Design Example Report

Title	***100 W Compact Power Supply Using PowiGaN™ InnoSwitch™4-CZ (INN4077C - H182) and ClampZero™ (CPZ1075M)***
Specification	100 VAC – 132 VAC Input; 5 V / 6.5 A, 9V / 6 A, 15 V / 5 A, 20 V / 5 A Outputs
Application	In-Wall Charger, USB Wall Outlet, Power Strip with USB Charging Ports
Author	Applications Engineering Department
Document Number	DER-979
Date	April 18, 2023
Revision	1.0

Summary and Features

- 100 W low profile compact power supply for high power USB Type-A/C port charging
- >94.5% Full Load Efficiency at nominal Input
- Optimized for 100 VAC to 132 VAC operation
- <25 mW system no-load input power
- PowiGaN-based InnoSwitch4-CZ benefits
    - Highly integrated switcher IC with integrated high-voltage switch, synchronous rectification and FluxLink™ feedback
    - Zero voltage switching in both CCM and DCM operating conditions
    - GAN-based Integrated MOSFET enables heat sink-less design
    - Fast instantaneous transient response with 0%-100%-0% load step
- Low components count (<60)
- Easily meets DOE6 efficiency requirements
- Integrated protection and reliability features
    - Output short-circuit protection
    - OVP, OCP and OTP protection
- Meets 2.0 kV differential surge and EN55022 conducted EMI
- Suitable for compact enclosures with high operating ambient temperature
- Very high power density: 35.7 W/in^3 without enclosure (100 W / 2.30 in X 1.52 in X 0.8 in)

PATENT INFORMATION

Power Integrations
5245 Hellyer Avenue, San Jose, CA 95138 USA.
Tel: +1 408 414 9200   Fax: +1 408 414 9201
www.power.com

Table of Contents

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

1 Introduction

This engineering report describes an off-line 100 W isolated flyback power supply designed to operate at an input voltage range from 100 VAC to 132 VAC within its 4 selectable output ranges (20 V / 5 A, 15 V / 5 A, 9 V / 6 A and 5 V / 6.5 A). This power supply uses active clamp flyback topology featuring Power Integrations' InnoSwitch4-CZ (INN4077C-H182) partnered with ClampZero (CPZ1075M).

The InnoSwitc4-CZ family of ICs partners with the ClampZero family of active clamp ICs to dramatically improve the efficiency of flyback power converters, particularly those requiring a compact form-factor. This combination of ICs greatly reduces system and primary switch losses, allowing for extremely high-power densities.

The InnoSwitch4-CZ family incorporates primary and secondary controllers and safety-rated feedback into a single IC. It also includes multiple protection features including output overvoltage and over-current limiting, and over-temperature shutdown.

DER-979 offers a high efficiency (94.5%), low component count, and heat sink-less design to meet increasing demands for power savings and small form factor enclosures. It is also suitable for compact enclosures with high operating ambient temperatures due to InnoSwitch4-CZ's excellent thermal performance and the use of a four-layer PCB design.

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

Figure 1 – Populated Circuit Board.

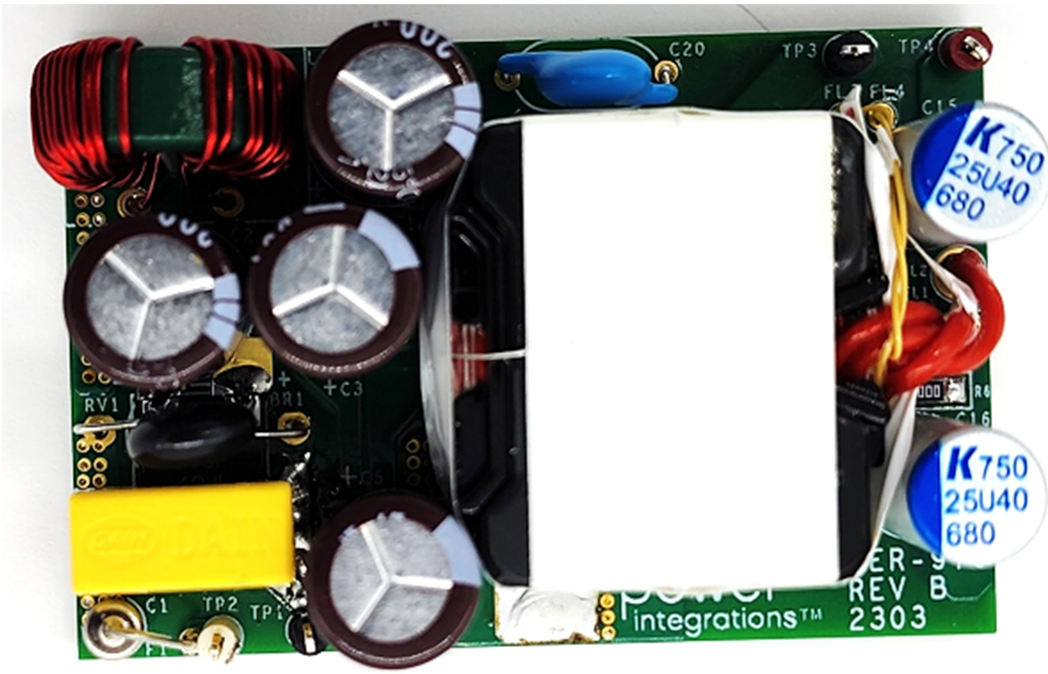


Figure 2 – Populated Circuit Board, Top View.

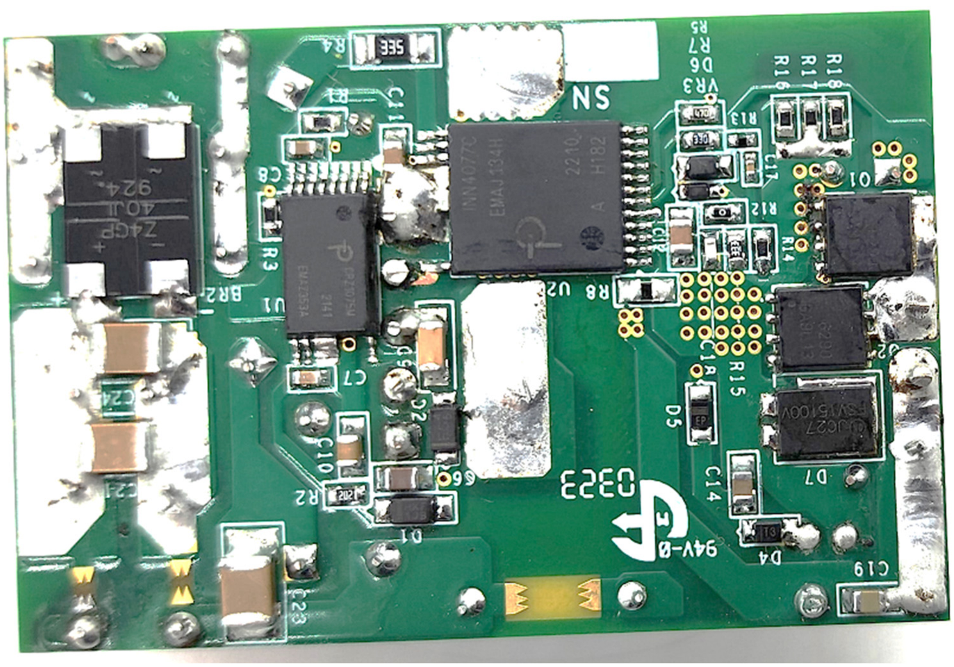


Figure 3 – Populated Circuit Board, Bottom View.

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}	100	115	132	VAC	2 Wire – no P.E.
Frequency	f_{LINE}		60		Hz	
No-load Input Power			< 30		mW	Measured at 115 VAC, 5 V Output.
5 V Output						
Output Voltage	V_{OUT}		5		V	±3% Voltage Regulation.
Output Ripple Voltage	V_{RIPPLE}			150	mV	End of 100mΩ cable Wire.
Output Current	I_{OUT}			6.5	A	
Efficiency	n		> 92.5		%	Measured at 115 VAC. V_{OUT} is measured on the board.
9 V Output						
Output Voltage	V_{OUT}		9		V	±3% Voltage Regulation.
Output Ripple Voltage	V_{RIPPLE}			150	mV	End of 100 mΩ Cable.
Output Current	I_{OUT}			6	A	
Efficiency	n		> 93.5		%	Measured at 115 VAC. V_{OUT} is Measured on the Board.
15 V Output						
Output Voltage	I_{OUT}		15		V	±3% Voltage Regulation.
Output Ripple Voltage	V_{RIPPLE}			150	mV	End of 100 mΩ Cable.
Output Current	I_{OUT}			5	A	
Efficiency	n		> 94		%	Measured at 115 VAC. V_{OUT} is Measured on the Board.
20 V Output						
Output Voltage	V_{OUT}		20		V	±3% Voltage Regulation.
Output Ripple Voltage	V_{RIPPLE}			150	mV	End of 100 mΩ Cable.
Output Current	I_{OUT}			5	A	
Efficiency	n		> 94.5		%	Measured at 115 VAC. V_{OUT} is Measured on the Board.

3 Schematic

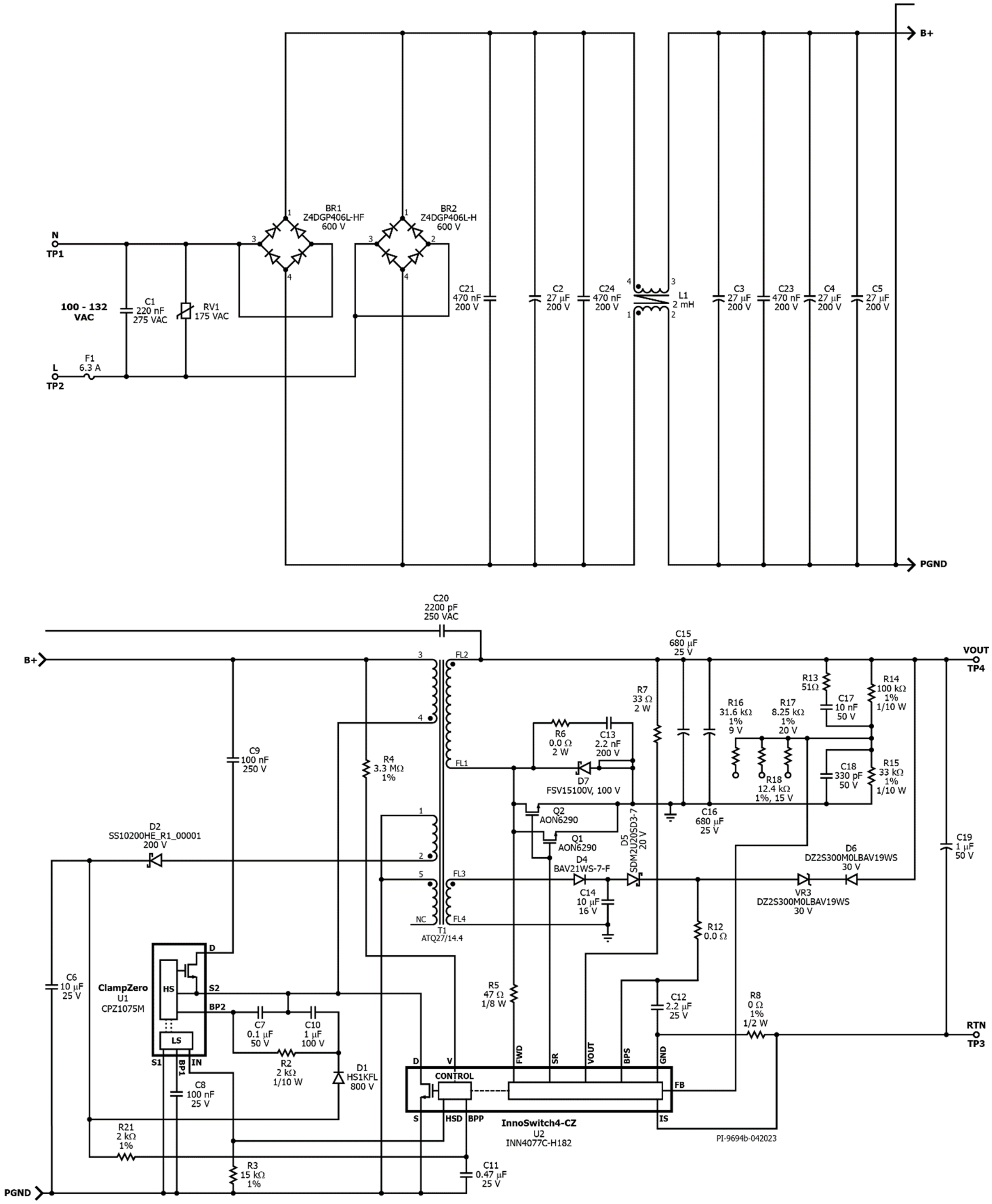


Figure 4 – Main Board Schematic.

4 Circuit Description

The circuit is an active clamp flyback power supply with synchronous rectification controlled by the InnoSwitch4-CZ IC (U2) using PowiGaN as primary-side switch. Besides the high-voltage PowiGaN switch, the IC incorporates primary-side controller, secondary-side controller and FluxLink feedback control in one single package. Moreover, it controls the ClampZero IC (U1) for the active clamp operation needed to obtain ultra-high efficiencies. The decreased switching losses allows the InnoSwitch4-CZ IC to operate at high switching frequencies, resulting to smaller magnetics and decreased overall form factor of the power supply.

4.1 Input EMI Filter and Rectifier

The input fuse (F1) provides safety protection from component failures. Metal oxide varistor (RV1) helps prevent component failure in the event of high-voltage input line surge. The AC input voltage is full wave rectified by the bridge rectifier (BR1 and (BR2) and then filtered by the bulk capacitors (C2, C3, C4, and C5) to provide a smooth DC input voltage supply to the flyback circuitry. Input differential mode choke (L1) is connected between C2 and C3, C4, and C5 to provide differential mode noise filtering and at the same time forms a PI filter circuit. A low ESR electrolytic capacitor is recommended for the bulk capacitors (C2, C3, C4, and C5) for better differential mode noise filtering and higher efficiency. Y capacitor (C20) bypass common mode noise back to the primary power ground. X capacitor (C1) helps reduce the differential mode EMI noise and input surge voltages.

4.2 Primary-Side Controller: InnoSwitch4-CZ

The power transformer (T1) is designed for flyback power conversion. For a better EMI shielding, the primary winding start terminal (pin 4) must be connected to the noisy DRAIN pin of the PowiGaN switch inside InnoSwitch4-CZ IC and the finish terminal (pin 3) is connected to the positive terminal of the bulk capacitor (C4).

In contrast with the traditional RCD clamp, this snubber configuration used by InnoSwitch4-CZ IC does not use resistors to dissipate energy from the leakage inductance. Rather, the energy from the leakage inductance gets stored in C9 and eventually recycled to achieve zero-voltage switching (ZVS) across the PowiGaN. Right before the next turn-on of the PowiGaN primary switch, the high-side switch of the ClampZero IC turns on, causing the leakage energy stored on the clamp capacitor C9 to flow in transformer primary winding in reverse direction delivering the leakage energy to the load in forward phase. The negative current on the transformer primary winding forces the output capacitance (Coss) of the primary switch to be discharged down to zero, just in time before the primary switch turns on again. This switching pattern leads to ZVS behavior which dramatically lowers the switching losses across the PowiGaN, allowing it to operate at much higher frequencies.

When the FluxLink signal is received from the secondary-side, the InnoSwitch4-CZ IC generates a signal coming from its HSD pin to turn on the ClampZero IC (via the IN pin) for a fixed duration, t_{HSD}. During this time, C9 charges the leakage inductance, in case of CCM operation, or both the leakage and magnetizing inductances, in case of DCM operation. After the ClampZero high-side switch on time, the InnoSwitch4-CZ IC waits for a certain delay time (t_{LLDL} at lowline) before turning on the PowiGaN primary switch. The t_{LLDL} is programmable ZVS delay time through resistor R3. In this design 140 ms delay is needed to fully discharge the Coss which will lead to a better ZVS operation.

The InnoSwitch4-CZ IC is self-starting, where an internal high-voltage current source coming from the DRAIN pin charges the PRIMARY BYPASS pin (BPP) capacitor C11 that powers the primary-side controller. During normal operation, the primary-side controller is powered via the bias winding of the transformer T1. Output of this bias winding is rectified by diode D2 and filtered by capacitor C6. The bias voltage across C6 powers limiting resistor R1.

Output regulation is achieved using a modulation technique where the switching frequency, F_{SW}, and primary current limit, I_{LIM}, are adjusted based on the output load. At heavy loads, the primary pulses occur at high F_{SW} and terminates at a high value of I_{LIM} in the selected I_{LIM} range. As the load decreases, both F_{SW} and I_{LIM} also decrease. At light loads or no-load condition, F_{SW} goes down to its minimum value and several pulses get disabled (cycle skipping).

The V pin resistor (R4) serves as input line voltage monitoring. It is connected between high-voltage positive bulk capacitor (C5) and V pin terminal. The input line voltage is checked to confirm that it is above the brown-in and below the overvoltage shutdown thresholds. The value selected for R4 in total was 3.3 MΩ to get the optimum efficiency at lowline input voltage.

4.3 Active Clamp: ClampZero

Capacitor C8 serves as local decoupling to the BP1 pin of the ClampZero IC, which provides power to its low-side control. Diode D1 and capacitor C10 form a bootstrap circuit to provide the bias for the high-side BP2 pin. Resistor R1 serves as current limiting to BP2 while C7 acts as a local decoupling capacitor.

Ultrafast diode D1 prevents current from the leakage inductance to flow through its body diode at the instant the PowiGaN switch of InnoSwitch4-CZ IC turns off.

Signal from the HSD pin of InnoSwitch4-CZ IC goes to the IN pin of ClampZero IC and is then communicated by the low-side control to the high-side drive to turn on the ClampZero switch. Once on, the ClampZero IC switch provides an energy path from C7 towards the leakage inductance of T1.

As previously mentioned, the on-time of the ClampZero IC is a constant, defined by t_{HSD}, while the delay time between the ClampZero IC turn-off and the InnoSwitch4-CZ IC turn-on is defined by R2 at lowline (t_{LLDL}) or a fixed value at highline (t_{HLDL}).

The latch-off/auto-restart primary-side overvoltage protection is obtained using current limiting resistor R1. In a flyback converter, output of the bias winding tracks the output voltage of the converter by the winding turns-ratio. In case of overvoltage at the output of the converter, the auxiliary winding voltage causing a current to flow into the BPP pin of InnoSwitch4-CZ IC U2. If the current flowing into the BPP pin increases above the I_{SD} threshold, the U2 controller auto-restarts to prevent any further increase in output voltage.

4.4 Secondary-Side Control

The secondary winding start terminal (FL2) of the transformer (T1) is connected to the positive terminal of output capacitor C15 and C16 while the finish terminal (FL1) is connected to the DRAIN pin of the SR FETs (Q1 and Q2). The secondary winding voltage is rectified by the SR FETs and then filtered by the output capacitors C15 and C16. Leakage voltage spike and ringing across SR FET drain to source during off time is minimized by the secondary RC snubber (R6 and C13). For high efficiency requirement, shorting R6 will help improve the efficiency. Schottky diode D7 helps improve full load efficiency specially at 5 V where output current is highest.

The secondary-side circuity of the IC is initially self-powered by the internal regulator which is supplied by either the secondary winding forward voltage (through FW pin) or by the output voltage (through VO pin). However, to improve the system efficiency and reduce the secondary-side internal consumption, a bias winding circuit was used. It is designed to supply current to the IC when the output voltage is set to 20 V. Bias winding voltage is rectified by diode D4 and filtered by capacitor C14. Resistor R12 limits the current flowing to the BPS pin of U2. Diode D5 blocks BPS from charging C14 that might affect startup operation. Capacitor C12 connected to the BPS pin of IC U2 provides decoupling for the internal circuitry.

When the external regulator does not supply enough power or when the output voltage (VO) falls during constant current mode operation, the secondary-side internal regulator will be supplied by the secondary winding forward voltage through FORWARD (FWD) pin resistor (R5). This will maintain the output current regulation down to the minimum BPS pin auto-restart voltage threshold. Below this level the unit enters auto-restart until the output load is reduced. A 47 Ω resistor is recommended for FWD pin resistor (R5) to ensure sufficient IC supply current.

The forward voltage sensed by FWD pin from secondary winding is also used for both handshaking and switching control for the SR FET (Q1 and Q2), which is driven by the SYNCHRONOUS RECTIFIER DRIVE (SR) pin. The FWD pin voltage is used to determine when to turn off the SR FET in discontinuous conduction mode (DCM). The SR FET is turned off when the voltage drop across the MOSFET falls below $V_{SR(TH)}$. In continuous conduction mode (CCM), the SR FET is turned off just prior to the secondary-side commanding a new switching cycle to the primary.

Output current is sensed by monitoring the voltage drop across resistors R8 between the IS and SECONDARY GROUND pins. The internal constant current sense threshold is approximately 35 mV. Once the internal current sense threshold is exceeded, the device regulates the number of switch pulses to maintain a fixed output current.

Below the CC threshold, the device operates in constant voltage mode. The external resistor divider network (R14 and R15) is used for output voltage sensing to regulate the output voltage. The rest of the lower voltage divider resistors (R16, R17, and R18) are used to set output voltage from 5 V to 9 V, 15 V and 20 V respectively. The internal voltage comparator reference voltage is V_{FB} (1.265 V). A phase boost RC network (R13 and C17) is added to optimize ripple voltage.

5 PCB Layout

PCB specifications:

- Layer count: 4 layers
- Board Thickness: 1.6 mm
- Copper Thickness: 2 oz.
- Material: FR4

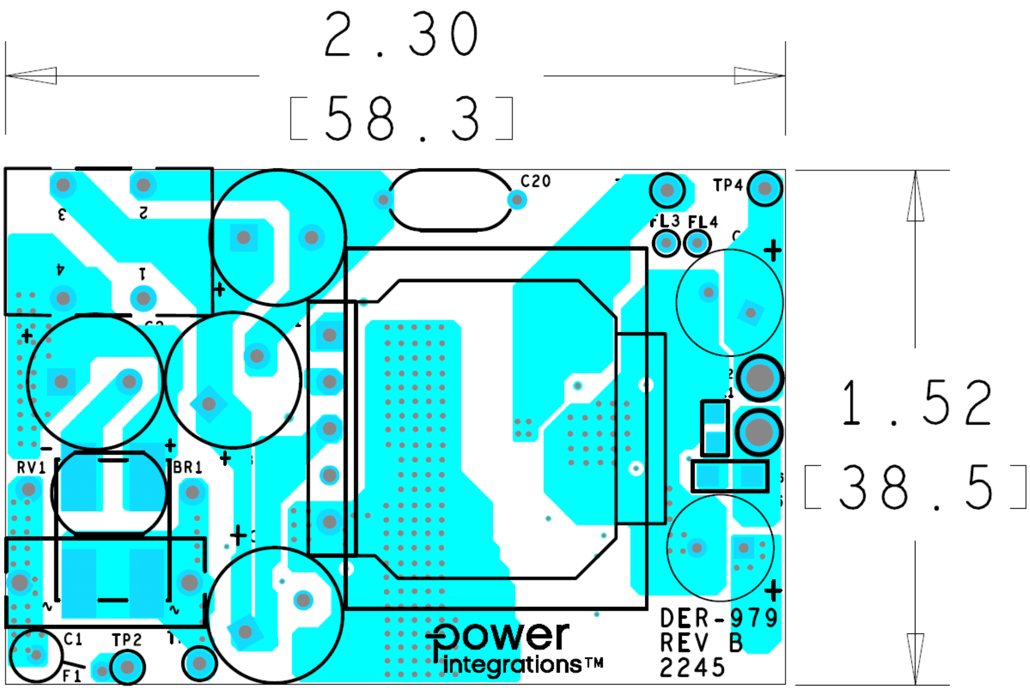


Figure 5 – Top Side.

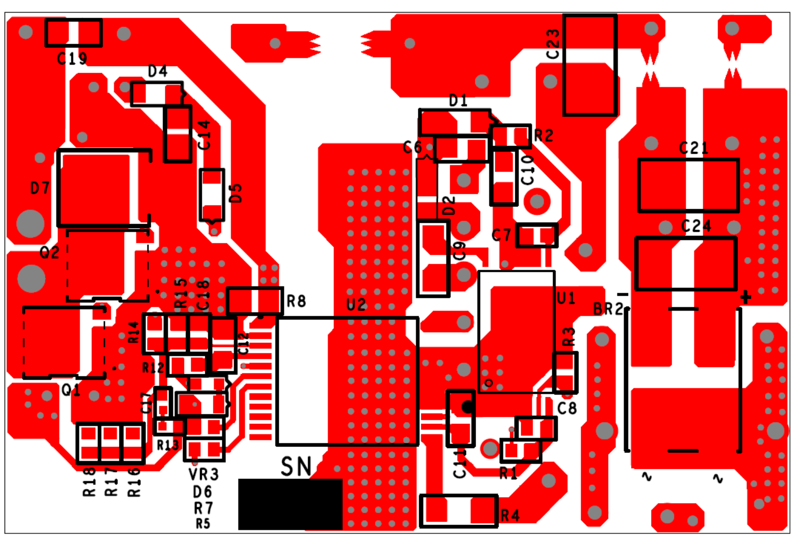


Figure 6 – Bottom Side (Flipped).

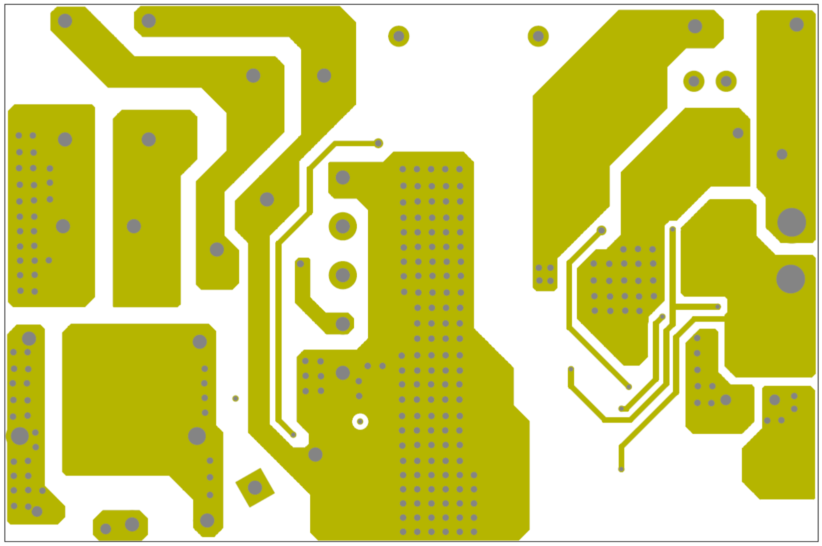


Figure 7 – Inner Layer 1.

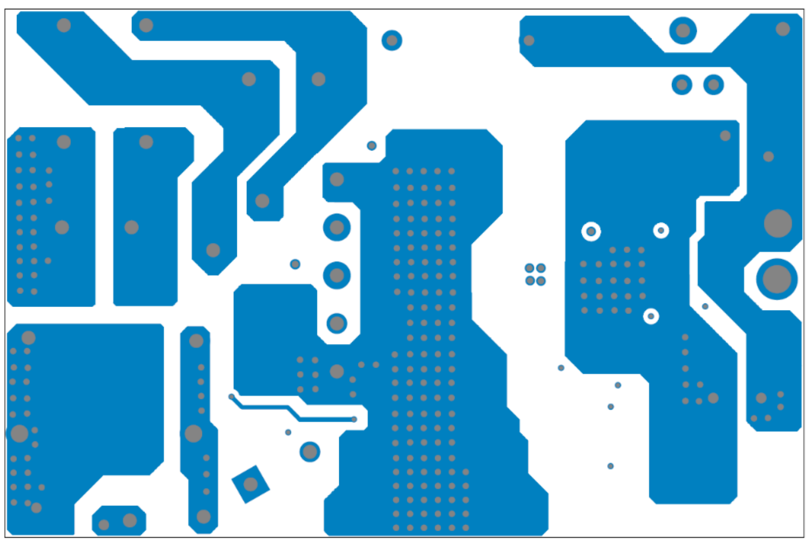


Figure 8 – Inner Layer 2.

6 Bill of Materials

6.1 Electrical Parts

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	2	BR1 BR2	RECT BRIDGE, GP, 600 V, 4A, Z4-D, -55 °C ~ 175 °C (TJ)	Z4DGP406L-HF	Comchip
2	1	C1	0.22 μF, 20%, 275 VAC, X2, -40 °C ~ 110 °C, 6 mm W x 13 mm L x 12 mm H	MPX224K2C3XAB1015	DAIN
3	4	C2-C5	27 μF, 200 V, Electrolytic, (10 x 16),	EKXJ201ELL270MJ16S	Nippon Chemi-Con
4	1	C6	10 μF, ±10%, 25 V, Ceramic, X7R, 0805	GRT21BC71E106KE13L	Murata
5	1	C7	0.1 μF ±10% 50 V Ceramic X7R 0603	CGA3E2X7R1H104K080AA	TDK
6	1	C8	0.1 μF (100 nF) ±10% 50 V Ceramic X7R 0603	GCM188R71H104KA57D	Murata
7	1	C9	100 nF, 250 V, Ceramic, X7R, 1206	C3216X7R2E104M	TDK
8	1	C10	1 μF, 100 V, Ceramic, X7S, 0805	C2012X7S2A105K125AB	TDK
9	1	C11	0.47 μF, ±10%,25 V, Ceramic, X7R, 0805	CGA4J2X7R1E474K125AA	TDK
10	1	C12	2.2 μF, ±10%, 25 V, Ceramic X7R, 0805	CL21B225KAFNFNE	Samsung
11	1	C13	2.2 nF, 200 V, Ceramic, X7R, 0805	08052C222KAT2A	AVX
12	1	C14	10 μF, ±10%, 16 V, X7R, Ceramic SMT, MLCC 0805	CL21B106KOQNNNE	Samsung
13	2	C15 C16	680 μF, ±20%, 25 V, Aluminum - Polymer Radial, Can 16 mΩ 2000 Hrs @ 105 °C (8 mm x 16 mm)	A750KW687M1EAAE016	KEMET
14	1	C17	10 nF 50 V, Ceramic, X7R, 0402	CL05B103KB5NNNC	Samsung
15	1	C18	330 pF, ±5%, 50 V, Ceramic, C0G, NP0, 0603	C0603C331J5GACAUTO	KEMET
16	1	C19	1 μF, 50 V, Ceramic, X5R, 0805	08055D105KAT2A	AVX
17	1	C20	2200 pF ±20%, 250 VAC Ceramic E Radial, Disc, X1, Y1	DE1E3RA222MN4AN01F	Murata
18	3	C21 C23 C24	470 nF, 200 V, Ceramic, X7R, 1812	C1812X474K2RACTU	Kemet
19	1	D1	800 V, 1 A, High Efficiency Fast Recovery, SOD-123FL	HS1KFL	Taiwan Semi
20	1	D2	Diode, Schottky, 200 V, 1A, SMT SOD-123HE	SS10200HE_R1_00001	Panjit
21	1	D4	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
22	1	D5	Diode, Schottky , 20 V, 2 A, SOD323	SDM2U20SD3-7	Diodes, Inc.
23	1	D6	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
24	1	D7	Diode, Schottky, 100 V, 15 A, SMT, TO-277-3, TO-277, 3-PowerDFN	FSV15100V	On semi
25	1	F1	6.3 A, 250 V, Slow, 3.6 mm x 10 mm, Axial	087706.3MXEP	Littelfuse
26	1	L1	Toroidal Common Mode Choke,2 mH, ±20%, Input, DER-979, wound on 32-00286-00 core (14.90 mm O.D. 6.5 mm Th 7.0 mm ID)	32-00443-00	Power Integrations
27	2	Q1 Q2	MOSFET, N-Channel 100 V 28 A (Ta), 85 A (Tc) 7.3 W (Ta), 208 W (Tc) SMT, 8-PowerSMD, Flat Leads, 8-DFN (5x6)	AON6290	Alpha & Omega Semi
28	1	R1	RES, 2 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF2001V	Panasonic
29	1	R2	RES, 2 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ202V	Panasonic
30	1	R3	RES, 15 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF1502V	Panasonic
31	1	R4	RES, 3.3 MΩ, 5%, 1/4 W, Thick Film, 1206	RC1206JR-073M3L	YAGEO
32	1	R5	RES, 47 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ470V	Panasonic
33	1	R6	RES, 0 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEY0R00V	Panasonic
34	1	R7	RES, 33 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ330V	Panasonic
35	1	R8	RES SMD 0 OHM JUMPER ½ W 0805	5106	Keystone
36	1	R12	RES, 0 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEY0R00V	Panasonic
37	1	R13	RES, 51 Ω, 5%, 1/10 W, Thick Film, 0402	ERJ-2GEJ510X	Panasonic
38	1	R14	RES, 100 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF1003V	Panasonic
39	1	R15	RES, SMD, 33 kΩ, 1%, 1/10 W, ±100ppm/°C, 0603	RC0603FR-0733KL	Yageo
40	1	R16	RES, 31.6 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF3162V	Panasonic
41	1	R17	RES, 8.25 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF8251V	Panasonic
42	1	R18	RES, 12.4 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF1242V	Panasonic
43	1	RV1	175 VAC, 17 J, 7 mm, RADIAL	ERZ-V07D271	Panasonic

44	1	T1	Bobbin, ATQ27/14.4, Horizontal, 5 pins	ATQ27-14.4-5P-TH-E5-17	TBI
45	1	U1	ClampZero, MinSOP-16	CPZ1075M	Power Integrations
46	1	U2	InnoSwitch4-CZ,115 W, insop-24D	INN4077C-H182	Power Integrations
47	1	VR3	30 V, 5%, 150 mW, SSMINI-2	DZ2S300M0L	Panasonic

6.2 Mechanical Parts

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	2	TP1 TP3	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
2	1	TP2	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
3	1	TP4	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone

7 Power Transformer Specification (T1)

7.1 Electrical Diagram

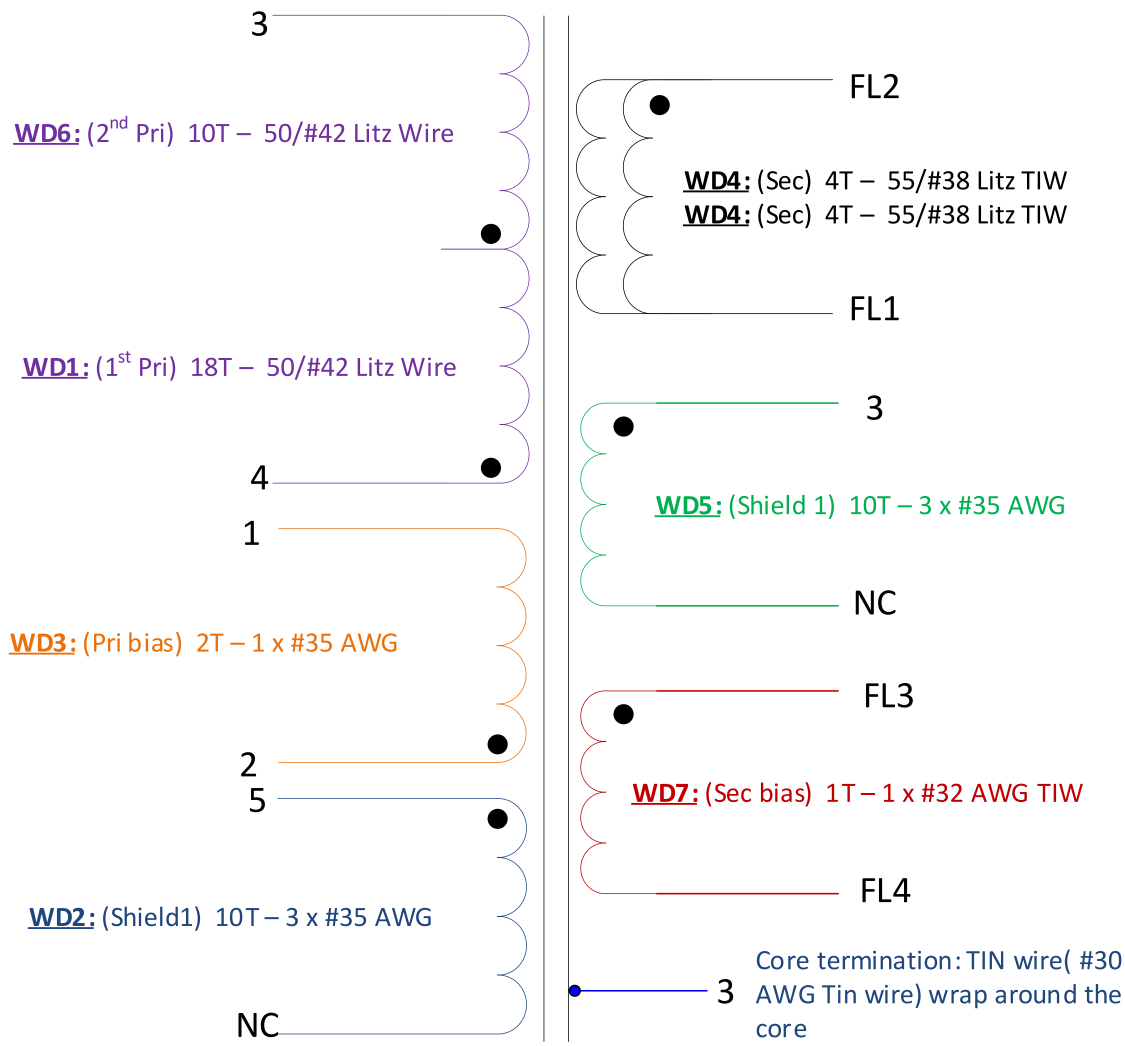


Figure 9 – Transformer Electrical Diagram.

7.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 2 and 1, with all other windings open.	310 μH ±5%
Resonant Frequency	Between pin 2 and 1, other windings open.	100 kHz
Primary Leakage Inductance	Between pin 2 and 1, with pins: FL2-FL1 shorted.	7.5 μH (Max.)

7.3 Material List

Item	Description
[1]	Core: ATQ27/14 P/N: 99-00102-00.
[2]	Bobbin: Bobbin, ATQ27/14.4, Vertical, 5 pin; P/N: 25-01209-00.
[3]	Magnet Wire: 50 / #42 Litz Wire.
[4]	Magnet Wire: #35 AWG, Double Coated.
[5]	Magnet Wire: 55 / #38 Litz Triple Insulated Wire.
[6]	Magnet Wire: #32 AWG, Triple Insulated Wire.
[7]	TIN Wire: #28 AWG.
[8]	Tape: 3M 1350F-1, Polyester Film, 1mil Thickness, 7 mm Width.
[9]	Tape: 3M 1350F-1, Polyester Film, 1mil Thickness, 18 mm Width.
[10]	Varnish: Dolph BC-239.

7.4 Transformer Build Diagram

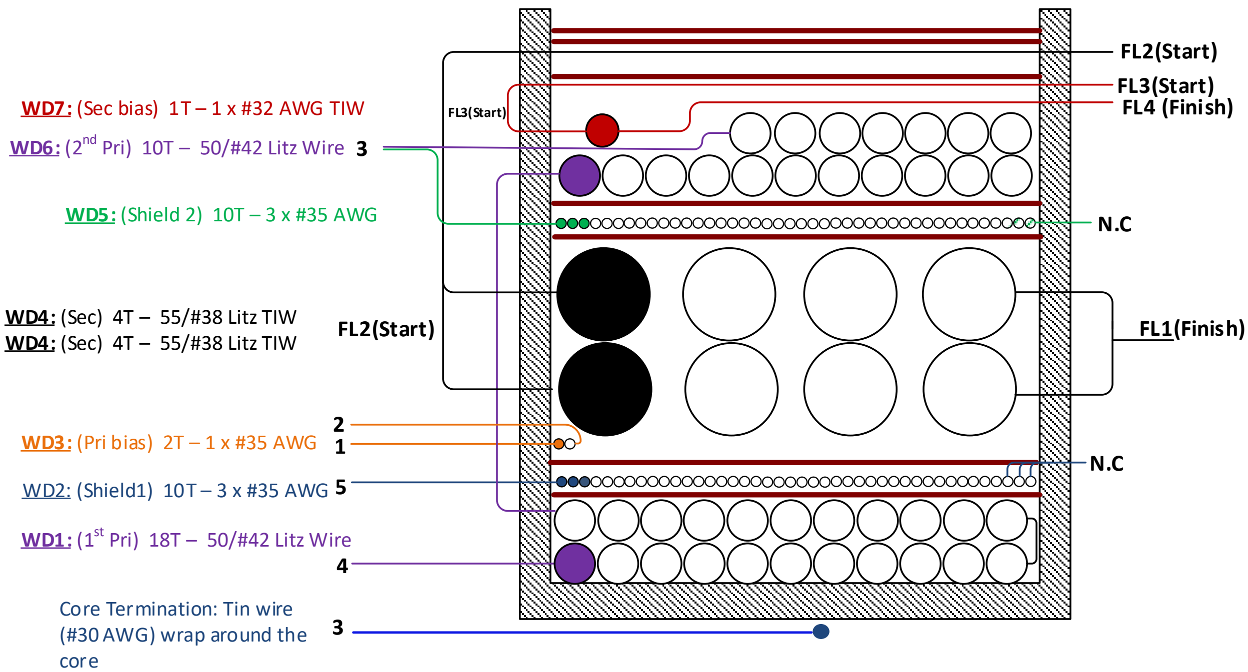
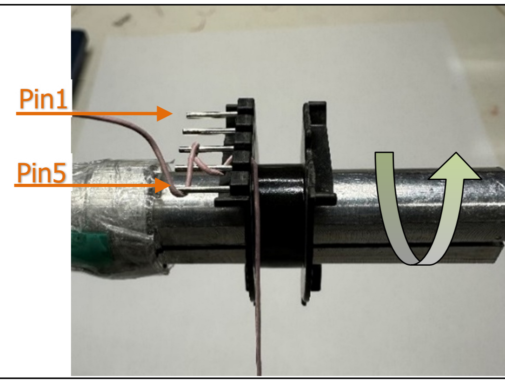
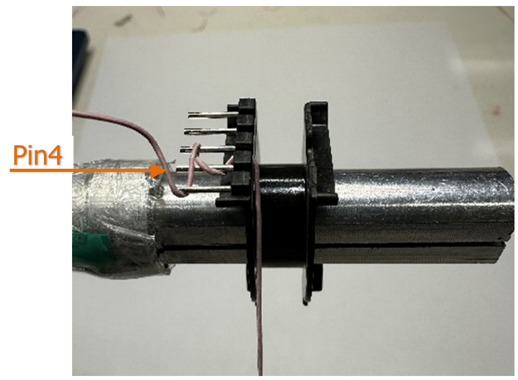
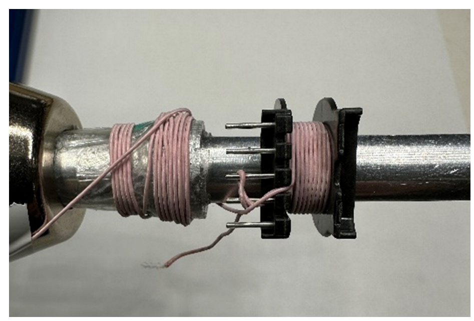
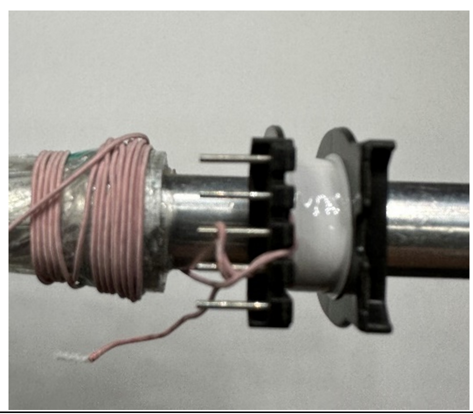


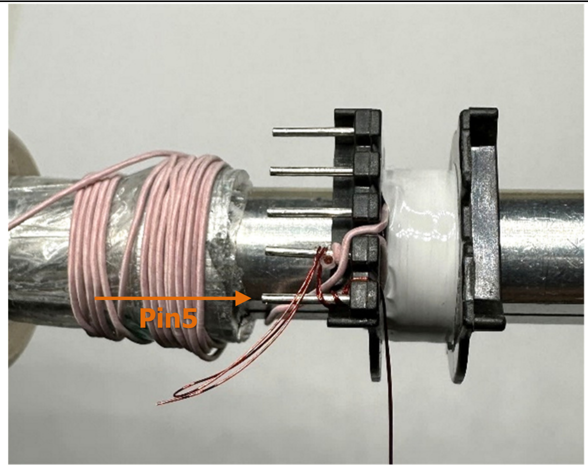
Figure 10 – Transformer Build Diagram.

7.5 Winding Illustrations

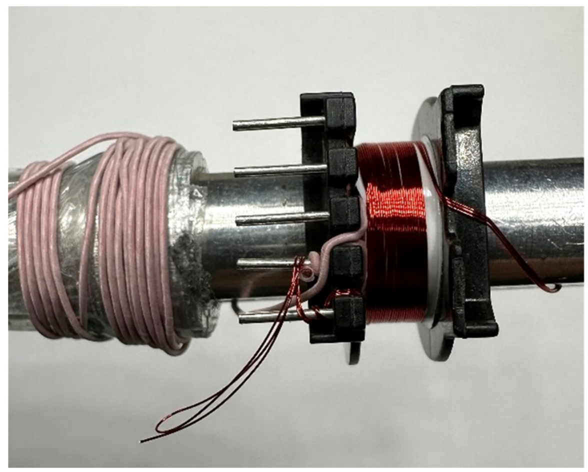
Winding Directions Bobbin is oriented on winder jig such that terminal Pin 1- 5 are in the left side facing upward. The winding direction is clockwise.	
Winding 1- 1st Primary Use a 50/#42 Litz wire, Item [3]. Start at Pin 4 and wind 18 turns evenly in 2 layers.	
Set aside an extension on the left side of the bobbin long enough for 9 turns (Winding 6).	
Apply 1 layer of polyester tape, Item [8] for insulation	

Winding 2 – Shield 1

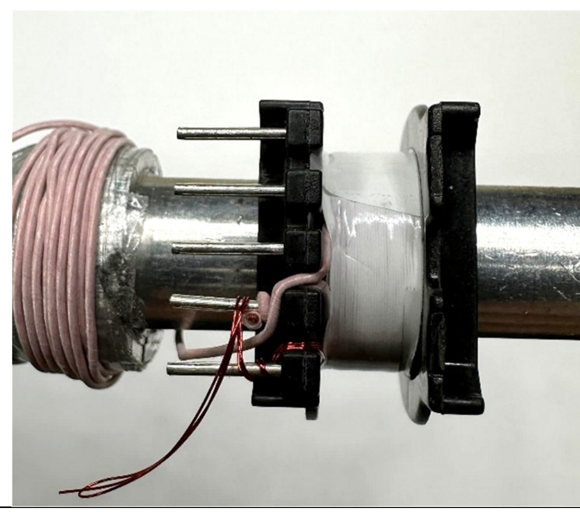
Use magnetic wire, Item [4] - AWG#35 for winding 2. Prepare three wires for winding 2. Start at Pin 5 for winding 2.



Wind winding 2 evenly together for 10 turns from left to right then cut the finish terminal

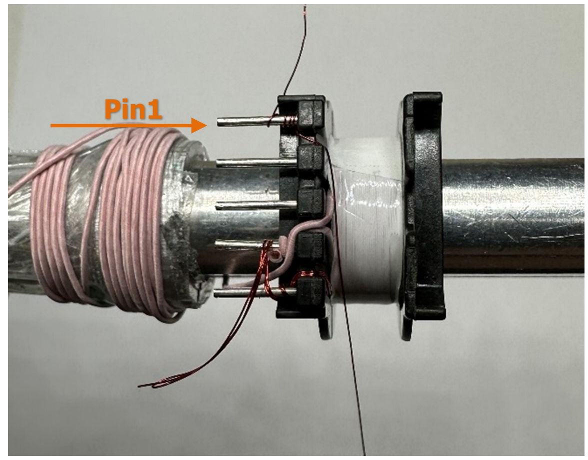
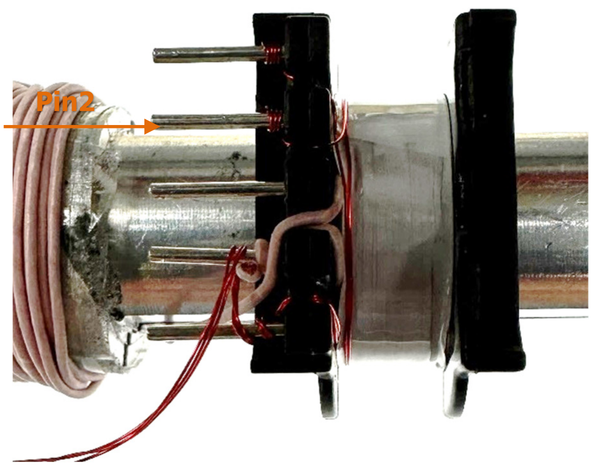


Apply 1 layer of polyester tape, Item [8] for insulation

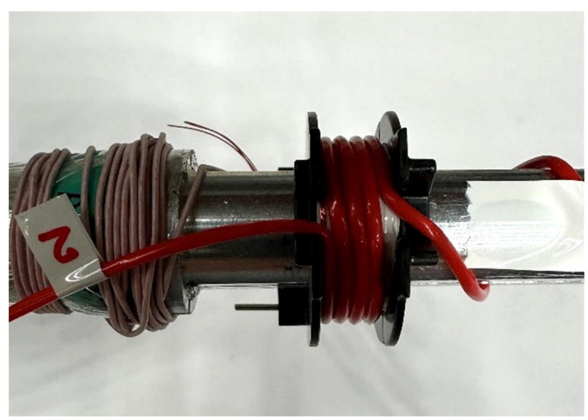


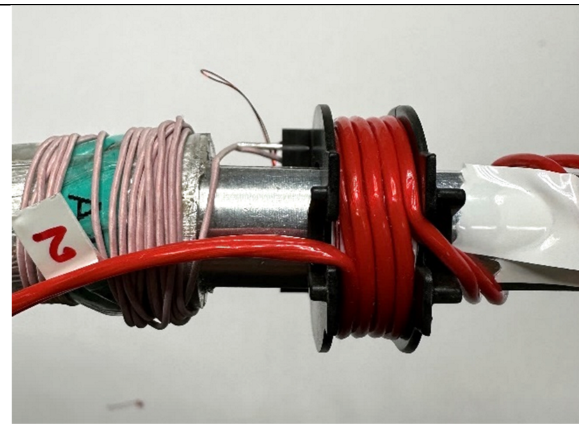
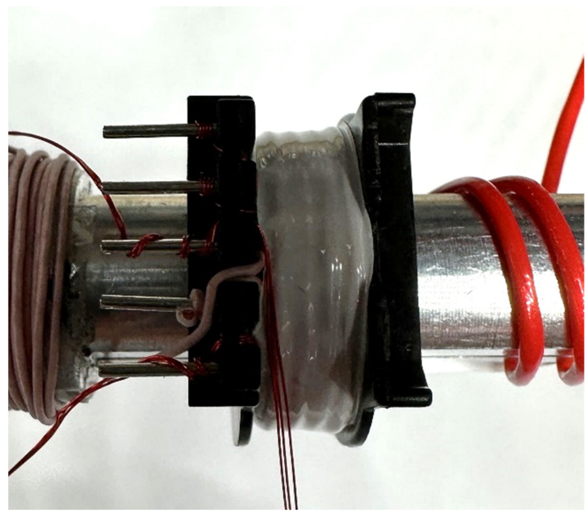
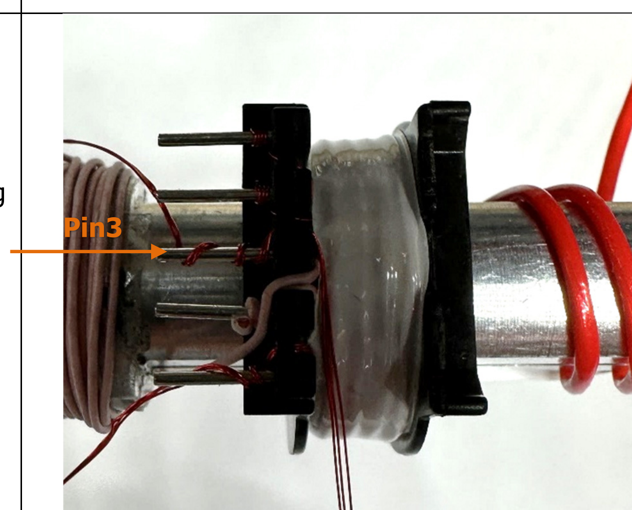
<table>
<tr><td>Winding 3 – Primary Bias Winding

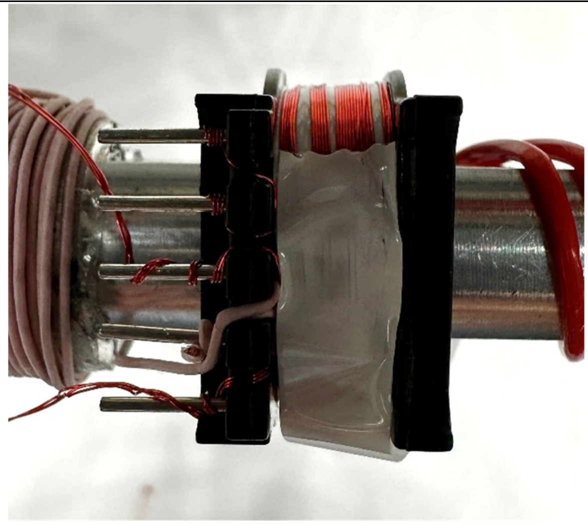
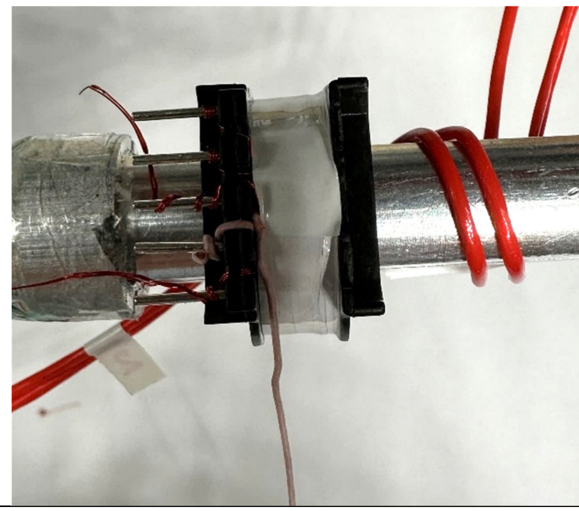
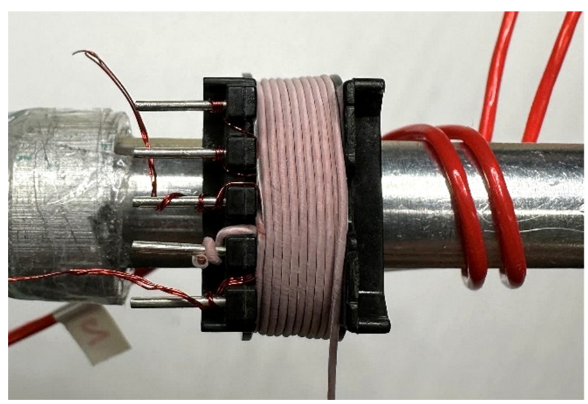
Use magnetic wire, Item [4] - AWG#35 for winding 3. Start at Pin 1 for winding 3.

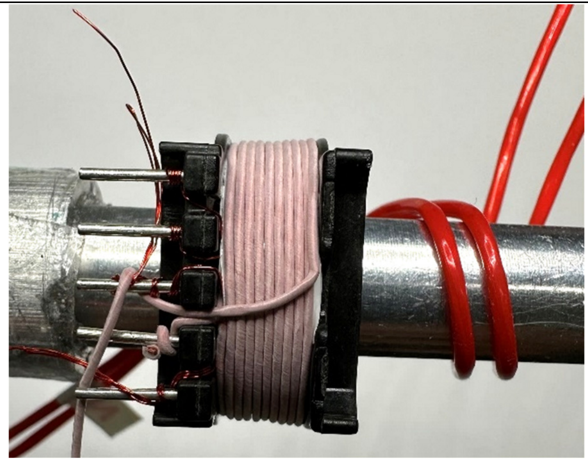
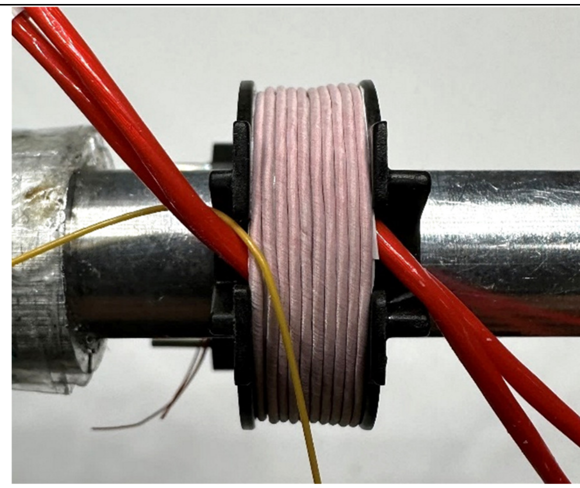
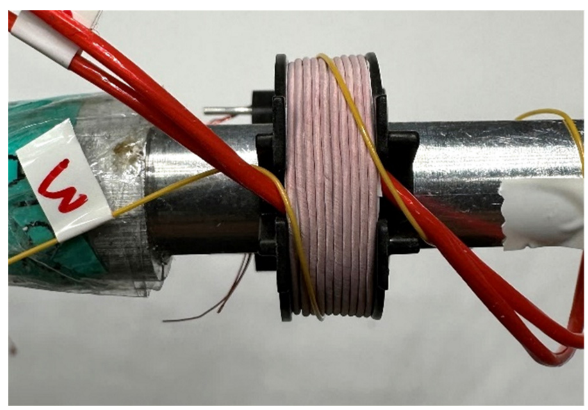
Wind wire for 2 turns then finish at the left terminating at Pin2</td><td></td></tr>
<tr><td>Winding 4 - Secondary

Use a 55/#38 Litz TIW wire, Item [5]. Rotate the bobbin a quarter turn and start winding (FL2) from the left side. Wind 4 turns evenly finishing at the right.

Finish the winding at the right side of the bobbin and cut the wire as shown in the figure.</td><td></td></tr>
</table>

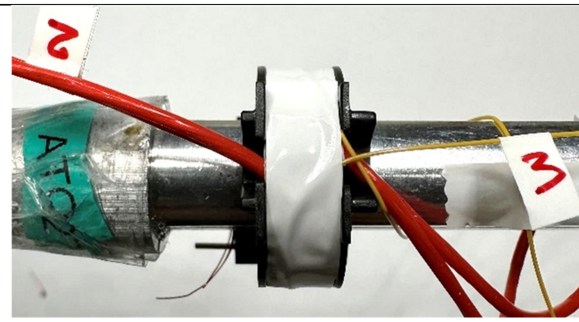
Repeat the previous steps by winding another layer with 4 turns of 55/#38 Litz TIW wire, Item [5], from left to right.	
Apply 1 layer of polyester tape, Item [8] for insulation	
Winding 5 – Shield 2 Use magnetic wire, Item [4] - AWG#35 for winding 5. Prepare three wires for winding 5. Start at Pin 3 for winding 5.	

Wind winding 5 evenly together for 10 turns from left to right then cut the finish terminal	
Apply 1 layer of polyester tape, Item [8] for insulation	
Winding 6 – 2nd Primary Using the remainder of wire in winding 1, wind 1 layer of 10 turns from left to right.	

Bend wire from right to left, finishing the winding at Pin3	
Winding 7 – Secondary Bias Use Magnetic wire #32 AWG TIW, Item [6]. Rotate the bobbin 90 degrees. Start winding 1 turn of FL3 starting from the left and ending on the right Bend FL3 from left to right	 

Bend FL3 from left to right

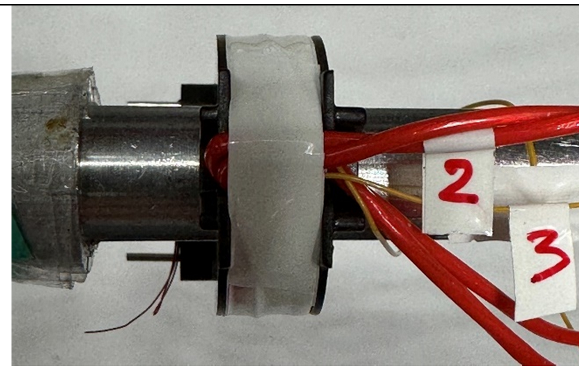
Apply 1 layer of polyester tape, Item [8] for insulation



Finishing FL

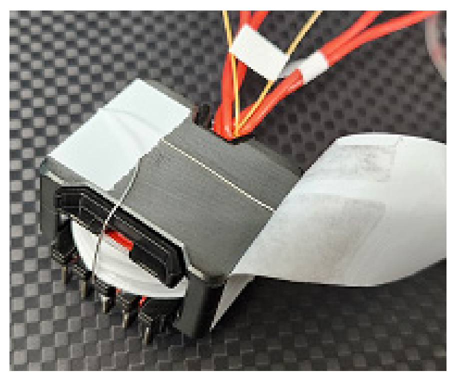
Bend FL2 from left to right then

Apply 2 layers of polyester tape, Item [8] for insulation.

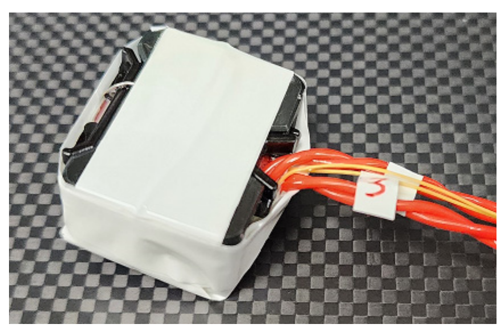


Core Fixing and Varnishing

Prepare a AWG # 30 Solder wire, Item [7]. Terminate the wire on Pin 3 and lay it out on top of the core as shown in the figure.



Fix the top and bottom core together with the TIN wire with tape, Item [9]. Apply safety isolation tape as shown in the figure



8 Transformer (T1) Spreadsheet

1	ACDC_InnoSwitch4-CZ_Flyback_083022; Rev.2.3; Copyright Power Integrations 2022	INPUT	INFO	OUTPUT	UNITS	InnoSwitch4 CZ Single/Multi Output Flyback Design Spreadsheet
2	**APPLICATION VARIABLES**					
3	INPUT_TYPE	AC		AC		Input Type
4	VIN_MIN	100		100	V	Minimum AC input voltage
5	VIN_MAX	132		132	V	Maximum AC input voltage
6	VIN_RANGE			LOW LINE		Range of AC input voltage
7	LINEFREQ			60	Hz	AC Input voltage frequency
8	CAP_INPUT	108.0		108.0	uF	Input capacitor
9	VOUT	20.00		20.00	V	Output voltage at the board
10	CDC			0	mV	Cable drop compensation desired at full load
11	IOUT	5.000		5.000	A	Output current
12	POUT			100.00	W	Output power
13	EFFICIENCY			0.92		AC-DC efficiency estimate at full load given that the converter is switching at the valley of the rectified minimum input AC voltage
14	FACTOR_Z			0.60		Z-factor estimate
15	ENCLOSURE	ADAPTER		ADAPTER		Power supply enclosure
16	**PRIMARY CONTROLLER SELECTION**					
17	ILIMIT_MODE	STANDARD		STANDARD		Device current limit mode
18	DEVICE_GENERIC	INN4077		INN4077		Generic device code
19	DEVICE_CODE			INN4077C		Actual device code
20	POUT_MAX			115	W	Power capability of the device based on thermal performance
21	RDSON_100DEG			0.29	Ω	Primary switch on time drain resistance at 100 degC
22	ILIMIT_MIN			3.162	A	Minimum current limit of the primary switch
23	ILIMIT_TYP			3.400	A	Typical current limit of the primary switch
24	ILIMIT_MAX			3.638	A	Maximum current limit of the primary switch
25	VDRAIN_BREAKDOWN			750	V	Device breakdown voltage
26	VDRAIN_ON_PRSW			0.34	V	Primary switch on time drain voltage
27	VDRAIN_OFF_PRSW			375.3	V	Peak drain voltage on the primary switch during turn-off
28	**WORST CASE ELECTRICAL PARAMETERS**					
29	FSWITCHING_MAX	80000		80000	Hz	Maximum switching frequency at full load and valley of the rectified minimum AC input voltage
30	VOR	140.0		140.0	V	Secondary voltage reflected to the primary when the primary switch turns off
31	VMIN			89.65	V	Valley of the minimum input AC voltage at full load
32	KP			0.74		Measure of continuous/discontinuous mode of operation
33	MODE_OPERATION			CCM		Mode of operation
34	DUTYCYCLE			0.611		Primary switch duty cycle
35	TIME_ON		Info	11.38	us	Primary switch on-time is greater than 10.5us: Increase the controller switching frequency or increase the VOR
36	TIME_OFF			4.37	us	Primary switch off-time
37	LPRIMARY_MIN			294.4	uH	Minimum primary inductance
38	LPRIMARY_TYP			309.9	uH	Typical primary inductance
39	LPRIMARY_TOL	5.0		5.0	%	Primary inductance tolerance
40	LPRIMARY_MAX			325.3	uH	Maximum primary inductance
41	**PRIMARY CURRENT**					

42	IPEAK_PRIMARY			3.425	A	Primary switch peak current
43	IPEDESTAL_PRIMARY			0.801	A	Primary switch current pedestal
44	IAVG_PRIMARY			1.178	A	Primary switch average current
45	IRIPPLE_PRIMARY			2.991	A	Primary switch ripple current
46	IRMS_PRIMARY			1.652	A	Primary switch RMS current
47	SECONDARY CURRENT					
48	IPEAK_SECONDARY			23.977	A	Secondary winding peak current
49	IPEDESTAL_SECONDARY			5.609	A	Secondary winding current pedestal
50	IRMS_SECONDARY			9.235	A	Secondary winding RMS current
51	**TRANSFORMER CONSTRUCTION PARAMETERS**					
52	**CORE SELECTION**					
53	CORE	ATQ27/18		ATQ27/18		Core selection. Refer to the 'Transformer Construction' tab to see the detailed report
54	CORE CODE			ATQ27/18		Core code
55	AE			131.00	mm^2	Core cross sectional area
56	LE			50.80	mm	Core magnetic path length
57	AL			7350	nH/turns^2	Ungapped core effective inductance
58	VE			6655.0	mm^3	Core volume
59	BOBBIN			TBI-238-03381.12XX		Bobbin
60	AW			50.96	mm^2	Window area of the bobbin
61	BW			10.40	mm	Bobbin width
62	MARGIN			0.0	mm	Safety margin width (Half the primary to secondary creepage distance)
63	**PRIMARY WINDING**					
64	NPRIMARY			28		Primary turns
65	BPEAK			3303	Gauss	Peak flux density
66	BMAX			3001	Gauss	Maximum flux density
67	BAC			1289	Gauss	AC flux density (0.5 x Peak to Peak)
68	ALG			395	nH/turns^2	Typical gapped core effective inductance
69	LG			0.394	mm	Core gap length
70	**PRIMARY BIAS WINDING**					
71	NBIAS_PRIMARY			3		Primary bias winding number of turns
72	**SECONDARY WINDING**					
73	NSECONDARY	4		4		Secondary winding number of turns
74	**SECONDARY BIAS WINDING**					
75	NBIAS_SECONDARY			2		Secondary bias winding number of turns
76	**PRIMARY COMPONENTS SELECTION**					
77	CLAMPZERO					
78	LLEAK			3.10	uH	Primary winding leakage inductance
79	CCLAMP			100.0	nF	Primary clamp capacitor
80	RD_CLAMPZERO	AUTO		60	kΩ	HSD resistor
81	TLLDL/THLDL			100.0	ns	HSD resistor programmed delay
82	TIME_CLAMPZERO_OFF_TO_PRIMARY_ON			45.0	ns	Time between the ClampZero FET turn off and the primary FET turns on based on the HSD resistor selection
83	TIME_VDS_VALLEY			36.3	ns	Time taken by the VDS ring to reach its first valley
84	IPEAK_CLAMPZERO			3.394	A	Active clamp peak current
85	**LINE UNDERVOLTAGE**					
86	BROWN-IN REQURED			80.0	V	Required AC RMS/DC line voltage brown-in threshold
87	RLS			4.10	MΩ	Connect two 2.05 MOhm resistors to the V-pin for the required UV/OV threshold
88	BROWN-IN ACTUAL			66.8V - 81V	V	Actual AC RMS/DC brown-in range
89	BROWN-OUT ACTUAL			59.3V - 73.7V	V	Actual AC RMS/DC brown-out range
90	**LINE OVERVOLTAGE**					

91	OVERVOLTAGE_LINE			304.7V - 346V	V	Actual AC RMS/DC line over-voltage range
92	**PRIMARY BIAS DIODE**					
93	VBIAS_PRIMARY			12.0	V	Rectified primary bias voltage
94	VF_BIAS_PRIMARY			0.70	V	Bias winding diode forward drop
95	VREVERSE_BIASDIODE_PRIMARY			32.00	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
96	CBIAS_PRIMARY			22	uF	Bias winding rectification capacitor
97	CBPP			0.47	uF	BPP pin capacitor
98	**SECONDARY COMPONENTS**					
99	RFB_UPPER			100.00	kΩ	Upper feedback resistor (connected to the first output voltage)
100	RFB_LOWER			6.81	kΩ	Lower feedback resistor
101	CFB_LOWER			330	pF	Lower feedback resistor decoupling capacitor
102	**SECONDARY BIAS DIODE**					
103	USE_SECONDARY_BIAS	AUTO		YES		Use secondary bias winding for the design
104	VBIAS_SECONDARY			5.0	V	Rectified secondary bias voltage
105	VF_BIAS_SECONDARY			0.70	V	Bias winding diode forward drop
106	VREVERSE_BIASDIODE_SECONDARY			18.33	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
107	CBIAS_SECONDARY			10	uF	Bias winding rectification capacitor
108	CBPS			2.20	uF	BPP pin capacitor
109	**MULTIPLE OUTPUT PARAMETERS**					
110	**OUTPUT 1**					
111	VOUT1			20.00	V	Output 1 voltage
112	IOUT1			5.00	A	Output 1 current
113	POUT1			100.00	W	Output 1 power
114	IRMS_SECONDARY1			9.235	A	Root mean squared value of the secondary current for output 1
115	IRIPPLE_CAP_OUTPUT1			7.765	A	Current ripple on the secondary waveform for output 1
116	NSECONDARY1			4		Number of turns for output 1
117	VREVERSE_RECTIFIER1			46.67	V	SRFET reverse voltage (not accounting parasitic voltage ring) for output 1
118	SRFET1	Auto		AON6244		Secondary rectifier (Logic MOSFET) for output 1
119	VF_SRFET1			0.031	V	SRFET on-time drain voltage for output 1
120	VBREAKDOWN_SRFET1			60	V	SRFET breakdown voltage for output 1
121	RDSON_SRFET1			6.2	mΩ	SRFET on-time drain resistance at 25degC and VGS=4.4V for output 1
122	PO_TOTAL			100.00	W	Total power of all outputs

9 Input Common Mode Choke Specification (L1)

9.1 Electrical Diagrams

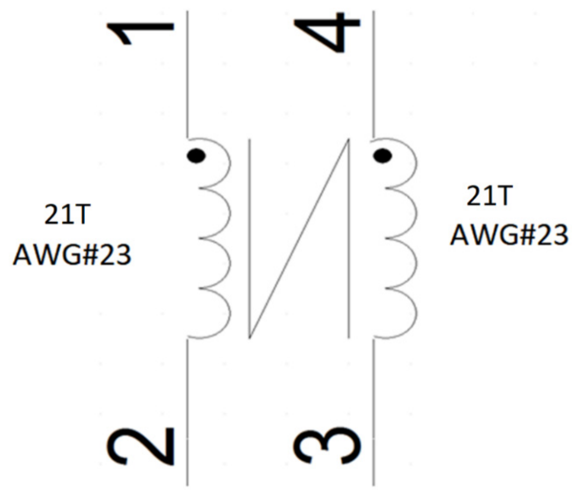


Figure 11 – Inductor Electrical Diagram.

9.2 Electrical Specifications

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V pk-pk, 100 kHz switching frequency, between pin 1 and pin 3 or pin 2 and pin 4 with all other windings open.	2.0 mH
Tolerance	Tolerance of Primary Inductance.	±20%

9.3 Material List

Item	Description
[1]	Toroid Core: 32-00286-00 (Green).
[2]	Magnet Wire: #23 AWG.
[3]	Fish Paper, 0.030" Thick, Cotton Rag, UL-94HB, Part No: 66-00042-00.

9.4 Transformer Build Diagram

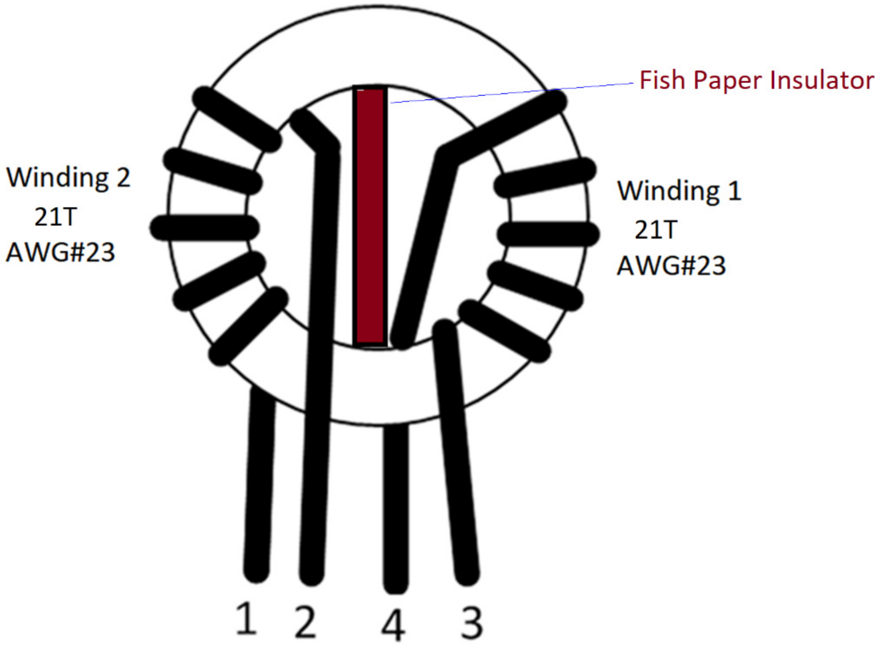


Figure 12 – Inductor Build Diagram.

9.5 Inductor Construction and Dimensions

1. Winding 1 - Wind 21 turns of item 2 as shown in above figure.
2. Winding 2 - Wind 21 turns of item 2 as shown in above figure.
3. Apply Varnish

10 Performance Data

All measurements were performed at room ambient temperature otherwise specified. Please refer to below output voltage selector guide when changing output voltage. The default output of this DER is 20V where R17 is connected(soldered) to GND.

Output Voltage Selector Guide

V_{OUT} = 5 V – R16, R17 and R18 are disconnected (not soldered) to GND

V_{OUT} = 9 V – R16 connected (Soldered) to GND. R17 and R18 are disconnected (not soldered) to GND

V_{OUT} = 15 V – R18 connected (Soldered) to GND. R16 and R17 are disconnected (not soldered) to GND

V_{OUT} = 20 V – R17 connected (Soldered) to GND. R16 and R18 are disconnected (not soldered) to GND

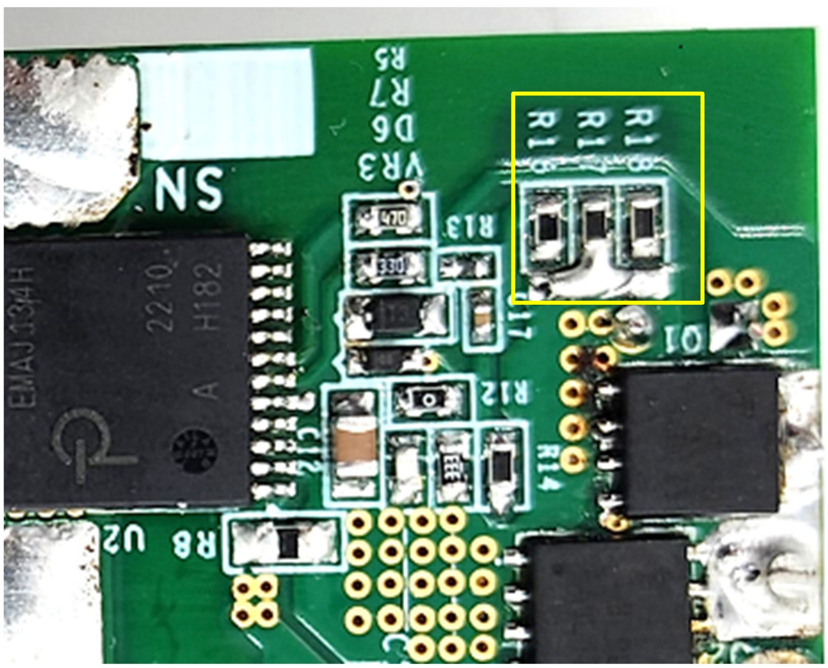


Figure 13 – Output Voltage Selector Guide.

10.1 System Full Load Efficiency

Output voltage was measured at PCB output terminal pin
Note: Unit tested with 10 mins soak time and 1 min soak time every input line.

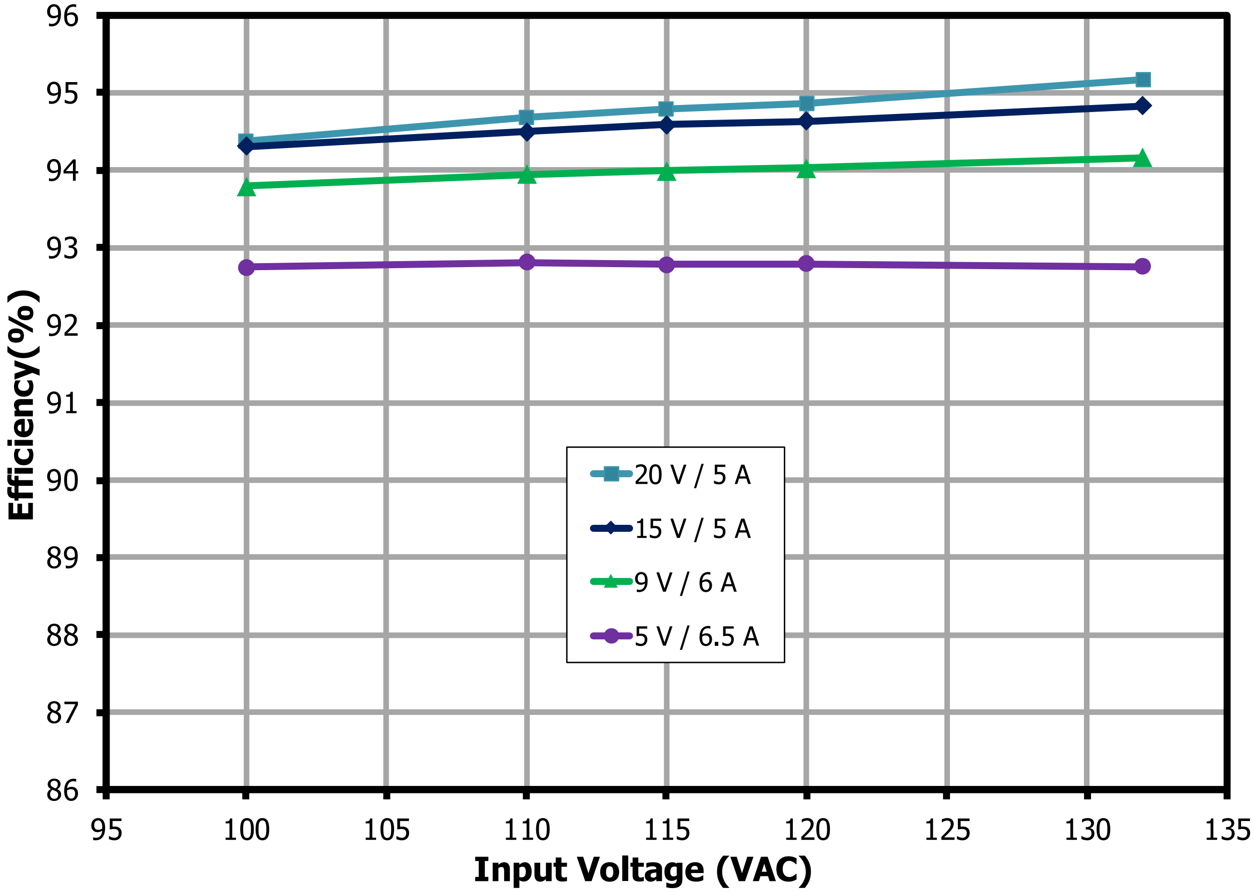


Figure 14 – System Full Load Efficiency vs. Line.

10.2 Energy Efficiency

10.2.1 System Average Efficiency

Note: Unit tested with 10 mins soak time and 1 min soak time per load step.

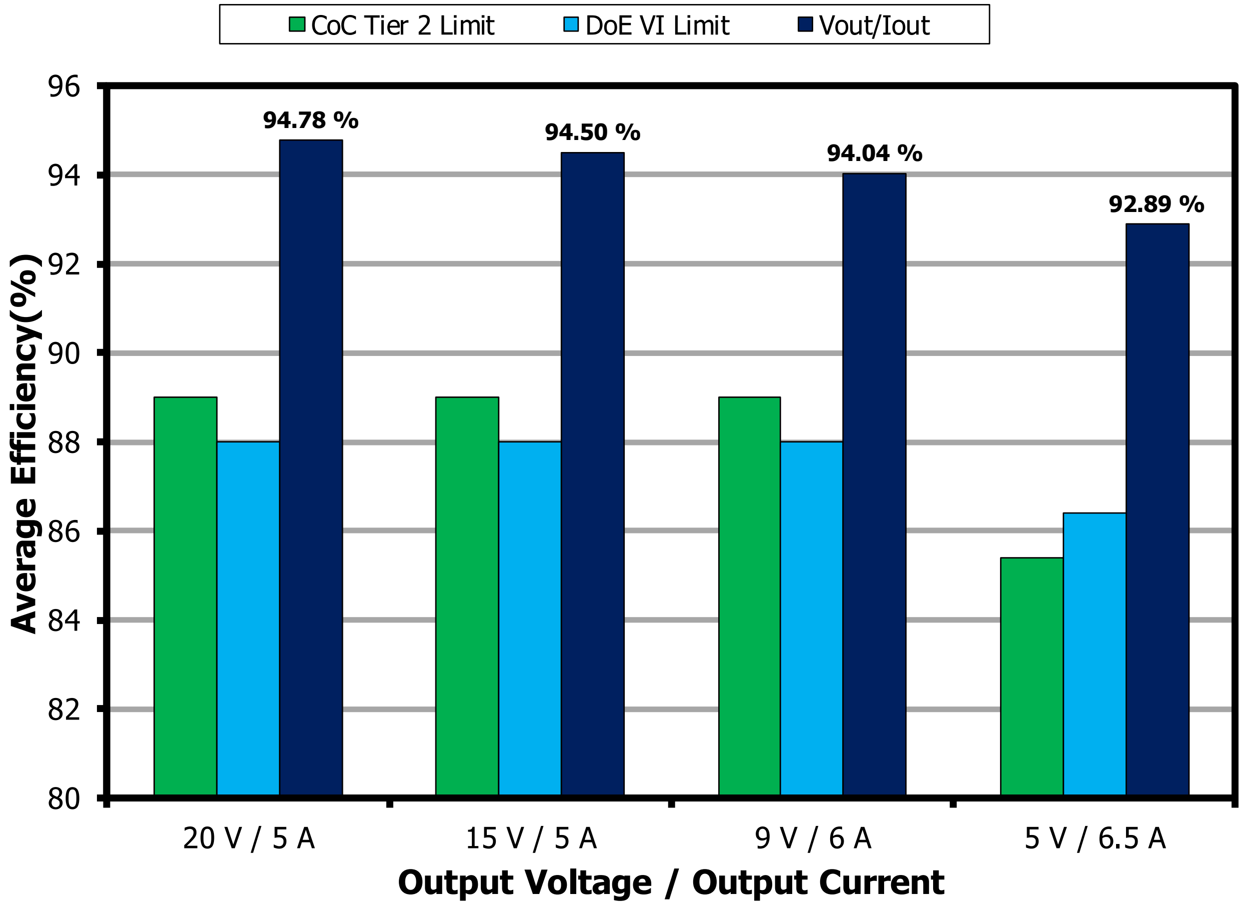


Figure 15 – Average Efficiency at 115 VAC 60 Hz.

10.2.2 Efficiency at 10% Load

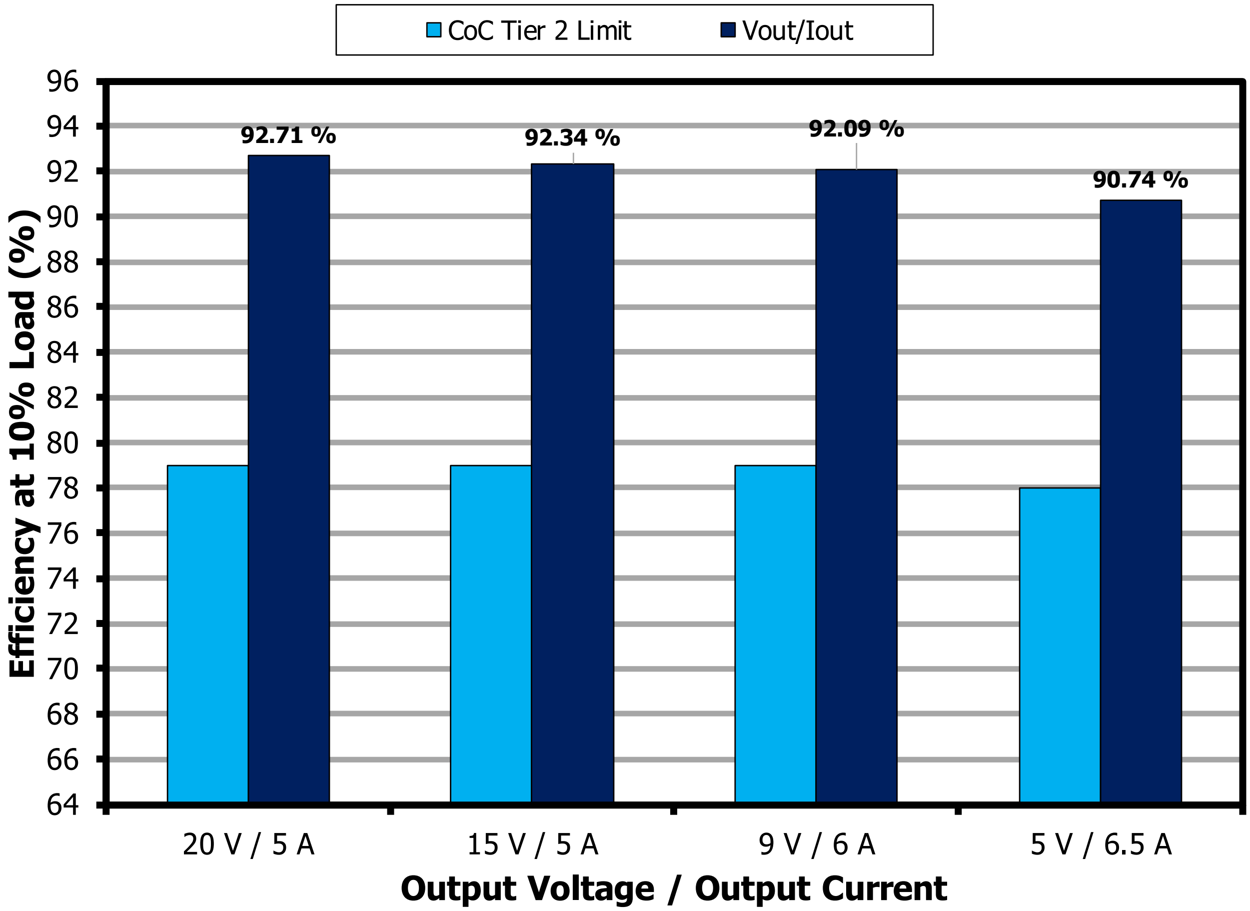


Figure 16 – Efficiency at 10 % Load, 115 VAC 50 Hz.

10.3 Efficiency vs. Load

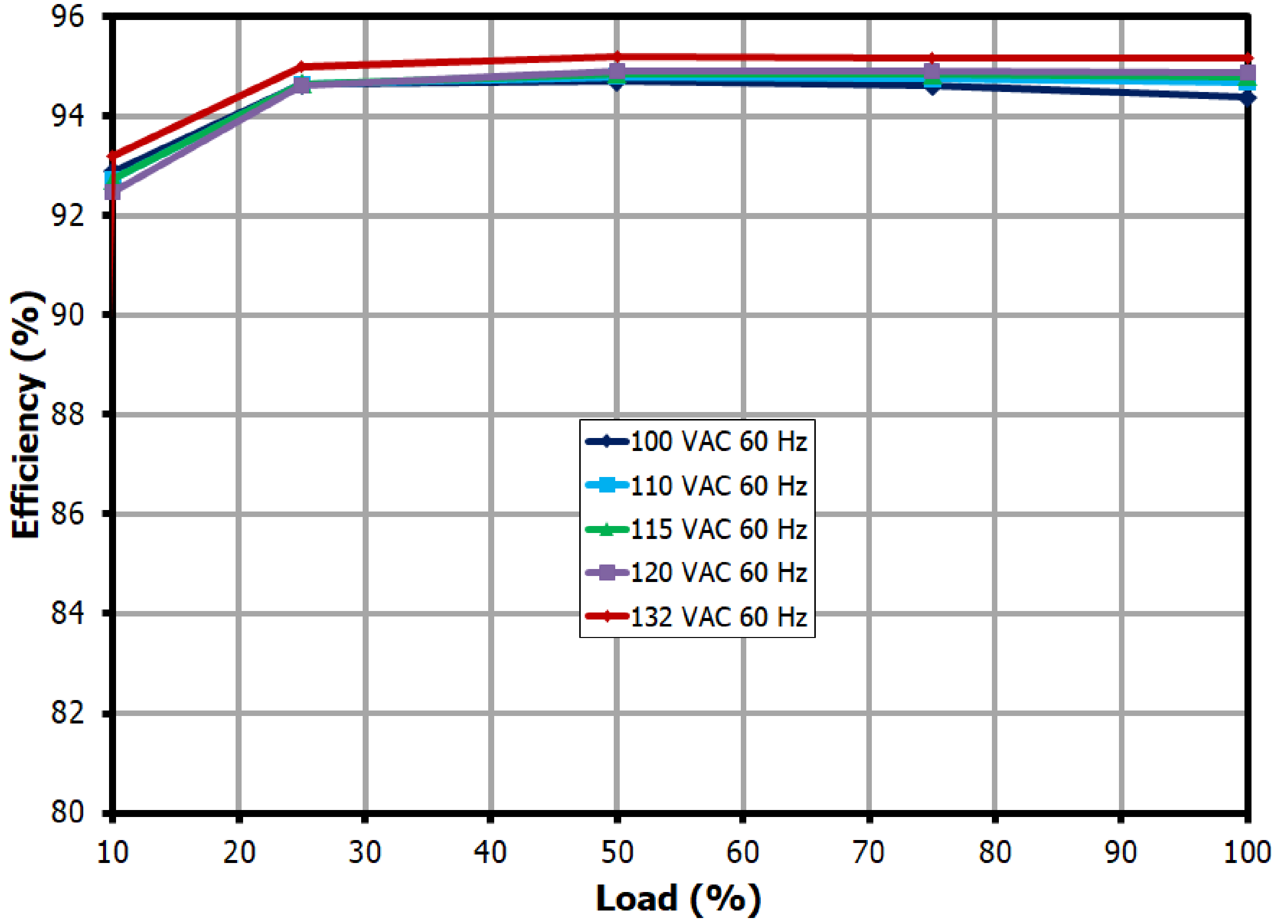


Figure 17 – System Efficiency vs. Load at V_{OUT} = 20 VDC.

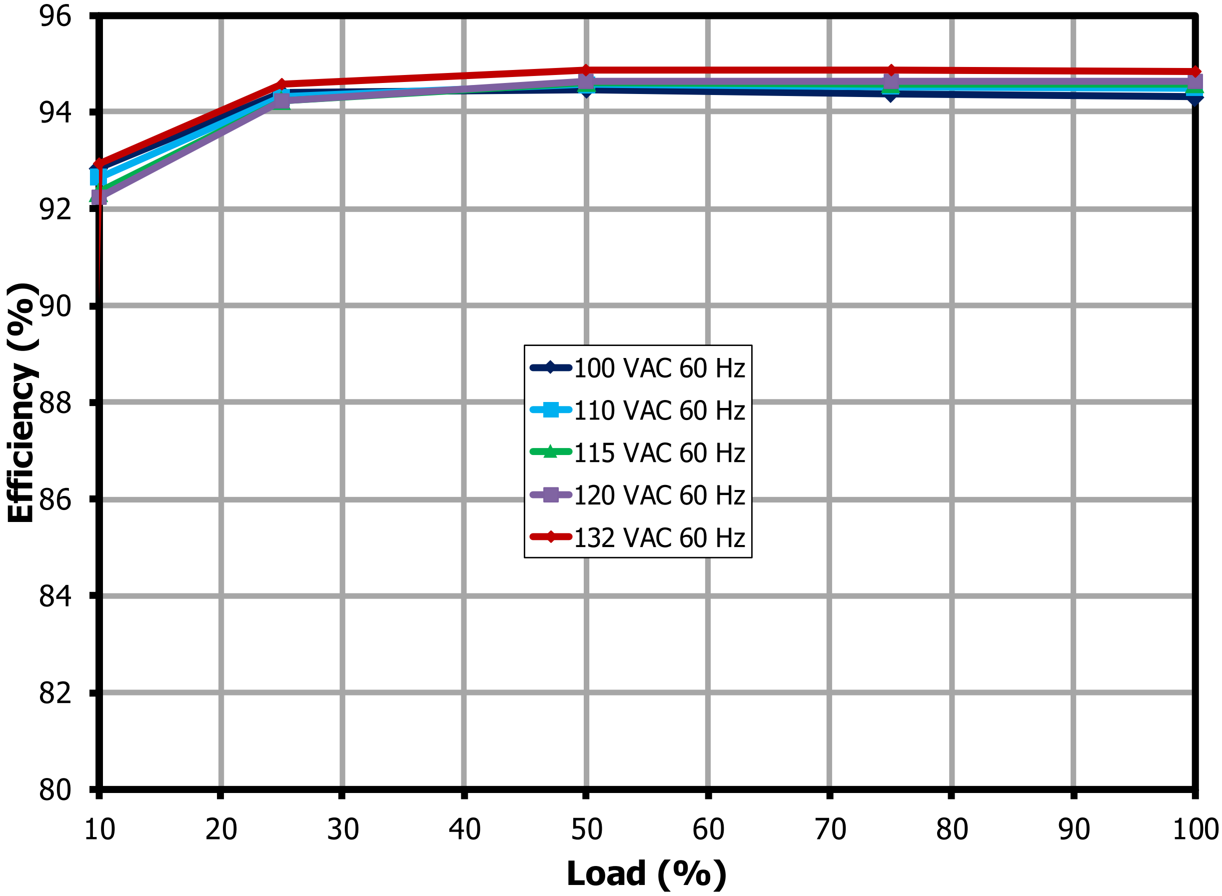


Figure 18 – System Efficiency vs. Load at V_{OUT} = 15 VDC.

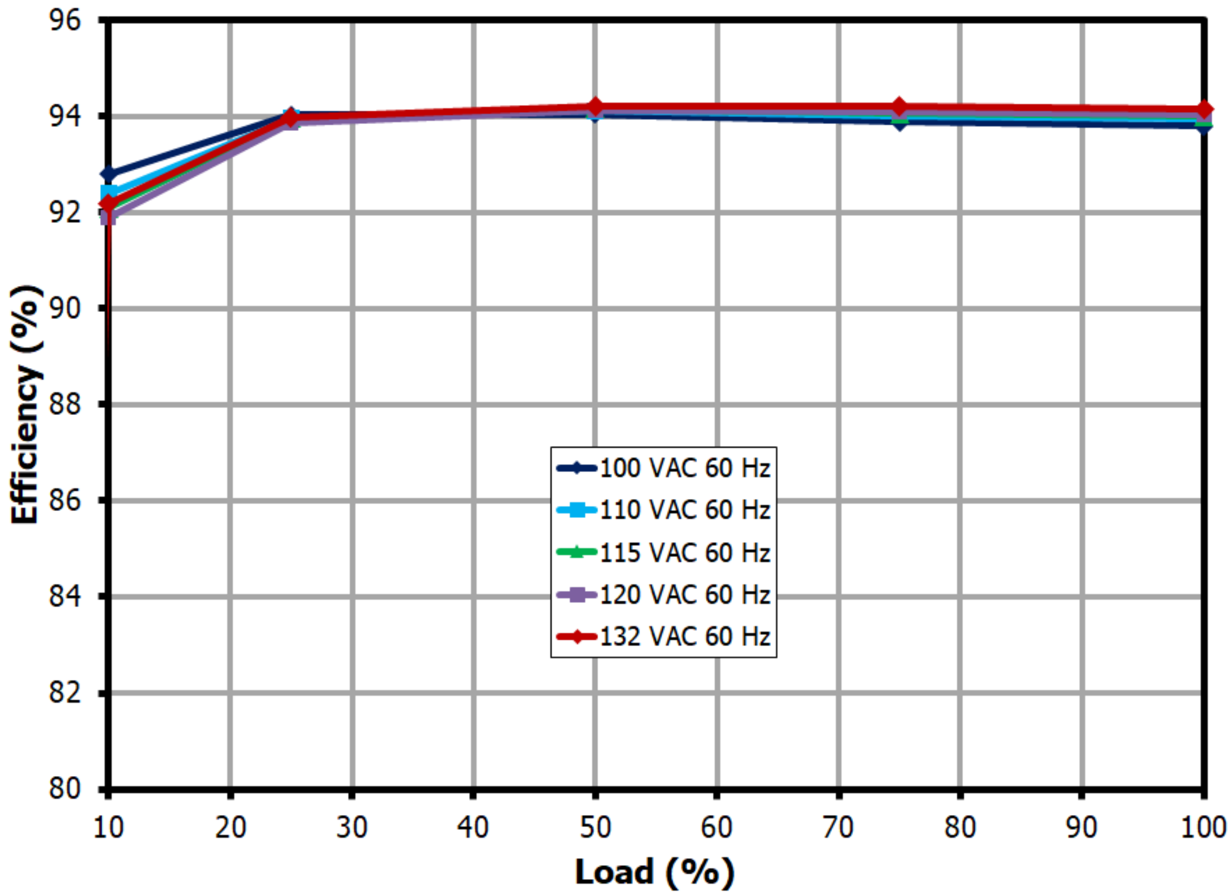


Figure 19 – System Efficiency vs. Load at V_{OUT} = 9 VDC.

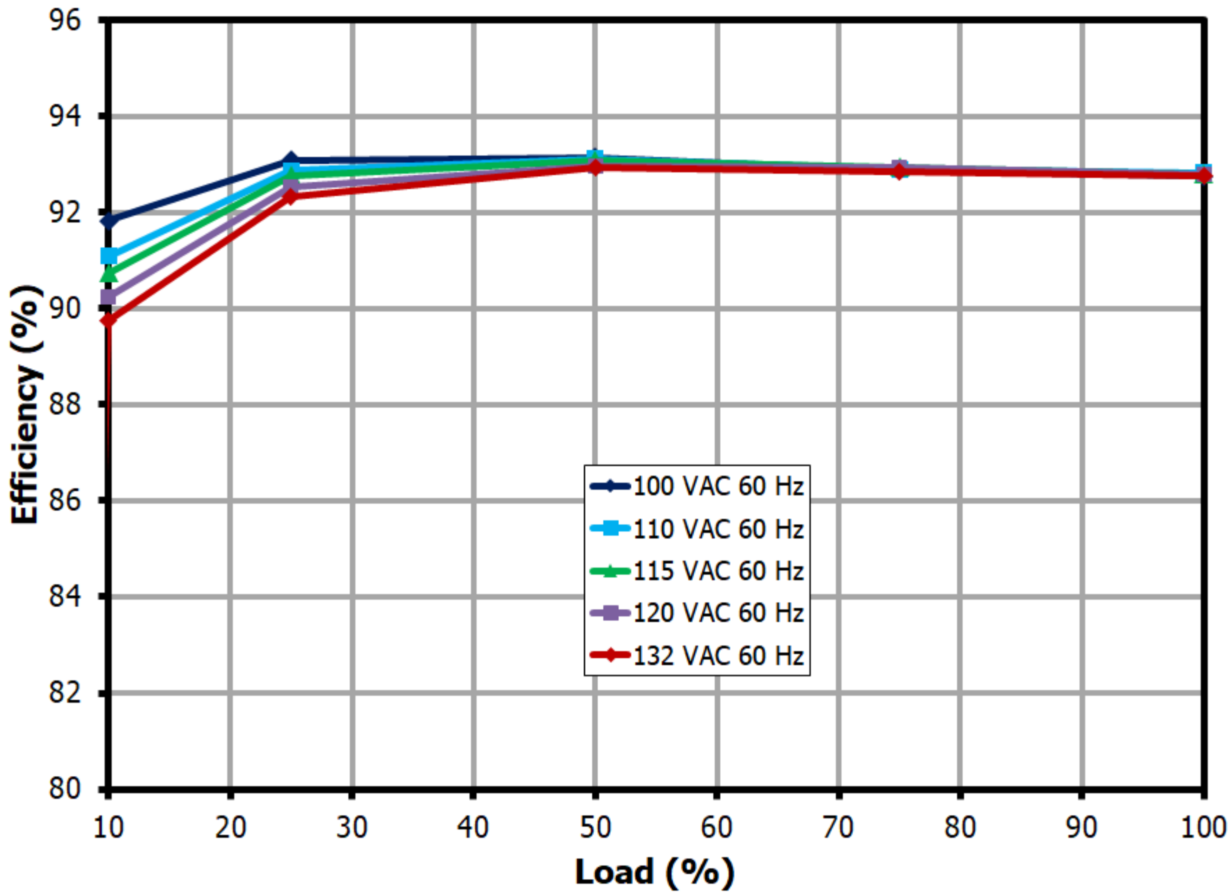


Figure 20 – System Efficiency vs. Load at V_{OUT} = 5 VDC.

10.4 No-Load Input Power

Note: Tested at V_{OUT} = 5 V, with 60 seconds soak time every input line.

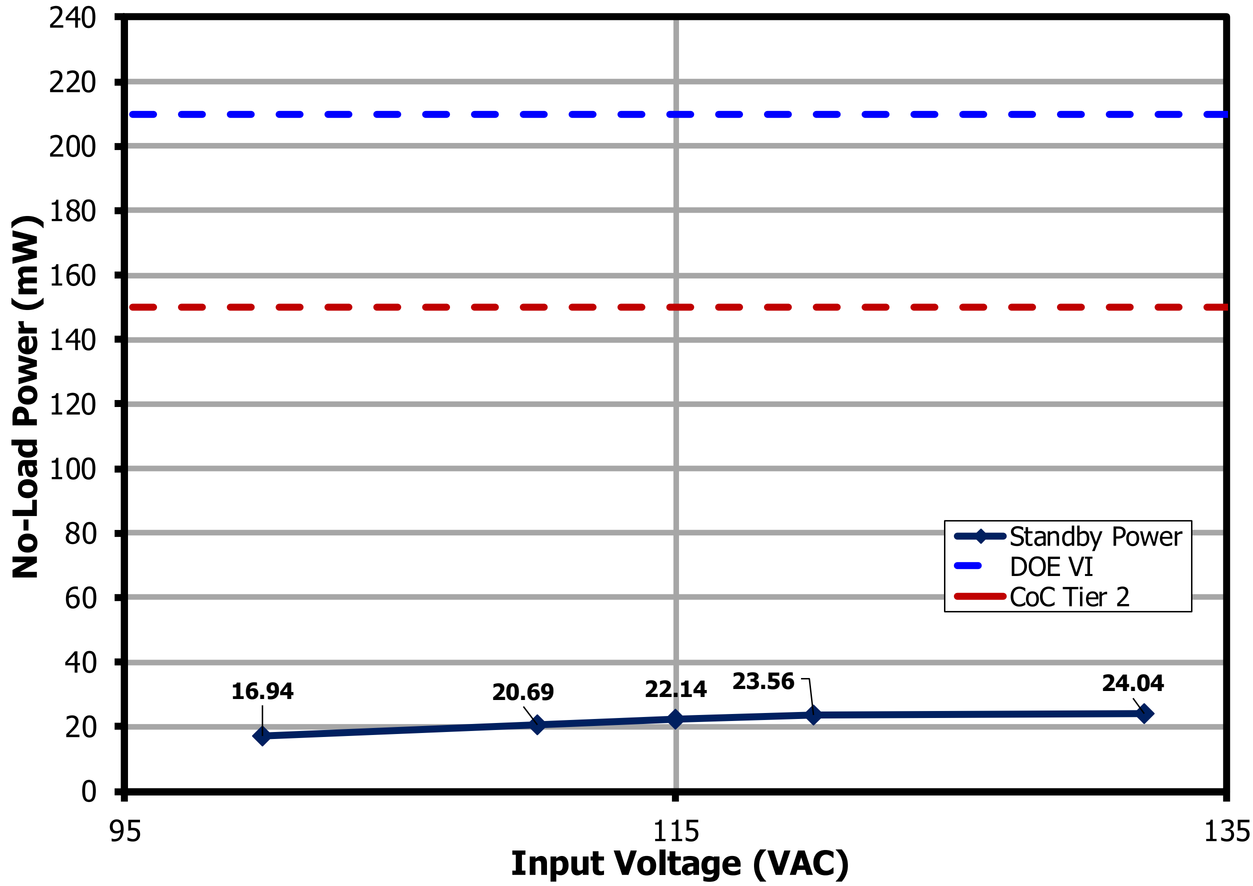


Figure 21 – No-Load Input Power vs. Line at V_{OUT} = 5 V.

10.5 Output Voltage Load Regulation

E-load is set at CC Mode Load

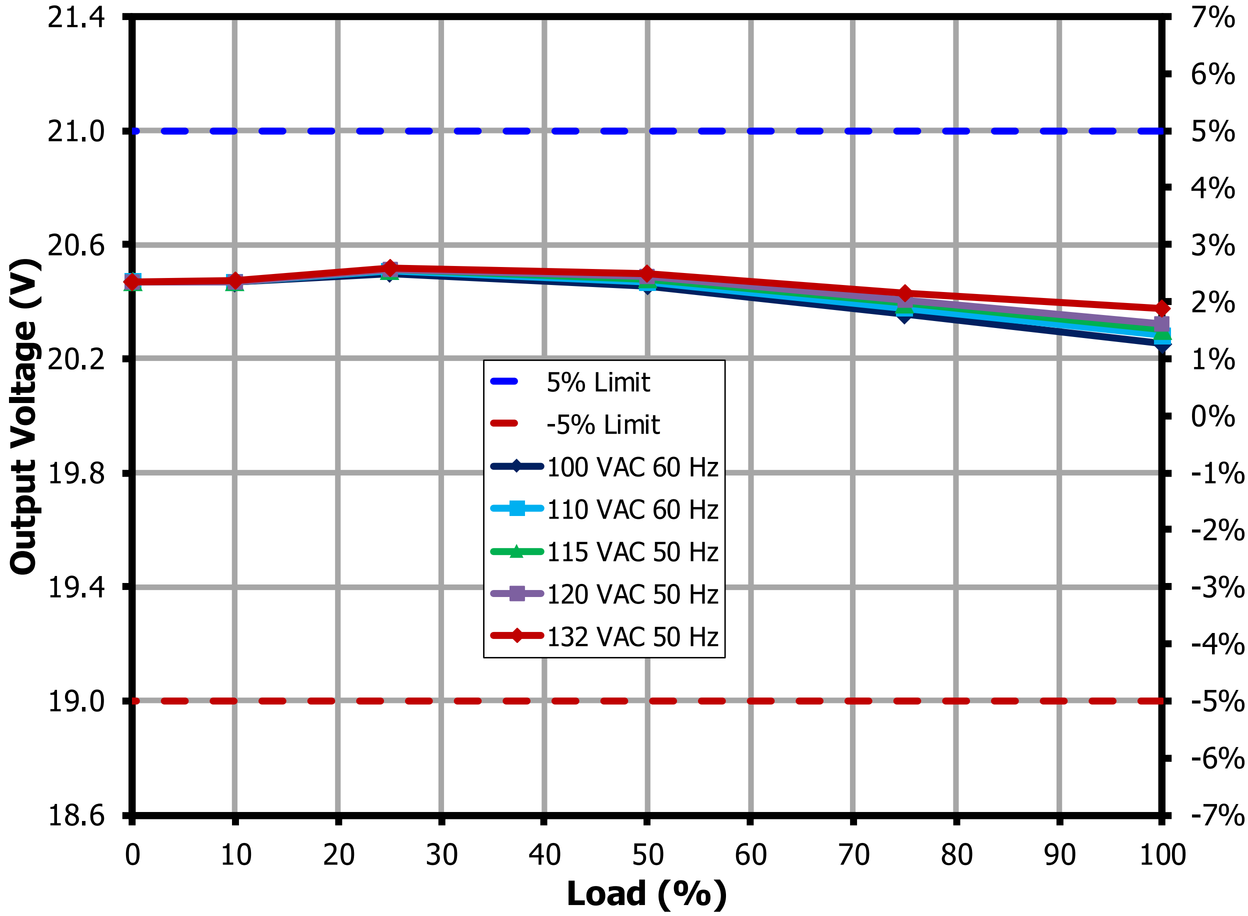


Figure 22 – Voltage Regulation vs. Load at V_{OUT} = 20 VDC / 5 A.

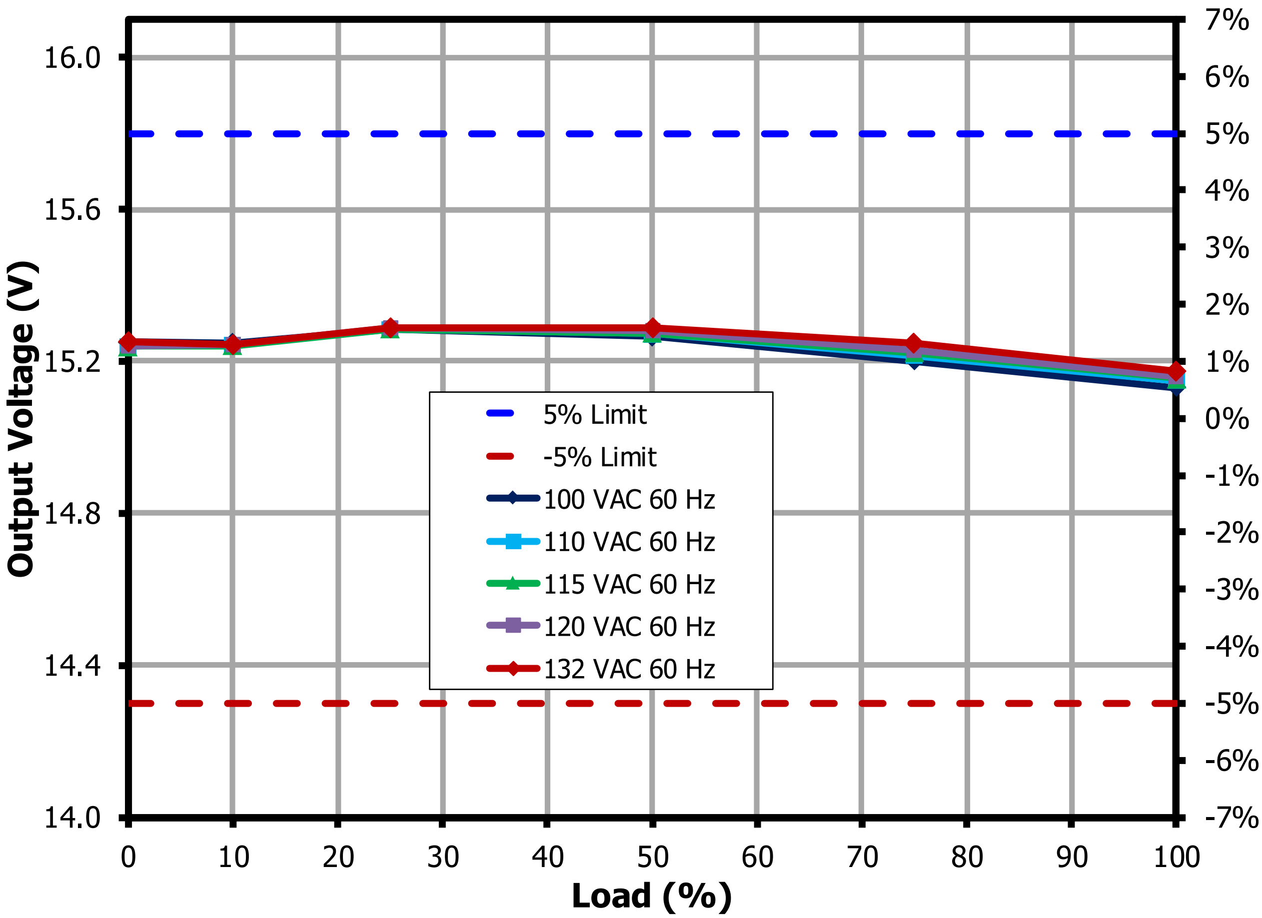


Figure 23 – Voltage Regulation vs. Load at V_{OUT} = 15 VDC / 5 A.

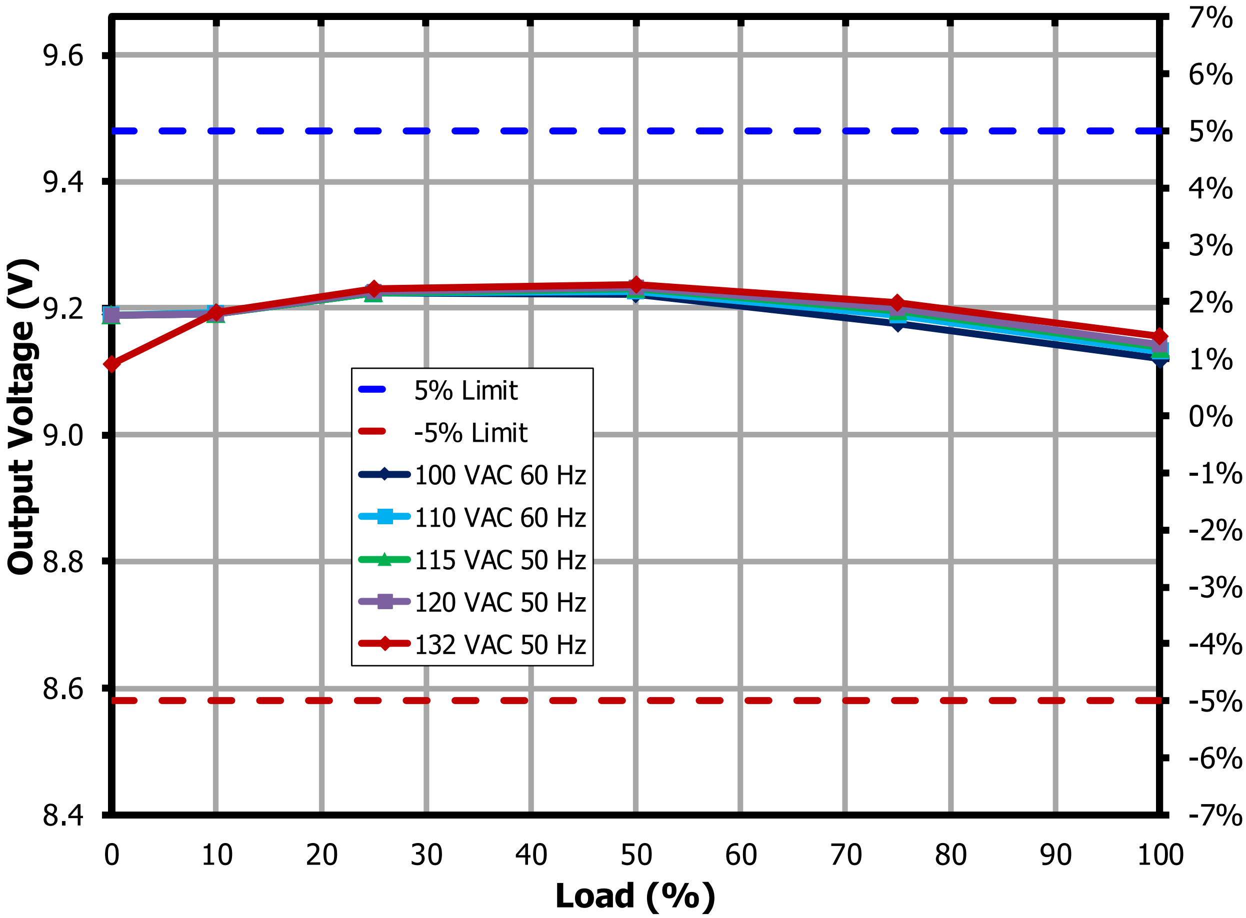


Figure 24 – Voltage Regulation vs. Load at V_{OUT} = 9 VDC / 6 A.

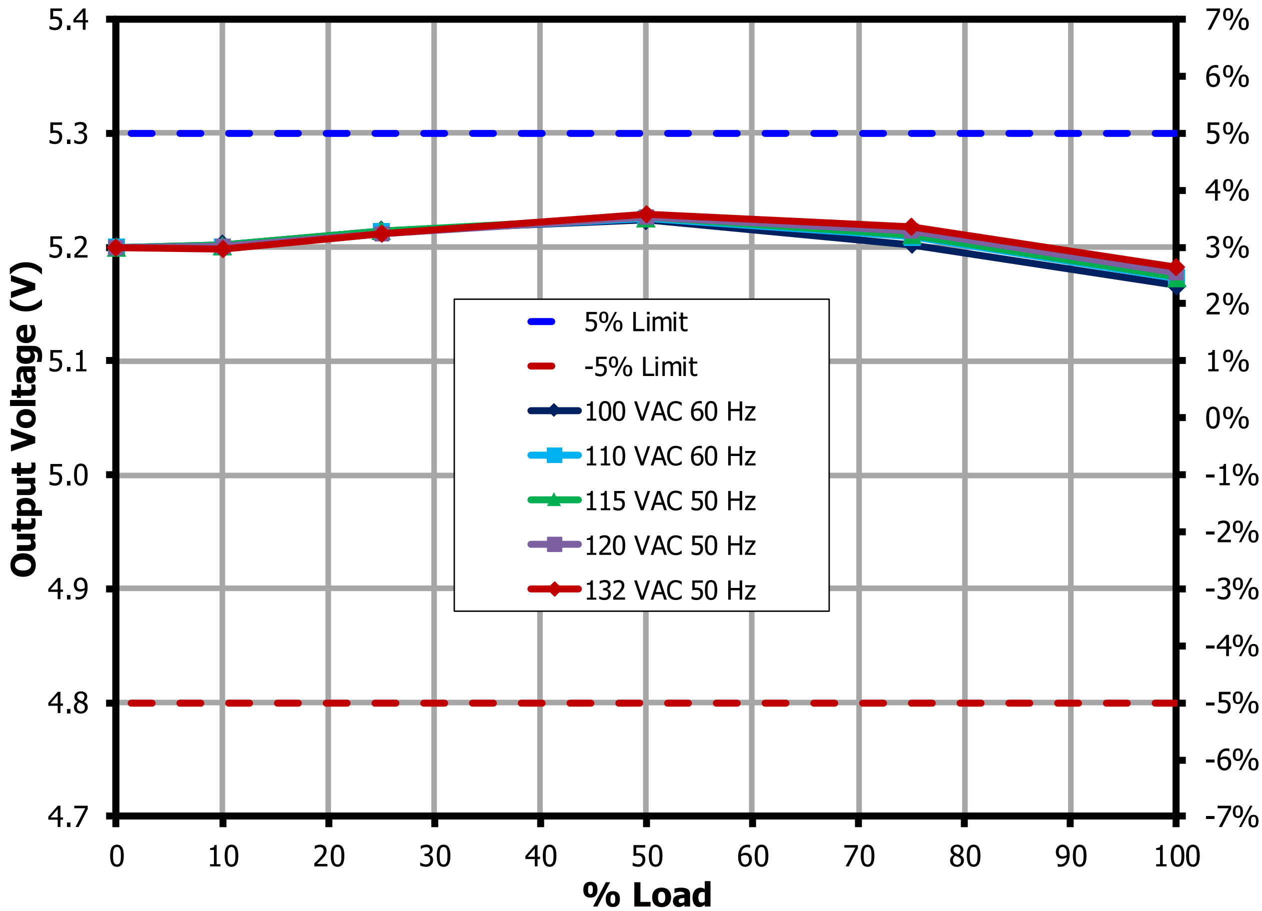


Figure 25 – Voltage Regulation vs. Load at V_{OUT} = 5 VDC / 6.5 A.

10.6 Test Data

10.6.1 Electrical Test Data at Full Load

Note: V_{OUT} is measured on the board

	Input		Input Measurement			Output 1 Measurement			Efficiency (%)
	Voltage (VAC)	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (VDC)	I_{OUT} (mA)	P_{OUT} (W)	
20 V / 5 A	100	60	99.91	1913.60	107.30	20.25	4999.87	101.26	94.37
	110	60	109.87	1791.70	107.10	20.28	4999.87	101.40	94.68
	115	60	114.93	1741.50	107.09	20.30	5000.25	101.52	94.80
	120	60	119.91	1696.90	107.10	20.32	4999.50	101.60	94.86
	132	60	131.91	1602.00	107.06	20.38	4999.87	101.88	95.16
	Input		Input Measurement			Output 1 Measurement			Efficiency (%)
	Voltage (VAC)	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (VDC)	I_{OUT} (mA)	P_{OUT} (W)	
15 V / 5 A	100	60	99.93	1488.70	79.94	15.08	4999.12	75.39	94.31
	110	60	109.89	1406.60	79.88	15.10	4999.50	75.49	94.50
	115	60	114.95	1369.70	79.84	15.10	4999.87	75.52	94.59
	120	60	119.93	1336.40	79.82	15.11	4999.50	75.53	94.63
	132	60	131.93	1266.80	79.73	15.12	4999.50	75.61	94.83
	Input		Input Measurement			Output 1 Measurement			Efficiency (%)
	Voltage (VAC)	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (VDC)	I_{OUT} (mA)	P_{OUT} (W)	
9 V / 6 A	100	60	99.95	1149.30	58.14	9.09	5999.17	54.53	93.79
	110	60	109.90	1089.00	58.13	9.10	5999.55	54.61	93.94
	115	60	114.96	1063.40	58.13	9.11	5999.17	54.64	93.99
	120	60	119.94	1040.70	58.14	9.11	5999.17	54.67	94.03
	132	60	131.94	992.00	58.14	9.12	5999.55	54.74	94.16
	Input		Input Measurement			Output 1 Measurement			Efficiency (%)
	Voltage (VAC)	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA)	P_{OUT} (W)	
5 V / 6.5 A	100	60	99.97	783.30	35.85	5.12	6499.20	33.25	92.75
	110	60	109.92	748.10	35.87	5.12	6499.20	33.29	92.82
	115	60	114.98	732.40	35.89	5.12	6499.57	33.30	92.79
	120	60	119.96	716.60	35.91	5.13	6499.20	33.32	92.79
	132	60	131.96	680.90	35.96	5.13	6499.20	33.36	92.76

10.6.2 Energy Efficiency Test Data

Note: V_{OUT} is measured on the board

	Load Setting		Input Measurement			Load Measurement			Efficiency (%)
	Load (%)	Load (A)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
20 V / 5 A	100	5	114.93	1741.50	107.09	20.30	5000.25	101.52	94.80
	75	3.75	114.95	1385.30	80.62	20.39	3749.25	76.46	94.84
	50	2.5	114.97	1012.80	53.96	20.48	2499.00	51.18	94.85
	25	1.25	114.99	595.90	27.08	20.51	1249.50	25.63	94.64
	10	0.5	115.01	307.00	11.04	20.47	500.02	10.24	92.71
	Average Efficiency at 20 V / 5 A								**94.78**
	Load Setting		**Input Measurement**			**Load Measurement**			**Efficiency (%)**
	Load (%)	Load (A)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
15 V / 5 A	100	5	114.95	1369.70	79.84	15.10	4999.87	75.52	94.59
	75	3.75	114.96	1096.20	60.14	15.17	3749.25	56.88	94.59
	50	2.5	114.98	807.40	40.21	15.22	2499.00	38.04	94.61
	25	1.25	115.00	477.00	20.19	15.24	1248.75	19.03	94.23
	10	0.5	115.01	236.80	8.22	15.19	499.65	7.59	92.34
	Average Efficiency at 15 V / 5 A								**94.50**
	Load Setting		**Input Measurement**			**Load Measurement**			**Efficiency (%)**
	Load (%)	Load (A)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
9 V / 6 A	100	6	114.96	1063.40	58.13	9.11	5999.17	54.64	93.99
	75	4.5	114.98	857.70	43.85	9.17	4499.47	41.24	94.06
	50	3	114.99	628.40	29.31	9.20	2999.03	27.60	94.15
	25	1.5	115.00	378.20	14.67	9.20	1498.95	13.78	93.96
	10	0.6	115.01	176.76	5.96	9.16	599.13	5.49	92.09
	Average Efficiency at 9 V / 6 A								**94.04**
	Load Setting		**Input Measurement**			**Load Measurement**			**Efficiency (%)**
	Load (%)	Load (A)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{IN} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
5 V / 6.5 A	100	6.5	114.98	732.40	35.89	5.12	6499.57	33.30	92.79
	75	4.875	114.99	587.70	27.07	5.16	4874.59	25.16	92.94
	50	3.25	115.00	436.00	18.07	5.18	3249.60	16.82	93.08
	25	1.625	115.01	255.90	9.04	5.16	1623.86	8.39	92.77
	10	0.65	115.01	115.16	3.69	5.15	649.62	3.35	90.74
	Average Efficiency at 5 V / 6.5 A								**92.89**

10.6.3 Electrical Test Data at 20 V / 5 A

	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
100 VAC 60 Hz	100	100	99.91	1913.60	107.30	20.25	4999.87	101.26	94.37
	75	100	99.93	1507.40	80.68	20.36	3749.62	76.33	94.60
	50	100	99.95	1091.10	53.99	20.46	2499.38	51.13	94.69
	25	100	99.98	642.30	27.07	20.50	1249.50	25.61	94.62
	10	100	100.00	328.10	11.01	20.47	499.65	10.23	92.88
	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
110 VAC 60 Hz	100	110	109.87	1791.70	107.10	20.28	4999.87	101.40	94.68
	75	110	109.89	1422.50	80.63	20.38	3749.25	76.40	94.75
	50	110	109.91	1036.60	53.96	20.47	2499.00	51.15	94.80
	25	110	109.93	610.10	27.07	20.51	1249.13	25.62	94.63
	10	110	109.95	314.80	11.03	20.47	499.65	10.23	92.72
	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
115 VAC 60 Hz	100	115	114.93	1741.50	107.09	20.30	5000.25	101.52	94.80
	75	115	114.95	1385.30	80.62	20.39	3749.25	76.46	94.84
	50	115	114.97	1012.80	53.96	20.48	2499.00	51.18	94.85
	25	115	114.99	595.90	27.08	20.51	1249.50	25.63	94.64
	10	115	115.01	307.00	11.04	20.47	500.02	10.24	92.71
	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
120 VAC 60 Hz	100	120	119.91	1696.90	107.10	20.32	4999.50	101.60	94.86
	75	120	119.93	1351.50	80.62	20.41	3749.62	76.52	94.91
	50	120	119.95	991.60	53.95	20.49	2499.38	51.21	94.91
	25	120	119.97	583.70	27.08	20.51	1249.13	25.62	94.62
	10	120	119.98	299.30	11.06	20.47	499.65	10.23	92.48
	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
132 VAC 60 Hz	100	132	131.91	1602.00	107.06	20.38	4999.87	101.88	95.16
	75	132	131.93	1280.50	80.49	20.43	3749.62	76.60	95.17
	50	132	131.95	944.50	53.83	20.50	2499.38	51.24	95.18
	25	132	131.97	558.10	26.99	20.52	1249.50	25.64	94.99
	10	132	131.98	276.70	10.97	20.47	499.28	10.22	93.18

Power Integrations, Inc.
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

10.6.4 Electrical Test Data at 15 V / 5 A

	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
100 VAC 60 Hz	100	100	99.93	1488.70	79.94	15.08	4999.12	75.39	94.31
	75	100	99.95	1183.40	60.19	15.15	3749.25	56.80	94.38
	50	100	99.96	863.50	40.25	15.22	2499.00	38.02	94.47
	25	100	99.98	506.90	20.16	15.23	1249.13	19.03	94.39
	10	100	100.00	258.70	8.18	15.20	499.65	7.59	92.83

	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
110 VAC 60 Hz	100	110	109.89	1406.60	79.88	15.10	4999.50	75.49	94.50
	75	110	109.90	1122.80	60.15	15.16	3749.25	56.86	94.53
	50	110	109.92	824.90	40.22	15.22	2499.00	38.04	94.58
	25	110	109.94	485.50	20.17	15.23	1248.75	19.02	94.31
	10	110	109.95	244.50	8.20	15.19	500.02	7.60	92.64

	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
115 VAC 60 Hz	100	115	114.95	1369.70	79.84	15.10	4999.87	75.52	94.59
	75	115	114.96	1096.20	60.14	15.17	3749.25	56.88	94.59
	50	115	114.98	807.40	40.21	15.22	2499.00	38.04	94.61
	25	115	115.00	477.00	20.19	15.24	1248.75	19.03	94.23
	10	115	115.01	236.80	8.22	15.19	499.65	7.59	92.34

	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
120 VAC 60 Hz	100	120	119.93	1336.40	79.82	15.11	4999.50	75.53	94.63
	75	120	119.94	1072.60	60.14	15.18	3749.62	56.92	94.64
	50	120	119.96	790.60	40.21	15.23	2498.63	38.05	94.64
	25	120	119.97	469.70	20.19	15.24	1248.38	19.02	94.22
	10	120	119.98	229.60	8.23	15.19	499.65	7.59	92.24

	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
132 VAC 60 Hz	100	132	131.93	1266.80	79.73	15.12	4999.50	75.61	94.83
	75	132	131.95	1021.60	60.07	15.20	3749.25	56.98	94.86
	50	132	131.96	748.90	40.14	15.24	2499.00	38.08	94.86
	25	132	131.97	452.20	20.12	15.24	1248.75	19.03	94.59
	10	132	131.98	211.33	8.17	15.19	499.65	7.59	92.94

10.6.5 Electrical Test Data at 9 V / 6 A

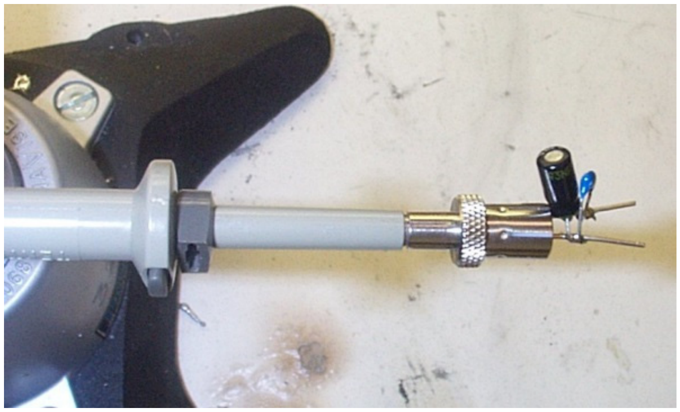
	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
100 VAC 60 Hz	100	100	99.95	1149.30	58.14	9.09	5999.17	54.53	93.79
	75	100	99.96	920.60	43.83	9.15	4499.10	41.15	93.88
	50	100	99.98	677.20	29.31	9.19	2998.65	27.56	94.04
	25	100	99.99	399.00	14.66	9.20	1498.95	13.78	94.02
	10	100	100.00	195.45	5.92	9.16	599.51	5.49	92.80
	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
110 VAC 60 Hz	100	110	109.90	1089.00	58.13	9.10	5999.55	54.61	93.94
	75	110	109.92	876.60	43.84	9.16	4499.10	41.21	94.01
	50	110	109.93	644.00	29.31	9.20	2999.03	27.58	94.11
	25	110	109.94	384.60	14.67	9.19	1498.95	13.78	93.94
	10	110	109.95	182.53	5.95	9.16	599.51	5.49	92.39
	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
115 VAC 60 Hz	100	115	114.96	1063.40	58.13	9.11	5999.17	54.64	93.99
	75	115	114.98	857.70	43.85	9.17	4499.47	41.24	94.06
	50	115	114.99	628.40	29.31	9.20	2999.03	27.60	94.15
	25	115	115.00	378.20	14.67	9.20	1498.95	13.78	93.96
	10	115	115.01	176.76	5.96	9.16	599.13	5.49	92.09
	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
120 VAC 60 Hz	100	120	119.94	1040.70	58.14	9.11	5999.17	54.67	94.03
	75	120	119.95	840.50	43.85	9.17	4499.10	41.26	94.09
	50	120	119.97	614.80	29.32	9.20	2999.03	27.60	94.13
	25	120	119.98	371.90	14.69	9.20	1498.95	13.79	93.85
	10	120	119.99	171.33	5.98	9.16	599.51	5.49	91.90
	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
132 VAC 60 Hz	100	132	131.94	992.00	58.14	9.12	5999.55	54.74	94.16
	75	132	131.96	799.60	43.84	9.18	4499.10	41.30	94.20
	50	132	131.97	586.80	29.31	9.21	2999.03	27.62	94.22
	25	132	131.98	353.90	14.68	9.20	1499.33	13.79	93.97
	10	132	131.98	158.45	5.96	9.16	599.51	5.49	92.19

10.6.6 Electrical Test Data at 5 V / 6.5 A

	Load (%)	Input	Input Measurement			Output 1 Measurement			Efficiency (%)
		VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	
100 VAC 60 Hz	100	100	99.97	783.30	35.85	5.12	6499.20	33.25	92.75
	75	100	99.98	631.90	27.04	5.15	4874.21	25.11	92.88
	50	100	99.99	461.60	18.05	5.17	3249.23	16.81	93.14
	25	100	100.00	276.10	9.01	5.16	1623.86	8.39	93.08
	10	100	100.00	126.33	3.65	5.15	649.62	3.35	91.83
	Load (%)	Input VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	Efficiency (%)
110 VAC 60 Hz	100	110	109.92	748.10	35.87	5.12	6499.20	33.29	92.82
	75	110	109.93	601.00	27.07	5.16	4874.21	25.15	92.89
	50	110	109.94	442.60	18.06	5.17	3249.60	16.82	93.11
	25	110	109.95	262.60	9.03	5.16	1624.24	8.39	92.87
	10	110	109.95	118.52	3.67	5.15	649.25	3.34	91.09
	Load (%)	Input VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	Efficiency (%)
115 VAC 60 Hz	100	115	114.98	732.40	35.89	5.12	6499.57	33.30	92.79
	75	115	114.99	587.70	27.07	5.16	4874.59	25.16	92.94
	50	115	115.00	436.00	18.07	5.18	3249.60	16.82	93.08
	25	115	115.01	255.90	9.04	5.16	1623.86	8.39	92.77
	10	115	115.01	115.16	3.69	5.15	649.62	3.35	90.74
	Load (%)	Input VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	Efficiency (%)
120 VAC 60 Hz	100	120	119.96	716.60	35.91	5.13	6499.20	33.32	92.79
	75	120	119.97	575.70	27.09	5.16	4874.59	25.17	92.93
	50	120	119.98	429.50	18.09	5.18	3249.23	16.82	92.97
	25	120	119.98	248.40	9.06	5.16	1623.86	8.38	92.52
	10	120	119.99	112.09	3.71	5.15	649.25	3.34	90.23
	Load (%)	Input VAC (RMS)	V_{IN} (RMS)	I_{IN} (mA)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (W)	Efficiency (%)
132 VAC 60 Hz	100	132	131.96	680.90	35.96	5.13	6499.20	33.36	92.76
	75	132	131.97	551.50	27.13	5.17	4874.59	25.19	92.85
	50	132	131.98	413.70	18.11	5.18	3249.60	16.83	92.93
	25	132	131.98	231.20	9.08	5.16	1623.86	8.38	92.32
	10	132	131.99	105.04	3.73	5.15	649.25	3.34	89.73

10.7 Output Ripple Voltage

Set-up: Use x1 voltage probe with 2 capacitors (0.1 μF / 50 V ceramic and 10 μ F/ 50 V E-cap) connected across the probe tip and ground as shown below. Oscilloscope was set to AC coupling with frequency bandwidth of 20 MHz. ripple voltage was measured at the end of 2-feet cable at room ambient temperature (25 ºC).



10.7.1 Output Ripple Voltage vs. Percent Load at 20 V / 5 A.

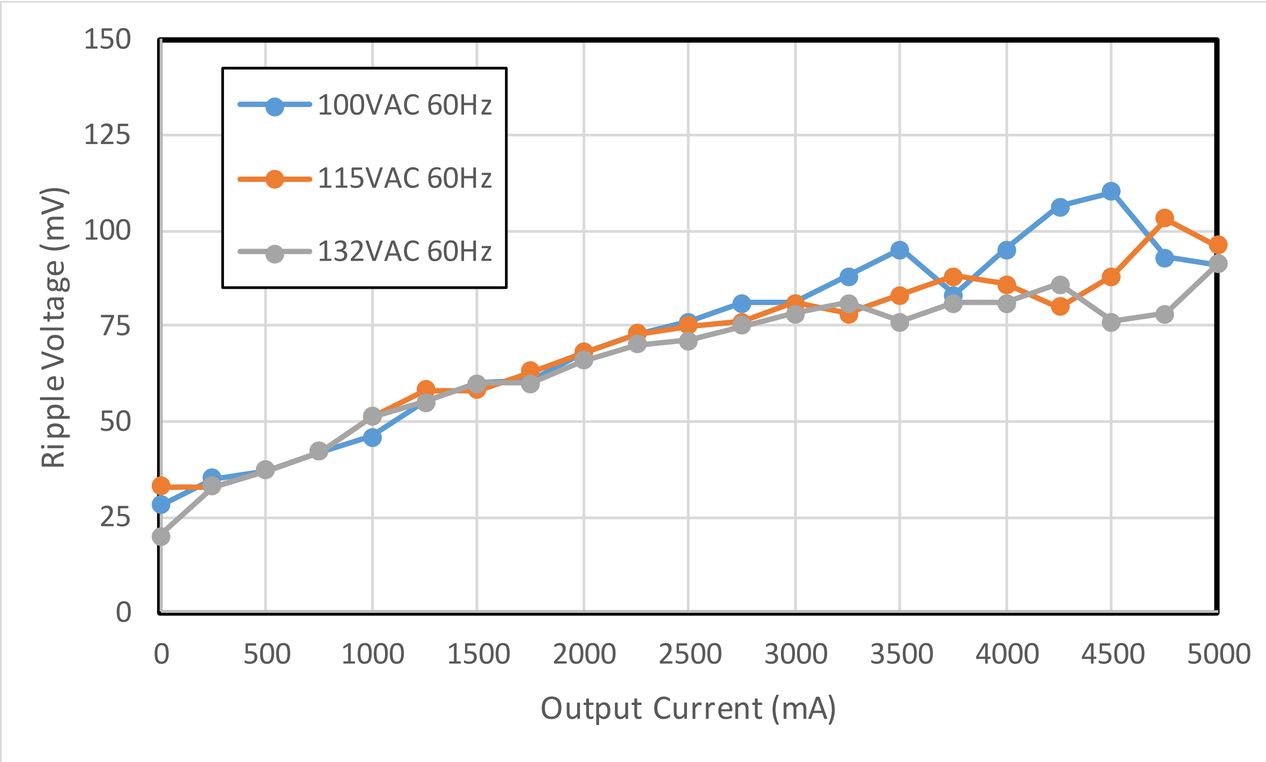


Figure 26 – Ripple Voltage vs. %Load at 20 V.

10.7.2 Output Ripple Voltage vs. Percent Load at 15 V / 5 A.

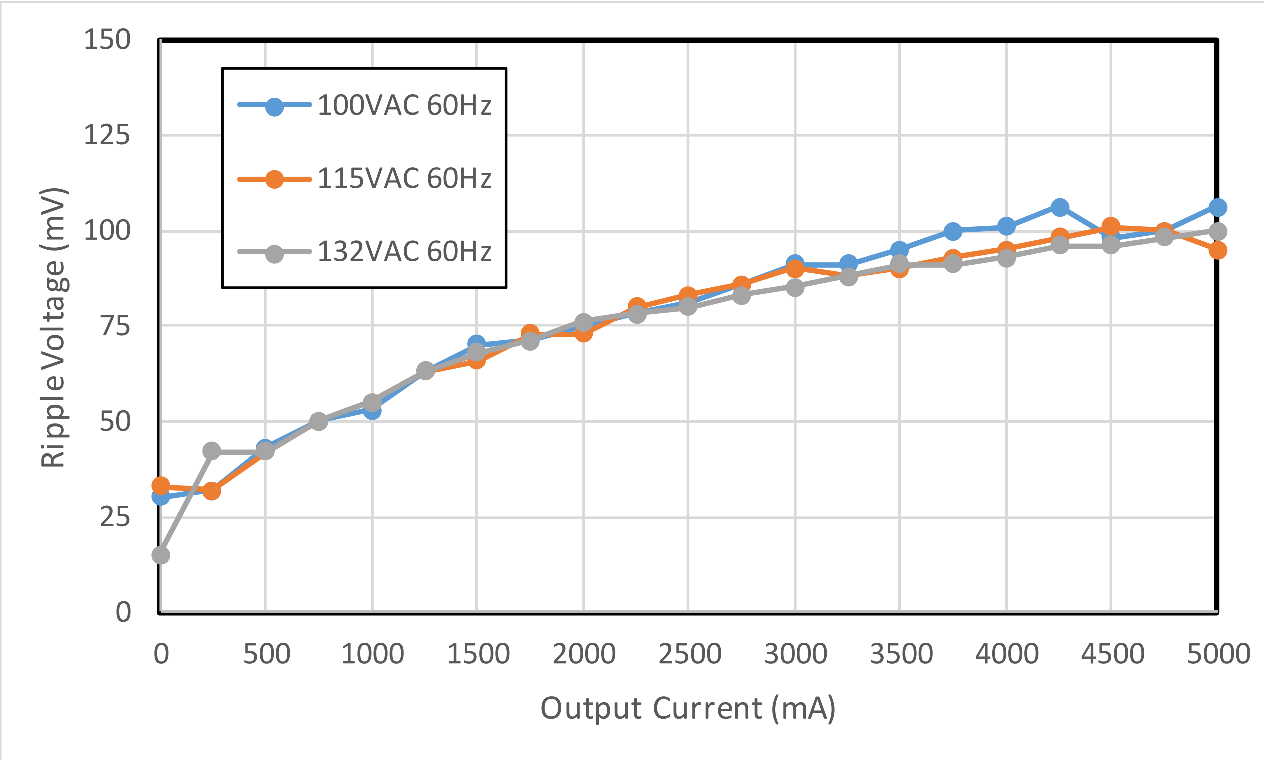


Figure 27 – Ripple Voltage vs. %Load at 15 V.

10.7.3 Output Ripple Voltage vs. Percent Load at 9 V / 6 A.

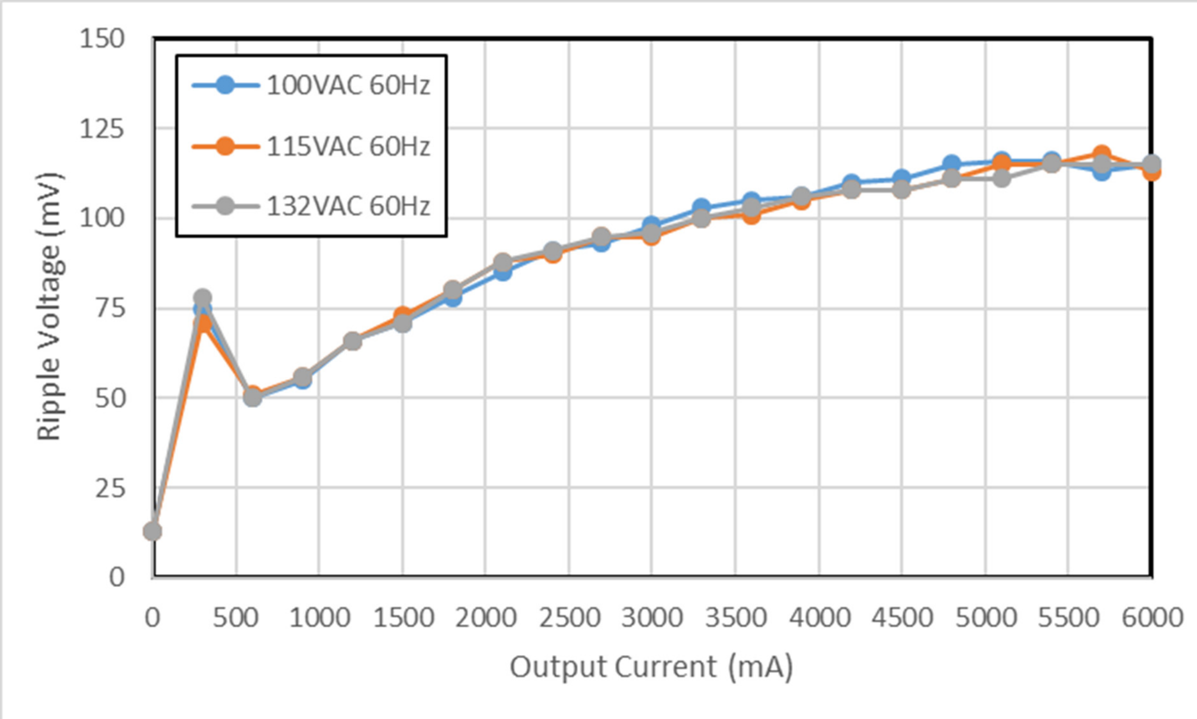


Figure 28 – Ripple Voltage vs. %Load at 9 V.

10.7.4 Output Ripple Voltage vs. Percent Load at 5 V / 6.5 A.

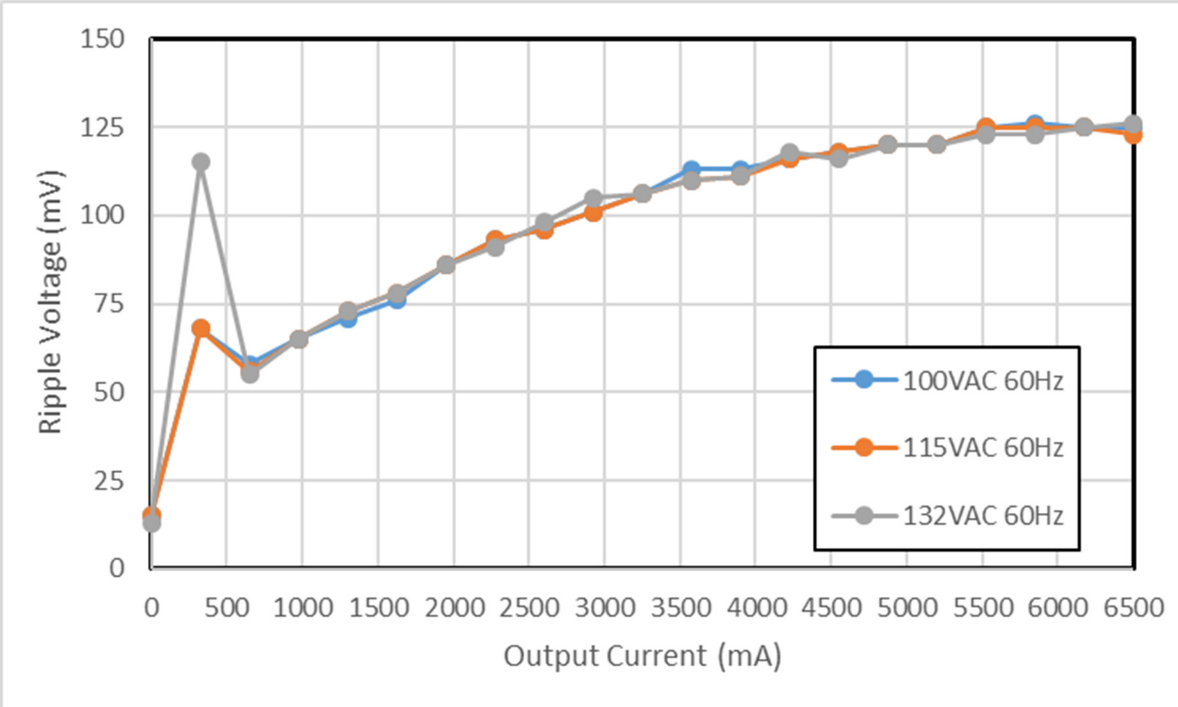


Figure 29 – Ripple Voltage vs. %Load at 5 V.

11 Thermal Performance

11.1 Thermal Scan at 25 ºC Ambient

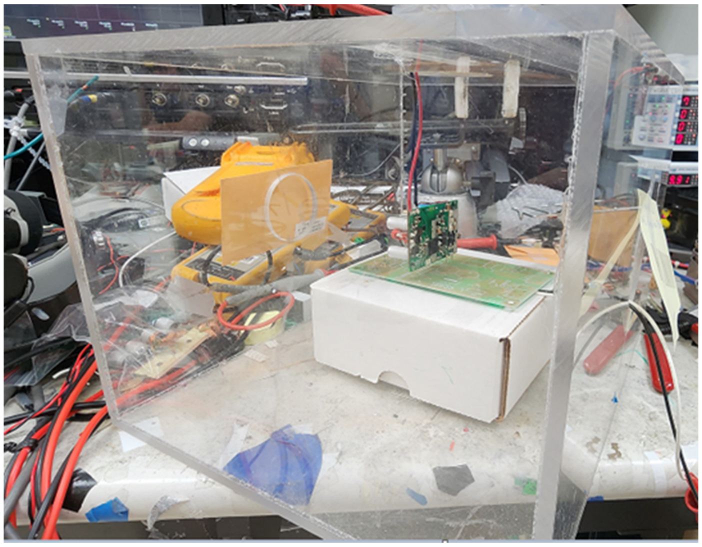


Figure 30 – Test Set-up Picture.

11.1.1 Thermal Scan Summary

Note: Tested using an IR Camera

20 V, 5 A Output				
Component	**Part Description**	**Case Temperature (°C)**		
		100 VAC 60 Hz	**115 VAC 60 Hz**	**132 VAC 60 Hz**
BR1	Bridge Diode 1	87.8	81.1	75.3
BR2	Bridge Diode 2	89.6	83	77.2
U1	ClampZero	95.6	90.2	85.7
U2	InnoSwitch4-CZ	100.3	94.1	85.2
D7	Output Rectifier	94.5	92.1	89.3
Q1	SRFET 1	96.7	94.1	91.2
Q2	SRFET 2	97.9	94.5	91.2
T1	Transformer	108.5	105.4	102.4
15 V, 5 A Output				
Component	**Part Description**	**Case Temperature (°C)**		
		100 VAC 60 Hz	**115 VAC 60 Hz**	**132 VAC 60 Hz**
BR1	Bridge Diode 1	70.9	66.5	62.8
BR2	Bridge Diode 2	72.1	67.8	63.7
U1	ClampZero	76.3	74.1	71.8
U2	InnoSwitch4-CZ	77.4	75.5	72.4
D7	Output Rectifier	79	77.2	77
Q1	SRFET 1	80	78.2	78.2
Q2	SRFET 2	79.8	78	77.8
T1	Transformer	90.7	87.6	87.8

9 V, 6 A Output				
Component	Part Description	Case Temperature (°C)		
		100 VAC 60 Hz	115 VAC 60 Hz	132 VAC 60 Hz
BR1	Bridge Diode 1	60.1	57.3	55.1
BR2	Bridge Diode 2	61.7	58.4	56.4
U1	ClampZero	66.1	65.3	64.8
U2	InnoSwitch4-CZ	66.7	66.6	66.2
D7	Output Rectifier	74.6	75	75.2
Q1	SRFET 1	75.5	75.9	76.1
Q2	SRFET 2	74.7	75.1	75.1
T1	Transformer	82.4	82.4	82.1
5 V, 6.5 A Output				
Component	**Part Description**	**Case Temperature (°C)**		
		100 VAC 60 Hz	**115 VAC 60 Hz**	**132 VAC 60 Hz**
BR1	Bridge Diode 1	49	47.7	46.6
BR2	Bridge Diode 2	50	48.7	48.3
U1	ClampZero	55.8	55.7	56.4
U2	InnoSwitch4-CZ	57.1	58.8	58.9
D7	Output Rectifier	69.4	70.1	70.6
Q1	SRFET 1	70.1	71.1	71.4
Q2	SRFET 2	69	70	70.3
T1	Transformer	72.7	73.5	74.2

11.1.2 100 VAC Input 20 V / 5 A

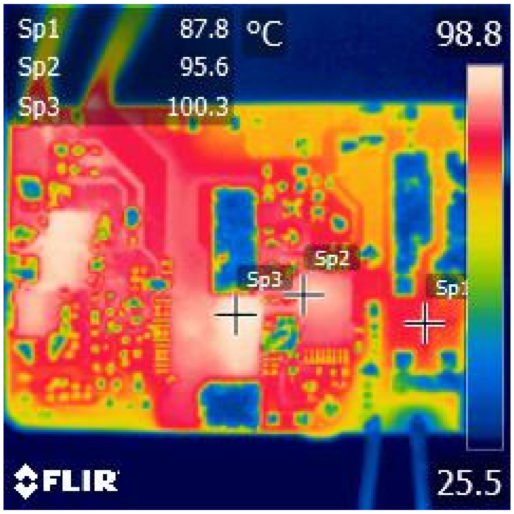


Figure 31 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	87.8
U1	ClampZero	95.6
U2	InnoSwitch4-CZ	100.3

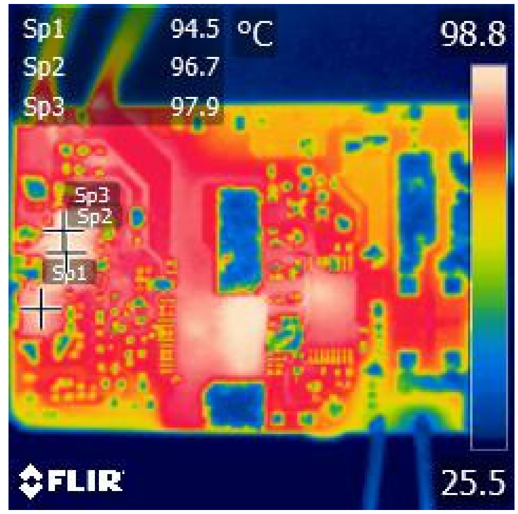


Figure 32 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	94.5
Q1	SRFET 1	96.7
Q2	SRFET 2	97.9

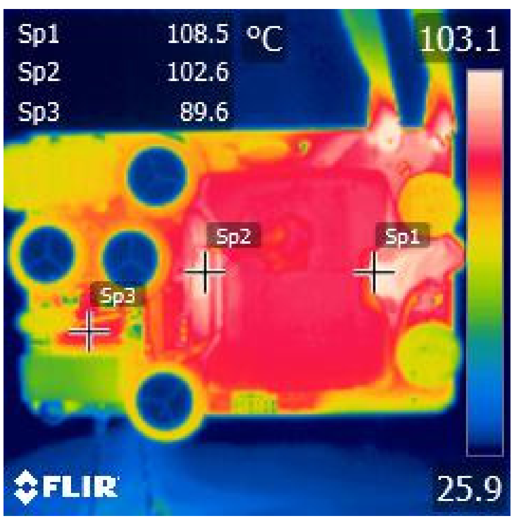


Figure 33 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	108.5
T1	Transformer	102.6
BR2	Bridge diode 2	89.6

11.1.3 115 VAC Input 20 V / 5 A

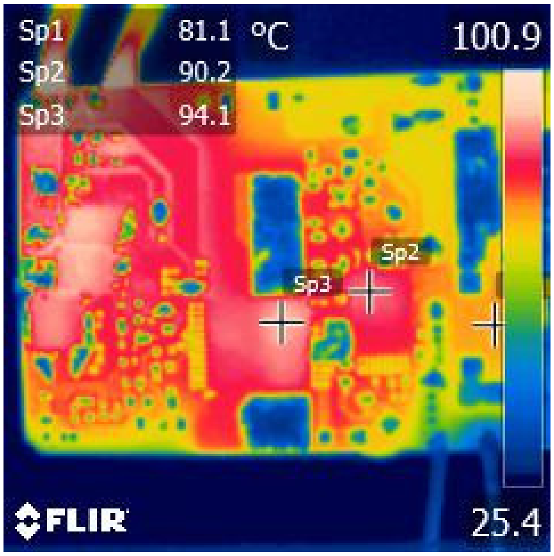


Figure 34 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	81.1
U1	ClampZero	90.2
U2	InnoSwitch4-CZ	94.1

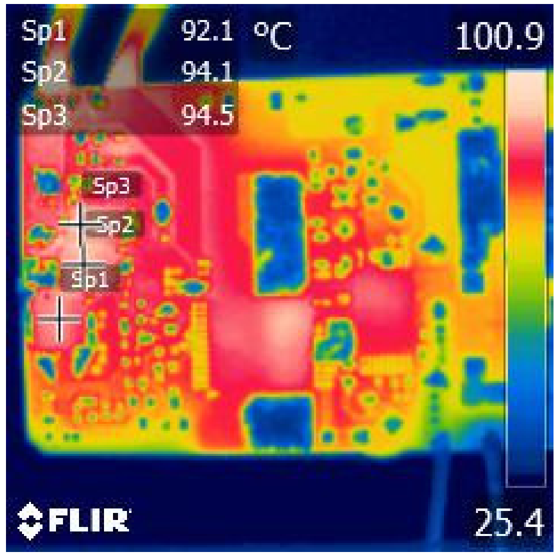


Figure 35 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	92.1
Q1	SRFET 1	94.1
Q2	SRFET 2	94.5

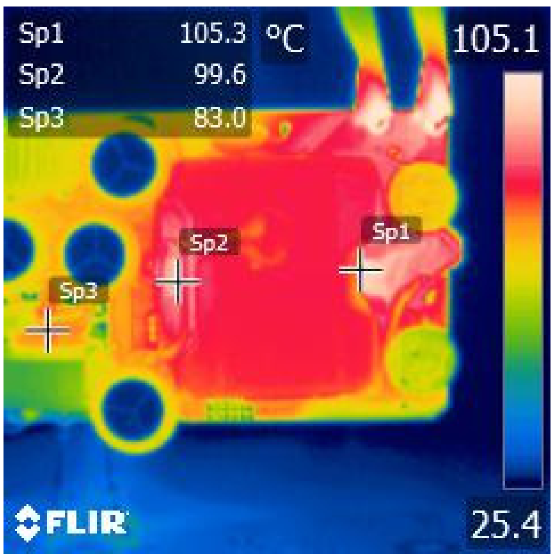


Figure 36 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	105.4
T1	Transformer	99.6
BR2	Bridge diode 2	83

11.1.4 132 VAC Input 20 V / 5 A

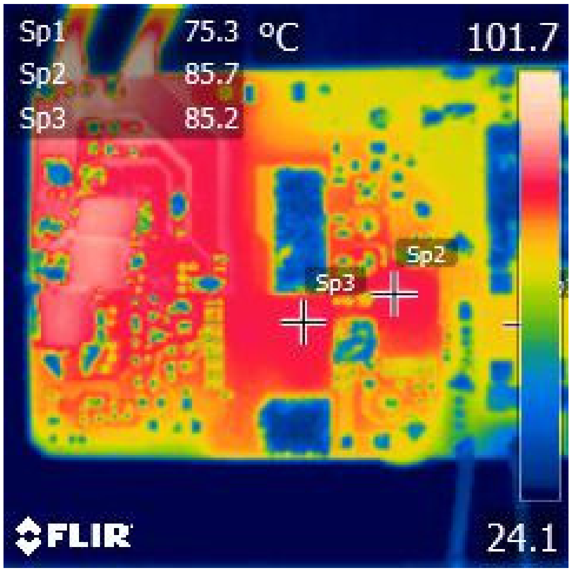


Figure 37 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	75.3
U1	ClampZero	85.7
U2	InnoSwitch4-CZ	85.2

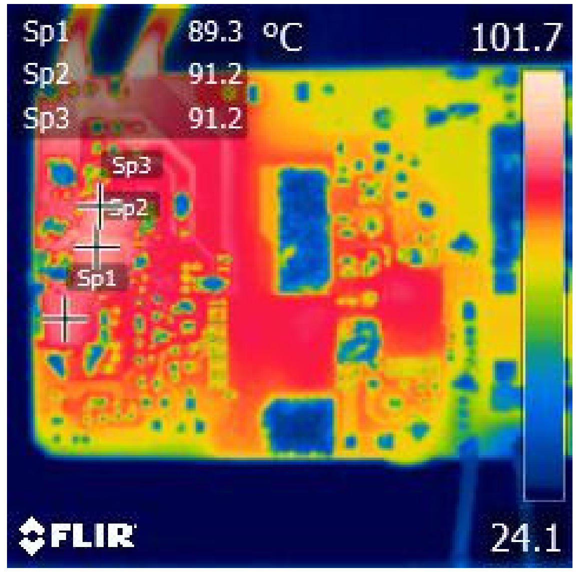


Figure 38 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	89.3
Q1	SRFET 1	91.2
Q2	SRFET 2	91.2

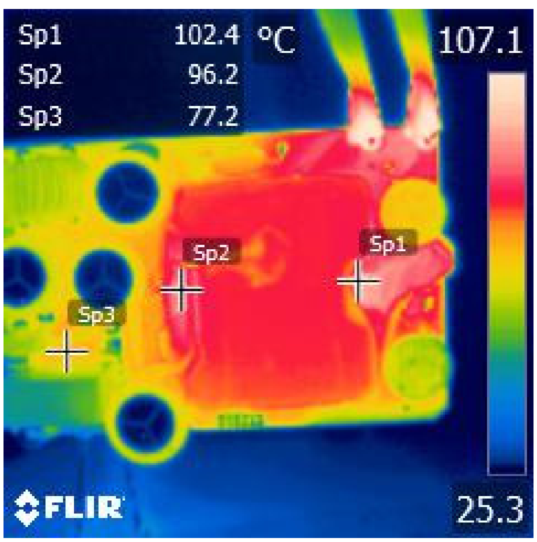


Figure 39 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	102.4
T1	Transformer	96.2
BR2	Bridge diode 2	77.2

11.1.5 100 VAC Input 15 V / 5 A

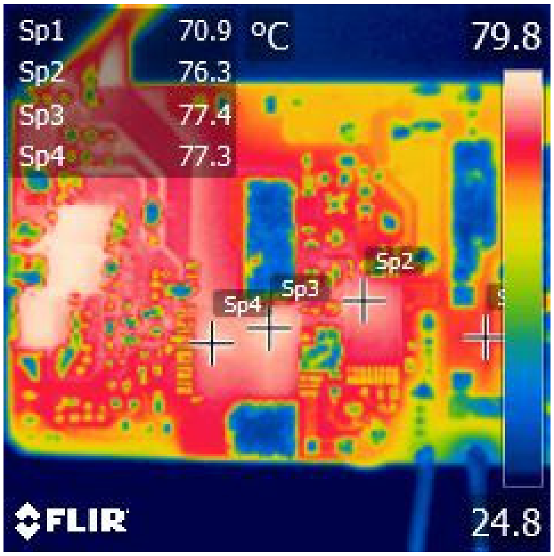


Figure 40 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	70.9
U1	ClampZero	76.3
U2	InnoSwitch4-CZ	77.4

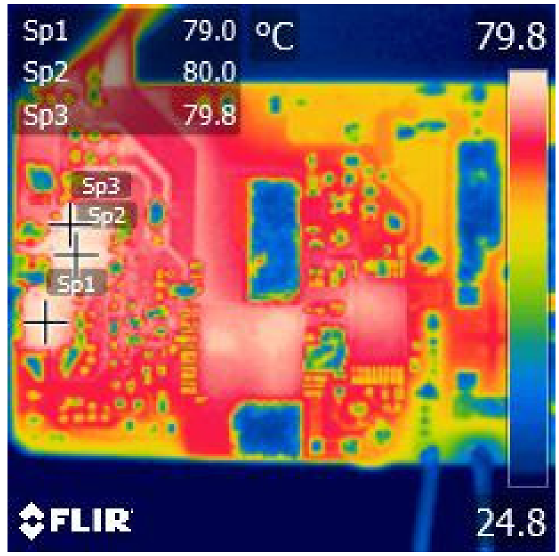


Figure 41 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	79
Q1	SRFET 1	80
Q2	SRFET 2	79.8

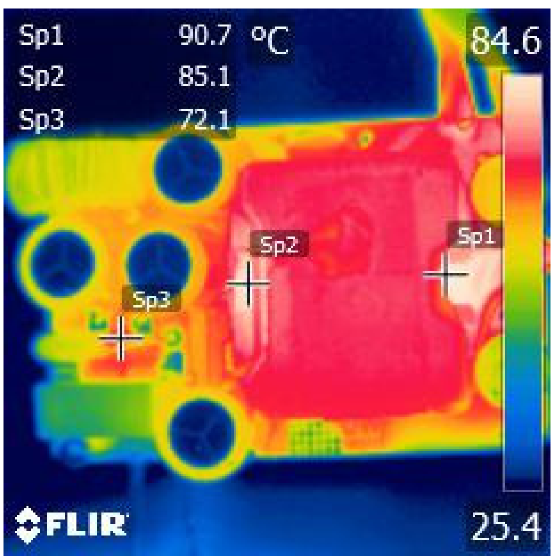


Figure 42 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	90.7
T1	Transformer	85.1
BR2	Bridge diode 2	72.1

11.1.6 115 VAC Input 15 V / 5 A

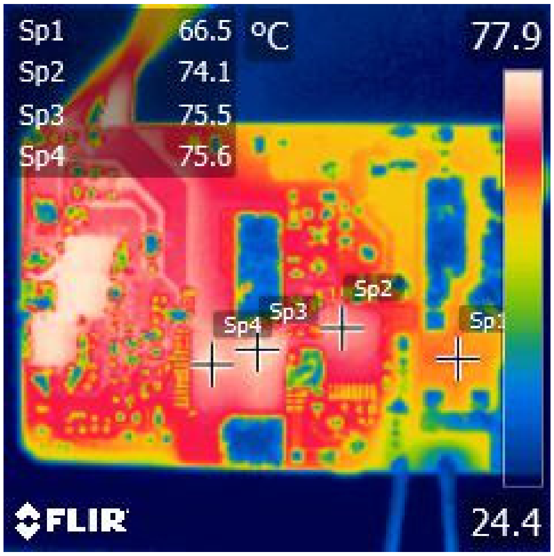


Figure 43 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	66.5
U1	ClampZero	74.1
U2	InnoSwitch4-CZ	75.5

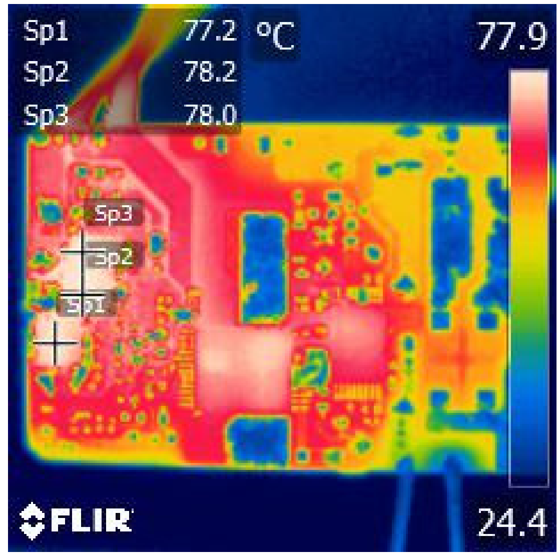


Figure 44 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	77.2
Q1	SRFET 1	78.2
Q2	SRFET 2	78.0

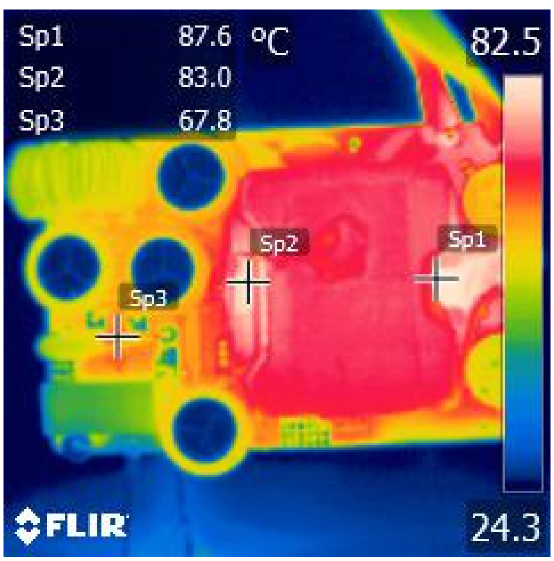


Figure 45 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	87.6
T1	Transformer	83.0
BR2	Bridge diode 2	67.8

11.1.7 132 VAC Input 9 V / 6 A

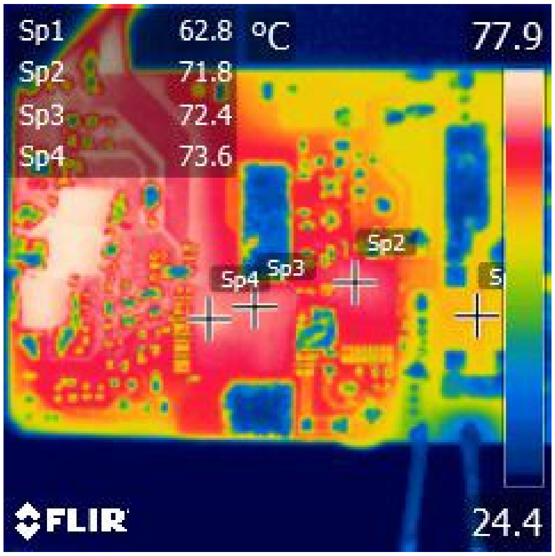


Figure 46 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	62.8
U1	ClampZero	71.8
U2	InnoSwitch4-CZ	72.4

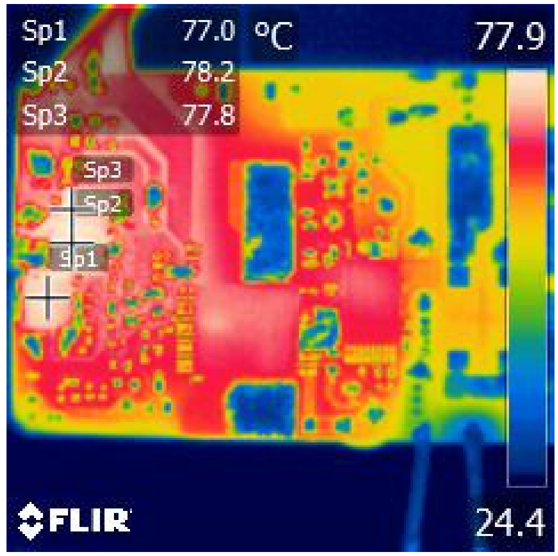


Figure 47 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	77
Q1	SRFET 1	78.2
Q2	SRFET 2	77.8

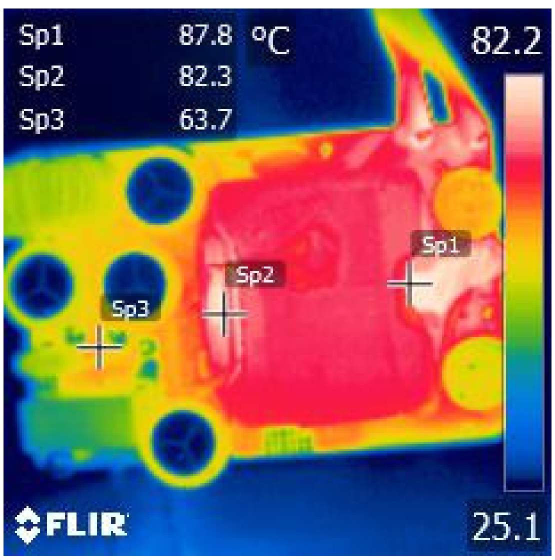


Figure 48 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	87.8
T1	Transformer	82.3
BR2	Bridge diode 2	63.7

11.1.8 100 VAC Input 9 V / 6 A

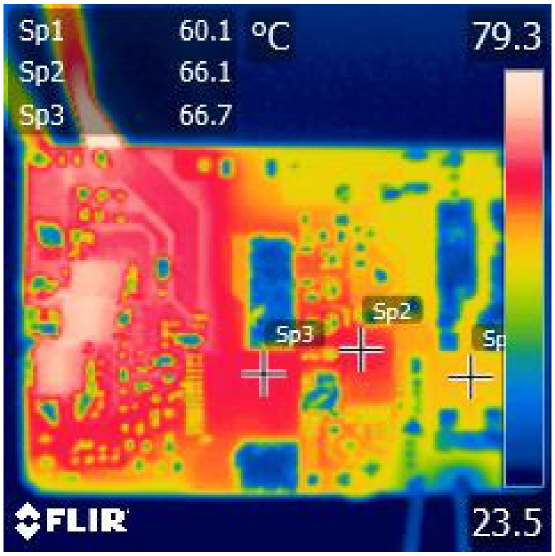


Figure 49 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	60.1
U1	ClampZero	66.1
U2	InnoSwitch4-CZ	66.7

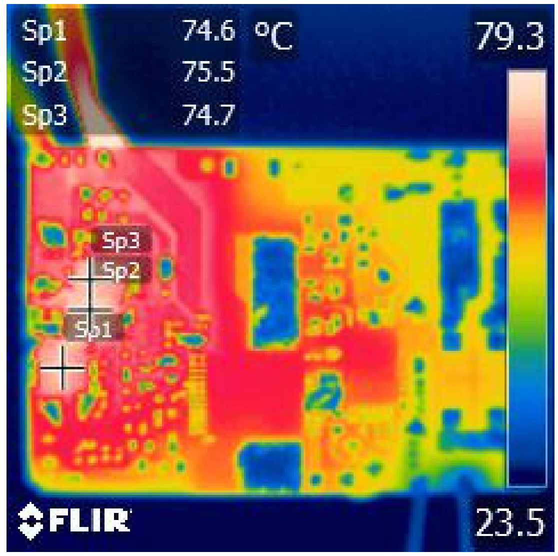


Figure 50 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	74.6
Q1	SRFET 1	75.5
Q2	SRFET 2	74.7

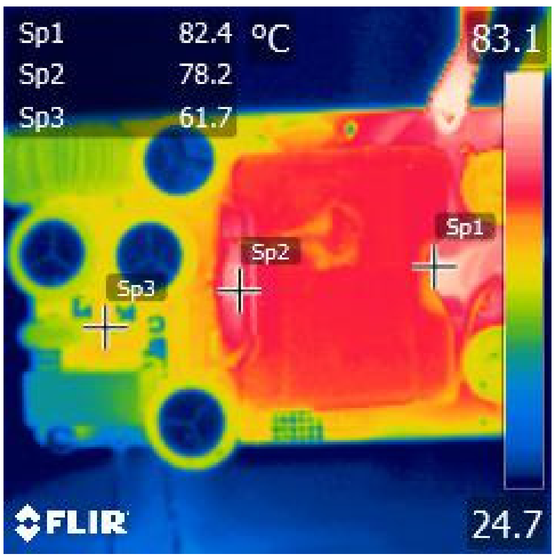


Figure 51 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	82.4
T1	Transformer	78.2
BR2	Bridge diode 2	61.7

11.1.9 115 VAC Input 9 V / 6 A

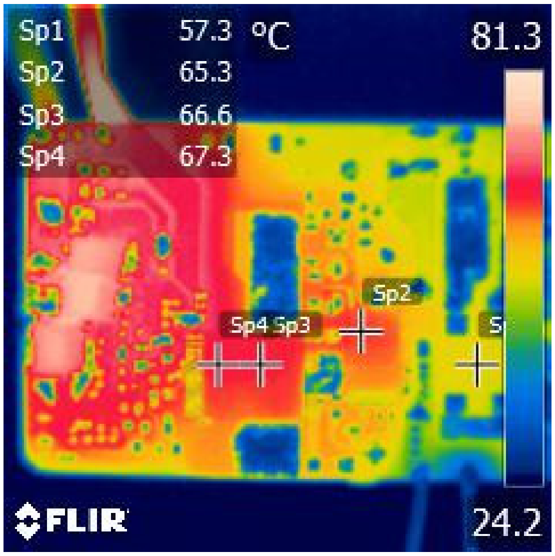


Figure 52 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	57.3
U1	ClampZero	65.3
U2	InnoSwitch4-CZ	66.6

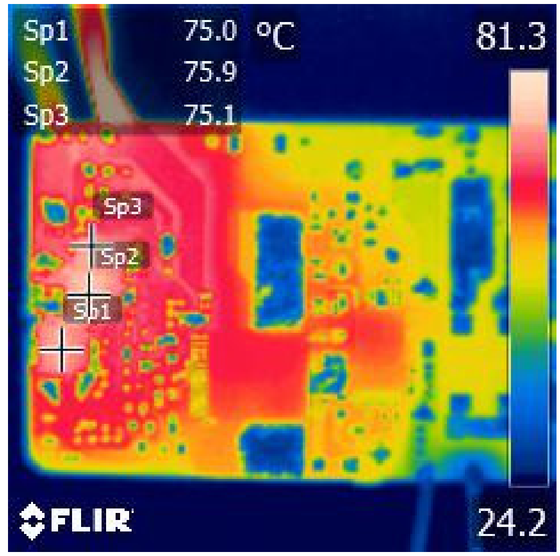


Figure 53 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	75
Q1	SRFET 1	75.9
Q2	SRFET 2	75.1

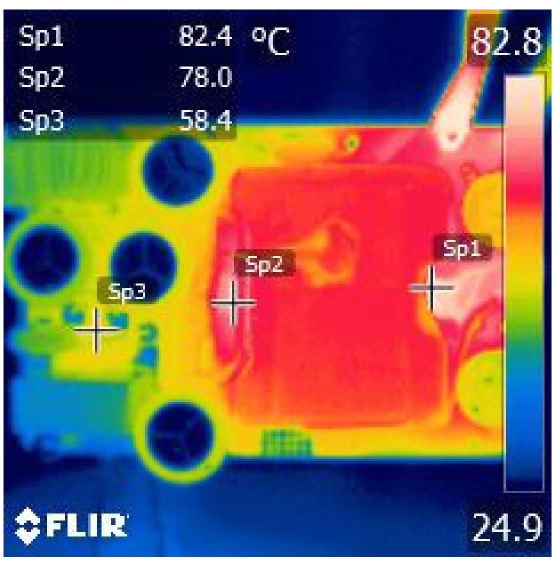


Figure 54 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	82.4
T1	Transformer	78.0
BR2	Bridge diode 2	58.4

11.1.10 132 VAC Input 9 V / 6 A

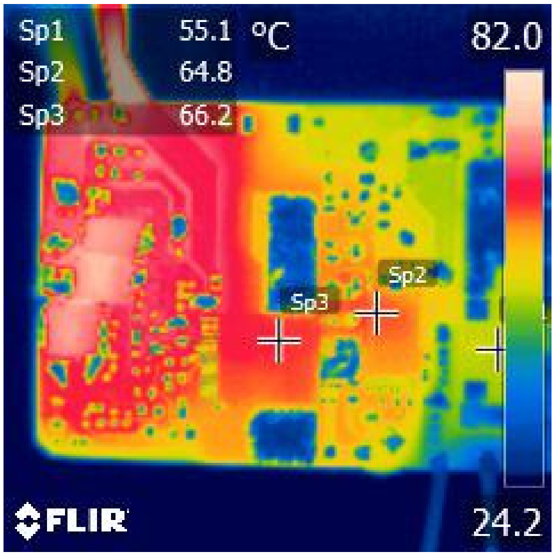


Figure 55 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	55.1
U1	ClampZero	64.8
U2	InnoSwitch4-CZ	66.2

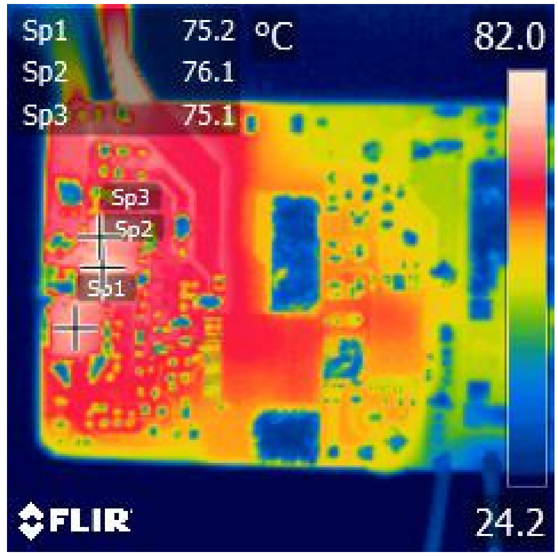


Figure 56 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	75.2
Q1	SRFET 1	76.1
Q2	SRFET 2	75.1

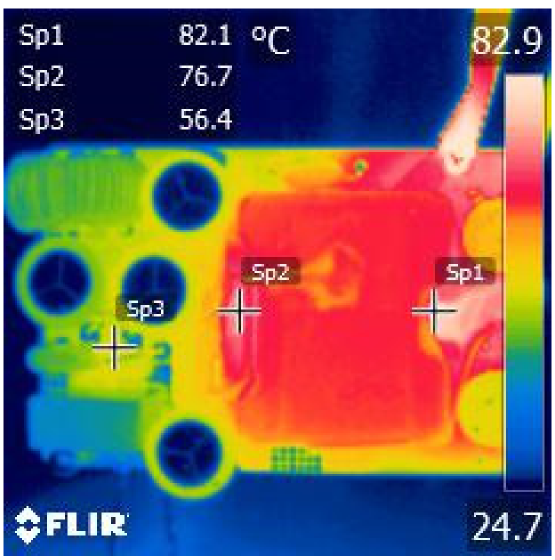


Figure 57 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	82.1
T1	Transformer	76.7
BR2	Bridge diode 2	56.4

11.1.11 100 VAC Input 5 V / 6.5 A

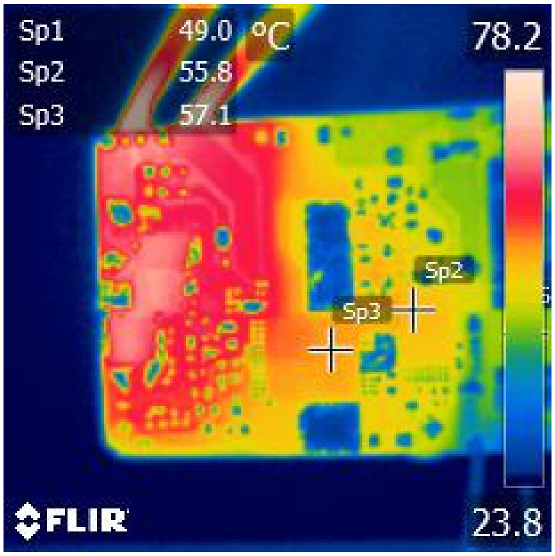


Figure 58 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	49
U1	ClampZero	55.8
U2	InnoSwitch4-CZ	57.1

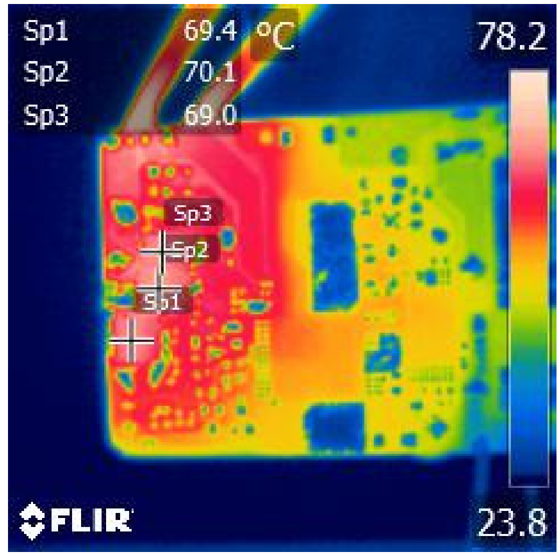


Figure 59 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	69.4
Q1	SRFET 1	70.1
Q2	SRFET 2	69

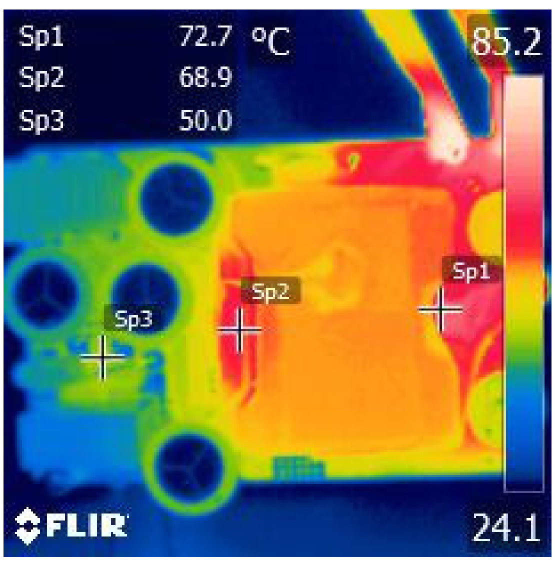


Figure 60 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	72.7
T1	Transformer	68.9
BR2	Bridge diode 2	50

11.1.12 115 VAC Input 5 V / 6.5 A

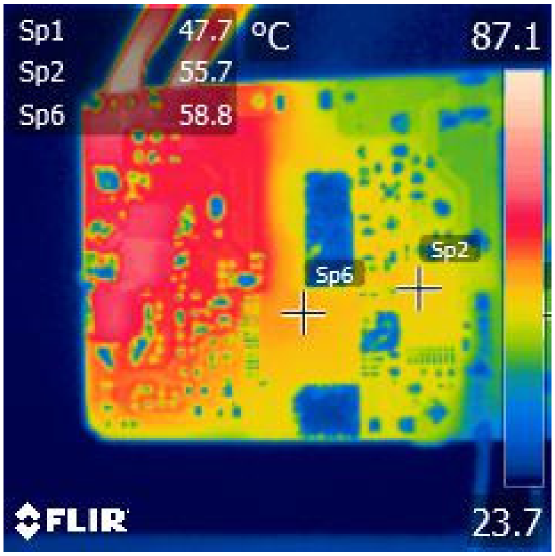


Figure 61 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	47.7
U1	ClampZero	55.7
U2	InnoSwitch4-CZ	58.8

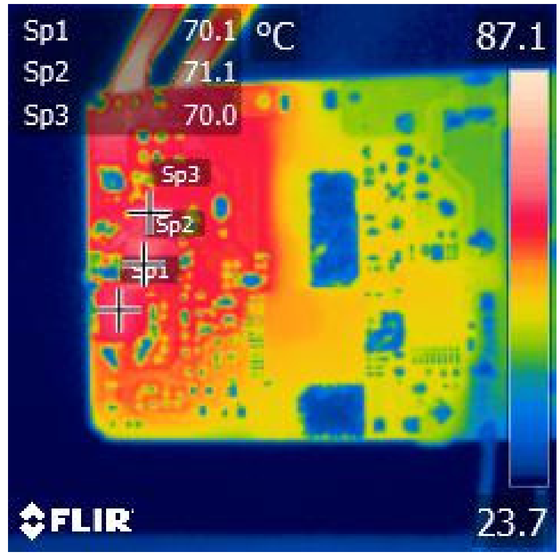


Figure 62 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	70.1
Q1	SRFET 1	71.1
Q2	SRFET 2	70

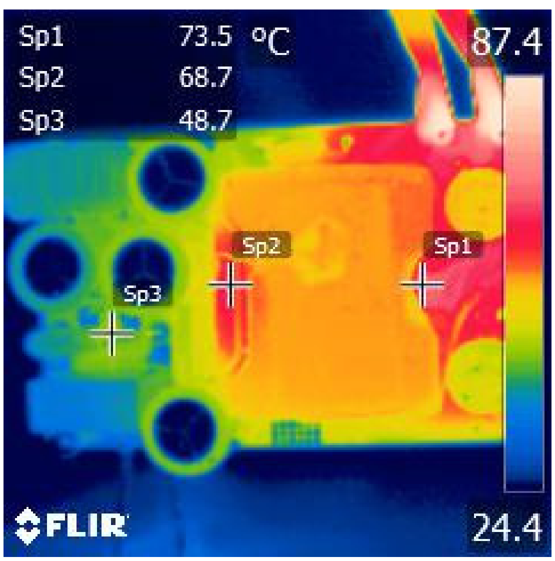


Figure 63 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	73.5
T1	Transformer	68.7
BR2	Bridge diode 2	48.7

11.1.13 132 VAC Input 5 V / 6.5 A

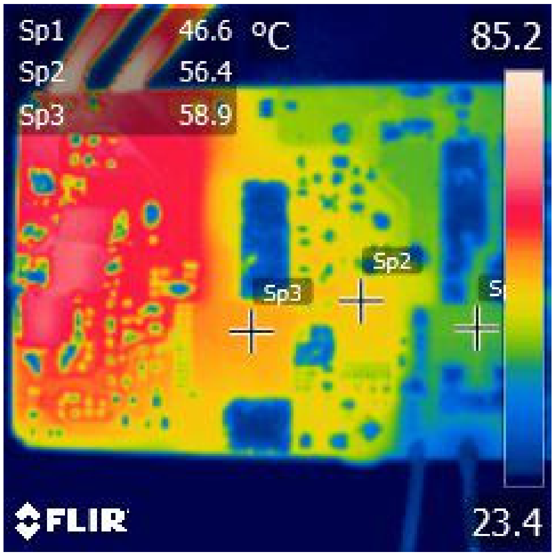


Figure 64 – Bottom Side Primary.

CKT Code	Part Description	Temperature (°C)
BR1	Bridge diode 1	46.6
U1	ClampZero	56.4
U2	InnoSwitch4-CZ	58.9

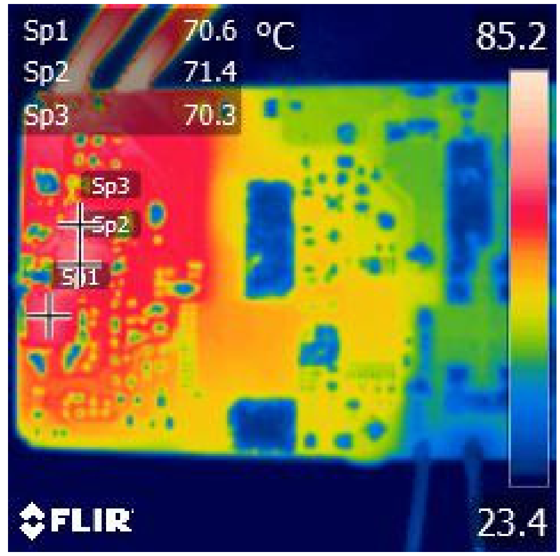


Figure 65 – Bottom Side Secondary.

CKT Code	Part Description	Temperature (°C)
D7	Output Rectifier	70.6
Q1	SRFET 1	71.4
Q2	SRFET 2	70.3

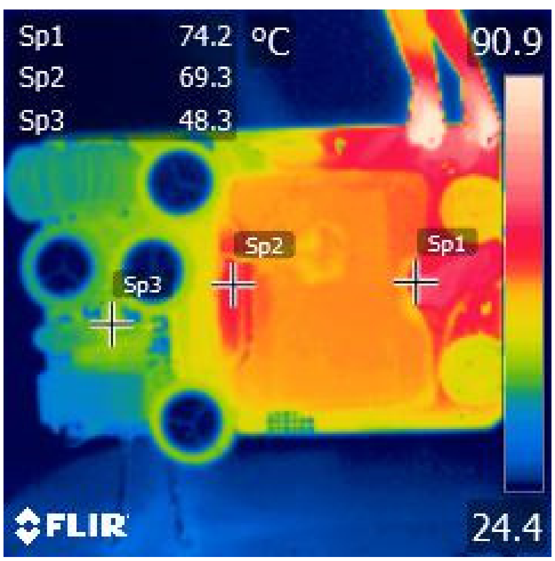


Figure 66 – Top Side.

CKT Code	Part Description	Temperature (°C)
T1	Transformer	74.2
T1	Transformer	69.3
BR2	Bridge diode 2	48.3

11.2 Thermal Performance at 50 ºC Ambient

11.2.1 Potting Material

Mix 1 is to 1 of LORD SC-320 part A and part B. Pour the mixture into the PSU within the case assembly. Curing time is at least 24 hours.

11.2.2 Set-up Picture

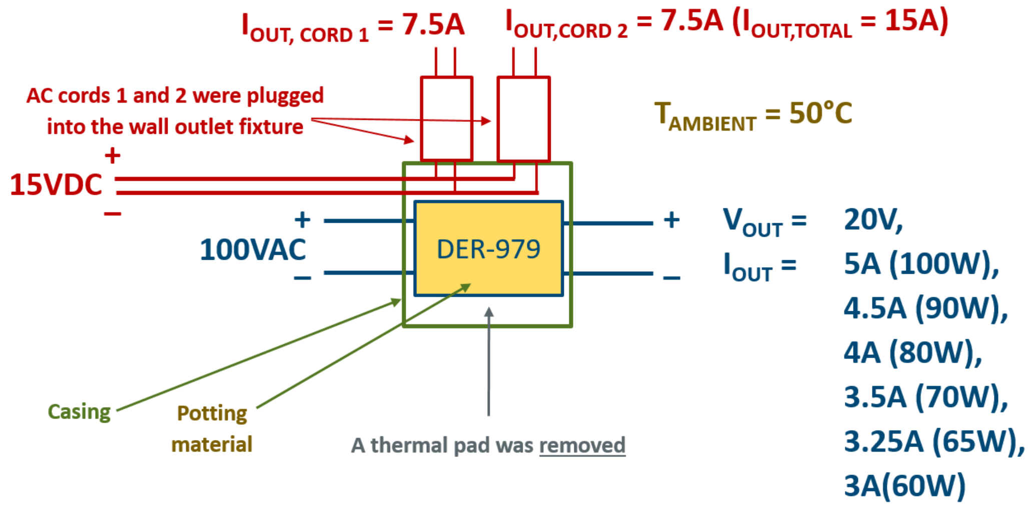


Figure 67 – Test Set-up Diagram.

Figure 68 – Unit Placed Inside a Box to Prevent Air Flow.

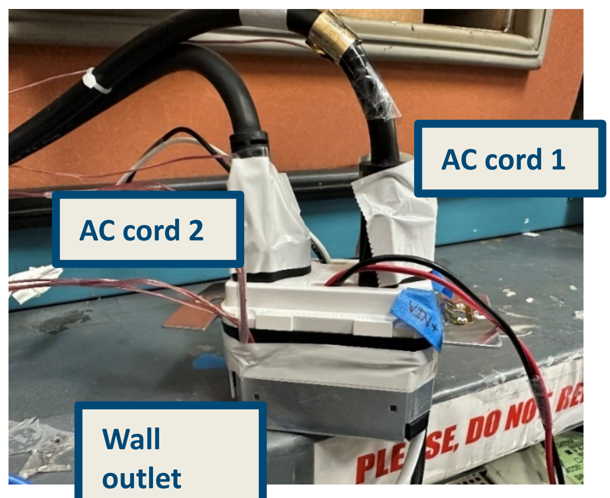


Figure 69 – Test Set-up Actual Wiring.

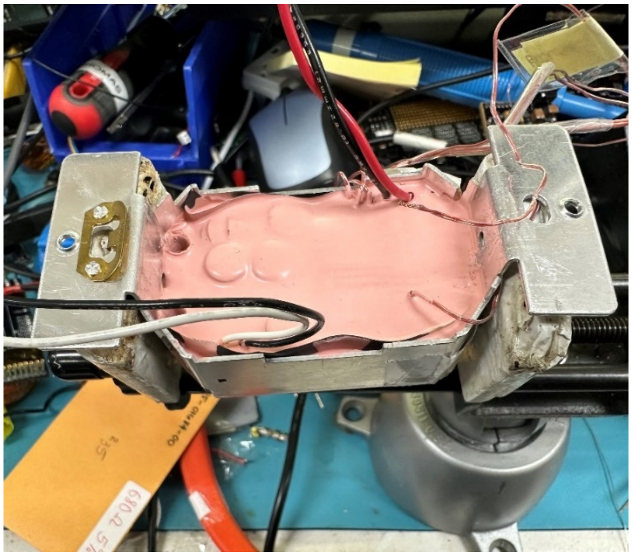


Figure 70 – Unit Submerged in Potting Material.

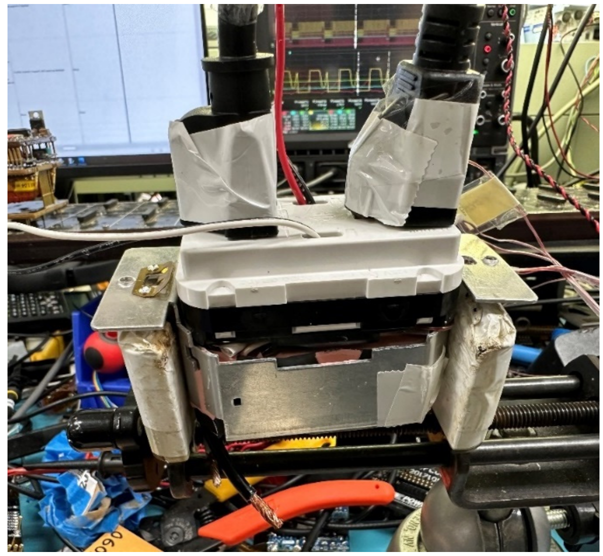


Figure 71 – DER Placed Inside a Case with Potting Insulator.

11.2.3 Thermal Test Summary

Note: Tested at 20 V, 5 A Output at 50 ºC Ambient temperature. The PSU is potted unit in enclosure. Thermal data were taken after 2 hours of soak time.

Input / Output Condition	Temperature (°C)							
	AMB	T1 (Main TRF)	U2 (InnoSwitch4-CZ)	U1 (ClampZero)	Q1 (SR FET)	BR1 (Bridge)	Case Temp	Enclosure
100 VAC / 20 V – 5 A	55.2	111.6	114.6	112.4	114.1	113.1	106.4	103.7
115 VAC / 20 V – 5 A	57.2	110.9	113.1	111.3	113	111.4	105.1	104.2
132 VAC / 20 V – 5 A	56.7	109.7	111.1	109.7	111.9	109.3	103.5	103

11.2.4 100 VAC Input 20 V / 5 A Output

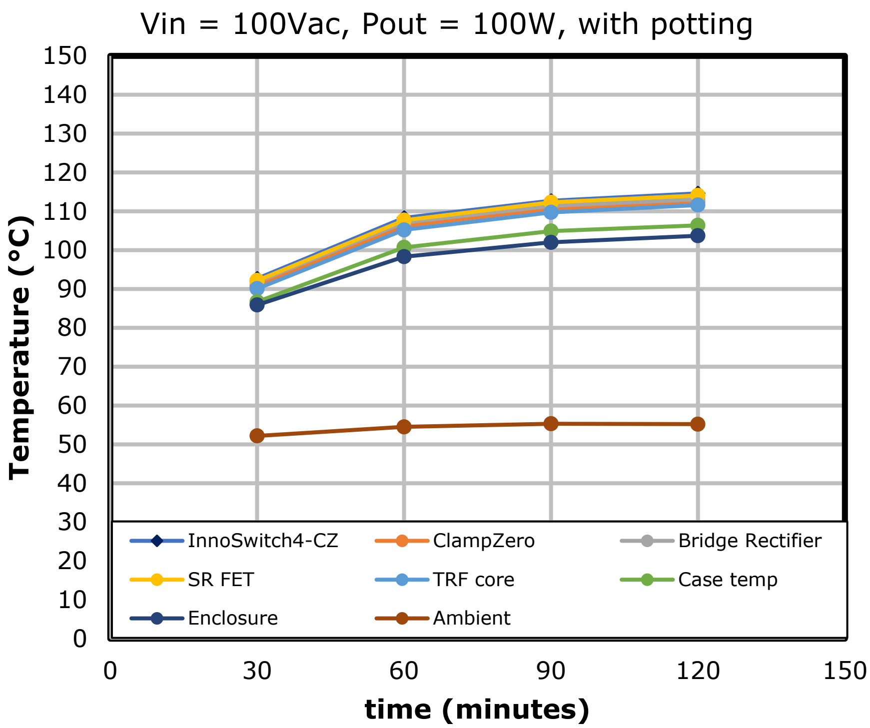


Figure 72 – Thermal Profile at 100 VAC, 20 V / 5 A.

V_{IN} = 100 VAC, P_{OUT} = 100 W, T_{AMB} = 50 °C				
Component	**30-minute Soak Data (°C)**	**1-hour Soak Data (°C)**	**1.5-hour Soak Data (°C)**	**2-hour Soak Data (°C)**
InnoSwitch4-CZ	92.7	108.3	112.7	114.6
ClampZero	90.8	106.2	110.7	112.4
Bridge Rectifier	91.9	107.1	111.4	113.1
SR FET	92.2	107.7	112.3	114.1
Transformer Core	90.1	105.2	109.7	111.6
Case Temperature	86.7	100.7	104.9	106.4
Enclosure	85.9	98.3	102	103.7
Ambient	52.2	54.5	55.3	55.2

11.2.5 115 VAC Input 20 V / 5 A Output

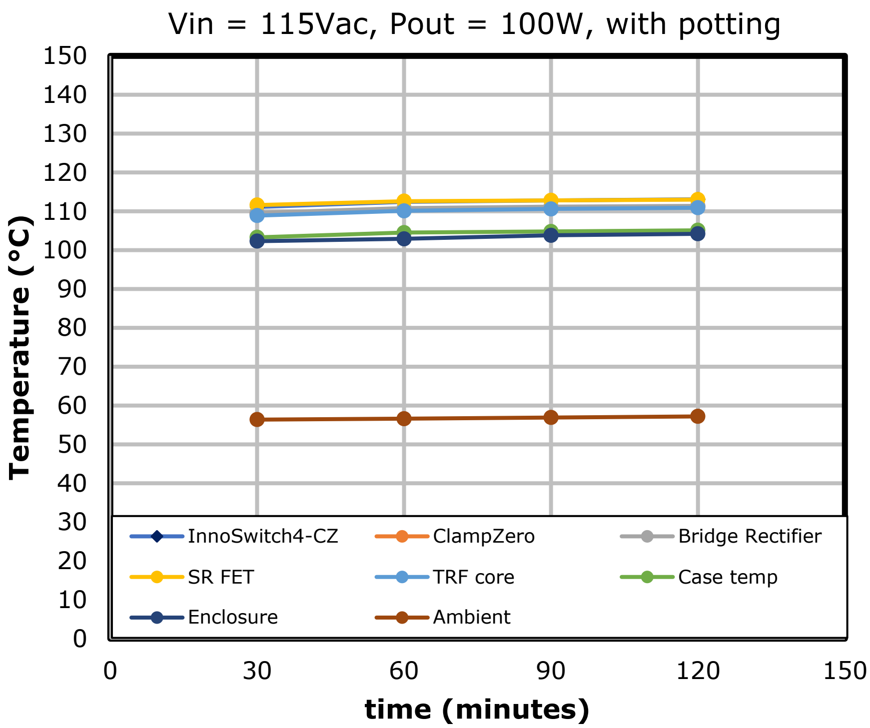


Figure 73 – Thermal Profile at 115 VAC. 20 V / 5

V_{IN} = 115 VAC, P_{OUT} = 100 W, T_{AMB} = 50 °C				
Component	**30-minute Soak Data (°C)**	**1-hour Soak Data (°C)**	**1.5-hour Soak Data (°C)**	**2-hour Soak Data (°C)**
InnoSwitch4-CZ	111.1	112.4	112.8	113.1
ClampZero	109.3	110.6	110.9	111.3
Bridge Rectifier	109.6	110.8	111.2	111.4
SR FET	111.6	112.6	112.8	113
Transformer Core	108.9	110.1	110.6	110.9
Case Temperature	103.3	104.5	104.8	105.1
enclosure	102.3	102.9	103.8	104.2
Ambient	56.4	56.6	56.9	57.2

11.2.6 132 VAC Input 20 V / 5 A Output

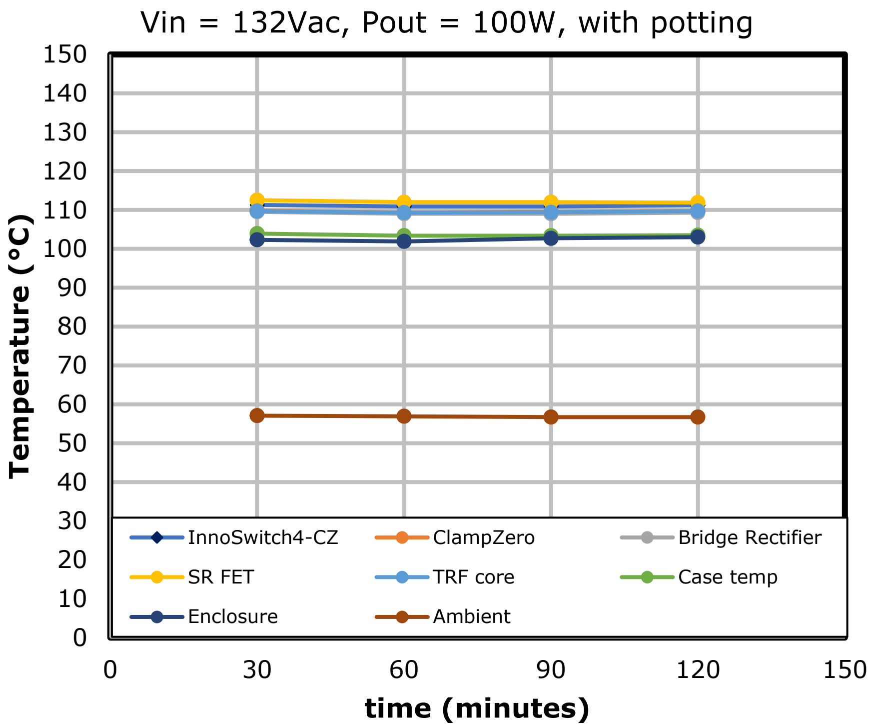


Figure 74 – Thermal Profile at 132 VAC, 20 V / 5 A.

V_{IN} = 132Vac, P_{OUT} = 100 W, T_{AMB} = 50 °C				
Component	**30-minute Soak Data (°C)**	**1-hour Soak Data (°C)**	**1.5-hour Soak Data (°C)**	**2-hour Soak Data (°C)**
InnoSwitch4-CZ	111.3	110.9	110.9	111.2
ClampZero	109.8	109.3	109.5	109.7
Bridge Rectifier	109.5	109	109	109.3
SR FET	112.5	112	112	111.9
Transformer Core	109.7	109.3	109.4	109.7
Case Temperature	103.9	103.4	103.4	103.5
Enclosure	102.3	101.9	102.7	103
Ambient	57.1	56.9	56.7	56.7

12 Waveforms

12.1 Primary Drain Voltage and Current Waveform

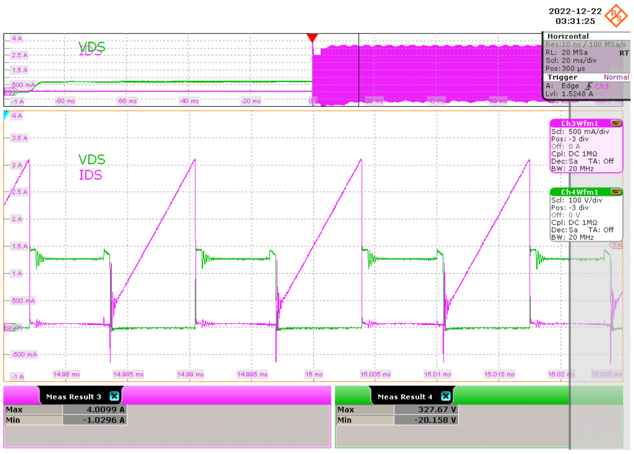


Figure 75 – 100 VAC 60 Hz, 20 V Full Load Start-up.
CH3(Pink): I_{DS}, 500 mA / div., 20 ms / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 327.67 V, I_{DS} = 4.01 A.

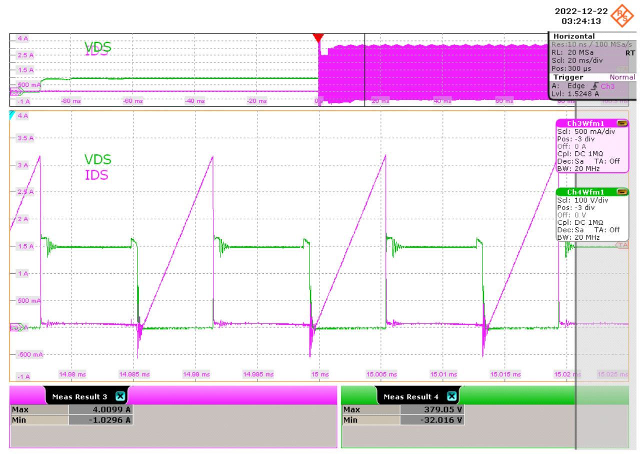


Figure 76 – 132 VAC 60 Hz, 20 V Full Load Start-up.
CH3(Pink): I_{DS}, 500 mA / div., 20 ms / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 379.05 V, I_{DS} = 4.01 A.

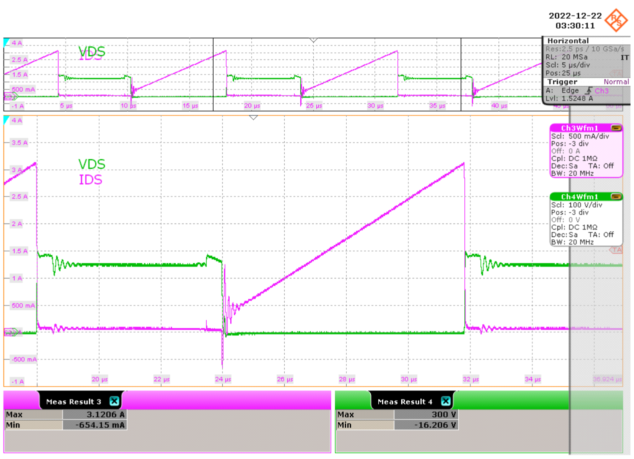


Figure 77 – 100 VAC 60 Hz, 20 V Full Load Normal.
CH3(Pink): I_{DS}, 500 mA / div., 5 us / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 300 V, I_{DS} = 3.12 A.

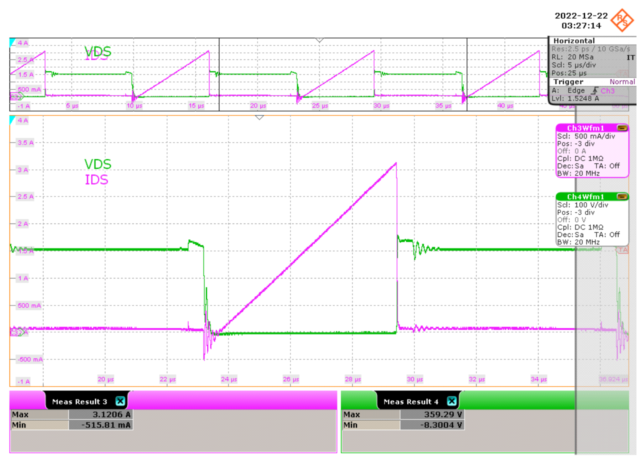


Figure 78 – 132 VAC 60 Hz, 20 V Full Load Normal.
CH3(Pink): I_{DS}, 500 mA / div., 5 us / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 359.29 V, I_{DS} = 3.12 A.

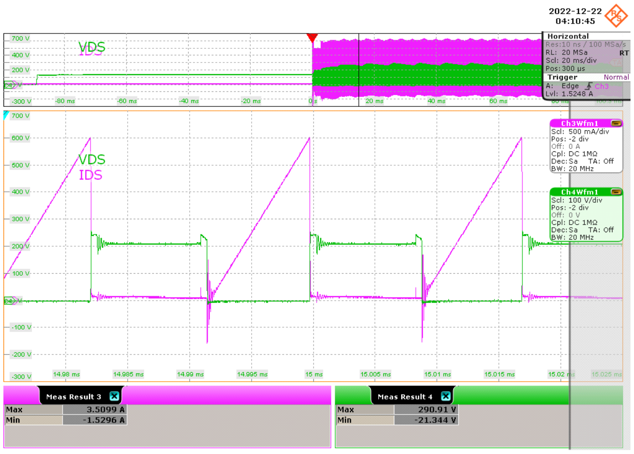


Figure 79 – 100 VAC 60 Hz, 15 V Full Load Start-up.
CH3(Pink): I_{DS}, 500 mA / div., 20 ms / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 290.91 V, I_{DS} = 3.51 A.

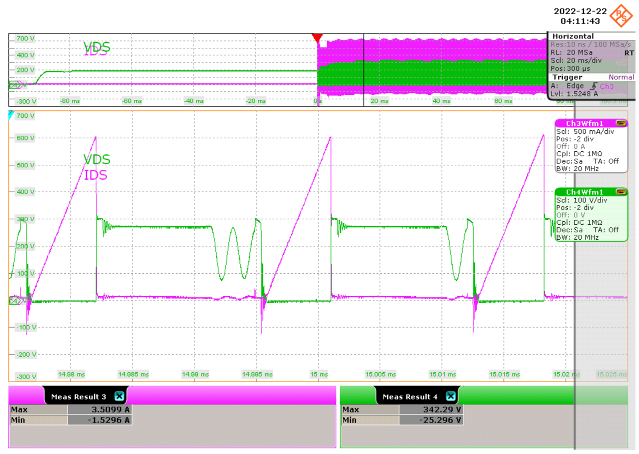


Figure 80 – 132 VAC 60 Hz, 15 V Full Load Start-up.
CH3(Pink): I_{DS}, 500 mA / div., 20 ms / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 342.29 V, I_{DS} = 3.51 A.

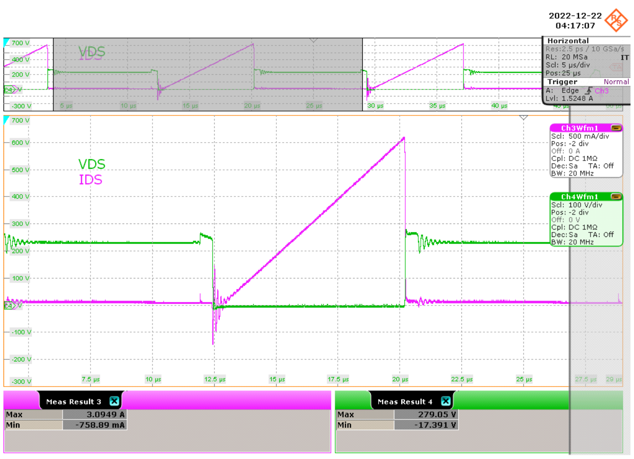


Figure 81 – 100 VAC 60 Hz, 15 V Full Load Normal.
CH3(Pink): I_{DS}, 500 mA / div., 5 us / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 279.05 V, I_{DS} = 3.09 A.

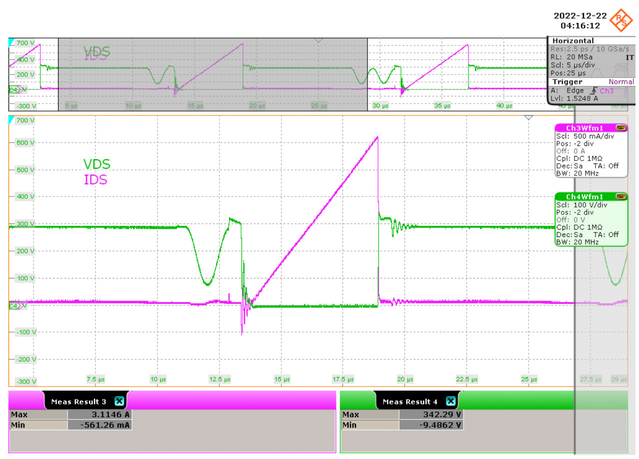


Figure 82 – 132 VAC 60 Hz, 15 V Full Load Normal.
CH3(Pink): I_{DS}, 500 mA / div., 5 us / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 342.29 V, I_{DS} = 3.11 A.

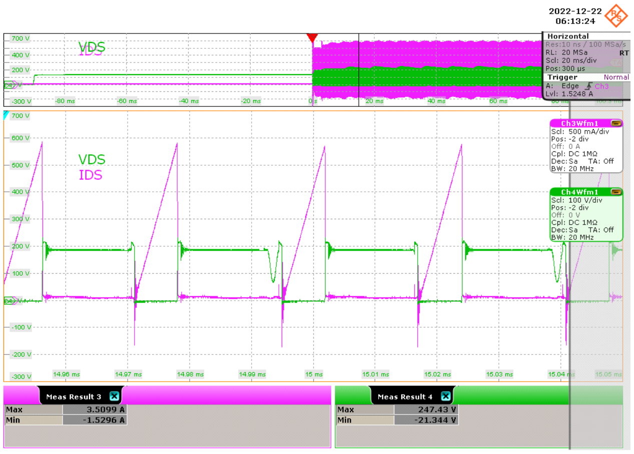


Figure 83 – 100 VAC 60 Hz, 9 V Full Load Start-up.
CH3(Pink): I_{DS}, 500 mA / div., 20 ms / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 247.43 V, I_{DS} = 3.51 A.

Figure 84 – 132 VAC 60 Hz, 9 V Full Load Start-up.
CH3(Pink): I_{DS}, 500 mA / div., 20 ms / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 298.81 V, I_{DS} = 3.51 A.

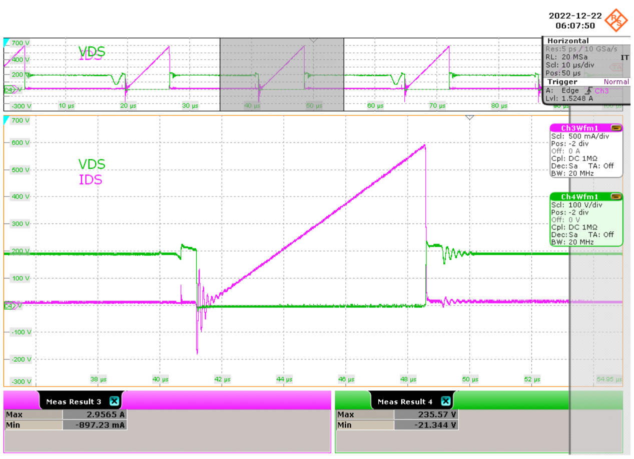


Figure 85 – 100 VAC 60 Hz, 9 V Full Load Normal.
CH3(Pink): I_{DS}, 500 mA / div., 10 us / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 235.57 V, I_{DS} = 2.96 A.

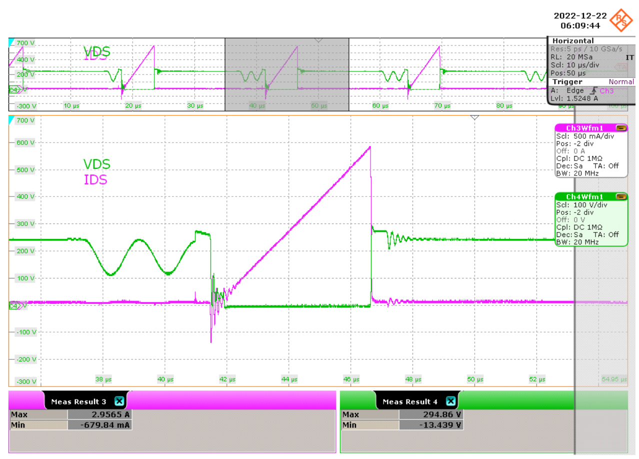


Figure 86 – 132 VAC 60 Hz, 9 V Full Load Normal.
CH3(Pink): I_{DS}, 500 mA / div., 10 us / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 294.86 V, I_{DS} = 2.96 A.

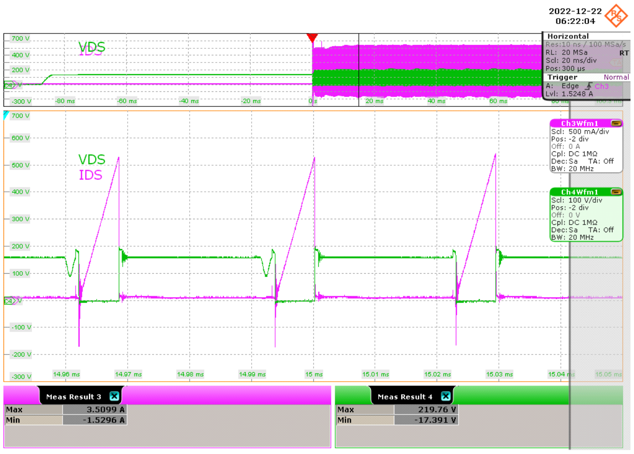


Figure 87 – 100 VAC 60 Hz, 5 V Full Load Start-up.
CH3(Pink): I_{DS}, 500 mA / div., 20 ms / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 219.76 V, I_{DS} = 3.51 A.

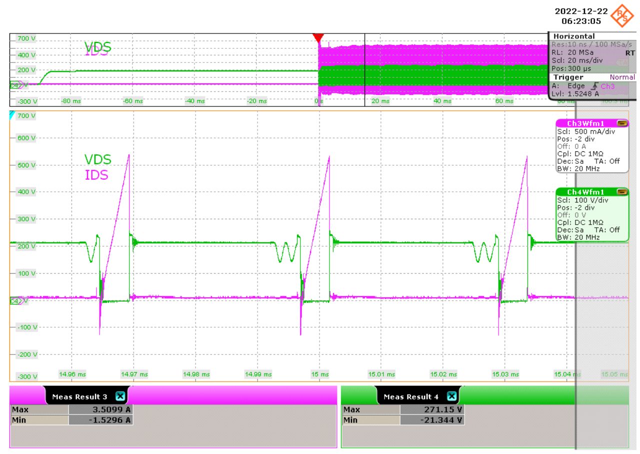


Figure 88 – 132 VAC 60 Hz, 5 V Full Load Start-up.
CH3(Pink): I_{DS}, 500 mA / div., 20 ms / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 271.15 V, I_{DS} = 3.51 A.

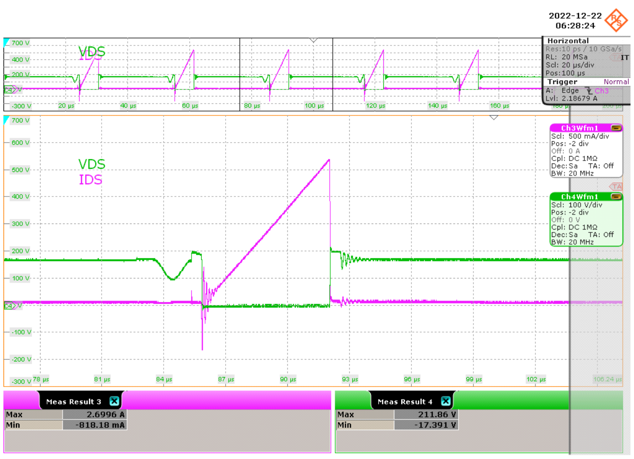


Figure 89 – 100 VAC 60 Hz, 5 V Full Load Normal.
CH3(Pink): I_{DS}, 500 mA / div., 20 us / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 211.86 V, I_{DS} = 2.69 A.

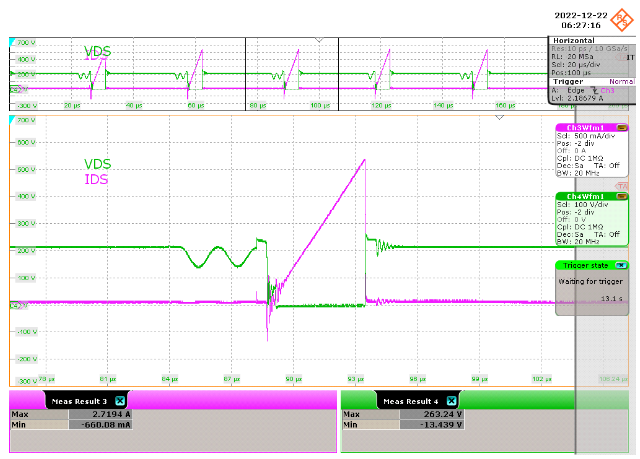


Figure 90 – 132 VAC 60 Hz, 5 V Full Load Normal.
CH3(Pink): I_{DS}, 500 mA / div., 20 us / div.
CH4(Green): V_{DS}, 100 V / div.
V_{DS} = 263.24 V, I_{DS} = 2.72 A.

12.2 SR FET Drain Voltage Waveform

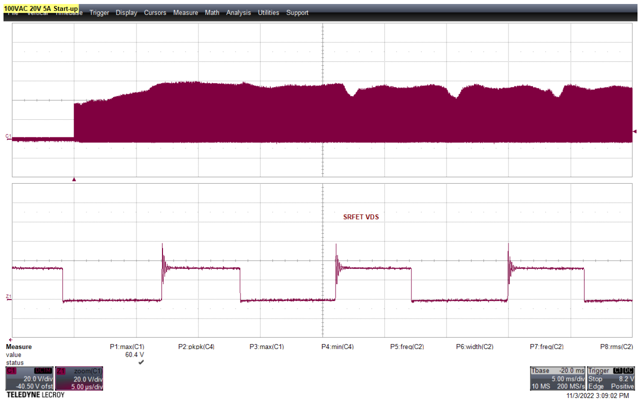


Figure 91 – 100 VAC 60 Hz, 20 V Full Load Start-up.
CH1(Violet): V_{DS}, 20 V / div., 5 ms / div.
Z1(Violet): V_{DS}, 20V / div., 5 µs / div.
V_{DS} = 60.4 V.

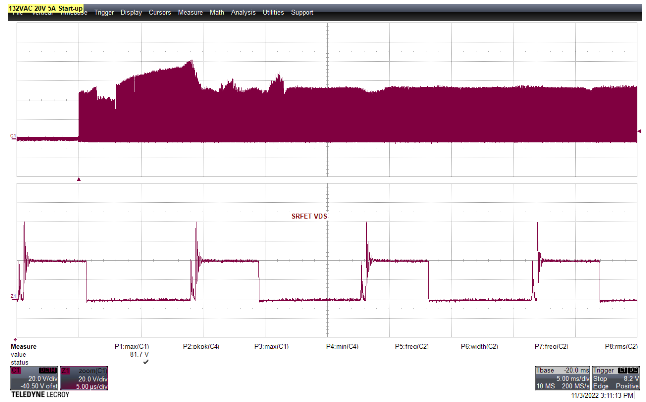


Figure 92 – 265 VAC 60 Hz, 20 V Full Load Start-up.
CH1(Violet): V_{DS}, 20 V / div., 20 ms / div.
Z1(Violet): V_{DS}, 20V / div., 5 µs / div.
V_{DS} = 81.7 V.

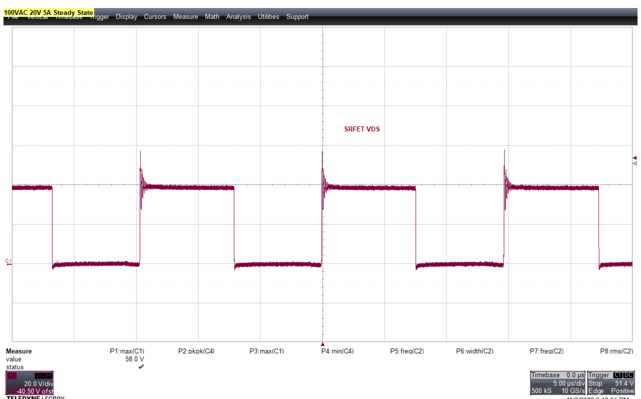


Figure 93 – 100 VAC 60 Hz, 20 V Full Load Normal.
CH1(Violet): V_{DS}, 20 V / div., 5 µs / div.
V_{DS} = 58.0 V.

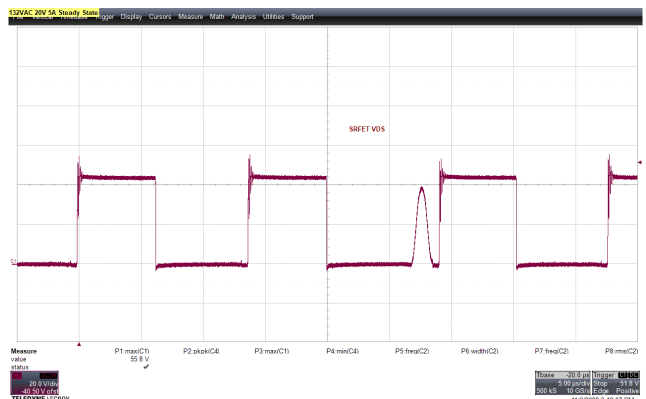


Figure 94 – 132 VAC 60 Hz, 20 V Full Load Normal.
CH1(Violet): V_{DS}, 20 V / div., 5 µs / div.
V_{DS} = 55.8 V.

12.3 Start-up Profile

Tested using an E-load set at constant current mode.

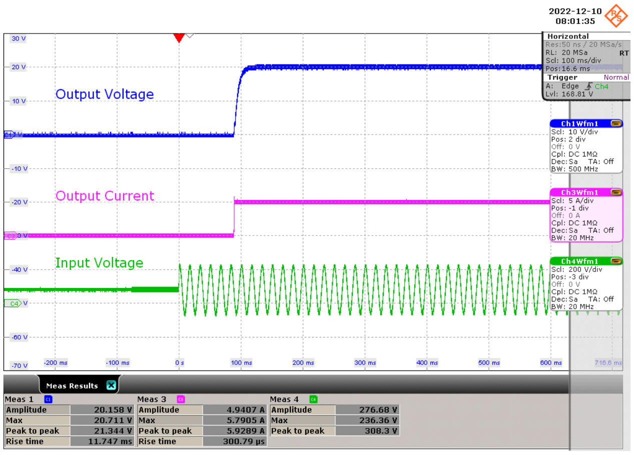


Figure 95 – 100 VAC 60 Hz, 20 V Full Load Start-up.
CH1(Blue): I_{OUT}, 10 V / div.
CH2(Pink): V_{OUT}, 5 A / div.
CH3(Green): V_{IN}, 200 V / div., 100 ms / div.

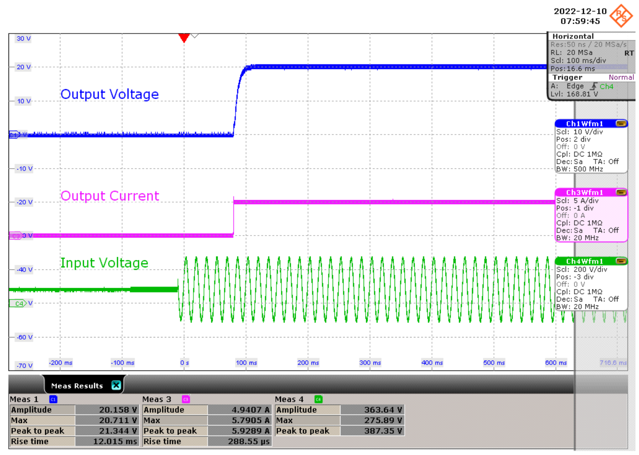


Figure 96 – 132 VAC 60 Hz, 20 V Full Load Start-up.
CH1(Blue): I_{OUT}, 10 A / div.
CH2(Pink): V_{OUT}, 5 V / div.
CH3(Green): V_{IN}, 200 V / div., 100 ms / div.

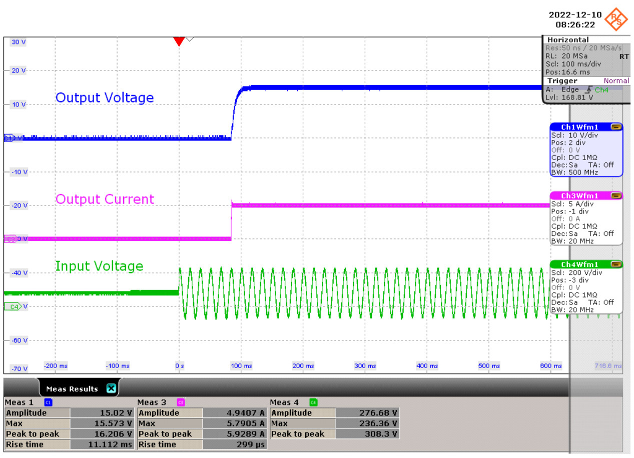


Figure 97 – 100 VAC 60 Hz, 15 V Full Load Start-up.
CH1(Blue): I_{OUT}, 10 V / div.
CH2(Pink): V_{OUT}, 5 A / div.
CH3(Green): V_{IN}, 200 V / div., 100 ms / div.

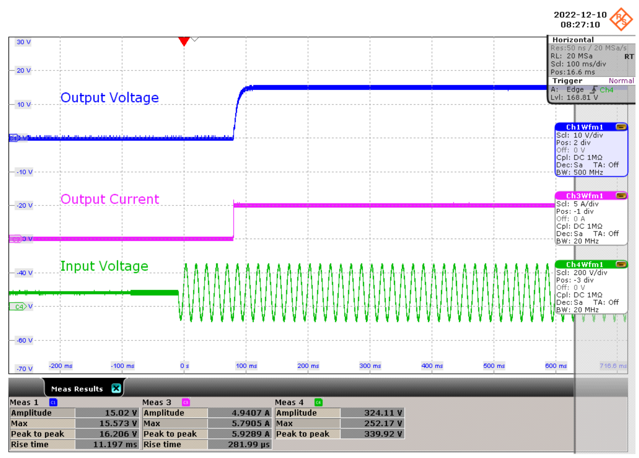


Figure 98 – 132 VAC 60 Hz, 15 V Full Load Start-up.
CH1(Blue): I_{OUT}, 10 V / div.
CH2(Pink): V_{OUT}, 5 A / div.
CH3(Green): V_{IN}, 200 V / div., 100 ms / div.

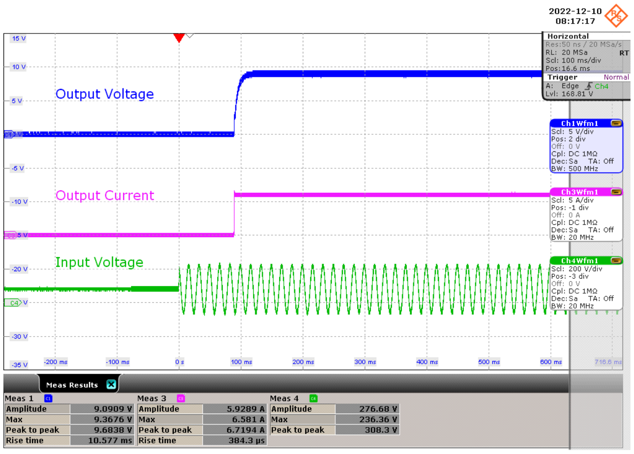


Figure 99 – 100 VAC 60 Hz, 9 V Full Load Start-up.
CH1(Blue): I_{OUT}, 5 V / div.
CH2(Pink): V_{OUT}, 5 A / div.
CH3(Green): V_{IN}, 200 V / div., 100 ms / div.

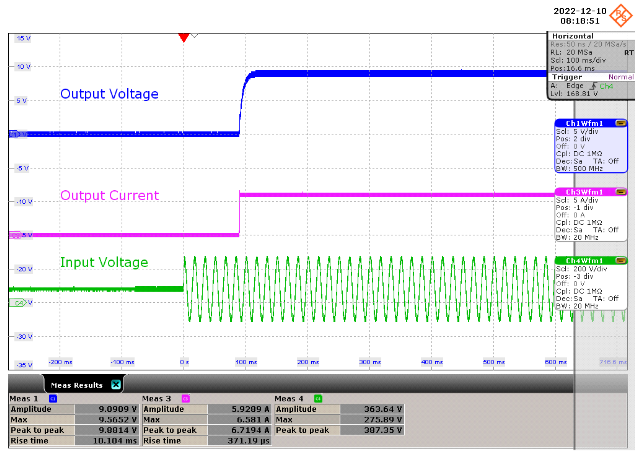


Figure 100 – 132 VAC 60 Hz, 9 V Full Load Start-up.
CH1(Blue): I_{OUT}, 5 V / div.
CH2(Pink): V_{OUT}, 5 A / div.
CH3(Green): V_{IN}, 200 V / div., 100 ms / div.

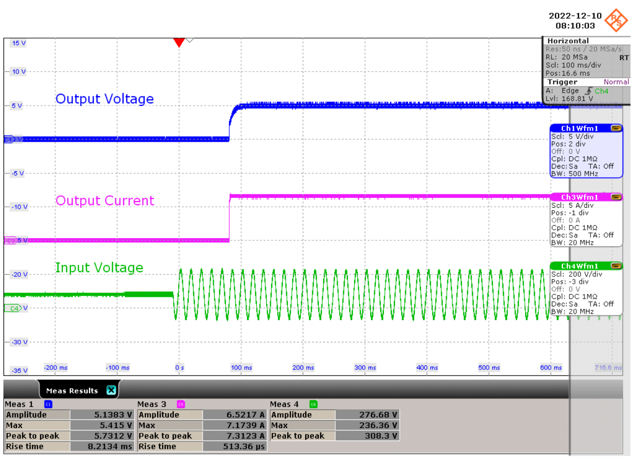


Figure 101 – 100 VAC 60 Hz, 5 V Full Load Start-up.
CH1(Blue): I_{OUT}, 5 V / div.
CH2(Pink): V_{OUT}, 5 A / div.
CH3(Green): V_{IN}, 200 V / div., 100 ms / div.

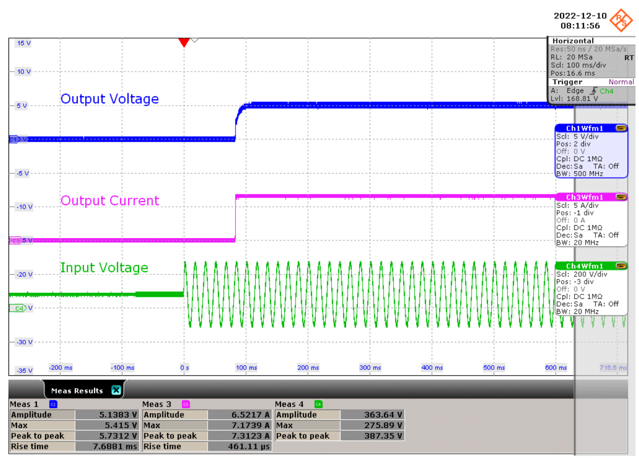


Figure 102 – 132 VAC 60 Hz, 5 V Full Load Start-up.
CH1(Blue): I_{OUT}, 5 V / div.
CH2(Pink): V_{OUT}, 5 A / div.
CH3(Green): V_{IN}, 200 V / div., 100 ms / div.

12.4 Transient Load Response

Tested using an E-Load set at dynamic constant current loading.

12.4.1 Transient Load at V_{OUT} = 20 V

Set-up: Duty Cycle = 50%, Frequency = 100 Hz, Slew Rate = 200 mA / µs

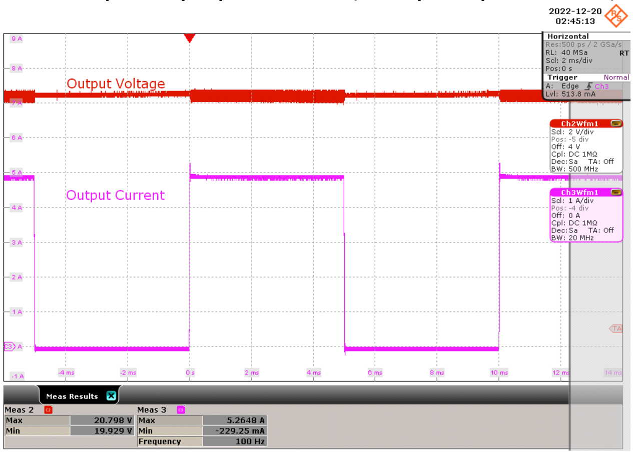


Figure 103 – 100 VAC 60 Hz, 0-5 A Transient Load.
CH2(Red): V_{OUT}, 2 V / div., 2 ms / div.
CH3(Pink): I_{OUT}, 1 A / div.
$V_{OUT(MAX)}$ = 20.79 V, $V_{OUT(MIN)}$ = 19.93 V.

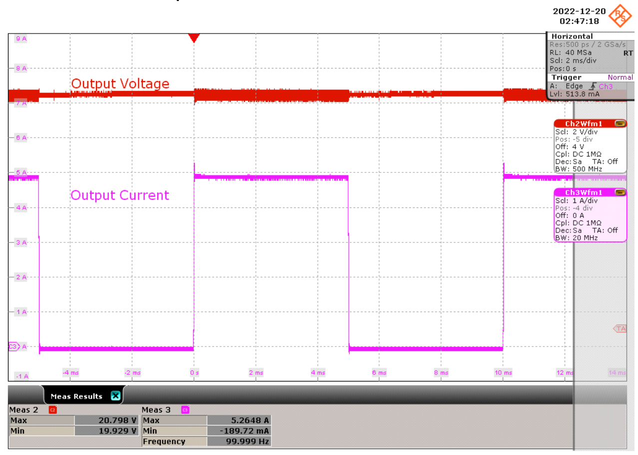


Figure 104 – 132 VAC 60 Hz, 0-5 A Transient Load.
CH2(Red): V_{OUT}, 2 V / div., 2 ms / div.
CH3(Pink): I_{OUT}, 1 A / div.
$V_{OUT(MAX)}$ = 20.79 V, $V_{OUT(MIN)}$ = 19.93 V.

12.4.2 Transient Load at V_{OUT} = 15 V

Set-up: Duty Cycle = 50%, Frequency = 100 Hz, Slew Rate = 200 mA / µs

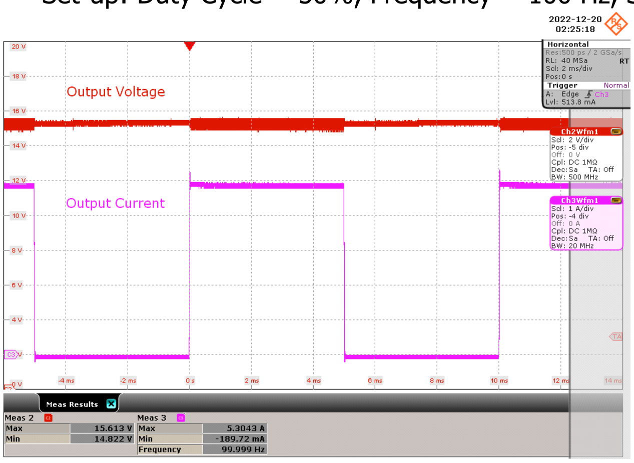


Figure 105 – 100 VAC 60 Hz, 0-5 A Transient Load.
CH2(Red): V_{OUT}, 2 V / div., 2 ms / div.
CH3(Pink): I_{OUT}, 1 A / div.
$V_{OUT(MAX)}$ = 15.61 V, $V_{OUT(MIN)}$ = 14.82 V.

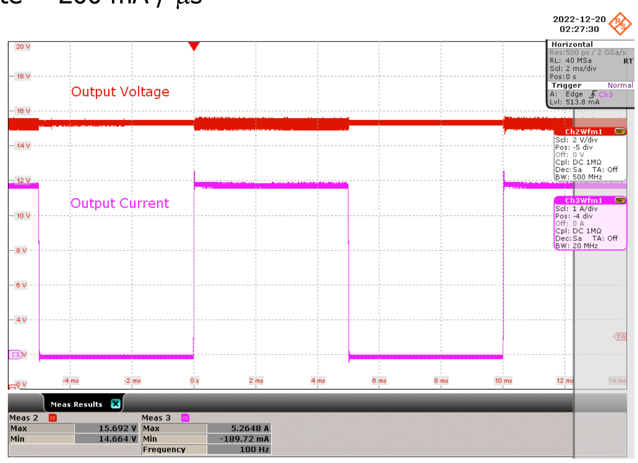


Figure 106 – 132 VAC 60 Hz, 0-5 A Transient Load.
CH1(Red): V_{OUT}, 2 V / div., 2 ms / div.
CH2(Pink): I_{OUT}, 1 A / div.
$V_{OUT(MAX)}$ = 15.69. V, $V_{OUT(MIN)}$ = 14.66 V.

12.4.3 Transient Load at V_{OUT} = 9 V

Set-up: Duty Cycle = 50%, Frequency = 100 Hz, Slew Rate = 200 mA / us

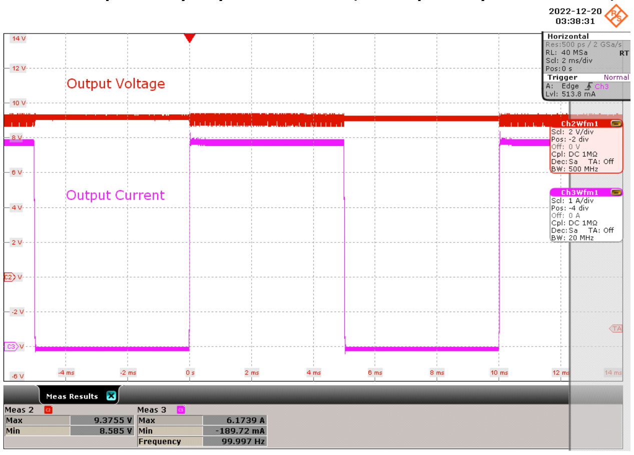


Figure 107 – 100 VAC 60 Hz, 0-6 A Transient Load.
CH1(Red): V_{OUT}, 2V / div., 2 ms / div.
CH2(Pink): I_{OUT}, 1 A / div.
$V_{OUT(MAX)}$ = 9.38 V, $V_{OUT(MIN)}$ = 8.59 V.

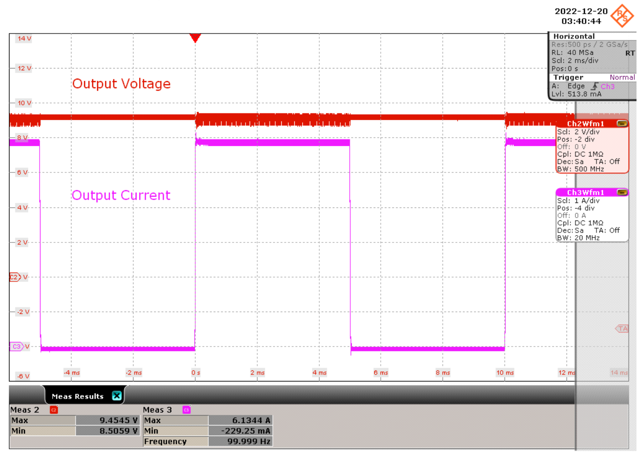


Figure 108 – 132 VAC 60 Hz, 0-6 A Transient Load.
CH1(Red): V_{OUT}, 2 V / div., 2 ms / div.
CH2(Pink): I_{OUT}, 1 A / div.
$V_{OUT(MAX)}$ = 9.455 V, $V_{OUT(MIN)}$ = 8.51 V.

12.4.4 Transient Load at V_{OUT} = 5 V

Set-up: Duty Cycle = 50%, Frequency = 100 Hz, Slew Rate = 200 mA / us

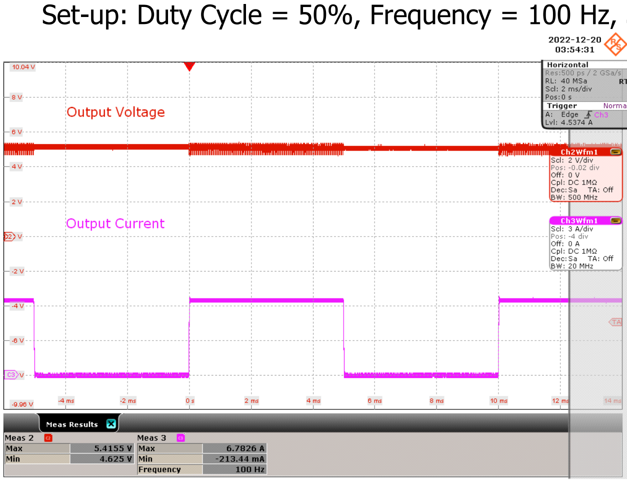


Figure 109 – 100 VAC 60 Hz, 0-6.5 A Transient Load.
CH1(Blue): V_{OUT}, 2 V / div., 2 ms / div.
CH2(Red): I_{OUT}, 3 A / div.
$V_{OUT(MAX)}$ =5.416 V, $V_{OUT(MIN)}$ = 4.63 V.

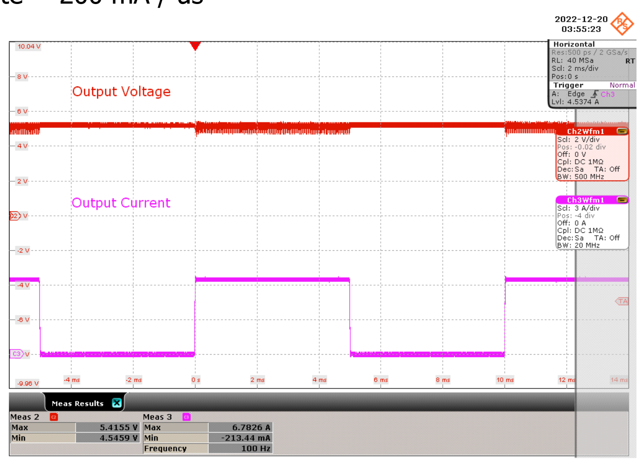


Figure 110 – 132 VAC 60 Hz, 0-6.5 A Transient Load.
CH1(Blue): V_{OUT}, 2 V / div., 2ms / div.
CH2(Red): I_{OUT}, 3 A / div.
$V_{OUT(MAX)}$ =5.416 V, $V_{OUT(MIN)}$ = 4.55 V.

12.5 Output Ripple Voltage Waveforms

Tested at room ambient temperature using an E-load at constant current mode setting.

12.5.1 Output Ripple Voltage at V_{OUT} = 20 VDC / 5 A

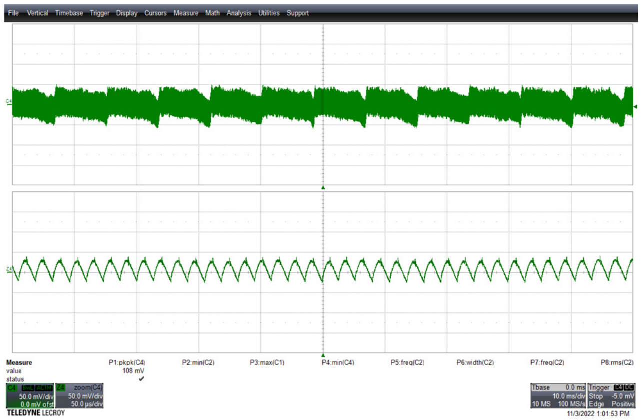


Figure 111 – 100 VAC 60 Hz, Full Load Normal.
Upper: V_{OUT}, 50 mV / div., 10 ms / div.
Lower: V_{OUT}, 50 mV / div., 50 μs / div.
V_{RIPPLE} = 108 mV.

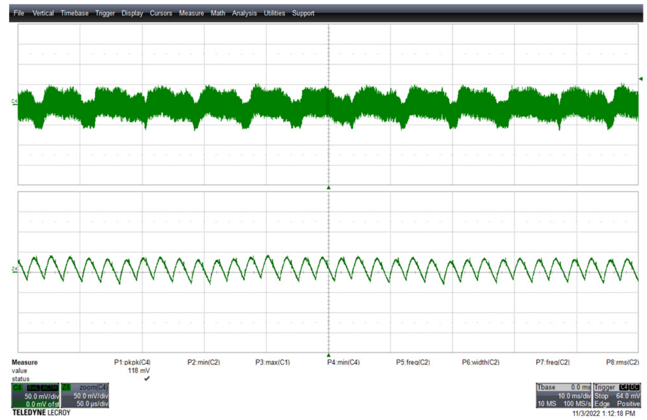


Figure 112 – 132 VAC 60 Hz, Full Load Normal.
Upper: V_{OUT}, 50 mV / div., 10 ms / div.
Lower: V_{OUT}, 50 mV / div., 50 μs / div.
V_{RIPPLE} = 118 mV.

12.5.2 Output Ripple Voltage at V_{OUT} = 15 VDC / 5 A

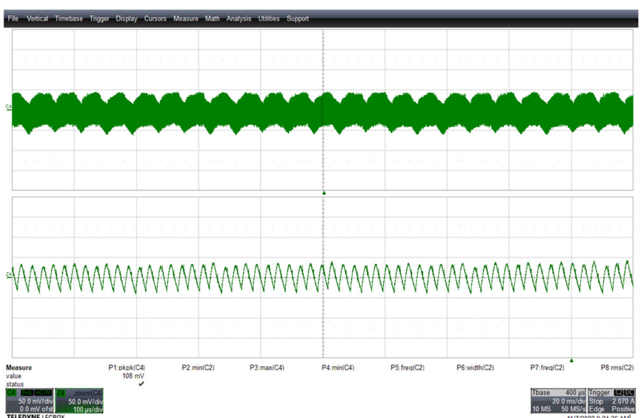


Figure 113 – 100 VAC 60 Hz, Full Load Normal.
Upper: V_{OUT}, 50 mV / div., 20 ms / div.
Lower: V_{OUT}, 50 mV / div., 100 μs / div.
V_{RIPPLE} = 108 mV.

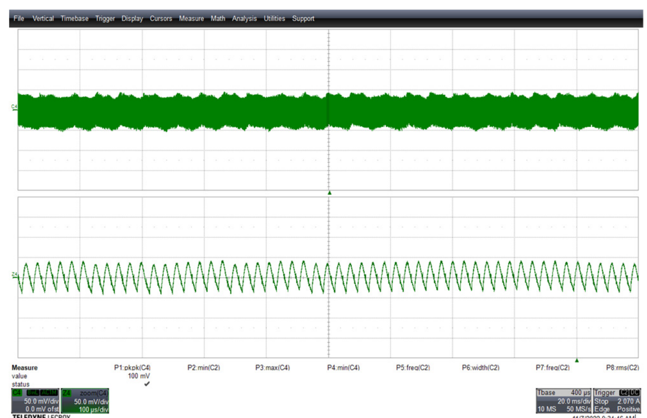


Figure 114 – 132 VAC 60 Hz, Full Load Normal.
Upper: V_{OUT}, 50 mV / div., 20 ms / div.
Lower: V_{OUT}, 50 mV / div., 100 μs / div.
V_{RIPPLE} = 100 mV.

12.5.3 Output Ripple Voltage at V_{OUT} = 9 VDC / 6 A

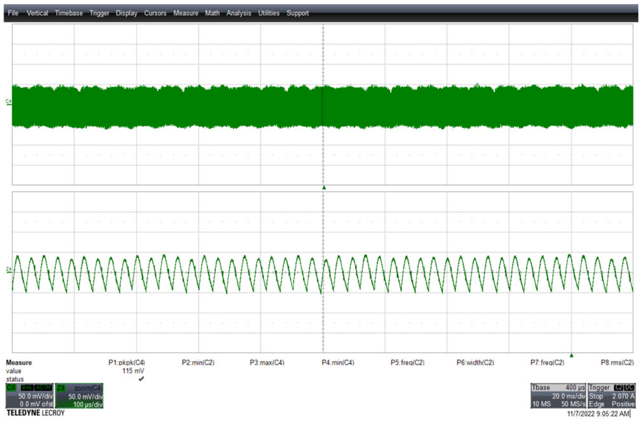


Figure 115 – 100 VAC 60 Hz, Full Load Normal.
Upper: V_{OUT}, 50 mV / div., 20 ms / div.
Lower: V_{OUT}, 50 mV / div., 100 μs / div.
V_{RIPPLE} = 115 mV.

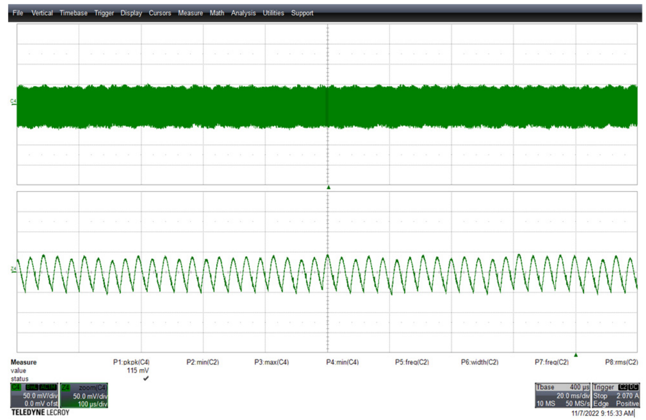


Figure 116 – 132 VAC 60 Hz, Full Load Normal.
Upper: V_{OUT}, 50 mV / div., 20 ms / div.
Lower: V_{OUT}, 50 mV / div., 100 μs / div.
V_{RIPPLE} = 115 mV.

12.5.4 Output Ripple Voltage at V_{OUT} = 5 VDC / 6.5 A

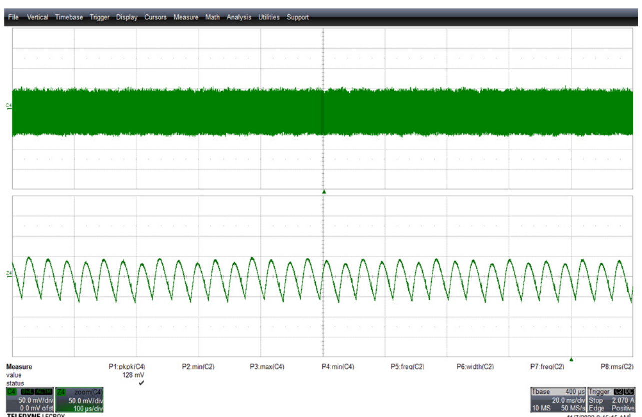


Figure 117 – 100 VAC 60 Hz, Full Load Normal.
Upper: V_{OUT}, 50 mV / div., 20 ms / div.
Lower: V_{OUT}, 50 mV / div., 100 μs / div.
V_{RIPPLE} = 128 mV.

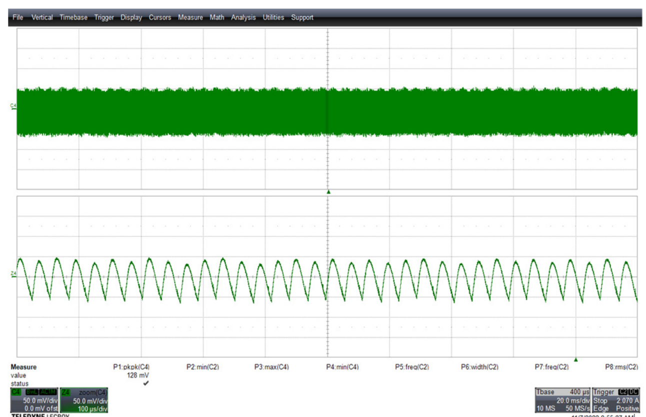


Figure 118 – 132 VAC 60 Hz, Full Load Normal.
Upper: V_{OUT}, 50 mV / div., 20 ms / div.
Lower: V_{OUT}, 50 mV / div., 100 μs / div.
V_{RIPPLE} = 128 mV.

12.6 Output Short-Circuit

12.6.1 Output Short-Circuit

Waveforms are captured during the unit was running with an output shorted

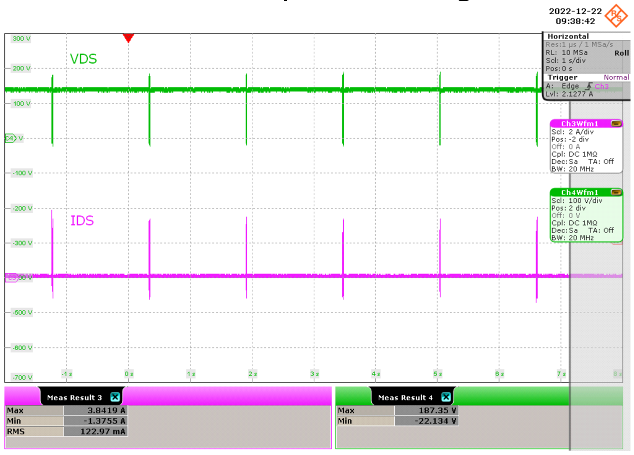


Figure 119 – 100 VAC 60 Hz, Output Short Normal.
CH3(Pink): I_D, 2 A / div., 1 s / div.
CH4(Green): V_D, 100 V / div.

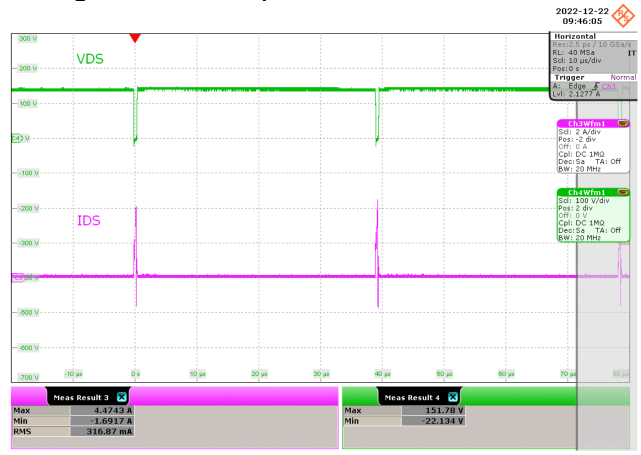


Figure 120 – 100 VAC 60 Hz, Output Short Normal.
Zoomed In.
CH1(Pink): I_D, 2 A / div., 10 us / div.
CH2(Green): V_D, 100 V / div.

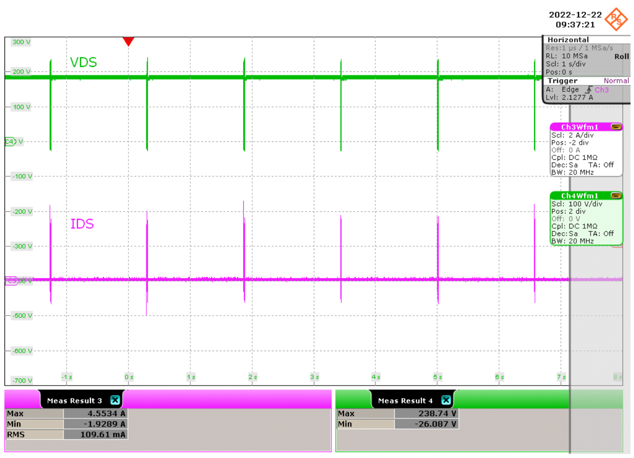


Figure 121 – 132 VAC 60 Hz, Output Short Normal.
CH3(Pink): I_D, 2 A / div., 1 s / div.
CH4(Green): V_D, 100 V / div.

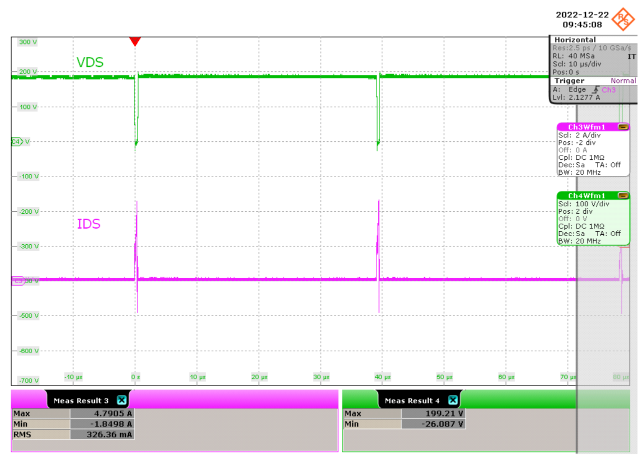


Figure 122 – 132 VAC 60 Hz, Output Short Normal.
Zoomed In.
CH3(Pink): I_D, 2 A / div., 10 us / div.
CH4(Green): V_D, 100 V / div.

12.6.2 Start Up with Output Shorted

Note: Unit was powered up with output shorted.

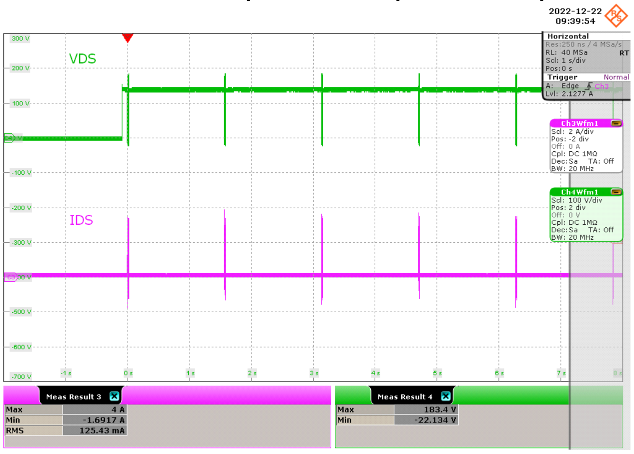


Figure 123 – 100 VAC 60 Hz, Short-Start-up.
CH3(Pink): I_D, 2 A / div., 1 s / div.
CH4(Green): V_D, 100 V / div.

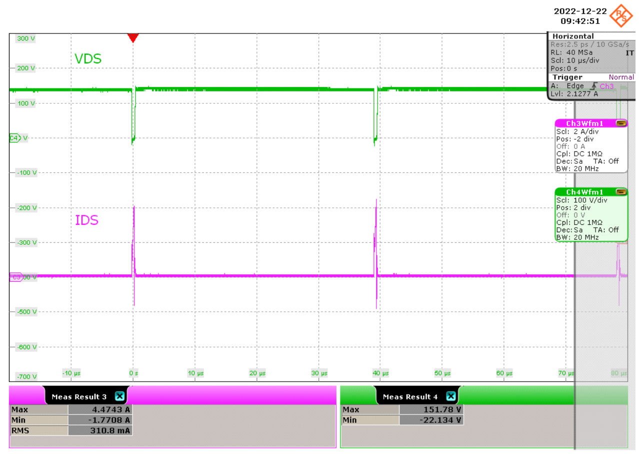


Figure 124 – 100 VAC 60 Hz, Short-Start-up.
Zoomed In.
CH3(Pink): I_D, 2 A / div., 10 μs / div.
CH4(Green): V_D, 100 V / div.

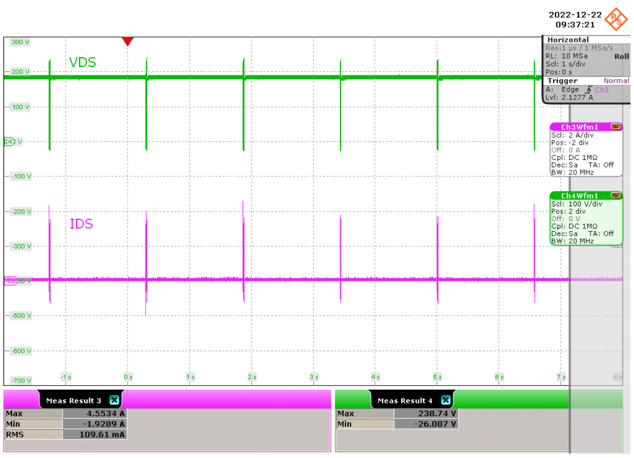


Figure 125 – 132 VAC 60 Hz, Short-Start-up
CH3(Pink): I_D, 2 A / div., 1 s / div.
CH4(Green): V_D, 100 V / div.

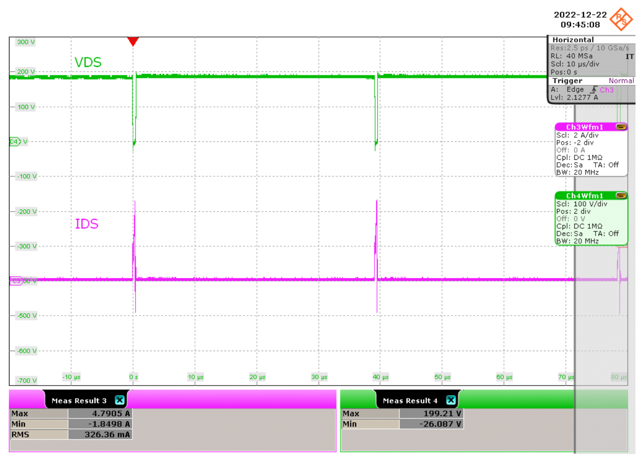


Figure 126 – 132 VAC 60 Hz, Short-Start-up.
Zoomed In.
CH1(Pink): I_D, 2 A / div., 10 μs / div.
CH2(Green): V_D, 100 V / div.

13 Conducted EMI

13.1 Test Set-up

EMI measurement was done using a resistor load.

13.2 Equipment and Load Used

1. Rohde and Schwarz ENV216 two-line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Variable Voltage Transformer set at 115 VAC

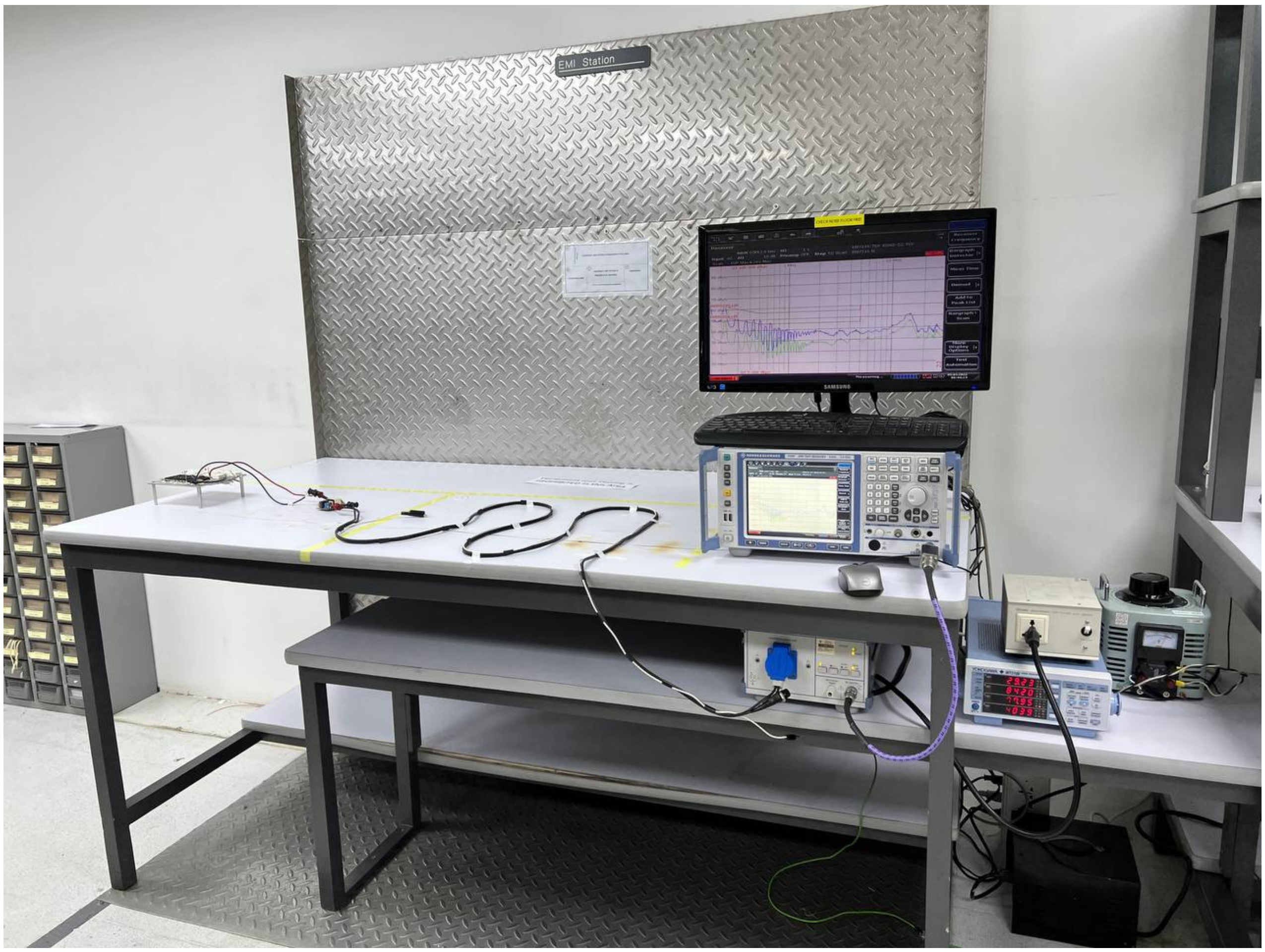


Figure 127 – Conducted EMI Test Set-up.

13.3 Conducted EMI at V_{OUT} = 20 V Full Load with Output Floating

13.3.1 Output Load: 4 Ω (20 V / 5 A) Fixed Resistor

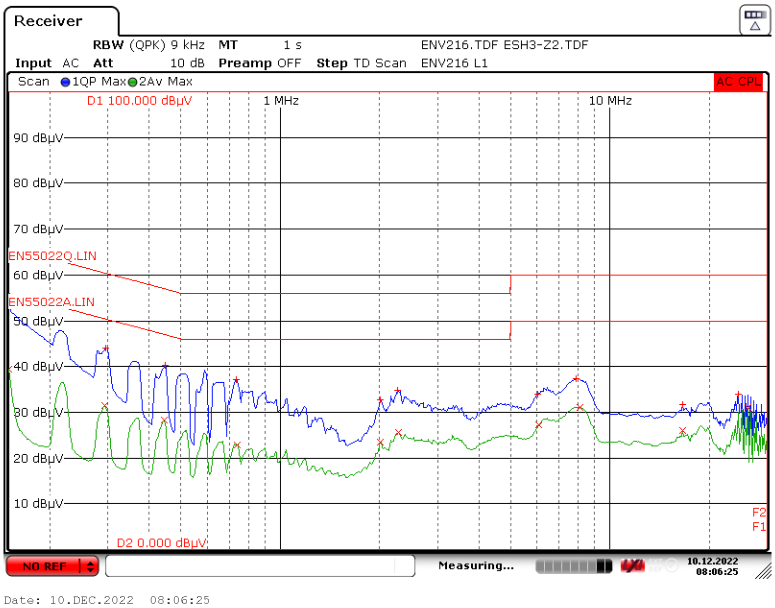


Figure 128 – Conducted EMI (LINE) at V_{OUT} = 20 V Full Load, 115 VAC 60 Hz, Floating Output.

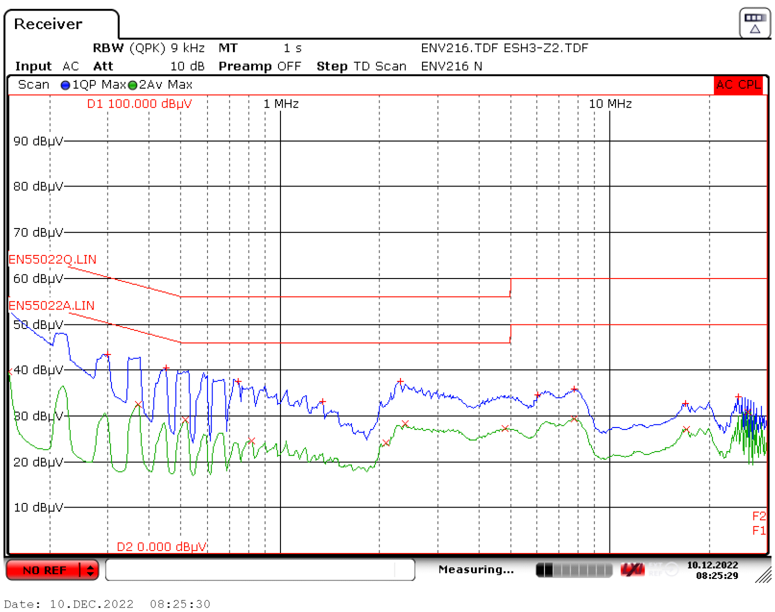


Figure 129 – Conducted EMI (NEUTRAL) at V_{OUT} = 20 V Full Load, 115 VAC 60 Hz, Floating Output.

13.4 Conducted EMI at V_{OUT} = 15 V Full Load with Output Floating

13.4.1 Output Load: 3 Ω (15 V / 5 A) Fixed Resistor

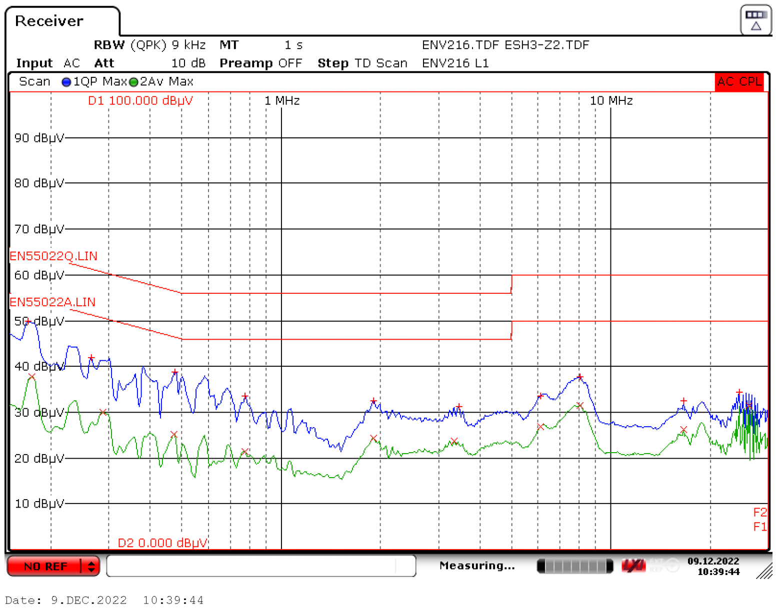


Figure 130 – Conducted EMI (LINE) at V_{OUT} = 15 V Full Load, 115 VAC 60 Hz, Floating Output.

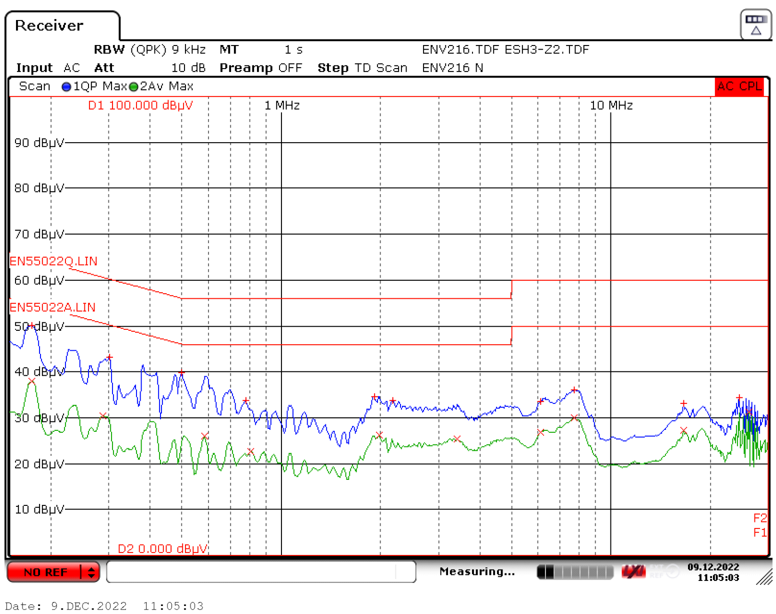


Figure 131 – Conducted EMI (NEUTRAL) at V_{OUT} = 15 V Full Load, 115 VAC 60 Hz, Floating Output.

13.5 Conducted EMI at VOUT = 9 V Full Load with Output Floating

13.5.1 Output Load: 1.5 Ω (9 V / 6 A) Fixed Resistor

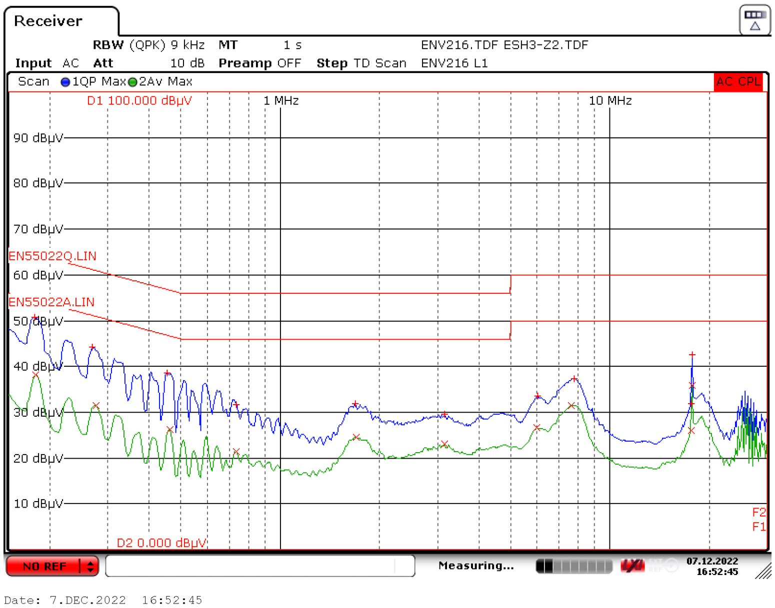


Figure 132 – Conducted EMI (LINE) at V_{OUT} = 9 V Full Load, 115 VAC 60 Hz, Floating Output.

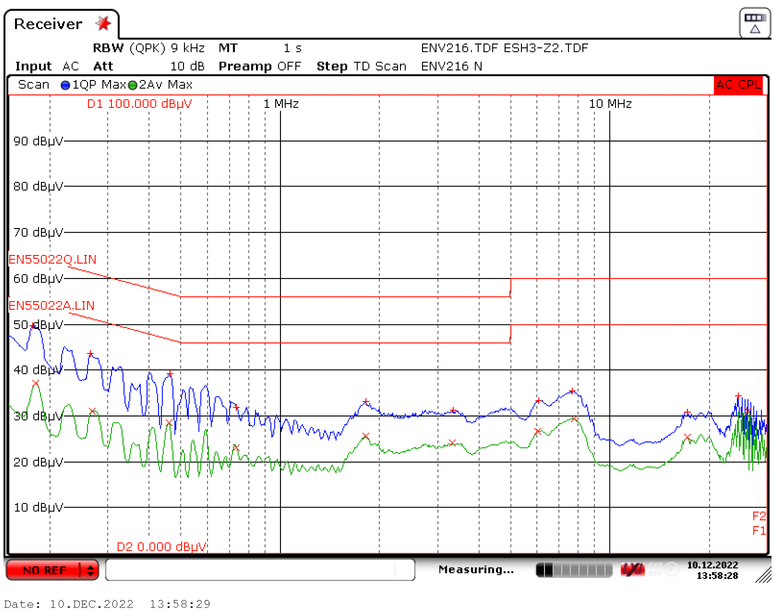
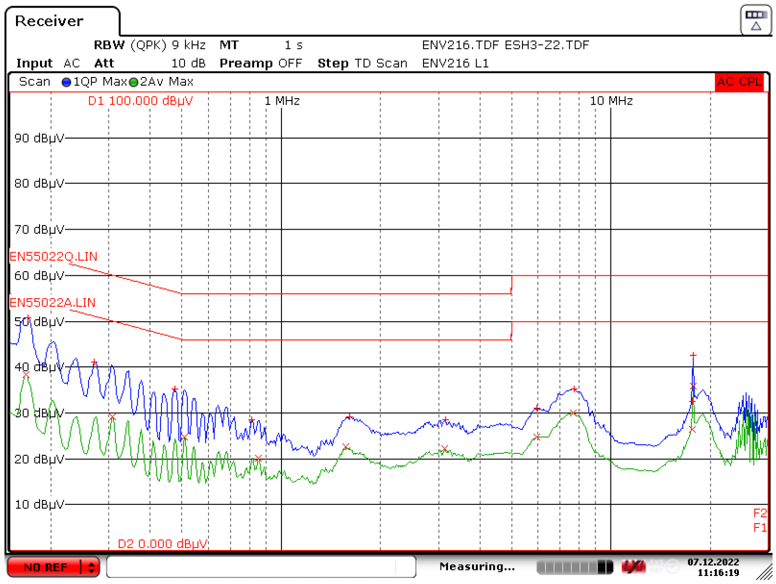


Figure 133 – Conducted EMI (NEUTRAL) at V_{OUT} = 9 V Full Load, 115 VAC 60 Hz, Floating Output.

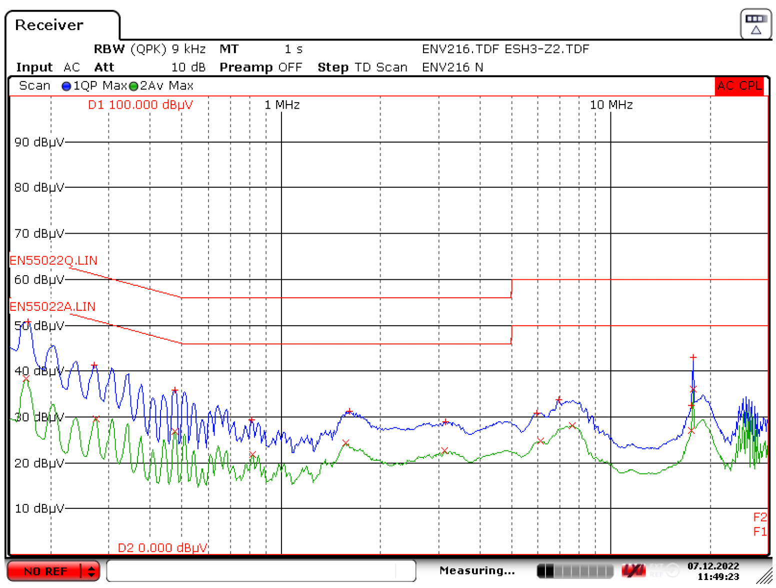
13.6 Conducted EMI at V_{OUT} = 5 V Full Load with Output Floating

13.6.1 Output Load: 0.77 Ω (5 V / 6.5 A) Fixed Resistor



Date: 7.DEC.2022 11:16:19

Figure 134 – Conducted EMI (LINE) at V_{OUT} = 5 V Full Load, 115 VAC 60 Hz, Floating Output.



Date: 7.DEC.2022 11:49:23

Figure 135 – Conducted EMI (NEUTRAL) at V_{OUT} = 5 V Full Load, 115 VAC 60 Hz, Floating Output.

14 Line Immunity

Output Load set at max load (20 V / 5 A) using a 4 Ω fixed resistor.

14.1 Differential Surge Test Results

Source Impedance: 2Ω
Repetition Rate: 1/30 s
No. of surge strike per location: 10 strikes

Differential Surge	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2000 V	120	L to N	0	Pass / Class A
+2000 V	120	L to N	90	Pass / Class A
+2000 V	120	L to N	270	Pass / Class A
-2000 V	120	L to N	0	Pass / Class A
-2000 V	120	L to N	90	Pass / Class A
-2000 V	120	L to N	270	Pass / Class A

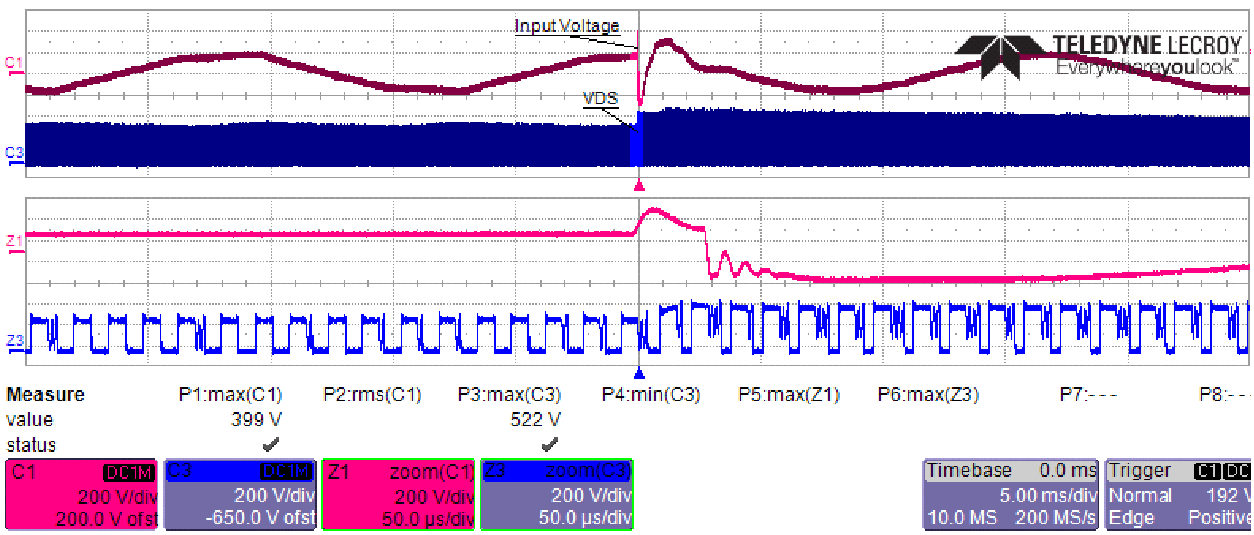


Figure 136 – 120 VAC 60 Hz, +2 kV Differential Surge L-N.
Injection Phase: -90º.
Upper: V_{IN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div., 50 µs / div.
V_{DS} = 522 V.

14.2 Ring Wave Surge Test Results

Source Impedance: 12Ω
Repetition Rate: 1/30 s
No. of surge strike per location: 10 strikes

Differential Ringwave Voltage	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
+2500 V	120	L to N	0	Pass / Class A
+2500 V	120	L to N	90	Pass / Class A
+2500 V	120	L to N	270	Pass / Class A
-2500 V	120	L to N	0	Pass / Class A
-2500 V	120	L to N	90	Pass / Class A
-2500 V	120	L to N	270	Pass / Class A

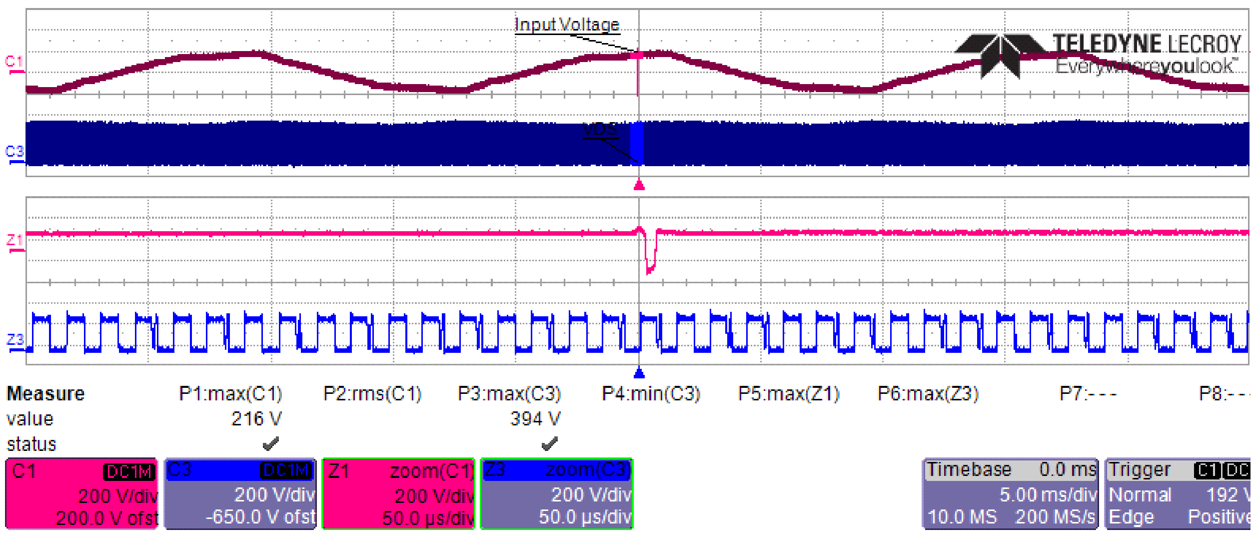


Figure 137 – 120 VAC 60 Hz, -2.5kV Ring Wave L-N.
Injection Phase: 90°.
Upper: V_{IN}, 200 V / div.
Lower: V_{DRAIN}, 200 V / div., 50 µs / div.
V_{DS} = 394 V.

14.3 Electrical Fast Transients (EFT) Test Results

Tested at 5 kHz and 100 kHz EFT Burst frequency. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

Note: Output Load set at max load (20 V / 5 A) using a 4.0 Ω Fixed Resistor.

14.3.1 5 kHz EFT

Test Voltage (V)	Input Voltage (VAC)	Test Time (s)	Frequency (kHz)	Burst Duration (ms)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)	Remarks
2000	120	60	5	15	L to N	0	Pass	No AR / No Damage
-2000	120	60	5	15	L to N	0	Pass	No AR / No Damage
2000	120	60	5	15	L to N	90	Pass	No AR / No Damage
-2000	120	60	5	15	L to N	90	Pass	No AR / No Damage
2000	120	60	5	15	L to N	270	Pass	No AR / No Damage
-2000	120	60	5	15	L to N	270	Pass	No AR / No Damage
4000	120	60	5	15	L to N	0	Pass	No AR / No Damage
-4000	120	60	5	15	L to N	0	Pass	No AR / No Damage
4000	120	60	5	15	L to N	90	Pass	No AR / No Damage
-4000	120	60	5	15	L to N	90	Pass	No AR / No Damage
4000	120	60	5	15	L to N	270	Pass	No AR / No Damage
-4000	120	60	5	15	L to N	270	Pass	No AR / No Damage

14.3.2 100 kHz EFT

Test Voltage (V)	Input Voltage (VAC)	Test Time (s)	Frequency (kHz)	Burst Duration (μs)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)	Remarks
2000	120	60	100	750	L to N	0	Pass	No AR / No Damage
-2000	120	60	100	750	L to N	0	Pass	No AR / No Damage
2000	120	60	100	750	L to N	90	Pass	No AR / No Damage
-2000	120	60	100	750	L to N	90	Pass	No AR / No Damage
2000	120	60	100	750	L to N	270	Pass	No AR / No Damage
-2000	120	60	100	750	L to N	270	Pass	No AR / No Damage
4000	120	60	100	750	L to N	0	Pass	No AR / No Damage
-4000	120	60	100	750	L to N	0	Pass	No AR / No Damage
4000	120	60	100	750	L to N	90	Pass	No AR / No Damage
-4000	120	60	100	750	L to N	90	Pass	No AR / No Damage
4000	120	60	100	750	L to N	270	Pass	No AR / No Damage
-4000	120	60	100	750	L to N	270	Pass	No AR / No Damage

15 ESD

Unit was subjected to ±8 kV ESD contact discharge test and ±8 kV ESD to ±16.5 kV ESD air discharge test. An LED indicator connected across the resistor load was used to observe the output behavior during to ESD. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

15.1 ESD Air Discharge 20 V 5 A Output (End of Output Cable)

Note: Output Load set at max load (20 V / 5 A) using a 4.0 Ω Fixed Resistor

No.	Test Voltage (kV)	No. of Strikes	Discharge Location	Remarks	Pass / Fail
1	+8	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	-8	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	+12	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	-12	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	+15	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	-15	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	+16.5	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	-16.5	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass

15.2 ESD Air Discharge 5 V 6.5 A Output (End of Output Cable)

Note: Output Load set at (5 V / 6.5 A) using a 0.77 Ω Fixed Resistor

No.	Test Voltage (kV)	No. of Strikes	Discharge Location	Remarks	Pass / Fail
1	+8	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	-8	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	+12	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	-12	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	+15	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	-15	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	+16.5	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass
1	-16.5	10	+ Output Terminal End of cable	No Damage / No AR	Pass
2		10	- Output Terminal End of cable	No Damage / No AR	Pass

16 Brown-In / Brown-Out Recovery Test

No abnormal overheating or voltage overshoot / undershoot was observed during and after 0.5 V / s. The unit works normally after the brown-out test.

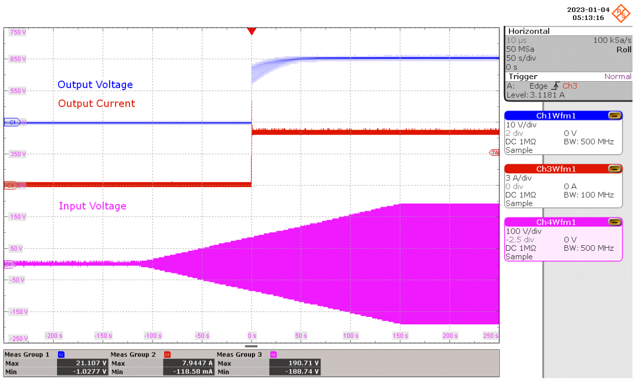


Figure 138 – Brown-In at V_{OUT} = 20 V.
V_{IN} = 0 V – 132 V, Slew Rate = 0.5 V / s.
CH1(Blue): V_{OUT},10 V / div., 50 s / div.
CH3(Red): I_{OUT}, 3 A / div.
CH4(Pink): V_{IN}, 100 V / div.

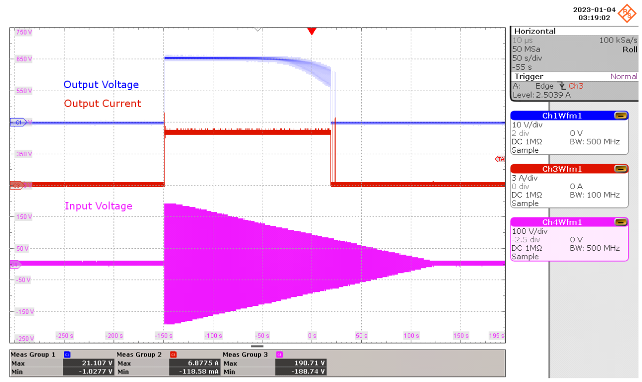


Figure 139 – Brown-in at V_{OUT} = 20 V.
V_{IN} = 132 V – 0 V, Slew Rate = 0.5 V / s.
CH1(Blue): V_{OUT},10 V / div., 50 s / div.
CH3(Red): I_{OUT}, 3 A / div.
CH4(Pink): V_{IN}, 100 V / div.

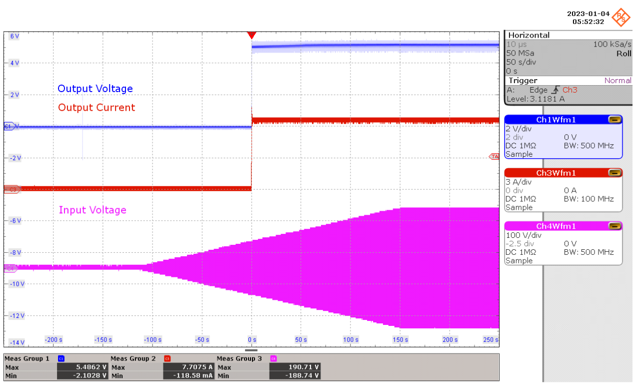


Figure 140 – Brown-In at V_{OUT} = 5 V.
V_{IN} = 0 V – 132 V, Slew Rate = 0.5 V / s.
CH1(Blue): V_{OUT}, 2 V / div., 50 s / div.
CH2(Red): I_{OUT}, 3 A / div.
CH4(Pink): V_{IN}, 100 V / div.

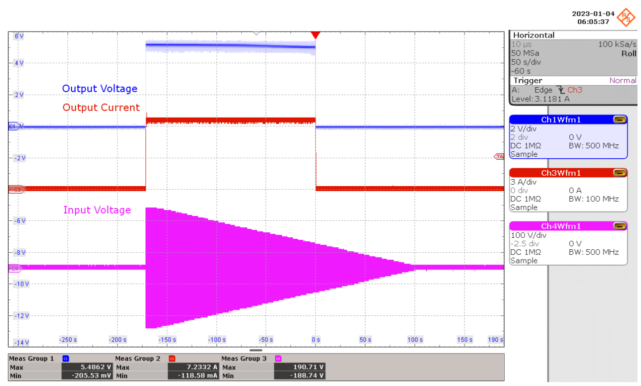


Figure 141 – Brown-Out at V_{OUT} = 5 V.
V_{IN} = 132 V – 0 V, Slew Rate = 0.5 V / s.
CH1(Blue): V_{OUT}, 2 V / div., 50 s / div.
CH2(Red): I_{OUT}, 3 A / div.
CH4(Pink): V_{IN}, 100 V / div.

17 Revision History

Date	Author	Revision	Description and Changes	Reviewed
18-Apr-23	JB/MGM	1.0	Initial release	Apps & Mktg

Power Integrations, Inc.
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

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

Power Integrations Worldwide Sales Support Locations

WORLD HEADQUARTERS
5245 Hellyer Avenue
San Jose, CA 95138, USA.
Main: +1-408-414-9200
Customer Service:
Worldwide: +1-65-635-64480
Americas: +1-408-414-9621
e-mail: usasales@power.com

CHINA (SHANGHAI)
Rm 2410, Charity Plaza, No. 88,
North Caoxi Road,
Shanghai, PRC 200030
Phone: +86-21-6354-6323
e-mail: chinasales@power.com

CHINA (SHENZHEN)
17/F, Hivac Building, No. 2, Keji
Nan 8th Road, Nanshan District,
Shenzhen, China, 518057
Phone: +86-755-8672-8689
e-mail: chinasales@power.com

GERMANY (AC-DC/LED Sales)
Einsteinring 24
85609 Dornach/Aschheim
Germany
Tel: +49-89-5527-39100
e-mail: eurosales@power.com

GERMANY (Gate Driver Sales)
HellwegForum 1
59469 Ense
Germany
Tel: +49-2938-64-39990
e-mail: igbt-driver.sales@
power.com

INDIA
#1, 14th Main Road
Vasanthanagar
Bangalore-560052
India
Phone: +91-80-4113-8020
e-mail: indiasales@power.com

ITALY
Via Milanese 20, 3rd. Fl.
20099 Sesto San Giovanni (MI) Italy
Phone: +39-024-550-8701
e-mail: eurosales@power.com

JAPAN
Yusen Shin-Yokohama 1-chome Bldg.
1-7-9, Shin-Yokohama, Kohoku-ku
Yokohama-shi,
Kanagawa 222-0033 Japan
Phone: +81-45-471-1021
e-mail: japansales@power.com

KOREA
RM 602, 6FL
Korea City Air Terminal B/D,
159-6
Samsung-Dong, Kangnam-Gu,
Seoul, 135-728 Korea
Phone: +82-2-2016-6610
e-mail: koreasales@power.com

SINGAPORE
51 Newton Road,
#19-01/05 Goldhill Plaza
Singapore, 308900
Phone: +65-6358-2160
e-mail:
singaporesales@power.com

TAIWAN
5F, No. 318, Nei Hu Rd.,
Sec. 1
Nei Hu District
Taipei 11493, Taiwan R.O.C.
Phone: +886-2-2659-4570
e-mail: taiwansales@power.com

UK
Building 5, Suite 21
The Westbrook Centre
Milton Road
Cambridge
CB4 1YG
Phone: +44 (0) 7823-557484
e-mail: eurosales@power.com