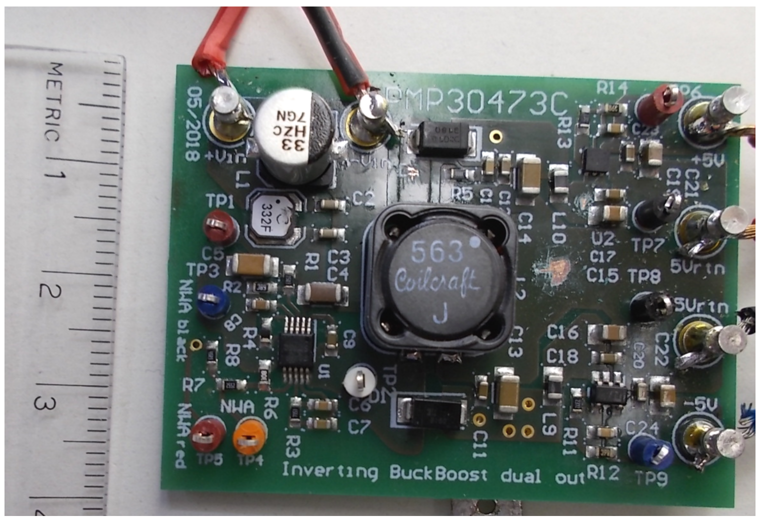
Test Report: PMP30473
Lowest Noise Auxiliary Dual Output Power Supply Reference Design

Description

This reference design is a 2 x 1-W inverting buck boost converter. The two output voltages (+5 V and -5 V) are produced from one single buck silicon (TPS57160-Q1). Post regulators (and post filters) ensure ripple free output voltages. Input voltage range covers automotive and industrial applications.

Figure 1.



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1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
V_{IN}	+4 V to +42 V (>5 V for startup)
V_{OUT}	-5 V; +5 V
I_{OUT}	200 mA (both channels)
Nominal switching frequency	300 kHz

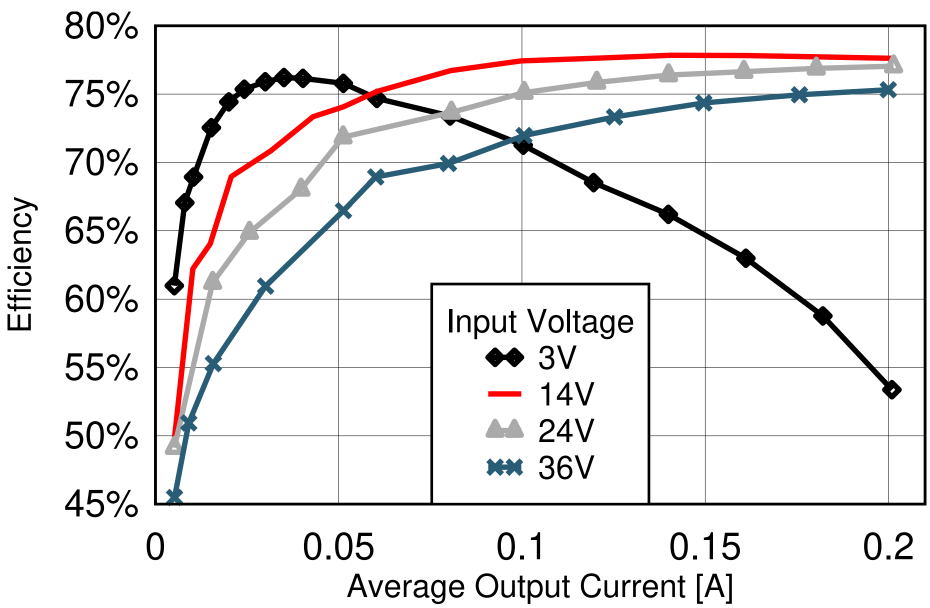
1.2 Considerations

The measured switching frequency is 273 kHz. At 50 mA output current the circuit switches on at 5 V. Unless otherwise mentioned the circuit was measured at 200 mA load on each channel (adjusted with a variable resistor)

2 Testing and Results

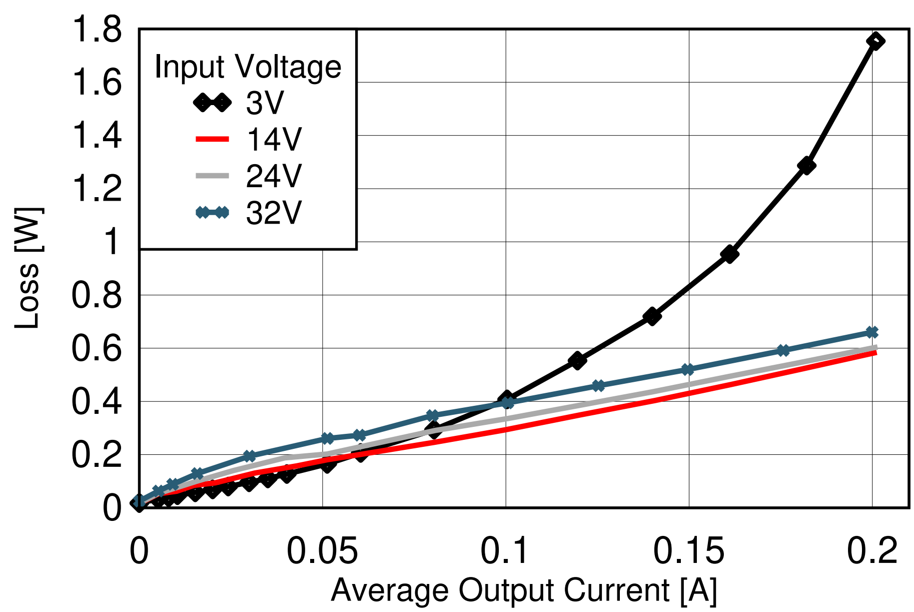
2.1 Efficiency Graph

Figure 2. Efficiency vs Output Current



Exce

Figure 3. Loss vs Output Current



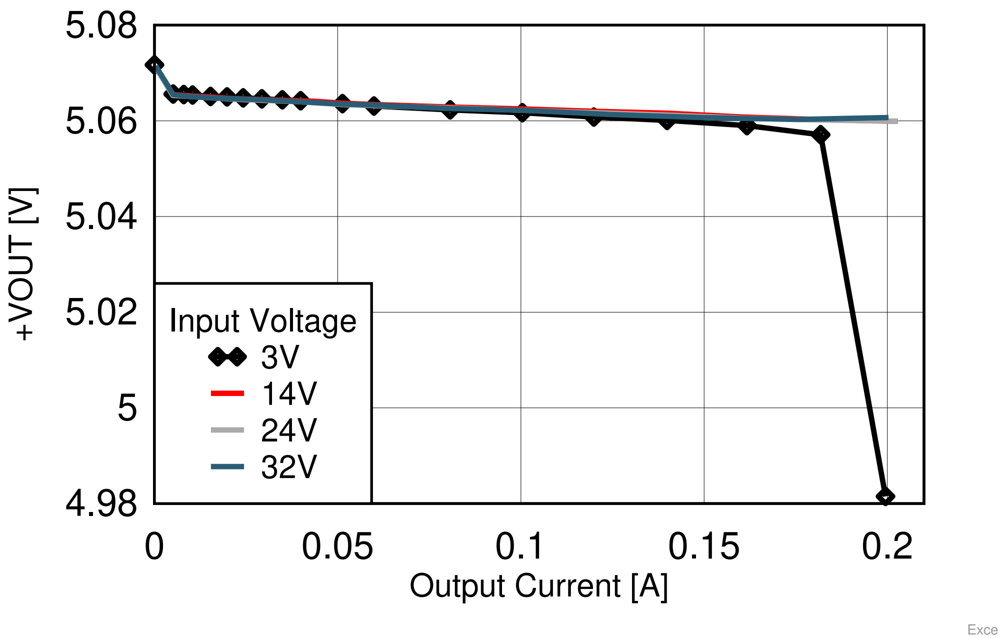
Exce

2.2 Load Regulation

2.2.1 VOUT (LDO)

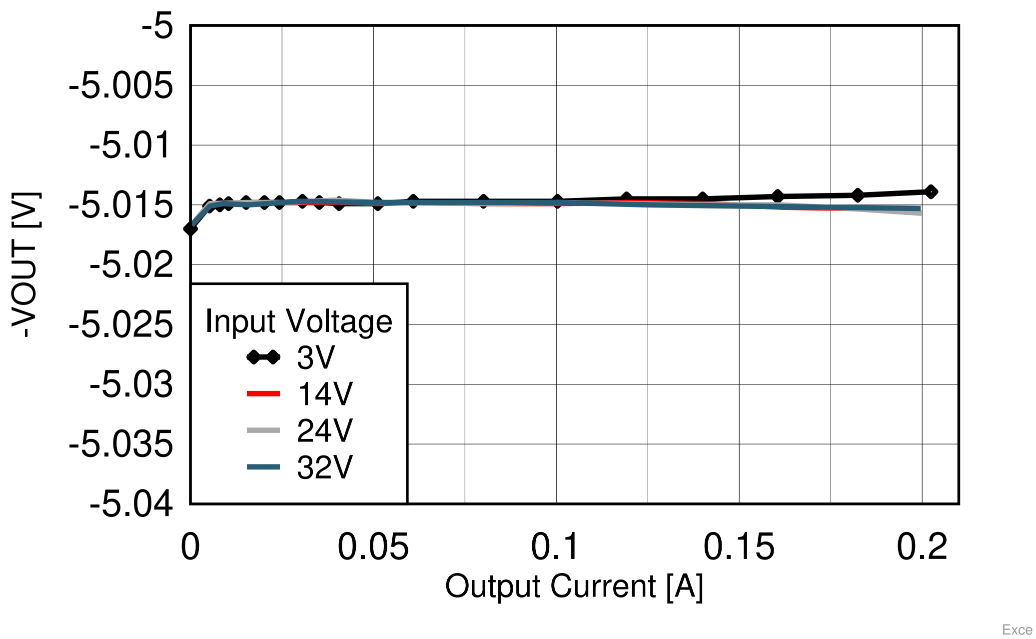
Output currents were varied symmetrical.

Figure 4. +VOUT vs Output Current



Following figure has nearly the same Y-scale for comparisons reasons.

Figure 5. -Vout vs Output Current



2.2.2 VOUT (Powerstage)

2.2.2.1 *Symmetrical Load*

Output currents were varied symmetrical.

Figure 6. +VOUT (Powerstage) vs Output Current

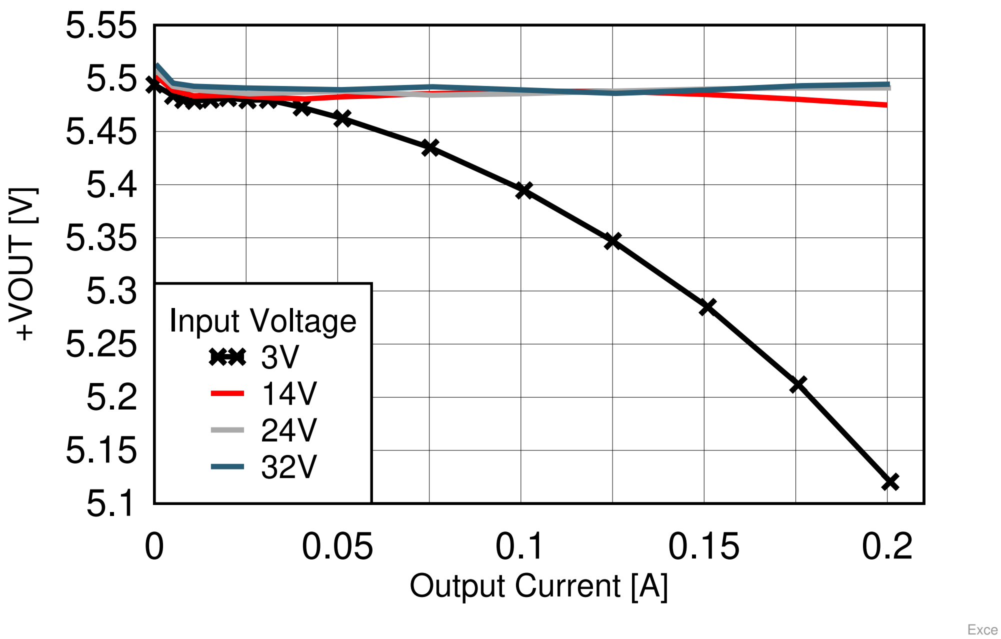
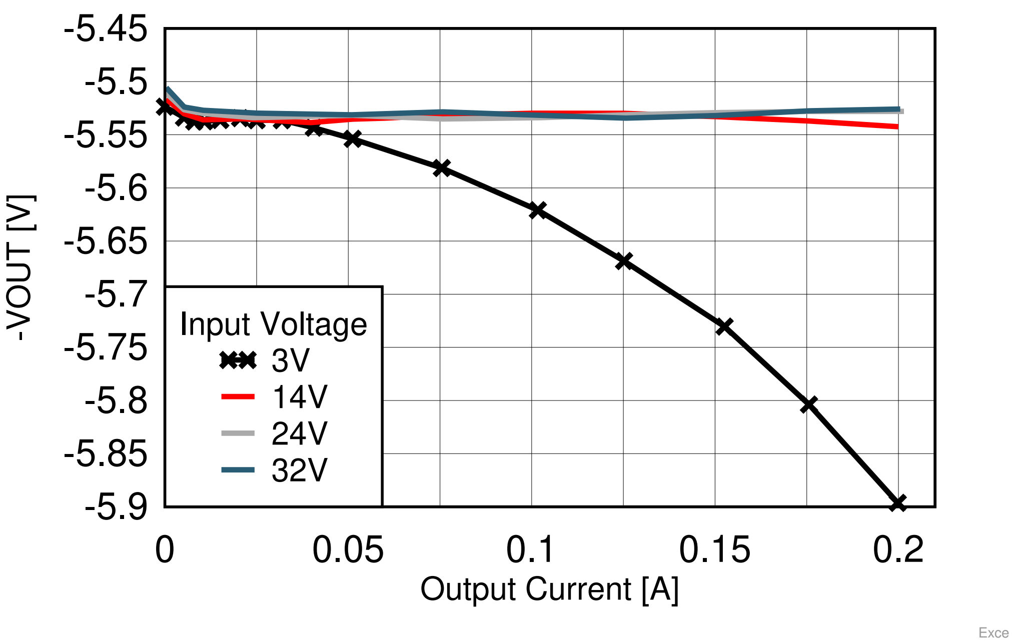


Figure 7. -VOUT (Powerstage) vs Output Current



2.2.2.2 Symmetrical-Unsymmetrical Load Comparison

The input voltage was 14 V.

Figure 8. +VOUT (Powerstage) vs Output Current

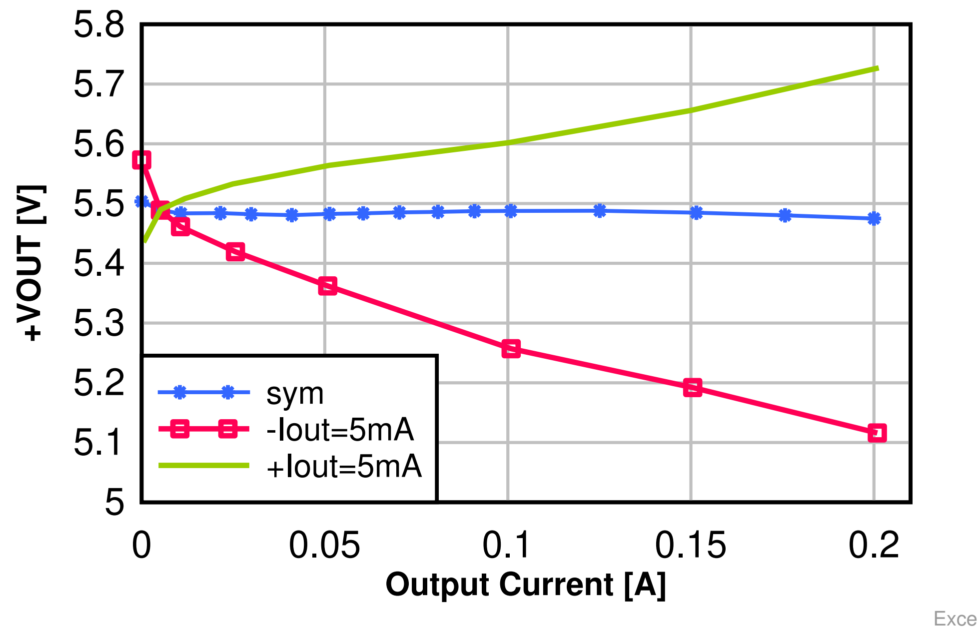
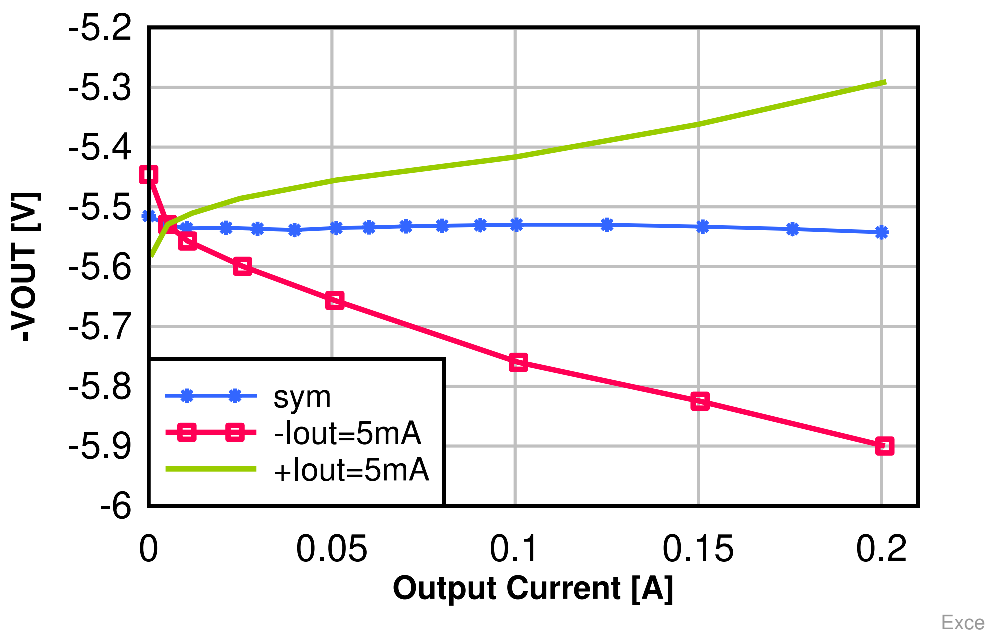


Figure 9. -VOUT (Powerstage) vs Output Current



blue curve -> -IOUT and +IOUT were varied together

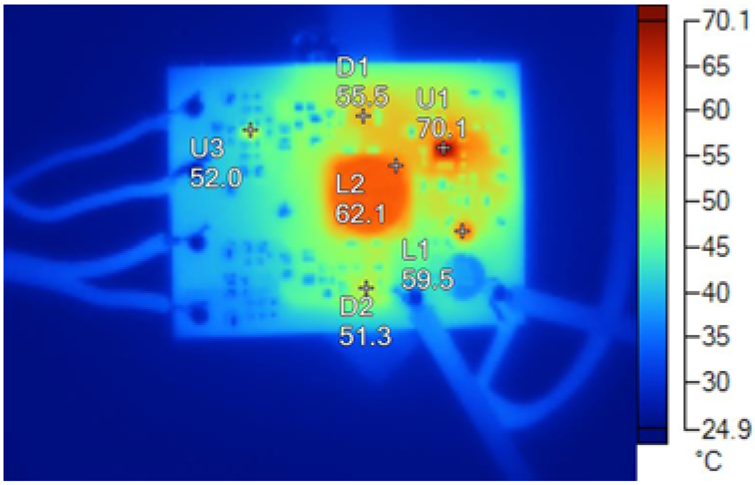
green curve -> -IOUT stays at 5 mA; only +IOUT was varied

red curve -> +IOUT stays at 5 mA; only -IOUT was varied

2.3 Thermal Images

2.3.1 3 V Input Voltage

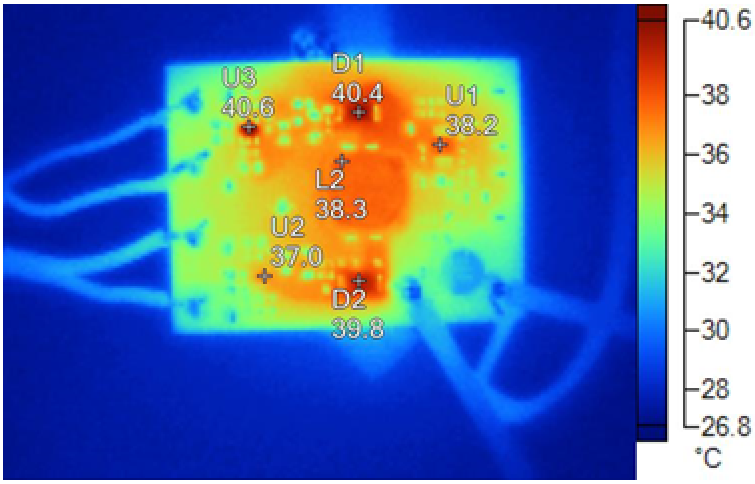
Figure 10. Thermal Image @ 3 V Input Voltage



Name	Temperature
D1	55.5°C
D2	51.3°C
L1	59.5°C
L2	62.1°C
U1	70.1°C
U3	52.0°C

2.3.2 14 V Input Voltage

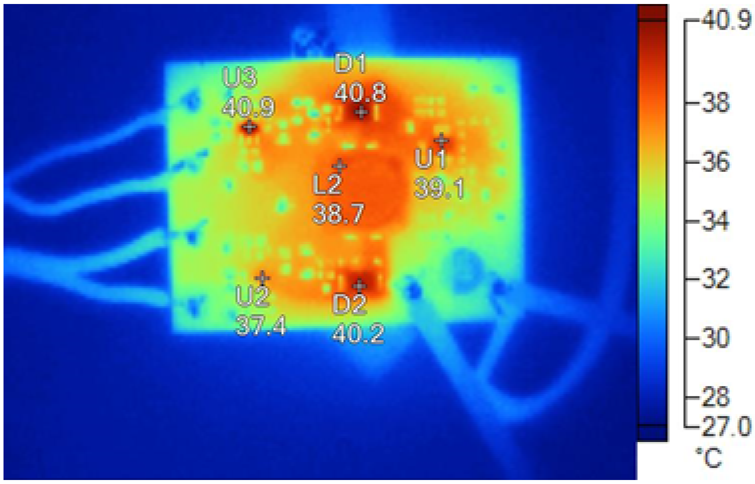
Figure 11. Thermal Image @ 14 V Input Voltage



Name	Temperature
D1	40.4°C
D2	39.8°C
L2	38.3°C
U1	38.2°C
U2	37.0°C
U3	40.6°C

2.3.3 24 V Input Voltage

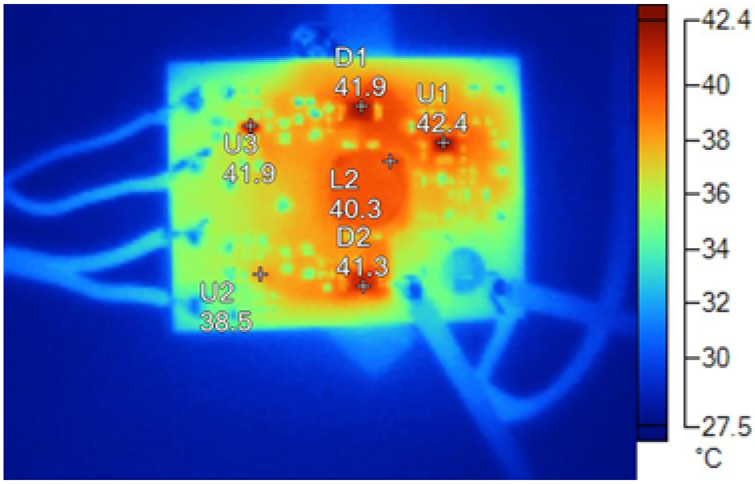
Figure 12. Thermal Image @ 24 V Input Voltage



Name	Temperature
D1	40.8°C
D2	40.2°C
L2	38.7°C
U1	39.1°C
U2	37.4°C
U3	40.9°C

2.3.4 36 V Input Voltage

Figure 13. Thermal Image @ 36 V Input Voltage



Name	Temperature
D1	41.9°C
D2	41.3°C
L2	40.3°C
U1	42.4°C
U2	38.5°C
U3	41.9°C

3 Waveforms

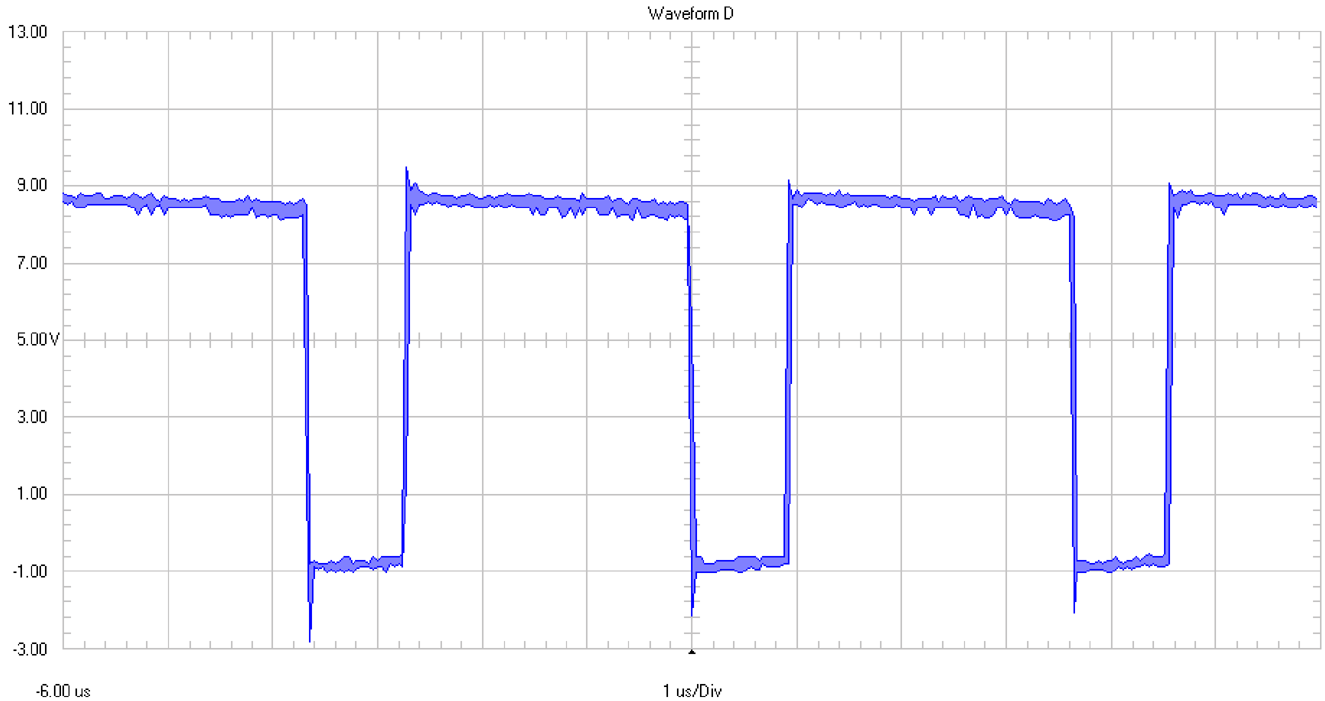
3.1 Switching

Measurements were done with full bandwidth.

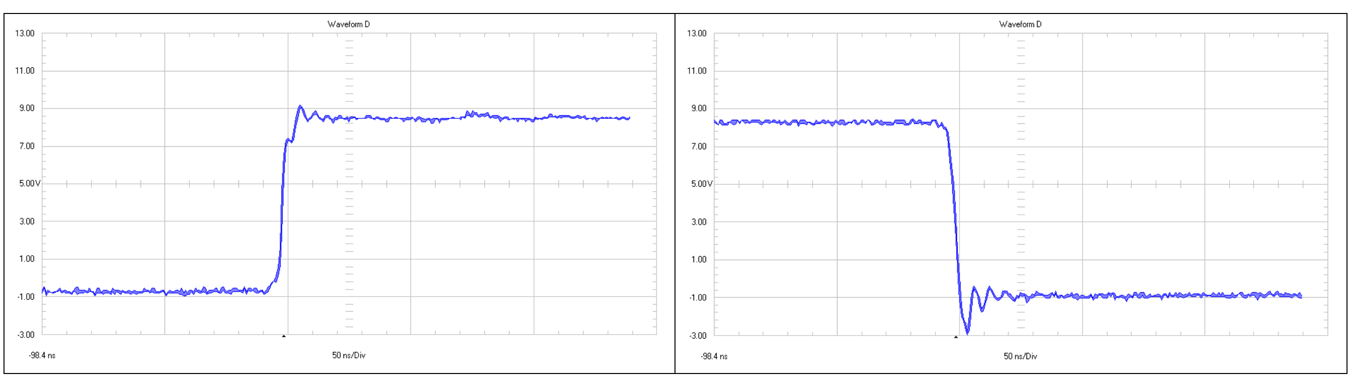
3.1.1 Waveforms D1

Figures below are measured at 3 V input voltage.

Figure 14. D1 at 3 V Input Voltage



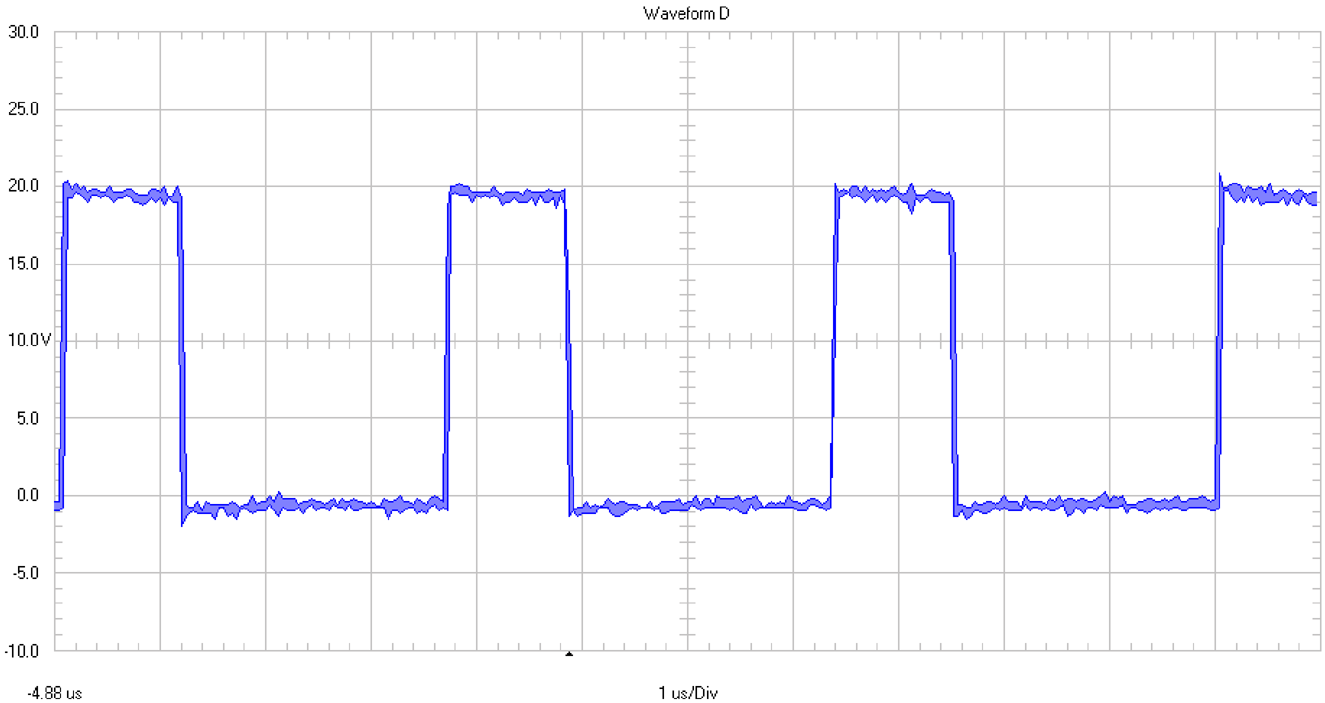
- 2 V/div
- 1 µs/div



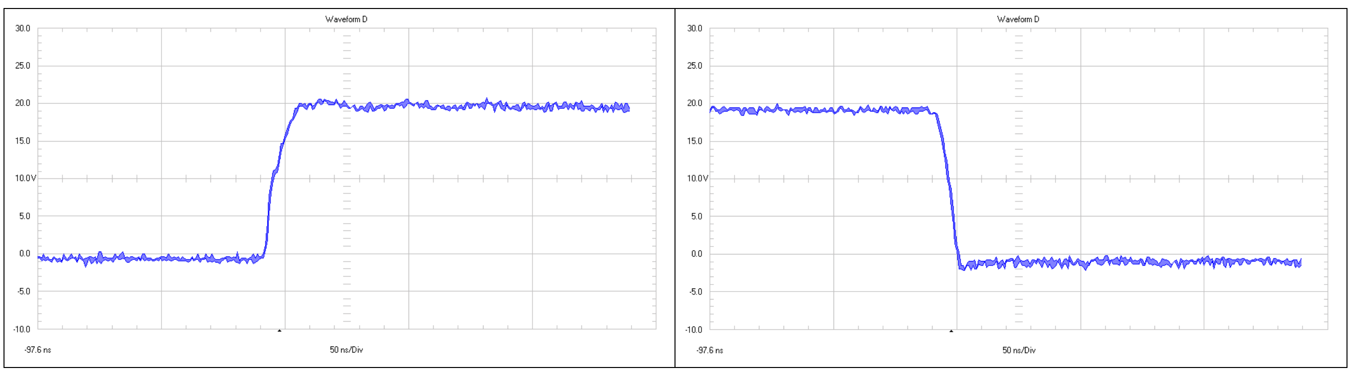
- 50 ns/div

Figures below are measured at 14 V input voltage.

Figure 15. D1 at 14 V Input Voltage



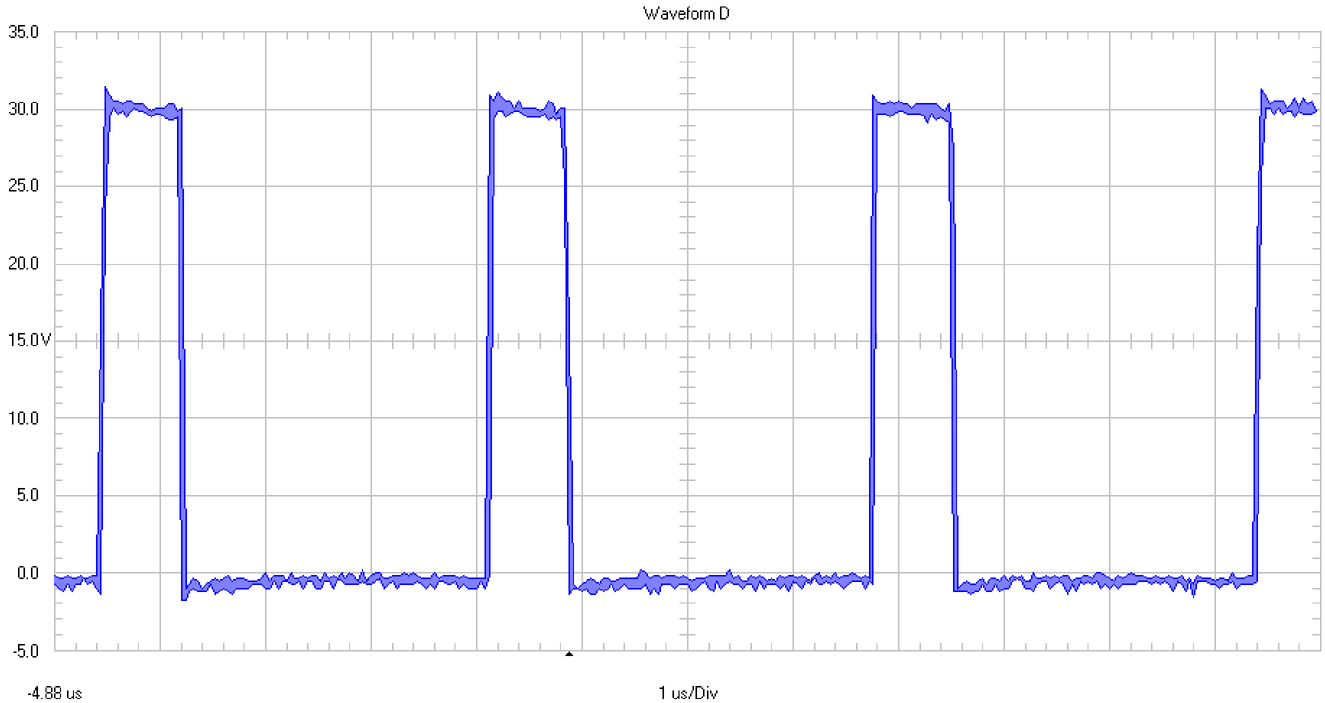
- 5 V/div
- 1 µs/div



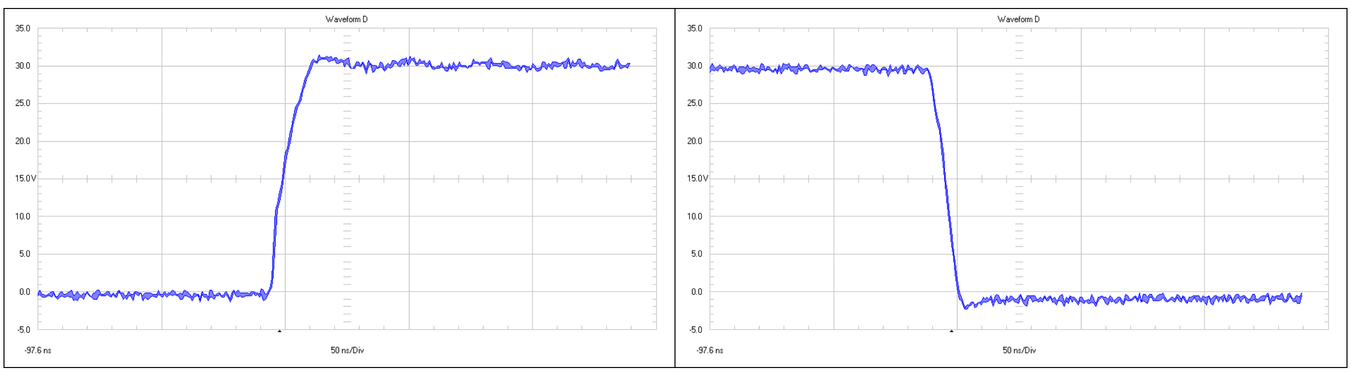
- 50 ns/div

The following waveforms are showing measurements at 24 V input voltage.

Figure 16. D1 at 24 V Input Voltage



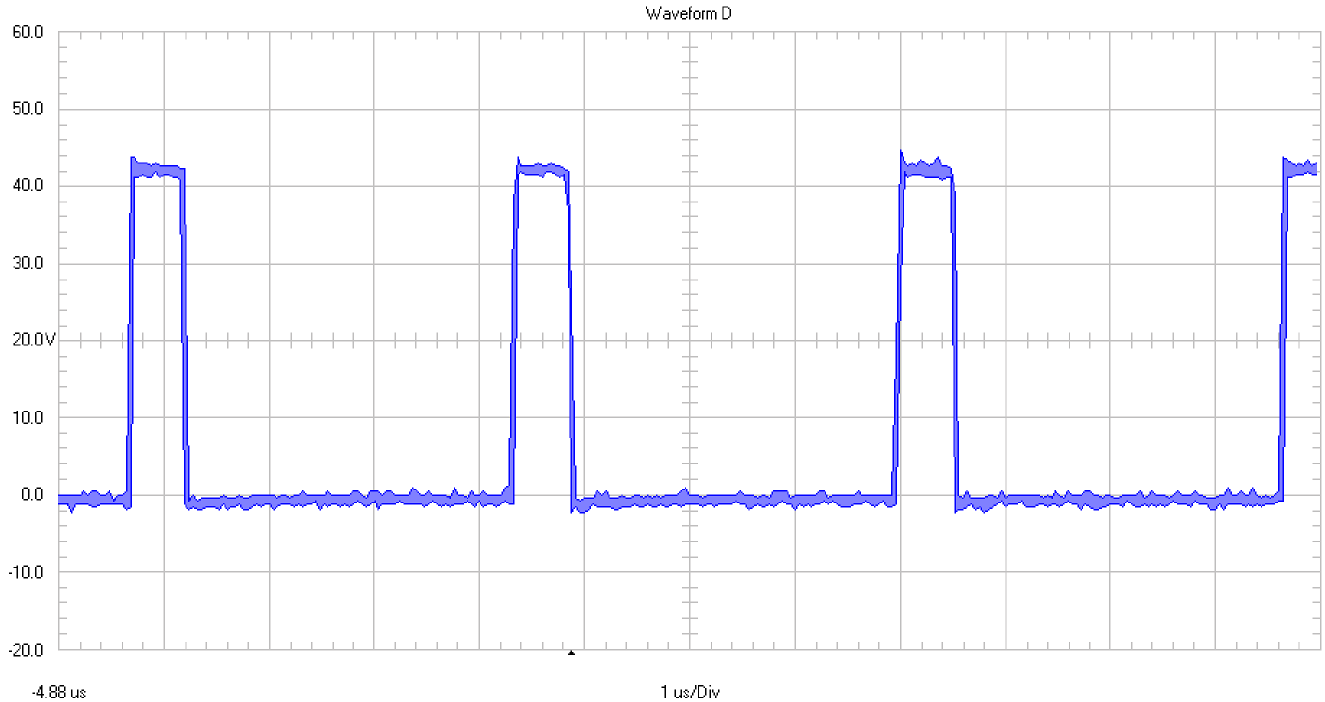
- 5 V/div
- 1 µs/div



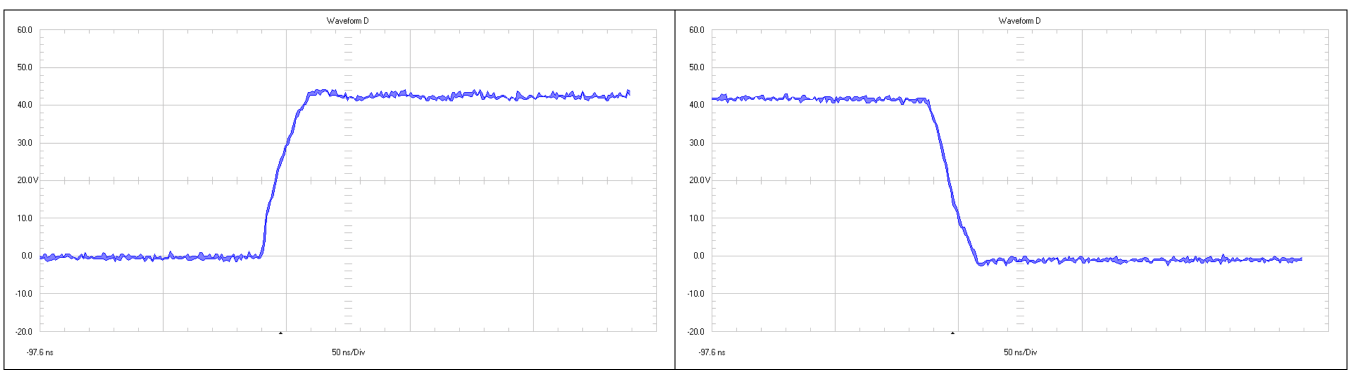
- 50 ns/div

The following waveforms are showing measurements at 36 V input voltage

Figure 17. D1 at 36 V Input Voltage



- 10 V/div
- 1 µs/div



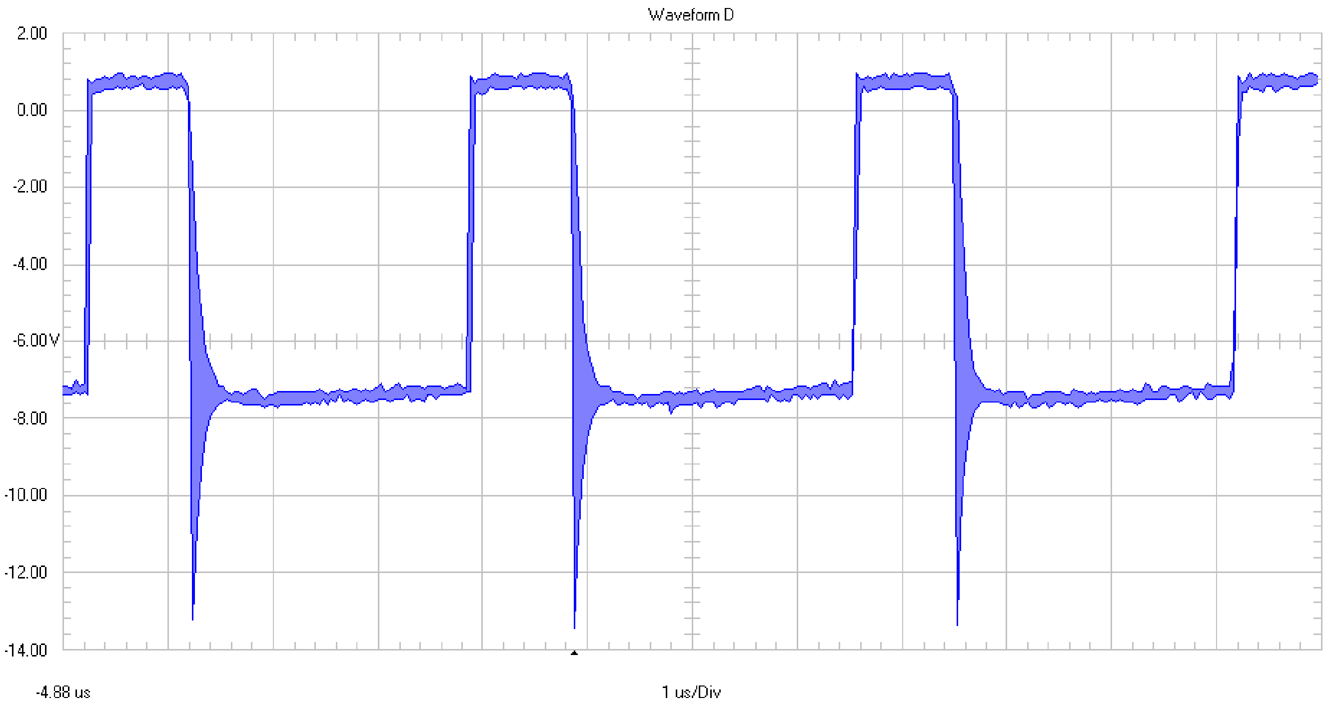
- 50 ns/div

3.1.2 Waveform D2

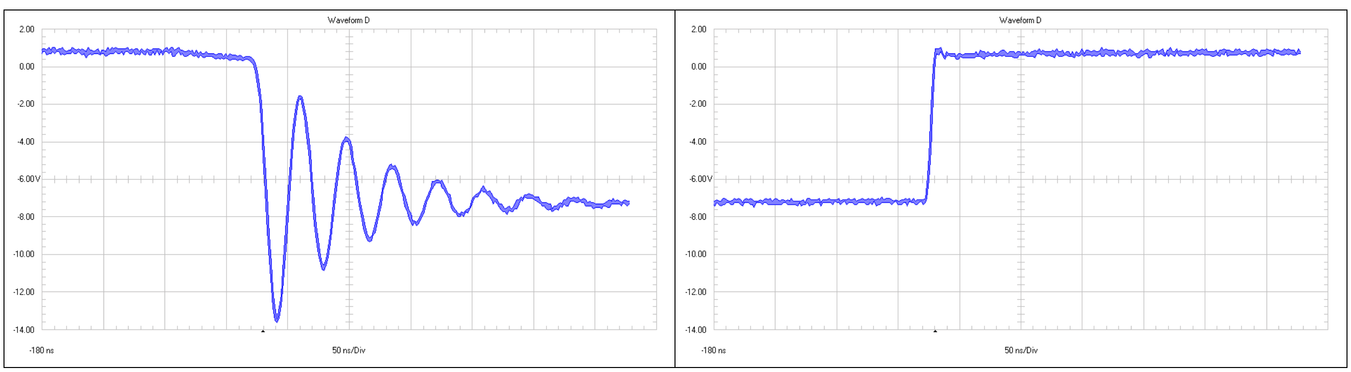
The following waveforms are showing measurements at 3 V input voltage.

(referenced to +5.5 V)

Figure 18. D1 at 3 V Input Voltage



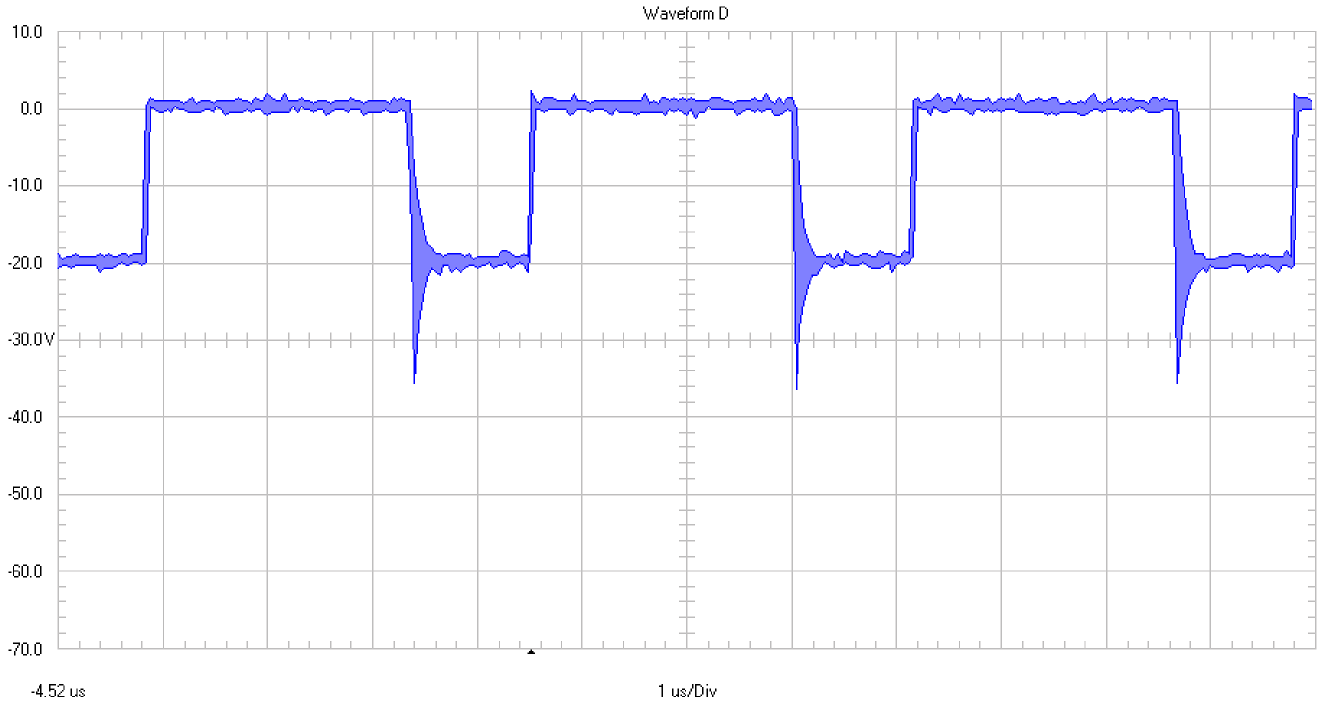
- 2 V/div
- 1 µs/div



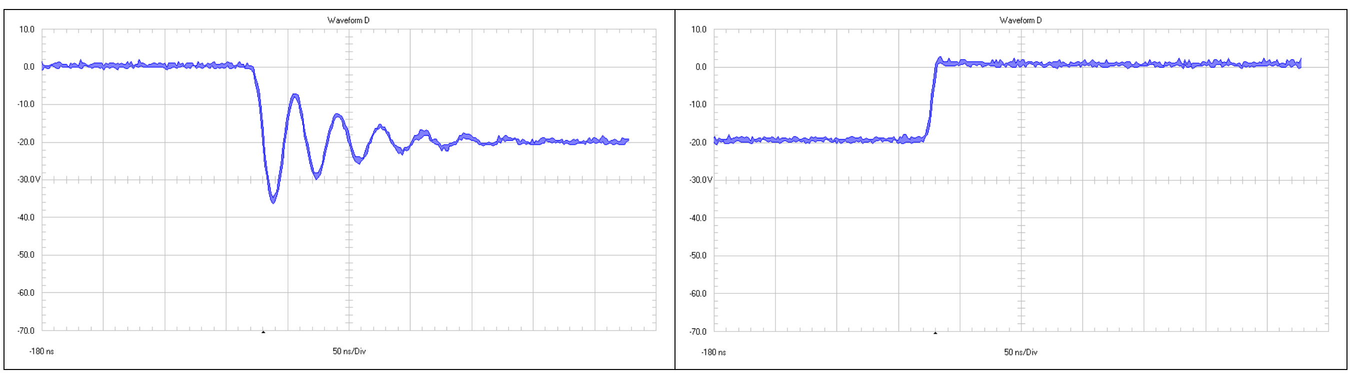
- 50 ns/div

The following waveforms are showing measurements at 14 V input voltage

Figure 19. D2 at 14 V Input Voltage



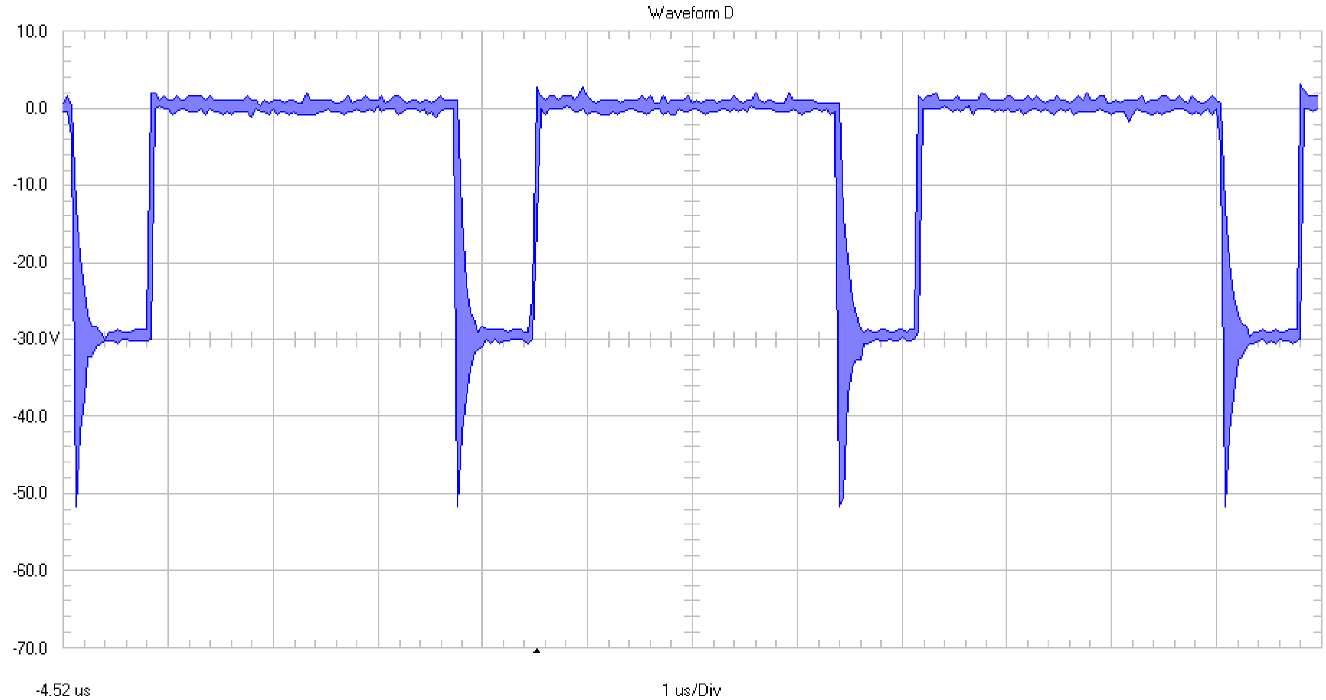
- 10 V/div
- 1 µs/div



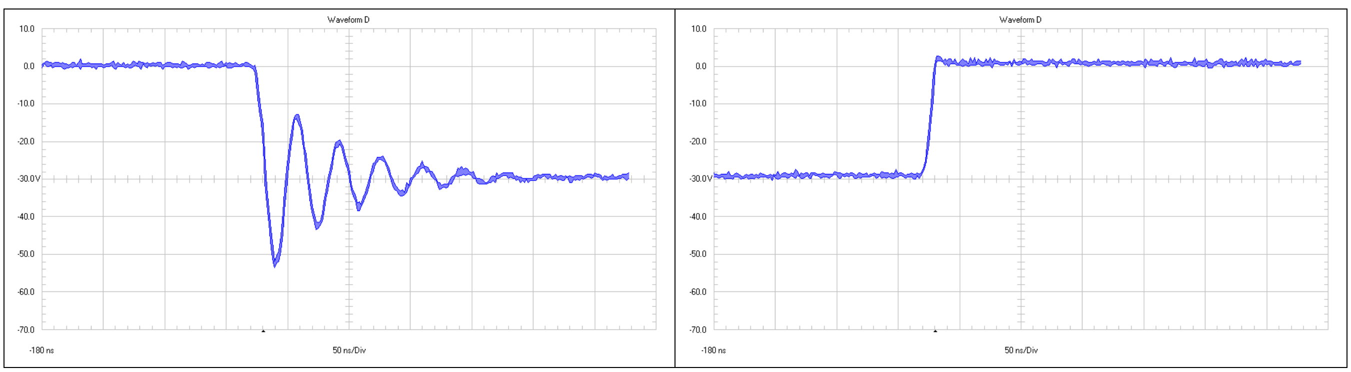
- 50 ns/div

The following waveforms are showing measurements at 24 V input voltage

Figure 20. D2 at 24 V Input Voltage



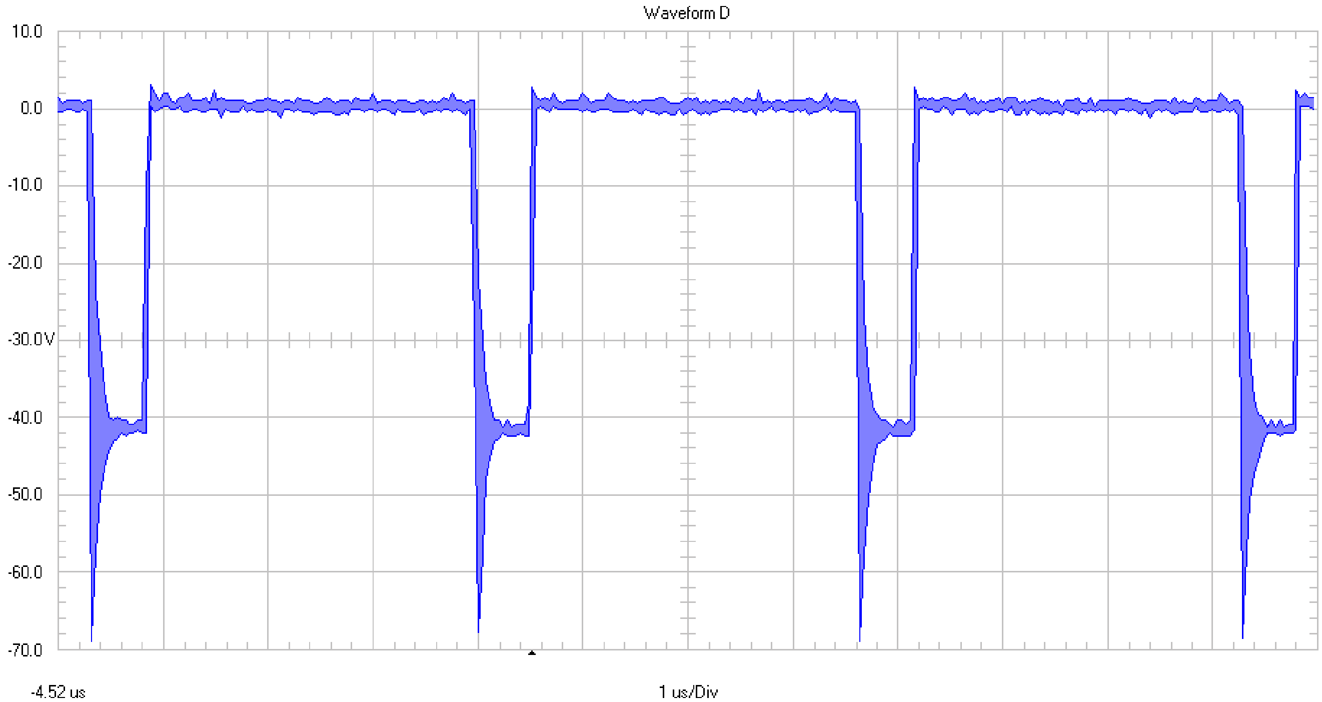
- 10 V/div
- 1 µs/div



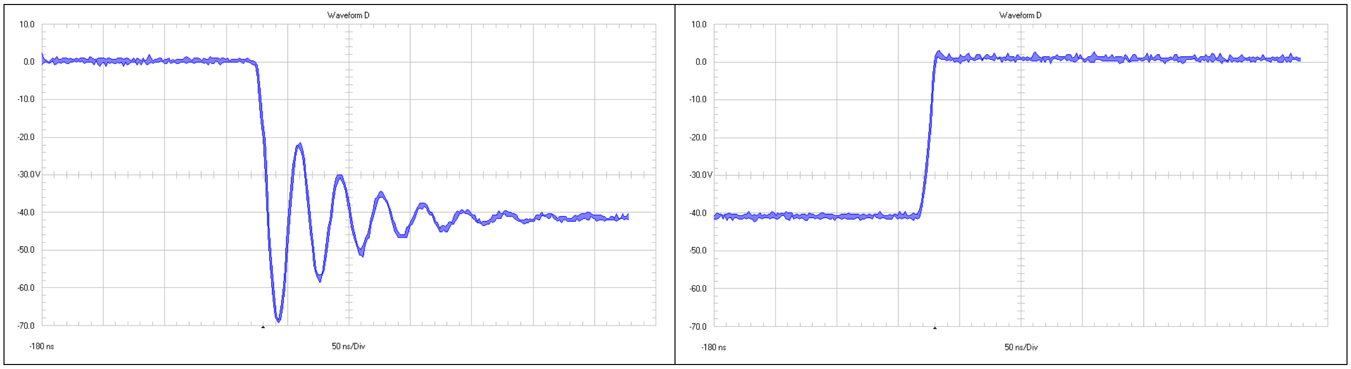
- 50 ns/div

The following waveforms are showing measurements at 36 V input voltage

Figure 21. D2 at 36 V Input Voltage



- 10 V/div
- 1 µs/div



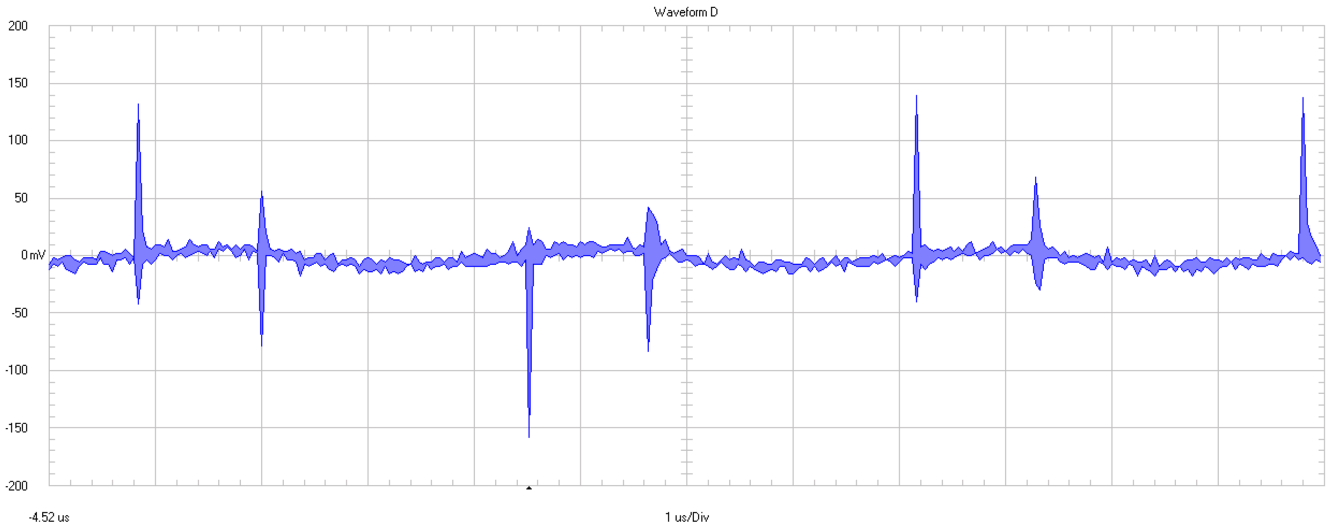
50 ns/div

3.2 Output Voltage Ripple

The input voltage was set to 14 V. Measurements were done with full bandwidth.

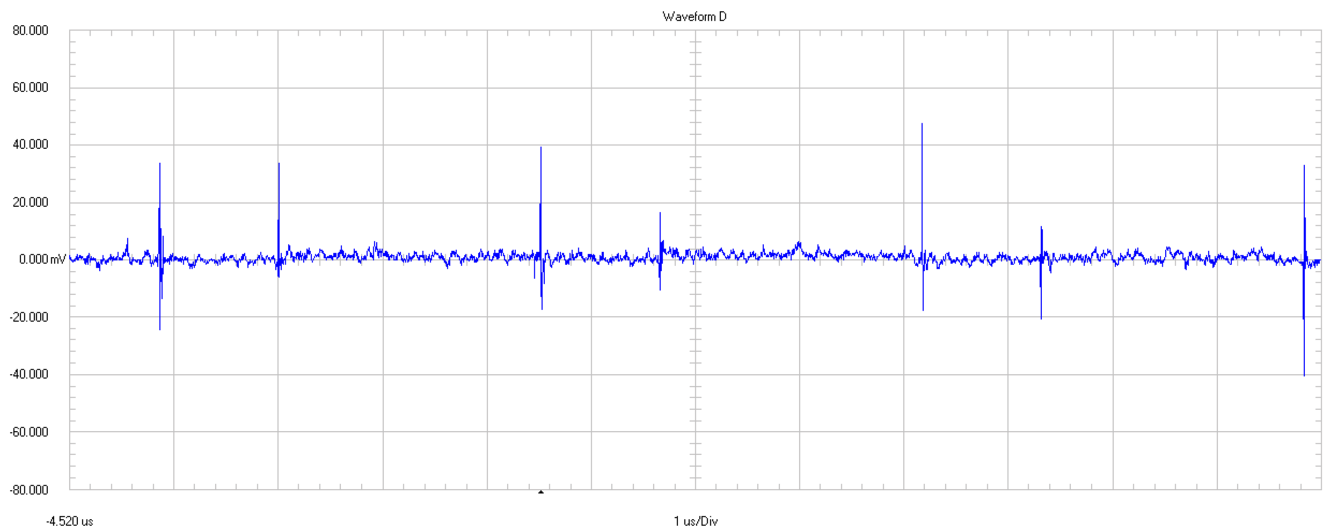
3.2.1 -VOUT

Figure 22. -VOUT (Powerstage)



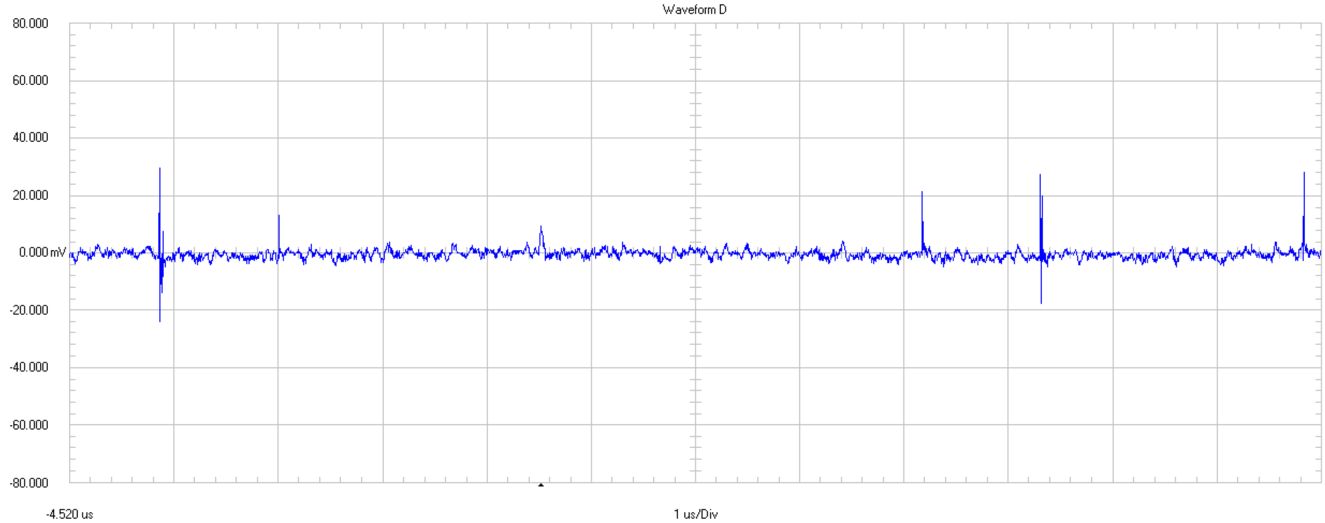
- 50 mV/div
- 1 µs/div

Figure 23. -VOUT (Powerstage) after filter inductor



- 20 mV/div
- 1 µs/div

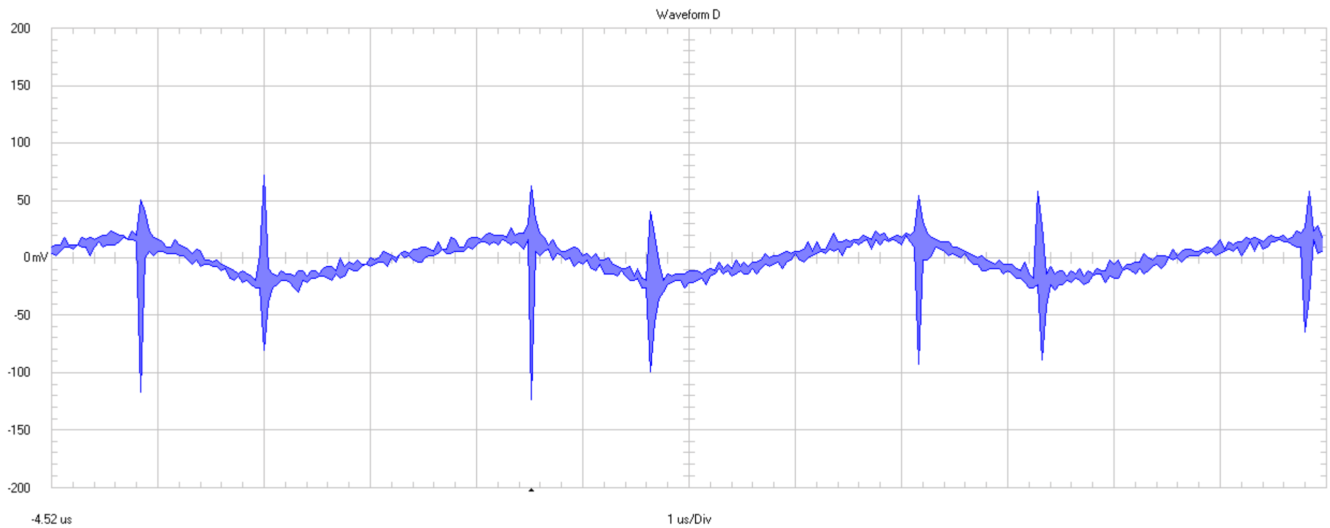
Figure 24. -VOUT (LDO)



- 20 mV/div
- 1 µs/div

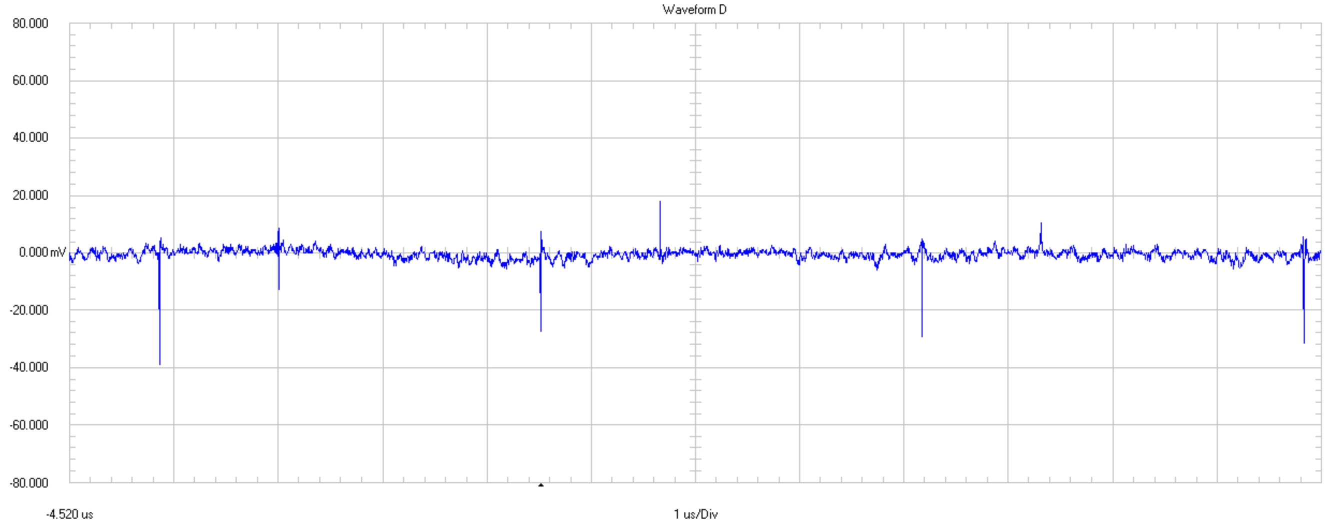
3.2.2 +VOUT

Figure 25. +VOUT (Powerstage)



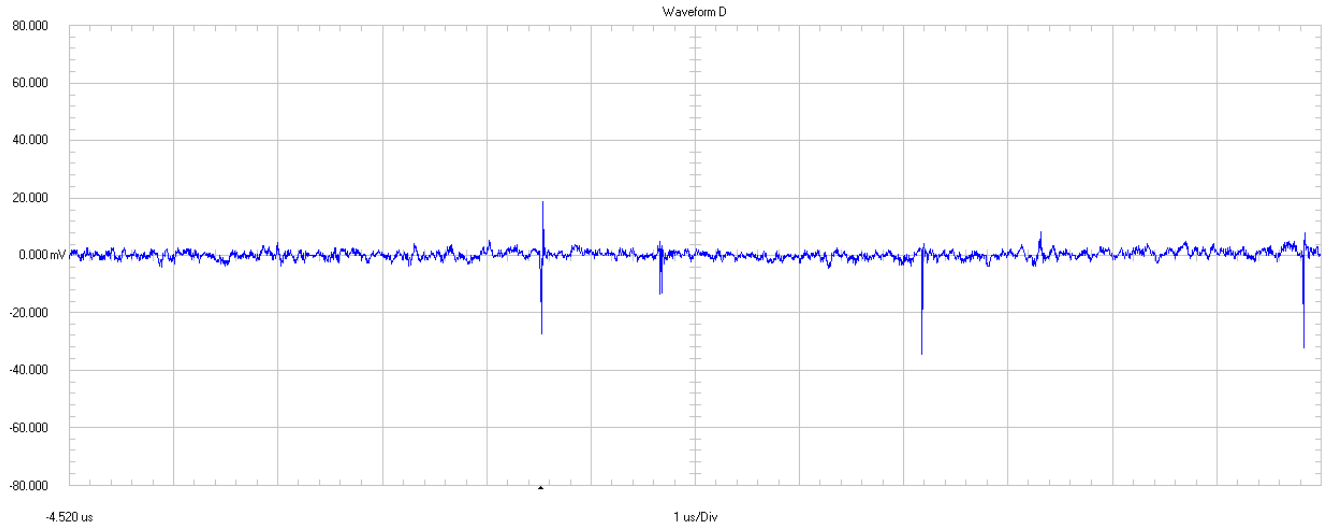
- 50 mV/div
- 1 µs/div

Figure 26. +VOUT (Powerstage) after filter inductor



- 20 mV/div
- 1 µs/div

Figure 27. +VOUT (LDO)



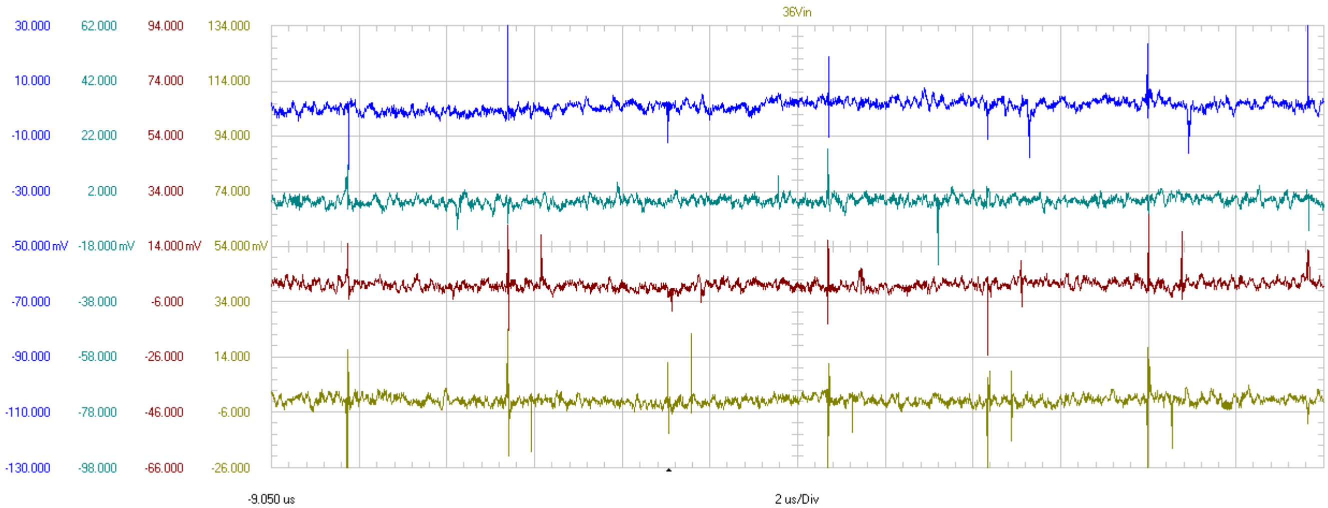
- 20 mV/div
- 1 µs/div

3.3 VIN (AC)

3.3.1 VIN (circuit input)

Measurements were done with full bandwidth

Figure 28. Input Voltage Ripple

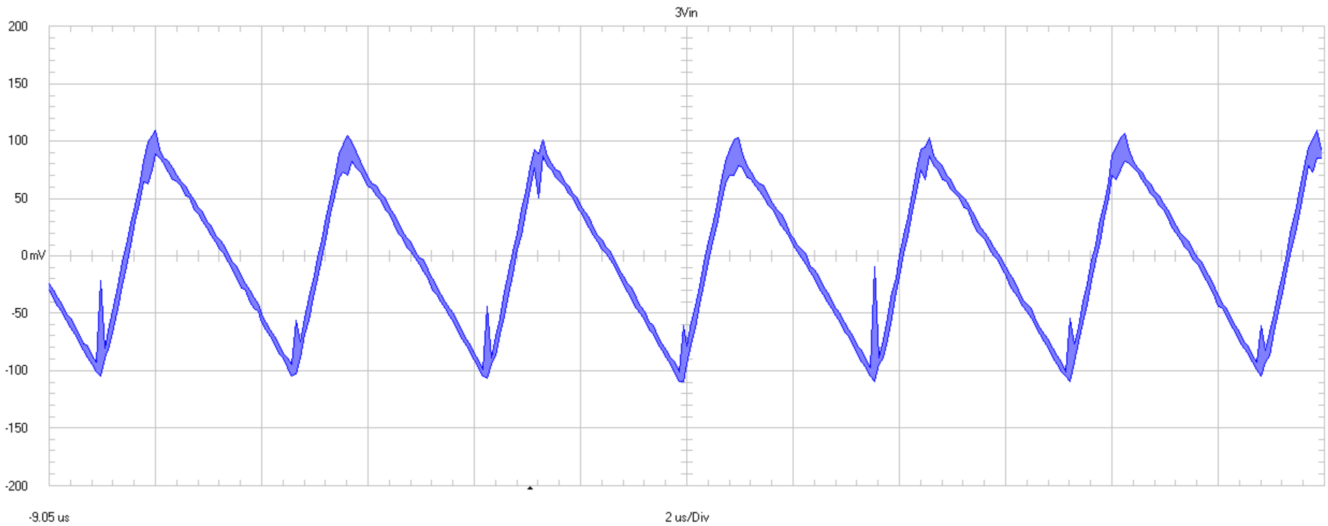


- ch1 :VIN 3 V => 20 mV/div
- ch2 :VIN 14 V => 20 mV/div
- ch3 :VIN 24 V => 20 mV/div
- ch4 :VIN 36 V => 20 mV/div
- 2 µs/div

3.3.2 VIN (after input filter)

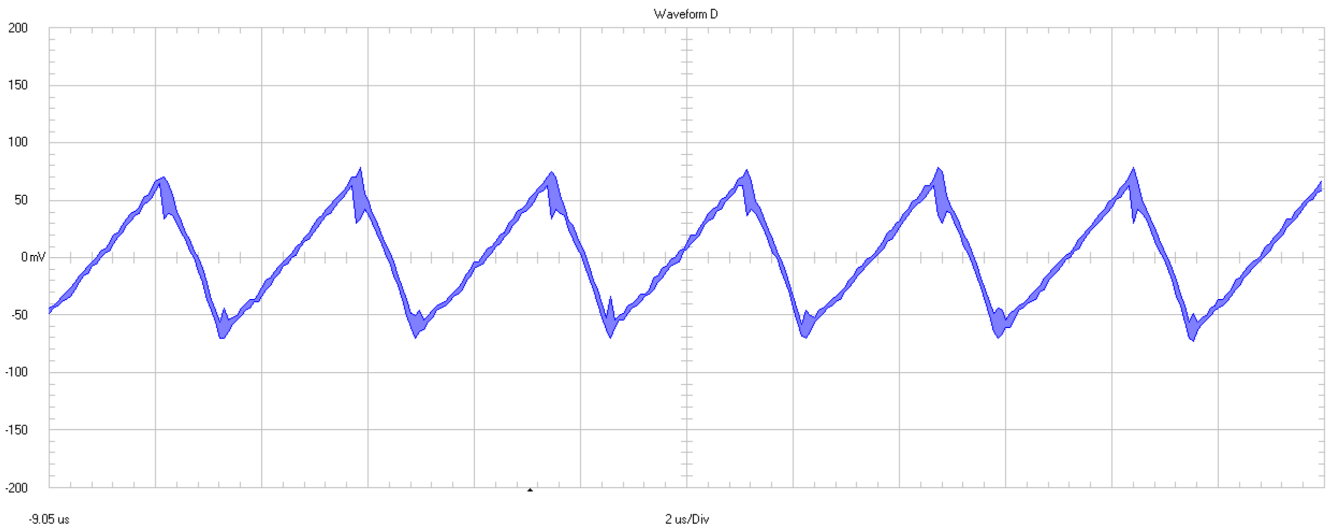
Measurements were done with 20 MHz bandwidth filter

Figure 29. 3 V VIN



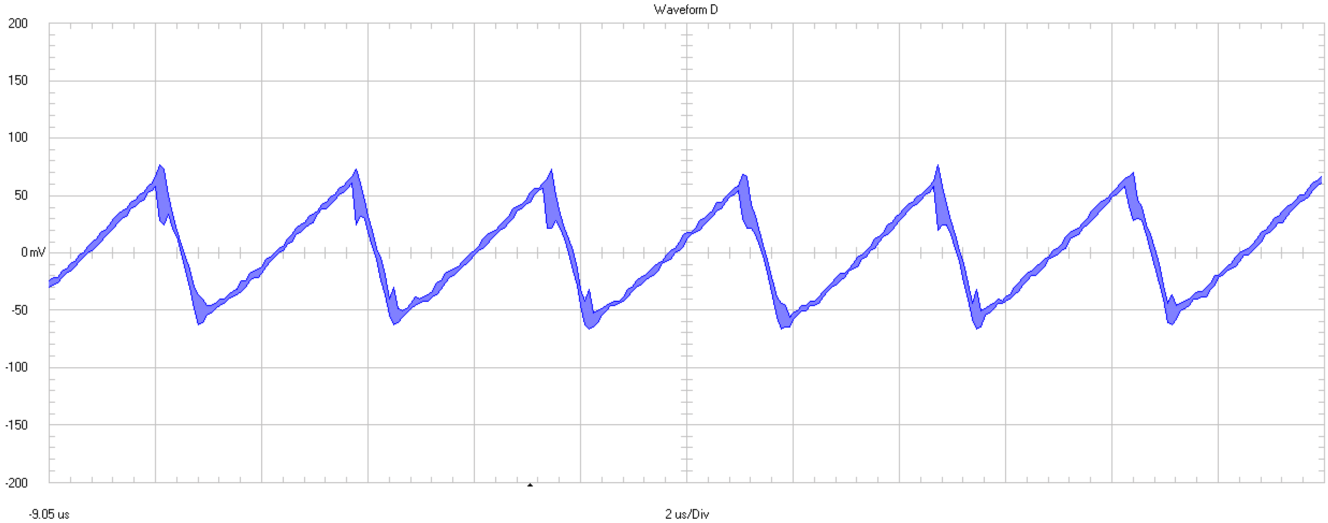
- 50 mV/div
- 2 µs/div

Figure 30. 14 V VIN



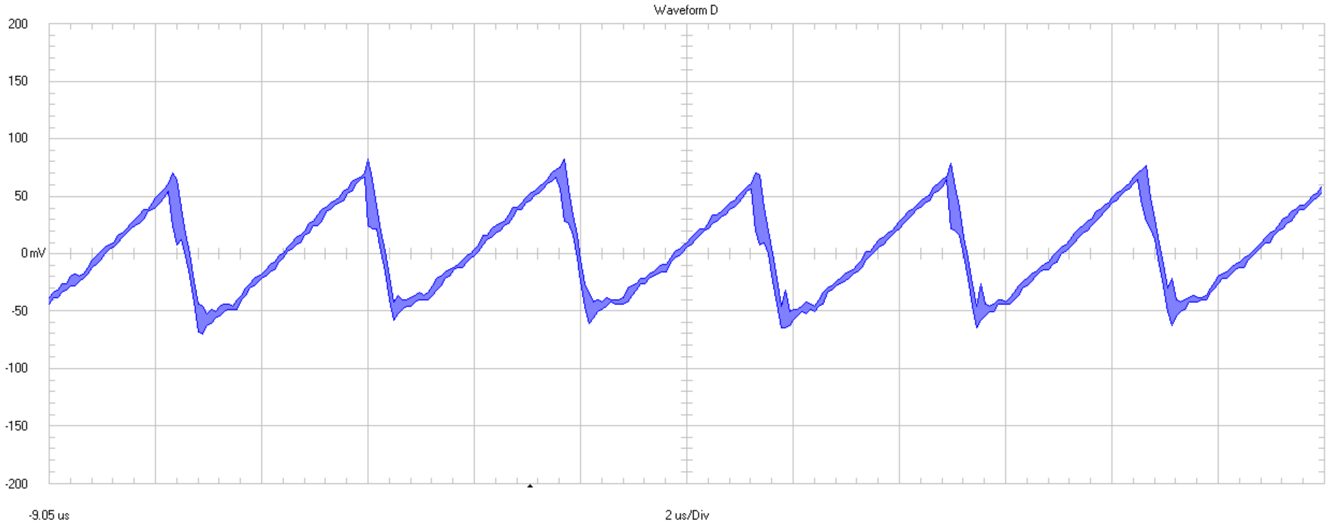
- 50 mV/div
- 2 µs/div

Figure 31. 24 V VIN



- 50 mV/div
- 2 µs/div

Figure 32. 36 V VIN



- 50 mV/div
- 2 µs/div

3.4 Bode Plot

The bode-box best for 100 Hz to 10 kHz were used.

Figure 33. Bode Plot for 3 V Input Voltage

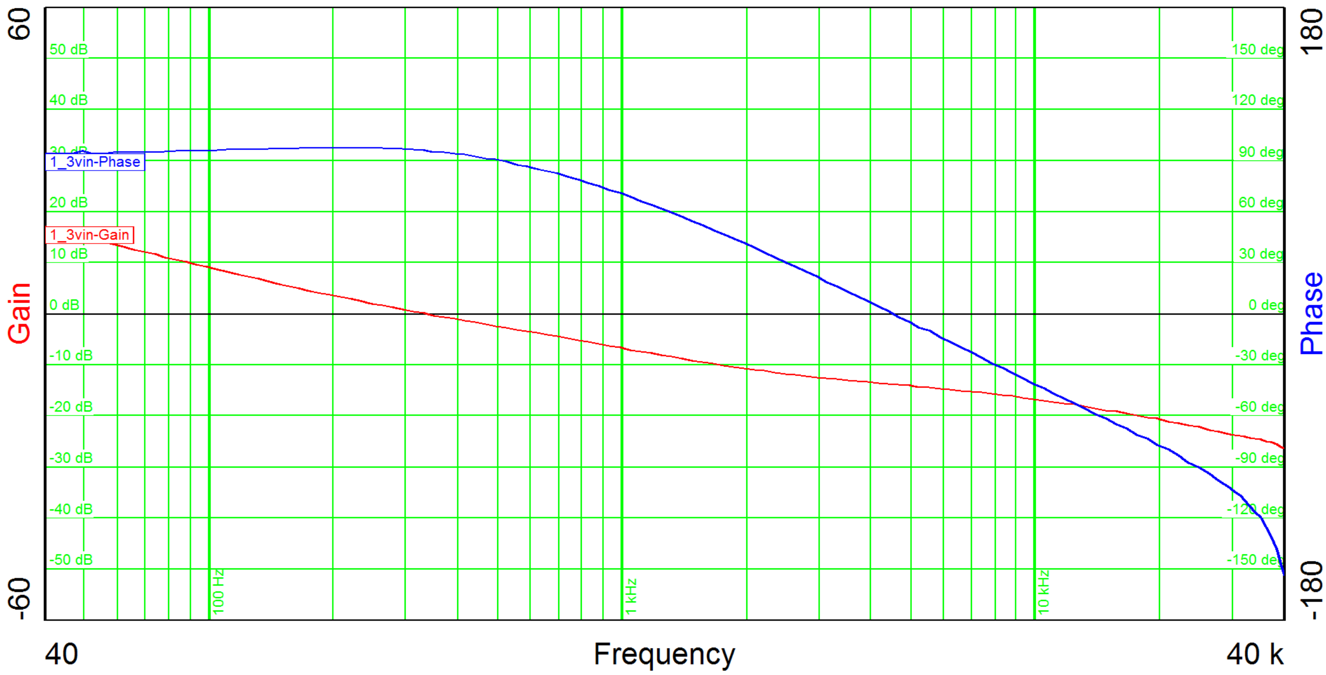


Figure 34. Bode Plot for 14 V Input Voltage

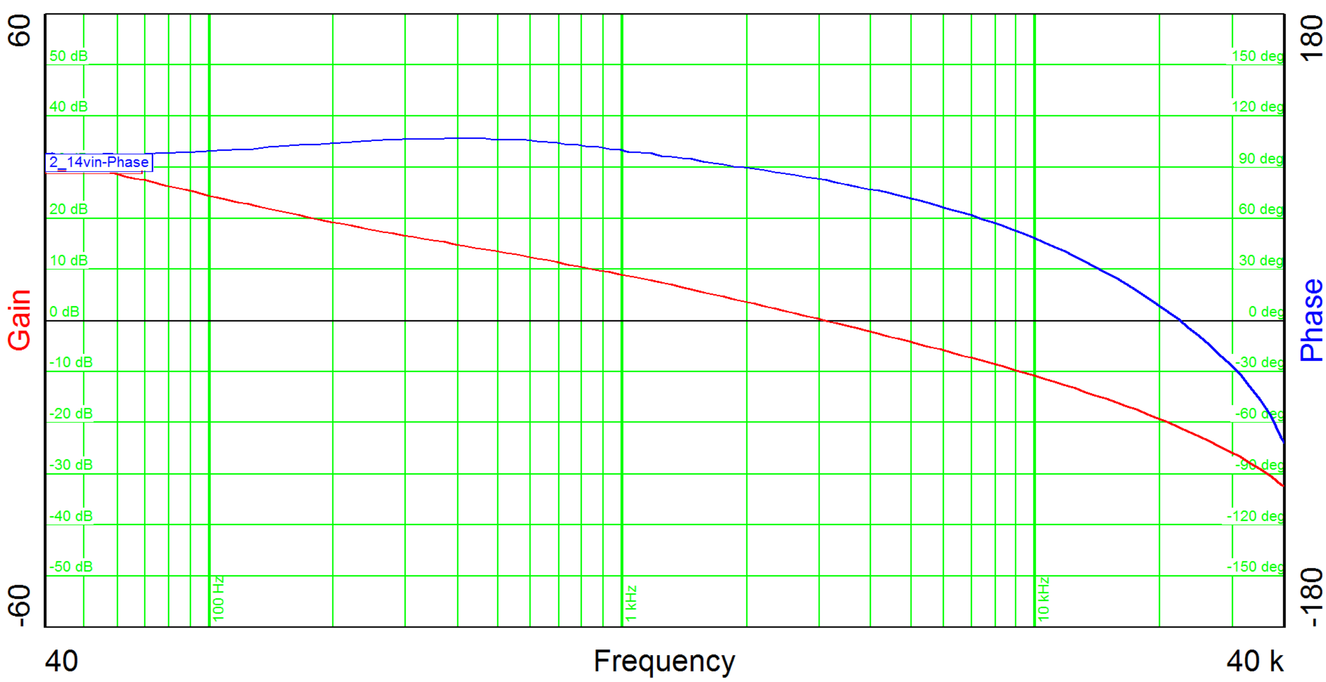


Figure 35. Bode Plot for 24 V Input Voltage

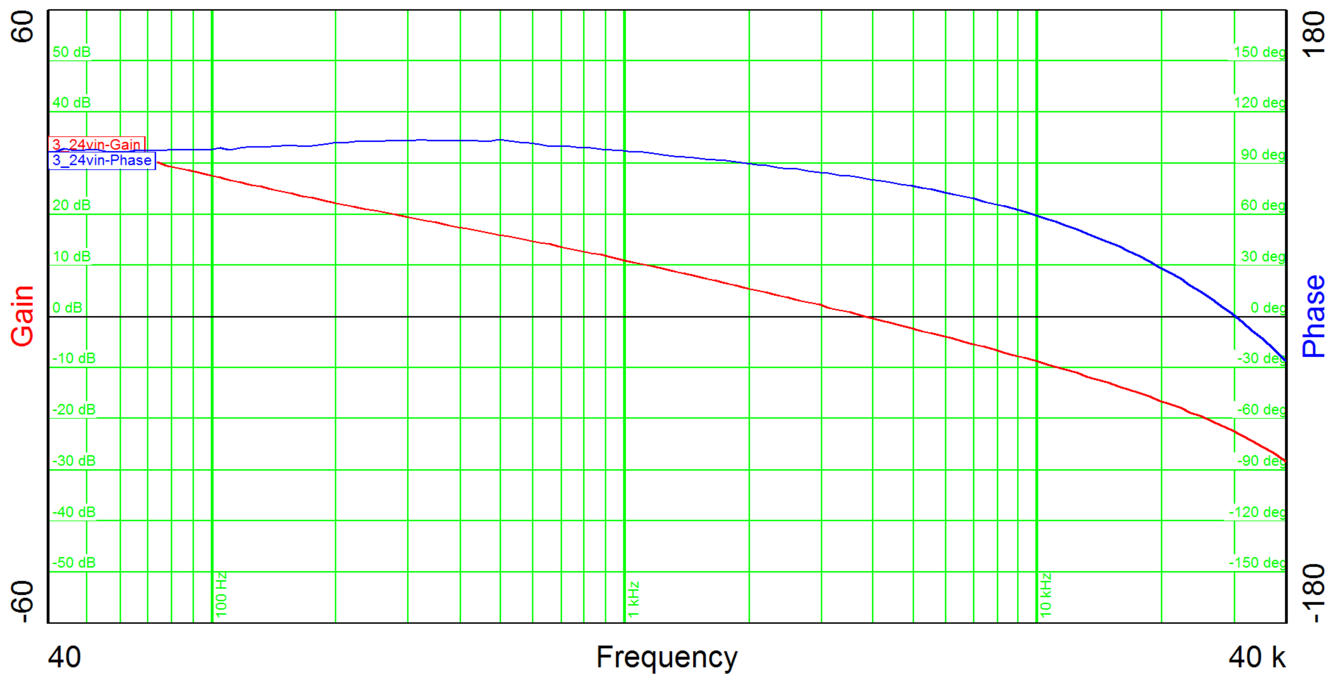
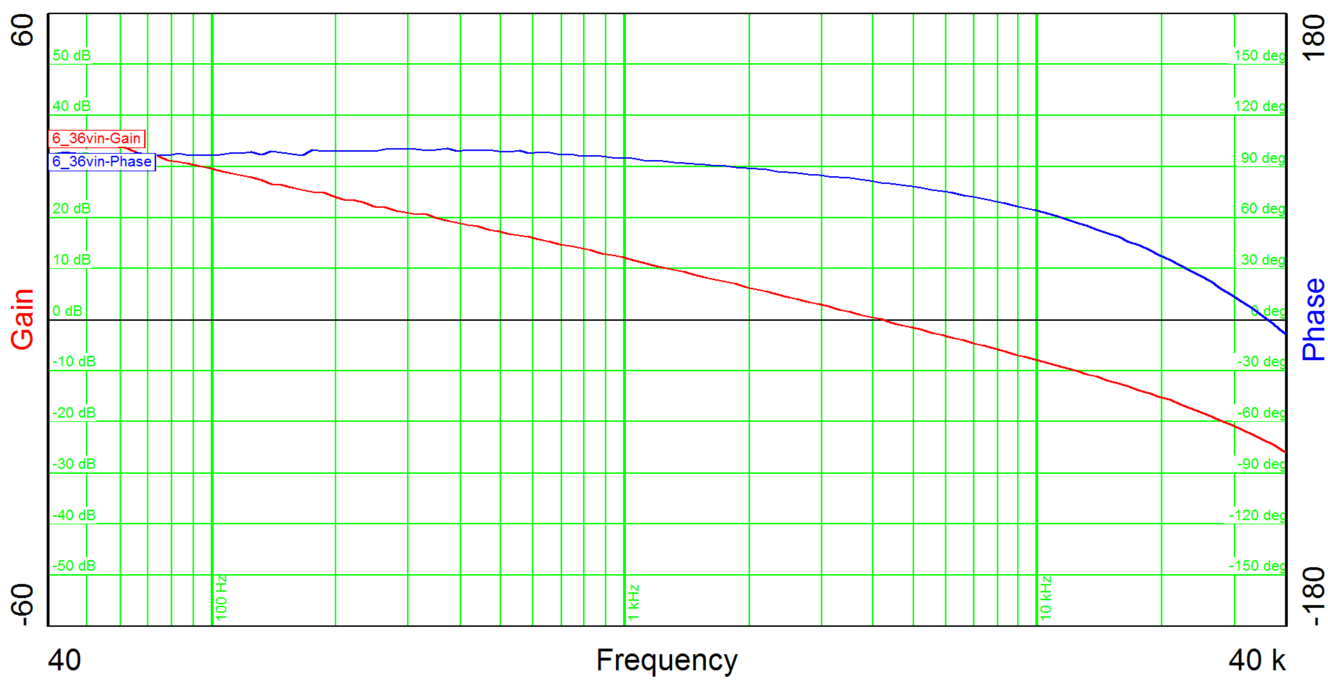


Figure 36. Bode Plot for 36 V Input Voltage



Vin	**3V**	**14V**	**24V**	**36V**
Bandwidth (Hz)	334	3090	3806	4171
Phase Margin	96°	82°	81°	81°
slope (20dB/decade)	-0.85	-0.95	-0.98	-1.02
gain margin (dB)	-13.8	-21	-22.6	-24
slope (20dB/decade)	-0.34	-1.86	-2.05	-2.09
freq (kHz)	4.5	22.3	30	36

3.5 Load Transients

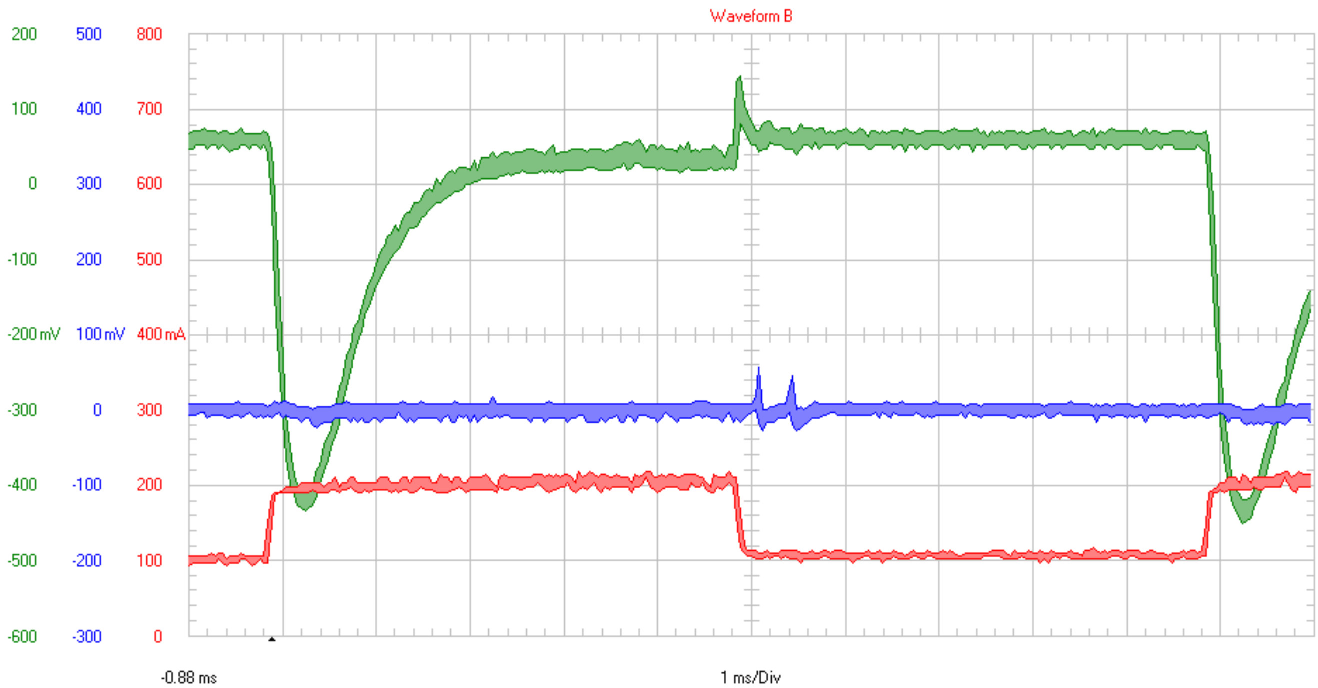
The time scale from the waveforms was 1 ms/div.

3.5.1 Transient on +VOUT

- +VOUT: electronic load was switching between 100 mA and 200 mA at 100 Hz.
- -VOUT was loaded with 200 mA

3.5.1.1 3 V Input Voltage

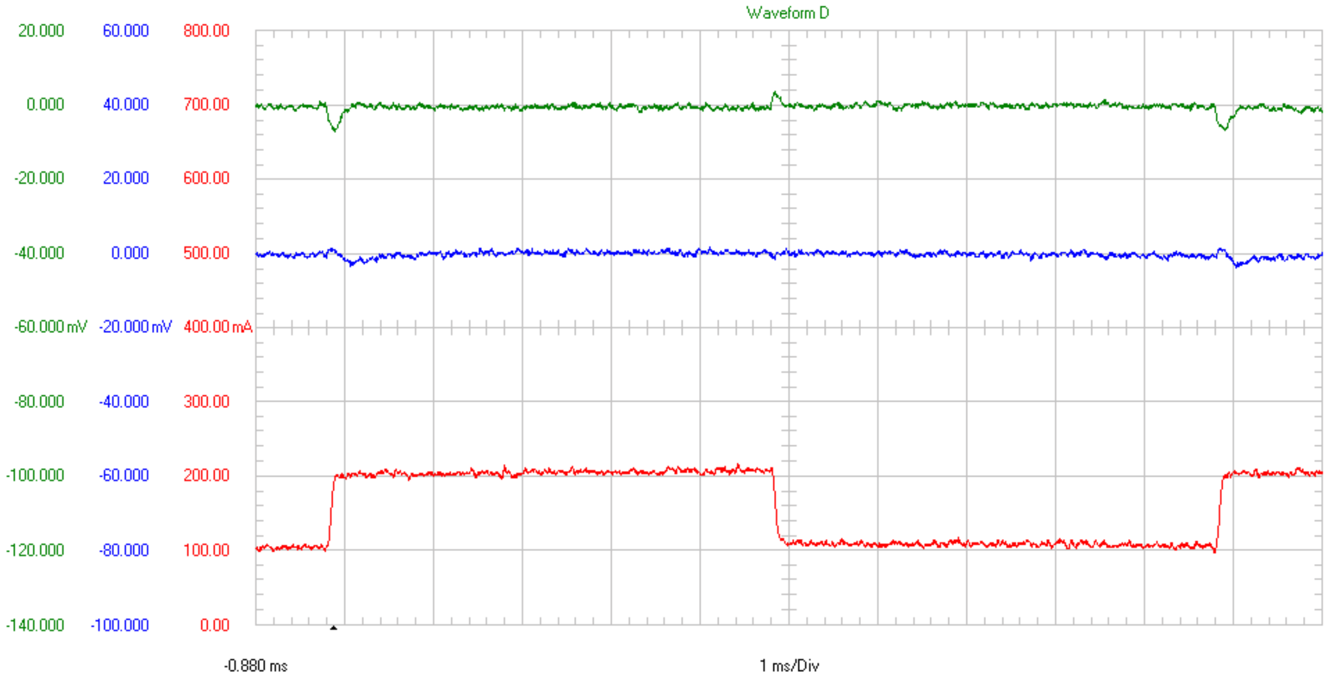
Figure 37. 100 mA - 200 mA Transient on +VOUT @ 3 V Input Voltage



- channel 1 (green): +VOUT -> 100 mV/div; 20 MHz bandwidth
- channel 2 (blue): -VOUT -> 100 mV/div; 20 MHz bandwidth
- channel 3 (red): +IOUT -> 100 mA/div; 10 kHz bandwidth

3.5.1.2 14V Input Voltage

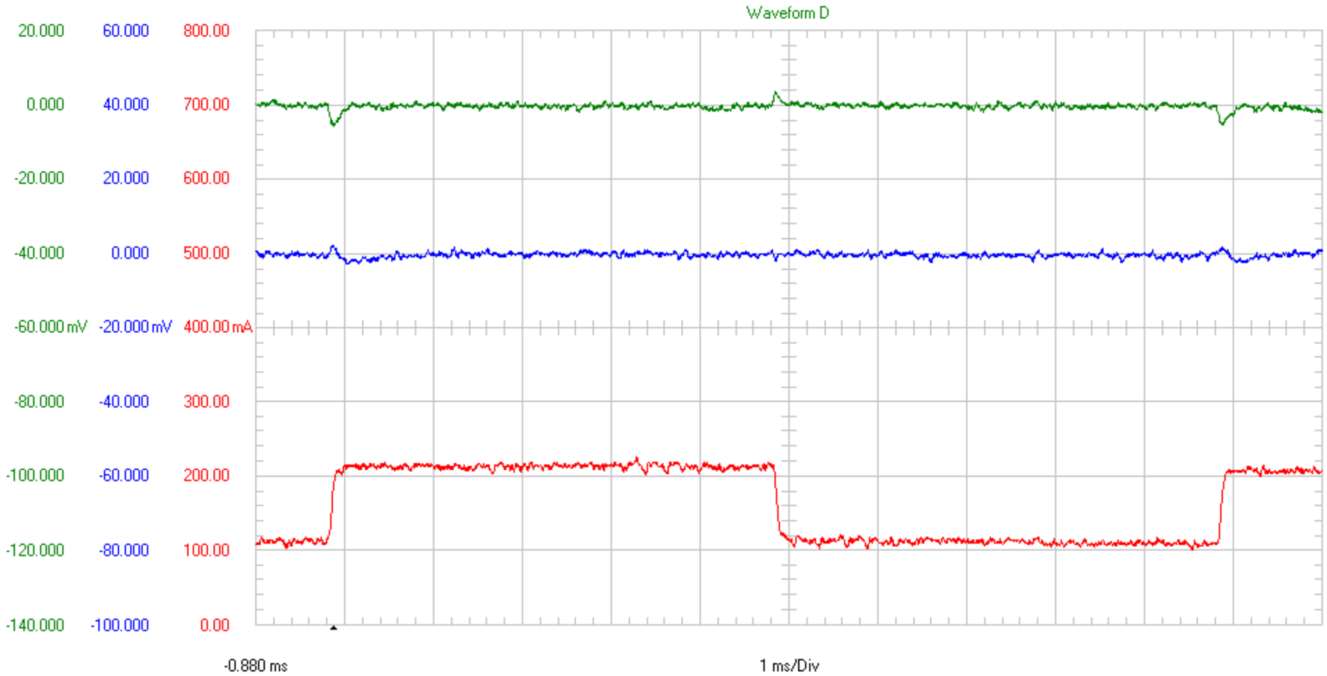
Figure 38. 100 mA - 200 mA Transient on +VOUT @ 14 V Input Voltage



- channel 1 (green): +VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 2 (blue): -VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 3 (red): +IOUT -> 100 mA/div; 10 kHz bandwidth

3.5.1.3 24 V Input Voltage

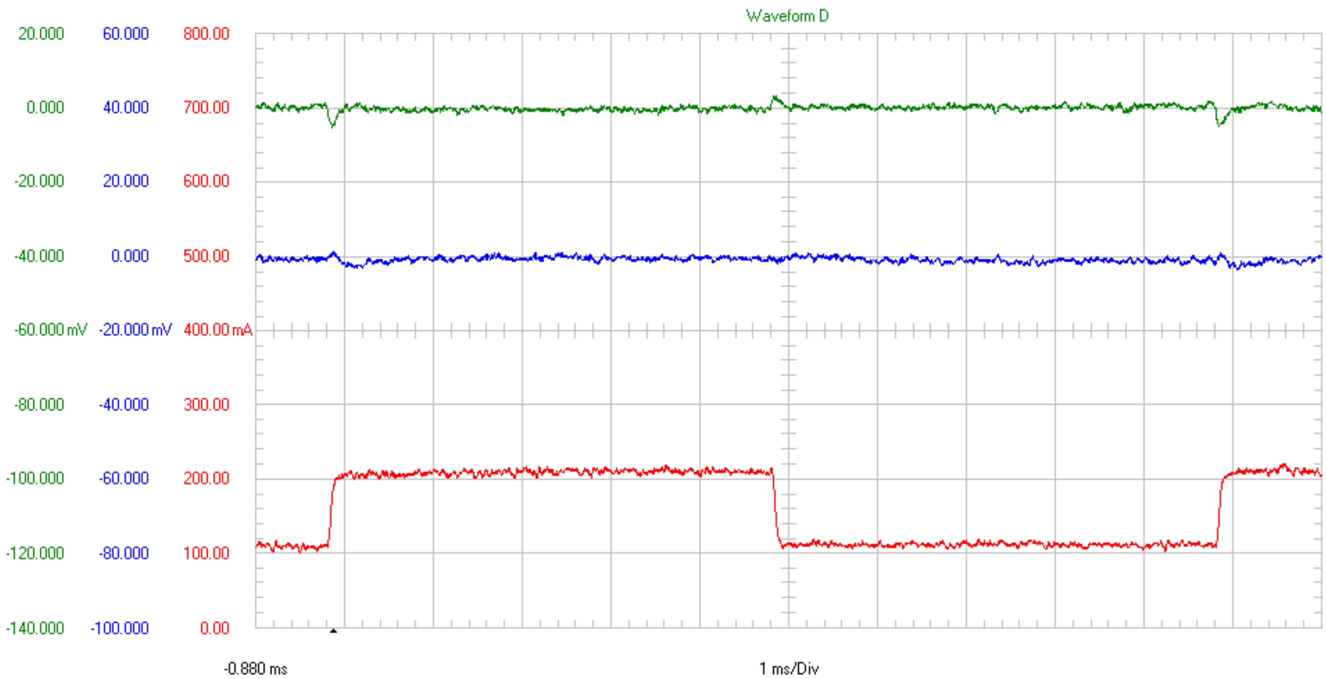
Figure 39. 100 mA - 200 mA Transient on +VOUT @ 24 V Input Voltage



- channel 1 (green): +VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 2 (blue): -VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 3 (red): +IOUT -> 100 mA/div; 10 kHz bandwidth

3.5.1.4 36V Input Voltage

Figure 40. 100 mA-200 mA Transient on +VOUT @ 36 V Input Voltage



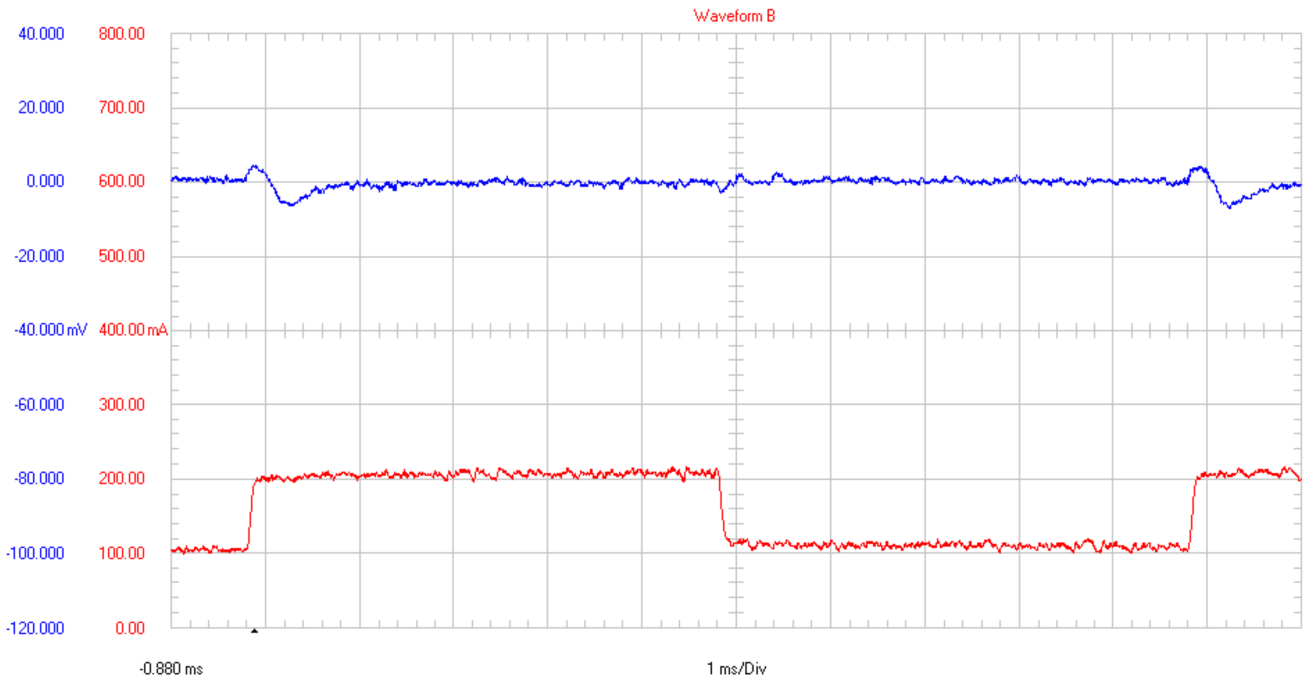
- channel 1 (green): +VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 2 (blue): -VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 3 (red): +IOUT -> 100 mA/div; 10 kHz bandwidth

3.5.2 Transient on - VOUT

+VOUT was loaded with 200mA and on -VOUT electronic load was switching between 100 to 200mA with a frequency of 100Hz

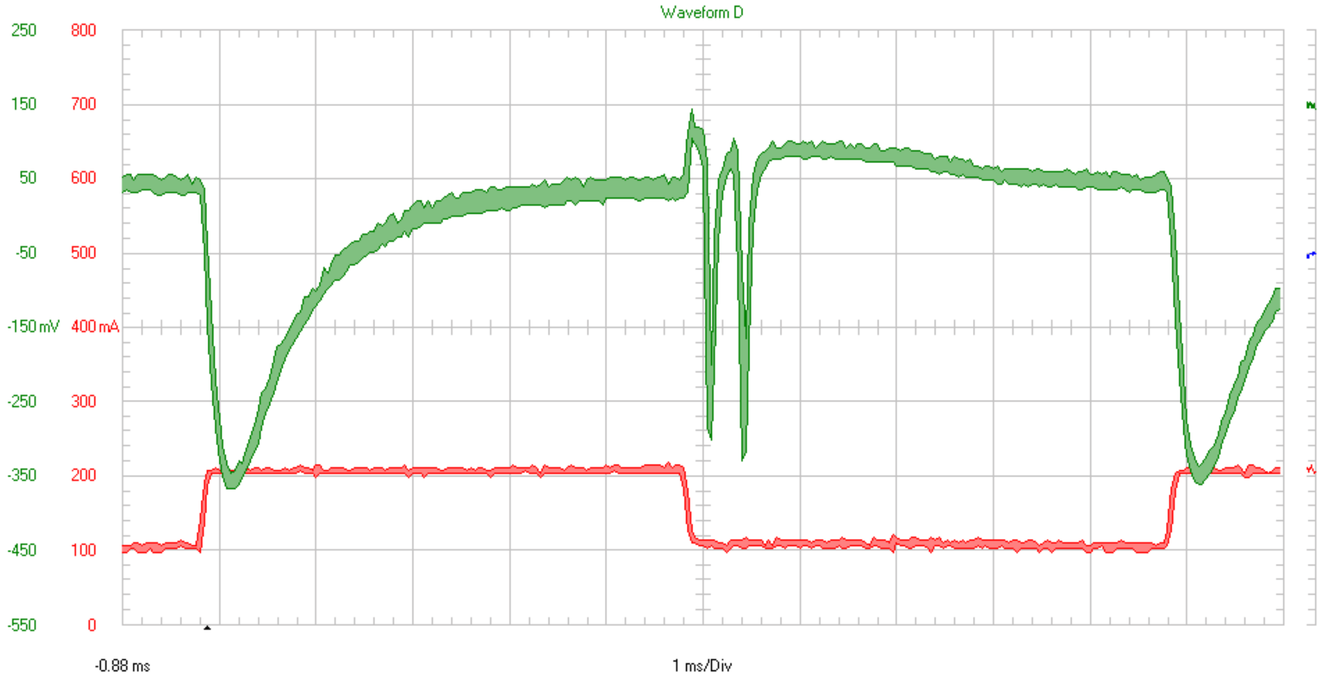
3.5.2.1 3 V Input Voltage

Figure 41. 100 mA - 200 mA Transient on -VOUT @ 3 V Input Voltage (-VOUT)



- channel 1 (blue): **-VOUT** -> 20 mV/div; 20 MHz bandwidth
- channel 2 (red): -IOUT -> 100 mA/div; 10 kHz bandwidth

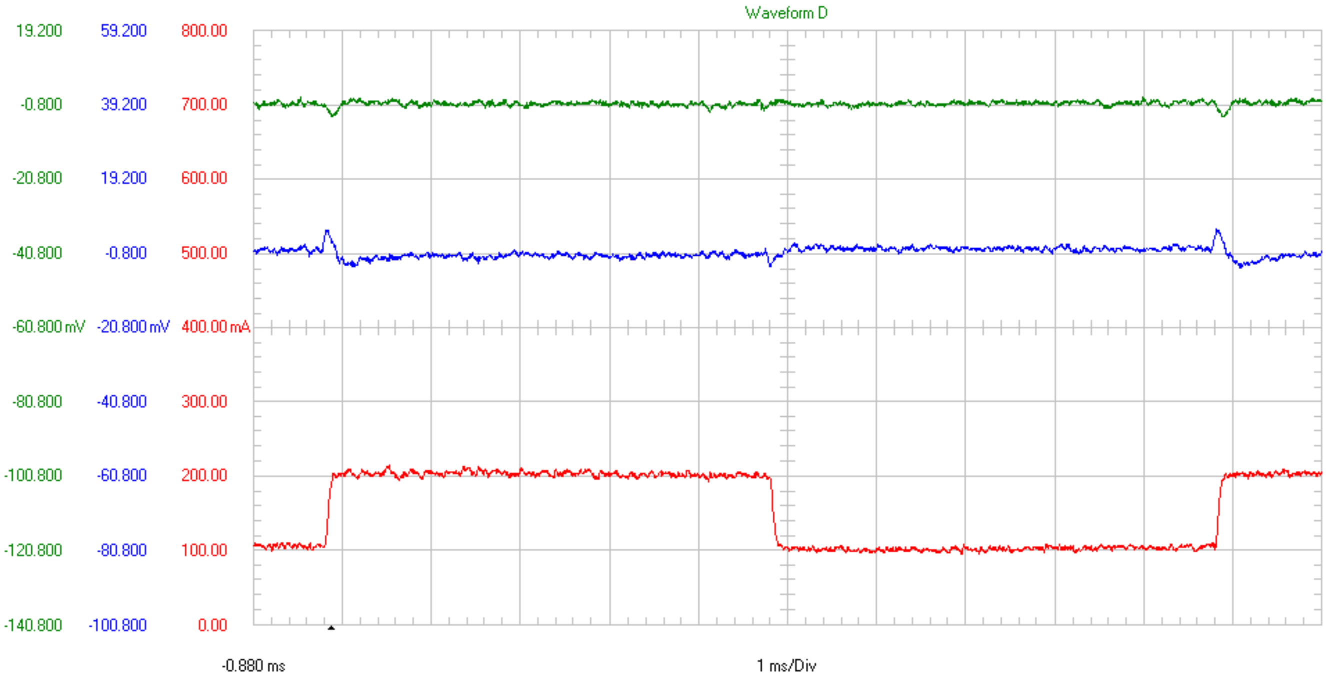
Figure 42. 100 mA - 200 mA Transient on -VOUT @ 3 V Input Voltage (+VOUT)



- channel 1 (blue): **+VOUT** -> **100 mV**/div; 20MHz bandwidth
- channel 2 (red): -IOUT -> 100 mA/div; 10 kHz bandwidth

3.5.2.2 14V Input

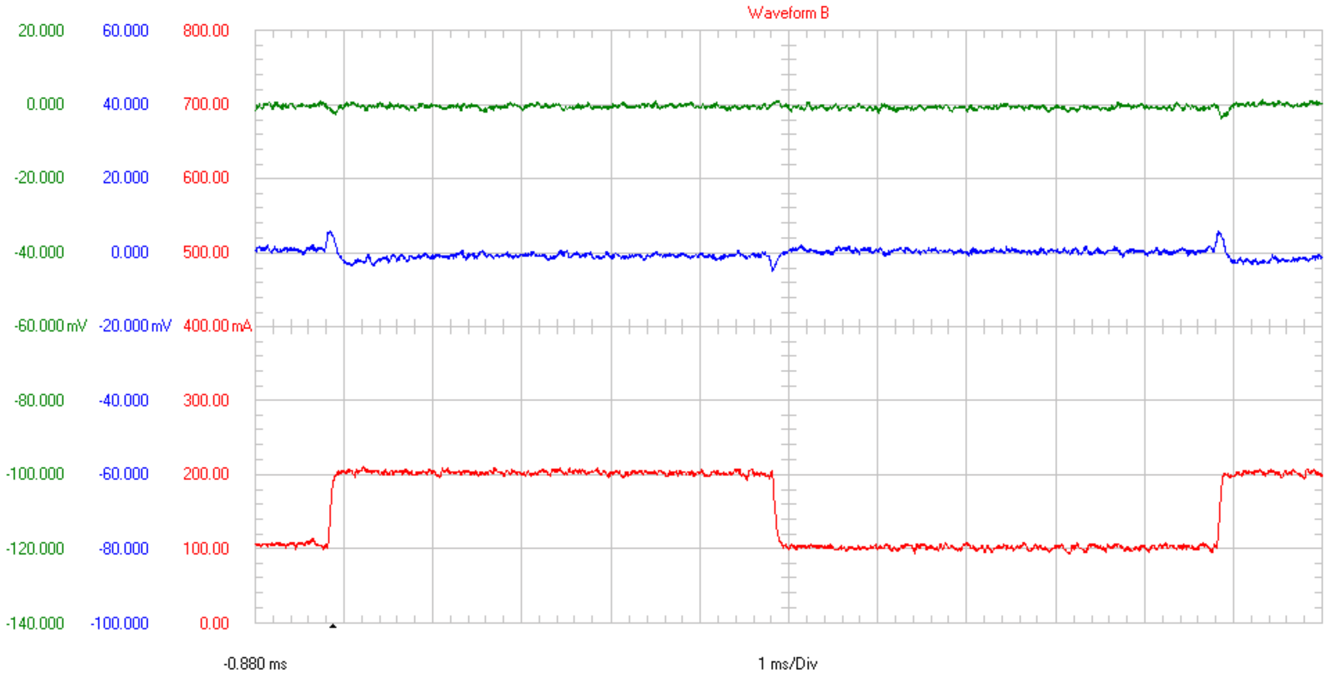
Figure 43. 100 mA - 200 mA Transient on -VOUT @ 14 V Input Voltage



- channel 1 (green): +VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 2 (blue): -VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 3 (red): +IOUT -> 100 mA/div; 10 kHz bandwidth

3.5.2.3 24V Input Voltage

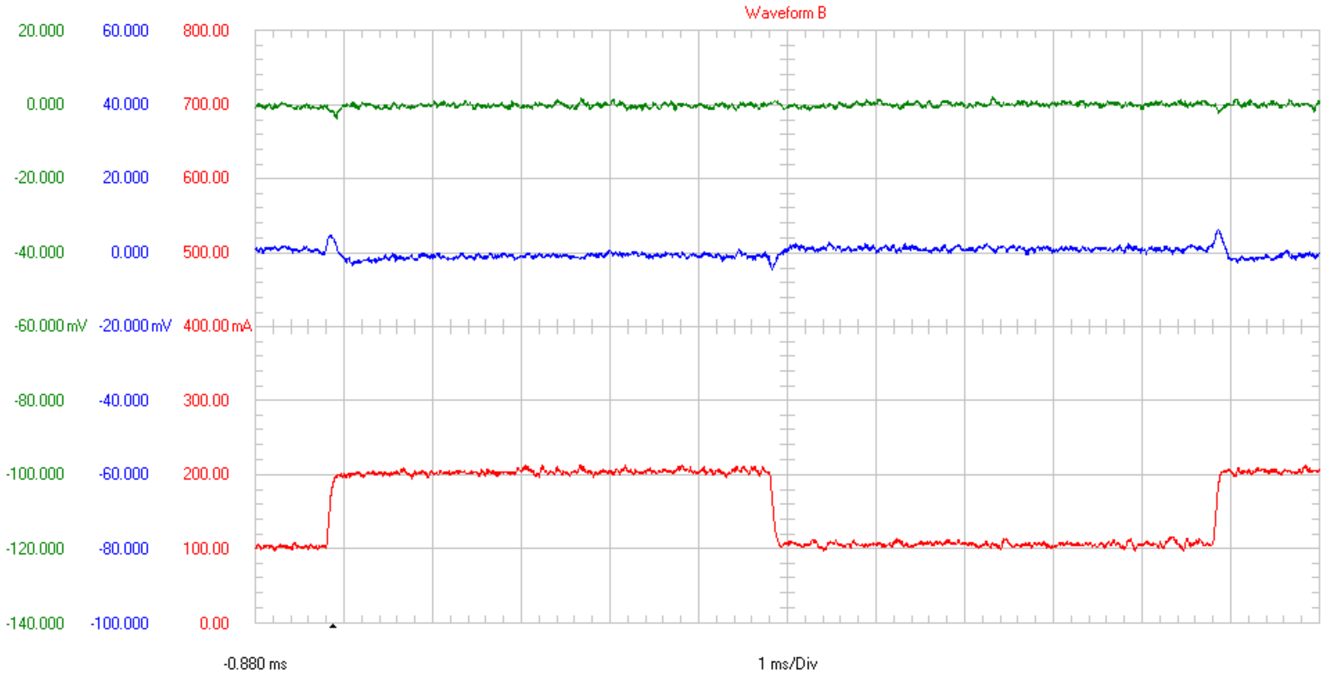
Figure 44. 100 mA - 200 mA Transient on -VOUT @ 24 V Input Voltage



- channel 1 (green): +VOUT -> 2 0mV/div; 20 MHz bandwidth
- channel 2 (blue): -VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 3 (red): +IOUT -> 100 mA/div; 10 kHz bandwidth

3.5.2.4 36V Input Voltage

Figure 45. 100 mA - 200 mA Transient on -VOUT @ 36 V Input Voltage

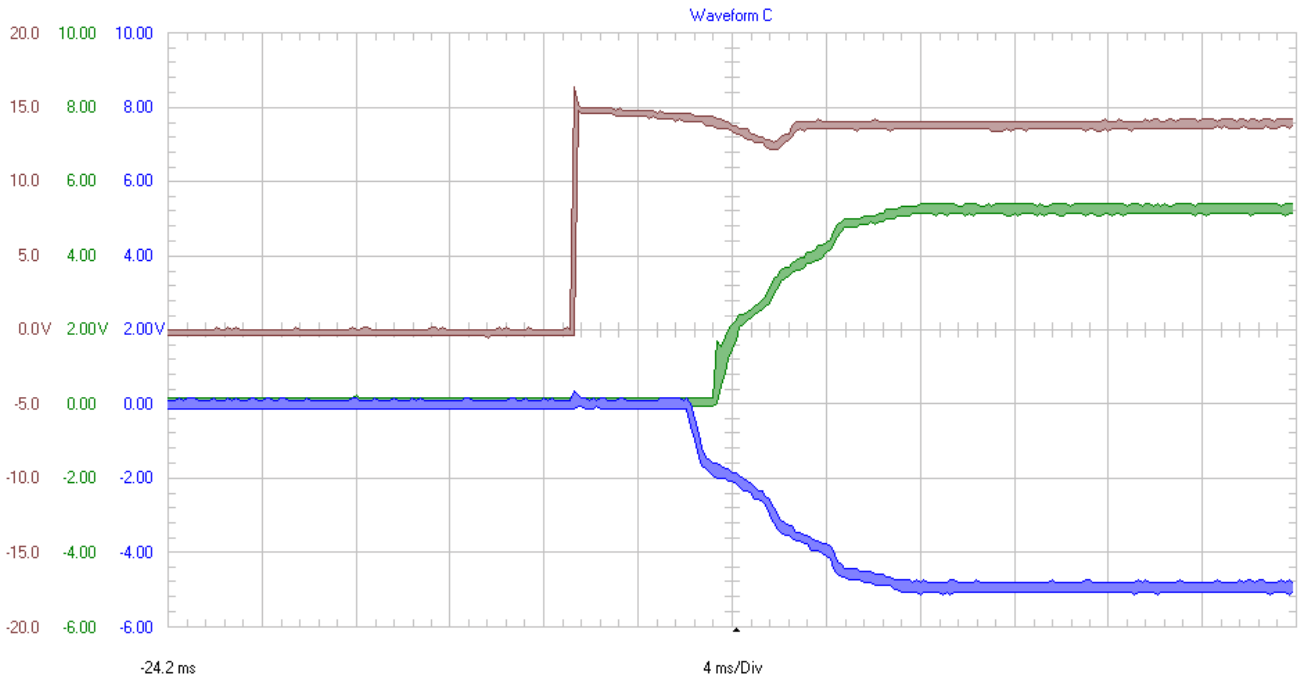


- channel 1 (green): +VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 2 (blue): -VOUT -> 20 mV/div; 20 MHz bandwidth
- channel 3 (red): +IOUT -> 100 mA/div; 10 kHz bandwidth

3.6 Start-up Sequence

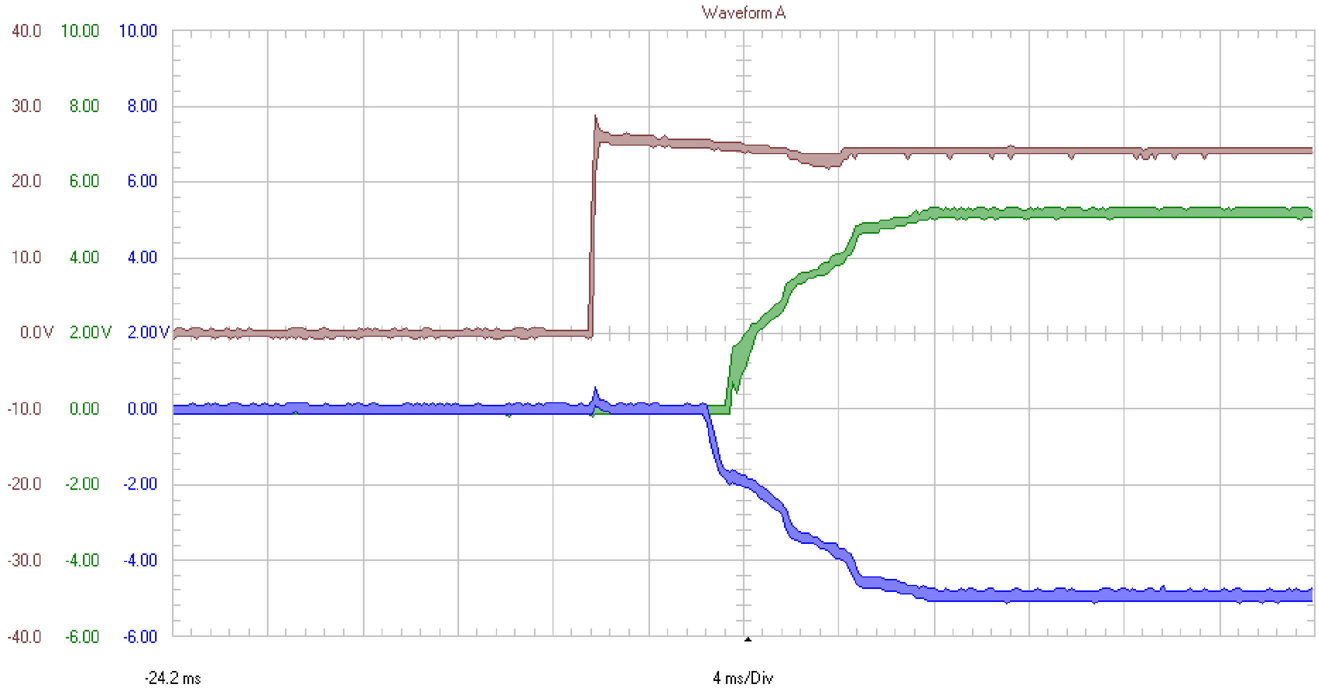
Power supply was plugged in. Waveform time scale was set to 4 ms/div

Figure 46. Start-up with 14 V Input Voltage



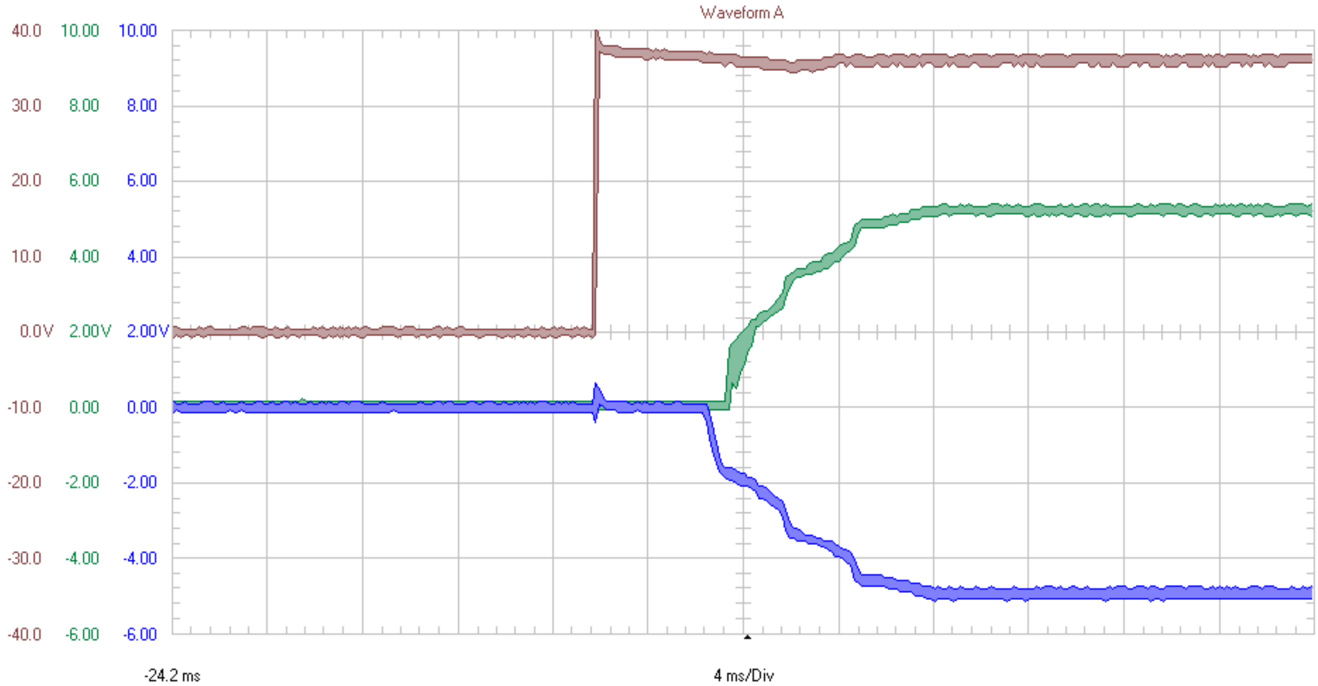
- Channel 1 (brown) : +VIN -> 5 V/div
- Channel 2 (green) : +VOUT -> 2 V/div
- Channel 3 (blue) : -VOUT -> 2 V/div

Figure 47. Start-up with 24 V Input Voltage



- Channel 1 (brown) : +VIN -> 10 V/div
- Channel 2 (green) : +VOUT -> 2 V/div
- Channel 3 (blue) : -VOUT -> 2 V/div

Figure 48. Start-up with 36 V Input Voltage

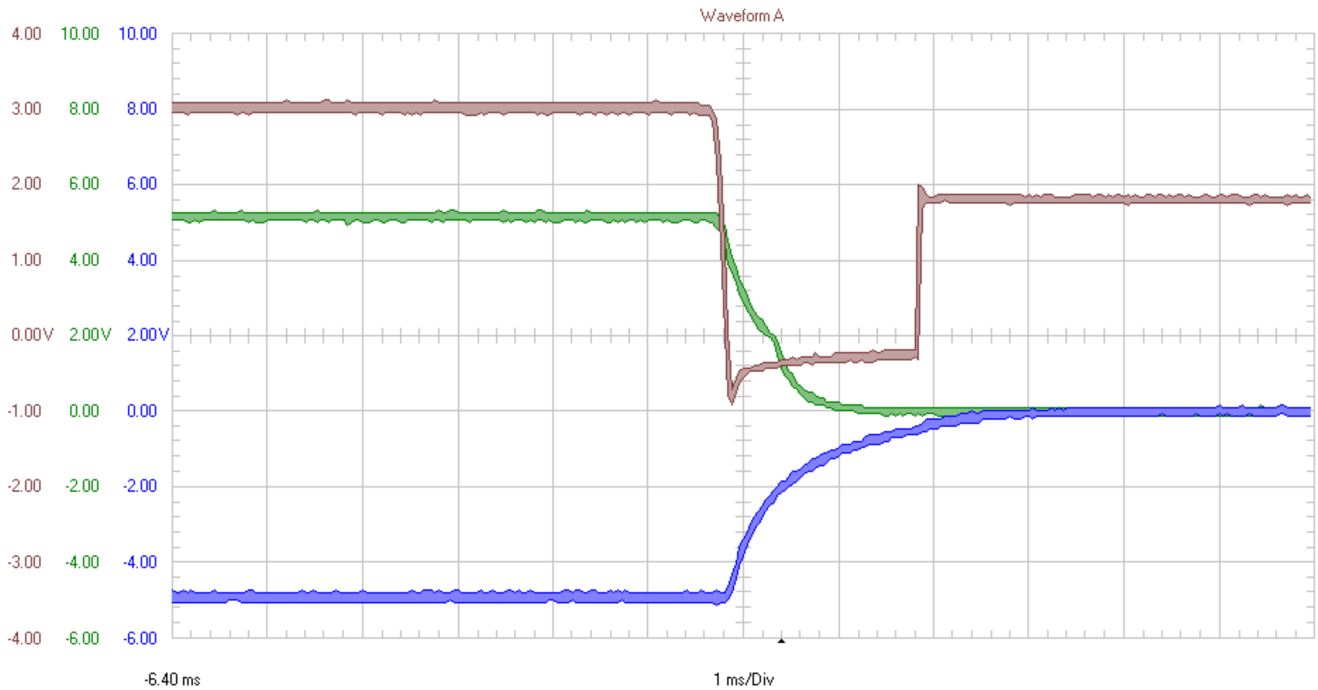


- Channel 1 (brown) : +VIN -> 10 V/div
- Channel 2 (green) : +VOUT -> 2 V/div
- Channel 3 (blue) : -VOUT -> 2 V/div

3.7 Shut-Down Sequence

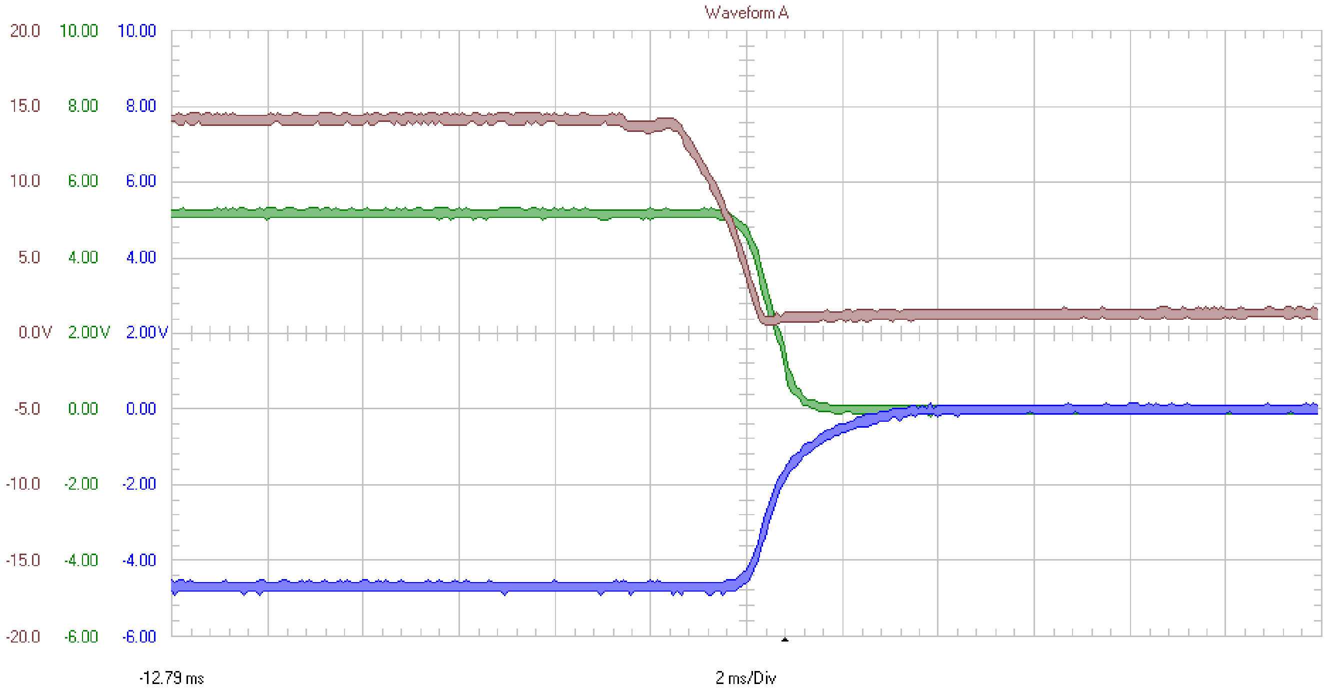
The power supply was disconnected.

Figure 49. Shut-Down @ 3 V Input Voltage



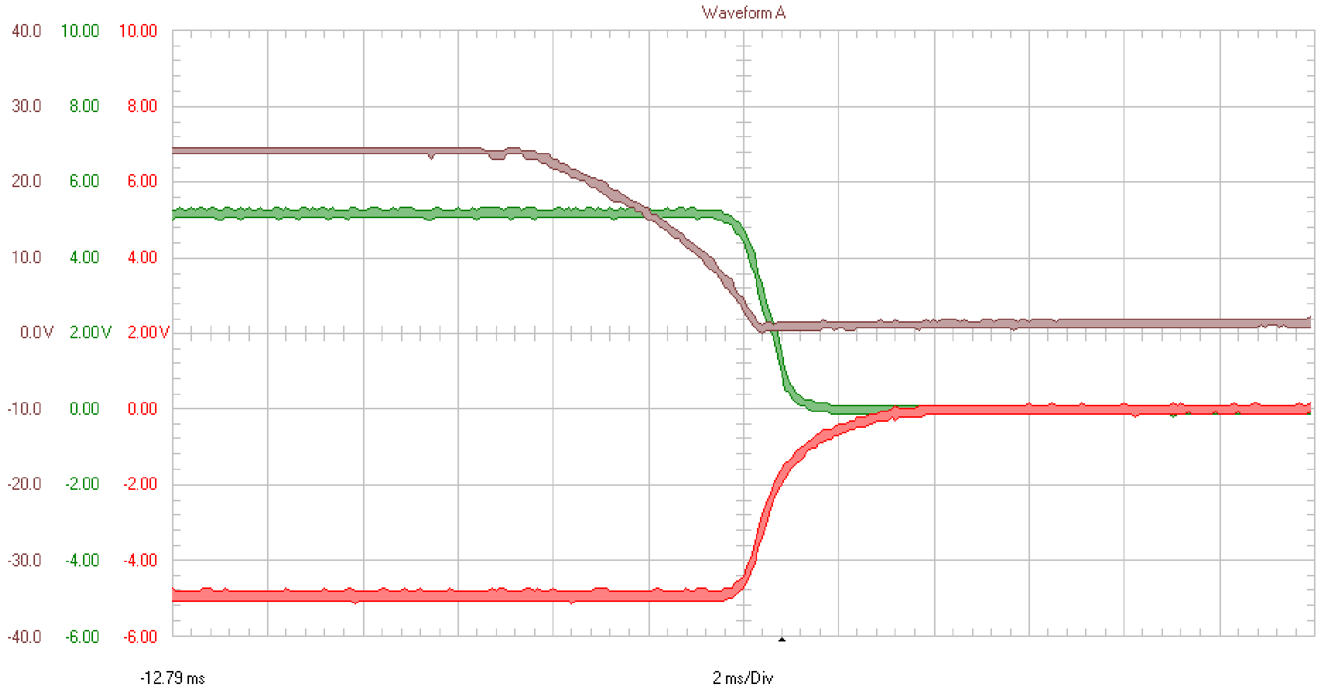
- Channel 1 (brown) : +VIN -> 1 V/div
- Channel 2 (green) : +VOUT -> 2 V/div
- Channel 3 (blue) : -VOUT -> 2 V/div
- 1ms/div

Figure 50. Shut-Down @ 14 V Input Voltage



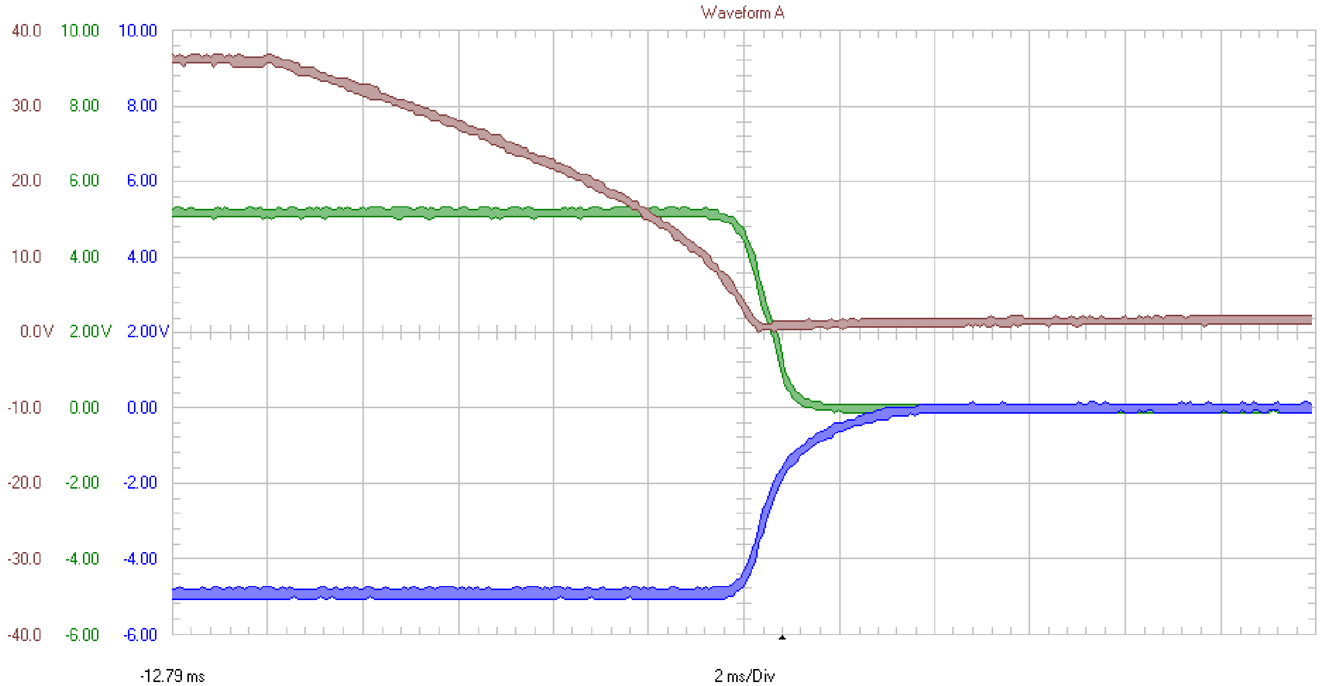
- Channel 1 (brown) : +VIN -> 5 V/div
- Channel 2 (green) : +VOUT -> 2 V/div
- Channel 3 (blue) : -VOUT -> 2 V/div
- 2 ms/div

Figure 51. Shut-Down @ 24V Input Voltage



- Channel 1 (brown) : +VIN -> 10 V/div
- Channel 2 (green) : +VOUT -> 2 V/div
- Channel 3 (red) : -VOUT -> 2 V/div
- 2 ms/div

Figure 52. Shut-Down @ 36 V Input Voltage



- Channel 1 (brown) : +VIN -> 10 V/div
- Channel 2 (green) : +VOUT -> 2 V/div
- Channel 3 (blue) : -VOUT -> 2 V/div
- 2 ms/div

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