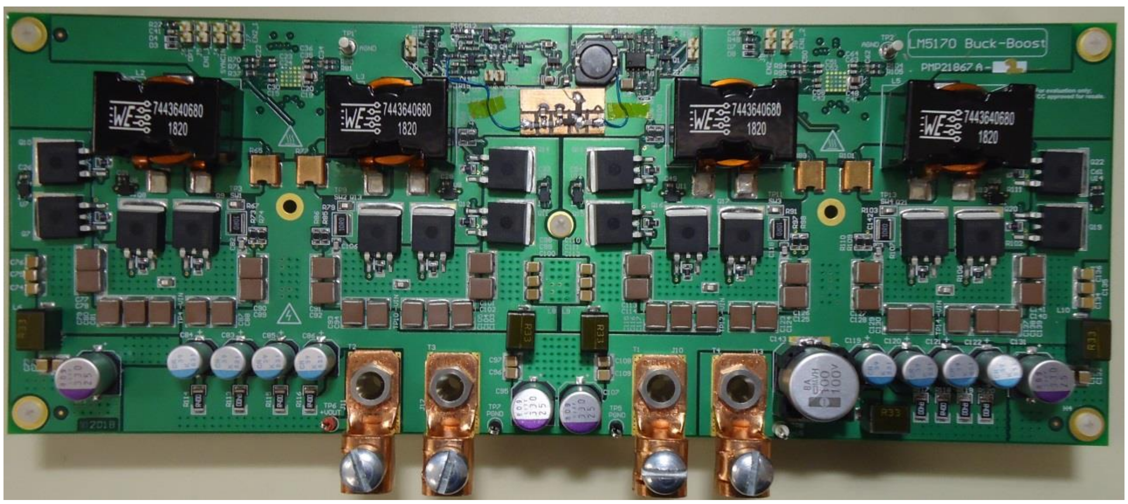
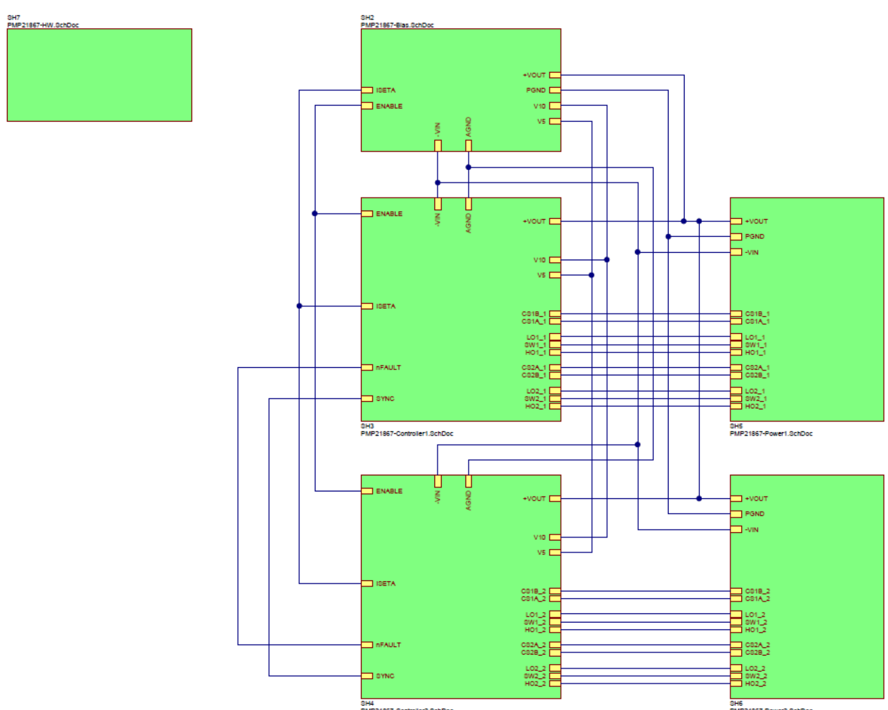
Test Report: PMP21867

12-V / 100-A Negative-to-Positive Synchronous Buck-Boost Reference Design for Power Amplifiers

Description

This reference design is a negative-to-positive synchronous buck-boost converter for power amplifier applications. The circuit is powered from the nominal -48-V system source to provide an output voltage of +12 V at 100 A. The design uses two dual synchronous boost controllers for 4-phase operation at a switching frequency of 100 kHz. Output voltage adjustment to +14.5 V is jumper selectable. 1 through 4 phase operation is also jumper selectable.





1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input Voltage	-36 V to -60 V
Output Voltage	+12 V or +14.5 V
Output Current	100 A

1.2 Required Equipment

- DC power supply
- Electronic load
- Oscilloscope

1.3 Considerations

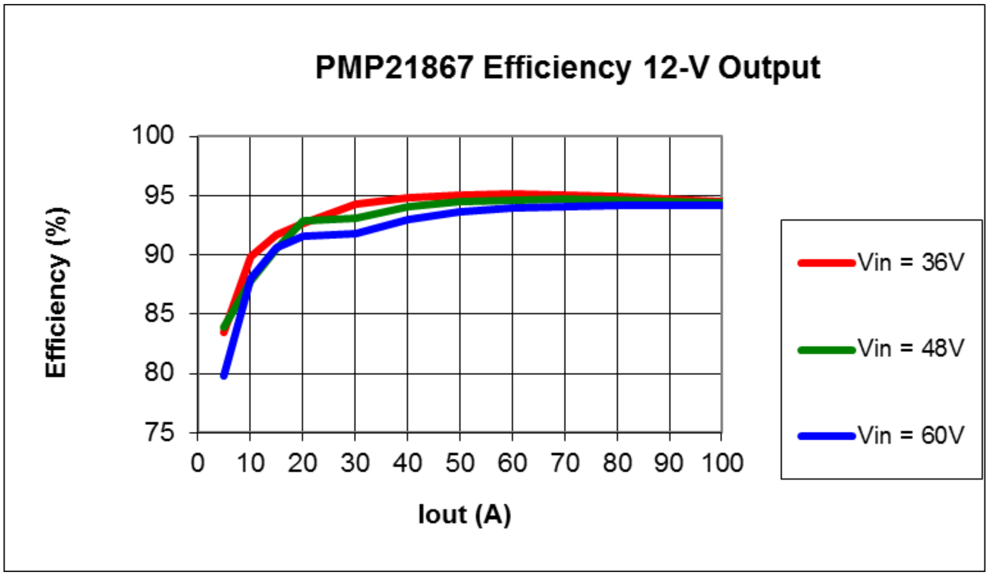
All tests were performed at room temperature on an open bench.

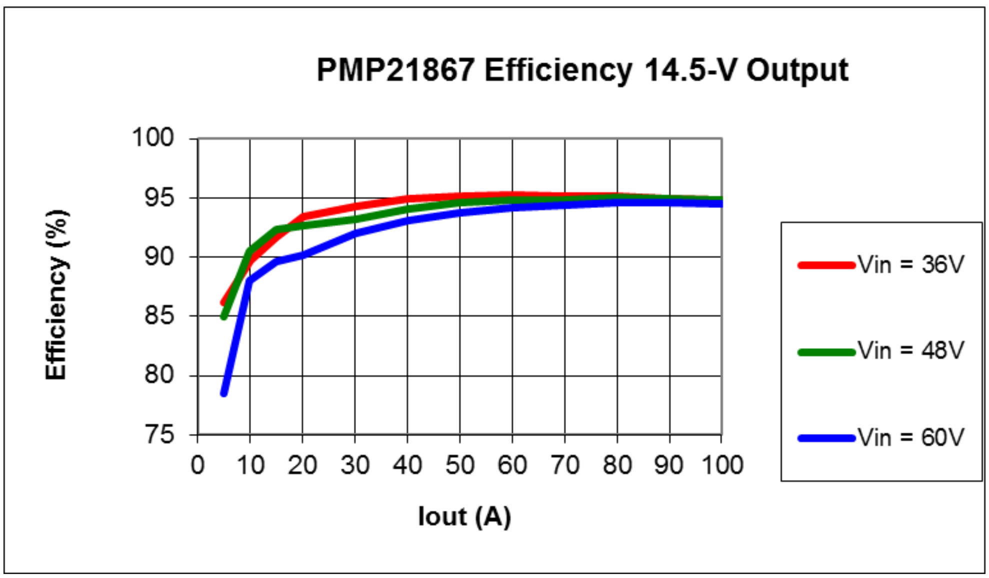
Heat sink and/or air flow is required for sustained operation above 50% load.

2 Testing and Results

2.1 Efficiency Graphs

Figures show the converter efficiency with 36-V, 48-V, and 60-V inputs.





2.2 Efficiency Data

Table 2, Table 3, Table 4, Table 5, Table 6, and Table 7 shows the efficiency data with 36-V, 48-V, and 60-V inputs.

Table 2. Efficiency Data 36-V Input, 12-V Output

V_{IN}	I_{IN}	V_{OUT}	I_{OUT}	P_{IN}	P_{OUT}	Losses	Efficiency
36.002	0.038	12.006	0.000	1.37	0.00	1.37	0.00
36.002	1.998	12.003	5.002	71.93	60.04	11.89	83.46
36.001	3.712	12.001	10.000	133.64	120.01	13.62	89.80
36.001	5.450	12.000	14.998	196.21	179.98	16.23	91.73
36.001	7.220	11.999	20.082	259.93	240.96	18.97	92.70
36.001	10.630	11.996	30.064	382.69	360.66	22.04	94.24
36.001	14.070	11.994	40.066	506.53	480.55	25.99	94.87
36.001	17.532	11.991	50.052	631.17	600.19	30.98	95.09
36.001	21.014	11.989	60.034	756.52	719.74	36.78	95.14
36.001	24.530	11.986	70.038	883.10	839.50	43.60	95.06
36.001	28.066	11.984	80.030	1010.40	959.08	51.32	94.92
36.001	31.628	11.982	90.018	1138.63	1078.57	60.06	94.72
36.001	35.218	11.979	99.986	1267.88	1197.73	70.14	94.47

Table 3. Efficiency Data 48-V Input, 12-V Output

V_{IN}	I_{IN}	V_{OUT}	I_{OUT}	P_{IN}	P_{OUT}	Losses	Efficiency
48.003	0.036	11.991	0.000	1.73	0.00	1.73	0.00
48.004	1.488	11.989	5.002	71.43	59.97	11.46	83.96
48.004	2.844	11.988	10.000	136.52	119.88	16.64	87.81
48.003	4.136	11.987	14.998	198.54	179.78	18.77	90.55
48.004	5.402	11.986	20.084	259.32	240.72	18.60	92.83
48.004	8.062	11.983	30.066	387.01	360.28	26.72	93.10
48.004	10.636	11.981	40.066	510.57	480.02	30.55	94.02
48.004	13.224	11.978	50.054	634.80	599.57	35.23	94.45
48.003	15.824	11.976	60.030	759.60	718.91	40.69	94.64
48.003	18.450	11.974	70.042	885.66	838.66	47.00	94.69
48.003	21.084	11.971	80.032	1012.11	958.07	54.04	94.66
48.003	23.740	11.969	90.020	1139.60	1077.43	62.17	94.54
48.003	26.391	11.964	99.986	1266.85	1196.23	70.62	94.43

Table 4. Efficiency Data 60-V Input, 12-V Output

V_{IN}	I_{IN}	V_{OUT}	I_{OUT}	P_{IN}	P_{OUT}	Losses	Efficiency
60.002	0.036	11.980	0.000	2.16	0.00	2.16	0.00
60.002	1.252	11.978	5.002	75.12	59.91	15.21	79.75
60.002	2.268	11.977	10.000	136.09	119.77	16.32	88.01
60.003	3.304	11.976	15.000	198.25	179.64	18.61	90.61
60.003	4.376	11.975	20.084	262.57	240.50	22.07	91.59
60.002	6.538	11.972	30.066	392.30	359.96	32.34	91.76
60.003	8.596	11.970	40.068	515.78	479.60	36.18	92.99
60.002	10.662	11.967	50.056	639.75	599.04	40.71	93.64
60.002	12.742	11.965	60.038	764.55	718.36	46.19	93.96

60.003	14.836	11.963	70.040	890.20	837.86	52.34	94.12
60.002	16.936	11.960	80.034	1016.20	957.20	59.00	94.19
60.003	19.052	11.958	90.022	1143.17	1076.44	66.73	94.16
60.002	21.156	11.953	99.984	1269.40	1195.11	74.29	94.15

Table 5. Efficiency Data 36-V Input, 14.5V Output

V_{IN}	I_{IN}	V_{OUT}	I_{OUT}	P_{IN}	P_{OUT}	Losses	Efficiency
36.001	0.046	14.428	0.000	1.66	0.00	1.66	0.00
36.002	2.326	14.424	5.002	83.74	72.15	11.59	86.16
36.001	4.462	14.423	10.000	160.64	144.23	16.41	89.78
36.001	6.554	14.421	14.998	235.95	216.29	19.67	91.67
36.001	8.612	14.419	20.080	310.04	289.54	20.50	93.39
36.001	12.766	14.417	30.064	459.59	433.43	26.15	94.31
36.001	16.896	14.415	40.064	608.27	577.51	30.76	94.94
36.001	21.050	14.412	50.050	757.83	721.32	36.51	95.18
36.001	25.230	14.409	60.034	908.30	865.04	43.26	95.24
36.001	29.446	14.407	70.036	1060.08	1008.98	51.10	95.18
36.001	33.608	14.392	80.022	1209.92	1151.68	58.24	95.19
36.000	37.882	14.390	90.006	1363.75	1295.19	68.57	94.97
36.001	42.164	14.388	99.988	1517.95	1438.63	79.32	94.77

Table 6. Efficiency Data 48-V Input, 14.5-V Output

V_{IN}	I_{IN}	V_{OUT}	I_{OUT}	P_{IN}	P_{OUT}	Losses	Efficiency
48.004	0.040	14.411	0.000	1.92	0.00	1.92	0.00
48.004	1.766	14.408	5.000	84.78	72.04	12.73	84.98
48.004	3.314	14.407	9.998	159.08	144.04	15.05	90.54
48.004	4.876	14.406	14.996	234.07	216.03	18.04	92.29
48.004	6.502	14.404	20.080	312.12	289.24	22.88	92.67
48.004	9.678	14.402	30.060	464.58	432.92	31.65	93.19
48.004	12.768	14.399	40.062	612.91	576.87	36.04	94.12
48.004	15.872	14.397	50.048	761.92	720.55	41.37	94.57
48.003	18.990	14.394	60.036	911.59	864.17	47.41	94.80
48.004	22.132	14.391	70.038	1062.43	1007.95	54.48	94.87
48.003	25.232	14.378	80.024	1211.21	1150.59	60.63	94.99
48.003	28.400	14.376	90.006	1363.29	1293.93	69.36	94.91
48.003	31.584	14.373	99.990	1516.13	1437.16	78.97	94.79

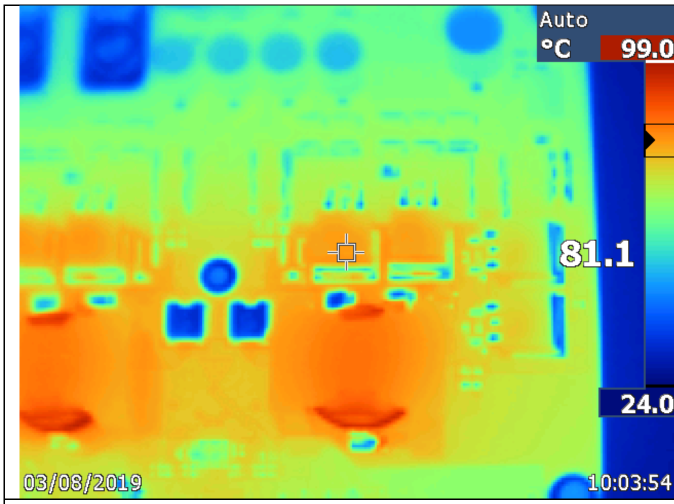
Table 7. Efficiency Data 60-V Input, 14.5-V Output

V_{IN}	I_{IN}	V_{OUT}	I_{OUT}	P_{IN}	P_{OUT}	Losses	Efficiency
60.003	0.038	14.398	0.000	2.28	0.00	2.28	0.00
60.003	1.528	14.395	5.000	91.68	71.98	19.71	78.50
60.003	2.726	14.394	9.998	163.57	143.91	19.66	87.98
60.003	4.014	14.393	14.998	240.85	215.87	24.98	89.63
60.003	5.344	14.392	20.080	320.65	288.98	31.67	90.12
60.003	7.836	14.389	30.064	470.18	432.59	37.59	92.01
60.003	10.314	14.387	40.064	618.87	576.39	42.48	93.14

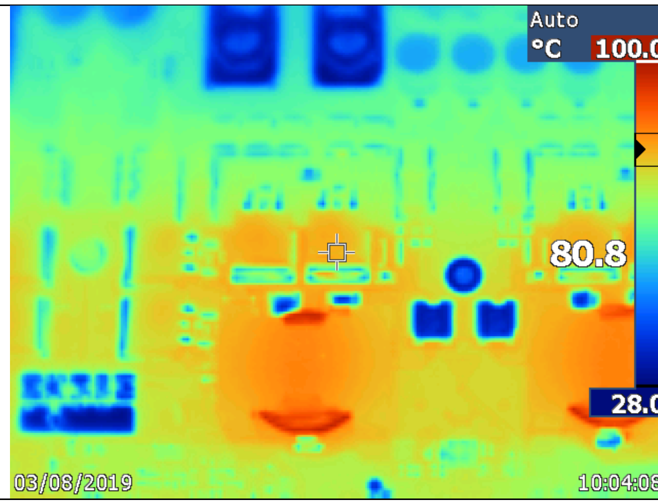
60.003	12.792	14.384	50.052	767.56	719.95	47.61	93.80
60.003	15.282	14.382	60.034	916.96	863.38	53.58	94.16
60.003	17.788	14.379	70.038	1067.33	1007.08	60.25	94.35
60.002	20.246	14.365	80.024	1214.80	1149.54	65.26	94.63
60.002	22.764	14.363	90.000	1365.89	1292.67	73.22	94.64
60.003	25.316	14.362	99.990	1519.04	1436.06	82.98	94.54

2.3 Thermal Images

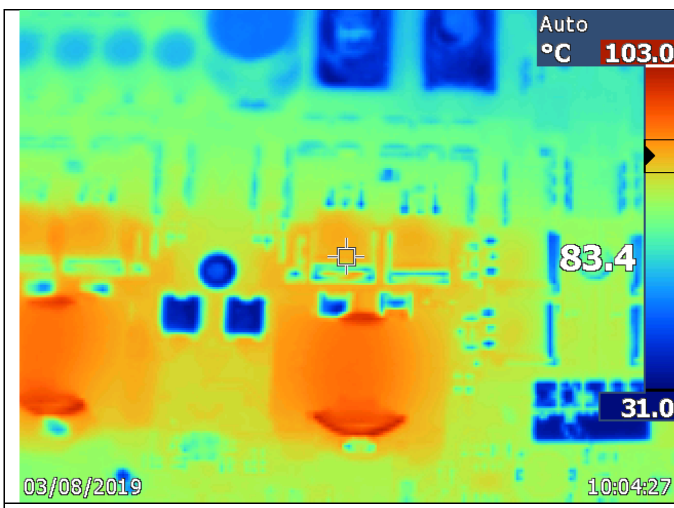
Figures show thermal performance for 4-phase operation at 48-V input and 12-V output at 50-A load with no airflow. The images were taken with the board at thermal equilibrium after 21 hour burn-in.



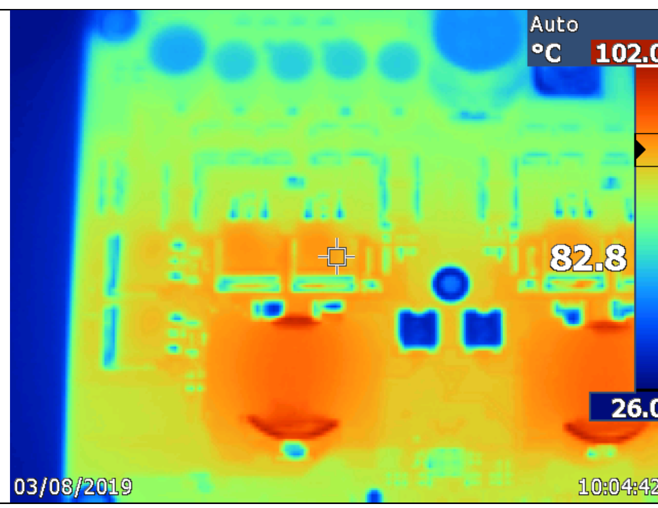
Phase-1 Thermal Image, 48-V Input, 12-V Output, 50-A Load



Phase-2 Thermal Image, 48-V Input, 12-V Output, 50-A Load



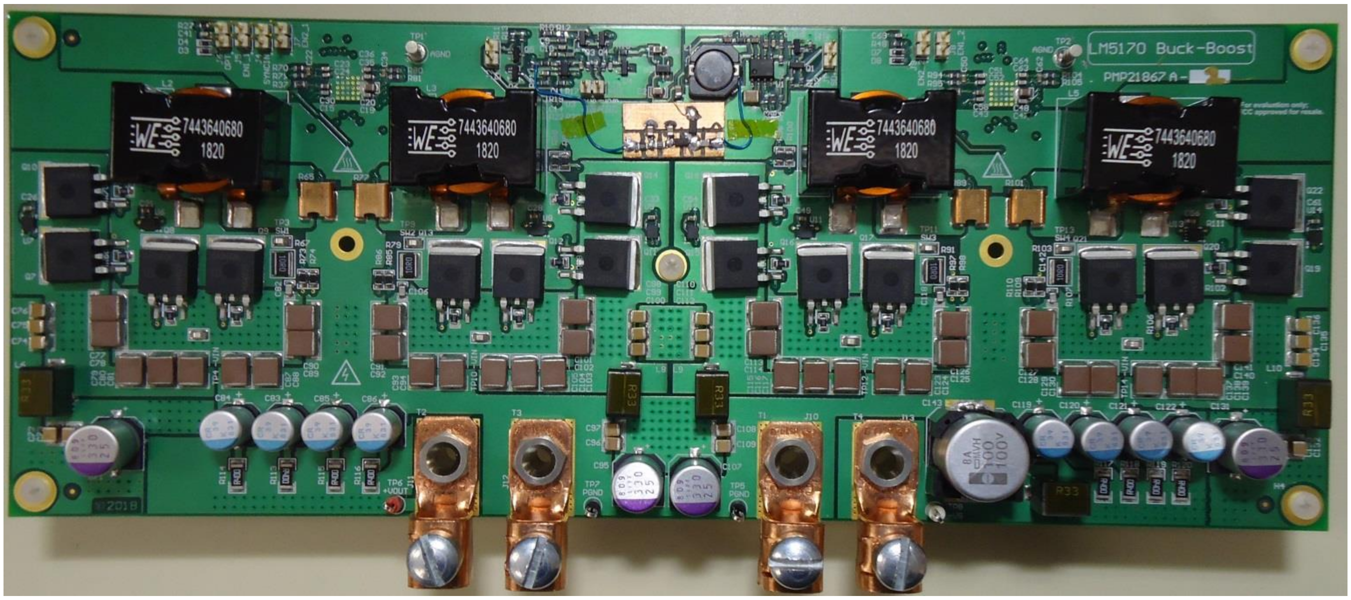
Phase-3 Thermal Image, 48-V Input, 12-V Output, 50-A Load



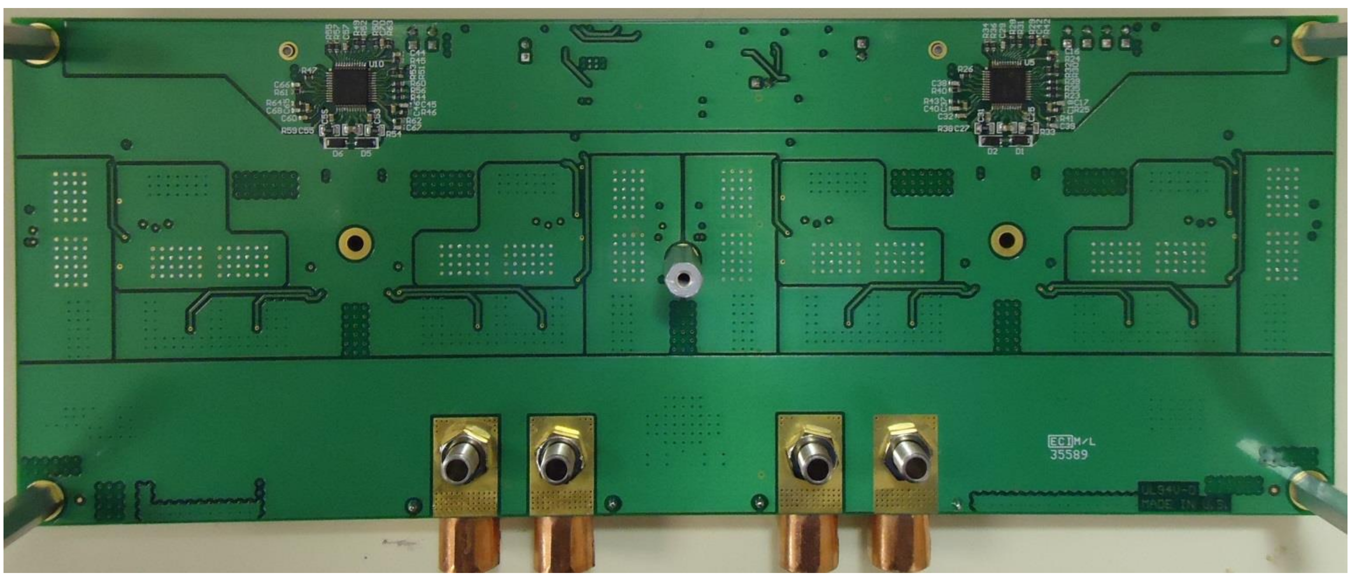
Phase-4 Thermal Image, 48-V Input, 12-V Output, 50-A Load

2.4 Dimensions

The design was built on PMP21867 Rev A printed circuit board. This is an 8-layer PCB with 2 oz. copper internal, 3 oz. copper external. Board dimensions are 10.2 in. x 3.9 in.



Top of PMP21867 Board

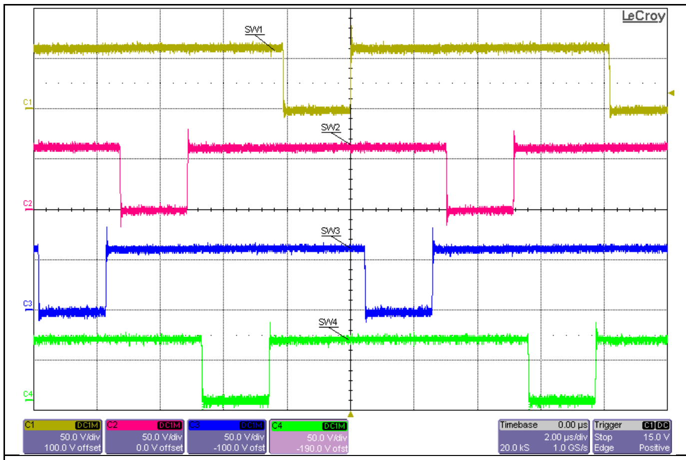


Bottom of PMP21867 Board

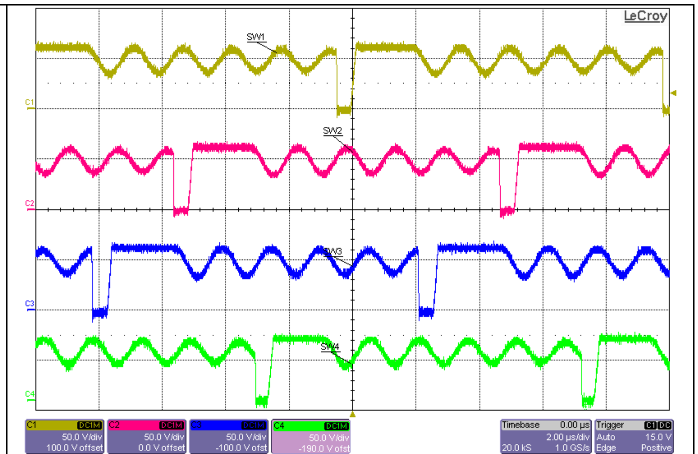
3 Waveforms

3.1 Switching

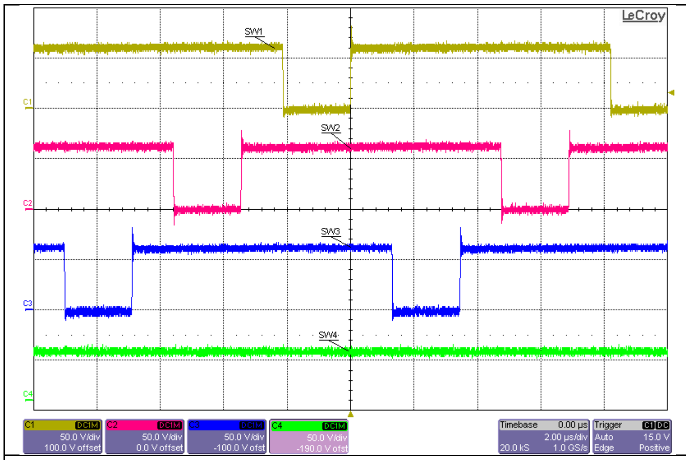
Figures show the switch node voltages of the converter.



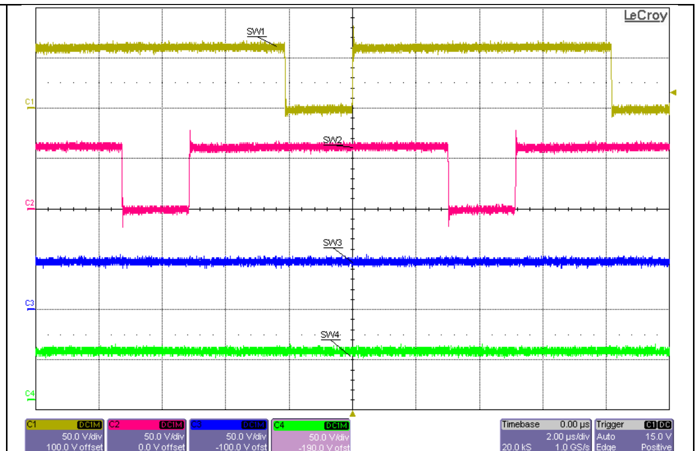
4-Phase Switching, 48-V Input, 100-A Load



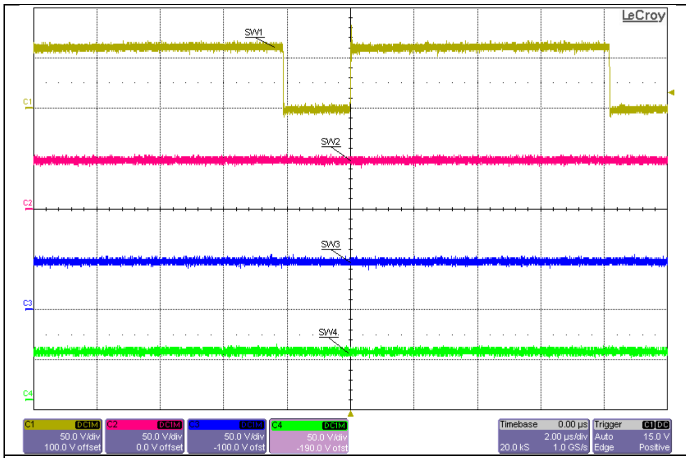
4-Phase Switching, 48-V Input, 1-A Load



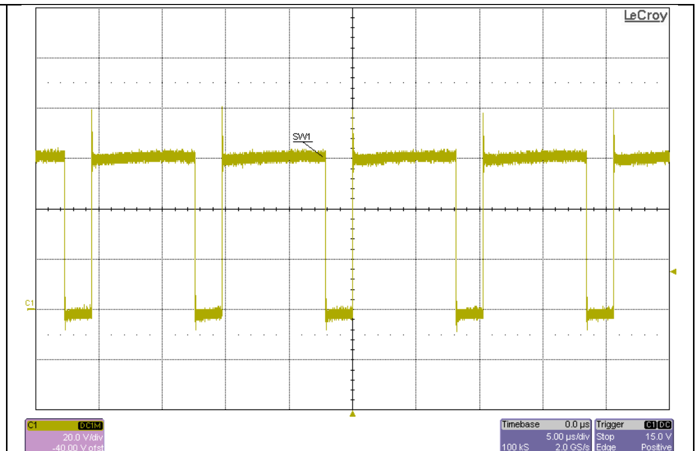
3-Phase Switching, 48-V Input, 75-A Load



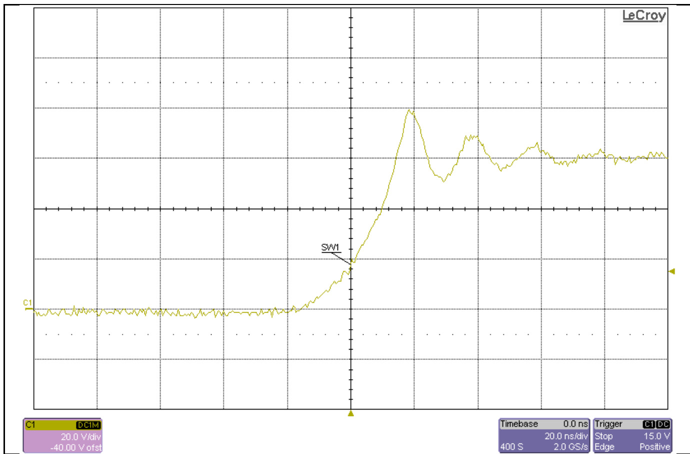
2-Phase Switching, 48-V Input, 50-A Load



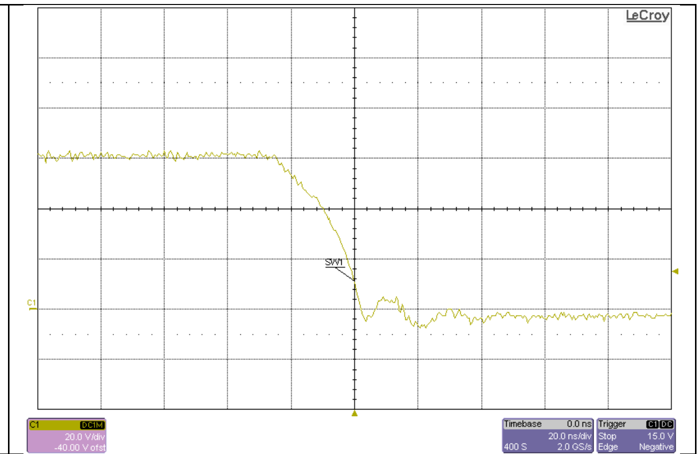
1-Phase Switching, 48-V Input, 25-A Load



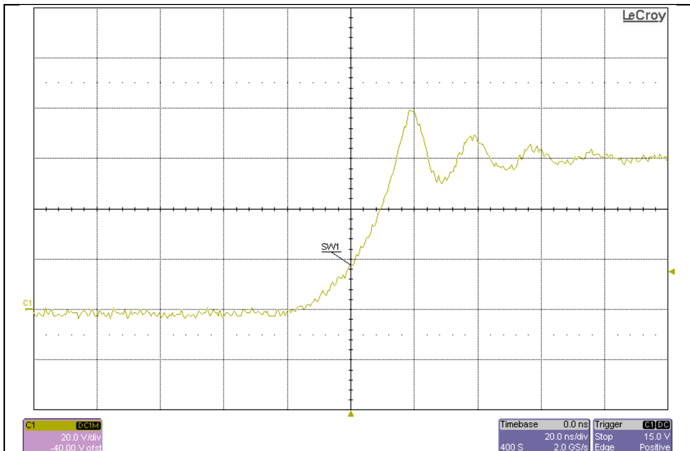
1-Phase Switching, 48-V Input, 25-A Load



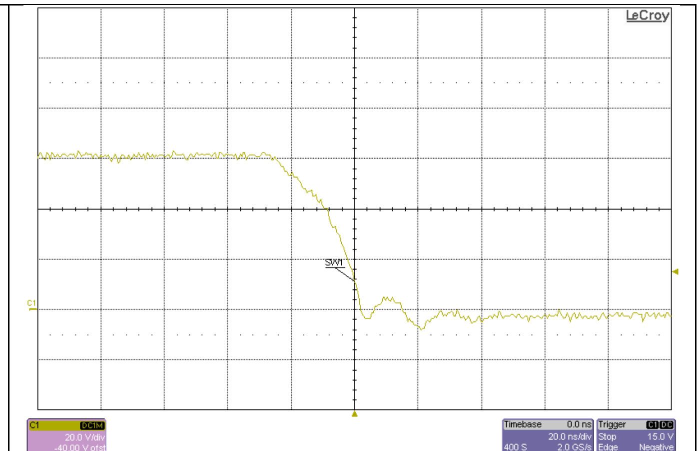
1-Phase Switching, 48-V Input, 25-A Load



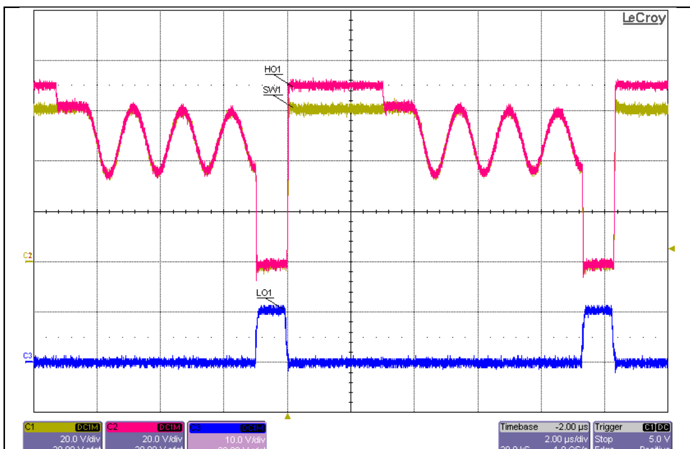
1-Phase Switching, 48-V Input, 25-A Load



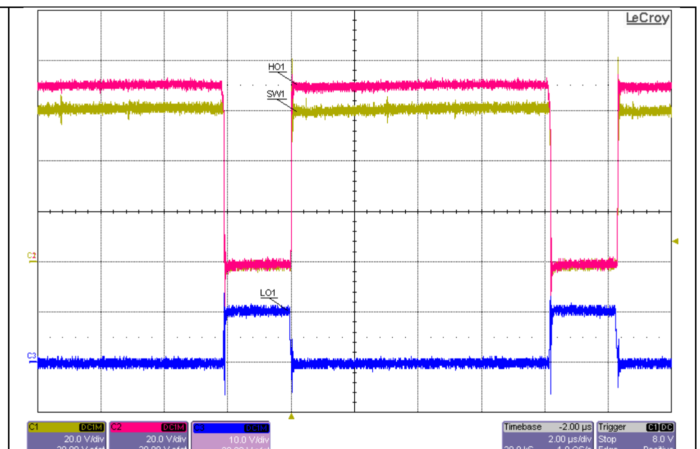
4-Phase Switching, 48-V Input, 100-A Load



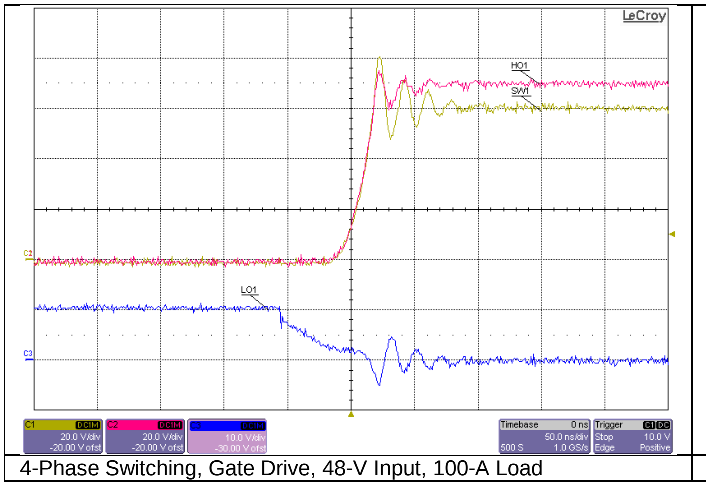
4-Phase Switching, 48-V Input, 100-A Load



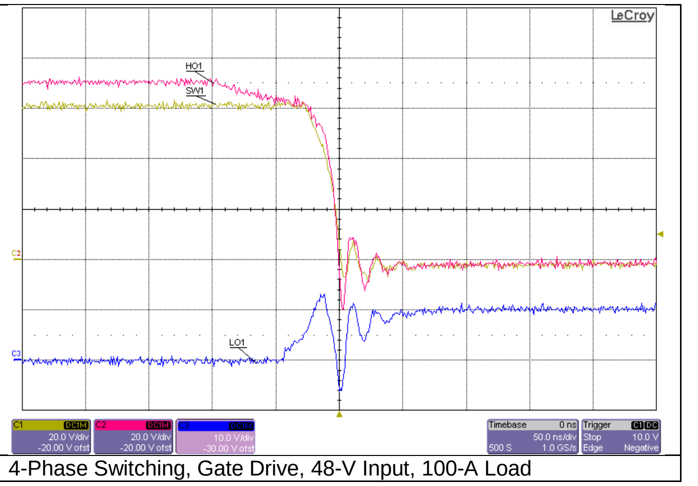
4-Phase Switching, Gate Drive, 48-V Input, 5-A Load



4-Phase Switching, Gate Drive, 48-V Input, 100-A Load



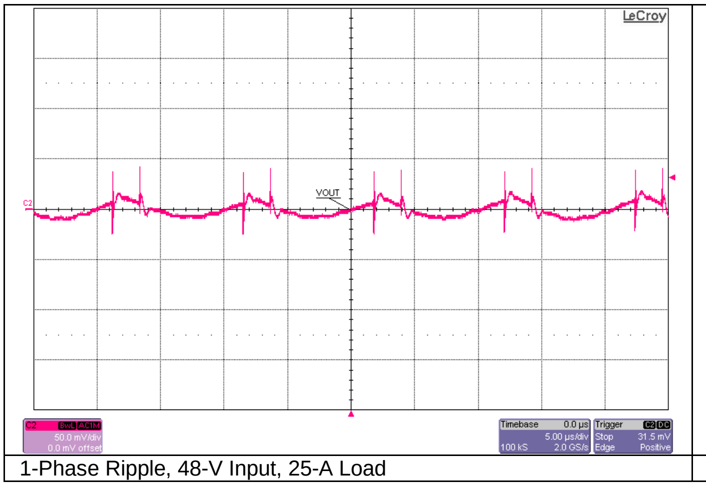
4-Phase Switching, Gate Drive, 48-V Input, 100-A Load



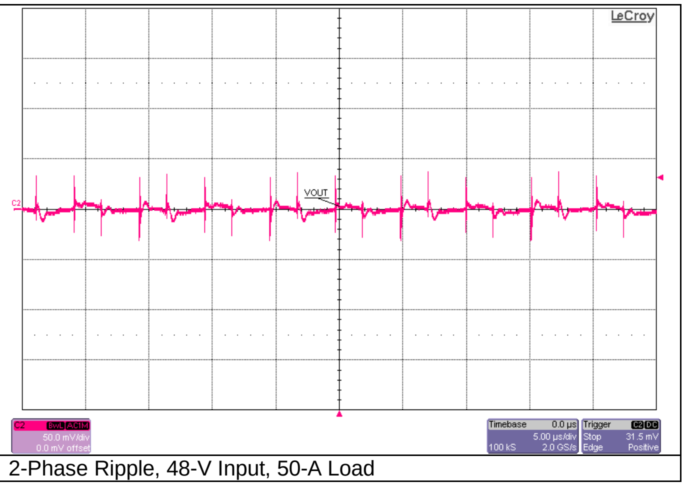
4-Phase Switching, Gate Drive, 48-V Input, 100-A Load

3.2 Output Voltage Ripple

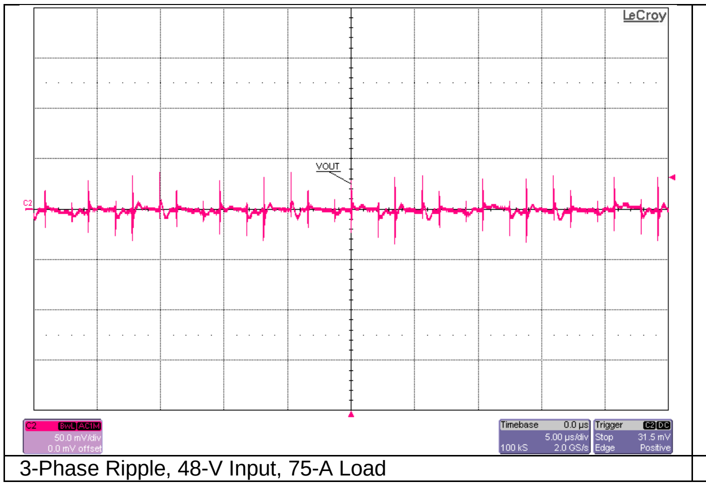
Figures show the output voltage ripple of the converter.



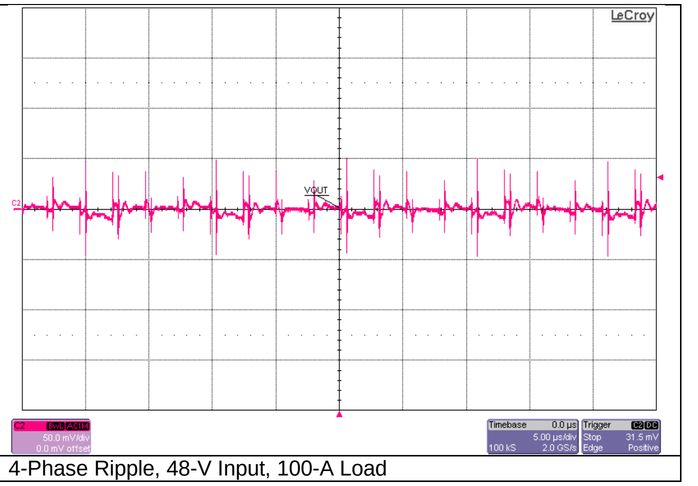
1-Phase Ripple, 48-V Input, 25-A Load



2-Phase Ripple, 48-V Input, 50-A Load



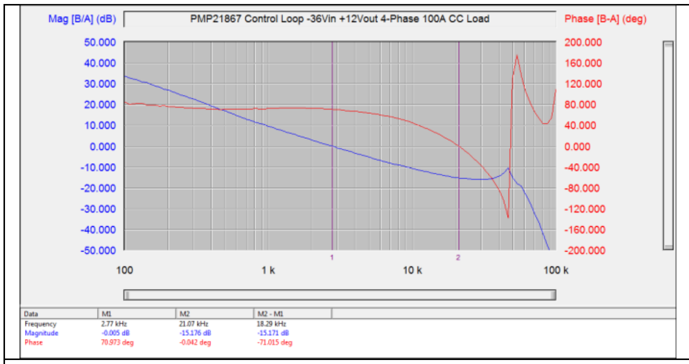
3-Phase Ripple, 48-V Input, 75-A Load



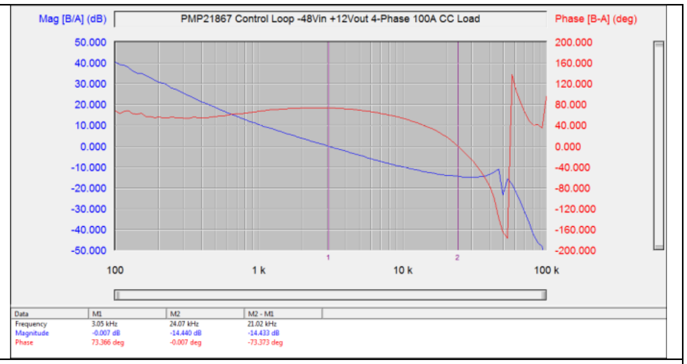
4-Phase Ripple, 48-V Input, 100-A Load

3.3 Bode Plots

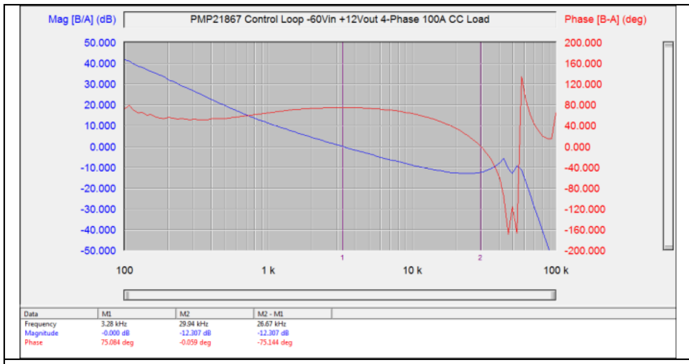
Figures show Bode plots of the control loop a constant current load.



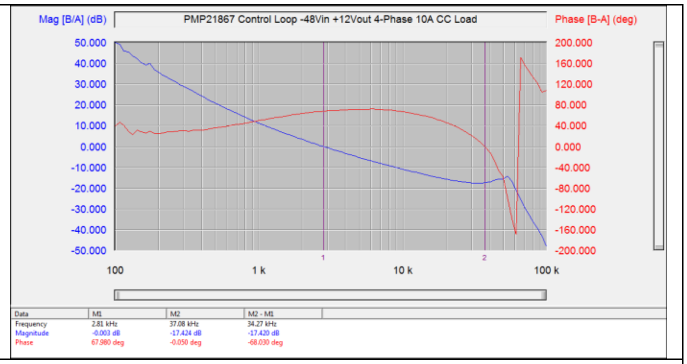
Control Loop, 36-V Input, 4-Phase,100-A Load



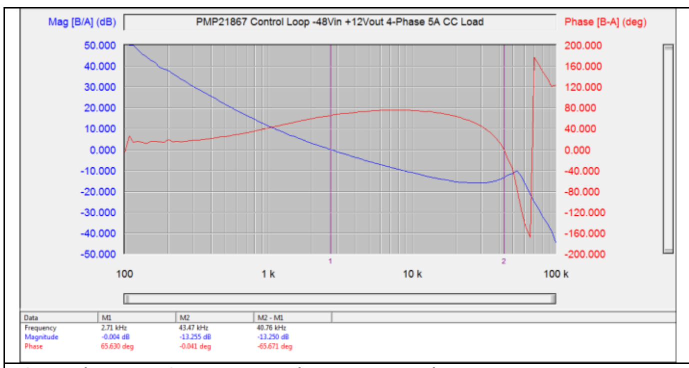
Control Loop, 48-V Input, 4-Phase, 100-A Load



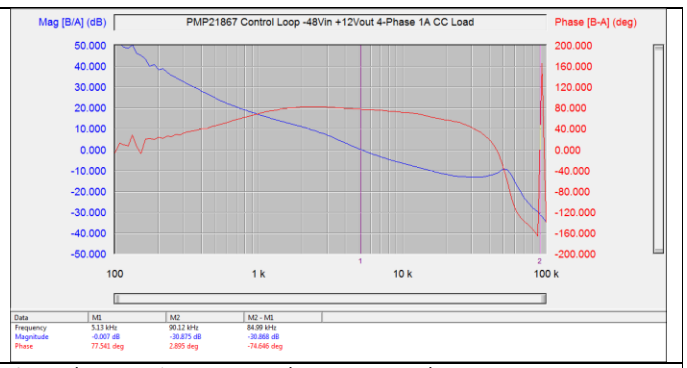
Control Loop, 60-V Input, 4-Phase, 100-A Load



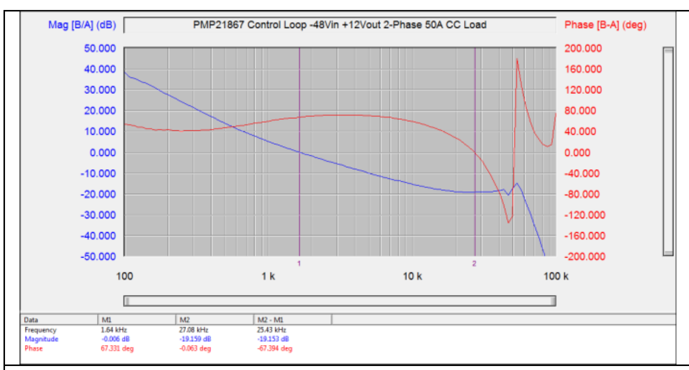
Control Loop, 48-V Input, 4-Phase, 10-A Load



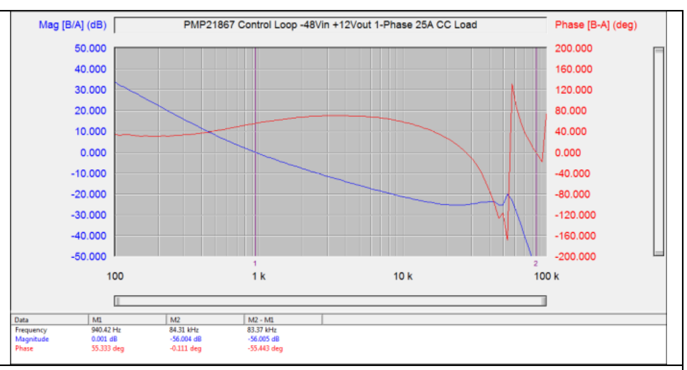
Control Loop, 48-V Input, 4-Phase,5-A Load



Control Loop, 48-V Input, 4-Phase, 1-A Load



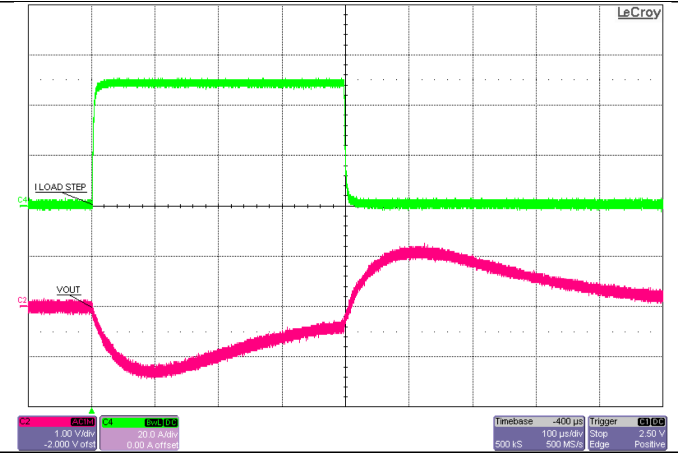
Control Loop, 48-V Input, 2-Phase, 50-A Load



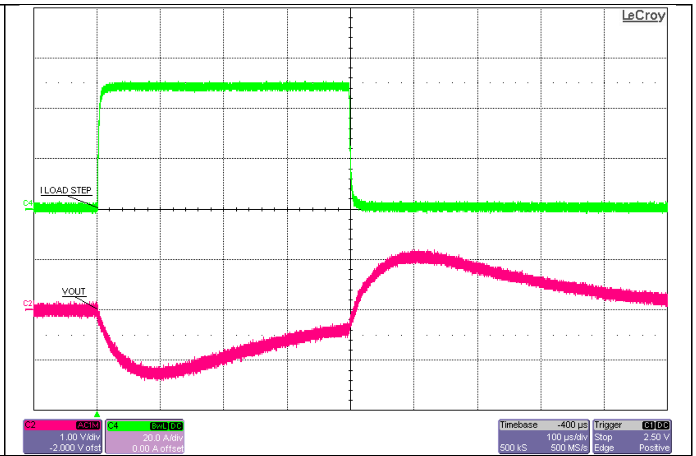
Control Loop, 48-V Input, 1-Phase, 25-A Load

3.4 Load Transients

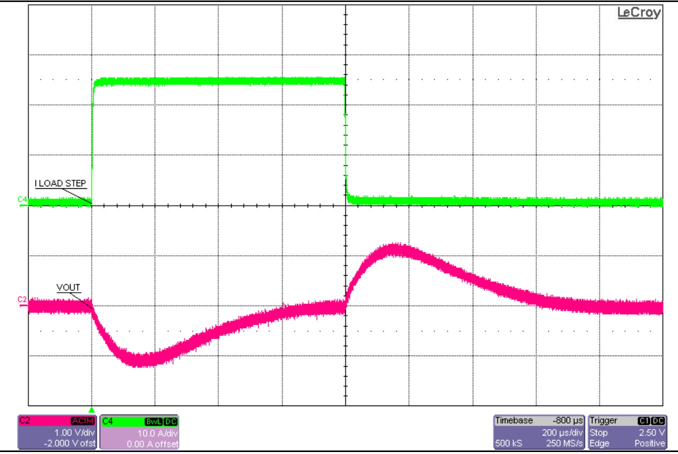
Figures show the load transient response of the converter for a 50% load step.



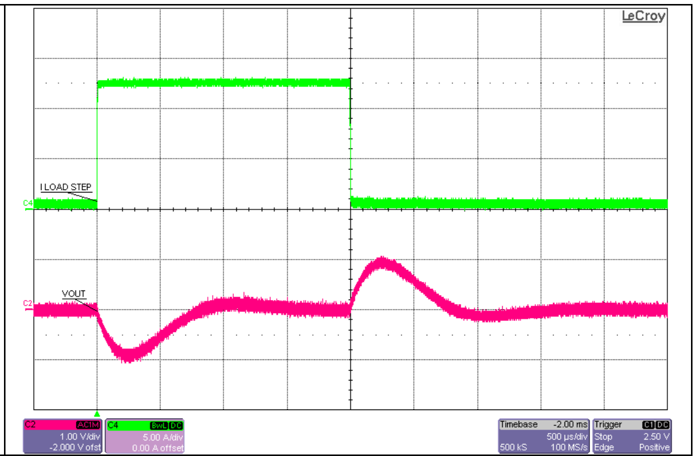
4-Phase, 48-V Input, 20-ADC Load, 50-A Load Step



4-Phase, 48-V Input, 50-ADC Load, 50-A Load Step



2-Phase, 48-V Input, 25-ADC Load, 25-A Load Step



1-Phase, 48-V Input, 12.5-ADC Load, 12.5-A Load Step

3.5 Current Sharing

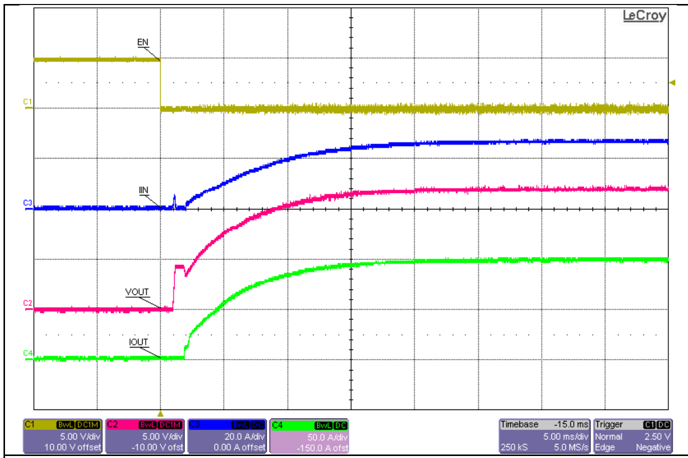
Table 8 shows the current sharing by measuring the current sense shunt voltages, where 1 mV = 1 A.

Table 8. Current Sharing at 48-V Input, 12-V Output

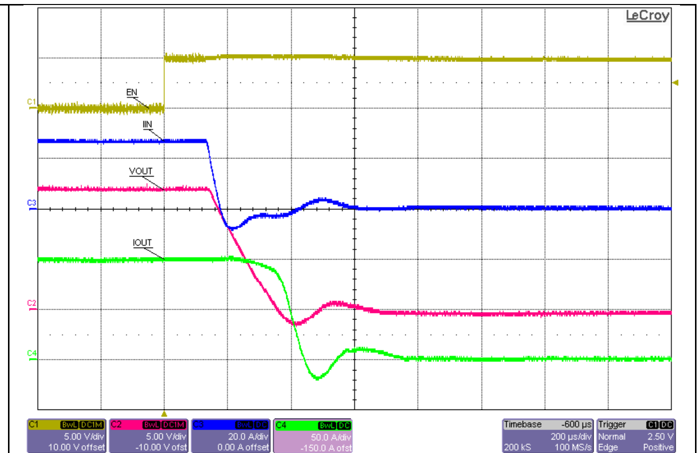
I_{LOAD}	I_{PH1}	I_{PH2}	I_{PH3}	I_{PH4}
10	3.322	3.115	3.220	3.272
50	15.871	15.685	15.861	15.731
100	31.664	31.447	31.721	31.502

3.6 Startup and Shutdown

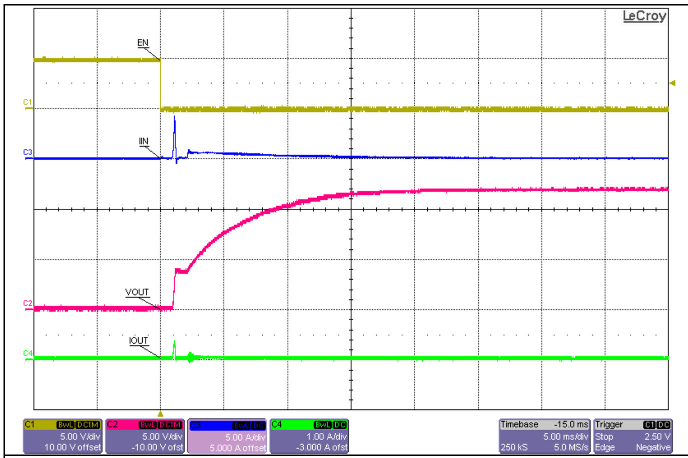
Figures show the startup and shutdown of the converter from the enable control.



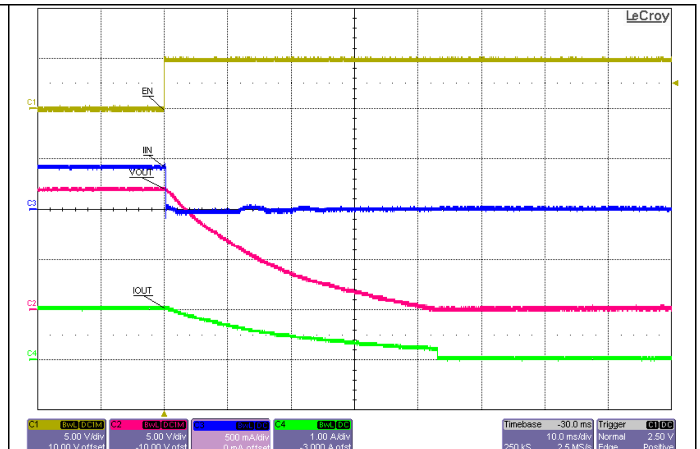
4-Phase Startup, 48-V Input, 100-A Load



4-Phase Shutdown, 48-V Input, 100-A Load



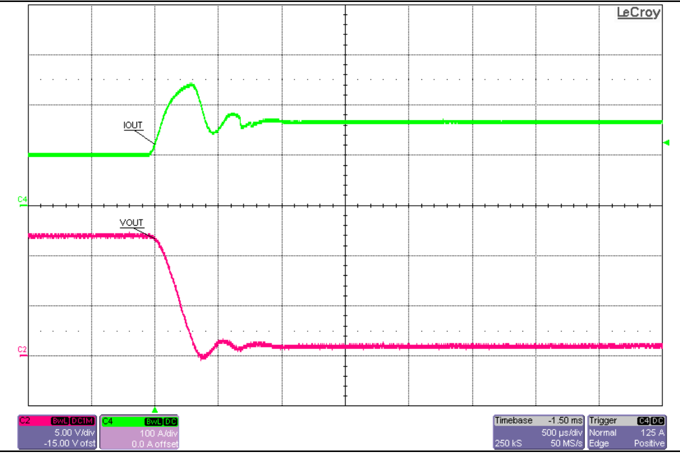
4-Phase Startup, 48-V Input, 0-A Load



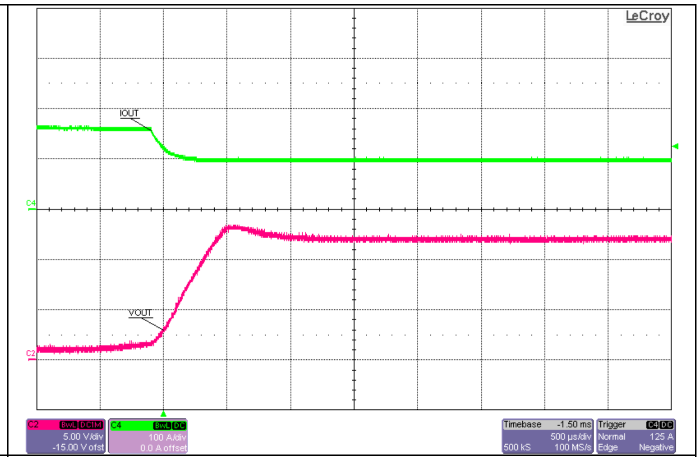
4-Phase Shutdown, 48-V Input, 1-A Load

3.7 Short Circuit Protection

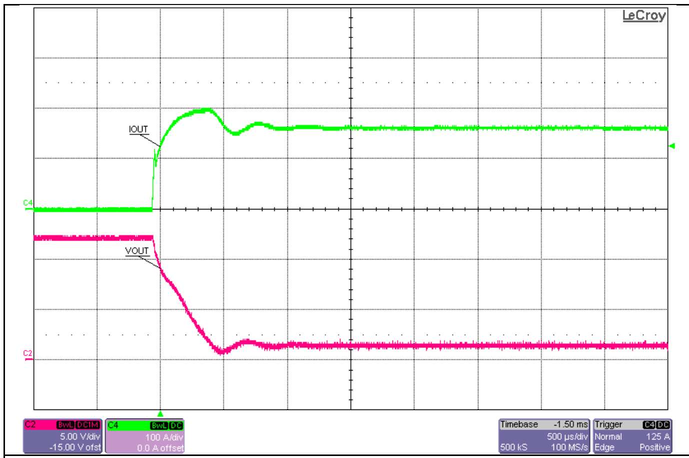
Figures show the output short circuit protection and recovery of the converter for a 48-V input. There is some overshoot due to bandwidth limiting of the control loop.



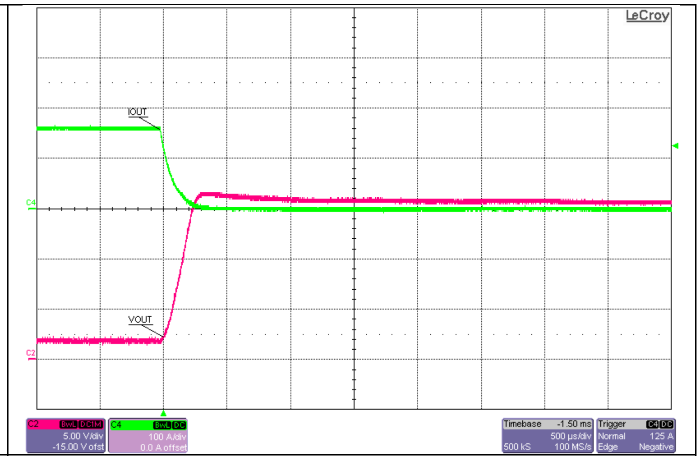
4-Phase Short Circuit, 48-V Input, 100-A Load



4-Phase Short Circuit Recovery, 48-V Input, 100-A Load



4-Phase Short Circuit, 48-V Input, 0-A Load



4-Phase Short Circuit Recovery, 48-V Input, 0-A Load