40-W, Low-Input Voltage, Non-Synchronous Boost Converter Reference Design

Description

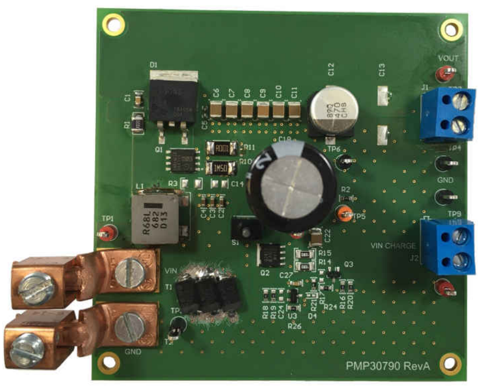
This reference design uses the LM5155-Q1 boost controller to supply an 8-V, 4.5-A load and has been optimized to operate from a single-cell supercapacitor at the input. The converter can discharge a supercapacitor as low as 1.5 V to leverage as much as possible of the stored energy to open a car door in an emergency situation, where the KL30 car battery voltage is not present anymore.

Features

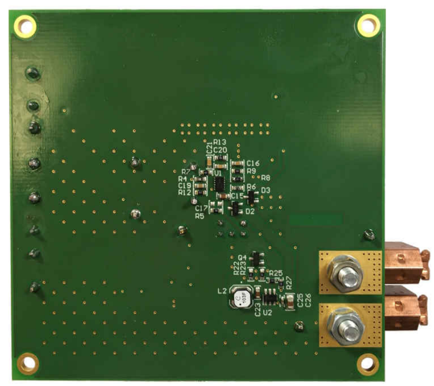
- Converter can operate from a single-cell supercapacitor and deliver 40 W of output power
- Operates down to 1.5-V input voltage enabling deep discharge of a supercapacitor
- Cost-effective design using a non-synchronous controller
- Starts up from as low as 1.5 V
- Design has been built and tested

Applications

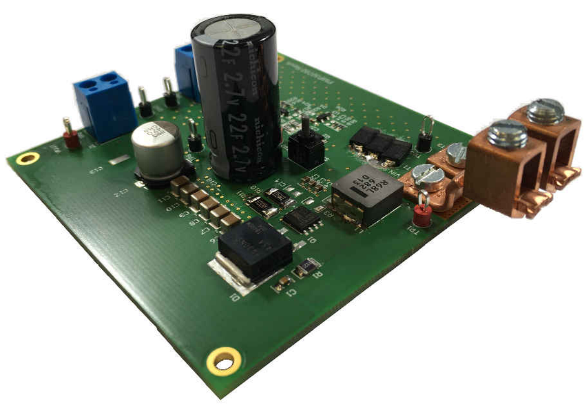
- Automotive door module
- Automotive sliding door module



Top Board Photo



Bottom Board Photo



Angled Board Photo

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
V_{IN}	1.5 V – 2.7 V
V_{OUT} TPS61071-Q1 (auxiliary supply)	5.0 V
V_{OUT}	9.0 V
I_{OUT}	4.5 A

1.2 Considerations

- The lab power supply must be connected to the PCB with very short cables (≤ 30 cm) to avoid resonances between the output of the lab power supply and the input circuit on the printed circuit board (PCB), which can influence the look and results of the frequency response analysis.
- Measurements have been executed with additional low ESR input bulk capacitance to lower the input impedance (3 × EEFSX0G221ER, no footprint on PCB).
- Target a minimum copper thickness on the PCB of 70 µm. The tested PCB, however, only had 35 µm due to worldwide supply bottlenecks.
- Measurements, including efficiency, were taken with forced air cooling.

1.3 Dimensions

The outline of the board is 83.3 mm × 82.5 mm.

2 Testing and Results

2.1 Efficiency Graph

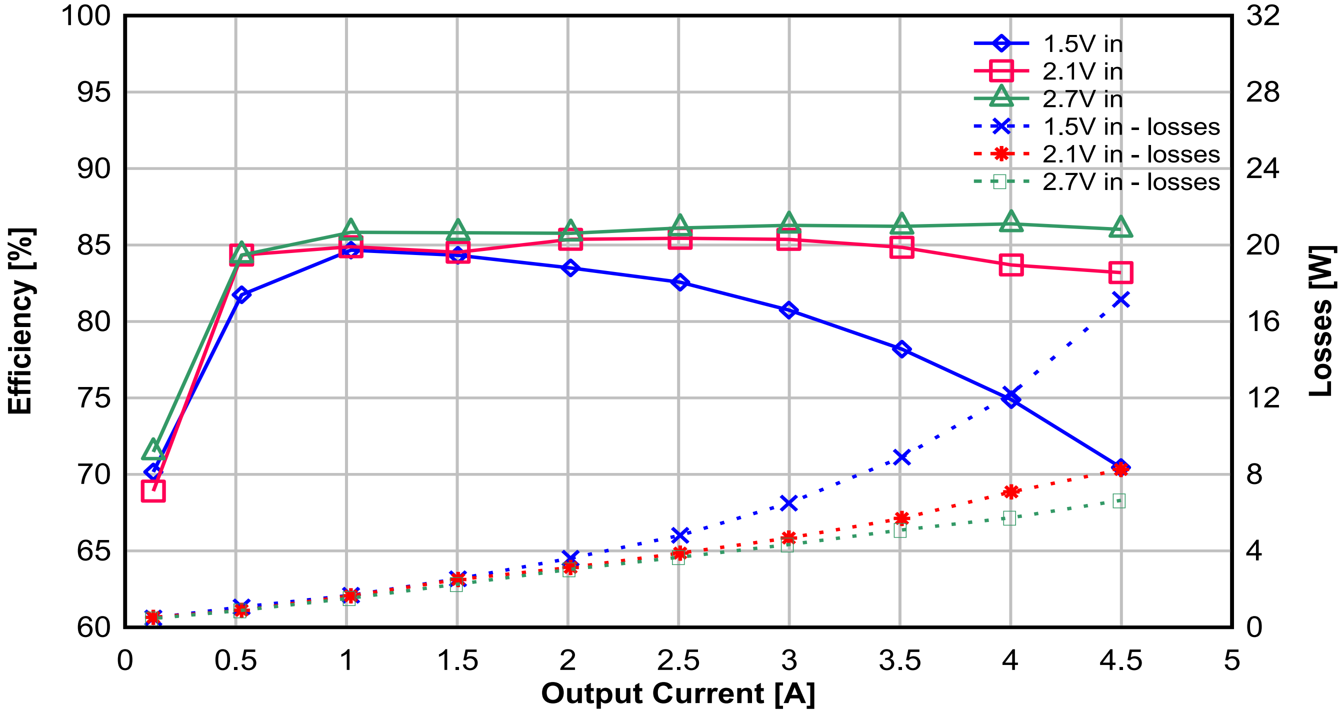


Figure 2-1. Efficiency Graph

2.2 Efficiency Data

Voltage [V]	Current [A]	Power [W]	Voltage [V]	Current [A]	Power [W]	Losses [W]	Efficiency [%]
1.500	38.700	58.050	9.092	4.498	40.896	17.154	70.4
1.500	32.400	48.600	9.092	4.003	36.395	12.205	74.9
1.500	27.200	40.800	9.091	3.509	31.900	8.900	78.2
1.500	22.500	33.750	9.090	2.998	27.252	6.498	80.7
1.500	18.400	27.600	9.090	2.507	22.789	4.811	82.6
1.500	14.600	21.900	9.089	2.012	18.287	3.613	83.5
1.500	10.800	16.200	9.089	1.503	13.661	2.539	84.3
1.500	7.300	10.950	9.088	1.020	9.271	1.679	84.7
1.500	3.900	5.850	9.088	0.526	4.782	1.068	81.7
1.500	1.100	1.650	9.087	0.127	1.158	0.492	70.2

Voltage [V]	Current [A]	Power [W]	Voltage [V]	Current [A]	Power [W]	Losses [W]	Efficiency [%]
2.100	23.400	49.140	9.089	4.498	40.882	8.258	83.2
2.100	20.700	43.470	9.089	4.003	36.383	7.087	83.7
2.100	17.900	37.590	9.089	3.509	31.893	5.697	84.8
2.100	15.200	31.920	9.089	2.998	27.249	4.671	85.4
2.100	12.700	26.670	9.089	2.507	22.786	3.884	85.4
2.100	10.200	21.420	9.089	2.012	18.287	3.133	85.4
2.100	7.700	16.170	9.088	1.504	13.668	2.502	84.5
2.100	5.200	10.920	9.088	1.020	9.270	1.650	84.9
2.100	2.700	5.670	9.088	0.526	4.782	0.888	84.3
2.100	0.800	1.680	9.087	0.127	1.158	0.522	68.9

Voltage [V]	Current [A]	Power [W]	Voltage [V]	Current [A]	Power [W]	Losses [W]	Efficiency [%]
2.700	17.600	47.520	9.088	4.498	40.878	6.642	86.0
2.700	15.600	42.120	9.089	4.003	36.383	5.737	86.4
2.700	13.700	36.990	9.089	3.509	31.893	5.097	86.2
2.700	11.700	31.590	9.089	2.999	27.258	4.332	86.3
2.700	9.800	26.460	9.089	2.507	22.786	3.674	86.1
2.700	7.900	21.330	9.088	2.013	18.294	3.036	85.8
2.700	5.900	15.930	9.088	1.504	13.668	2.262	85.8
2.700	4.000	10.800	9.088	1.020	9.270	1.530	85.8
2.700	2.100	5.670	9.088	0.526	4.782	0.888	84.3
2.700	0.600	1.620	9.088	0.127	1.158	0.462	71.5

2.3 Bode Plots

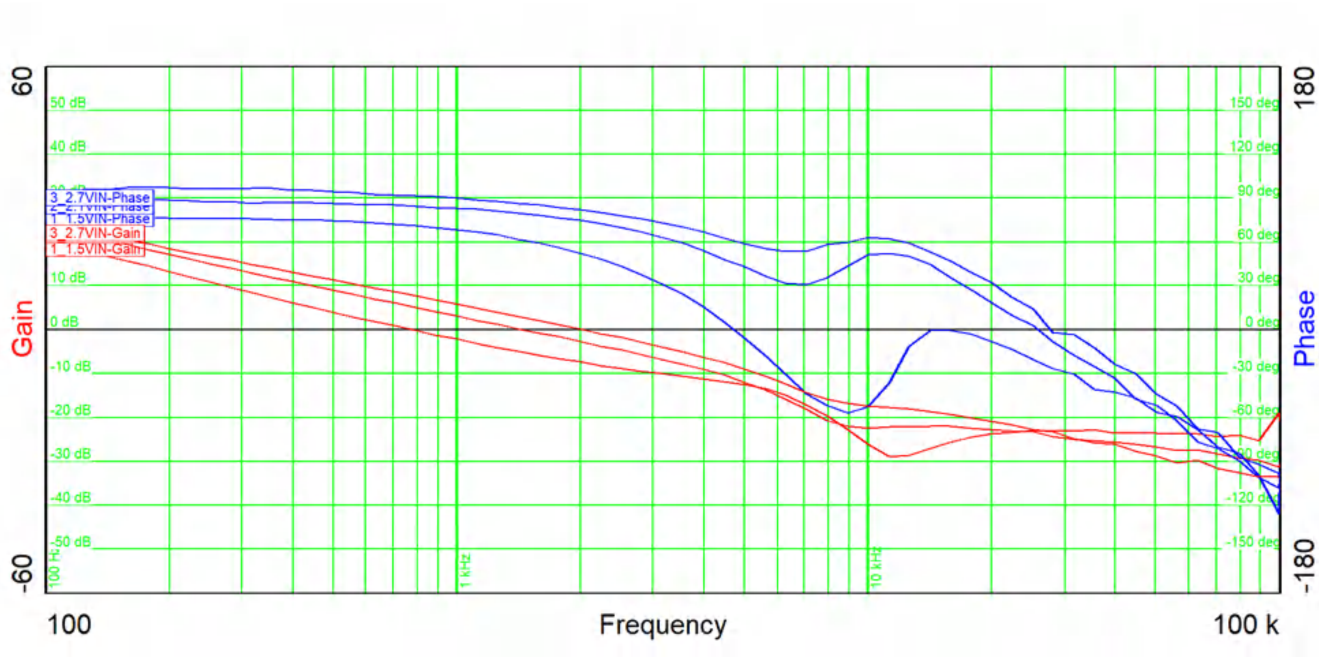


Figure 2-2. Bode Plot

- 1.5 V_{IN}, 4.5-A load current: f_{CO} 0.77 kHz, 71° phase margin, –12 dB gain margin
- 2.1 V_{IN}, 4.5-A load current: f_{CO} 1.44 kHz, 79° phase margin, –24 dB gain margin
- 2.7V $_{IN}$, 4.5-A load current: f_{CO} 2.00 kHz, 82° phase margin, –23 dB gain margin

3 Waveforms

3.1 Switching

3.1.1 2.7-V Input Voltage

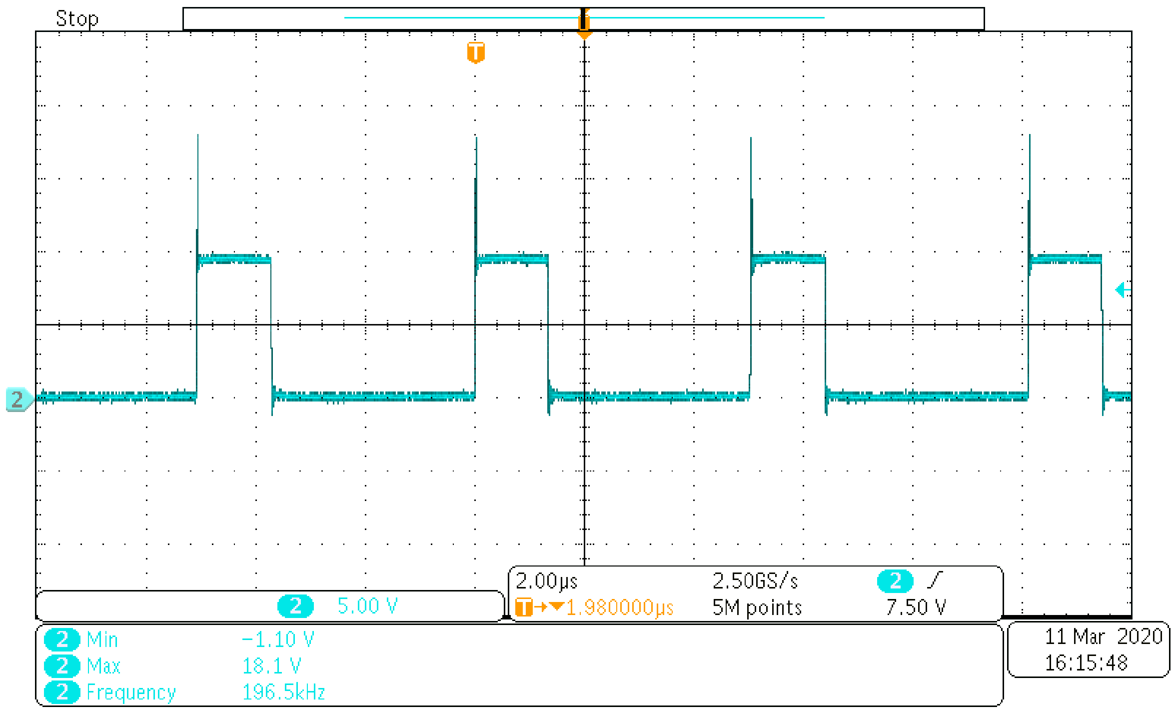


Figure 3-1. Switching Node at 2.7 V_{IN} and 4.5-A Load Current [Scale: 5.0 V / div, 2.0 µs / div]

3.1.2 2.1-V Input Voltage

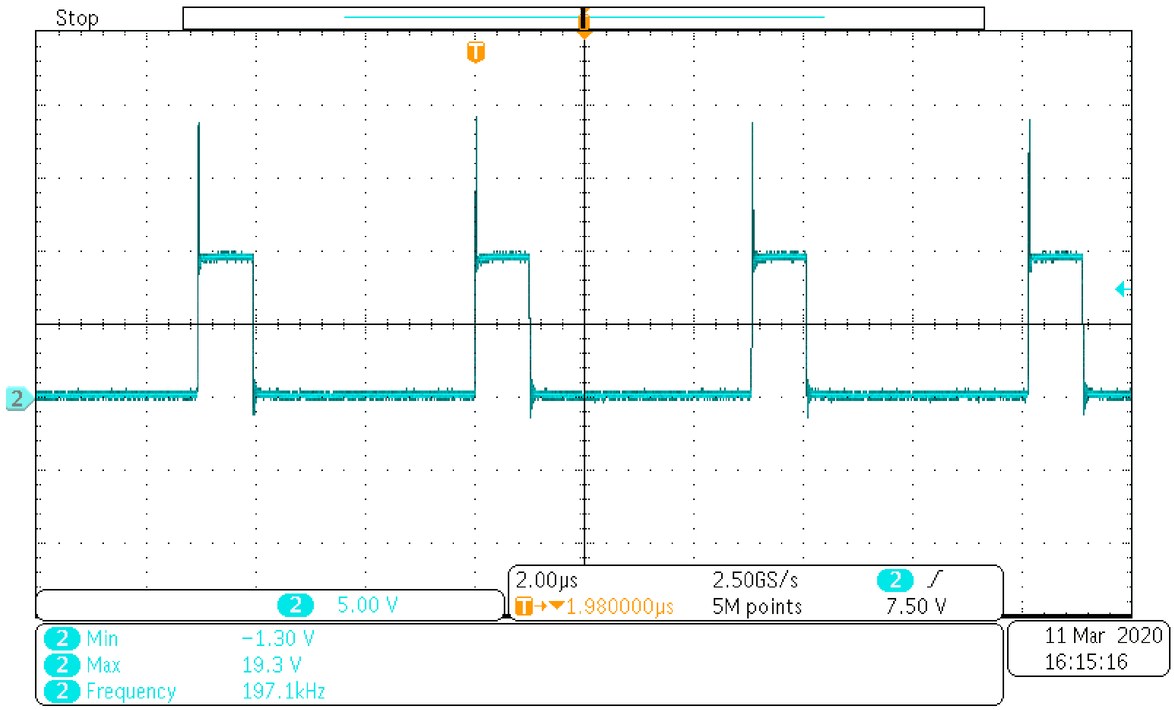


Figure 3-2. Switching Node at 2.1 V_{IN} and 4.5-A Load Current [Scale: 5.0 V / div, 2.0 μs / div]

3.1.3 1.5-V Input Voltage

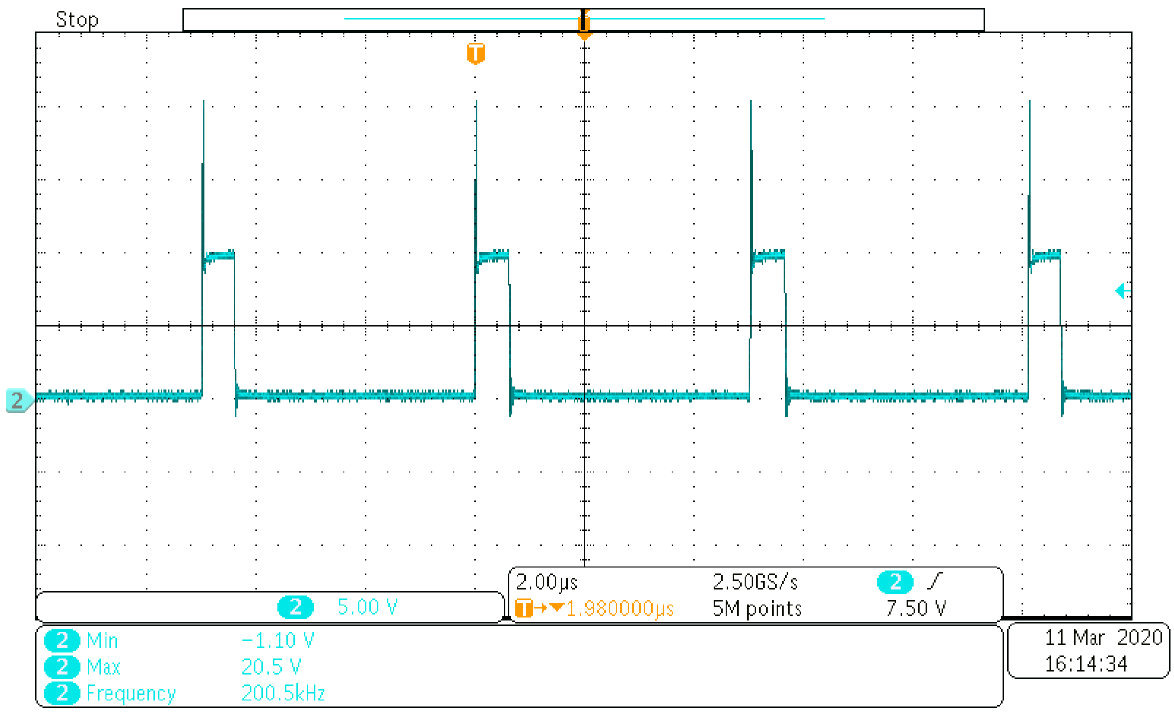


Figure 3-3. Switching Node at 1.5 V_{IN} and 4.5-A Load Current [Scale: 5.0 V / div, 2.0 μs / div]

3.2 Output Voltage Ripple

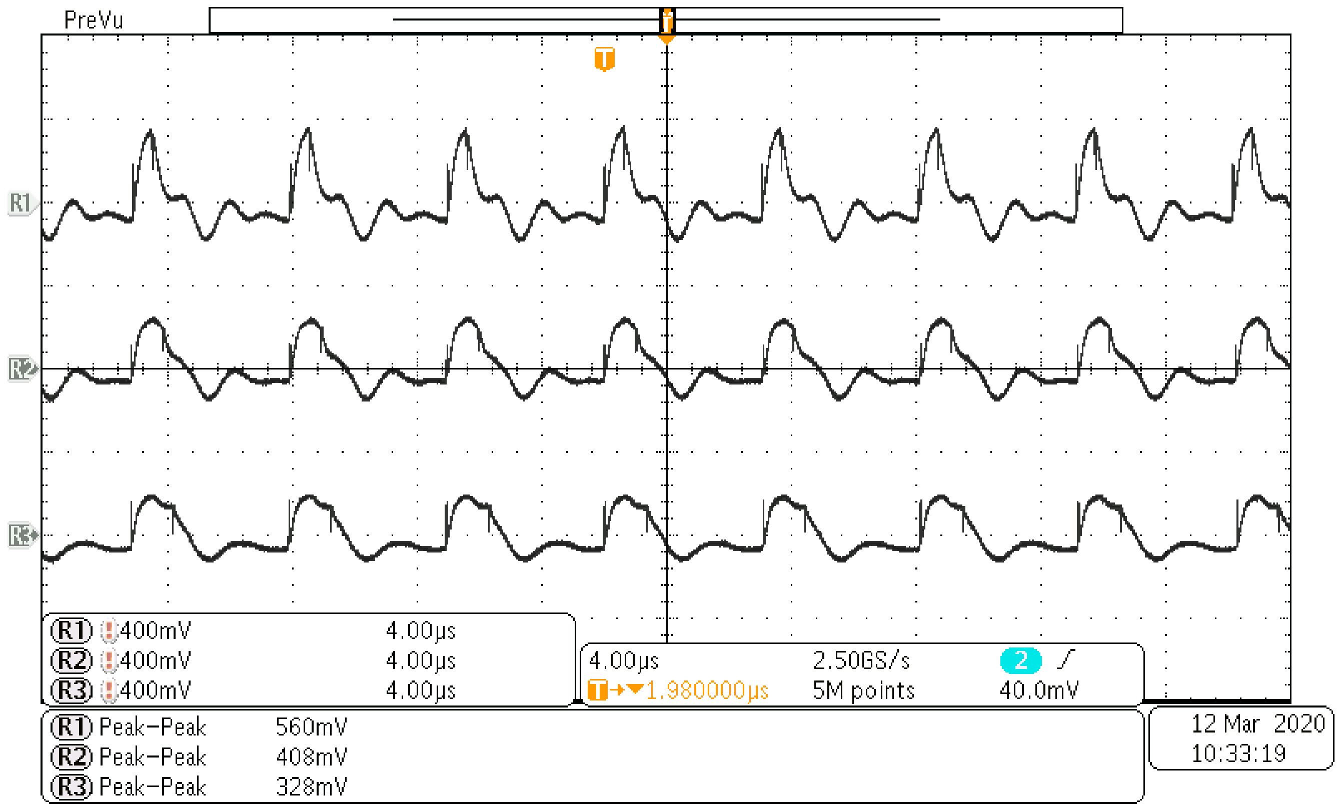


Figure 3-4. Output Voltage Ripple

- R1: 1.5 V_{IN}, 4.5-A load, 560-mV peak-peak-ripple [Scale: 400 mV / div, 4.0 µs / div]
- R2: 2.0 V_{IN}, 4.5-A load, 408-mV peak-peak-ripple [Scale: 400 mV / div, 4.0 µs / div]
- R3: 2.7 V_{IN}, 4.5-A load, 328-mV peak-peak-ripple [Scale: 400 mV / div, 4.0 µs / div]

3.3 Load Transients

3.3.1 0.2-A to 2.2-A Load Transient

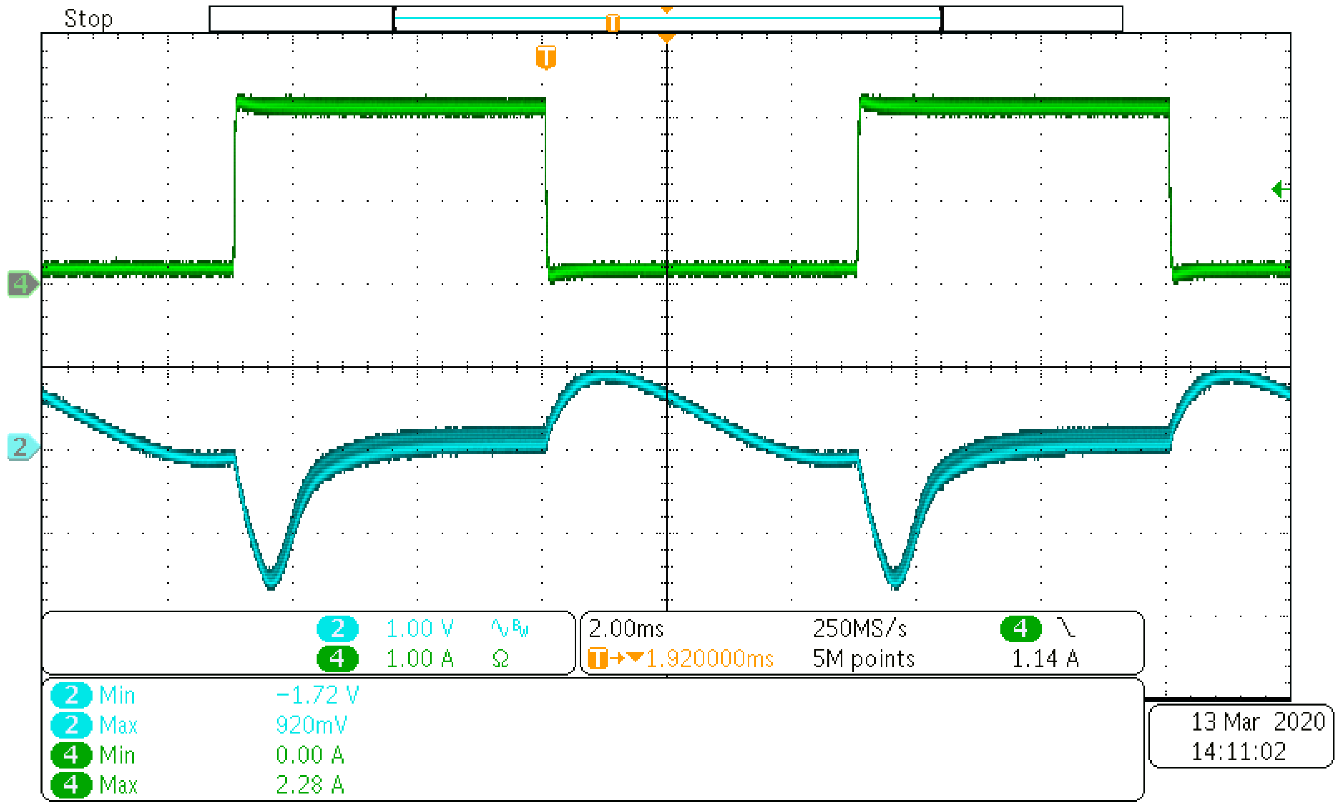


Figure 3-5. Load Transient From 0.2 A to 2.2 A

- CH2: AC-coupled output voltage at 2.0 V_{IN}, bandwidth limited (20 MHz) [Scale: 1.0 V / div, 2.0 ms / div]
- CH4: Load transient from 0.2 A to 2.2 A, slew rate 0.2 A / µs [Scale: 1.0 A / div, 2.0 ms / div]

3.3.2 2-A to 4.5-A Load Transient

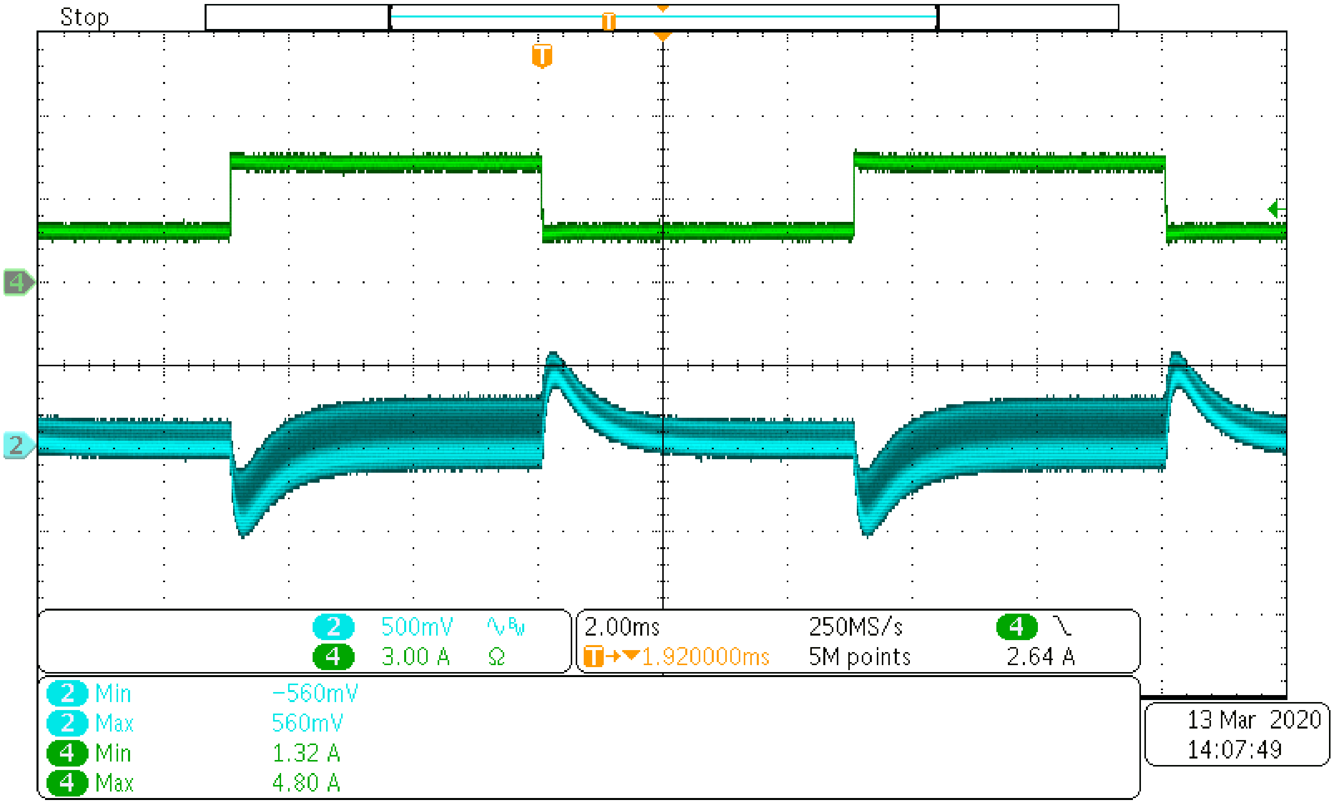


Figure 3-6. Load Transient From 2 A to 4.5 A

- CH2: AC-coupled output voltage at 2.0 V_{IN}, bandwidth limited (20 MHz) [Scale: 500 mV / div, 2.0 ms / div]
- CH4: Load transient from 2.0 A to 4.5 A, slew rate 1.0 A / µs [Scale: 2.0 A / div, 2.0 ms / div]

3.4 Start-Up Sequence

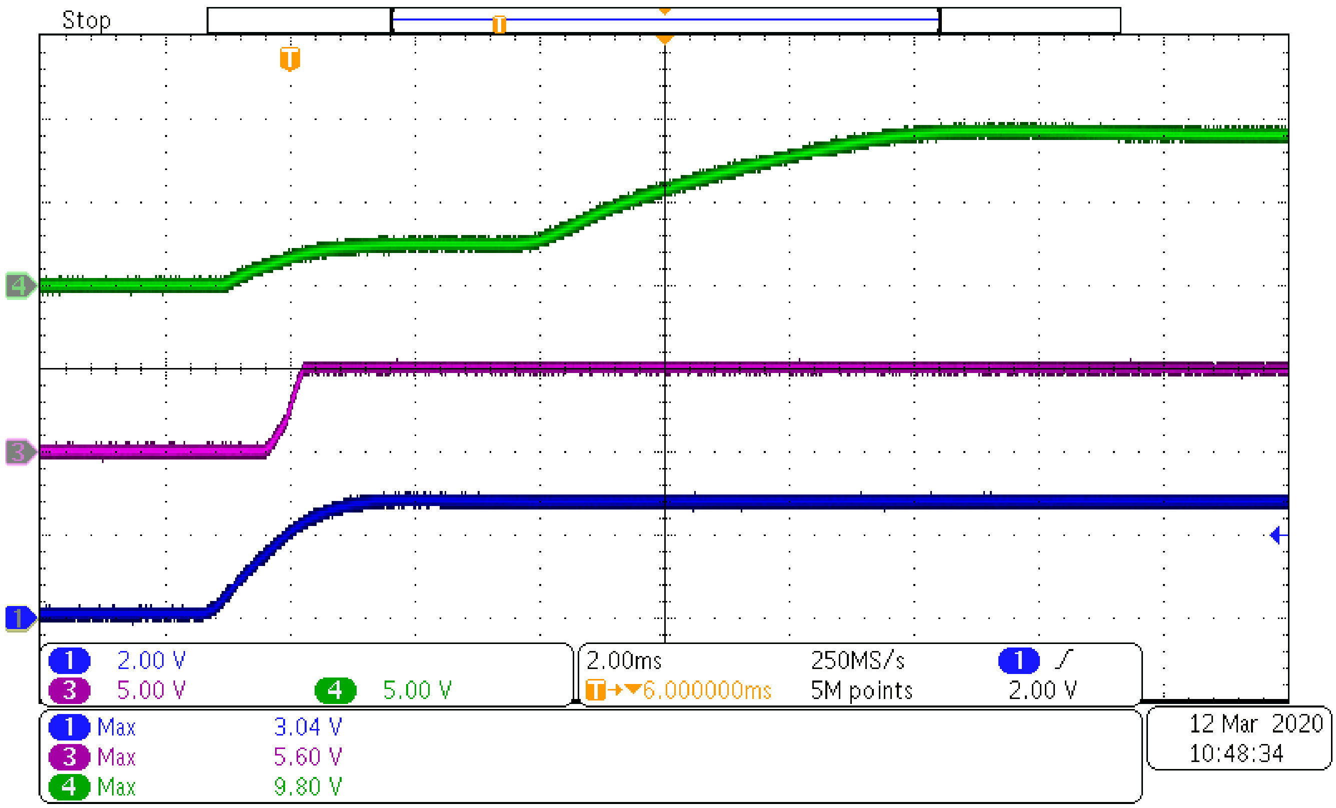


Figure 3-7. Start-Up

- CH1: Input voltage at 2.7 V, [Scale: 2.0 V / div, 2.0 ms / div]
- CH3: Auxiliary Voltage [Scale: 5.0 V / div, 2.0 ms / div]
- CH4: Output Voltage [Scale: 5.0 V / div, 2.0 ms / div]