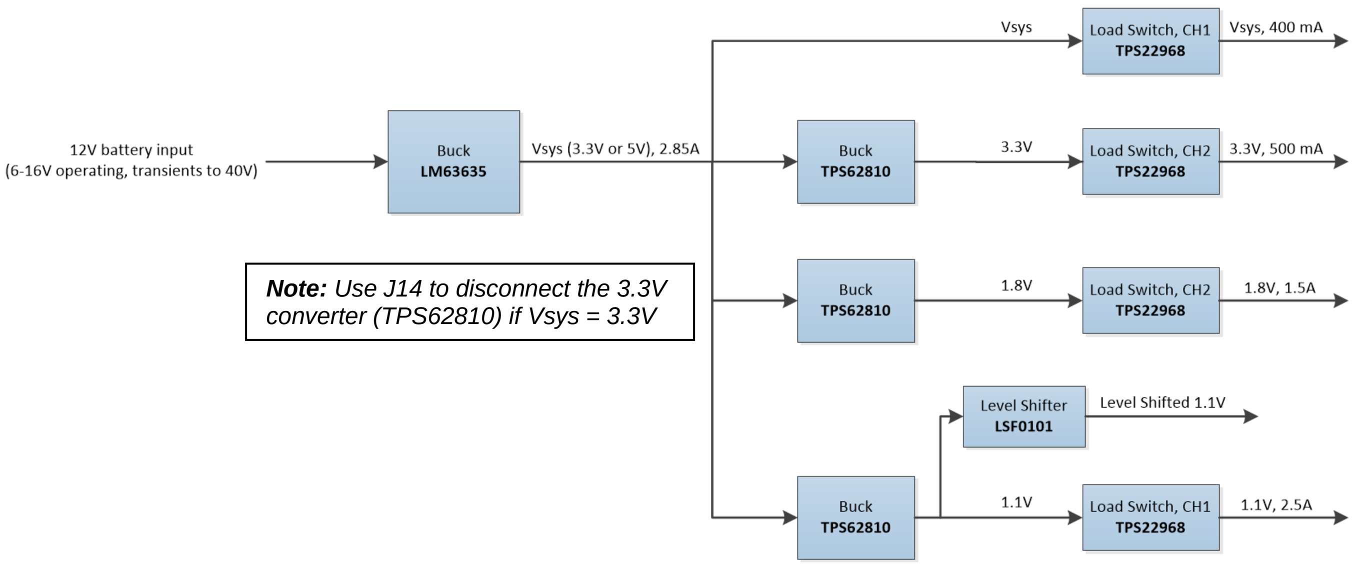
Test Report: PMP21939

Four-Output Synchronous Buck Reference Design for Automotive Telematics Control Units

Description

This reference design uses an LM63635-Q1 synchronous buck converter to output either a 3.3-V or 5-V rail. The bus converter switches at 2.1 MHz, and the load converters (TPS62810-Q1) switch at 2.2 MHz. The system is designed for telematics control unit power. Easily configurable jumpers allow users to enable and disable the bus converter, load converters and load switches for up to 3-A maximum load at each output.



1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements for 3.3V or 5V Output (LM63635)

PARAMETER	SPECIFICATIONS
Input Voltage	12V battery, 6-16V operating
Output Voltage	3.3V or 5V (Vsys)
Maximum Output Current	2.85 A
Switching Frequency	2.1 MHz

Table 2. Voltage and Current Requirements for 3.3V Converter (TPS62810-Q1)

PARAMETER	SPECIFICATIONS
Input Voltage	5V
Output Voltage	3.3V
Maximum Output Current	0.5A (max of 3A)
Switching Frequency	2.2 MHz

Table 3. Voltage and Current Requirements for 1.8V Converter (TPS62810-Q1)

PARAMETER	SPECIFICATIONS
Input Voltage	3.3V or 5V
Output Voltage	1.8V
Maximum Output Current	1.5A (max of 3A)
Switching Frequency	2.2 MHz

Table 4. Voltage and Current Requirements for 1.1V Converter (TPS62810-Q1)

PARAMETER	SPECIFICATIONS
Input Voltage	3.3V or 5V
Output Voltage	1.1V
Maximum Output Current	2.5A (max of 3A)
Switching Frequency	2.2 MHz

1.2 Required Equipment*

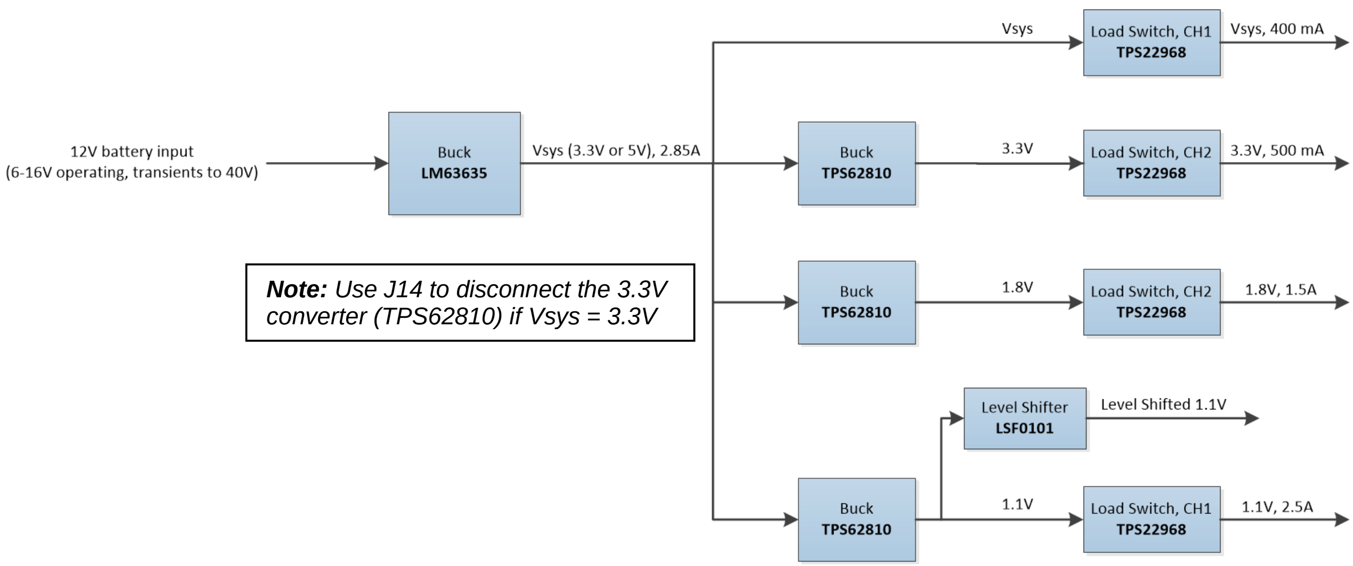
- Power supply
- Electronic or resistive load
- Oscilloscope

1.3 Considerations

All testing was performed with a 12V input, unless mentioned otherwise.

“Vsys” is used throughout the report to refer to the output of the LM63635 bus converter. Vsys can have a value of 3.3V or 5V.

The currents shown in the block diagram (repeated below) are specific to the application. The design, however, includes enable and disable options for the bus converter, load converters, and load switches. A maximum load of 3A can be achieved for each load converter, separately. The testing performed in this report takes this max load into consideration. See schematic for specific jumper descriptions.



2 Testing and Results

2.1 Efficiency Graphs

Peak efficiencies are bolded in the efficiency raw data tables.

2.1.1 LM63635 Efficiencies

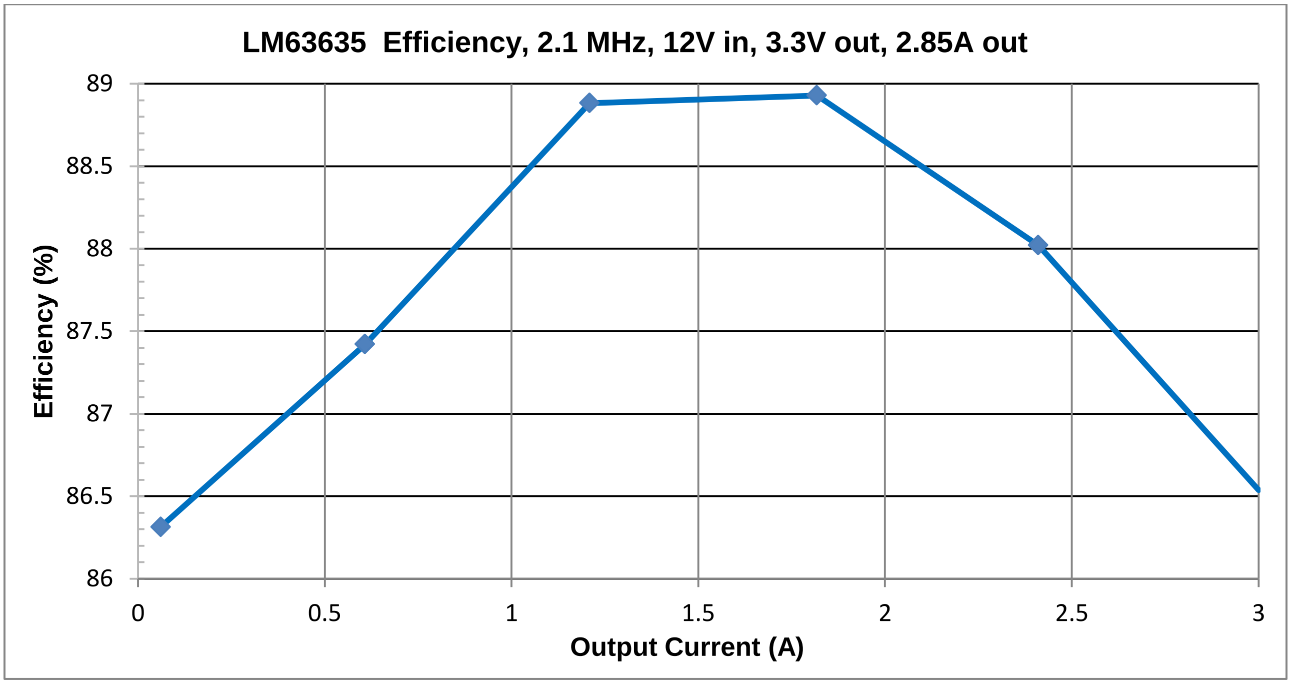


Figure 1. LM63635 Efficiency vs. I_{OUT}, Vsys = 3.3V

Table 5. LM63635 Efficiency Raw Data, Vsys = 3.3V

V_{in} (V)	I_{in} (A)	I_{out} (A)	V_{out} (V)	P_{in} (W)	P_{out} (W)	Efficiency (%)
12.01	0.0194	0.06066	3.3153	0.232994	0.201106098	86.31385272
12.009	0.191	0.608	3.298	2.293719	2.005184	87.42064743
12.009	0.3736	1.209	3.2984	4.4865624	3.9877656	88.88242811
12.008	0.5616	1.8178	3.2991	6.7436928	5.99710398	**88.92908022**
12.008	0.7525	2.4106	3.2994	9.03602	7.95353364	88.02031912
12.007	0.953	3.0004	3.3003	11.442671	9.90222012	86.53766345

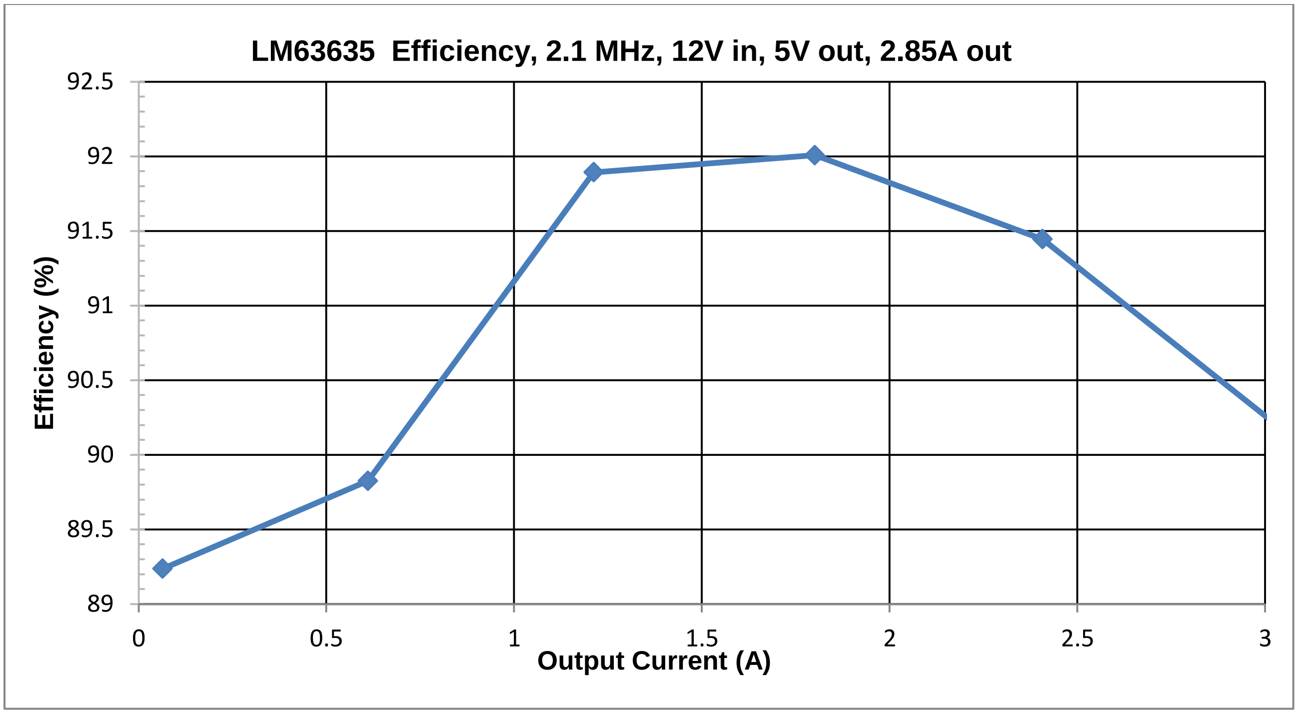


Figure 2. LM63635 Efficiency vs. I_{OUT}, Vsys = 5V

Table 6. LM63635 Efficiency Raw Data, Vsys = 5V

V_{in} (V)	I_{in} (A)	I_{out} (A)	V_{out} (V)	P_{in} (W)	P_{out} (W)	Efficiency (%)
12.01	0.02987	0.0638	5.0176	0.3587387	0.32012288	89.2356693
12.009	0.2828	0.611	4.9928	3.3961452	3.0506008	89.8253938
12.008	0.5484	1.212	4.9928	6.5851872	6.0512736	91.89220316
12.007	0.814	1.801	4.9931	9.773698	8.9925731	**92.0078879**
12.007	1.095	2.4075	4.9939	13.147665	12.02281425	91.44448273
12.006	1.3887	3.012	4.995	16.6727322	15.04494	90.23679994

2.1.2 TPS62810-Q1 Efficiencies

For each of these buck converter efficiencies, the other two TPS62810-Q1 converters were disabled when taking efficiency measurements on one. The load switches were also disabled.

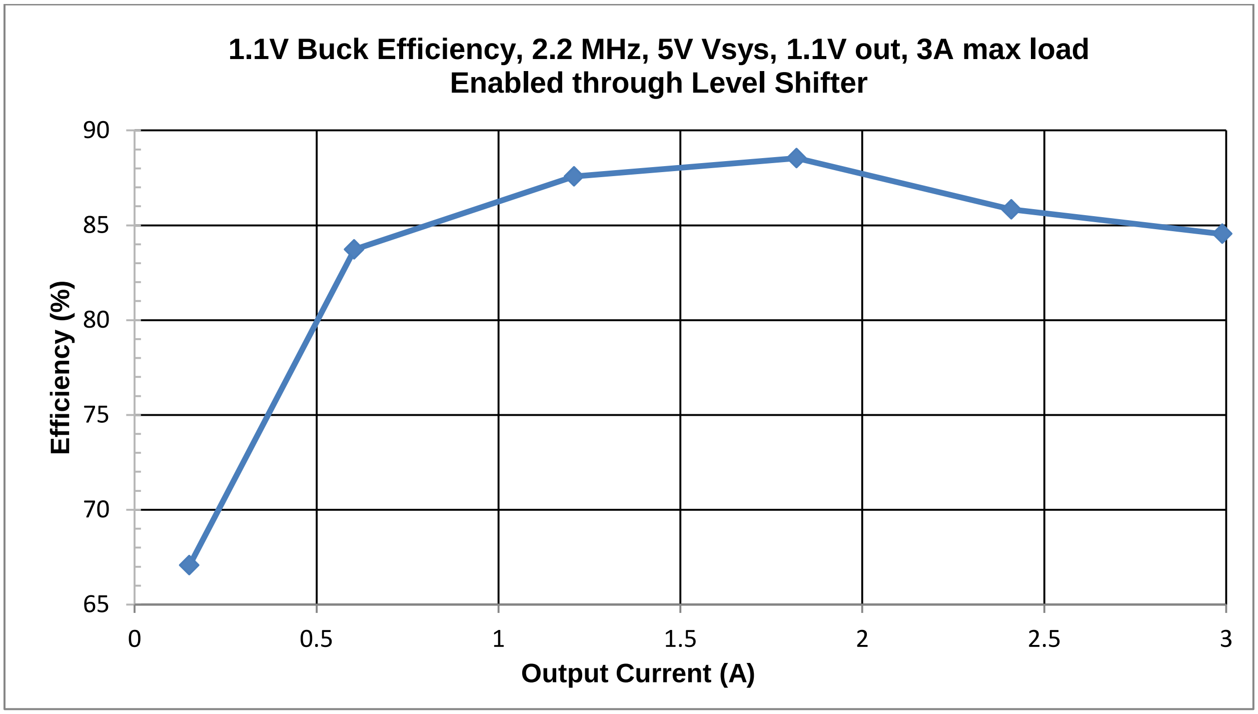


Figure 3. 1.1V Converter Efficiency vs. I_{OUT}

Table 7. 1.1V Converter Efficiency Raw Data

V_{in} (V)	I_{in} (A)	I_{out} (A)	V_{out} (V)	P_{in} (W)	P_{out} (W)	Efficiency (%)
5.0096	0.0495	0.151	1.1015	0.2479752	0.1663265	67.07384448
5.0069	0.159	0.604	1.1035	0.7960971	0.666514	83.72270167
5.0036	0.305	1.208	1.1063	1.526098	1.3364104	87.57041815
4.9993	0.456	1.82	1.109	2.2796808	2.01838	**88.53783389**
4.9952	0.625	2.41	1.1119	3.122	2.679679	85.83212684
4.9904	0.79	2.99	1.1147	3.942416	3.332953	84.54087544

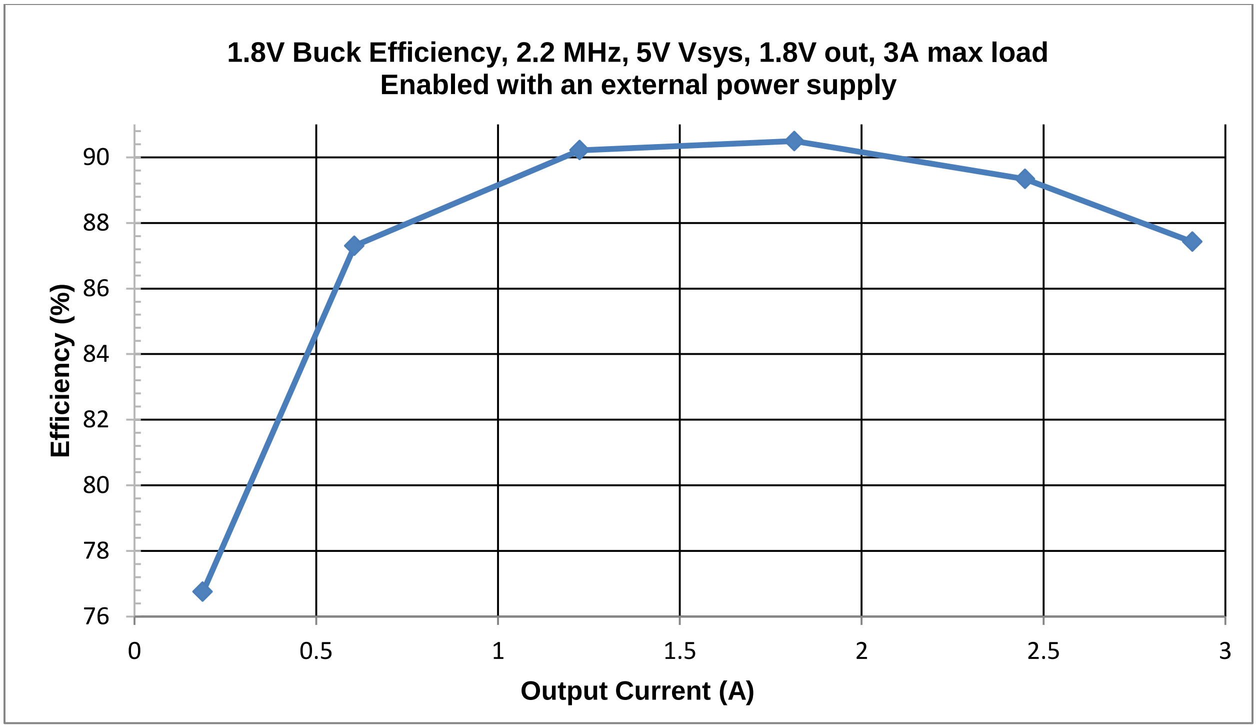


Figure 4. 1.8V Converter Efficiency vs. I_{OUT}

Table 8. 1.8V Converter Efficiency Raw Data

V_{in} (V)	I_{in} (A)	I_{out} (A)	V_{out} (V)	P_{in} (W)	P_{out} (W)	Efficiency (%)
5.0082	0.088	0.188	1.7993	0.4407216	0.3382684	76.7533064
5.0039	0.249	0.605	1.7979	1.2459711	1.0877295	87.29973753
4.9964	0.488	1.225	1.7957	2.4382432	2.1997325	90.21792822
4.9895	0.721	1.815	1.7936	3.5974295	3.255384	**90.4919471**
4.9815	0.986	2.45	1.791	4.911759	4.38795	89.33561276
4.9754	1.197	2.91	1.7892	5.9555538	5.206572	87.42380935

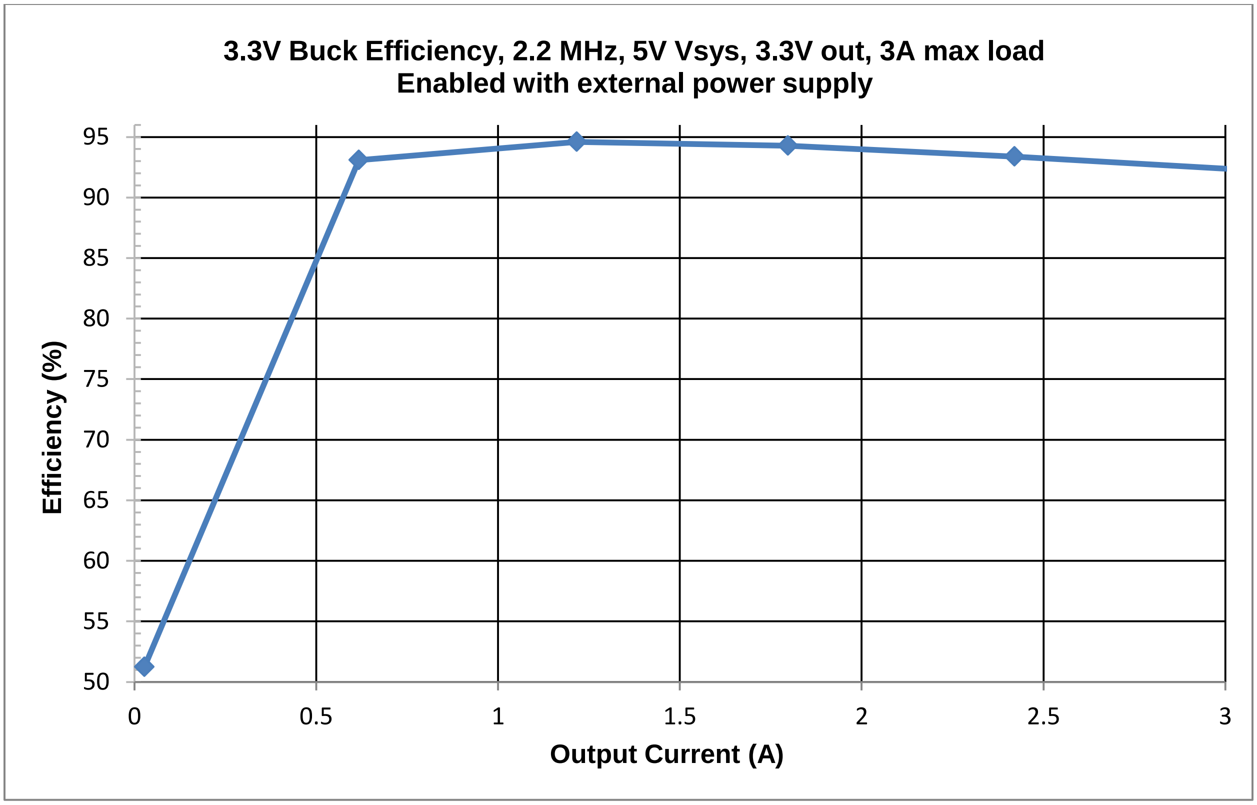


Figure 5. 3.3V Converter Efficiency vs. I_{OUT}

Table 9. 3.3V Converter Efficiency Raw Data

V_{in} (V)	I_{in} (A)	I_{out} (A)	V_{out} (V)	P_{in} (W)	P_{out} (W)	Efficiency (%)
5.0095	0.0353	0.0273	3.3195	0.17683535	0.09062235	51.24673884
4.9912	0.4405	0.617	3.3174	2.1986236	2.0468358	93.0962353
4.9722	0.8576	1.2166	3.3158	4.26415872	4.03400228	**94.60253581**
4.9529	1.276	1.798	3.3141	6.3199004	5.9587518	94.28553336
4.9305	1.7413	2.4204	3.3124	8.58547965	8.01733296	93.38247002
4.9082	2.1942	3.0053	3.3106	10.76957244	9.94934618	92.38385493

2.2 *Load Regulation*

Load regulation data was extracted from the efficiency measurement data.

2.2.1 LM63635 Load Regulation

Vsys = 3.3V

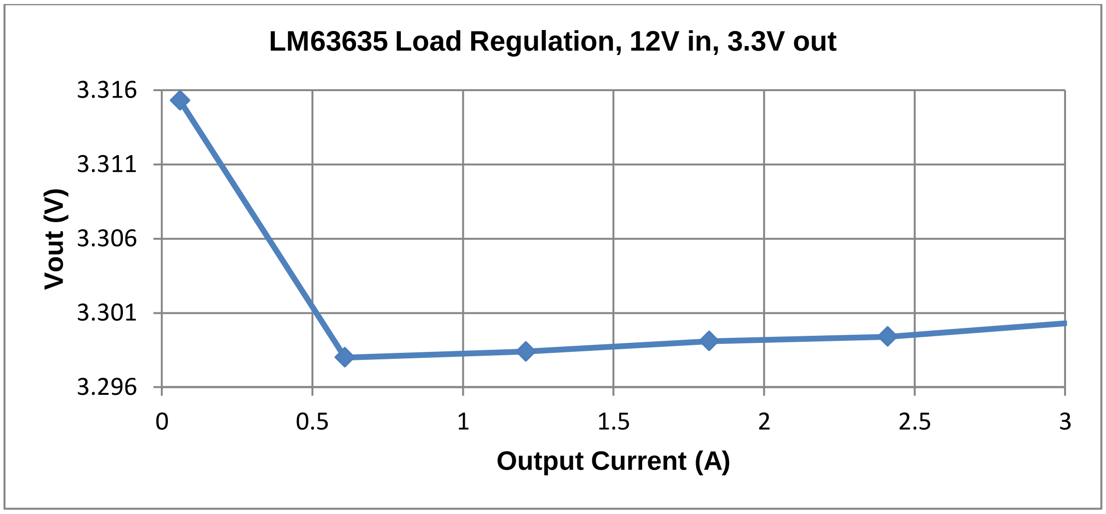


Figure 6. LM63635 Load Regulation, 3.3V out

Vsys = 5V

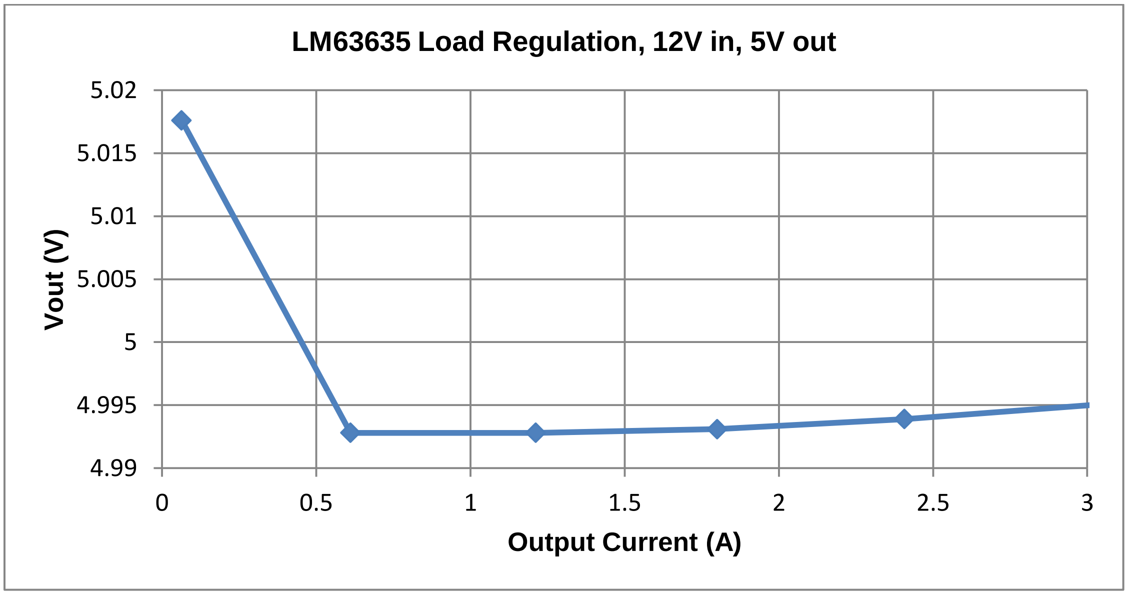


Figure 7. LM63635 Load Regulation, 5V out

2.2.2 Load Converters (TPS62810) Load Regulation

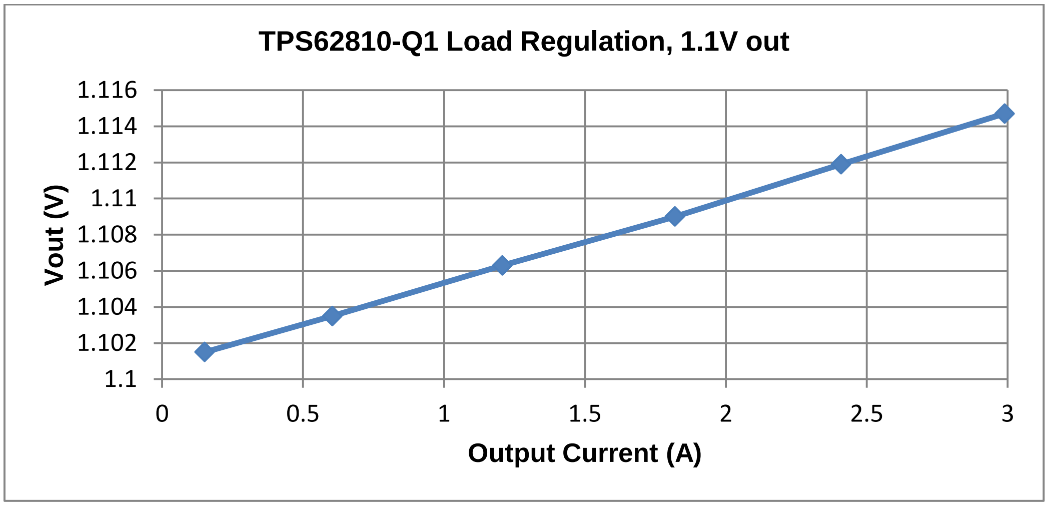


Figure 8. 1.1V Converter Load Regulation

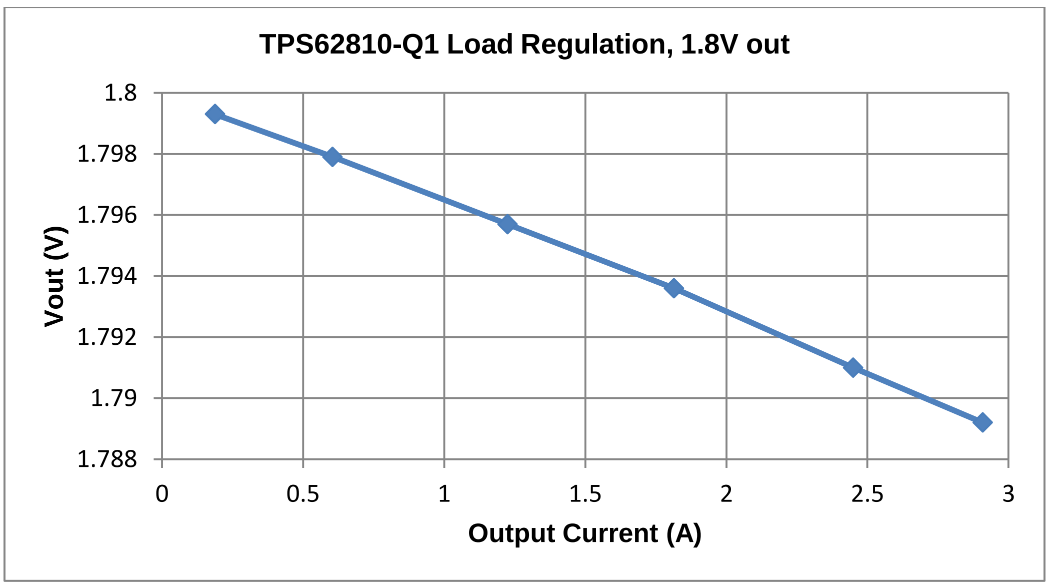


Figure 9. 1.8V Converter Load Regulation

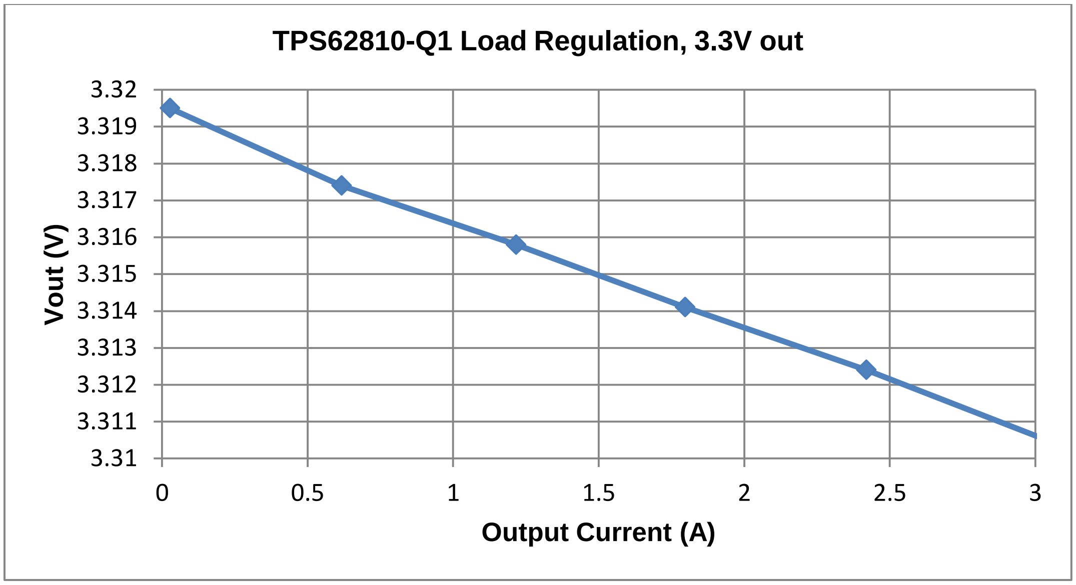


Figure 10. 3.3V Converter Load Regulation

2.3 Thermal Images

All thermal images were taken with the system left running for 10 minutes, a 3A load applied, and no airflow to allow the converter to reach thermal equilibrium.

2.3.1 1.1V Converter

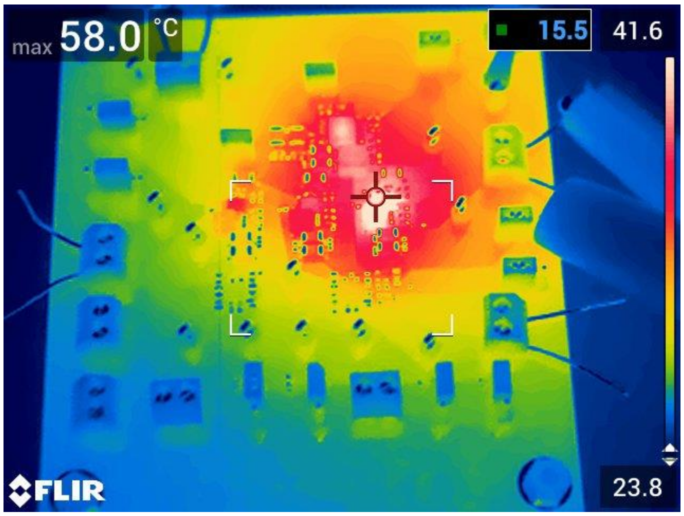


Figure 11. 1.1V Converter, System Vin = 12V, Iout = 3A

2.3.2 1.8V Converter

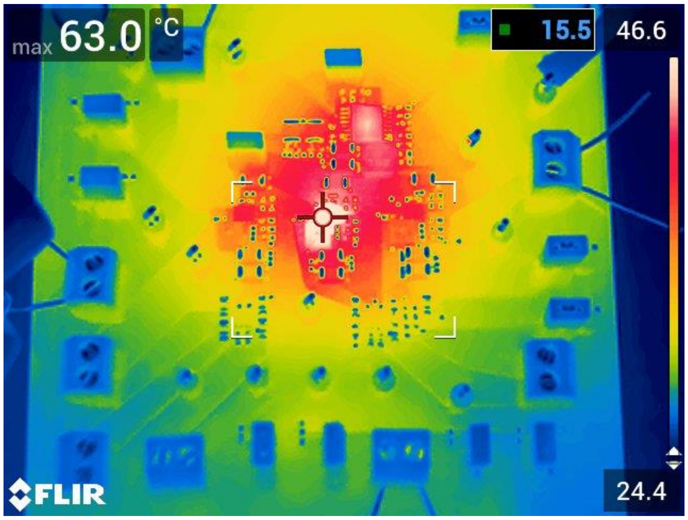


Figure 12. 1.8V Converter, System Vin = 12V, Iout = 3A

2.3.3 3.3V Converter

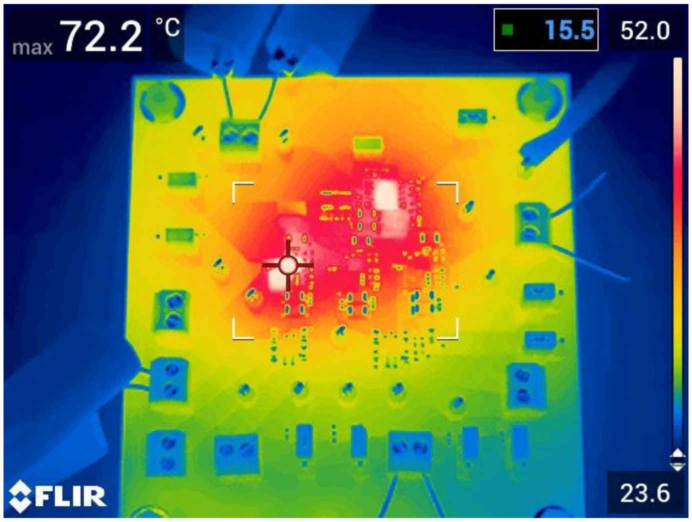


Figure 13. 3.3V Converter, System Vin = 12V, Iout = 3A

2.4 Dimensions

The evaluation board dimensions are 87.13 mm x 82.25 mm. It is a 4-layer board with 1 oz. copper per layer.

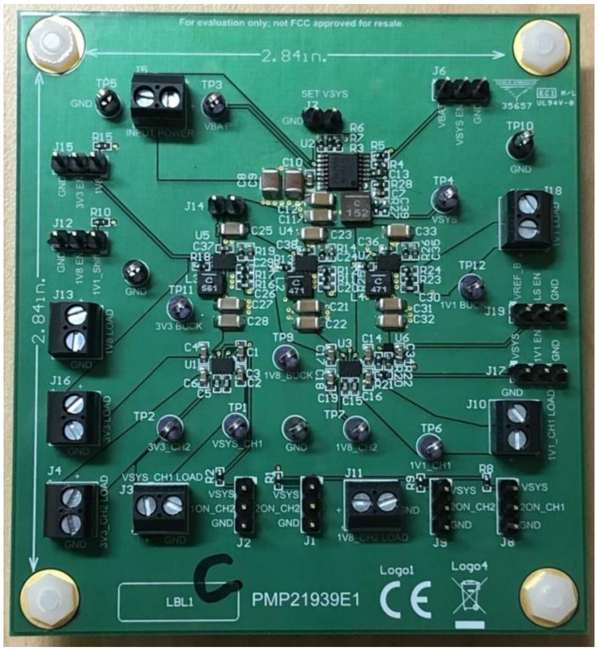


Figure 14. PMP21939 Evaluation Board – Front

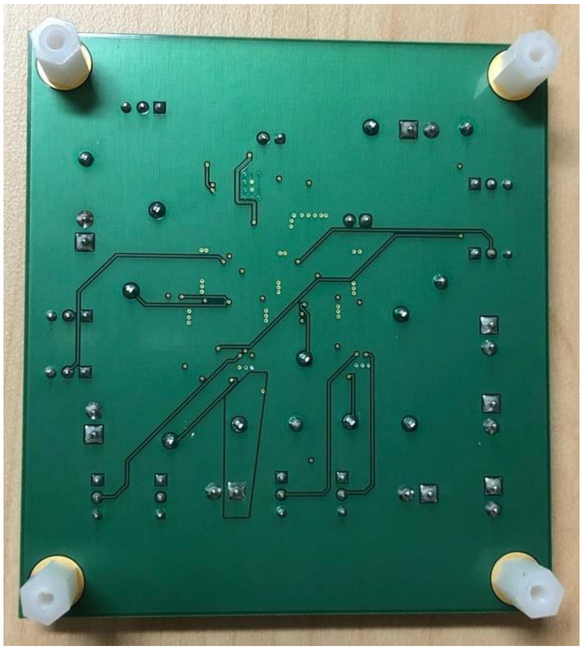


Figure 15. PMP21939 Evaluation Board – Back

3 Waveforms

3.1 Switching

3.1.1 LM63635 Switching Waveforms

The LM63635 converter is switching at 2.1 MHz as shown in the below scope shots.

This waveform was taken at the switch node of the LM63635 for Vsys = 3.3V:

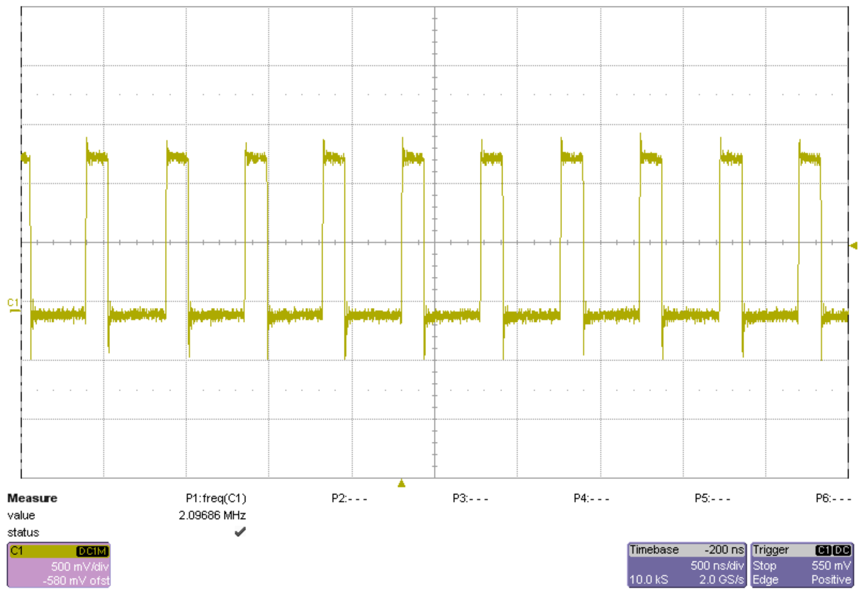


Figure 16. LM63635 Switch Node Waveform, Vsys = 3.3V, 1A Load

This waveform was taken at the switch node of the LM63635 for Vsys = 5V:

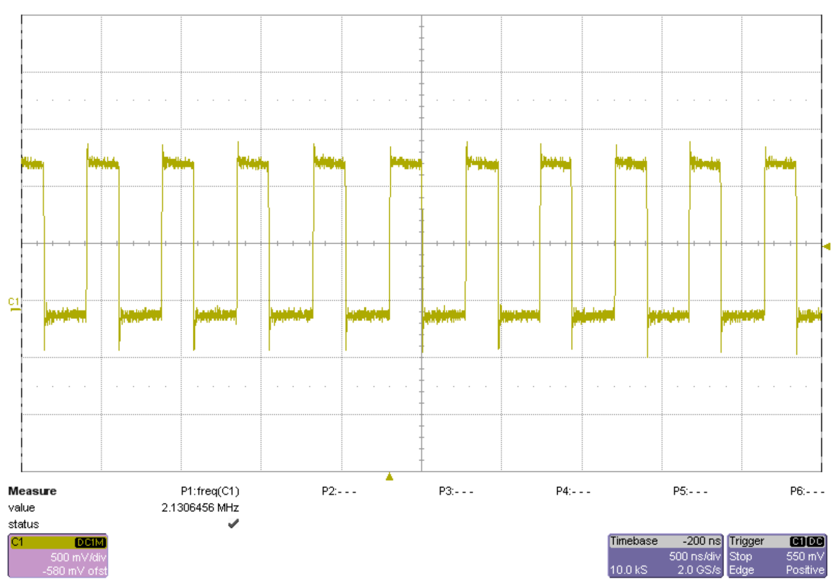


Figure 17. LM63635 Switch Node Waveform, Vsys = 5V, 1A Load

3.1.2 TPS62810 Switching Waveforms

The TPS62810 converters are switching at 2.2 MHz as shown in the below scope shots.

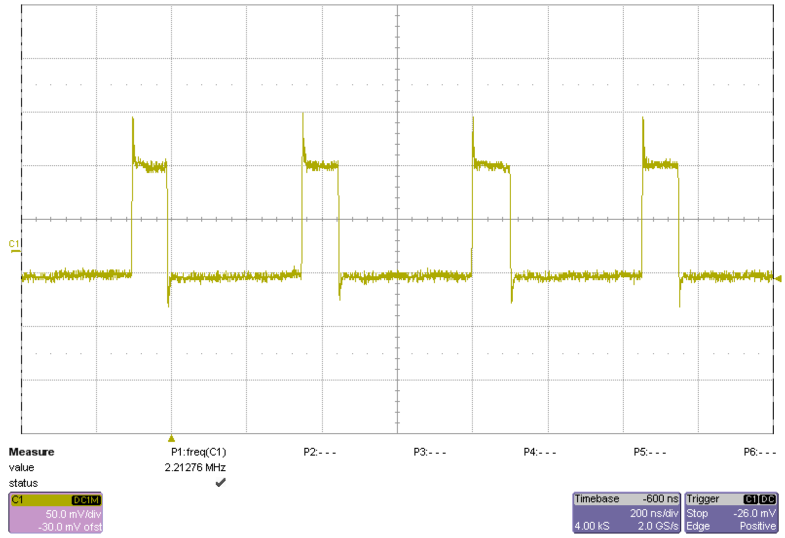


Figure 18. 1.1V Converter Switch Node Waveform, 0A Load

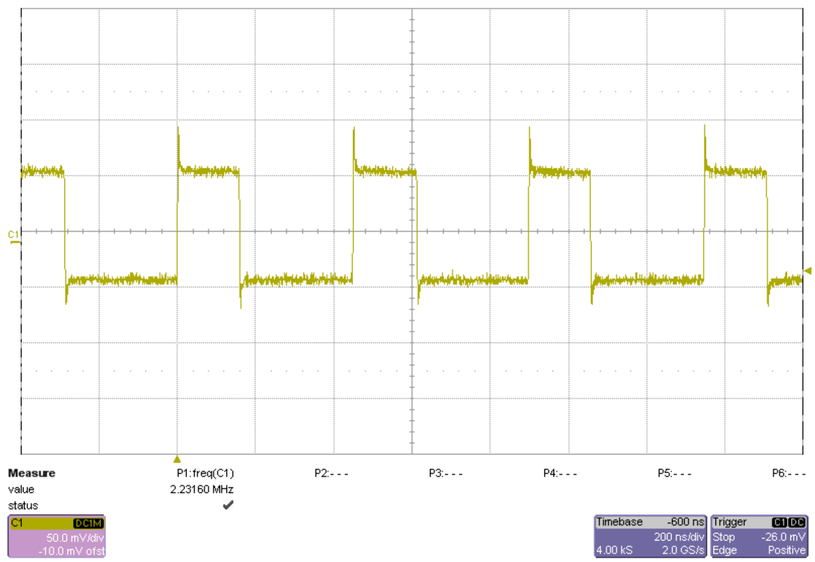


Figure 19. 1.8V Converter Switch Node Waveform, 0A Load

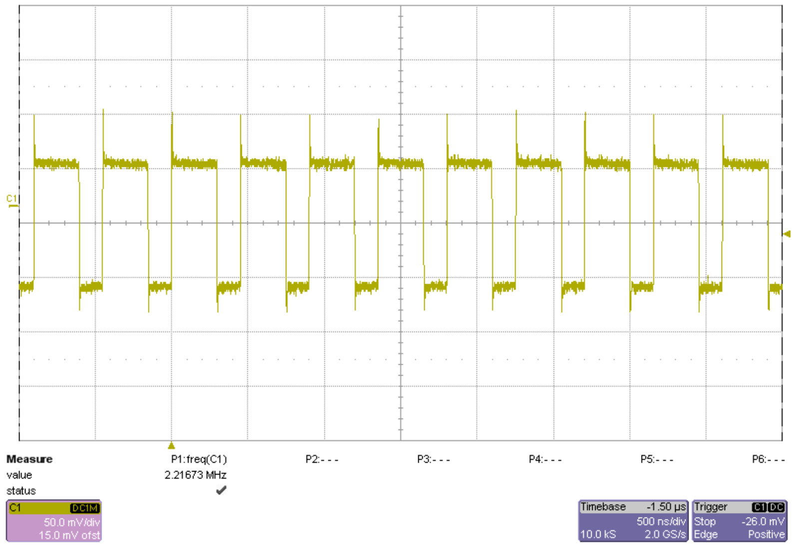


Figure 20. 3.3V Converter Switch Node Waveform, 0A Load

3.2 Output Voltage Ripple

All converters are operating with an output ripple of less than 1% under no load and under full load. All measurements were taken with Vsys = 5V.

3.2.1 LM63635

The output ripple was measured across C12.

0A load – Output voltage ripple is 34 mV (around 0.68%):

Note: Output ripple for the no load condition was measured sing a 10x attenuated probe. The value on this scope shot should be multiplied by 10 to get the correct value.

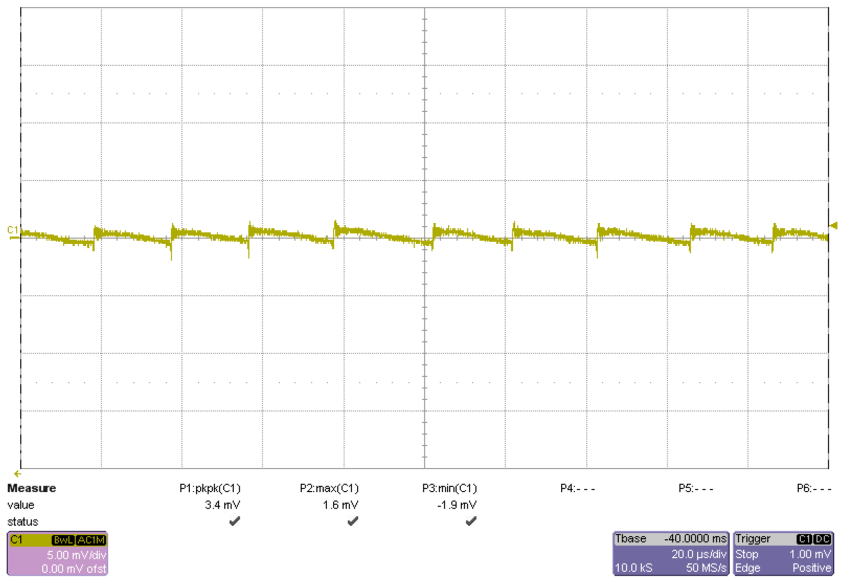


Figure 21. LM63635 Output Ripple, 0A Load

2A load – Output voltage ripple is 48 mV (around 0.96%):

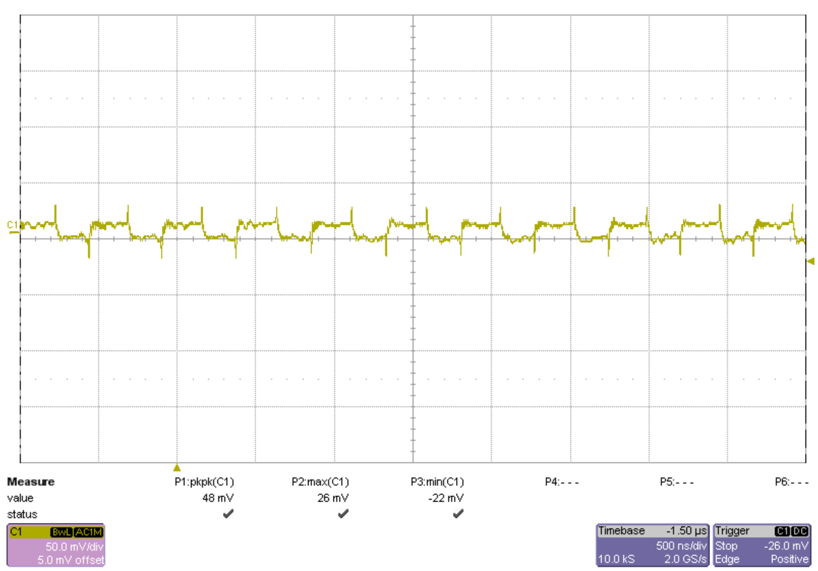


Figure 22. LM63635 Output Ripple, 2A Load

3.2.2 1.1V Buck Converter

The output ripple was measured across C31.

0A load - Output voltage ripple is 9.4 mV (around 0.85%):

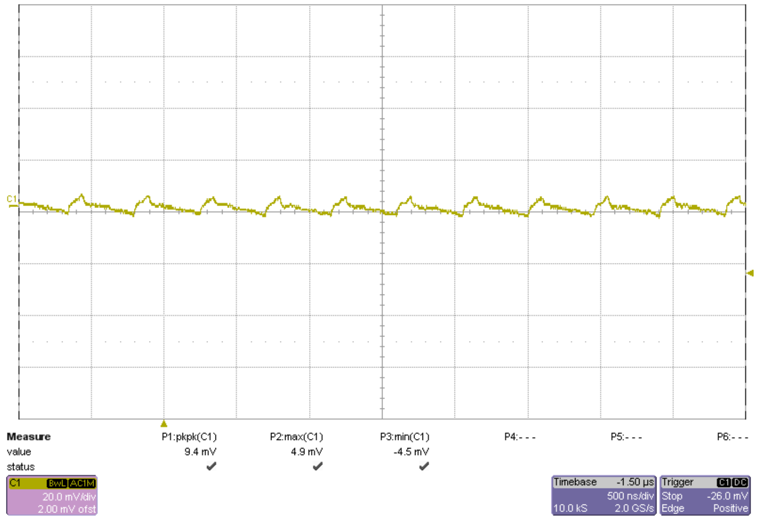


Figure 23. 1.1V Converter Output Ripple, 0A Load

3A load – Output voltage ripple is 9.4 mV (around 0.85%):

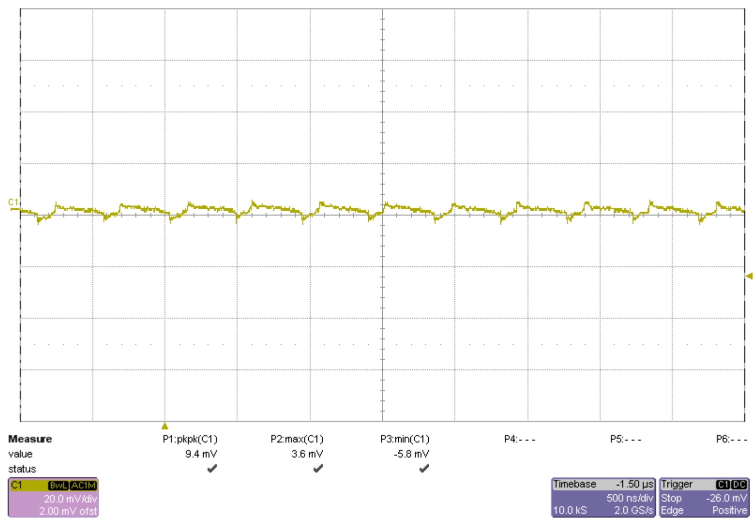


Figure 24. 1.1V Converter Output Ripple, 3A Load

3.2.3 1.8V Buck Converter

The output ripple was measured across C21.

0A load - Output voltage ripple is 6.3 mV (around 0.35%):

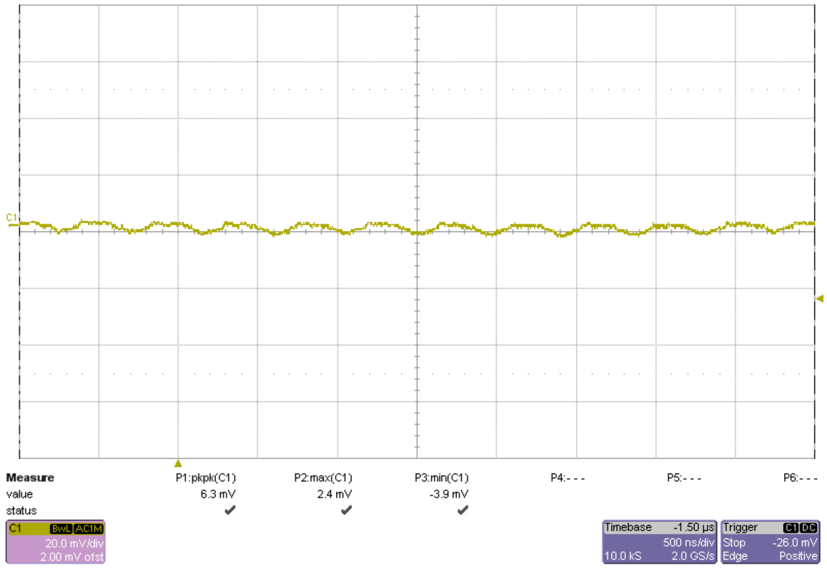


Figure 25. 1.8V Converter Output Ripple, 0A Load

3A load – Output ripple is 8.8 mV (around 0.49%):

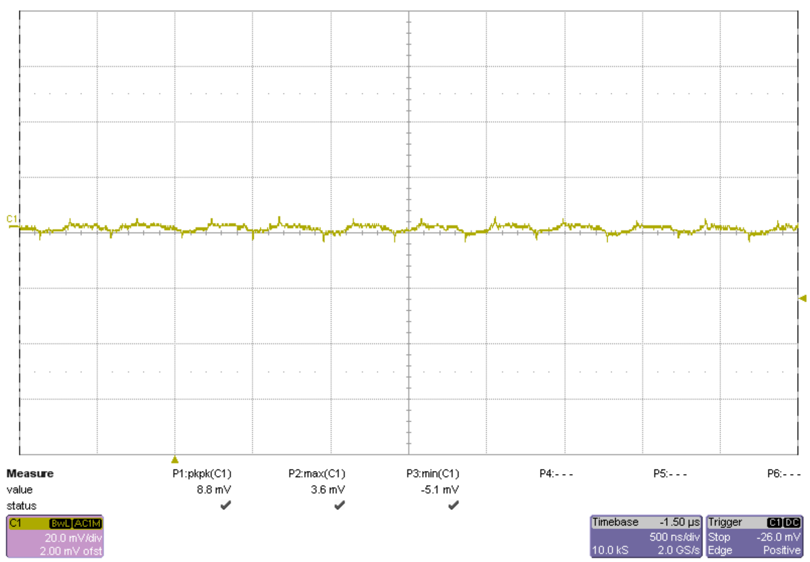


Figure 26. 1.8V Converter Output Ripple, 3A Load

3.2.4 3.3V Buck Converter

The output ripple was measured across C27.

0A load - Output voltage ripple is 6.9 mV (around 0.21%):

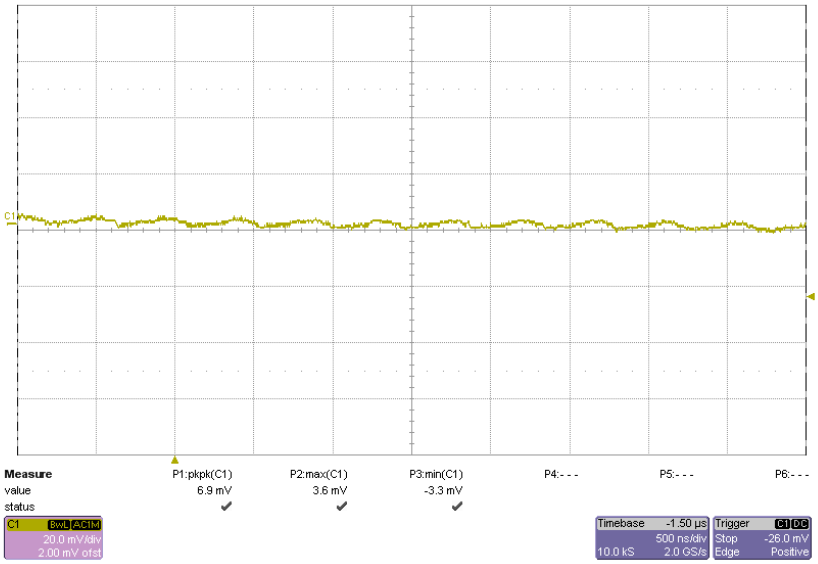


Figure 27. 3.3V Converter Output Ripple, 0A Load

3A load - Output voltage ripple is 6.3 mV (around 0.19%):

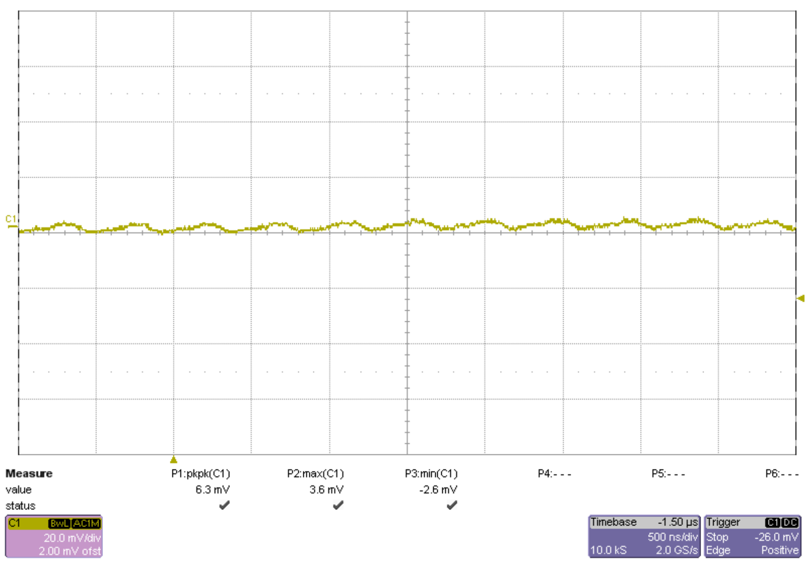


Figure 28. 3.3V Converter Output Ripple, 3A Load

3.3 Load Transients

The load transient tests were conducted stepping from 20% to 80% of full load (300mA to 2.4A step). The slew rate is ~150mA/us. An electronic load was used for testing.

CH1 (Yellow trace): Load current
CH4 (Green trace): Output voltage

3.3.1 1.1V Converter

Undershoot is 19mV (1.7% of output), Overshoot is 26mV (2.1% of output)

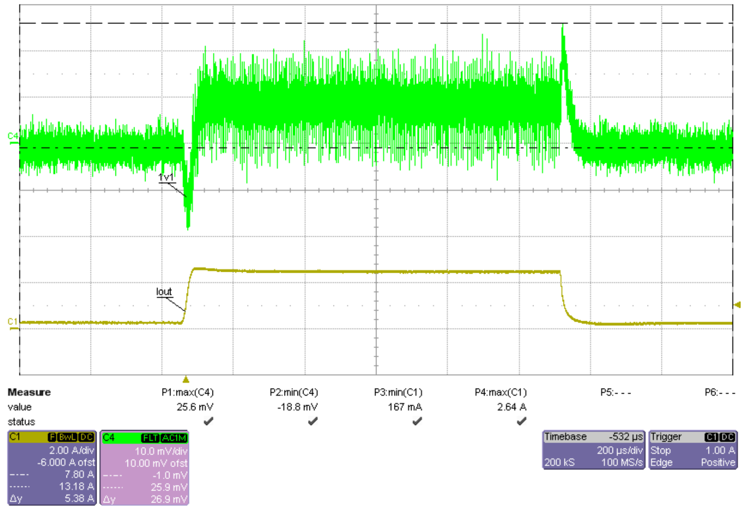


Figure 29. 1.1V Converter Load Transient

3.3.2 1.8V Converter

Undershoot is 48mV (2.7% of output), Overshoot is 32.5mV (1.8% of output)

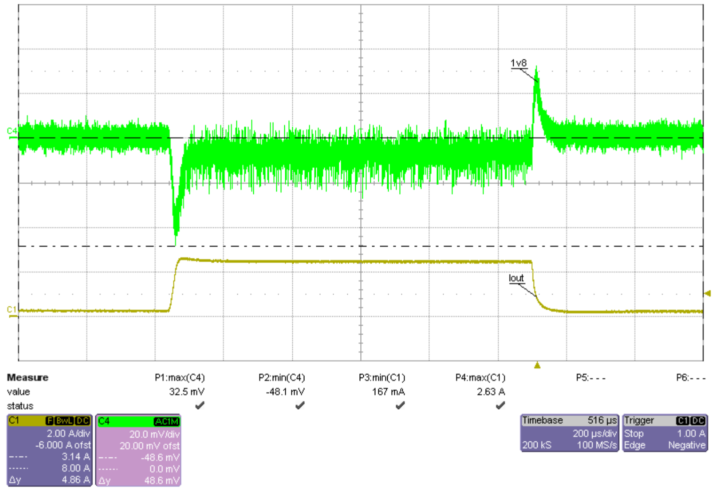


Figure 30. 1.8V Converter Load Transient

3.3.3 3.3V Converter

Undershoot is 66mV (2% of output), Overshoot is 49mV (1.5% of output)

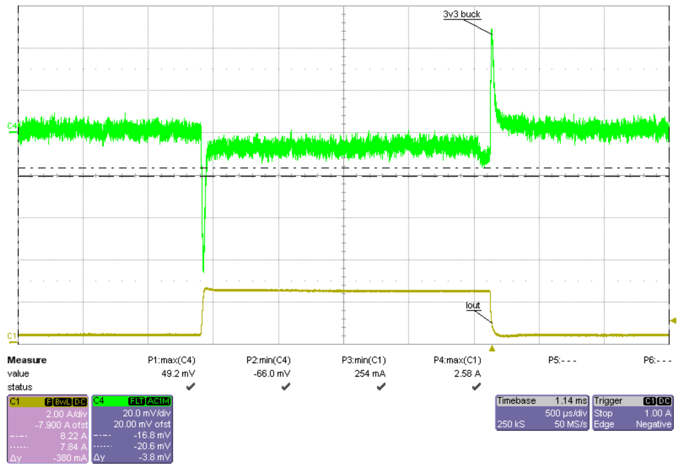


Figure 31. 3.3V Converter Load Transient

3.4 Start-up Sequence

The following images show the start-up profile of each converter in the design. For each test, Vsys = 5V, and the converters are not loaded (0A).

CH1 (Yellow trace): Input supply, 12V
CH2 (Pink trace): Output of each converter

3.4.1 LM63635 Start-up

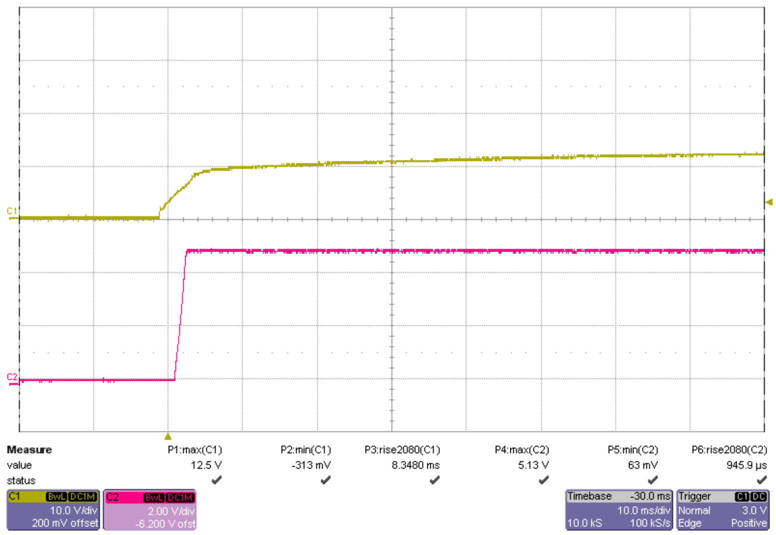


Figure 32. LM63635 Start-up, Vin = 12V, Vout = 5V

3.4.2 TPS62810 Converters Start-up

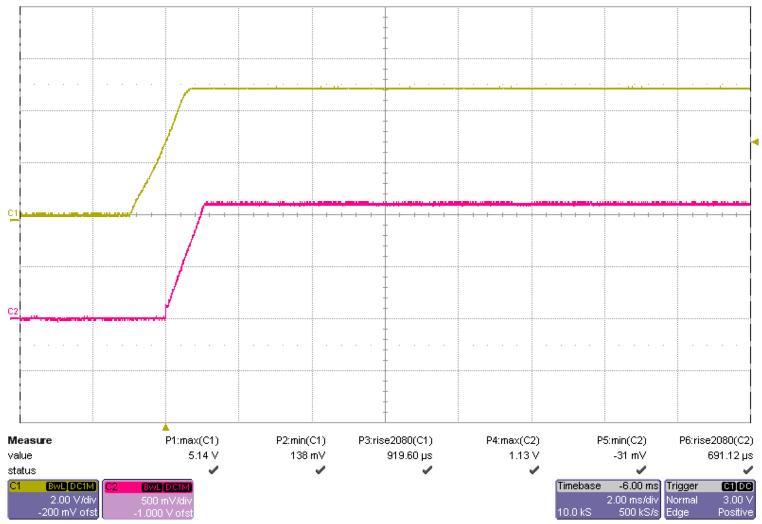


Figure 33. 1.1V Converter Start-up, Vin = 5V

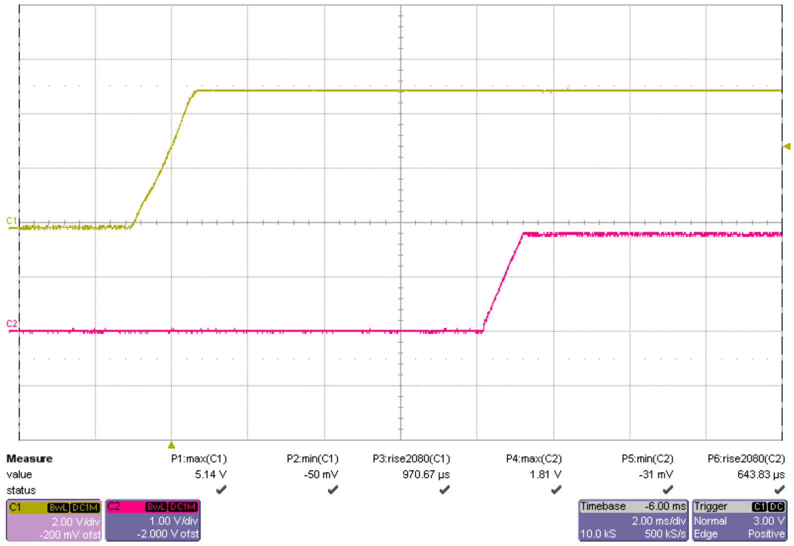


Figure 34. 1.8V Converter Start-up, Vin = 5V

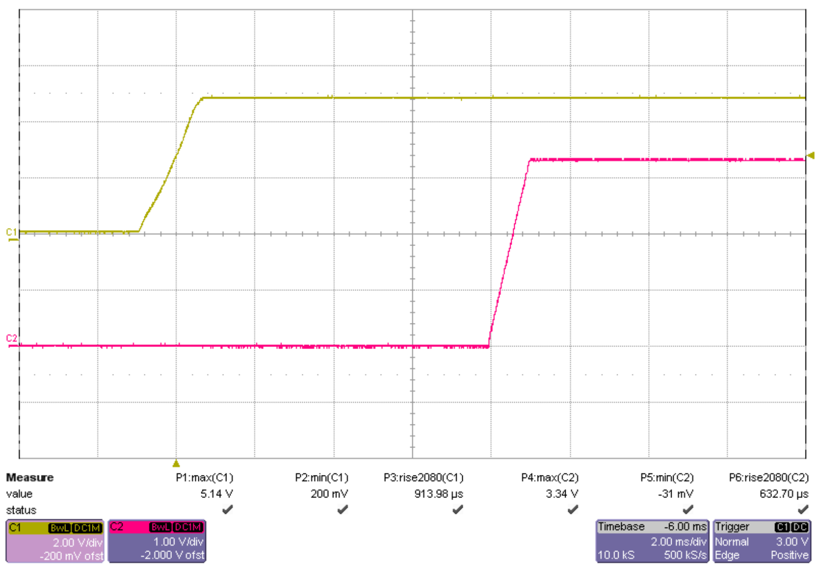


Figure 35. 3.3V Converter Start-up, Vin = 5V