Test Report: PMP23391

300W, 12V Output ZVS Full-Bridge Converter Reference Design for 100kRad Applications

Description

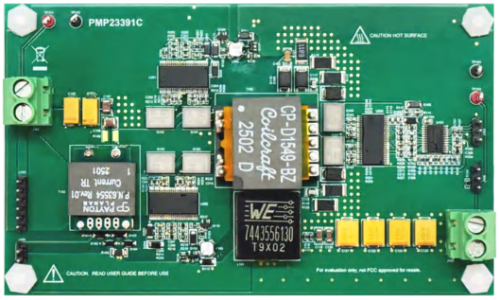
This reference design is a full-bridge topology that is comprised of a TPS7H5005-SEP referenced on secondary ground that controls three TPS7H6005-SEP half-bridge gate drivers. The two drivers referenced to the primary side operate in PWM mode which allows for the design to achieve zero-voltage switching (ZVS) at higher loading conditions. On the secondary side the other driver controls a pair of secondary rectifiers to further improve the conversion efficiency. In this design the controller, half-bridge drivers and GaN field-effect transistors (FET) are chosen to meet radiation for geostationary orbit (GEO). These components can be swapped out to meet other mission specifications.

Features

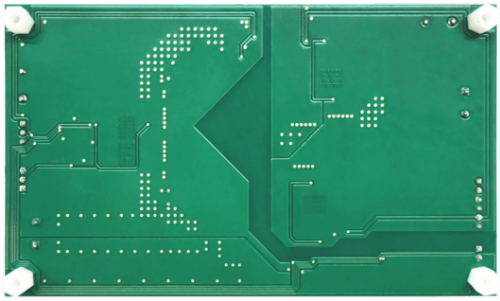
- GEO class radiation performance
- GaN FETs on primary and secondary side to increase efficiency
- Secondary-side controller for faster control loop
- < 1% voltage ripple on output
- Single-side assembly, two-layer, 3.25 in × 5.5 in PCB

Applications

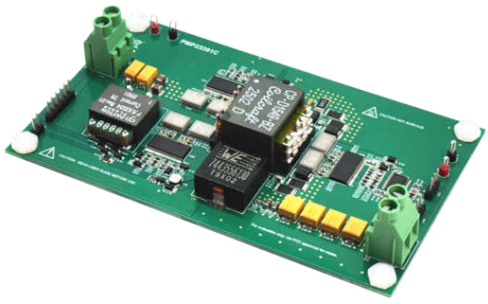
- Command and data handling (C and DH)
- Optical imaging payload
- Radar imaging payload



Top of Board



Bottom of Board



Angled Image

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input voltage	22V to 36V
Output voltage	12V
Maximum output current	25V
Switching frequency	500kHz (primary side)

1.2 Considerations

- Unless noted, all tests were conducted with 25A loading on the output
- Local airflow used
- External 12V bias applied to primary and secondary sides

1.3 Dimensions

Board size: 3.25in × 5.5in, tallest component = 0.67in (bridge transformer).

1.4 Test Setup

Air flow is recommended to test at full load conditions. Thermal image shows relative temperature rise across the PCBA.

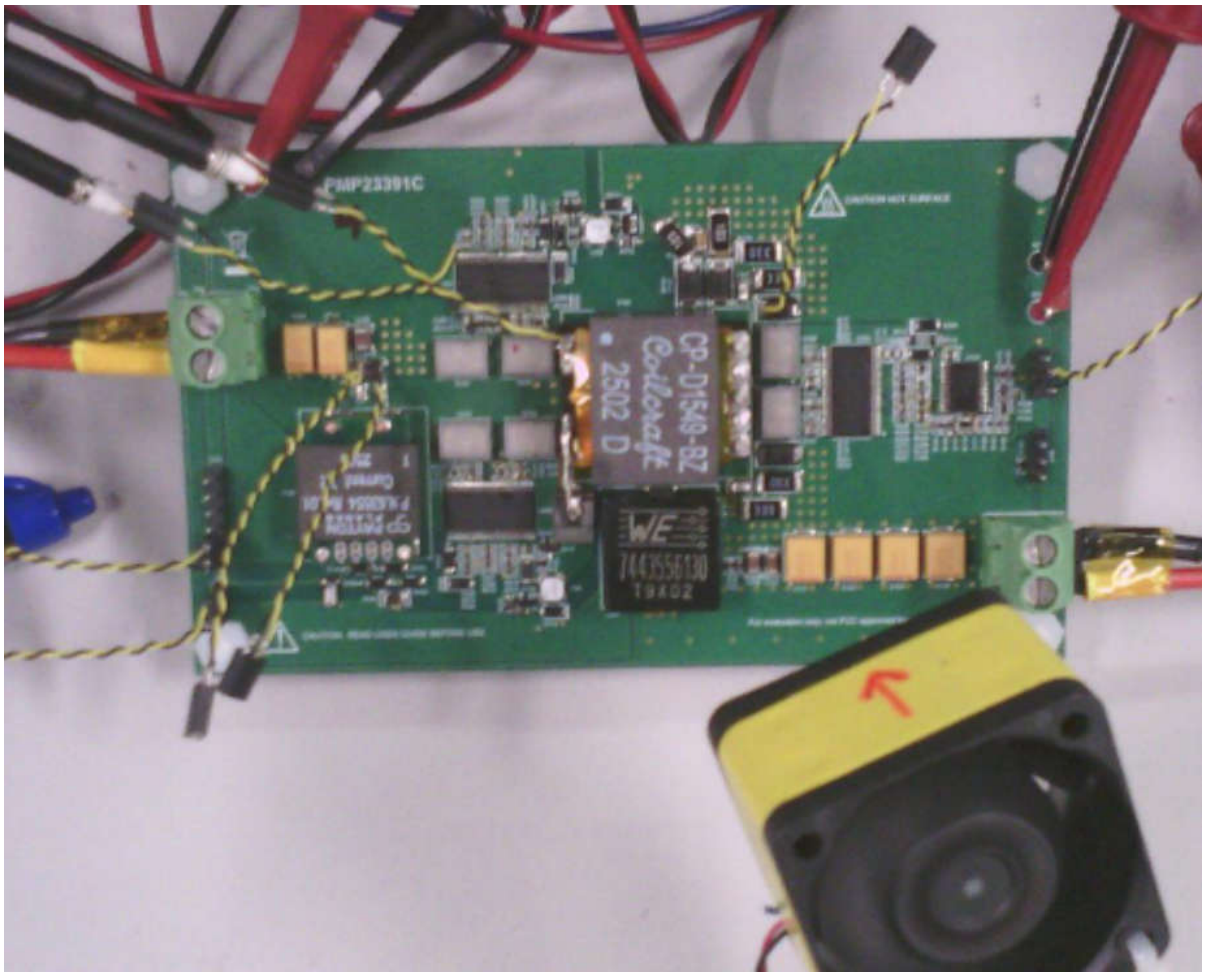


Figure 1-1. Test Setup

2 Testing and Results

2.1 Efficiency Graphs

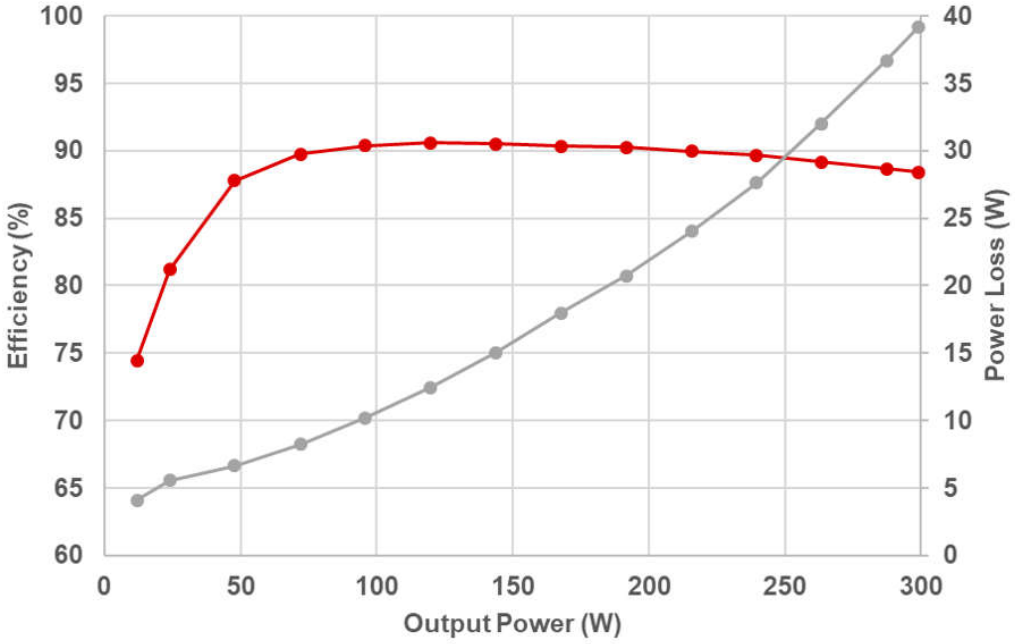


Figure 2-1. Efficiency and Power Loss With Nominal Input (28V)

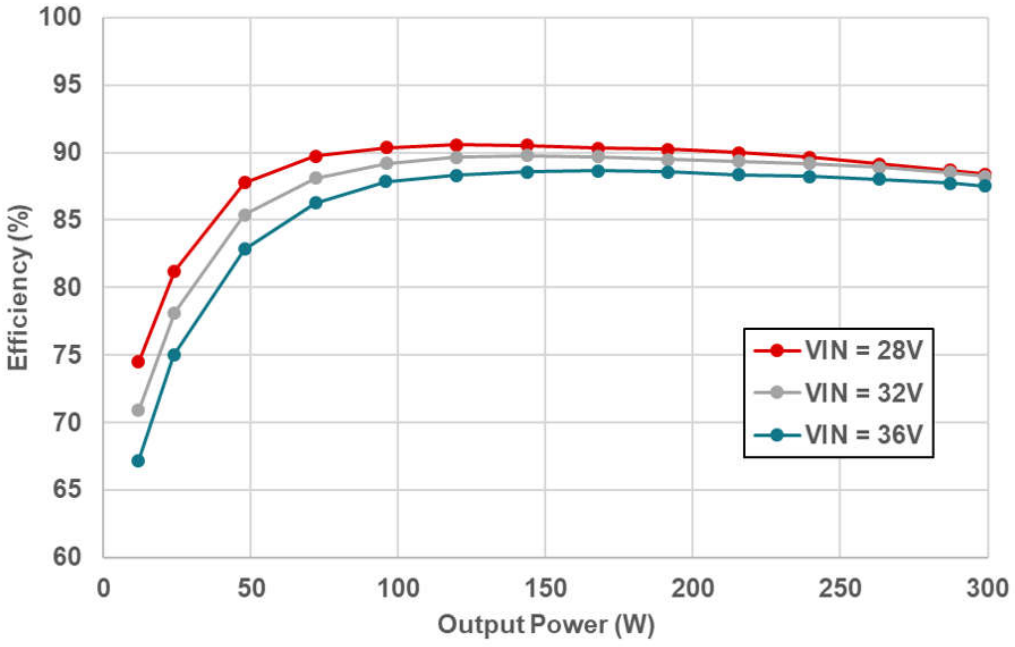


Figure 2-2. Efficiency Across Input Range

2.2 Efficiency Data

Table 2-1. Efficiency Data With 28V Input

Input			Output			Total	
Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Loss (W)	Efficiency (%)
27.994	0.572	16.012	12.01	0.993	11.926	4.086	74.481
27.991	1.0557	29.551	12.009	1.998	23.994	5.557	81.195
27.99	1.9498	54.57	12.006	3.99	47.904	6.666	87.784
27.988	2.8657	80.21	12.004	5.997	71.988	8.222	89.749
27.985	3.791	106.1	12.001	7.99	95.888	10.212	90.375
27.983	4.727	132.26	11.999	9.983	119.786	12.474	90.569
27.979	5.68	158.91	11.996	11.991	143.844	15.066	90.519
27.979	6.636	185.68	11.993	13.985	167.722	17.958	90.329
27.984	7.588	212.34	11.991	15.979	191.604	20.736	90.235
27.986	8.564	239.66	11.988	17.988	215.640	24.020	89.978
27.985	9.544	267.11	11.986	19.981	239.492	27.618	89.661
27.983	10.555	295.36	11.983	21.976	263.338	32.022	89.158
27.976	11.582	324.01	11.98	23.984	287.328	36.682	88.679
27.978	12.095	338.38	11.979	24.974	299.164	39.216	88.411

Table 2-2. Efficiency Data With 32V Input

Input			Output			Total	
Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Loss (W)	Efficiency (%)
31.946	0.5264	16.816	12.009	0.993	11.925	4.891	70.914
31.942	0.9616	30.714	12.008	1.998	23.992	6.722	78.114
31.941	1.7566	56.106	12.005	3.99	47.900	8.206	85.374
31.939	2.5581	81.703	12.003	5.998	71.994	9.709	88.117
31.937	3.3671	107.53	12.001	7.991	95.900	11.630	89.184
31.935	4.1841	133.62	11.998	9.984	119.788	13.832	89.648
31.932	5.0176	160.22	11.996	11.992	143.856	16.364	89.787
31.929	5.8563	186.99	11.993	13.987	167.746	19.244	89.709
31.928	6.706	214.1	11.991	15.98	191.616	22.484	89.498
31.931	7.557	241.3	11.988	17.988	215.640	25.660	89.366
31.934	8.408	268.51	11.986	19.982	239.504	29.006	89.198
31.935	9.274	296.16	11.983	21.976	263.338	32.822	88.918
31.933	10.167	324.67	11.981	23.984	287.352	37.318	88.506
31.932	10.618	339.05	11.979	24.974	299.164	39.886	88.236

Table 2-3. Efficiency Data With 36V Input

Input			Output			Total	
Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Loss (W)	Efficiency (%)
35.947	0.4923	17.696	12.009	0.99	11.889	5.807	67.184
35.944	0.8883	31.928	12.008	1.994	23.944	7.984	74.994
35.942	1.6079	57.79	12.006	3.987	47.868	9.922	82.831
35.941	2.3199	83.378	12.003	5.994	71.946	11.432	86.289
35.941	3.0358	109.11	12.001	7.987	95.852	13.258	87.849
35.938	3.7726	135.58	11.998	9.98	119.740	15.840	88.317
35.937	4.519	162.4	11.996	11.989	143.820	18.580	88.559
35.934	5.2639	189.15	11.993	13.983	167.698	21.452	88.659
35.932	6.0207	216.33	11.991	15.977	191.580	24.750	88.559
35.931	6.791	244	11.988	17.985	215.604	28.396	88.362
35.933	7.559	271.42	11.986	19.978	239.456	31.964	88.224
35.935	8.322	299.06	11.983	21.971	263.278	35.782	88.035
35.936	9.111	327.43	11.98	23.98	287.280	40.150	87.738
35.936	9.508	341.69	11.979	24.97	299.116	42.574	87.540

2.3 Thermal Images

The thermal image was captured after operating at full load for 15 minutes with airflow.

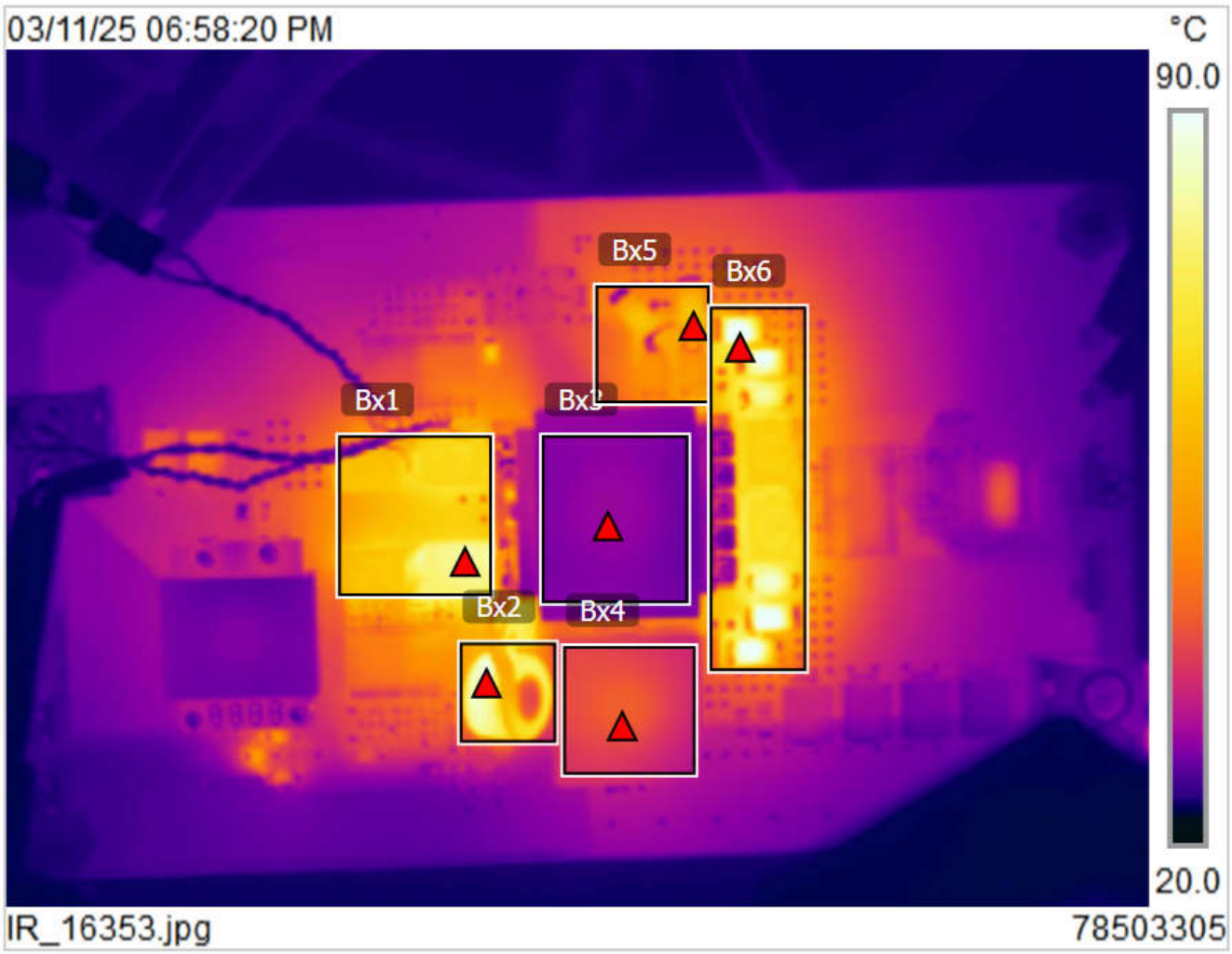


Figure 2-3. Thermal Image

Table 2-4. Temperature by Section

Area	Component	Maximum Temperature (°C)
Bx1	Primary FETs	85.3
Bx2	Shim Inductor	89.8
Bx3	Bridge Transformer	32.9
Bx4	Output Inductor	46.2
Bx5	Secondary Clamp	66.0
Bx6	Secondary Snubbers	100.4

2.4 Bode Plots

The Bode plot is measured at full load with nominal input voltage. Phase margin = 94.22° at 23.86kHz. Gain margin = –18.37dB at 131.92kHz.

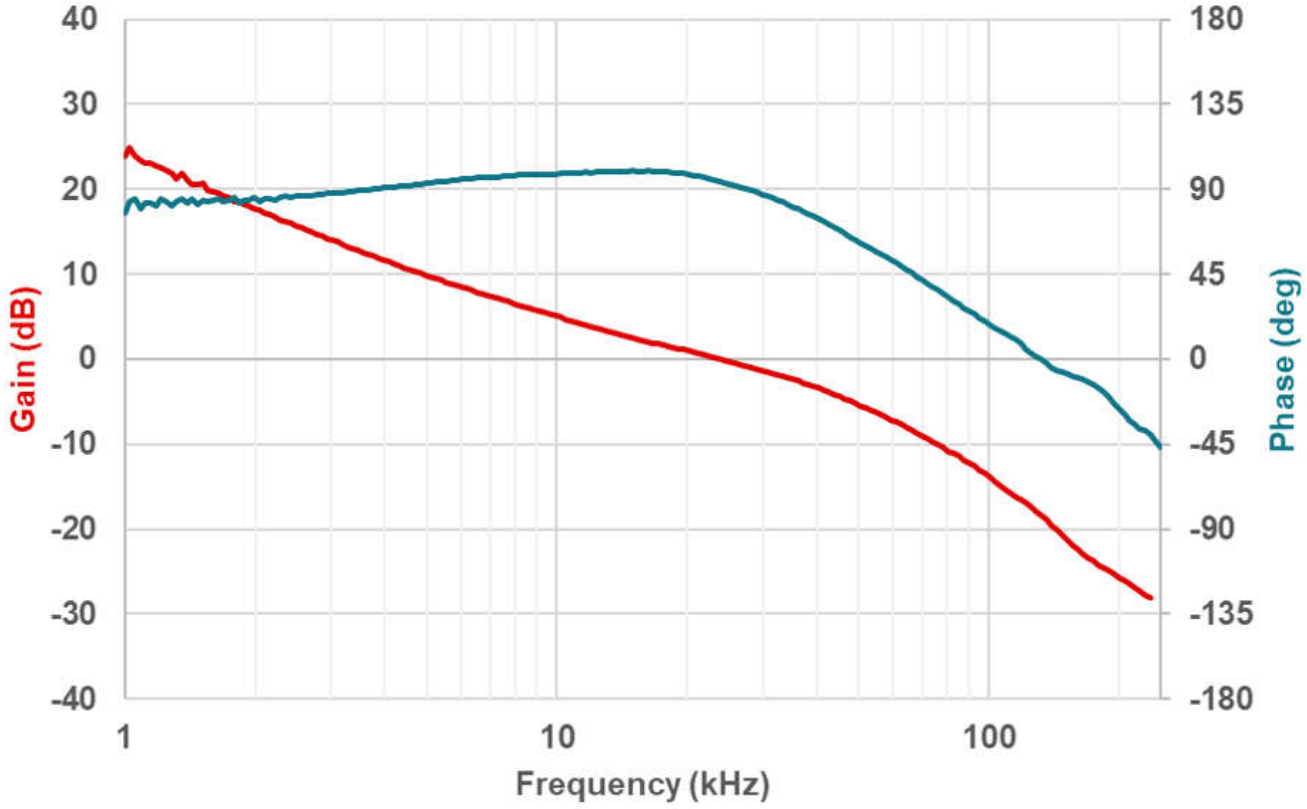


Figure 2-4. Bode Plot

3 Waveforms

3.1 Switching

Switching behavior is shown in Figure 3-1 and Figure 3-3.

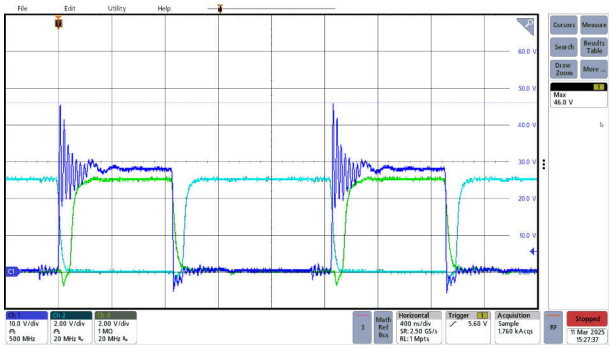


Figure 3-1. Primary Switch Node With High-Side and Low-Side Gate Drive Signals 28V Input

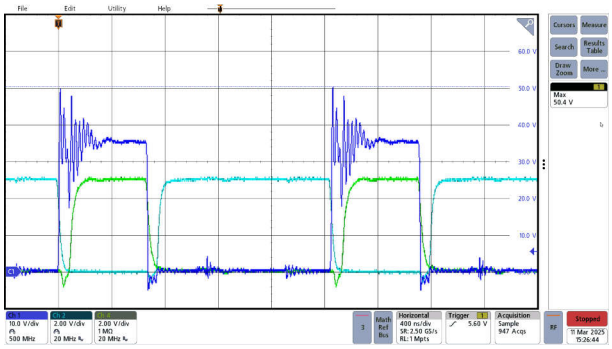


Figure 3-2. Primary Switch Node With High-Side and Low-Side Gate Drive Signals 36V Input

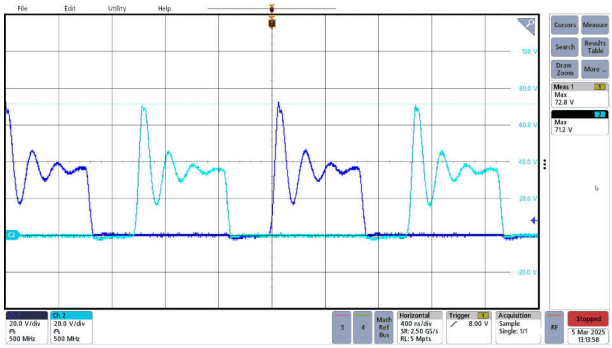


Figure 3-3. Secondary Switch Nodes

3.2 Output Voltage Ripple

Output voltage ripple is shown in Figure 3-4.

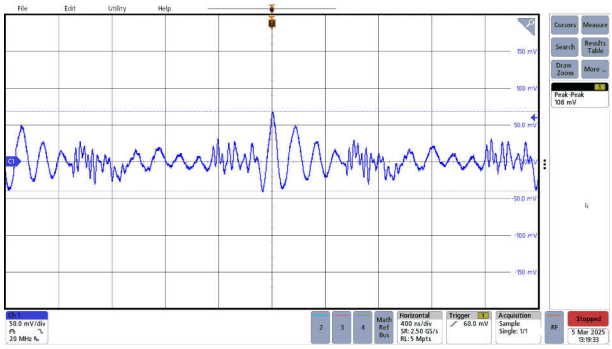


Figure 3-4. Output Voltage Ripple

3.3 Load Transients

Load transient response is shown for a 5A to 20A step.

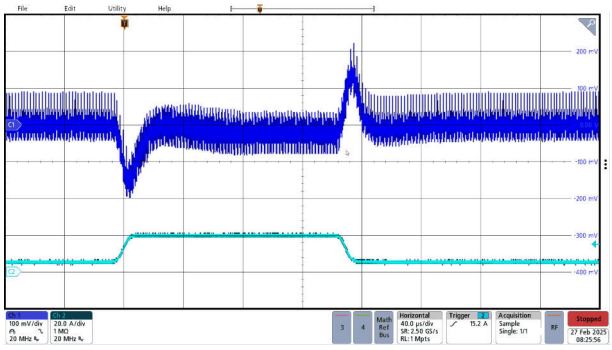


Figure 3-5. Load Transient

3.4 Start-up Sequence

Start-up behavior is shown in Figure 3-6.

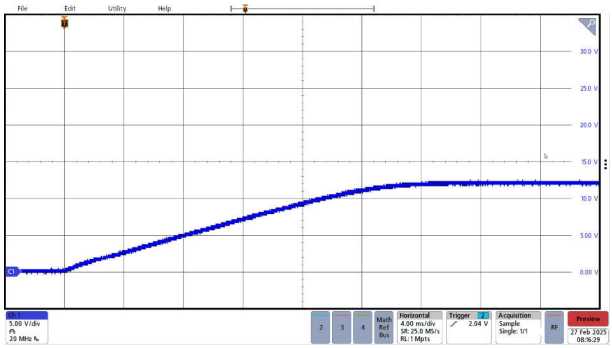


Figure 3-6. Start-up Timing

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