18W QC3.0 SSR Premium Charger EV1Board User Guide

Contents

Chapter 1. Summary

1.1 General Description

The 18W QC 3.0 charger Evaluation Board EV1 is composed of three main parts, AP3302 offers the QR/DCM PWM switching, APR34509 is an N-Mosfet SO-8EP co-packaged Synchronous Rectification Switcher, and the AP43331N performs QC 3.0 class A decoding function. Based on monitoring D+ & D- signals in USB Type A port, the AP43331N interprets desired voltage and current setting and provides the real time feedback information to primary side AP3302 controller for voltage regulation. The 18W QC3.0 quick charger reference design exemplifies the cost-effective performance-optimized QC3.0 charging solution.

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1.2 Key Features

1.2.1 System Key Features

- SSR Topology Implementation with an Opto-coupler for Accurate Step Constant Voltage and Current Control
- QC 3.0 Compliance
- Meet DOE6 and CoC Tier 2 Efficiency Requirements
- <75mW No-Load Standby Power

1.2.2 AP3302 Key Features

- Quasi-Resonant Operation with Valley Lock under all Lines and Load Conditions
- Switching Frequency: 22kHz-120kHz
- Non-audible-noise QR Controlling
- Soft Start Process during the Start-up Turn-on Moment
- During the burst mode operation and Low start-up operating quiescent currents, 75mW standby power can be achieved
- Built-in Jittering Frequency Function which is the EMI emission can be improved
- Internal Auto Recovery OCP, OVP, OLP, OTP Power Protection, cycle by cycle current limit, also with DC polarity & transformer short and Brown out Protection

1.2.3 APR34509 Key Features

- Co-package (SO-8EP) N-Mosfet and synchronous rectification controller IC
- Synchronous Rectification supporting the DCM,CCM mode and QR Flyback
- Eliminate Resonant Ringing Interference
- Fewest External Components used & the total SR space reduced.

1.2.4 AP43331N Key Feature

- Supporting Qualcomm QC 3.0 and QC2.0
- Built in Shunt Regulator for Constant Voltage and Constant Current
- Programmable OVP/UVP/OCP/OTP
- Internal Discharge MOS
- Certified Qualcomm QC3.0 protocol spec (UL Report Number – 4787662260-1, 3/22/2017)
- Output cable voltage compensation

1.3 Applications

- **18W QC3.0 Quick Charge**

1.4 Main Power Specifications (CV & CC Mode)

Parameter	Value
Input Voltage	90Vac to 264Vac
Input standby power	< 75mW
Main Output Vo / Io	QC2.0: 5V/3A, 9V/2A, 12V/1.5A, QC3.0: 3.6V ~12V, Io <3A,
Efficiency	87.5%
Voltage step	+ / - 0.2V
Total constant Output Power	<= 18W
Protections	OVP, UVP, OLP, BNO, FOCP, SSCP, OTP
XYZ Dimension	37 x 39 x 20 mm
ROHS Compliance	Yes

1.5 Evaluation Board Pictures

Figure 1: Top View

Figure 2: Bottom View

Chapter 2. Power Supply Specification

2.1 Specification and Test Results

Parameter	Test conditions	Min	Nom	Max	Eff / DoE VI	Eff / Tier2	Test Summary
V_{ac-in} Input Voltage		90 V_{rms}	115/230	264 V_{rms}			
F_{line} Frequency		47 Hz	50/60	64 Hz			
I_{in} Input Current				0.8 A_{rms}			Pass
No load Pin	At 230Vac_in/50Hz , @ 5V, Pin < 75mW			75mW			Pass , the test result is 48mW
5V/3A @115Vac/230Vac Average efficiency	Board end		5V/3A		81.39%	81.84%	Pass, average efficiency is 86.4%
5V/3A @115Vac/230Vac 10% efficiency	Board end		5V/0.3A			72.48%	Pass, efficiency is 83.1%
9V/2A @115Vac/230Vac Average efficiency	Board end		9V/2A		85.0%	85.45%	Pass, average efficiency is 87.85%
9V/2A @115Vac/230Vac 10% efficiency	Board end		9V/0.2A			75.45%	Pass, efficiency is 83.4%
12V/ 1.5A @115Vac/230Vac Average efficiency	Board end		12V/1.5A		85.0%	85.45%	Pass, average efficiency is 88.89%
12V/ 1.5A @115Vac/230Vac 10% efficiency	Board end		12V/0.15A			75.45%	Pass, efficiency is 79.3%

2.2 Compliance

Parameter	Test conditions	Min	Nom	Max	Test Summary
Standby Power (mW)	5V Output			75mW	Pass
Output Voltage Tolerance	5V/0-3A	4.75V	5V	5.25V	Pass
Output Voltage Tolerance	9V/0-2A	8.55V	9V	9.45V	Pass
Output Voltage Tolerance	12V/0-1.5A	11.4V	12V	12.6V	Pass
Output Connector	USB Type A				
Temperature	90Vac , 9V / 2A				Pass
Dimensions (W/D/H)	37mm x 39mm x 20mm				
Safety	IEC/EN/UL 60950 Standard				
EMI/EMC	FCC/EN55022 Class B				Pass

Chapter 3. Schematic

3.1 EV1 Board Schematic

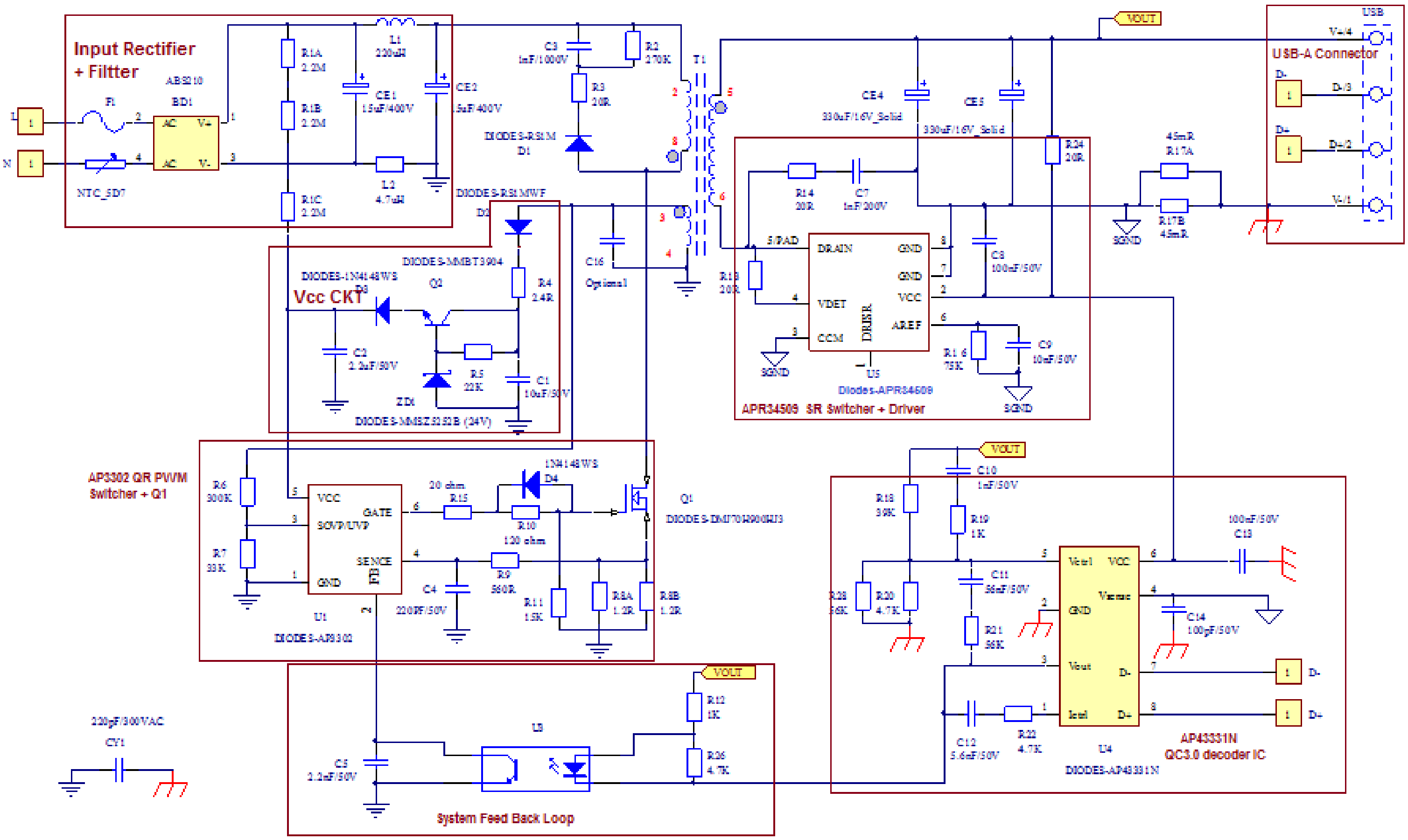


Figure 3: Evaluation Board Schematic

3.2 Bill of Material (BOM)

Designator	Comment	Footprint	Quantity	Remark
BD1	ABS210	D-46_6A	1	
C1	10uF/50V	0805	1	
C2	2.2uF	0805	1	
C3	1nF/1000V	0805	1	
C4	220PF/16V	0603	1	
C5	2.2nF/16V	0603	1	
C7	1nF/100V	0603	1	
C10	1nF/25V	0603	1	
C8，C13	100nF/25V	0603	2	
C9	10nF/25V	0603	1	
C11	56nF/25V	0603	1	
C12	5.6nF/25V	0603	1	
C14	100pF/16V	0603	1	
C16	Optional			
CE1, CE2	15uF/400V E-Cap	CE5-D10	2	
CE4	330uF/16V,Solid Cap	CE5-D5	1	
CE5	470uF/16V,Solid Cap	CE5-D5	1	
CY1	220pF	CY7.5	1	
D1	US1M	SMA	1	
D2	RS1MWF	SOD123F	1	
D3,D4	1N4148W	SOD323	2	
F1	3.15A/300VAC	Fuse-P5.0	1	
L1	DM Chock，D5, 220uH	LD-D4.5XP2.5	1	
L2	4.7uH	0805	1	
NTC	5D-7	C5-3X8	1	
Q1	DIODES-DMJ70H900HJ3 , Vds=700VDC, Rds_on =0.9ohm	TO-251	1	DMJ70H900HJ

Designator	Comment	Footprint	Quantity	Remark
Q2	MMBT3904	SOT-23	1	
R1A, R1B, R1C	2.2M ohm	0805	3	
R2	270K	1206	1	
R3	20R	1206	1	
R4	2.4R	0805	1	
R5 , R11	15K	0603	2	
R6	300K	0603	1	
R7	33K	0603	1	
R8A,R8B	1.2R	0805	2	
R9	560R	0603	1	
R10	120 ohm	0603	1	
R15	20 ohm	0603	1	
R12, R19	1K	0603	2	
R13, R14, R24	20R	0603	3	
R16	75K	0603	1	
R17A, R17B	45 mohm	1206	2	
R18	39K	0603	1	
R20, R22, R26	4.7K	0603	3	
R21, R28	56K	0603	2	
U1	AP3302	SOT26	1	
U3	TCLT1006	OP817-SOD	1	Or PIC817
U4	AP43331N	SO-8	1	
U5	APR34509	SO-8EP	1	
ZD1	MMSZ5251B,24V Zener Doide	SOD123	1	
USB	USB CLASS A Connector	USB-A	1	
T1	PQ2016 Low Height Bobin ,H=12mm	PQ2016D	1	
PCB	37mm*39mm double-side		1	

3.3 Transformer design

PQ2016 （Ae=64mm2）Height=12mm						
NO	NAME	TERMINAL NO.		WINDING		
		START	FINISH	WIRE	TURNS	Layers
1	Np1	8	7	Φ0.23*1	45	3
2	Na	3	4（GND）	Φ0.18*1	18	1
3	Shield	4（GND）	NC	Φ0.13*1	5	疏绕
4	Ns	5	6	Φ0.65 TIW *1	6	2
5	Shield	4（GND）	NC	Φ0.13*1	Full	1
6	Np2	7	2（VBUS）	Φ0.23*1	20	2

Primary Inductance	Pin 8-2,all other windings open, measured at 1kHz, 0.4VRMS	950uH, ±5%
Primary Leakage Inductance	Pin 8-2, all other windings shorted, measured at 10kHz, 0.4VRMS	20 uH (Max.)

3.4 Schematics Description

3.4.1 AC Input Circuit & Differential Filter

There are three components in the section. The Fuse F1 protects against over-current conditions which occur when some main components failed. The line filter is consisted of L1, L2 & two bulk caps CE1 & CE2, it will block the switching noise back to AC line. The BD1 is rectifier, and basically converts alternating current & voltage into direct current & voltage.

3.4.2 AP3302 PWM Controller

The AP3302 PWM controller U1 & Opto-Coupler U3 and Q1 are the power converting core components. The R1A, R1B, R1C resistor path will provide start-up voltage and current during starting up through Vcc (Pin 5). The subsequent VCC power will be provided by voltage feedback from the auxiliary winding through D2, D3, Q2, R4, R5, ZD1 regulator circuit. This design is to accommodate with the required wide voltage range to support QC3.0 various protocols from 3.6V to 12V.

Based on feedback of secondary side from Pin 3 of AP43331N Decoder to primary side FB pin of AP3302 through Opto-coupler U3, the AP3302 PWM controller will switch Q1 ON and Off by certain duty cycle to regulate desired voltage and current on the secondary side.

3.4.3 APR34509 Mosfet Co-packaged Synchronous Rectification (SR) Switcher

APR34509 operates in DCM mode in this design and drive the internal MOSFET based on the secondary side transformer on/off duty cycle.

3.4.4 AP43331N QC3.0 Decoder Interface to Power Devices

AP43331N is highly integrated secondary side constant voltage (CV) and constant current (CC) controller with QC3.0 decoder.

1) **D+ & D- (Pin 7, 8)**: D+ & D- pin voltage are defined by QC3.0 spec to provide the channel communication link between power AC source and sink devices.
2) **Constant Voltage (CV)**: The CV is implemented by sensing the ratio of R20 & R18 voltage (pin 5) and comparing with internal reference voltage to generate a CV compensation signal on the pin 3. There is a voltage loop compensation circuit C11 & R21 between Pin5 & Pin3, the fast voltage response can be obtained by adjusting their value. The output voltages can be adjusted by firmware programming.
3) **Constant Current (CC)**: The CC is implemented by sensing the voltage across current sense resistor (R17A & R18B) and current sense amplifier, then comparing with internal programmable reference voltage to generate a compensation signal on the pin3.
4) **CC Loop Compensation:** between Pin3 & Pin1's C12, R22 are for the current loop compensation circuit.
5) **Vout Pin 3**: It is the key interface link from secondary decoder (AP43331N) to primary regulation circuit (AP3302). It is connected to Opto-coupler through U3 for feedback information based all sensed D+ & D- voltage status for getting desired output charging voltage & current.

Chapter 4. The Evaluation Board (EVB) Connections

4.1 EVB PCB Layout

The thickness for both sides of PCB board trace cooper is 2 Oz.

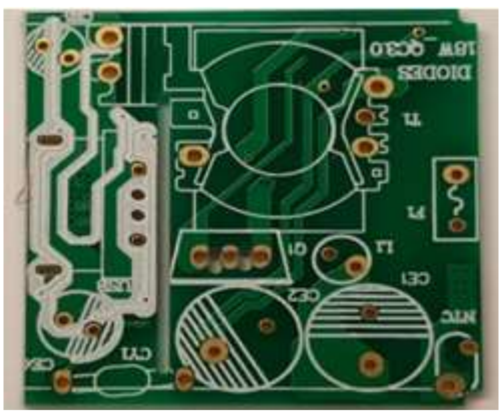


Figure 4: PCB Board Layout Top View

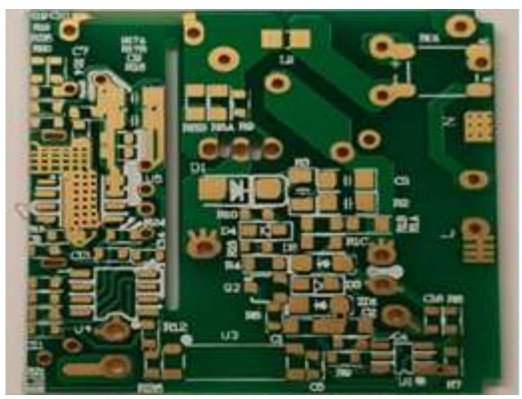


Figure 5: PCB Board Layout Bottom View

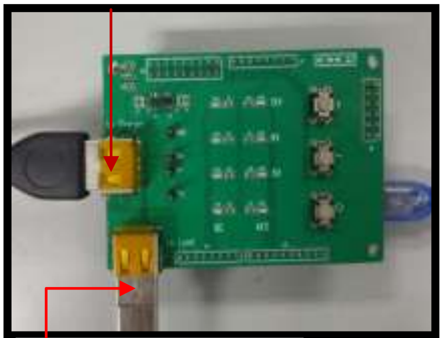
4.2 Quick Start Guide Before Connection

1) Before starting the 18W QC3.0 EVB test, the end user needs to prepare the following tool. For details,
    - Test Kit: Diodes 18W QC3.0 & 2.0 Test Kit

QC2.0 & QC3.0 test Kit

USB-A to Micro-B Cable

Connect to Charger output



Connect to Load

Figure 6: Test Kit

Figure 7 Test Cable

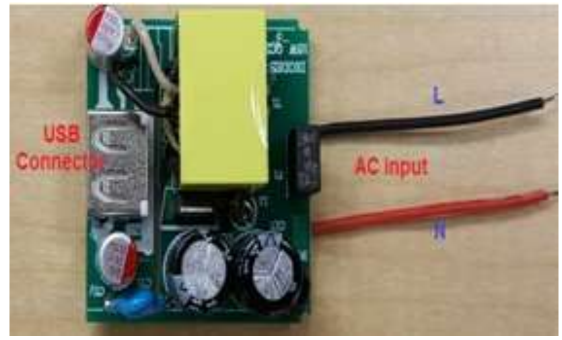


Figure 8: The QC3.0 Board Input & Output

2) Prepare a one-foot USB 3.0 - Micro B cable and a one side cut USB-3.0 Cable to the E-load.

3) Connect the sample input AC L & N wires 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) Use 2 banana jack cables, one port of the cables are connected to E-load + & - terminals while the other port Of the cables

6) Or use a smart phone instead of E-load to connected with A Standard-A to Micro-B cable output

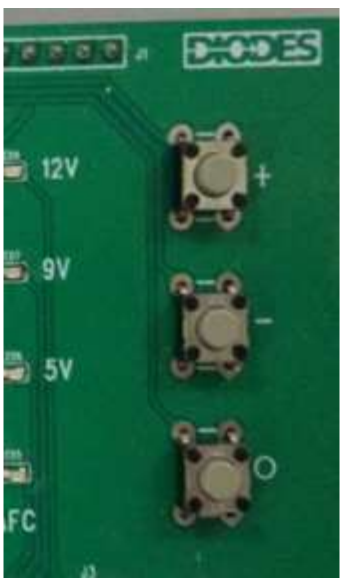
Figure 9: the connection between the 18W QC3.0 Evaluation Board to a QC3.0-equipped smart phone

4.3 System Setup

4.3.1 QC 3.0 sample load connection + Test Kit

Figure 10: The Test Kit Input & Output and E-load Connections

4.3.2 QC3.0 test Kit test procedures



- The charger output default setting is 5V when was turned on
- Chose mode of QC2.0 or QC3.0 by pushing O button
- If in QC2.0 mode, the charger output will be increased
  To 9V or 12V when push the "+" button once time from 5V
  And the charger voltage will be decreased to 9V then to 5V from 12V when push the "-" button once time
- If in QC3.0 mode, the charger voltage will be increased by 200mV/per step when push the "+" button once time until from 3.6V to 12V
- If in QC3.0 mode, the charger voltage will be decreased by 200mV/per step when push the "-" button once time from 12V to 3.6V

Figure 11: The Test Kit test Buttons

Chapter 5. Testing the Evaluation Board

5.1 Input & Output Characteristics

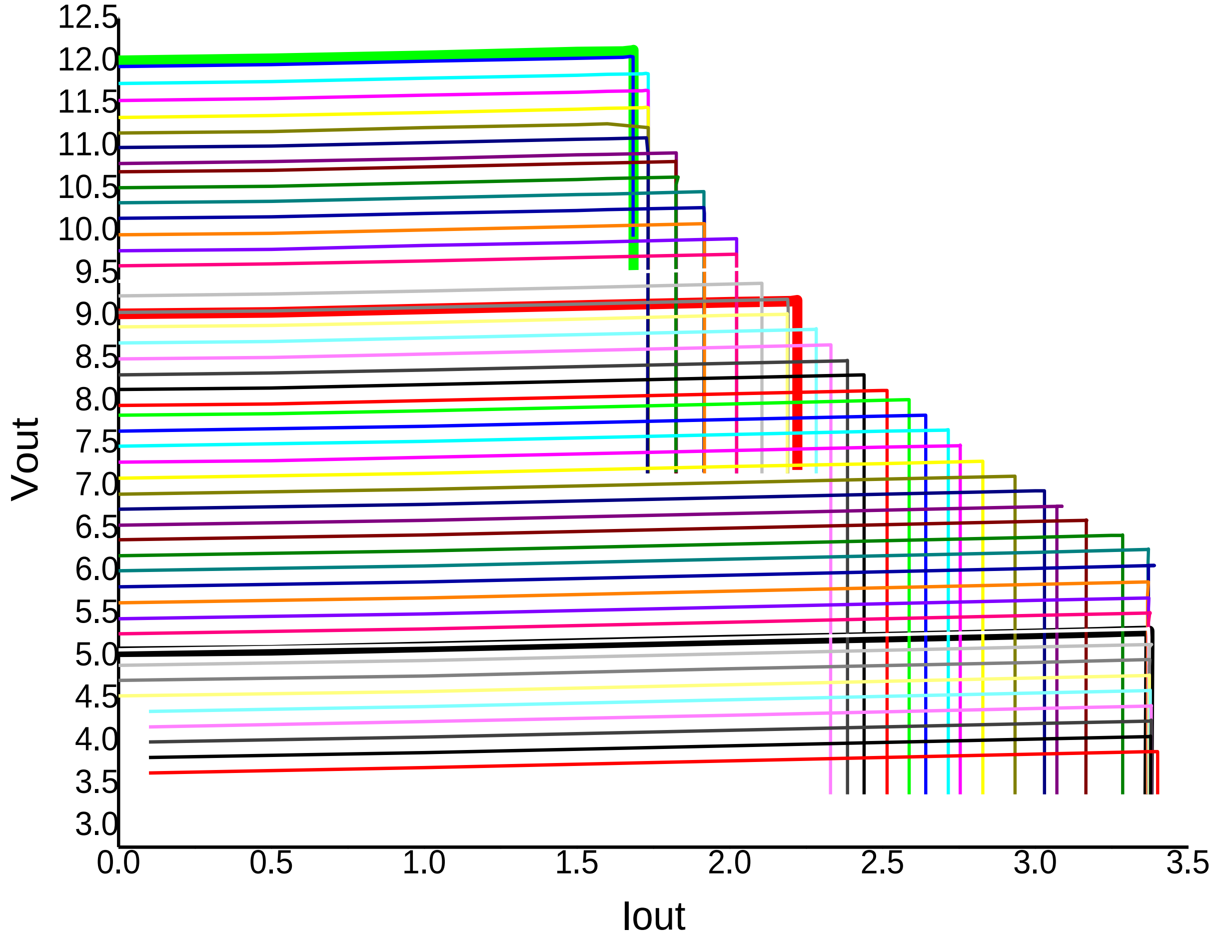
5.1.1 Input Standby Power

Output Voltage	Input Voltage	Standby Power (mW)
5V	85	**31**
	115	**33**
	230	**48**
	264	**62**

5.1.2 Power Conversion Efficiency at Different AC Line Input Voltage (PCB End)

Vin	**Vo**	**25%**	**50%**	**75%**	**100%**	**Average Efficiency**	**Energy Star Level VI**	**10% load efficiency**
115VAC/60HZ	5.0V	87.67	87.5	86.02	84.47	86.42	>81.39%	86.83
230VAC/60HZ	5.0V	86.88	87.56	86.66	85.94	86.76		83.17
115VAC/60HZ	9.0V	88.07	88.2	87.82	87.34	87.85	>85.00%	85.84
230VAC/60HZ	9.0V	87.82	88.8	88.96	88.78	88.59		83.43
115VAC/60HZ	12.0V	87.06	88.09	87.95	87.85	87.74	>85.00%	81.17
230VAC/60HZ	12.0V	86.91	88.79	89.14	89.28	88.53		79.29

5.1.3 Output I – V Curve @ Board End



5.2 Key Performance Waveforms

5.2.1 18W QC3.0 System Start-up Time & Hold-up Time

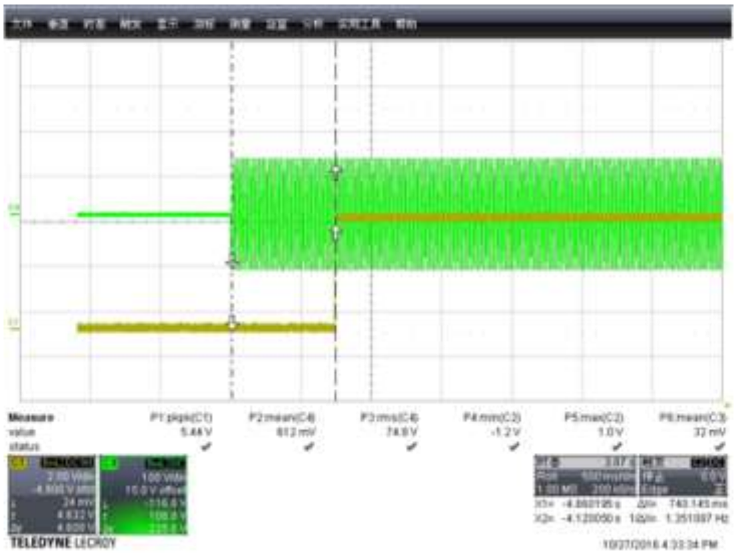


Figure 12: 18W QC 3.0 turn on time 0.27s 15V/3A at 90Vac

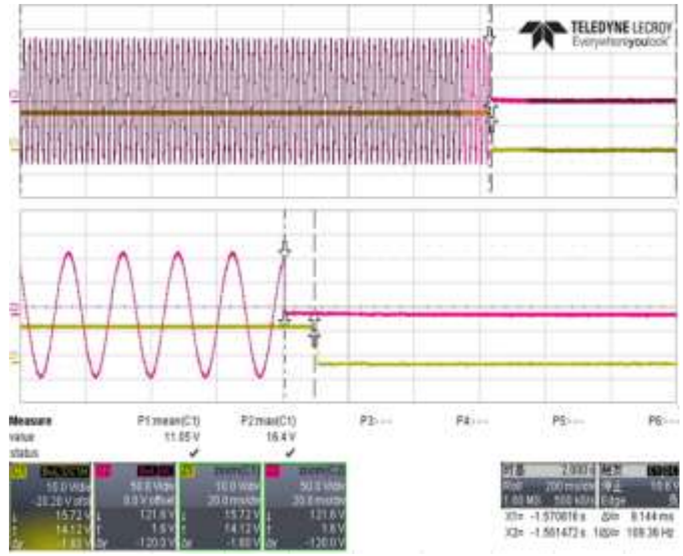


Figure 13: 18W QC3.0 hold time 9.14ms at 15V- 3A, at 90Vac

5.2.2 Q1 and AP34509 Main Switching MOSFET Stress on at 12V/ 1.5A Loading @264Vac

Primary side mosfet-Q1

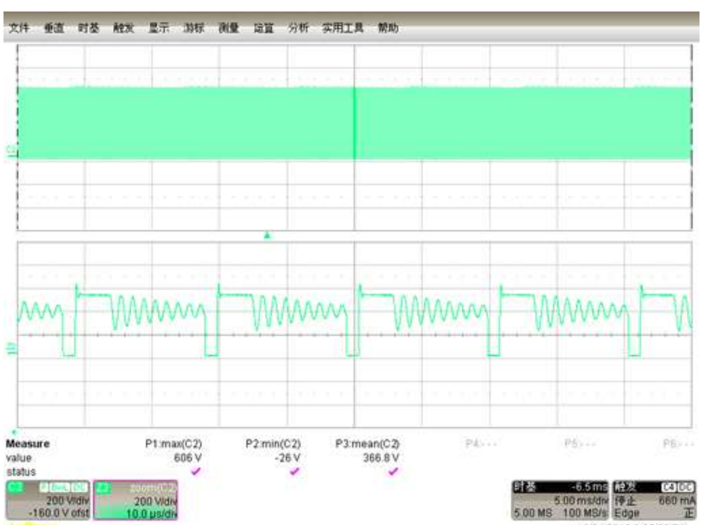


Figure14

Vout	Vds(V)
12V	606 /700V

Secondary side SR –AP34509 U3

Figure 15

Vout	Vdiode(V) peak
12V	55.7 / 60V

5.2.3 System Output Ripple & Noise with @ 1.2m Cable End

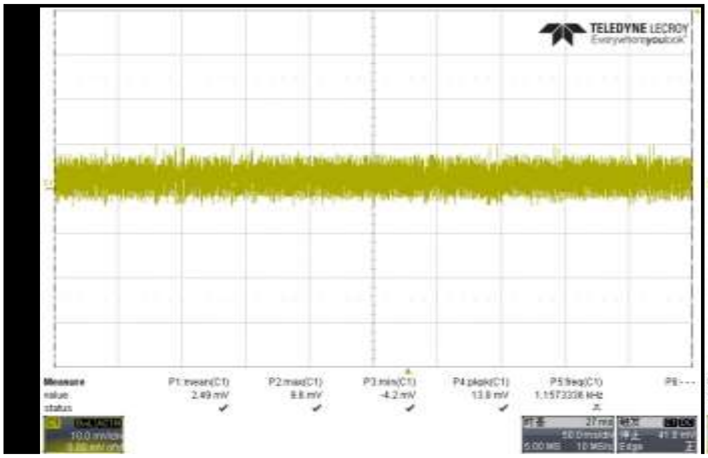


Figure 16: The Ripple at 90Vac/60Hz ΔV=14mV **5V/0A**

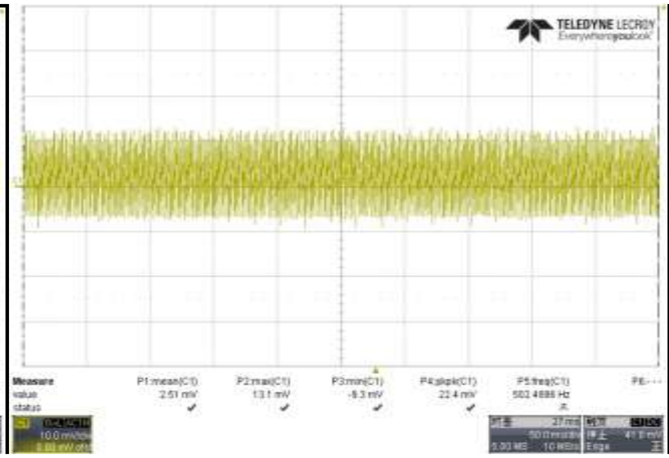


Figure 17: The Ripple at 264Vac/50Hz ΔV=23mv **5V/0A**

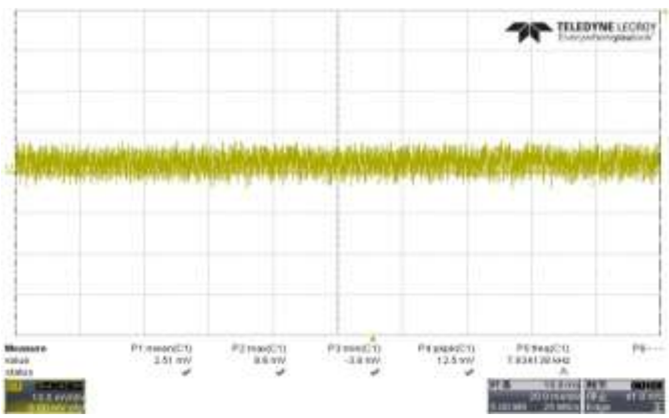


Figure 18: The Ripple at 90Vac/60Hz ΔV=13mV **9V/0A**

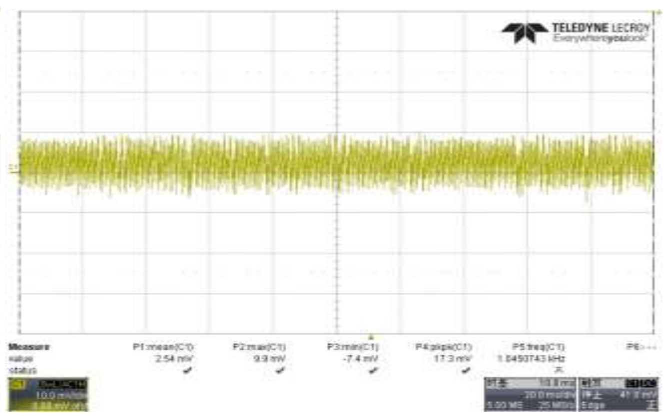


Figure 19: The Ripple at 264Vac/50Hz ΔV=18mv **9V/0A**

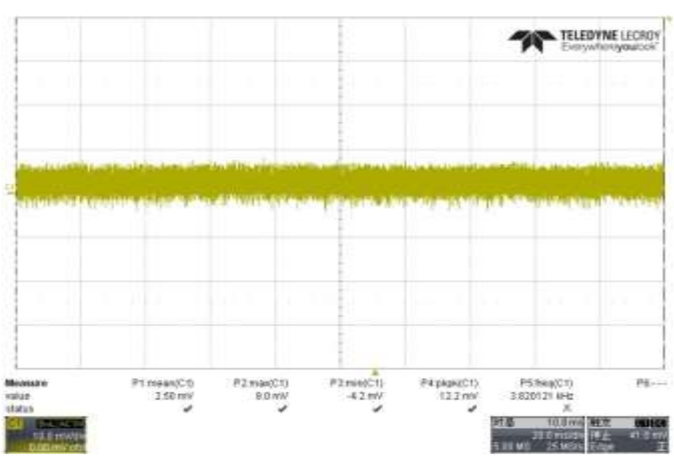


Figure 20: The Ripple at 90Vac/60Hz ΔV=12mV **12V/0A**

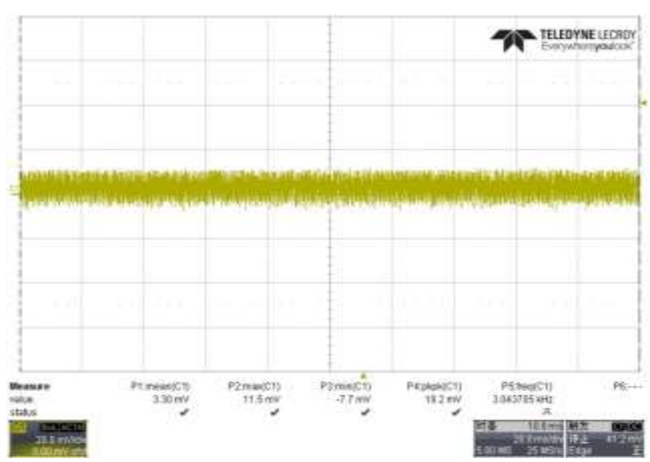


Figure 21: The Ripple at 264Vac/50Hz ΔV=19mv **12V/0A**

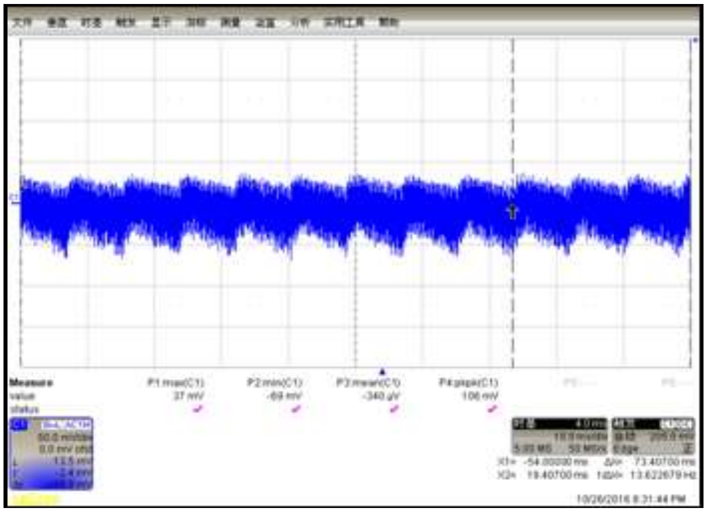


Figure 22: 90Vac/60Hz 5V/3A ΔV=106mV

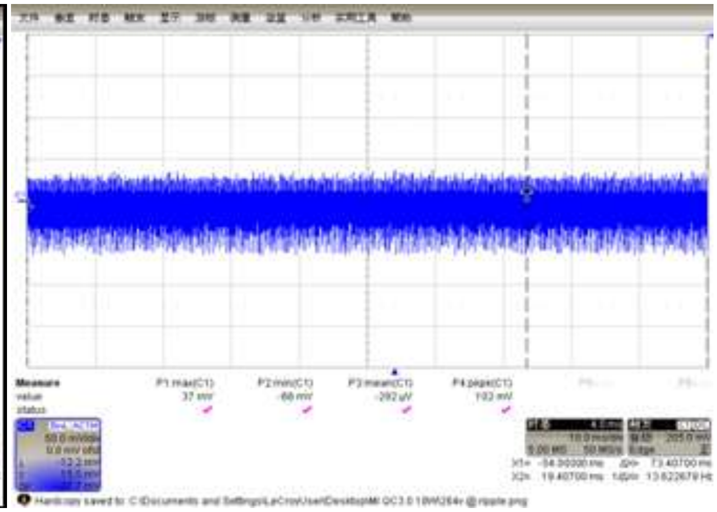


Figure 23: 264Vac/50Hz 5V/3A ΔV=102mv

5.3 Output Voltage Transition Time

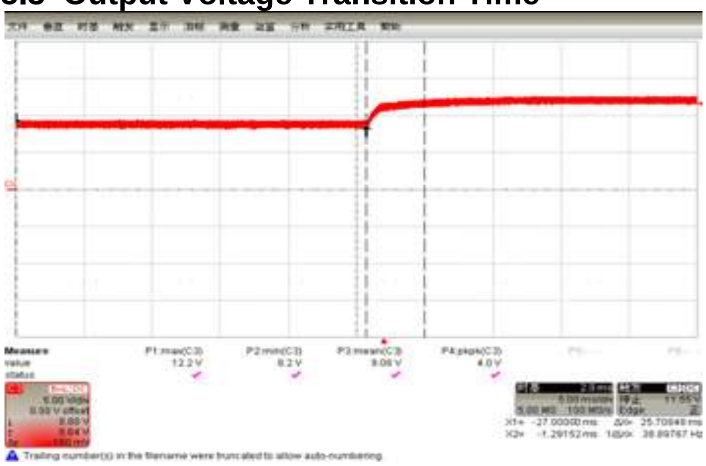


Figure 24: 90Vac/60Hz 5v – 9V

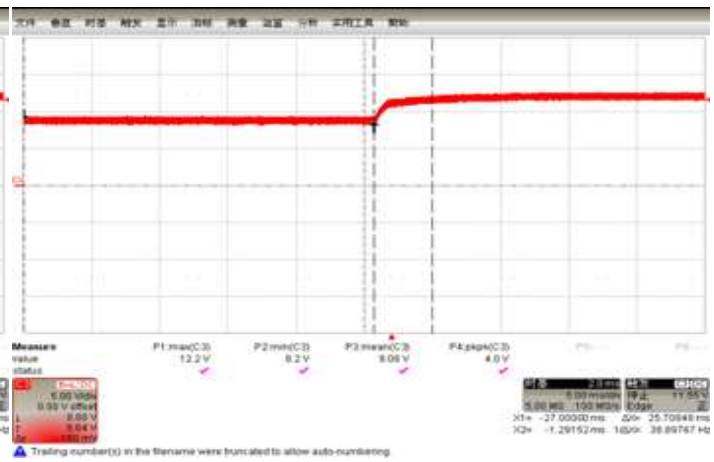


Figure 25: 90Vac/60Hz 9v – 12V

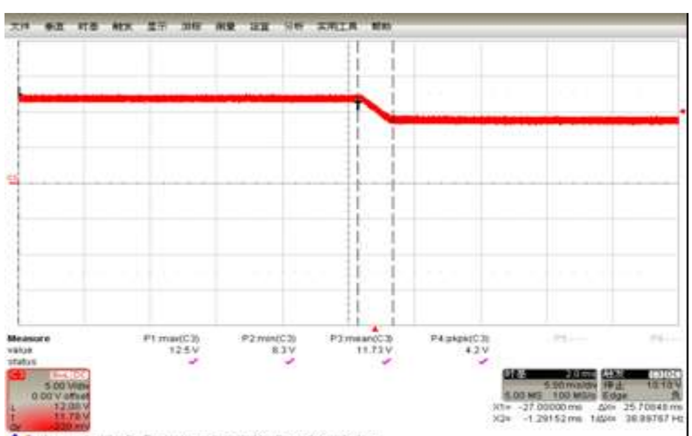


Figure 26: 90Vac/60Hz 12v – 9V

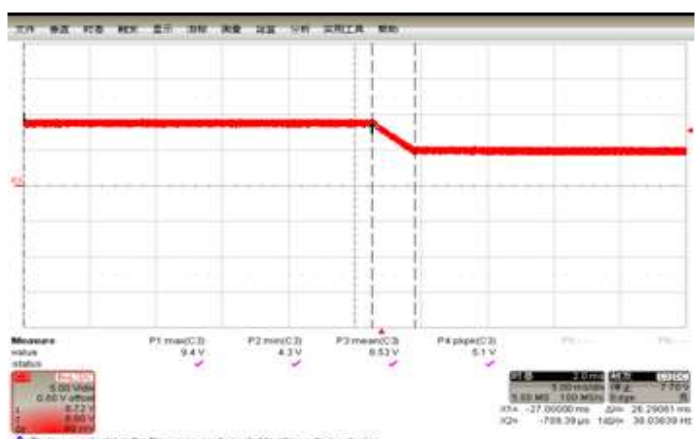


Figure 27: 90Vac/60Hz 9v – 5V

5.3.1 Dynamic load: The test condition

5V Dynamic loading between 10% ~ 90% of 3A, Fd = 250mA /us 50% duty Tr =1mS

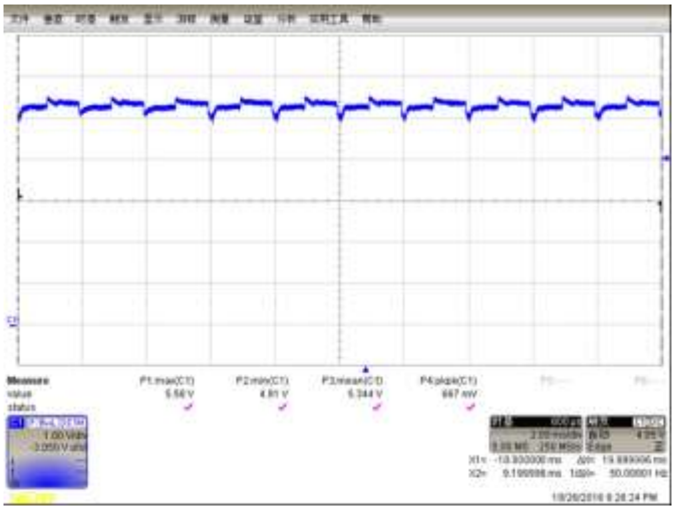


Fig 28: Vin= 90Vac Vmin=4.91V Vmax=5.58V

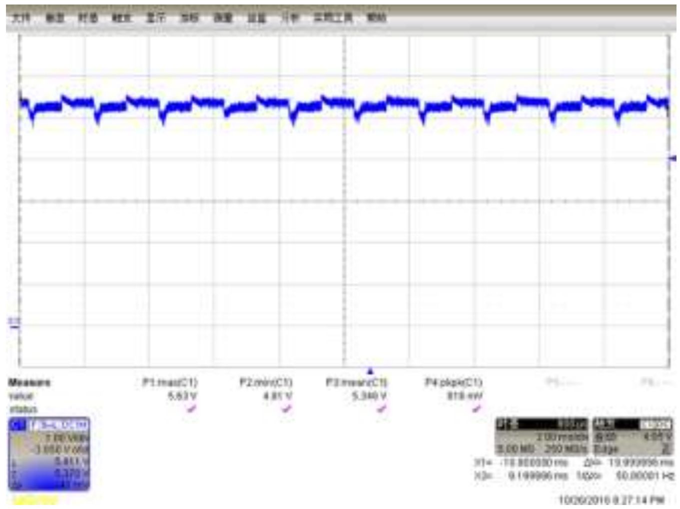


Fig 29: Vin= 264Vac Vmin=4.81V Vmax = 5.63V

5V Dynamic Load

Loading	10ms-10ms		100ms-100ms		200ms-200ms	
	Vo_min	Vo_max	Vo_min	Vo_max	Vo_min	Vo_max
0-->100%	4.81	5.51	5.04	5.5	4.99	5.5
0-->50%	4.96	5.33	5.04	5.32	5.01	5.32
10-->90%	4.92	5.43	4.91	5.44	4.88	5.42

9V Dynamic Load

Loading	10ms-10ms		100ms-100ms		200ms-200ms	
	Vo_min	Vo_max	Vo_min	Vo_max	Vo_min	Vo_max
0-->100%	8.85	9.38	8.97	9.39	8.95	9.39
0-->50%	8.91	9.24	8.98	9.27	8.95	9.25
10-->90%	8.89	9.35	8.9	9.33	8.89	9.32

12V Dynamic Load

Loading	10ms-10ms		100ms-100ms		200ms-200ms	
	Vo_min	Vo_max	Vo_min	Vo_max	Vo_min	Vo_max
0-->100%	11.77	12.24	11.9	12.25	11.88	12.25
0-->50%	11.82	12.17	11.89	12.17	11.88	12.16
10-->90%	11.85	12.21	11.84	12.23	11.82	12.2

5.3.2 Thermal Testing

Test Condition: Vin=90Vac & 264Vac Vo=9.0V Io=2.0A Open Frame

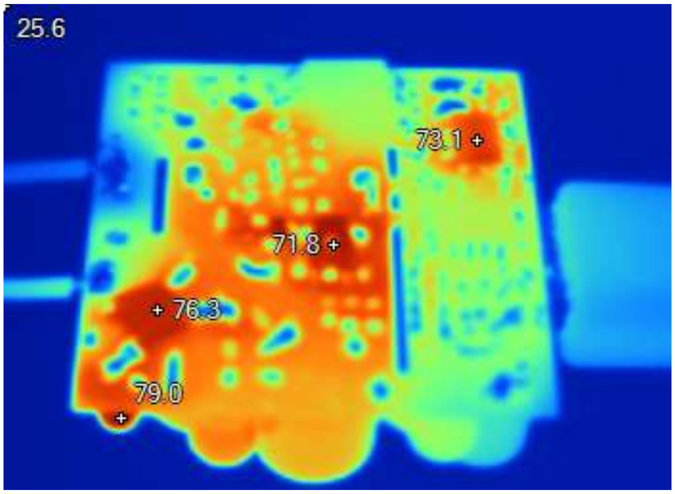


Figure 30: Surface Mount side at 90Vac 9V-2A

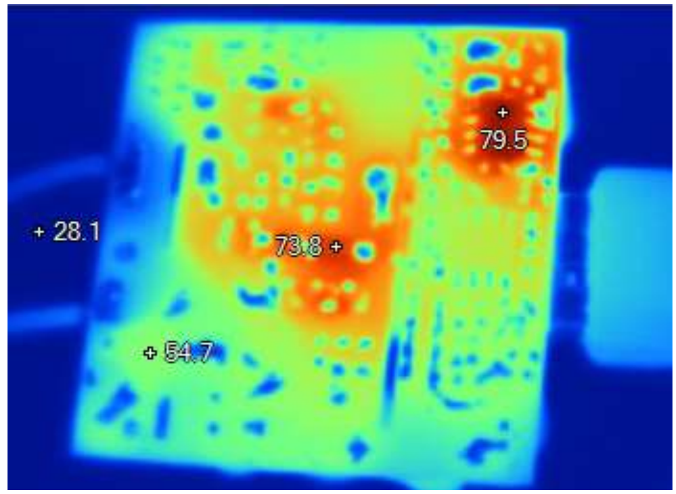


Figure 31: surface mount side at 264Vac 9V-2A

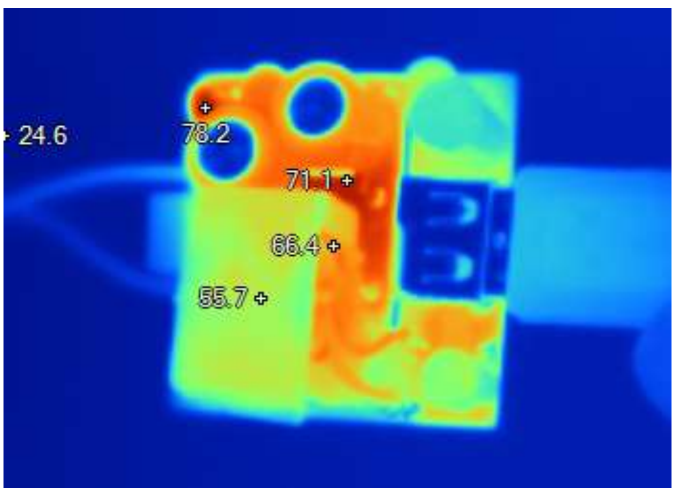


Figure 32: components side at 90Vac 9V-2A

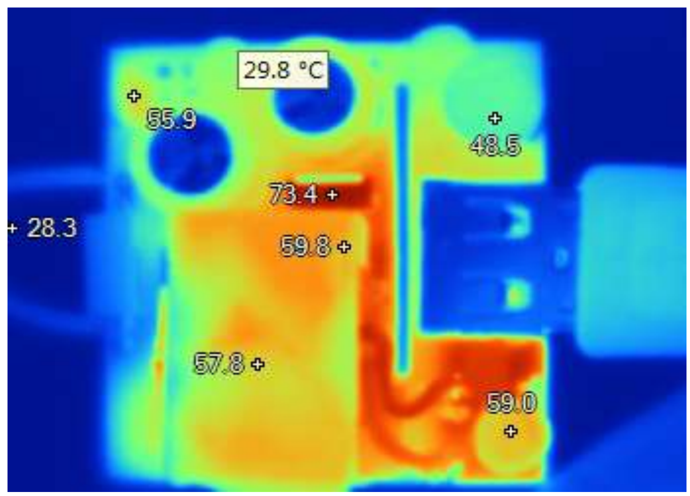


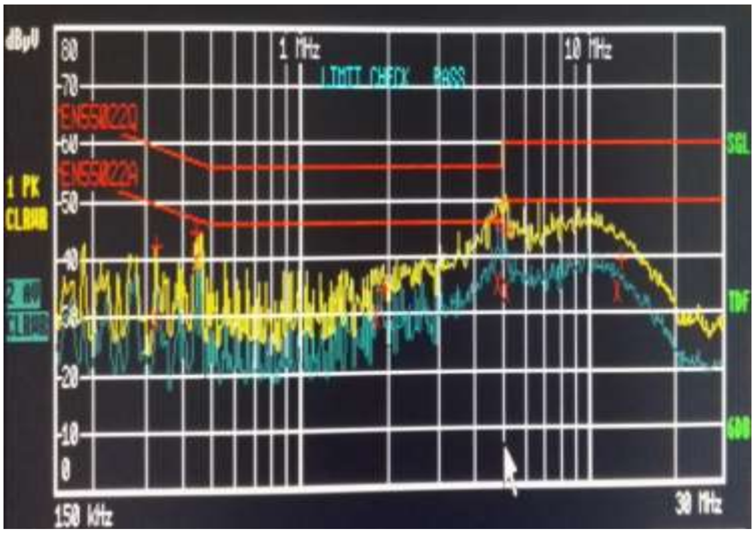
Figure 33: components side at 264Vac 9V-2A

Test Items	Unit	Temperature
Transformer wire	℃	66.6
Transformer core	℃	55.7
Primary Switching MOSFET	℃	71.1
Secondary Rectifier	℃	73.1
Ambient Temp	℃	25

Test Items	Unit	Temperature
Transformer wire	℃	59.8
Transformer core	℃	57.8
Primary Switching MOSFET	℃	73.4
Secondary Rectifier	℃	79.5
Ambient Temp	℃	25

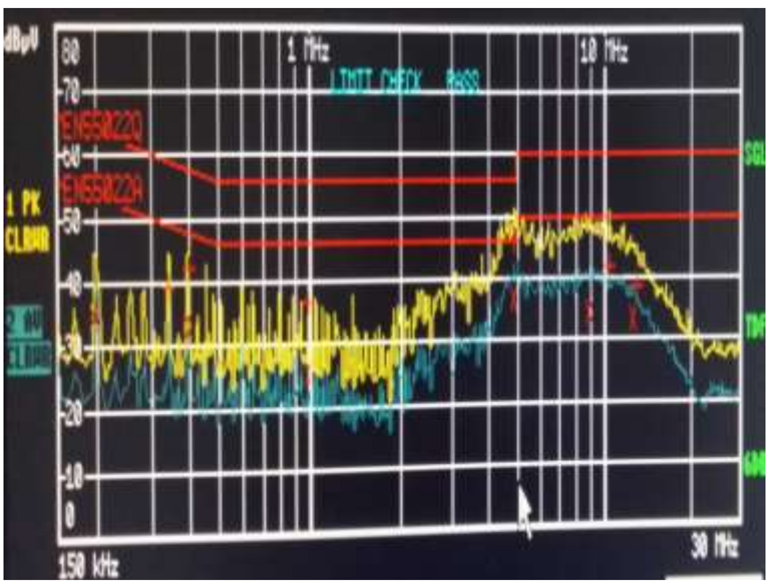
5.3.3 EMI (CE) Conductive Emission Testing

Test Condition: Vin=230Vac, Vo=12V, Io=1.5A



TRACE	FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
2 Average	322 kHz	30.07	-19.58
1 Quasi Peak	326 kHz	42.43	-17.11
1 Quasi Peak	442 kHz	44.74	-12.28
2 Average	442 kHz	39.76	-7.26
2 Average	1.822 MHz	29.65	-16.34
1 Quasi Peak	1.93 MHz	34.24	-21.75
1 Quasi Peak	4.794 MHz	46.61	-9.38
2 Average	4.862 MHz	35.10	-10.89
1 Quasi Peak	5.138 MHz	44.74	-15.25
2 Average	5.138 MHz	33.70	-16.29
2 Average	12.718 MHz	34.03	-15.97
1 Quasi Peak	13.106 MHz	39.31	-20.68

Figure 34: 230Vac/50Hz 12V/1.5A (L)



TRACE	FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
2 Average	198 kHz	34.68	-19.01
1 Quasi Peak	338 kHz	39.76	-19.49
2 Average	394 kHz	33.38	-14.59
1 Quasi Peak	398 kHz	42.47	-15.41
1 Quasi Peak	982 kHz	36.61	-19.38
2 Average	986 kHz	25.44	-20.56
1 Quasi Peak	4.894 MHz	46.04	-9.95
2 Average	4.894 MHz	36.54	-9.45
2 Average	8.962 MHz	34.30	-15.69
1 Quasi Peak	10.542 MHz	41.95	-18.04
2 Average	12.754 MHz	33.64	-16.35
1 Quasi Peak	13.054 MHz	38.75	-21.24

Figure 35: 230Vac/50Hz 12V/1.5A (N)