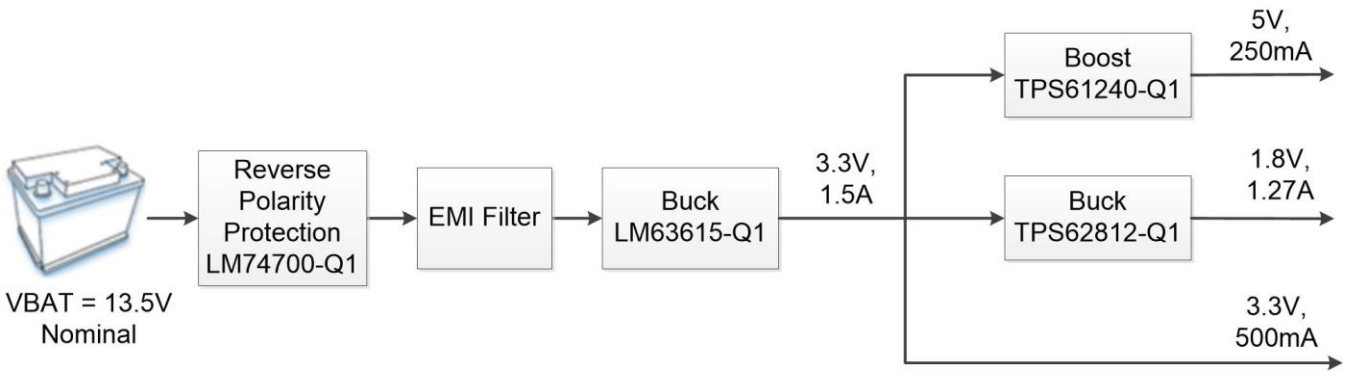
Test Report: PMP22063

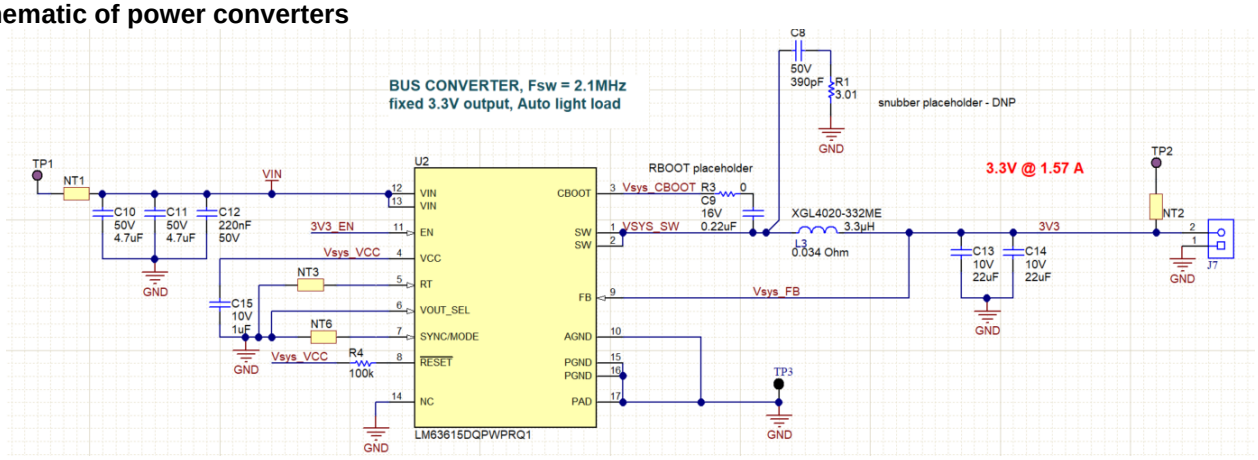
Automotive Cluster and Display Power Reference Design With Warm/Cold-Crank Capability

Description

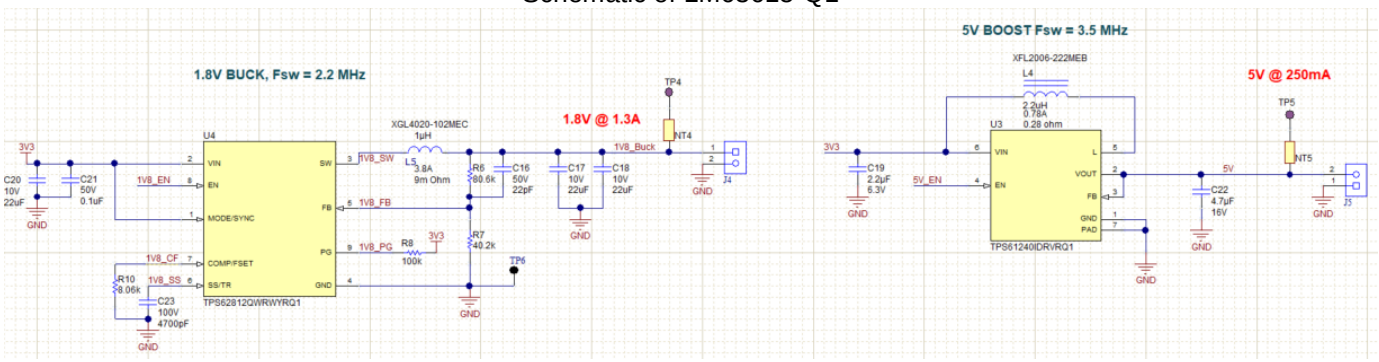
This reference design provides the system rails for automotive HUD, center information display, cluster display, or other automotive displays. A 3.3V bus is generated by an off-battery buck converter. A boost converter provides 3.3V to 5V conversion and a buck provides 1.8V from the 3.3V rail. Display panel, CAN bus, microcontroller (MCU), FPD-Link, touch controller, and switch packs are all examples of what can be driven by the power rails in this design. EMI filtering and reverse battery protection are included.



Schematic of power converters



Schematic of LM63615-Q1



Schematic of TPS62812-Q1 and TPS61240-Q1

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements for 3V3 output

PARAMETER	SPECIFICATIONS
Input voltage	13.5V Nominal
Output voltage	3.3V
Output current	1.57A
Switching frequency	2.1MHz

Table 2. Voltage and Current Requirements for 5V output

PARAMETER	SPECIFICATIONS
Input voltage	3.3V
Output voltage	5V
Output current	250mA
Switching frequency	3.5MHz

Table 3. Voltage and Current Requirements for 1V8 output

PARAMETER	SPECIFICATIONS
Input voltage	3.3V
Output voltage	1.8V
Output current	1.27A
Switching frequency	2.2MHz

1.2 Considerations

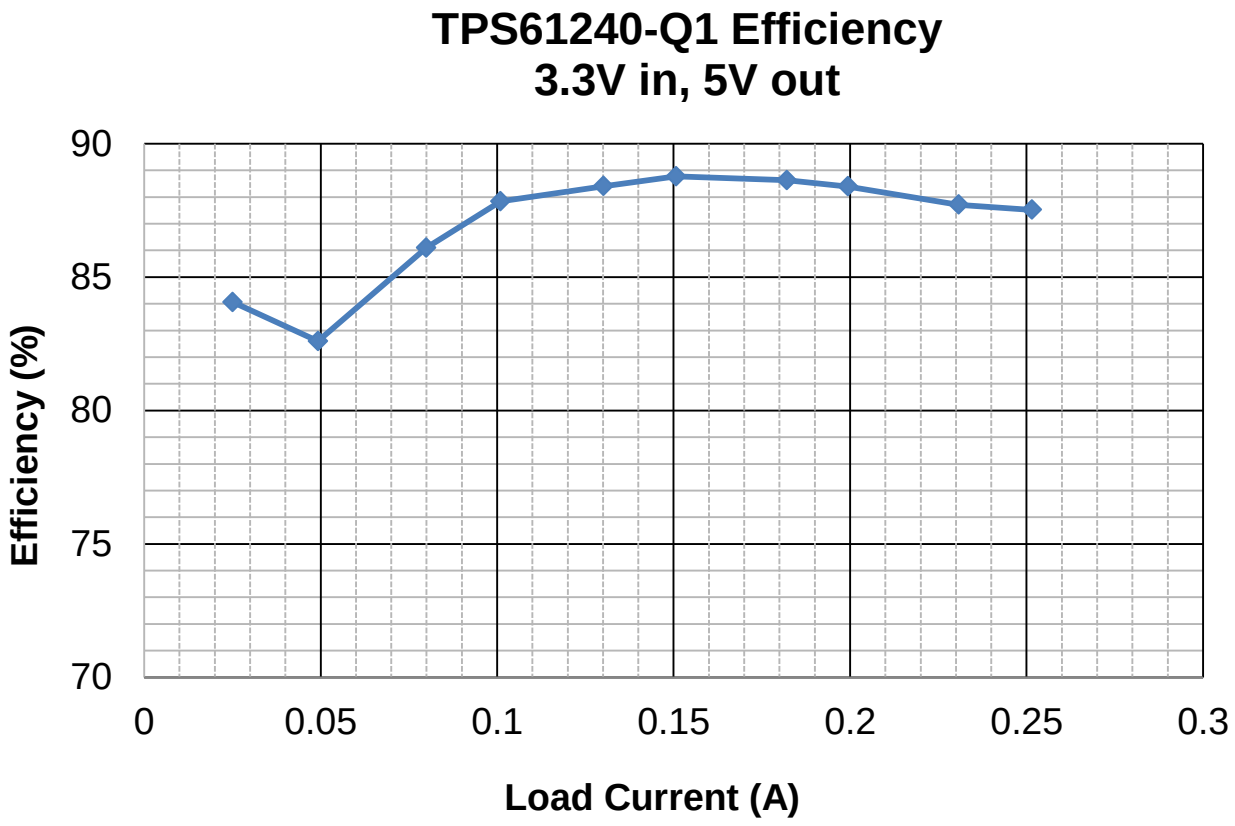
Unless stated otherwise, tests were performed at 13.5V input. The input supply was connected to the input of the EMI filter (instead of being directly connected to the input of the converter).

2 Testing and Results

2.1 Efficiency Graphs

2.1.1 5V output rail

Efficiency was taken with the converter operating with 3.3V input, 5V output using an automated efficiency measurement station. The input supply was connected directly at the input of the converter. All other converters on the board were disabled. Peak efficiency is over 87%.

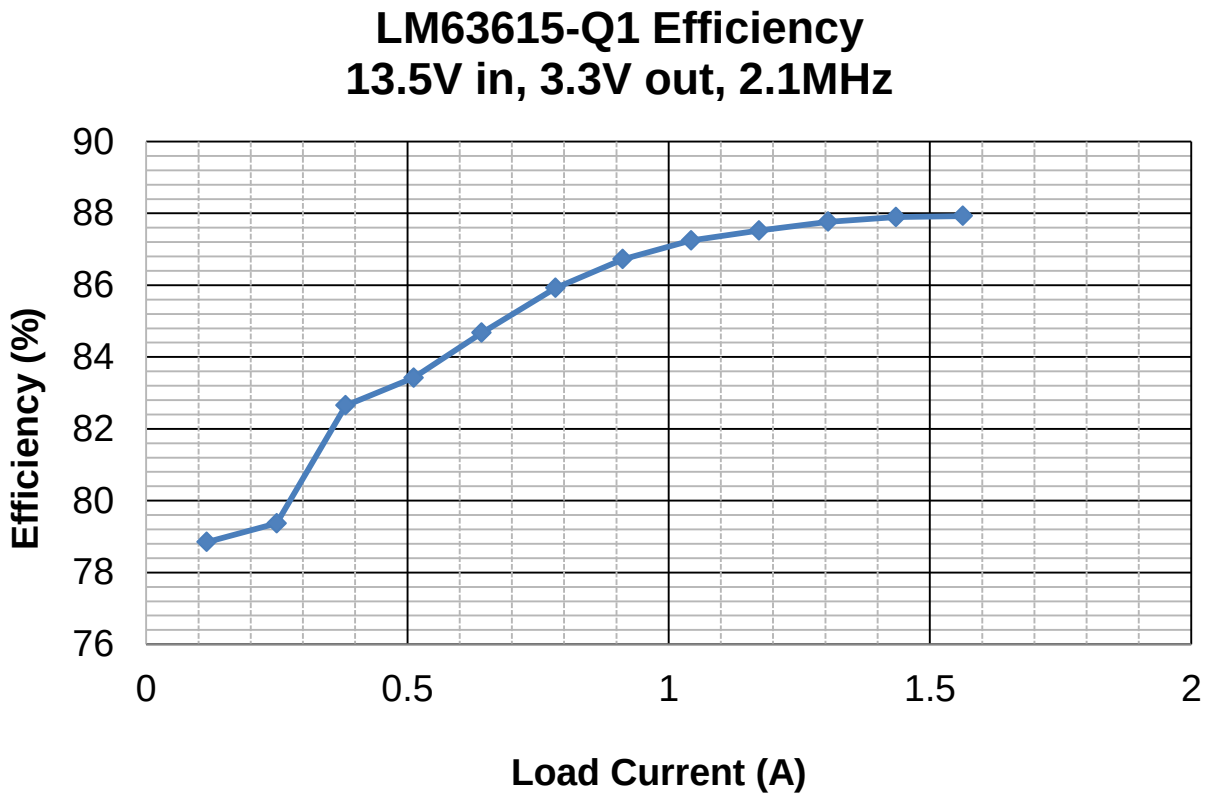


Efficiency Data

Vin (V)	Iin (A)	Iout(A)	Vout (V)	Efficiency (%)
13.53155	0.035835	0.115662	3.30556	78.84743
13.52687	0.076785	0.249769	3.300455	79.36662
13.52284	0.112763	0.38188	3.300387	82.653
13.51861	0.149865	0.512118	3.300187	83.42136
13.51455	0.185192	0.642174	3.300052	84.67407
13.51029	0.22267	0.783295	3.299848	85.91974
13.50631	0.256969	0.912191	3.299611	86.7223
13.50229	0.292129	1.042983	3.299452	87.24422
13.49824	0.327675	1.173303	3.299349	87.52212
13.49416	0.363566	1.30515	3.299136	87.76696

2.1.2 3V3 output rail

Efficiency was taken with the converter operating with 13.5V input, 3.3V output using an automated efficiency measurement station. The input was connected directly at the input of the converter. All other converters on the board were disabled. Peak efficiency is above 87%. AUTO light load mode enabled.



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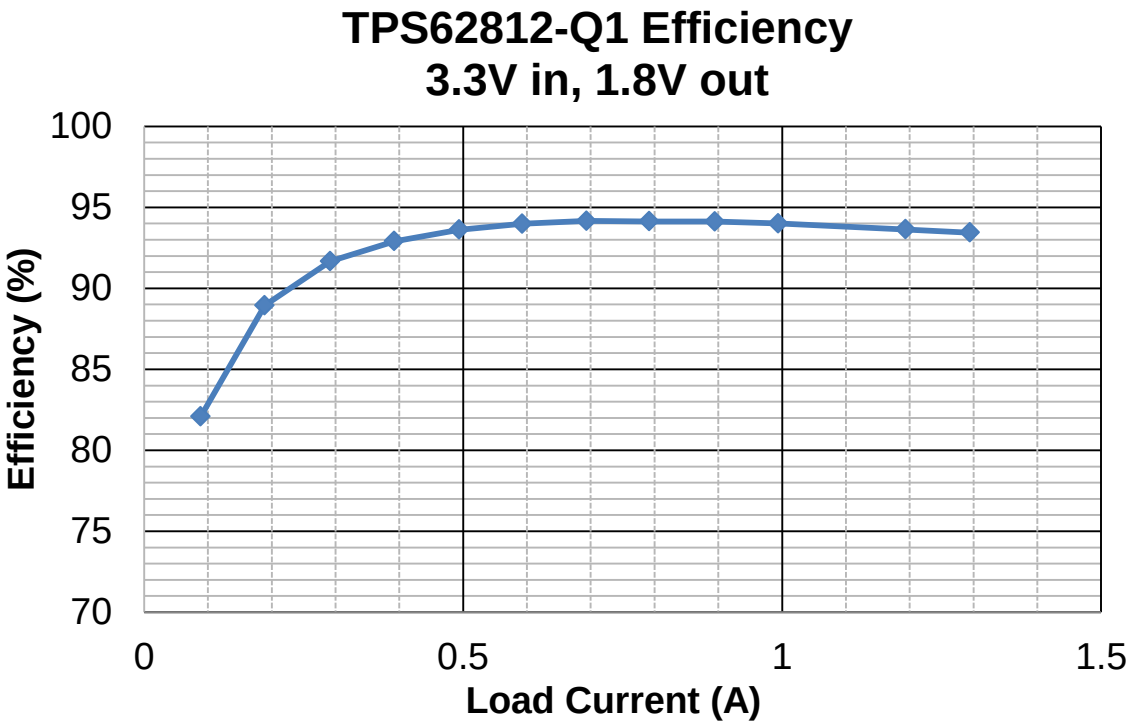
13.49416	0.363566	1.30515	3.299136	87.76696

2.1.3 1V8 output rail

Efficiency was taken for the TPS62812-Q1, operating with 3.3V input, 1.8V output using an automated efficiency measurement station. The input was connected directly at the input of the converter. All other parts on the board were disabled. Peak efficiency is above 94%.



Efficiency Data

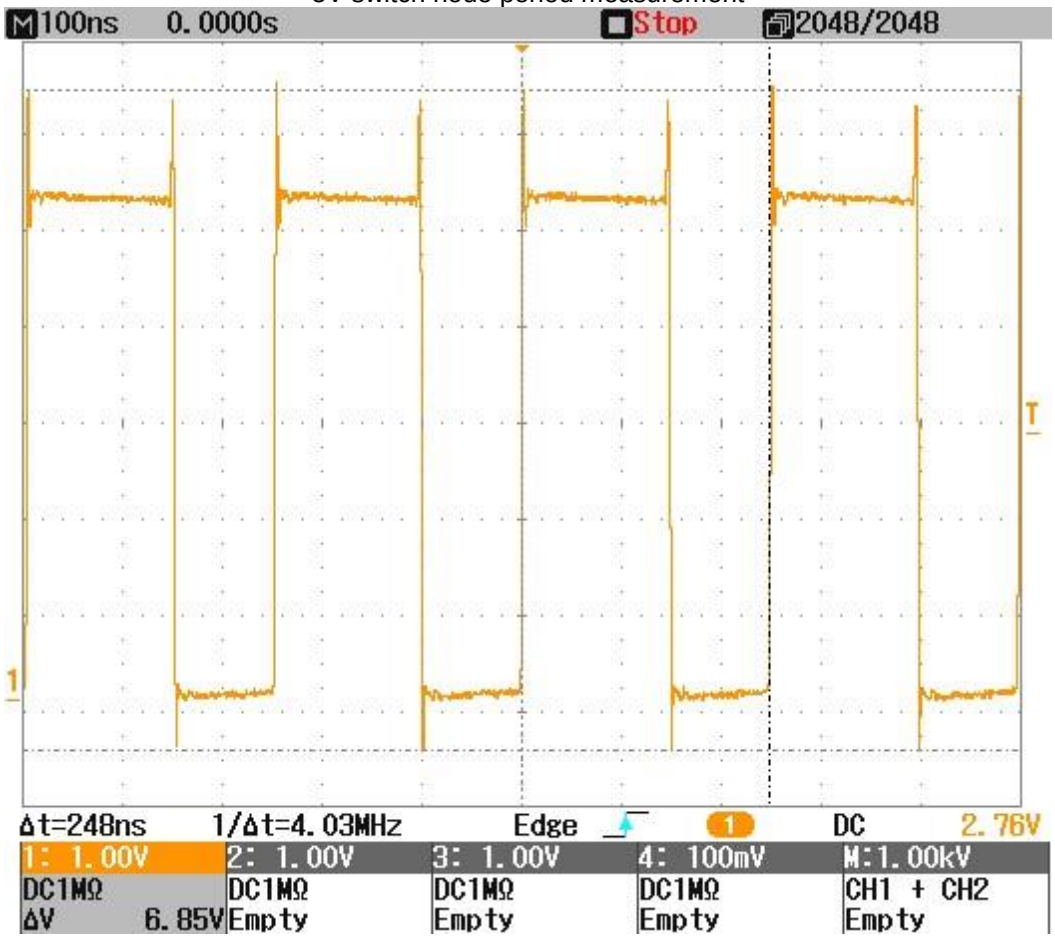
VIN	IVIN	ILOAD	VOUT	EFFI%
3.3769986	0.057417384	0.088603441	1.7965025	82.09262295
3.3700429	0.113213022	0.188927571	1.7962814	88.94835103
3.3629258	0.170057834	0.291884754	1.7961858	91.67454042
3.3559835	0.225911105	0.392156863	1.796238	92.91082211
3.3488468	0.282826329	0.493683473	1.7961461	93.62140005
3.3418499	0.338775572	0.59242497	1.7960529	93.98389777
3.3346139	0.396711153	0.693601441	1.7959623	94.16450684
3.3275867	0.454032565	0.791842737	1.7959548	94.12781052
3.3201772	0.514015376	0.89442377	1.7958518	94.1188156
3.3128842	0.573170023	0.993993597	1.7957835	94.00432591
3.2979743	0.693919454	1.193359344	1.7957077	93.63766014
3.2904472	0.755901382	1.294207683	1.795694	93.43643062

2.2 Switch Node

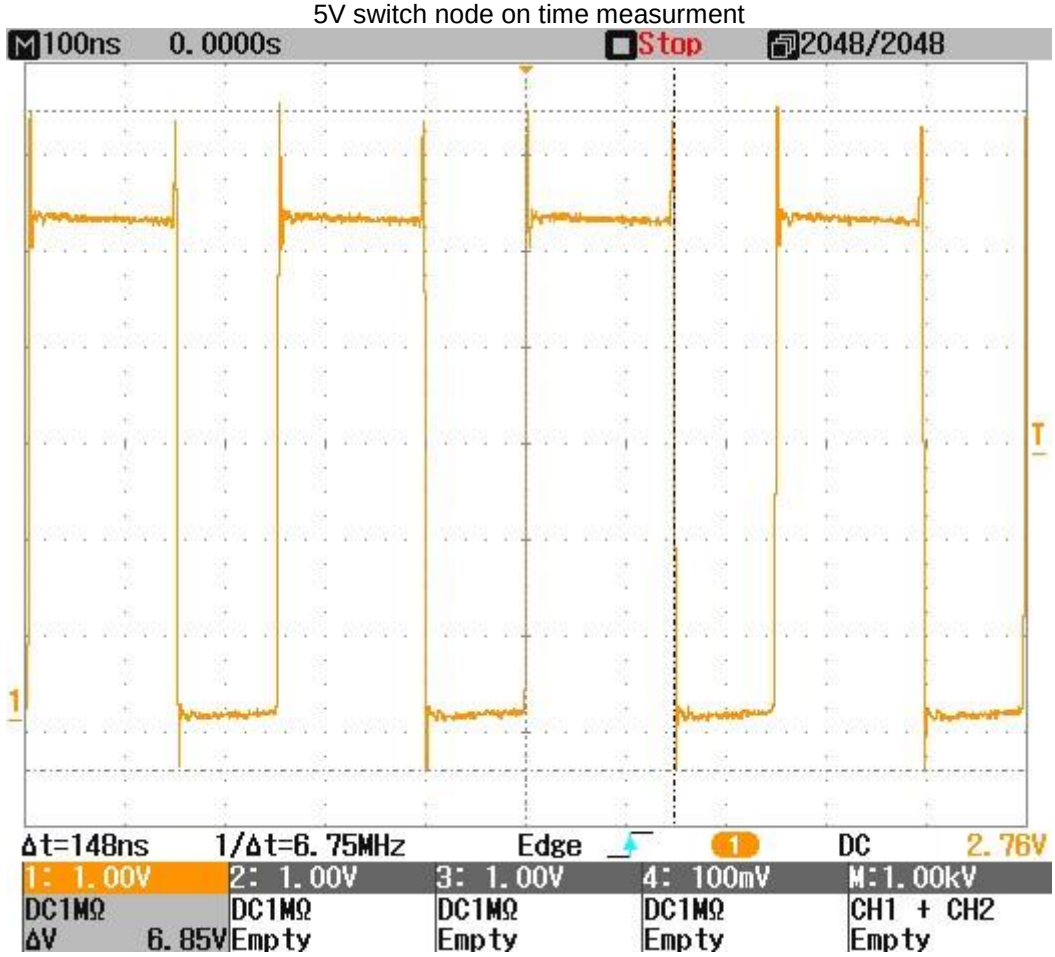
Switch node measurements were made using a tip and barrel probe on a Teledyne LeCroy WaveJet Touch 354 oscilloscope. 12V power was supplied by a HP 6655A and a Kikusui PLZ303W was used as the load. Rails were loaded to their rated maximum output currents for all measurements.

2.2.1 5V output rail

5V switch node period measurement



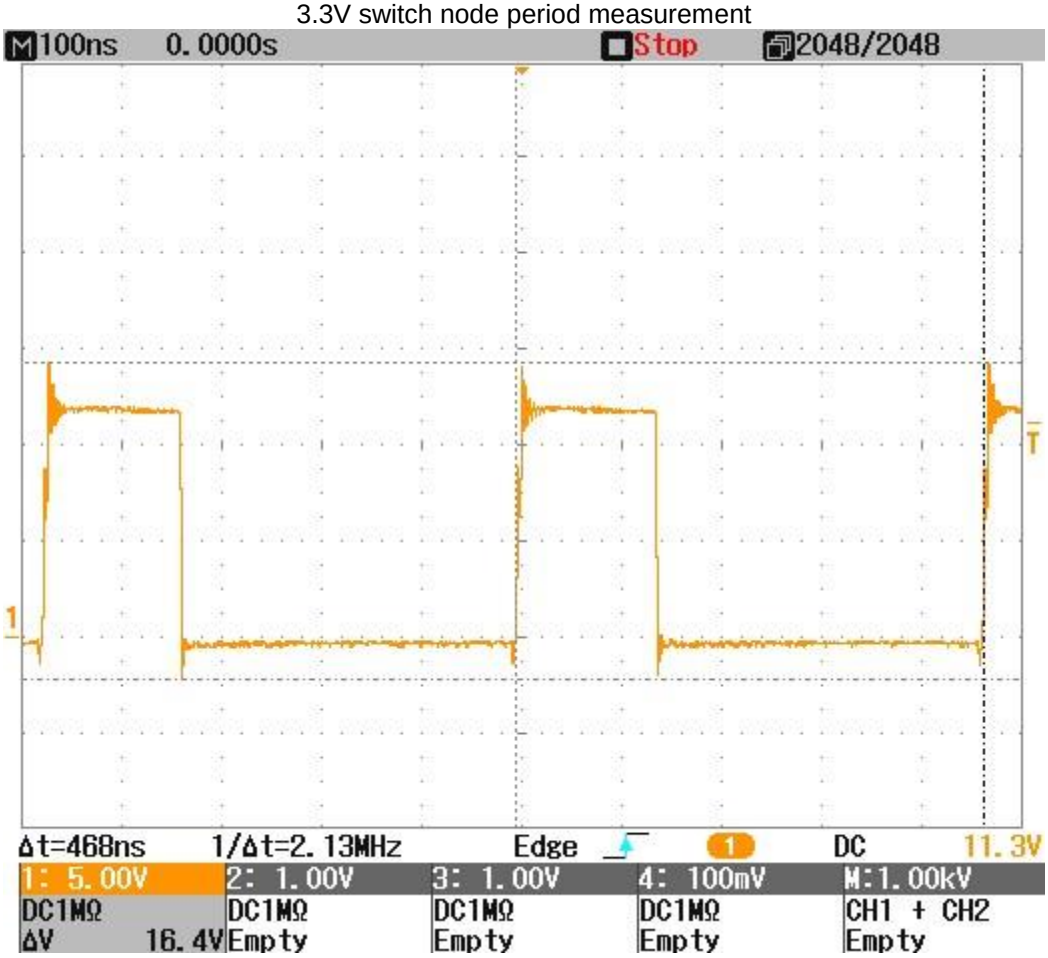
5V switch node on time measurment



5V switch node rise time measurement

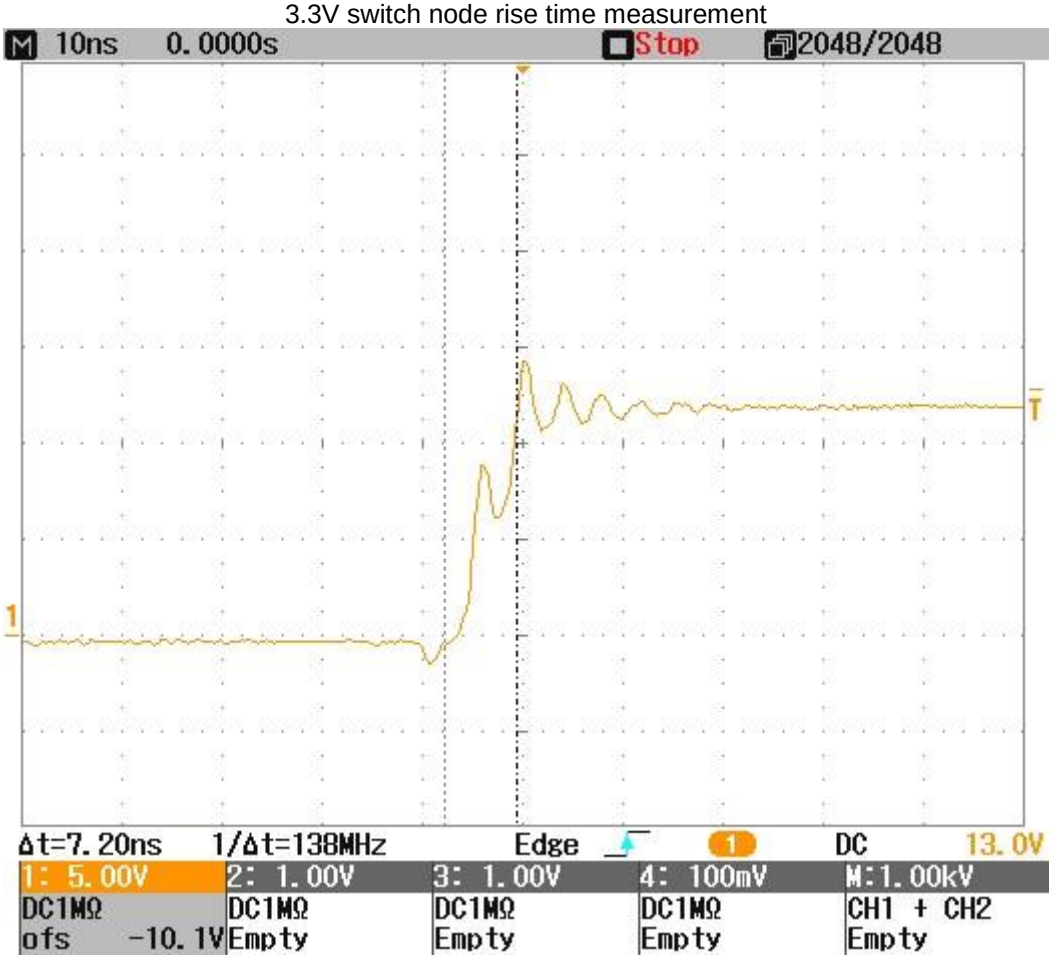
2.2.2 3.3V output rail

3.3V switch node period measurement

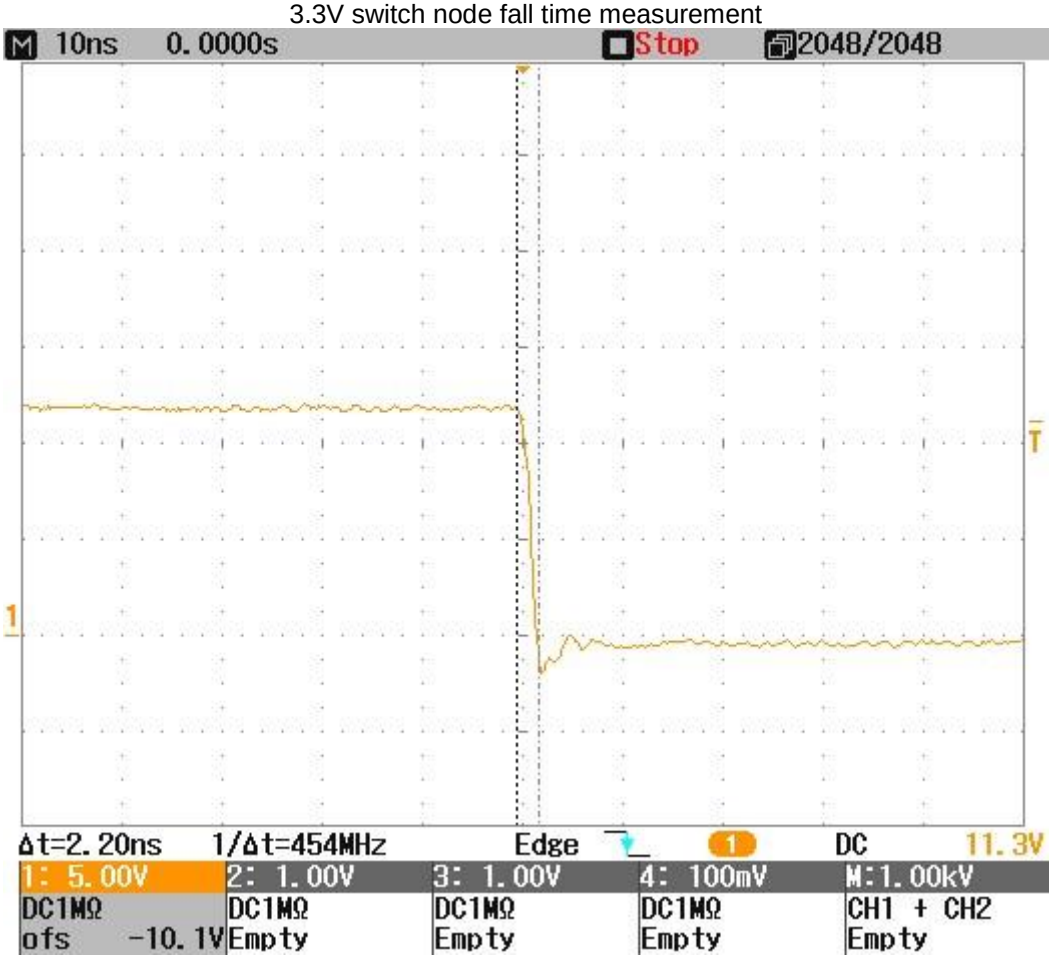


3.3V switch node on time measurement

3.3V switch node rise time measurement



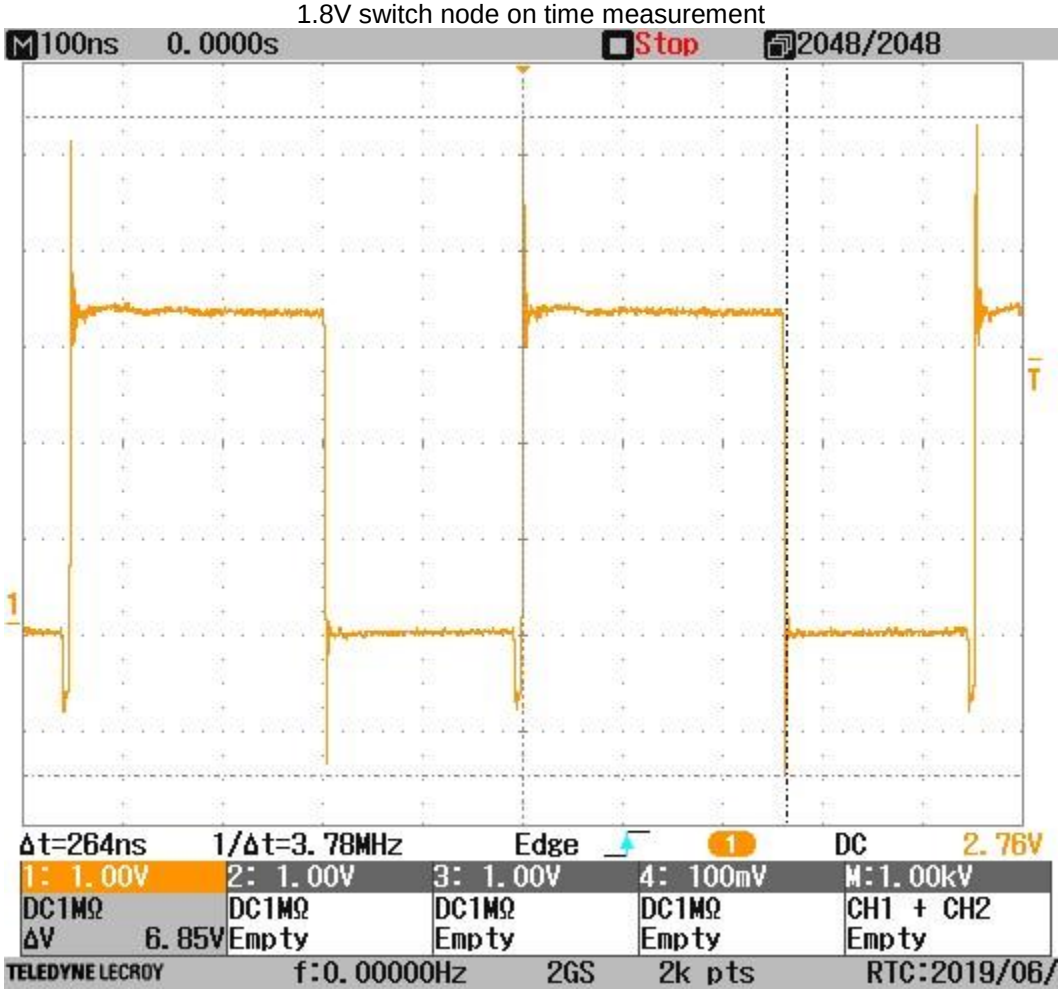
3.3V switch node fall time measurement



2.2.3 1.8V output rail

1.8V switch node period measurement

1.8V switch node on time measurement

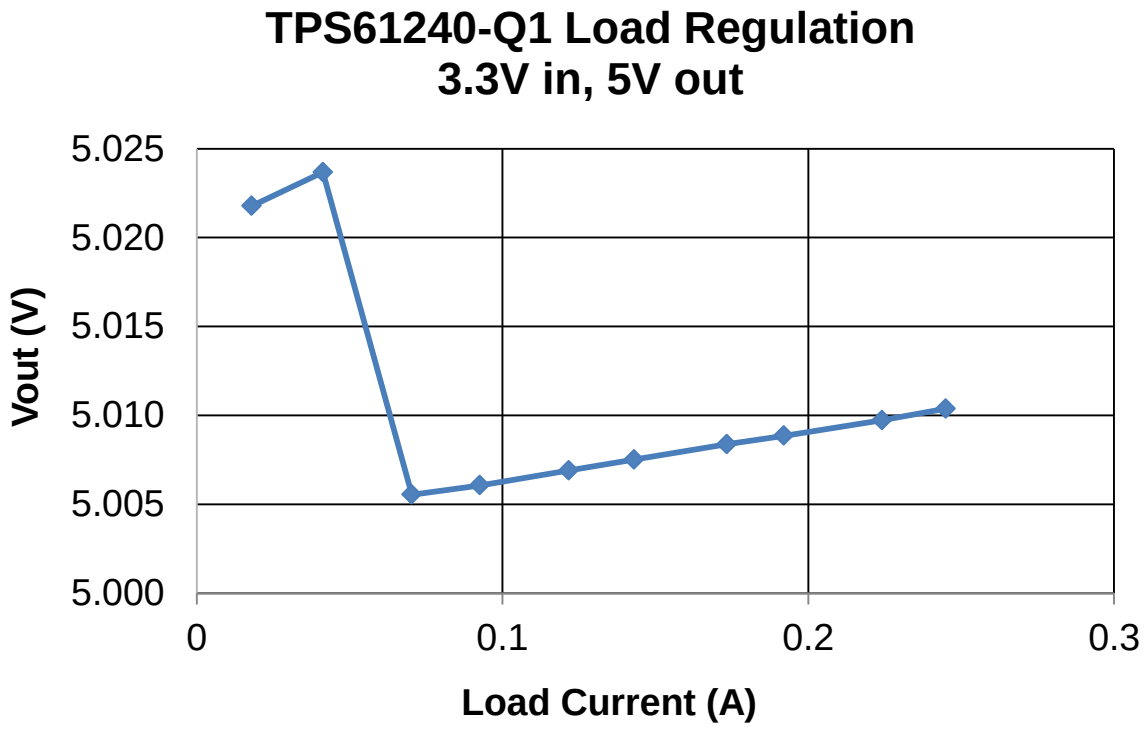


1.8V switch node rise time measurement

2.3 Load Regulation

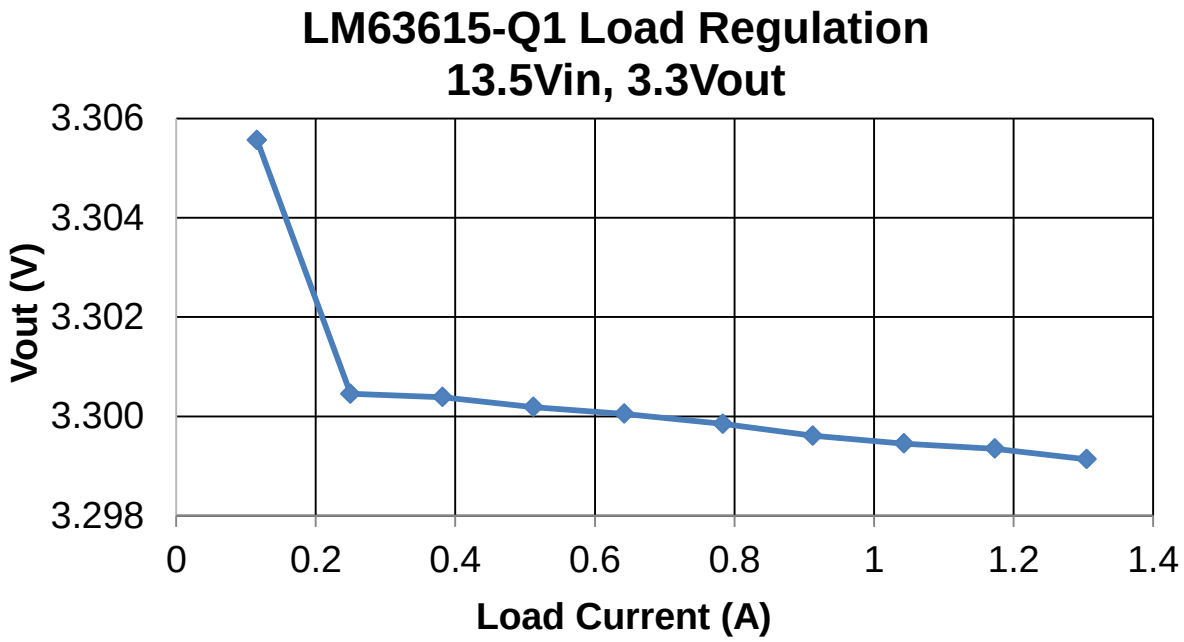
2.3.1 5V output rail – TPS61240-Q1

Load regulation data was extracted from the efficiency measurement data. The load regulation is less than 0.4% over the given load range.



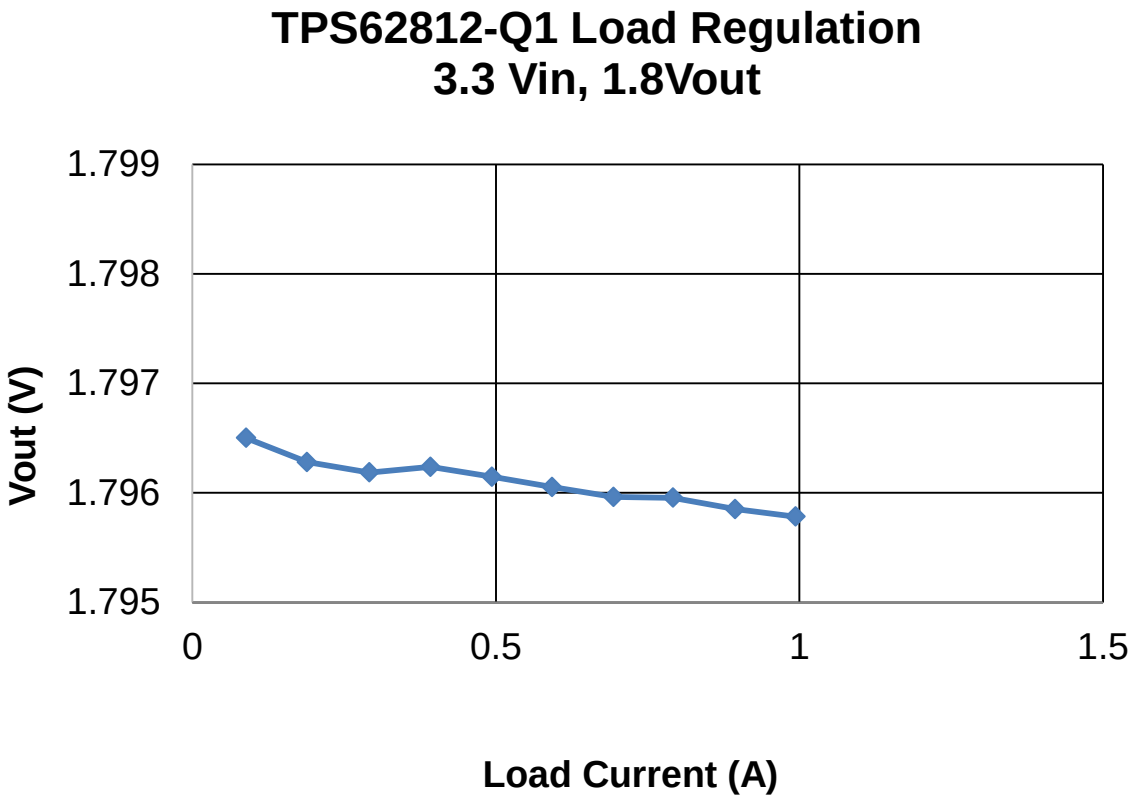
2.3.2 3V3 output rail

Load regulation data was extracted from the efficiency measurement data.



2.3.3 1V8 output rail

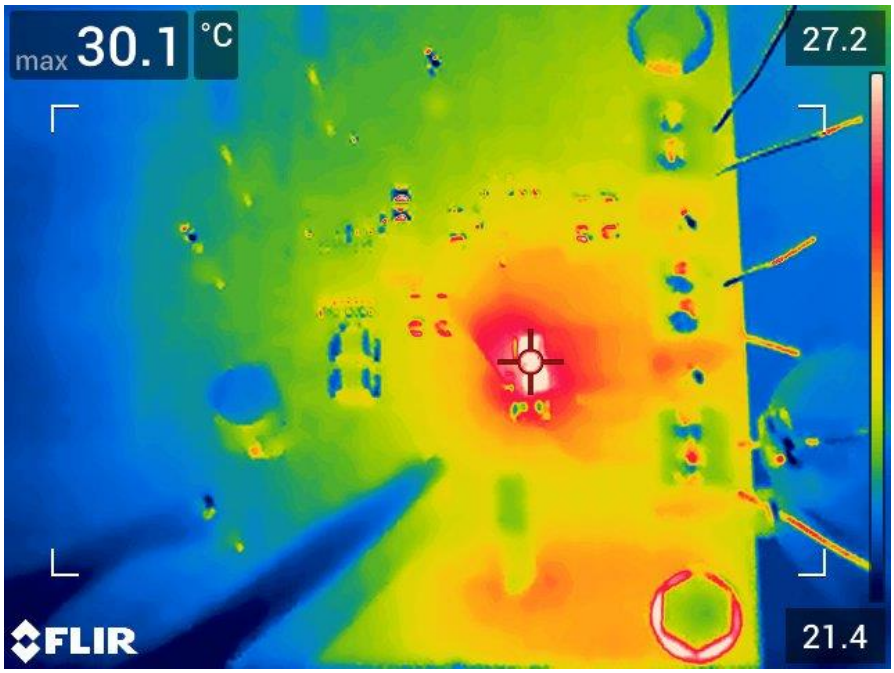
Load regulation data was extracted from the efficiency measurement data.



2.4 Thermal Images

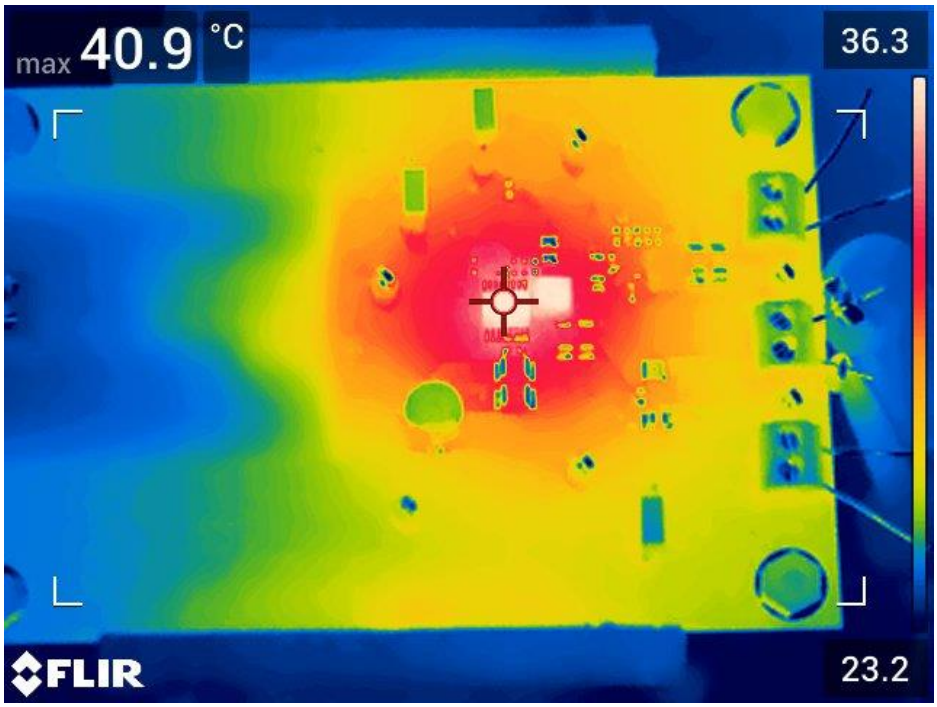
2.4.1 5V output rail

A thermal image was taken with a 3.3V input and 250mA load applied, no airflow, and an approximately 10 minute soak time to allow the converter to reach thermal equilibrium. The 3.3V input voltage is applied directly to the converter so it is the only converter running on the board.



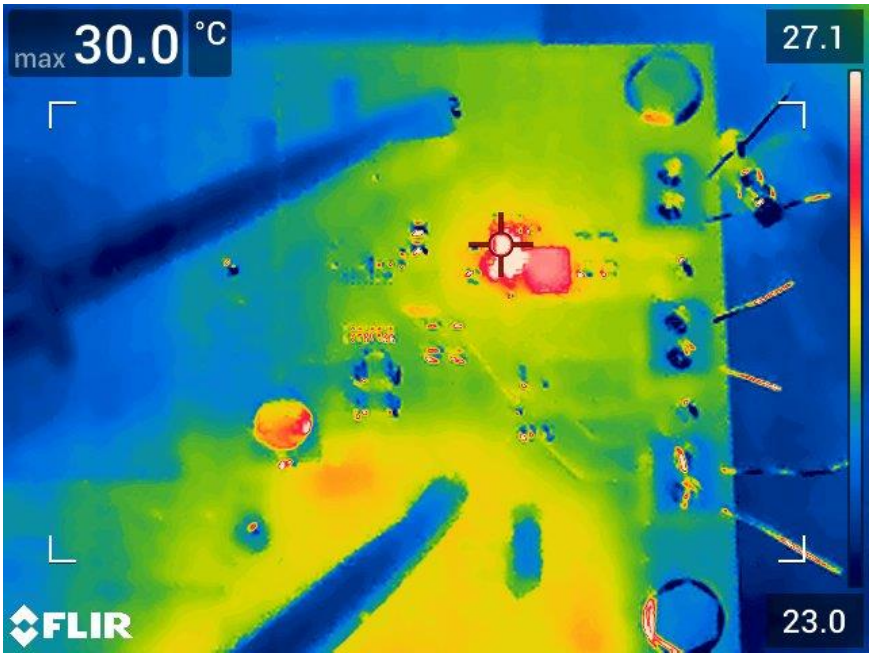
2.4.2 3V3 output rail

Thermal image was taken with a 13.5V input and 1.5A load applied, no airflow, and an approximately 10 minute soak time to allow the converter to reach thermal equilibrium. The other two converters on the board disabled.



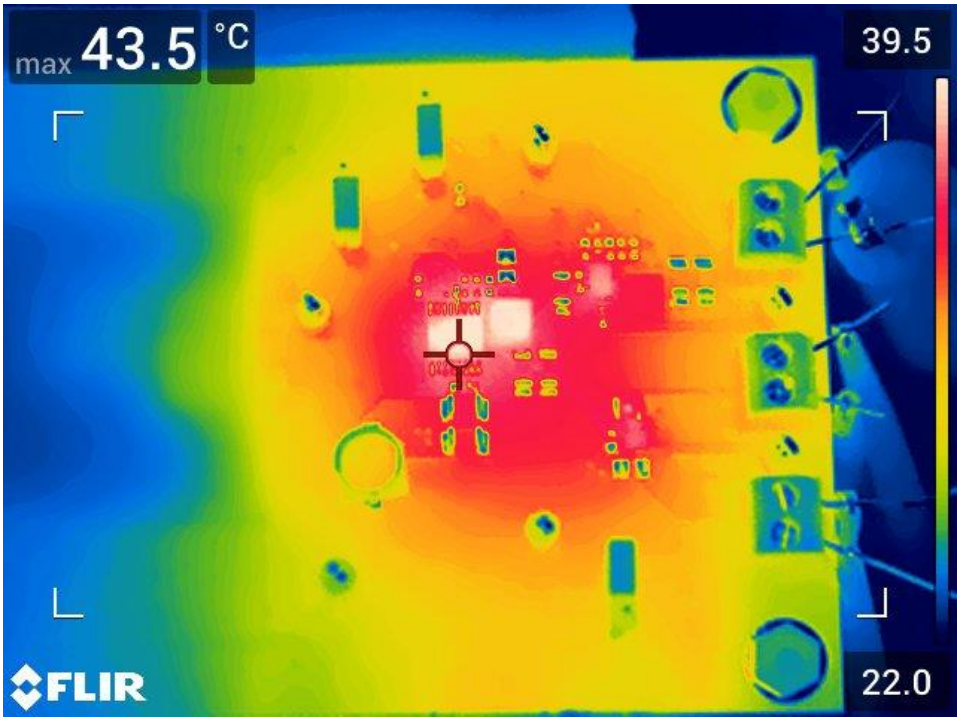
2.4.3 1V8 output rail

Thermal image was taken with a 3.3V input and 1.25A load applied, no airflow, and an approximately 10 minute soak time to allow the converter to reach thermal equilibrium. The 3.3V input voltage is applied directly to the converter so that it is the only converter running on the board.



2.4.4 Fully loaded system (all rails)

Thermal image was taken with a 13.5V input and fully loaded outputs on all rails (5V rail: 250mA, 3.3V rail: 500mA, 1.8V rail: 1.3A), no airflow, and an approximately 10 minute soak time to allow the converters to reach thermal equilibrium. With all converters loaded, the temperature rise from ambient is less than 25 degrees C.



3 Waveforms

3.1 Output Voltage Ripple

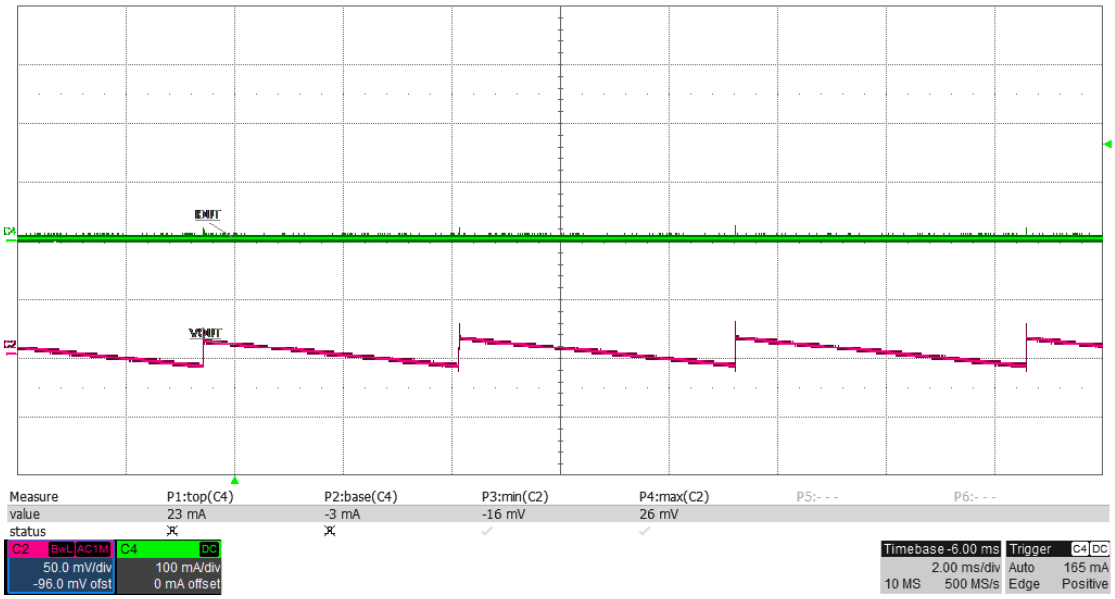
All converters are operating with an output ripple of 0.5% or less under no load, and 0.3% or less under full load.

3.1.1 5V output rail

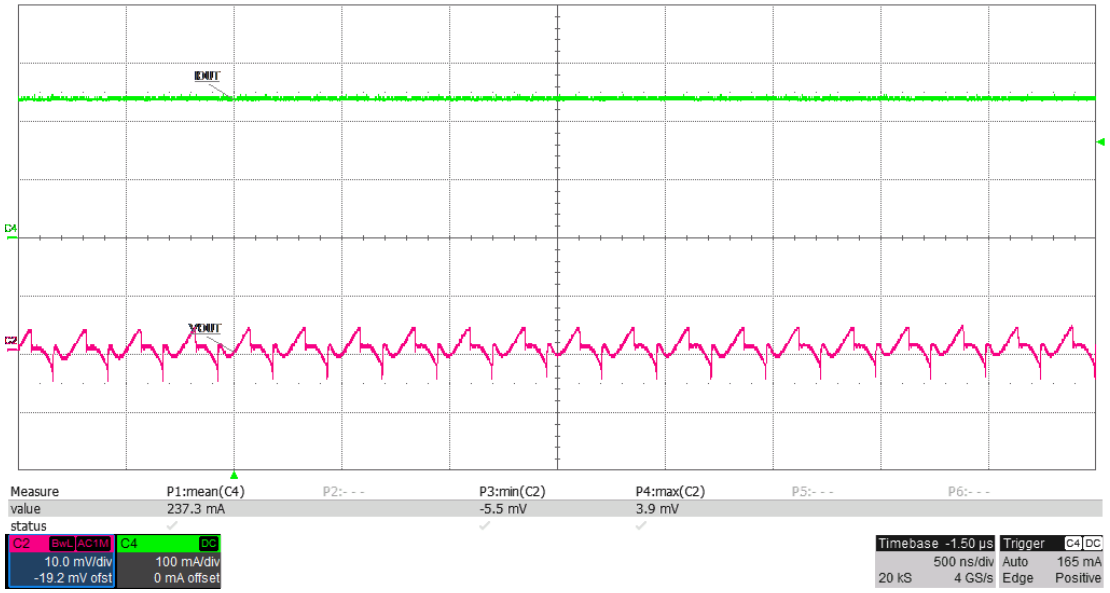
Output voltage was measured at no load (0A) and full load (250mA).

CH 4 (Green trace): Load current, 100mA/division
CH2 (Magenta trace): Output Voltage, 50mV/division

0A load - Output voltage ripple is around 0.5%:



250mA load - Output voltage ripple is around 0.2%:

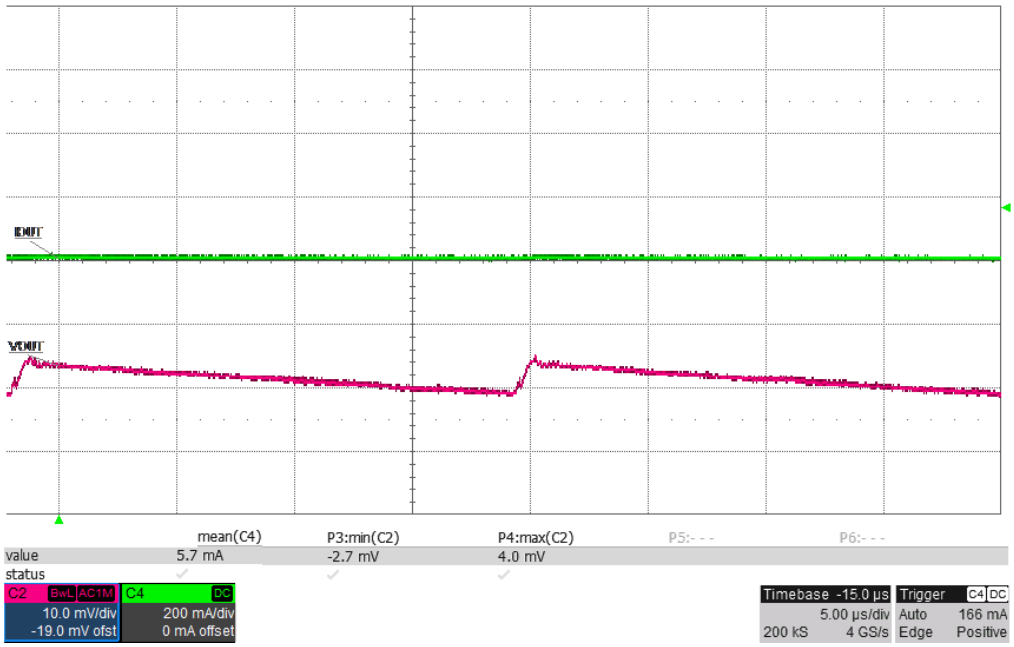


3.1.2 3V3 output rail

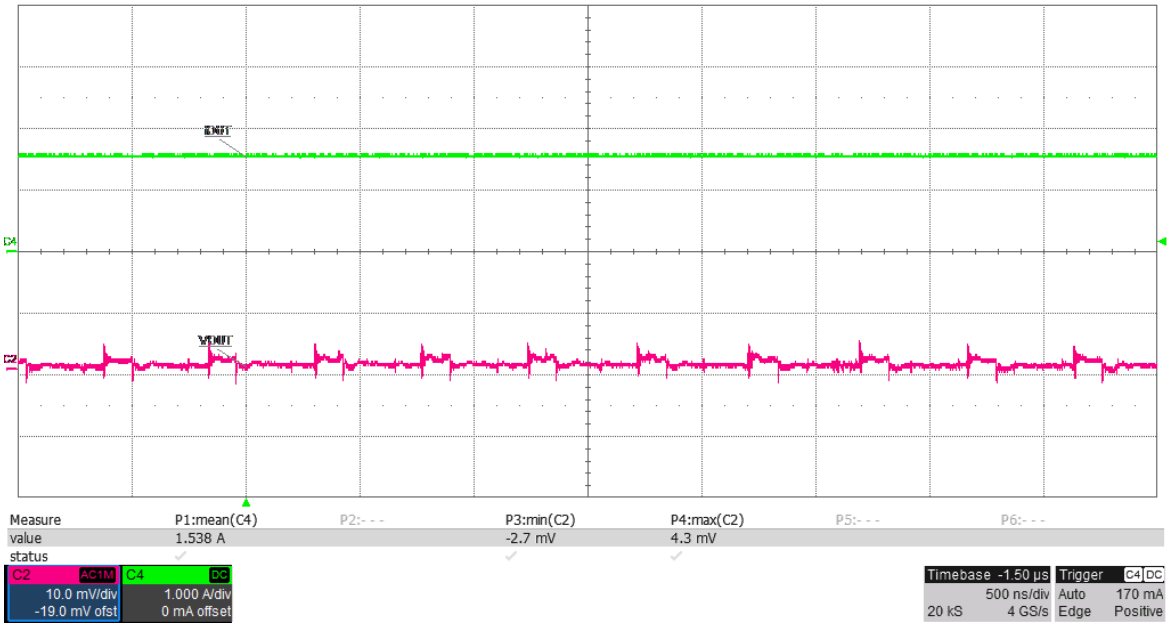
Output voltage was measured at no load (0A) and full load (1.5A)

CH 4 (Green trace): Load current, 1A/division
CH2 (Magenta trace): Output Voltage, 10mV/division

0A load – Output voltage ripple is around 0.2%:



1.5A load – Output voltage ripple is around 0.2%:
Some switching noise is being detected by the probe. Output voltage probed with a tip and barrel technique.

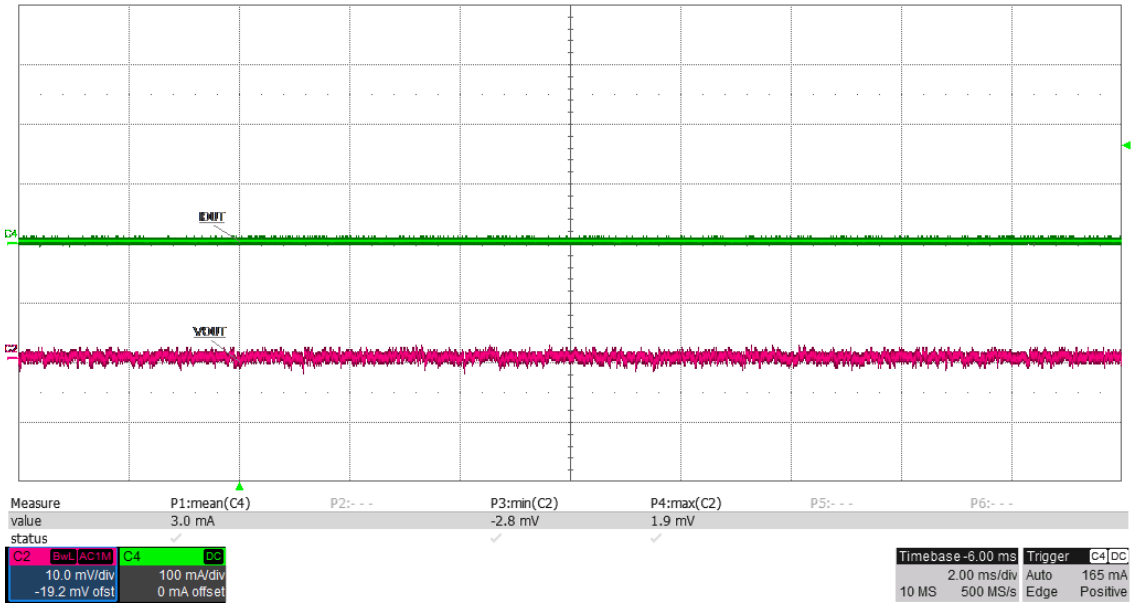


3.1.3 1V8 output rail

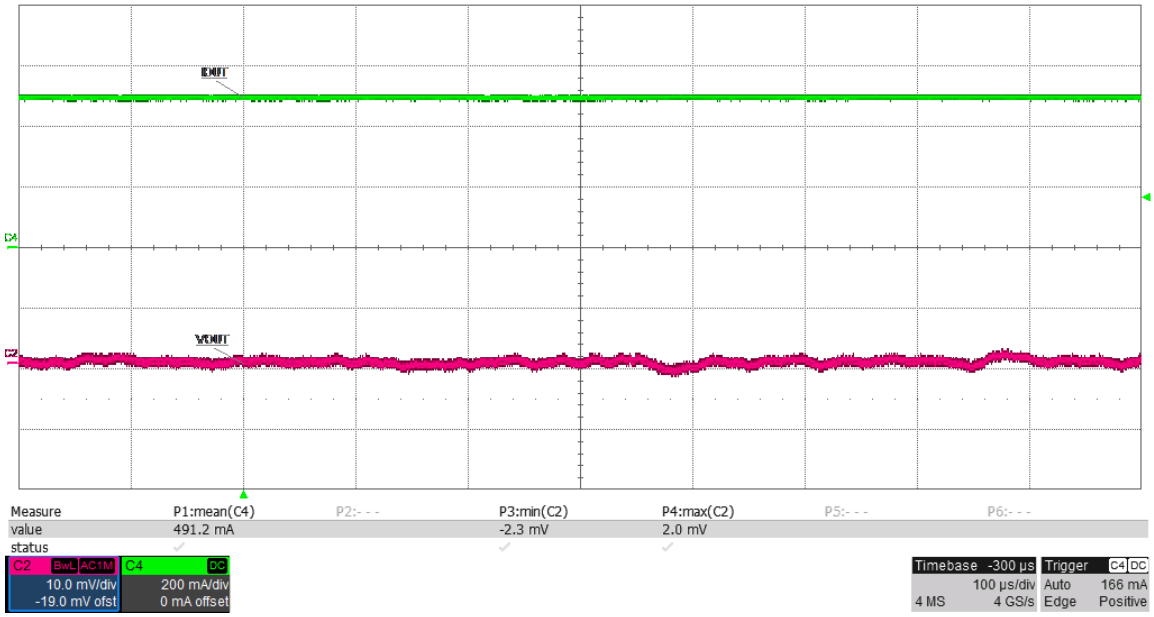
Output voltage measured at no load and full load (1.2A)

CH 4 (Green trace): Load current
CH 2 (Magenta trace): Output voltage

0A load – output voltage ripple is less than 0.3%:



1.2A load – output voltage ripple is less than 0.3%



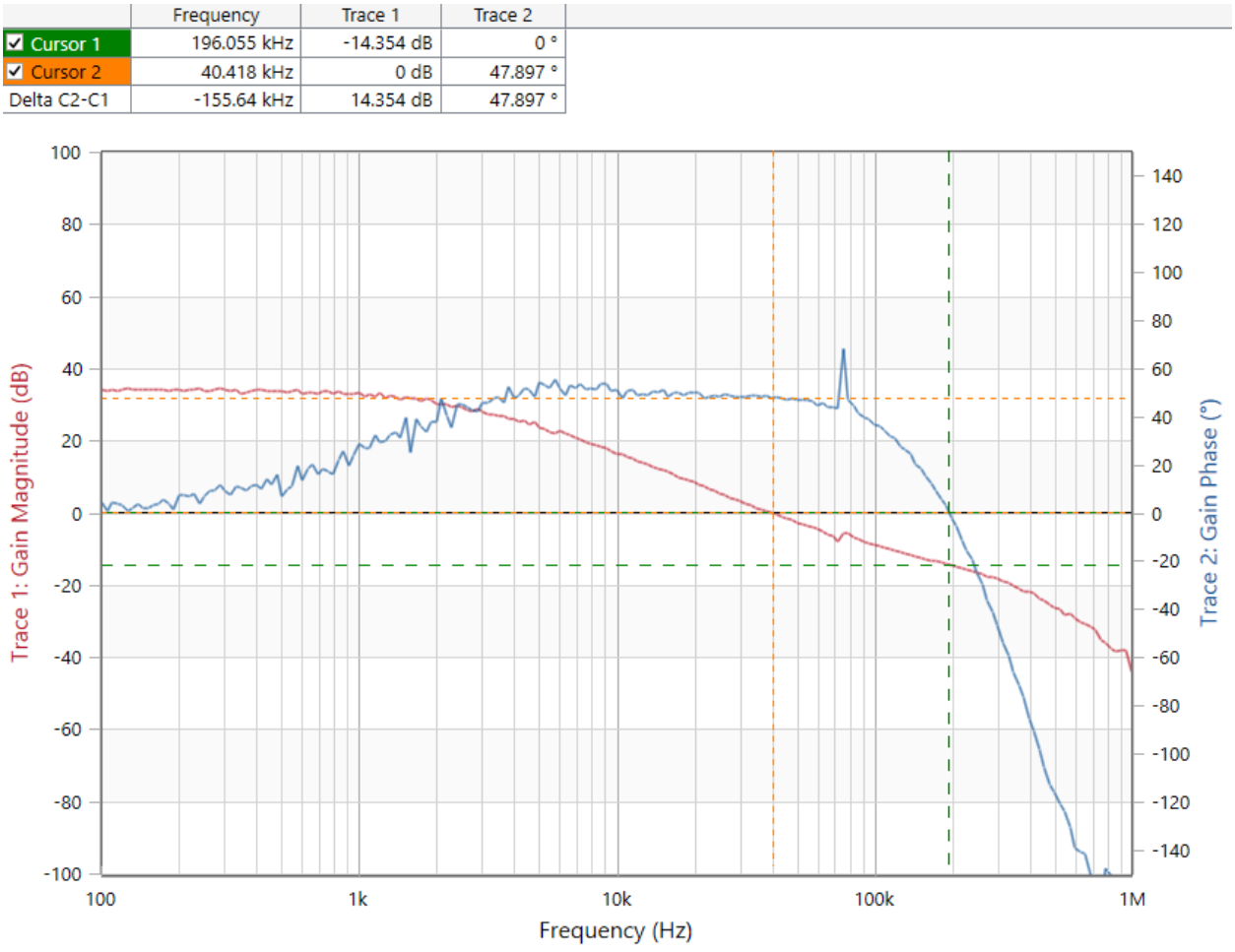
3.2 Bode Plots

All converters exhibit stable operation with a phase margin greater than 45 degrees (and less than 80 degrees), and a gain margin of greater than 10dB.

3.2.1 5V output rail (TPS61240-Q1)

Converter is operating on its own, with all other converters on the board disabled. Vin = 3.3V, Vout = 5V, with a 250mA load current.

Phase Margin: 47.9 degrees
Gain Margin: 14.4 dB

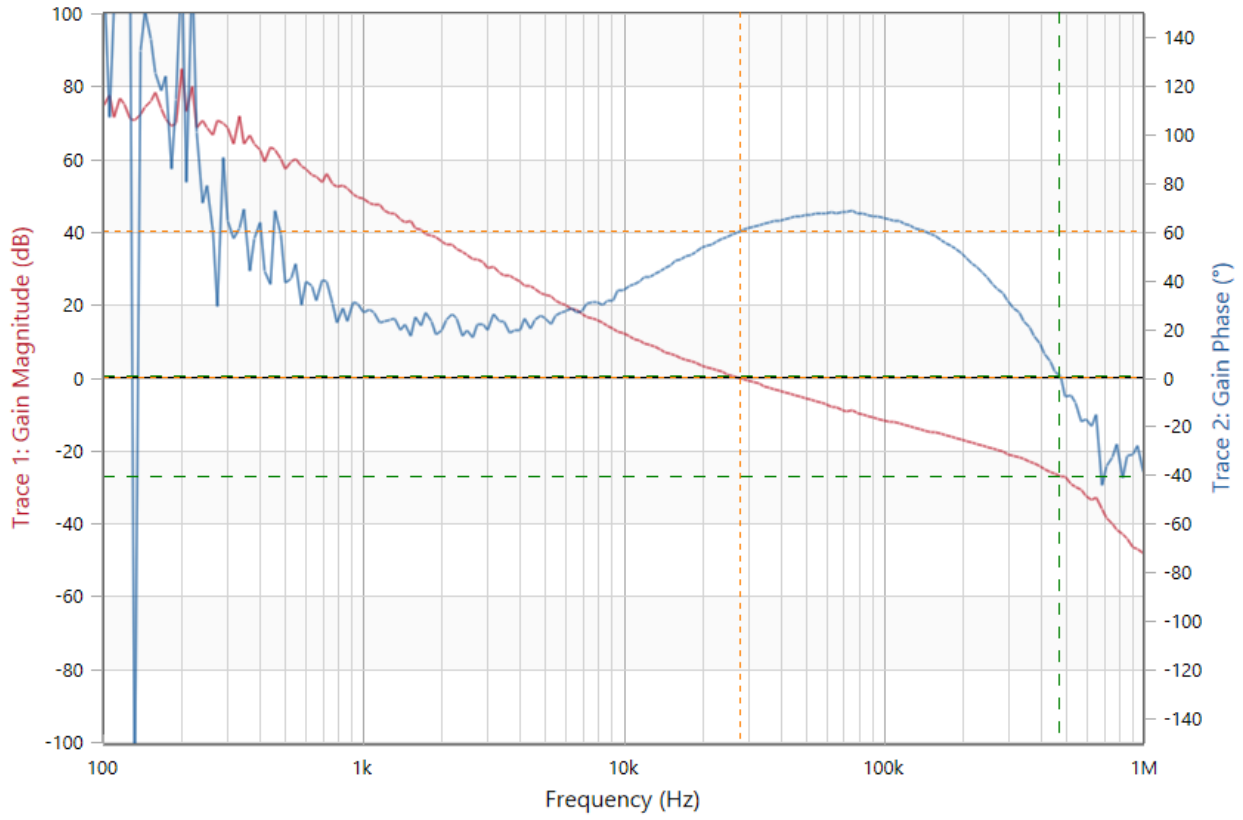


3.2.2 3V3 output rail (LM63615-Q1)

Converter is operating on its own, with the other converters on the board disabled. Vin = 12V, Vout = 3.3V, with a 1.5A load current.

Phase Margin: 60.5 degrees
Gain Margin: 27 dB

	Frequency	Trace 1	Trace 2
Cursor 1	474.391 kHz	-26.977 dB	1.002 °
Cursor 2	28.141 kHz	0 dB	60.485 °
Delta C2-C1	-446.25 kHz	26.977 dB	59.482 °

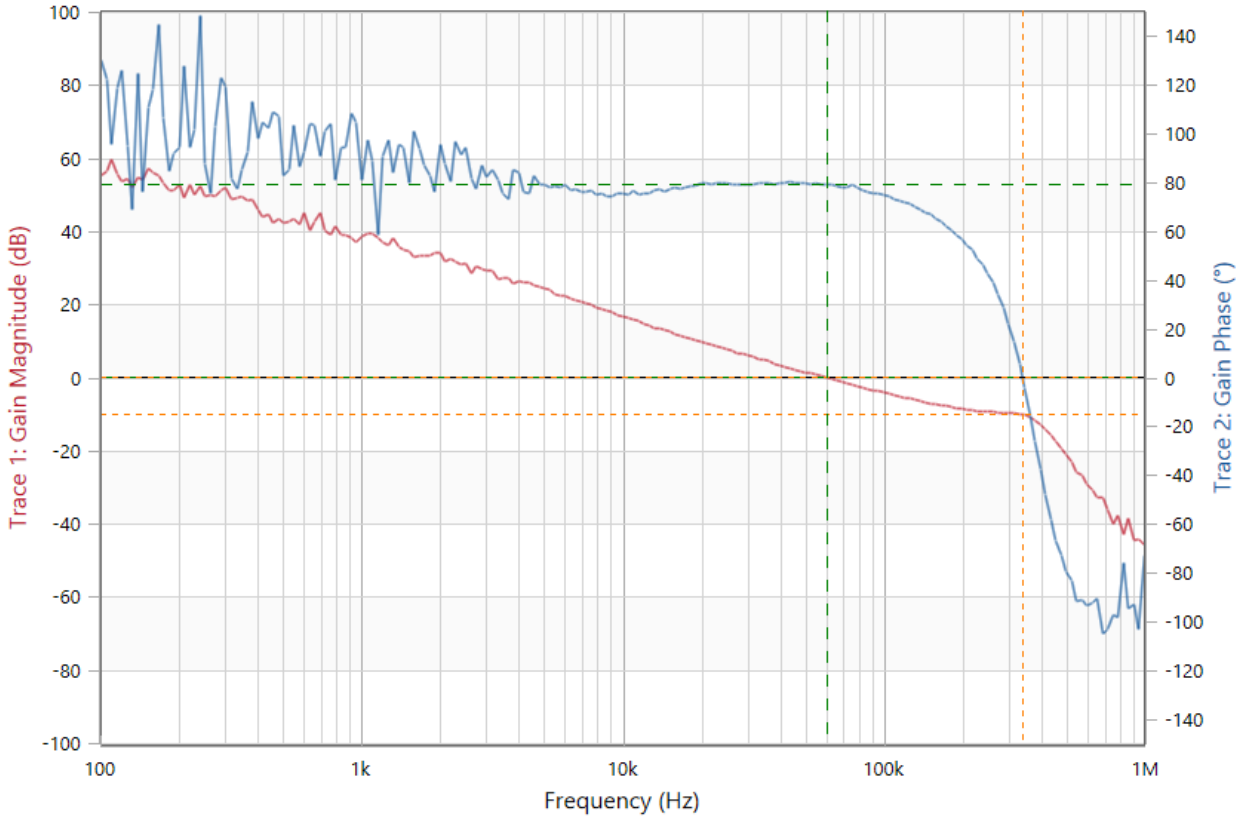


3.2.3 1V8 output rail (TPS62812-Q1)

Converter is operating on its own, with the other converters on the board disabled. Vin = 3.3V, Vout = 1.8V, with a 500mA load current.

Phase Margin: 79.5 degrees
Gain Margin: 10 dB

	Frequency	Trace 1	Trace 2
Cursor 1	60.848 kHz	0 dB	79.508 °
Cursor 2	340.534 kHz	-10.025 dB	0 °
Delta C2-C1	279.685 kHz	-10.025 dB	-79.508 °



3.3 Load Transients

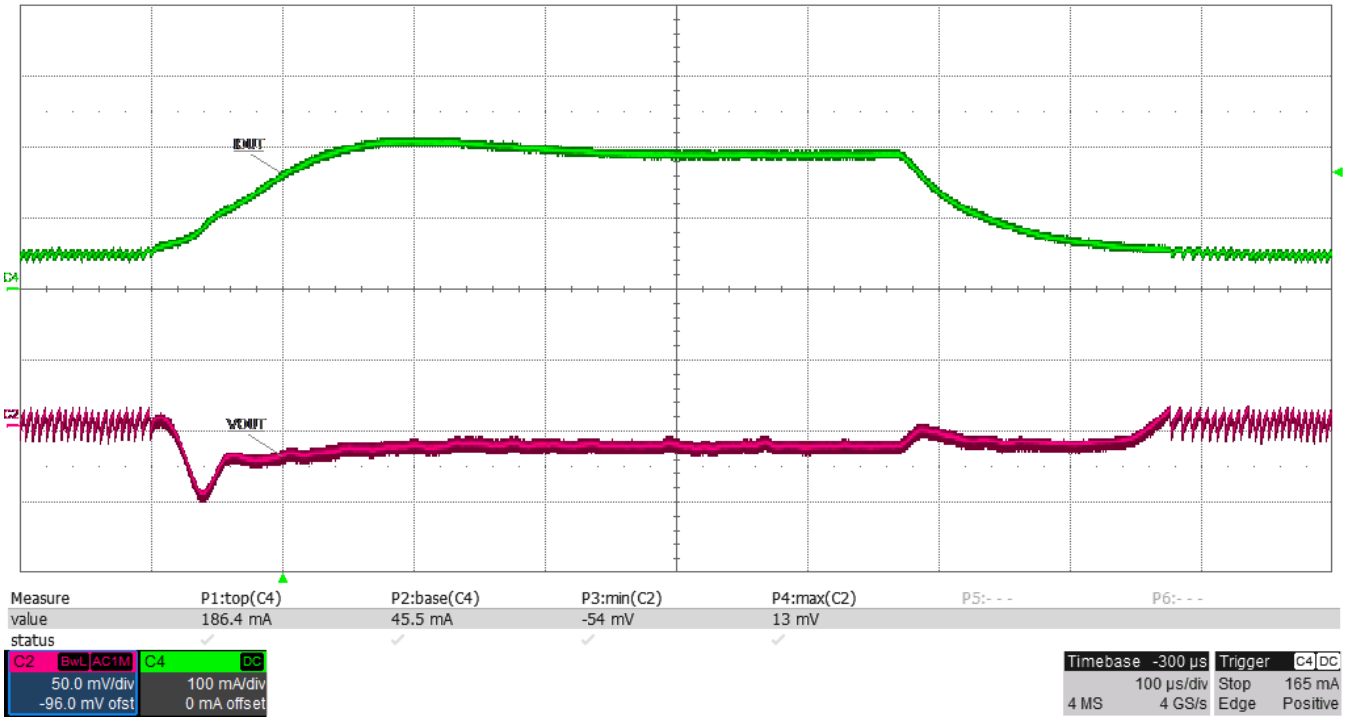
The load transient tests for all converters have an overshoot of 2.3% or less and an undershoot of 1.9%. An electronic load was used for testing.

3.3.1 5V output rail

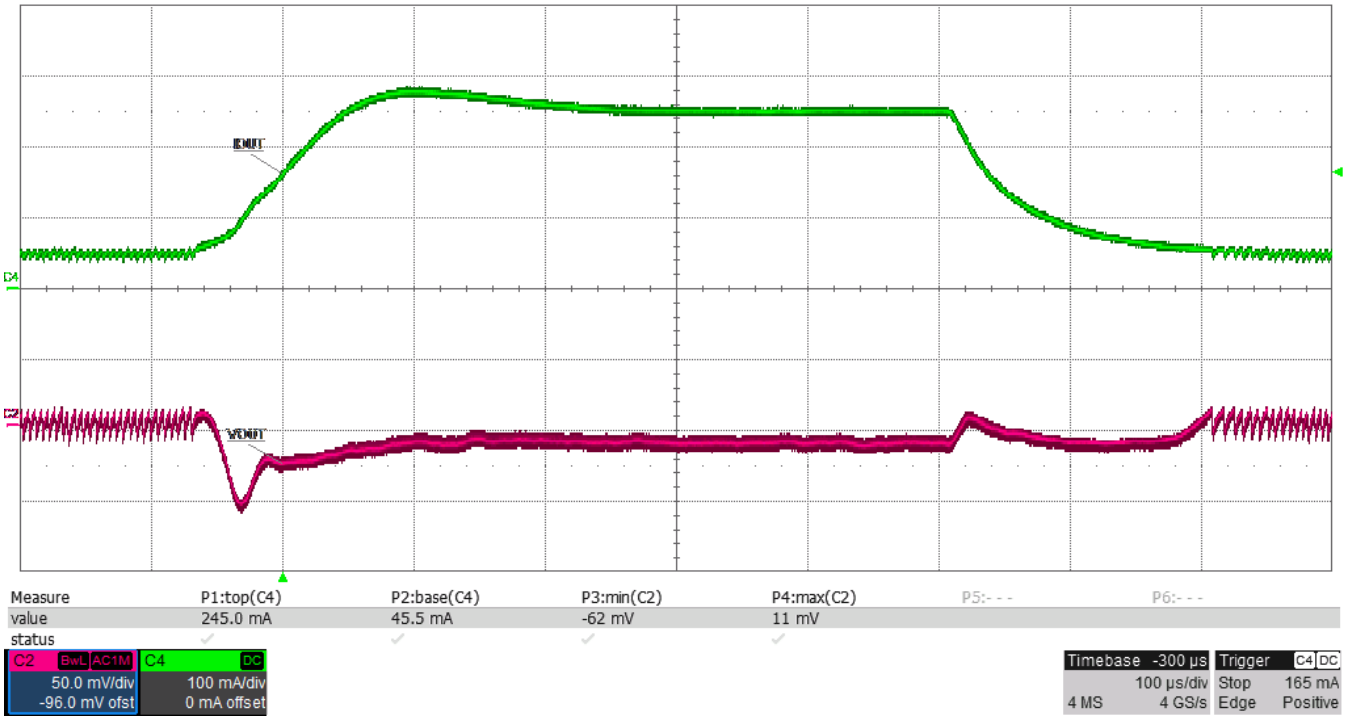
At low currents, the device enters pulse-skipping mode, which is why the regulated voltage at that load is a jagged waveform.

CH 4 (Green trace) Load Current
CH 2 (Magenta trace): Output Voltage

15% to 75% load step (~45mA to 186mA)
Undershoot is 54mV (1% of output), Overshoot is 13mV (.2% of output)

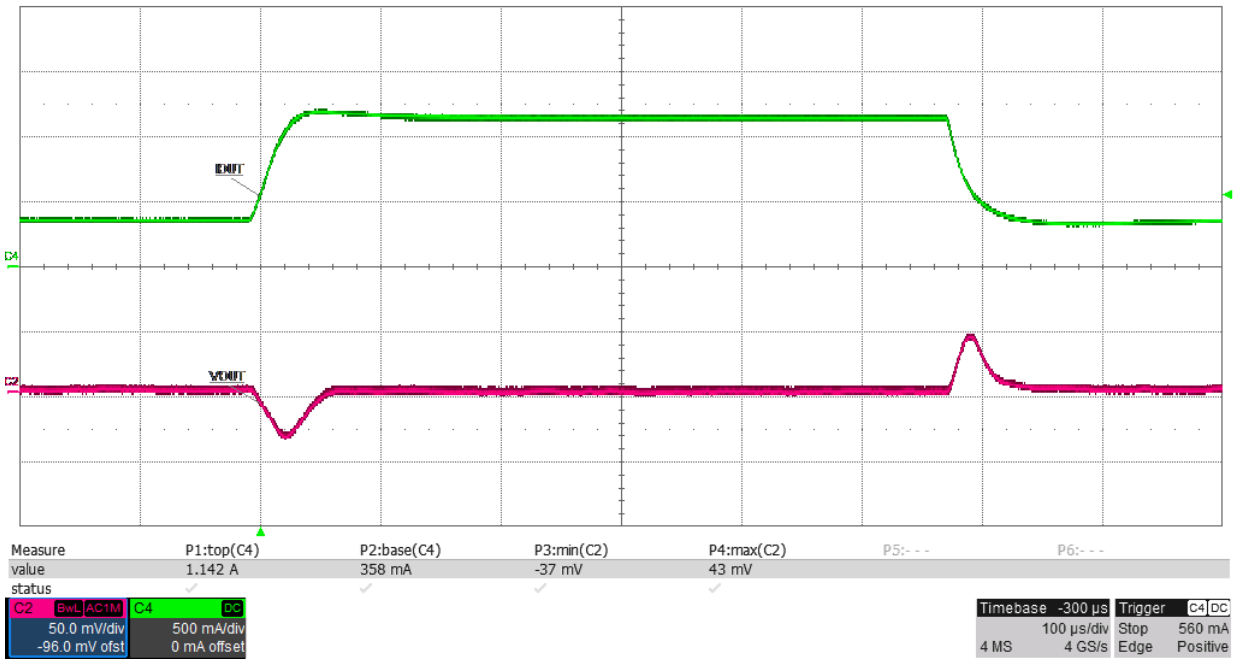


15% to 100% load step (~45mA to 245mA)
Undershoot is 62 mV (1.2% of output), Overshoot is 11mV (.2% of output)

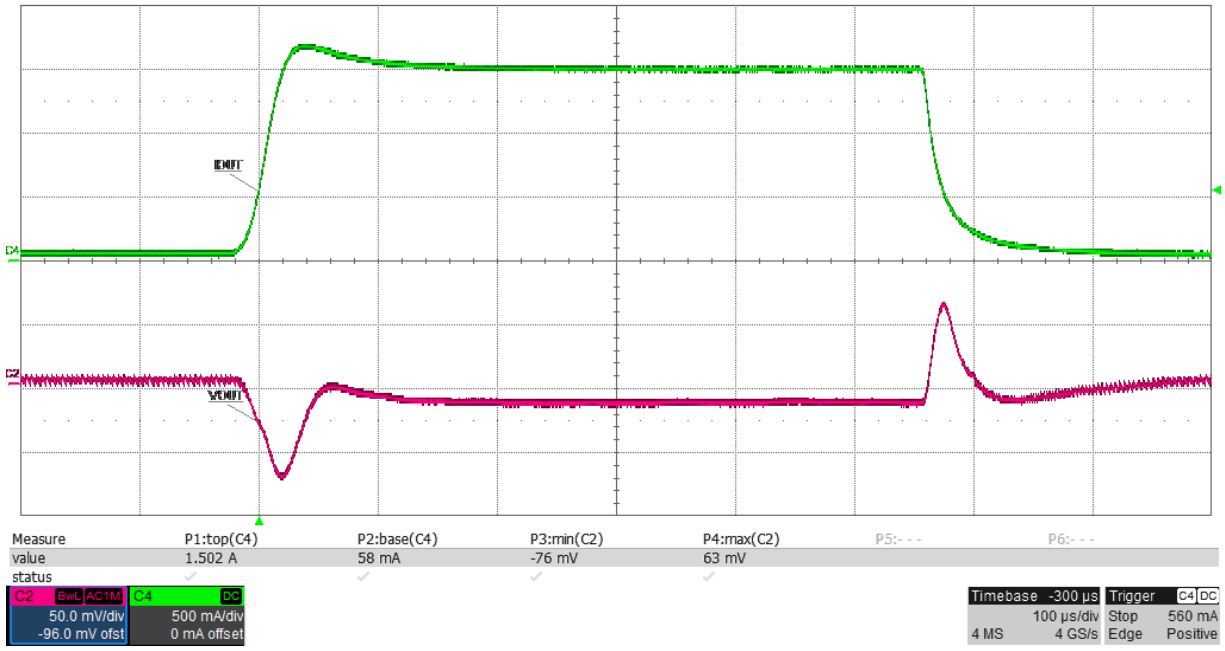


3.3.2 3V3 output rail

Load step from 24% to 75%:
Undershoot is 37mV (1.1% of output), Overshoot is 43 mV (1.3% of output)

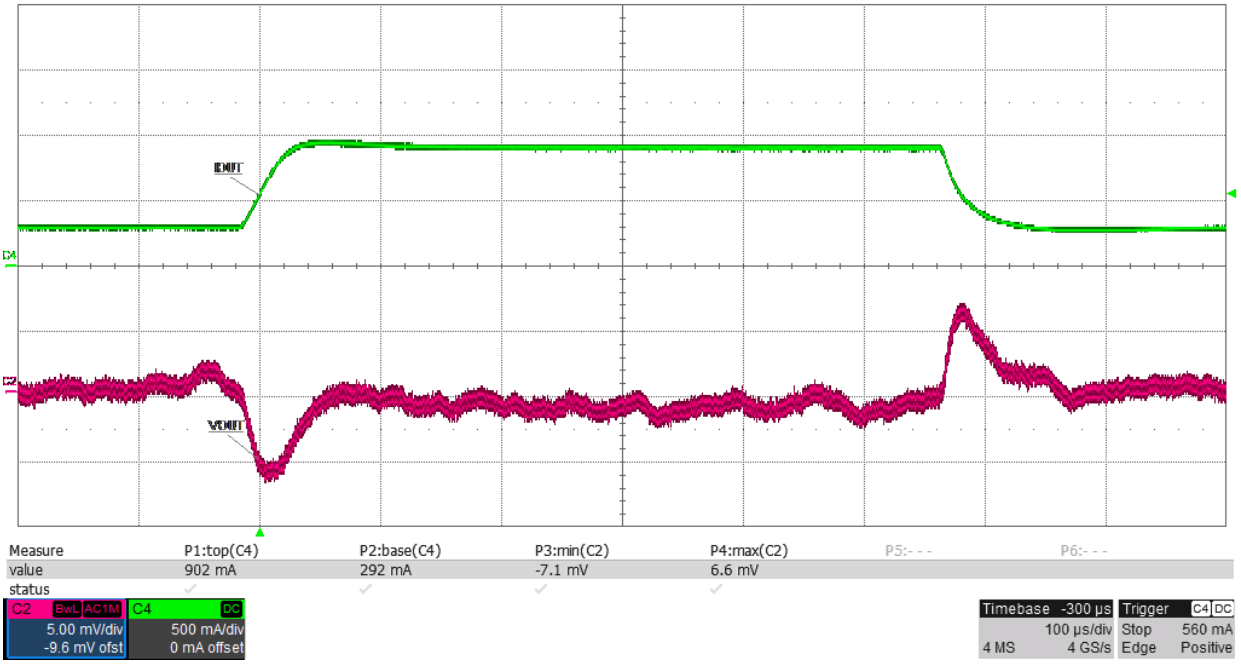


Load step from 0% to 100%:
Undershoot is 76mV (2.3% of output), Overshoot is 63 mV (1.9% of output)

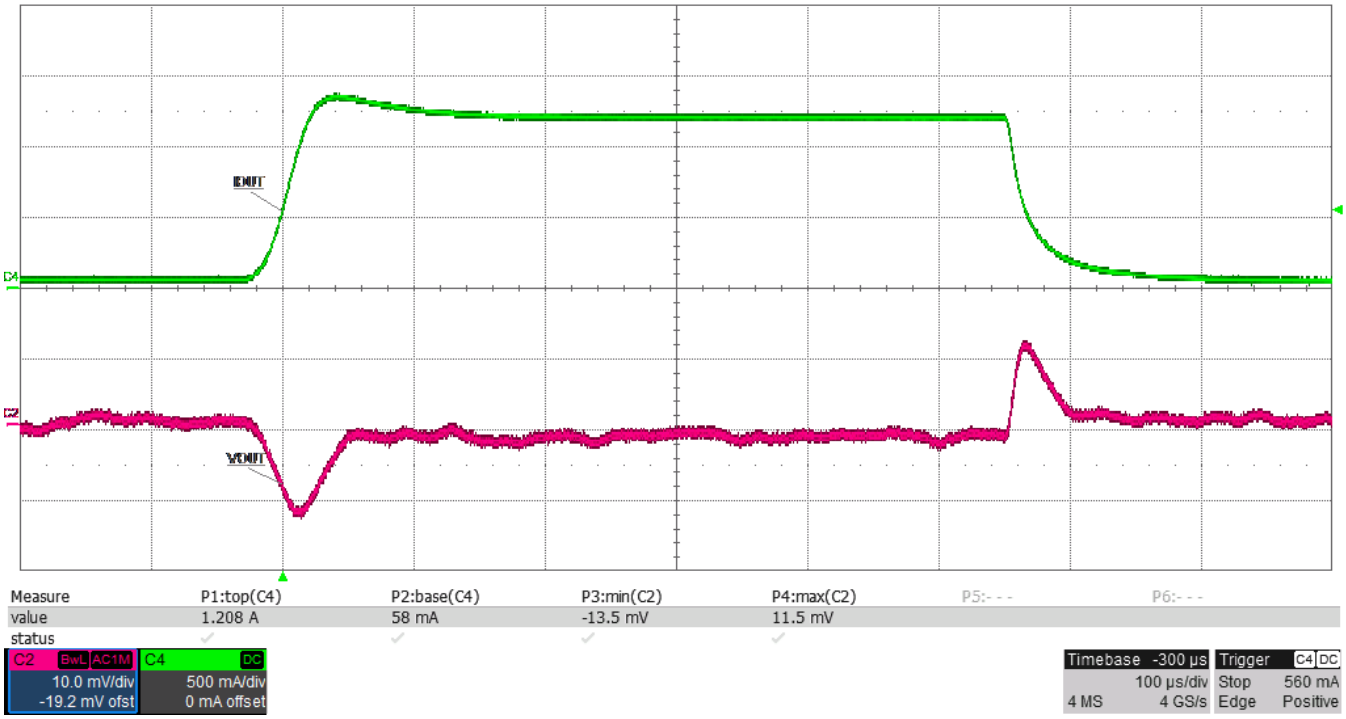


3.3.3 1V8 output rail

Load step from 24% to 75% load:
Undershoot is 7mV (.4% of output), Overshoot is 6.6mV (.3% of output)



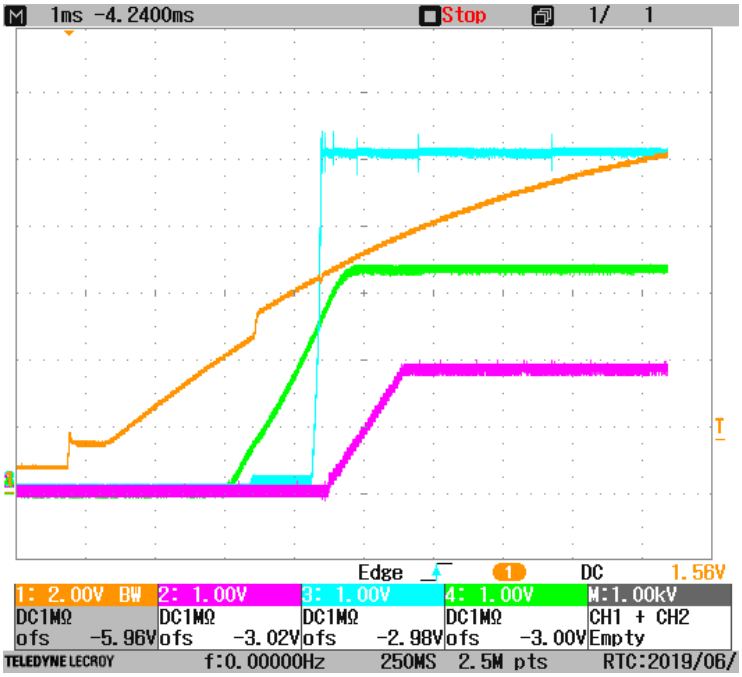
Load step from 10% to 100% load
Undershoot is 13.5mV (0.75% of output), overshoot is 11.5mV (0.6% of output)



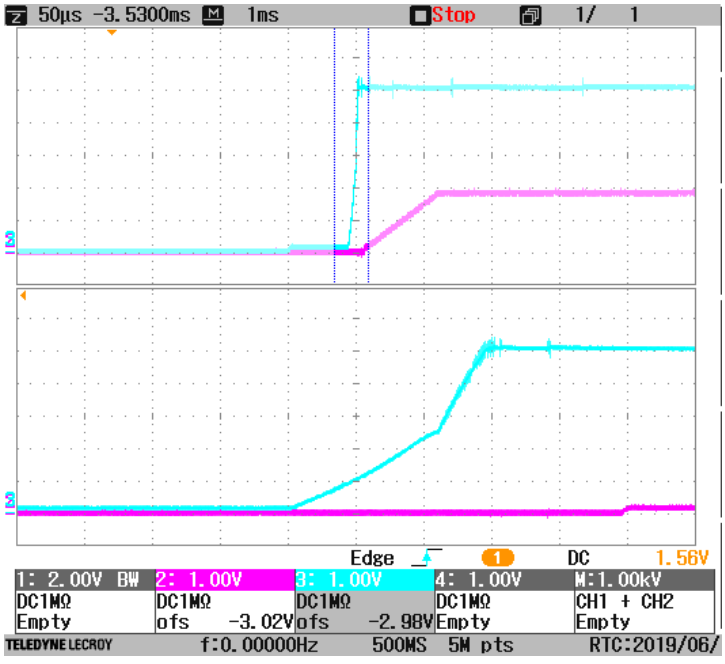
3.4 Start-up Sequence

The following images show the soft start profile of each converter in the design. Smooth, monotonic startup is observed for each converter.

CH 1 (Yellow trace): Input supply, 12V
CH 2 (Magenta trace): 1.8V rail, TPS62812-Q1 – soft start time of about 1 ms
CH 3 (Cyan trace): 5V rail, TPS61240-Q1 – soft start time of about 150 us (see zoomed-in image below)
CH 4 (Green trace): 3.3V rail, LM63615-Q1 – soft start time of about 2 ms.



Zoom in on startup of 5V rail

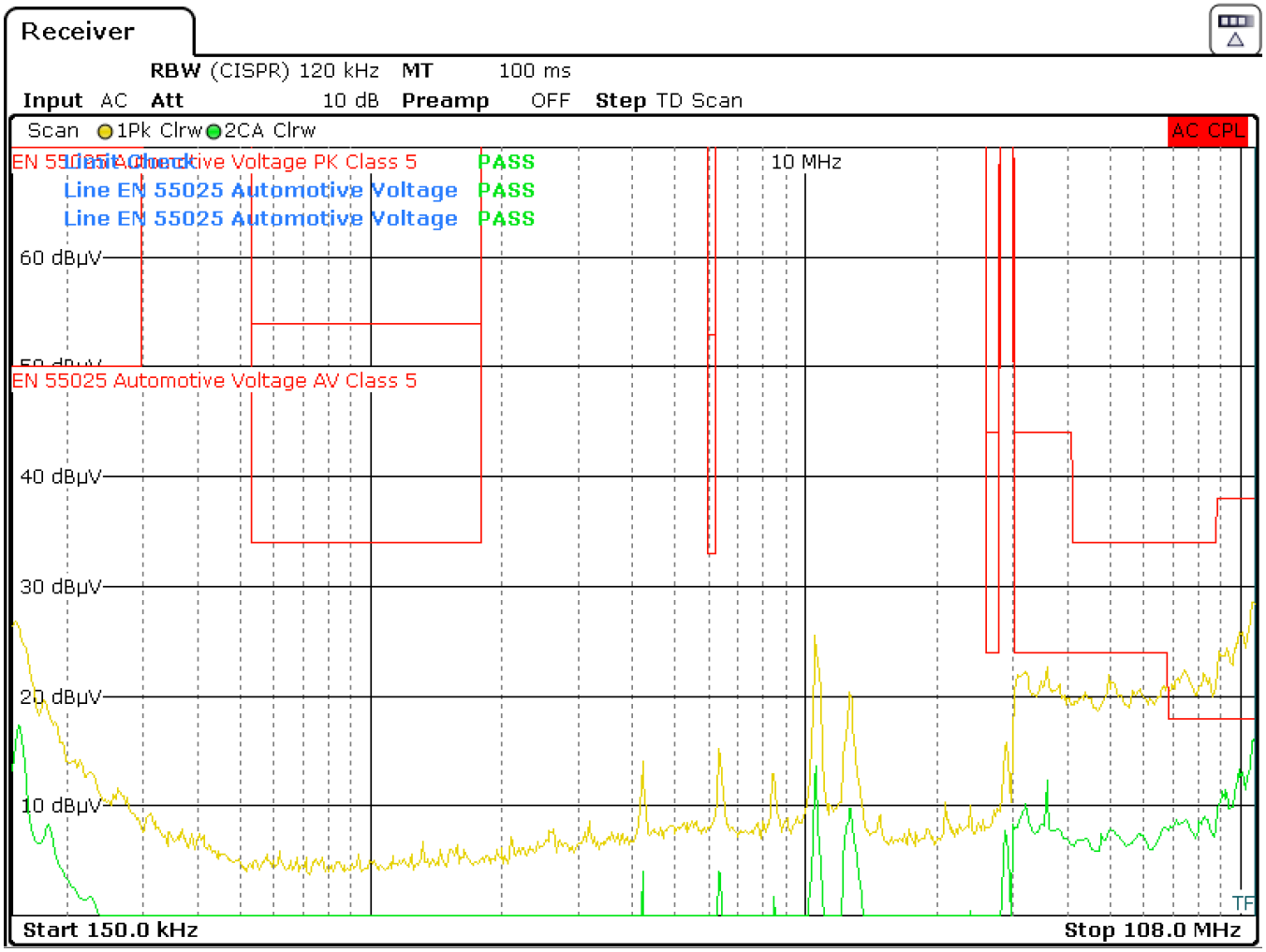


3.5 Conducted Emission (Standard: EN55025 (CISPR 25))

Tests were carried out with a) only 3.3V rail loaded; and b) all the rails (5V, 3V3 and 1V8) loaded. The design passes CISPR 25 Class 5 with only the 3.3V rail loaded. To pass the Class 5 average limits with all converters loaded, a common mode choke was added.

3.5.1 13.5 VDC input, 3.3V converter only, 3 ohm load resistor

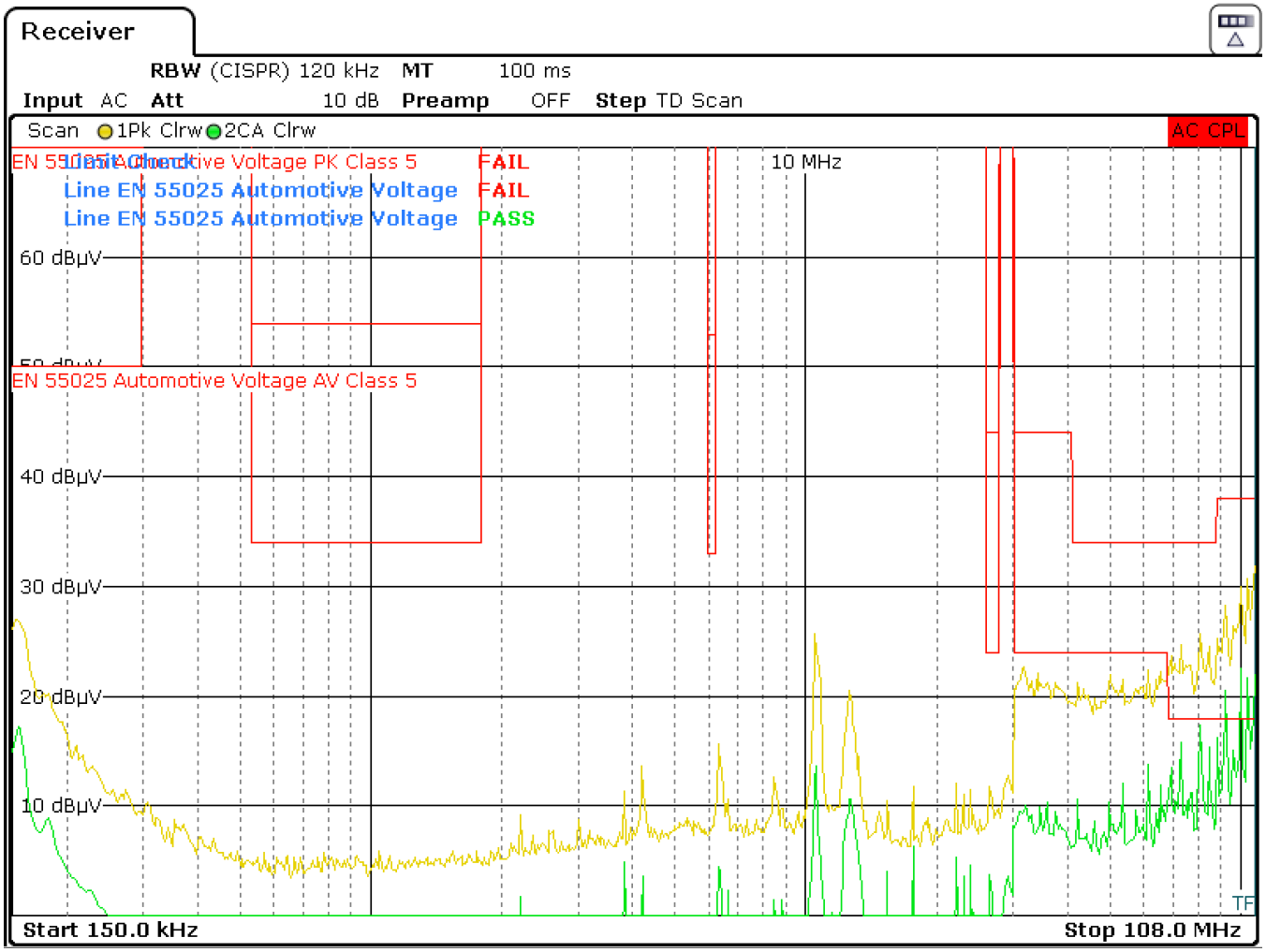
The converter passes Class 5 peak and average limits with only the off battery converter active. There is no common mode choke used in this result.



Date: 3.JUL.2019 14:04:12

3.5.2 13.5 VDC input, all converters active and loaded

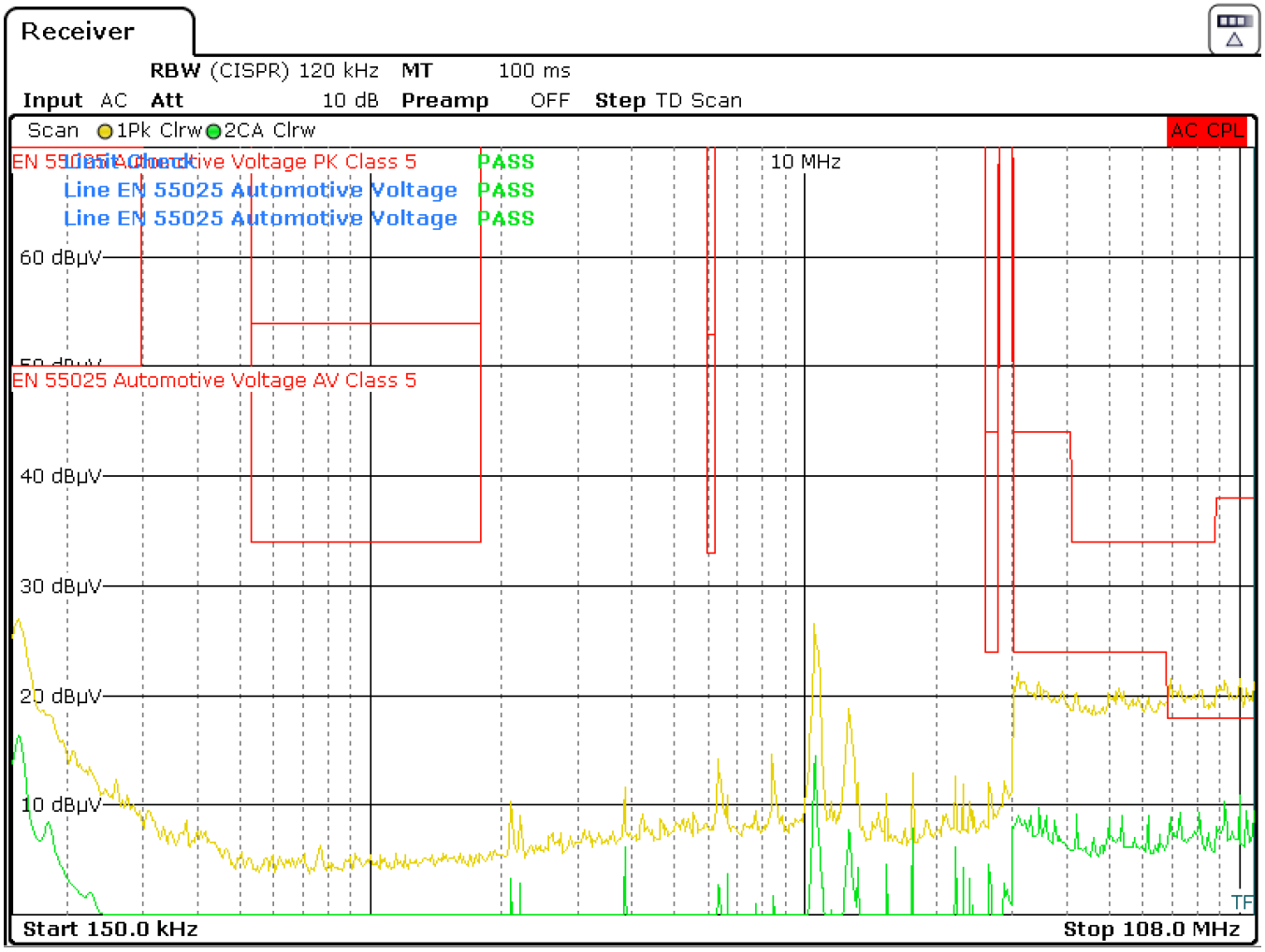
With all converters active and loaded, the design passes Class 5 peak limits. The average measurement is a few dBµV above the Class 5 average limit around 100MHz. There is no common mode choke used in this result.



Date: 3.JUL.2019 14:43:49

3.5.3 13.5 VDC input, all converters active and loaded – with Common Mode Choke

With all converters active and loaded, the design can pass Class 5 limits with a common mode choke (part number 744273102) installed. In this case, there is ample margin to pass Class 5 peak and average limits.



Date: 3.JUL.2019 14:46:16

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