Table of Contents

Chapter1: Summary

1.1 General Description

The DC-DC 33W PD3.0 PPS Car Charger EV1 Evaluation Board is composed of two main parts. The AT8901 is a synchronous four-switch buck-boost DC/DC controller capable of regulating the output voltage at, above, or below the input voltage. The AT8901 operates over a wide input voltage range of 4.5 V to 40 V to support a variety of applications. The AP43771 is USB PD3.0 PPS and Qualcomm® Quick Charge™ 4/4+ Decoder for implementing quick charger decoder functions. Based on monitoring D+ & D- and CC1 & CC2 signals, AP43771 interprets desired voltage and current setting, and then feeds information back to AT8901 switcher for providing well-regulated voltage and current as well as related power protections.

1.2 Key Features

1.2.1 System Key Features

- Small size
- Meet DOE 6 and COC Tier2 Efficiency Requirements
- Comprehensive System Protection Feature

1.2.2 AP43771 Key Features

- Supports USB PD3.0 PPS Type-C and QC4/QC4+
- Drives N-Channel MOSFET for Load Switch
- Built-in VBUS Discharger Pin
- 3V – 21V operation voltage without external regulator
- On-chip OVP, OCP, UVP, and SCP
- Supports OTP through integrated ADC circuit
- USB PD 3.0 PPS Compliance (TID: 1100023)

1.2.3 AT8901 Key Features

- Single Inductor Buck-Boost Controller for Step-Up/Step-Down DC/DC Conversion
- Wide Input Voltage from 4.5V to 40V
- High Efficiency
- Adjustable Switching Frequency
- Programmable External Soft-Start
- Auto Recovery after Faults
- Output Cord Voltage Drop Compensation
- Programmable Over Current Setting
- Power Good and Output Overvoltage Protection
- Over-Temperature Protection
- Thermal Enhanced QFN4x4-24L Package1.3

1.2.4 Applications

- Car Charger
- Rechargeable Portable Devices
- USB Power Delivery
- Power Bank

1.3 Main Power Specifications (CV& CC mode)

Parameter	Value
Input Voltage	8Vdc to 40Vdc
Main Output Vo / Io	5V/3A, 9V/3A,15V2.2A
Per Step Voltage	PPS1 20mV step voltage, 3.3V-5.9V3A
	PPS2 20mV step voltage, 3.3V-11V3A
Efficiency	Comply with DOE VI and COC Tier2(refer to adaptor)
Total Output Power	33W
Protections	OCP, OVP, UVP, OLP, OTP
Dimension	L*H*W=53 * 18.9 * 27.4mm

1.4 Evaluation Board Picture:

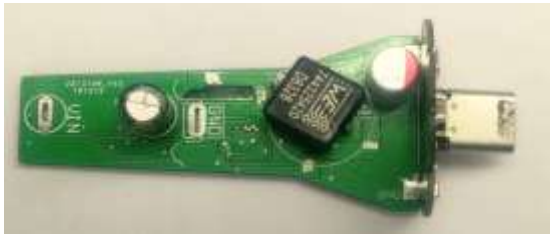
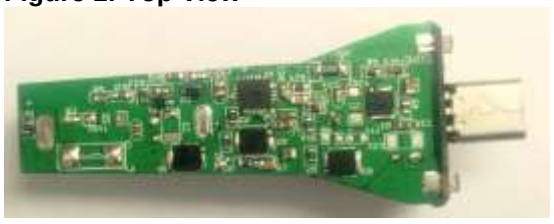


Figure 1: Top View



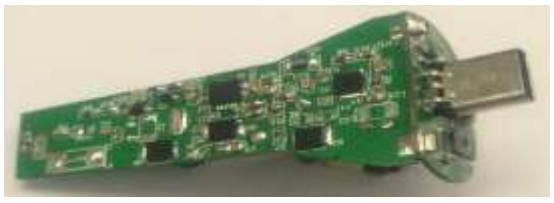


Figure 2 Bottom View

Chapter 2: Power Supply Specification

Parameter	Value	Test Summary
Input Voltage	$8V_{DC}$ to $40V_{DC}$	
5V3A Average Efficiency	(Refer to adaptor)DoE VI Eff >81.39%	**90.64% @12VDC,84.16%@24VDC**
	(Refer to adaptor)COC Tier2 Eff >81.84%	
5V/0.3A Efficiency (10% Load)	(Refer to adaptor)COC Tier2 Eff >71.84%	**83.33% @12VDC,75.00%@24VDC**
9V3A Average Efficiency	(Refer to adaptor)DoE VI Eff >86.62%	**94.71% @12VDC,89.865@24VDC**
	(Refer to adaptor)COC Tier2 Eff >87.30%	
9V/0.3A Efficiency (10% Load)	(Refer to adaptor)COC Tier2 Eff >77.30%	**89.21% @12VDC,80.95%@24VDC**
15V2.2A Average Efficiency	(Refer to adaptor)DoE VI Eff >87.21%	**95.59% @12VDC,91.64%@24VDC**
	(Refer to adaptor)COC Tier2 Eff >88.03%	
15V/0.22A Efficiency (10% Load)	(Refer to adaptor)COC Tier2 Eff >78.03%	**88.23% @12VDC,86.85%@24VDC**

Chapter 3: Schematic and BOM

3.1 Evaluation Board Schematic

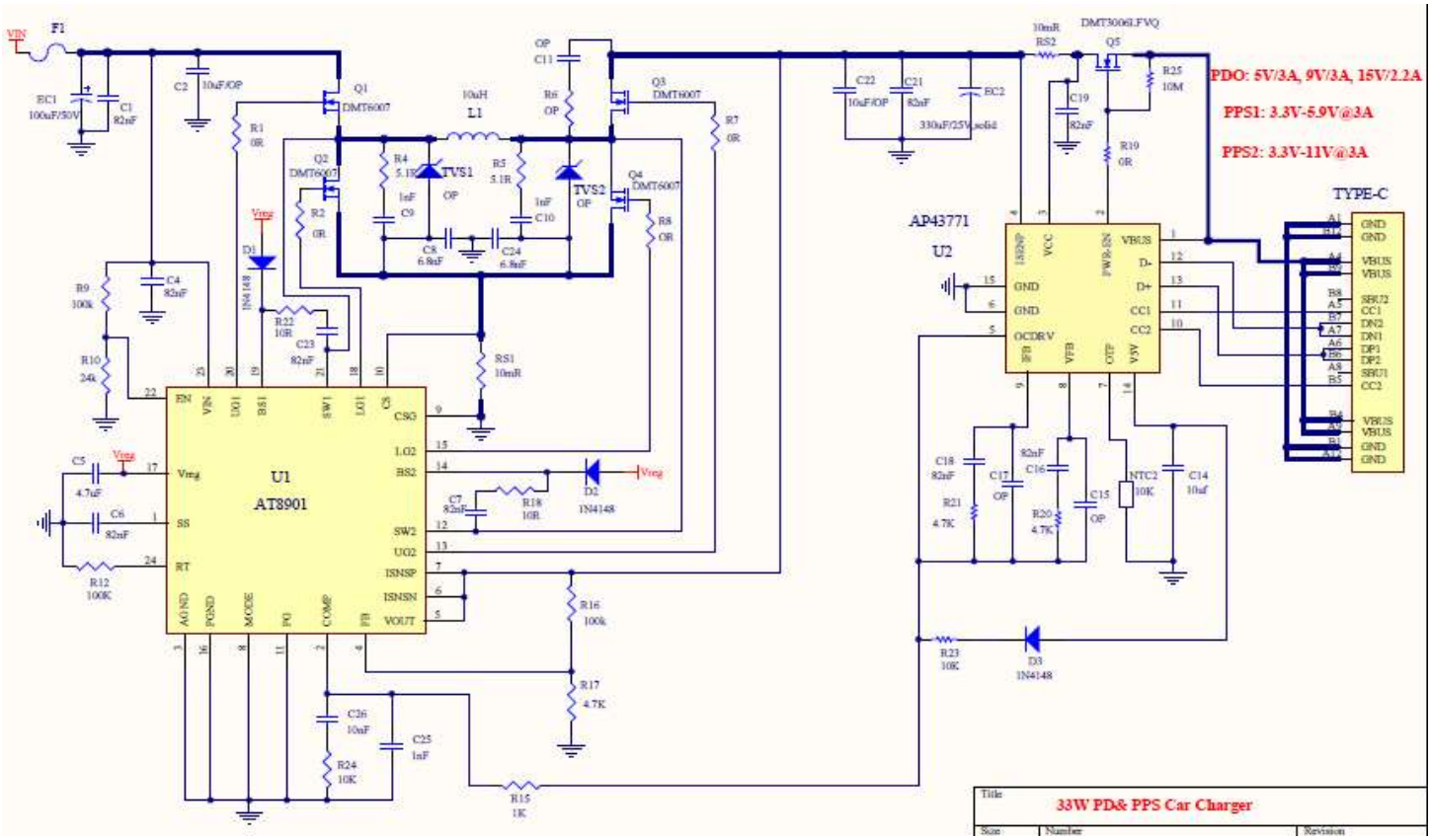


Figure 3: Schematic of 33W PD3.0 PPS Car Charger Evaluation Board

3.2 Bill of Material (BOM)

Item	Designator	Description	Footprint	Manufactory	Quantity
1	D1, D2, D3	1N4148WS	SOD-323	DIODES	3
2	Q1, Q2, Q3, Q4	DMT6007LFG	DFN3*3	DIODES	4
3	Q5	DMT3006LFVQ	DFN3*3	DIODES	1
4	U2	PD Controller, AP43771	DFN14*3*3	DIODES	1
5	U1	Buck-Boost Controller, AT8901	QFN24*4*4	ATKIC	1
6	C1,C4,C6,C7,C16,C18,C19, C21,C23,	100nF/50V	0603		9
7	C5	4.7uF/10V	0603		1
8	C8, C24	6.8nF/50V	0603		2
9	C9, C10, C25	1nF/50V	0603		3
10	C11, C15,C17	OP	0603		3
11	C2,C22	OP	1206		2
12	C14	10uf/6.3V	0603		1
13	C26	10nF/25V	0603		1
14	C17	3.3nF/25V	0603		1
15	EC1	100uF/50V, E-Cap	6*11mm		1
16	EC2	330uF/25V, Solid Cap	6*11mm		1
17	F1	Fuse,5A	1206		1
18	USB1	TYPE-C(vertical-SMT)			1
19	L1	Ring Inductor, Lp=10uH	0.5mm,D=13mm		1
20	NTC2,R23,R24	10K**(If NTC2 don't use, one 10K resistor must be installed)**	0603		3
21	R1,R2,R7,R8,R19	0R	0603		5
22	R4, R5	5.1R	0603		2
23	R6	OP	0603		1
24	R9, R12,R16	100k	0603		3
25	R10	24k	0603		1
26	R15	1K	0603		1
27	R16	82k	0603		1
28	R17,R20,R21	5.1K	0603		3
29	R18, R22	10R	0603		2
30	R25	OP	0603		1
31	RS1, RS2	Sense Resistor, 10mR	1206		2
32	TVS1,TVS2	OP	SOD123		2

Chapter 4: The Evaluation Board (EVB) Connections

4.1 Evaluation of PCB Board Layout

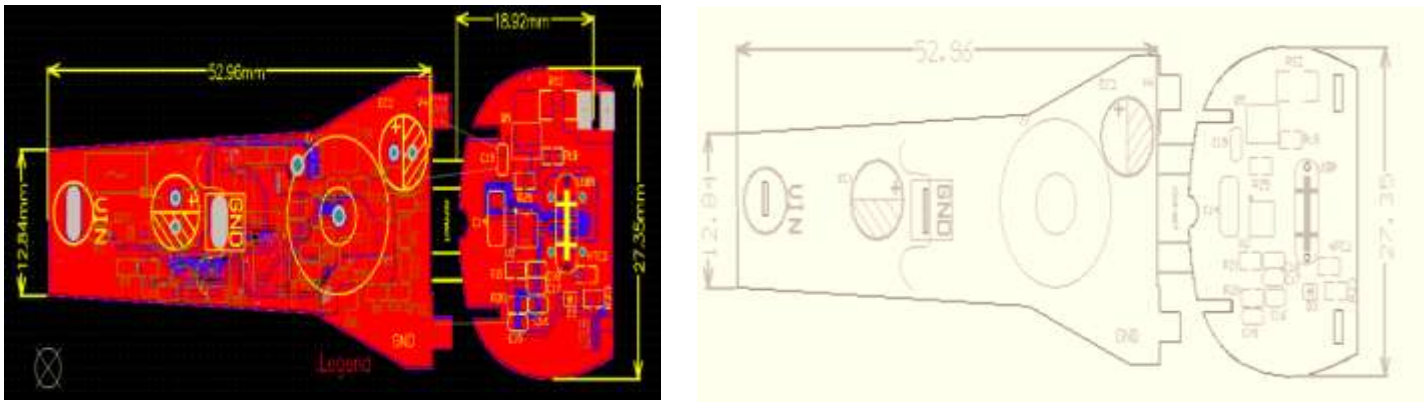


Figure 4: PCB Board Layout Top View

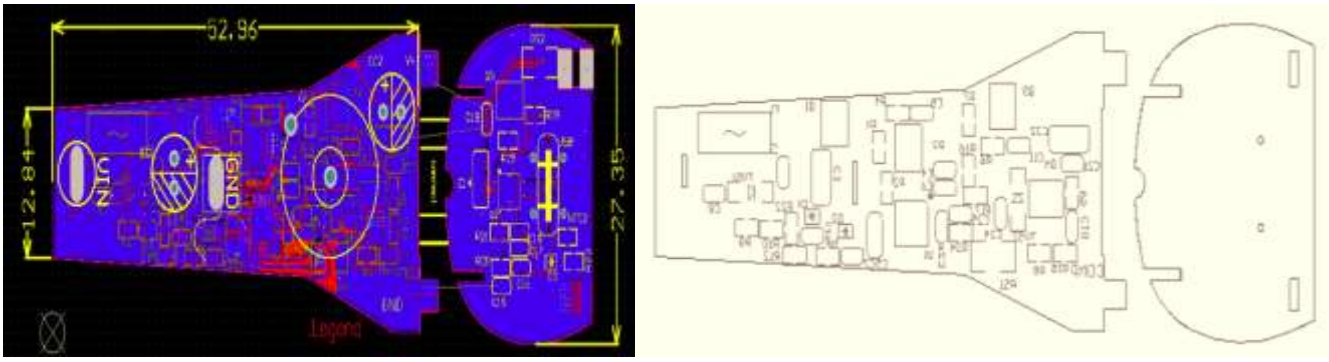


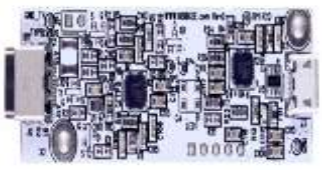
Figure 5: PCB Board Layout Bottom View

4.2 Quick Start Guide Before Connection

1) Before starting the 33W PD3.0 PPS Car Charger EVB test, the end user needs to prepare the following tool, software and manuals.

   For details, please contact DIODES Semiconductor local sales 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
			

2) Prepare a certified three-foot Type-C cable and a Standard-A to Micro-B Cable.
3) Connect the input wires to DC power supply.
4) Ensure that the DC source is switched OFF or disconnected before the connection steps.
5) Use a type-C cable for the connection between EV1 Board to Type-C receptacles.
6) Use 2 banana jack cables, one port of the cables is connected to E-load + & - terminals while the other port of the cables is connected to 33W PD3.0 PPS Car Charger unit's VBUS & GND holes.
7) A Standard-A to Micro-B cable to be connected to the test kit's Micro-B receptacle & PC Standard-A receptacle respectively.

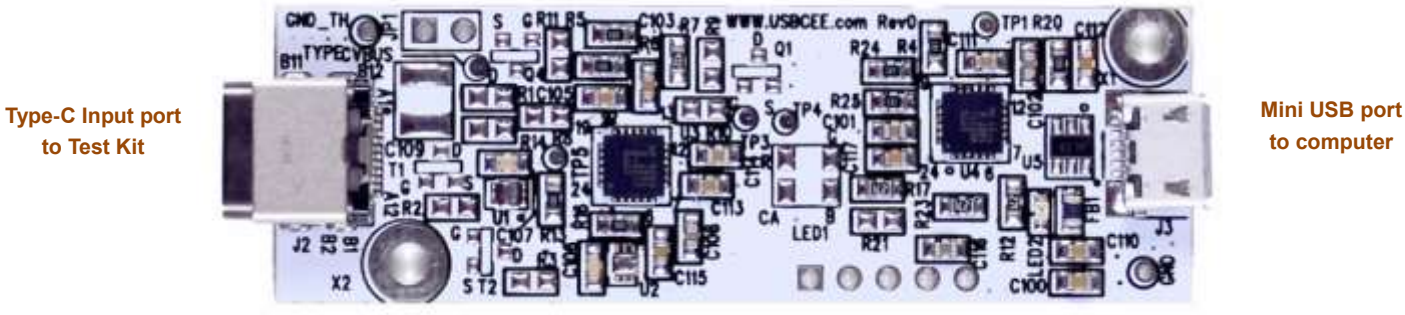


Figure 6: The Test Kit Input & Output and E-load Connections

4.3 Connection with E-Load

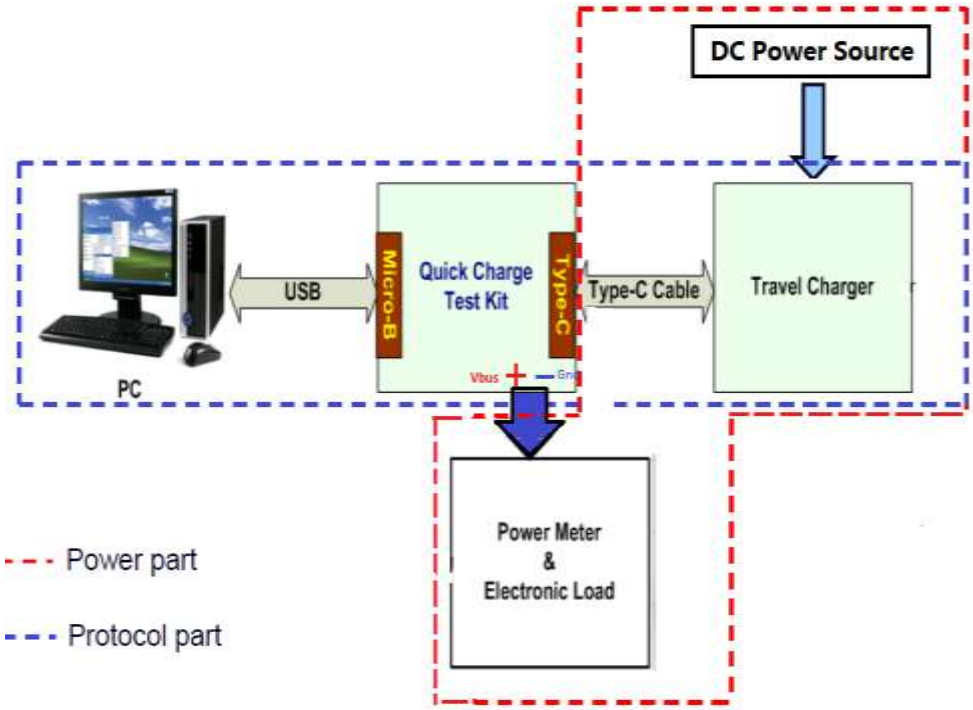


Figure 7: Diagram of Connections in the Sample Board

4.4 The sample board Input & Output Wires Connection

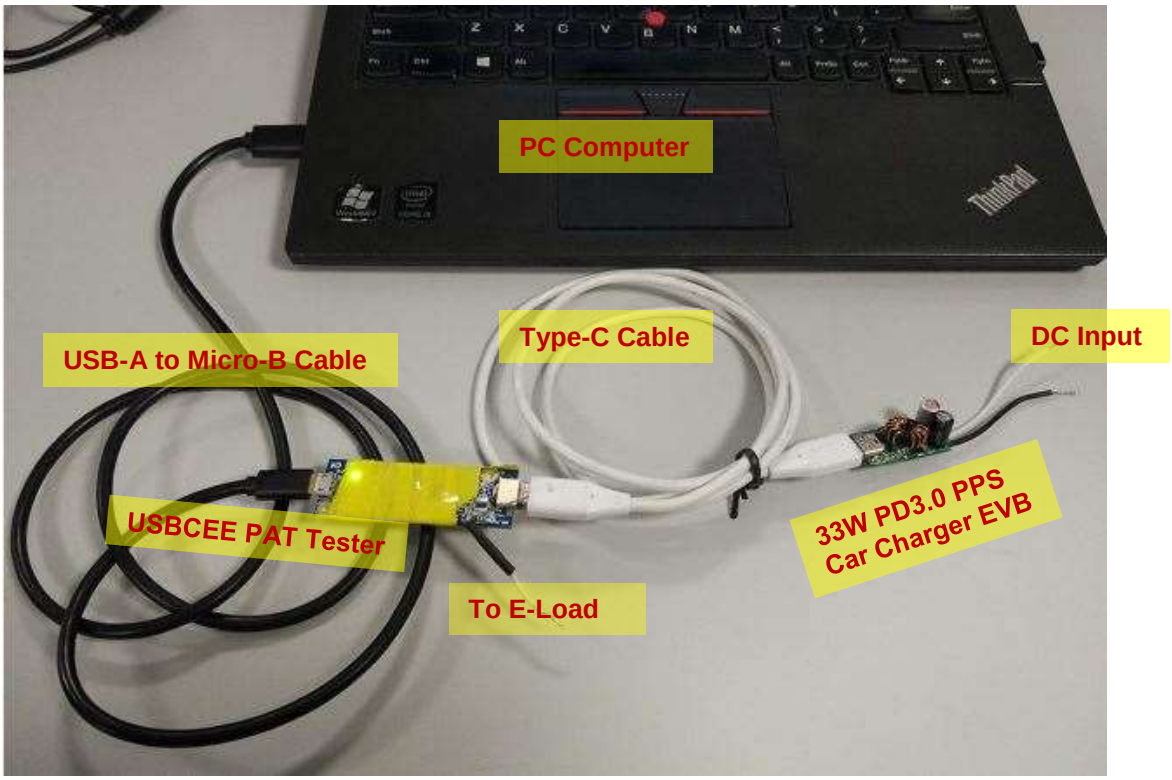


Figure 8: **Wire Connection of 33W PD3.0 PPS Car Charger EVB to Test Kit and PC Computer**

Chapter 5: Evaluation Board Testing Data

5.1 Input power Efficiency at different loading

	VIN(VDC)	IOUT(A)	VOUT(V)	PIN(W)	Efficiency	Average Efficiency	Refer to adaptor's DOE&COC
5V3A	**12**	3.00	5.23	17.28	90.80%	90.64%	DoE VI Eff >81.39%
		2.25	5.17	12.74	91.31%		
		1.50	5.10	8.42	90.86%		COC Tier2 Eff >81.84%
		0.75	5.04	4.22	89.58%		
		0.3	5.00	1.8	83.33%		COC Tier2 Eff >71.84%
	24	3.00	5.23	18.05	86.93%	84.16%	DoE VI Eff >81.39%
		2.25	5.17	13.45	86.49%		
		1.50	5.10	9.15	83.62%		COC Tier2 Eff >81.84%
		0.75	5.04	4.75	79.60%		
		0.3	5.00	2.00	75.00%		COC Tier2 Eff >71.84%

	VIN(VDC)	IOUT(A)	VOUT(V)	PIN(W)	Efficiency	Average Efficiency	Refer to adaptor's DOE&COC
9V3A:	**12**	3.00	9.28	29.82	93.36%	94.71%	DoE VI Eff >86.62%
		2.25	9.22	21.81	95.12%		
		1.50	9.15	14.41	95.24%		COC Tier2 Eff >87.30%
		0.75	9.08	7.16	95.11%		
		0.3	9.04	3.04	89.21%		COC Tier2 Eff >77.30%
	24	3.00	9.28	31.07	89.61%	89.86%	DoE VI Eff >86.62%
		2.25	9.22	23.13	89.71%		
		1.50	9.15	15.67	87.59%		COC Tier2 Eff >87.30%
		0.75	9.08	7.61	89.48%		
		0.3	9.04	3.35	80.95%		COC Tier2 Eff >77.30%

	VIN(VD)	IOUT(A)	VOUT(V)	PIN(W)	Efficiency	Average Efficiency	Refer to adaptor's DOE&COC
15V2.2A	**12**	2.2	15.23	34.91	95.98%	95.59%	DoE VI Eff >87.21%
		1.65	15.22	26.08	96.29%		
		1.1	15.19	17.42	95.92%		COC Tier2 Eff >88.03%
		0.55	15.14	8.85	94.15%		
		0.22	15.12	3.77	88.23%		COC Tier2 Eff >78.03%
	24	2.2	15.23	35.85	93.46%	91.64%	DoE VI Eff >87.21%
		1.65	15.22	27.27	92.09%		
		1.1	15.19	18.19	91.86%		COC Tier2 Eff >88.03%
		0.55	15.14	9.34	89.15%		
		0.22	15.12	3.83	86.85%		COC Tier2 Eff >78.03%

5.2 Output voltage transition time

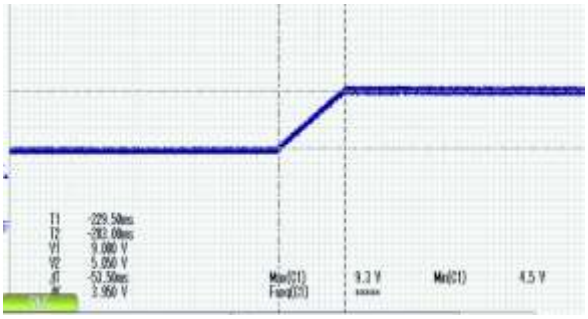


Figure 9: 5V⟶9V, Tr=53.5ms

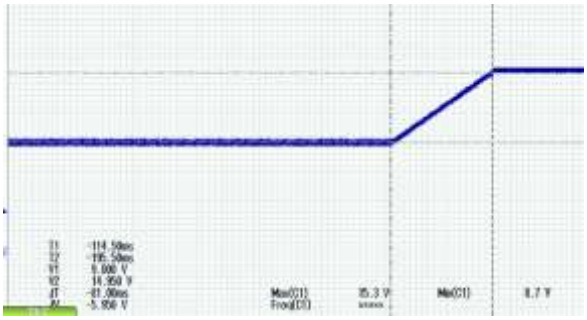


Figure 10: 9V⟶15V, Tr=81ms

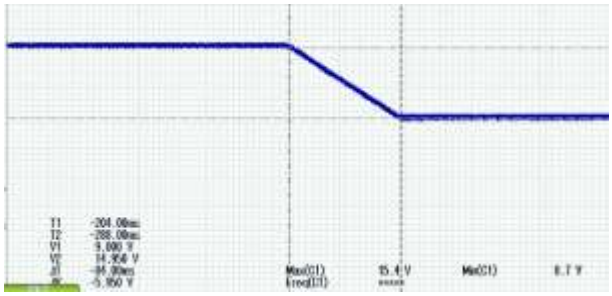


Figure 11: 15V⟶9V, Tr=84ms

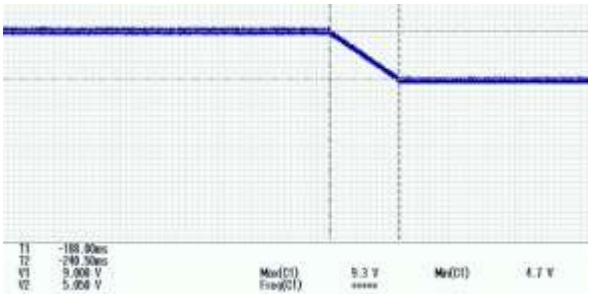


Figure 12: 9V⟶5V, Tr=51ms

5.3 System Output Ripple & Noise at PCB End

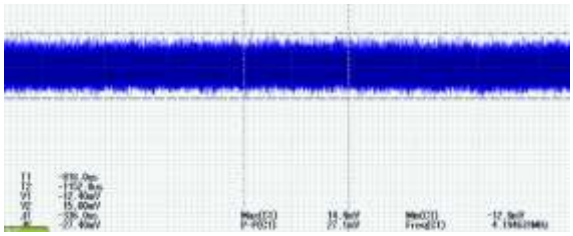


Figure 13: ΔV=27.4mV, VIN=12VDC @ 5V/3A

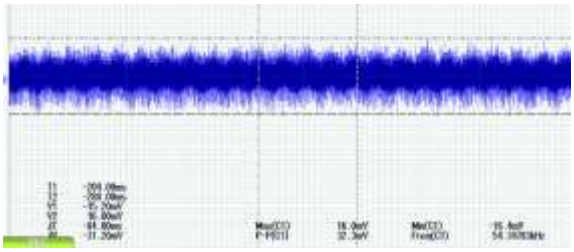


Figure 14: ΔV=31.2mv, VIN=24VDC @ 5V/3A

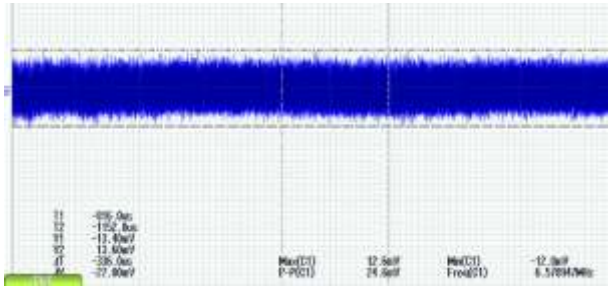


Figure 15: ΔV=27mV, VIN=12VDC @ 9V/3A

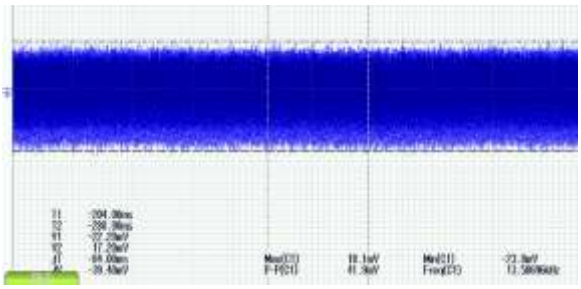


Figure 16: ΔV=41.9mv, VIN=24VDC @ 9V/3A

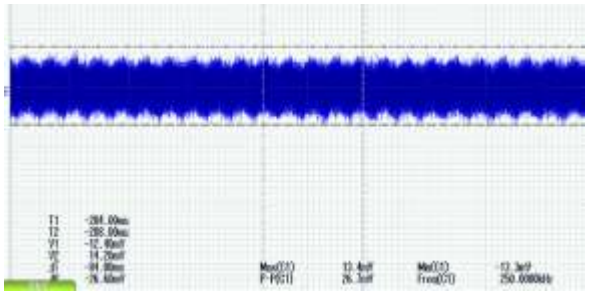


Figure 17: ΔV=26.6mV, VIN=12VDC @ 15V/2.2A

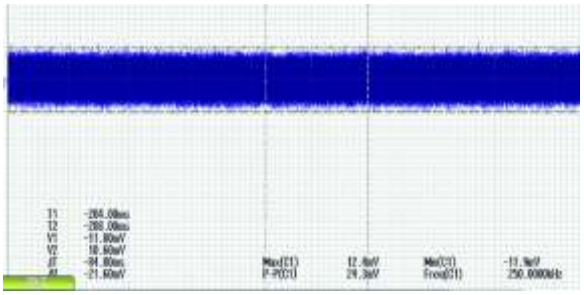


Figure 18: ΔV=21.6mv, VIN=24VDC @ 15V/2.2A

5.4 Dynamic Load Test

5.4.1 Dynamic load ----5V0.3A to 5V2.7A ,Tr=100mS, 500mA/uS(PCB End)

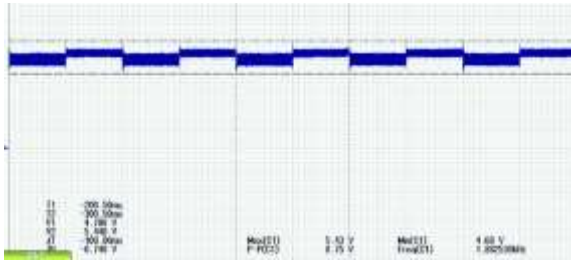


Figure 19: VIN=12VDC @ Vout =5V 0.3A ~ 2.7A

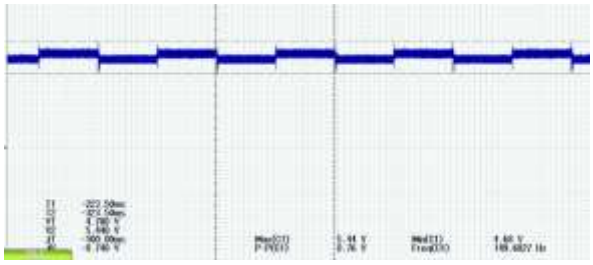


Figure 20: VIN=24VDC @ Vout =5V 0.3A ~ 2.7A

	Vo _Undershoot(V)	Vo _Overshoot(V)
VIN=12VDC	4.68	5.43
VIN=24VDC	4.68	5.44

5.4.2 Dynamic load ----9V0.3A to 9V2.7A ,Tr=100mS, 500mA/uS(PCB End)

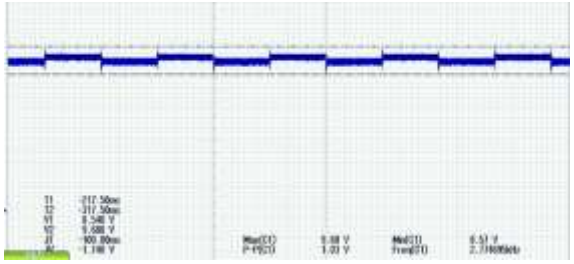


Figure 21: VIN=12VDC @ Vout=9V 0.3A ~ 2.7A

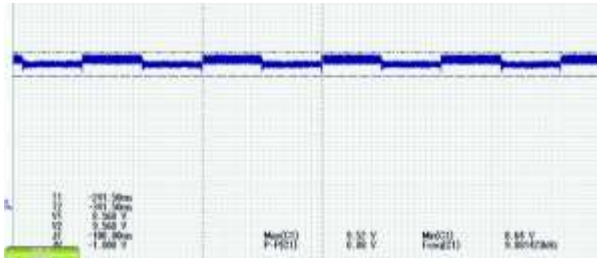


Figure 22: VIN=24VDC @ Vout=9V 0.3A ~ 2.7A

	Vo _Undershoot(V)	Vo _Overshoot(V)
VIN=12VDC	8.57	9.60
VIN=24VDC	8.64	9.52

5.4.3 Dynamic load ----15V0.2A to 15V1.8A ,Tr=100mS, 500mA/uS(PCB End)

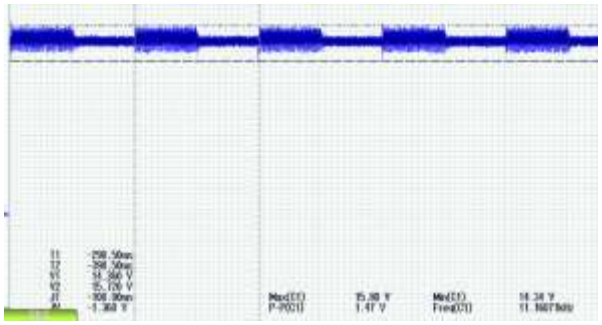


Figure 23: VIN=**12VDC @ Vout=15V 0.2A ~ 1.8A**

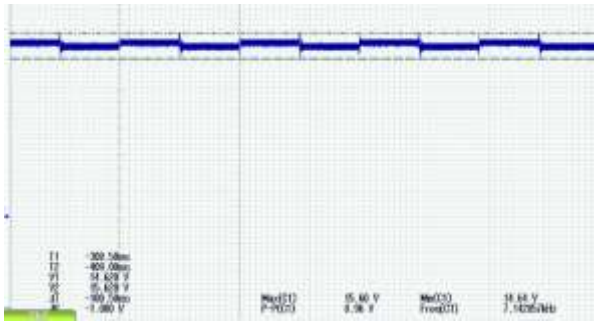


Figure 24: VIN=**24VDC @ Vout=15V 0.2A ~ 1.8A**

	Vo_Undershoot(V)	Vo_Overshoot(V)
VIN=12VDC	14.34	15.80
VIN=24VDC	14.64	15.60

5.5 Output OCP set point

	OCP		
VIN=12VDC or 24V	5V3A	9V3A	15V2.2A
	3.09A	3.19A	2.42A

5.6 Thermal Testing

5.6.1 Test condition: Load 9V3A, 15V2.2A, after running 2 hours, Open Frame

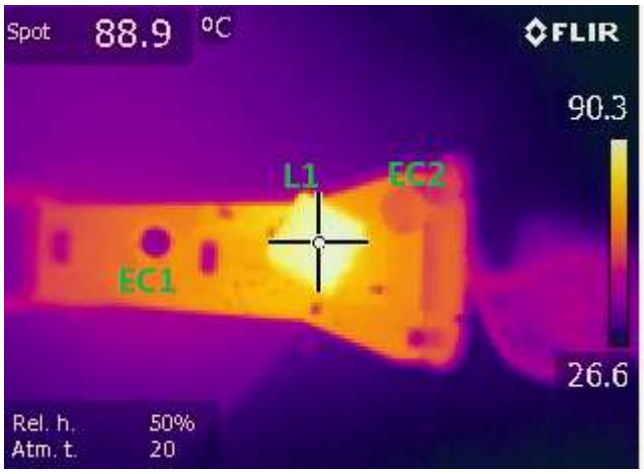


Figure 25: VIN=12V&24VDC, surface mount Side

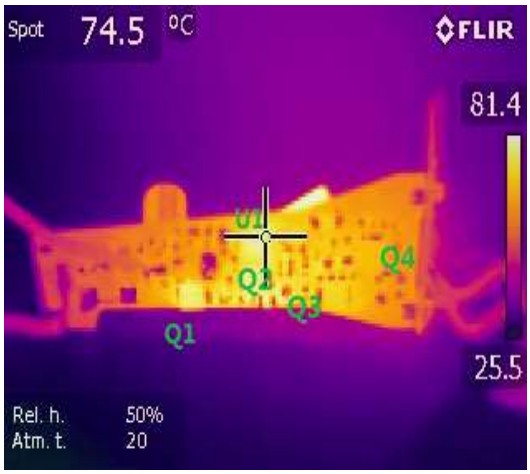


Figure 26: VIN=12V&24VDC, components side

Test Items	Temperature		Unit
	VIN=12VDC @ 9V3A	**VIN=24VDC @ 9V3A**	
Ambient Temp	26.6	26.3	℃
Q1-DMT6007	84.3	87.3	℃
Q2-DMT6007	83.6	92.4	℃
Q3-DMT6007	82.7	86.4	℃
Q4-DMT6007	76.2	85.8	℃
Q5-DMT3006	67.8	68.9	℃
U1-AT8901	88.9	90.3	℃
U2-AP43771	53.4	55.1	℃
EC1-100uF	69.2	58.1	℃
L1-10uH	88.3	94.7	℃
EC2-330uF	56.1	58.5	℃

Test Items	Temperature		Unit
	VIN=12VDC @ 15V2.2A	**VIN=24VDC @ 15V2.2A**	
Ambient Temp	25.5	25.6	℃
Q1-DMT6007	70.1	75.1	℃
Q2-DMT6007	66.8	80.4	℃
Q3-DMT6007	77.9	76.2	℃
Q4-DMT6007	79.6	77.1	℃
Q5-DMT3006	65.1	64.5	℃
U1-AT8901	77.7	88.4	℃
U2-AP43771	56.3	60.4	℃
EC1-100uF	51.5	54.0	℃
L1-10uH	77.8	91.1	℃
EC2-330uF	53.1	55.7	℃

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2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.

B. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or to affect its safety or effectiveness.

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