Test Report: PMP23366

Dual-Input Redundant PoE Class 6 PD With Smooth Transition and Telemetry Reference Design

Description

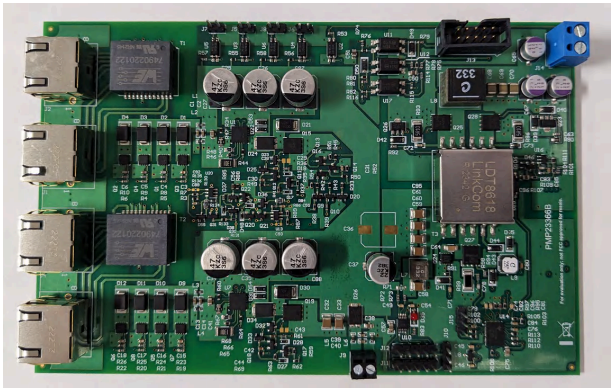
This reference design implements a Power over Ethernet (PoE) Class 6 Powered Device (PD) with dual redundant PoE inputs and smooth transition between these inputs and an auxiliary input. Three power sources decrease the probability of power and data loss in equipment. The auxiliary input has priority. PoE Port 1 has priority over PoE Port 2 when the auxiliary is not connected. Telemetry (input current, voltage, and power) is provided via I2C using an INA237A. Two TPS2373-3 PD controllers interface with a Power Source Equipment (PSE) on ports 1 and 2. A 5V, 9A active clamp forward converter is implemented with the PWM portion of a TPS23734 PD, PWM controller integrated circuit (IC).

Features

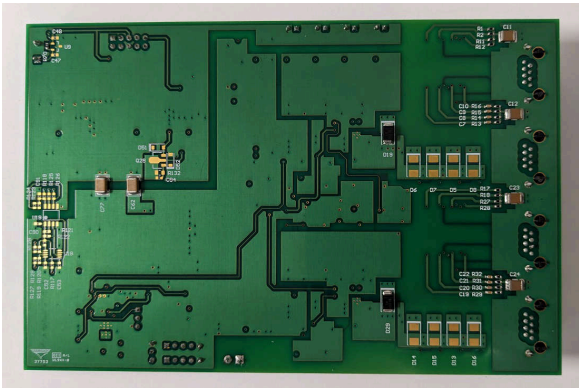
- Dual redundant PoE inputs plus auxiliary 48V input
- Smooth transition between all inputs
- PoE Port 1 priority over PoE Port 2
- Auxiliary priority over either PoE Port
- Telemetry for input voltage, current, and power through I2C
- 88% efficiency from PoE input; 90% efficiency from auxiliary input

Applications

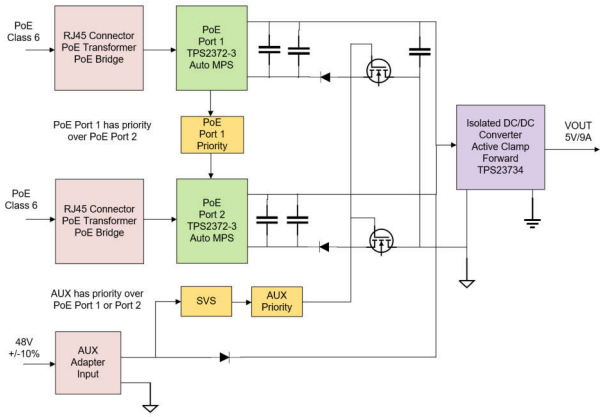
- WLAN, Wi-Fi access point
- Occupancy detection (people tracking, people counting)
- IP network camera



Top of Board



Bottom of Board



Block Diagram

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
PoE input voltage	42.5–57VDC
Auxiliary input voltage	48VDC ±10%
Output voltage	5VDC
Output current	9ADC maximum
Switching frequency	250kHz

1.2 Required Equipment

- Two IEEE802.3bt Type 3 PSE Ports
- Isolated wall adapter, 48VDC, 1.5A minimum
- 5VDC, 10ADC active load
- USB2ANY interface adapter
- USB2ANY-Explorer GUI

1.3 Considerations

The following conditions pertain to the testing of this design:

- All testing was performed with a 9ADC load, unless otherwise specified.
- Auxiliary input is 48VDC, unless otherwise specified.
- PoE inputs are typically 55–57VDC.
- All testing performed at 25°C ambient temperature, unless otherwise specified.

1.4 Dimensions

The PCB is 108mm × 165mm.

2 Testing and Results

2.1 Efficiency Graphs

The efficiency is shown in the following graph.

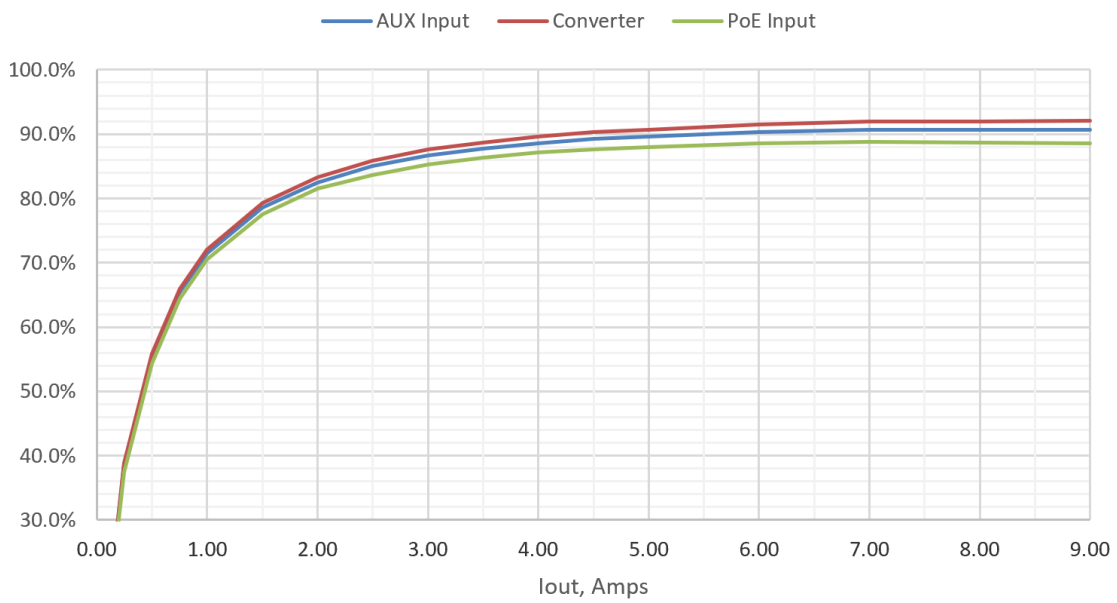


Figure 2-1. Efficiency Graph

2.2 Efficiency Data

Efficiency data is shown in the following table.

AUX, J9	AUX, J9	J14	J14	AUX	Converter	Converter	PoE, J1	PoE, J1	PoE
V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	Efficiency (%)	V_{IN} (V)	Efficiency (%)	V_{IN} (V)	I_{IN} (A)	Efficiency (%)
48.02	0.043	5.111	0.00	0.0	47.68	0.00	48.02	0.044	0.00
48.02	0.069	5.111	0.25	38.6	47.66	38.9	48.01	0.071	37.5
48.01	0.096	5.110	0.5	55.4	47.64	55.9	48.01	0.098	54.3
48.01	0.122	5.110	0.75	65.4	47.62	66.0	48.01	0.124	64.4
48.01	0.149	5.110	1.00	71.4	47.61	72.0	48.00	0.151	70.5
48.01	0.203	5.109	1.50	78.6	47.58	79.3	48.00	0.206	77.5
48.00	0.258	5.108	2.00	82.5	47.56	83.3	48.03	0.261	81.5
48.00	0.313	5.108	2.50	85.0	47.53	85.8	48.02	0.318	83.6
48.02	0.368	5.107	3.00	86.7	47.54	87.6	48.01	0.374	85.3
48.02	0.424	5.106	3.50	87.8	47.51	88.7	48.02	0.431	86.3
48.02	0.480	5.106	4.00	88.6	47.49	89.6	48.02	0.488	87.2
48.01	0.536	5.105	4.50	89.3	47.47	90.3	48.01	0.546	87.6
48.01	0.593	5.104	5.00	89.6	47.44	90.7	48.03	0.604	88.0
48.00	0.706	5.103	6.00	90.4	47.40	91.5	48.01	0.720	88.6
48.01	0.820	5.101	7.00	90.7	47.38	91.9	48.03	0.837	88.8
48.00	0.937	5.100	8.00	90.7	47.33	92.0	48.02	0.958	88.7
48.03	1.053	5.098	9.00	90.7	47.33	92.1	48.00	1.080	88.5

2.3 Thermal Images

Thermal images are shown in the following figures.

Measurements	
Sp1	49.4 °C
Sp2	44.6 °C
Sp3	50.6 °C
Sp4	51.1 °C
Sp5	49.9 °C
Sp6	45.2 °C
Sp7	45.3 °C
Sp8	51.1 °C
Sp9	40.9 °C
Sp10	43.5 °C
Sp11	44.2 °C
Sp12	46.1 °C
Sp13	39.0 °C
Parameters	
Emissivity	0.95
Refl. temp.	20 °C

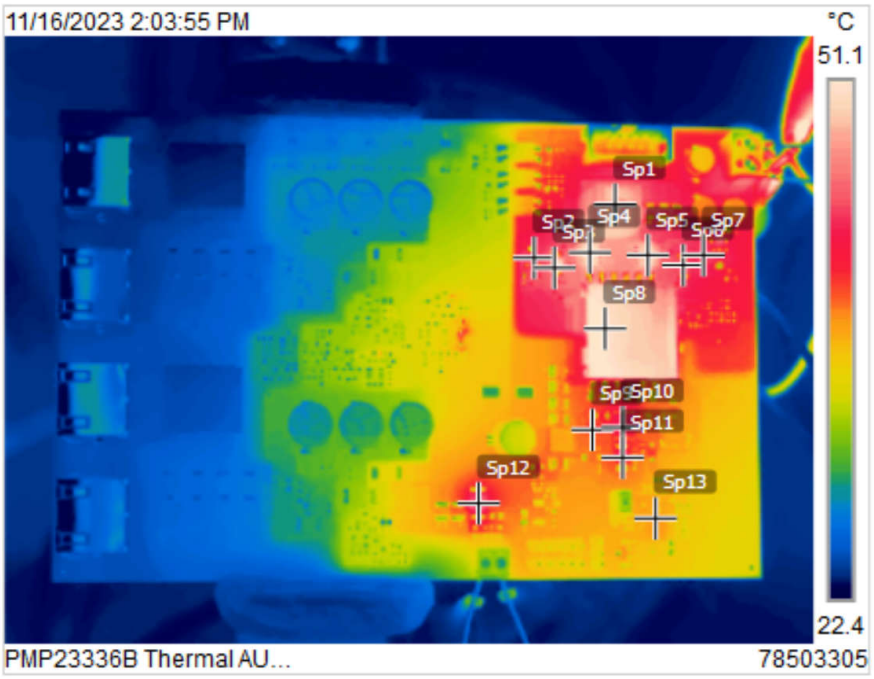


Figure 2-2. Thermal Image, Auxiliary Input, Top Side of Board

Measurements	
Sp1	48.0 °C
Sp2	45.3 °C
Sp3	51.2 °C
Sp4	51.3 °C
Sp5	50.0 °C
Sp6	45.1 °C
Sp7	43.6 °C
Sp8	51.2 °C
Sp9	39.3 °C
Sp10	42.0 °C
Sp11	43.2 °C
Sp12	37.4 °C
Sp13	52.5 °C
Sp14	56.9 °C
Sp15	56.4 °C
Sp16	52.6 °C

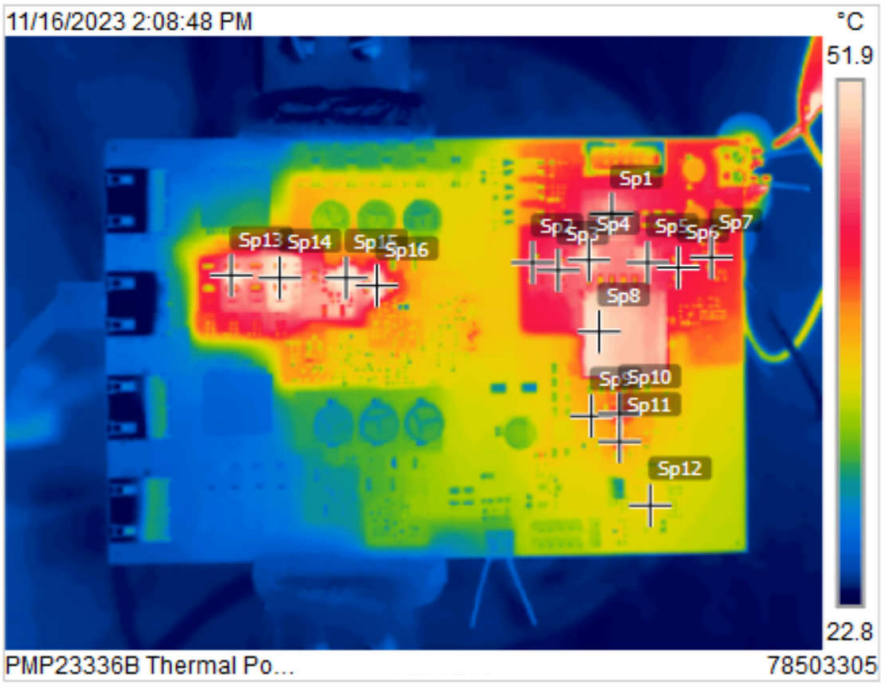
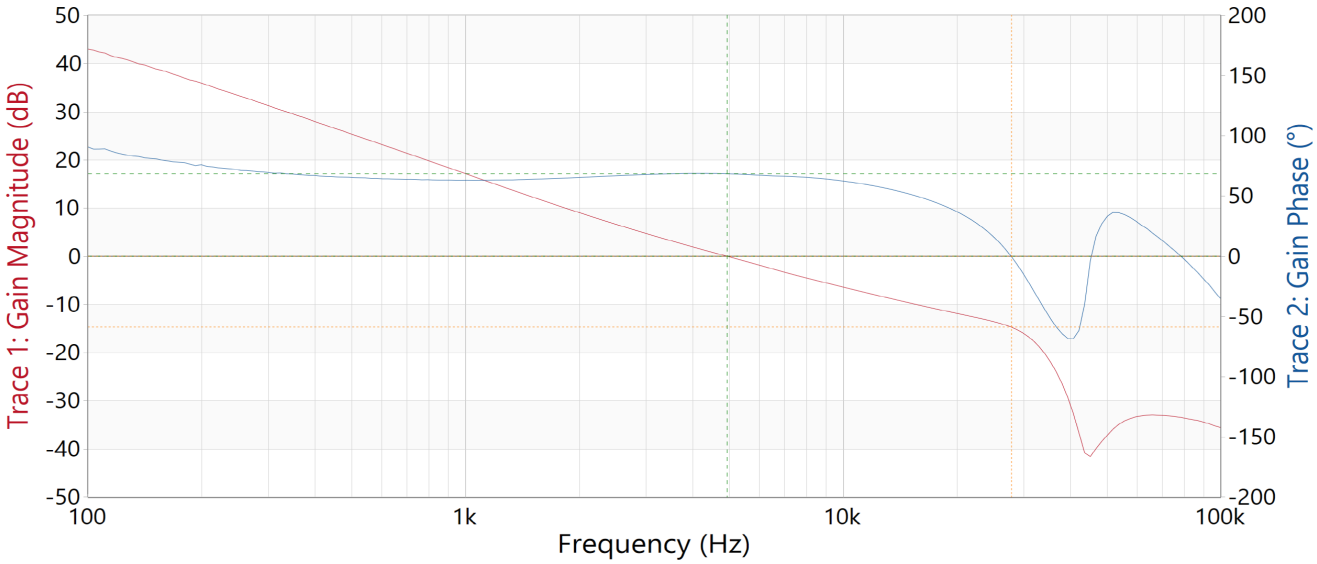


Figure 2-3. Thermal Image, PoE Port 1 Input, Top Side of Board

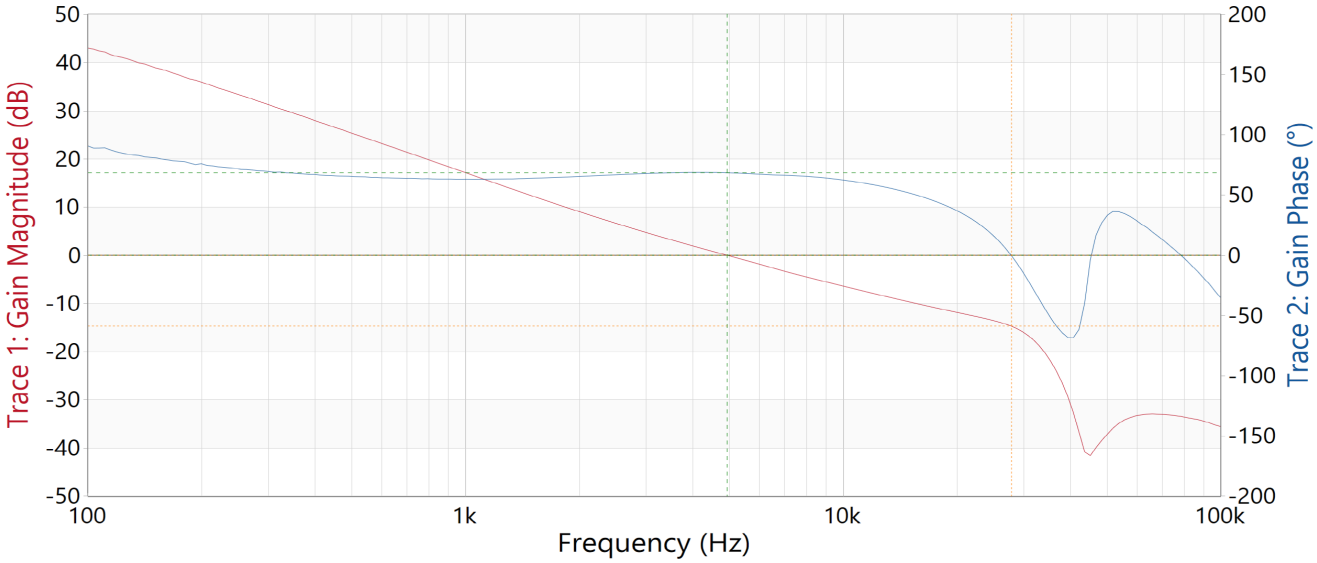
2.4 Bode Plots

Bode plots are shown in the following figures.



Bandwidth = 4.9kHz, Phase Margin = 68.5 degrees, Gain Margin = 14.6dB

Figure 2-4. Bode Plot, 0A Load Current



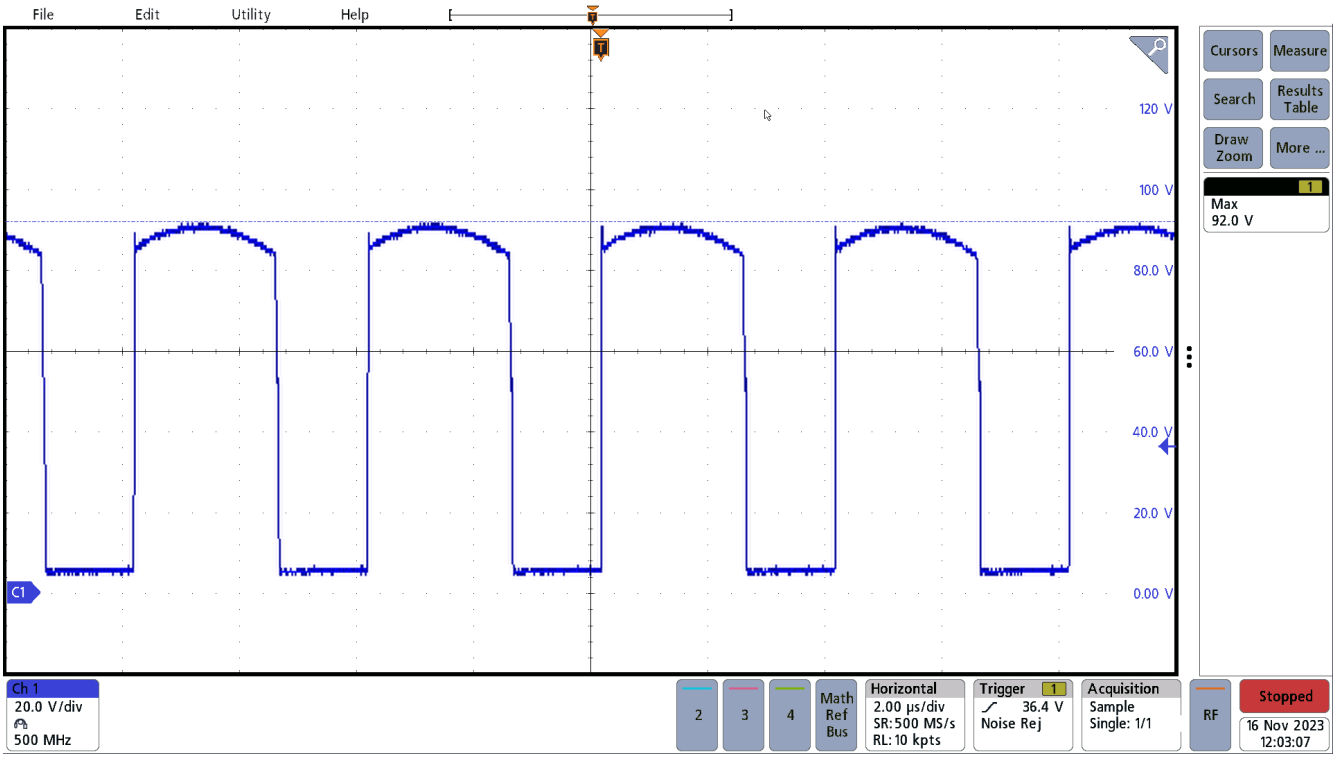
Bandwidth = 4.6kHz, Phase Margin = 69.1 degrees, Gain Margin = 15.0dB

Figure 2-5. Bode Plot, 9A Load Current

3 Waveforms

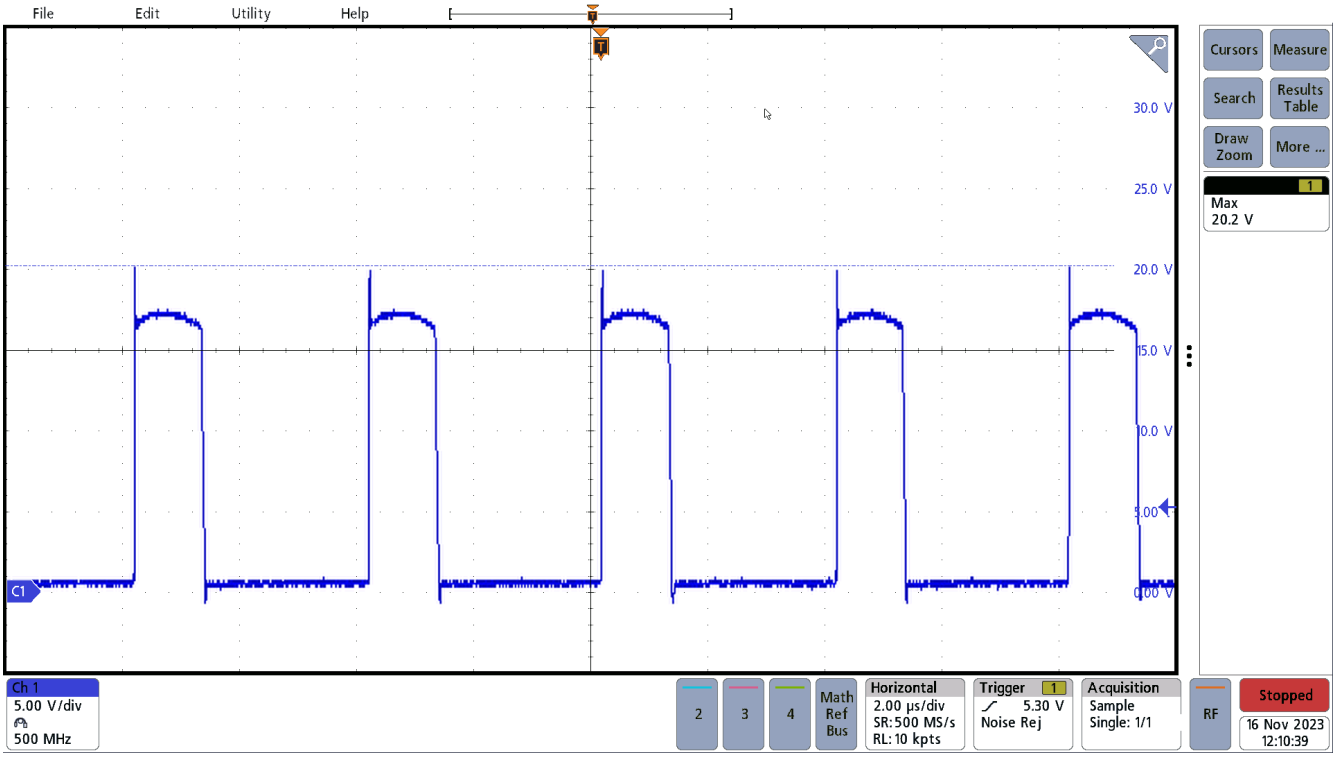
3.1 Switching Waveforms

Switching behavior is shown in the following figures.



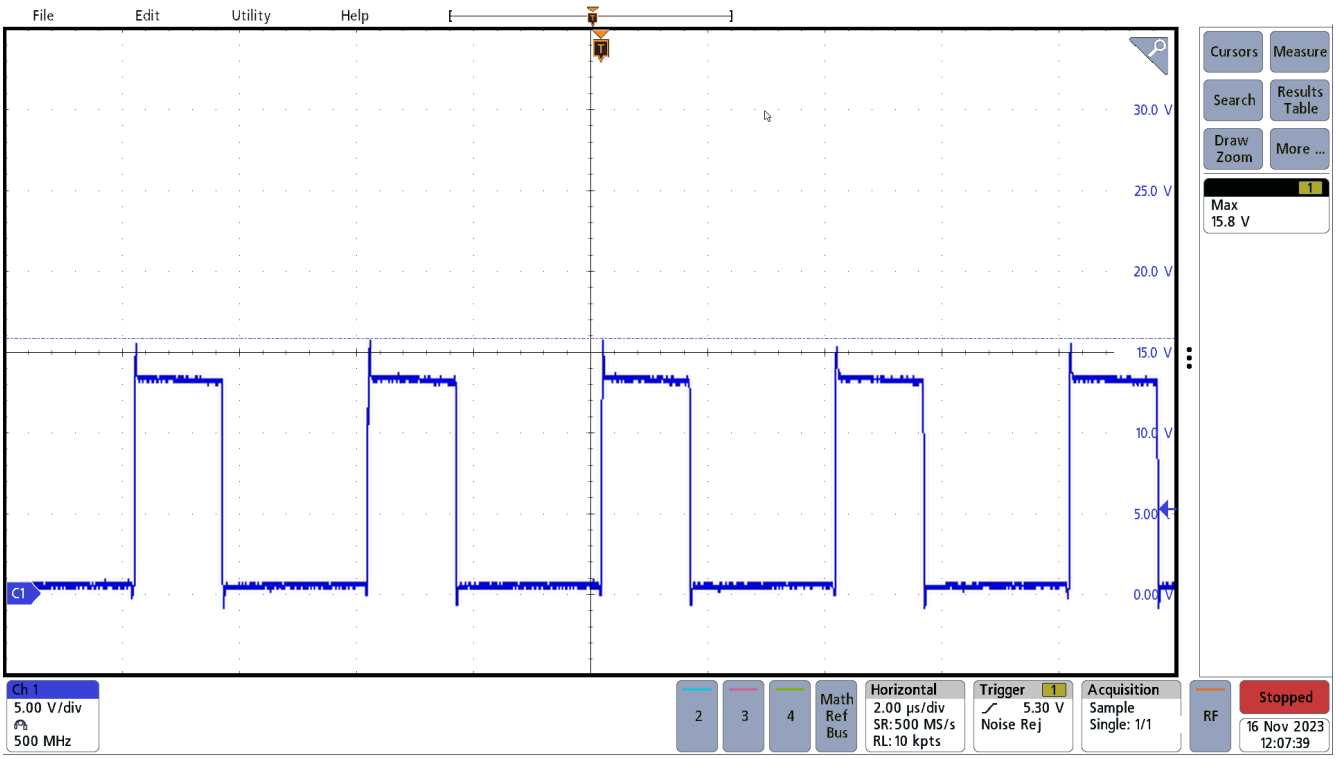
57VDC input, 20V / div, 2µs / div, measured 92.0V peak

Figure 3-1. Primary FET Q27, Drain to PGND



32VDC input, 5V / div, 2µs / div, measured 20.2V peak

Figure 3-2. Secondary Synchronous FET Q28, Drain to GND

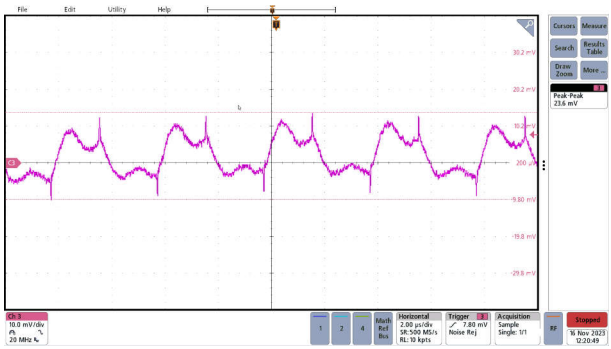


57VDC input, 5V / div, 2µs / div, measured 15.8V peak

Figure 3-3. Secondary Synchronous FET Q25, Drain to GND

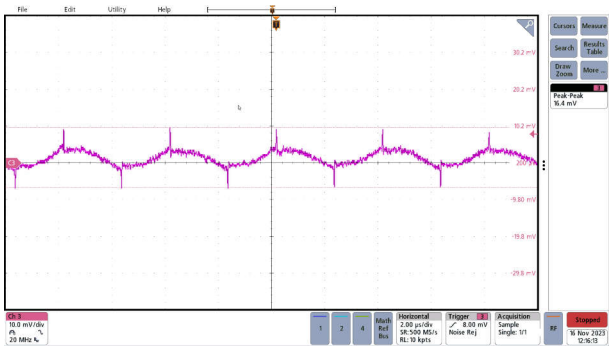
3.2 Voltage Ripple

Input and output voltage ripple is shown in the following figures.



10mV / div, 2µs / div, measured 23.6mV peak to peak across C58

Figure 3-4. Input Voltage Ripple

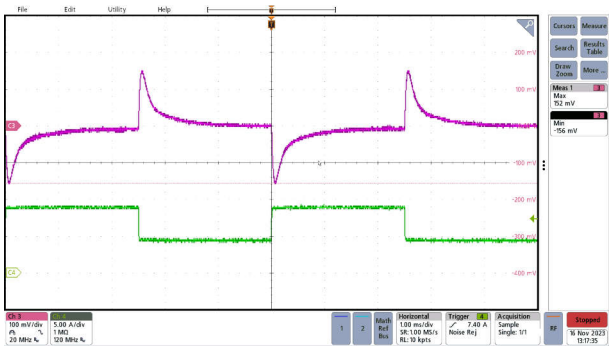


10mV / div, 2µs / div, measured 16.4mV peak to peak across J14

Figure 3-5. Output Voltage Ripple

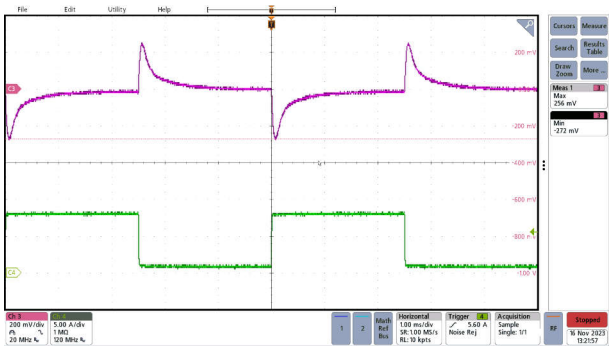
3.3 Load Transients

Load transient response is shown in the following figures.



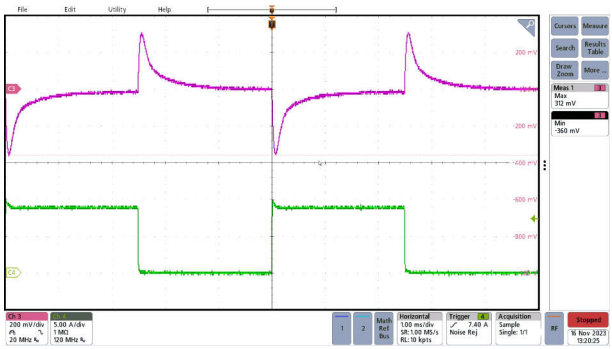
4.5A to 9A load step, 100mV / div, 5A / div, 1ms / div, measured +152mV and –156mV

Figure 3-6. Load Transient, 50% to 100%



0.9A to 8.1A load step, 200mV / div, 5A / div, 1ms / div, measured +256mV and –272mV

Figure 3-7. Load Transient, 10% to 90%

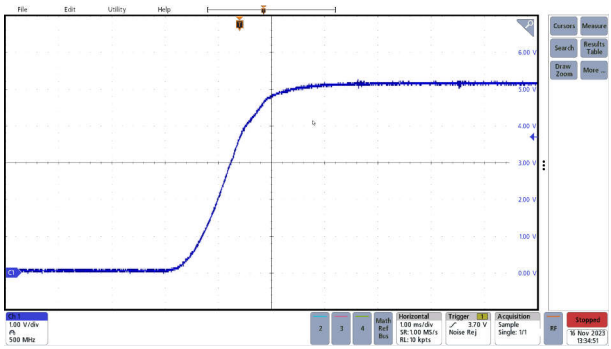


0A to 9A load step, 200mV / div, 5A / div, 1ms / div, measured +312mV and –360mV

Figure 3-8. Load Transient, 0% to 100%

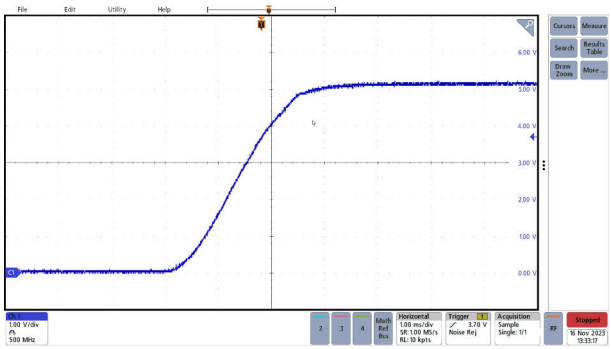
3.4 Start-Up Sequence

Start-up behavior is shown in the following figures.



Output voltage, 1V / div, 1ms / div

Figure 3-9. Start-Up, 0A Load



Output voltage, 1V / div, 1ms / div

Figure 3-10. Start-Up, 9A Load

3.5 Input Telemetry

A USB2ANY interface adapter and USB2ANY-Explorer GUI were used to measure the input voltage and current through I2C from the INA237A. The optocoupler circuit was used for the isolated interface. The BIT rate is limited to 10kHz when using the optocouplers. For higher BIT rates, the ISO1640, TCA9517A can be used for isolation of the I2C signals.

Simplified instructions for making the telemetry measurements are shown in the following list. Consult the documentation for the USB2ANY hardware and GUI for more information.

1. Open USB2ANY-Explorer
2. Click *Select Interfaces*, check *I2C* and close
3. Select the *I2C* tab
4. The INA237A Slave Address is 0x45 (both A0 and A1 pulled high by shorting J11 and J12, pins 3 and 4, on the PMP22366 board)
5. BIT rate is 10kHz
6. *Bus Timeout* is 10ms
7. Entering Internal Address (HEX) of 04 and clicking *Read* provides the input current in HEX
8. Entering Internal Address (HEX) of 05 and clicking *Read* provides the input voltage in HEX
9. The INA237A decimal values in Table 3-1 are converted from the HEX measurements provided by the INA237A. Microsoft® Excel® has a HEX-to-decimal conversion function
10. The actual input voltage was measured with a DMM across C57
11. The actual input current was measured as the voltage across R71 divided by 0.1Ω

Table 3-1. Input Telemetry From INA237A I2C vs Actual Circuit Measurements

I_{OUT}, J14, Amps	V_{OUT}, J14, Volts	I_{IN}, INA237A, Amps	V_{IN}, INA237A, Volts	I_{IN}, R71, Amps	V_{IN}, C57, Volts	Error, I_{IN}, %	Error, V_{IN}, %
0.00	5.136	0.0344	55.26	0.0330	55.27	4.07	–0.02
0.25	5.136	0.0572	55.20	0.0558	55.21	2.45	–0.02
0.50	5.135	0.0789	55.15	0.0789	55.16	0.00	–0.02
0.75	5.135	0.1033	55.08	0.1020	55.10	1.26	–0.04
1.00	5.135	0.1254	55.04	0.1252	55.04	0.16	0.00
2.00	5.133	0.2219	54.86	0.2205	54.87	0.63	–0.02
3.00	5.132	0.3195	54.71	0.3182	54.72	0.41	–0.02
4.00	5.130	0.4177	54.55	0.4165	54.56	0.29	–0.02
5.00	5.128	0.5171	54.39	0.5172	54.41	–0.02	–0.04
6.00	5.127	0.6161	54.26	0.6181	54.25	–0.32	0.02
7.00	5.125	0.7212	54.11	0.7198	54.09	0.19	0.04
8.00	5.123	0.8230	53.97	0.8245	53.95	–0.18	0.04
9.00	5.121	0.9283	53.82	0.9292	53.82	–0.10	0.00

3.6 Smooth Transition

The smooth transition (no output voltage interruption) is shown in Figure 3-11 through Figure 3-28. For all waveforms:

1. Channel 1 is output voltage, 1V / div
2. Channel 2 is PoE Port 1 input current, 500mA / div
3. Channel 4 is PoE Port2 input current, 500mA / div
4. The time base is 100ms / div
5. For all *Expected Results*, the output voltage remains within transient limits
6. Standby indicates that the PoE PD MPS (maintain power signature) is active

Table 3-2. Transitions Between Two PoE Inputs

Case	Initial State	Transition	Expected Result
1	PoE Port 1 connected	Add PoE Port 2	PoE Port 1 continues to power converter. PoE Port 2 connects in standby
2	PoE Port 2 connected	Add PoE Port 1	Power transitions to PoE Port 1. PoE Port 2 stays connected in standby.
3	PoE Port 1 and Port 2 connected. PoE Port 1 powers converter. PoE Port 2 connected in standby.	Remove PoE Port 1	Power transitions to PoE Port 2
4	PoE Port 1 and Port 2 connected. PoE Port 1 powers converter, PoE Port 2 connected in standby.	Remove PoE Port 2	PoE Port 1 continues to power converter

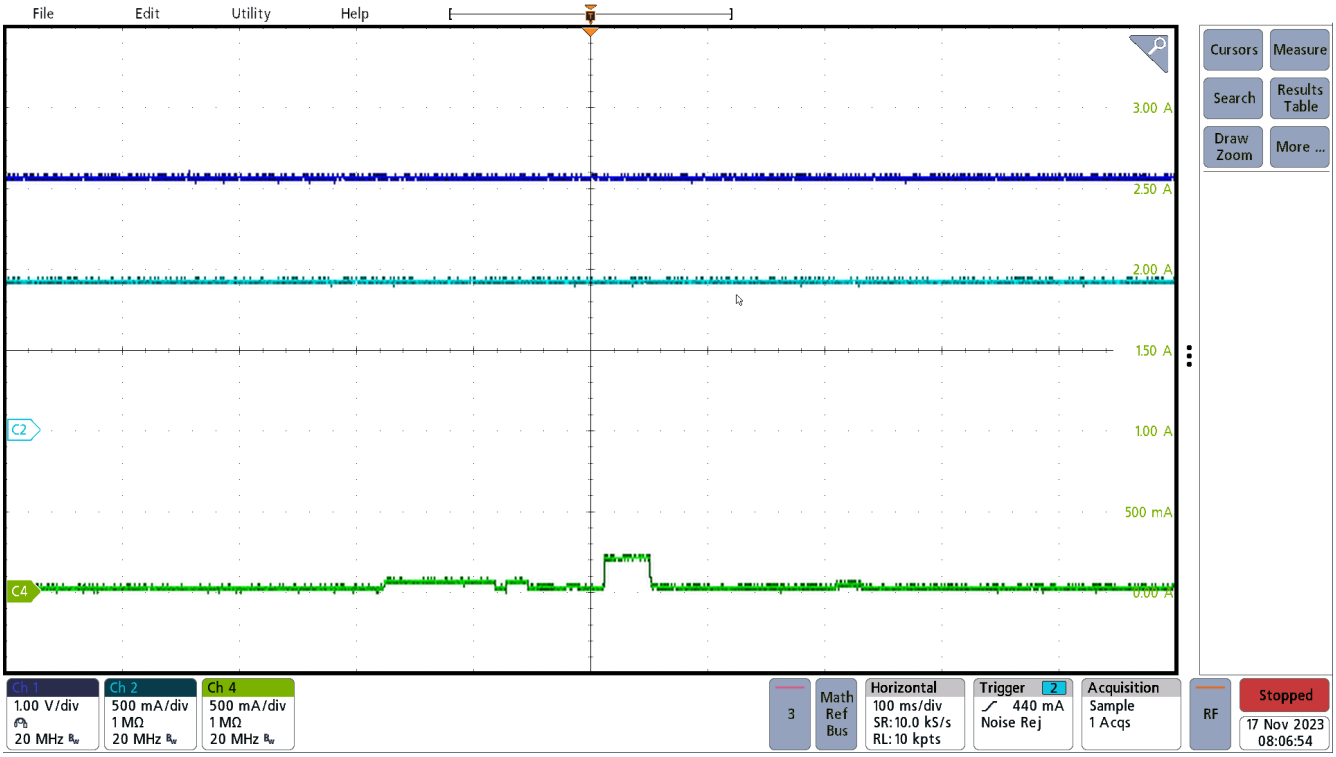


Figure 3-11. Case 1

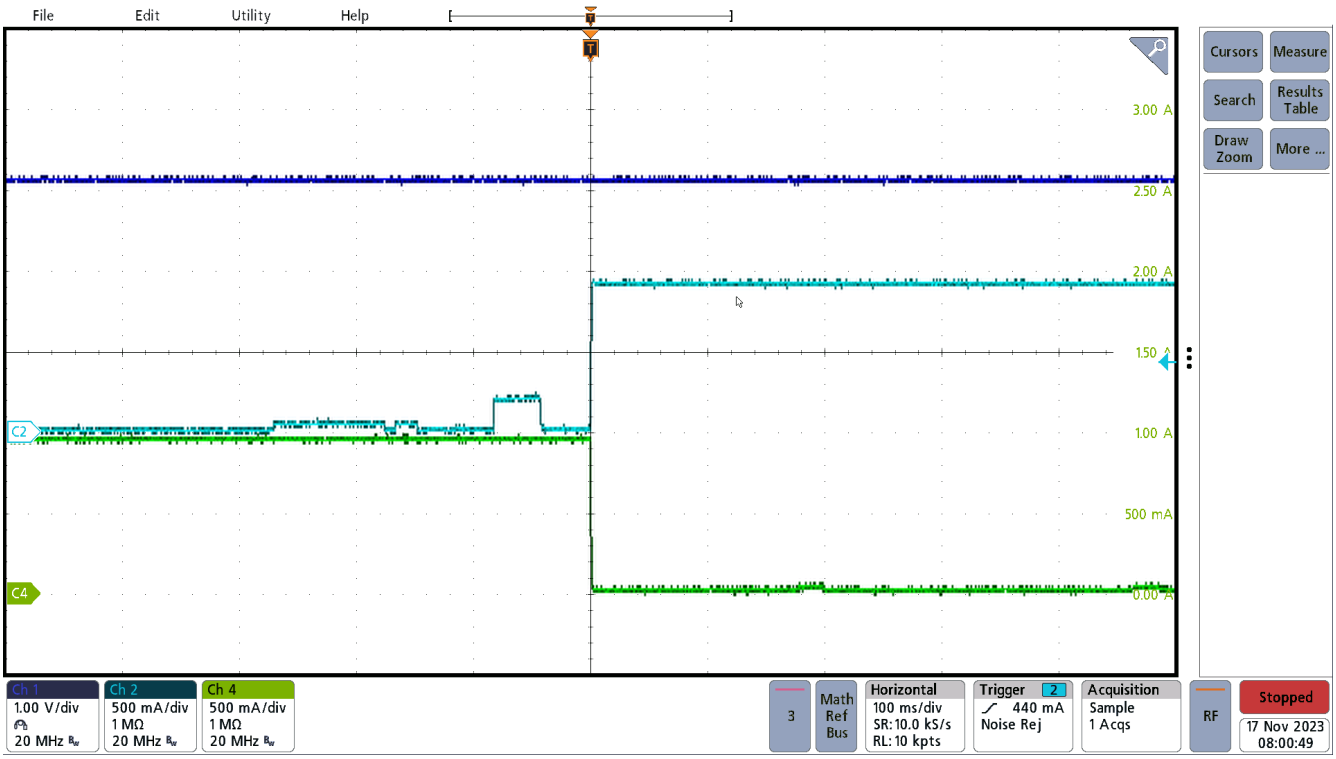


Figure 3-12. Case 2

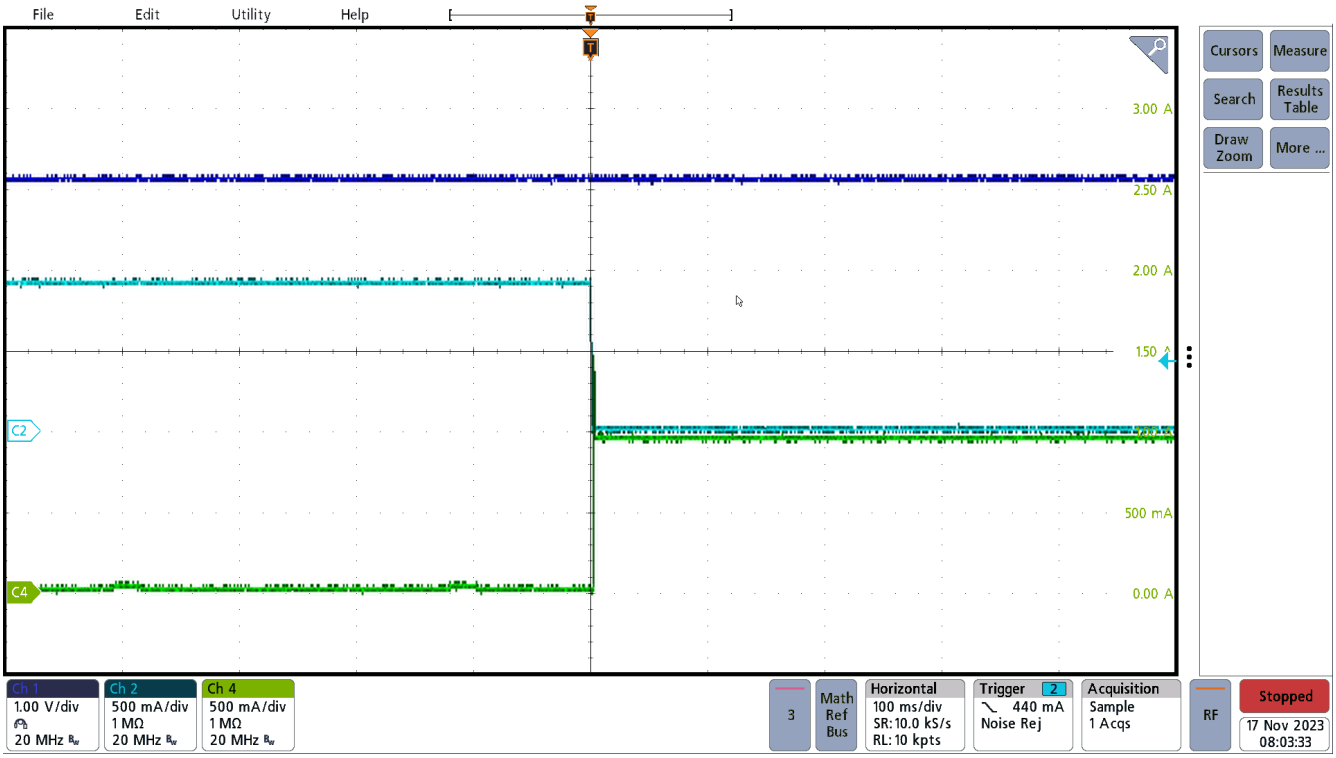


Figure 3-13. Case 3

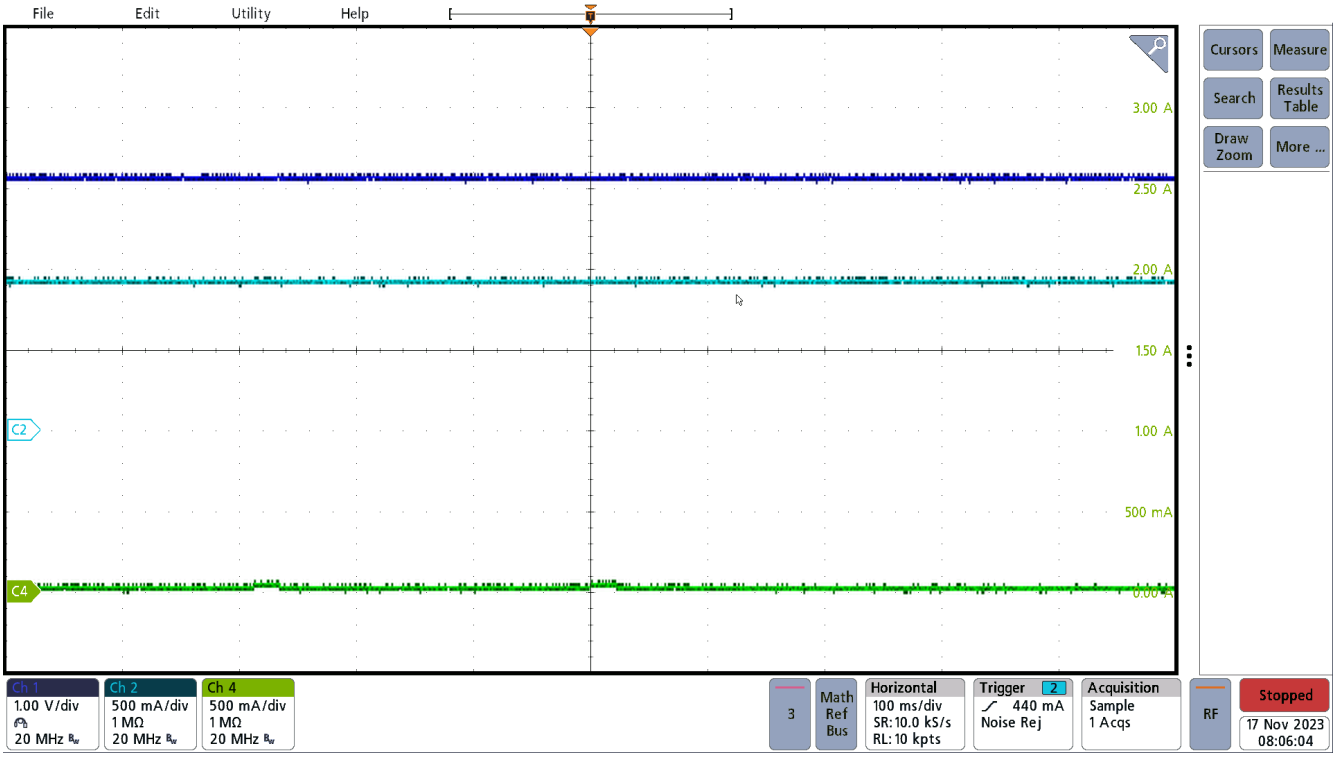


Figure 3-14. Case 4

Table 3-3. Transitions Between Single PoE Input and Auxiliary

Case	Initial State	Transition	Expected Result
5	PoE Port 1 connected	Add auxiliary	Auxiliary provides power. PoE Port 1 stays connected in standby.
6	PoE Port 2 connected	Add auxiliary	Auxiliary provides power. PoE Port 2 stays connected in standby.
7	Auxiliary connected	Add PoE Port 1	Auxiliary continues to provide power. PoE Port 1 connects in standby.
8	Auxiliary connected	Add PoE Port 2	Auxiliary continues to provide power. PoE Port 2 connects in standby.
9	PoE Port 1 and auxiliary connected	Remove auxiliary	Power transitions to PoE Port 1
10	PoE Port 1 and auxiliary connected	Remove PoE Port 1	Auxiliary continues to provide power.
11	PoE Port 2and auxiliary connected	Remove auxiliary	Power transitions to PoE Port 2
12	PoE Port 2and auxiliary connected	Remove PoE Port 2	Auxiliary continues to provide power.

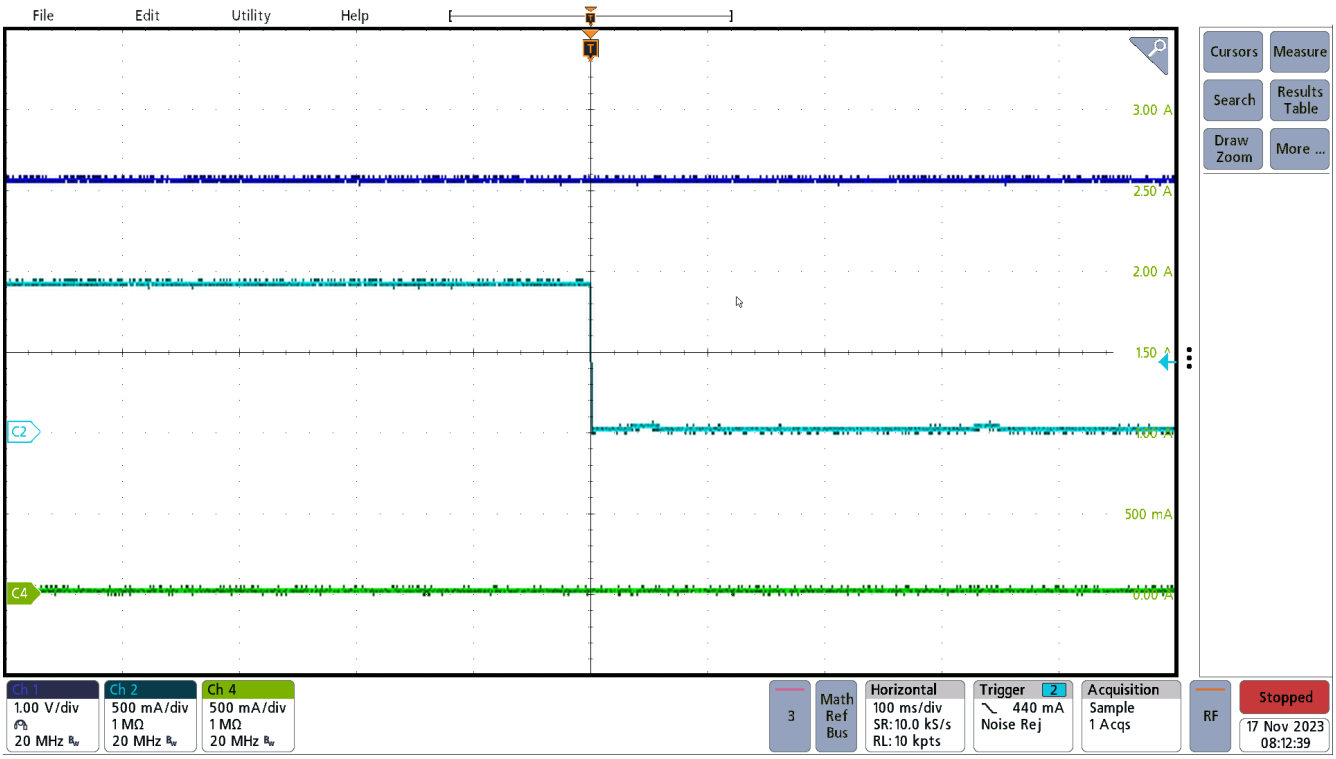


Figure 3-15. Case 5

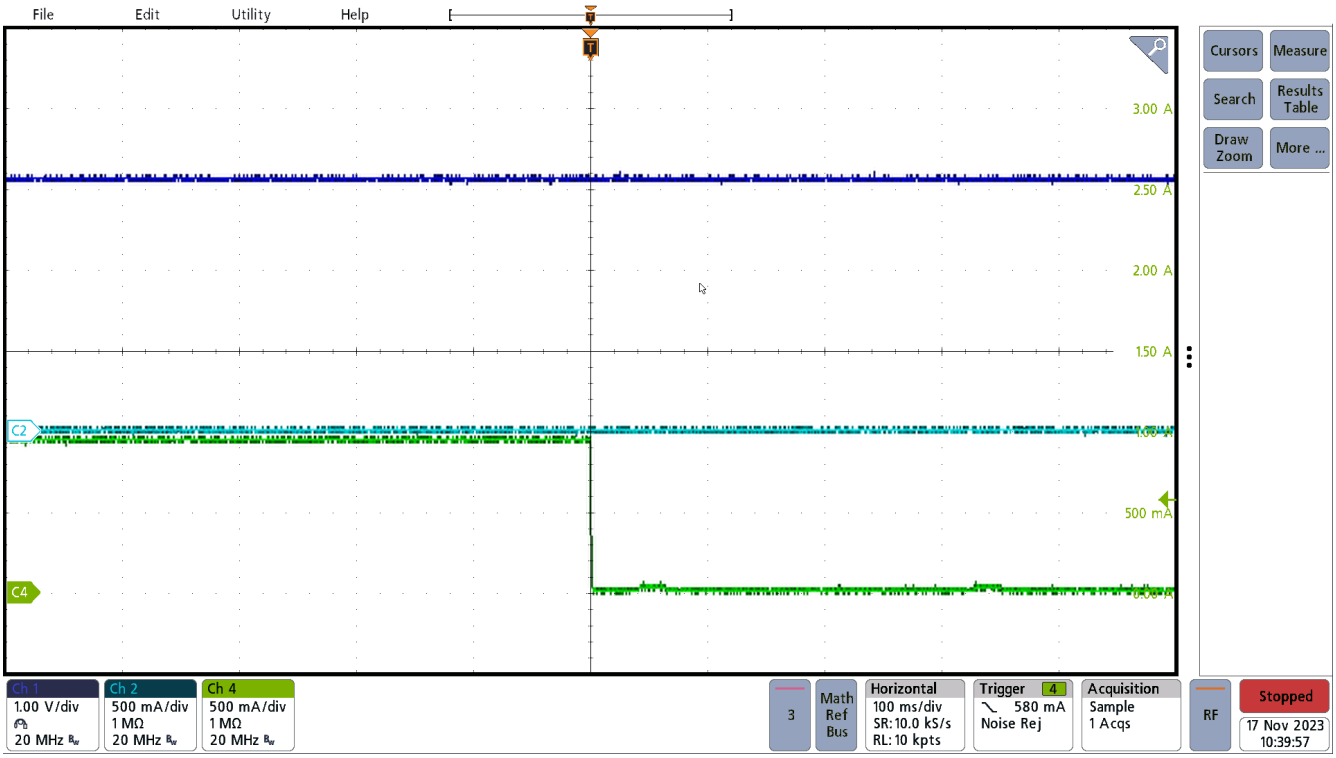


Figure 3-16. Case 6

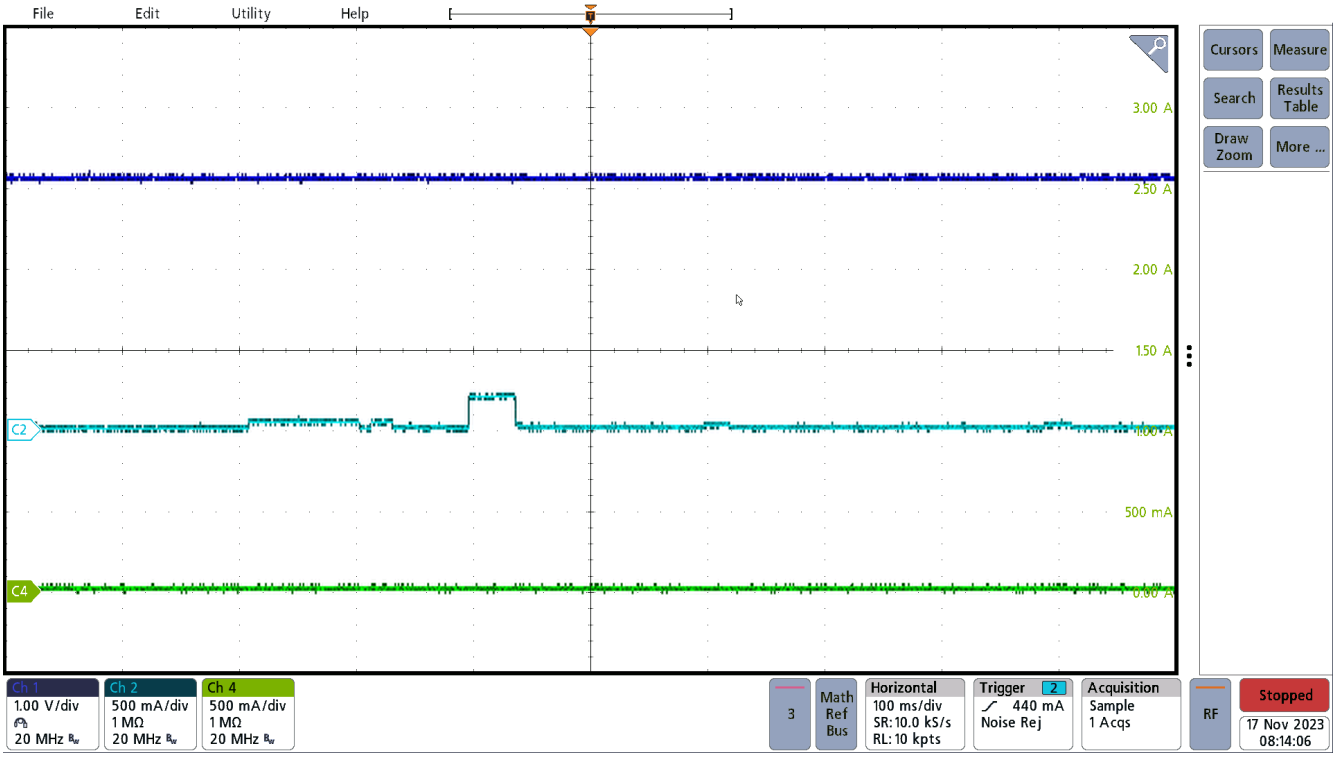


Figure 3-17. Case 7

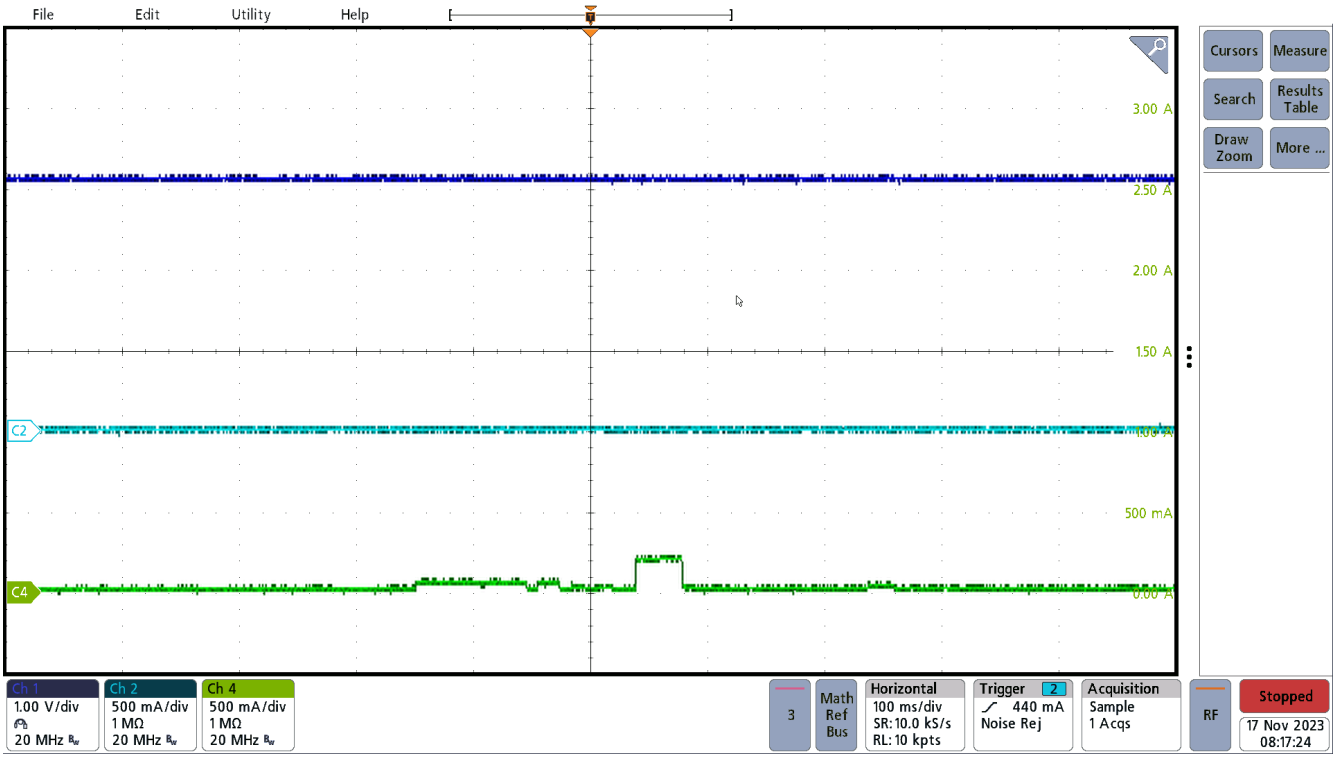


Figure 3-18. Case 8

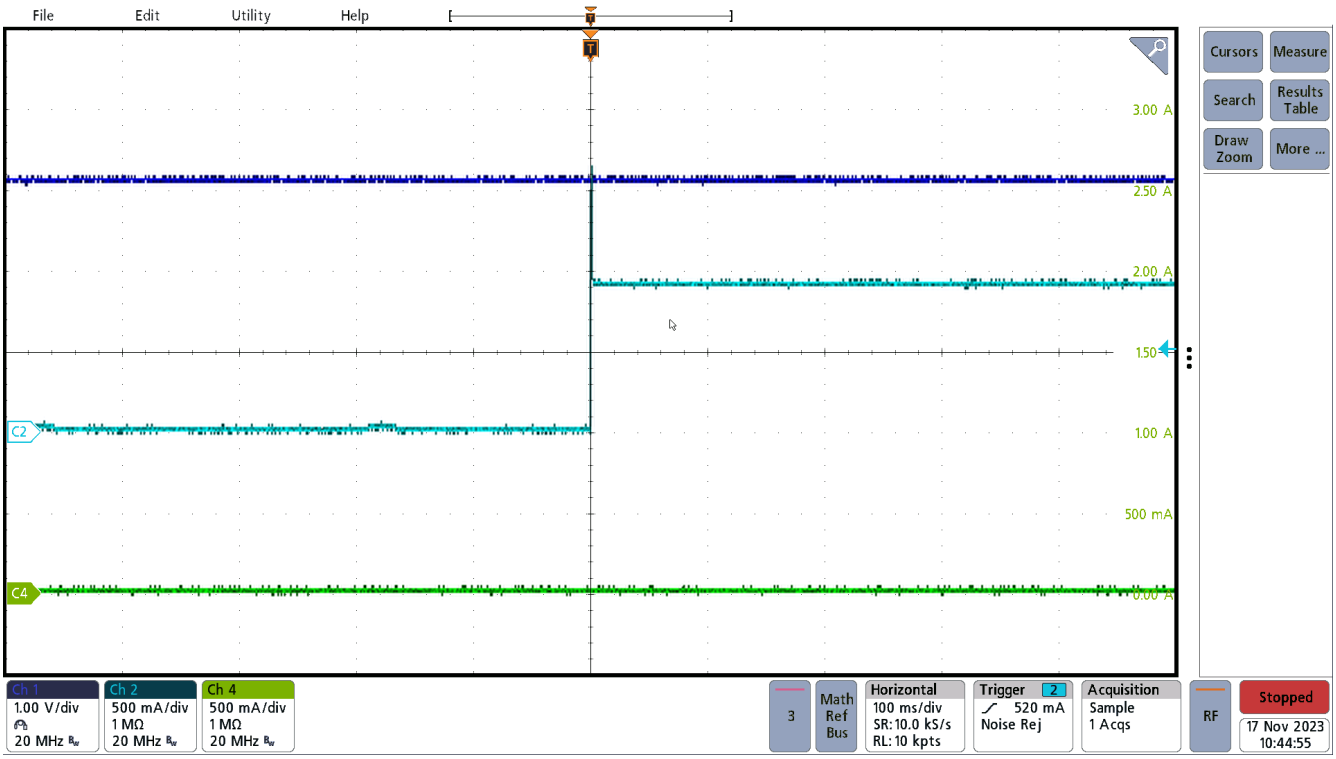


Figure 3-19. Case 9

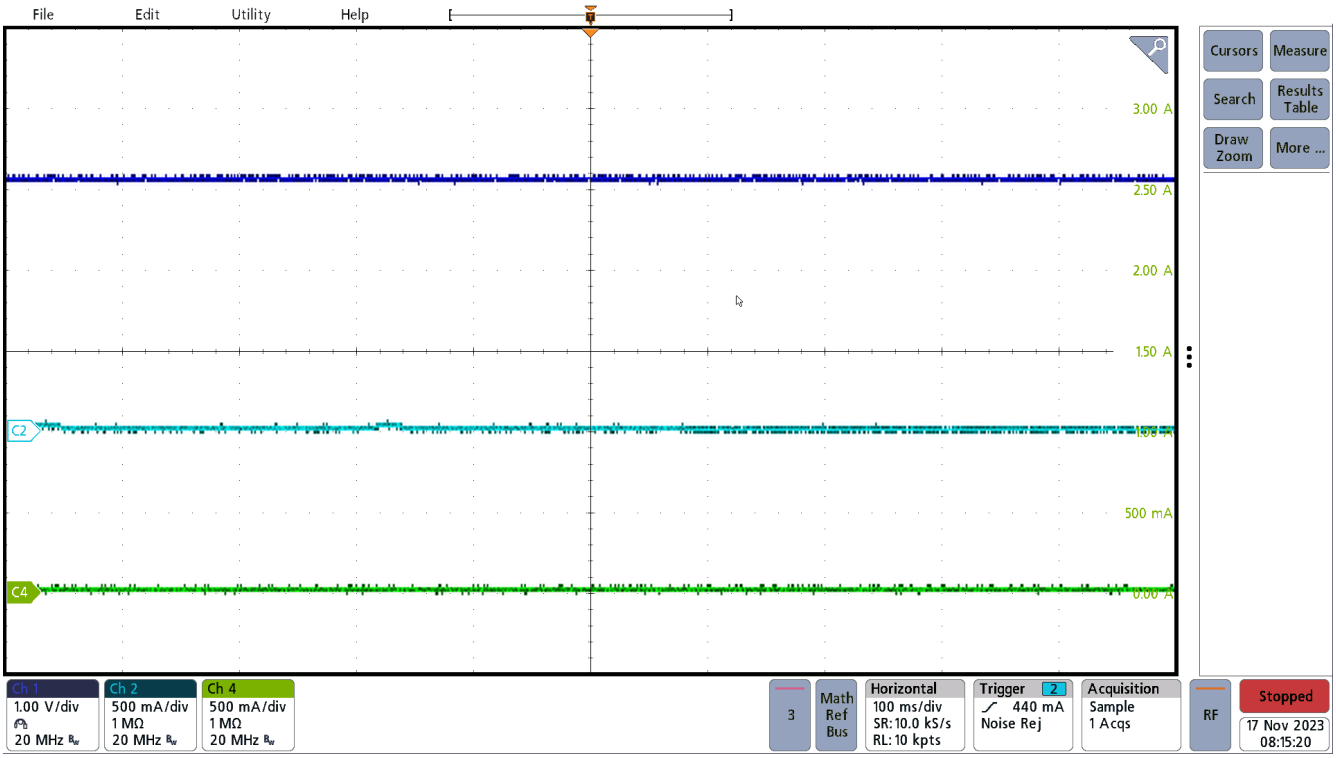


Figure 3-20. Case 10

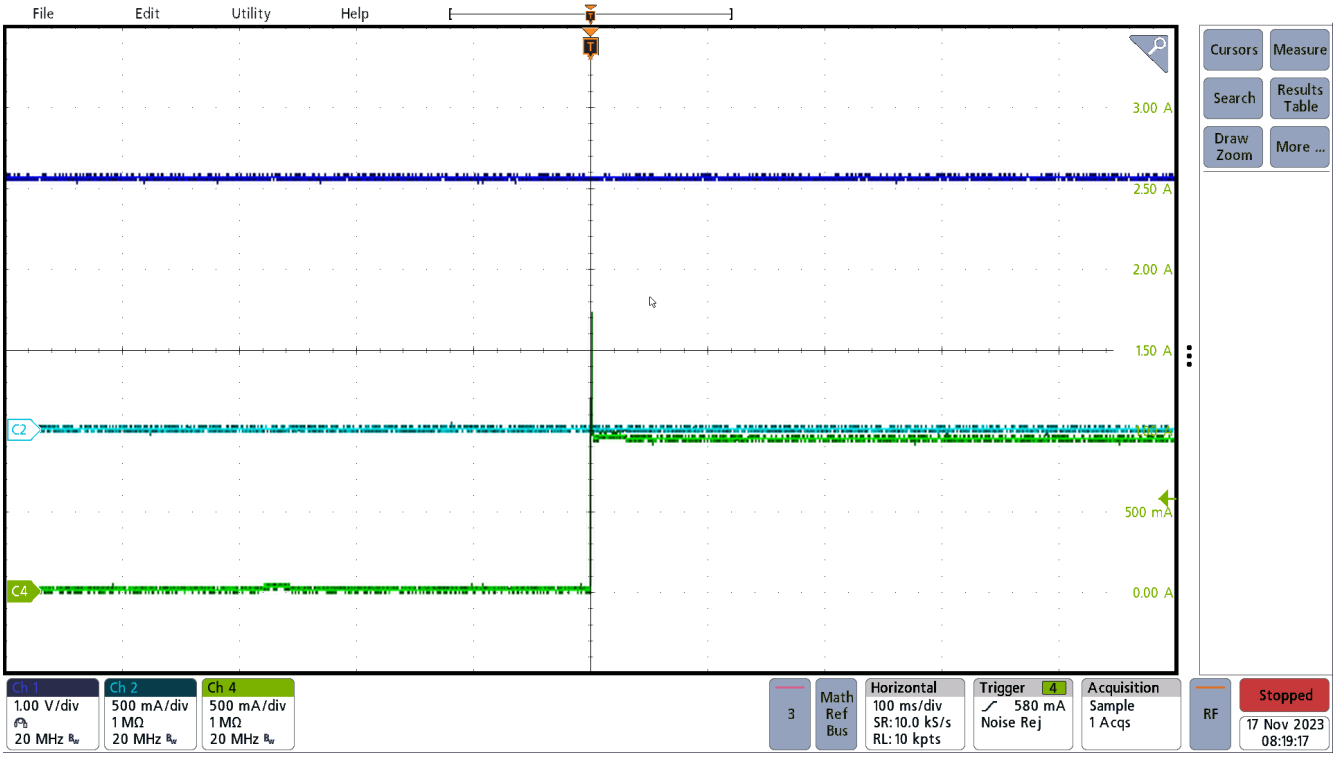


Figure 3-21. Case 11

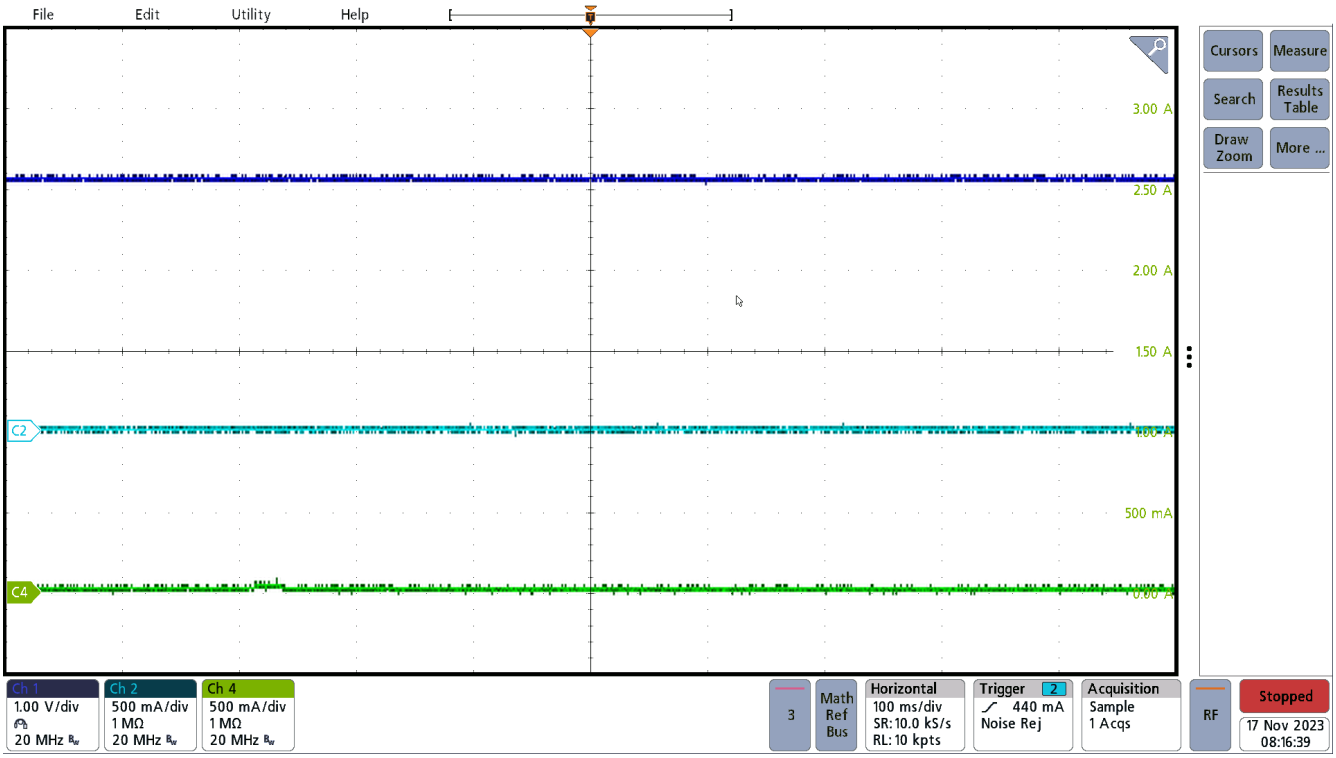


Figure 3-22. Case 12

Table 3-4. Transitions Between Dual PoE Inputs and Auxiliary

Case	Initial State	Transition	Expected Result
13	PoE Port 1, PoE Port 2 and Auxiliary connected	Remove Auxiliary	Power transitions to PoE Port 1. PoE Port 2 stays connected in standby.
14	PoE Port 1, PoE Port 2 and Auxiliary connected	Remove PoE Port 1	Auxiliary continues to provide power. PoE Port 2 stays connected in standby.
15	PoE Port 1, PoE Port 2 and Auxiliary connected	Remove PoE Port 2	Auxiliary continues to provide power. PoE Port 1 stays connected in standby.
16	PoE Port 1 and PoE Port 2 connected	Add Auxiliary	Power transitions to auxiliary. PoE Port 1 and Port 2 stay connected in standby.
17	PoE Port 1 and Auxiliary connected	Add PoE Port 2	Auxiliary continues to provide power. PoE Port 1 stays connected in standby. PoE Port 2 connects in standby.
18	PoE Port 2 and Auxiliary connected	Add PoE Port 1	Auxiliary continues to provide power. PoE Port 2 stays connected in standby. PoE Port 1 connects in standby.

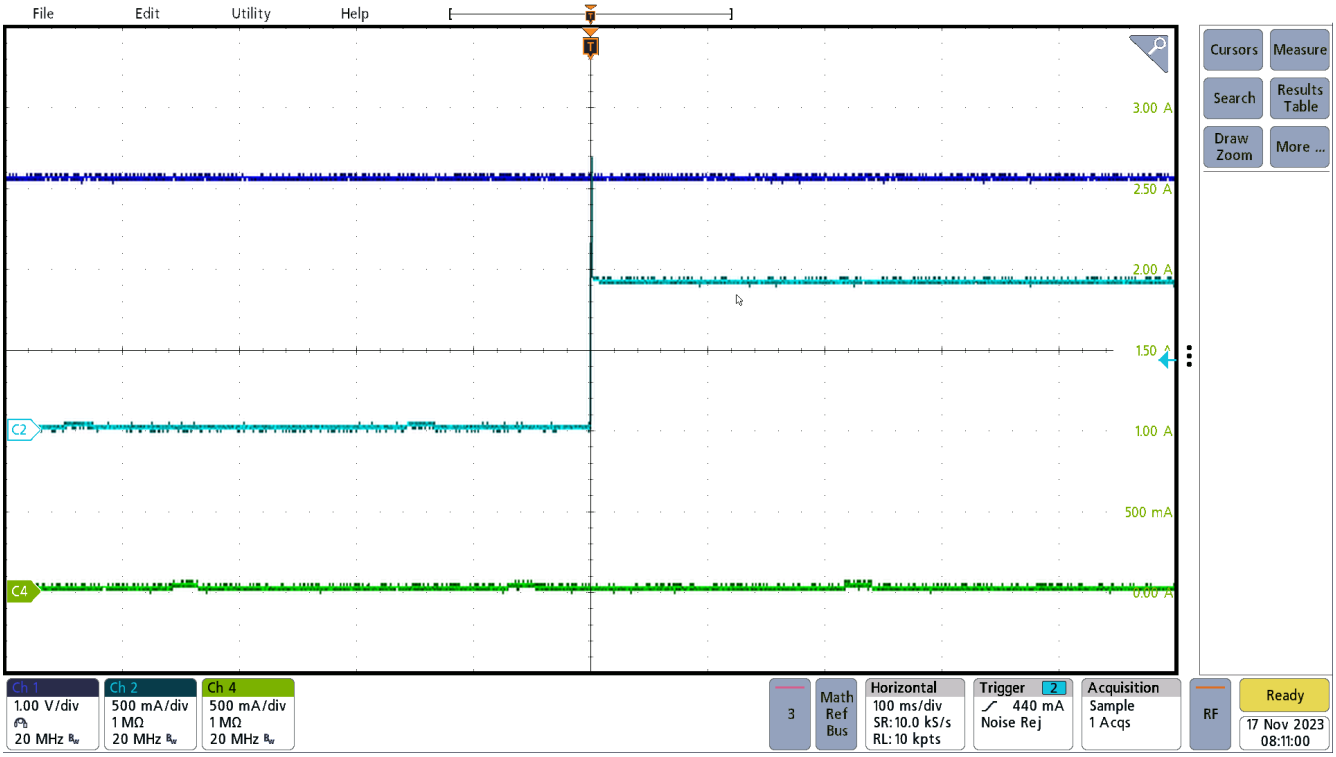


Figure 3-23. Case 13

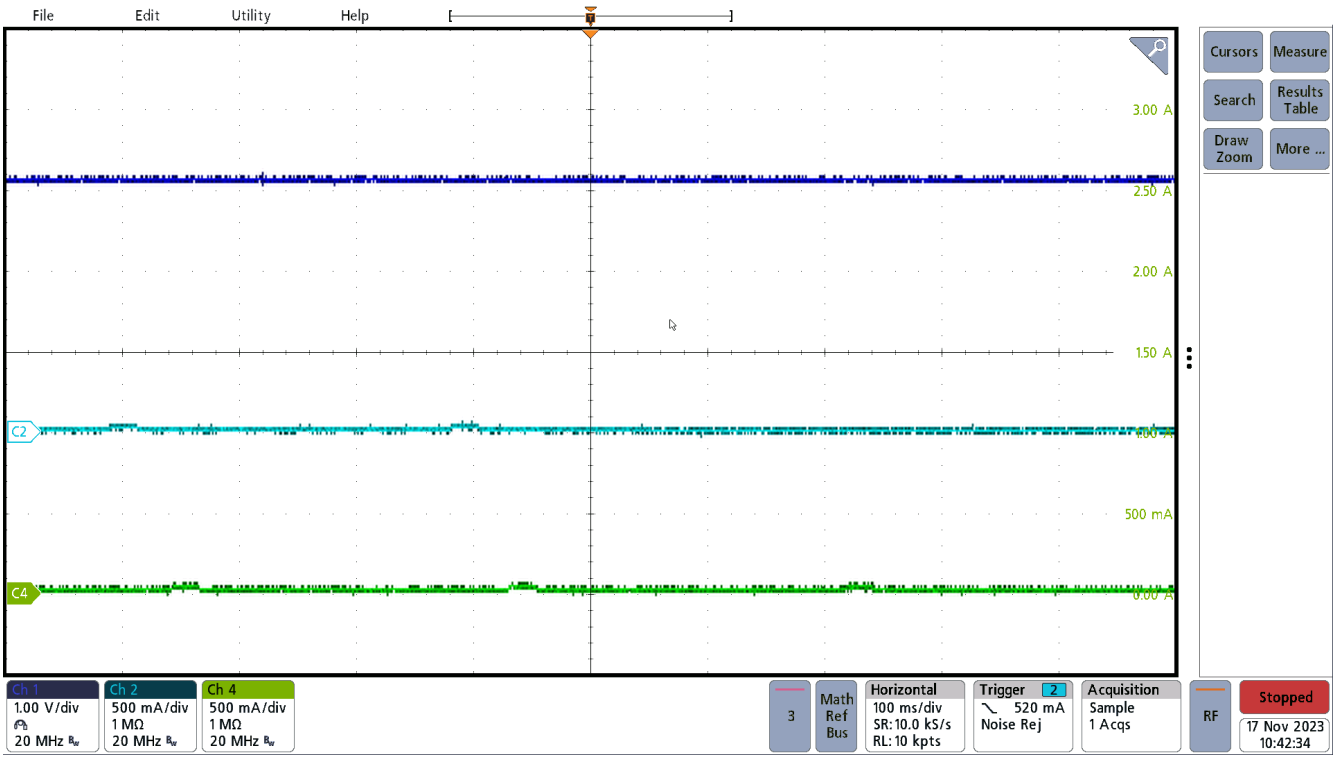


Figure 3-24. Case 14

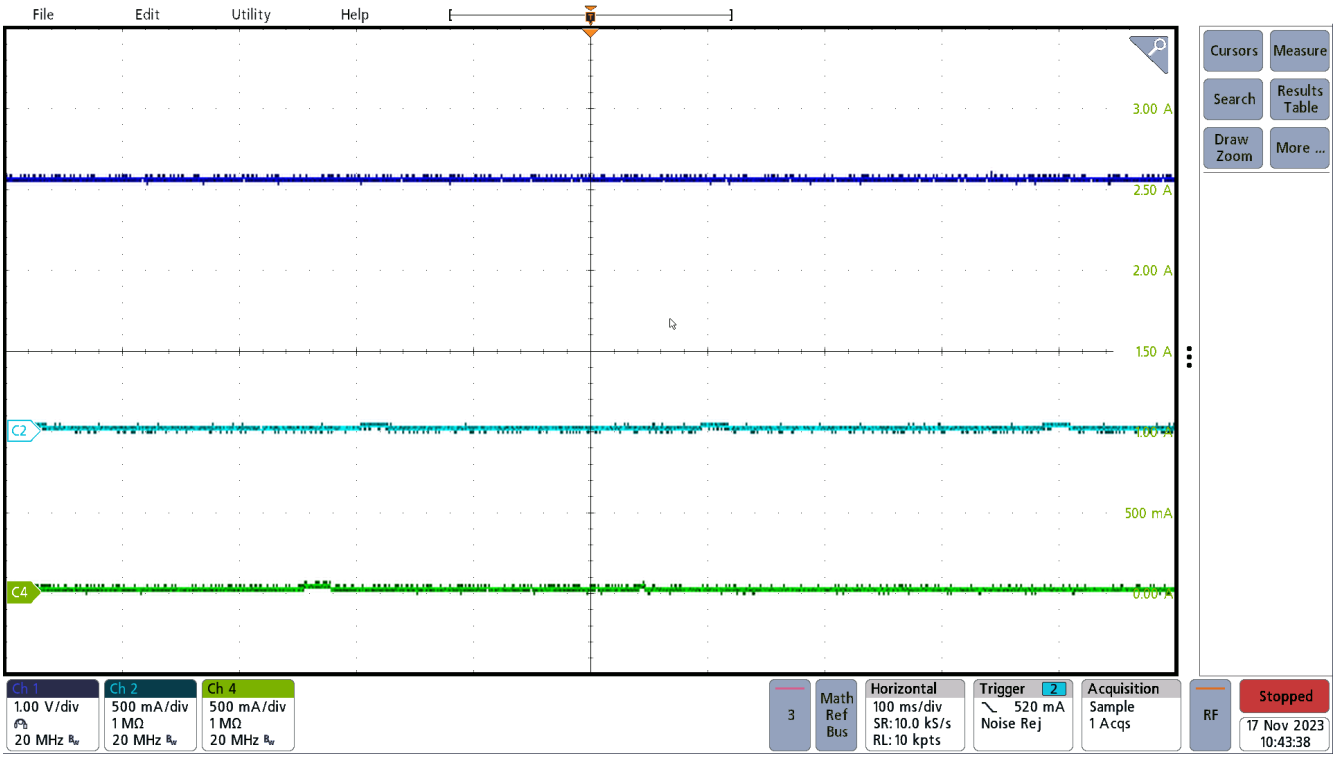


Figure 3-25. Case 15

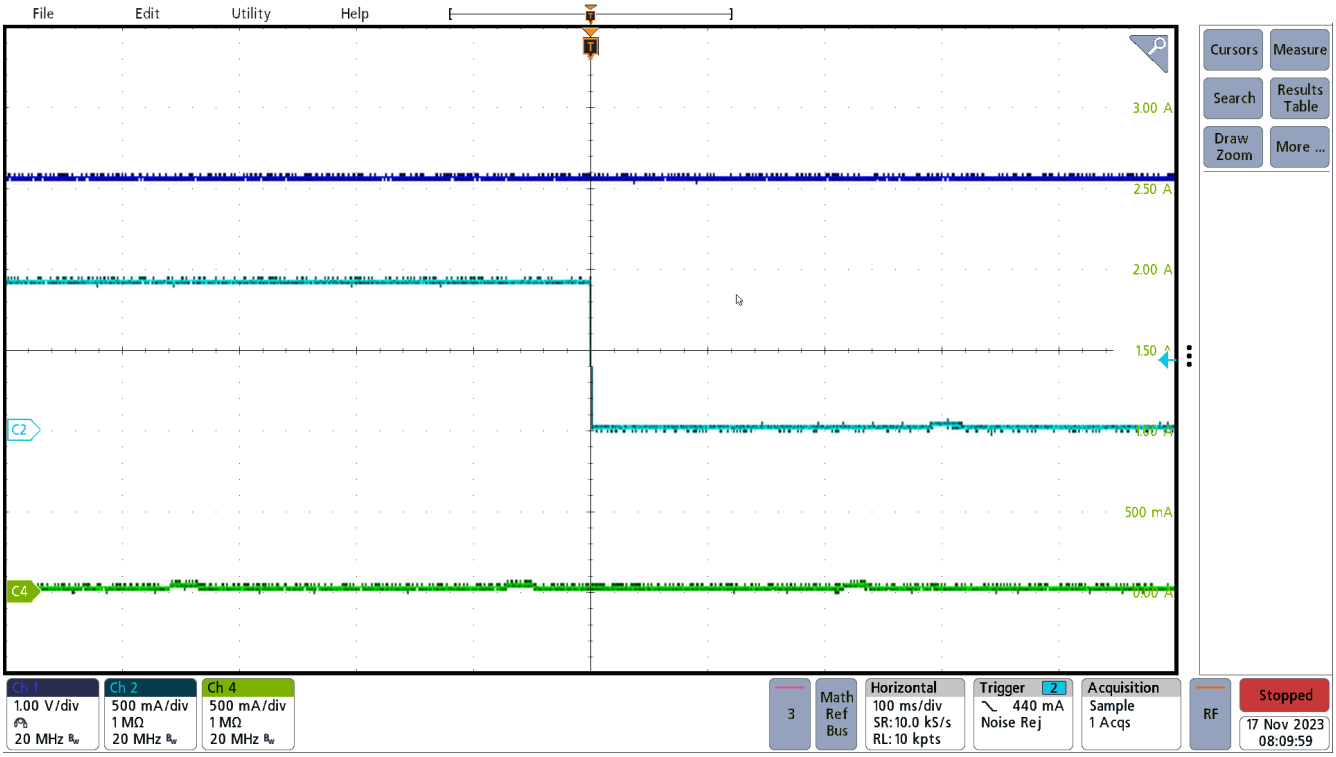


Figure 3-26. Case 16

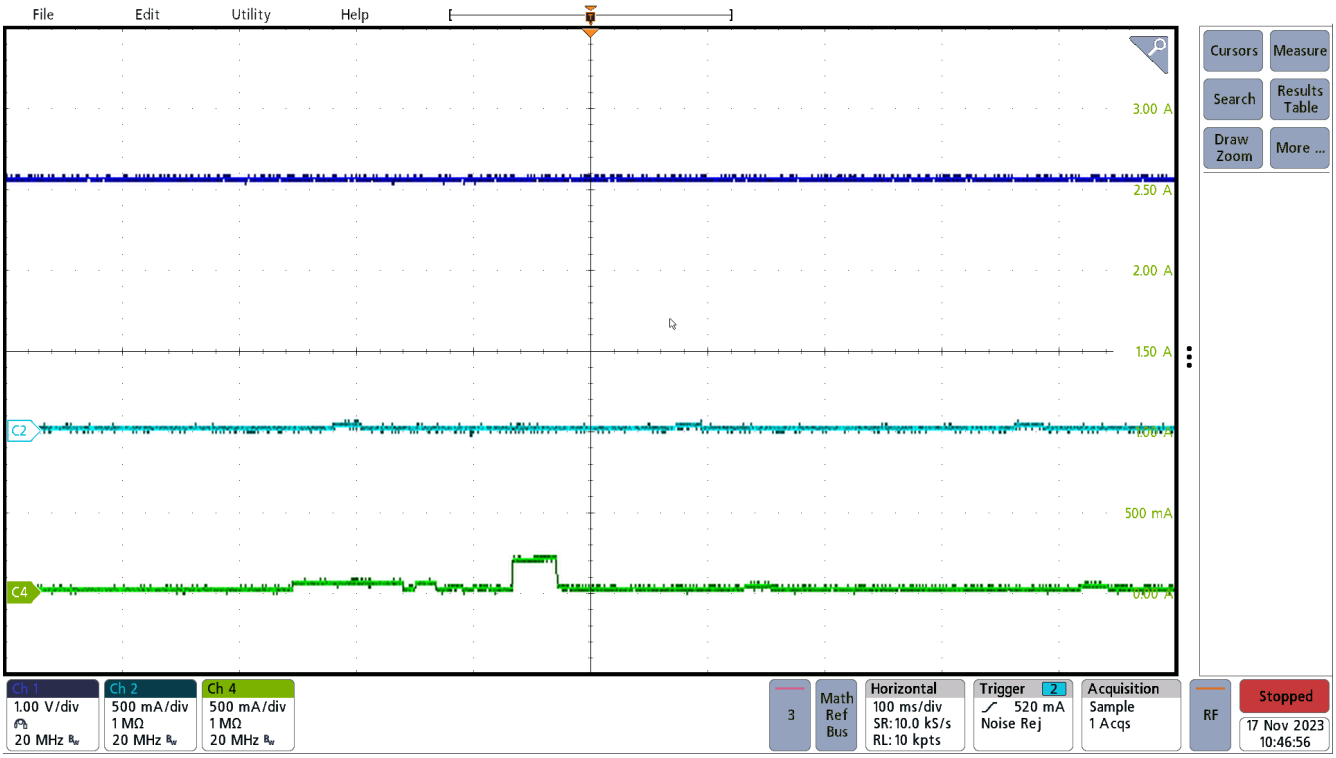


Figure 3-27. Case 17

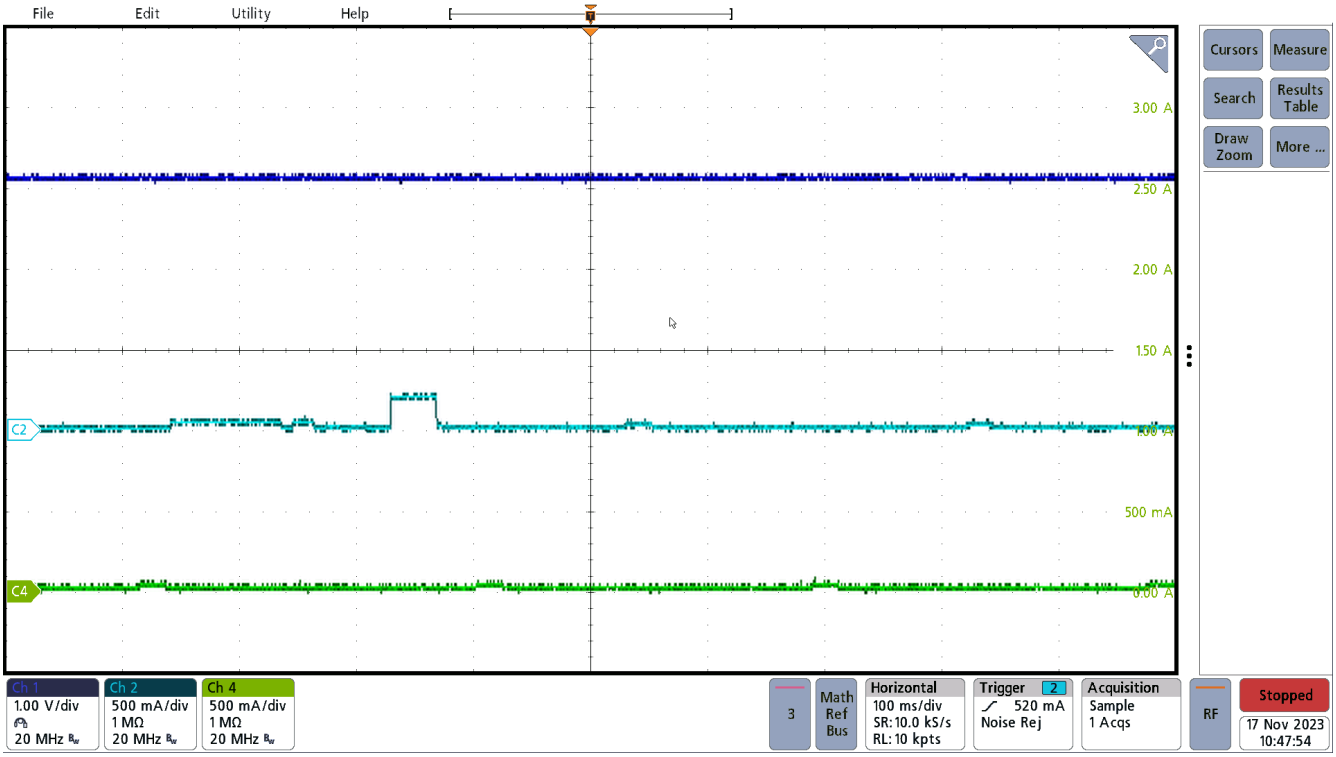


Figure 3-28. Case 18

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