Test Report: PMP31144

SEPIC Reference Design Fitting for Battery Chargers

Description

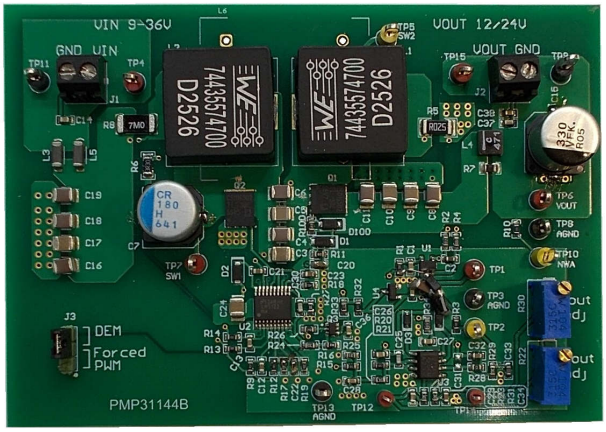
This reference design shows the use of a Buck-Boost capability of a single-ended primary-inductor converter (SEPIC) converter. Since the input and output are separated by a capacitor, this topology can be used to charge a battery with variable V_{IN} as well as variable V_{OUT}. A synchronous peak-current mode controller LM5122 is employed; this IC can drive the high-side sync-FET by means of level shift (RCD network). By applying 9-V to 36-V input, this board can be used to charge two batteries in series with a voltage range of 8 V to 28 V, up to 2-A charging current, or simply used as standard constant-voltage power supply. Both setpoints of output voltage and current are defined by means of two trimmers, even though both references can also be replaced by employing two digital-to-analog converters.

Features

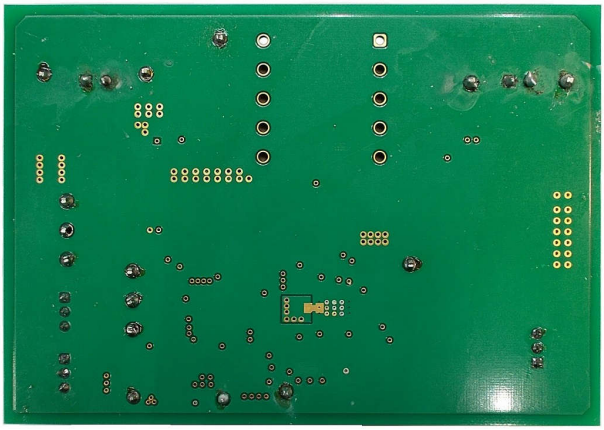
- Can be used as battery charger or standard power supply
- Synchronous SEPIC topology with external high-side field-effect transistors (FETs) and low-side FETs
- Constant charging current: adjustable in the range 0 A to 2 A
- Constant supply voltage : adjustable in the range 8 V to 28 V
- ±2% charging voltage accuracy and ±2.5% charging current accuracy
- Selectable Forced PWM Mode or Diode Emulation Mode for efficiency improvement at light load

Applications

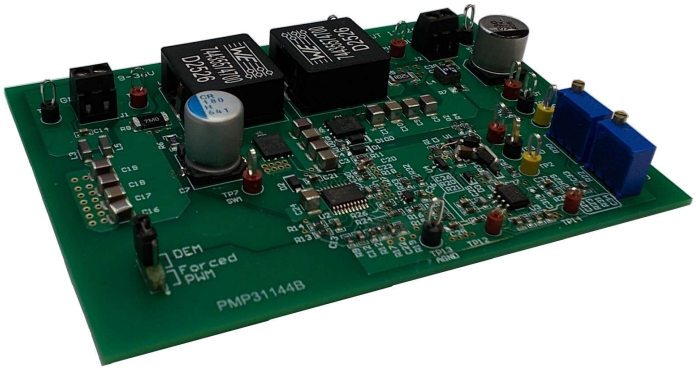
- Appliances: battery charger



Top of Board



Bottom of Board



Angled View of Board

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage Range	9 V to 36 V
Output Voltage	8 V to 28 V (24 V nominal)
Maximum Output Current	2 A (adjustable)
IC	LM5122
Topology	SEPIC

1.2 Required Equipment

The following equipment is required for testing this design:

- Bench power supply with output voltage range 0–36 V, current limit up to 10 A
- Electronic load 0–30 V, 0–3 A, settable in constant-current and constant-voltage regulation

1.3 Dimensions

The size of the board is 104.1 mm × 73.2 mm. The board was manufactured with 4 copper layers. The outer layers are 70 µm and the inner layers are 35-µm copper thickness.

1.4 Test Setup

To avoid mistakes that can lead to unwanted behavior of this SEPIC charger (like setting a current limit threshold on this board less than the constant-current sink set to your electronic load), please observe the following procedure during testing:

1. Supply the board with the bench PSU (Vin) on J1 (pin 1 positive)
2. Connect a constant current load to the output on J2 (positive on pin 2)
3. **If this power supply is used as standard PSU (therefore not charging a battery)** set “Mode select” on J3 by placing a jumper between pins 1 and 2 (Forced PWM)
4. **Please use “diode emulation mode” as the battery charger**
5. Set the constant current setpoint (I_{LOAD}) of the load to 0.1 A
6. Set V_{IN} to 24 V and the current limit to 1 A
7. Turn on V_{IN} and check the output voltage
8. Rotate the trimmer R22 (V_{OUT} Adjust) so that V_{OUT} is 26 V
9. If the output voltage does not reach 26 V, then R30 is set to very low current; in this case rotate R30 until V_{OUT} increases. As V_{OUT} increases, then rotate R22 to reach 26 V
10. Now increase the current limit of the bench PSU Vin to 8 A
11. Change the electronic load into “constant voltage” and set the voltage at 24 V
12. At this point the output current is dependent on the position of R30, while V_{OUT} is fixed by the load to 24 V
13. Now rotate R30 until the output current is 2 A
14. Start measuring the standard parameters as desired, versus output current
15. **Please remember that if you are using this charger with a battery, the converter must be set in “diode emulation mode” by moving the jumper over J3 from pins 1-2 to 2-3; in this case keep the diode emulation mode always on**

2 Testing and Results

2.1 Efficiency Graph

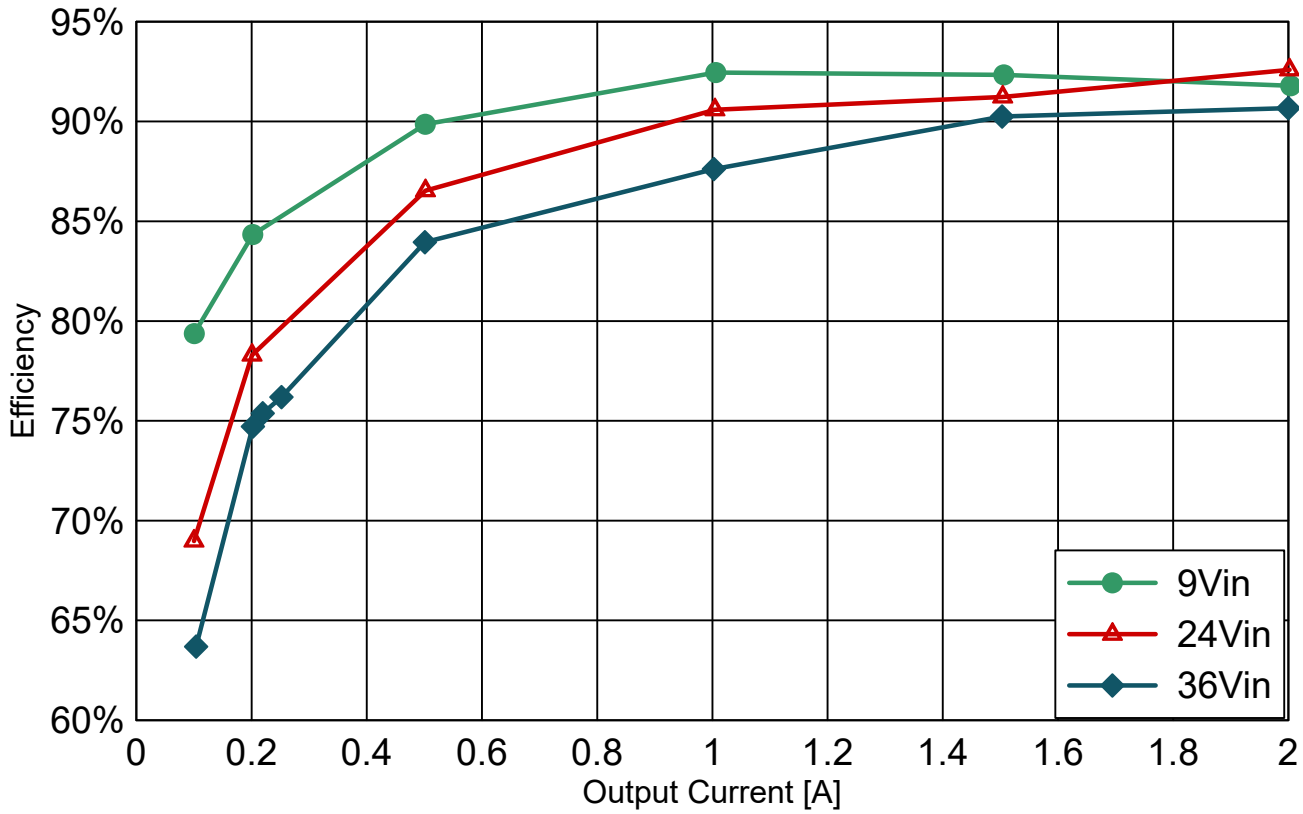


Figure 2-1. Efficiency Graph

2.2 Thermal Images

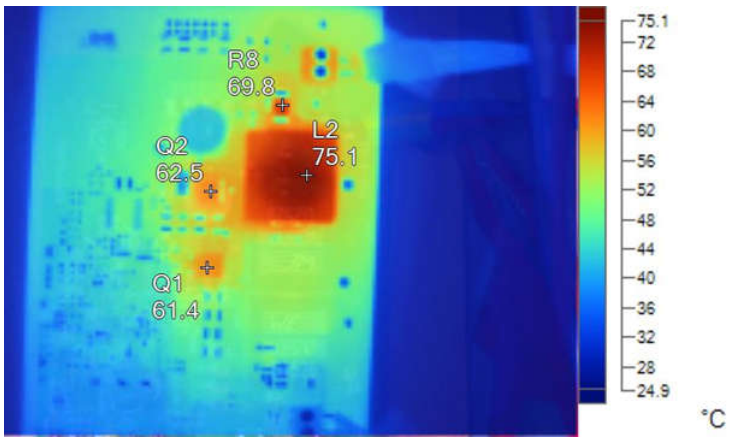


Figure 2-2. Thermal Image (9-V Input voltage, 24-V Output Voltage, 2-A Output Current)

Temperature Values

Name	Temperature
L2	75.1°C
Q1	61.4°C
Q2	62.5°C
R8	69.8°C

2.3 Bode Plots

2.3.1 Bode Plot With Battery

Three different bode plot measurements were taken. This first one refers to a connection of two 12-V valve regulated lead–acid (VRLA) batteries in series, model Yuasa NPH5-12 (12 V, 5 Ah).

2.3.1.1 Bode Plot With Battery During Recharging Phase (Constant Current)

For this measurement the battery did not reach the charge voltage; therefore, the SEPIC converter runs in constant-current mode. V_{IN} was set to 15 V, 18 V, and 26 V. Charge current is 1 A, while the battery voltage was 25 V. The line with dots in Figure 2-3 refers to V_{IN} = 24 V

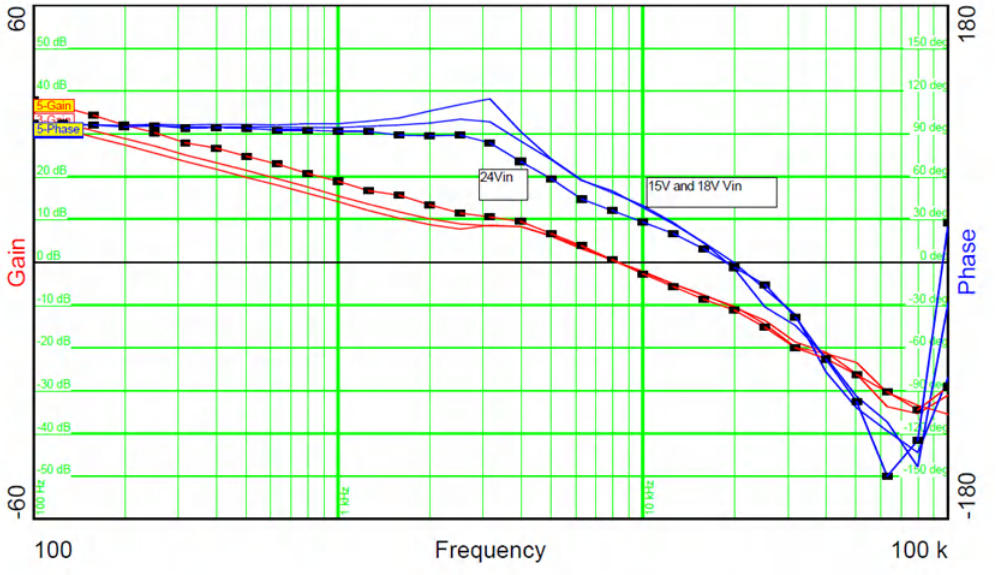


Figure 2-3. Bode Plot With Battery During Recharging Phase

2.3.1.2 Bode Plot With Battery at Constant Battery Voltage

Figure 2-4 shows where the battery reached the charge voltage set point; in this case the SEPIC converter runs in constant-voltage mode. V_{IN} was set to 24 V, V_{OUT} to 26 V (on the charger) and the charge current is 0.8 A

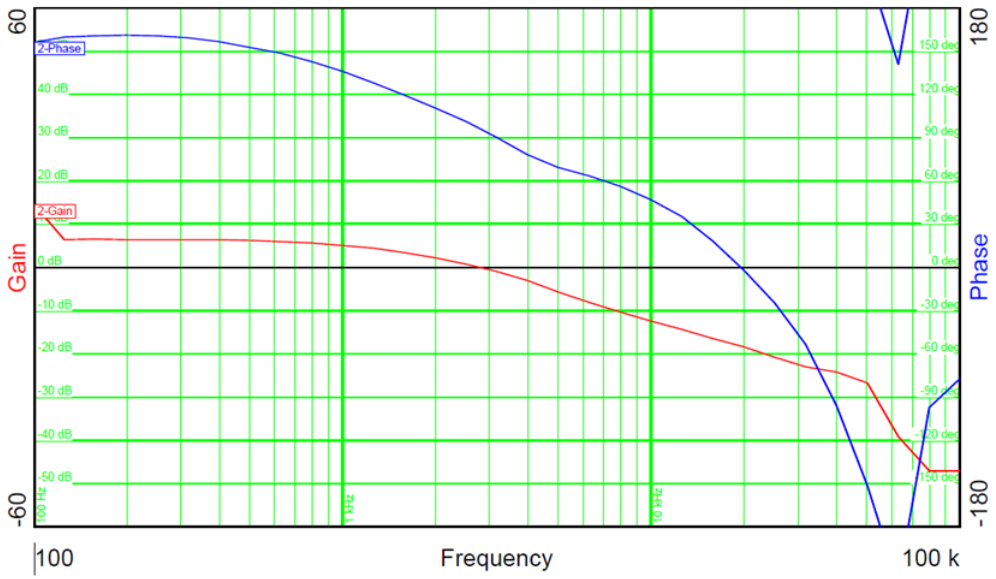


Figure 2-4. Bode Plot With Battery at Constant Battery Voltage

2.3.2 Bode Plot With Electronic Load

For this measurement the electronic load has been set to constant-current at 800 mA. Vin was set to 24 V_{IN} and V_{OUT} to 26 V (on the charger).

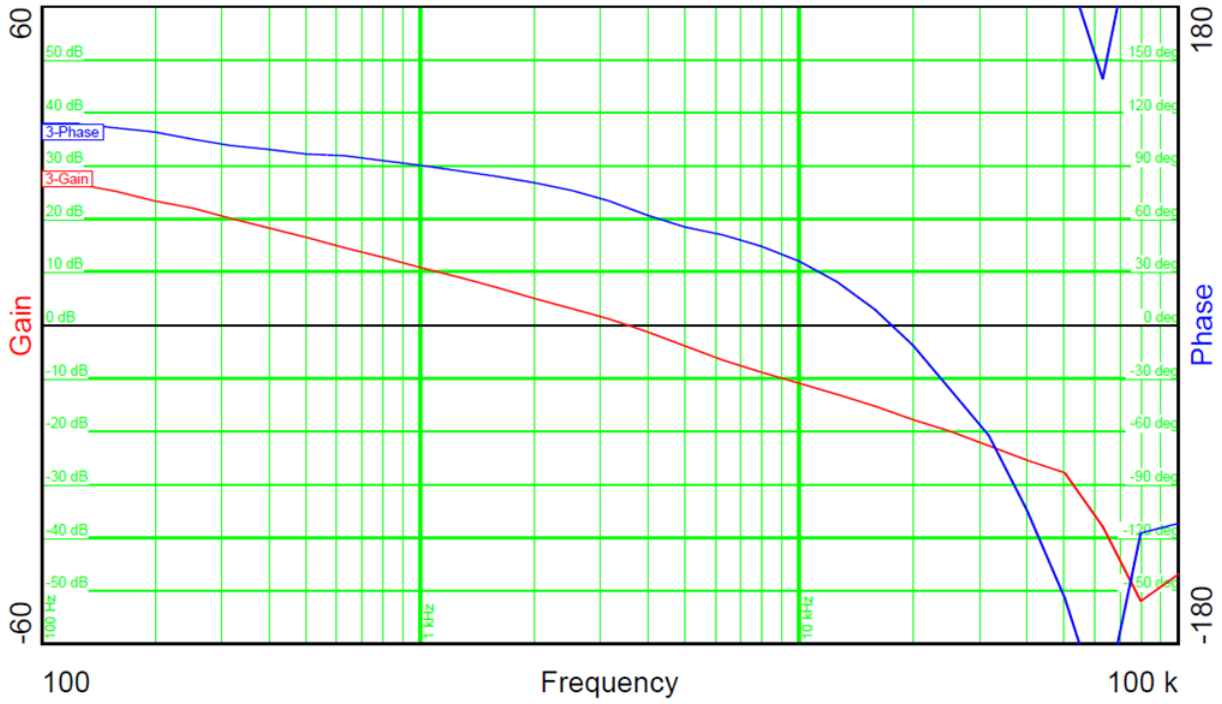


Figure 2-5. Bode Plot With Electronic Load

3 Waveforms

3.1 Switching

The measurements were done at 2-A output current and 24-V output voltage. The electronic load works in constant voltage mode.

3.1.1 Transistor Q2 Drain to Source

3.1.1.1 9-V Input Voltage

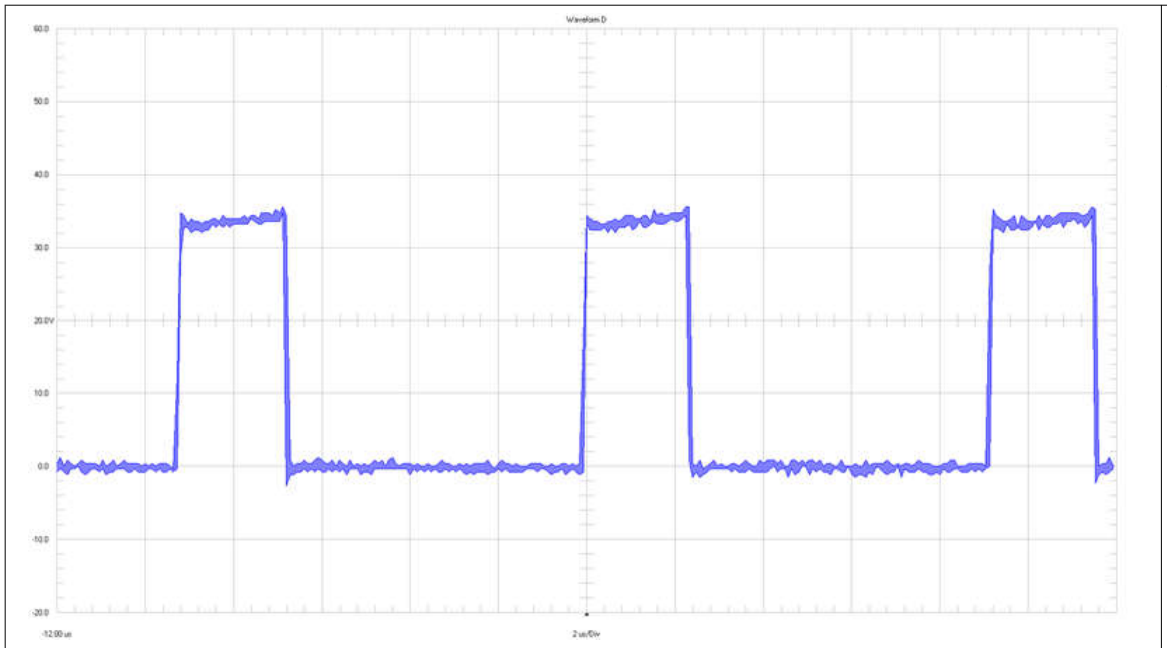


Figure 3-1. Switching Q2 at 9-V Input Voltage

3.1.1.2 36-V Input Voltage

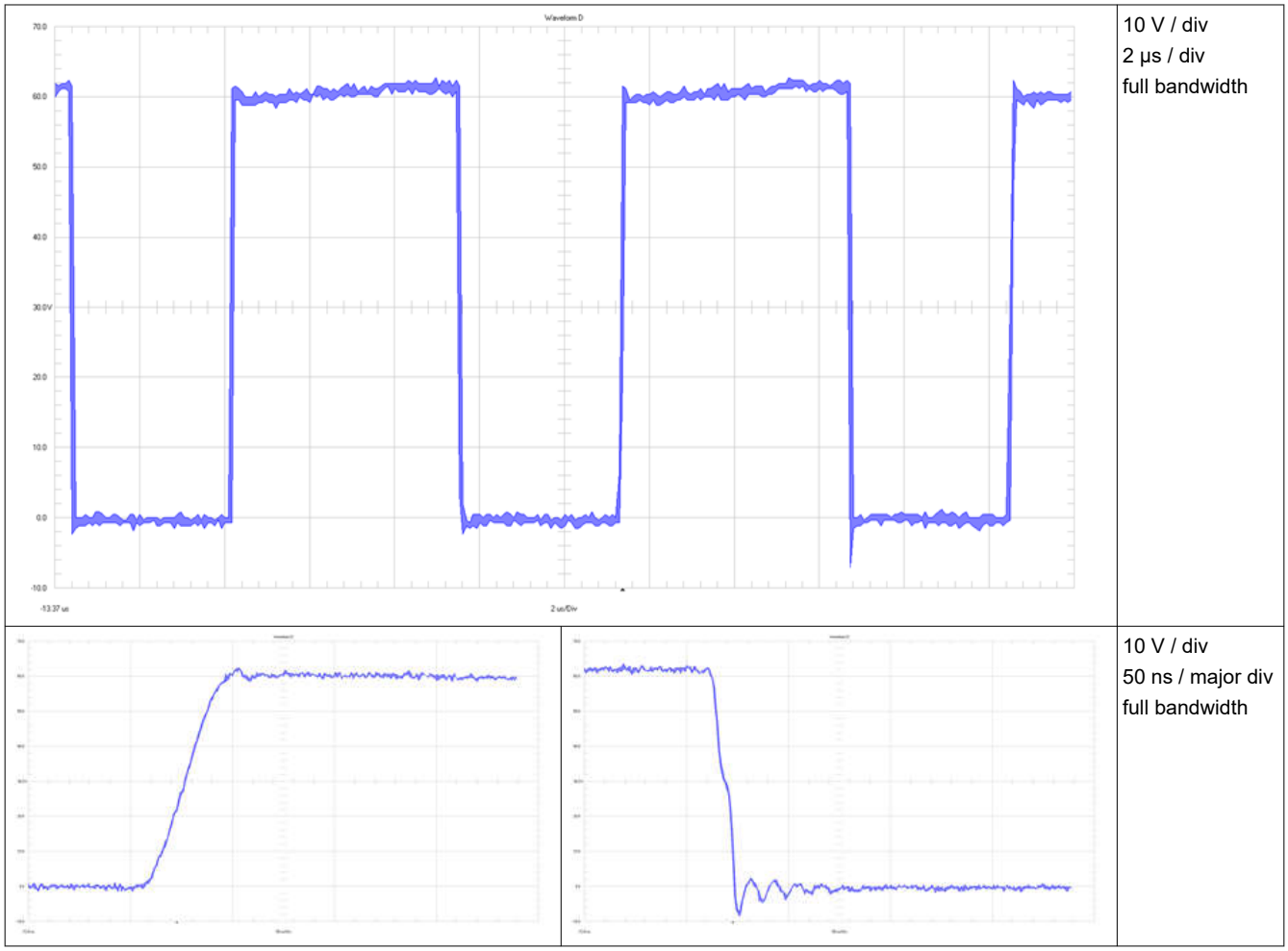


Figure 3-2. Switching Q2 at 36-V Input Voltage

3.1.2 Transistor Q1 Source to Drain

Note

On the falling edge the first overshoot is more than 80 V. The FET is rated for 80 V. Please introduce a snubber circuit or use a FET with a higher voltage rating.

3.1.2.1 9-V Input Voltage

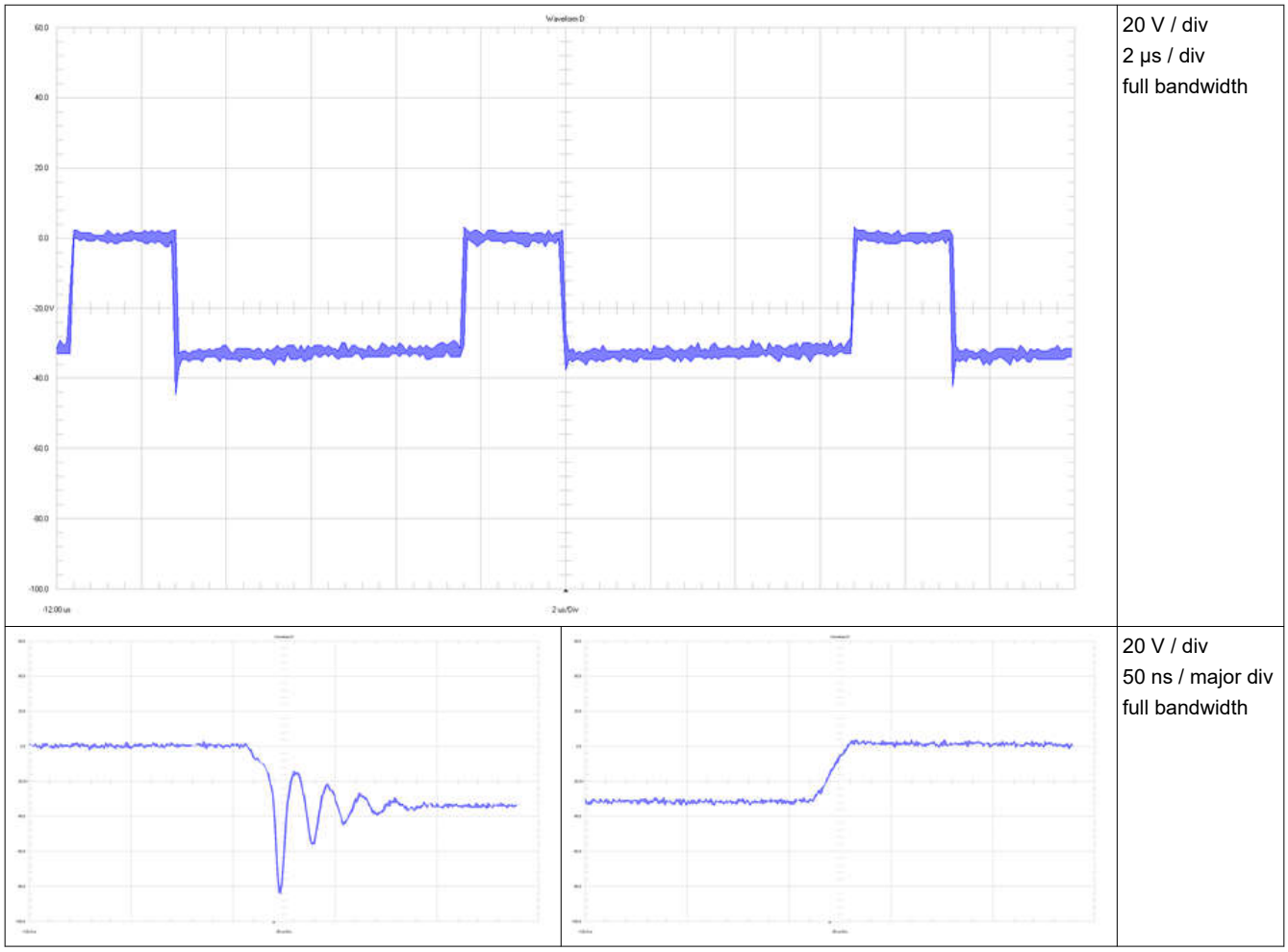


Figure 3-3. Switching Q1 at 9-V Input Voltage

3.1.2.2 36-V Input Voltage

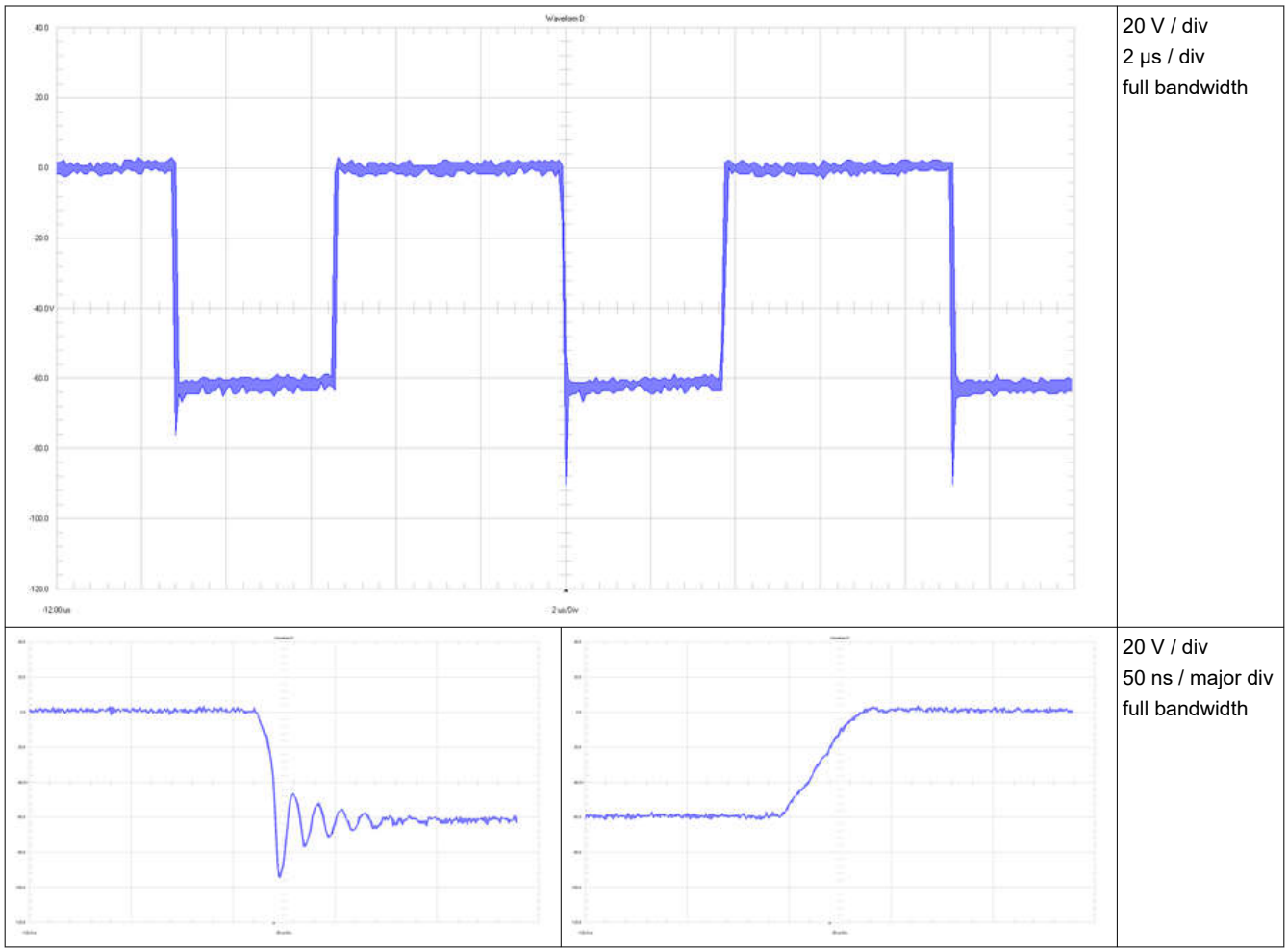
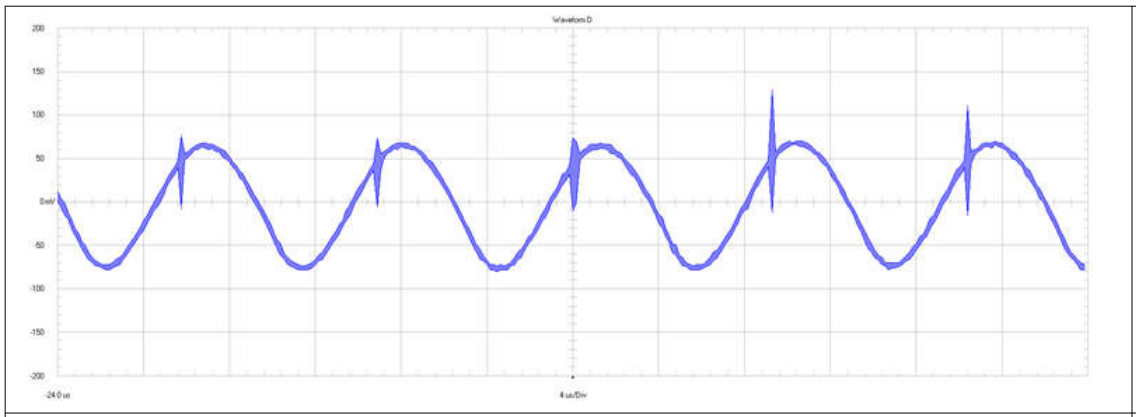


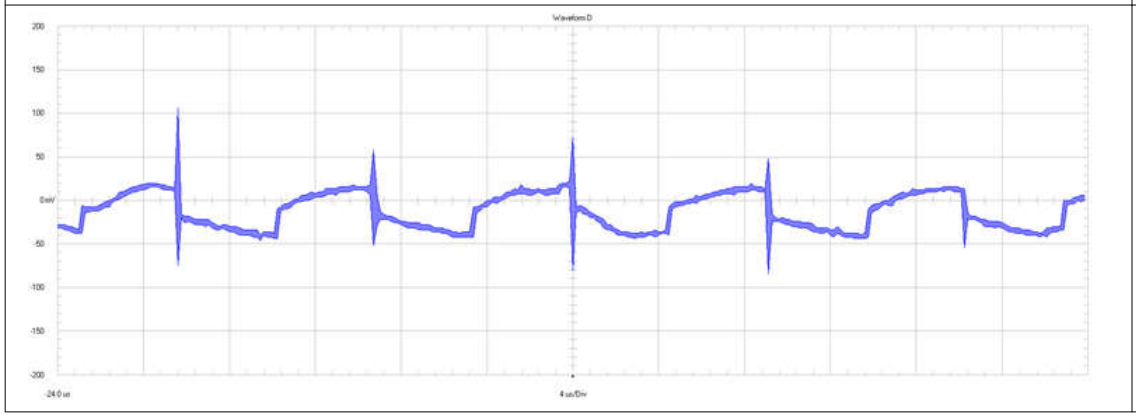
Figure 3-4. Switching Q1 at 36-V Input Voltage

3.2 Output Voltage Ripple



measured on J2

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



power stage output

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

Figure 3-5. Output Voltage Ripple

3.3 Load Transients

The electronic load operates in constant-current mode. The current is switched from 0.5 A to 1.5 A with a frequency of 25 Hz. The input voltage was set to 24 V.

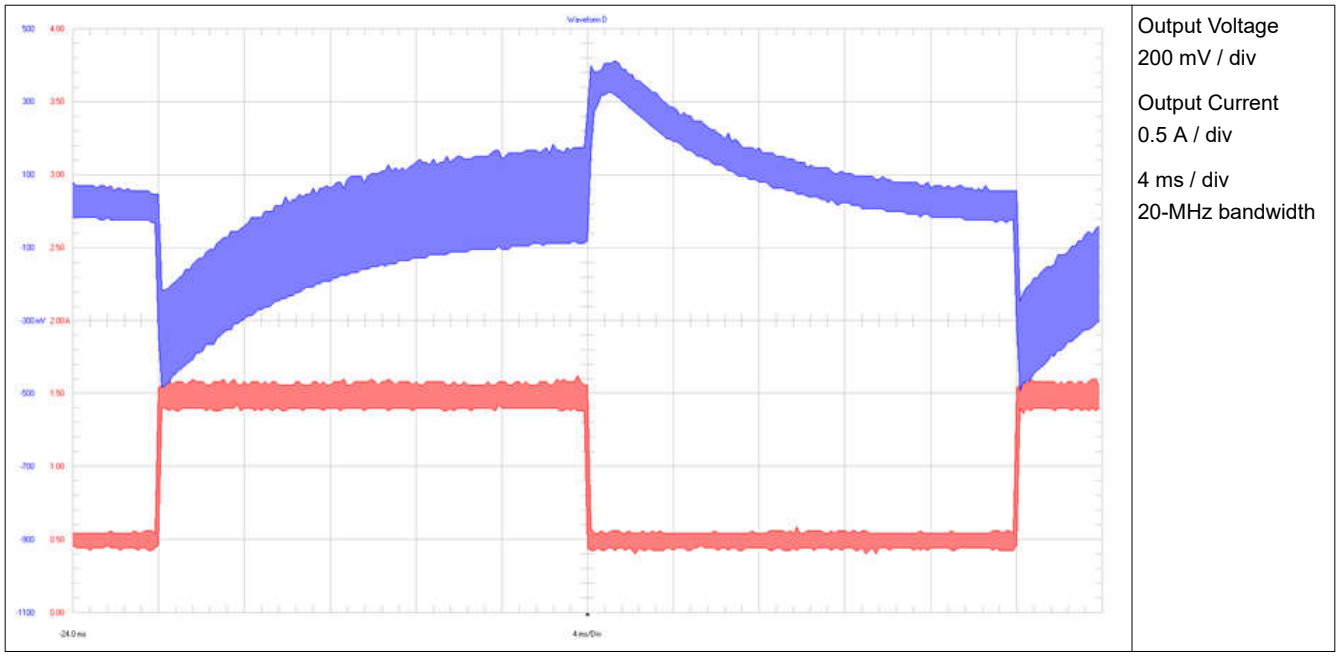


Figure 3-6. Load Transient 0.5 A to 1.5 A

3.4 Start-Up Sequence

Start-up behavior is shown in the following figure.

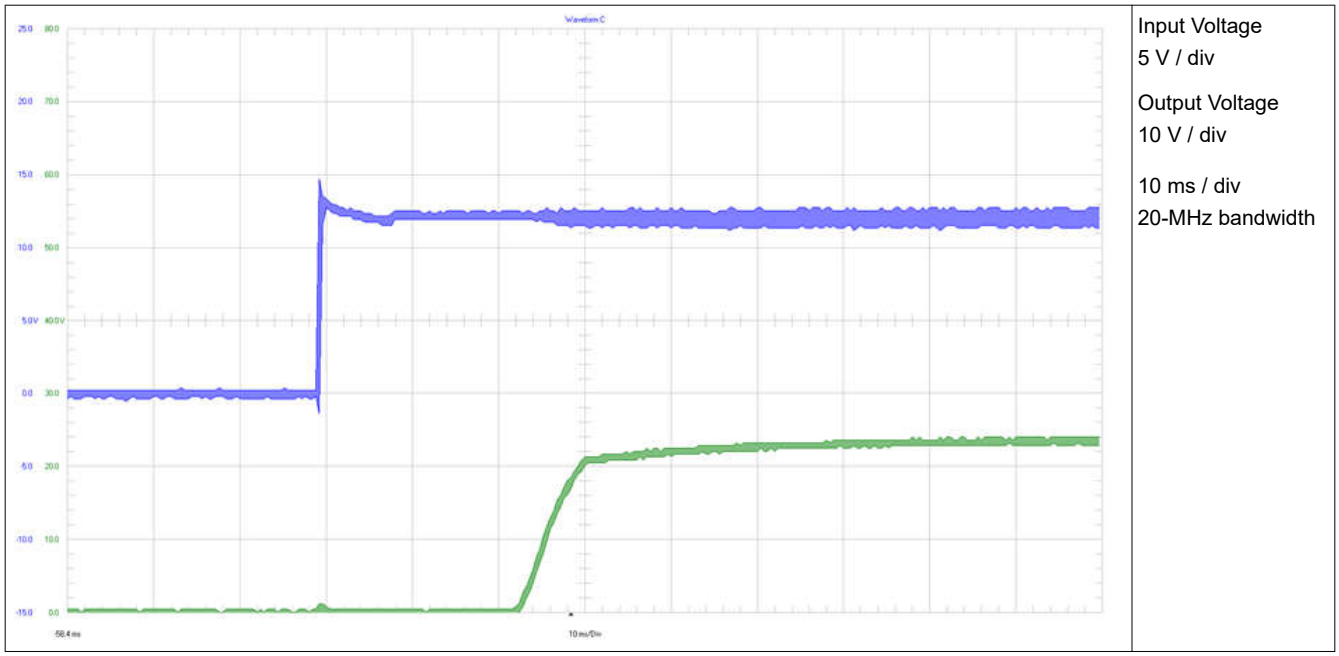


Figure 3-7. Start-up With 12-V Input Voltage

3.5 Shutdown Sequence

Shutdown behavior is shown in the following figure.

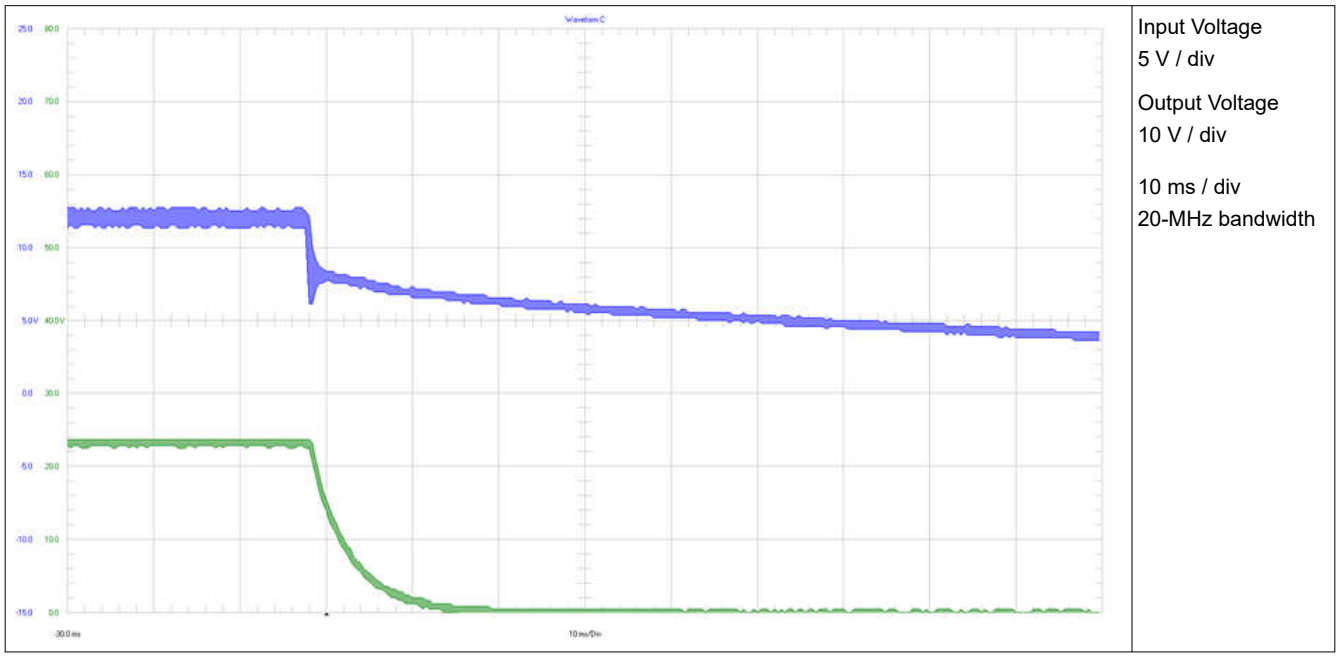


Figure 3-8. Shutdown With 12-V Input Voltage

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