Design Example Report

Title	***60 W USB PD 3.0 Power Supply with 3.3 V – 21 V PPS Output Using InnoSwitch™ 3-Pro GaN-based INN3379C-H302 and Weltrend WT6635P Controller***
Specification	85 VAC – 265 VAC Input; 5 V / 3 A; 9 V / 3 A; 15 V / 3 A; 20 V / 3 A; or 3.3 V – 21 V PPS Outputs
Application	Mobile Phone Charger
Author	Applications Engineering Department
Document Number	RDR-802
Date	September 20, 2020
Revision	1.3

Summary and Features

- InnoSwitch3-Pro - digitally controllable CV/CC QR flyback switcher IC with integrated high-voltage MOSFET, synchronous rectification and FluxLink™ feedback
    - I^2C Interface enables low pin count USB PD controller (10 pin)
    - Sophisticated telemetry and comprehensive protection features
- USB PD 3.0 with PPS using highly optimized, low pin count USB PD controller WT6635P
- All the benefits of secondary-side control with the simplicity of primary-side regulation
    - Insensitive to transformer variation
- Meets DOE6 and CoC v5 2016 efficiency requirement (>2% efficiency margin)
- Micro stepping of voltages (20 mV) and CC thresholds (50 mA) in compliance with PPS protocol
- Output overvoltage and overcurrent protection
- Integrated thermal protection
- <35 mW no-load input power

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

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

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.

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

1 Introduction

This document is an engineering report describing a 60 W USB PD power supply with 5 V / 3 A, 9 V / 3 A, 15 V / 3 A, 20 V / 3 A or 3.3 V – 21 V Programmable Power Supply (PPS) output using InnoSwitch3-Pro INN3379C-H302 IC and Weltrend WT6635P USB PD controller. This design shows the high power density and efficiency that is possible due to the high level of integration of the InnoSwitch3-Pro controller providing exceptional performance.

The report contains the power supply specification, schematic diagram, printed circuit board layout, bill of materials, transformer documentation, and performance data.

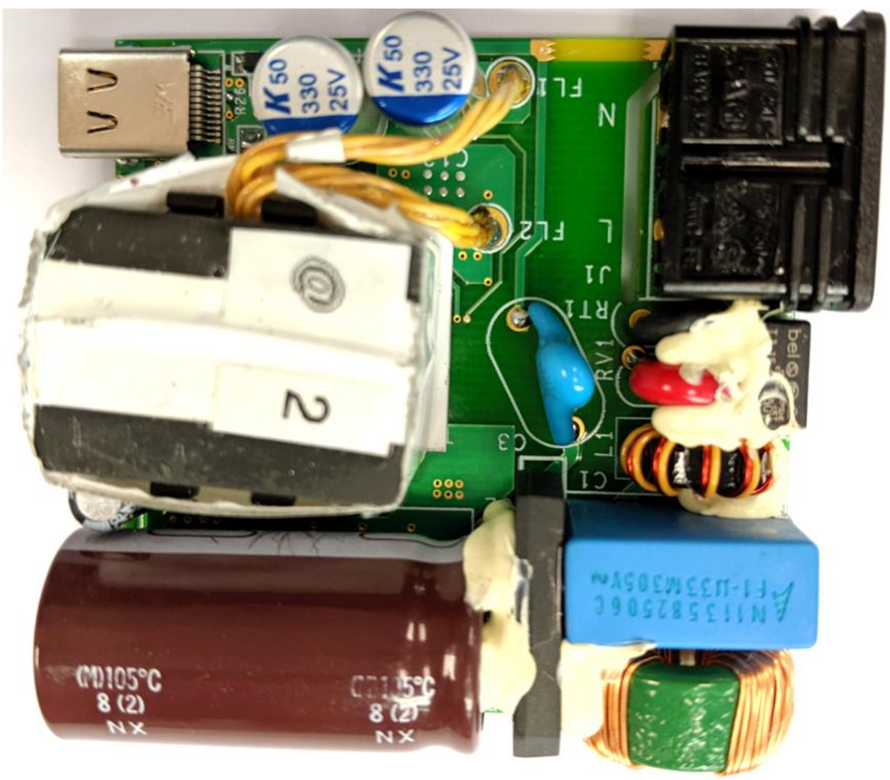


Figure 1 – Populated Circuit Board Photograph - Top.

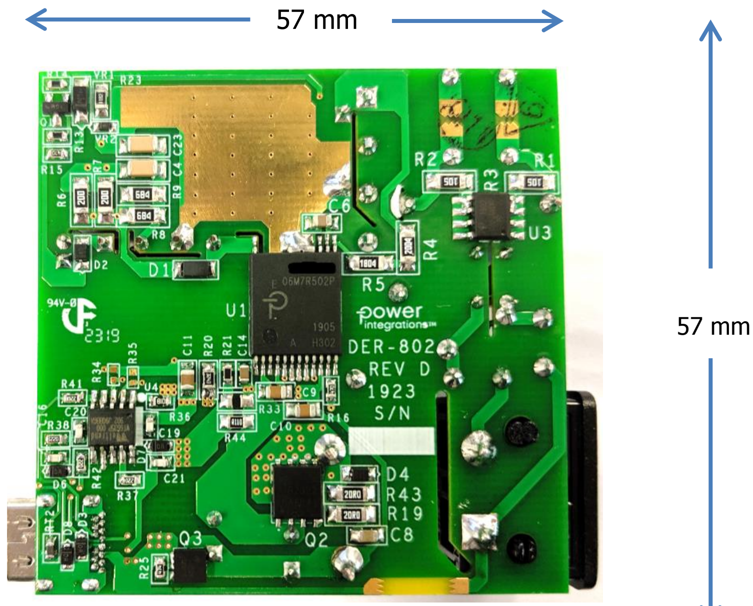


Figure 2 – Populated Circuit Board Photograph - Bottom.

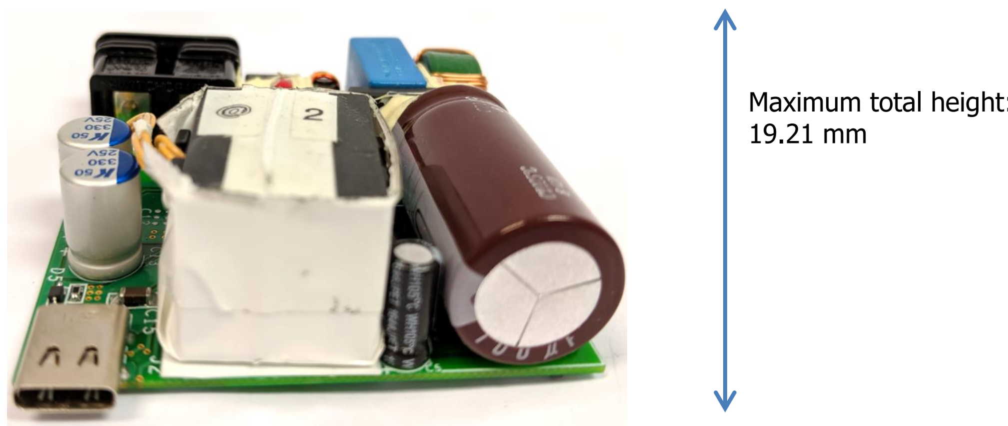


Figure 3 – Populated Circuit Board Photograph (Side View).

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

2 Power Supply Specification

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

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	85		265	VAC	2 Wire – no P.E.
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load Input Power			32	35	mW	Measured at 230 VAC.
5 V Setting						
Output Voltage	$V_{OUT(5\ V)}$		5.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(5\ V)}$			150	mV	Measured at End of Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(5\ V)}$			3.0	A	±3%
Average Efficiency	η_{5V}		89.5		%	Measured at 115 VAC from AC Receptacle to End of Cable.
Continuous Output Power	$P_{OUT(5\ V)}$			15	W	
9 V Setting						
Output Voltage	$V_{OUT(9\ V)}$		9.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(9\ V)}$			150	mV	Measured at End of Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(9\ V)}$			3.0	A	±3%
Average Efficiency	η_{9V}		91.0		%	Measured at 115 VAC from AC Receptacle to End of Cable.
Continuous Output Power	$P_{OUT(9\ V)}$			27	W	
15 V Setting						
Output Voltage	$V_{OUT(15\ V)}$		15.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(15\ V)}$			150	mV	Measured at End of Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(15\ V)}$			3.0	A	±3%
Average Efficiency	η_{15V}		91.1		%	Measured at 115 VAC from AC Receptacle to End of Cable.
Continuous Output Power	$P_{OUT(15\ V)}$			45	W	
20 V Setting						
Output Voltage	$V_{OUT(20\ V)}$		20.0		V	±3%
Output Voltage Ripple	$V_{RIPPLE(20\ V)}$			200	mV	Measured at End of Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(20\ V)}$			3.0	A	±3%
Average Efficiency	η_{20V}		91.2		%	Measured at 115 VAC from AC Receptacle to End of Cable.
Continuous Output Power	$P_{OUT(20\ V)}$			60	W	
3.3 – 21 V PPS Setting						
Maximum Programmable Output Voltage	$V_{OUT(MAX)}$			21	V	APDO Maximum Voltage.
Minimum Programmable Output Voltage	$V_{OUT(MIN)}$	3.3			V	APDO Minimum Voltage.
Output Voltage Ripple 1	$V_{RIPPLE1(PPS)}$			200	mV	15 V – 21 V PPS, measured at the End of Cable (20 MHz Bandwidth).
Output Voltage Ripple 2	$V_{RIPPLE2(PPS)}$			150	mV	Below 15 V PPS voltage, measured at the End of Cable (20 MHz Bandwidth).
Output Current	$I_{OUT(PPS)}$			3.0	A	±3%
PPS Voltage Step	$V_{STEP(PPS)}$		20		mV	PPS Voltage Step (USB PD 3.0).
PPS Current Step	$I_{STEP(PPS)}$		50		mA	PPS Current Step (USB PD 3.0).
Continuous Output Power	$P_{OUT(20\ V)}$			60	W	

Conducted EMI		Meets CISPR22B / EN55022B				
Ambient Temperature	T_{AMB}	0		40	ºC	Free Convection, Sea Level.

Note: To use this design for a charger/adapter, circuit board would need to be modified depending on shape and form factor of the housing. ESD and Line surge performance should be evaluated and layout adjusted to meet the target specification.

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

3 Schematic

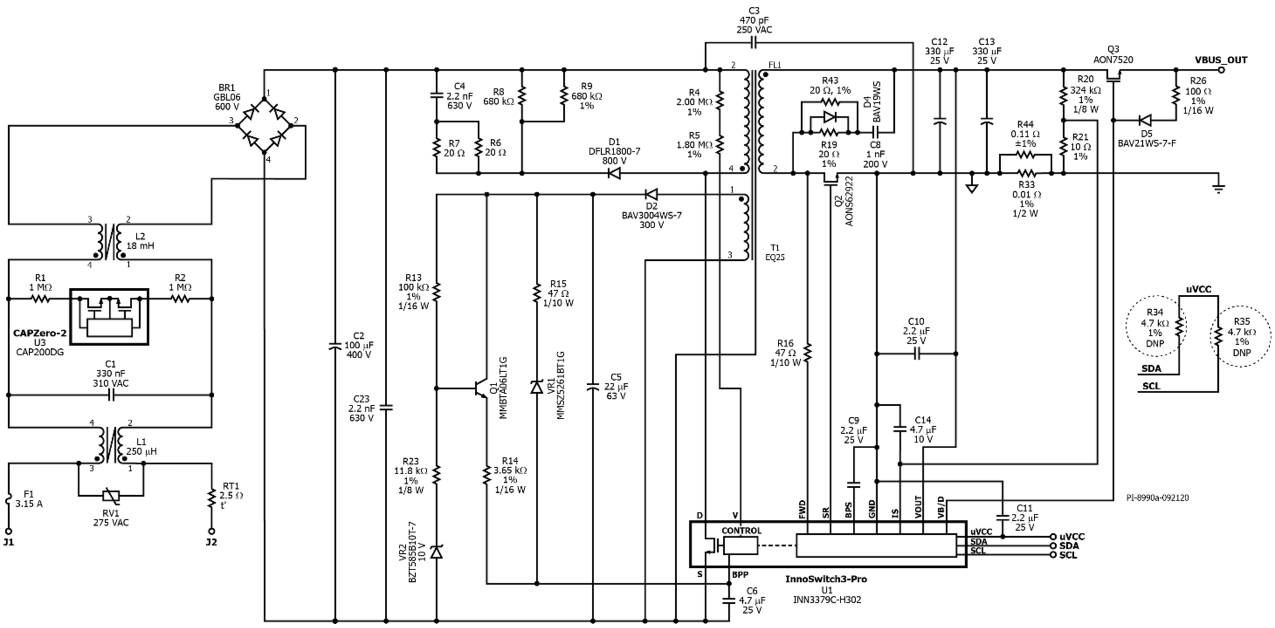


Figure 4 – Schematic, Power Section.

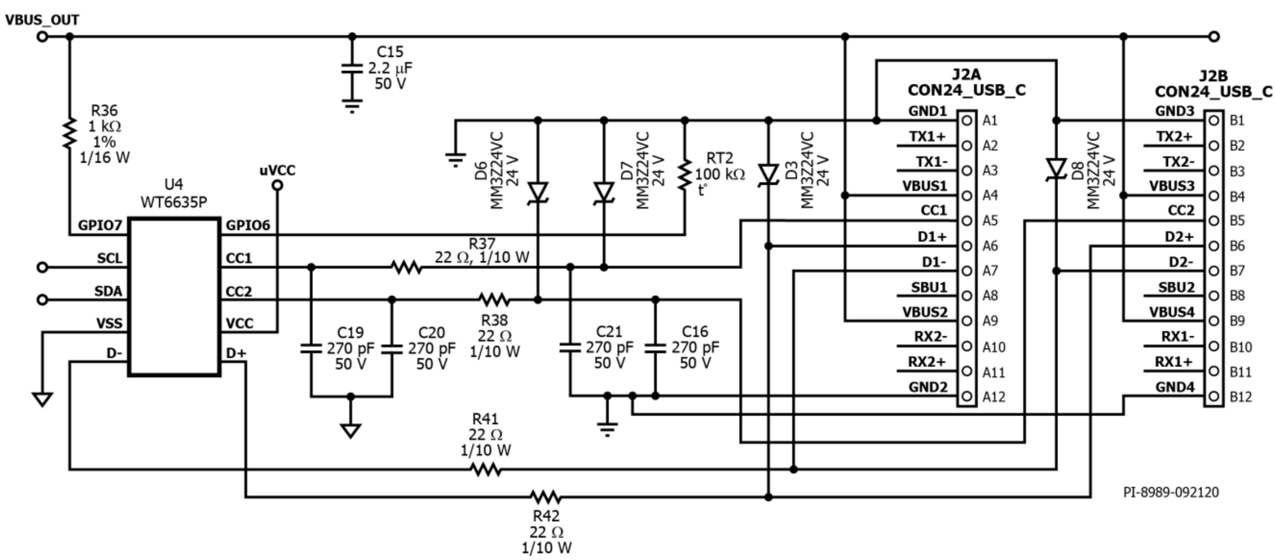


Figure 5 – Schematic, USB PD Controller Section**.**

Note: Component references R3, R25, R34 and R35, although present in the layout, should not be populated.

4 Circuit Description

4.1 *Input Rectifier and EMI Filter*

Fuse F1 isolates the circuit and provides protection from component failure, and thermistor RT1 limits the inrush current when the power supply is connected to the input AC supply. Varistor RV1 provides safety during high voltage transients in case of input line surge.

Common mode chokes L1 and L2 with capacitors C1, C3, and C23 provide common mode and differential mode noise filtering for EMI attenuation. Bridge rectifier BR1 rectifies the AC line voltage and provides a full wave rectified DC across C2.

Resistors R1 and R2 along with CapZero-2 IC U3 discharges capacitor C1 when the power supply is disconnected from AC mains.

4.2 *InnoSwitch3-Pro IC Primary*

One end of the transformer primary is connected to the rectified DC bus and the other end is connected to the drain terminal of the switch inside the InnoSwitch3-Pro IC U1. Resistors R4 and R5 provide input voltage sensing for protection in case of AC input undervoltage or overvoltage.

A low-cost RCD clamp formed by diode D1, resistors R6, R7, R8, R9, and capacitor C4 limits the peak drain-source voltage of U2 at the instant the switch inside U2 turns off. The clamp helps to dissipate the energy stored in the leakage reactance of transformer T1.

The IC is self-starting, using an internal high-voltage current source to charge the BPP pin capacitor C6 when AC is first applied. During normal operation the primary-side block is powered from an auxiliary winding on the transformer T1. The output of the auxiliary (or bias) winding is rectified using diode D2 and filtered using capacitor C5. Resistor R14 limits the current being supplied to the BPP pin of the InnoSwitch3-Pro IC U1. A linear regulator comprising resistor R13, R23, BJT Q1 and Zener diode VR2 ensures sufficient current flows through R14 such that the internal current source of U1 is not required to charge C6 during normal operation.

Zener diode VR1 offers primary sensed output overvoltage protection. In a flyback converter, output of the auxiliary winding tracks the output voltage of the converter. In case of overvoltage at output of the converter, the auxiliary winding voltage increases and causes breakdown of VR1 which then causes excess current to flow into the BPP pin of InnoSwitch3-Pro IC U1. If the current flowing into the BPP pin increases above the I_{SD} threshold, the InnoSwitch3-Pro controller will latch off and prevent any further increase in output voltage. Resistor R15 limits the current injected to BPP pin when the output overvoltage protection is triggered.

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

4.3 *InnoSwitch3-Pro IC Secondary and USB Power Delivery Controller*

The secondary-side of the InnoSwitch3-Pro IC provides output voltage and current sensing and a gate drive to a FET for synchronous rectification. The voltage across the transformer secondary winding is rectified by the secondary-side FET (or SR FET) Q2 and filtered by capacitors C12 and C13. High frequency ringing during switching transients that would otherwise create radiated EMI is reduced via a RCD snubber, R19, R43, C8, and D4.

The gate of Q2 is turned on by secondary-side controller inside IC U1, based on the secondary winding voltage sensed via resistor R16 and fed into the FWD pin of the IC.

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

The secondary-side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. Capacitor C9 connected to the BPS pin of InnoSwitch3-Pro IC U1 provides decoupling for the internal circuitry.

The output current is sensed by monitoring the voltage drop across resistors R33 and R44. Resistors R20 and R21 add an offset to the sensed output current to provide a positive slope to the CC characteristic. The resulting current measurement is filtered with decoupling capacitor C14 and monitored across the IS and SECONDARY GROUND pins. An internal current sense threshold which is configured via the I^2C interface up to approximately 32 mV is used to reduce losses. Once the threshold is exceeded, the InnoSwitch3-Pro IC U1 regulates the number of switch pulses to maintain a fixed output current.

During constant current (CC) operation, when the output voltage falls, the secondary side controller inside InnoSwitch3-Pro IC U1 will power itself from the secondary winding directly. During the on-time of the primary-side power switch, the forward voltage that appears across the secondary winding is used to charge the SECONDARY BYPASS pin decoupling capacitor C9 via resistor R16 and an internal regulator. This allows output current regulation to be maintained down to the minimum UV threshold. Below this level the unit enters auto-restart until the output load is reduced.

When the output current is below the CC threshold, the converter operates in constant voltage mode. The output voltage is monitored by the VOUT pin of the InnoSwitch3-Pro IC. Similar with current regulation, the output voltage is also compared to an internal voltage threshold that is set via the I^2C interface and the controller inside IC U1 regulates the output voltage by controlling the number of switch pulses. Capacitor C10 is needed between the VOUT pin and the SECONDARY GROUND pin for ESD protection of the VOUT pin.

N-channel MOSFET Q3 functions as the bus switch which connects or disconnects the output of the flyback converter from the USB Type-C receptacle. Q3 is controlled by the VB/D pin on the InnoSwitch3-Pro IC. Resistors R25, R26, and diode D5 are connected across the Source and Gate terminals of the Q3 to provide a discharge path for the bus voltage when the Q3 is turned off. Capacitor C15 is needed at the output for ESD protection.

In this design, WT6635P (U4) is the USB Power Delivery (USB PD) controller. It is powered by the InnoSwitch3-Pro IC through the μVCC pin. USB PD protocol is communicated over either CC1 or CC2 line depending on the orientation in which Type-C plug is connected.

WT6635P communicates with InnoSwitch3-Pro IC through the I^2C interface using the SCL and SDA lines in which it sets the CV, CC, V_{kp}, OVA and UVA parameters. These parameters correspond to the output voltage, constant output current, constant output power voltage threshold, output overvoltage threshold, and output undervoltage threshold registers of the InnoSwitch3-Pro IC, respectively. The status of the InnoSwitch3-Pro IC is read by the WT6635P IC from the telemetry registers also using the I^2C interface.

Capacitor C11 provides decoupling to VCC of the WT6635P IC. Capacitors C19, C20, C21, C16, resistors R37, R38, R41, R42, and TVS D3, D6, D7, and D8 provide protection from ESD to pins CC1, CC2, D- and D+.

Thermistor RT2 is connected to pin GPIO6 of the WT6635P IC to provide temperature detection of the USB Type-C receptacle. Resistor R36 is used by the WT6635P IC to sense the output voltage at the USB Type-C receptacle, which is the voltage after the bus switch Q3. R36 is also used for discharging the capacitor C15 through the GPIO converted as sink after the bus switch Q3 is opened.

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

5 PCB Layout

PCB copper thickness is 0.062 inches.

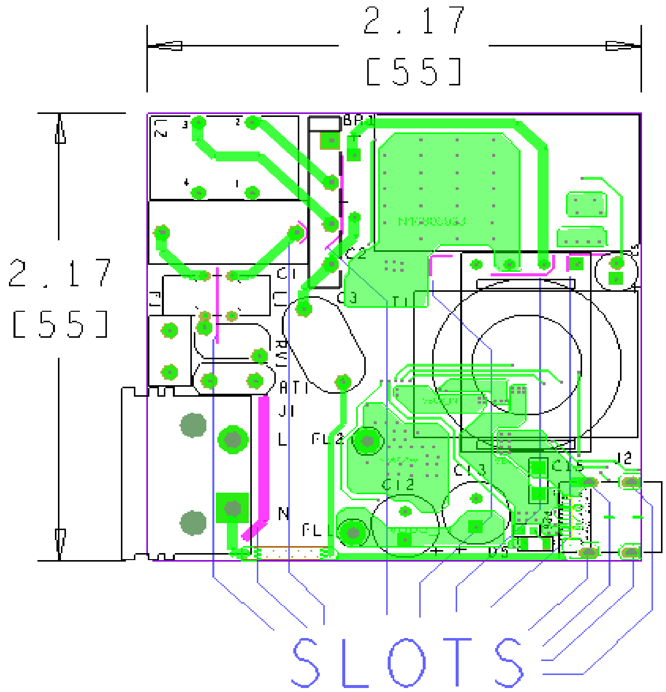


Figure 6 – Printed Circuit Layout, Top.

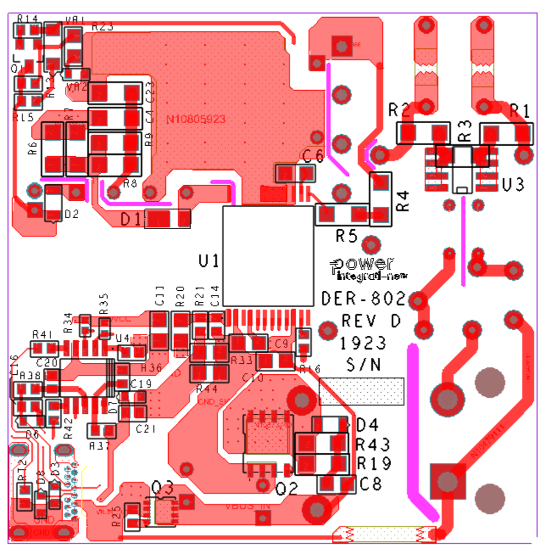


Figure 7 – Printed Circuit Layout, Bottom.

Note:
Component references R3, R25, R34 and R35, although present in the layout, should not be populated.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	DIODE BRIDGE 600 V 4 A GB	GBL06	Genesic Semi
2	1	C1	330 nF, ±10%, 310 VAC, Polypropylene Film, X2, 15.00 mm x 8.0 mm	B32922C3334M	Epcos
3	1	C2	100 μF, 400 V, Electrolytic, Low ESR, (16 x 30)	EPAG401ELL101ML30S	Nippon Chemi-Con
4	1	C3	470 pF, 250 VAC, Film, X1Y1	DE1B3KX471KN4AN01F	Murata
5	1	C4, C23	2.2 nF, 630 V, Ceramic, X7R, 1206	C3216X7R2J222K	TDK
6	1	C5	22 μF, ±20%, 63 V, Electrolytic, (5 x 12.5), LS 2 mm	63YXJ22M5X11	Rubycon
7	1	C6	4.7 μF ±10%, 25V, X7R, 0805,-55°C ~ 125°C	TMK212AB7475KG-T	Taiyo Yuden
8	1	C8	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
9	3	C9, C10, C11	2.2 μF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
10	2	C12 C13	330 μF,±20%, 25 V, Al Organic Polymer, Gen. Purpose, Can, 18 mΩ, 2000 Hrs @ 105°C, (8 mm x 13 mm)	A750KS337M1EAAE018	KEMET
11	1	C14	4.7 μF, 10 V, Ceramic, X5R, 0603	C1608X5R1A475M/0.50	TDK
12	1	C15	2.2 μF, 50 V, Ceramic, X7R, 1206	CL31B225KBHNNNE	Samsung
13	4	C16, C19, C20, C21	CAP, CER, 270 pF,±5%, 50 V, Low ESL,C0G/NP0, 0603	C0603C271J5GACTU	Kemet
14	1	D1	800 V, 1 A, Rectifier, POWERDI123	DFLR1800-7	Diodes, Inc.
15	1	D2	DIODE, GEN PURP, FAST RECOVERY, 300 V, 225 mA, SOD323	BAV3004WS-7	Diodes, Inc.
16	4	D3, D6, D7, D8	DIODE, ZENER, 24 V, 200 mW, SC-90, SOD-323F	MM3Z24VC	ON Semiconductor
17	1	D4	100 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV19WS-7-F	Diodes, Inc.
18	1	D5	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
19	1	F1	3.15 A, 250 V, Slow, RST	507-1181	Belfuse
20	1	J1	Power Entry Connector Receptacle, Male Pins, IEC 320-C8, Non-Polarized, Panel Mount, Snap-In; Through Hole, Right Angle	RAPC322X	Switchcraft
21	1	J2	Connector, "Certified",USB - C, USB 3.1, For 0.062" PCB Material!,Superspeed+, Receptacle Connector, 24 Position, SMT, Right Angle, TH	632723300011	Wurth
22	1	L1	250 μH, Toroidal Common Mode Choke, custom Assembled CMC (alternate)	32-00367-00 TSD-4500	Power Integrations Premier Magnetics
23	1	L2	CMC, 18 mH @ 10 kHz, Toroidal, 17.5 mm OD x 11.0 mm thick. 40 turns x 2, 0.40 mm wire 190 mΩ max	04291-T231	Sumida
24	1	Q1	NPN, Small Signal BJT, 80 V, 0.5 A, SOT-23	MMBTA06LT1G	On Semi
25	1	Q2	MOSFET, N-CH, 120V, 85A (at VGS=10V), Trench Power AlphaSGT 120V TM technology, DFN5X6	AONS62922	Alpha & Omega Semi
26	1	Q3	MOSFET, N-CH, 30V, 21A, 8-DFN-EP (3.3x3.3),8-PowerWDFN	AON7520	Alpha & Omega Semi
27	2	R1, R2	RES, 1 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
28	1	R4	RES, 2.00 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2004V	Panasonic
29	1	R5	RES, 1.80 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1804V	Panasonic
30	2	R6, R7	RES, 20 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ200V	Panasonic
31	2	R8, R9	RES, 680 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ684V	Panasonic
32	1	R13	RES, 100 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1003V	Panasonic
33	1	R14	RES, 3.65 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3EKF3651V	Panasonic
34	2	R15, R16	RES, 47 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ470V	Panasonic
35	2	R19, R43	RES, 20 Ω, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF20R0V	Panasonic
36	1	R20	RES, 324 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF3243V	Panasonic
37	1	R21	RES, 10 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF10R0V	Panasonic

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

38	1	R23	RES, 11.8 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1182V	Panasonic
39	1	R26	RES, 100 Ω, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1000V	Panasonic
40	1	R33	RES, SMD, 0.010 R, ±1%, 1/4 W, 100 PPM / C, 0805 (2012 Metric), Current Sense, Thick Film,	PE0805FRF7W0R01L	Yageo
41	1	R36	RES, 1 kΩ, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1001V	Panasonic
42	4	R37, R38, R41, R42	RES, 22 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ220V	Panasonic
43	1	R44	RES, 0.11 Ω , ±1%, 1/4 W, 0805, Current Sense, Thick Film	RLP73N2AR11FTDF	TE Connectivity
44	1	RT1	NTC Thermistor, 2.5 Ω, 3 A	SL08 2R503	Ametherm
45	1	RT2	NTC Thermistor, 100 kΩ, 1%, 4250K, 0603 (1608 Metric)	NCU18WF104E03RB	Murata
46	1	RV1	275 Vac, 23 J, 7 mm, RADIAL	V275LA4P	Littlefuse
47	1	T1	Custom, DER-802 Transformer, Lp = 458uH, EQ25, 3C95 core material, Bobbin TBI-235-01091.1206, 4 pins, 4pri, 0sec Assembled Transformer (alternate)	 POL-INNO39	Power Integrations Premier Magnetics
48	1	U1	InnoSwitch3-Pro, InSOP24D	INN3379C-H302	Power Integrations
49	1	U3	CAPZero-2, SO-8C	CAP200DG	Power Integrations
50	1	U4	USB PD Type-C Controller for SMPS	WT6635P	Weltrend
51	1	VR1	DIODE ZENER 47 V 500 mW SOD123	MMSZ5261BT1G	ON Semi
52	1	VR2	Zener Diode 10V 350mW ±2% Surface Mount SOD-523	BZT585B10T-7	Diodes Incorporated

7 Transformer Specification

7.1 *Electrical Diagram*

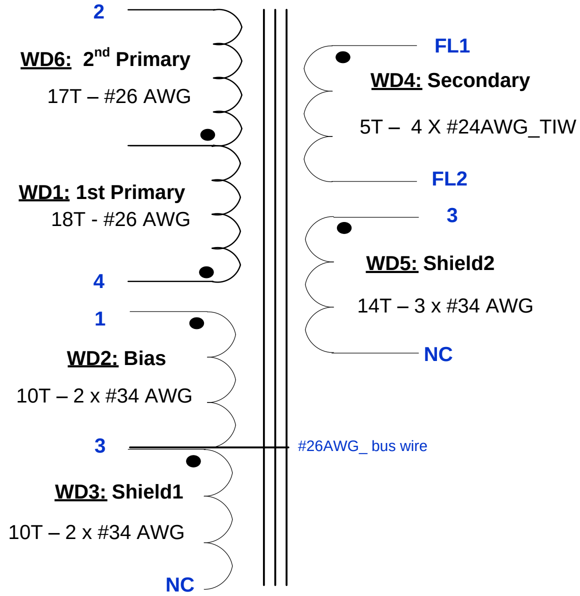


Figure 8 – Transformer Electrical Diagram.

7.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 2 and 4, with all other windings open.	458 µH ±5%
Resonant Frequency	Between pin 2 and 4, other windings open.	1,500 kHz (Min.)
Primary Leakage Inductance	Between pin 2 and 4, with pins FL1-FL2 shorted.	9.5 µH (Max.)

7.3 *Material List*

Item	Description
[1]	Core: EQ25-3C95, Ferroxcube.
[2]	Bobbin: EQ25-Vertical, 4pins (4/0), PI custom, P/N: 25-01141-00.
[3]	Magnet wire: #26 AWG, double coated.
[4]	Magnet wire: #34 AWG, double coated.
[5]	Magnet wire: #24 AWG, Triple Insulated Wire.
[6]	Bus wire: #26AWG, Alpha wire, tinned copper.
[7]	Tape: 3M 1350-F, Polyester Film, 1 mil thickness, 8.2 mm width.
[8]	Tape: 3M 1350-F, Polyester Film, 1 mil thickness, 30 mm x 55 mm.
[9]	Glue: Loctite, 409, Gel, Mf #:40904; or equivalent.
[10]	Epoxy: Devcon, 5 mins Epoxy, Mfr#: 14270; or equivalent.
[11]	Varnish: Dolph BC-359.

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

7.4 ***Transformer Build Diagram***

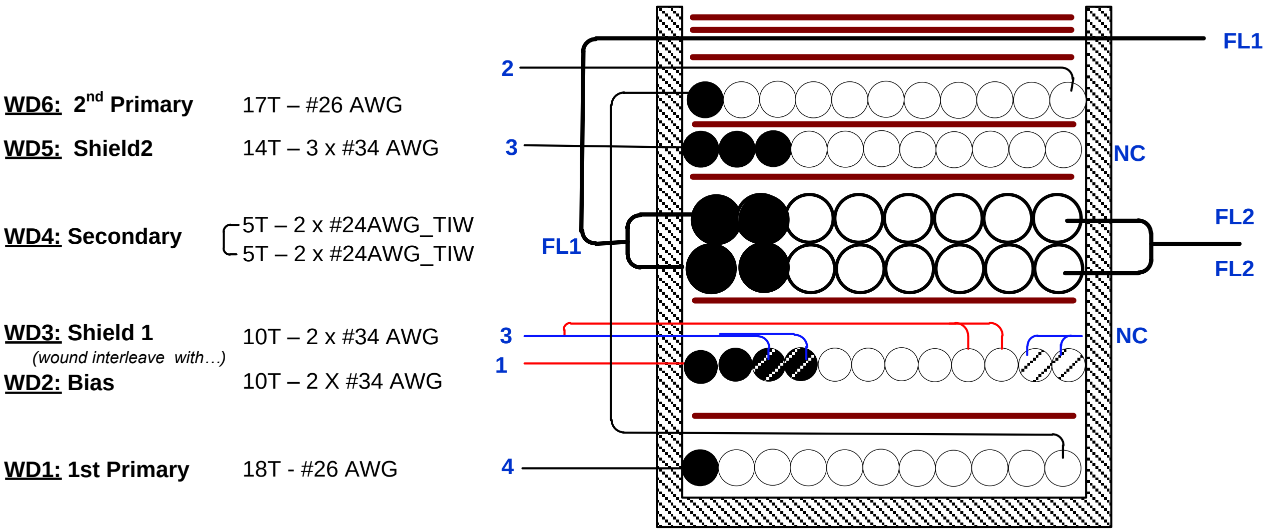


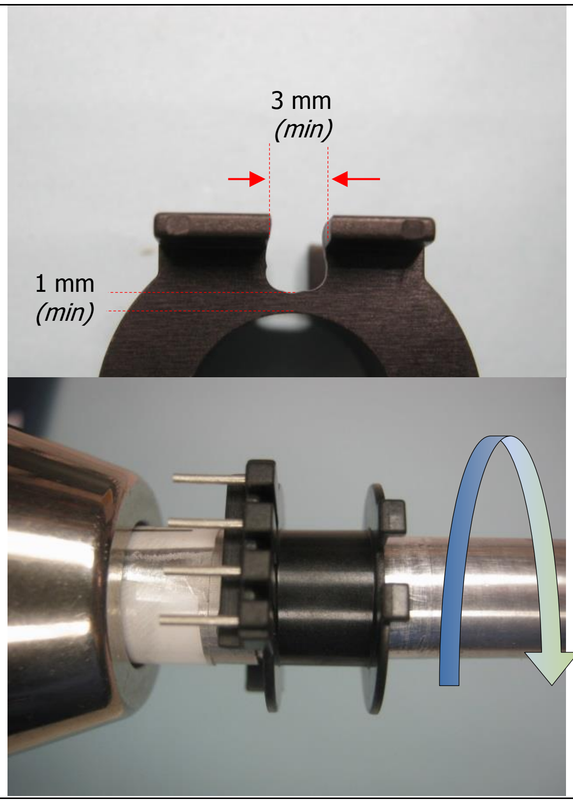
Figure 9 – Transformer Build Diagram.

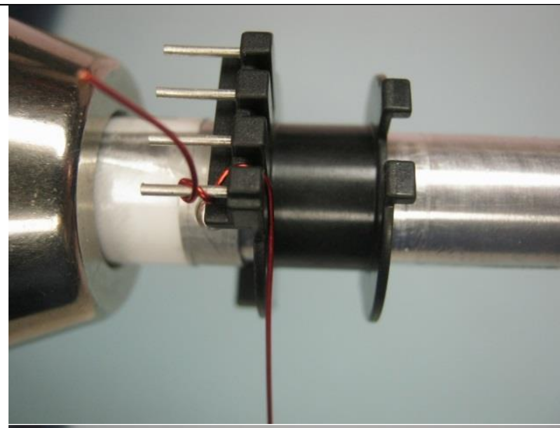
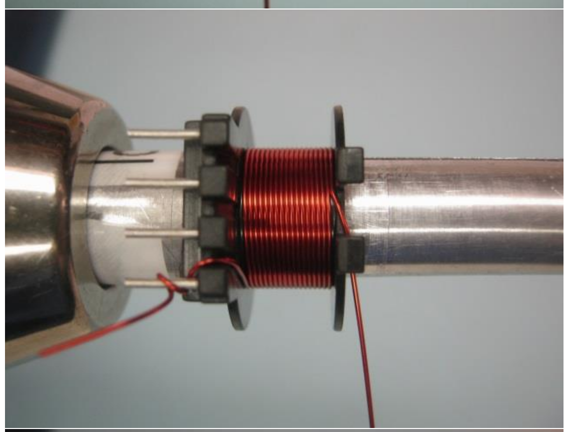
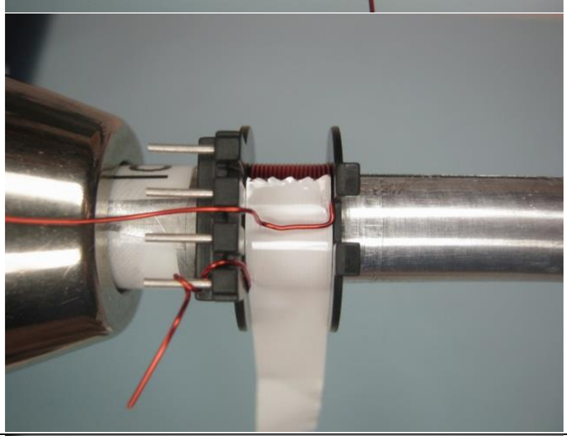
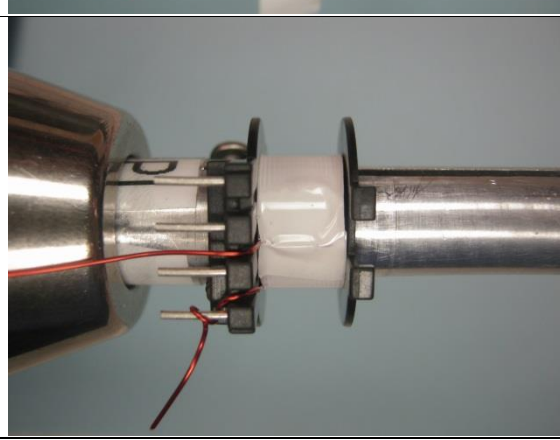
7.5 *Transformer Construction*

Winding preparation	Make slot with 3.0mm width on bottom secondary flange of the bobbin item [2]. Position the bobbin item [2] on the mandrel such that the primary side of the bobbin is on the left side. Winding direction is clock-wise direction for forward direction.
WD1 1st Primary	Start at pin 4, wind 18 turns of wire item [3] in 1 layer, with tight tension, from left to right. At the last turn, bring the wire back to left, and leave enough length of wire-floating for WD6-2nd Primary.
Insulation	1 layer of tape item [7].
WD2: Bias & WD3: Shield1	Use 2 wires item [4] start at pin 1 for Bias winding, also use 2 wires same item [4] start at pin 3 for Shield1 winding. Wind all 4 wires in parallel, at the 10th turn: - bring 2 wires for Bias winding to the left and terminate at pin 3, - cut short 2 wires for Shield1 Winding as No-Connect.
Insulation	1 layer of tape item [7].
WD4 Secondary	Start at left slot of secondary side, use 2 wires item [5], leaving ~ 40.0mm floating, and mark as FL1.Wind 5 bifilar turns in 1 layer, from left to right, at the last turn exit the wires at right slot, also leaving ~ 30.0mm floating, and mark FL2. Repeat the same winding above on top previous winding, also mark start and finish ends as FL1 and FL2.
Insulation	1 layer of tape item [7].
WD5 Shield2	Start at pin 3, wind 14 tri-filar turns of wire item [4], from left to right. At the last turn, cut short to leave as No-Connect.
Insulation	1 layer of tape item [7].
WD6 2nd Primary	Use floating wire from WD1-1st Primary, wind 17 turns from right to left and finish at pin 2.
Insulation	1 layer of tape item [7]. Bring 4 wires marked as FL1 to the right and secure with 2 layers of` tape item [7].
Finish	Gap core halves to get 458uH. Place tape item [8] on both sides and for both core halves *(see pictures below).* Apply glue item [10] at center legs of cores. Solder pin 3 with bus-wire item [6] then lean along core halves and secure with tape. Apply epoxy item [11] between cores to body of the transformer. Varnish with item [12]. Place 2 layers of tape item [9] at the bottom then wrap up to the body of transformer, and tape around 1turn of tape item [7]. (*See pictures below).*

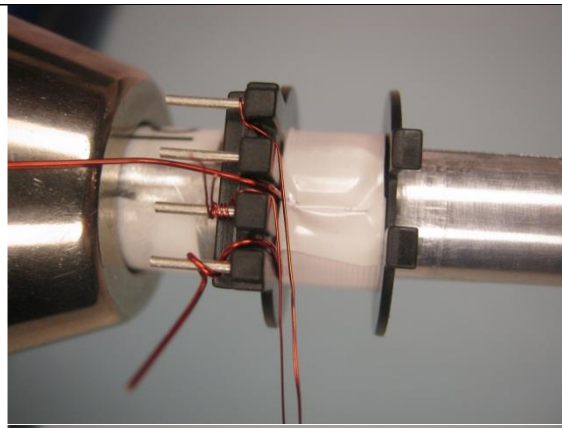
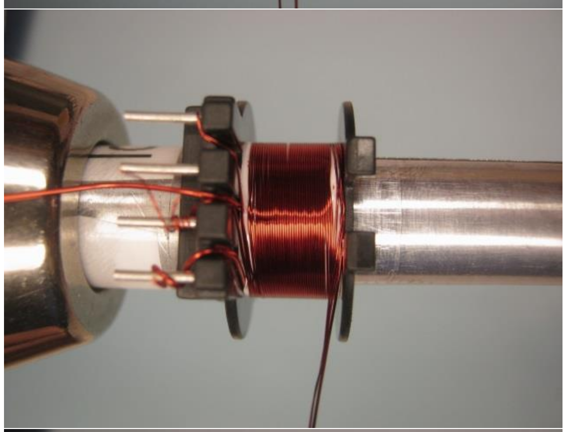
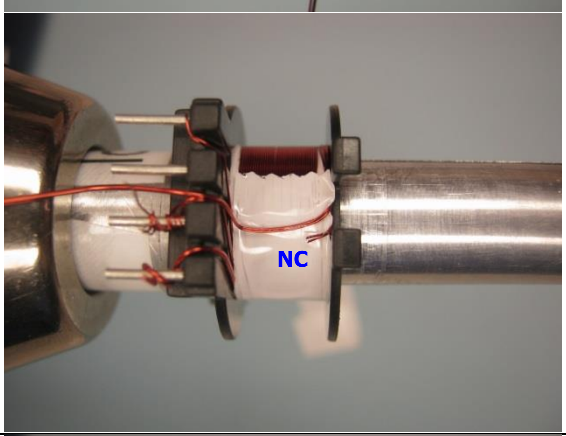
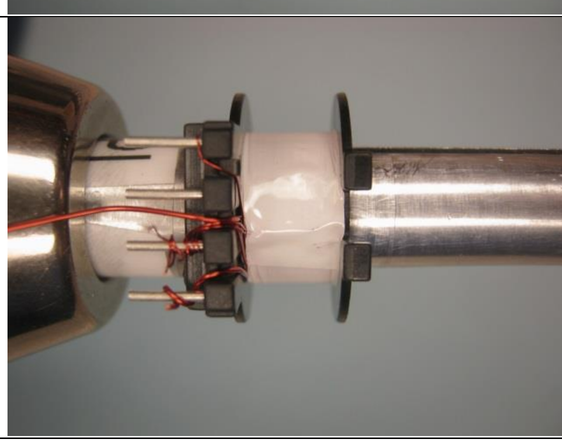
Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

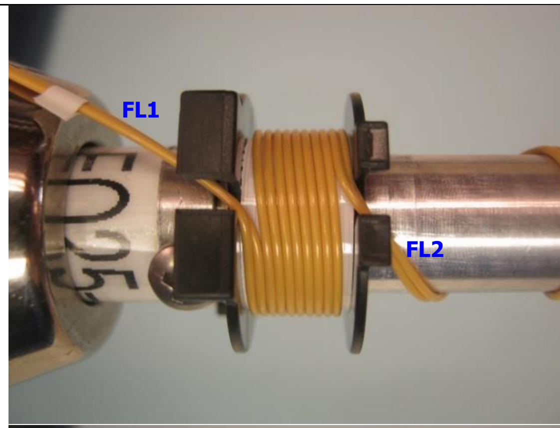
7.6 *Winding Illustrations*

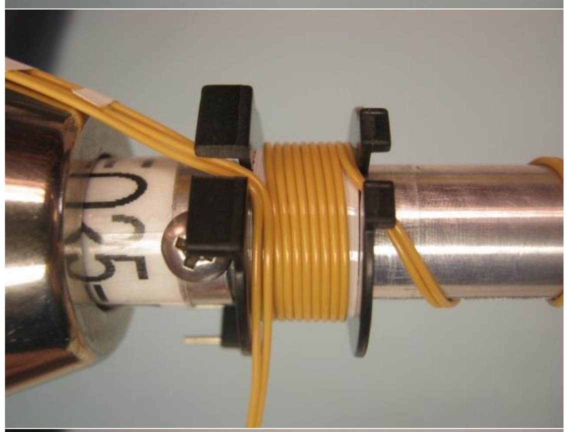
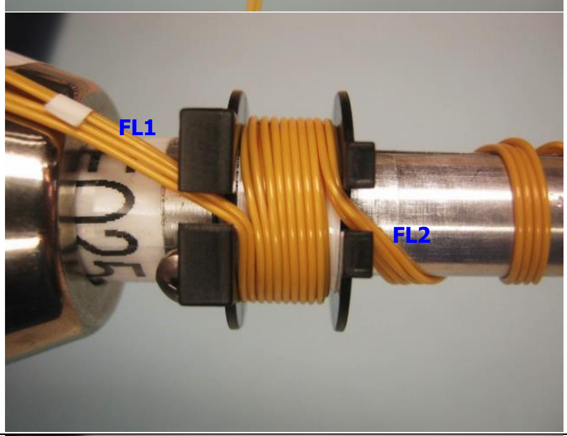
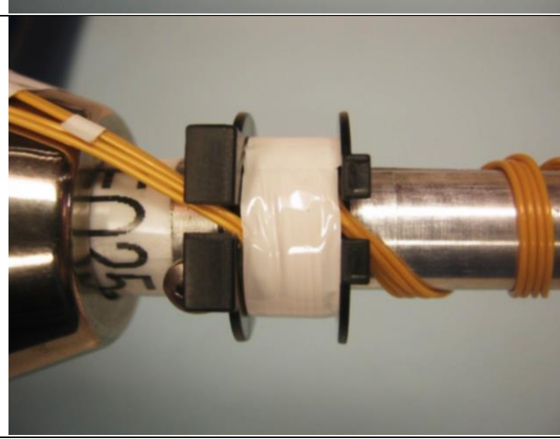
Winding preparation		Make slot with 3.0mm width on bottom secondary flange of the bobbin item [2]. Position the bobbin item [2] on the mandrel such that the primary side of the bobbin is on the left side. Winding direction is clock-wise direction for forward direction.

WD1 **1st Primary**	  	Start at pin 4, wind 18 turns of wire item [3] in 1 layer, with tight tension, from left to right. At the last turn, bring the wire back to left, and leave enough length of wire-floating for WD6-2nd Primary.
Insulation		1 layer of tape item [7].

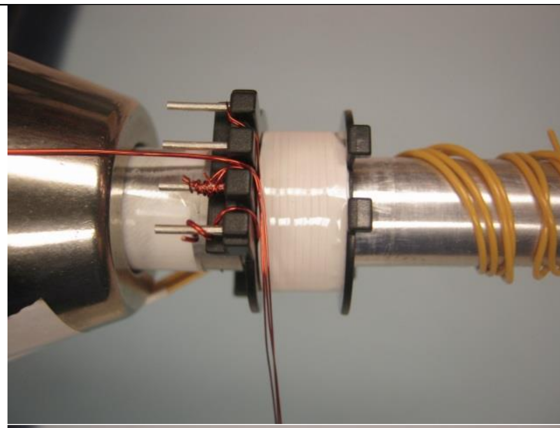
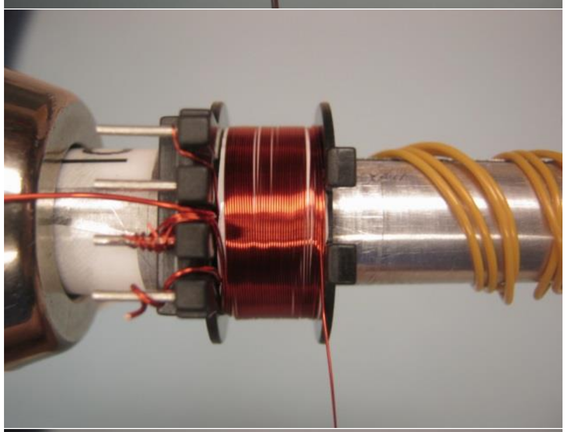
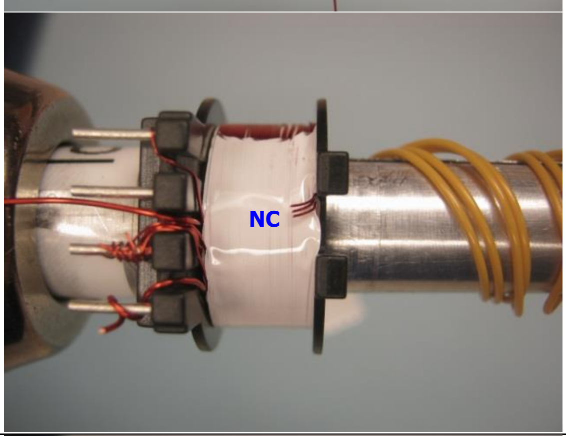
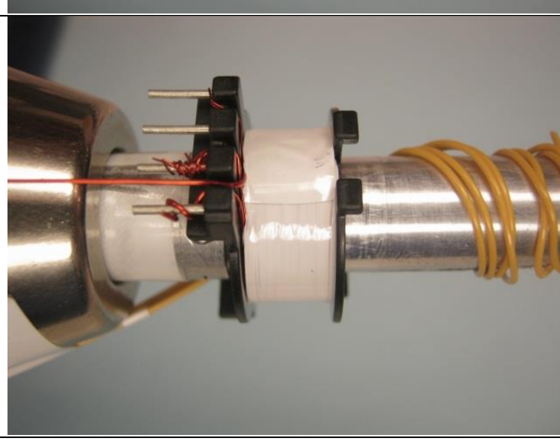
Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

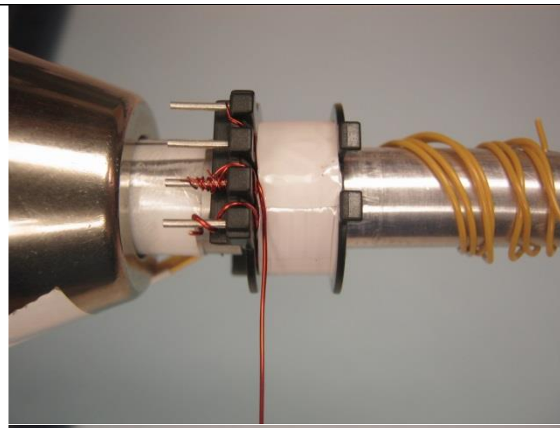
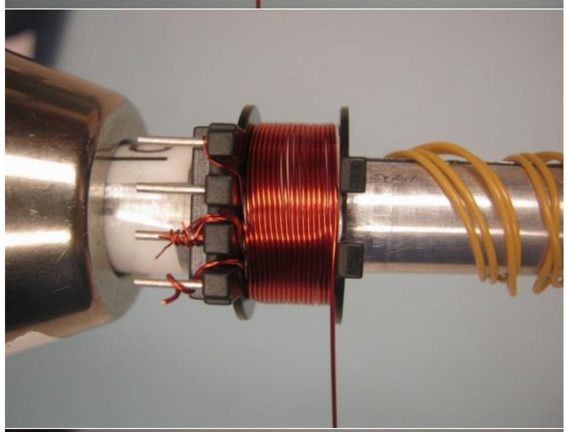
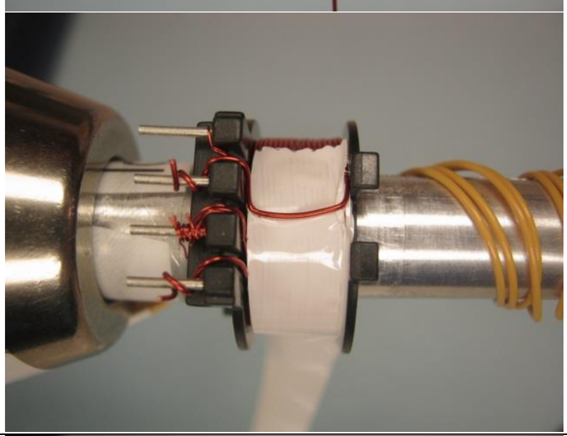
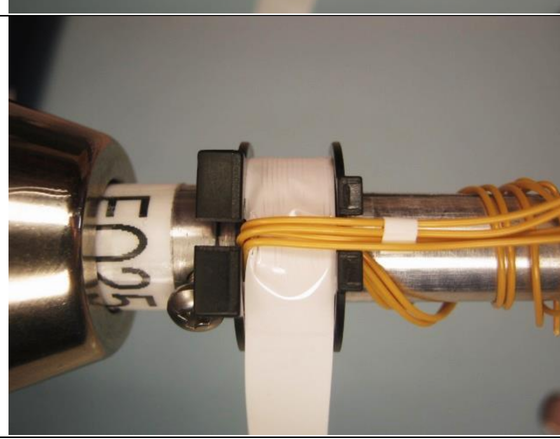
WD2: Bias & WD3: Shield1	   	Use 2 wires item [4] start at pin 1 for Bias winding, also use 2 wires same item [4] start at pin 3 for Shield1 winding. Wind all 4 wires in parallel, at the 10th turn: - bring 2 wires for Bias winding to the left and terminate at pin 3, - cut short 2 wires for Shield1 Winding as No-Connect.
Insulation		1 layer of tape item [7].

<table>
<tr>
<td>WD4
Secondary</td>
<td>

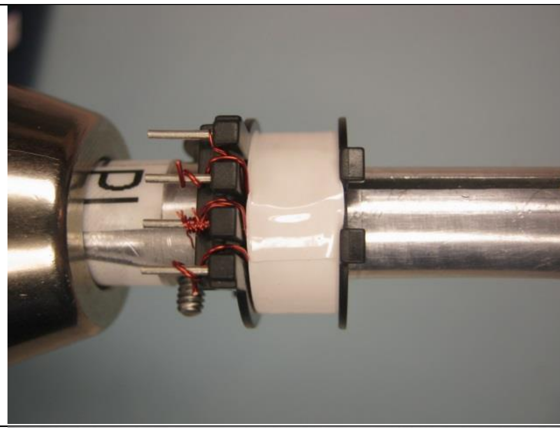
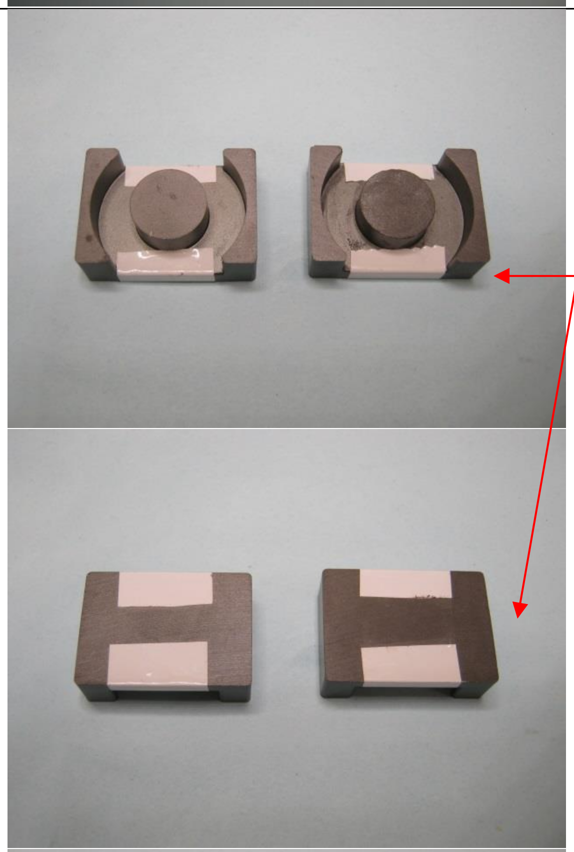


</td>
<td>Start at left slot of secondary side, use 2 wires item [5], leaving ~ 40.0mm floating, and mark as FL1.Wind 5 bifilar turns in 1 layer, from left to right, at the last turn exit the wires at right slot, also leaving ~ 30.0mm floating, and mark FL2. Repeat the same winding above on top previous winding, also mark start and finish ends as FL1 and FL2.</td>
</tr>
<tr>
<td>Insulation</td>
<td></td>
<td>1 layer of tape item [7].</td>
</tr>
</table>

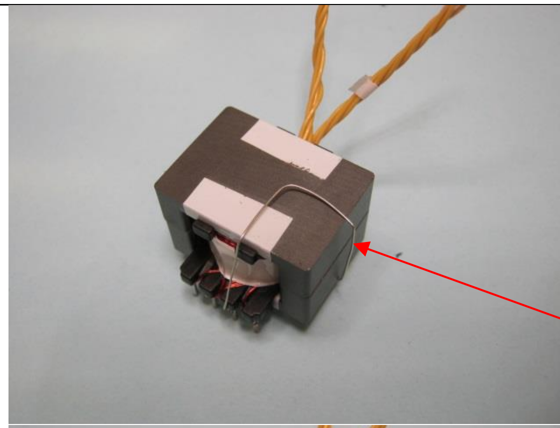
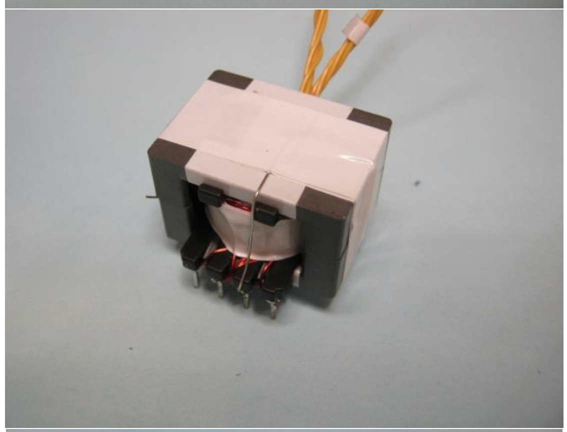
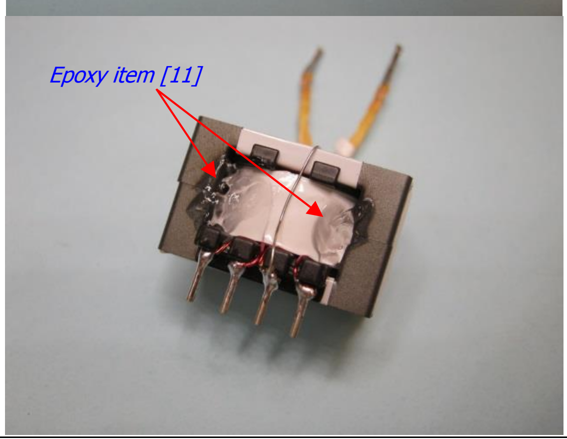
Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

WD5 **Shield2**	  	Start at pin 3, wind 14 tri-filar turns of wire item [4], from left to right. At the last turn, cut short to leave as No-Connect.
Insulation		1 layer of tape item [7].

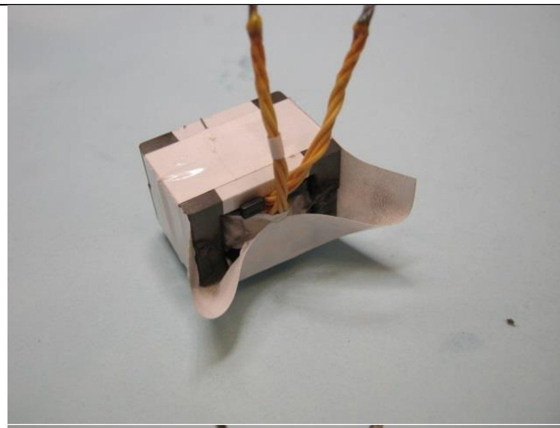
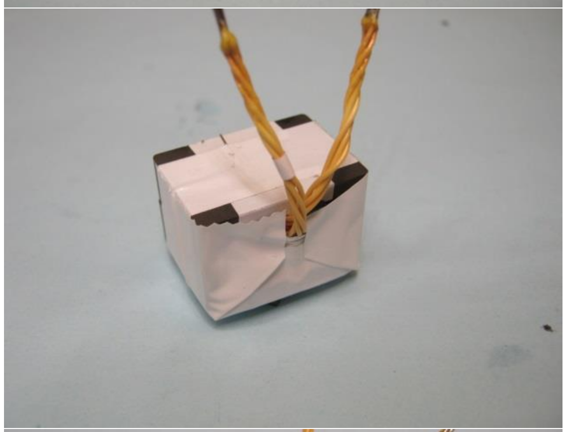
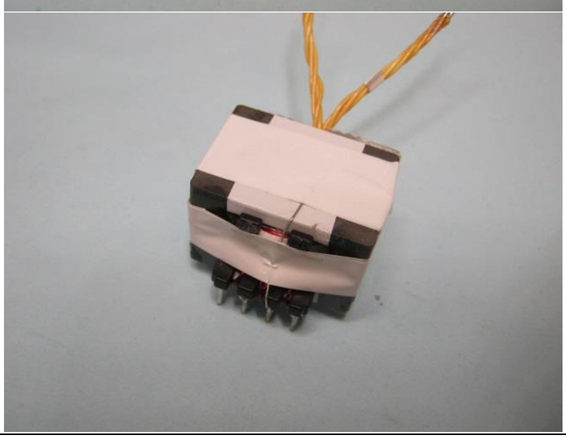
WD6 **2nd Primary**	  	Use floating wire from WD1-1st Primary, wind 17 turns from right to left and finish at pin 2.
Insulation		1 layer of tape item [7]. Bring 4 wires marked as FL1 to the right and secure with 2 layers of` tape item [7].

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

		
Finish	 	Gap core halves to get 458uH. <u>Place tape item [8] on both sides and for both core halves</u> (see pictures beside). Apply glue item [10] at center legs of cores.

	 	Solder pin 3 with bus-wire item [6] then lean along core halves and secure with tape.
	 	Apply epoxy item [11] between cores to body of the transformer. Varnish with item [12].

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

		.
		Place 2 layers of tape item [9] at the bottom then wrap up to the body of transformer, and tape around 1turn of tape item [7]. (*See pictures beside).*
		Finish

8 Common Mode Choke Specifications

8.1 *250 μH Common Mode Choke (L1)*

8.1.1 Electrical Diagram

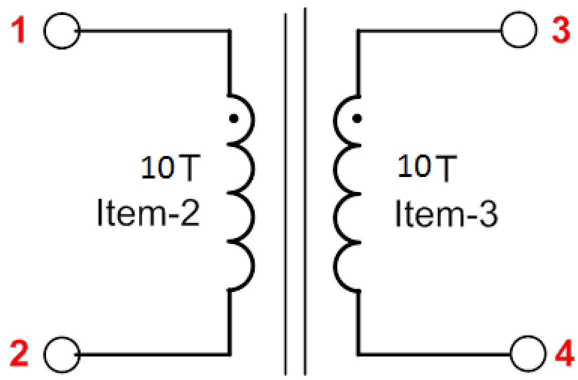


Figure 10 – Inductor Electrical Diagram.

8.1.2 Electrical Specifications

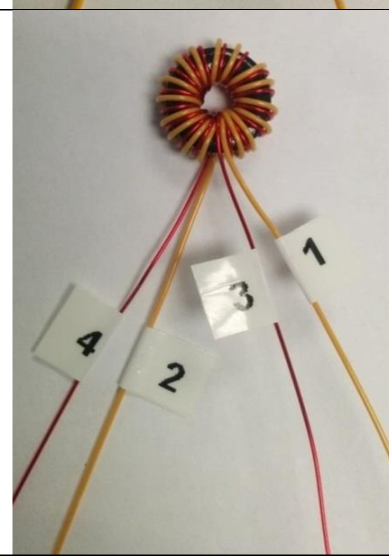
Winding Inductance	Pin 1 – pin 2 (pin 3 – pin 4), all other windings open, measured at 100 kHz, 0.4 V_{RMS}.	250 μH ±20%

8.1.3 Material List

Item	Description
[1]	Toroidal Core: 35T0375-10H, PI#: 32-00275-00.
[2]	Triple Insulated Wire: #26 AWG, Triple Coated.
[3]	Magnet Wire: #26 AWG, Double Coated.

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

8.1.4 Winding Instructions

Mark the start end of the winding as 1 and wind 10 turns of Item [2] on Item [1]. Mark the end of this winding as 2	
Repeat the same procedure as above for the other winding using Item [3], making sure that the start/end and the direction of winding is the same as the first winding. Varnish using Item [4]. Mark the start of this winding as 3 and the end as 4.	

8.2 ***18 mH Common Mode Choke (L2)***

8.2.1 Electrical Diagram

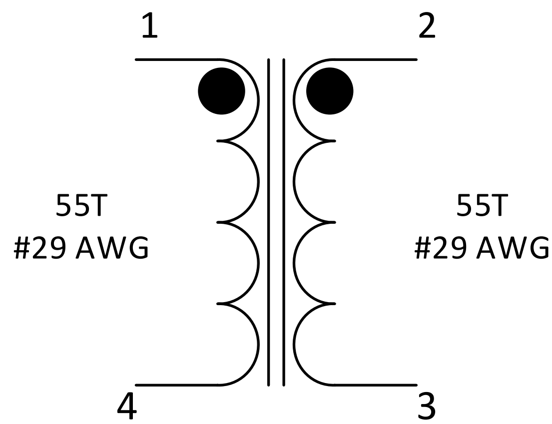


Figure 11 – Inductor Electrical Diagram.

8.2.2 Electrical Specifications

Inductance	Pins 1 - 4 and pins 2 - 3 measured at 100 kHz, 0.4 RMS.	18 mH ±25%
Core effective Inductance Index		5950 nH/N^2
Leakage Inductance	Pins 1 - 4, with pins 2 - 3 shorted.	80 μH ±10%

8.2.3 Material List

Item	Description
[1]	Toroid: FERRITE INDUCTOR TOROID T14 x 8 x 5.5, PI#: 32-00286-00.
[2]	Divider: Cable Tie, Panduit - Fish Paper, Insulating Cotton Rag, 0.010” Thick, PI#: 66-00042-00.
[3]	Magnet Wire: #29 AWG Heavy Nyleze.
[4]	Epoxy: Devon, 5mins Epoxy; or Equivalent.

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

8.2.4 Winding Instructions

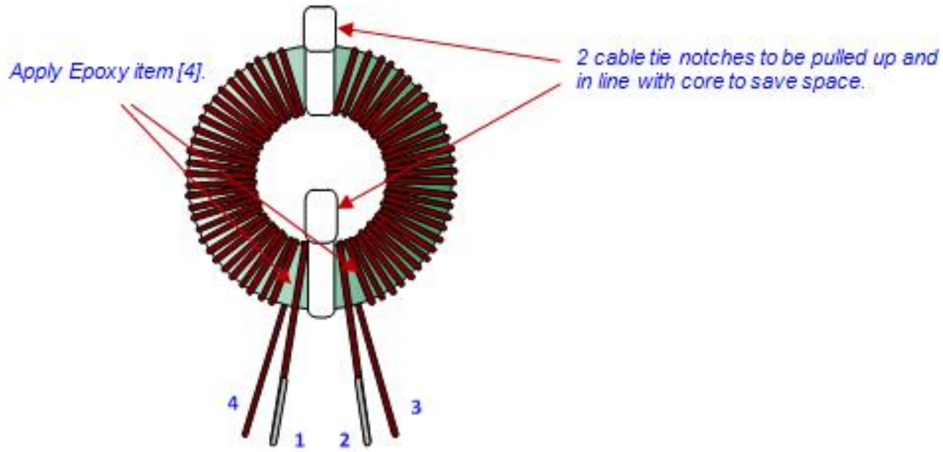


Figure 12 – 18 mH CMC Illustration Image.

- Place 2 pieces of cable tie Item [2] on to toroid Item [1] to divide 2 equal sections.
- Use 4 ft of wire Item [3], start as 1, wind 55 turns in 2 layers in a half section of toroid, and end as 4.
- Do the same for another half of Toroid, start as 2 and end as 3.
- Pull up 2 notches of cable ties to be in line with toroid body (to save space), and apply Epoxy Item [4] where leads floating.

9 Transformer Design Spreadsheet

1	ACDC_Flyback_061319; Rev.0.1; Copyright Power Integrations 2019	INPUT	INFO	OUTPUT	UNITS	Flyback Design Spreadsheet
2	**APPLICATION VARIABLES**					
3	APPLICATION VARIABLES					Design Title
4	VAC_MIN			85	V	Minimum AC line voltage
5	VAC_MAX			265	V	Maximum AC input voltage
6	VAC_RANGE			UNIVERSAL		AC line voltage range
7	FLINE			60	Hz	AC line voltage frequency
9	**SETPOINT 1**					
10	VOUT1	21.00		21.00	V	Output voltage 1, should be the highest output voltage required
11	IOUT1	3.000		3.000	A	Output current 1
12	POUT1			63.00	W	Output power 1
13	EFFICIENCY1	0.88		0.88		Converter efficiency for output 1
14	Z_FACTOR1	0.50		0.50		Z-factor for output 1
16	**SETPOINT 2**					
17	VOUT2	20.00		20.00	V	Output voltage 2
18	IOUT2	3.000		3.000	A	Output current 2
19	POUT2			60.00	W	Output power 2
20	EFFICIENCY2	0.88		0.88		Converter efficiency for output 2
21	Z_FACTOR2	0.50		0.50		Z-factor for output 2
23	**SETPOINT 3**					
24	VOUT3	15.00		15.00	V	Output voltage 3
25	IOUT3	3.000		3.000	A	Output current 3
26	POUT3			45.00	W	Output power 3
27	EFFICIENCY3	0.88		0.88		Converter efficiency for output 3
28	Z_FACTOR3	0.50		0.50		Z-factor for output 3
30	**SETPOINT 4**					
31	VOUT4	9.00		9.00	V	Output voltage 4
32	IOUT4	3.000		3.000	A	Output current 4
33	POUT4			27.00	W	Output power 4
34	EFFICIENCY4	0.88		0.88		Converter efficiency for output 4
35	Z_FACTOR4	0.50		0.50		Z-factor for output 4
37	**SETPOINT 5**					
38	VOUT5	5.00		5.00	V	Output voltage 5
39	IOUT5	3.000		3.000	A	Output current 5
40	POUT5			15.00	W	Output power 5
41	EFFICIENCY5	0.88		0.88		Converter efficiency for output 5
42	Z_FACTOR5	0.50		0.50		Z-factor for output 5
44	**SETPOINT 6**					
45	VOUT6	3.30		3.30	V	Output voltage 6
46	IOUT6	3.000		3.000	A	Output current 6
47	POUT6			9.90	W	Output power 6
48	EFFICIENCY6	0.88		0.88		Converter efficiency for output 6
49	Z_FACTOR6	0.50		0.50		Z-factor for output 6
51	**SETPOINT 7**					
52	VOUT7			0.00	V	Output voltage 7
53	IOUT7			0.000	A	Output current 7
54	POUT7			0.00	W	Output power 7
55	EFFICIENCY7			0.00		Converter efficiency for output 7
56	Z_FACTOR7			0.00		Z-factor for output 7
58	**SETPOINT 8**					
59	VOUT8			0.00	V	Output voltage 8
60	IOUT8			0.000	A	Output current 8
61	POUT8			0.00	W	Output power 8
62	EFFICIENCY8			0.00		Converter efficiency for output 8
63	Z_FACTOR8			0.00		Z-factor for output 8

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

65	**SETPOINT 9**					
66	VOUT9			0.00	V	Output voltage 9
67	IOUT9			0.000	A	Output current 9
68	POUT9			0.00	W	Output power 9
69	EFFICIENCY9			0.00		Converter efficiency for output 9
70	Z_FACTOR9			0.00		Z-factor for output 9
72	VOLTAGE_CDC	0.000		0.000	V	Cable drop compensation desired at full load
76	**PRIMARY CONTROLLER SELECTION**					
78	ENCLOSURE	ADAPTER		ADAPTER		Power supply enclosure
79	ILIMIT_MODE	INCREASED		INCREASED		Device current limit mode
80	VDRAIN_BREAKDOWN	750		750	V	Device breakdown voltage
81	DEVICE_GENERIC	INN3379		INN3379		Device selection
82	DEVICE_CODE			INN3379C		Device code
83	PDEVICE_MAX			65	W	Device maximum power capability
84	RDSON_25DEG			0.44	Ω	Primary switch on-time resistance at 25°C
85	RDSON_100DEG			0.62	Ω	Primary switch on-time resistance at 100°C
86	ILIMIT_MIN			1.980	A	Primary switch minimum current limit
87	ILIMIT_TYP			2.130	A	Primary switch typical current limit
88	ILIMIT_MAX			2.279	A	Primary switch maximum current limit
89	VDRAIN_ON_PRSW			0.55	V	Primary switch on-time voltage drop
90	VDRAIN_OFF_PRSW			588.31	V	Peak drain voltage on the primary switch during turn-off
93	**WORST CASE ELECTRICAL PARAMETERS**					
95	FSWITCHING_MAX	92904	Info	92904	Hz	The worst case minimum operating frequency is less than 25kHz: may result in audible noise
96	VOR	145.0		145.0	V	Voltage reflected to the primary winding (corresponding to set-point 1) when the primary switch turns off
97	VMIN			76.61	V	Valley of the rectified minimum input AC voltage at full load
98	KP			0.617		Measure of continuous/discontinuous mode of operation
99	MODE_OPERATION			CCM		Mode of operation
100	DUTYCYCLE			0.656		Primary switch duty cycle
101	TIME_ON			11.93	us	Primary switch on-time
102	TIME_OFF		Warning	3.70	us	Primary switch off-time is shorter than 4.37us: Decrease the controller switching frequency or decrease the VOR
103	LPRIMARY_MIN			435.0	uH	Minimum primary magnetizing inductance
104	LPRIMARY_TYP			457.9	uH	Typical primary magnetizing inductance
105	LPRIMARY_TOL			5.0	%	Primary magnetizing inductance tolerance
106	LPRIMARY_MAX			480.7	uH	Maximum primary magnetizing inductance
107	**PRIMARY CURRENT**					
109	IAVG_PRIMARY			0.885	A	Primary switch average current
110	IPEAK_PRIMARY			2.181	A	Primary switch peak current
111	IPEDESTAL_PRIMARY			0.747	A	Primary switch current pedestal
112	IRIPPLE_PRIMARY			2.074	A	Primary switch ripple current
113	IRMS_PRIMARY			1.160	A	Primary switch RMS current
114	**SECONDARY CURRENT**					
116	IPEAK_SECONDARY			15.269	A	Secondary winding peak current

117	IPEDESTAL_SECONDARY			5.231	A	Secondary winding pedestal current
118	IRMS_SECONDARY			5.880	A	Secondary winding RMS current
119	IRIPPLE_CAP_OUT			5.057	A	Output capacitor ripple current
122	**TRANSFORMER CONSTRUCTION PARAMETERS**					
123	**CORE SELECTION**					
124	CORE	CUSTOM	Info	CUSTOM		The transformer windings may not fit: pick a bigger core or bobbin and refer to the Transformer Parameters tab for fit calculations
126	CORE NAME	EQ25		EQ25		Core code
127	AE	95.0		95.0	mm^2	Core cross sectional area
128	LE	41.4		41.4	mm	Core magnetic path length
129	AL	5710		5710	nH	Ungapped core effective inductance per turns squared
130	VE	4145		4145	mm^3	Core volume
131	BOBBIN NAME	EQ25-Custom		EQ25-Custom		Bobbin name
132	AW	44.0		44.0	mm^2	Bobbin window area
133	BW	8.00		8.00	mm	Bobbin width
134	MARGIN	0.0		0.0	mm	Bobbin safety margin
135	**PRIMARY WINDING**					
137	NPRIMARY			35		Primary winding number of turns
138	BPEAK			3373	Gauss	Peak flux density
139	BMAX			3120	Gauss	Maximum flux density
140	BAC			1477	Gauss	AC flux density (0.5 x Peak to Peak)
141	ALG			374	nH	Typical gapped core effective inductance per turns squared
142	LG			0.298	mm	Core gap length
143	LAYERS_PRIMARY	3		3		Primary winding number of layers
144	AWG_PRIMARY	25		25		Primary wire gauge
145	OD_PRIMARY_INSULATED			0.518	mm	Primary wire insulated outer diameter
146	OD_PRIMARY_BARE			0.455	mm	Primary wire bare outer diameter
147	CMA_PRIMARY			276.3	Cmils/A	Primary winding wire CMA
148	**SECONDARY WINDING**					
150	NSECONDARY	5		5		Secondary winding number of turns
151	AWG_SECONDARY			19		Secondary wire gauge
152	OD_SECONDARY_INSULATED			1.217	mm	Secondary wire insulated outer diameter
153	OD_SECONDARY_BARE			0.912	mm	Secondary wire bare outer diameter
154	CMA_SECONDARY			219.1	Cmils/A	Secondary winding wire CMA
155	**BIAS WINDING**					
157	NBIAS			10		Bias winding number of turns
160	**PRIMARY COMPONENTS SELECTION**					
161	**LINE UNDERVOLTAGE**					
163	BROWN-IN REQURED	76.00		76.00	V	Required line brown-in threshold
164	RLS			3.82	MΩ	Connect two 1.91 MOhm resistors to the V-pin for the required UV/OV threshold
165	BROWN-IN ACTUAL			76.58	V	Actual brown-in threshold using standard resistors
166	BROWN-OUT ACTUAL			69.26	V	Actual brown-out threshold using standard resistors
167	**LINE OVERVOLTAGE**					
169	OVERVOLTAGE_LINE		Warning	319.20	V	The device voltage stress will be higher than 600V when overvoltage is trigerred
170	**BIAS WINDING**					
172	VBIAS			6.00	V	Rectified bias voltage at the lowest output setpoint
173	VF_BIAS			0.70	V	Bias winding diode forward drop

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

174	VREVERSE_BIASDIODE			80.66	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
175	CBIAS			22	uF	Bias winding rectification capacitor
176	CBPP			4.70	uF	BPP pin capacitor
179	**SECONDARY COMPONENTS SELECTION**					
180	**RECTIFIER**					
182	VDRAIN_OFF_SRFET			74.33	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
183	SRFET	AUTO		Si4190ADY		Secondary rectifier (Logic MOSFET)
184	VBREAKDOWN_SRFET			100	V	Secondary rectifier breakdown voltage
185	RDSON_SRFET			12	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
188	**SET-POINTS ANALYSIS**					
189	**TOLERANCE CORNER**					
196	USER_VAC	115		115	V	Input AC RMS voltage corner to be evaluated
197	USER_ILIMIT	TYP		2.130	A	Current limit corner to be evaluated
198	USER_LPRIMARY	TYP		457.9	uH	Primary inductance corner to be evaluated
194	**SETPOINT SELECTION**					
201	SET-POINT	1		1		Select the set-point which needs to be evaluated
202	FSWITCHING			70314.3	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
203	VOR			145.0	V	Voltage reflected to the primary winding when the primary switch turns off
204	VMIN			130.88	V	Valley of the minimum input AC voltage
205	KP			1.092		Measure of continuous/discontinuous mode of operation
206	MODE_OPERATION			DCM		Mode of operation
207	DUTYCYCLE			0.504		Primary switch duty cycle
208	TIME_ON			7.17	us	Primary switch on-time
209	TIME_OFF			7.05	us	Primary switch off-time
205	**PRIMARY CURRENT**					
212	IAVG_PRIMARY			0.515	A	Primary switch average current
213	IPEAK_PRIMARY			2.045	A	Primary switch peak current
214	IPEDESTAL_PRIMARY			0.000	A	Primary switch current pedestal
215	IRIPPLE_PRIMARY			2.045	A	Primary switch ripple current
216	IRMS_PRIMARY			0.838	A	Primary switch RMS current
212	**SECONDARY CURRENT**					
219	IPEAK_SECONDARY			14.313	A	Secondary winding peak current
220	IPEDESTAL_SECONDARY			0.000	A	Secondary winding pedestal current
221	IRMS_SECONDARY			5.568	A	Secondary winding RMS current
222	IRIPPLE_CAP_OUT			4.690	A	Output capacitor ripple current
218	**MAGNETIC FLUX DENSITY**					
225	BPEAK			3002	Gauss	Peak flux density
226	BMAX			2816	Gauss	Maximum flux density
227	BAC			1408	Gauss	AC flux density (0.5 x Peak to Peak)

Notes:

1. (Overvoltage Line) Warning: We find that there is sufficient margin above the data sheet specified breakdown voltage at normal operating voltage of 265 VAC. This warning is for abnormal operating conditions and can be ignored.

2. The Off time warning indicates that the power adapter will be power limited for the worst-case tolerance conditions at 85VAC and valley of the DC bus ripple. Acceptance is based on power adapter meeting required ripple performance.

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

10 Adapter Case Dimensions

10.1 *Case Bottom Dimensions*

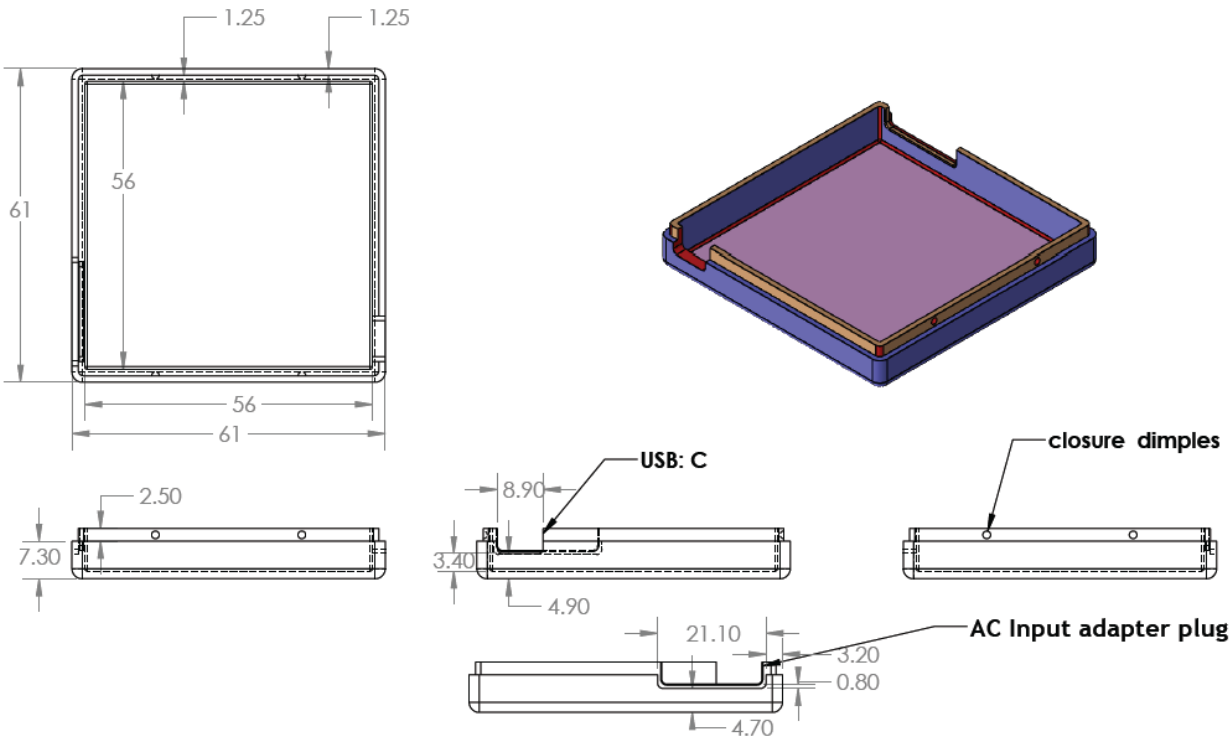


Figure 13 – DER-802 Adapter Case Bottom.

10.2 *Case Top Dimensions*

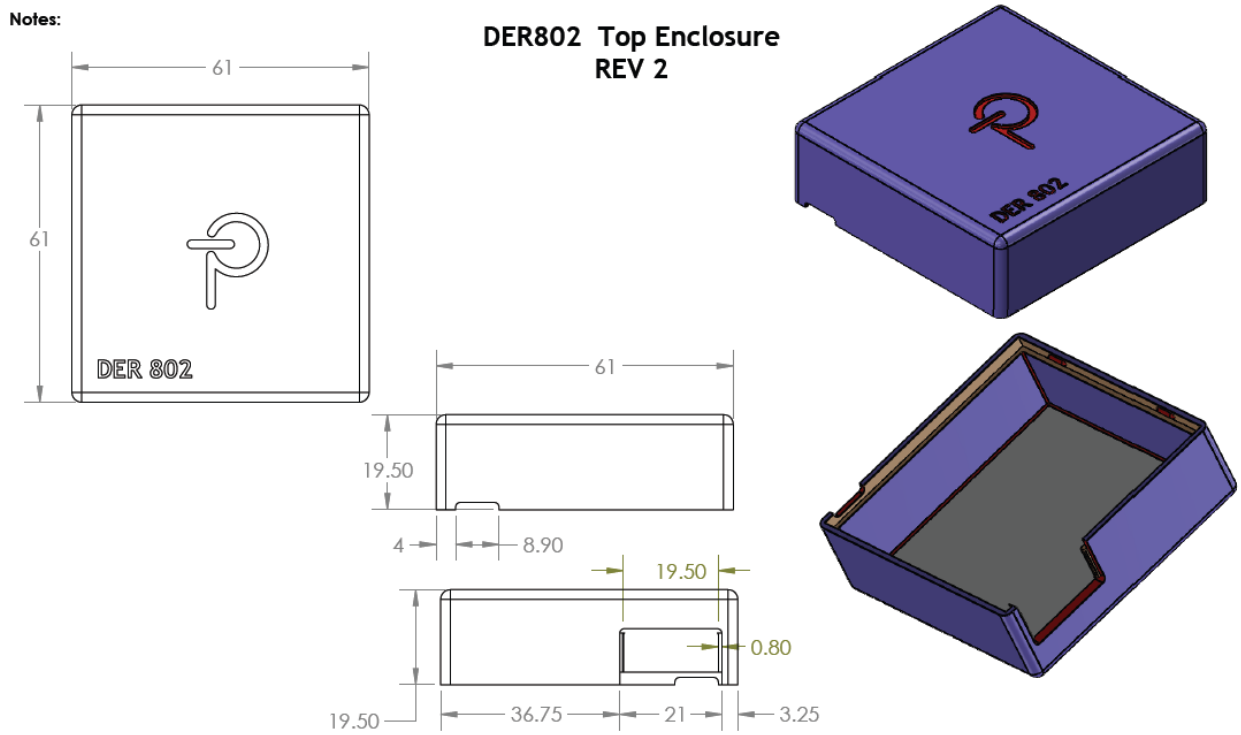


Figure 14 – DER-802 Adapter Case Top.

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

10.3 *Adapter Assembly Drawing*

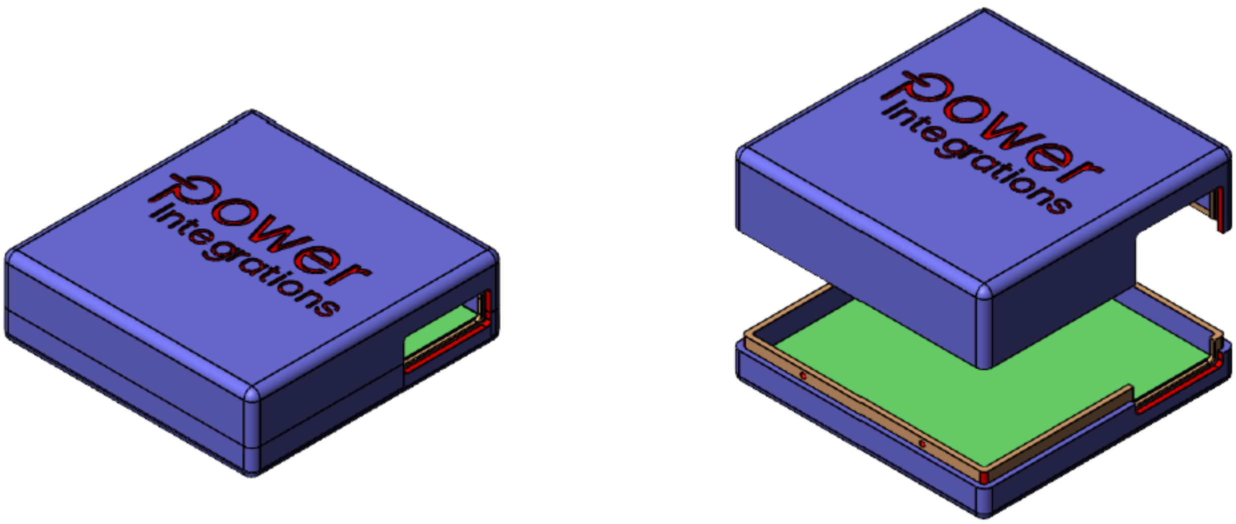


Figure 15 – DER-802 Adapter Assembly Drawing.

11 Heat Spreader Drawings

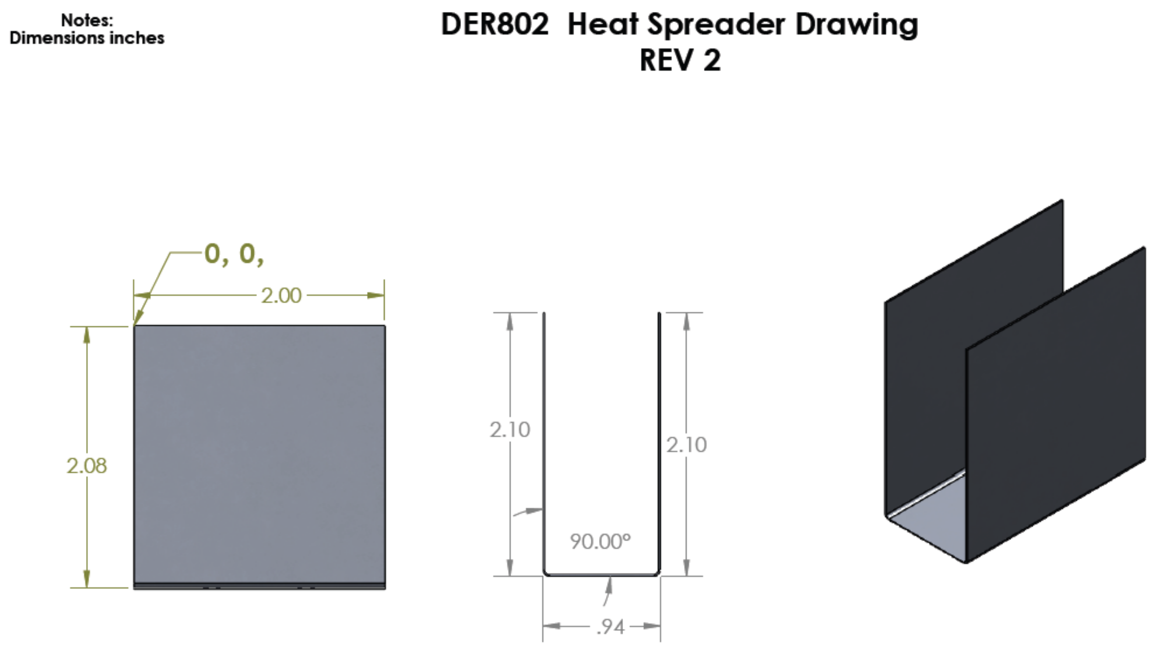


Figure 16 – Heat Spreader Drawing.

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

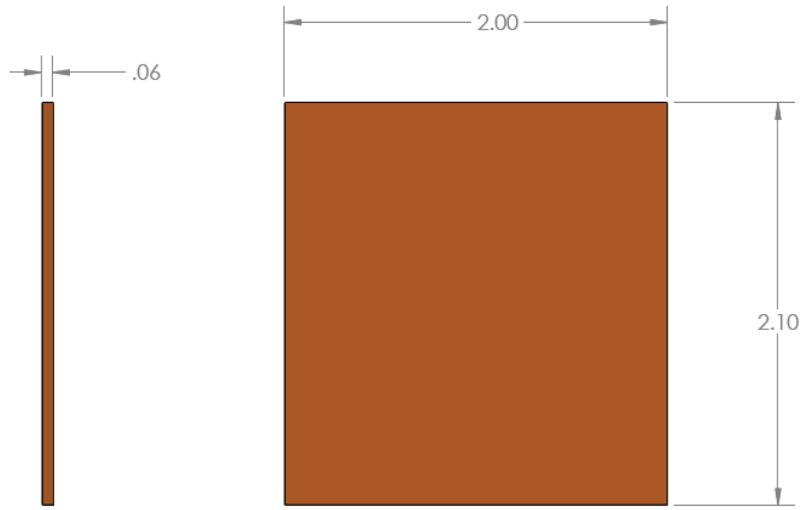


Figure 17 – 3M Silicone Thermal Pad.

DER802 Mylar Insulator Template

Controlling dimensions are: Inches.

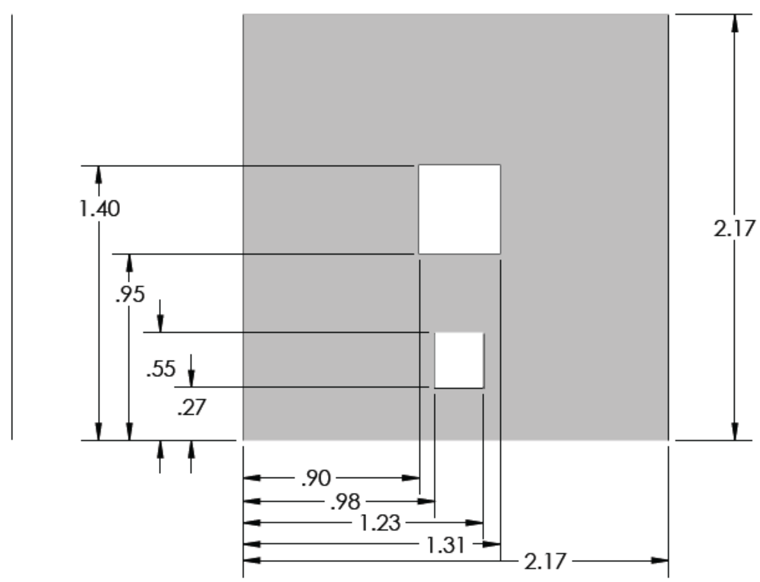


Figure 18 – Mylar Insulator Drawings.

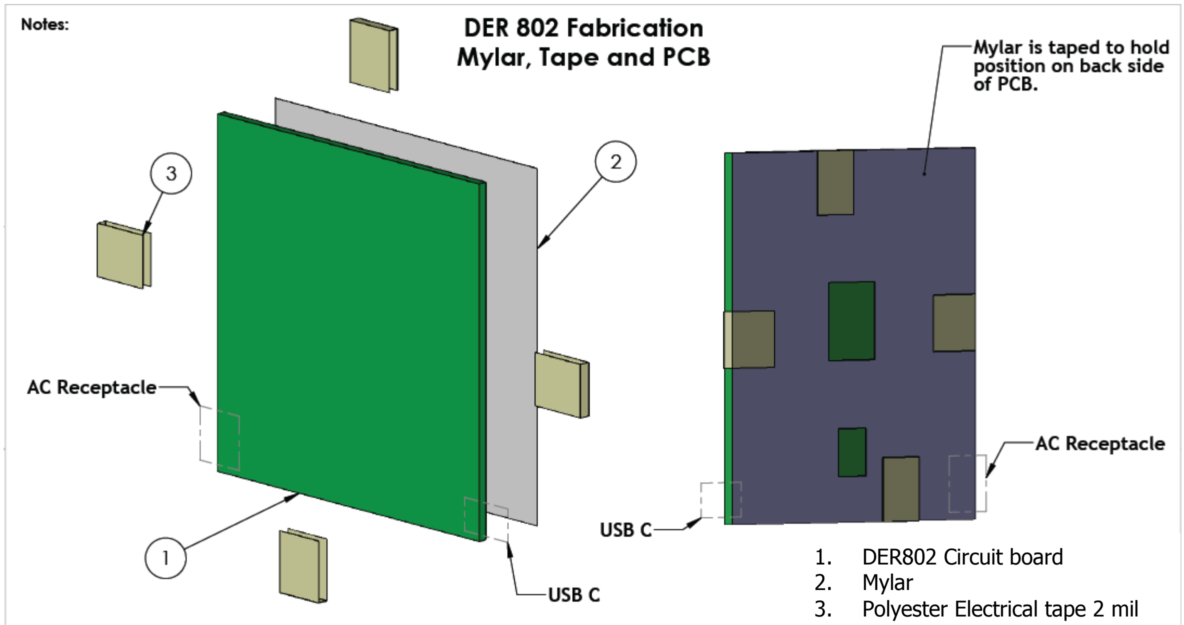


Figure 19 – Mylar and PCB Assembly.

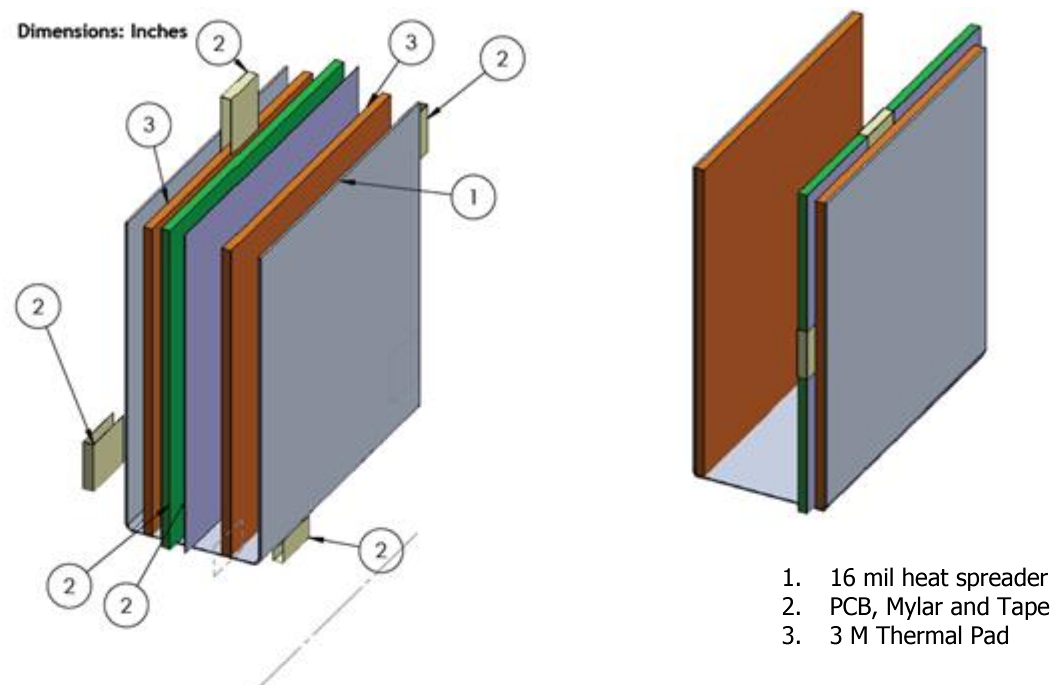


Figure 20 – Heat Spreader, Thermal Pad and Mylar Assembly Drawings. Detailed Assembly Images in Next Section.

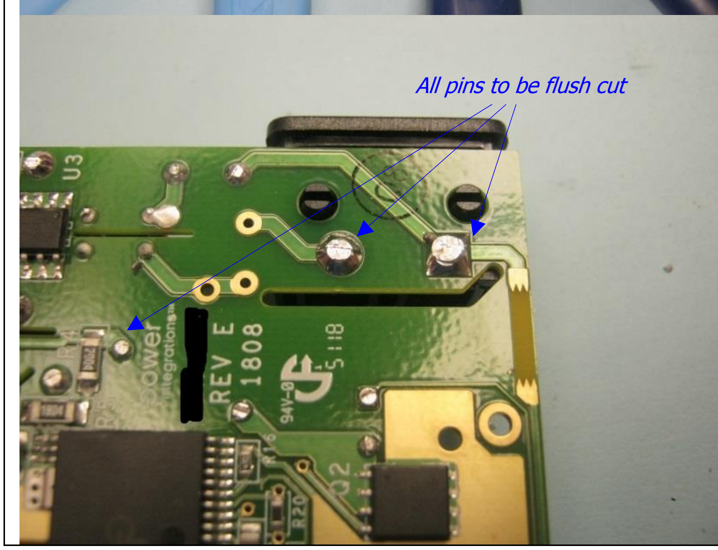
Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

12 Heat Spreader and Adapter Case Assembly

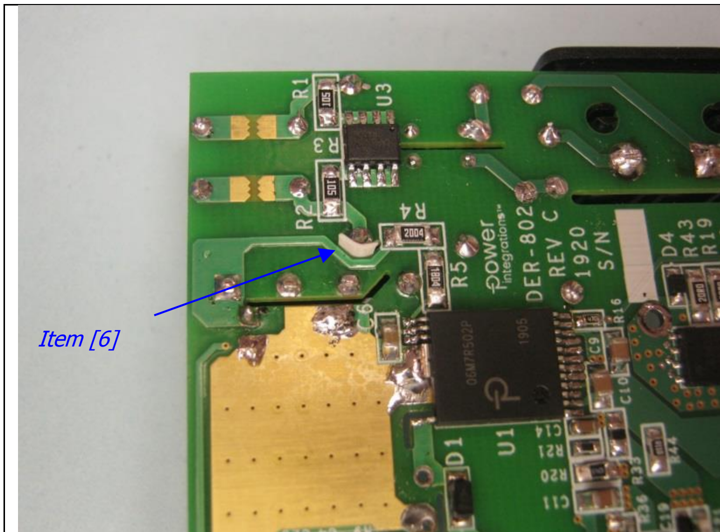
12.1 *Material List*

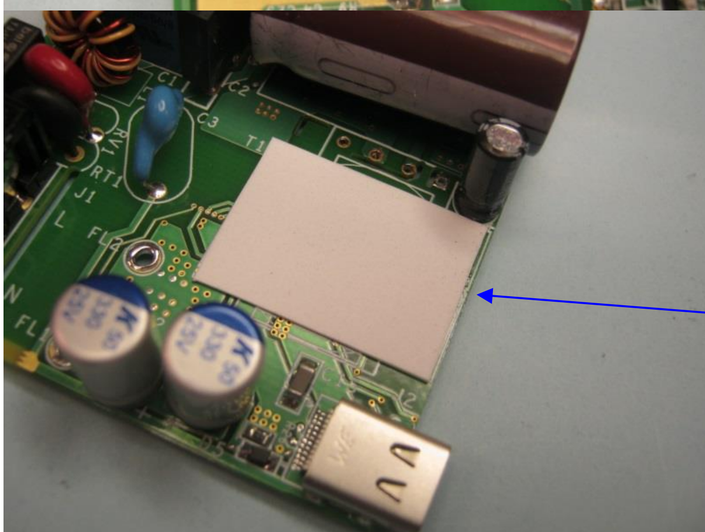
Item	Description
[1]	Heat spreader; Aluminum, 16 mil thick, PI#: 61-00248-00.
[2]	Clear, Mylar Teijin, 3 mil tick, PI#: 66-00230-00
[3]	Thermal pad, 3M, Pad5549S, PI#: 66-00231-00.
[4]	Use Item [2] to make with dimension shown in PI#: 76-00049-00.
[5]	Use Item [3] to make with dimension shown in PI#: 61-00231-00.
[6]	Tape: 3M 1298 Polyester Film, 1 mil thick, 7.0mm wide.
[7]	Tape: 3M 1298 Polyester Film, 1 mil thick, 21.0mm wide, 27 mm long.
[8]	Tape: 3M 1298 Polyester Film, 1 mil thick, 14.0mm wide

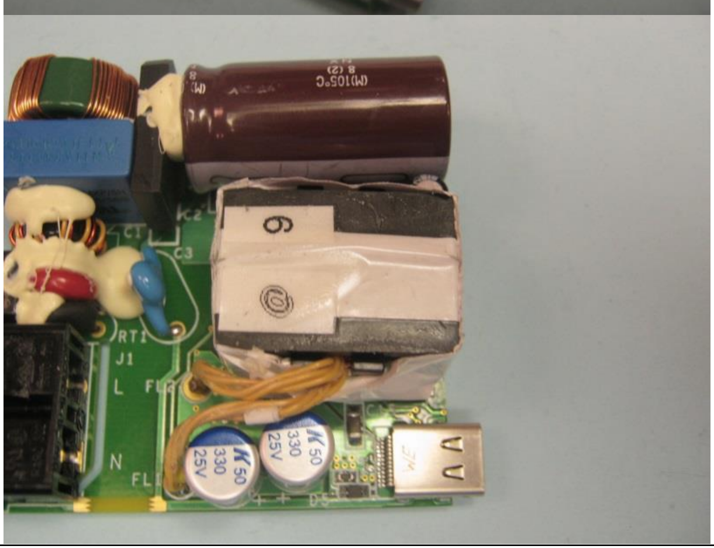
Assembly Illustrations



Use proper flush cutters such as shown in this picture to have all pin of PCB to be flush cut in order to avoid any pins poking into the thermal pads. *(see illustration beside for reference).*



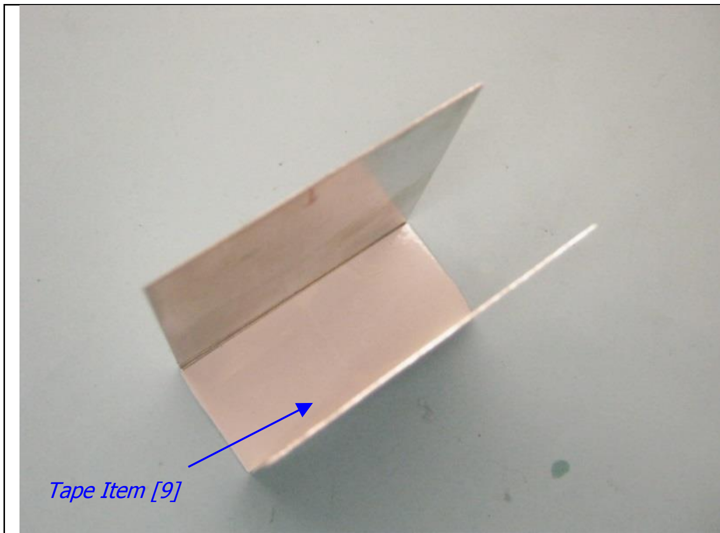
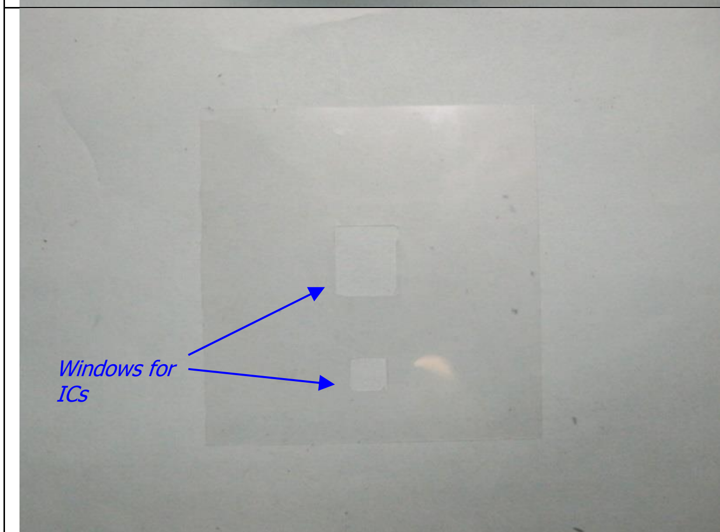
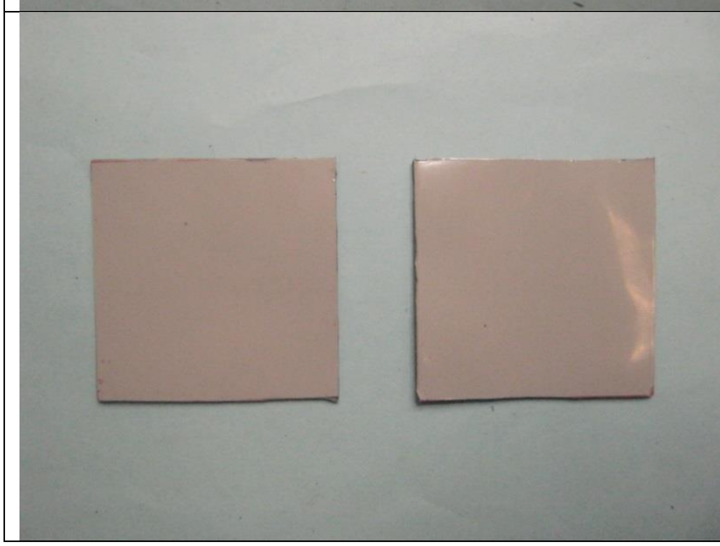


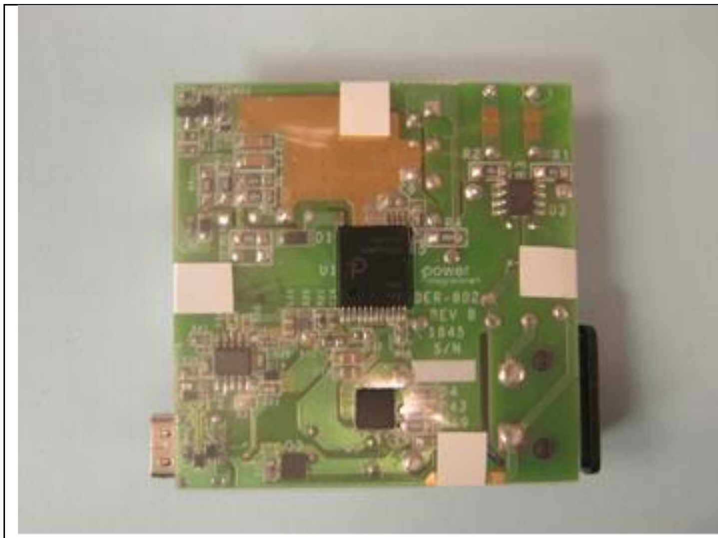
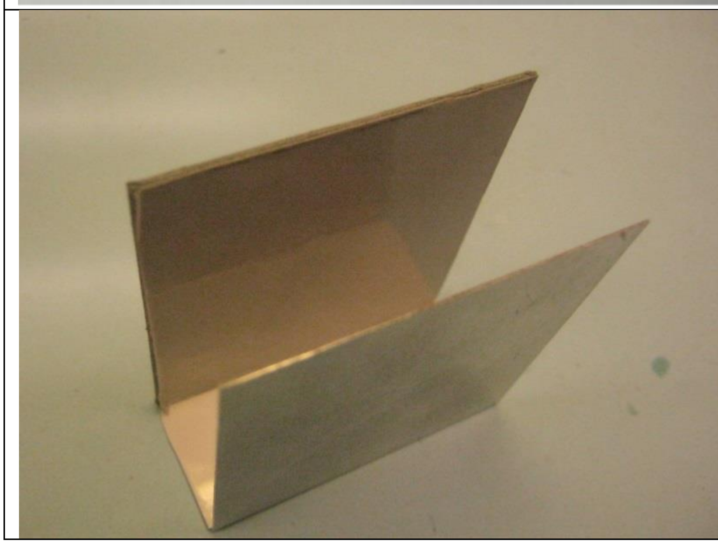


Insert item [6] into this slot to create better isolation between pin and trace as shown in the left side image.

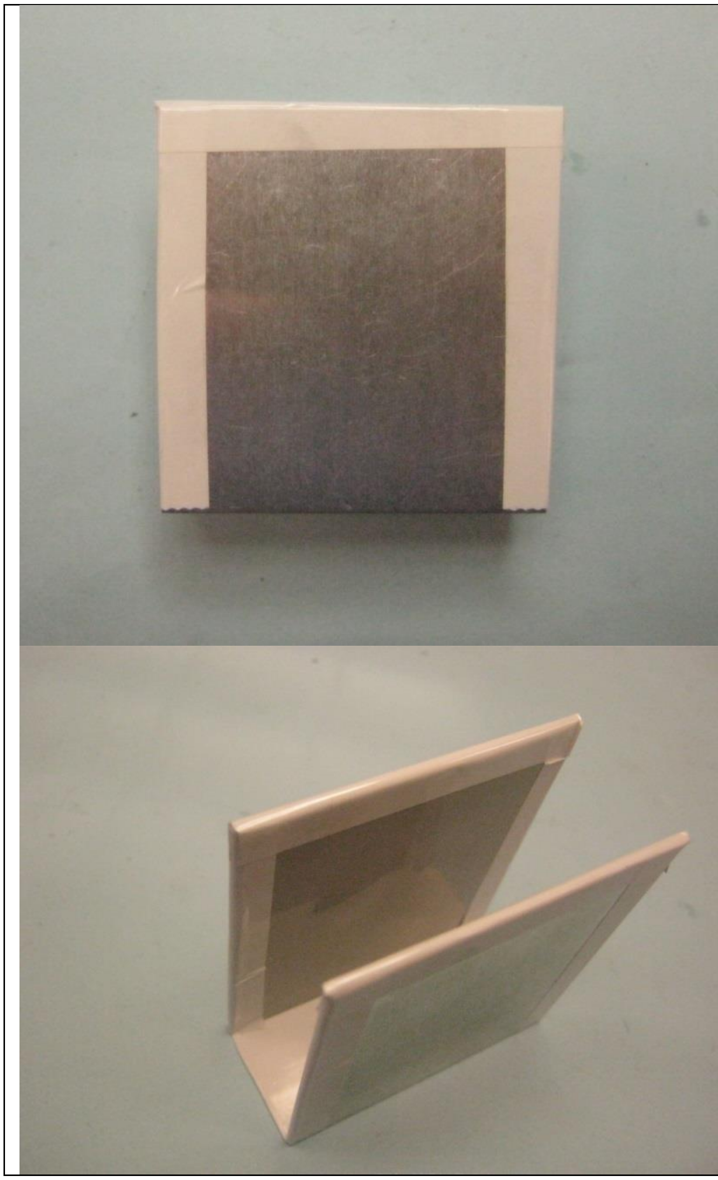
Place item [7] with glue on the PCB where the transformer will be sitting on.

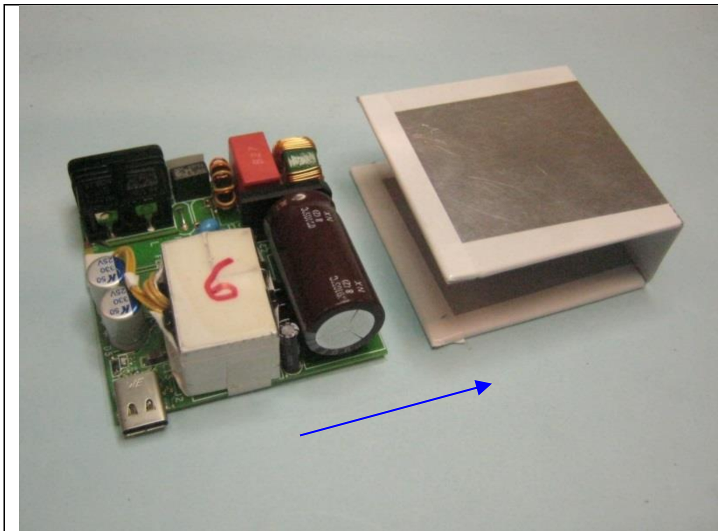
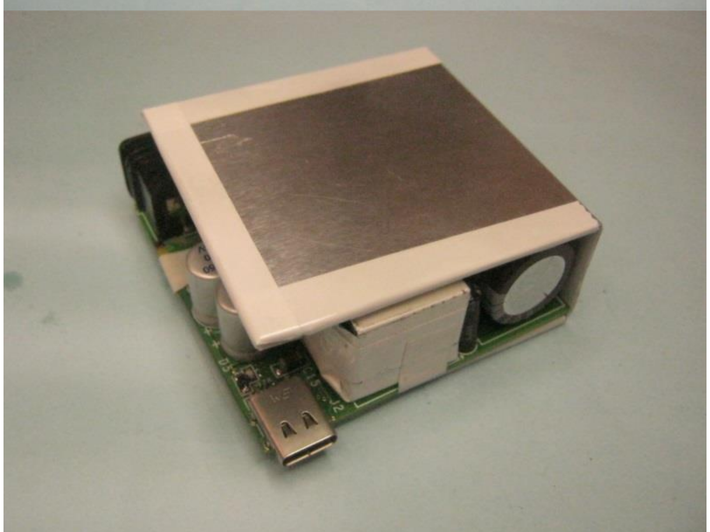
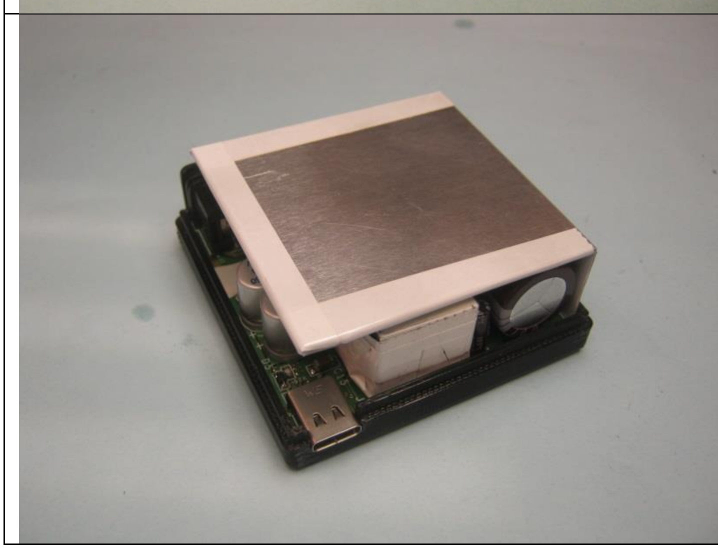
Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

	Place 1 layer of tape Item [9] at inner edge of heat spreader Item [1].
	Prepare Item [4].
	Prepare 2 pieces of Item [5].

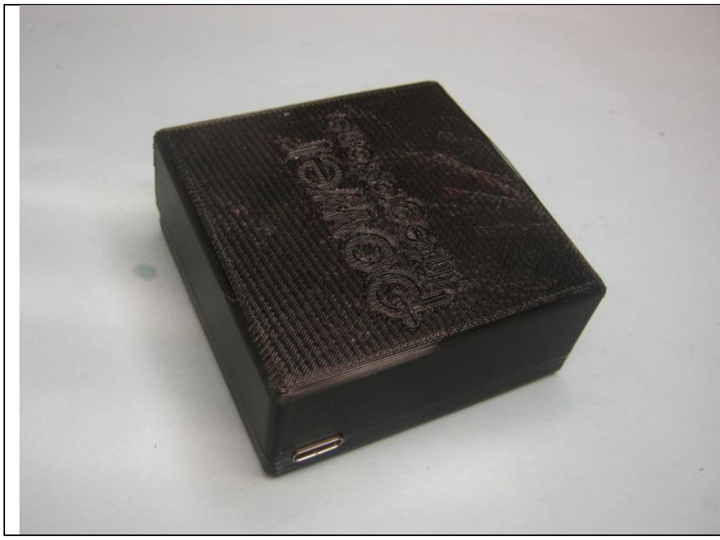
	Place Item [2] onto PCB, align its windows with ICs of PCB, and tape 4 sides to PCB with tape Item [8].
	Use 1 piece Item [5], peel the clear plastic cover to show the sticky side and attach this side to one side heat spreader Item [1]. Wrap around 3 edges with tape Item [8]. Repeat for other side of heat spreader with other piece Item [5].

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



 	Insert board into heat spreader assembly.
	Place whole set onto bottom half of the case and snap top half in place.

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



13 Performance Data

Notes

1: Voltages measured on the PCB end

2: Measurements taken at room temperature (approximately 24 °C)

3: Some power supply designs are made with enclosures and/or heat spreaders to achieve the desired form factor. In such situations, these designs are tested with enclosure and any additional heat spreaders as indicated in the report. Although the DER boards are shipped without any enclosures and /or heat spreaders, the report should be reviewed carefully regarding test conditions used for assessment of performance. Unless otherwise specified, the DER boards can be evaluated without enclosures or heat spreaders though some performance results such as EMI, temperature rise of components and efficiency may vary.

13.1 *No-Load Input Power at 5 V_{OUT}*

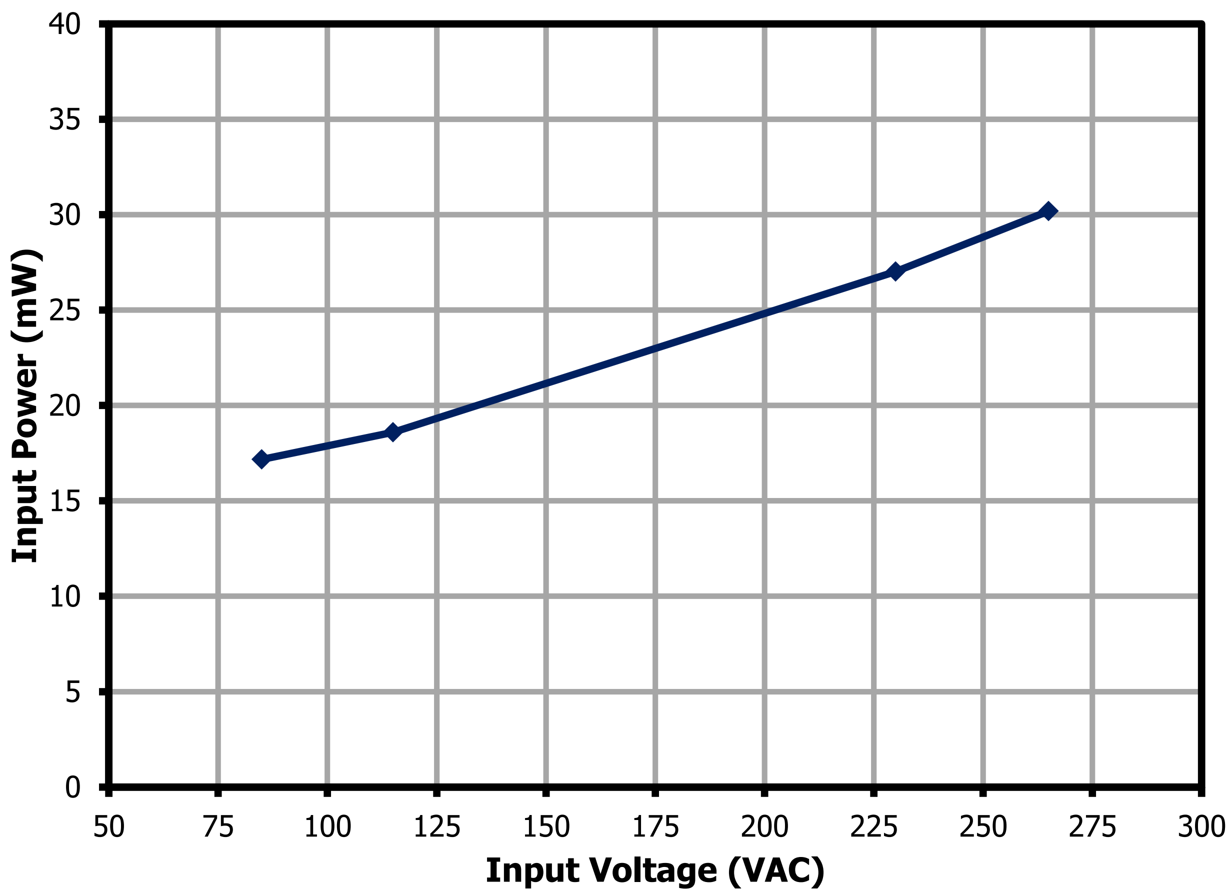


Figure 21 – No-Load Input Power vs. Input Line Voltage, Room Temperature.

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

13.2 ***Average and 10% Load Efficiency***

13.2.1 Efficiency Requirements

		Test Effective	Average 2016	Average Jan-16	10% Load Jan-16
V_{OUT} (V)	**Model**	**Power (W)**	**New EISA2007**	**CoC v5 Tier 2**	**CoC v5 Tier 2**
5	<6 V	15	81.4%	81.8%	72.5%
9	>6 V	27	86.6 %	87.3%	77.3%
15	>6 V	45	88.0%	88.9%	78.9%
20	>6 V	60	88.0%	89.0%	79.0%

13.2.2 Efficiency Performance Summary (End of Cable with CDC Enabled)

V_{OUT} (V)	Current (A)	Average Efficiency (%)		10% Load Efficiency (%)	
		115 VAC	**230 VAC**	**115 VAC**	**230 VAC**
5	3	90.06	89.22	86.03	86.58
9	3	91.40	91.20	91.94	88.10
15	3	91.59	92.06	88.80	87.48
20	3	91.69	92.34	88.70	87.98

13.2.3 Average and 10% Load Efficiency at 115 VAC (End of 60 mΩ Cable)

13.2.3.1 Output: 5 V / 3 A

Load (%)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	5.28	2.99	89.06	**90.06**
75	5.23	2.25	90.05	
50	5.18	1.5	90.91	
25	5.11	0.75	90.21	
10	5.07	0.3	**86.03**	

13.2.3.2 Output: 9 V / 3 A

Load (%)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	9.24	3.0	90.43	**91.40**
75	9.19	2.25	91.14	
50	9.14	1.5	91.80	
25	9.08	0.75	92.24	
10	9.04	0.3	**91.94**	

13.2.3.3 Output: 15 V / 3 A

Load (%)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	15.36	3.0	90.92	**91.59**
75	15.32	2.25	91.47	
50	15.28	1.5	91.90	
25	15.23	0.75	92.05	
10	15.19	0.3	**88.80**	

13.2.3.4 Output: 20 V / 3 A

Load (%)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	20.35	3.0	91.13	**91.69**
75	20.31	2.25	91.70	
50	20.28	1.5	92.06	
25	20.23	0.75	91.88	
10	20.19	0.3	**88.70**	

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

13.2.4 Average and 10% Load Efficiency at 230 VAC (End of 60 mΩ Cable)

13.2.4.1 Output: 5 V / 3 A

Load (%)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	5.3	2.99	89.16	**89.22**
75	5.24	2.25	89.55	
50	5.19	1.5	89.59	
25	5.12	0.75	88.58	
10	5.07	0.3	**86.58**	

13.2.4.2 Output: 9 V / 3 A

Load (%)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	9.26	3.0	91.23	**91.20**
75	9.20	2.25	91.46	
50	9.15	1.5	91.64	
25	9.08	0.75	90.48	
10	9.04	0.3	**88.10**	

13.2.4.3 Output: 15 V / 3 A

Load (%)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	15.39	3.0	92.20	**92.06**
75	15.35	2.25	92.42	
50	15.29	1.5	92.46	
25	15.23	0.75	91.18	
10	15.19	0.3	**87.48**	

13.2.4.4 Output: 20 V / 3 A

Load (%)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)	Average Efficiency (%) [100% - 25% Load]
100	20.38	3.0	92.53	**92.34**
75	20.34	2.25	92.73	
50	20.29	1.5	92.63	
25	20.24	0.75	91.48	
10	20.19	0.3	**87.98**	

13.3 *Efficiency Across Line (End of cable)*

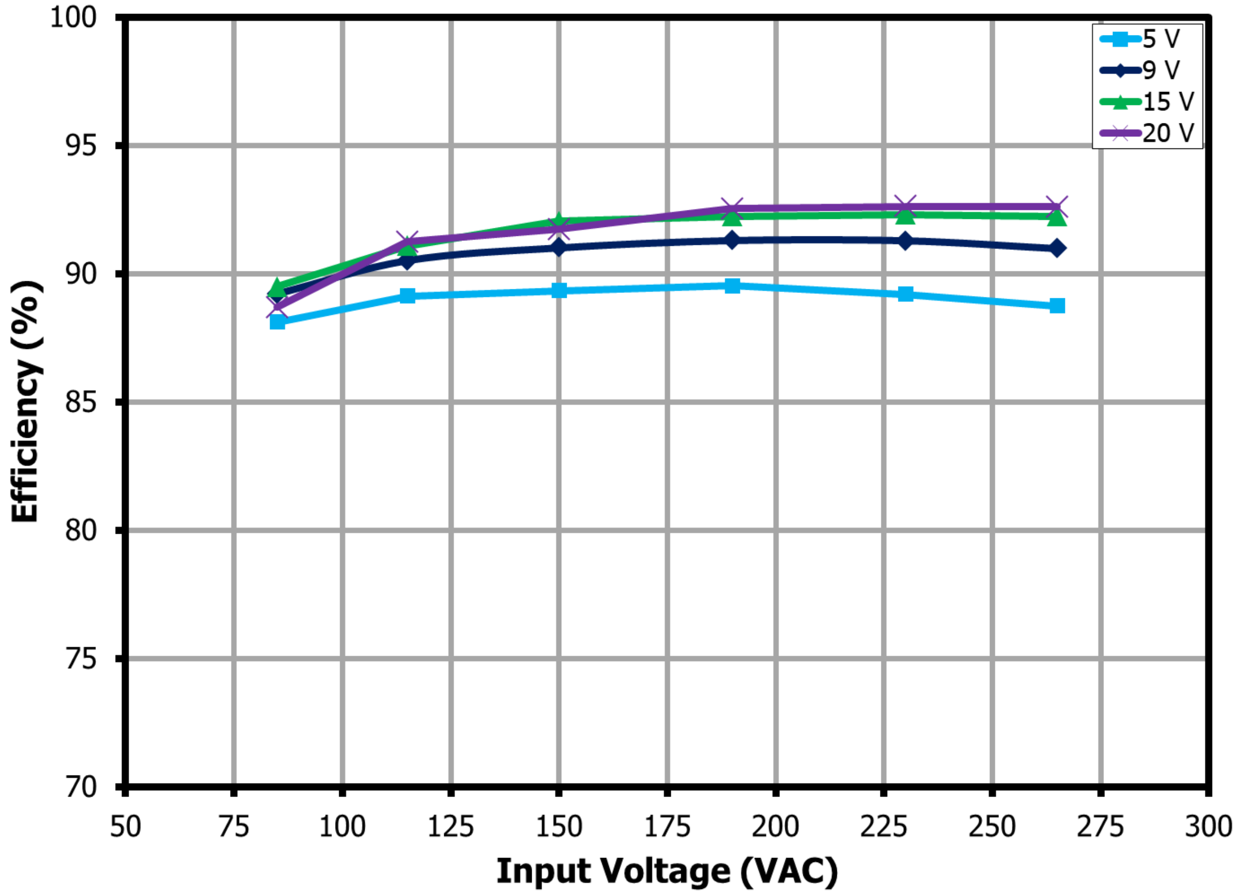


Figure 21 – Full Load Efficiency vs. Input Line for 5 V, 9 V, 15 V, and 20 V Output, Room Temperature.

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

13.4 ***Line Regulation (End of Cable)***

13.4.1 Output: 5 V / 3 A

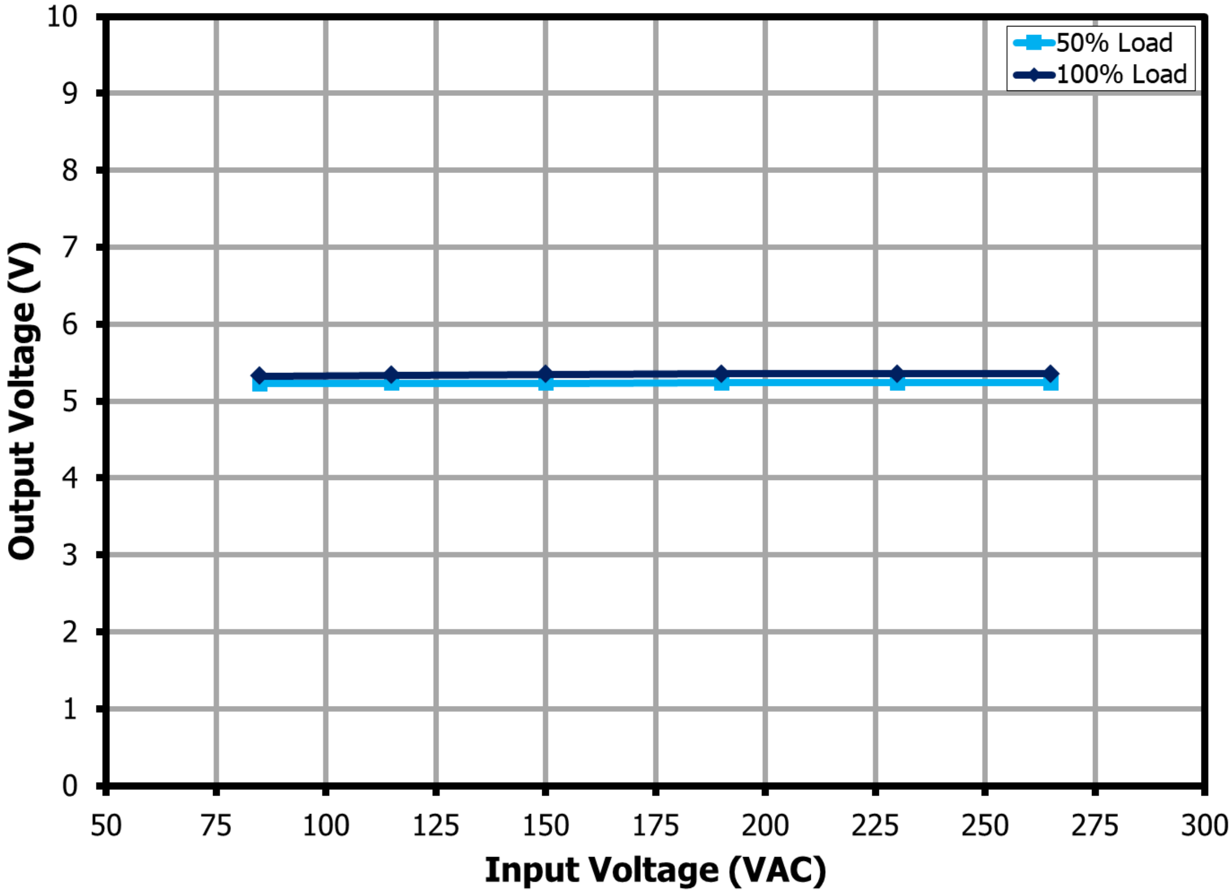


Figure 22 – Output Voltage vs. Input Line Voltage for 5 V Output, Room Temperature.

13.4.2 Output: 9 V / 3 A

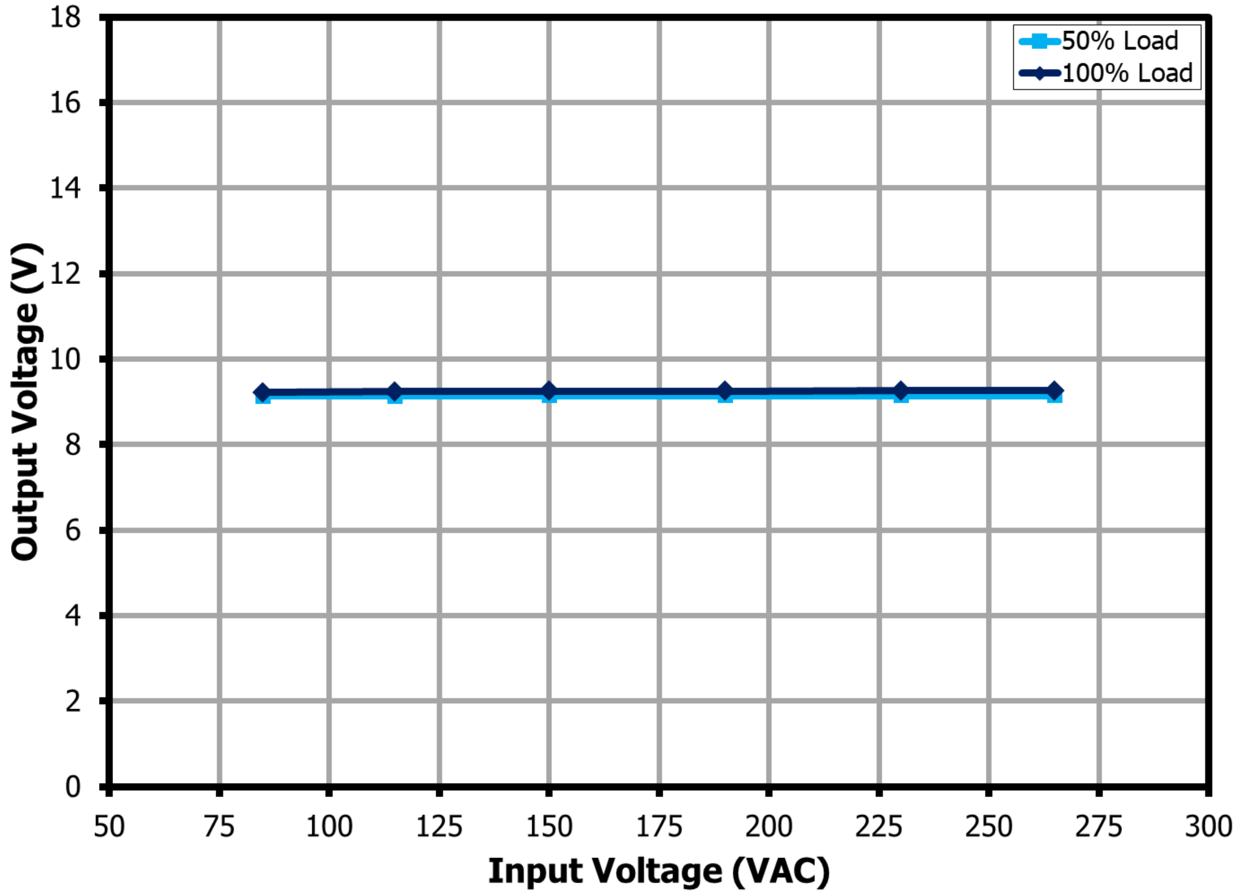


Figure 23 – Output Voltage vs. Input Line Voltage for 9 V Output, Room Temperature.

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

13.4.3 Output: 15 V / 3 A

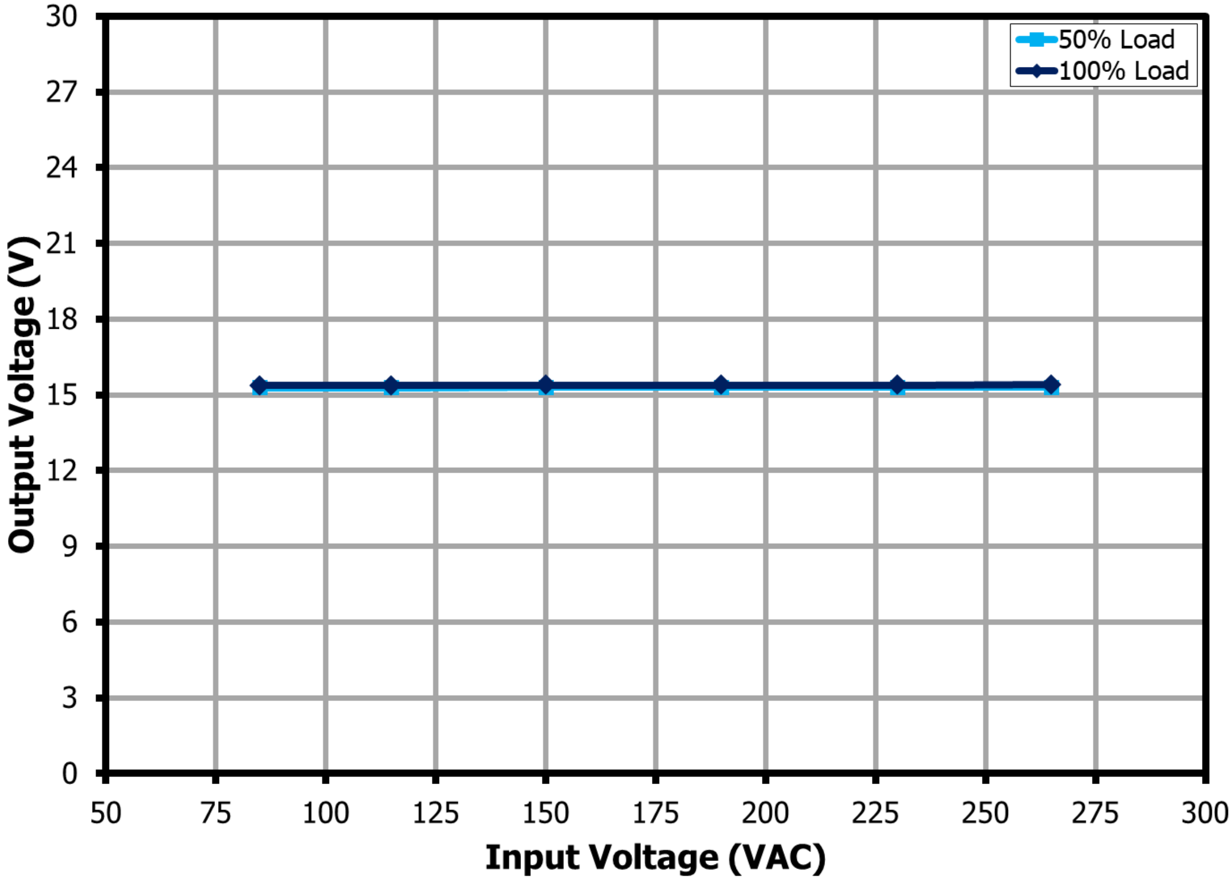


Figure 24 – Output Voltage vs. Input Line Voltage for 15 V Output, Room Temperature.

13.4.4 Output: 20 V / 3 A

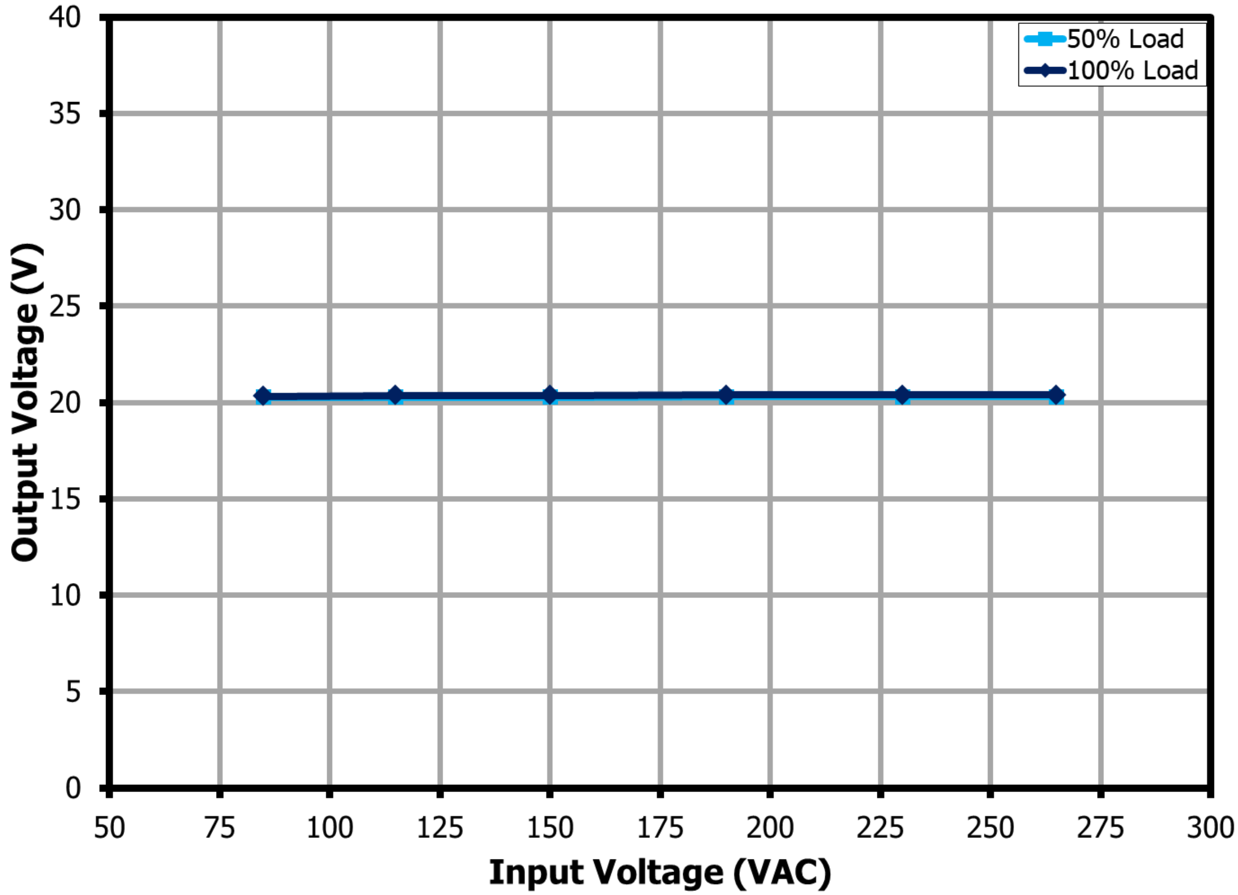


Figure 25 – Output Voltage vs. Input Line Voltage for 20 V Output, Room Temperature.

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

13.5 ***Load Regulation (End of Cable)***

13.5.1 Output: 5 V / 3 A

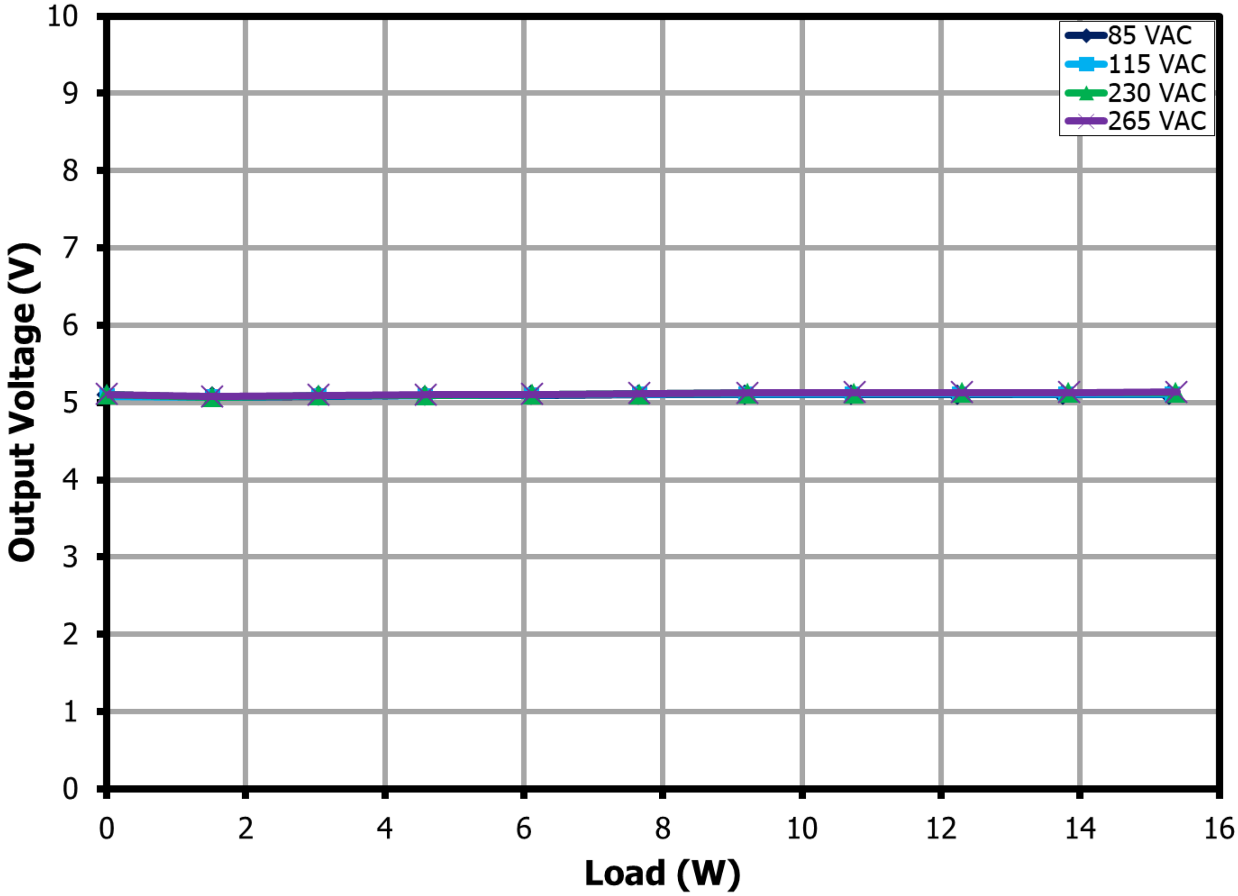


Figure 26 – Output Voltage vs. Output Load for 5 V Output, Room Temperature.

13.5.2 Output: 9 V / 3 A

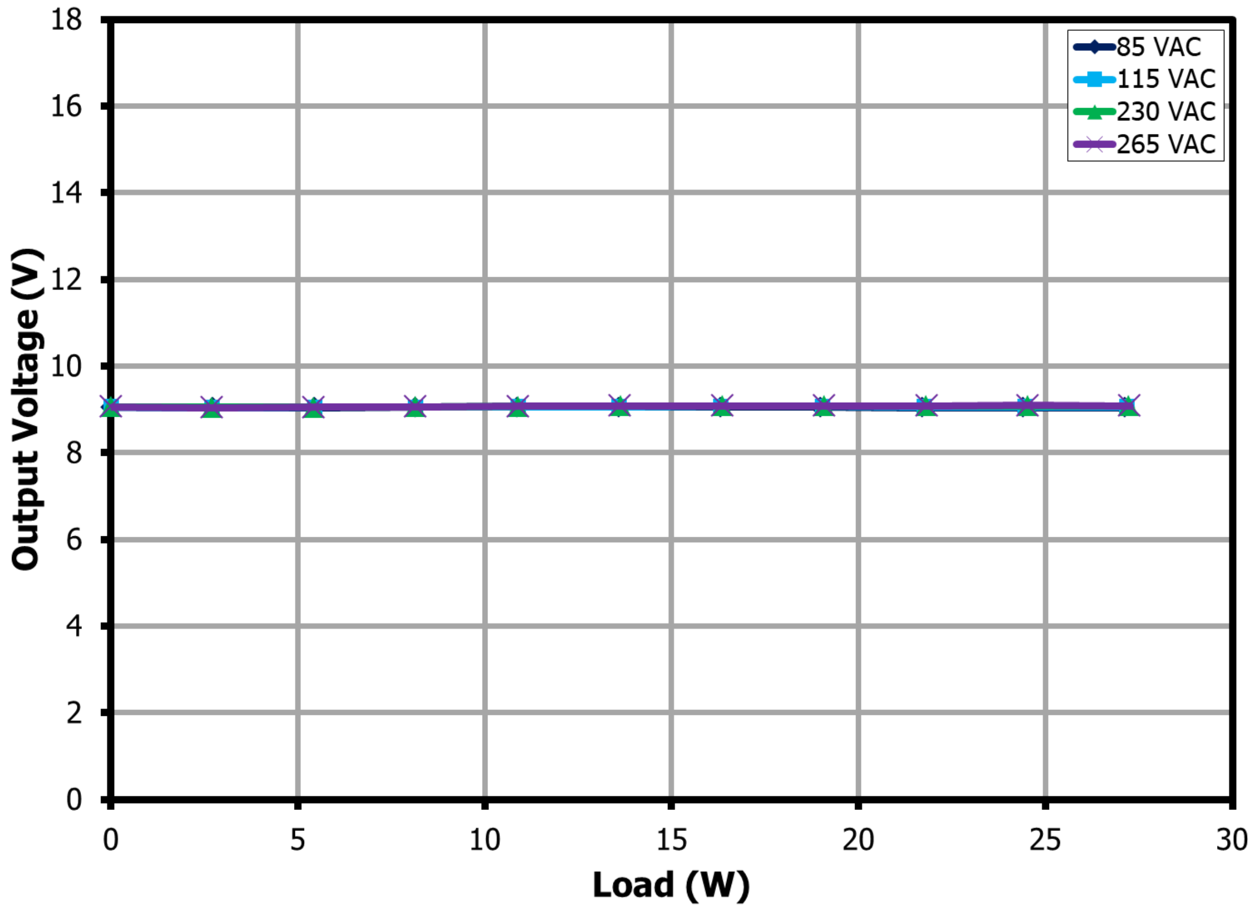


Figure 27 – Output Voltage vs. Output Load for 9 V Output, Room Temperature.

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

13.5.3 Output: 15 V / 3 A

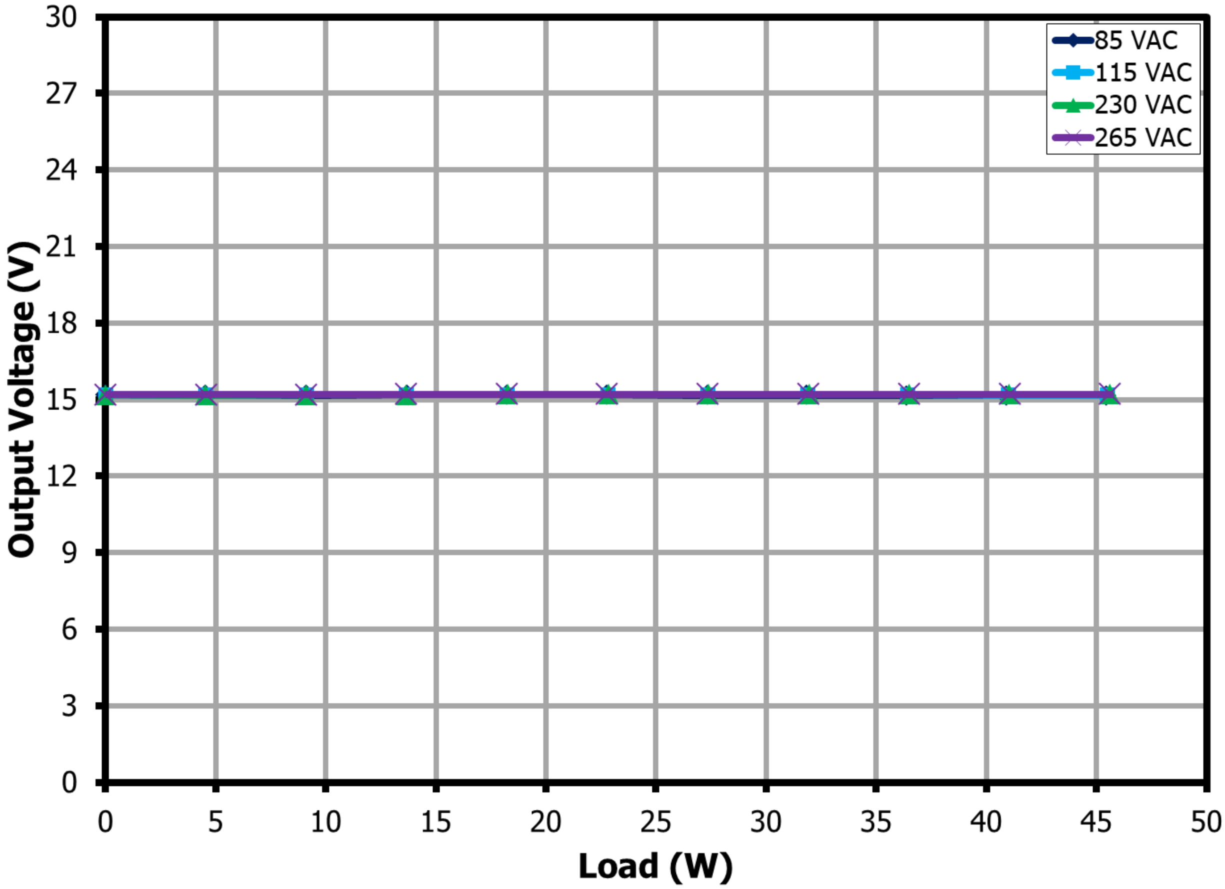


Figure 28 – Output Voltage vs. Output Load for 15 V Output, Room Temperature.

13.5.4 Output: 20 V / 3 A

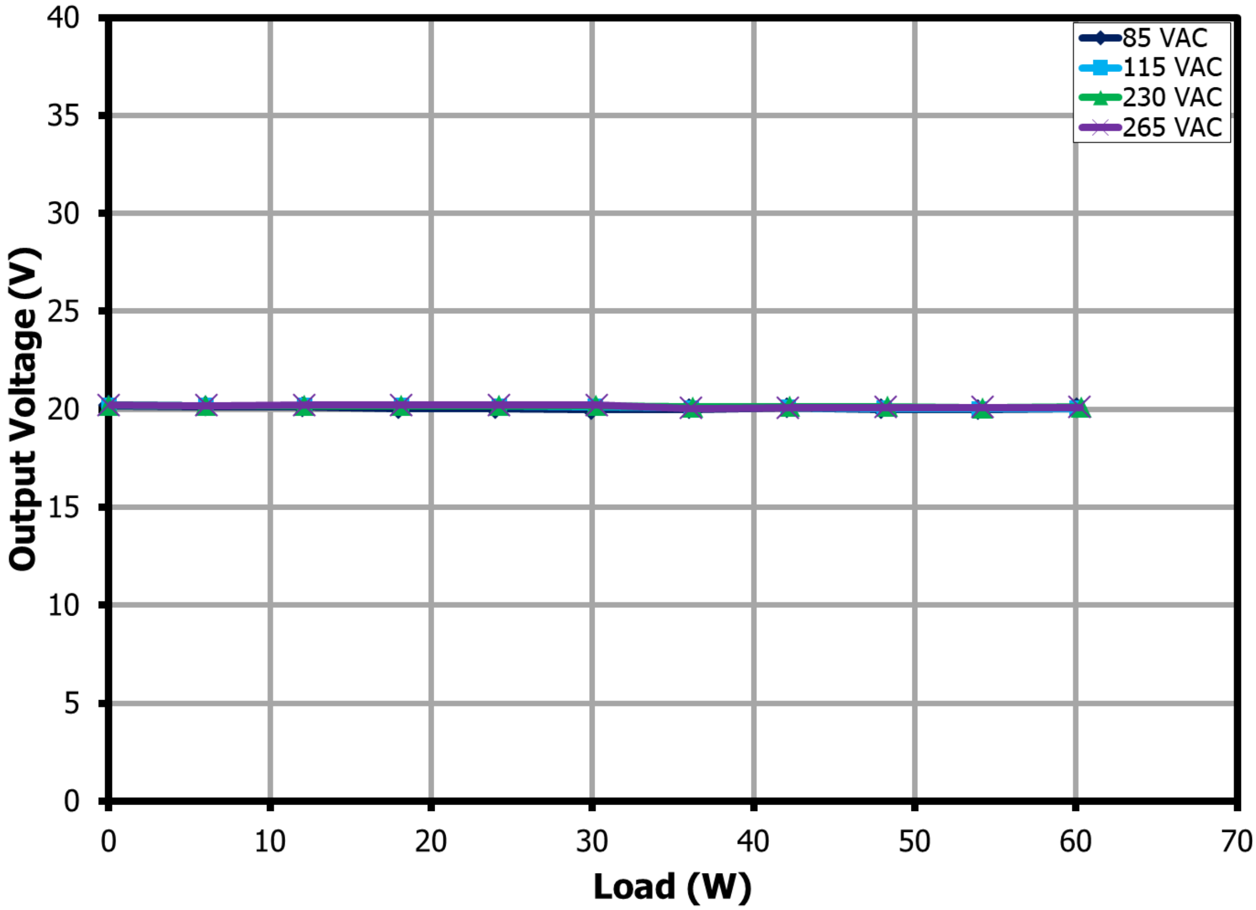


Figure 30 – Output Voltage vs. Output Load for 20 V Output, Room Temperature.

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

14 Thermal Performance in Open Case

Note 1: For plastic enclosed adapters, this design requires use of a metallic heat spreader and suitable thermally conductive insulator pads to ensure sufficiently low temperature of the InnoSwitch-3 Pro IC and Transformer. The performance data below is for open case operation and does not use the heat spreader for cooling.

14.1 *Output: 5 V / 3 A (85 VAC)*

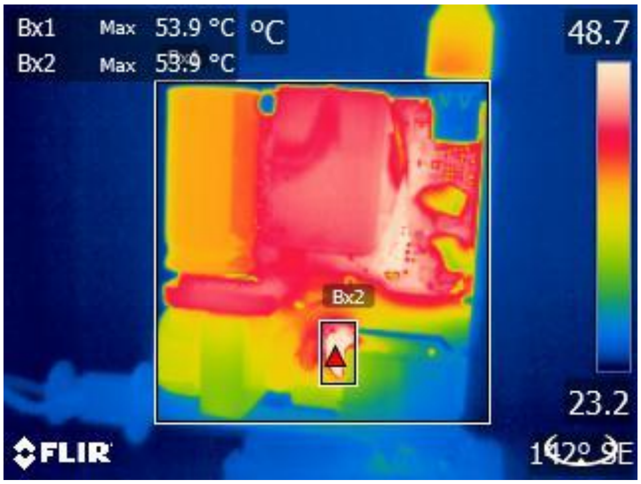


Figure 29 – Top Side Thermal Image.
Ambient: 23.8 ºC.
Bx2: Thermistor RT1 = 53.9 ºC**.**

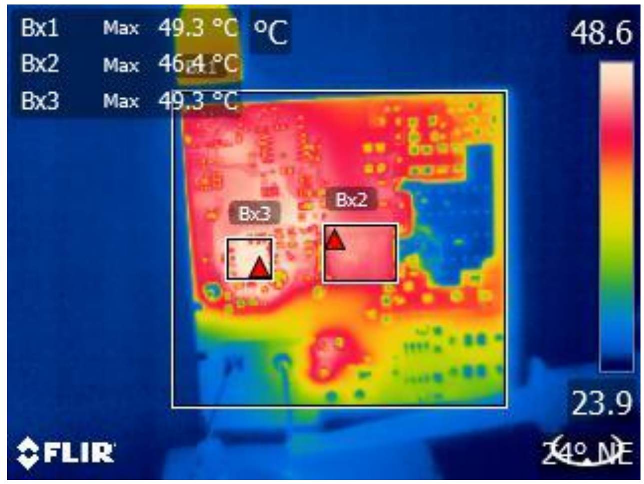


Figure 30 – Bottom Side Thermal Image.
Ambient: 23.8 ºC.
Bx2: InnoSwitch3-Pro = 46.4 ºC.
Bx3: SR FET = 49.3 ºC.

14.2 *Output: 5 V / 3 A (265 VAC)*

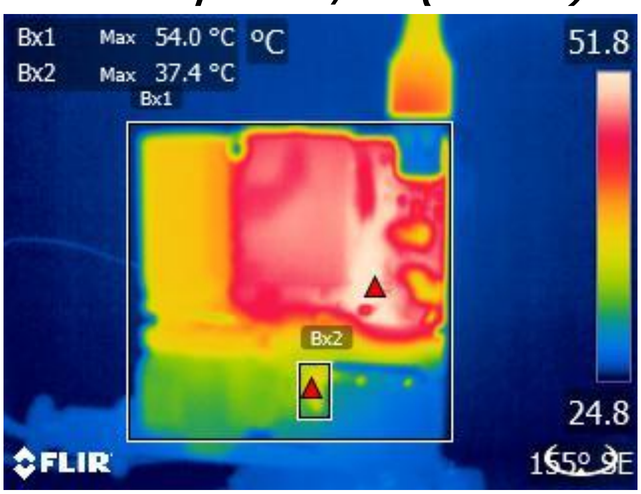


Figure 31 – Top Side Thermal Image.
Ambient: 25.3 ºC.
Bx1: Transformer Winding = 54 ºC.
Bx2: Thermistor RT1 = 37.4 ºC.

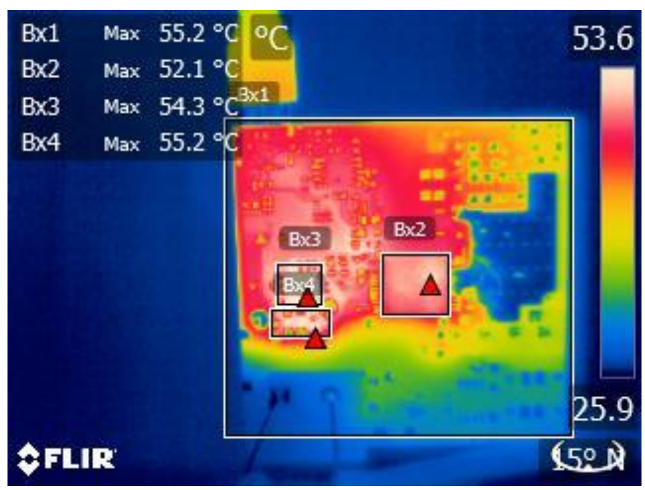


Figure 32 – Bottom Side Thermal Image.
Ambient: 25.3 ºC.
Bx2: InnoSwitch3-Pro = 52.1 ºC.
Bx3: SR FET = 54.3 ºC.
Bx4: SR FET RC snubber = 55.2 ºC.

14.3 *Output: 9V / 3 A (85 VAC)*

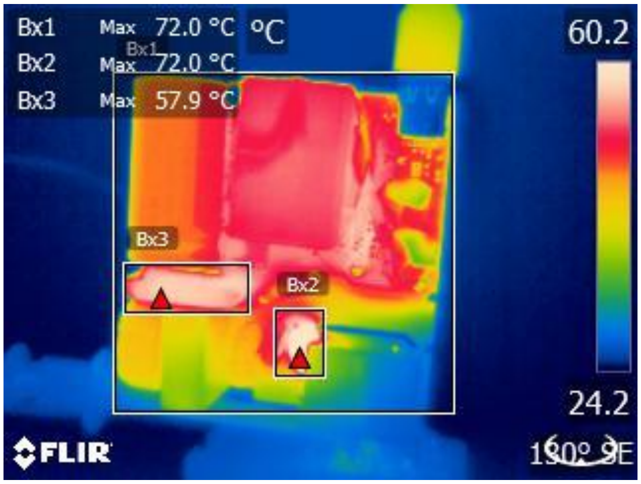


Figure 33 – Top Side Thermal Image.
Ambient: 24.5 ºC.
Bx2: Thermistor RT1 = 72 ºC.
Bx3: Bridge Rectifier BR1 = 57.9 ºC

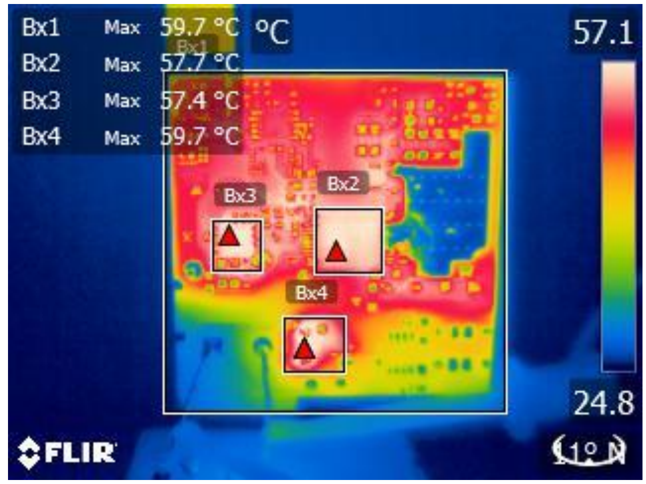


Figure 34 – Bottom Side Thermal Image.
Ambient: 24.5 ºC.
Bx2: InnoSwitch3-Pro = 57.7 ºC.
Bx3: SR FET = 57.4 ºC.
Bx4: SR FET = 59.7 ºC.

14.4 *Output: 9 V / 3 A (265 VAC)*

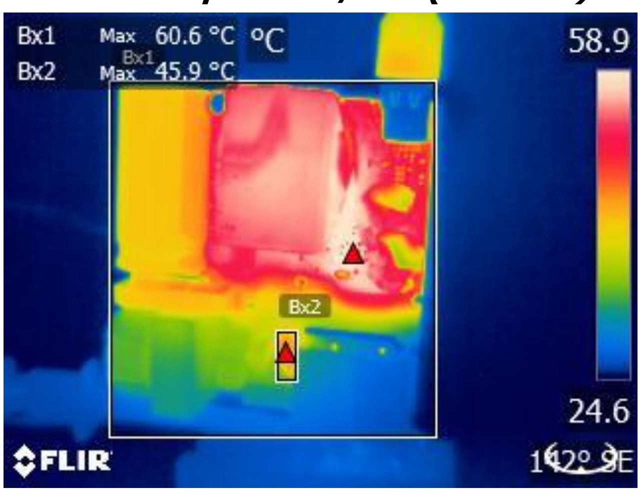


Figure 35 – Top Side Thermal Image.
Ambient: 24.8 ºC.
Bx1: Transformer Winding = 60.6 ºC.
Bx2: Thermistor RT1 = 45.9 ºC.

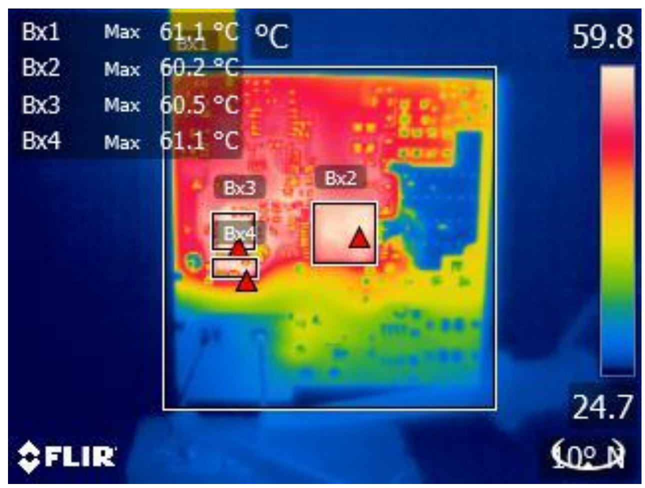


Figure 36 – Bottom Side Thermal Image.
Ambient: 24.8 ºC.
Bx2: InnoSwitch3-Pro = 60.2 ºC.
Bx3: SR FET = 60.5 ºC.
Bx4: SR FET = 61.1 ºC.

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

14.5 *Output: 15 V / 3 A (85 VAC)*

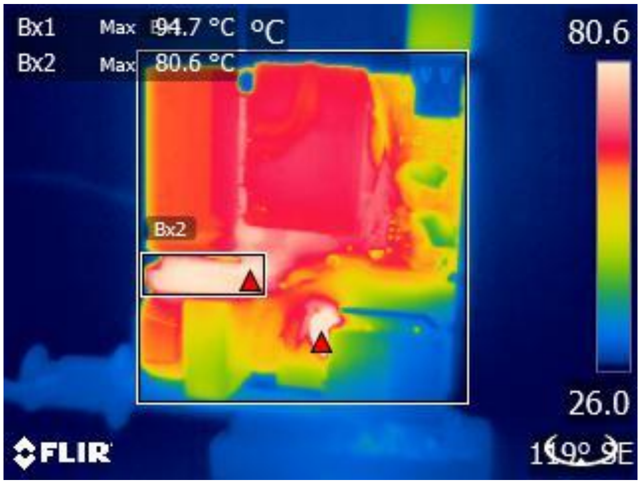


Figure 37 – Top Side Thermal Image.
Ambient: 25.6 ºC.
Bx1: Thermistor RT1 = 94.7 ºC.
Bx2: Bridge Rectifier BR1 = 80.6 ºC

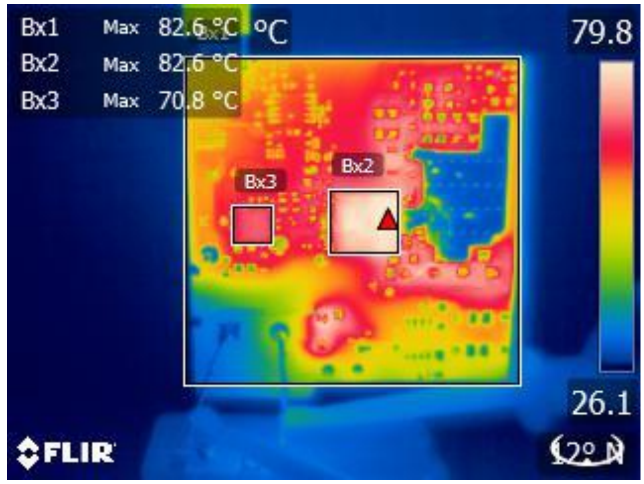


Figure 38 – Bottom Side Thermal Image.
Ambient: 25.6 ºC.
Bx2: InnoSwitch3-Pro = 82.6 ºC.
Bx3: SR FET = 70.8 ºC.

14.6 *Output: 15 V / 3 A (265 VAC)*

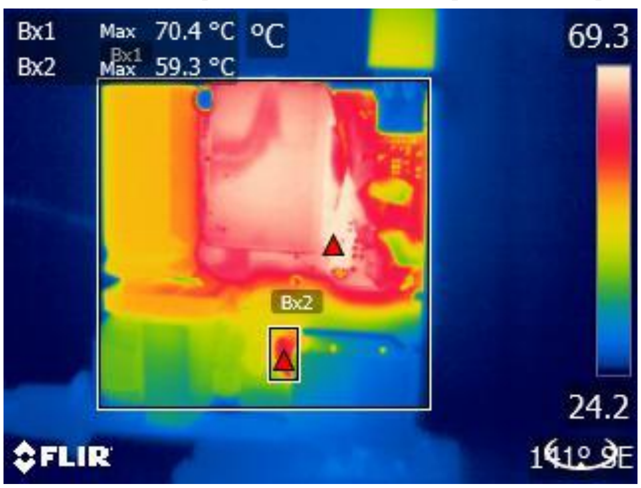


Figure 39 – Top Side Thermal Image.
Ambient: 24.6 ºC.
Bx1: Transformer Winding = 70.4 ºC.
Bx2: Thermistor RT1 = 59.3 ºC.

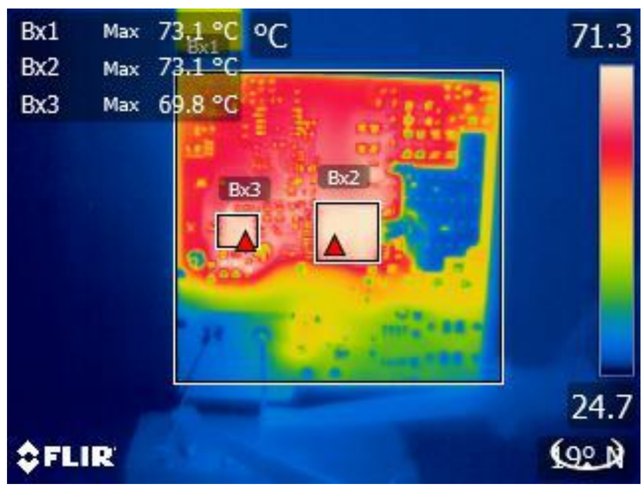


Figure 40 – Bottom Side Thermal Image.
Ambient: 24.6 ºC.
Bx2: InnoSwitch3-Pro = 73.1 ºC.
Bx3: SR FET = 69.8 ºC.

14.7 *Output: 20 V / 3 A (85 VAC)*

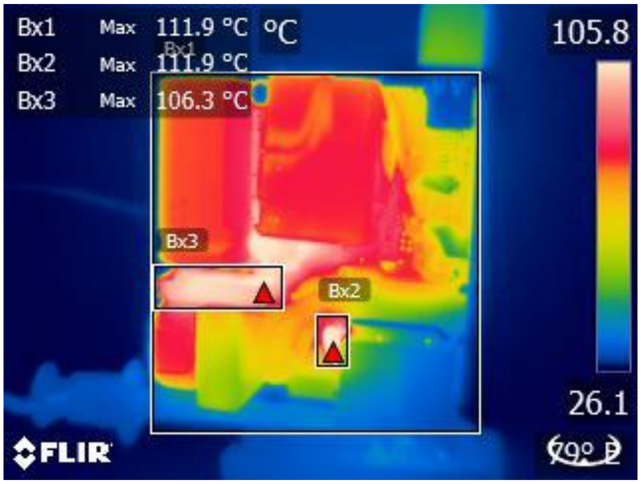


Figure 41 – Top Side Thermal Image.
Ambient: 26.3 ºC.
Bx2: Thermistor RT1 = 111.9 ºC.
Bx3: Bridge Rectifier BR1 = 106.3 ºC

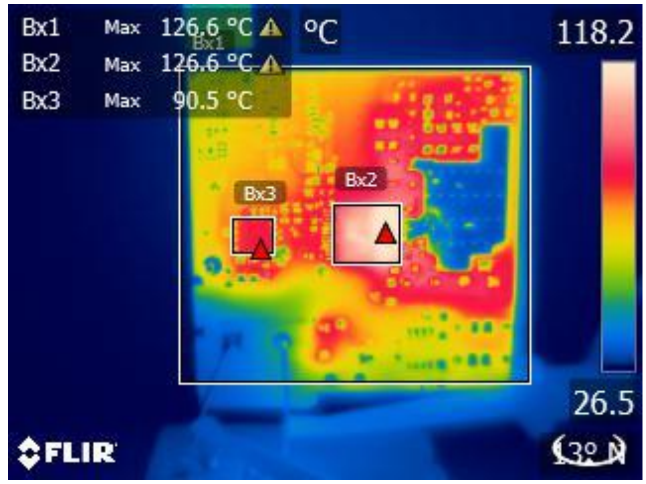


Figure 42 – Bottom Side Thermal Image.
Ambient: 26.3 ºC.
Bx1: InnoSwitch3-Pro = 126.6 ºC.
Bx2: SR FET = 90.5 ºC.

Note 2: To bring down the high temperature of the InnoSwitch3-Pro and SRFET ICs below 100 ºC, a thermal insulator pad and heat spreader as described in section 11 in this report needs to be used.
Note 3: These measurements are made with no heat spreader and unit will thermally shutdown if left in operation under this condition for extended period of time.

14.8 *Output: 20 V / 3 A (265 VAC)*

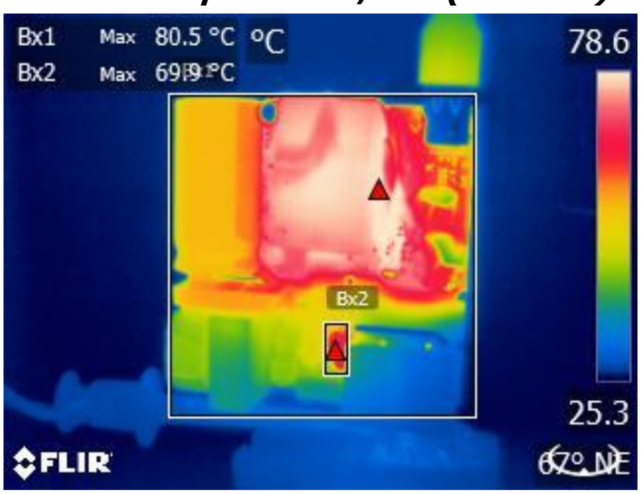


Figure 43 – Top Side Thermal Image.
Ambient: 26.4 ºC.
Bx1: Transformer winding= 80.5 ºC.
Bx2: Thermistor RT1 = 69.9 ºC.

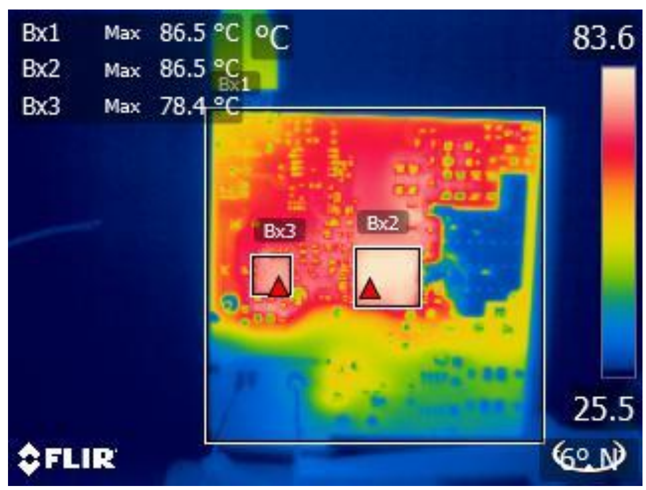


Figure 44 – Bottom Side Thermal Image.
Ambient: 26.4 ºC.
Bx2: InnoSwitch3-Pro = 86.5 ºC.
Bx3: SR FET = 78.4 ºC.

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

15 Waveforms

15.1 *Load Transient Response*

Note 1: Output voltages captured at the end of cable
2: Measurements taken at room temperature

15.1.1 Output: 5 V / 3 A

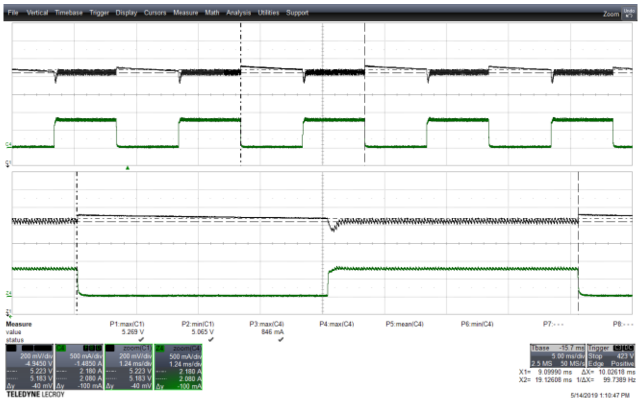


Figure 45 – Transient Response.
85 VAC, 5.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 5.065 V, V_{MAX}: 5.269 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

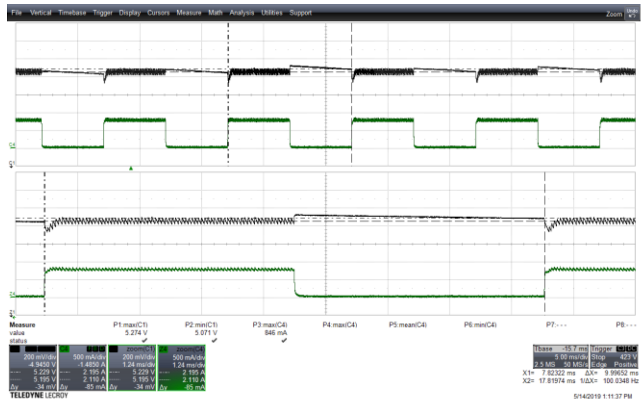


Figure 46 – Transient Response.
265 VAC, 5.0 V, 0 – 0.75 A Load Step.
V_{MIN} : 5.071 V, V_{MAX}: 5.274 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

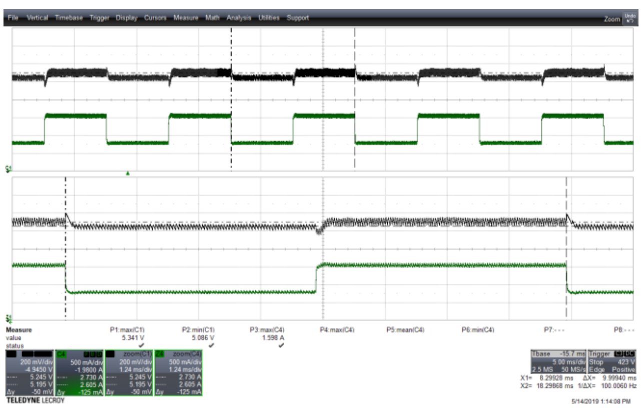


Figure 47 – Transient Response.
85 VAC, 5.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 5.086 V, V_{MAX}: 5.341 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

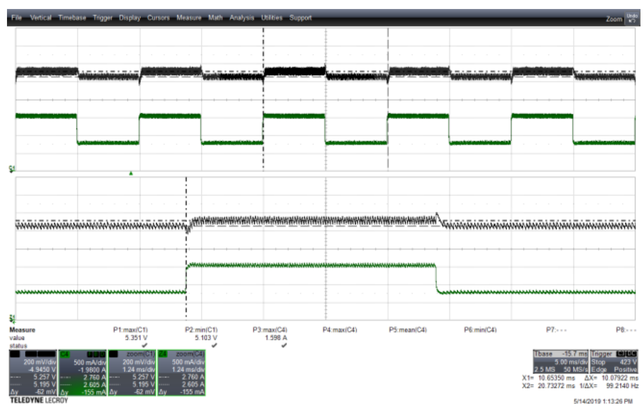


Figure 48 – Transient Response.
265 VAC, 5.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 5.103 V, V_{MAX}: 5.351 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

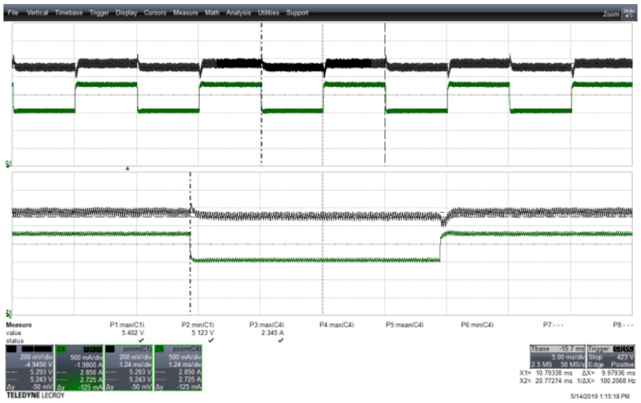


Figure 49 – Transient Response.
85 VAC, 5.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 5.123 V, V_{MAX}: 5.402 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

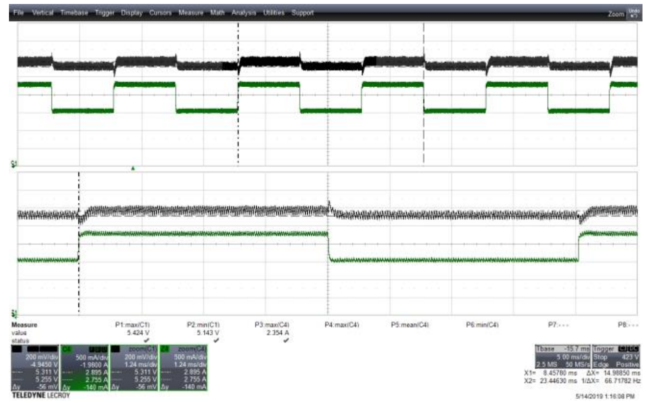


Figure 50 – Transient Response.
265 VAC, 5.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 5.143 V, V_{MAX}: 5.424 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

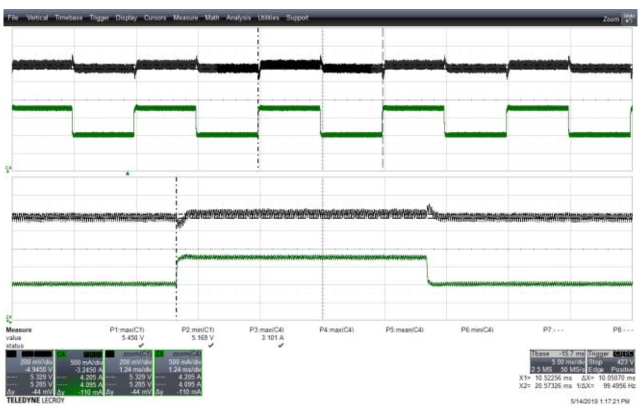


Figure 51 – Transient Response.
85 VAC, 5.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 5.169 V, V_{MAX}: 5.450 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

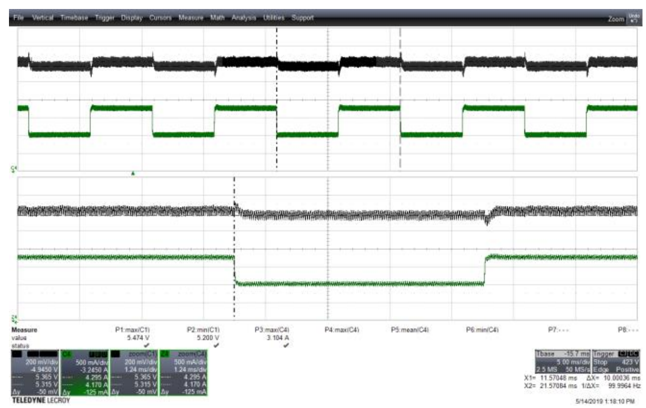


Figure 52 – Transient Response.
265 VAC, 5.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 5.200 V, V_{MAX}: 5.474 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

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

15.1.2 Output: 9 V / 3 A

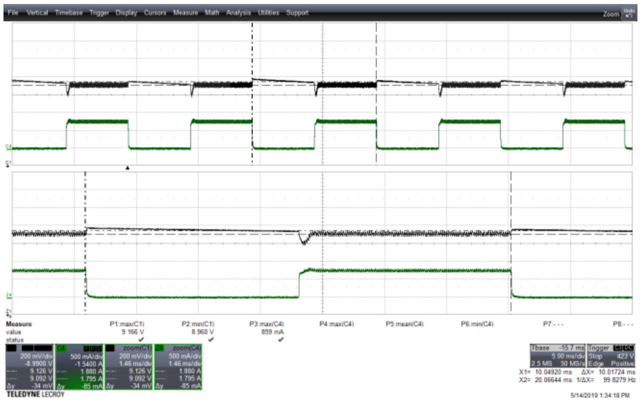


Figure 53 – Transient Response.
85 VAC, 9.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 8.960 V, V_{MAX}: 9.166 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

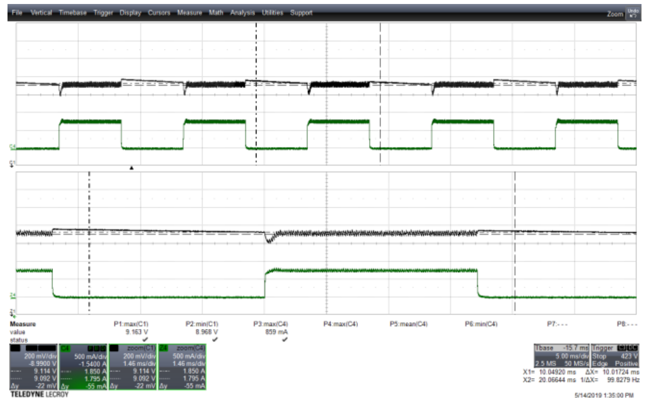


Figure 54 – Transient Response.
265 VAC, 9.0 V, 0 – 0.75 A Load Step.
V_{MIN} 8.968 V, V_{MAX}: 9.163 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

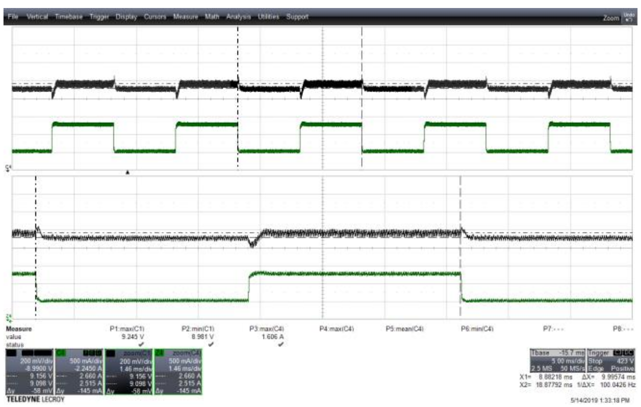


Figure 55 – Transient Response.
85 VAC, 9.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 8.981 V, V_{MAX}: 9.245 V.
Upper: V_{OUT}, 0.2 V / div., 53 ms / div.
Lower: I_{LOAD}, 1 A / div.
Zoom: 1.46 ms / div.

Figure 56 – Transient Response.
265 VAC, 9.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 8.994 V, V_{MAX}: 9.257 V.
Upper: V_{OUT}, 0.2 V / div., 53 ms / div.
Lower: I_{LOAD}, 1 A / div.
Zoom: 1.46 ms / div.

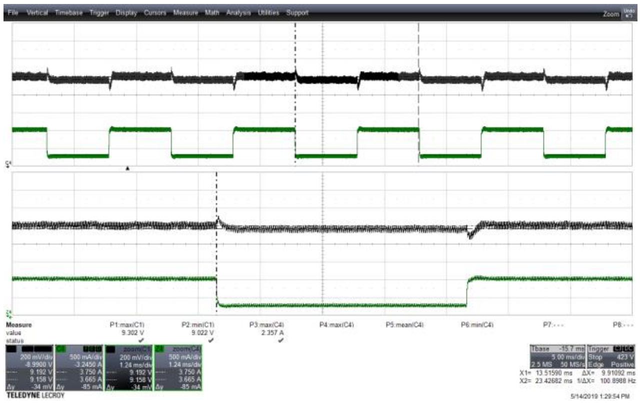


Figure 57 – Transient Response.
85 VAC, 9.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 9.022 V, V_{MAX}: 9.302V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.

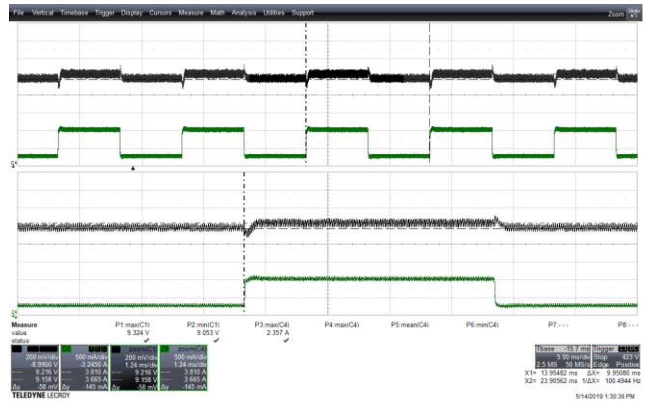


Figure 58 – Transient Response.
265 VAC, 9.0 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 9.053 V, V_{MAX}: 9.325 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.

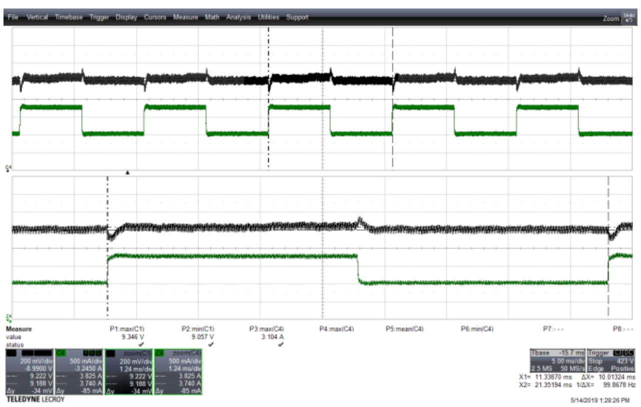


Figure 59 – Transient Response.
85 VAC, 9.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 9.057 V, V_{MAX}: 9.346 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

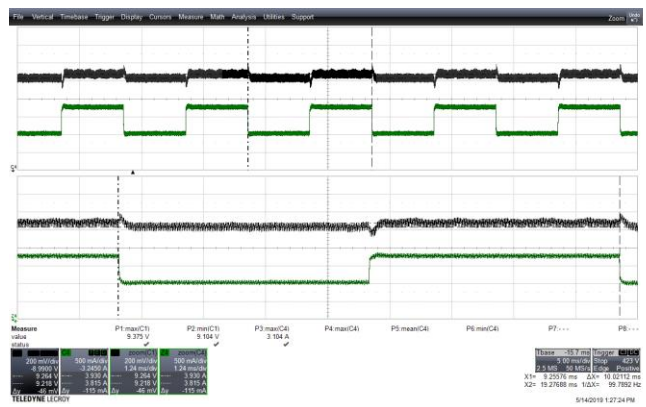


Figure 60 – Transient Response.
265 VAC, 9.0 V, 2.25 – 3 A Load Step.
V_{MIN}: 9.104 V, V_{MAX}: 9.375 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.24 ms / div.

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

15.1.3 Output: 15 V / 3 A

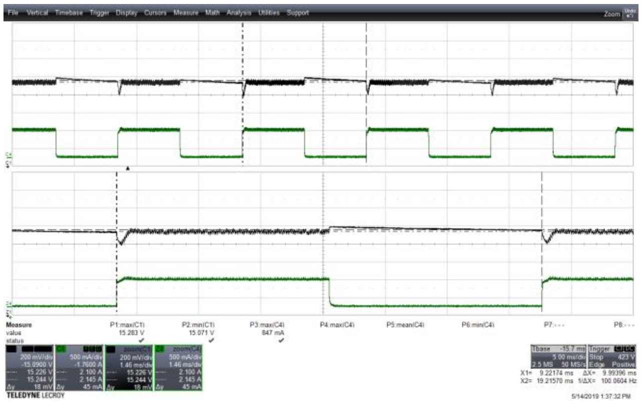


Figure 61 – Transient Response.
85 VAC, 15.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 15.071 V, V_{MAX}: 15.283 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

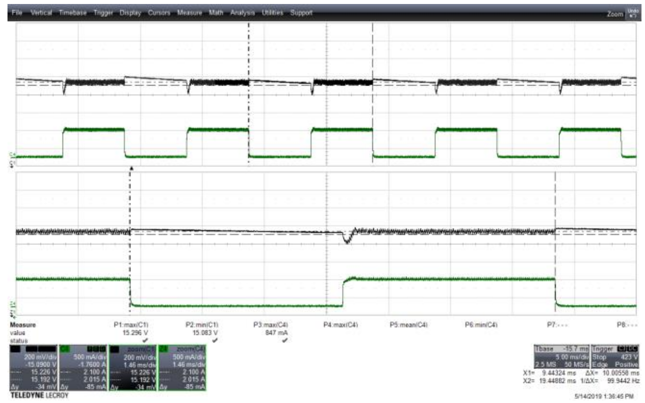


Figure 62 – Transient Response.
265 VAC, 15.0 V, 0 – 0.75 A Load Step.
V_{MIN}: 15.083 V, V_{MAX}: 15.296 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

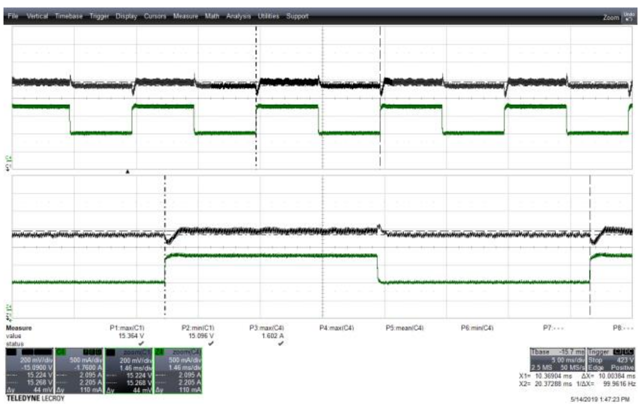


Figure 63 – Transient Response.
85 VAC, 15.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 15.096 V, V_{MAX}: 15.364 V.
Upper: V_{OUT}, 0.2 V / div., 56 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

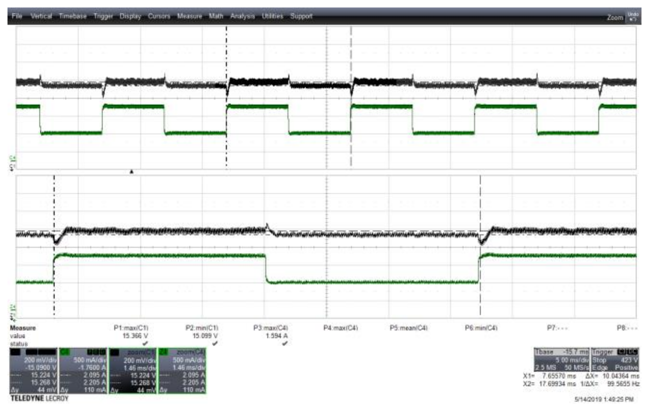


Figure 64 – Transient Response.
265 VAC, 15.0 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 15.099V, V_{MAX}: 15.366 V.
Upper: V_{OUT}, 0.2 V / div., 56 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

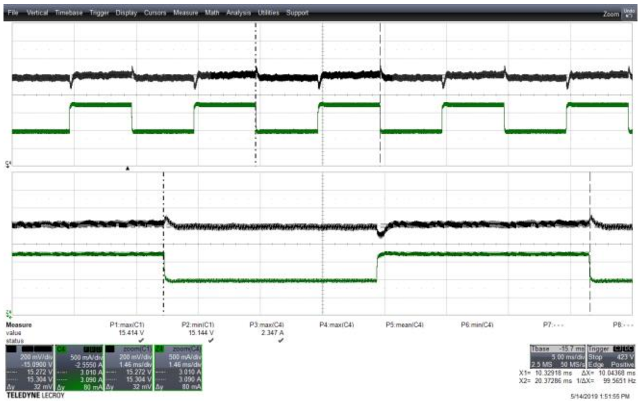


Figure 65 – Transient Response.
85 VAC, 15 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 15.144 V, V_{MAX}: 15.414 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

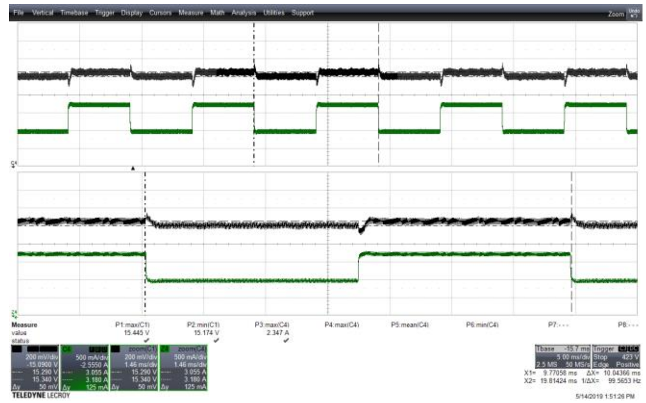


Figure 66 – Transient Response.
265 VAC, 15 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 15.174 V, V_{MAX}: 15.445 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

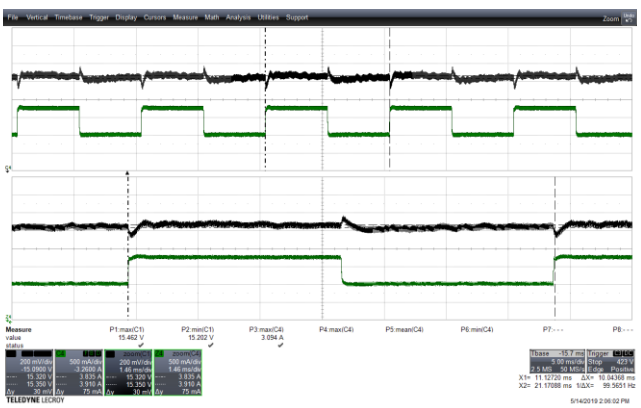


Figure 67 – Transient Response.
85 VAC, 15 V, 2.25 – 3.0 A Load Step.
V_{MIN}: 15.202 V, V_{MAX}: 15.462 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

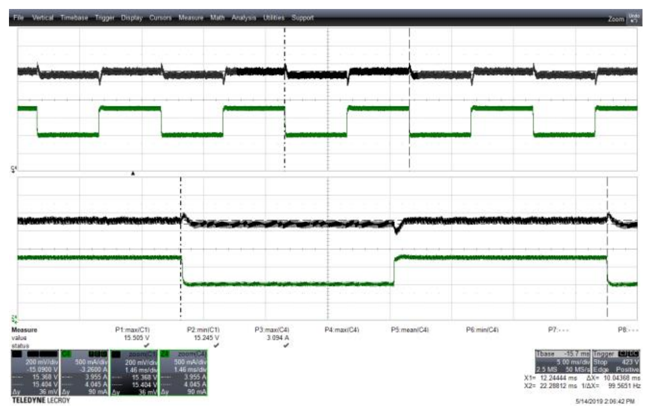


Figure 68 – Transient Response.
265 VAC, 15 V, 2.25 – 3.0 A Load Step.
V_{MIN}: 15.505 V, V_{MAX}: 15.245 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

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

15.1.4 Output: 20 V / 3 A

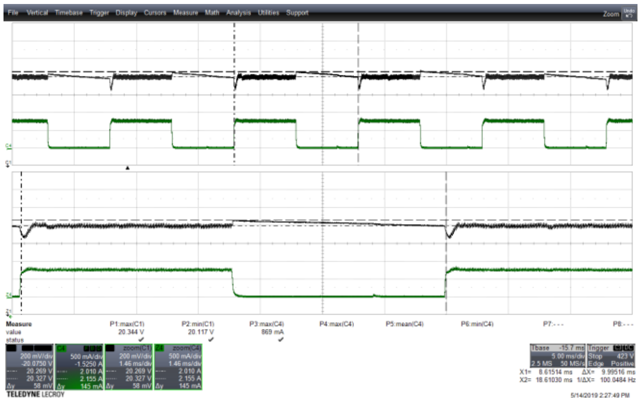


Figure 69 – Transient Response.
85 VAC, 20 V, 0 – 0.75 A Load Step.
V_{MIN}: 20.117 V, V_{MAX}: 20.344 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

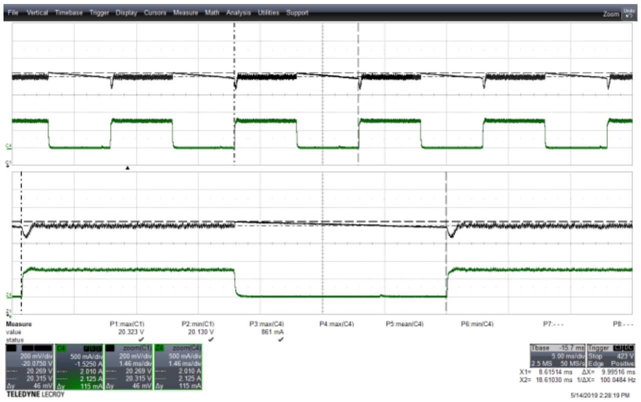


Figure 70 – Transient Response.
265 VAC, 20 V, 0 – 0.75A Load Step.
V_{MIN}: 20.323 V, V_{MAX}: 20.130 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

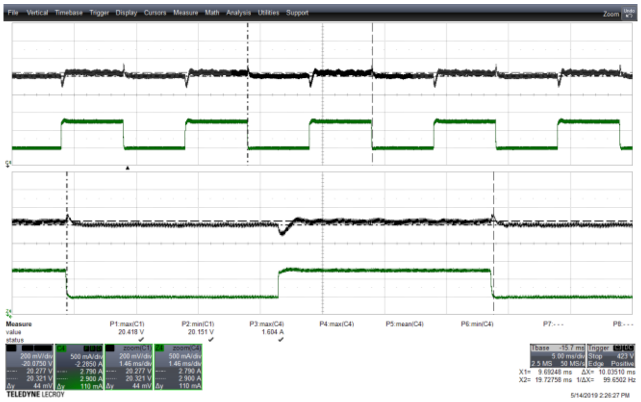


Figure 71 – Transient Response.
85 VAC, 20 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 20.151 V, V_{MAX}: 20.418 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

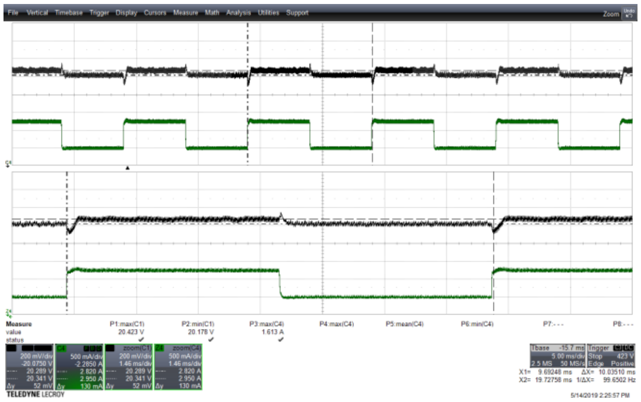


Figure 72 – Transient Response.
265 VAC, 20 V, 0.75 – 1.5 A Load Step.
V_{MIN}: 20.178 V, V_{MAX}: 20.423 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

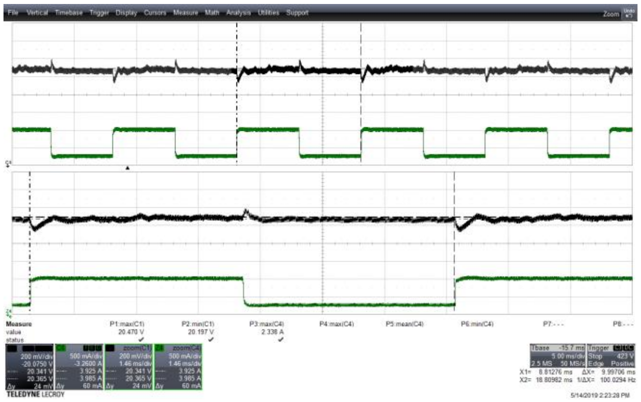


Figure 73 – Transient Response.
85 VAC, 20 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 20.197 V, V_{MAX}: 20.470 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

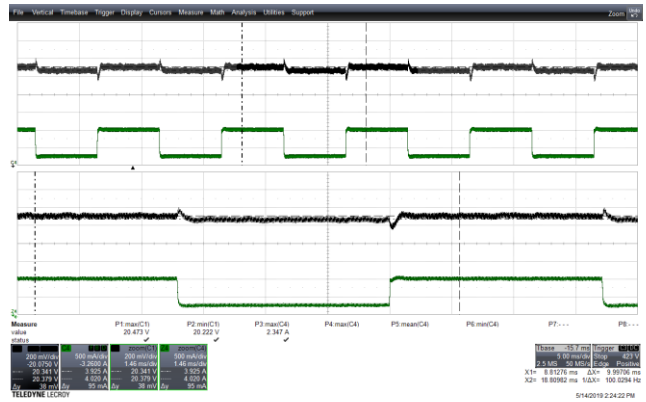


Figure 74 – Transient Response.
265 VAC, 20 V, 1.5 – 2.25 A Load Step.
V_{MIN}: 20.222 V, V_{MAX}: 20.473 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

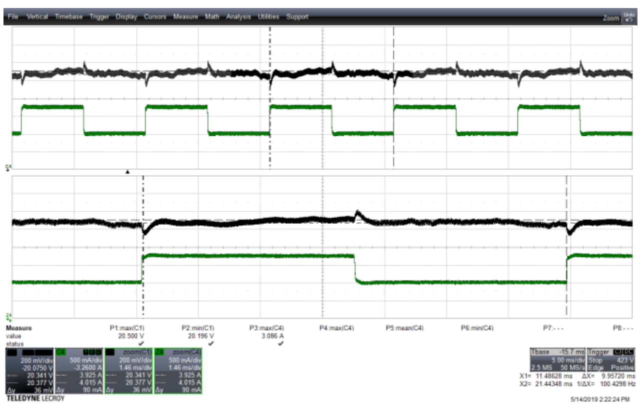


Figure 75 – Transient Response.
85 VAC, 20 V, 2.25 – 3 A Load Step.
V_{MIN}: 20.196 V, V_{MAX}: 20.500 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

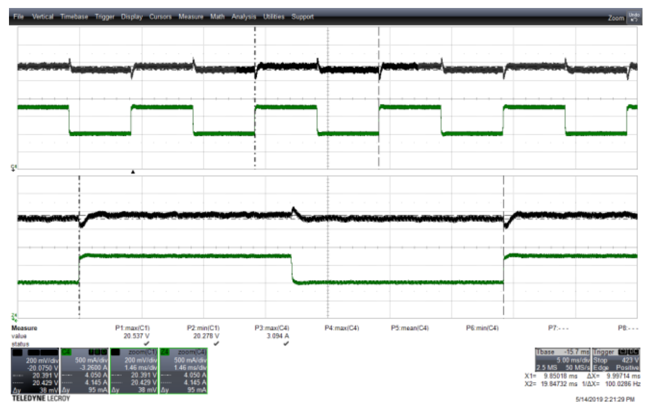


Figure 76 – Transient Response.
265 VAC, 20 V, 2.25 – 3 A Load Step.
V_{MIN}: 20.278 V, V_{MAX}: 20.537 V.
Upper: V_{OUT}, 0.2 V / div., 5 ms / div.
Lower: I_{LOAD}, 0.5 A / div.
Zoom: 1.46 ms / div.

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

15.2 ***Switching Waveforms***

Note 1: Measurements taken at room temperature.

15.2.1 Primary Drain Voltage

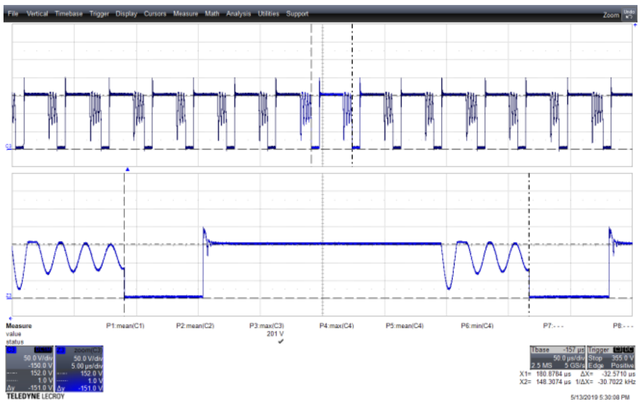


Figure 77 – Drain Voltage Waveforms.
85 VAC, 5.0 V, 3 A Load (201 V_{MAX}).
Blue: V_{DRAIN}, 50 V, 50 µs / div.
Zoom: 5 µs / div.

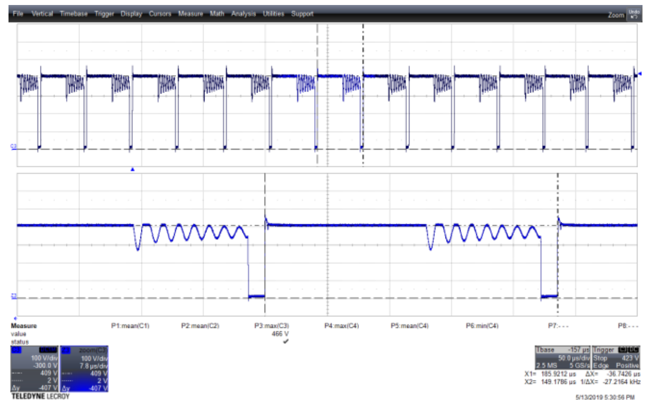


Figure 78 – Drain Voltage Waveforms.
265 VAC, 5.0 V, 3 A Load (466 V_{MAX}).
Blue: V_{DRAIN}, 100 V, 50 µs / div.
Zoom: 7.8 µs / div.

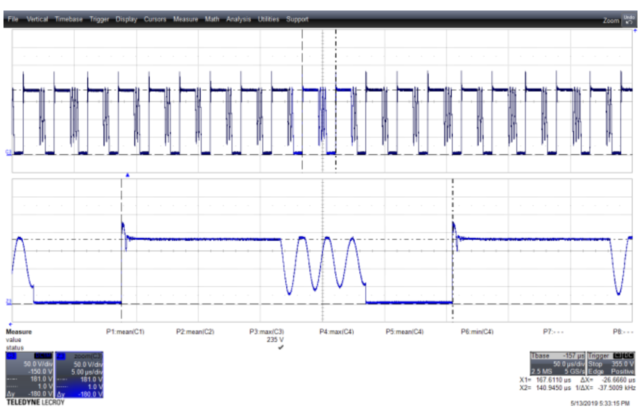


Figure 79 – Drain Voltage Waveforms.
85 VAC, 9.0 V, 3 A Load (235 V_{MAX}).
Blue: V_{DRAIN}, 50 V, 50 µs / div.
Zoom: 5 µs / div.

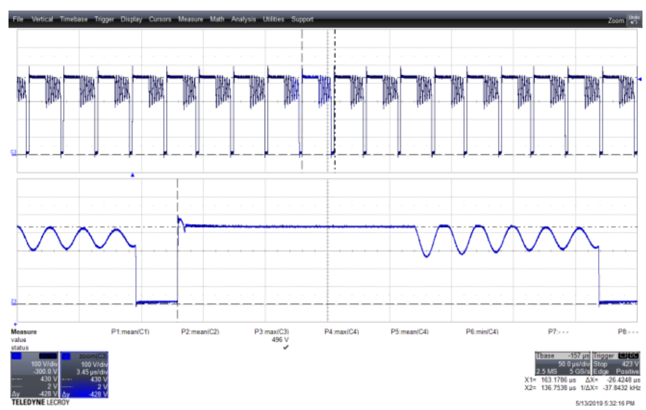


Figure 80 – Drain Voltage Waveforms.
265 VAC, 9 V, 3 A Load (496 V_{MAX}).
Blue: V_{DRAIN}, 100 V, 50 µs / div.
Zoom: 3.45 µs / div.

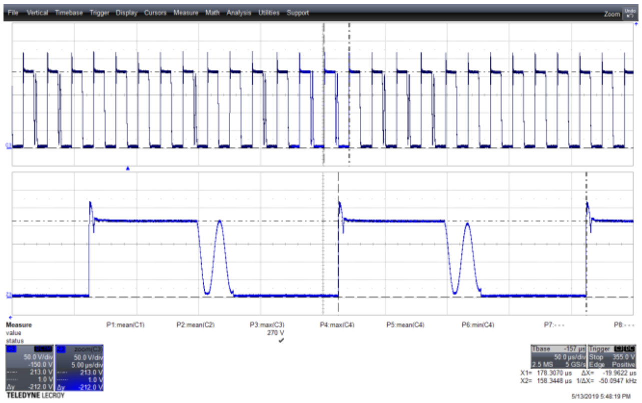


Figure 81 – Drain Voltage Waveforms.
85 VAC, 15.0 V, 3 A Load (270 V_{MAX}).
Blue: V_{DRAIN}, 50 V, 20 µs / div.
Zoom: 5 µs / div.

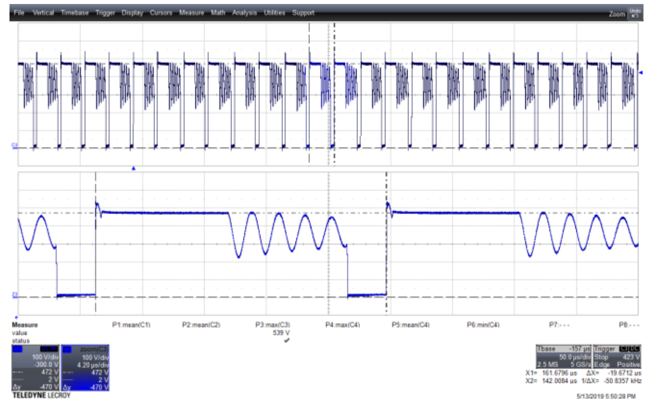


Figure 82 – Drain Voltage Waveforms.
265 VAC, 15.0 V, 3 A Load (539 V_{MAX}).
Blue: V_{DRAIN}, 100 V, 50 µs / div.
Zoom: 4.2 µs / div.

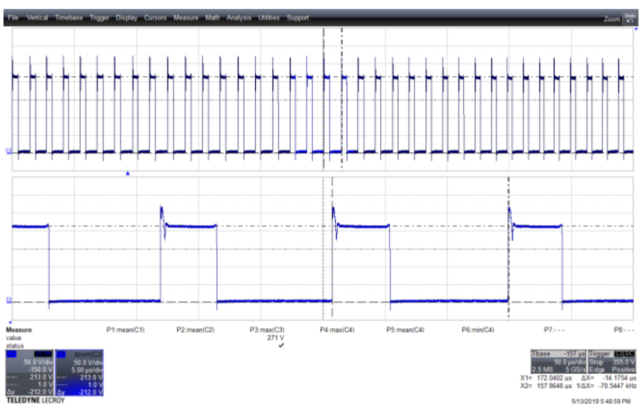


Figure 83 – Drain Voltage Waveforms.
85 VAC, 20 V, 3 A Load (271 V_{MAX}).
Blue: V_{DRAIN}, 50 V, 50 µs / div.
Zoom: 5 µs / div.

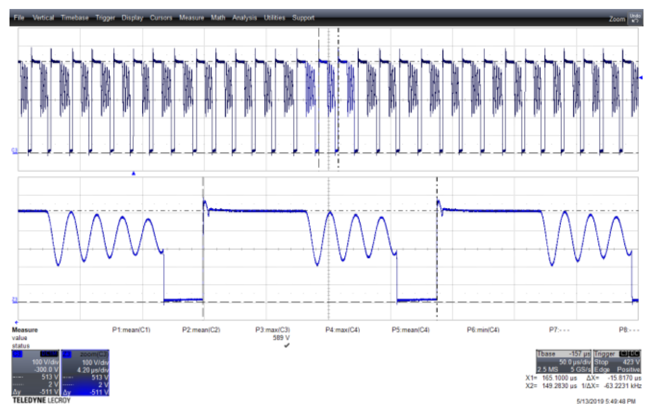


Figure 84 – Drain Voltage Waveforms.
265 VAC, 20 V, 3 A Load (589 V_{MAX}).
Blue: V_{DRAIN}, 100 V, 50 µs / div.
Zoom: 4.2 µs / div.

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

15.2.2 SR FET Voltage

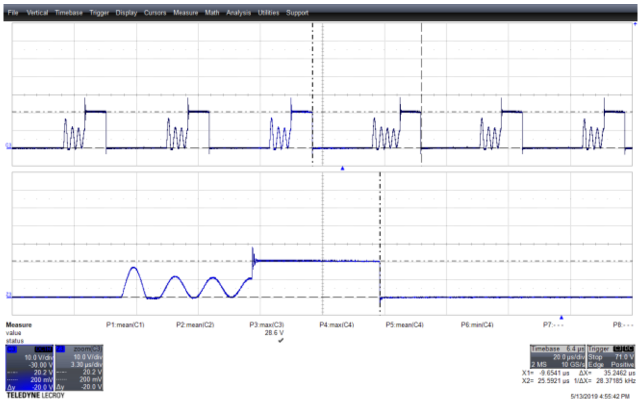


Figure 85 – SR FET Voltage Waveforms.
85 VAC, 5.0 V, 3 A Load (28.6 V_{MAX}).
Blue: V_{DRAIN}, 10 V, 20 µs / div.
Zoom: 1.96 µs / div.

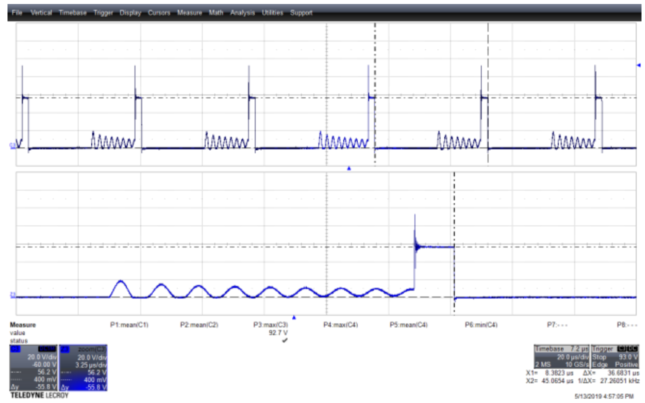


Figure 86 – SR FET Voltage Waveforms.
265 VAC, 5.0 V, 3 A Load (92.7 V_{MAX}).
Blue: V_{DRAIN}, 20 V, 10 µs / div.
Zoom: 3.25 µs / div.

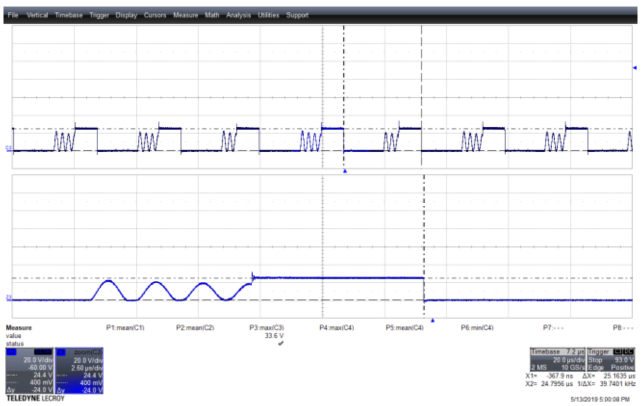


Figure 87 – SR FET Voltage Waveforms.
85 VAC, 9.0 V, 3 A Load (33.6 V_{MAX}).
Blue: V_{DRAIN}, 20 V, 20 µs / div.
Zoom: 2.6 µs / div.

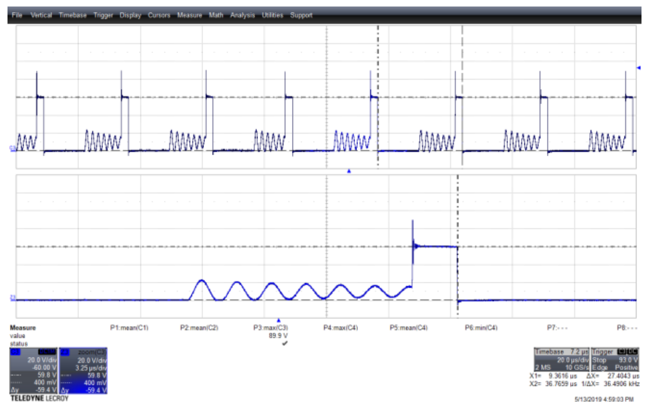


Figure 88 – SR FET Voltage Waveforms.
265 VAC, 9.0 V, 3 A Load (89.9 V_{MAX}).
Blue: V_{DRAIN}, 20 V, 20 µs / div.
Zoom: 3.25 µs / div.

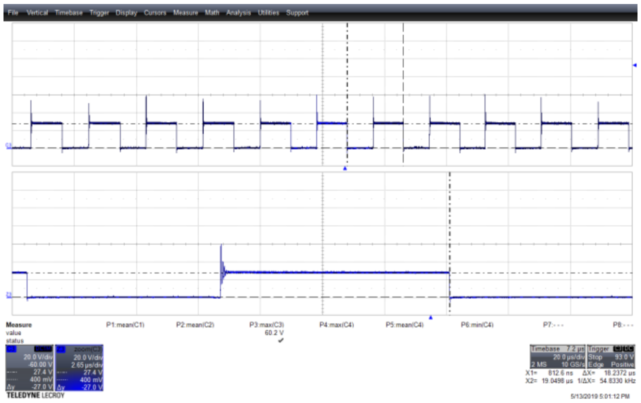


Figure 89 – SR FET Voltage Waveforms.
85 VAC, 15.0 V, 3 A Load(60.2 V_{MAX}).
Blue: V_{DRAIN}, 20 V, 20 µs / div.
Zoom: 2.65 µs / div.

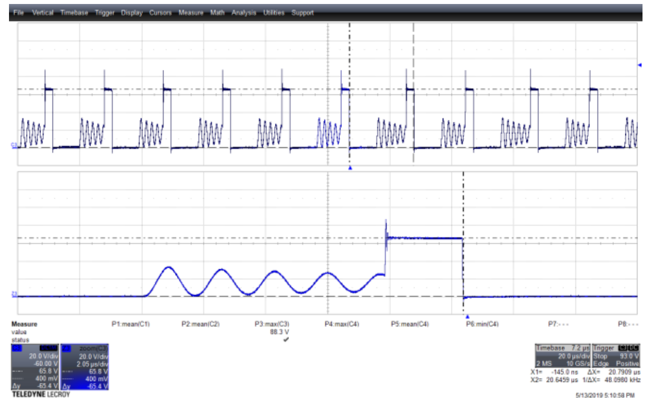


Figure 90 – SR FET Voltage Waveforms.
265 VAC, 15.0 V,3 A Load (88.3 V_{MAX}).
Blue: V_{DRAIN}, 20 V, 20 µs / div.
Zoom: 2.05 µs / div.

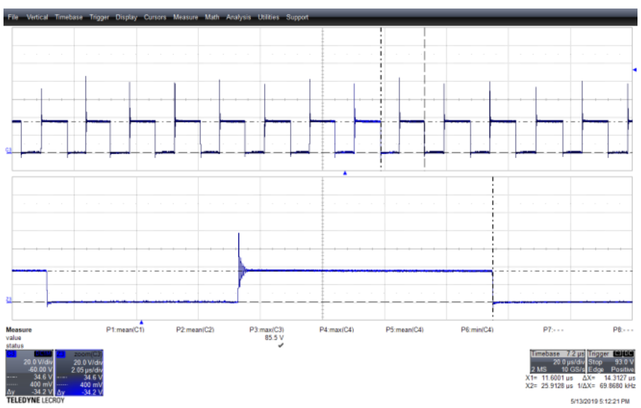


Figure 91 – SR FET Voltage Waveforms.
85 VAC, 20 V, 3 A Load (85.5 V_{MAX}).
Blue: V_{DRAIN}, 20 V, 20 µs / div.
Zoom: 2.05 µs / div.

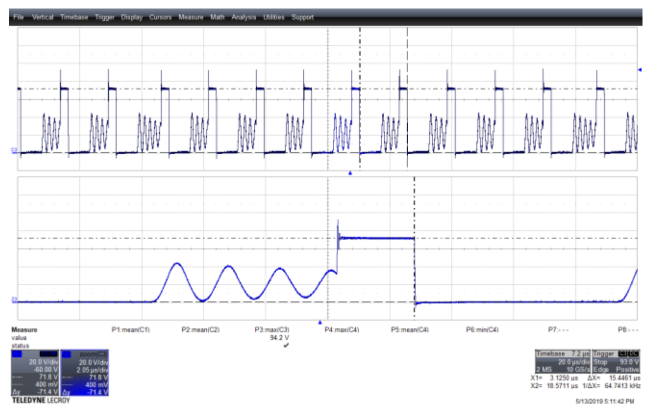


Figure 92 – SR FET Voltage Waveforms.
265 VAC, 20 V, 3 A Load (94.2 V_{MAX}).
Blue: V_{DRAIN}, 20 V, 20 µs / div.
Zoom: 2.05 µs / div.

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

15.3 *Start-up*

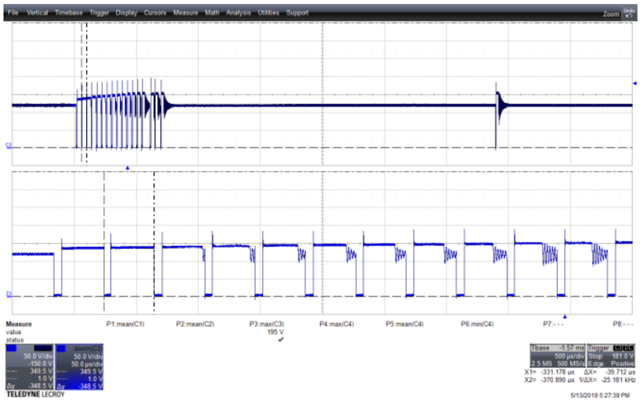


Figure 93 – Prim Drain Voltage Waveforms.
85 VAC, 5.0 V (195.0 V_{MAX}).
Blue: V_{DRAIN}, 50 V, 500 μs / div.
Zoom: 50 μs / div.

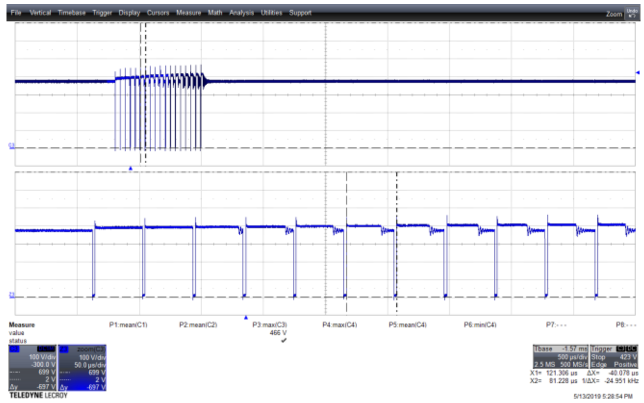


Figure 94 – Prim Drain Voltage Waveforms.
265 VAC, 5.0 V (466.0 V_{MAX}).
Blue: V_{DRAIN}, 50 V, 500 μs / div.
Zoom: 50 μs / div.

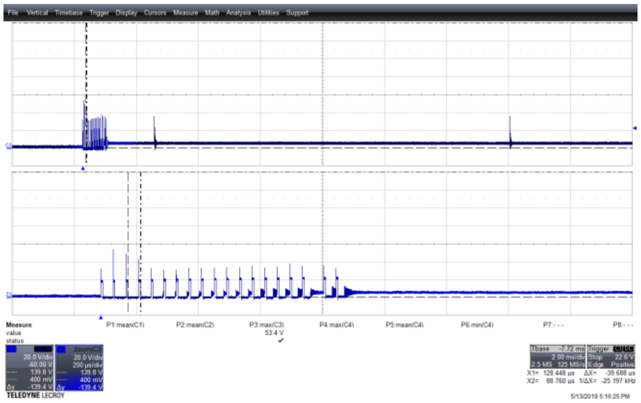


Figure 95 – SRFET Drain Voltage Waveforms.
85 VAC, 5.0 V (53.4 V_{MAX}).
Blue: V_{DRAIN}, 20 V, 2 ms / div.
Zoom: 200 μs / div.

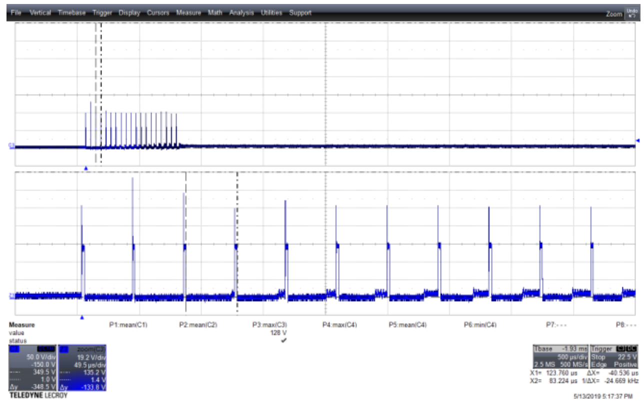


Figure 96 – SRFET Drain Voltage Waveforms.
265 VAC, 5.0 V (128.0 V_{MAX}).
Blue: V_{DRAIN}, 20 V, 500 μs / div.
Zoom: 49.5 μs / div.

16 Output Ripple Measurements

16.1 *Ripple Measurement Technique*

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

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

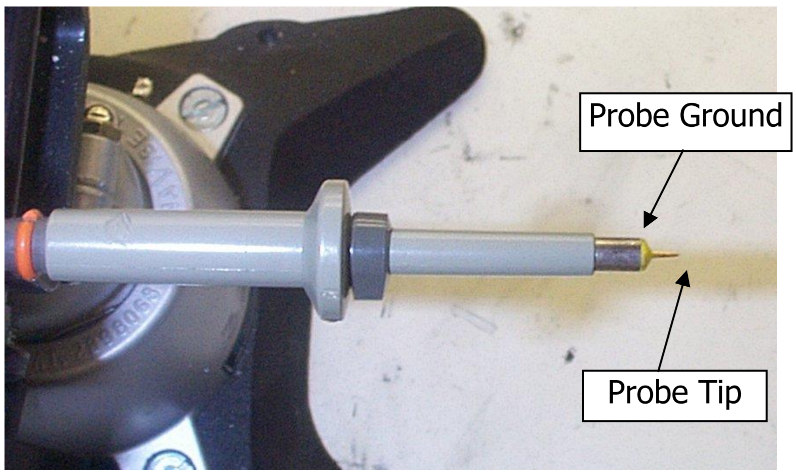


Figure 97 – Oscilloscope Probe Prepared for Ripple Measurement. (End Cap and Ground Lead Removed)

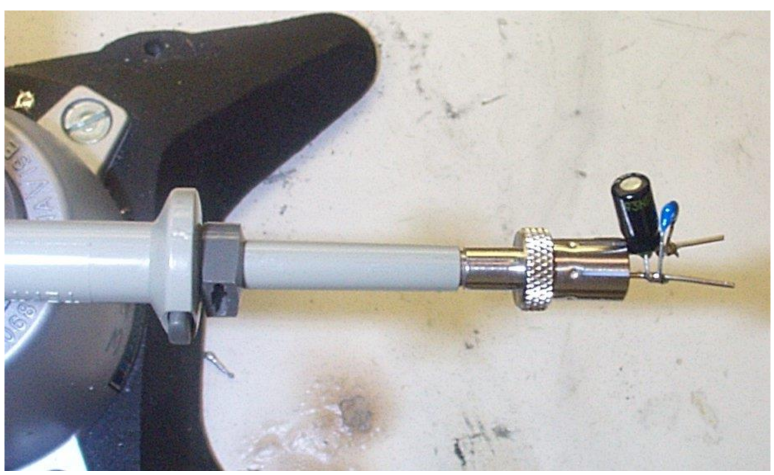


Figure 98 – Oscilloscope Probe with Probe Master (**www.probemaster.com**) 4987A BNC Adapter. (Modified with wires for ripple measurement, and two parallel decoupling capacitors added)

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

16.2 *Output Voltage Ripple Waveforms*

Note 1: Output voltages captured at the end of cable
2: Measurements taken at room temperature

16.2.1 Output: 5 V / 3 A

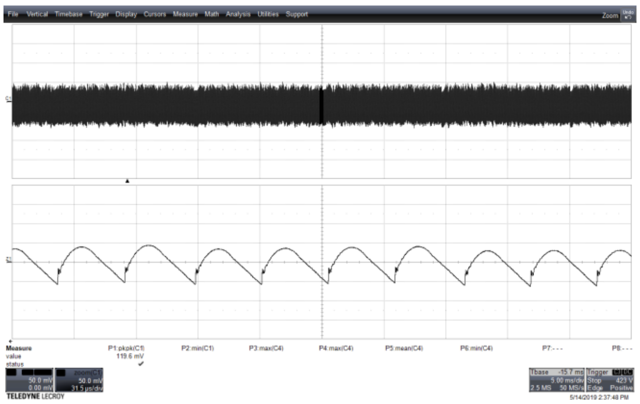


Figure 99 – Output Ripple. PK-PK = 119.6 mV.
85 VAC_{IN} 5.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

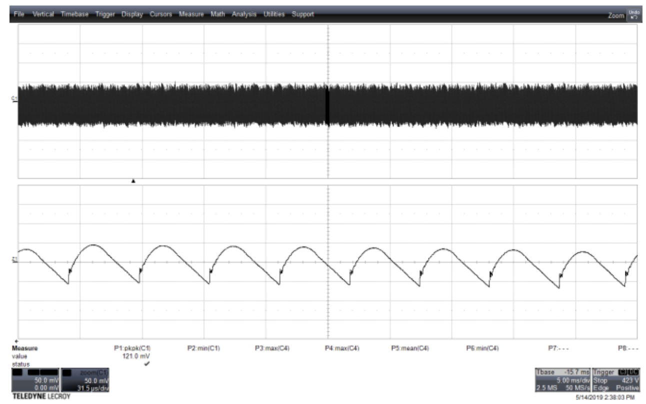


Figure 100 – Output Ripple. PK-PK = 121 mV.
115 VAC_{IN} 5.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

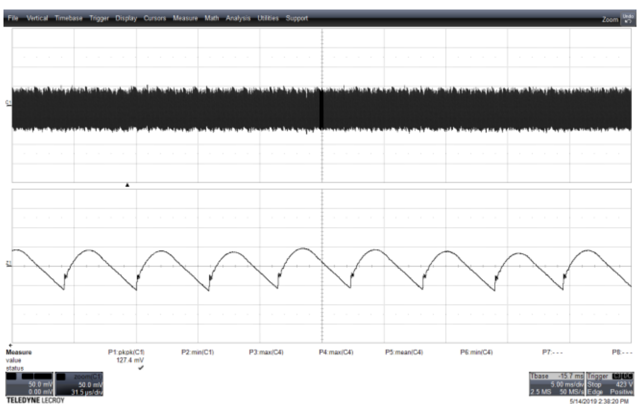


Figure 101 – Output Ripple. PK-PK = 127.4 mV.
230 VAC_{IN} 5.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

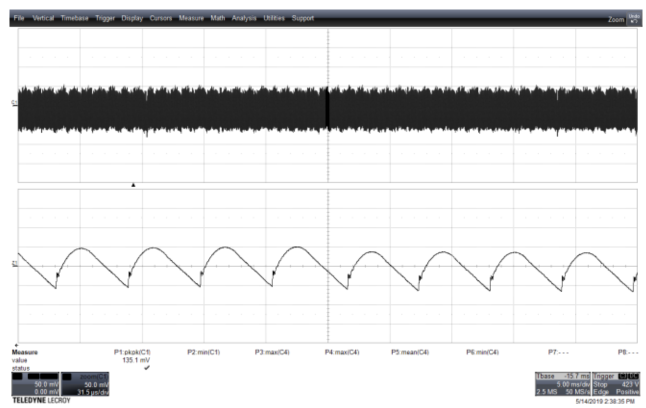


Figure 102 – Output Ripple. PK-PK = 135.1 mV.
265 VAC_{IN} 5.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

16.2.2 Output: 9 V / 3 A

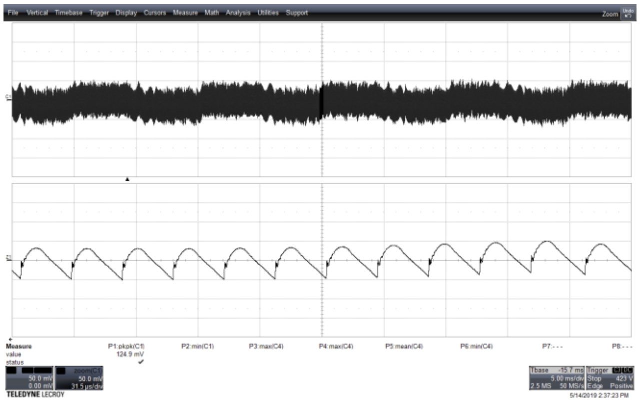


Figure 103 – Output Ripple. PK-PK = 124.9 mV
85 VAC_{IN} 9.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

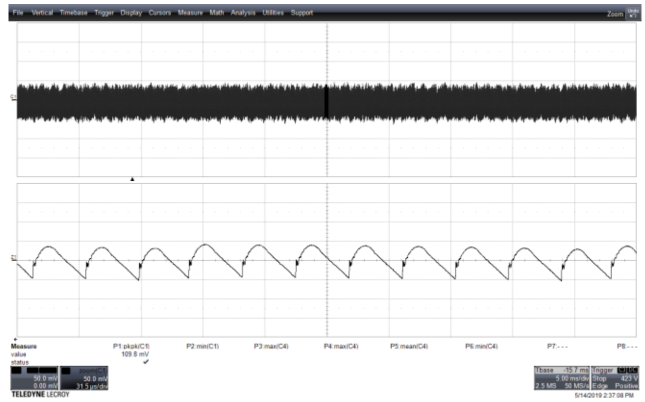


Figure 104 – Output Ripple. PK-PK = 109.8 mV
115 VAC_{IN} 9.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

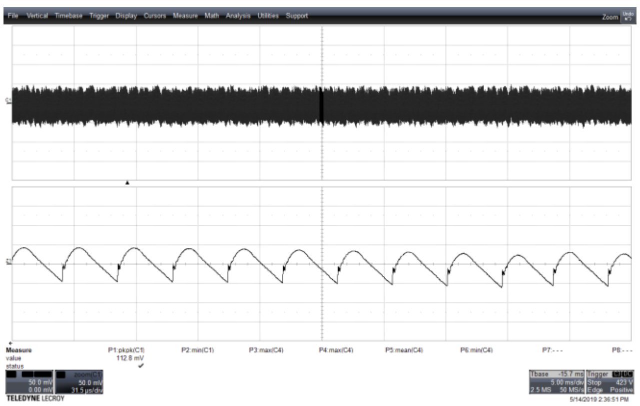


Figure 105 – Output Ripple. PK-PK = 112.8 mV
230 VAC_{IN} 9.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

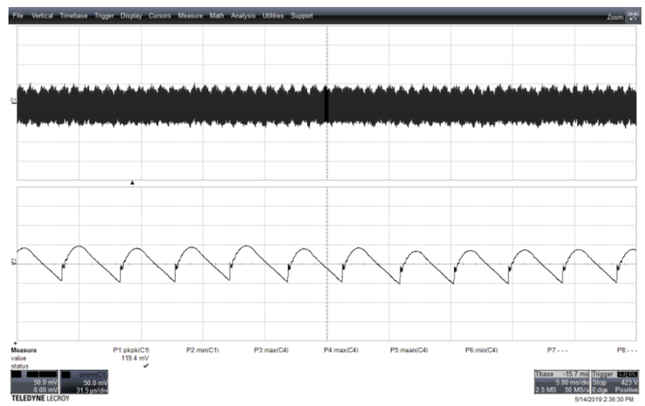


Figure 106 – Output Ripple. PK-PK = 119.4 mV
265 VAC_{IN} 9.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

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

16.2.3 Output: 15 V / 3 A

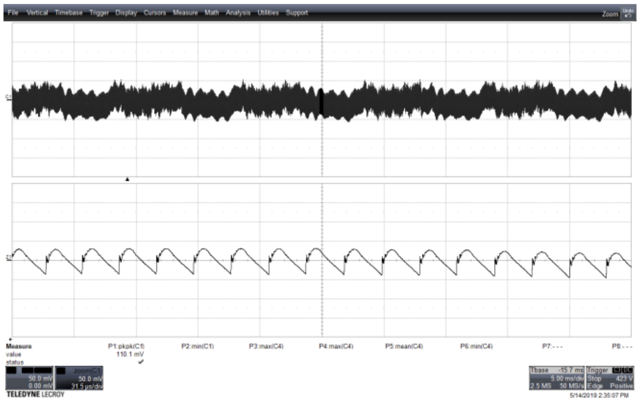


Figure 107 – Output Ripple. PK-PK = 110.1 mV.
85 VAC_{IN}, 15.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

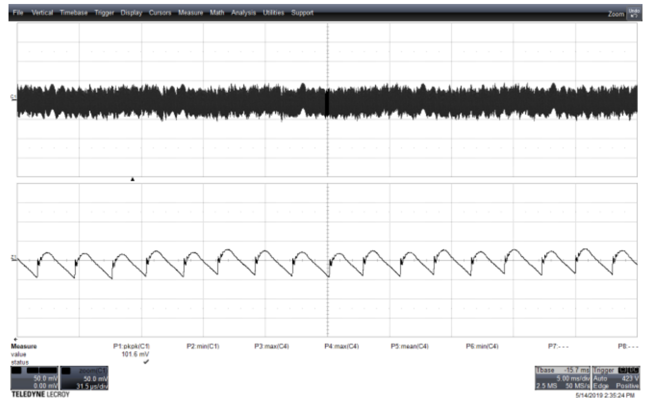


Figure 108 – Output Ripple. PK-PK = 101.6 mV.
115 VAC_{IN} 15.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

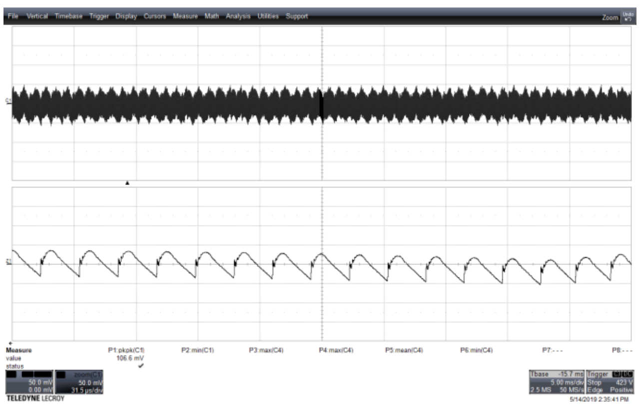


Figure 109 – Output Ripple. PK-PK = 106.6 mV.
230 VAC_{IN} 15.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

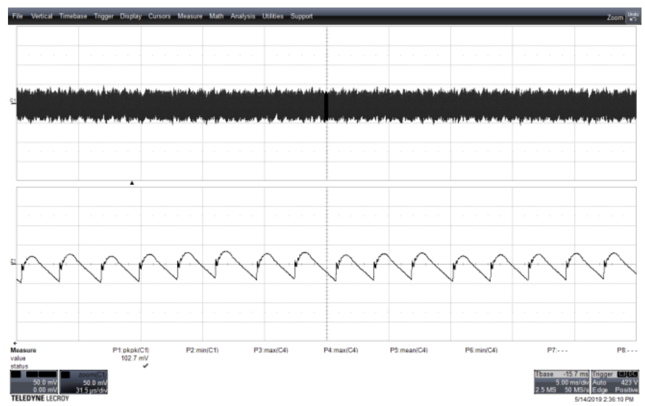


Figure 110 – Output Ripple. PK-PK = 102.7 mV.
265 VAC_{IN} 15.0 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

16.2.4 Output: 20 V / 3 A

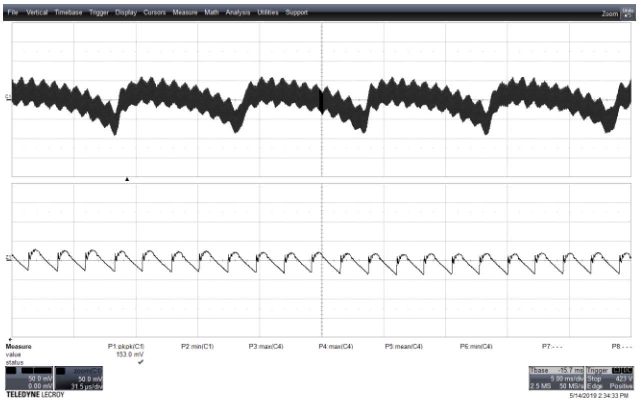


Figure 111 – Output Ripple. PK-PK = 153 mV.
85 VAC_{IN}, 20 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

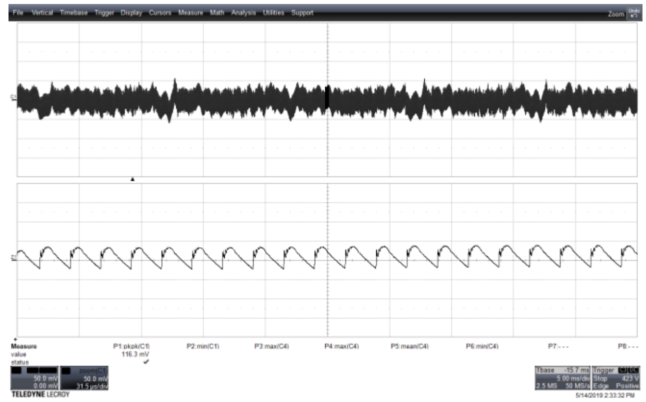


Figure 112 – Output Ripple. PK-PK = 116.3 mV.
115 VAC_{IN}, 20 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

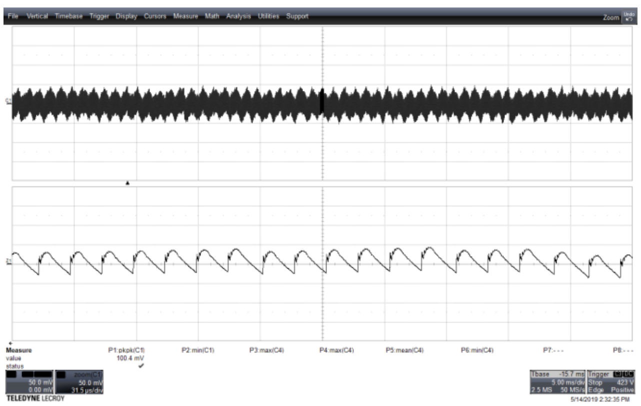


Figure 113 – Output Ripple. PK-PK = 100.4 mV.
230 VAC_{IN} 20 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

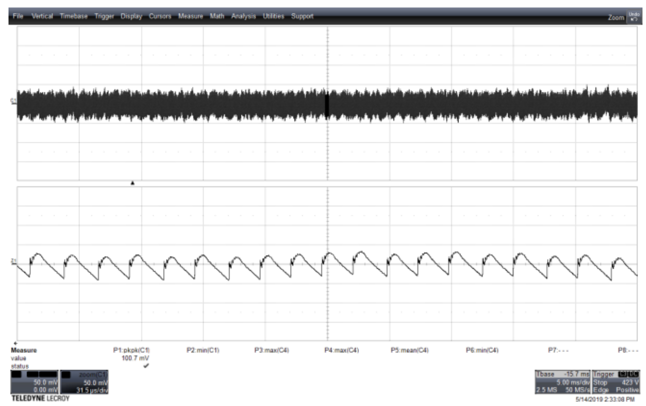


Figure 114 – Output Ripple. PK-PK = 100.7 mV.
265 VAC_{IN} 20 V, 3 A Load.
V_{OUT}, 50 mV / div., 5 ms / div.
Zoom: 31.5 μs / div.

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

17 CV/CC Profile

Note:

1. Voltages measured end of cable.
2. Positive slope in CC region is per the guidelines of USB PD3.0 PPS specification.

17.1 *Output: 21 V / 3 A*

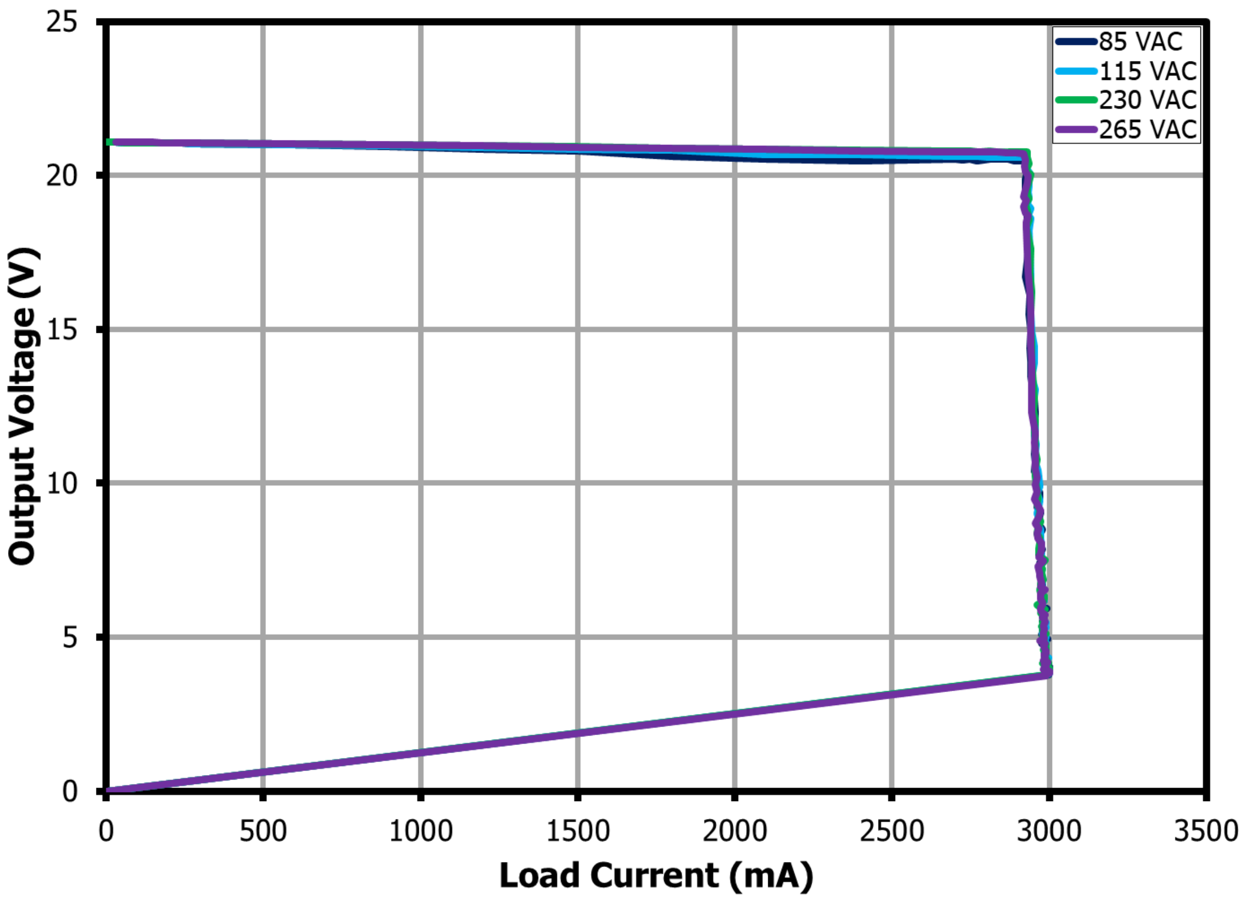


Figure 115 – CV/CC Profile with Output 21 V, 3 A.

17.2 ***Output: 15 V / 3 A***

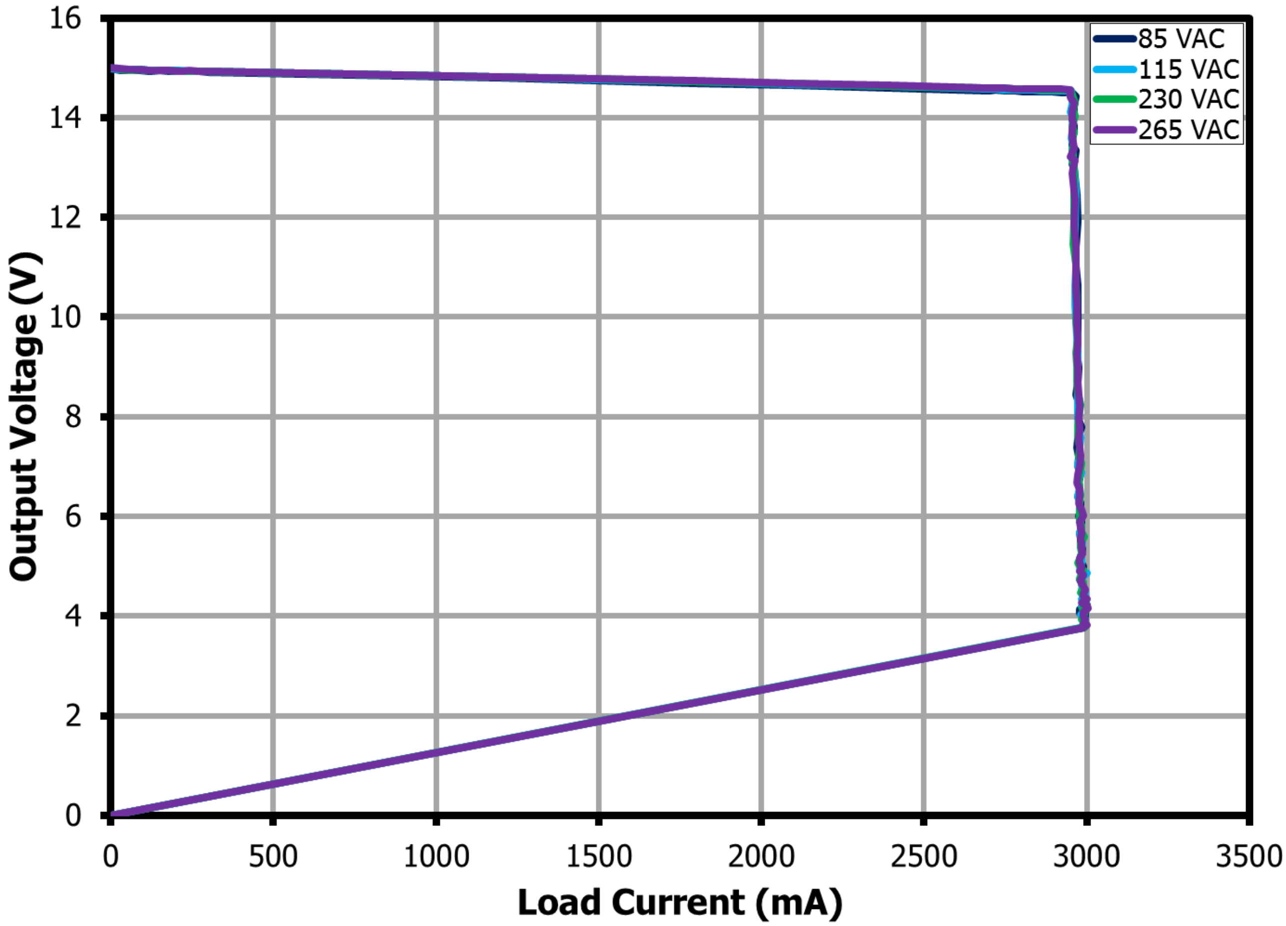


Figure 116 – CV/CC Profile with Output 15 V, 3 A.

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

17.3 ***Output: 9 V / 3 A***

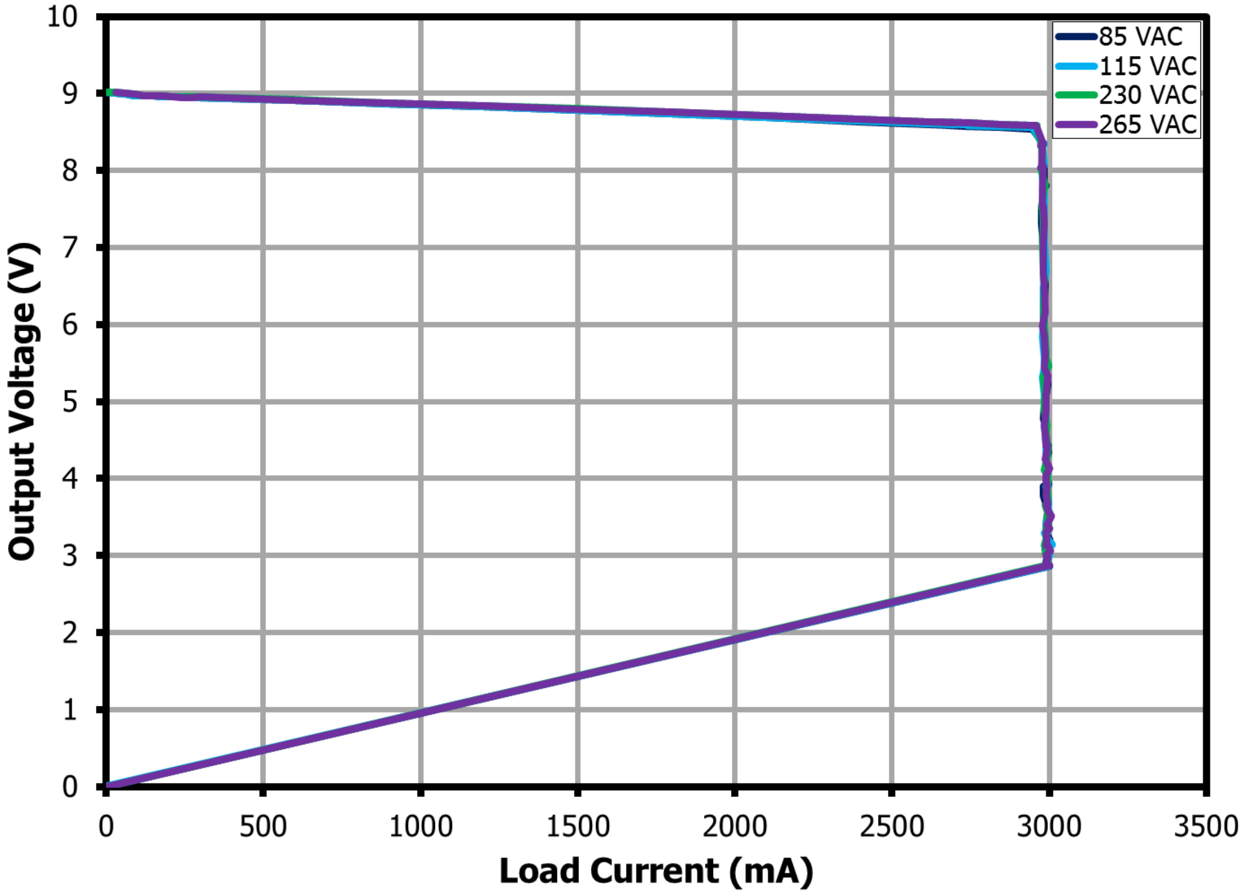


Figure 117 – CV/CC Profile with Output 9 V, 3 A.

17.4 ***Output: 5 V / 3 A***

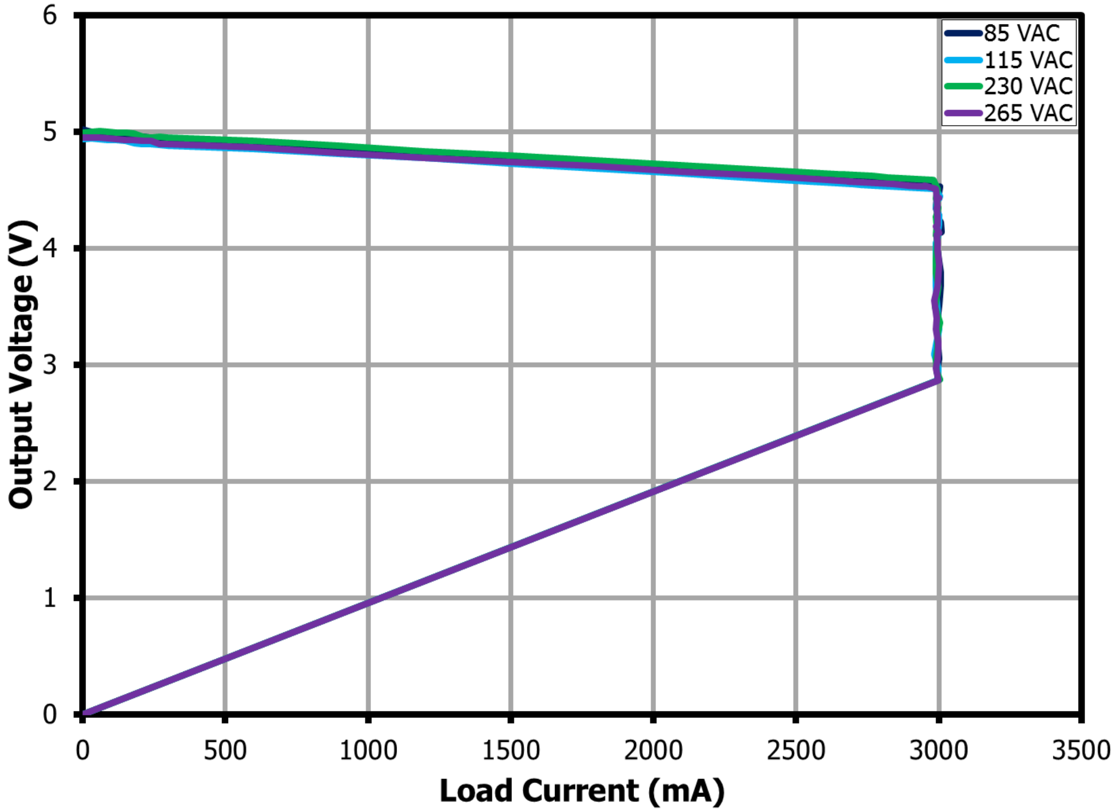


Figure 118 – CV/CC Profile with Output 9 V, 3 A.

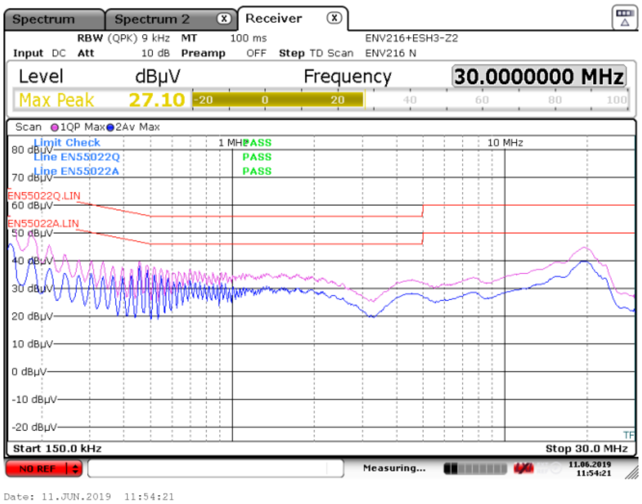
Power Integrations
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

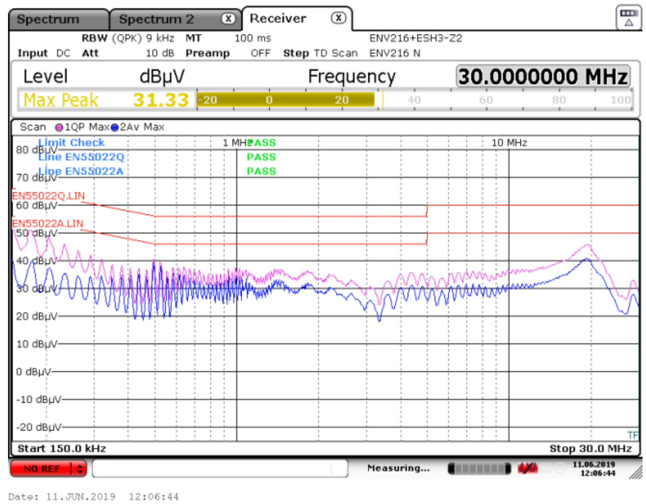
18 Conducted EMI

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

18.1 ***Floating Ground (QPK / AV)***

18.1.1 Output: 5 V / 3 A

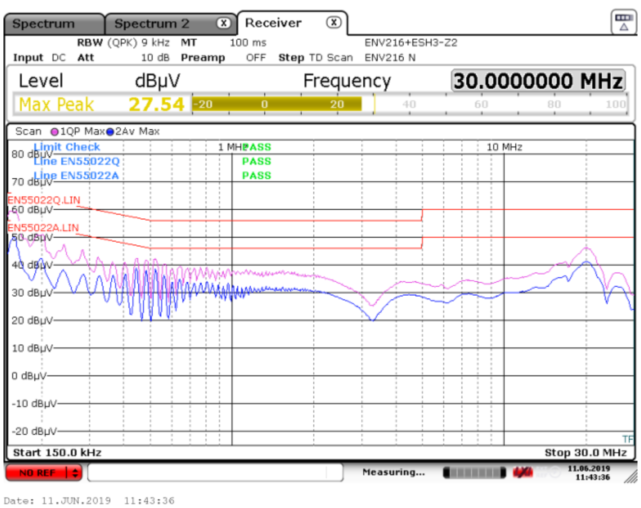


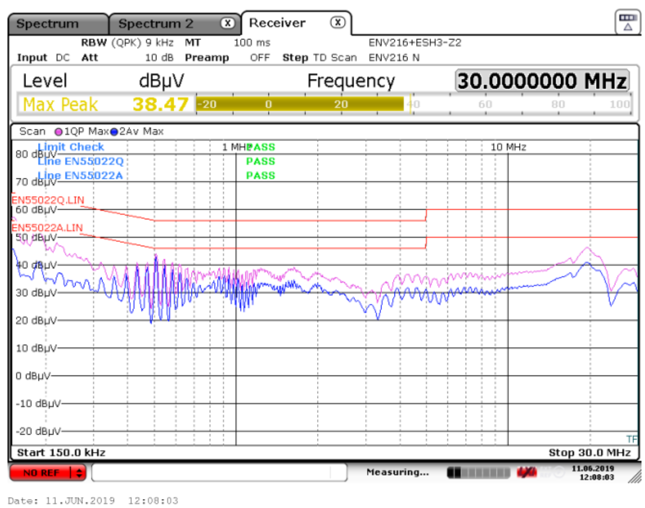


115 VAC$_{IN}$. 230 VAC$_{IN}$.

Figure 119 – Floating Ground EMI, 5 V / 3 A Load

18.1.2 Output: 9 V / 3 A

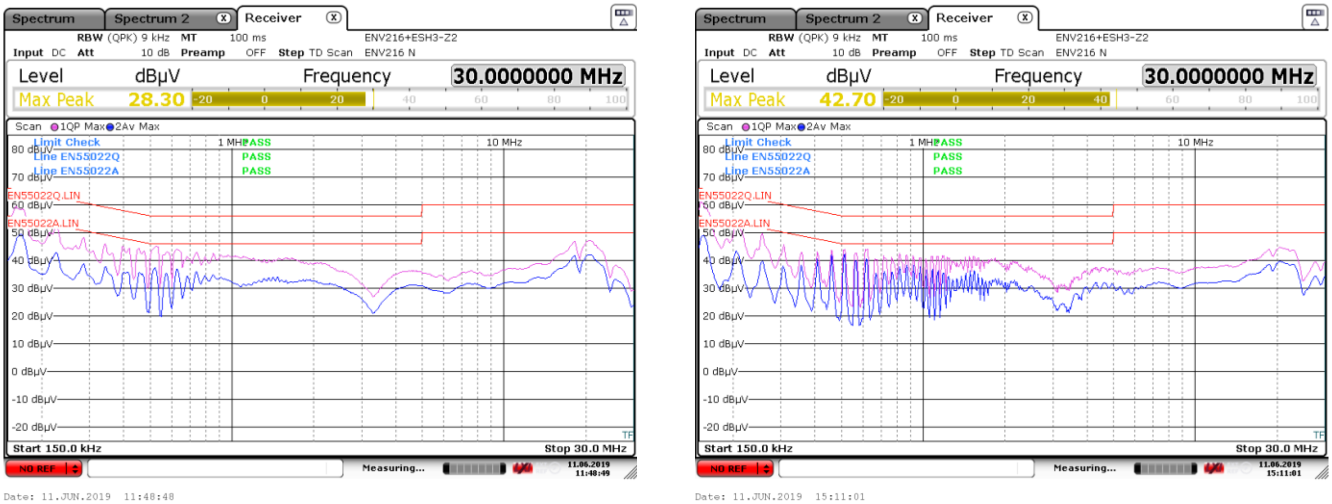




115 VAC$_{IN}$. 230 VAC$_{IN}$.

Figure 120 – Floating Ground EMI, 9 V / 3 A Load.

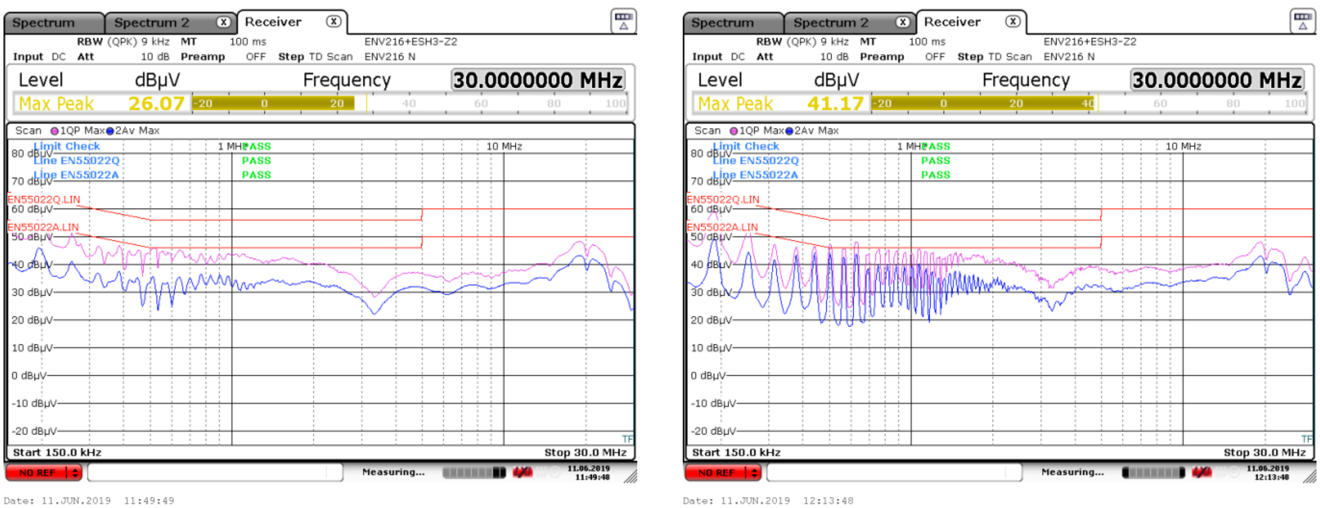
18.1.3 Output: 15 V / 3 A



115 VAC$_{IN}$. 230 VAC$_{IN}$.

Figure 121 – Floating Ground EMI, 15 V / 3 A Load.

18.1.4 Output: 20 V / 3 A



115 VAC$_{IN}$. 230 VAC$_{IN}$.

Figure 122 – Floating Ground EMI, 20 V / 3 A Load.

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

19 Combination Wave Surge

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

19.1 *Differential Mode Surge (L1 to L2), 230 VAC input*

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 20 V / 0 A (Pass/Fail)	Test Result 20 V / 3 A (Pass/Fail)
+1000	L1 to L2	0	Pass	Pass
-1000	L1 to L2	0	Pass	Pass
+1000	L1 to L2	90	Pass	Pass
-1000	L1 to L2	90	Pass	Pass
+1000	L1 to L2	180	Pass	Pass
-1000	L1 to L2	180	Pass	Pass
+1000	L1 to L2	270	Pass	Pass
-1000	L1 to L2	270	Pass	Pass

19.2 *Common Mode Surge (L1 to PE), 230 VAC input*

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 20 V / 0 A (Pass/Fail)	Test Result 20 V / 3 A (Pass/Fail)
+2000	L1 to PE	0	Pass	Pass
-2000	L1 to PE	0	Pass	Pass
+2000	L1 to PE	90	Pass	Pass
-2000	L1 to PE	90	Pass	Pass
+2000	L1 to PE	180	Pass	Pass
-2000	L1 to PE	180	Pass	Pass
+2000	L1 to PE	270	Pass	Pass
-2000	L1 to PE	270	Pass	Pass

19.3 *Common Mode Surge (L2 to PE), 230 VAC input*

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 20 V / 0 A (Pass/Fail)	Test Result 20 V / 3 A (Pass/Fail)
+2000	L2 to PE	0	Pass	Pass
-2000	L2 to PE	0	Pass	Pass
+2000	L2 to PE	90	Pass	Pass
-2000	L2 to PE	90	Pass	Pass
+2000	L2 to PE	180	Pass	Pass
-2000	L2 to PE	180	Pass	Pass
+2000	L2 to PE	270	Pass	Pass
-2000	L2 to PE	270	Pass	Pass

19.4 *Common Mode Surge (L1, L2 to PE), 230 VAC input*

Surge Level (V)	Injection Location	Injection Phase (°)	Test Result 20 V / 0 A (Pass/Fail)	Test Result 20 V / 3 A (Pass/Fail)
+2000	L1, L2 to PE	0	Pass	Pass
-2000	L1, L2 to PE	0	Pass	Pass
+2000	L1, L2 to PE	90	Pass	Pass
-2000	L1, L2 to PE	90	Pass	Pass
+2000	L1, L2 to PE	180	Pass	Pass
-2000	L1, L2 to PE	180	Pass	Pass
+2000	L1, L2 to PE	270	Pass	Pass
-2000	L1, L2 to PE	270	Pass	Pass

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

20 Electrostatic Discharge

The unit was tested with ±8 kV to ±16.5 kV air discharge and ±8.8 kV contact discharge at the positive and negative nodes of the output with 10 strikes for each condition.

A test failure was defined as a temporary interruption of output (Auto-restart), even if it is self-recoverable or needs operator intervention to recover, or a complete loss of function which is not recoverable.

20.1 *Contact Discharge, 230 VAC Input*

Discharge Voltage (kV)	ESD Strike Location (End of Type-C Cable)	Test Result 20 V / 0 A	Test Result 20 V / 3 A
+8.8	+VOUT	Pass	Pass
	GND	Pass	Pass
-8.8	+VOUT	Pass	Pass
	GND	Pass	Pass

20.2 *Air Discharge, 230 VAC Input*

Discharge Voltage (kV)	ESD Strike Location (End of Type-C Cable)	Test Result 20 V / 0 A	Test Result 20 V / 3 A
+8	+VOUT	Pass	Pass
	GND	Pass	Pass
-8	+VOUT	Pass	Pass
	GND	Pass	Pass
+10	+VOUT	Pass	Pass
	GND	Pass	Pass
-10	+VOUT	Pass	Pass
	GND	Pass	Pass
+12	+VOUT	Pass	Pass
	GND	Pass	Pass
-12	+VOUT	Pass	Pass
	GND	Pass	Pass
+14	+VOUT	Pass	Pass
	GND	Pass	Pass
-14	+VOUT	Pass	Pass
	GND	Pass	Pass
+16.5	+VOUT	Pass	Pass
	GND	Pass	Pass
-16.5	+VOUT	Pass	Pass
	GND	Pass	Pass

21 Voltage and Current Step Test using Quadramax and Total Phase Analyzer

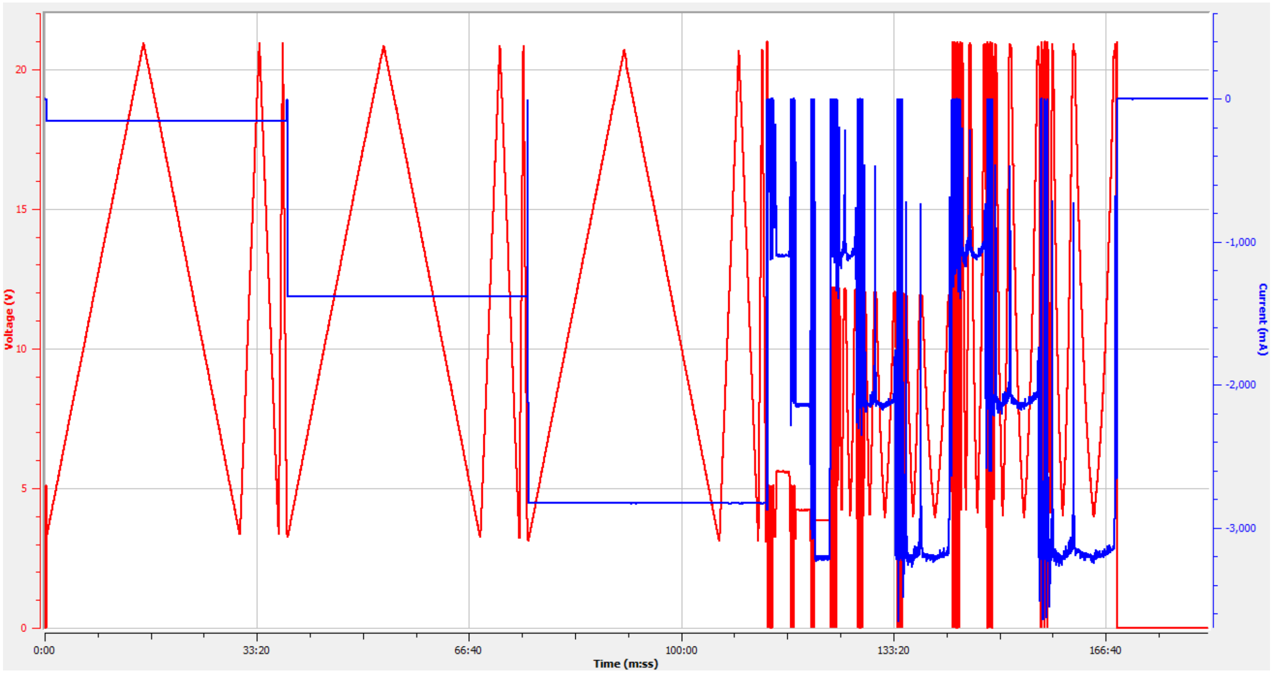


Figure 123 – Total Phase Plot for a Passing Result for VST and CLT Test in Quadramax.

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

22 Revision History

Date	Author	Revision	Description & Changes	Reviewed
24-Jul-19	AP	1.0	Initial Release.	Apps & Mktg
10-Sep-20	DB	1.1	Updated various Mfg Part numbers, Schematic Diagram, Circuit Description, and Transformer tape instructions.	Apps & Mktg
16-Sep-20	KM	1.2	Converted to RDR	Apps & Mktg
21-Sep-20	KM	1.3	Updated VR2 and D3, D6, D7, D8 in the BOM and Schematic.	Apps & Mktg

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