Reference Design Report

Title	**65 W Automotive Power Supply for 400 V Systems Using InnoSwitch3-AQ INN3997CQ**
Specification	200 VDC – 480 VDC Input; 50.0 V / 1.3 A Output
Application	µDCDC / 48 V Battery Management System
Author	Automotive Systems Engineering Department
Document Number	RDR-1074Q
Date	July 06, 2026
Revision	A

Summary and Features

- Ultra-compact design for 400 VDC Automotive BEV applications
- Low component count (only 64 electrical components)[1]
- Wide-range start-up and operating voltage from <200 VDC to 480 VDC[2]
- Wire wound transformer with basic isolation up to 480 VDC input and complies with Hi-Pot requirements (IEC-60664-1 and IEC-60664-4)
- ≥92% full load efficiency across the input voltage range
- Accurate secondary-side regulation without optocouplers
- Comprehensive fault protection including output current limit and short-circuit
- INN3997CQ H100 with 3.45 V_{OUT} pin AR threshold
- Uses automotive qualified AEC-Q surface-mount (SMD) components[3]
- Low profile, 19 mm high
- Single-sided assembly (top side only) for cost-optimized manufacturing

[1] Power conversion stage only, excluding unpopulated components, input and output ports.
[2] Derated power below 200 VDC input. See Figure 133.
[3] Excluding customized transformer.

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Table of Contents

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No responsibility is accepted for the accuracy or sufficiency of any of the statements, technical information, recommendations, or opinions communicated and any liability for any direct, indirect, or consequential loss or damage suffered by any person arising therefrom is expressly disclaimed.

1 Introduction

This engineering report describes a 65 W single-output automotive power supply. It is intended for use in 400 V battery powered electric vehicles and supports a wide input range of 200 VDC to 480 VDC. This design uses the 900 V rated INN3997CQ from the InnoSwitch™3-AQ family of ICs in a flyback converter configuration. The design incorporates the INN3997CQ H100 variant with the $V_{O(AR)}$ threshold of 3.45 V to support the specific requirement of 48 V battery charging applications.

The design provides basic isolation between the primary (high-voltage input) and secondary (low-voltage output) sides by observing the creepage and clearance requirements described in IEC-60664 parts 1 and 4.

This report contains the power supply specification, schematic, printed circuit board (PCB) layout, bill of materials (BOM), specification for the magnetics, and performance data.

Figure 1 – Populated Circuit Board, Oblique View of Top Side.

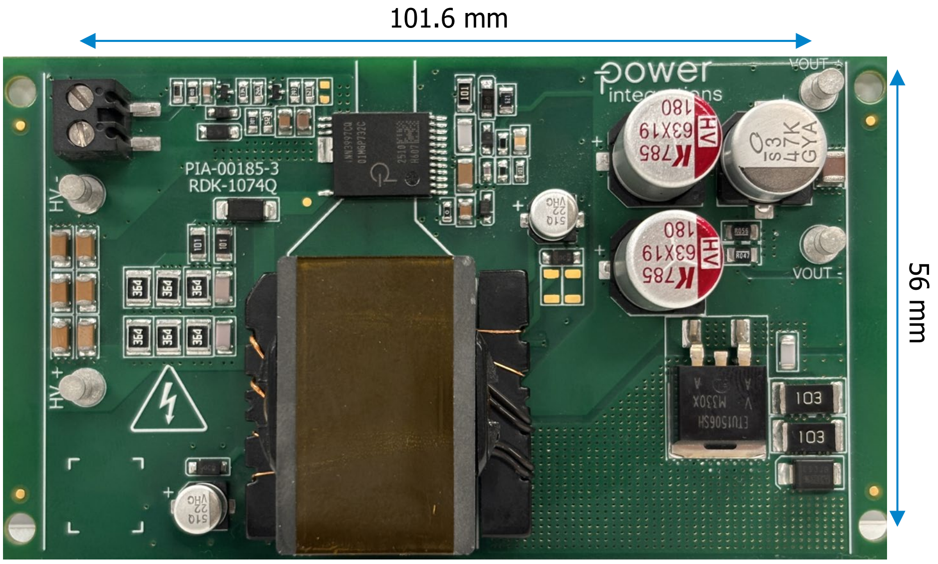


Figure 2 – Populated Circuit Board, Top View.

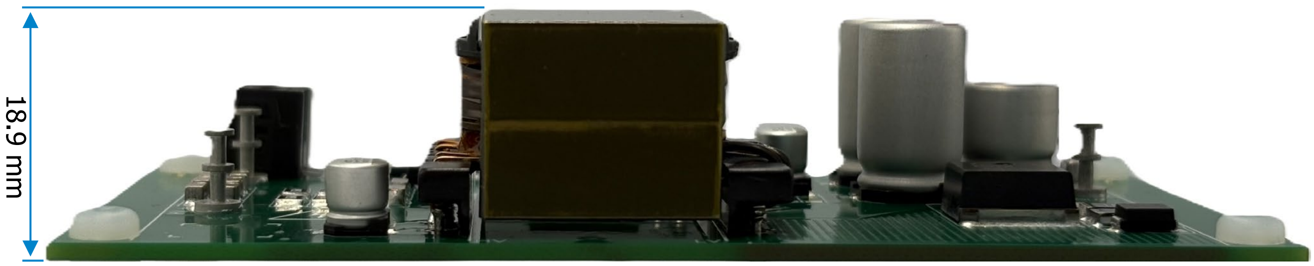


Figure 3 – Populated Circuit Board, Side View.

The design can deliver the rated 65 W output power continuously at 85 ºC ambient at an input voltage range of 200 VDC to 480 VDC input. The 50 V output configuration allows the design to be used in 48 V bus battery management system as well as to support Advanced Driver Assistance Systems (ADAS).

The InnoSwitch3-AQ IC maintains regulation by directly sensing the output voltage and providing fast, accurate feedback to the primary-side via FluxLink™ magneto-inductive coupling. The secondary-side controller also simplifies the implementation of synchronous rectification improving overall efficiency (compared to diode rectification)—saving cost and space and eliminating the need for heat sinks.

2 Design Specification

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

2.1 Electrical Specifications

Description	Symbol	Min.	Typ.	Max.	Units
Input Parameters					
Positive DC-Link Input Voltage Referenced to HV-	**HV**	200	400	480	VDC
Output Parameters					
Output Voltage Parameters					
Regulated Output Voltage	V_{OUT}	47.5	50	52.5	VDC
Output Voltage Load and Line Regulation	V_{REG}	-5		+5	%
Ripple Voltage Measured on Board	V_{RIPPLE}			250	mV
Output Current Parameters					
Output Current	I_{OUT}		1.3		A
Output Power Parameters					
Continuous Output Power at 200 VDC – 480 VDC Input	P_{OUT}		65[4]		W
Output Overshoot and Undershoot During Dynamic Load Condition					
0% - 50% - 0% Transient Load 50% - 100% - 50% Transient Load 10% - 90% - 10% Transient Load	ΔV_{OUT}	-5		+5	%
Operating Parameters					
Operating Switching Frequency	f_{SW}			85	kHz

Table 1 – Electrical Specifications.

[4] For maximum output power capability at V_{IN} less than 200 V_{DC}, see Section 14.

2.2 Isolation

Description	Symbol	Min.	Typ.	Max.	Units
Maximum Blocking Voltage of INN3997CQ	BV_{DSS}			900	V
System Voltage	V_{SYSTEM}			720	V
Working Voltage	$V_{WORKING}$			480	V
Pollution Degree	**PD**			2	
CTI for FR4	**CTI**	175		400	
Rated Impulse Voltage	$V_{IMPULSE}$			2.50	kV
Altitude Correction Factor for h_a	c_{ha}			1.59	mm
Basic Clearance Distance Requirement	CLR_{BASIC}	2.4			mm
Basic Creepage Distance Requirement for PCB	$CPG_{BASIC(PCB)}$	3.2			mm
Isolation Test Voltage Between Primary and Secondary-Side for 60s	V_{ISO}	2000			V_{RMS}

Table 2 – Isolation Coordination[5].

2.3 Environmental Specification

Description	Symbol	Min.	Typ.	Max.	Units
Ambient Temperature	Ta	-40		85	°C
Altitude of Operation	h_a			5500	m

Table 3 – Environmental Specifications.

[5] Clearance and creepage distances were calculated according to IEC 60664-1 and IEC 60664-4 with the assumption that final design application will use conformally coated PCB's.

3 Schematic

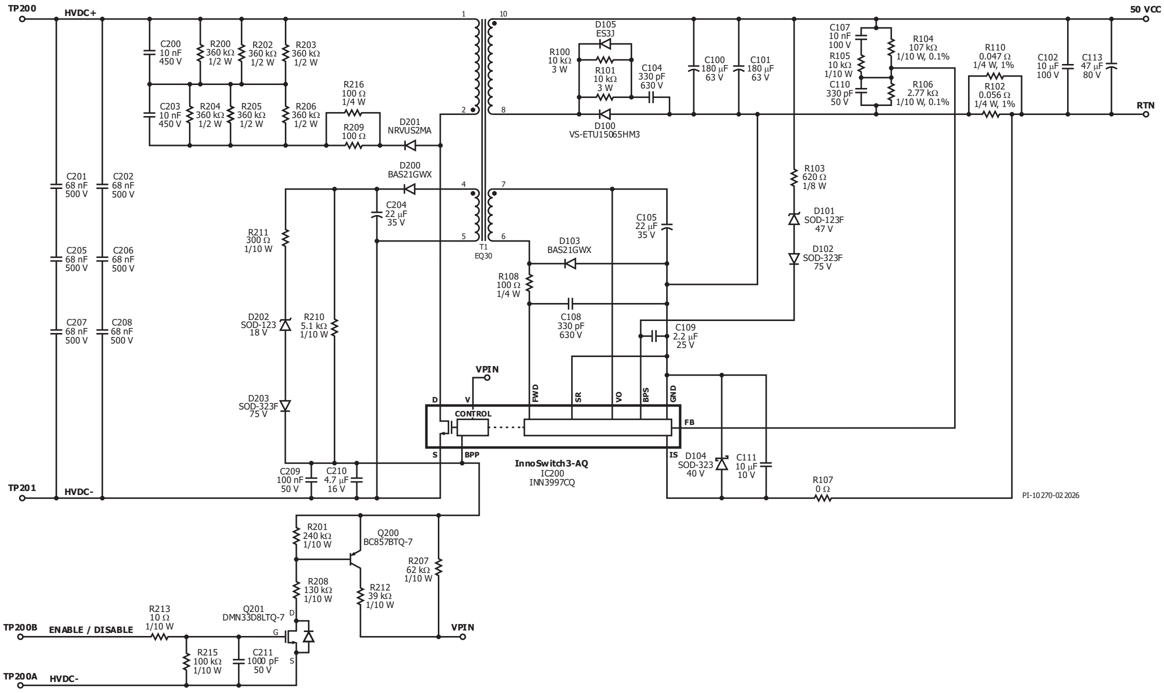


Figure 4 – RDR-1074Q Schematic.

4 Circuit Description

4.1 Input Filter

The automotive inverter environment is harsh and characterized by high dv/dt and di/dt from the switching action of the power modules. These transient events can create high levels of electrical noise that can interfere with the power supply's operation. The bypass capacitors C201, C202, C205, C206, C207 and C208 reduce the noise entering the power supply and prevent it from affecting the overall performance of the design. These capacitors also minimize the primary-side current loop. The capacitors are selected not to exceed 65% of their voltage rating and to maintain enough pad separation to enable a design that meets creepage and clearance requirements.

4.2 High-Voltage Circuit

The power supply uses a flyback converter topology that provides an isolated low-voltage output from the high-voltage input. The primary winding of the wire-wound flyback transformer T1 is connected between the high-voltage DC input and the drain terminal of the 900 V PowiGaN power switch which is internal to the InnoSwitch3-AQ IC (IC100).

An R2CD-type (Resistor-Resistor-Capacitor-Diode) snubber circuit is placed across the primary winding to limit the drain-source voltage peak during turn-off. Super-fast diode D201 was placed to meet voltage, current, creepage and clearance requirements. Capacitors C200 and C203 store the energy from the leakage inductance of transformer T1. The capacitor values were selected to minimize the voltage ripple across the snubber resistor network and maintain near-constant power dissipation through the switching cycle. Resistors R200, R202, R203, R204, R205, and R206 dissipate the energy stored in the snubber capacitors. The resistor values were selected such that their average voltage will not exceed 80% of their maximum rated voltage and to ensure that they will dissipate less than 50% of their rated power.

During normal operation, the primary side is powered by an auxiliary winding on transformer T1. This improves efficiency and reduces the heating of InnoSwitch3-AQ IC. The auxiliary winding output is rectified and filtered using diode D200 and capacitor C204. The InnoSwitch3-AQ is self-starting, using an internal high-voltage current source to charge the Bias Power Pin (BPP) capacitors, C209 and C210. Current is injected into the BPP capacitors through resistor R210. Diodes D202, D203, and resistor R211 serve as a primary-sensed output overvoltage protection (primary OVP) circuit, which injects current to the BPP pin of InnoSwitch3-AQ IC during output overvoltage events, driving the IC to enter auto-restart (AR) in the event of an output overvoltage fault.

4.3 Low-Voltage Circuit

The secondary-side of the InnoSwitch3-AQ IC provides output voltage sensing, output current sensing, and rectification. D100 rectifies the voltage across the secondary winding of the transformer T1, then is filtered by output capacitors C100 to C101. An RCD snubber formed by resistors R100, R101, capacitor C104 and diode D105 damps the high-frequency ringing across the cathode-anode nodes of the rectification diode D100.

A separate auxiliary winding of transformer T1 provides both power and sensing signals to the secondary side of InnoSwitch3-AQ while ensuring that the VOUT and FWD pins do not exceed their maximum rating. Timing is based on the negative edge voltage transition sensed by the FWD pin via resistor R108. Capacitor C108 and resistor R108 form a low-pass filter that reduces voltage spikes seen by the FWD pin and ensures that the maximum rating of 150 V is not exceeded.

The secondary-side of the InnoSwitch3-AQ IC is powered by either the auxiliary winding (through R108 and the FWD pin) or the rectified output voltage of the auxiliary winding. The BPS capacitor C110 is charged via an internal regulator in both cases.

Diodes D101, D102, and resistor R103 form the secondary-side output overvoltage protection circuit. During output overvoltage events, the diodes conduct, and current is injected into the BPS pin of InnoSwitch3-AQ IC, triggering AR. This network protects for faults on the secondary when the secondary controller is operating. When the secondary controller is not directing switching, the primary side BPP pin-based output overvoltage (OV) function provides protection.

The InnoSwitch3-AQ IC's FB pin has an internal 1.265 V reference. Resistors R104 and R106 form the feedback voltage divider network. Capacitor C110 provides decoupling of high-frequency noise. C107 and R105 increase the ripple content of the FB pin for improved transient response and lower output ripple.

The parallel combination of output current sense resistors R110[6] and R102 sets the output current limit. The voltage across R110 and R102 is compared to an internal threshold of around 35 mV. Once reached, secondary requests will be inhibited, causing output voltage to drop. The IC will enter auto-restart (AR) operation when the V_{OUT} pin voltage falls to 3.45 V during CC mode and recovers when the load current is reduced below the CC limit.

4.4 Remote Enable-Disable[7]

The V pin of the InnoSwitch3-AQ IC can be used to implement a remote enable/disable function.

The InnoSwitch3-AQ IC is enabled when the current injected into the V pin is between the UV/OV pin brown-in threshold (I_{UV+} = 30.4 μA) and the UV/OV pin line overvoltage threshold (I_{OV+} = 98 μA).

Resistor R207 injects the enable current ($I_{UV+} < I_{VPIN} < I_{OV+}$). It is possible to remotely disable the power supply by applying 5 V at ports X200B-X200A. This will trigger transistors Q201 and Q200 to turn on. Resistors R201, R208, R212 and transistor Q200 are used to inject additional current to disable the InnoSwitch3-AQ ($I_{VPIN} > I_{OV+}$).

[6] Resistors R110 and R102 should have a high pulse current rating capable of high energy surge during output short.
[7] Circuit implementation is optional.

5 PCB Layout

Layers: Four (4)
Board Material: FR4
Board Thickness: 1.6 mm
Copper Weight: 2 oz for outer layers, 1.5 oz for inner layers

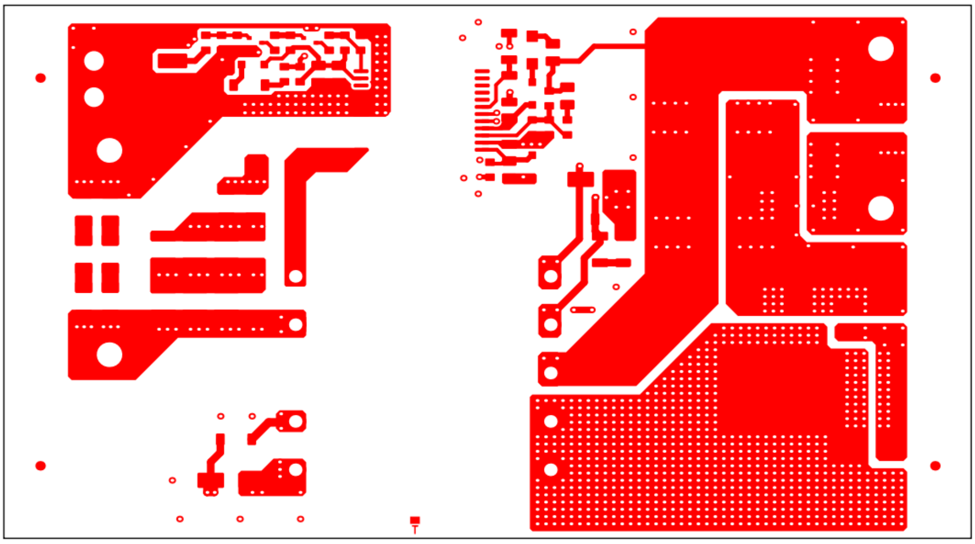


Figure 5 – RDR-1074Q Top Layer PCB Layout.

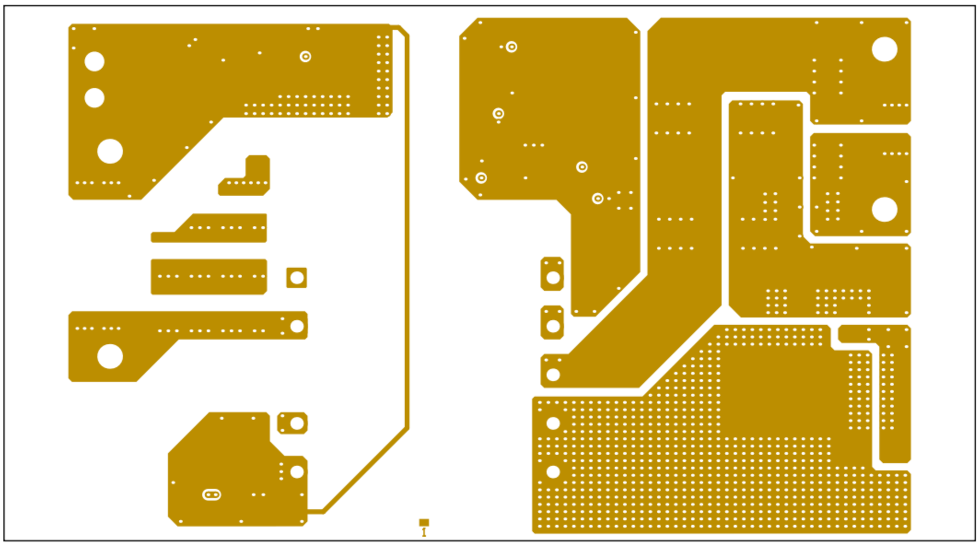


Figure 6 – RDR-1074Q Mid-Layer 1 PCB Layout.

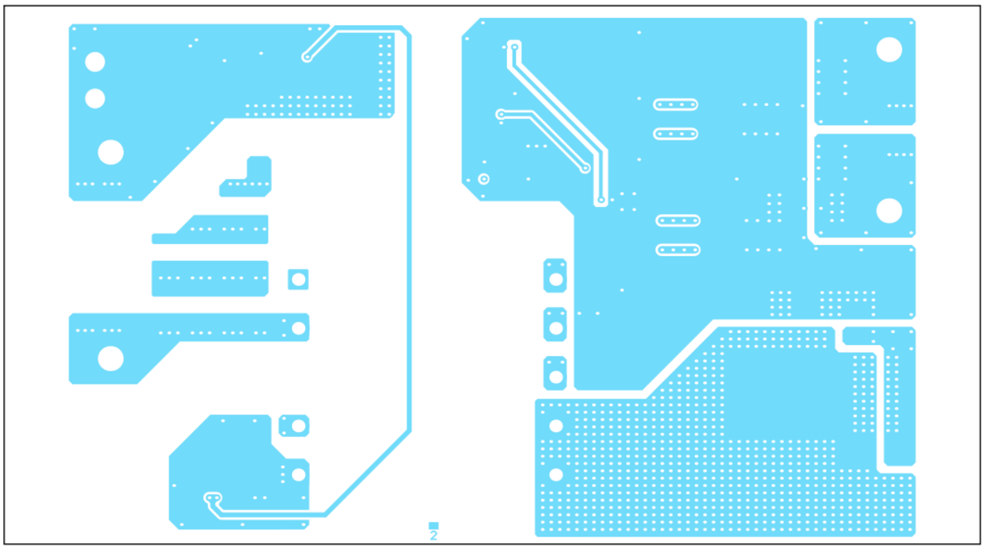


Figure 7 – RDR-1074Q Mid-Layer 2 PCB Layout.

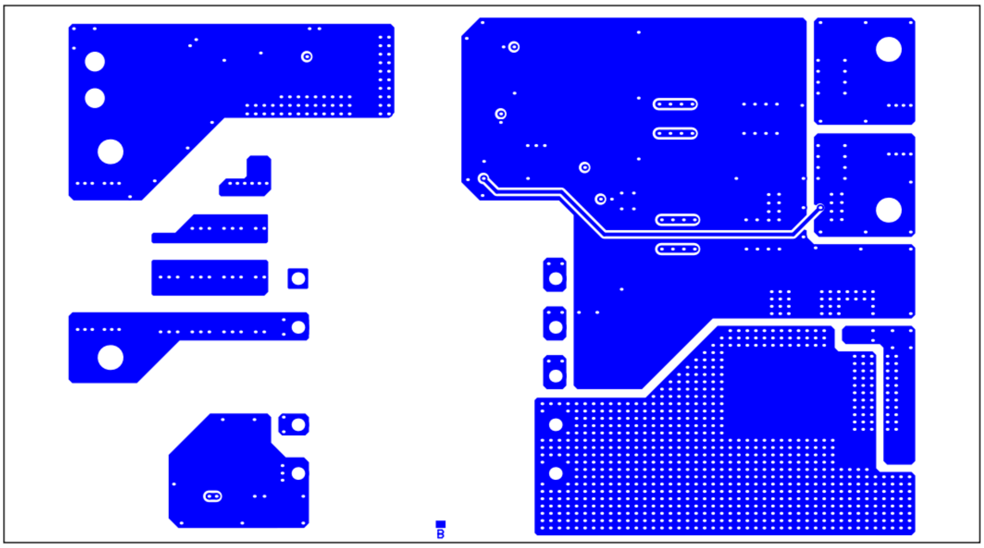


Figure 8 – RDR-1074Q Bottom Layer PCB Layout.

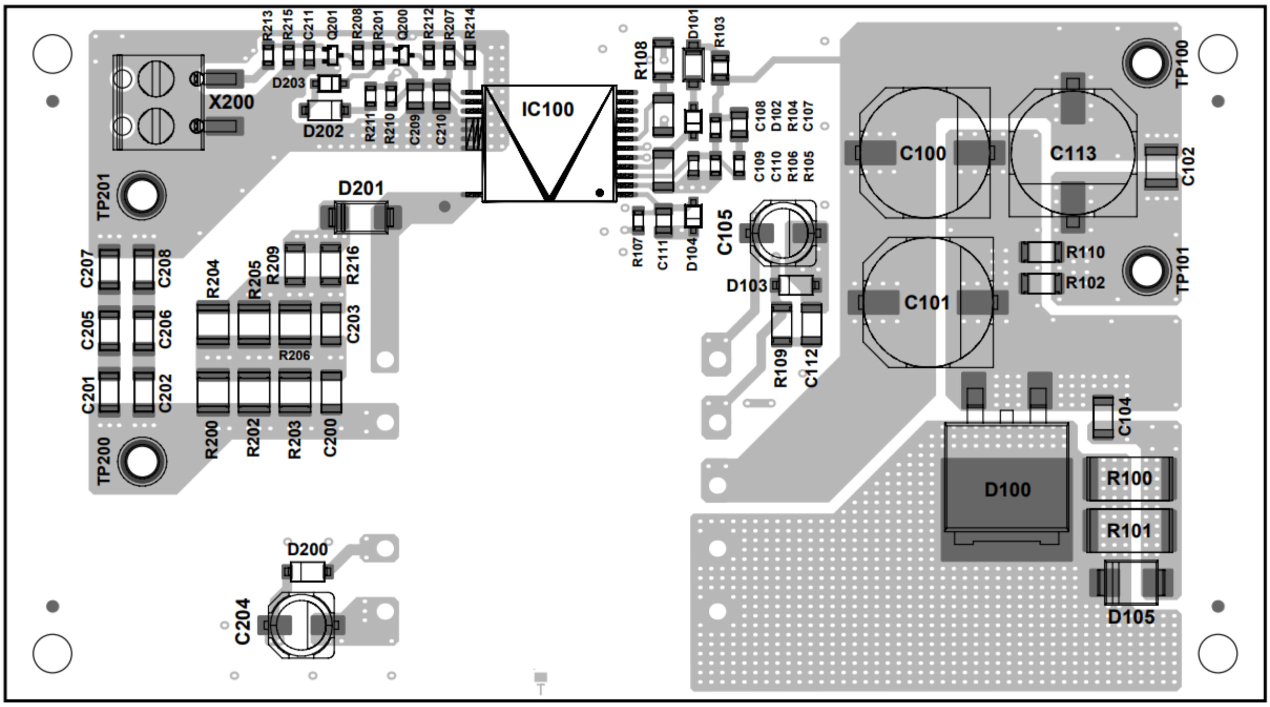


Figure 9 - RDR-1074Q PCB Assembly (no bottom components).

6 Bill of Materials

Item	Quantity	Designator	Description	MFR Part Number	Manufacturer
1	2	C100, 101	180 µF 63 V Aluminum - Polymer Capacitors Radial, Can - SMD 13 mOhm 1000 Hrs @ 150°C	A785MW187M1JLAS013	KEMET
2	1	C102	Multilayer Ceramic Capacitors MLCC - SMD/SMT Automotive Grade, MLCC, 1210, X7R, 100 V, 10 µF, +/-10%, 2.5 mm	CGA6P1X7R2A106K250AC	TDK
3	2	C104, C108	330 pF ±5% 630V Ceramic Capacitor C0G, NP0 1206 (3216 Metric)	CGA5C4C0G2J331J060AA	TDK
4	2	C105, C204	22 µF 35 V Aluminum - Polymer Capacitors Radial, Can - SMD 100mOhm 4000 Hrs @ 125°C	HHXC350ARA220ME61G	United Chemi-Con
5	1	C107	10000 pF ±5% 100V Ceramic Capacitor X7R 0805 (2012 Metric)	KAF21BR72A103JT	KYOCERA AVX
6	1	C109	2.2 µF ±10% 25V Ceramic Capacitor X7R 0805 (2012 Metric)	CGA5L2X7R1E225M160AA	TDK
7	1	C110	330 pF ±10% 500V Ceramic Capacitor C0G, NP0 1206 (3216 Metric)	CL10C331JB81PNC	Samsung Electro-Mechanics
8	1	C111	Multilayer Ceramic Capacitors MLCC - SMD/SMT 10 µF 10 VDC 10% 0805 X7R AEC-Q200	GCM21BR71A106KE22L	MURATA
9	1	C113	CAP ALUM HYBRID 47UF 20% 80V SMD	GYA1K470MCQ1GS	Nichicon
10	2	C200, C203	10000 pF ±5% 450V Ceramic Capacitor C0G, NP0 1206 (3216 Metric)	CGA5L4C0G2W103J160AA	TDK
11	6	C201, C202, C205, C206, C207, C208	0.068 µF ±10% 500V Ceramic Capacitor X7R 1206 (3216 Metric)	C1206C683KCRACAUTO	KEMET
12	1	C209	0.1 µF ±10% 50V Ceramic Capacitor X7R 0805 (2012 Metric)	CGA4J2X7R1H104K125AE	TDK
13	1	C210	4.7 µF ±10% 25V Ceramic Capacitor X7R 0805 (2012 Metric)	C0805C475K3RACAUTO	KEMET
14	1	C211	1000 pF ±10% 50V Ceramic Capacitor X7R 0603 (1608 Metric)	CGA3E2X7R1H102K080AA	TDK
15	1	D100	Ultrafast Rectifier, 15 A FRED Pt 600 V	VS-ETU1506SHM3	Vishay
16	1	D101	Zener Diode 47 V 375 mW ±1% Surface Mount SOD-123F	BZT52H-A47-QX	NEXPERIA
17	2	D102, D203	Diode 75 V 150mA Surface Mount SOD-323F	1N4148WS-Q	DIOTEC
18	2	D103, D200	Diode 200 V 225mA Surface Mount SOD-123	BAS21GWX	NEXPERIA
19	1	D104	Diode 40 V 350mA Surface Mount SOD-323	SD103AWS-AU_R1_000A1	Panjit International Inc.
20	1	D105	Diode 600 V 3A Surface Mount DO-214AA (SMB)	ES3JBHR5G	Taiwan Semiconductor Corporation
21	1	D201	Diode 1000 V 1A Surface Mount DO-214AC (SMA)	NRVUS2MA	ONSEMI
22	1	D202	Zener Diode 18 V 370 mW ±6.39% Surface Mount SOD-123	BZT52C18Q-7-F	DIODES INCORPORATED
23	1	IC100	InnoSwitch3-AQ InSOP-24D CV/CC QR H100 Flyback Switcher IC with Integrated 900 V Switch and FluxLink Feedback for Automotive Applications	INN3997CQ	Power Integrations, Inc.
24	1	Q200	Bipolar (BJT) Transistor PNP 45 V 100 mA 100MHz 150 mW Surface Mount SOT-523	BC857BTQ-7	DIODES INCORPORATED
25	1	Q201	N-Channel 30 V 115mA (Ta) 240mW (Ta) Surface Mount SOT-523	DMN33D8LTQ-7	DIODES INCORPORATED
26	2	R100, R101	10 kOhms ±5% 3W Chip Resistor 2512 (6332 Metric) Automotive AEC-Q200 Thick Film	352210KJT	TE Connectivity
27	1	R102	Current Sense Resistors - SMD 1/4watt .056ohms 1%	WSL1206R0560FEA	Vishay

28	1	R103	620 Ohms ±5% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Automotive AEC-Q200 Thick Film	CRCW0805620RJNTA	Vishay
29	1	R104	107 kOhms ±0.1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thin Film	ERA-3AEB1073V	Panasonic Electronic Components
30	1	R105	10 kOhms ±5% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	ERJ-3GEYJ103V	Panasonic Electronic Components
31	1	R106	2.77 kOhms ±0.1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200, Moisture Resistant Thin Film	RN73R1JTTD2771B25	KOA Speer Electronics, Inc.
32	1	R107	0 Ohms Jumper Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	ERJ-3EKF10R0V	Panasonic Electronic Components
33	3	R108, R209, R216	100 Ohms ±5% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Automotive AEC-Q200 Thick Film	RMCF1206JT100R	Stackpole Electronics Inc
34	1	R110	Current Sense Resistors - SMD 1/4watt .047ohms 1%	WSL1206R0470FEA	Vishay
35	6	R200, R202, R203, R204, R205, R206	360 kOhms ±5% 0.5W, 1/2W Chip Resistor 1210 (3225 Metric) Automotive AEC-Q200, Pulse Withstanding Thick Film	ERJ-P14J364U	Panasonic Electronic Components
36	1	R201	240 kOhms ±5% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	ERJ-3GEYJ244V	Panasonic Electronic Components
37	1	R207	62 kOhms ±5% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	ERJ-3GEYJ623V	Panasonic Electronic Components
38	1	R208	130 kOhms ±5% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200, Moisture Resistant Thick Film	AC0603JR-07130KL	YAGEO
39	1	R210	5.1 kOhms ±5% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200, Moisture Resistant Thick Film	AC0603JR-075K1L	YAGEO
40	1	R211	300 Ohms ±5% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	RMCF0603JT300R	Stackpole Electronics Inc
41	1	R212	39 kOhms ±5% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200, Moisture Resistant Thick Film	AC0603JR-0739KL	YAGEO
42	1	R213	10 Ohms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	ERJ-3EKF10R0V	Panasonic Electronic Components
43	1	R215	100 kOhms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film	RMCF0603FT100K	Stackpole Electronics Inc
44	1	T1	EQ30 Transformer		
45	4	TP100, TP101, TP200, TP201	Terminal Turret Connector Single End 0.281" (7.14mm) Tin	1514-2	Keystone
46	1	X200	2 Position Wire to Board Terminal Block Horizontal with Board 0.150" (3.81mm) Surface Mount	2383945-2	TE Connectivity AMP Connectors
47	1	Z1	Printed Circuit Board		

Table 4 – RDR-1074Q Bill of Materials[8].

[8] All components are AEC-Q qualified except the connectors and transformer.

7 Transformer Specification (T1)

7.1 Electrical Diagram

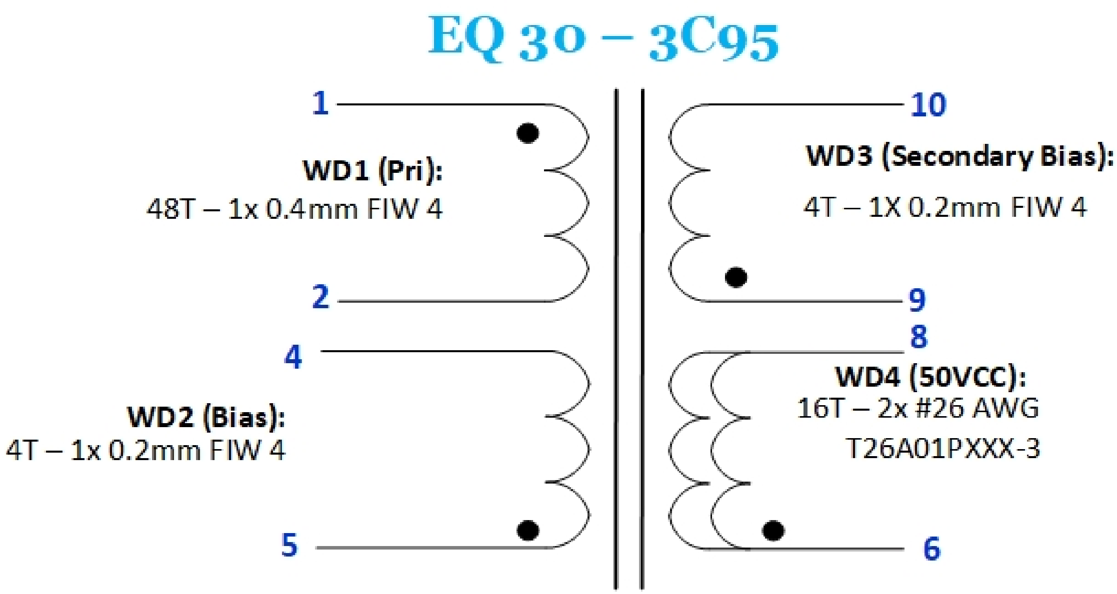


Figure 10 – Transformer Electrical Diagram.

7.2 Transformer Build Diagram

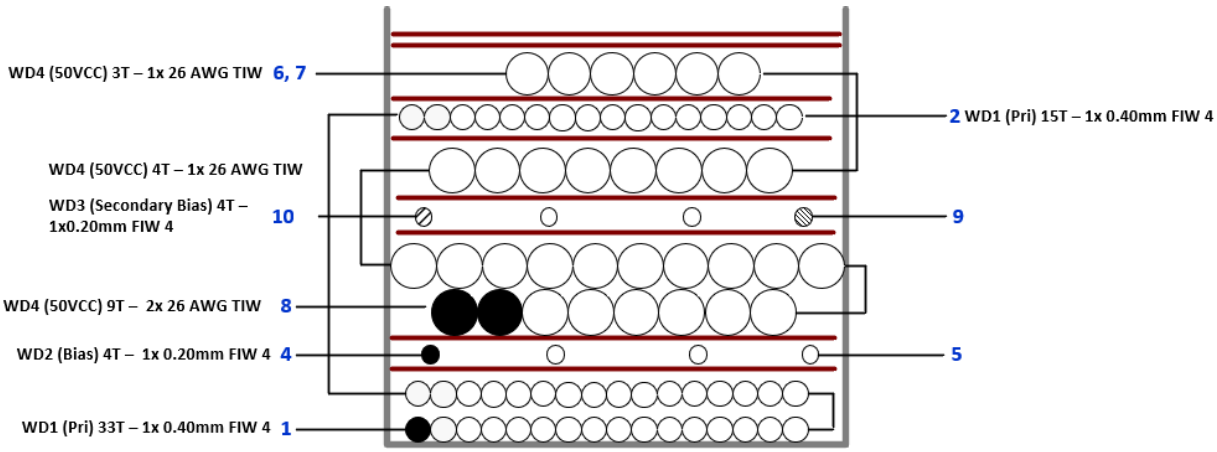


Figure 11 – Transformer Build Diagram.

7.3 Electrical Specifications

Parameter	Conditions	Min.	Typ.	Max.	Unit
Power	Output power secondary-side		65		W
Input voltage VDC	Flyback topology	200	400	480	VDC
Switching frequency				85	kHz
Duty cycle				43	%
Turns Ratio (N_P:N_S)			3.0		
Primary Winding Resistance ($R_{DC,PRI}$)	All windings open		356.8		mΩ
Secondary Winding Resistance ($R_{DC,SEC}$)			68		mΩ
Coupling capacitance	Primary-side to secondary-side Measured at 1 V_{PK-PK}, 100 kHz frequency, between node 2 to node 6, with nodes 1 - 2 shorted and nodes 5 - 6 shorted at 25 °C		59.13		pF
Primary inductance	Measured at 1 V_{PK-PK}, 100 kHz frequency, between node 1 to node 2, with all other windings open at 25 °C		1132		µH
Part-to-part tolerance	Tolerance of Primary Inductance	-10.0		10.0	%
Primary leakage inductance	Measured between node 1 to node 2, with all other windings shorted.		9.19		µH

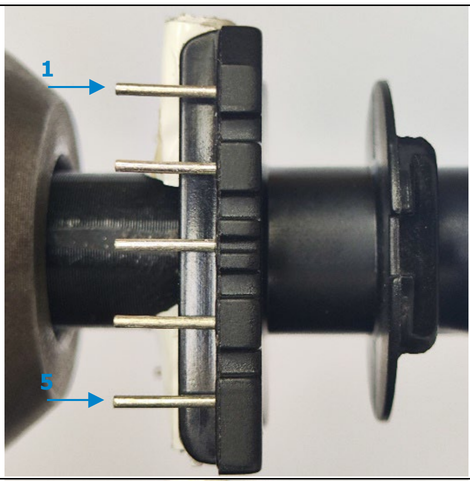
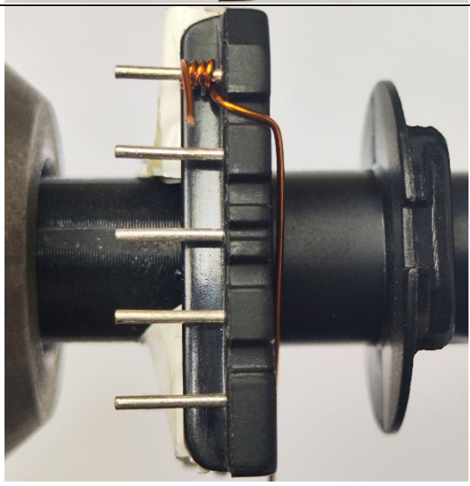
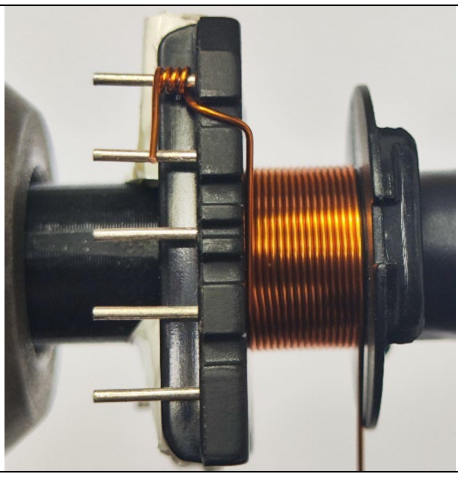
Table 5 – Transformer (T1) Electrical Specifications.

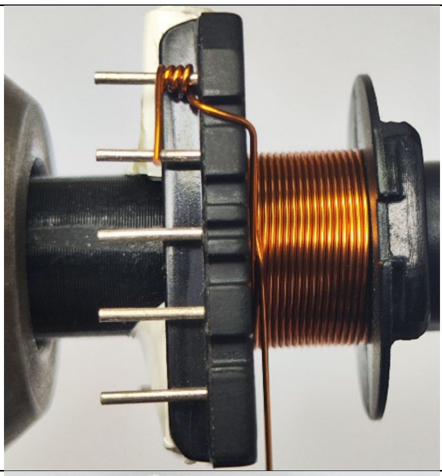
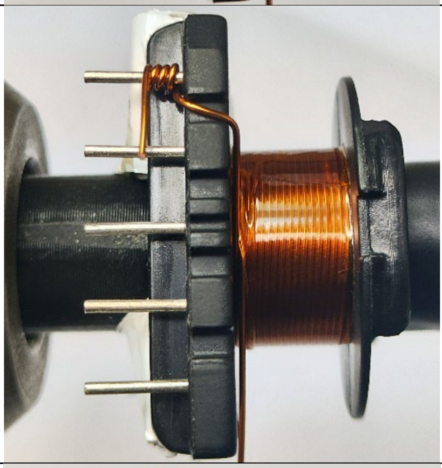
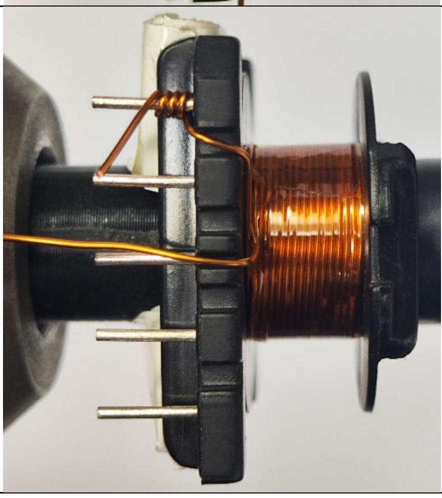
7.4 Material List

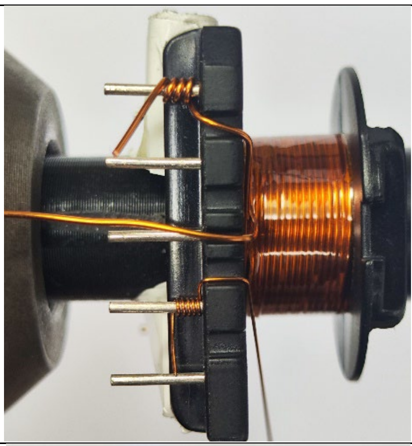
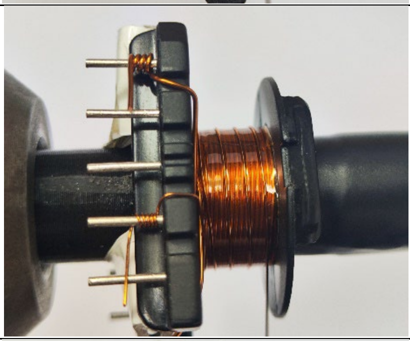
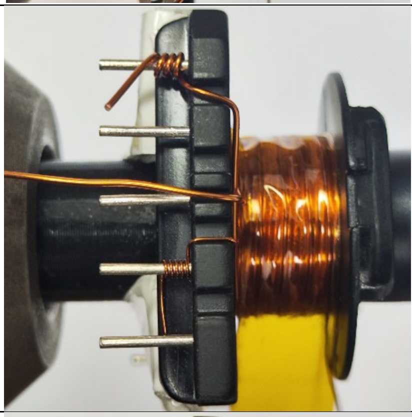
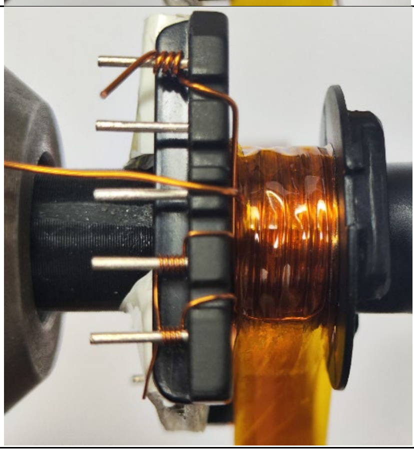
Item	Description	Qty	UOM	Material	Manufacturer
[1]	Core: EQ30	2	PC	3C95 (or equivalent)	Ferroxcube
[2]	Bobbin: CSV-EQ30/16/20-1S-10P-Z	1	PC	Sumikon PM9820	Ferroxcube
[3]	WD1 (Pri): 0.40 mm FIW 4		mm	Copper Wire	Elektrisola
[4]	WD2(Bias) and WD3 (Secondary Bias): 0.20 mm FIW 4		mm		Elektrisola
[5]	WD3 (Sec): AWG 26 TIW T26A01P0XX-3		mm		Rubadue
[6]	3/8” and 3/4” 3M Polymide Film Tape			Silicone	3M

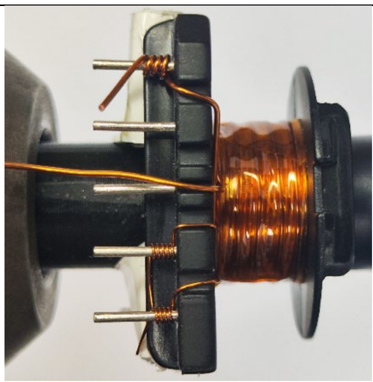
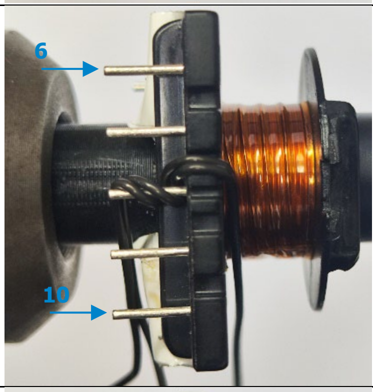
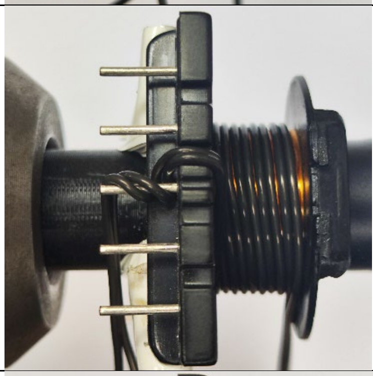
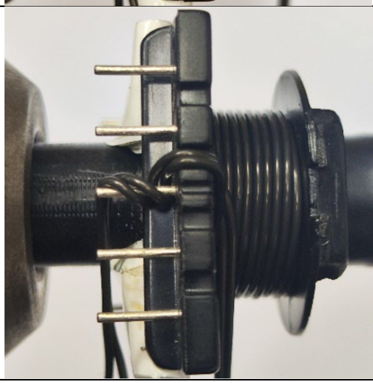
Table 6 – Transformer (T1) Material List

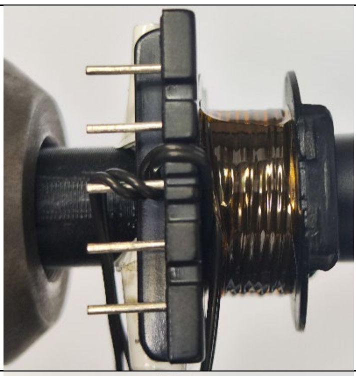
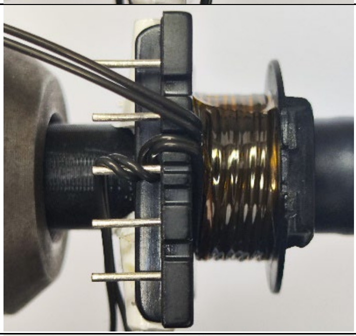
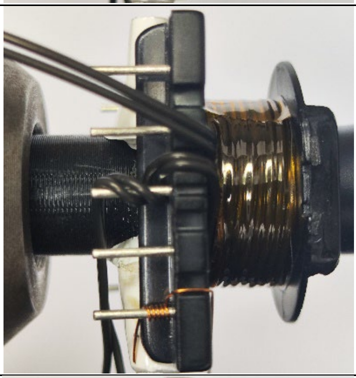
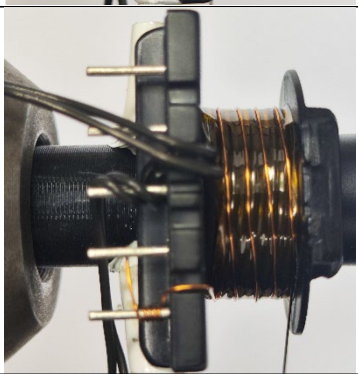
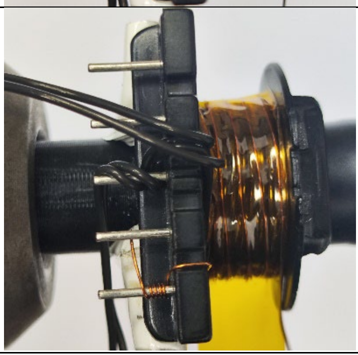
7.5 Transformer Assembly Instructions

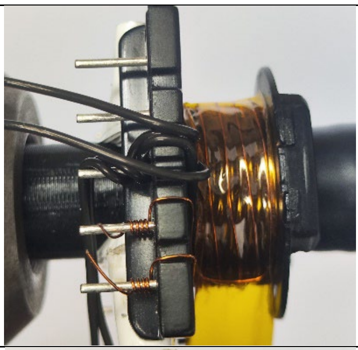
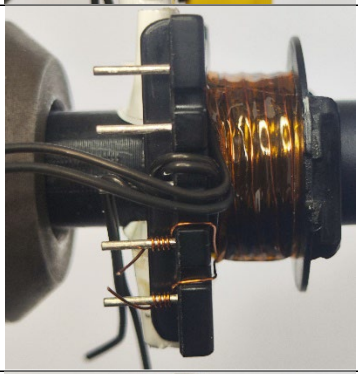
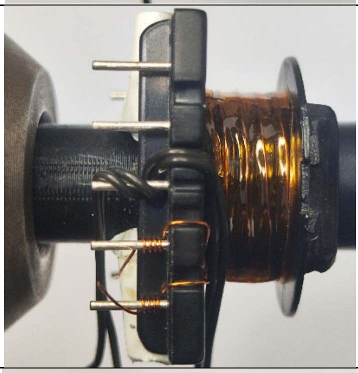
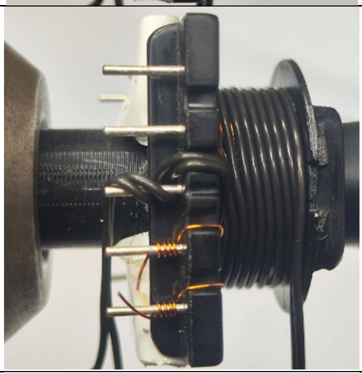
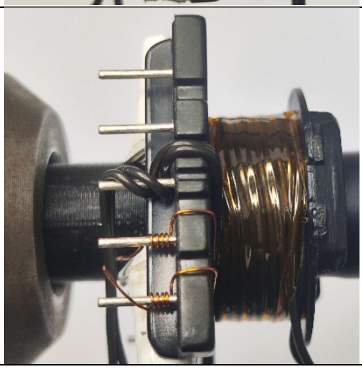
Winding preparation		Position the bobbin on the mandrel such that the pins are facing left.
WD1: Primary		Using 0.40 mm FIW4, route the start lead from the 1st pin going to the 1st lead guide of the bobbin
WD1: Primary		Wind the primary winding's first layer, 16 turns from left to right with tight tension, spread the winding evenly along the bobbin width.

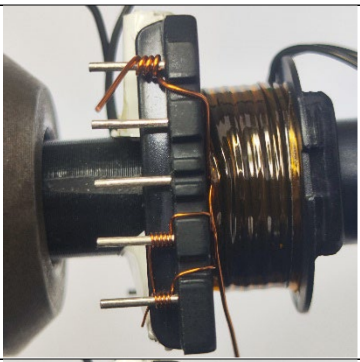
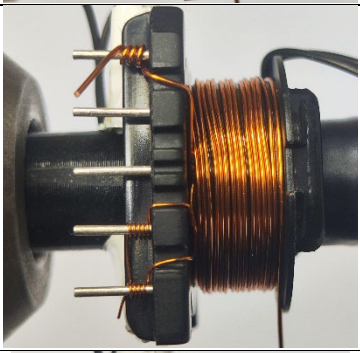
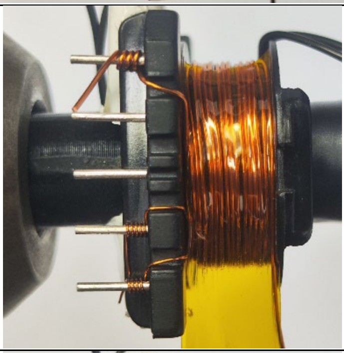
WD1: Primary		Wind the primary winding's second layer, 17 turns from right to left with tight tension, spread the winding evenly along the bobbin width.
WD1: Primary		Apply 1 layer of 3/8" kapton tape.
WD1: Primary		Temporarily route the primary winding to the 3rd lead guide.

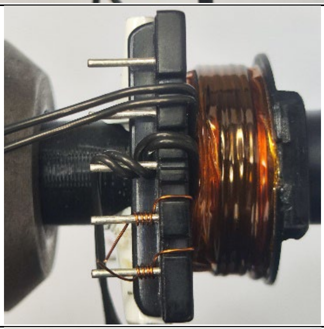
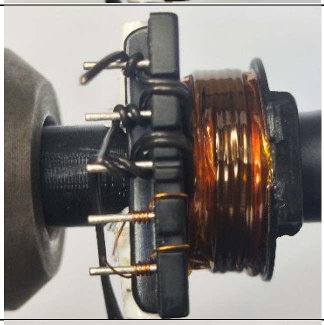
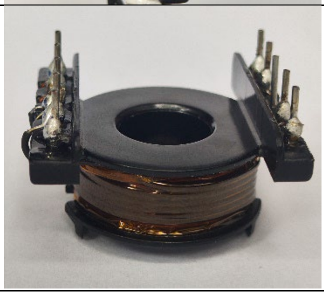
WD2: Bias		Using 0.20 mm FIW4, route the start lead from the 4th pin going to the 4th lead guide of the bobbin
WD2: Bias		Wind the primary bias winding, 4 turns from left to right with tight tension, spread the winding evenly along the bobbin width.
WD2: Bias		Secure the primary bias winding using 3/8" kapton tape. (Do not fully close in the tape.)
WD2: Bias		Route the primary bias winding to the 5th lead guide and terminate to the 5th pin. (See the termination process on the photo)

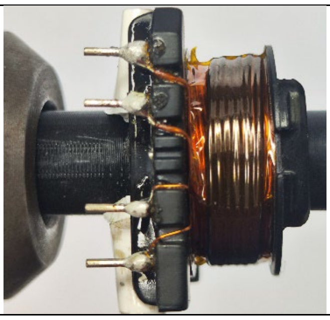
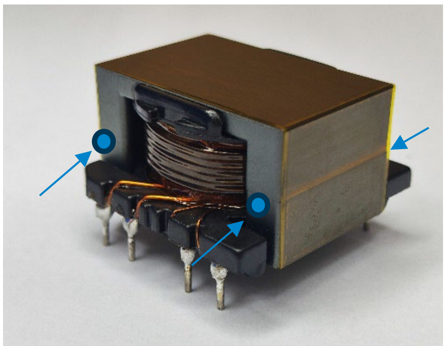
WD2: Bias		Close in the 1 layer of 3/8" kapton tape.
WD4: Secondary 50VCC		Using two filar of gauge 26 TIW, route the start lead from the 8th pin going to the 2nd lead guide of the secondary side of the bobbin
WD4: Secondary 50VCC		Wind the secondary winding's first layer, 4 turns from left to right with tight tension, spread the winding evenly along the bobbin width.
WD4: Secondary 50VCC		Wind the secondary winding's second layer, 5 turns from right to left with tight tension, spread the winding evenly along the bobbin width.

WD4: Secondary 50VCC		Apply 1 layer of 3/8" kapton tape.
WD4: Secondary 50VCC		Temporarily route the secondary winding as shown.
WD3: Secondary Bias		Using 0.20 mm FIW4, route the start lead from the 10th pin going to the 5th lead guide of the secondary side of the bobbin.
WD3: Secondary Bias		Wind the secondary bias winding, 4 turns from left to right with tight tension, spread the winding evenly along the bobbin width.
WD3: Secondary Bias		Secure the secondary bias winding using 3/8" kapton tape. (Do not fully close in the tape.)

WD3: Secondary Bias		Route the secondary bias winding to the 4th lead guide of the secondary side of the bobbin and terminate to the 9th pin. (See the termination process on the photo)
WD3: Secondary Bias		Close in the 1 layer of 3/8" kapton tape.
WD4: Secondary 50VCC		Continue to wind the secondary winding from the left most of the bobbin.
WD4: Secondary 50VCC		Wind the secondary winding's third layer, 4 turns from left to right with tight tension, spread the winding evenly along the bobbin width.
WD4: Secondary 50VCC		Apply 1 layer of 3/8" kapton tape and do not terminate the secondary winding. (See photo)

WD1: Primary		On the primary side of the bobbin, continue to wind the primary winding from the left most of the bobbin.
WD1: Primary		Wind the primary winding's third layer, 15 turns from left to right with tight tension, spread the winding evenly along the bobbin width.
WD1: Primary		Secure the primary winding using 3/8" kapton tape. (Do not fully close in the tape.)
WD1: Primary		Route the primary winding to the 2nd lead guide of the primary side of the bobbin and terminate to the 2nd pin. (See the termination process on the photo)
WD1: Primary		Close in the 1 layer of 3/8" kapton tape.

WD4: Secondary 50VCC		Continue to wind the secondary winding from the right most of the bobbin.
WD4: Secondary 50VCC		Wind the secondary winding's third layer, 3 turns from right to left with tight tension, spread the winding evenly along the bobbin width.
WD4: Secondary 50VCC		Apply 2 layers of 3/8" kapton tape.
Finishing		Terminate the secondary winding. (See the termination process on the photo)
Finishing		Cut excess wires and solder all terminated pins (pins 1, 2, 4, 5, 6, 7, 8, 9, and 10)

Finishing		Remove pin number 3
Finishing		Gap one of the core halves and fasten the cores tightly. The measured inductance between pin 1 and pin 2 should be 1132 μH with ± 10% tolerance. In fastening the core, it is preferred to use glue instead of tape that was used in the illustration.

8 Transformer Design Spreadsheet

1	DCDC_InnoSwitch3AQ_Flyback_032525; Rev.4.0; Copyright Power Integrations 2025	INPUT	INFO	OUTPUT	UNITS	InnoSwitch3-AQ Flyback Design Spreadsheet
2	APPLICATION VARIABLES					Design Title
3	VOUT	50.00		50.00	V	Output Voltage
4	OPERATING CONDITION 1					
5	VINDC1	480.00		480.00	V	Input DC voltage 1
6	IOUT1	1.300		1.300	A	Output current 1
7	POUT1		Info	65.00	W	The device is capable of delivering 55 W at the specified input voltage. Verify thermal performance.
8	EFFICIENCY1			0.85		Converter efficiency for output 1
9	Z_FACTOR1			0.50		Z-factor for output 1
10						
11	OPERATING CONDITION 2					
12	VINDC2	200.00		200.00	V	Input DC voltage 2
13	IOUT2	1.300		1.300	A	Output current 2
14	POUT2		Info	65.00	W	The device is capable of delivering 55 W at the specified input voltage. Verify thermal performance.
15	EFFICIENCY2			0.85		Converter efficiency for output 2
16	Z_FACTOR2			0.50		Z-factor for output 2
67	TEMPERATURE_AMBIENT	85.0		85.0	°C	System ambient temperature
71	PRIMARY CONTROLLER SELECTION					
72	ILIMIT_MODE	INCREASED		INCREASED		INCREASED Device current limit mode
73	VDRAIN_BREAKDOWN	900		900	V	Device breakdown voltage
74	DEVICE_GENERIC			INN39X7		Device selection
75	DEVICE_CODE	INN3997CQ		INN3997CQ		Device code
76	PDEVICE_MAX			55	W	Device maximum power capability
77	RDSON_25DEG			1.30	Ω	Primary switch on-time resistance at 25 °C
78	RDSON_125DEG			2.17	Ω	Primary switch on-time resistance at 125 °C
79	ILIMIT_MIN			1.343	A	Primary switch minimum current limit
80	ILIMIT_TYP			1.460	A	Primary switch typical current limit
81	ILIMIT_MAX			1.577	A	Primary switch maximum current limit
82	VDRAIN_ON_PRSW			0.77	V	Primary switch on-time voltage drop
83	VDRAIN_OFF_PRSW			720	V	Peak drain voltage on the primary switch during turn-off at maximum input DC voltage and allowable leakage ring
84	VCLAMP	240.0		240.0	V	Voltage across clamp circuit
85	CU_AREA_INNO			1.00	in2	Primary switch copper cooling area
86	TEMP_INNO_MIN			109.04	°C	Device minimum operating temperature with respect to ambient, observed at 480V VINDC
87	TEMP_INNO_MAX		Warning [9]	137.80	°C	Device OTP can be triggered, consider lowering down the full load switching frequency or increasing the copper cooling area
91	WORST CASE ELECTRICAL PARAMETERS					
92	FSWITCHING_MAX	85000		85000	Hz	Maximum switching frequency at full load and minimum DC input voltage
93	VOR	150.0		150.0	V	Voltage reflected to the primary winding (corresponding to set-point 1) when the primary switch turns off

[9] Calculated operating temp is based on worst case tolerance analysis. If temp calculated is above or equal to 142C, design changes should be made. But if calculated temp is between 125 °C and 142 °C, it is recommended to validate at bench testing if OTP will be triggered.

94	KP			0.725		Measure of continuous/discontinuous mode of operation
95	MODE_OPERATION			CCM		Mode of operation
96	DUTYCYCLE			0.430		Primary switch duty cycle
97	TIME_ON_MIN			2.787	us	Minimum primary switch on-time
98	TIME_ON_MAX			8.85	us	Maximum primary switch on-time
99	TIME_OFF			6.71	us	Primary switch off-time
100	LPRIMARY_MIN			1018.6	uH	Minimum primary magnetizing inductance
101	LPRIMARY_TYP			1131.8	uH	Typical primary magnetizing inductance
102	LPRIMARY_TOL	10.0		10.0	%	Primary magnetizing inductance tolerance
103	LPRIMARY_MAX			1245.0	uH	Maximum primary magnetizing inductance
105	PRIMARY CURRENT					
106	IAVG_PRIMARY			0.355	A	Primary switch average current
107	IPEAK_PRIMARY			1.490	A	Primary switch peak current
108	IPEDESTAL_PRIMARY			0.357	A	Primary switch current pedestal
109	IRIPPLE_PRIMARY			1.488	A	Primary switch ripple current
110	IRMS_PRIMARY			0.597	A	Primary switch RMS current
114	TRANSFORMER CONSTRUCTION PARAMETERS					
115	CORE SELECTION					
116	CORE	EQ30		EQ30		Core selection
117	CORE NAME			EQ30-3C95		Core code
118	AE			108.0	mm^2	Core cross sectional area
119	LE			46.0	mm	Core magnetic path length
120	AL			6630	nH	Ungapped core effective inductance per turns squared
121	VE			4970	mm^3	Core volume
122	BOBBIN NAME			CSV-EQ30-1S-10P		Bobbin name
123	AW			53.3	mm^2	Bobbin window area - only the bobbin width and height are used to assess fit by the magnetics builder
124	BW			8.40	mm	Bobbin width
125	BH			6.35	mm	Bobbin height
126	MARGIN			0.0	mm	Bobbin safety margin
128	PRIMARY WINDING					
129	NPRIMARY			48		Primary winding number of turns
130	BPEAK			3876	Gauss	Peak flux density
131	BMAX			3490	Gauss	Maximum flux density
132	BAC			1741	Gauss	AC flux density (0.5 x Peak to Peak)
133	ALG			491	nH	Typical gapped core effective inductance per turns squared
134	LG			0.256	mm	Core gap length
136	SECONDARY WINDING					
137	NSECONDARY			16		Secondary winding number of turns
139	BIAS WINDING					
140	NBIAS			5		Bias winding number of turns
144	PRIMARY COMPONENTS SELECTION					
145	LINE UNDERVOLTAGE/OVERVOLTAGE					
146	UVOV Type	UV Only		UV Only		Input Undervoltage/Overvoltage protection type
147	UNDERVOLTAGE PARAMETERS					
148	BROWN-IN REQUIRED	200.00		200.00	V	Required DC bus brown-in voltage threshold
149	UNDERVOLTAGE ZENER DIODE	BZM55C9V1		BZM55C9V1		Undervoltage protection zener diode
150	VZ			9.10	V	Zener diode reverse voltage
151	VR			6.80	V	Zener diode reverse voltage at the maximum reverse leakage current
152	ILKG			2.00	uA	Zener diode maximum reverse leakage current (at high ambient temperatures, typically 125 degC)
153	ILKG_MIN			0.10	uA	Zener diode minimum reverse leakage current (at low ambient temperatures, typically 25 degC)

154	BROWN-IN ACTUAL			133.19 - 197.72	V	Actual brown-in voltage range using standard resistors considering tolerances due to part and temperature variations
155	BROWN-OUT ACTUAL			118.93 - 177.11	V	Actual brown-out voltage range using standard resistors considering tolerances due to part and temperature variations
156	OVERVOLTAGE PARAMETERS					
157	OVERVOLTAGE REQUIRED		Info		V	For UV Only design, overvoltage feature is disabled
158	OVERVOLTAGE DIODE		Info			OV diode is used only for the overvoltage protection circuit
159	VF				V	OV diode forward voltage
160	VRRM				V	OV diode reverse voltage
161	PIV				V	OV diode peak inverse voltage
162	LINE_OVERVOLTAGE				V	For UV Only design, line overvoltage feature is disabled
163	DC BUS SENSE RESISTORS					
164	RLS_H			5.88	MΩ	Connect three 1.96 MOhm DC bus upper sense resistors to the V-pin for the required UV/OV threshold
165	RLS_L			124.00	kΩ	DC bus lower sense resistor to the V-pin for the required UV/OV threshold
168	BIAS WINDING					
169	VBIAS	12.00		12.00	V	Rectified bias voltage
170	VF_BIAS			0.70	V	Bias winding diode forward drop
171	VREVERSE_BIASDIODE			62.00	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
172	CBIAS			22	uF	Bias winding rectification capacitor
173	CBPP			4.70	uF	BPP pin capacitor
177	SECONDARY COMPONENTS SELECTION					
178	FEEDBACK COMPONENTS					
179	RFB_UPPER			107.00	kΩ	Upper feedback resistor (connected to the output terminal)
180	RFB_LOWER			2.77	kΩ	Lower feedback resistor
181	CFB_LOWER			330	pF	Lower feedback resistor decoupling capacitor
185	MULTIPLE OUTPUT PARAMETERS					
186	OUTPUT 1					
187	VOUT1			50.00	V	Output 1 voltage
188	IOUT1			1.300	A	Output 1 current
189	POUT1			65.00	W	Output 1 power
190	IRMS_SECONDARY1			2.064	A	Root mean squared value of the secondary current for output 1
191	IRIPPLE_CAP_OUTPUT1			1.604	A	Current ripple on the secondary waveform for output 1
192	NSECONDARY1			16		Number of turns for output 1
193	VREVERSE_RECTIFIER1		Warning[10]	210.00	V	Assuming this output is connected to the FWD pin, then the voltage stress may exceed the FWD pin voltage rating of 150 V. Increase the VOR to reduce voltage stress and allow for sufficient margin
194	SRFET1	SQJ454EP	Warning	SQJ454EP		Expected voltage stress (including the parasitic ring) on the secondary MOSFET selected exceeds the device BVDSS: pick a MOSFET with a higher BVDSS
195	NUM_SRFET1	1		1		Number of SRFETs in parallel for output 1
196	VF_SRFET1			0.83	V	SRFET typical on-time drain voltage for output 1
197	VBREAKDOWN_SRFET1			200	V	SRFET breakdown voltage for output 1
198	RDSON_SRFET1			217.5	mΩ	SRFET estimated on-time drain resistance at 100 °C and VGS = 4.4 V for output 1

[10] Rectifier diode used is VS-ETU1506SHM3 and is rated 600 V. Also, FWD and VOUT pin will be connected to secondary bias winding thus warning can be disregarded.

199	RTHJA_SRFET1			68.00	°C/W	SRFET max. thermal impedance for output 1
200	TEMP_SRFET1_MIN			152.5	°C	SRFET minimum operating temperature for output 1 (for each SRFET in parallel) with respect to ambient, observed at 480 V VINDC
201	TEMP_SRFET1_MAX		Warning	189.2	°C	Expected operating temperature of the SRFET is exceeding the maximum recommended operating temperature of 125 °C. Consider implementing a parallel SRFET, or select an SRFET with lower RDSON, VF, and effective RTHJA
203	OUTPUT 2[11]					
204	VOUT2	12.00		12.00	V	Output 2 voltage
205	IOUT2	0.001		0.001	A	Output 2 current
206	POUT2			0.01	W	Output 2 power
207	IRMS_SECONDARY2			0.002	A	Root mean squared value of the secondary current for output 2
208	IRIPPLE_CAP_OUTPUT2			0.001	A	Current ripple on the secondary waveform for output 2
209	NSECONDARY2			4		Number of turns for output 2
210	VREVERSE_RECTIFIER2			52.00	V	SRFET reverse voltage (not accounting parasitic voltage ring) for output 2
211	SRFET2	AUTO		SQJA68EP[12]		Secondary rectifier (Logic MOSFET) for output 2
212	NUM_SRFET2	1		1		Number of SRFETS in parallel for output 2
213	VF_SRFET2			0.88	V	SRFET typical on-time drain voltage for output 2
214	VBREAKDOWN_SRFET2			100	V	SRFET breakdown voltage for output 2
215	RDSON_SRFET2			169.7	mΩ	SRFET on-time drain resistance at 100°C and VGS=4.4 V for output 2
216	RTHJA_SRFET2			70.00	°C/W	SRFET max. thermal impedance for output 2
217	TEMP_SRFET2_MIN			85.6	°C	SRFET minimum operating temperature for output 2 (for each SRFET in parallel) with respect to ambient, observed at 480 V VINDC
218	TEMP_SRFET2_MAX			87.6	°C	SRFET maximum operating temperature for output 2 (for each SRFET in parallel) with respect to ambient, observed at 200 V VINDC

Table 7 – RDR-1074Q PIXls Spreadsheet.

[11] Output 2 is only used as secondary bias winding for FWD and VOUT pin.
[12] Diode used is BAS21GWX.

9 Hi-Pot Testing for Transformer

Hi-Pot testing measures the dielectric breakdown of the primary-to-secondary isolation used in the transformer. This test is done to assess the ability of the insulation to withstand steady state working voltage stress. Hi-pot testing also checks for the existence of damage in the isolation barrier.

Figure 12 shows the test profile used to evaluate the wire wound transformer of RDR-1074Q.

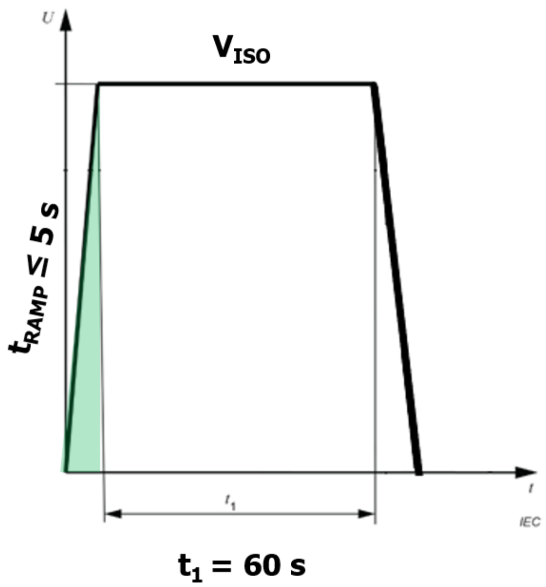


Figure 12 – Hi-Pot Test Profile of RDR-1074Q.

The unit under test was tested with an isolation voltage of 1000 V_{RMS} to 2000 V_{RMS} with a 5-second ramp-up and 60-second dwell time. The isolation test was done between pin 1 to pin 6 at 25 °C ambient, with pin 1-5 and 6-10 shorted. Refer to section 7.1 for the transformer electrical diagram.

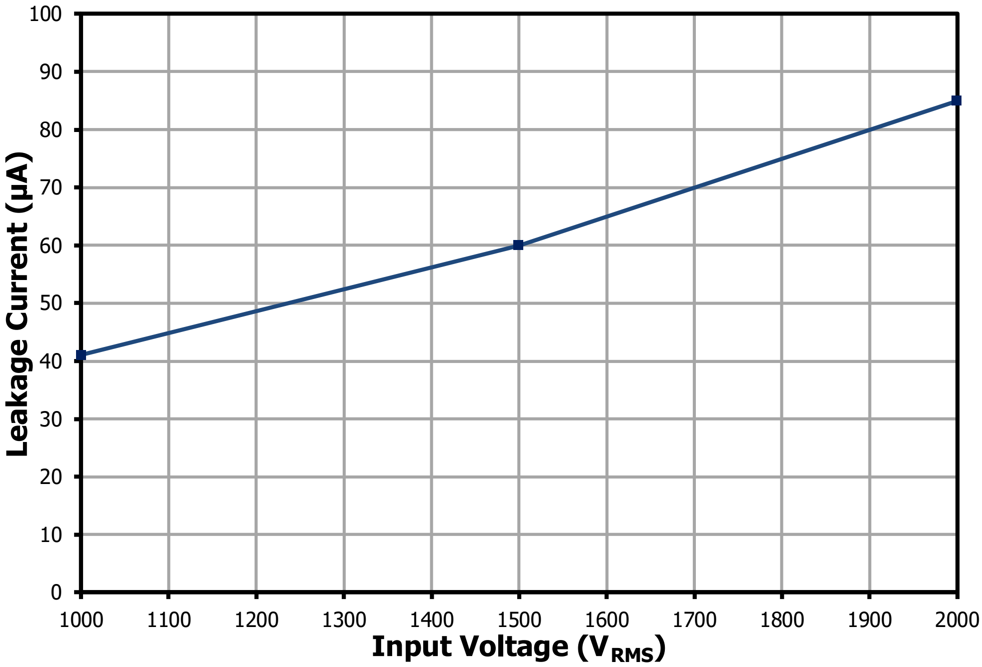


Figure 13 – Isolation Voltage vs. Leakage Current (25 °C Ambient).

Note: The leakage current across the isolation barrier above is due to the primary to secondary coupling capacitance. When the high voltage 60 Hz AC test voltage is applied, current flows through this capacitance (~59 pF). Under DC voltage conditions, this leakage is not present (< 3 µA measured)

10 Performance data

Note: 1. Measurements were taken with the unit under test inside a thermal chamber.
2. The RDR-1074Q board was placed inside a box (within the thermal chamber) to eliminate the effects of airflow.

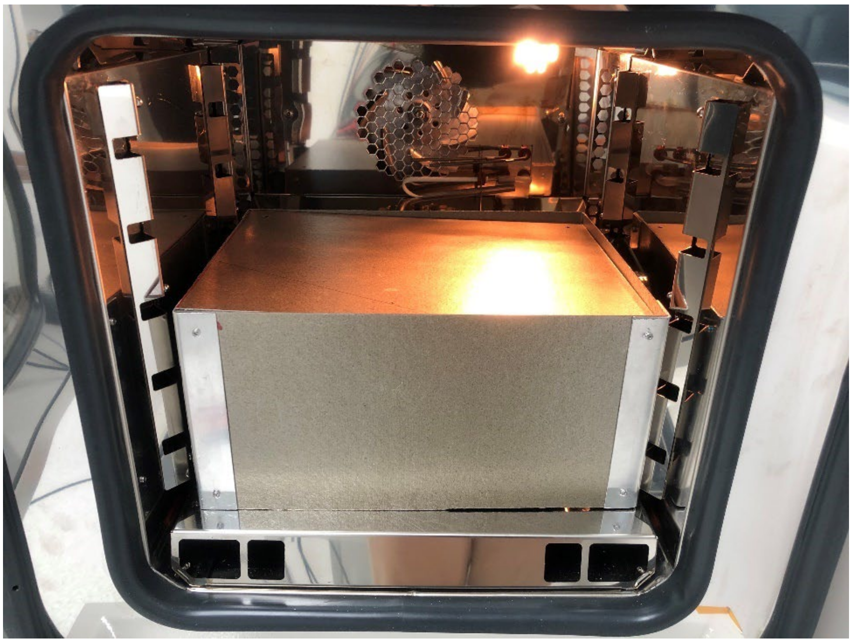


Figure 14 – Unit under test placed inside a box to eliminate the effect of airflow.

3. The RDR board was allowed to stabilize for 5 minutes at full load at the start of every test. For each loading condition, the RDR-1074Q test board was allowed to stabilize for 1 minute before measurements were taken.
4. List of Equipment Used for Testing

Equipment Type	Model Number	Specifications	Manufacturer
Power Supply	MR100020	1000 V/20 A/5 kW Programmable DC PSU	BK Precision
Electronic Load	PEL-2020A	80 V/20 A/100 W DC Electronic Load	GW Instek
Power Meter	66205	600 V/30 A Digital Power Meter	Chroma
Power Meter	WT310E	600 V/20 A Digital Power Meter	Yokogawa
High-Voltage Measurement	TT-SI 9101	100 MHz 700 V Differential Probe	Testec
High-Voltage Measurement	TT-SI 9110	100 MHz 1400 V Differential Probe	Testec
Low-Voltage Measurement	701937	500 MHz 600 V Passive Probe	Yokogawa
Current Measurement	701928	100 MHz 30 A_{rms} Current Probe	Yokogawa
Current Measurement	CWTUM/06/R	30 MHz 120 A_{peak} Rogowski Coil	CWT
Thermocouple Measurement	GL840	20-Channel Data Logger	Graphtec
Thermal Image	TiX580	1000 °C Thermal Imaging Camera	Fluke
Thermal Chamber	SH-242	Temperature & Humidity Chamber	Espec
Oscilloscope	DLM5058	2.5GS/s 500MHz Mixed Signal	Yokogawa

Table 8 – List of Equipment Used for Testing.

10.1 No-Load Input Power

Figure 15 shows the test circuit used for the no-load input power measurement. The voltmeter was placed before the ammeter. This was done to prevent the voltmeter bias current from affecting the input current measurements. A Chroma Digital Power Meter 66205 was used to measure the current and voltage.

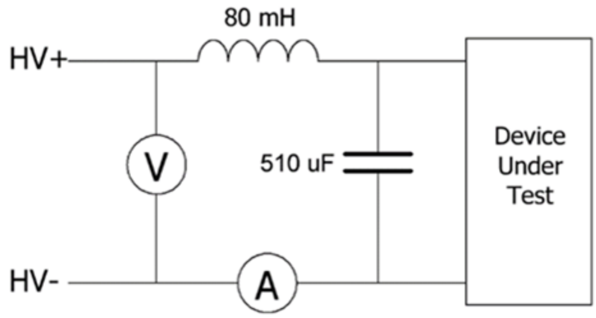


Figure 15 – No-Load Input Power Measurement Diagram.

For each input voltage, the unit was soaked for ten minutes before measurements were made. The leakage current through the DC-Link capacitor was also measured before testing and was subtracted from the measured no-load input current. The voltage across the input inductor was assumed to be negligible due to its very low DCR (40 mΩ) and low input current. AC losses in the inductor were also assumed to be negligible.

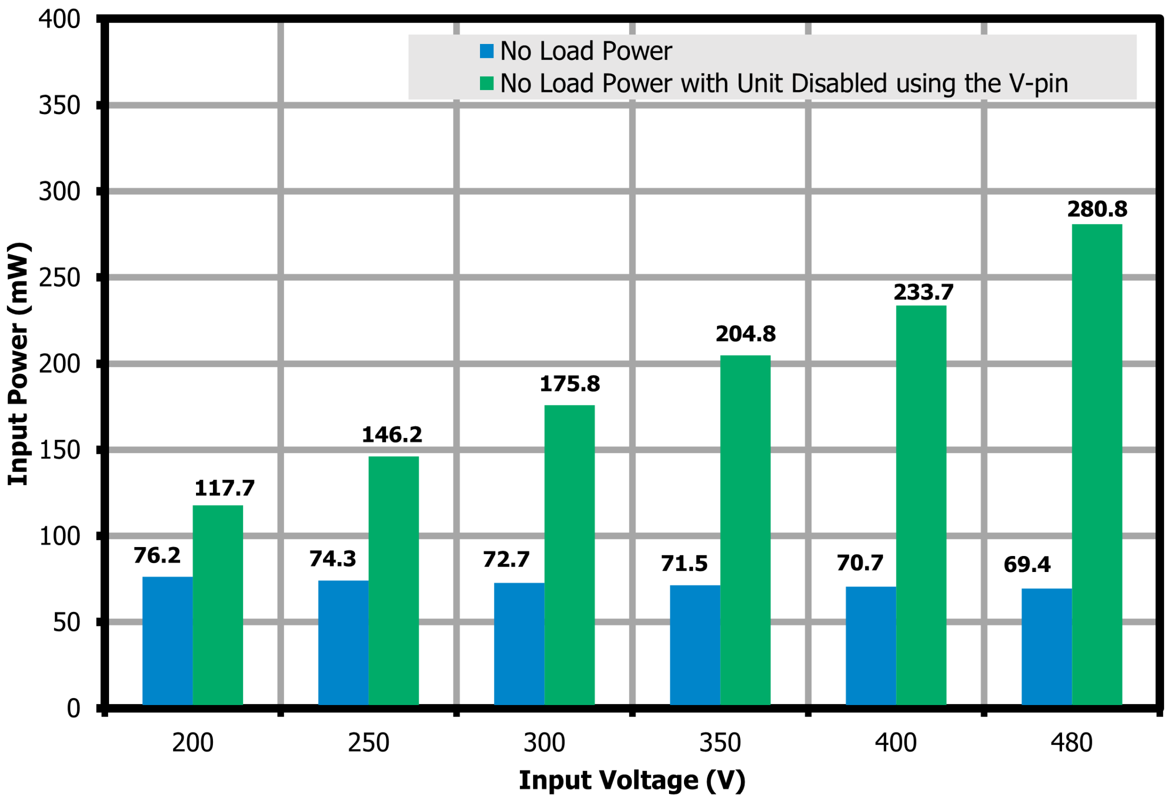


Figure 16 – No-Load Input Power vs. Input Voltage (25 °C Ambient).

10.2 Efficiency

10.2.1 Efficiency Across Line

Efficiency across line describes how the change in input voltage affects the overall efficiency of the unit. The points in the graph were taken at 100% load conditions (1.3 A).

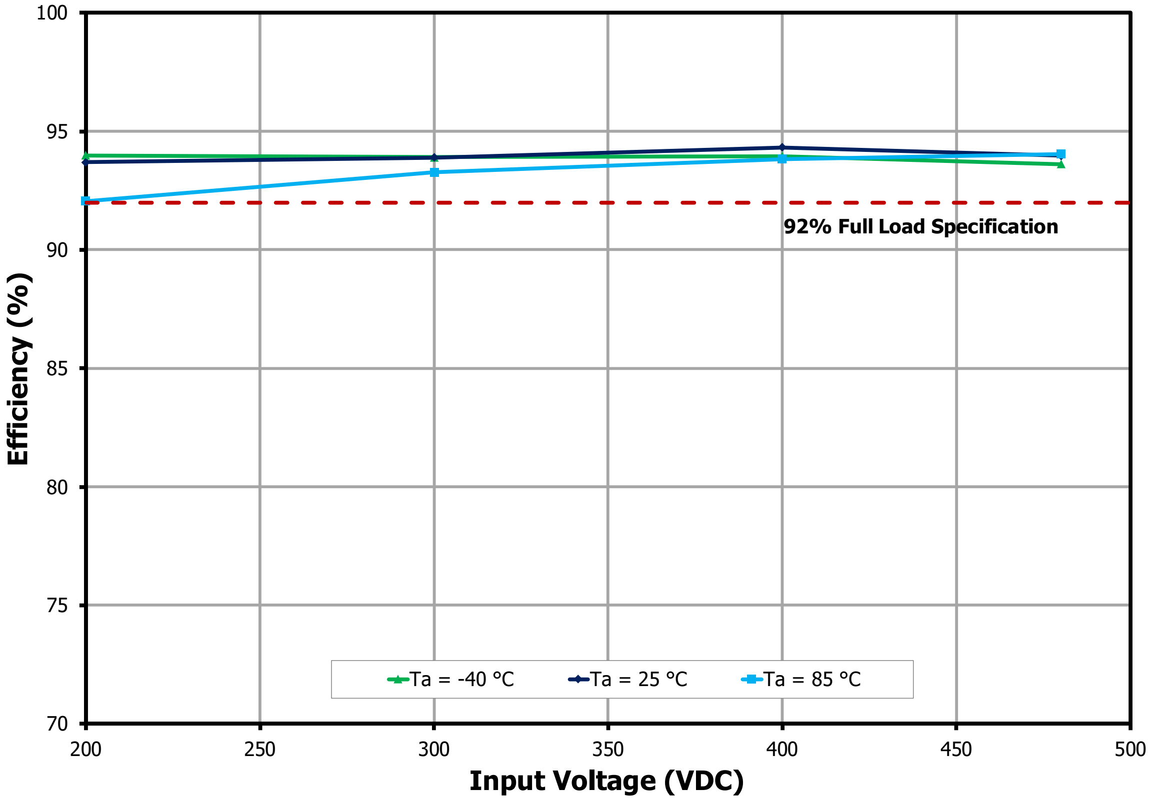


Figure 17 – Full Load Efficiency vs. Input Line Voltage.

10.2.2 Efficiency Across Load

Efficiency across load describes how output loading affects the overall efficiency of the power supply. 100% load was defined at the 1.3 A full load output current.

10.2.2.1 Efficiency Across Load at -40 °C Ambient

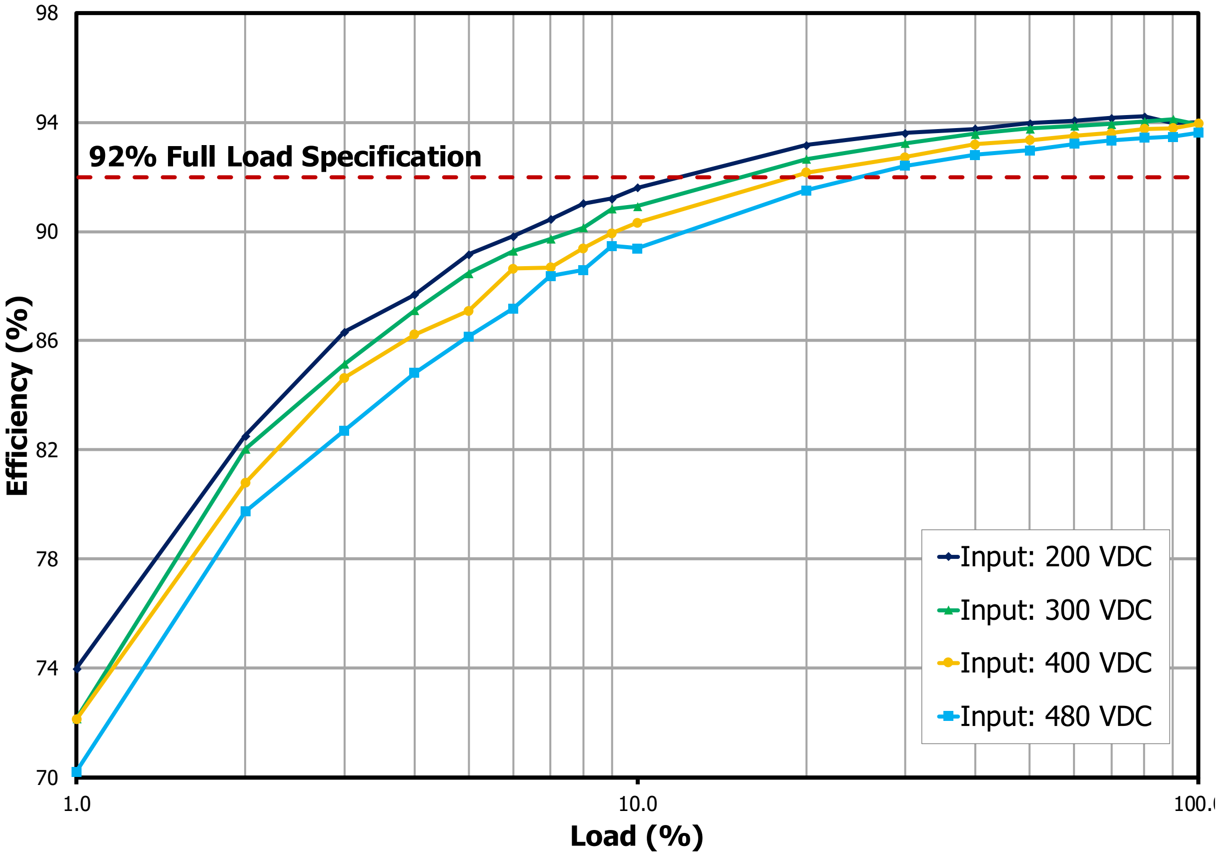


Figure 18 – Efficiency vs. Load at Different Input Voltages (-40 °C Ambient).

10.2.2.2 Efficiency Across Load at 25 °C Ambient

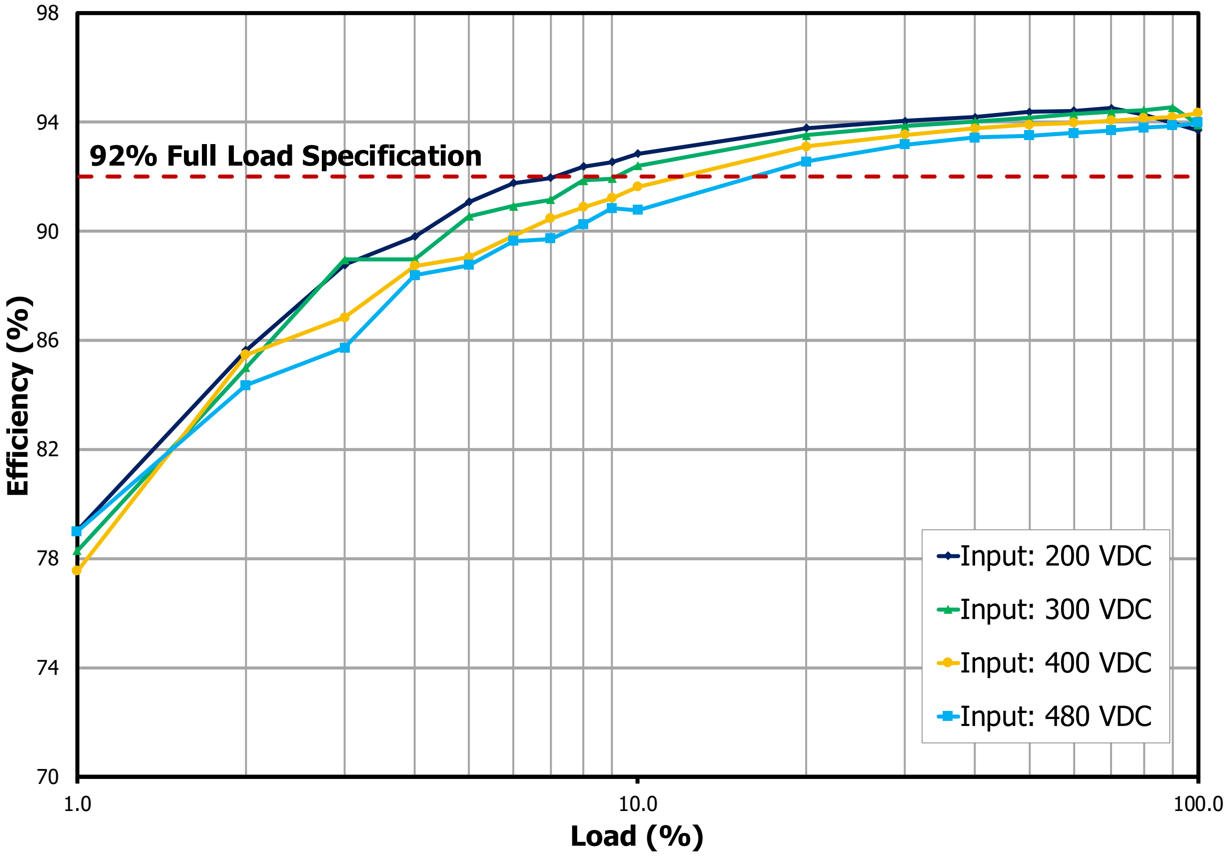


Figure 19 – Efficiency vs. Load at Different Input Voltages (25 °C Ambient).

10.2.2.1 Efficiency Across Load at 85 °C Ambient

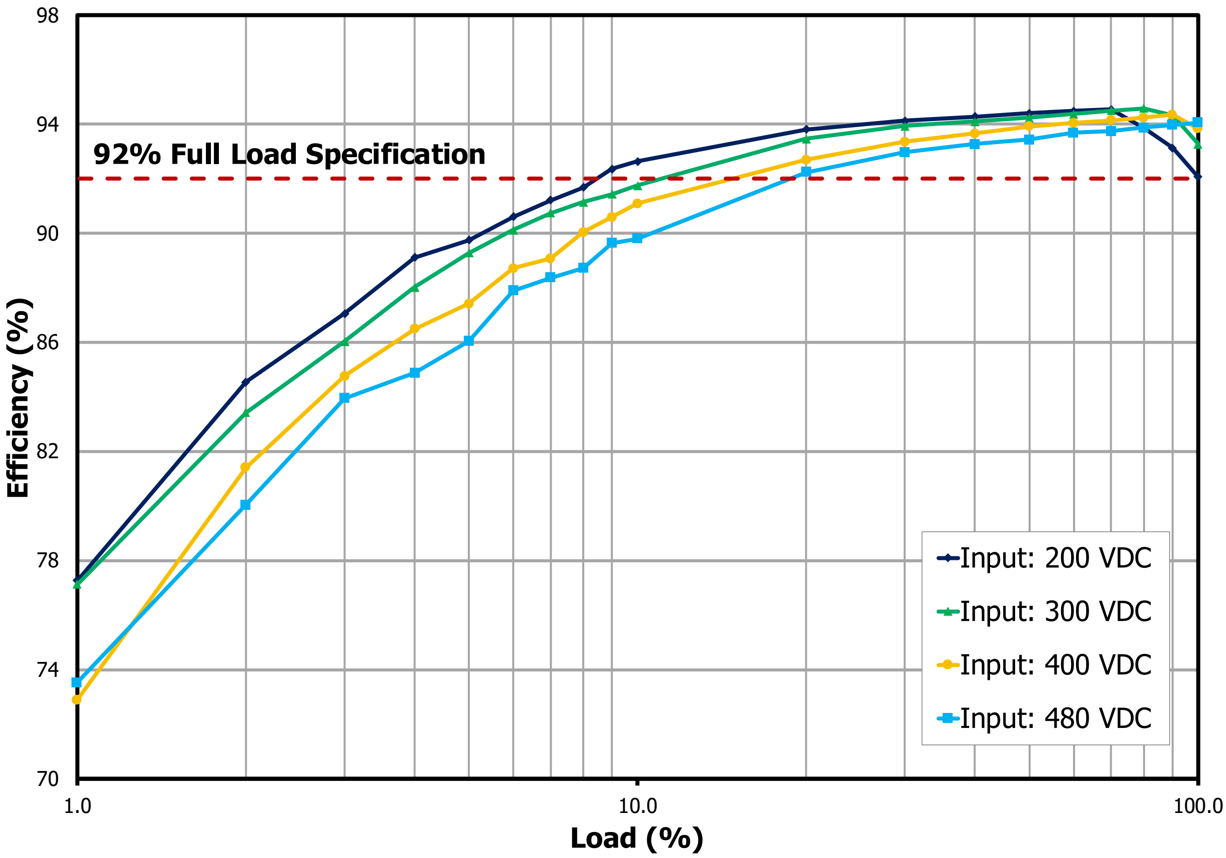


Figure 20 – Efficiency vs. Load at Different Input Voltages (85 °C Ambient).

10.3 Line and Load Regulation

10.3.1 Load Regulation

Load regulation describes how a change in load affects output voltage. 100% load was defined at the 1.3 A full load output current.

10.3.1.1 Load Regulation at -40 °C Ambient

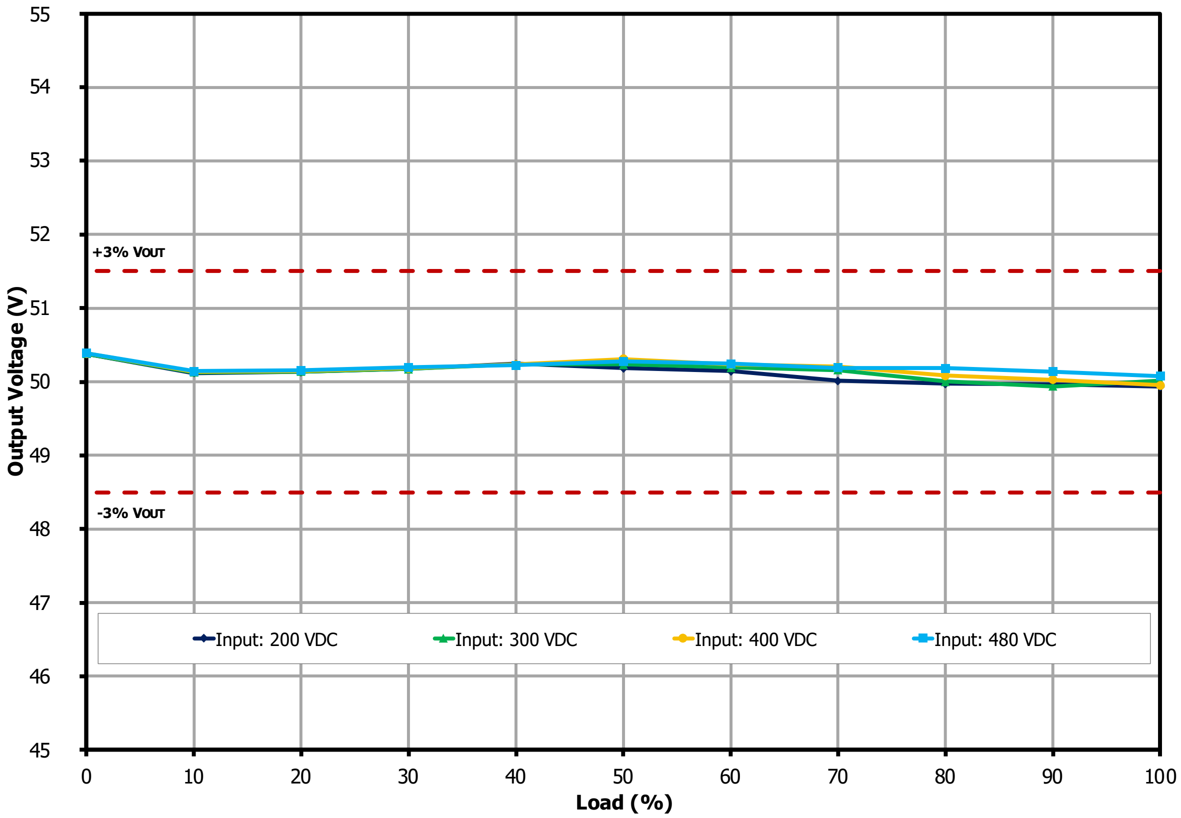


Figure 21 – Output Regulation vs. Load at Different Input Voltages (-40 °C Ambient).

10.3.1.1 Load Regulation at 25 °C Ambient

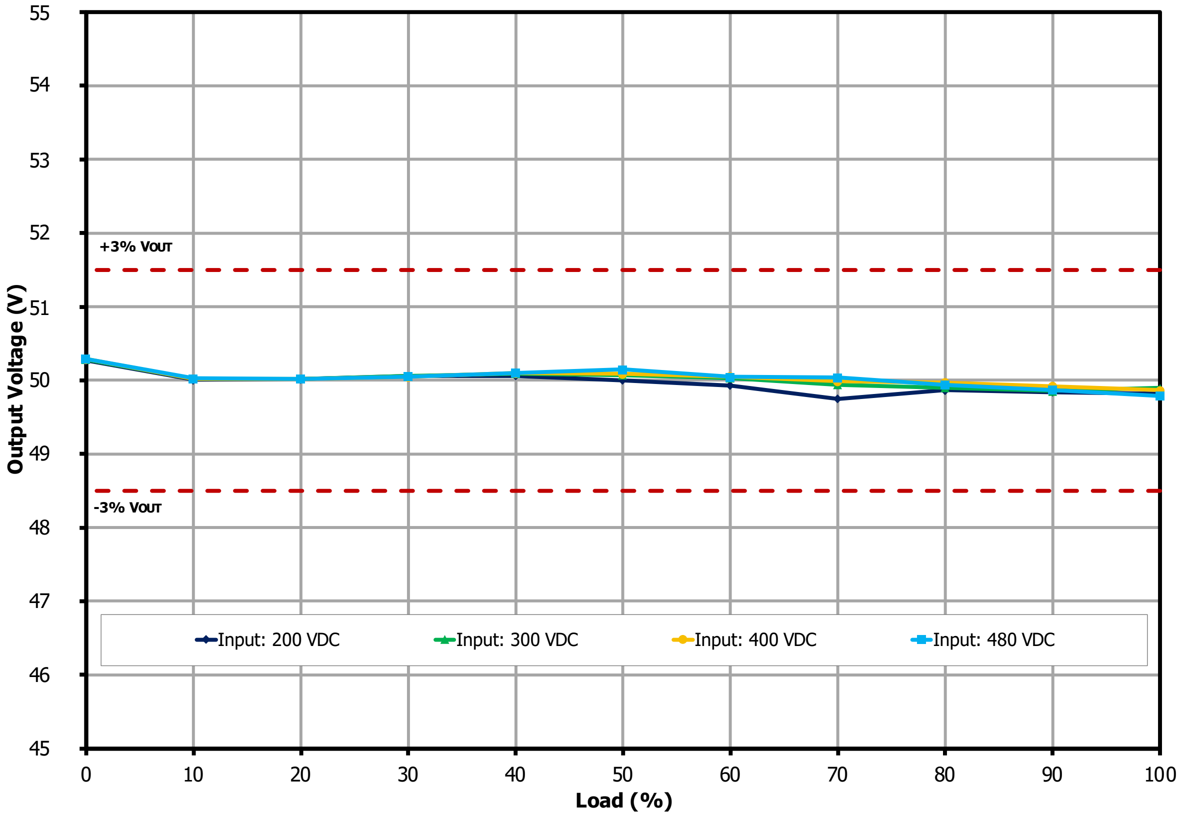


Figure 22 – Output Regulation vs. Load at Different Input Voltages (25 °C Ambient).

10.3.1.2 Load Regulation at 85 °C Ambient

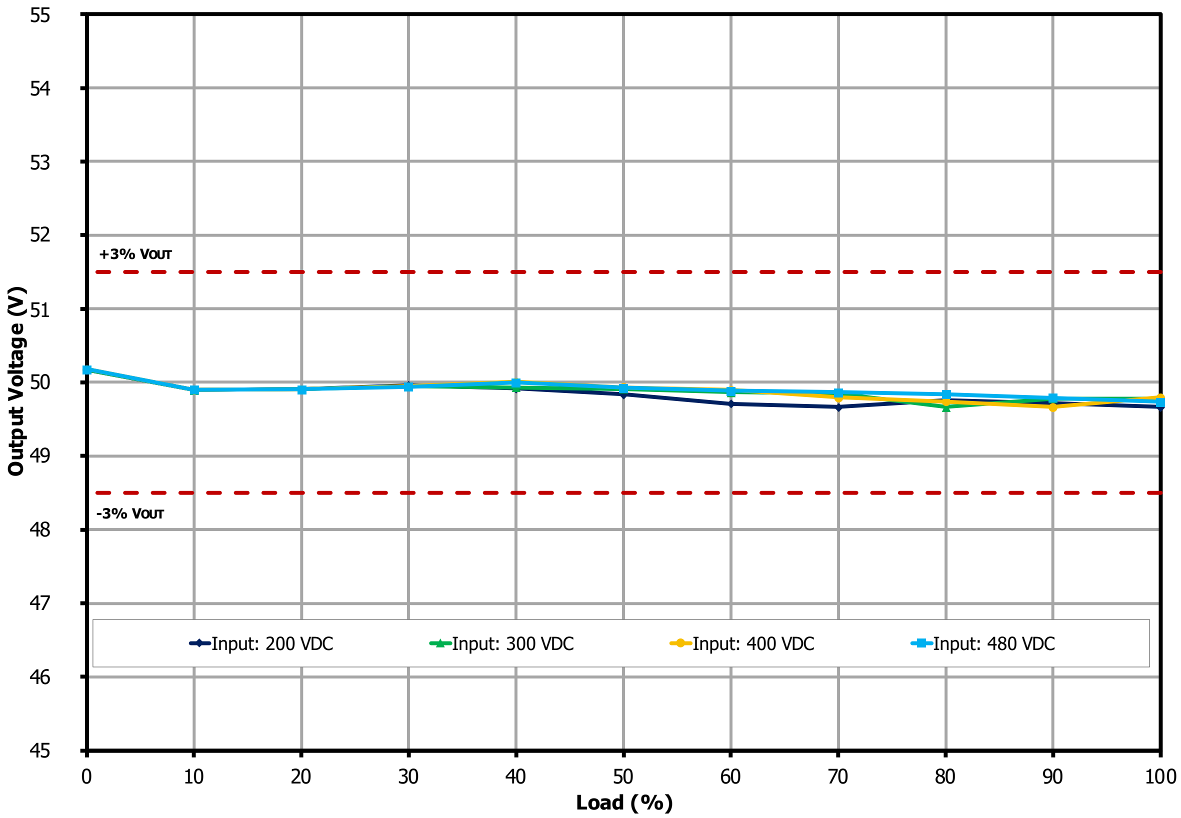


Figure 23 – Output Regulation vs. Load at Different Input Voltages (85 °C Ambient).

10.3.2 Line Regulation

Line regulation describes how a change in input voltage affects the output voltage. The points in the graph were taken at 100% (1.3 A) load.

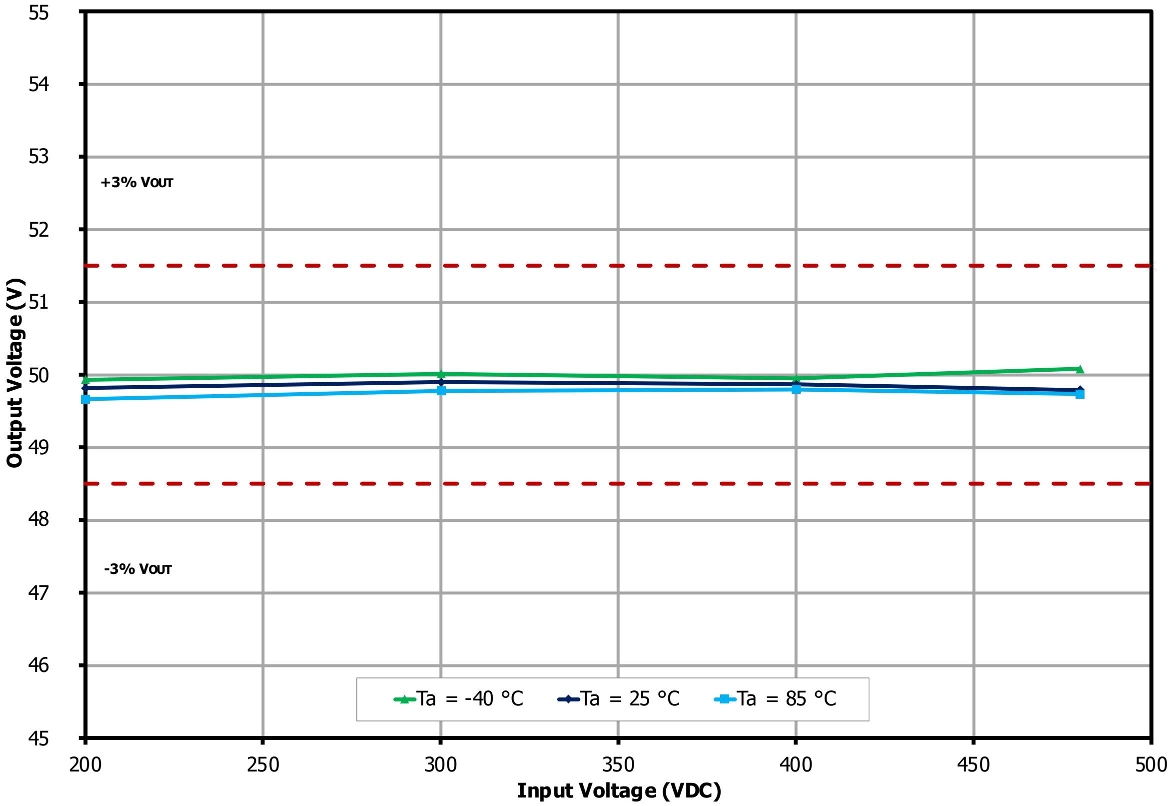


Figure 24 – Output Voltage vs Input Voltage at Full Load (1.3 A).

11 Thermal Performance

11.1 Thermal Data at 85 °C Ambient

The unit was placed inside a thermal chamber and was allowed to stabilize at 100% load for at least 1 hour. Figure 14 shows the test setup for thermal measurement.

Critical Components	Temperature (°C)		
	200 VDC	400 VDC	480 VDC
Transformer Secondary Winding	119	109	110
Transformer Core	114	112	113
INN3997CQ (IC100A)	117	105	103
Secondary Snubber Diode (D105)	121	109	110
Secondary Rectifier Diode (D100)	125	109	109
Secondary Snubber Resistor (R100)	121	111	112
Output Capacitor (C100)	105	97	97
Primary Snubber Diode (D201)	102	97	96
Transformer Primary Winding	105	102	102
Primary Snubber Resistor (R201)	111	101	99

Table 9 – Thermal Data of 65 W Continuous Output Power at 85 °C at Different Input Voltages.

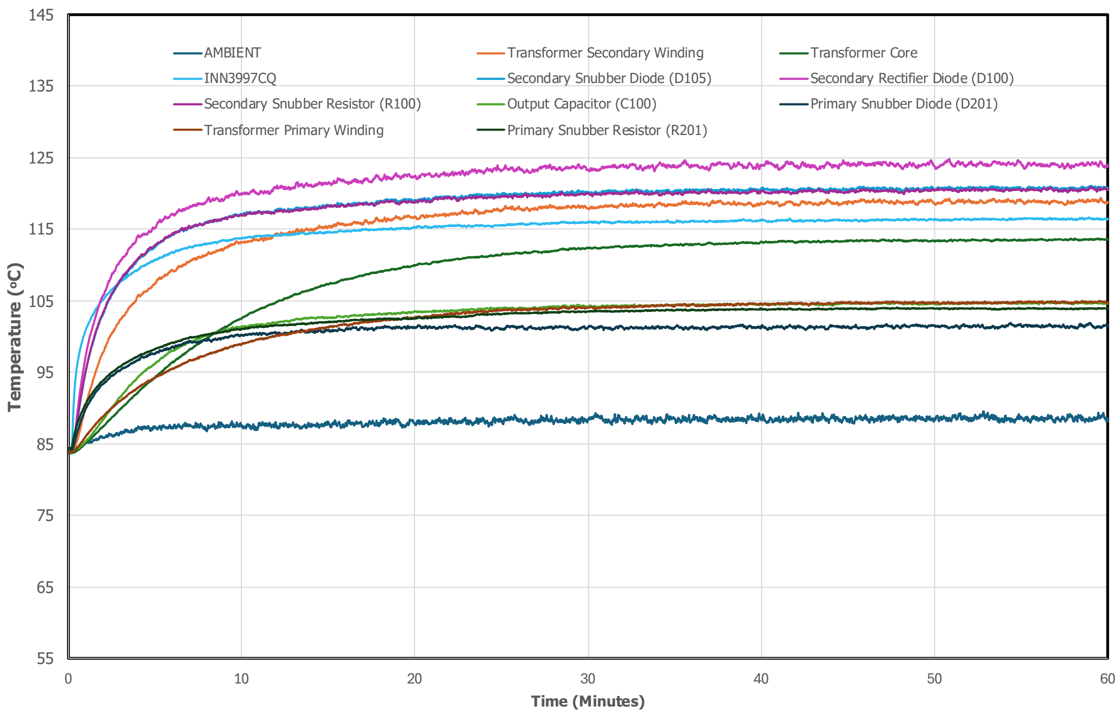


Figure 25 – Component Temperatures at 85 °C Ambient, 200 VDC Input, 1.3 A Load.

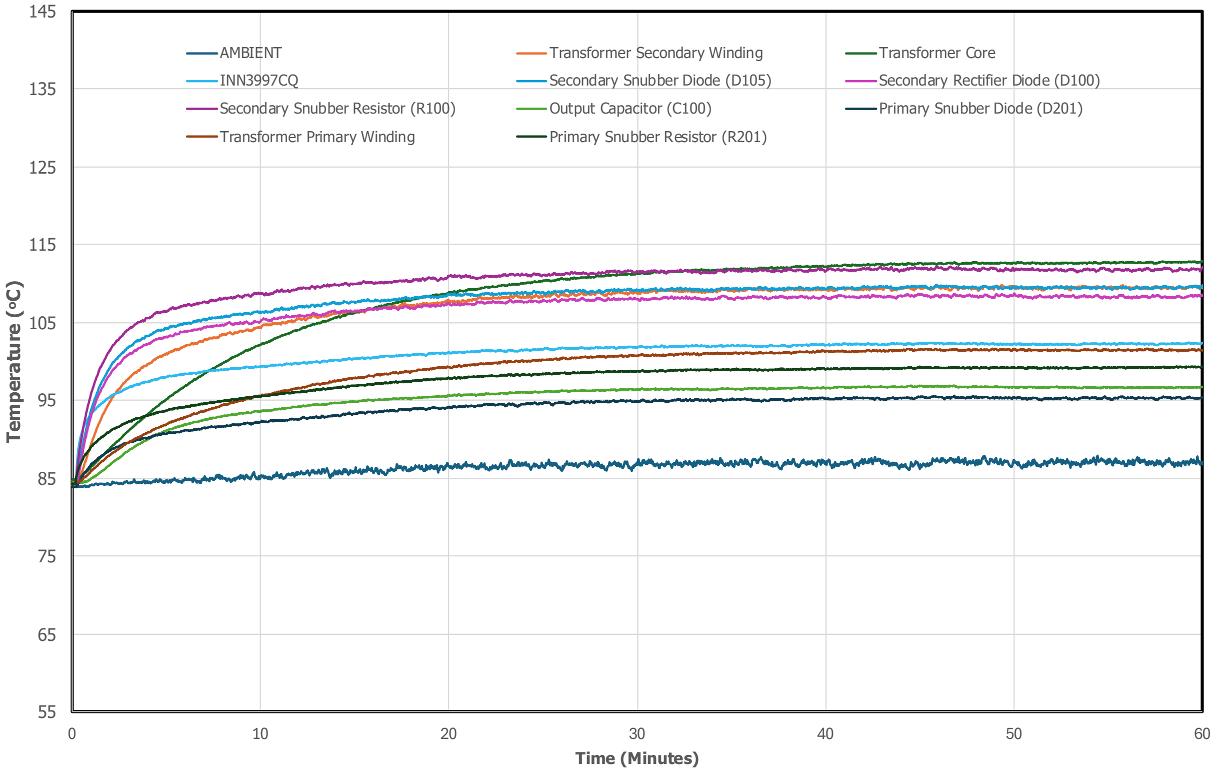


Figure 26 - Component Temperatures at 85 °C Ambient, 480 VDC Input, 1.3 A Load.

11.2 Thermal Data at 25 °C Ambient

The following thermal scans were captured using a Fluke thermal imager after soaking the power supply in an enclosure to minimize the effect of airflow for 30 minutes.

Critical Components	Temperature (°C)		
	200 VDC	400 VDC	480 VDC
Transformer Secondary Winding	56	54	55
Transformer Core	54	56	57
INN3997CQ (IC100A)	58	46	47
Secondary Snubber Diode (D105)	59	55	57
Secondary Rectifier Diode (D100)	61	55	57
Secondary Snubber Resistor (R100)	60	57	58
Output Capacitor (C100)	44	40	41
Primary Snubber Diode (D201)	46	41	42
Transformer Primary Winding	51	51	52
Primary Snubber Resistor (R201)	42	39	40

Table 10 – Thermal Data at 25 °C at Different Input Voltages.

Figure 27 – PCB Top Thermal Scan at 200 VDC Input, 1.3 A Load.

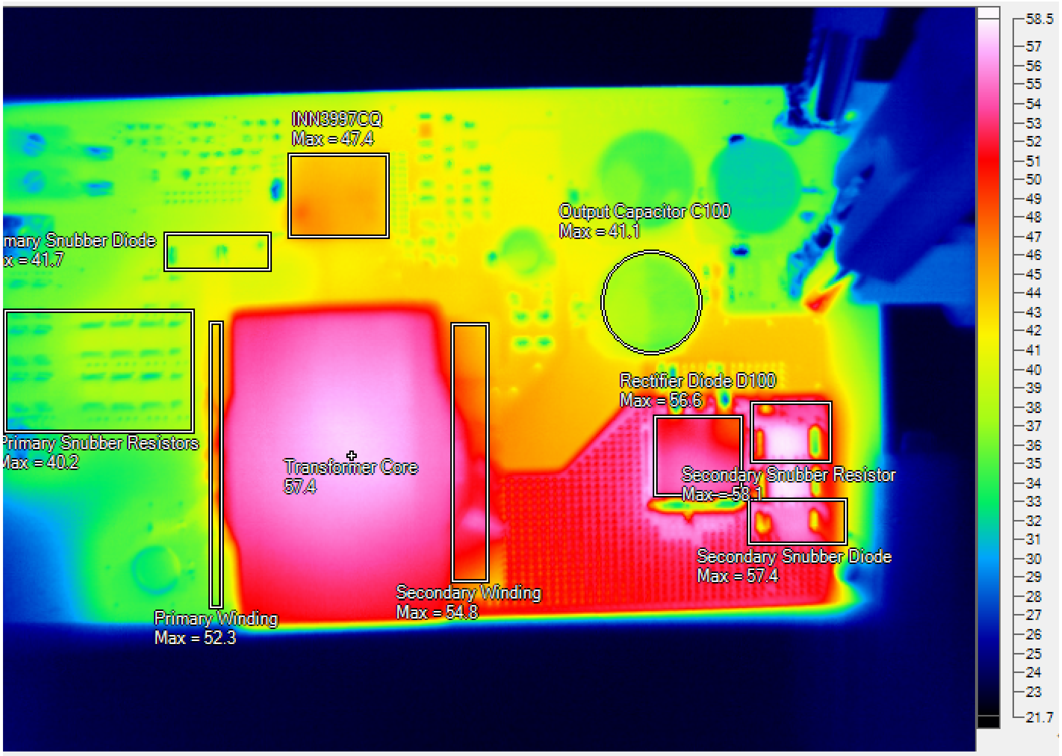


Figure 28 – PCB Top Thermal Scan at 480 VDC Input, 1.3 A Load.

12 Waveforms

12.1 Start-Up Waveforms

The following measurements were taken by connecting the unit to a fully charged DC-link capacitor[13] at different input voltages. A constant resistance load configuration was used for all start-up tests.

12.1.1 Output Voltage and Current at 85 °C Ambient[14]

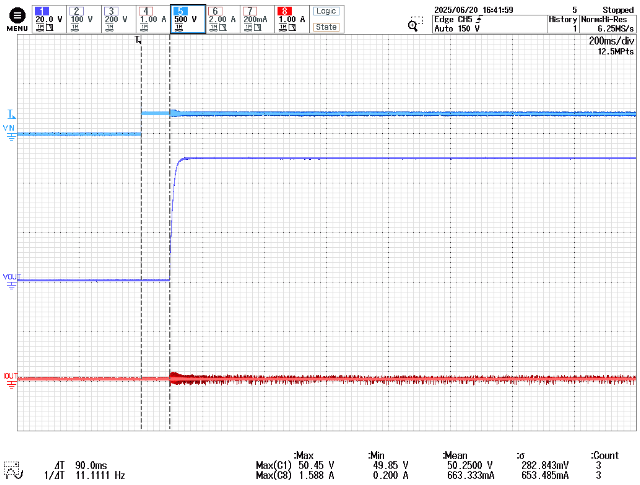


Figure 29 – Output Voltage and Current.
200 VDC, No Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

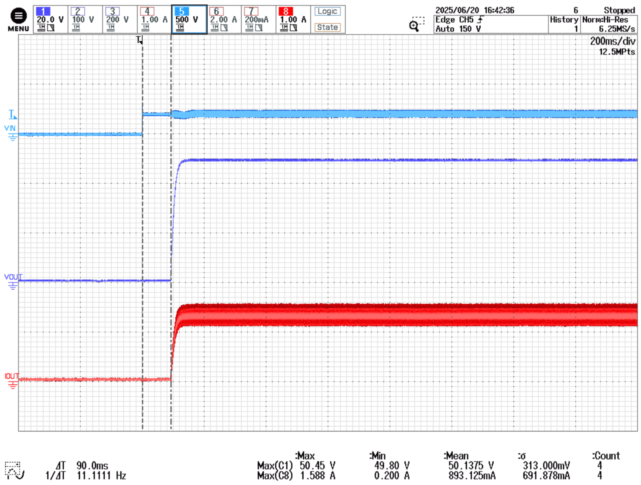


Figure 30 – Output Voltage and Current.
200 VDC, 38 Ω Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

[13] Inrush current was limited by adding a 10 Ω series resistor between the DC-link capacitor and the unit under test.
[14] Current waveforms were measured using a Yokogawa current probe. See Table 8 for list of equipment.

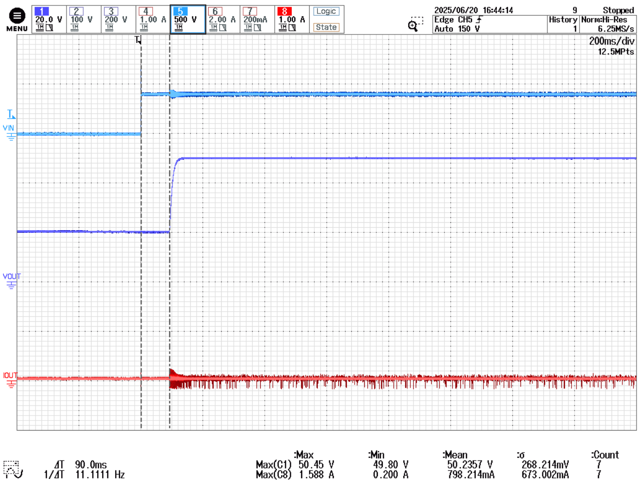


Figure 31 – Output Voltage and Current.
400 VDC, No Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

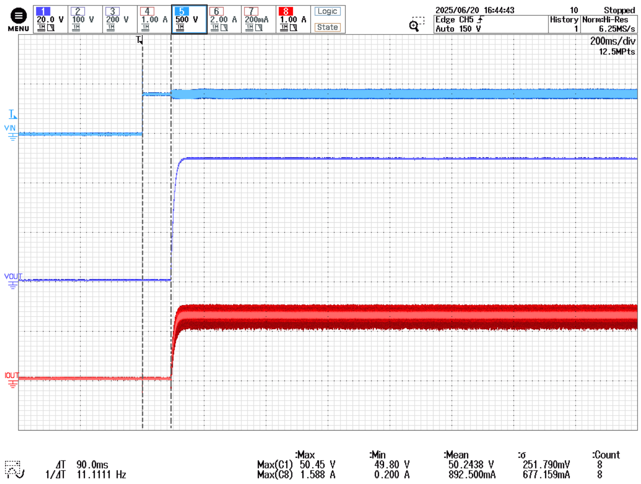


Figure 32 – Output Voltage and Current.
400 VDC, 38 Ω Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

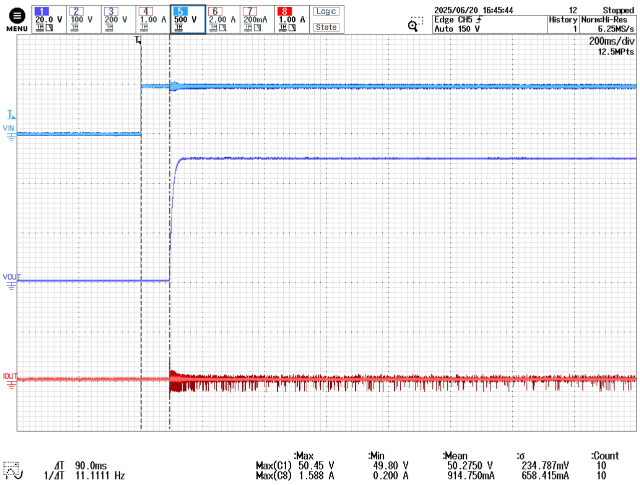


Figure 33 – Output Voltage and Current.
480 VDC, No Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

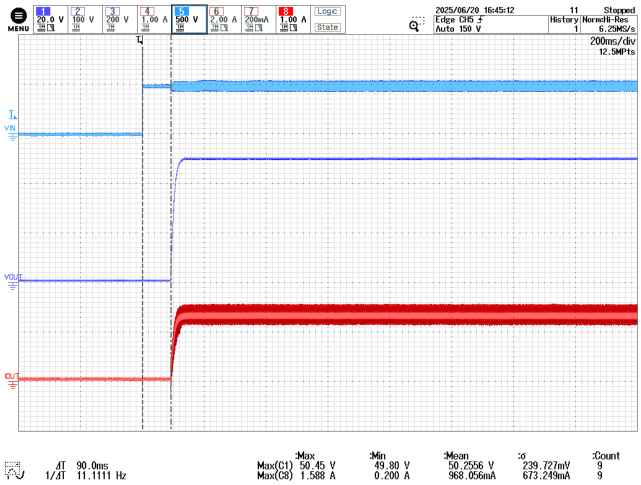


Figure 34 – Output Voltage and Current.
480 VDC, 38 Ω Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

12.1.2 InnoSwitch3-AQ Drain Voltage and Current at 85 °C Ambient[15,16]

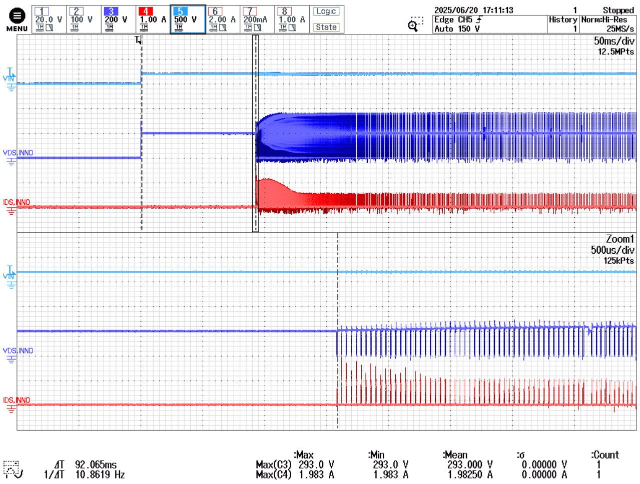


Figure 35 – INN3997CQ Drain Voltage and Current.
200 VDC, No Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

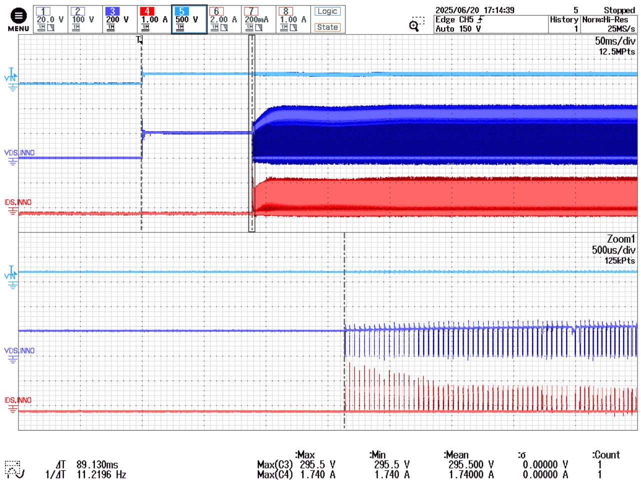


Figure 36 – INN3997CQ Drain Voltage and Current.
200 VDC, 38 Ω Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

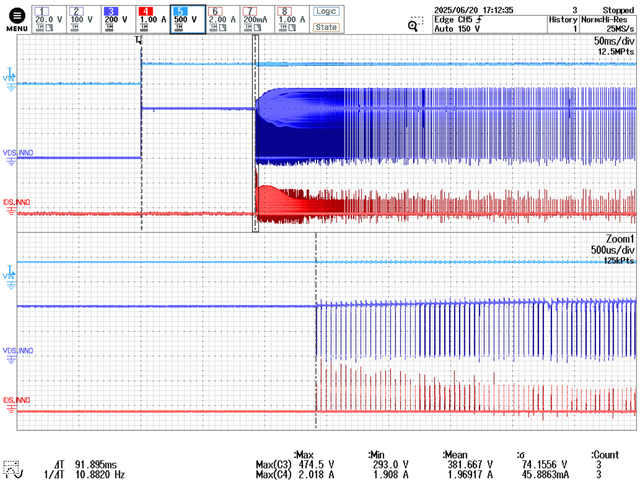


Figure 37 – INN3997CQ Drain Voltage and Current.
400 VDC, No Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

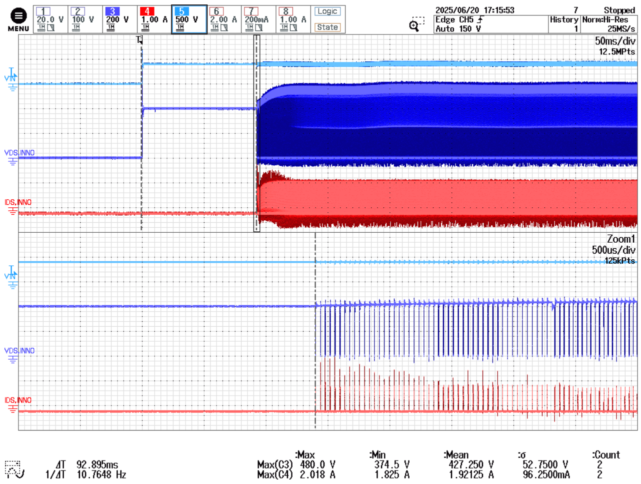


Figure 38 – INN3997CQ Drain Voltage and Current.
400 VDC, 38 Ω Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

[15] The time between when V_{IN} turned on and the InnoSwitch3 starts switching is due to the "Wait and Listen" period of the InnoSwitch3.
[16] Current waveforms were measured using Yokogawa 100 MHz 30 Arms Current Probe with 250 cm twisted pair of wire. This long-twisted lead adds capacitance to the drain node which causes additional current spike. See Table 8 for list of equipment.

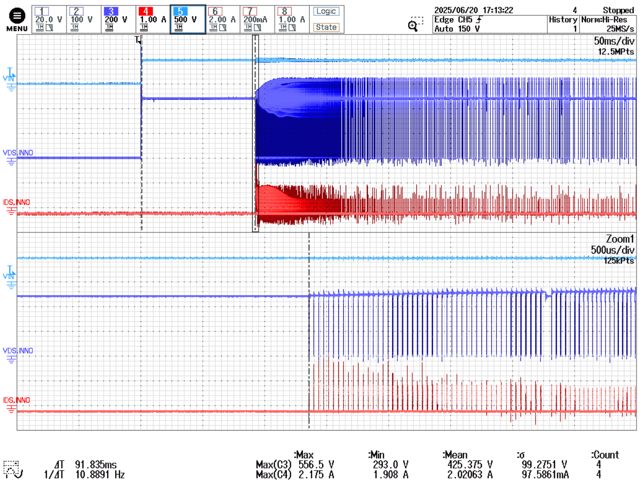


Figure 39 – INN3997CQ Drain Voltage and Current.
480 VDC, No Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

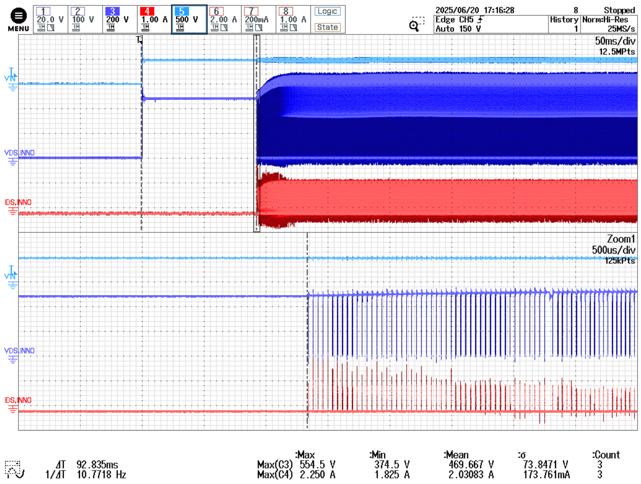


Figure 40 – INN3997CQ Drain Voltage and Current.
480 VDC, 38 Ω Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

12.1.3 Rectifier Diode Voltage and Current at 85 °C Ambient[17,18]

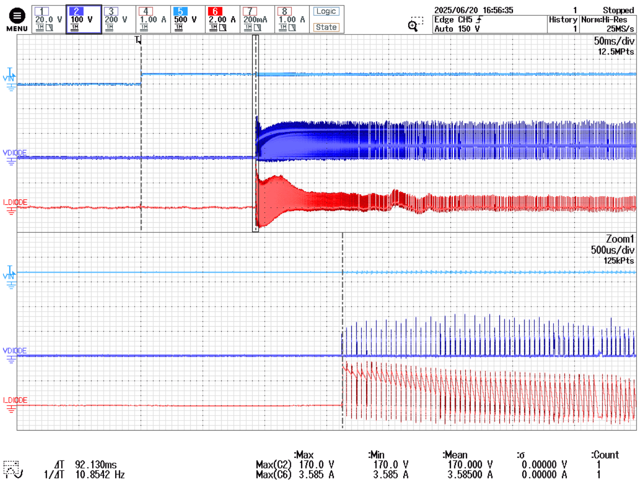


Figure 41 – Rectifier Diode Voltage and Current.
200 VDC, No Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

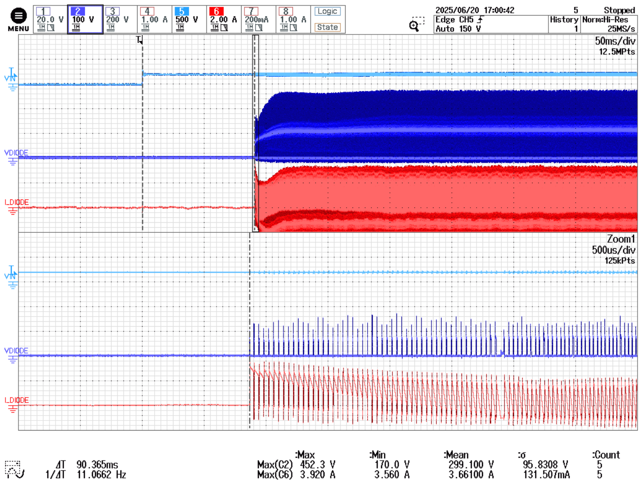


Figure 42 – Rectifier Diode Voltage and Current.
200 VDC, 38 Ω Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

[17] The time between when V_{IN} turned on and the InnoSwitch3 starts switching is due to the "Wait and Listen" period of the InnoSwitch3.
[18] Current waveforms were measured using a 120 A_{peak} Rogowski Coil, 5 MHz bandwidth-limited to reduce high frequency noise. See Table 8 for list of equipment.

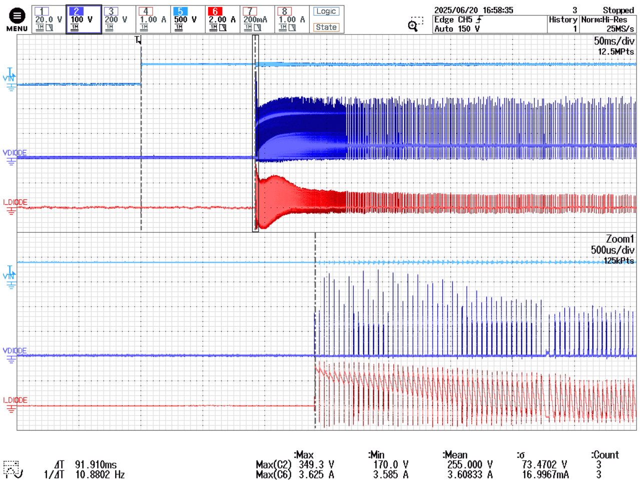


Figure 43 – Rectifier Diode Voltage and Current.
400 VDC, No Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

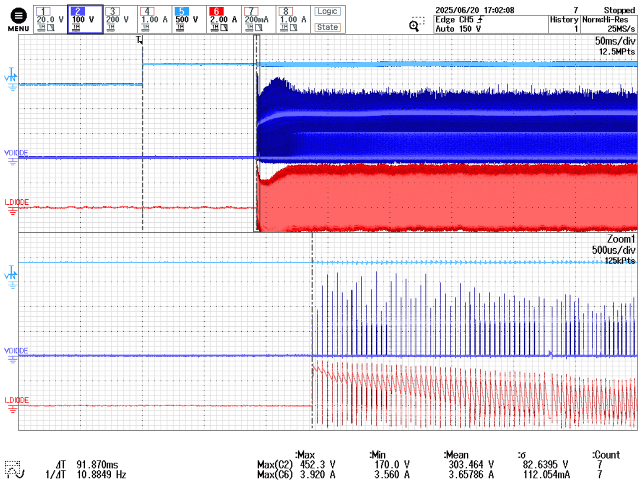


Figure 44 – Rectifier Diode Voltage and Current.
400 VDC, 38 Ω Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

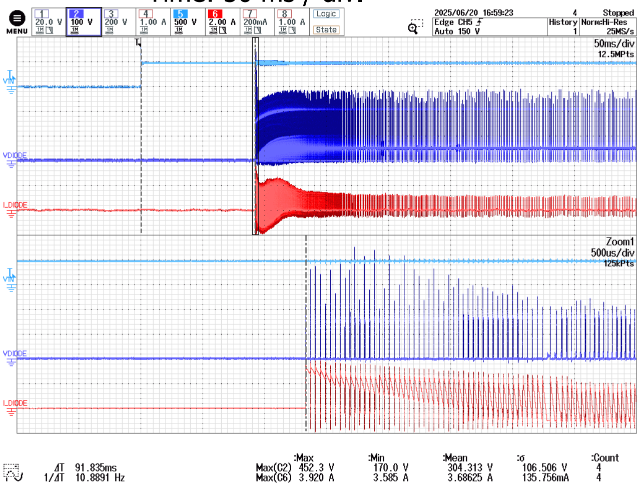


Figure 45 – Rectifier Diode Voltage and Current.
480 VDC, No Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

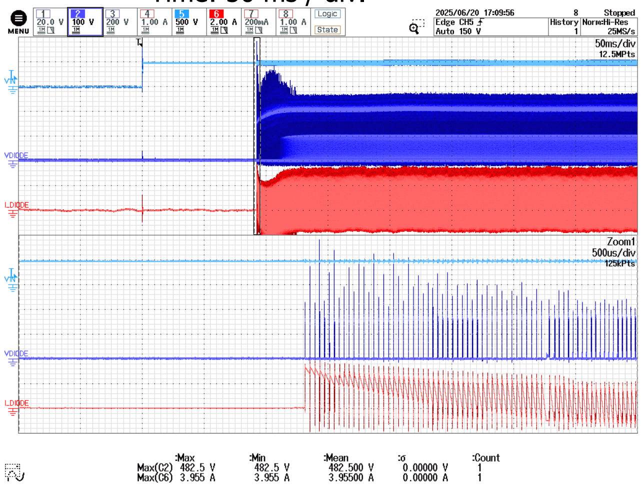


Figure 46 – Rectifier Diode Voltage and Current.
480 VDC, 38 Ω Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

12.1.4 Output Voltage and Current at -40 °C Ambient[19]

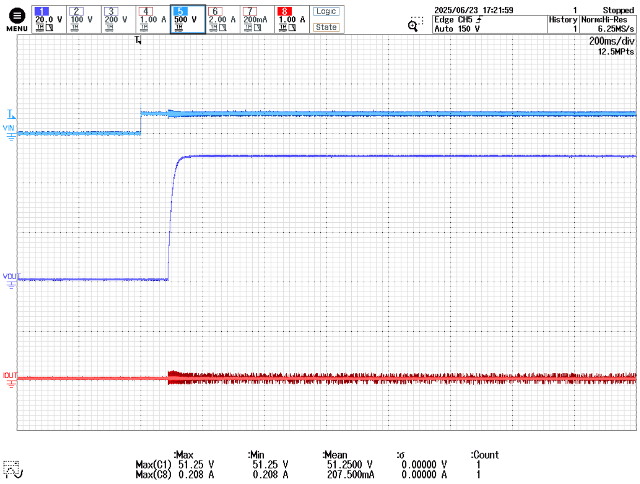


Figure 47 – Output Voltage and Current.
200 VDC, No Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

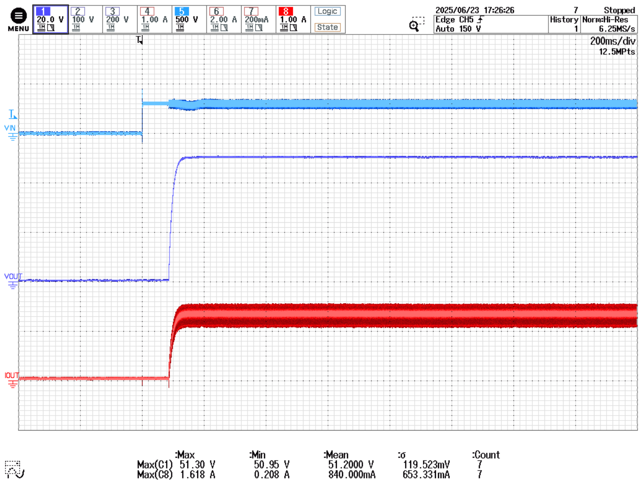


Figure 48 – Output Voltage and Current.
200 VDC, 38 Ω Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

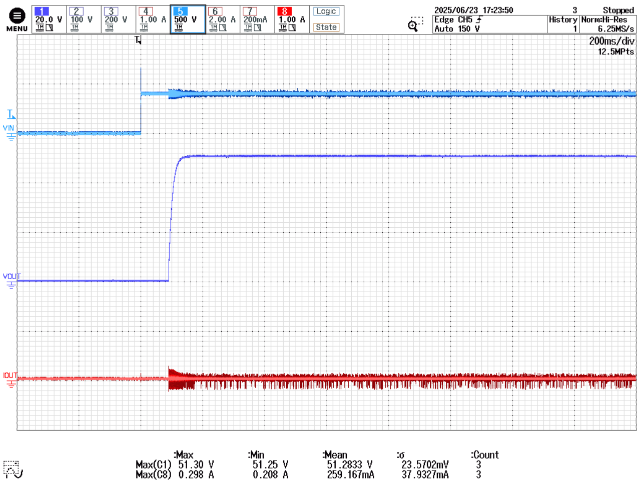


Figure 49 – Output Voltage and Current.
400 VDC, No Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

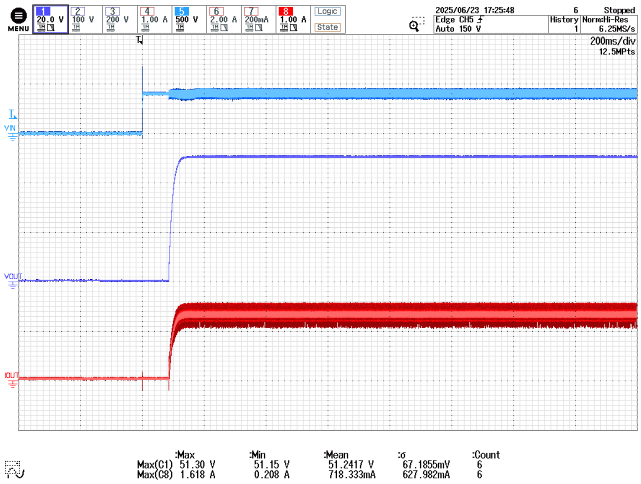


Figure 50 – Output Voltage and Current.
400 VDC, 38 Ω Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

[19] Current waveforms were measured using a Yokogawa current probe. See Table 8 for list of equipment.

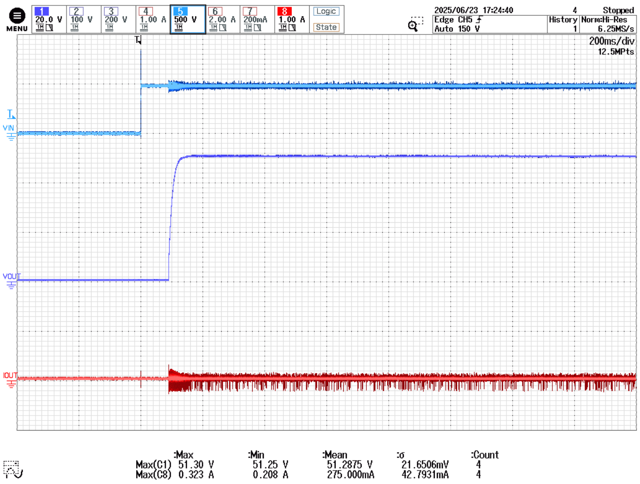


Figure 51 – Output Voltage and Current.
480 VDC, No Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

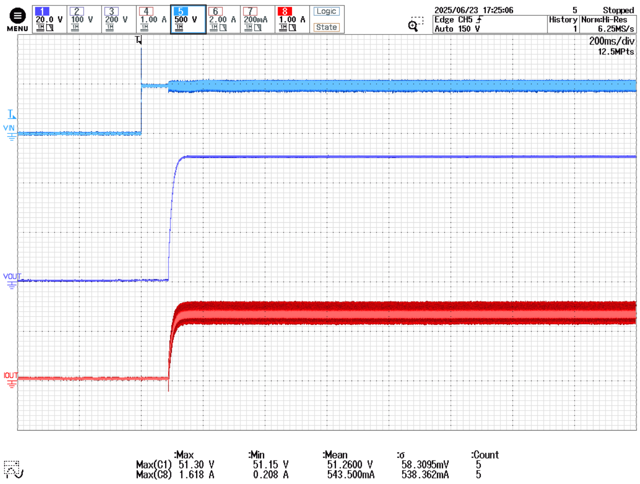


Figure 52 – Output Voltage and Current.
480 VDC, 38 Ω Load.
CH1: V_{OUT}, 20 V / div.
CH5: V_{IN}, 500 V / div.
CH8: I_{OUT}, 1.00 A / div.
Time: 200 ms / div.

12.1.5 InnoSwitch3-AQ Drain Voltage and Current at -40 °C Ambient[20,21]

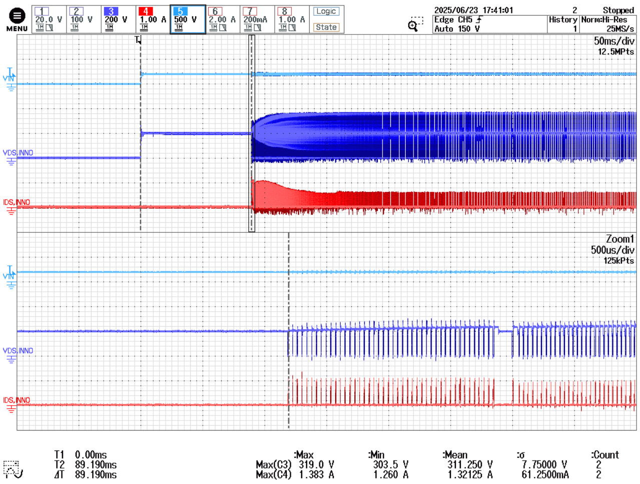


Figure 53 – INN3997CQ Drain Voltage and Current.
200 VDC, No Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

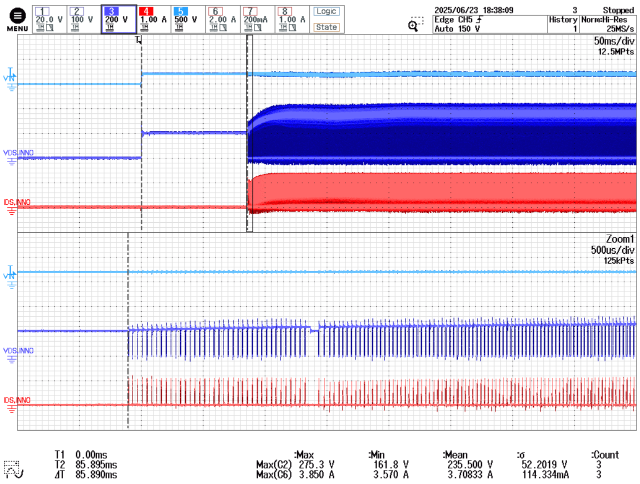


Figure 54 – INN3997CQ Drain Voltage and Current.
200 VDC, 38 Ω Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

[20] The time between when V_{IN} turned on and the InnoSwitch3 starts switching is due to the "Wait and Listen" period of the InnoSwitch3.
[21] Current waveforms were measured using Yokogawa 100 MHz 30 Arms Current Probe with 250 cm twisted pair of wire. This long-twisted lead adds capacitance to the drain node which causes additional current spike. See Table 8 for list of equipment.

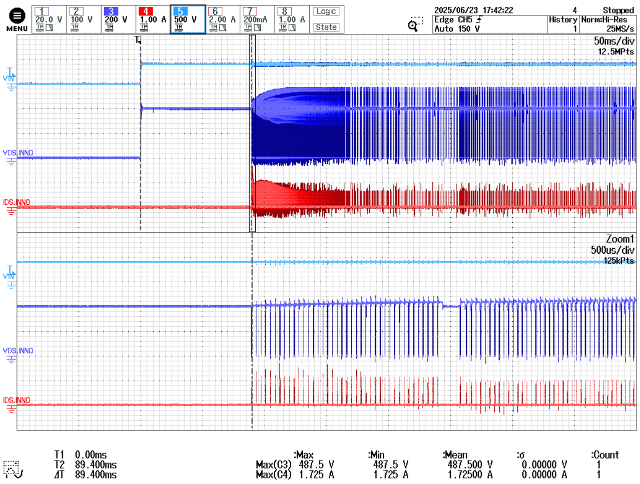


Figure 55 – INN3997CQ Drain Voltage and Current.
400 VDC, No Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

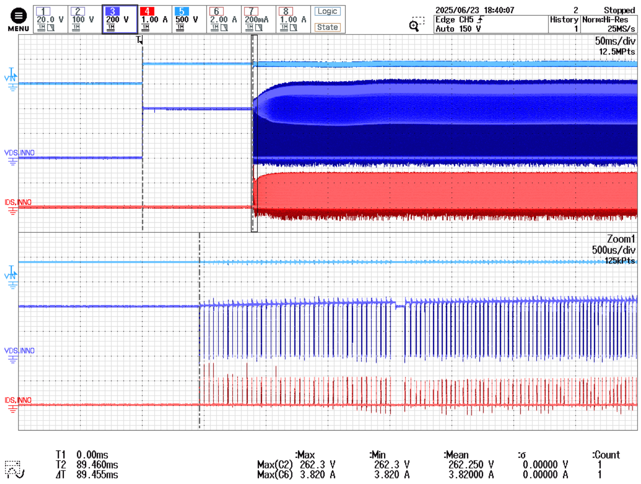


Figure 56 – INN3997CQ Drain Voltage and Current.
400 VDC, 38 Ω Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

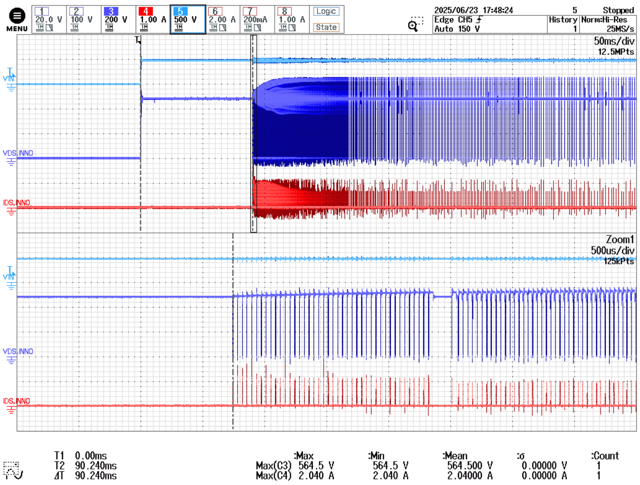


Figure 57 – INN3997CQ Drain Voltage and Current.
480 VDC, No Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

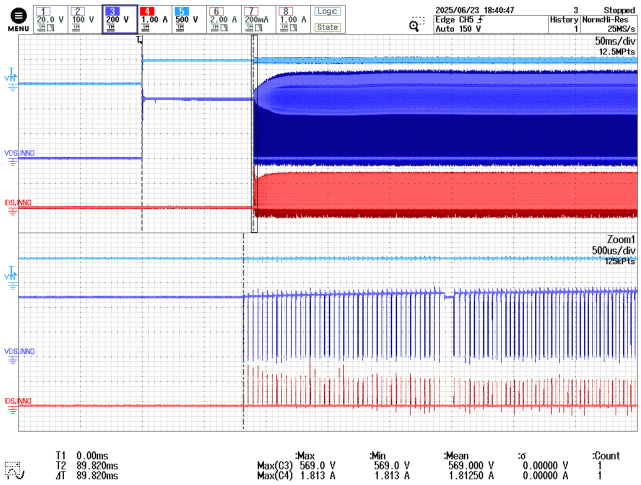


Figure 58 – INN3997CQ Drain Voltage and Current.
480 VDC, 38 Ω Load.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1 A / div.
CH5: V_{IN}, 500 V / div.
Time: 50 ms / div.

12.1.6 Rectifier Diode Voltage and Current at -40 °C Ambient[22, 23]

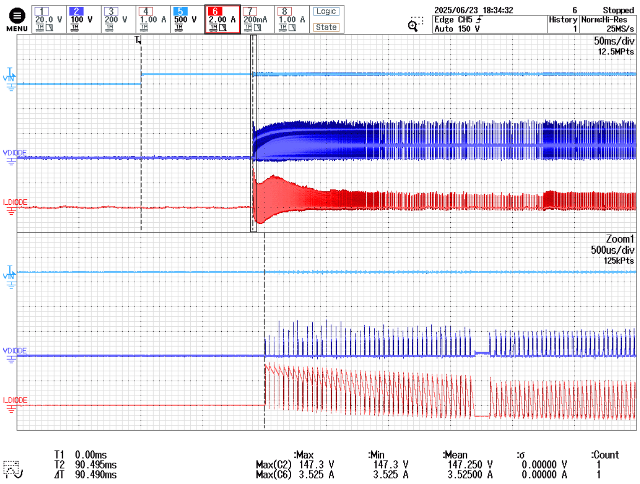


Figure 59 – Rectifier Diode Voltage and Current.
200 VDC, No Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

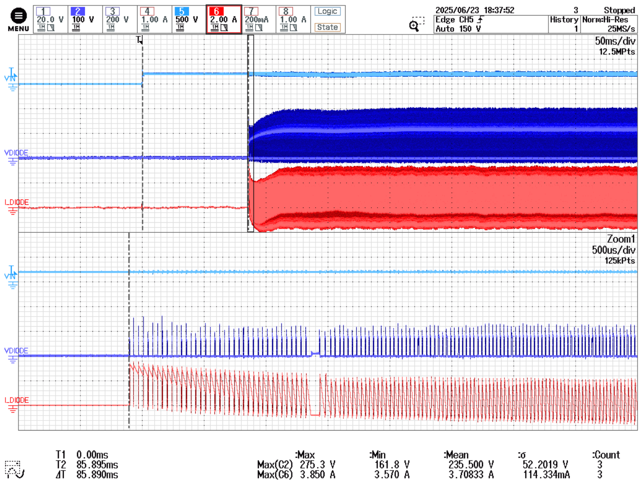


Figure 60 – Rectifier Diode Voltage and Current.
200 VDC, 38 Ω Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

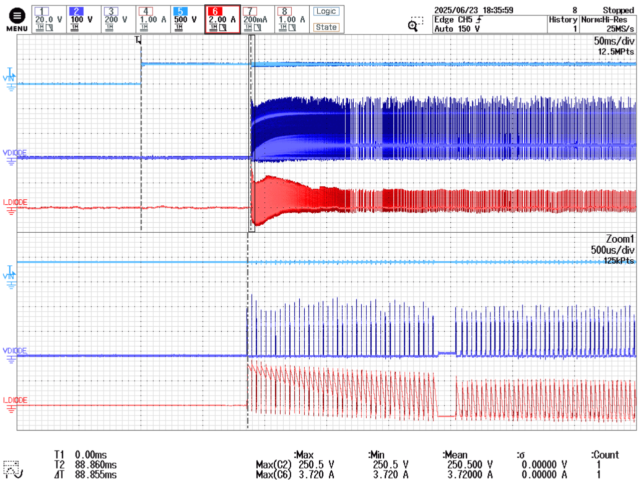


Figure 61 – Rectifier Diode Voltage and Current.
400 VDC, No Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

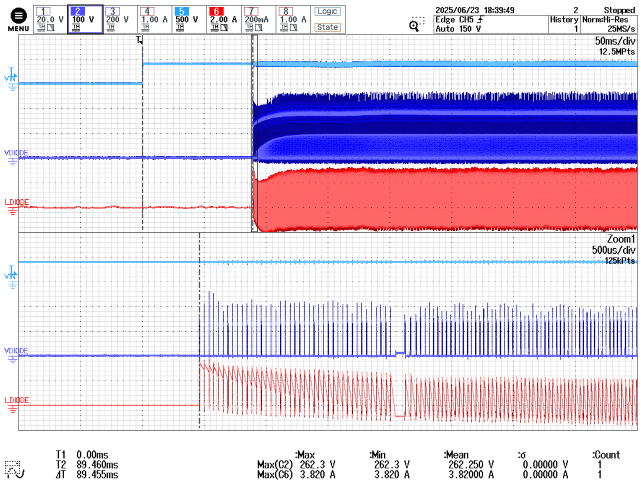


Figure 62 – Rectifier Diode Voltage and Current.
400 VDC, 38 Ω Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

[22] The time between when V_{IN} turned on and the InnoSwitch3 starts switching is due to the "Wait and Listen" period of the InnoSwitch3.
[23] Current waveforms were measured using a 120 Apeak Rogowski Coil, 5 MHz bandwidth-limited to reduce high frequency noise. See Table 8 for list of equipment.

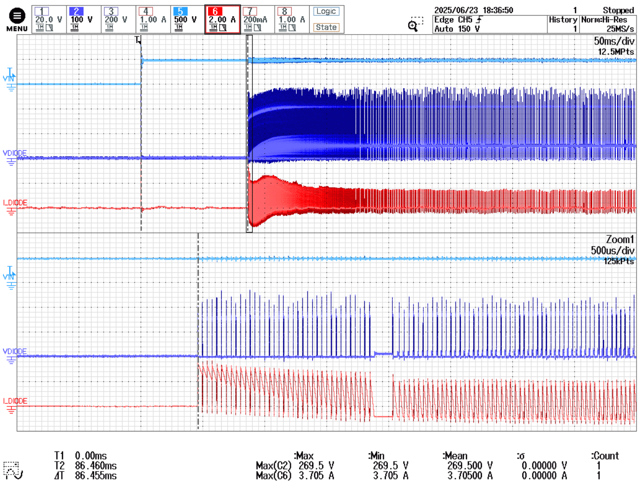


Figure 63 – Rectifier Diode Voltage and Current.
480 VDC, No Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

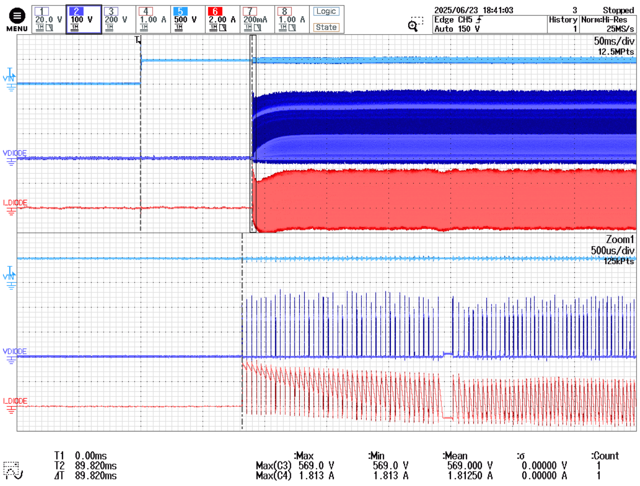


Figure 64 – Rectifier Diode Voltage and Current.
480 VDC, 38 Ω Load.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH5: V_{IN}, 500 V / div.
CH6: I_{D100}, 2 A / div.
Time: 50 ms / div.

12.2 Steady-State Waveforms

12.2.1 Switching Waveforms at 85 °C Ambient

12.2.1.1 Normal Operation Component Stress

Steady-State Switching Waveforms 85 °C Ambient							
Input	**Load**	**INN3997CQ**			**Rectifier Diode**		
V_{IN} (VDC)	**I_{OUT} (A)**	**I_D (A)[24]**	**V_{DS} (V)[25]**	**V_{STRESS} (%)**	**I_D (A)[26]**	**V_{KA} (V)**	**V_{STRESS} (%)**
200	0	0.58	364	40.4	0.82	123	20.5
	1.3	1.38	447	49.7	3.88	309	51.6
400	0	1.03	566	62.9	0.93	153	25.5
	1.3	1.38	648	72.0	3.88	302	50.4
480	0	1.18	644	71.6	1.04	283	47.3
	1.3	1.38	728	80.9	3.88	301	50.2

Table 11 – Summary of Voltage Stress on Critical Components at 85 °C Ambient.

[24] Current waveforms were measured using Yokogawa 100 MHz 30 Arms Current Probe with 250 cm twisted pair of wire. This long-twisted lead adds capacitance to the drain node which causes additional current spike. See Table 8 for list of equipment.
[25] INN3997CQ V_{DS} is probed with a 250 cm-long twisted pair wire. This long lead adds wire inductance that couples with the probe's capacitance which causes ringing and adds to the measured voltage.
[26] Current waveforms were measured using a 120 Apeak Rogowski Coil, 5 MHz bandwidth-limited to reduce high frequency noise. See Table 8 for list of equipment.

12.2.1.2 InnoSwitch3-AQ Drain Voltage and Current at 85 °C Ambient

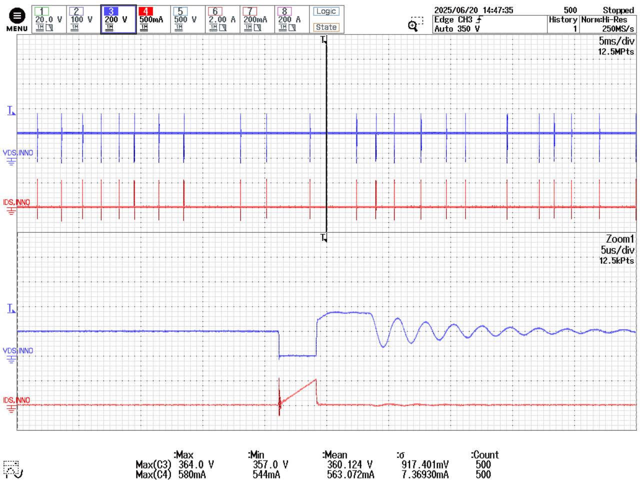


Figure 65 – INN3997CQ Drain Voltage and Current.
200 VDC, No Load, 85 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 500 mA / div.
Time: 5 ms / div.

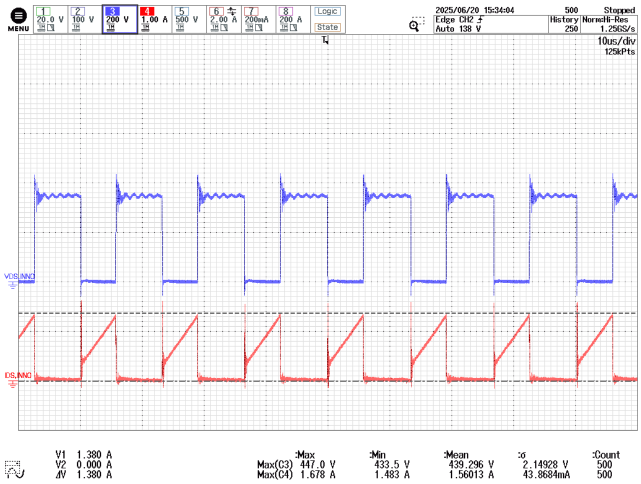


Figure 66 – INN3997CQ Drain Voltage and Current.
200 VDC, 1.3 A Load, 85 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1.0 A / div.
Time: 10 µs / div.

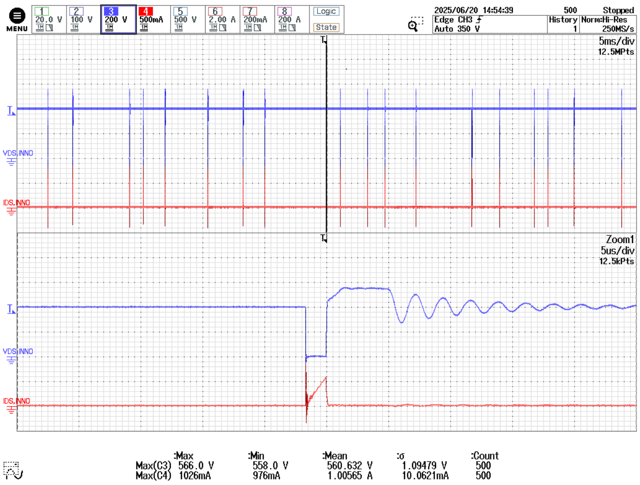


Figure 67 – INN3997CQ Drain Voltage and Current.
400 VDC, No Load, 85 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 500 mA / div.
Time: 5 ms / div.

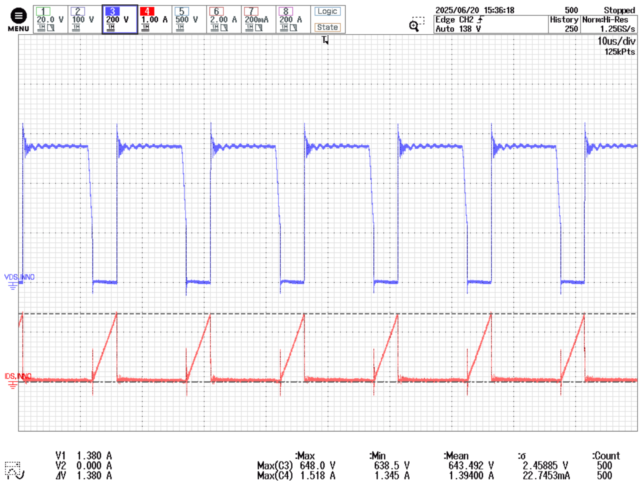


Figure 68 – INN3997CQ Drain Voltage and Current.
400 VDC, 1.3 A Load, 85 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1.0 A / div.
Time: 10 µs / div.

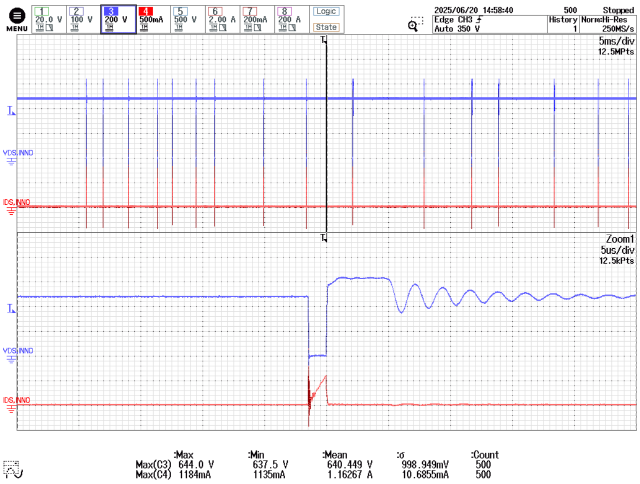


Figure 69 – INN3997CQ Drain Voltage and Current.
480 VDC, No Load, 85 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 500 mA / div.
Time: 5 ms / div.

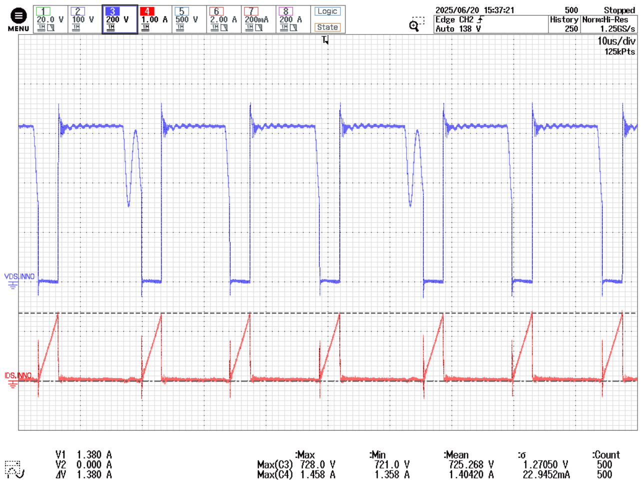


Figure 70 – INN3997CQ Drain Voltage and Current.
480 VDC, 1.3 A Load, 85 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1.0 A / div.
Time: 10 µs / div.

12.2.1.3 Rectifier Diode Voltage and Current at 85 °C Ambient

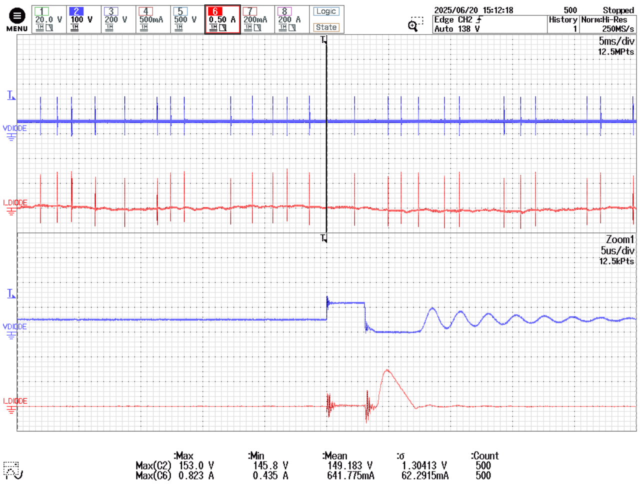


Figure 71 – Rectifier Diode Voltage and Current.
200 VDC, No Load, 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH6: I_{D100}, 500 mA / div.
Time: 5 ms / div.

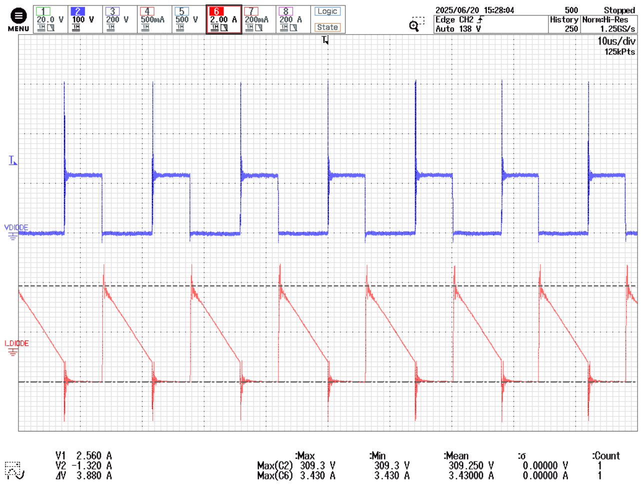


Figure 72 – Rectifier Diode Voltage and Current.
200 VDC, 1.3 A Load, 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH6: I_{D100}, 2 A / div.
Time: 10 µs / div.

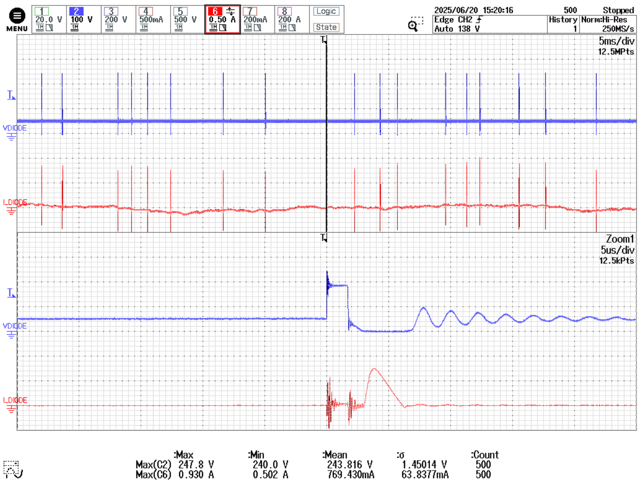


Figure 73 – Rectifier Diode Voltage and Current.
400 VDC, No Load, 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH6: I_{D100}, 500 mA / div.
Time: 5 ms / div.

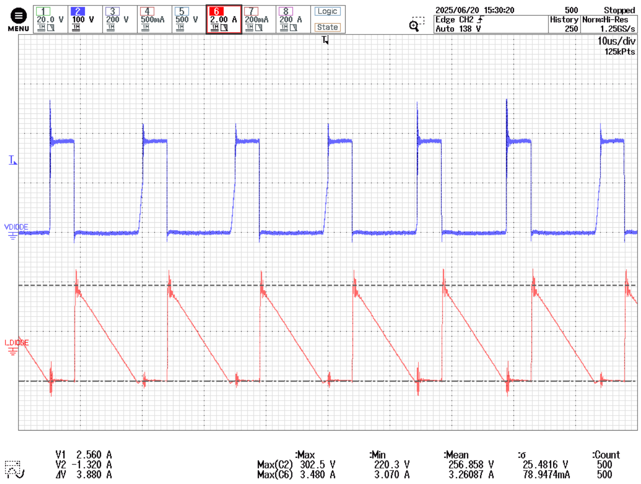


Figure 74 – Rectifier Diode Voltage and Current.
400 VDC, 1.3 A Load, 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH6: I_{D100}, 2 A / div.
Time: 10 µs / div.

Figure 75 – Rectifier Diode Voltage and Current.
480 VDC, No Load, 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH6: I_{D100}, 500 mA / div.
Time: 5 ms / div.

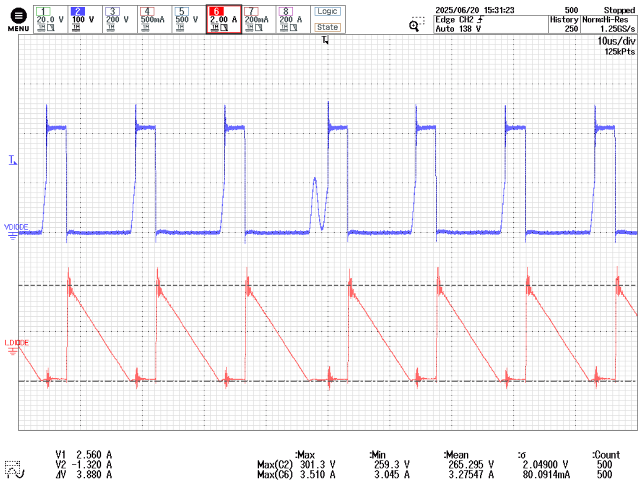


Figure 76 – Rectifier Diode Voltage and Current.
480 VDC, 1.3 A Load, 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH6: I_{D100}, 2 A / div.
Time: 10 µs / div.

12.2.2 Switching Waveforms at 25 °C Ambient

12.2.2.1 Normal Operation Component Stress

Steady-State Switching Waveforms 25 °C Ambient							
Input	**Load**	**INN3997CQ**			**Rectifier Diode**		
V_{IN} (VDC)	**I_{OUT} (A)**	**I_D (A)[27]**	**V_{DS} (V)[28]**	**V_{STRESS} (%)**	**I_D (A)[29]**	**V_{KA} (V)**	**V_{STRESS} (%)**
200	0	0.54	365	40.6	0.86	151	25.2
	1.3	1.4	457	50.8	5.18	215	36.0
400	0	0.84	566	62.9	1.12	243	40.6
	1.3	1.42	641	71.2	4.88	231	38.5
480	0	0.98	647	71.9	1.19	280	46.8
	1.3	1.42	725	80.6	4.89	268	44.7

Table 12 – Summary of Voltage Stress on Critical Components at 25 °C Ambient.

[27] Current waveforms were measured using a Yokogawa current probe. See Table 8 for list of equipment.
[28] INN3997CQ V_{DS} is probed with shorter twisted pair wire, reducing coupled noise.
[29] Current waveforms were measured using a Yokogawa current probe. See Table 8 for list of equipment.

12.2.2.2 InnoSwitch3-AQ Drain Voltage and Current at 25 °C Ambient

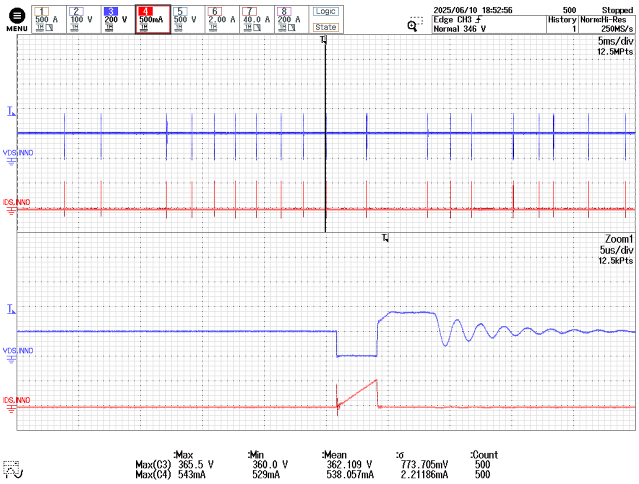


Figure 77 – INN3997CQ Drain Voltage and Current.
200 VDC, No Load, 25 °C Ambient.
CH3: $V_{DS, INNO}$, 200 V / div.
CH4: $I_{D, INNO}$, 500 mA / div.
Time: 5 ms / div.

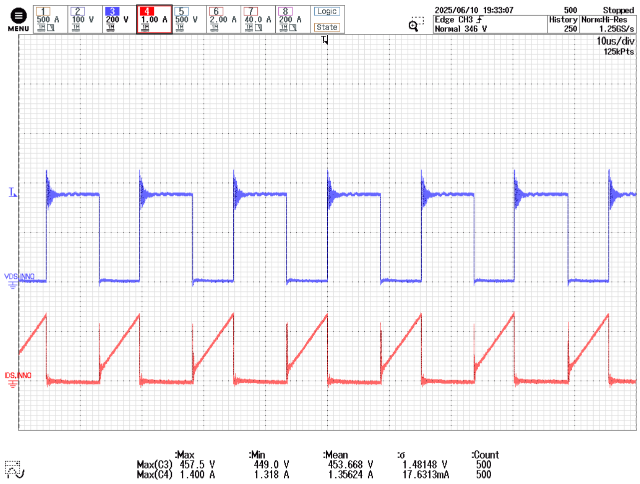


Figure 78 – INN3997CQ Drain Voltage and Current.
200 VDC, 1.3 A Load, 25 °C Ambient.
CH3: $V_{DS, INNO}$, 200 V / div.
CH4: $I_{D, INNO}$, 1.0 A / div.
Time: 10 µs / div.

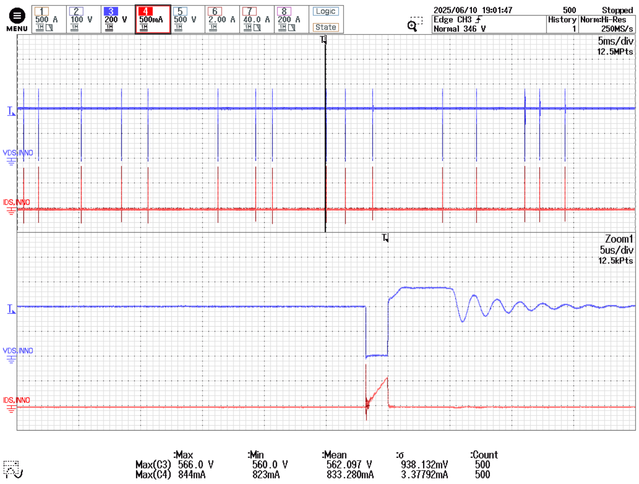


Figure 79 – INN3997CQ Drain Voltage and Current.
400 VDC, No Load, 25 °C Ambient.
CH3: $V_{DS, INNO}$, 200 V / div.
CH4: $I_{D, INNO}$, 500 mA / div.
Time: 5 ms / div.

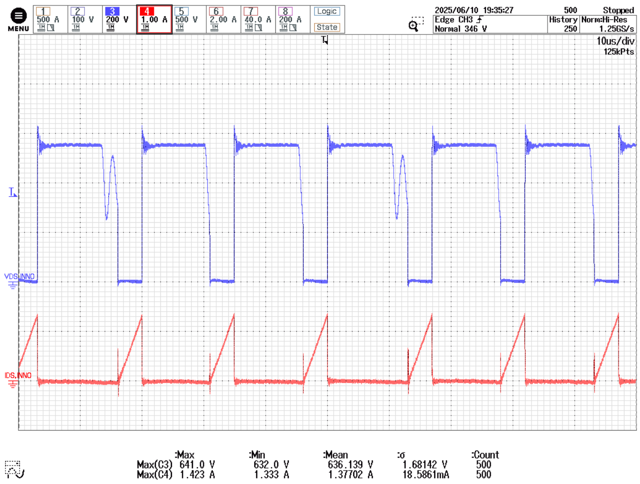


Figure 80 – INN3997CQ Drain Voltage and Current.
400 VDC, 1.3 A Load, 25 °C Ambient.
CH3: $V_{DS, INNO}$, 200 V / div.
CH4: $I_{D, INNO}$, 1.0 A / div.
Time: 10 µs / div.

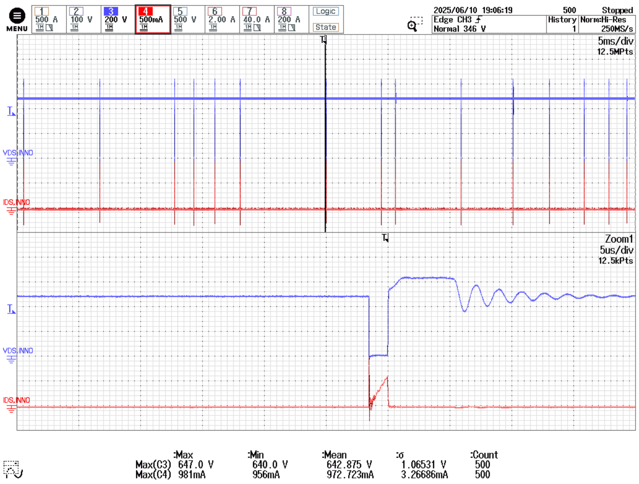


Figure 81 – INN3997CQ Drain Voltage and Current.
480 VDC, No Load, 25 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 500 mA / div.
Time: 5 ms / div.

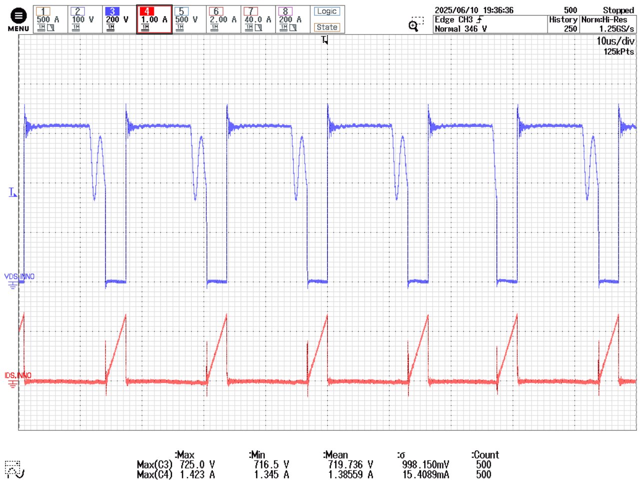


Figure 82 – INN3997CQ Drain Voltage and Current.
480 VDC, 1.3 A Load, 25 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 1.0 A / div.
Time: 10 µs / div.

12.2.2.3 Rectifier Diode Voltage and Current at 25 °C Ambient

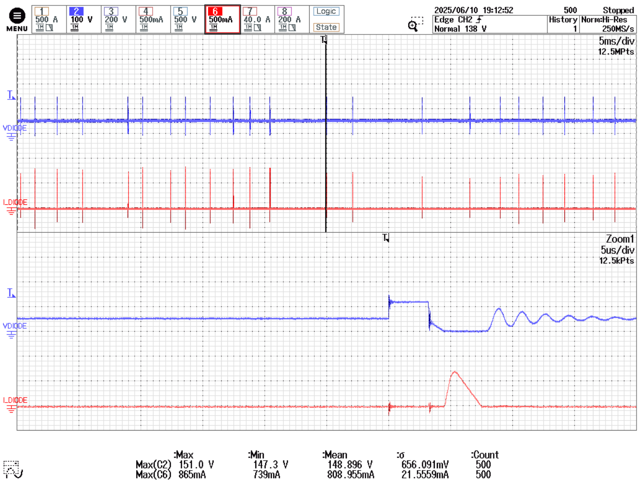


Figure 83 – Rectifier Diode Voltage and Current.
200 VDC, No Load, 25 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 500 mA / div.
Time: 5 ms / div.

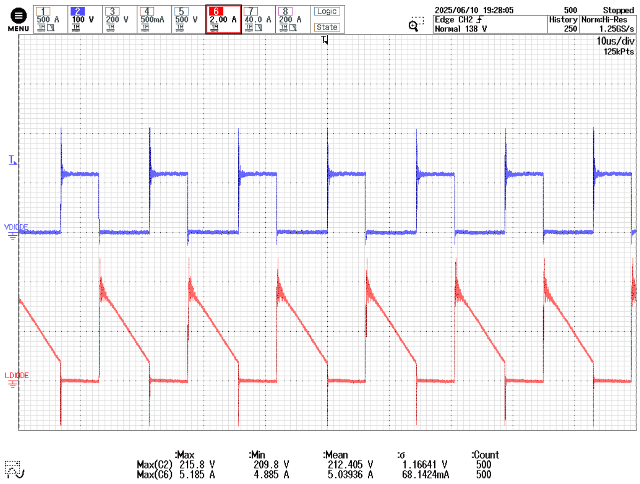


Figure 84 – Rectifier Diode Voltage and Current.
200 VDC, 1.3 A Load, 25 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 2.0 A / div.
Time: 10 µs / div.

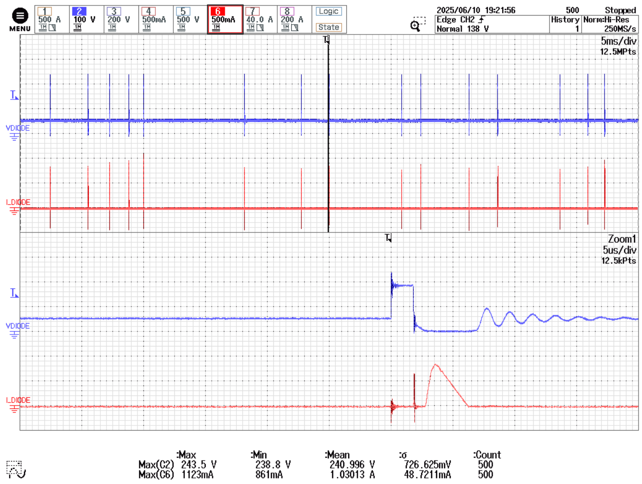


Figure 85 – Rectifier Diode Voltage and Current.
400 VDC, No Load, 25 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 500 mA / div.
Time: 5 ms / div.

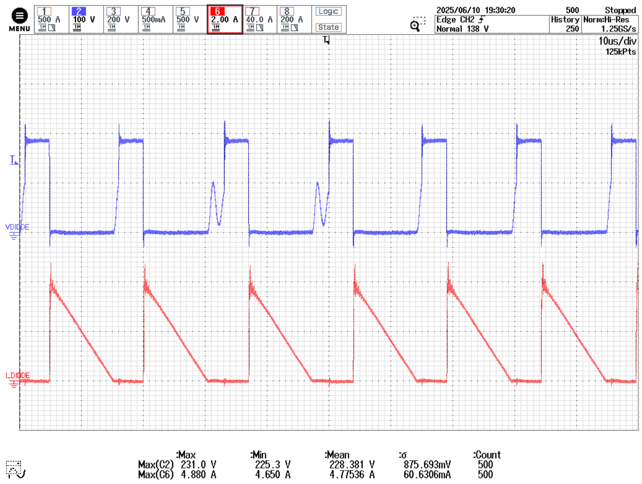


Figure 86 – Rectifier Diode Voltage and Current.
400 VDC, 1.3 A Load, 25 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 2.0 A / div.
Time: 10 µs / div.

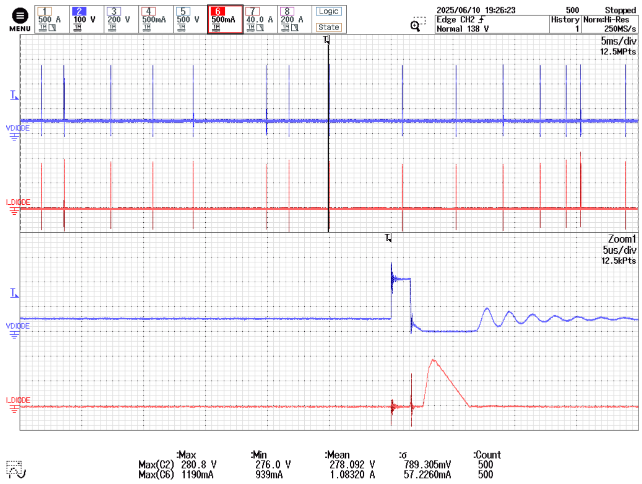


Figure 87 – Rectifier Diode Voltage and Current.
480 VDC, No Load, 25 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 500 mA / div.
Time: 5 ms / div.

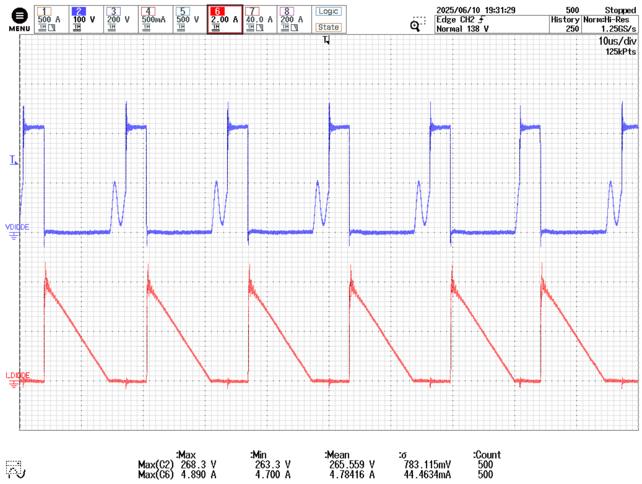


Figure 88 – Rectifier Diode Voltage and Current.
480 VDC, 1.3 A Load, 25 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 2.0 A / div.
Time: 10 µs / div.

12.2.3 Switching Waveforms at -40 °C Ambient

12.2.3.1 Normal Operation Component Stress

Steady-State Switching Waveforms -40 °C Ambient							
Input	Load	INN3997CQ			Rectifier Diode		
V_{IN} (VDC)	I_{OUT} (A)	I_D (A)[30]	V_{DS} (V)[31]	V_{STRESS} (%)	I_D (A)[32]	V_{KA} (V)	V_{STRESS} (%)
200	0	0.63	372	41.3	1.34	153	25.6
	1.3	1.38	474	52.7	4.1	204	34.1
400	0	0.99	570	63.3	1.51	247	41.3
	1.3	1.38	660	73.3	4.1	237	39.6
480	0	1.14	651	72.3	1.55	284	47.4
	1.3	1.38	735	81.7	4.1	275	45.9

Table 13 – Summary of Voltage Stress on Critical Components at -40 °C Ambient.

[30] Current waveforms were measured using Yokogawa 100 MHz 30 Arms Current Probe with 250 cm twisted pair of wire. This long-twisted lead adds capacitance to the drain node which causes additional current spike. Current spike during turn on is due to high drain node capacitance. See Table 8 for list of equipment.
[31] INN3997CQ V_{DS} is probed with a 250 cm-long twisted pair wire. This long lead adds wire inductance that couples with the probe's capacitance which causes ringing and adds to the measured voltage.
[32] Current waveforms were measured using a 120 Apeak Rogowski Coil, 5 MHz bandwidth-limited to reduce high frequency noise. See Table 8 for list of equipment.

12.2.3.2 InnoSwitch3-AQ Drain Voltage and Current at -40 °C Ambient

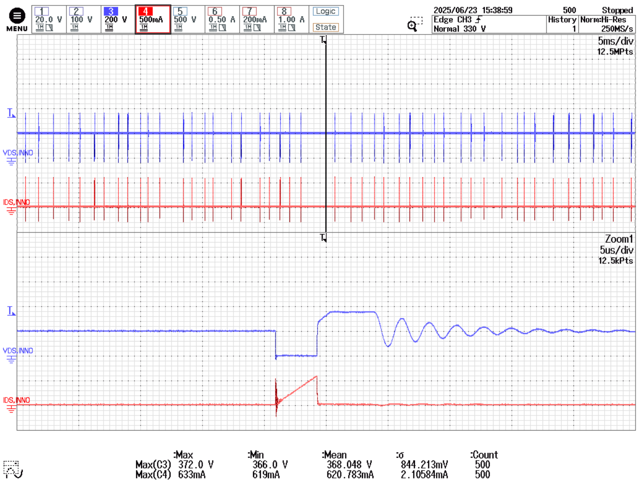


Figure 89 – INN3997CQ Drain Voltage and Current.
200 VDC, No Load, -40 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 500 mA / div.
Time: 5 ms / div.

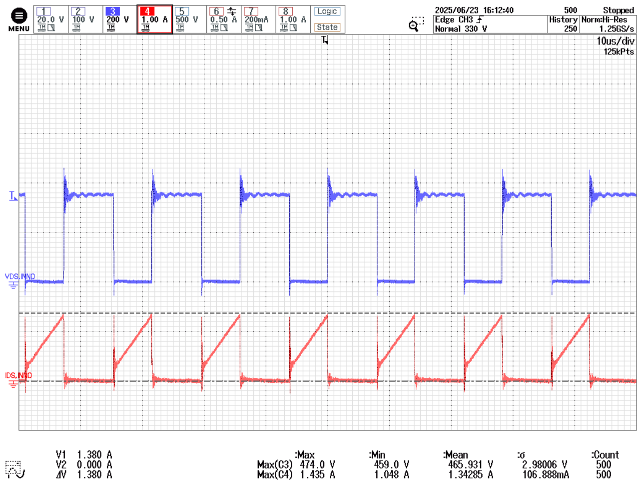


Figure 90 – INN3997CQ Drain Voltage and Current.
200 VDC, 1.3 A Load, -40 °C Ambient.
CH1: $V_{DS,\ INNO}$, 200 V / div.
CH3: $I_{D,\ INNO}$, 1.0 A / div.
Time: 10 µs / div.

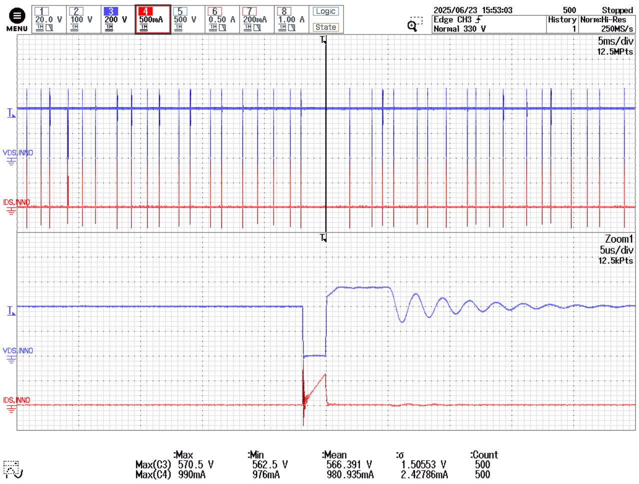


Figure 91 – INN3997CQ Drain Voltage and Current.
400 VDC, No Load, -40 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 500 mA / div.
Time: 5 ms / div.

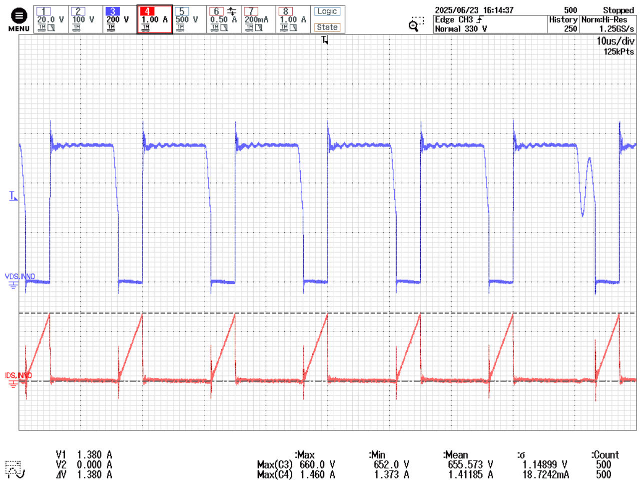


Figure 92 – INN3997CQ Drain Voltage and Current.
400 VDC, 1.3 A Load, -40 °C Ambient.
CH1: $V_{DS,\ INNO}$, 200 V / div.
CH3: $I_{D,\ INNO}$, 1.0 A / div.
Time: 10 µs / div.

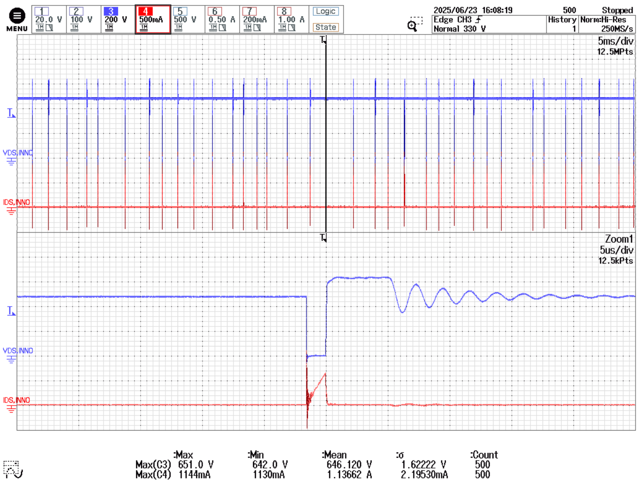


Figure 93 – INN3997CQ Drain Voltage and Current.
480 VDC, No Load, -40 °C Ambient.
CH3: $V_{DS,\ INNO}$, 200 V / div.
CH4: $I_{D,\ INNO}$, 500 mA / div.
Time: 5 ms / div.

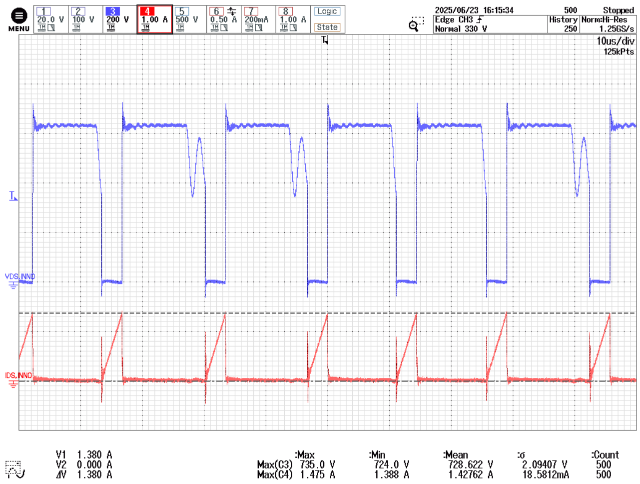


Figure 94 – INN3997CQ Drain Voltage and Current.
480 VDC, 1.3 A Load, -40 °C Ambient.
CH1: $V_{DS,\ INNO}$, 200 V / div.
CH3: $I_{D,\ INNO}$, 1.0 A / div.
Time: 10 µs / div.

12.2.3.3 Rectifier Diode Voltage and Current at -40 °C Ambient

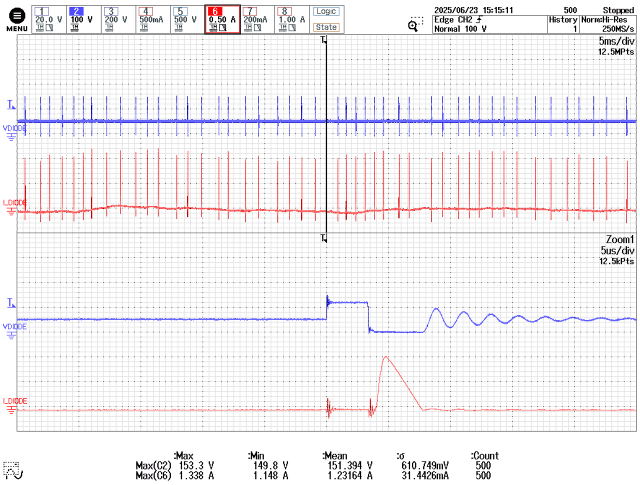


Figure 95 – Rectifier Diode Voltage and Current.
200 VDC, No Load, -40 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 500 mA / div.
Time: 5 ms / div.

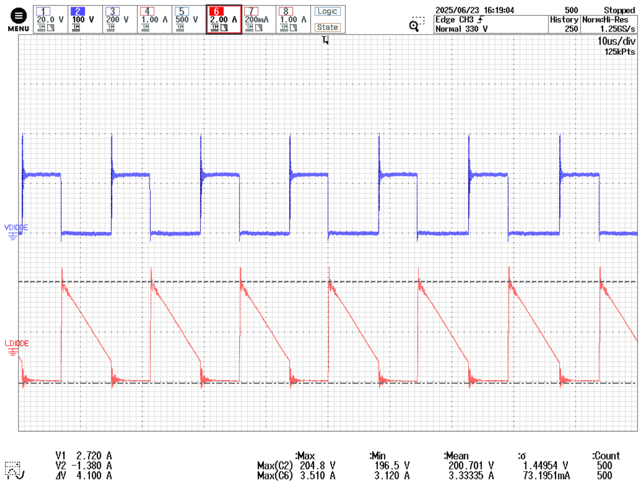


Figure 96 – Rectifier Diode Voltage and Current.
200 VDC, 1.3 A Load, -40 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 2.0 A / div.
Time: 10 µs / div.

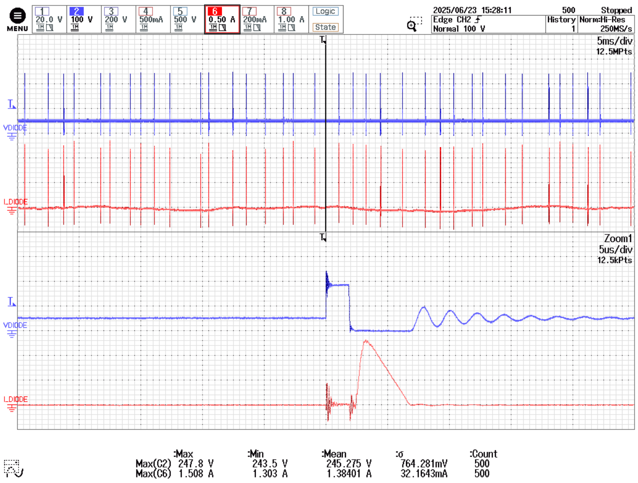


Figure 97 – Rectifier Diode Voltage and Current.
400 VDC, No Load, -40 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 500 mA / div.
Time: 5 ms / div.

Figure 98 – Rectifier Diode Voltage and Current.
400 VDC, 1.3 A Load, -40 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 2.0 A / div.
Time: 10 µs / div.

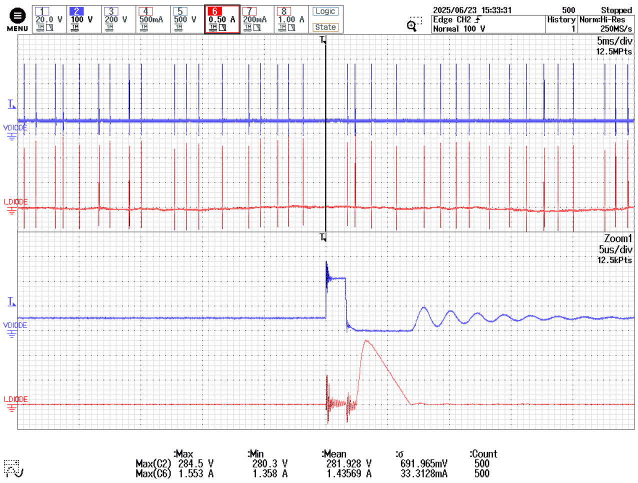


Figure 99 – Rectifier Diode Voltage and Current.
480 VDC, No Load, -40 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 500 mA / div.
Time: 5 ms / div.

Figure 100 – Rectifier Diode Voltage and Current.
480 VDC, 1.3 A Load, -40 °C Ambient.
CH2: $V_{KA,\ D100}$, 100 V / div.
CH6: I_{D100}, 2.0 A / div.
Time: 10 µs / div.

12.2.4 Short-Circuit Response at 85 °C Ambient

The unit was tested by applying an output short-circuit during normal working conditions and then removing the short-circuit to determine whether the unit would recover and operate normally. During a short-circuit, the expected response is for the unit to enter auto-restart (AR) mode and attempt to recover every 1.7 to 2.11 seconds. Full load configuration is at 38 Ω constant resistance.

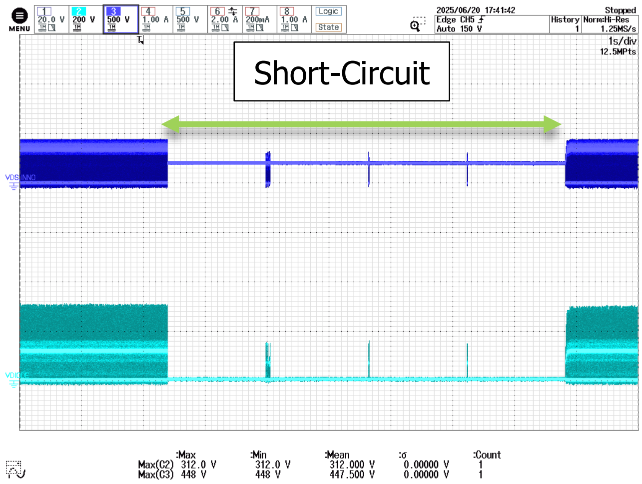


Figure 101 – INN3997CQ Drain and Rectifier Diode Cathode Voltage, 200 VDC, 38 Ω-Short-38 Ω 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH3: $V_{DS,\ INNO}$, 500 V / div.
Time: 1 s / div.

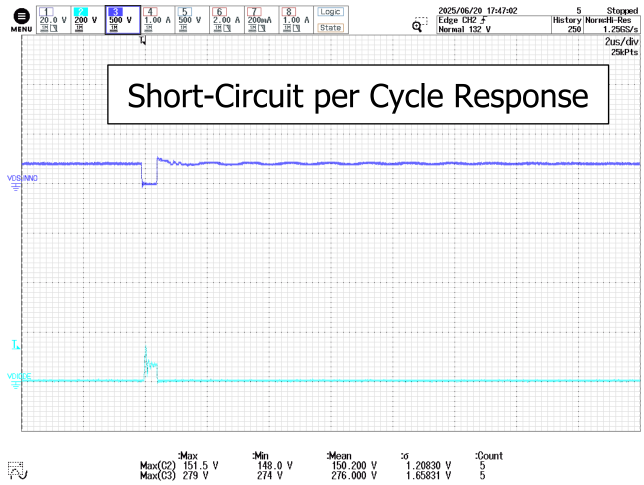


Figure 102 – INN3997CQ Drain and Rectifier Diode Cathode Voltage, 200 VDC 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH3: $V_{DS,\ INNO}$, 500 V / div.
Time: 2 µs / div.

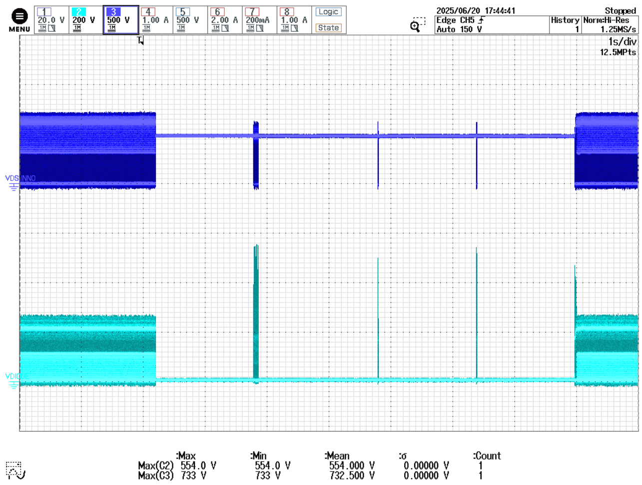


Figure 103 – INN3997CQ Drain and Rectifier Diode Cathode Voltage, 480 VDC, 38 Ω-Short-38 Ω 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH3: $V_{DS,\ INNO}$, 500 V / div.
Time: 1 s / div.

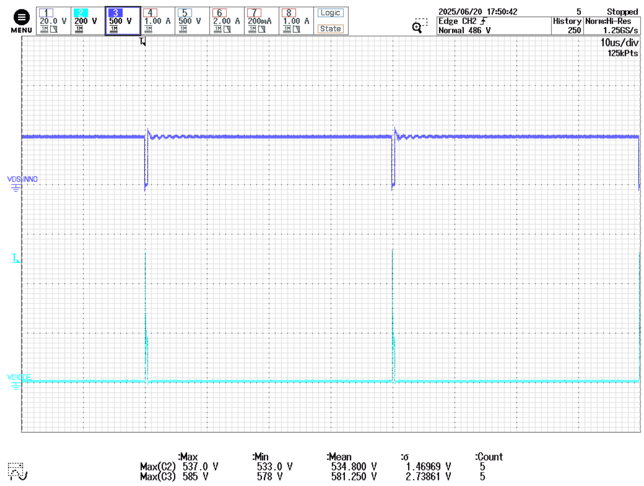


Figure 104 – INN3997CQ Drain and Rectifier Diode Cathode Voltage, 480 VDC 85 °C Ambient.
CH2: $V_{KA,\ D100}$, 200 V / div.
CH3: $V_{DS,\ INNO}$, 500 V / div.
Time: 10 µs / div.

12.3 Load Transient Response

Output voltage waveforms were captured under dynamic loading from 0% to 50%, 50% to 100%, and 10% to 90%. The time duration for the load at each state was set to 500 ms with a load slew rate of 400 mA / µs. The test was performed at 85 °C ambient.

Dynamic Load Settings	V_{IN} (VDC)	$V_{OUT(Overshoot)}$ (V)	$V_{OUT(Undershoot)}$ (V)
0% - 50% - 0% (0 A – 0.65 A – 0 A)	200	0.208	-0.434
	400	0.161	-0.406
	480	0.211	-0.412
50% - 100% - 50% (0.65 A – 1.3 A – 0.65 A)	200	0.202	-0.241
	400	0.181	-0.209
	480	0.248	-0.242
10% - 90% - 10% (0.13 A – 1.17 A – 0.13 A)	200	0.258	-0.614
	400	0.274	-0.503
	480	0.211	-0.518

Table 14 – Load Transient Response.

12.3.1 Output Voltage Ripple with 0% - 50% - 0% Transient Load at 85 °C Ambient

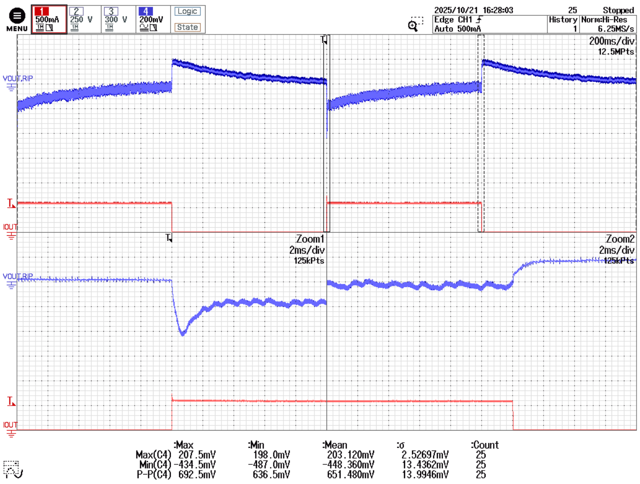


Figure 105 – Output Voltage and Current.
200 VDC, 0 A – 0.65 A – 0 A Transient Load,
85 °C Ambient.
CH1: I_{OUT}, 500 mA / div.
CH4: V_{OUT}, 200 mV / div
Time: 200 ms / div.

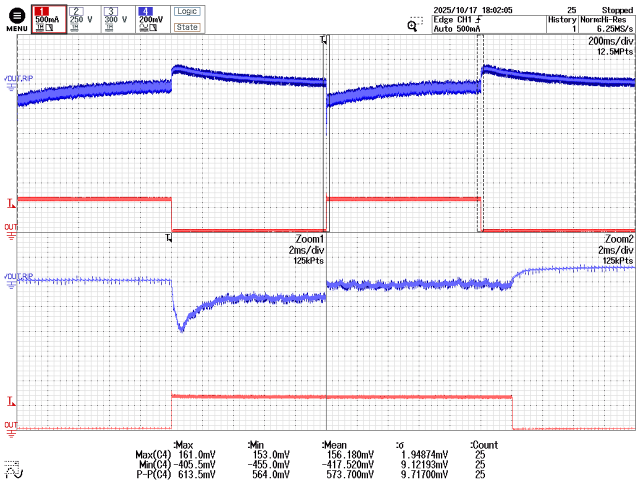


Figure 106 – Output Voltage and Current.
400 VDC, 0 A – 0.65 A – 0 A Transient Load,
85 °C Ambient.
CH1: I_{OUT}, 500 mA / div.
CH4: V_{OUT}, 200 mV / div
Time: 200 ms / div.

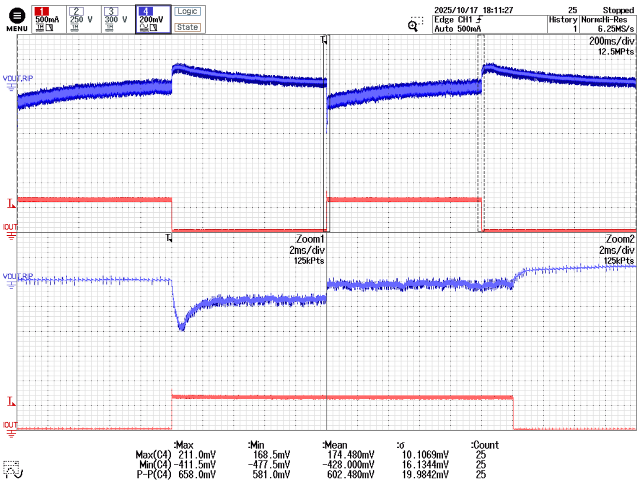


Figure 107 – Output Voltage and Current.
480 VDC, 0 A – 0.65 A – 0 A Transient Load,
85 °C Ambient.
CH1: I_{OUT}, 500 mA / div.
CH4: V_{OUT}, 200 mV / div
Time: 200 ms / div.

12.3.2 Output Voltage Ripple with 50% - 100% - 50% Transient Load at 85 °C Ambient

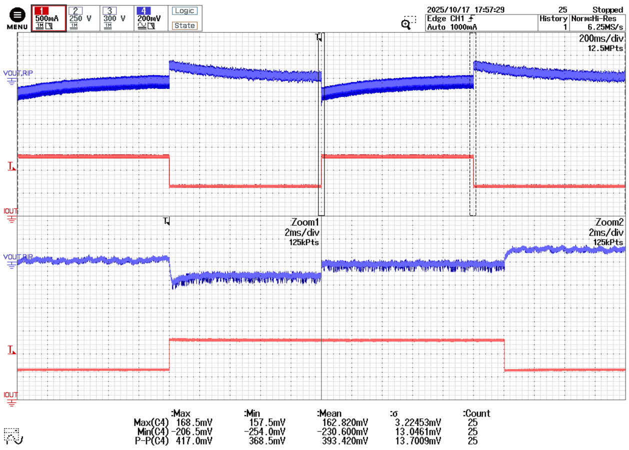


Figure 108 – Output Voltage and Current.
200 VDC, 1.30 A – 0.65 A – 1.30 A Transient Load,
85 °C Ambient.
CH1: I_{OUT}, 500 mA / div.
CH4: V_{OUT}, 200 mV / div
Time: 200 ms / div

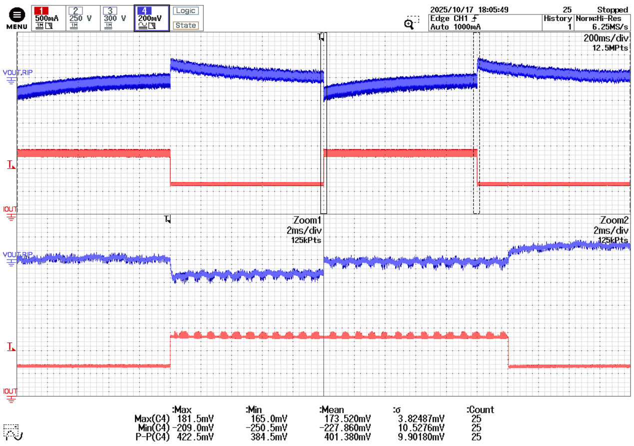


Figure 109 – Output Voltage and Current.
400 VDC, 1.30 A – 0.65 A – 1.30 A Transient Load,
85 °C Ambient.
CH1: I_{OUT}, 500 mA / div.
CH4: V_{OUT}, 200 mV / div
Time: 200 ms / div

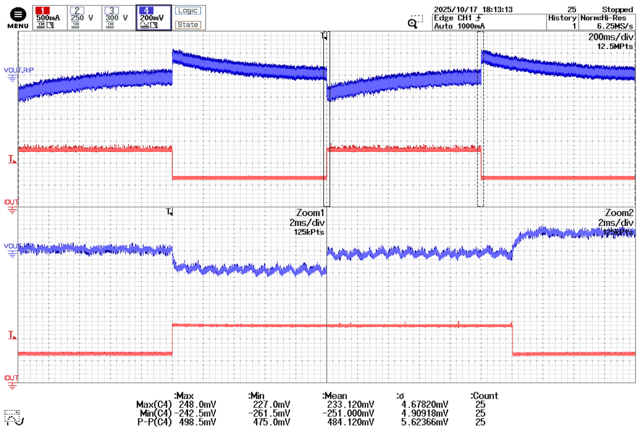


Figure 110 – Output Voltage and Current.
480 VDC, 1.30 A – 0.65 A – 1.30 A Transient Load,
85 °C Ambient.
CH1: I_{OUT}, 500 mA / div.
CH4: V_{OUT}, 200 mV / div
Time: 200 ms / div

12.3.3 Output Voltage Ripple with 10% - 90% - 10% Transient Load at 85 °C Ambient

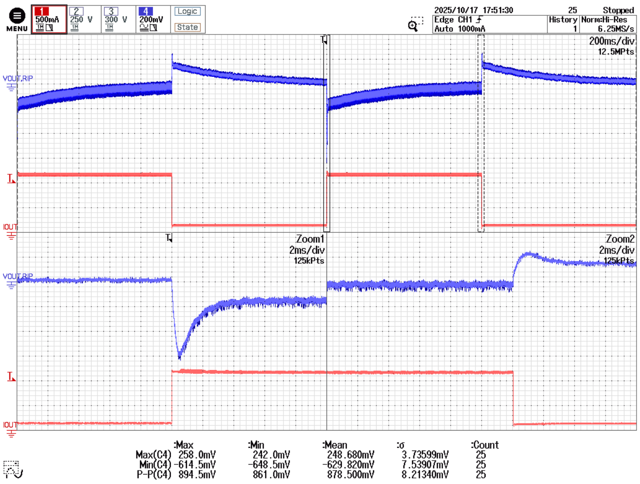


Figure 111 – Output Voltage and Current.
200 VDC, 1.17 A – 0.13 A – 1.17 A
Transient Load,
85 °C Ambient.
CH1: I_{OUT}, 500 mA / div.
CH4: V_{OUT}, 200 mV / div
Time: 200 ms / div

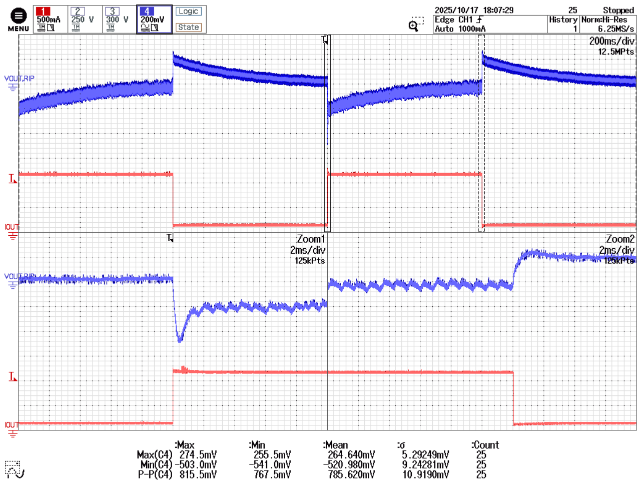


Figure 112 – Output Voltage and Current.
400 VDC, 1.17 A – 0.13 A – 1.17 A
Transient Load,
85 °C Ambient.
CH1: I_{OUT}, 500 mA / div.
CH4: V_{OUT}, 200 mV / div
Time: 200 ms / div

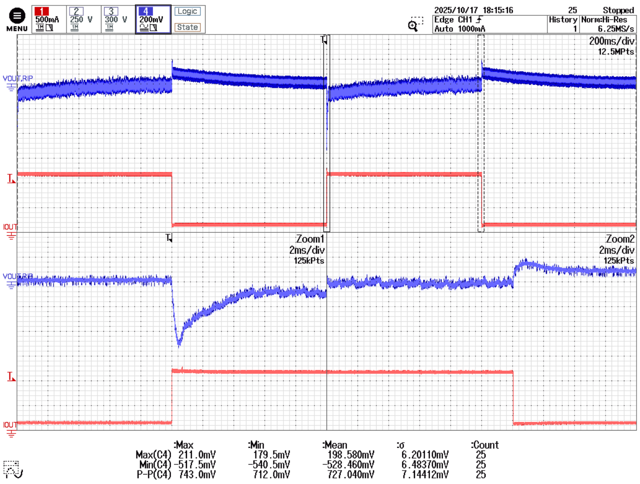


Figure 113 – Output Voltage and Current.
480 VDC, 1.17 A – 0.13 A – 1.17 A
Transient Load,
85 °C Ambient.
CH1: I_{OUT}, 500 mA / div.
CH4: V_{OUT}, 200 mV / div
Time: 200 ms / div

12.4 Output Ripple Measurements

12.4.1 Ripple Measurement Technique

A modified oscilloscope test probe was used for output voltage ripple measurements to eliminate spurious signals due to pick-up. Figure 114 and Figure 115 below provide details of the probe modification.

A 1 μF / 50 V ceramic capacitor parallel to the probe tip of a CT2708 probe and GND terminal. A twisted pair of wires kept as short as possible, were soldered directly between the probe and the output terminals.

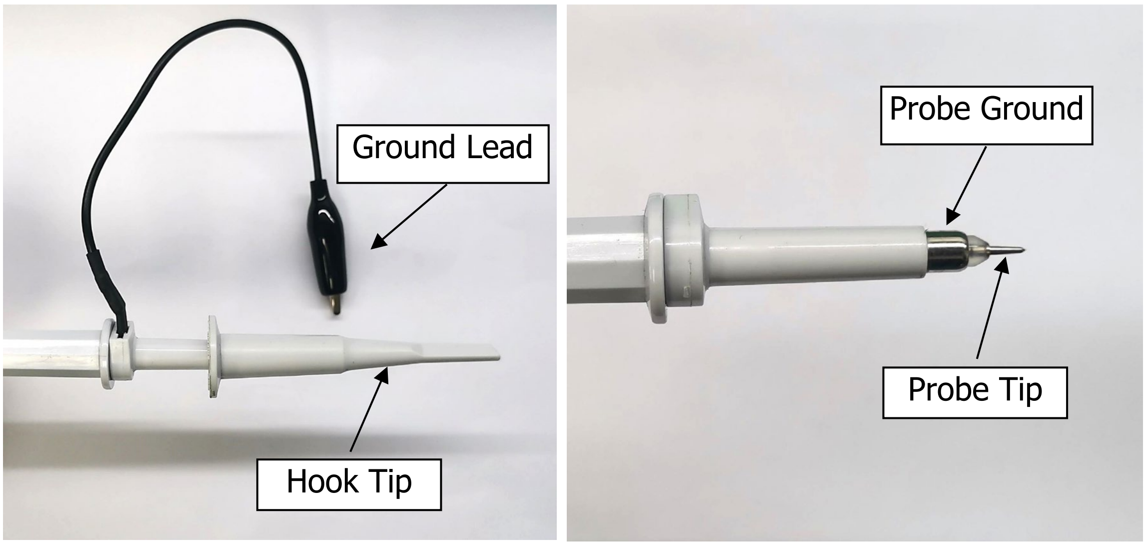


Figure 114 – Oscilloscope Probe Prepared for Ripple Measurement. (Hook Tip and Ground Lead Removed.)

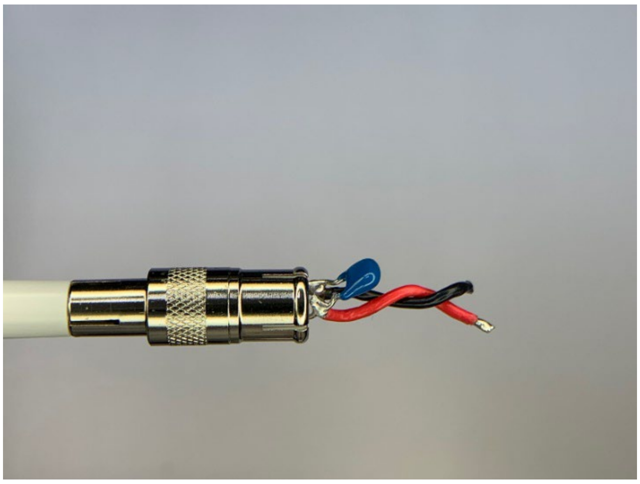


Figure 115 – Oscilloscope Probe with Cal Test CT2708 BNC Adapter. (Modified with Wires for Ripple Measurement and a Parallel Decoupling Capacitor Added.)

12.4.2 Output Voltage Ripple Waveforms

The output voltage ripple waveform was recorded at the output terminals at full load (1.3 A) using the ripple measurement probe with a decoupling capacitor.

12.4.2.1 Output Voltage Ripple at 85 °C Ambient with Constant Full Load[33]

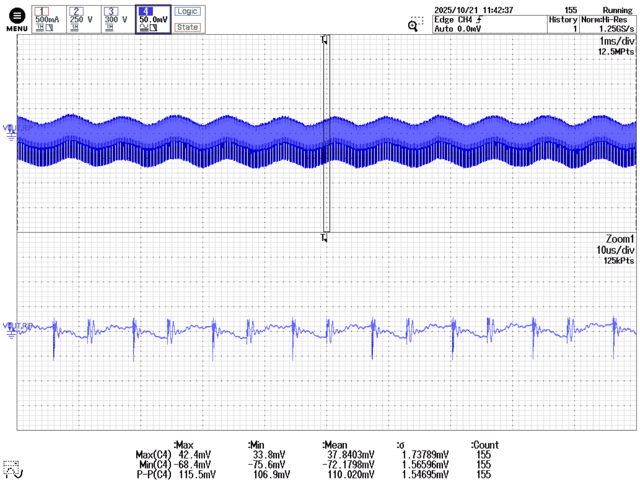


Figure 116 – Output Voltage Ripple.
200 VDC, 1.3 A Load, 85 °C Ambient.
CH4: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 115.5 mV.

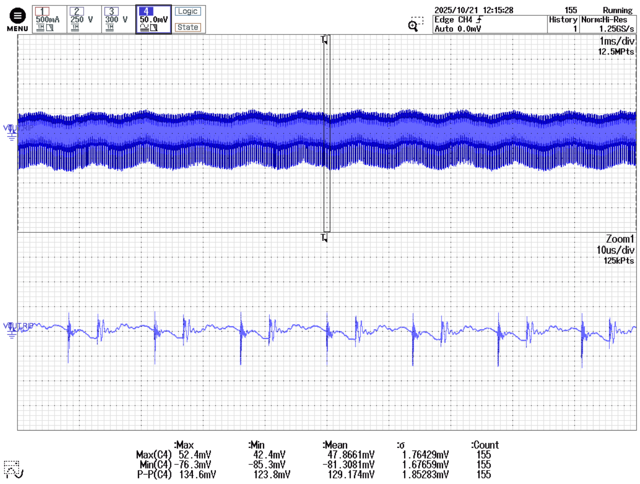


Figure 117 – Output Voltage Ripple.
300 VDC, 1.3 A Load, 85 °C Ambient.
CH4: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 134.6 mV.

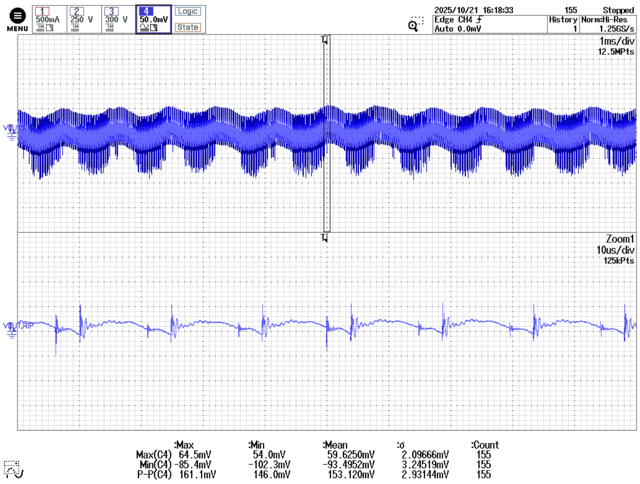


Figure 118 – Output Voltage Ripple.
400 VDC, 1.3 A Load, 85 °C Ambient.
CH4: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 161.1 mV.

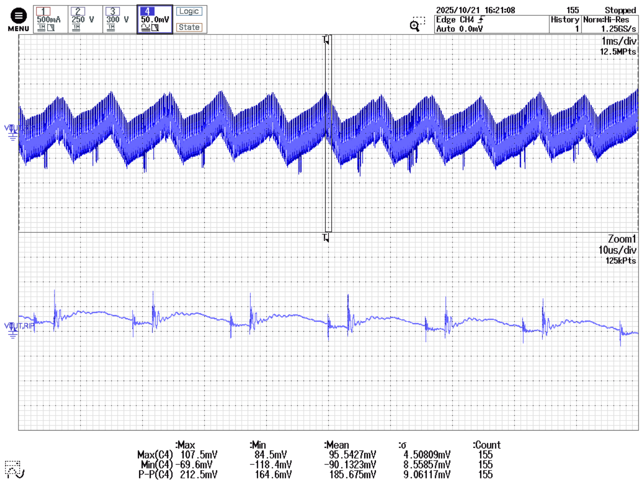


Figure 119 – Output Voltage Ripple.
480 VDC, 1.3 A Load, 85 °C Ambient.
CH4: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 212.5 mV.

33 Peak-to-peak voltage measurement recorded in each oscilloscope capture was the worst-case ripple which included both the low frequency and high frequency switching voltage ripple (top portion of each capture).

12.4.2.2 Output Voltage Ripple at 25 °C Ambient with Constant Full Load[34]

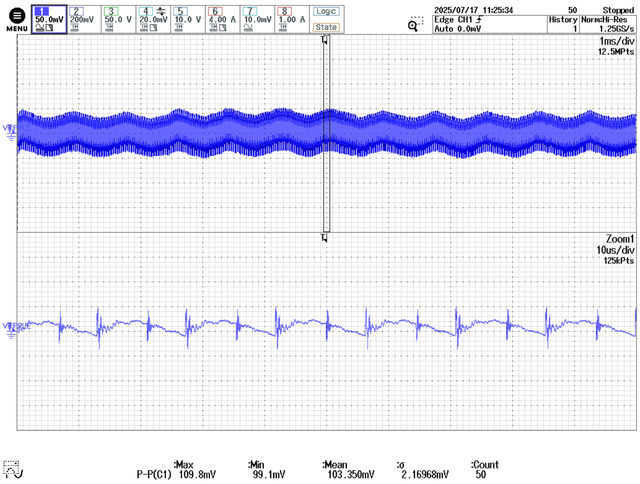


Figure 120 – Output Voltage Ripple.
200 VDC, 1.3 A Load, 25 °C Ambient.
CH1: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 109.8 mV.

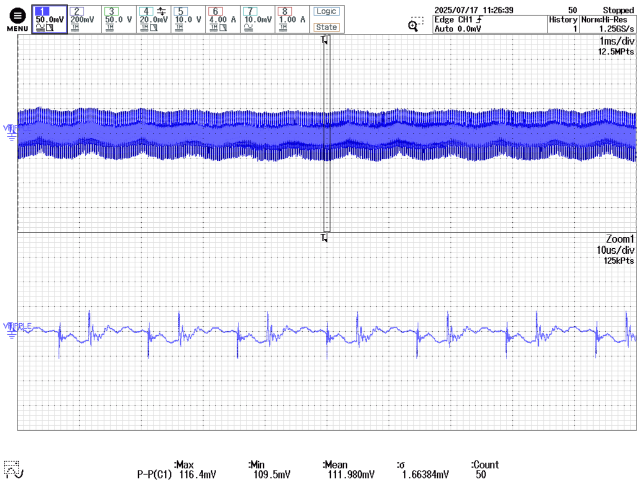


Figure 121 – Output Voltage Ripple.
300 VDC, 1.3 A Load, 25 °C Ambient.
CH1: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 116.4 mV.

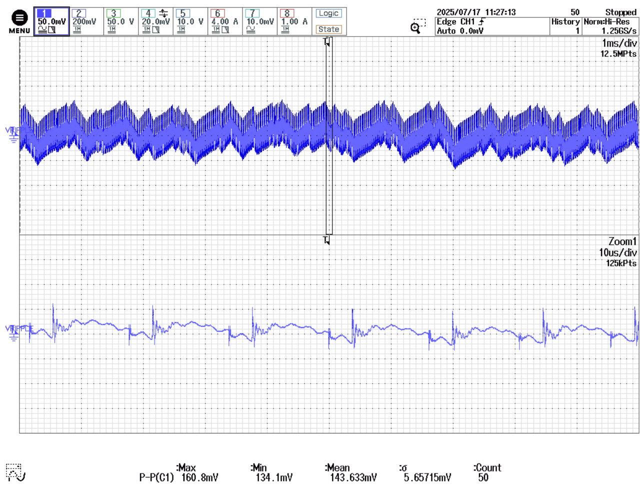


Figure 122 – Output Voltage Ripple.
400 VDC, 1.3 A Load, 25 °C Ambient.
CH1: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 160.8 mV.

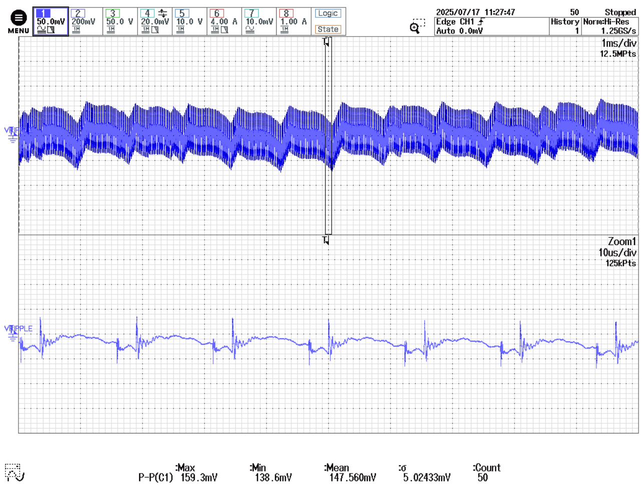


Figure 123 – Output Voltage Ripple.
480 VDC, 1.3 A Load, 25 °C Ambient.
CH1: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 159.3 mV.

[34] Peak-to-peak voltage measurement recorded in each oscilloscope capture was the worst-case ripple which included both the low frequency and high frequency switching voltage ripple (top portion of each capture).

12.4.2.3 Output Voltage Ripple at -40 °C Ambient with Constant Full Load[35]

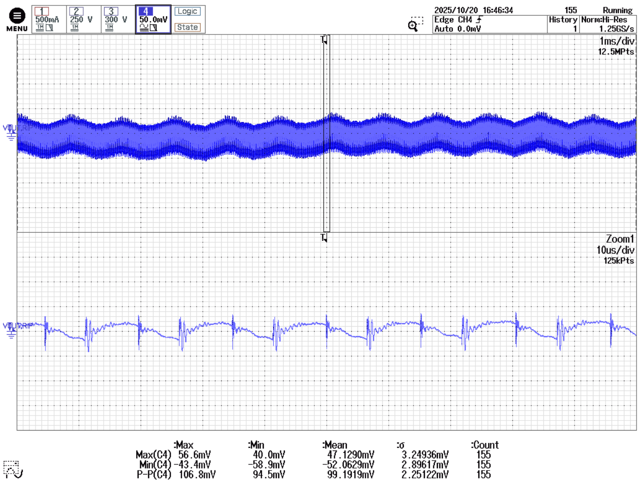


Figure 124 – Output Voltage Ripple.
200 VDC, 1.3 A Load, -40 °C Ambient.
CH1: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 106.8 mV.

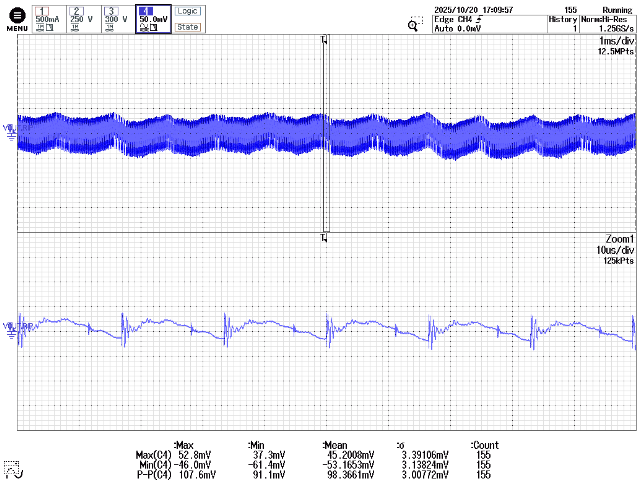


Figure 125 – Output Voltage Ripple.
300 VDC, 1.3 A Load, -40 °C Ambient.
CH1: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 107.6 mV.

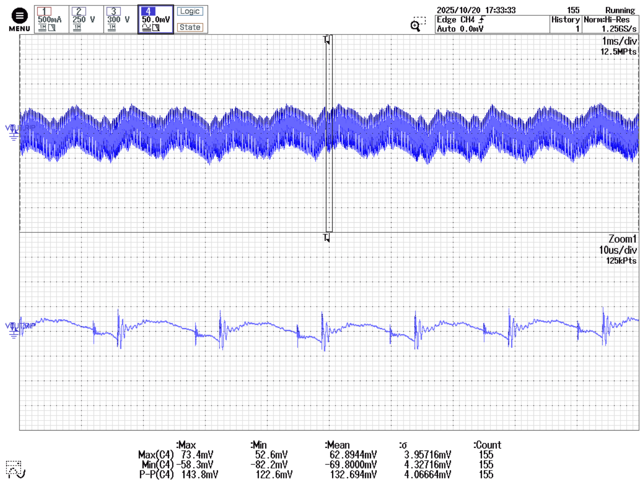


Figure 126 – Output Voltage Ripple.
400 VDC, 1.3 A Load, -40 °C Ambient.
CH1: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 143.8 mV.

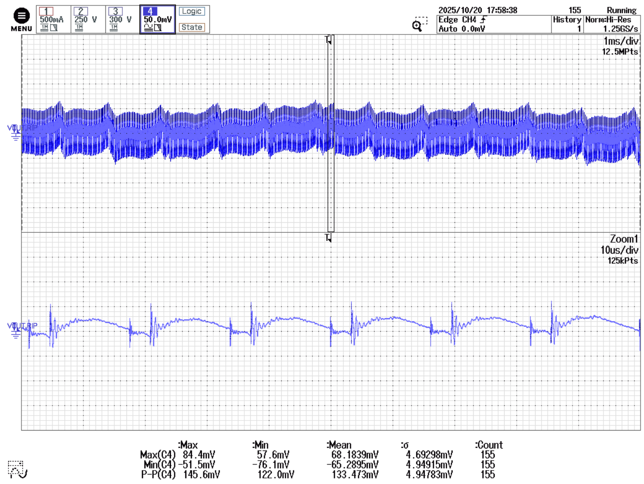


Figure 127 – Output Voltage Ripple.
480 VDC, 1.3 A Load, -40 °C Ambient.
CH1: V_{OUT}, 50 mV / div.
Time: 1 ms / div.
V_{RIPPLE} = 145.6 mV.

[35] Peak-to-peak voltage measurement recorded in each oscilloscope capture was the worst-case ripple which included both the low frequency and high frequency switching voltage ripple (top portion of each capture).

12.4.3 Output Ripple vs. Load

12.4.3.1 Output Ripple at 85 °C Ambient

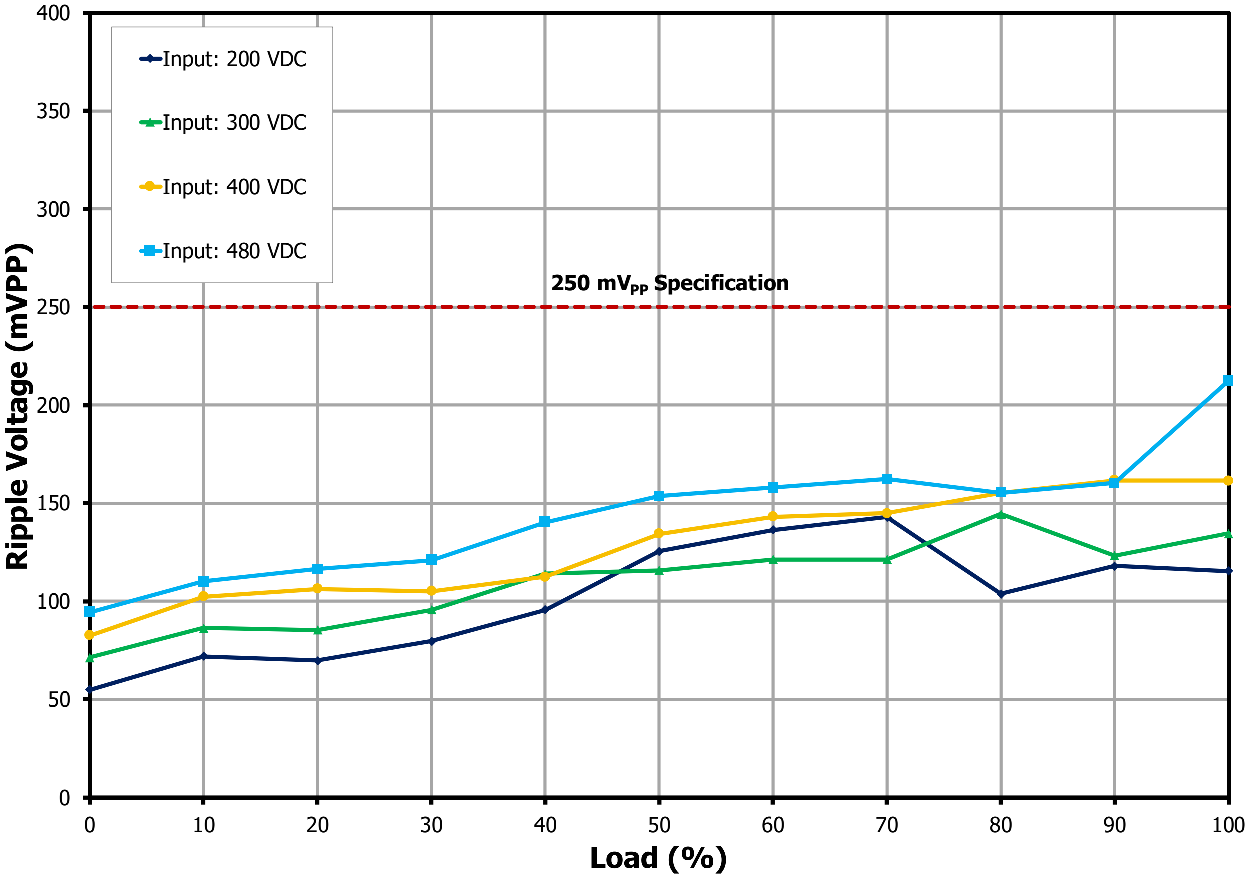


Figure 128 – Output Ripple Voltage Across Full Load (1.3 A) Range (85 °C Ambient).

12.4.3.2 Output Ripple at 25 °C Ambient

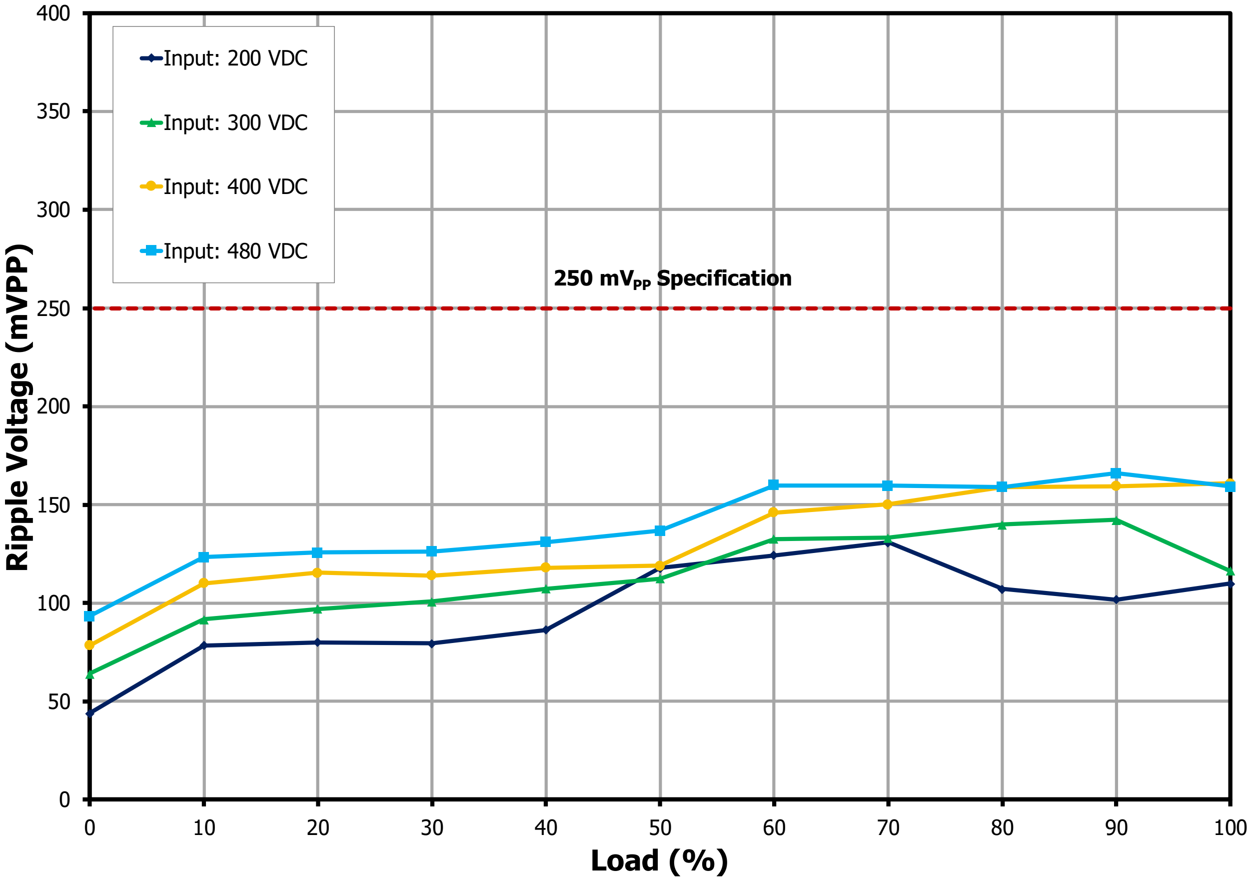


Figure 129 – Output Ripple Voltage Across Full Load (1.3 A) Range (25 °C Ambient).

12.4.3.3 Output Ripple at -40 °C Ambient

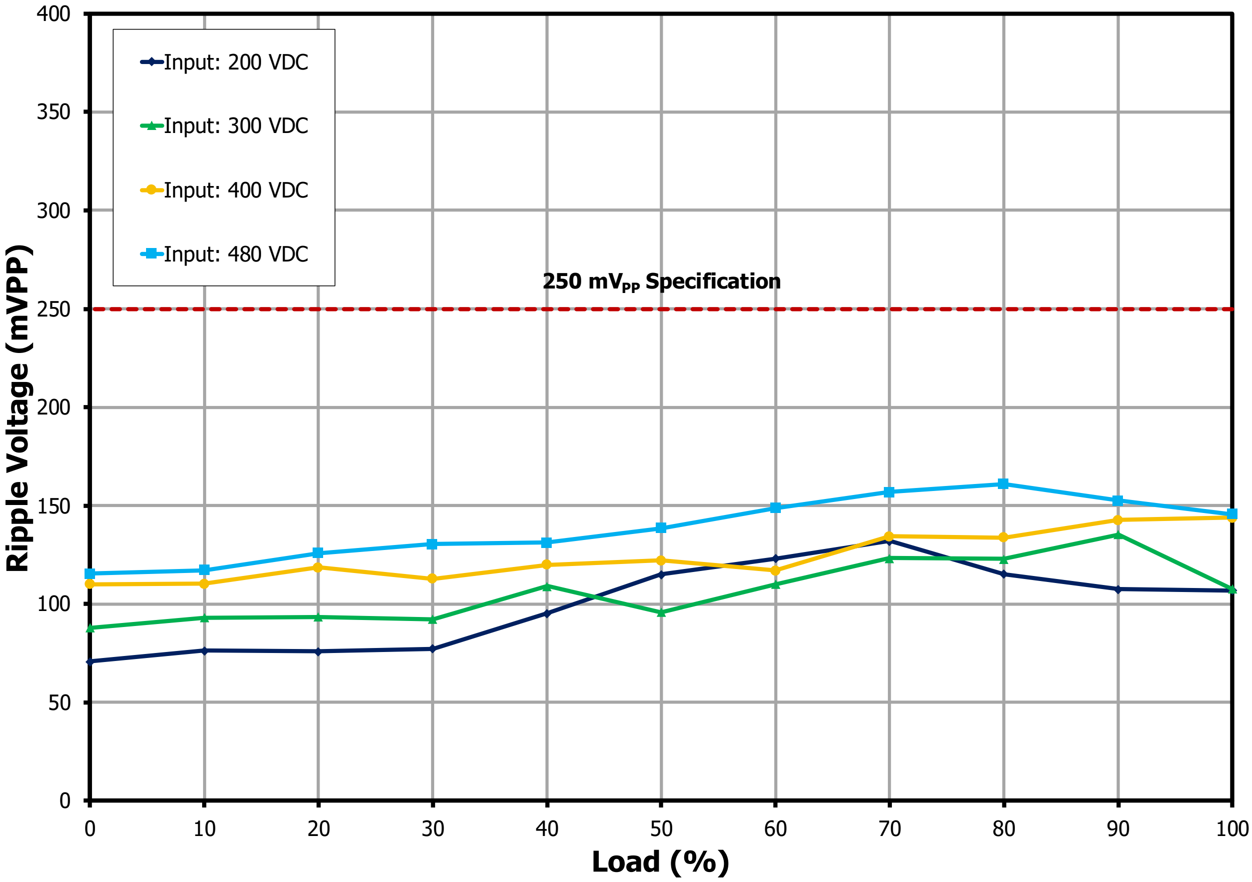


Figure 130 – Output Ripple Voltage Across Full Load (1.3 A) Range (-40 °C Ambient).

13 Output Overload

The unit under test was placed inside a thermal chamber. The chamber was pre-heated to 85 °C and allowed to stabilize for 30 minutes before turning on the unit under test. The unit was also allowed to stabilize for 20 minutes after each change in input voltage. Output voltage and output current measurements were taken 60 seconds after every change in loading condition. The INN3997CQ-H100 enters Auto-Restart (AR) mode when the voltage at the VOUT pin falls to approximately 3.45 V. Since the FWD and VOUT pins are connected to Winding 3 (the secondary bias winding), this threshold corresponds to an equivalent voltage of approximately 13.8 V on Winding 4 (50 V output winding). Therefore, the converter is expected to enter Auto-Restart mode when the voltage on the 50 V output winding decreases to approximately 13.8 V.

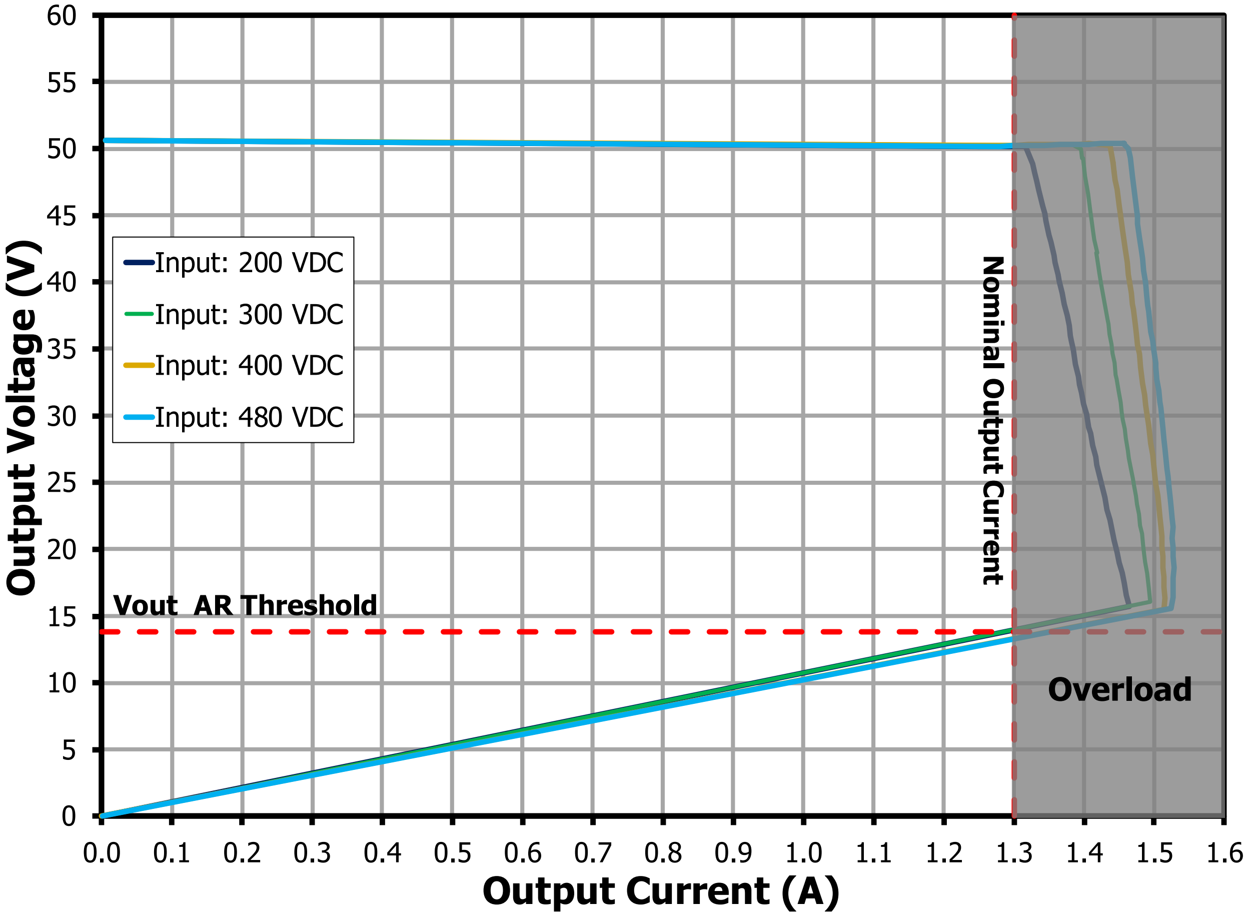


Figure 131 – Output Overload Curve at 85 °C Ambient.

14 Maximum Output Power

The unit under test was placed inside a thermal chamber. The chamber was pre-heated to 85 °C and stabilized for 30 minutes before the unit under test was turned on. Maximum output power at each given input voltage was determined by finding the maximum loading condition at which the unit started up (did not enter auto-restart (AR)) or trigger any overtemperature protection. Case temperatures for critical components were also considered when determining the maximum output power capability for the power supply.

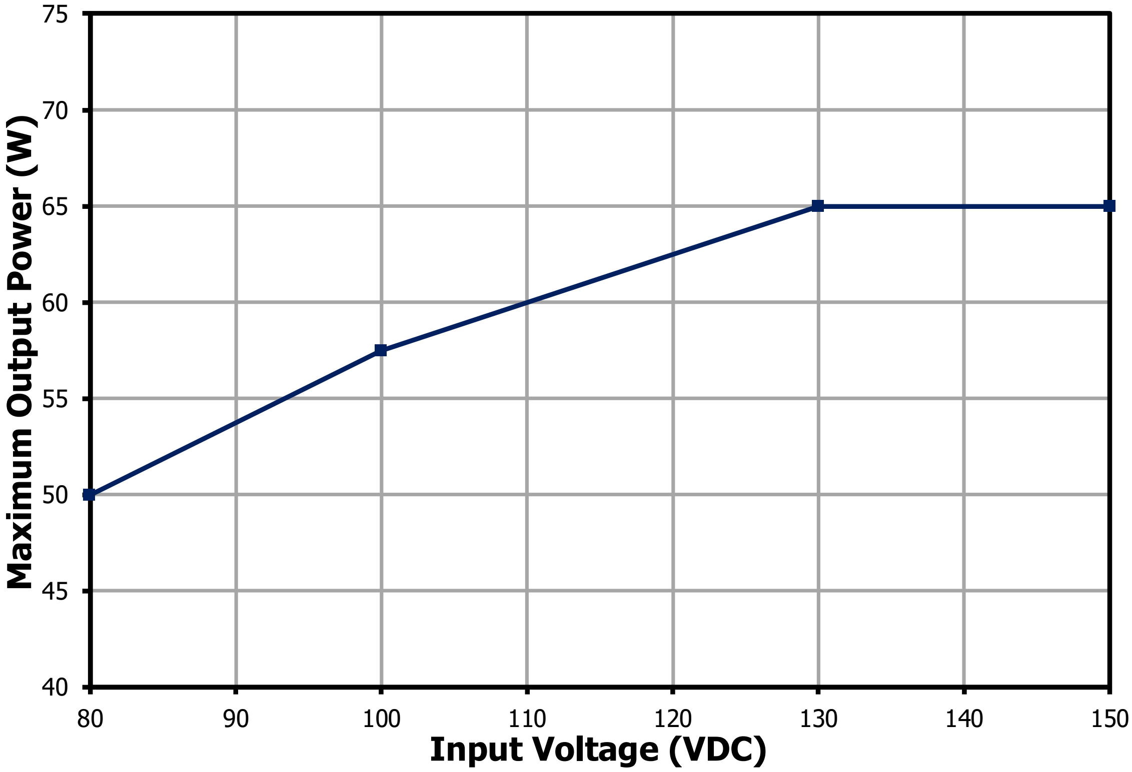


Figure 132 – Maximum Continuous Output Power Curve at 85 °C Ambient.

Input Voltage	Maximum Output Power	Limiting Factor	Value
150 VDC	65 W	Can still provide full power	
130 VDC	65 W	Can still provide full power	
100 VDC	57.5 W	InnoSwitch3-AQ	> 125 °C
80 VDC	50 W	InnoSwitch3-AQ	> 125 °C

Table 15 – Maximum Continuous Output Power Capability Limiting Factor at 85 °C Ambient.

15 Revision History

Date	Author	Revision	Description & Changes	Reviewed
06-Jul-2026	PAO / FGB	A	Initial Release.	JRLC

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