Test Report: PMP31248

Universal AC Input, 12-V, 25-W PSR Reference Design

Description

This reference design is a quasi-resonant flyback power supply based on the UCC28730 primary side regulation (PSR) controller and UCC24650 (wake-up monitor). Using PSR topology eliminates the need of an optocoupler, increases reliability, and optimizes system cost. The design achieves less than 6-mW standby power (at 230 V_{AC}) and over 85% efficiency at 25-W load.

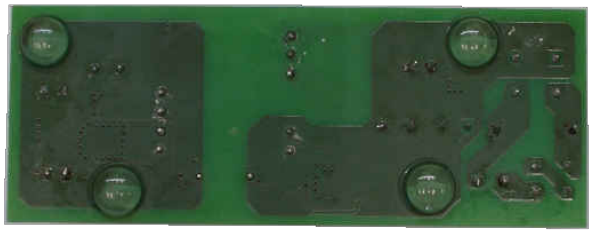
Features

- 185-V_{AC} to 265-V_{AC} input, 50 Hz and 60 Hz; 12-V, 2.1-A output
- Over 85% average 4-point efficiency
- Over 82% efficiency at 2% load (0.4 W)
- Less than 6-mW standby power losses
- Protected against output short circuits

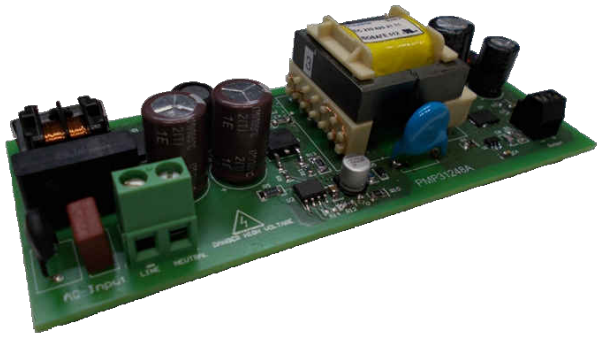
Applications

- Dishwasher

Top Photo



Bottom Photo



Angled Photo

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage	185 V_{AC} – 265 V_{AC}
Frequency	47 Hz – 63 Hz
Output Voltage	12 V_{DC}
Output Current	1.67 A (average), 2.1 A (peak)

1.2 Required Equipment

- 0 V_{AC} – 265 V_{AC}, 45 Hz – 65 Hz (minimum current limit 1 A_{RMS}), AC constant voltage source (VS1)
- Electronic load, (constant current range 0 A – 3 A)
- Oscilloscope (minimum 100-MHz bandwidth)
- Current probe (minimum 100-kHz bandwidth)
- Optional: infrared camera
- Spectrum analyzer (typical frequency range 9 kHz – 3.5 GHz)
- AC Line Impedance Stabilization Network (LISN)
- Variable isolation transformer (100 W minimum)

1.3 Testing Conditions

1. Connect the source VS1 to J1-1 and J1-2.
2. Connect the load to J2-1 (positive) and J2-2 (negative).
3. Attach a current probe in series to the output to take load transient response behavior.
4. Turn on VS1 (accepted range: 185 V_{AC} – 265 V_{AC}).
5. Increase the load on the output.
6. After turn off, discharge the capacitors C1 and C2 by means of an external resistor (warning: HIGH VOLTAGE)

1.4 Considerations

The reference design PMP31248 Rev_C was built on PMP31248 Rev_A PCB.

1.5 Dimensions

The board dimensions are 114.30 mm × 41.91 mm, the height is 24 mm (transformer T1).

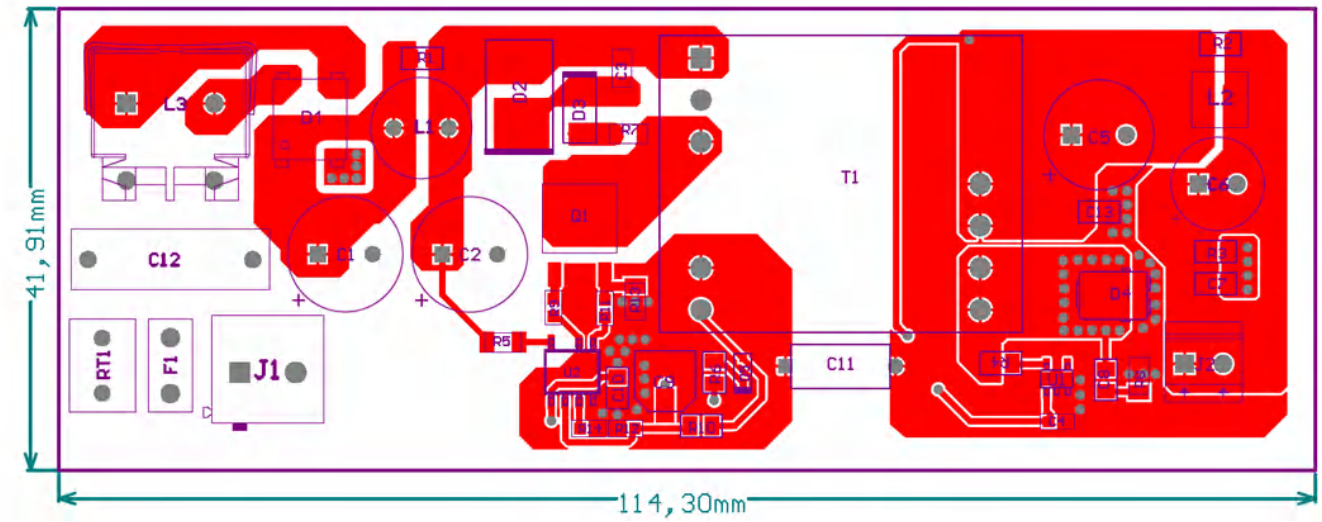


Figure 1-1. Outline

2 Testing and Results

2.1 Efficiency Graphs and Data

2.1.1 Efficiency Graph: Light Load Performance

The efficiency graph in Figure 2-1 shows the converter efficiency, versus output current, during light load.

The input voltage was set to 185 V_{AC}, 230 V_{AC}, and 265 V_{AC}, and the load current range restricted between zero and 70 mA.

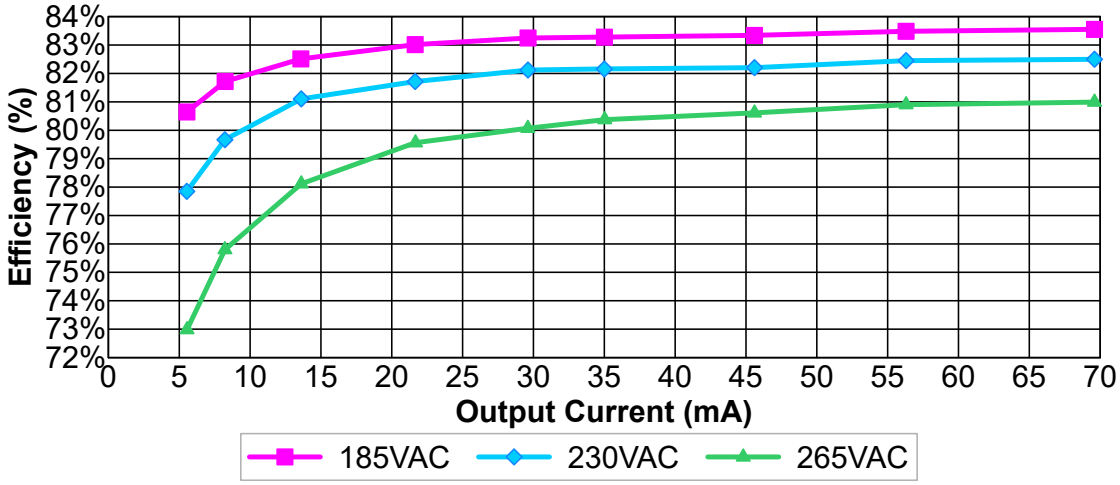


Figure 2-1. Light Load Efficiency

2.1.2 Efficiency Graph: Available Output Power Versus Input Power

The graph in Figure 2-2 shows the available output power versus input power at 230 V_{AC}.

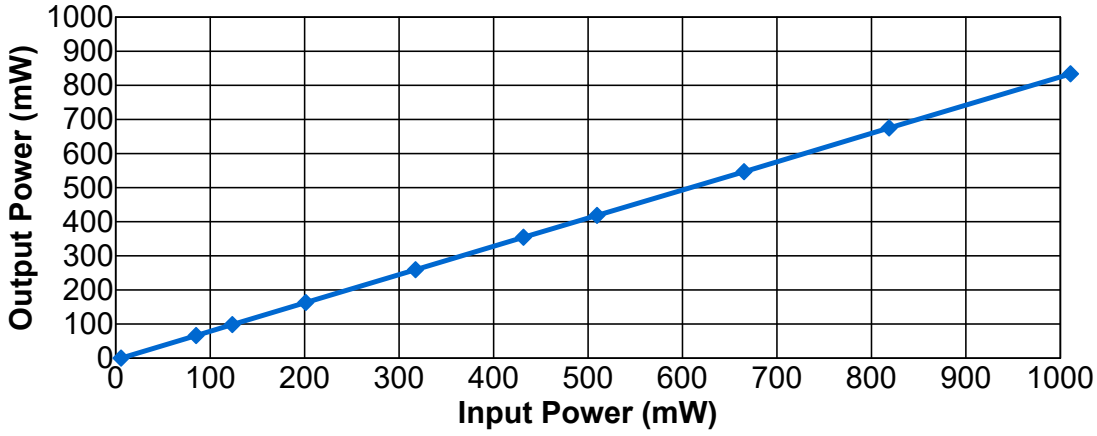


Figure 2-2. Output Power vs Input Power

2.1.3 Efficiency Graph: Full Load Performance

The efficiency graph in Figure 2-3 shows the converter efficiency, versus output current, from light to full load.

The input voltage was set to 185 V_{AC}, 230 V_{AC}, and 265 V_{AC}.

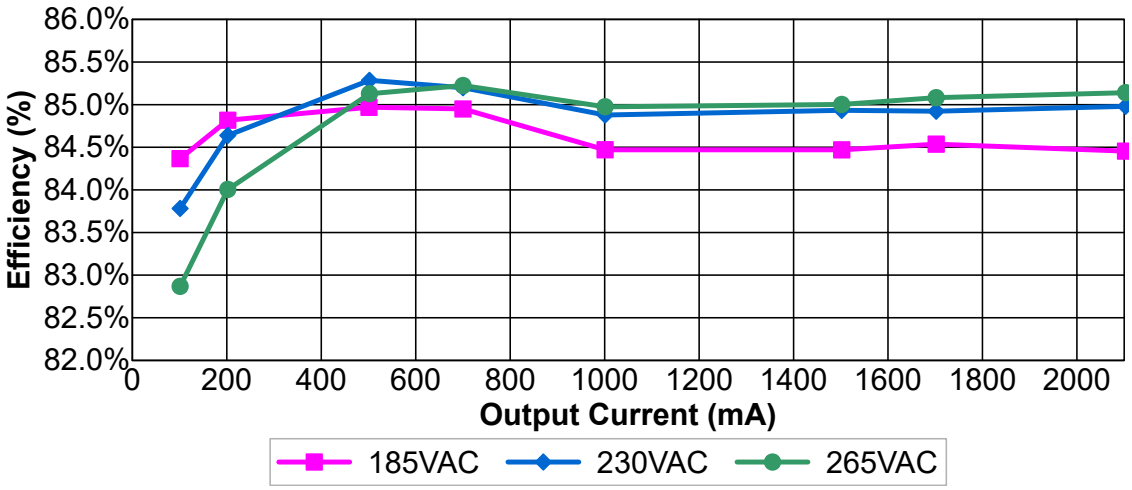


Figure 2-3. Full Load Efficiency

2.1.4 Efficiency Data

The efficiency graphs (Figure 2-1, Figure 2-2, and Figure 2-3) report the data from the tables shown below at 185 V_{AC}, 230 V_{AC}, and 265 V_{AC}.

Table 2-1. V_{IN} = 185 V_{AC}, f = 50 Hz

P_{IN} (mW)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (mW)	Efficiency (%)
3.7	12.13	0.0	0.00	0.00%
82.3	11.98	5.54	66.37	80.64%
120.7	11.97	8.24	98.63	81.72%
197.5	12.00	13.58	162.96	82.51%
312.7	11.99	21.65	259.58	83.01%
425.9	11.97	29.62	354.55	83.25%
502.8	11.96	35.01	418.72	83.28%
656.6	12.00	45.6	547.20	83.34%
808.6	11.99	56.3	675.04	83.48%
998.8	11.99	69.6	834.50	83.55%

Table 2-2. V_{IN} = 230 V_{AC}, f = 50 Hz

P_{IN} (mW)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (mW)	Efficiency (%)
5.6	12.15	0.0	0.00	0.00%
85.1	11.98	5.53	66.25	77.85%
123.4	11.96	8.22	98.31	79.67%
201.2	11.99	13.61	163.18	81.11%
317.4	11.98	21.65	259.37	81.72%
431.6	11.97	29.61	354.43	82.12%
509.5	11.96	35.00	418.60	82.16%
665.1	11.99	45.6	546.74	82.20%
818.7	11.99	56.3	675.04	82.45%
1010.7	11.98	69.6	833.81	82.50%

Table 2-3. V_{IN} = 265, V_{AC}, f = 50 Hz

P_{IN} (mW)	V_{OUT} (V)	I_{OUT} (mA)	P_{OUT} (mW)	Efficiency (%)
11.3	12.15	0.0	0.00	0.00%
91.1	11.98	5.55	66.49	72.98%
129.7	11.96	8.22	98.31	75.80%
208.9	11.99	13.61	163.18	78.12%
326.3	11.98	21.67	259.61	79.56%
442.5	11.97	29.60	354.31	80.07%
523.0	12.00	35.03	420.36	80.37%
678.8	12.00	45.6	547.20	80.61%
834.4	11.99	56.3	675.04	80.90%
1029.5	11.98	69.6	833.81	80.99%

2.2 Thermal Images

Figure 2-4 and Table 2-4 show the thermal picture of the converter supplied at 230 V_{AC} and 50 Hz, taken after 30 minutes soak time, at 25.5°C ambient temperature, and placed horizontally to the bench.

The board runs at 1.7 A under still air conditions.

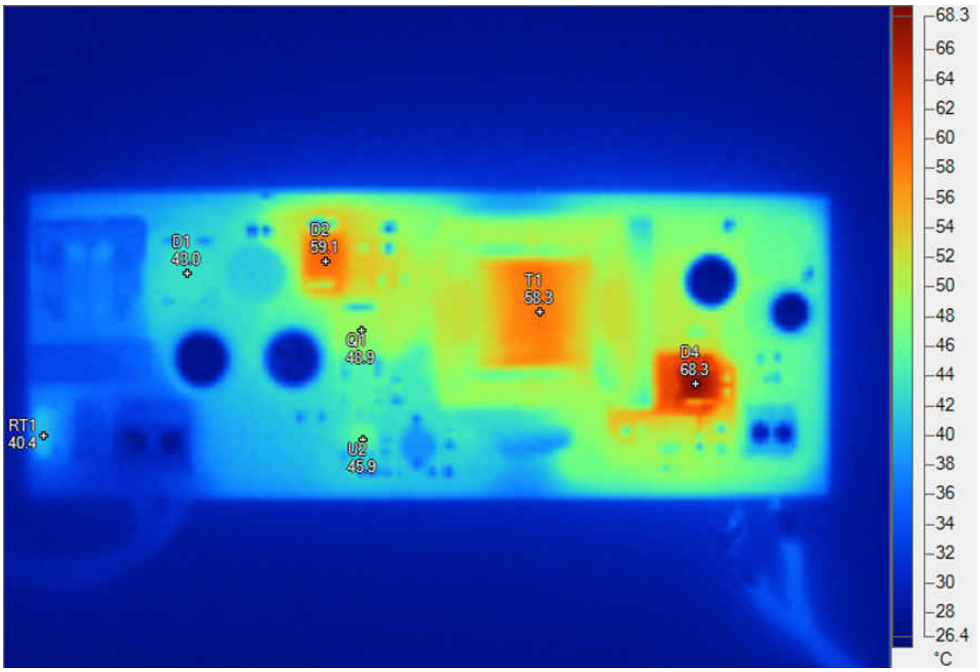


Figure 2-4. Thermal Image

Table 2-4. Main Image Markers

Name	Temperature	Emissivity	Background
D2	59.1°C	0.96	25.5°C
D1	43.0°C	0.96	25.5°C
RT1	40.4°C	0.96	25.5°C
U2	45.9°C	0.96	25.5°C
Q1	48.9°C	0.96	25.5°C
T1	58.3°C	0.96	25.5°C
D4	68.3°C	0.96	25.5°C

2.3 Static Output Voltage Variation versus Load

The output voltage versus load current is shown in Figure 2-5 and Figure 2-6.

2.3.1 Light Load Range

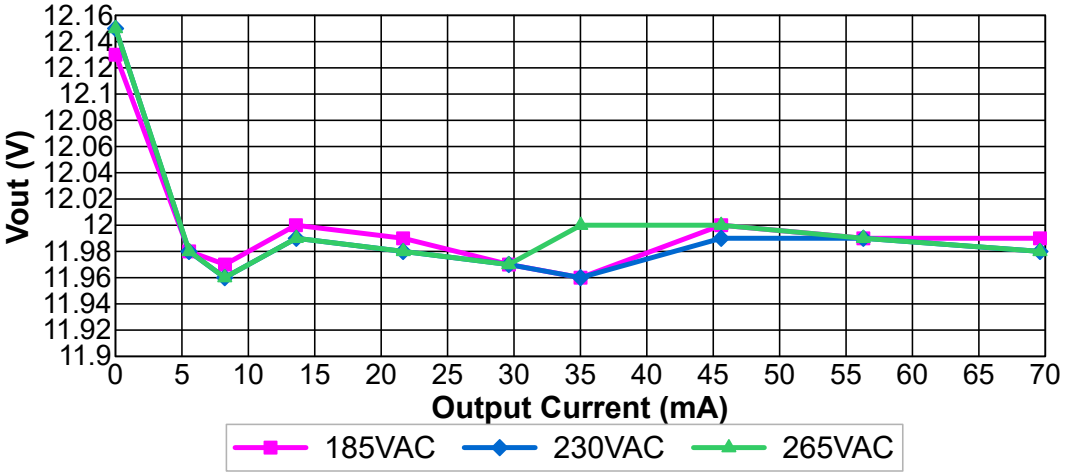


Figure 2-5. Output Voltage vs Output Current (Light Load)

2.3.2 Light to Full Load Range

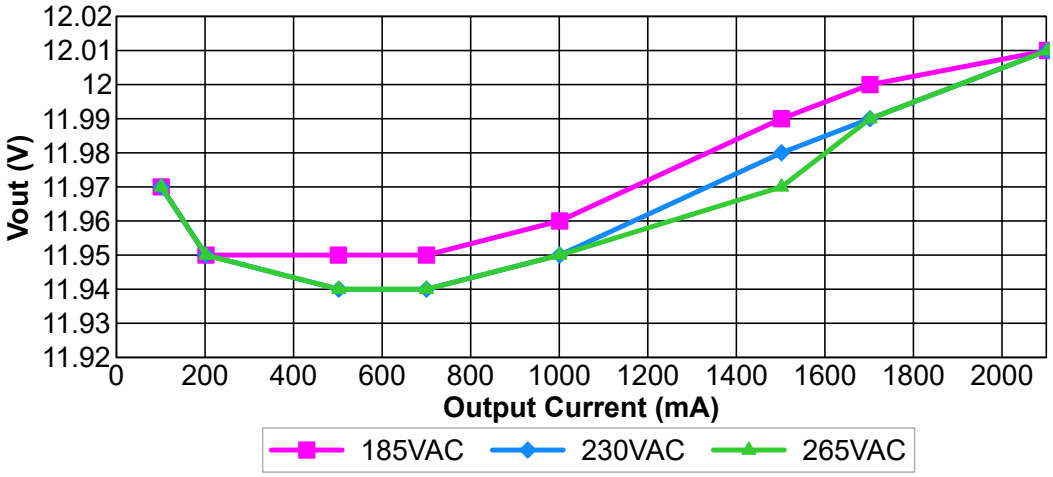


Figure 2-6. Output Voltage vs Output Current (whole load range)

2.4 EMI Measurement According to EN55022 Class-B Quasi-Peak Limits

The EMI signature of this converter was measured by using the following devices:

- **Spectrum Analyzer**
  - Manufacturer: Rohde & Schwarz
  - Part number: 1065.6000.20
  - Freq. range: 9 kHz – 3.5 GHz
- **LISN**
  - Manufacturer: Hameg
  - Model: HM6050-2
- **Load resistor 7.06 Ω**
- **Variable isolation transformer**
  - Manufacturer: Block TE
  - Model: BR350

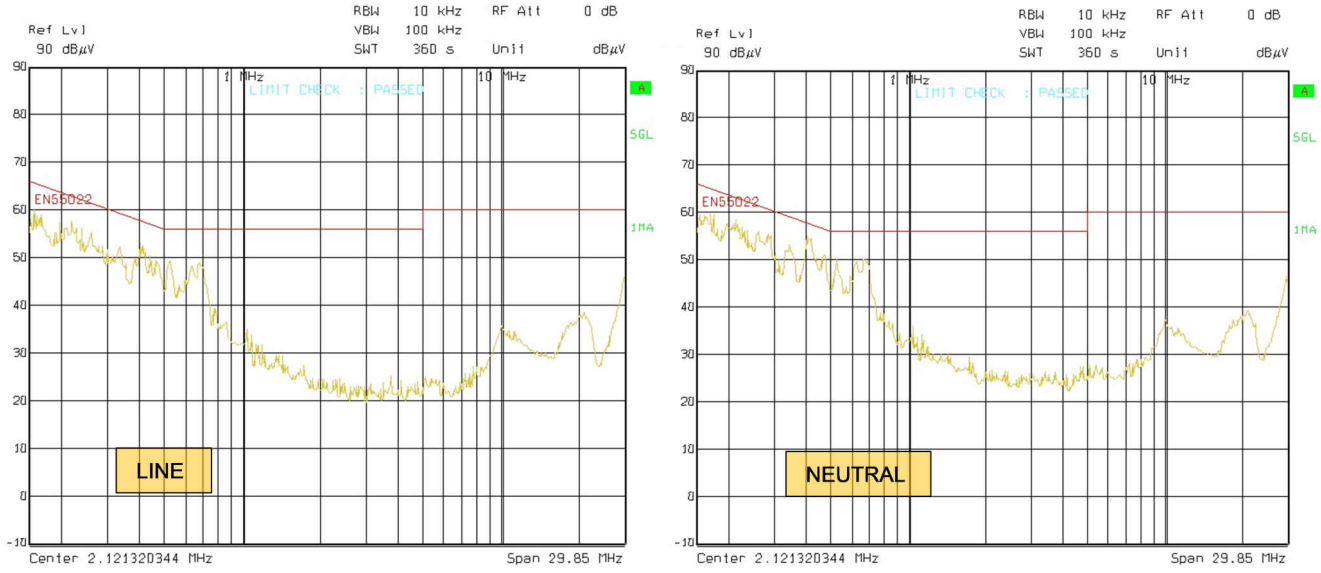


Figure 2-7. EMI: V_{IN} = 230 V_{AC}, R_{LOAD} = 7.06 Ω, Negative Output Terminal Connected to LISN Ground

3 Waveforms

3.1 Switching on Q1 (V_{DS} Voltage) at Full Load

The switching waveforms were measured by supplying the converter at maximum V_{IN} of 265 V_{AC} with 1.7-A load current.

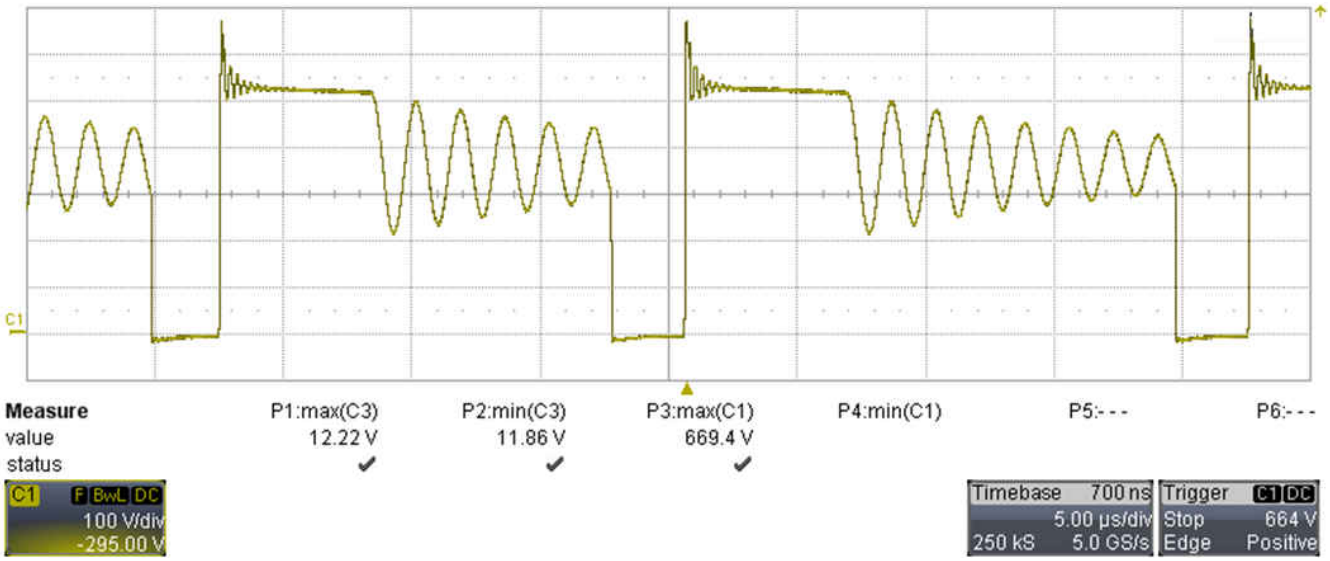


Figure 3-1. Waveform Q1-V_{DS} (100 V/div, 5 µs/div, 200 MHz BWL)

The image in Figure 3-2 is the same measurement as in Figure 3-1 but with time base of 1 µs/div to enlarge the overshoot.

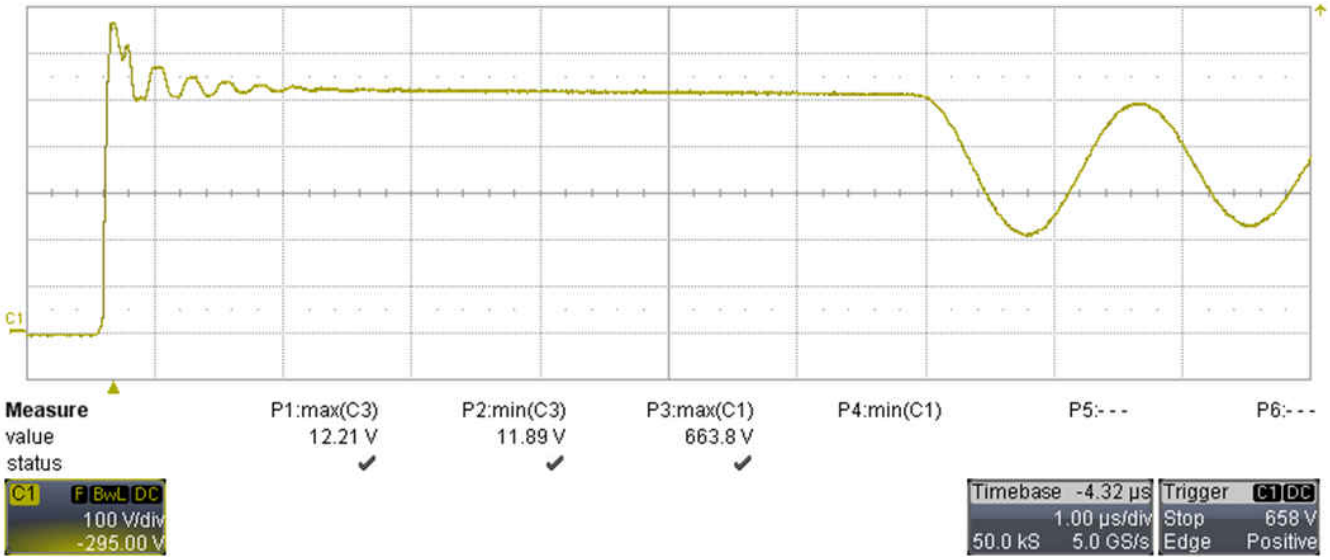


Figure 3-2. Waveform Q1-V_{DS} (100 V/div, 1 µs/div, 200 MHz BWL)

3.2 Output Voltage Ripple

The output voltage ripple was measured by supplying the converter at 230 V_{AC}, while loaded at 1.7 A; the bandwidth limit of oscilloscope (BWL) was set to 20 MHz.

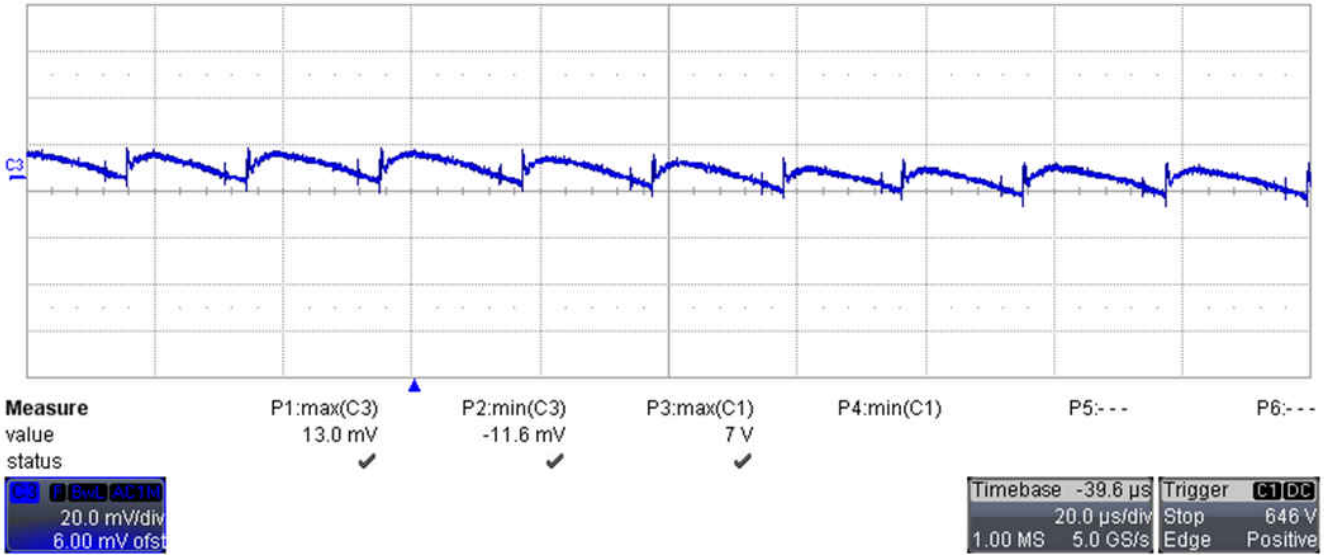


Figure 3-3. Output Voltage (20 mV/div, 20 µs/div, AC coupling)

Figure 3-4 is the same measurement as in Figure 3-3 but with longer time division, showing details about low frequency ripple.

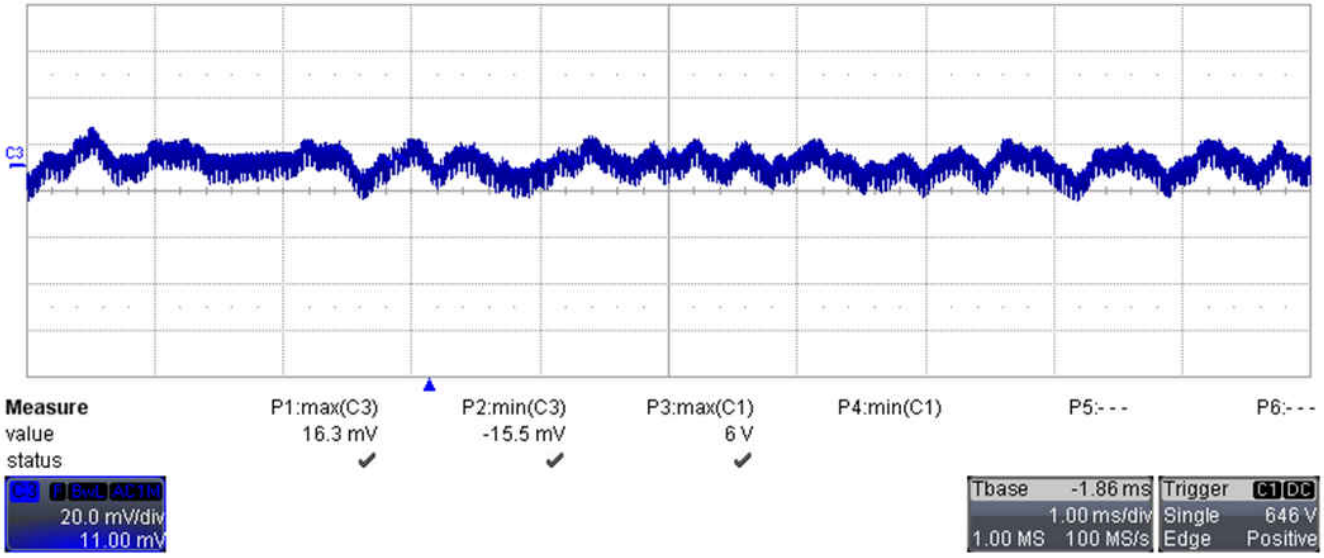


Figure 3-4. Output Voltage (20 mV/div, 1 ms/div, AC coupling)

3.3 Load Transients

The output voltage variation, during load transients, was measured by supplying the converter at 230 V_{AC}. The load was switched between 0 A and 1.7 A. For voltage and current measurement, the bandwidth limit of oscilloscope was set to 20 MHz.

- C3: Output voltage (200 mV/div, 10 ms/div, AC coupling)
- C4: Output current (1 A/div, DC coupling)

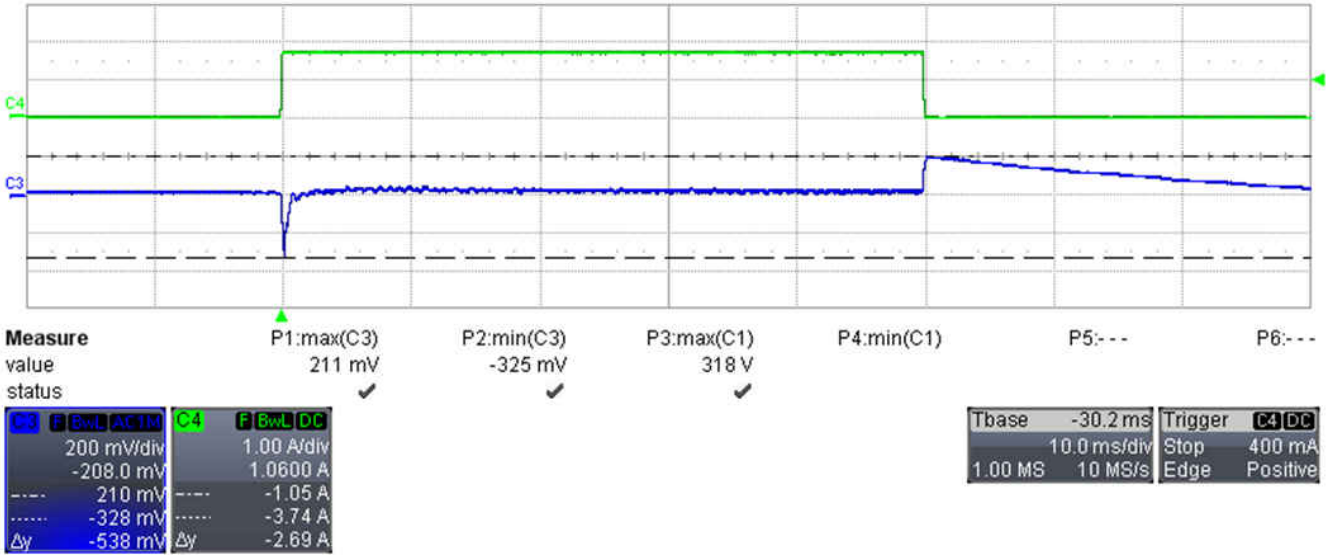


Figure 3-5. Load Transient

3.4 Start-Up and Shutdown Sequence

During these tests, the AC source was turned on and off. The input (230 V_{AC}) and output voltages were measured (BWL limited to 20 MHz).

3.4.1 Start-Up Sequence

3.4.1.1 Load Current 0 A

- C1: Input AC voltage (200 V/div, 100 ms/div, DC coupling)
- C3: Output voltage (5 V/div, DC coupling)

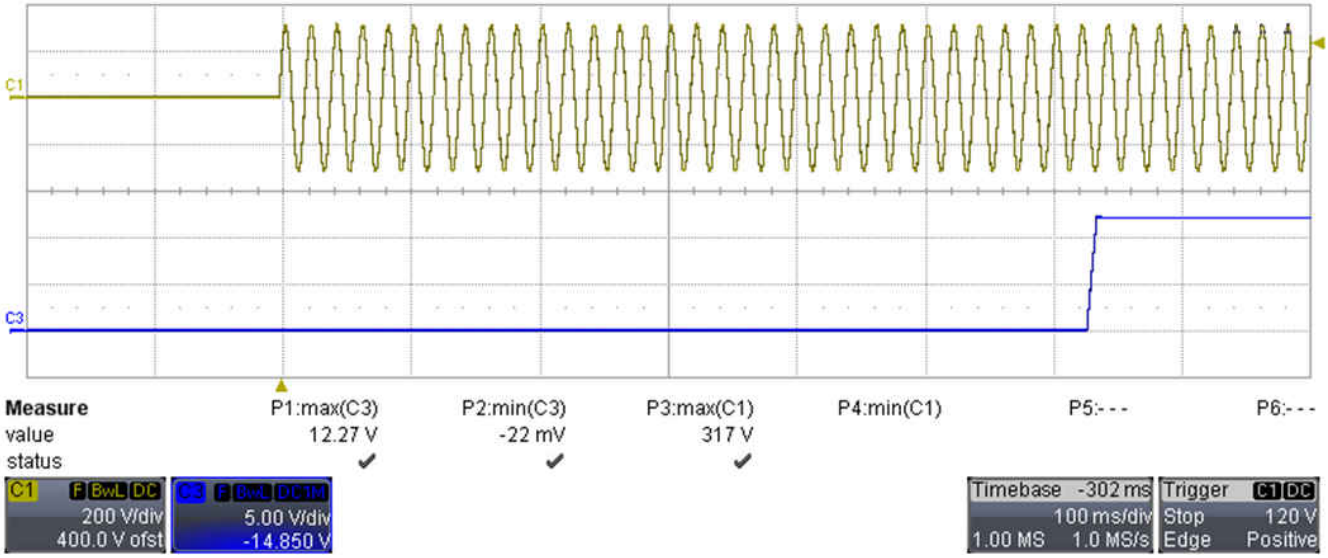


Figure 3-6. Start-Up With 0-A Load (100 ms/div)

Figure 3-7 is the same measurement as in Figure 3-6 but with smaller time division (20 ms/div).

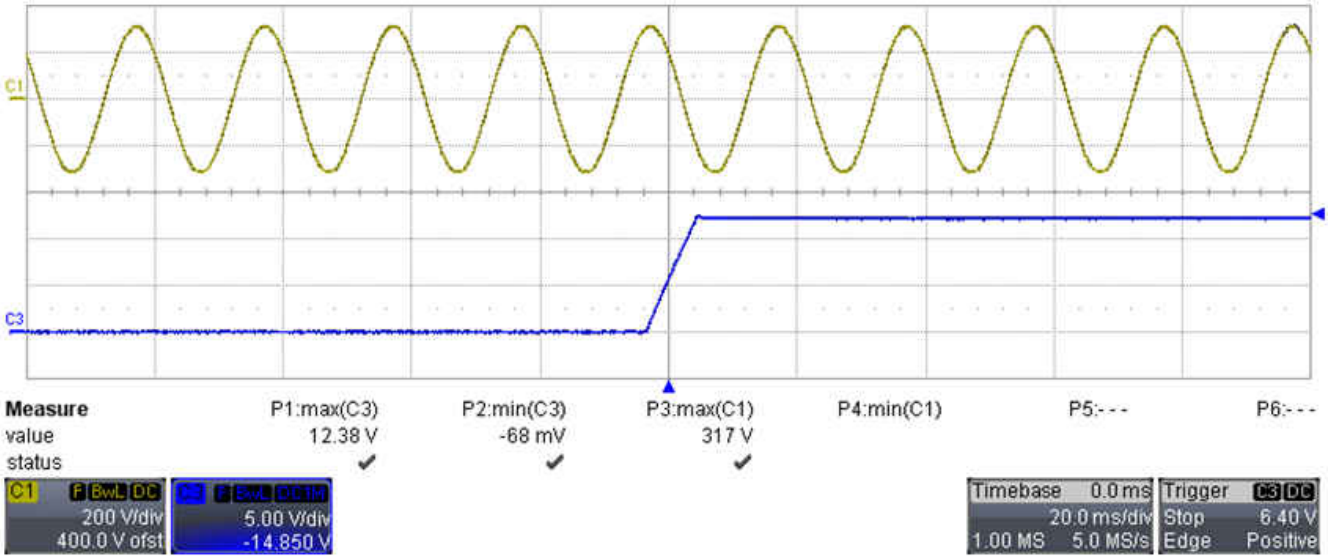


Figure 3-7. Start-Up With 0-A Load (20 ms/div)

3.4.1.2 Load Current 1.7 A

- C1: Input AC voltage (200 V/div, 100 ms/div, DC coupling)
- C3: Output voltage (5 V/div, DC coupling)

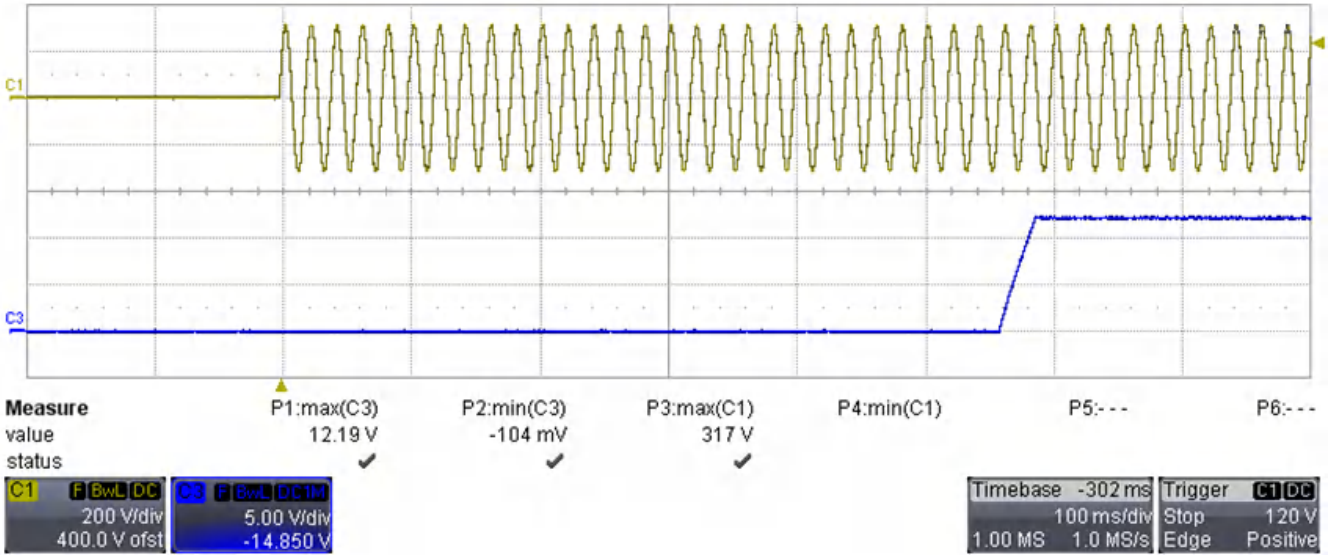


Figure 3-8. Start-Up With 1.7-A Load (100 ms/div)

Figure 3-9 is the same measurement as in Figure 3-8 but with smaller time division (20 ms/div).

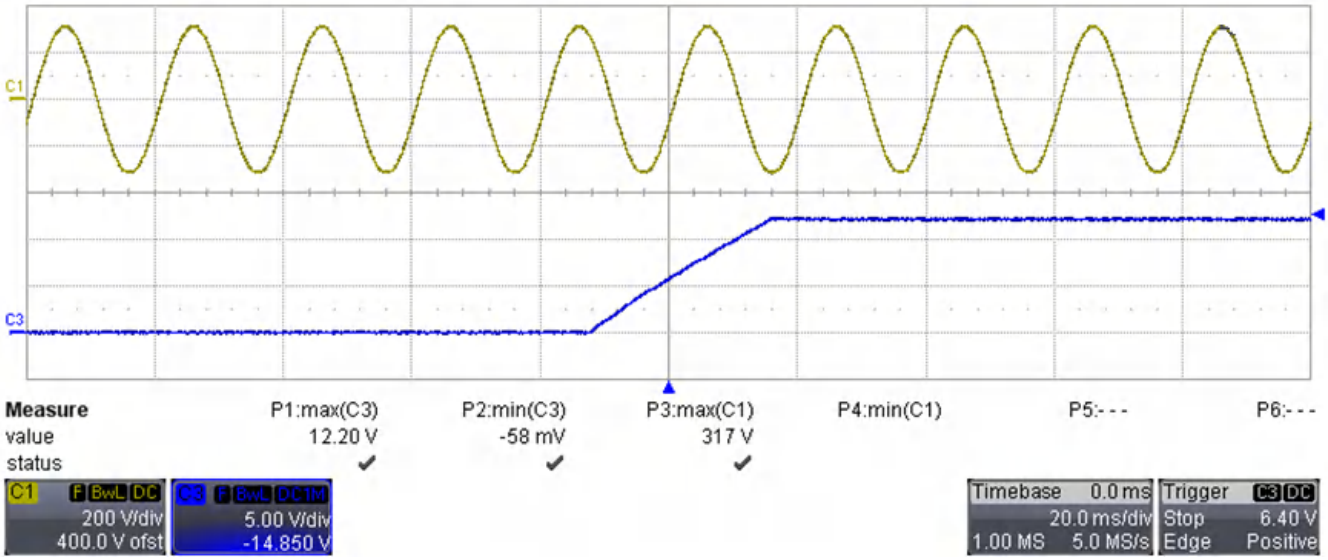


Figure 3-9. Start-Up With 1.7-A Load (20 ms/div)

3.4.2 Shutdown Sequence

The output voltage was measured by switching off the AC voltage source while the load was set to 1.7 A and V_{IN} to 230 V_{AC}.

- C1: Input AC voltage (200 V/div, 20 ms/div, DC coupling)
- C3: Output voltage (5 V/div, DC coupling)

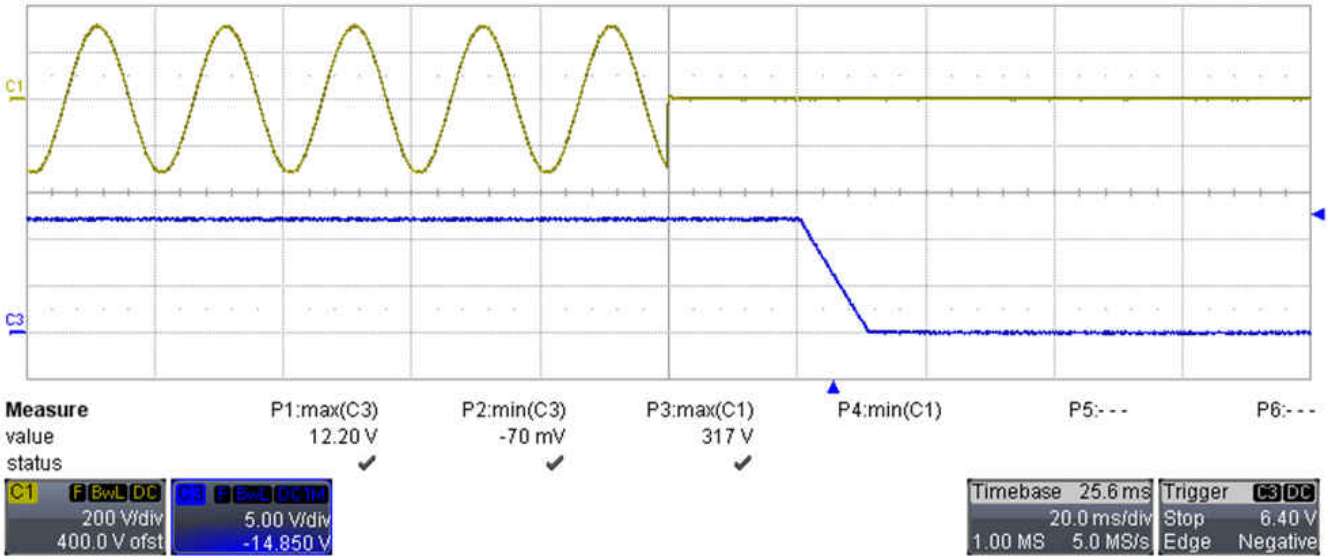


Figure 3-10. Shutdown Sequence With 1.7-A Load Current

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