Test Report: PMP23389

Space-Grade 12V to 5V–15A Synchronous Buck Converter Reference Design

Description

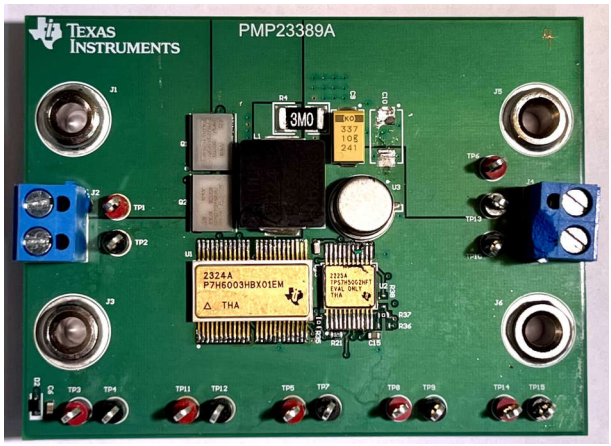
This reference design uses the TPS7H5002-SP PWM controller to control a synchronous buck for a nominal 12V input to a fixed output at 5.1V, up to 15A load. The TPS7H6023-SP drives GaN FETs for a robust design in space-based applications. The output current is directly sensed for telemetry and over-current protection. This design switches at 750kHz, and achieves over 92% efficiency with output ripple below 30mV.

Features

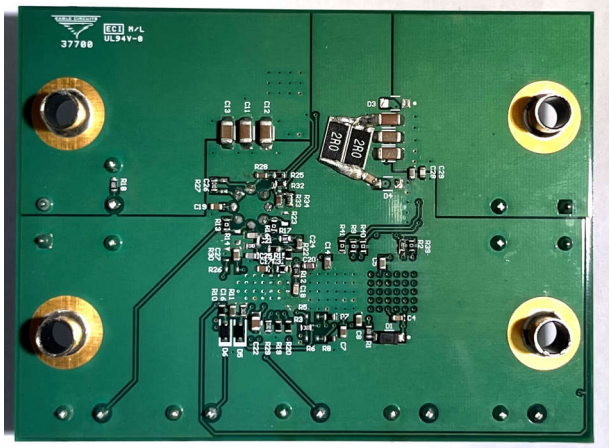
- Nominal 12V DC input for space-based applications
- Up to 92% efficiency at 5.1V, 15A
- Packaged GaN assembly
- 750kHz for optimized switching and thermal performance

Applications

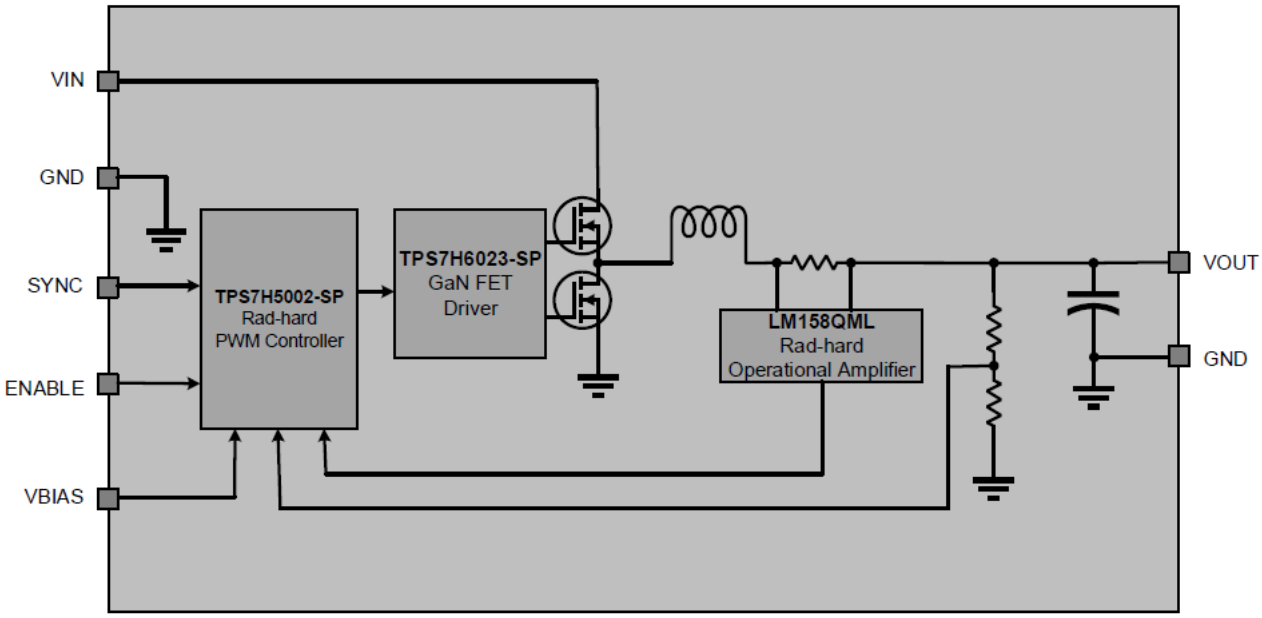
- Satellite electrical power system (EPS)
- Radar imaging payload
- Optical imaging payload
- On-board computer (OBC)
- Communications payload
- Command and data handling (C&DH)
- Geosynchronous systems
- Scalable, radiation-hardened end equipment



Top Side of Board



Bottom Side of Board



Block Diagram

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage Range	10VDC–14VDC
Output Voltage	5.1V
Maximum Load Current	15A
Switching Frequency	750kHz

1.2 Required Equipment

- DC Power Supply, 20V and 30A
- Multimeter
- Oscilloscope
- 15A Load

1.3 Considerations

Input current for this board is up to approximately 7A so verify that power supply is appropriately rated. Additionally, be aware of possible transients that power supply can have. To mitigate effects of potential transients, slowly increase input voltage on power supply until desired voltage level is reached.

1.4 Dimensions

The board measures 80mm × 61mm × 24mm.

2 Testing and Results

2.1 Efficiency Graphs

Figure 2-1 and Figure 2-2 show the PMP23389 efficiency and power loss graphs, respectively.

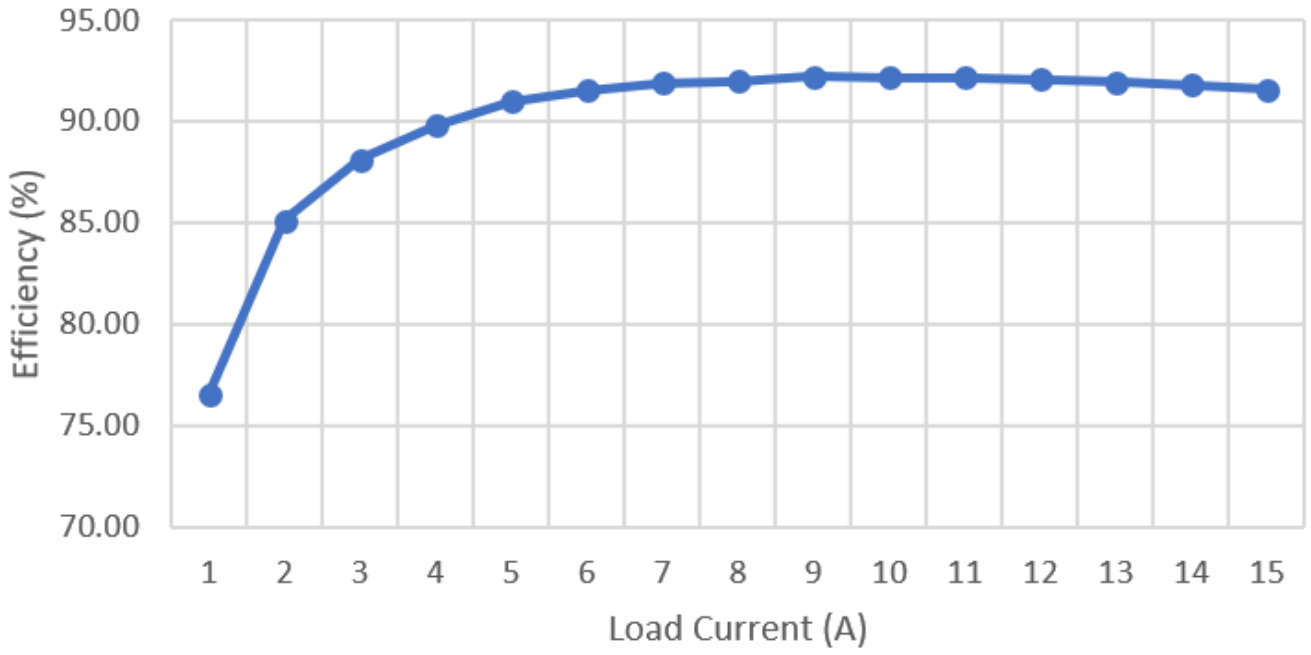


Figure 2-1. PMP23389 Efficiency, 12V Input, 5.1V Output

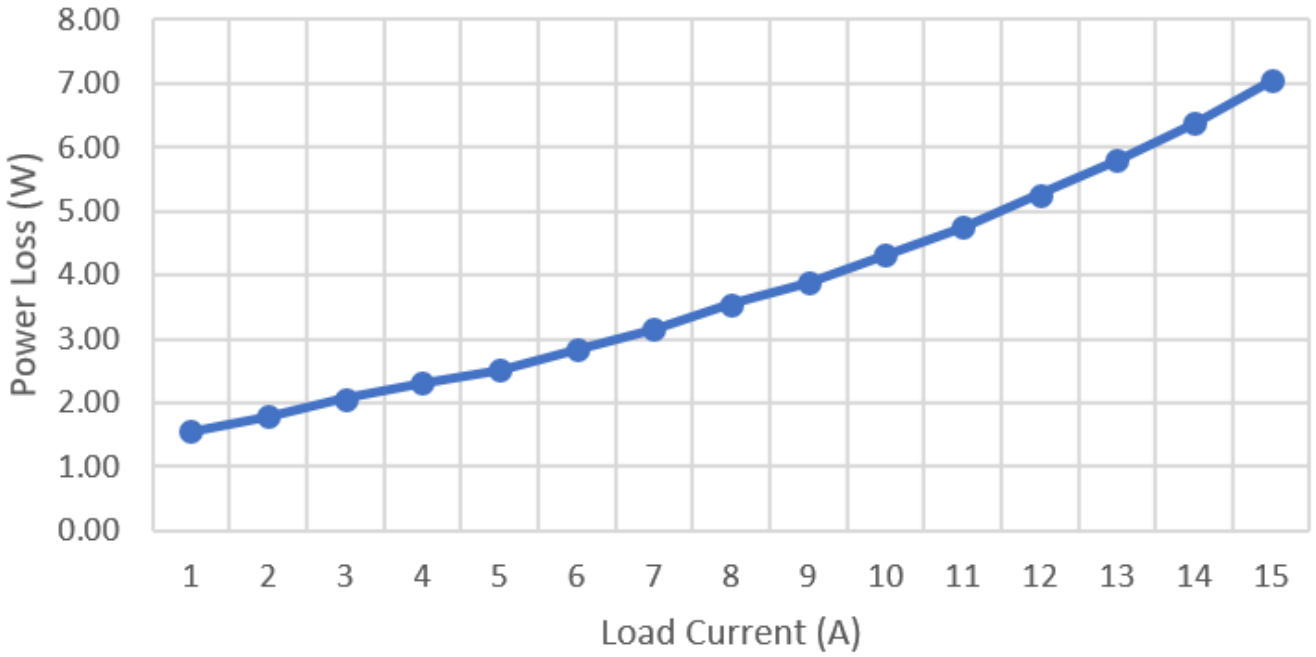


Figure 2-2. PMP23389 Power Loss, 12V Input, 5.1V Output

2.2 Efficiency Data

Table 2-1 displays the PMP23389 efficiency data.

Table 2-1. PMP23389 Efficiency Data

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
12.00	0.130	5.091	0	1.56	0	1.56	0
12.00	0.554	5.092	1	6.65	5.09	1.56	76.54
12.00	0.997	5.092	2	11.96	10.18	1.78	85.12
12.00	1.445	5.093	3	17.34	15.28	2.06	88.12
12.00	1.891	5.094	4	22.69	20.38	2.31	89.82
12.00	2.333	5.095	5	28.00	25.48	2.52	91.00
12.00	2.78	5.095	6	33.40	30.57	2.83	91.53
12.00	3.235	5.096	7	38.82	35.67	3.15	91.89
12.00	3.693	5.097	8	44.32	40.78	3.54	92.01
12.00	4.147	5.098	9	49.76	45.88	3.88	92.20
12.00	4.610	5.100	10	55.32	51	4.32	92.19
12.00	5.072	5.101	11	60.86	56.11	4.75	92.20
12.00	5.540	5.102	12	66.48	61.22	5.26	92.09
12.00	6.012	5.103	13	72.14	66.34	5.80	91.96
12.00	6.486	5.104	14	77.83	71.46	6.37	91.82
12.00	6.970	5.106	15	83.64	76.59	7.05	91.57

Table 2-2 displays the no load and off state power consumption for the PMP23389.

Table 2-2. PMP23389 No Load and Off State Power Consumption

	I_{OUT} (A)	V_{OUT} (V)	I_{IN} (A)	V_{IN} (V)	P_{OUT} (W)	P_{IN} (W)	P_{LOSS} (W)
No Load	0	5.091	0.130	12.00	0	1.56	1.56
Off State	0	0	0.012	12.00	0	0.144	0.144

2.3 Thermal Images

Figure 2-3 and Figure 2-4 show the thermal performance of the top and bottom side of the PMP23389 board, respectively. All images captured with the PMP23389 board on an open bench top, 25ºC ambient, and after a 30-minute warm up.

Measurements	
Sp1	105.0 °C
Sp2	101.4 °C
Sp3	91.4 °C
Sp4	97.3 °C
Sp5	72.3 °C
Sp6	65.2 °C

Parameters	
Emissivity	0.95
Refl. temp.	20 °C

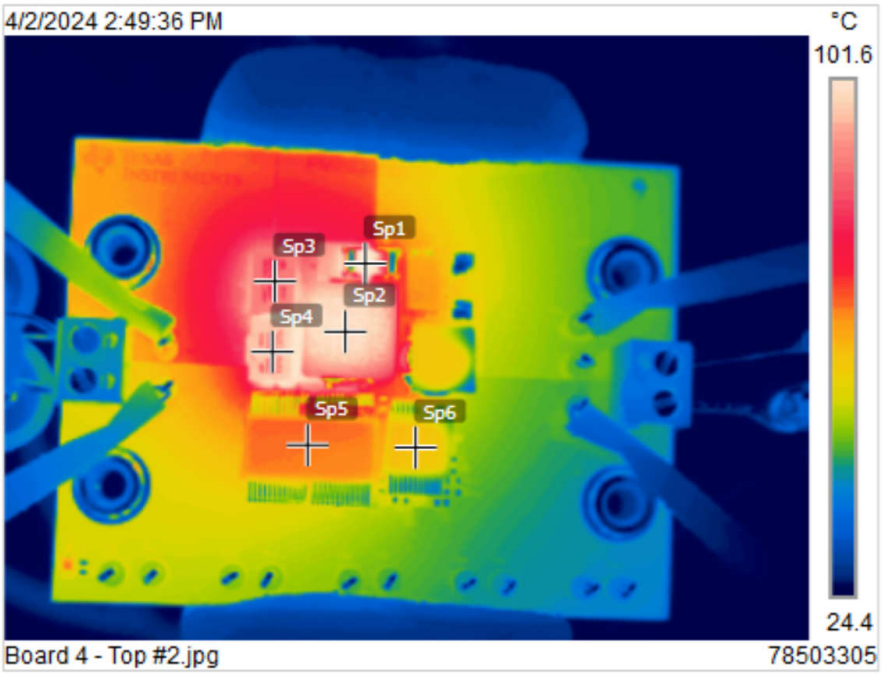


Figure 2-3. Top View, 12V Input, 5.1V Output

Measurements	
Sp1	109.1 °C
Sp2	109.4 °C

Parameters	
Emissivity	0.95
Refl. temp.	20 °C

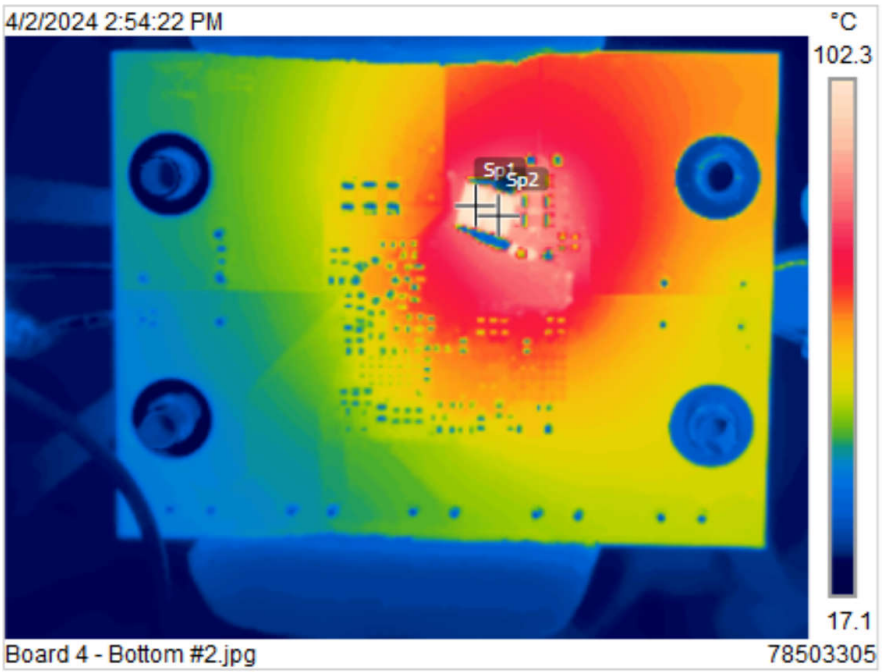


Figure 2-4. Bottom View, 12V Input, 5.1V Output

2.4 Bode Plots

Figure 2-5 illustrates the PMP23389 bode plot.

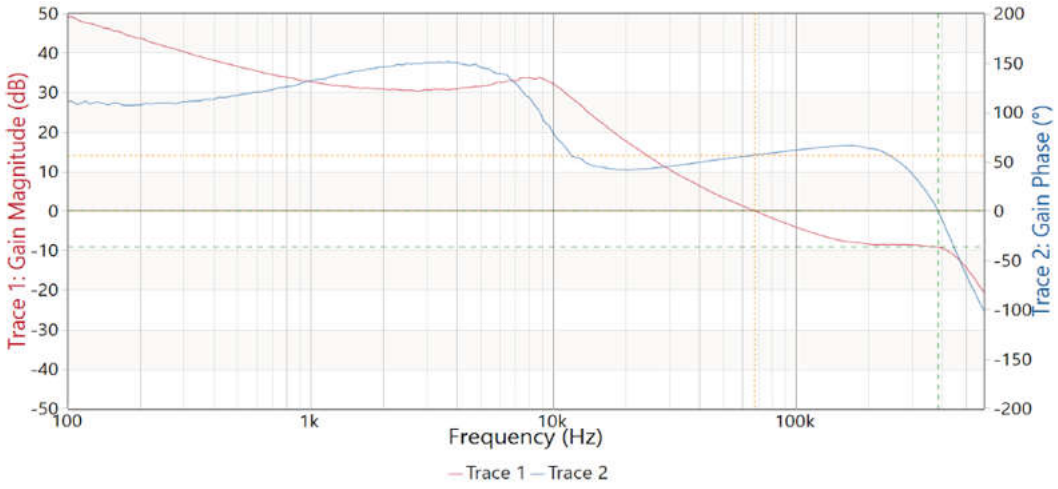


Figure 2-5. 12V Input, 5.1V, 15A Output; Bandwidth = 68kHz, Phase Margin = 56.5 Degrees, Gain Margin = 9.2dB

3 Waveforms

3.1 Switching

Figure 3-1 shows the switching behavior for PMP23389.

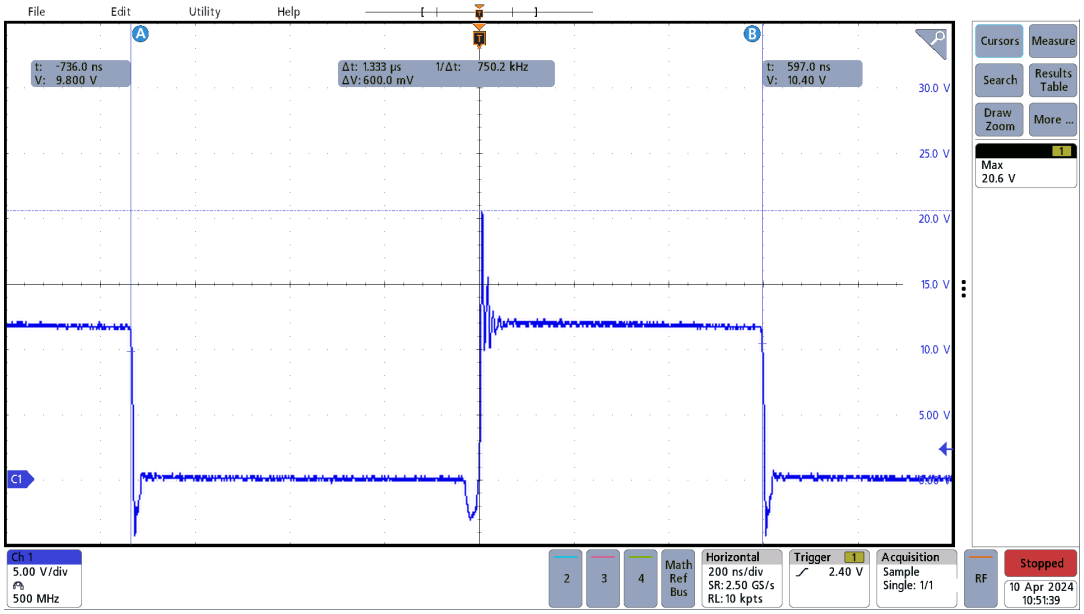


Figure 3-1. 12V Input, 15A Load; 750kHz Switching Frequency

3.2 Voltage Ripple

Figure 3-2 and Figure 3-3 illustrate the PMP23389 voltage ripple waveforms. Output voltage ripple taken across C10 and input voltage ripple taken across J2 with 330µF capacitor across input to filter out high frequencies.

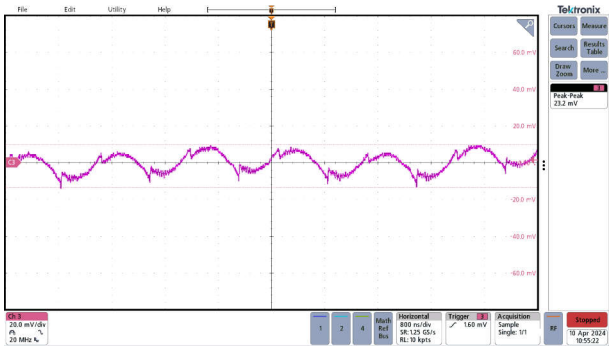


Figure 3-2. Output Voltage Ripple (AC Coupled) With 12V input and 15A Load; Measured 23.2mV Peak to Peak

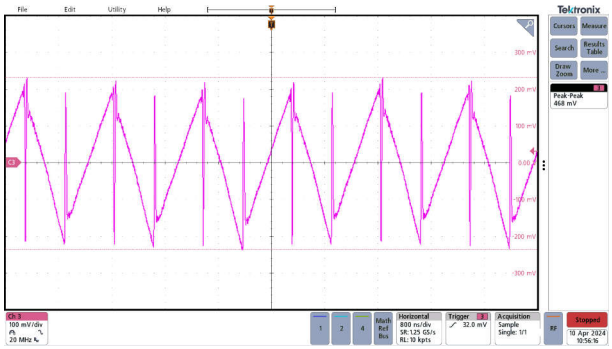


Figure 3-3. Input Voltage Ripple (AC Coupled) With 12V Input and 15A Load; Measured 468mV Peak to Peak

3.3 Short-Circuit Protection

Figure 3-4 and Figure 3-5 illustrate how the PMP23389 behaves under short-circuit protection. Output across J4 was shorted momentarily in order capture meaningful data on oscilloscope to illustrate that short-circuit protection functions effectively as the output voltage returns to the steady state. The short-circuit protection is leveraged by the FAULT pin of the TPS7H5002-SP, which is an optional functionality.

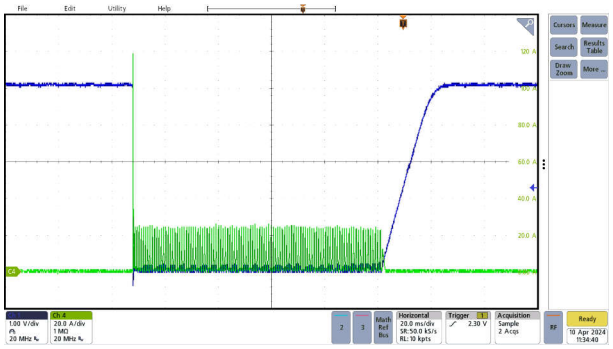


Figure 3-4. Short-Circuit Protection

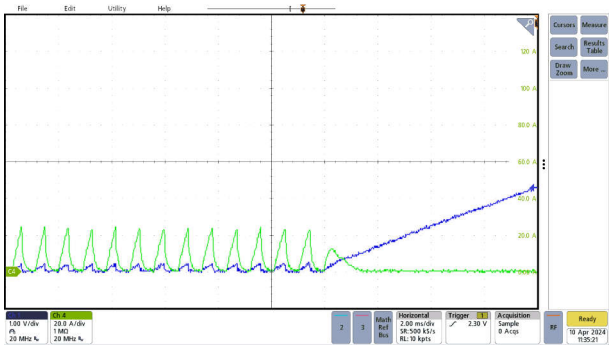


Figure 3-5. Short-Circuit Protection, Zoomed in Window

3.4 Load Transients

Figure 3-6 shows the behavior of the PMP23389 during a load transient at 5.1V output, 7.5 to 15A and 15A to 7.5A load steps.

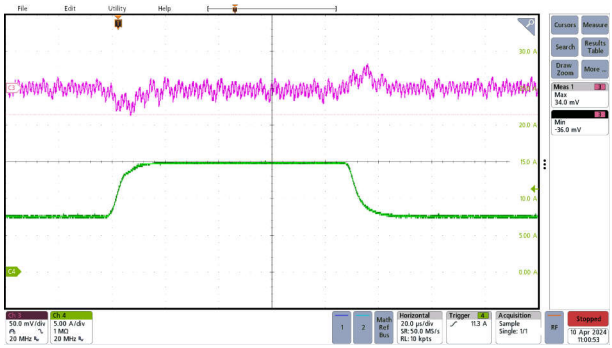


Figure 3-6. 12V Input; CH3: Output Voltage, AC Coupled, 50mV/div; CH4: Output Current, 5A/div

3.5 Start-up Sequence

Figure 3-7 and Figure 3-8 show start-up behavior for PMP23389. The power supply was enabled using the ENABLE signal or by shorting TP8 to TP9 on the board.

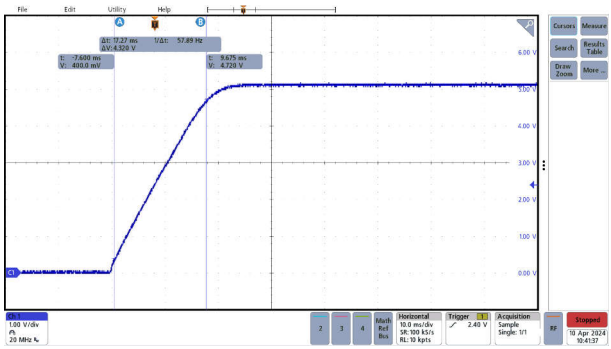


Figure 3-7. 12V Input, 5.1V Output, No Load; CH1: Output Voltage, 1V/div

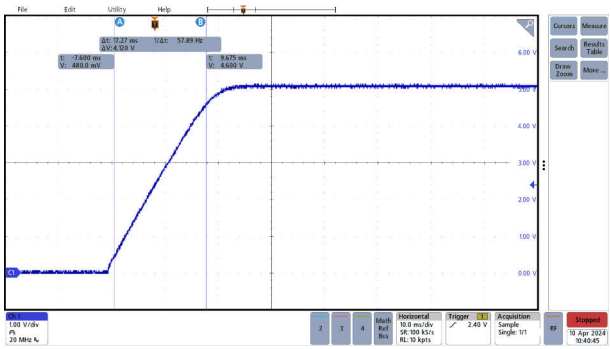


Figure 3-8. 12V Input, 5.1V Output, 15A Maximum Load; CH1: Output Voltage, 1V/div

3.6 Current Monitor Output

Figure 3-9 shows the current monitor output graph.

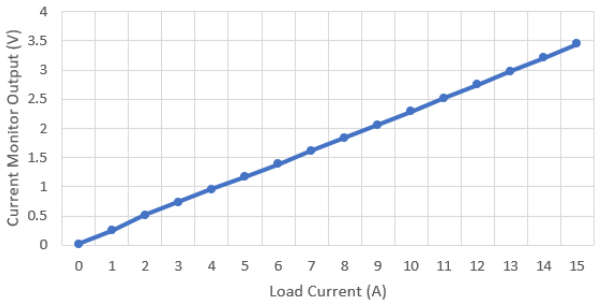


Figure 3-9. Current Monitor Output, Measure Voltage Across TP14 and TP15

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