Design Example Report

Title	*65 W Dual USB-C Shared Capacity Ports with Current Sharing Using InnoSwitch™3-Pro PowiGaN™ INN3379C-H315*
Specification	90 VAC – 132 VAC Input; 65 W Power Limited Single Port: 5 V / 3 A, 9 V / 3 A, 12 V / 3 A, 15 V / 3 A, 20 V / 3.25 A Dual Port, Port 1: 5 V / 3 A, 9 V / 3 A, 12 V / 3 A, 15 V / 3 A, 20 V / 2.25 A Dual Port, Port 2: 5 V / 3 A, 9 V / 2.22 A, 12 V / 1.66 A, 15 V / 1.33 A 20 V / 1 A[1]
Application	Wall Outlet, Power Strip and Surge Protectors
Author	Applications Engineering Department
Document Number	DER-1024
Date	February 26, 2024
Revision	1.0

Summary and Features

- InnoSwitch3-Pro - digitally controllable CV/CC QR flyback switcher IC with integrated high-voltage MOSFET, synchronous rectification and FluxLink™ feedback
  - I^2C Interface enables low pin count USB PD controller (8 pin)
  - Sophisticated telemetry and comprehensive protection features
- Dual Type-C USB PD 3.0 shared capacity ports using IP2738 USB PD controller
- 65 W available on both Type-C ports

[1] Port designation depends on loading order. See the table on page 6 for details.

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- 5/9/12/15/20 V supported on both ports, no dc/dc converters
- >91% end to end efficiency at full load
- Meets DOE6 and CoC v5 2016 efficiency requirement
- Maximum component temperature <100 ºC at 25 ºC ambient temperature operation
- Output overvoltage and overcurrent protection
- Integrated thermal protection

PATENT INFORMATION

The products and applications illustrated herein (including transformer construction and circuits external to the products) may be covered by one or more U.S. and foreign patents, or potentially by pending U.S. and foreign patent applications assigned to Power Integrations. A complete list of Power Integrations' patents may be found at www.power.com. Power Integrations grants its customers a license under certain patent rights as set forth at https://www.power.com/company/intellectual-property-licensing/.

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Important Note:

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

1 Introduction

This engineering report describes a 65 W Dual USB PD 3.0 power supply using InnoSwitch3-Pro INN3379-H315 IC and Injoinic IP2738 USB PD controller. The USB PD source capabilities of the power supply are listed below.

Single Port Mode:

- 5 V / 3 A (Fixed Supply PDO)
- 9 V / 3 A (Fixed Supply PDO)
- 12 V / 3 A (Fixed Supply PDO)
- 15 V / 3 A (Fixed Supply PDO)
- 20 V / 3.25 A (Fixed Supply PDO)

Dual Port Mode (Power Limited to 65 W):

Port 1:

- 5 V / 3 A (Fixed Supply PDO)
- 9 V / 3 A (Fixed Supply PDO)
- 12 V / 3 A (Fixed Supply PDO)
- 15 V / 3 A (Fixed Supply PDO)
- 20 V / 2.25 A (Fixed Supply PDO)

Port 2:

- 5 V / 3 A (Fixed Supply PDO)
- 9 V / 2.22 A (Fixed Supply PDO)
- 12 V / 1.66 A (Fixed Supply PDO)
- 15 V / 1.33 A (Fixed Supply PDO)
- 20 V / 1 A (Fixed Supply PDO)

The operation of the power supply is described in the table below.

Operating Mode	USB Port 1 Max power	USB Port 2 Max Power	Description
Single Port Operation	65 W	Unused	Output of both flyback converters combine to supply Port 1 Both power supplies provide 32.5 W and in parallel
Single Port Operation	Unused	65 W	Output of both flyback converters combine to supply Port 2 Both power supplies provide 32.5 W and in parallel
Port 1 in use, Port 2 load inserted	45 W	20 W	Port 1 starts at 65 W maximum power then drop to 45 W Port 2 maximum will be 20 W Ports operate independently
Port 2 in use, Port 1 load inserted	20 W	45 W	Port 2 starts at 65 W maximum power then drop to 45 W Port 1 maximum will be 20 W Ports operate independently

This design shows the high power density and efficiency that is possible due to the high level of integration of the InnoSwitch3-Pro controller providing exceptional performance. The report contains the power supply specification, schematic diagrams, PCB layouts, bill of materials (BOM), magnetics design, and performance data.

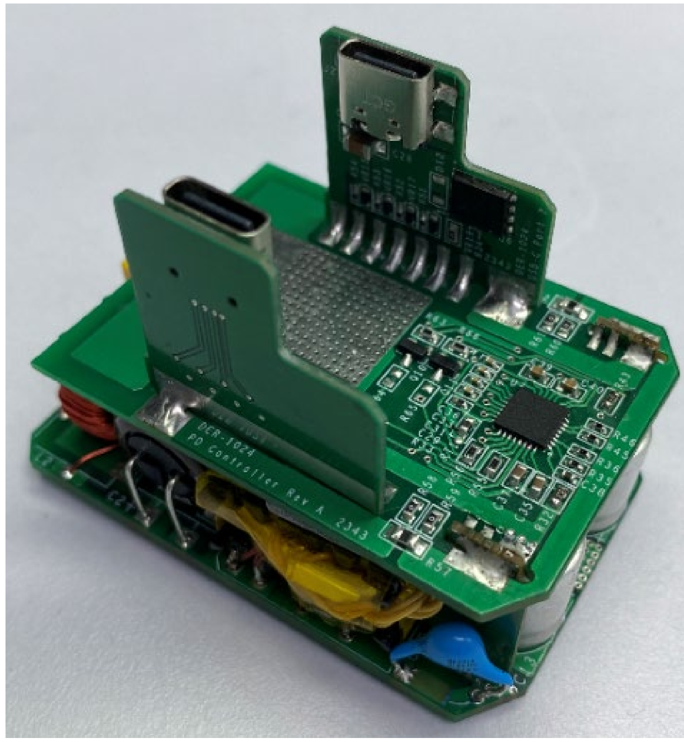


Figure 1 – Populated Circuit Board Photograph, Entire Assembly.

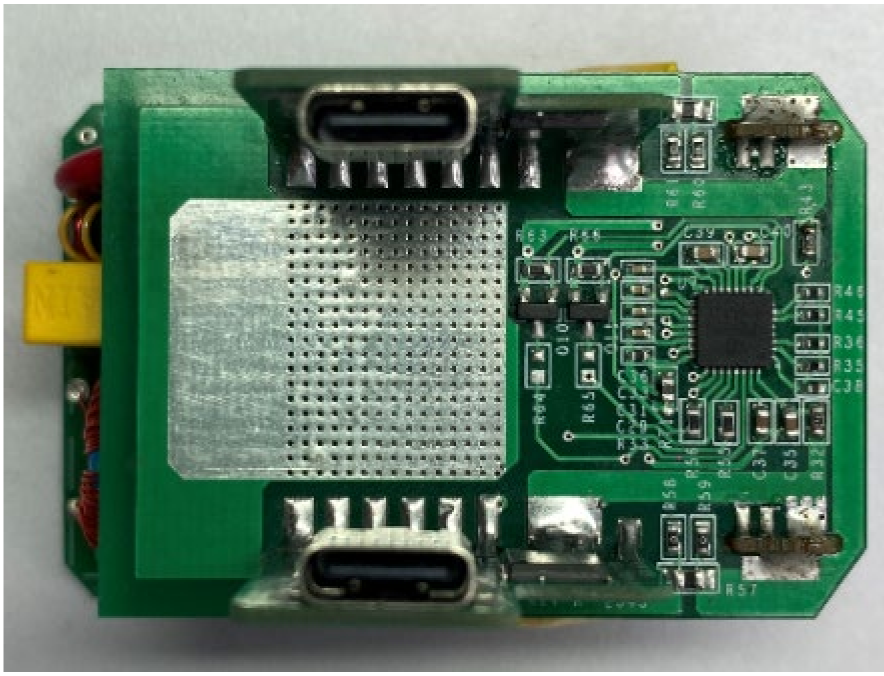


Figure 2 – Populated Circuit Board Photograph - Top.

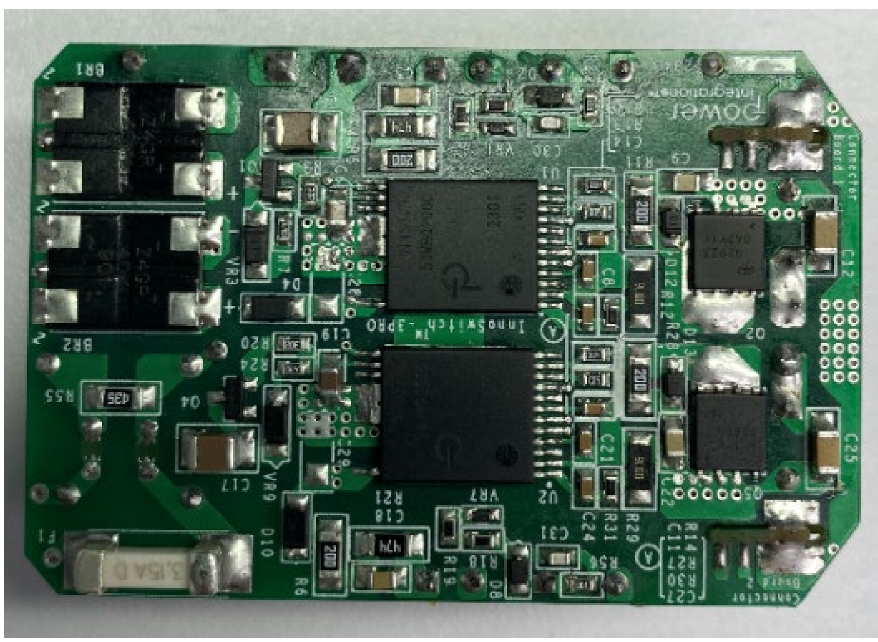


Figure 3 – Populated Circuit Board Photograph - Bottom.

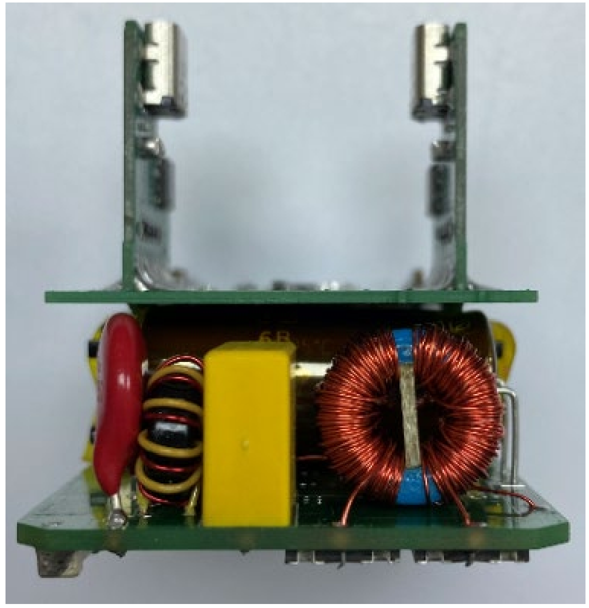


Figure 4 – Populated Circuit Board Photograph - Front.

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		132	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	56	60	64	Hz	
No-load Input Power				200	mW	Measured at 115 VAC.
5 V / 3 A Setting						
Output Voltage	$V_{OUT(5\ V)}$		5.0		V	±5%
Output Voltage Ripple	$V_{RIPPLE(5\ V)}$			150	mV	Measured at End of 100 mΩ Cable at 115 VAC
Output Current	$I_{OUT(5\ V)}$			3.0	A	±3%
Average Efficiency	$\eta_{(5\ V)}$		89		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(5\ V)}$			15	W	
9 V / 3 A Setting						
Output Voltage	$V_{OUT(9\ V)}$		9.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(9\ V)}$			150	mV	Measured at End of 100 mΩ Cable at 115 VAC
Output Current	$I_{OUT(9\ V)}$			3.0	A	±3%
Average Efficiency	$\eta_{(9\ V)}$		90		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(9\ V)}$			27	W	
12 V / 3 A Setting						
Output Voltage	$V_{OUT(12\ V)}$		12.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(12\ V)}$			150	mV	Measured at End of 100 mΩ Cable at 115 VAC
Output Current	$I_{OUT(12\ V)}$			3.0	A	±3%
Average Efficiency	$\eta_{(12\ V)}$		91		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(12\ V)}$			36	W	
15 V / 3 A Setting						
Output Voltage	$V_{OUT(15\ V)}$		15.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(15\ V)}$			150	mV	Measured at End of 100 mΩ Cable at 115 VAC
Output Current	$I_{OUT(15\ V)}$			3	A	±3%
Average Efficiency	$\eta_{(15\ V)}$		91		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(15\ V)}$			45	W	
20 V / 3.25 A Setting						
Output Voltage	$V_{OUT(20\ V)}$		20.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(20\ V)}$			150	mV	Measured at End of 100 mΩ Cable at 115 VAC
Output Current	$I_{OUT(20\ V)}$			3.25	A	±3%
Average Efficiency	$\eta_{(20\ V)}$		91		%	Measured at 115 VAC from AC Receptacle to Type-C Receptacle on the Board.
Continuous Output Power	$P_{OUT(20\ V)}$			65	W	
Conducted EMI		Meets CISPR22B / EN55022B				
Ambient Temperature	T_{AMB}		25		ºC	Closed Frame, Sea Level.

3 Schematic

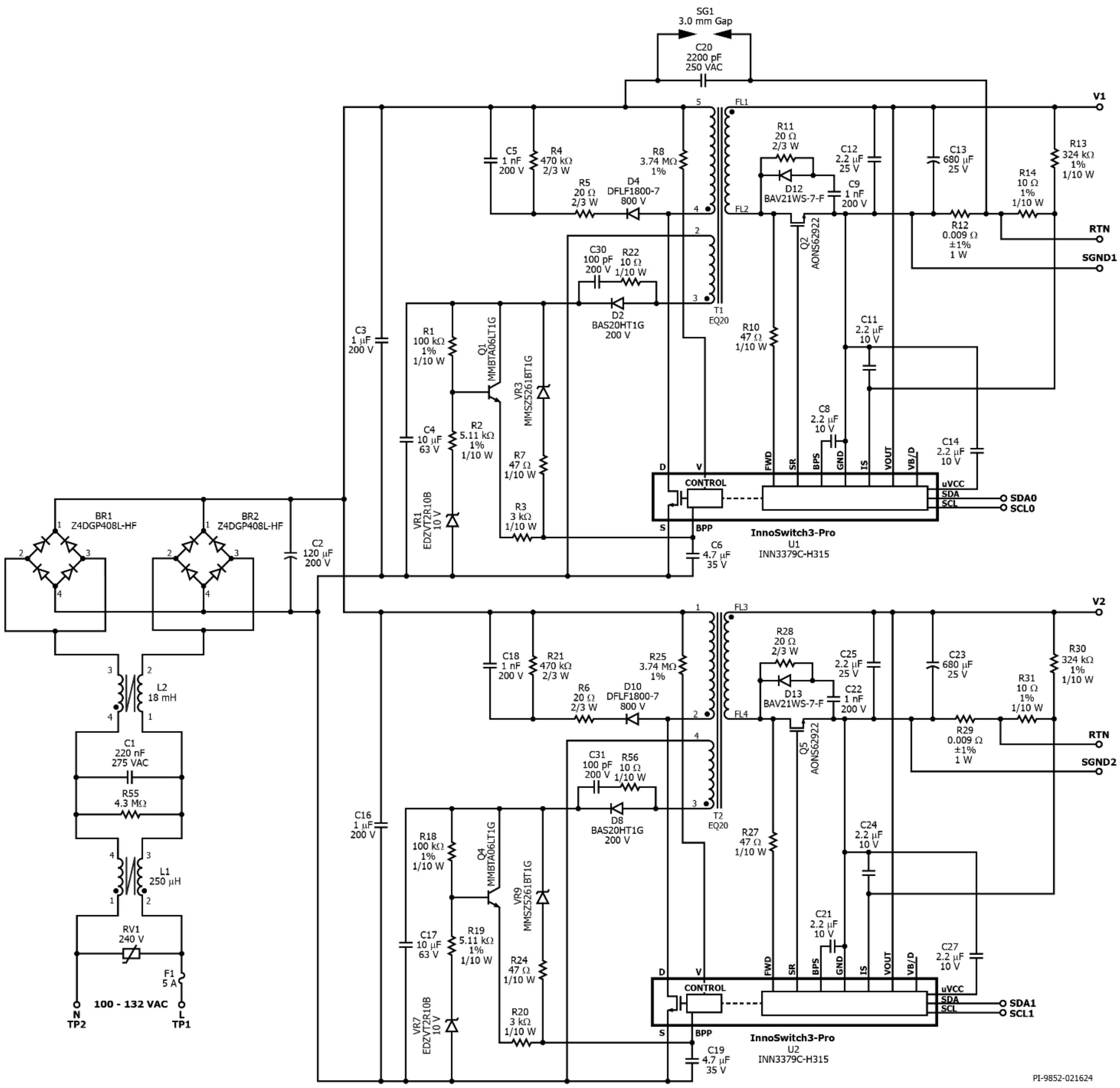


Figure 5 – DER-1024 Rev B Schematic, Input EMI Filter, Flyback 1 and Flyback 2 Sections.

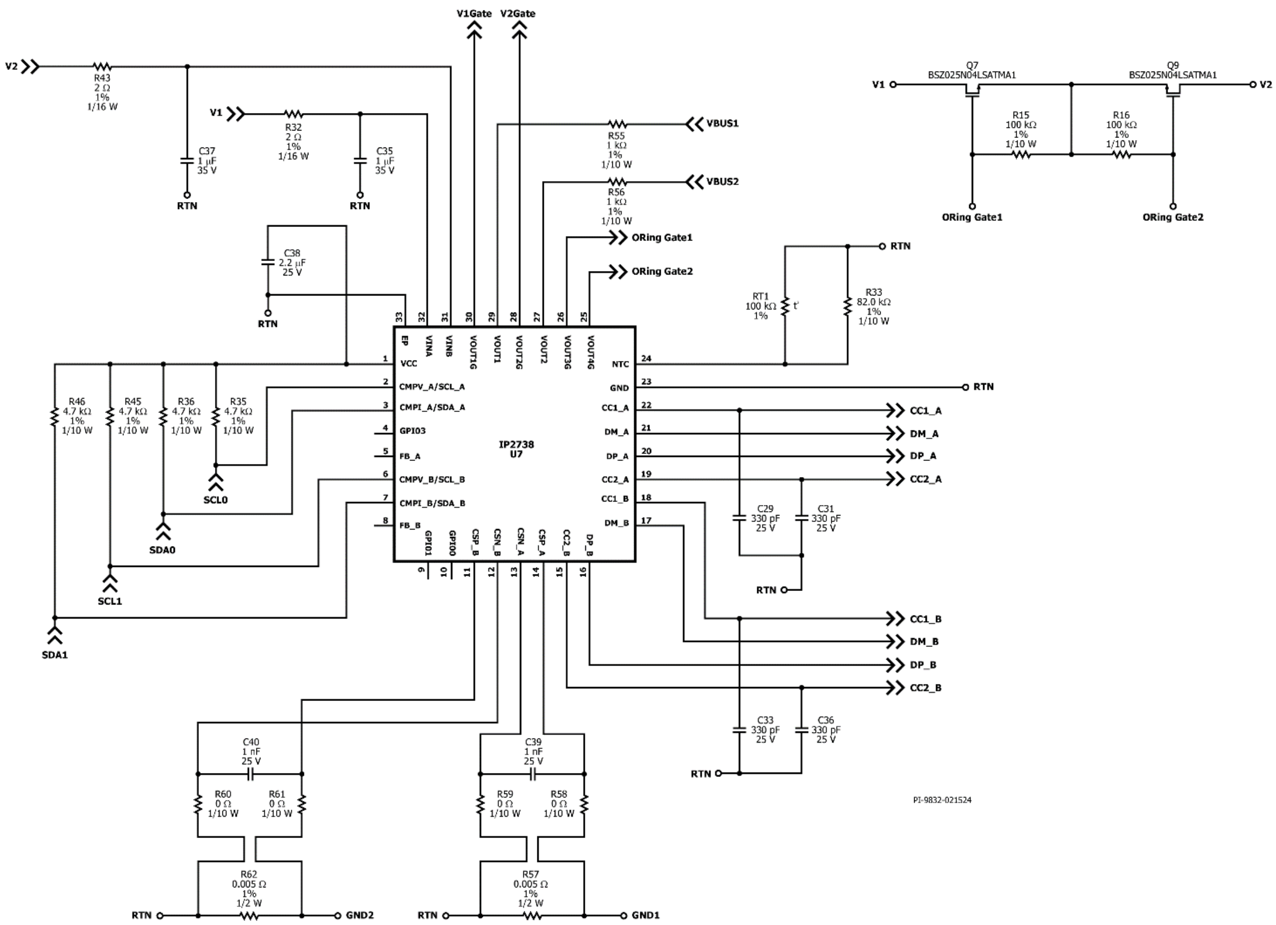


Figure 6 – DER-1024 Rev B Schematic, USB-PD Controller Board.

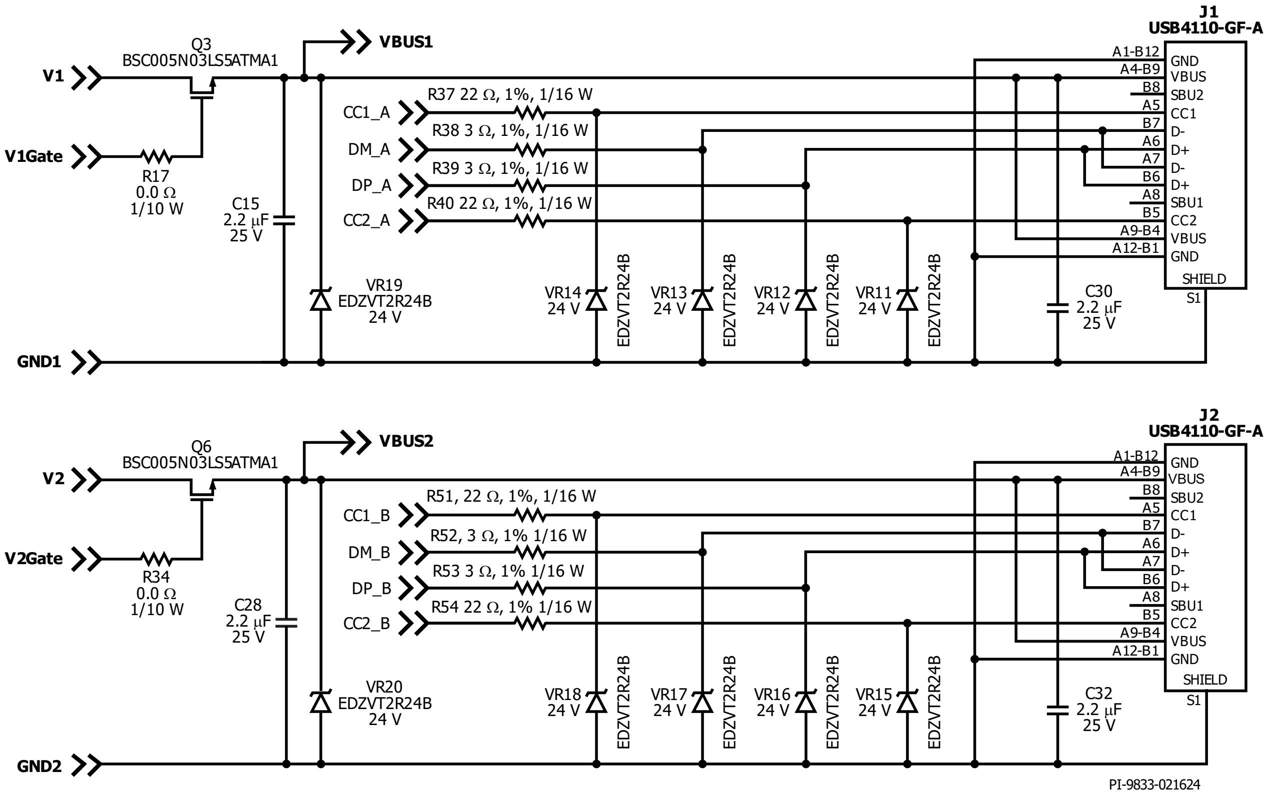


Figure 7 – DER-1024 Rev B Schematic, USB-C Ports.

4 Circuit Description

4.1 Input Rectifier and EMI Filter

The input fuse F1 isolates the circuit and provides protection from component failure. Varistor RV1 protects against line transients. Common mode chokes L1 and L2, with capacitors C1 and C20 provide common mode and differential mode noise filtering for EMI attenuation. Bridge rectifiers BR1 and BR2 rectify the AC line voltage to have a full wave rectified DC, which is filtered by the bulk capacitor C2.

Resistor R55 discharges capacitor C1 when the power supply is disconnected from AC mains.

4.2 InnoSwitch3-Pro IC Primary

This design uses two identical flyback converters that operate independently from each other. The following paragraphs describe only one of the converters but is applicable to the other by cross-referencing the part designators in the schematic.

One end of the flyback transformer T1 primary winding is connected to the rectified DC bus while the other end is connected to the drain terminal of the switch inside the InnoSwitch3-Pro IC U1. Resistors R8 provide input voltage sensing for AC input undervoltage or overvoltage protection.

A low-cost RCD clamp formed by diode D4, resistors R4 and R5, and capacitor C5 limits the peak drain-source voltage of U1 at the instant the switch inside U1 turns off. The clamp helps to dissipate the energy stored in the leakage reactance of transformer T1.

The IC is self-starting, using an internal high-voltage current source to charge the BPP pin capacitor C6 when the AC is first applied. During normal operation, the primary-side block is powered by the auxiliary winding of transformer T1. The output of the auxiliary (or bias) winding is rectified using diode D2 and filtered using capacitor C4. The NPN BJT Q1, resistors R1 and R2, and Zener diode D1 form a linear regulator to maintain the voltage at the Emitter terminal of Q1 to approximately 9V regardless of the output voltage set point. Resistor R3 limits the BPP pin current of the InnoSwitch3-Pro IC U1 to a value sufficient for normal operation without incurring excessive losses.

Zener diode VR3 offers primary sensed output overvoltage protection. In a flyback converter, the output of the auxiliary winding tracks the output voltage of the converter. In case of overvoltage at the output of the converter, the auxiliary winding voltage increases causing VR1 to breakdown resulting in a very low impedance. This will cause excessive current to flow into the BPP pin of InnoSwitch3-Pro IC U1. If the current flowing into the BPP pin increases above the I_{SD} threshold, the InnoSwitch3-Pro controller will latch off to prevent any further increase in output voltage. Resistor R3 limits the current injected to BPP pin when the output overvoltage protection is triggered.

4.3 InnoSwitch3-Pro IC Secondary and USB Power Delivery Controller

The secondary-side of the InnoSwitch3-Pro IC provides output voltage and current sensing as well as a gate driver for the synchronous rectification FET (SR FET). The voltage across the transformer secondary winding is rectified by the SR FET Q2 and filtered by capacitors C12 and C13. High frequency ringing during switching transients that would otherwise create radiated EMI is reduced via the RCD snubber formed by resistor R11 and capacitor C9, and diode D12.

Switching of Q3 is controlled by the secondary-side controller inside IC U1. Control is based on the secondary winding voltage sensed by the FWD pin via resistor R10.

In continuous conduction mode (CCM) of operation, the SR FET is turned off just prior to the secondary-side commanding a new switching cycle to the primary. In discontinuous mode of operation, the SR FET is turned off when the magnitude of the voltage drop across the SR FET falls below a certain threshold of approximately $V_{SR(TH)}$. Secondary-side control of the primary-side power switch avoids any possibility of cross conduction of the two switches and ensures reliable synchronous rectifier operation.

The secondary-side of the IC is powered either by the secondary winding forward voltage (thru R10 and the FWM pin) or by the output voltage (thru the VOUT pin). Capacitor C8 connected to the BPS pin of InnoSwitch3-Pro IC U1 provides decoupling for the internal circuitry.

Output current is sensed by monitoring the voltage drop across resistor R12. Resistors R13 and R14 add an offset to the sensed output current to provide a positive slope to the CC characteristic. The resulting current measurement is filtered with decoupling capacitor C11 and monitored across the IS and SECONDARY GROUND pins. An internal current sense threshold, programmable up to 32mV through the I^2C interface, is used to reduce losses. Once the threshold is exceeded, the InnoSwitch3-Pro IC U1 regulates the number of switch pulses to maintain a fixed output current.

During constant current (CC) operation, when the output voltage falls significantly, the secondary-side controller inside InnoSwitch3-Pro IC U1 derives power from the secondary winding directly. During the ON-time of the primary-side power switch, the forward voltage that appears across the secondary winding is used to charge the SECONDARY BYPASS pin decoupling capacitor C8 via resistor R10 and an internal regulator. This allows output current regulation to be maintained down to the minimum UV threshold. Below this threshold, the unit enters auto-restart until the output load is reduced.

When the output current is below the CC threshold, the converter operates in constant voltage mode. The output voltage is monitored by the VOUT pin of the InnoSwitch3-Pro

IC. Similar with current regulation, the output voltage is also compared to an internal voltage reference that is set via the I^{2}C interface. Capacitor C12 is placed directly across the VOUT pin and the SECONDARY GROUND pin for ESD protection of the VOUT pin.

N-channel MOSFET Q3 is the bus switch used to connect or disconnect the output of the flyback converter to the USB Type-C port V_{BUS} pin. MOSFET Q3 is controlled by the USB-PD controller IC. Resistor R17 is a pulldown resistor to prevent unwanted triggering of Q3 and while also acting as a discharge path for the bus voltage when the Q3 is turned off. Capacitor C15 is used at the output for ESD protection.

In this design, IP2738 IC is used as the USB Power Delivery (USB PD) controller. The IP2738 also controls paralleling of the power supplies for 65W peak power operation. The USB-PD controllers are powered from the outputs of both flyback converters. USB PD protocol is communicated over either CC1 or CC2 line depending on the orientation in which Type-C plug is connected.

The IP2738 IC communicates with InnoSwitch3-Pro IC through the I^{2}C interface using the SCL and SDA lines in which it sets the CV, CC, V_{KP}, OVA and UVA parameters. These parameters correspond to the output voltage, constant output current, constant output power voltage threshold, output overvoltage threshold, and output undervoltage threshold registers of the InnoSwitch3-Pro IC, respectively. The status of the InnoSwitch3-Pro IC is read by the IP2738 IC from the telemetry registers also using the I^{2}C interface.

Capacitors C29 and C31, resistors R37 to R40, and TVS diodes VR11 to VR14 provide protection from ESD to pins D+, D-, CC1 and CC2. VR19 also provide protection from ESD for the VOUT1 pin of the PD controller IC. The IP2738 has a dedicated sense resistor R57 to measure the USB Port output current. The signal from R57 is filtered by the low pass filter formed by R58 and C39 before entering the ADC port inputs of the IP2738. RT1 is used for temperature sensing while R33 is used to trim the readings of the temperature ADC. Resistors R35 and R36 are the pull-up resistors of the I^{2}C lines (SDA/SCL). Resistor R32 and C35 form the low pass filter for the V_{IN} input pin of the USB-PC controller.

MOSFETs Q7 and Q9 are used as OR-in FETs for parallel operation. Resistors R15 and R16 are the pull-down resistors for the OR-in FETs.

5 PCB Layout

5.1 Mother Board

PCB Mother Board Details:

- Material: FR4 Copper 2oz
- Thickness: 0.062”

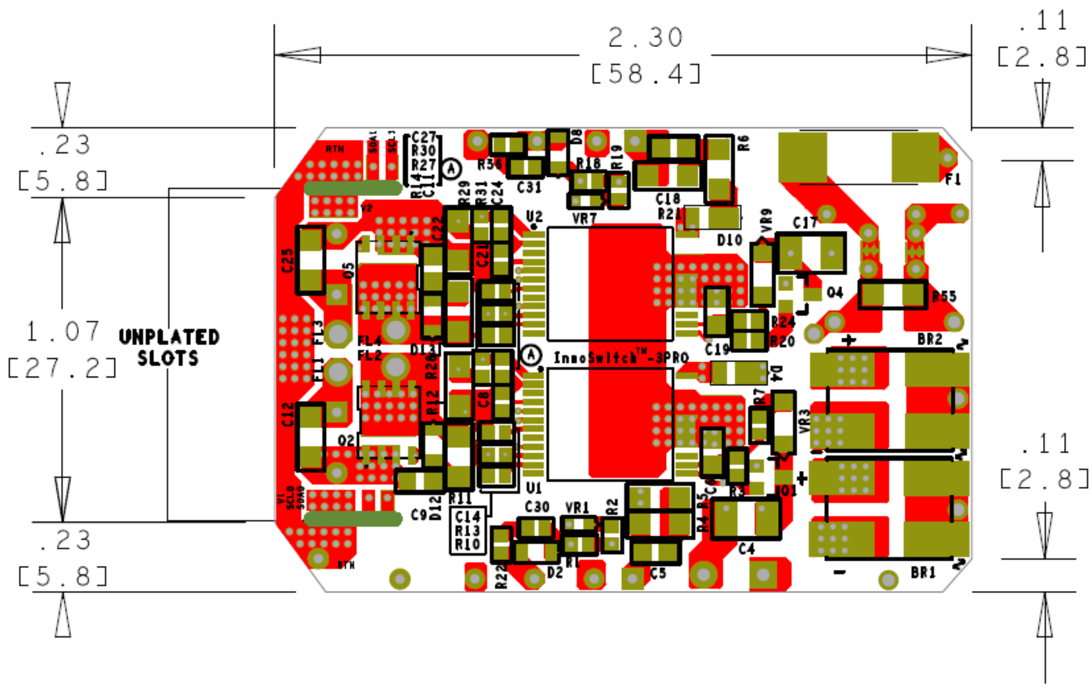


Figure 8 – DER-1024 Mother Board Rev B Printed Circuit Layout (Bottom).

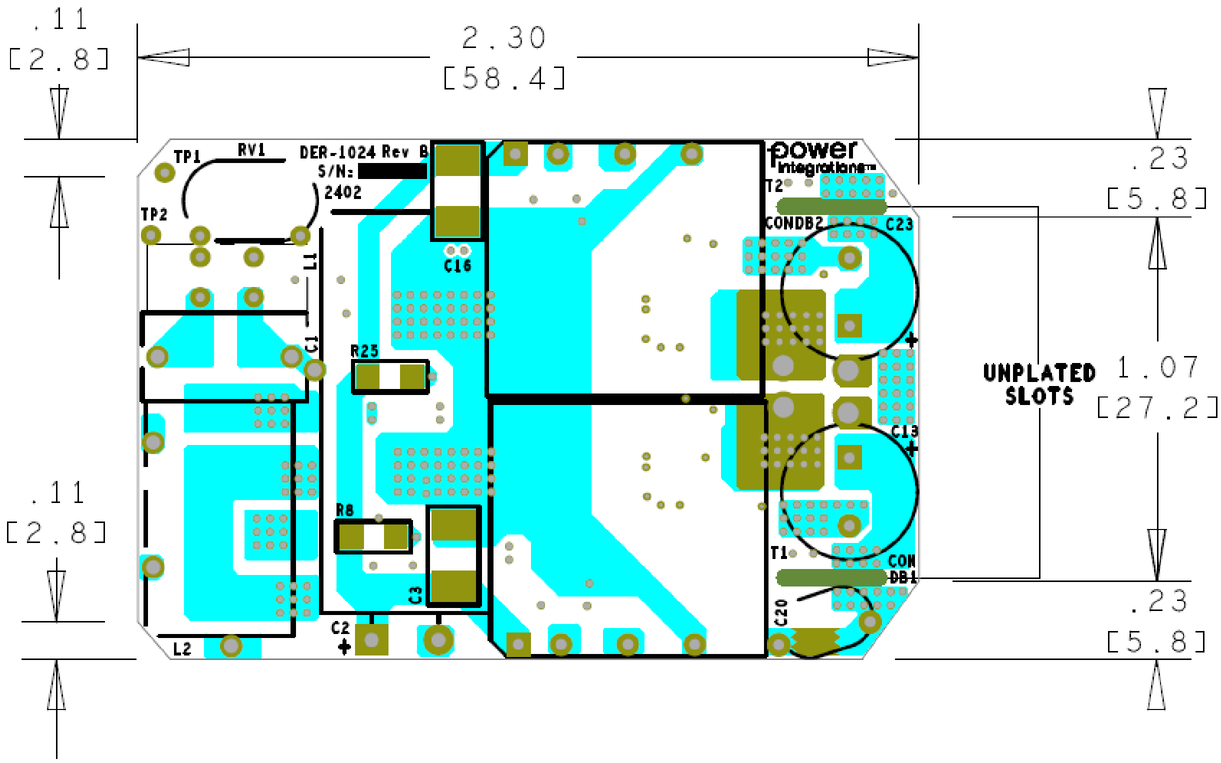


Figure 9 – DER-1024 Mother Board Rev B Printed Circuit Layout (Top).

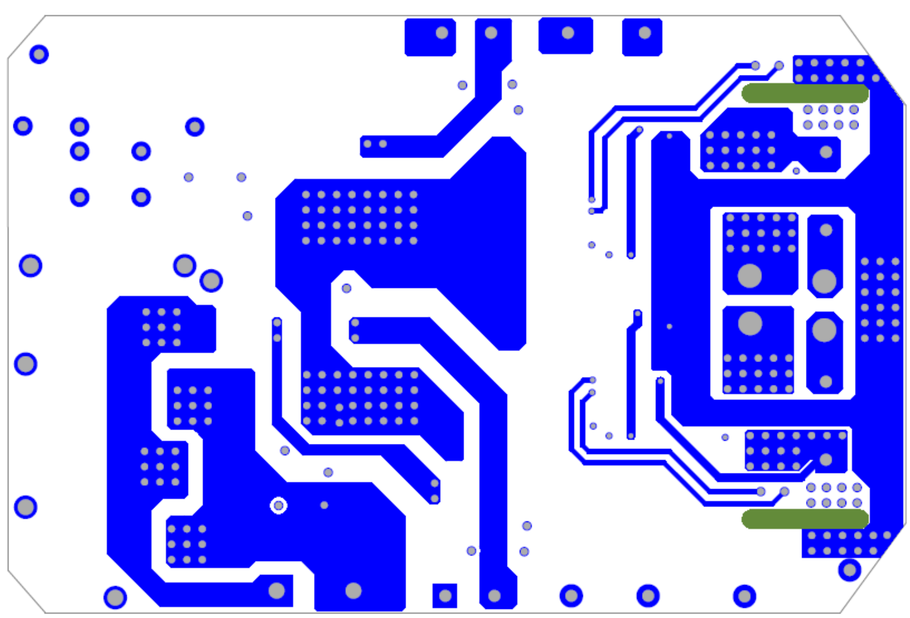


Figure 10 – DER-1024 Mother Board Rev B Printed Circuit Layout (Inner Layer 1).

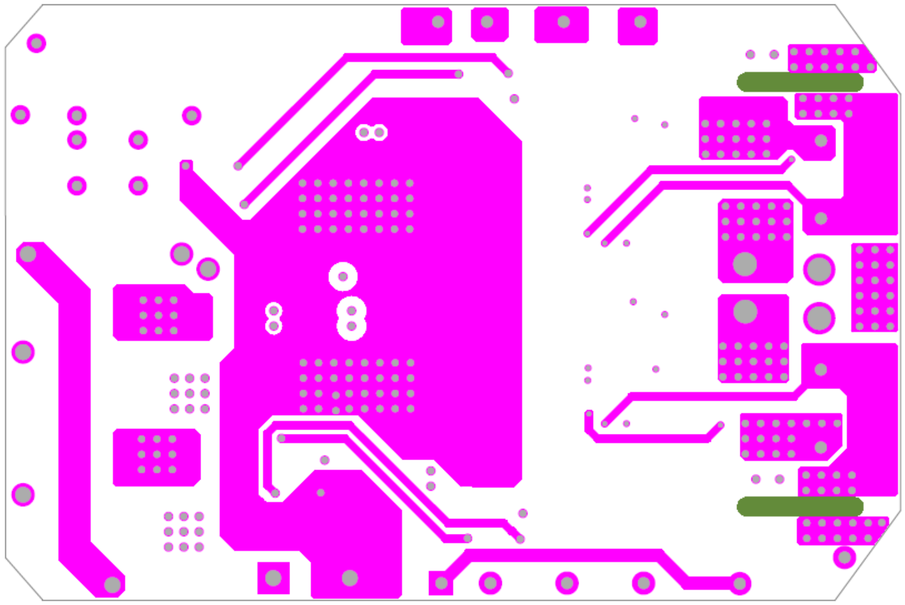


Figure 11 – DER-1024 Mother Board Rev B Printed Circuit Layout (Inner Layer 2).

5.2 USB-PD Controller Board

USB-PD Controller Board Details:

- Material: FR4 Copper 2oz
- Thickness: 0.062"

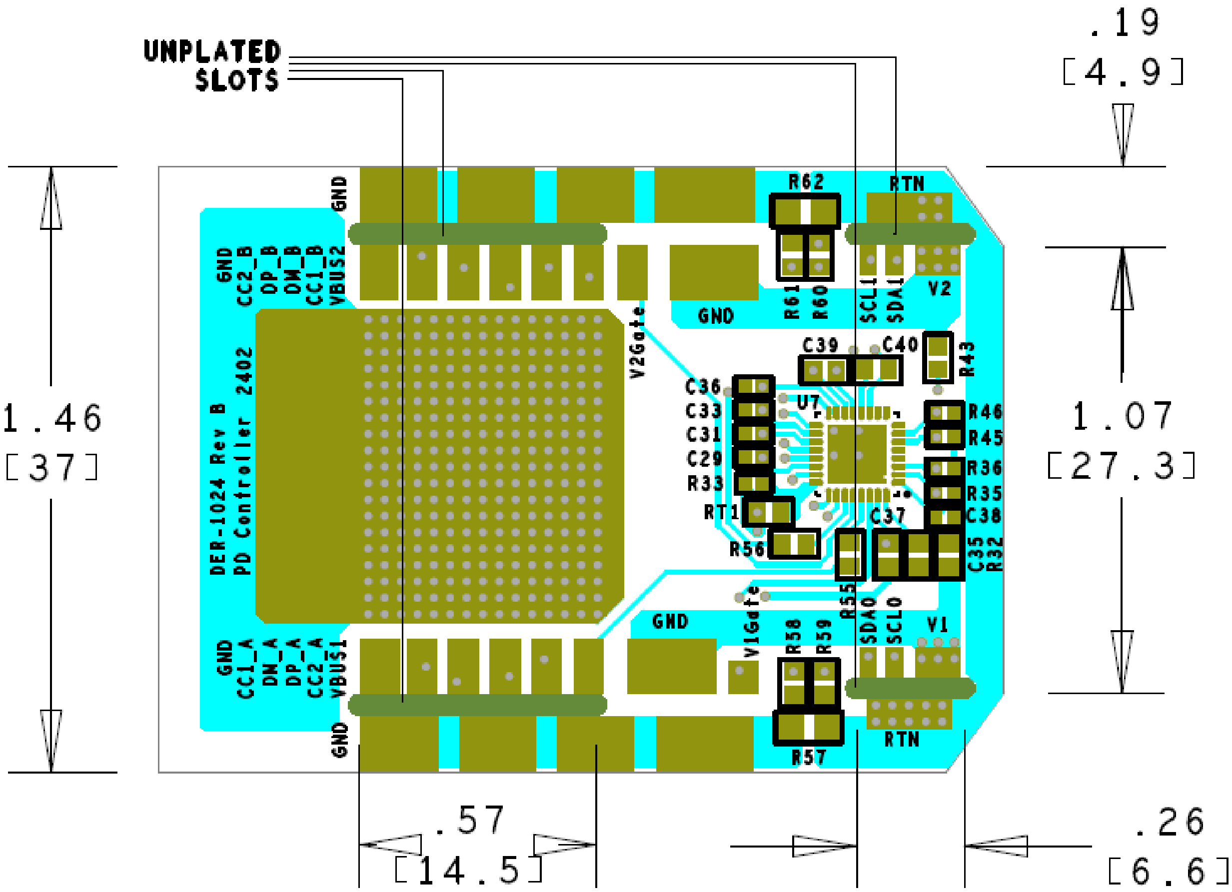


Figure 12 – DER-1024 USB-PD Controller Board (Top).

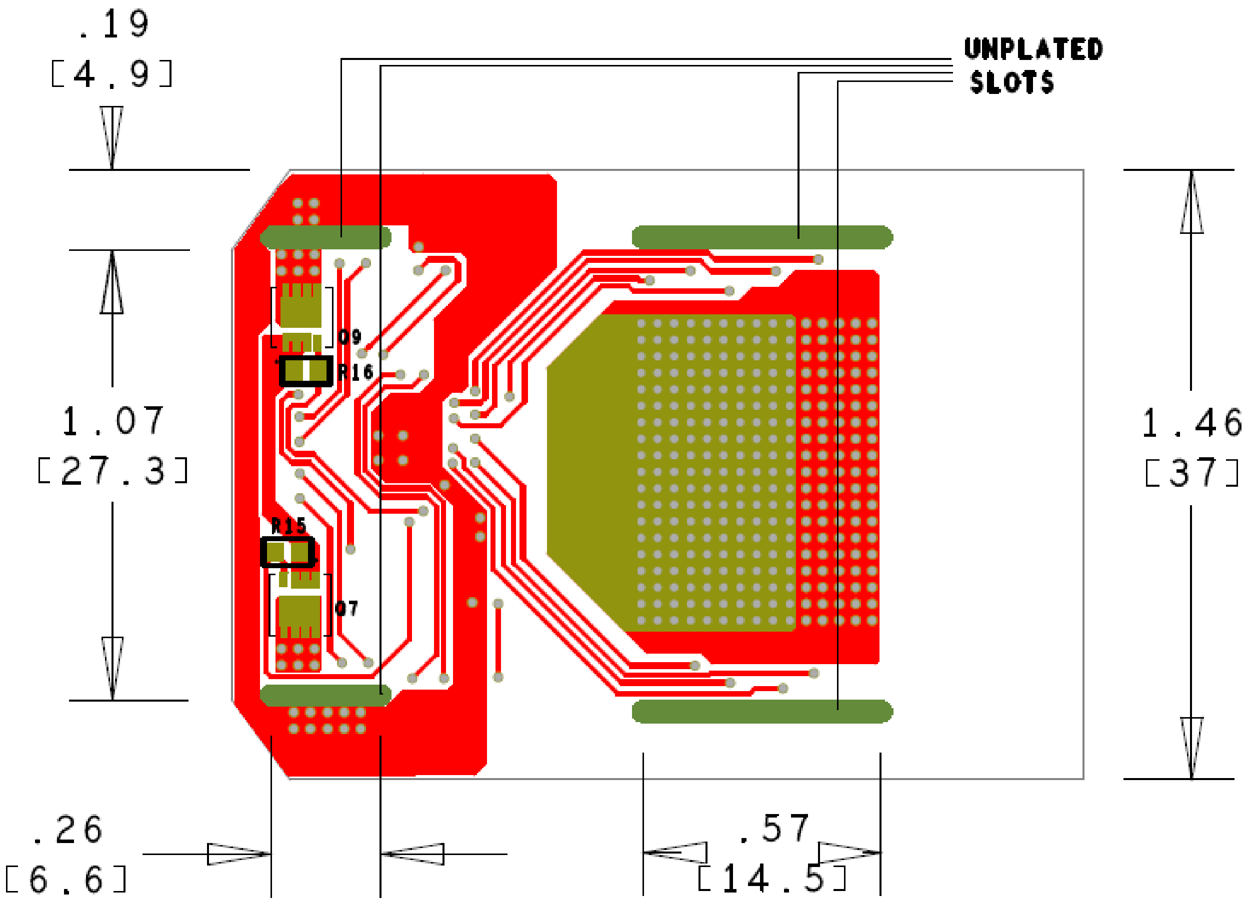


Figure 13 – DER-1024 USB-PD Controller Board (Bottom).

5.3 USB-C Port Daughter Board

USB-C Port Daughter Board:

- Material: FR4 Copper 2oz
- Thickness: 0.039”

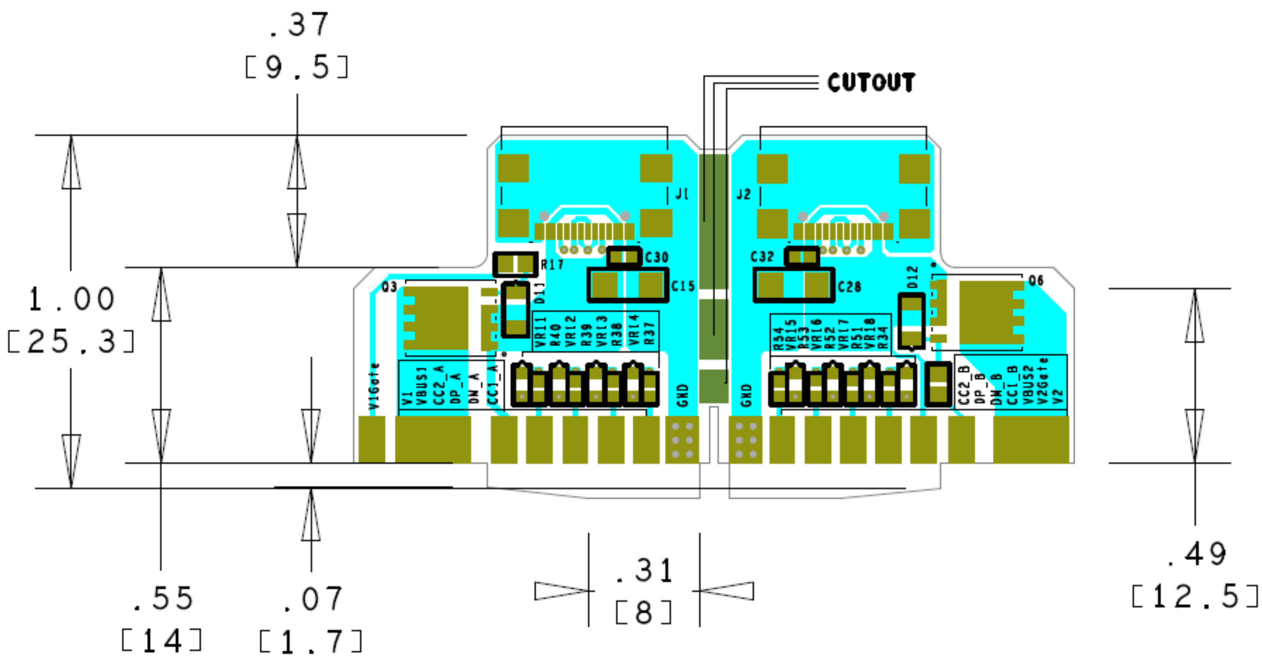


Figure 14 – DER-1024 USB-C Port Daughter Board (Top).

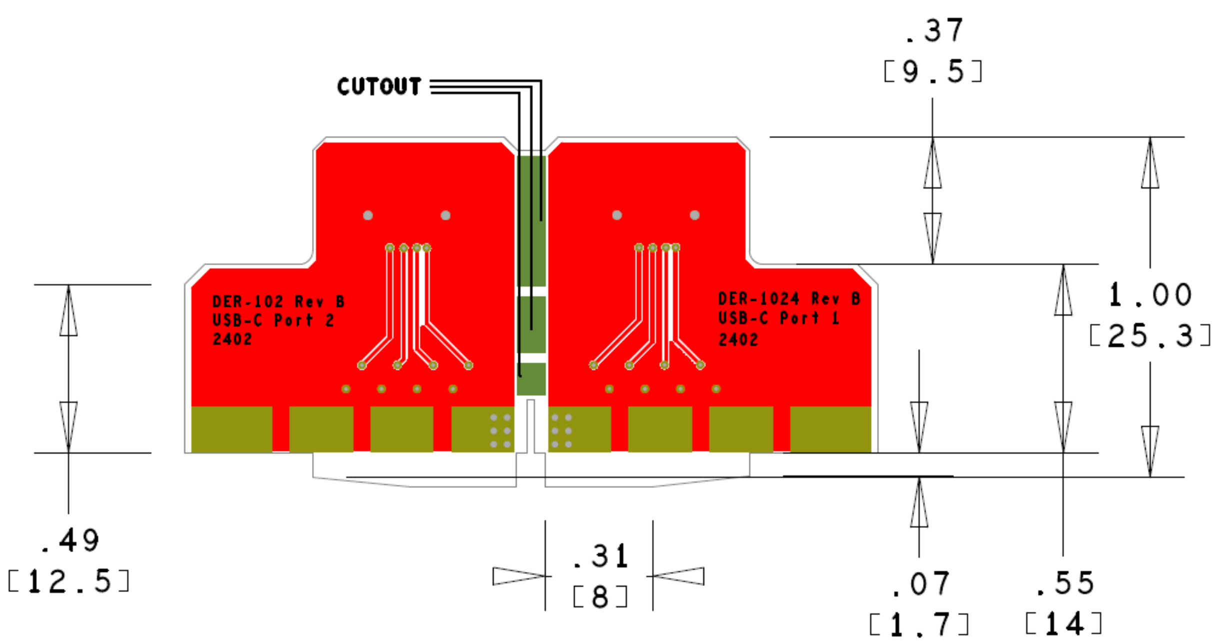


Figure 15 – DER-1024 USB-C Port Daughter Board (Bottom).

5.4 Connector Boards

USB-C Port Daughter Board:

- Material: FR4 Copper 2oz
- Thickness: 0.039"

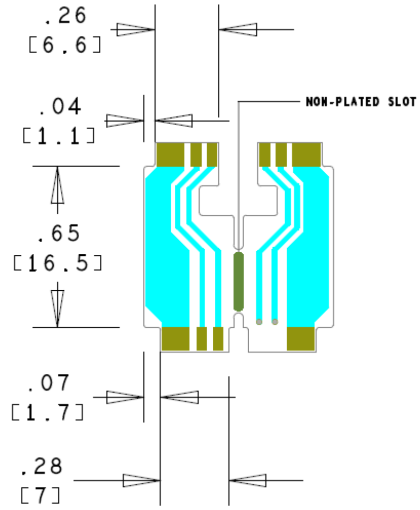


Figure 16 – DER-1024 Connector Board (Top).

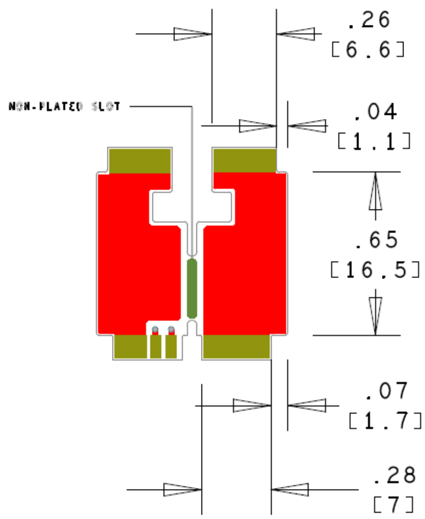


Figure 17 – DER-1024 Connector Board (Bottom).

6 Bill of Materials

6.1 Mother Board

No	Ref Des	Qty	Value	Description	Mfg	Mfg Part Number
1	BR1 BR2	2	Z4DGP408L-HF	RECT BRIDGE, GP, 800V, 4A, Z4-D	Comchip Technology	Z4DGP408L-HF
2	C1	1	220 nF	0.22UF, 20%, 275VAC, X2, -40°C ~ 110°C, 6 mm W x 13 mm L x 12 mm H	DAIN ELECTRONICS CO., LTD.	MPX224K2C3XAB1015
3	C2	1	120 uF	120 µF, ±20%, 200 V, Aluminum Electrolytic Capacitors Radial, Can - 12000 Hrs @ 105°C, (12.5 x 31.5)	United Chemi-Con	EKXJ201ELL121MK30S
4	C3 C16	2	1 uF	1 µF, ±5%, 200V Ceramic Capacitor, X7R, 1812 (4532 Metric)	AVX Corporation	18122C105JAT2A
5	C4 C17	2	10 uF	10 µF ±10%, 63V, Ceramic Capacitor, X7R, 1210 (3225 Metric)	Samsung Electro-Mechanics	CL32B106KMVNNWE
6	C5 C9 C18 C22	4	1 nF	1 nF, 200 V, Ceramic, X7R, 0805	AVX Corp	08052C102KAT2A
7	C6 C19	2	4.7 uF	4.7 uF, ±10%, 35V, Ceramic, X7R, 0805 (2012 Metric)	TDK	C2012X7R1V475K125AC
8	C8 C11 C14 C21 C24 C27	6	2.2 uF	2.2 uF, 10 V, Ceramic, X7R, 0603	Murata	GRM188R71A225KE15D
9	C12 C25	2	2.2 uF	2.2 uF, ±10%, 25 V, Ceramic, X7R, 1206 (3216 Metric)	AVX Corporation Murata	12063C225K4Z2A
10	C13 C23	2	680 uF	680µF, ±20%, 25V, Aluminum Polymer Capacitor Radial, Can, 292.56 mOhm, 1500 Hrs @ 125°C, (10 x 13.5)	Illinois Capacitor	687AVG025MGBJ
11	C20	1	2200 pF	2200 pF, ±20%, 400VAC, X1, Y2, Ceramic Capacitor Y5V (F), Radial, Disc, 7 mm diameter	KEMET	C901U222MYVDBA7317
12	C30 C31	2	100 pF	100 pF 200 V, Ceramic, NP0, 0603	Kemet	C0603C101J2GAC7867
13	D2 D8	2	BAS20HT1G	Diode, High Voltage, General Purpose, Power, Switching, SS SWCH DIO, 200V, 200mA, SC-76, SOD-323	ON Semiconductor	BAS20HT1G
14	D4 D10	2	DFLF1800-7	800 V, 1 A, Fast Recovery Rectifier, POWERDI123	Diodes Inc	DFLF1800-7
15	D12 D13	2	BAV21WS-7-F	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	Diode Inc.	BAV21WS-7-F
16	F1	1	5 A	5 A, 250 V AC, 125 V DC, Fuse, AEC-Q200, cURus, Board Mount (Cartridge Style Excluded), Surface Mount 2-SMD, Square End Block	Bel Fuse Inc	0678H5000-02
17	L1	1	250 uH	250 uH, Toroidal Common Mode Choke, custom, DER-538, wound on 32-00275-00 core.	Power Integrations	32-00367-00
18	L2	1	18 mH	Custom, CMC, 18mH @ 10KHz, Toroidal, 17.5 mm OD x 11.0 mm thick. 40 turns x 2, 0.40mm wire 190mOhm max	Sumida	04291-T231
19	Q1 Q4	2	MMBTA06LT1G	NPN, Small Signal BJT, 80 V, 0.5 A, SOT-23	On Semiconductor	MMBTA06LT1G
20	Q2 Q5	2	AONS62922	MOSFET, N-CH, 120V, 85A (at VGS=10V), Trench Power AlphaSGT 120V TM technology, DFN5X6	Alpha & Omega Semiconductor Inc.	AONS62922
21	R1 R18	2	100 k	RES, 100 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF1003V

22	R2 R19	2	5.11 k	RES, 5.11 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF5111V
23	R3 R20	2	3 k	RES, 3 k, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ302V
24	R4 R21	2	470 k	RES, 470 k, 5%, 2/3 W, Thick Film, 1206	Panasonic	ERJ-P08J474V
25	R5 R6 R11 R28	4	20	RES, 20 R, 5%, 2/3 W, Thick Film, 1206	Panasonic	ERJ-P08J200V
26	R7 R10 R24 R27	4	47	RES, 47 R, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ470V
27	R8 R25	2	3.74 M	RES, 3.74 M, 1%, 1/4 W, Thick Film, 1206	Vishay Dale	CRCW12063M74FKEA
28	R12 R29	2	0.009	RES, 0.009 OHM, 1 W, ±1%, Current Sense, Thick Film,1206 (3216 Metric)	Rohm Semiconductor	PMR18EZPFU9L00
29	R13 R30	2	324 k	RES, 324 kOhms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Moisture Resistant Thick Film	Yageo	RC0603FR-07324KL
30	R14 R31	2	10	RES, 10 R, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF10R0V
31	R22 R56	2	10	RES, 10 R, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEYJ100V
32	R55	1	4.3 M	RES, 4.3 M, 5%, 1/4 W, Thick Film, 1206	YAGEO	RC1206JR-074M3L
33	RV1	1	240 V	240 V, 3.5 kA Varistor, 1 Circuit, Through Hole Disc 10mm	Littelfuse Inc.	V10E150P
34	T1 T2	2	EQ20	Bobbin, EQ20, 10 pins, 5pri, 5sec	sales@pishine.com	P-2042
35	U1 U2	2	INN3379C-H315	InnoSwitchPro, InSOP24D	Power Integrations	INN3379C-H315
36	VR1 VR7	2	EDZVT2R10B	10 V, 5%, 150 mW, SSMINI-2, SC-79, SOD-523, EMD2	Rohm Semiconductor	EDZVT2R10B
37	VR3 VR9	2	MMSZ5261BT1G	DIODE ZENER 47V 500MW SOD123	ON Semi	MMSZ5261BT1G

6.2 PD Controller Board

No	Ref Des	Qty	Value	Description	Mfg	Mfg Part Number
1	C29 C31 C33 C36	4	330 pF	330 pF, ±10%, 25V, Ceramic Capacitor, X7R, 0402 (1005 Metric)	AVX Corporation	04023C331KAT2A
2	C35 C37	2	1 uF	1μF, ±10%, 35V, Ceramic Capacitor, X7R, 0603 (1608 Metric)	TDK Corp	C1608X7R1V105K080AE
3	C38	1	2.2 uF	2.2 μF, ±10%, 25V, Ceramic Capacitor, X5R, 0402 (1005 Metric)	TDK Corporation	C1005X5R1E225K050BC
4	C39 C40	2	1 nF	1 nF, ±10%,25 V, Ceramic, X7R, 0603 (1608 Metric)	Murata	GCM188R71E102KA37D
5	Q7 Q9	2	BSZ025N04LSATMA1	MOSFET, N-Channel, 40 V, 22A (Ta), 40A (Tc), 2.1W (Ta), 69W (Tc), Surface Mount PG-TSDSON-8-FL, PG-TSDSON-8 FL,8-PowerTDFN	Infineon	BSZ025N04LSATMA1
6	R15 R16	2	100 k	RES, 100 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF1003V
7	R32 R43	2	2.00	RES, 2.00 R, 1%, 1/16 W, Thick Film, 0603	Panasonic	RC0603FR-072RL
8	R33	1	82.0 k	RES, 82.0 k, 1%, 1/10 W, Thick Film, 0402	Panasonic	ERJ-2RKF8202X
9	R35 R36 R45 R46	4	4.70 k	RES, 4.70 k, 1%, 1/10 W, Thick Film, 0402	Panasonic	ERJ-2RKF4701X
10	R55 R56	2	1 k	RES, 1 k, 1%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3EKF1001V
11	R57 R62	2	0.005	RES, 0.005 Ohm, ±1%, 0.5W, 1/2W, 0805 (2012 Metric), Current Sense, Thick Film,±300ppm/°C,-55°C ~ 155°C	Panasonic Electronic Components	ERJ-6LWFR005V
12	R58-R61	4	0.0	RES, 0 R, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEY0R00V
13	RT1	1	100 k	NTC Thermistor, 100 k, 1%,4250K, 0603 (1608 Metric)	Murata	NCU18WF104F60RB
14	U7	1	IP2738	IC, TypeC/PX2.0/PD3.1,QC5/QC4+/QC3.0/QC2.0,FCP,SCP,AFC, SFCP,MTK PE+2.0/1.1, UFCS,APPLE,BC1.2, 32QFN	INJOINIC	IP2738

6.3 USB-C Daughter Board

No	Ref Des	Qty	Value	Description	Mfg	Mfg Part Number
1	C15 C28	2	2.2 uF	2.2 uF, ±10%, 25 V, Ceramic, X7R, 1206 (3216 Metric)	AVX Corporation Murata	12063C225K4Z2A
2	C30 C32	2	2.2 uF	2.2 µF, ±10%, 25V, Ceramic Capacitor, X5R, 0402 (1005 Metric)	TDK Corporation	C1005X5R1E225K050BC
3	J1 J2	2	USB_C	USB-C (USB TYPE-C), USB 3.1, Plug Connector, 18pin (12p + 6 Shield)	GCT	USB4110-GF-A
4	Q3 Q6	2	BSC005N03LS5ATMA1	MOSFET,N-Channel, 30 V, 42A (Ta), 433A (Tc), 3W (Ta), 188W (Tc),Surface Mount PG-TDSON-8 FL,8-PowerTDFN	Infineon Technologies	BSC005N03LS5ATMA1
5	R17 R34	2	0.0	RES, 0 R, 5%, 1/10 W, Thick Film, 0603	Panasonic	ERJ-3GEY0R00V
6	R37 R40 R51 R54	4	22	RES, 22, ±1%, 0.063W, 1/16W, Chip Resistor, 0402 (1005 Metric), Thick Film	Delta Electronics/ Cyntec	PFR05S-220-FNH
7	R38 R39 R52 R53	4	3.0	RES, 3 ohm, ±1%, 0.063W, 1/16W, Chip Resistor, 0402 (1005 Metric), Thick Film	Stackpole Electronics Inc	RMCF0402FT3R00
8	VR11-VR20	10	EDZVT2R24B	24 V, 2%, 150 mW, SSMINI-2, SC-79, SOD-523, EMD2	Rohm Semiconductor	EDZVT2R24B

7 Transformer Specification (T1)

7.1 Electrical Diagram

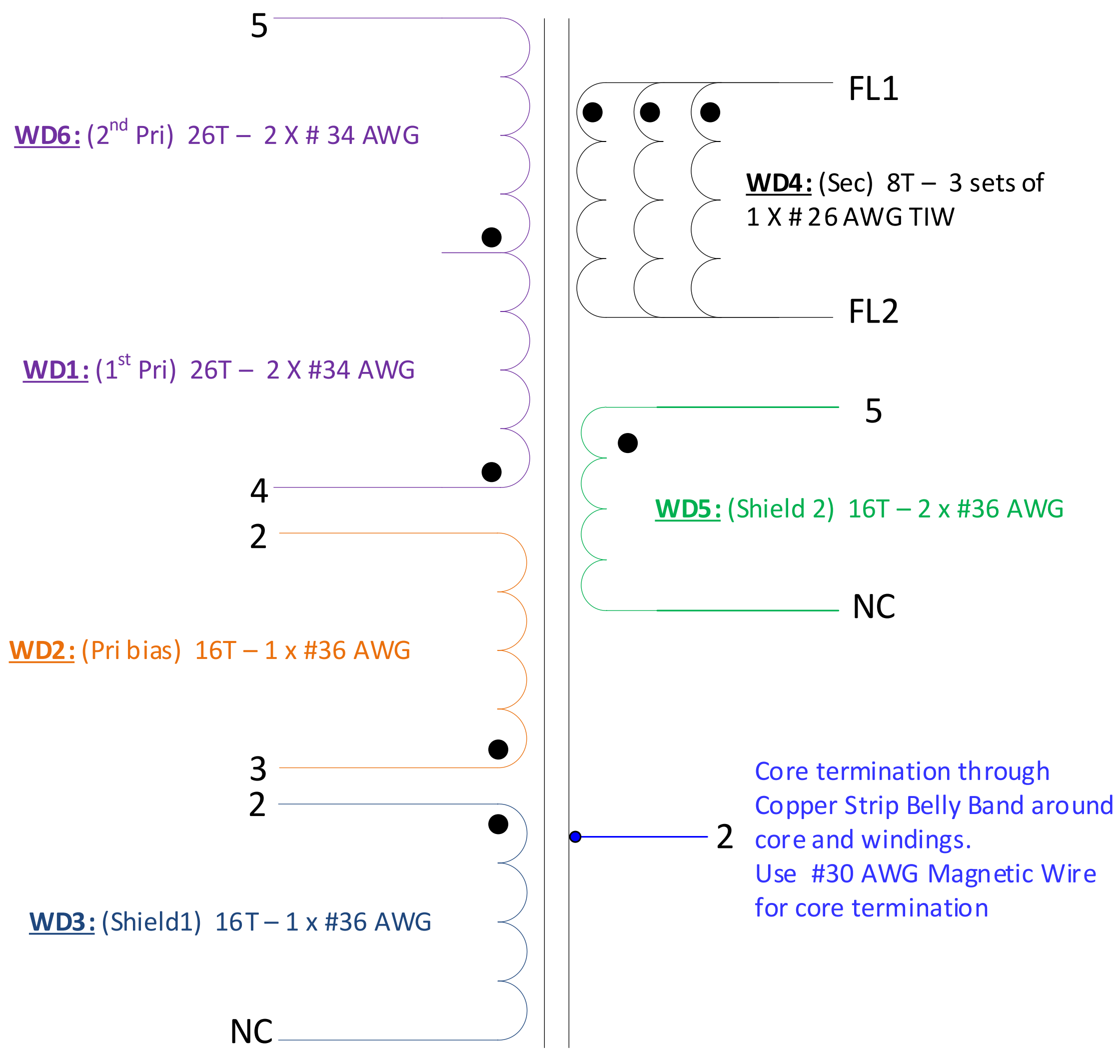


Figure 18 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V pk-pk, 100 kHz switching frequency, between pin 5 and 4, with all other windings open.	649.3 uH ± 5%
Primary Leakage Inductance	Between pin 5 and 4, other windings shorted.	10 μH (Max.)

7.3 Material List

Item	Description
[1]	Core: EQ20
[2]	Bobbin: Bobbin, EQ20/14, Vertical, 10 pins. P/N: 25-01121-00
[3]	Magnet wire: #34 AWG, double coated
[4]	Magnet wire: #36 AWG, double coated
[5]	TIW Magnet wire: #26 AWG, Triple Insulated Wire.
[6]	Bus wire: #30 AWG, Alpha wire, tinned copper.
[7]	3M Copper Foil (Width: 6 mm)
[8]	3M Copper Foil (Width: 10 mm)
[9]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 6.5 mm width.
[10]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 13.5 mm width
[11]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 18 mm width
[12]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 19.5 mm width
[13]	Tape: Kapton-Tape, 20 mm width
[14]	Varnish: Dolph BC-359.

7.4 Transformer Build Diagram

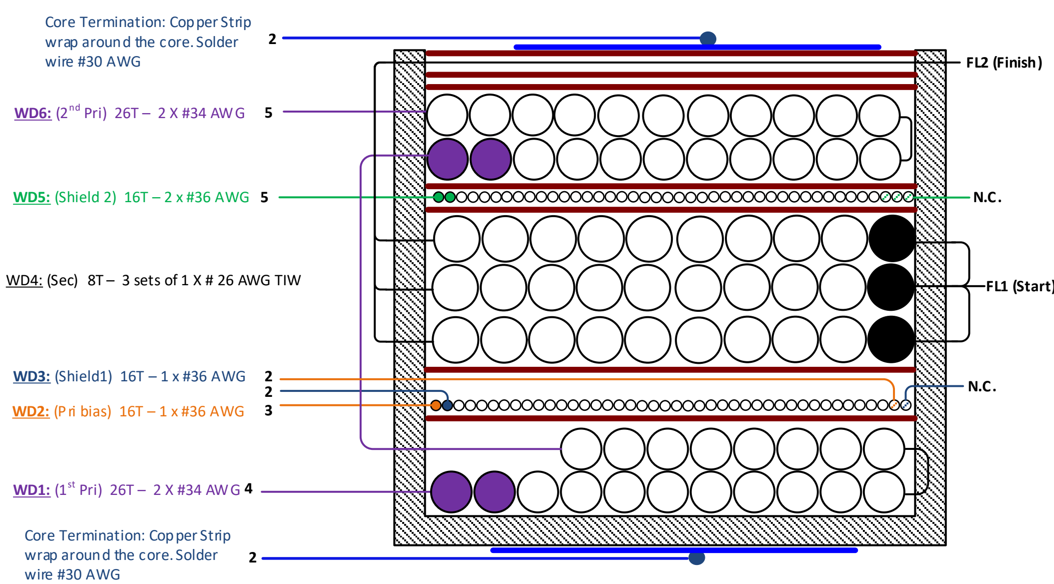
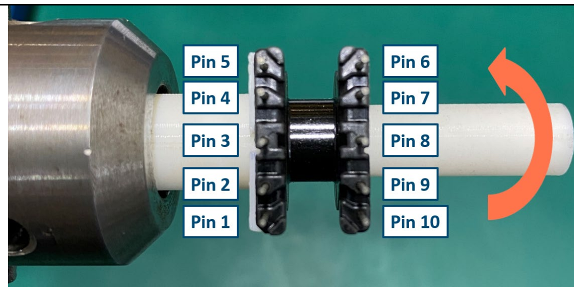
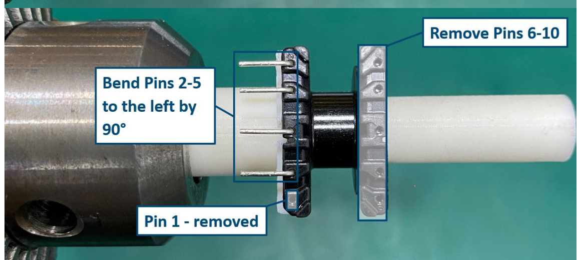


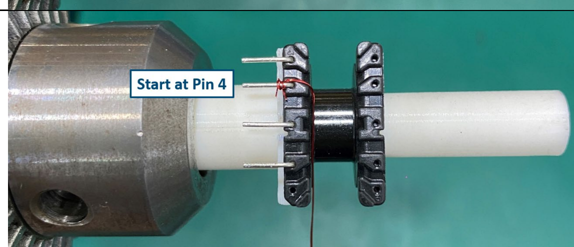
Figure 19 – Transformer Build Diagram.

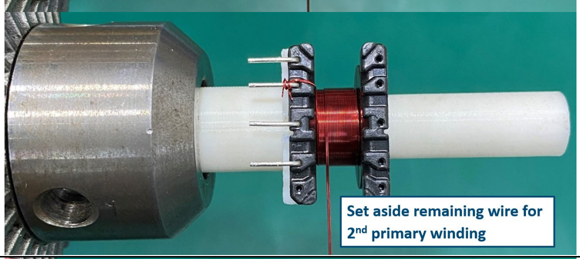
7.5 Transformer Winding Illustrations

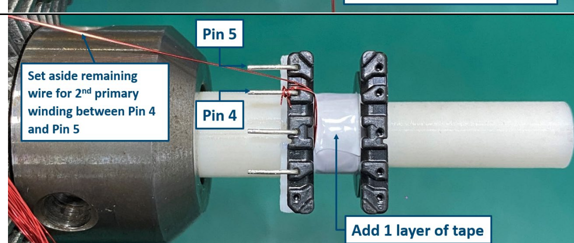
<table>
<tr>
<td>Bobbin Preparation</td>
<td>




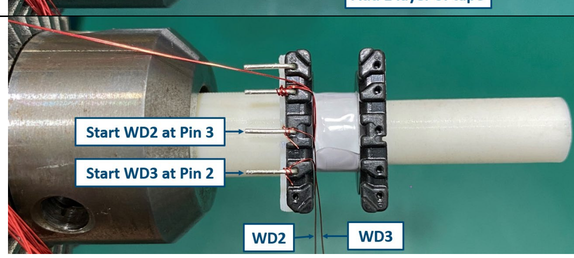
</td>
<td>Use EQ20/14 bobbin (Item 2). Position bobbin on the winding jig such that pins 1-5 is on the left side. Winding direction is clock-wise.

Bend pins 2-5 to the left at 90°. Then, remove pins 1, 6-10.</td>
</tr>
<tr>
<td>WD1
1st Primary</td>
<td>




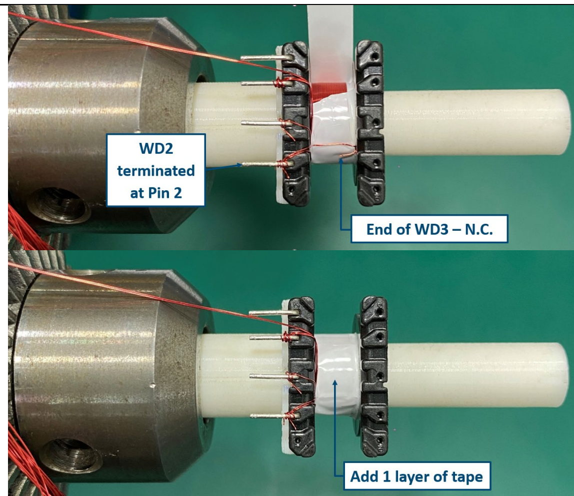
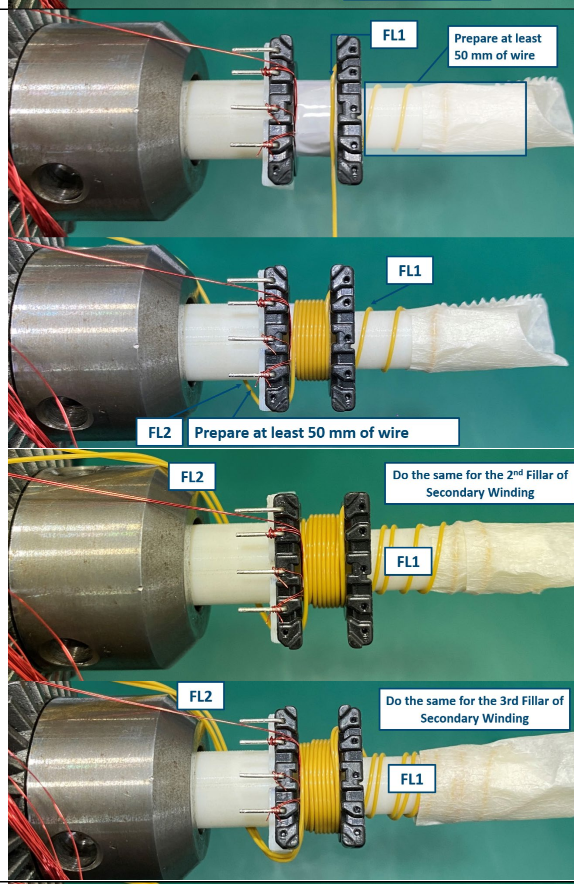
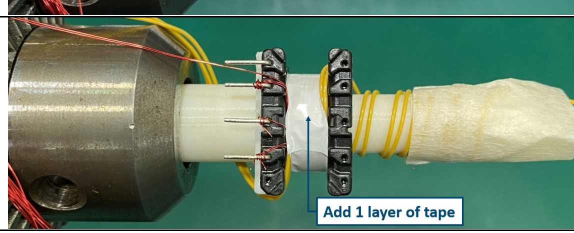
</td>
<td>Use AWG#34 magnet wire (Item 3) long enough for WD1 and WD6. Starting at Pin 4, wind 26 turns for 2 layers.</td>
</tr>
<tr>
<td>Insulation</td>
<td>


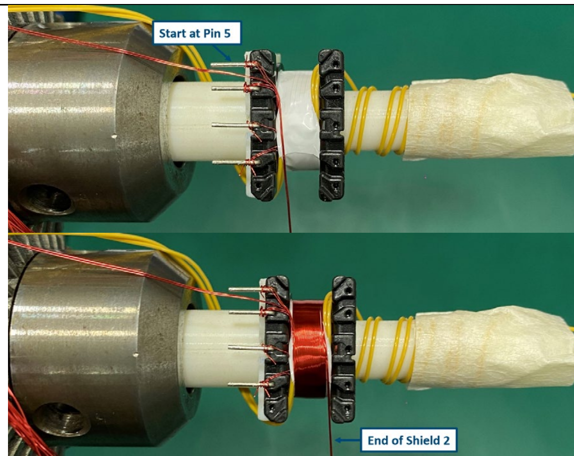
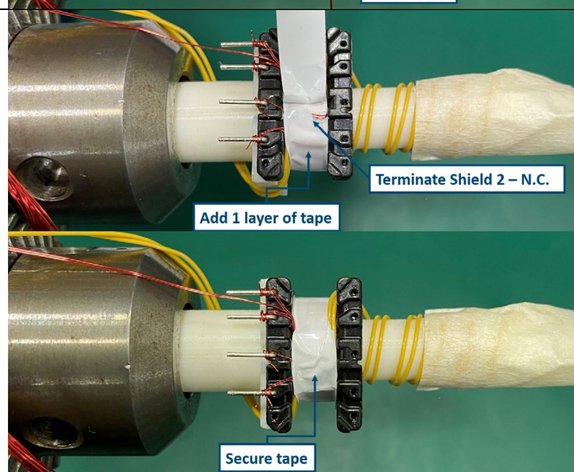
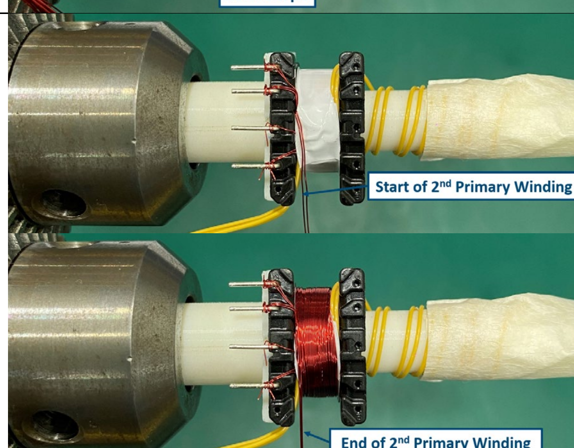
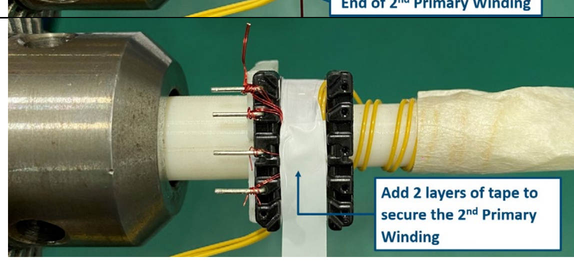
</td>
<td>Set aside the remaining wires on the left side and fix it with tape as shown in the figure.

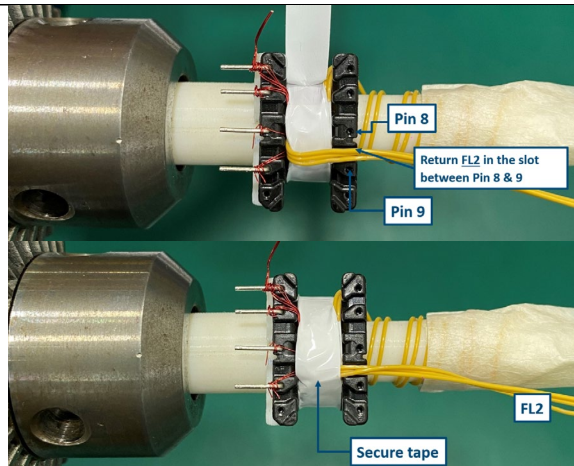
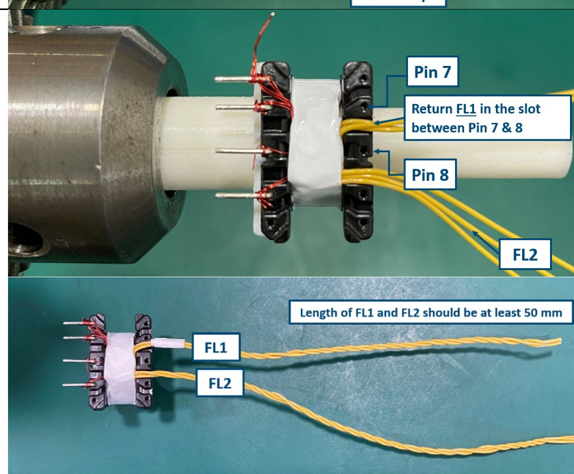
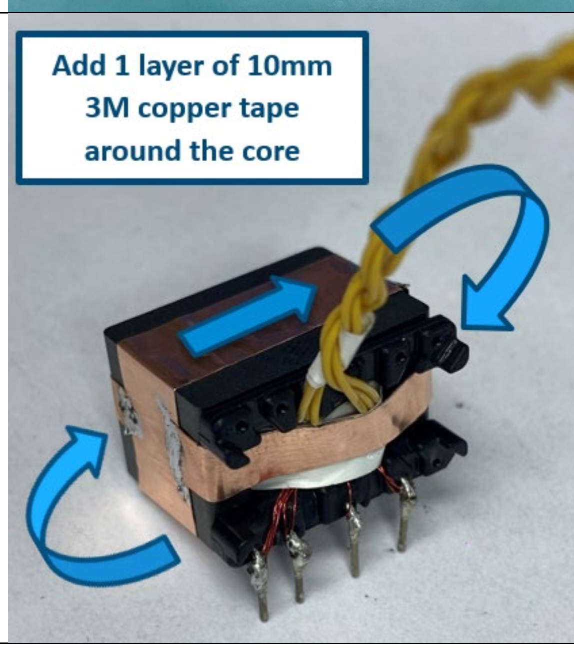
Apply 6.5 mm (Item 9) 1-layer polyester tape for insulation.</td>
</tr>
<tr>
<td>WD2: Primary Bias
&
WD3: Shield 1</td>
<td>


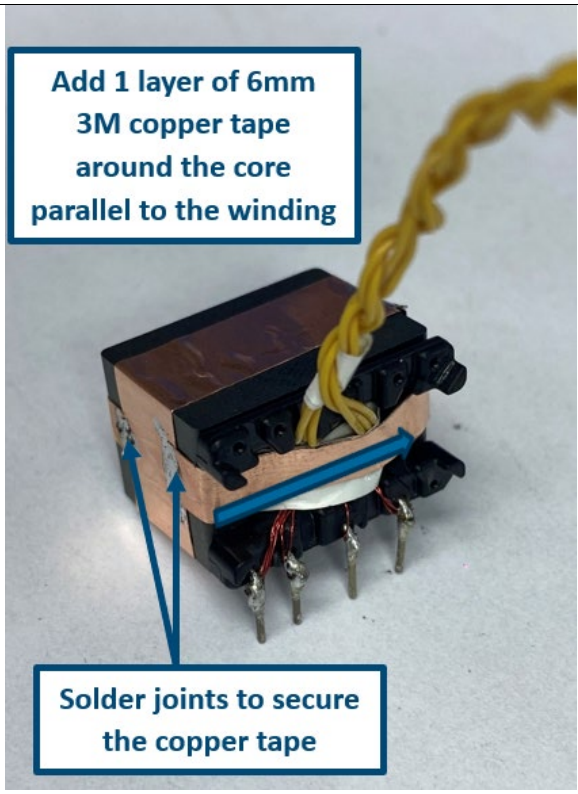
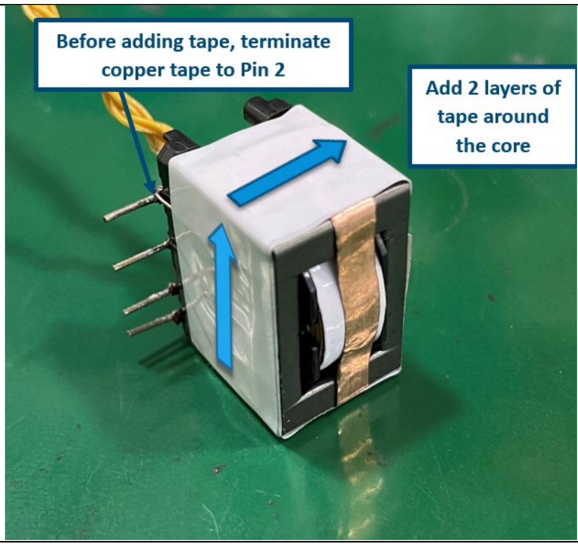
</td>
<td>Use AWG#36 magnet wire (Item 4). Prepare single filar wire for WD2 and WD3.

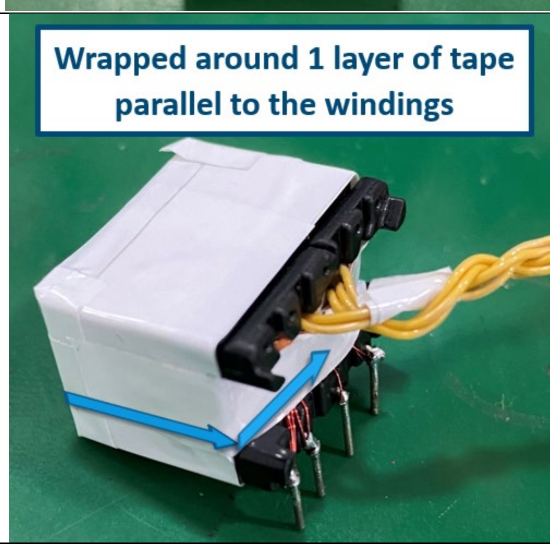
WD3 will start at Pin 2 and WD2 will start at Pin 3. Wind WD2 and WD3 together for 16 turns. Finish WD2 on Pin 2 while WD3 is not connected (N.C.).</td>
</tr>
</table>

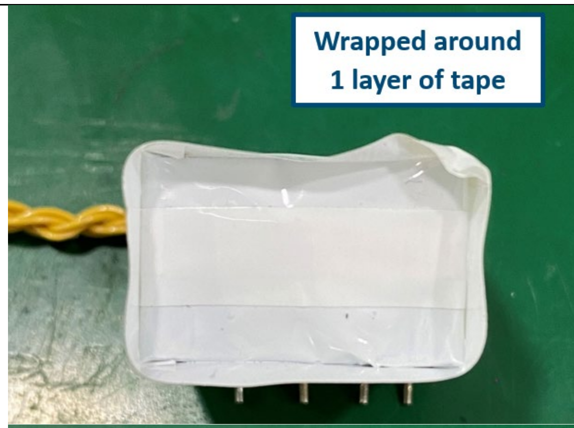
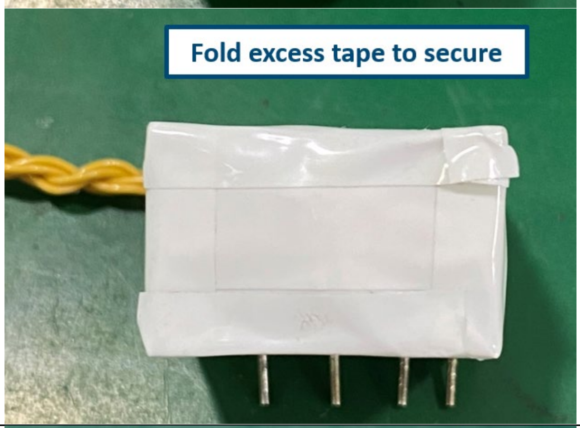
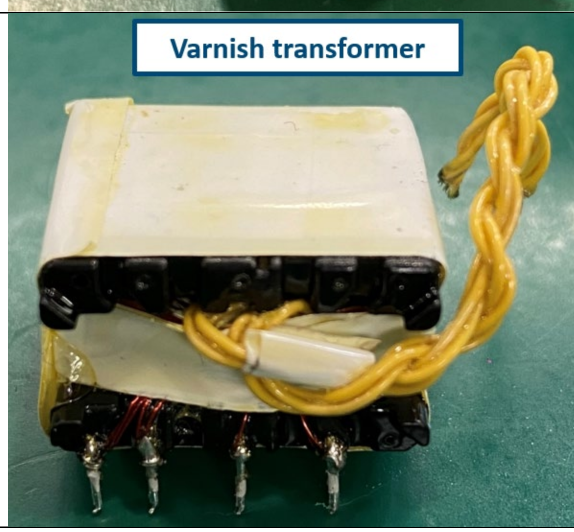
Insulation		Apply 6.5 mm (Item 9) 1-layer polyester tape for insulation.
WD4: Secondary		Use AWG#25 TIW (Item 5). Prepare at least 50 mm of single filar of AWG#25 TIW (Item 5) before starting to wind. Use tape to hold the wire to secure it in place before starting to wind. Start FL1 wind 8 turns from right to left clock-wise. Prepare at least 50 mm of AWG#25 TIW (Item 5) before securing it on the left side of the jig. Do the same for the second and third filar.
Insulation		Apply 6.5 mm (Item 9) 1-layer polyester tape for insulation.

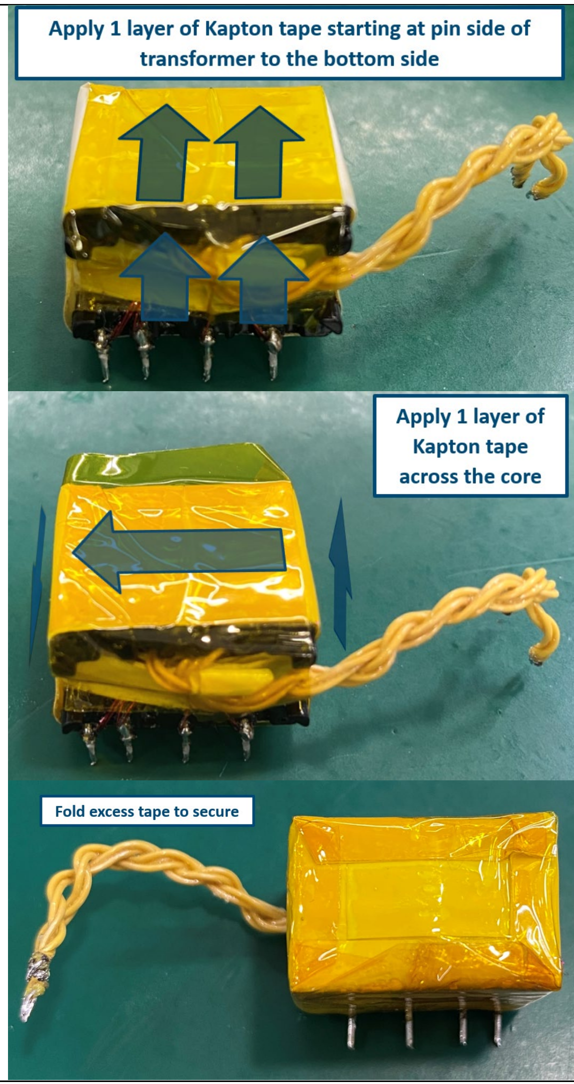
WD5 **Shield2**		Use AWG#36 magnet wire (Item 4). Prepare bifilar wire for WD5. Starting at Pin 5, wind 16 turns evenly from left to right in one layer. Terminate WD5 since this is a no connect (N.C.)
Insulation		Apply 6.5 mm (Item 9) 1-layer polyester tape for insulation.
WD6 **2nd Primary**		Use AWG#34 magnet wire (Item 3) that was set aside on the left from WD1. Start the winding on the left side of the bobbin and wind 26 turns for 2 layers. Finish the winding on Pin 5.
Insulation		Apply 6.5 mm (Item 9) 2-layer polyester tape for insulation. Before proceeding for the 3rd layer of tape, transfer FL2 termination from the left side of the bobbin to the right side of the bobbin. Make sure that FL2 wire is in between the slot of Pin 8 & Pin 9.

		
Insulation		Adjust FL1 winding termination to fit the slot between Pin 7 and Pin 8. Twist FL1 and FL2 with at least 50 mm in total length. Tape the start of FL1 to serve as a marker. Twist both FL1 and FL2 together to form a braided connection.
Gap core and install		Use EQ20 Core (Item 1). Grind the center leg of the ferrite core evenly to meet the required inductance. Wrap 10 mm of 3M Copper Foil (Item 8) around the perimeter of the core. Afterwards wrap 6 mm of 3M Copper Foil (Item 7) around the core parallel to the windings. Solder joins to secure copper tape. Ground the core to Pin 2 using AWG#30 bus wire (Item 6).

		
Insulation		Terminate copper tape to Pin 2. Apply 13.5 mm (Item 10) 2-layer polyester tape at the perimeter of the core.

		Apply 18 mm (Item 11) 1-layer polyester tape at the side of the transformer. Cut the corners of the excess tape to allow folding. Secure the tape afterwards just as shown in the figure.
		Apply 6.5 mm (Item 9) 1-layer polyester tape around the core parallel to the windings.

	 	Apply 19.5 mm (Item 12) 1-layer polyester tape at the perimeter of the core. Fold excess tape to secure.
Varnish		Dip the whole transformer in a pure varnish solution (Item 14) for 10 minutes. Cure the varnished transformer in hot (100˚C) oven for 30 minutes.

Finish Assembly		Apply 1 layer of 20 mm Kapton tape (Item 14) starting from the pins of the transformer up to the bottom side of the transformer. Then, apply 1 layer of 20 mm Kapton tape (Item 14) at the perimeter of the core. Fold excess tape to secure like as shown in the figure.

8 Transformer Specification (T2)

8.1 Electrical Diagram

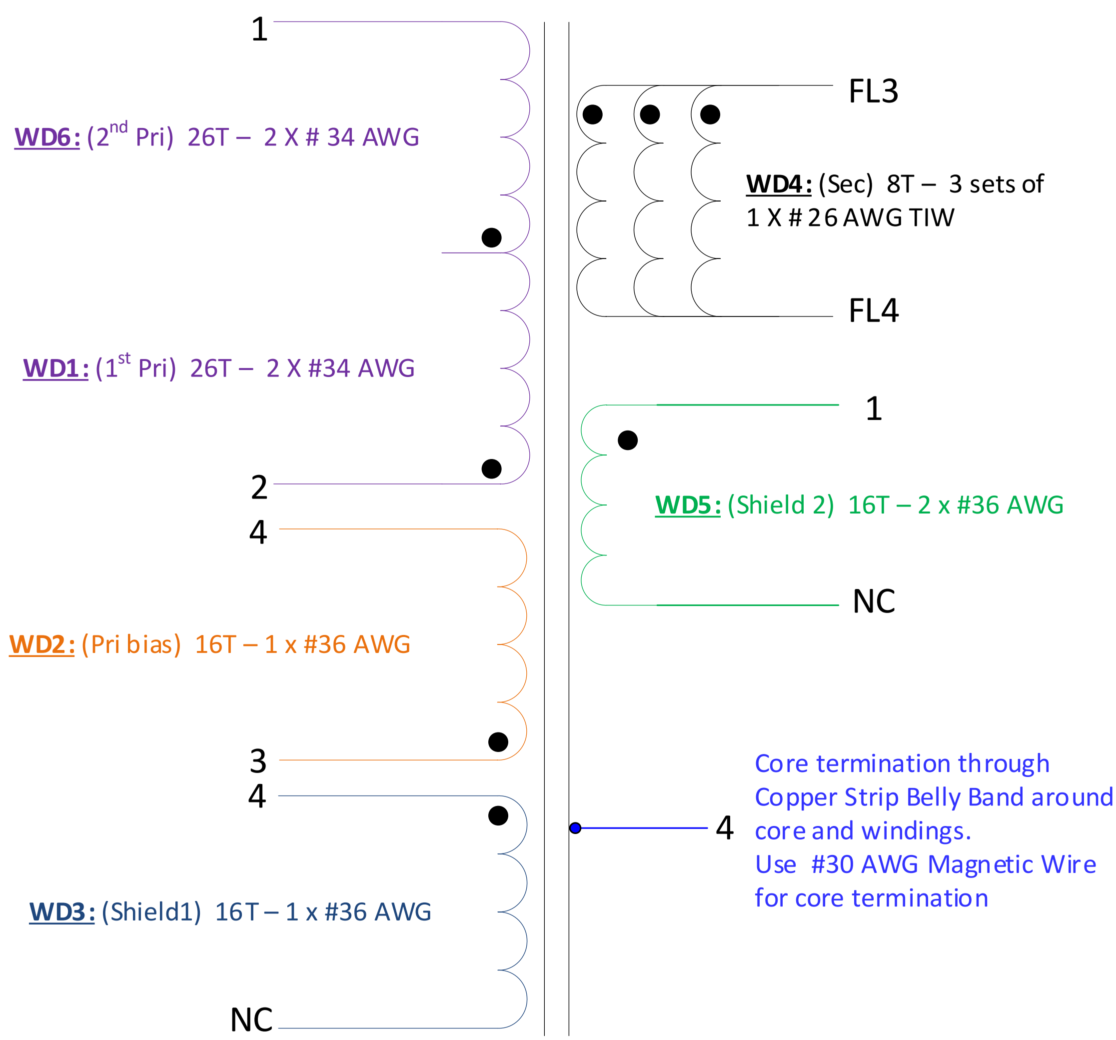


Figure 20 – Transformer Electrical Diagram.

8.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V pk-pk, 100 kHz switching frequency, between pin 1 and 2, with all other windings open.	649.3 uH ± 5%
Primary Leakage Inductance	Between pin 1 and 2, other windings shorted.	10 μH (Max.)

8.3 Material List

Item	Description

[1]	Core: EQ20
[2]	Bobbin: Bobbin, EQ20/14, Vertical, 10 pins. P/N: 25-01121-00
[3]	Magnet wire: #34 AWG, double coated
[4]	Magnet wire: #36 AWG, double coated
[5]	TIW Magnet wire: #26 AWG, Triple Insulated Wire.
[6]	Bus wire: #30 AWG, Alpha wire, tinned copper.
[7]	3M Copper Foil (Width: 6 mm)
[8]	3M Copper Foil (Width: 10 mm)
[9]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 6.5 mm width.
[10]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 13.5 mm width
[11]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 18 mm width
[12]	Tape: 3M 13450-F, Polyester Film, 1 mil thickness, 19.5 mm width
[13]	Tape: Kapton-Tape, 20 mm width
[14]	Varnish: Dolph BC-359.

8.4 Transformer Build Diagram

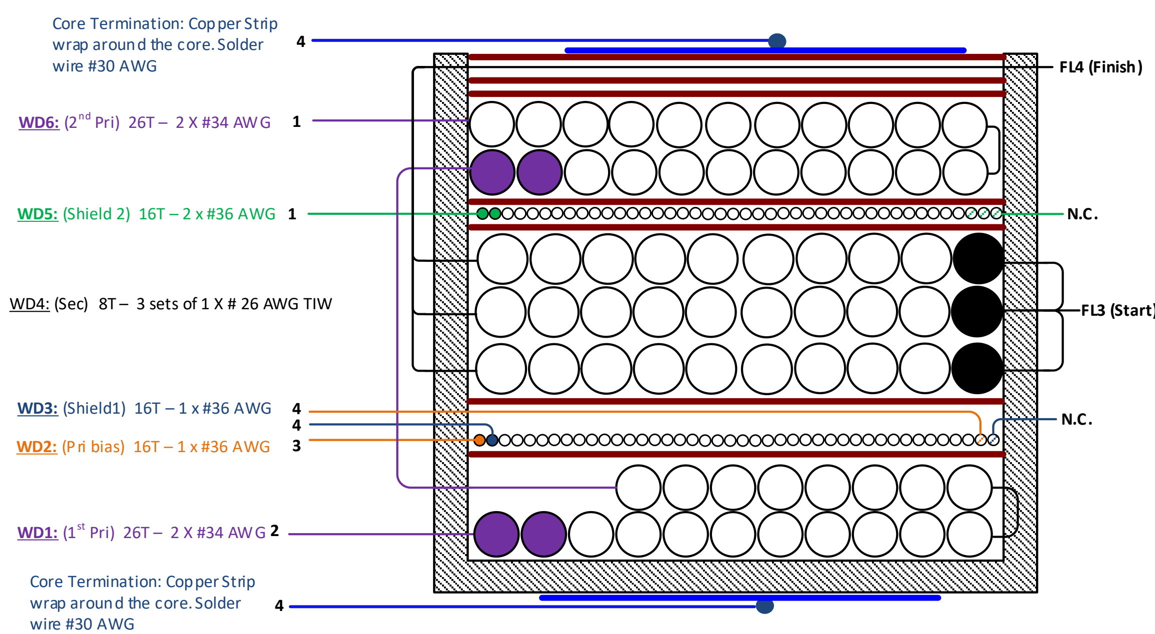
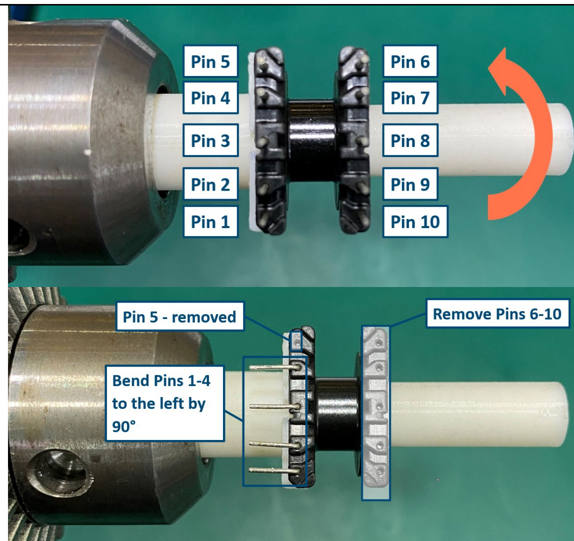
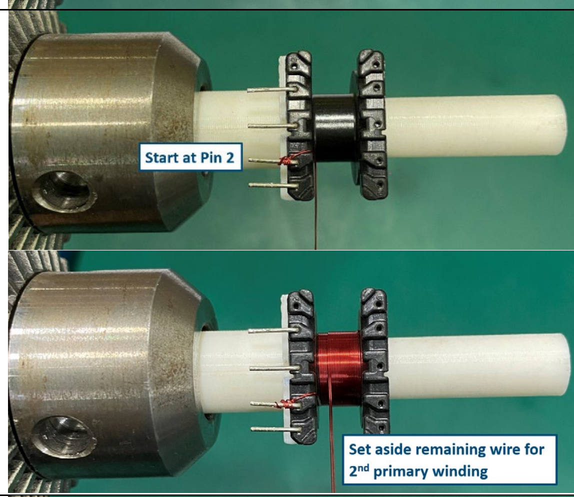
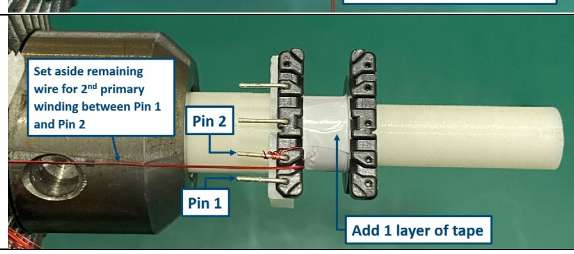
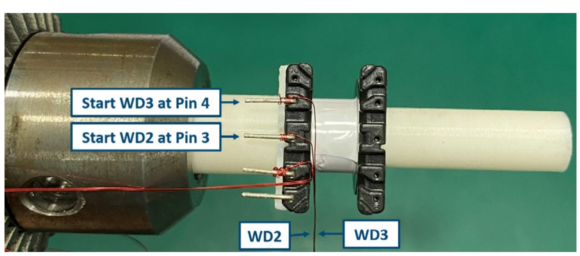
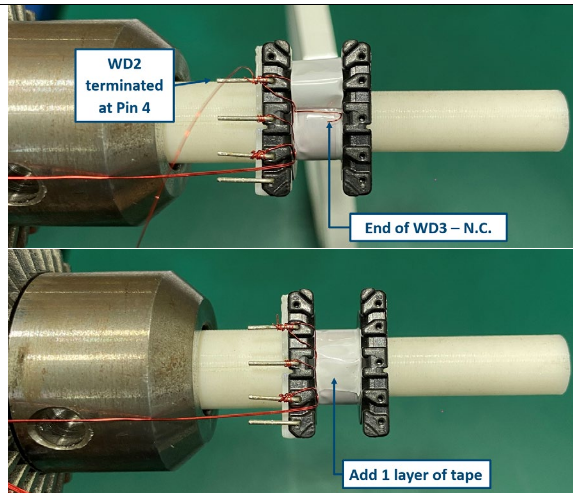
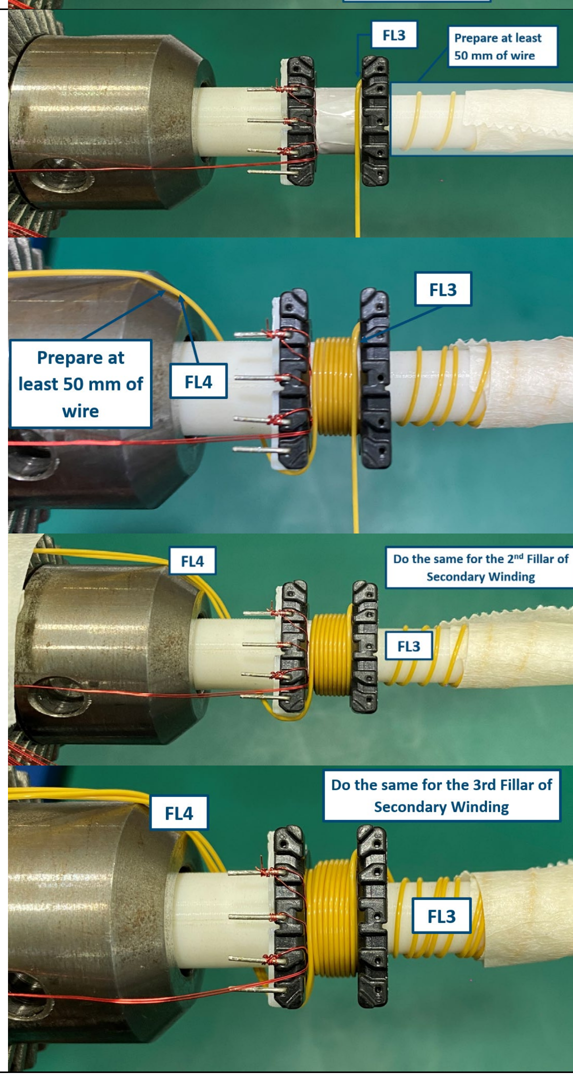
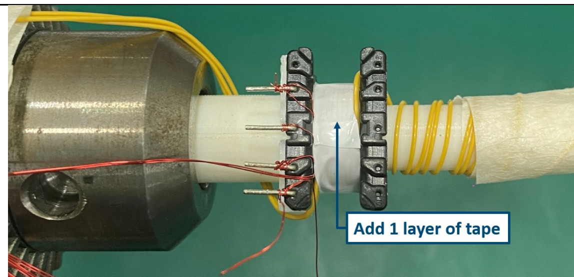
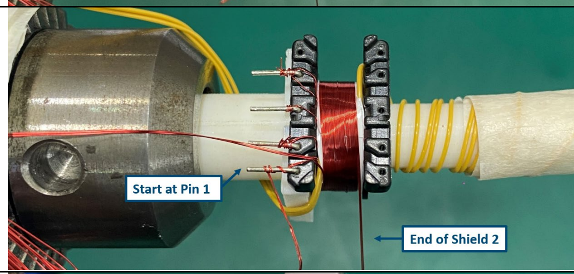
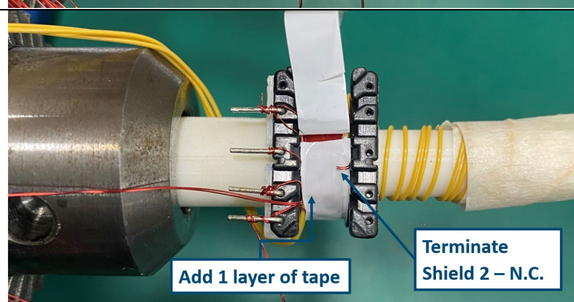
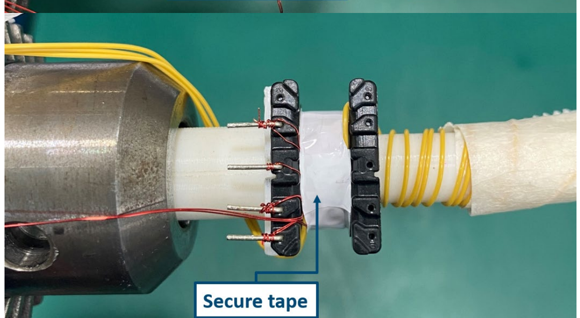
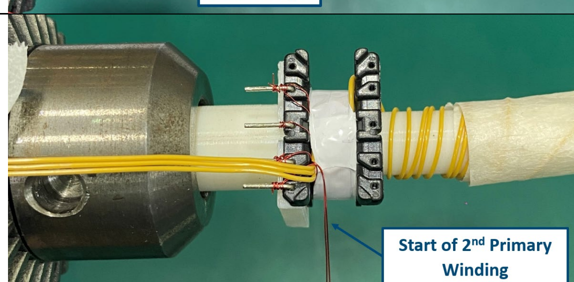
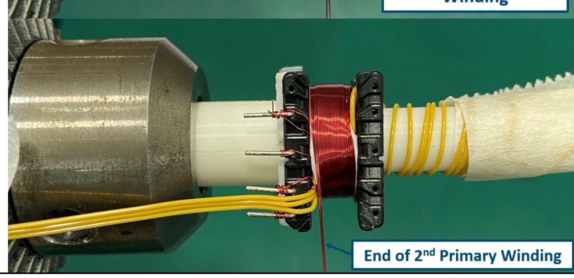


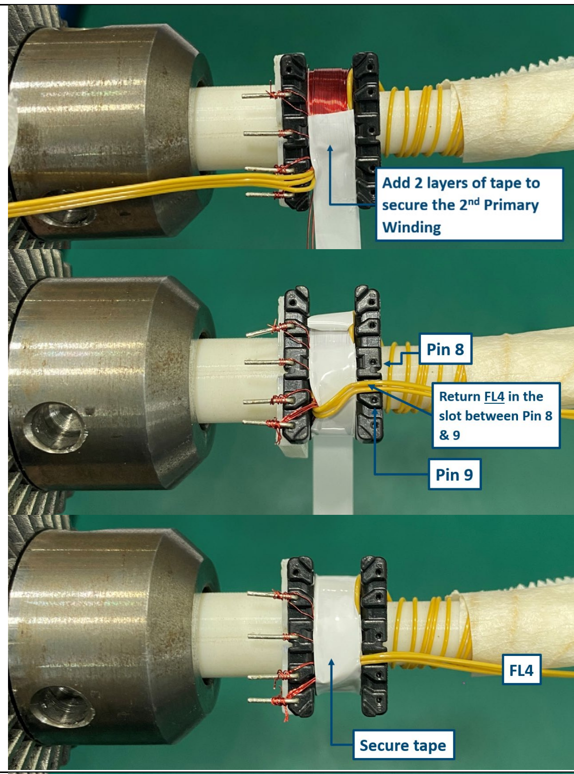
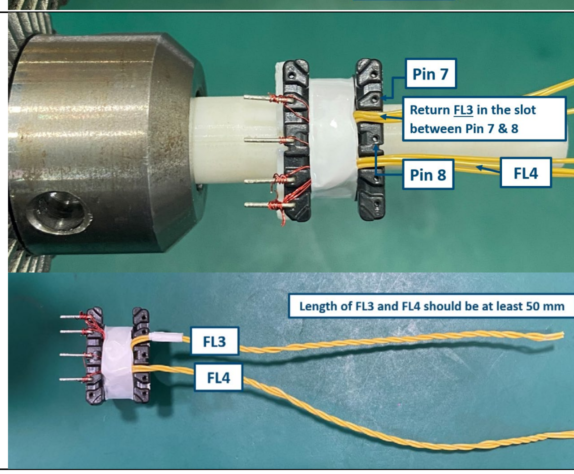
Figure 21 – Transformer Build Diagram.

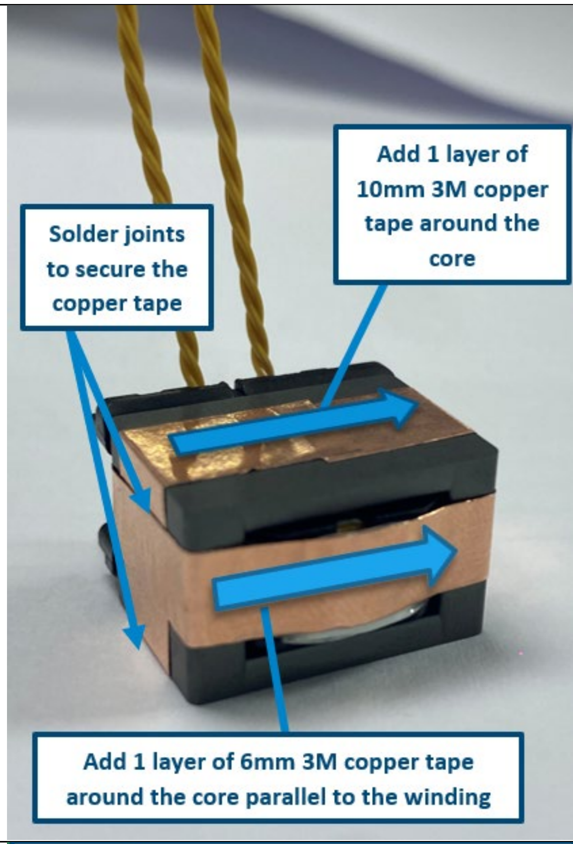
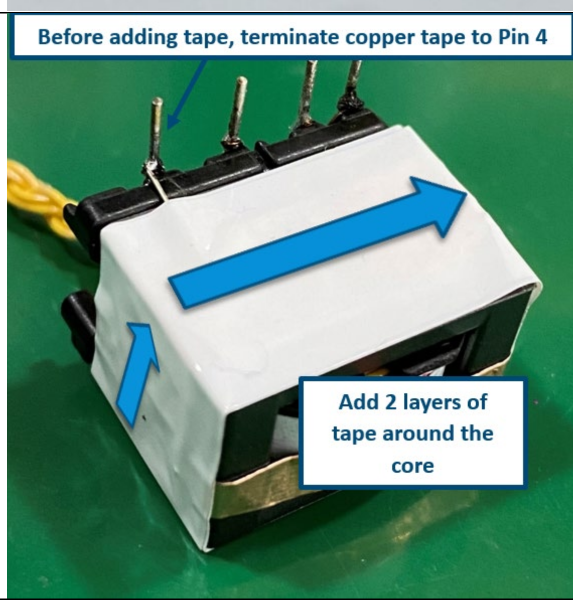
8.5 Transformer Winding Illustrations

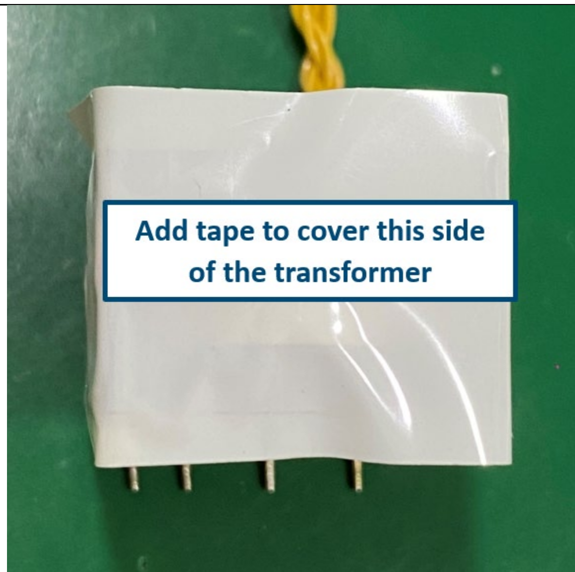
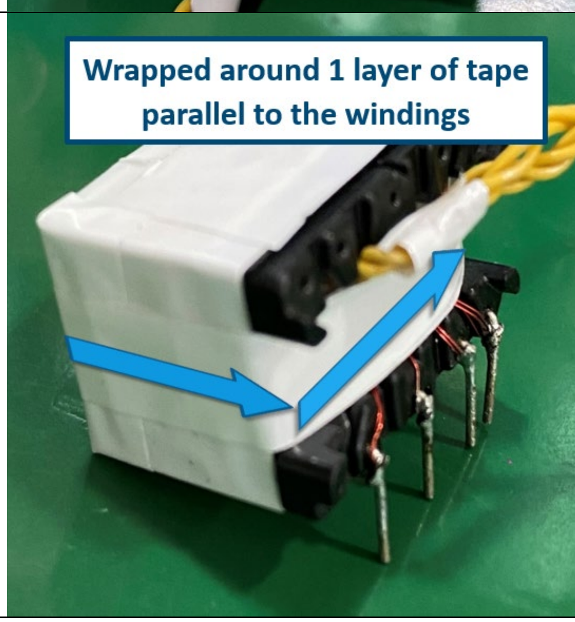
Bobbin Preparation		Use EQ20/14 bobbin (Item 2). Position bobbin on the winding jig such that pins 1-5 is on the left side. Winding direction is clock-wise. Bend pins 1-4 to the left by 90°. Then, remove pins 5, 6-10.
WD1 **1st Primary**		Use AWG#34 magnet wire (Item 3) long enough for WD1 and WD6. Starting at Pin 2, wind 26 turns for 2 layers.
Insulation		Set aside the remaining wires on the left side and fix it with tape as shown in the figure. Apply 6.5 mm (Item 9) 1-layer polyester tape for insulation.
WD2: Primary Bias **&** **WD3: Shield 1**		Use AWG#36 magnet wire (Item 4). Prepare single filar wire for WD2 and WD3. WD2 will start at Pin 3 and WD3 will start at Pin 4. Wind WD2 and WD3 together for 16 turns. Finish WD2 on Pin 4 while WD3 is not connected (N.C.).

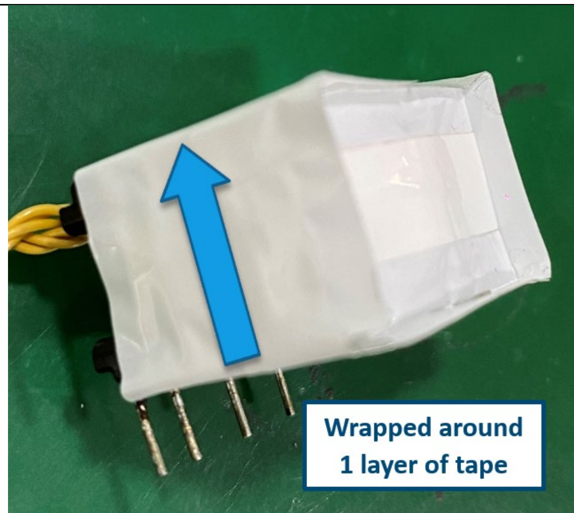
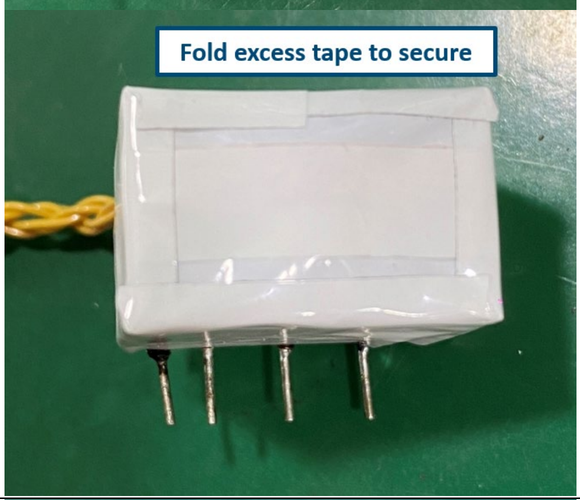
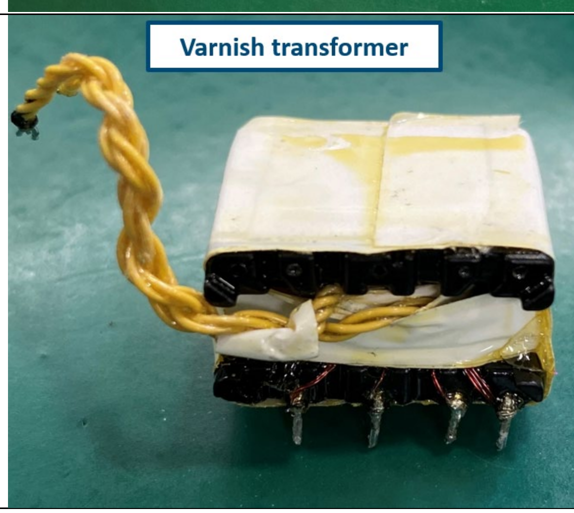
Insulation		Apply 6.5 mm (Item 9) 1-layer polyester tape for insulation.
WD4: Secondary		Use AWG#25 TIW (Item 5). Prepare at least 50 mm of single filar of AWG#25 TIW (Item 5) before starting to wind. Use tape to hold the wire to secure it in place before starting to wind. Start FL3 wind 8 turns from right to left clock-wise. Prepare at least 50 mm of AWG#25 TIW (Item 5) before securing it on the left side of the jig. Do the same for the second and third filar.

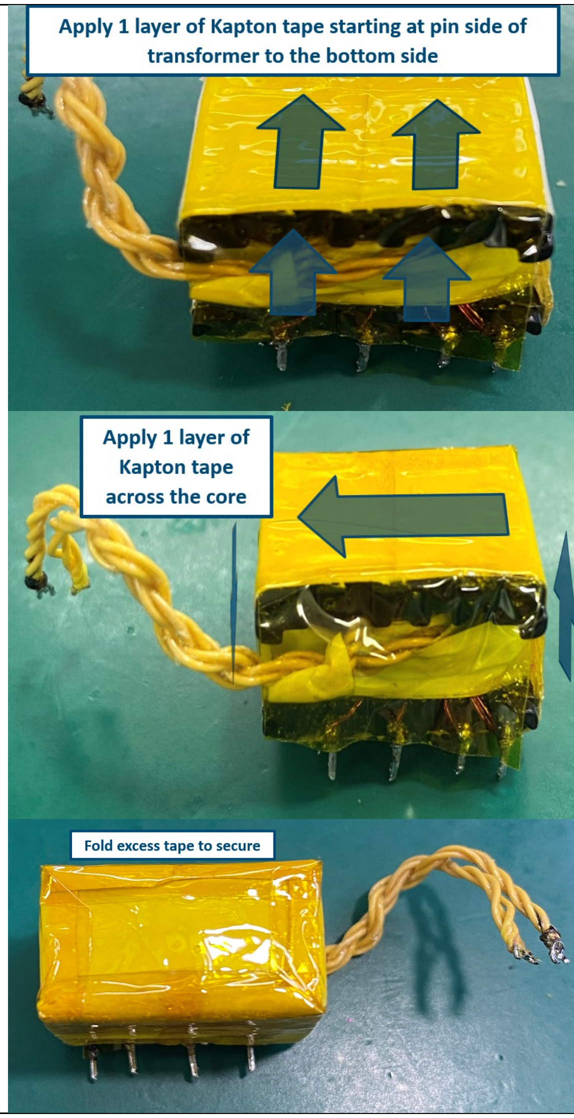
Insulation		Apply 6.5 mm (Item 9) 1-layer polyester tape for insulation.
WD5 **Shield2**		Use AWG#36 magnet wire (Item 4). Prepare bifilar wire for WD5. Starting at Pin 1, wind 16 turns evenly from left to right in one layer. Terminate WD5 since this is a no connect (N.C.)
Insulation	 	Apply 6.5 mm (Item 9) 1-layer polyester tape for insulation.
WD6 **2nd Primary**	 	Use AWG#34 magnet wire (Item 3) that was set aside on the left from WD1. Start the winding on the left side of the bobbin and wind 26 turns for 2 layers. Finish the winding on Pin 1.

Insulation		Apply 6.5 mm (Item 9) 2-layer polyester tape for insulation. Before proceeding for the 3rd layer of tape, transfer FL4 termination from the left side of the bobbin to the right side of the bobbin. Make sure that FL4 wire is in between the slot of Pin 8 & Pin 9.
Insulation		Adjust FL3 winding termination to fit the slot between Pin 7 and Pin 8. Twist FL3 and FL4 with at least 50 mm in total length. Tape the start of FL3 to serve as a marker. Twist both FL3 and FL4 together to form a braided connection.

Gap core and install		Use EQ20 Core (Item 1). Grind the center leg of the ferrite core evenly to meet the required inductance. Wrap 10 mm of 3M Copper Foil (Item 8) around the perimeter of the core. Afterwards wrap 6 mm of 3M Copper Foil (Item 7) around the core parallel to the windings. Solder joins to secure copper tape. Ground the core to Pin 4 using AWG#30 bus wire (Item 6).
Insulation		Terminate copper tape to Pin 4. Apply 13.5 mm (Item 10) 2-layer polyester tape at the perimeter of the core.

		Apply 18 mm (Item 11) 1-layer polyester tape at the side of the transformer. Cut the corners of the excess tape to allow folding. Secure the tape afterwards just as shown in the figure.
		Apply 6.5 mm (Item 9) 1-layer polyester tape around the core parallel to the windings.

	 	Apply 19.5 mm (Item 12) 1-layer polyester tape at the perimeter of the core. Fold excess tape to secure.
Varnish		Dip the whole transformer in a pure varnish solution (Item 14) for 10 minutes. Cure the varnished transformer in hot (100˚C) oven for 30 minutes.

Finish Assembly		Apply 1 layer of 20 mm Kapton tape (Item 13) starting from the pins of the transformer up to the bottom side of the transformer. Then, apply 1 layer of 20 mm Kapton tape (Item 13) at the perimeter of the core. Fold excess tape to secure like as shown in the figure.

9 Common Mode Choke Specifications

9.1 250 µH Common Mode Choke (L1)

9.1.1 Electrical Diagram

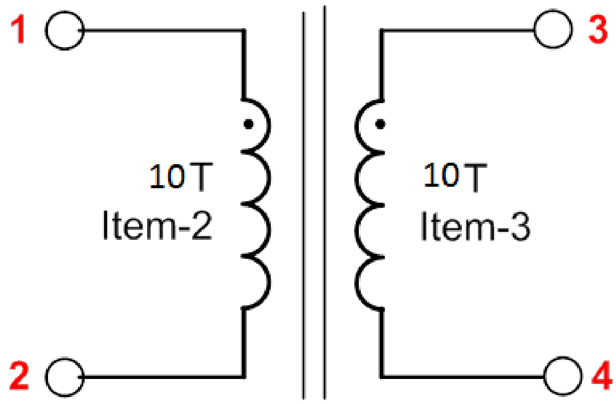


Figure 22 – Inductor Electrical Diagram.

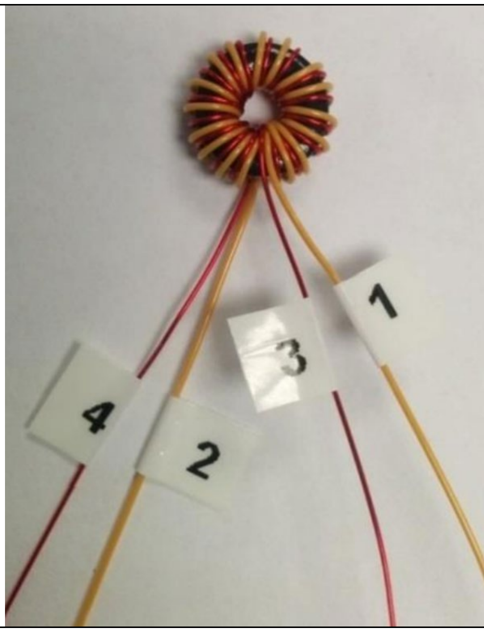
9.1.2 Electrical Specifications

Winding Inductance	Pin 1 – pin 2 (pin 3 – pin 4), all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	250 µH ± 20%

9.1.3 Material List

Item	Description
[1]	Toroidal Core: 35T0375-10H, PI#: 32-00275-00.
[2]	Triple Insulated Wire: #27 AWG, Triple Coated.
[3]	Magnet Wire: #27 AWG, Double Coated.

9.1.4 Winding Instructions

	Start as pin 1 for Item [2] and pin 4 for Item [3]. Wind together 10 turns on core Item [1]. Mark end of Item [2] as pin 2 and end of Item [3] as pin 3.

10 Transformer Design Spreadsheet (PIxls)

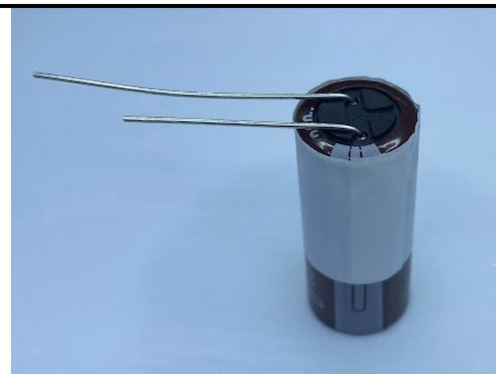
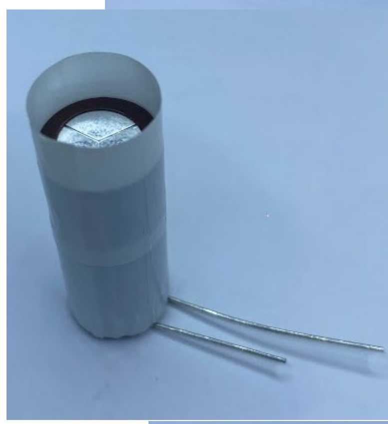
1	ACDC_InnoSwitch3-Pro_Flyback_011524; Rev.2.8; Copyright Power Integrations 2023	INPUT	INFO	OUTPUT	UNITS	InnoSwitch3-Pro Flyback Design Spreadsheet
2	**APPLICATION VARIABLES**					
3	VAC_MIN	90		90	V	Minimum AC line voltage
4	VAC_MAX	132		132	V	Maximum AC input voltage
5	VAC_RANGE			LOW LINE		AC line voltage range
6	FLINE			60	Hz	AC line voltage frequency
7	CAP_INPUT			90.0	uF	Input capacitance
8						
9	**SET-POINT 1**					
10	VOUT1	20.00		20.00	V	Output voltage 1, should be the highest output voltage required
11	IOUT1	2.250		2.250	A	Output current 1
12	POUT1			45.00	W	Output power 1
13	EFFICIENCY1	0.92		0.92		Converter efficiency for output 1
14	Z_FACTOR1	0.50		0.50		Z-factor for output 1
15	TYPE	PDO		PDO		Select whether this set-point is a PDO (Power Delivery Object) or APDO (Additional Power Delivery Object)
16						
17	**SET-POINT 2**					
18	VOUT2	15.00		15.00	V	Output voltage 2
19	IOUT2	3.000		3.000	A	Output current 2
20	POUT2			45.00	W	Output power 2
21	EFFICIENCY2	0.92		0.92		Converter efficiency for output 2
22	Z_FACTOR2	0.50		0.50		Z-factor for output 2
23	TYPE	PDO		PDO		Select whether this set-point is a PDO (Power Delivery Object) or APDO (Additional Power Delivery Object)
24						
25	**SET-POINT 3**					
26	VOUT3	9.00		9.00	V	Output voltage 3
27	IOUT3	3.000		3.000	A	Output current 3
28	POUT3			27.00	W	Output power 3
29	EFFICIENCY3	0.92		0.92		Converter efficiency for output 3
30	Z_FACTOR3	0.50		0.50		Z-factor for output 3
31	TYPE	PDO		PDO		Select whether this set-point is a PDO (Power Delivery Object) or APDO (Additional Power Delivery Object)
32						
33	**SET-POINT 4**					
34	VOUT4	5.00		5.00	V	Output voltage 4
35	IOUT4	3.000		3.000	A	Output current 4
36	POUT4			15.00	W	Output power 4
37	EFFICIENCY4	0.92		0.92		Converter efficiency for output 4
38	Z_FACTOR4	0.50		0.50		Z-factor for output 4

39	TYPE	PDO		PDO		Select whether this set-point is a PDO (Power Delivery Object) or APDO (Additional Power Delivery Object)
85	**PRIMARY CONTROLLER SELECTION**					
86	ENCLOSURE	ADAPTER		ADAPTER		Power supply enclosure
87	ILIMIT_MODE	INCREASED		INCREASED		Device current limit mode
88	VDRAIN_BREAKDOWN	750		750	V	Device breakdown voltage
89	DEVICE_GENERIC	INN33X9-H315		INN33X9-H315		Device selection
90	DEVICE_CODE			INN3379C-H315		Device code
91	PDEVICE_MAX			65	W	Device maximum power capability
92	RDSON_25DEG			0.44	Ω	Primary switch on-time resistance at 25°C
93	RDSON_100DEG			0.62	Ω	Primary switch on-time resistance at 100°C
94	ILIMIT_MIN			1.442	A	Primary switch minimum current limit
95	ILIMIT_TYP			1.550	A	Primary switch typical current limit
96	ILIMIT_MAX			1.659	A	Primary switch maximum current limit
97	VDRAIN_ON_PRSW			0.30	V	Primary switch on-time voltage drops
98	VDRAIN_OFF_PRSW			385.248	V	Peak drain voltage on the primary switch during turn-off
99						
100						
101						
102	**WORST CASE ELECTRICAL PARAMETERS**					
103	FSWITCHING_MAX	87000		87000	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
104	VOR	130.0		130.0	V	Voltage reflected to the primary winding (corresponding to set-point 1) when the primary switch turns off
105	VMIN			96.17	V	Valley of the rectified minimum input AC voltage at full load
106	KP			0.623		Measure of continuous/discontinuous mode of operation
107	MODE_OPERATION			CCM		Mode of operation
108	DUTYCYCLE			0.576		Primary switch duty cycle
109	TIME_ON			10.52	us	Primary switch on-time
110	TIME_OFF			5.29	us	Primary switch off-time
111	LPRIMARY_MIN			616.8	uH	Minimum primary magnetizing inductance
112	LPRIMARY_TYP			649.3	uH	Typical primary magnetizing inductance
113	LPRIMARY_TOL			5.0	%	Primary magnetizing inductance tolerance
114	LPRIMARY_MAX			681.8	uH	Maximum primary magnetizing inductance
115						
116	PRIMARY CURRENT					
117	IAVG_PRIMARY			0.490	A	Primary switch average current
118	IPEAK_PRIMARY			1.574	A	Primary switch peak current
119	IPEDESTAL_PRIMARY			0.532	A	Primary switch current pedestal
120	IRIPPLE_PRIMARY			1.427	A	Primary switch ripple current
121	IRMS_PRIMARY			0.733	A	Primary switch RMS current
122						
123	SECONDARY CURRENT					

124	IPEAK_SECONDARY			10.229	A	Secondary winding peak current
125	IPEDESTAL_SECONDARY			3.457	A	Secondary winding pedestal current
126	IRMS_SECONDARY			4.717	A	Secondary winding RMS current
127	IRIPPLE_CAP_OUT			3.641	A	Output capacitor ripple current
128						
129						
130						
131	**TRANSFORMER CONSTRUCTION PARAMETERS**					
132	CORE SELECTION					
133	CORE	Custom		Custom		Core selection
134	CORE NAME	EQ20		EQ20		Core code
135	AE	59.0		59.0	mm^2	Core cross sectional area
136	LE	33.2		33.2	mm	Core magnetic path length
137	AL	5660		5660	nH	Ungapped core effective inductance per turns squared
138	VE	1960		1960	mm^3	Core volume
139	BOBBIN NAME	EQ20		EQ20		Bobbin name
140	AW	19.4		19.4	mm^2	Bobbin window area - only the bobbin width and height are used to assess fit by the magnetics builder
141	BW	5.90		5.90	mm	Bobbin width
142	BH	3.30		3.30	mm	Bobbin height
143	MARGIN			0.0	mm	Bobbin safety margin
144						
145	PRIMARY WINDING					
146	NPRIMARY			52		Primary winding number of turns
147	BPEAK			3772	Gauss	Peak flux density
148	BMAX			3458	Gauss	Maximum flux density
149	BAC			1543	Gauss	AC flux density (0.5 x Peak to Peak)
150	ALG			240	nH	Typical gapped core effective inductance per turns squared
151	LG			0.296	mm	Core gap length
152	LAYERS_PRIMARY			4		Primary winding number of layers
153	AWG_PRIMARY			27		Primary wire gauge
154	OD_PRIMARY_INSULATED			0.418	mm	Primary wire insulated outer diameter
155	OD_PRIMARY_BARE			0.361	mm	Primary wire bare outer diameter
156	CMA_PRIMARY			275.1	Cmils/A	Primary winding wire CMA
157						
158	SECONDARY WINDING					
159	NSECONDARY	8		8		Secondary winding number of turns
164						
165	BIAS WINDING					
166	NBIAS			16		Bias winding number of turns
167						
168						
169						
170	**PRIMARY COMPONENTS SELECTION**					
171	LINE UNDERVOLTAGE					
172	BROWN-IN REQURED			72.00	V	Required line brown-in threshold

173	RLS			3.74	MΩ	Connect two 1.87 MOhm resistors to the V-pin for the required UV/OV threshold
174	BROWN-IN ACTUAL			60.1 - 72.8	V	Actual brown-in range
175	BROWN-OUT ACTUAL			51.2 - 64.2	V	Actual brown-out range
176						
177	LINE OVERVOLTAGE					
178	OVERVOLTAGE_LINE			279.0 - 316.6	V	Actual over-voltage range
179						
180	BIAS WINDING					
181	VBIAS			9.00	V	Rectified bias voltage at the lowest output set-point
182	VF_BIAS			0.70	V	Bias winding diode forward drop
183	VREVERSE_BIASDIODE			66.00	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
184	CBIAS			22	uF	Bias winding rectification capacitor
185	CBPP			4.70	uF	BPP pin capacitor
186						
187						
188						
189	**SECONDARY COMPONENTS SELECTION**					
190	RECTIFIER					
191	VDRAIN_OFF_SRFET			48.50	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
192	SRFET	AONS62922		AONS62922		Secondary rectifier (Logic MOSFET)
193	VBREAKDOWN_SRFET			120	V	Secondary rectifier breakdown voltage
194	RDSON_SRFET			7.0	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
195						
196						

11 Special Assembly Instructions

C2 – Input Capacitor Wrap the capacitors with tape to increase the creepage distance between the core and secondary side. Wrap the side and top of the capacitor.	   

12 Performance Data

Note: 1. Tests performed using a 3D-printed case with potting.
2. Output voltage measured on the PCB.
3. Measurements taken at room temperature ambient (approximately 25 °C).

12.1 No-Load Input Power

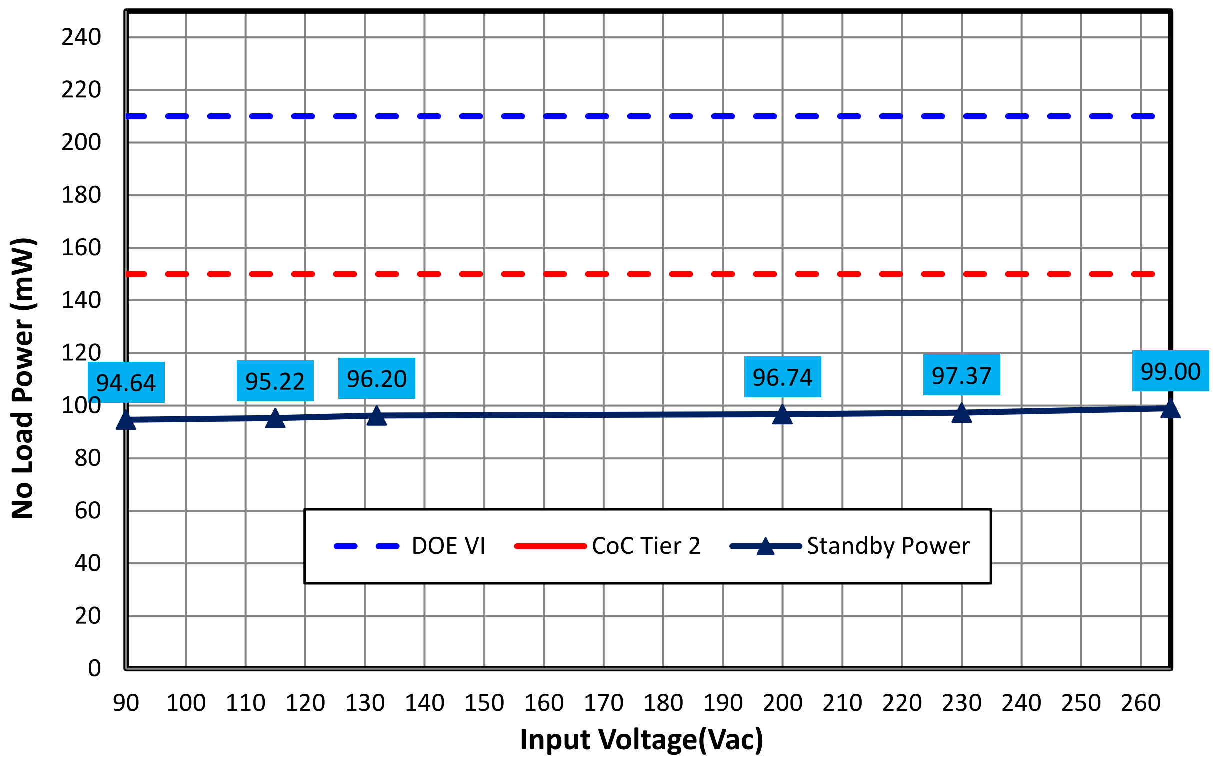


Figure 23 – No-Load Input Power vs. Input Line Voltage.

12.2 Average and 10% Load Efficiency

12.2.1 Efficiency Requirements

		Test	Average	Average	10% Load
		Effective	2016	Jan-16	Jan-16
V_{OUT} (V)	**Model (V)**	**Power (W)**	**New EISA2007**	**CoC v5 Tier 2**	**CoC v5 Tier 2**
5	<6	15	84.25%	85.00%	75.47%
9	>6	27	87.73%	88.85%	78.85%
12	>6	36	87.73%	88.85%	78.85%
15	>6	45	87.73%	88.85%	78.85%
20	>6	60	87.73%	88.85%	78.85%

12.2.2 Efficiency Performance Summary (On Board)

V_{OUT}	Power	Average Efficiency (%)	10% Load Efficiency (%)
(V)	**(W)**	**115 VAC**	
5	15	88.77%	85.63%
9	27	90.41%	86.75%
12	36	90.72%	86.76%
15	45	90.86%	86.53%
20	65	90.79%	86.46%

12.2.3 Average and 10% Load Efficiency Measurements

12.2.3.1 Output: 20 V / 3.25 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	DOE6 Requirement (%)	CoC v5 Tier 2 Requirement (%)	Remarks
115	100	64.69	91.13	**90.79**	**87.73**	**88.85**	**PASS**
	75	48.64	91.36				
	50	32.43	90.49				
	25	16.24	90.18				
	10	6.50	86.46			**78.85**	**PASS**

12.2.3.2 Output: 15 V / 3 A

Input (VAC)	Load (%)	P_{OUT} (W)	Efficiency (%)	Average Efficiency (%)	DOE6 Requirement (%)	CoC v5 Tier 2 Requirement (%)	Remarks
115	100	44.88	91.16	**90.86**	**87.73**	**88.85**	**PASS**
	75	33.70	91.37				
	50	22.48	90.62				

	25	11.26	90.28				
	10	4.51	86.53			**78.85**	**PASS**

12.2.3.3 Output: 12 V / 3 A

Input (VAC)	**Load (%)**	**P_{OUT} (W)**	**Efficiency (%)**	**Average Efficiency (%)**	**DOE6 Requirement (%)**	**CoC v5 Tier 2 Requirement (%)**	**Remarks**
115	100	35.85	91.04	**90.72**	**87.73**	**88.85**	**PASS**
	75	26.93	91.18				
	50	17.98	90.47				
	25	9.00	90.20				
	10	3.60	86.76			**78.85**	**PASS**

12.2.3.4 Output: 9 V / 3 A

Input (VAC)	**Load (%)**	**P_{OUT} (W)**	**Efficiency (%)**	**Average Efficiency (%)**	**DOE6 Requirement (%)**	**CoC v5 Tier 2 Requirement (%)**	**Remarks**
115	100	26.85	90.75	**90.41**	**87.73**	**88.85**	**PASS**
	75	20.17	91.02				
	50	13.47	90.03				
	25	6.75	89.82				
	10	2.71	86.75			**78.85**	**PASS**

12.2.3.5 Output: 5 V / 3 A

Input (VAC)	**Load (%)**	**P_{OUT} (W)**	**Efficiency (%)**	**Average Efficiency (%)**	**DOE6 Requirement (%)**	**CoC v5 Tier 2 Requirement (%)**	**Remarks**
115	100	15.14	88.99	**88.7**	**84.25**	**85.00**	**PASS**
	75	11.39	89.48				
	50	7.61	88.18				
	25	3.82	88.42				
	10	1.53	85.63			**75.47**	**PASS**

12.3 Electrical Test Data (On Board)

	Input		Input Measurement					Output 1 Measurement				
	VAC (RMS)	Freq (Hz)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	PF	% THD	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	%V Reg	Efficiency (%)
20 V / 3.25 A	90	60	89.85	1401.90	71.25	0.57	123.96	19.84	3249.10	64.46	-0.81	90.47
	100	60	99.89	1305.10	71.05	0.55	136.26	19.87	3249.00	64.56	-0.65	90.87
	110	60	109.84	1229.50	70.92	0.53	147.22	19.89	3249.10	64.63	-0.55	91.13
	115	60	114.90	1196.70	70.88	0.52	152.63	19.90	3249.10	64.67	-0.48	91.24
	120	60	119.88	1167.00	70.82	0.51	156.70	19.91	3249.00	64.70	-0.43	91.36
	132	60	131.88	1104.50	70.76	0.49	167.91	19.95	3249.00	64.81	-0.26	91.59
	Input		Input Measurement					Output 1 Measurement				
	VAC (RMS)	Freq (Hz)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	PF	% THD	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	%V Reg	Efficiency (%)
15 V / 3 A	90	60	89.88	1040.70	49.57	0.53	144.06	14.95	2999.00	44.83	-0.35	90.44
	100	60	99.92	974.30	49.40	0.51	156.51	14.96	2999.00	44.86	-0.27	90.81
	110	60	109.86	921.30	49.29	0.49	167.38	14.98	2999.00	44.93	-0.13	91.14
	115	60	114.93	897.60	49.23	0.48	172.09	14.98	2999.10	44.93	-0.13	91.26
	120	60	119.90	875.90	49.19	0.47	178.12	14.98	2999.10	44.93	-0.13	91.33
	132	60	131.90	831.60	49.09	0.45	189.46	14.98	2999.00	44.92	-0.14	91.51
	Input		Input Measurement					Output 1 Measurement				
	VAC (RMS)	Freq (Hz)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	PF	% THD	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	%V Reg	Efficiency (%)
12 V / 3 A	90	60	89.89	870.30	39.66	0.51	156.75	11.96	2999.10	35.88	-0.32	90.46
	100	60	99.93	816.80	39.53	0.48	168.08	11.97	2999.10	35.89	-0.28	90.78
	110	60	109.88	773.20	39.43	0.46	179.80	11.97	2999.10	35.89	-0.28	91.02
	115	60	114.94	754.40	39.38	0.45	185.93	11.97	2999.10	35.89	-0.29	91.12
	120	60	119.91	737.40	39.35	0.44	190.41	11.97	2999.10	35.88	-0.29	91.19
	132	60	131.91	701.50	39.29	0.42	202.46	11.97	2999.10	35.89	-0.28	91.34
	Input		Input Measurement					Output 1 Measurement				
	VAC (RMS)	Freq (Hz)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	PF	% THD	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	%V Reg	Efficiency (%)
9 V / 3 A	90	60	89.89	690.60	29.72	0.48	171.42	8.95	2998.60	26.83	-0.60	90.26
	100	60	99.93	651.30	29.65	0.46	185.46	8.95	2998.40	26.84	-0.56	90.51
	110	60	109.88	620.20	29.61	0.43	198.34	8.96	2998.30	26.85	-0.50	90.68
	115	60	114.94	606.00	29.58	0.42	202.94	8.95	2998.20	26.85	-0.51	90.76
	120	60	119.91	593.50	29.57	0.42	208.96	8.96	2998.20	26.85	-0.49	90.81
	132	60	131.91	565.60	29.54	0.40	222.91	8.96	2998.20	26.85	-0.49	90.90
	Input		Input Measurement					Output 1 Measurement				
	VAC (RMS)	Freq (Hz)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	PF	% THD	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	%V Reg	Efficiency (%)
5 V / 3 A	90	60	89.92	451.30	16.99	0.42	207.51	5.04	2998.80	15.11	0.73	88.91
	100	60	99.95	428.20	16.98	0.40	221.12	5.04	2998.80	15.12	0.81	89.02
	110	60	109.90	407.90	16.97	0.38	234.04	5.04	2998.80	15.12	0.85	89.12
	115	60	114.96	398.00	16.96	0.37	237.99	5.04	2998.70	15.12	0.83	89.15
	120	60	119.93	388.30	16.96	0.36	241.60	5.04	2998.80	15.12	0.83	89.15
	132	60	131.93	365.50	16.94	0.35	248.00	5.04	2998.70	15.11	0.77	89.21

12.4 Efficiency Across Line at 100% Load (On Board)

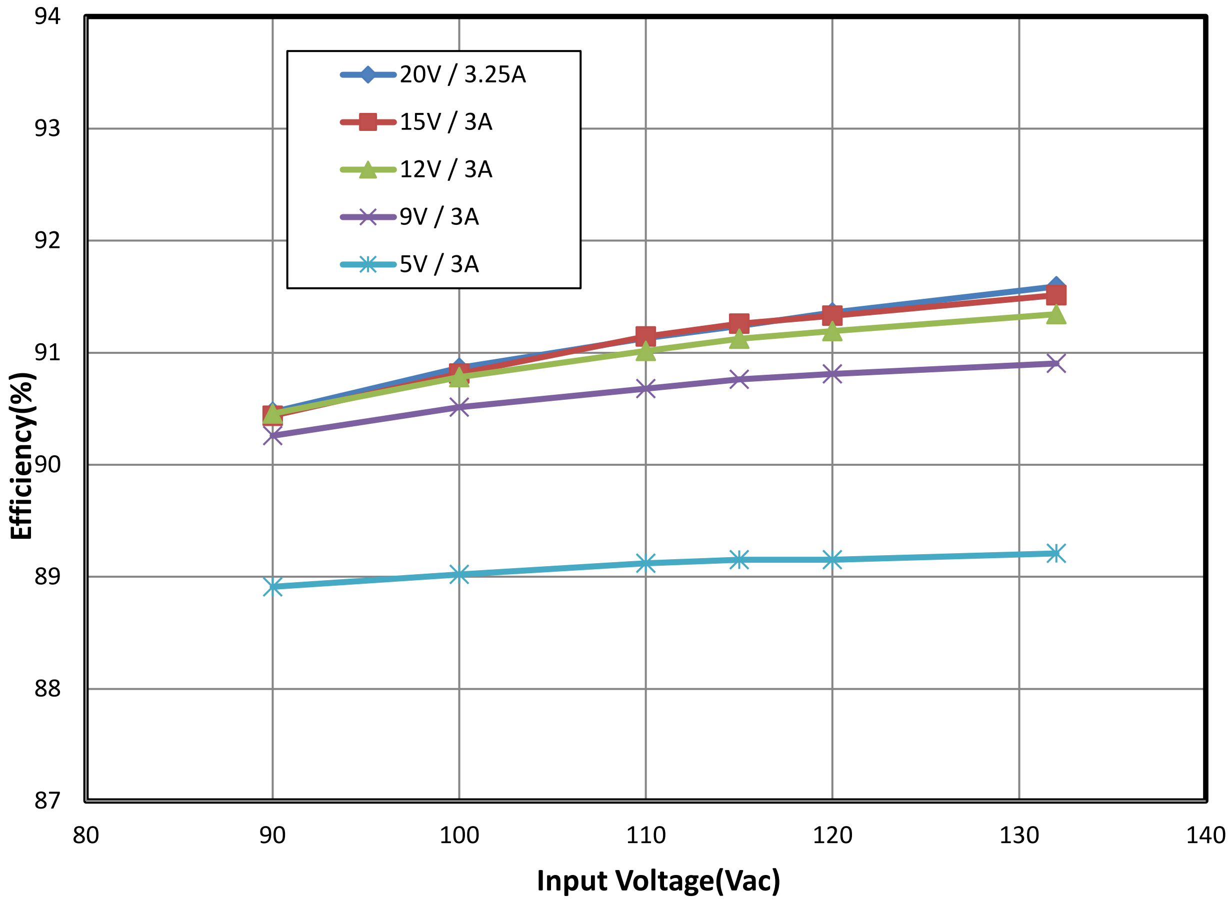


Figure 24 – Full Load Efficiency vs. Input Line for 5 V, 9 V, 12 V, 15 V, and 20 V Output, Room Temperature.

12.5 Efficiency Across Load (On Board)

12.5.1 Output: 20 V / 3.25 A

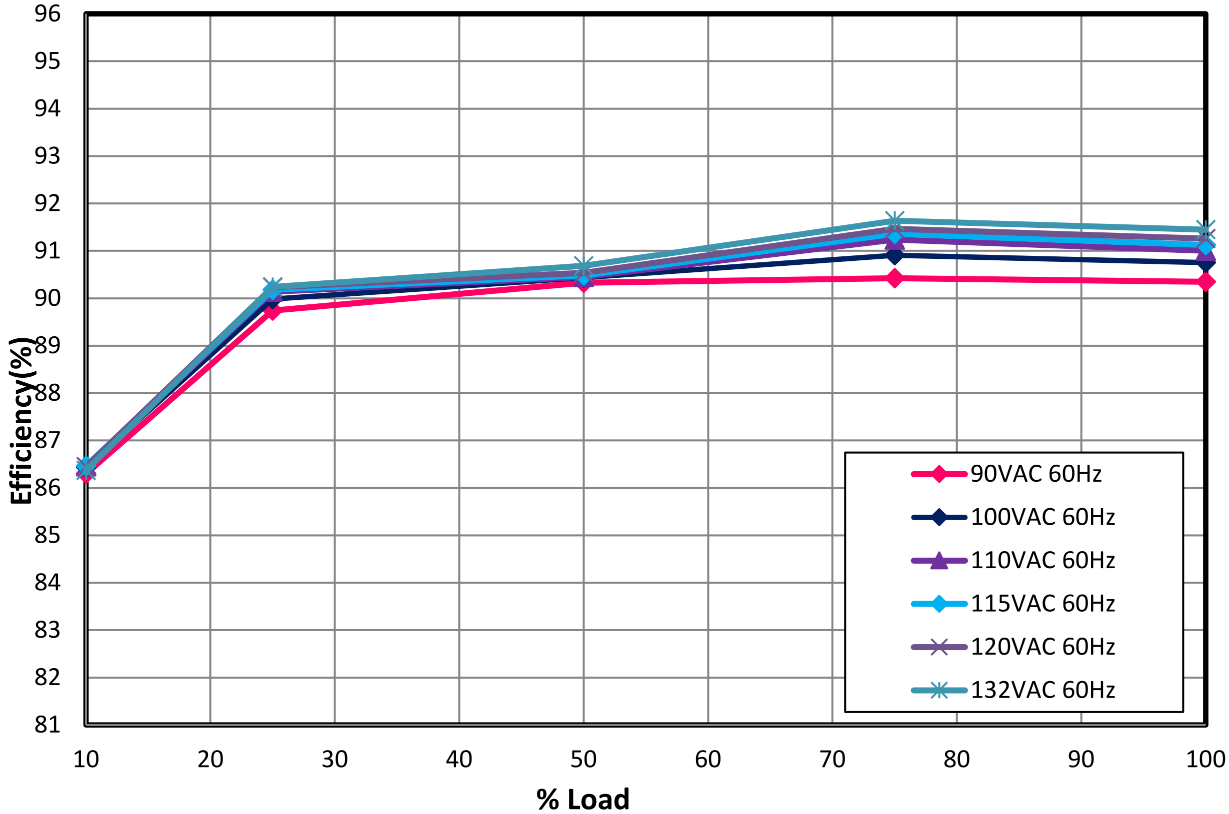


Figure 25 – Efficiency vs. Load for 20 V Output, Room Temperature.

12.5.2 Output: 15 V / 3 A

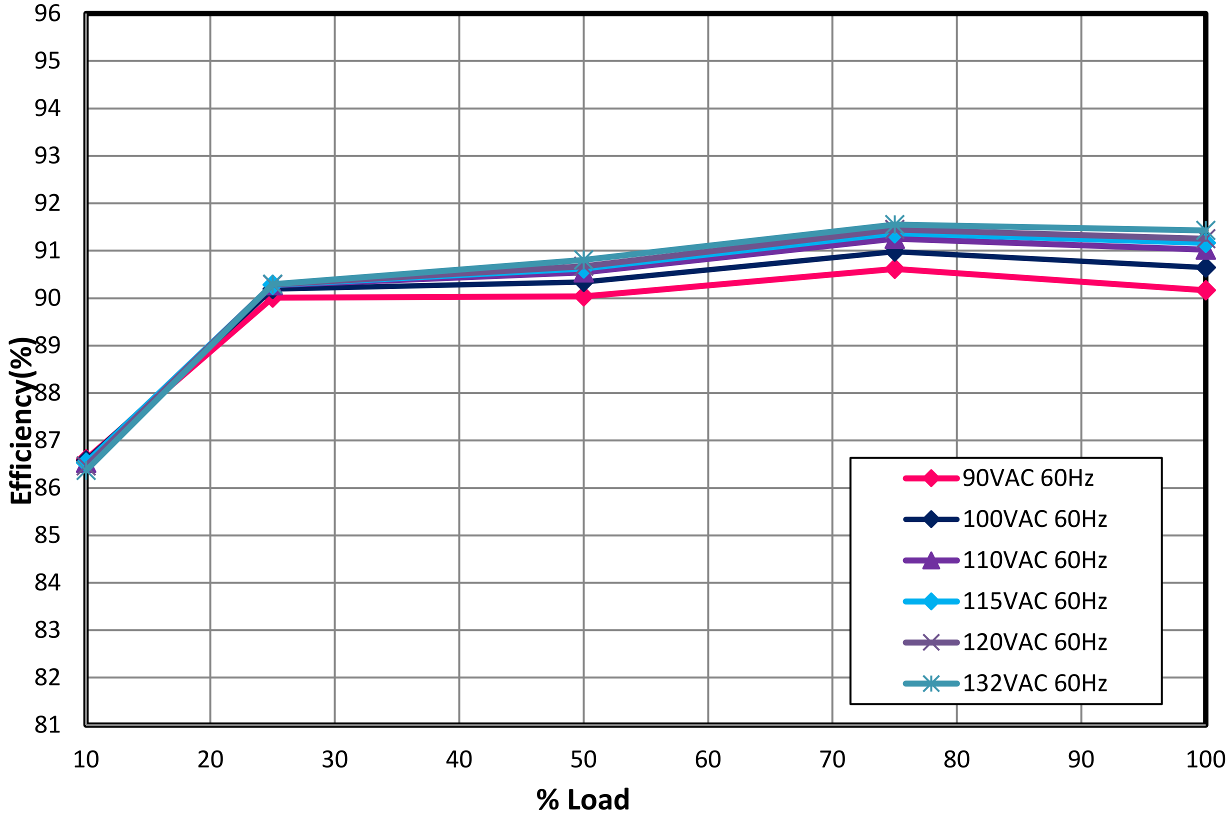


Figure 26 – Efficiency vs. Load for 15 V Output, Room Temperature.

12.5.3 Output: 12 V / 3 A

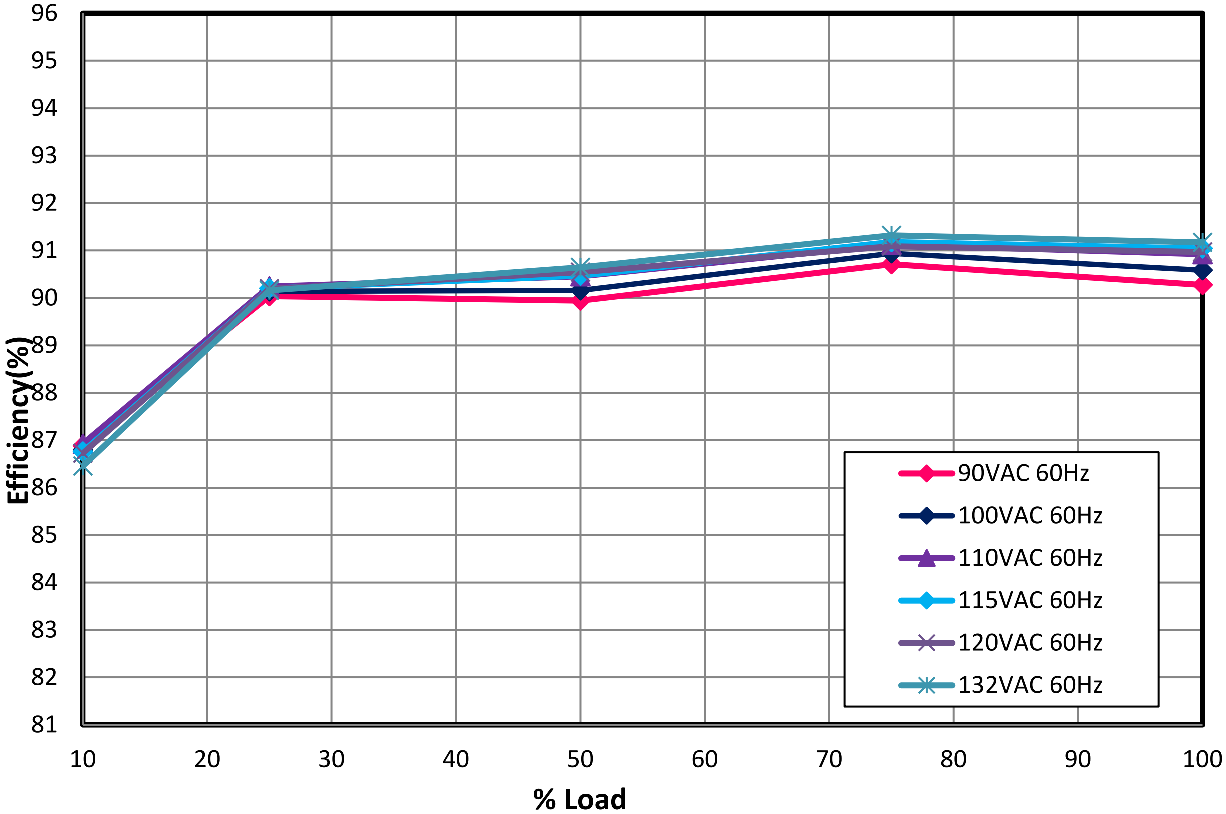


Figure 27 – Efficiency vs. Load for 12 V Output, Room Temperature.

12.5.4 Output: 9 V / 3 A

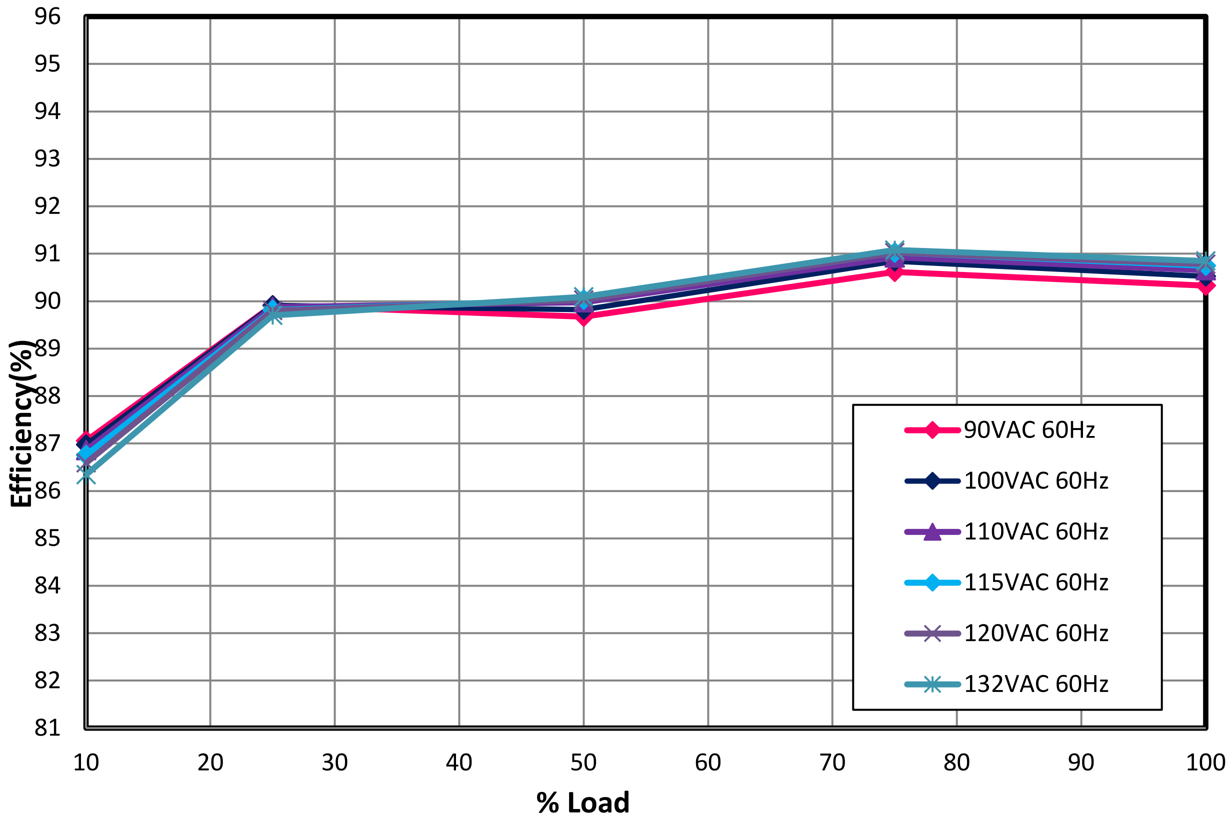


Figure 28 – Efficiency vs. Load for 9 V Output, Room Temperature.

12.5.5 Output: 5 V / 3 A

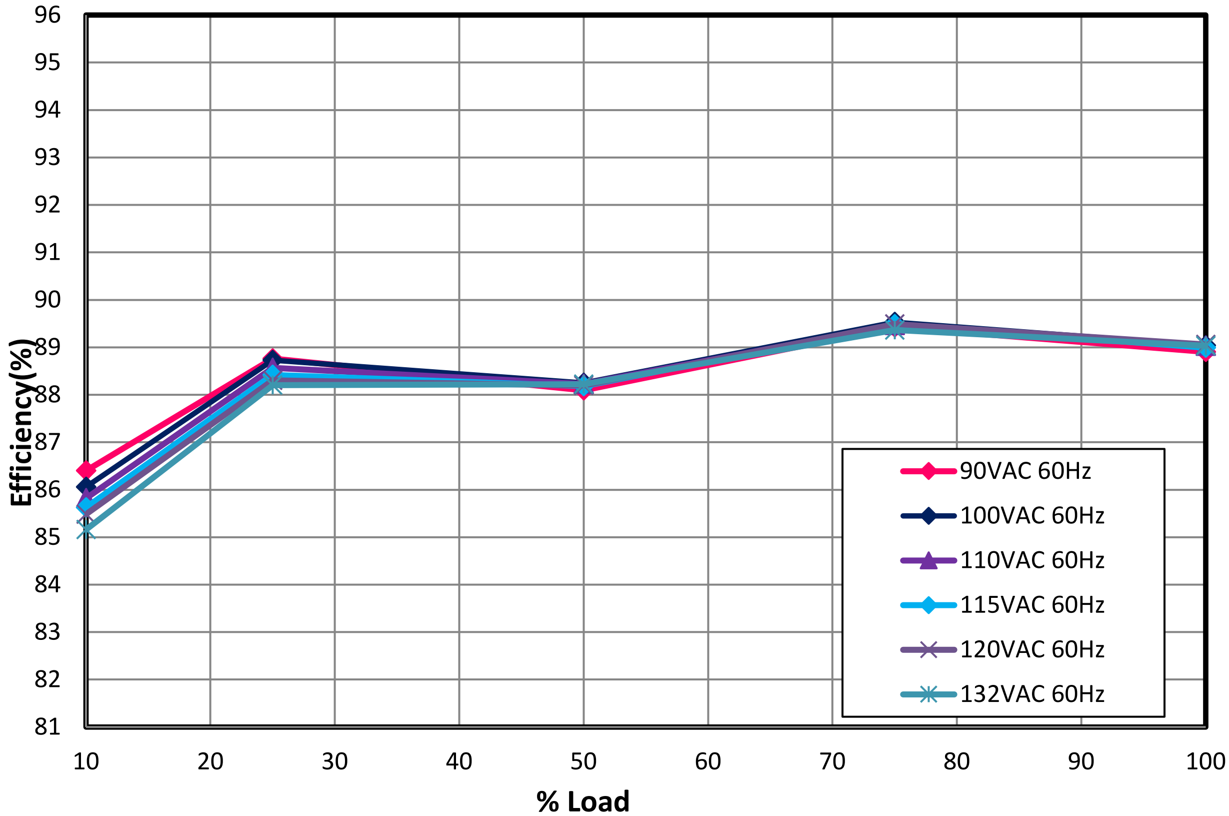


Figure 29 – Efficiency vs. Load for 5 V Output, Room Temperature.

12.5.6 Dual Output Mode Efficiency Spread

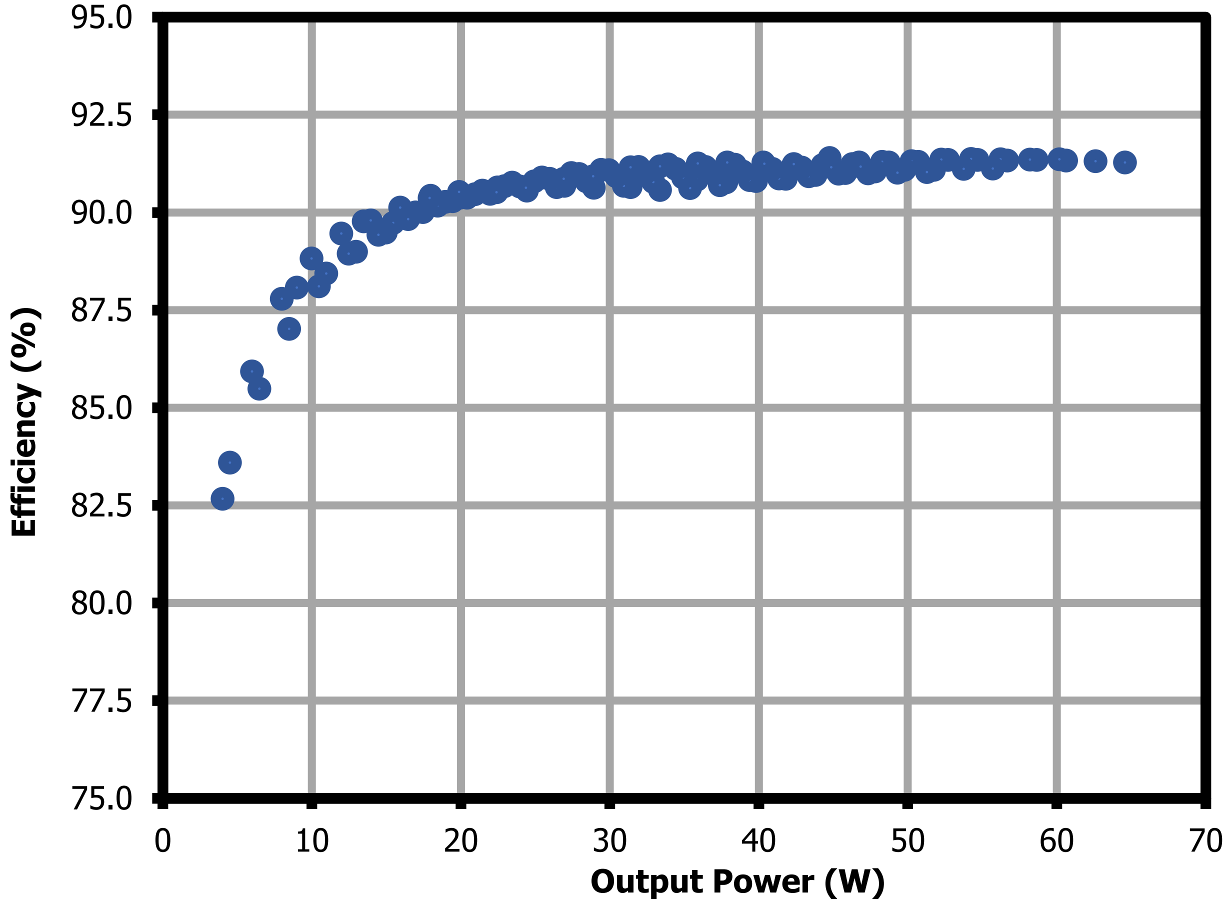


Figure 30 – DER-1024 Efficiency vs Load across various combinations of Vout=20V and Iout at 115 VAC Input

12.6 Line Regulation (On Board)

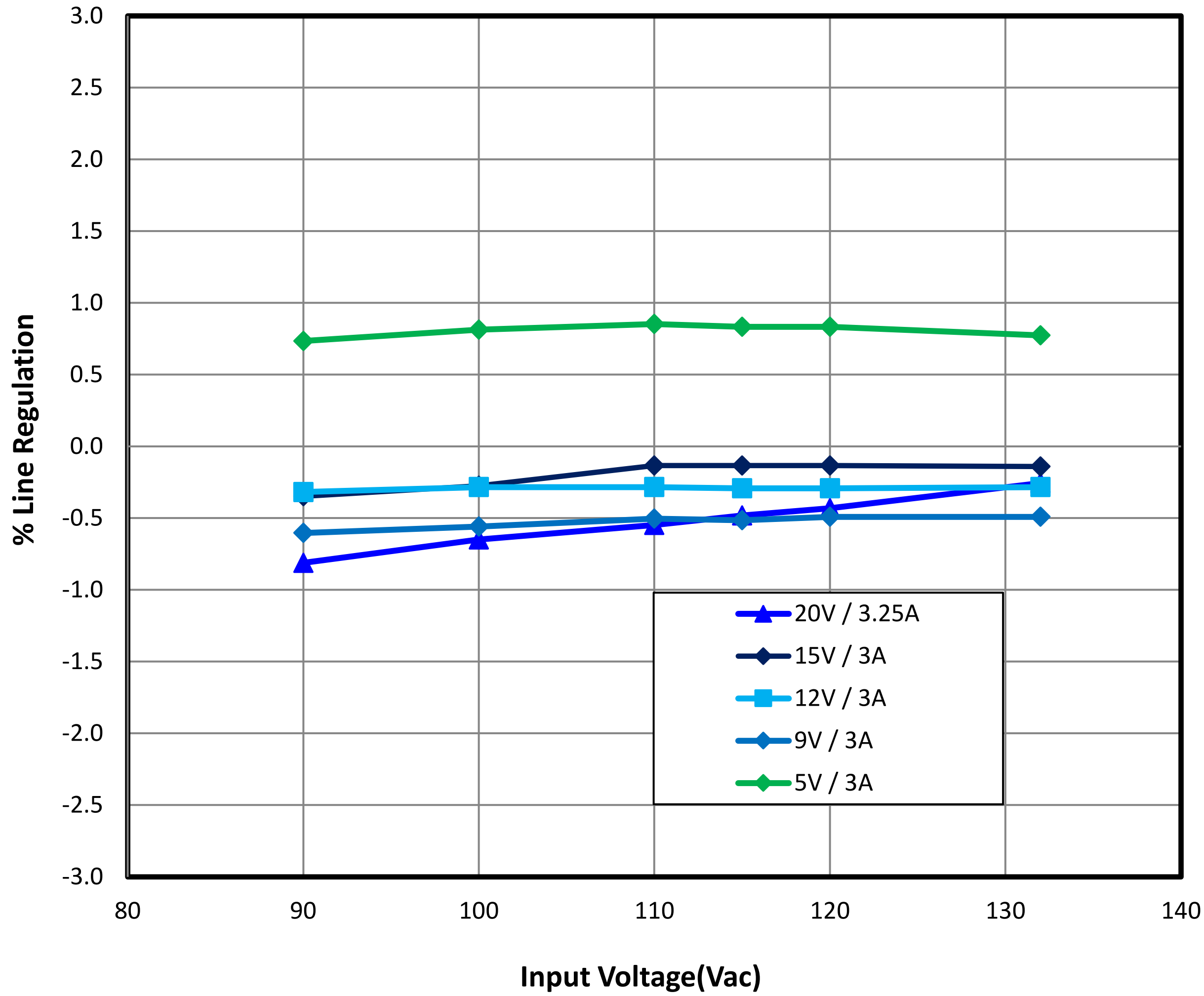


Figure 31 – Output Voltage vs. Input Line Voltage for 20 V Output, Room Temperature.

12.7 Load Regulation (On Board)

12.7.1 Output: 20 V / 3.25 A

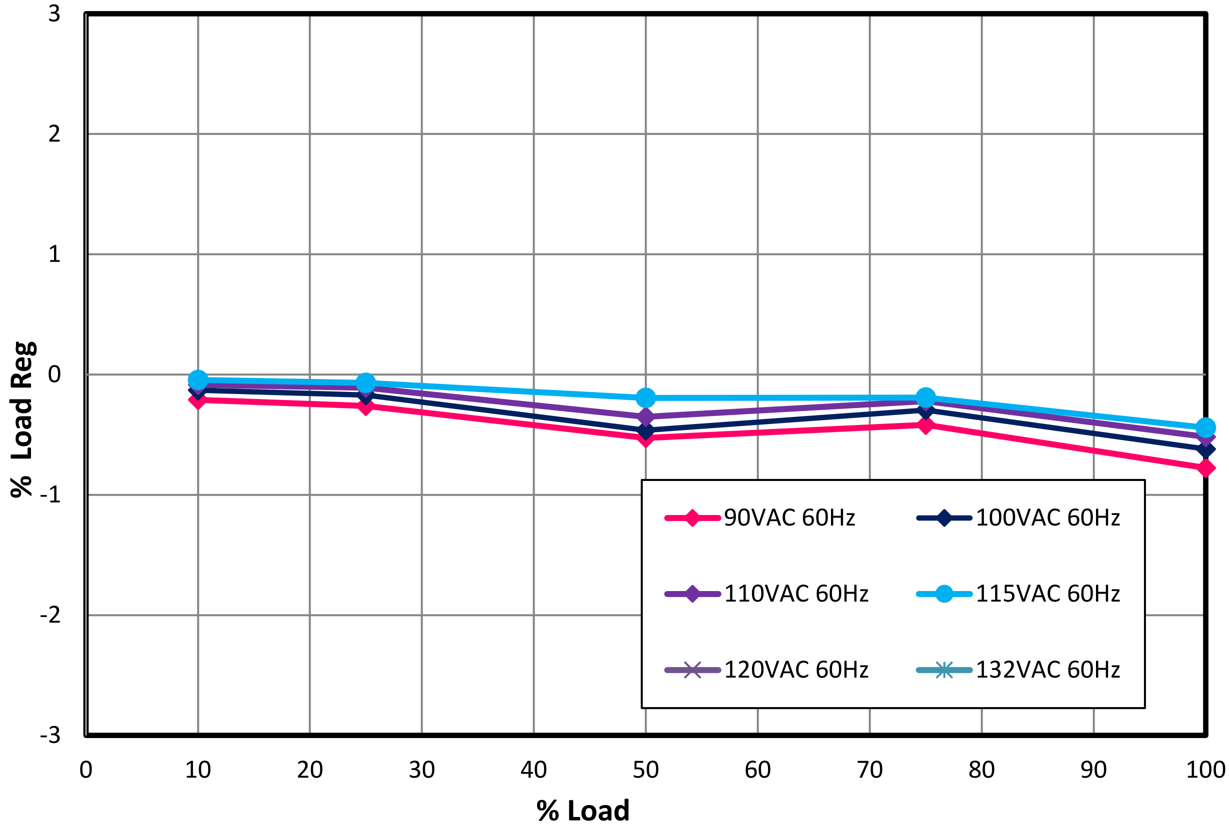


Figure 32 – Output Voltage vs. Output Load for 20 V Output, Room Temperature.

12.7.2 Output: 15 V / 3 A

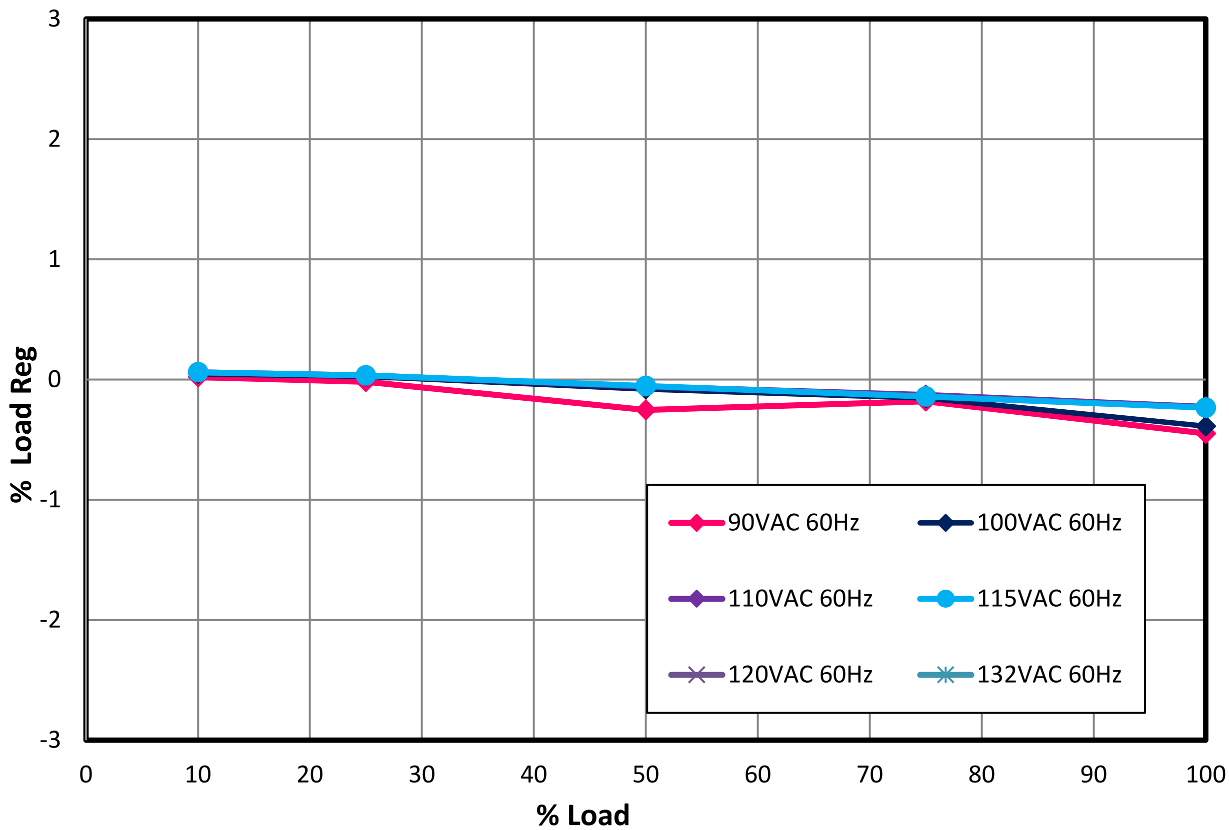


Figure 33 – Output Voltage vs. Output Load for 15 V Output, Room Temperature.

12.7.3 Output: 12 V / 3 A

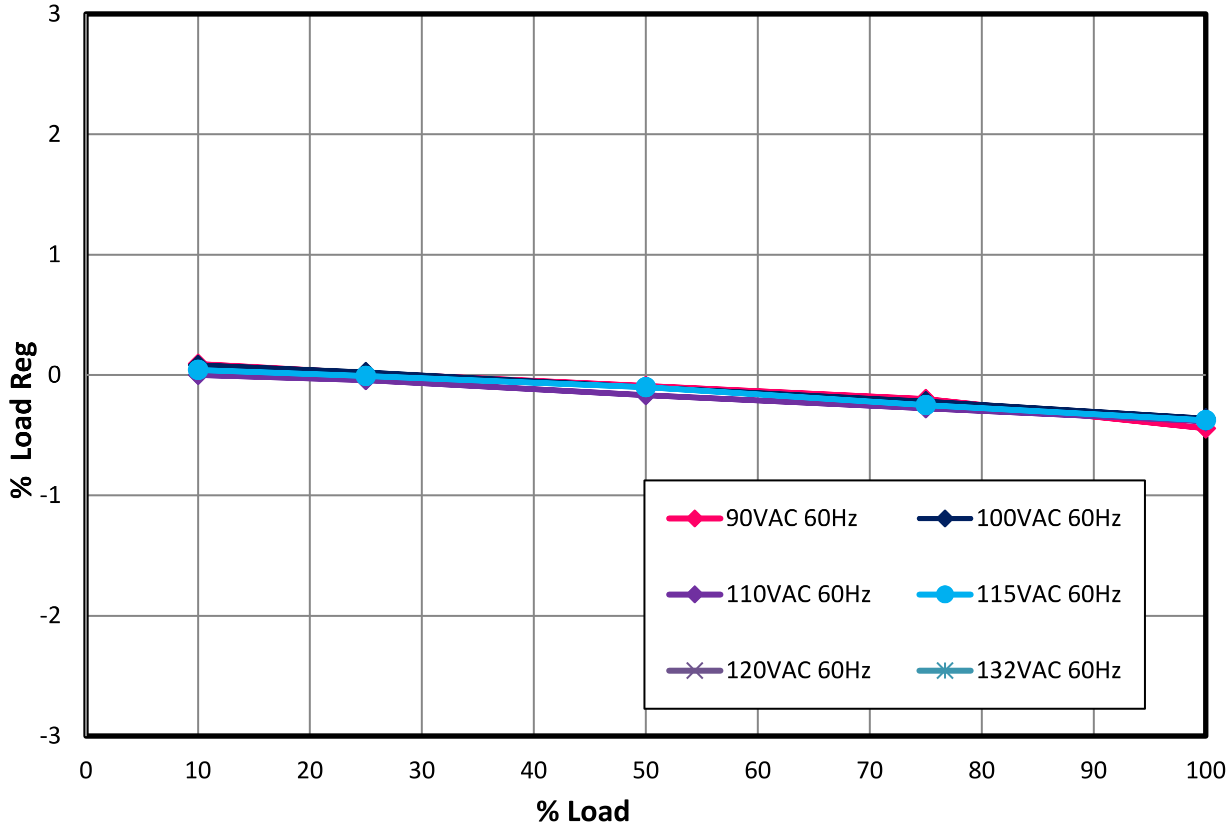


Figure 34 – Output Voltage vs. Output Load for 12 V Output, Room Temperature.

12.7.4 Output: 9 V / 3 A

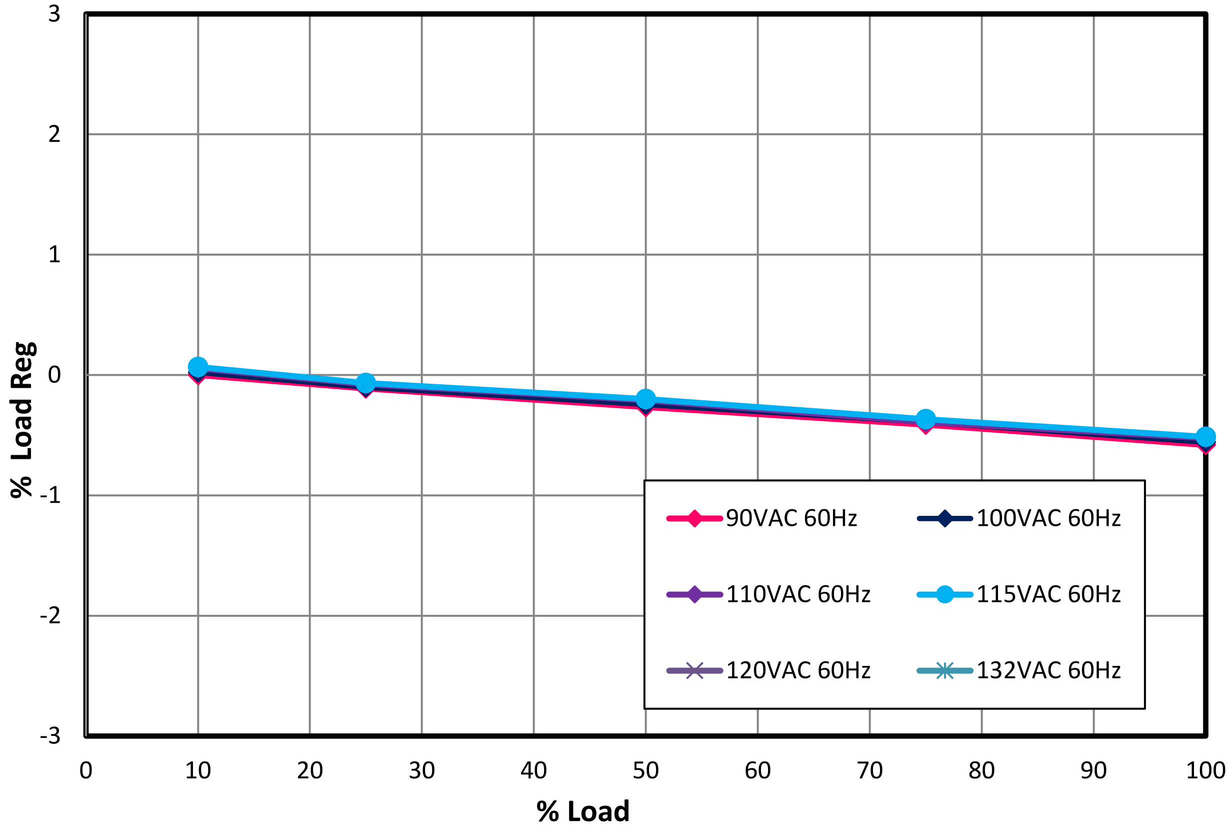


Figure 35 – Output Voltage vs. Output Load for 9 V Output, Room Temperature.

12.7.5 Output: 5 V / 3 A

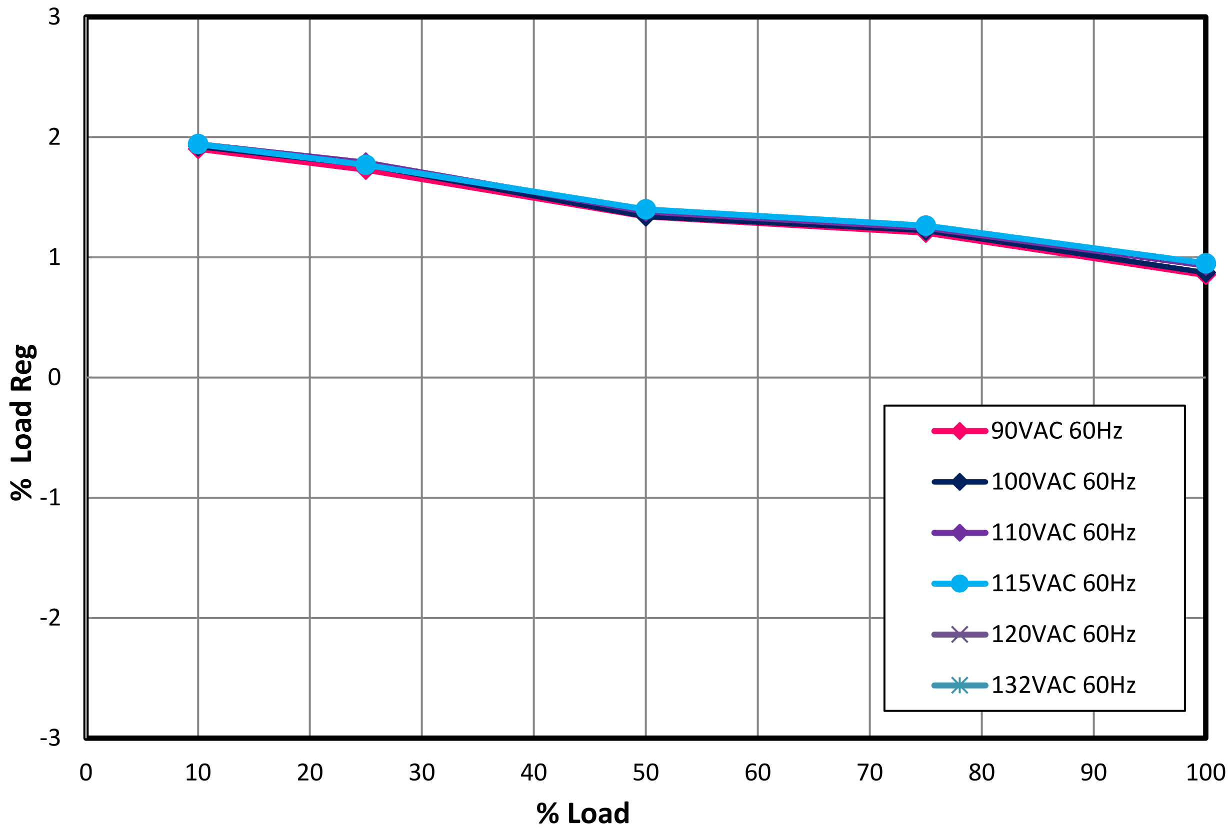


Figure 36 – Output Voltage vs. Output Load for 5 V Output, Room Temperature.

13 Thermal Performance

13.1 Thermal Potting

13.1.1 Material

The thermal potting used for this design is CoolTherm™ SC-320 Thermally Conductive Silicone Encapsulant.

- Thermal Conductivity: 3.2 W/m-K
- Typical Properties

Properties	SC-320 Resin	SC-320 Hardener	Mixed
Appearance	Pink Liquid	White Liquid	Light Pink Liquid
Viscosity, cps @ 25°C	25,000	20,000	22,000
Specific Gravity	3.1	3.1	3.1
Gel Time, min @ 121°C	-	-	2-5

13.1.2 Application

Procedure:

1. Prepare 1:1 ratio for SC-320 Resin and SC-320 Hardener either by volume or by weight.
2. Thoroughly mix each component separately before mixing.
3. Mix each component together until the color is light pink liquid and has a consistent viscosity.
4. Optional: Remove miniscule air bobbles in the mixture by using vacuum degassing technique.
5. Pour the mixture into the unit with 3D print case.
6. Allow encapsulant to cure for 12 hours at 40°C ambient temperature or for 24 hours at room temperature (25°C).

13.2 Thermal Setup at Room Ambient Temperature

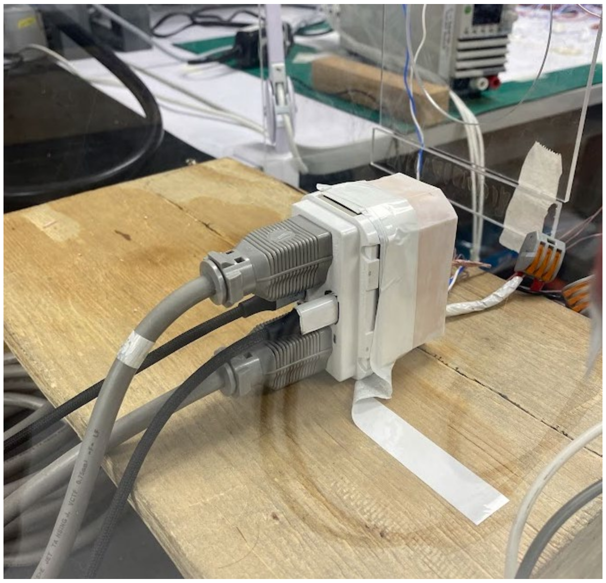


Figure 37 – Thermal Setup Inside an Acrylic Box at Room Temperature.

13.3 Thermal Performance at Plastic Case with Potting at Room Ambient Temperature

Notes:

- 65 W Dual Port - Port A 20 V / 2.25 A and Port B 20 V / 1 A at 120Vac
- Measurements taken at room temperature ambient (approximately 25 °C)
- Unit was placed inside a 3D printed plastic case (PCA material) with CoolTherm™ SC-320 Thermally Conductive Silicone Encapsulant Potting Material

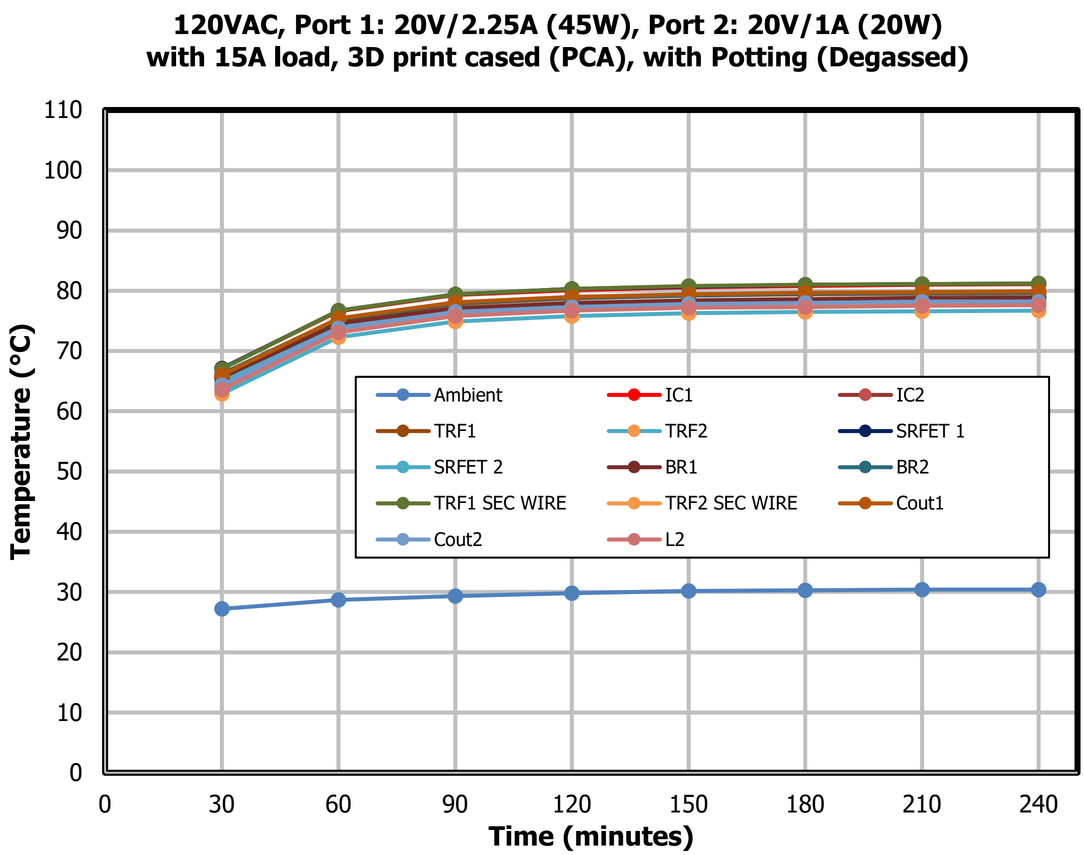


Figure 38 – Thermal Performance at Plastic Case with Potting at Room Ambient Temperature

120VAC, Port 1: 20V/2.25A (45W), Port 2: 20V/1A (20W)
with 15A load, 3D print cased (PCA), with Potting (Degassed)

Component	30 mins	1 hr	1.5 hrs	2 hrs	2.5 hrs	3 hrs	3.5 hrs	4 hrs
Ambient	27.2	28.7	29.3	29.8	30.2	30.3	30.4	30.4
IC1	67.1	76.6	79.3	80.1	80.6	80.8	81	81.1
IC2	65.7	75.2	77.9	78.8	79.2	79.5	79.7	79.7
TRF1	65.6	75.1	77.8	78.7	79.2	79.4	79.5	79.6
TRF2	62.9	72.3	74.9	75.8	76.3	76.5	76.6	76.7
TRF1 SEC WIRE	67	76.7	79.4	80.3	80.8	81	81.1	81.2
TRF2 SEC WIRE	64.2	73.7	76.4	77.2	77.7	77.9	78.1	78.1
SRFET 1	67.1	76.7	79.4	80.3	80.7	81	81.1	81.2
SRFET 2	64.9	74.3	77	77.8	78.3	78.5	78.6	78.7
BR1	65.6	74.6	77.1	78	78.4	78.6	78.8	78.9
BR2	66.2	75.3	77.9	78.8	79.2	79.5	79.6	79.7
Cout1	66	75.4	78.1	79	79.4	79.7	79.8	79.9
Cout2	64.3	73.8	76.5	77.3	77.8	78	78.2	78.2
L2	63.6	73.1	75.8	76.7	77.2	77.3	77.5	77.6

13.4 Thermal Performance at Metal Case at Room Ambient Temperature

Notes:

- 65 W Dual Port - Port A 20 V / 2.25 A and Port B 20 V / 1 A at 120Vac
- Measurements taken at room temperature ambient (approximately 25 °C)
- The unit was placed inside a metal casing.

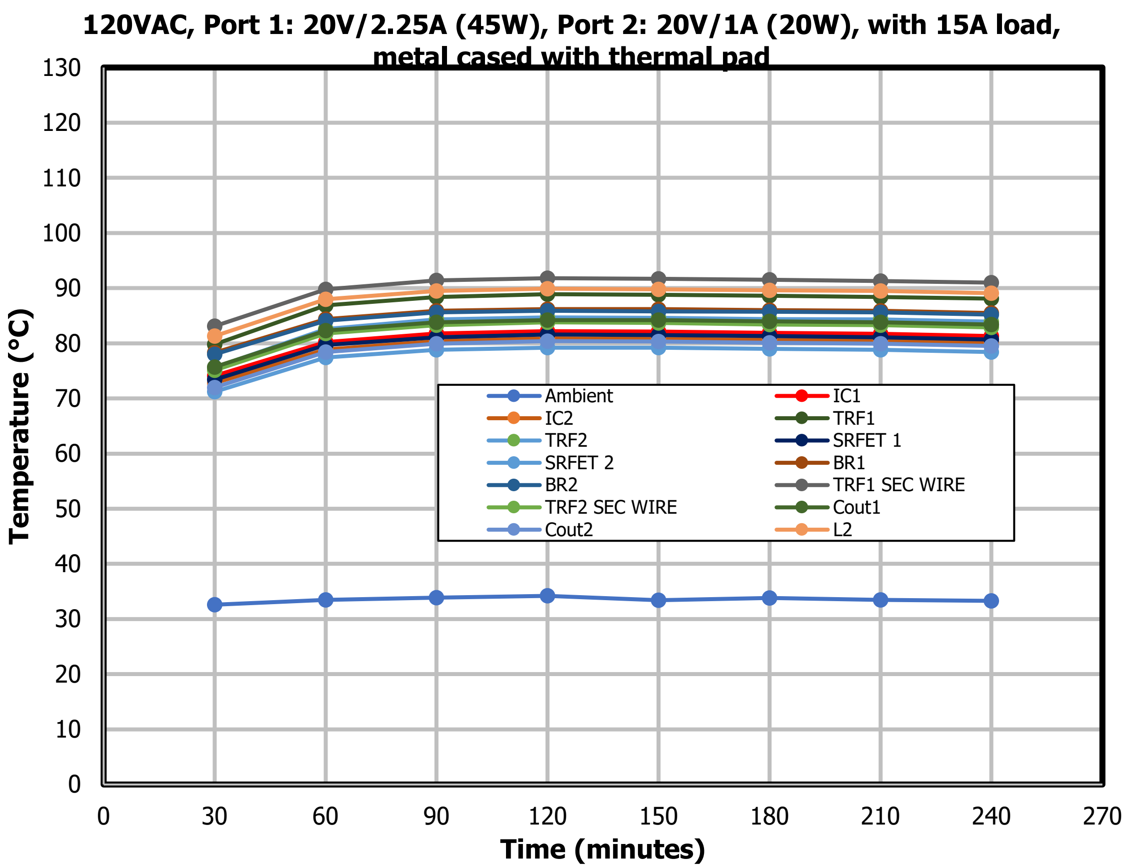


Figure 39 – Thermal Performance at Metal Case at Room Ambient Temperature

120VAC, Port 1: 20V/2.25A (45W), Port 2: 20V/1A (20W), with 15A load, metal cased with thermal pad								
Component	**30 mins**	**1 hr**	**1.5 hrs**	**2 hrs**	**2.5 hrs**	**3 hrs**	**3.5 hrs**	**4 hrs**
Ambient	32.6	33.5	33.9	34.2	33.4	33.8	33.5	33.3
IC1	74.1	80.2	81.8	82.2	82.1	81.9	81.7	81.3
IC2	72.8	78.9	80.4	80.9	80.8	80.6	80.5	80.1
TRF1	79.8	86.9	88.4	88.9	88.8	88.6	88.4	88.1
TRF2	75.6	82.6	84.3	84.7	84.6	84.4	84.3	83.9
TRF1 SEC WIRE	83.1	89.8	91.4	91.8	91.7	91.5	91.3	91
TRF2 SEC WIRE	75.1	81.8	83.3	83.8	83.7	83.4	83.3	82.9
SRFET 1	73.4	79.7	81.1	81.6	81.5	81.3	81.1	80.7
SRFET 2	71.2	77.4	78.8	79.2	79.2	79	78.8	78.4
BR1	78.3	84.4	85.9	86.2	86.2	86	85.9	85.5
BR2	78	84.1	85.6	85.9	85.8	85.7	85.6	85.2
Cout1	75.7	82.3	83.8	84.2	84.2	84	83.8	83.4
Cout2	72	78.4	79.9	80.4	80.3	80.1	79.9	79.5
L2	81.3	88	89.5	89.9	89.8	89.6	89.5	89.1

13.5 Thermal Performance at Plastic Case with Potting at 50 °C Ambient Temperature

Notes:

- 65 W Dual Port - Port A 20 V / 2.25 A and Port B 20 V / 1 A at 120Vac
- Measurements taken at 50 °C room ambient temperature
- Unit was placed inside a 3D printed plastic case (PCA material) with CoolTherm™ SC-320 Thermally Conductive Silicone Encapsulant Potting Material

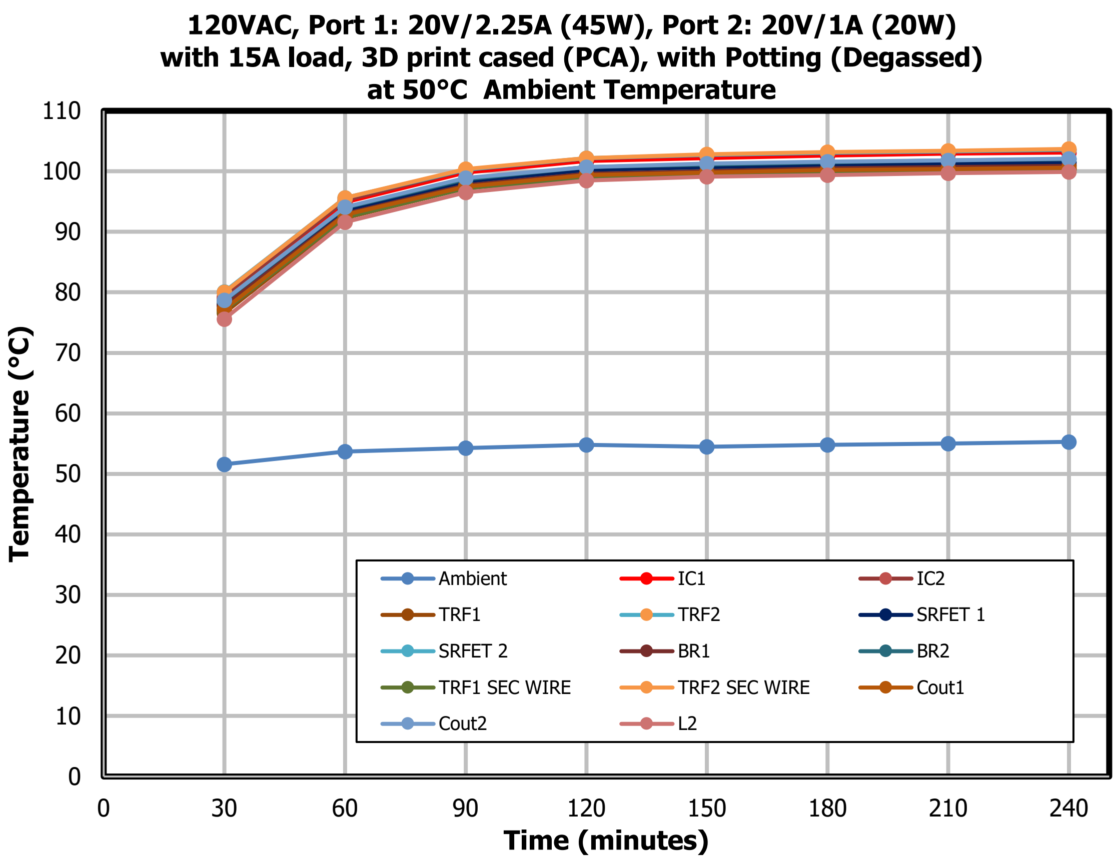


Figure 40 – Thermal Performance at Plastic Case with Potting at 50°C Ambient Temperature

120VAC, Port 1: 20V/2.25A (45W), Port 2: 20V/1A (20W)
with 15A load, 3D print cased (PCA), with Potting (Degassed)
at 50°C Ambient Temperature

Component	30 mins	1 hr	1.5 hrs	2 hrs	2.5 hrs	3 hrs	3.5 hrs	4 hrs
Ambient	51.6	53.7	54.3	54.8	54.5	54.8	55	55.3
IC1	79	94.9	99.8	101.7	102.2	102.6	102.9	103.1
IC2	79.3	95.2	100.2	102.1	102.7	103	103.3	103.5
TRF1	76.6	92.3	97.2	99	99.6	99.9	100.2	100.4
TRF2	77.3	93.1	97.9	99.8	100.3	100.7	100.9	101.1
TRF1 SEC WIRE	77	92.4	97.2	98.9	99.5	99.9	100.1	100.3
TRF2 SEC WIRE	80	95.6	100.4	102.2	102.8	103.2	103.4	103.7
SRFET 1	78	93.6	98.3	100.2	100.7	101	101.3	101.5
SRFET 2	80.1	95.6	100.3	102.2	102.7	103.1	103.3	103.6
BR1	77.8	93	97.7	99.6	100	100.5	100.7	100.9
BR2	78.6	94	98.7	100.7	101.1	101.5	101.8	102
Cout1	77.2	92.8	97.5	99.4	99.8	100.2	100.4	100.6
Cout2	78.7	94.1	98.9	100.7	101.3	101.6	101.8	102.1
L2	75.6	91.6	96.5	98.5	99.1	99.4	99.7	99.9

14 Waveforms

Note: Waveforms taken at room temperature ambient (approximately 25 °C)

14.1 Start-up Waveforms

14.1.1 Output Voltage and Current

Note: Output voltage waveforms captured at the end of PCB.

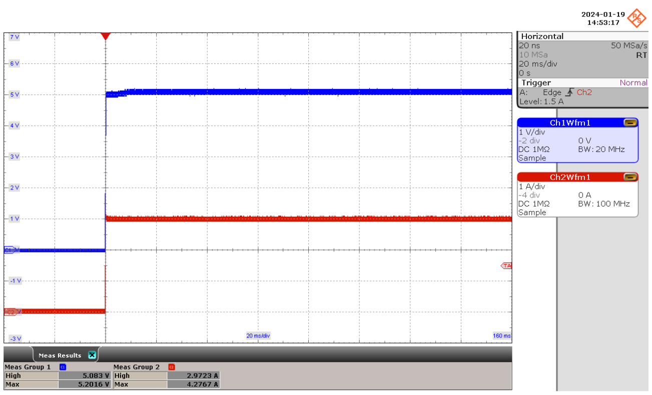


Figure 41 – Output Voltage and Current.
90 VAC, 5.0 V, 3 A Load (5.08 V_{MAX}).
CH1: V_{OUT1}, 1 V / div.
CH2: I_{LOAD1}, 1 A / div.
Time: 20 ms / div.

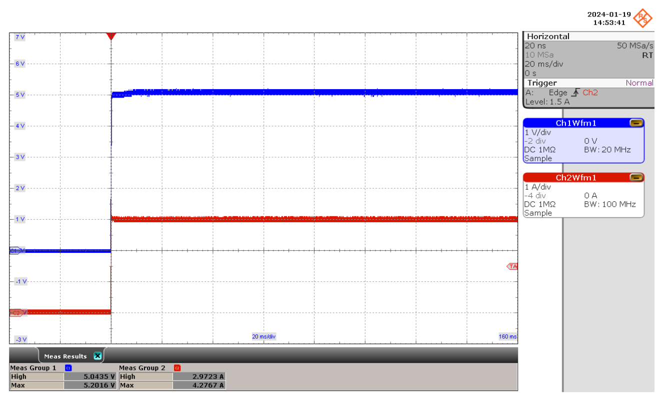


Figure 42 – Output Voltage and Current.
132 VAC, 5.0 V, 3 A Load (5.04 V_{MAX}).
CH1: V_{OUT1}, 1 V / div.
CH2: I_{LOAD1}, 1 A / div.
Time: 20 ms / div.

14.1.2 Primary Drain Voltage and Current

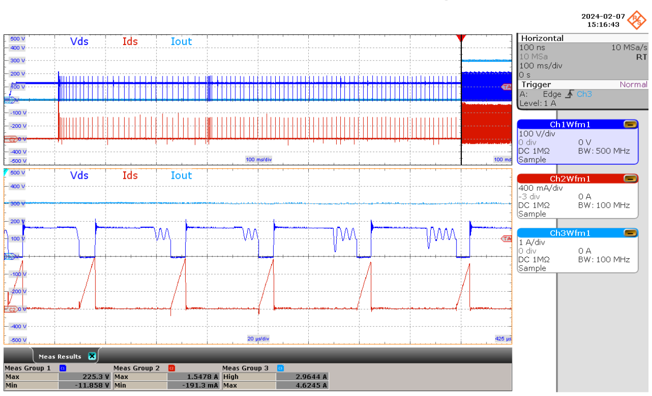


Figure 43 – Primary Drain Voltage and Current
90 VAC, 5 V, 3 A
V_{MAX} = 225.3 V
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 400 mA / div.
CH3: I_{OUT}, 1 A / div.
Time: 100 ms / div. (20 µs / div. Zoom)

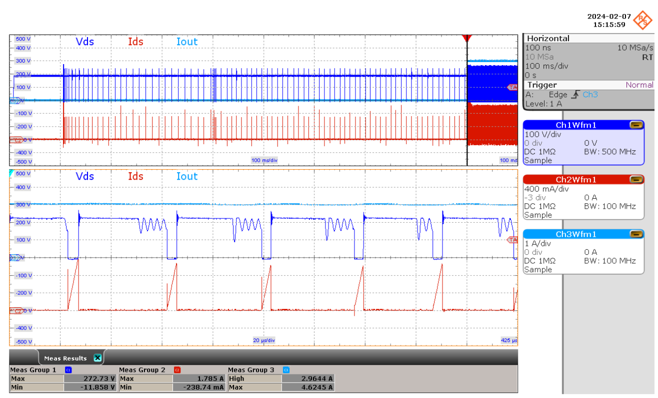


Figure 44 – Primary Drain Voltage and Current
132 VAC, 5 V, 3 A
V_{MAX} = 272.73 V
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 400 mA / div.
CH3: I_{OUT}, 1 A / div.
Time: 100 ms / div. (20 µs / div. Zoom)

14.1.3 SR FET Drain Voltage and Current

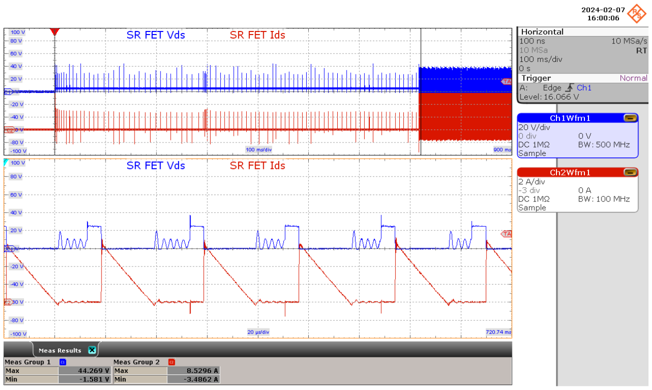


Figure 45 – SR FET Drain Voltage and Current
90 VAC, 5 V, 3 A
V_{MAX} = 44.27 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 2 A / div.
Time: 100 ms / div. (20 μs / div. Zoom)

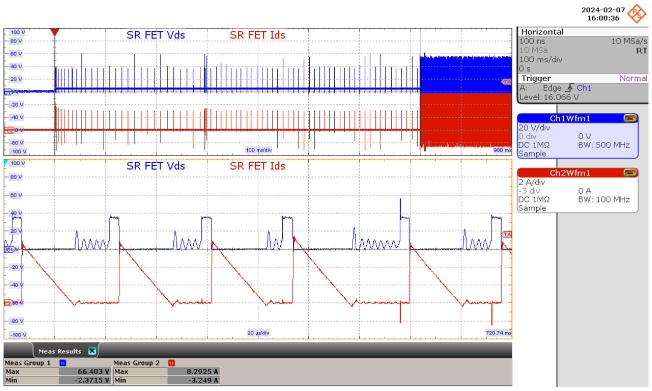


Figure 46 – SR FET Drain Voltage and Current
132 VAC, 5 V, 3 A
V_{MAX} = 66.40 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 2 A / div.
Time: 100 ms / div. (20 μs / div. Zoom)

14.2 Load Transient Response

Note: Output voltage waveforms are captured at the end of the PCB. Load setting is as follows: 10% - 100% load current step, 25 Hz, 50% duty cycle, slew rate of 800 mA / µs.

20V / 3.25A						
Vac (rms)	Freq (Hz)	VoMax	VoMin	Overshoot	Undershoot	Pass/Fail
90	60	20.46	19.97	2.30	-0.15	Pass
132	60	20.48	19.99	2.40	-0.05	Pass
15V / 3A						
Vac (rms)	Freq (Hz)	VoMax	VoMin	Overshoot	Undershoot	Pass/Fail
90	60	15.36	14.95	2.40	-0.33	Pass
132	60	15.36	14.95	2.40	-0.33	Pass
12V / 3A						
Vac (rms)	Freq (Hz)	VoMax	VoMin	Overshoot	Undershoot	Pass/Fail
90	60	12.32	11.95	2.67	-0.42	Pass
132	60	12.34	11.91	2.83	-0.75	Pass
9V / 3A						
Vac (rms)	Freq (Hz)	VoMax	VoMin	Overshoot	Undershoot	Pass/Fail
90	60	9.3	8.85	3.33	-1.67	Pass
132	60	9.3	8.89	3.33	-1.22	Pass
5V / 3A						
Vac (rms)	Freq (Hz)	VoMax	VoMin	Overshoot	Undershoot	Pass/Fail
90	60	5.25	4.91	5.00	-1.80	Pass
132	60	5.25	4.93	5.00	-1.40	Pass

14.2.1 Output: 20 V / 3.25 A

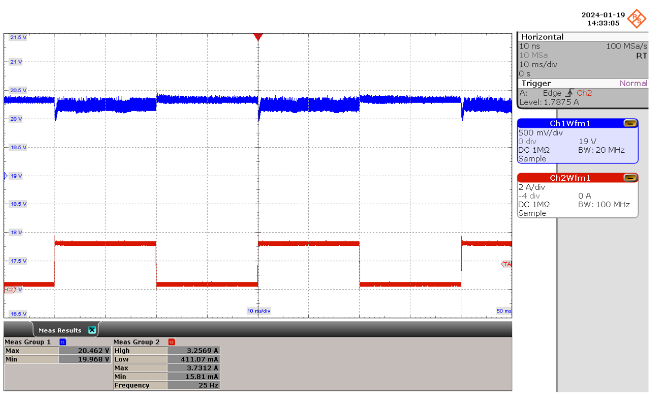


Figure 47 – Transient Response.
90 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 19.97 V, V_{MAX}: 20.46 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

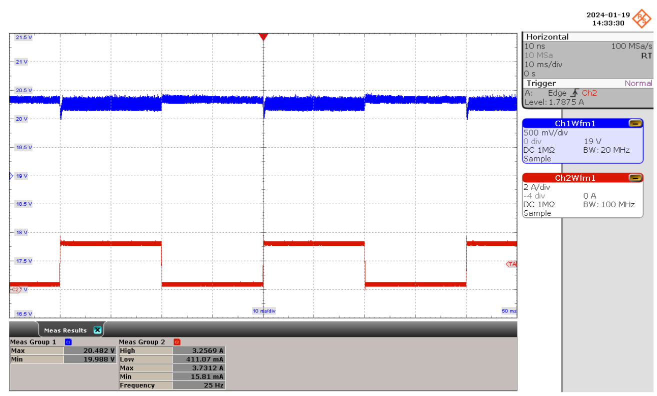


Figure 48 – Transient Response.
132 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 19.99 V, V_{MAX}: 20.48 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

14.2.2 Output: 15 V / 3 A

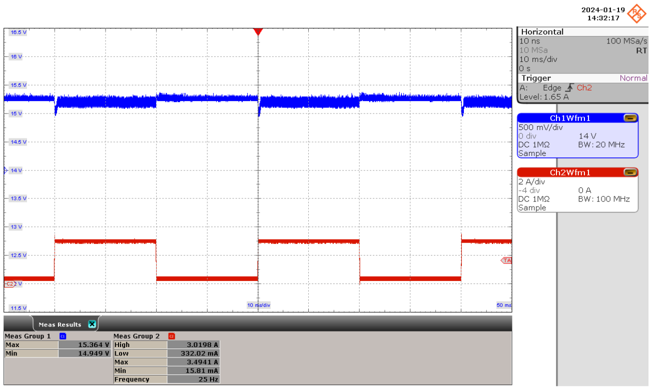


Figure 49 – Transient Response.
90 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 14.95 V, V_{MAX}: 15.36 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

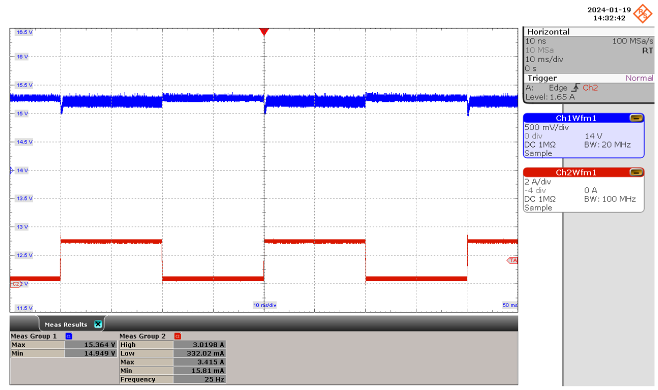


Figure 50 – Transient Response.
132 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 14.95 V, V_{MAX}: 15.36 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

14.2.3 Output: 12 V / 3 A

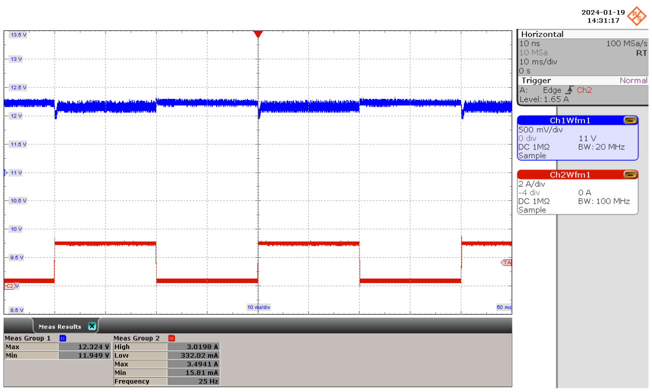


Figure 51 – Transient Response.
90 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 11.95 V, V_{MAX}: 12.32 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

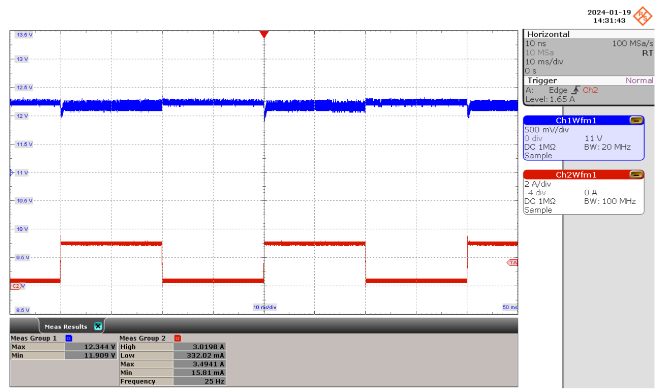


Figure 52 – Transient Response.
132 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 11.91 V, V_{MAX}: 12.34 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

14.2.4 Output: 9 V / 3 A

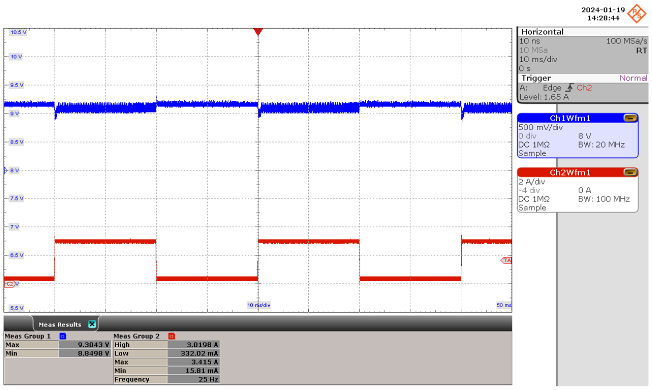


Figure 53 – Transient Response.
90 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 8.85 V, V_{MAX}: 9.3 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

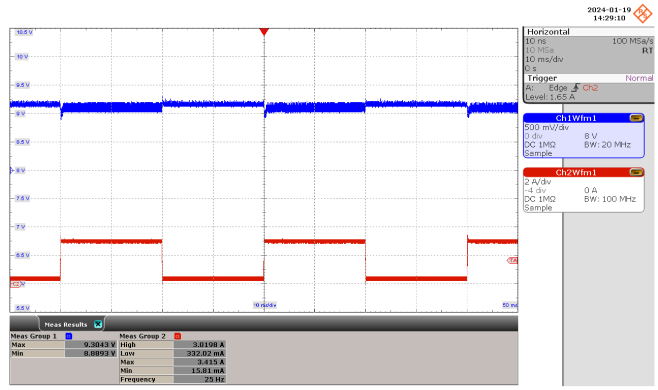


Figure 54 – Transient Response.
132 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 8.89 V, V_{MAX}: 9.3 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

14.2.5 Output: 5 V / 3 A

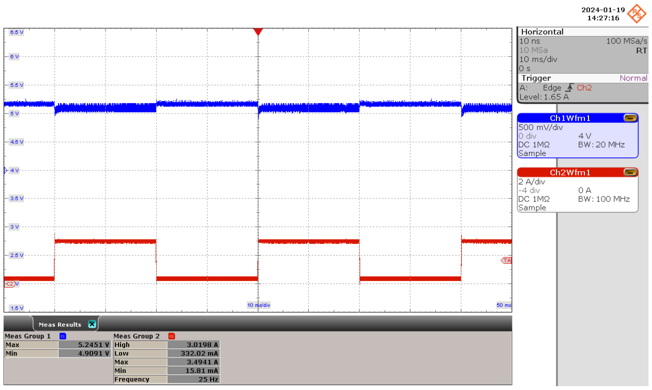


Figure 55 – Transient Response.
90 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 4.91 V, V_{MAX}: 5.25 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

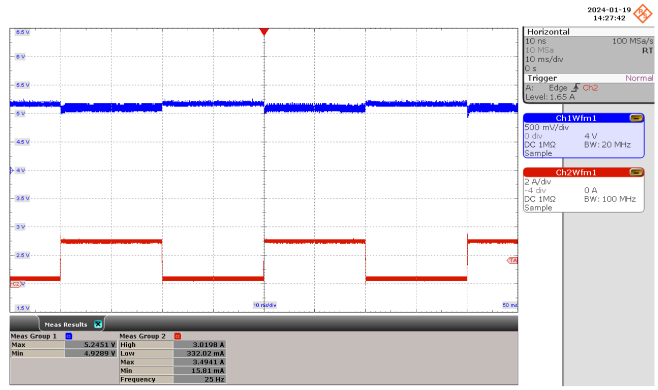


Figure 56 – Transient Response.
132 VAC, 5 V, 10% – 100% Load Step.
V_{MIN}: 4.93 V, V_{MAX}: 5.25 V.
C1: V_{OUT}, 0.5 V / div.
C2: I_{LOAD}, 2 A / div.
Time: 10 ms / div.

14.3 Primary Drain Voltage and Current (Steady-State)

14.3.1 Output: Port 1: 20 V / 3.25 A (65 W), Port 2: No-Load

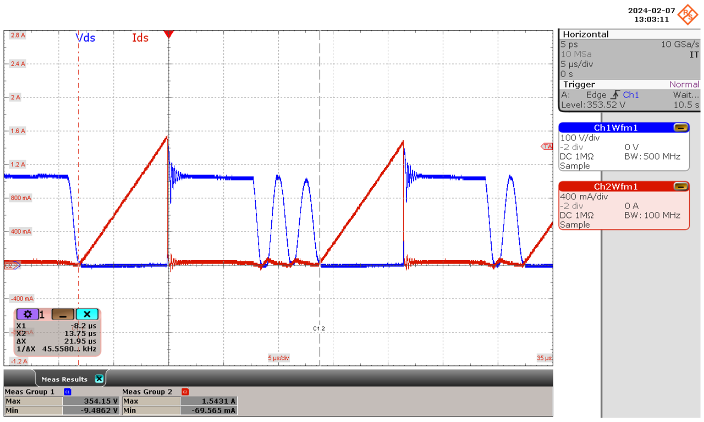


Figure 57 – Primary Drain Voltage and Current in Port 1 at 90 VAC, Port 1: 20.0 V, 3.25 A, 65 W, Port 2: No-Load
V_{MAX} = 354.15 V
f_{SW} = 45.56 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 μs / div.

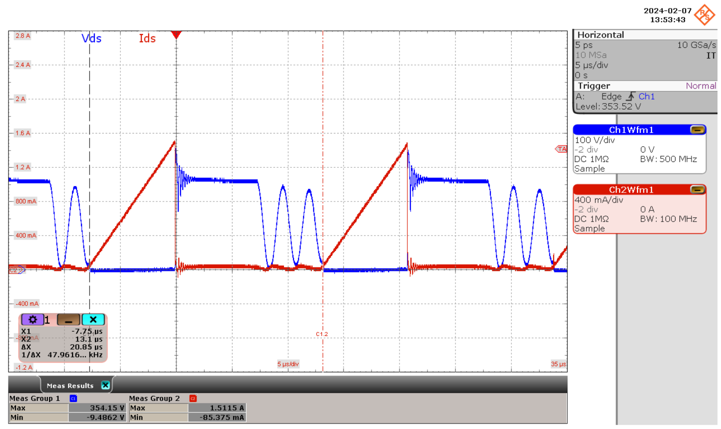


Figure 58 – Primary Drain Voltage and Current in Port 2 at 90 VAC, Port 1: 20.0 V, 3.25 A, 65 W, Port 2: No-Load
V_{MAX} = 354.15 V
f_{SW} = 47.96 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 μs / div.

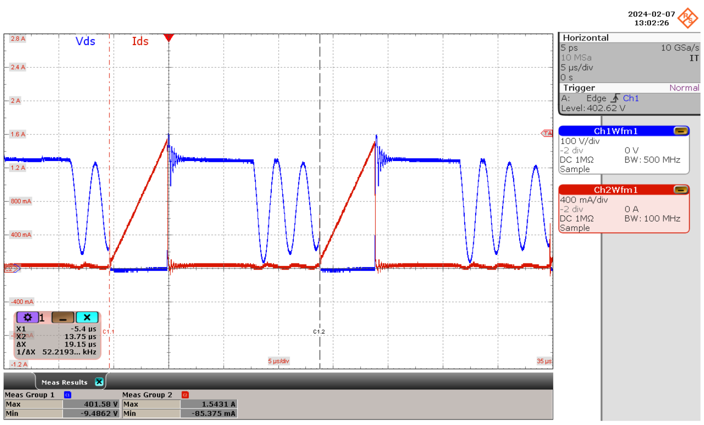


Figure 59 – Primary Drain Voltage and Current in Port 1 at 132 VAC, Port 1: 20.0 V, 3.25 A, 65 W, Port 2: No-Load
V_{MAX} = 401.58 V
f_{SW} = 52.22 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 μs / div.

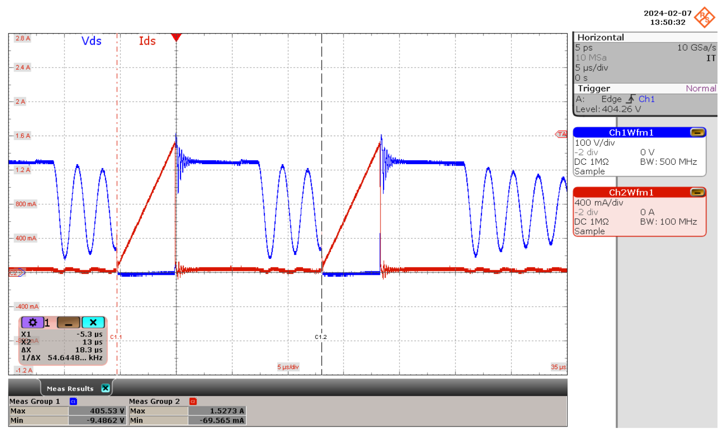


Figure 60 – Primary Drain Voltage and Current in Port 2 at 132 VAC, Port 1: 20.0 V, 3.25 A, 65 W, Port 2: No-Load
V_{MAX} = 405.53 V
f_{SW} = 54.64 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 μs / div.

14.3.2 Output: Port 1: No-Load, Port 2: 20 V / 3.25 A (65 W)

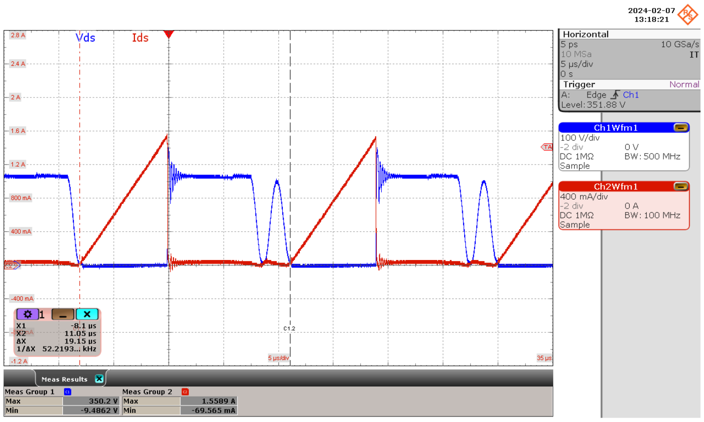


Figure 61 – Primary Drain Voltage and Current in Port 1 at 90 VAC, Port 1: No-Load, Port 2: 20 V / 3.25 A, 65 W
V_{MAX} = 350.2 V
f_{SW} = 52.22 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

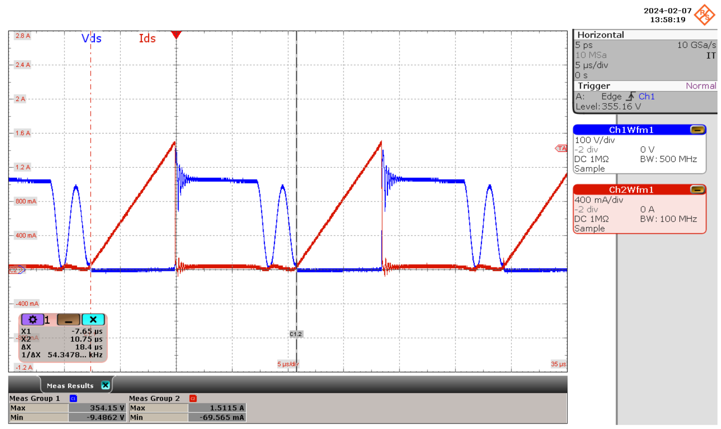


Figure 62 – Primary Drain Voltage and Current in Port 2 at 90 VAC, Port 1: No-Load, Port 2: 20 V / 3.25 A, 65 W
V_{MAX} = 354.15 V
f_{SW} = 54.35 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

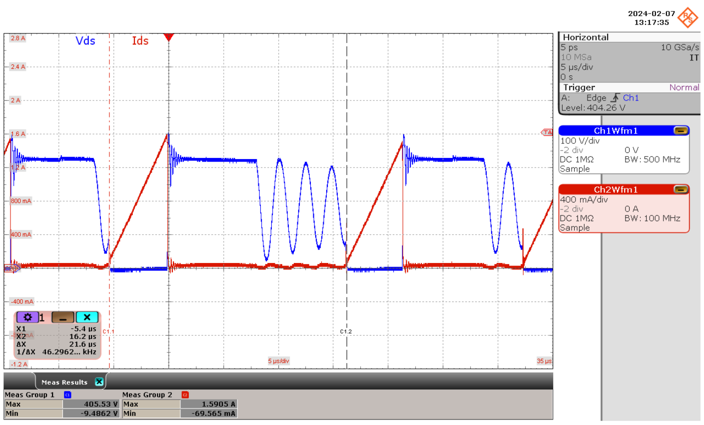


Figure 63 – Primary Drain Voltage and Current in Port 1 at 132 VAC, Port 1: No-Load, Port 2: 20 V / 3.25 A, 65 W
V_{MAX} = 405.53 V
f_{SW} = 46.30 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

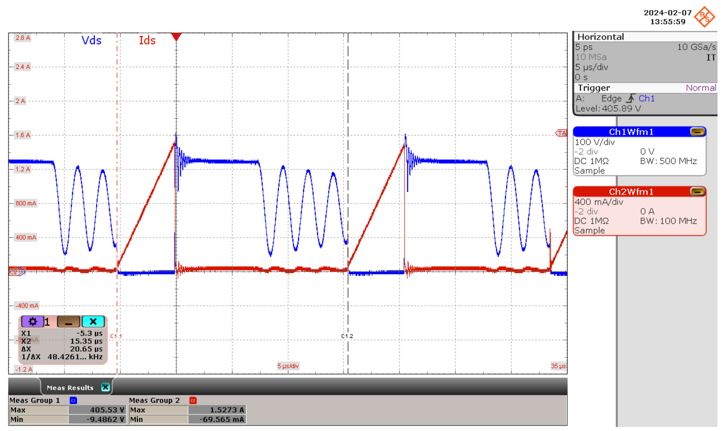


Figure 64 – Primary Drain Voltage and Current in Port 2 at 132 VAC, Port 1: No-Load, Port 2: 20 V / 3.25 A, 65 W
V_{MAX} = 405.53 V
f_{SW} = 48.26 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

14.3.3 Output: Port 1: 20 V / 2.25 A (45 W), Port 2: 20 V / 1 A (20 W)

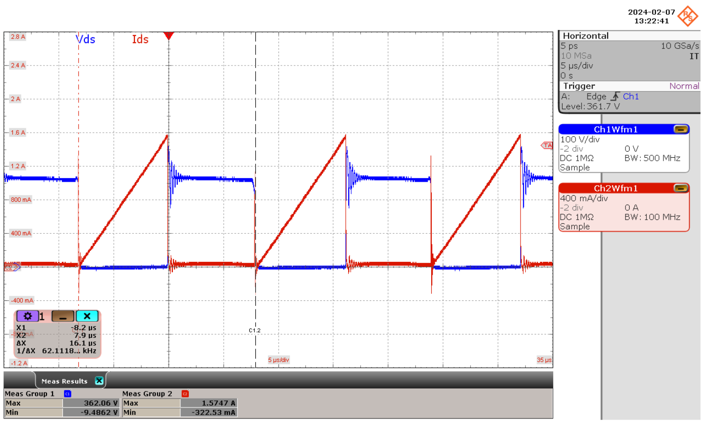


Figure 65 – Primary Drain Voltage and Current in Port 1 at 90 VAC, Port 1: 20.0 V, 2.25 A, 45 W, Port 2: 20.0 V, 1 A, 20 W
V_{MAX} = 362.06 V
f_{SW} = 62.11 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

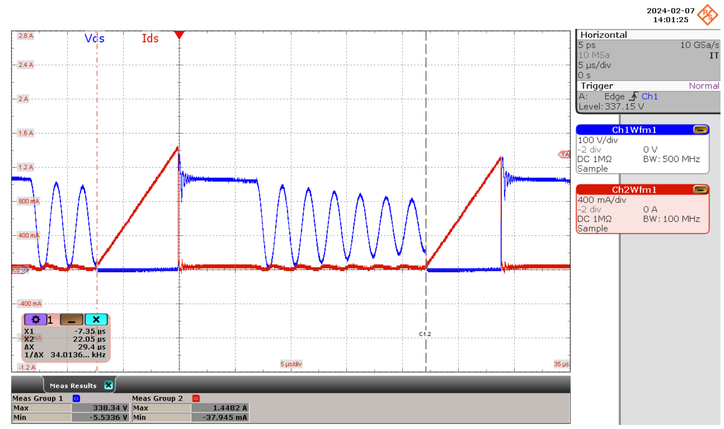


Figure 66 – Primary Drain Voltage and Current in Port 2 at 90 VAC, Port 1: 20.0 V, 2.25 A, 45 W, Port 2: 20.0 V, 1 A, 20 W
V_{MAX} = 338.34 V
f_{SW} = 34.01 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

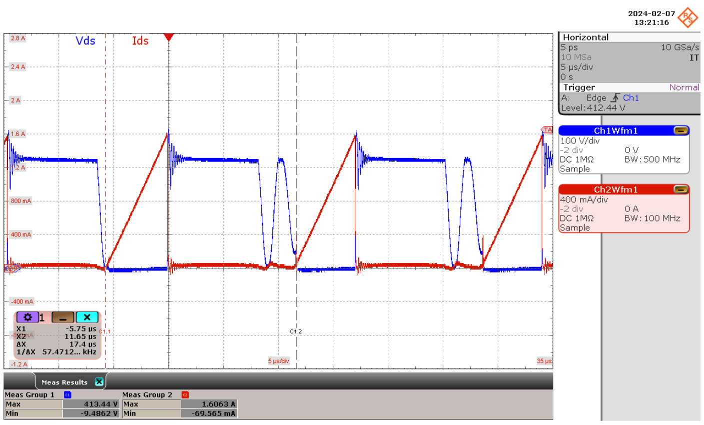


Figure 67 – Primary Drain Voltage and Current in Port 1 at 132 VAC, Port 1: 20.0 V, 2.25 A, 45 W, Port 2: 20.0 V, 1 A, 20 W
V_{MAX} = 413.44 V
f_{SW} = 57.47 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

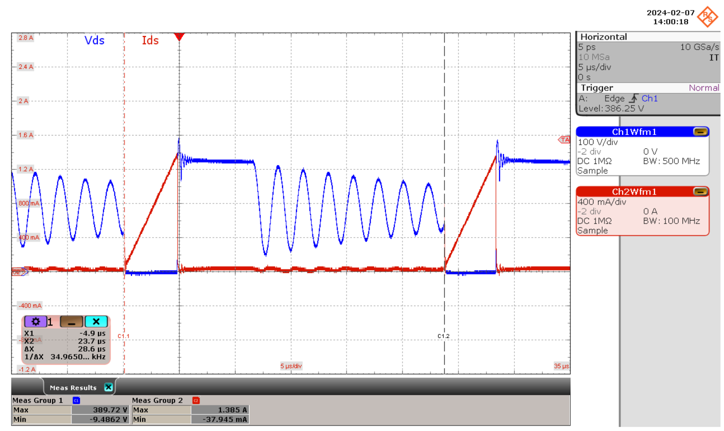


Figure 68 – Primary Drain Voltage and Current in Port 2 at 132 VAC, Port 1: 20.0 V, 2.25 A, 45 W, Port 2: 20.0 V, 1 A, 20 W
V_{MAX} = 389.72 V
f_{SW} = 34.97 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

14.3.4 Output: Port 1: 20 V / 1 A (20 W), Port 2: 20 V / 2.25 A (45 W)

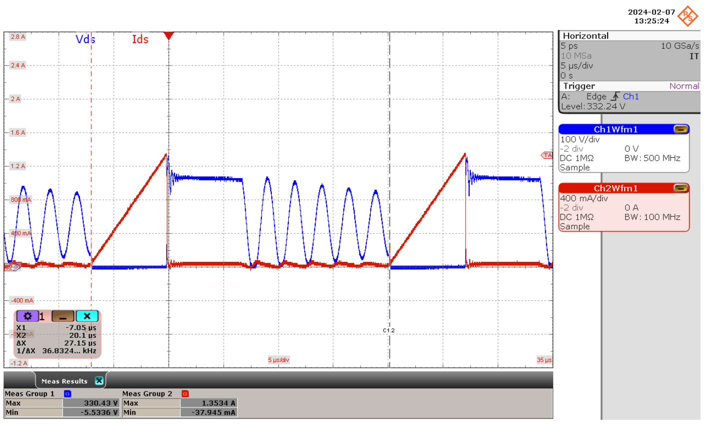


Figure 69 – Primary Drain Voltage and Current in Port 1 at 90 VAC, Port 1: 20.0 V, 1 A, 20 W, Port 2: 20.0 V, 2.25 A, 45 W
V_{MAX} = 330.43 V
f_{SW} = 36.83 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

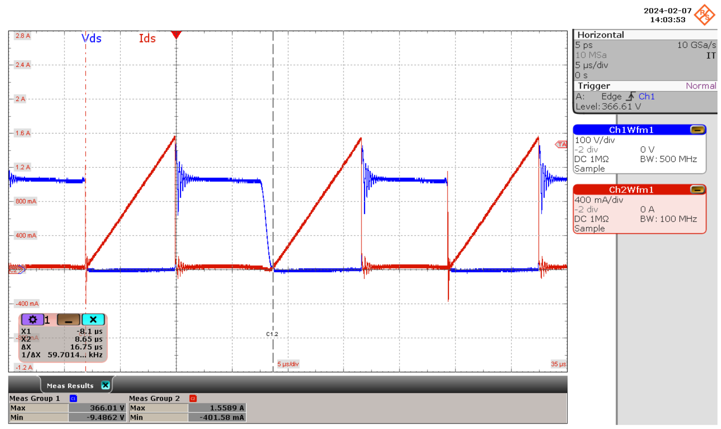


Figure 70 – Primary Drain Voltage and Current in Port 2 at 90 VAC, Port 1: 20.0 V, 1 A, 20 W, Port 2: 20.0 V, 2.25 A, 45 W
V_{MAX} = 366.01 V
f_{SW} = 59.70 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

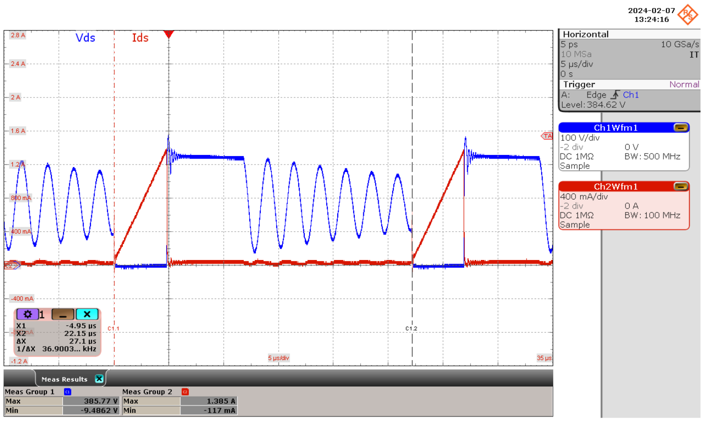


Figure 71 – Primary Drain Voltage and Current in Port 1 at 132 VAC, Port 1: 20.0 V, 1 A, 20 W, Port 2: 20.0 V, 2.25 A, 45 W
V_{MAX} = 385.77 V
f_{SW} = 36.90 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

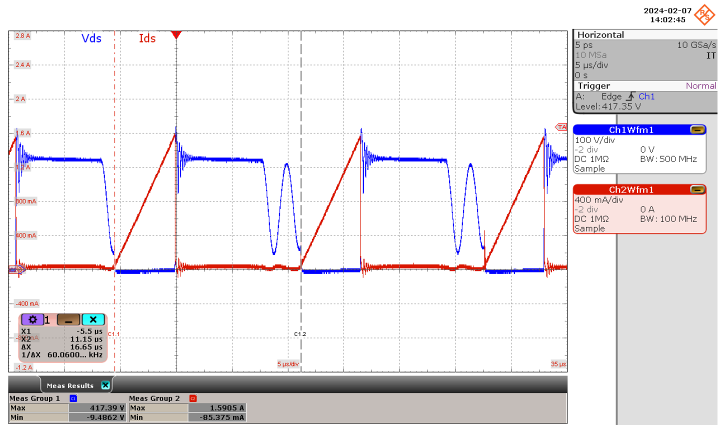


Figure 72 – Primary Drain Voltage and Current in Port 2 at 132 VAC, Port 1: 20.0 V, 1 A, 20 W, Port 2: 20.0 V, 2.25 A, 45 W
V_{MAX} = 417.39 V
f_{SW} = 60.06 kHz
CH1: V_{DRAIN}, 100 V / div.
CH2: I_{DRAIN}, 0.4 A / div.
Time: 5 µs / div.

14.4 SR FET Drain Voltage and Current (Steady-State)

14.4.1 Output: Port 1: 20 V / 3.25 A (65 W), Port 2: No-Load

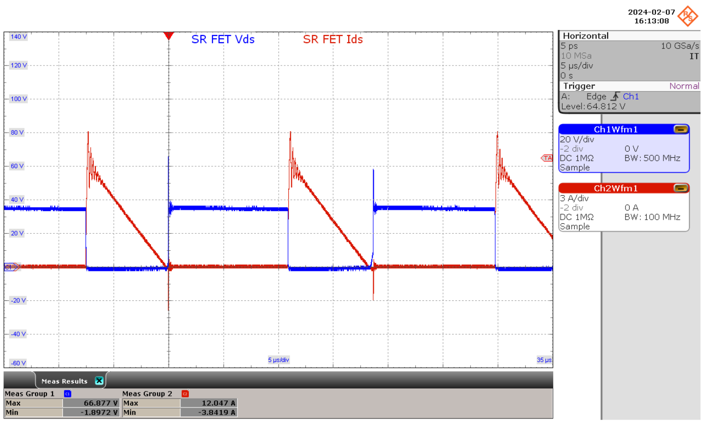


Figure 73 – SR FET Drain Voltage and Current in Port 1 at 90 VAC, Port 1: 20.0 V, 3.25 A, 65 W, Port 2: No-Load
V_{MAX} = 66.88 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

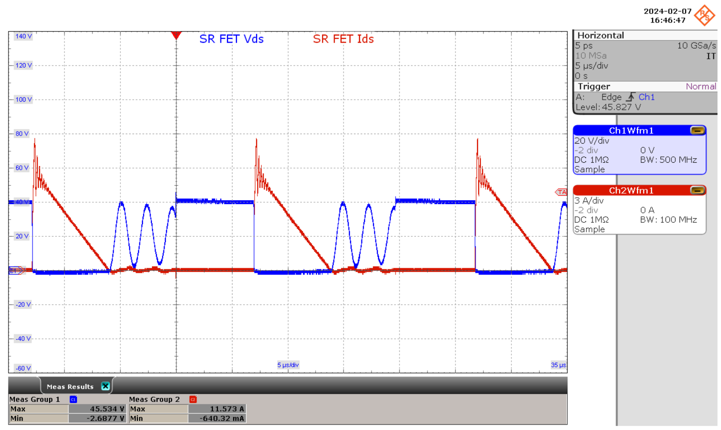


Figure 74 – SR FET Drain Voltage and Current in Port 2 at 90 VAC, Port 1: 20.0 V, 3.25 A, 65 W, Port 2: No-Load
V_{MAX} = 45.53 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

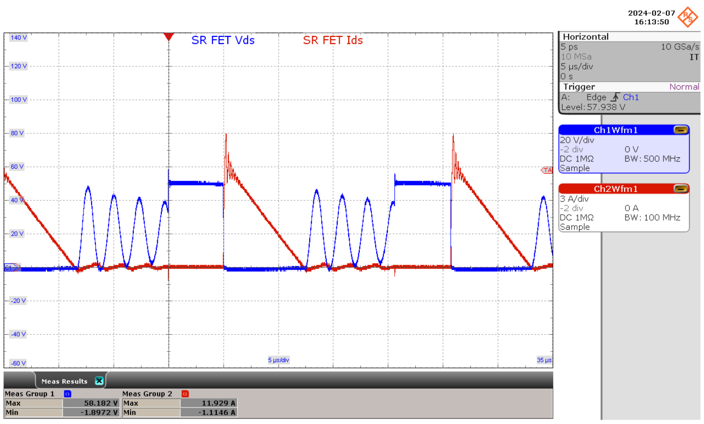


Figure 75 – SR FET Drain Voltage and Current in Port 1 at 132 VAC, Port 1: 20.0 V, 3.25 A, 65 W, Port 2: No-Load
V_{MAX} = 58.18 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

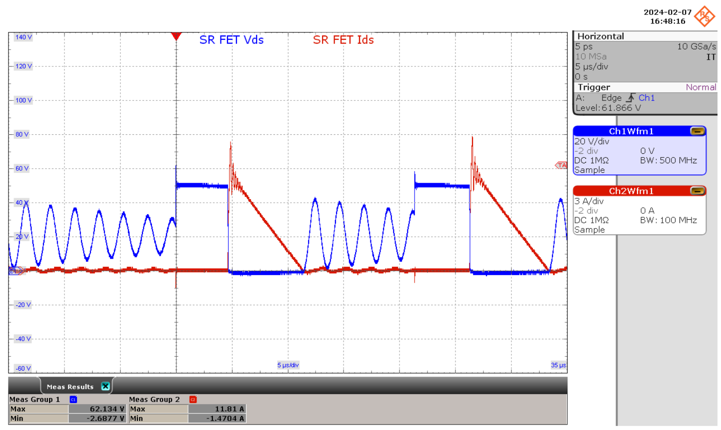


Figure 76 – SR FET Drain Voltage and Current in Port 2 at 132 VAC, Port 1: 20.0 V, 3.25 A, 65 W, Port 2: No-Load
V_{MAX} = 62.13 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

14.4.2 Output: Port 1: No-Load, Port 2: 20 V / 3.25 A (65 W)

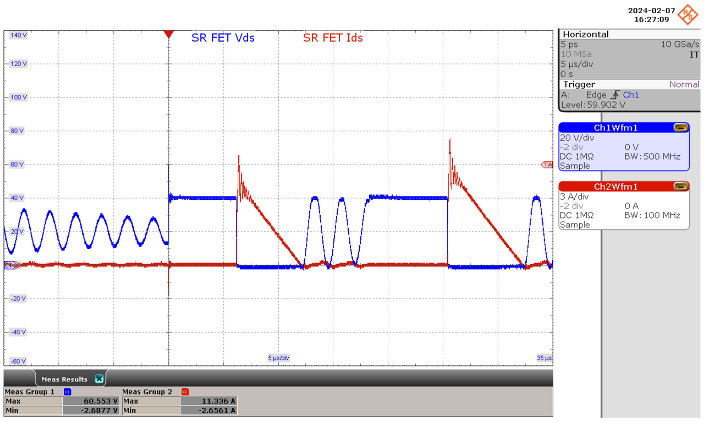


Figure 77 – SR FET Drain Voltage and Current in Port 1 at 90 VAC, Port 1: No-Load, Port 2: 20 V / 3.25 A, 65 W
V_{MAX} = 60.55 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

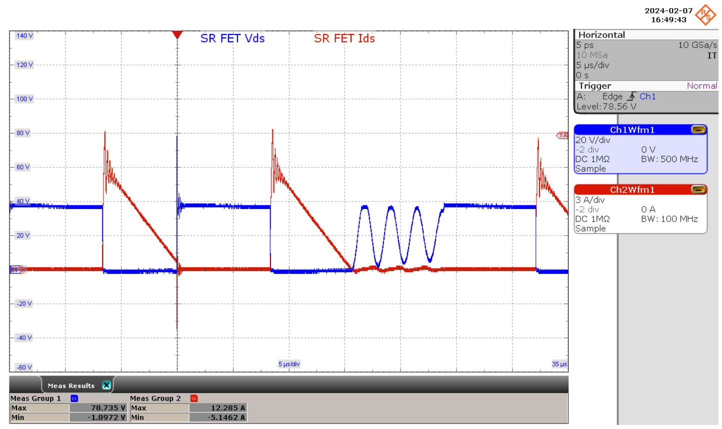


Figure 78 – SR FET Drain Voltage and Current in Port 2 at 90 VAC, Port 1: No-Load, Port 2: 20 V / 3.25 A, 65 W
V_{MAX} = 78.74 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

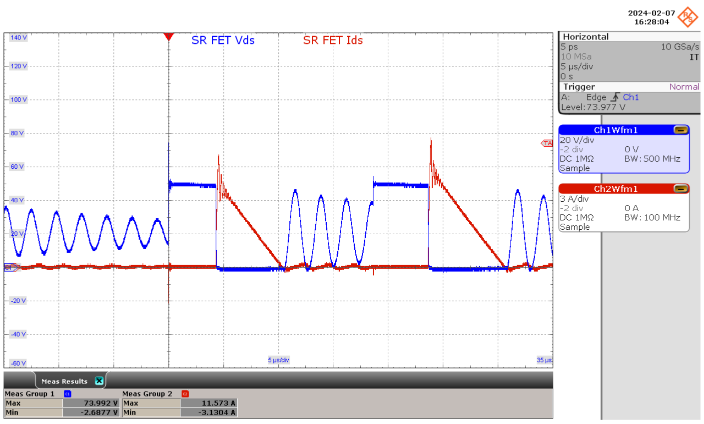


Figure 79 – SR FET Drain Voltage and Current in Port 1 at 132 VAC, Port 1: No-Load, Port 2: 20 V / 3.25 A, 65 W
V_{MAX} = 73.99 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

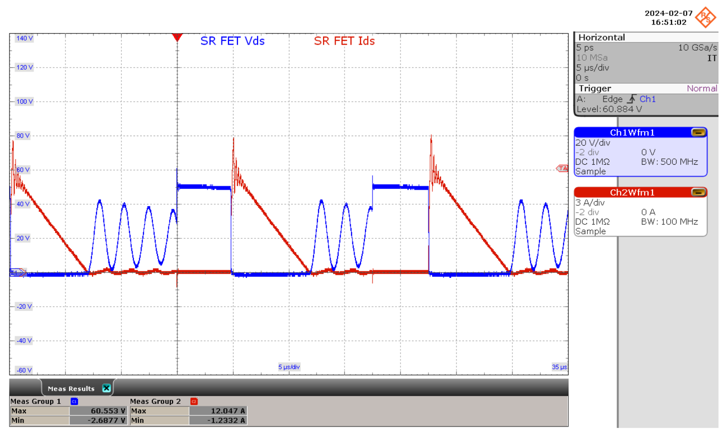


Figure 80 – SR FET Drain Voltage and Current in Port 2 at 132 VAC, Port 1: No-Load, Port 2: 20 V / 3.25 A, 65 W
V_{MAX} = 60.55 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

14.4.3 Output: Port 1: 20 V / 2.25 A (45 W), Port 2: 20 V / 1 A (20 W)

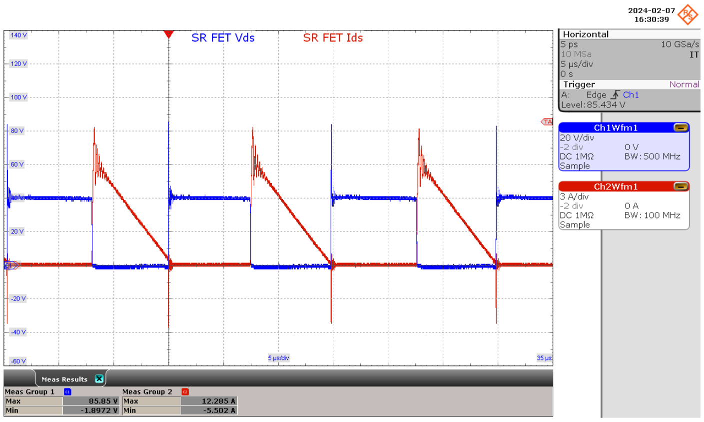


Figure 81 – SR FET Drain Voltage and Current in Port 1 at 90 VAC, Port 1: 20.0 V, 2.25 A, 45 W, Port 2: 20.0 V, 1 A, 20 W
V_{MAX} = 85.85 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

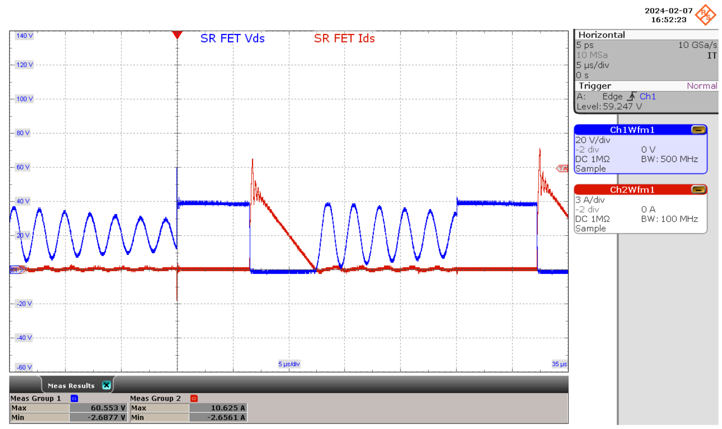


Figure 82 – SR FET Drain Voltage and Current in Port 2 at 90 VAC, Port 1: 20.0 V, 2.25 A, 45 W, Port 2: 20.0 V, 1 A, 20 W
V_{MAX} = 60.55 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

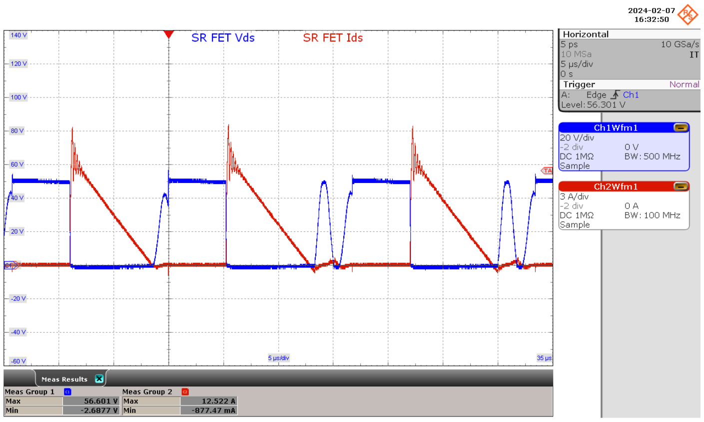


Figure 83 – SR FET Drain Voltage and Current in Port 1 at 132 VAC, Port 1: 20.0 V, 2.25 A, 45 W, Port 2: 20.0 V, 1 A, 20 W
V_{MAX} = 56.60 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

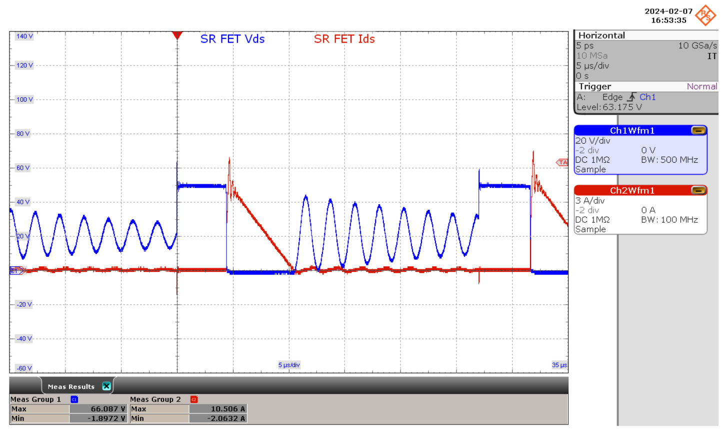


Figure 84 – SR FET Drain Voltage and Current in Port 2 at 132 VAC, Port 1: 20.0 V, 2.25 A, 45 W, Port 2: 20.0 V, 1 A, 20 W
V_{MAX} = 66.09 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

14.4.4 Output: Port 1: 20 V / 1 A (20 W), Port 2: 20 V / 2.25 A (45 W)

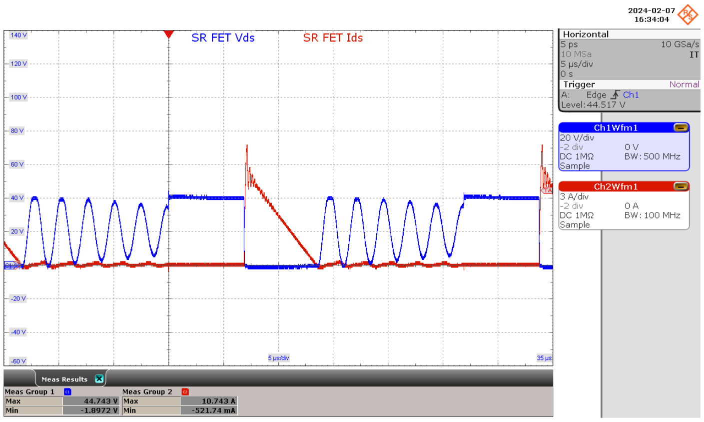


Figure 85 – SR FET Drain Voltage and Current in Port 1 at 90 VAC, Port 1: 20.0 V, 1 A, 20 W, Port 2: 20.0 V, 2.25 A, 45 W
V_{MAX} = 44.74 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

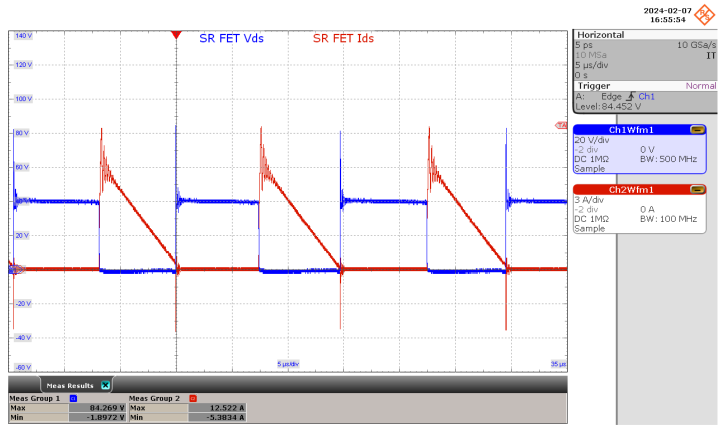


Figure 86 – SR FET Drain Voltage and Current in Port 2 at 90 VAC, Port 1: 20.0 V, 1 A, 20 W, Port 2: 20.0 V, 2.25 A, 45 W
V_{MAX} = 84.27 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

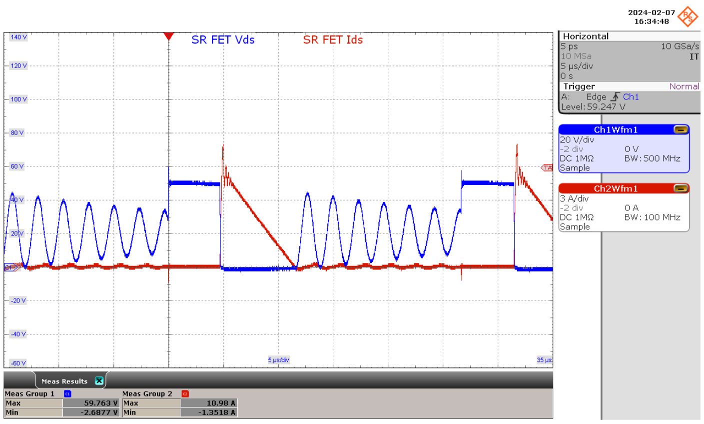


Figure 87 – SR FET Drain Voltage and Current in Port 1 at 132 VAC, Port 1: 20.0 V, 1 A, 20 W, Port 2: 20.0 V, 2.25 A, 45 W
V_{MAX} = 59.76 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

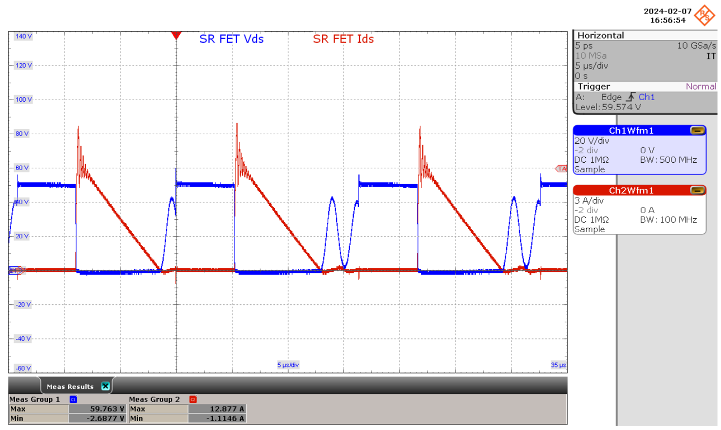


Figure 88 – SR FET Drain Voltage and Current in Port 2 at 132 VAC, Port 1: 20.0 V, 1 A, 20 W, Port 2: 20.0 V, 2.25 A, 45 W
V_{MAX} = 59.76 V
CH1: V_{SRFET_DRAIN}, 20 V / div.
CH2: I_{SRFET_DRAIN}, 3 A / div.
Time: 5 µs / div.

15 Output Ripple Measurements

15.1 Ripple Measurement Technique

For DC output ripple measurements, a modified oscilloscope test probe must be utilized to reduce spurious signals due to pick-up. Details of the probe modification are provided in the Figures below.

The 4987BA probe adapter is affixed with two capacitors tied in parallel across the probe tip. The capacitors include one (1) 0.1 μF / 50 V ceramic type and one (1) 47 μF / 50 V aluminum electrolytic. The aluminum electrolytic type capacitor is polarized, so proper polarity across DC outputs must be maintained (see below).

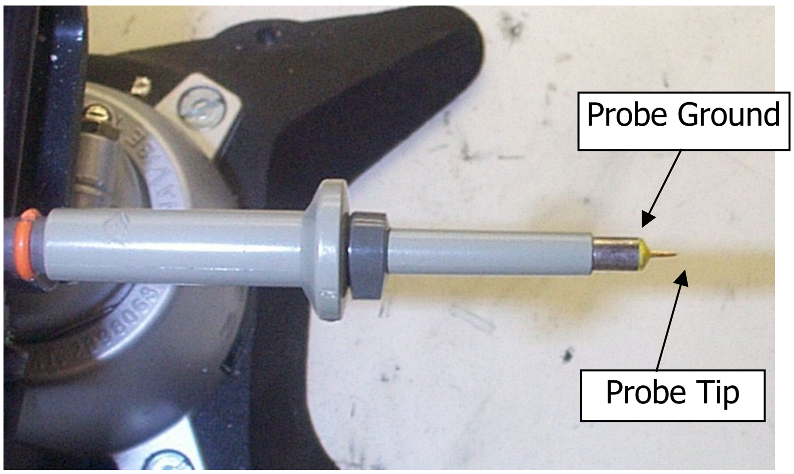


Figure 89 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

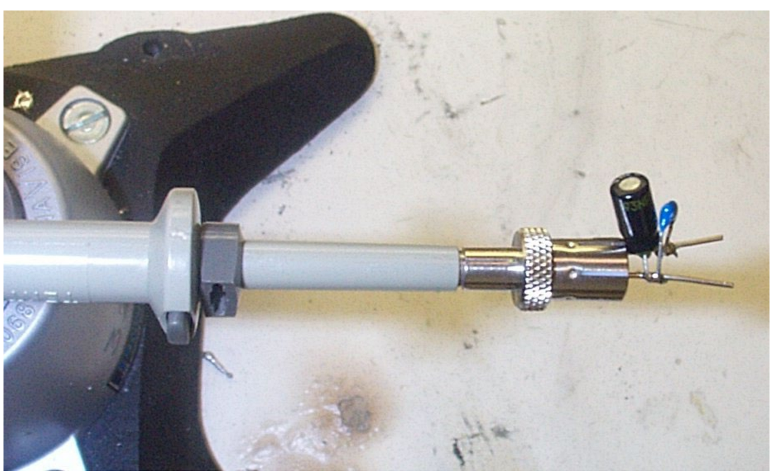


Figure 90 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

15.2 Output Voltage Ripple Waveforms

Note: 1. Output voltages captured at the end of 100 mΩ cable.
2. Measurements taken at room temperature ambient (approximately 25 °C).

15.2.1 Output: 20 V / 3.25 A

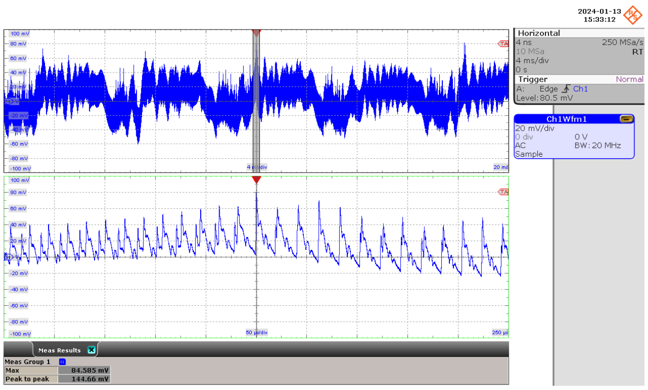


Figure 91 – Output Voltage Ripple.
90 VAC, 20 V,
3.25 A Load (144.66 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

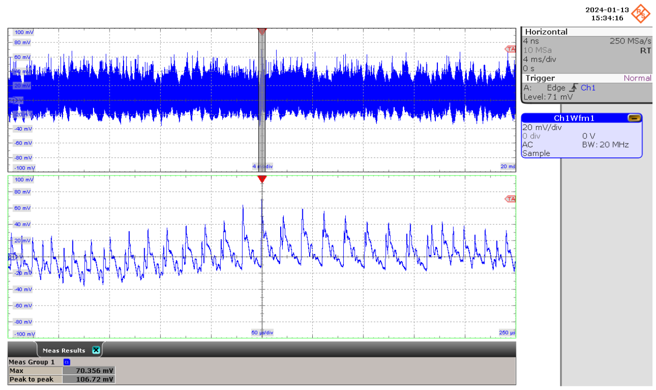


Figure 92 – Output Voltage Ripple.
132 VAC, 20 V,
3.25 A Load (106.72 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

15.2.2 Output: 15 V / 3 A

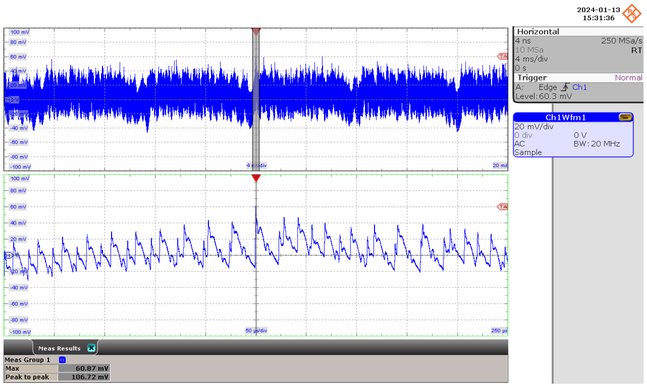


Figure 93 – Output Voltage Ripple.
90 VAC, 15 V,
3 A Load (106.72 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

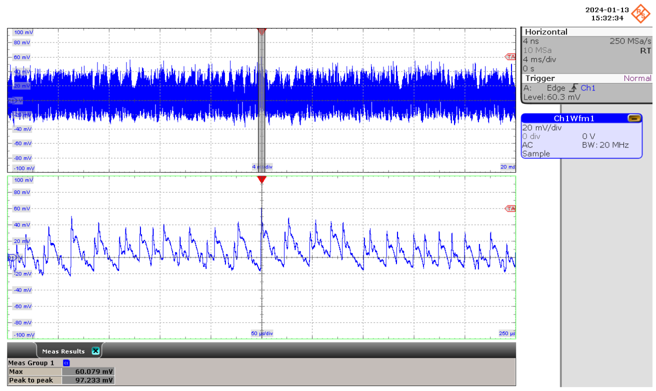


Figure 94 – Output Voltage Ripple.
132 VAC, 15 V,
3 A Load (97.23 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

15.2.3 Output: 12 V / 3 A

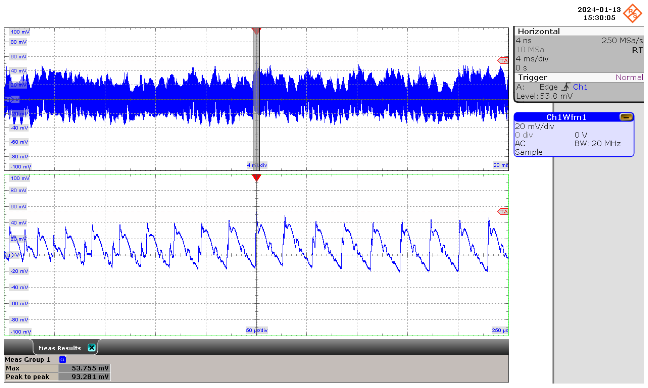


Figure 95 – Output Voltage Ripple.
90 VAC, 12 V,
3 A Load (93.28 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

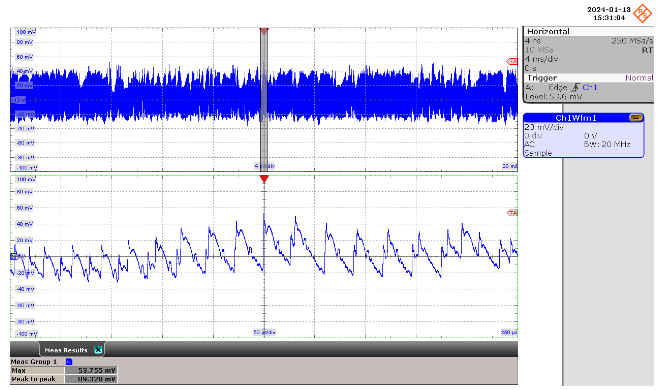


Figure 96 – Output Voltage Ripple.
132 VAC, 12 V,
3 A Load (89.33 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

15.2.4 Output: 9 V / 3 A

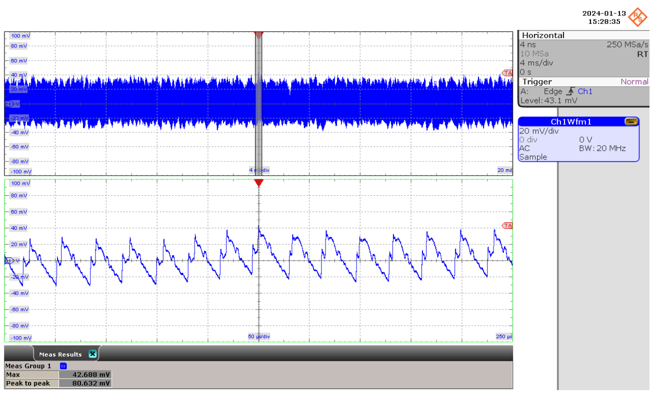


Figure 97 – Output Voltage Ripple.
90 VAC, 9 V,
3 A Load (80.63 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

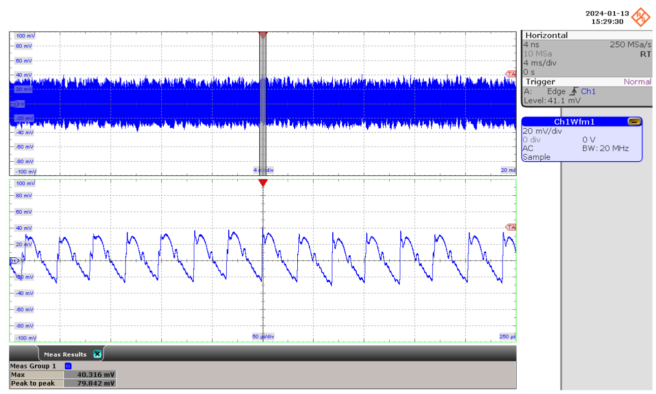


Figure 98 – Output Voltage Ripple.
132 VAC, 9 V,
3 A Load (79.84 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

15.2.5 Output: 5 V / 3 A

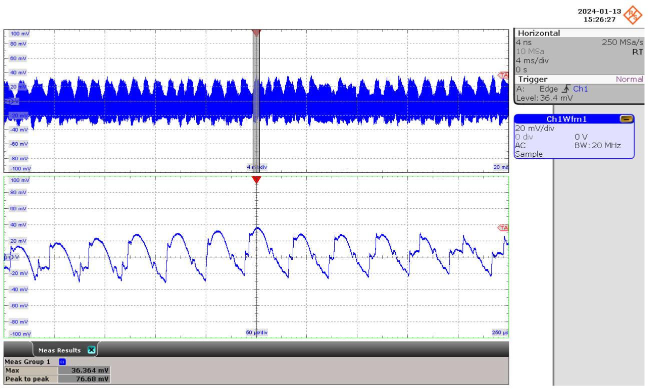


Figure 99 – Output Voltage Ripple.
90 VAC, 5 V,
3 A Load (76.68 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

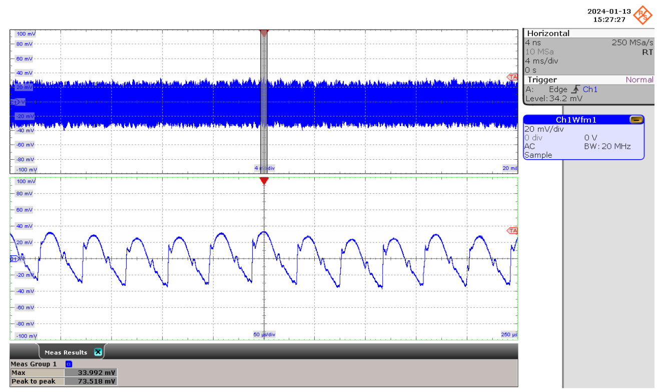


Figure 100 – Output Voltage Ripple.
132 VAC, 5 V,
3 A Load (73.52 mV_{PP}).
CH1: $V_{OUT(AC)}$, 20 mV / div.
Time: 4 ms / div.
Zoom: 50 µs / div. Zoom

15.3 Output Voltage Ripple Amplitude vs. Load

15.3.1 Output: 20 V / 3.25 A

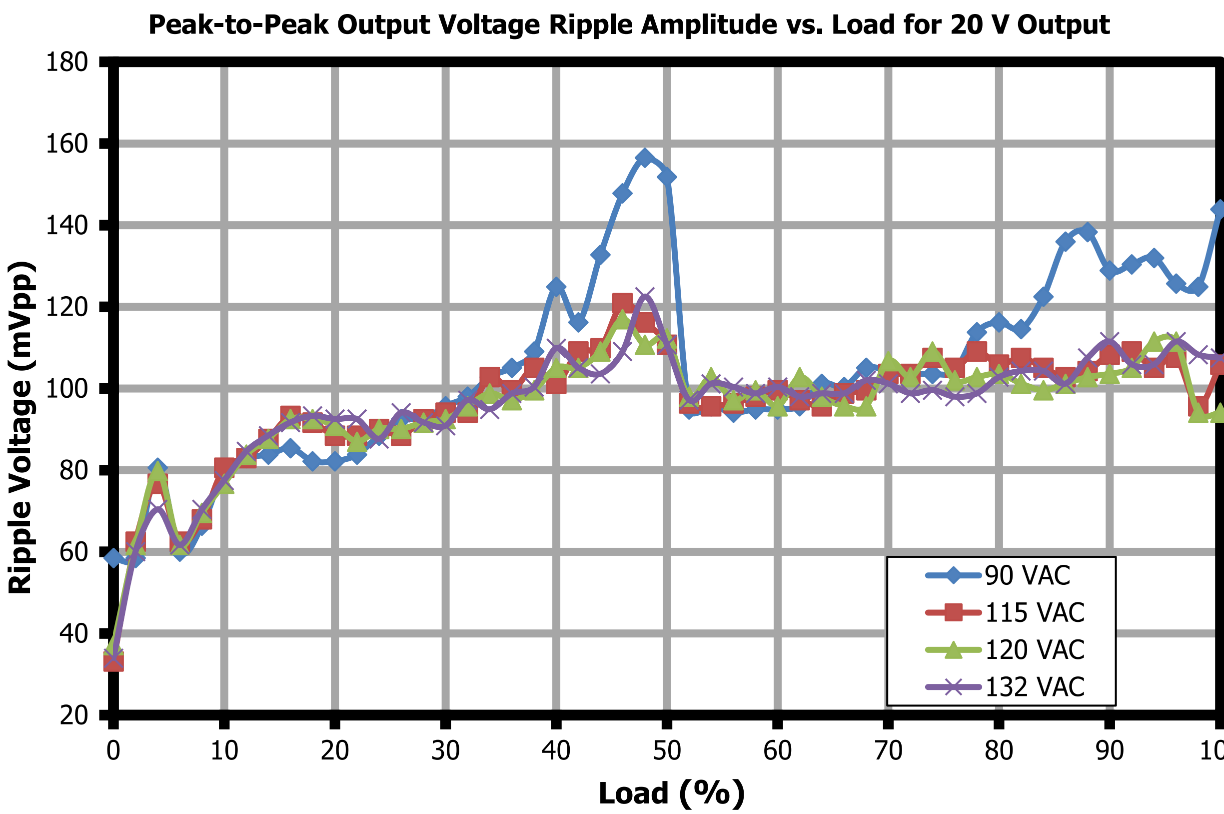


Figure 101. Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 20 V Output.

15.3.2 Output: 15 V / 3 A

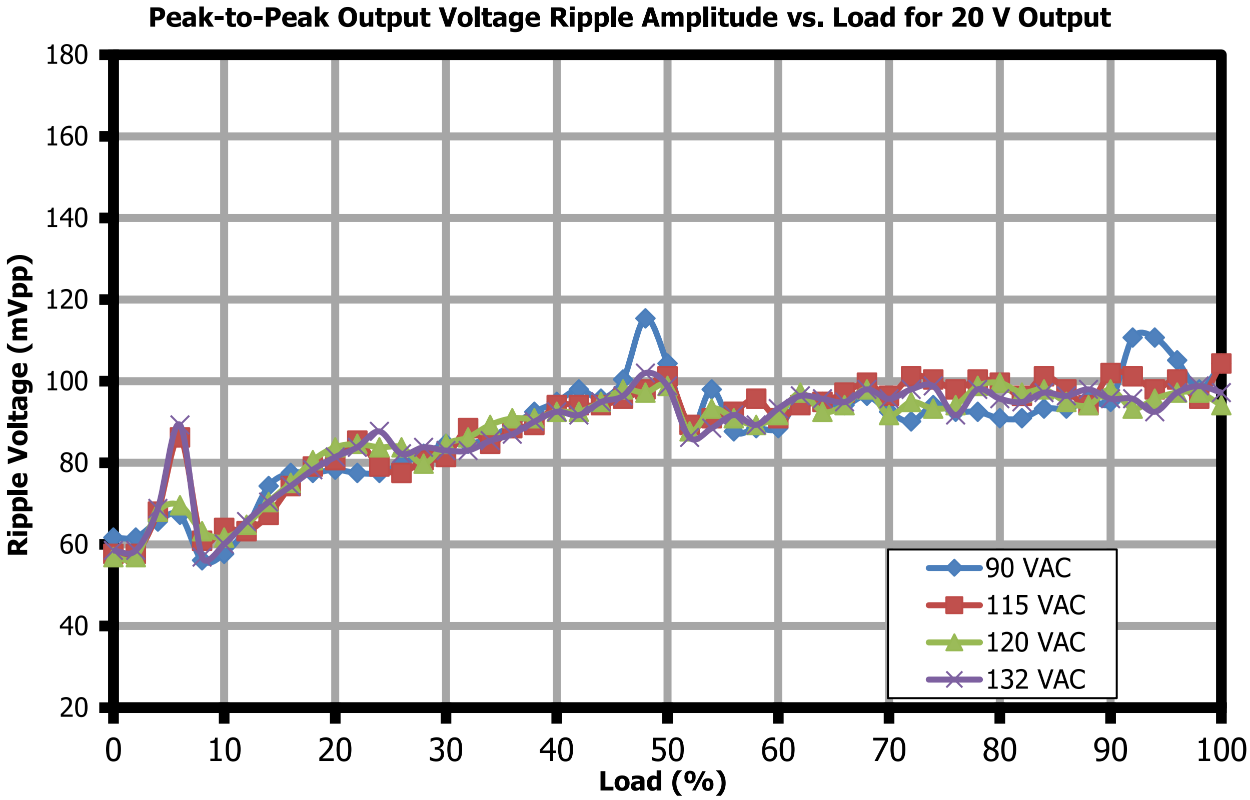


Figure 102 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 15 V Output.

15.3.3 Output: 12 V / 3 A

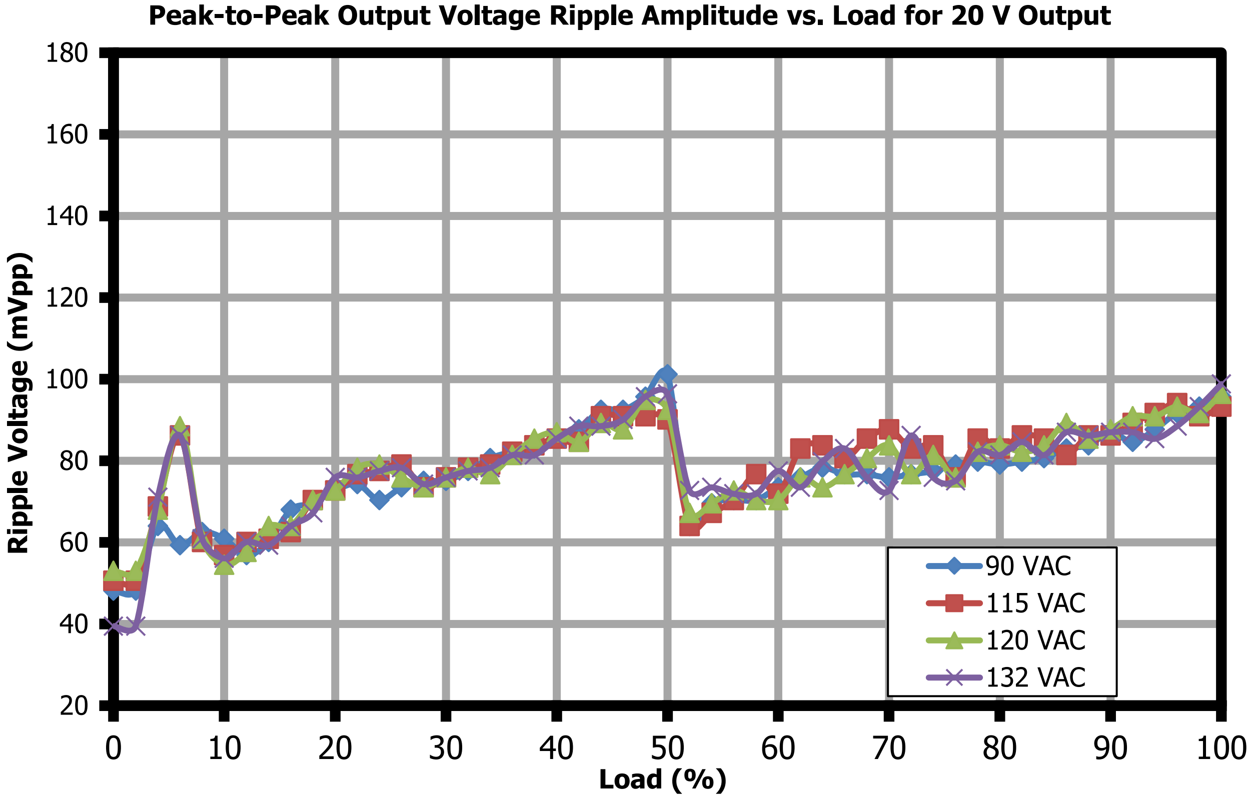


Figure 103 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 12 V Output.

15.3.4 Output: 9 V / 3 A

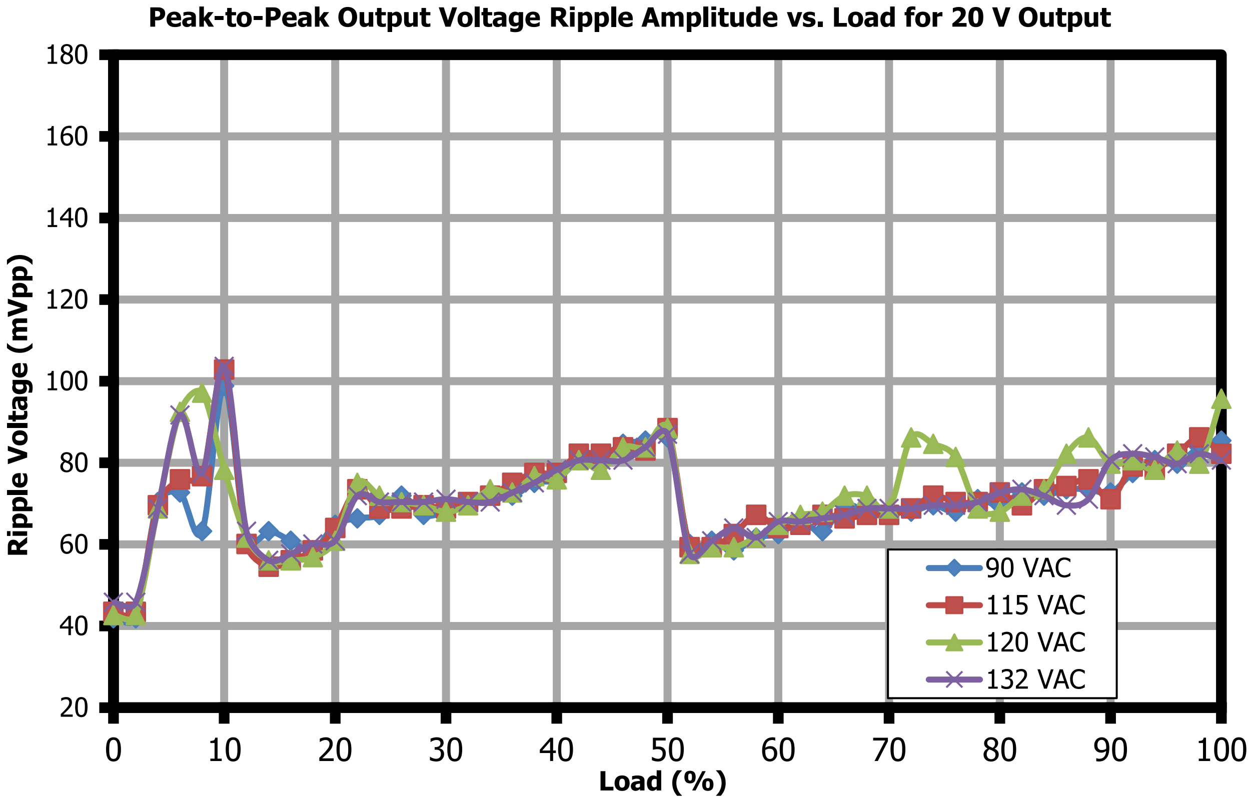


Figure 104 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 9 V Output.

15.3.5 Output: 5 V / 3 A

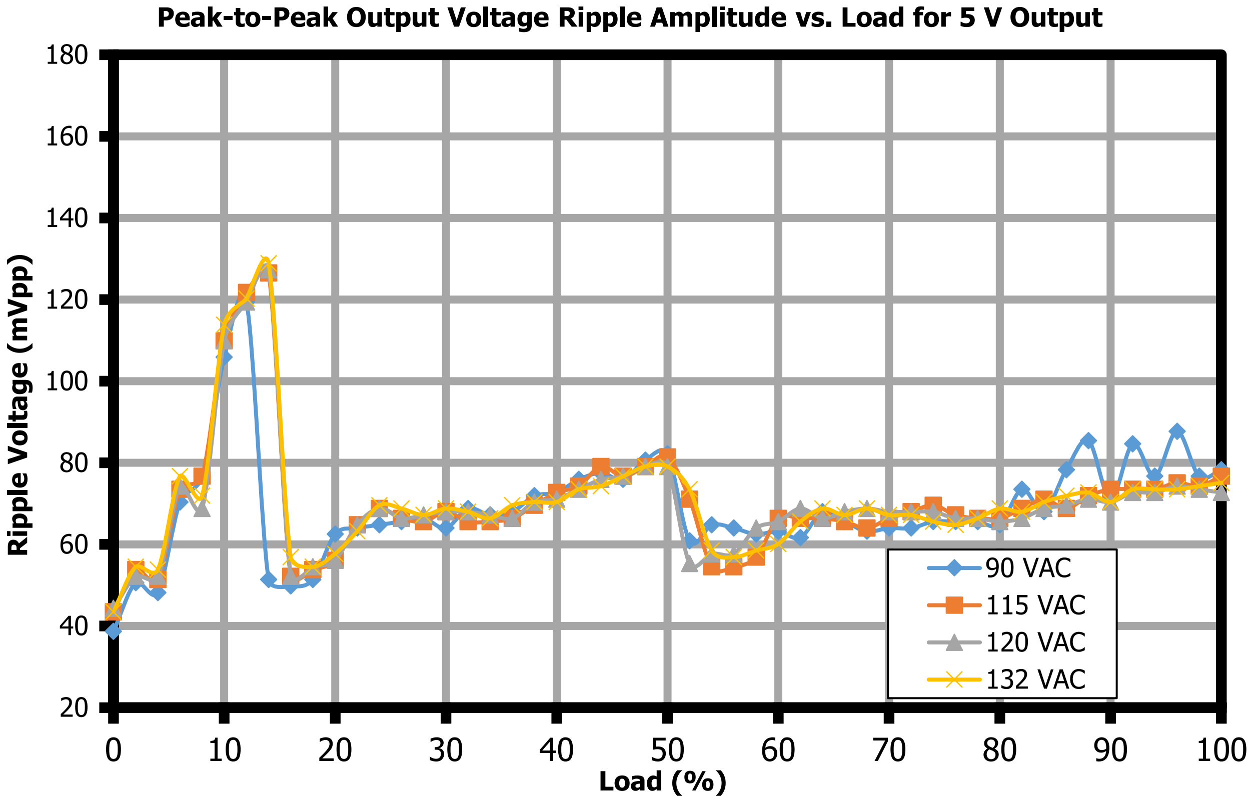


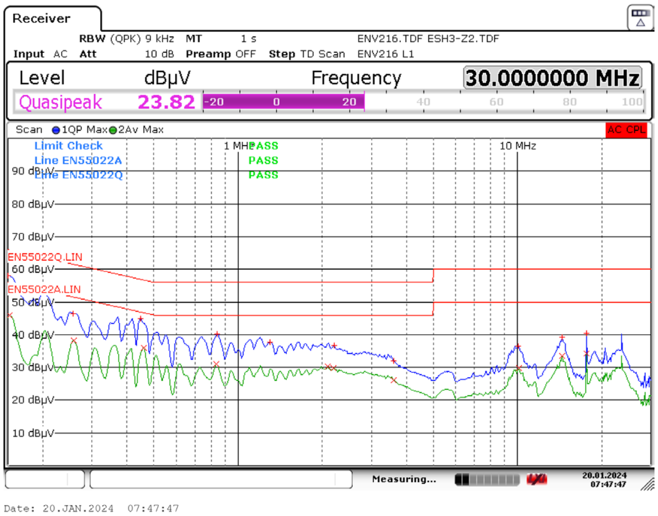
Figure 105 – Peak-to-Peak Output Voltage Ripple Amplitude vs. Load for 5 V Output.

16 Conducted EMI

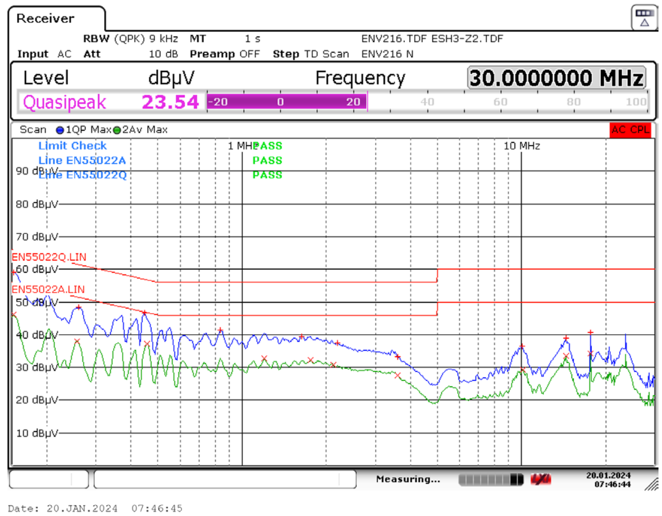
Note: EMI plots captured with heat spreader and adapter case enclosed.

16.1 Floating Ground (QPK / AV)

16.1.1 Single Port Output: Port A 65 W 20 V / 3.25 A and Port B Open



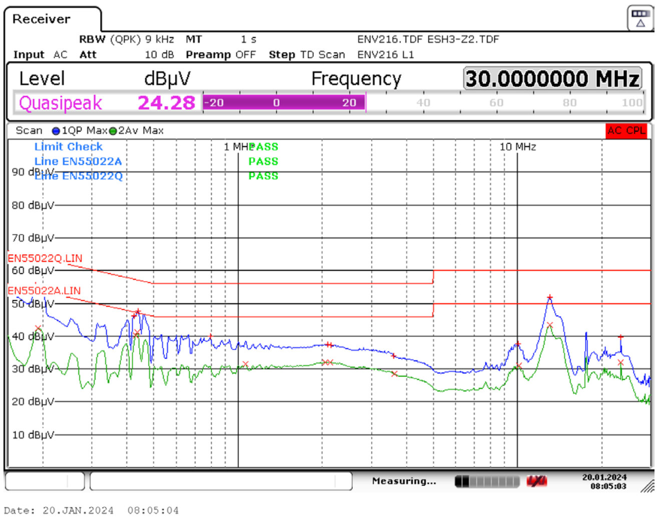
115 VAC Line Scan



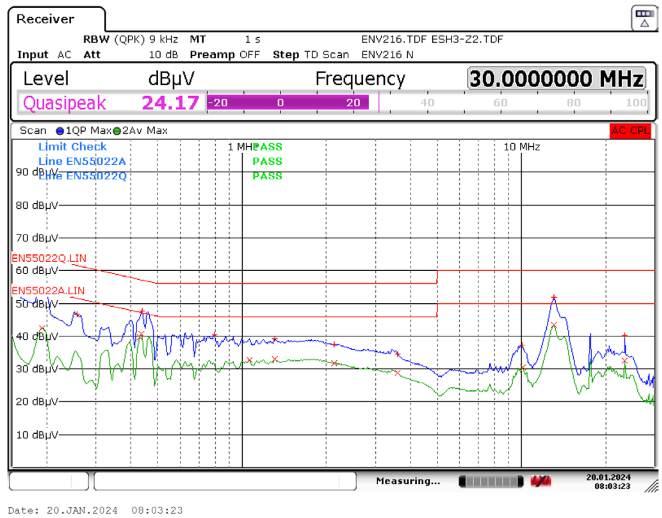
115 VAC Neutral Scan

Figure 106 – Floating Ground EMI, 20 V / 3.25 A Load.

16.1.2 Dual Port Output: Port A 45 W 20 V / 2.25 A and Port B 20 W 20 V / 1 A



115 VAC Line Scan.



115 VAC Neutral Scan

Figure 107 – Floating Ground EMI, 20 V / 2.25 A and 20 V / 1 A Load.

17 Surge

The unit was subjected to ±1000 V differential mode, ±2000 V common mode combination wave surge, ±2500 V differential ring wave at several line phase angles with 10 strikes for each condition.

A test failure was defined as an output latch-off that needs operator intervention to recover, or a complete loss of function that is not recoverable.

Note: Surge tested on the power supply with potting and plastic case enclosure.

17.1 Combination Wave Surge at 115 VAC, Differential Mode

Test Voltage (V)	Input Voltage (VAC)	Coupling	Injection Phase (°)	Test Result (Pass/Fail)
1000	115	L to N	0	Pass
-1000	115	L to N	0	Pass
1000	115	L to N	90	Pass
-1000	115	L to N	90	Pass
1000	115	L to N	270	Pass
-1000	115	L to N	270	Pass

17.2 Combination Wave Surge at 115 VAC, Common Mode

Test Voltage (V)	Input Voltage (VAC)	Coupling	Injection Phase (°)	Test Result (Pass/Fail)
2000	115	L, N to PE	0	Pass
-2000	115	L, N to PE	0	Pass
2000	115	L, N to PE	90	Pass
-2000	115	L, N to PE	90	Pass
2000	115	L, N to PE	270	Pass
-2000	115	L, N to PE	270	Pass

17.3 Ring Wave Surge at 115 VAC, Differential Mode

Test Voltage (V)	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
2500	115	L to N	0	Pass
-2500	115	L to N	0	Pass
2500	115	L to N	90	Pass

-2500	115	L to N	90	Pass
2500	115	L to N	180	Pass
-2500	115	L to N	180	Pass
2500	115	L to N	270	Pass
-2500	115	L to N	270	Pass

18 Electrostatic Discharge

The unit was tested with ±8 kV to ±16.5 kV air discharge and ±8.8 kV contact discharge with 10 strikes for each condition at the following locations:

- End of cable +VOUT
- End of cable GND

A test failure was defined as a complete loss of function without resetting the AC input that is not recoverable even with operator intervention.

Note:

1. End of cable discharge points (VOUT, GND) located on the USB-C power adapter tester Power-Z
2. Type-C cable for VOUT and GND strikes: UGREEN 240W USB C to USB C Cable, Fast Charging USB C Cable, 1 meter.

18.1 Contact Discharge, +VOUT and GND, 115 VAC Input

Discharge Voltage (kV)	**ESD Strike Location**		**Test Result Port A: 20 V / 2.25 A Port B: 20 V / 1 A**	**Test Result Single Port 20 V / 3.25 A**
+8.8	End of Cable	+VOUT	Pass with AR	Pass with AR
		GND	Pass with AR	Pass with AR
-8.8		+VOUT	Pass	Pass
		GND	Pass	Pass

18.2 Air Discharge, +VOUT and GND, 115 VAC Input

Discharge Voltage (kV)	**ESD Strike Location (End of Type-C Cable)**		**Test Result Port A: 20 V / 2.25 A Port B: 20 V / 1 A**	**Test Result Single Port 20 V / 3.25 A**
+8	End of Cable	+VOUT	Pass with AR	Pass with AR
		GND	Pass with AR	Pass with AR
-8		+VOUT	Pass	Pass
		GND	Pass	Pass
+10		+VOUT	Pass with AR	Pass with AR
		GND	Pass with AR	Pass with AR
-10		+VOUT	Pass	Pass
		GND	Pass	Pass
+12		+VOUT	Pass with AR	Pass with AR
		GND	Pass with AR	Pass with AR
-12		+VOUT	Pass	Pass
		GND	Pass	Pass
+14		+VOUT	Pass with AR	Pass with AR
		GND	Pass with AR	Pass with AR
-14		+VOUT	Pass	Pass
		GND	Pass	Pass
+16.5		+VOUT	Pass with IP2738 latching but recovered with output reset	Pass with AR
		GND	Pass with IP2738 latching but recovered with output reset	Pass with AR
-16.5		+VOUT	Pass with IP2738 latching but recovered with output reset	Pass
		GND	Pass	Pass

19 Revision History

Date	Author	Revision	Description & Changes	Reviewed
26-Feb-24	CMC/MGM	1.0	Initial Release.	Apps & Mktg

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

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