

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



Description

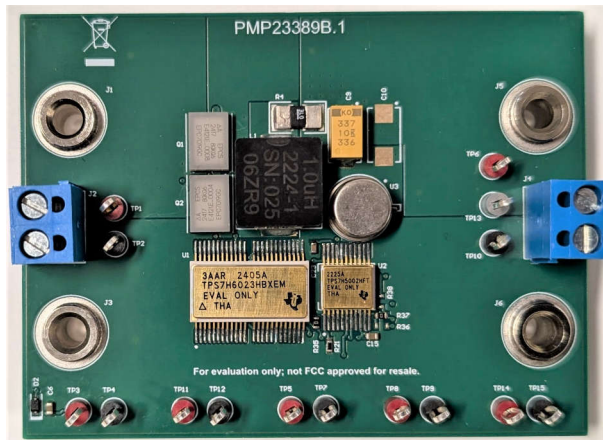
This reference design uses the TPS7H5002-SP PWM controller to control a synchronous buck for a nominal 12V input to a fixed output at 5.1V, up to 15A load. The TPS7H6023-SP drives GaN FETs for a robust design in space-based applications. The output current is directly sensed for telemetry and over-current protection. This design switches at 750kHz, and achieves over 93% efficiency with output ripple below 30mV.

Features

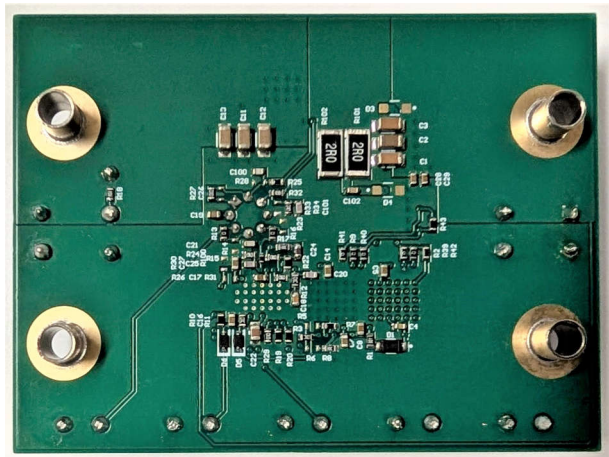
- Nominal 12V DC input for space-based applications
- Up to 93% efficiency at 5.1V, 15A
- Packaged GaN FETs
- 750kHz switching frequency to reduce size

Applications

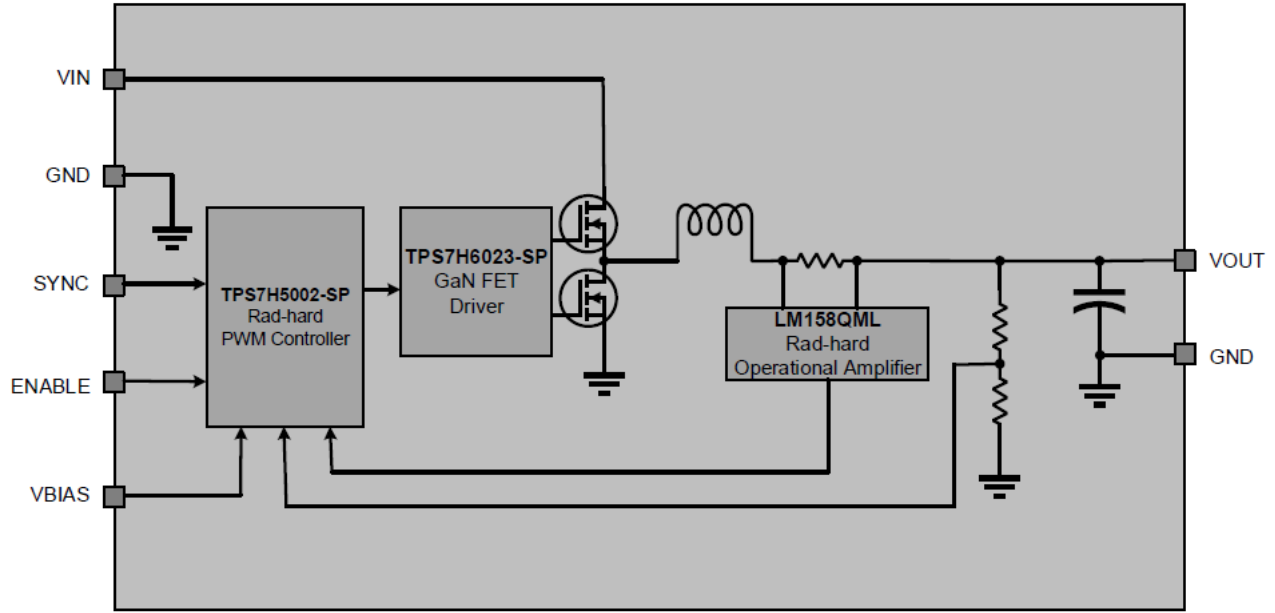
- [Satellite electrical power system \(EPS\)](#)
- [Radar imaging payload](#)
- [Optical imaging payload](#)
- [Communications payload](#)
- [Command and data handling \(C&DH\)](#)



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

Board does not contain any bulk capacitance on the input. If input cables to DC power supply are long, add bulk capacitance on input. All testing was performed with a 330uF/25V aluminum capacitor add at the input.

1.4 Dimensions

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

2 Testing and Results

2.1 Efficiency Graphs

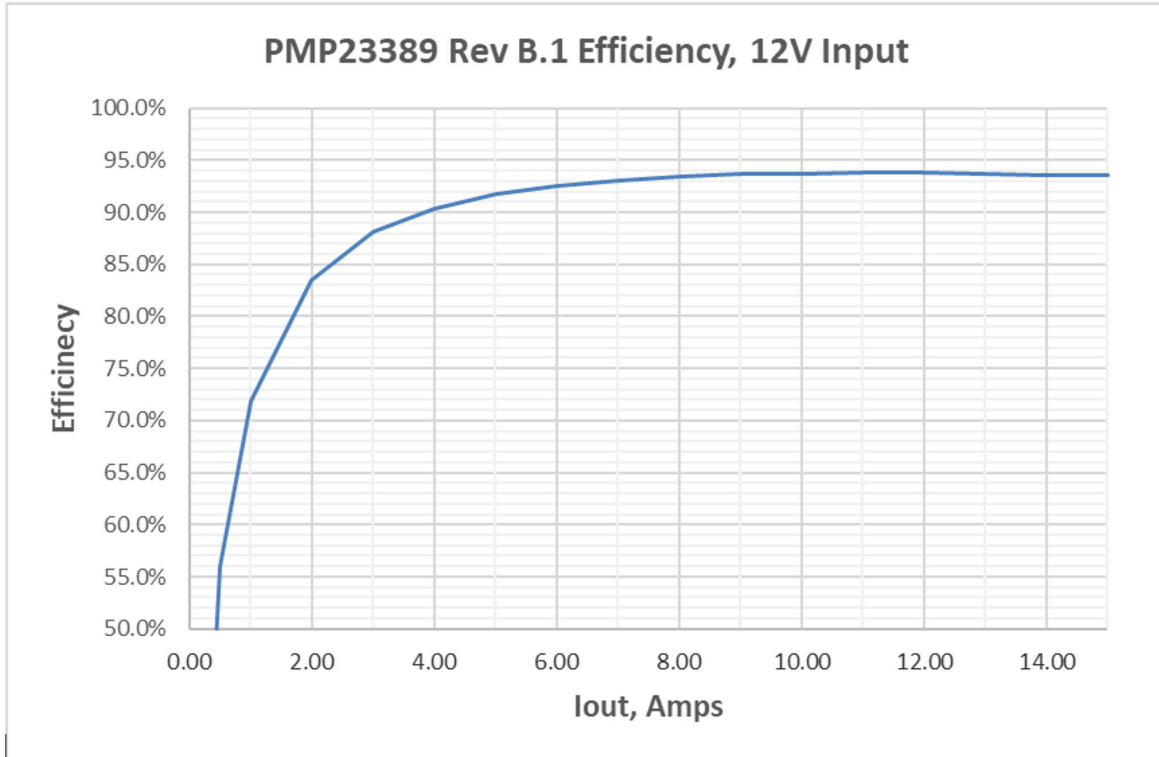


Figure 2-1. Efficiency, 12V Input

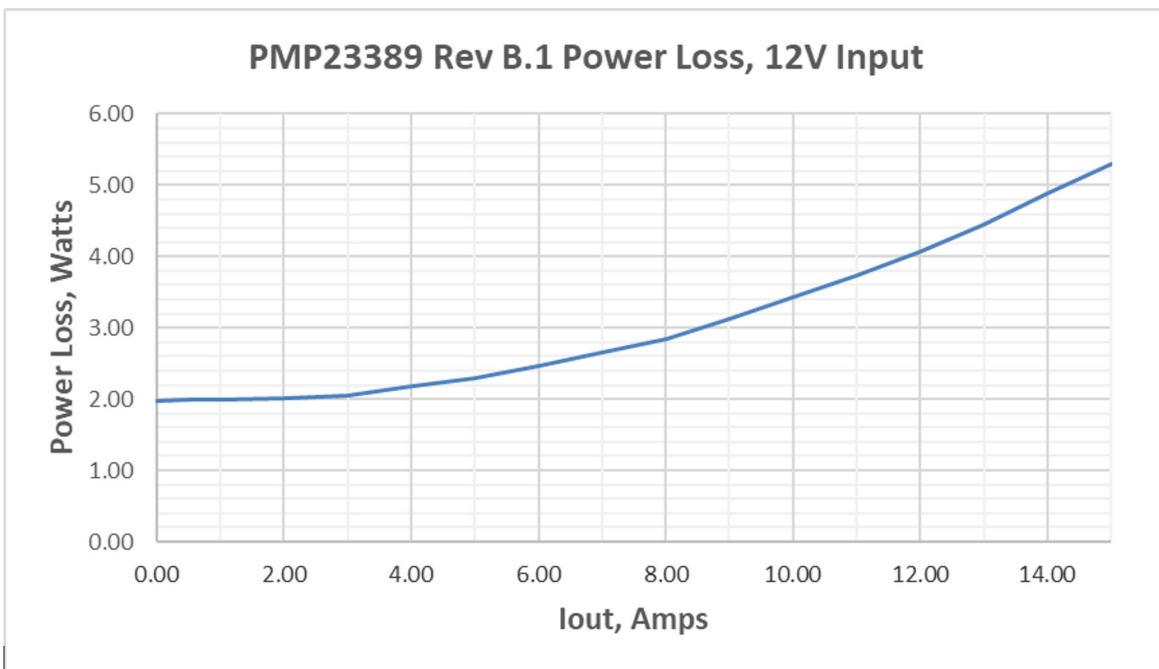


Figure 2-2. Power Loss, 12V Input

2.2 Efficiency Data

Table 2-1. Efficiency Data

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
12.06	0.164	5.098	0	1.98	0	1.98	0.0
12.04	0.378	5.098	0.5	4.55	2.55	2.00	56.0
12.02	0.590	5.098	1	7.09	5.10	1.99	71.9
12.05	1.013	5.098	2	12.21	10.20	2.01	83.5
12.01	1.445	5.099	3	17.35	15.30	2.06	88.1
12.07	1.870	5.099	4	22.57	20.40	2.17	90.4
12.03	2.310	5.100	5	27.79	25.50	2.29	91.8
12.06	2.741	5.100	6	33.06	30.60	2.46	92.6
12.02	3.191	5.101	7	38.36	35.71	2.65	93.1
12.06	3.62	5.102	8	43.66	40.82	2.84	93.5
12.02	4.08	5.102	9	49.04	45.92	3.12	93.6
12.02	4.53	5.103	10	54.45	51.03	3.42	93.7
12.02	4.98	5.103	11	59.86	56.13	3.73	93.8
12.05	5.42	5.104	12	65.31	61.25	4.06	93.8
12.00	5.90	5.104	13	70.80	66.35	4.45	93.7
12.08	6.32	5.104	14	76.35	71.46	4.89	93.6
12.04	6.80	5.105	15	81.87	76.58	5.30	93.5

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	5.098	0.164	12.06	0	1.98	1.98
Off State	0	0	0.012	12.00	0	0.144	0.144

2.3 Thermal Images

All images captured with the board on an open bench top, 25°C ambient and after 30 minutes of operation at 15A load.

Measurements

Sp1	81.6 °C
Sp2	71.3 °C
Sp3	59.5 °C
Sp4	61.6 °C
Sp5	55.1 °C
Sp6	51.9 °C

Parameters

Emissivity	0.95
Refl. temp.	20 °C

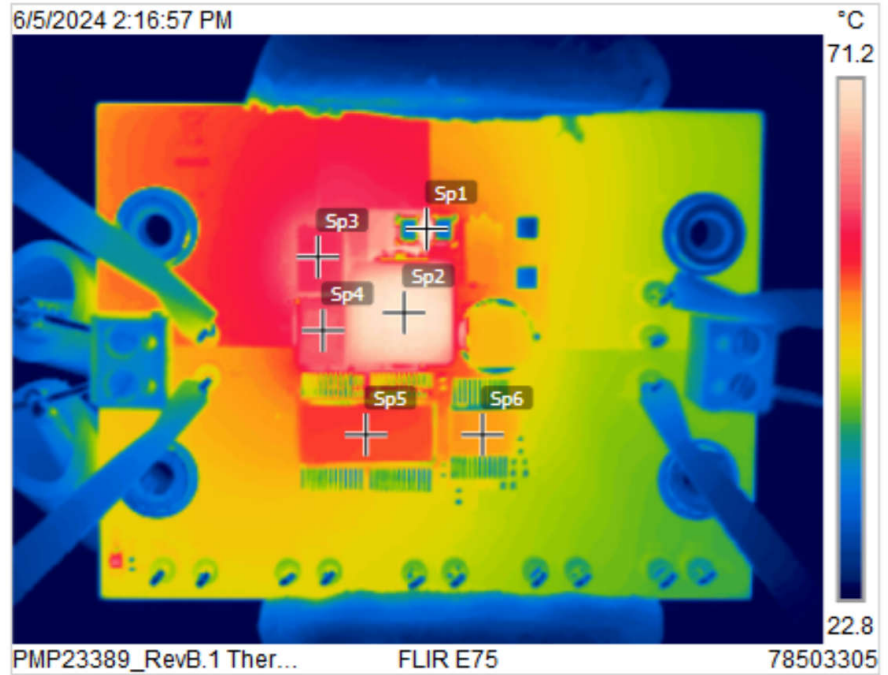


Figure 2-3. Top View, 12V Input

Measurements

Sp1	70.3 °C
Sp2	70.4 °C

Parameters

Emissivity	0.95
Refl. temp.	20 °C

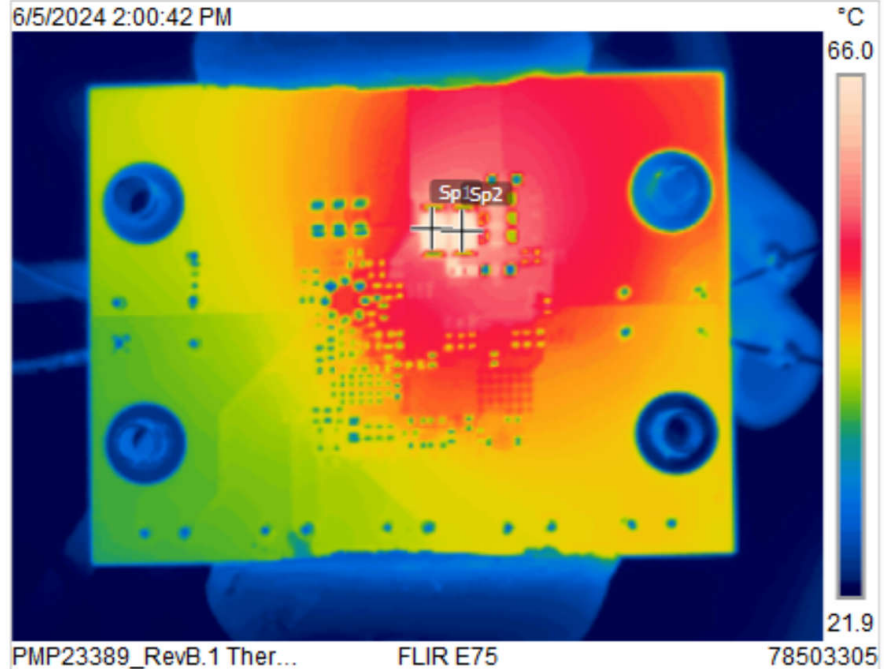


Figure 2-4. Bottom View, 12V Input

2.4 Bode Plots

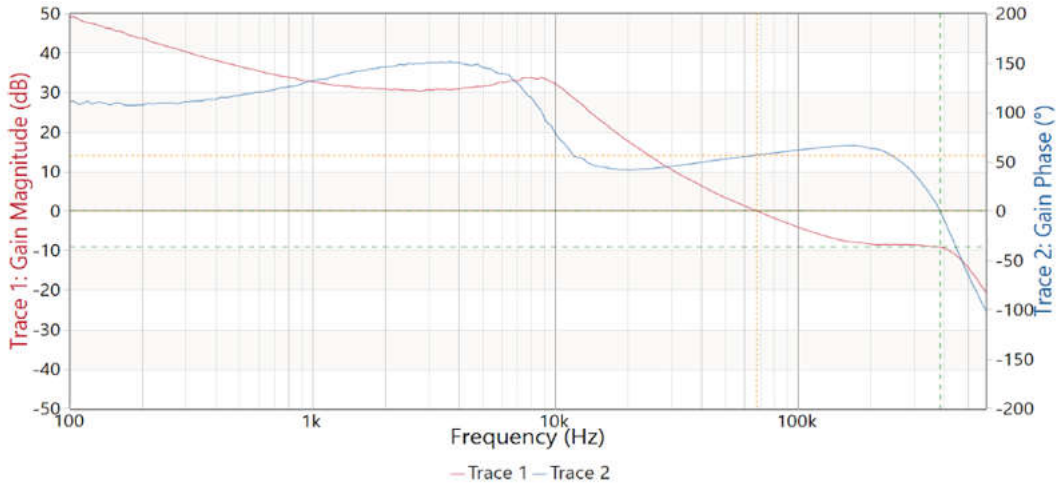


Figure 2-5. 12V Input, 5.1V, 15A Output; Bandwidth = 68kHz, Phase Margin = 56.5 Degrees, Gain Margin = 9.2dB

3 Waveforms

3.1 Switching

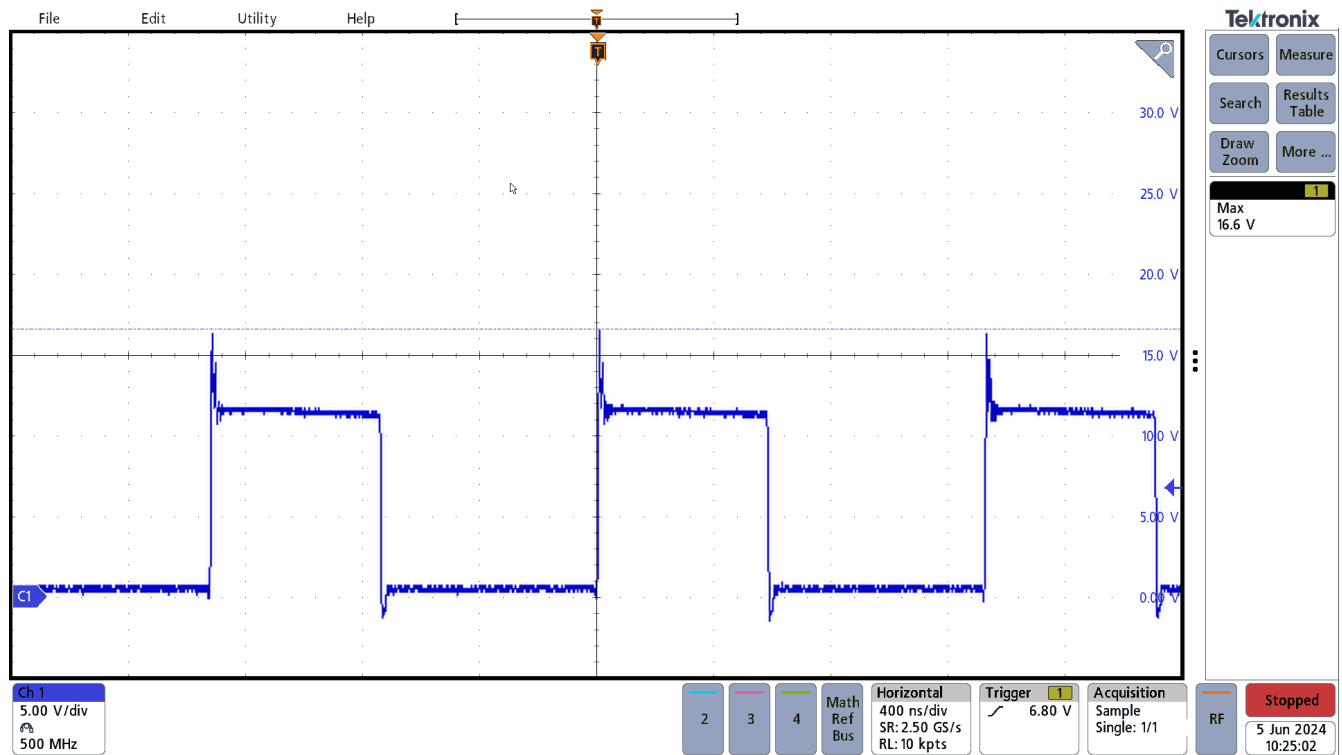


Figure 3-1. Switch-node (Q2 drain to GND), 12V Input, 15A Load

3.2 Voltage Ripple

Output voltage ripple taken across C10 and input voltage ripple taken across J2 with 330 μ F/25V aluminum capacitor across input.

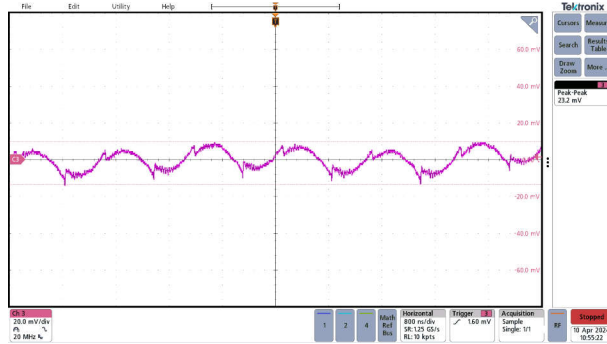


Figure 3-2. Output Voltage Ripple (AC Coupled) With 12V input and 15A Load; Measured 23.2mV Peak to Peak

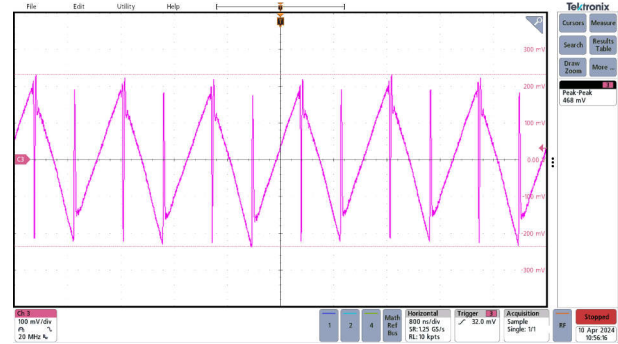


Figure 3-3. Input Voltage Ripple (AC Coupled) With 12V Input and 15A Load; Measured 468mV Peak to Peak

3.3 Short-Circuit Protection

Output across J4 was shorted momentarily to illustrate that short-circuit protection functions effectively and the output voltage returns to the steady state value. The short-circuit protection is provided by the FAULT pin of the TPS7H5002-SP, which is optional. Ch 1: Output voltage, 1V/div Ch 4: Output current, 20A/div

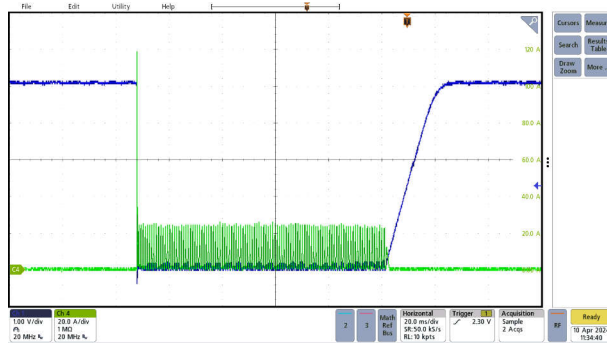


Figure 3-4. Short-Circuit Protection, 20ms/div

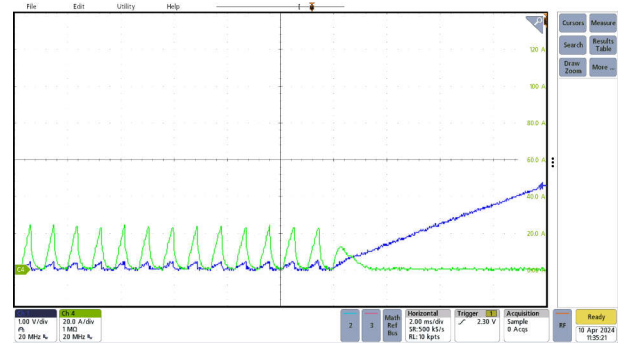


Figure 3-5. Short-Circuit Protection, Zoomed in Window, 2ms/div

3.4 Load Transients

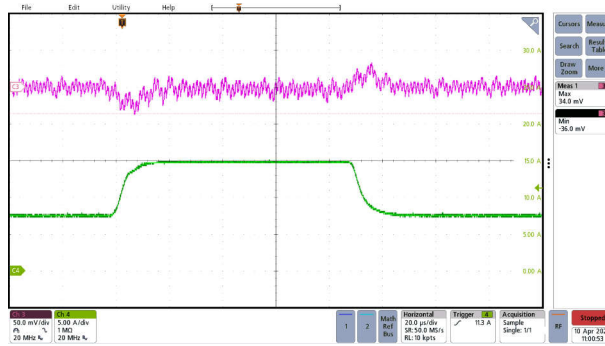


Figure 3-6. 7.5A to 15A load step; CH3: Output Voltage, AC Coupled, 50mV/div; CH4: Output Current, 5A/div

3.5 Start-up Sequence

The power supply was enabled using the ENABLE signal, TP8 to TP9.

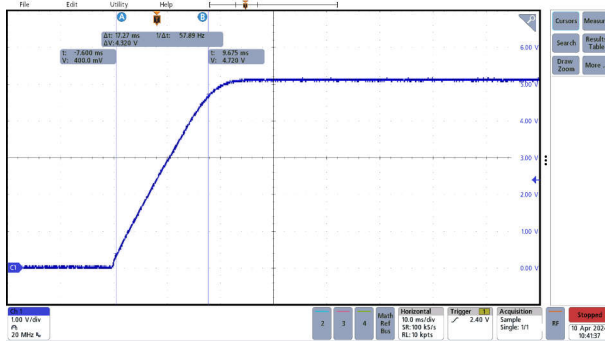


Figure 3-7. 12V Input, 5.1V Output, No Load; CH1: Output Voltage, 1V/div

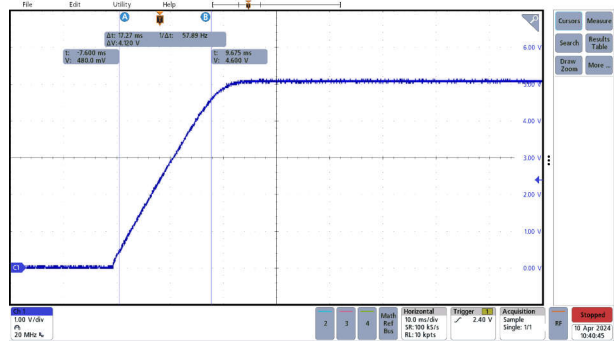


Figure 3-8. 12V Input, 5.1V Output, 15A Load; CH1: Output Voltage, 1V/div

3.6 Current Monitor Output

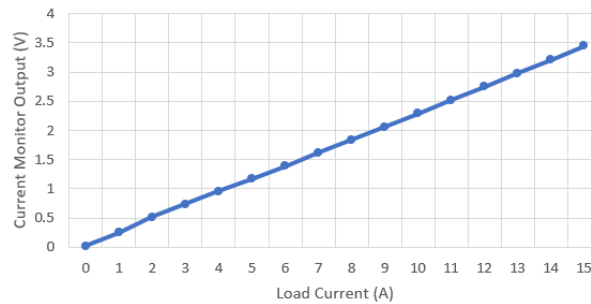


Figure 3-9. Current Monitor Output, Measured Voltage Across TP14 and TP15

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