RD29 65W USB PD REPORT

RD-29 Description

This reference design describes a 65 W universal input offline power supply with programmable output voltage (5 V/3 A, 9 V/3 A, 15V/3A, 20 V/3.25A). The power supply uses SZ1131 (Flyback PWM controller with integrated active clamp circuit) IC, Transphorm TP65H300G4LSG (650 V SuperGaN FET) and Weltrend WT6633P 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 SZ1131 controller.

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

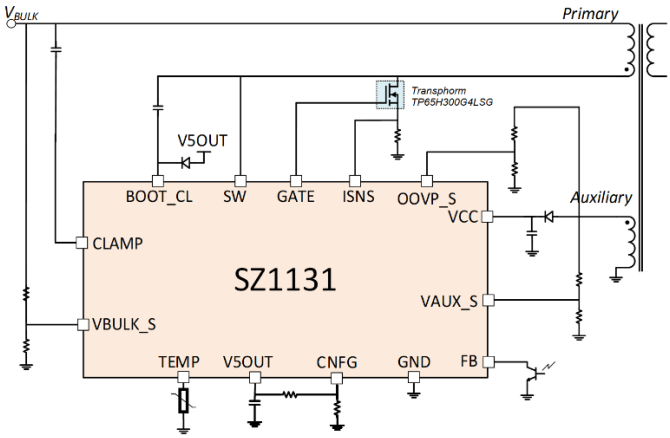
Key Specs	
Input	90-265 Vac
Output Voltages	5 V, 9 V, 15 V, 20 V
Max Output Current	3 A @ 5 V, 9 V, 15V ,3.25 @ 20V
Max Output Power	65 W
Output Port	USB-PD Type C Connector
Standby power(no-load)	<30 milliwatts
Form factor (volume)	33.9mm x 30.4mm x 34.5mm or 2.17 in^3 or 35.5 cm^3
Power Density (uncased)	>29.8W/in^3
Efficiency	93% 65W Efficiency @ 90 Vac 94% 65W Efficiency @ 115 Vac 94.5% 65W Efficiency @ 230 Vac

SZ1131 Features

- Integrated High Voltage Active Clamp FET, Active Clamp Driver, and Start-up Regulator
- Capable of Over 94% 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
- < 30mW No Load Power Consumption
- Up to 65 W Output Power

Applications

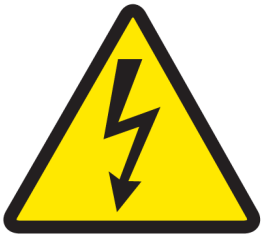
- High-Power-Density USB-PD AC/DC Power Supplies



transphorm

SuperGaN

Warning



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						
Current	I_{out}			3.25	A	
Output Power Continuous	P_{out}			65	W	
Efficiency						
5 V/3 A	$\eta_{5V/3A}$		90		%	@ 115 Vac, 25 °C ambient
9 V/3 A	$\eta_{9V/3A}$		93		%	
15 V/3 A	$\eta_{15V/3A}$		93		%	
20 V/3.25 A	$\eta_{20V/3.25A}$		93		%	
DoE Level VI 4-Point Average Efficiency						
5 V	η_{ave_5V}		81.39%		%	DoE Level VI 4-point (25%, 50%, 75%, 100%) average efficiency
9 V	η_{ave_9V}		86.62%		%	
15 V	η_{ave_15V}		87.73%		%	
20 V	η_{ave_20V}		88.00%		%	
CoC V5 Tier-2 4-Point Average Efficiency						
5 V	η_{ave_5V}		81.84%		%	CoC version 5 tier 2 4-point (25%, 50%, 75%, 100%) average efficiency
9 V	η_{ave_9V}		87.30%		%	
15 V	η_{ave_15V}		88.85%		%	
20 V	η_{ave_20V}		89.00%		%	
CoC V5 Tier-2 10% Efficiency						
5 V	$\eta_{10\%\_5V}$		72.48%			CoC Version 5 Tier-2 10% load efficiency requirements.
9 V	$\eta_{10\%\_9V}$		77.30%			
15 V	$\eta_{10\%\_15V}$		78.85%			
20 V	$\eta_{10\%\_20V}$		79.00%			
No-Load Input Power	P_{in}			30	mW	@ 265 Vac, 25 °C ambient
Programmable Output Voltage	V_{OUT}	5		20	V	
Environmental Conducted & Radiated EMI	Meets CISPR22B/EN55022 (>6dB margin)					
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

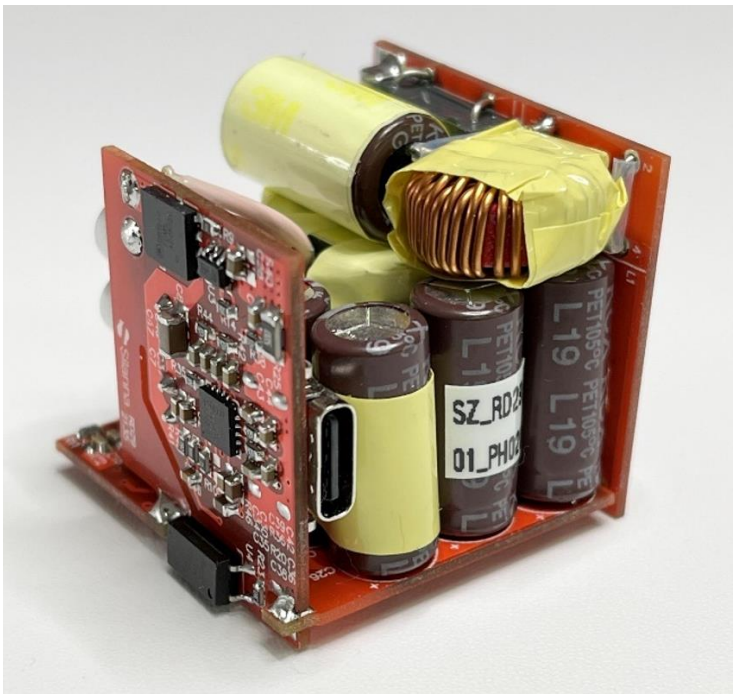


Figure 1: Top Side

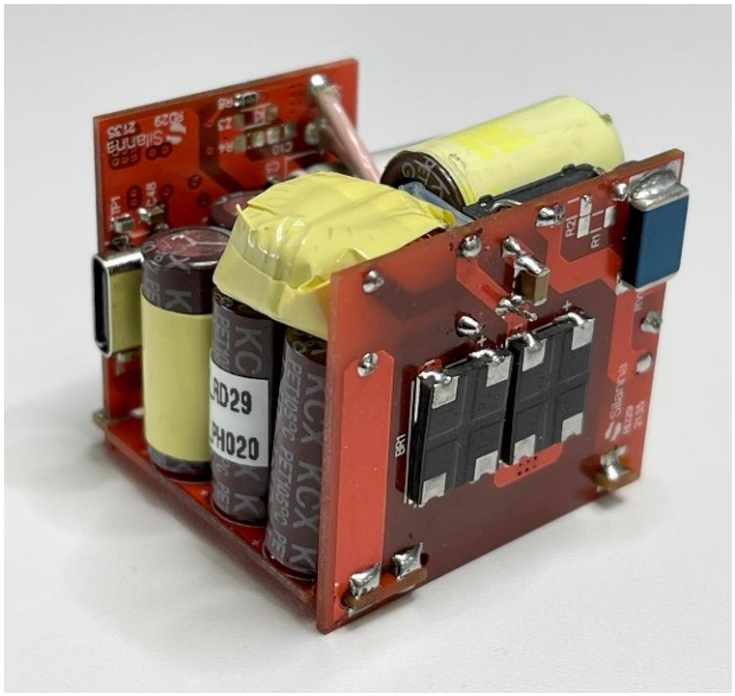


Figure 2: Bottom Side

Schematics

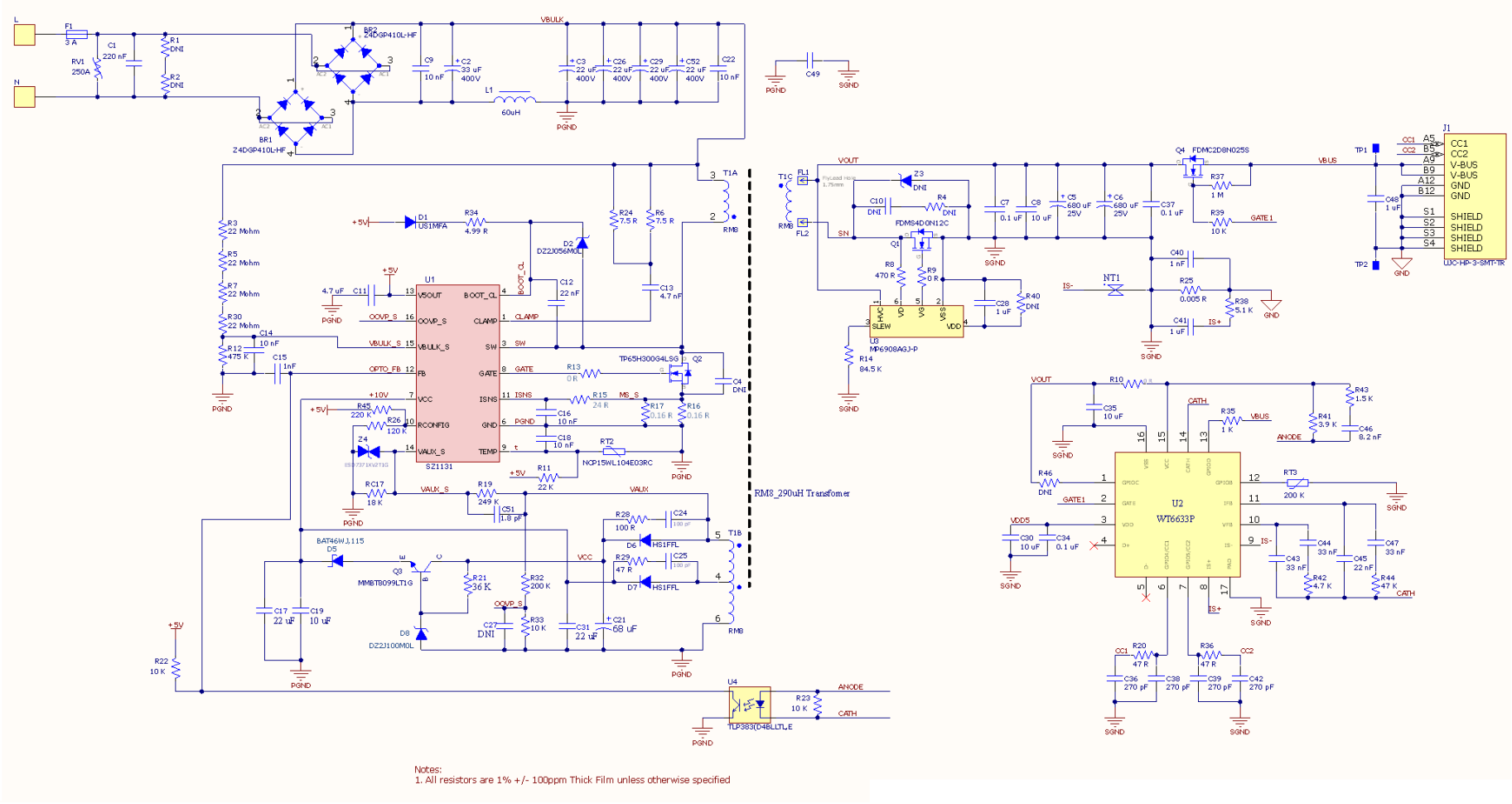


Figure 3: 65W Schematic

PCB Layout

PCB Top Board

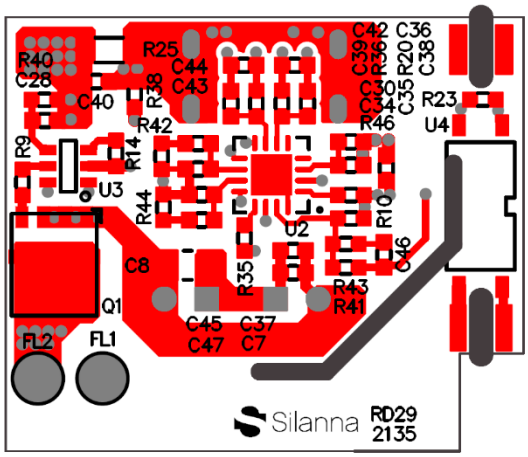


Figure 4: Component side Top board, top layer

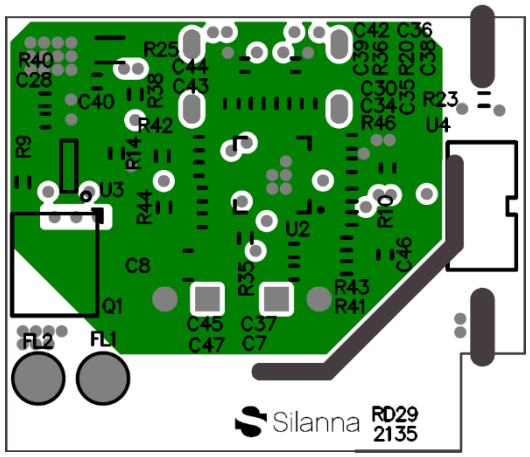


Figure 5: Component side Top board, middle1

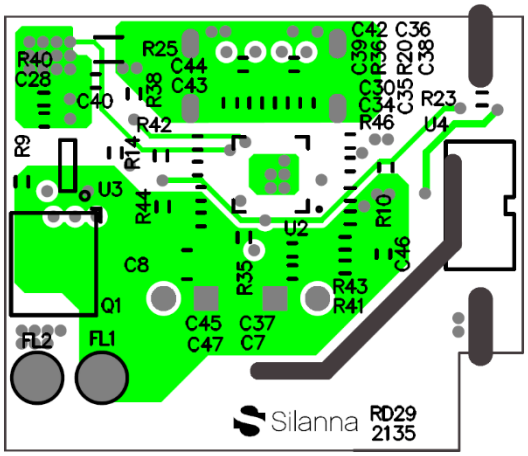


Figure 6: Component side Top board, middle2

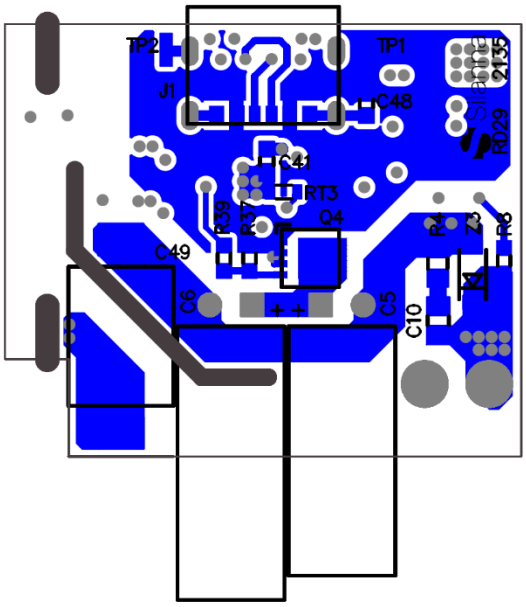


Figure 7: Solder side Top board, bottom layer

PCB Middle Board

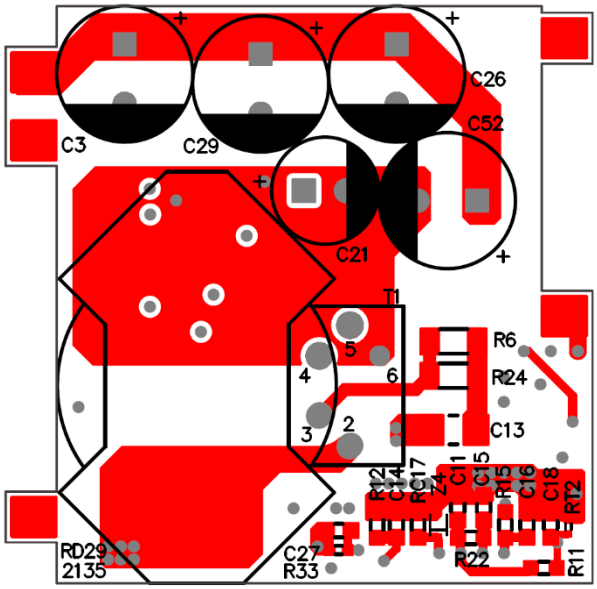


Figure 8: Component side Middle board, top layer

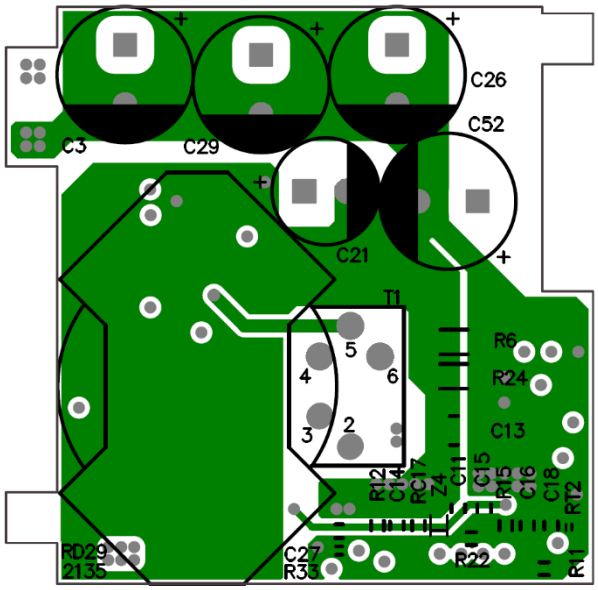


Figure 9: Component side Middle board, middle1

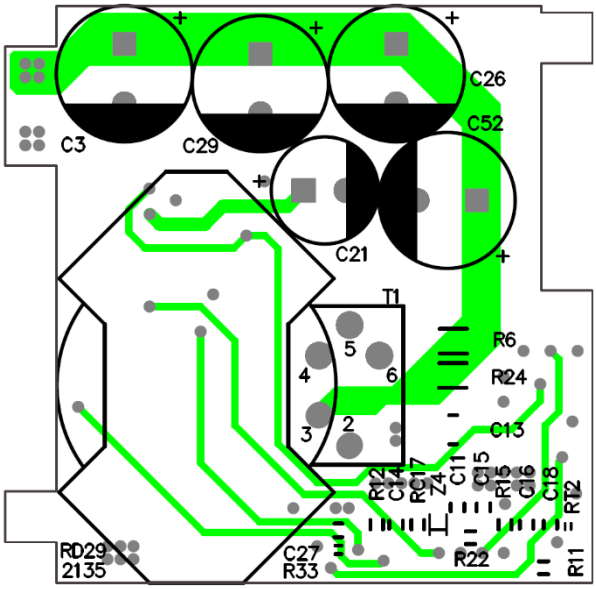


Figure 10: Component side Middle board, middle2

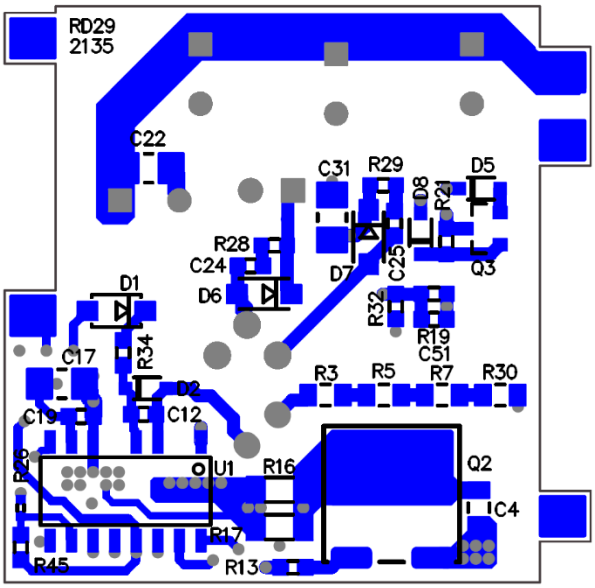


Figure 11: Solder side Middle board, bottom layer

PCB Bottom Board

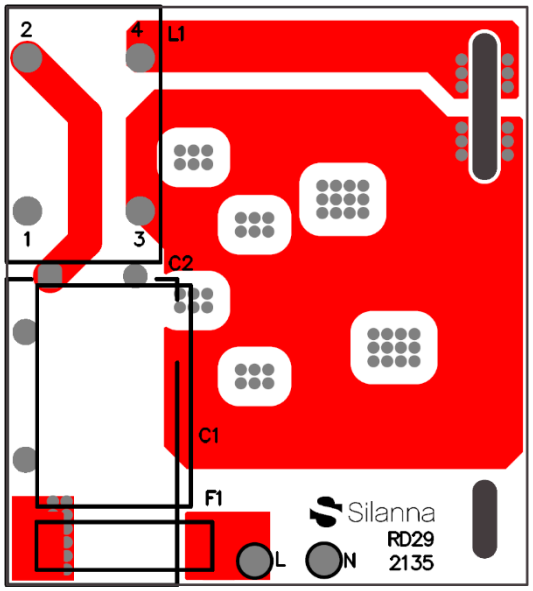


Figure 12: Component side Bottom board, top layer

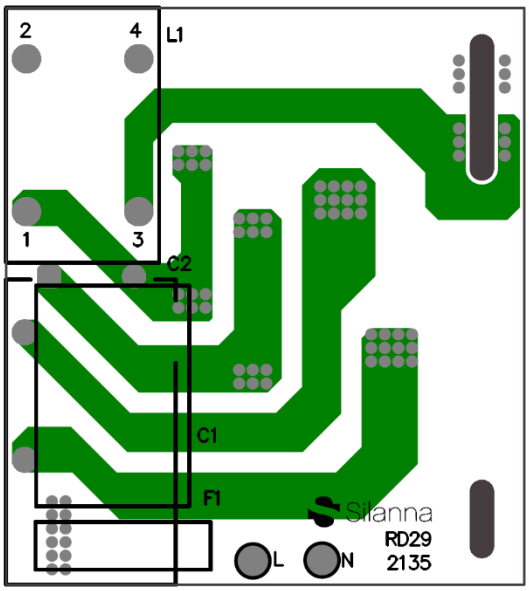


Figure 13: Component side Bottom board, middle1

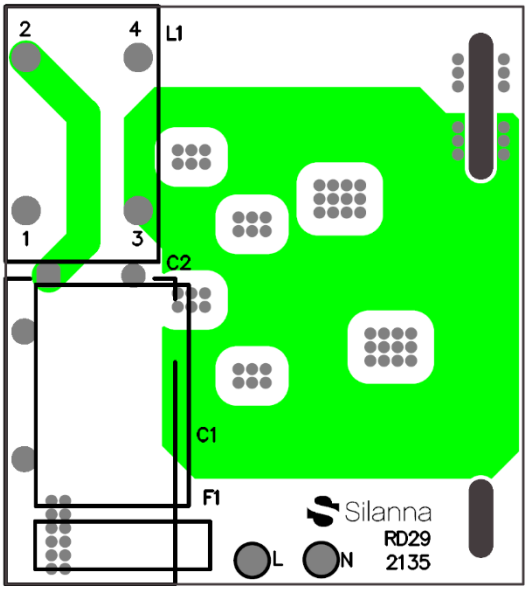


Figure 14: Component side Bottom board, middle2

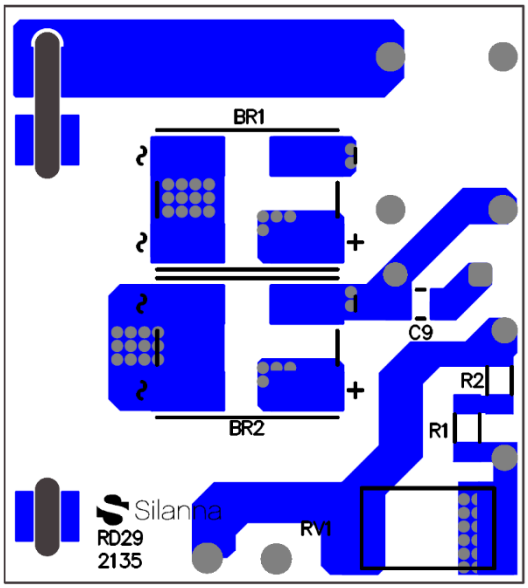


Figure 15: Solder side Bottom board, bottom layer

Bill of Materials (BOM)

Table 2: Reference Design BOM

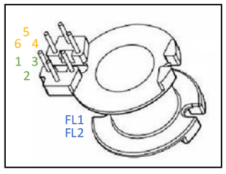
Description	Manufacturer	Manufacturer Part Number	Designator
Top Board (USB Type-C Connector)			
CAP ALUM 680UF 20% 25V T/H	YMIN	SPT1EM681E16OR	C5, C6
CAP CER 0.1UF 50V X7R 0603	Samsung Electro-Mechanics	CL10B104KB8NNNC	C7, C34, C37
CAP CER 10UF 25V X7R 1206	TDK Corporation	C3216X7R1E106K160AB	C8
DNI CAP 0805			C10
CAP CER 1UF 25V X7R 0603	Samsung Electro-Mechanics	CL10B105KA8NNNC	C28
CAP CER 10UF 25V X5R 0603	Murata Electronics	GRM188R61E106MA73D	C30, C35
CAP CER 270PF 50V X7R 0603	Yageo	CC0603KRX7R9BB271	C36, C38, C39, C42
CAP CER 1000PF 25V X7R 0603	KEMET	C0603C102K3RACTU	C40
CAP CER 1UF 35V X7R 0603	TDK Corporation	CGA3E1X7R1V105K080AC	C41, C48
CAP CER 0.033UF 50V X7R 0603	Yageo	CC0603KRX7R9BB333	C43, C44, C47
CAP CER 0.022UF 50V X7R 0603	Yageo	CC0603KRX7R9BB223	C45
CAP CER 8200PF 50V X7R 0603	KEMET	C0603C822K5RACTU	C46
Plastic package type chip 400VAC-Y1 safety capacitor	Anshan Qifa Electronic Ceramic Technology Co., Ltd.	CT7-400VAC-Y1-B-681K	C49
FLYLEAD 1.75MM			FL1, FL2
USB JACK, C TYPE, POWER ONLY, 6	CUI Devices	UJC-HP-3-SMT-TR	J1
MOSFET N-CH 120V 18.5A/114A 8QFN	ON Semiconductor	FDMS4D0N12C	Q1
MOSFET N-CH 25V 124A 8PQFN	ON Semiconductor	FDMC2D8N025S	Q4
DNI RES 0805			R4
RES SMD 470 OHM 1% 1/10W 0603	Yageo	RC0603FR-07470RL	R8
RES 0 OHM JUMPER 1/10W 0603	Stackpole Electronics Inc	RMCF0603ZT0R00	R9
RES SMD 0 OHM 1/10W 0603	Yageo	RC0603JR-070RL	R10
RES SMD 84.5K OHM 1% 1/10W 0603	Yageo	RC0603FR-0784K5L	R14
RES SMD 47 OHM 1% 1/10W 0603	Yageo	RC0603FR-0747RL	R20, R36
RES SMD 10K OHM 1% 1/10W 0603	Yageo	RC0603FR-0710KL	R23, R39
RES 0.005 OHM 1% 1W 1206	Bourns Inc.	CFN1206-FX-R005ELF	R25
RES SMD 1K OHM 1% 1/10W 0603	Yageo	RC0603FR-071KL	R35
RES SMD 1M OHM 1% 1/10W 0603	Yageo	RC0603FR-071ML	R37
RES SMD 5.1K OHM 1% 1/10W 0603	Yageo	RC0603FR-075K1L	R38
DNI RES 0603			R40, R46
RES SMD 3.9K OHM 1% 1/10W 0603	Yageo	RC0603FR-073K9L	R41
RES SMD 4.7K OHM 1% 1/10W 0603	Yageo	RC0603FR-074K7L	R42
RES SMD 1.5K OHM 1% 1/10W 0603	Bourns Inc.	CR0603-FX-1501ELF	R43
RES SMD 47K OHM 1% 1/10W 0603	Yageo	AC0603FR-0747KL	R44
THERMISTOR NTC 200K OHM 5% 0603	Vishay Dale	NTHS0603N17N2003JE	RT3
PC TEST POINT NATURAL	TE Connectivity AMP Connectors	RCU-0C	TP1, TP2

Description	Manufacturer	Manufacturer Part Number	Designator
WT6633P USB PD Controller QFN16	Weltrend	WT6633P	U2
FAST TURN-OFF INTELLIGENT RECTIF	Monolithic Power Systems Inc.	MP6908AGJ-P	U3
OPTOISO 5KV TRANSISTOR SO6L	Toshiba Semiconductor and Storage	TLP383(D4BLLTL,E)	U4
DNI DIODE SOD-123			Z3
Middle Board			
CAP ALUM 22UF 20% 400V T/H	KNSCHA	87EC0147MHT22uF400V	C3, C26, C29, C52
DNI CAP 0805			C4
CAP CER 4.7UF 25V X6S 0603	Murata Electronics	GRM188C81E475KE11D	C11
CAP CER 0.022UF 50V X7R 0603	Yageo	CC0603KRX7R9BB223	C12
CAP CER 4700PF 630V X7R 1206	TDK Corporation	C3216X7R2J472K115AA	C13
CAP CER 10000PF 25V X7R 0603	Samsung Electro-Mechanics	CL10B103KA8NNNC	C14, C16, C18
CAP CER 1000PF 16V X7R 0603	Yageo	CC0603KRX7R7BB102	C15
CAP CER 10UF 25V X5R 0603	Murata Electronics	GRM188R61E106MA73D	C19
CAP ALUM 68UF 80V 20% T/H	YMIN	LKMC0902A190MF	C21
CAP CER 10000PF 630V X7R 1206	KEMET	C1206C103KBRACTU	C22
CAP CER 22UF 25V X6S 1206	Murata Electronics	GRM31CC81E226KE11L	C17, C31
CAP CER 100PF 200V NPO 0603	Yageo	CC0603JRNPOABN101	C24, C25
DNI CAP 0603			C27
1.8 pF ±0.25pF 50V Ceramic Capacitor C0G, NP0 0603	KEMET	C0603C189C5GACTU	C51
DIODE GEN PURP 1KV 1A SOD123FA	ON Semiconductor	US1MFA	D1
DIODE ZENER 5.6V 200MW SMINI2	Panasonic Electronic Components	DZ2J056M0L	D2
DIODE SCHOTTKY 100V 250MA SOD323	Nexperia USA Inc.	BAT46WJ,115	D5
50NS 1A 300V HIGH EFFICIENT RECO	Taiwan Semiconductor Corporation	HS1FFL	D6, D7
DIODE ZENER 10V 200MW SMINI2	Panasonic Electronic Components	DZ2J100M0L	D8
GANFET N-CH 650V 6.5A 3PQFN	Transphorm	TP65H300G4LSG	Q2
Bipolar (BJT) Transistor NPN 80V 500mA 150MHz 225mW	ON Semiconductor	MMBT8099LT1G	Q3
RES SMD 22M OHM 1% 1/4W 0805	Stackpole Electronics Inc	RMCF0805FT22M0	R3, R5, R7, R30
RES SMD 7.5 OHM 1% 1/4W 1206	Stackpole Electronics Inc	RMCF1206FT7R50CT-ND	R6, R24
RES SMD 22K OHM 1% 1/10W 0603	Yageo	RC0603FR-0722KL	R11
RES SMD 475K OHM 1% 1/10W 0603	Yageo	RC0603FR-07475KL	R12
RES 0 OHM JUMPER 1/10W 0603	Stackpole Electronics Inc	RMCF0603ZT0R00	R13
RES SMD 24 OHM 1% 1/10W 0603	Yageo	RC0603FR-0724RL	R15
RES 0.16 OHM 1% 1/2W 1206	TE Connectivity Passive Product	RLP73K2BR16FTDF	R16, R17
RES SMD 249K OHM 1% 1/10W 0603	Panasonic Electronic Components	ERJ-3EKF2493V	R19
RES 36K OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT36K0CT-ND	R21

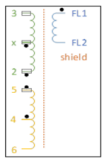
Description	Manufacturer	Manufacturer Part Number	Designator
RES SMD 10K OHM 1% 1/10W 0603	Yageo	RC0603FR-0710KL	R22
RES SMD 120K OHM 1% 1/16W 0402	TE Connectivity Passive Product	CRGCQ0402F120K	R26
RES SMD 100 OHM 1% 1/10W 0603	Yageo	RC0603FR-07100RL	R28
RES SMD 47 OHM 1% 1/10W 0603	Yageo	RC0603FR-0747RL	R29
RES SMD 200K OHM 1% 1/10W 0603	Yageo	RC0603FR-07200KL	R32
RES 10K OHM 0.5% 1/16W 0402	Stackpole Electronics Inc	RNCF0402DTE10K0	R33
RES 4.99 OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT4R99	R34
RES SMD 220K OHM 1% 1/10W 0603	Bourns Inc	CR0603-FX-2203ELF	R45
18 kOhms ±1% 0.1W, 1/10W Chip Resistor 0603	Yageo	RC0603FR-0718KL	RC17
THERM NTC 100KOHM 4485K 0402	Murata Electronics	NCP15WL104E03RC	RT2
TRANSFORMER RM 8	TBD	YT-0803	T1
Flyback PWM Controller with Integrated Active Clamp Circuit	Silanna Semiconductor	SZ1131	U1
TVS DIODE 5.3V SOD523	ON Semiconductor	ESD7371XV2T1G	Z4
Bottom Board			
BRIDGE RECT 1PHASE 1KV 4A Z4-D	Comchip Technology	Z4DGP410L-HF	BR1, BR2
CAP CER 220NF X2	DGCX	DGCX X2 224K/275VAC	C1
CAP ALUM 33UF 20% 400V T/H	YMIN	KCX(33UF-10X18P5)	C2
CAP CER 10000PF 630V X7R 1206	KEMET	C1206C103KBRACTU	C9
FUSE BOARD MNT 3A 250VAC 125VDC	Eaton - Electronics Division	TR2/1025TD3-R	F1
WE-FI Leaded Toroidal Line Choke 60uH	Wurth Elektronik	7447023	L1
INPUT 1MM HOLE			L, N
DNI RES 1206			R1, R2
VARISTOR 430V 250A 2SMD NO LEAD	Littelfuse Inc.	V430CH8	RV1

Transformer Specification

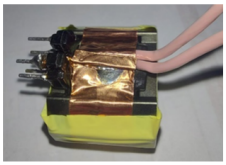
Transformer Specification

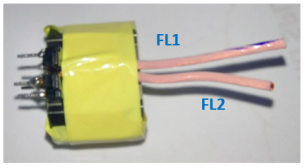


Pinout



Electrical





Actual Picture

Winding Specification

Winding	1	2	3	4	5	6	7
Material	AWG31	AWG34	AWG34	AWG34	400/44 LITZ	AWG34	AWG31
Turns	18	3	8	5.5	5	5.5	18
Parallel wires	2	1	1	8	1	8	2
Layers	1	1	1	1	1	1	1
Start Pin	2	4	5	6	FL1	6	x
End Pin	x	6	4	NC	FL2	NC	3
Comment	PRI1 - First half of primary winding	AUX - Auxiliary Windings 2 and 3 should be on the same layer, wounded simultaneously.		SHIELD 1 - CM shield. Should be wounded flat and evenly across the bobbin.	SEC - Secondary Winding	SHIELD2 - CM shield. Should be wounded flat and evenly across the bobbin.	PRI1 - Second half of primary winding
Insulation	TAPE A (1 Layer)	TAPE A (1 Layer)		TAPE A (2 Layer)	TAPE A (2 Layer)	TAPE A (1 Layer)	TAPE A (2 Layer)
Copper Shield	Wrap one complete loop of copper tape (6mm wide) around the core, without insulation in-between (e.g. kapton tape). Terminate the copper tape to PIN 6 (GND pin) with a wire.						

Electrical Test Parameters:

INDUCTANCE @ 100kHz/0.1VAC
L (2-3) = 290uH ± 5%

INDUCTANCE @ 100kHz/0.1VAC
SHORT PINS: FL1, FL2
LL (2-3) =< 4.6uH MAX
LL (2-3) >= 3.6uH MIN

TURNS RATIO/POLARITY
APPLY: 1.00V @ 10kHz TO PINS (5-6)

DC RESISTANCE OHMS (Ω) @ 25ºC
DCR (1-3) = 0.5Ω MAX
DCR (FL1-FL2) = 0.015Ω MAX

Table 3: Transformer Material Lists

Material	*Specification*	*Manufacturer*	*Mfr. Part Number*
Bobbin	RM8 6-pin	DONGUAN YANGTONG ELECTRONICS Co.	
Core	ML29-D	Hitachi	RM8 /I-ML29D
AWG31	Magnet wire, dual insulation layer	Various	
AWG34	Magnet wire, dual insulation layer	Various	
TIW	400 strand AWG44 Litz wire	Rubadue or equivalent	TXXL400/44T9XX-1.5(MW80)
TAPE A	Insulating Tape 5kV	3M or equivalent	

Performance Data

This test report represents the typical performance of the RD-29 65 W boards. Some board-to-board variations are expected due to component tolerances, test measurement setup, etc.

Efficiency

The following efficiency data are typical values of the RD-29 65W board. The board is soaked for 10 minutes at low line, full power, before measuring the efficiency with output measured at the end of board (after the USB-PD disconnect FET).

Table 4: Load Efficiency Summary

115Vac

Vout/Iout	4 - Point Average Efficiency Measurements	DOE level VI 4 - Point Average Efficiency Requirements	CoC version 5 tier 2 4 - Point Average Efficiency Requirements	Margin (Worst Case)
5 V/3 A	91.11%	81.39%	81.84%	9.27%
9 V/3 A	92.68%	86.62%	87.30%	5.38%
15 V/3 A	93.00%	87.73%	88.85%	4.15%
20 V/3.25 A	93.67%	88.00%	89.00%	4.67%

230Vac

Vout/Iout	4 - Point Average Efficiency Measurements	DOE level VI 4 - Point Average Efficiency Requirements	CoC version 5 tier 2 4 - Point Average Efficiency Requirements	Margin (Worst Case)
5 V/3 A	87.10%	81.39%	81.84%	5.26%
9 V/3 A	90.07%	86.62%	87.30%	2.77%
15 V/3 A	91.79%	87.73%	88.85%	2.94%
20 V/3.25 A	93.10%	88.00%	89.00%	4.10%

115 Vac 4-point average efficiency

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

%LOAD	Efficiency	Average Efficiency
100	91.80%	91.11%
75	91.36%	
50	91.08%	
25	90.19%	
10	88.24%	

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

%LOAD	Efficiency	Average Efficiency
100	93.81%	92.68%
75	93.44%	
50	92.71%	
25	90.77%	
10	89.07%	

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

%LOAD	Efficiency	Average Efficiency
100	93.93%	93.00%
75	93.76%	
50	93.30%	
25	91.02%	
10	87.74%	

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

%LOAD	Efficiency	Average Efficiency
100	94.06%	93.67%
75	94.02%	
50	94.03%	
25	92.58%	
10	89.34%	

The listed efficiency values are the average of the data collected from RD29 EVB's. The boards are soaked for 10 minutes before measuring the efficiency with output measured at end of board (TP1 to TP2).

The boards pass the DOE Level VI, CoC V5 Tier-2 Average Efficiency and COC V5 Tier-2 10% efficiency targets with more than 2% margin at all the operating conditions.

230 Vac 4-point average efficiency

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

%LOAD	Efficiency	Average Efficiency
100	88.49%	87.10%
75	87.73%	
50	86.97%	
25	85.21%	
10	83.06%	

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

%LOAD	Efficiency	Average Efficiency
100	92.42%	90.07%
75	91.13%	
50	89.37%	
25	87.37%	
10	85.00%	

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

%LOAD	Efficiency	Average Efficiency
100	94.00%	91.79%
75	93.29%	
50	91.62%	
25	88.25%	
10	85.47%	

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

%LOAD	Efficiency	Average Efficiency
100	94.53%	93.10%
75	94.21%	
50	93.36%	
25	90.31%	
10	87.24%	

The listed efficiency values are the average of the data collected from RD29 EVB's. The boards are soaked for 10 minutes before measuring the efficiency with output measured at end of board (TP1 to TP2).

The boards pass the DOE Level VI, CoC V5 Tier-2 Average Efficiency and COC V5 Tier-2 10% efficiency targets with more than 2% margin at all the operating conditions.

Full Load Efficiencies at 90 Vac/115 Vac/230 Vac/265 Vac; 5 V/9 V/15 V/20 V

Vout = 5 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	91.84%
115 Vac @ 60 Hz	3 A	91.81%
230 Vac @ 50 Hz	3 A	88.49%
265 Vac @ 50Hz	3 A	86.93%

Vout = 9 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	93.36%
115 Vac @ 60 Hz	3 A	93.81%
230 Vac @ 50 Hz	3.A	92.42%
265 Vac @ 50Hz	3 A	91.51%

Vout = 15 V

Vin	Iout	Efficiency
90Vac @ 60Hz	3 A	93.42%
115 Vac @ 60 Hz	3 A	93.93%
230 Vac @ 50 Hz	3.A	94.00%
265 Vac @ 50Hz	3 A	93.49%

Vout = 20 V

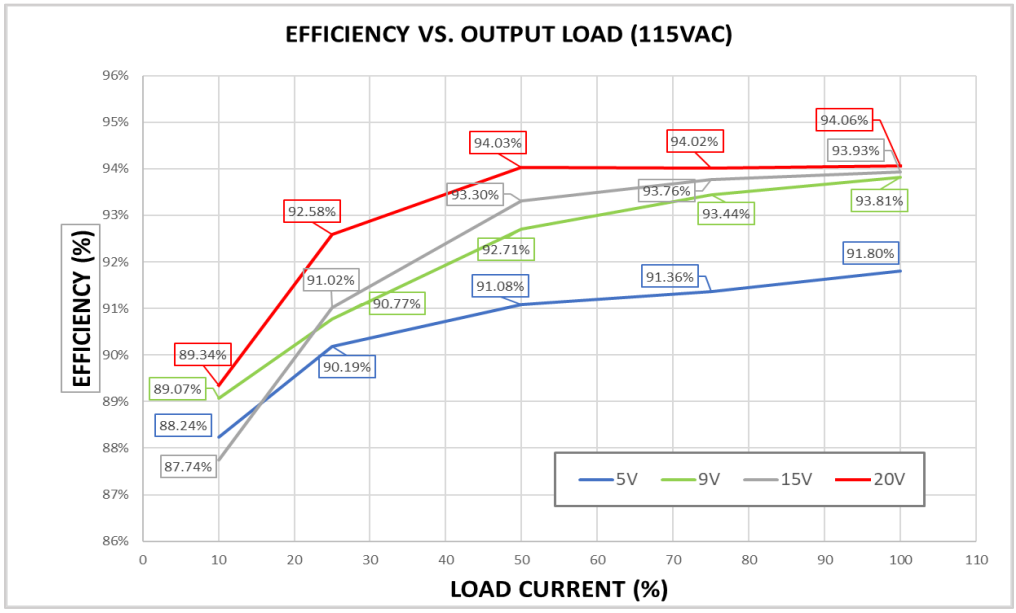
Vin	Iout	Efficiency
90Vac @ 60Hz	3.25 A	93.05%
115 Vac @ 60 Hz	3.25 A	94.06%
230 Vac @ 50 Hz	3.25 A	94.53%
265 Vac @ 50Hz	3.25 A	94.36%

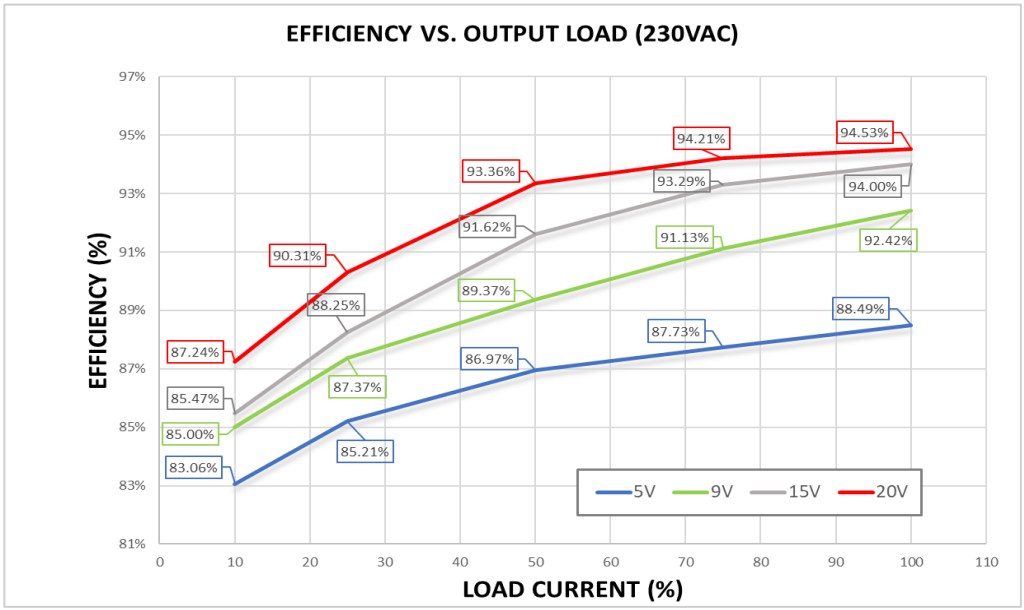
The listed efficiency values are the average of the data collected from RD29 EVB's. The boards are soaked for 10 minutes before measuring the efficiency with output measured at end of board (TP1 to TP2).

The boards pass the DOE Level VI, CoC V5 Tier-2 Average Efficiency and COC V5 Tier-2 10% efficiency targets with more than 2% margin at all the operating conditions.

Efficiency Graphs

The following graphs demonstrate 5 V, 9 V, 15 V and 20 V efficiency results with output measured at end of board (TP1 to TP2).





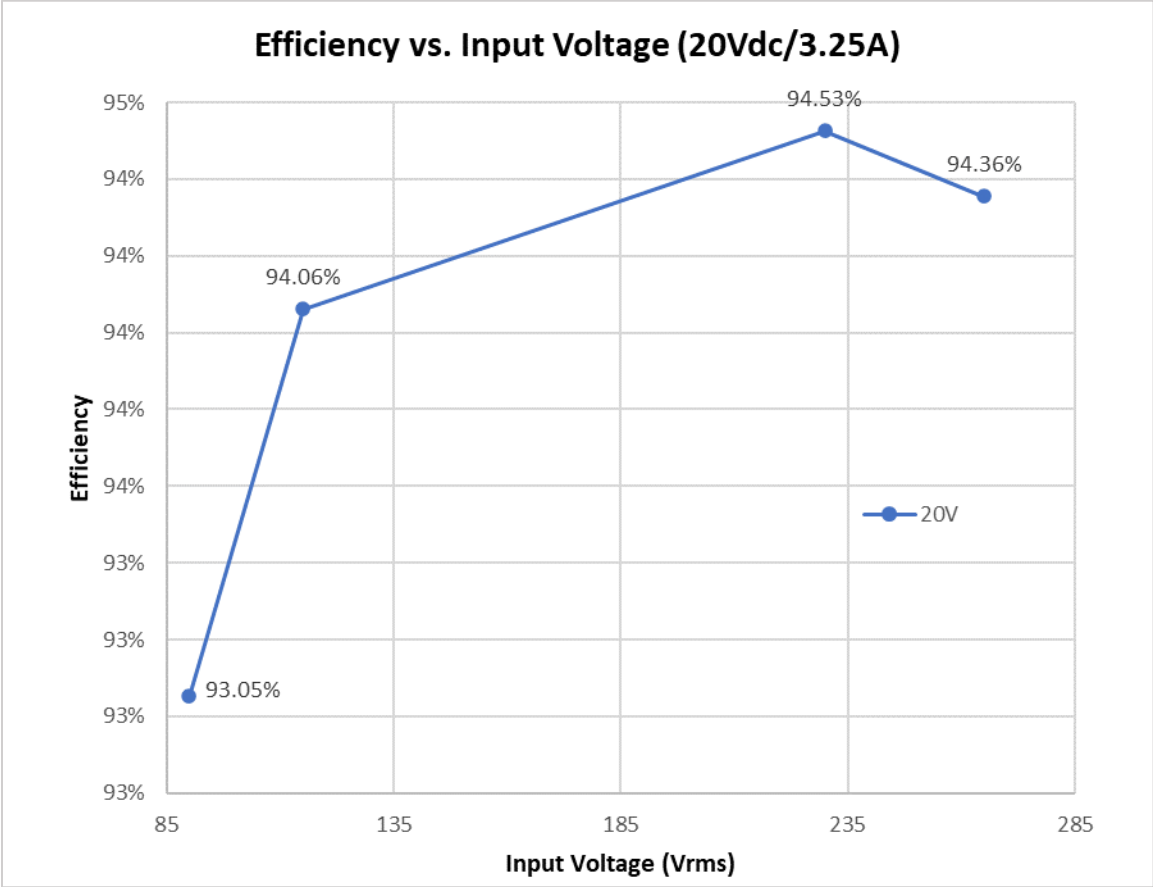


Figure 16: Efficiency graphs for various input voltages and 65W

No Load Input Power

lists the average no-load / light load input power consumption measured at nominal line voltages 115 Vac and 230 Vac. The measurement of the input power has an integration time of 5 minutes.

Table 5 lists the average no-load / light load input power consumption measured at nominal line voltages 115 Vac and 230 Vac. The measurement of the input power has an integration time of 5 minutes.

Table 5: No-load Power Consumption

Input Voltage	No-Load Power Measurements
90Vac	14.99 mW
115Vac	15.80 mW
230Vac	22.39 mW
265Vac	28.60 mW

Load/Line Regulation

The following table shows load/line regulation (at the output cable connector) for 5 V-20 V output voltages for variation of the line input voltage (115 Vac – 230 Vac) measured at the end of board.

Table 6: Line/Load Regulation Summary (End of Board)

Output Voltage	Line / Load Range		Measured Regulation	
	Min	Max	Min	Max
5 V	0 A	3 A	4. 946 V	4.987 V
9 V	0 A	3 A	8.957 V	9.002 V
15 V	0 A	3 A	14.970 V	15.022 V
20 V	0 A	3.25 A	19.954 V	20.009 V

The following table shows typical line regulation for 5 V-20 V output voltages for variation of line input voltage (115 Vac – 230 Vac) measured at the end of a 1 meter output cable connector (E-mark cable). Output voltage regulation at the end of the cable can be improved by adding cable drop compensation.

Table 7: Line/Load Regulation Summary (End of 1.0m Meter E-mark Cable)

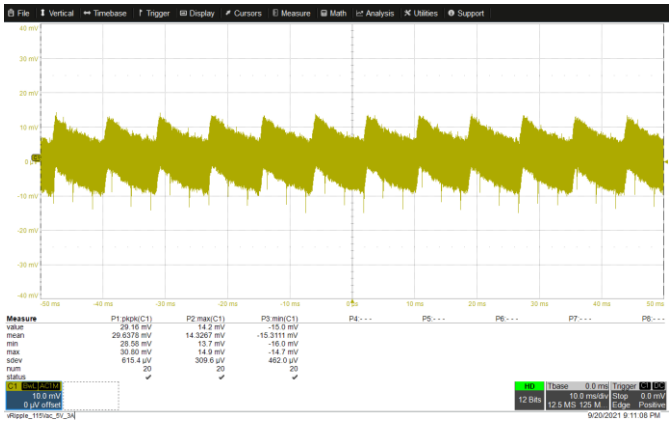
Output Voltage	Line / Load Range		Measured Regulation	
	Min	Max	Min	Max
5 V	0 A	3 A	4.675 V	4.985 V
9 V	0 A	3 A	8.690 V	9.002 V
15 V	0 A	3 A	14.704 V	15.024 V
20 V	0 A	3.25 A	19.666 V	20.007 V

Output Voltage Ripple Noise

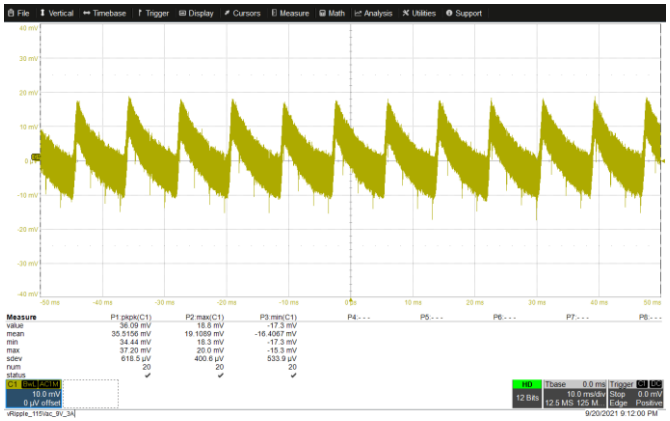
The output voltage ripple was measured using a voltage probe with two capacitors (1 µF/50 V ceramic and 33 µF/50 V low ESR electrolytic) tied in parallel across it. Measurements are done at the end of 1 meter output cable connector (E-mark cable).

Table 8: 115Vac Output Ripple Noise Summary

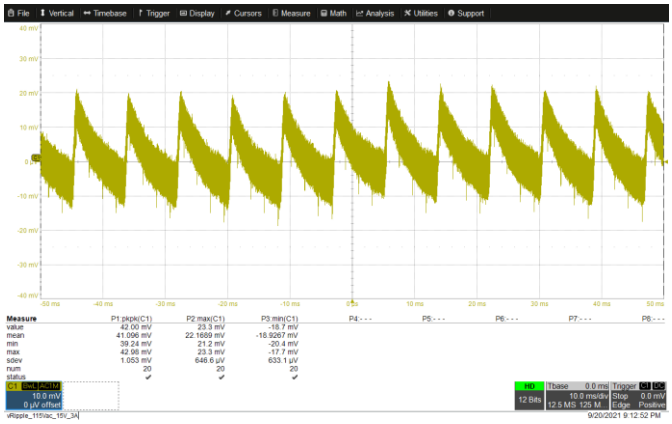
Vout/Iout	Measured Output Ripple at 3A load	Measured Output Ripple at 0A load
5 V/3 A	30.80 mV	21.07 mV
9 V/3 A	37.20 mV	20.31 mV
15 V/3 A	42.98 mV	18.62 mV
20 V/3.25 A	66.84 mV	20.49 mV



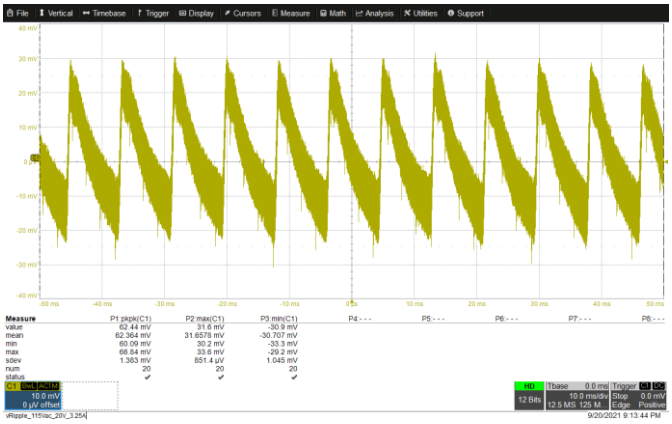
Vin=115 Vac, Vout=5 V @ 3A



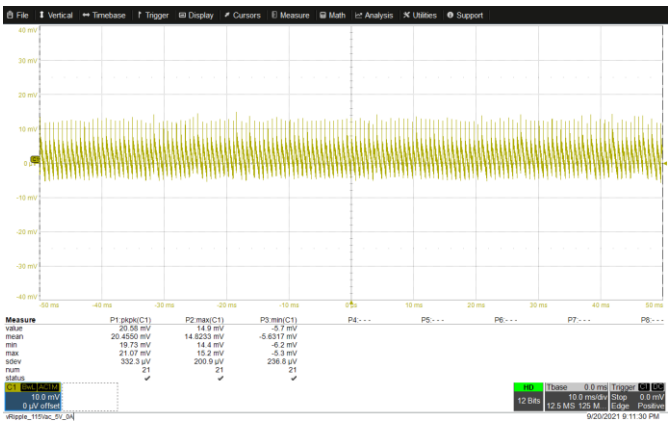
Vin=115 Vac, Vout=9 V @ 3A



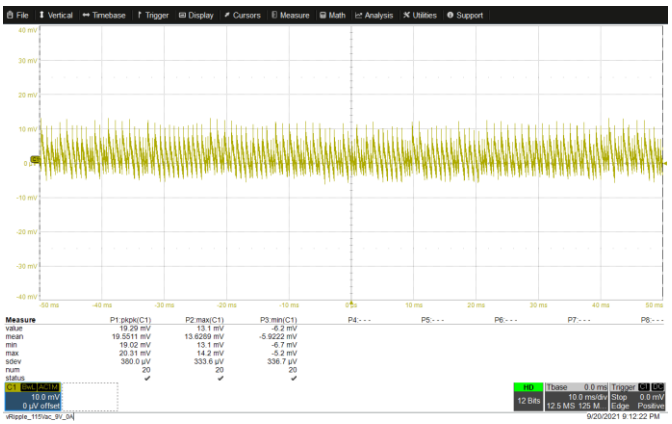
Vin=115 Vac, Vout=15 V @ 3A



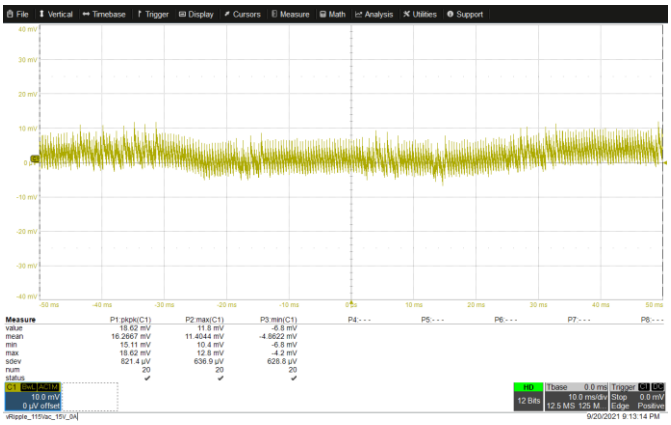
Vin= 115 Vac, Vout=20 V 3.25A



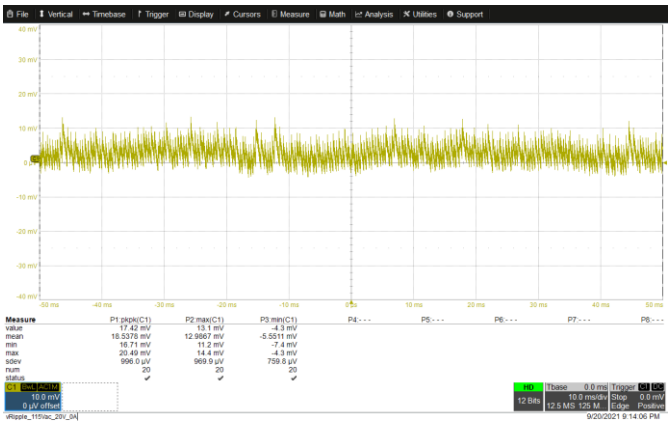
Vin=115 Vac, Vout=5 V @ 0A



Vin=115 Vac, Vout=9 V @ 0A



Vin=115 Vac, Vout=15 V @ 0A

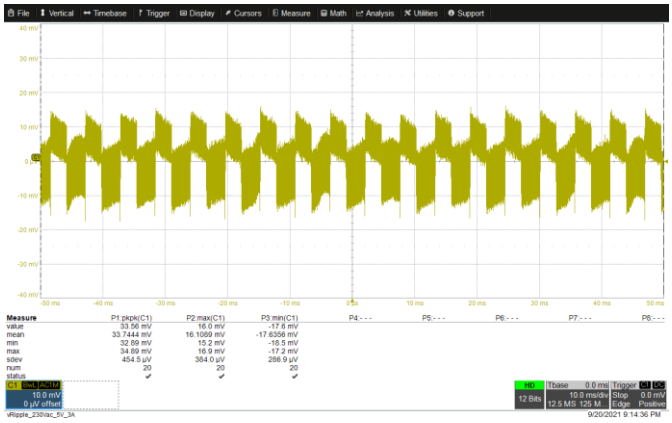


Vin=115 Vac, Vout=20V @ 0A

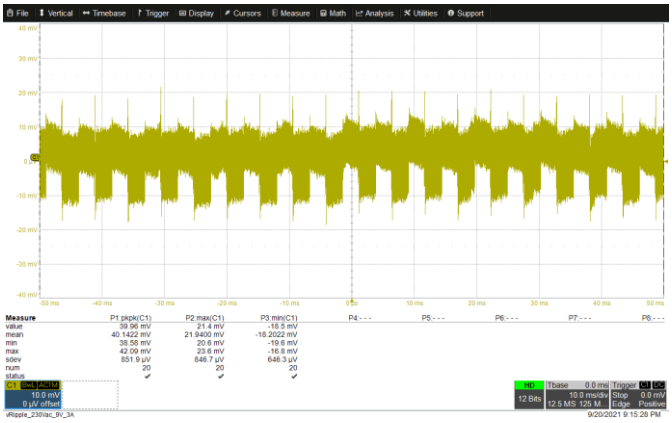
Figure 17: Output voltage ripple measurements at 115Vac input voltage and 5 V/9 V/15 V/20 V full-power and No-load (end of 1.0m cable)

Table 9: 230Vac Output Ripple Noise Summary

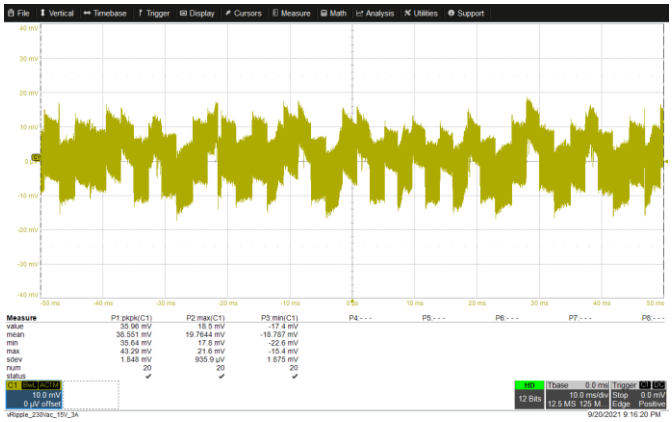
Vout/Iout	Measured Output Ripple at 3A load	Measured Output Ripple at 0A load
5 V/3 A	34.89 mV	22.89 mV
9 V/3 A	42.09 mV	22.18 mV
15 V/3 A	43.29 mV	16.71 mV
20 V/3.25 A	55.24 mV	18.71 mV



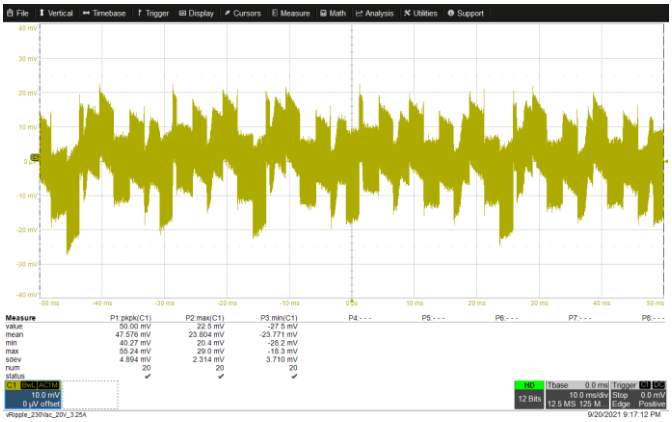
Vin=230 Vac, Vout=5 V @ 3A



Vin=230 Vac, Vout=9 V @ 3A

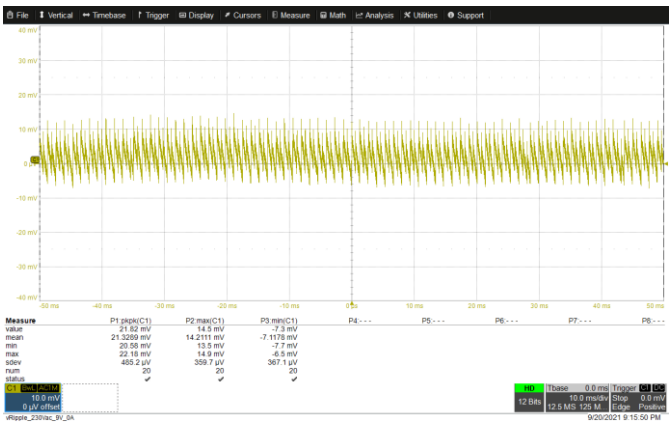


Vin=230 Vac, Vout=15 V @ 3A

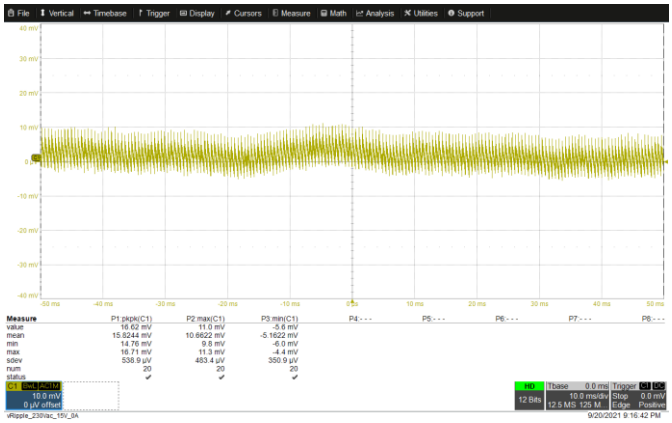


Vin= 230 Vac, Vout=20 V 3.25A

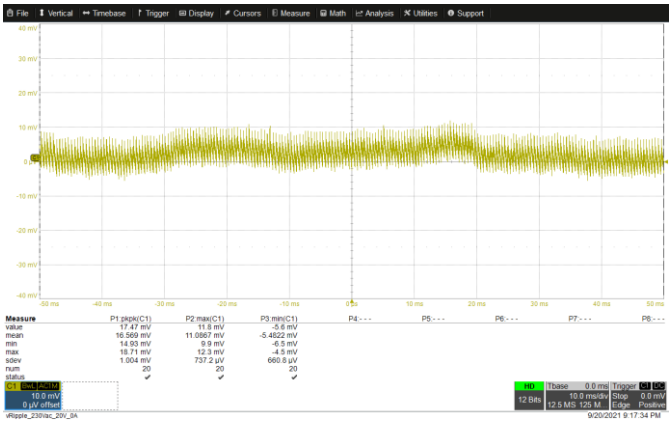
Vin=230 Vac, Vout=5 V @ 0A



Vin=230 Vac, Vout=9 V @ 0A



Vin=230 Vac, Vout=15 V @ 0A

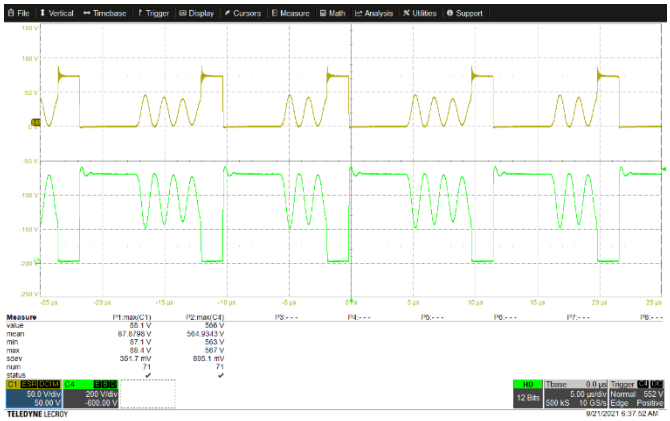


Vin=230 Vac, Vout=20V @ 0A

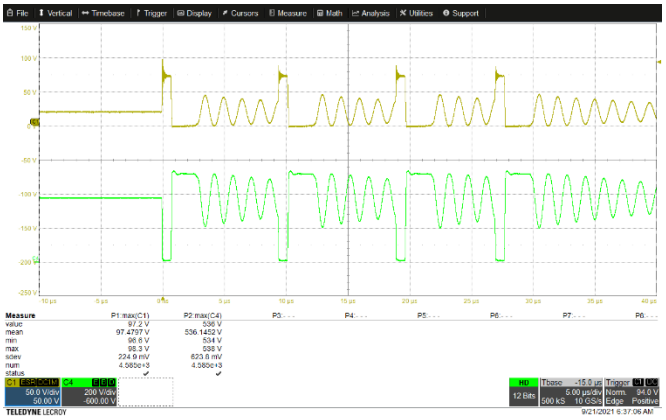
Figure 18: Output voltage ripple measurements at 230Vac input voltage and 5 V/9 V/15 V/20 V full-power and no-load (end of 1.0m cable)

Drain Voltage Waveforms at Steady State

The waveforms presented in this section show no components are over stressed under normal operating conditions. Measurement done at 265 Vac at full and no-load condition and 20V output voltage.



Vin=265 Vac, Vout=20 V, Iout=3.25 A, V_{ds_MAIN}=567.0 V



Vin=265 Vac, Vout=20 V, Iout=0 A, V_{ds_SRFET}=98.3 V

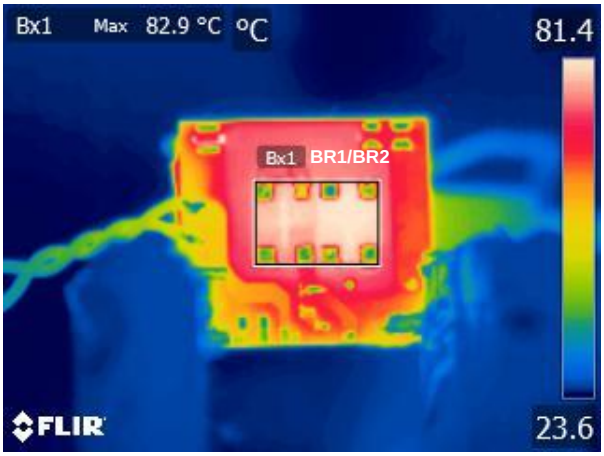
Figure 19: Main Primary and SR FET drain voltage waveforms under various operating conditions at 265 Vac input

Thermal Measurements

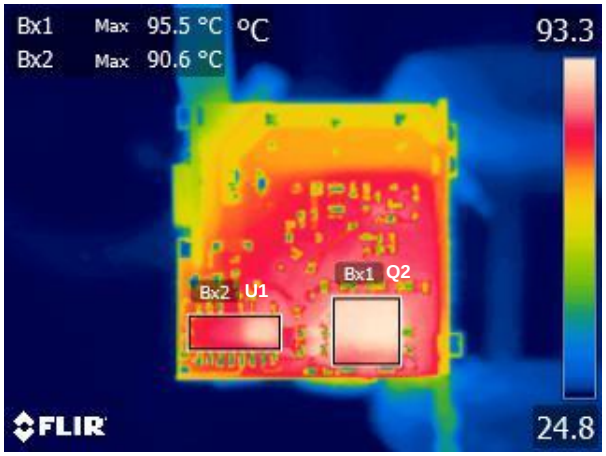
The following thermal data show the temperatures of key semiconductor components after 1hr operation at 20V/3.25A and 90Vac and 265Vac input voltages. No thermal management was utilized, and the unit was outside of the case with ambient temperature ~25 degrees Celsius.

Table 10: Measured Components Temperature with 20V, 3.25A

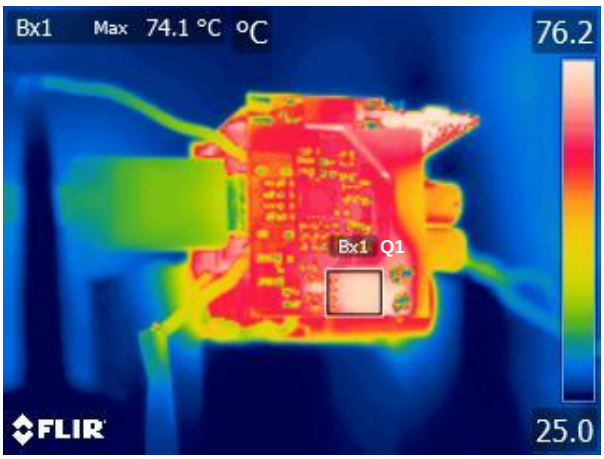
Designator	Components	90 Vac	265VAC
BR1/BR2	Bridge Rectifier	82.9°C	60.5°C
Q2	Transphorm GANFET	95.5°C	97.4°C
U1	SZ1131	90.6°C	88.9°C
Q1	Secondary SR MOSFET	74.1°C	73.1°C
T1	Flyback Transformer	89.3°C	85.8°C



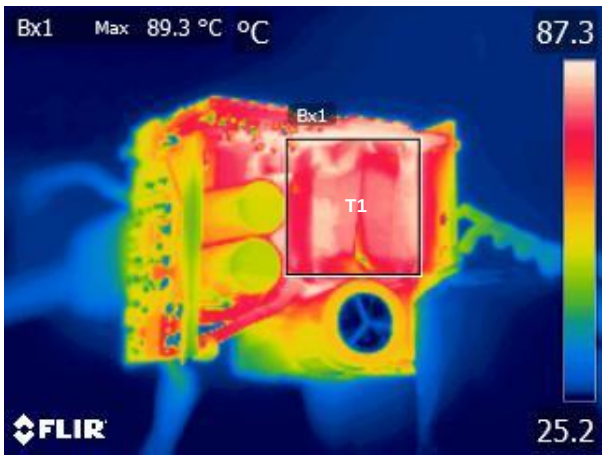
Vin=90 Vac, Vout=20 V, Iout=3.25 A (bottom)



Vin=90 Vac, Vout=20 V, Iout=3.25 A (middle)

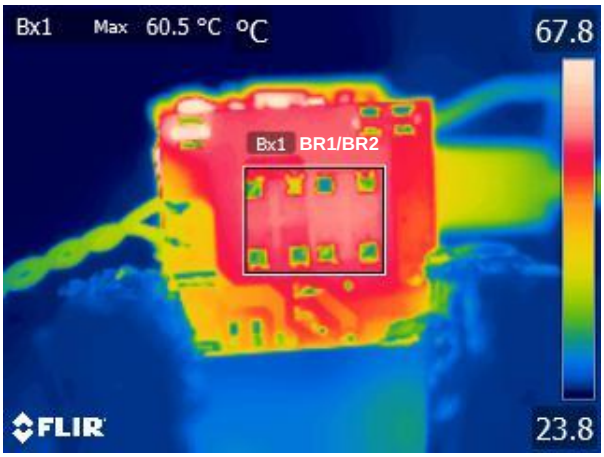


Vin=90 Vac, Vout=20 V, Iout=3.25 A (top)

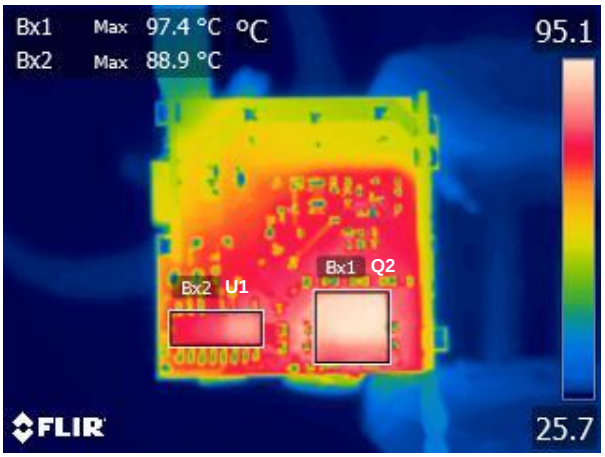


Vin=90 Vac, Vout=20 V, Iout=3.25 A (Transformer)

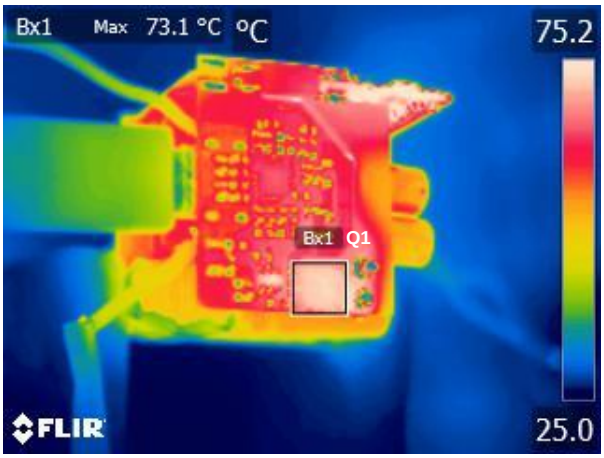
Figure 20: Thermal images captured at 90 Vac/20V/3.25A condition.



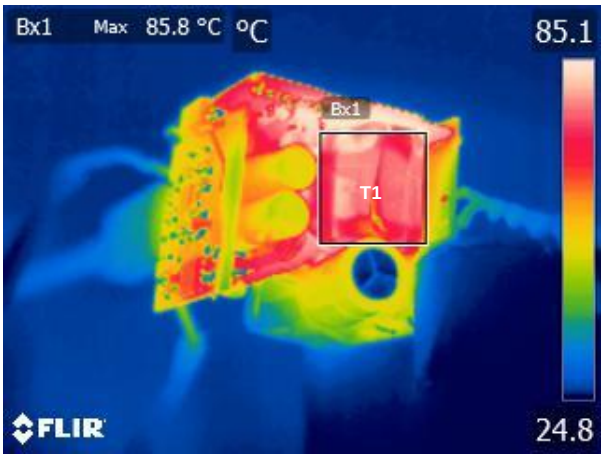
Vin=265 Vac, Vout=20 V, Iout=3.25 A (bottom)



Vin=265 Vac, Vout=20 V, Iout=3.25 A (middle)



Vin=265 Vac, Vout=20 V, Iout=3.25 A (top)



Vin=265 Vac, Vout=20 V, Iout=3.25 A (Transformer)

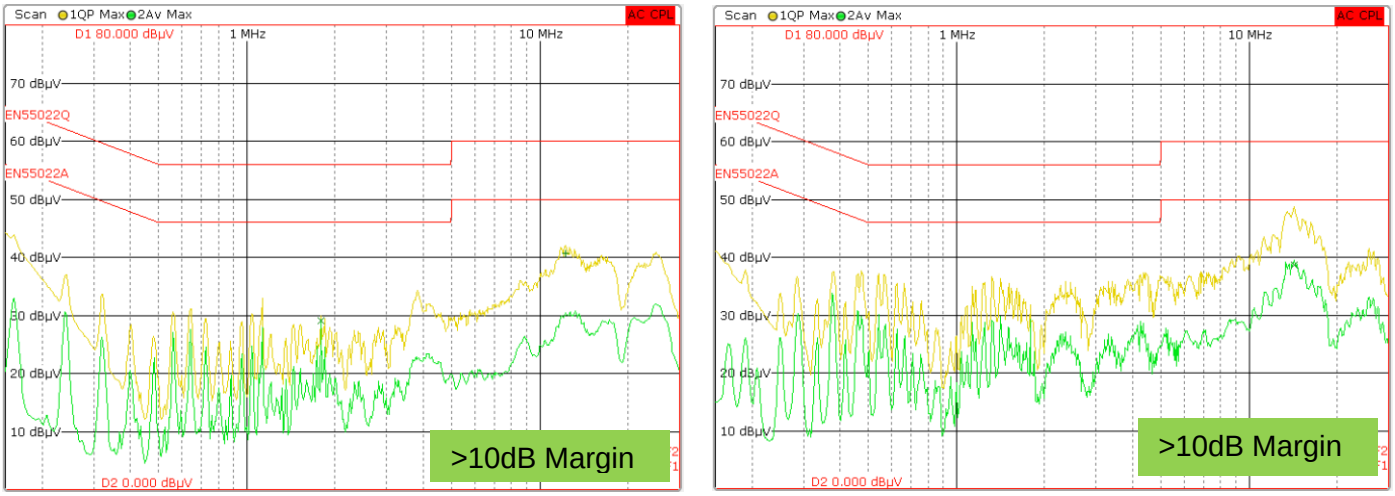
Figure 21: Thermal images captured at 265 Vac/20V/3.25A condition.

Conducted EMI Measurements

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

Under all operating conditions, the results show the evaluation board passes EN55022 standard with more than 6dB margin for conducted EMI measurement.

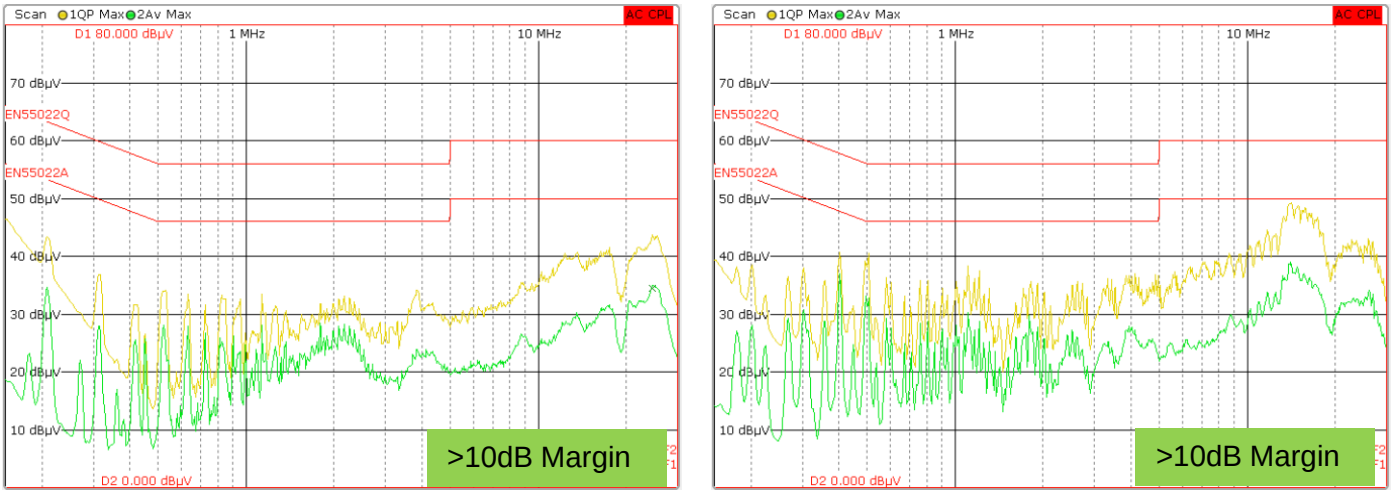
V_{out}/ I_{out}: 5 V/ 3 A



115 Vac (Line/ Neutral) 230 Vac (Line/ Neutral)

Figure 22: 5 V/ 3 A conducted EMI measurement results (Line and Neutral) for 115 Vac and 230 Vac input

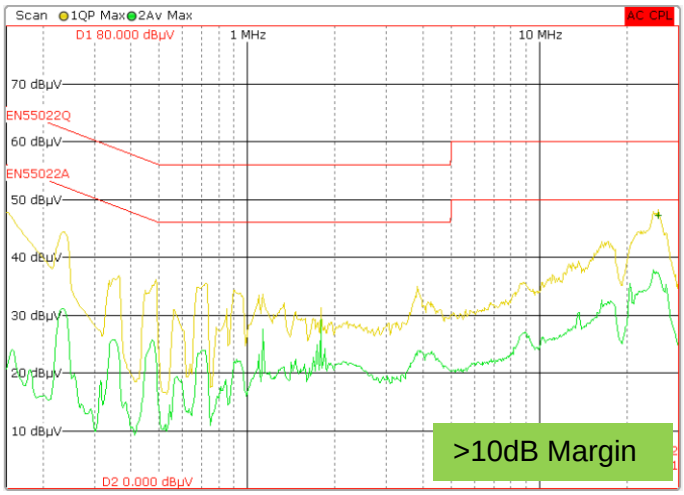
V_{out}/ I_{out}: 9 V/ 3 A



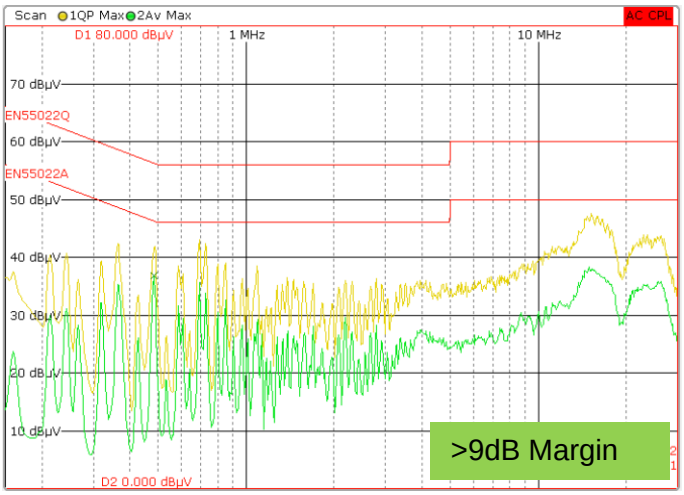
115 Vac (Line/ Neutral) 230 Vac (Line/ Neutral)

Figure 23: 9 V/ 3 A conducted EMI measurement results (Line and Neutral) for 115 Vac and 230 Vac inputs

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



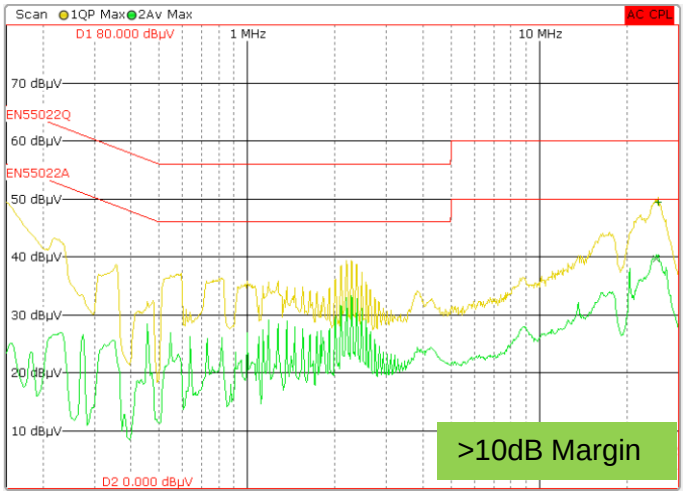
115 Vac (Line/ Neutral)



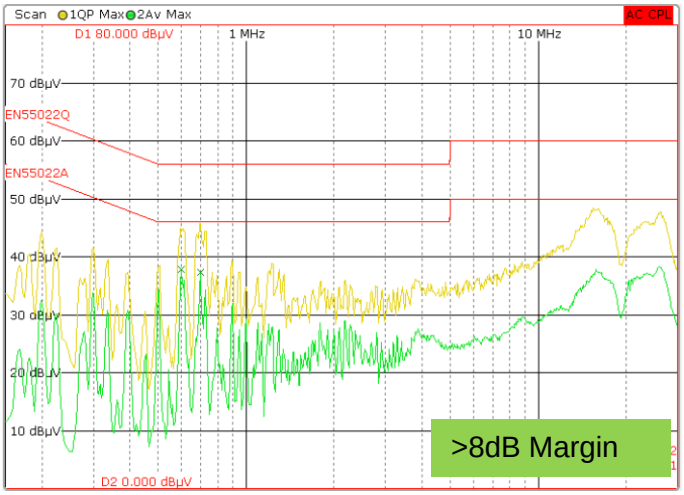
230 Vac (Line/ Neutral)

Figure 24: 15 V/ 3 A conducted EMI measurement results (Line and Neutral) for 115 Vac and 230 Vac inputs

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



115 Vac (Line/ Neutral)



230 Vac (Line/ Neutral)

Figure 25: 20 V/ 3.25 A conducted EMI measurement results (Line and Neutral) for 115 Vac and 230 Vac inputs

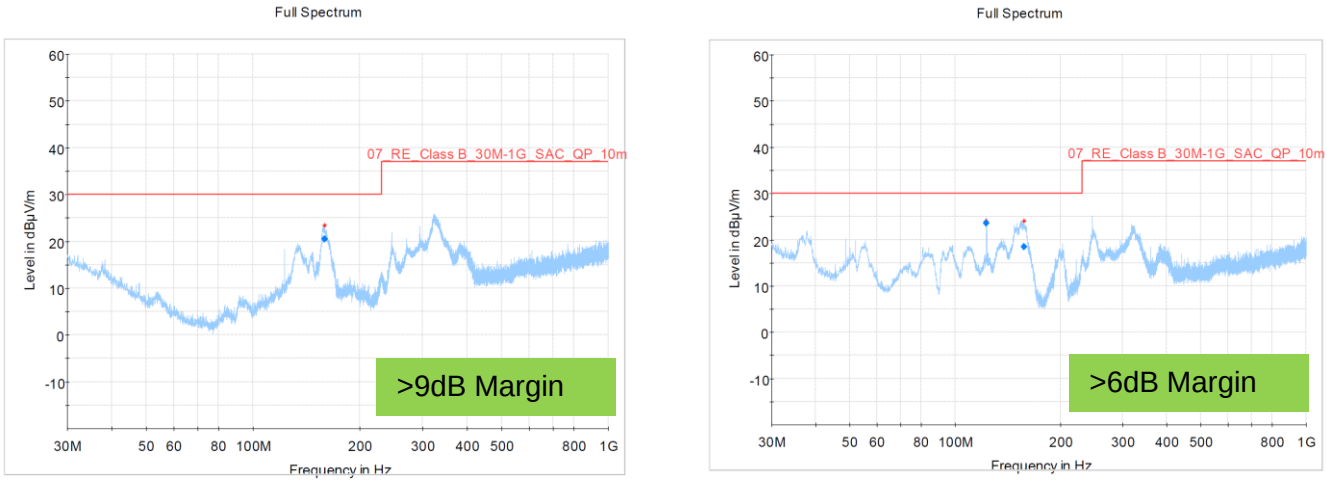
The RD29 EVBs pass the Conducted EMI with >6dB margin at 115Vac and 230Vac.

Radiated EMI Measurements

This section presents the radiated EMI measurements taken on the reference design. Tests were performed at the maximum load current for 20V output voltage. The peak measurements for 115 V_{AC} and 230 V_{AC} input voltages are shown for floating output.

Under the 20V output voltage operating condition, the results show the evaluation board passes EN55022 standard with more than 6dB margin for radiated EMI measurement.

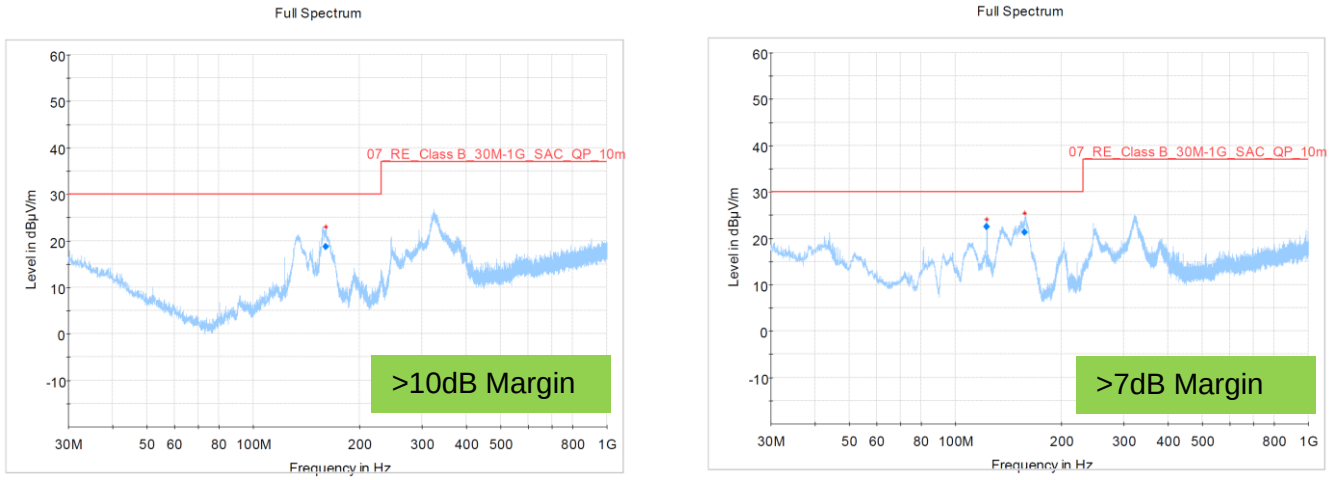
V_{out}/ I_{out}: 20 V/ 3.25 A



115 Vac (Horizontal Scan) 115 Vac (Vertical Scan)

Figure 26: 20 V/ 3.25 A radiated EMI measurement results (Horizontal and Vertical) for 115 Vac input

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



230 Vac (Horizontal Scan) 230 Vac (Vertical Scanl)

Figure 27: 20 V/ 3.25 A radiated EMI measurement results (Horizontal and Vertical) for 230 Vac input

The RD29 EVBs pass the Radiated EMI with >6dB margin at 115Vac and 230Vac.

Revision History

Revision	Date	Author	Note
1.0	09/27/2021	ACE Team	Initial Release

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