Table of Contents

Chapter 1 Summary

1.1 General Description

The 140W ACF PD3.0 Evaluation Board is composed of four main controllers, UCC28056, AP3306, APR340 and AP43771V. UCC28056B is transition mode boost PFC controller. AP3306 is a highly integrated Active Clamp Flyback (ACF) controller that is optimally designed for offline power supply to meet ultra-low standby power, high power density, and comprehensive protection requirements. The APR340 is a secondary side Synchronous Rectification (SR) Controller. The AP43771V, a protocol decoder in charge of matching the associated charger capacity and request by an attached Type C-equipped device under charged (DUC), regulates the feedback network of the charger to fulfill voltage and current requirements from DUC. In addition, Gallium Nitride (GaN) FET is employed to further improve the efficiency and thermal performance.

1.2 Key Features

1.2.1 System Key Features

- Optimal system implementation for high-efficiency BOM-optimized High Power Density Chargers
- Diodes Patented ACF Topology Implementation for Critical Efficiency Improvement Approaches
- High-Voltage Startup low standby power
- Meets DOE VI and COC Tier 2 Efficiency Requirements
- USB Type-C Output Cable - Support the Maximum Output of 140W PD 3.0 Function

1.2.2 AP3306 Key Features

- Active Clamp Flyback Topology with Recycled Leakage Energy and Zero Voltage Switching Functions
- High-Voltage Startup
- Embedded VCC LDO for VCCL pin to Guarantee Wide Range Output Voltage
- Constant, Low Output Current in Output Short Situation
- Non-Audible-Noise Quasi-Resonant Control
- Soft Start During Startup Process
- Frequency Fold Back for High Average Efficiency
- Secondary Winding Short Protection with FOCP
- Frequency Dithering for Reducing EMI
- X-CAP Discharge Function
- Useful Pin fault protection:
  SENSE Pin Floating Protection/
  FB/Opto-Coupler Open/Short Protection
- Comprehensive System Protection Feature:
  VOVP/OLP/BNO/SOVP/SUVP

1.2.3 APR340 Key Features

- Synchronous Rectification Works with DCM / QR / ACF operation modes
- Eliminate Resonant Ringing Interference
- Fewest External Components used

1.2.4 AP43771V Key Feature

- Support USB PD Rev 3.0 V1.2
- USB-IF PD3.0/PPS Certified TID 4312
- Qualcomm QC5 Certified: QC20201127203
- MTP for System Configuration
- OTP for Main Firmware
- Operating Voltage Range: 3.3V to 21V
- Built-In Regulator for CV and CC Control
- Programmable OVP/UVP/OCP/OTP
- Support Power Saving Mode
- External N -MOSFET Control for VBUS Power Delivery
- Support e-Marker Cable Detection
- W-DFN3030-14

1.3 Applications

- Quick Charger with full power range of PD3.0

1.4 Main Power Specifications

Parameter	Value
Input Voltage	$90V_{AC}$ to $264V_{AC}$
Input standby power	< 100mW
Main Output (Vo / Io)	PDO: 5V/3A, 9V/3A, 15V/3A, 20V/7A,
Efficiency	Comply with CoC version 5 tier-2
Max. Output Power	140W (at PDO 20V/7A)
Protections	OCP, OVP, UVP, OLP, OTP, SCP
Dimensions	PCB: 125*55*30mm

1.5 Evaluation Board Picture

Figure 1: Top View

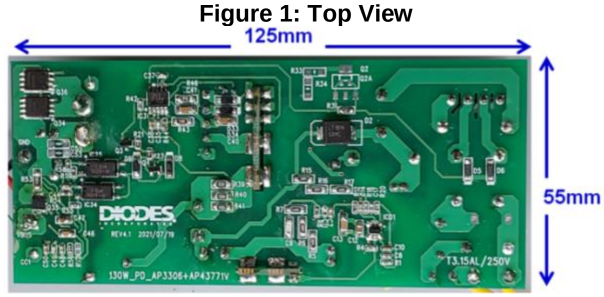


Figure 2: Bottom View

Chapter 2 Power Supply Specification

2.1 Specification and Test Results

Parameter	Value	Test Summary
Input Voltage / Frequency	$90V_{AC}$ to $264V_{AC}$ / 50Hz or 60Hz	Test Condition
Input Current	$<2A_{RMS}$	
Standby Power	<100mW; load disconnected	**PASS,** 42.7mW @230V_{AC}/50Hz
5V/3A Average Efficiency	CoC Version 5, Tier2 Efficiency >81.84%	**PASS,** 89.75% @115V_{AC}/60Hz 89.92% @230V_{AC}/50Hz
5V/0.3A Efficiency (10% Load)	CoC Version 5, Tier2 Efficiency >72.48%	**PASS,** 86.69% @115V_{AC}/60Hz 85.59% @230V_{AC}/50Hz
9V/3A Average Efficiency	CoC Version 5, Tier2 Efficiency >87.30%	**PASS,** 91.81% @115V_{AC}/60Hz 92.53% @230V_{AC}/50Hz
9V/0.3A Efficiency (10% Load)	CoC Version 5, Tier2 Efficiency >77.30%	**PASS,** 88.70% @115V_{AC}/60Hz 89.10% @230V_{AC}/50Hz
15V/3A Average Efficiency	CoC Version 5, Tier2 Efficiency >88.85%	**PASS,** 92.11% @115V_{AC}/60Hz 93.12% @230V_{AC}/50Hz
15V/0.3A Efficiency (10% Load)	CoC Version 5, Tier2 Efficiency >78.85%	**PASS,** 89.20% @115V_{AC}/60Hz 89.04% @230V_{AC}/50Hz
20V/7A Average Efficiency	CoC Version 5, Tier2 Efficiency >88.85%	**PASS,** 91.38% @115V_{AC}/60Hz 92.48% @230V_{AC}/50Hz
20V/0.7A Efficiency (10% Load)	CoC Version 5, Tier2 Efficiency >78.85%	**PASS,** 88.20% @115V_{AC}/60Hz 89.43% @230V_{AC}/50Hz
Output Voltage Regulation Tolerance	+/- 5%	**PASS,**
Power Factor	>0.9; when output power is over 70W	**PASS,** 0.9822 @115 V_{AC} /60Hz 0.9271 @230 V_{AC} /50Hz
THD	<20%; when output power is over 70W	**PASS,** 15.9% @115 V_{AC} /60Hz 15.1% @230 V_{AC} /50Hz
Conducted EMI	>6dB Margin, according to EN55032 Class B	

Chapter 3 Schematic

3.1 Board Schematic

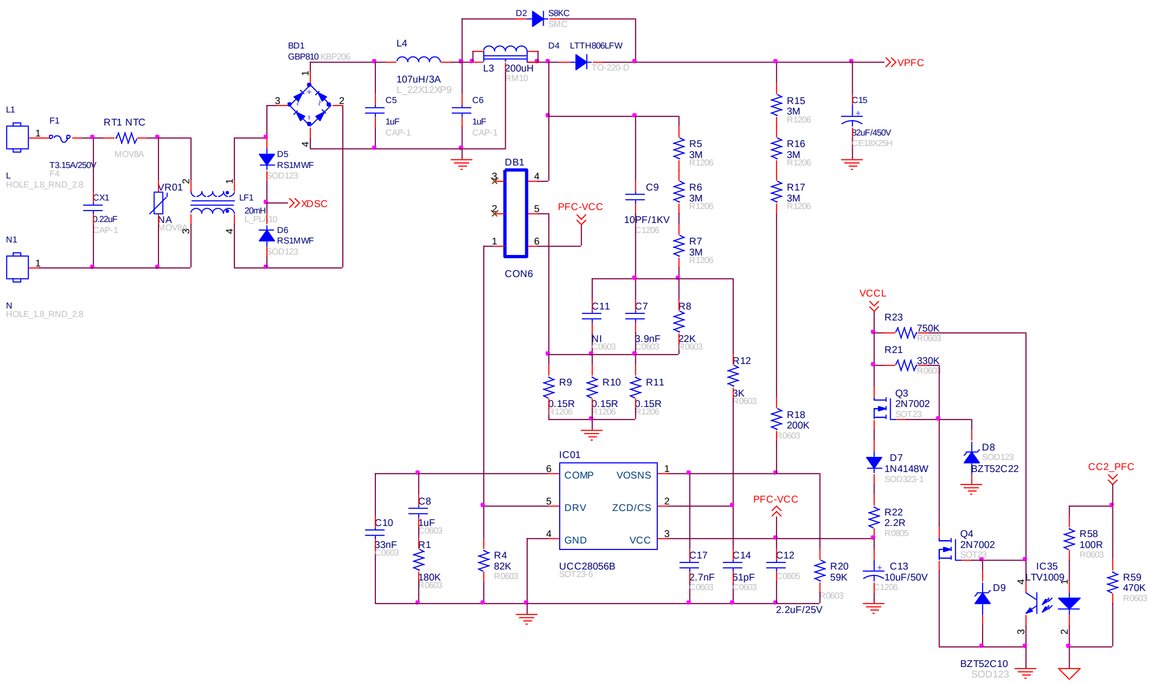


Figure 3: 140W ACF+GaN PD3.0 Adapter EVB Schematic – PFC Circuit

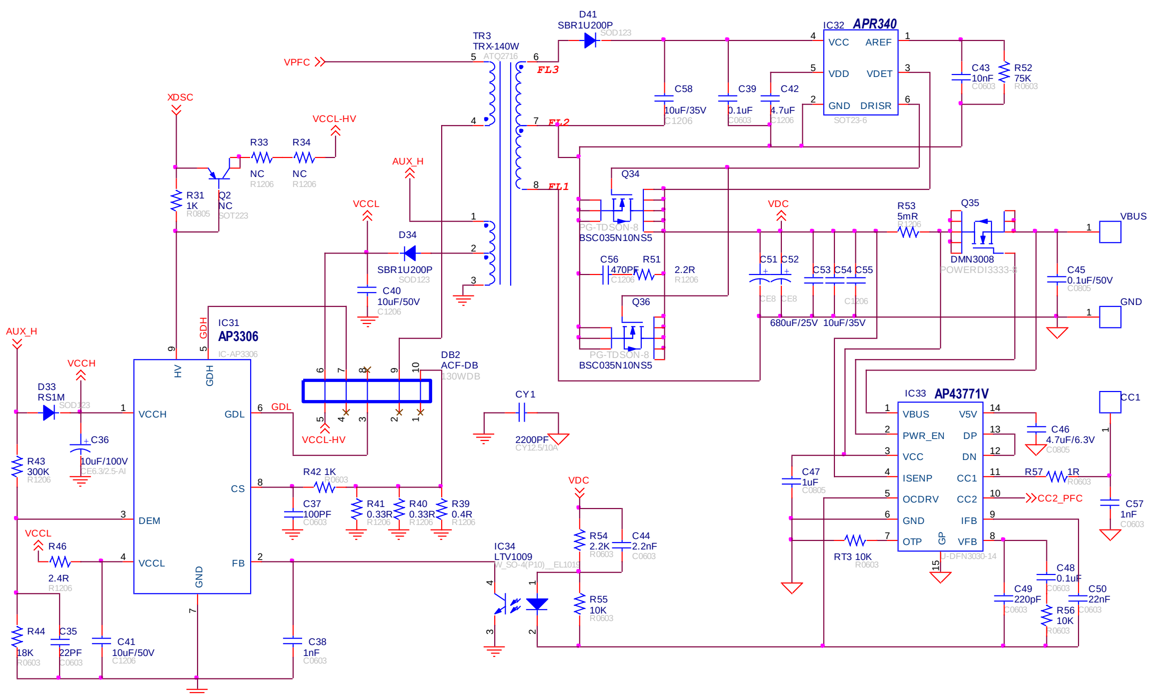


Figure 4: 140W ACF+GaN PD3.0 Adapter EVB Schematic – ACF Circuit

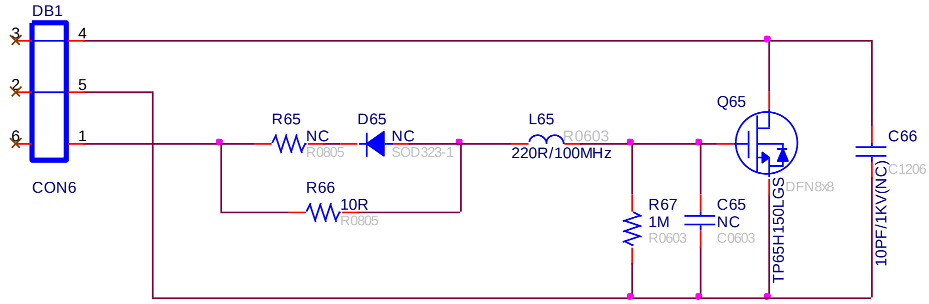


Figure 5: 140W ACF+GaN PD3.0 Adapter EVB Schematic – PFC Daughter Board Circuit

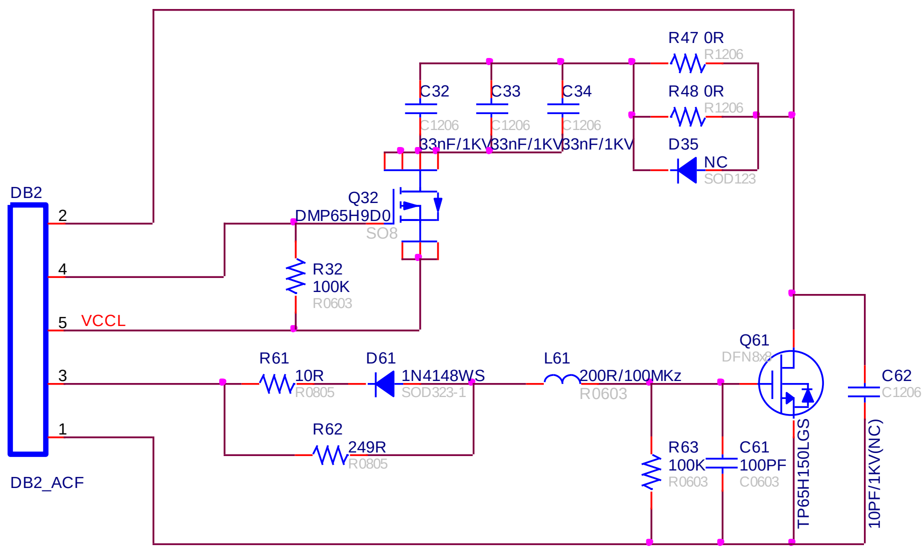


Figure 6: 140W ACF+GaN PD3.0 Adapter EVB Schematic – ACF Daughter Board Circuit

3.2 Bill of Material (BOM)

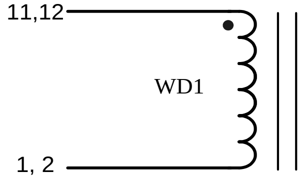
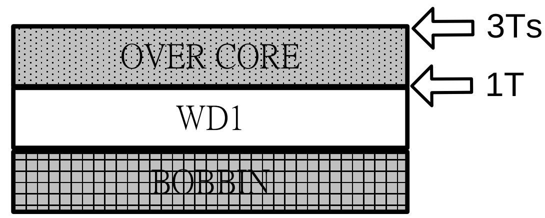
Item	Quantity	Reference	Description	Manufacturer Part Number	Manufacturer
MAIN#1	1	IC31	AP3306 ACF PWM Controller	**AP3306S10-13**	**Diodes Inc.**
MAIN#2	1	IC32	APR340 SR Controller	**APR340W6-7**	**Diodes Inc.**
MAIN#3	1	IC33	AP43771V PD3.0 Decoder IC	**AP43771VFBZ-13**	**Diodes Inc.**
MAIN#4	2	IC34,IC35	LTV1009	**LTV-1009TP1-G**	**Lite-ON Inc.**
MAIN#5	1	IC01	UCC28056B PFC Controller	UCC28056B	
MAIN#6	1	BD1	GBP810	**GBP810**	**Diodes Inc.**
MAIN#7	1	D2	S8KC/ SMC	**S8KC-13**	**Diodes Inc.**
MAIN#8	1	D4	DTH8L06FP/ ITO-220AC	**DTH8L06FP**	**Diodes Inc.**
MAIN#9	2	D6,D5	S1MWF/ SOD123	**S1MWF-7**	**Diodes Inc.**
MAIN#10	1	D7	1N4148W/ SOD123	**1N4148W-13-F**	**Diodes Inc.**
MAIN#11	1	D8	BZT52C20/ SOD123	**BZT52C20-7-F**	**Diodes Inc.**
MAIN#12	1	D9	BZT52C10/ SOD123	**BZT52C10-7-F**	**Diodes Inc.**
MAIN#13	1	D33	DFLR1600/ PowerDI123	**DFLR1600-7**	**Diodes Inc.**
MAIN#14	2	D41,D34	SBR1U200P1/ PowerDI123	**SBR1U200P1-7**	**Diodes Inc.**
MAIN#15	2	Q4,Q3	2N7002A/ SOT23	**2N7002A-7**	**Diodes Inc.**
MAIN#16	1	Q35	DMN3008/ POWERDI3333-8	**DMN3008SFG-13**	**Diodes Inc.**
MAIN#17	2	Q34,Q36	BSC035N10NS5	BSC035N10NS5	
MAIN#18	1	C7	3.9nF/50V/ 0603		
MAIN#19	1	C8	1uF/10V/ 0603		
MAIN#20	1	C10	33nF/50V/ 0603		
MAIN#21	1	C14	56pF/50V/ 0603		
MAIN#22	1	C17	2.7nF/50V/ 0603		
MAIN#23	1	C35	22PF/50V/ 0603		
MAIN#24	1	C37	100PF/50V/ 0603		
MAIN#25	2	C57,C38	1nF/50V/ 0603		
MAIN#26	2	C39,C48	0.1uF/50V/ 0603		
MAIN#27	2	C47,C12	2.2uF/25V/ 0805		
MAIN#28	1	C9	10PF/1KV/ 1206		
MAIN#29	5	C53,C54,C55,C58,C13	10uF/35V /1206		
MAIN#30	2	C40,C41	10uF/50V/ 1206		
MAIN#31	1	C15	100uF/450V/18*30		
MAIN#32	1	C36	10uF/100V/ 6.3*10		
MAIN#33	2	C51,C52	680uF/25V/ 8*16		
MAIN#34	2	C6,C5	1uF/450V (ECW-FD2W105KC)		
MAIN#35	1	CX1	0.22uF X-CAP		
MAIN#36	1	CY1	1000pF Y-CAP		
MAIN#37	1	C42	4.7uF/10V/ 1206		
MAIN#38	1	C43	10nF/ 0603		
MAIN#39	1	C44	2.2nF/ 0603		
MAIN#40	1	C45	0.1uF/50V/ 0805		
MAIN#41	1	C46	4.7uF/10V/ 0805		
MAIN#42	1	C49	220pF/ 0603		
MAIN#43	1	C50	22nF/ 0603		
MAIN#44	1	C56	470PF/1KV/ 1206		
MAIN#45	1	F1	Fuse T3.15A/250V		
MAIN#46	1	TR3	210uH, ACF Transformer ATQ27		
MAIN#47	1	L3	200uH, PFC Inductance RM10		
MAIN#48	1	LF1	20mH, EMI Common Choke		
MAIN#49	1	L4	107uH/3A, Inductance Filter		

Item	Quantity	Reference	Description	Manufacturer Part Number	Manufacturer
MAIN#50	1	RT1	Jumper		
MAIN#51	2	R55,R56	10K/ 0603		
MAIN#52	1	R1	180K/ 0603		
MAIN#53	1	R4	82K/ 0603		
MAIN#54	1	R52	75K/ 0603		
MAIN#55	1	R8	22K/ 0603		
MAIN#56	3	R9,R10,R11	0.15R/1W/1206	**SMD12A1FR150T**	**SART Inc.**
MAIN#57	1	R12	3K/ 0603		
MAIN#58	1	R18	200K/ 0603		
MAIN#59	1	R20	59K/ 0603		
MAIN#60	1	R21	330K/ 0603		
MAIN#61	1	R22	2.2R/ 0805		
MAIN#62	1	R23	750K/ 0603		
MAIN#63	1	R39	0.4R/1W/1206	**SMD12A1FR400T**	**SART Inc.**
MAIN#64	2	R40,R41	0.33R/1W/1206	**SMD12A1FR330T**	**SART Inc.**
MAIN#65	1	R42	1K/ 0603		
MAIN#66	1	R43	300K/ 1206		
MAIN#67	1	R44	18K/ 0603		
MAIN#68	2	R46, R51	2.2R/ 1206		
MAIN#69	6	R5,R6,R7,R15,R16,R17	3M/ 1206		
MAIN#70	1	R53	5mR/1W/ 1206	**SMF12M1FR005T**	**SART Inc.**
MAIN#71	1	R54	2.2K/ 0603		
MAIN#72	1	R57	1R/ 0603		
MAIN#73	1	R58	100R/ 0603		
MAIN#74	1	R59	470K/ 0603		
MAIN#75	1	R31	1K/ 0805		
DB1	**PFC Daughter Board**				
DB1#1	1	L65	Bead 220R	**Z2K221-RD-10**	**Superworld Inc.**
DB1#2	1	Q65	TP65H150LGS - GaN	**TP65H150LGS**	**Transphorm Inc.**
DB1#3	1	R66	10R/ 0805		
DB1#4	1	R67	1M/ 0603		
DB2	**ACF Daughter Board**				
BD2#1	3	C32,C33,C34	33nF/1KV		
BD2#2	1	C61	100PF/0603		
BD2#3	1	D61	1N4148WS/ SOD323	**1N4148WS-7-F**	**Diodes Inc.**
BD2#4	1	L61	Bead 220R/ 0603	**Z2K221-RD-10**	**Superworld Inc.**
BD2#5	1	Q32	DMP65H9D0HSS/ SO8	**DMP65H9D0HSS-13**	
BD2#6	1	Q61	TP65H150LGS - GaN	**TP65H150LGS**	**Transphorm Inc.**
BD2#7	2	R32,R63	100K/ 0603		
BD2#8	2	R48,R47	0R/ 1206		
BD2#9	1	R61	10R/ 0805		
BD2#10	1	R62	249R/ 0805		

Note:
SuperGaN® Power FETs is the trademark of Transphorm Inc. Detailed product information can be found on https://www.transphormusa.com//

3.3 PFC Inductance, Transformer Design

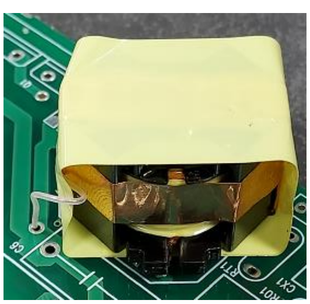
3.3.1 PFC Inductance

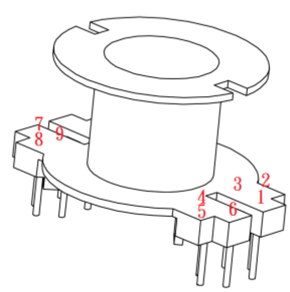
Circuit：	Cross sectional view：
	

Definition	Pin define (Start >> End)	Wire *(φ)*	Turn *(Ts)*	Layers	Layers of Tape
WD1	11,12 **>>** 1,2	2UEW Litz Wire 0.1mm x 60P	36		
	OVER CORE				3Ts

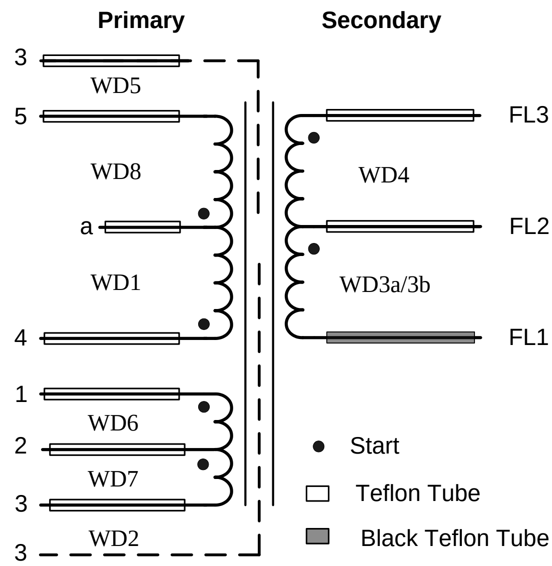
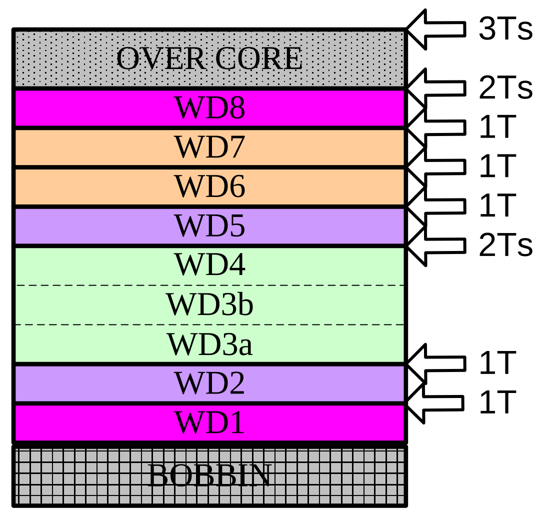
Note:

1) L=200uH, RM10, Bobbin: BOJUN: BJ-RM-1002
2) Core plus cross capper foil for EMI shielding.
3) Picture and Pin define





3.3.2 ACF Transformer

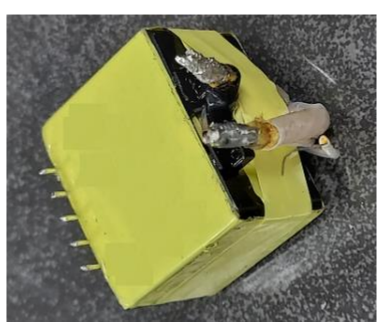
Circuit：	Cross sectional view：
	

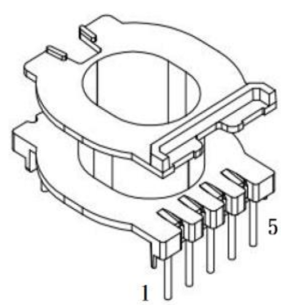
Definition	Pin define (Start >> End)			Wire (*φ*)	Turn *(Ts)*	Layers	Layers of Tape
WD1	*4*	*>>*	*a*	*2UEW-B Litz Wire 0.1mm*22 x1P*	***21***	*2*	*1T*
WD2	*3*	*>>*	*Null*	*2UEW-B 0.2mm x 1P*	*20*	*1*	*1T*
WD3a	*FL2*	*>>*	*FL1*	*Triple Litz wire-B 0.22mm*7 x 2P*	*4*	*1*	*2Ts*
WD3b	*FL2*	*>>*	*FL1*	*Triple Litz wire-B 0.22mm*7 x 2P*	*4*	*1*	
WD4	*FL3*	*>>*	*FL2*	*Triple wire-B 0.25mm x 1P*	*4*	*1*	
WD5	*3*	*>>*	*Null*	*2UEW-B 0.2mm x 1P*	*18*	*1*	*1T*
WD6	*1*	*>>*	*2*	*2UEW-B 0.2mm x 1P*	*5*	*1*	*1T*
WD7	*2*	*>>*	*3*	*2UEW-B 0.2mm x 1P*	*5*		
WD8	*a*	*>>*	*5*	*2UEW-B Litz Wire 0.1mm*22x1P*	*9*	*1*	*2Ts*
	OVER CORE (22mm)						*3Ts*

Note:

a.> Core: ATQ27-16.6-1 GP95, Bobbin: XHW ATQ2716 (5+2)

b.> Lm=210uH





3.4 Schematics Description

3.4.1 AC Input Circuit & Differential Filter

The Fuse F1 protects against over-current conditions which occur when some main components fails. The LF1 is common mode chocks for the common mode noise suppression. The BD is a bridge rectifier which converts alternating current and voltage into direct current and voltage. The C5, C6, L4 are composed of the Pi filter for filtering the differential switching noise back to AC source.

3.4.2 UCC28056 PFC Controller

The UCC28056 device drives PFC boost stages based on an innovative mixed mode method that operates in transition mode (TM) at full load and transitions seamlessly into discontinuous conduction mode (DCM) at reduced load, automatically reducing switching frequency. This device incorporates burst mode operation to further improve light load performance, enabling systems to meet challenging energy standards while eliminating the need to switch off the PFC.

3.4.3 AP3306 PWM Controller

AP3306, a highly integrated Active Clamp Flyback (ACF) controller, integrates high-voltage start-up function through HV pin and X-Cap discharging function. It also integrates a VCCL LDO circuit, which allows the LDO to regulate the wide range VCCL to an acceptable value. This makes AP3306 an ideal candidate for wide range output voltage applications such as USB-PD3.0. With embedded high-side and low-side switch control mechanism, AP3306 provides proper timing sequences to control Q32 (high-side Switch) and Q61 (low-side Switch) operations to implement two key efficiency improvement approaches, namely, ZVS (Zero Voltage Switching) and leakage energy recycling (stored in Csn1) to achieve high-power density charger applications. At no load or light load, the AP3306 will enter the burst mode to minimize standby power consumption.

3.4.4 APR340 Synchronous Rectification (SR) MOSFET Driver

As a high performance solution, APR340 is a secondary side SR controller to effectively reduce the secondary side rectifier power dissipation which works in DCM-QR/ACF operation.

3.4.5 AP43771V PD 3.0 Decoder & Protection on/off N MOSFET and Interface to Power Devices

Few important pins provide critical protocol decoding and regulation functions in AP43771V:

1) **CC1 (Pin 11)**: CC1 is defined by USB Type-C spec to provide the channel communication link between power source and sink device.
2) **CC2 (Pin 10):** To control PFC Converter turn on/off, “0” To disable PFC converter, “1” To enable PFC converter. When PD request to 20V PDO, AP43771V_CC2 output “1” to turn on PFC Converter. It through Opto-coupler IC35 to control VCC_PFC of PFC Converter to turn on/off.
3) **Constant Voltage (CV)**: The CV is implemented by sensing VFB (pin 8) and comparing with internal reference voltage to generate a CV compensation signal on the OCDRV pin (pin 5). The output voltage is controlled by firmware through CC1 channel communication with the sink device.
4) **Constant Current (CC)**: The CC is implemented by sensing the current sense resistor (RCS, 10mΩ, 1%, Low TCR) and compared with internal programmable reference voltage. The output current is controlled by firmware through CC1 channel communication with the sink device.
5) **Loop Compensation:** R56, C48 & C49 form the voltage loop compensation circuit, and C50 form the current loop compensation circuit.
6) **OCDRV (Pin5)**: It is the key interface link from secondary decoder (AP43771V) to primary regulation circuit (AP3306). It is connected to Opto-coupler IC34 Pin 2 (Cathode) for feedback information based on all sensed CC1 signals for getting desired Vbus voltage & current.
7) **PWR_EN (Pin2) to N-MOSFET Gate**: The pin is used to turn on/off N-MOSFET (Q35) to enable/disable voltage output to the Vbus.

Chapter 4 The Evaluation Board (EVB) Connections

4.1 EVB PCB Layout

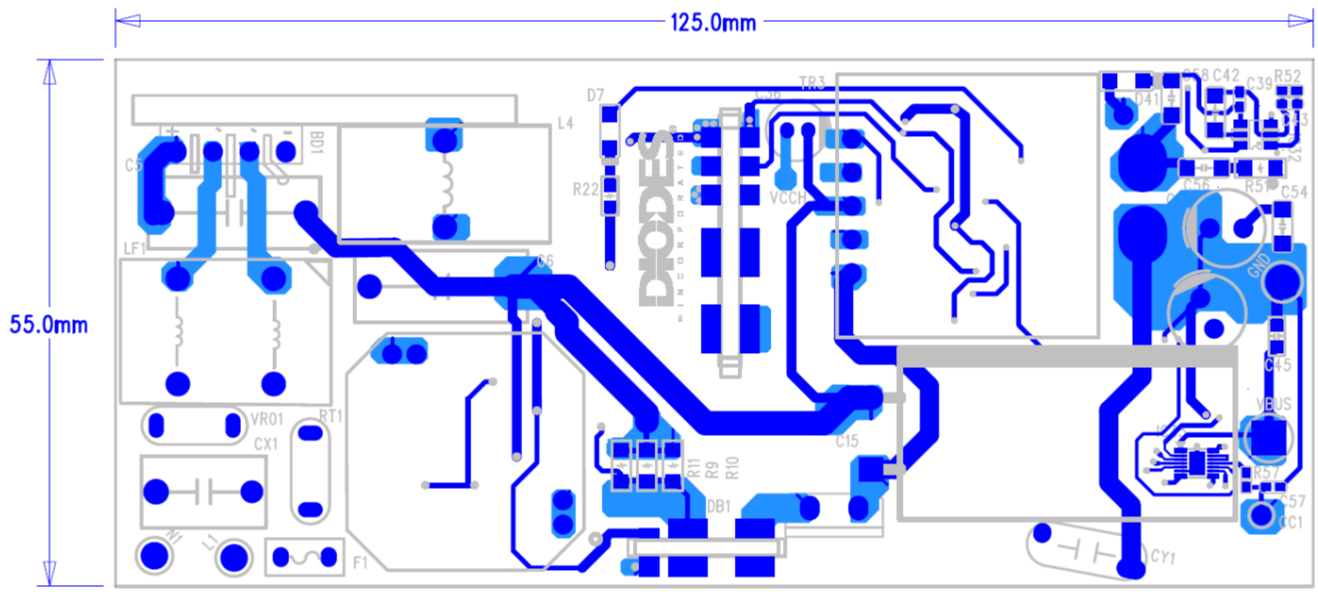


Figure 7: 140W ACF+GaN PD3.0 Adapter EVB Main Board PCB Layout – Top View

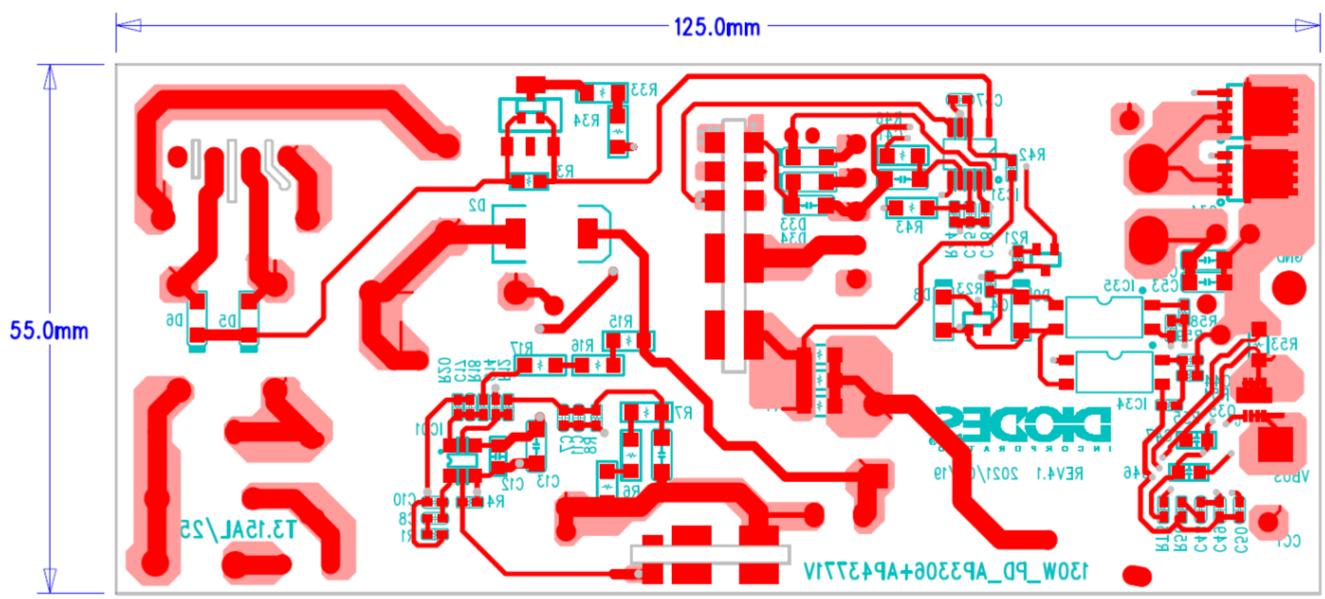


Figure 8: 140W ACF+GaN PD3.0 Adapter EVB Main Board PCB Layout – Bottom View

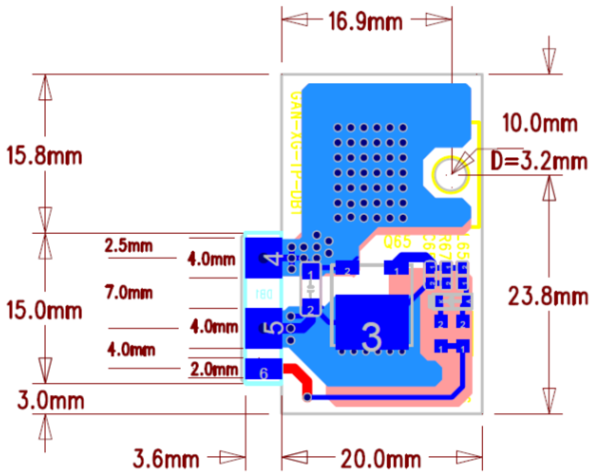


Figure 9-1: DB1- PFC Daughter Board Drawing

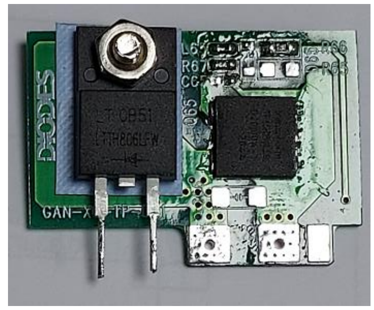


Figure 9-2: DB1 Top View

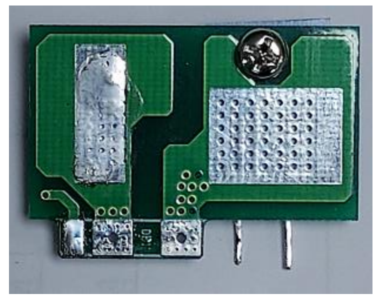


Figure 9-3: DB1 Bottom View

Figure 9: 140W ACF+GaN PD3.0 Adapter EVB DB1 PCB Layout

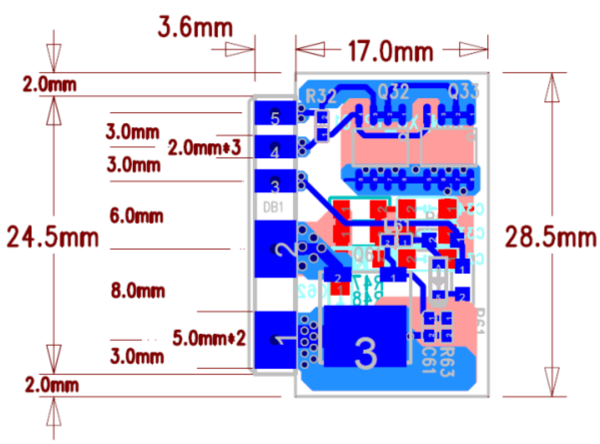


Figure 10-1: DB2- ACF Daughter Board Drawing

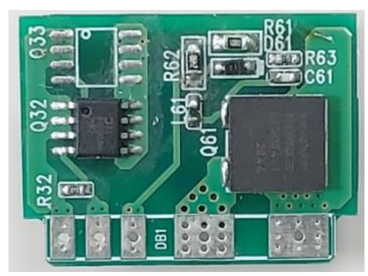


Figure 10-2: DB2 Top View

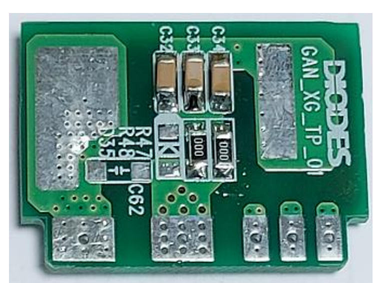


Figure 10-3: DB2 Bottom View

Figure 10: 140W ACF+GaN PD3.0 Adapter EVB DB2 PCB Layout

4.2 Quick Start Guide before Connection

1) Before starting the 140W EVB test, the end user needs to prepare the following tool, software and manuals.

For details, please consult USBCEE sales through below link for further information.

USBCEE PD3.0 Test Kit: USBCEE Power Adapter Tester. https://www.usbcee.com/product-details/4

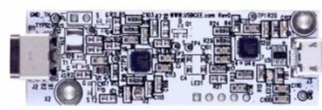
USBCEE PAT Tester	GUI Display	USB-A to Micro-B Cable
		

Figure 11: Test Kit / Test Cables

2) Prepare a certified three-foot Type-C cable and a Standard-A to Micro-B Cable.

3) Connect the AC inputs: L & N wires of EVB to AC power supply output “L and N “wires.

4) Ensure that the AC source is switched OFF or disconnected before the connection steps.

5) Output of Type-C cable & USB A-port are connected to E-load + & - terminals by cables.

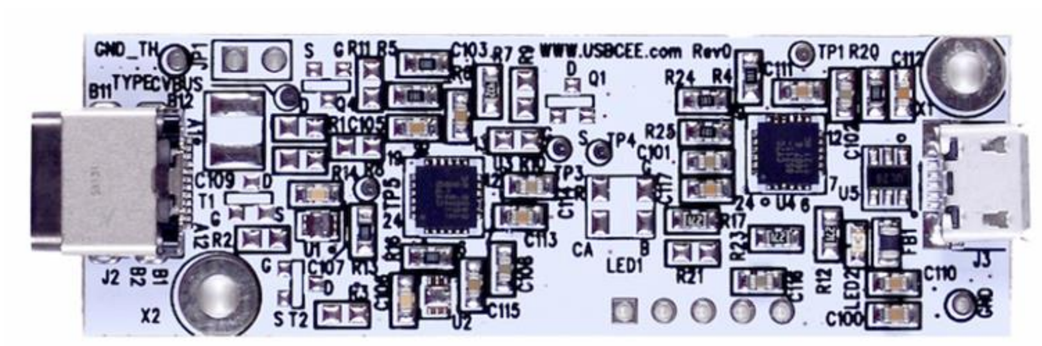


Figure 12: The Test Kit Input & Output and E-load Connections

4.3 Connection with E-Load

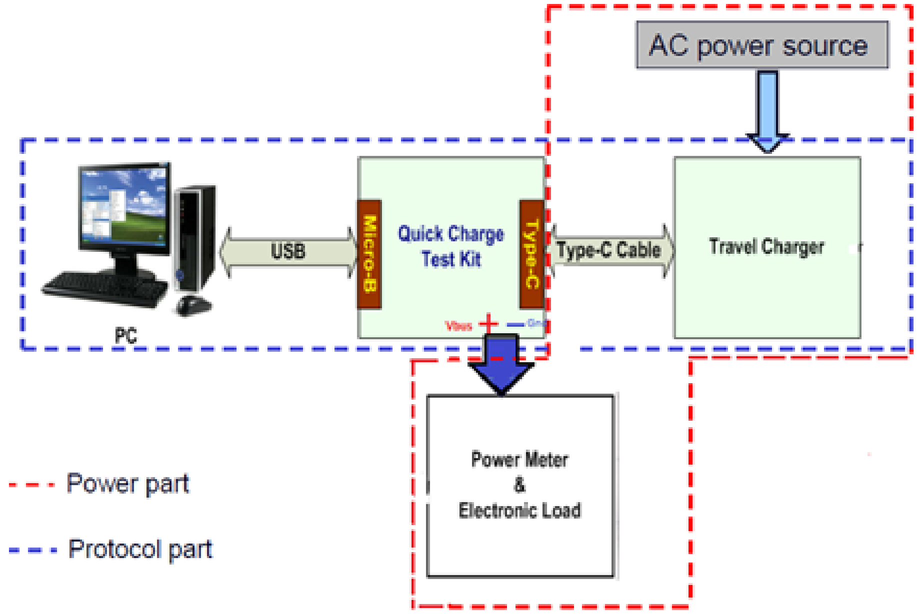


Figure 13: Diagram of Connections in the Sample Board

Chapter 5 Testing the Evaluation Board

5.1 Input & Output Characteristics

5.1.1 Input Standby Power

Vin(V_{AC})	F(Hz)	Pin(mW)
90	60	19.2
115	60	21.9
230	50	42.7
264	50	51.7

5.1.2 Multiple Output Efficiency at Different AC Line Input Voltage

Vin (V_{AC})	F (Hz)	Iout (A)	Vout_Board (V)	Pin (W)	Pout (W)	Eff (%)
90	60	7.0	20.26	155.45	141.46	91.00%
115	60	7.0	20.26	154.21	141.45	91.73%
230	50	7.0	20.26	152.19	141.46	92.95%
264	50	7.0	20.26	151.79	141.45	93.18%
90	60	3.0	15.16	49.70	45.45	91.46%
115	60	3.0	15.17	49.34	45.48	92.17%
230	50	3.0	15.17	48.59	45.46	93.55%
264	50	3.0	15.17	48.62	45.46	93.49%
90	60	3.0	9.15	30.11	27.41	91.03%
115	60	3.0	9.15	29.89	27.42	91.61%
230	50	3.0	9.15	29.47	27.41	93.02%
264	50	3.0	9.15	29.57	27.42	92.73%
90	60	3.0	5.12	17.10	15.4	91.13%
115	60	3.0	5.12	16.96	15.4	91.47%
230	50	3.0	5.12	16.7	15.4	91.73%
264	50	3.0	5.11	16.9	15.4	91.04%

NOTE:

When PDO request to 20V-PDO, the PFC Converter turn on

5.1.3 Efficiency vs. AC Line Input Voltage

Figure 14 illustrates the efficiency vs. input voltage

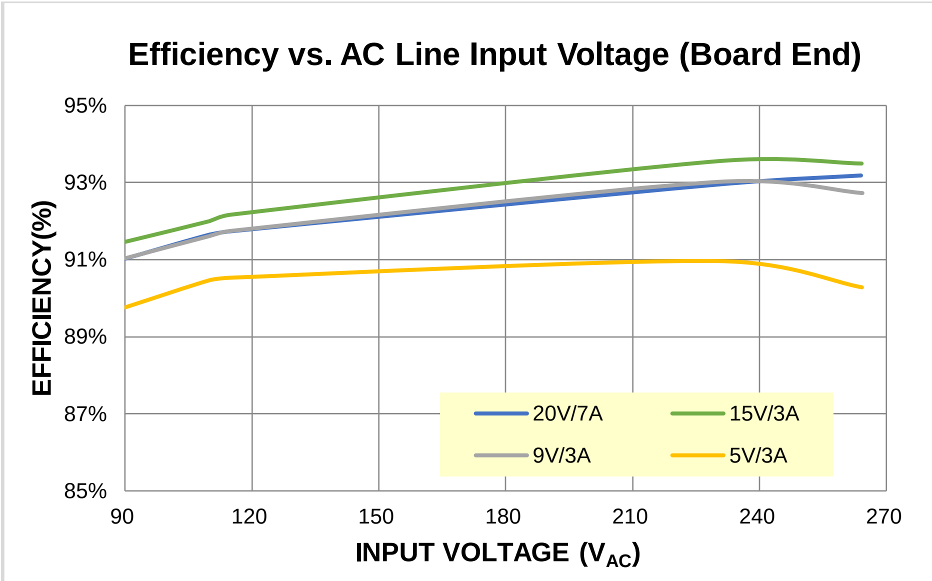


Figure 14: Efficiency vs. AC Line Input Voltage – PDO_5V/3A, 9V/3A, 15V/3A, and 20V/7A

5.1.4 Total Harmonic Distortion (THD) and Power Factor Correction (PFC)

Figure 15 illustrates the THD vs Output Power

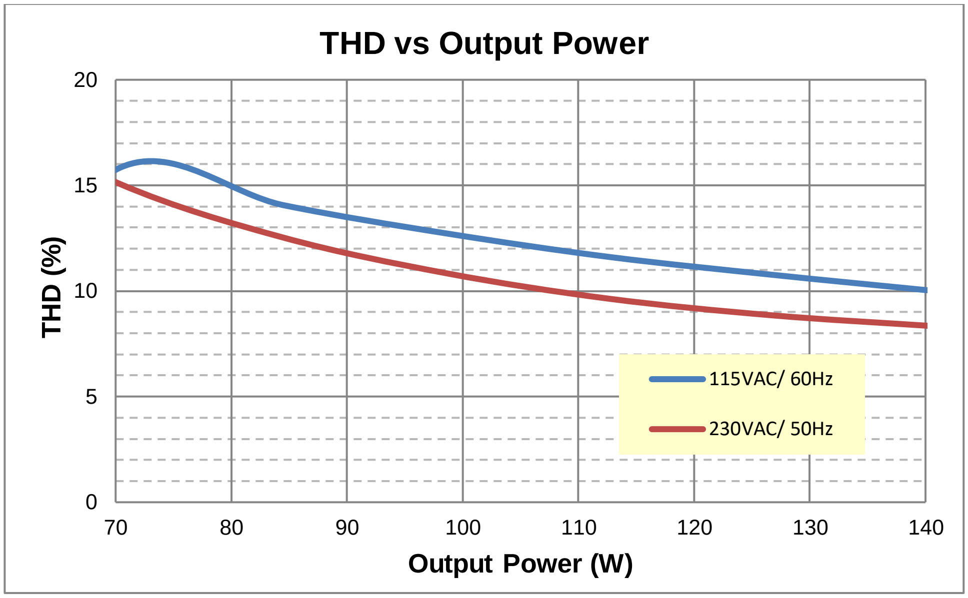


Figure 15: THD vs. Output Power – Full Load 140W PDO_20V/7A

Figure 16 illustrates the Power Factor (PF) vs Output Power

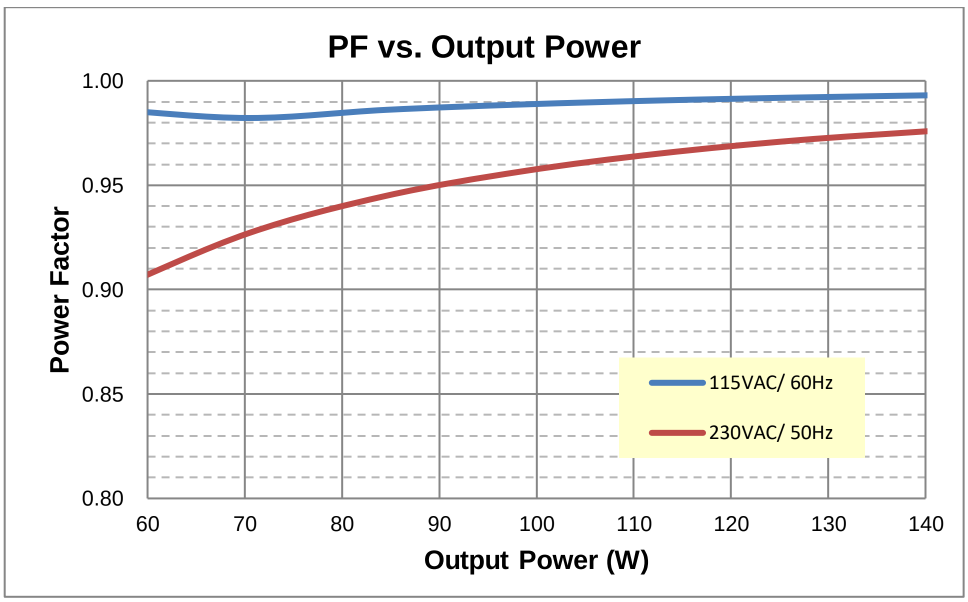


Figure 16: PF vs. Output Power – Full Load 140W PDO_20V/7A

5.1.5 Multiple Output Average Efficiency at Different Loading

PDO_20V / 15V / 9V / 5V Average Efficiency

PDO Mode	Vin (V_{AC})	F (Hz)	Remarks	Iout (A)	Vout_Board (V)	Pin (W)	Pout_MB (W)	Eff (%)	Average Efficiency
20V/7A	115	60	100%	6.98	20.26	154.19 W	141.45 W	91.74%	91.38%
			75%	5.25	20.25	115.74 W	106.22 W	91.77%	
			50%	3.49	20.23	77.25 W	70.61 W	91.41%	
			25%	1.74	20.21	38.74 W	35.09 W	90.59%	
			10%	0.69	20.20	15.74 W	13.88 W	88.20%	
	230	50	100%	6.98	20.26	152.24 W	141.43 W	92.90%	92.48%
			75%	5.24	20.25	114.31 W	106.19 W	92.89%	
			50%	3.49	20.23	76.25 W	70.60 W	92.58%	
			25%	1.74	20.21	38.33 W	35.08 W	91.54%	
			10%	0.69	20.19	15.53 W	13.89 W	89.43%	
15V/3A	115	60	100%	3.00	15.17	49.36 W	45.48 W	92.14%	92.11%
			75%	2.25	15.16	36.95 W	34.06 W	92.18%	
			50%	1.50	15.14	24.57 W	22.66 W	92.24%	
			25%	0.75	15.12	12.29 W	11.30 W	91.91%	
			10%	0.30	15.11	5.02 W	4.48 W	89.20%	
	230	50	100%	3.00	15.17	48.57 W	45.46 W	93.59%	93.12%
			75%	2.25	15.16	36.43 W	34.06 W	93.49%	
			50%	1.50	15.14	24.32 W	22.66 W	93.18%	
			25%	0.75	15.12	12.25 W	11.29 W	92.22%	
			10%	0.30	15.10	5.03 W	4.48 W	89.04%	
9V/3A	115	60	100%	3.00	9.15	29.89 W	27.42 W	91.74%	91.81%
			75%	2.25	9.12	22.31 W	20.50 W	91.88%	
			50%	1.50	9.09	14.81 W	13.62 W	91.94%	
			25%	0.75	9.06	7.39 W	6.78 W	91.69%	
			10%	0.30	9.04	3.02 W	2.68 W	88.70%	
	230	50	100%	3.00	9.15	29.47 W	27.41 W	93.02%	92.53%
			75%	2.25	9.11	22.05 W	20.48 W	92.87%	
			50%	1.50	9.09	14.68 W	13.62 W	92.74%	
			25%	0.75	9.07	7.41 W	6.78 W	91.50%	
			10%	0.30	9.04	3.01 W	2.68 W	89.10%	
5V/3A	115	60	100%	3.00	5.12	17.00 W	15.35 W	90.28%	89.75%
			75%	2.25	5.09	12.68 W	11.44 W	90.26%	
			50%	1.50	5.05	8.44 W	7.58 W	89.83%	
			25%	0.75	5.02	4.25 W	3.77 W	88.61%	
			10%	0.30	5.00	1.72 W	1.49 W	86.69%	
	230	50	100%	3.00	5.12	16.87 W	15.34 W	90.96%	89.92%
			75%	2.25	5.09	12.62 W	11.44 W	90.66%	
			50%	1.50	5.05	8.47 W	7.58 W	89.52%	
			25%	0.75	5.02	4.25 W	3.77 W	88.54%	
			10%	0.30	5.00	1.75 W	1.50 W	85.59%	

5.2 Key Performance Waveforms

5.2.1 System Start-up Time

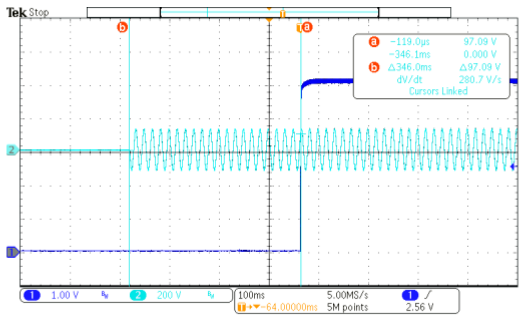


Figure 17: Start-up Time: 346ms at 3A Load @90V$_{AC}$/60Hz

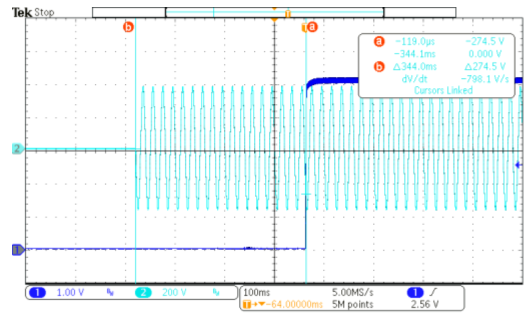
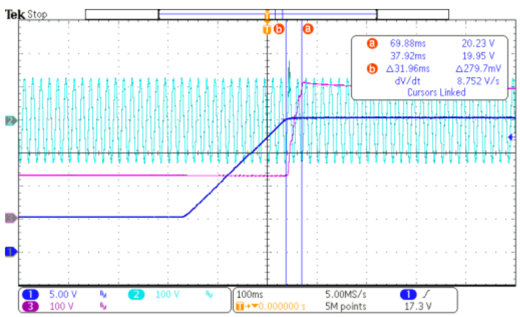


Figure 18: Start-up Time: 344ms at 3A Load @264V$_{AC}$/50Hz

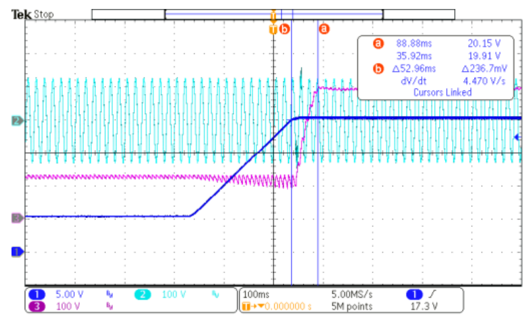
5.2.2 PFC Start-up

The following waveforms show the output voltage been set to the 20V, PFC start-up waveform:



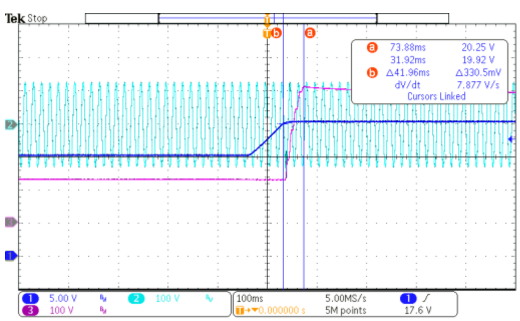
CH1:VBUS, CH2:AC Input, CH3:VPFC

Figure 19: 5V to 20V @90V$_{AC}$/60Hz; Load=0A



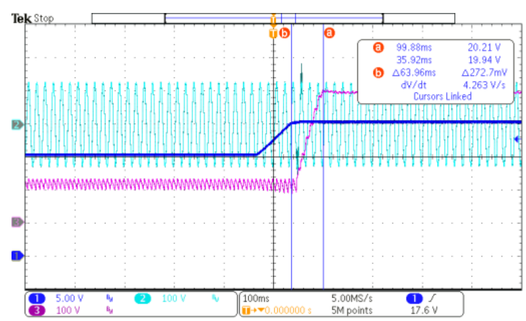
CH1:VBUS, CH2:AC Input, CH3:VPFC

Figure 20: 5V to 20V @90V$_{AC}$/60Hz; Load=3A



CH1:VBUS, CH2:AC Input, CH3:VPFC

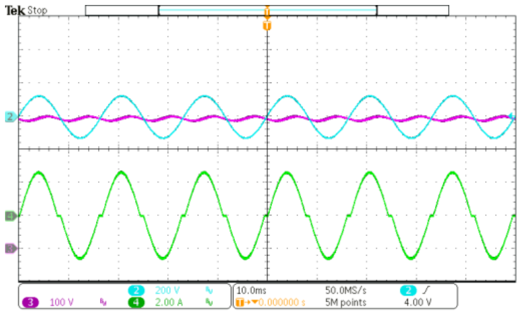
Figure 21: 15V to 20V @90V$_{AC}$/60Hz; Load=0A



CH1:VBUS, CH2:AC Input, CH3:VPFC

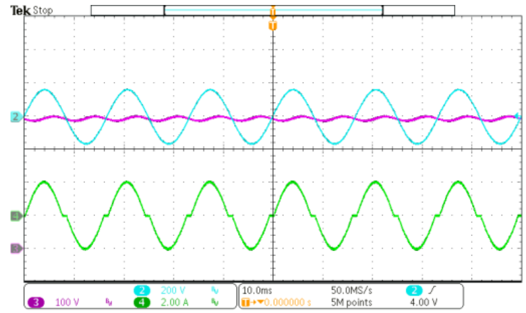
Figure 22: 15V to 20V @90V$_{AC}$/60Hz; Load=3A

5.2.3 Line Voltage and Line Current



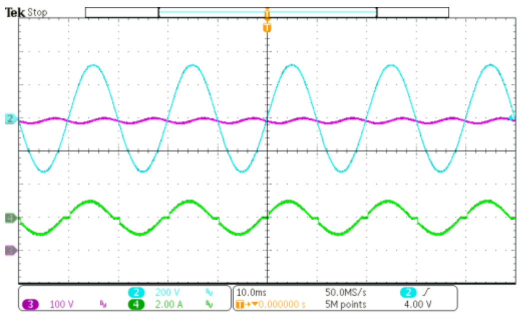
CH2:AC Input, CH3:VPFC, CH4:AC Input Current

Figure 23: 20V/7A @90V$_{AC}$/60Hz



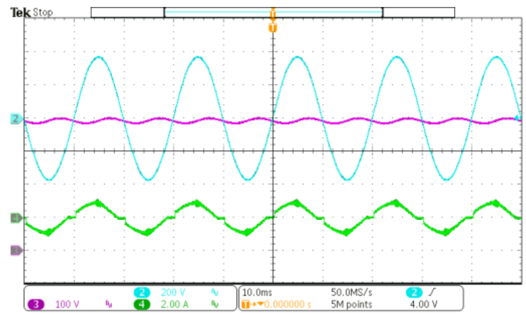
CH2:AC Input, CH3:VPFC, CH4:AC Input Current

Figure 24: 20V/7A @115V$_{AC}$/60Hz



CH2:AC Input, CH3:VPFC, CH4:AC Input Current

Figure 25: 20V/7A @230$_{AC}$/50Hz



CH2:AC Input, CH3:VPFC, CH4:AC Input Current

Figure 26: 20V/7A @264V$_{AC}$/50Hz

5.2.4 Switching Transistor Voltage Stress

5.2.4.1 PFC Q65 GaN Vds Voltage stress

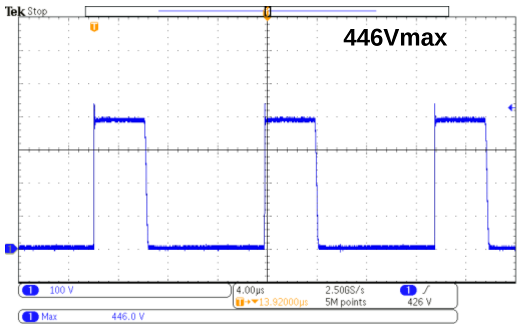


Figure 27: 20V/7A @90V$_{AC}$/60Hz

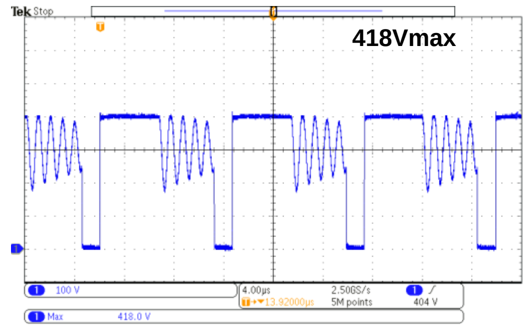


Figure 28: 20V/7A @264V$_{AC}$/50Hz

Component	Input Voltage	Output	Vds	Vds_Max_Spec	Ratio of voltage stress
Q65	90 V$_{AC}$ /60Hz	20V/7A	446V	650V	68.62%
	264 V$_{AC}$ /50Hz		418V		64.31%

5.2.4.2 ACF Q61 GaN Vds Voltage stress

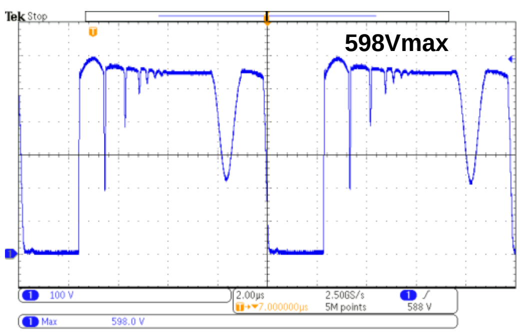


Figure 29: 20V/7A @90V$_{AC}$/60Hz

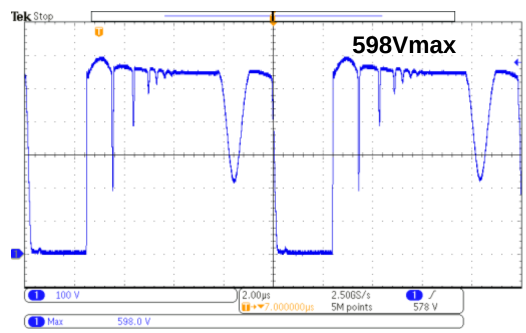


Figure 30: 20V/7A @264V$_{AC}$/50Hz

Component	Input Voltage	Output	Vds	Vds_Max_Spec	Ratio of voltage stress
Q61	90 V$_{AC}$ /60Hz	20V/7A	598V	650V	92%
	264 V$_{AC}$ /50Hz		598V		92%

5.2.4.3 ACF P-MOSFET Q32 Vds Voltage stress

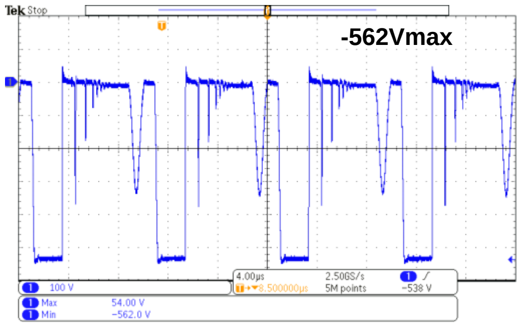


Figure 31: 20V/7A @90V$_{AC}$/60Hz

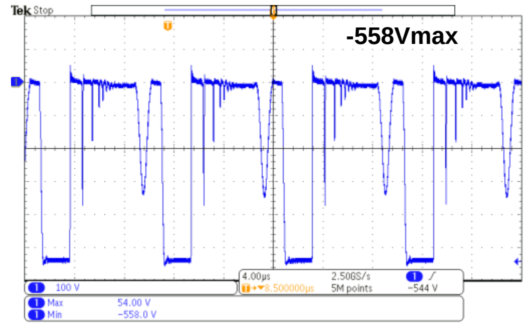


Figure 32: 20V/7A @264V$_{AC}$/50Hz

Component	Input Voltage	Output	Vds	Vds_Max_Spec	Ratio of voltage stress
Q32	90 V$_{AC}$ /60Hz	20V/7A	-562V	-600V	93.67%
	264 V$_{AC}$ /50Hz		-558V		93.00%

5.2.4.4 MOSFET Q34, Q36 Vds Voltage stress

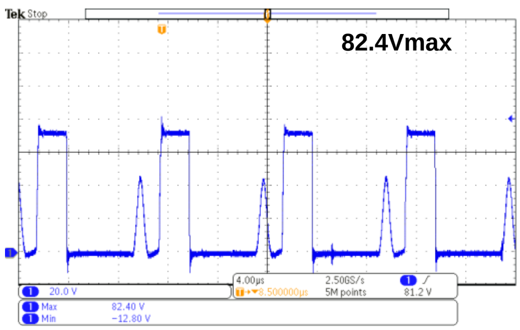


Figure 33: 20V/7A @90V$_{AC}$/60Hz

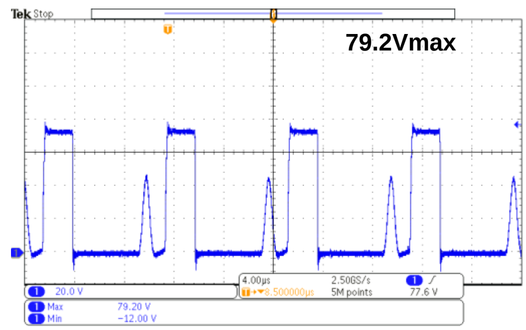


Figure 34: 20V/7A @264V$_{AC}$/50Hz

Component	Input Voltage	Output	Vds	Vds_Max_Spec	Ratio of voltage stress
Q34, Q36	90 V$_{AC}$ /60Hz	20V/7A	82.4V	100V	82.40%
	264 V$_{AC}$ /50Hz		79.2V		79.20%

5.2.5 System Output Ripple & Noise with the Cable

5.2.5.1 5VPDO Output Ripple-Noise

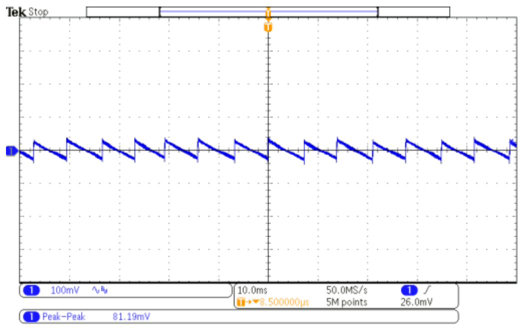


Figure 35: 90VAC/60Hz @5V/0A, △V=81.19mV

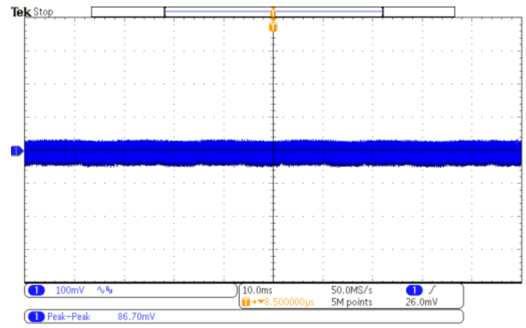


Figure 36: 90VAC/60Hz @5V/3A, △V=86.70mV

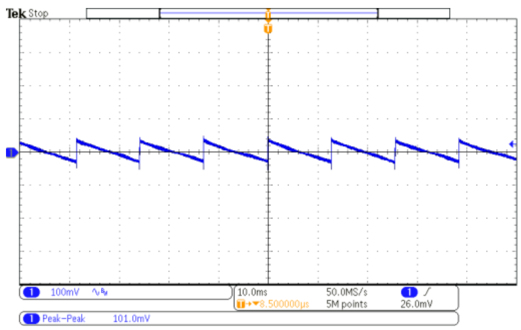


Figure 37: 264VAC/50Hz @5V/0A, △V=101.0mV

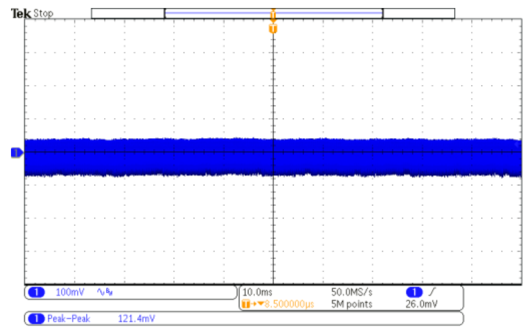


Figure38: 264VAC/50Hz @5V/3A, △V=121.4mV

5.2.5.2 9VPDO Output Ripple-Noise

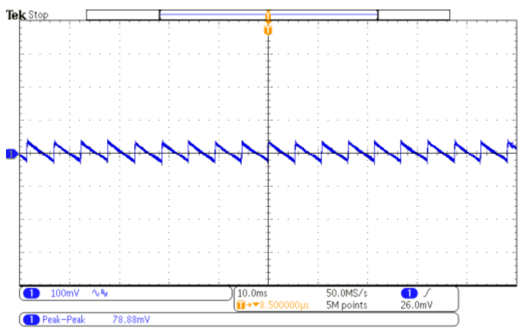


Figure 39: 90VAC/60Hz @9V/0A, △V=78.88mV

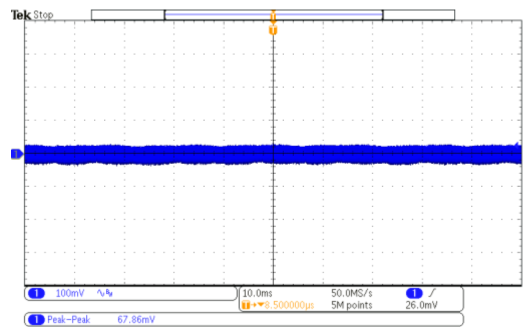


Figure 40: 90VAC/60Hz @9V/3A, △V=67.86mV

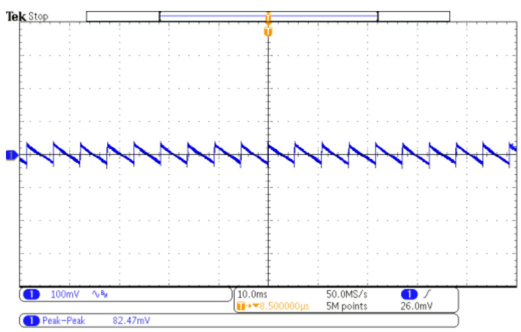


Figure 41: 264VAC/50Hz @9V/0A, △V=82.47mV

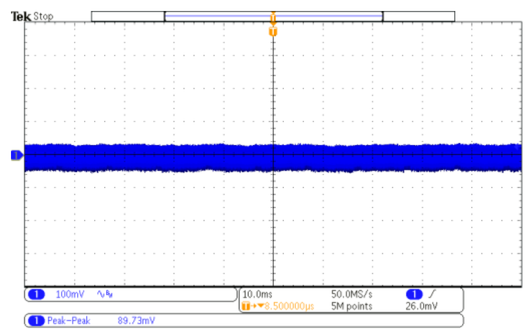


Figure 42: 264VAC/50Hz @9V/3A, △V=89.73mV

5.2.5.3 15VPDO Output Ripple-Noise

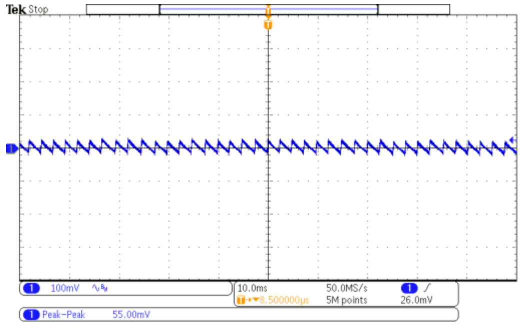


Figure 43: 90V_{AC}/60Hz @15V/0A, △V=55.00mV

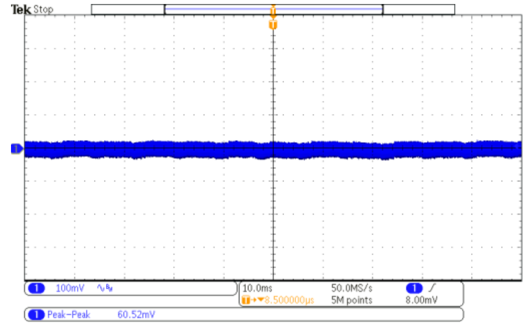


Figure 44: 90V_{AC}/60Hz @15V/3A, △V=60.52mV

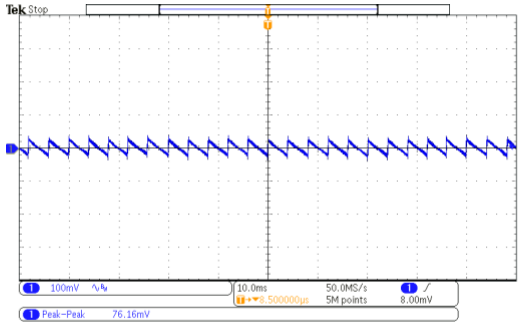


Figure 45: 264V_{AC}/50Hz @15V/0A, △V=76.16mV

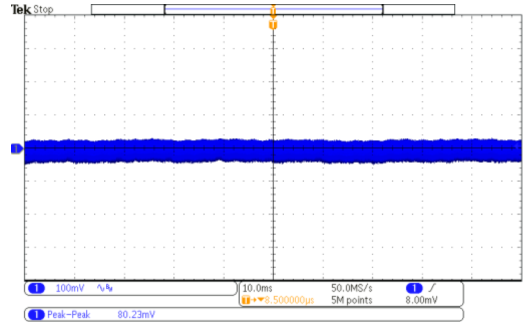


Figure 46: 264V_{AC}/50Hz @15V/3A, △V=80.23mV

5.2.5.4 20VPDO Output Ripple-Noise

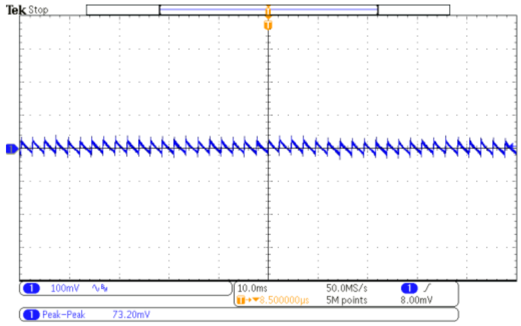


Figure 47: 90V_{AC}/60Hz @20V/0A, △V=73.2mV

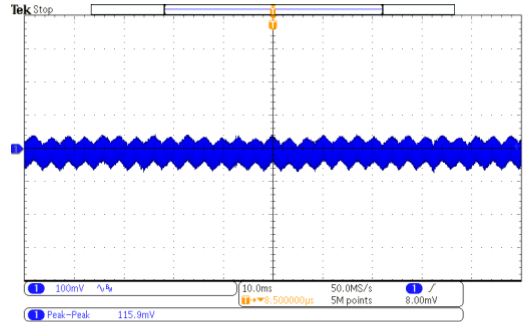


Figure 48: 90V_{AC}/60Hz @20V/7A, △V=115.9mV

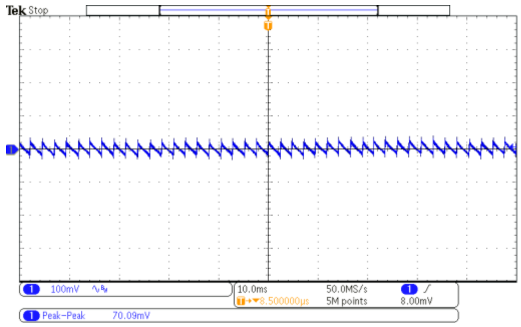


Figure 49: 264V_{AC}/50Hz @20V/0A, △V=70.09mV

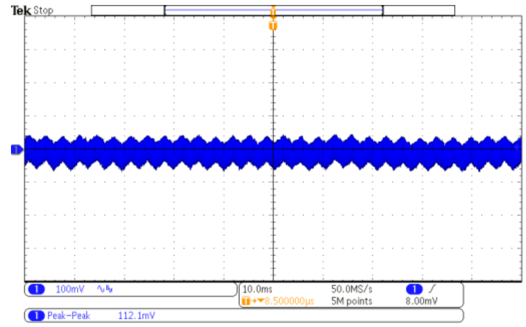


Figure 50: 264V_{AC}/50Hz @20V/7A, △V=112.1mV

Note Test condition: Connect 47uF AL Cap and 0.1uF MLCC to the cable output unit in parallel

5.2.6 Dynamic load

10% Load~100% Load, T=20mS, Rate=5mA/us (PCB End)

5.2.6.1 5V Dynamic Load

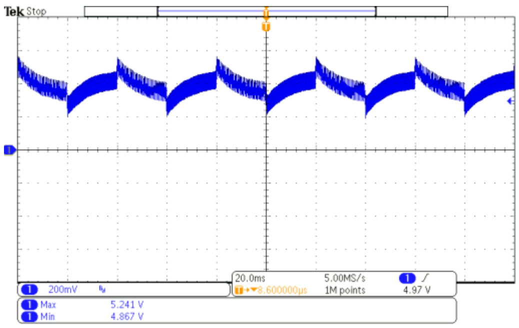


Figure 51: 90V$_{AC}$/60Hz Port-C@ Vout=5V

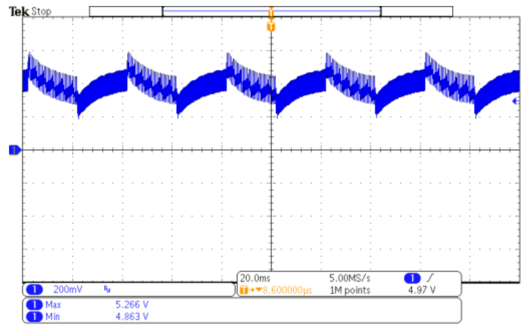


Figure 52: 264V$_{AC}$/50Hz Port-C@ Vout=5V

	Vo_ Undershoot(V)	Vo_ Overshoot(V)
Vin=90V$_{AC}$/60Hz @5V	4.867	5.241
Vin=264V$_{AC}$/50Hz @5V	4.863	5.266

5.2.6.2 9V Dynamic Load

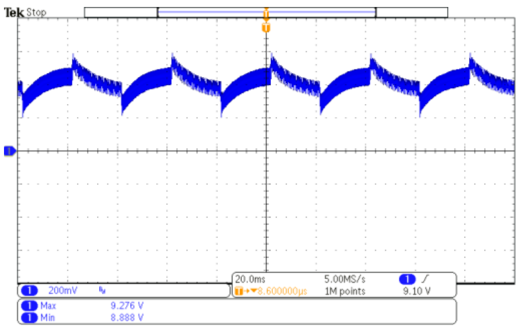


Figure 53: 90V$_{AC}$/60Hz Port-C@ Vout=9V

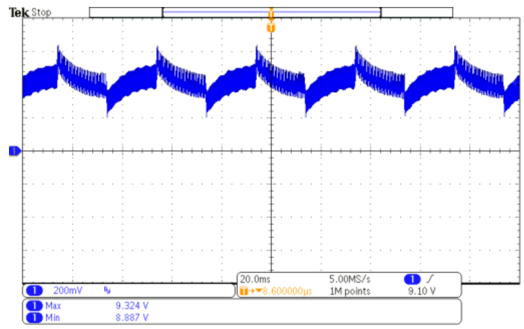


Figure 54: 264V$_{AC}$/50Hz Port-C@ Vout=9V

	Vo_ Undershoot(V)	Vo_ Overshoot(V)
Vin=90V$_{AC}$/60Hz @9V	8.888	9.276
Vin=264V$_{AC}$/50Hz @9V	8.887	9.324

5.2.6.3 15V Dynamic Load

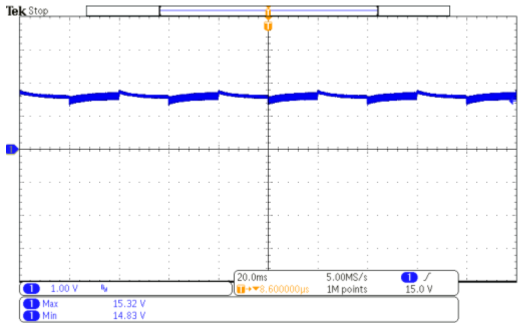


Figure 55: 90V$_{AC}$/60Hz Port-C@ Vout=15V

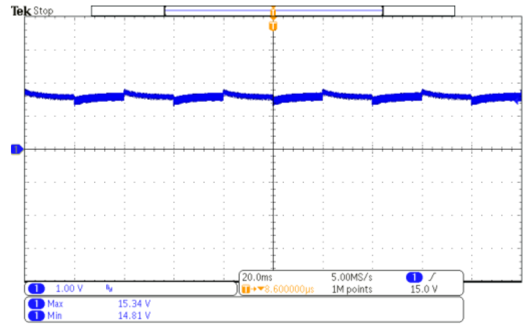


Figure 56: 264V$_{AC}$/50Hz Port-C@ Vout=15V

	Vo_ Undershoot(V)	Vo_ Overshoot(V)
Vin=90V$_{AC}$/60Hz @15V	14.83	15.32
Vin=264V$_{AC}$/50Hz @15V	14.81	15.34

5.2.6.4 20V Dynamic Load

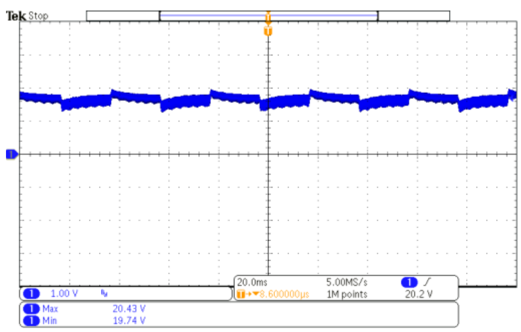


Figure 57: 90V$_{AC}$/60Hz Port-C@ Vout=20V

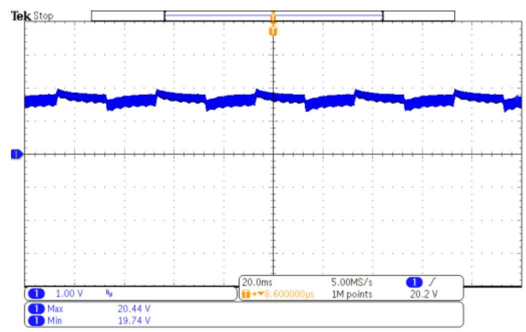


Figure 58: 264V$_{AC}$/50Hz Port-C@ Vout=20V

	Vo_ Undershoot(V)	Vo_ Overshoot(V)
Vin=90V$_{AC}$/60Hz @20V	19.74	20.43
Vin=264V$_{AC}$/50Hz @20V	19.74	20.44

5.2.7 Output Voltage Transition Time

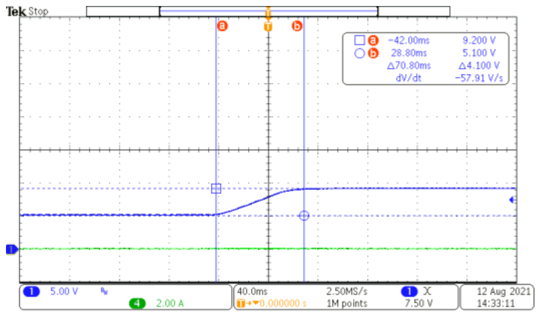


Figure 59: 5V→9V Transition Time =70.8ms

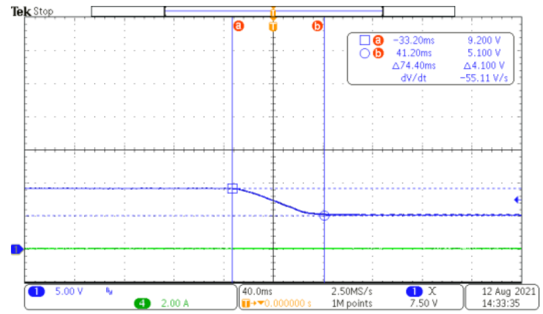


Figure 60: 9V→5V Transition Time =74.4ms

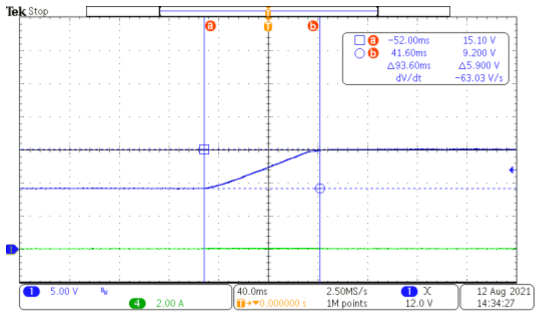


Figure 61: 9V→15V Transition Time =93.6ms

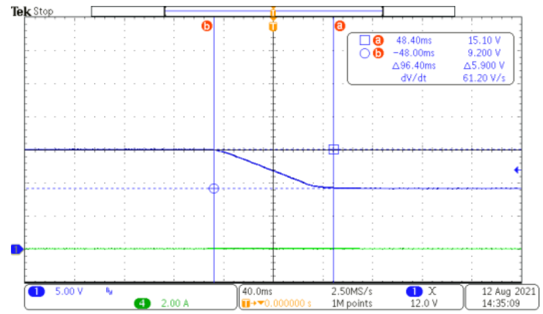


Figure 62: 15V→9V Transition Time =96.4ms

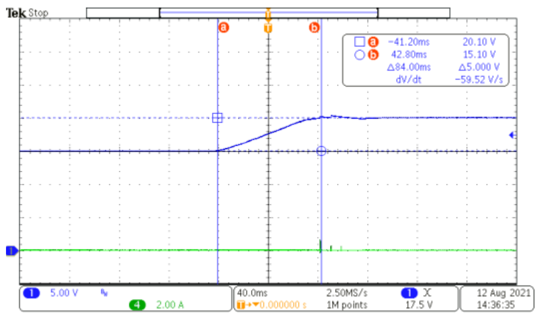


Figure 63: 15V→20V Transition Time =84.0ms

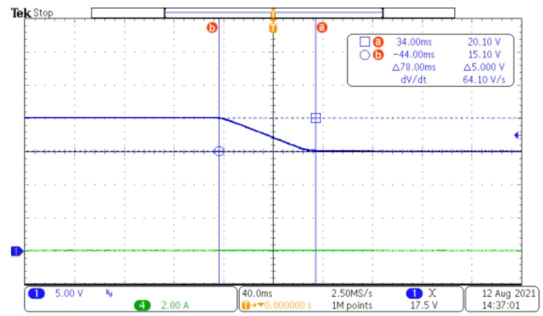


Figure 64: 20V→15V Transition Time =78.0ms

5.2.8 Thermal Testing

Test Condition : 20V/7A @90V$_{AC}$/60Hz

Location	BD1	L3	Q65	IC01	D3	TR3	IC31
Temperature (°C)	91.6	68.4	74.5	68.2	67.7	100.0	88.9
Location	**Q61**	**Q32**	**Q34**	**Q36**	**IC32**	**Q35**	**R35**
Temperature (°C)	76.6	90.7	93.7	91.4	99.3	81.8	84.4

Note:
- ✓ The Q32 added thermal pad to improve the component thermal.
- ✓ The Q34, Q36 and TR3 added thermal glue to improve thermal.
- ✓ Component temperatures can be further optimized with various system design and thermal management approaches by manufacturers.

Test Condition: Vin=90V$_{AC}$ @ 20V/7A Full load Open Frame.

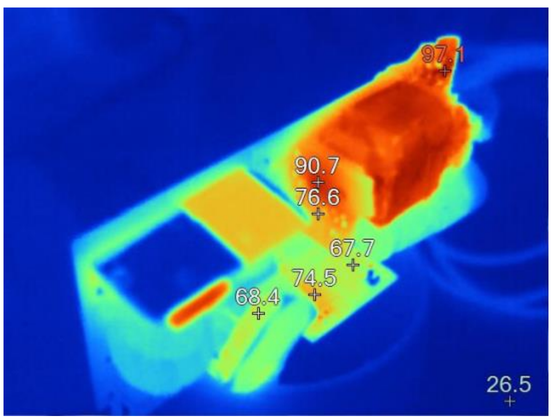


Figure 65: DB1 Components side

- BD1: Bridge Rectifier
- Q65: PFC High Voltage GaN FET
- Q61: ACF Primary Side High Voltage GaN FET
- Q32: ACF Primary Side High Voltage P-MOS
- Q34/Q36: ACF Secondary Side Sync-Rectifier
- IC31: AP3306, ACF Controller
- IC32: APR340, Sync-Rectifier Controller
- IC01: Transition-Mode PFC Controller
- L3: PFC Inductance
- D3: PFC HYPER-FAST Rectifier Diode
- TR3: ACF Transformer
- Q35: PD Load Switch
- R35: PD Current Sense Resistor

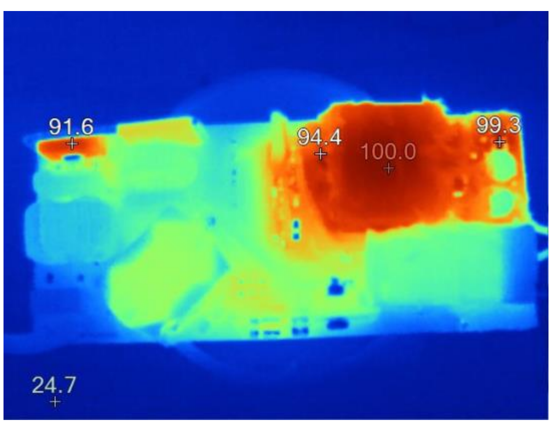


Figure 66: Top Components side

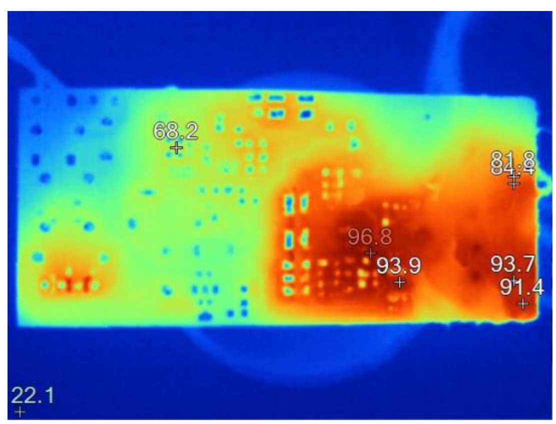


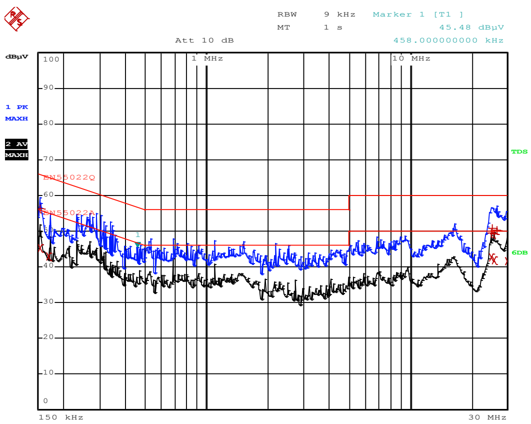
Figure 67: Bottom Surface Mount side

5.3 EMI (Conduction) Testing

EMI can be further optimized with various system design approaches by manufacturers.

5.3.1 115VAC testing results

Output Condition : 20V/7A

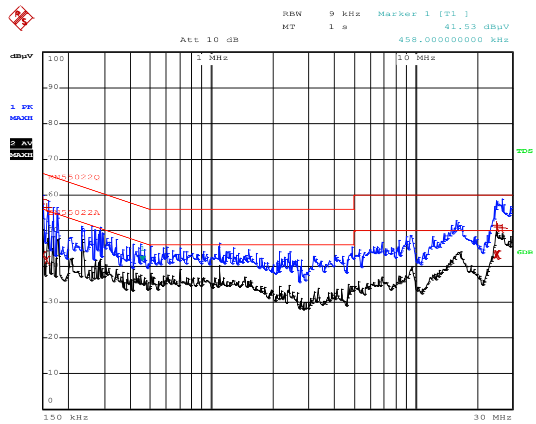


EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

TRACE	FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1 Quasi Peak	154 kHz	56.20	-9.58
2 Average	154 kHz	45.16	-10.61
2 Average	170 kHz	42.93	-12.02
2 Average	25.174 MHz	42.52	-7.47
1 Quasi Peak	25.182 MHz	49.60	-10.39
1 Quasi Peak	25.378 MHz	50.86	-9.13
2 Average	25.838 MHz	41.87	-8.12
1 Quasi Peak	25.986 MHz	49.30	-10.69
1 Quasi Peak	26.662 MHz	50.22	-9.77
2 Average	29.85 MHz	41.58	-8.41

Figure 68: 115V$_{AC}$/60Hz L line



EDIT PEAK LIST (Final Measurement Results)

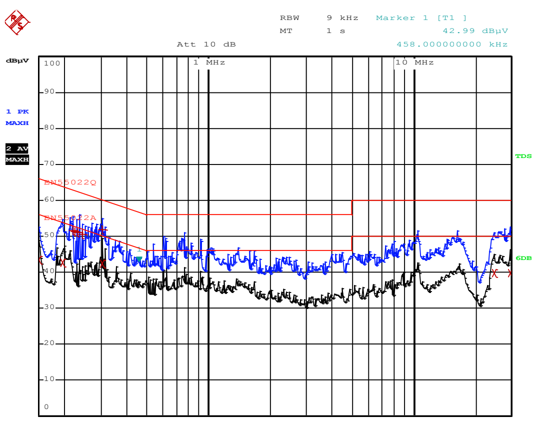
Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

TRACE	FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1 Quasi Peak	150 kHz	58.73	-7.26
2 Average	150 kHz	43.28	-12.71
1 Quasi Peak	158 kHz	56.63	-8.93
2 Average	158 kHz	41.81	-13.75
1 Quasi Peak	24.95 MHz	51.56	-8.43
2 Average	24.95 MHz	43.05	-6.94
2 Average	25.09 MHz	43.37	-6.62
2 Average	25.202 MHz	43.53	-6.46
1 Quasi Peak	25.434 MHz	51.11	-8.88
1 Quasi Peak	26.558 MHz	50.91	-9.08

Figure 69: 115V$_{AC}$/60Hz N line

5.3.2 230VAC testing results

Output Condition : 20V/7A

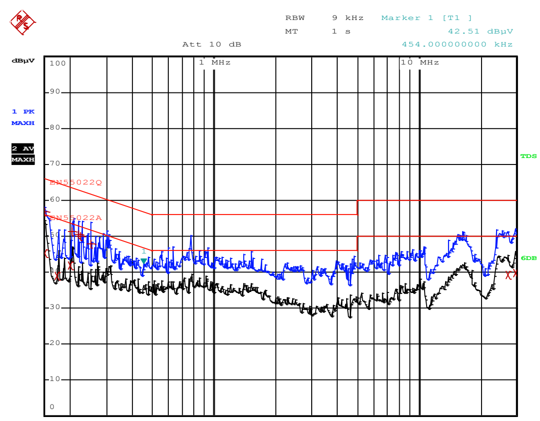


EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

TRACE	FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
2 Average	150 kHz	43.31	-12.68
2 Average	198 kHz	42.75	-10.93
1 Quasi Peak	218 kHz	51.62	-11.27
1 Quasi Peak	226 kHz	51.41	-11.17
1 Quasi Peak	234 kHz	51.03	-11.27
1 Quasi Peak	242 kHz	50.49	-11.53
1 Quasi Peak	302 kHz	51.79	-8.39
2 Average	302 kHz	42.44	-7.74
2 Average	24.862 MHz	39.69	-10.30
2 Average	29.666 MHz	39.70	-10.29

Figure 70: 230V$_{AC}$/50Hz L line



EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

TRACE	FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1 Quasi Peak	150 kHz	56.90	-9.09
2 Average	150 kHz	45.25	-10.74
2 Average	174 kHz	38.97	-15.79
2 Average	202 kHz	41.76	-11.76
1 Quasi Peak	206 kHz	51.35	-12.01
1 Quasi Peak	218 kHz	50.46	-12.43
1 Quasi Peak	226 kHz	49.88	-12.70
1 Quasi Peak	250 kHz	47.81	-13.94
2 Average	27.262 MHz	39.22	-10.77
2 Average	29.782 MHz	39.68	-10.31

Figure 71: 230V$_{AC}$/50Hz N line