Test Report: PMP31279

12-W Nonsynchronous Automotive SEPIC Reference Design

Description

This design showcases a 1-A (1.5-A peak) output current nonsynchronous SEPIC converter based on LM51561, which covers an input voltage range of 6 V to 36 V with an output voltage of 12 V. The efficiency reaches up to 90.5% at 12-V input voltage. The design can operate down to 4.5 V to support automotive cranking.

The 2-MHz switching frequency allows the use of a smaller inductor and therefore enables a smaller circuit size.

Features

- Converter can step up and down the input voltage
- Cost-effective topology that uses only two semiconductor devices in the power stage
- Due to continuous input current SEPIC topology and high switching frequency of 2 MHz, low conducted emissions are achieved which is above AM broadcast band
- The switching high frequency of 2 MHz enables a smaller physical form factor of the circuit

Applications

- Emergency call (eCall)
- Telematics control unit

Top Photo

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage	6 to 16 V, down to 4.5 V during cranking
Output Voltage	12 V
Output Current	1 A
Peak Output Current	1.5 A
Nominal Switching Frequency	2 MHz

1.2 Considerations

The board is built on the PMP31676 Rev D board.

1.3 Dimensions

The size of the four-layer board is 64.8 mm × 50.2 mm. The boards are manufactured with a copper thickness of 35 µm on each layer.

2 Testing and Results

2.1 Efficiency Graphs

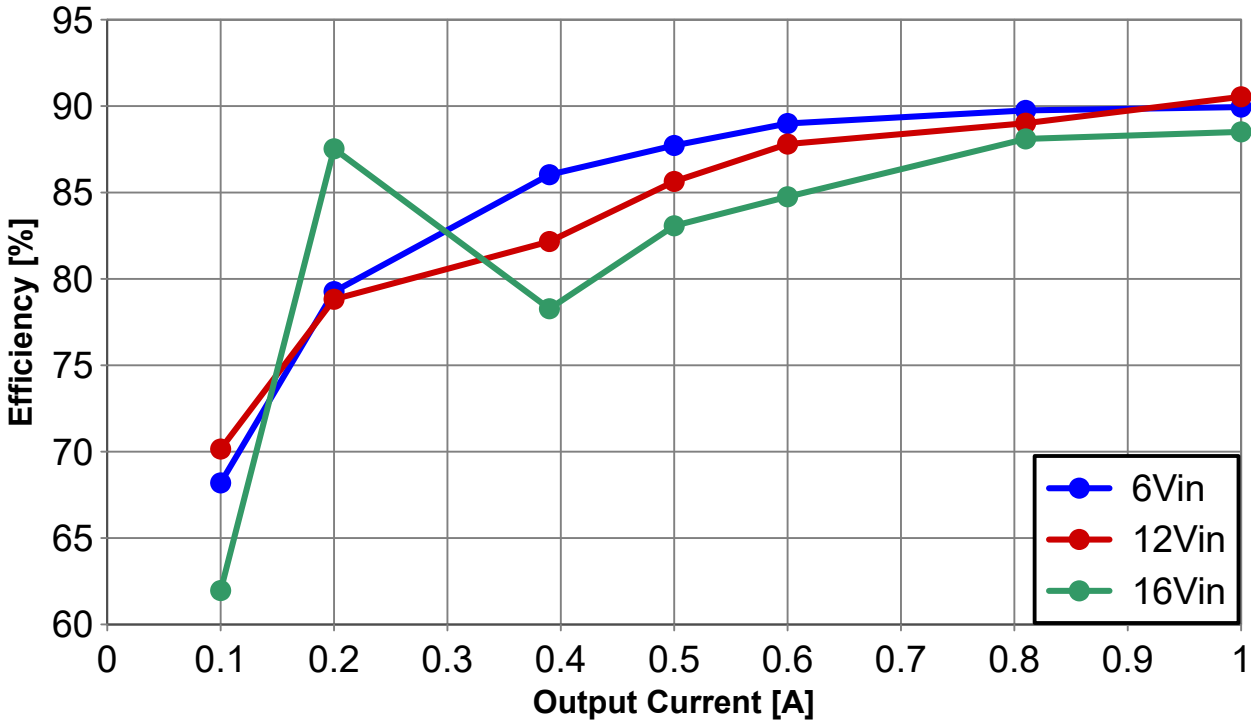

Figure 2-1. Efficiency With the Snubber

2.2 Efficiency Data

2.2.1 6-V Input Voltage

Table 2-1. Efficiency Data for 6-V Input Voltage

Input Voltage [V]	Input Current [A]	Input Power [W]	Output Voltage [V]	Output Current [A]	Output Power [W]	Power Loss [W]	Efficiency [%]
6.78	0.26	1.76	12.02	0.1	1.20	0.56	68.19
6.74	0.45	3.03	12.02	0.2	2.40	0.63	79.26
6.645	0.82	5.45	12.02	0.39	4.69	0.76	86.03
6.588	1.04	6.85	12.02	0.5	6.01	0.84	87.72
6.536	1.24	8.10	12.02	0.6	7.21	0.89	88.99
6.419	1.69	10.85	12.02	0.81	9.74	1.11	89.75
6.304	2.12	13.36	12.02	1	12.02	1.34	89.94

2.2.2 12-V Input Voltage

Table 2-2. Efficiency Data for 12-V Input Voltage

Input Voltage [V]	Input Current [A]	Input Power [W]	Output Voltage [V]	Output Current [A]	Output Power [W]	Power Loss [W]	Efficiency [%]
12.25	0.14	1.72	12.03	0.1	1.20	0.51	70.15
12.21	0.25	3.05	12.03	0.2	2.41	0.65	78.82
12.15	0.47	5.71	12.03	0.39	4.69	1.02	82.16
12.11	0.58	7.02	12.03	0.5	6.02	1.01	85.64
12.09	0.68	8.22	12.03	0.6	7.22	1.00	87.80
12.03	0.91	10.95	12.03	0.81	9.74	1.20	89.01
11.97	1.11	13.29	12.03	1	12.03	1.26	90.54

2.2.3 16-V Input Voltage

Table 2-3. Efficiency Data for 16-V Input Voltage

Input Voltage [V]	Input Current [A]	Input Power [W]	Output Voltage [V]	Output Current [A]	Output Power [W]	Power Loss [W]	Efficiency [%]
16.18	0.12	1.94	12.03	0.1	1.20	0.74	61.96
16.17	0.17	2.75	12.03	0.2	2.41	0.34	87.53
16.2	0.37	5.99	12.03	0.39	4.69	1.30	78.27
16.09	0.45	7.24	12.03	0.5	6.02	1.23	83.07
16.07	0.53	8.52	12.03	0.6	7.22	1.30	84.75
16.03	0.69	11.06	12.03	0.81	9.74	1.32	88.10
15.99	0.85	13.59	12.03	1	12.03	1.56	88.51

2.3 Thermal Images

Thermal images were taken at an ambient temperature of 25°C without artificial airflow and the board was placed flat on the table.

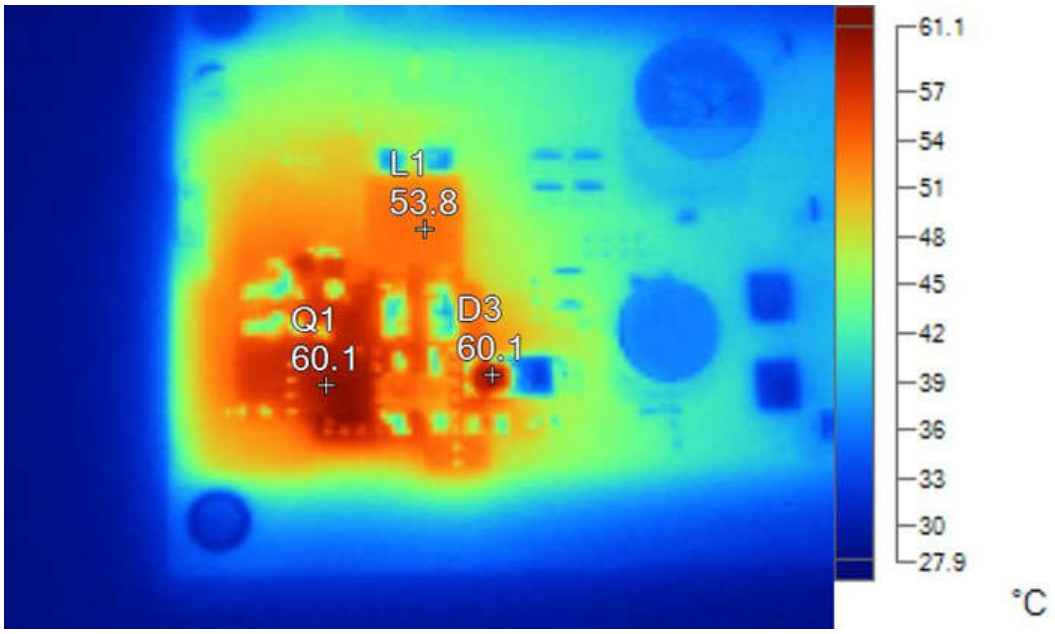

Figure 2-2. 4.5-V Input Voltage and 1-A Output Current

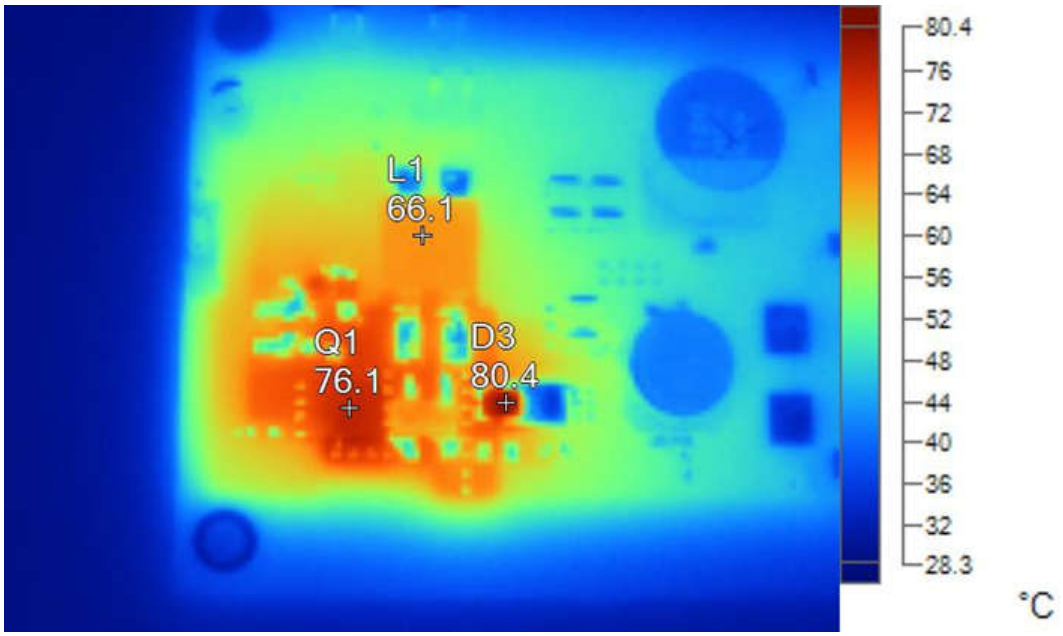

Figure 2-3. 6-V Input Voltage and 1.5-A Output Current

2.4 Bode Plots

Bode plot results are displayed in Table 2-4.

Table 2-4. Bode Plots Results

	4.5 V_{IN}	6 V_{IN}	16 V_{IN}
Bandwidth [kHz]	9.289	12.89	24.91
Phase margin [degree]	77.51	78.32	79.3
Slope (20 dB / decade)	–0.951	–0.985	–1.02

2.4.1 4.5-V Input Voltage

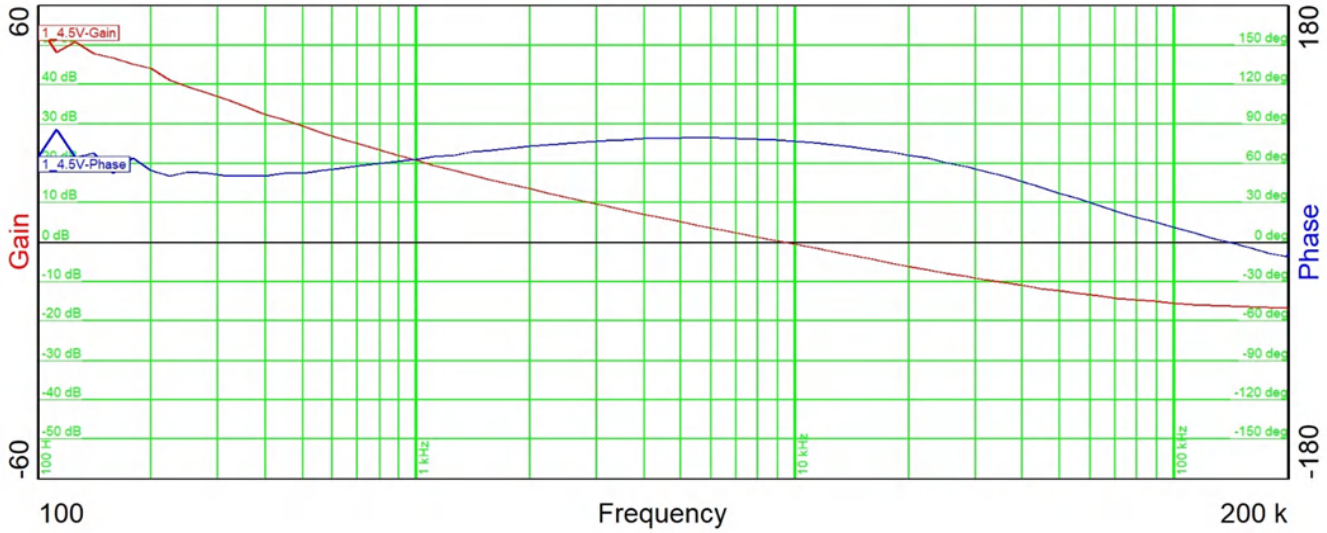

Figure 2-4. Frequency Response at V_{IN} 4.5 V, V_{OUT} 12 V at 1 A (worst case)

2.4.2 6-V Input Voltage

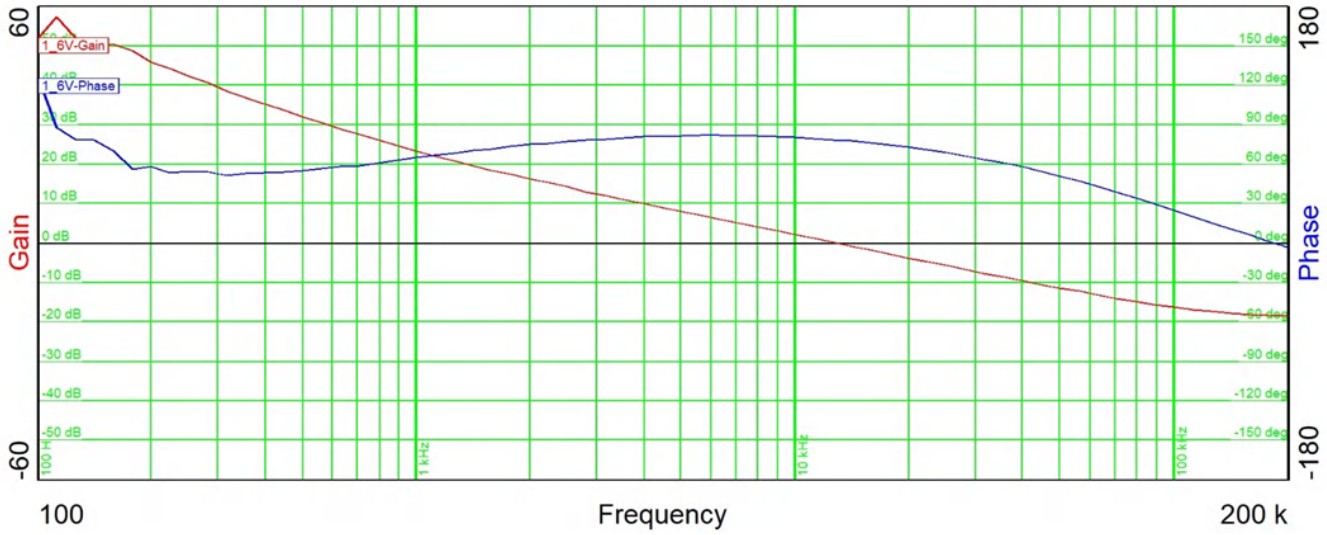

Figure 2-5. Frequency Response at V_{IN} 6 V, V_{OUT} 12 V at 1 A

2.4.3 12-V Input Voltage

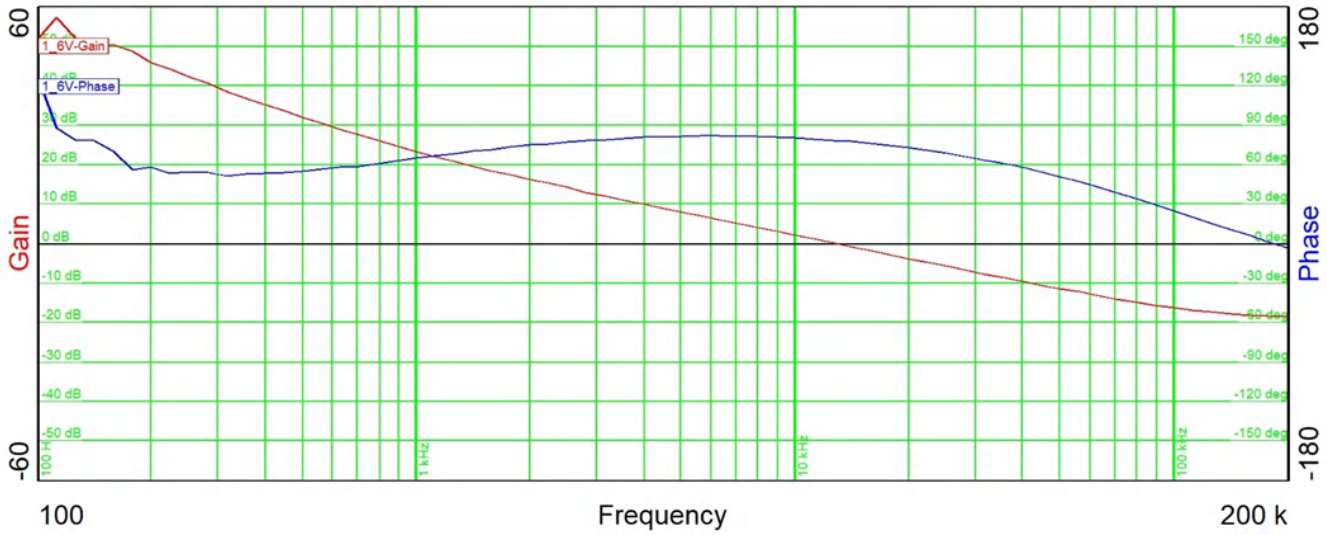

Figure 2-6. Frequency Response at V_{IN} 16 V, V_{OUT} 12 V at 1 A

3 Waveforms

3.1 Switching

3.1.1 6-V Input Voltage and 1-A Load

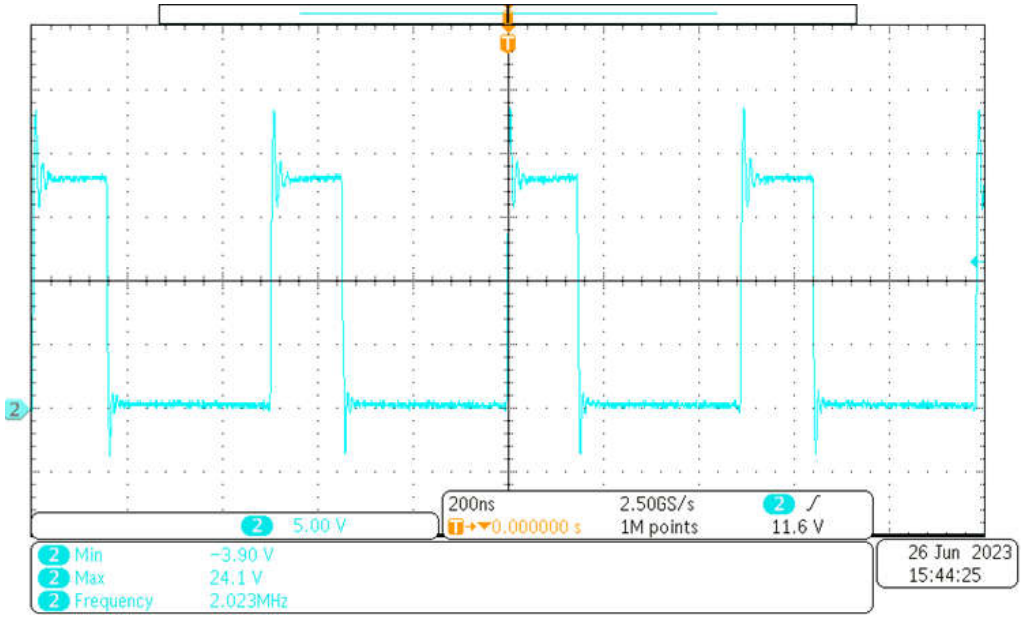

Figure 3-1. Switching Node at 6-V V_{IN}, 1-A I_{OUT} [scale: 5 V / div, 200 ns / div, 500-MHz BW, DC coupling]

3.1.2 16-V Input Voltage and 1-A Load

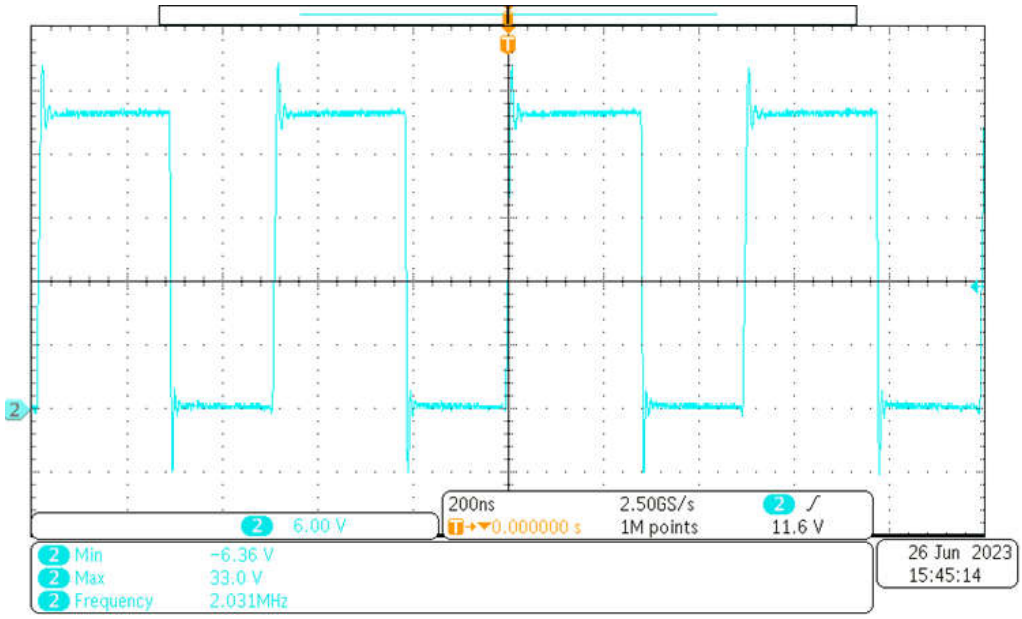

Figure 3-2. Switching Node at 16-V V_{IN}, 1-A I_{OUT} [scale: 6 V / div, 200 ns / div, 500-MHz BW, DC coupling]

3.1.3 Overshoot at V_{IN} 12 V and 1-A Load Current

Figure 3-3 displays the overshoot and ringing of the switching wave.

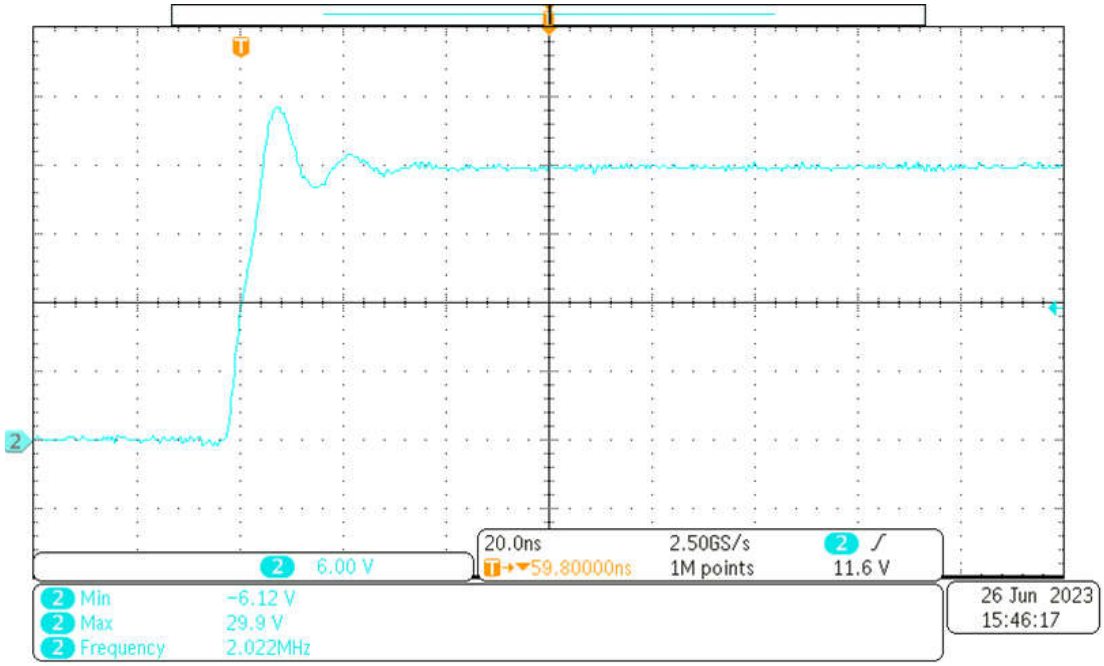

Figure 3-3. Switching Node at 12-V V_{IN}, 1-A I_{OUT} [scale: 6 V / div, 20 ns / div, 500-MHz BW, DC coupling]

3.1.4 Undershoot at 12 V_{IN} and 1-A Load Current

Figure 3-4 displays the undershoot and ringing of switching wave.

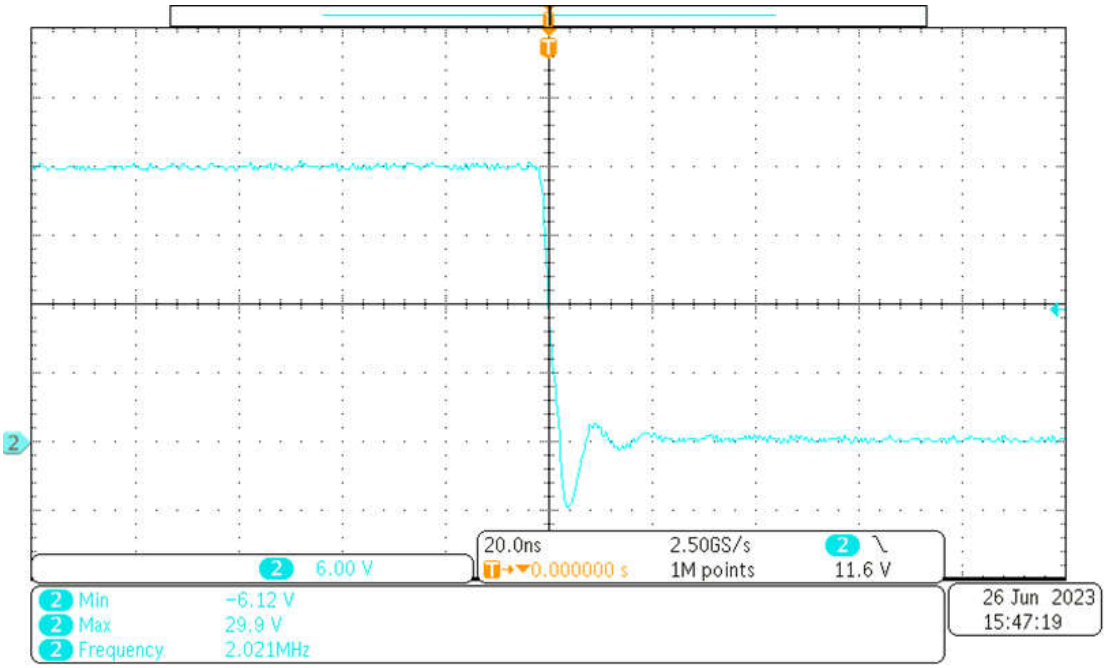

Figure 3-4. Switching Node at 12-V V_{IN}, 1-A I_{OUT} [scale: 6 V / div, 20 ns / div, 500-MHz BW, DC coupling]

3.2 Output Voltage Ripple

Figure 3-5. Output Voltage at 6-V V_{IN} and 1-A I_{OUT} [scale: 100 mV / div, 200 ns / div, 20-MHz BW, AC coupling]

3.3 Input Voltage Ripple

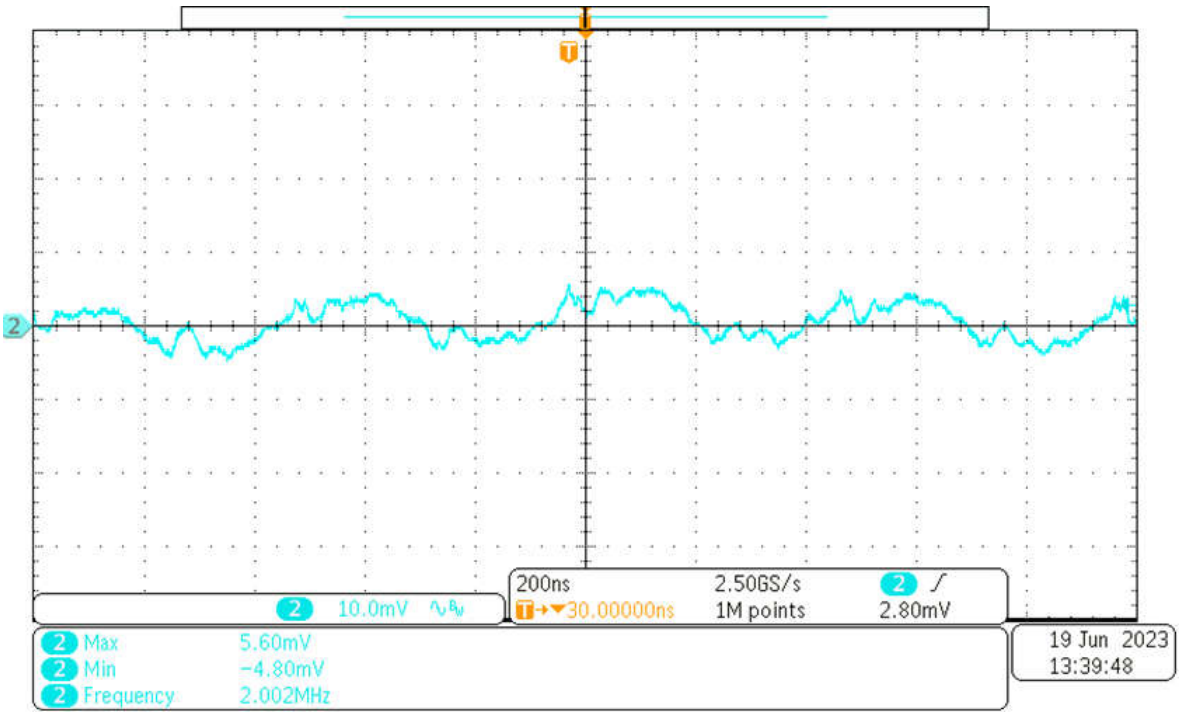

Figure 3-6. Input Voltage at 6-V V_{IN}, 1-A I_{OUT} [scale: 10 mV / div, 200 ns / div, 20-MHz BW, AC coupling]

3.4 Load Transients

The load switches between 0.8-A and 1.1-A output current.

3.4.1 6-V Input Voltage

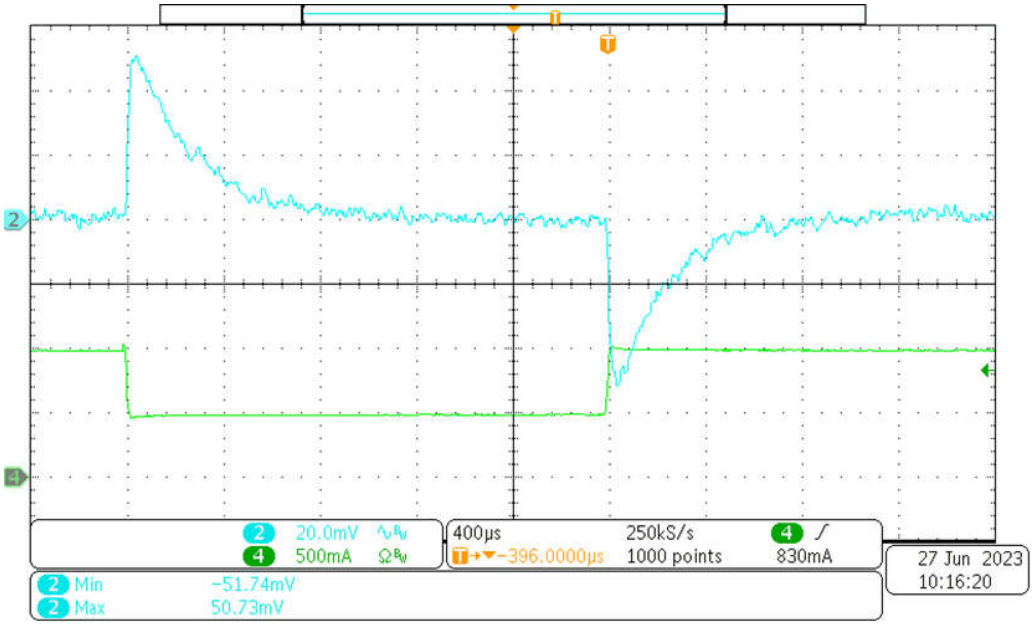

Figure 3-7. Load Step Response at 6-V Input Voltage

- CH2: Output Voltage [scale: 20 mV/div, 400 µs / div, 20-MHz BW, AC coupling]
- CH4: Load transient from 0.5 A to 1 A [scale: 500 mA / div, 400 µs / div]

3.4.2 16-V Input Voltage

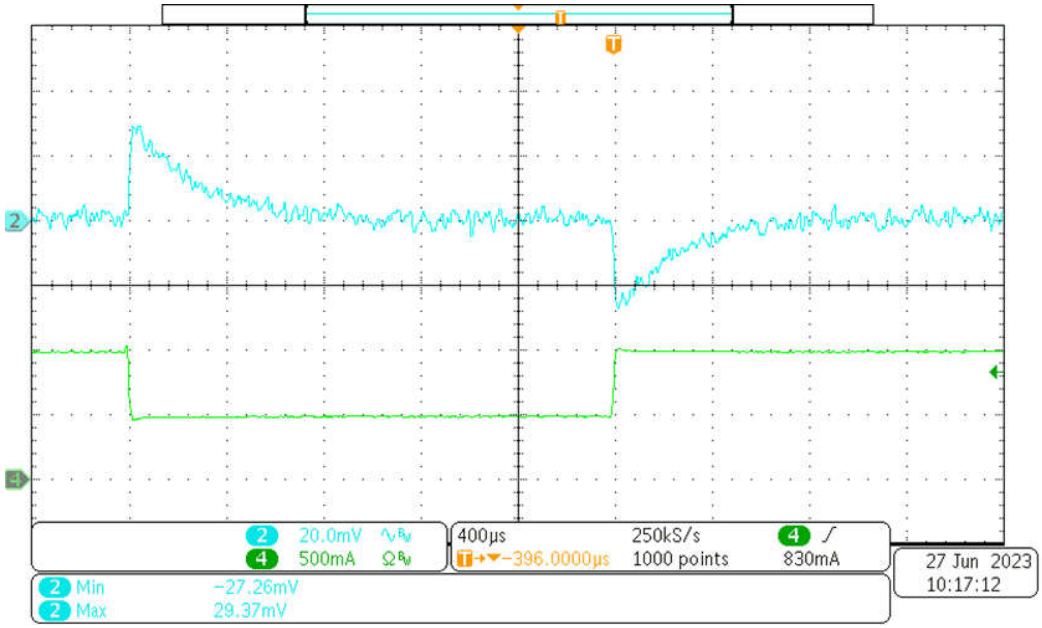

Figure 3-8. Load Step Response at 16-V Input Voltage

- CH2: Output Voltage [scale: 20 mV / div, 400 µs/div, 20-MHz BW, AC coupling]
- CH4: Load transient from 0.5 A to 1 A [scale: 500 mA / div, 400 µs/div]

3.5 Start-Up Sequence (1-A Load)

Input is provided by turning on the power supply switch.

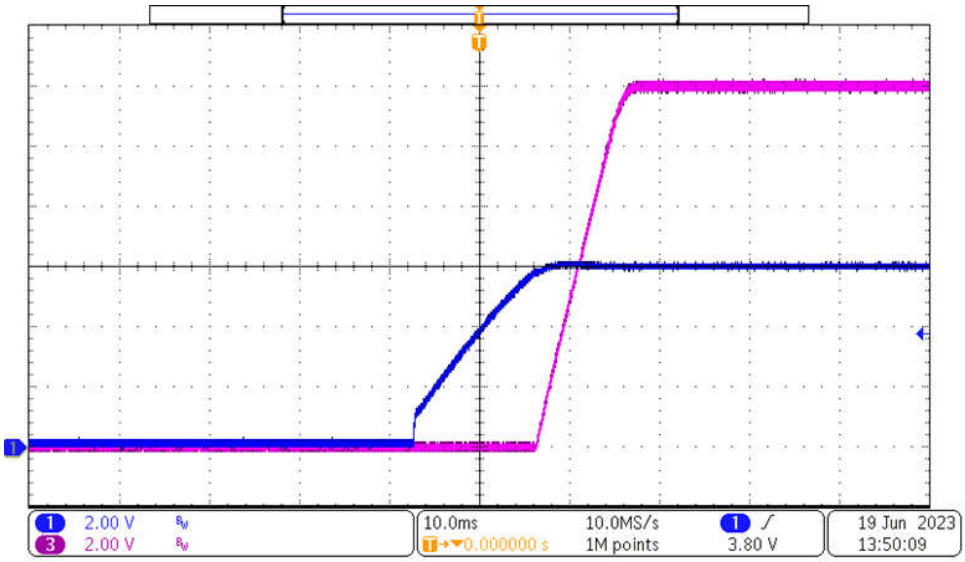

Figure 3-9. Start-Up Behavior of the Converter

- CH1: Input Voltage [scale: 2 V / div, 10 ms / div, 20-MHz BW, DC coupling]
- CH3: Output Voltage [scale: 2 V / div, 10 ms / div, 20-MHz BW, DC coupling]

3.6 Shutdown Sequence

3.6.1 No Load

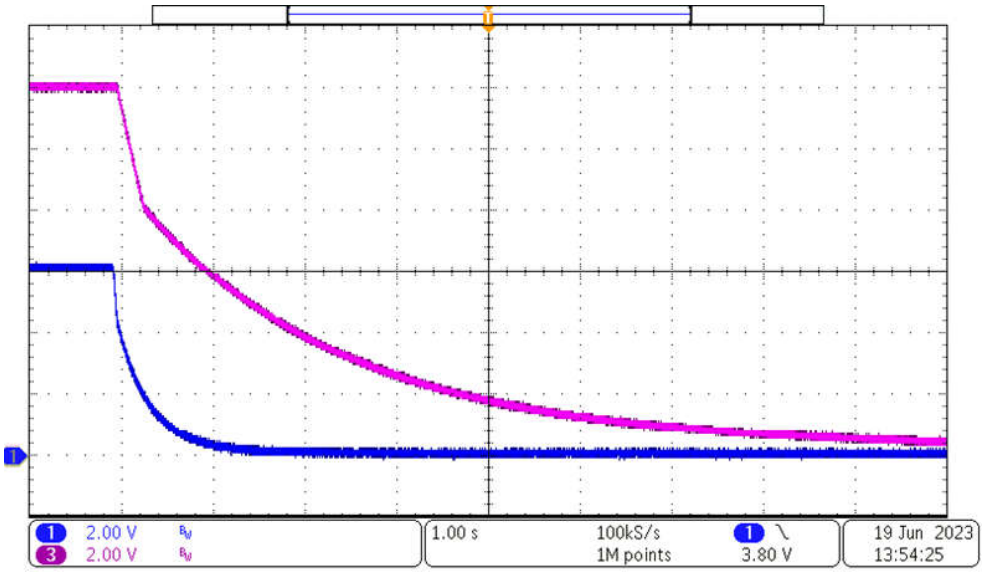

Figure 3-10. Shutdown Waveform Without the Load

- CH1: Input Voltage [scale: 2 V / div, 1 s /div, 20-MHz BW, DC coupling]
- CH3: Output Voltage [scale: 2 V / div, 1 s / div, 20-MHz BW, DC coupling]

3.6.2 1-A Load

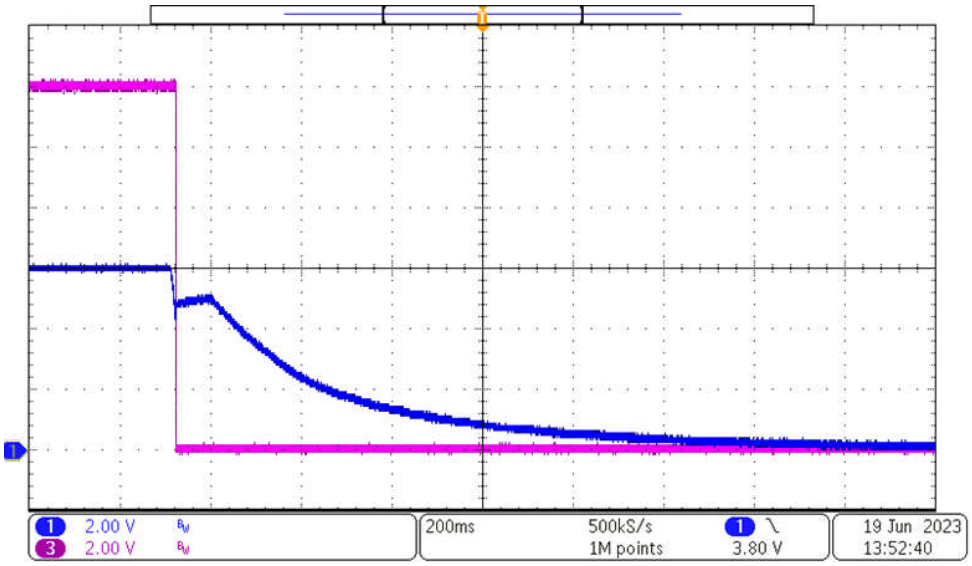

Figure 3-11. Shutdown Waveform With 1-A Load

- CH1: Input Voltage [scale: 2 V / div, 200 ms / div, 20-MHz BW, DC coupling]
- CH3: Output Voltage [scale: 2 V / div, 200 ms / div, 20-MHz BW, DC coupling]

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