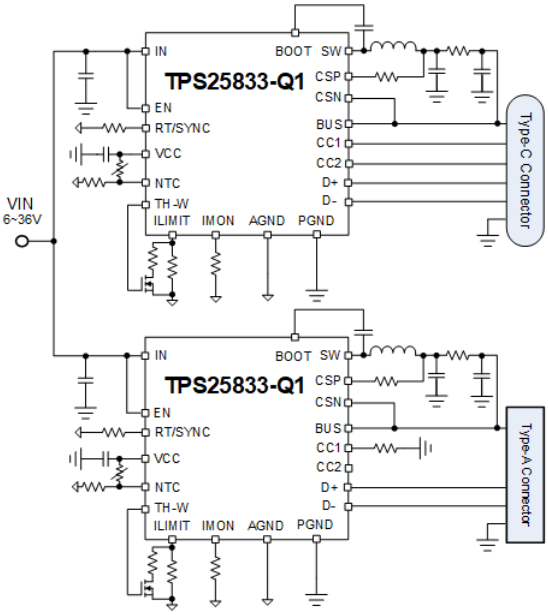
Test Report: PMP40543

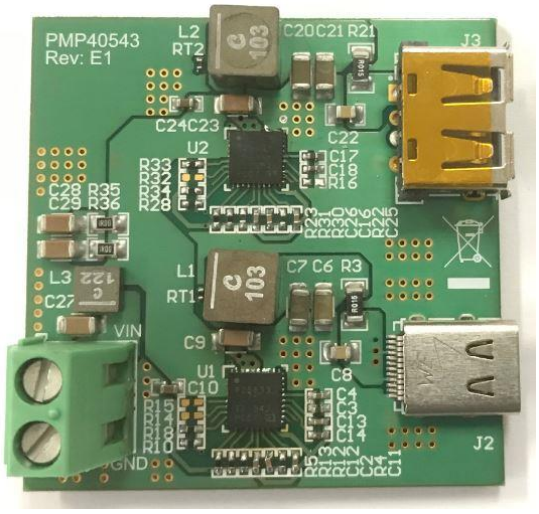
Automotive 15-W USB Type-C™ and 12-W USB Type-A Charger Reference Design

Description

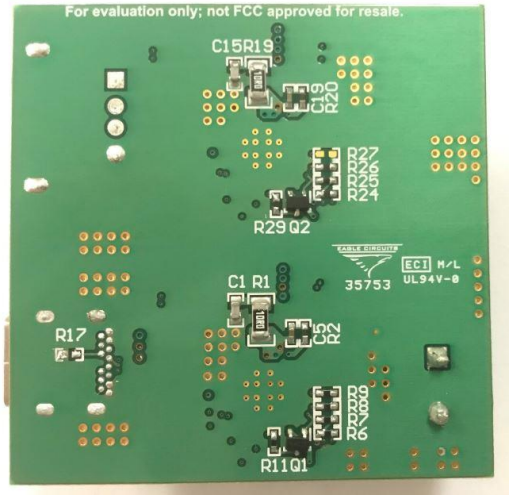
This reference design is for an automotive USB Type-C and USB Type-A charger in 45-mm×45-mm dimension. The TPS25833-Q1 is used in each port as DC-DC regulator and port controller. The efficiency of the solution is 93.2% at 27-W output, which leads to only 40.8°C temperature rise. In an 85°C environment, the highest temperature on the board is 126.4°C. Programmable cable droop compensation helps portable devices charge at optimum current and voltage under heavy loads. A negative temperature coefficient (NTC) thermistor is implemented for intelligent thermal management to reprogram the output current limit.



Top



Bottom



1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

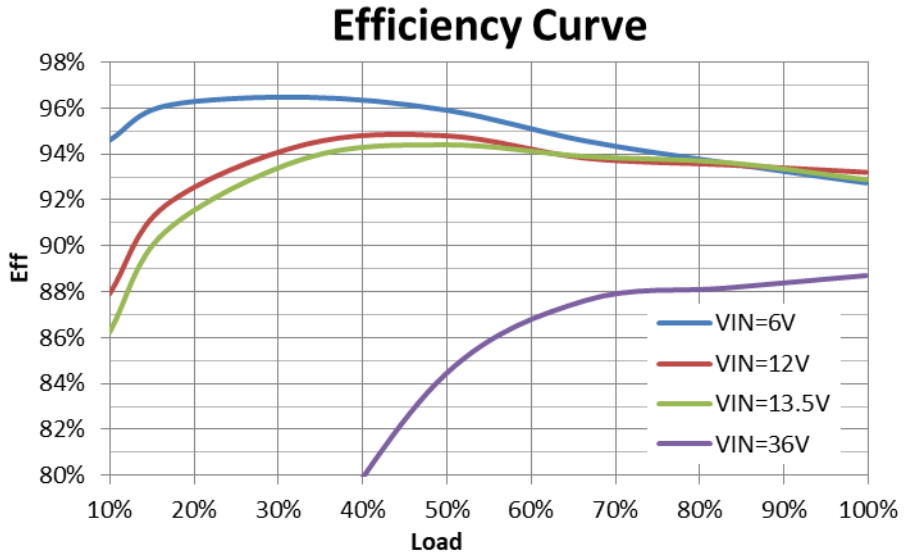
PARAMETER	SPECIFICATIONS
Input Voltage	6~36 Vdc
Port 1 Output Voltage	5 Vdc
Port 1 Maximum Output Current	3 A
Port 2 Output Voltage	5 Vdc
Port 2 Maximum Output Current	2.4 A
Switching Frequency	400k Hz

1.2 Required Equipment

- Multi-meter (current): Fluke 287C
- Multi-meter (voltage): Fluke 287C
- DC Source: Chroma 62006P-100-25
- E-Load: Chroma 63105A module
- Oscilloscope: Tektronix DPO3054
- Electrical Thermography: Fluke TiS55
- Thermal Data Acquisition: Agilent 34970A

2 Testing and Results

2.1 Efficiency Graphs

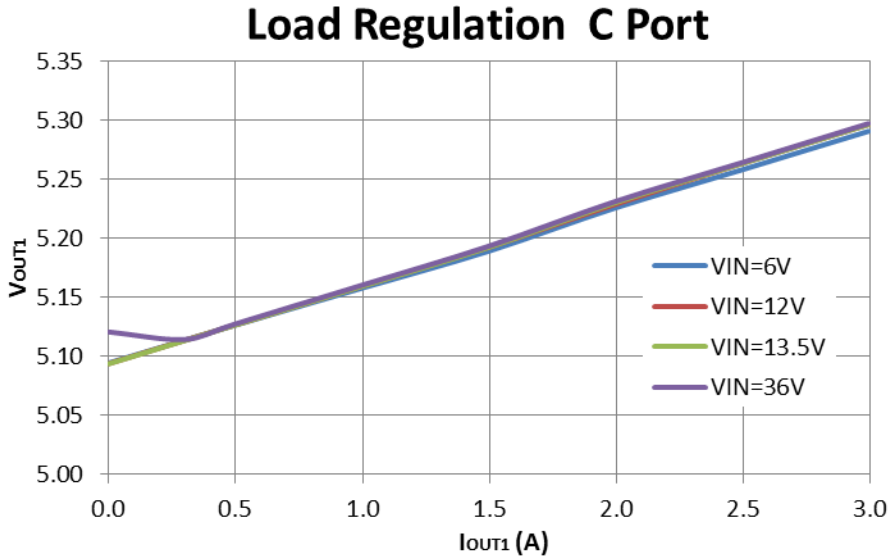


2.2 Efficiency Data

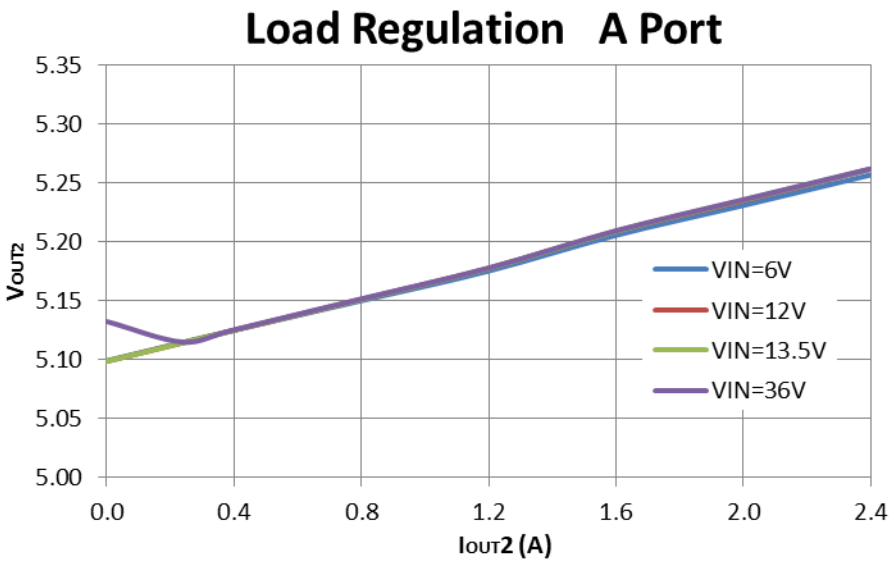
V_{IN} (V)	I_{IN} (A)	V_{OUT1} (V)	I_{OUT1} (A)	V_{OUT2} (V)	I_{OUT2} (A)	Eff
5.994	5.115	5.291	2.992	5.257	2.398	**92.74%**
5.994	4.197	5.258	2.492	5.231	1.997	**93.61%**
5.996	3.304	5.226	1.994	5.205	1.597	**94.56%**
5.997	2.428	5.189	1.496	5.175	1.199	**95.91%**
5.998	1.599	5.158	0.996	5.150	0.799	**96.47%**
5.994	0.798	5.126	0.498	5.125	0.399	**96.09%**
5.999	0.486	5.114	0.299	5.115	0.240	**94.60%**
6.006	0.020	5.094	0.001	5.099	0.000	
11.996	2.546	5.296	2.992	5.262	2.398	**93.20%**
11.997	2.101	5.263	2.492	5.235	1.997	**93.53%**
11.997	1.665	5.229	1.994	5.209	1.598	**93.82%**
11.998	1.229	5.192	1.496	5.178	1.199	**94.80%**
11.999	0.817	5.159	0.996	5.151	0.799	**94.42%**
11.995	0.418	5.127	0.498	5.125	0.399	**91.76%**
11.998	0.261	5.113	0.299	5.114	0.240	**87.91%**
12.001	0.030	5.094	0.000	5.099	0.000	

13.497	2.271	5.296	2.992	5.262	2.398	**92.88%**
13.498	1.865	5.263	2.492	5.235	1.997	**93.63%**
13.498	1.479	5.230	1.994	5.209	1.597	**93.89%**
13.492	1.097	5.192	1.496	5.177	1.199	**94.40%**
13.499	0.731	5.159	0.996	5.151	0.799	**93.81%**
13.504	0.376	5.126	0.498	5.125	0.399	**90.62%**
13.506	0.237	5.113	0.299	5.114	0.240	**86.24%**
13.509	0.031	5.094	0.000	5.099	0.000	**0.45%**
36.007	0.890	5.297	2.992	5.262	2.398	**88.81%**
36.009	0.738	5.264	2.492	5.236	1.997	**88.70%**
36.001	0.591	5.231	1.994	5.209	1.597	**88.16%**
36.002	0.443	5.193	1.496	5.178	1.199	**87.62%**
36.001	0.305	5.160	0.996	5.151	0.799	**84.42%**
36.002	0.167	5.127	0.498	5.125	0.399	**76.31%**
36.002	0.113	5.114	0.299	5.115	0.240	**67.64%**
36.002	0.002	5.121	0.001	5.132	0.000	

2.3 Load Regulation



(A 2.74KΩ resistor on IMON pin for cable droop compensation.)

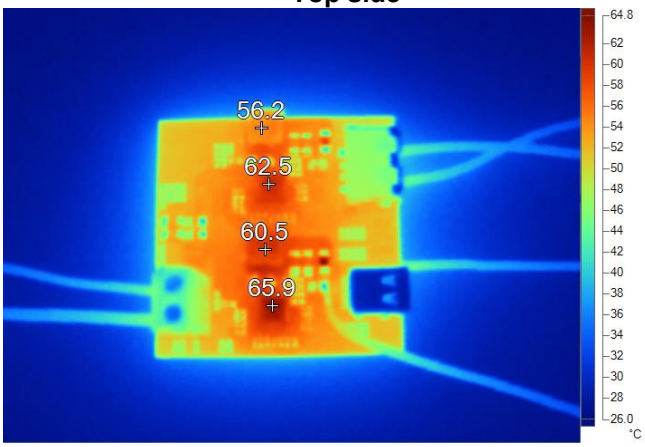


(A 2.74KΩ resistor on IMON pin for cable droop compensation.)

2.4 Thermal Images

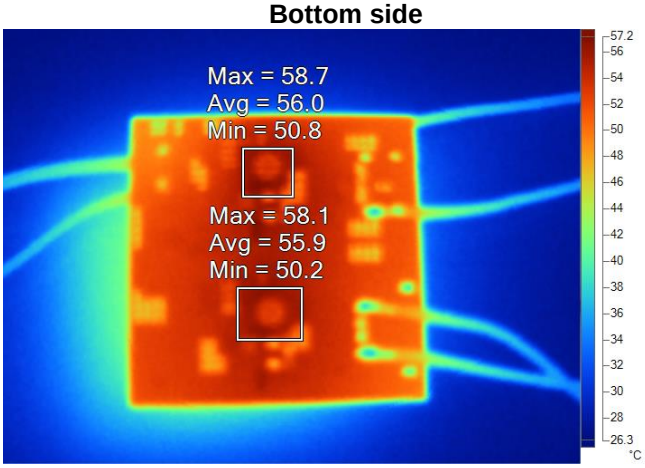
Ta=25.1°C, 12V input, 3A+2.4A output
(4-layer PCB, 2 oz copper on top and bottom layers, 1 oz copper on middle layers.)

Top side



T_{case_max}=**65.9°C**, ΔT=**40.8°C**

Bottom side



2.5 High Temp Test

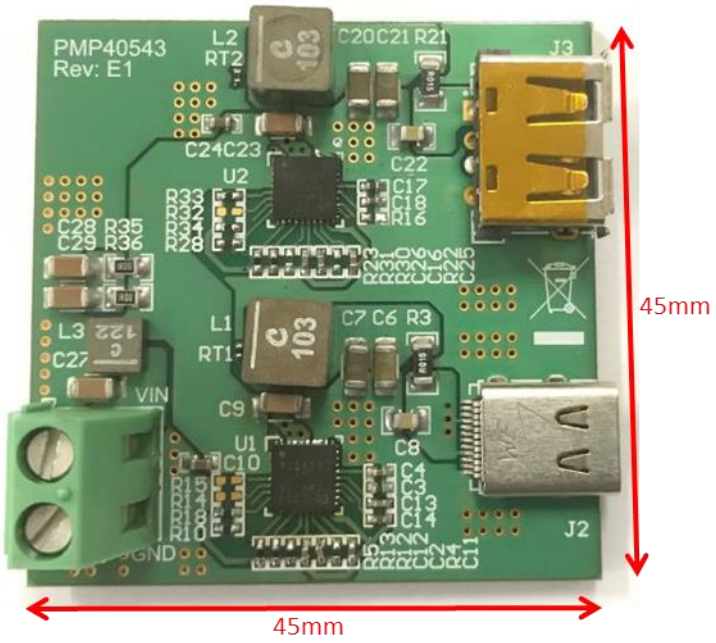
Run the board in the 85°C test chamber; detect the temperature of IC and inductors with thermocouple to 34970A.

Ta=85°C Chamber, V input, 3A+2.4A output

Component	T_{CASE}	ΔT
U1	126.4°C	41.4°C
L1	123.1°C	38.1°C
U2	125.9°C	40.9°C
L2	120.8°C	35.8°C

2.6 Dimensions

The dimension of this board is 45mm (length)*45mm (width)*7.5mm (height, ignore J1).

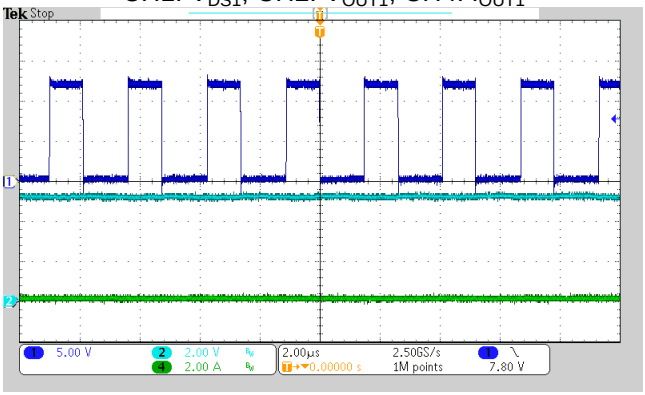


3 Waveforms

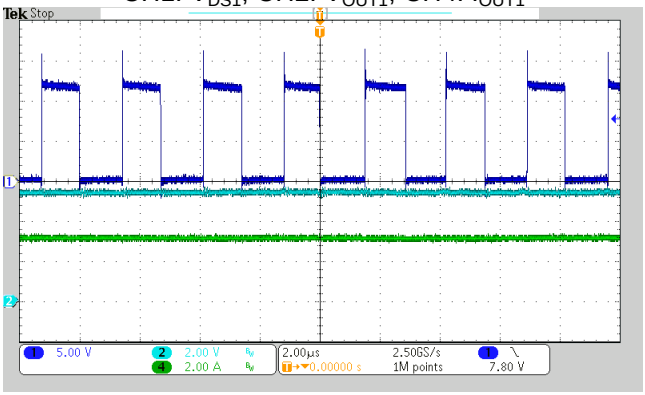
3.1 Switching

The waveforms of switching nodes at no load and full load condition are shown in following pictures.

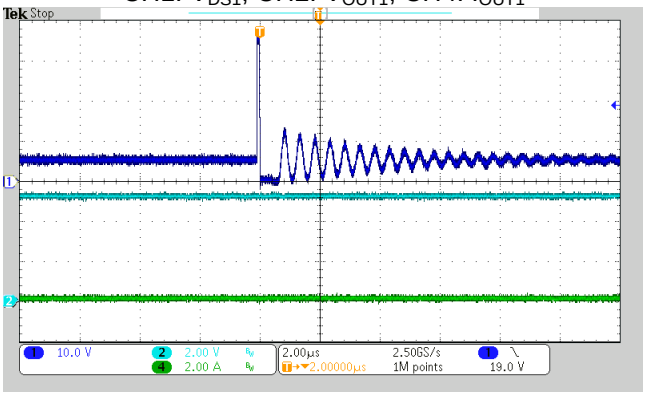
U1, 12V input, 5V no-load
CH1: V_{DS1}, CH2: V_{OUT1}, CH4: I_{OUT1}



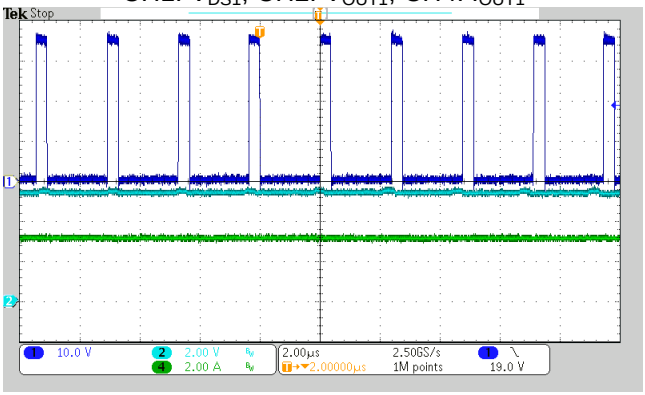
U1, 12V input, 5V 3A load
CH1: V_{DS1}, CH2: V_{OUT1}, CH4: I_{OUT1}



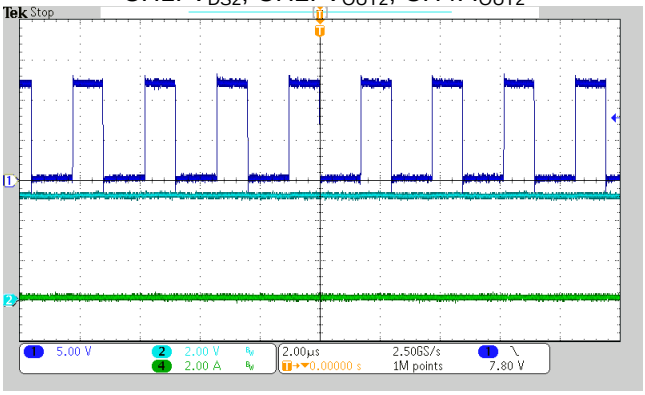
U1, 36V input, 5V no-load
CH1: V_{DS1}, CH2: V_{OUT1}, CH4: I_{OUT1}



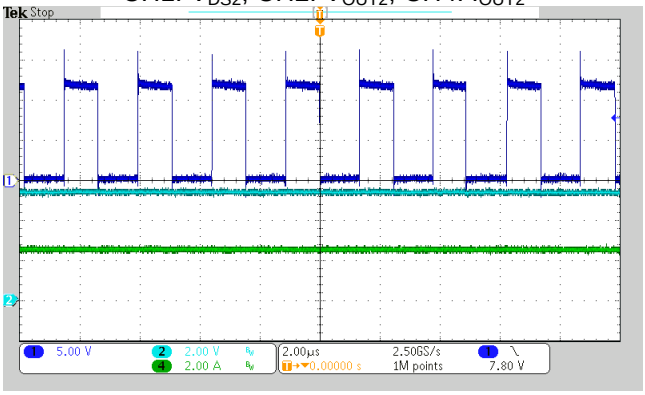
U1, 36V input, 5V 3A load
CH1: V_{DS1}, CH2: V_{OUT1}, CH4: I_{OUT1}



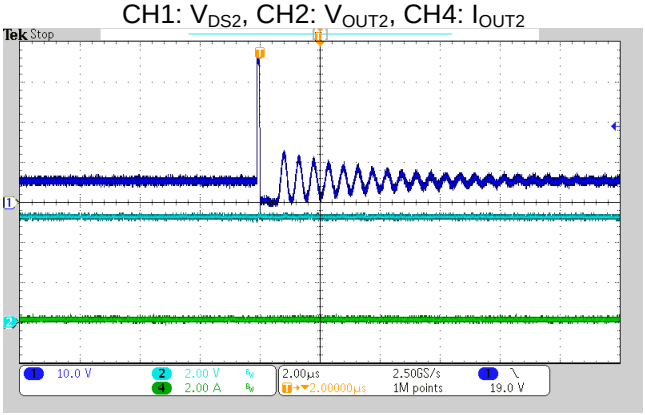
U2, 12V input, 5V no-load
CH1: V_{DS2}, CH2: V_{OUT2}, CH4: I_{OUT2}



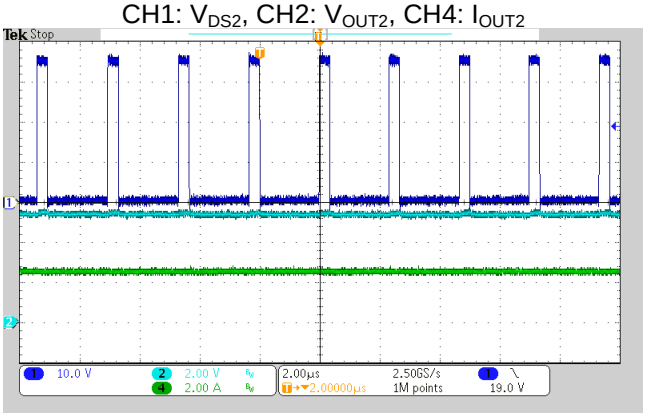
U2, 12V input, 5V 3A load
CH1: V_{DS2}, CH2: V_{OUT2}, CH4: I_{OUT2}



U2, 36V input, 5V no-load
CH1: V_{DS2}, CH2: V_{OUT2}, CH4: I_{OUT2}



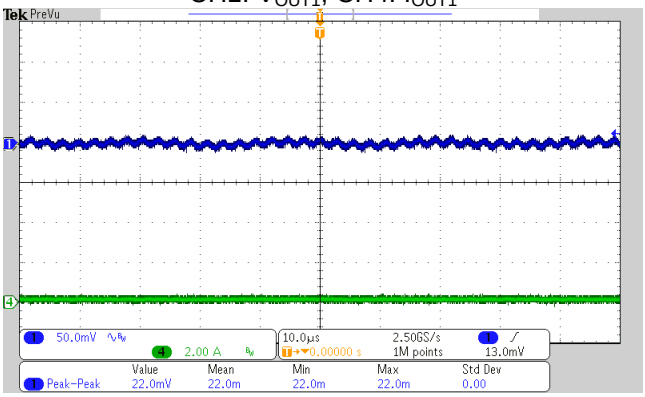
U2, 36V input, 5V 3A load
CH1: V_{DS2}, CH2: V_{OUT2}, CH4: I_{OUT2}



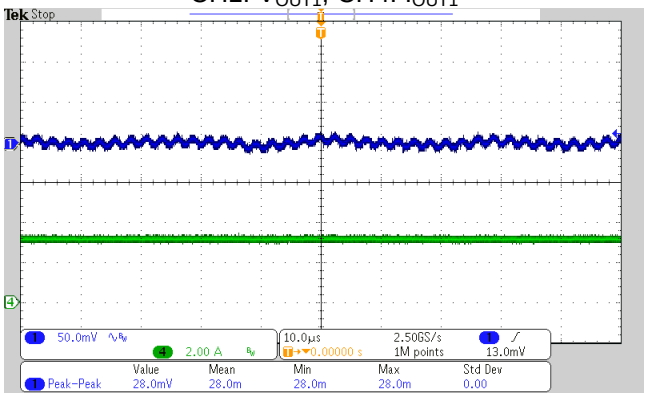
3.2 Output Voltage Ripple

The waveforms of output AC ripples at no load and full load condition are shown in following pictures.

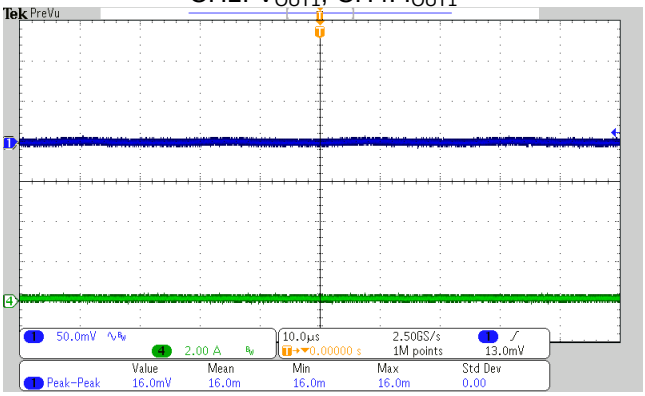
Port 1, 12V input, 5V no-load
CH1: V_{OUT1}, CH4: I_{OUT1}



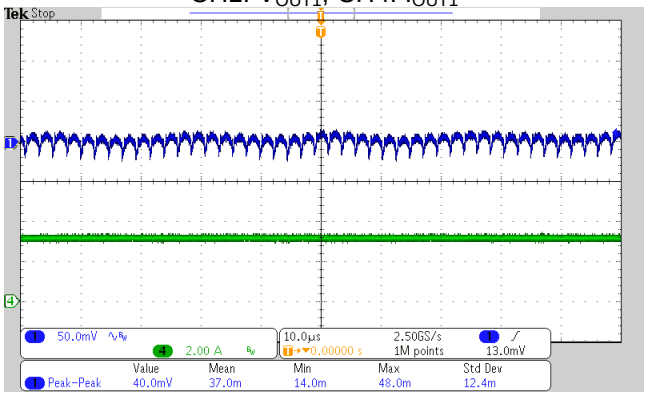
Port 1, 12V input, 5V 3A load
CH1: V_{OUT1}, CH4: I_{OUT1}



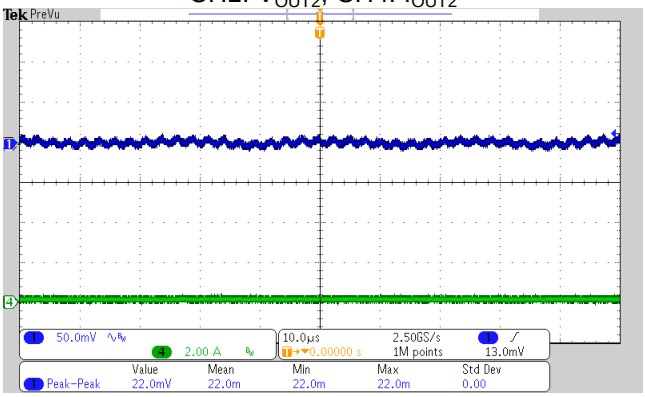
Port 1, 36V input, 5V no-load
CH1: V_{OUT1}, CH4: I_{OUT1}



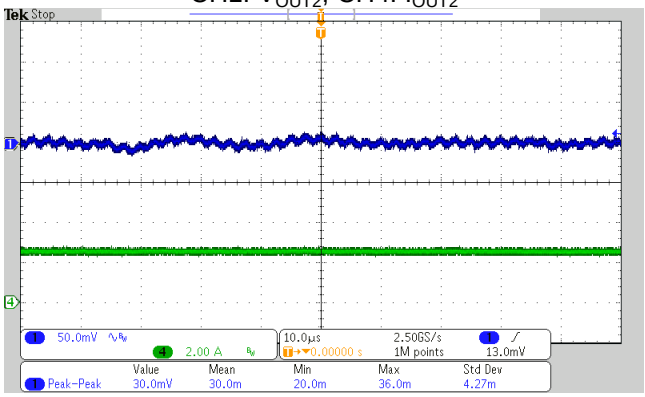
Port 1, 36V input, 5V 3A load
CH1: V_{OUT1}, CH4: I_{OUT1}



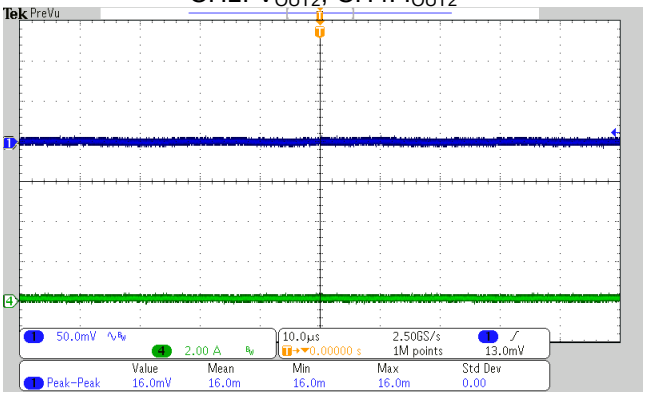
Port 2, 12V input, 5V no-load
CH1: V_{OUT2}, CH4: I_{OUT2}



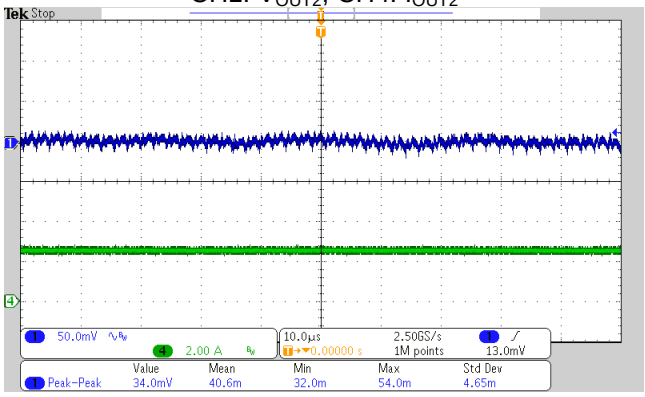
Port 2, 12V input, 5V 2.4A load
CH1: V_{OUT2}, CH4: I_{OUT2}



Port 2, 36V input, 5V no-load
CH1: V_{OUT2}, CH4: I_{OUT2}



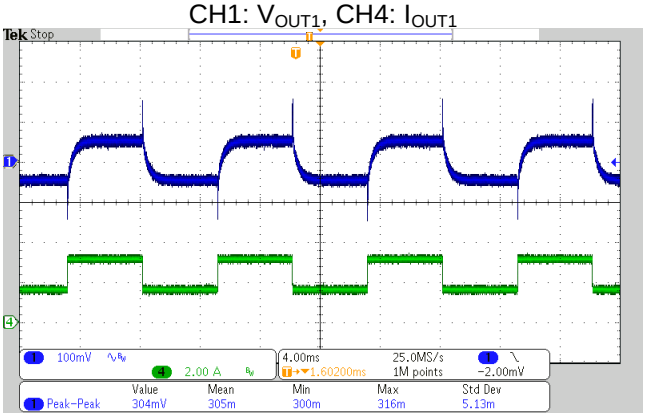
Port 2, 36V input, 5V 2.4A load
CH1: V_{OUT2}, CH4: I_{OUT2}



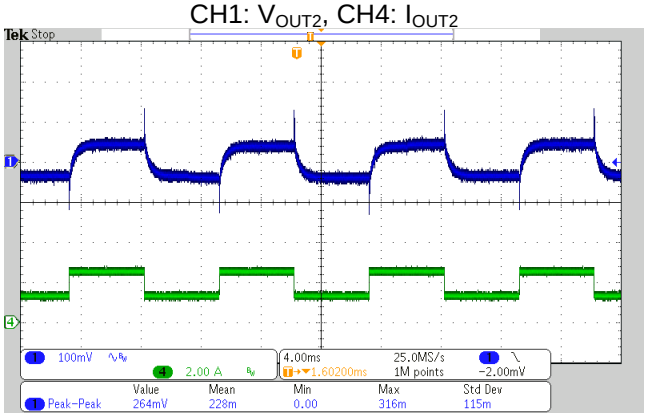
3.3 Load Transient

The waveforms of output AC ripples at load transient are shown in following pictures. The high current level is full load for 5ms; the low current level is half load for 5ms, with a slew rate of 0.1A/us.

Port 1, 12V input, 1.5A->3A
CH1: V_{OUT1}, CH4: I_{OUT1}



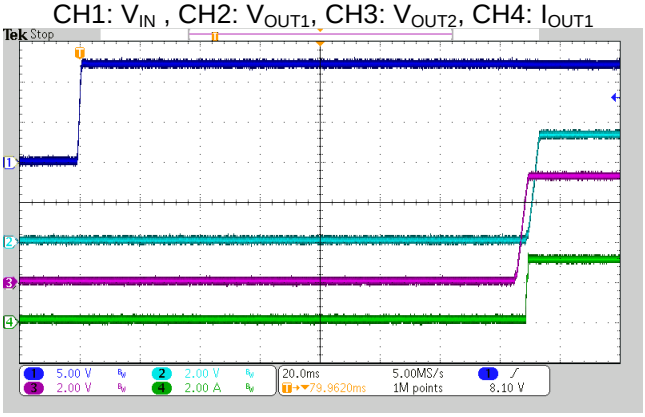
Port 2, 12V input, 1.2A->2.4A
CH1: V_{OUT2}, CH4: I_{OUT2}



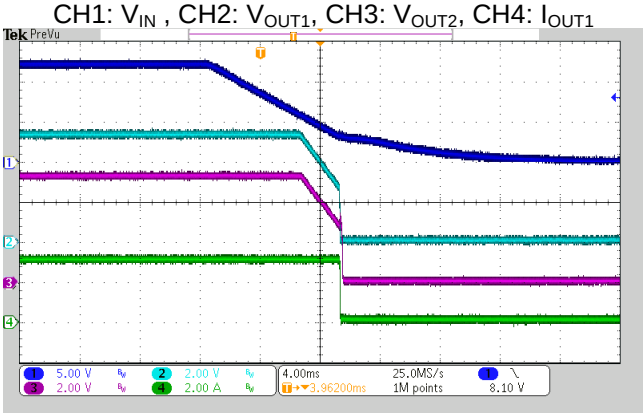
3.4 Power on/off

The waveforms of system power on and off with full load outputs are shown in following pictures.

Power on
CH1: V_{IN} , CH2: V_{OUT1}, CH3: V_{OUT2}, CH4: I_{OUT1}



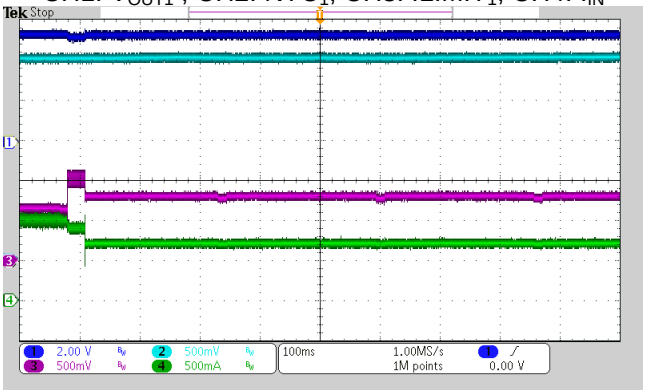
Power off
CH1: V_{IN} , CH2: V_{OUT1}, CH3: V_{OUT2}, CH4: I_{OUT1}



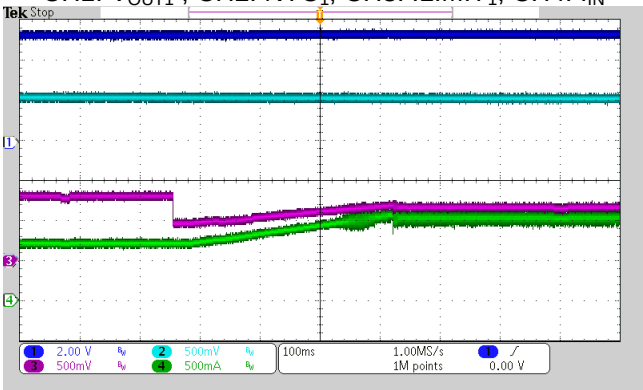
3.5 Thermal managements

The waveforms of thermal managements are shown in following pictures. The test is simulated using a 150°C hot air generator.

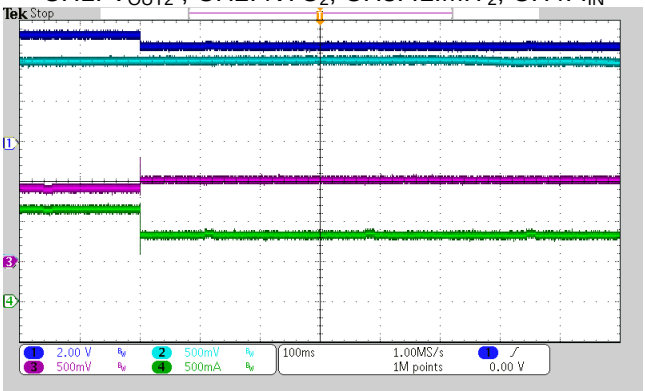
Port 1 connected to Google Pixel 2, Port 2 no-load, board heated by a hot air generator
CH1: V_{OUT1} , CH2: NTC_1, CH3: $ILIMIT_1$, CH4: I_{IN}



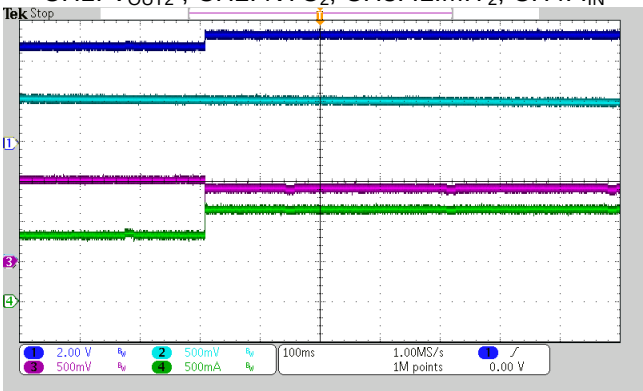
Port 1 connected to Google Pixel 2, Port 2 no-load, remove hot air generator
CH1: V_{OUT1} , CH2: NTC_1, CH3: $ILIMIT_1$, CH4: I_{IN}



Port 1 no-load, Port 2 connected to iPad, board heated by a hot air generator
CH1: V_{OUT2} , CH2: NTC_2, CH3: $ILIMIT_2$, CH4: I_{IN}



Port 1 no-load, Port 2 connected to iPad, remove hot air generator
CH1: V_{OUT2} , CH2: NTC_2, CH3: $ILIMIT_2$, CH4: I_{IN}



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