Test Report: PMP23241

Synchronous Inverting Buck-Boost Converter With Adjustable Negative Output Voltage Reference Design

Description

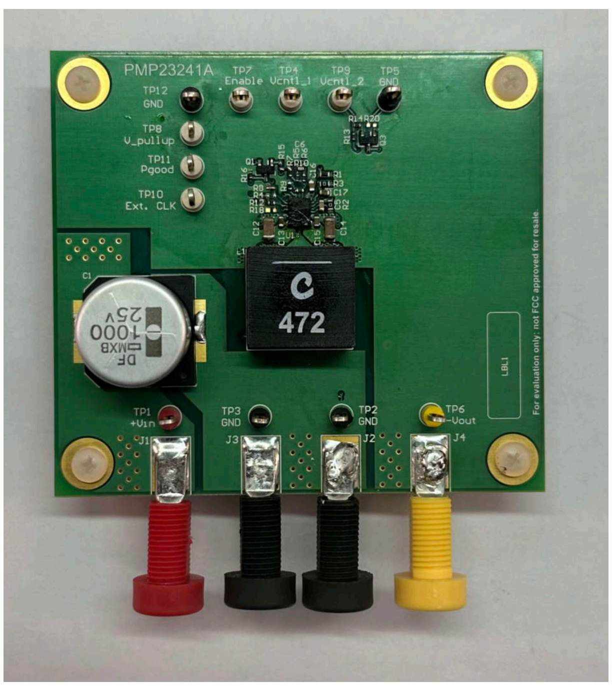
This reference design utilizes the LM61495-Q1 synchronous buck regulator. This device features internal top and bottom field-effect transistors (FET), which are configured as a synchronous inverting buck-boost converter to provide an adjustable output of between –7.5V and –12V capable of delivering a maximum of 4A of current to the load from a +9V to +18V input. The output voltage is adjusted by providing an analog voltage signal to the *Vcntl_1* (TP4) test point, referenced to GND. Control voltages between 0V and 5V correspond to output voltages between –12V and –7.5V, respectively.

Features

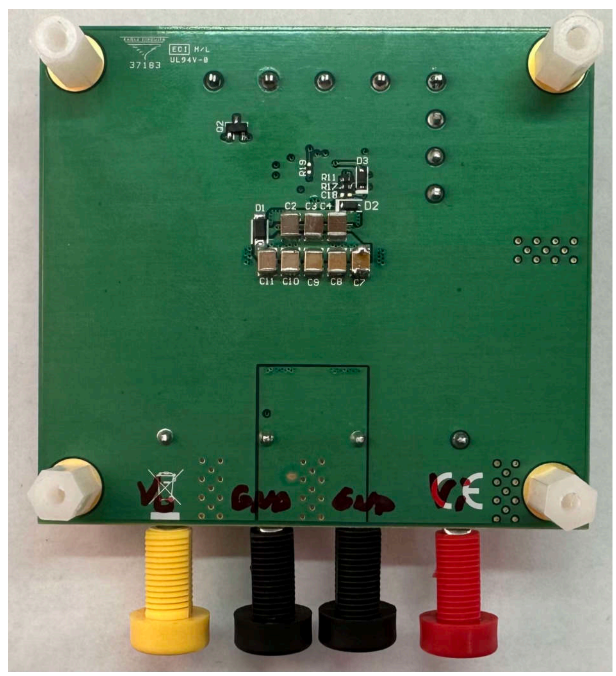
- Peak efficiency of 95% at $–12V_{OUT}$ and 2.2A load
- Switching frequency of 400kHz
- Regulator includes integrated FETs
- 4-layer board (1oz copper, each layer)
- Small design size: 17.0mm × 30.5mm (board size: 76.2mm × 68.6mm)
- Dithering feature improves EMI performance

Applications

- Automotive center information display
- Automotive cluster display
- Automotive display module
- Head-up display
- Active antenna system mMIMO (AAS)



Top of Board



Bottom of Board

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
V_{IN}	$9V_{DC}$ to $18V_{DC}$
V_{OUT}	$–7.5V_{DC}$ to $–12V_{DC}$ (adjustable)
I_{OUT}	4A, Maximum
F_{SW}	400kHz, Nominal

1.2 Required Equipment

- Power supply (capable of 9V to 18V output and greater than 7A)
- Auxiliary power supply (to adjust output voltage; 0V to 5V capable)
- Electronic load
- Digital multimeters
- Oscilloscope

1.3 Considerations

All voltage measurements were made relative to the 0V common GND. When taking measurements, make sure to connect the GND clips of the oscilloscope to the GND (that is, 0V) connection. Do not connect the oscilloscope GND clips to the $–V_{out}$ node. Though this $–V_{OUT}$ is the reference for the GND pins of the regulator IC, the output is no longer considered 0V common GND, but is a negative voltage relative to GND.

In the inverting buck-boost topology, the voltage potential between the V_{in} and GND pins of the converter or regulator is the sum of the magnitudes of V_{IN} and V_{OUT} voltages. For example, with the input voltage of +18V and the output voltage set to –12V, the total voltage potential exhibited by the LM61495-Q1 is:

$$|+18V| + |-12V| = 30V \tag{1}$$

The LM61495 has a maximum recommended supply voltage of 36V. Therefore, do not apply an input voltage greater than $24V_{IN}$ to the converter, preferably lower, to provide an extra buffer to accommodate for switching voltage spikes.

1.4 Dimensions

The board dimensions are 3.0 in × 2.7in (76.2mm × 68.58mm). The actual design size is approximately 0.67in × 1.17in (17mm × 29.7mm).

2 Testing and Results

2.1 Efficiency Graphs

Figure 2-1 shows the converter efficiency for a 12V input with –7.5V and –12V outputs with the output being swept from 0.4A to 4A.

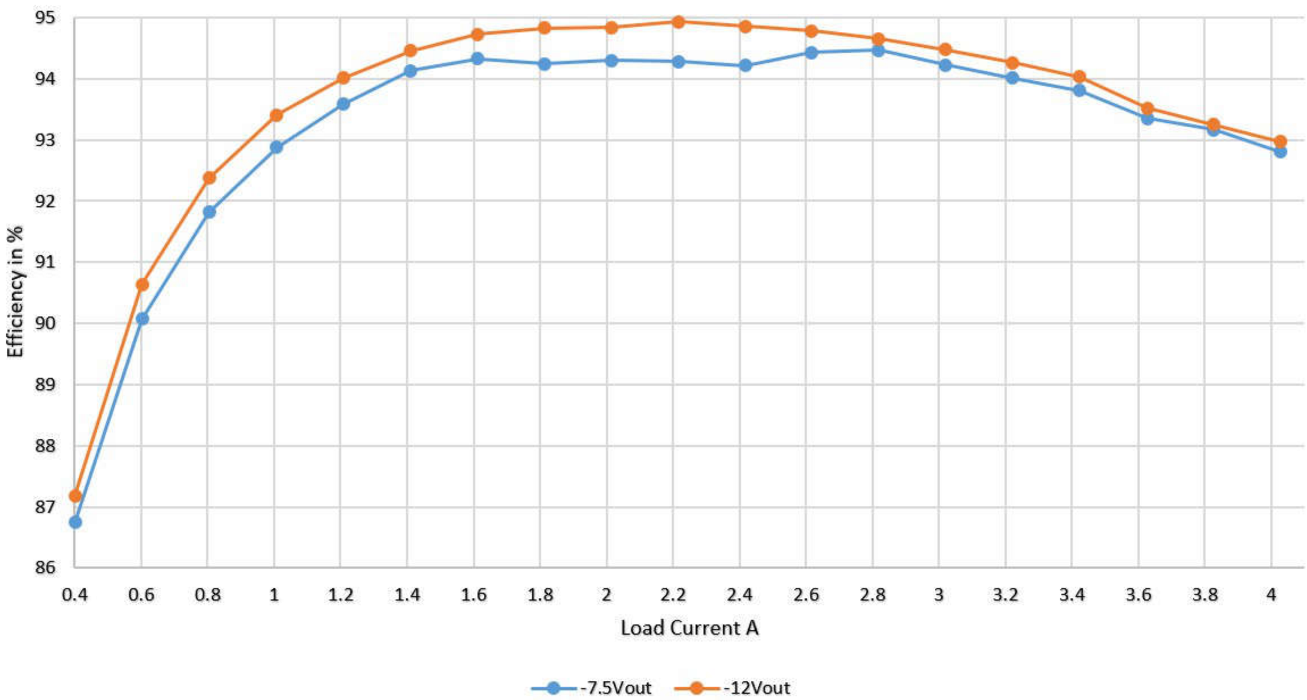


Figure 2-1. Converter Efficiency 12V Input, –7.5V and –12V Outputs

2.2 Thermal Images

The thermal images in Figure 2-2 and Figure 2-3 show operation at 12V input, –7.5V and –12V outputs, at 3A load, with no airflow. Thermals images were taken of both top and bottom side of the board and were captured after the board had reached thermal equilibrium.

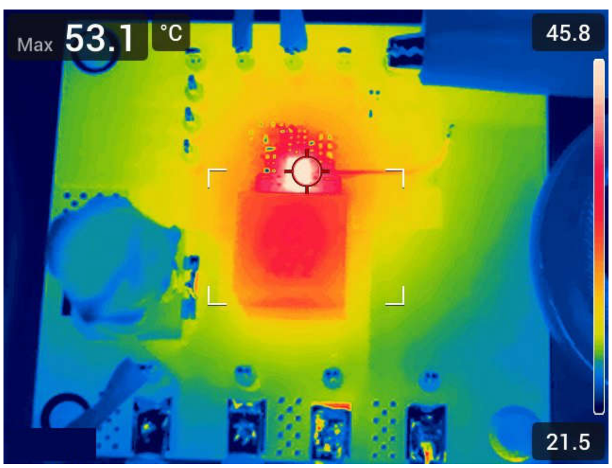


Figure 2-2. Thermal Image, 12V Input, –7.5V Output at 3A Load

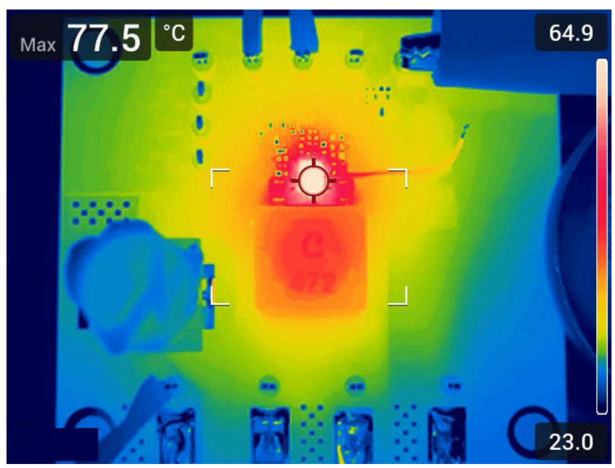


Figure 2-3. Thermal Image, 12V Input, –12V Output at 3A Load

2.3 Bode Plots

The following Bode plots were captured with a 12V input.

The Bode plots in Figure 2-4 and Figure 2-5 were created at a 4A load with Figure 2-4 having a –7.5V output and Figure 2-5 having a –12V output. The Bode plots were constructed via a combination of the output impedance with the loop open and closed.

The –7.5V output at 4A load Bode plot results in a gain margin of 17dB, a phase margin of 50°, and a crossover of 20kHz. The –12V output at 4A load Bode plot results in a gain margin of 13dB, a phase margin of 49°, and a crossover of 19kHz.

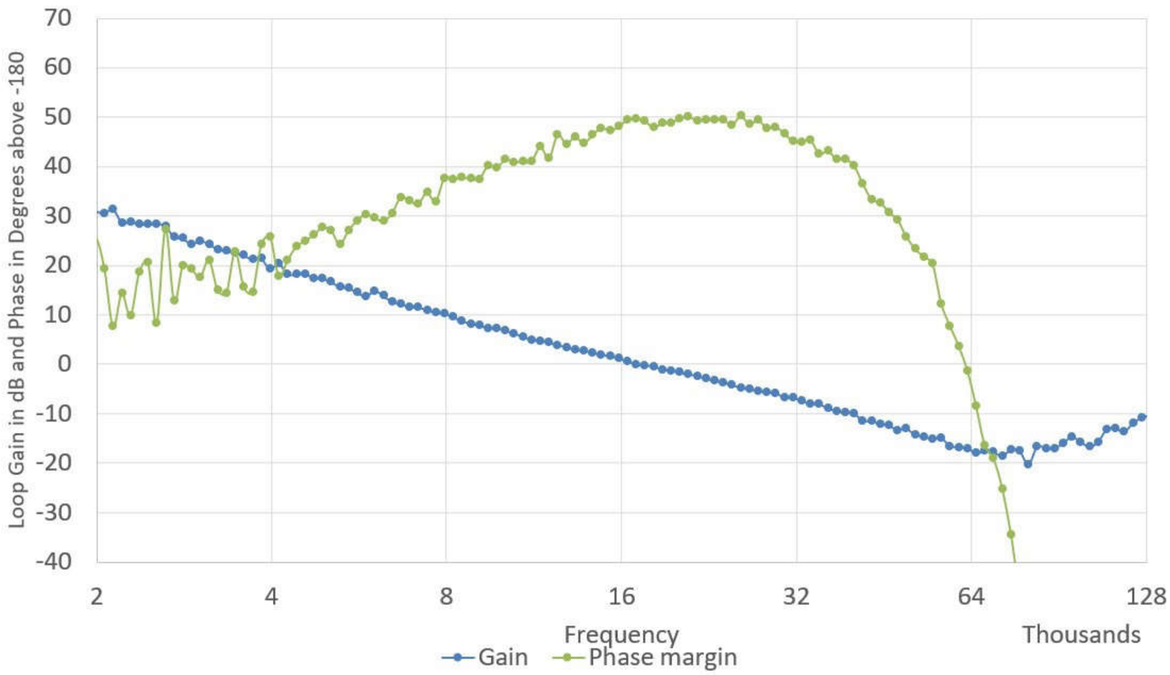


Figure 2-4. Bode Plot, 12V input, –7.5V Output, 4A Load

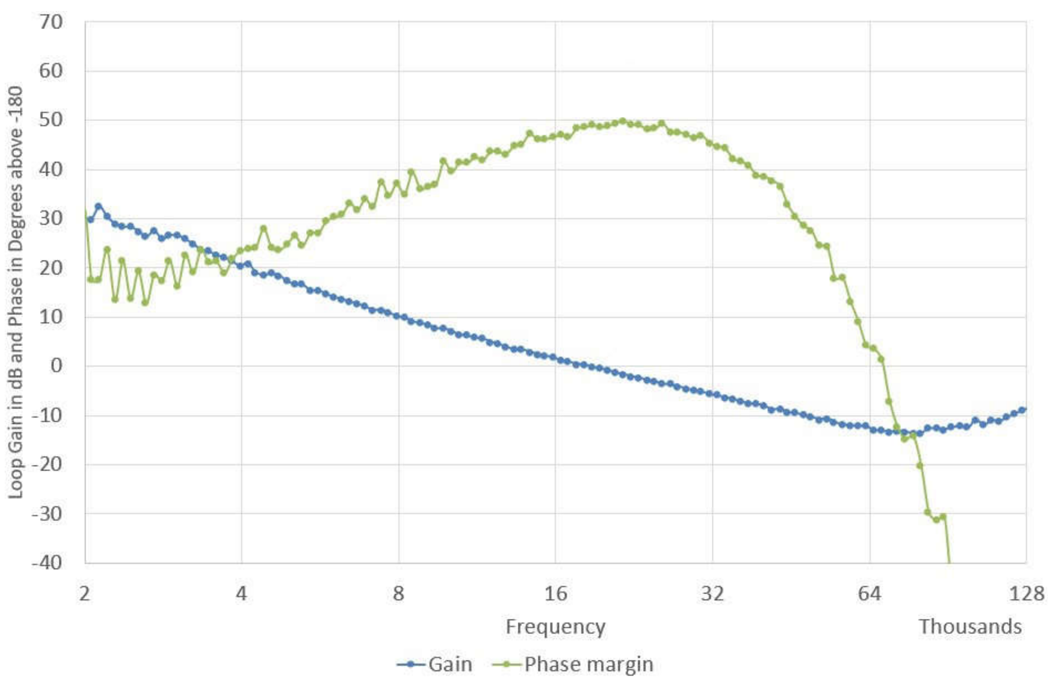


Figure 2-5. Bode Plot, 12V input, –12V Output, 4A Load

3 Waveforms

3.1 Switching

Figure 3-1 through Figure 3-4 show the switch node voltage waveforms of the converter at 12V input and –7.5V and –12V output at no load and 4A load conditions.

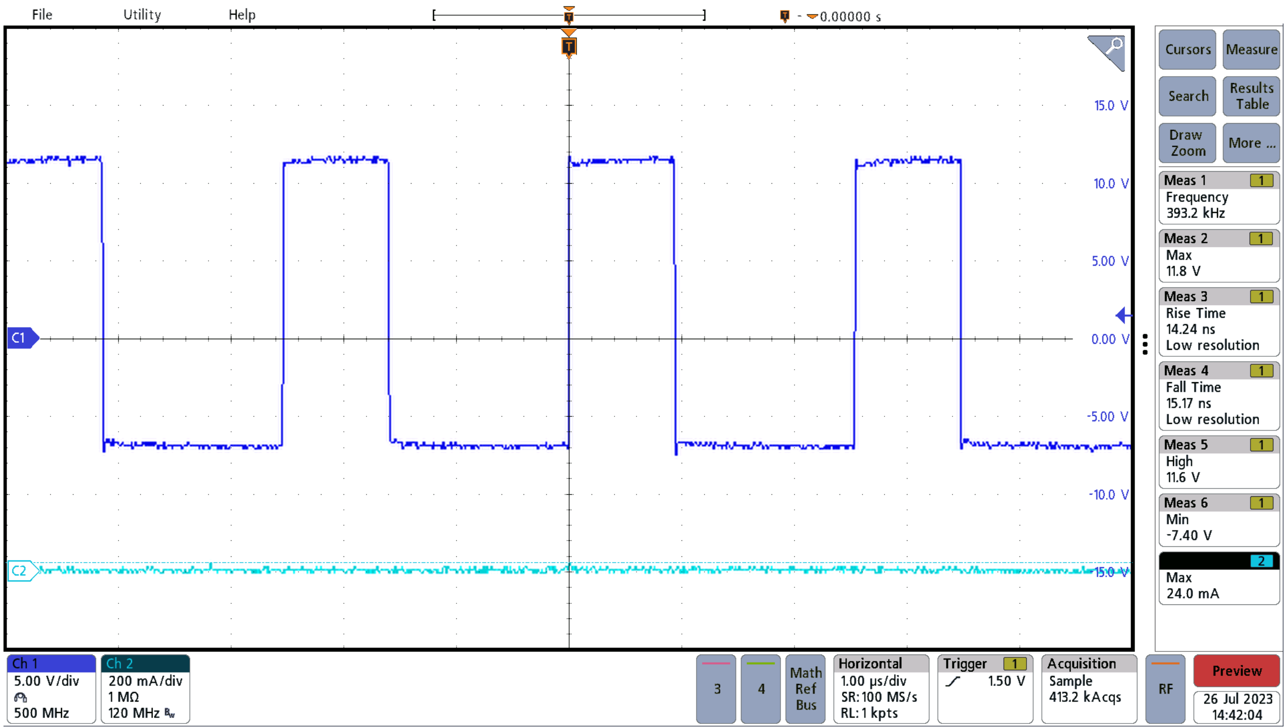


Figure 3-1. Switch Node Voltage, 12V Input, –7.5V Output, No Load

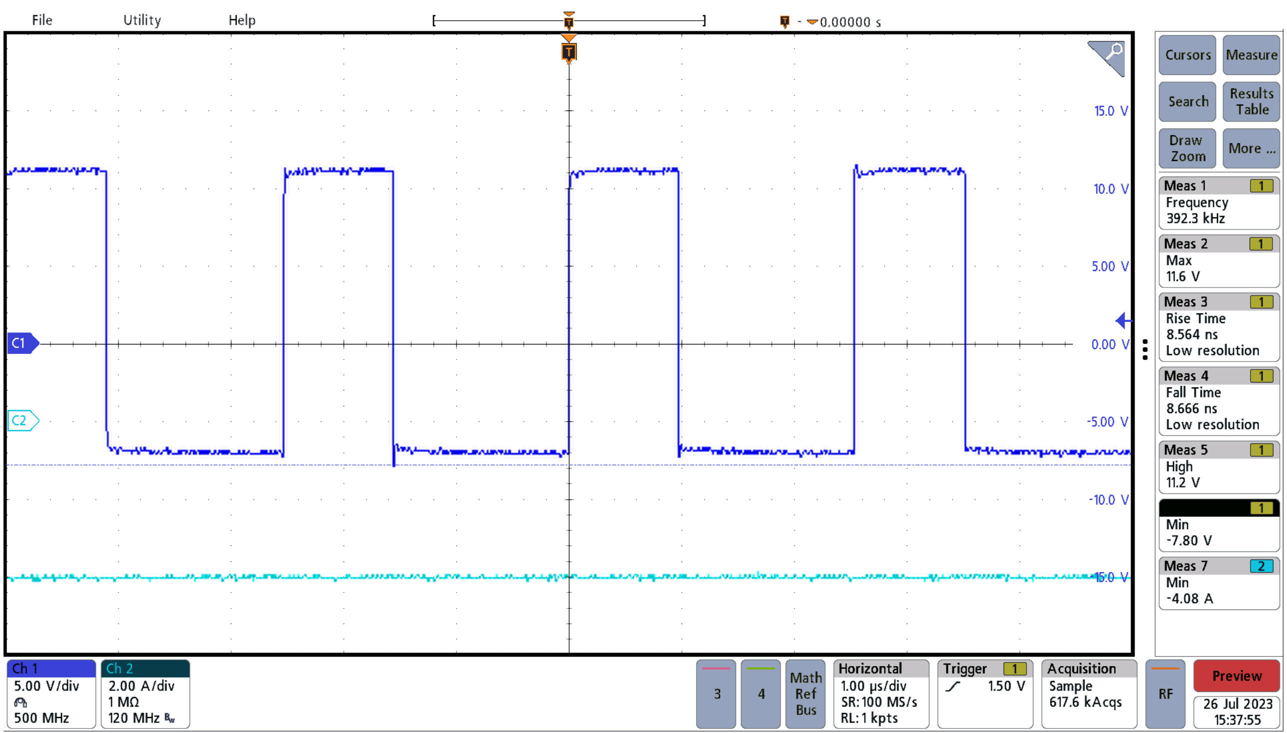


Figure 3-2. Switch Node Voltage, 12V Input, –7.5V Output, 4A Load

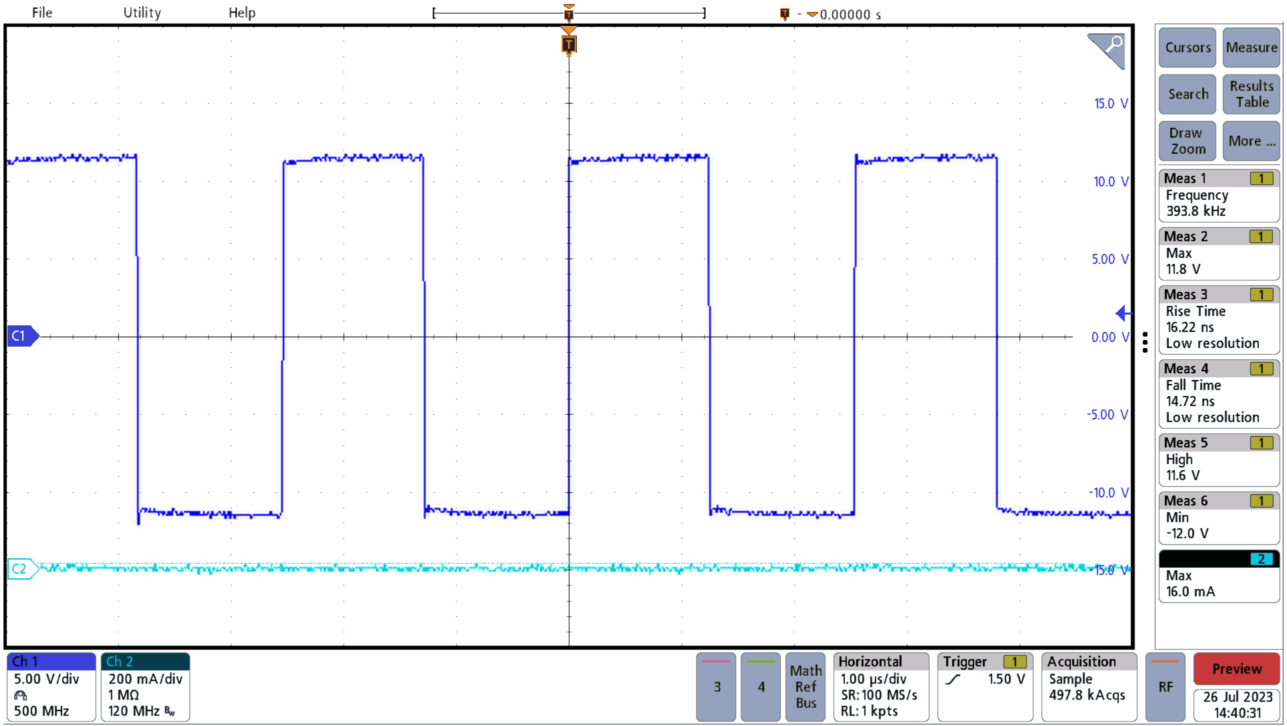


Figure 3-3. Switch Node Voltage, 12V Input, –12V Output, No Load

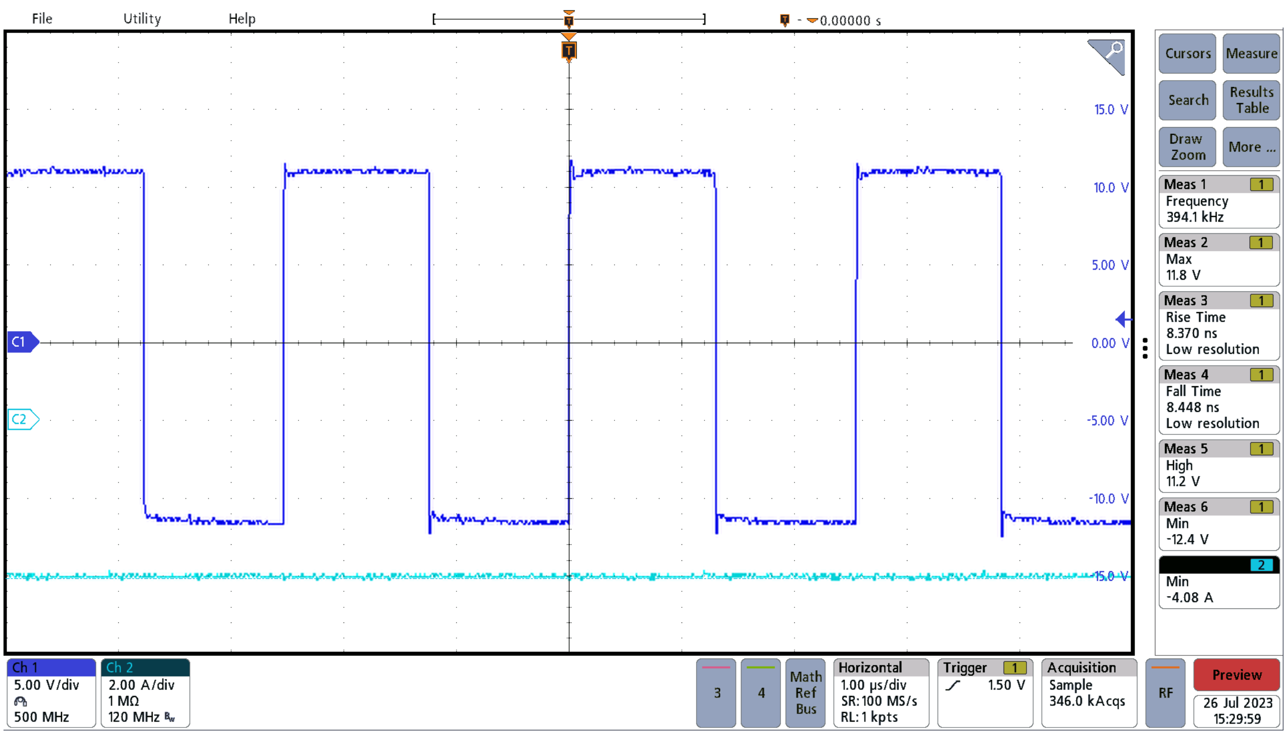


Figure 3-4. Switch Node Voltage, 12V Input, –12V Output, 4A Load

3.2 Output Voltage Ripple

Figure 3-5 to Figure 3-8 show the output voltage ripple waveforms. The images are taken at 12V input, –7.5V and –12V outputs, both at no load and 4A load conditions.

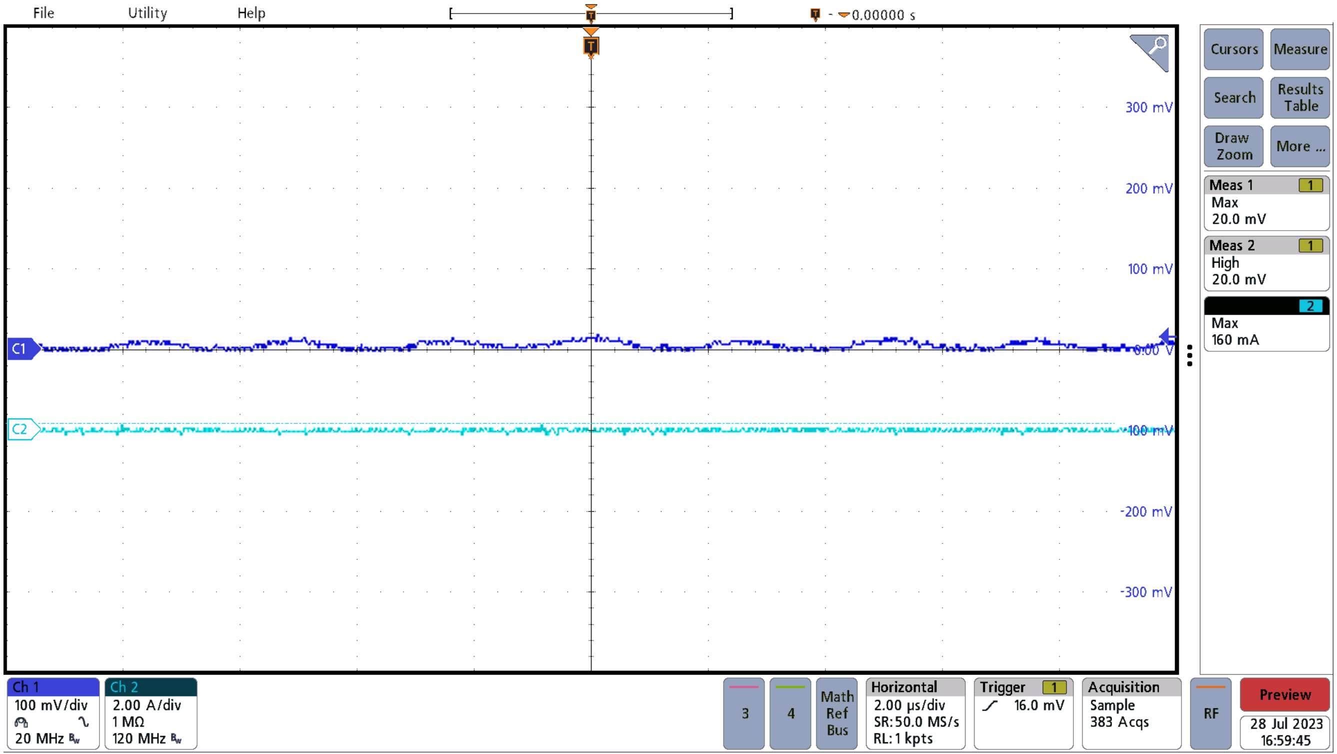


Figure 3-5. Output Ripple Voltage, 12V Input, –7.5V Output, No Load

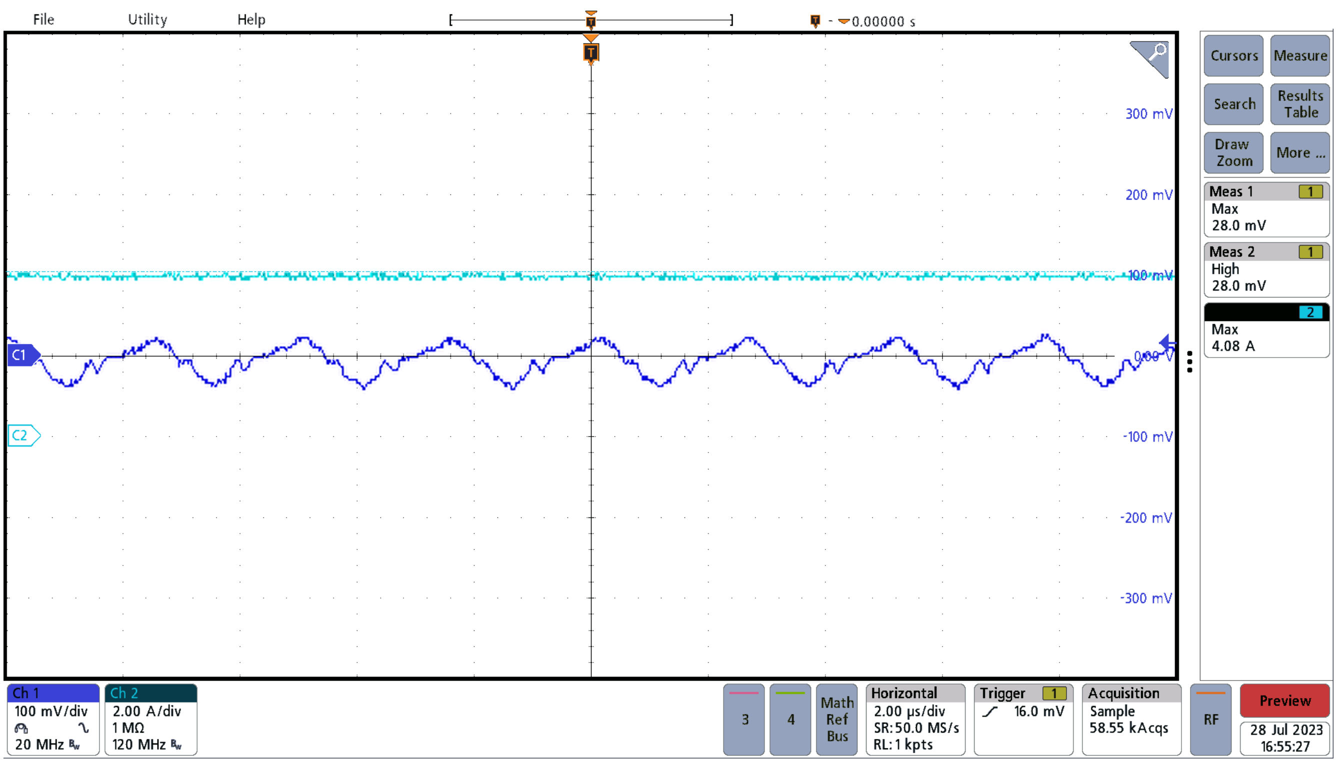


Figure 3-6. Output Ripple Voltage, 12V Input, –7.5V Output, 4A Load

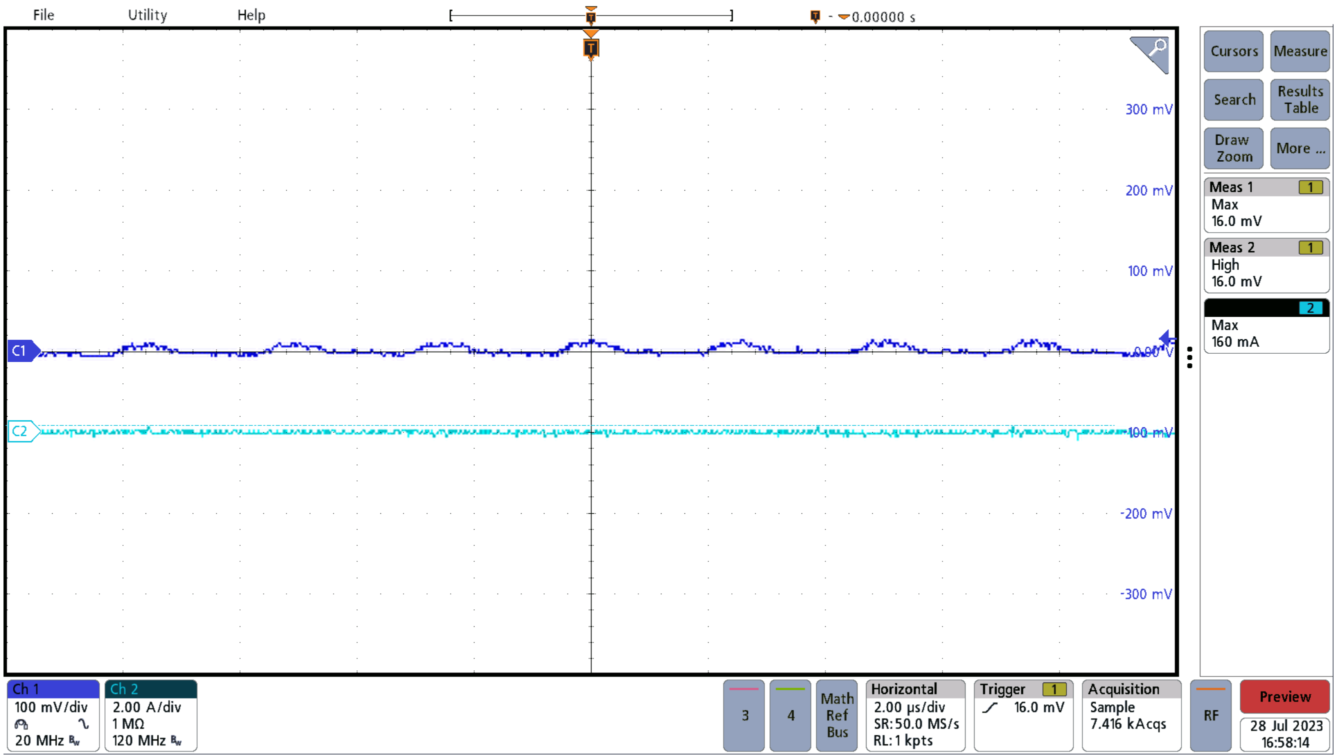


Figure 3-7. Output Ripple Voltage, 12V Input, –12V Output, No Load

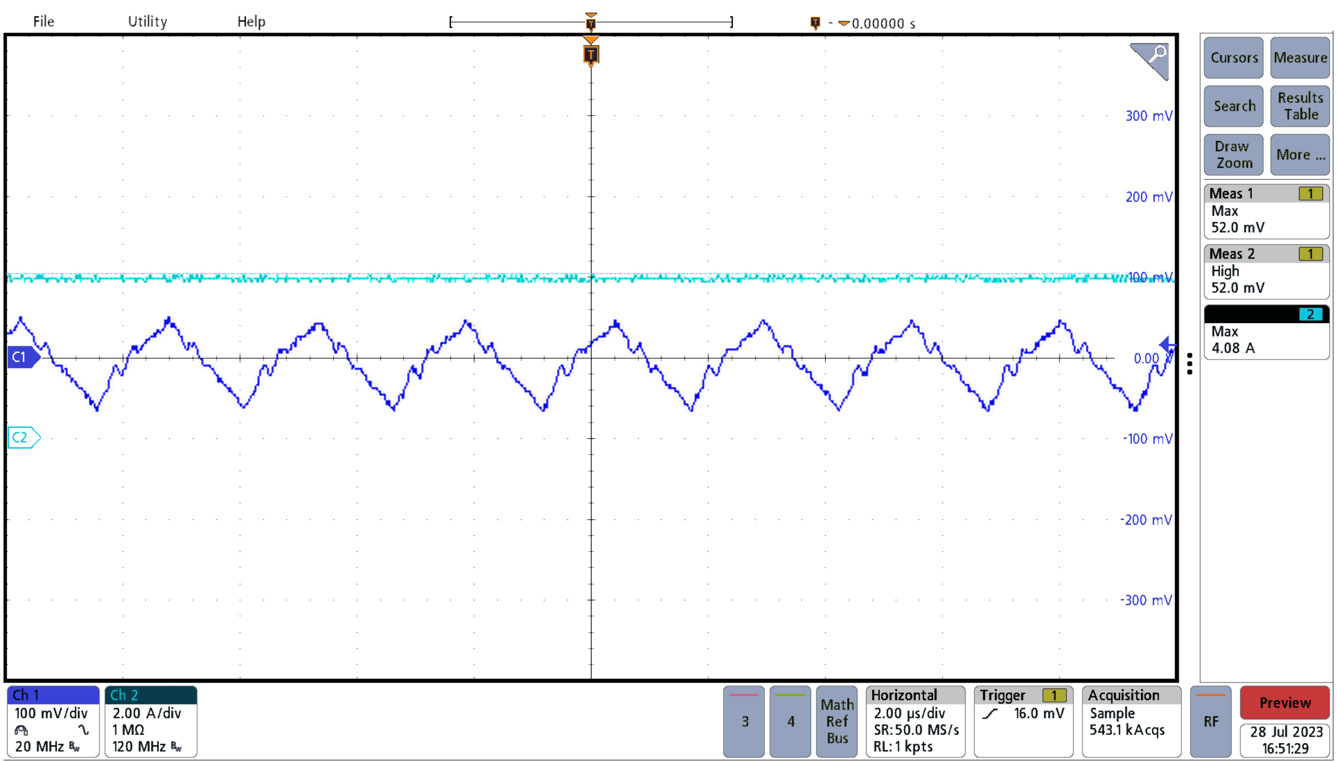


Figure 3-8. Output Ripple Voltage, 12V Input, –12V Output, 4A Load

3.3 Load Transients

Figure 3-9 and Figure 3-10 show the load transient response of the converter at 12V input and –7.5V and –12V outputs. The load is stepped from 50% to 100% of the load, corresponding to a 2A to 4A step.

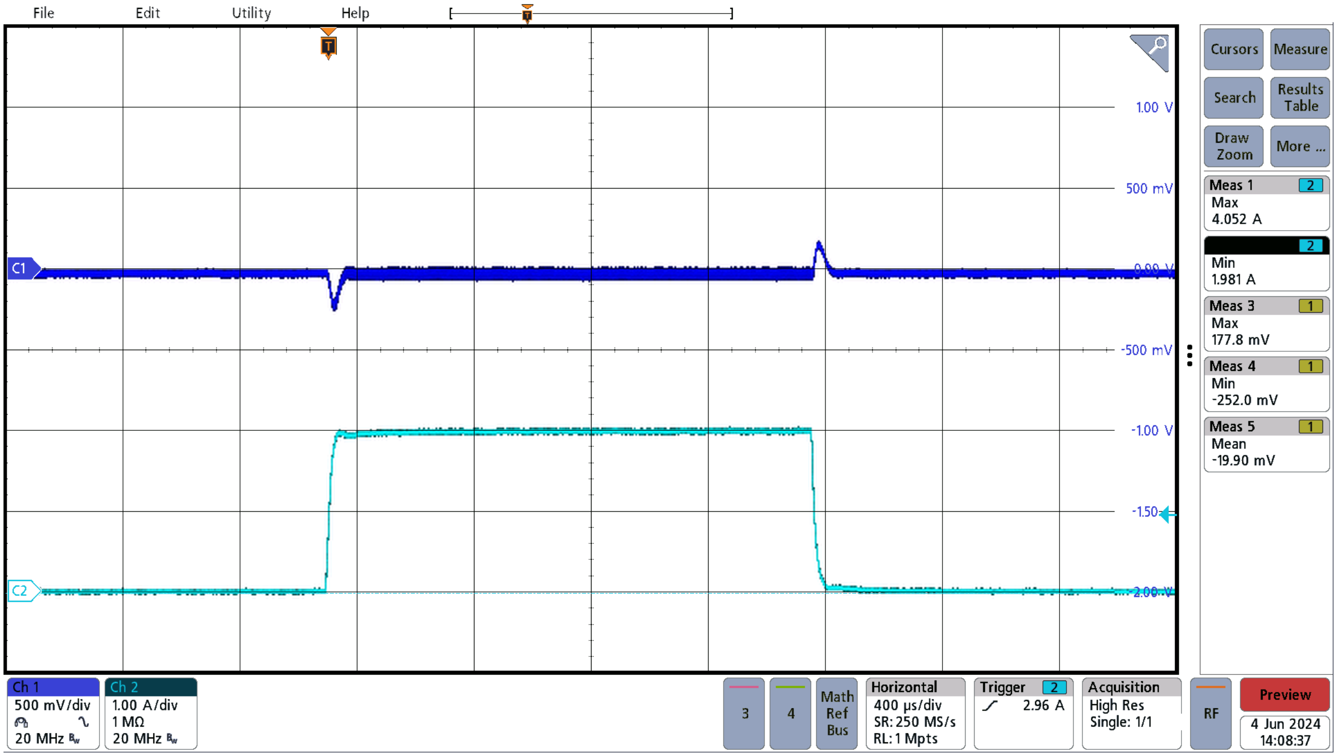


Figure 3-9. Load Transient Response, 12V Input, –7.5V Output, 2A to 4A Load Step

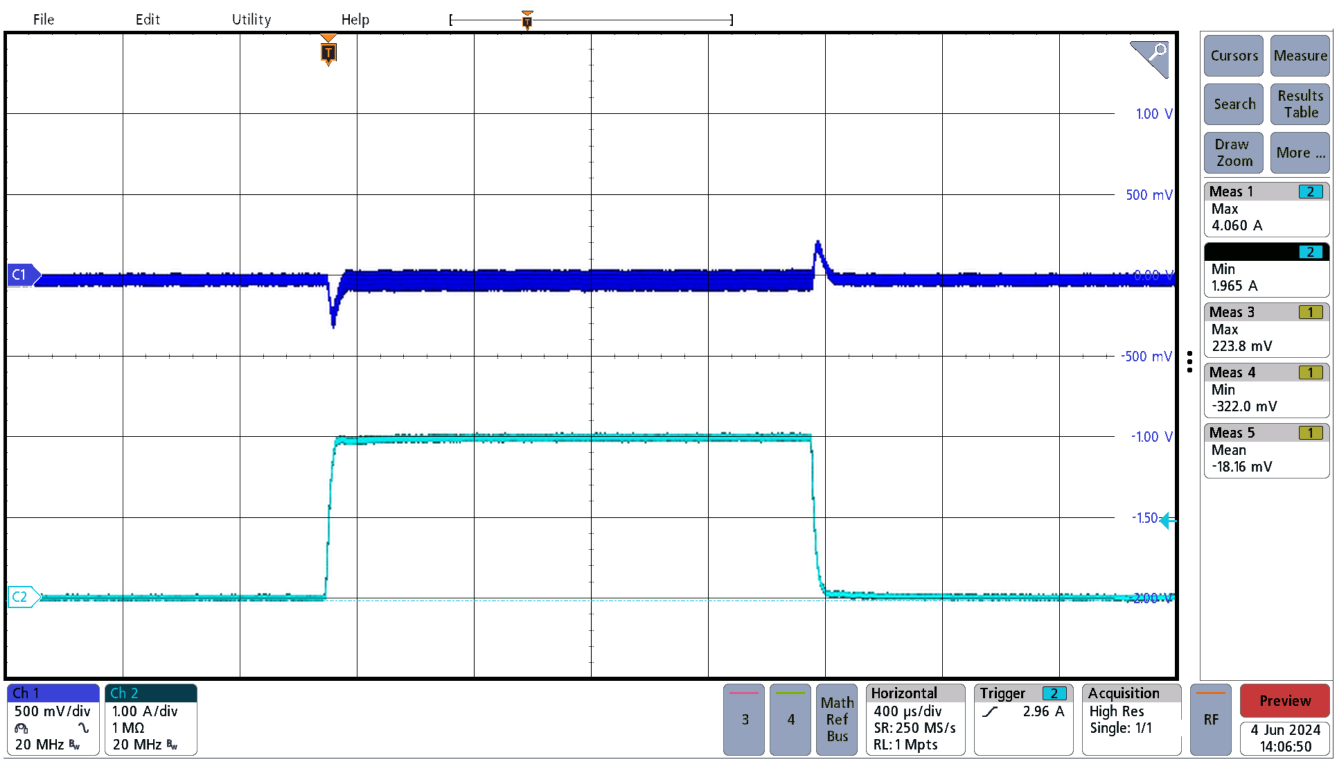


Figure 3-10. Load Transient Response, 12V Input, –12V Output, 2A to 4A Load Step

3.4 Start-Up Sequence

Figure 3-11 to Figure 3-14 show the output voltage start-up waveforms at 12V input and –7.5V and –12V output with the converter starting up into no load and into 4A constant-current load using the electronic load. The board *Enable* is pulled *high*, by connecting *Enable* to *+Vin*, applying the Vcntl voltage corresponding to the desired output voltage, then turning the benchtop power supply *on*.

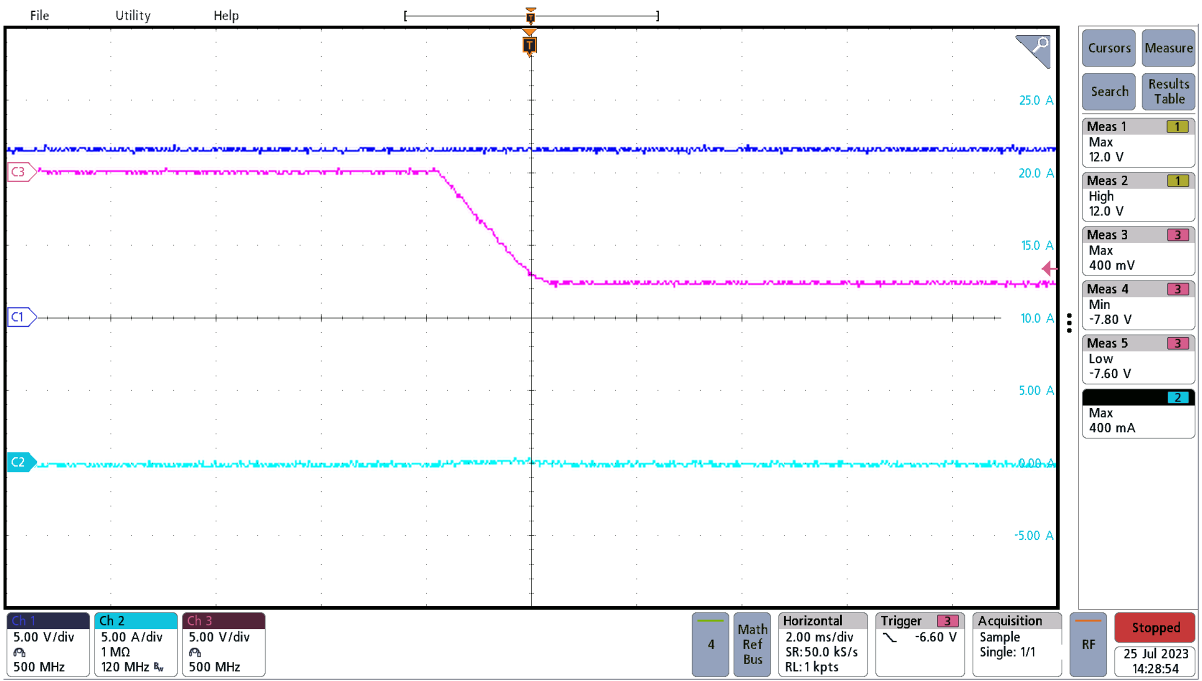


Figure 3-11. Start-Up Into No Load, 12V Input, –7.5V Output, Start-Up Initiated Through Input Supply Power-Up (Enable Signal Already set High by Connecting to +V_{IN})

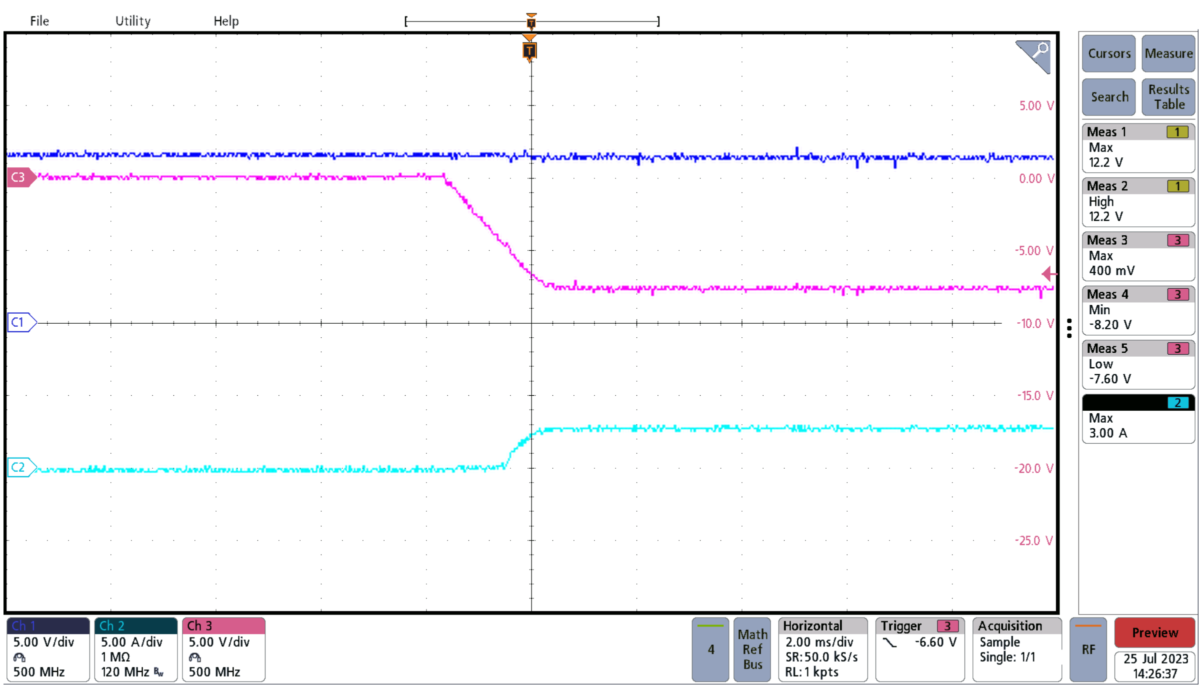


Figure 3-12. Start-Up Into 4A Load, 12V Input, –7.5V Output, Start-Up Initiated Through Input Supply Power-Up (Enable Signal Already set High by Connecting to +V_{IN})

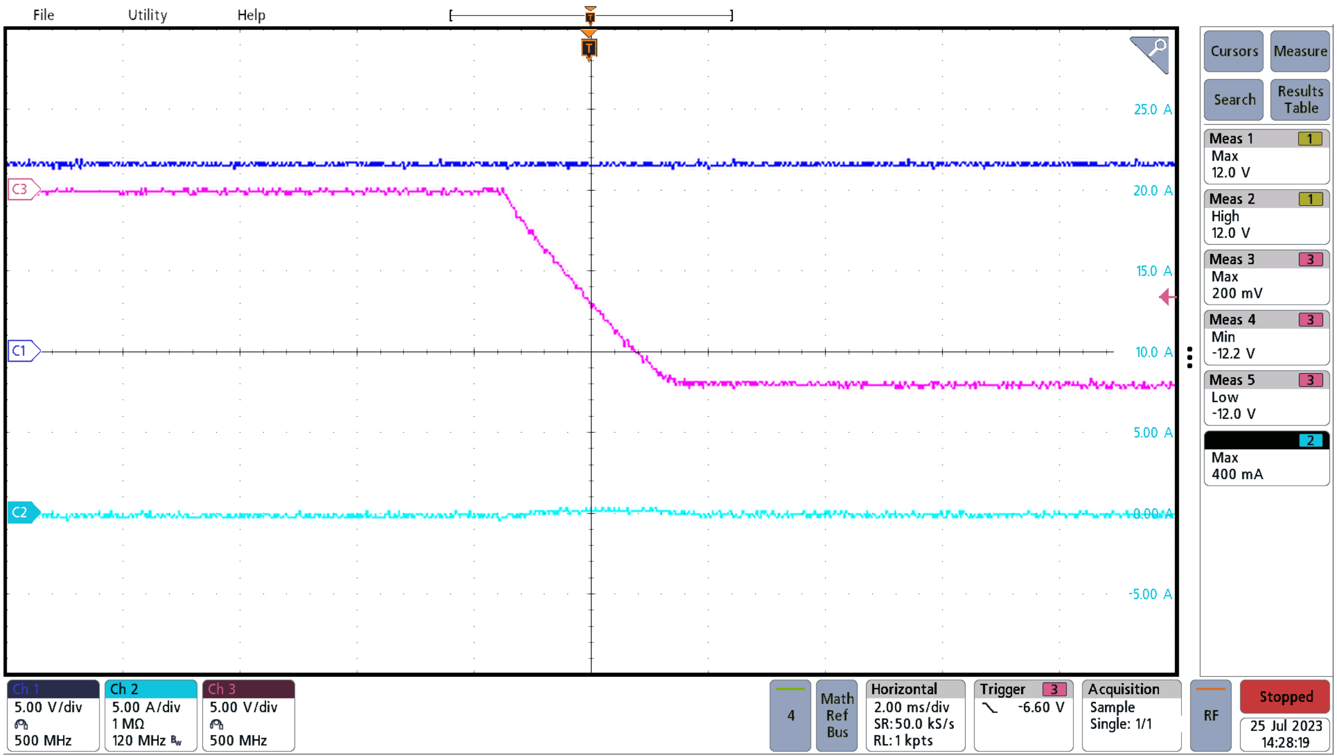


Figure 3-13. Start-Up Into No Load, 12V Input, –12V Output, Start-Up Initiated Through Input Supply Power-Up (Enable Signal Already set High by Connecting to +V_{IN})

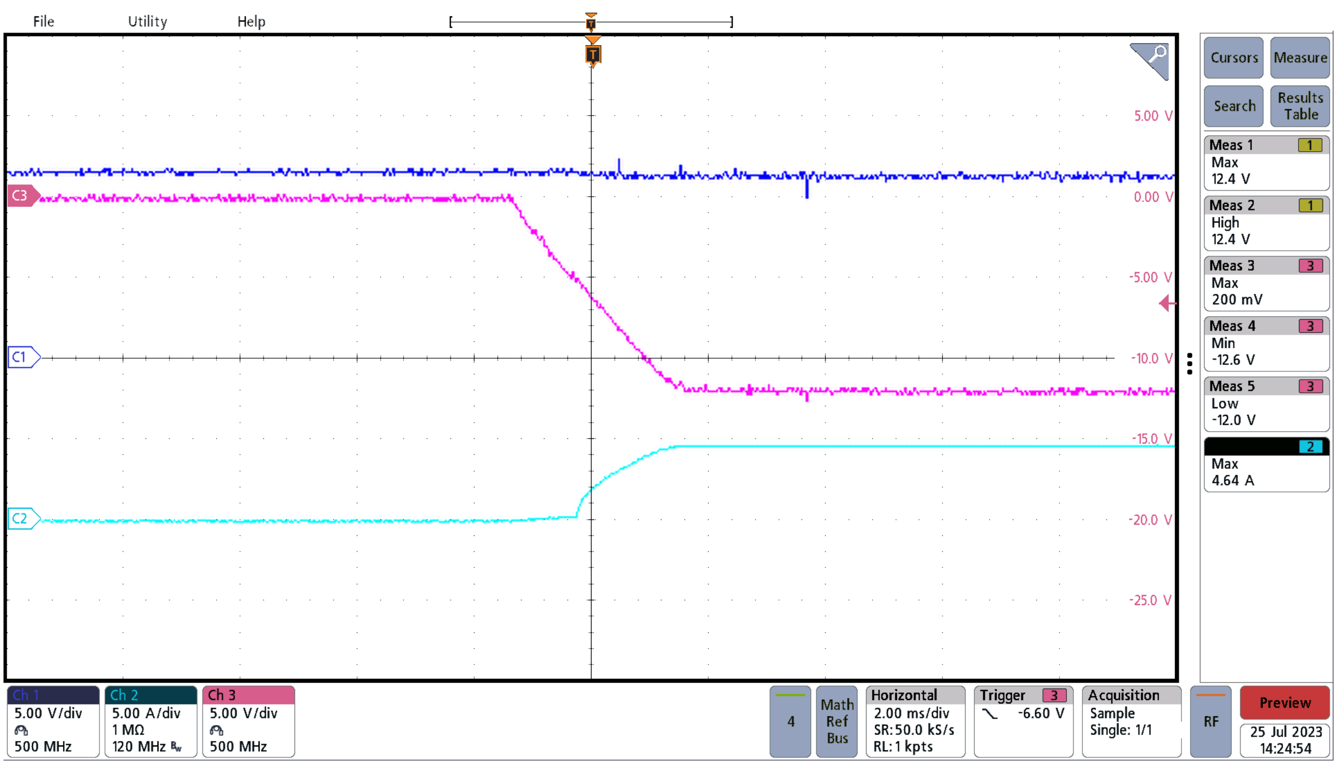


Figure 3-14. Start-Up Into 4A Load, 12V Input, –12V Output, Start-Up Initiated Through Input Supply Power-Up (Enable Signal Already set High by Connecting to +V_{IN})

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