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Chapter 1 Summary

1.1 General Description

The 100W PD3.0 Evaluation Board (EVB1) is composed of four main controllers, AP33510, APR349, AP43771V and UCC28056B (TI). The AP33510, a highly integrated Quasi-Resonant (QR) controller with direct Enhancement-mode Gallium Nitride (E-GaN) driver integration, is optimally designed to meet ultra-low standby power and high power density (HPD) charger applications. The APR349, a secondary side synchronous rectifier (SR) controller, is adopted for efficiency optimization. The AP43771V, a PD3.0 PPS protocol controller, automatically manages the PD3.0 PPS attachment process for the attached USB Type C®-equipped device under charge (DUC), regulates the feedback information of the charger to fulfill voltage and current requirements from DUC. By adopting growing popularity of E-GaN FETs, the 100W EVB1 exemplifies HPD charger design with system BOM optimization to meet market trend.

1.2 Key Features

1.2.1 System Key Features

- Quasi-Resonant operation for Critical E-GaN switch Operation and Efficiency Improvement Approaches
- Cost-Effective Implementation for HPD Chargers
- High-Voltage Startup low standby power (<20mW)
- Meets DOE VI and COC Tier 2 Efficiency Requirements
- USB Type-C Port - Support the Maximum Output of 100W PD3.0 PPS (3.3V to 21V@20mV/step, 50mA/step)
- SSR Topology Implementation with an Opto-coupler for Accurate Step Voltage / Current Control
- Low overall system BOM cost

1.2.2 AP33510 Key Features

- QR Flyback Topology with Valley-on and Valley lock
- High-Voltage Startup
- Embedded VCC LDO for VCCIN pin to Guarantee Wide Range Output Voltage
- Integration of Accurate E-GaN direct-driver
- Low Constant Output Current for Output Short
- Non-Audible-Noise QR Control
- Soft Start During Startup Process
- Frequency Foldback for High Average Efficiency
- Secondary Winding Short Protection with FOCP
- Frequency Dithering for Reducing EMI
- Integration of 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 APR349 Key Features

- SR Works with CCM / DCM / QR 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® Quick Charge™ 5 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
- Supports E-Marker Cable Detection
- QFN-14 and QFN-24

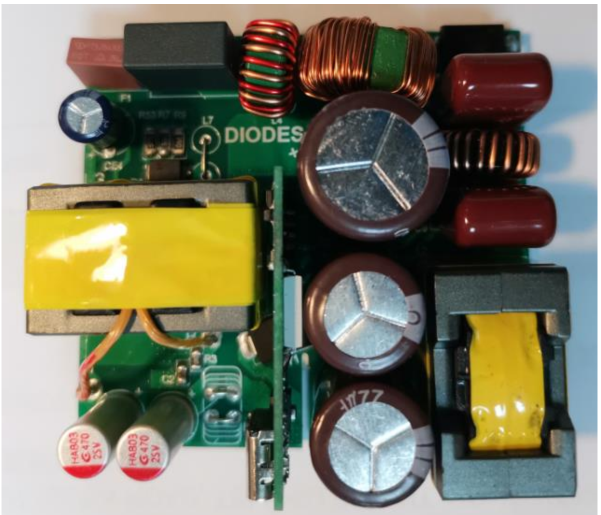
1.3 Applications

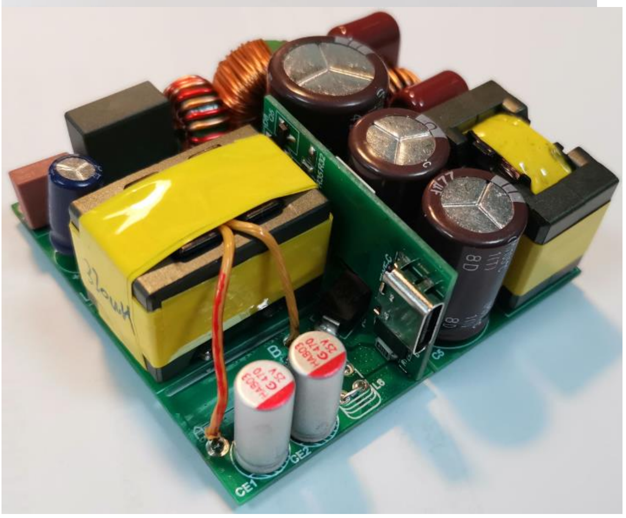
- Quick Charger with PD3.0

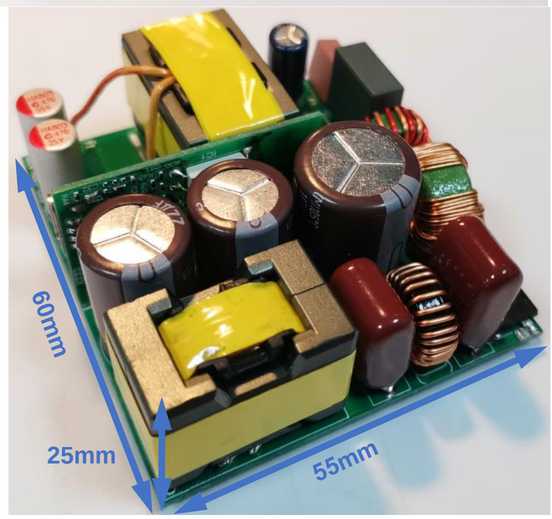
1.4 Main Power Specifications

Parameter	Value
Input Voltage	$90V_{AC}$ to $264V_{AC}$
Input standby power	< 50mW@$230V_{AC}$/50Hz
Main Output (Vo / Io)	PDO: 5V/3A, 9V/3A, 15V/3A, 20V/5A,
Efficiency	Comply with CoC version 5 tier-2
Total Output Power	100W (at PDO 20V/3.25A)
Protections	OCP, OVP, UVP, OLP, OTP, SCP
Dimensions	PCB: 60 * 55 * 25 mm^3, 2.362" * 2.165" * 0.984" $inch^3$
Power Density Index	1.25 W/CC; 20.48 W/CI

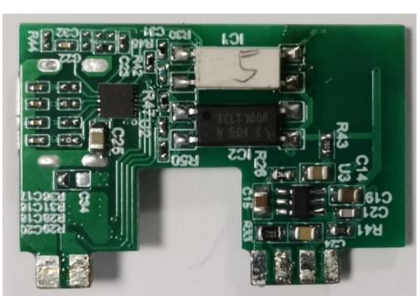
1.5 Evaluation Board Pictures

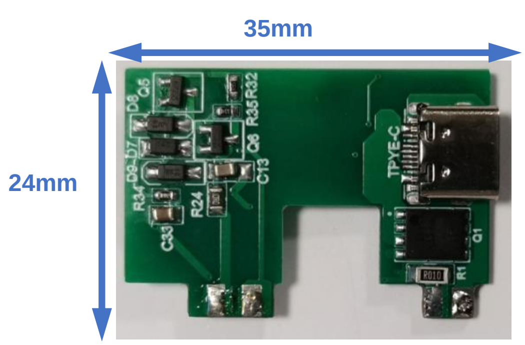






The dimension "25mm" includes the height of components





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	< 50mW, load disconnected	**PASS,** 45mW@$230V_{AC}$/50Hz
5V/3A Average Efficiency	CoC Version 5, Tier-2 Efficiency >81.84%	**PASS,** 91.88@115VAC/60Hz 89.74@230VAC/50Hz
5V/0.3A Efficiency (10% Load)	CoC Version 5, Tier2 Efficiency >72.48%	**PASS,** 89.77@115VAC/60Hz 85.70@230VAC/50Hz
9V/3A Average Efficiency	CoC Version 5,Tier2 Efficiency >87.30%	**PASS,** 92.93@115VAC/60Hz 91.94@230VAC/50Hz
9V/0.3A Efficiency (10% Load)	CoC Version 5,Tier2 Efficiency >77.30%	**PASS,** 91.19@115VAC/60Hz 87.98@230VAC/50Hz
15V/3A Average Efficiency	CoC Version 5,Tier2 Efficiency >88.85%	**PASS,** 92.94@115VAC/60Hz 92.62@230VAC/50Hz
15V/0.3A Efficiency (10% Load)	CoC Version 5,Tier2 Efficiency >78.85%	**PASS,** 90.06@115VAC/60Hz 87.48@230VAC/50Hz
20V/5A Average Efficiency	CoC Version 5,Tier2 Efficiency >89%	**PASS,** 92.69@115VAC/60Hz 93.43@230VAC/50Hz
20V/0.5A Efficiency (10% Load)	CoC Version 5,Tier2 Efficiency >79%	**PASS,** 91.09@115VAC/60Hz 89.80@230VAC/50Hz
Output Voltage Regulation Tolerance	+/- 5%	**PASS,**

2.2 Compliance

Parameter	Test conditions	Low to High	High to Low	standard	Test Summary
Output Voltage Transition time	5V/3A to 9V/3A, 90Vac/60Hz	59.91ms	60.44ms	275ms <	Pass
	5V/3A to 9V/3A, 264Vac/50Hz	59.61ms	66.24ms		Pass
	9V/3A to 15V/3A, 90Vac/60Hz	76.88ms	78.60ms		Pass
	9V/3A to 15V/3A, 2640Vac/50Hz	79.62ms	81.15ms		Pass
	15V/3A to 20V/3A, 90Vac/60Hz	66.95ms	61.62ms		Pass
	15V/3A to 20V/3A, 264Vac/50Hz	63.36ms	68.73ms		Pass
	USB Type-C *1-				
	90Vac , Full Load				
Output Connector	L46mm x 46mm x 22mm (with foldable AC pin)				

Chapter 3 Schematic

3.1 Board Schematic

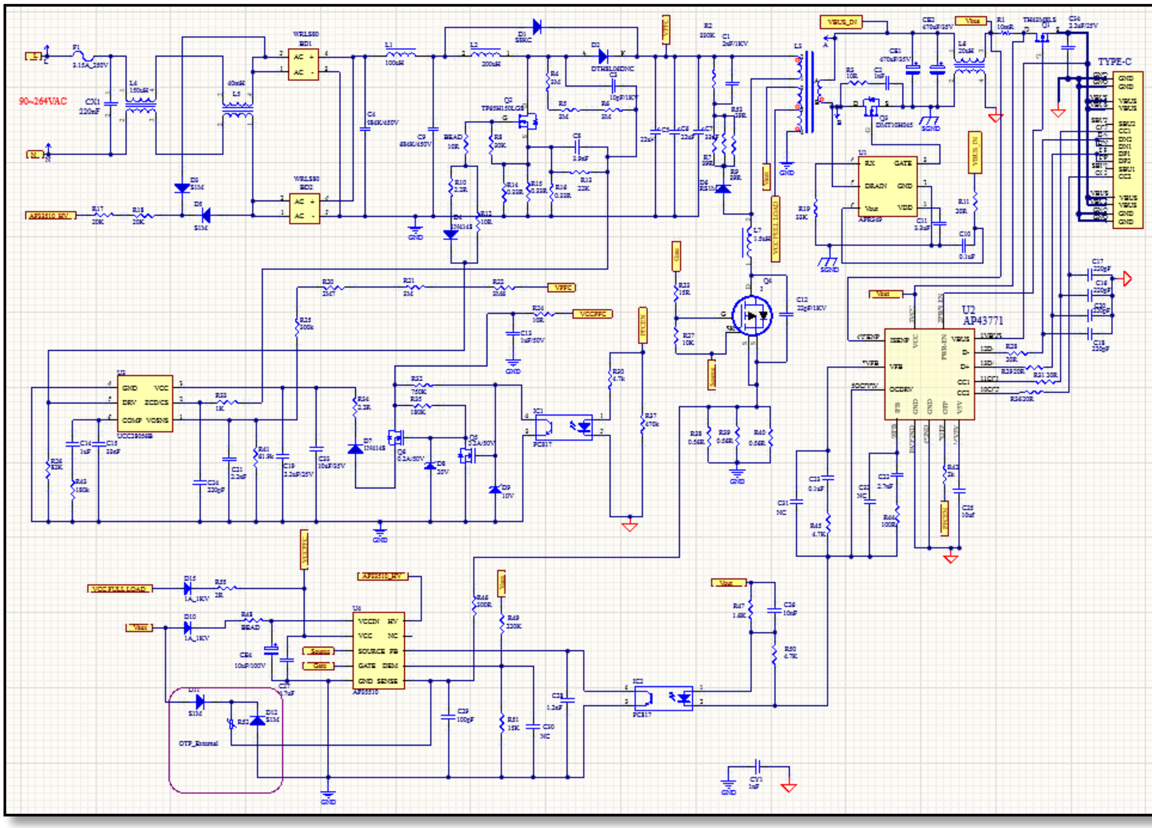


Figure 1. 100W PD3.0 Adapter EVB1 Schematic

3.2 Bill of Material (BOM)

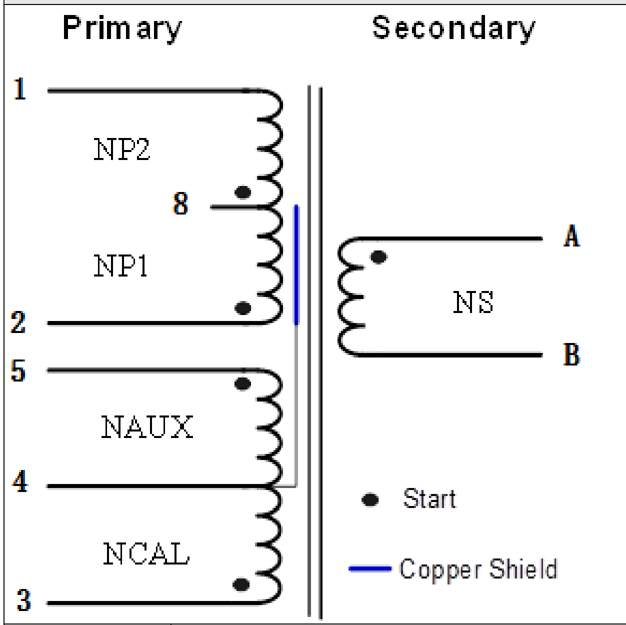
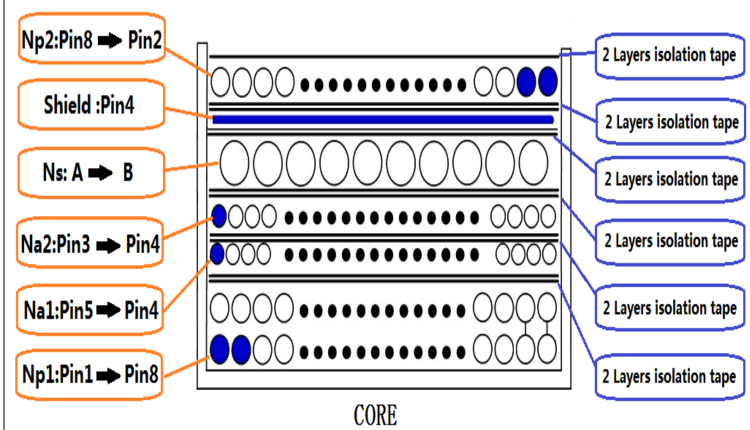
Item	Quantity	Reference	Description	Manufacturer
1	1	U1	APR349	Diodes Incorporated (Diodes)
2	1	U2	AP43771	Diodes
3	1	U3	UCC28056B	TI
4	1	U4	AP35510	Diodes
5	1	TPYE-C	TYPE-C	
6	1	R8	30K 0603_R	fenghua
7	3	R7, R9, R53	39R 1206_R	fenghua
8	1	R55	2R 0805_R	fenghua
9	1	R51	15K 0603_R	fenghua
10	1	R49	220K 0603_R	fenghua
11	1	R48	BEAD 0805_R	muRata(村田)
12	1	R47	1.6K 0402_R	fenghua
13	1	R46	300R 0603_R	fenghua
14	1	R44	100R 0402_R	fenghua
15	1	R42	2k 0402_R	fenghua
16	1	R41	61.9k 0603_R	fenghua
17	3	R4, R5, R6	3M1206_R	fenghua
18	3	R38, R39, R40	0.56R 1206_R	fenghua
19	1	R37	470K 0402_R	fenghua
20	2	R35, R43	180K 0603_R	fenghua
21	1	R33	1K 0805_R	fenghua
22	1	R32	750K 0603_R	fenghua
23	3	R30, R45, R50	4.7K 0402_R	fenghua
24	2	R3, R24	10R 0805_R	fenghua
25	4	R28, R29, R31, R36	20R 0402_R	fenghua
26	1	R27	10K 0603_R	fenghua
27	1	R26	82K 0603_R	fenghua
28	1	R25	300K 0603_R	fenghua
29	1	R23	15R 0603_R	fenghua
30	1	R22	3M6 1206_R	fenghua
31	1	R21	3M 1206_R	fenghua
32	1	R20	2M7 1206_R	fenghua
33	1	R2	330K 1206_R	fenghua
34	1	R19	33K 0603_R	fenghua
35	2	R17, R18	20K 1206_R	fenghua
36	2	R15, R16, R14	0.33R 1206_R	fenghua
37	1	R13	22K 1206_R	fenghua
38	1	R11	20R 0805_R	fenghua
39	2	R10, R34	2.2R 0603_R	fenghua
40	1	R1	10mR 1206_R	YAGE/国巨

41	2	Q5, Q6	2N7002 SOT23_B	Diodes
42	1	Q4	INN650D260A DFN8*8	InnoScience
43	1	Q3	DMT10H045 DFN5*6	Diodes
44	1	Q2	TP65H300G4LSG	Transphorm
45	1	Q1	TH43M8LS DFN5*6	Diodes
46	1	L6	20uHRING_D9.8	SANCI/深圳三磁
47	1	L5	40mHEMC_14*8.5 SQ1010	SANCI/深圳三磁
48	1	L4	150uHRING_D9.8	SANCI/深圳三磁
49	1	L3	320uH ATQ2516	深圳博众达
50	1	L2	200uH ATQ2315	深圳博众达
51	1	L1	100uHLS_D10	SANCI/深圳三磁
52	2	IC1, IC2	HK1010HCU	Liteon/光宝
53	1	F1	Fuse 3.15A_250V	JDTfuse集电通
54	1	D8	20V_1/2W_MINI-MELF SOD_123_B	Diodes
55	1	D9	10V_1/2W_MINI-MELF SOD_123_B	Diodes
56	1	D6	RS1M SMA	Diodes
57	2	D4, D7	1N4148 SOD-123(W)	Diodes
58	2	D3, D5	S1M SMA	Diodes
59	1	D2	DTH8L06DNC TO-252	Diodes
60	2	D10, D15	RS1M_1A_1KV_500NS_SMA	Diodes
61	1	D1	S8KCD	Diodes
62	1	CY1	1nF	TRX/特锐祥
63	1	CX1	220nF/X2	SRD/圣融达
64	1	CE4	10uF/100V ELECTRO2	AISHI/艾华
65	2	CE1, CE2	470uF/25V ELECTRO2	AISHI/艾华
66	1	C8	3.9nF CAP	muRata(村田)
67	1	C7	33μF_±20%_450V_18*25	NCC/日本贵弥功
68	2	C5, C6	22μF_±20%_450V_12.5*25	NCC/日本贵弥功
69	2	C4, C9	CBB21L_474K/450V_10mm	JOEY/久亦
70	1	C33	10uF/35V 0805CAP	AISHI/艾华
71	2	C31, C32	NC0402_R	
72	1	C30	NC0603_R	
73	1	C3	10pF/1KV1206R	SAMSUNG/三星
74	1	C29	100pF0603_R	muRata(村田)
75	1	C28	1.2nF0805_R	muRata(村田)
76	1	C27	4.7uF0805_R	muRata(村田)
77	1	C26	10nF0402_R	muRata(村田)
78	1	C25	10uf0805_R	SAMSUNG/三星
79	1	C24	220pF0805_R	muRata(村田)

80	1	C23	0.1uF0402_R	muRata(村田)
81	1	C22	2.7nF0402_R	muRata(村田)
82	1	C21	2.2nF0603_R	muRata(村田)
83	1	C2	1nF0805_R	muRata(村田)
84	2	C19, C34	2.2uF/25V0805_R	SAMSUNG/三星
85	4	C16, C17, C18, C20	220pF0402_R	muRata(村田)
86	1	C15	33nF0805_R	muRata(村田)
87	1	C14	1uF0805_R	muRata(村田)
88	1	C13	1uF/50V1206_R	muRata(村田)
89	1	C12	22pF/1KV1206_R	SAMSUNG/三星
90	1	C11	3.3uF0603_R	SAMSUNG/三星
91	1	C10	0.1uF0603_R	muRata(村田)
92	1	C1	2nF/1KV1206R	SAMSUNG/三星
93	2	BEAD, R12	10R0603_R	muRata(村田)
94	2	BD1, BD2	WRLS80BD	WRL

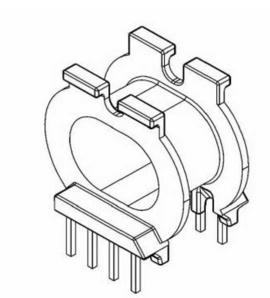
* Note: GaN device spec can find in InnoScience website http://www.innoscience.com.cn/
  Note: transphorm GaN device spec can find in transphorm website https://www.transphormchina.com/

3.3 Transformer Design

Schematic	Structure
	

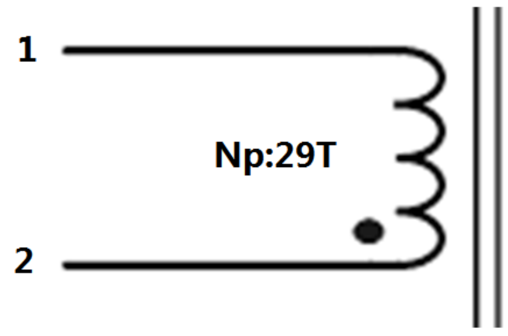
Windings	Wire Gauge	Turns	Start Pin	End Pin	Tape
Np1	Φ0.1 2UEW*20P	21	1	8	2T
Na1	0.12 2UEW	4	5	4	2T
Na2	Φ0.12 2UEW*4P	12	3	4	2T
Ns	Φ0.30 TEX-E*7P	5	F+	F-	2T
Shield	Φ0.14 2UEW*2P	22	4	NC	2T
Np2	Φ0.1 2UEW*20P	11	8	2	2T

BOBBIN PIN Define:

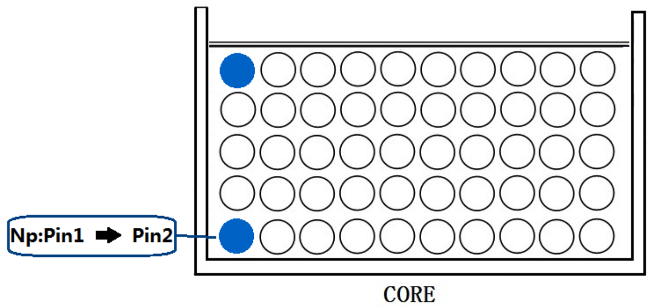


Item	Test Condition	Rating
Primary Inductance	Pin1-2,all other windings open, measured at 100kHz / 1V	390uH+/- 5%
Note	Bobbin: 深圳博众达, ATQ2516 Core： 深圳博众达, ATQ2516	

Schematic

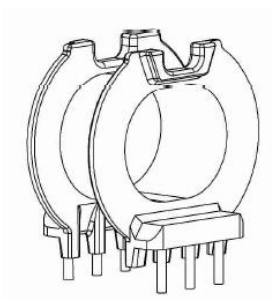


Structure



Windings	Wire Gauge	Turns	Start Pin	End Pin	Tape
Np	Φ0.15 2UEW*20P	29	1	2	2T

BOBBIN PIN Define:



Item	**Test Condition**	**Rating**
Primary Inductance	Pin1-2,all other windings open, measured at 100kHz / 1V	200uH+/- 5%
Note	Bobbin: 深圳博众达, ATQ2315 Core： 深圳博众达, ATQ2315	

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 L4 and L5 are common-mode chocks for the common mode noise suppression. The BD1 and BD2 are bridge rectifier which converts alternating current and voltage into direct current and voltage. The C4, C9, L1 are composed of the Pi filter for filtering the differential switching noise back to AC source.

3.4.2 AP33510 PWM Controller

AP33510, a highly integrated Quasi-Resonant Flyback (QR) controller, integrates high-voltage start-up function through HV pin and X-capacitor discharging function. It also integrates a VCC LDO circuit, which allows the LDO to regulate the wide range VCCL to an acceptable value. This makes the AP33510 an ideal candidate for wide range output voltage applications such as USB PD3.0 PPS. With embedded E-GaN drive, the AP33510 provides a safe and accurate gate signal to control switch Q4 (GaN FET) operations and achieve high-power density charger applications. At no load or light load, the AP33510 enters the burst mode to minimize standby power consumption.

3.4.3 APR349 Synchronous Rectification (SR) MOSFET Driver

As a high performance solution, the APR349 is a secondary-side SR controller to effectively reduce the secondary side rectifier power dissipation which works in both QR/DCM/CCM operation.

3.4.4 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 & CC2 (Pin 11, 10)**: CC1 & CC2 (Configuration Channel 1 & 2) are defined by USB Type-C spec to provide the channel communication link between power source and sink device.
2) **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/CC2 channel communication with the sink device.
3) **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/CC2 channel communication with the sink device.
4) **Loop Compensation:**
   R19 & C19 form the voltage loop compensation circuit, and C18 form the current loop compensation circuit.
5) **OCDRV (Pin5)**: It is the key interface link from secondary decoder (AP43771V) to primary regulation circuit (AP33510). It is connected to Opto-coupler PC1 Pin 2 (Cathode) for feedback information based on all sensed CC1 & CC2 signals for getting desired Vbus voltage & current.
6) **PWR_EN (Pin2) to N-MOSFET Gate**: The pin is used to turn on/off N-MOSFET (Q1) to enable/disable voltage output to the Vbus.

Chapter 4 The Evaluation Board (EVB) Connections

4.1 EVB PCB Layout

Main Board – 1

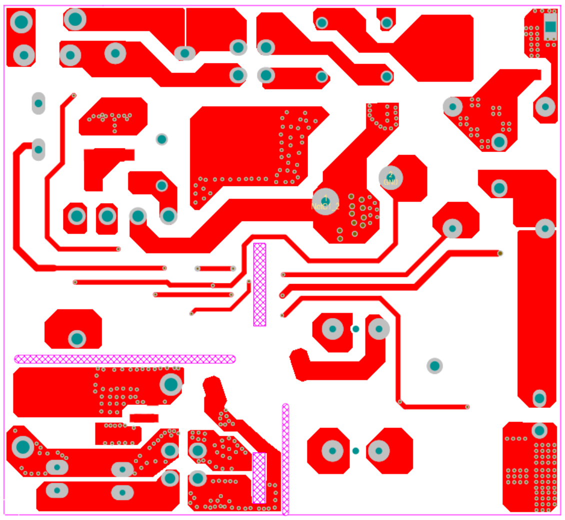


Figure 2. PCB Layout Top View

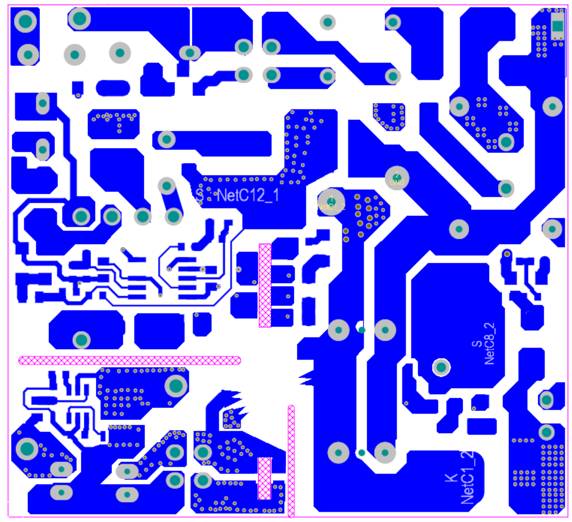


Figure 3. PCB Layout Bottom View

Daughter Board

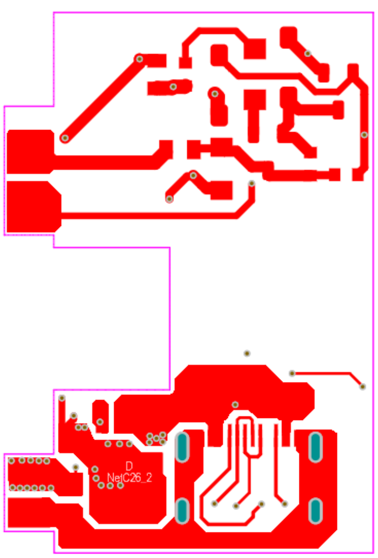


Figure 4. PCB Layout Top View

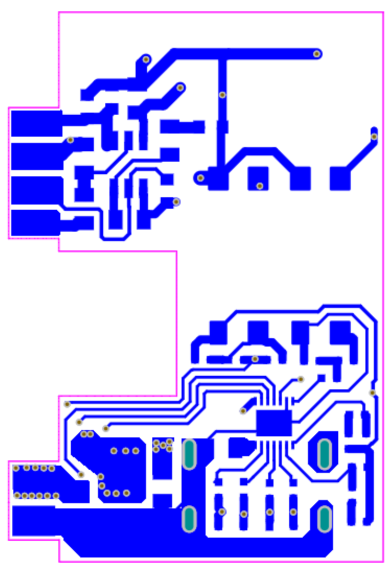


Figure 5. PCB Layout Bottom View

4.2 Quick Start Guide before Connection

1) Before starting the 100W 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

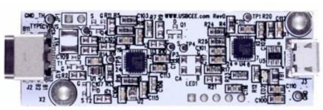
USBCEE PAT Tester	GUI Display	USB-A to Micro-B Cable	Type-C Cable
			

Figure 6. Test Kit / Test Cables

2) Prepare a certified three-foot USB 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) A type-C cable for the connection between EVB's and Type-C receptacles of test kit.

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

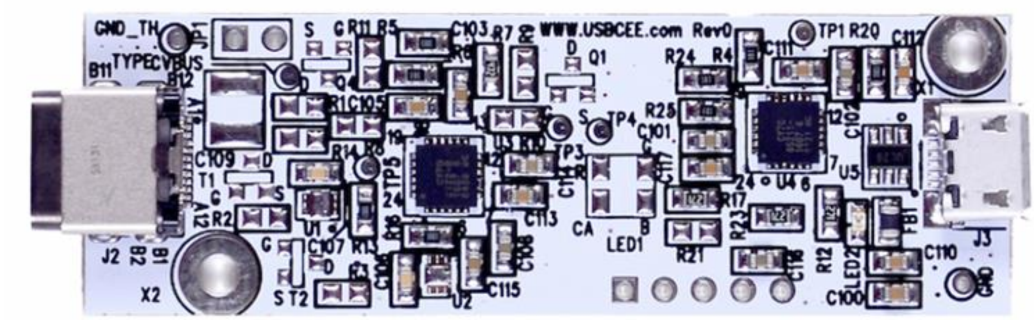


Figure 7. The Test Kit Input & Output and E-load Connections

4.3 Connection with E-Load

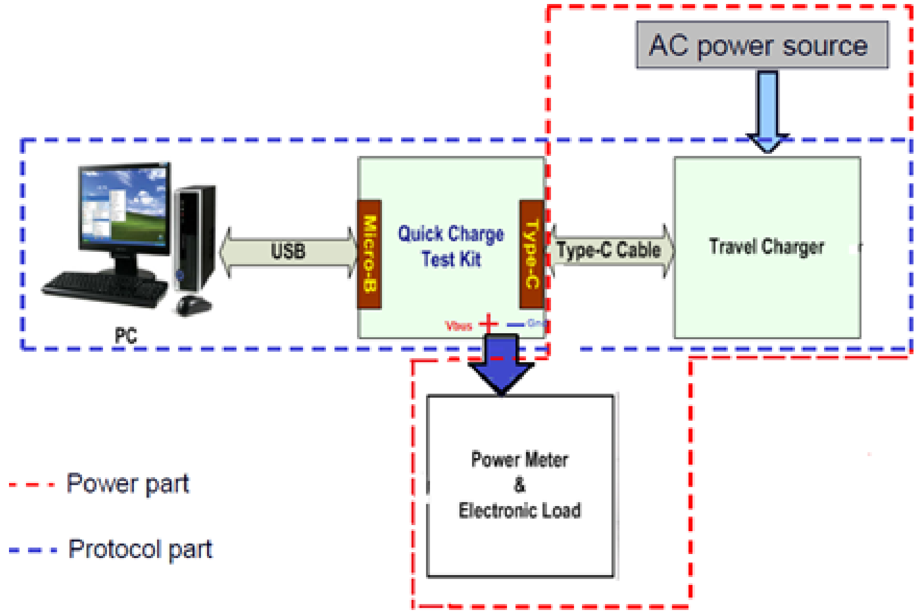


Figure 8. Diagram of Connections in the Sample Board

Chapter 5 Testing the Evaluation Board

5.1 Input & Output Characteristics

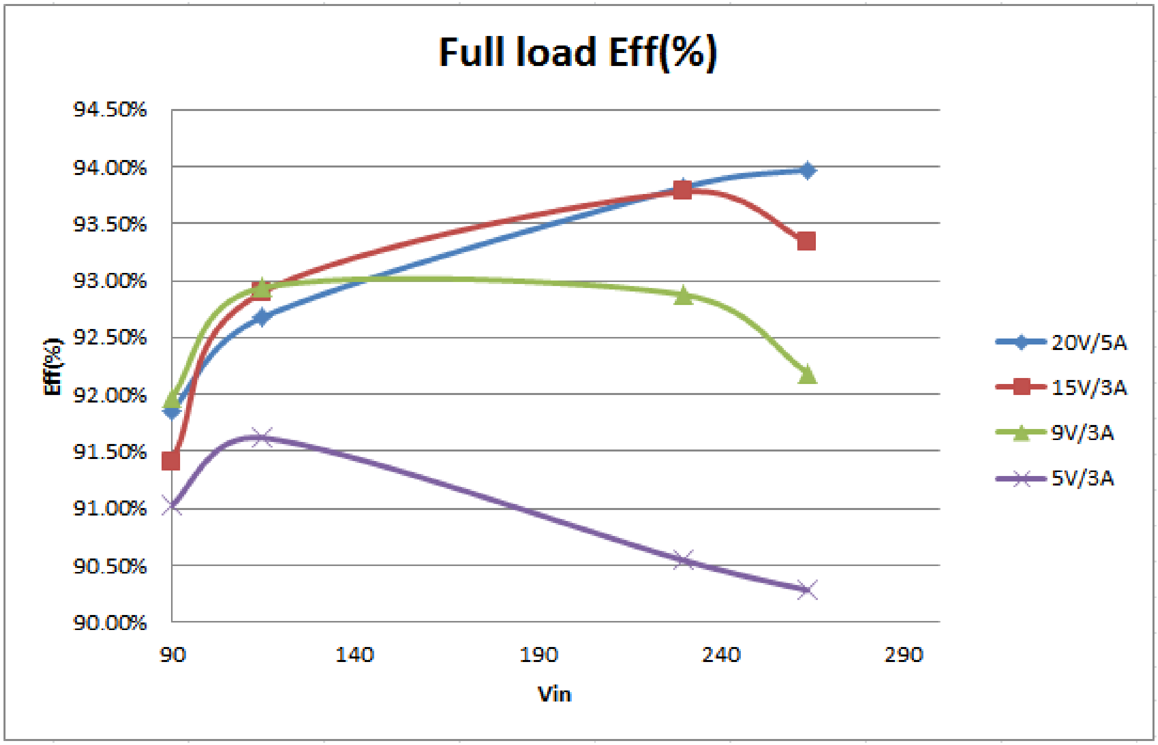
5.1.1 Input Standby Power

Vin(Vac)	F(Hz)	Pin(mW)
90	**60**	21.5
115	**60**	23.9
230	**50**	45
264	**50**	55

5.1.2 Multiple Output Full Load Efficiency at Different AC Line Input Voltage

PDO Mode	Vin(Vac)	F(Hz)	Vout_Board(V)	Iout(A)	Pin(W)	Pout(W)	Eff(%)
20V/5A	90	60	20.38	4.996	110.85	101.82	91.85%
	115	60	20.38	4.996	109.86	101.82	92.68%
	230	50	20.38	4.996	108.53	101.82	93.82%
	264	50	20.38	4.996	108.35	101.82	93.97%
15V/3A	90	60	15.21	3.002	49.95	45.66	91.41%
	115	60	15.21	3.002	49.15	45.66	92.90%
	230	50	15.21	3.002	48.69	45.66	93.78%
	264	50	15.21	3.002	48.92	45.66	93.34%
9V/3A	90	60	9.17	3.002	29.93	27.53	91.98%
	115	60	9.17	3.002	29.62	27.53	92.94%
	230	50	9.17	3.002	29.64	27.53	92.88%
	264	50	9.17	3.002	29.86	27.53	92.19%
5V/3A	90	60	5.15	3.003	16.99	15.47	91.03%
	115	60	5.15	3.003	16.88	15.47	91.62%
	230	50	5.15	3.003	17.08	15.47	90.55%
	264	50	5.15	3.003	17.13	15.47	90.28%

Efficiency vs AC Line At Board End



5.1.3 Multiple Output Average Efficiency at Different Loading

Port-C PD3.0_PDO_20V / 5V Average Efficiency

Vin (Vrms)	Load %	Pin1 (W)	Vout (V)	Iout (A)	Pout (W)	Effi. (%)	Avg. Effi. (%)
115 Vac	100%	109.86	20.38	4.996	101.82	92.68%	92.69%
	75%	82.45	20.29	3.75	76.09	92.28%	
	50%	54.58	20.22	2.51	50.75	92.99%	
	25%	27.14	20.15	1.25	25.19	92.81%	
230 Vac	100%	108.53	20.38	4.996	101.82	93.82%	93.43%
	75%	81.31	20.29	3.75	76.09	93.58%	
	50%	54.08	20.22	2.51	50.75	93.85%	
	25%	27.25	20.16	1.25	25.20	92.48%	
115 Vac	100%	16.88	5.15	3.003	15.47	91.62%	91.88%
	75%	12.51	5.11	2.258	11.54	92.23%	
	50%	8.26	5.06	1.502	7.60	92.01%	
	25%	4.14	5.02	0.756	3.80	91.67%	
230 Vac	100%	17.08	5.15	3.003	15.47	90.55%	89.74%
	75%	12.72	5.11	2.258	11.54	90.71%	
	50%	8.44	5.06	1.502	7.60	90.05%	
	25%	4.33	5.02	0.756	3.80	87.65%	

Port-C PD3.0_PDO_9V / 15V Average Efficiency

Vin	Load %	Pin1	Vout	Iout	Pout	Effi.	Avg. Effi.

(Vrms)		(W)	(V)	(A)	(W)	(%)	(%)
115 Vac	100%	29.62	9.17	3.002	27.53	92.94%	92.93%
	75%	22.16	9.13	2.258	20.62	93.03%	
	50%	14.66	9.08	1.502	13.64	93.03%	
	25%	7.37	9.04	0.756	6.83	92.73%	
230 Vac	100%	29.64	9.17	3.002	27.53	92.88%	91.94%
	75%	22.3	9.13	2.258	20.62	92.45%	
	50%	14.87	9.09	1.502	13.65	91.82%	
	25%	7.54	9.04	0.756	6.83	90.64%	
115 Vac	100%	49.15	15.21	3.002	45.66	92.90%	92.94%
	75%	36.71	15.17	2.258	34.25	93.31%	
	50%	24.41	15.13	1.502	22.73	93.10%	
	25%	12.33	15.08	0.756	11.40	92.46%	
230 Vac	100%	48.69	15.21	3.002	45.66	93.78%	92.62%
	75%	36.77	15.17	2.258	34.25	93.16%	
	50%	24.57	15.13	1.502	22.73	92.49%	
	25%	12.52	15.08	0.756	11.40	91.06%	

5.2 Key Performance Waveforms

5.2.1 100W PD3.0 System Start-up Time

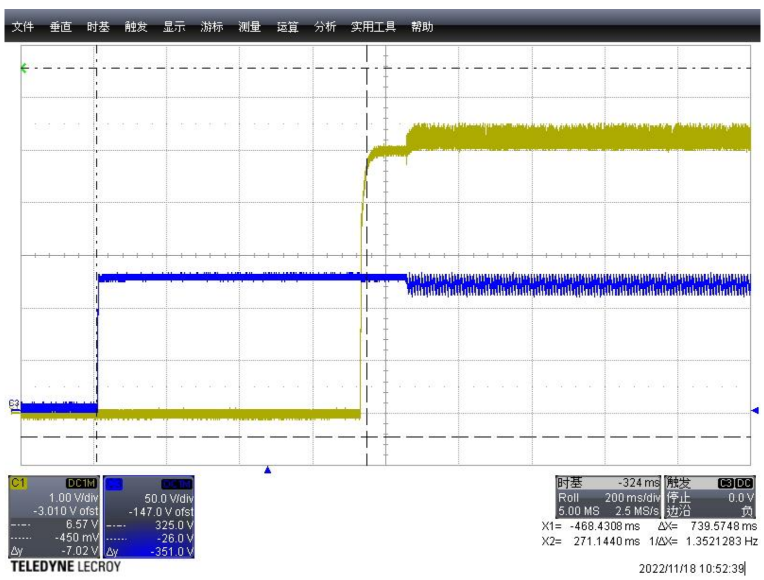


Figure 9. Turn on time is 739ms at Full Load@ 90Vac

5.2.2 Q1 / Q2 MOSFET Voltage Stress at Full Load @264Vac

Primary side MOSFET : Q1 and Secondary side SR MOSFET- Q2

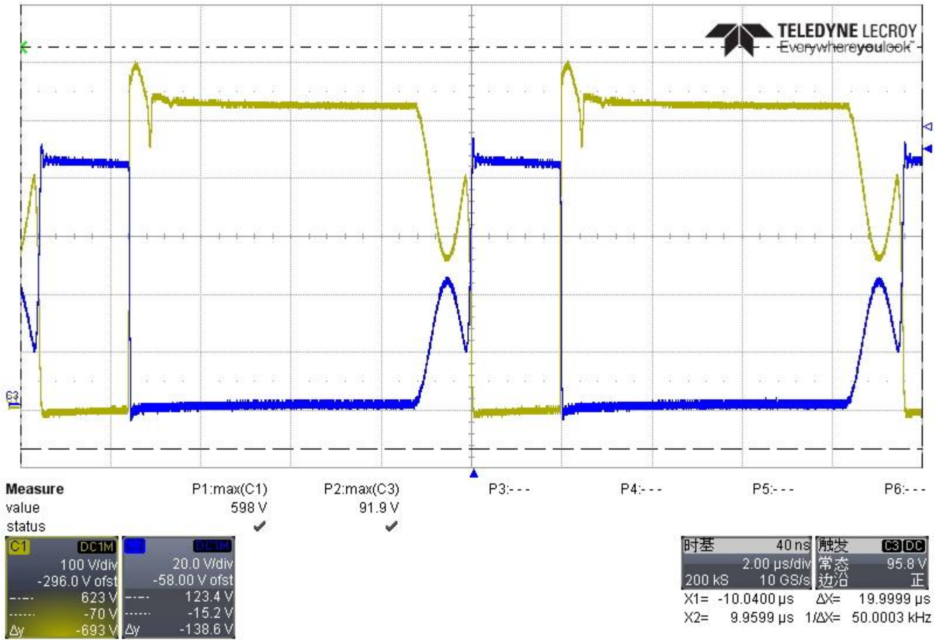


Figure 10. Q3/Q4 Vds Voltage stress

Component	Vout	Vds	Vds_Max_Spec	Ratio of voltage stress
Q1	20V	598V	650V	92%
Q2		91.9V	100V	91.9%

5.2.3 System Output Ripple & Noise with the Cable

Connect 47uF AL Cap and 104MLCC to the cable output unit in parallel

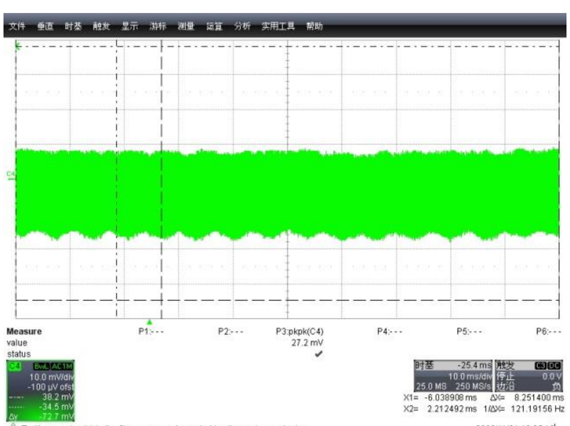


Figure 11. 90Vac/60Hz@ 5V/3A ΔV=27.2mV

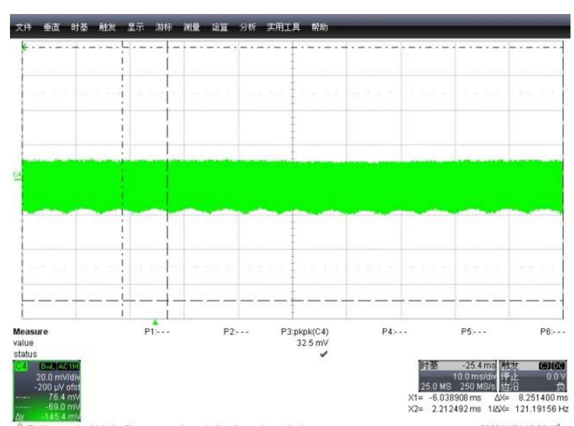


Figure 12. 264Vac/50Hz@5V/3A ΔV=32.5mV

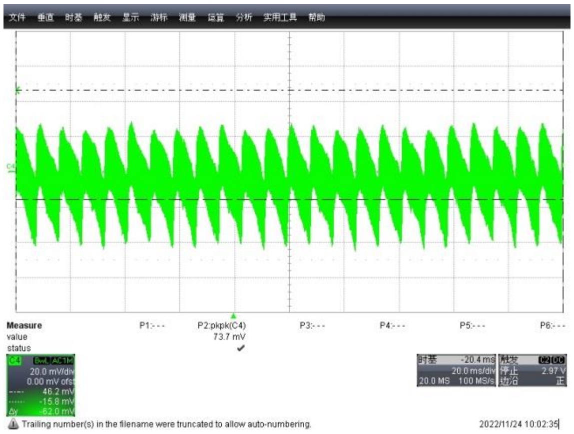


Figure 13. 90Vac/60Hz@9V/3A ΔV=73.7mV

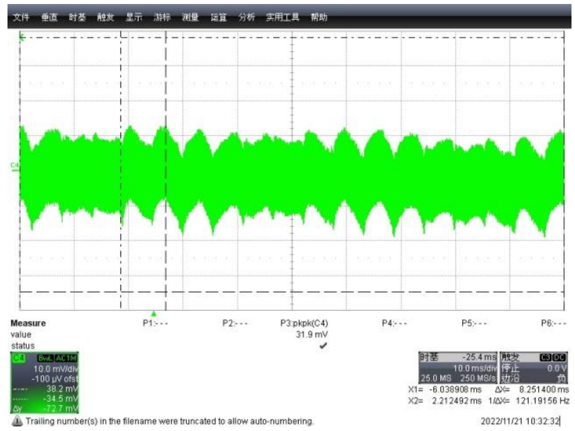


Figure 14. 264Vac/50Hz@9V/3A ΔV=31.9mV

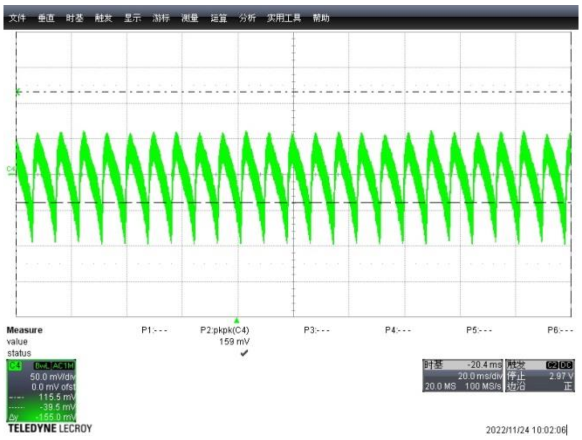


Figure 15. 90Vac/60Hz@15V/3A ΔV=159mV

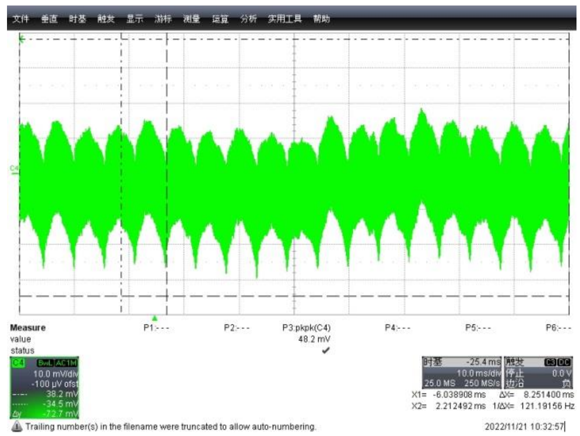


Figure 16. 264Vac/50Hz@15V/3A ΔV=48.2mV

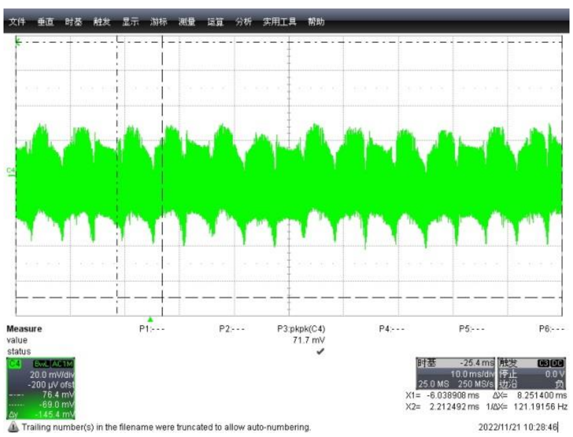


Figure 17. 90Vac/60Hz@20V/5A ΔV=71.7mV

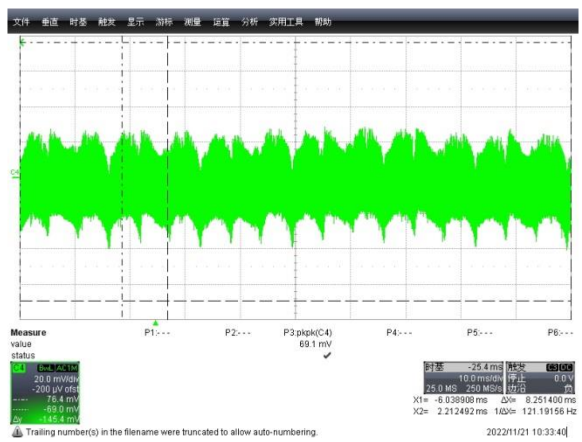


Figure 18. 264Vac/50Hz@20V/5A ΔV=69.1mV

5.2.4 Dynamic load ----10% Load~90% Load, T=5mS, Rate=100mA/uS (PCB End)

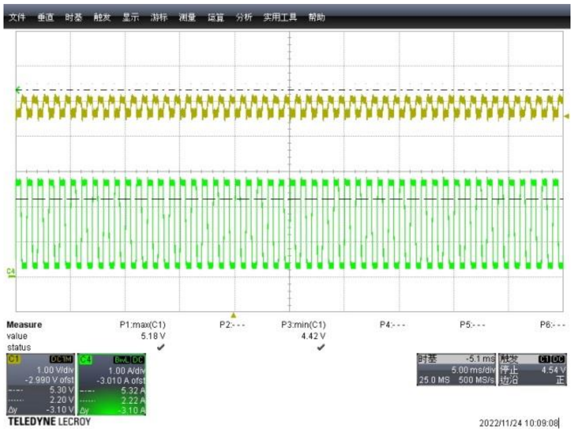


Figure 19. 90Vac/60Hz Port-C@ Vout=5V

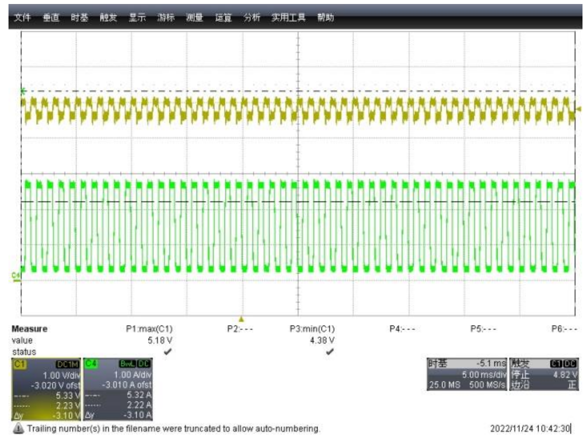


Figure 20. 264Vac/50Hz Port-C@ Vout=5V

Figure 21. 90Vac/60Hz Port-C@ Vout=9V

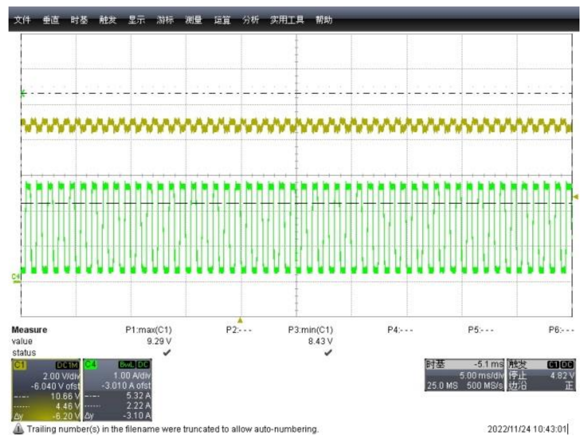


Figure 22. 264Vac/50Hz Port-C@ Vout=9V

	Vo_ Undershoot(V)	Vo_ Overshoot(V)		Vo_Undershoot(V)	Vo_Overshoot(V)
Vin=90Vac@5V	4.42	5.18	Vin=90Vac@9V	8.37	9.30
Vin=264Vac@5V	4.38	5.18	Vin=264Vac@9V	8.43	9.29

Figure 23. 90Vac/60Hz Port-C@ Vout=15V

Figure 24. 264Vac/50Hz Port-C@ Vout=15V

Figure 25. 90Vac/60Hz Port-C@ Vout=20V

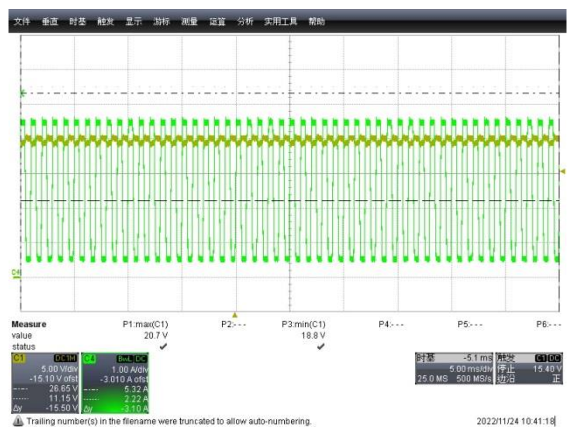


Figure 26. 264Vac/50Hz Port-C@ Vout=20V

	Vo_ Undershoot(V)	**Vo_ Overshoot(V)**		**Vo_Undershoot(V)**	**Vo_Overshoot(V)**
Vin=90Vac@15V	14.30	15.7	Vin=90Vac@20V	18.8	20.80
Vin=264Vac@15V	14.30	15.6	Vin=264Vac@20V	18.8	20.70

5.2.5 Output Voltage Transition Time from Low to High

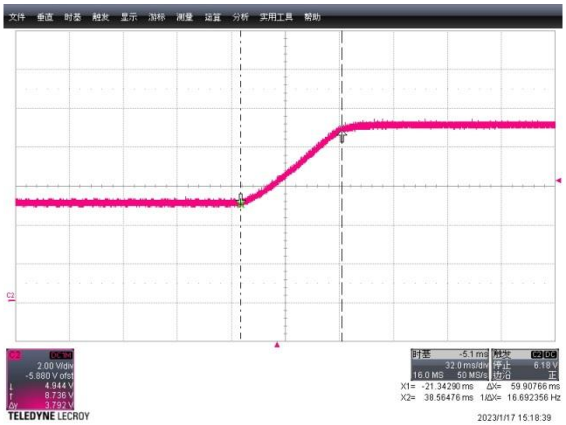


Figure 27. 5V→9V Rise Time = 59.91ms @90Vac

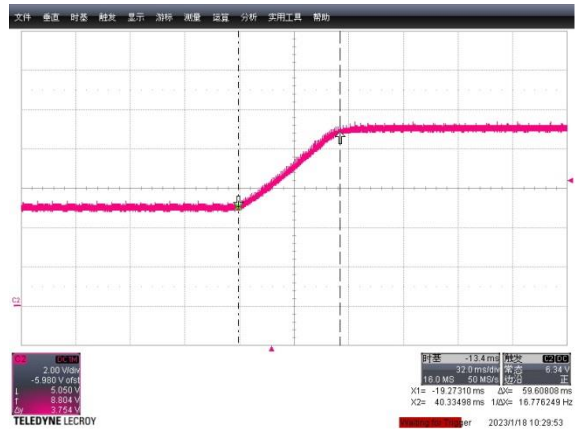


Figure 28. 5V→9V Rise Time = 59.61ms @264Vac

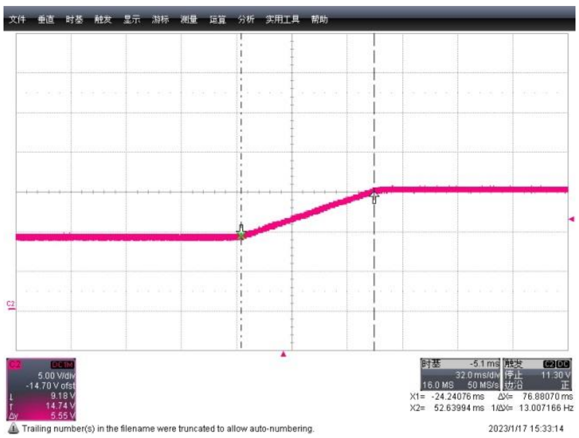


Figure 29. 9V→15V Rise Time = 76.88ms@90Vac

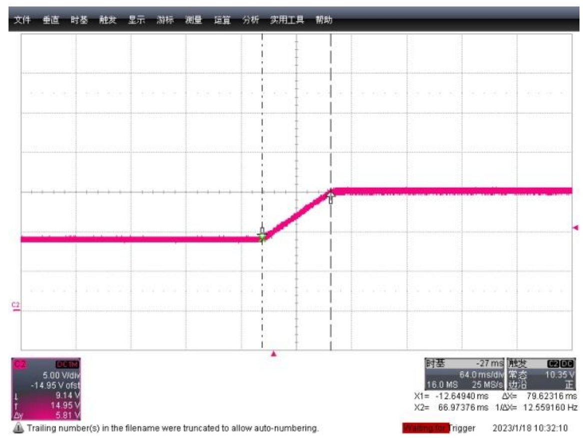


Figure 30. 9V→15V Rise Time = 79.62ms@264Vac

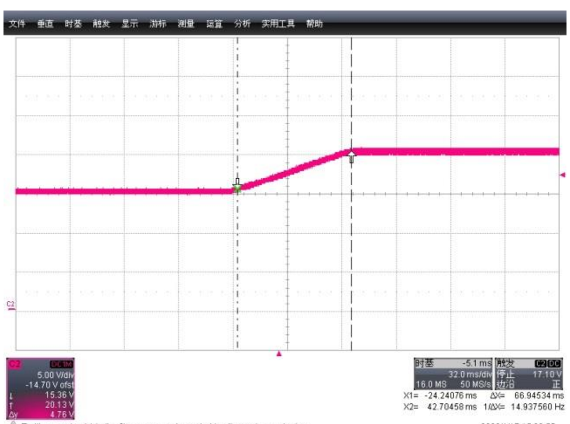


Figure 31. 15V→20V Rise Time = 66.95ms @90Vac

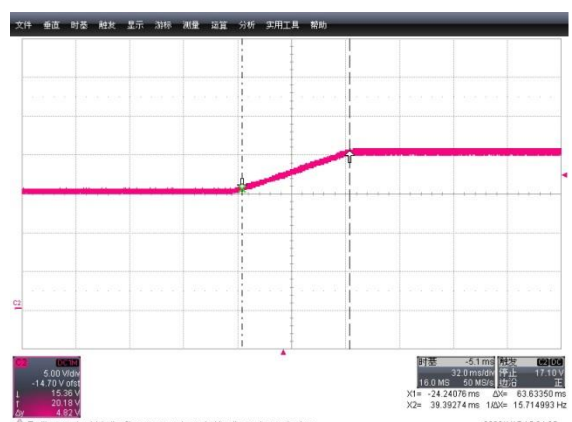


Figure 32. 15V→20V Rise Time = 63.63 ms @264Vac

5.2.6 Output Voltage Transition Time from High to Low

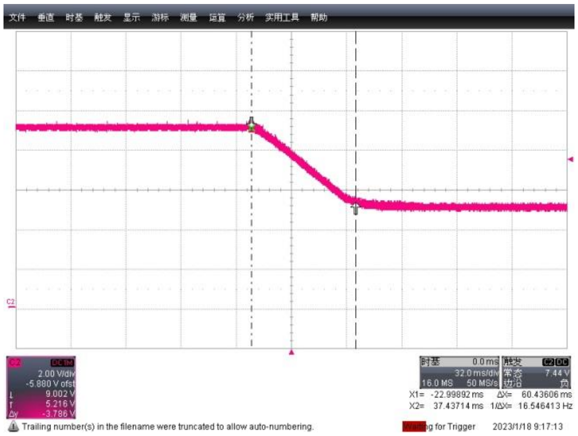


Figure 33. 9V→5V Fall Time = 60.44ms @90Vac

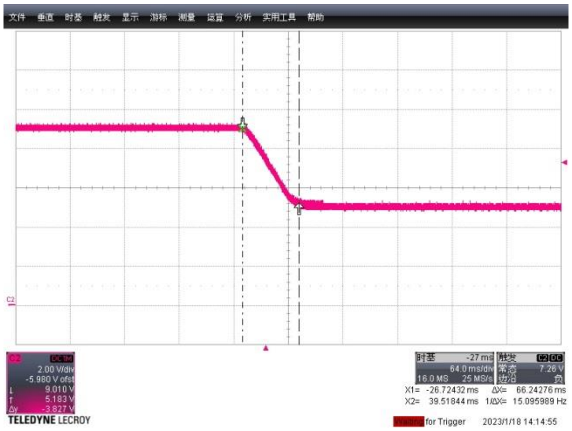


Figure 34. 9V→5V Fall Time = 66.24ms @264Vac

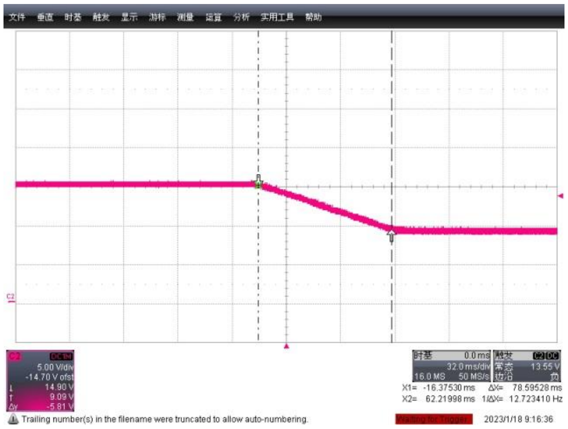


Figure 35. 15V→9V Fall Time = 78.60ms @90Vac

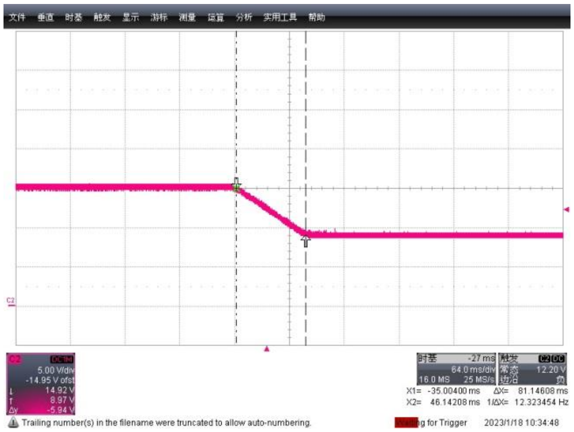


Figure 36. 15V→9V Fall Time = 81.15ms @264Vac

Figure 37. 20V→15V Fall Time = 61.62ms @90Vac

Figure 38. 20V→15V Fall Time = 68.73ms @264Vac

5.2.7 Thermal Testing

Output Condition : 20V/3.25A

Main Voltage	Temperature (°C)					
	BD1	Q4	Q3	Q2	U1	U4
90Vac/60Hz	107.6	118.5	109.3	97.4	110.0	89.5
264Vac/60Hz	69.6	121.3	116.7	68.5	115.7	97.2

Test Condition: Vin=90Vac @ 20V-3.25A Full load Open Frame

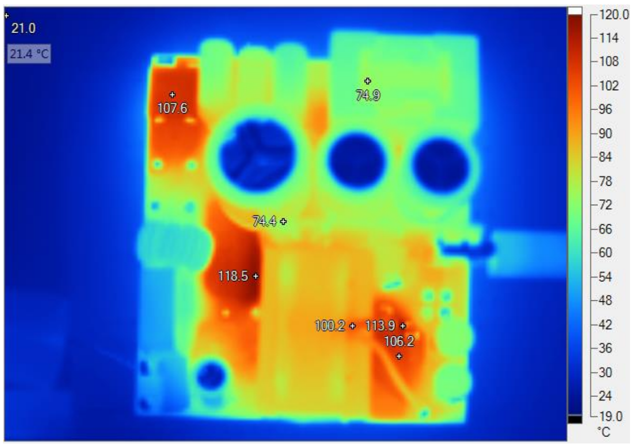


Figure 39. Top Components side

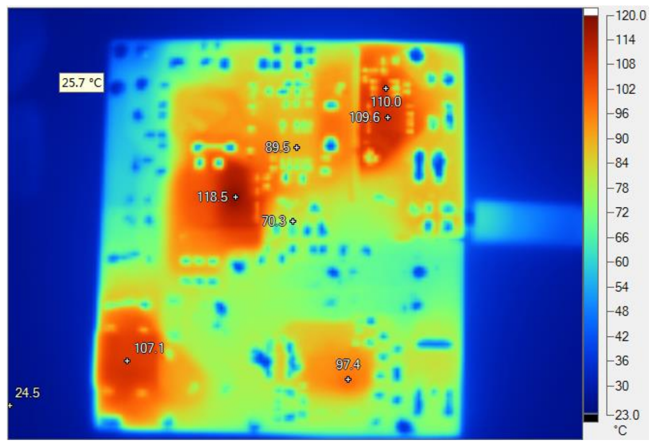


Figure 40. Bottom Suface Mount side

Test Condition: Vin=264Vac @ 20V-3.25A Full load Open Frame

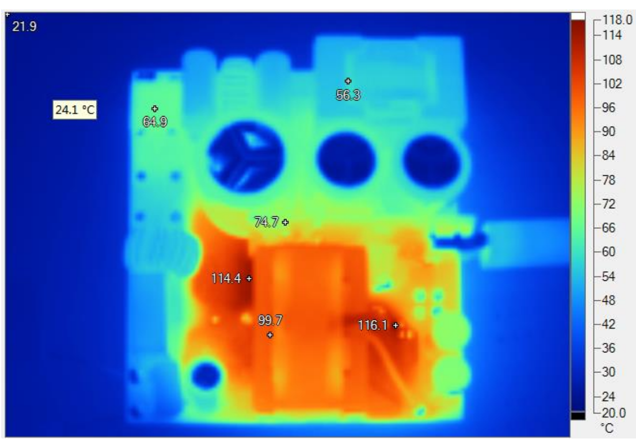


Figure 41. Top Components side

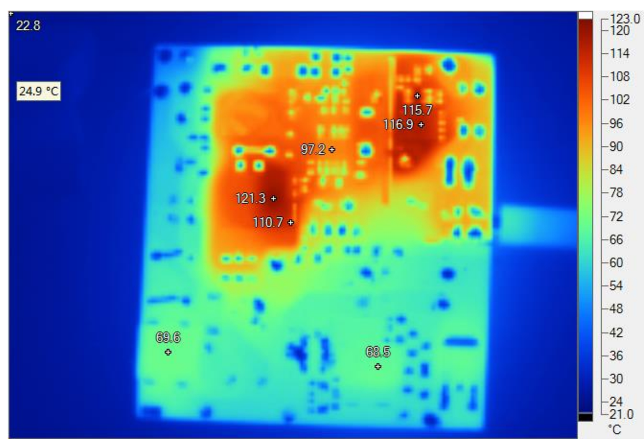


Figure 42. Bottom Suface Mount side

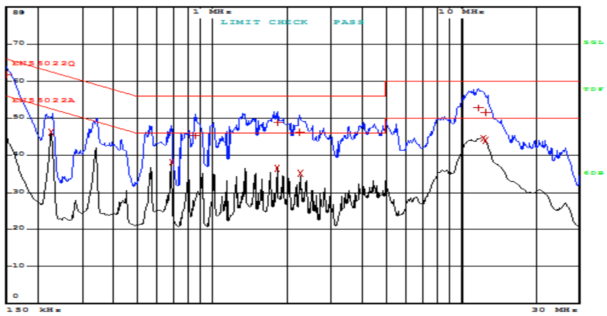
BD1: Bridge Rectifier
Q4 : Primary Side High Voltage GaN FET
Q3 : Secondary Side Sync-Rectifier
Q2 : APFC High Voltage GaN FET
U1 : AP33510, QR Controller
U4 : APR349, Sync-Rectifier Controller

Note: Component temperature can be further optimized with various system design and thermal management approaches by manufacturers.

5.3 EMI (Conduction) Testing

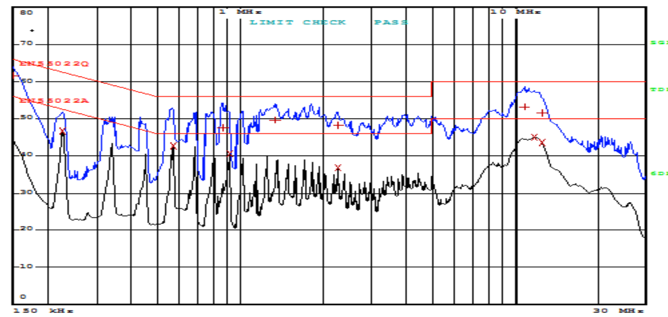
115Vac testing results

Output Condition : 20V/5A



EDIT PEAK LIST (Final Measurement Results)			
Trace1:	EN55022Q		
Trace2:	EN55022A		
Trace3:	---		
TRACE	FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1 Quasi Peak	150 kHz	61.75	-4.24
2 Average	225.562855639 kHz	46.29	-6.31
2 Average	680.675429436 kHz	38.04	-7.95
1 Quasi Peak	855.719977385 kHz	45.33	-10.66
2 Average	1.80482336524 MHz	36.49	-9.50
1 Quasi Peak	1.8228715989 MHz	48.76	-7.23
1 Quasi Peak	2.24649226677 MHz	46.38	-9.61
2 Average	2.26895718944 MHz	35.27	-10.72
1 Quasi Peak	11.7179860284 MHz	52.86	-7.13
2 Average	12.1937832503 MHz	44.54	-5.45
1 Quasi Peak	12.4388782936 MHz	51.57	-8.42
2 Average	12.4388782936 MHz	43.90	-6.09

Figure 43. 115Vac/60Hz L line

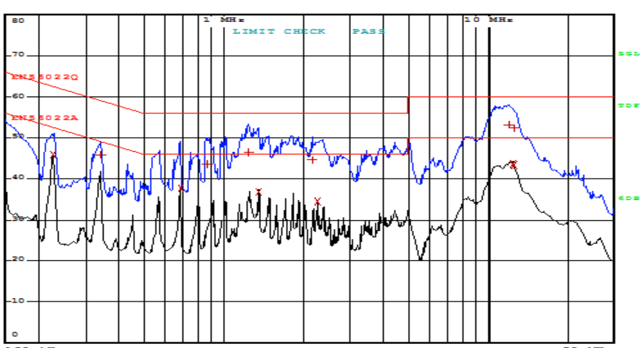


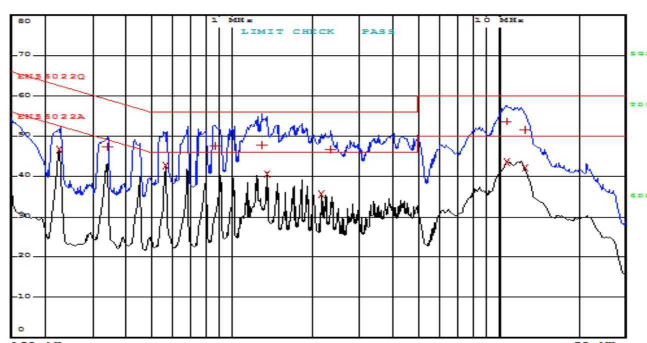
EDIT PEAK LIST (Final Measurement Results)			
Trace1:	EN55022Q		
Trace2:	EN55022A		
Trace3:	---		
TRACE	FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1 Quasi Peak	150 kHz	61.71	-4.28
2 Average	225.562855639 kHz	46.76	-5.84
2 Average	569.056444353 kHz	42.68	-3.31
1 Quasi Peak	864.277177159 kHz	47.66	-8.33
2 Average	908.363999266 kHz	40.73	-5.26
1 Quasi Peak	1.32578199726 MHz	49.58	-6.41
1 Quasi Peak	2.26895718944 MHz	48.29	-7.70
2 Average	2.26895718944 MHz	36.76	-9.23
1 Quasi Peak	10.7142212856 MHz	53.26	-6.73
2 Average	11.7179860284 MHz	44.99	-5.00
1 Quasi Peak	12.4388782936 MHz	51.50	-8.49
2 Average	12.4388782936 MHz	43.62	-6.37

Figure 44. 115Vac/60Hz N line

230Vac testing results

Output Condition : 20V/5A





EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
2	Average	225.562855639 kHz	45.85	-6.76
1	Quasi Peak	339.190678959 kHz	45.91	-13.31
2	Average	680.675429436 kHz	37.68	-8.31
1	Quasi Peak	864.277177159 kHz	43.59	-12.40
1	Quasi Peak	1.23658080545 MHz	46.47	-9.52
2	Average	1.3524302154 MHz	36.79	-9.20
1	Quasi Peak	2.1374603093 MHz	44.54	-11.45
2	Average	2.26895718944 MHz	34.61	-11.38
1	Quasi Peak	11.9535175476 MHz	53.33	-6.66
2	Average	12.3157210828 MHz	43.64	-6.35
1	Quasi Peak	12.4388782936 MHz	52.29	-7.70
2	Average	12.4388782936 MHz	43.32	-6.67

Figure 45. 230Vac/50Hz L line

EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
2	Average	225.562855639 kHz	46.72	-5.88
1	Quasi Peak	339.190678959 kHz	47.32	-11.89
2	Average	563.422222132 kHz	42.68	-3.31
1	Quasi Peak	864.277177159 kHz	47.59	-8.40
1	Quasi Peak	1.28679094484 MHz	47.69	-8.30
2	Average	1.3524302154 MHz	40.57	-5.43
2	Average	2.1374603093 MHz	35.55	-10.44
1	Quasi Peak	2.33770886123 MHz	46.72	-9.27
1	Quasi Peak	10.6081398868 MHz	53.58	-6.41
2	Average	10.6081398868 MHz	43.59	-6.40
1	Quasi Peak	12.4388782936 MHz	51.44	-8.55
2	Average	12.4388782936 MHz	42.19	-7.80

Figure 46. 230Vac/50Hz N line