RD-05 65W 2C Charger Test Report

RD-5 Description

This reference design describes a 65 W dual port Type-C (2C) universal input offline power supply with programmable output voltage 5 V/3 A, 9 V/3 A, 12 V/3 A, 15 V/3 A, 20 V/3.25 A for single port and power sharing for dual port (5 V/3 A, 5 V/3 A; 9 V/3 A,9 V/3 A; 12V/2.5A, 12 V/2.5 A; 15 V/2 A, 15 V/2 A; 20 V/1.5 A, 20 V 1.5A. The power supply uses Silanna SZ1130-02 (Flyback PWM controller with integrated active clamp circuit) IC, Silanna SZPL3102A (High efficiency synchronous buck converter) and Cypress CYPD3175 USB PD controller. This design shows the high-power density and efficiency that can be achieved due to the high level of integration of the SZ1130-02 controller and high switching frequency operation of SZPL3102A synchronous buck controller.

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

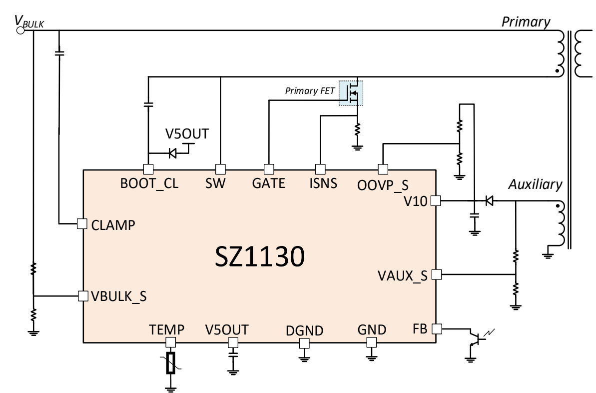
Key Specs	
Input	90-264 Vac
Output Voltages	5 V, 9 V, 12 V, 15 V, 20 V
Max Output Current	3 A @ 5 V, 9 V, 12 V, 15 V; 3.25 A @ 20 V
Max Output Power	65 W
Output Port	USB-PD 2C
Efficiency	>91% 65W Efficiency

SZ1130 Features

- Integrated High Voltage Active Clamp FET, Active Clamp Driver, and Start-up Regulator
- Capable of Over 93% Efficiency
- Flat Efficiency Across Universal (90-265 VAC) Input Voltage and Load
- Tight Switching Frequency Regulation for Improved Input EMI Filter Utilization
- Up to 140 kHz Switching Frequency Operation
- OptiMode™ Cycle-by-Cycle Adaptive Digital Control
- Multi-Mode Operation (Burst Mode, Quasi-Resonant, Valley Mode Switching)
- Advanced Valley Mode Switching for low EMI
- Self-Tuning Valley Detection
- OTP, UVLO, OVLO, PCL, OPP and OSCP Protections
- <50mW No Load Power Consumption of the IC
- Up to 65 W Output Power

SZ1130 Applications

- High-Power-Density USB-PD AC/DC Power Supplies

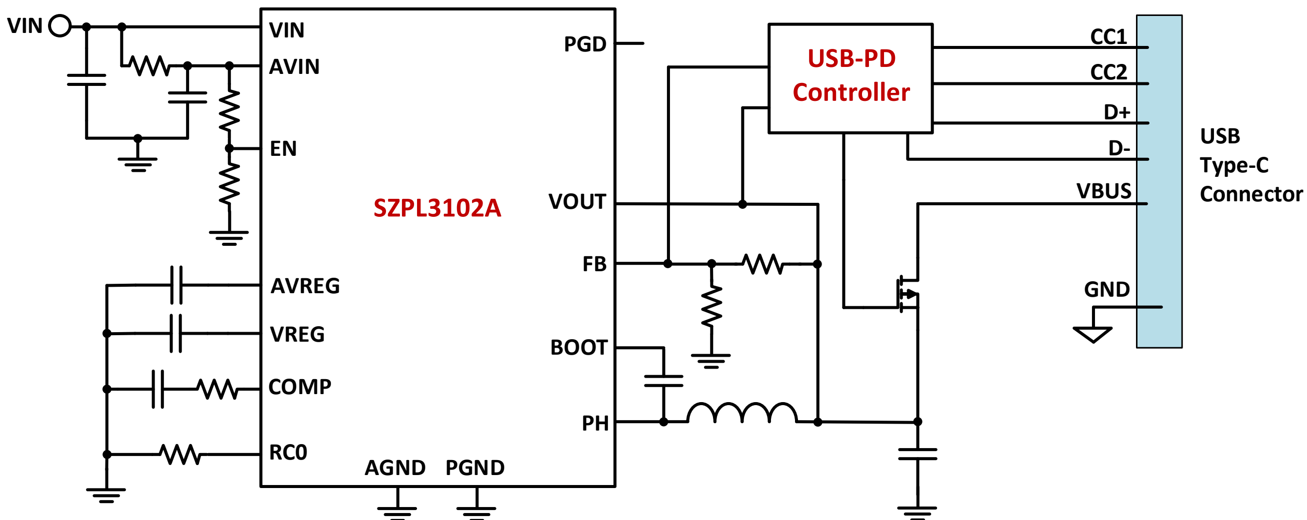


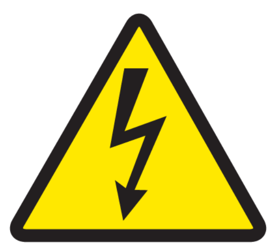
SZPL3102A Features

- Selectable Switching Frequency up to 2MHz
- Optimal High Efficiencies at 3.3 V to 21 V Vout
- Maximum Output Current of 3.25 A
- Wide Input Voltage Range: 7 V to 27 V
- Selectable Soft Start Times
- OCP/OVP/OTP Protections
- Programmable UVLO
- 3 mm x 3 mm QFN Package

SZPL3102A Applications

- VBUS Supply Generation for USB-PD Ports:
  - Multiple Output USB-PD Chargers
  - Charging Hubs
  - Displays and Televisions
  - Laptop Docking Stations
- High Voltage POL Supplies





Disclaimers:

1. **Caution – High Voltage Operation:** Lethal high voltages are present when this evaluation board is powered from AC mains. Improper contact with high voltages could lead to electrical shock, burn and/or fire hazards, risking property damage, personal injury, and death.
2. **Evaluation Purpose Only:** This evaluation board is intended for evaluation purpose only and not for commercial use. Care must be taken when testing the board, and an isolation transformer should be utilized.
3. **Patents:** The evaluation board design, along with circuits shown in this test report, may be covered by one or more U.S. and foreign existing/pending patents.

Contents

Tables

Power Supply Specifications

The reference design performance data presented in this report meets the power supply specifications listed in the following table.

Table 1: Key Specifications

Description	Symbol	Min.	Typ.	Max.	Units	Comments
Input						
Voltage	V_{in}	90	115/230	265	Vac	2 Wire Input
Frequency	f_{line}	47	60/50	63	Hz	
Output A & Output B						
Voltage (5 V)	V_{out_5V}	4.75	5.0	5.25	V	± 5%
Ripple (5 V)	V_{ripple_5V}			200	mV	20 MHz BW (End of Cable)
Voltage (9 V)	V_{out_9V}	8.55	9	9.45	V	± 5%
Ripple (9 V)	V_{ripple_9V}			200	mV	20 MHz BW (End of Cable)
Voltage (12 V)	V_{out_12V}	11.4	12	12.6	V	± 5%
Ripple (12V)	V_{ripple_12V}			200	mV	20 MHz BW (End of Cable)
Voltage (15 V)	V_{out_15V}	14.25	15	15.75	V	± 5%
Ripple (15 V)	V_{ripple_15V}			200	mV	20 MHz BW (End of Cable)
Voltage (20 V)	V_{out_20V}	19	20	21	V	± 5%
Ripple (20 V)	V_{ripple_20V}			200	mV	20 MHz BW (End of Cable)
Max. Current (5 / 9 / 12 / 15 V)	I_{out_max}			3	A	Single Port
Max Current (20 V)	I_{out_max}			3.25	A	Single Port
Max. Current (5 / 9 / 12 / 15 / 20 V)	I_{out_max}			1.5	A	Dual Port
Total Output Power Continuous	P_{out}			65	W	
4-Point Ave Efficiency						
5 V / 3A	η_{ave_5V}	77.0	83.3		%	U.S. DOE Level VI 4-point (25%, 50%, 75%, 100%) average efficiency, 115VAC Input
9 V / 3A	η_{ave_9V}	81.4	87.2		%	
12 V / 3A	η_{ave_12V}	83.6	88.7		%	
15 V / 3A	η_{ave_15V}	85.3	89.8		%	
20 V / 3.25A	η_{ave_20V}	86.0	91.2		%	
No-Load Input Power	P_{in}		163.2	300	mW	115Vac, 60Hz
Programmable Output Voltage	V_{OUT}	5		20	V	
Conducted and Radiated EMI	Meets CISPR22B/EN55022					
Ambient Temperature	T_{AMB}	0		40	˚C	No airflow, sea level.

NOTE: The circuit board needs to be evaluated for additional tests, such as ESD and Line Surge to use the evaluation board design presented in this test report as a charger/adapter. Furthermore, the layout of the board needs to be adjusted according to the target shape and form factor of the end application.

Board Pictures

Figure 1: Top Side

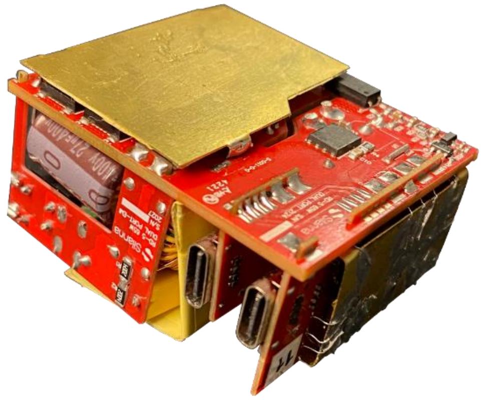


Figure 2: Isometric View

Schematics

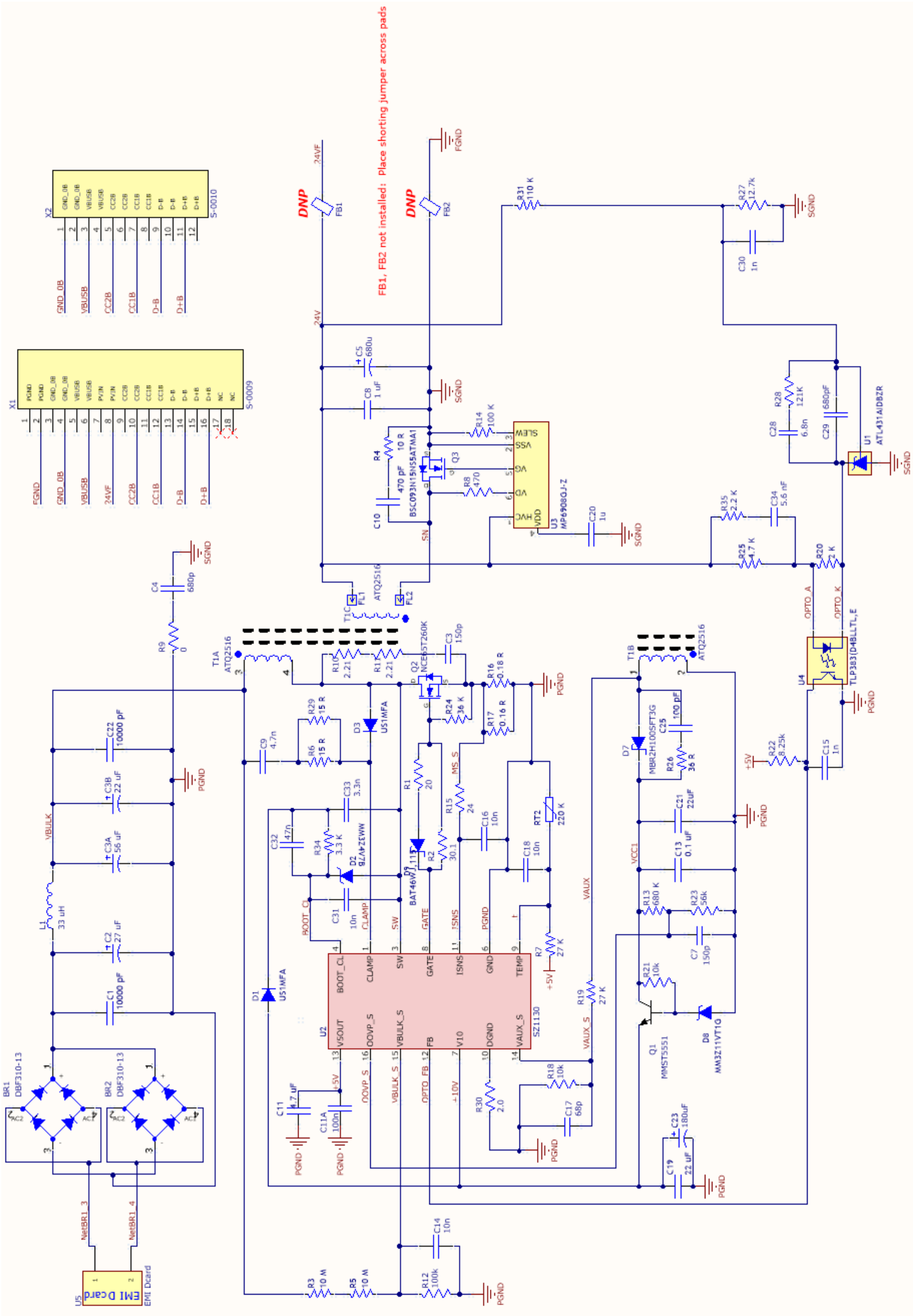


Figure 3: Main Board Schematic

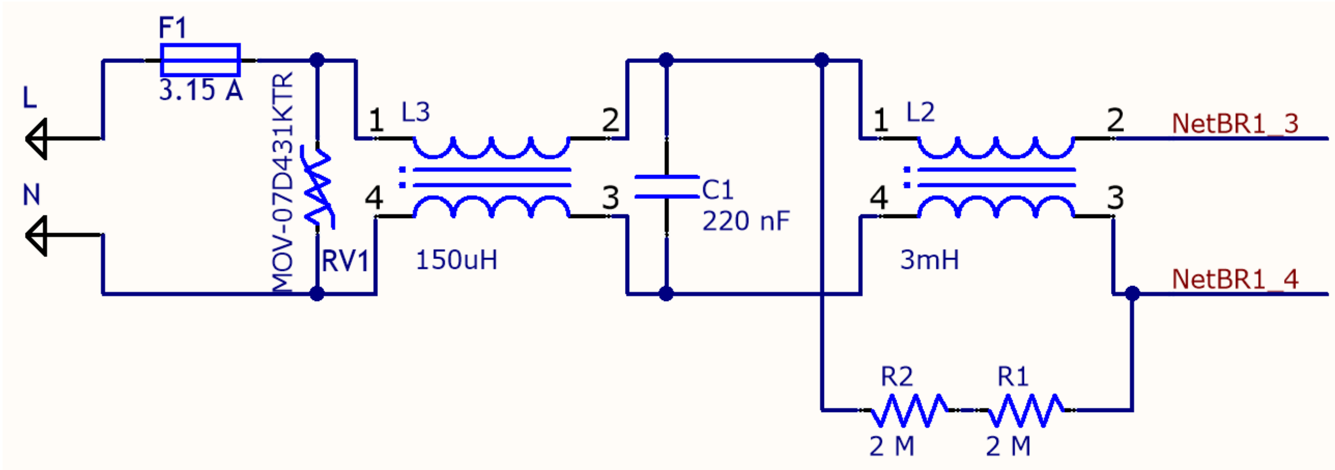


Figure 4: EMI Board

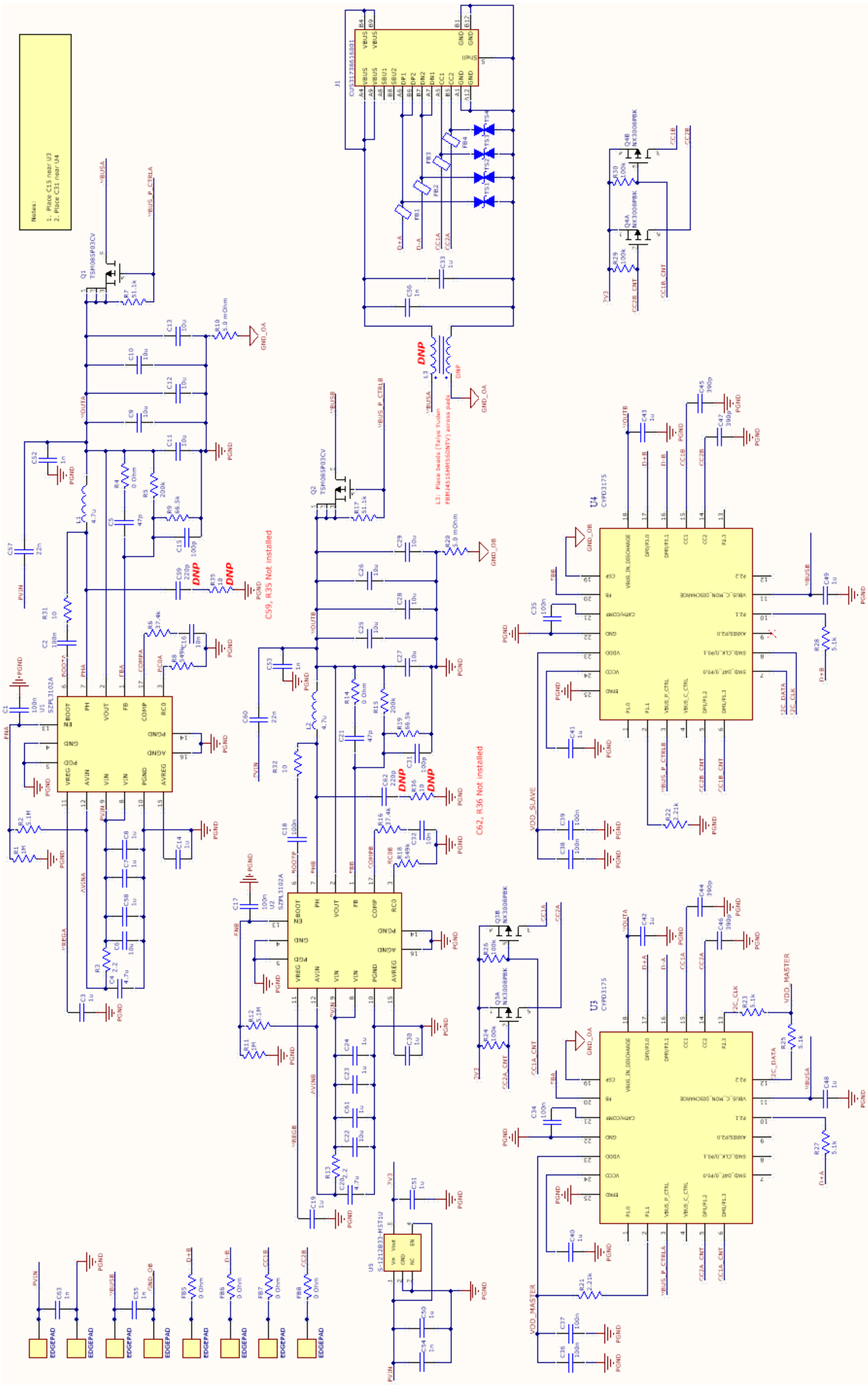


Figure 5: DC-DC Board

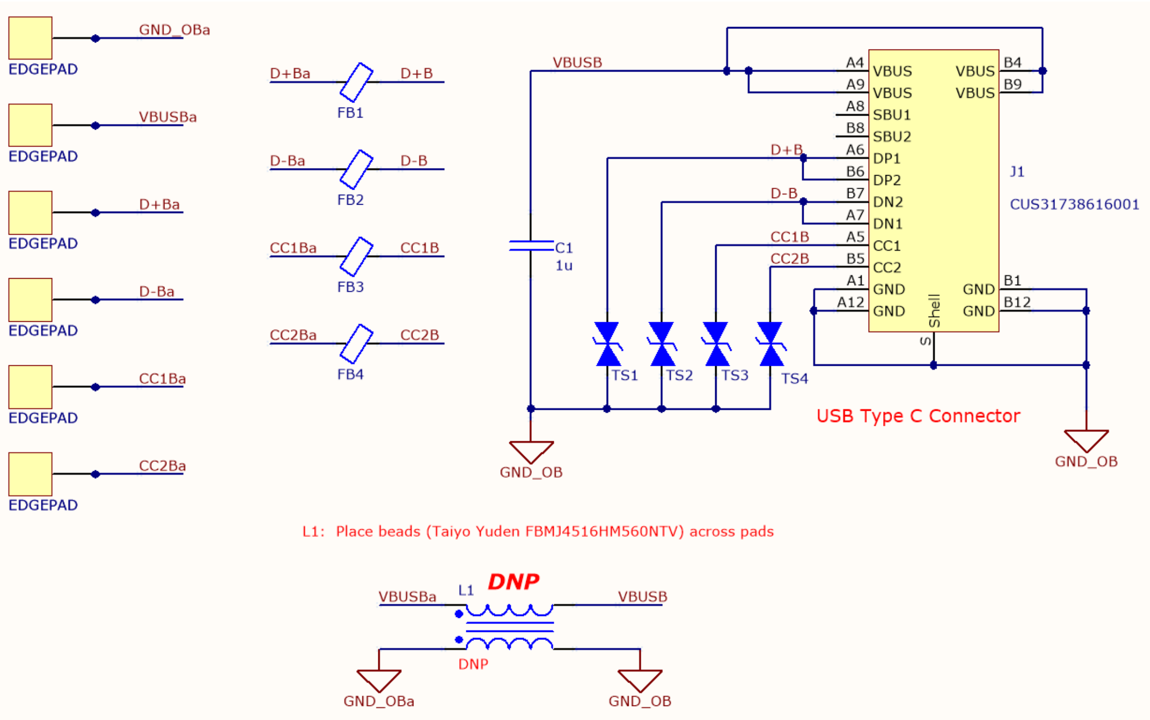


Figure 6: Port B Connector Board

PCB Layout

PCB Prints

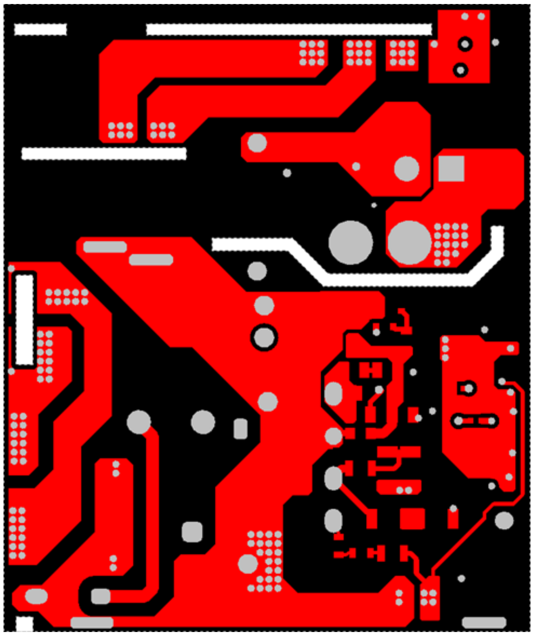


Figure 7: PCB layout, Main board top layer

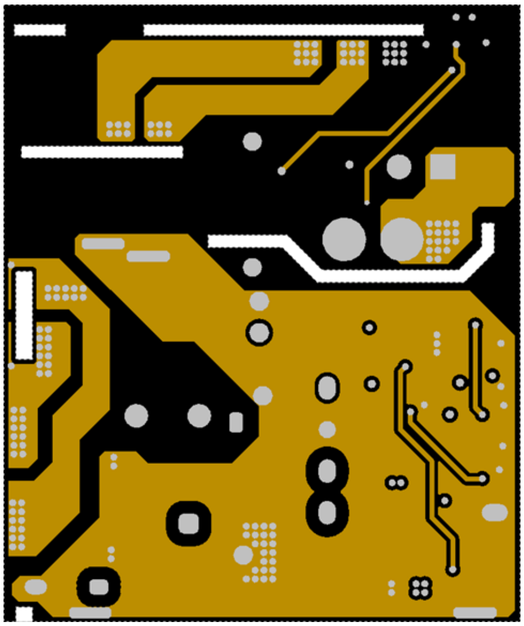


Figure 8: PCB layout, Main board middle1 layer

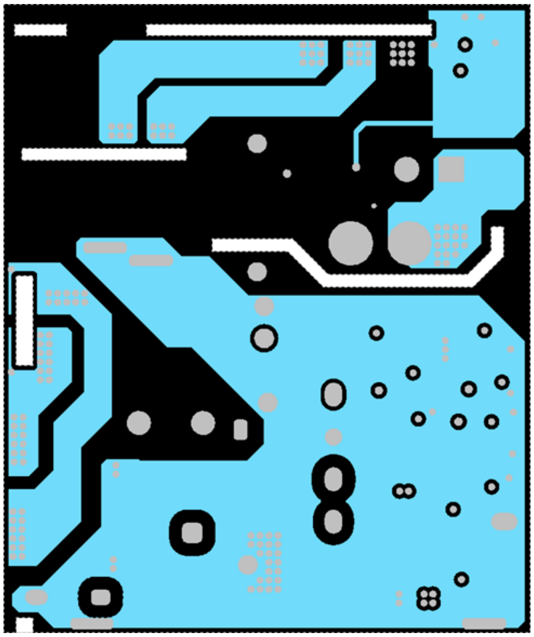


Figure 9: PCB layout, Main board middle2 layer

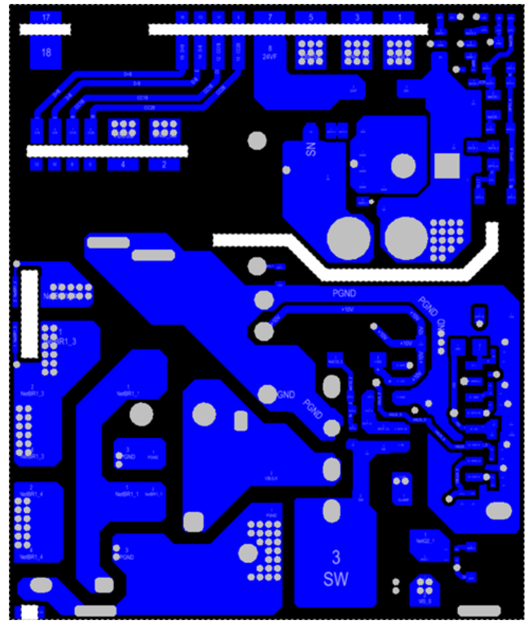


Figure 10: PCB layout, Main board bottom layer

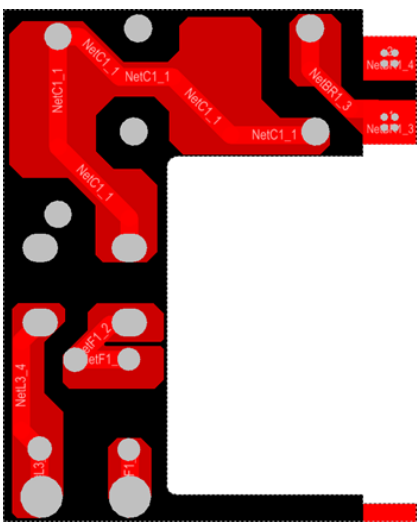


Figure 11: PCB layout, EMI board top layer

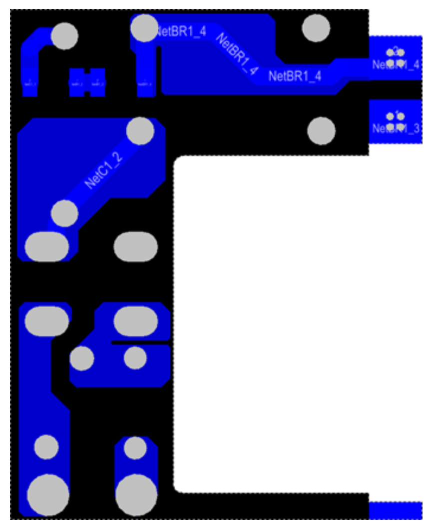


Figure 12: PCB layout, EMI board bottom layer

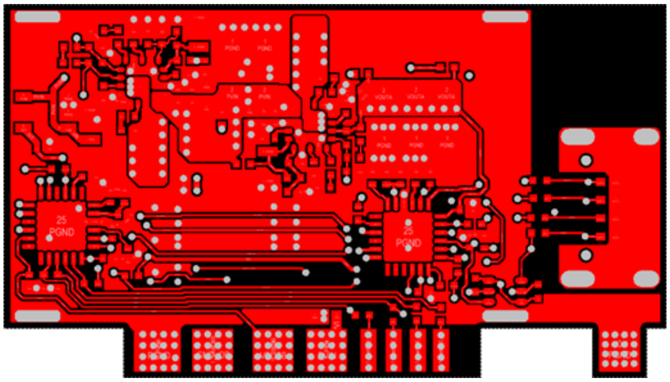


Figure 13: PCB layout, DC-DC board top layer

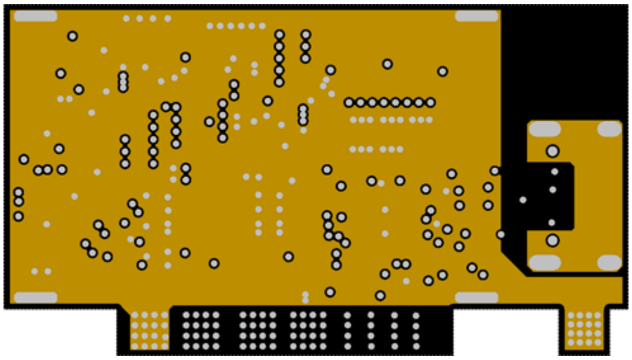


Figure 14: PCB layout, DC-DC board inner layer 1

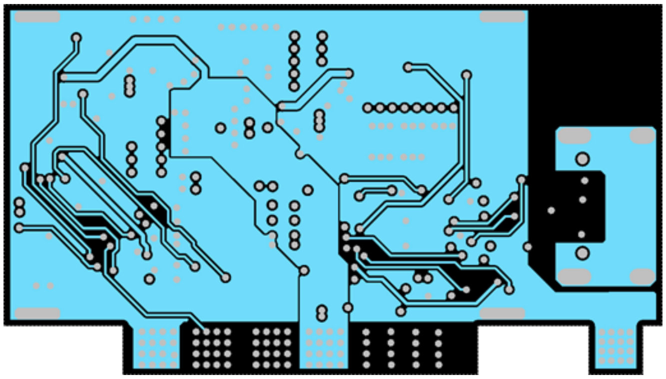


Figure 15: PCB layout, DC-DC board inner layer 2

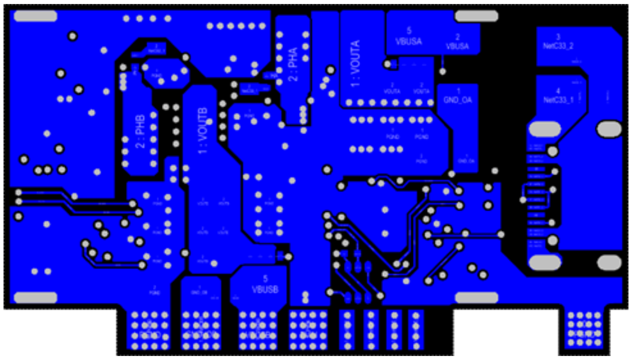


Figure 16: PCB layout, DC-DC board bottom layer

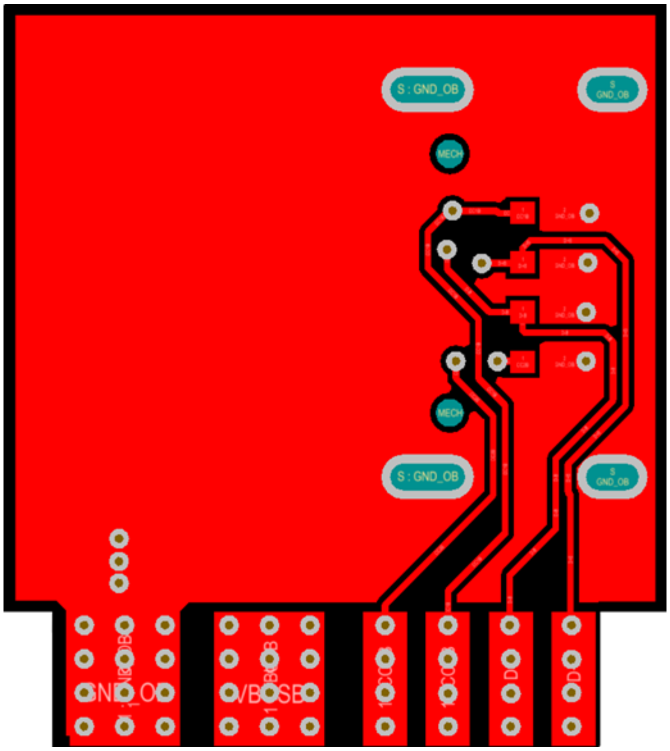


Figure 17: PCB layout, Port B Connector Board top layer

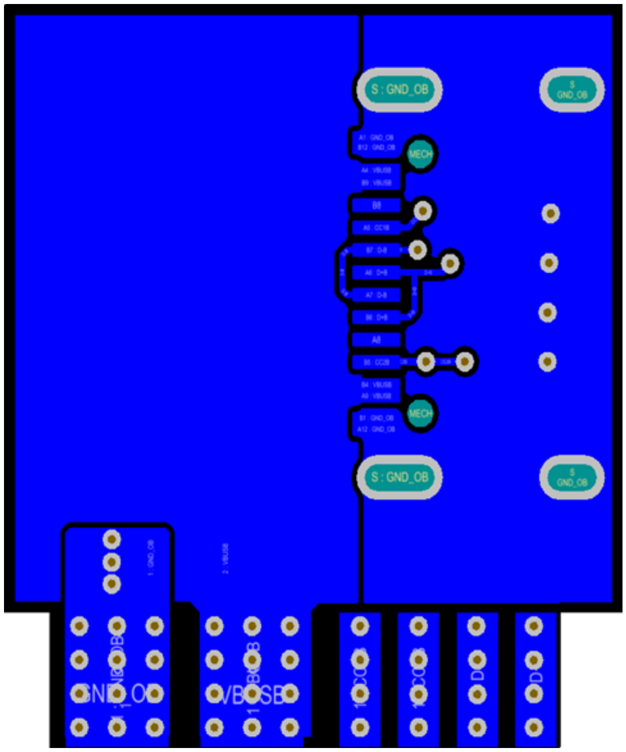


Figure 18: PCB layout, Port B Connector Board bottom layer

Bill of Materials (BOM)

Table 2: ACDC Board BOM

Description	Manufacturer	Manufacturer Part #	Designator	Qty
BRIDGE RECT 1PHASE 1KV 3A DBF	Diodes Incorporated	DBF310-13	BR1, BR2	2
CAP CER 10000PF 630V X7R 1206	KEMET	C1206C103KBRACTU	C1	1
CAP ALUM 27UF 20% 400V T/H	YMIN	KCX(27UF-10X15P5)	C2	1
Capacitor, 150pF, 500V, C0G, NP0, 0805	KEMET	C0805C151JCGACAUTO	C3	1
CAP ALUM 56UF 20% 400V T/H	YMIN	KCX(56UF-13X19P5)	C3A	1
CAP ALUM 22UF 20% 400V T/H	YMIN	KCX(22UF-8X18P3.5)	C3B	1
Capacitor, 680pF, 250Vac, X1, Y1	Murata Electronics	DE1B3RA681KN4AN01F	C4	1
Solid Al Poly, 680uF, 25V, 20% TH Radial	Kemet	A750KW687M1EAAE016	C5	1
Capacitor, 150pF, 50V, NP0, G0G, 0402	Yageo	CC0402JRNPO9BN151	C7	1
CAP CER 1UF 35V X7R 0603	Taiyo Yuden	GMK107AB7105KAHT	C8	1
Capacitor, 4.7nF, 500V, X7R, 0805	Yageo	AC0805KRX7RBBB472	C9	1
CAP CER 470PF 200V X7R 0805	Yageo	CC0805KRX7RABB471	C10	1
CAP CER 4.7UF 25V X6S 0603	Murata Electronics	GRM188C81E475KE11D	C11	1
Capacitor, 100nF,50V, X7R, 0603	Murata Electronics North America	GRM188R71H104KA93D	C11A	1
CAP CER 0.1UF 50V X7R 0603	Samsung Electro-Mechanics	CL10B104KB8NNNC	C13	1
Capacitor, 10nF, 50V, X7R, 0402	Murata Electronics North America	GRM155R71H103KA88D	C14, C16, C18	3
Capacitor, 1nF, 25V, NPO, 0402	Murata Electronics North America	GRM1555C1E102JA01D	C15	1
Capacitor, 68pF, 50V, NP0, G0G, 0402	Yageo	AC0402JRNPO9BN680	C17	1
CAP CER 22UF 16V X6S 0805	Murata Electronics	GRM21BC81C226ME44L	C19	1
Capacitor, 1uF, 35V, X5R, 0402	Murata Electronics North America	GRM155R6YA105ME11D	C20	1
CAP CER 22UF 16V X6S 1206	TDK Corporation	C3216X6S1C226M160AC	C21	1
CAP CER 10000PF 630V X7R 1206	KEMET	C1206C103KBRACTU	C22	1
CAP ALUM 180UF 20% 16V RADIAL	Nichicon	UPM1C181MED1TD	C23	1
CAP CER 100PF 250V C0G/NP0 0805	KEMET	C0805C101JAGAC7800	C25	1
Capacitor, 6.8nF, 50V, X7R, 0603	Samsung Electro-Mechanics	CL10B682JB8NNNC	C28	1
Capacitor, 680pF, 50V, X7R, 0603	Vishay Vitramon	VJ0603Y681KXACW1BC	C29	1
CAP CER 1000PF 50V C0G 0402	TDK	C1005C0G1H102J050BA	C30	1
Capacitor, 10nF, 50V, X7R, 0603	Murata Electronics North America	GRM188R71H103KA01D	C31	1
Capacitor, 47nF, 50V, X7R, 0603	YAGEO	CC0603JRX7R9BB473	C32	1
Capacitor, 3.3nF, 50V, X7R, 0603	KEMET	C0603C332J5RACTU	C33	1
CAP CER 5600PF 25V X7R 0603	KEMET	C0603C562K3RAC7867	C34	1
DIODE GEN PURP 1KV 1A SOD123FA	ON Semiconductor	US1MFA	D1, D3	2
DIODE ZENER 4.7V 200MW SOD323F	ON Semiconductor	MM3Z4V7B	D2	1
DIODE SCHOTTKY 100V 2A SOD123FL	ON Semiconductor	MBR2H100SFT3G	D7	1
DIODE ZENER 11V 300MW SOD323	ON Semiconductor	MM3Z11VT1G	D8	1
DIODE SCHOTTKY 100V 250MA SOD323	Nexperia USA Inc.	BAT46WJ,115	D9	1
CUSTOM FIXED IND 33UH T/H FOR RD-5 65W L1	Custom	Custom	L1	1
Transistor, NPN, 160V, 200mA, MMST5551-TP, SOT-323	Diodes Incorporated	MMST5551-TP	Q1	1

Description	Manufacturer	Manufacturer Part #	Designator	Qty
MOSFET N-CH 650V 0.22OHM 15A TO-252	NCE Power	NCE65T260K	Q2	1
MOSFET N-CH 150V 87A TDSON-8	Infineon Technologies	BSC093N15NS5ATMA1	Q3	1
Resistor, 20 ohm, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0720RL	R1	1
Resistor, 30.1 ohm, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0730R1L	R2	1
RES SMD 10M OHM 0.5% 1/4W 1206	Vishay Dale	CRCW120610M0DHEAP	R3, R5	2
RES 10 OHM 1% 1/4W 0805	Stackpole Electronics Inc	RNCP0805FTD10R0	R4	1
RES 15 OHM 1% 1/2W 1206	Stackpole Electronics Inc	RNCP1206FTD15R0	R6, R29	2
RES SMD 27K OHM 1% 1/8W 0805	Yageo	RC0805FR-0727KL	R7, R19	2
Resistor, 470 ohm, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-07470RL	R8	1
Resistor, 0ohm, 0603	Yageo	RC0603JR-070RL	R9	1
Resistor, 2.21ohm, 0603, 0.1W, Thick Film, +-200ppm/C	Yageo	RC0603FR-072R2L	R10, R11	2
Resistor, 100k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-07100KL	R12	1
RES SMD 680K OHM 1% 1/8W 0805	Yageo	RC0805FR-07680KL	R13	1
RES SMD 100K OHM 1% 1/16W 0402	Yageo	RC0402FR-07100KL	R14	1
Resistor, 24 ohm, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0724RL	R15	1
RES 0.18 OHM 1% 1/4W 1206	Yageo	RL1206FR-070R18L	R16	1
RES 0.16 OHM 1% 1/2W 1206	TE Connectivity Passive Product	RLP73K2BR16FTDF	R17	1
Resistor, 10k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0710KL	R18	1
RES SMD 2K OHM 1% 1/10W 0603	Yageo	RC0603FR-072KL	R20	1
Resistor, 10k, 0603, 0.1W, Thick film, +-100ppm/C	Yageo	RC0603FR-0710KL	R21	1
Resistor, 8.25k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-078K25L	R22	1
Resistor, 56k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0756KL	R23	1
RES 36K OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT36K0	R24	1
RES SMD 4.7K OHM 1% 1/16W 0402	Yageo	RC0402FR-074K7L	R25	1
RES SMD 36 OHM 1% 1/8W 0805	Yageo	RC0805FR-0736RL	R26	1
Resistor,12.7k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0712K7L	R27	1
Resistor, 121k, 0805, 1%, Thick film, 1/8W	Panasonic Electronic Components	ERJ-6ENF1213V	R28	1
Resistor, 2.0 ohm, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-072RL	R30	1
RES SMD 110K OHM 1% 1/10W 0603	Yageo	RC0603FR-07110KL	R31	1
RES SMD 3.3K OHM 1% 1/10W 0603	Yageo	RC0603FR-073K3L	R34	1
RES 2.2K OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT2K20	R35	1
NTC THERMISTOR 220K 1% 0402	Panasonic Electronic Components	ERT-J0EV224F	RT2	1
Transformer, ATQ for RD-05	Custom	Custom	T1	1
IC VREF SHUNT 36V 1% SOT23-3	Texas Instruments	ATL431AIDBZR	U1	1
Flyback PWM Controller with Integrated Active Clamp Circuit	Silanna Semiconductor	SZ1130	U2	1
FAST TURN-OFF INTELLIGENT RECTIFIER	Monolithic Power Systems Inc.	MP6908GJ-Z	U3	1
OPTOISO 5KV TRANSISTOR SO6L	Toshiba Semiconductor and Storage	TLP383(D4BLLTL,E	U4	1

Table 3: EMI Daughter Board BOM

Description	Manufacturer	Manufacturer Part Number	Designator	Qty
CAP FILM 220NF 10% 310V RAD	Weidy Industrial Electronic	W42Q3224KK6L00F0	C1	1
FUSE BRD MNT 3.15A 250VAC RADIAL	Bel Fuse Inc.	RST 3.15-BULK	F1	1
CUSTOM CMC 3MH FOR RD-5 65W L2	Custom	Custom	L2	1
CUSTOM CMC 150UH FOR RD-5 65W L3	Custom	Custom	L3	1
RES SMD 2M OHM 1% 1/4W 1206	Yageo	RC1206FR-072ML	R1, R2	2
VARISTOR 275VAC 1.2KA DISC 7MM	Bourns Inc.	MOV-07D431KTR	RV1	1

Table 4: DCDC Main Board BOM

Description	Manufacturer	Manufacturer Part Number	Designator	Qty
Capacitor, 100nF,50V, X7R, 0402	TDK	C1005X7R1H104K050BB	C1, C2, C17, C18, C34, C35, C36, C37, C38, C39	10
Capacitor, 1uF, 35V, X5R, 0402	Murata Electronics North America	GRM155R6YA105ME11D	C3, C7, C8, C14, C19, C23, C24, C30, C40, C41, C42, C43, C48, C49, C51	15
Capacitor, 4.7uF, 50V, X5R, 0805	Murata Electronics North America	GRT21BR61H475KE13L	C4, C20	2
Capacitor, 47pF, 50V, NPO, 0402	Murata Electronics North America	GCM1555C1H470JA16D	C5, C21	2
Capacitor, 10uF, 50V, X7R, 1206	TDK	CGA5L1X7R1H106K160AC	C6, C9, C10, C11, C12, C13, C22, C25, C26, C27, C28, C29	12
Capacitor, 100pF, 16V, NPO, 0402	KEMET	C0402C101K4GACTU	C15, C31	2
Capacitor, 10nF, 50V, X7R, 0402	Murata Electronics North America	GRM155R71H103KA88D	C16, C32	2
Capacitor, 1uF, 50V, X7R, 0805	Murata Electronics North America	GCM21BR71H105KA03K	C33, C50	2
Capacitor, 390pF, 50V, NPO, 0402	TDK Corporation	CGA2B2C0G1H391J050BA	C44, C45, C46, C47	4
Capacitor, 1nF, 50V, X7R, 0402	TDK Corporation	C1005X7R1H102K050BA	C52, C53, C54	3
Capacitor, 1nF, 50V, X7R, 0603	Murata Electronics North America	GRM188R71H102KA01D	C55, C56, C63	3
Capacitor, 22nF, 50V, X7R, 0402	Murata Electronics North America	GRM155R71H223KA12J	C57, C60	2
Capacitor, 1uF, 35V, X6S, 0603	Murata Electronics	GRT188C8YA105KE13D	C58, C61	2
Ferrite Bead 0402, 200mA, 1.8k @ 1MHz 2.2Ohm DC	Murata Electronics	BLM15HD182SZ1D	FB1, FB2, FB3, FB4	4
Resistor, 0 ohm, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402JR-070RL	FB5, FB6, FB7, FB8	4
CONN USB-C FEMALE 16P SMT	CSCONN	CUS31738616001	J1	1
Inductor, 4.7uH, 12.1A, 15.02mohm	Coilcraft	XEL6060-472MEB	L1, L2	2
MOSFET P-CH 30V 64A, 8.2mohm, PDFN33	TSMC	TSM085P03CV RGG	Q1, Q2	2
Mosfet Array 2 P-Channel (Dual) 30V 200mA 445mW Surface Mount 6-TSSOP	Nexperia USA Inc.	NX3008PBKS,115	Q3, Q4	2
Resistor, 1M, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-071ML	R1, R11	2
Resistor, 5.1M, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402JR-075M1L	R2, R12	2

Description	Manufacturer	Manufacturer Part Number	Designator	Qty
Resistor, 2.2 ohm, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-072R2L	R3, R13	2
Resistor, 0 ohm, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402JR-070RL	R4, R14	2
Resistor, 200k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-07200KL	R5, R15	2
Resistor, 37.4k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0737K4L	R6, R16	2
Resistor, 51.1k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0751K1L	R7, R17	2
Resistor, 549k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-07549KL	R8, R18	2
Resistor, 66.5k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0766K5L	R9, R19	2
Resistor, 5.0 mOhm, 1206, 2%, Thick film, 3/4W	Susumu	KRL1632E-M-R005-G-T5	R10, R20	2
Resistor, 2.21k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-072K21L	R21, R22	2
Resistor, 5.1k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-075K1L	R23, R25, R27, R28	4
Resistor, 100k, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-07100KL	R24, R26, R29, R30	4
Resistor, 10 ohm, 0402, 1/16W, Thick Film, +-100ppm/C	Yageo	RC0402FR-0710RL	R31, R32	2
TVS DIODE 5V SOD882	STMicroelectronics	ESDALC5-1BM2	TS1, TS2, TS3, TS4	4
Synchronous Buck Converter, 65W	Silanna Semiconductor	SZPL3102A	U1, U2	2
USB TYPE-C Controller, 24QFN	Cypress Semiconductor Corp	CYPD3175-24LQXQ	U3, U4	2
IC Reg Linear, 3.3V, 250mA, SOT23-5	ABLIC U.S.A. Inc.	S-1212B33-M5T1U	U5	1
Ferrite Bead 1806, 6A, 56ohm @ 1MHz, 7mOhm DC	Taiyo Yuden	FBMJ4516HM560NTV	N/A See note below	2

****The FBMJ4516HM560NTV are to be installed on the pads for L3 on the schematic. See schematic note.**

Table 5: DCDC Daughter Board BOM

Description	Manufacturer	Manufacturer Part Number	Designator	Qty
Capacitor, 1uF, 50V, X7R, 0805	Murata Electronics North America	GCM21BR71H105KA03K	C1	1
Ferrite Bead 0402, 100mA, 1.8k @ 1MHz1.4Ohm DC	Murata Electronics	BLM15BD182SN1D	FB1, FB2, FB3, FB4	4
CONN USB-C FEMALE 16P SMT	CSCONN	CUS31738616001	J1	1
TVS DIODE 5V SOD882	STMicroelectronics	ESDALC5-1BM2	TS1, TS2, TS3, TS4	4
Ferrite Bead 1806, 6A, 56ohm @ 1MHz, 7mOhm DC	Taiyo Yuden	FBMJ4516HM560NTV	N/A See note below	2

****The FBMJ4516HM560NTV are to be installed on the pads for L3 on the schematic. See schematic note.**

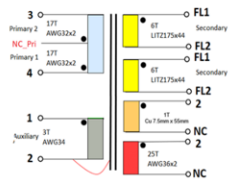
Table 6: Mechanicals BOM

Description	Manufacturer	Manufacturer Part Number	Designator	Qty
Case, 2 piece 3D printed	-	-	-	1
Brass Heat spreader for case	-	-	-	1
ITW Formex GK-17 insulator for case	-	-	-	1
Copper heat spreader for main board	-	-	-	1
Copper heat spreader for DC-DC board	-	-	-	1

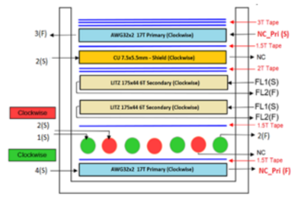
Description	Manufacturer	Manufacturer Part Number	Designator	Qty
Thermal interface material	Bergquist	TGF-3600	-	5g
Hookup wire	-	-	-	8in.
AC terminal prongs	-	-	-	2

Transformer Specification

Pinout



Electrical



Stackup

ELECTRICAL TEST PARAMETERS:

INDUCTANCE @ 100kHz/0.1VAC
L(1-2) =400uH ±5%

INDUCTANCE @ 100kHz/0.1VAC
SHORT PINTS: FL1, FL2
LL(1-2) = 8uH MAX

TURNS RATIO/POLARITY
APPLY: 1.00V @ 10kHz TO PINS (1-2)
Primary:Auxiliary = 0.083V ±3%
Primary:Secondary = 0.166V ±3%

DC RESISTANCE OHMS (Ω) @ 25°C
DCR: (1-2) = 0.6Ω MAX

DCR: (4-5)=0.2Ω MAX

DCR: (FL1-FL2) = 0.01Ω MAX

Winding Specification

Winding	1	2-a	2-b	3	4	5	6
Material*	AWG32	AWG34	AWG36	LITZ 175x44	LITZ 175x44	Copper	AWG32
Turns	17	3	25	6	6	1	17
Parallel wires	2	1	2	1	1	1	2
Layers	1	1	1	1	1	1	1
Start Pin	4	1	2	FL1	FL1	2	NC_Pri
End Pin	NC_Pri	2	NC	FL2	FL2	NC	3
	PRI1 - First half of primary	Aux and shield		Secondary_1	Secondary_2	PRI2 - Second half of primary	PRI1 - Second half of primary
Shielding	1.5T Tape A	1.5T Tape A	No Tape	2T Tape A	1.5T Tape A	3T Tape A	

Note1 : 2-a and 2-b are wound bifilar. Temporary start 2b at pin 4 then transfer to pin5 after winding. Temporary terminate 2a to pin2 and transfer to pin5 after winding.
Note2 : Start FL1 from the primary side.

Table 7: Transformer Material Lists

Material	*Specification*	*Manufacturer*	*Mfr. Part Number*
Bobbin	ATQ2516 - long pin version	Various	
Core	gap for 450uH (3C95 or equivalent)		
AWG32	Magnet wire, dual insulation layer	Various	
AWG34	Magnet wire, dual insulation layer	Various	
AWG36	Magnet wire, dual insulation layer	Various	
TIW	Litz AWG44 x 175 strand	Rubadue or equivalent	TXXL175/44FXXX-2
Copper	Copper sheet	Various	
TAPE	Insulating Tape	3M or equivalent	

Performance Data

Electrical Data

Efficiency

The following tables detail 5 V, 9 V, 12V, 15 V and 20 V efficiency results at 115Vac and 230Vac. Measurements taken via breakout board (after connector, before cable drop). Resistive drops of the breakout board contribute significantly to the efficiency results; approximately 250mW loss at 3A load.

115 Vac 4-point average efficiency

$V_{OUT\ A}$ / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	84.87	83.48
75	84.93	
50	83.95	
25	80.18	
10	75.86	

$V_{OUT\ A}$ / I_{LOAD_MAX} = 9 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	88.53	87.21
75	88.55	
50	87.66	
25	84.11	
10	79.81	

$V_{OUT\ A}$ / I_{LOAD_MAX} = 12 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	89.62	88.71
75	89.79	
50	89.14	
25	86.29	
10	81.55	

$V_{OUT\ A}$ / I_{LOAD_MAX} = 15 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	90.53	89.79
75	90.64	
50	90.31	
25	87.68	
10	83.31	

$V_{OUT\ A}$ / I_{LOAD_MAX} = 20 V / 3.25 A

%LOAD	Efficiency	Average Efficiency
100	91.07	91.24
75	91.8	
50	91.81	
25	90.28	
10	85.27	

$V_{OUT\ B}$ / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	84.22	83.08
75	84.41	
50	83.61	
25	80.1	
10	75.64	

$V_{OUT\ B}$ / I_{LOAD_MAX} = 9 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	88.25	87.12
75	88.37	
50	87.6	
25	84.25	
10	79.89	

$V_{OUT\ B}$ / I_{LOAD_MAX} = 12 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	89.57	88.75
75	89.73	
50	89.19	
25	86.49	
10	82.02	

$V_{OUT\ B}$ / I_{LOAD_MAX} = 15 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	90.52	89.89
75	90.71	
50	90.44	
25	87.9	
10	83.73	

$V_{OUT\ B}$ / I_{LOAD_MAX} = 20 V / 3.25 A

%LOAD	Efficiency	Average Efficiency
100	91.09	91.16
75	91.63	
50	91.66	
25	90.28	
10	85.18	

230 Vac 4-point average efficiency

$V_{OUT\ A}$ / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	81.58	79.78
75	80.92	
50	79.8	
25	76.81	
10	71.81	

$V_{OUT\ A}$ / I_{LOAD_MAX} = 9 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	86.68	84.06
75	85.67	
50	83.78	
25	80.09	
10	76.04	

$V_{OUT\ A}$ / I_{LOAD_MAX} = 12 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	89.01	86.24
75	88.1	
50	85.91	
25	81.94	
10	78.33	

$V_{OUT\ A}$ / I_{LOAD_MAX} = 15 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	90.37	87.88
75	89.73	
50	87.87	
25	83.55	
10	79.73	

$V_{OUT\ A}$ / I_{LOAD_MAX} = 20 V / 3.25 A

%LOAD	Efficiency	Average Efficiency
100	91.53	90.2
75	91.64	
50	90.64	
25	86.99	
10	80.95	

$V_{OUT\ B}$ / I_{LOAD_MAX} = 5 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	81.01	79.61
75	80.59	
50	79.78	
25	77.07	
10	72.1	

$V_{OUT\ B}$ / I_{LOAD_MAX} = 9 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	86.6	84.03
75	85.57	
50	83.74	
25	80.2	
10	76.37	

$V_{OUT\ B}$ / I_{LOAD_MAX} = 12 V / 3 A

%LOAD	Efficiency	Average Efficiency
100	88.95	86.19
75	87.98	
50	85.83	
25	82.02	
10	78.46	

$V_{OUT\ B}$ / I_{LOAD_MAX} = 15 V / 3 A

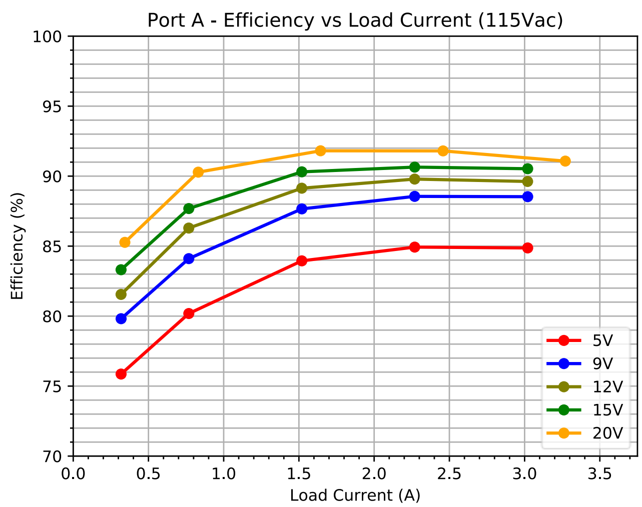
%LOAD	Efficiency	Average Efficiency
100	90.19	87.87
75	89.64	
50	87.91	
25	83.73	
10	80.09	

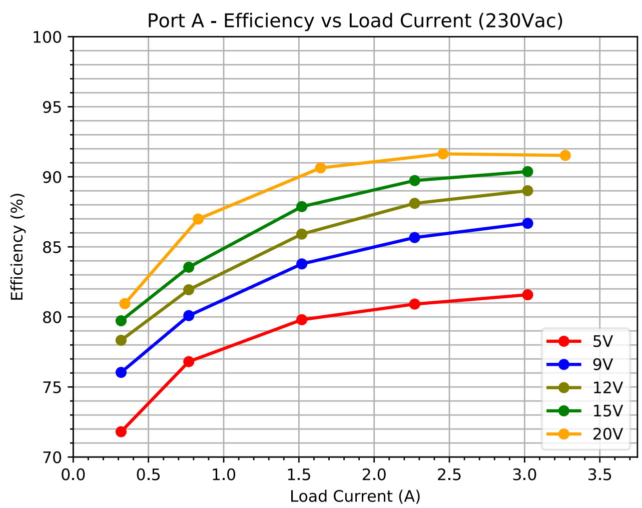
$V_{OUT\ B}$ / I_{LOAD_MAX} = 20 V / 3.25 A

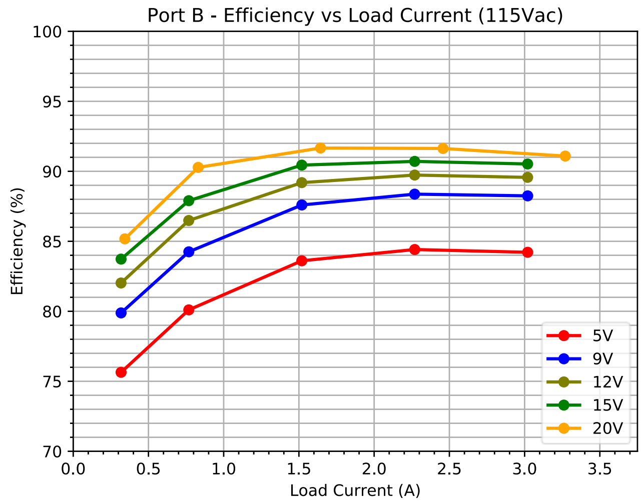
%LOAD	Efficiency	Average Efficiency
100	91.27	90.05
75	91.45	
50	90.48	
25	87.02	
10	81.06	

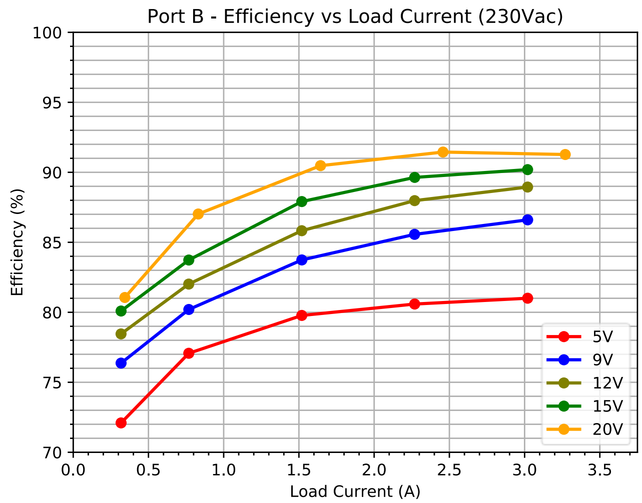
Efficiency Graphs

The following graphs demonstrate 5 V, 9 V, 12V, 15 V and 20 V efficiency results at 115Vac and 230Vac. Measurements taken via breakout board (after connector, before cable drop). Resistive drops of the breakout board contribute significantly to the efficiency results; approximately 250mW loss at 3A load.









No Load Input Power

Table 8 lists no-load input power consumption of the reference design measured at nominal line voltages.

Table 8: No-load Input Power Consumption

Input Voltage (Vac)	No-Load Power (mW)
115	163.2
230	205.1

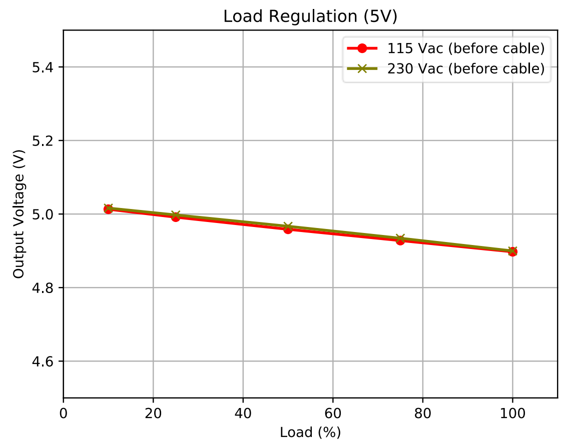
Static Output Characteristics

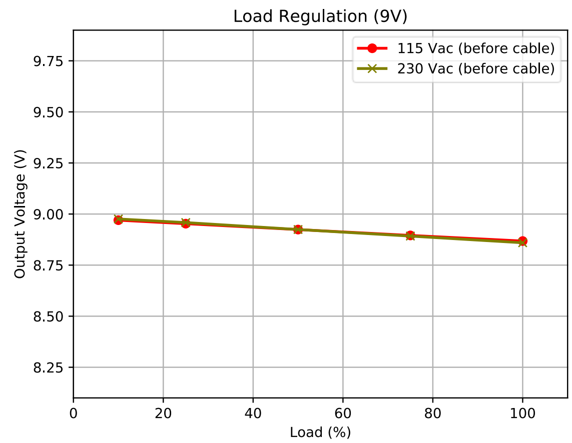
Table 9 summarizes line/load regulation (at the DC-DC output) for 5 V-20 V output, 10% to 100% load, 115Vac and 230Vac line input voltage for both ports. Measurements taken via breakout board (after connector, before cable drop). Resistive drops of the breakout board contribute significantly to the regulation results; approximately 100mV drop at 3A load.

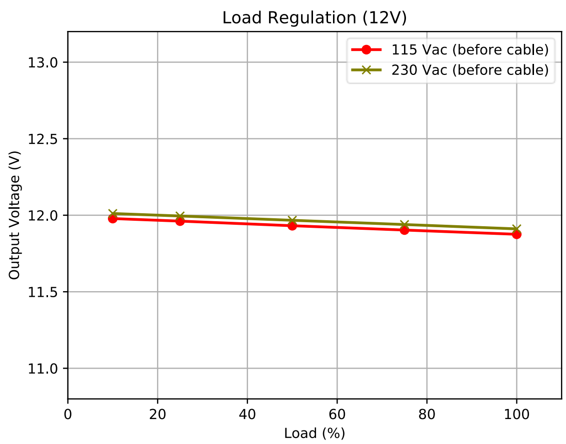
Table 9: Line/Load Regulation Summary

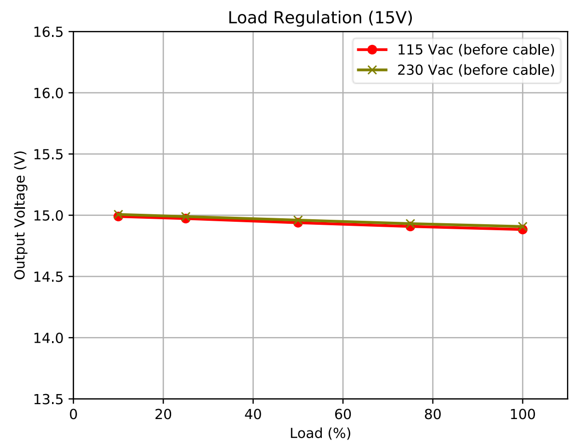
Output Conditions	Vout A		Vout B		5% Regulation Specs
	Min	Max	Min	Max	
5 V	4.84 V	5.06 V	4.81 V	5.06 V	4.75 V – 5.25 V
9 V	8.79 V	9.02 V	8.8 V	9.03 V	8.55 V – 9.45 V
12 V	11.8 V	12.05 V	11.81 V	12.11 V	11.40 V – 12.60 V
15 V	14.76 V	15.11 V	14.83 V	15.04 V	14.25 V – 15.75 V
20 V	19.79 V	20.08 V	19.75 V	20.04 V	19.00 V – 21.00 V

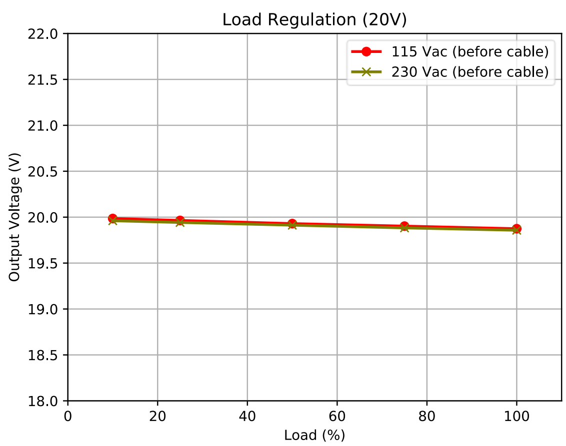
The following figures show line/load regulation (at the DC-DC output) for 5 V-20 V output voltages for variation of output loads for port A. Measurements taken via breakout board (after connector, before cable drop). Resistive drops of the breakout board contribute significantly to the regulation results; approximately 100mV drop at 3A load.



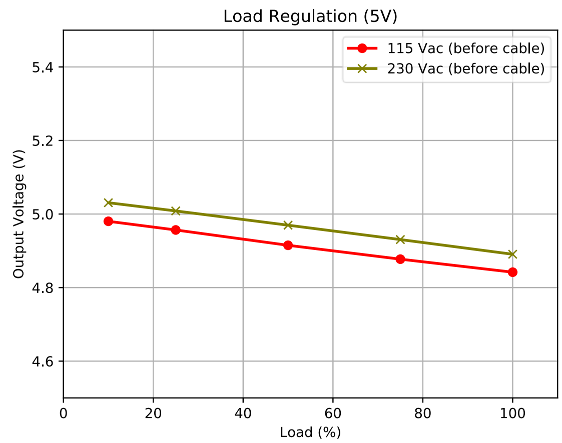


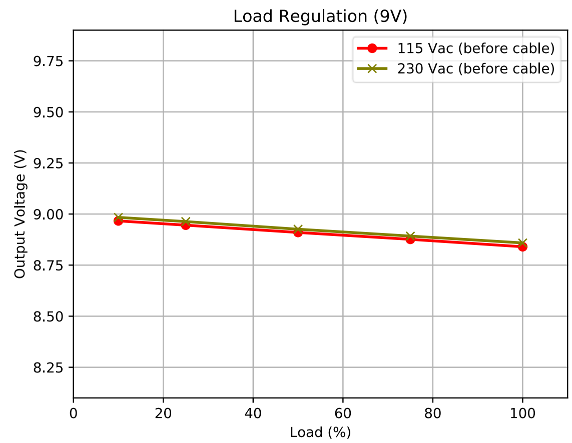


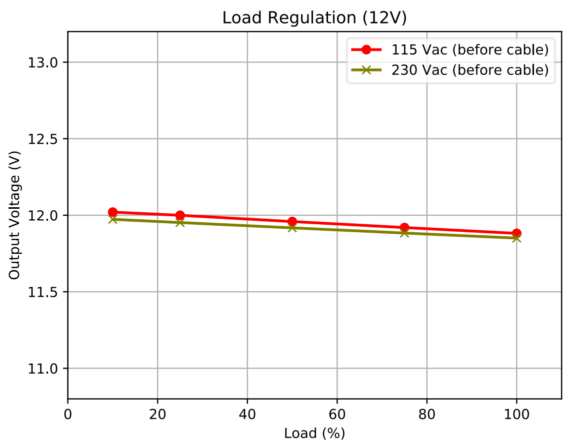


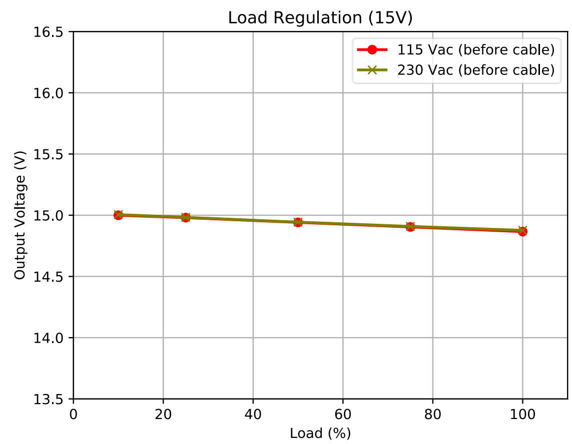


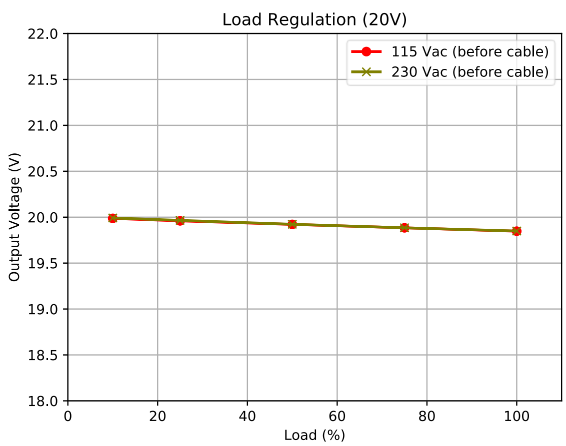
The following figures show line/load regulation (at the DC-DC output) for 5 V-20 V output voltages for variation of output loads for port B. Measurements taken via breakout board (after connector, before cable drop). Resistive drops of the breakout board contribute significantly to the regulation results; approximately 100mV drop at 3A load.











Waveforms

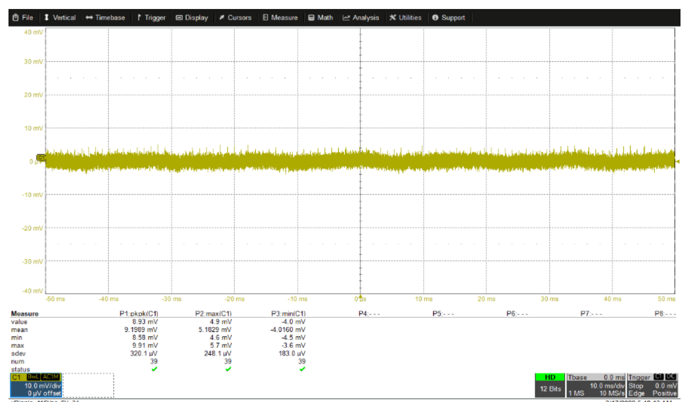
Output Voltage Ripple

The output voltage ripple was measured at the output of the DC-DC converter stages and is typical of both channels. Waveforms shown are VoutA measured at the DC-DC converter output at an input voltage of 115Vac. Measurements taken after connector, before cable drop. Waveforms and data were also examined at 230Vac with little appreciable difference.

Table 10: Output Ripple Summary

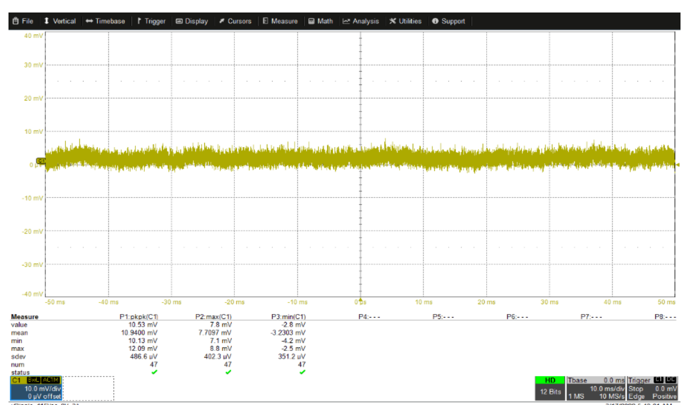
Input Settings		Output Settings		Ripple
Vin (rms)	Freq (Hz)	Vo (V)	Io (A)	Vr_pkpk (mV)
115	60.0	5.0	0.0	15.5
115	60.0	5.0	3.0	9.9
115	60.0	9.0	0.0	19.9
115	60.0	9.0	3.0	12.1
115	60.0	12.0	0.0	24.4
115	60.0	12.0	3.0	15.3
115	60.0	15.0	0.0	28.5
115	60.0	15.0	3.0	18.6
115	60.0	20.0	0.0	35.8
115	60.0	20.0	3.25	24.8

Vin=115 Vac, 60Hz, VoutA=5 V, Iout=0 A (ΔVout=15.5 mV)

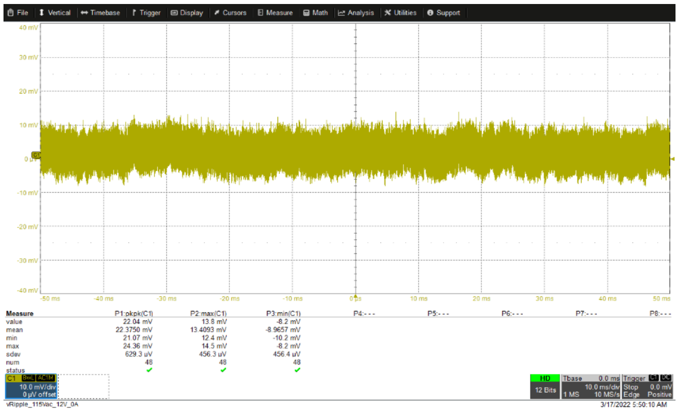


Vin=115 Vac, 60Hz, VoutA=5 V, Iout=3 A (ΔVout=9.9 mV)

Vin=115 Vac, 60Hz, VoutA=9 V, Iout=0 A (ΔVout=19.9 mV)



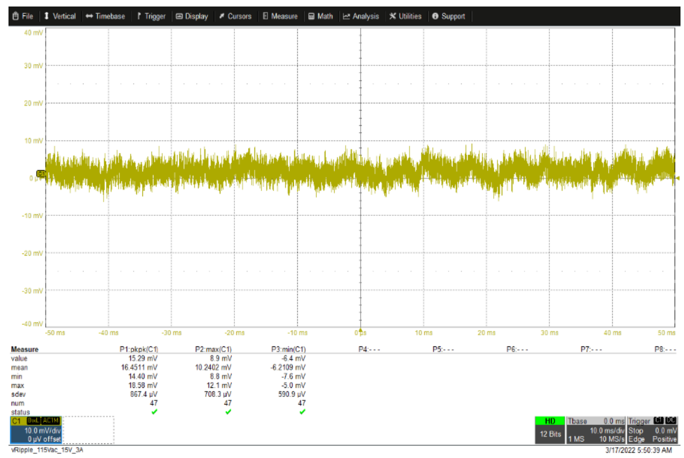
Vin=115 Vac, 60Hz, VoutA=9 V, Iout=3 A (ΔVout=12.1 mV)



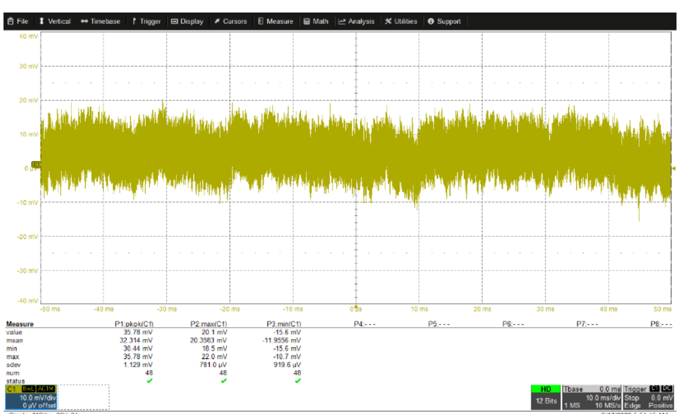
Vin=115 Vac, 60Hz, VoutA=12 V, Iout=0 A (ΔVout=24.4 mV)

Vin=115 Vac, 60Hz, VoutA=12 V, Iout=3 A (ΔVout=15.3 mV)

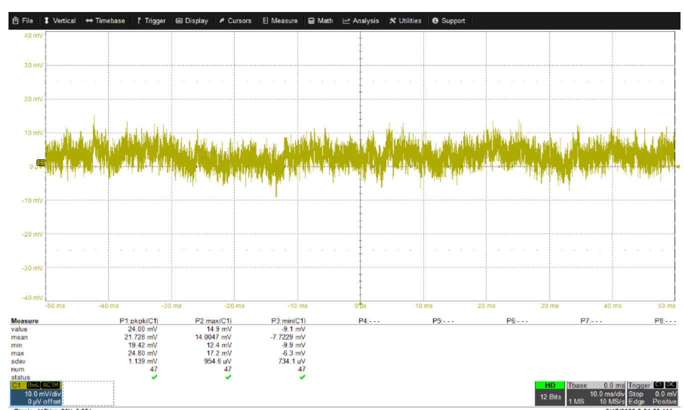
Vin=115 Vac, 60Hz, VoutA=15 V, Iout=0 A (ΔVout=28.5 mV)



Vin=115 Vac, 60Hz, VoutA=15 V, Iout=3 A (ΔVout=18.6 mV)



Vin=115 Vac, 60H z, VoutA=20 V, Iout=0 A (ΔVout=35.8 mV)



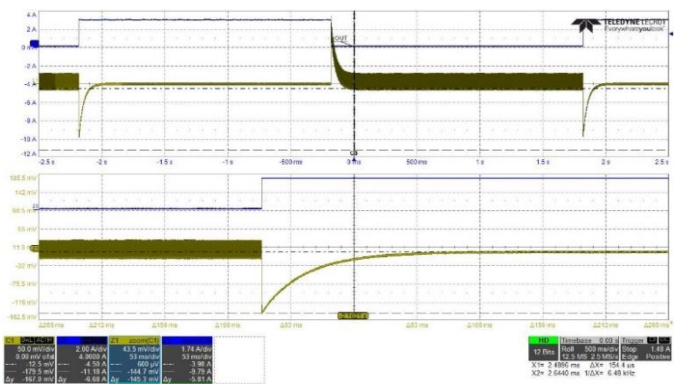
Vin=115 Vac, 60Hz, VoutA=20 V, Iout=3.25 A (ΔVout=24.8 mV)

Dynamic Output Characteristics

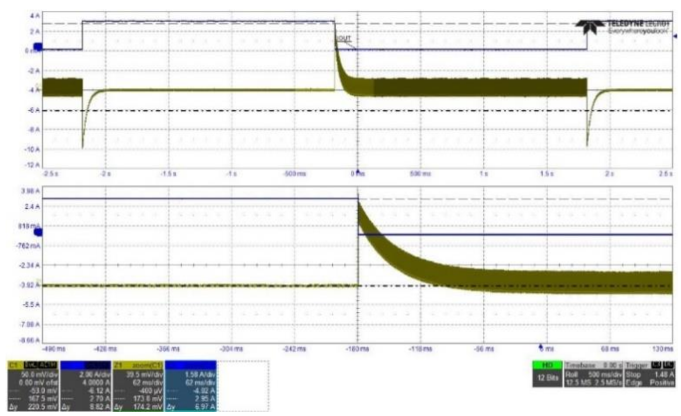
The following waveforms show transient responses for different output voltages. Load variations from 0.1A to full load. Measured at the output of the DC-DC converter with the load slew rate set to 150mA/us per USB PD specification. The waveforms shown are the VoutA measured at the DC-DC converter output (yellow) and the load current (blue). Measurements taken after connector, before cable drop.

Table 11: Dynamic Output Characteristics Summary

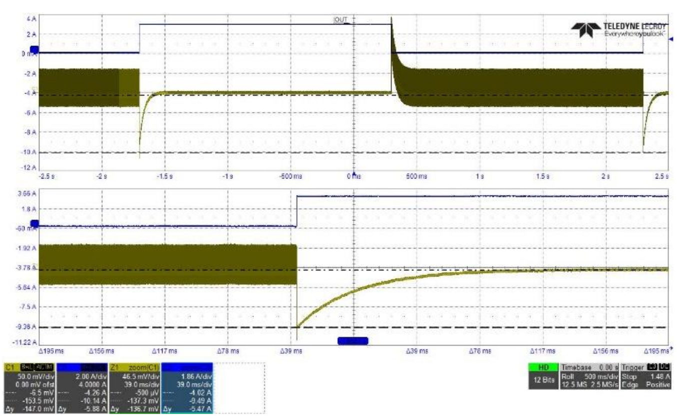
Input Voltage	Output Voltage	Load Range		Disturbance (rising)		Disturbance (falling)	
		Min	Max	Min (mV)	Max (mV)	Min (mV)	Max (mV)
115 V	5 V	0.1 A	3.0 A	-145.3	27.8	-16.2	174.2
	9 V	0.1 A	3.0 A	-136.7	59.1	-38.0	190.0
	12 V	0.1 A	3.0 A	-140.0	86.0	-44.0	205.6
	15 V	0.1 A	3.0 A	-145.6	90.4	-44.3	220.6
	20 V	0.1 A	3.25 A	-198.7	69.0	-45.5	190.7



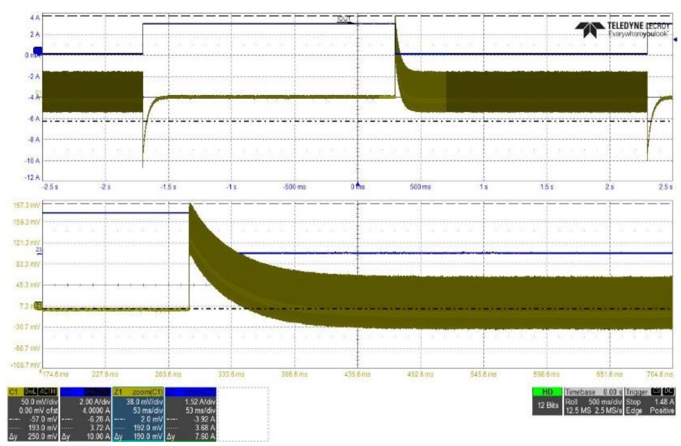
Vin=115 V, VoutA=5 V, Iout=0.1 A to 3 A



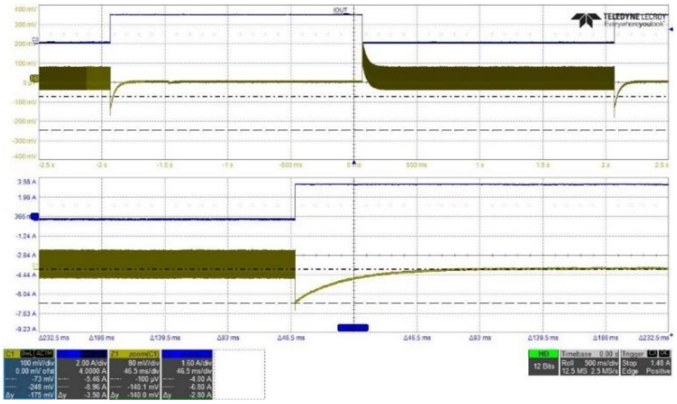
Vin=115 V, VoutA=5 V, Iout=3 A to 0.1 A



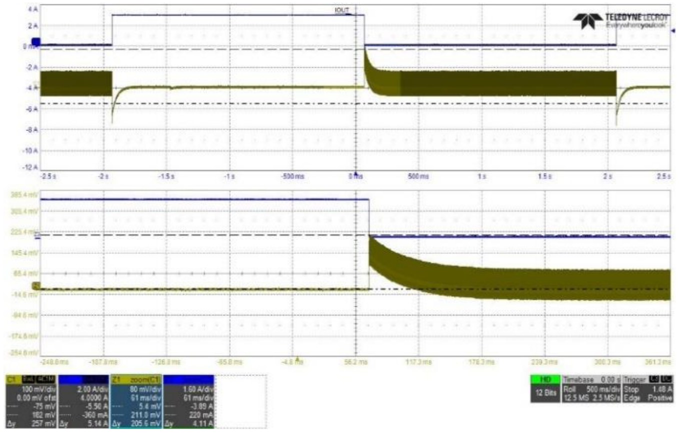
Vin=115 V, VoutA=9 V, Iout=0.1 A to 3 A



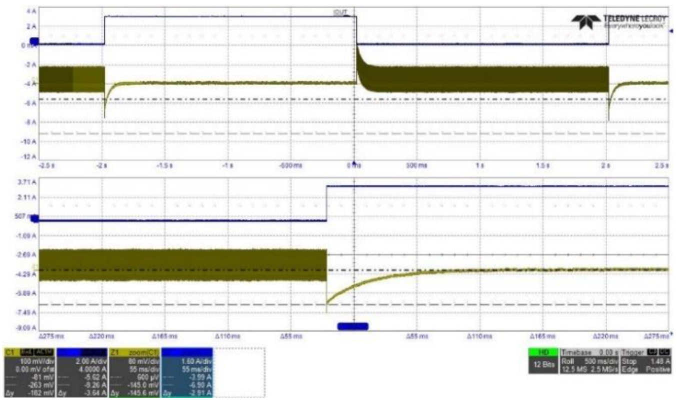
Vin=115 V, VoutA=9 V, Iout=3 A to 0.1 A



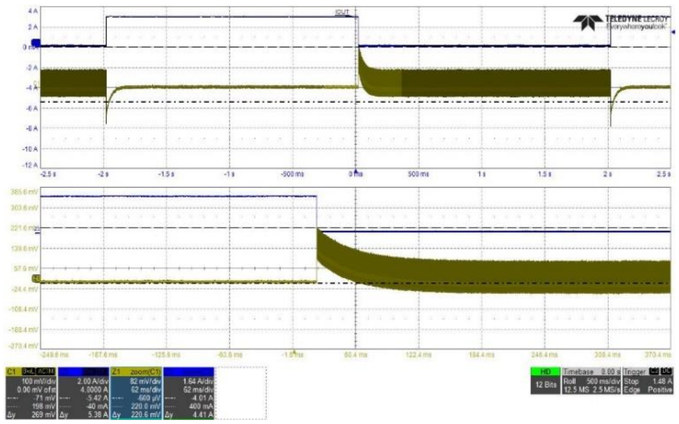
Vin=115 V, VouA=12 V, Iout=0.1 A to 3 A



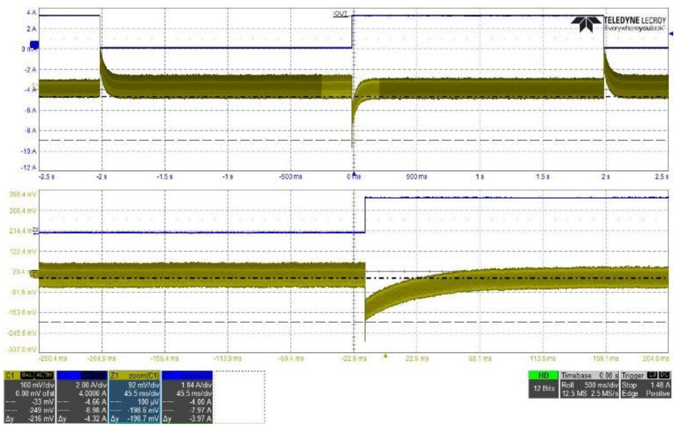
Vin=115 V, VoutA=12 V, Iout=3 A to 0.1 A



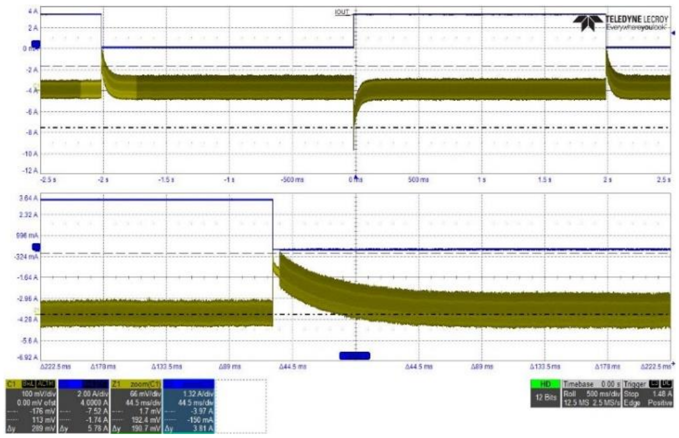
Vin=115 V, VoutA=15 V, Iout=0.1 A to 3 A



Vin=115 V, VoutA=15 V, Iout=3 A to 0.1 A



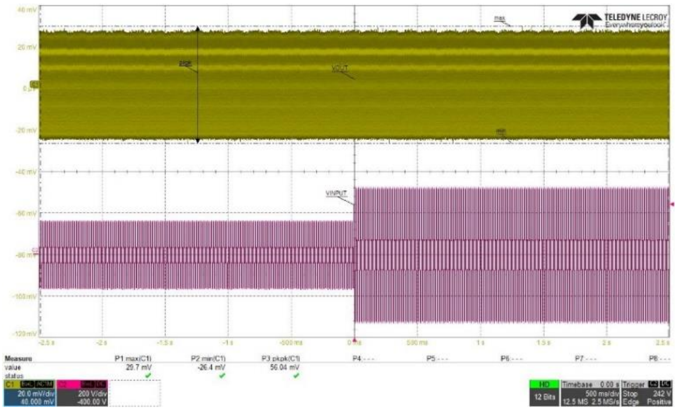
Vin=115 V, VoutA=20 V, Iout=0.1 A to 3.25 A



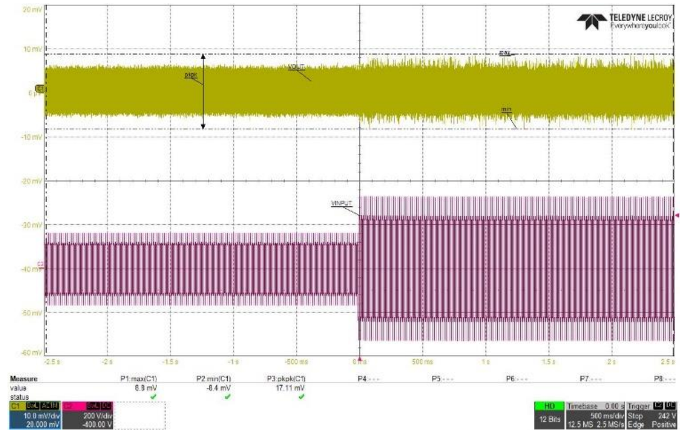
Vin=115 V, VoutA=20 V, Iout=3.25 A to 0.1 A

Line Transient Response

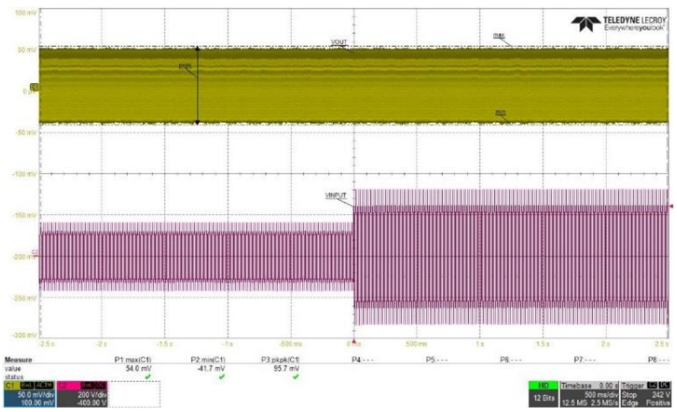
The following figures show output voltage response to a step change in the input voltage from 115Vac to 230Vac at light load and at full load. The line voltage (pink) is shown with VoutA (gold). The output voltage is measured at the output of the DC-DC converter. No measurable response detected in any case.



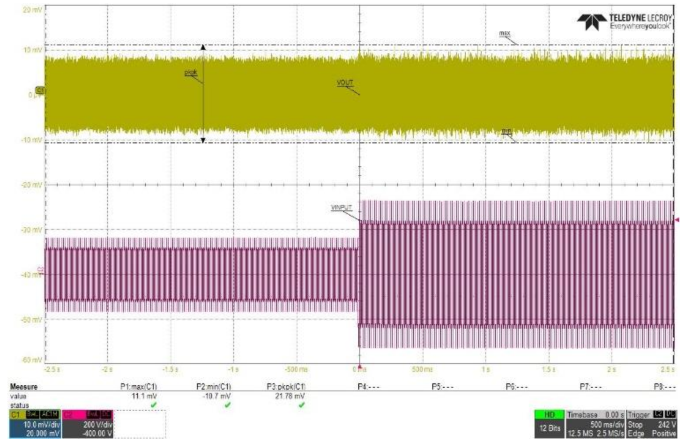
Vin=115 V to 230 V, VoutA=5 V, Iout=0.11 A



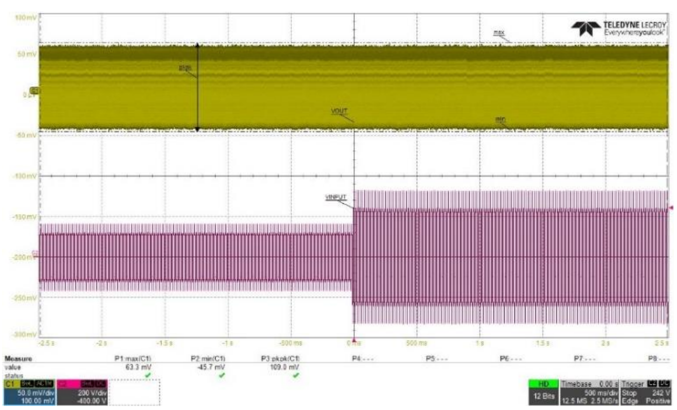
Vin=115 V to 230 V, VoutA=5 V, Iout=3.25 A



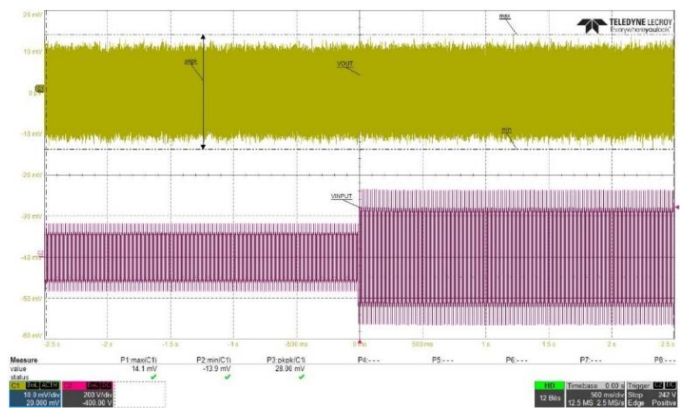
Vin=115 V to 230 V, VoutA=9 V, Iout=0.07 A



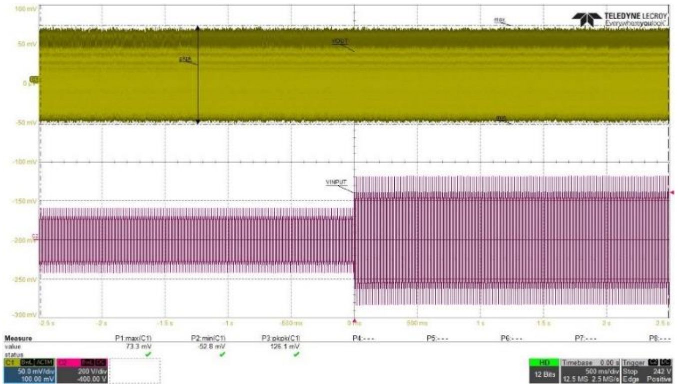
Vin=115 V to 230 V, VoutA=9 V, Iout=3.25 A



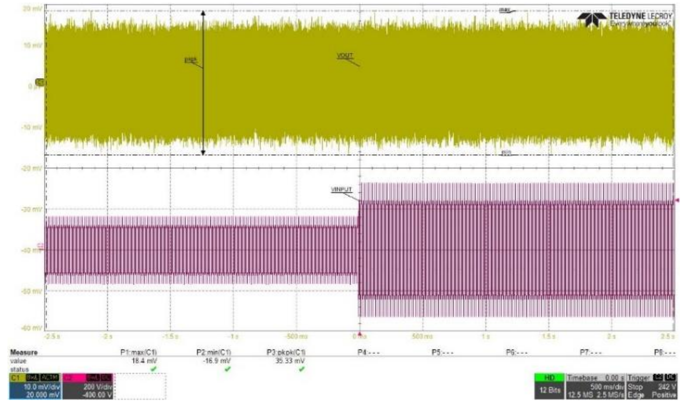
Vin=115 V to 230 V, VoutA=12 V, Iout=0.06 A



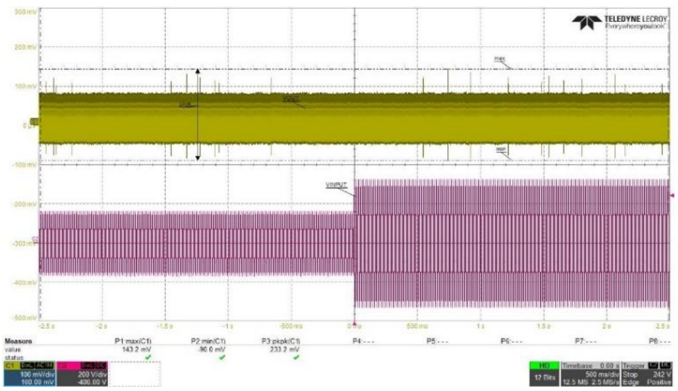
Vin=115 V to 230 V, VoutA=12 V, Iout=3.25 A



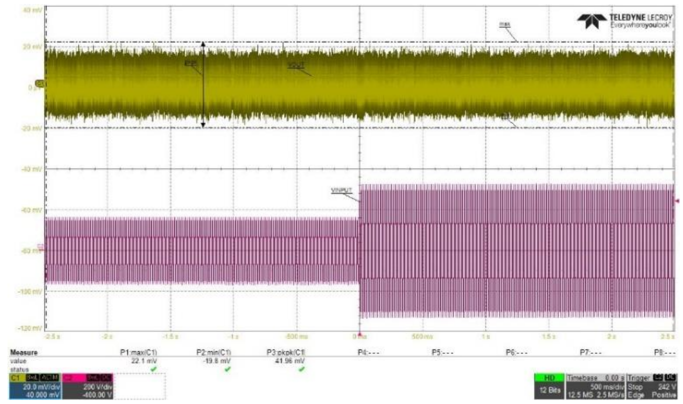
Vin=115 V to 230 V, VoutA=15 V, Iout=0.05 A



Vin=115 V to 230 V, VoutA=15 V, Iout=3.25 A



Vin=115 V to 230 V, VoutA=20 V, Iout=0.045 A



Vin=115 V to 230 V, VoutA=20 V, Iout=3.25 A

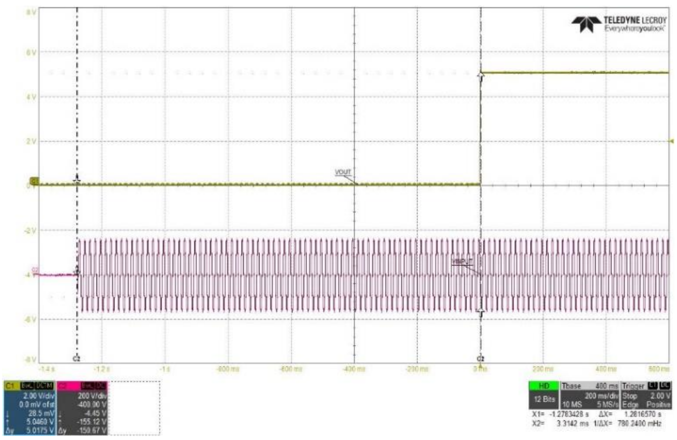
Output Voltage Start-up & Turn-on Delay

The following figures show output voltage (V_{OUTA} - Yellow) and AC input voltage (Vac - Pink) waveforms during start up for 115 Vac and 230 Vac input voltages.

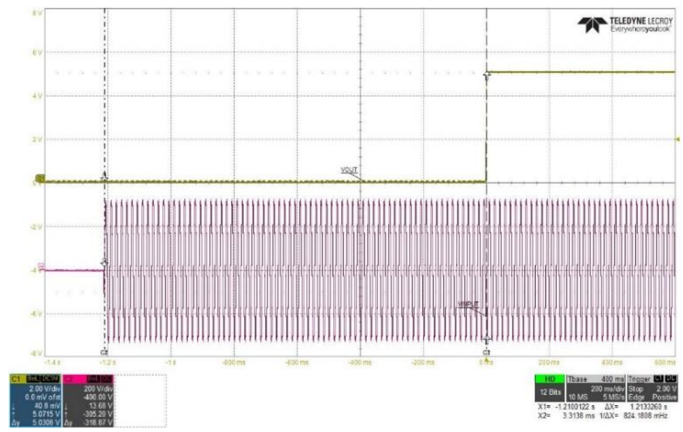
The start-up waveforms show the 5 V output voltage, which is the required default output voltage for USB-PD applications. A monotonic rise of output is always observed during output voltage start-up.

Table 12: Turn-On Delay Summary

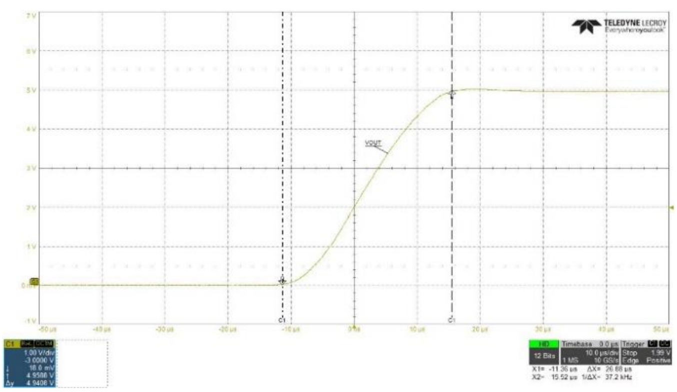
Line Input	Turn-On Delay Measurement
	No load
115 V	1.28 s
230 V	1.21 s



Vin=115 Vac, VoutA=5 V, Iout=0 A, T_{ON_DELAY}=1.28 s



Vin=230 Vac, VoutA=5 V, Iout=0 A, T_{ON_DELAY}=1.21 s



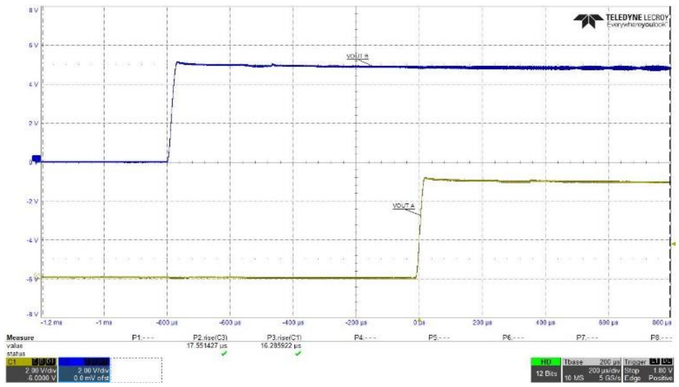
Zoom view of DC-DC converter VoutA at startup

USB-PD Output Voltage Transition & Rise Time

The following waveforms show 5 V rise time upon start-up and various USB-PD output voltage transitions.

Table 13: Output Voltage Rise Time Summary

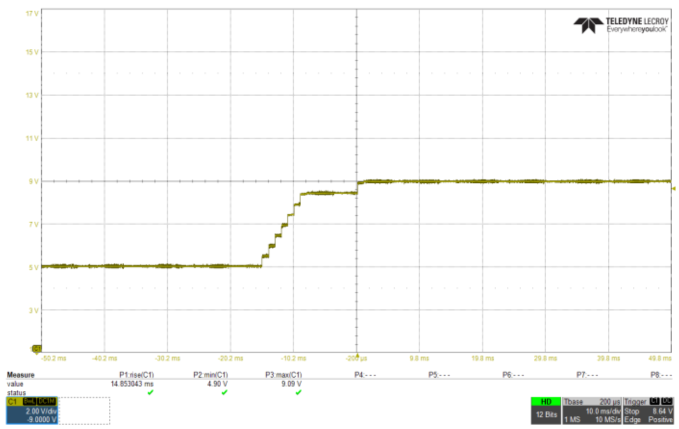
Output Voltage	Rise Time Measurements
0 V to 5 V (VOUTA - Yellow)	16.3 us
0 V to 5 V (VOUTB - Blue)	17.5 us



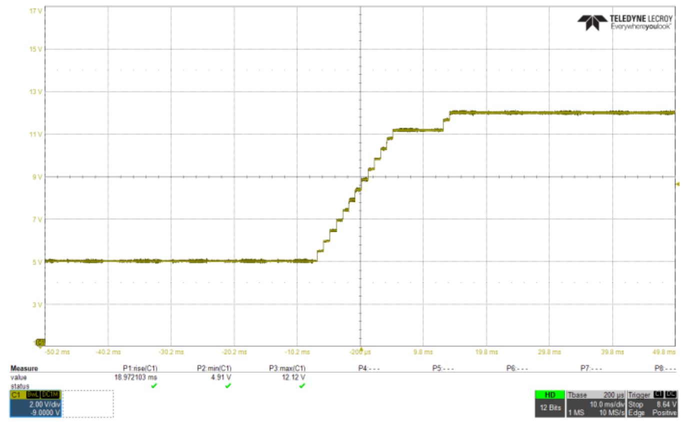
Vin=90 Vac, VoutA=5 V, IoutA=3 A, VoutB=5 V, IoutB=3 A

Table 14: Output Voltage Transition Time Summary

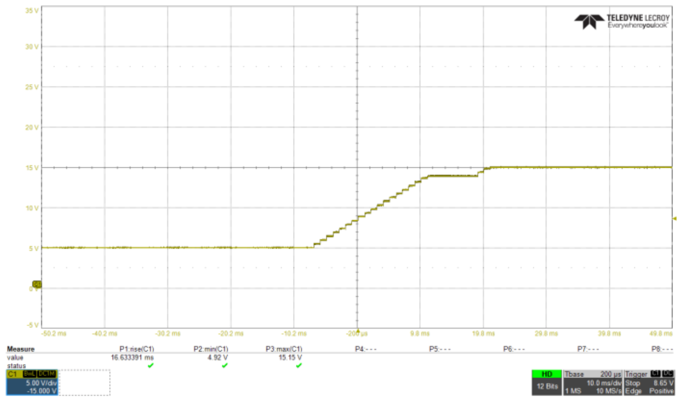
Output Voltage (VoutA measured)	Rise Time Measurements (ms)
5 V to 9 V	14.9
5 V to 12 V	19.0
5 V to 15 V	16.6
5 V to 20 V	24.0
9 V to 12 V	11.0
9 V to 15 V	17.0
9 V to 20 V	25.0
12 V to 15V	12.0
12 V to 20V	19.9
15 V to 20 V	15.0



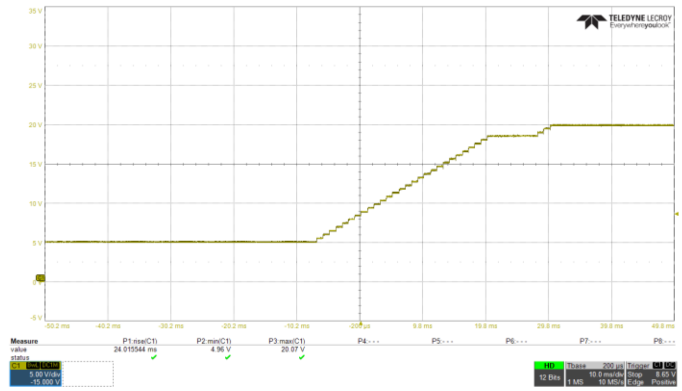
VoutA 5 to 9 volt transition, 14.9ms



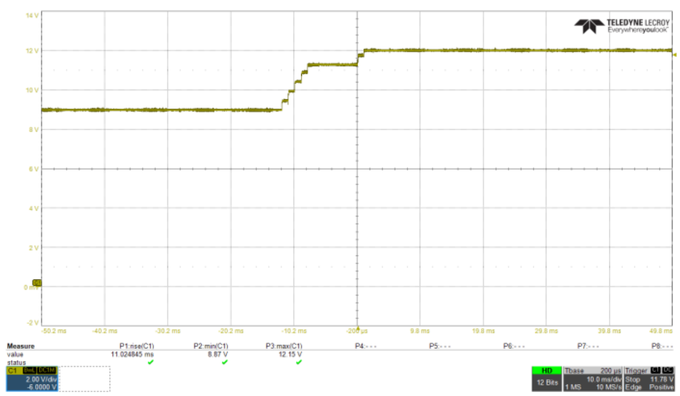
VoutA 5 to 12 volt transition, 19.0ms



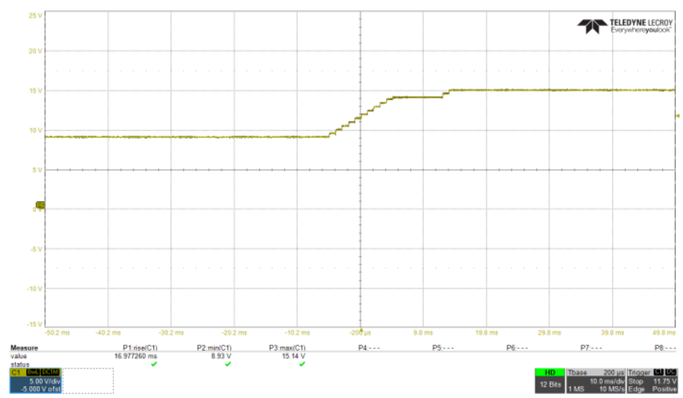
VoutA 5 to 15 volt transition, 16.6ms



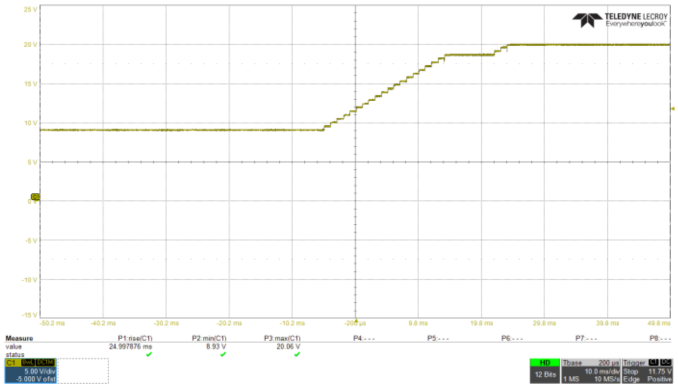
VoutA 5 to 20 volt transition, 24.0ms



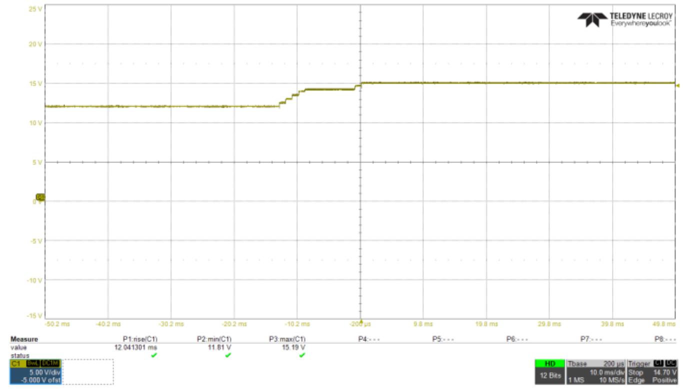
VoutA 9 to 12 volt transition, 11.0 ms



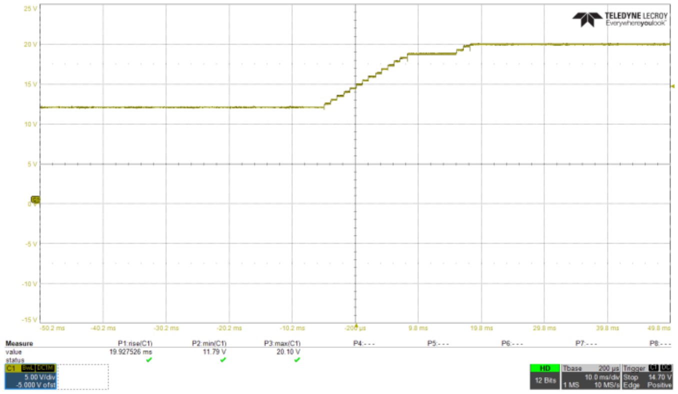
VoutA 9 to 15 volt transition, 17.0 ms



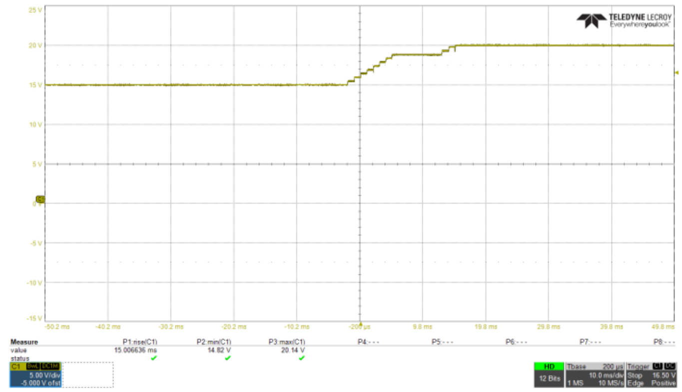
VoutA 9 to 20 volt transition, 25.0 ms



VoutA 12 to 15 volt transition, 12.0 ms



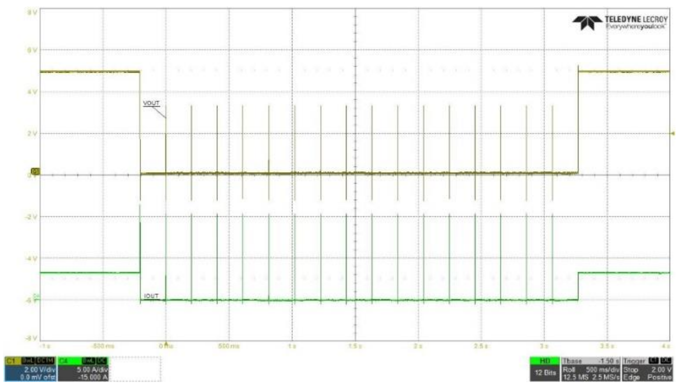
VoutA 12 to 20 volt transition, 19.9 ms



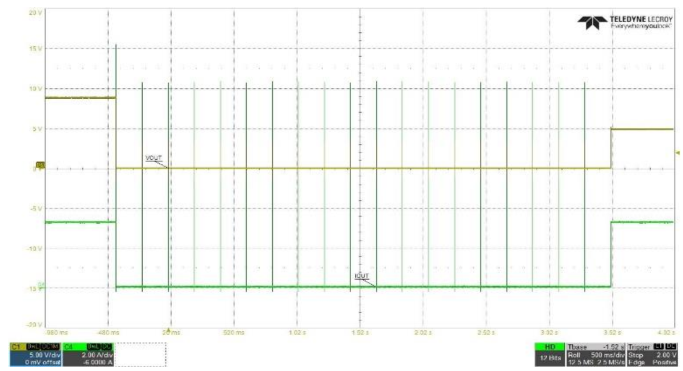
VoutA 15 to 20 volt transition, 15.0 ms

Output Voltage Short and Auto-recovery

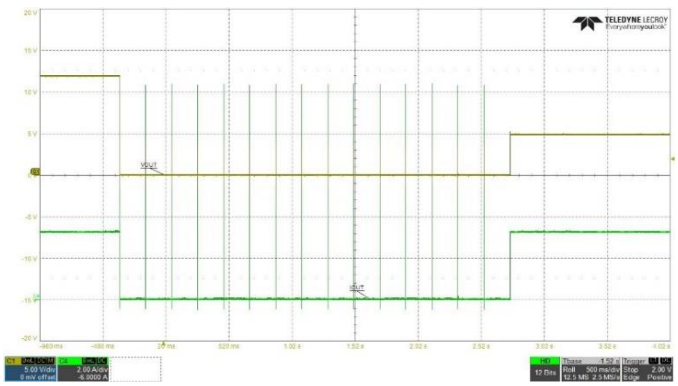
The reference design features Hiccup Mode Fault Protections for both SZ1130-02 and SZPL3102A. Under applicable fault conditions (all except over-temperature protections for SZ1130), the device attempts to auto-restart. The images below show hiccup mode fault recovery behaviour when a short is applied at the VBUS output (after the USB-PD disconnect FET). Once the short is detected, the device triggers output short circuit protection (OSCP) fault, the device attempts to auto-restart and will continue to do so until the fault is cleared. During output short at higher voltage, the device will auto-restart to 5V output once the output voltage short fault is removed. Waveforms in the images below are VbusA – Yellow, IoutA – Green.



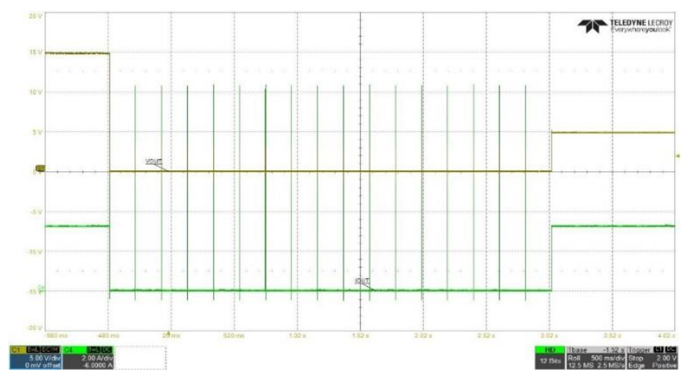
VbusA=5 V, normal running then short, Recovery=5 V



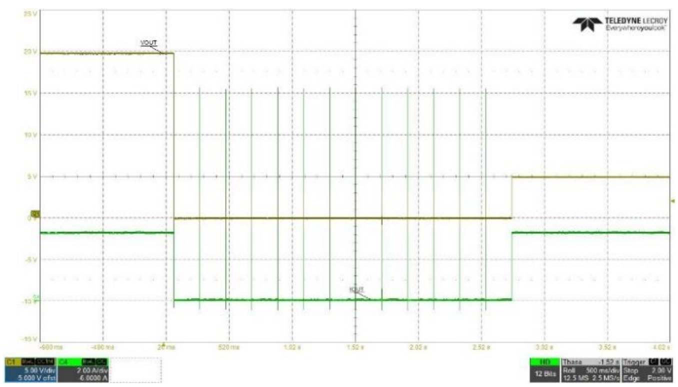
VbusA=9 V, normal running then short, Recovery=5V



VbusA=12 V, normal running then short, Recovery=5 V



VbusA=15 V, normal running then short, Recovery=5 V



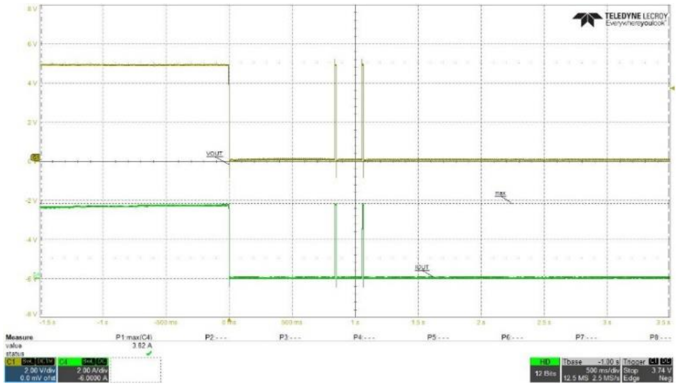
VbusA=20 V, normal running then short, Recovery=5 V

Output Voltage Over-Current Protection (OCP)

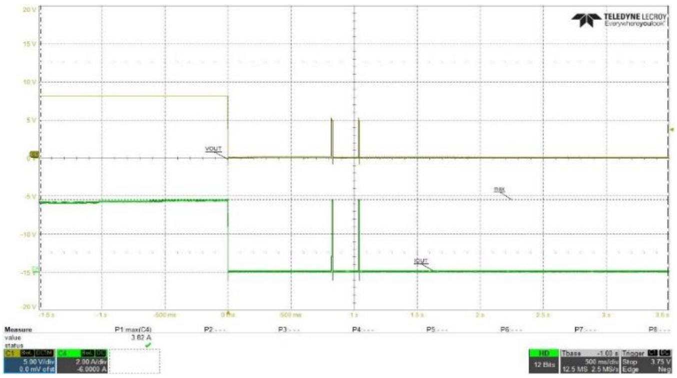
The reference design features Hiccup Mode Fault Protections using SZ1130-02 & SZPL3102A. Under applicable fault conditions (all except over-temperature protections for SZ1130), the device attempts to auto-restart. The images below show hiccup mode fault recovery behaviour when an output over current occurs. Once the over current is detected, the device triggers output over current protection (OOCP) fault, the device attempts to auto-restart and will continue to do so until the fault is cleared. During over current at higher voltage, the device will auto-restart to 5V output once the output voltage over current fault is removed. However, the Cypress USB-PD controller OCP is latched when the fault is not cleared after 3 auto-retries and can be reset via removal of the AC input or removal of USB connector. If the auto-retry is less than 3, then the mode is auto-restart. Waveforms in the images below are VbusA – Yellow, IoutA – Green.

Table 15: Over-Current Level Summary

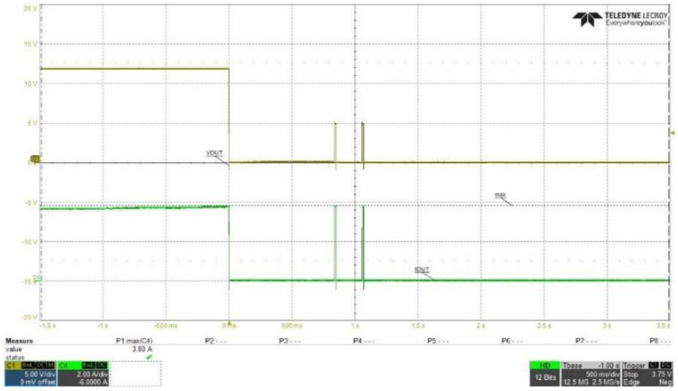
Output Voltage	Measured OCP
5 V	3.82
9 V	3.82
12 V	3.80
15 V	3.82
20 V	4.12



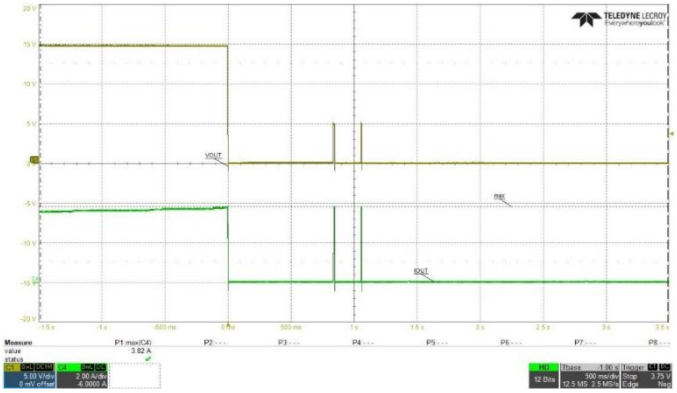
VbusA=5 V, OCP=3.82 A, Latch



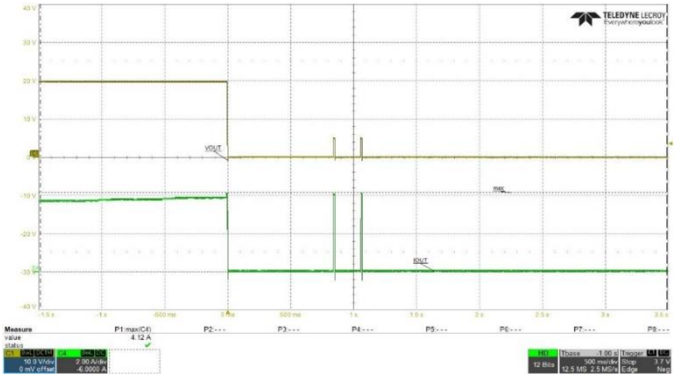
VbusA =9 V, OCP=3.82 A, Latch



VbusA =12 V, OCP=3.80 A, Latch



VbusA =15 V, OCP=3.82 A, Latch



VbusA =20 V, OCP=4.12 A, Latch

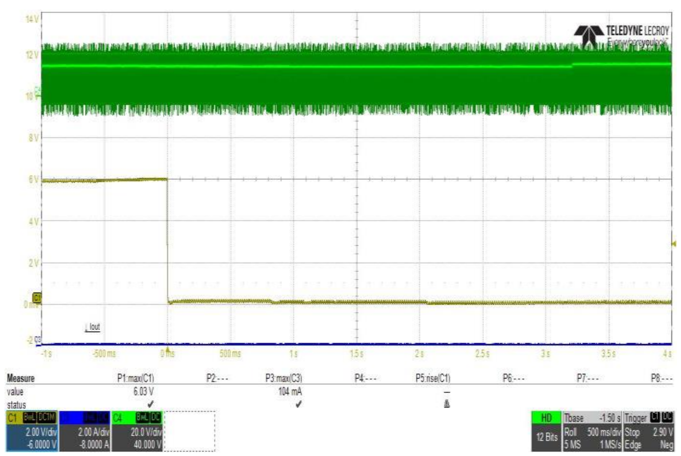
Output Over-Voltage Protection / Feedback Loop Open Protection

The reference design features Hiccup Mode Fault Protections using the SZ1130-02. Under applicable fault conditions (all except over-temperature protections for SZ1130), the device attempts to auto-restart.

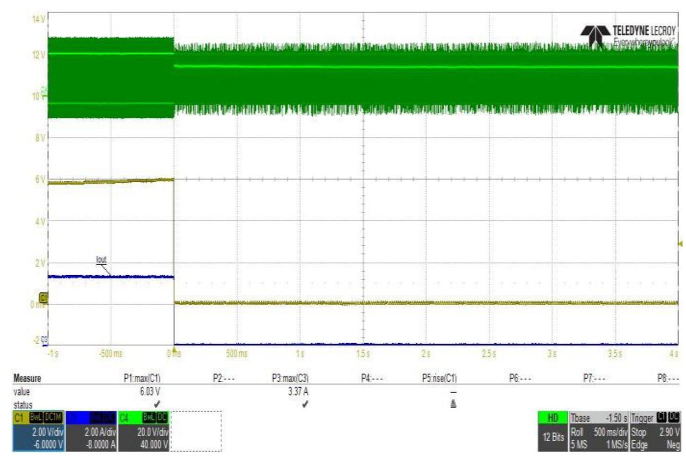
The images below show fault behaviour when the output over-voltage protection occurs due to a loss of feedback. Tests were made using a variable resistor across the FB and GND pins of the SZPL3102A. Once the voltage on the FB pin becomes lower via the FB resistors voltage divider, the output will rise and the Cypress USB PD controller senses this voltage and once the OVP threshold was reached it turns-off the disconnect switch. Waveforms in the images below are VbusA – Yellow, IoutA – Blue and the SZ3103A upper FET drain to source voltage for channel A – Green.

Table 16: Over-Voltage Level Summary

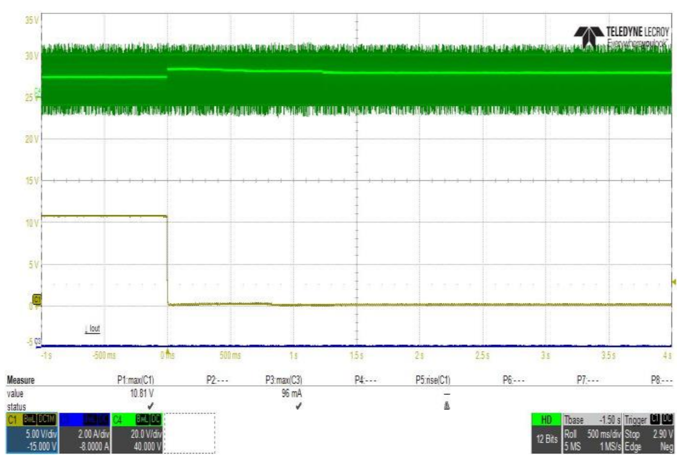
Output Voltage	No Load OVP	Full Load OVP
5 V	6.03 V	6.03 V
9 V	10.8 V	10.8 V
12 V	14.4 V	14.4 V
15 V	18.0 V	18.0 V
20 V	23.4 V	23.2 V



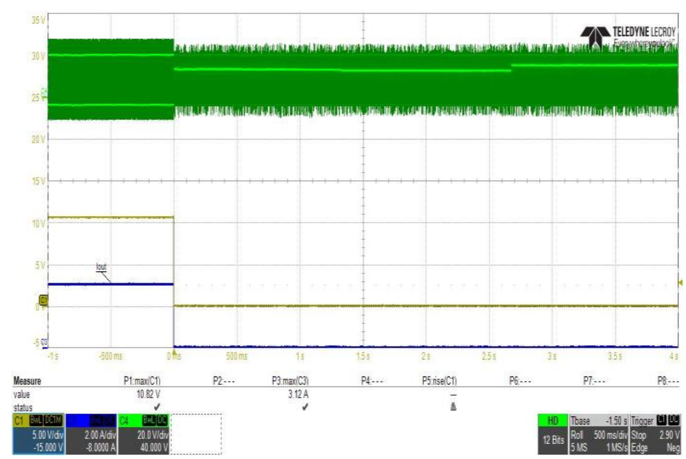
VbusA=5 V, 0 A, V_OVP=6.03 V



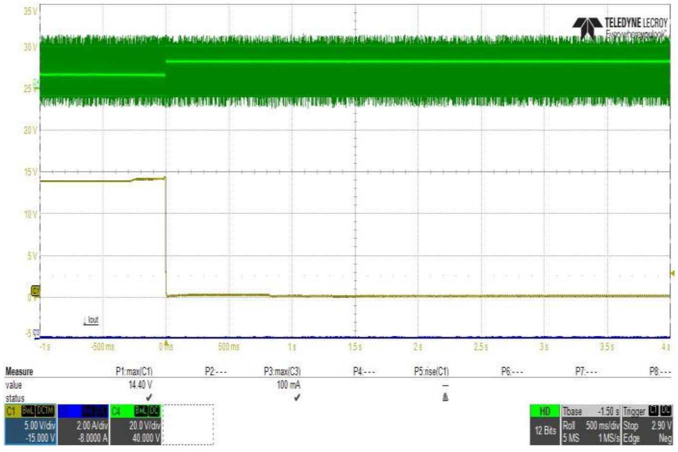
VbusA=5 V, 3.25 A, V_OVP=6.03 V



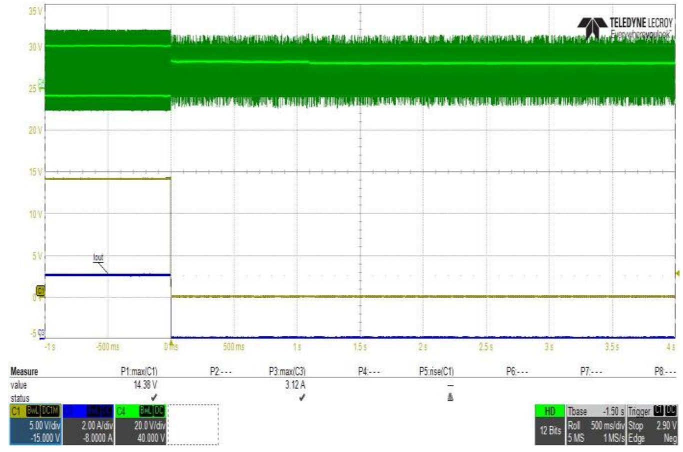
VbusA=9 V, 0 A, V_OVP=10.8 V



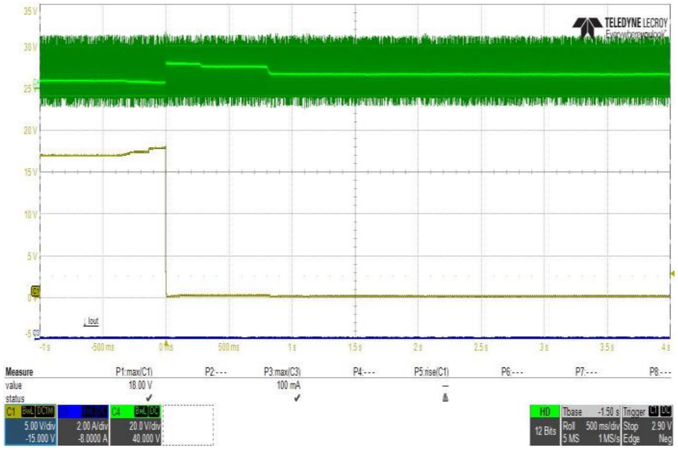
VbusA=9 V, 3.25 A, V_OVP=10.8 V



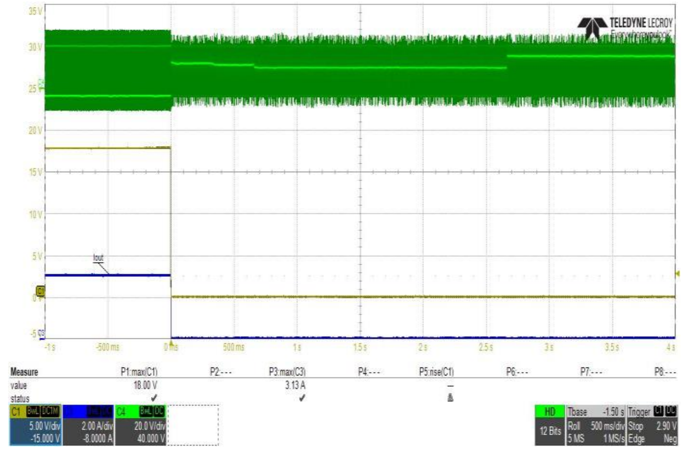
VbusA=12 V, 0 A, V_OVP=14.4 V



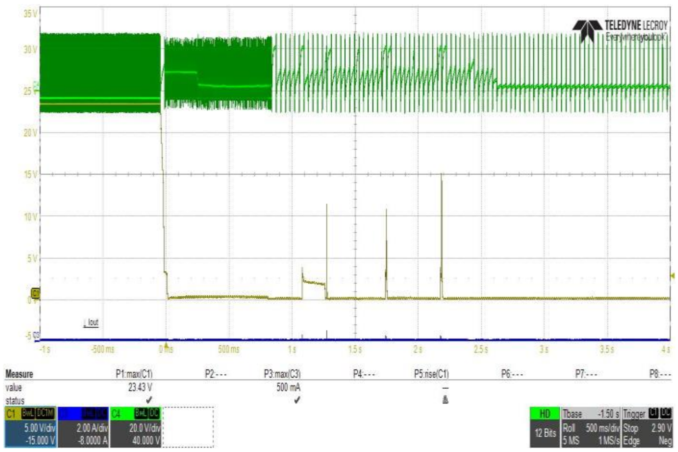
VbusA=12 V, 3.25 A, V_OVP=14.4 V



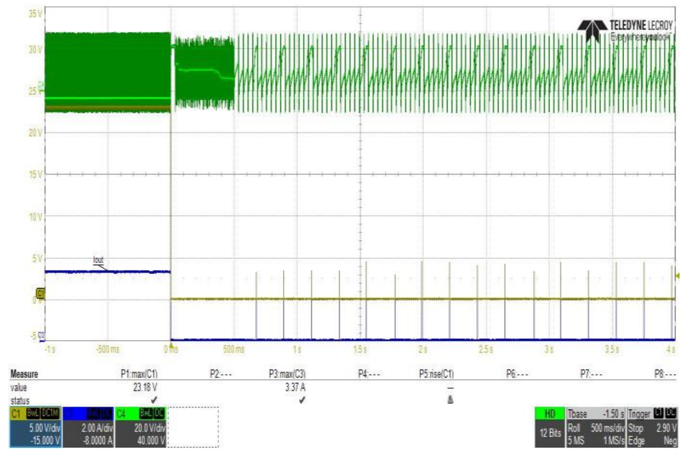
VbusA=15 V, 0 A, V_OVP=18.0 V



VbusA=15 V, 3.25 A, V_OVP=18.0 V



VbusA=20 V, 0 A, V_OVP=23.4 V

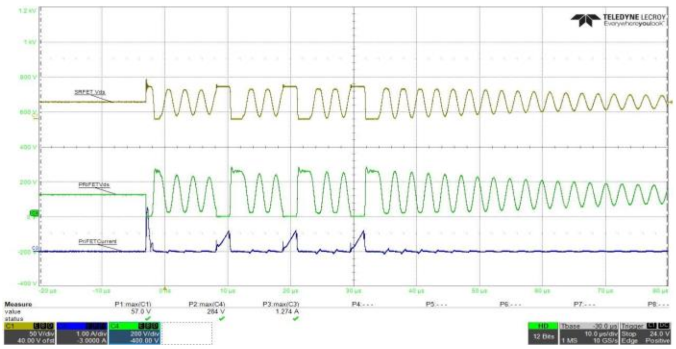


VbusA=20 V, 3.25 A, V_OVP=23.2 V

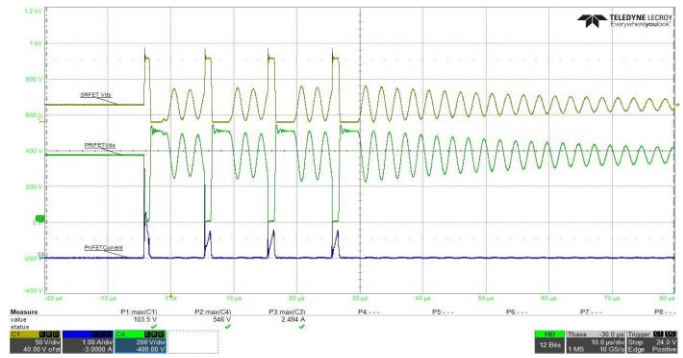
Note: At 20V output the DC-DC converter runs out of headroom to Vin in this test. This causes an undervoltage fault in the SZ3103A and a shutdown and subsequent restart of the DC-DC stage. This is the response seen in the 20V output images and is strictly a consequence of the test method used. The initial shutdown of Vbus is what is being shown and is the object of the test.

Drain Voltage and Current Waveforms at Steady State (AC-DC)

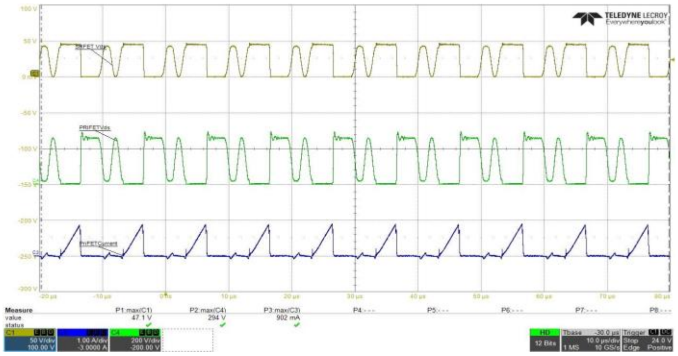
The waveforms presented in this section indicate that no components are over stressed under normal operating conditions. Measurements were made at 90 Vac and 265 Vac at full and no-load conditions. Waveforms shown are the rectifier FET Vds (Yellow), primary switching FET Vds (Green) and the primary switching FET current (Blue).



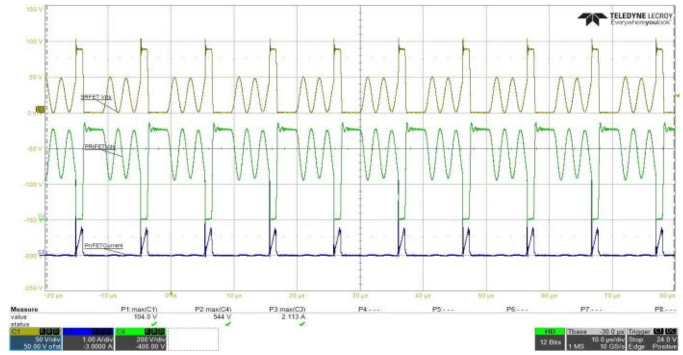
Vin=90 Vac, VoutA=5 V, IoutA=0 A (V_{ds_MAIN}=284 V, I_{d_MAIN}= 1.27 A V_{ds_SR}=57 V)



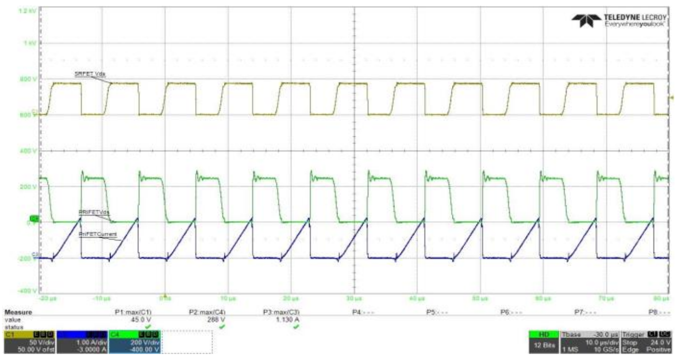
Vin=265 Vac, VoutA=5 V, IoutA=0 A (V_{ds_MAIN}=546 V, I_{d_MAIN}= 2.49 A V_{ds_SR}=104 V)



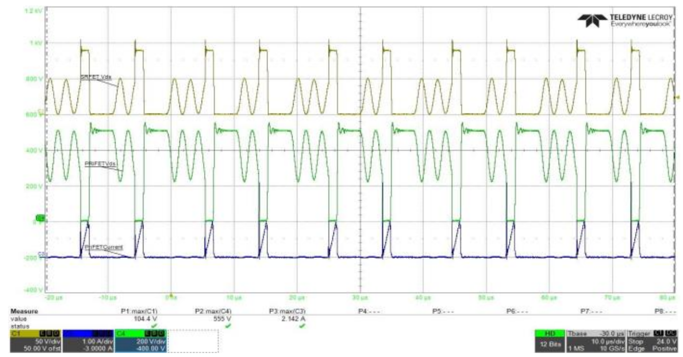
Vin=90 Vac, VoutA=5 V, IouA=3 A (V_{ds_MAIN}=294 V, I_{d_MAIN}= 0.90 A V_{ds_SR}=47 V)



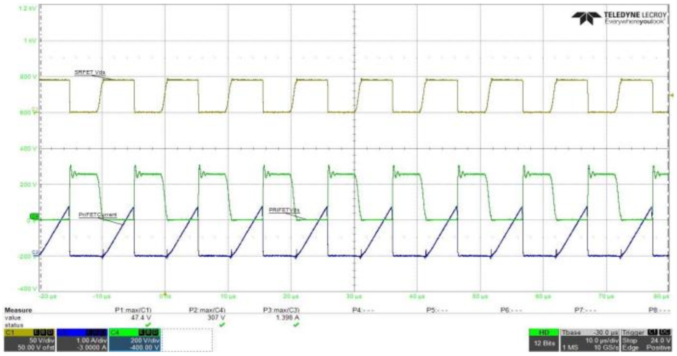
Vin=265 Vac, VoutA=5 V, IoutA=3 A (V_{ds_MAIN}=544 V, I_{d_MAIN}= 2.11 A V_{ds_SR}=104 V)



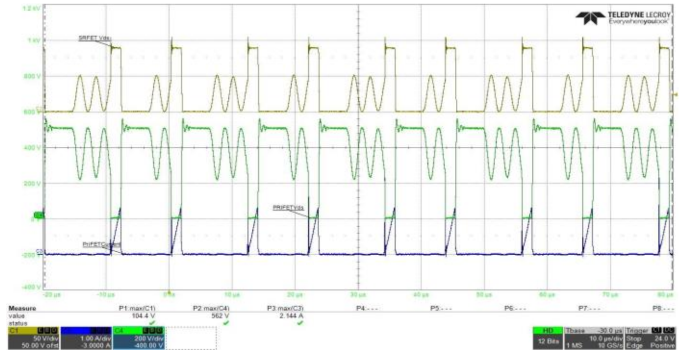
Vin=90 Vac, VoutA=9 V, IoutA=3 A (V_{ds_MAIN}=288 V, I_{d_MAIN}= 1.13 A V_{ds_SR}=45 V)



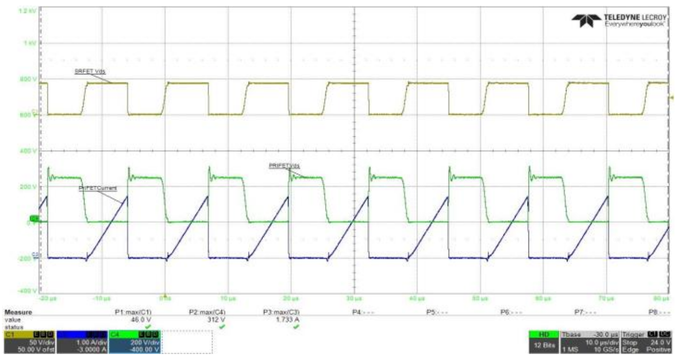
Vin=265 Vac, VoutA=9 V, IoutA=3 A (V_{ds_MAIN}=555 V, I_{d_MAIN}= 2.14 A V_{ds_SR}=104 V)



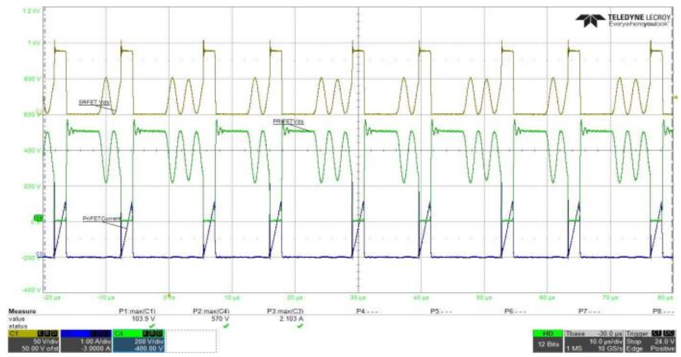
Vin=90 Vac, VoutA=12 V, IouA=3 A (V_{ds_MAIN}=307 V, I_{d_MAIN}= 1.40 A V_{ds_SR}=47.4 V)



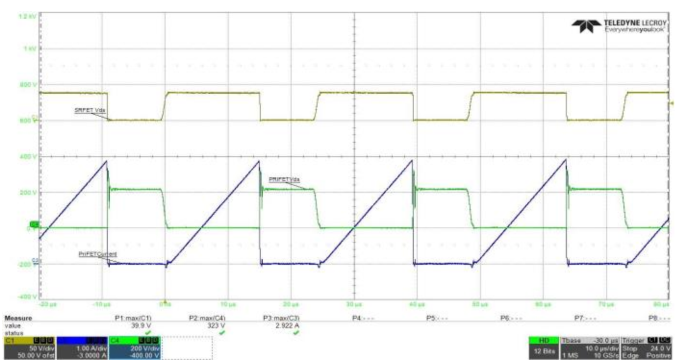
Vin=265 Vac, VoutA=12 V, IoutA=3.25 A (V_{ds_MAIN}=562 V, I_{d_MAIN}= 2.14 A V_{ds_SR}=104 V)



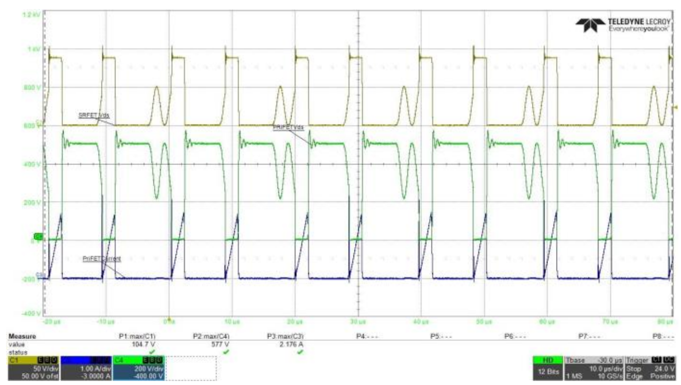
Vin=90 Vac, VoutA=15 V, IoutA=3 A (V_{ds_MAIN}=312 V, I_{d_MAIN}= 1.73 A V_{ds_SR}=46 V)



Vin=265 Vac, VoutA=15 V, IoutA=3 A (V_{ds_MAIN}=570 V, I_{d_MAIN}= 2.10 A V_{ds_SR}=104 V)



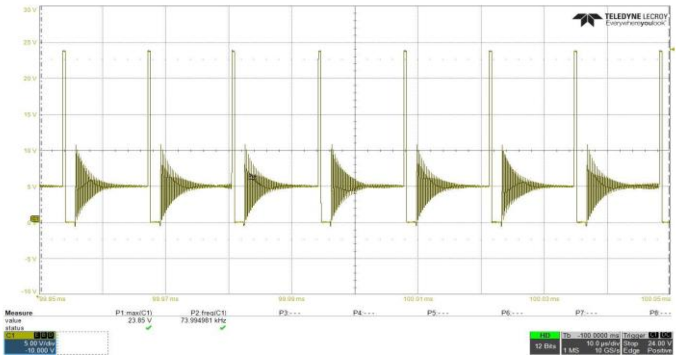
Vin=90 Vac, VoutA=20 V, IoutA=3.25 A (V_{ds_MAIN}=323 V, I_{d_MAIN}= 2.92 A V_{ds_SR}=40 V)



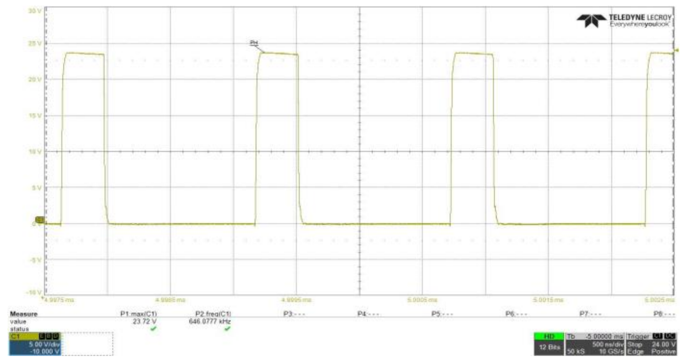
Vin=265 Vac, VoutA=20 V, IoutA=3.25 A (V_{ds_MAIN}=577 V, I_{d_MAIN}= 2.18 A V_{ds_SR}=105 V)

Drain Voltage and Current Waveforms at Steady State (DC-DC)

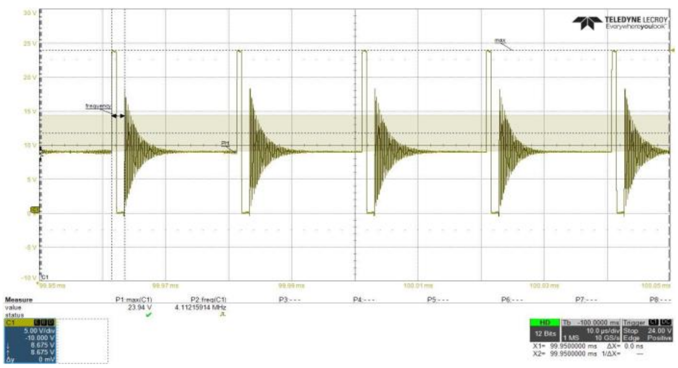
The waveforms presented in this section indicate that no components are over stressed under normal operating conditions for the SZPL3102A synchronous buck converter. Measurements were made at 115 Vac full and light-load conditions. The waveforms shown are the PH pin voltage of the channel A SZ3103A.



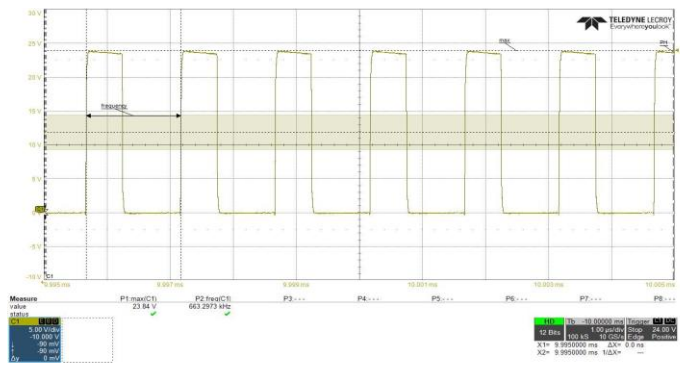
VoutA=5 V, IoutA=0.11 A (max PH voltage 23.9 V)



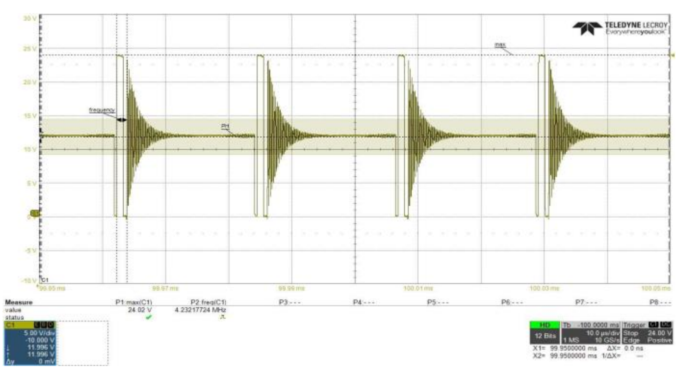
VoutA=5 V, IoutA=3.25 A (max PH voltage 23.7 V)



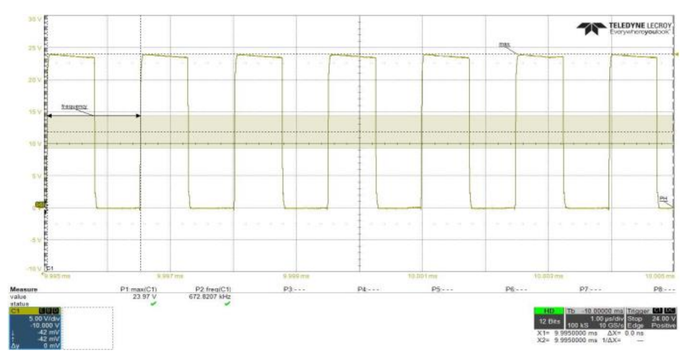
VoutA=9 V, IoutA=0.10 A (max PH voltage 23.9 V)



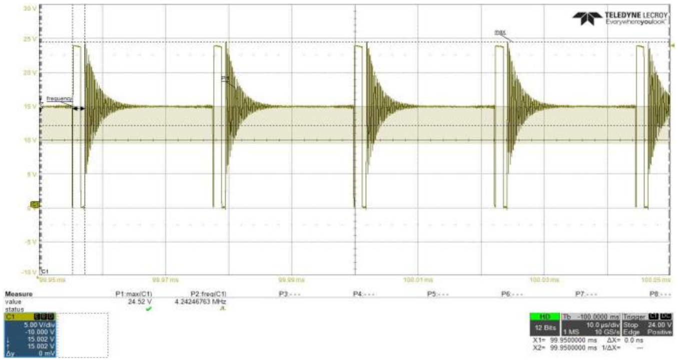
VoutA=9 V, IoutA=3.25 A (max PH voltage 23.8 V)



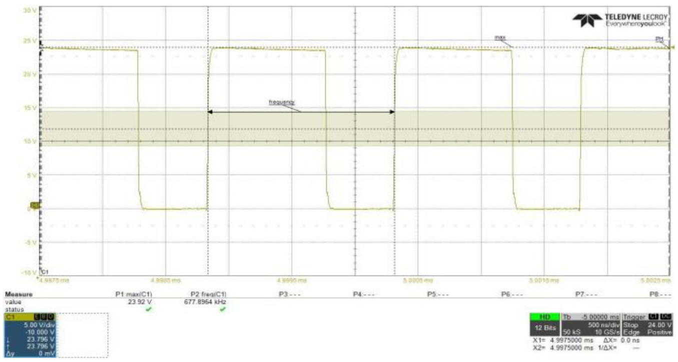
VoutA=12 V, IoutA=0.01 A (max PH voltage 24.0 V)



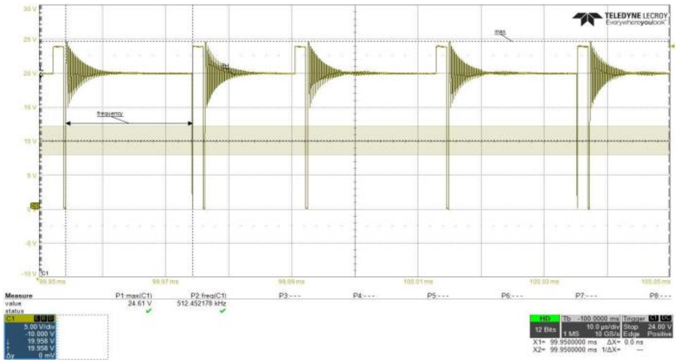
VoutA=12 V, IoutA=3.25 A (max PH voltage 24.0 V)



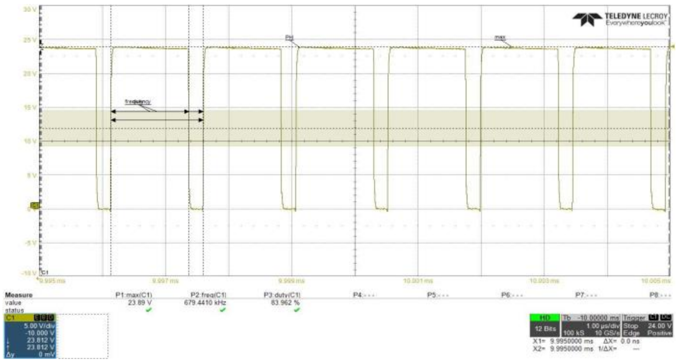
VoutA=15 V, IoutA=0.05 A (max PH voltage 24.5 V)



VoutA=15 V, IoutA=3.25 A (max PH voltage 23.9V)



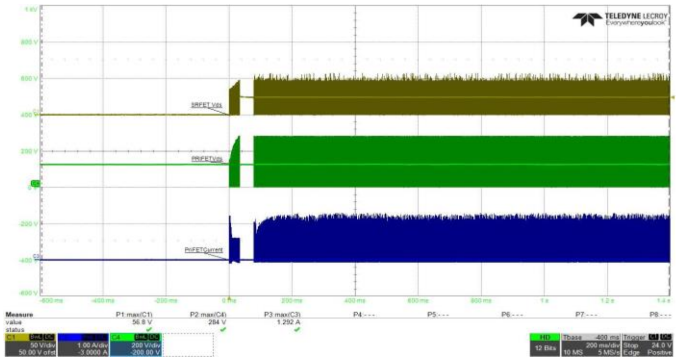
VoutA=20 V, IoutA=0.05 A (max PH voltage 24.6 V)



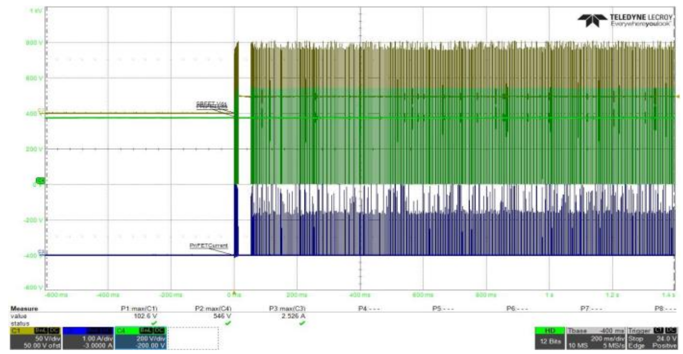
VoutA=20 V, IoutA=3.25 A (max PH voltage 23.9 V)

Drain Voltage Waveforms at Start-up (AC-DC)

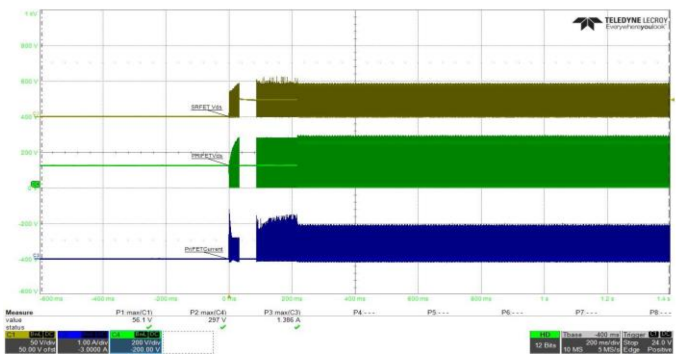
The waveforms presented in this section indicate that no components are over stressed under start-up operating conditions. Measurements were made at 90 Vac and 265 Vac at full and no-load conditions. Waveforms shown are the rectifier FET Vds (Yellow), primary switching FET Vds (Green) and the primary switching FET current (Blue).



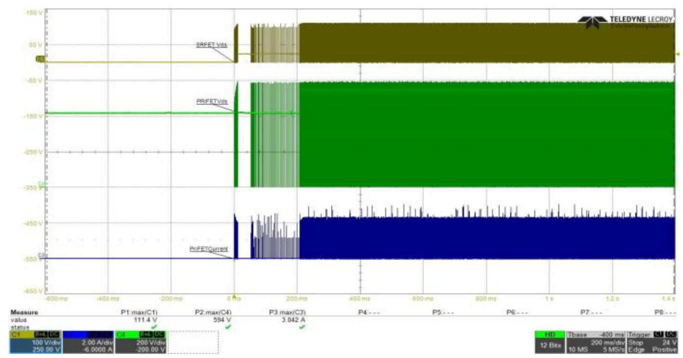
Vin=90 Vac, VoutA=5 V, IoutA=0 A (V_{ds_MAIN}=284 V, I_{d_MAIN}= 1.29 A V_{ds_SR}=57 V)



Vin=265 Vac, VoutA=5 V, IoutA=0 (V_{ds_MAIN}=546 V, I_{d_MAIN}= 2.53 A, V_{ds_SR}=103 V)



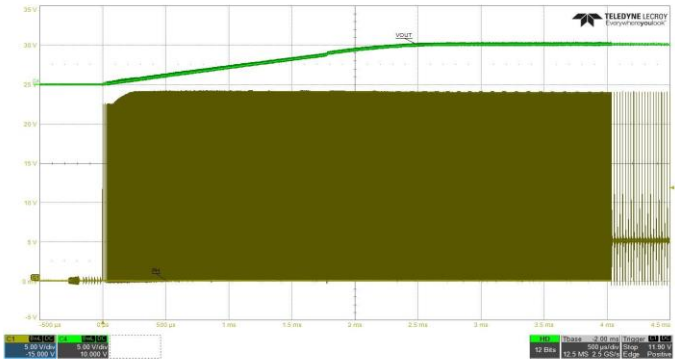
Vin=90 Vac, VoutA=5 V, IoutA=3.25 A (V_{ds_MAIN}=297 V, I_{d_MAIN}= 1.39 A V_{ds_SR}=56 V)



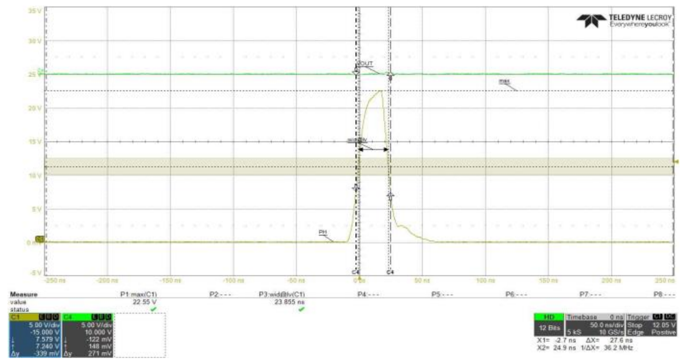
Vin=265 Vac, VoutA=5 V, IoutA=3.25 A (V_{ds_MAIN}=594 V, I_{d_MAIN}= 3.04 A V_{ds_SR}=111 V)

Drain Voltage Waveforms at Start-up (DC-DC)

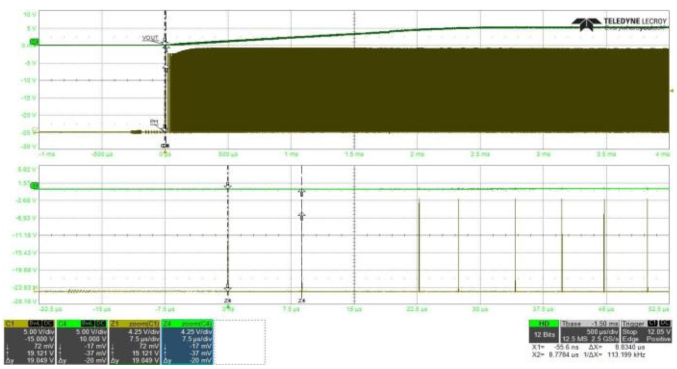
The waveforms presented in this section indicate that no components are over stressed under normal startup conditions for the SZPL3102A synchronous buck converter. Measurements were made at 115 Vac. The buck converter channel A output voltage (Yellow) and PH pin (Blue) waveforms are shown.



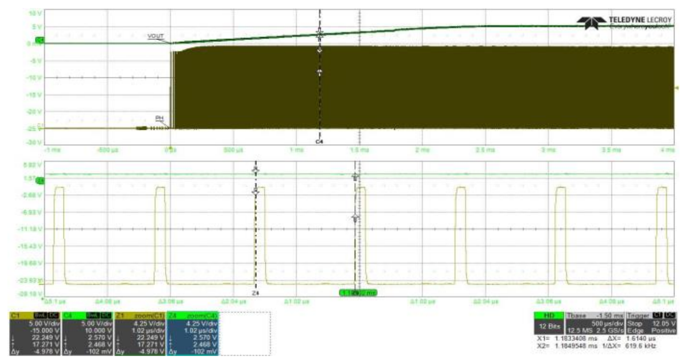
Full start sequence



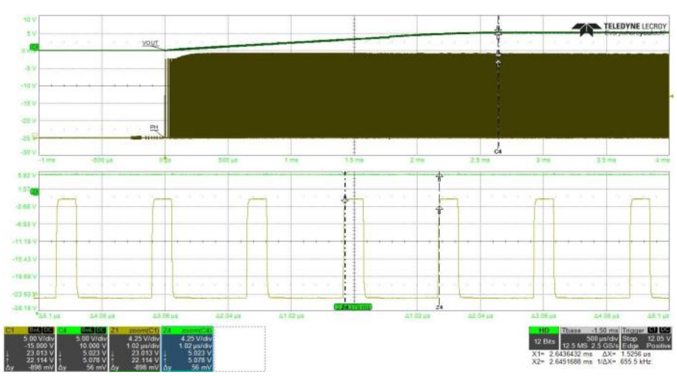
First pulse, 24ns, 22.6V



First to second pulse, 8.8 µs



Mid startup, 620kHz, 24V



End of startup, 656 kHz

End of startup, 352 ns

Conducted EMI Measurements

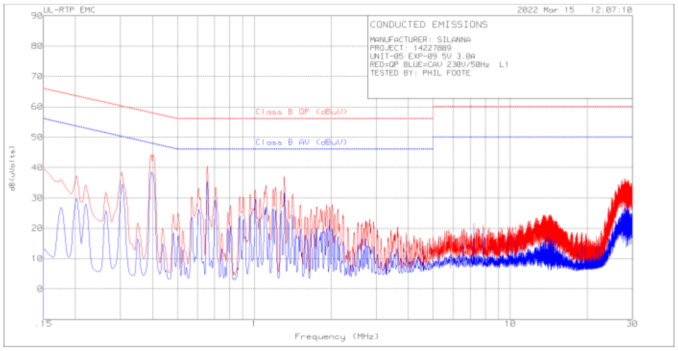
This section presents the conducted EMI measurements taken on the reference design. Tests were performed at various load currents for various output voltages on both ports. The quasi-peak and average measurements for 115 V_{AC} and 230 V_{AC} input voltages are shown.

Under all operating conditions, the results show the Reference Design passes EN55022 standard for conducted EMI measurement with no less than 7dB of margin.

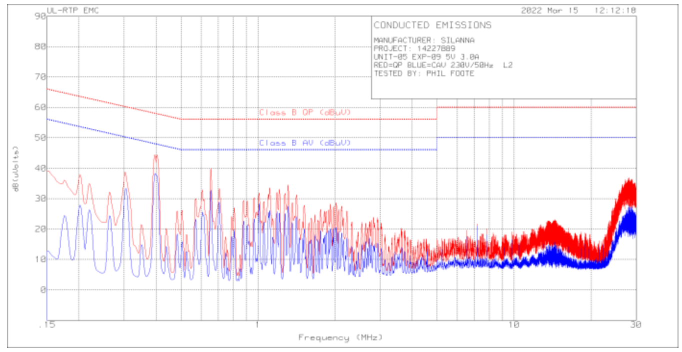
Conducted EMI Test Setup

Port A (65W)

V_{out}/ I_{out}: 5 V/ 3 A

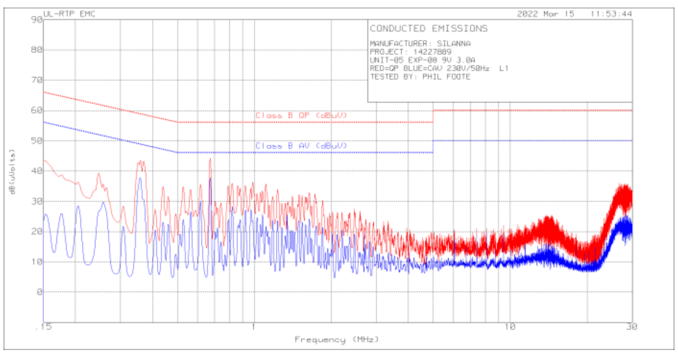


230 Vac, L1 (QP, Avg)

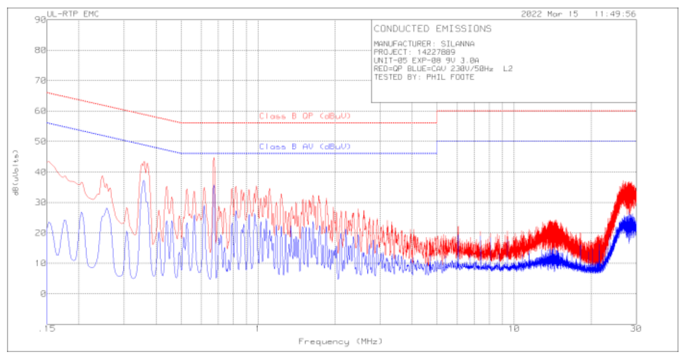


230 Vac, L2 (QP, Avg)

V_{out}/ I_{out}: 9 V/ 3 A

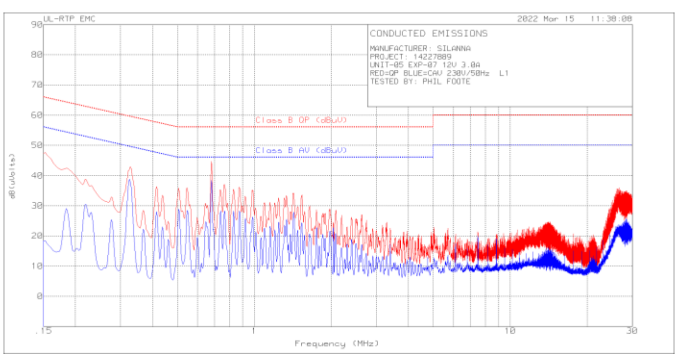


230 Vac, L1 (QP, Avg)

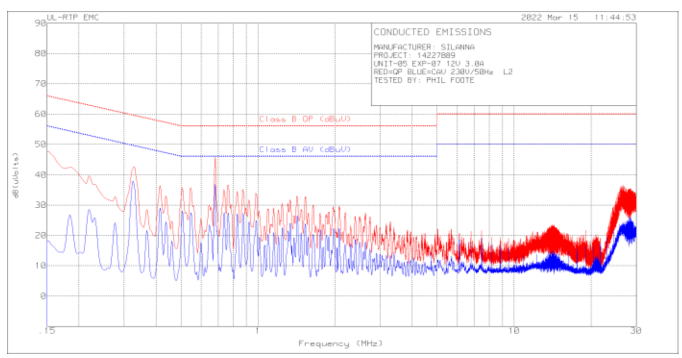


230 Vac, L2 (QP, Avg)

V_{out}/ I_{out}: 12 V/ 3 A

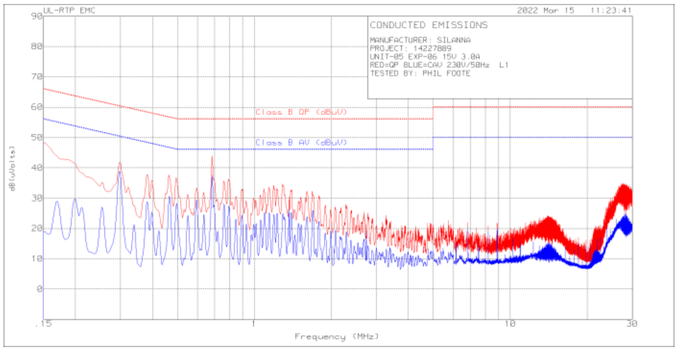


230 Vac, L1 (QP, Avg)

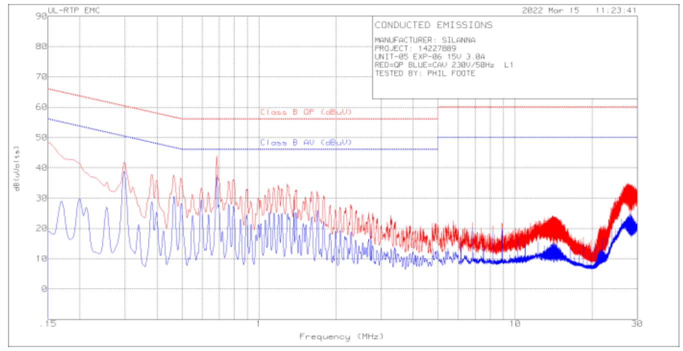


230 Vac, L2 (QP, Avg)

V_{out}/ I_{out}: 15 V/ 3 A

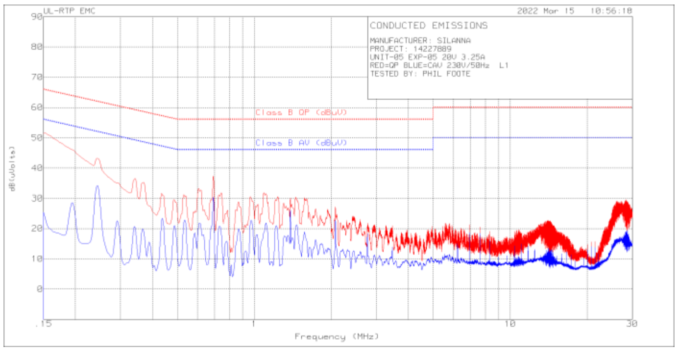


230 Vac, L1 (QP, Avg)

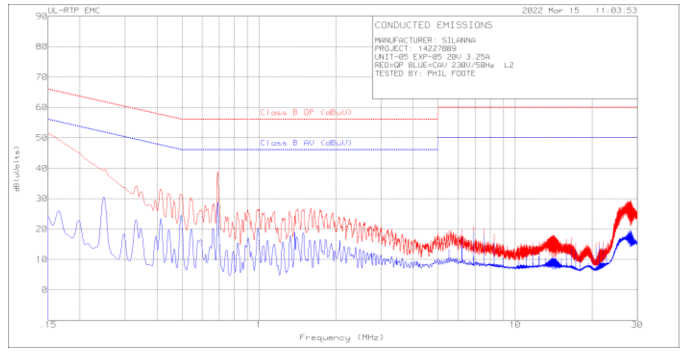


230 Vac, L2 (QP, Avg)

V_{out}/ I_{out}: 20 V/ 3.25 A



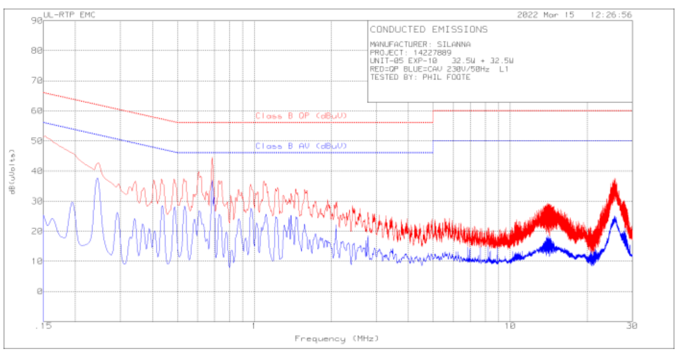
230 Vac, L1 (QP, Avg)



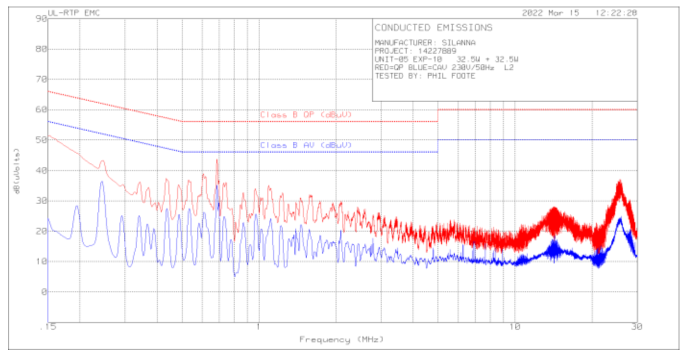
230 Vac, L2 (QP, Avg)

Dual Port (2C)

V_{outA}/ I_{outA}: 20 V / 1.625 A; V_{outB}/ I_{outB}: 15V / 2.17 A (65W total)



230 Vac, L1 (QP, Avg)



230 Vac, L2 (QP, Avg)

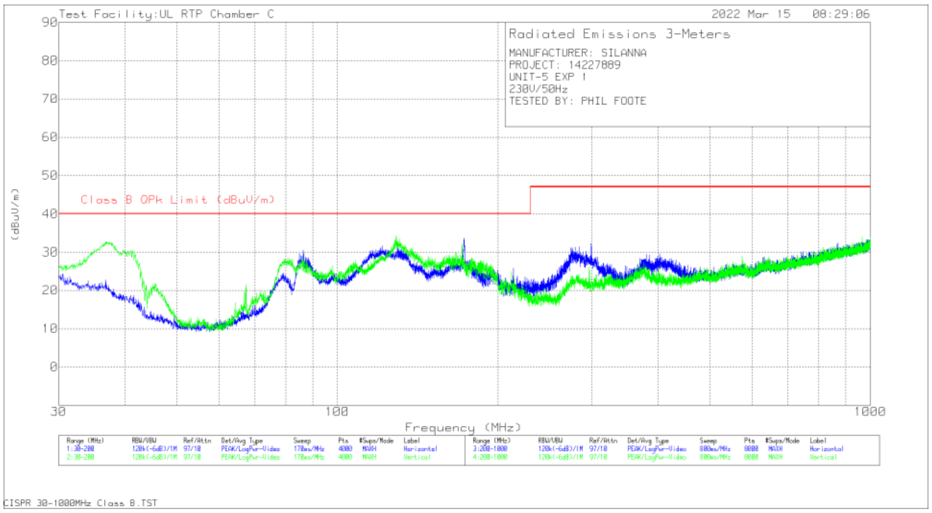
Radiated EMI Measurements

This section presents the radiated EMI measurements taken on the reference design. Tests were performed at various load currents for various output voltages on both ports. The peak and quasi-peak measurements for 115 V_{AC} and 230 V_{AC} input voltages are shown.

Under all operating conditions, the results show the Reference Design passes EN55022 standard for radiated EMI measurement with no less than 8dB of margin.

Port A (65W)

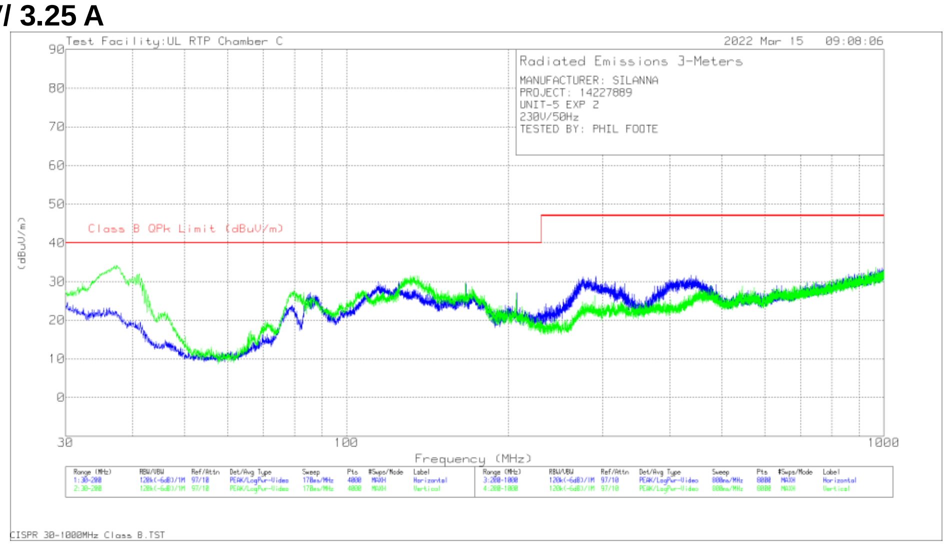
V_{out}/ I_{out}: 20 V/ 3.25 A



Radiated EMI measurement results (Horizontal and Vertical) for 230 Vac (>9dB QP margin)

Port B (65W)

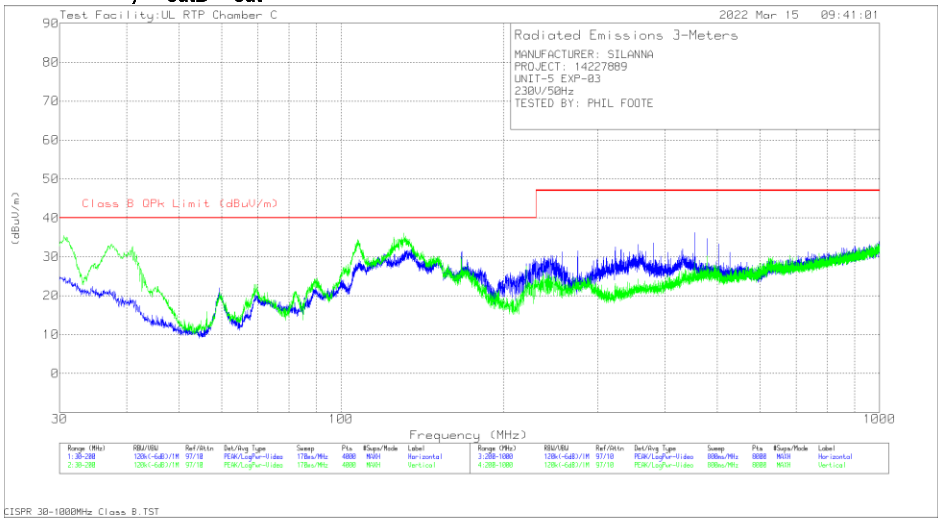
V_{out}/ I_{out}: 20 V/ 3.25 A



Radiated EMI measurement results (Horizontal and Vertical) for 230 Vac (>8dB QP margin)

Dual Port (65W)

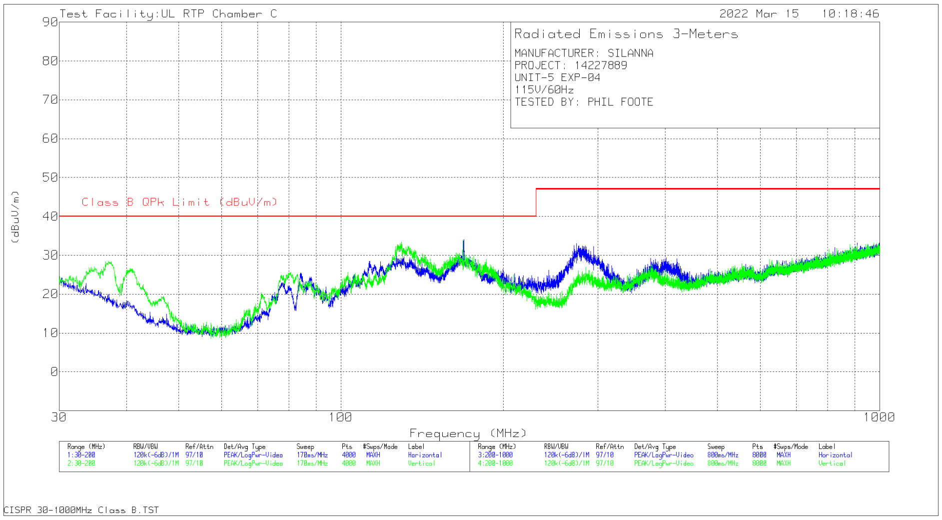
V_{outA}/ I_{out}: 20 V/ 1.625 A; V_{outB}/ I_{out}: 15 V/ 2.17 A



Radiated EMI measurement results (Horizontal and Vertical) for 230 Vac (>8dB QP margin)

Port A (65W)

V_{out}/ I_{out}: 20 V/ 3.25 A



Radiated EMI measurement results (Horizontal and Vertical) for 115 Vac (>9dB QP margin)

Thermal Measurements Uncased

The following thermal images show the highest temperatures for the power semiconductors at 20 V/3.25 A output, 90 Vac 60Hz input, 27C ambient. The component temperatures were measured using a thermal camera and soak for more than 1 hour, reaching thermal equilibrium.

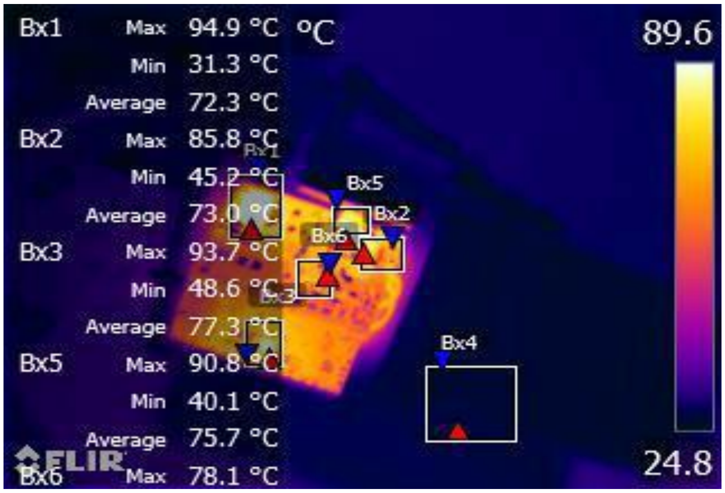
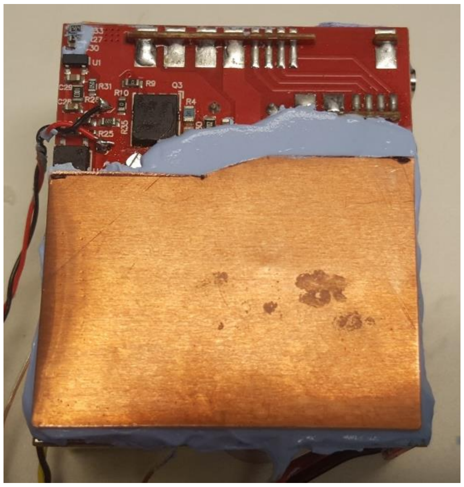


Table 17: Uncased Components Temperature, 90Vac input, 20V 3.25A output

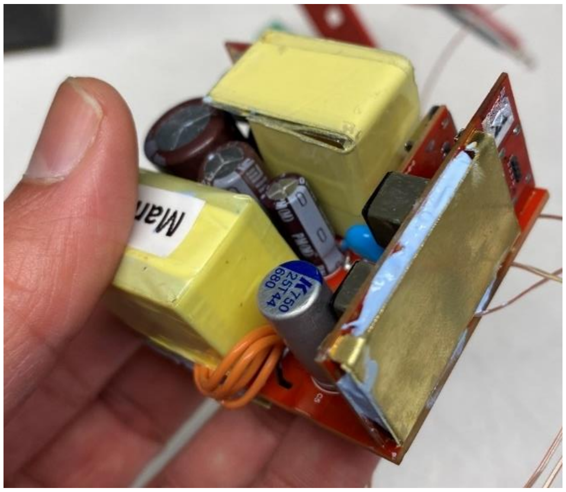
Item	Temperature (C)
Br. Rectifiers (box1)	94.6
SZ1130-02 (box 2)	85.8
SZPL3102A (box 3)	93.5
ACF FET (box 5)	90.8
SR FET (box 6)	78.5

Thermal Measurements Cased

The key components temperatures were also measured inside the case. To help in thermal management, a heat sink was applied to the top of some primary side components of the Flyback circuit (Bridge, Main FET and SZ1130). A heatsink was also used on top of SZPL3102A IC is to lower their case temperature. The figures below show the thermal setup as well as the heatsink / heat spreaders that were implemented on the unit before putting inside the case.



Metal heatsink on top of Bridge Rectifier, SZ1130 & Main FET



Metal heatsink on top of SZPL3102A

The case also had a brass metal heat spreader applied to its interior (4 sides only) with adhesive and a layer of ITW Formex GK-17 insulation over top of that. The picture below left shows the brass heat spreader applied to the case interior befor the GK-17 insulation was applied. The picture below right shows the unit inside the case (thermocouple wires visible exiting unit for thermal testing), prior to L-shaped mating piece of case attached.

Heat spreader applied to case interior

PCB assembly inside plastic case (L-shaped mating piece absent)

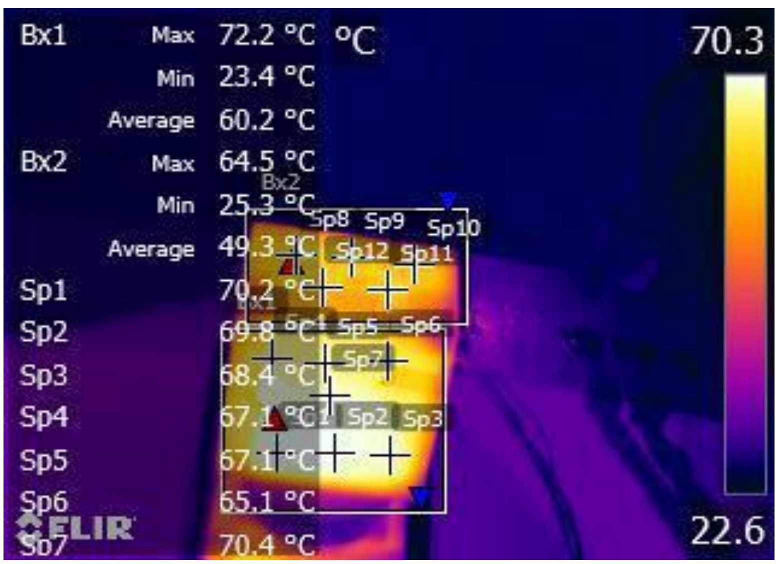
Table 17 lists temperatures of the hottest critical components at 20V, 3.25A, 90Vac, 23C ambient after operation for more than 75 min inside the casing, reaching thermal equilibrium. Some components not shown but thermals there were shown to be well within acceptable limits. The components shown are the hottest identified. External ambient at 24°C.

Table 18: Cased Components Temperature, 90Vac input, 20V 3.25A output

Designator	Components	90 Vac (60 Hz)
U2 (Main board)	SZ1130-02	97.1 °C
BR1, BR2	Bridge Rectifier 1	99.2 °C
Q2 (Primary FET)	ACF FET	96.6 °C
U1 (DCDC Board)	SZPL3102A	102.2 °C

Case Temperature

The following thermal image show the highest temperatures observed on the case using a thermal camera after >75min soak, reaching thermal equilibrium. Measured with 100Vac input and 20V/3.25A output on port A, 23C ambient.



Case temperature, hot side

Table 19: Case temperature summary, 100Vac input, 20V 3.25A output

Item	Location	Temperature
Box 1	Hot side of case, next to primary side heat spreader	72.2°C
Box 2	Top of case, next to DC-DC board heat spreader	64.5 °C
Spots	Various, to show heat distribution	65 - 72 °C

Revision History

Revision	Date	Author	Note
1.0	12/02/2020	KH	For Review
1.1	12/02/2020	KH	For Review
2.0	3/18/2022	Internal Application Team	Initial Release