Test Report: PMP31253

3-Phase Non-Isolated High-Side Buck Controller Reference Design

Description

This reference design is an 3-phase input offline high-side buck controller power supply that provides an 12-V output at a maximum of 1 A. The input accepts a voltage range of 43 V_{AC} to 255 V_{AC} per phase. The reference design uses the UCC28C55 low-power current-mode PWM controller.

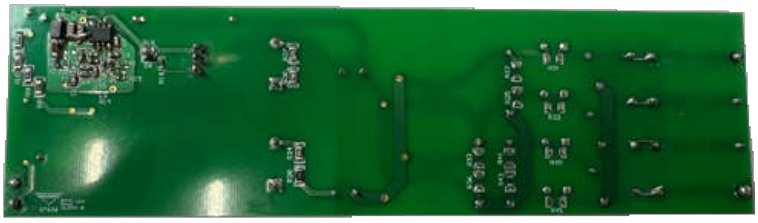
Features

- Current-mode PWM controller
- Very wide input voltage range: 40 V_{DC}–623 V_{DC}
- Non-isolated high-side buck controller topology eliminates the need for an optocoupler

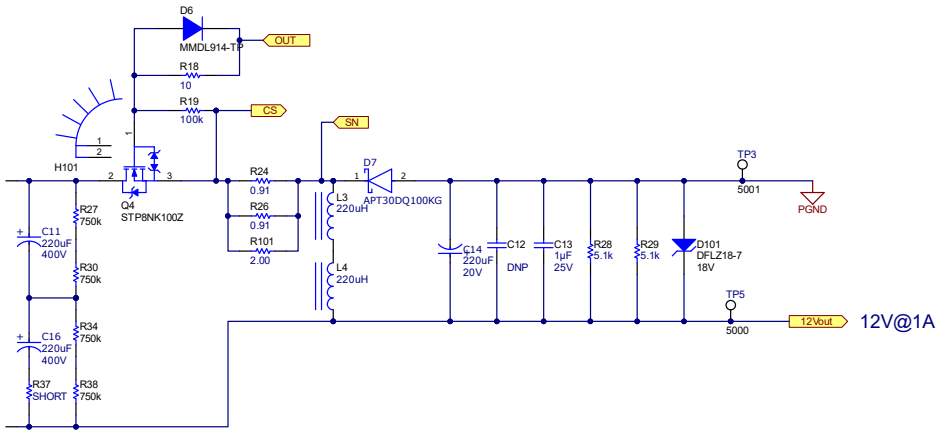
Applications

- Electricity meter

Top of Board



Bottom of Board



Schematic

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input voltage (per phase)	43 V_{AC}–255 V_{AC}
DC input voltage range	40 V_{DC}–623 V_{DC}
Output voltage	12 V
Maximum output current	1 A

1.2 Dimensions

The dimensions of the two-layer board are 180.7 mm × 50.5 mm. The copper thickness is 35 µm on each layer.

2 Testing and Results

2.1 Efficiency

The efficiency graph is shown in the following image.

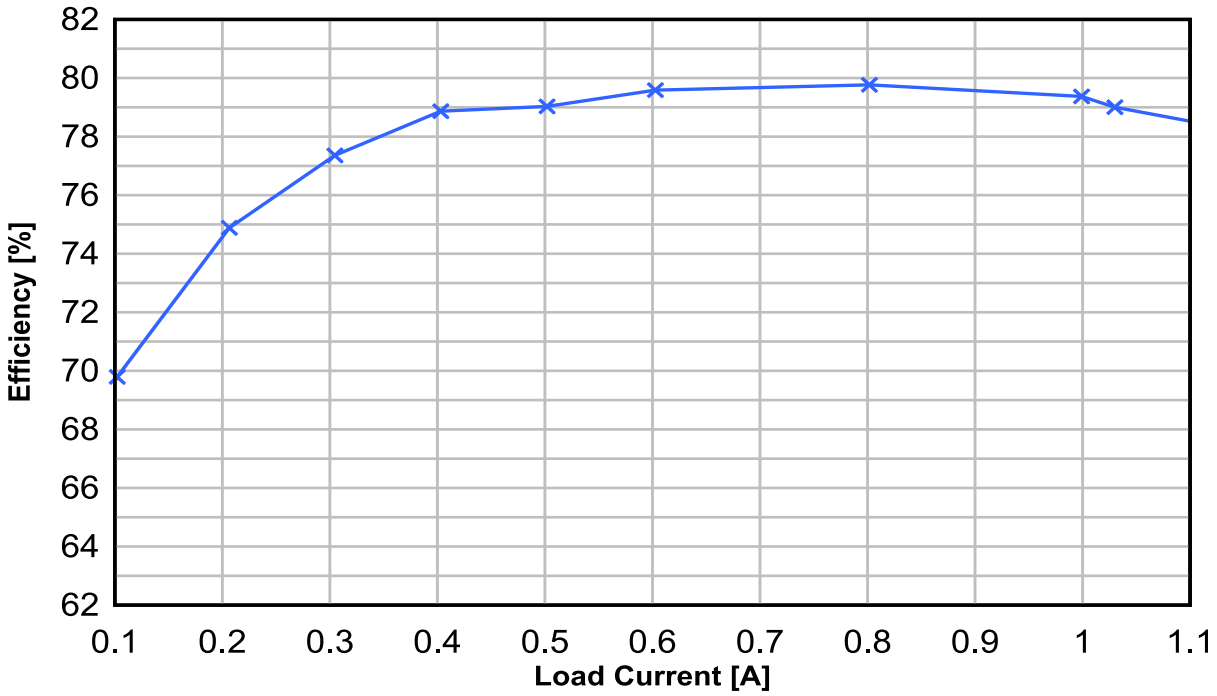


Figure 2-1. Efficiency vs Load Current at 230-V_{AC} Input Voltage

2.2 Standby Power

The following information shows standby power data:

110 V_{AC} input = 270 mW
230 V_{AC} input = 450 mW

2.3 Load Regulation

The load regulation graph is illustrated in the following image.

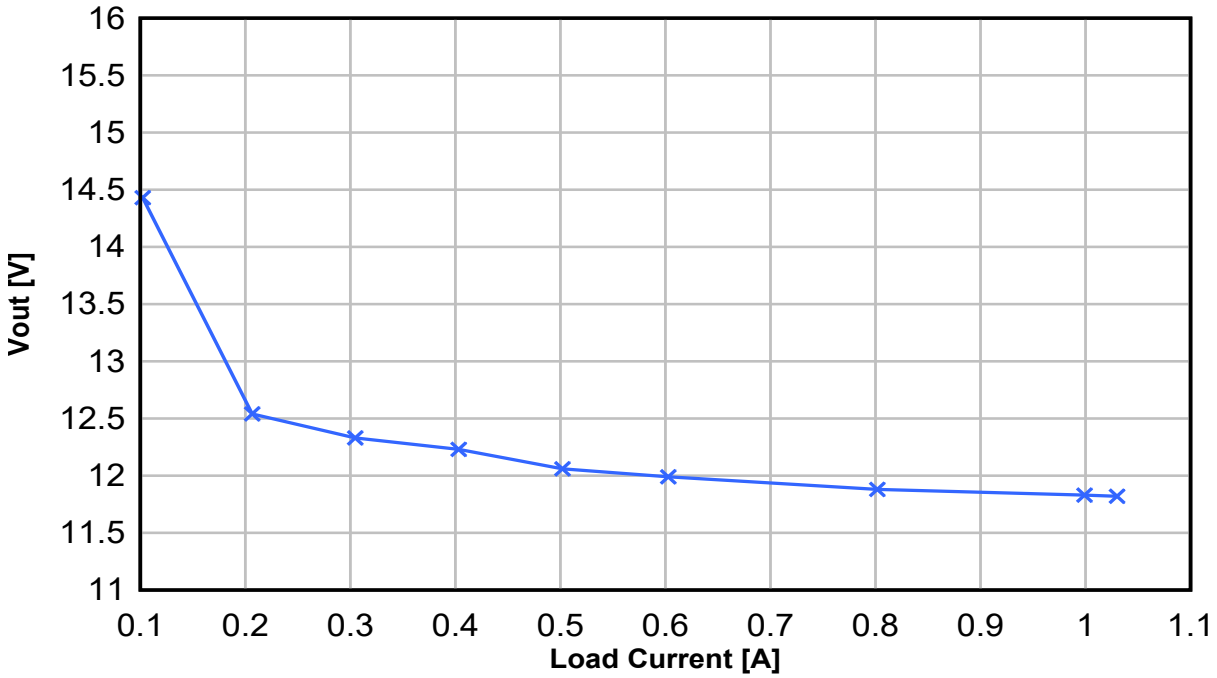


Figure 2-2. Load Current vs V_{OUT} at 230-V_{AC} Input Voltage

2.4 Line Regulation

The line regulation graph is illustrated in the following graph.

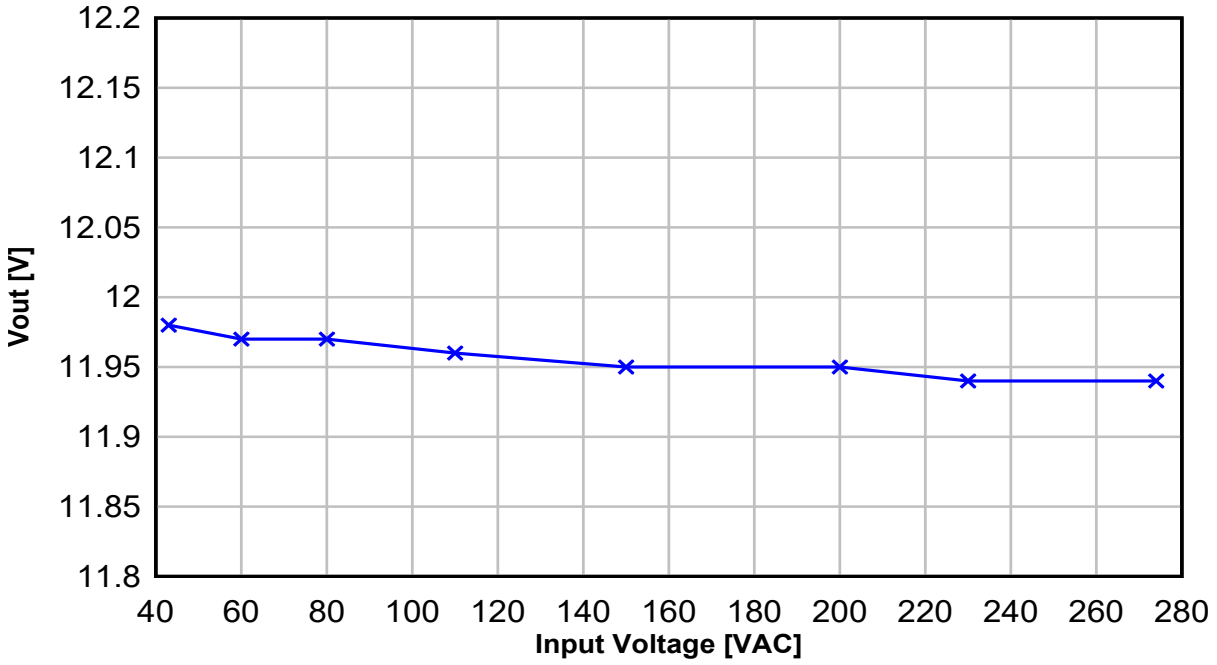


Figure 2-3. Input Voltage vs V_{OUT} at Full Load

2.5 Thermal Images

Figure 2-4 and Figure 2-5 show the thermal images.

2.5.1 43 V_{AC} Input Voltage

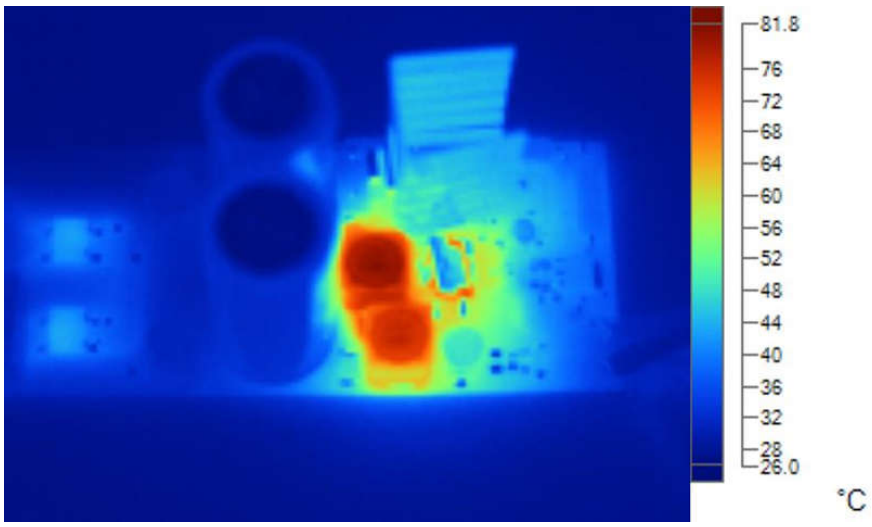


Figure 2-4. Thermal Image at 43-V_{AC} Input Voltage and Full Load

2.5.2 274 V_{AC} Input Voltage

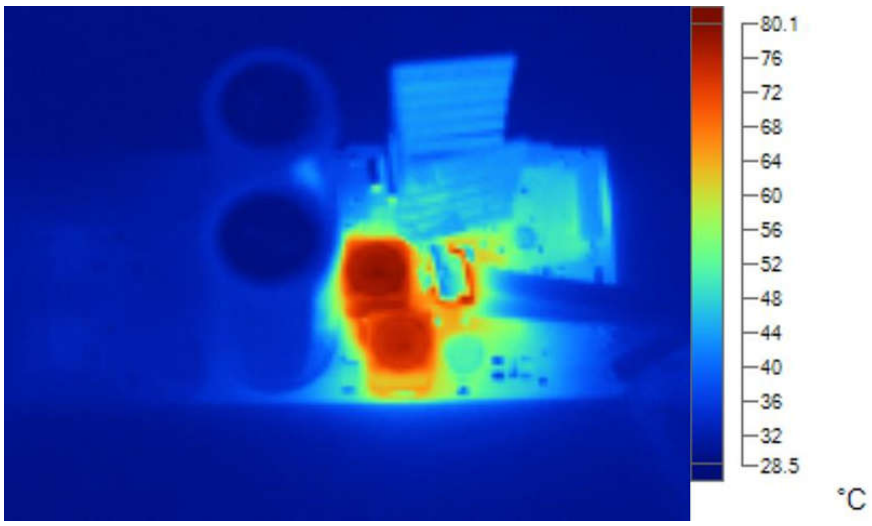


Figure 2-5. Thermal Image at 274-V_{AC} Input Voltage and Full Load

2.6 Bode Plots

Bode plot is shown in the following figure.

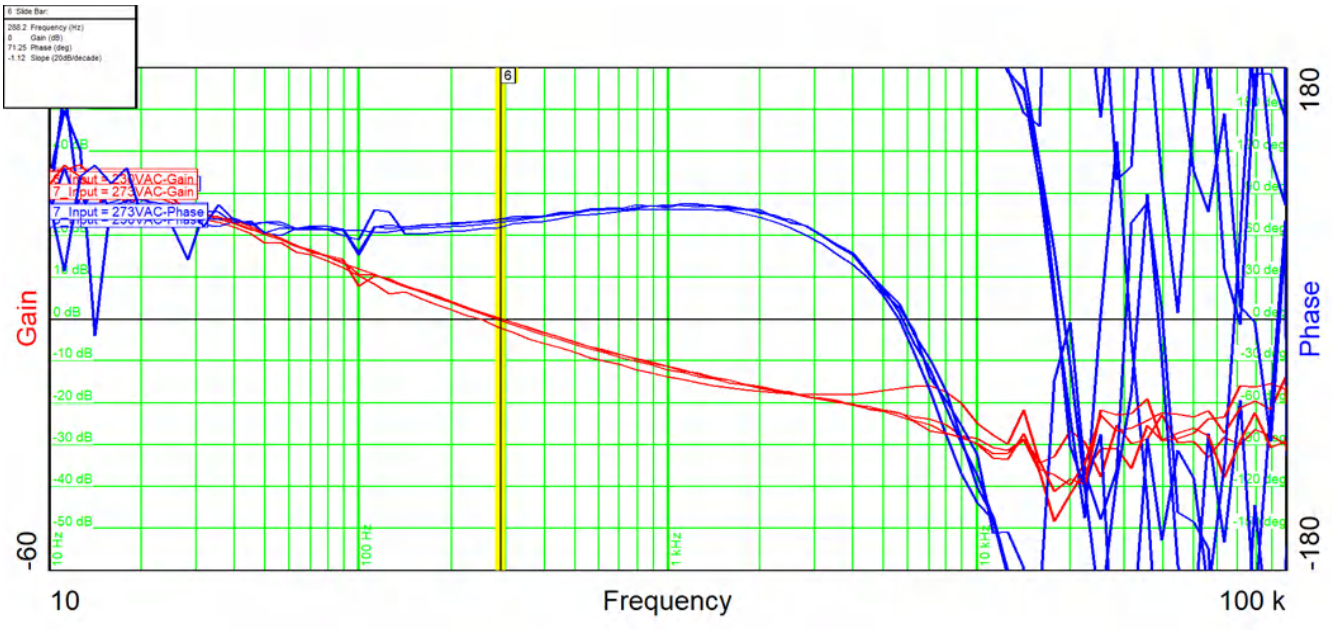


Figure 2-6. Bode Plot

Input voltage	43 V_{AC}	110 V_{AC}	230 V_{AC}
Load current	1 A	1 A	1 A
Phase margin	64° (deg)	69° (deg)	71° (deg)
Gain margin	> 15 dB	> 20 dB	> 20 dB
Bandwidth	245 Hz	279 Hz	288 Hz

3 Waveforms

3.1 Switch Node Voltage

3.1.1 40 V_{DC} Input Voltage

Figure 3-1 through Figure 3-3 show 40-V_{DC} input voltage waveforms at various load conditions.

3.1.1.1 No Load

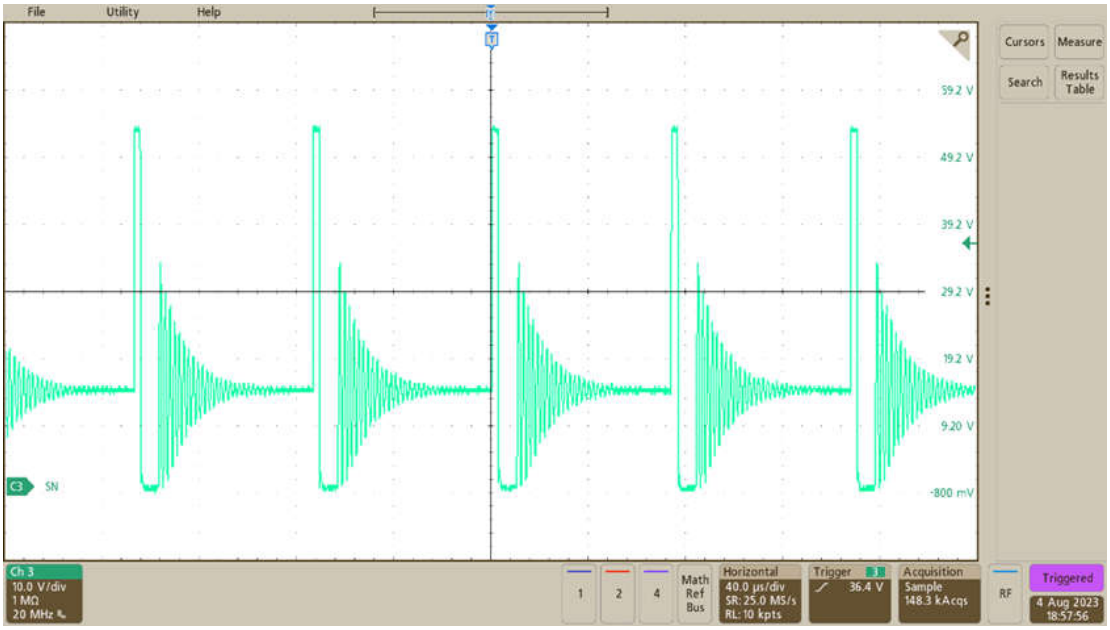


Figure 3-1. Switching 40-V_{DC} Input Voltage; No Load

3.1.1.2 100-mA Load Current

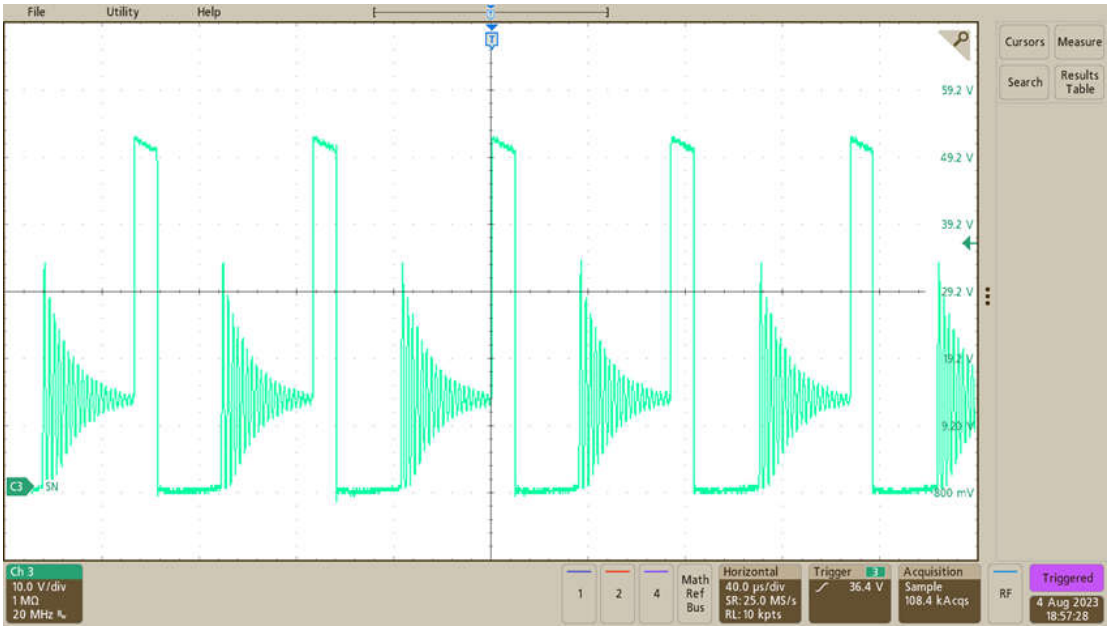


Figure 3-2. Switching 40-V_{DC} Input Voltage; 100-mA Load Current

3.1.1.3 1-A Load Current

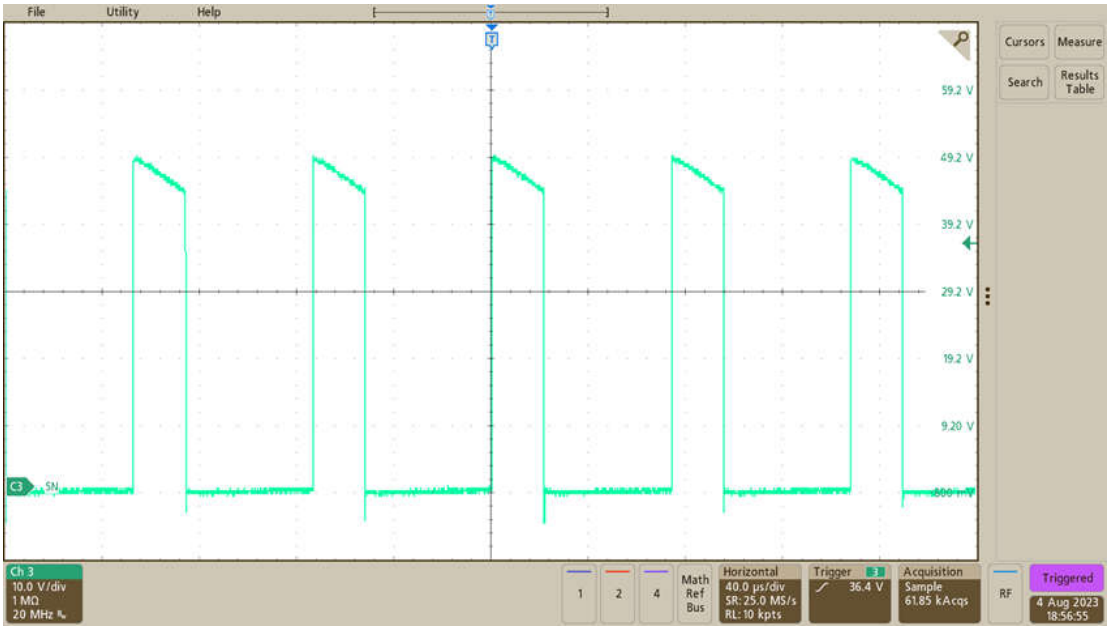


Figure 3-3. Switching 40-VDC Input Voltage; 1-A Load Current

3.1.2 630-V_{DC} Input Voltage

Figure 3-4 through Figure 3-9 show 630-V_{DC} input voltage waveforms.

3.1.2.1 No Load

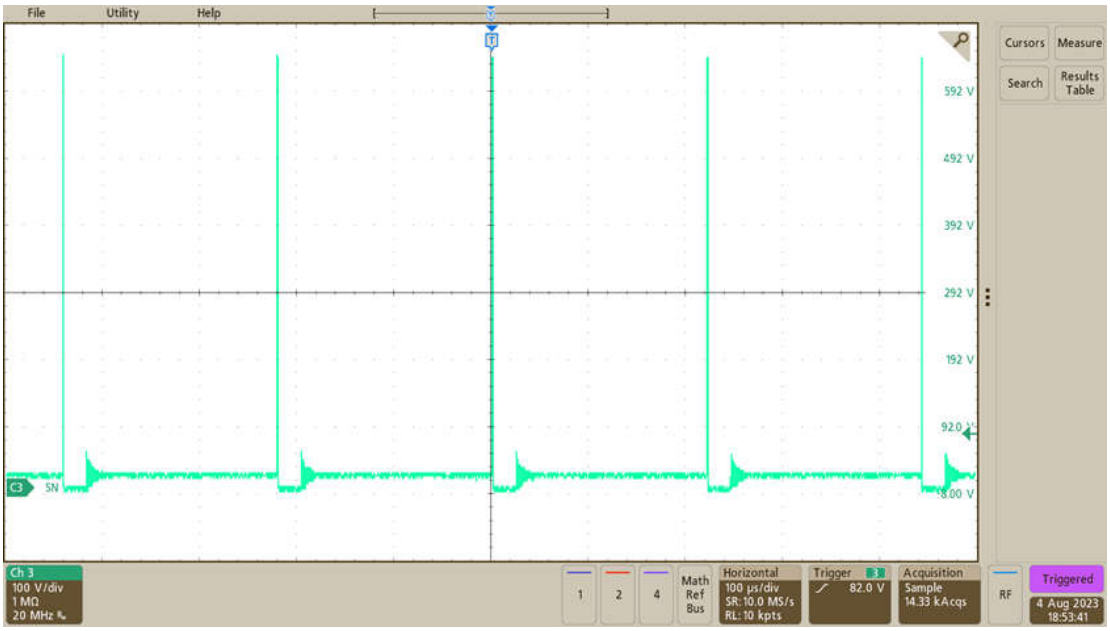


Figure 3-4. Switching at 630-V_{DC} Input Voltage; No Load; 100 µs / div

The waveform in Figure 3-5 displays the same measurement as in Figure 3-4 with a different time scale.

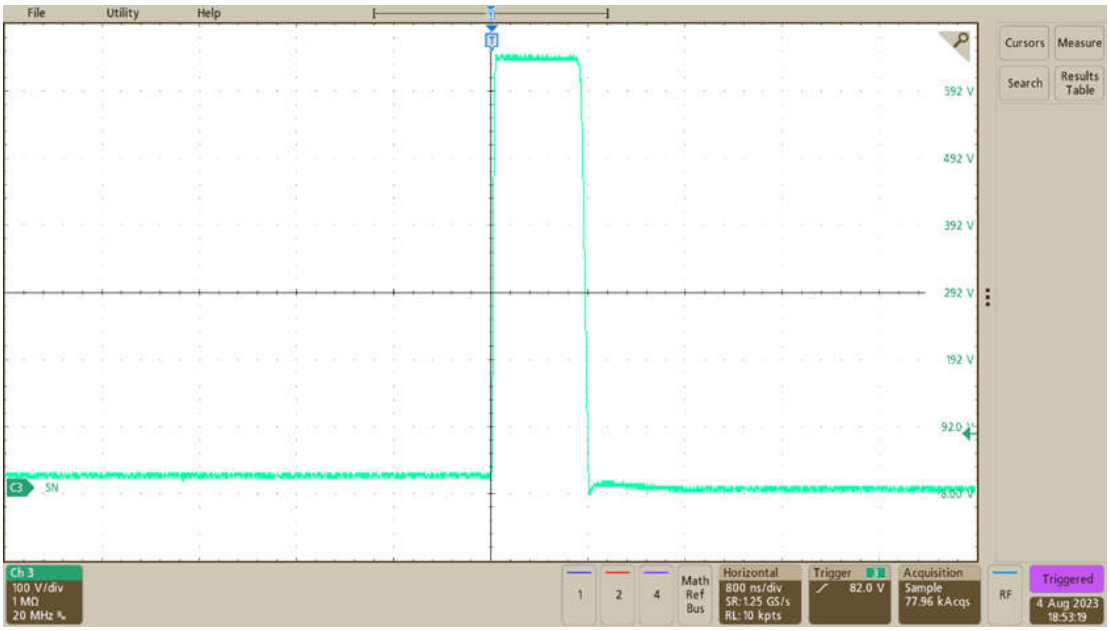


Figure 3-5. Switching at 630-V_{DC} Input Voltage; No Load; 800 ns / div

3.1.2.2 500-mA Load Current

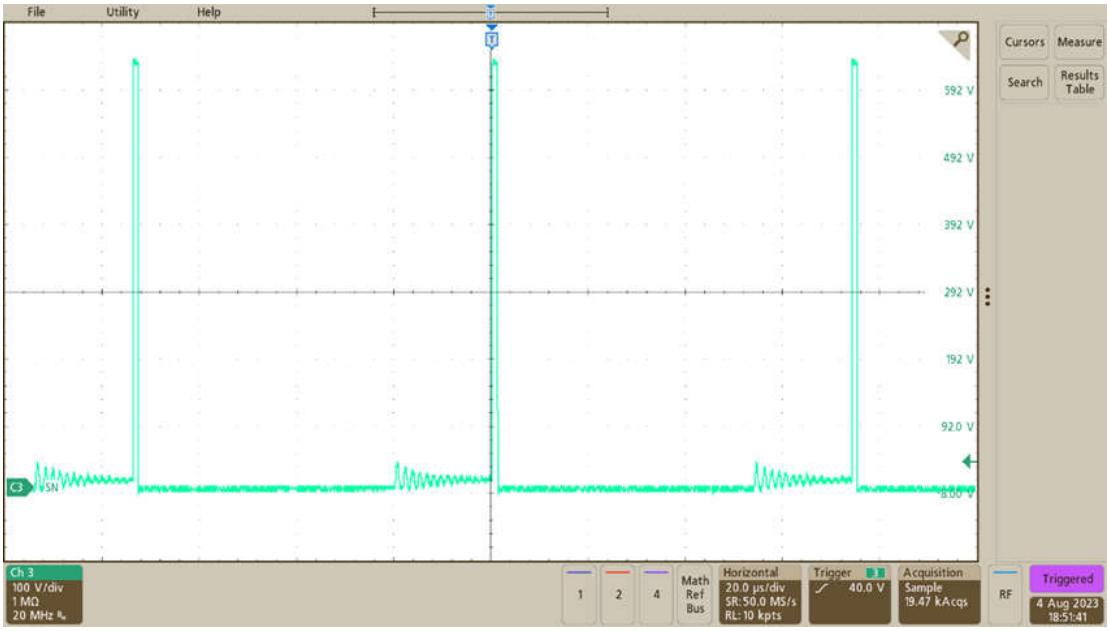


Figure 3-6. Switching at 630-V_{DC} Input Voltage; 500-mA Load Current; 20 µs / div

The waveform in Figure 3-7 displays the same measurement as in Figure 3-6 with a different time scale.

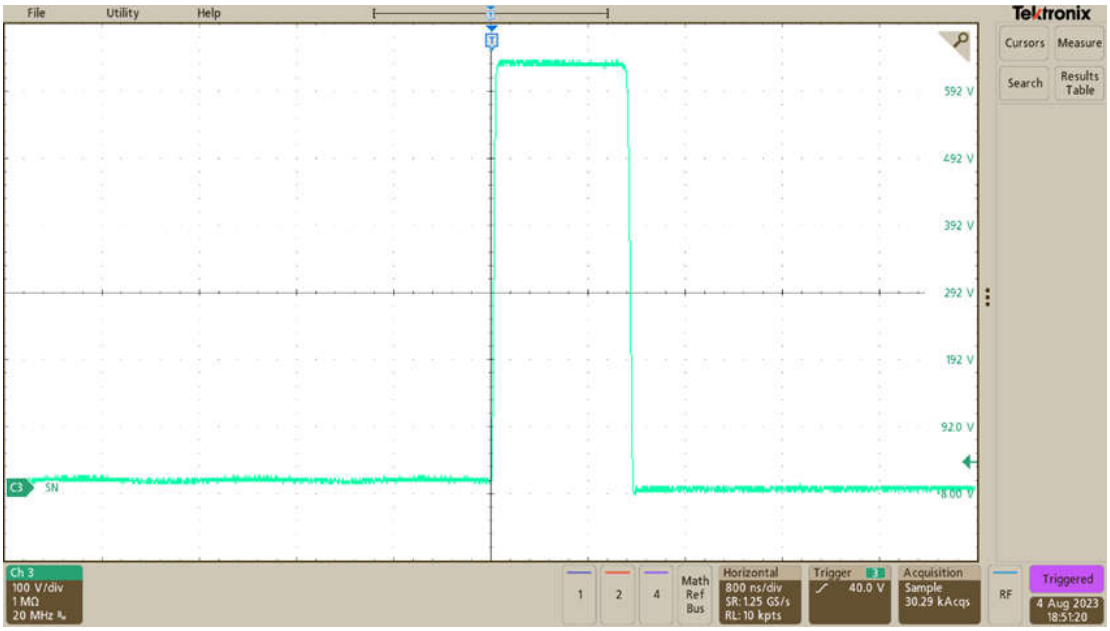


Figure 3-7. Switching at 630-V_{DC} Input Voltage; 500-mA Load Current; 800 ns / div

3.1.2.3 1-A Load Current

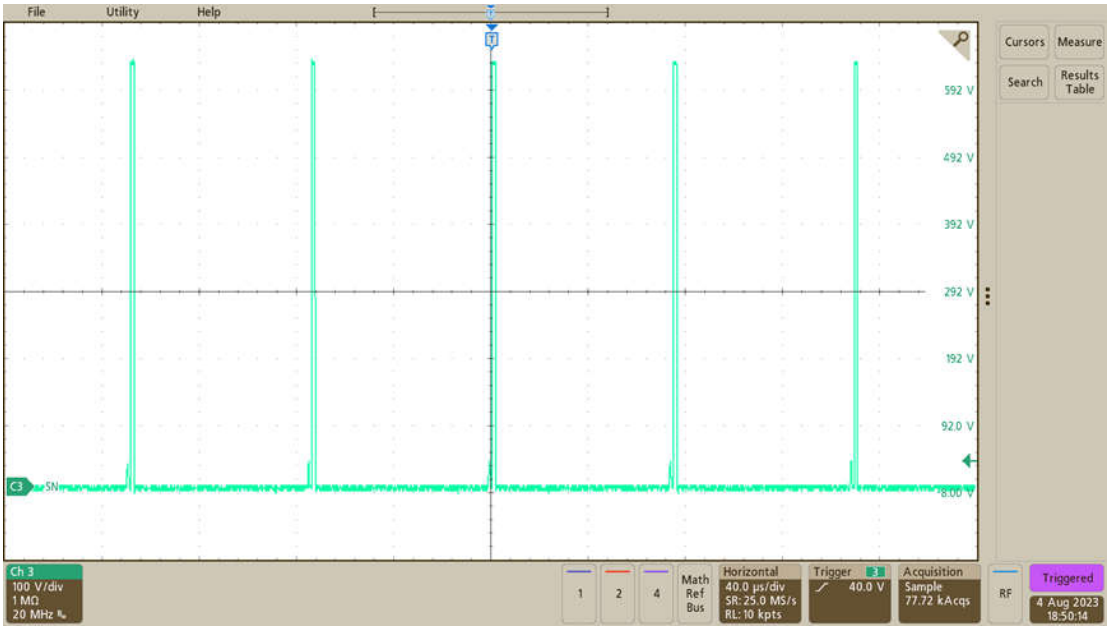


Figure 3-8. Switching at 630-V_{DC} Input Voltage; 1-A Load Current; 20 µs / div

The waveform in Figure 3-9 displays the same measurement as in Figure 3-8 with a different time scale.

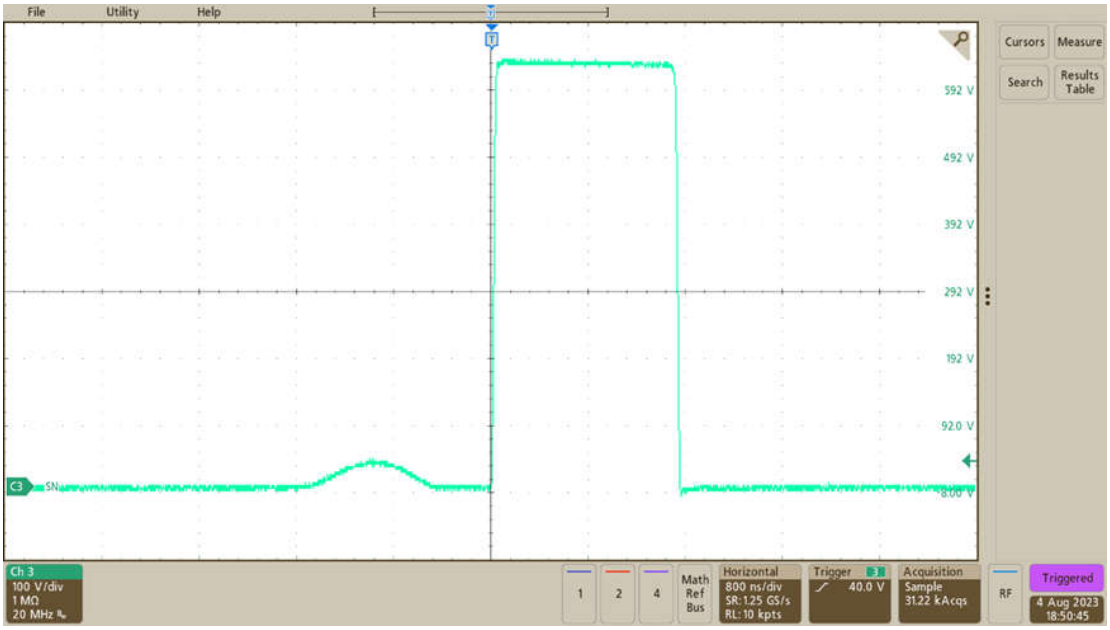


Figure 3-9. Switching at 630-V_{DC} Input Voltage; 1-A Load Current; 800 ns / div

3.2 Output Voltage Ripple

Figure 3-10 through Figure 3-12 show the output voltage ripple waveforms.

3.2.1 40-V_{DC} Input Voltage

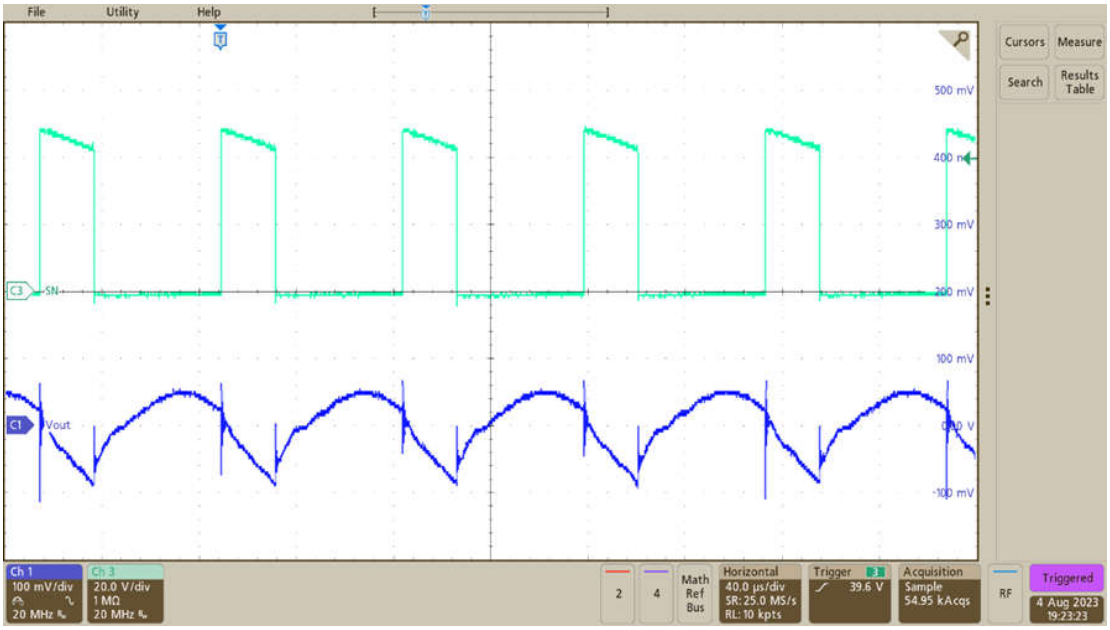


Figure 3-10. Output Voltage Ripple at 40-V_{DC} Input Voltage; Full Load

3.2.2 325-V_{DC} Input Voltage

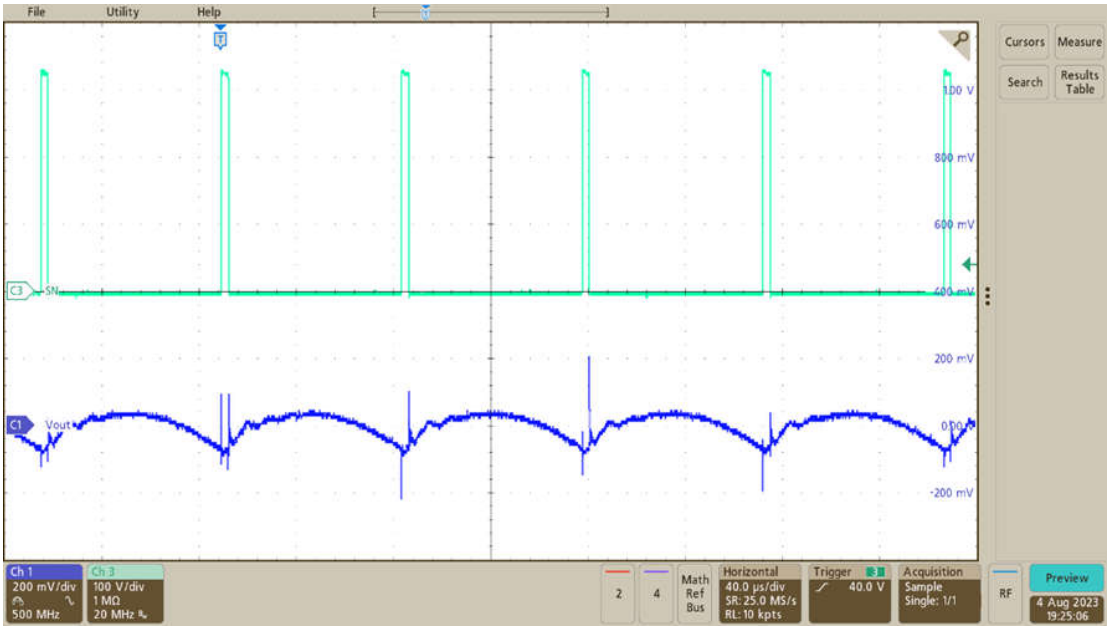


Figure 3-11. Output Voltage Ripple at 325-V_{DC} Input Voltage; Full Load

3.2.3 630 V_{DC} Input Voltage

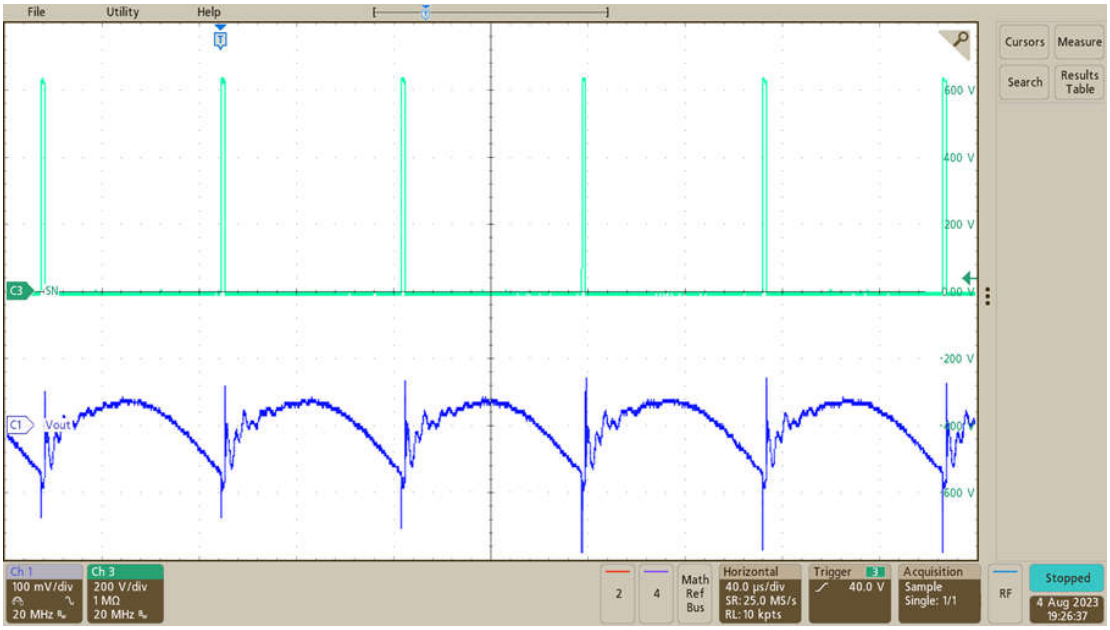


Figure 3-12. Output Voltage Ripple at 630-V_{DC} Input Voltage; Full Load

3.3 Input Voltage Ripple

The input voltage waveform is shown in the following image.

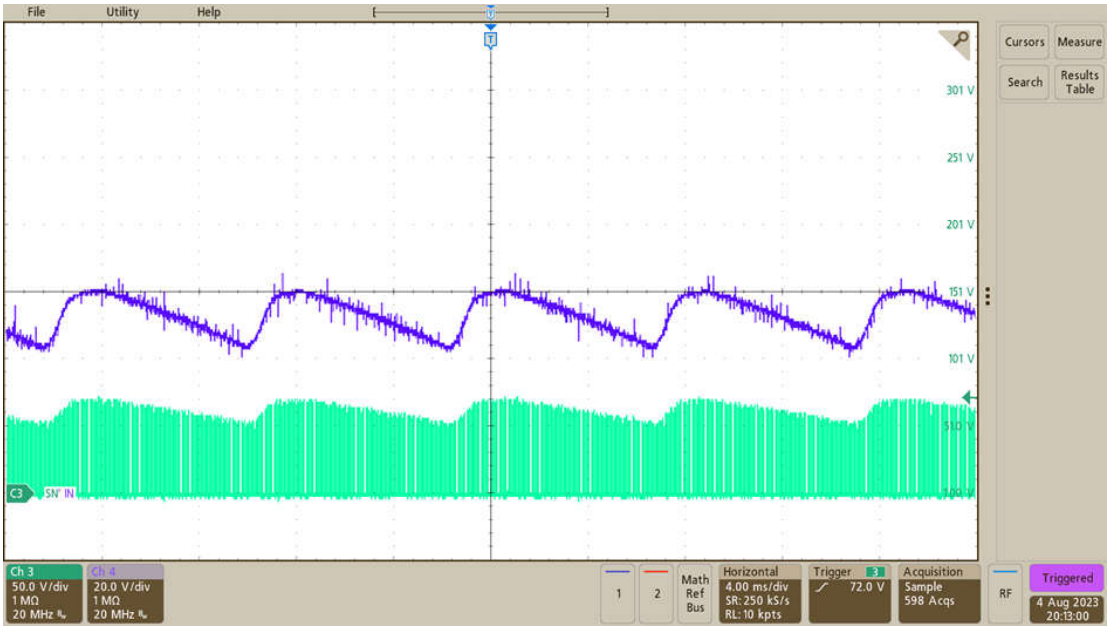


Figure 3-13. Input Voltage Ripple With 43-V_{AC}; 1-A Load Current

3.4 Load Transients

Figure 3-14 through Figure 3-16 illustrate the load transient waveforms.

3.4.1 40-V_{DC} Input Voltage

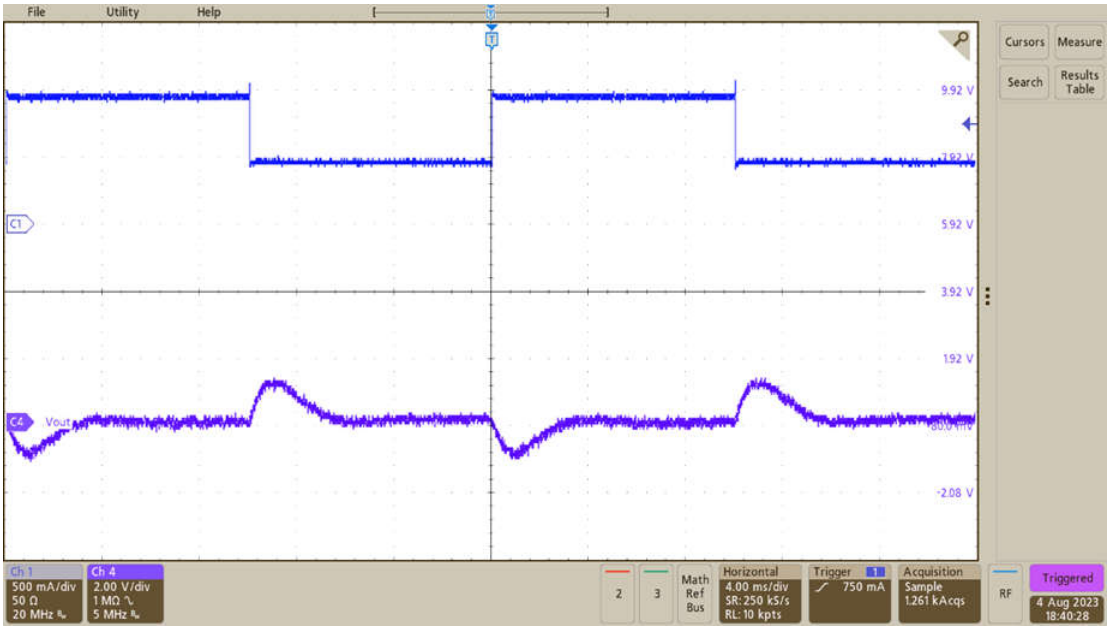


Figure 3-14. Load Transient at 40-V_{DC} Input Voltage; 500-mA to 1-A Load Step

3.4.2 325-V_{DC} Input Voltage

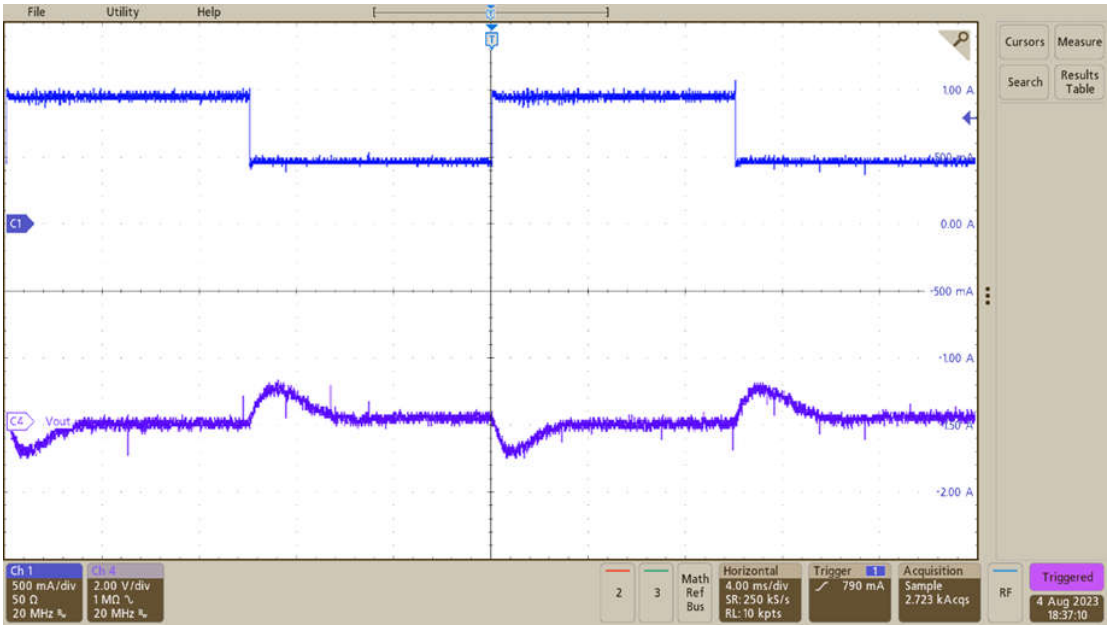


Figure 3-15. Load Transient at 325-V_{DC} Input Voltage; 500-mA to 1-A Load Step

3.4.3 630-V_{DC} Input Voltage

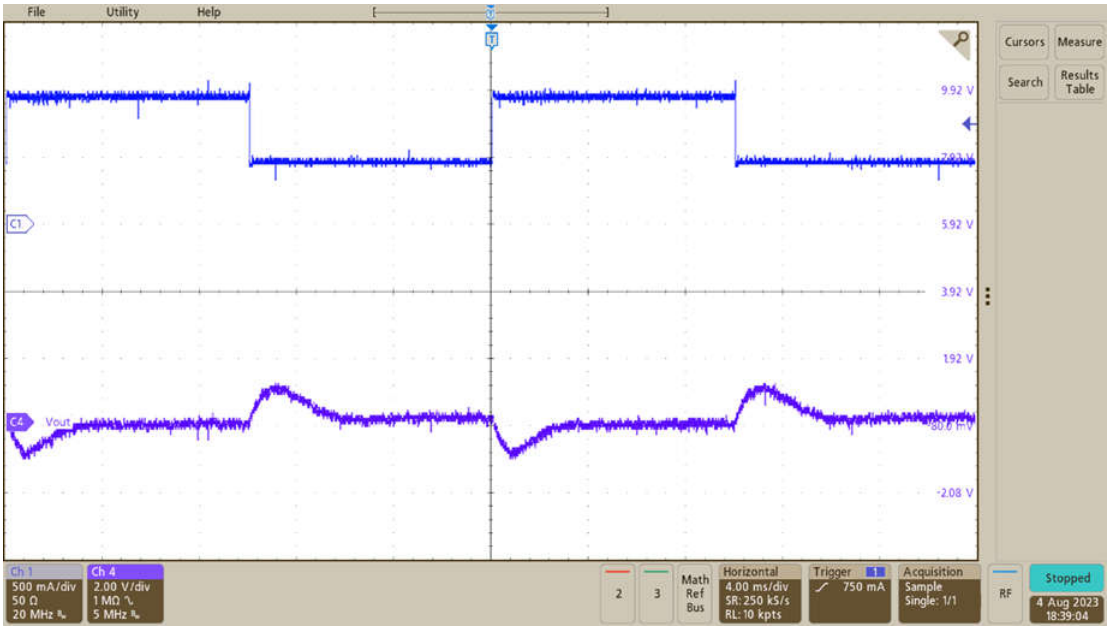


Figure 3-16. Load Transient at 630-V_{DC} Input Voltage; 500-mA to 1-A Load Step

3.5 Start-Up Sequence

3.5.1 With Load

Figure 3-17 and Figure 3-18 show the start-up sequence waveforms with a load.

3.5.1.1 43-V_{AC} Input Voltage

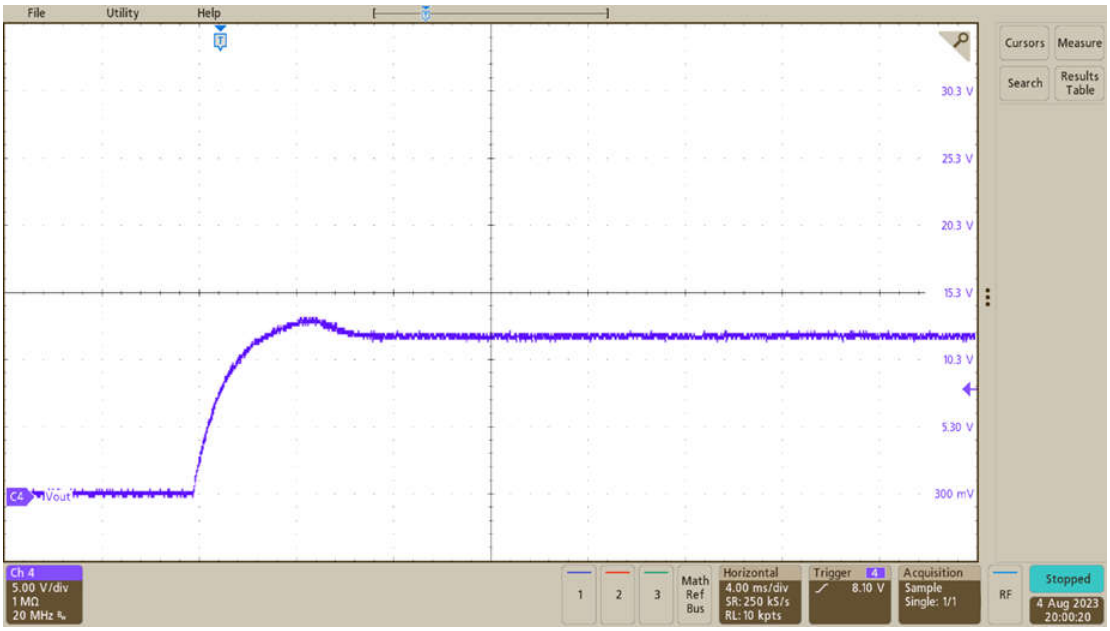


Figure 3-17. Start-up With 43-V_{AC} Input Voltage; 12-Ω Load Resistor

3.5.1.2 630-V_{DC} Input Voltage

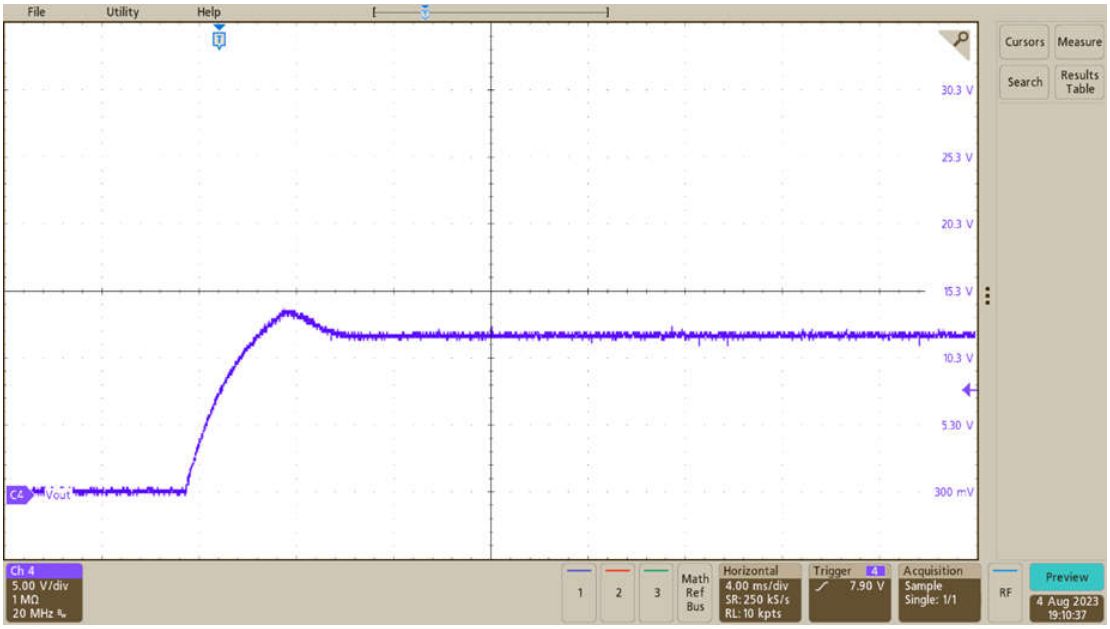


Figure 3-18. Start-up With 630-V_{DC} Input Voltage; 1-A Load Current

3.5.2 Without Load

Figure 3-19 and Figure 3-20 show the start-up sequence waveforms with no load.

3.5.2.1 40-V_{DC} Input Voltage

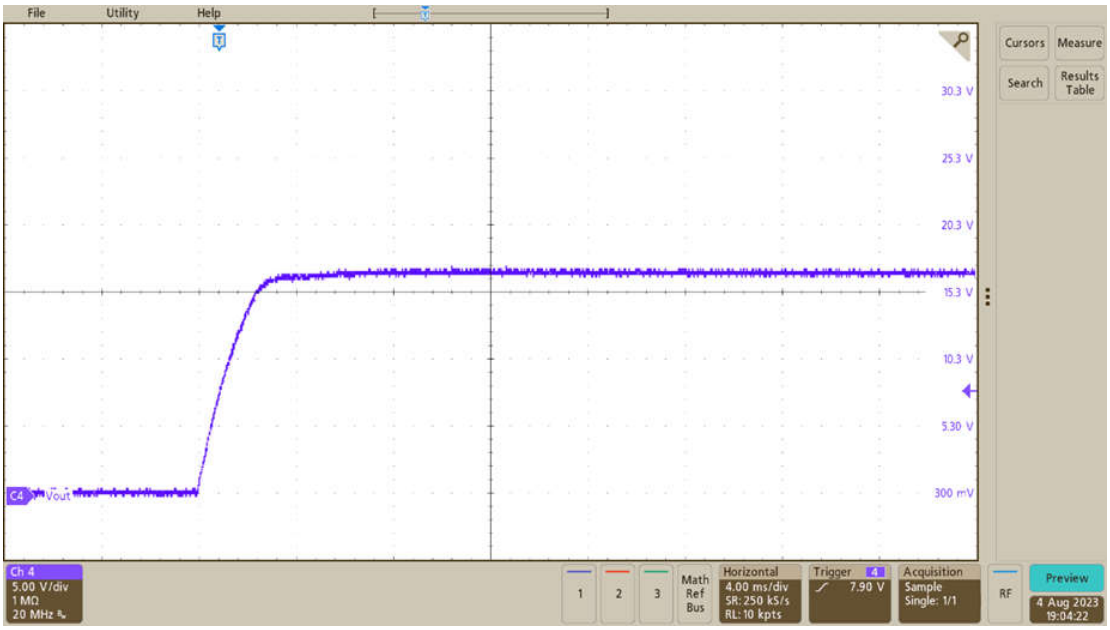


Figure 3-19. Start-up With 40-V_{DC} Input Voltage; No Load

3.5.2.2 630-V_{DC} Input Voltage

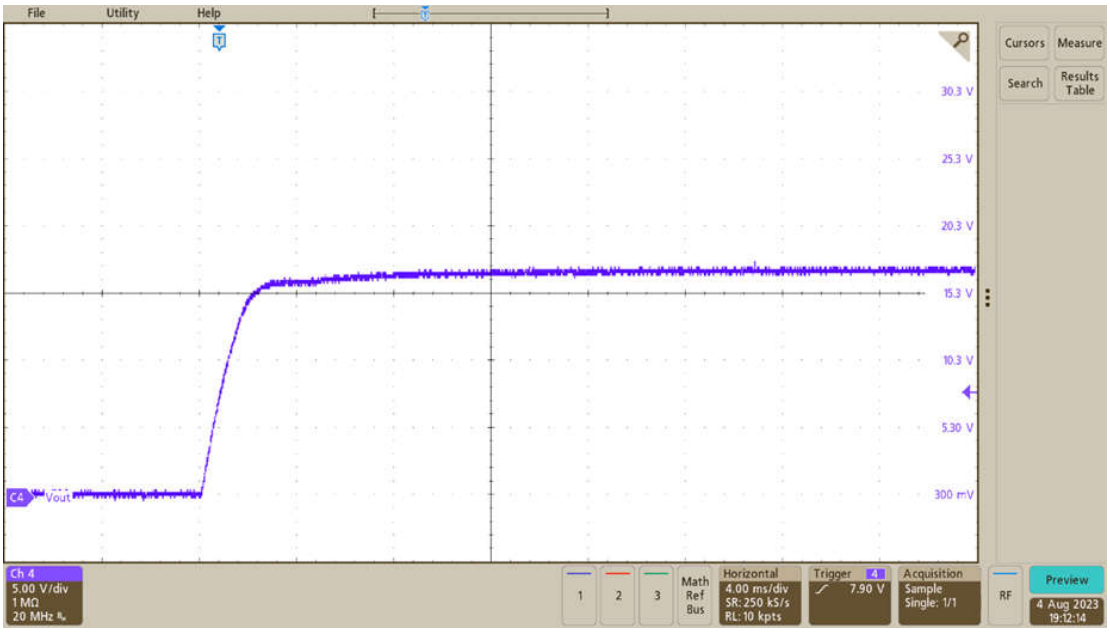


Figure 3-20. Start-up With 630-V_{DC} Input Voltage; No Load

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