Test Report: PMP23595

48VIN, 960W Four-Phase Buck Converter With Integrated GaN Reference Design

Description

This reference design uses four LMG708B0-Q1 synchronous buck controllers configured as four-phase, interleaved, synchronous buck converters. The converter generates a regulated 12V output from a nominal 48V input and can handle up to 80A max current at 20A per phase. The LMG708B0-Q1 provides integrated switching with Gallium Nitride (GaN) field-effect transistors (FETs).

Resources

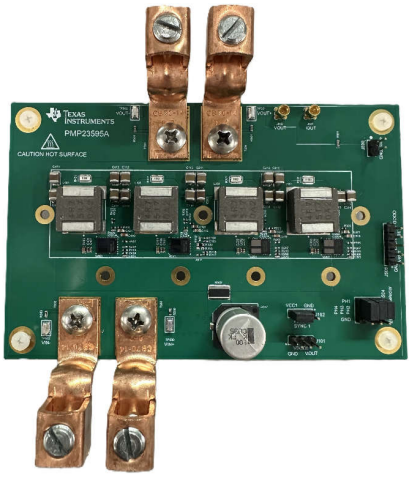
PMP23595	Design Folder
LMG708B0-Q1	Product Folder

Features

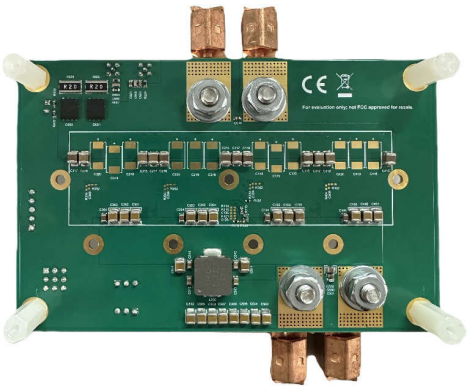
- High-power-density design
- Peak conversion efficiency of 97% to 98% in the 36V to 60V input voltage range
- Four-phase integrated-switch regulators for small design size
- LMG708B0-Q1 has dual-side cooling capability

Applications

- ADAS domain controller
- In-cabin monitoring ECU
- Zone control module



Top of Board



Bottom of Board

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
V_{IN}	24VDC to 60VDC
V_{OUT}	12VDC
I_{OUT}	80A maximum
F_{SW}	400KHz nominal

1.2 Required Equipment

- Power supply
- Electronic load
- Digital multimeters
- Oscilloscope

1.3 Safety Considerations

- Hot surface.
- Contact can cause burn.
- Do not touch.
- When testing for steady state load above 40A, consider the use of a fan on the board.

2 Testing and Results

2.1 Efficiency Graphs

Figure 2-1 shows the converter efficiency at 36V, 48V, and 60V input voltages.

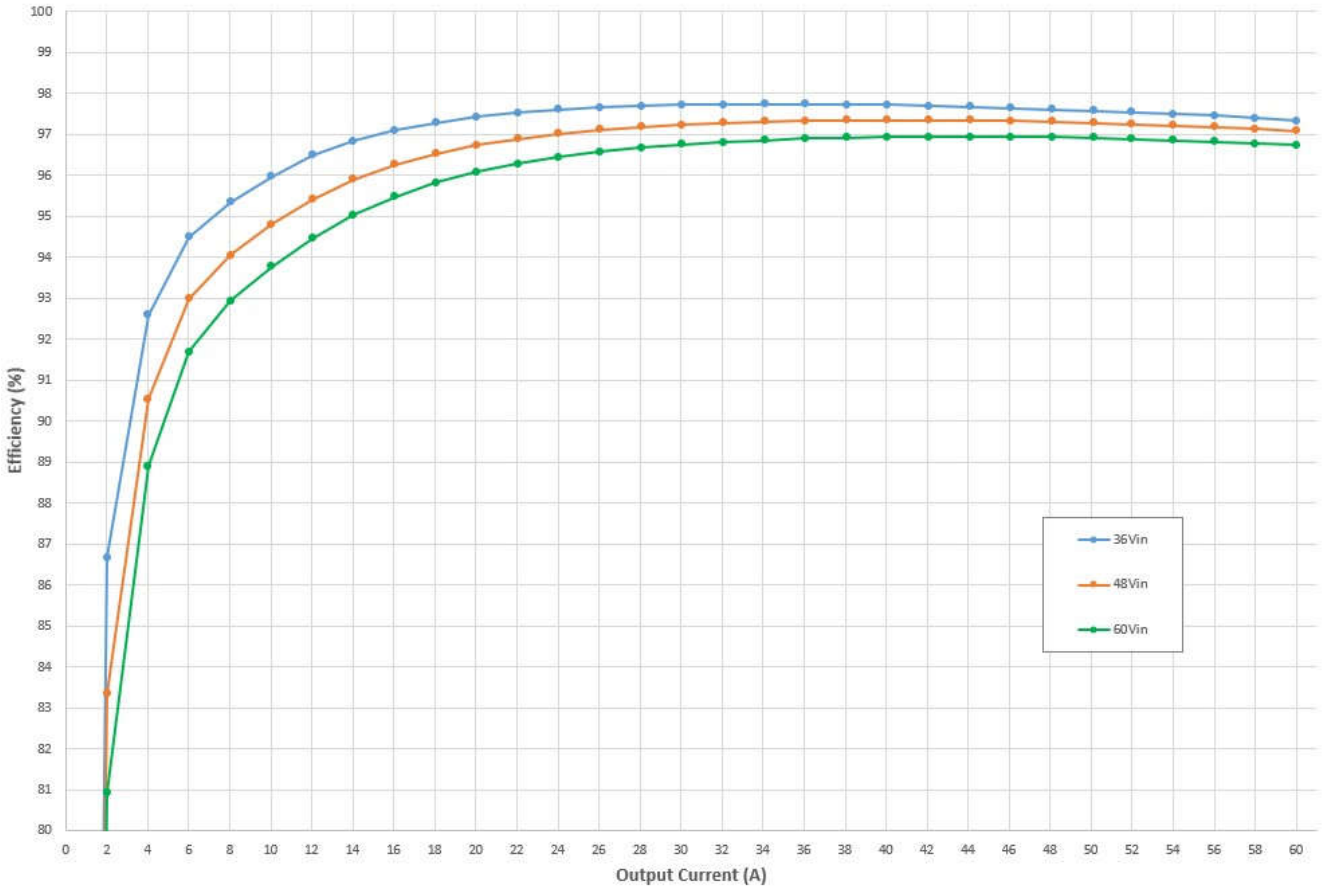


Figure 2-1. Converter Efficiency

2.2 Efficiency Data

This section details the efficiency data at various input voltages.

Table 2-1. Efficiency Data 36V Input

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{Loss} (W)	Efficiency (%)
36.146	0.101	11.982	0.000	3.664	0.000	3.664	0.000
36.132	0.776	11.982	2.029	28.044	24.307	3.738	86.673
36.118	1.445	11.982	4.032	52.179	48.315	3.864	92.595
36.103	2.119	11.982	6.034	76.519	72.300	4.219	94.486
36.089	2.798	11.981	8.035	100.976	96.272	4.704	95.341
36.075	3.474	11.980	10.038	125.317	120.263	5.053	95.967
36.061	4.146	11.980	12.042	149.519	144.262	5.257	96.484
36.046	4.820	11.980	14.044	173.739	168.248	5.491	96.840
36.032	5.495	11.979	16.048	198.004	192.242	5.761	97.090
36.018	6.172	11.979	18.052	222.302	216.249	6.053	97.277
36.004	6.849	11.979	20.054	246.591	240.223	6.368	97.418
35.989	7.528	11.978	22.058	270.938	264.213	6.725	97.518
35.975	8.208	11.978	24.061	295.295	288.202	7.093	97.598
35.960	8.889	11.978	26.061	319.661	312.155	7.507	97.652
35.946	9.573	11.977	28.065	344.113	336.148	7.964	97.686
35.932	10.257	11.977	30.069	368.553	360.127	8.427	97.714
35.917	10.943	11.977	32.071	393.034	384.102	8.931	97.728
35.902	11.631	11.976	34.078	417.577	408.118	9.459	97.735
35.888	12.319	11.976	36.081	442.109	432.102	10.007	97.736
35.873	13.010	11.975	38.085	466.698	456.081	10.617	97.725
35.859	13.701	11.975	40.088	491.288	480.055	11.233	97.714
35.844	14.394	11.975	42.093	515.942	504.040	11.902	97.693
35.829	15.088	11.974	44.096	540.588	528.009	12.579	97.673
35.814	15.784	11.974	46.099	565.282	551.964	13.318	97.644
35.799	16.482	11.973	48.103	590.024	575.943	14.081	97.614
35.784	17.182	11.973	50.109	614.825	599.939	14.885	97.579
35.770	17.863	11.972	52.054	638.951	623.188	15.763	97.533
35.758	18.563	11.970	54.065	663.766	647.149	16.617	97.497
35.743	19.253	11.967	56.042	688.172	670.645	17.527	97.453
35.744	19.960	11.964	58.081	713.434	694.869	18.565	97.398
35.682	20.683	11.961	60.048	738.009	718.223	19.786	97.319

Table 2-2. Efficiency Data 48V Input

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{Loss} (W)	Efficiency (%)
48.026	0.099	11.982	0.000	4.747	0.000	4.747	0.000
48.015	0.608	11.982	2.031	29.193	24.333	4.860	83.351
48.004	1.112	11.982	4.034	53.390	48.333	5.057	90.528
47.994	1.621	11.981	6.036	77.774	72.317	5.457	92.984
47.983	2.134	11.980	8.037	102.388	96.286	6.102	94.040
47.972	2.645	11.980	10.040	126.863	120.276	6.586	94.808
47.962	3.153	11.980	12.043	151.213	144.277	6.936	95.413
47.951	3.659	11.979	14.046	175.460	168.258	7.202	95.895
47.940	4.166	11.979	16.050	199.740	192.260	7.480	96.255
47.930	4.674	11.979	18.053	224.038	216.247	7.790	96.523

Table 2-2. Efficiency Data 48V Input (continued)

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{Loss} (W)	Efficiency (%)
47.919	5.183	11.978	20.055	248.352	240.232	8.120	96.731
47.908	5.692	11.978	22.060	272.705	264.226	8.479	96.891
47.897	6.202	11.978	24.062	297.076	288.207	8.869	97.014
47.887	6.713	11.977	26.063	321.463	312.168	9.296	97.108
47.876	7.225	11.977	28.068	345.897	336.159	9.738	97.185
47.865	7.738	11.976	30.070	370.363	360.129	10.234	97.237
47.854	8.251	11.976	32.072	394.837	384.088	10.749	97.278
47.843	8.766	11.975	34.079	419.400	408.102	11.298	97.306
47.833	9.281	11.975	36.083	443.946	432.083	11.863	97.328
47.822	9.797	11.975	38.086	468.521	456.062	12.459	97.341
47.811	10.314	11.974	40.090	493.130	480.037	13.093	97.345
47.800	10.832	11.973	42.094	517.782	504.006	13.776	97.339
47.789	11.350	11.973	44.096	542.412	527.959	14.453	97.335
47.778	11.870	11.973	46.100	567.129	551.940	15.188	97.322
47.767	12.391	11.972	48.105	591.866	575.910	15.956	97.304
47.756	12.913	11.972	50.111	616.674	599.909	16.765	97.281
47.745	13.421	11.971	52.054	640.776	623.151	17.625	97.249
47.733	13.949	11.971	54.065	665.824	647.205	18.619	97.204
47.722	14.466	11.970	56.042	690.342	670.838	19.504	97.175
47.712	15.001	11.969	58.081	715.734	695.197	20.537	97.131
47.016	15.747	11.969	60.048	740.378	718.731	21.647	97.076

Table 2-3. Efficiency Data 60V Input

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{Loss} (W)	Efficiency (%)
60.120	0.093	11.983	0.000	5.578	0.000	5.578	0.000
60.112	0.501	11.982	2.032	30.092	24.350	5.742	80.919
60.103	0.905	11.982	4.036	54.390	48.355	6.034	88.906
60.095	1.313	11.981	6.037	78.888	72.324	6.564	91.680
60.086	1.725	11.980	8.038	103.627	96.303	7.323	92.933
60.077	2.136	11.980	10.042	128.297	120.298	7.998	93.766
60.069	2.543	11.979	12.044	152.763	144.284	8.478	94.450
60.060	2.948	11.979	14.048	177.087	168.280	8.806	95.027
60.052	3.354	11.979	16.052	201.396	192.281	9.114	95.474
60.043	3.759	11.978	18.055	225.722	216.271	9.451	95.813
60.035	4.165	11.978	20.057	250.061	240.242	9.819	96.074
60.026	4.572	11.978	22.061	274.440	264.233	10.207	96.281
60.018	4.980	11.977	24.064	298.865	288.215	10.650	96.437
60.009	5.387	11.977	26.065	323.280	312.182	11.098	96.567
60.000	5.796	11.976	28.069	347.750	336.161	11.589	96.667
59.992	6.205	11.976	30.072	372.241	360.135	12.106	96.748
59.983	6.614	11.975	32.073	396.749	384.090	12.659	96.809
59.975	7.026	11.975	34.081	421.352	408.112	13.241	96.858
59.966	7.436	11.974	36.084	445.923	432.078	13.845	96.895
59.957	7.849	11.974	38.088	470.583	456.056	14.526	96.913
59.949	8.261	11.973	40.092	495.228	480.037	15.191	96.933
59.940	8.674	11.973	42.096	519.924	504.003	15.921	96.938
59.931	9.087	11.972	44.098	544.622	527.957	16.665	96.940

Table 2-3. Efficiency Data 60V Input (continued)

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{Loss} (W)	Efficiency (%)
59.922	9.502	11.972	46.102	569.375	551.927	17.448	96.936
59.914	9.917	11.971	48.106	594.147	575.888	18.260	96.927
59.905	10.333	11.970	50.113	619.000	599.870	19.131	96.909
59.895	10.737	11.970	52.054	643.117	623.079	20.038	96.884
59.886	11.157	11.969	54.065	668.143	647.113	21.030	96.853
59.875	11.571	11.970	56.042	692.838	670.791	22.046	96.818
59.866	11.999	11.969	58.081	718.327	695.166	23.160	96.776
59.858	12.411	11.968	60.048	742.873	718.669	24.204	96.742

2.3 Thermal Images

The thermal images in Figure 2-2 and Figure 2-3 show operation at 48V input and 12V output at 50A load. Thermals images were taken after the board had reached thermal equilibrium.

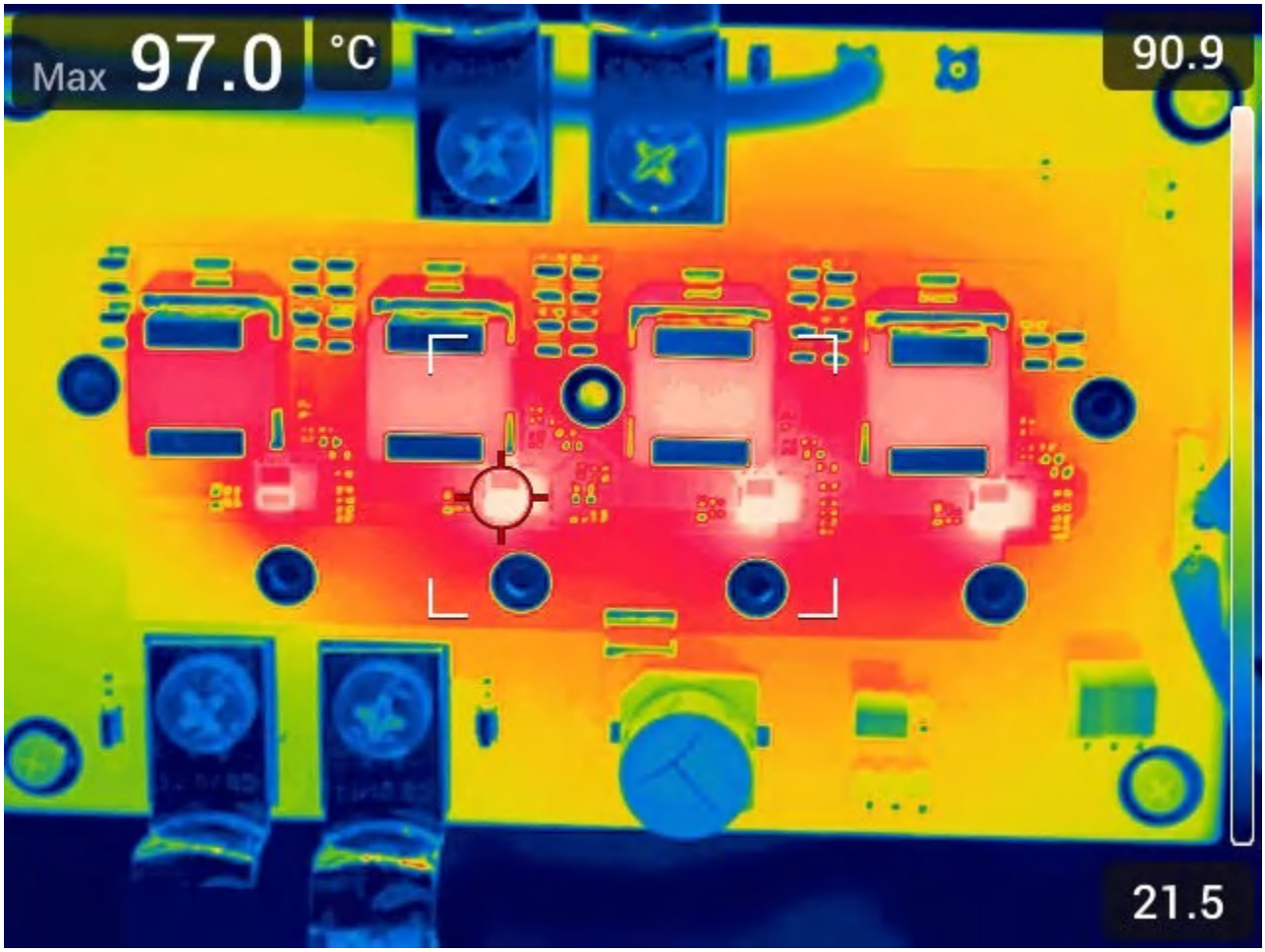


Figure 2-2. Thermal Image, 48V Input, 12V Output at 50A Load, No Fan

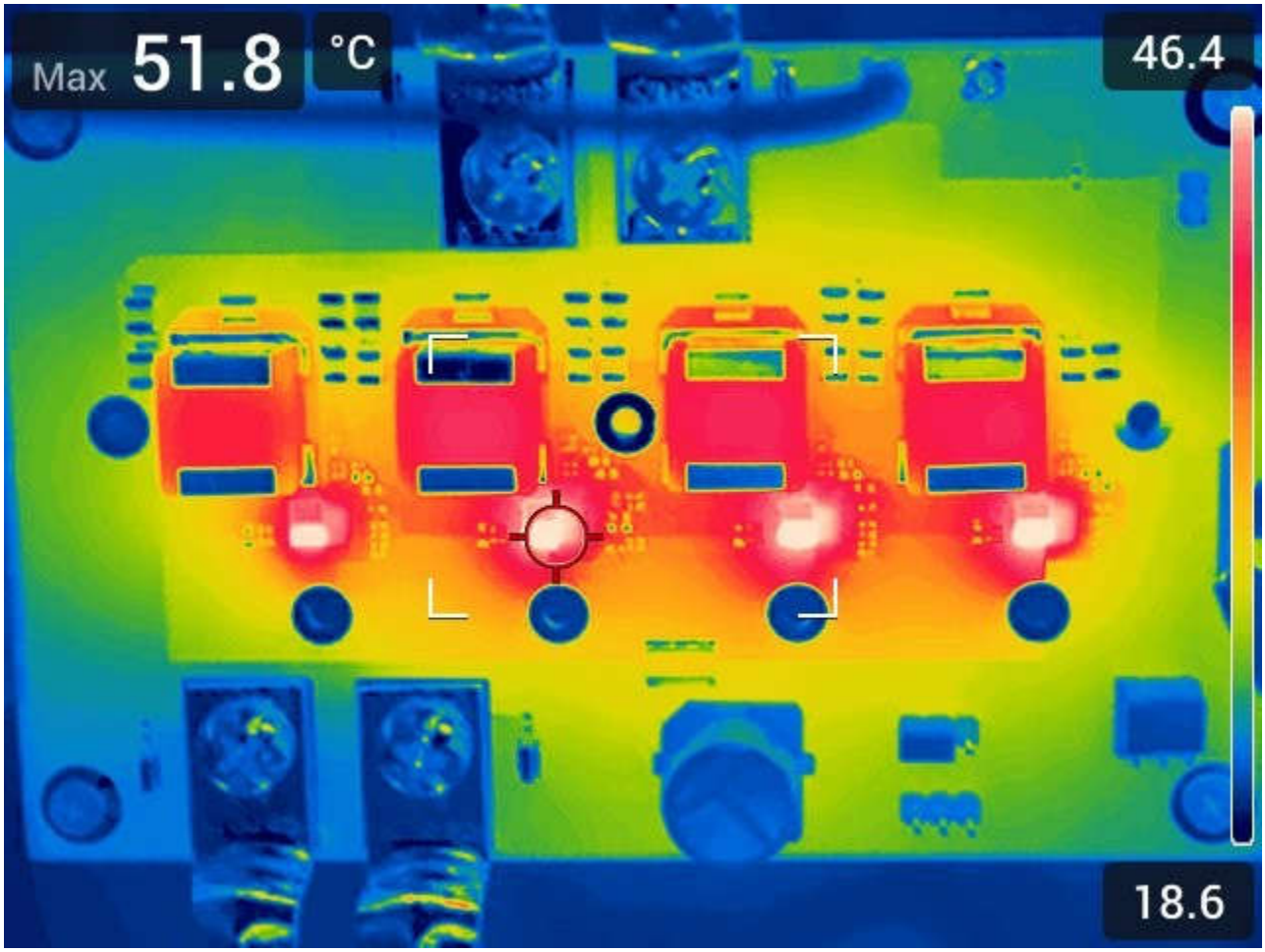


Figure 2-3. Thermal Image, 48V Input, 12V Output at 50A Load, With Fan

2.4 Bode Plots

The Bode plot shown in Figure 2-4 was created at a 50A load. The Bode plots for different loads exhibit similar results with the main difference being the slight appearance of noise. Thus, one Bode plot is shown for a 48V input voltage.

The 12V output at 50A load Bode plot results in a gain margin of 15dB, a phase margin of 53°, and a crossover of 23kHz.

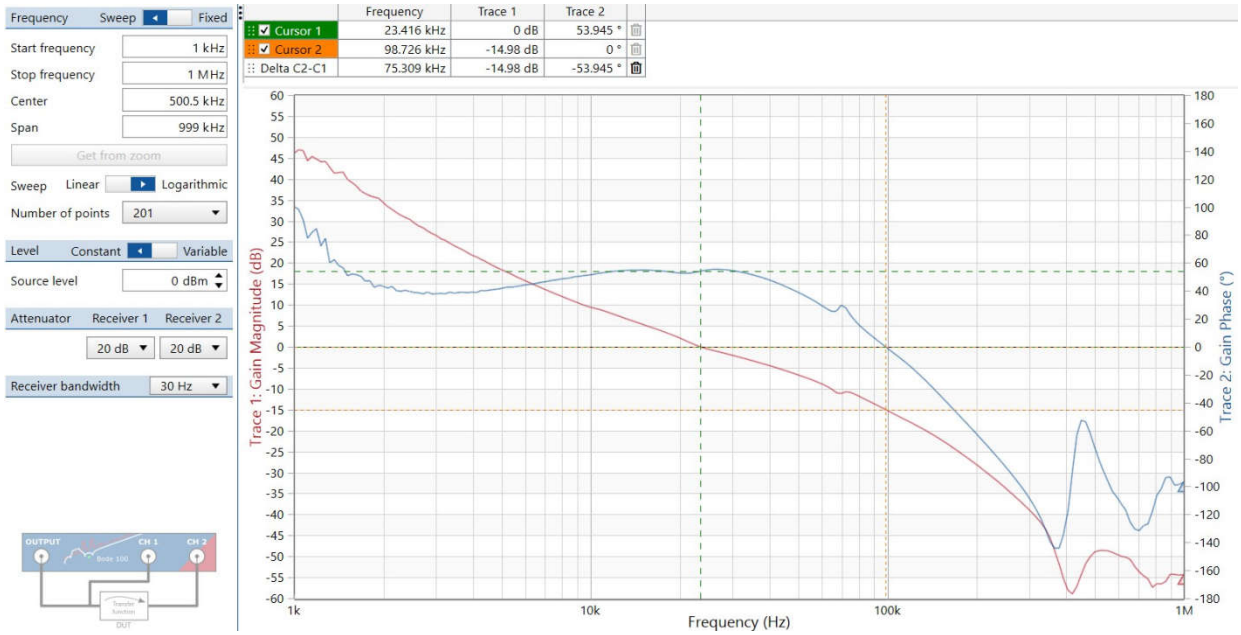


Figure 2-4. Bode Plot, 48V Input, 12V Output at 50A Load

3 Waveforms

3.1 Switching

Figure 3-1 displays the switch node voltage of the four-phase converter at 12V output with a 50A load.

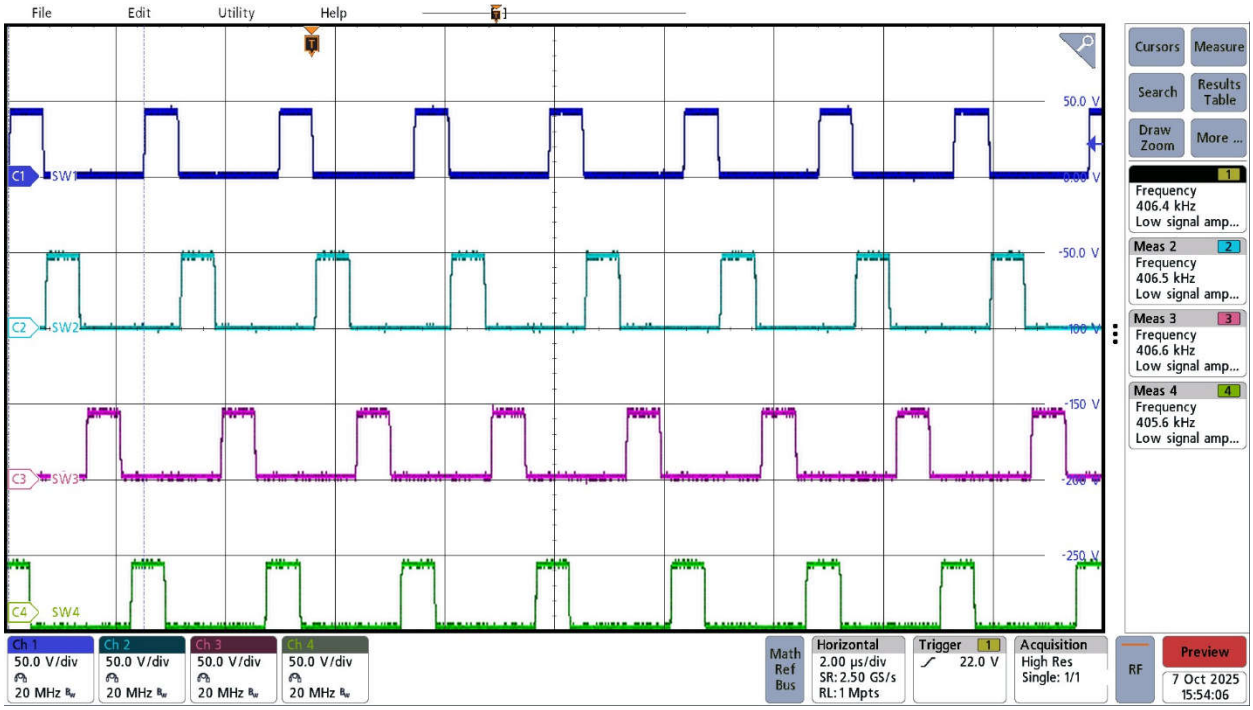


Figure 3-1. Switch Node Voltage, 48V Input, 12V Output at 50A Load

3.2 Output Voltage Ripple

Figure 3-2 shows the output voltage ripple. The image was taken at 48V input, 12V output at 50A load condition. The peak-to-peak ripple is 13.6mV under the 50A load condition.

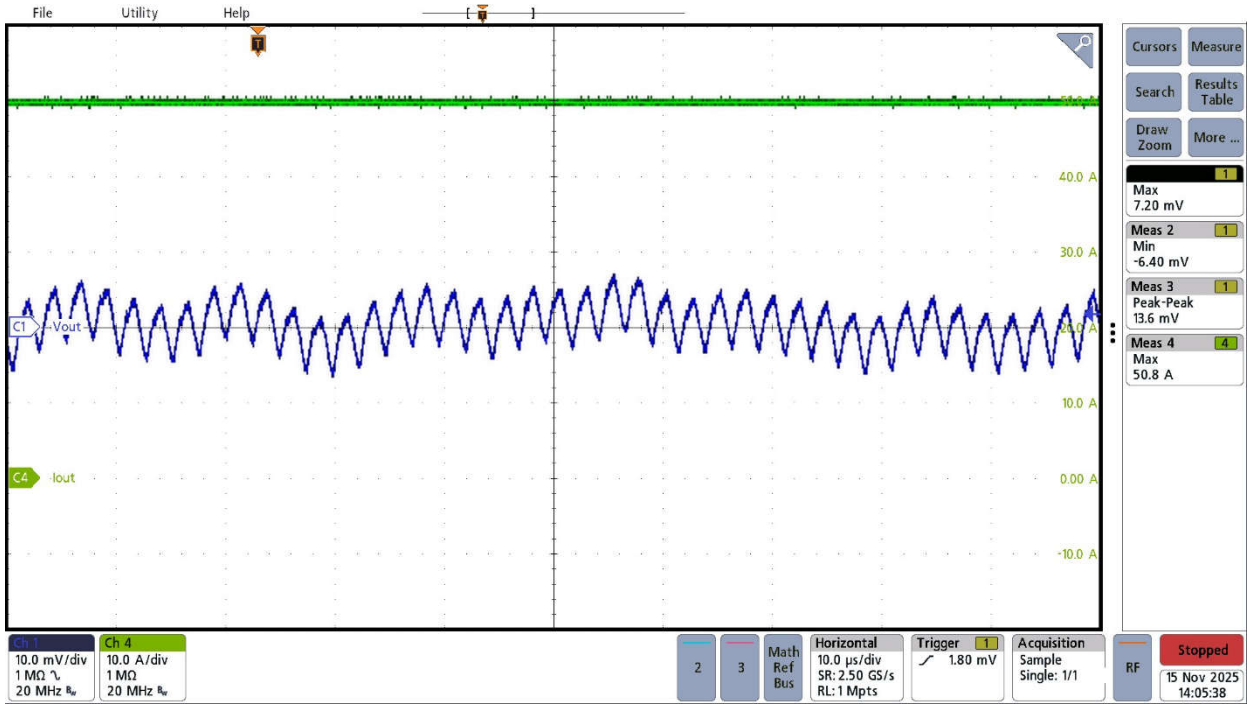


Figure 3-2. Output Voltage Ripple, 48V Input, 12V Output at 50A Load

3.3 Load Transients

Figure 3-3 shows the load transient response of the converter at 48V input. The load is stepped from 25% to 75% of the load, corresponding to a 20A to 60A step, at a slew rate of 40A/us.

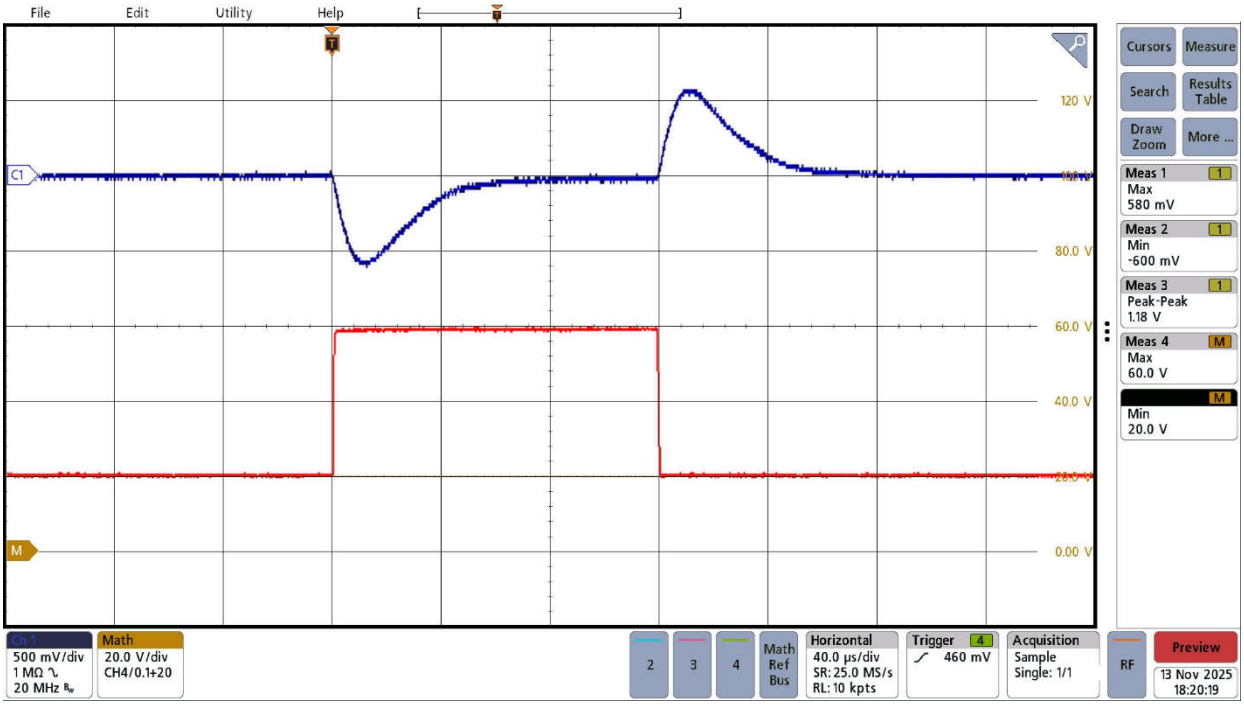


Figure 3-3. Output Voltage Ripple, 48V Input, 12V Output at 50A Load

3.4 Startup

Figure 3-4 and Figure 3-5 show the output voltage startup waveforms at 48V input and 12V output with the converter startup up into no load and into a 25A constant-resistance load using an electronic load.

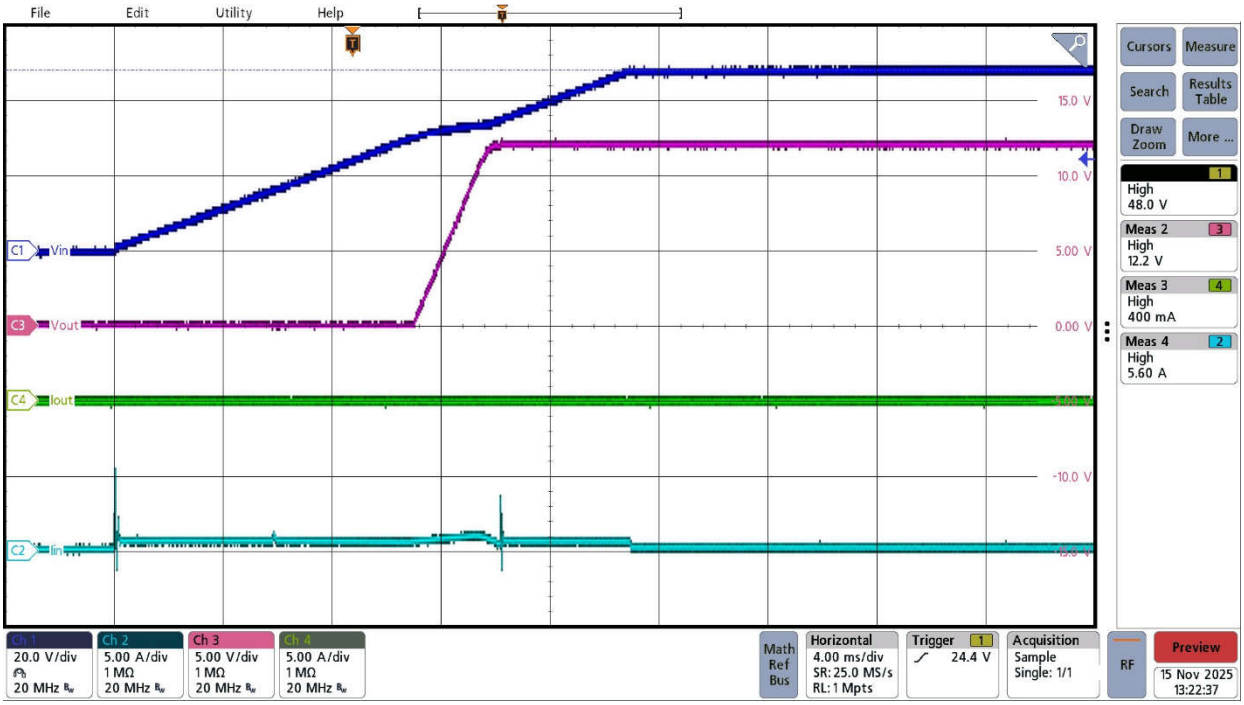


Figure 3-4. Startup Into No Load, 48V Input, 12V Output, Startup Initiated by Input Supply Power-Up

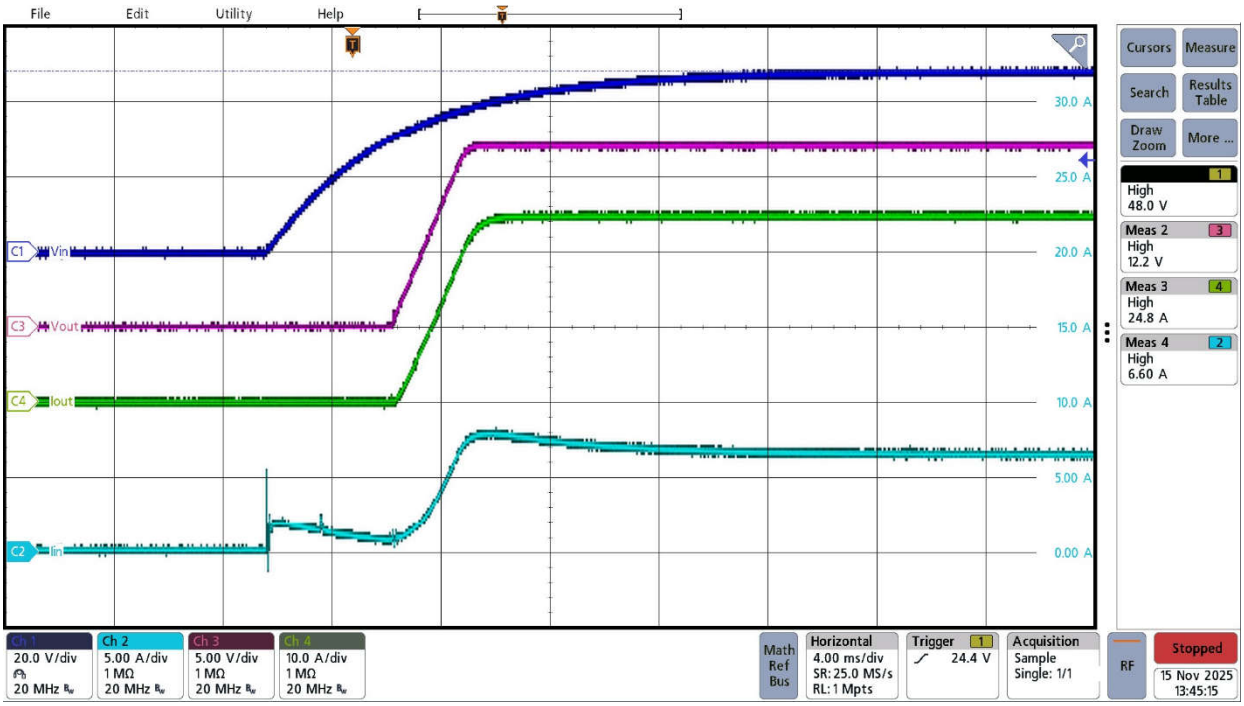


Figure 3-5. Startup Into 25A Constant-Resistance Load, 48V Input, 12V Output, Startup Initiated by Input Supply Power-Up

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