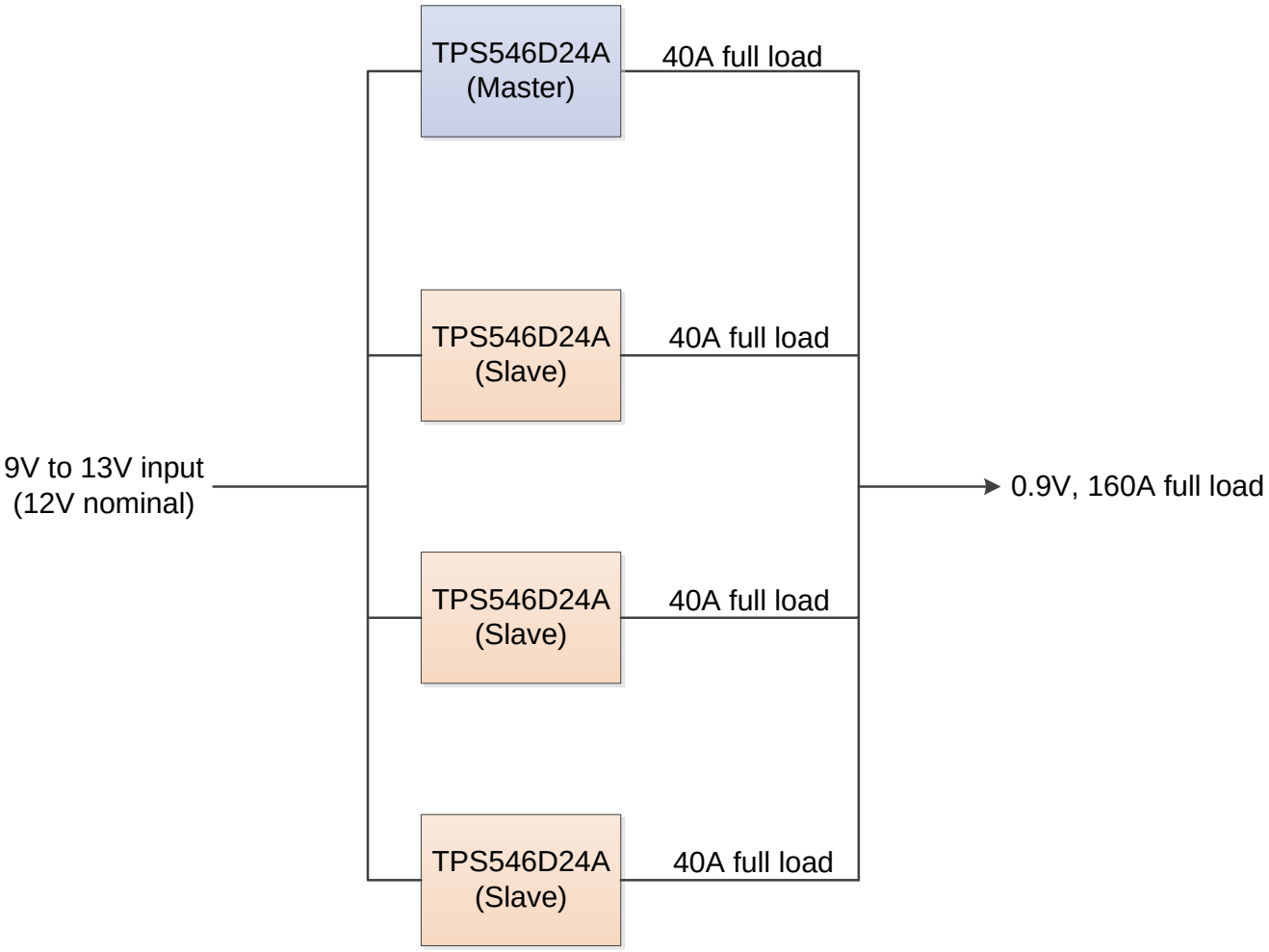
Test Report: PMP21814

4-phase, 160-A Synchronous Buck Converter Reference Design for Communications Processor Power

TEXAS INSTRUMENTS

Description

This reference design uses four TPS546D24A converters with integrated MOSFETs to support a full load of 160-A at a 0.9-V output. The system operates at a switching frequency of 650 kHz and has a PMBus interface that can be used to configure key converter parameters, including internal compensation. The detailed test report includes efficiency, thermal, stability, and load transient results.



1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input Voltage	12 V
Output Voltage	0.9 V
Maximum Output Current	160 A
Switching Frequency	650 kHz

1.2 Required Equipment

- Power supply
- Electronic or resistive load
- Oscilloscope

1.3 Considerations

All testing was performed with a 12 V input.

2 Testing and Results

2.1 Efficiency

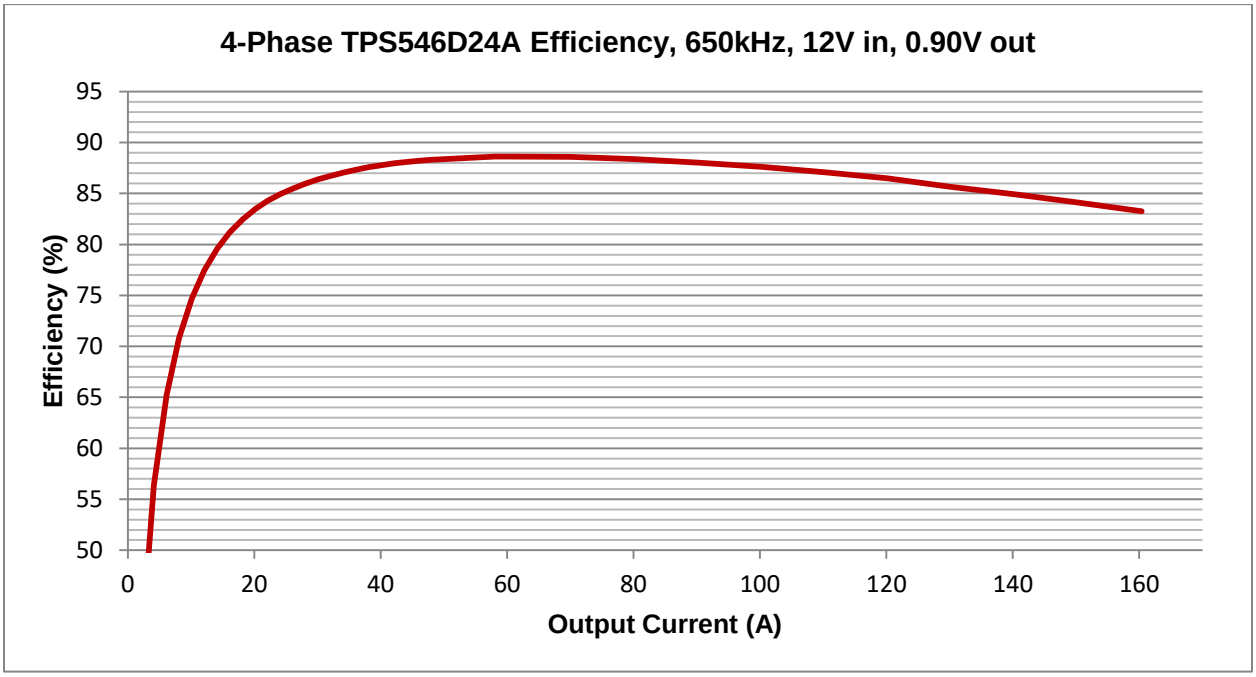


Figure 1. Efficiency vs. I_{OUT}

2.2 Power Loss

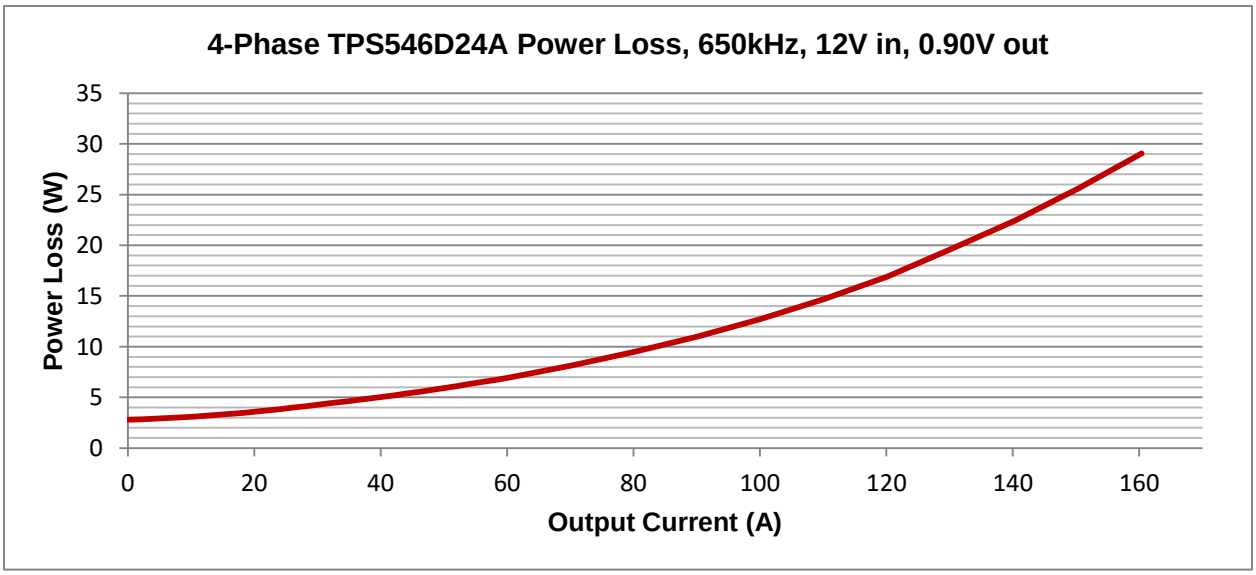


Figure 2. Power Loss vs. I_{OUT}

2.3 Load Regulation

The output voltage is regulated to within 0.11% of the nominal 0.9V.

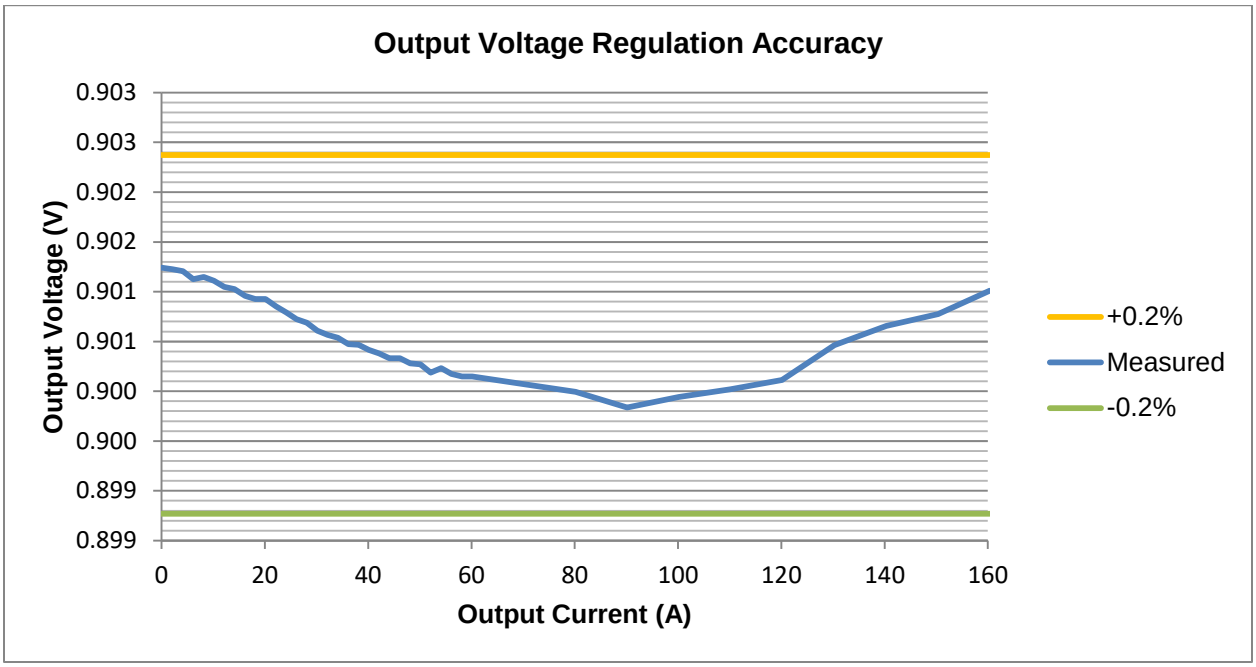


Figure 3. Load Regulation Graph

2.4 Efficiency Data

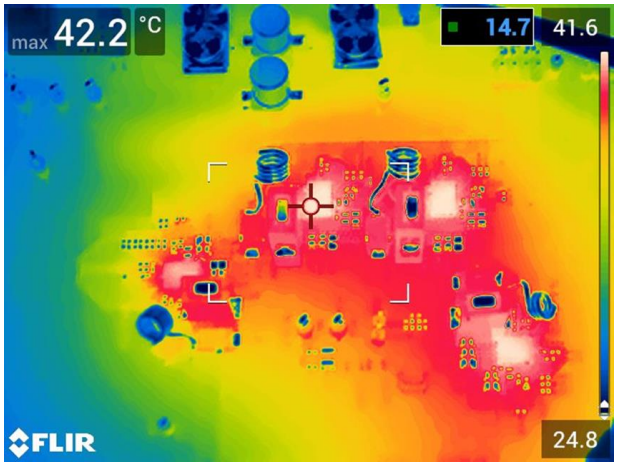
Table 2. Efficiency Raw Data (V_{IN} = 12 V)

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)
11.999	0.232	0.901	-0.001	0.044
11.999	0.396	0.901	2.130	40.377
11.999	0.550	0.901	4.131	56.362
11.999	0.705	0.901	6.132	65.249
11.999	0.861	0.901	8.131	70.856
11.999	1.018	0.901	10.132	74.713
11.999	1.175	0.901	12.129	77.480
11.999	1.333	0.901	14.133	79.583
11.999	1.492	0.900	16.130	81.175
11.999	1.651	0.900	18.135	82.452
11.999	1.811	0.900	20.137	83.473
11.999	1.971	0.900	22.134	84.285
11.999	2.132	0.900	24.134	84.953
11.999	2.294	0.900	26.134	85.491
11.999	2.456	0.900	28.135	85.975
11.999	2.618	0.900	30.133	86.384
11.999	2.780	0.900	32.130	86.733

11.999	2.942	0.900	34.138	87.069
11.999	3.105	0.900	36.139	87.343
11.999	3.267	0.900	38.134	87.576
11.999	3.430	0.900	40.133	87.779
11.999	3.594	0.900	42.135	87.955
11.999	3.758	0.900	44.125	88.088
11.999	3.923	0.900	46.120	88.210
11.999	4.087	0.900	48.111	88.305
11.999	4.253	0.900	50.105	88.383
11.999	4.419	0.900	52.104	88.444
11.999	4.586	0.900	54.107	88.509
11.999	4.753	0.900	56.120	88.574
11.999	4.920	0.900	58.133	88.623
11.999	5.089	0.900	60.128	88.630
11.999	5.938	0.900	70.133	88.587
11.999	6.801	0.899	80.142	88.384
11.999	7.679	0.899	90.155	88.043
11.999	8.575	0.899	100.179	87.614
11.999	9.488	0.900	110.168	87.087
11.999	10.420	0.900	120.139	86.485
12.028	11.389	0.900	130.317	85.655
12.028	12.373	0.900	140.351	84.931
12.028	13.391	0.900	150.386	84.099
12.028	14.428	0.901	160.361	83.250

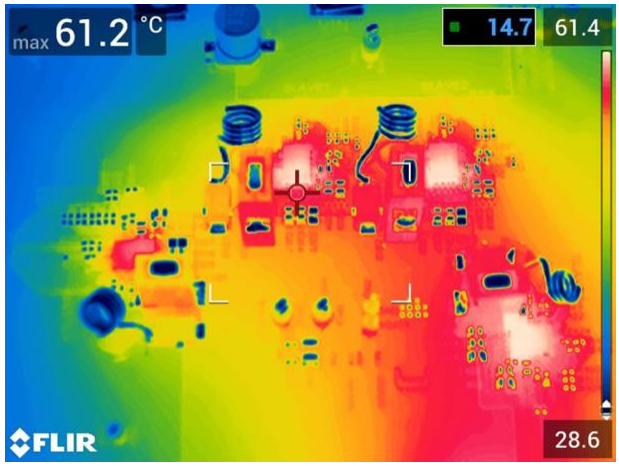
2.5 Thermal Images

Figures 4, 5, 6, and 7 show the board temperature at four different loads. All thermal measurements were taken with V_{IN} = 12 V. The TPS546D24A ICs get the hottest. The full load was connected to the Vout connector on the bottom right-hand side of the board in these images. The board will not get as hot on the bottom right-hand side if the load is split between the two Vout connectors.



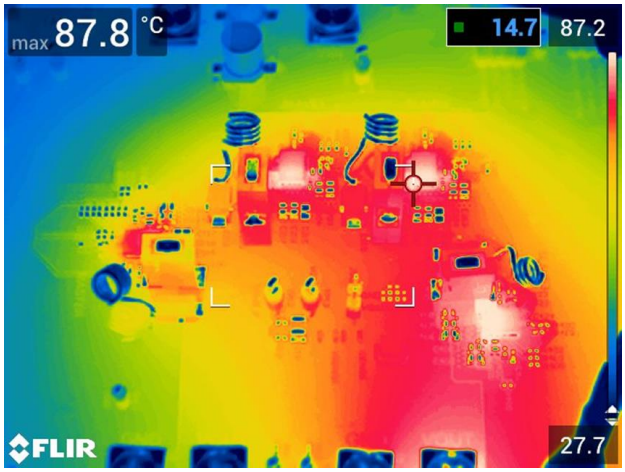
Max temperature = 42.2ºC, run for 10 minutes

Figure 4. V_{IN} = 12 V, I_{OUT} = 40 A



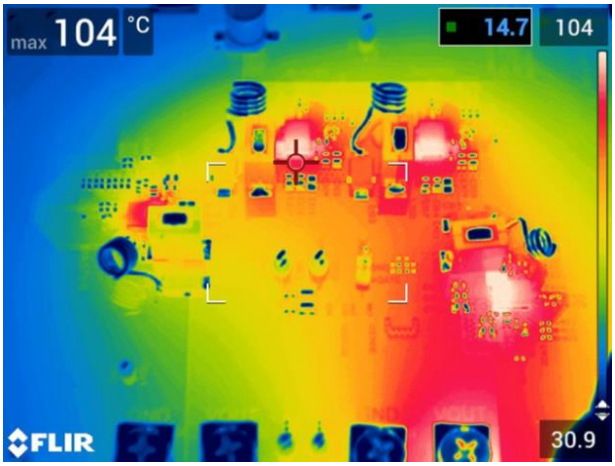
Max temperature = 61.2ºC, run for 10 minutes

Figure 5. V_{IN} = 12 V, I_{OUT} = 80 A



Max temperature = 87.8ºC, run for 10 minutes

Figure 6. V_{IN} = 12 V, I_{OUT} = 120 A



Max temperature = 104ºC, run for 5 minutes

Figure 7. V_{IN} = 12 V, I_{OUT} = 160 A

2.6 Dimensions

The evaluation board dimensions are 7 in x 5 in. All 4 phases are populated on the 8-layer board with 2 oz. copper per layer.

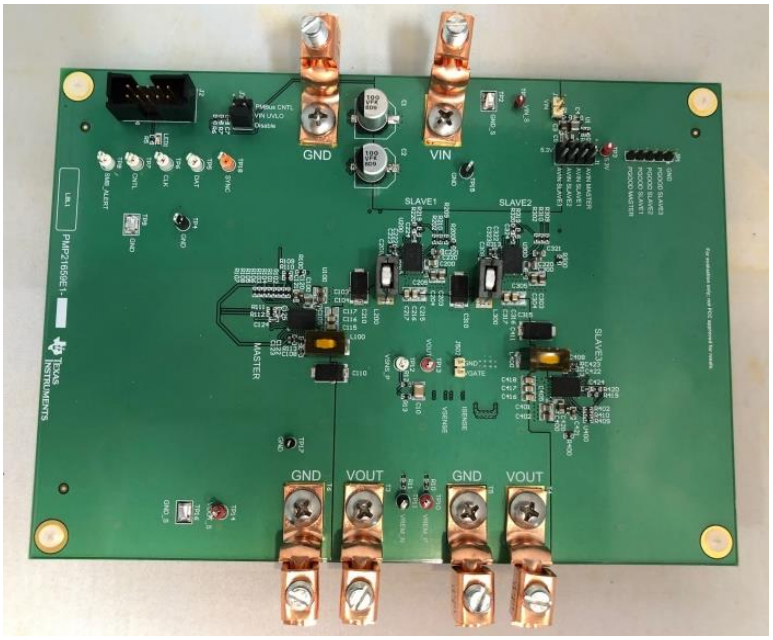


Figure 8. Front of Evaluation Board

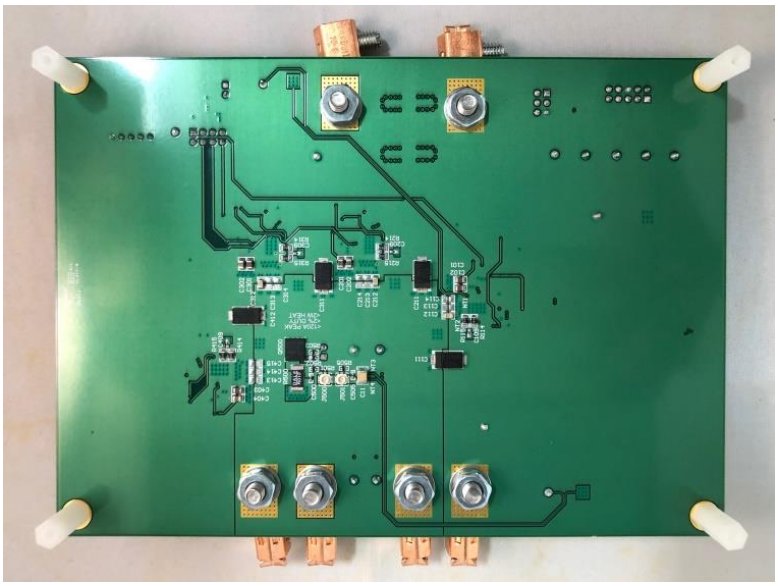


Figure 9. Back of Evaluation Board

3 Waveforms

3.1 Switching

The converter switches at 650 kHz. Correct phase interleaving is observed.

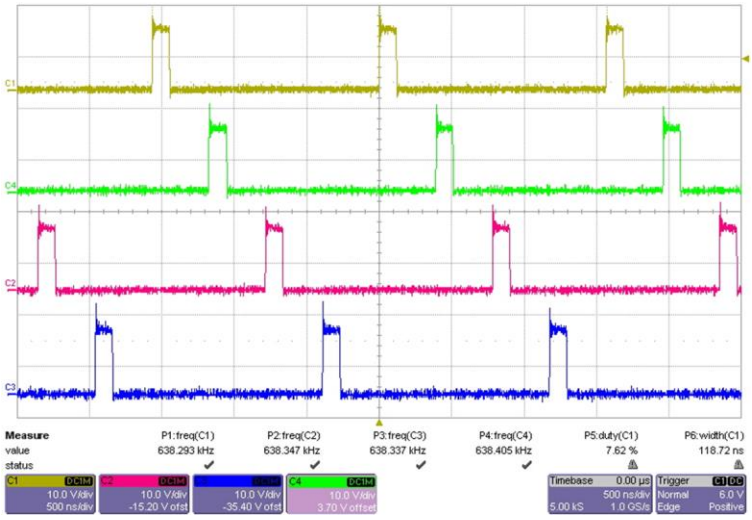


Figure 10. Switch Node Waveforms (No Load)

3.2 Output Voltage Ripple

The magnitude of the output ripple is ~4.0 mV – about 0.44% of the output voltage.

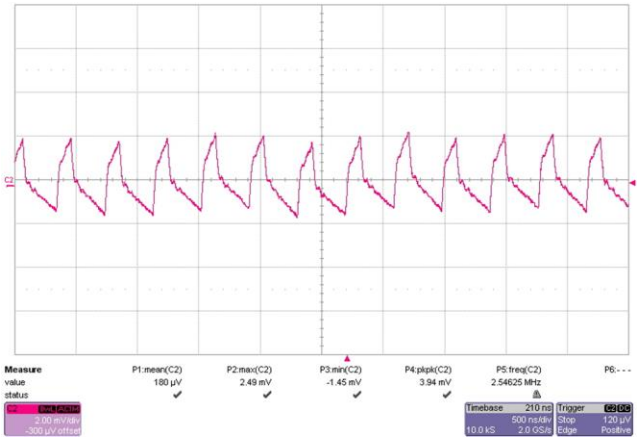


Figure 11. V_{IN} = 12 V, I_{OUT} = 0 A

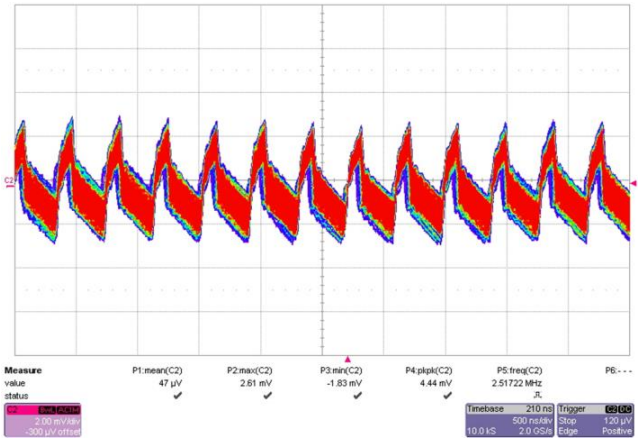


Figure 12. V_{IN} = 12 V, I_{OUT} = 0 A (with persistence)

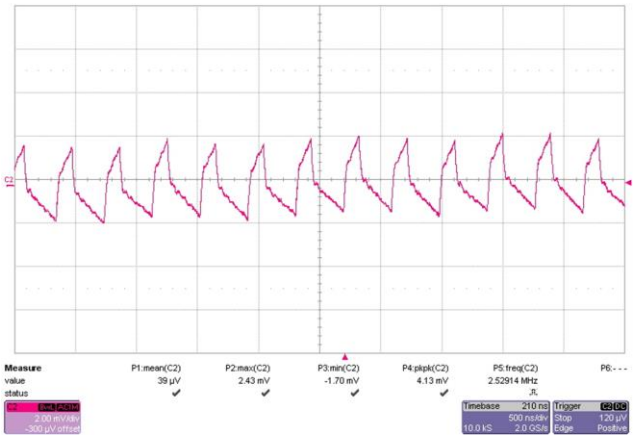


Figure 13. V_{IN} = 12 V, I_{OUT} = 80 A

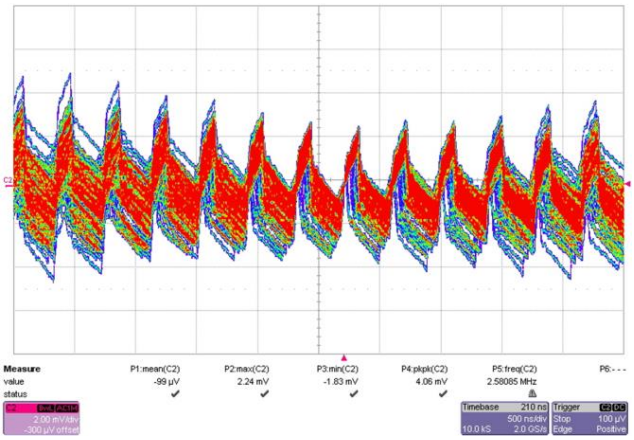


Figure 14. V_{IN} = 12 V, I_{OUT} = 80 A (with persistence)

3.3 Short Circuit Recovery

The waveform below shows the converter's response when FET Q500 (on the board) is shorted. The converter is able to recover successfully after being shorted.

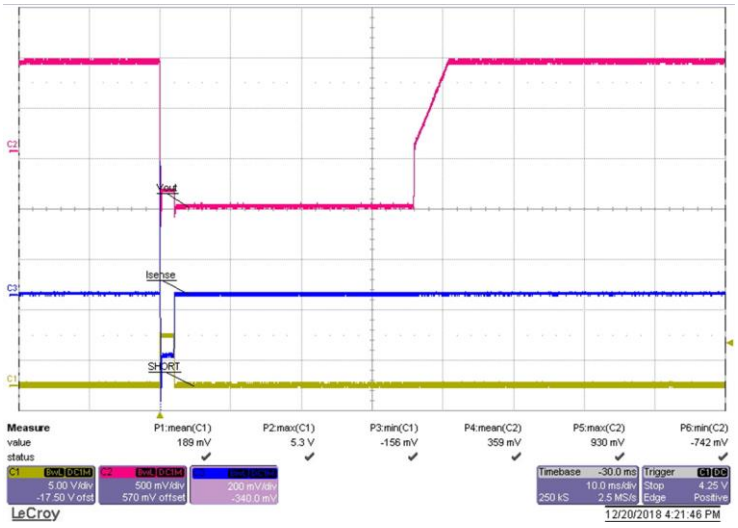


Figure 15. V_{IN} = 12 V, I_{OUT} = 160 A, Short Circuit and Recovery

3.4 Bode Plots

The crossover frequency is 69.372 kHz. The gain margin is 19.139 dB and the phase margin is 49.763°.

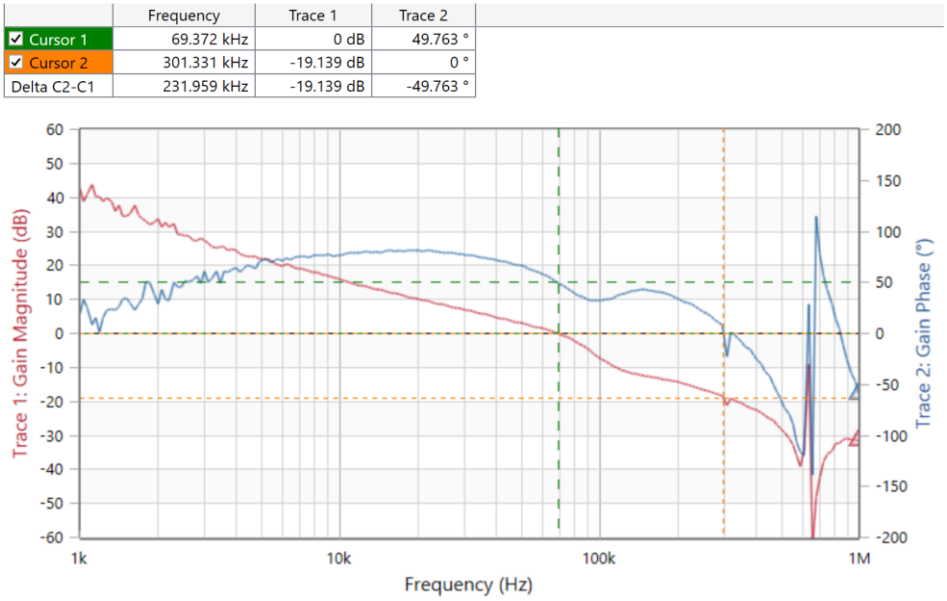


Figure 16. V_{IN} = 12 V, I_{OUT} = 0 A

With a 40 A load applied, the crossover frequency is 73.341 kHz. The gain margin is 18.357 dB and the phase margin is 45.049°.

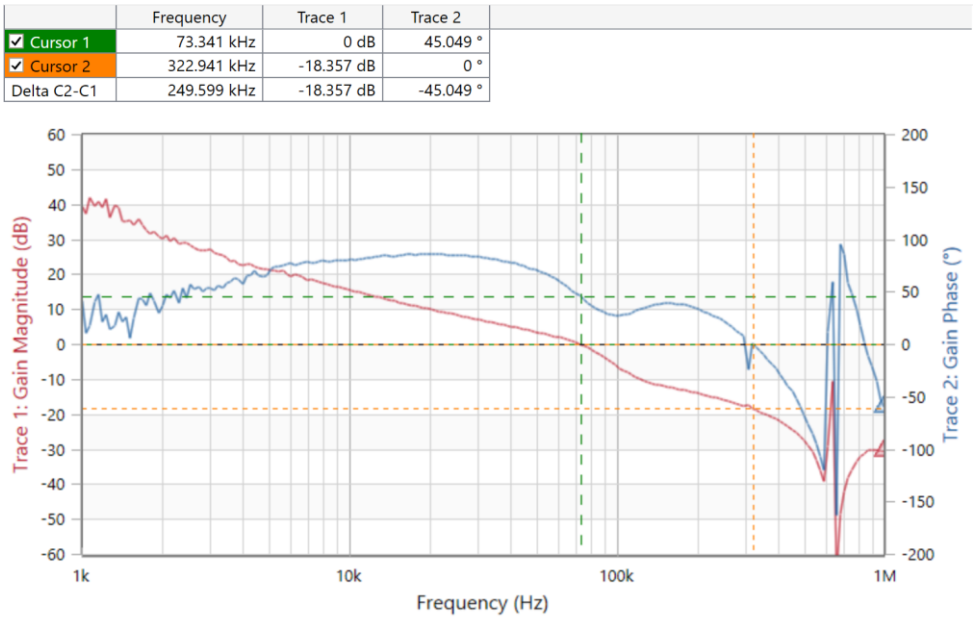


Figure 17. V_{IN} = 12 V, I_{OUT} = 40 A

3.5 Load Transient

Figure 18 shows the converter's response when a load step from 0 to 60 A is applied. The load current is on a scale of 10 A/ div and the output voltage is on a scale of 20 mV / div. The output voltage deviates by + 40.0 mV (4.44% of the output voltage) and – 43.1 mV (4.79% of the output voltage).

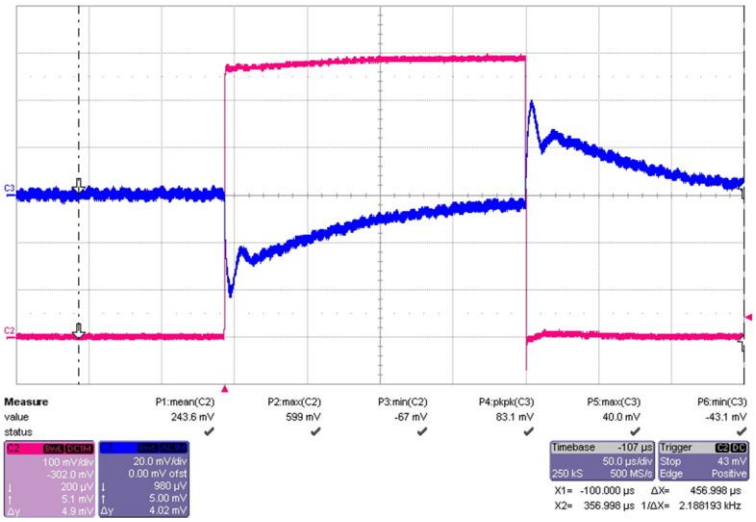


Figure 18. V_{IN} = 12 V, I_{OUT} = 60 A

3.6 Start-up Sequence

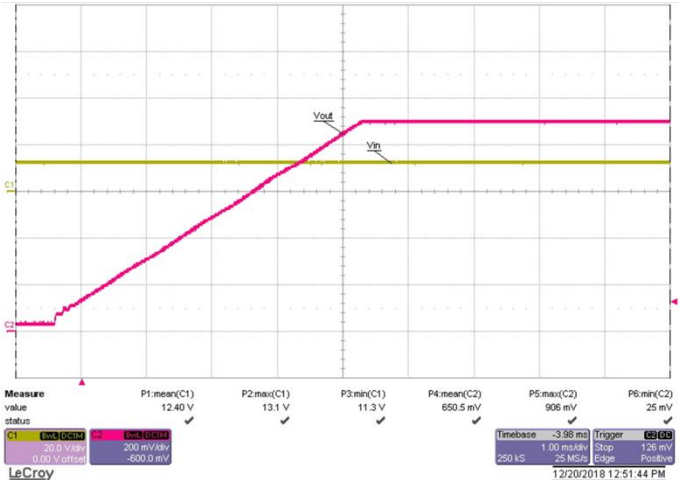


Figure 19. V_{IN} = 12 V, I_{OUT} = 0 A

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