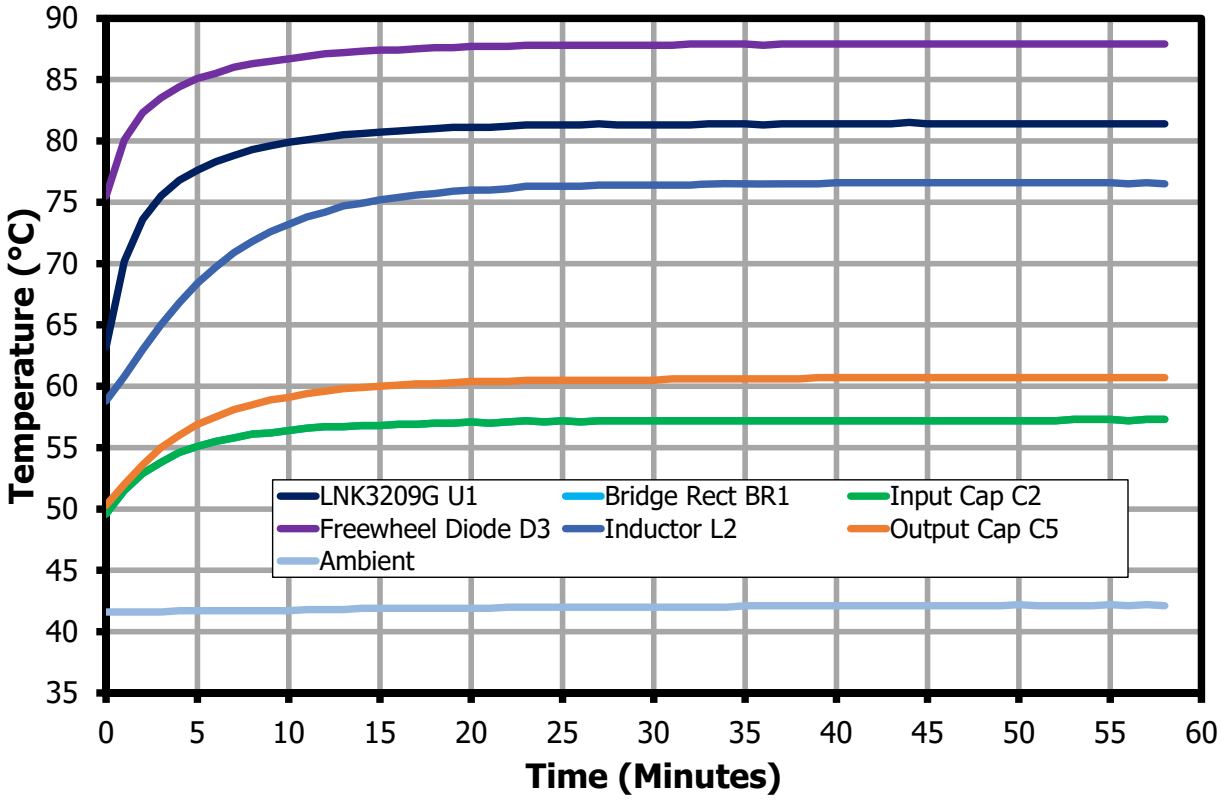

Figure 20 – 135 VAC Thermal Performance at Full Load.

Component	Temperature (°C)
LNK3209G U1	81.4
Bridge Rectifier BR1	57.3
Input Capacitor C2	56.2
Freewheel Diode D3	87.9
Inductor L2	76.5
Output Capacitor C5	60.7
Ambient Temperature	42.1

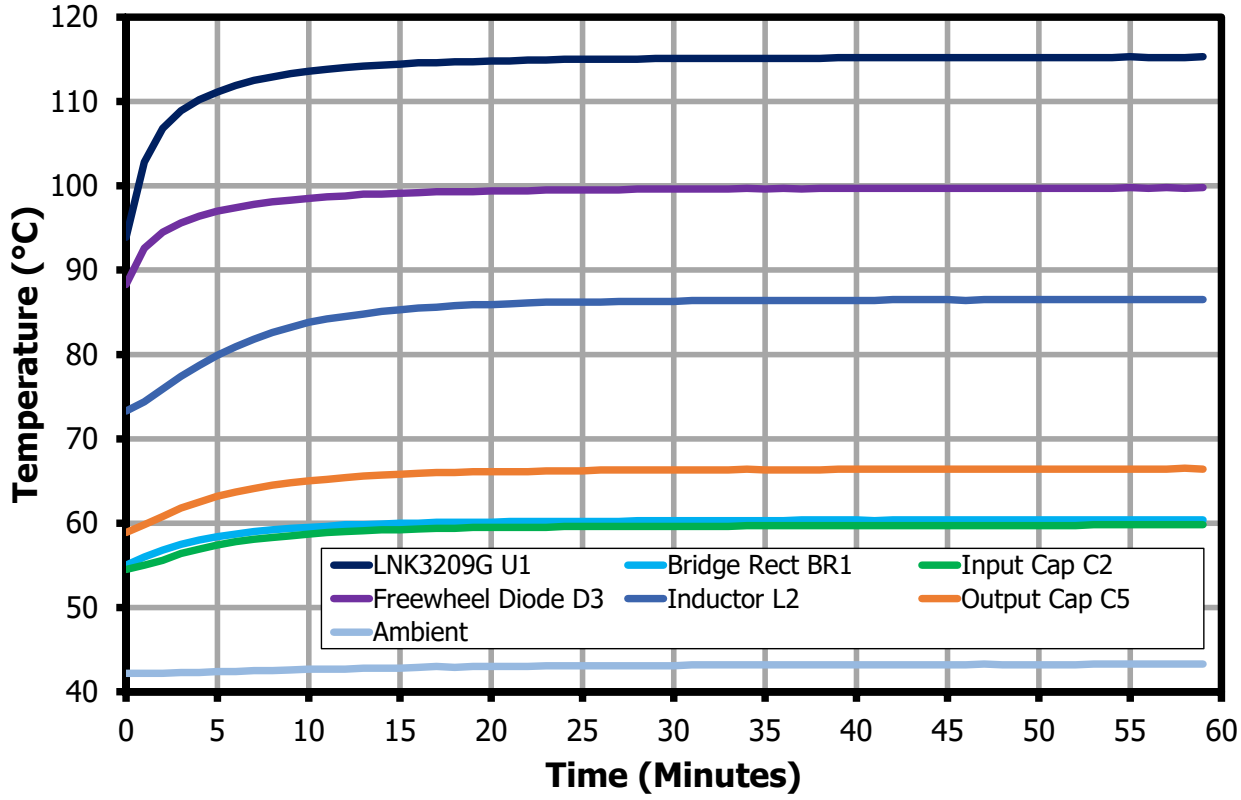

Figure 21 – 265 VAC Thermal Performance at Full Load.

Component	Temperature (°C)
LNK3209G U1	115.3
Bridge Rectifier BR1	60.4
Input Capacitor C2	59.8
Freewheel Diode D3	99.8
Inductor L2	86.5
Output Capacitor C5	66.4
Ambient Temperature	43.3

10.3 *Thermal Shutdown and Hysteresis*

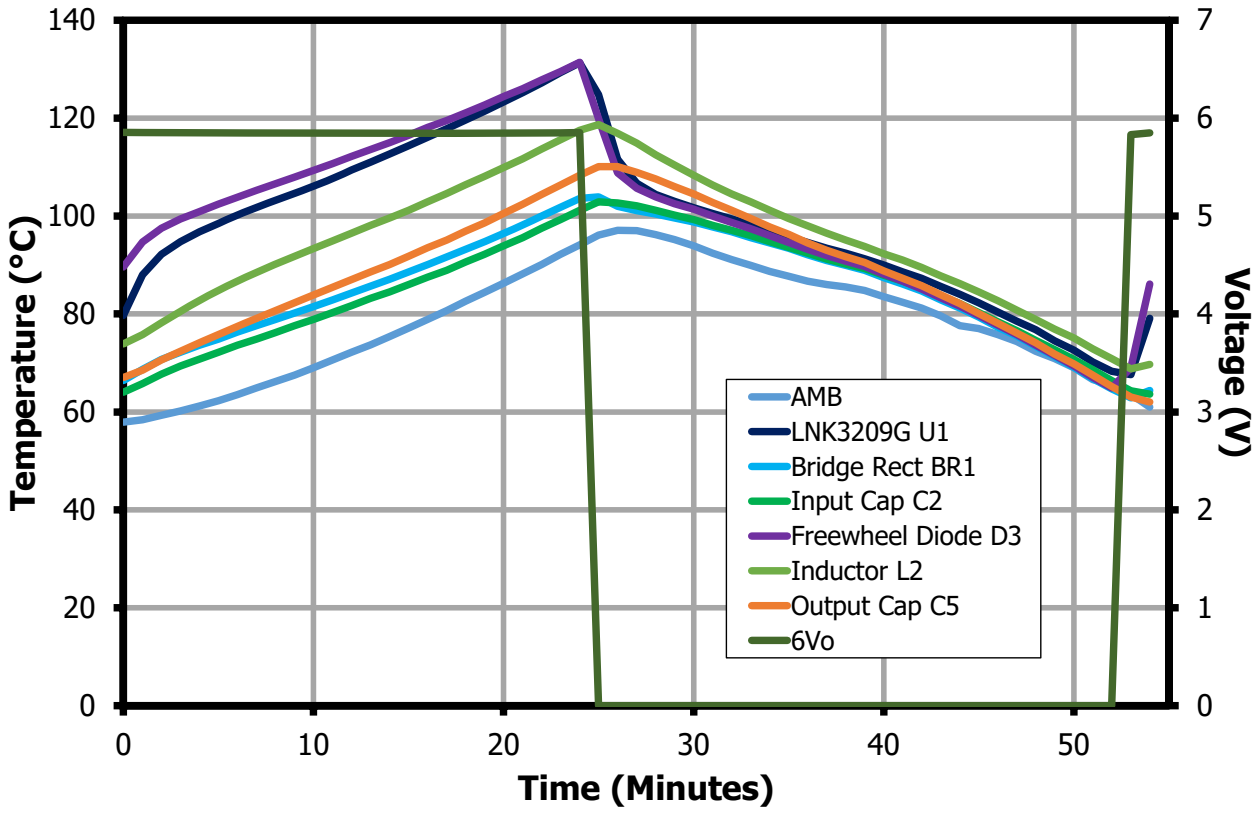

Figure 22 – 85 VAC, Io = 100% Load.
LNK3209G OTP: 131.3 ºC.
LNK3209G Recovery: 67.6 ºC.

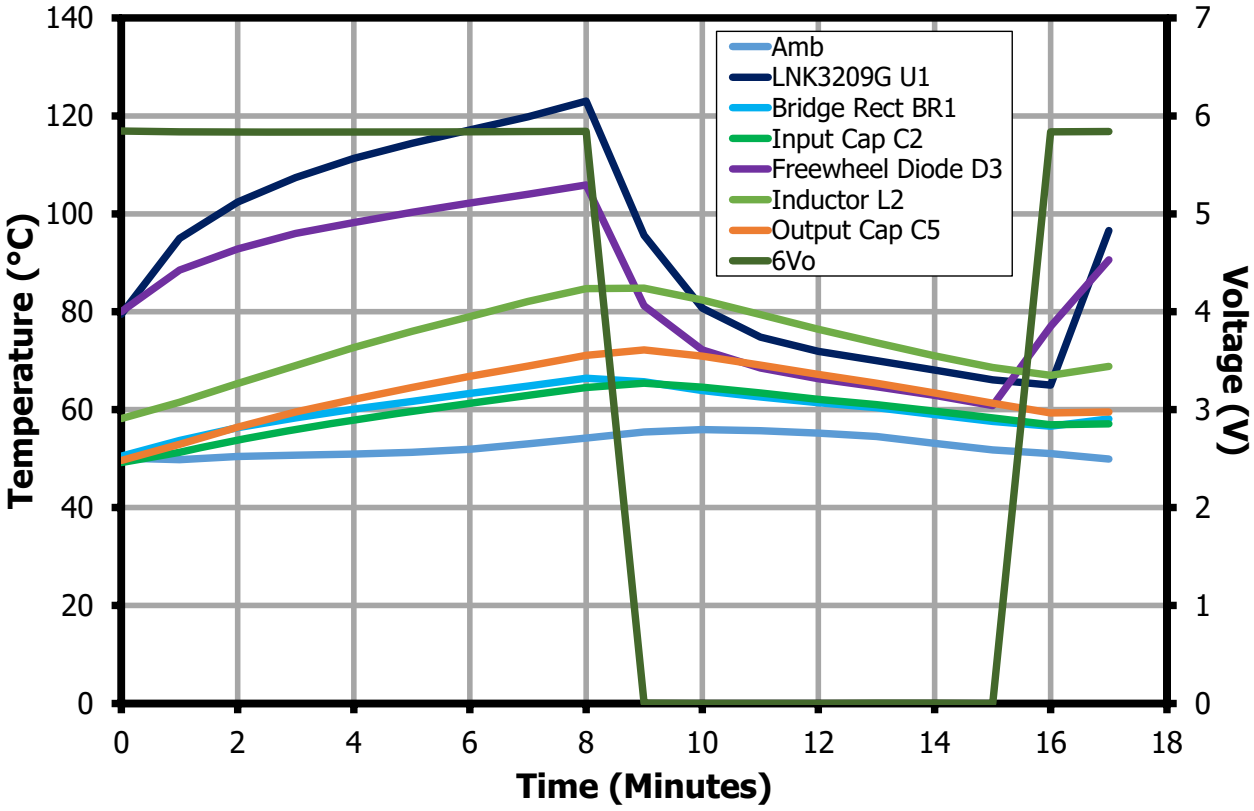

Figure 23 – 265 VAC, Io = 100% Load.
LNK3209G OTP: 123 ºC.
LNK3209G Recovery: 65 ºC.

11 Waveforms

11.1 *Switching Waveforms*

11.1.1 V_{DS} and I_{DS} Waveforms Normal Operation

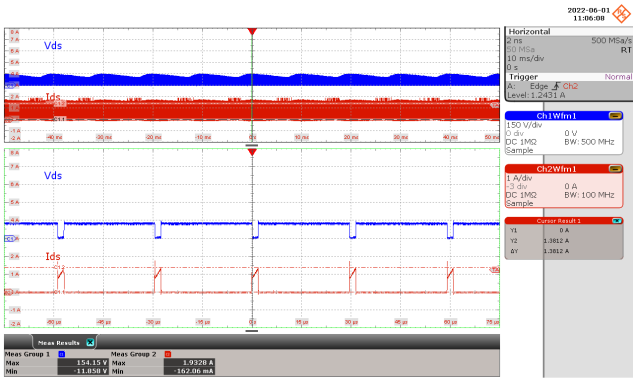

Figure 24 – Drain Voltage and Current Waveforms.
85 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.9328 A, $V_{DS(MAX)}$ = 154.15 V.

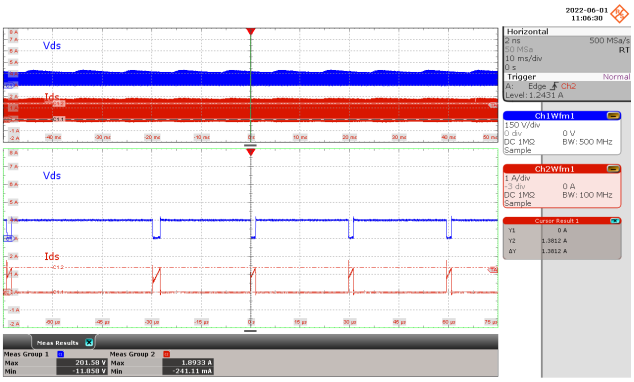

Figure 25 – Drain Voltage and Current Waveforms.
115 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.8933 A, $V_{DS(MAX)}$ = 201.58 V.

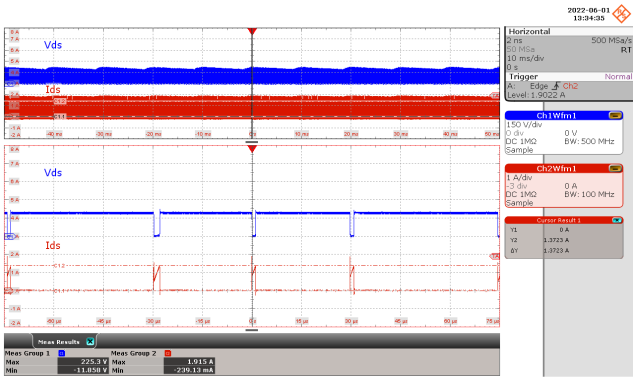

Figure 26 – Drain Voltage and Current Waveforms.
135 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.915 A, $V_{DS(MAX)}$ = 225.3 V.

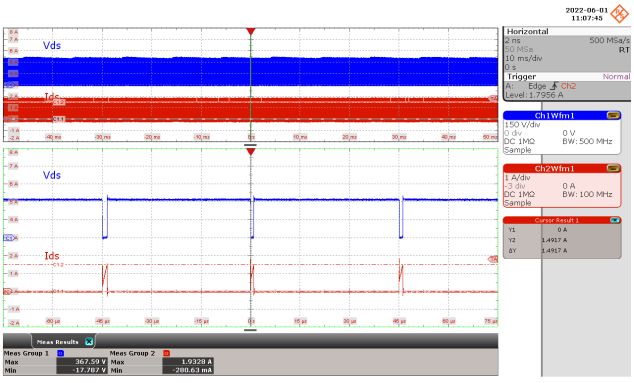

Figure 27 – Drain Voltage and Current Waveforms.
230 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.9328 A, $V_{DS(MAX)}$ = 367.59 V.

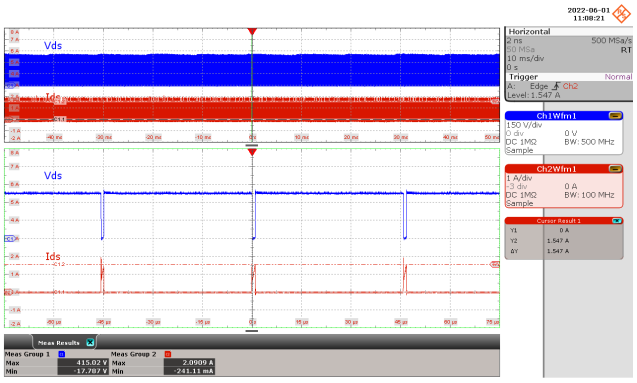

Figure 28 – Drain Voltage and Current Waveforms.
265 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 2.0909 A, $V_{DS(MAX)}$ = 415.02 V.

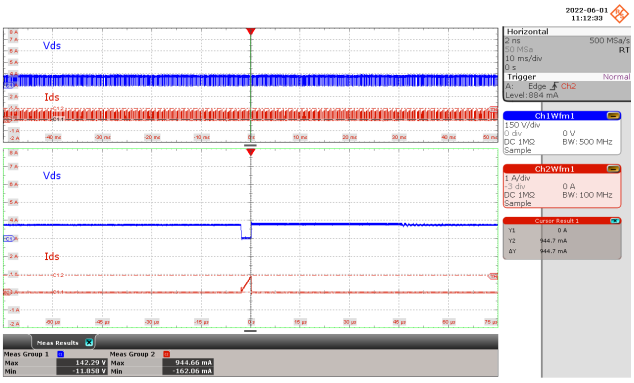

Figure 29 – Drain Voltage and Current Waveforms.
85 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 944.66 mA, $V_{DS(MAX)}$ = 142.29 V.

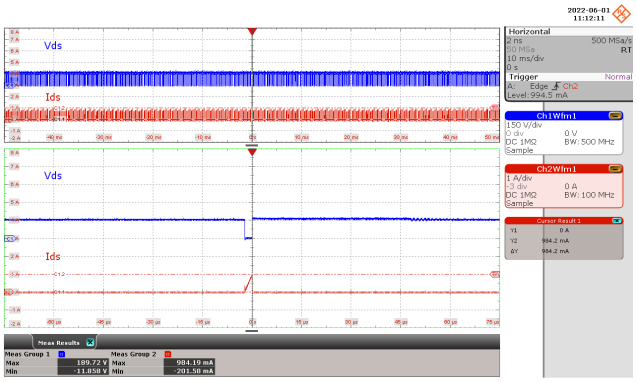

Figure 30 – Drain Voltage and Current Waveforms.
115 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 984.19 mA, $V_{DS(MAX)}$ = 189.72 V.

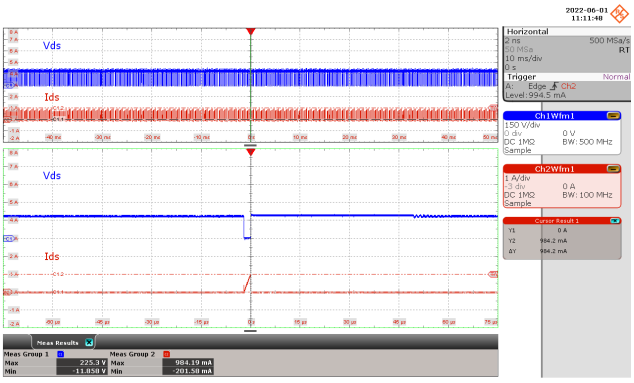

Figure 31 – Drain Voltage and Current Waveforms.
135 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 984.19 mA, $V_{DS(MAX)}$ = 225.3 V.

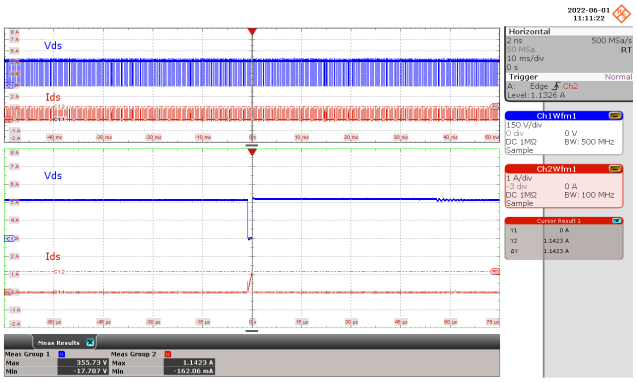

Figure 32 – Drain Voltage and Current Waveforms.
230 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.1423 A, $V_{DS(MAX)}$ = 355.73 V.

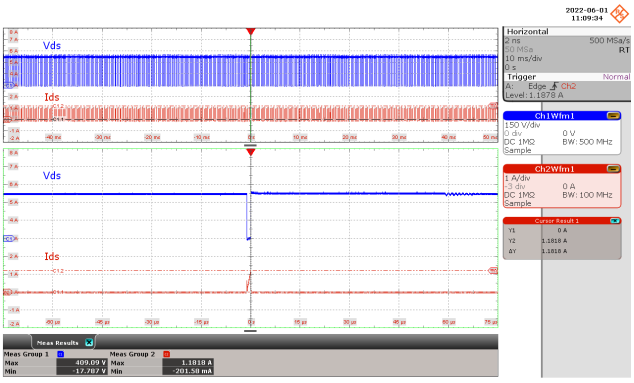

Figure 33 – Drain Voltage and Current Waveforms.
265 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.1818 mA, $V_{DS(MAX)}$ = 409.09 V.

11.1.2 Drain Voltage and Current Waveforms During Start-Up

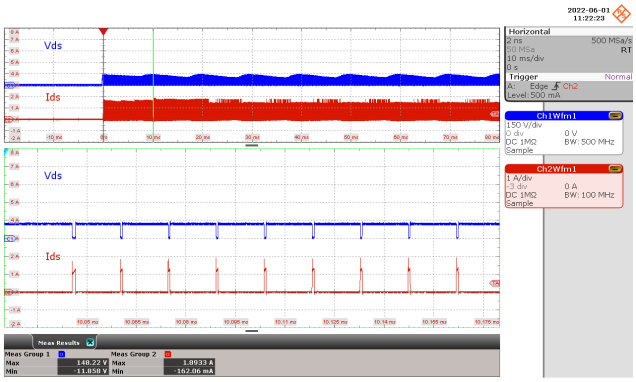

Figure 34 – Drain Voltage and Current Waveforms.
85 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.8933 A, $V_{DS(MAX)}$ = 148.22 V.

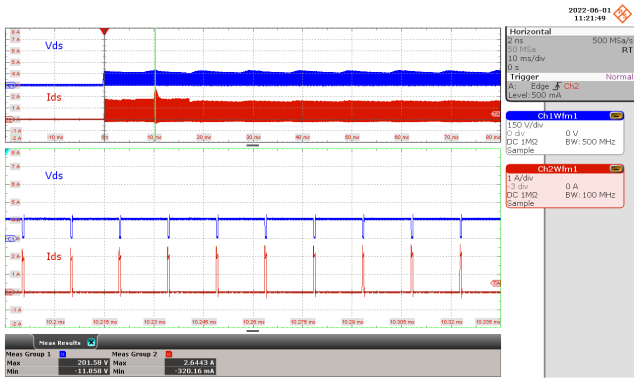

Figure 35 – Drain Voltage and Current Waveforms.
115 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 2.6443 A, $V_{DS(MAX)}$ = 201.58 V.

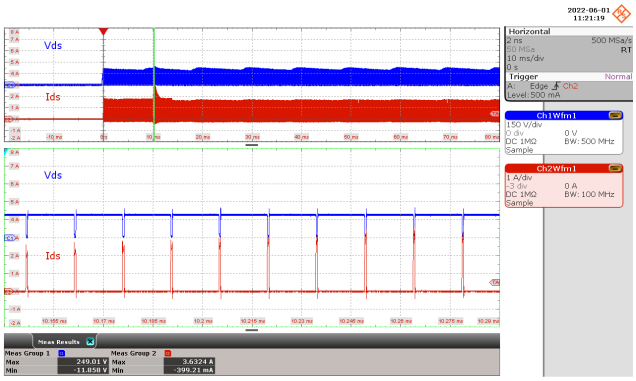

Figure 36 – Drain Voltage and Current Waveforms.
135 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 3.6324 A, $V_{DS(MAX)}$ = 249.01 V.

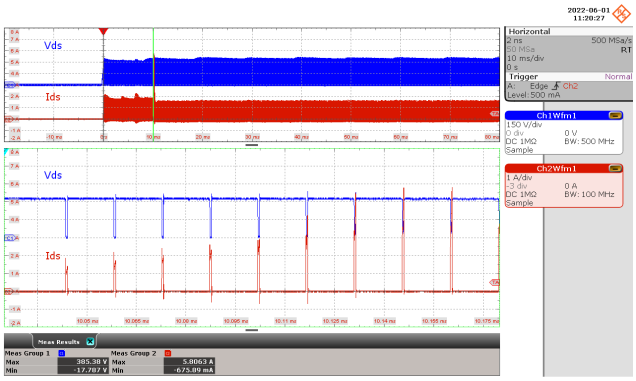

Figure 37 – Drain Voltage and Current Waveforms.
230 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 5.8063 A, $V_{DS(MAX)}$ = 385.38 V.

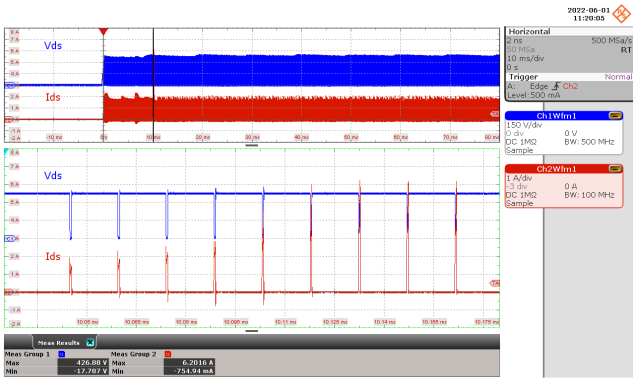

Figure 38 – Drain Voltage and Current Waveforms.
265 VAC, 1 A Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 6.2016 A, $V_{DS(MAX)}$ = 426.88 V.

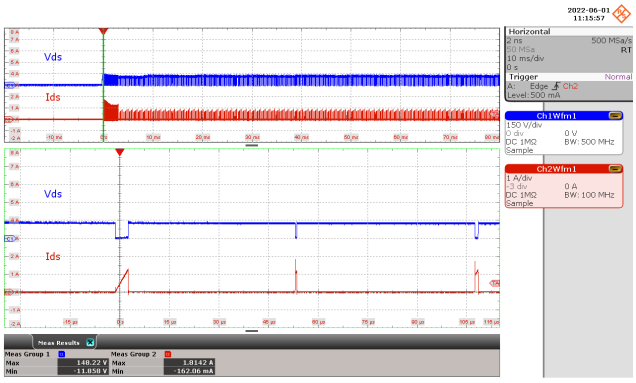

Figure 39 – Drain Voltage and Current Waveforms.
85 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.8142 A, $V_{DS(MAX)}$ = 148.22 V.

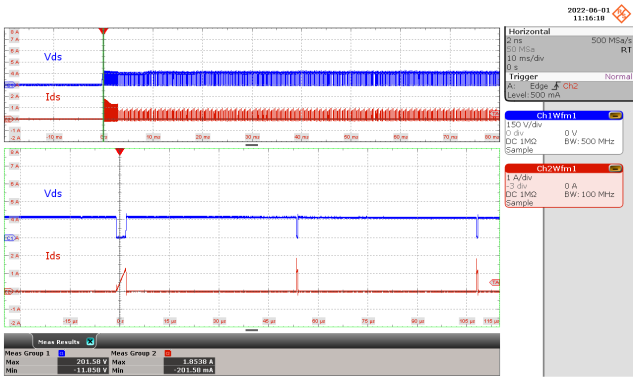

Figure 40 – Drain Voltage and Current Waveforms.
115 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.8538 A, $V_{DS(MAX)}$ = 201.58 V.

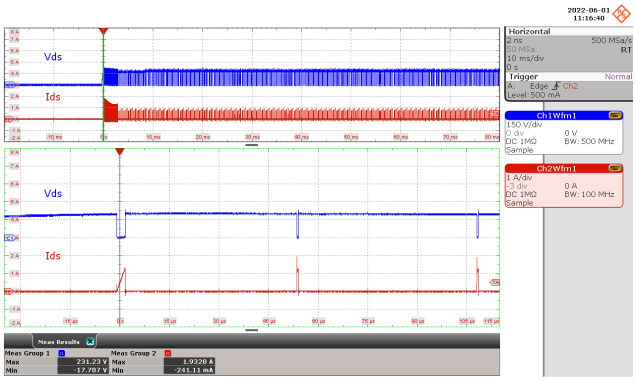

Figure 41 – Drain Voltage and Current Waveforms.
135 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 1.9328 A, $V_{DS(MAX)}$ = 231.23 V.

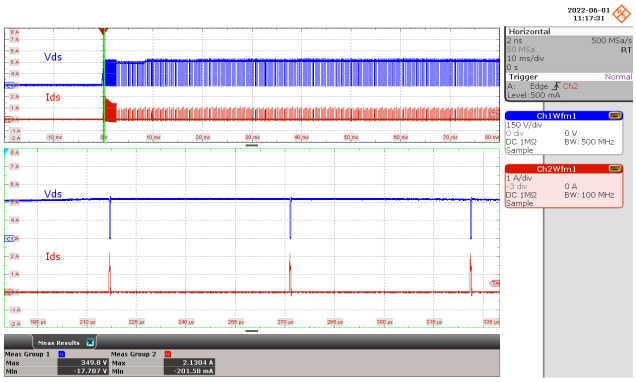

Figure 42 – Drain Voltage and Current Waveforms.
230 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 2.1304 A, $V_{DS(MAX)}$ = 349.8 V.

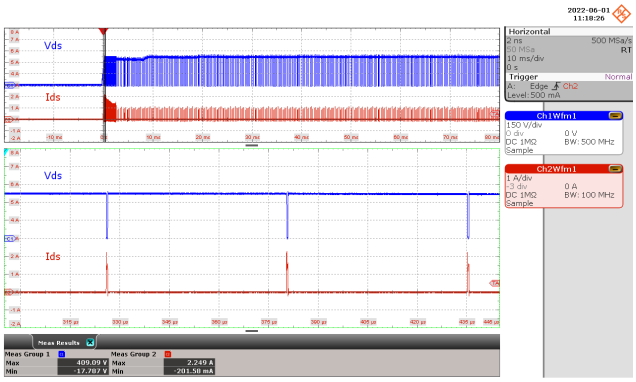

Figure 43 – Drain Voltage and Current Waveforms.
265 VAC, 100 mA Output.
Drain Voltage: 150 V / div., 10 ms / div.
Drain Current: 1 A / div., 10 ms / div.
Zoom = 15 µs / div.
$I_{DS(MAX)}$ = 2.249 A, $V_{DS(MAX)}$ = 409.09 V.

11.1.3 Drain Current and Output Waveform During Output Short

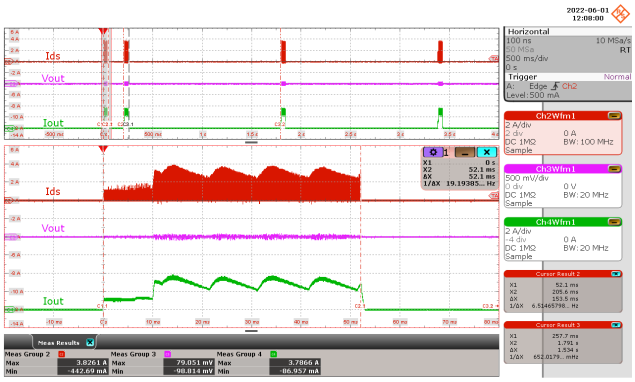

Figure 44 – Drain Current and Output Waveforms.
85 VAC Input.
Drain Current: 2 A / div., 500 ms / div.
Output Voltage: 500 mV / div., 500 ms / div.
Output Current: 2 A / div., 500 ms / div.
Zoom = 10 ms / div.

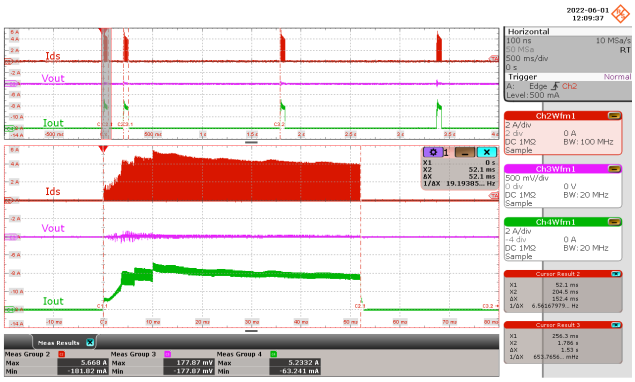

Figure 45 – Drain Current and Output Waveforms.
265 VAC Input.
Drain Current: 2 A / div., 500 ms / div.
Output Voltage: 500 mV / div., 500 ms / div.
Output Current: 2 A / div., 500 ms / div.
Zoom = 10 ms / div.

11.1.4 Freewheeling Diode Waveforms Normal Operation

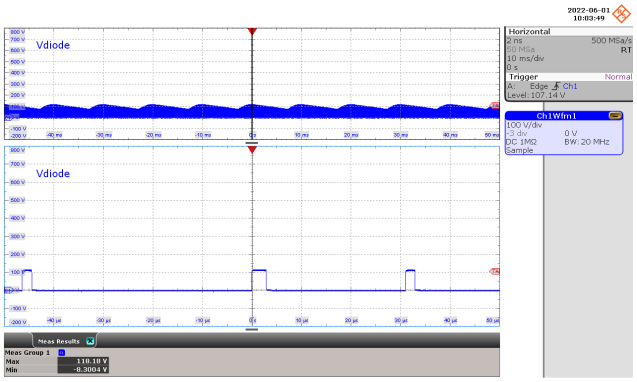

Figure 46 – Freewheeling Diode Voltage Waveforms.
85 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 118.18 V.

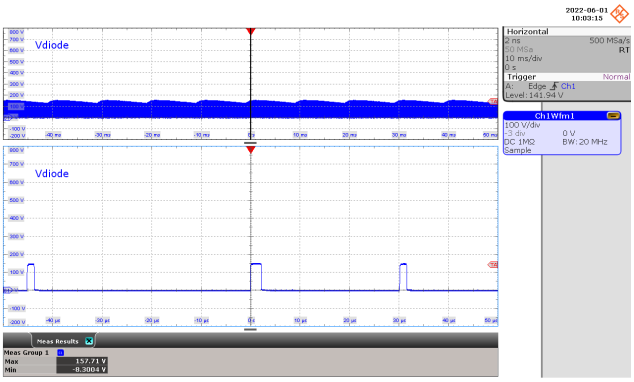

Figure 47 – Freewheeling Diode Voltage Waveforms.
115 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 157.71 V.

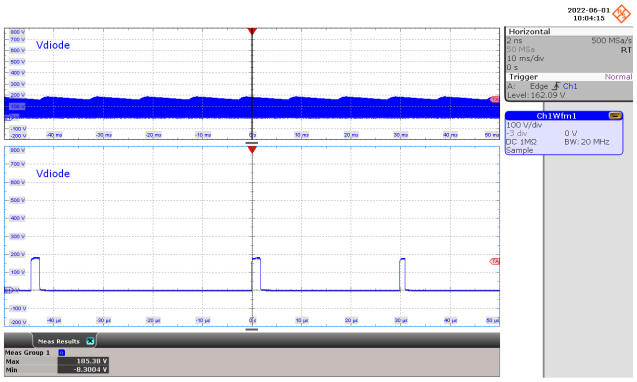

Figure 48 – Freewheeling Diode Voltage Waveforms.
135 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 185.38 V.

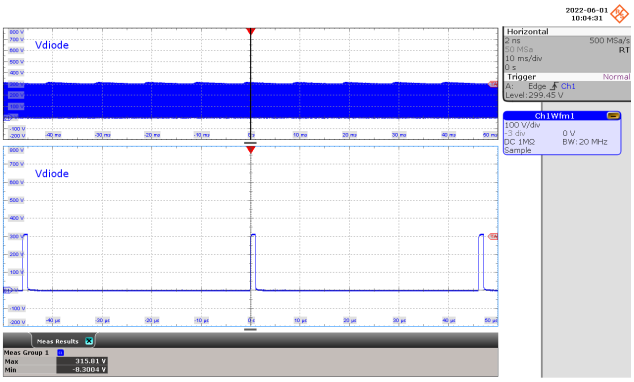

Figure 49 – Freewheeling Diode Voltage Waveforms.
230 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 315.81 V.

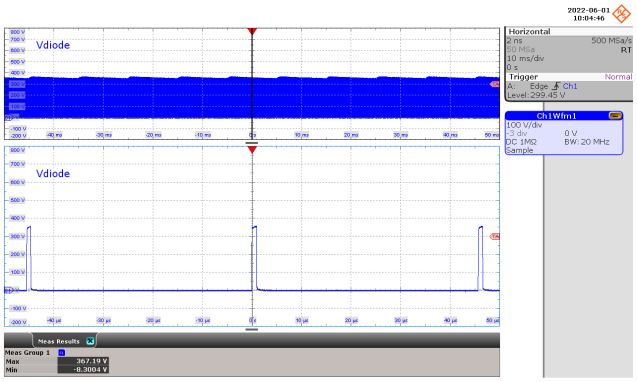

Figure 50 – Freewheeling Diode Voltage Waveforms.
265 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 367.19 V.

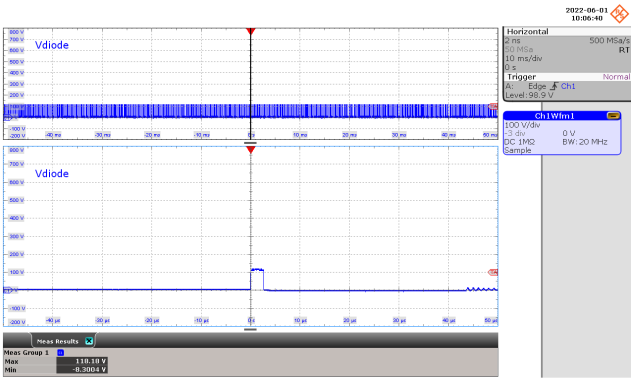

Figure 51 – Freewheeling Diode Voltage Waveforms.
85 VAC, 100 mA Output.
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 118.18 V.

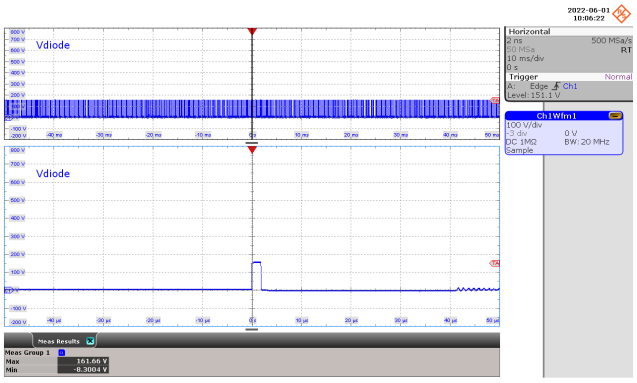

Figure 52 – Freewheeling Diode Voltage Waveforms.
115 VAC, 100 mA Output..
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 161.66 V.

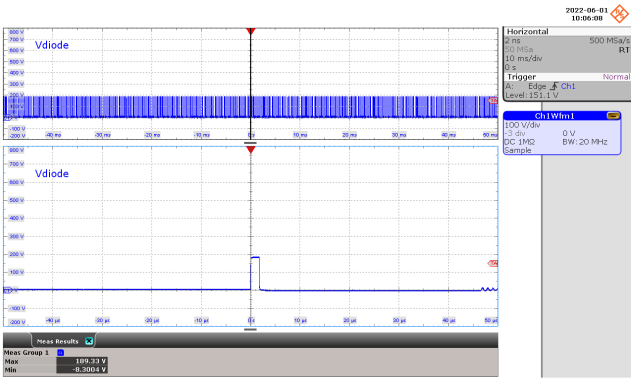

Figure 53 – Freewheeling Diode Voltage Waveforms.
135 VAC, 100 mA Output.
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 189.33 V.

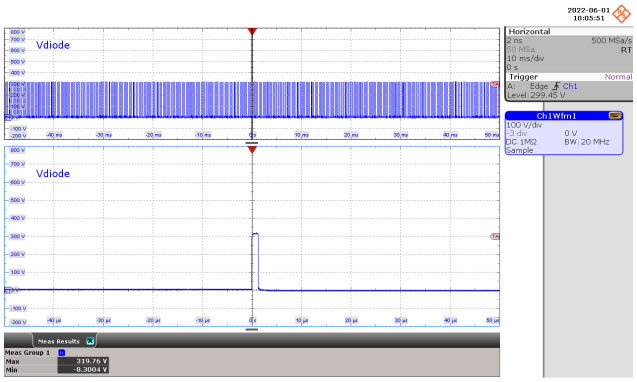

Figure 54 – Freewheeling Diode Voltage Waveforms.
230 VAC, 100 mA Output..
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 319.76 V.

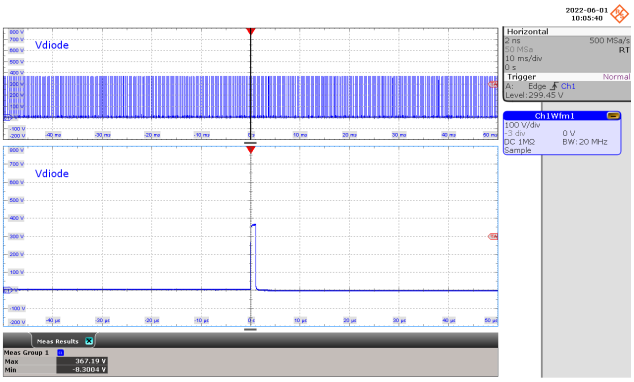

Figure 55 – Freewheeling Diode Voltage Waveforms.
265 VAC, 100 mA Output.
Diode Voltage: 100 V / div., 10 ms / div.
Zoom: 10 µs / div.
V_{MAX}: 367.19 V.

11.1.6 Freewheeling Diode Waveforms Start-Up

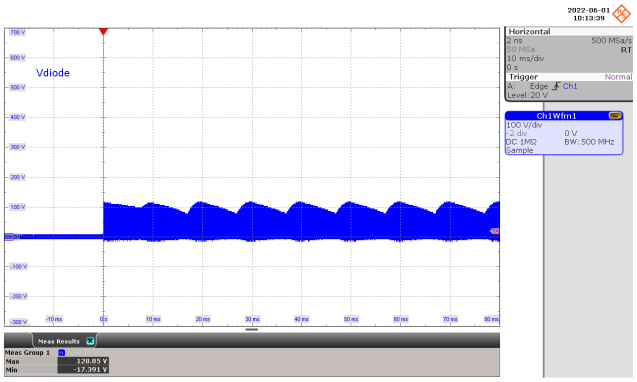

Figure 56 – Freewheeling Diode Voltage Waveforms.
85 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 128.85 V.

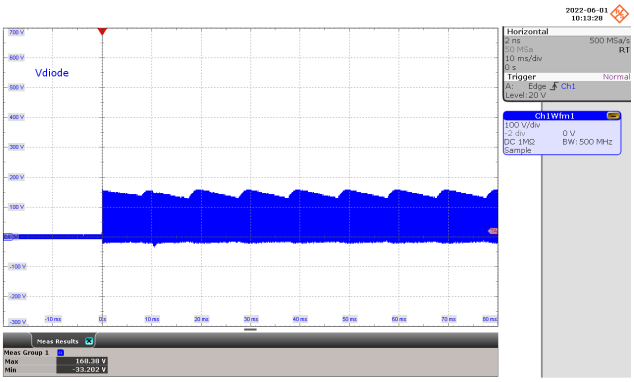

Figure 57 – Freewheeling Diode Voltage Waveforms.
115 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 168.38 V.

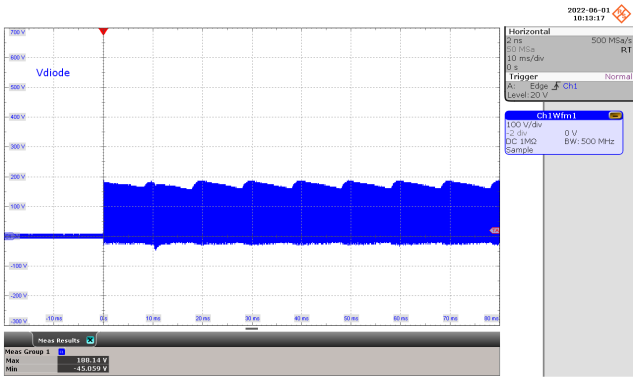

Figure 58 – Freewheeling Diode Voltage Waveforms.
135 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 188.14 V.

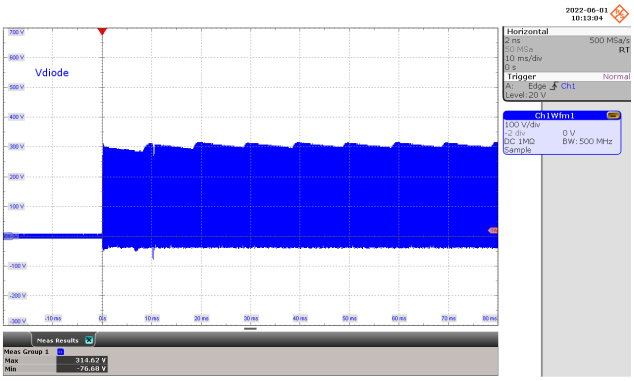

Figure 59 – Freewheeling Diode Voltage Waveforms.
230 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 314.62 V.

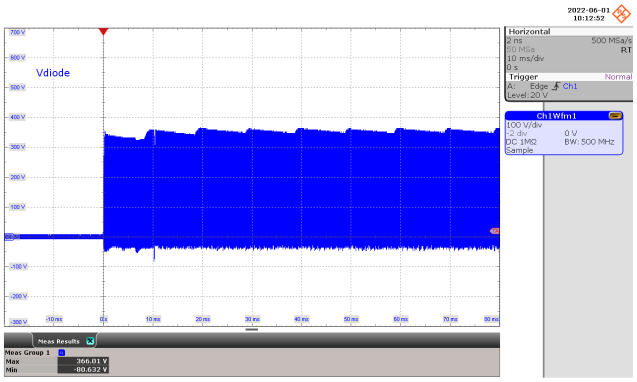

Figure 60 – Freewheeling Diode Voltage Waveforms.
265 VAC, 1 A Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 366.01 V.

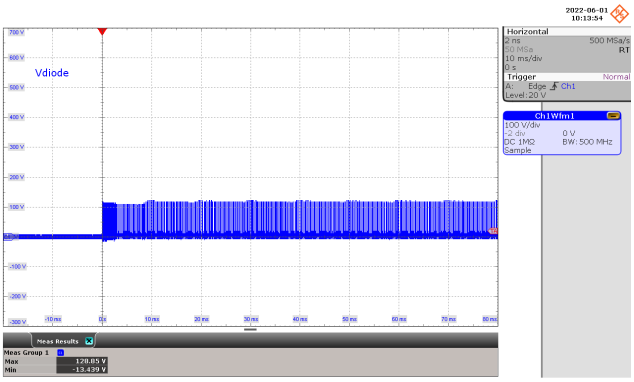

Figure 61 – Freewheeling Diode Voltage Waveforms.
85 VAC, 100 mA Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 128.85 V.

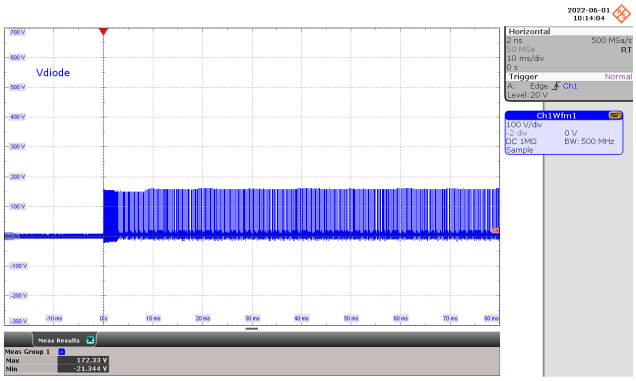

Figure 62 – Freewheeling Diode Voltage Waveforms.
115 VAC, 100 mA Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 172.33 V.

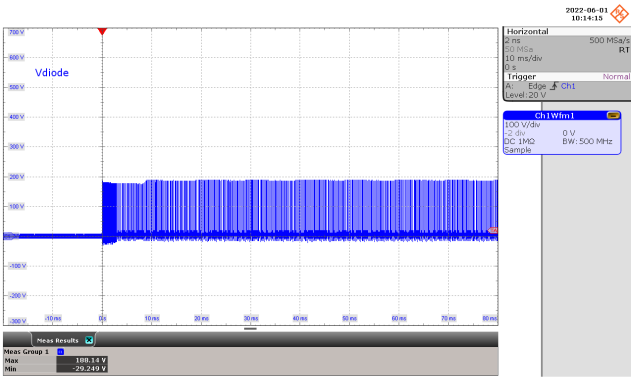

Figure 63 – Freewheeling Diode Voltage Waveforms.
135 VAC, 100 mA Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 188.14 V.

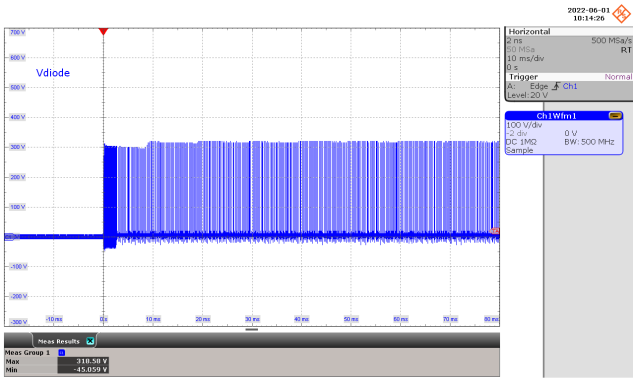

Figure 64 – Freewheeling Diode Voltage Waveforms.
230 VAC, 100 mA Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 318.58 V.

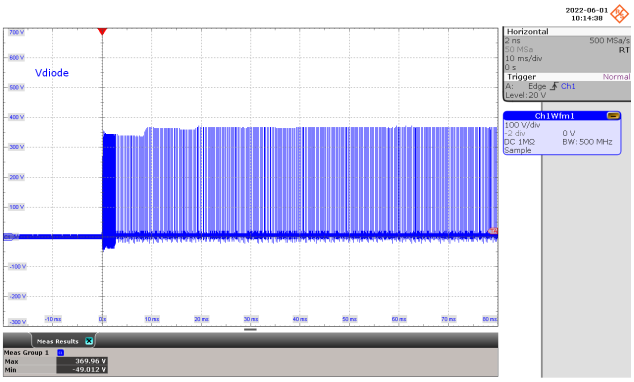

Figure 65 – Freewheeling Diode Voltage Waveforms.
265 VAC, 100 mA Output.
Diode Voltage: 100 V / div., 10 ms / div.
V_{MAX}: 369.96 V.

11.1.7 Output Voltage and Current Waveforms Start-Up (CC mode)

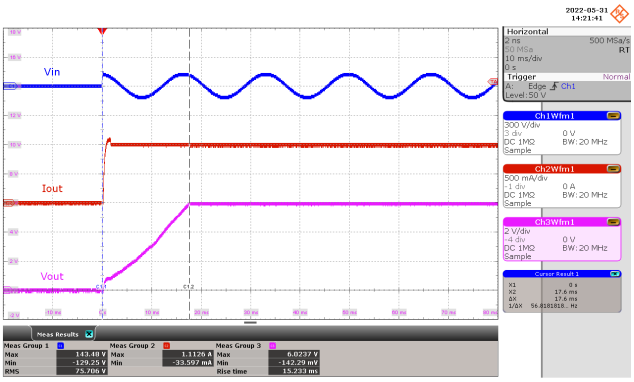

Figure 66 – Output Voltage and Current Waveforms.
85 VAC, 1 A Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 15.233 ms.

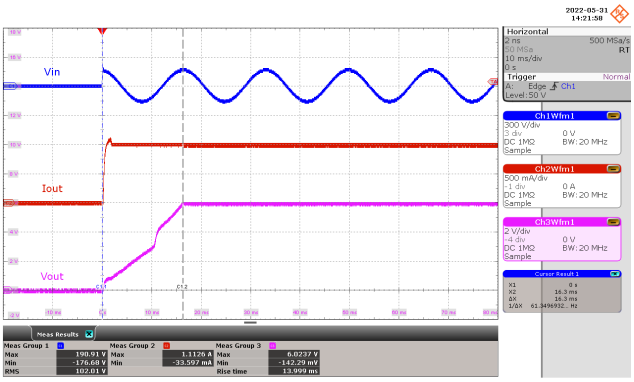

Figure 67 – Output Voltage and Current Waveforms.
115 VAC, 1 A Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 13.999 ms.

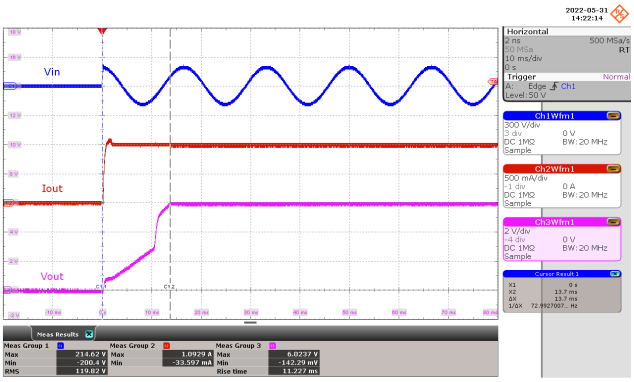

Figure 68 – Output Voltage and Current Waveforms.
135 VAC, 1 A Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 11.227 ms.

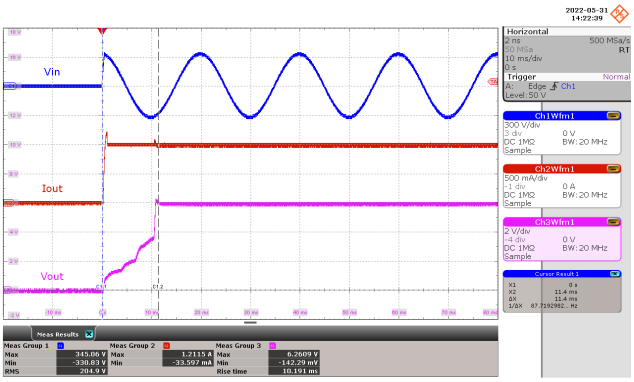

Figure 69 – Output Voltage and Current Waveforms.
230 VAC, 1 A Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 10.191 ms.

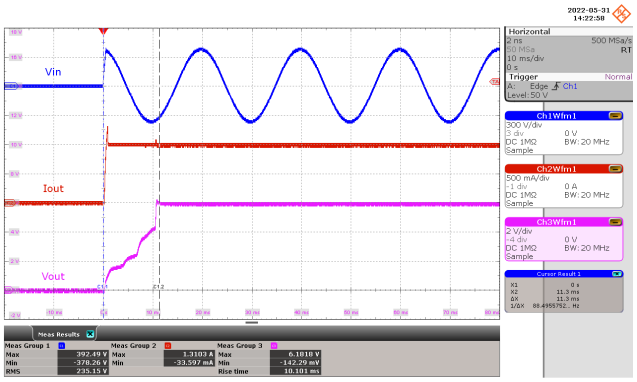

Figure 70 – Output Voltage and Current Waveforms.
265 VAC, 1 A Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 10.101 ms.

11.1.8 Output Voltage and Current Waveforms Start-Up (CR mode)

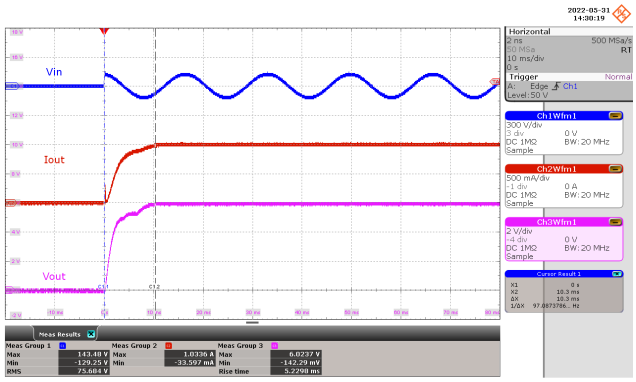

Figure 71 – Output Voltage and Current Waveforms.
85 VAC, 6 Ω Load.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 5.2298 ms.

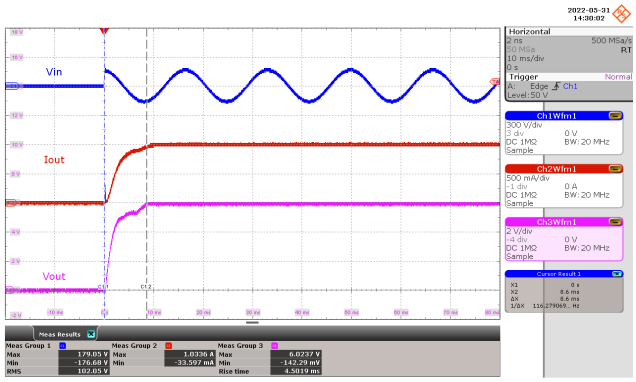

Figure 72 – Output Voltage and Current Waveforms.
115 VAC, 6 Ω Load.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 4.5019 ms.

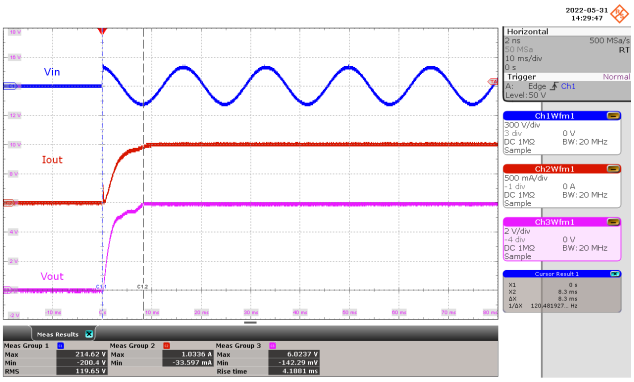

Figure 73 – Output Voltage and Current Waveforms.
135 VAC, 6 Ω Load.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 4.1881 ms.

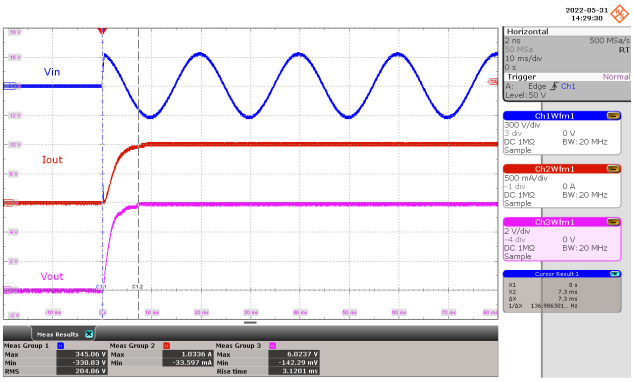

Figure 74 – Output Voltage and Current Waveforms.
230 VAC, 6 Ω Load.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 3.1201 ms.

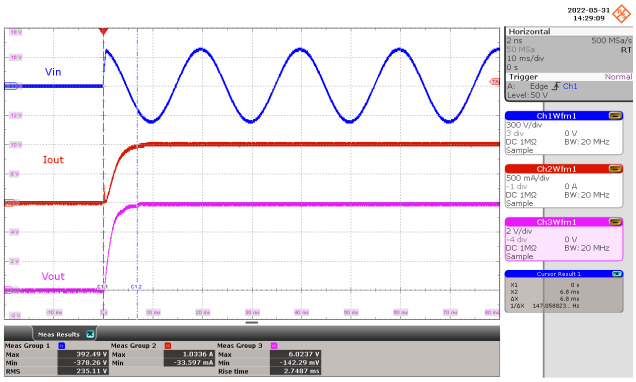

Figure 75 – Output Voltage and Current Waveforms.
265 VAC, 6 Ω Load.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 2.7487 ms.

11.1.9 Output Voltage and Current Waveforms Start-Up (Minimum Load)

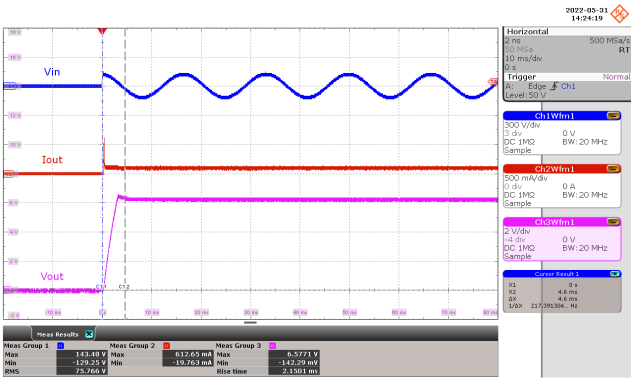

Figure 76 – Output Voltage and Current Waveforms.
85 VAC, 100 mA Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 2.1501 ms.

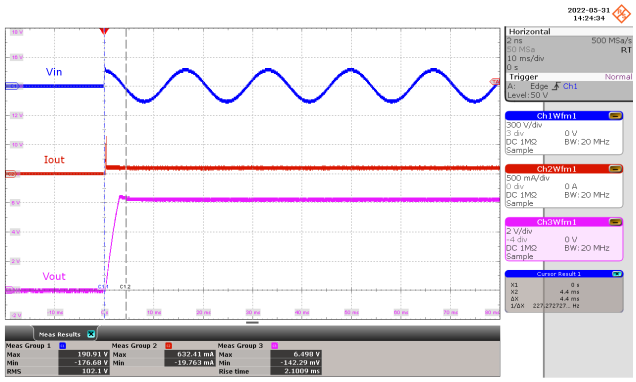

Figure 77 – Output Voltage and Current Waveforms.
115 VAC, 100 mA Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div..
Rise Time = 2.1009 ms.

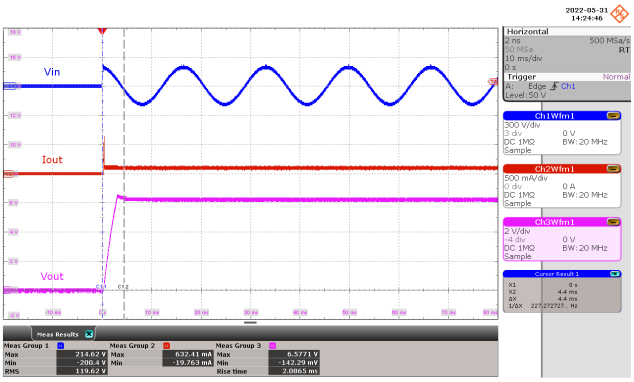

Figure 78 – Output Voltage and Current Waveforms.
135 VAC, 100 mA Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 2.0865 ms.

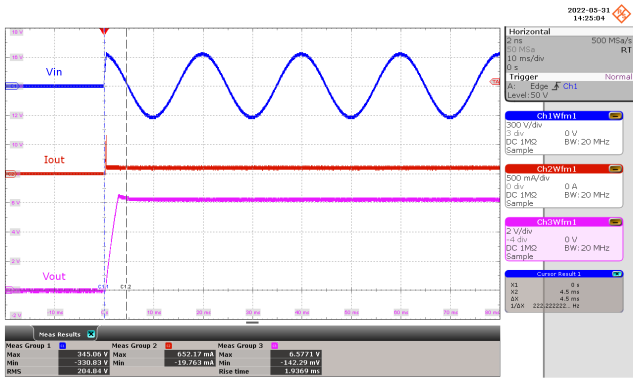

Figure 79 – Output Voltage and Current Waveforms.
230 VAC, 100 mA Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 1.9369 ms.

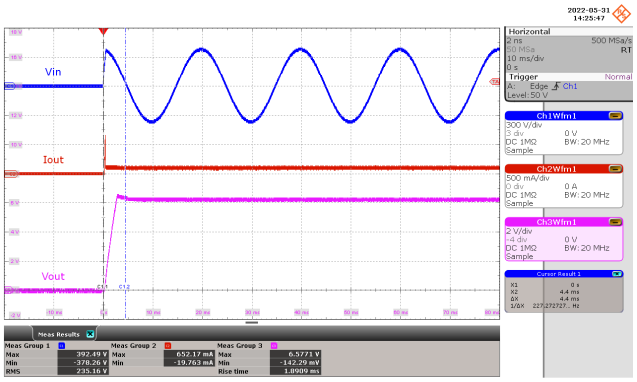

Figure 80 – Output Voltage and Current Waveforms.
265 VAC, 100 mA Output.
Input Voltage: 300 V / div., 10 ms / div.
Output Current: 500 mA / div., 10 ms / div.
Output Voltage: 2 V / div., 10 ms / div.
Rise Time = 1.8909 ms.

11.2 ***Output Ripple Measurements***

11.2.1 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) 1 μF/50 V aluminum electrolytic. The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).

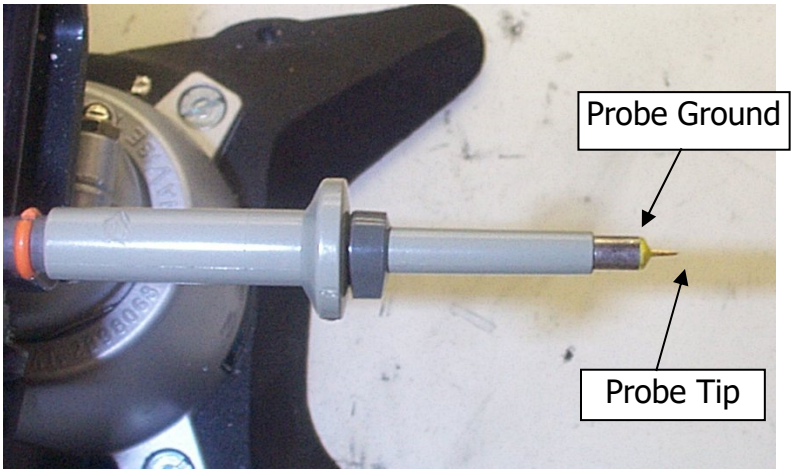

Figure 81 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed.)

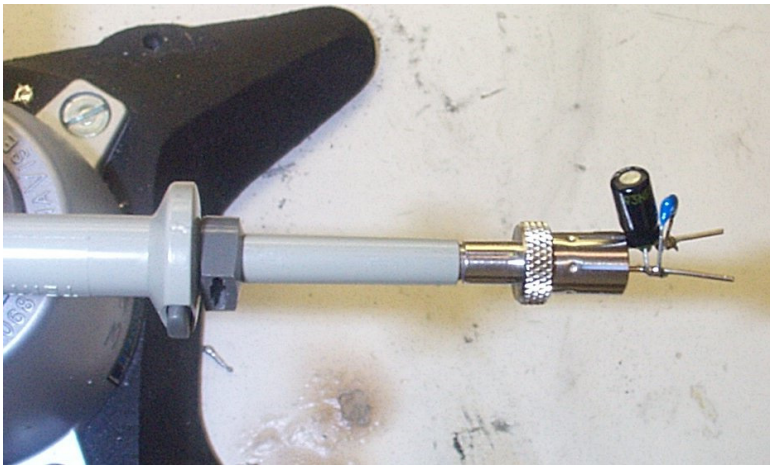

Figure 82 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added.)

11.2.2 Measurement Results

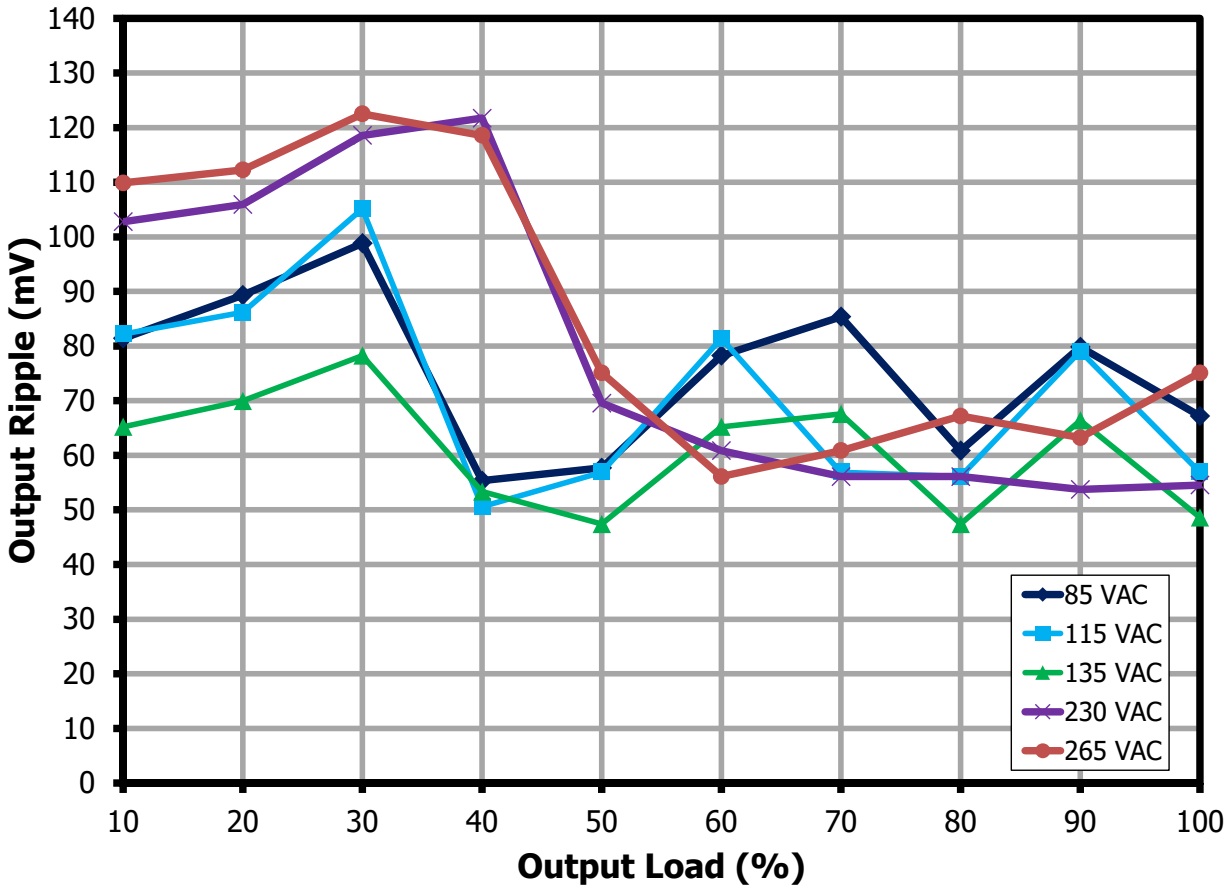

Figure 83 – Output Ripple Voltage.

11.2.3 Ripple Voltage Waveforms

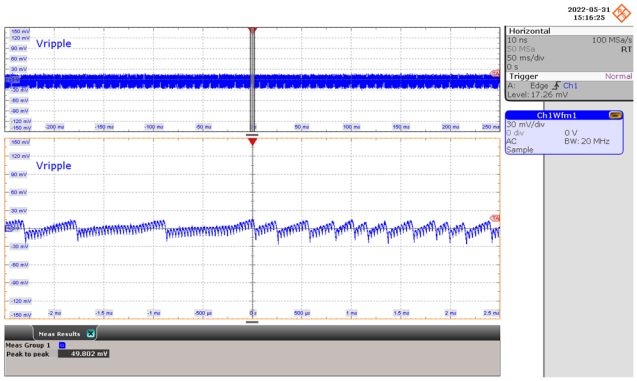

Figure 84 – Output Voltage Ripple Waveforms.
85 VAC, 1 A Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 49.802 mV.

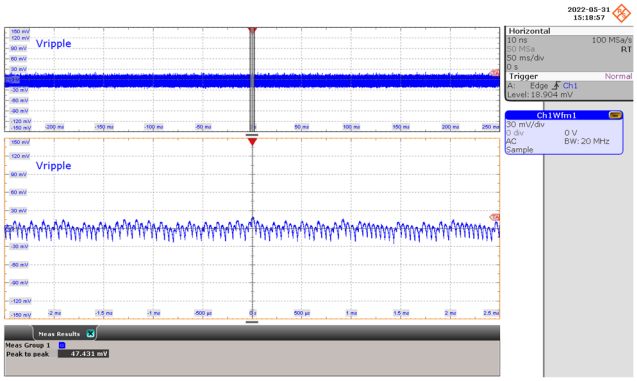

Figure 85 – Output Voltage Ripple Waveforms.
85 VAC, 750 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 47.431 mV.

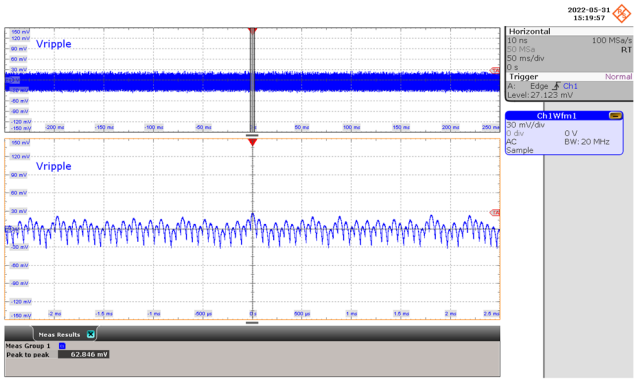

Figure 86 – Output Voltage Ripple Waveforms.
85 VAC, 500 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 62.846 mV.

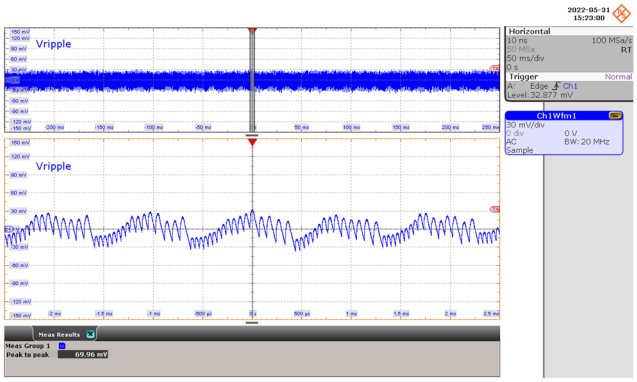

Figure 87 – Output Voltage Ripple Waveforms.
85 VAC, 250 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 69.96 mV.

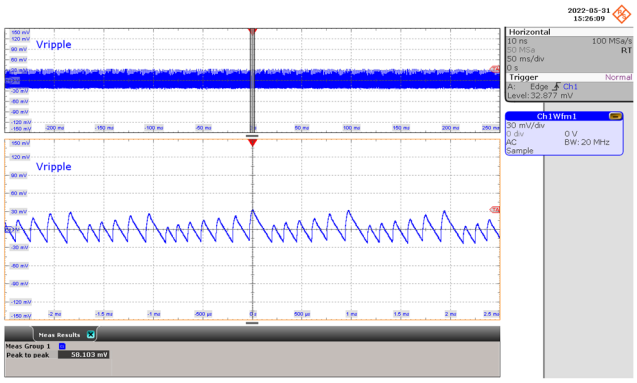

Figure 88 – Output Voltage Ripple Waveforms.
85 VAC, 100 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 58.103 mV.

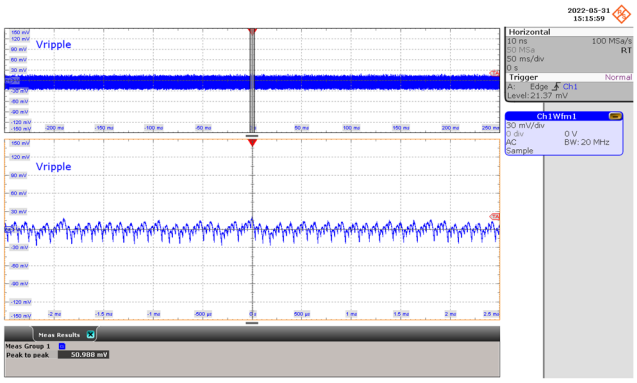

Figure 89 – Output Voltage Ripple Waveforms.
115 VAC, 1 A Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 50.988 mV.

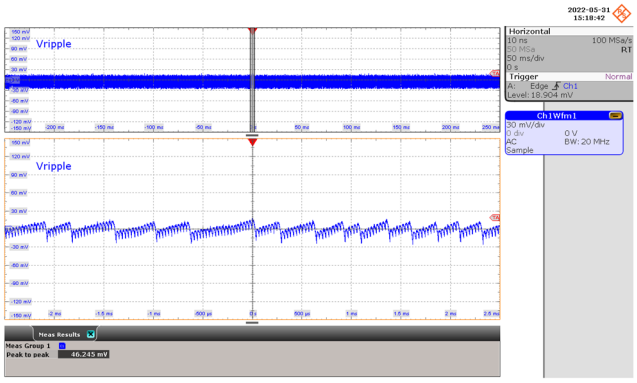

Figure 90 – Output Voltage Ripple Waveforms.
115 VAC, 750 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 46.245 mV.

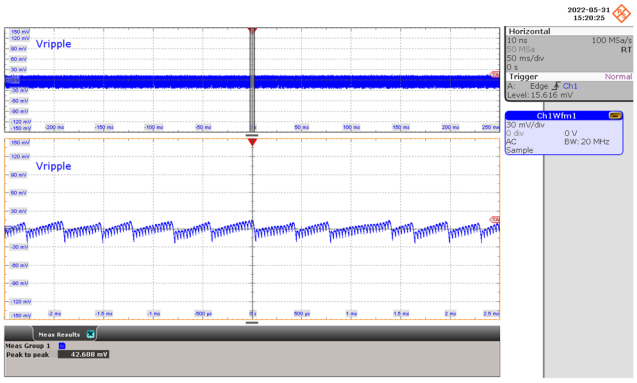

Figure 91 – Output Voltage Ripple Waveforms.
115 VAC, 500 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 42.688 mV.

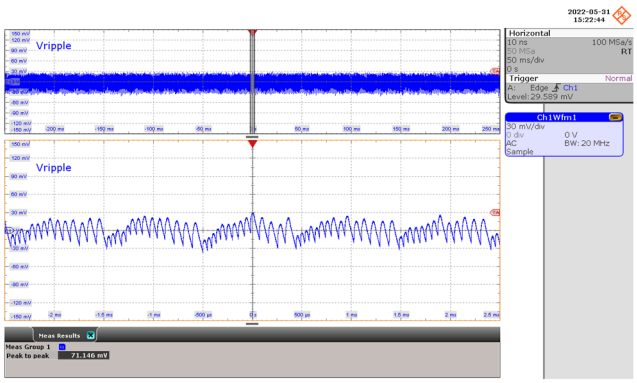

Figure 92 – Output Voltage Ripple Waveforms.
115 VAC, 250 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 71.146 mV.

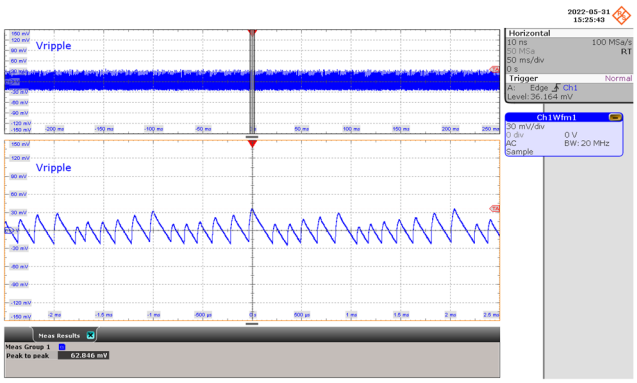

Figure 93 – Output Voltage Ripple Waveforms.
115 VAC,100 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 62.846 mV.

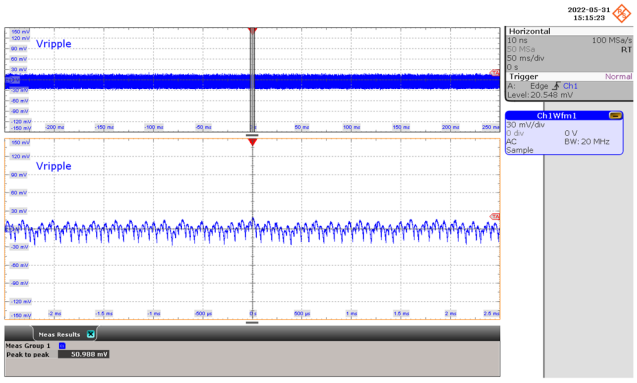

Figure 94 – Output Voltage Ripple Waveforms.
135 VAC, 1 A Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 50.988 mV.

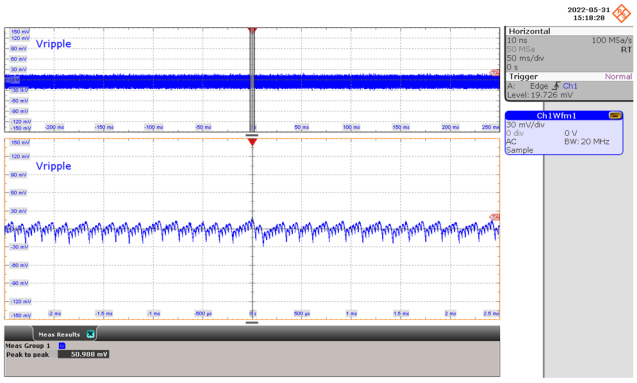

Figure 95 – Output Voltage Ripple Waveforms.
135 VAC, 750 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 50.988 mV.

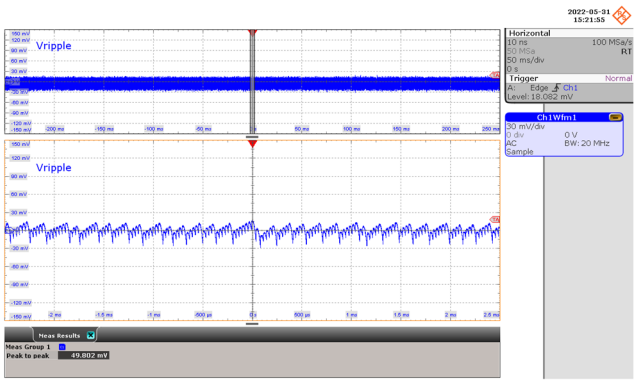

Figure 96 – Output Voltage Ripple Waveforms.
135 VAC, 500 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 49.802 mV.

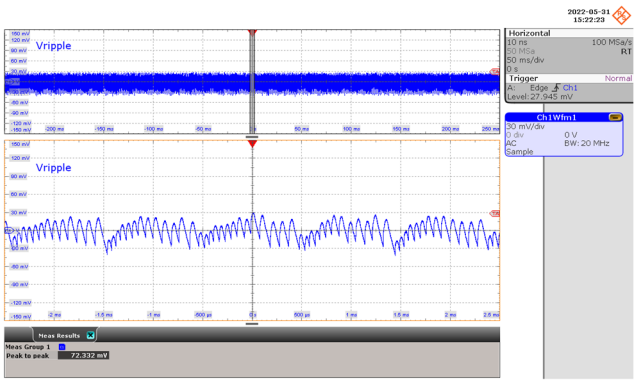

Figure 97 – Output Voltage Ripple Waveforms.
135 VAC, 250 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 72.332 mV.

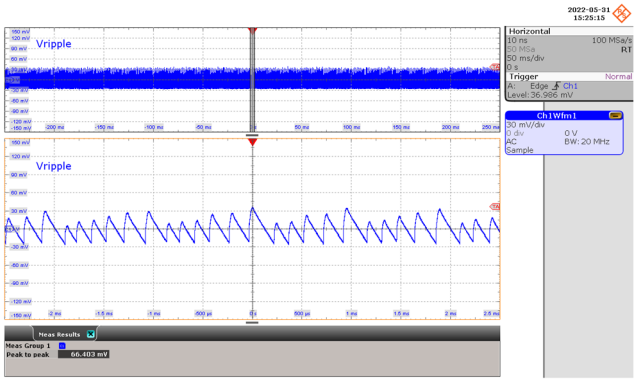

Figure 98 – Output Voltage Ripple Waveforms.
135 VAC, 100 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 66.403 mV.

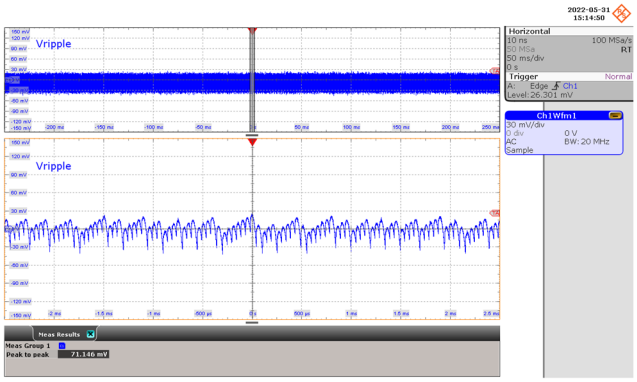

Figure 99 – Output Voltage Ripple Waveforms.
230 VAC, 1 A Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 71.146 mV.

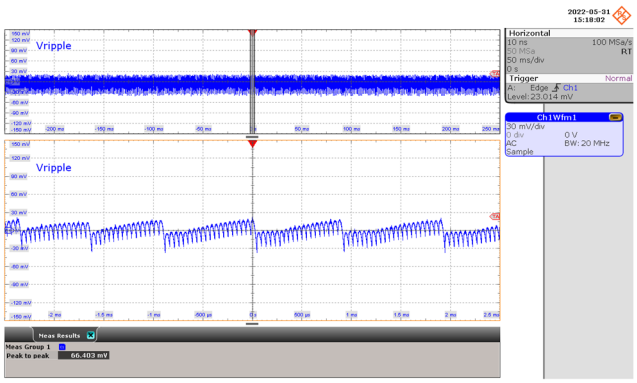

Figure 100 – Output Voltage Ripple Waveforms.
230 VAC, 750 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 66.403 mV.

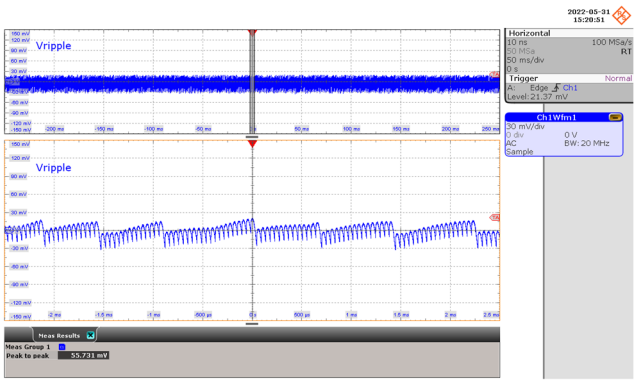

Figure 101 – Output Voltage Ripple Waveforms.
230 VAC, 500 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 55.731 mV.

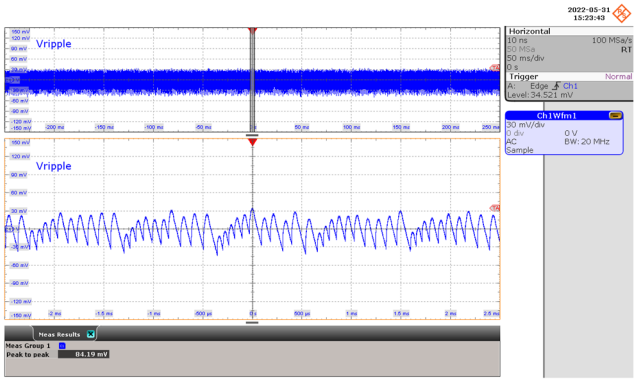

Figure 102 – Output Voltage Ripple Waveforms.
230 VAC, 250 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 84.19 mV.

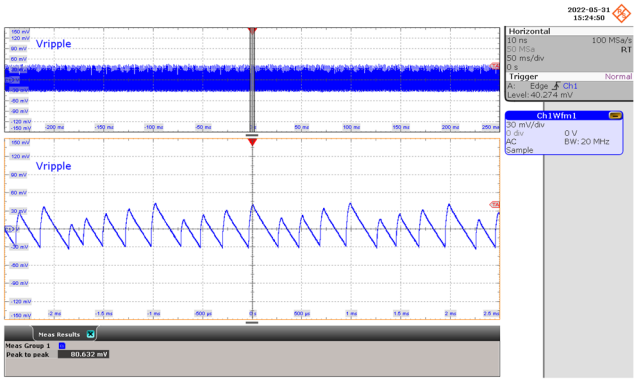

Figure 103 – Output Voltage Ripple Waveforms.
230 VAC, 100 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 80.632 mV.

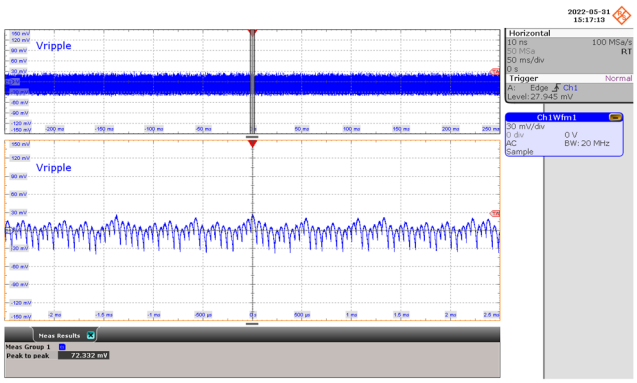

Figure 104 – Output Voltage Ripple Waveforms.
265 VAC, 1 A Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 72.332 mV.

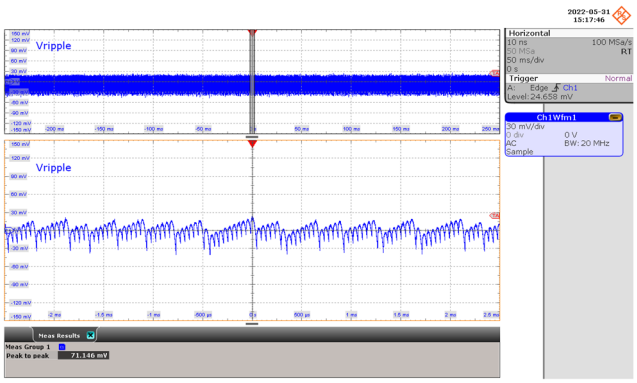

Figure 105 – Output Voltage Ripple Waveforms.
265 VAC, 750 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 71.146 mV.

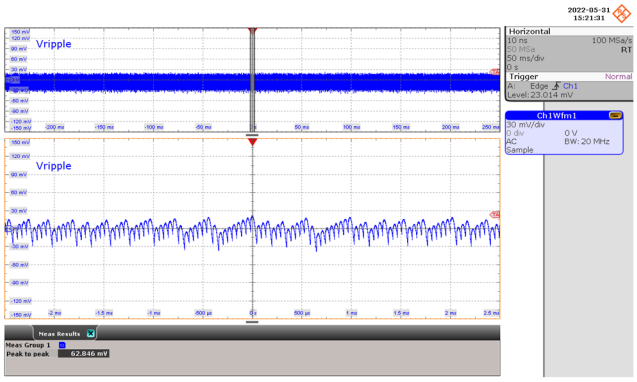

Figure 106 – Output Voltage Ripple Waveforms.
265 VAC, 500 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 62.846 mV.

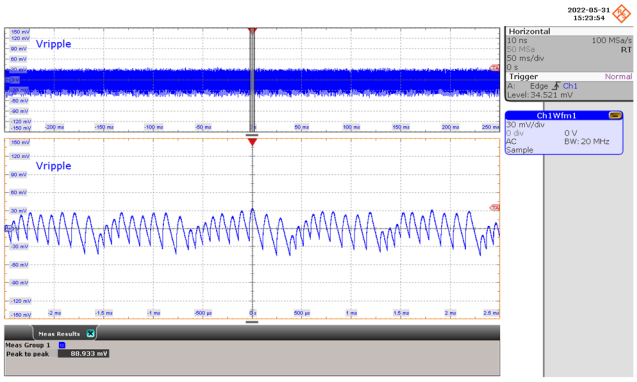

Figure 107 – Output Voltage Ripple Waveforms.
265 VAC, 250 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 µs / div.
V_{PK-PK}: 88.933 mV.

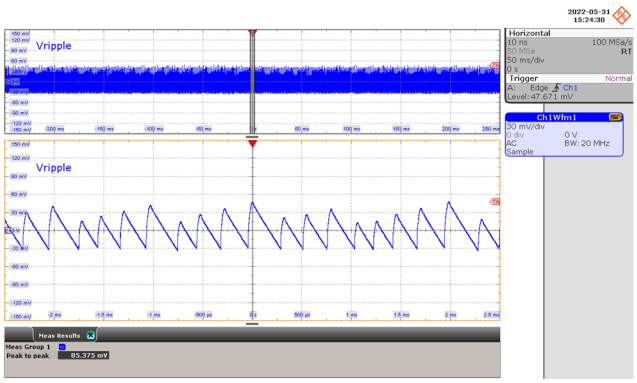

Figure 108 – Output Voltage Ripple Waveforms.
265 VAC, 100 mA Output.
Ripple: 30 mV / div., 50 ms / div.
Zoom: 500 μs / div.
V_{PK-PK}: 85.375 mV.

11.3 *Transient Response*

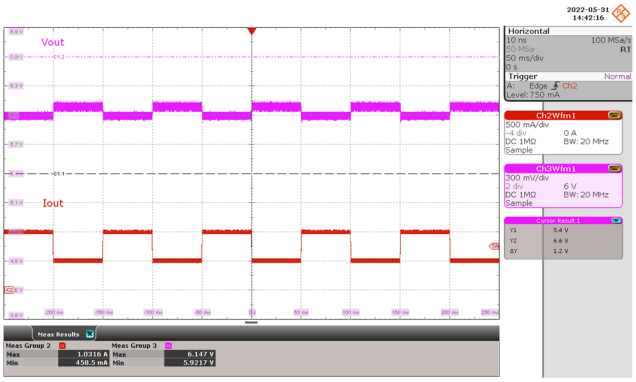

Figure 109 – Transient Output Waveforms.
85 VAC.
Output Current: 500 mA / div., 50 ms / div.
Output Voltage: 300 mV / div., 50 ms / div.
Load Transient: 50 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / µs.
Frequency: 10 Hz.
V_{MAX}: 6.147 V, V_{MIN}: 5.9217 V.

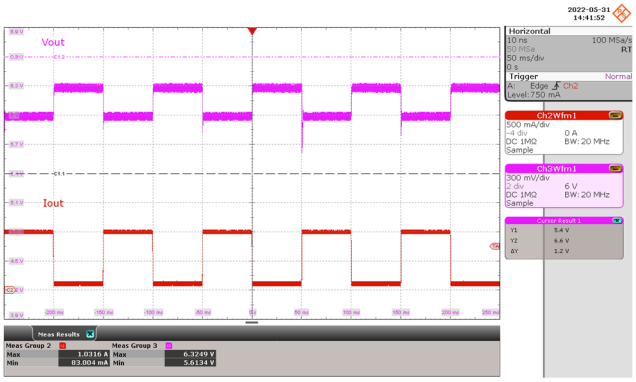

Figure 110 – Transient Output Waveforms.
85 VAC.
Output Current: 500 mA / div., 50 ms / div.
Output Voltage: 300 mV / div., 50 ms / div.
Load Transient: 10 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / µs.
Frequency: 10 Hz.
V_{MAX}: 6.3249 V, V_{MIN}: 5.6134 V.

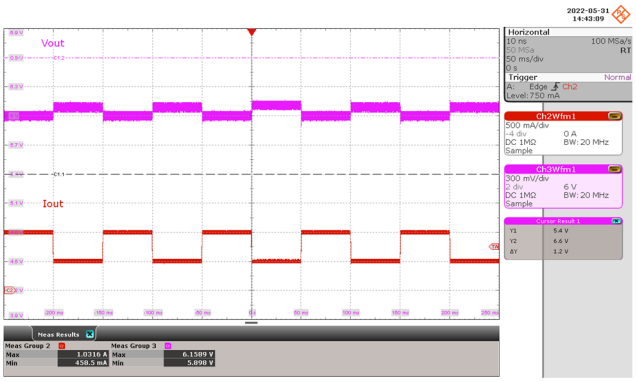

Figure 111 – Transient Output Waveforms.
115 VAC.
Output Current: 500 mA / div., 50 ms / div.
Output Voltage: 300 mV / div., 50 ms / div.
Load Transient: 50 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / µs.
Frequency: 10 Hz.
V_{MAX}: 6.1589 V, V_{MIN}: 5.898 V.

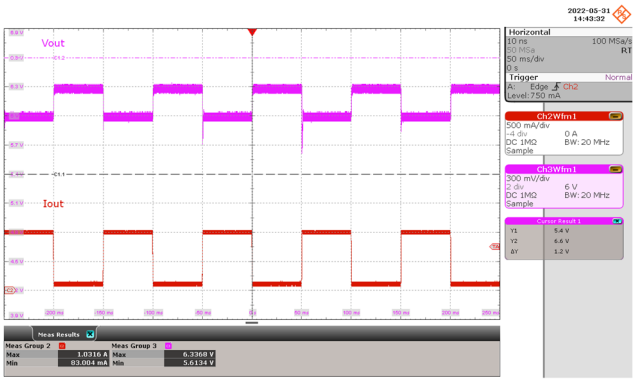

Figure 112 – Transient Output Waveforms.
115 VAC.
Output Current: 200 mA / div., 50 ms / div.
Output Voltage: 500 mV / div., 50 ms / div.
Load Transient: 10 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / µs.
Frequency: 10 Hz.
V_{MAX}: 6.3368 V, V_{MIN}: 5.6134 V.

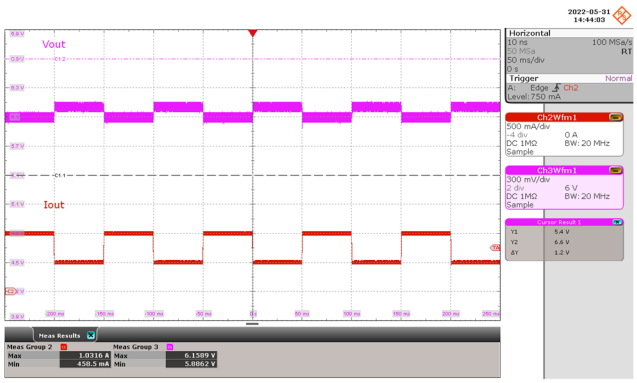

Figure 113 – Transient Output Waveforms.
135 VAC.
Output Current: 500 mA / div., 50 ms / div.
Output Voltage: 300 mV / div., 50 ms / div.
Load Transient: 50 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / µs.
Frequency: 10 Hz.
V_{MAX}: 6.1589 V, V_{MIN}: 5.8862 V.

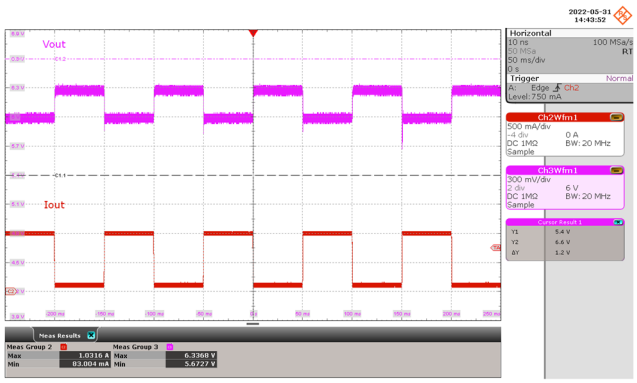

Figure 114 – Transient Output Waveforms.
135 VAC.
Output Current: 500 mA / div., 50 ms / div.
Output Voltage: 300 mV / div., 50 ms / div.
Load Transient: 10 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / µs.
Frequency: 10 Hz.
V_{MAX}: 6.3368 V, V_{MIN}: 5.6727 V.

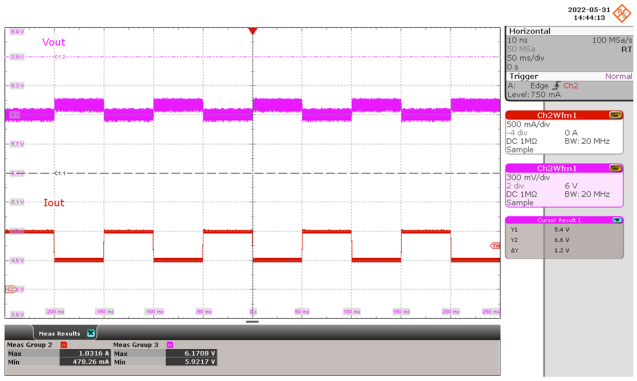

Figure 115 – Transient Output Waveforms.
230 VAC.
Output Current: 500 mA / div., 50 ms / div.
Output Voltage: 300 mV / div., 50 ms / div.
Load Transient: 50 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / µs.
Frequency: 10 Hz.
V_{MAX}: 6.1708 V, V_{MIN}: 5.9217 V.

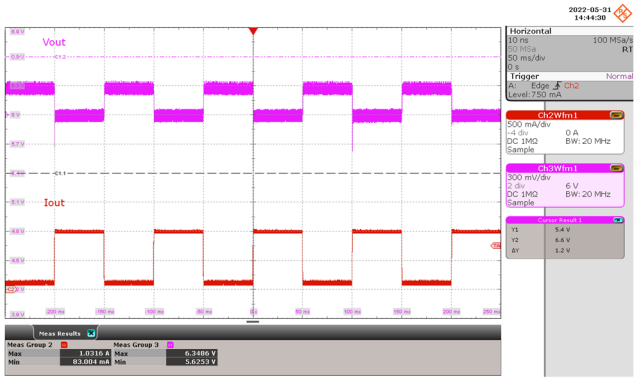

Figure 116 – Transient Output Waveforms.
230 VAC.
Output Current: 500 mA / div., 50 ms / div.
Output Voltage: 300 mV / div., 50 ms / div.
Load Transient: 10 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / µs.
Frequency: 10 Hz.
V_{MAX}: 6.3486 V, V_{MIN}: 5.6253 V.

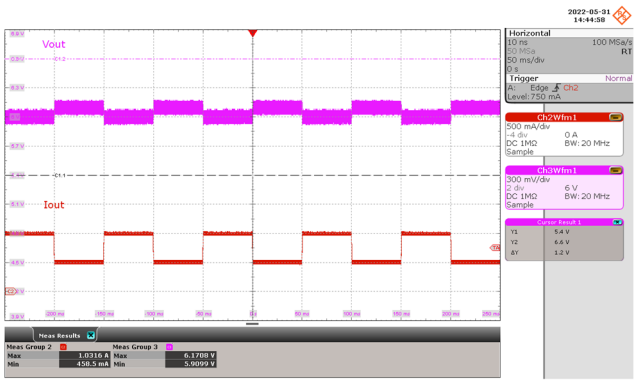

Figure 117 – Transient Output Waveforms.
265 VAC.
Output Current: 500 mA / div., 50 ms / div.
Output Voltage: 300 mV / div., 50 ms / div.
Load Transient: 50 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / μs.
Frequency: 10 Hz.
V_{MAX}: 6.1708 V, V_{MIN}: 5.9099 V.

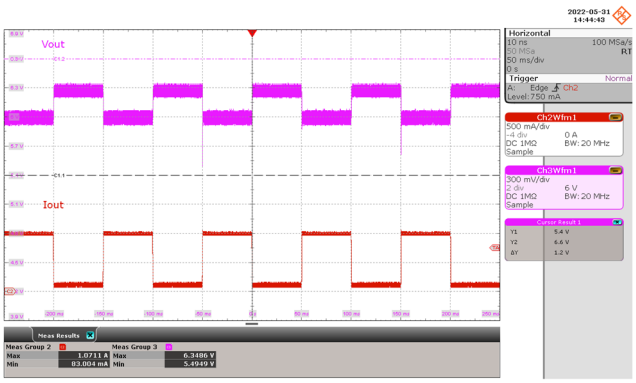

Figure 118 – Transient Output Waveforms.
265 VAC.
Output Current: 500 mA / div., 50 ms / div.
Output Voltage: 300 mV / div., 50 ms / div.
Load Transient: 10 % - 100%.
Duty Cycle, Slew Rate: 50%, 0.8 A / μs.
Frequency: 10 Hz.
V_{MAX}: 6.3486 V, V_{MIN}: 5.4949 V.

12 Conducted EMI

12.1 *1 A Resistive Load, Floating Output (QPK / AV)*

After running for 15 minutes.

12.1.1 115 VAC

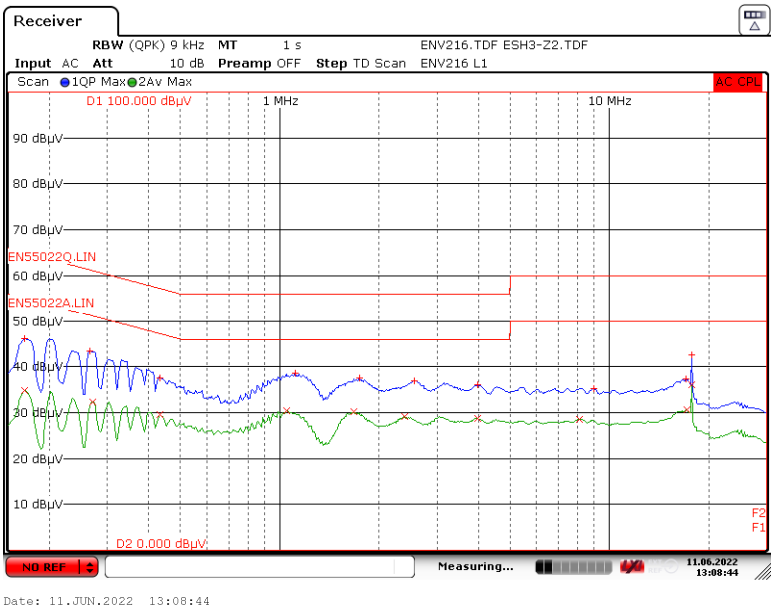

Figure 119 – Floating Ground EMI at 115 VAC Line

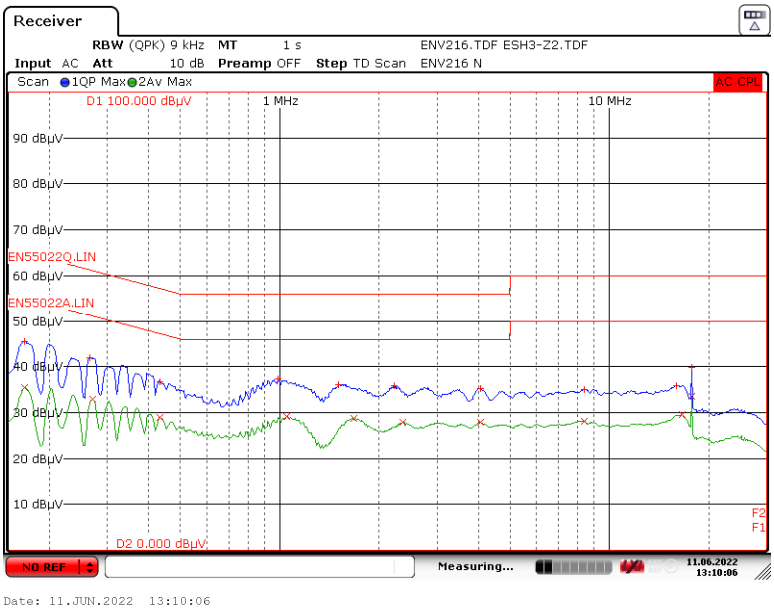

Figure 120 – Floating Ground EMI at 115 VAC Neutral

12.1.2 230 VAC

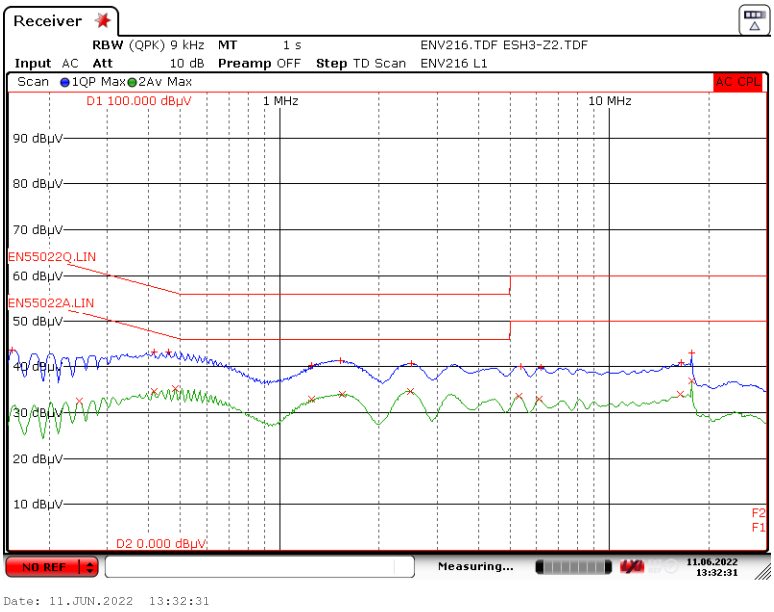

Figure 121 – Floating Ground EMI at 230 VAC Line

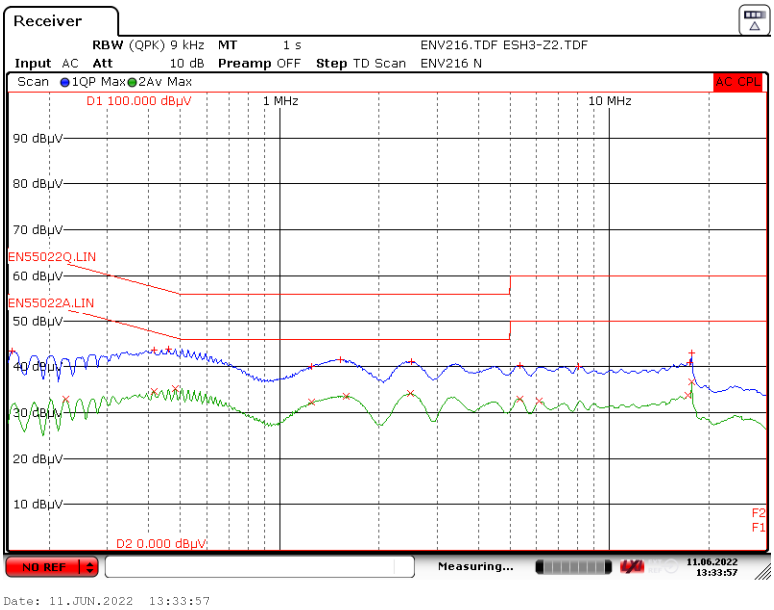

Figure 122 – Floating Ground EMI at 230 VAC Neutral

12.2 *Differential Mode Test*

Passed ±1 kV surge test.

Surge Voltage (kV)	Phase Angle	IEC Coupling	Generator Impedance (Ω)	Number Strikes	Result	Remarks
+1	0	L1/L2	2	10	PASS	No Auto-restart
-1	0	L1/L2	2	10	PASS	No Auto-restart
+1	90	L1/L2	2	10	PASS	No Auto-restart
-1	90	L1/L2	2	10	PASS	No Auto-restart
+1	180	L1/L2	2	10	PASS	No Auto-restart
-1	180	L1/L2	2	10	PASS	No Auto-restart
+1	270	L1/L2	2	10	PASS	No Auto-restart
-1	270	L1/L2	2	10	PASS	No Auto-restart

12.2.1 1000 V 90º Differential Mode Surge

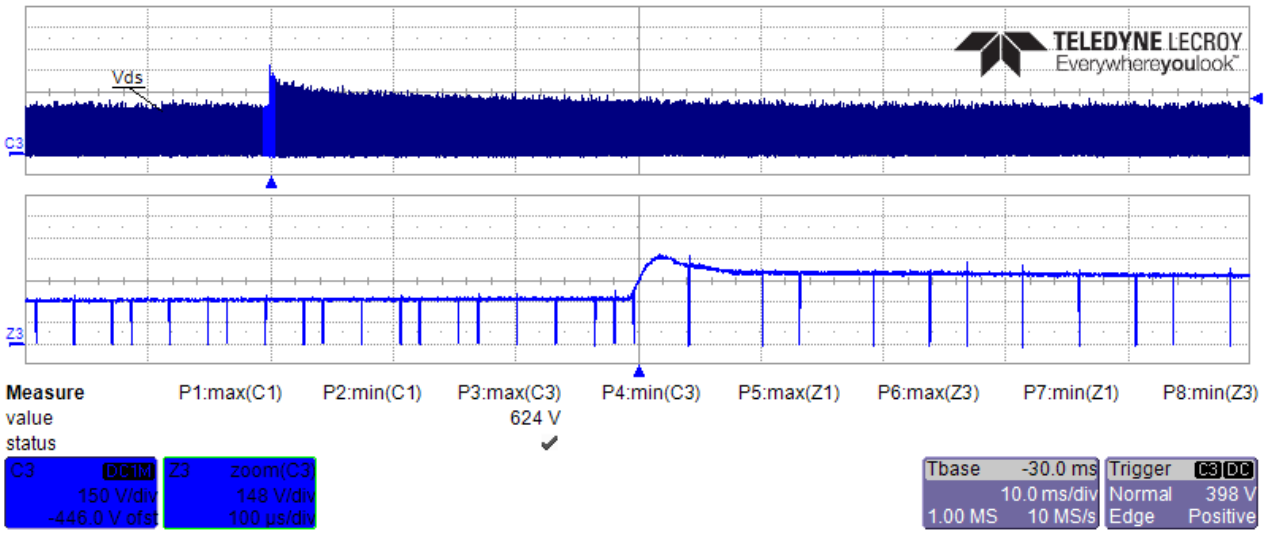

Figure 123 – Drain Voltage, 230 VAC, Full Load.

13 Revision History

Date	Author	Revision	Description & Changes	Reviewed
18-Aug-22	RPA/JD/RN	1.0	Initial Release.	Apps & Mktg

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