Test Report: PMP23680

48V_{IN}, 5V_{OUT}, 400W 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 5V 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

PMP23680	Design Folder
LMG708B0-Q1	Product Folder

Features

- High power density design
- Peak conversion efficiency of 94% to 96% 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

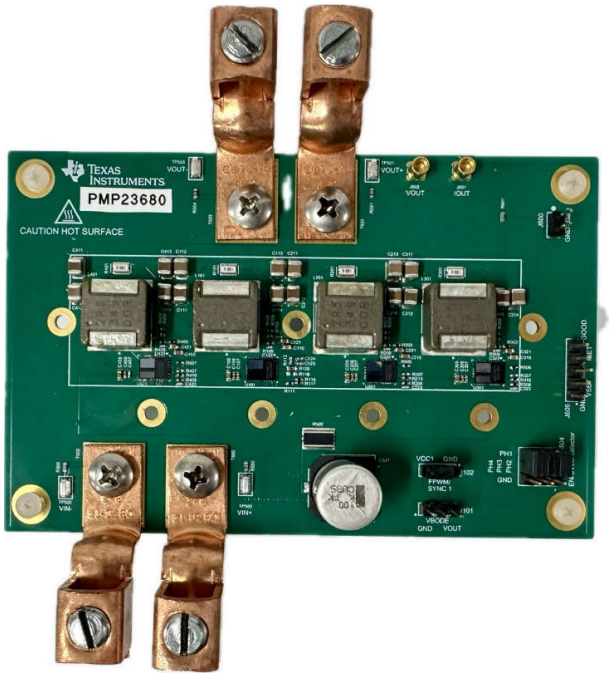

Figure 1-1. Top of Board

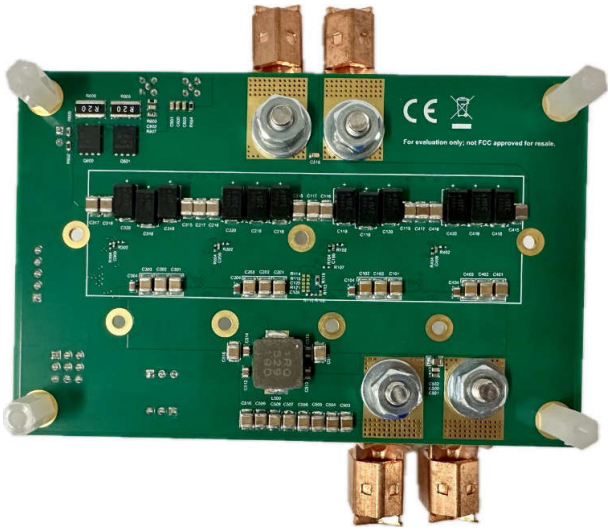

Figure 1-2. Bottom of Board

1 Test Prerequisites

1.1 Voltage and Current Requirements

Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
V_{IN}	24VDC to 60VDC
V_{OUT}	5VDC
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 45A, please 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.

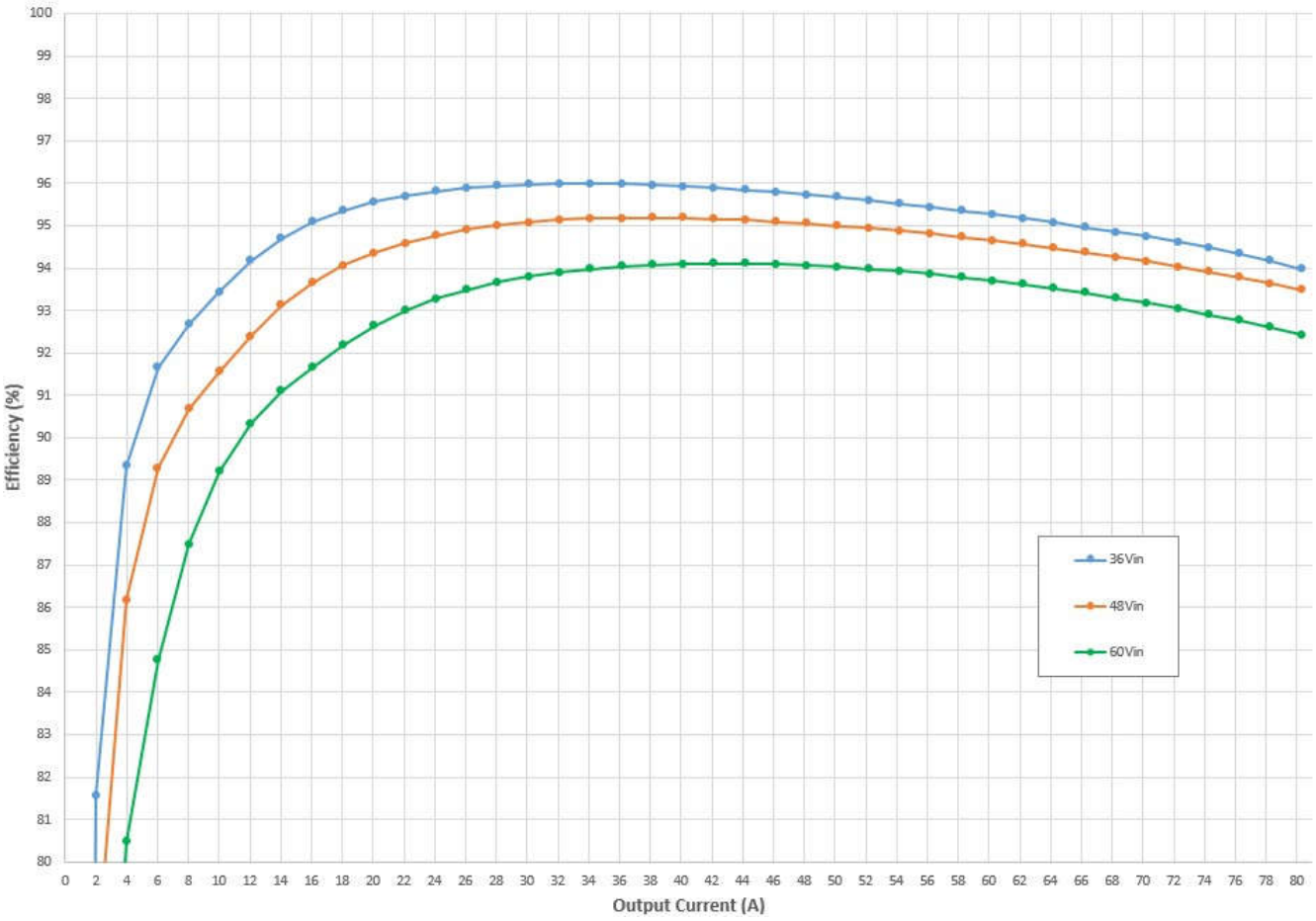

Figure 2-1. Converter Efficiency

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 (%)
36.556	0.059	5.019	0.000	2.141	0.000	2.141	0.000
36.543	0.337	5.019	2.000	12.306	10.038	2.267	81.574
36.530	0.617	5.019	4.009	22.521	20.119	2.402	89.336
36.517	0.902	5.019	6.016	32.942	30.191	2.750	91.651
36.503	1.190	5.018	8.023	43.446	40.261	3.185	92.668
36.490	1.476	5.018	10.031	53.875	50.334	3.541	93.428
36.477	1.759	5.017	12.039	64.151	60.408	3.743	94.166
36.464	2.041	5.017	14.048	74.424	70.476	3.948	94.696
36.450	2.324	5.017	16.057	84.720	80.554	4.166	95.082
36.437	2.609	5.016	18.065	95.048	90.624	4.424	95.345
36.424	2.893	5.016	20.073	105.368	100.684	4.684	95.554
36.410	3.179	5.016	22.082	115.735	110.753	4.983	95.695
36.397	3.465	5.015	24.089	126.101	120.814	5.288	95.807
36.383	3.751	5.015	26.096	136.483	130.868	5.615	95.886
36.370	4.039	5.015	28.104	146.898	140.928	5.969	95.936
36.356	4.327	5.014	30.112	157.330	150.989	6.341	95.969
36.342	4.616	5.014	32.119	167.764	161.034	6.730	95.988
36.329	4.907	5.013	34.130	178.254	171.104	7.150	95.989
36.315	5.197	5.013	36.138	188.746	181.159	7.587	95.980
36.302	5.489	5.012	38.146	199.263	191.206	8.057	95.956
36.288	5.781	5.012	40.154	209.797	201.252	8.546	95.927
36.274	6.075	5.012	42.162	220.358	211.296	9.062	95.888
36.261	6.369	5.011	44.168	230.934	221.334	9.600	95.843
36.247	6.664	5.011	46.177	241.541	231.379	10.162	95.793
36.233	6.960	5.010	48.184	252.174	241.411	10.763	95.732
36.219	7.257	5.010	50.194	262.849	251.462	11.387	95.668
36.206	7.555	5.009	52.202	273.539	261.494	12.045	95.597
36.192	7.854	5.009	54.211	284.267	271.524	12.742	95.517
36.178	8.154	5.008	56.217	295.005	281.537	13.468	95.435
36.164	8.455	5.008	58.225	305.761	291.562	14.199	95.356
36.150	8.757	5.007	60.232	316.576	301.577	14.999	95.262
36.137	9.060	5.006	62.238	327.407	311.583	15.823	95.167
36.128	9.364	5.006	64.245	338.281	321.593	16.689	95.067
36.119	9.668	5.005	66.254	349.213	331.611	17.601	94.960
36.112	9.973	5.004	68.261	360.151	341.604	18.547	94.850
36.099	10.281	5.004	70.270	371.141	351.609	19.533	94.737
36.085	10.588	5.003	72.257	382.072	361.509	20.562	94.618
36.079	10.899	5.003	74.237	393.214	371.383	21.830	94.448
36.070	11.209	5.002	76.242	404.311	381.380	22.931	94.328
36.064	11.524	5.002	78.239	415.589	391.338	24.251	94.165
36.057	11.842	5.002	80.233	426.975	401.285	25.690	93.983

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 (%)
48.740	0.057	5.020	0.000	2.771	0.000	2.771	0.000
48.729	0.268	5.020	2.013	13.063	10.105	2.958	77.358
48.718	0.481	5.019	4.022	23.428	20.185	3.243	86.157
48.707	0.696	5.019	6.029	33.893	30.260	3.633	89.280
48.695	0.913	5.019	8.035	44.472	40.323	4.149	90.672
48.684	1.131	5.018	10.044	55.050	50.403	4.646	91.560
48.672	1.345	5.018	12.051	65.450	60.469	4.981	92.390
48.661	1.557	5.018	14.058	75.747	70.539	5.208	93.124
48.650	1.769	5.017	16.068	86.080	80.617	5.463	93.654
48.638	1.982	5.017	18.075	96.417	90.682	5.735	94.052
48.627	2.196	5.016	20.082	106.768	100.742	6.027	94.355
48.616	2.410	5.016	22.092	117.157	110.816	6.341	94.587
48.604	2.624	5.016	24.099	127.555	120.877	6.678	94.765
48.593	2.839	5.015	26.106	137.968	130.932	7.037	94.900
48.581	3.055	5.015	28.114	148.408	140.996	7.412	95.006
48.570	3.271	5.015	30.121	158.870	151.047	7.823	95.076
48.558	3.487	5.014	32.128	169.334	161.102	8.232	95.139
48.546	3.705	5.014	34.140	179.872	171.174	8.698	95.164
48.535	3.923	5.013	36.147	190.412	181.222	9.190	95.174
48.523	4.141	5.013	38.155	200.948	191.274	9.674	95.186
48.511	4.360	5.013	40.163	211.515	201.324	10.191	95.182
48.500	4.580	5.012	42.171	222.119	211.366	10.753	95.159
48.488	4.800	5.012	44.177	232.735	221.403	11.332	95.131
48.477	5.021	5.011	46.185	243.392	231.448	11.944	95.093
48.465	5.242	5.011	48.193	254.060	241.484	12.576	95.050
48.453	5.465	5.010	50.204	264.791	251.544	13.247	94.997
48.442	5.688	5.010	52.213	275.518	261.581	13.937	94.942
48.431	5.911	5.009	54.222	286.280	271.616	14.664	94.878
48.418	6.136	5.009	56.230	297.078	281.645	15.433	94.805
48.407	6.361	5.008	58.236	307.890	291.662	16.228	94.729
48.395	6.587	5.008	60.245	318.764	301.692	17.071	94.645
48.385	6.813	5.007	62.252	329.637	311.714	17.923	94.563
48.373	7.041	5.007	64.260	340.584	321.717	18.866	94.461
48.362	7.269	5.006	66.271	351.541	331.747	19.794	94.369
48.349	7.499	5.005	68.278	362.559	341.749	20.809	94.260
48.336	7.729	5.005	70.287	373.598	351.750	21.848	94.152
48.325	7.961	5.004	72.295	384.717	361.755	22.961	94.032
48.313	8.194	5.003	74.303	395.874	371.751	24.123	93.906
48.296	8.429	5.002	76.312	407.077	381.745	25.332	93.777
48.289	8.663	5.002	78.319	418.333	391.724	26.610	93.639
48.280	8.899	5.001	80.328	429.666	401.709	27.958	93.493

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 (%)
60.92652	0.065303	5.019638	0.000	3.979	0.000	3.979	0.000
60.91809	0.238129	5.019221	2.013862	14.506	10.108	4.398	69.680
60.9096	0.411878	5.018833	4.022784	25.087	20.190	4.898	80.478
60.90106	0.586199	5.018341	6.029056	35.700	30.256	5.444	84.750
60.89273	0.756938	5.017961	8.035635	46.092	40.323	5.770	87.483
60.88432	0.928022	5.017603	10.04401	56.502	50.397	6.105	89.195
60.87597	1.099653	5.017191	12.05145	66.942	60.464	6.478	90.323
60.86756	1.271992	5.016849	14.05884	77.423	70.531	6.892	91.098
60.85909	1.445	5.016438	16.0687	87.941	80.608	7.334	91.661
60.85068	1.616396	5.01609	18.07633	98.359	90.672	7.686	92.185
60.84234	1.787376	5.015804	20.08382	108.748	100.736	8.012	92.633
60.83398	1.95872	5.015333	22.09264	119.157	110.802	8.355	92.988
60.82555	2.130566	5.015045	24.10029	129.593	120.864	8.729	93.264
60.81705	2.302631	5.014621	26.10716	140.039	130.917	9.122	93.486
60.80862	2.47547	5.014293	28.11624	150.530	140.983	9.547	93.658
60.80016	2.64853	5.013789	30.12298	161.031	151.030	10.001	93.790
60.79157	2.822077	5.013556	32.1305	171.559	161.088	10.470	93.897
60.78299	2.996529	5.013002	34.14207	182.138	171.154	10.984	93.970
60.77447	3.17076	5.012538	36.15082	192.701	181.207	11.494	94.035
60.7659	3.345659	5.01205	38.15867	203.302	191.253	12.049	94.073
60.75728	3.521046	5.011562	40.16739	213.929	201.301	12.628	94.097
60.74855	3.696831	5.0111	42.17595	224.577	211.348	13.229	94.109
60.73987	3.873212	5.010699	44.18396	235.258	221.393	13.866	94.106
60.73109	4.050049	5.010152	46.19221	245.964	231.430	14.534	94.091
60.72233	4.227849	5.009538	48.2011	256.725	241.465	15.260	94.056
60.71352	4.405979	5.0091	50.21146	267.503	251.514	15.988	94.023
60.70474	4.584851	5.008389	52.22257	278.322	261.551	16.771	93.974
60.69601	4.764028	5.007837	54.23162	289.157	271.583	17.574	93.922
60.68725	4.943894	5.007179	56.23919	300.031	281.600	18.432	93.857
60.67838	5.124435	5.00654	58.24749	310.942	291.618	19.324	93.785
60.66965	5.306123	5.005944	60.25634	321.921	301.640	20.281	93.700
60.6607	5.487952	5.005287	62.2644	332.903	311.651	21.252	93.616
60.65174	5.670945	5.004556	64.27257	343.953	321.656	22.297	93.517
60.64334	5.854874	5.003843	66.28309	355.059	331.670	23.389	93.413
60.63476	6.039843	5.003056	68.29071	366.224	341.662	24.562	93.293
60.62625	6.225448	5.002273	70.29973	377.426	351.658	25.767	93.173
60.61717	6.411861	5.001318	72.30788	388.669	361.635	27.034	93.044
60.60815	6.599872	5.000343	74.31704	400.006	371.611	28.395	92.901
60.59937	6.788533	4.999488	76.32575	411.381	381.590	29.791	92.758
60.59016	6.978625	4.99846	78.33374	422.836	391.548	31.288	92.600
60.58125	7.170322	4.997413	80.34295	434.387	401.507	32.880	92.431

2.3 Thermal Images

The thermal images in Figure 2-2 and Figure 2-3 show operation at 48V input and 5V output at 50A load. Thermals images were taken after the board had reached thermal equilibrium.

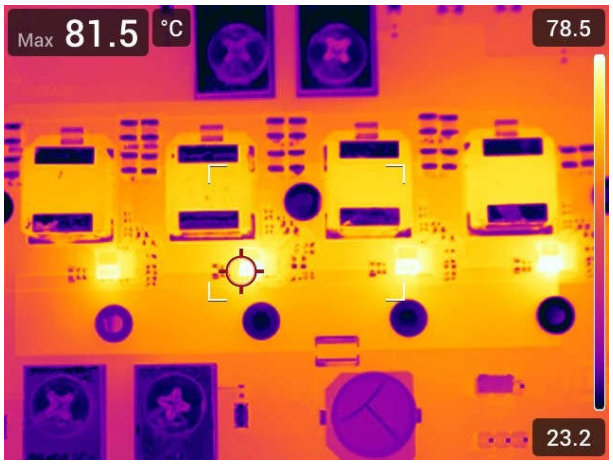

Figure 2-2. Thermal Image, 48V Input, 5V Output at 50A Load, No Fan

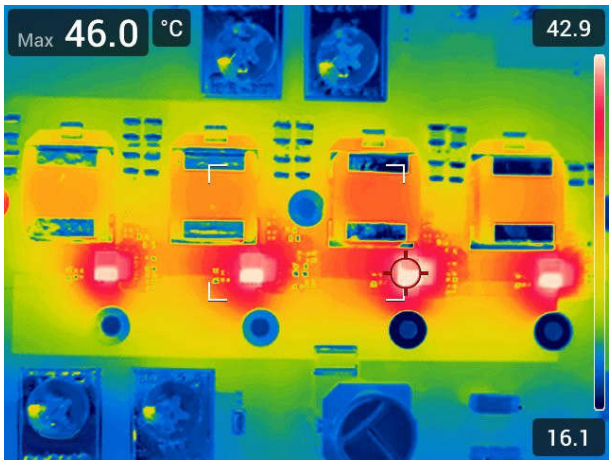

Figure 2-3. Thermal Image, 48V Input, 5V Output at 50A Load, With Fan

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 5V output at 50A load Bode plot results in a gain margin of 12dB, a phase margin of 72°, and a crossover of 32kHz.

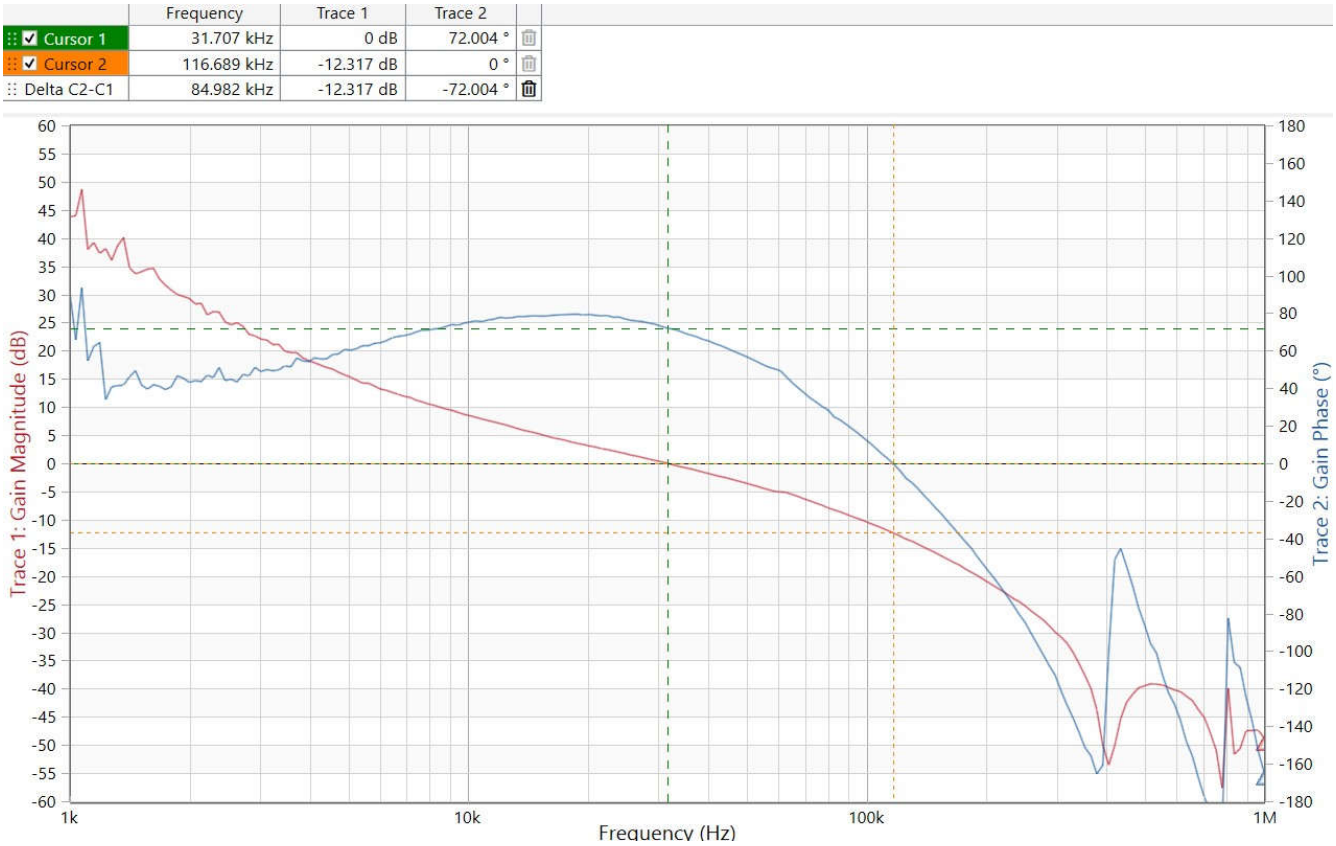

Figure 2-4. Bode Plot, 48V Input, 5V Output at 50A Load

3 Waveforms

3.1 Switching

Figure 3-1 displays the switch node voltage of the four-phase converter at 5V output with a 50A load.

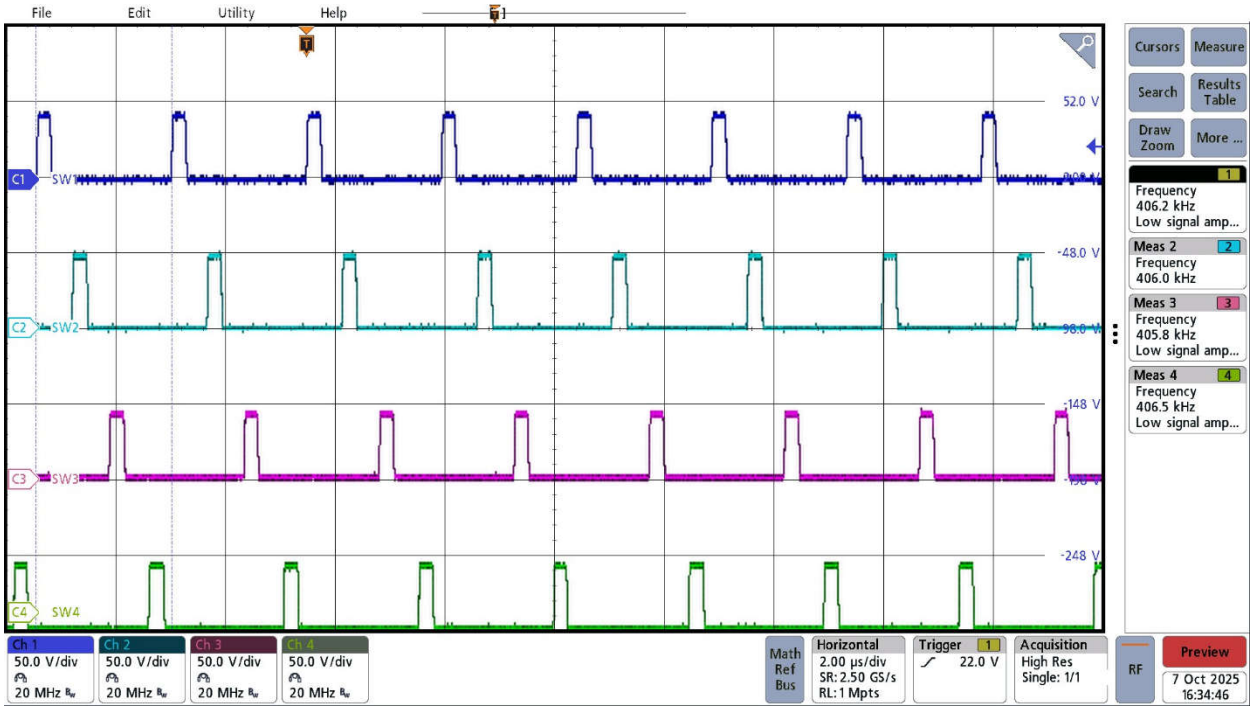

Figure 3-1. Switch Node Voltage, 48V Input, 5V Output at 50A Load

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.

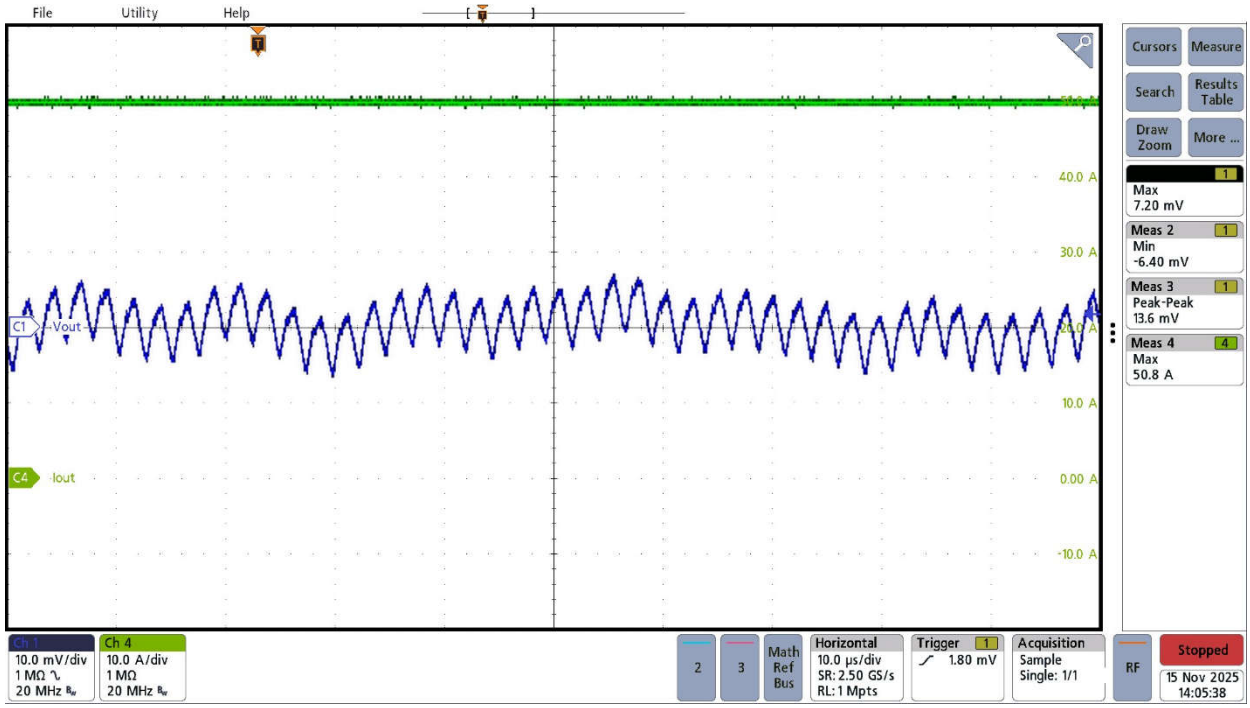

Figure 3-2. Output Voltage Ripple, 48V Input, 5V Output at 50A Load

3.3 Load Transients

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

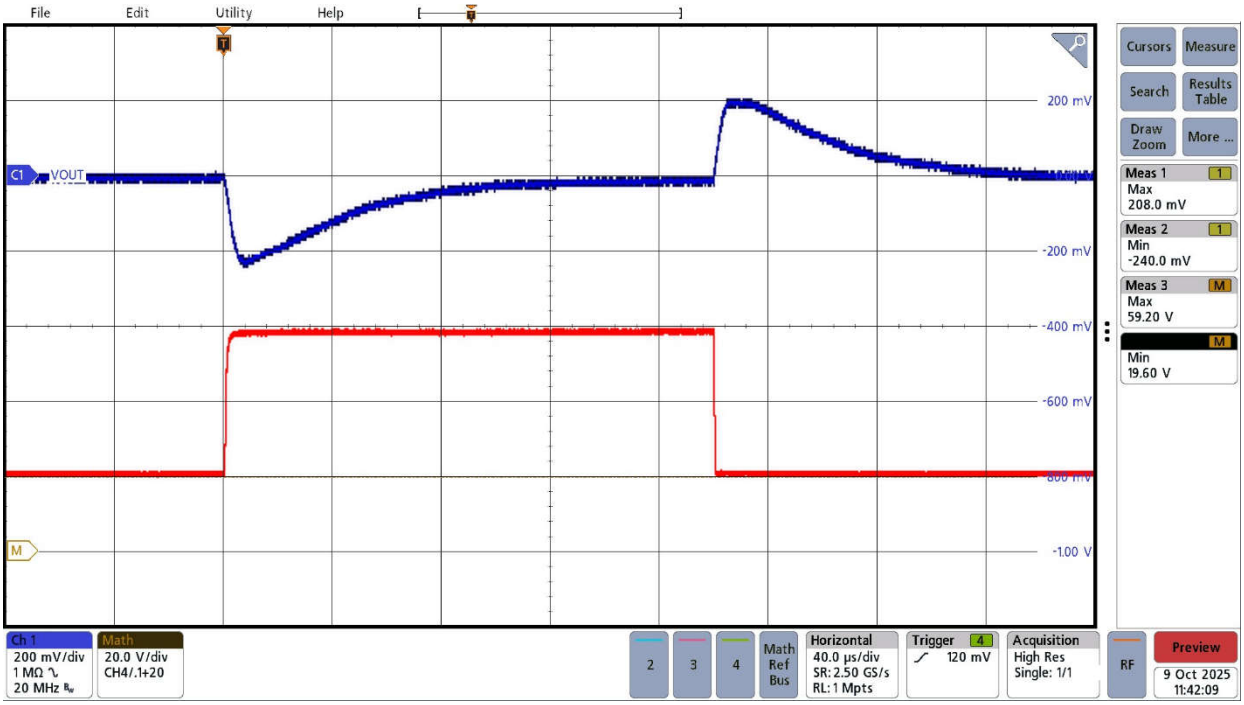

Figure 3-3. Output Voltage Ripple, 48V Input, 5V Output at 50A Load

3.4 Start-up

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

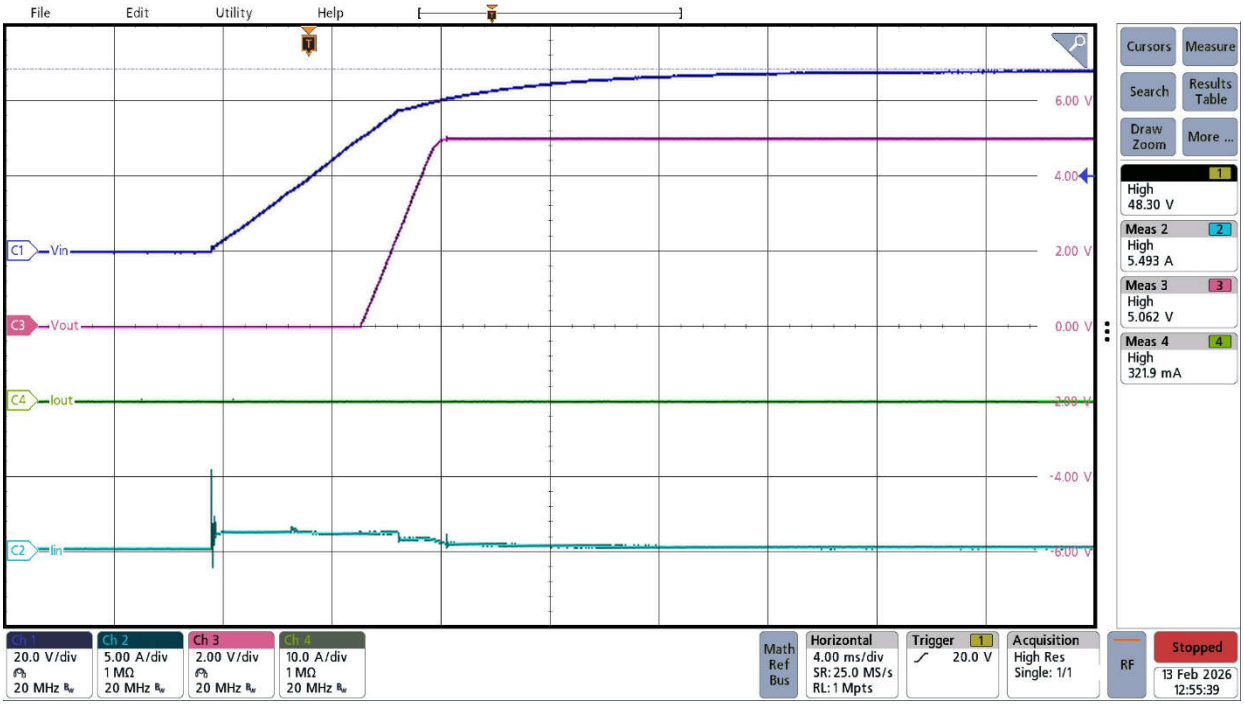

Figure 3-4. Start-up Into No Load, 48V Input, 5V Output, Start-up Initiated by Input Supply Power-Up

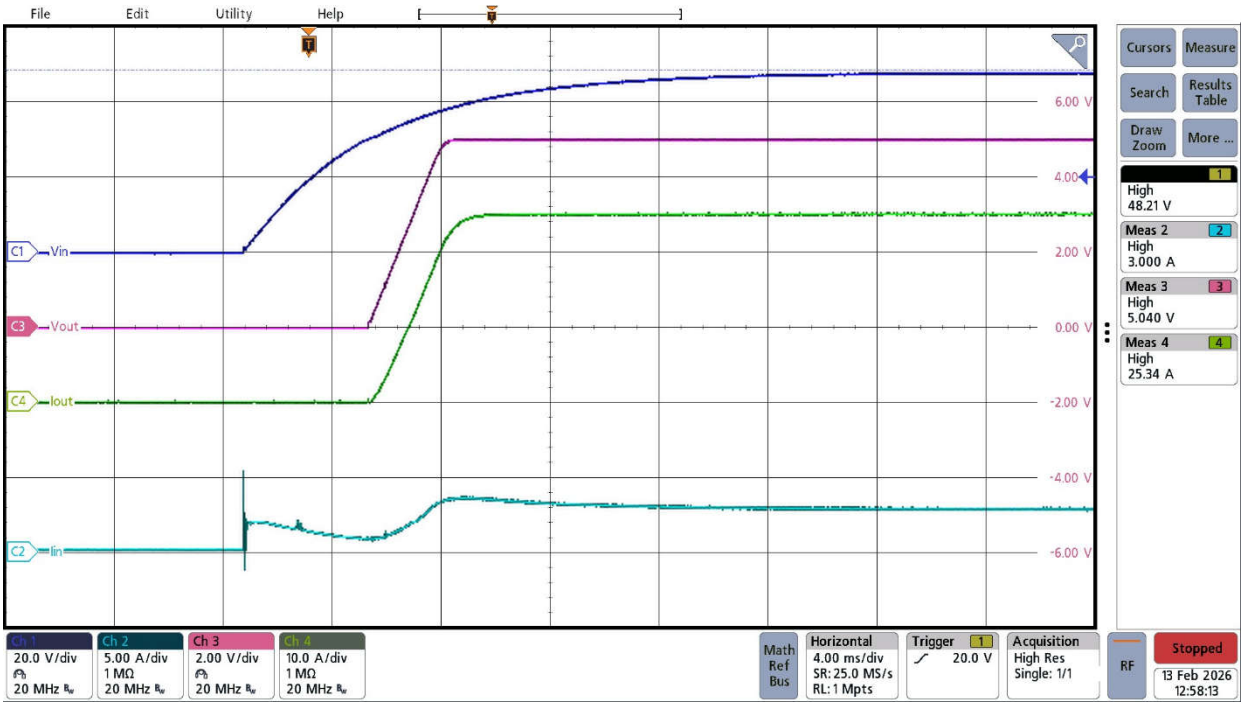

Figure 3-5. Start-up Into 25A Constant-Resistance Load, 48V input, 5V Output, Start-up Initiated by Input Supply Power-Up

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