Test Report: PMP31011

24-W, Low-Input Voltage Synchronous Boost Converter Reference Design

Description

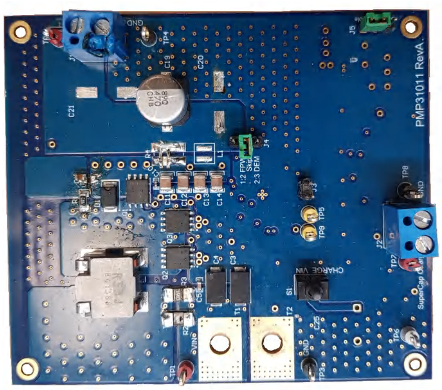
This reference design uses the LM51521-Q1 boost controller to supply an 8-V, 3-A load and has been optimized to operate from a single-cell supercapacitor at the input. The converter can discharge a supercapacitor as low as 1.0 V to leverage as much of the stored energy as possible to open a car door in an emergency situation, where the KL30 car battery voltage is no longer present.

Features

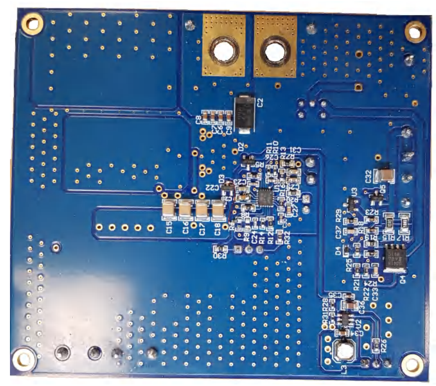
- Converter can operate from a single-cell supercapacitor and deliver 24 W of output power
- Operates down to 1.0-V input voltage enabling deep discharge of a supercapacitor
- High-efficiency conversion due to use of synchronous rectification
- Starts up from as low as 1.25 V
- Design has been built and tested

Applications

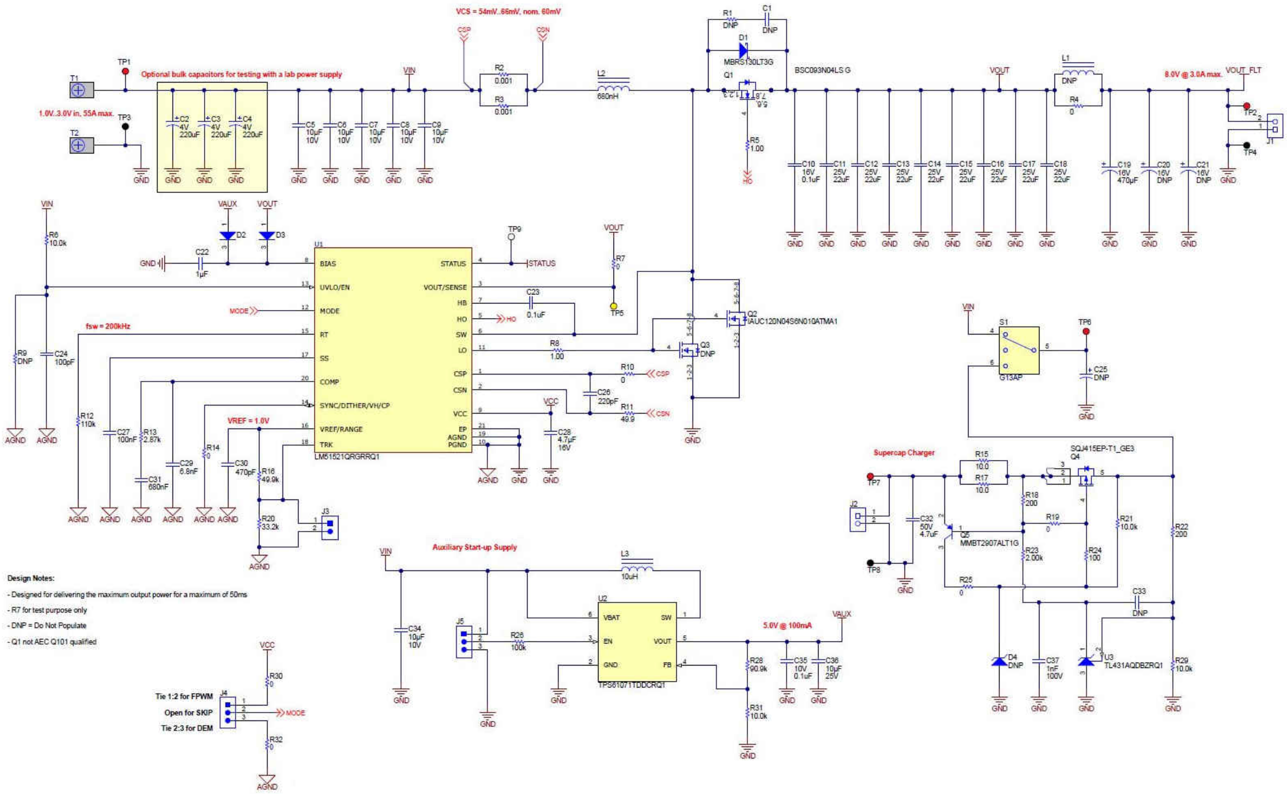
- Automotive door module
- Automotive sliding door module



Top Photo



Bottom Photo


VCS = 54mV..66mV, nom. 60mV
Optional bulk capacitors for testing with a lab power supply
1.0V..3.0V in, 55A max.
8.0V @ 3.0A max.
fsw = 200kHz
VREF = 1.0V
Supercap Charger
Auxiliary Start-up Supply
5.0V @ 100mA
Tie 1:2 for FPWM
Open for SKIP
Tie 2:3 for DEM
LM51521QRGRRQ1
TPS61071TDDCRQ1
MMBT2907ALT1G
TL431AQDBZRQ1
SQJ415EP-T1_GE3
G13AP
MBRS130LT3G
BSC093N04LS G
IAUC120N04S6N010ATMA1
Design Notes:
- Designed for delivering the maximum output power for a maximum of 50ms
- R7 for test purpose only
- DNP = Do Not Populate
- Q1 not AEC Q101 qualified

Schematic

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage	1.0 V to 3.0 V
Output Voltage	8.0 V
Output Current (maximum)	3.0 A
Isolation	no

1.2 Considerations

The lab power supply must be connected to the printed-circuit board (PCB). Make this connection with very short cables (≤ 30 cm) to avoid resonances between the output of the lab power supply and the input circuit on the PCB, which can influence the look and results of the frequency analysis.

The copper thickness on the PCB must be a minimum of 70 µm. The tested PCB had 105 µm for the top and bottom layer. Measurements, including efficiency, were taken at room temperature without forced-air cooling.

Unless otherwise indicated:

- The board was assembled with two low-side FETs (Q2, Q3) and a 330-nH inductor L2
- The output current was adjusted to 3.0 A

The circuit switches on at 1.10 V and off at about 0.45 V ($V_{EN\text{-}Falling}$ level). This individual circuit switches around 200 kHz.

The converter works in continuous conduction mode (CCM) at low input voltage and in discontinuous conduction mode (DCM) at higher input voltage. Under light load conditions the converter was operating in skip mode.

The transfer region DCM to CCM can be seen around:

- 1 V_{IN} ⇒ 0.57 A_{OUT}
- 2 V_{IN} ⇒ 2.1 A_{OUT}
- > 2.48 V_{IN} ⇒ 3 A_{OUT}

1.3 Dimensions

The size of the four-layer board is 83.5 mm × 95.3 mm. The copper thickness of the outer layer is 105 µm and the inner layer is 35 µm.

2 Testing and Results

2.1 Efficiency Graphs

2.1.1 One Low-Side FET , 680-nH Coil , 1.0 V_{IN} – 1.5 V_{IN}

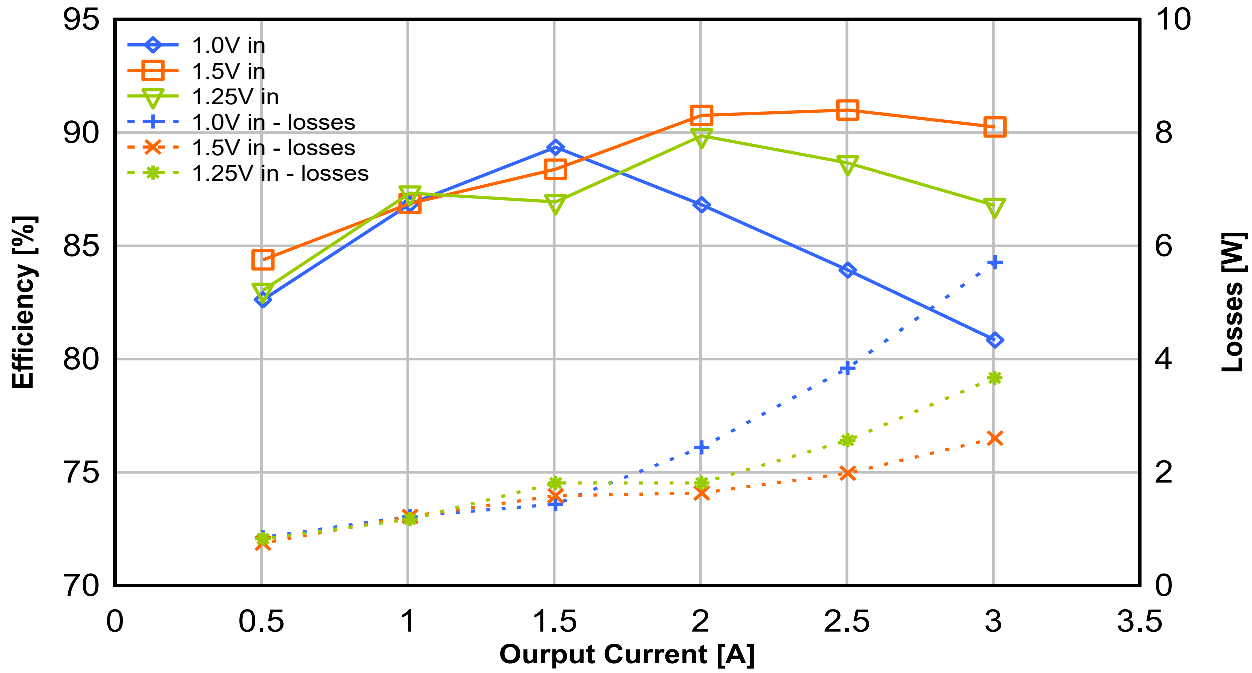


Figure 2-1. Efficiency and Losses vs Output Current From 1-V to 1.5-V Input Voltage

2.1.2 One Low-Side FET , 680-nH Coil , 2.0 V_{IN} – 3.0 V_{IN}

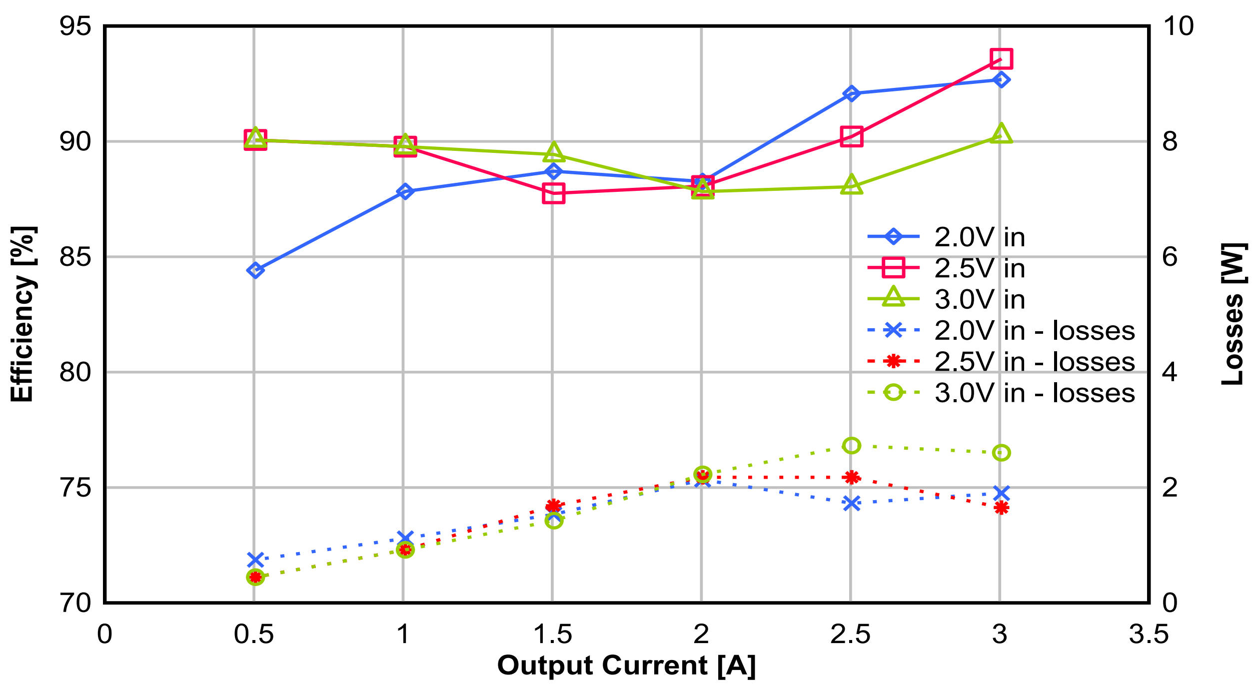


Figure 2-2. Efficiency and Losses vs Output Current from 2-V to 3-V Input Voltage

2.2 Load Regulation

2.2.1 One Low-Side FET, 680-nH Coil, 1.0 V_{IN} – 1.5 V_{IN}

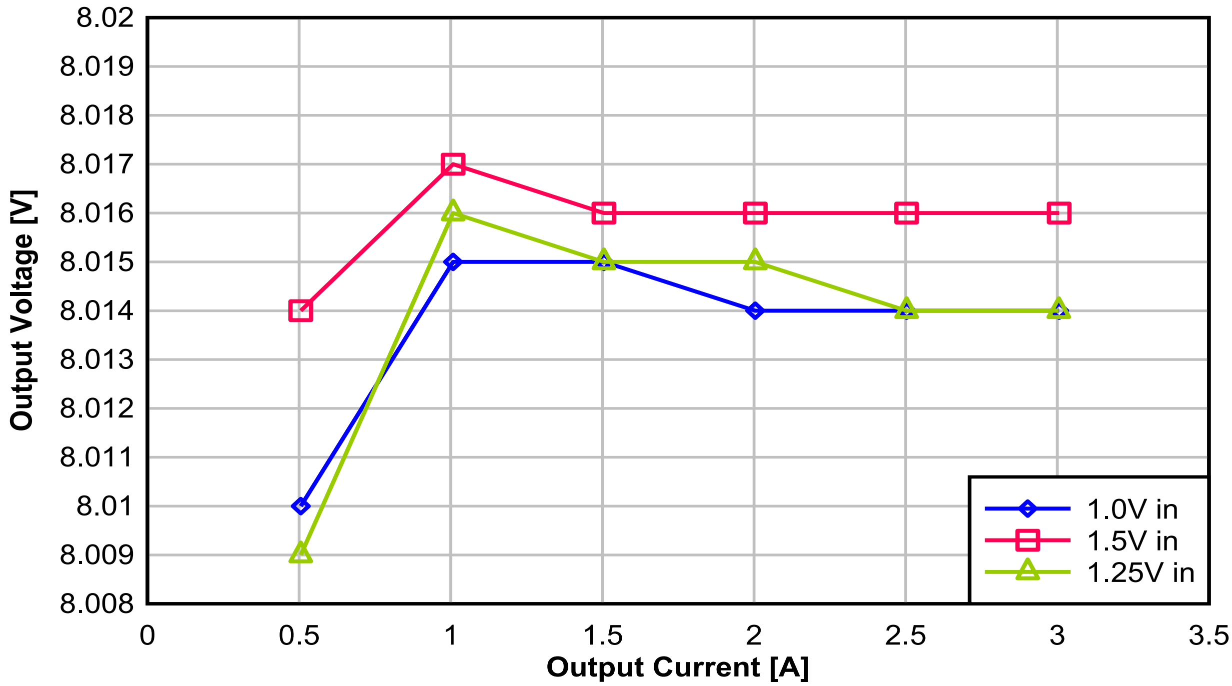


Figure 2-3. Load Regulation From 1-V to 1.5-V Input Voltage

2.2.2 One Low-Side FET, 680-nH Coil, 2.0 V_{IN} – 3.0 V_{IN}

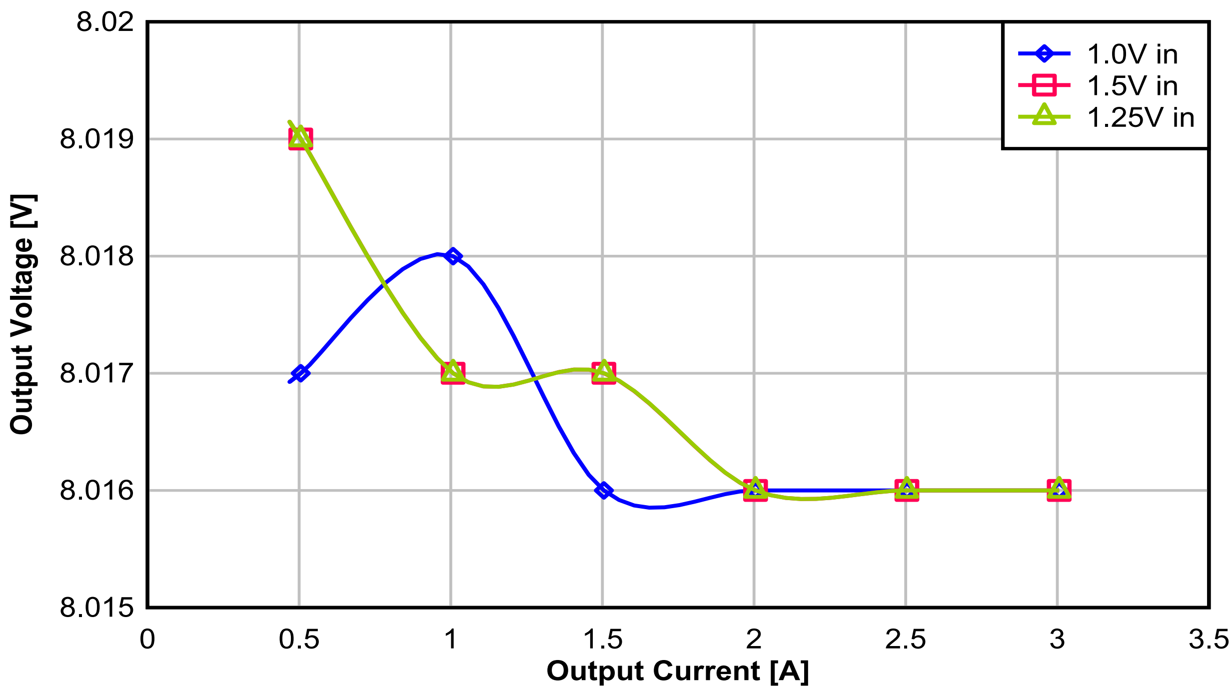


Figure 2-4. Load Regulation From 2-V to 3-V Input Voltage

2.3 Thermal Images

2.3.1 1.0-V Input Voltage – Full Load 3.0 A

2.3.1.1 Two Low-Side FETs, 330-nH Coil

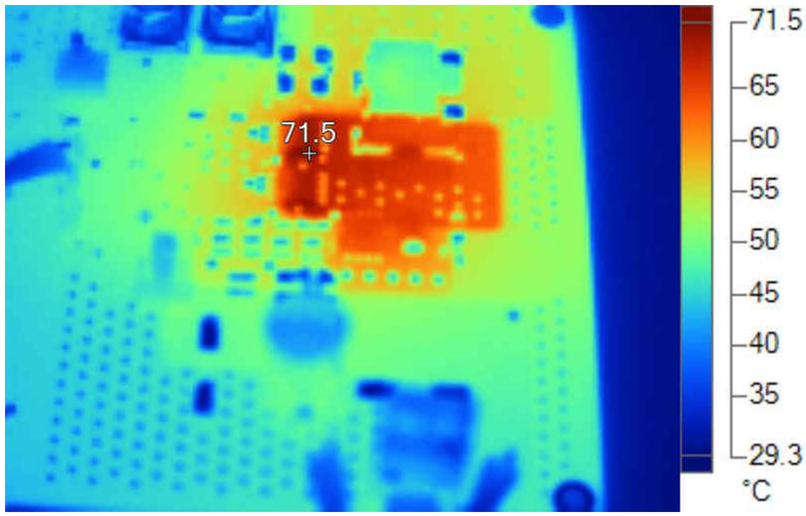


Figure 2-5. IR Photo for 1.0-V Input Voltage, 2 Low-Side FETs and 330-nH Coil

Name	Temperature
Q2, Q3	71.5°C

2.3.1.2 One Low-Side FET, 680-nH Coil

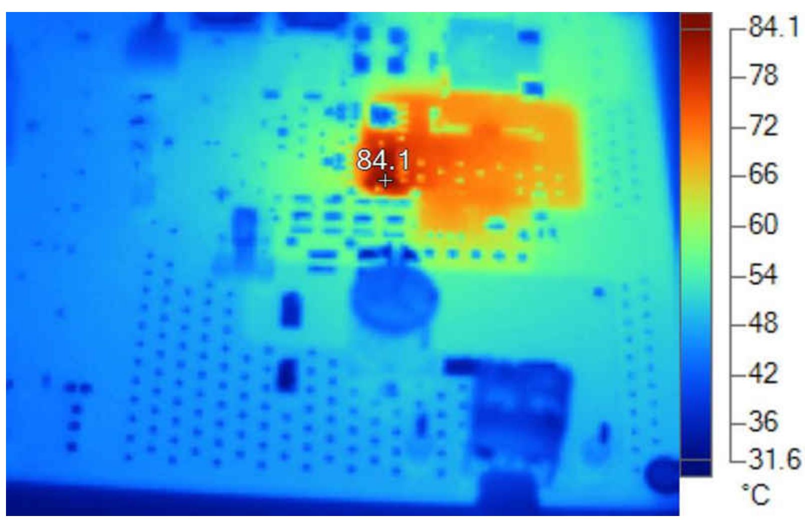


Figure 2-6. IR Photo for 1.0-V Input Voltage, One Low-Side FET and 680-nH Coil

Name	Temperature
Q2, Q3	84.1°C

2.3.2 2.0-V Input Voltage, Full Load 3.0 A

2.3.2.1 Two Low-Side FETs, 330-nH Coil

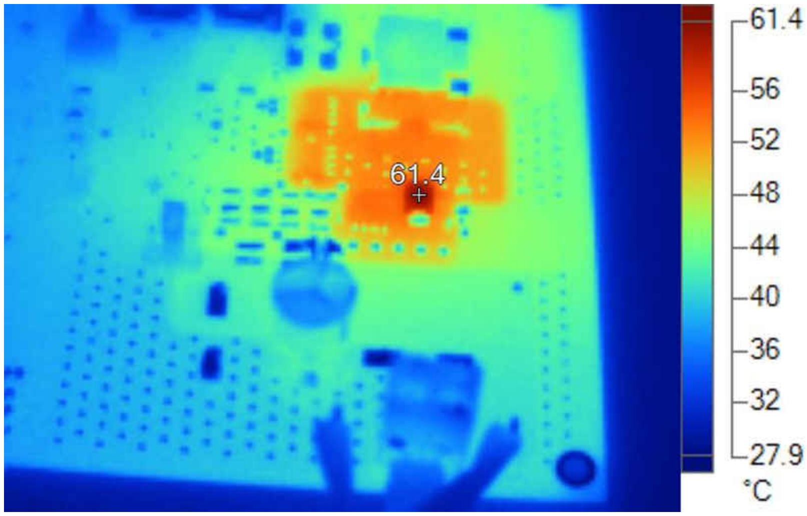


Figure 2-7. IR Photo for 2.0-V Input Voltage

Name	Temperature
D1	61.4°C

2.3.3 3.0-V Input Voltage, Full Load 3.0 A

2.3.3.1 Two Low-Side FETs, 330-nH Coil

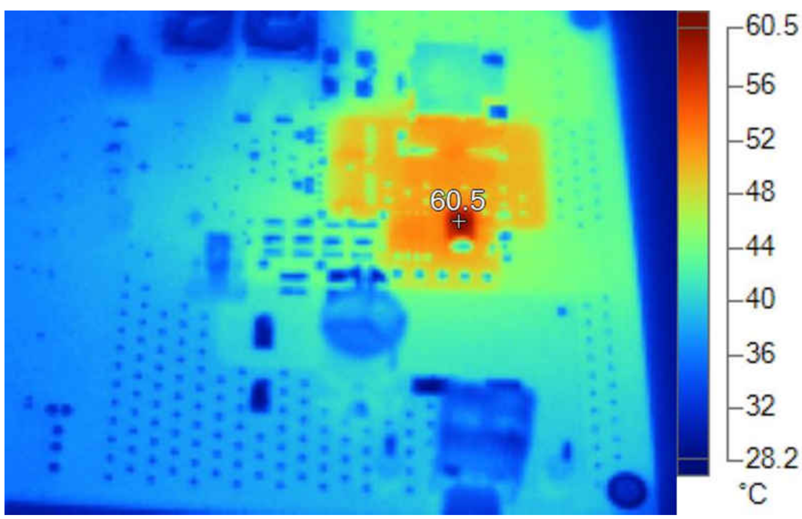


Figure 2-8. IR Photo for 3.0-V Input Voltage

Name	Temperature
D1	60.5°C

2.4 Bode Plots

This section includes a summary of the bode plots in Table 2-1 and Figure 2-9 through Figure 2-11 illustrate the bode plots at various input voltages.

Table 2-1. Summery of the Bode Plots

	1.0 V_{IN}	2.0 V_{IN}	3.0 V_{IN}
Bandwidth (Hz)	524	1224	1030
Phase Margin	81.66	88.3	92,8
Slope (20 dB/decade)	–0.962	–1.05	–1.03
Gain margin (dB)	–15.37	–34	–35.6
Slope (20 dB/decade)	–0.468	–6.93	–6.6
Frequency (kHz)	4.4kHz	30.5	30.02

2.4.1 1.0-V Input Voltage

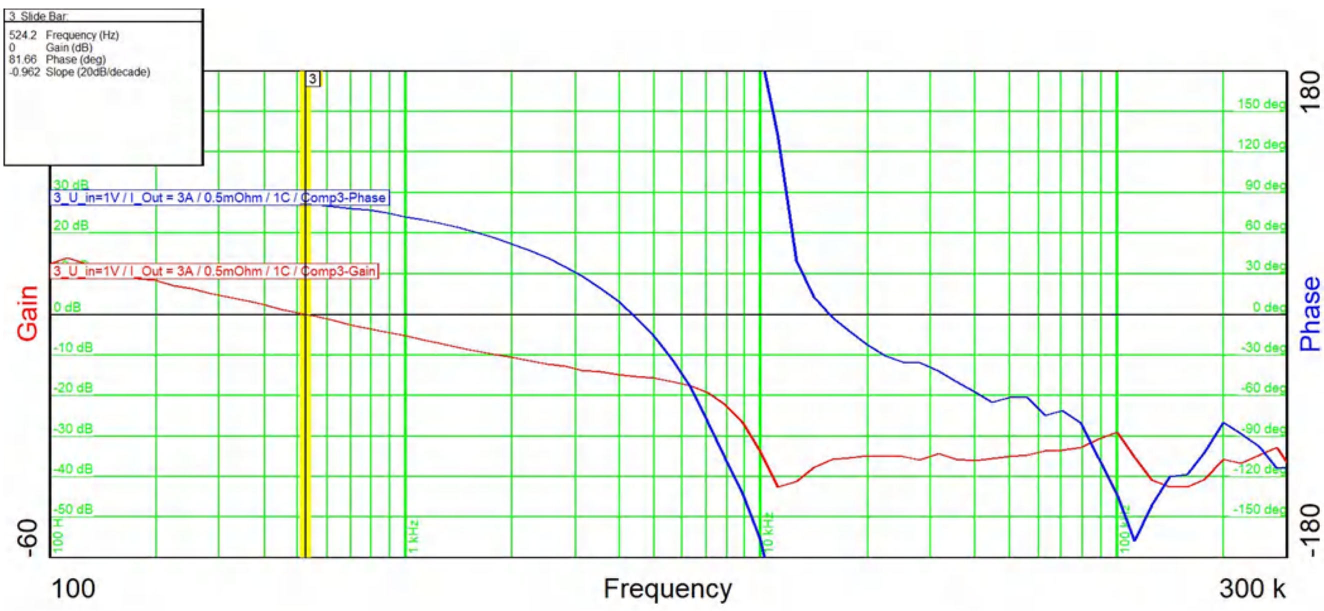


Figure 2-9. Bode Plot for 1.0-V Input Voltage

2.4.2 2.0-V Input Voltage

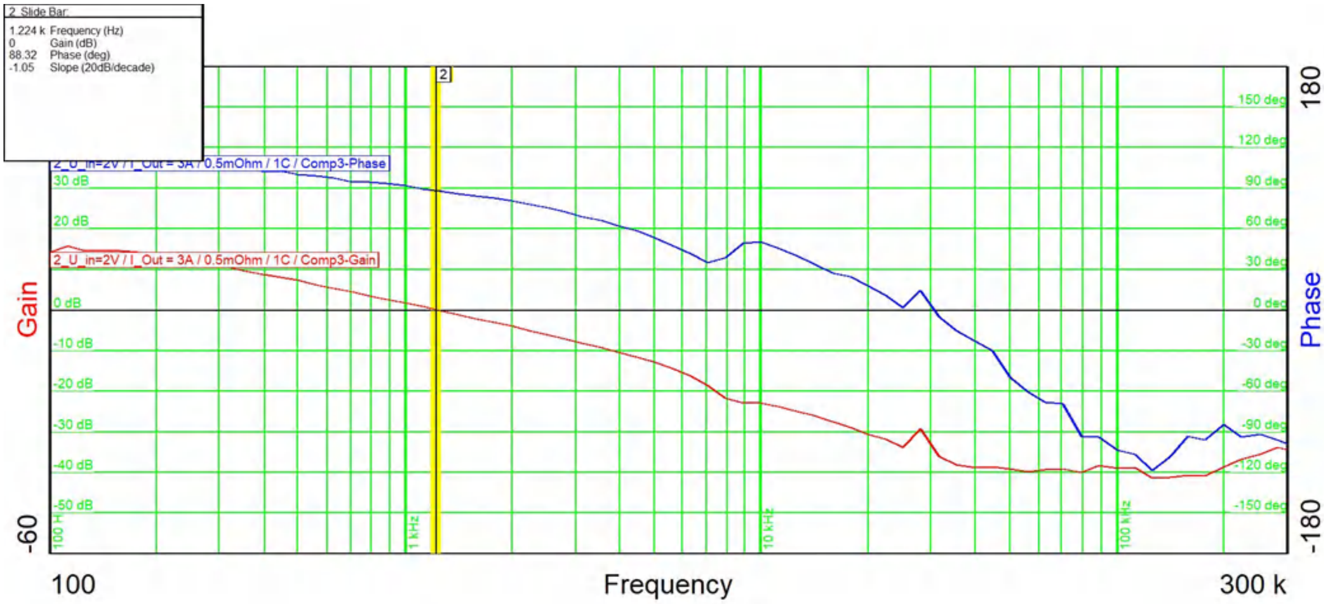


Figure 2-10. Bode Plot for 2.0-V Input Voltage

2.4.3 3.0-V Input Voltage

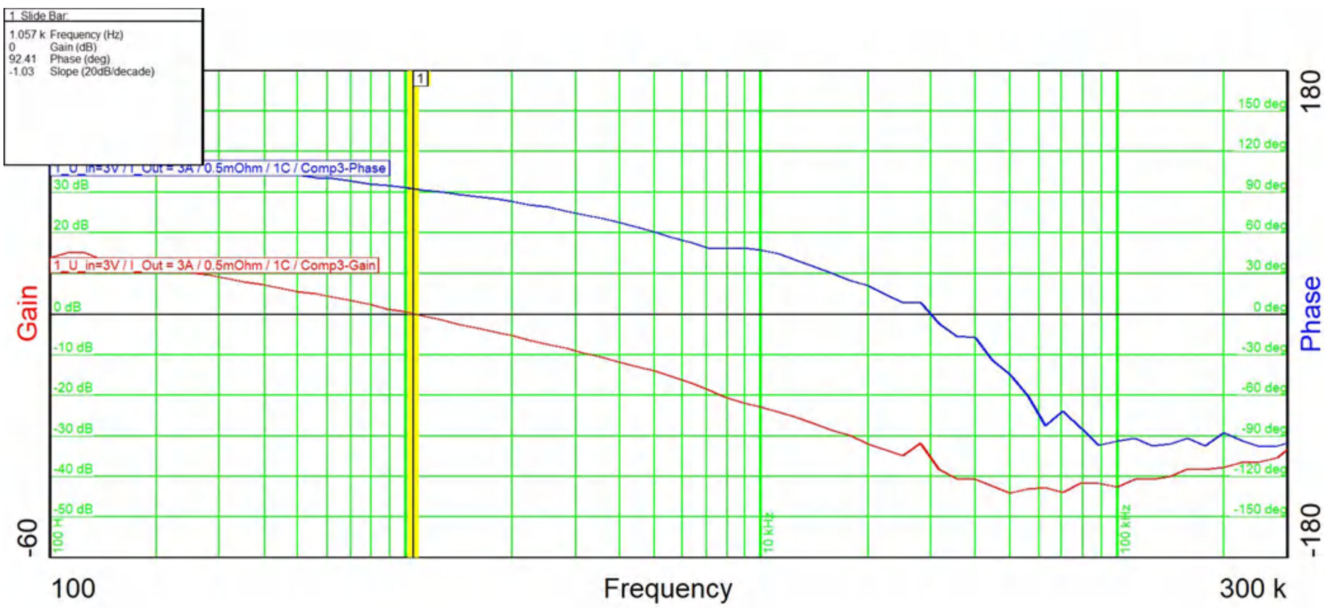


Figure 2-11. Bode Plot for 3.0-V Input Voltage

3 Waveforms

3.1 Switching Q2 FET (Drain to Source)

3.1.1 1.0-V Input Voltage

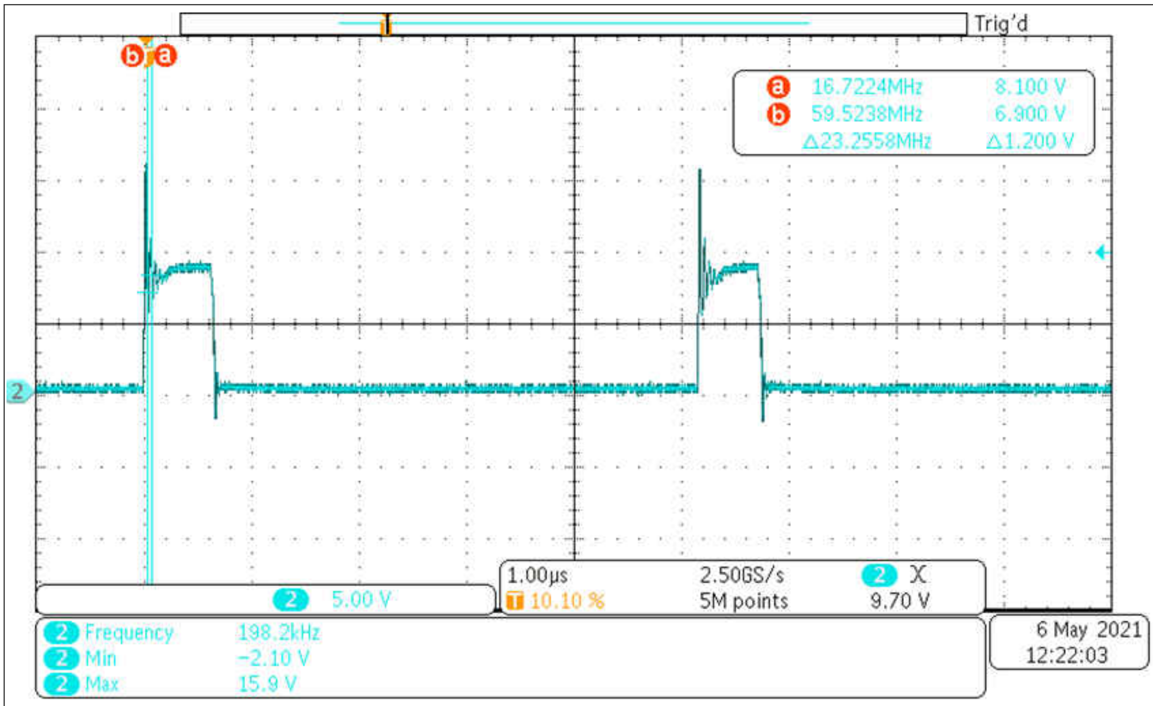
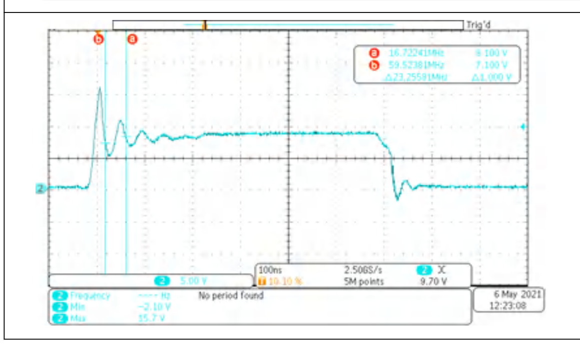
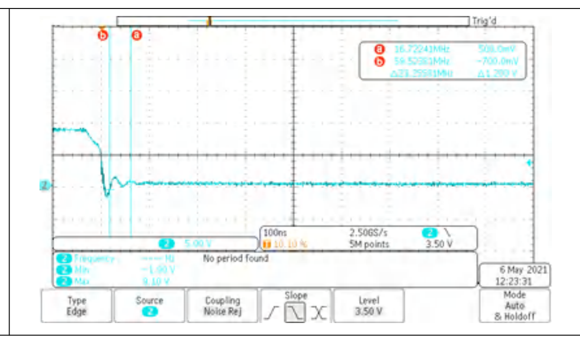
		5 V / div full bandwidth 1 µs / div
		5 V / div full bandwidth 100 ns / div

Figure 3-1. Switching Node Q2 at 1.0-V Input Voltage

3.1.2 3.0-V Input Voltage

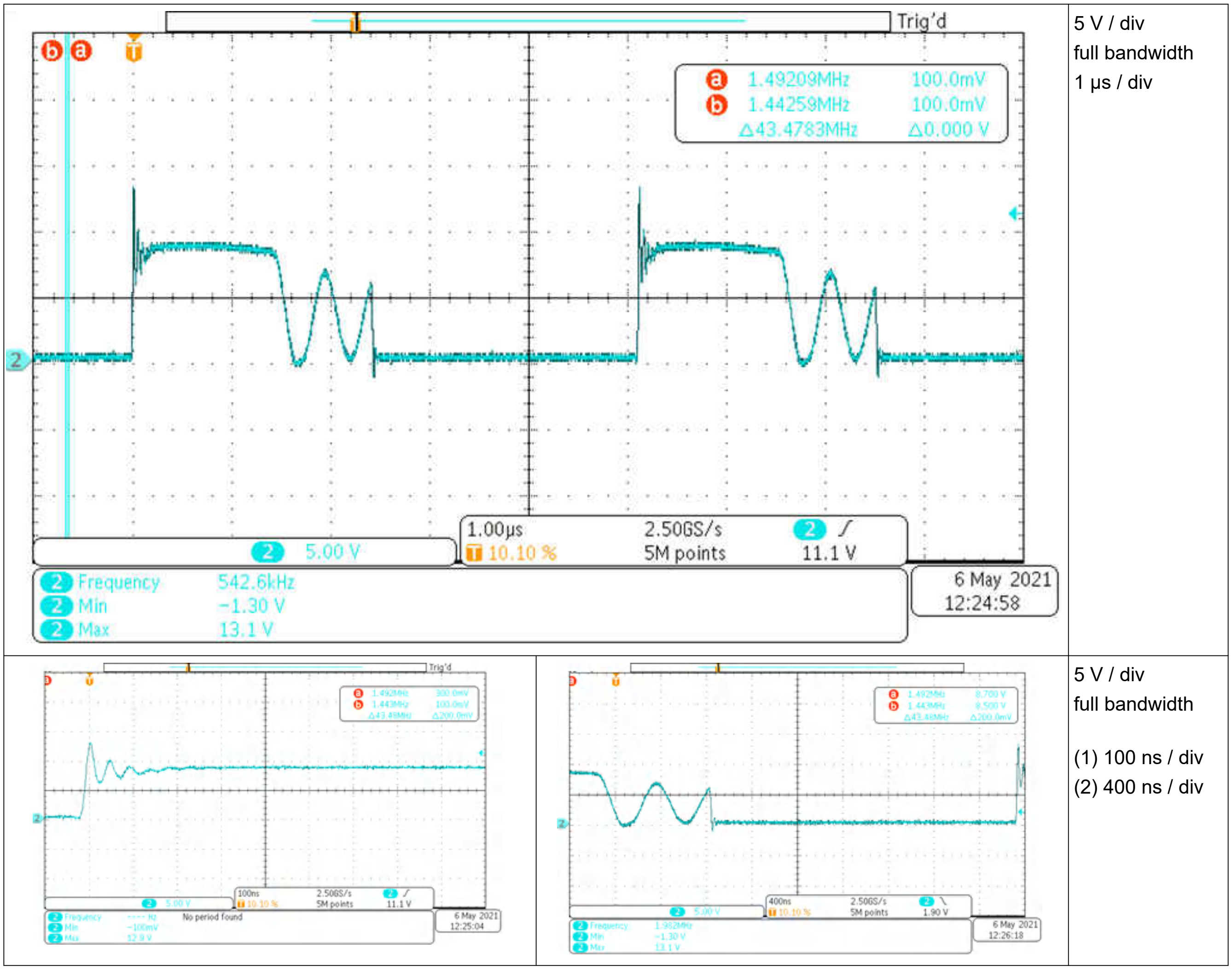
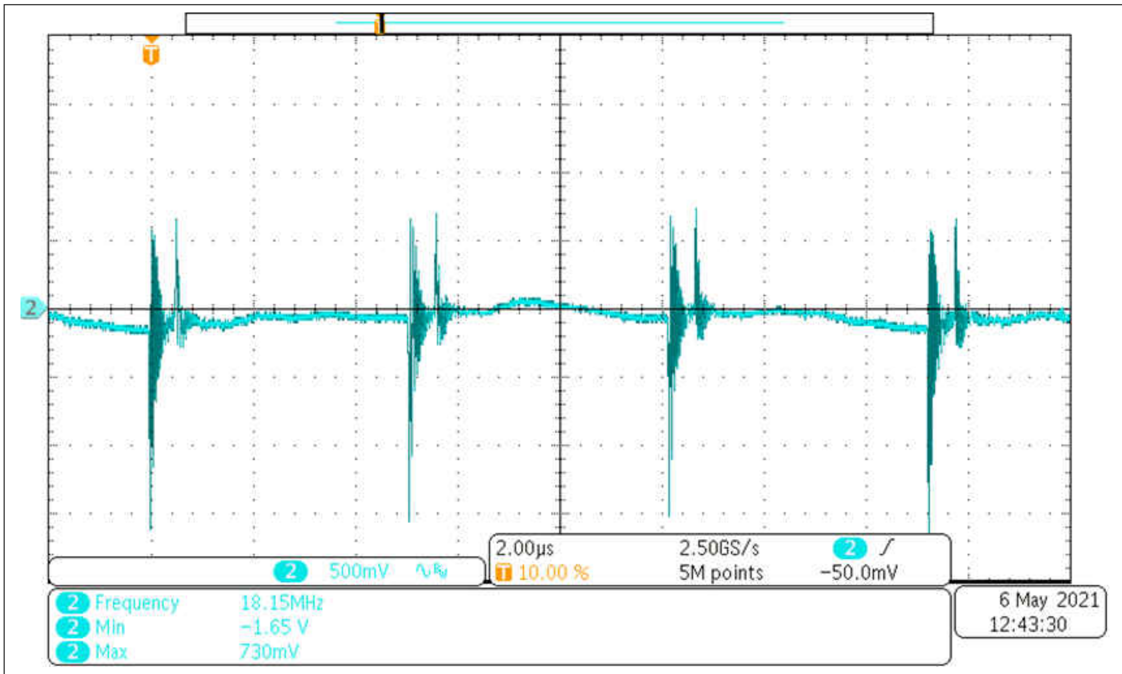


Figure 3-2. Switching Node Q2 at 3.0-V Input Voltage

3.2 Output Voltage Ripple

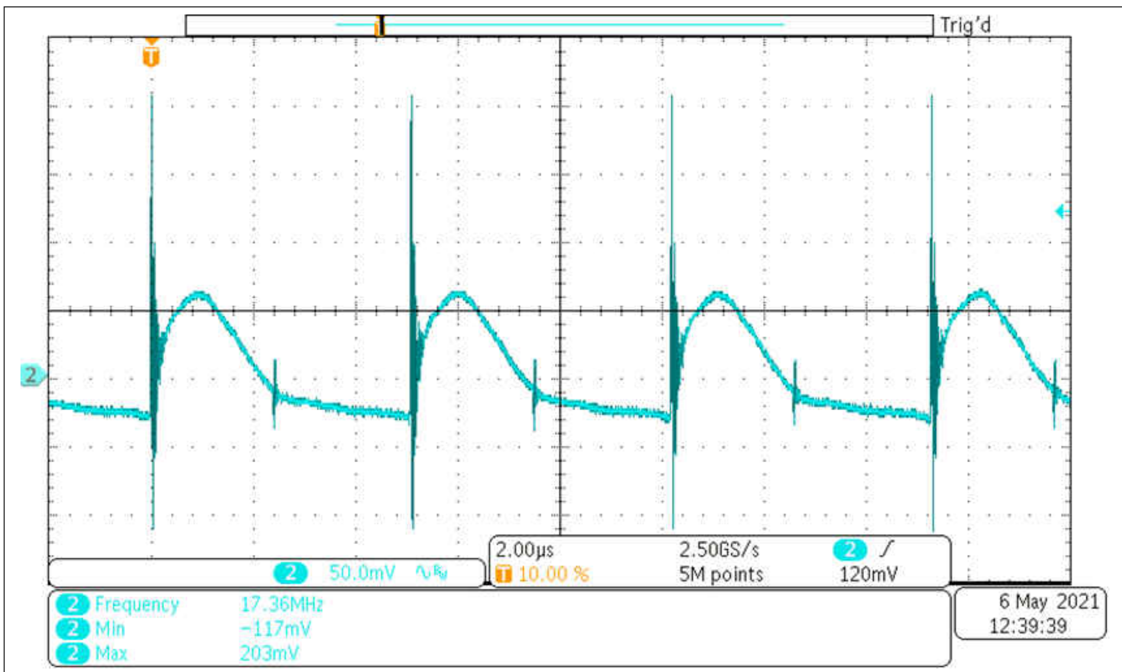
3.2.1 1.0-V Input Voltage



500 mV / div
20-MHz bandwidth
2 µs / div

Figure 3-3. Output Voltage Ripple (1.0-V Input Voltage)

3.2.2 3.0-V Input Voltage

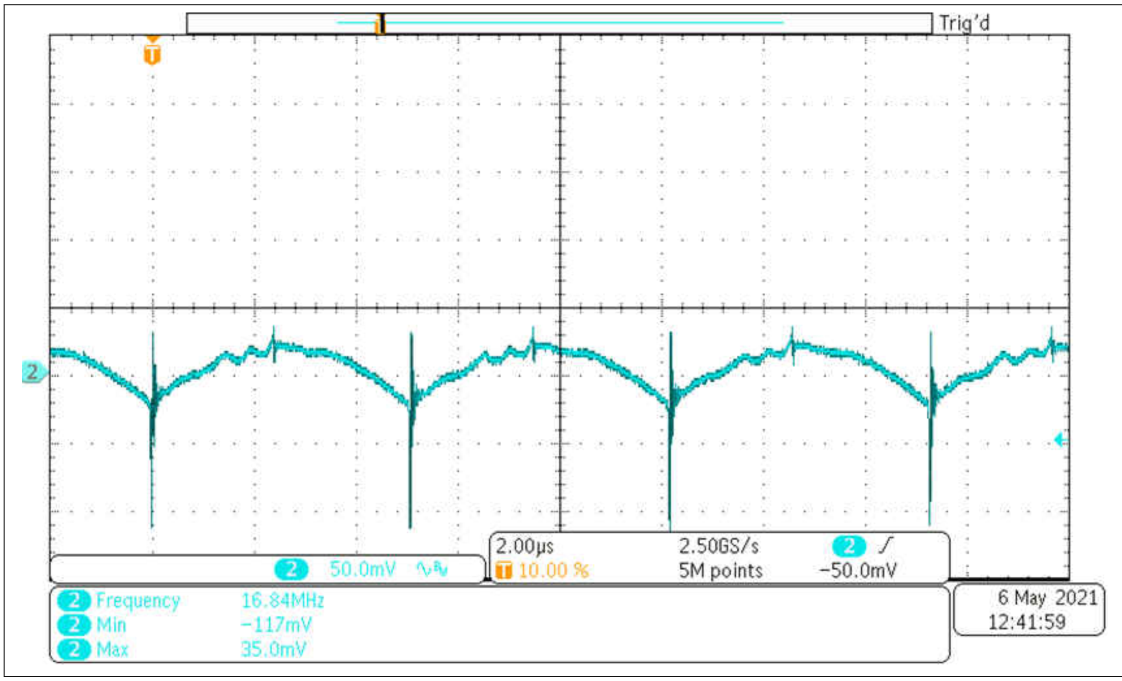


50 mV / div
20-MHz bandwidth
2 µs / div

Figure 3-4. Output Voltage Ripple (3.0-V Input Voltage)

3.3 Input Voltage Ripple

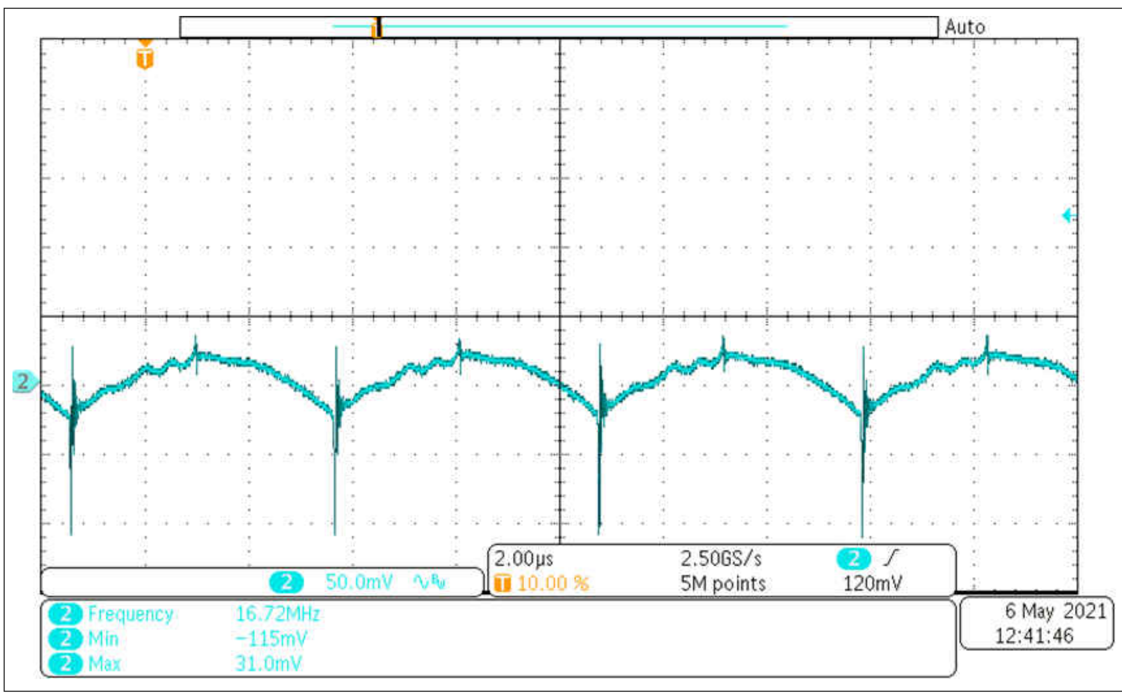
3.3.1 1.0-V Input Voltage



50 mV / div
20-MHz bandwidth
2 µs / div

Figure 3-5. Input Voltage Ripple (1.0-V Input Voltage)

3.3.2 3.0-V Input Voltage



50 mV / div
20-MHz bandwidth
2 µs / div

Figure 3-6. Input Voltage Ripple (3.0-V Input Voltage)

3.4 Load Transients

3.4.1 Load Steps of 1.5 A to 3 A

Electronic load was used to create the load steps of 1.5 A to 3.0 A (30 Hz).

3.4.1.1 1.0-V Input Voltage

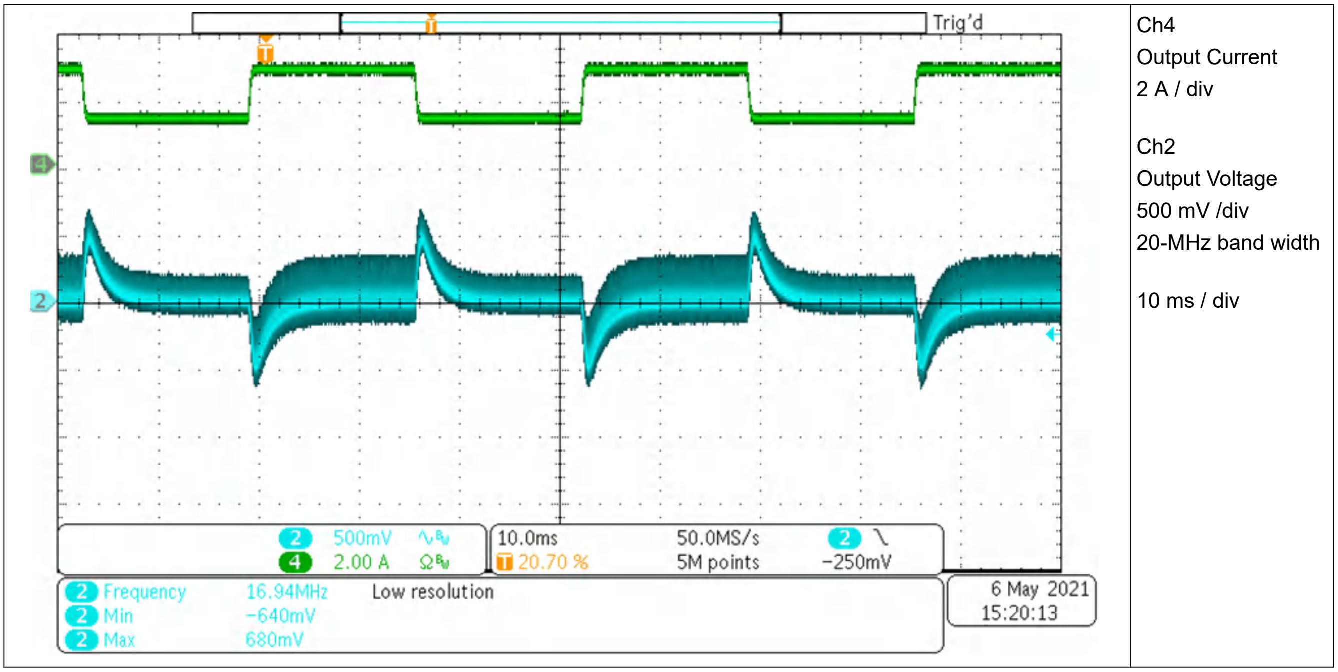


Figure 3-7. 1.5-A to 3-A Load Transient With 1.0-V Input Voltage

3.4.1.2 3.0-V Input Voltage

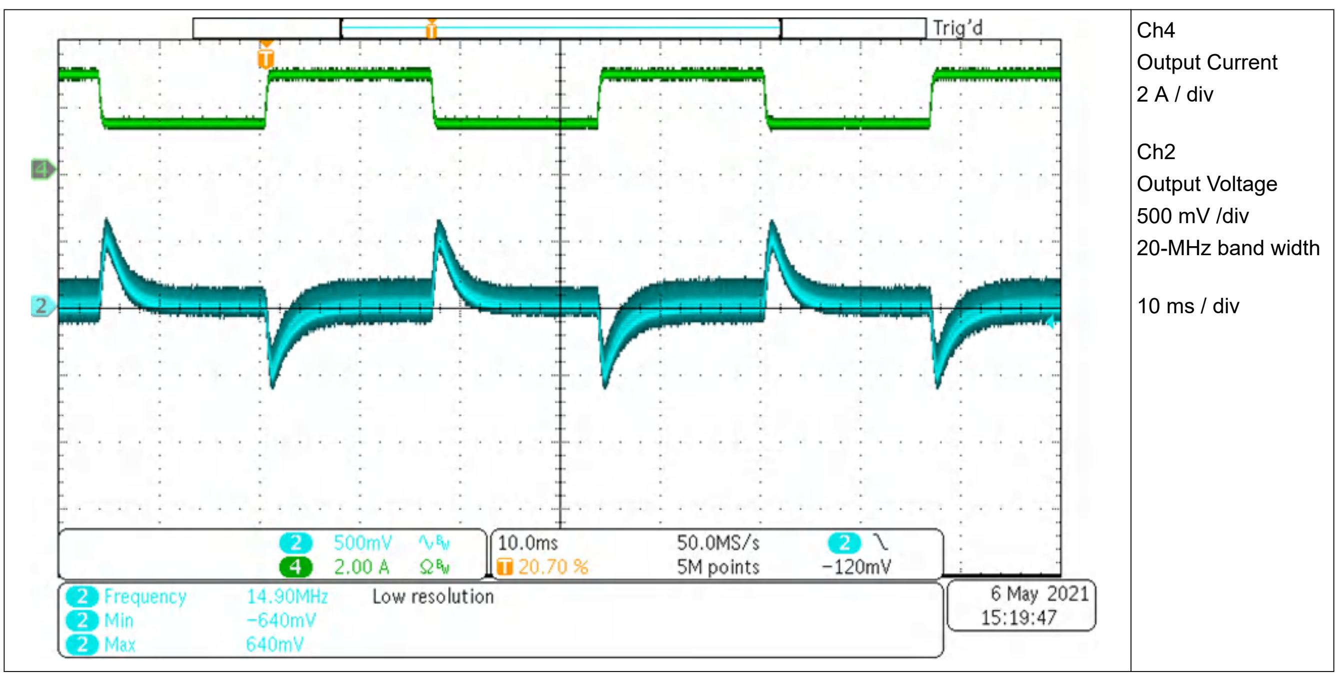


Figure 3-8. 1.5-A to 3-A Load Transient With 3.0-V Input Voltage

3.4.2 Load Steps of 0.2 A to 3 A

Electronic load has been used to create the load steps of 0.2 A to 3.0 A (30 Hz).

3.4.2.1 1.0-V Input Voltage

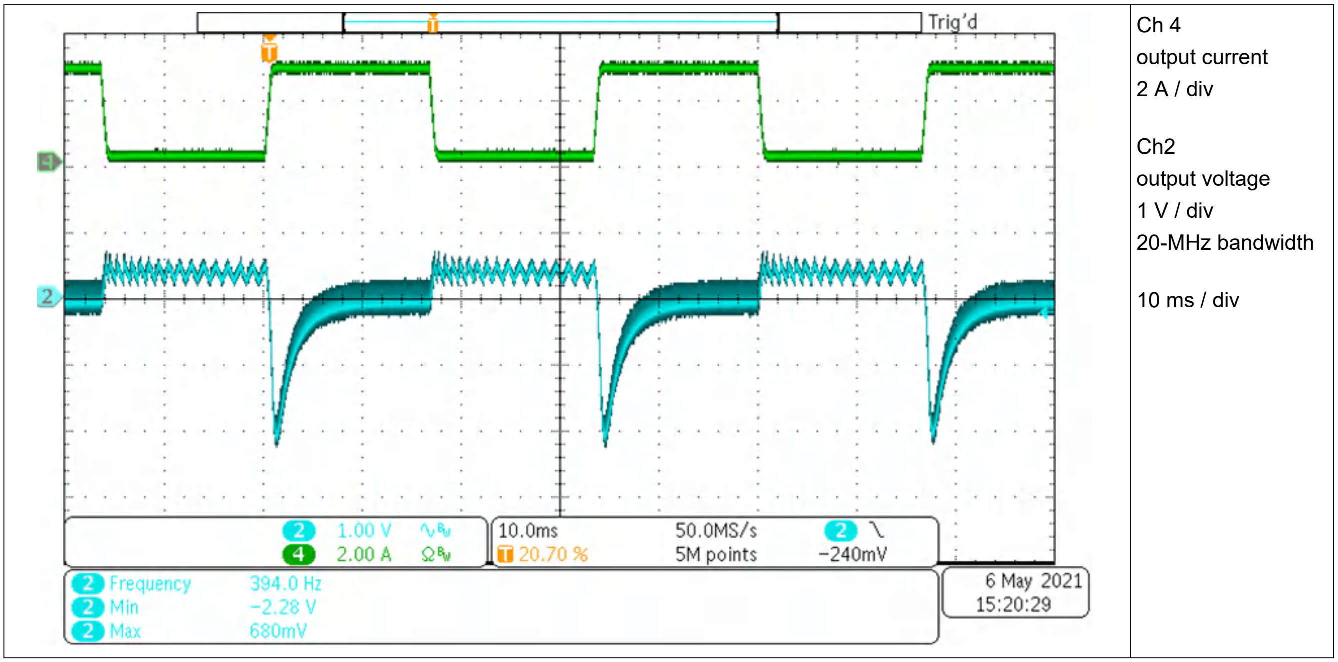


Figure 3-9. 0.2-A to 3-A Load Transient With 1.0-V Input Voltage

3.4.2.2 3.0-V Input Voltage

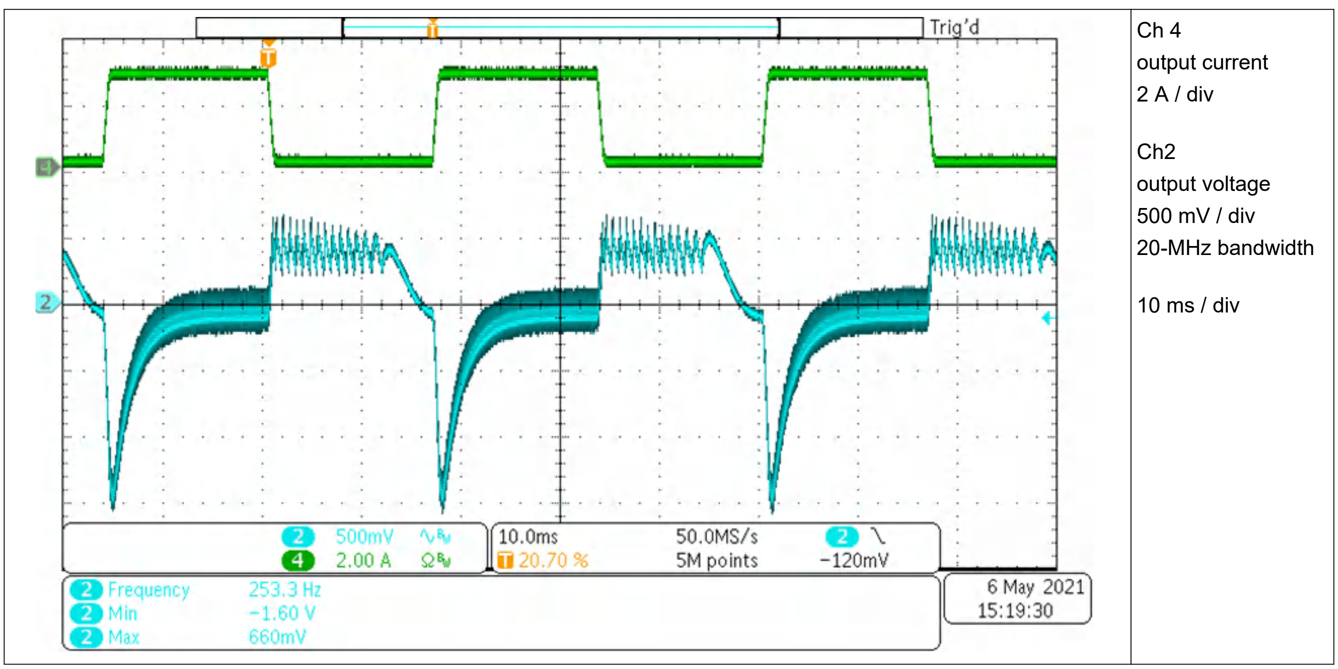
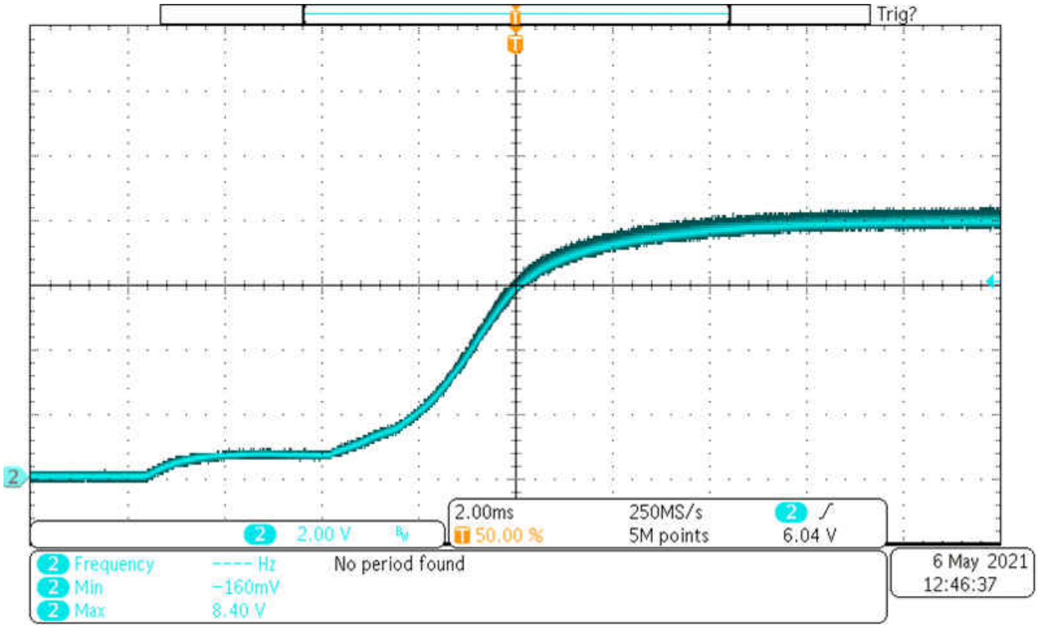


Figure 3-10. 0.2-A to 3-A Load Transient With 3.0-V Input Voltage

3.5 Start-Up Sequence

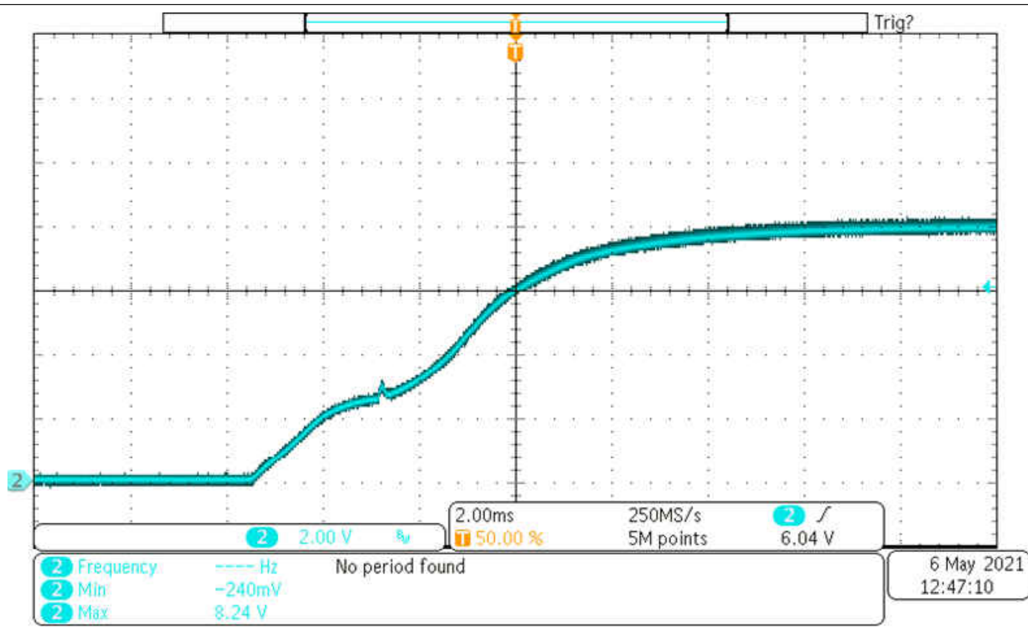
3.5.1 1.0-V Input Voltage



2 V /div
20-MHz bandwidth
2 ms / div

Figure 3-11. Start-Up With 1.0-V Input Voltage

3.5.2 3.0-V Input Voltage

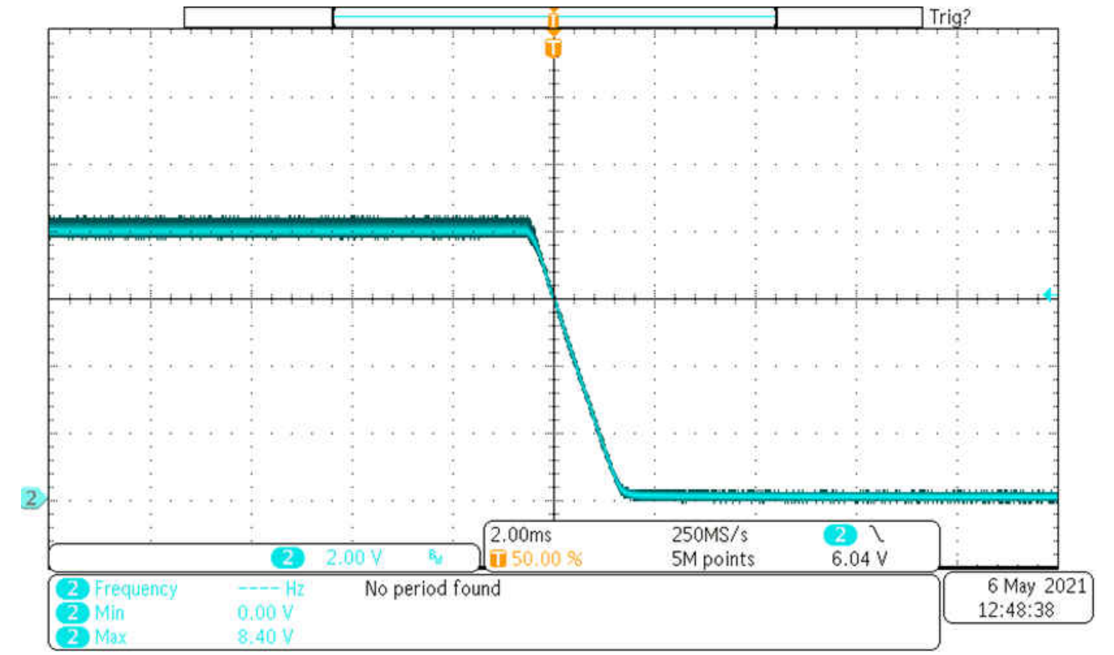


2 V /div
20-MHz bandwidth
2 ms / div

Figure 3-12. Start-Up With 3.0-V Input Voltage

3.6 Shutdown Sequence

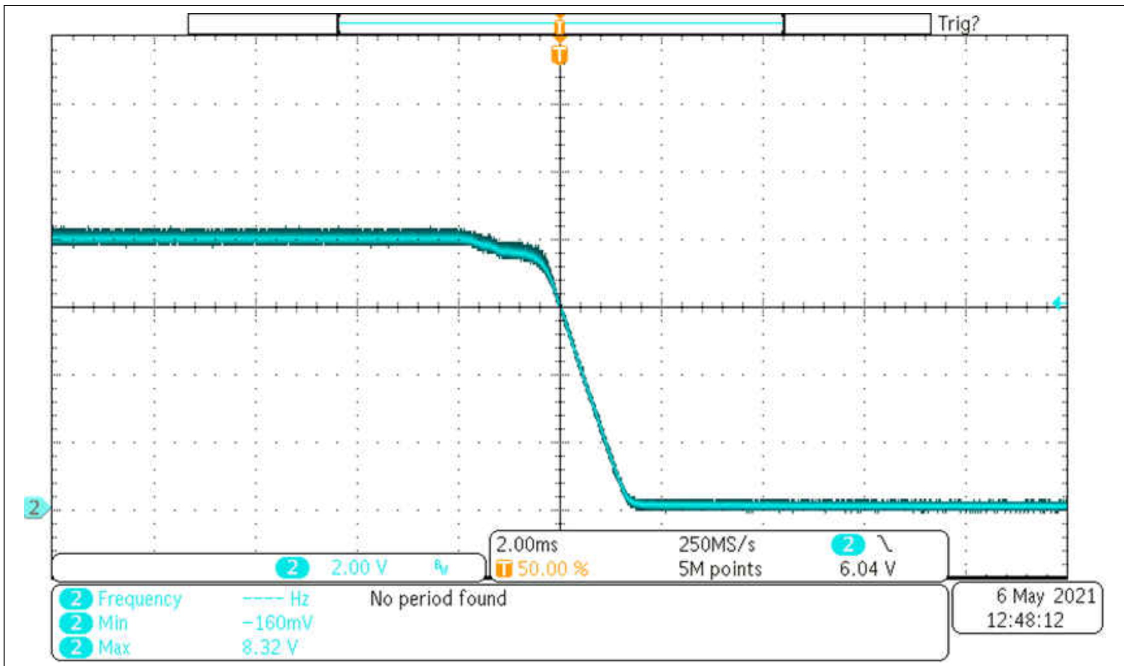
3.6.1 1.0-V Input Voltage



2 V / div
20-MHz bandwidth
2 ms / div

Figure 3-13. Shutdown With 1.0-V Input Voltage

3.6.2 3.0-V Input Voltage



2 V / div
20-MHz bandwidth
2 ms / div

Figure 3-14. Shutdown With 3.0-V Input Voltage

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