Test Report: PMP23598

75W Synchronous Forward Converter Reference Design for Space Applications

Description

This reference design uses a rad-tolerant TPS7H5020-SEP pulse-width modulation (PWM) controller and rad-tolerant TPS7H6005-SEP 200V GaN half-bridge gate-driver to create a high efficiency synchronous forward topology. To have an accurate, direct sense of the output voltage and achieve a high loop bandwidth, the PWM controller is placed on the secondary side. The capacitively isolated TX and RX level shifters that are within the half-bridge gate-driver, transfer the PWM waveform from secondary to primary while maintaining electrical isolation.

Resources

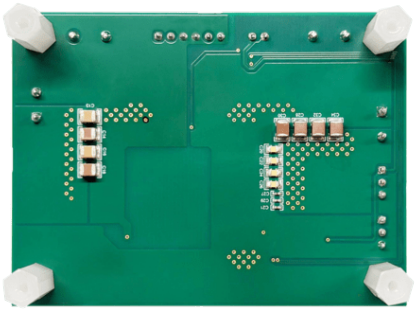
PMP23598	Design Folder
PMP23546	Design Folder
TPS7H5020-SEP, TPS7H5020-SP	Product Folder
TPS7H6005-SEP, TPS7H6005-SP	Product Folder

Features

- Over 90% efficiency at mid and full load operation
- 200V galvanic isolation through half-bridge gate-driver
- 55mm × 45mm design size, two-layer PCB
- GaN FETs and synchronous rectification
- Plastic pin-to-pin population options for rad-tolerant or rad-hard configurations
  - Rad-tolerant (TID 50krad, SEE immune to 43MeV×cm2 /mg: TPS7H5020-SEP and TPS7H6005-SEP)
  - Rad-hard (TID 100krad, SEE immune to 75MeV×cm2 /mg: TPS7H5020-SP and TPS7H6005-SP)

Applications

- Satellite electrical power system (EPS)
- Bus power supply



1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input voltage	24 - 36Vdc, 28Vdc nominal
Output voltage	5Vdc
Output current	15A max

1.2 Required Equipment

- DC power supply
- Electronic load
- Oscilloscope
- Digital multimeters

1.3 Considerations

- Local airflow used during testing.
- Headers J1 and J3 connected to PMP23546 DCM flyback bias supply reference design.
  - Efficiency numbers include energy required to power bias suply.

1.4 Dimensions

PMP23598A PCB measures 80mm × 60mm, design size fits within a 55mm × 45mm box.

2 Testing and Results

2.1 Efficiency Graphs

Efficiency is shown in Figure 2-1 and Figure 2-2.

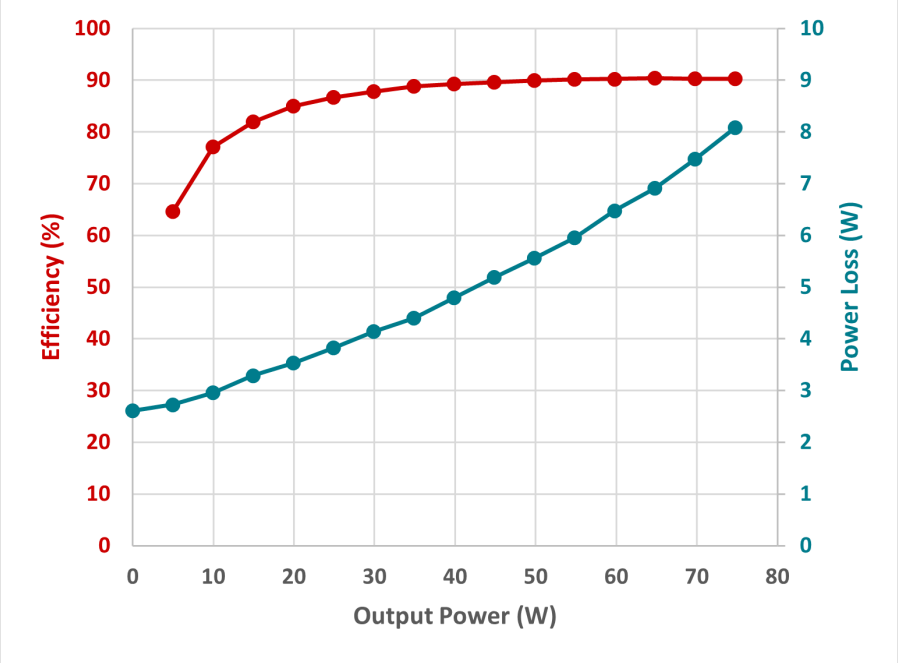


Figure 2-1. Efficiency and Power Loss for 28V Input

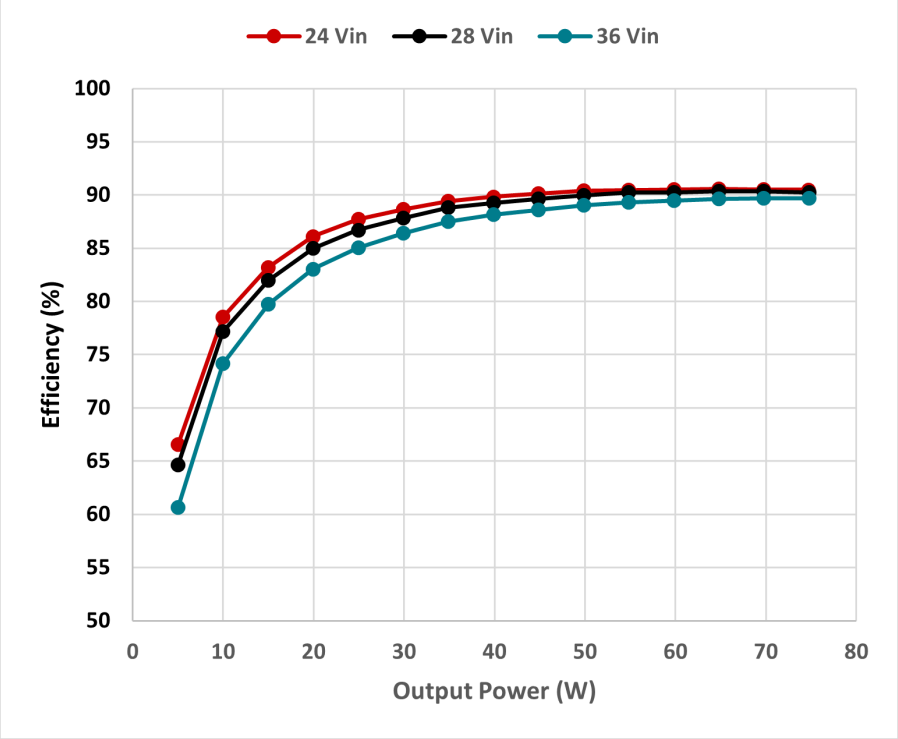


Figure 2-2. Efficiency Across Input Voltage

2.2 Efficiency Data

Efficiency data for 24VDC input is shown in Table 2-1.

Table 2-1. 24VDC Input

Input			Output			Total	
Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Loss (W)	Efficiency (%)
23.93	0.100	2.395	4.987	0	0.000	2.395	0.000
23.93	0.313	7.493	4.987	1	4.987	2.506	66.552
23.93	0.531	12.699	4.987	2	9.974	2.725	78.544
23.93	0.752	17.986	4.986	3	14.958	3.028	83.166
23.93	0.968	23.164	4.986	4	19.944	3.220	86.098
23.93	1.188	28.426	4.986	5	24.930	3.496	87.700
23.93	1.410	33.746	4.986	6	29.916	3.830	88.650
23.93	1.631	39.032	4.985	7	34.895	4.137	89.400
23.93	1.855	44.397	4.985	8	39.880	4.517	89.825
23.93	2.080	49.784	4.985	9	44.865	4.919	90.119
23.93	2.305	55.147	4.984	10	49.840	5.307	90.377
23.93	2.533	60.624	4.984	11	54.824	5.800	90.432
23.93	2.762	66.097	4.984	12	59.808	6.289	90.485
23.93	2.989	71.529	4.983	13	64.779	6.750	90.563
23.93	3.221	77.079	4.983	14	69.762	7.317	90.508
23.92	3.452	82.581	4.981	15	74.715	7.866	90.474

Efficiency data for 28VDC input is shown in Table 2-2.

Table 2-2. 28VDC Input

Input			Output			Total	
Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Loss (W)	Efficiency (%)
27.93	0.093	2.609	4.988	0	0.000	2.609	0.000
27.93	0.276	7.713	4.987	1	4.987	2.726	64.653
27.93	0.463	12.930	4.987	2	9.974	2.956	77.141
27.93	0.653	18.249	4.987	3	14.961	3.288	81.980
27.92	0.841	23.472	4.986	4	19.944	3.528	84.968
27.92	1.030	28.752	4.986	5	24.930	3.822	86.707
27.93	1.219	34.055	4.986	6	29.916	4.139	87.846
27.92	1.408	39.297	4.985	7	34.895	4.402	88.797
27.92	1.600	44.678	4.985	8	39.880	4.798	89.262
27.92	1.793	50.049	4.985	9	44.865	5.184	89.641
27.92	1.984	55.402	4.984	10	49.840	5.562	89.961
27.92	2.177	60.773	4.984	11	54.824	5.949	90.210
27.92	2.374	66.285	4.984	12	59.808	6.477	90.229
27.92	2.568	71.701	4.984	13	64.792	6.909	90.364
27.92	2.767	77.255	4.984	14	69.776	7.479	90.319

Table 2-2. 28VDC Input (continued)

Input			Output			Total	
Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Loss (W)	Efficiency (%)
27.92	2.967	82.827	4.983	15	74.745	8.082	90.242

Efficiency data for 36VDC input is shown in Table 2-3.

Table 2-3. 36VDC Input

Input			Output			Total	
Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Loss (W)	Efficiency (%)
35.94	0.086	3.090	4.988	0	0.000	3.090	0.000
35.94	0.229	8.222	4.987	1	4.987	3.235	60.654
35.94	0.374	13.451	4.987	2	9.974	3.477	74.149
35.94	0.522	18.766	4.987	3	14.961	3.805	79.725
35.94	0.668	24.022	4.987	4	19.948	4.074	83.040
35.94	0.816	29.323	4.986	5	24.930	4.393	85.017
35.94	0.964	34.632	4.986	6	29.916	4.716	86.383
35.94	1.110	39.883	4.986	7	34.902	4.981	87.512
35.94	1.259	45.238	4.985	8	39.880	5.358	88.157
35.94	1.409	50.636	4.985	9	44.865	5.771	88.603
35.94	1.558	55.995	4.985	10	49.850	6.145	89.027
35.94	1.708	61.400	4.985	11	54.835	6.565	89.308
35.94	1.860	66.859	4.984	12	59.808	7.051	89.454
35.94	2.011	72.279	4.984	13	64.792	7.487	89.642
35.94	2.165	77.799	4.984	14	69.776	8.023	89.687
35.94	2.319	83.356	4.984	15	74.760	8.596	89.688

2.3 Thermal Images

The thermal image was captured after operating for 15 minutes at full load, 28 Vin with local airflow.

Figure 2-3. Thermal Image

Table 2-4. Local maxima measurements

Label	Component	Temperature
Bx1	Q1 - Primary FET	39.2 °C
Bx2	Q2 - Free-wheeling rectifier	58.5 °C
Bx3	Q3 - Synchronous FET	51.0 °C
Bx4	T1 - Transformer	35.6 °C
Bx5	L1 - Output inductor	50.3 °C

2.4 Bode Plots

Figure 2-4 was captured with a 28VDC input and full loading conditions.

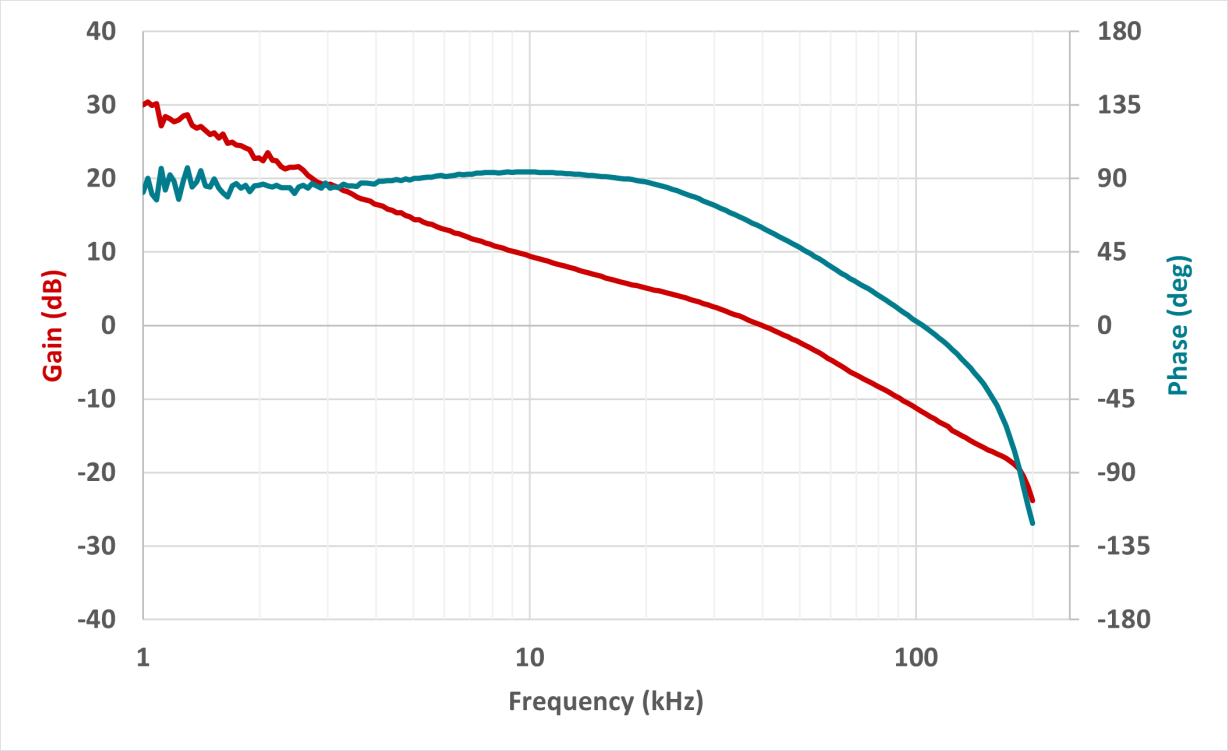


Figure 2-4. Bode Plot

Table 2-5. Control loop measurements

Crossover frequency	Phase margin
39.944kHz	59.738°

3 Waveforms

3.1 Switching

Switching behavior waveforms are shown in Figure 3-1.

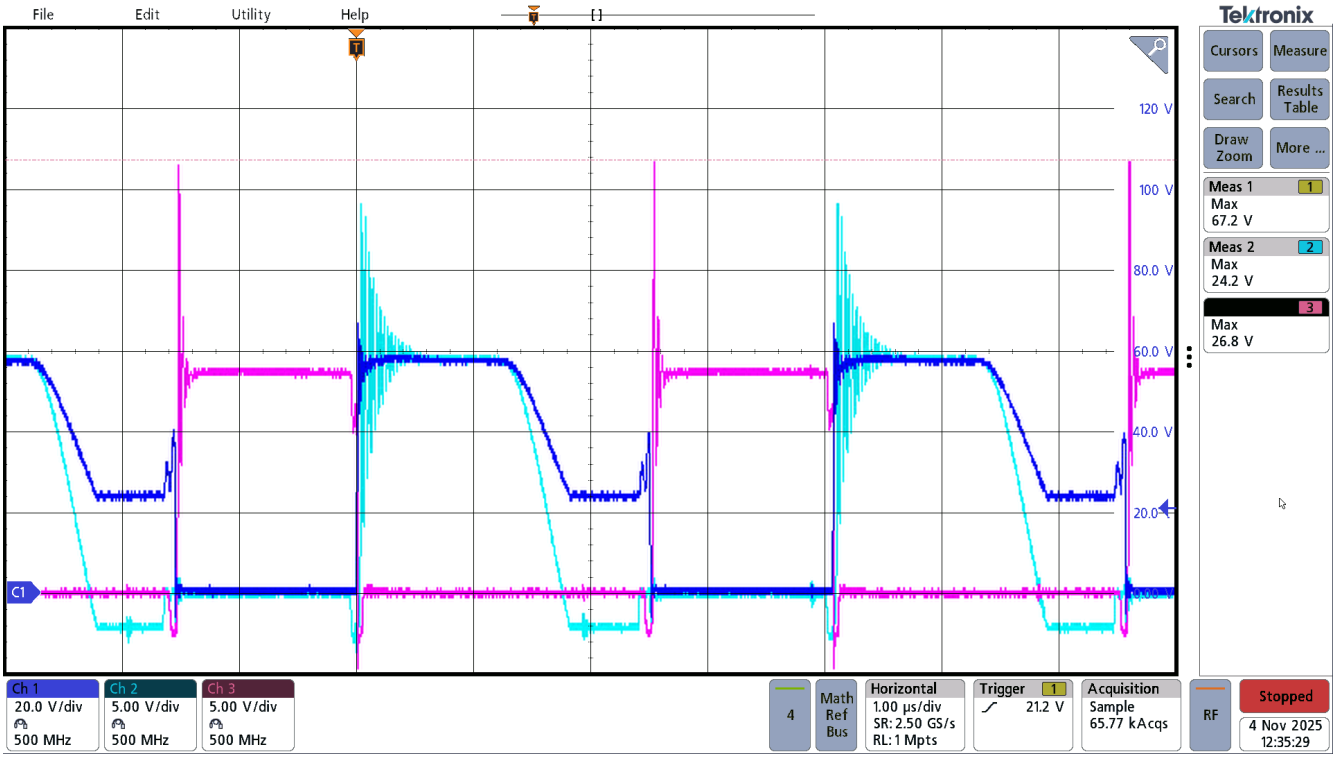


Figure 3-1. Switching with 28V Input, Max Loading Conditions

Table 3-1. Switch node waveform labels

Channel	Waveform	Max Voltage
1 - dark blue	Q1 - Primary FET	67.2V
2 - light blue	Q3 - Synchronous FET	24.2V
3 - magenta	Q2 - Free-wheeling rectifier	26.8V

3.2 Output Voltage Ripple

Output voltage ripple waveforms are shown in Figure 3-2.

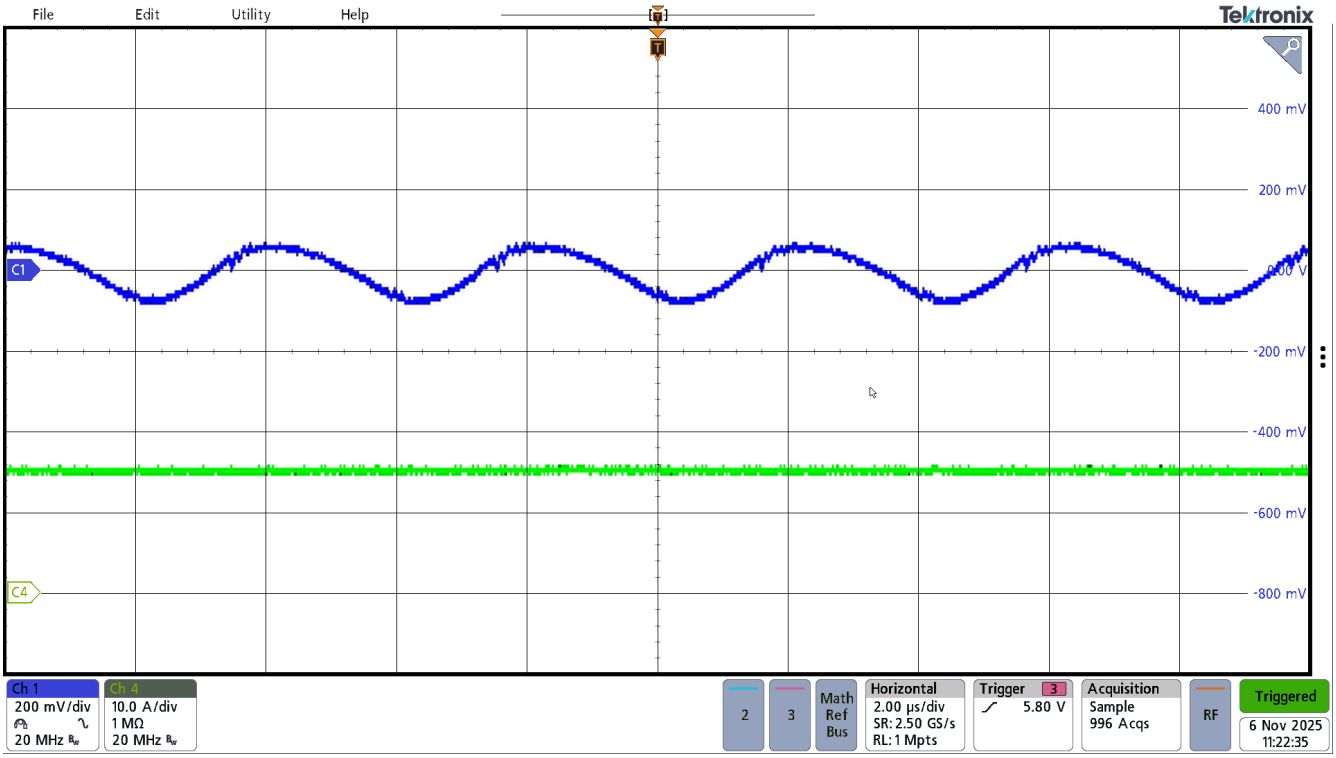


Figure 3-2. Output Voltage Ripple With 28V Input, Max Loading Conditions

Table 3-2. Output ripple waveform labels

Channel	Waveform
1 - dark blue	Output voltage (AC coupled)
4 - green	Output current (DC coupled)

3.3 Load Transients

Load transient response waveforms are shown in Figure 3-3 through Figure 3-5.

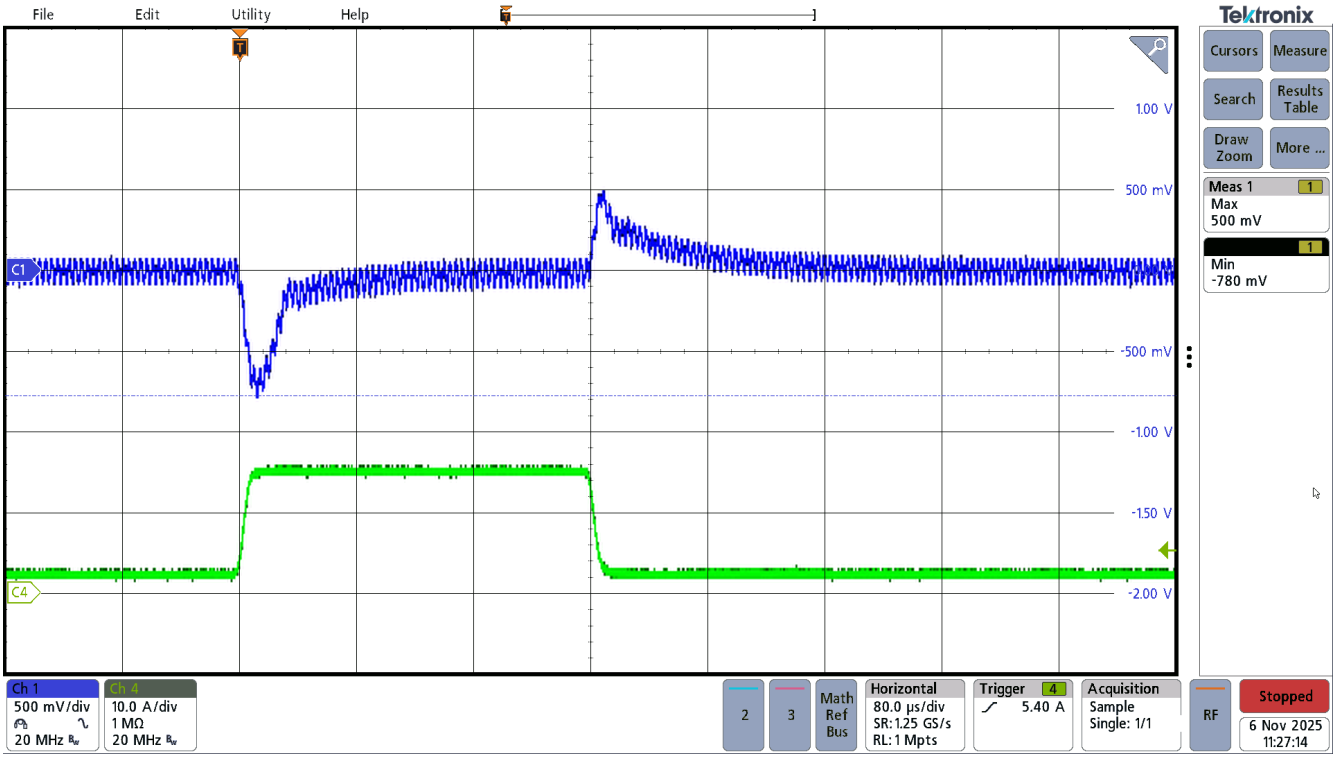


Figure 3-3. Load Transient with 28V Input, Stepping from 2A to 15A Load

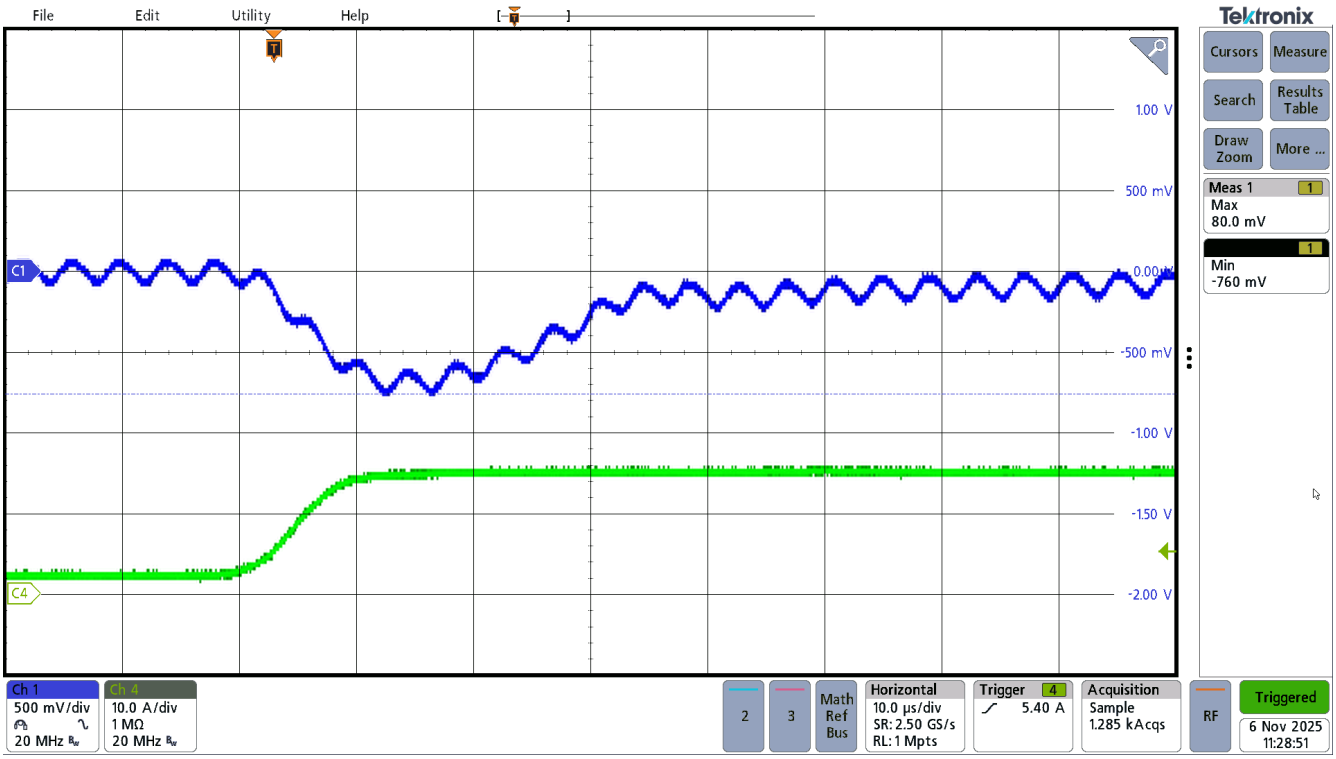


Figure 3-4. Load Step Detail

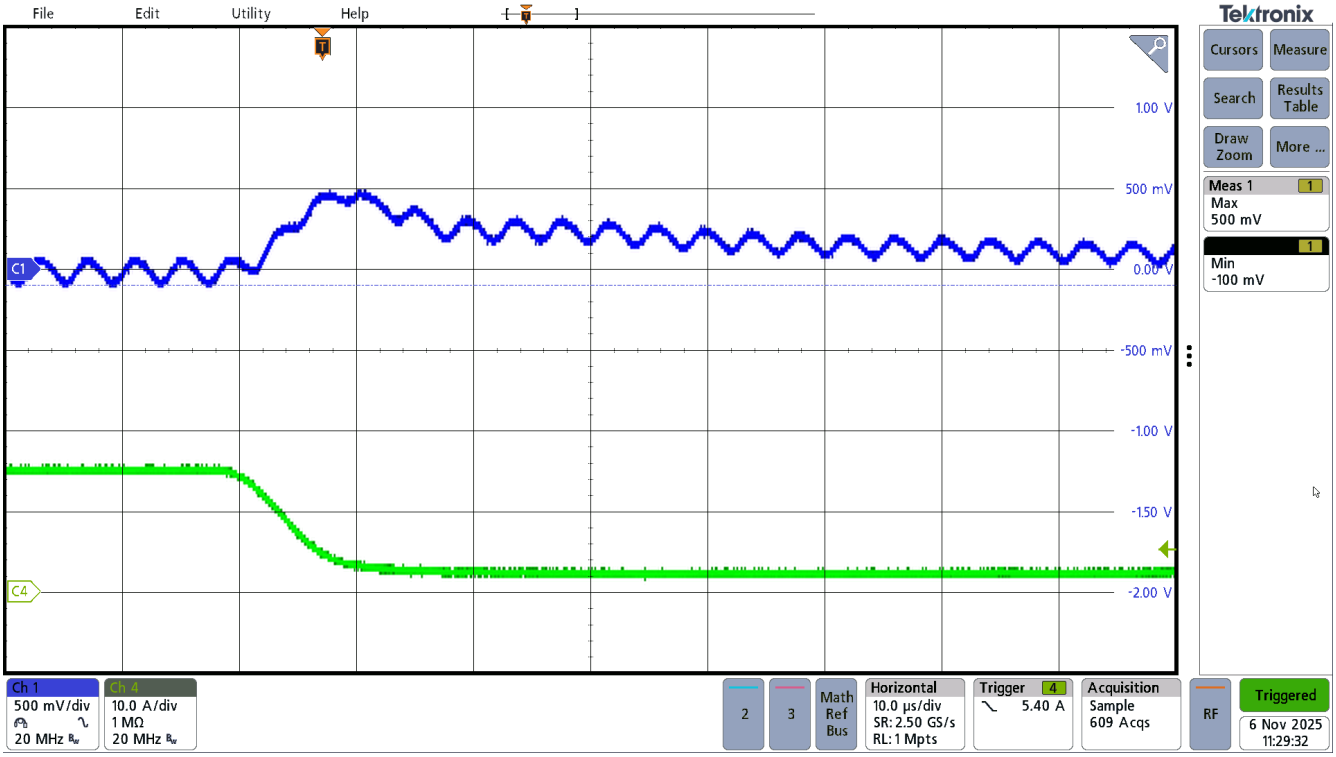


Figure 3-5. Load Dump Detail

Table 3-3. Load transient waveform labels

Channel	Waveform
1 - dark blue	Output voltage (AC coupled)
4 - green	Output current (DC coupled)

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