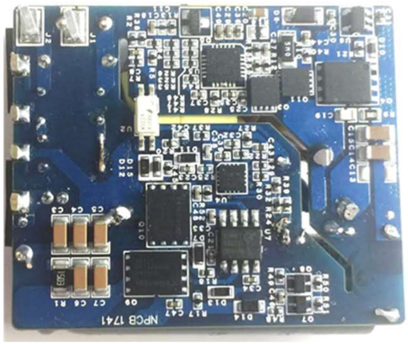
65 W USB PD (Type-C) Demo Board

UG018

This user's guide covers:

Demo Board#	Description	Part(s) Used	F_{SW}
NVE028B-A	65 W USB PD Adapter 5V/3A, 9V/3A, 15V/3A, 20V/3.25A	NV6115, NV6117 UCC28780	140-490 kHz



IMPORTANT NOTICE:

Hazardous voltages are present on this demo board. Personal contact with high voltages may result in injury or death. Correct handling and safety procedures must be observed. Boards are for lab bench evaluation only. Not for installation in end-user equipment.

CAUTION:

This product contains parts that are susceptible to damage by electrostatic discharge (ESD). Always follow ESD prevention procedures when handling the product.

Description:

This demo board uses one NV6115 and one NV6117 GaN Power ICs in an Active Clamp Flyback (ACF) AC-DC converter, for applications such as smartphone, tablet, and laptop chargers with USB Power Delivery (USB-PD) capability. The NV6115 and NV6117 are 650V 160 mΩ and 110 mΩ eMode GaN Power IC with iDrive™ integrated-driver stage respectively, each requiring only a low-current digital input. For the datasheet and other information, please refer to www.navitassemi.com or contact info@navitassemi.com.

This board achieves world smallest size (51 x 43 x 20.5 mm cased) and breakthrough power density (1.5 W/cc, 24 W/in^3 cased). The switching frequency is adjustable in range of 140-490 kHz for universal AC input. The design is fully compliant with European CoC Tier 2 and US DoE Level VI efficiency standards, in addition to reaching peak efficiencies of over 94% at full load.

Note: The demo board runs to 65 W (20 V, 3.25 A) assuming a captive cable. USB-PD protocol limits type-C receptacle current to 3 A.

Thanks are due to the Texas Instruments team in Manchester, NH for their assistance.

This revision uses a low-profile RM8 core operating at moderate frequency. For information on higher-frequency designs and alternative transformer sizes / form-factors, please contact Navitas.

Note: Board is **NOT** designed to meet lightning strikes, etc. so **DO NOT** test under adverse conditions.

For individual files for schematic, PCB (gerber, .dxf), etc., please contact info@navitassemi.com.

Overall Operation Conditions, Performance:

	Parameter		Value	Units
V_{IN}	Input Voltage		90-264 47-63	V_{AC} Hz
V_{OUT}	Output Voltage		5, 9, 15, 20	V
I_{OUT}	Output Current (max)	V_{OUT} = 5V, 9V, 15V V_{OUT} = 20V	3 3.25	A
P_{OUT}	Output Power (max)		65	W
$P_{LOSS(STB)}$	Standby Power Loss	230 V_{AC} 115 V_{AC}	35 25	mW mW
	Dimensions	(uncased)	46 x 38 x 15.5 27	mm cc
	Power Density	(uncased)	2.40 39.3	W/cc W/in^3

V_{OUT} = 20 V Operation Conditions and Performance

F_{SW}	Switching Frequency	Typical Full Load (230 V_{AC})	354 – 358	kHz
		Typical Half Load (230 V_{AC})	483 – 488	kHz
		Typical Full Load (115 V_{AC})	260 – 305	kHz
		Typical Half Load (115 V_{AC})	426 – 446	kHz
η	Efficiency (full load)	230 V_{AC}	94.5	%
		115 V_{AC}	94.3	%
		90 V_{AC}	93.4	%
	Efficiency (4–pt. ave.)	230 V_{AC}	92.3	%
	(25%, 50%, 75%, 100% load)	115 V_{AC}	93.4	%

V_{OUT} = 15 V Operation Conditions and Performance

F_{SW}	Switching Frequency	Typical Full Load (230 V_{AC})	314 – 316	kHz
		Typical Half load (230 V_{AC})	393 – 397	kHz
		Typical Full Load (115 V_{AC})	274 – 292	kHz
		Typical Half Load (115 V_{AC})	361 – 371	kHz
η	Efficiency (full load)	230 V_{AC}	94.3	%
		115 V_{AC}	94.1	%
	Efficiency (4–pt. ave.)	230 V_{AC}	92.4	%
	(25%, 50%, 75%, 100% load)	115 V_{AC}	93.3	%

V_{OUT} = 9 V Operation Conditions and Performance

F_{SW}	Switching Frequency	Typical Full Load (230 V_{AC})	216 – 218	kHz
		Typical Half load (230 V_{AC})	260 – 290	kHz
		Typical Full Load (115 V_{AC})	223 – 227	kHz
		Typical Half Load (115 V_{AC})	257 – 261	kHz
η	Efficiency (full load)	230 V_{AC}	93.4	%
		115 V_{AC}	93.5	%
	Efficiency (4–pt. ave.)	230 V_{AC}	91.0	%
	(25%, 50%, 75%, 100% load)	115 V_{AC}	92.4	%

V_{OUT} = 5 V Operation Conditions and Performance

F_{SW}	Switching Frequency	Typical Full Load (230 V_{AC})	136 – 138	kHz
		Typical Half load (230 V_{AC})	155 – 157	kHz
		Typical Full Load (115 V_{AC})	153 – 156	kHz
		Typical Half Load (115 V_{AC})	165 – 167	kHz
η	Efficiency (full load)	230 V_{AC}	90.2	%
		115 V_{AC}	90.3	%
	Efficiency (4–pt. ave.)	230 V_{AC}	88.4	%
	(25%, 50%, 75%, 100% load)	115 V_{AC}	89.0	%

Active Clamp Flyback (ACF) Topology

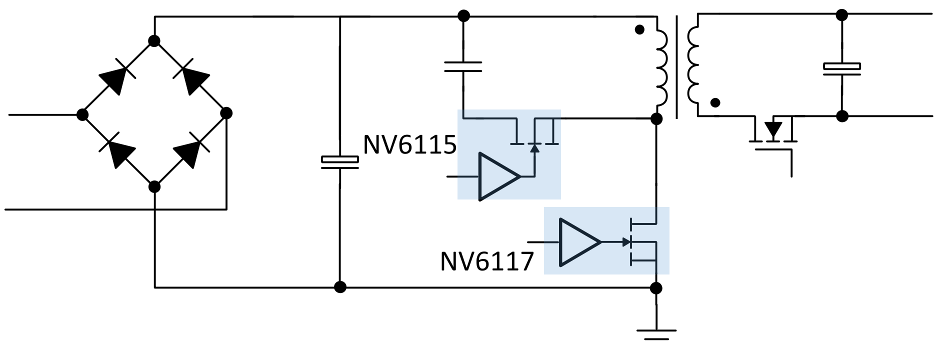


Fig. 1: ACF topology showing NV6115 + NV6117 GaN Power ICs

The soft-switching Active Clamp Flyback (ACF) topology is an advancement on the standard hard-switching Quasi-Resonant Flyback. By adding an extra switch, the switching loss is eliminated and frequency can be increased to minimize transformer, EMI filter size and cost. Power density has been increased by 75% (W/cc or W/in^3) using this demo board.

For a more detailed study of ACF, please refer to the work below:

- "Active Clamp Flyback Using GaN Power IC for Power Adapter Applications", Xue, Zhang, Navitas, APEC 2017
- "Conducted EMI Analysis and Filter Design for MHz Active Clamp Flyback Front-End Converter", Huang, et al, VPT, APEC 2016
- "Techniques of the Modeling, Measurement and Reduction of Common Mode Noise for a Multi-winding Switching Transformer", Li, Zhang, Wang, et al, APEC 2017
- "Design Considerations of MHz Active Clamp Flyback Converter with GaN Devices for Low Power Adapter Application", Huang, et al, VPT, APEC 2016
- "Utilization of an active-clamp circuit to achieve soft switching in flyback converters" (PESC 1994)

Schematic:

This demo board includes one mother board and two daughter boards. One daughter board contains the AC diode bridge and the other one holds the USB Type-C connector. Please see next pages for details.

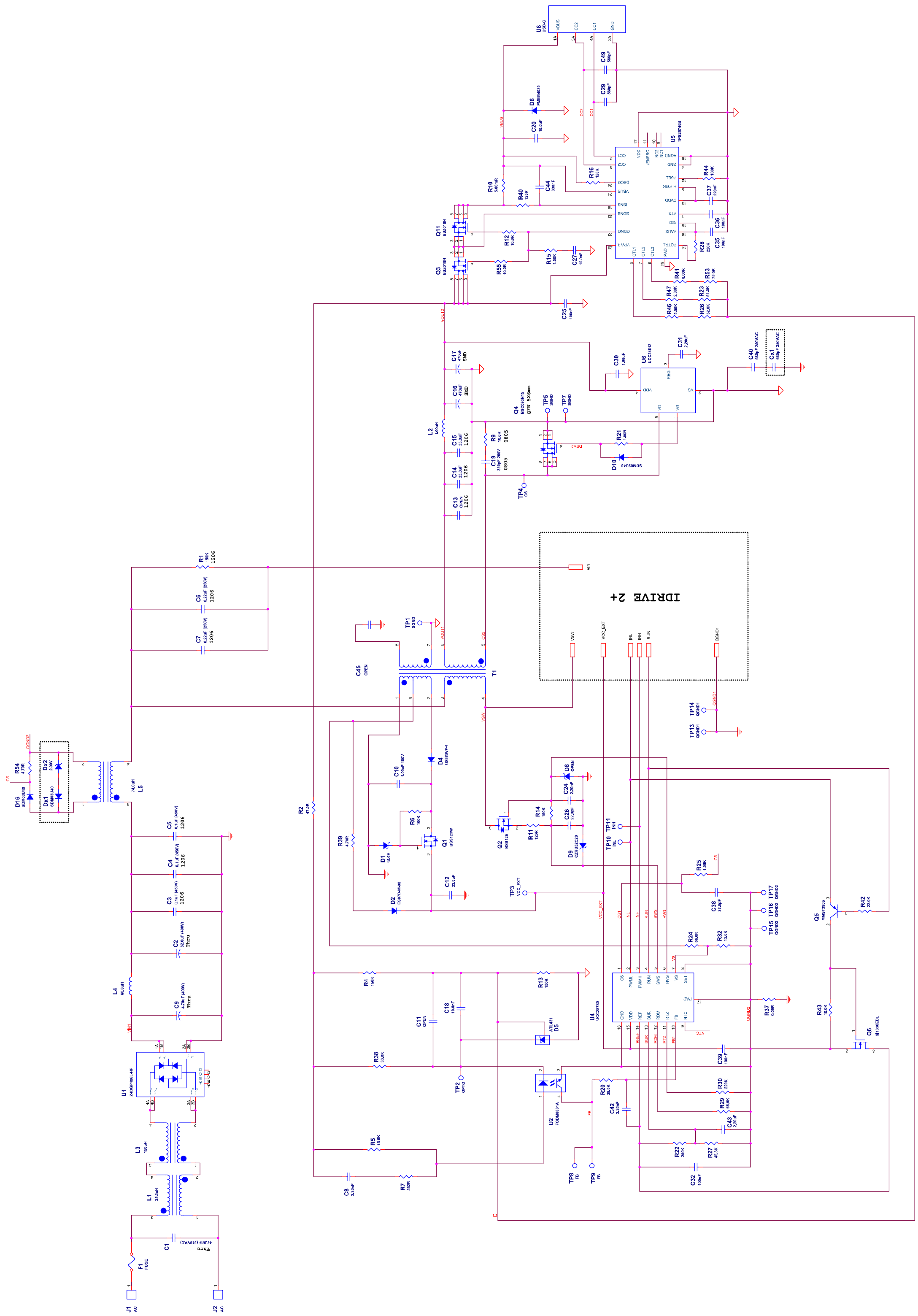
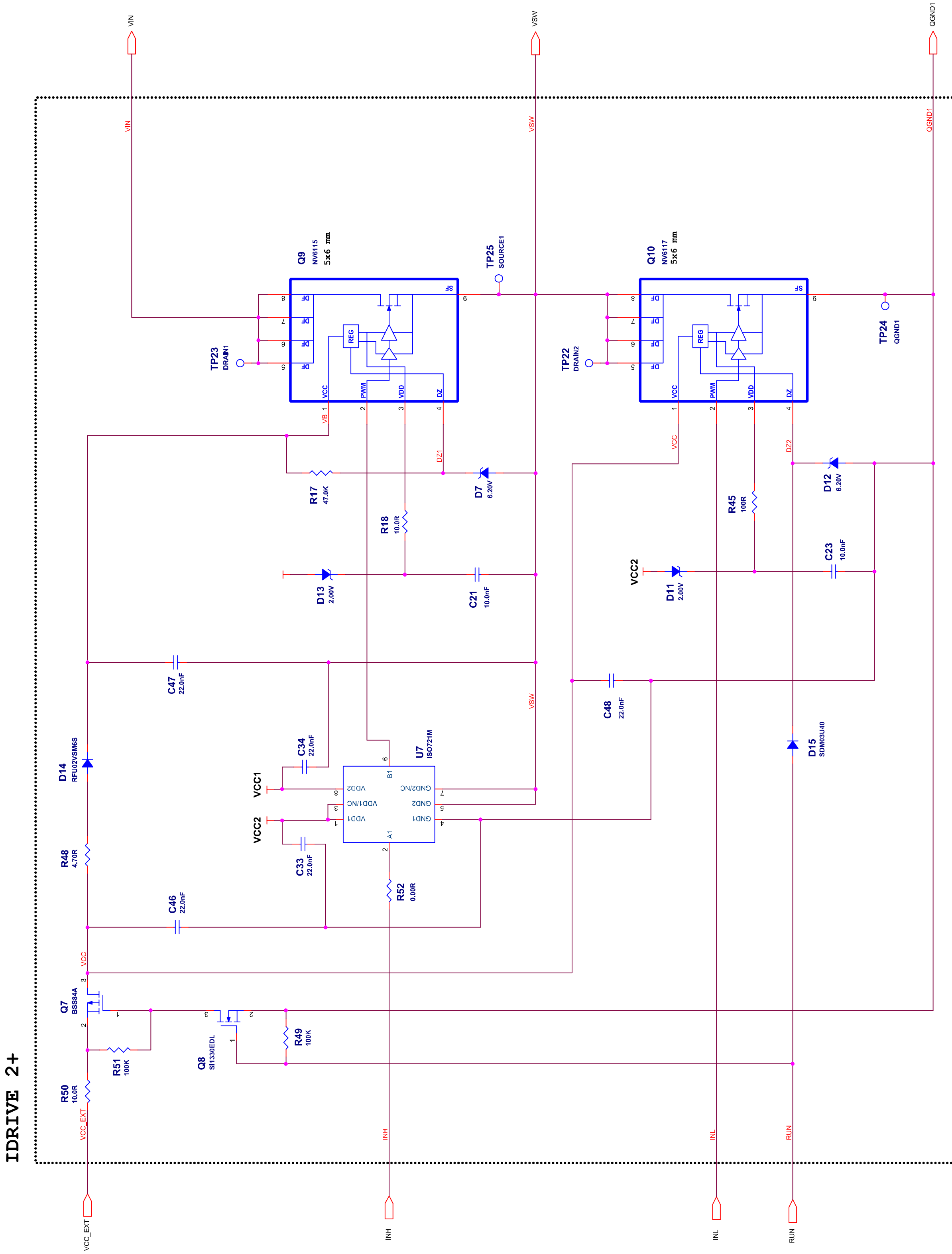


Fig. 2a: System Schematic

Fig. 2b: GaN Power IC Powertrain



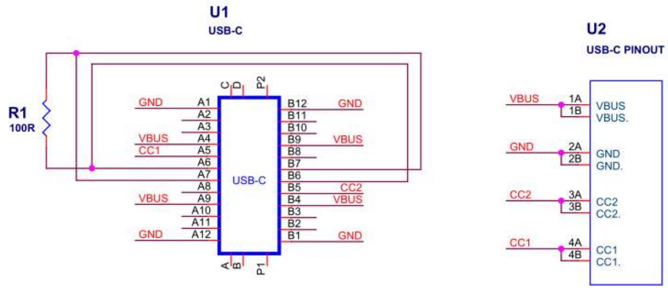


Fig. 2c: Input Diode Bridge Daughter Board

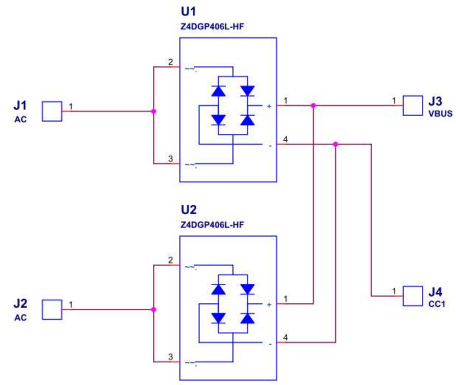


Fig. 2c: Output USB Type-C Daughter Board

Board, Component Placement:

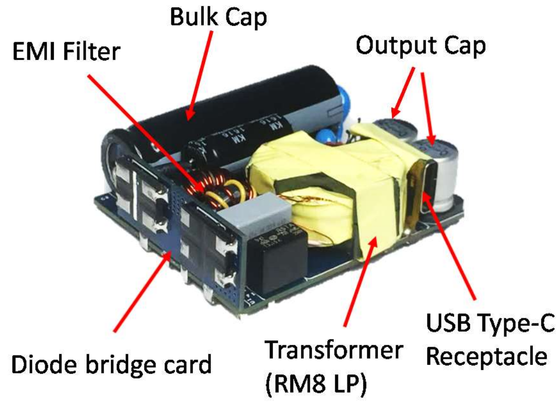


Fig. 3a: Top-side components

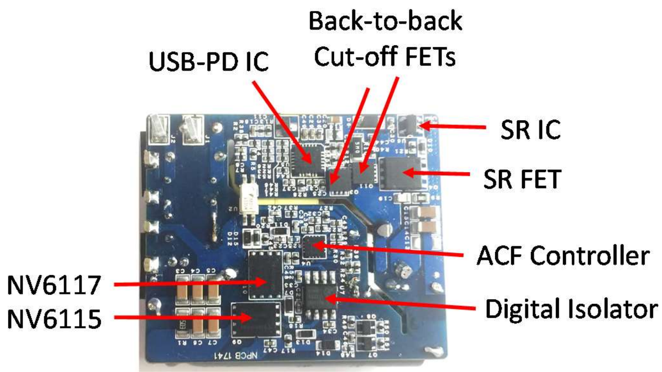


Fig. 3b: Bottom-side components

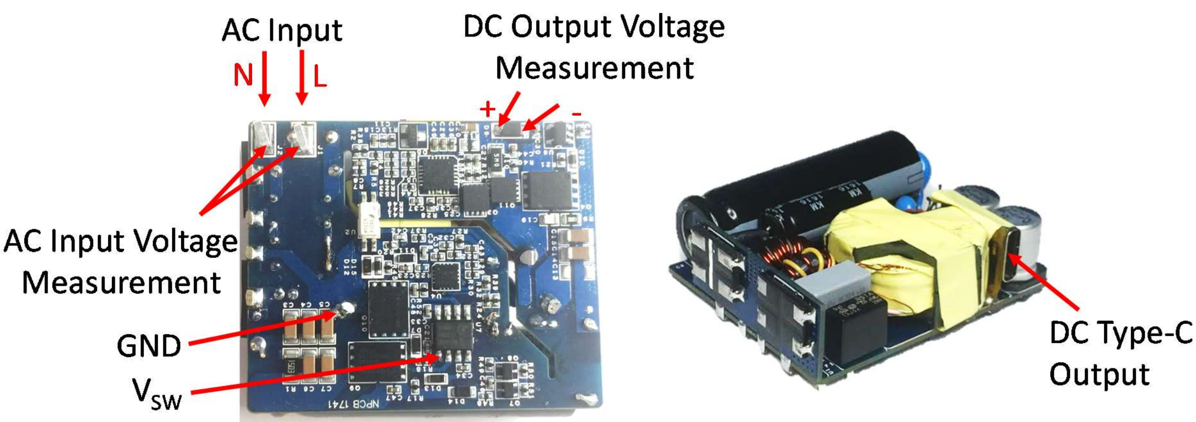


Fig 3c: Connections

Connections and Start-up Sequence:

Please refer to the connection diagram in Fig 3c.

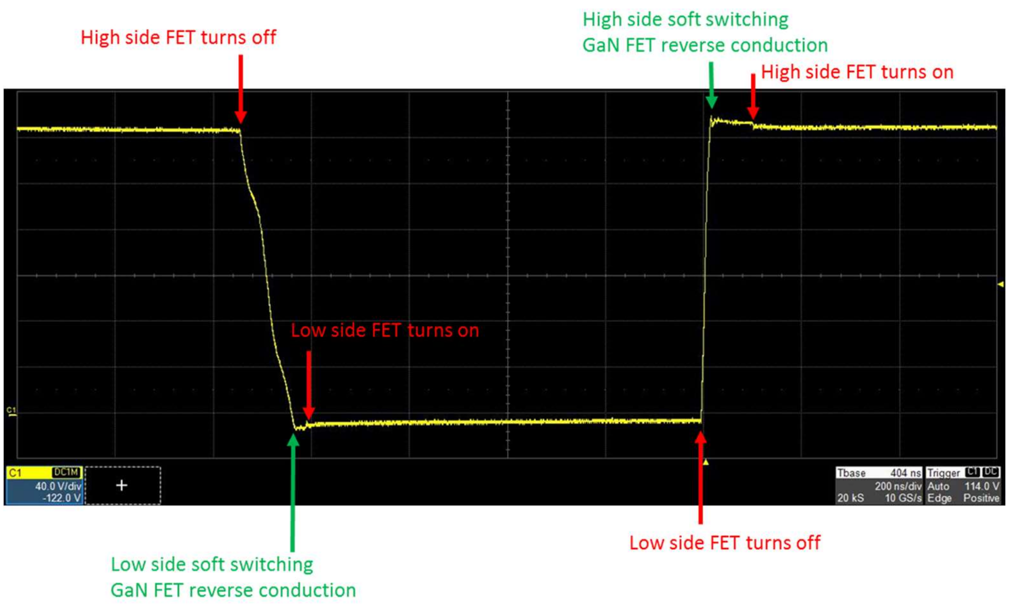
1. Connect USB PD sink load through Type-C Receptacle
2. Connect AC Input to AC source (90 – 264 V_{AC})
3. Output voltage (5 V, 9 V, 15 V, or 20 V) will be negotiated between the board and PD sink load
4. Set load current to 0 – 3 A for 5 V, 9 V, 15 V outputs, 0 – 3.25 A for 20 V output.

Measurement:

Switching waveforms can be measured between V_{SW} and GND (shown in Fig 3c). GaN half-bridge circuits are fast and sensitive to parasitic capacitance introduced by voltage probes.

DO NOT probe high-side circuit during operation. The voltage probe capacitance (~10pF) will add dv/dt noise and adversely impact the half bridge operation.

All high-side and low-side switching timing can be conveniently observed by studying V_{SW}. GaN FETs' reverse-conduction voltage (equivalent to Si FET's "body-diode voltage") can be used to precisely determine the FET turn-on timings.

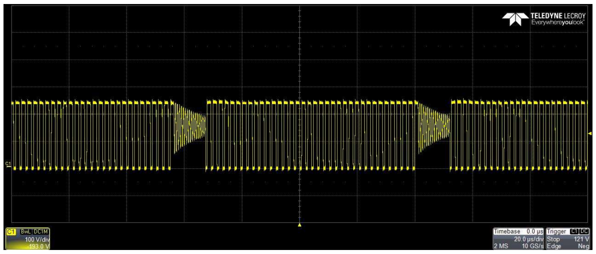


1. For full load efficiency measurement, connect both input and output voltage meters at board edges (Fig 3c). Run > 15min before measuring.

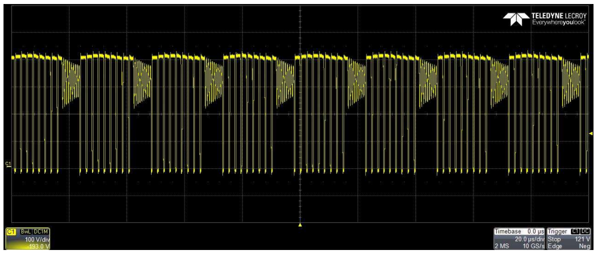
Power-down sequence:

1. Turn off AC power source
2. Turn off the load

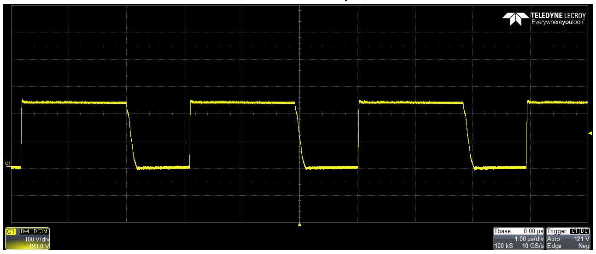
V_{OUT} = 20 V Switching Waveforms:



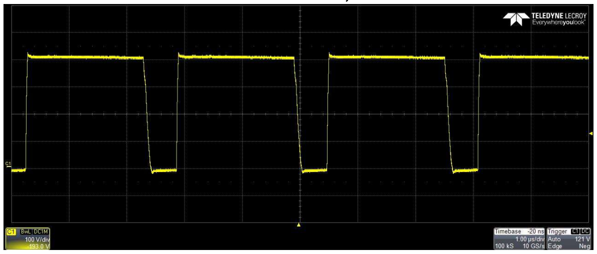
a: V_{SW} at 115 V_{AC}, half load



b: V_{SW} at 230 V_{AC}, half load

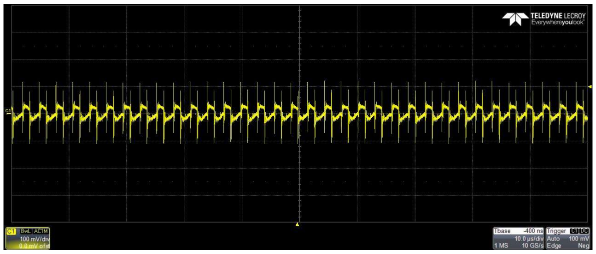


c: V_{SW} at 115 V_{AC}, full load

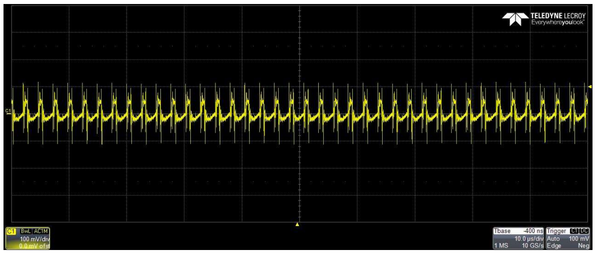


d: V_{SW} at 230 V_{AC}, full load

Fig. 5 V_{SW} Steady State Waveforms at V_{OUT} = 20 V.

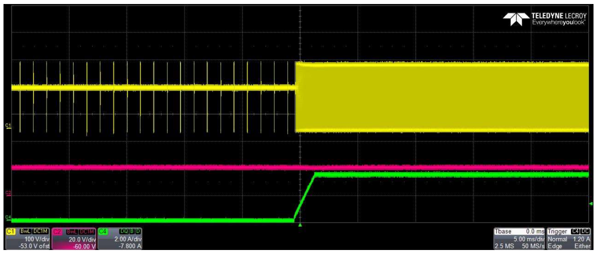


a: Output Ripple at at 115 V_{AC}, full load

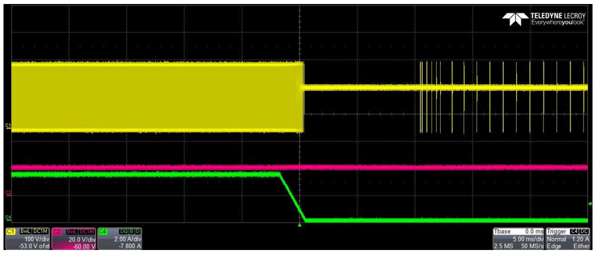


b: Output Ripple at at 230 V_{AC}, full load

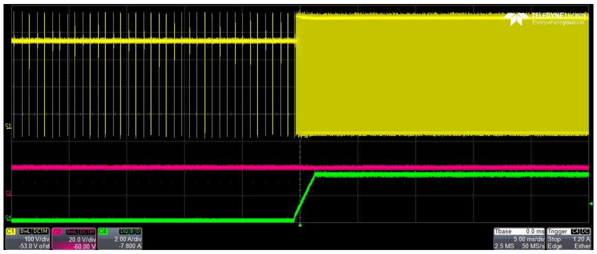
Fig. 6 Output Ripple at V_{OUT} = 20 V.



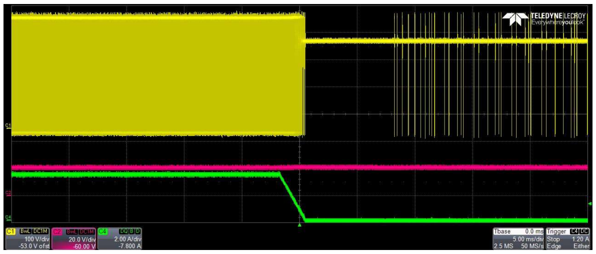
a: 115 V_{AC} from no load to 3.25 A load



b: 115 V_{AC} from 3.25 A to no load



c: 230 V_{AC} from no load to 3.25 A load

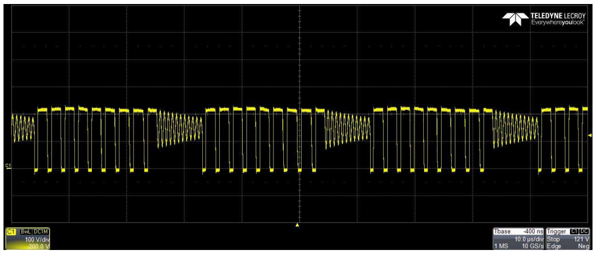
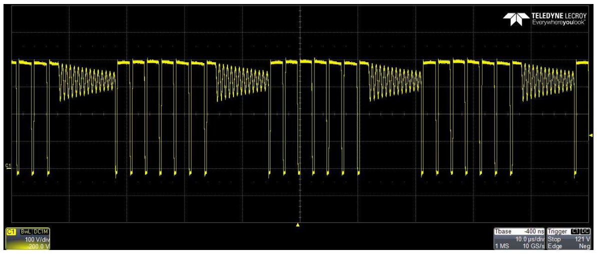


d: 230 V_{AC} from 3.25 A to no load

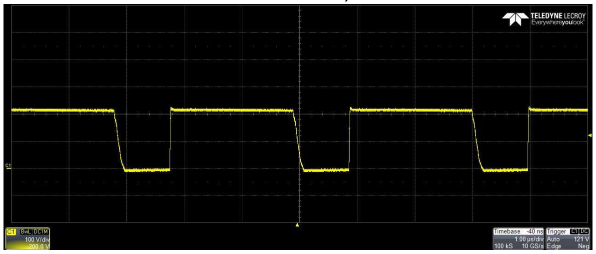
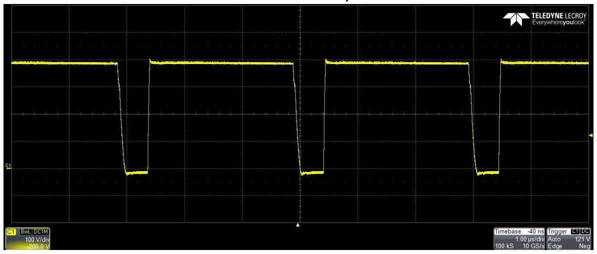
Fig. 7 Load Transient at V_{OUT} = 20 V.

Yellow: switch node voltage; Red: output voltage; Green: output current

V_{OUT} = 15V Switching Waveforms:

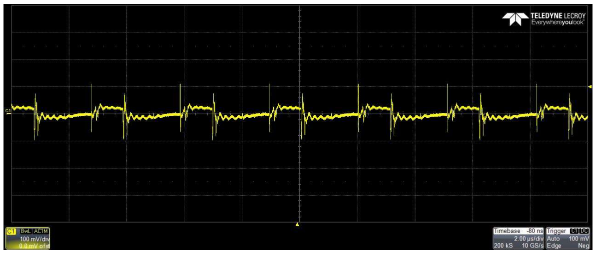
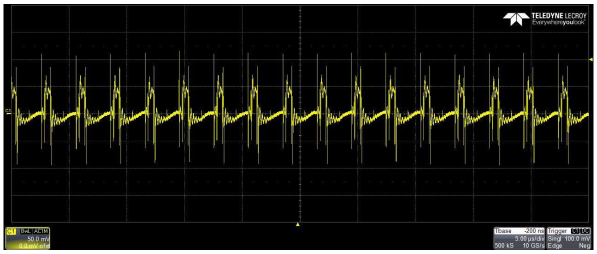



a: V_{SW} at 115 V_{AC}, half load b: V_{SW} at 230 V_{AC}, half load

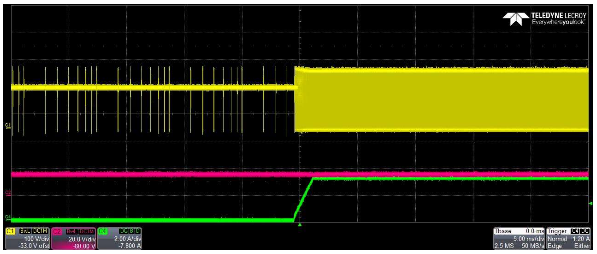
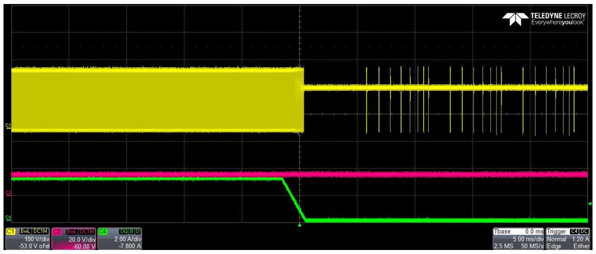
c: V_{SW} at 115 V_{AC}, full load d: V_{SW} at 230 V_{AC}, full load

Fig. 8 V_{SW} Steady State Waveforms at V_{OUT} = 15 V.

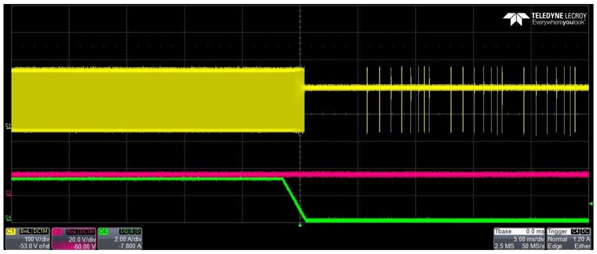
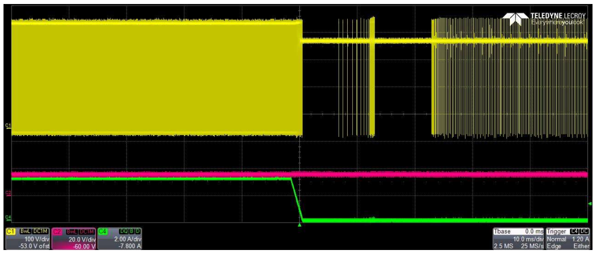



a: Output Ripple at at 115 V_{AC}, full load b: Output Ripple at at 230 V_{AC}, full load

Fig. 9 Output Ripple at V_{OUT} = 15 V.

a: 115 V_{AC} from no load to 3A load b: 115 V_{AC} from 3A to no load

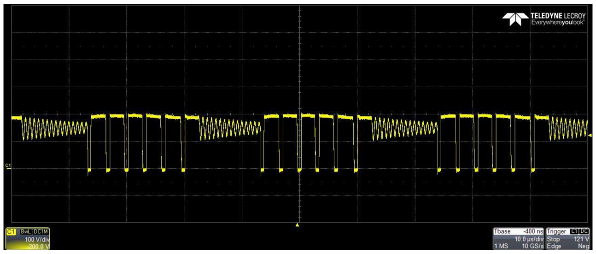



c: 230 V_{AC} from no load to 3 A load d: 230 V_{AC} from 3 A to no load

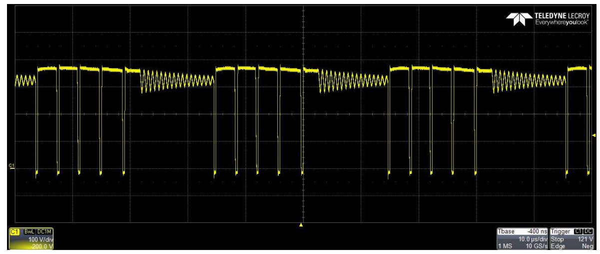
Fig. 10 Load Transient at V_{OUT} = 15 V.

Yellow: switch node voltage; Red: output voltage; Green: output current

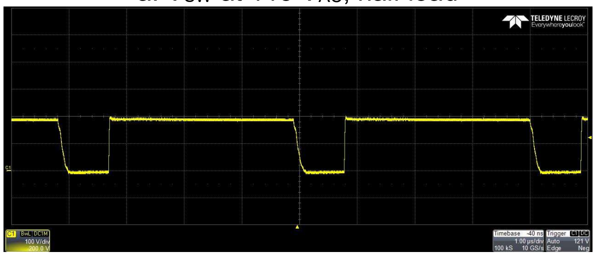
V_{OUT} = 9 V Switching Waveforms:



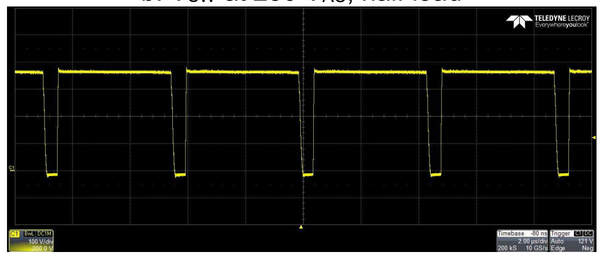
a: V_{SW} at 115 V_{AC}, half load



b: V_{SW} at 230 V_{AC}, half load

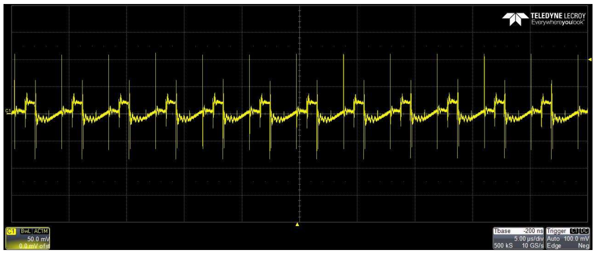


c: V_{SW} at 115 V_{AC}, full load

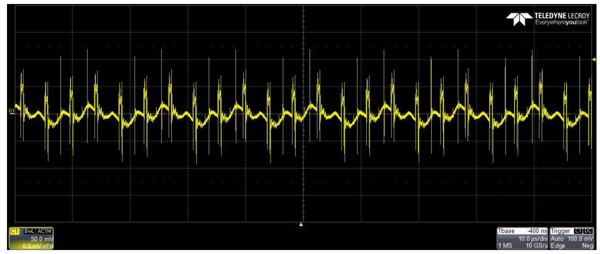


d: V_{SW} at 230 V_{AC}, full load

Fig. 11 V_{SW} Steady State Waveforms at V_{OUT} = 9 V.

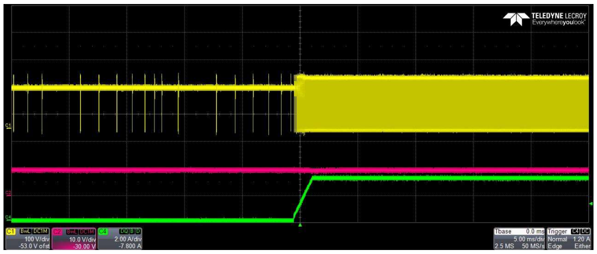


a: Output Ripple at at 115 V_{AC}, full load

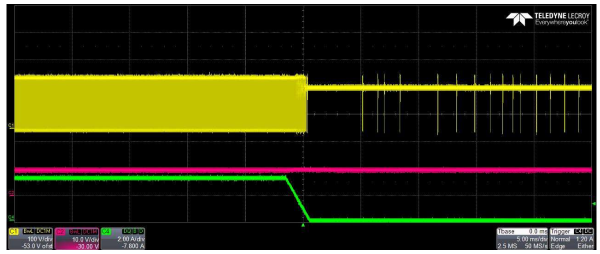


b: Output Ripple at at 230 V_{AC}, full load

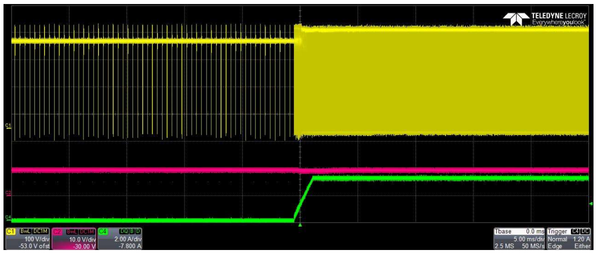
Fig. 12 Output Ripple at V_{OUT} = 9 V.



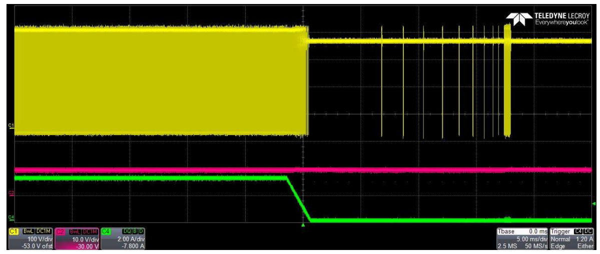
a: 115 V_{AC} from no load to 3 A load



b: 115 V_{AC} from 3 A to no load



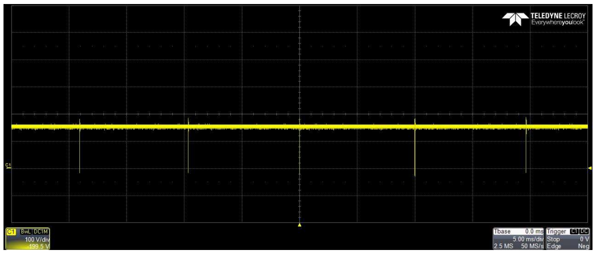
c: 230 V_{AC} from no load to 3 A load

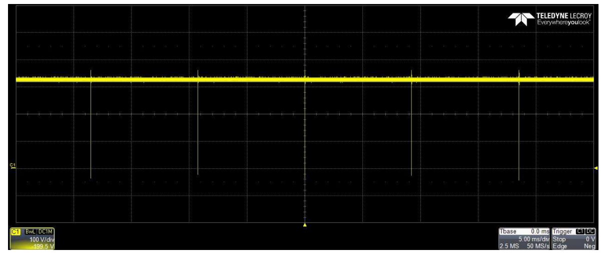


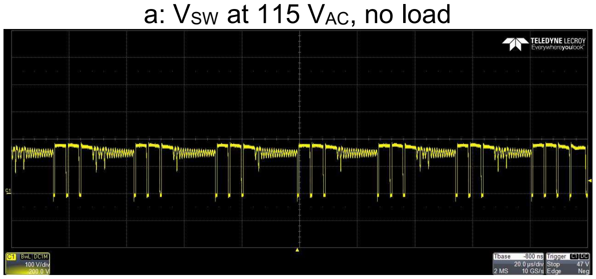
d: 230 V_{AC} from 3 A to no load

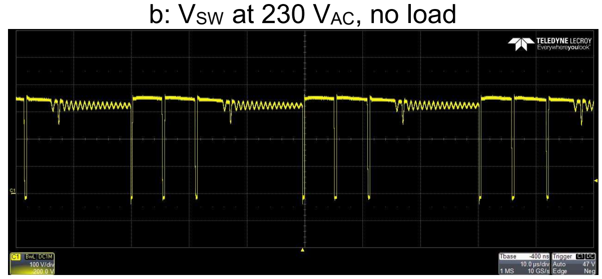
Fig. 13 Load Transient at V_{OUT} = 9 V.
Yellow: switch node voltage; Red: output voltage; Green: output current

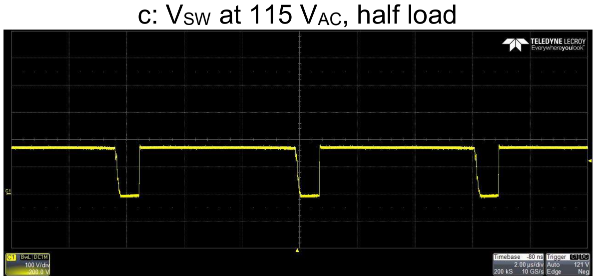
V_{OUT} = 5V Switching Waveforms (including no load):


a: V_{SW} at 115 V_{AC}, no load


b: V_{SW} at 230 V_{AC}, no load


c: V_{SW} at 115 V_{AC}, half load


d: V_{SW} at 230 V_{AC}, half load


e: V_{SW} at 115 V_{AC}, full load

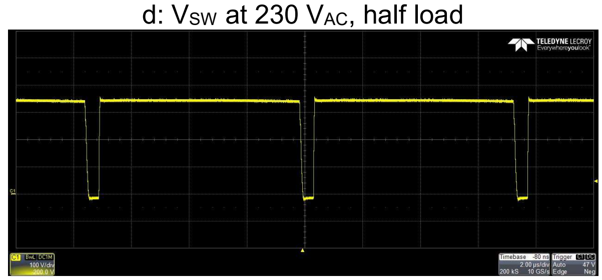
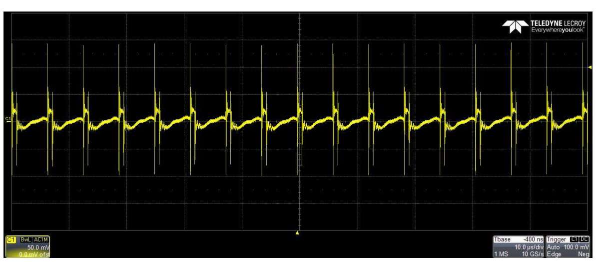

f: V_{SW} at 230 V_{AC}, full load

Fig. 14 V_{SW} Steady State Waveforms at V_{OUT} = 5 V.
For USB PD adapter, no load only happens at V_{OUT} = 5 V (shown in Fig 14a and Fig 14b)


a: Output Ripple at at 115 V_{AC}, full load

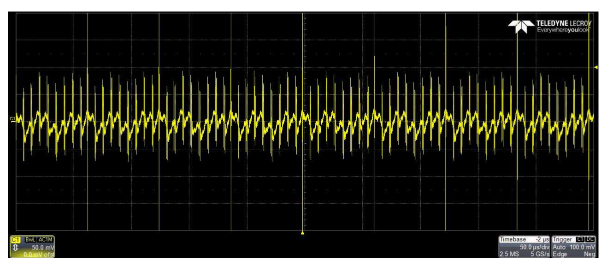
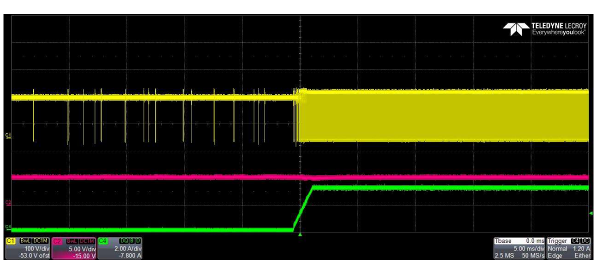
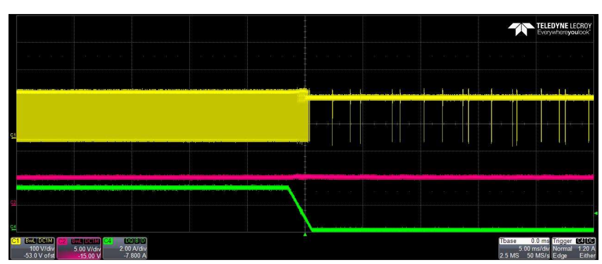
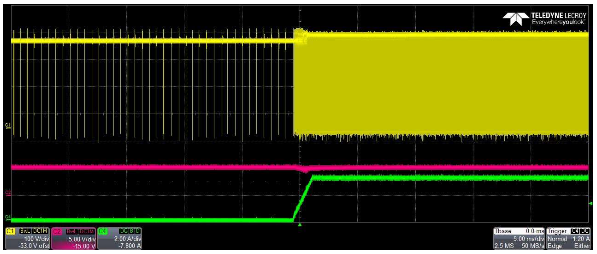

b: Output Ripple at at 230 V_{AC}, full load

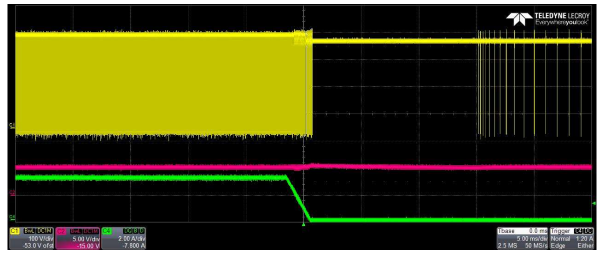
Fig. 15 Output Ripple at V_{OUT} = 5 V.


a: 115 V_{AC} from no load to 3 A load


b: 115 V_{AC} from 3 A to no load



a: 230 V_{AC} from no load to 3 A load



b: 230 V_{AC} from 3 A to no load

Fig. 16 Load Transient at V_{OUT} = 5 V.
Yellow: switch node voltage; Red: output voltage; Green: output current

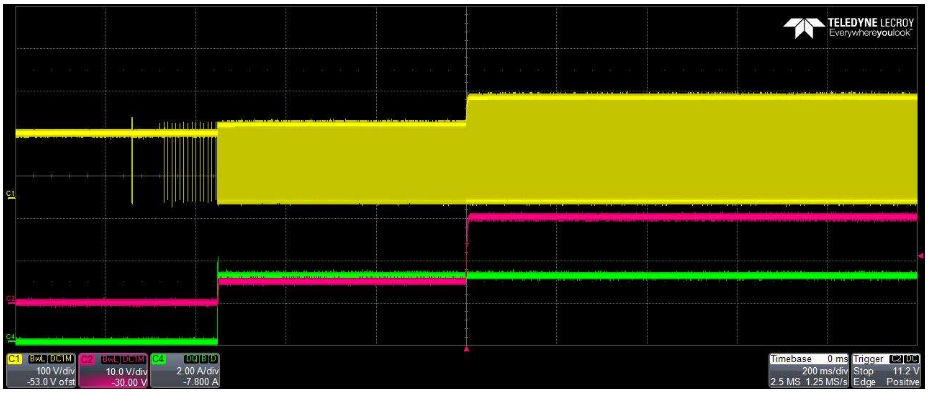


Fig. 17 Startup Waveforms at 115 V_{AC} with a 20 V-capable PD sink.
Yellow: switch node voltage; Red: output voltage; Green: output current.
Converter first outputs 5 V and then increases to 20V after high power setting has been negotiated.

Efficiency:

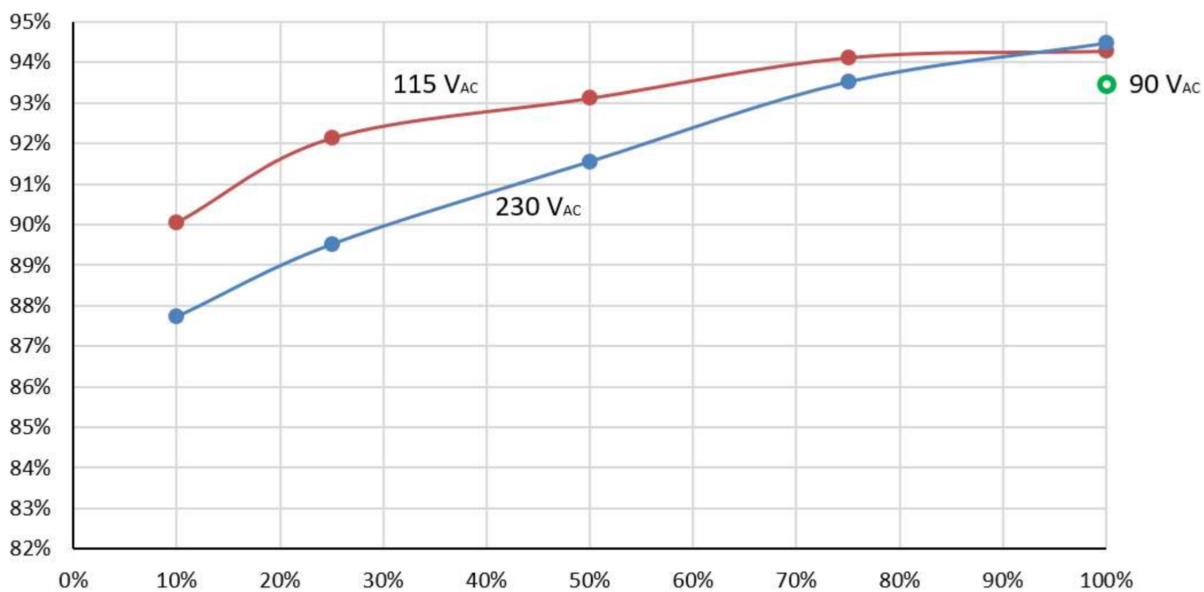


Fig. 18a) Efficiency vs. load (max 65 W), room ambient, no airflow, uncased

Typical efficiency is shown in the table below.

a. V_{OUT} = 20 V Efficiency Data

90 V_{AC} Input					
Io (A)	Vo (V)	Po (W)	Pin (W)	Loss (W)	Efficiency
3.251	19.942	64.83	69.38	4.55	93.44%

115 V_{AC} Input					
Io (A)	Vo (V)	Po (W)	Pin (W)	Loss (W)	Efficiency
3.251	19.943	64.82	68.75	3.93	94.29%
2.432	19.952	48.52	51.55	3.03	94.13%
1.624	19.961	32.42	34.81	2.39	93.12%
0.811	19.969	16.19	17.57	1.38	92.14%

230 V_{AC} Input					
Io (A)	Vo (V)	Po (W)	Pin (W)	Loss (W)	Efficiency
3.251	19.943	64.83	68.61	3.78	94.49%
2.442	19.952	48.72	52.09	3.37	93.54%
1.624	19.960	32.42	35.40	2.98	91.57%
0.817	19.969	16.31	18.22	1.91	89.52%

b. V_{OUT} = 15 V Efficiency Data

115 V AC Input					
Io (A)	Vo (V)	Po (W)	Pin (W)	Loss (W)	Efficiency
3.002	14.985	44.98	47.80	2.82	94.11%
2.242	14.993	33.61	35.81	2.20	93.87%
1.493	15.001	22.40	24.08	1.68	93.03%
0.744	15.008	11.17	12.14	0.97	91.99%

230 V_{AC} Input					
Io (A)	Vo (V)	Po (W)	Pin (W)	Loss (W)	Efficiency
2.991	14.985	44.82	47.51	2.69	94.34%
2.242	14.993	33.61	35.87	2.26	93.71%
1.493	15.002	22.40	24.66	2.26	90.85%
0.744	15.009	11.17	12.30	1.13	90.84%

c. V_{OUT} = 9 V Efficiency Data

115 V_{AC} Input					
Io (A)	Vo (V)	Po (W)	Pin (W)	Loss (W)	Efficiency
2.991	8.975	26.84	28.71	1.87	93.50%
2.242	8.983	20.14	21.66	1.52	92.98%
1.493	8.990	13.42	14.56	1.13	92.23%
0.744	8.997	6.69	7.35	0.66	91.01%

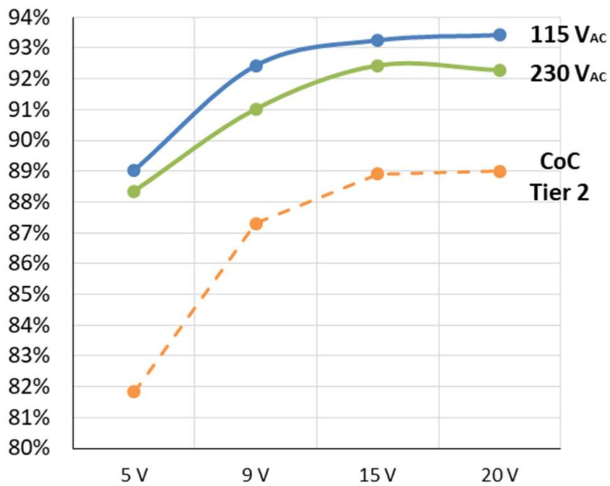
230 V_{AC} Input					
Io (A)	Vo (V)	Po (W)	Pin (W)	Loss (W)	Efficiency
2.991	8.975	26.84	28.74	1.90	93.40%
2.242	8.982	20.14	21.70	1.56	92.80%

1.493	8.990	13.42	14.95	1.53	89.76%
0.744	8.997	6.69	7.59	0.90	88.12%

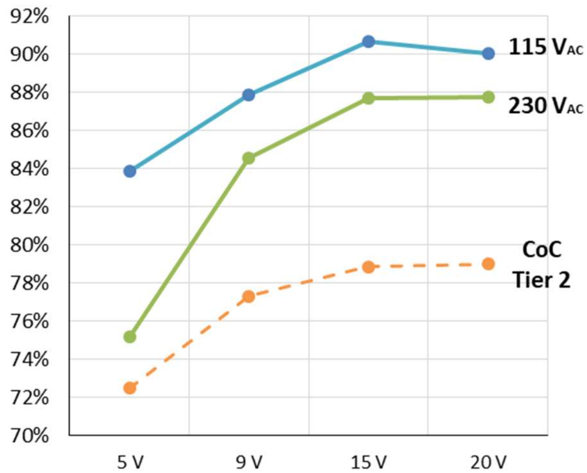
d. V_{OUT} = 5 V Efficiency Data

115 V_{AC} Input					
Io (A)	Vo (V)	Po (W)	Pin (W)	Loss (W)	Efficiency
2.991	4.974	14.88	16.48	1.60	90.27%
2.242	4.982	11.17	12.43	1.26	89.87%
1.493	4.989	7.45	8.37	0.92	89.01%
0.744	4.996	3.72	4.28	0.56	86.94%
230 V_{AC} Input					
Io (A)	Vo (V)	Po (W)	Pin (W)	Loss (W)	Efficiency
2.991	4.974	14.88	16.49	1.61	90.21%
2.242	4.982	11.17	12.40	1.23	90.06%
1.493	4.991	7.45	8.48	1.03	87.88%
0.744	4.996	3.72	4.36	0.64	85.25%

For each of the name-plate output voltage (5 V, 9 V, 15 V, 20 V), four-point average efficiency (100%, 75%, 50%, and 20% load) are calculated and compared with CoC Tier 2 standard in Fig 18a and 10% load efficiency is shown in Fig 18b.



b. Four-point Average Efficiency (25%, 50%, 75%, 100% Load)



c. Efficiency at 10% Load

Fig 18: Efficiency vs. output voltage, plus CoC Tier 2 standard comparison

Thermal Performance:

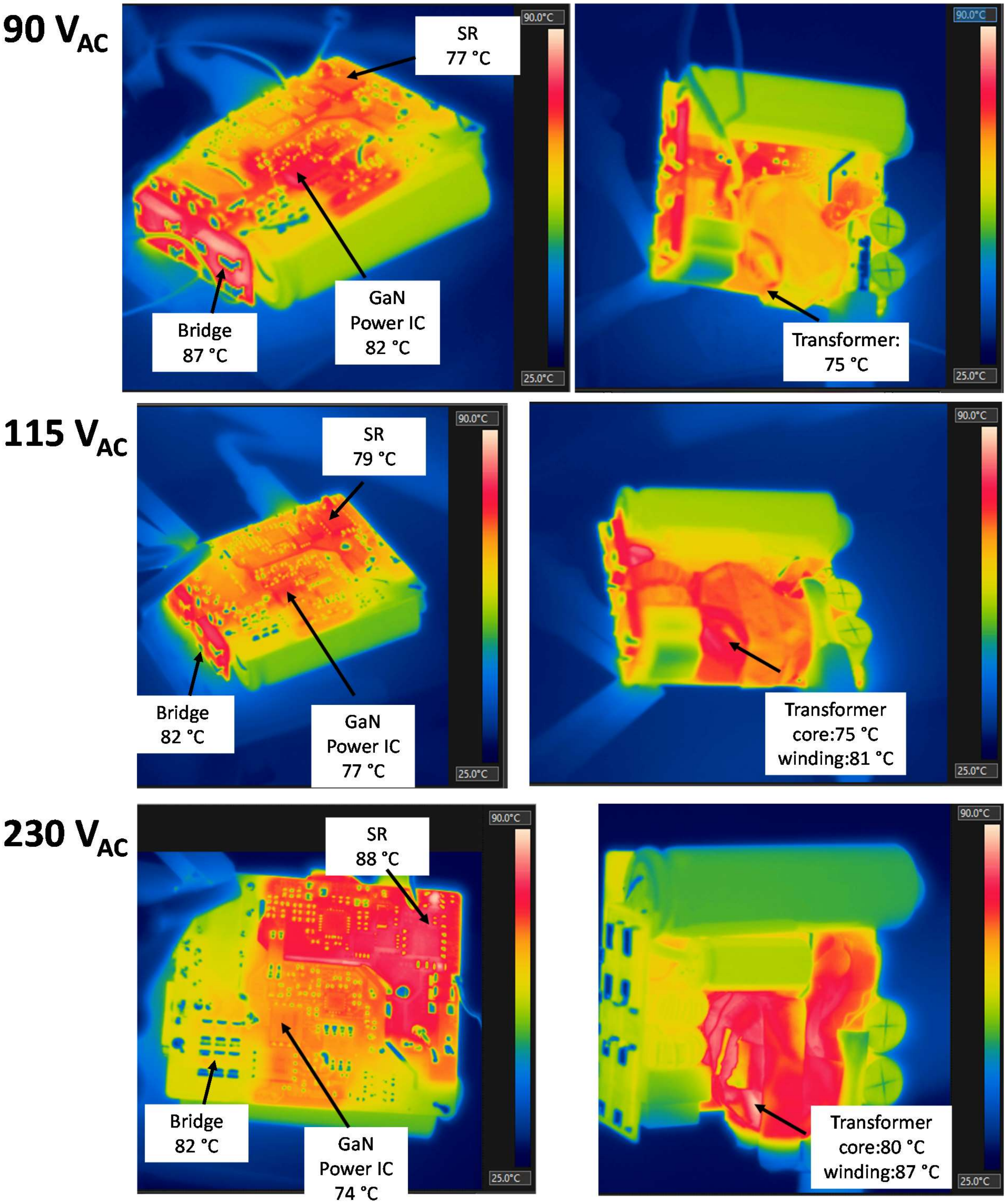


Fig 19: Thermal performance at 90 V, 115 V, 230 V_{AC} input, 20 V / 3.25 A output

PCB Layout:

Layout files (gerber, .dxf, etc.) are available on request at info@navitassemi.com.

1. Motherboard

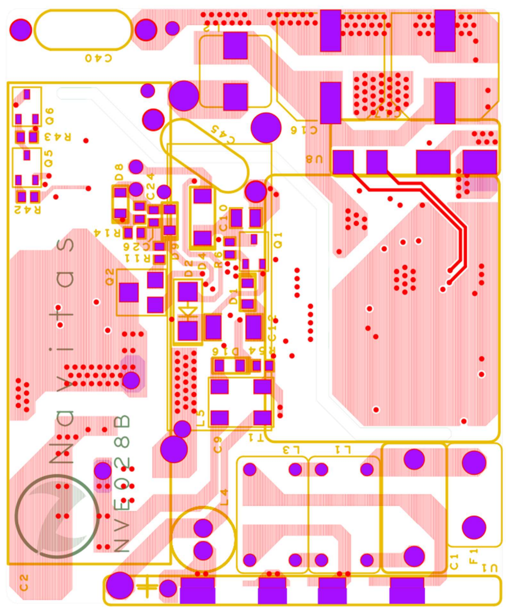


Fig. 20a) Top layer

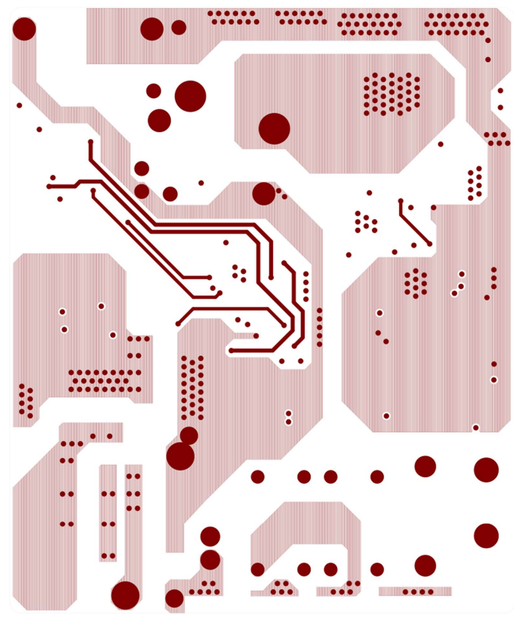


Fig. 20b) Mid-1 layer

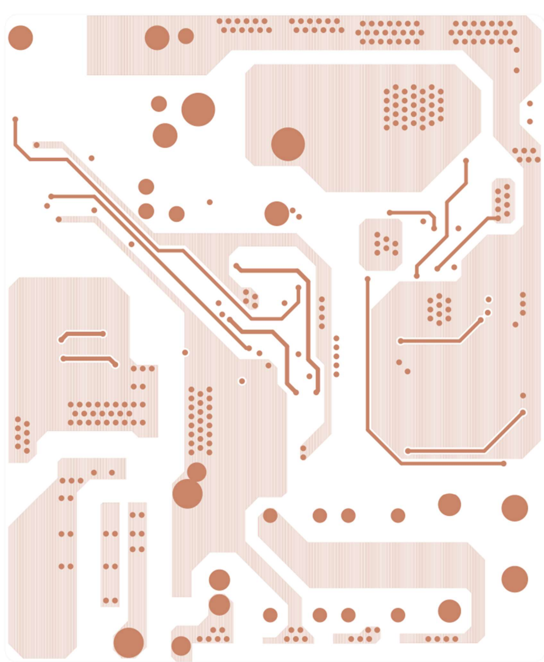


Fig. 20c) Mid-2 layer

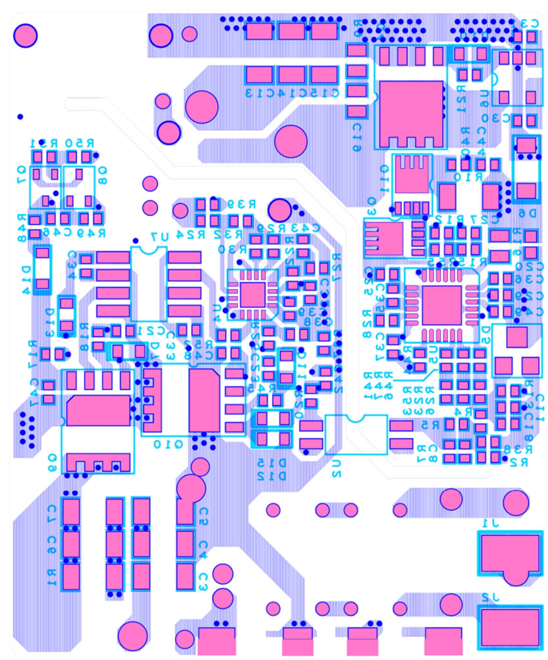


Fig. 20d) Bot layer

2. AC Diode Bridge Daughter Board

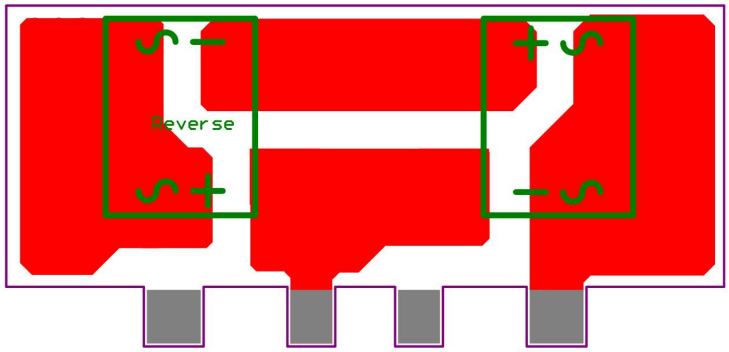


Fig. 21a) Top layer

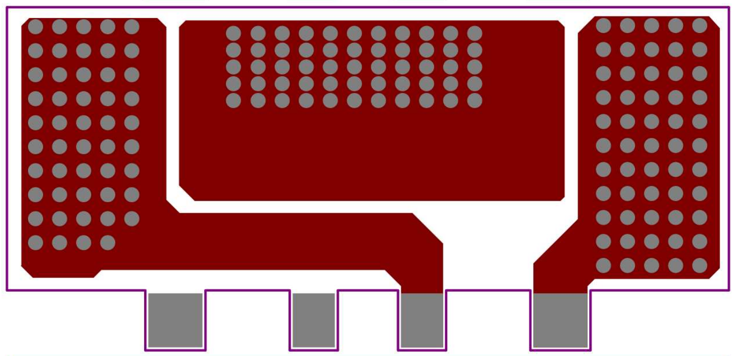


Fig. 21b) Mid-1 layer

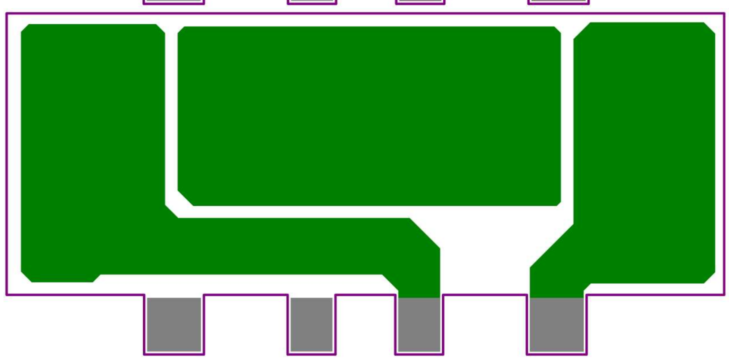


Fig. 21c) Mid-2 layer

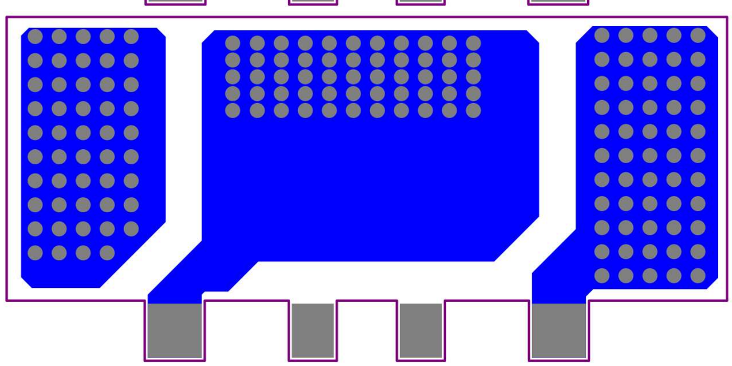


Fig. 21d) Bottom

3. **USB Type-C Connector Daughter Board**

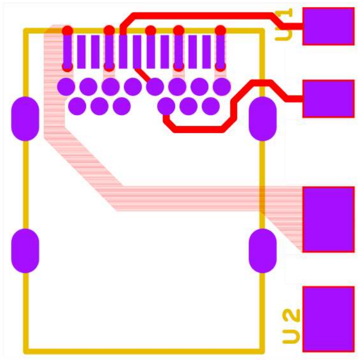


Fig. 22a) Top layer

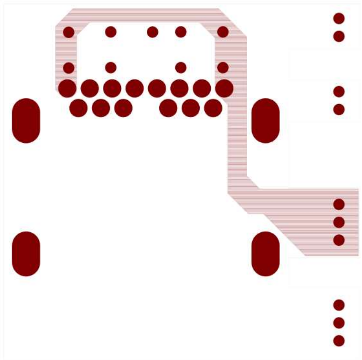


Fig. 22b) Mid-1 layer

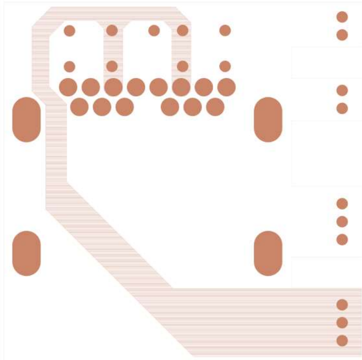


Fig. 22c) Mid-2 layer

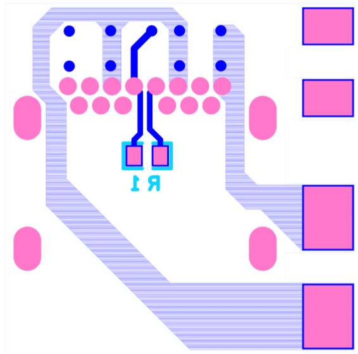


Fig. 22d) Bottom

EMI Performance

EMI performance is improved by using two transformer shielding layers connected to the primary DC bus. Average measurements were taken at 115 V_{AC} and 230 V_{AC}, 20 V / 3.25 A, vs. CISPR Class B using uncalibrated in-house equipment and a floating (non-grounded) load resistor. Quasi peak measurement is being scheduled.

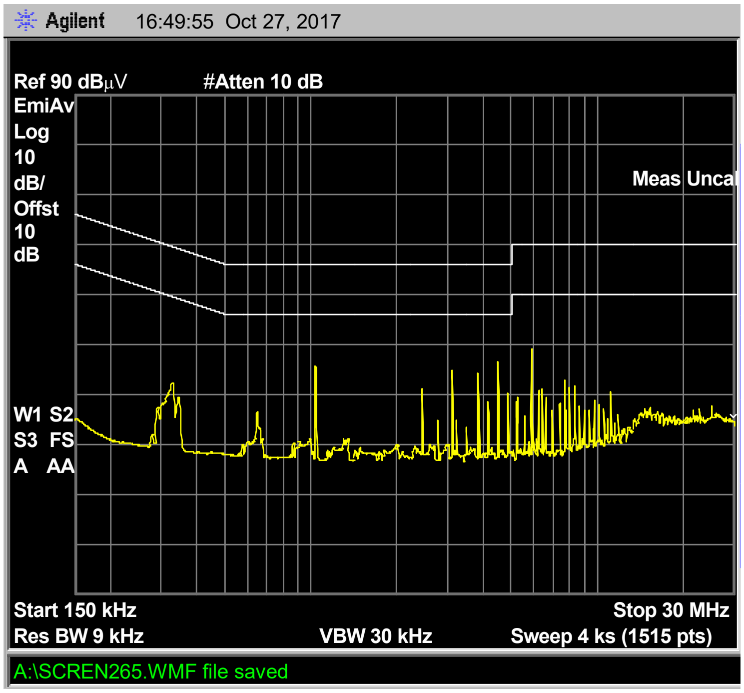


Fig. 11a: Conducted Average EMI at 115 V_{AC}.

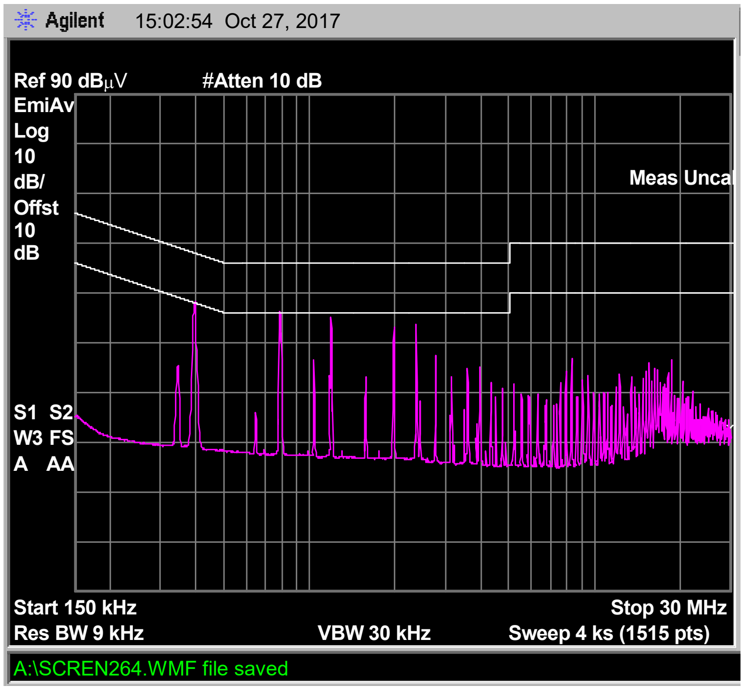


Fig. 23b: Conducted Average EMI at 230 V_{AC}.

Bill of Materials:

Qty	Reference Designator	Part #
23	C11, C13, J1, J2, TP1, TP10, TP11, TP13, TP14, TP15, TP16, TP17, TP2, TP22, TP23, TP24, TP25, TP3, TP4, TP5, TP7, TP8, TP9	Open component

Bottom Layer Components:

Item	Qty	Ref. Designator	Description	Manufacturer	Part Number
2	2	C14, C15	33µF 25V Ceramic Capacitor JB 1206	TDK Corporation	C3216JB1E336M160AC
3	4	C18, C21, C23, C27	CAP CER 10000PF 50V X7R 0402	Murata	GRM155R71H103JA88D
4	1	C19	330pF ±5% 200V Cer Cap C0G, NP0 0805	AVX Corporation	08052A331JAT2A
5	1	C20	CAP CER 10UF 25V 20% X5R 0603	Murata	GRM188R61E106MA73D
6	5	C25, C32, C35, C36, C39	CAP CER 0.1UF 50V X5R 0402	Murata	GRM155R61H104KE19D
7	2	C29, C49	CAP CER 560PF 50V X7R 0402	Murata	GRM155R71H561KA01D
8	3	C3, C4, C5	CAP CER 0.1UF 450V 10% X7T 1206	TDK Corporation	C3216X7T2W104K160AA
9	1	C30	CAP CER 1UF 35V X5R 0402	Murata	GRM155R6YA105KE11D
10	2	C31, C43	CAP CER 2.2UF 35V X5R 0402	TDK Corporation	C1005X5R1V225K050BC
11	5	C33, C34, C46, C47, C48	CAP CER 0.022UF 50V X7R 0402	Murata	GRM155R71H223KA12D
12	1	C37	CAP CER 0.22UF 50V X5R 0402	Taiyo Yuden	UMK105BJ224KV-F
13	1	C38	CAP CER 22PF 50V C0G/NP0 0402	Murata	GRM1555C1H220JA01D
14	2	C40, Cx1	680pF 250VAC Ceramic Capacitor X7R	Murata	GA352QR7GF681KW01L
15	1	C42	CAP CER 2200PF 50V X7R 0402	Murata	GRM155R71H222KA01D
16	1	C44	CAP CER 0.33UF 35V X5R 0402	TDK Corporation	C1005X5R1V334K050BC
17	2	C6, C7	CAP CER 0.22UF 250V X7T 1206	TDK Corporation	C3216X7T2E224M160AA
18	1	C8	CAP CER 3300PF 50V X7R 0402	Murata	GRM155R71H332JA01D
19	2	D10, D15	Schottky Diodes & Rectifiers 40V 150mW	Diodes Inc.	SDM03U40-7
20	2	D11, D13	Zener Diode 2V 150mW ±5% SMT 0603/SOD-523F	Comchip	CZRU52C2
21	2	D12, D7	DIODE ZENER 6.2V 150MW 0603	Comchip	CZRU52C6V2
22	1	D14	DIODE GP 600V 200MA TUMD2SM	Rohm	RFU02VSM6STR
23	1	D5	IC VREF SHUNT ADJ SOT23-3	Texas Instruments	ATL431AIDBZR
24	1	D6	DIODE SCHOTTKY 40V 3A SOD123W	Nexperia	PMEG4030ER
25	1	Q10	Navitas Semiconductor GaN Power IC	Navitas	NV6117
26	2	Q11, Q3	MOSFET N-CH 25V 23A TSDSON-8	Infineon	BSZ018NE2LS
27	1	Q4	MOSFET N-CH 150V 87A TDSON-8	Infineon	BSC093N15NS5ATMA1
28	1	Q7	MOSFET P-CH 50V 150MA SOT323	Nexperia	BSS84AKW
29	1	Q8	MOSFET N-CH 60V 240MA SOT323-3	Vishay	SI1330EDL-T1-E3
30	1	Q9	Navitas Semiconductor GaN Power IC	Navitas	NV6115
31	1	R1	RES SMD 150K OHM 1% 1/4W 1206	Yageo	RC1206FR-07150KL
32	1	R10	RES SMD 0.005 OHM 1% 1/2W 1206	Panasonic	ERJ-MP2KF5M0U
33	4	R12, R18, R50, R55	RES SMD 10 OHM 1% 1/16W 0402	Yageo	RC0402FR-0710RL

34	2	R13, R4	RES SMD 150K OHM 1% 1/16W 0402	Yageo	RC0402FR-07150KL
35	1	R15	RES SMD 1K OHM 1% 1/16W 0402	Yageo	RC0402FR-071KL
36	2	R16, R40	RES SMD 120 OHM 1% 1/16W 0402	Yageo	RC0402FR-07120RL
37	1	R17	RES SMD 47K OHM 1% 1/16W 0402	Yageo	RC0402FR-0747KL
38	1	R2	RES SMD 47 OHM 1% 1/16W 0402	Yageo	RC0402FR-0747RL
39	1	R20	RES SMD 39K OHM 1% 1/16W 0402	Yageo	RC0402FR-0739KL
40	1	R21	RES SMD 1 OHM 1% 1/16W 0402	Yageo	RC0402FR-071RL
41	1	R22	RES SMD 200K OHM 1% 1/16W 0402	Yageo	RC0402FR-07200KL
42	1	R23	RES SMD 91K OHM 1% 1/16W 0402	Yageo	RC0402FR-0791KL
43	1	R24	RES SMD 56K OHM 1% 1/16W 0402	Yageo	RC0402FR-0756KL
44	1	R25	RES SMD 1K OHM 1% 1/10W 0402	Panasonic	ERJ-2RKF1001X
45	1	R26	RES SMD 62K OHM 1% 1/16W 0402	Yageo	RC0402FR-0762KL
46	1	R27	RES SMD 45.3K OHM 1% 1/16W 0402	Yageo	RC0402FR-0745K3L
47	2	R28, R30	RES SMD 220K OHM 1% 1/16W 0402	Yageo	RC0402FR-07220KL
48	1	R29	RES SMD 68K OHM 1% 1/16W 0402	Yageo	RC0402FR-0768KL
49	1	R32	RES SMD 13K OHM 1% 1/16W 0402	Yageo	RC0402FR-0713KL
50	2	R37, R52	RES SMD 0.0OHM JUMPER 1/16W 0402	Yageo	RC0402JR-070RL
51	1	R38	RES SMD 33K OHM 1% 1/16W 0402	Yageo	RC0402FR-0733KL
52	2	R39, R48	RES SMD 4.7 OHM 1% 1/16W 0402	Yageo	RC0402FR-074R7L
53	2	R41, R46	RES SMD 0.0 OHM JUMPER 1/10W	Panasonic	ERJ-2GE0R00X
54	3	R44, R49, R51	RES SMD 100K OHM 1% 1/16W 0402	Yageo	RC0402FR-07100KL
55	1	R45	RES SMD 100 OHM 1% 1/16W 0402	Yageo	RC0402FR-07100RL
56	1	R47	RES SMD 2K OHM 1% 1/16W 0402	Vishay	CRCW04022K00FKED
57	1	R5	RES SMD 15K OHM 1% 1/10W 0402	Panasonic	ERJ-2RKF1502X
58	1	R53	RES SMD 75K OHM 1% 1/10W 0402	Panasonic	ERJ-2RKF7502X
59	1	R7	RES SMD 562 OHM 1% 1/16W 0402	Yageo	RC0402FR-07562RL
60	1	R9	RES SMD 10 OHM 1% 1/8W 0805	Yageo	RC0805FR-0710RL
61	1	U2	OPTOISO 3.75KV TRANS 4-MINI-FLAT	Fairchild	FODM8801AV
62	1	U4	ACF IC	Texas Instruments	UCC28780RTER
63	1	U5	USB-PD IC	Texas Instruments	TPS25740BRGER
64	1	U6	SR IC	Texas Instruments	UCC24612-1DBVR
65	1	U7	DGTL ISO 4KV 1CH GEN PURP 8SOIC	Texas Instruments	ISO721MMDREP

Top Layer Components:

Item	Qty	Ref. Designator	Description	Manufacturer	Part Number
1	1	C1	CAP FILM 0.047UF 20% 630VDC RAD	Vishay	BFC233920473
2	1	C10	CAP CER 1UF 100V X7S 0805	Taiyo Yuden	HMK212BC7105MG-TE
3	1	C12	33µF 25V Ceramic Capacitor JB 1206	TDK Corporation	C3216JB1E336M160AC
4	2	C16, C17	CAP ALUM 470UF 20% 25V SMD	Nichicon	UCM1E471MNL1GS
5	1	C2	CAP ALUM 82UF 20% 400V T/H	Rubycon	400BXW82MEFR12.5X45
6	1	C24	CAP CER 2200PF 50V X7R 0402	Murata	GRM155R71H222KA01D
7	1	C26	CAP CER 22PF 50V C0G/NP0 0402	Murata	GRM1555C1H220JA01D
8	2	C45, D8	Open component	-	-
9	1	C9	CAP ALUM 4.7UF 20% 400V RADIAL	Rubycon	400AX4R7MEFC6.3X14
10	1	D1	DIODE ZENER 15V 150MW 0603	Comchip	CZRU52C15
11	2	D16, Dx1	Schottky Diodes & Rectifiers 40V 150mW	Diodes Inc.	SDM03U40-7
12	1	D2	DIODE GEN PURP 200V 500MA DO219	Vishay	ES07D-M-08
13	1	D4	DIODE GEN PURP 400V 1A SOD123F	Diodes Inc.	US1GWF-7
14	1	D9	DIODE ZENER 20V 150MW 0603	Comchip	CZRU52C20
15	1	Dx2	Zener Diode 2V 150mW ±5% SMT 0603/SOD-523F	Comchip	CZRU52C2
16	1	F1	FUSE 3.15A 250/277V RADIAL	Bel Fuse Inc.	RSTA 3.15-BULK
17	1	L1	TRANSFORMER - 25uH	Navitas	*See Instructions
18	1	L2	FIXED IND 1UH 11.5A 4.75 MOHM	Wurth	744316100
19	1	L3	TRANSFORMER - 150uH	Navitas	*See Instructions
20	1	L4	INDUCTOR - 66uH	Navitas	*See Instructions
21	1	L5	TRANSF CURRENT SENSE 74UH SMD	EPCOS	B82801A0743A030
22	1	Q1	MOSFET N-CH 100V 170MA SC70-3	Diodes Inc.	BSS123W-7-F
23	1	Q2	MOSFET N-CH 600V 0.021A SOT23	Infineon	BSS126 H6906
24	1	Q5	TRANS PNP 40V 0.2A SC70-3	Diodes Inc.	MMST3906-7-F
25	1	Q6	MOSFET N-CH 60V 240MA SOT323-3	Vishay	SI1330EDL-T1-E3
26	1	R11	RES SMD 120 OHM 1% 1/16W 0402	Yageo	RC0402FR-07120RL
27	1	R14	RES SMD 150K OHM 1% 1/16W 0402	Yageo	RC0402FR-07150KL
28	1	R42	RES SMD 22K OHM 1% 1/16W 0402	Yageo	RC0402FR-0722KL
29	1	R43	RES SMD 10K OHM 1% 1/16W 0402	Yageo	RC0402FR-0710KL
30	1	R54	RES SMD 4.7 OHM 1% 1/16W 0402	Yageo	RC0402FR-074R7L
31	1	R6	RES SMD 100K OHM 1% 1/16W 0402	Yageo	RC0402FR-07100KL
32	1	T1	INDUCTOR - 65uH	Precision	019-8999-00R
33	1	U1	PD 65W DIODE BRIDGE DAUGHTERCARD	-	-
34	1	U8	PD 65W USB-C DAUGHTERCARD	-	-

EMI Choke Construction

Item	Magnetic Core	Windings	Inductance (uH)	Notes
L1	C0-55040-A2, Magnetics (Spang)	#24,18 turns, each	25 / each	2 windings, sectionalized
L3	TC9.5/4.8/3.2-3C81, Ferroxcube	#24, 9 turns, each	150 / each	2 windings, bifilar
L4	C0-55280-A2, Magnetics (Spang)	#24, 36 turns	66	1 winding

Revision History:

Date	Status	Notes
11-1-17	RELEASED	First publication

Additional Information:

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