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Design Note – DN05102/D

45W TYPE-C PD3.0 / QC3.0 Power Adapter Solution with WT6632F

ON's Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1340B3 NCP4306D NTMFS6B03 ATP104	Smart phone, PAD and NB adapter supporting PD3.0 and QC3.0	90 Vac to 264 Vac	45 W	Flyback	Isolated (3 kV)

	PD Output Specification	QC Output Specification
Output Voltage	5 V, 9 V, 12 V, 15 V, 20 V	5 V, 9 V, 12 V
Nominal Current	5V/3A, 9V/3A, 12V/3A,15V3A, 20V/2.25A	5 V / 3 A, 9 V / 3 A, 12 V / 3 A
Max Current	5V/3A, 9V/3A, 12V/3A,15V3A, 20V/2.25A	5 V / 3 A, 9 V / 3 A, 12 V / 3 A
Min Current	zero	zero

Avg. Efficiency	>90% @ 20 V 2.25 A at board end, 115 & 230 Vac
Ripple	<100mV
Standby Power	<30mW @ 5 V & 230 Vac (No cable plug in)
Power Density	1.15W/cm^3
Protection	Adaptive UVP, OVP, OVP, SCP, OTP
Size	57mmx36mmx19mm

Circuit Description

This design note describes a 45 W, Type C interface PD2.0, universal AC input, constant voltage power supply intended for smart phone, PAD and NB adaptor supporting PD3.0 or QC3.0 protocol, where isolation from the AC mains is required, and low cost, high efficiency, and low standby power are essential.

The featured power supply is a simple QR flyback topology utilizing ON Semiconductor's NCP1340B3 HF PWM controller, NCP4306D synchronous rectified controller, NTMFS6B03 synchronous MOSFET and ATP104 Switch MOSFET. This Design Note provides the complete circuit schematic details, PCB and BOM for 45 W Type C Interface PD3.0 Power adapter solution which supports PD output (5 V / 3 A, 9 V / 3 A, 12 V / 3 A, 15 V / 3 A, 20 V / 2.25 A).

This design combined with Weltrend WT6632F PD3.0 protocol controller to provide PD3.0 and QC3.0 functions. This design also proposes a dual auxiliary power supply to supply PWM controller, the PWM controller is supplied by high voltage auxiliary voltage at low output voltage and supplied by low voltage auxiliary voltage at high output voltage and also shuts down the Zener bias of high voltage Vcc while low voltage auxiliary voltage supplies controller.

This design also uses NCP4306 synchronous rectified controller to provide high efficiency and also has no external Vcc regulator to supply synchronous controller to ensure controller can works below 3.6 V.

Key Features

- Universal AC input range (90 – 264 Vac)
- Very low standby (5 V & 230 Vac) power consumption with no cable plug in
- Very low ripple and noise
- Inherent SCP and OCP protection
- High operation frequency up to 150kHz
- High power density (1.15 W/cm^3)
- Quick switching off FET while unplugging cable and switching on FET at Vbus dropping to 5 V while plugging cable again
- Quasi-Resonant current mode control with Valley Switching
- Valley lockout avoids audible noise at valley jumping operation
- Support TYPE-C PD3.0 & QC3.0 protocol
- Adaptive Output OVP and UVP
- Open loop protection
- Board size: 57mmx36mmx19mm

Block Diagram and Board Images

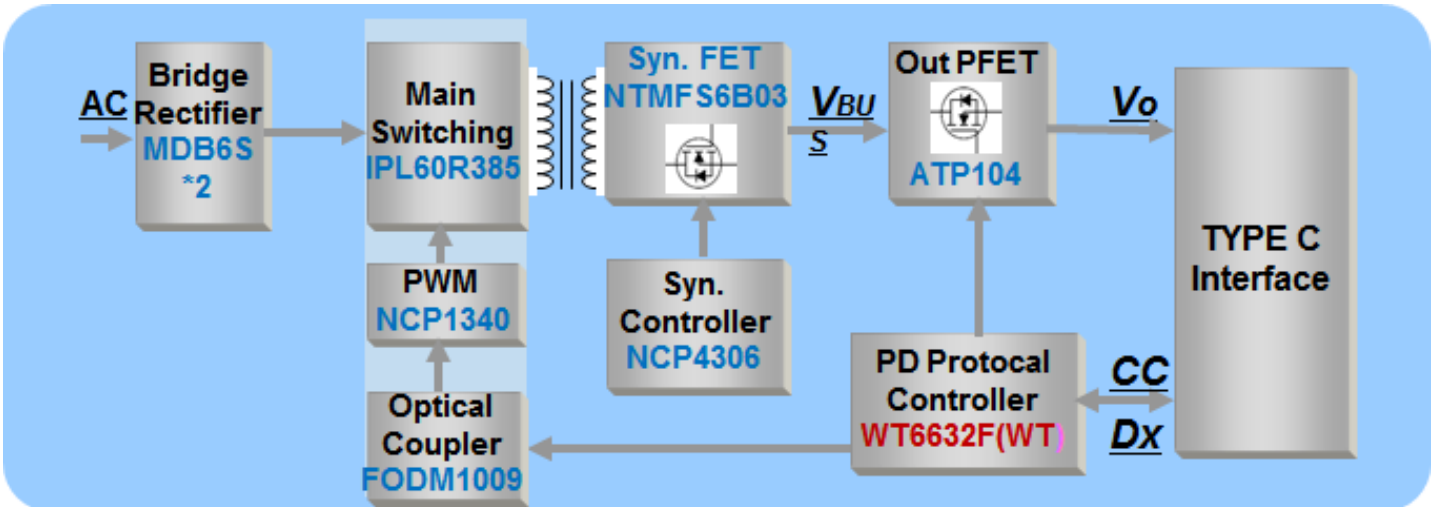


Figure 1, High level schematic of 45 W TYPE-C PD adapter

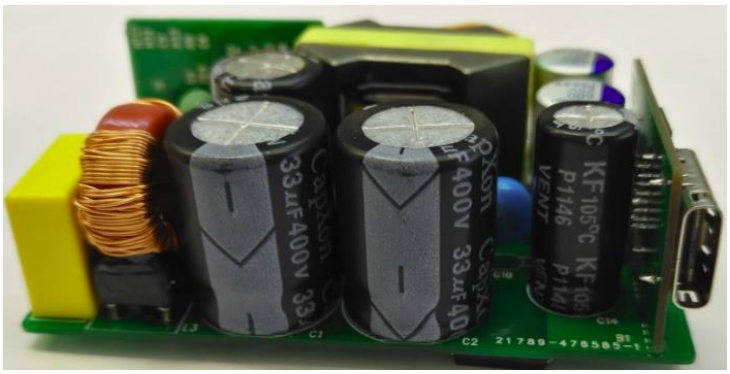


Figure 2, Side view 1 of the demo board

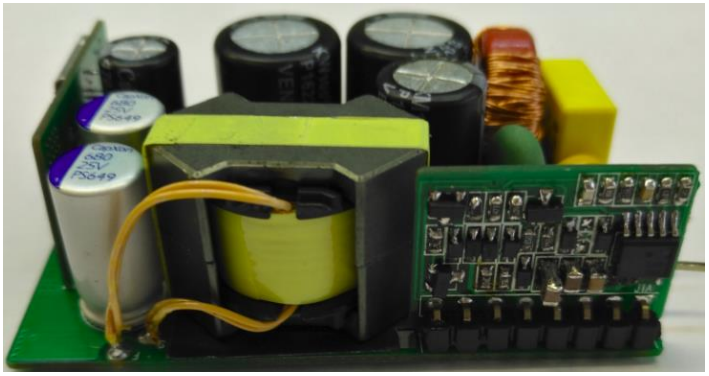
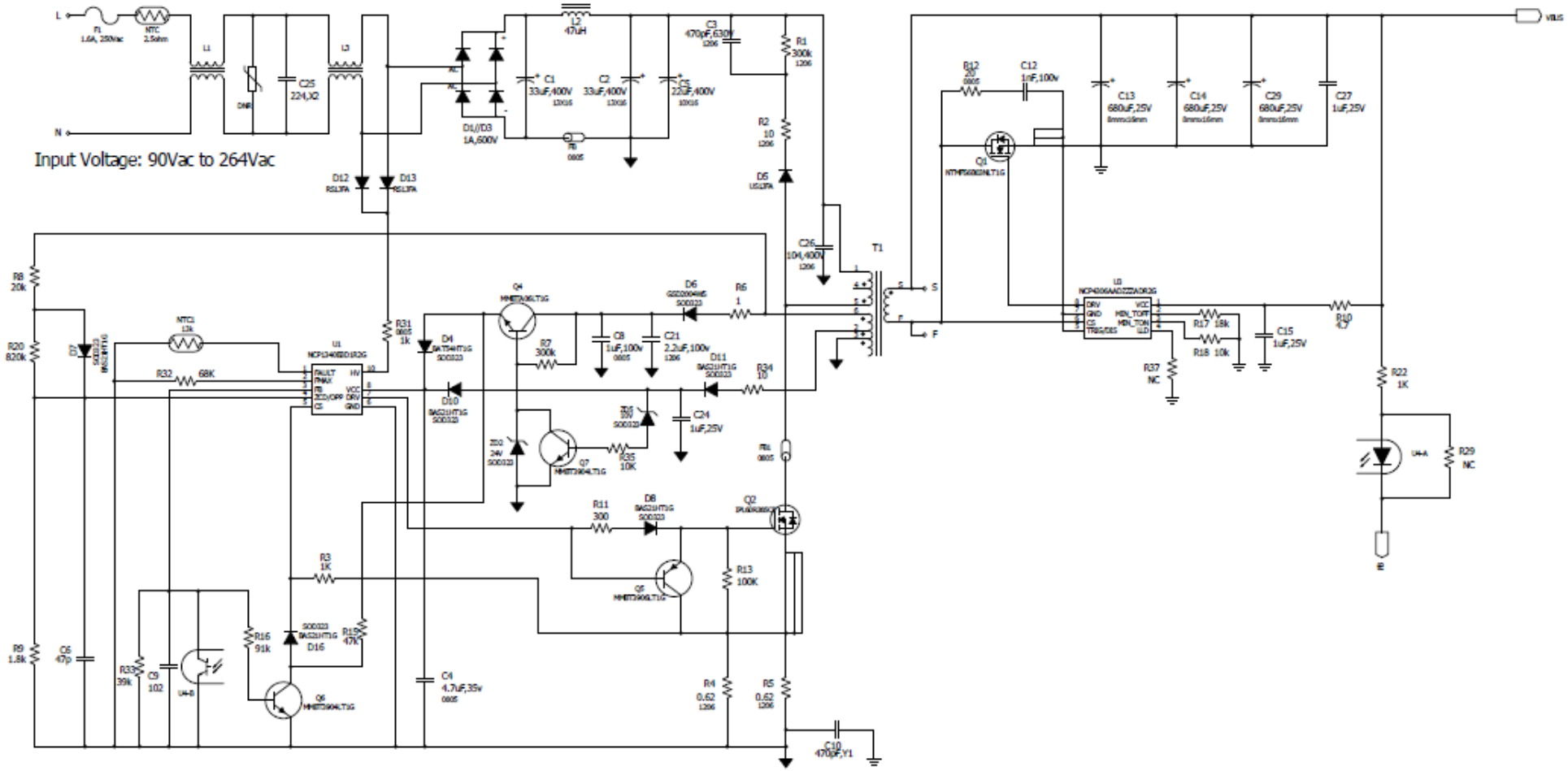
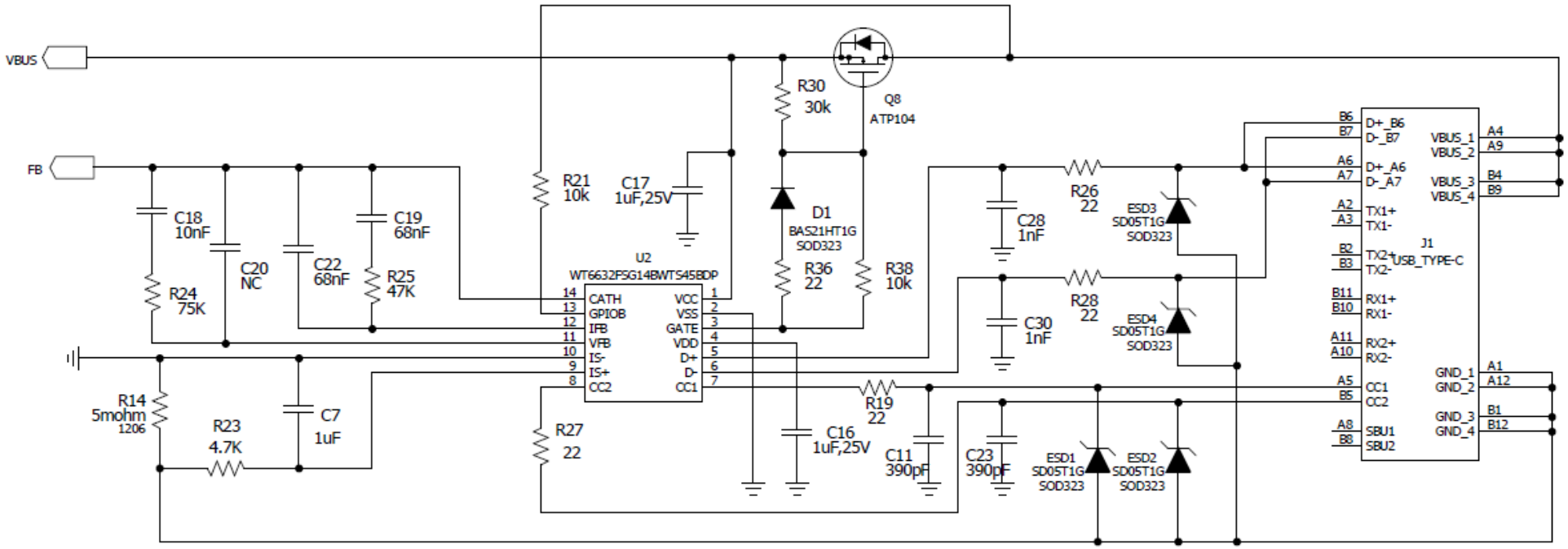


Figure 3, Side view 2 of the demo board

Circuit Schematic



Circuit Schematic (Continued)



PCB

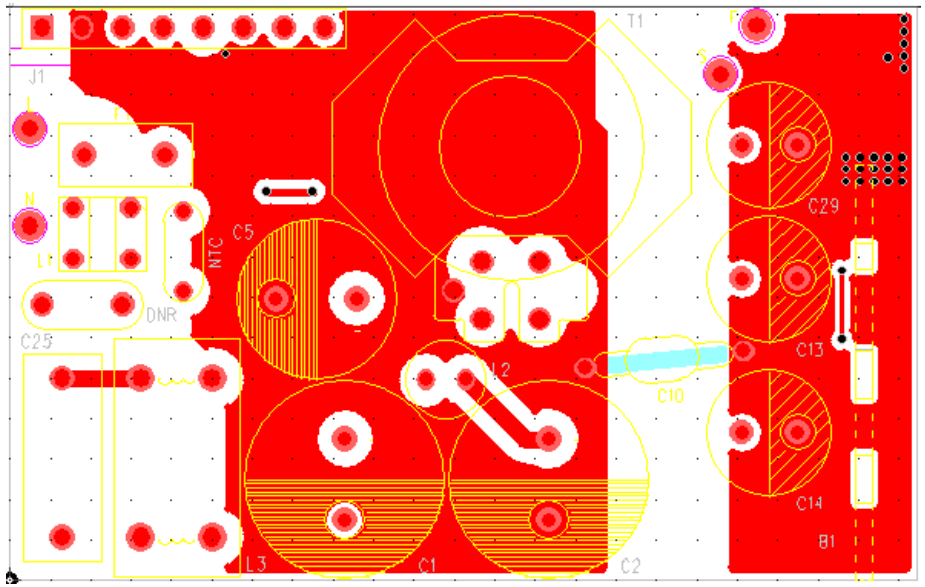


Figure 3, Top View of Mainboard's PCB

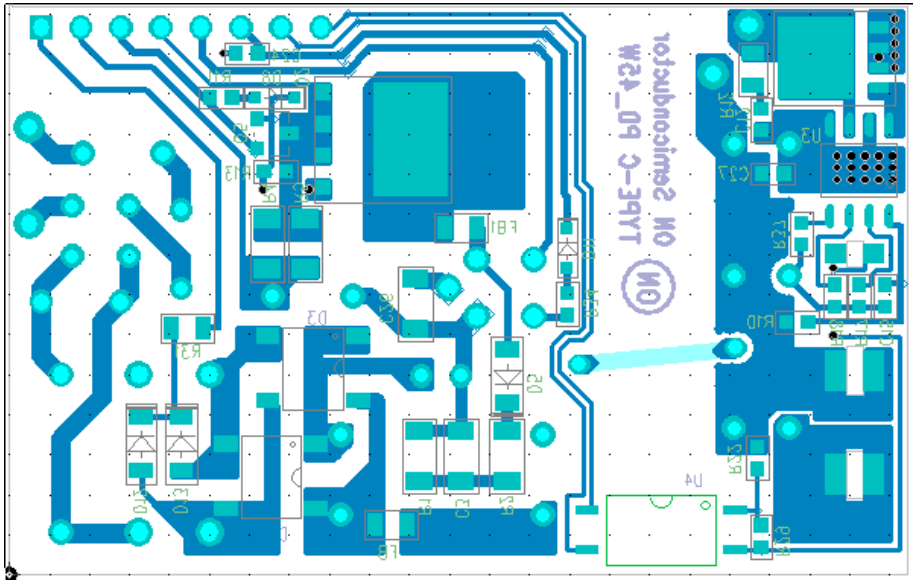


Figure 4, Bottom View of Mainboard's PCB

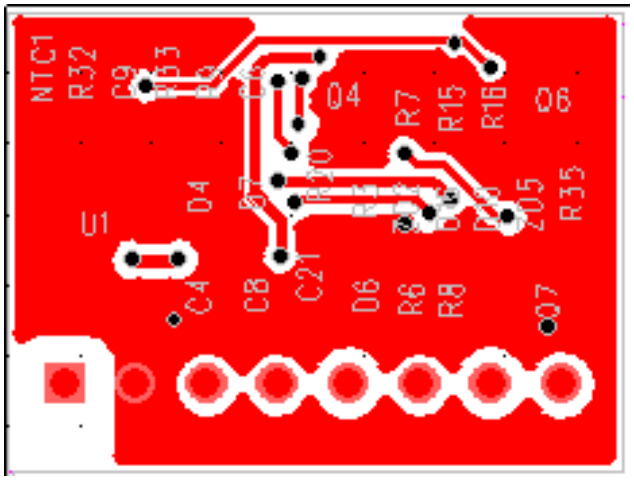


Figure 5, Top View of PWM control board's PCB

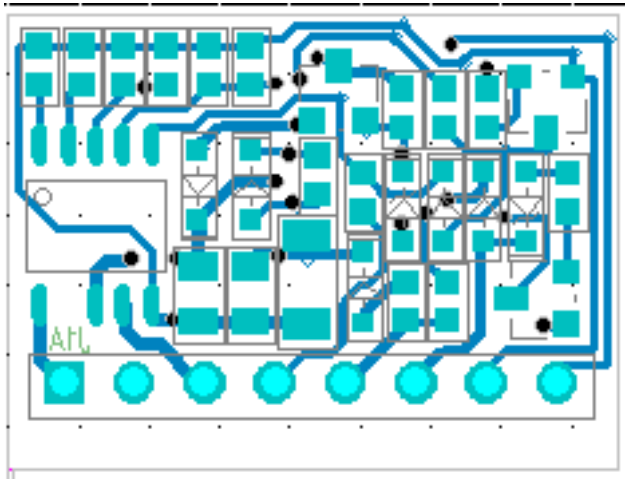


Figure 6, Bottom View of PWM control board's PCB

PCB Layout(Cont'd)

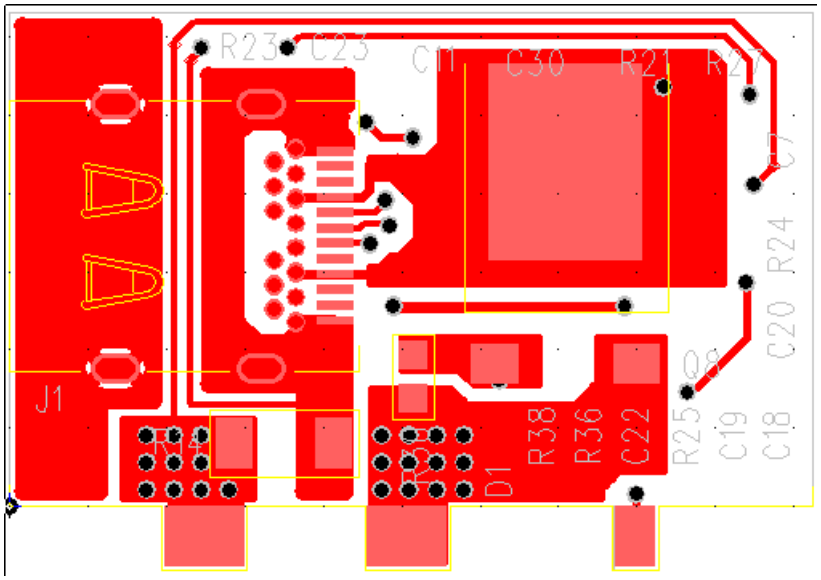


Figure 7, Top View of PD control board (WT6632F)'s PCB

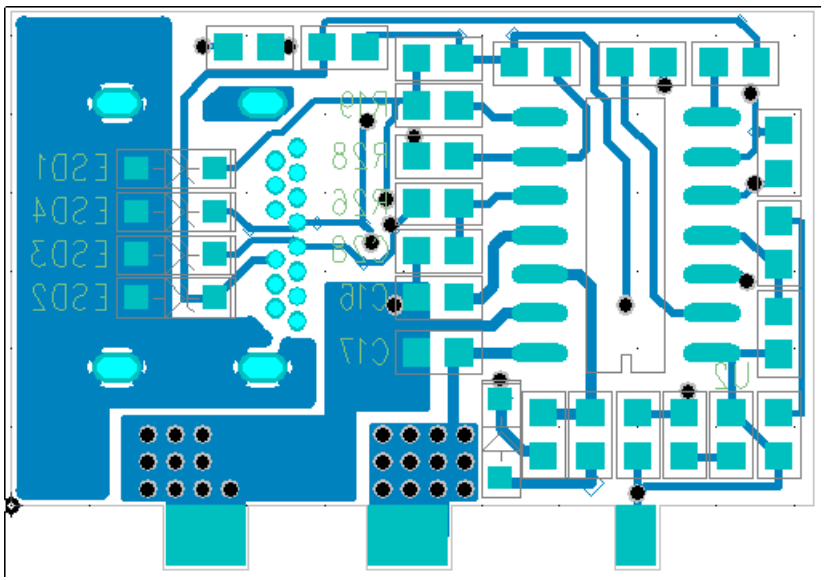
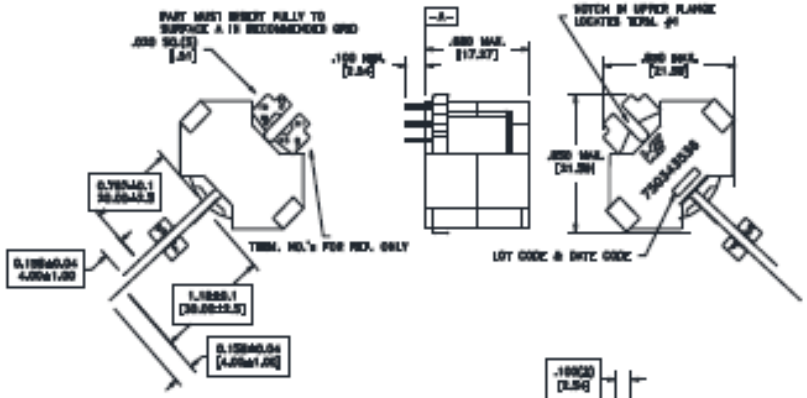
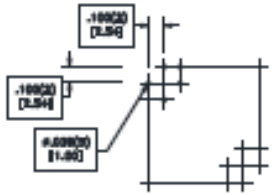


Figure 8, Bottom View of PD control board (WT6632F)'s PCB

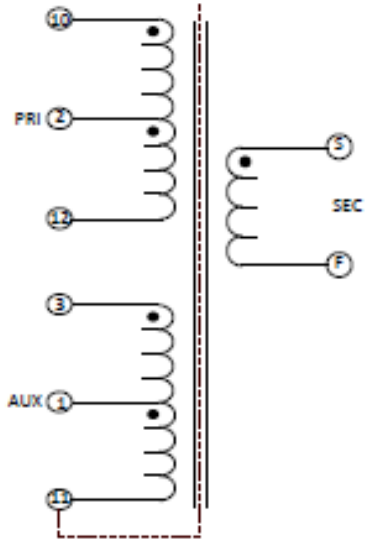
T1 Transformer Designs (Available from Wurth Electronics)

CUSTOMER TERMINAL	RoHS	LEAD(Pb)–FREE
Sn 96%, Ag 4%	Yes	Yes





RECOMMENDED P.C. PATTERN, COMPONENT SIDE



ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	10-12	@20°C	0.560 ohms max.
D.C. RESISTANCE	3-1	@20°C	0.380 ohms max.
D.C. RESISTANCE	1-11	@20°C	0.210 ohms max.
D.C. RESISTANCE	8-F	@20°C	0.021 ohms max.
INDUCTANCE	10-12	10kHz, 1V, Ls	360.00µH ±10%
SATURATION CURRENT	10-12	20% rolloff from initial	2.5A
LEAKAGE INDUCTANCE	10-12	tie(1+3+10+8+F),100kHz, 1V, Ls	5.5µH max.
DIELECTRIC	1-8	tie(1+2+3+10+11+12), 3750VAC, 1 second	3000VAC, 1 minute
DIELECTRIC	8-CORE	3750VAC, 1 second	3000VAC, 1 minute
TURNS RATIO		(10-12):(3-1)	3.25:1, ±2%
TURNS RATIO		(10-12):(1-11)	6.5:1, ±2%
TURNS RATIO		(10-12):(8-F)	6.5:1, ±2%

GENERAL SPECIFICATIONS:

OPERATING TEMPERATURE RANGE: -40°C to +125°C including temp rise.

Designed to comply with the following requirements as defined by IEC60950-1, EN60950-1, UL60950-1/CSA60950-1 and AS/NZS60950.1:

- Reinforced insulation for a primary circuit at a working voltage of 265Vrms, 400Vpeak, Overvoltage Category II.

Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

DFM	
DATE	
ENG	HWE
REV.	00
DATE	6/30/2017

Packaging Specifications
Method: Tray
PKG-TBD

CONVENTION PLACEMENT

Tolerances unless otherwise specified:
Angles: ±1° Decimals: ±.005 [.13]
Fractions: ±1/64 Footprint: ± .001 [.03]

This drawing is dual dimensioned. Dimensions in brackets are in millimeters.

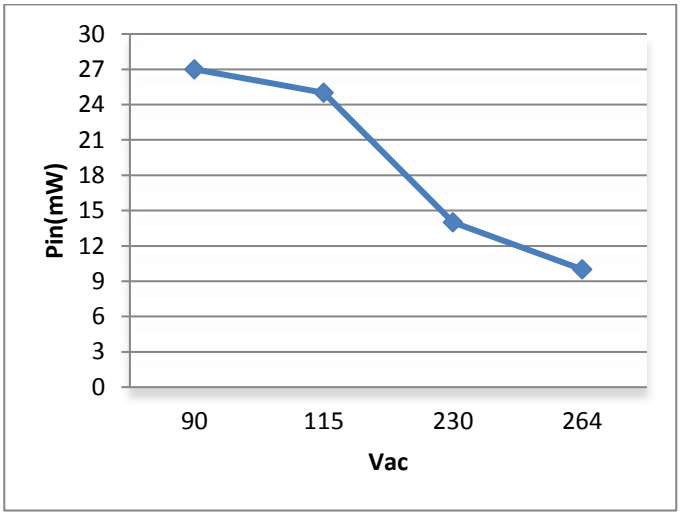
DRAWING TITLE
TRANSFORMER

PART NO.
750343635

SPECIFICATION SHEET 1 OF 1

Standby Power at 5V Output (Cable unplug) @ 90 Vac to 264 Vac Input

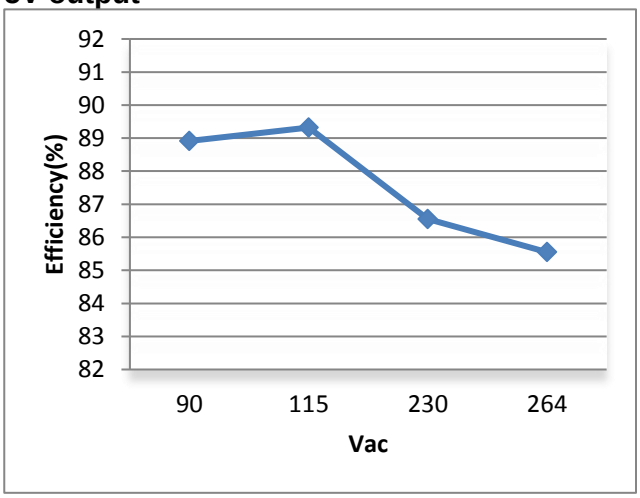
Test condition: all efficiency are tested at board end



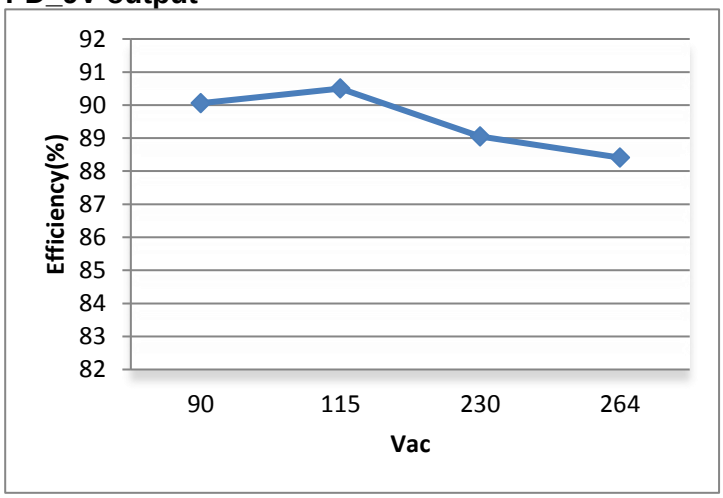
Average Efficiency

Test condition: all efficiency are tested at board end

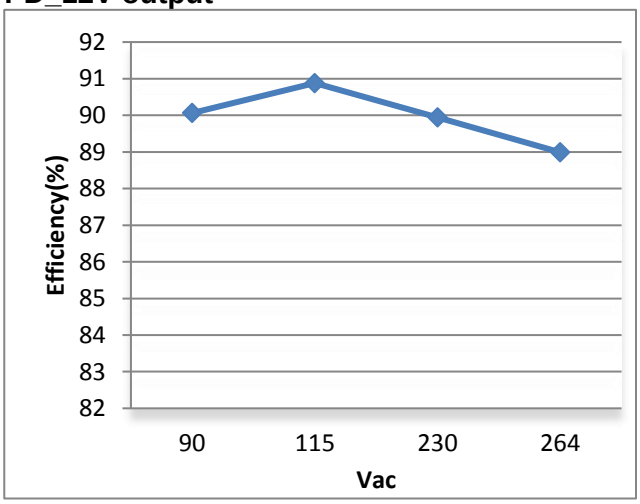
5V output



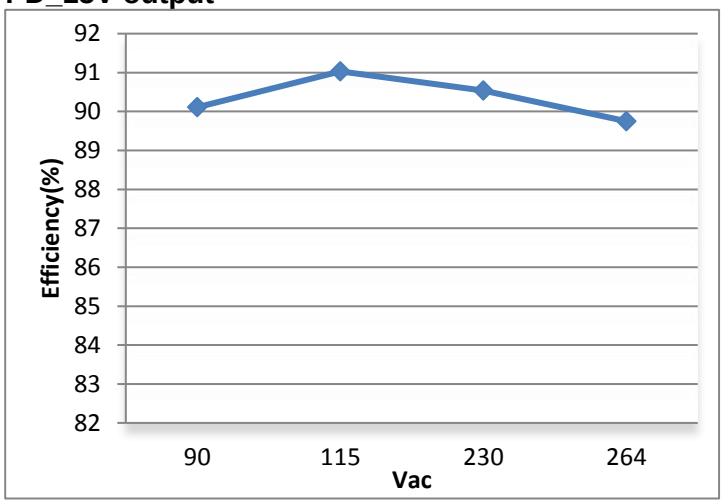
PD_9V output



PD_12V output



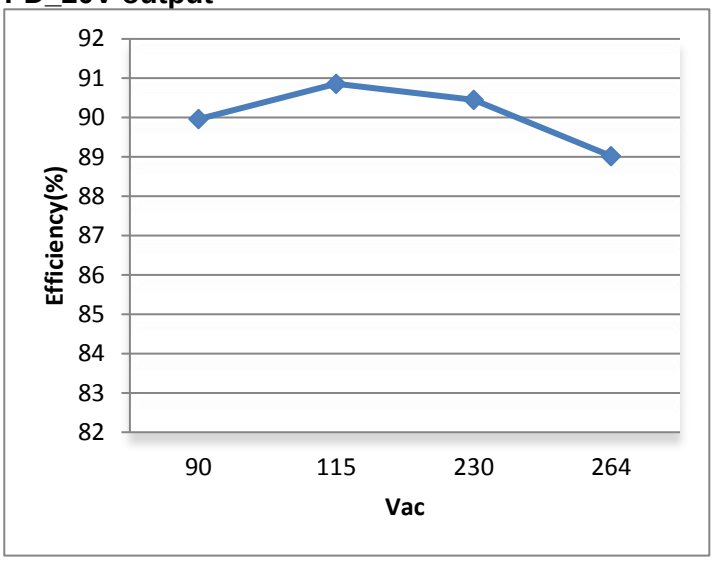
PD_15V output



Average Efficiency (Continued)

Test condition: all efficiency are tested at board end

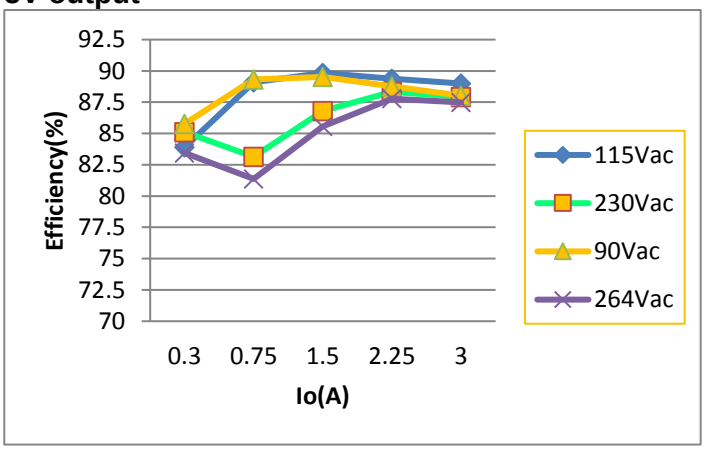
PD_20V output



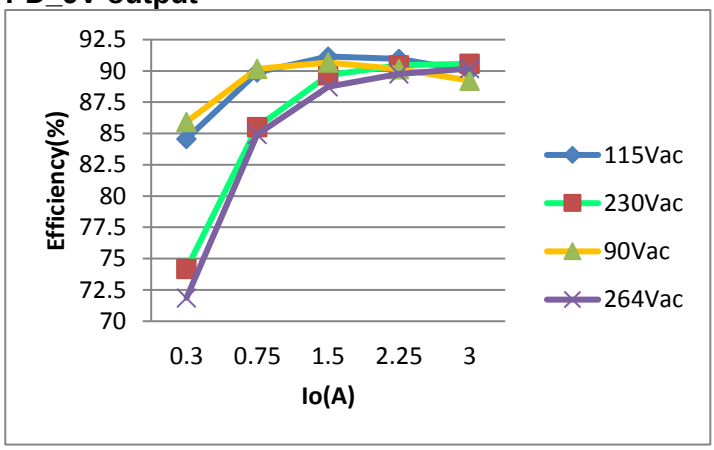
Efficiency vs Output Load Curves

Test condition: all efficiency are tested at board end

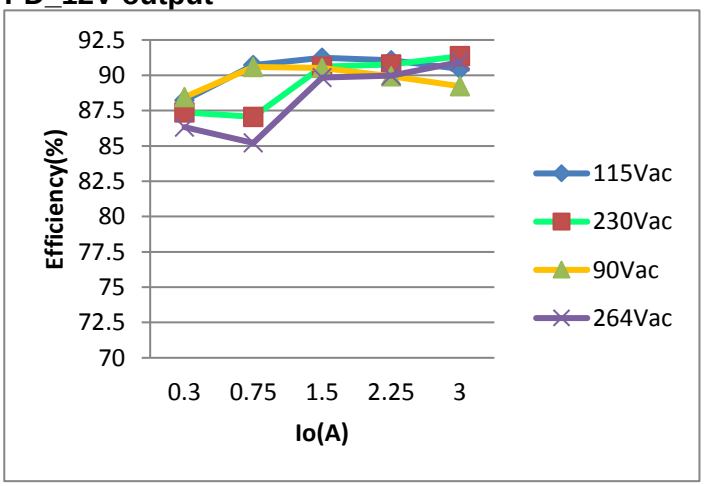
5V output



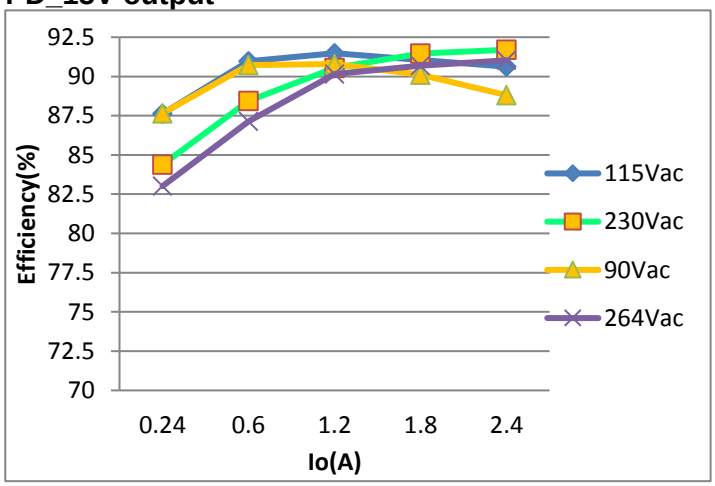
PD_9V output



PD_12V output



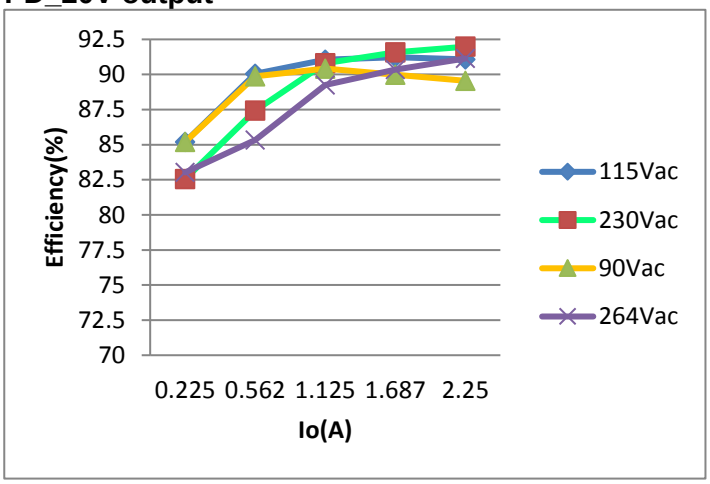
PD_15V output



Efficiency vs Output Load Curves (Continued)

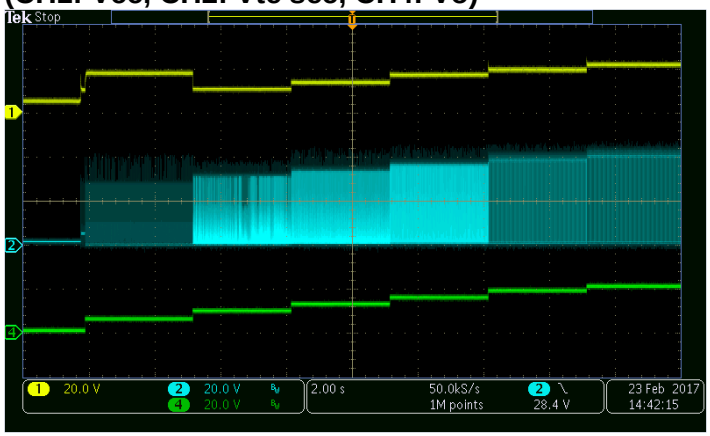
Test condition: all efficiency are tested at board end

PD_20V output



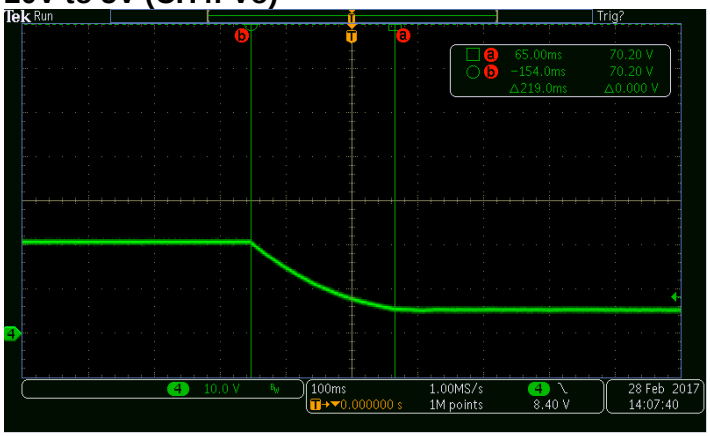
Power On and PD Voltage Change (5V > 9V > 12V > 15V > 18V >20V)

(CH1: Vcc, CH2: Vte sec, CH4: Vo)



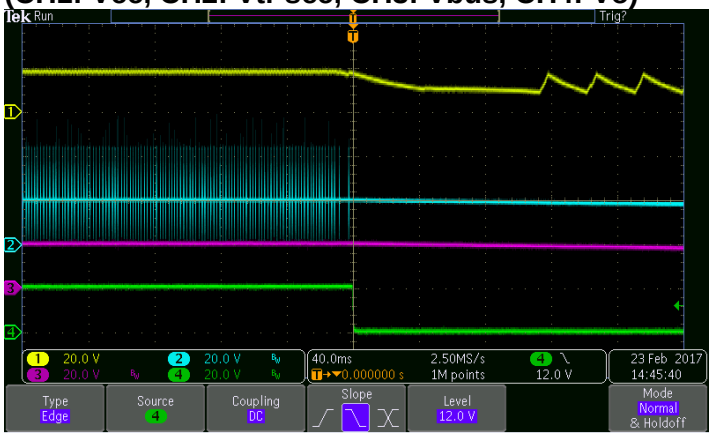
PD Transition with PD Emulator

20V to 5V (CH4: Vo)



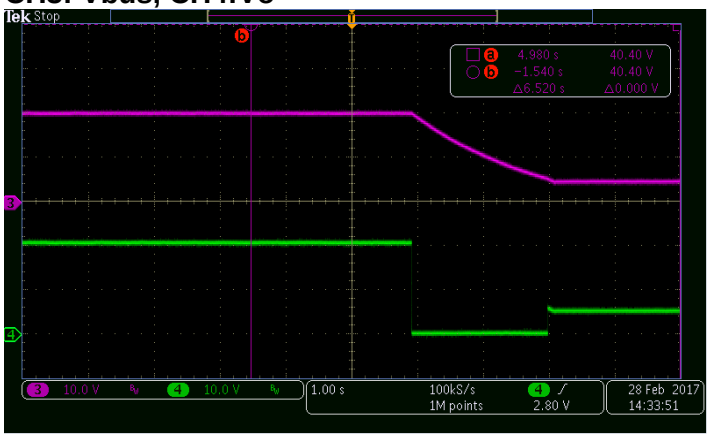
Discharge Time @ Cable Unplug

PD (20V to 5V)
(CH1: Vcc, CH2: Vtr sec, CH3: Vbus, CH4: Vo)



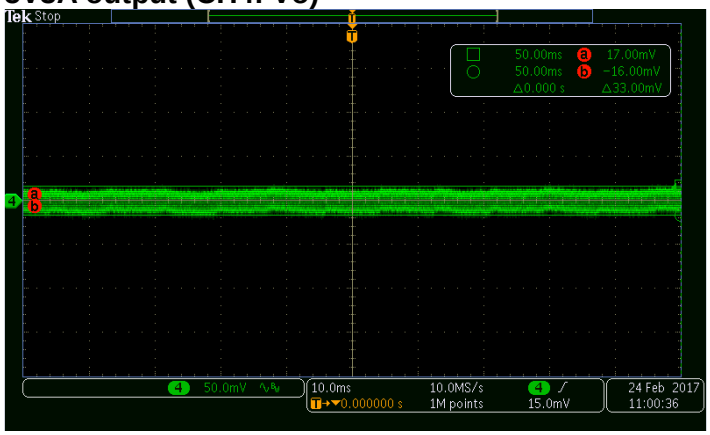
Quick Unplug/Plug Cable

CH3: Vbus, CH4:Vo

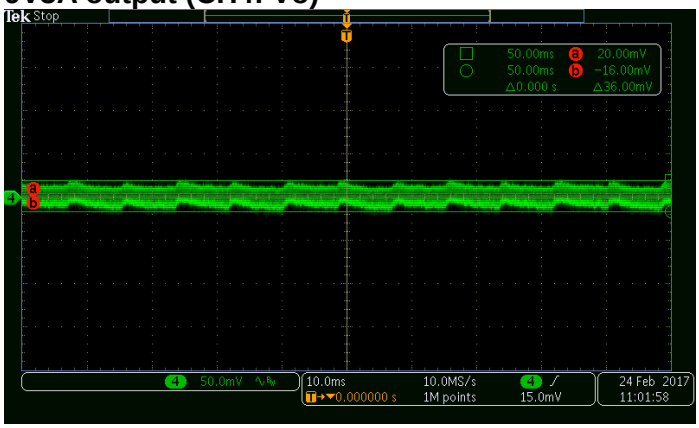


Output Ripple @ 90 Vac Input, 3A Output

5V3A output (CH4: Vo)

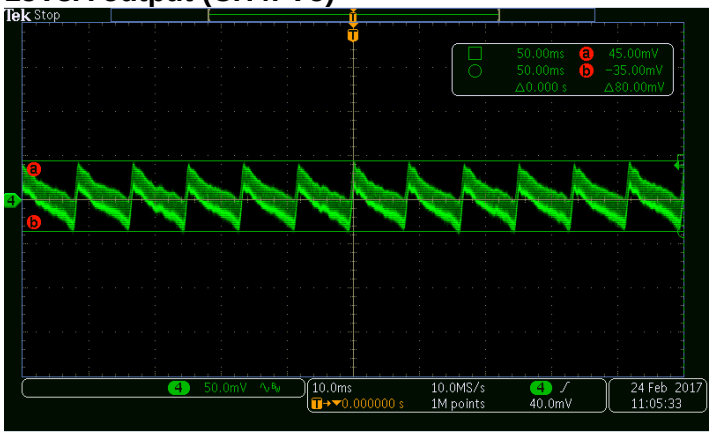


9V3A output (CH4: Vo)

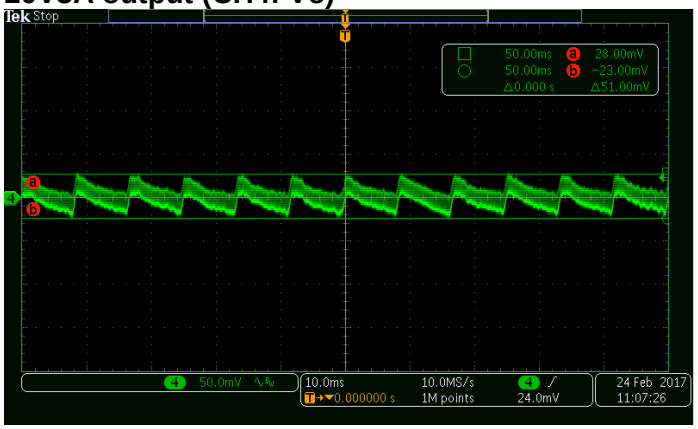


Output Ripple @ 90 Vac Input, 3A Output (Continued)

15V3A output (CH4: Vo)

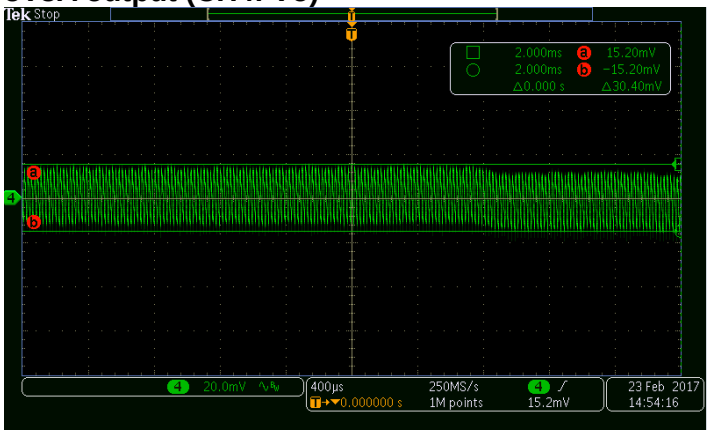


20V3A output (CH4: Vo)

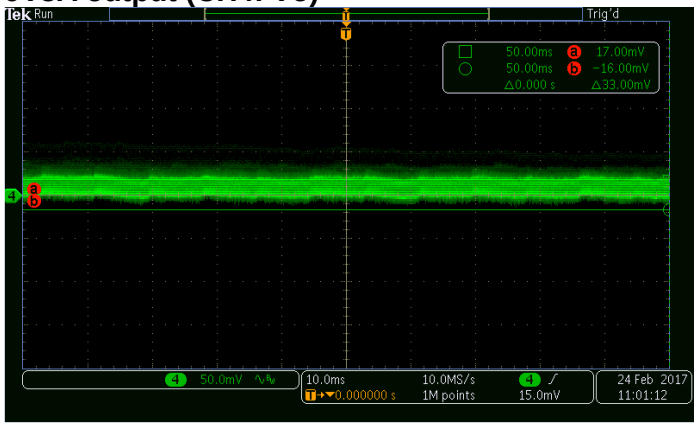


Output Ripple @ 115 Vac Input, 3A Output

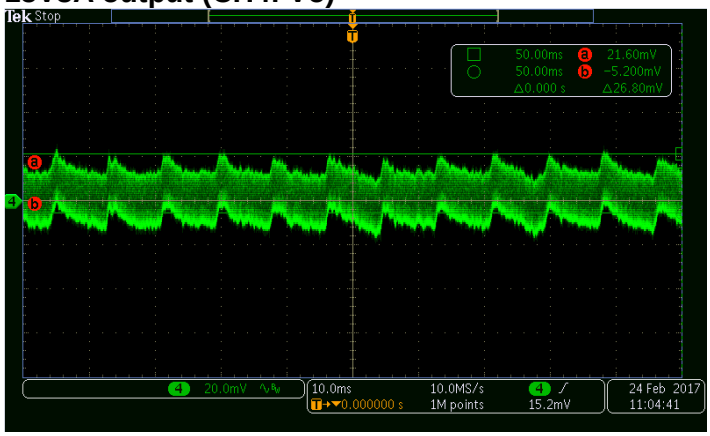
5V3A output (CH4: Vo)



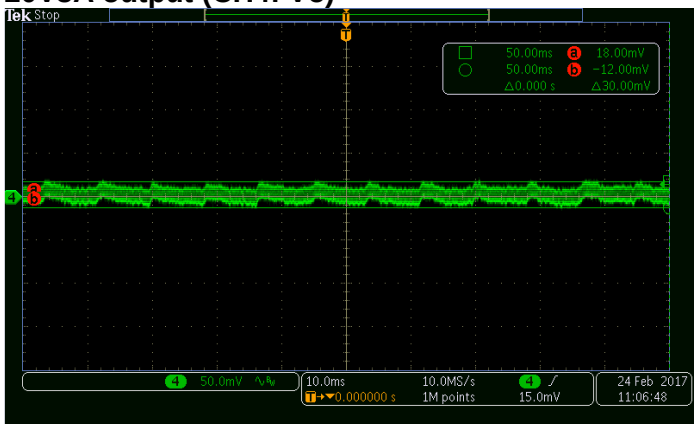
9V3A output (CH4: Vo)



15V3A output (CH4: Vo)

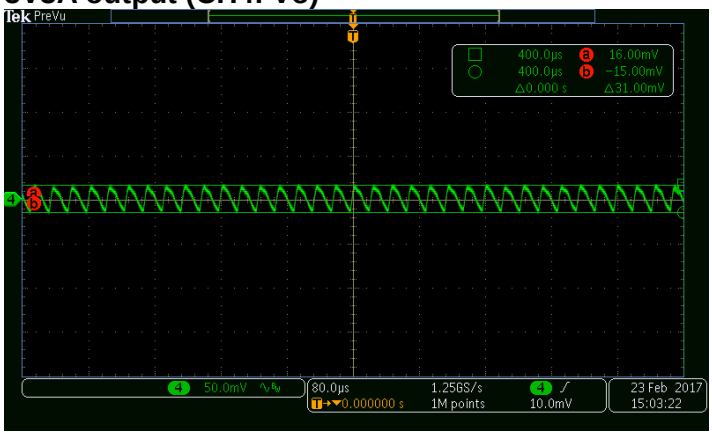


20V3A output (CH4: Vo)

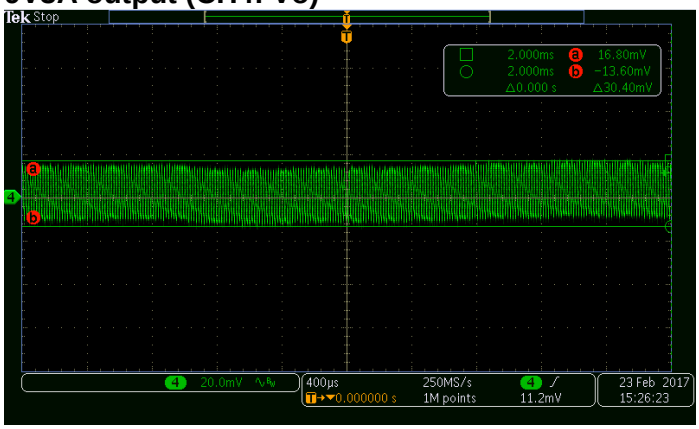


Output Ripple @ 230 Vac Input, 3A Output

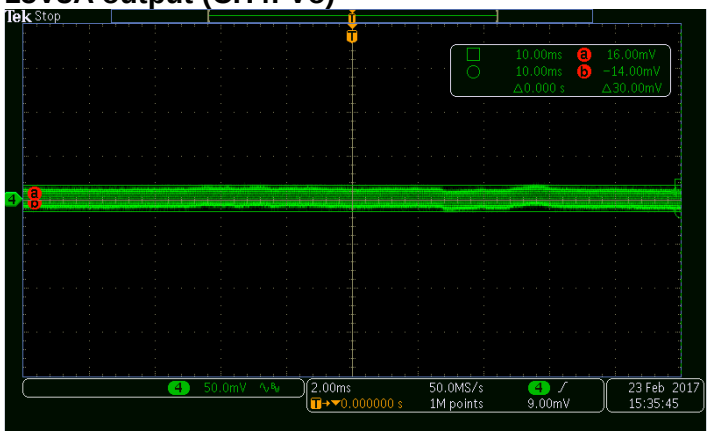
5V3A output (CH4: Vo)



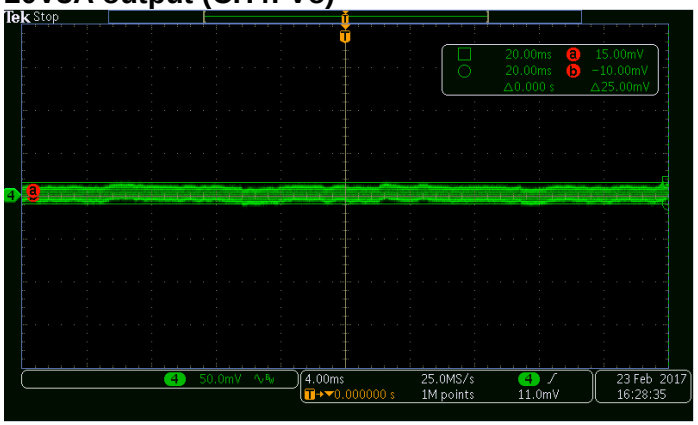
9V3A output (CH4: Vo)



15V3A output (CH4: Vo)

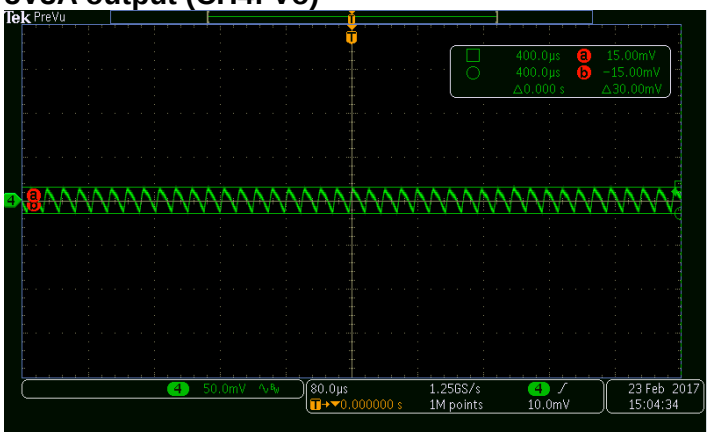


20V3A output (CH4: Vo)

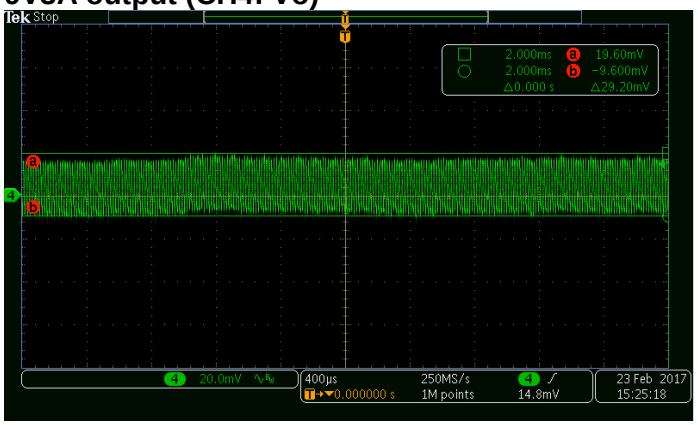


Output Ripple @ 264 Vac Input, 3A Output

5V3A output (CH4: Vo)

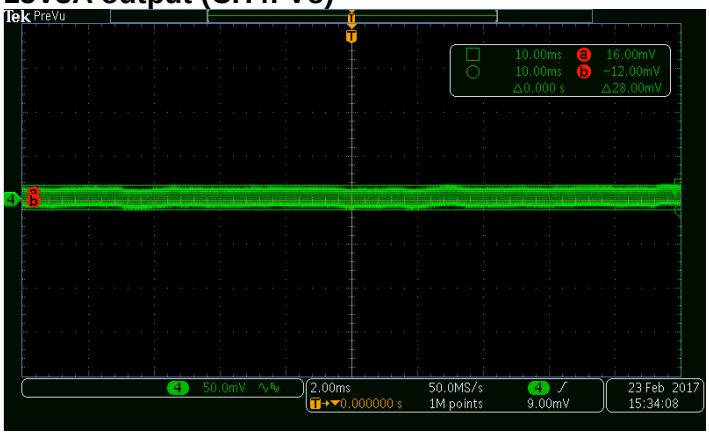


9V3A output (CH4: Vo)

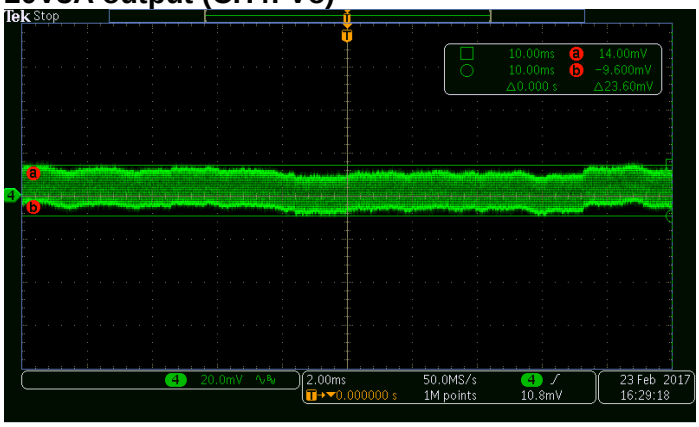


Output Ripple @ 264 Vac Input, 3A Output (Continued)

15V3A output (CH4: Vo)

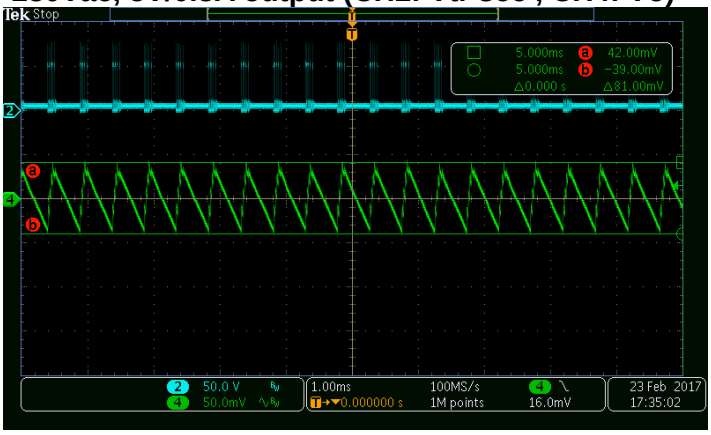


20V3A output (CH4: Vo)

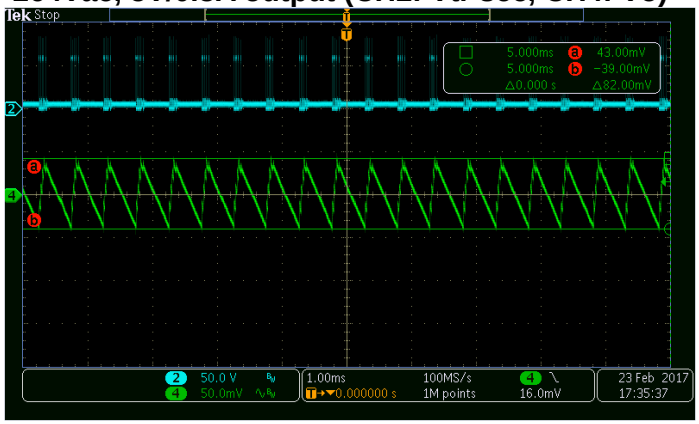


Output Ripple @ High Line & Light Load

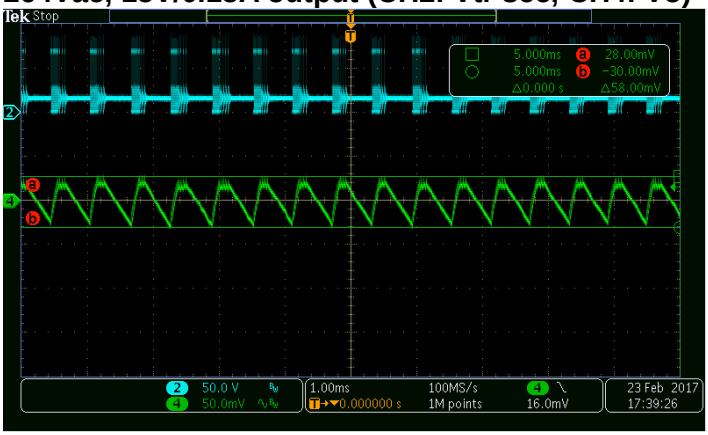
230Vac, 5V/0.3A output (CH2: Vtr sec , CH4: Vo)



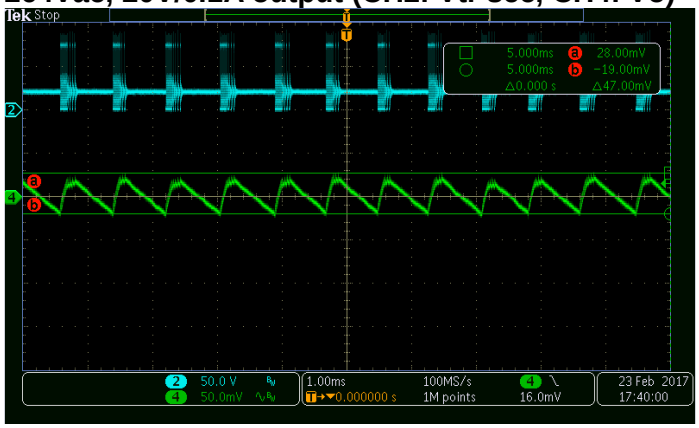
264Vac, 5V/0.3A output (CH2: Vtr sec, CH4: Vo)



264Vac, 15V/0.15A output (CH2: Vtr sec, CH4: Vo)

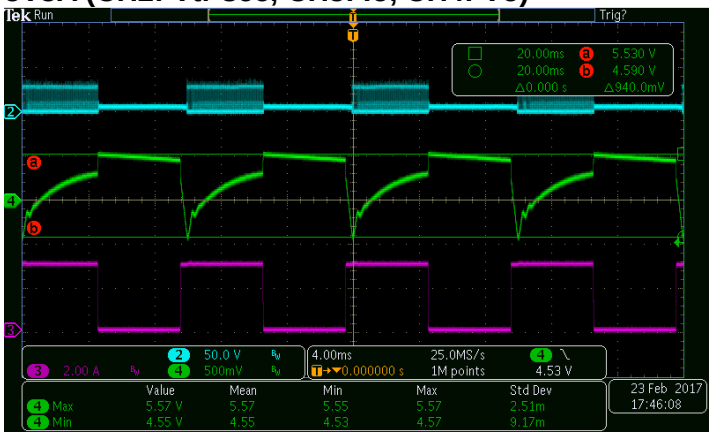


264Vac, 20V/0.1A output (CH2: Vtr sec, CH4: Vo)



Dynamic Test @ 115 Vac Input

5V3A (CH2: Vtr sec, CH3: Io, CH4: Vo)

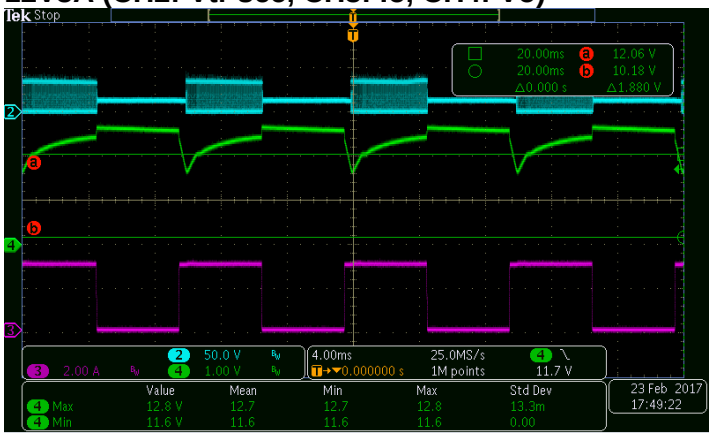


Test condition: 0-3A, 10mS cycle, 125mA/Us
1m cable, tested at E-load

9V3A (CH2: Vtr sec, CH3: Io, CH4: Vo)

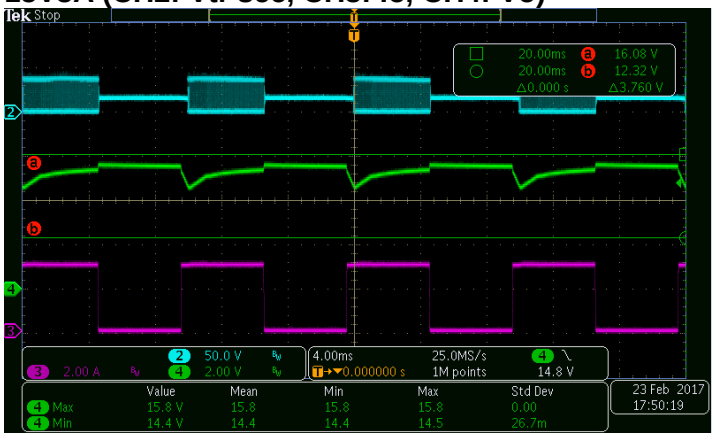
Test condition: 0-3A, 10mS cycle, 125mA/Us
1m cable, tested at E-load

12V3A (CH2: Vtr sec, CH3: Io, CH4: Vo)



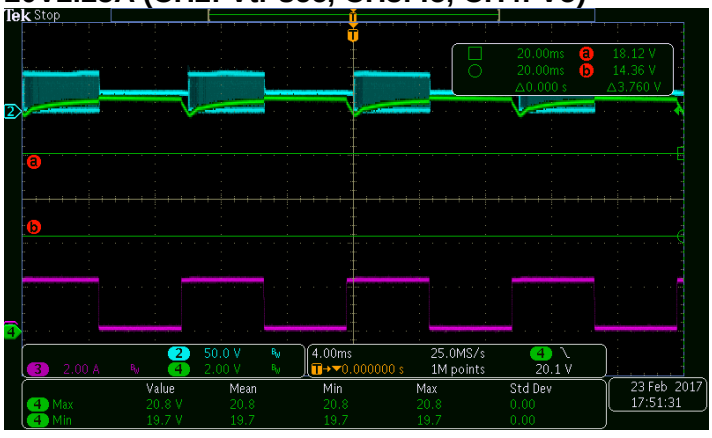
Test condition: 0-3A, 10mS cycle, 125mA/Us
1m cable, tested at E-load

15V3A (CH2: Vtr sec, CH3: Io, CH4: Vo)



Test condition: 0-3A, 10mS cycle, 125mA/Us
1m cable, tested at E-load

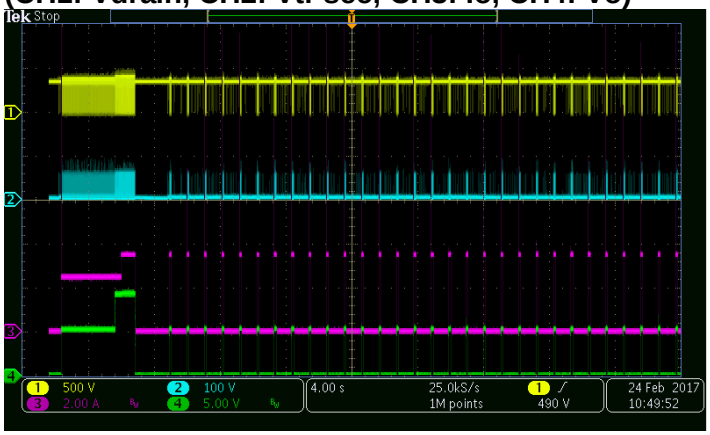
20V2.25A (CH2: Vtr sec, CH3: Io, CH4: Vo)



Test condition: 0-2.25A, 10mS cycle, 125mA/Us
1m cable, tested at E-load

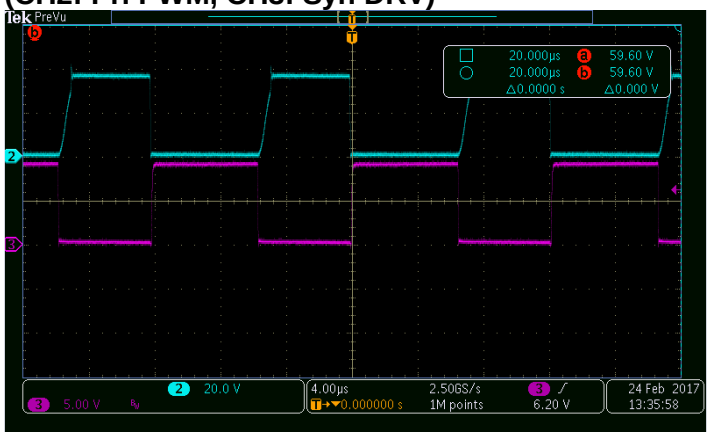
OCP @ 264 Vac Input, 9 Vdc Output

(CH1: Vdrain, CH2: Vtr sec, CH3: Io, CH4: Vo)

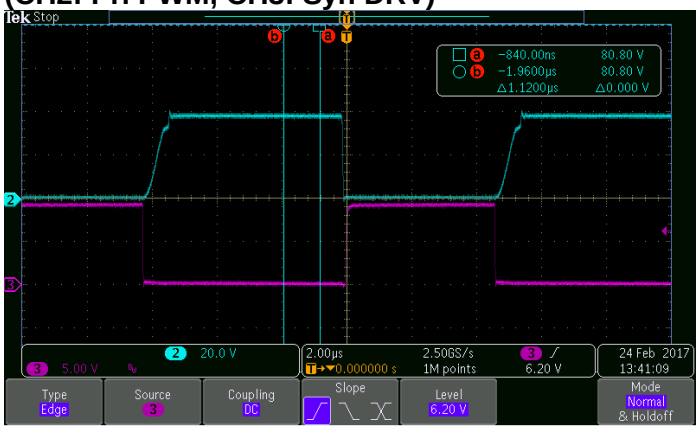


Synchronous Rectifier Drive Signal

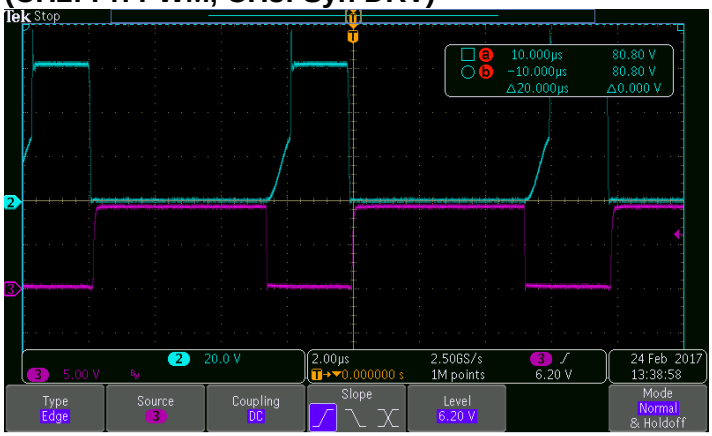
115 Vac input, 15V3A output
(CH2: Pri PWM, CH3: Syn DRV)



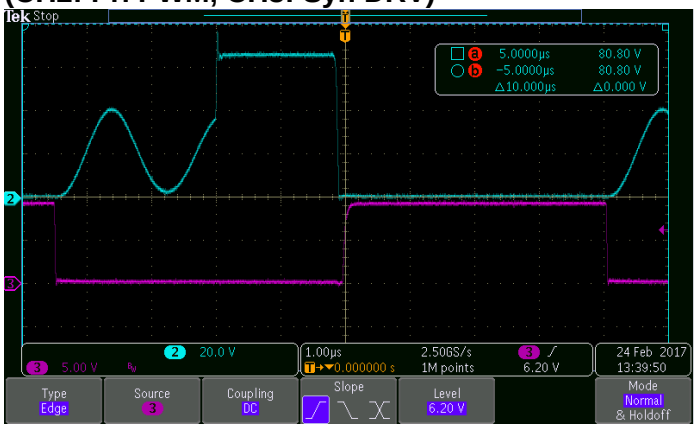
115 Vac input, 20V2.25A output
(CH2: Pri PWM, CH3: Syn DRV)



230 Vac input, 15V3A output
(CH2: Pri PWM, CH3: Syn DRV)

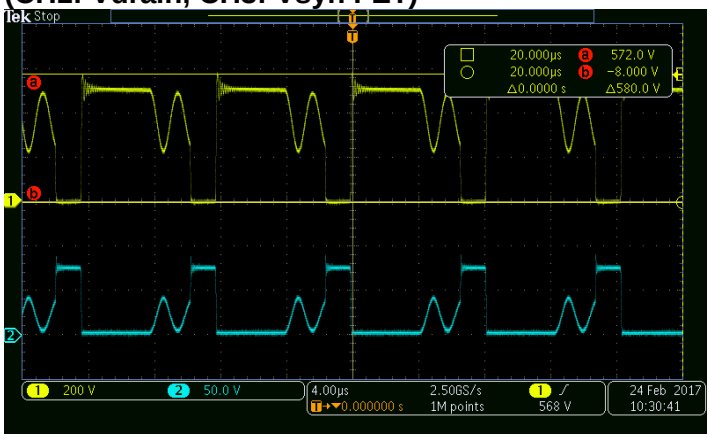


230 Vac input, 20V2.25A output
(CH2: Pri PWM, CH3: Syn DRV)



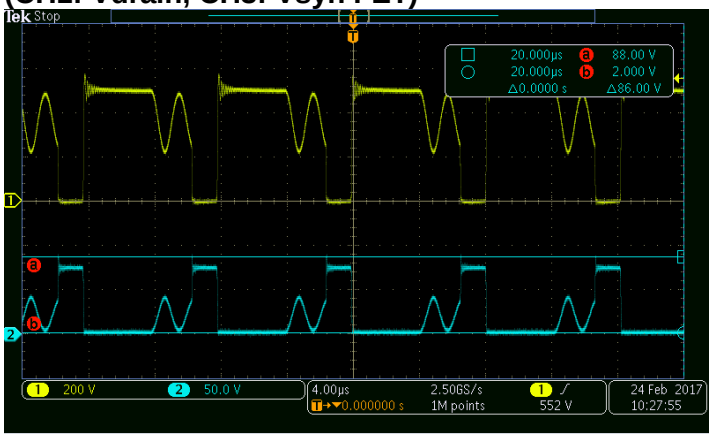
Primary FET Drain Voltage @ 264 Vax input, 20V2.25A output

(CH1: Vdrain, CH3: Vsyn FET)

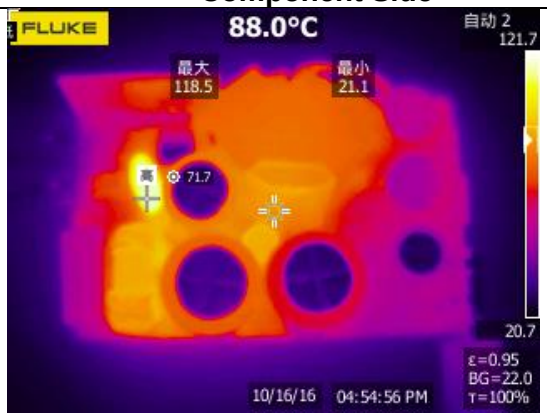
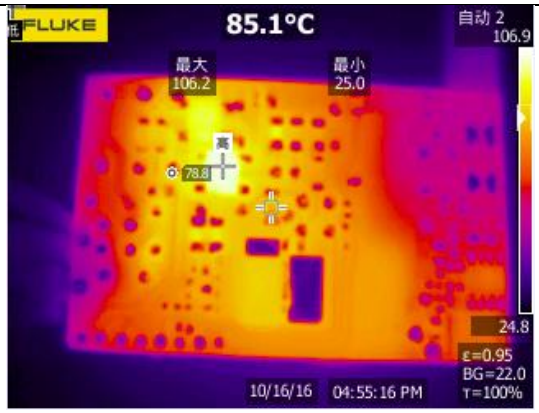
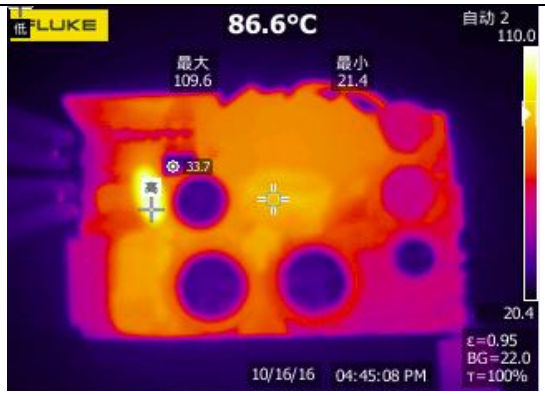
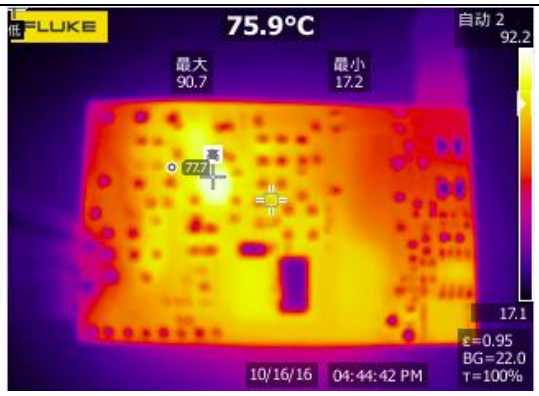
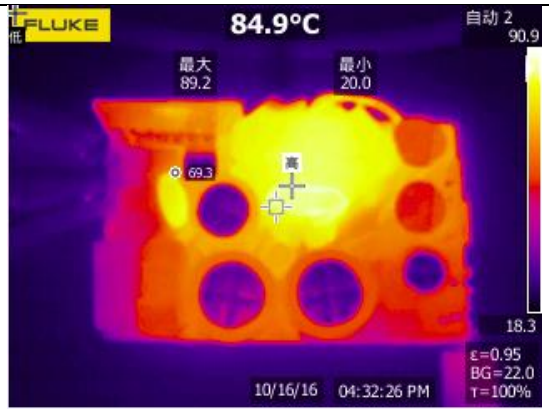
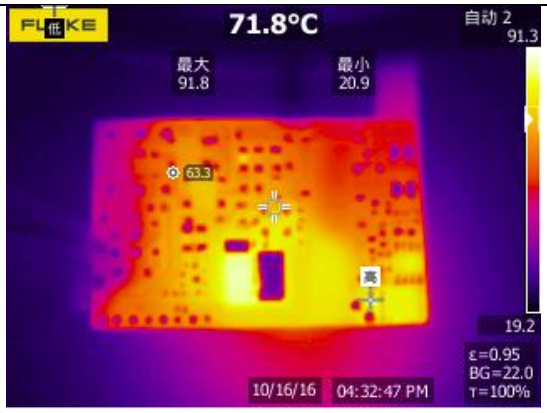
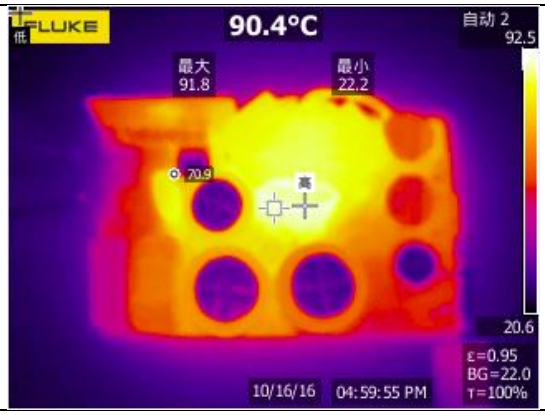
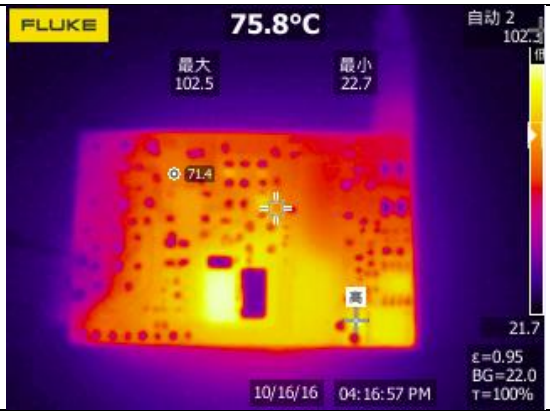


Synchronous FET Drain Voltage @ 264 Vax input, 20V2.25A output

(CH1: Vdrain, CH3: Vsyn FET)



Thermal Image @ 20V2.25A Output

Input	Component Side	Back side
90 Vac		
115 Vac		
230 Vac		
264 Vac		

DN05102/D
BOM

Item	Qty	Reference	Type	Part Name	MFR	Value	Package	Description
1	1	C9	Ceramic Capacitor	Std	std	102	603	Capacitor, Ceramic, 50V, 10%
2	1	C26	Ceramic Capcitor	C3216X7T2W104K	TDK	104,400V	1206	Capacitor, Ceramic, SMD, 5%
3	1	C18	Ceramic Capacitor	Std	std	10nF	603	Capacitor, Ceramic, 50V, 10%
4	2	C28 C30	Ceramic Capacitor	std	std	1nF	603	Capacitor, Ceramic, 50V, 10%
5	1	C12	Ceramic Capacitor	C1608C0G2A102J	TDK	1nF,100v	603	Capacitor, Ceramic, SMD, 5%
6	5	C15-17 C24 C2	Ceramic Capacitor	C1608X7R1E105K	TDK	1uF,25V	603	Capacitor, Ceramic, 25V, 10%
7	1	C8	Ceramic Capacitor	C3216X7S2A225K	TDK	2.2uF,100v	1206	Capacitor, Ceramic, 100V, 10%
8	1	C21	Ceramic Capacitor	C2012X7S2A105K	TDK	1uF,100v	805	Capacitor, Ceramic, 100V, 10%
9	1	C25	X2 Capcitor	/890334022017	Wueth	224,X2	THT, 7.5	X2 capacitor, Safety standard approved, 10
10	2	C11 C23	Ceramic Capacitor	std	std	390pF	603	Capacitor, Ceramic, 50V, 10%
11	1	C4	Ceramic Capacitor	C2012X7R1V475K	TDK	4.7uF,35v	805	Capacitor, Ceramic, 35V, 10%
12	1	C3	Ceramic Capcitor	C3216C0G2J471J	TDK	470pF,630V	1206	Capacitor, Ceramic, Chip, 5%
13	1	C10	Ceramic Capcitor	CS65-B2GA101KYNI	TDK	470pF,Y1	Lead typ	HV Ceramic Capacitor,safety standard appro
14	1	C6	Ceramic Capacitor	Std	std	47p	603	Capacitor, Ceramic, 50V, 10%
15	1	C7	Ceramic Capacitor	Std	std	1uF,25v	603	Capacitor, Ceramic,25V, 10%
16	2	C19 C22	Ceramic Capacitor	Std	std	68nF	603	Capacitor, Ceramic, 50V, 10%
17	1	C20	Ceramic Capacitor	Std	std	NC	603	Capacitor, Ceramic, 50V, 10%
18	1	D1 D3	Bridge rectifier	MDB6S	ON(FSC)	1A,600V	Micro-DI	Bridge Rectifier, 600V, 1A
19	1	DNR	Varistor	820573011	Wurth	10D471K	TH	Varistor, 10D471K
20	5	D1 D7 D10-11	Switching diode	BAS21HT1G	ON	0.2A,250V	SOD323	Switching diode, SMD
21	1	D6	Switching diode	GSD2004WS	Vishay	0.2A,300V	SOD323	Switching diode, SMD
22	1	D4	Switching diode	BAT54HT1G	ON	0.2A,30V	SOD323	Switching diode, SMD
23	1	D5	Ultrafast rectifi	US1JFA	ON(FSC)	0.8A,600V	SOD123FL	Standard Rectifier, 0.8A, 600V
24	2	D12-13	Standard rectifie	RS1JFA	ON(FSC)	0.8A,600V	SOD123FL	Standard Rectifier, 0.8A, 600V
25	1	D8	Switching diode	BAS21HT1G	ON	0.2A,250V	SOD323	Switching diode, SMD
26	1	FB	Ferrite bead	UPZ2012E102-1R5	Sunlord/Wueth		805	1000ohm@100MHz
27	1	FB1	Ferrite bead	UPZ2012E601-2R0	Sunlord/Wueth		805	600ohm@100MHz
28	1	L3	Common filter	744821110	Wueth	10mH	TH type	CM Filter, T type core
29	1	L1	Common filter	150-1327	Wurth-M	500uH	TH	T type, 6.3x3x3, 11T, 0.2mmx2 in parallel winding
30	1	F1	Fuse	20T-016H	Hollyfu	1.6A, 250V	Axial le	Micro Fuse, 1.6A/250V
31	1	Q4	NPN Transistor	MMBTA06LT1G	ON		SOT23	General NPN Transistor, SMD

BOM (Continued)

Item	Qty	Reference	Type	Part Name	MFR	Value	Package	Description
32	2	Q6-7	NPN Transistor	MMBT3904LT1G	ON		SOT23	General NPN Transistor, SMD
33	1	Q5	PNP Transistor	MMBT3906LT1G	ON		SOT23	General PNP Transistor, SMD
34	1	U3	Syn. rectified co	NCP4306AADZZZADI	ON		SO8	Syn. Rectified Controller
35	1	U1	PWM Controller	NCP1340B3D1R2G	ON		SOP9	QR PWM controller
36	1	NTC1	NTC	std	std	13k	603	replaced by 13k resisotor
37	1	NTC	NTC	SPNL09D2R5MBI	Sunlord	2.5ohm	lead typ	9mm Die, 2.5ohm
38	1	U4	Optical coupler	FODM1009	ON(FSC)		LSOP4	optical coupler, standard SOP package
39	1	Q8	PMOS	ATP104	ON	-30V, 8.4m	ATPAK	PMOS
40	1	L2	Axial leaded fixe	7447462470	Wurth	47uH		Axial leaded fixed inductor
41	1	Q2	MOSFET	IPL60R385CP	Infineon		THINKPAK	MOSFET, NChan, 600V
42	1	R6	Resistor	Std	Std	1	603	Resistor, Chip, 1/8W, 1%
43	1	R34	Resistor	Std	Std	10	603	Resistor, Chip, 1/8W, 1%
44	1	R13	Resistor	Std	Std	100K	603	Resistor, Chip, 1/8W, 1%
45	1	R35	Resistor	Std	Std	10K	603	Resistor, Chip, 1/8W, 1%
46	3	R18 R21 R38	Resistor	Std	Std	10k	603	Resistor, Chip, 1/8W, 1%
47	1	R17	Resistor	Std	Std	18k	603	Resistor, Chip, 1/8W, 1%
48	1	R3	Resistor	Std	Std	1K	603	Resistor, Chip, 1/8W, 1%
49	1	R22	Resistor	Std	Std	1K	603	Resistor, Chip, 1/8W, 1%,
50	1	R8	Resistor	Std	Std	20k	603	Resistor, Chip, 1/8W, 1%
51	5	R19 R26-28 R3	Resistor	Std	Std	22	603	Resistor, Chip, 1/8W, 1%
52	1	R9	Resistor	Std	Std	1.8k	603	Resistor, Chip, 1/8W, 1%
53	1	R11	Resistor	Std	Std	300	603	Resistor, Chip, 1/8W, 1%
54	1	R7	Resistor	Std	Std	300k	603	Resistor, Chip, 1/8W, 1%
55	1	R30	Resistor	Std	Std	30k	603	Resistor, Chip, 1/8W, 1%
56	1	R33	Resistor	Std	Std	39k	603	Resistor, Chip, 1/8W, 1%
57	1	R10	Resistor	Std	Std	4.7	603	Resistor, Chip, 1/8W, 1%
58	1	R23	Resistor	Std	Std	4.7K	603	Resistor, Chip, 1/8W, 1%
59	1	R25	Resistor	Std	Std	47K	603	Resistor, Chip, 1/8W, 1%
60	1	R15	Resistor	Std	Std	47k	603	Resistor, Chip, 1/8W, 1%
61	1	R32	Resistor	Std	Std	68K	603	Resistor, Chip, 1/8W, 1%
62	1	R24	Resistor	Std	Std	75K	603	Resistor, Chip, 1/8W, 1%
63	1	R20	Resistor	Std	Std	820k	603	Resistor, Chip, 1/8W, 1%

BOM (Continued)

Item	Qty	Reference	Type	Part Name	MFR	Value	Package	Description
64	1	R16	Resistor	Std	Std	91k	603	Resistor, Chip, 1/8W, 1%
65	1	R29	Resistor	Std	Std	NC	603	Resistor, Chip, 1/8W, 1%,
66	1	R37	Resistor	Std	Std	NC	603	Resistor, Chip, 1/8W, 1%
67	2	R4-5	Resistor	ERJ8BQFR062V	Panason	0.62	1206	Resistor, Chip, 1/2W, 1%
68	1	R2	Resistor	Std	Std	10	1206	Resistor, Chip, 1/4W, 1%
69	1	R31	Resistor	Std	Std	1k	805	Resistor, Chip, 1/5W, 1%
70	1	R12	Resistor	Std	Std	20	805	Resistor, Chip, 1/5W, 1%
71	1	R1	Resistor	Std	Std	300k	1206	Resistor, Chip, 1/4W, 1%
72	1	R14	Resistor	ERJ8BWFR005V	Panason	5mohm	1206	Resistor, Chip, 1/2W, 1%
73	1	T1	Transformer	750343635	WE-midcon		TH type	RM8, 12Pin
74	1	C5	Electrolytic capa	KM series/ERK2GM	CapXon/	22uF,400V	10X16	size,13mmx16mm
75	2	C1-2	Electrolytic capa	KM series	CapXon	33uF,400V	13X16	size,10mmx16mm
76	3	C13-14 C29	Electrolytic soli	PS681M025F080P	CapXon	680uF,25V	8mmx16mm	size:8mmx16mm
77	1	Q1	MOSFET	NTMFS6B03NLT1G	ON		SO8FL	MOSFET, NChan, 100V
78	1	J1	USB Type C connec	632 723 300 011	Wueth		TH/SMD	Type C connector, SMT
79	1	U2	PD controller	WT6632FSG14BWTS4	Weltrend		SO14	PD3.0/QC3.0 protocal controller
80	1	ZD5	Zener	MM3Z10VT1G	ON	10V	SOD323	GENERIC ZENER-DIODE
81	1	ZD2	Zener	MM3Z24VT1G	ON	24V	SOD323	GENERIC ZENER-DIODE
82	4	ESD1-4	ESD	SD05T1G	ON	5V	SOD323	ESD protection device

References

ON Semiconductor datasheet for NCP1340, 4306, NTMFS6B03, ATP104

ON Semiconductor Design Notes DN05043

Weltrend semiconductor datasheet for WT6632F

Design note created by David Dou. E-mail: david.dou@onsemi.com