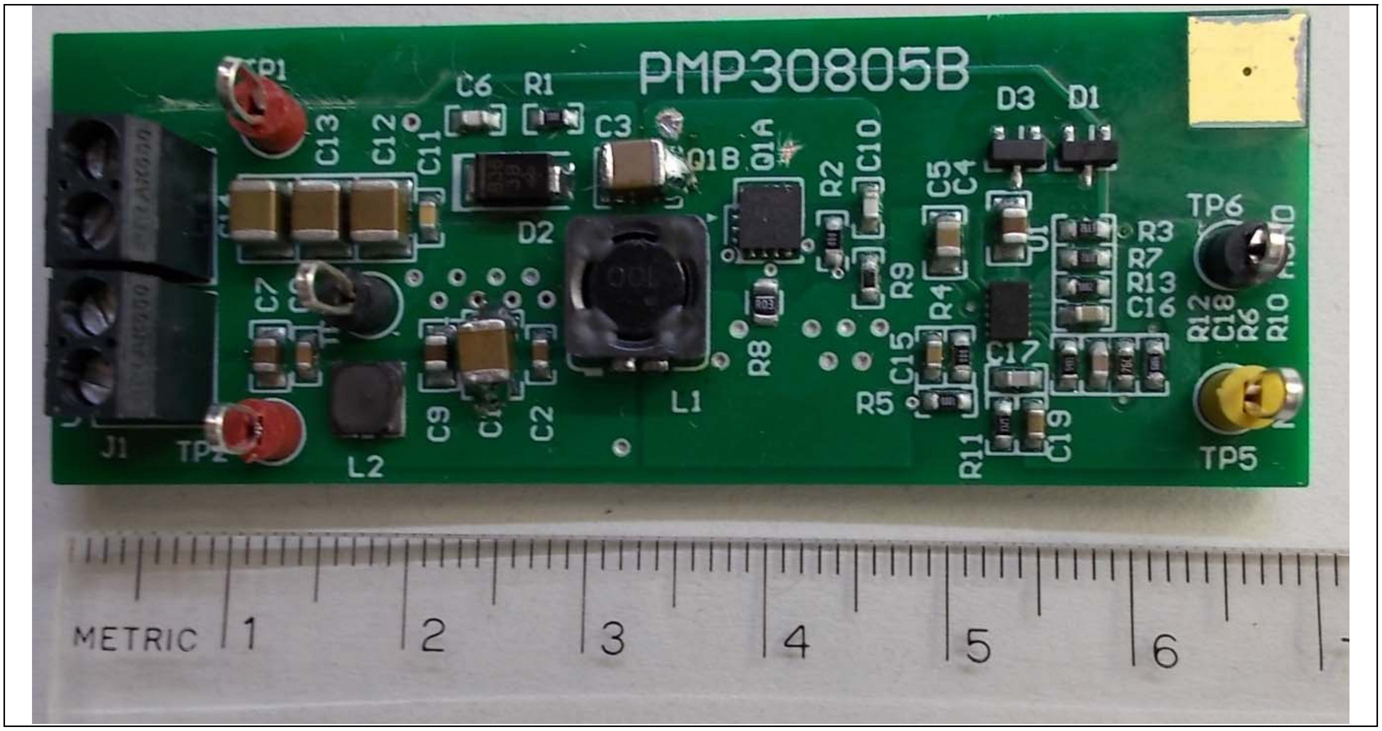
Test Report: PMP30805

Tiny Automotive SEPIC Reference Design

Description

This tiny automotive SEPIC reference design contains a 6 W auxiliary power supply and is designed for a 12 V bias rail. The wide input accepts cranking down to 4.5 Vmin and surge up to 40 Vmax. Due to switching frequency of 2 MHz, the dual inductor is fairly small, resulting in excellent dynamic behavior. TI controller LM5155x-Q1 is cost effective and its housekeeping currents are minimized. The optional input filter attenuates reflected ripple, and the SEPIC topology supports fine EMI behavior by continuous input current.



1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input Voltage Range	6.0 V-18 V, 12.0 V nom., 4.5 V cranking, 40.0 V peak
Output Voltage	12 V @ 500 mA
Switching Frequency	2 MHz
Topology	Nonsynchronous SEPIC

1.2 Considerations

- Due to availability **BSZ340N08NS3** was used as Q1A.
- The circuit started up at 5.7 V input voltage and shut down at 4.4 V.
- Switching frequency has been verified at 2.022MHz for this prototype.
- Current sense trips at load current 670mA at minimum input voltage 4.5V, margin 30%+.
- At nominal input 12V the converter has been tested up to 800mA.

Unless otherwise indicated, the input voltage was set to 12 V and the output current was adjusted to full load 500 mA with a variable resistor.

2 Testing and Results

2.1 Efficiency Graphs

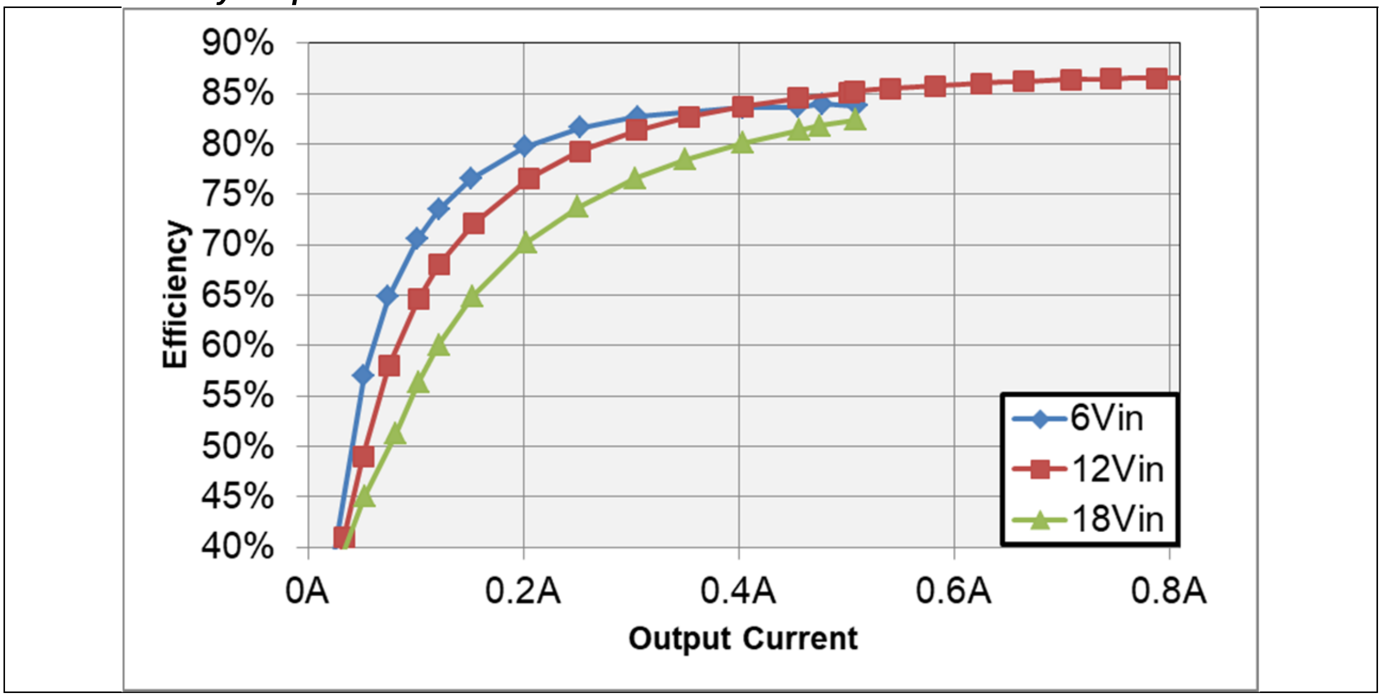


Figure 1 Efficiency vs Output Current

2.2 Loss

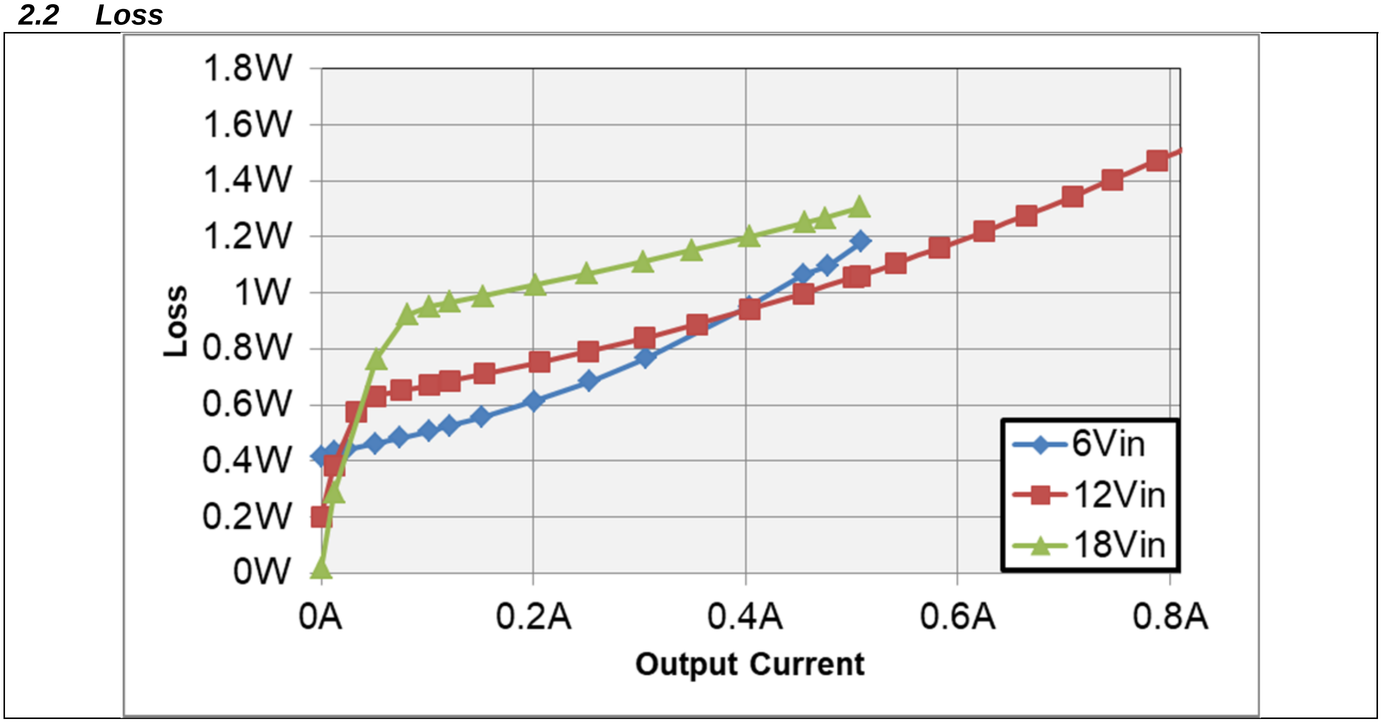


Figure 2 Loss vs Output Current

2.3 Load Regulation

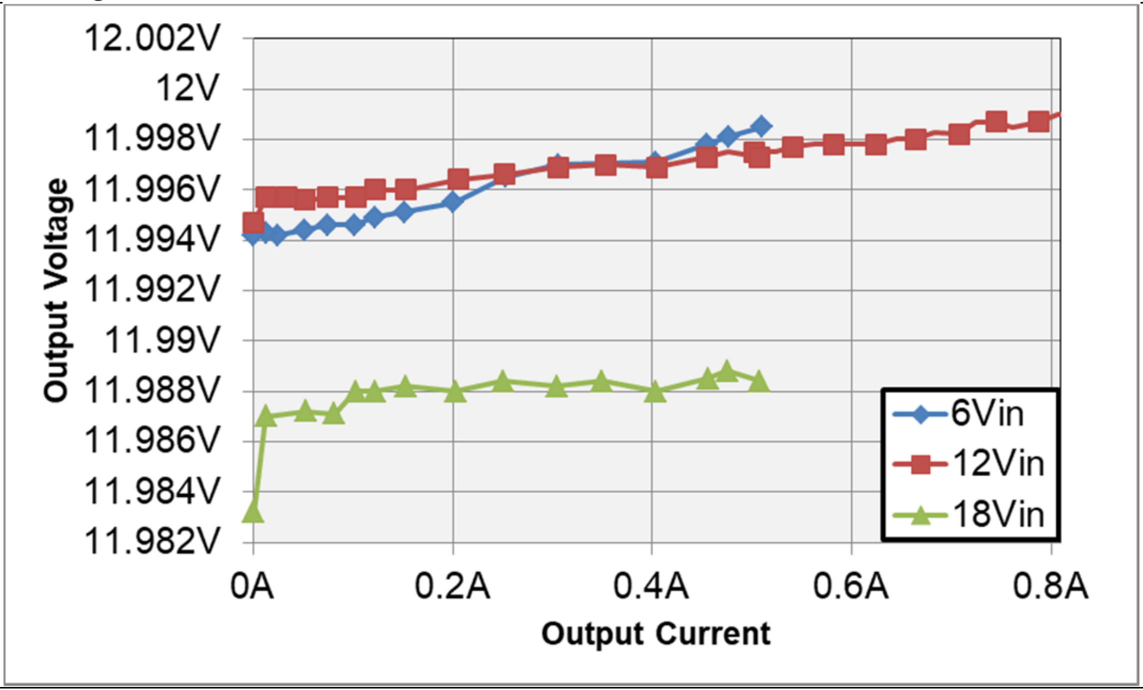


Figure 3 Output Voltage vs Output Current

2.4 Line Regulation

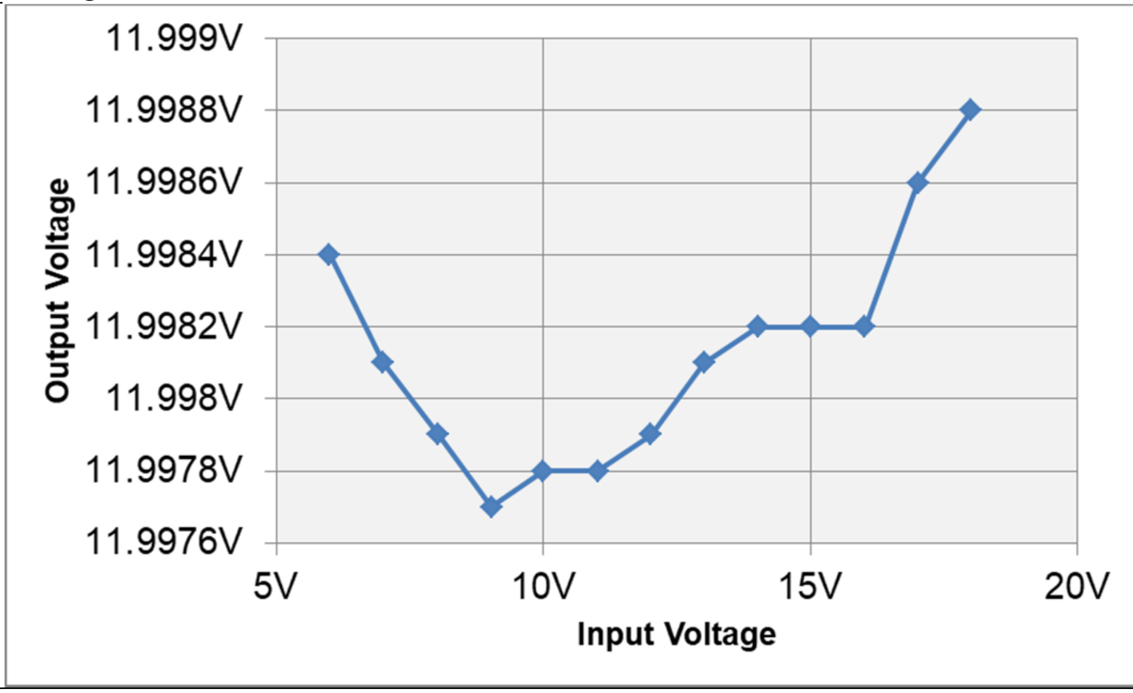


Figure 4 Output Voltage vs Input Voltage

Efficiency and Loss were also calculated.

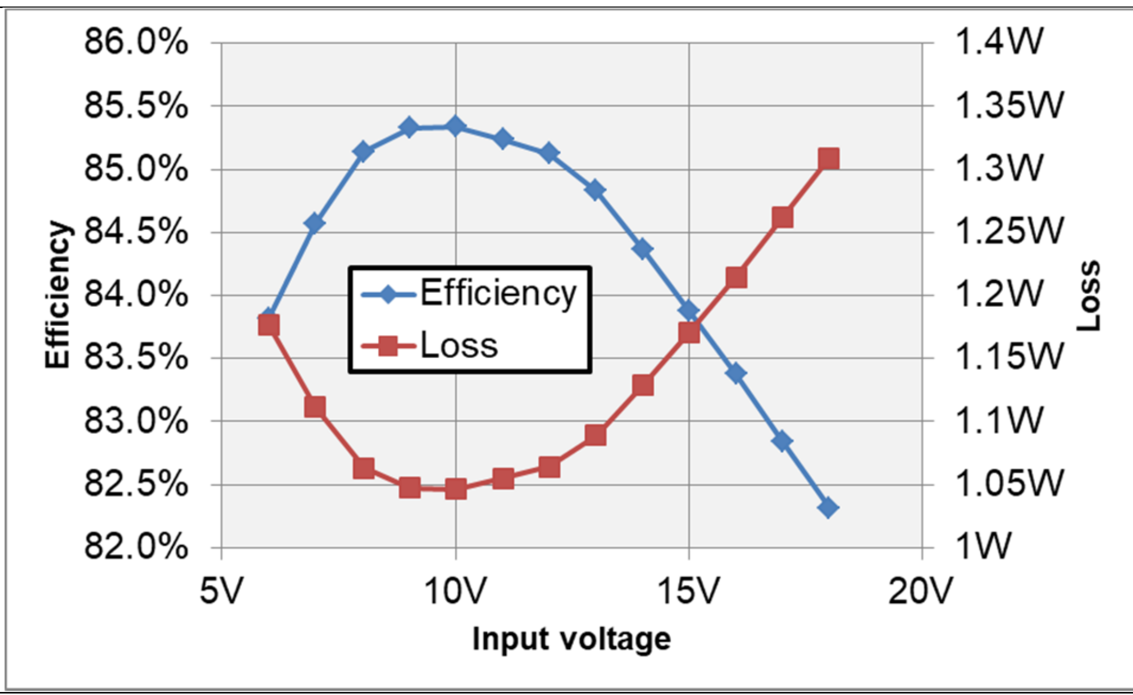
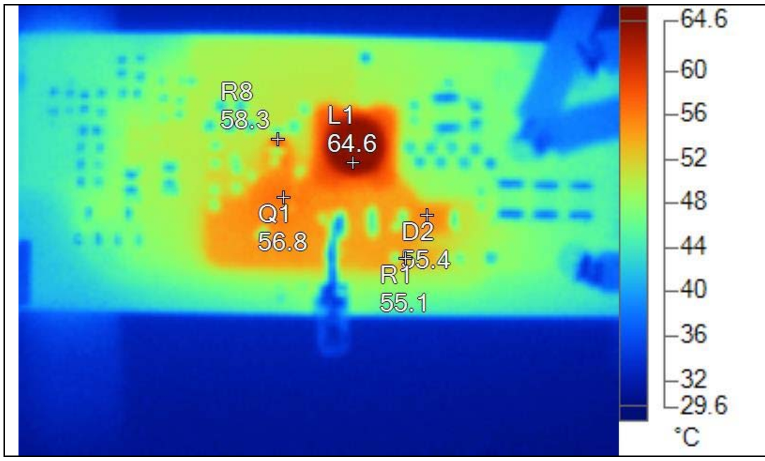


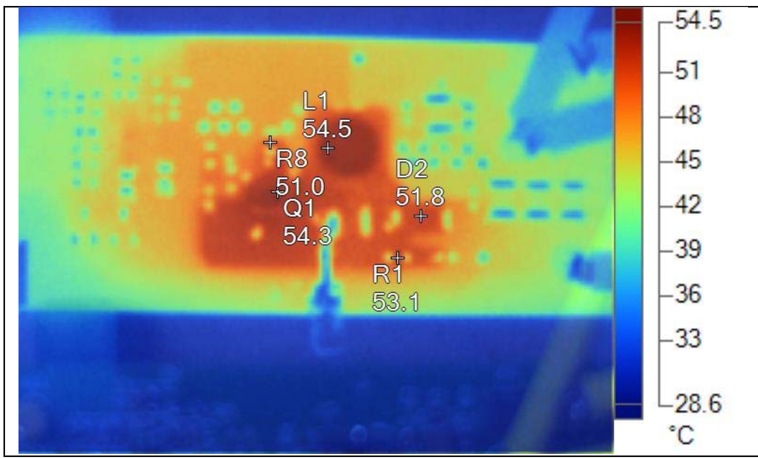
Figure 5 Efficiency and Loss vs Input Voltage

2.5 Thermal Images



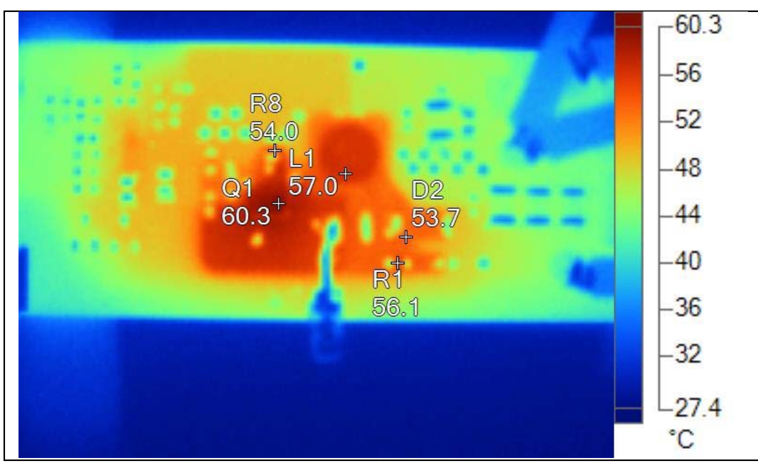
Name	Temperature
D2	55.4°C
L1	64.6°C
Q1	56.8°C
R1	55.1°C
R8	58.3°C

Figure 6 IR-Image @ 6 V Input Voltage



Name	Temperature
D2	51.8°C
L1	54.5°C
Q1	54.3°C
R1	53.1°C
R8	51.0°C

Figure 7 IR-Image @ 12 V Input Voltage – at nominal input dt < +35K (!)



Name	Temperature
D2	53.7°C
L1	57.0°C
Q1	60.3°C
R1	56.1°C
R8	54.0°C

Figure 8 IR-Image @ 18 V Input Voltage

2.6 Dimensions

The size of this PCB is 68.6 mm x 25.4 mm, two layers board 70um each and assembly is single sided

3 Waveforms

3.1 *Switching*

3.1.1 Q1 Drain to GND

3.1.1.1 6 V Input Voltage

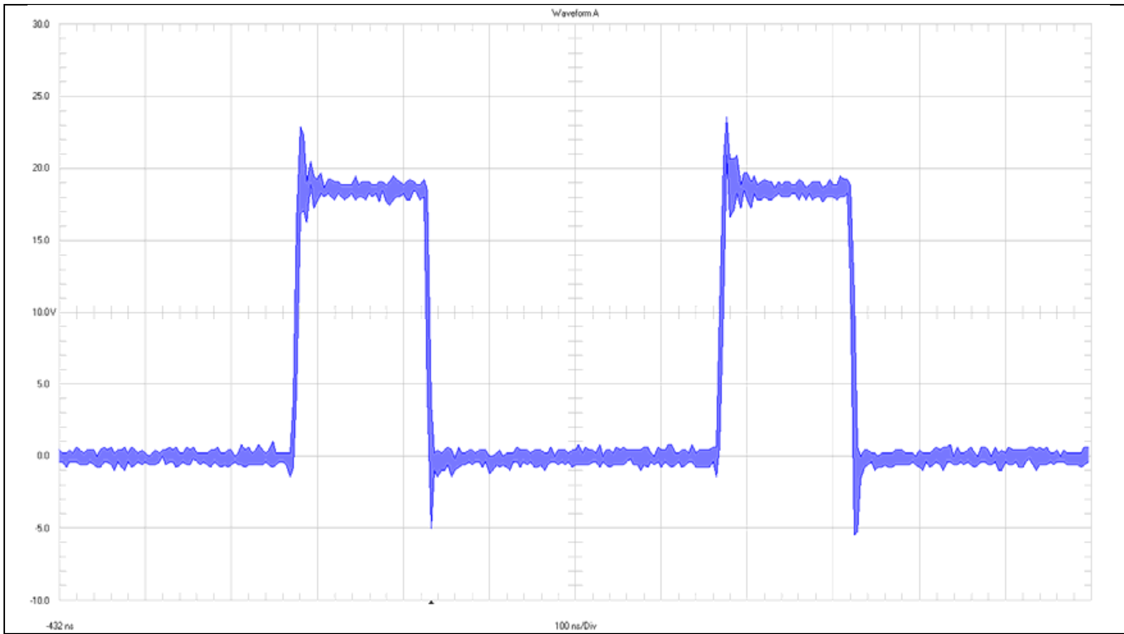
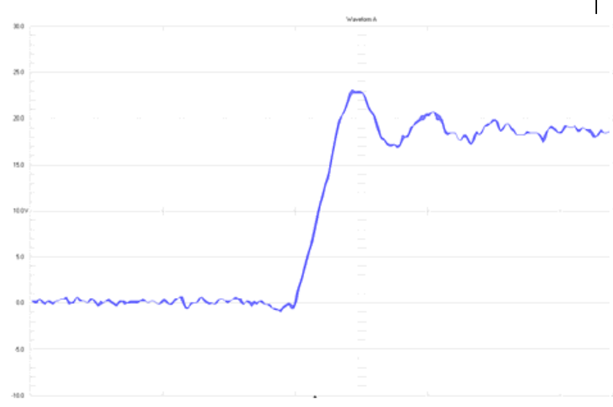
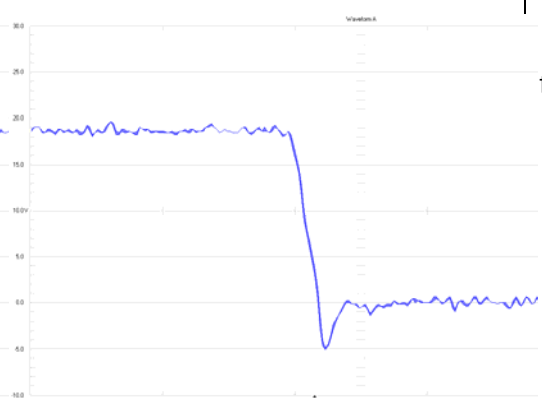
	5 V / div 100 ns / div full bandwidth
 	5 V / div 100 ns (full scale) full bandwidth

Figure 9 Waveform Q1 Drain to GND @ 6 Vin

3.1.1.2 12 V Input Voltage

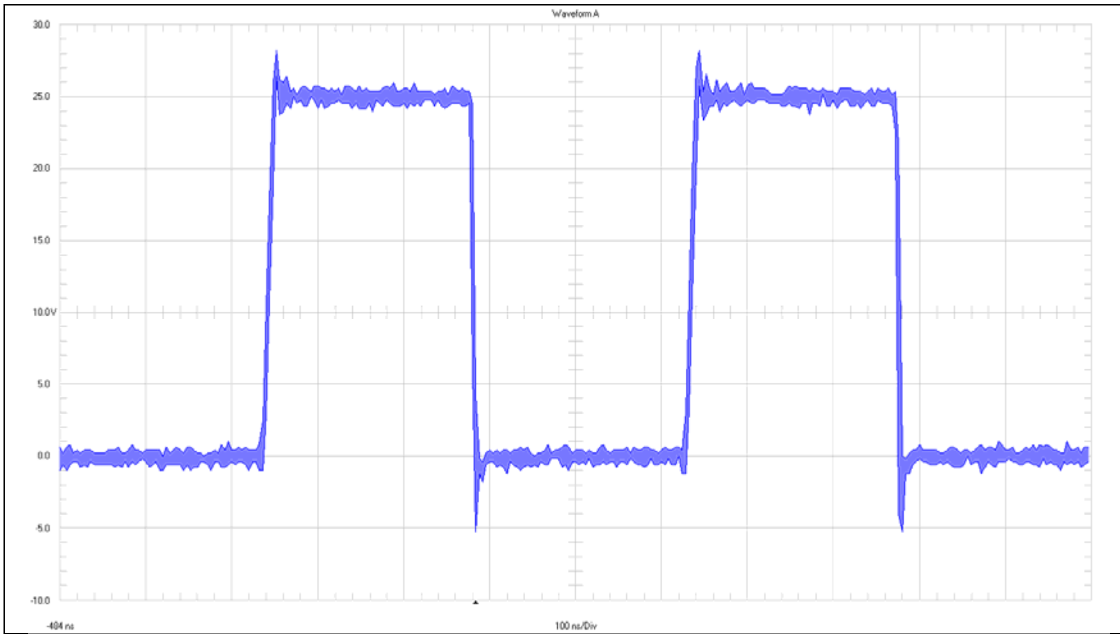
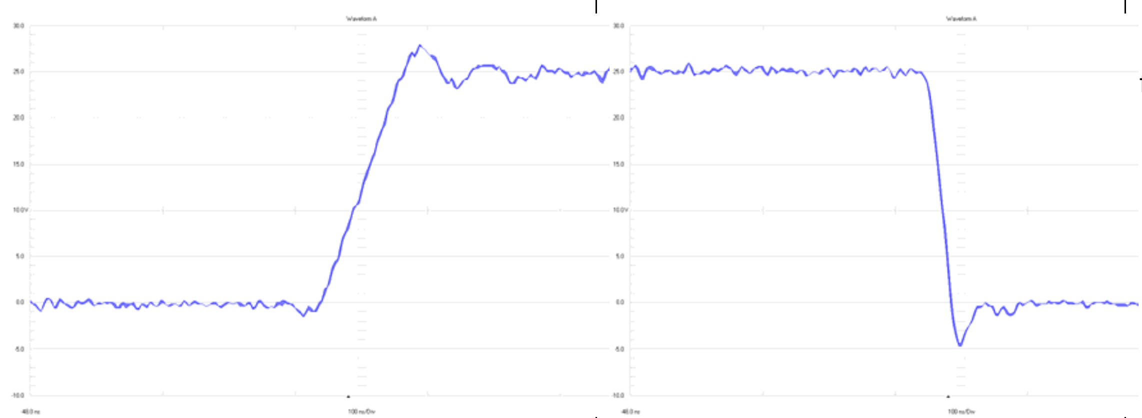
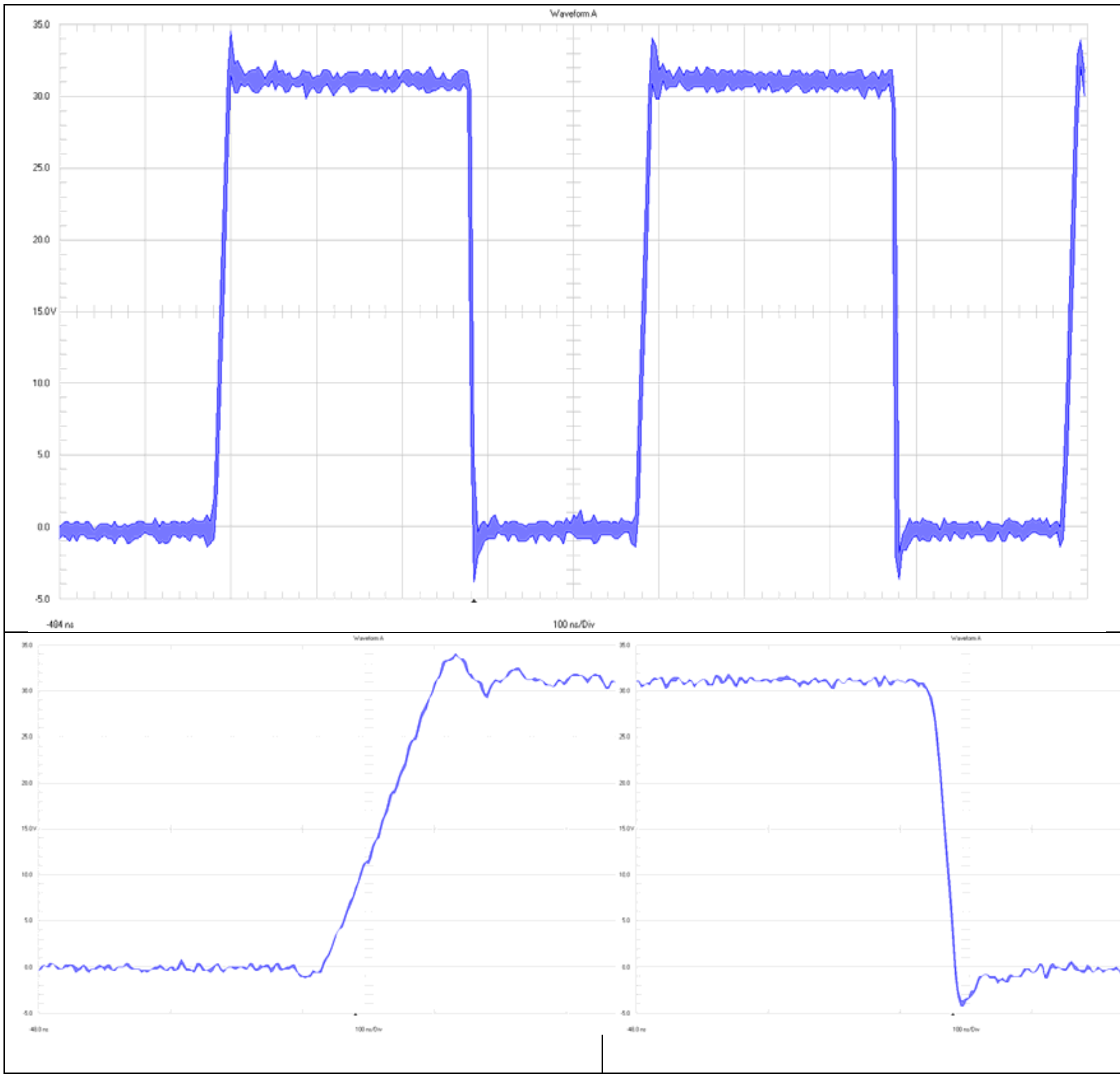
	5 V / div 100 ns / div full bandwidth
	5 V / div 100 ns (full scale) full bandwidth

Figure 10 Waveform Q1 Drain to GND @ 12 Vin – almost neither overshoot nor ringing (!)

3.1.1.3 18 V Input Voltage



5 V / div
100 ns / div
full bandwidth

10 V / div
100 ns (full scale)
full bandwidth

Figure 11 Waveform Q1 Drain to GND @ 18 Vin

3.1.2 Q1 Gate to GND

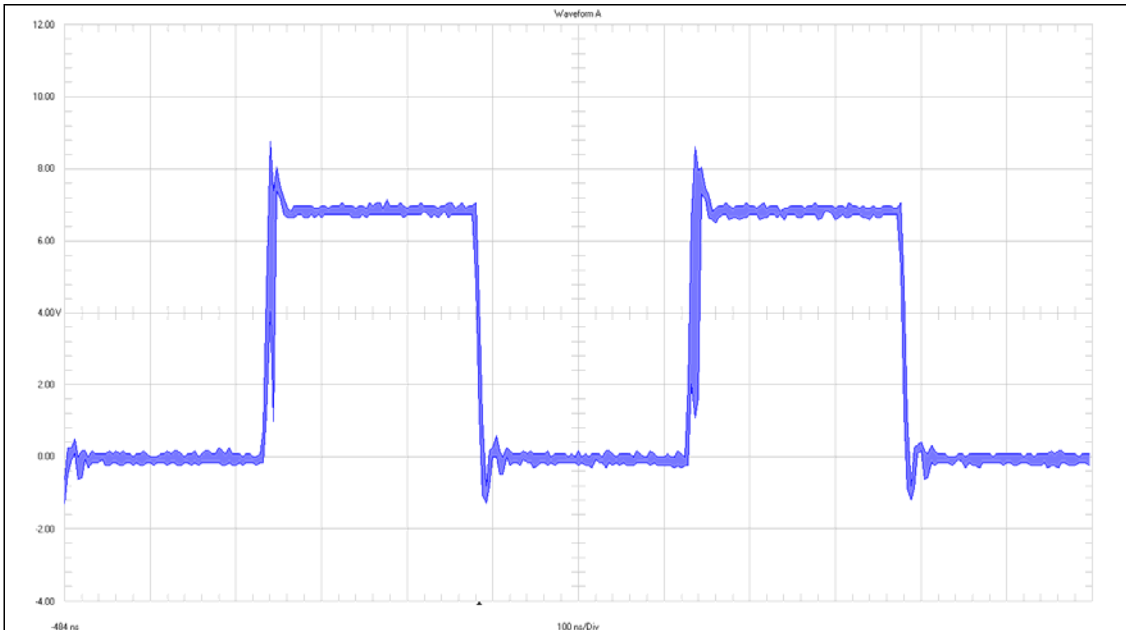
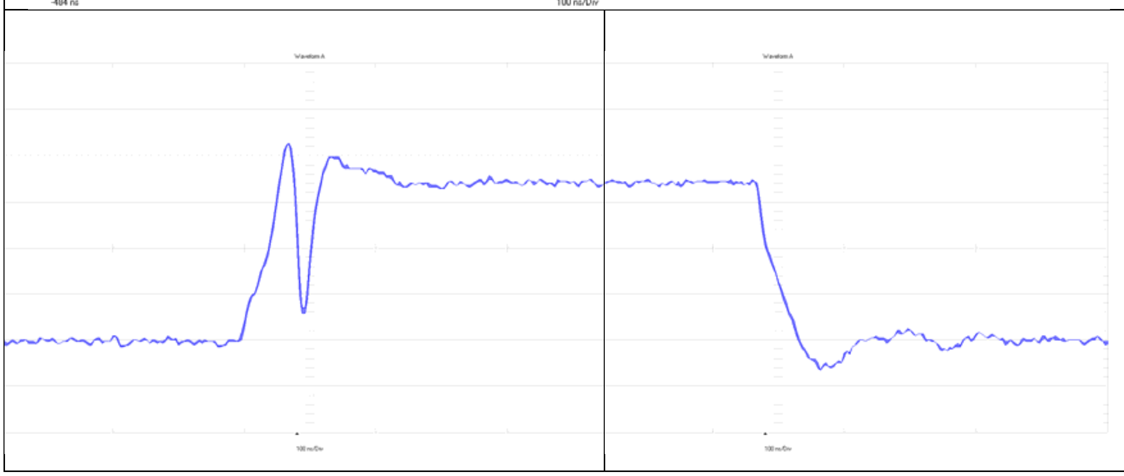
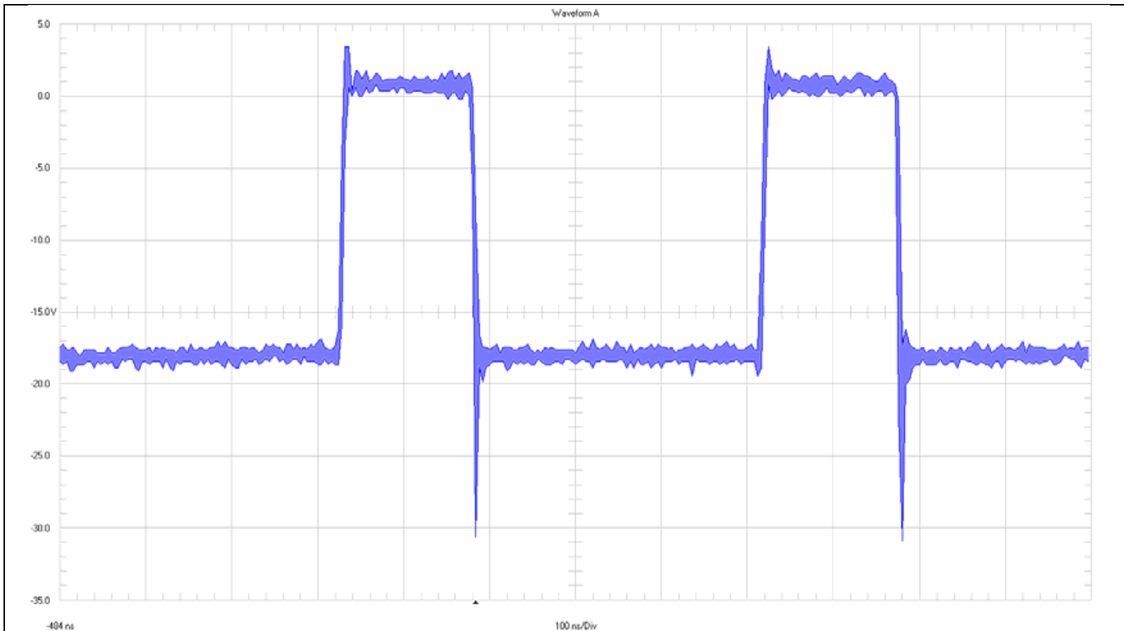
	2 V / div 100 ns / div full bandwidth
	2 V / div 100 ns (full scale) full bandwidth

Figure 12 Waveform Q1 Gate to GND @ 12 Vin

3.1.3 Diode D2 (referenced to VOUT)

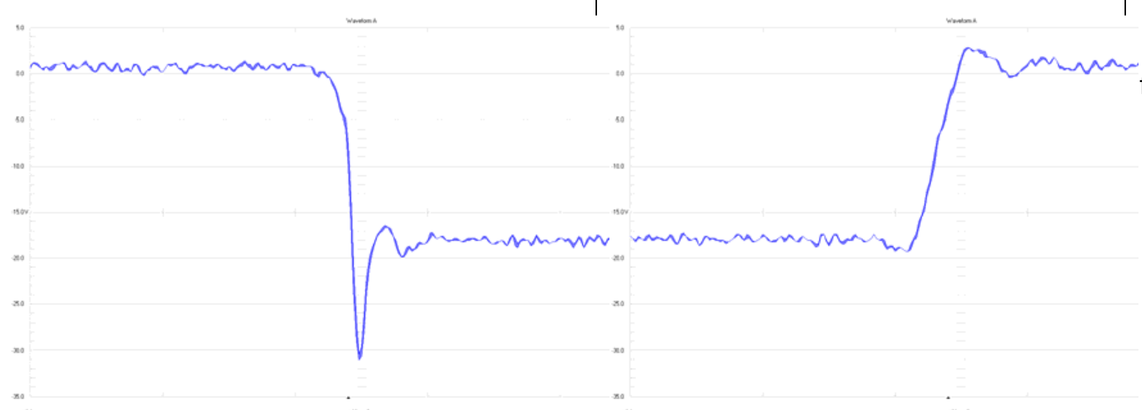
3.1.3.1 6 V Input Voltage



5 V / div

100 ns / div

full bandwidth



5 V / div

100 ns (full scale)

full bandwidth

Figure 13 Waveform D2 to VOUT @ 6 Vin

3.1.3.2 12 V Input Voltage

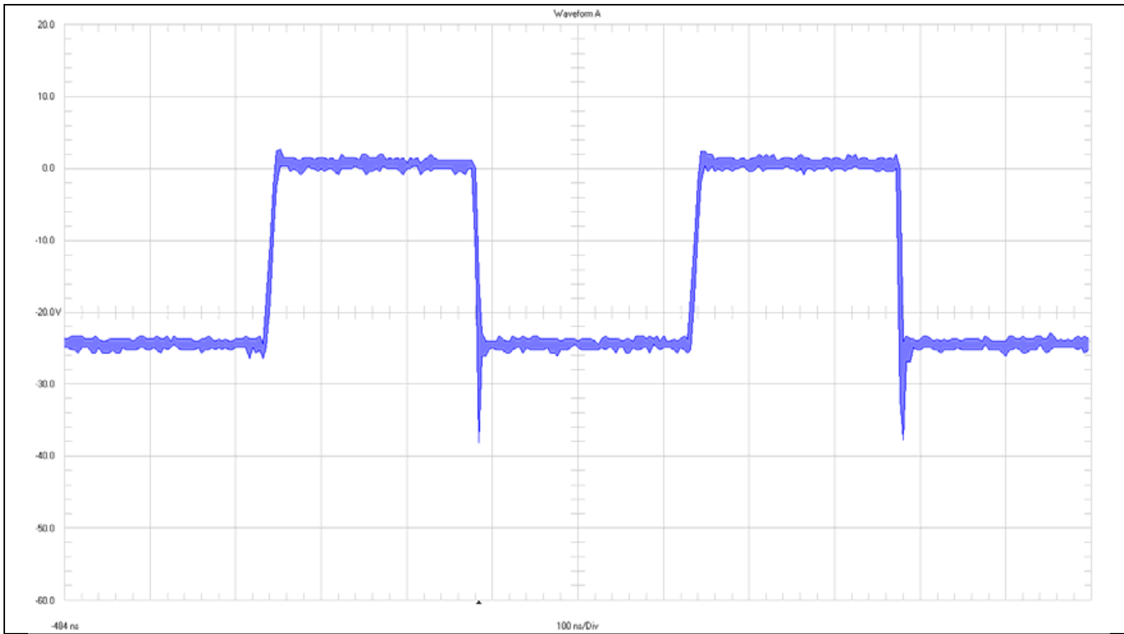
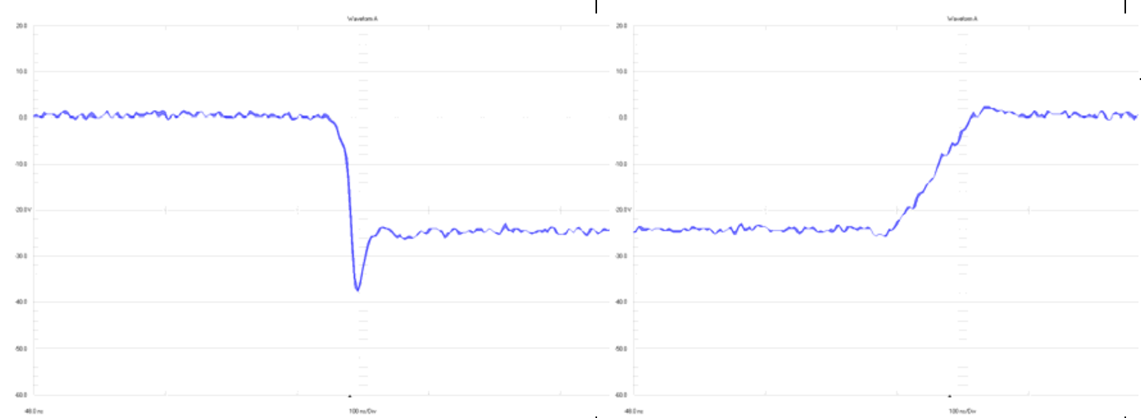
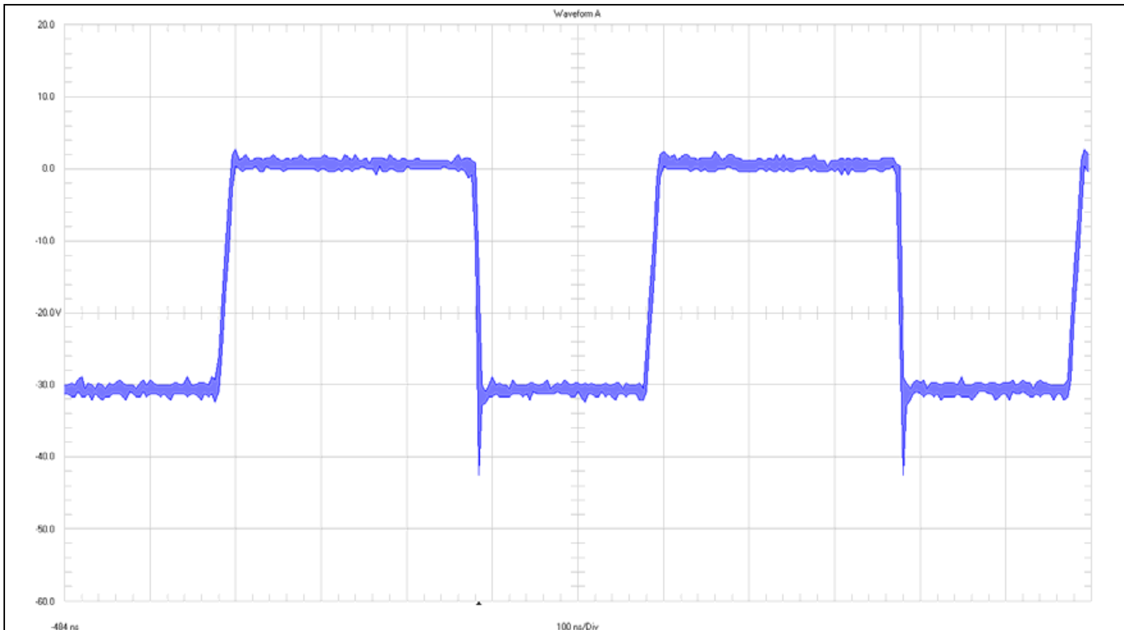
	10 V / div 100 ns / div full bandwidth
	10 V / div 100 ns (full scale) full bandwidth

Figure 14 Waveform D2 to VOUT @ 12 Vin

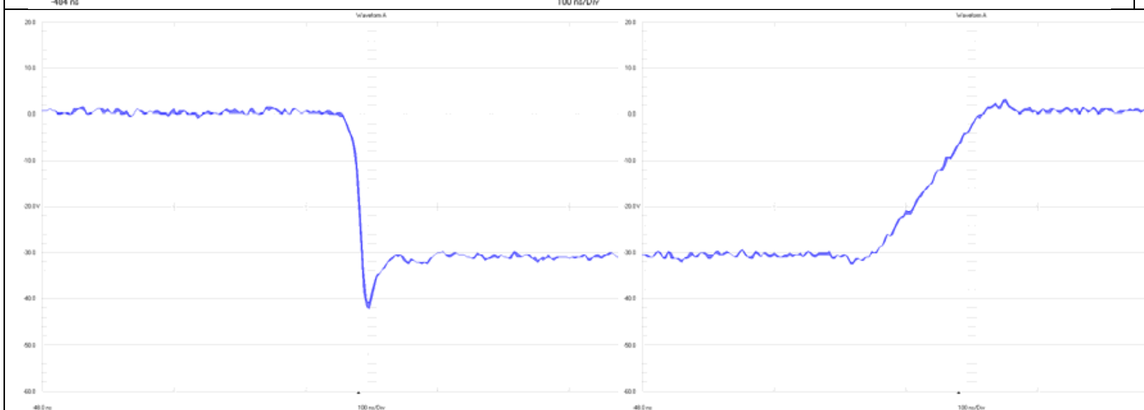
3.1.3.3 18 V Input Voltage



5 V / div

100 ns / div

full bandwidth



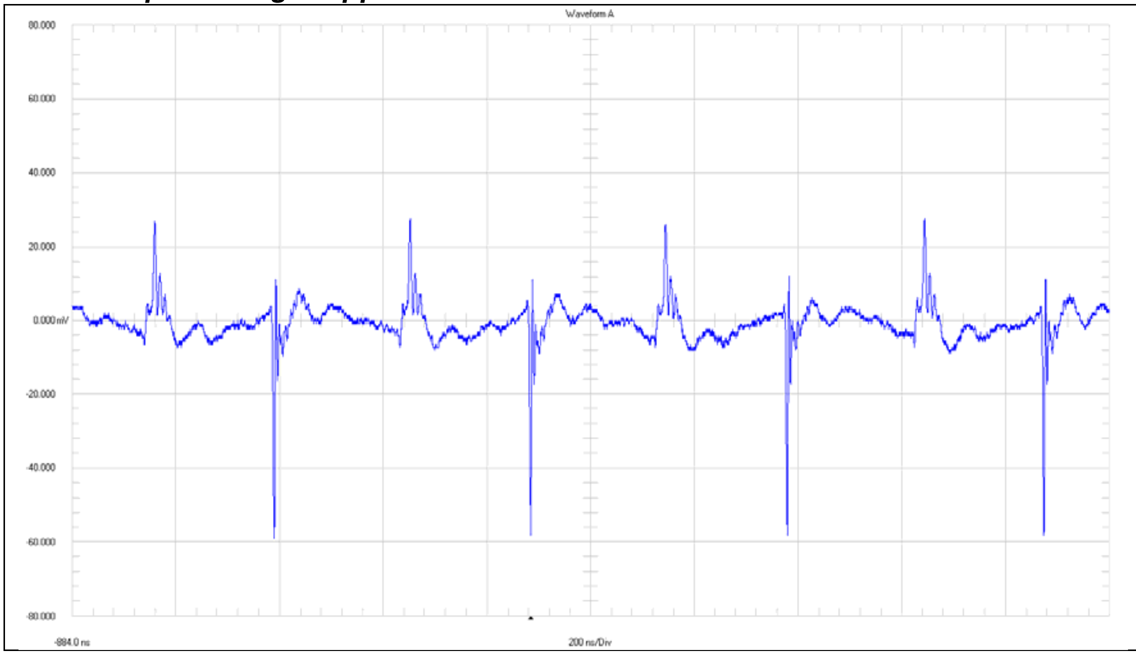
10 V / div

100 ns (full scale)

full bandwidth

Figure 15 Waveform D2 to VOUT @ 18 Vin

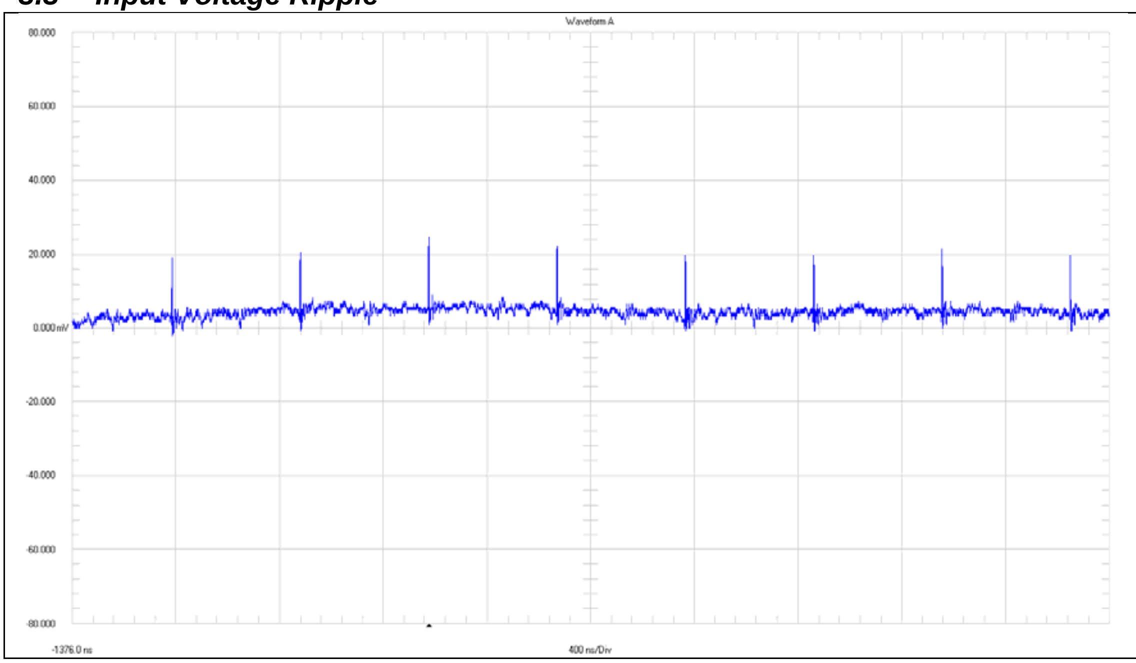
3.2 Output Voltage Ripple



20 mV / div
200 ns / div
20 MHz bw

Figure 16 Output Ripple @ 12 V Input Voltage, output ripple 90mVpp, <1% Vout (!)

3.3 Input Voltage Ripple



20 mV / div
400 ns / div
20 MHz bw

Figure 17 Filtered Input Ripple @ 12 V Input Voltage, reflected ripple 20mVpp (!)

3.4 Bode Plot

	4.5 Vin	6 Vin	12 Vin	18 Vin
Bandwidth (kHz)	5.28	7.32	12.7	16.6
Phasemargin	74°	75°	76°	71°
slope (20dB/decade)	-0.98	-1.0	-1.0	-1.0
gain margin (dB)	-13.3	-14.9	-17.4	-17.6
slope (20dB/decade)	-0.7	-0.74	-1.31	-1.45
freq (kHz)	33.1	45.1	72.4	84.6

Table 1 Summery of the Bode Plots

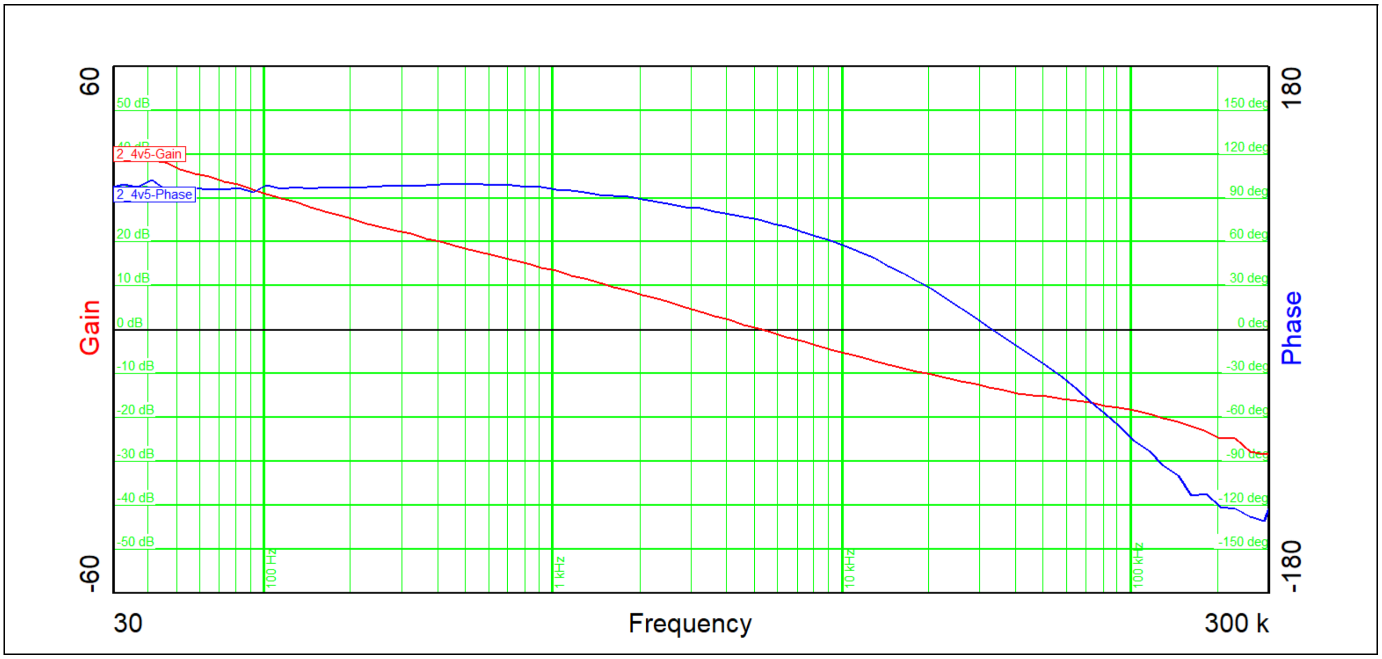


Figure 18 Bode Plot for 4.5 V Input Voltage

Loop bandwidth >5kHz ensures best dynamic behavior. Due to high Fsw 2MHz resulting in small magnetizing inductance the RHPZ is fairly high, so Fco could be increased.

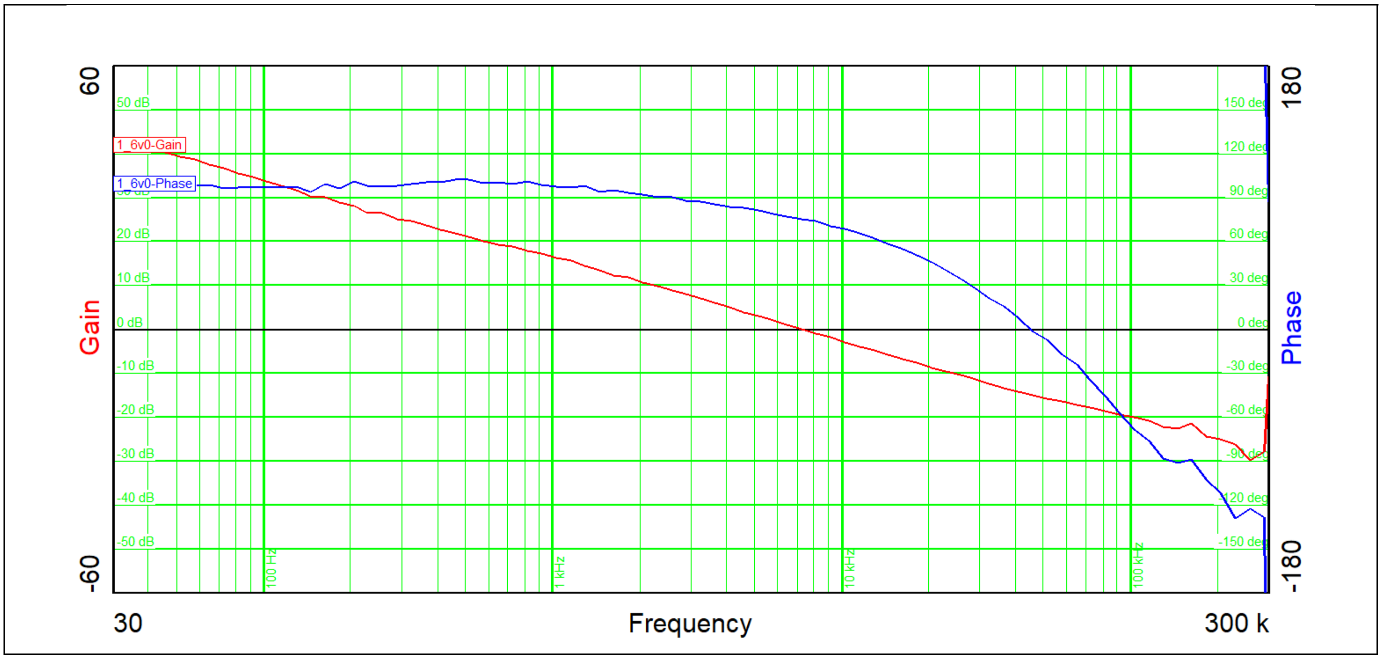


Figure 19 Bode Plot for 6 V Input Voltage

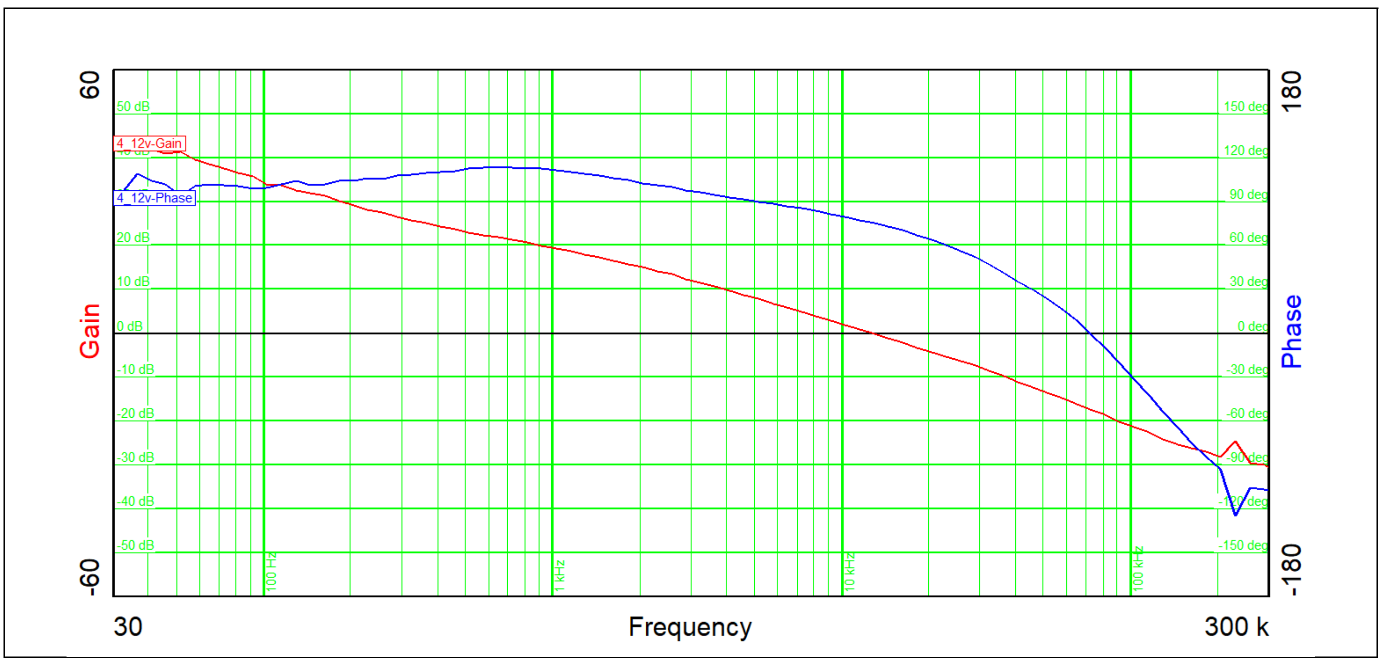


Figure 20 Bode Plot for 12 V Input Voltage

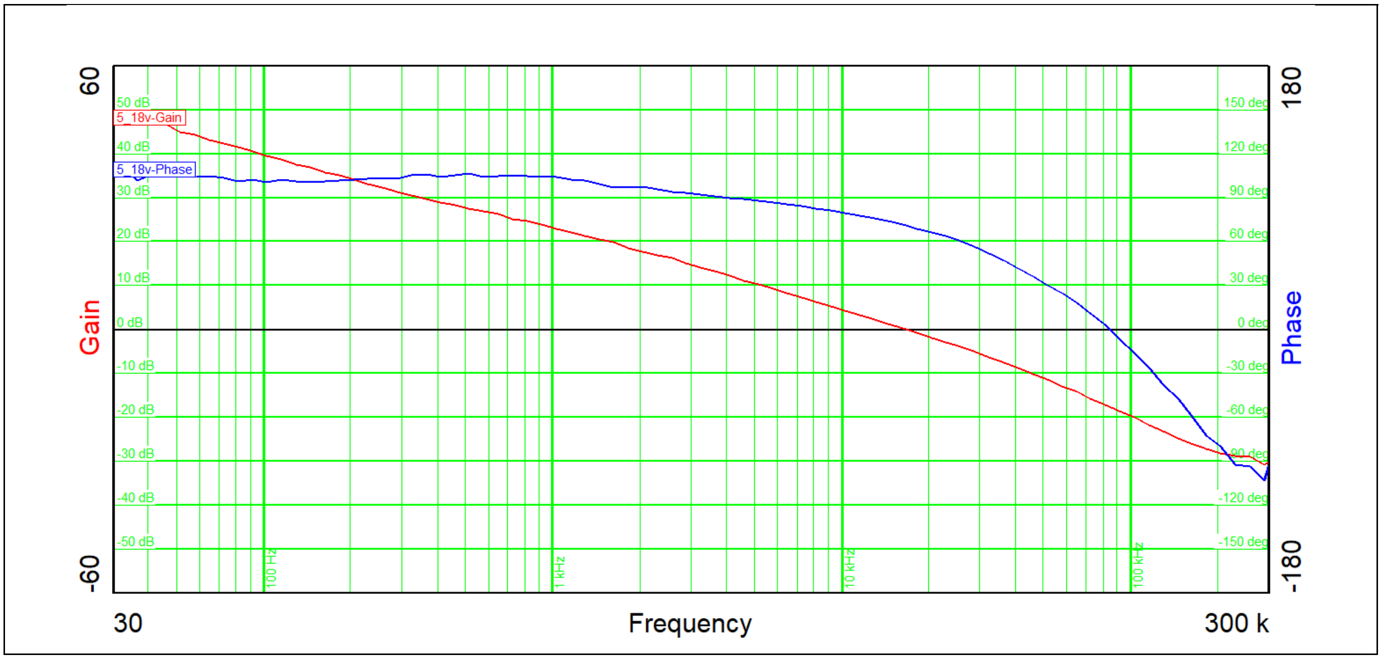
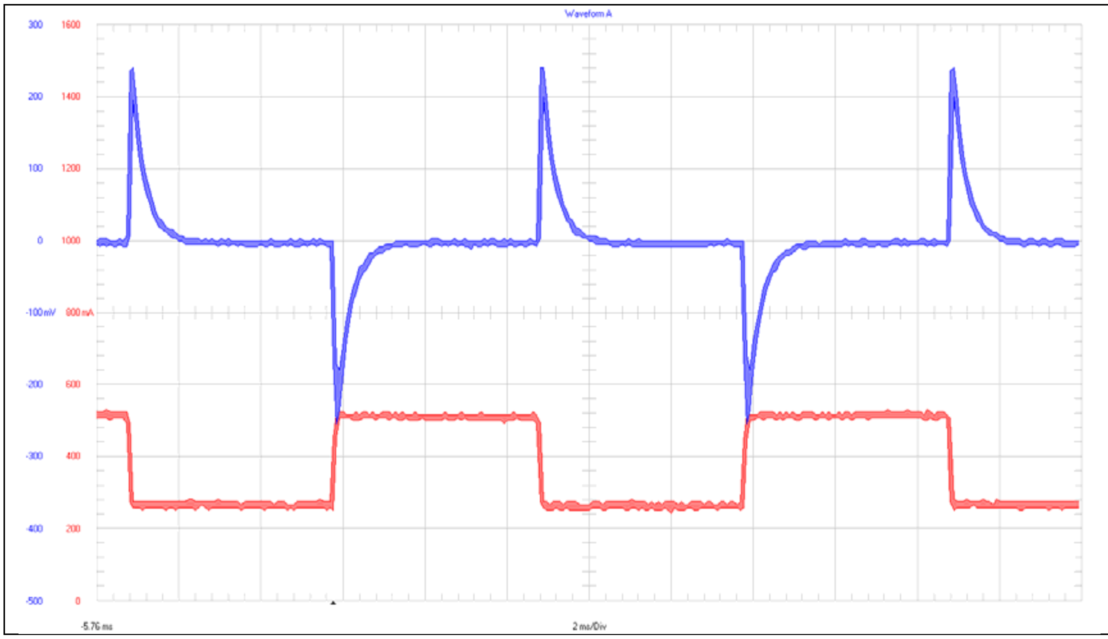


Figure 21 Bode Plot for 18 V Input Voltage

3.5 *Load Transients*

The electronic load switches from 0.25 A to 0.5 A @ 100 Hz

3.5.1 6 V Input Voltage



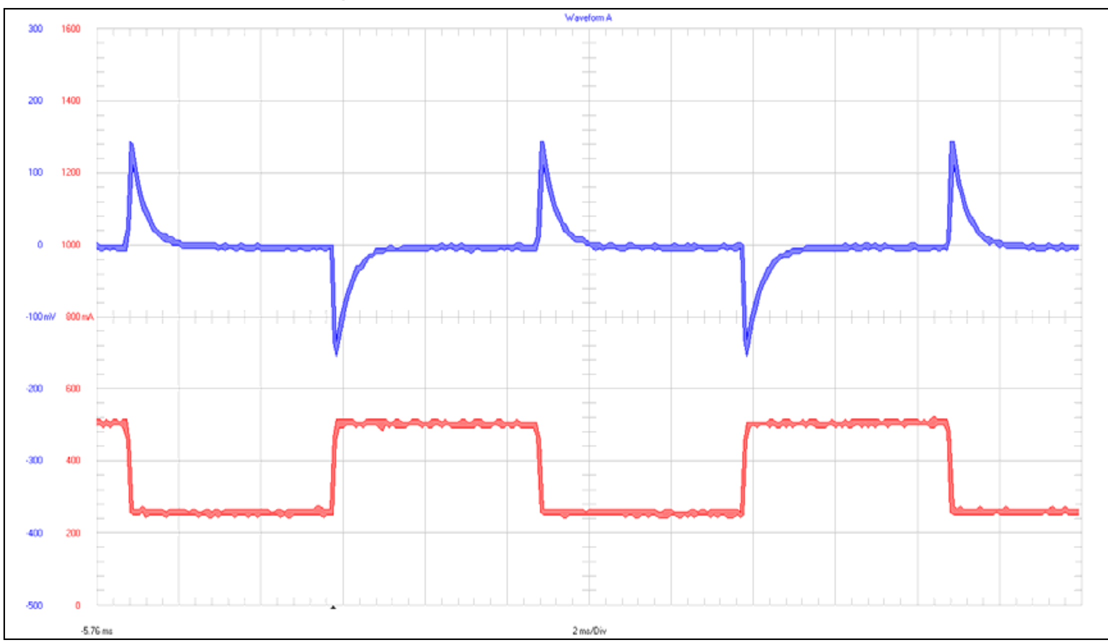
Output Voltage => 100 mV / div

Output Current => 200 mA / div

10 kHz bw

Figure 22 Load Transient @ 6 V Input Voltage – worst case deviation 240mVpk, 2% of Vout (!)

3.5.2 12 V Input Voltage



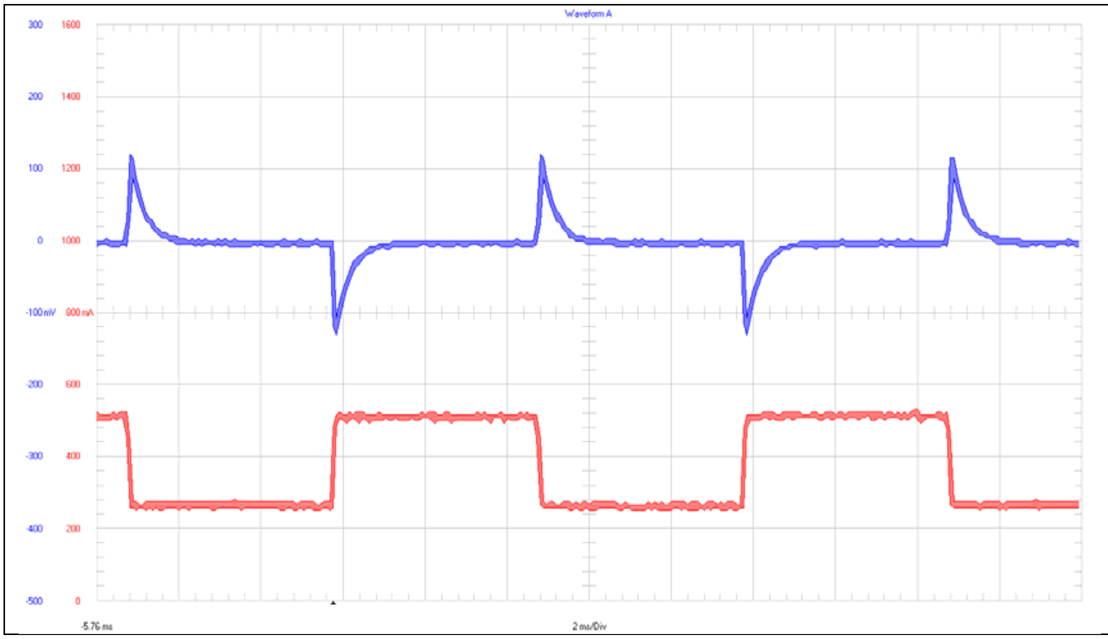
Output Voltage => 100 mV / div

Output Current => 200 mA / div

10 kHz bw

Figure 23 Load Transient @ 12 V Input Voltage

3.5.3 18 V Input Voltage



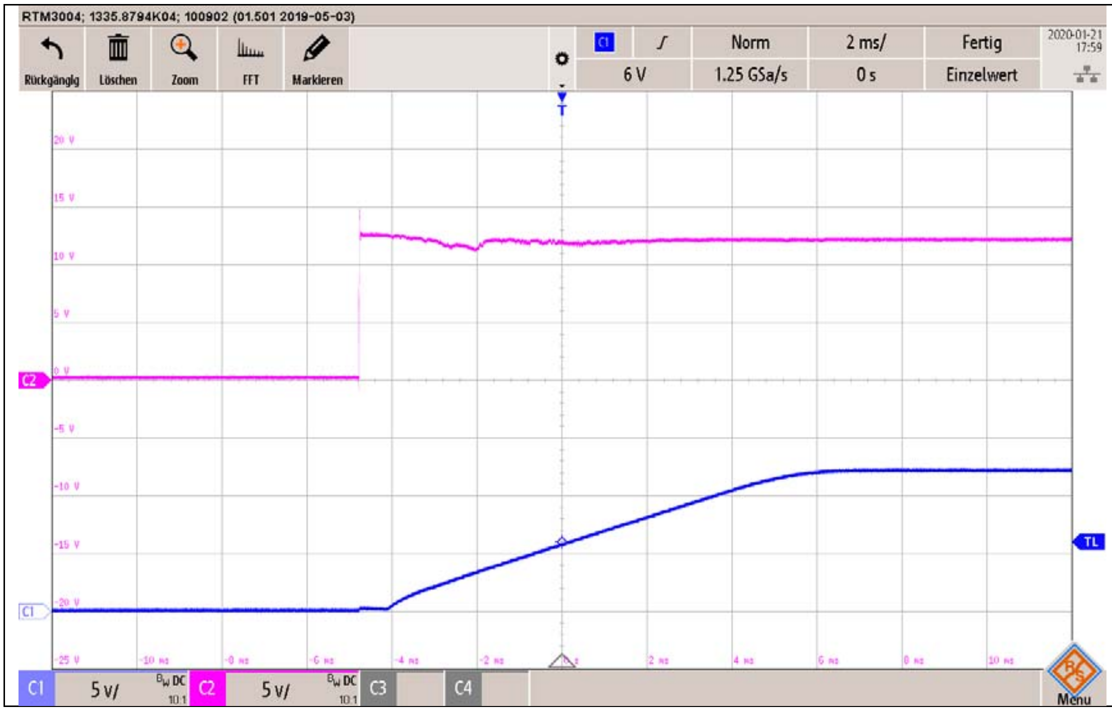
Output Voltage => 100 mV / div

Output Current => 200 mA / div

10 kHz bw

Figure 24 Load Transient @ 18 V Input Voltage

3.6 Start-up Sequence, soft start time 10ms



Input Voltage =>
5 V / div

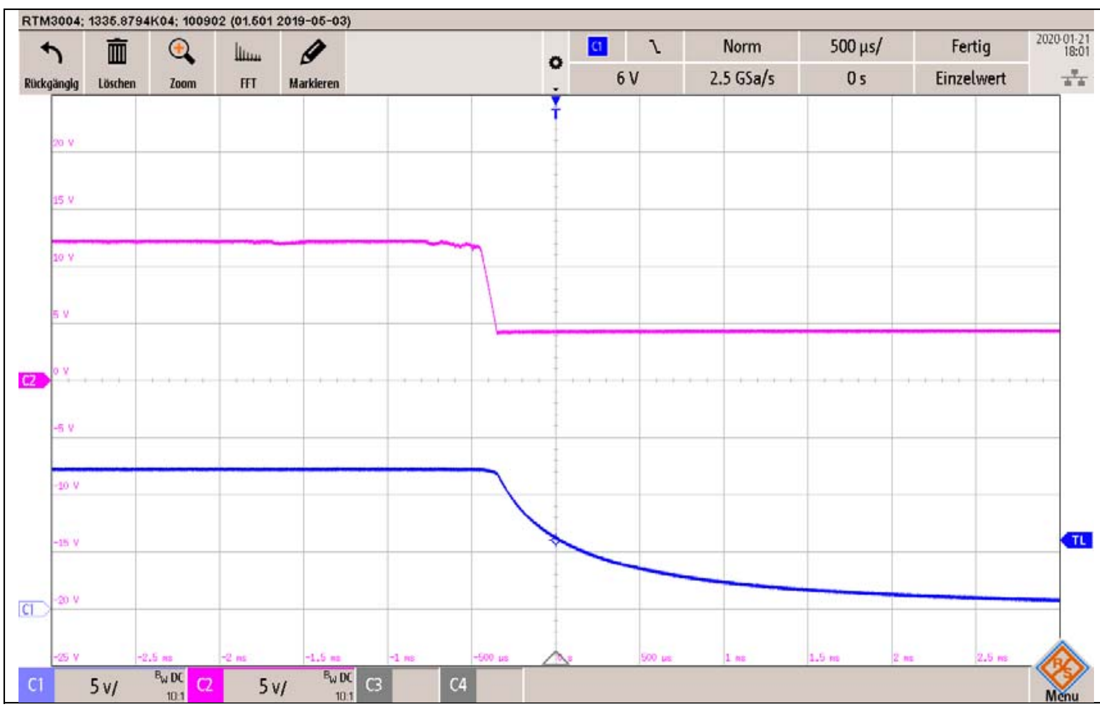
Output Voltage =>
5 V / div

2ms / div

20 MHz bw

Figure 25 Start-Up @ 12 V Input Voltage, tss 10ms ensures low inrush current during startup

3.7 Shutdown Sequence



Input Voltage =>
5 V / div

Output Voltage =>
5 V / div

500 µs / div

20 MHz bw

Figure 26 Shutdown @ 12 V Input Voltage