Design Guide: TIDA-050090

54V 5kW Power Path Protection Reference Design for AI Data Centers Using TPS1689 and TPS1685 eFuses

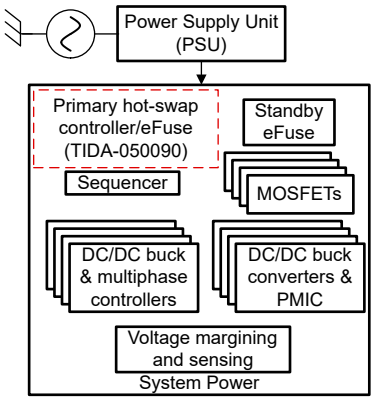
Description

This reference design illustrates a 54V, 5kW input power path protection circuit for AI-powered data centers, utilizing one TPS1689 and five TPS1685 eFuse devices in parallel. These integrated high-current circuit protection devices provide multiple protections using a few external components, serving as a robust defense against overloads, short circuits, and excessive inrush current. The integrated PMBus® interface in the TPS1689 eFuse enables real-time monitoring, control, and configuration. Three devices are located on the top layer, three on the bottom layer.

Resources

TIDA-050090	Design Folder
TPS1685, TPS1689, TPS7A4001	Product Folder

Ask our TI E2E™ support experts

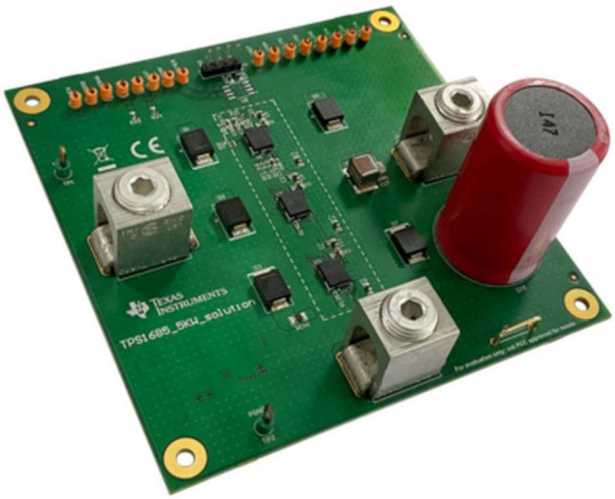


Features

- Capable of carrying $100A_{RMS}$ current at an elevated ambient temperature of 55°C without any external airflow
- Options to engage the enable power cycle and the quick output discharge (QOD)
- Control, telemetry, and configuration functionalities using PMBus through TPS1689 eFuse
- EEPROM to store the configuration file and the black box data after a fault
- Undervoltage, overvoltage, overcurrent, short-circuit, and overtemperature protections

Applications

- Power distribution board with 48V input
- Intel server
- High-performance computing
- Network interface card (NIC)
- AI accelerator module or card



1 System Description

Figure 1-1 depicts a typical power distribution architecture in a 48V or 54V enterprise server motherboard. The image also indicates the location in the power tree at which the TIDA-050090 reference design can be used in a server motherboard.

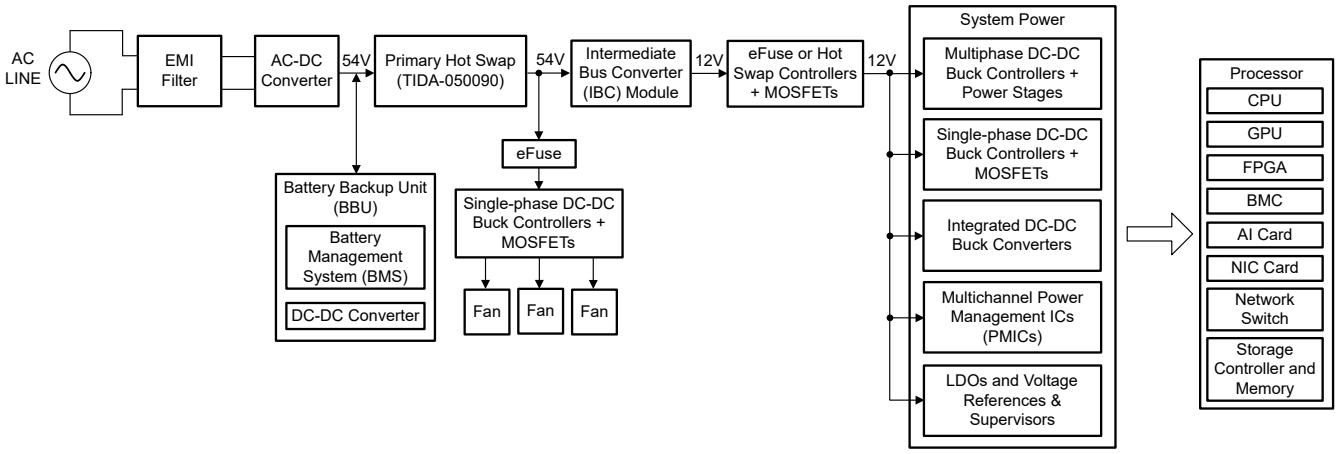


Figure 1-1. System Block Diagram

1.1 Key System Specifications

Table 1-1 shows the design parameters for this reference design.

Table 1-1. Design Parameters

PARAMETER	VALUE
Input voltage range (V_{IN})	40V to 60V
Maximum DC load current ($I_{OUT(max)}$)	100A
Peak current	200A
Maximum output capacitance (C_{LOAD})	5mF
Are all the loads off until the PG is asserted?	Yes
Maximum ambient temperature	55°C
Transient overload blanking timer	1.5ms
Need to survive a hot-short on the output condition?	Yes
Need to survive a power-up in a short condition?	Yes
Can a board be hot-plugged or power-cycled?	Yes
Does the system require load current monitoring?	Yes
Fault response	Latch-off

2 System Overview

The TIDA-050090 reference design features a 54V, 5kW input power path protection system in data center servers, utilizing six TPS1685 eFuse devices or one TPS1689 and five TPS1685 eFuse devices arranged in parallel. The TPS1685 and TPS1689 eFuses are compact, package-integrated, parallelizable designs for high-current circuit protection and power management. The devices offer multiple protection modes with minimal external components. The eFuses provide robust defense against overloads, short circuits, and excessive inrush current. This reference design demonstrates the performance of the TPS1685 and TPS1689 eFuses when multiple devices are in parallel to support a higher load current.

2.1 Block Diagram

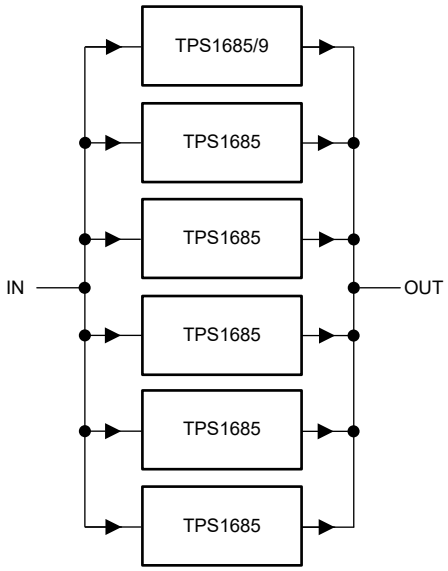


Figure 2-1. TIDA-050090 Block Diagram

2.2 Highlighted Products

2.2.1 TPS1685

The TPS1685x is an integrated high-current circuit protection and power management device. The device provides multiple protection modes using very few external components and is a robust defense against overloads, short-circuits, and excessive inrush current. Applications with particular inrush current requirements can set the output slew rate with a single external capacitor. The user can set the output current limit level as per system needs. A user-adjustable overcurrent blanking timer allows systems to support transient peaks in the load current without tripping the eFuse. An integrated fast and accurate analog load current monitor enables predictive maintenance and advanced dynamic platform power management, such as Intel® Platform System Power (PSYS) and PROCHOT#, to optimize server and data center performance.

Multiple TPS1685x devices can be connected in parallel to increase the total current capacity for high-power systems. All devices actively synchronize the operating state and share current during start-up as well as steady state to avoid over-stressing some of the devices, which can result in premature or partial shutdown of the parallel chain. The devices are characterized for operation over a junction temperature range of –40°C to +125°C.

2.2.2 TPS1689

The TPS1689x is an integrated high-current circuit protection and power management design in a small package. The device provides multiple protection modes using very few external components and is a robust defense against overloads, short circuits, and excessive inrush current. The integrated PMBus® interface allows a host controller to monitor, control, and configure the system in real-time. Key system parameters can be read back for remote telemetry. Various protection and warning thresholds and coefficients can be configured through PMBus or stored in nonvolatile configuration memory. An integrated fast and accurate sense analog load current monitor facilitates predictive maintenance and advanced dynamic platform power management, such as Intel® PSYS and PROCHOT#, to optimize server and data-center performance. The black box fault recording feature helps in debugging field failure or returns. For higher current support, TPS1689x can be connected in parallel with TPS1685x. The devices are characterized for operation over a junction temperature range of –40°C to +125°C.

2.2.3 TPS7A4001

The TPS7A4001 device is a very high-voltage-tolerant linear regulator that offers the benefits of a thermally-enhanced package (HVSSOP), and can withstand continuous DC or transient input voltages of up to 100V.

The TPS7A4001 device is stable with any output capacitance greater than 4.7µF and any input capacitance greater than 1µF (overtemperature and tolerance). Therefore, implementation of this device requires minimal board space because of the miniaturized packaging (HVSSOP) and a potentially small output capacitor. In addition, the TPS7A4001 device offers an enable pin (EN) compatible with standard CMOS logic to enable a low-current shutdown mode.

The TPS7A4001 device has an internal thermal shutdown and current limiting to protect the system during fault conditions. The HVSSOP packages have an operating temperature range of T_J = –40°C to 125°C.

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware Requirements

- TIDA-050090 reference design board
- DC power supply: N8951A, auto-ranging system DC power-supply, 80V, 510A, 15kW
- DC electronic load: 63210A-150-1000, high-power DC electronic load, 150V, 1000A, 10kW
- Digital multimeters
- Fluke® Ti480 PRO infrared camera
- MDO4000C mixed domain oscilloscope

Figure 3-1 and Figure 3-2 show the reference design schematics.

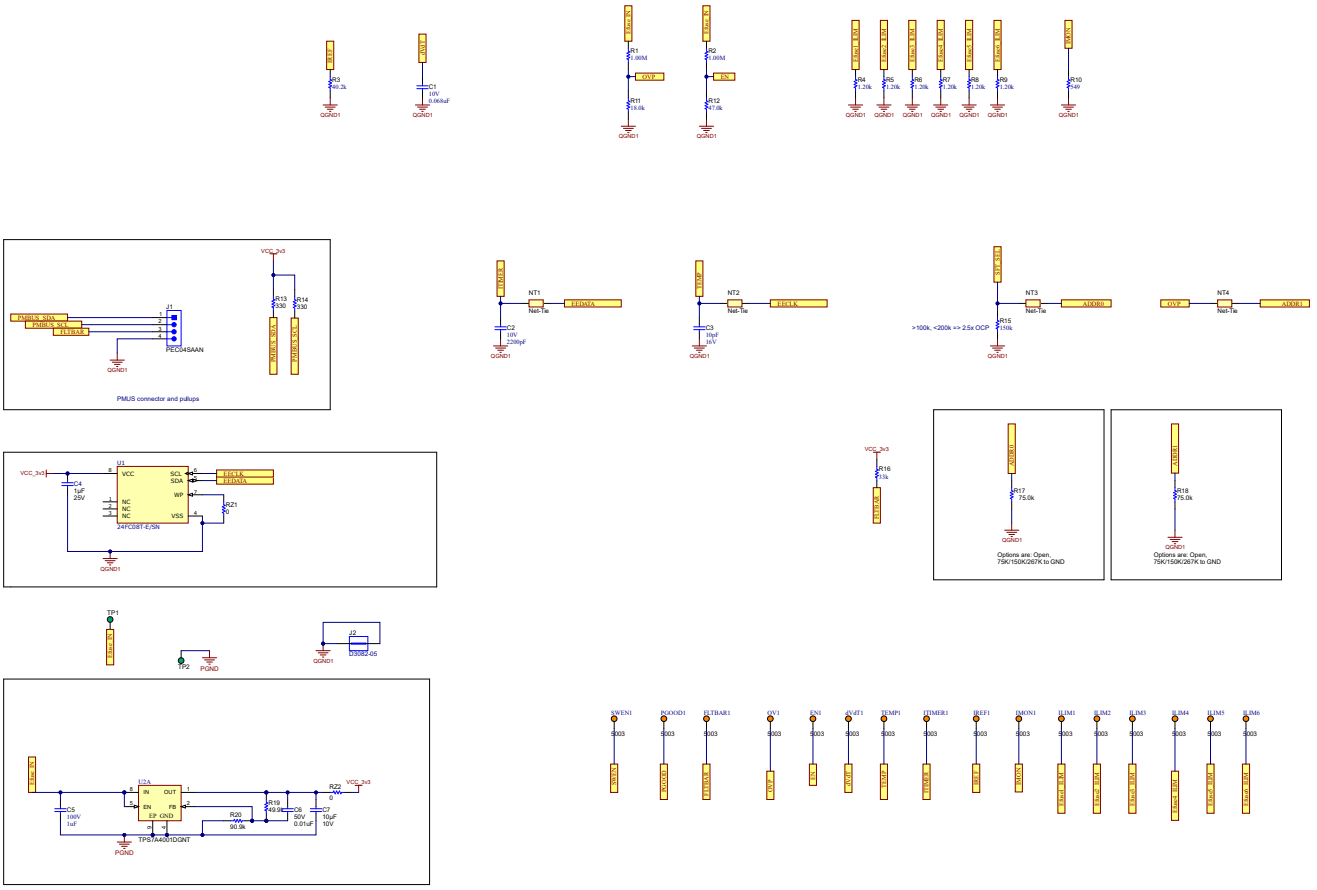


Figure 3-1. TIDA-050090 Reference Design (Schematic Image 1)

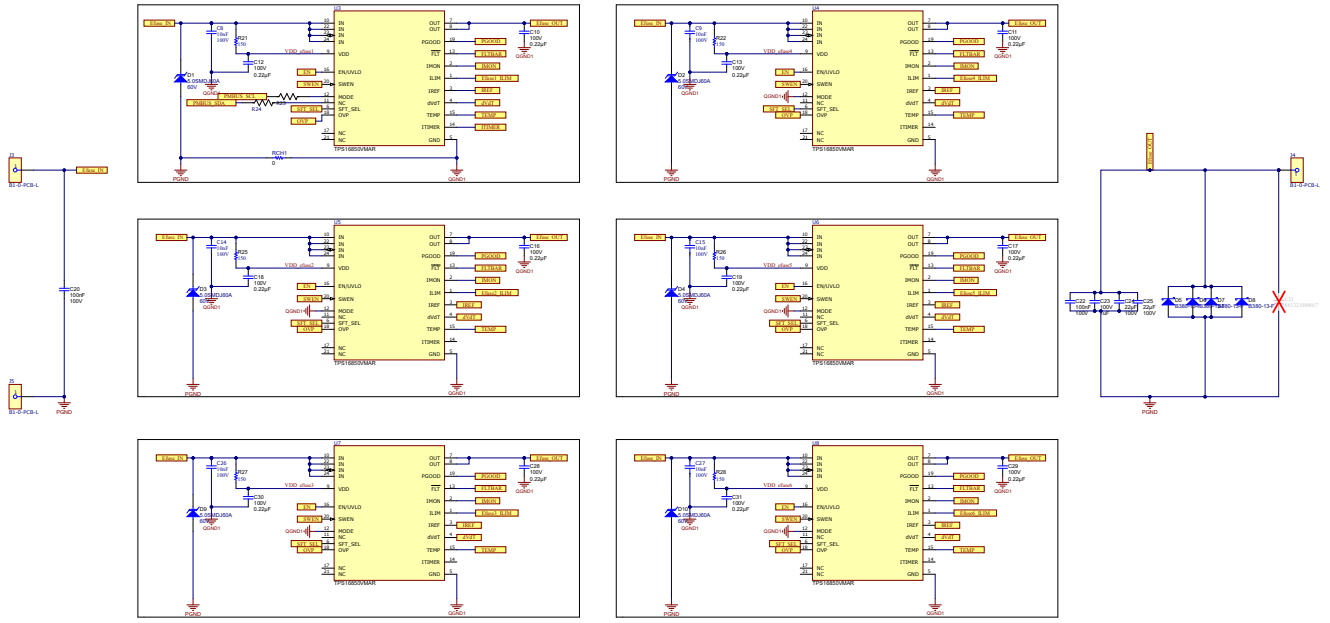


Figure 3-2. TIDA-050090 Reference Design (Schematic Image 2)

Figure 3-3 through Figure 3-5 show the reference design board images.

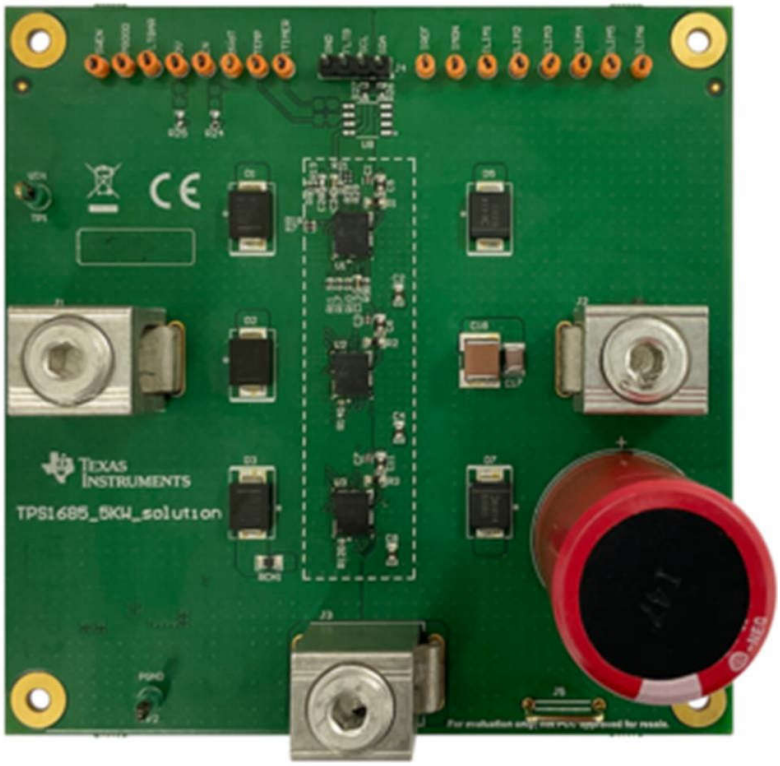


Figure 3-3. TIDA-050090 Reference Design: Top View

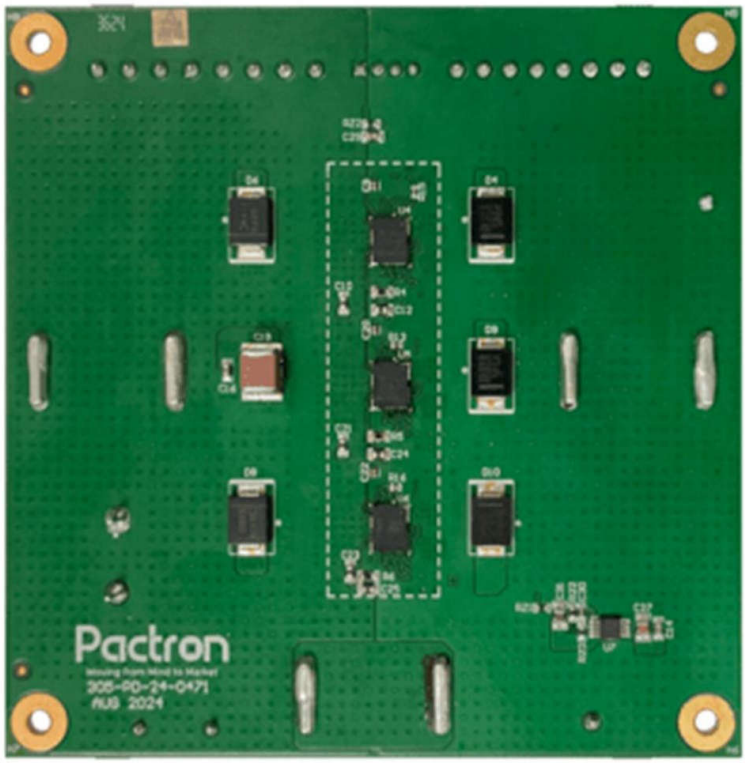


Figure 3-4. TIDA-050090 Reference Design: Bottom View

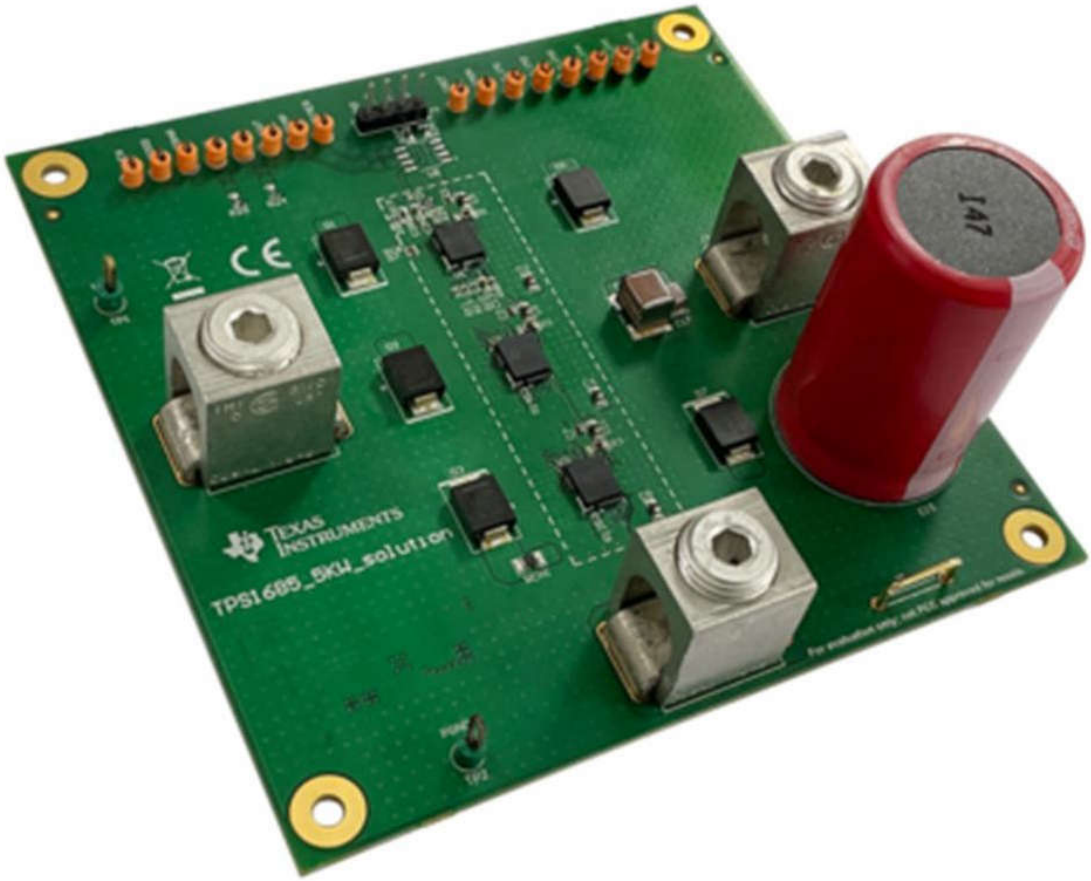


Figure 3-5. TIDA-050090 Reference Design: Angle View

3.2 Test Setup

Figure 3-6 shows a block diagram of the test setup.

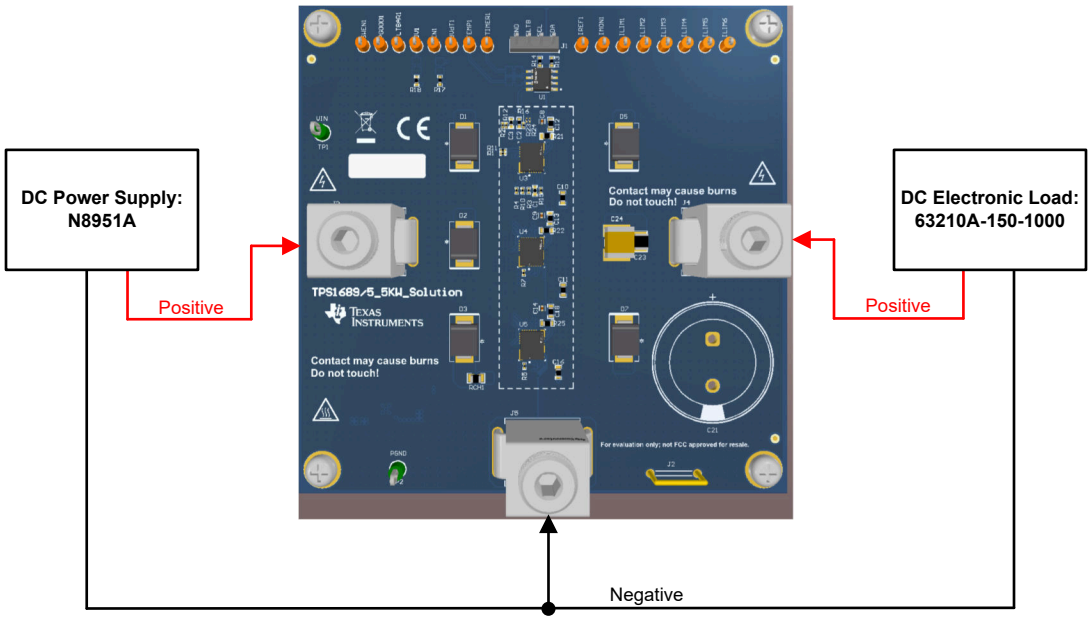
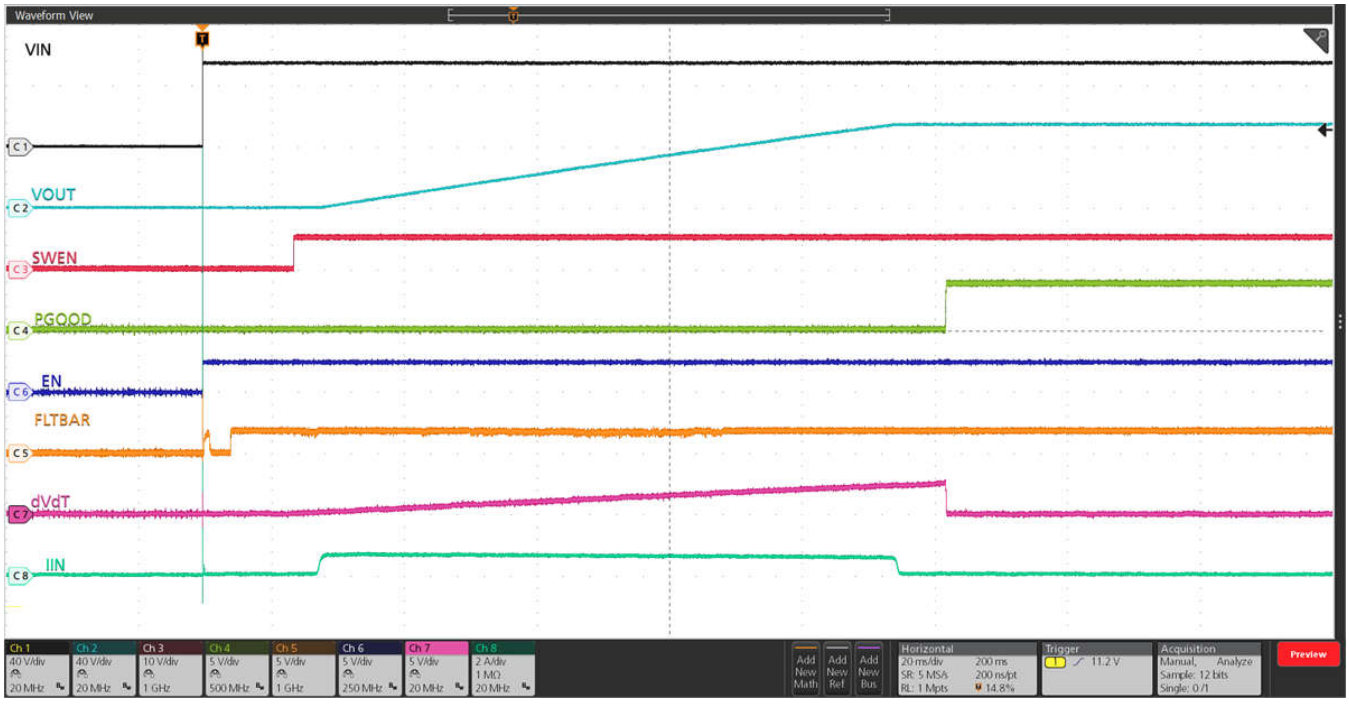


Figure 3-6. TIDA-050090 Test Setup

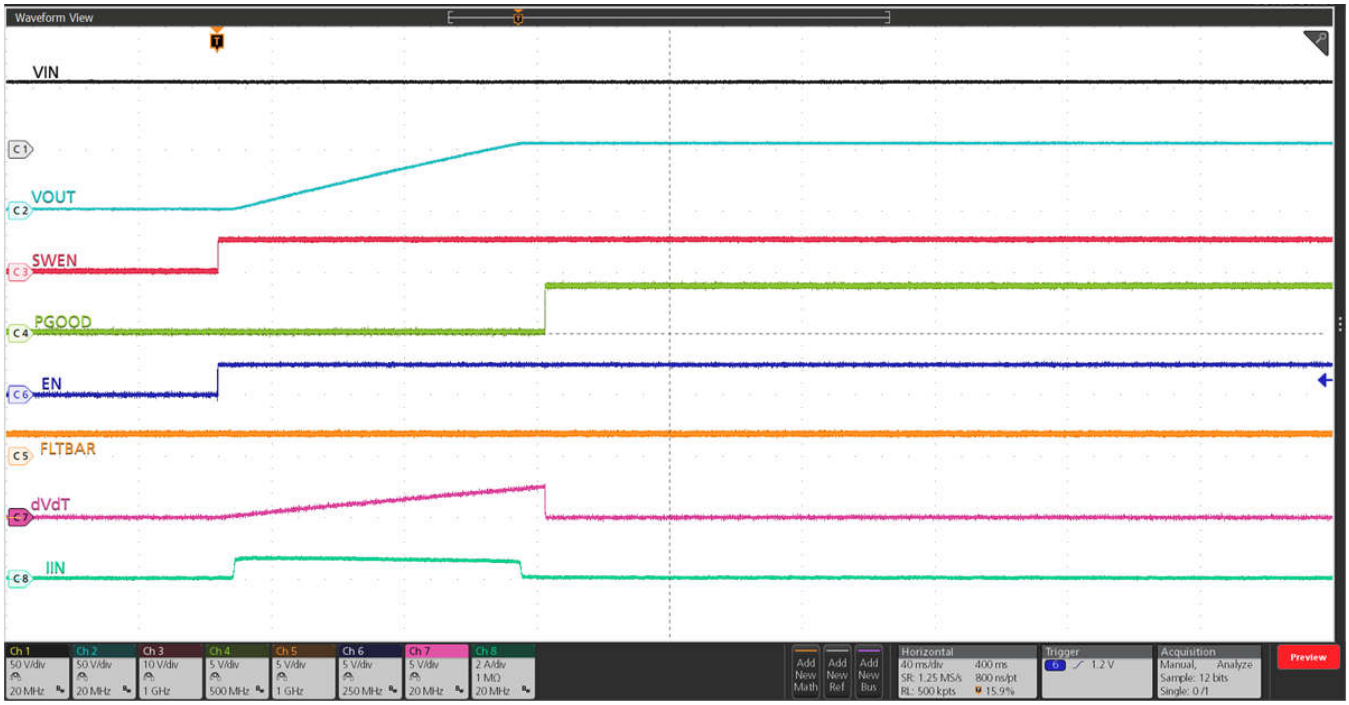
3.3 Test Results

Figure 3-7 through Figure 3-16 show various test results in the TIDA-050090 reference design.



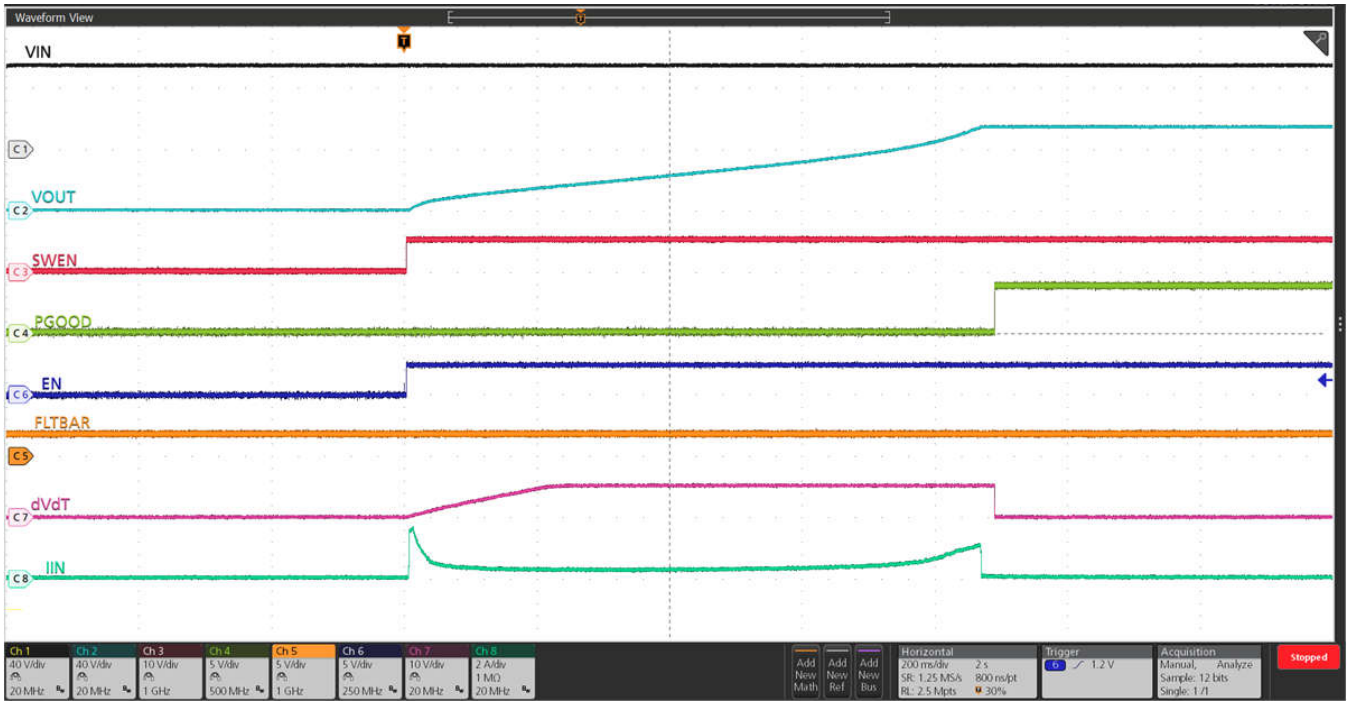
V_{IN} stepped up from 0V to 54V, C_{OUT} = 1mF, and C_{DVDT} = 68nF

Figure 3-7. Hot-Plug Profile With Six Devices in Parallel



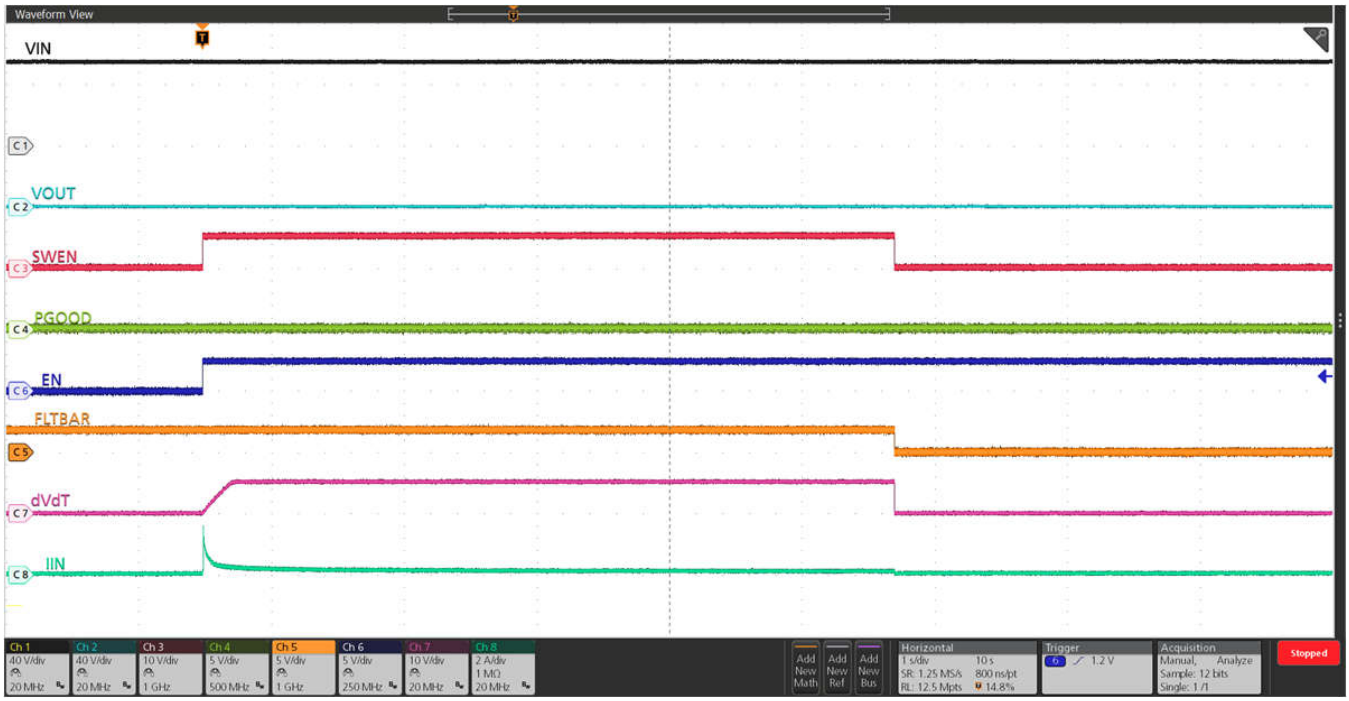
V_{IN} = 54V, EN stepped up from 0V to 3V, C_{OUT} = 1mF, and C_{DVDT} = 68nF

Figure 3-8. Power-Up Using ENABLE With Six Devices in Parallel (Condition 1)



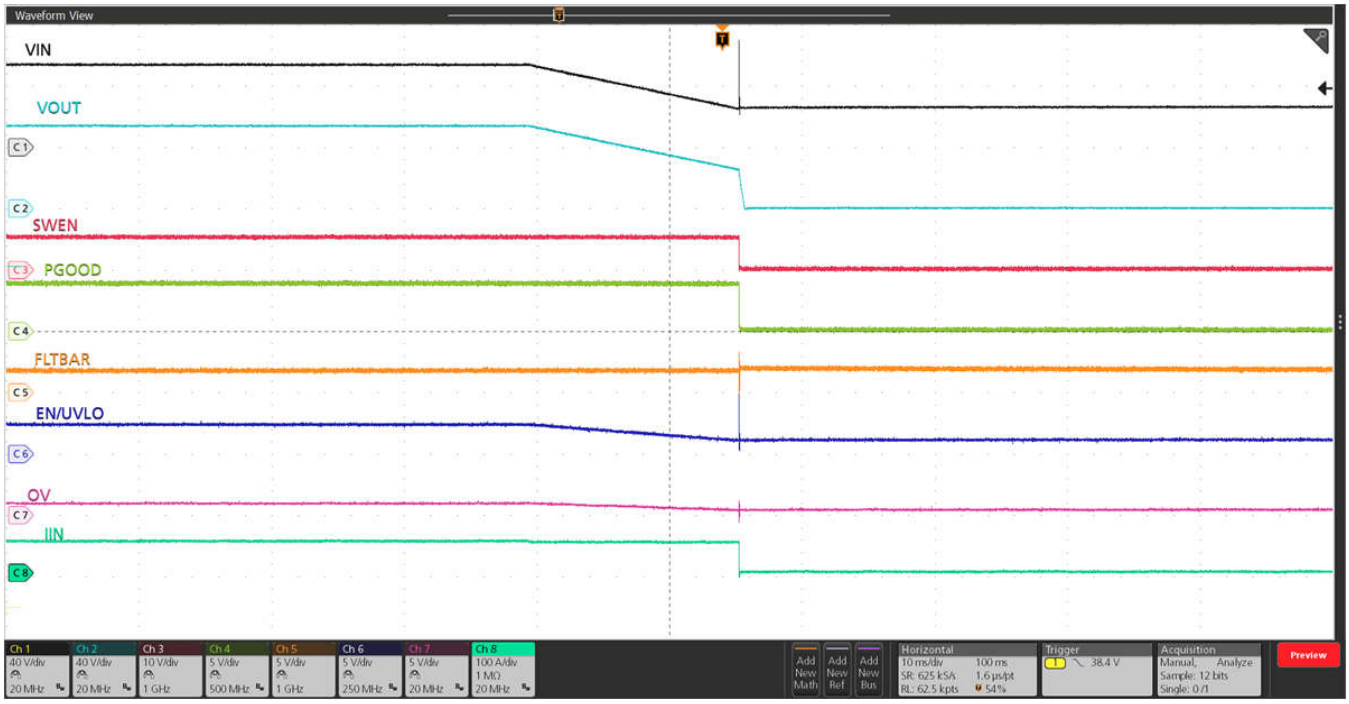
V_{IN} = 54V, EN stepped up from 0V to 3V, C_{OUT} = 6mF, and C_{DVDT} = 68nF

Figure 3-9. Power-Up Using ENABLE With Six Devices in Parallel (Condition 2)



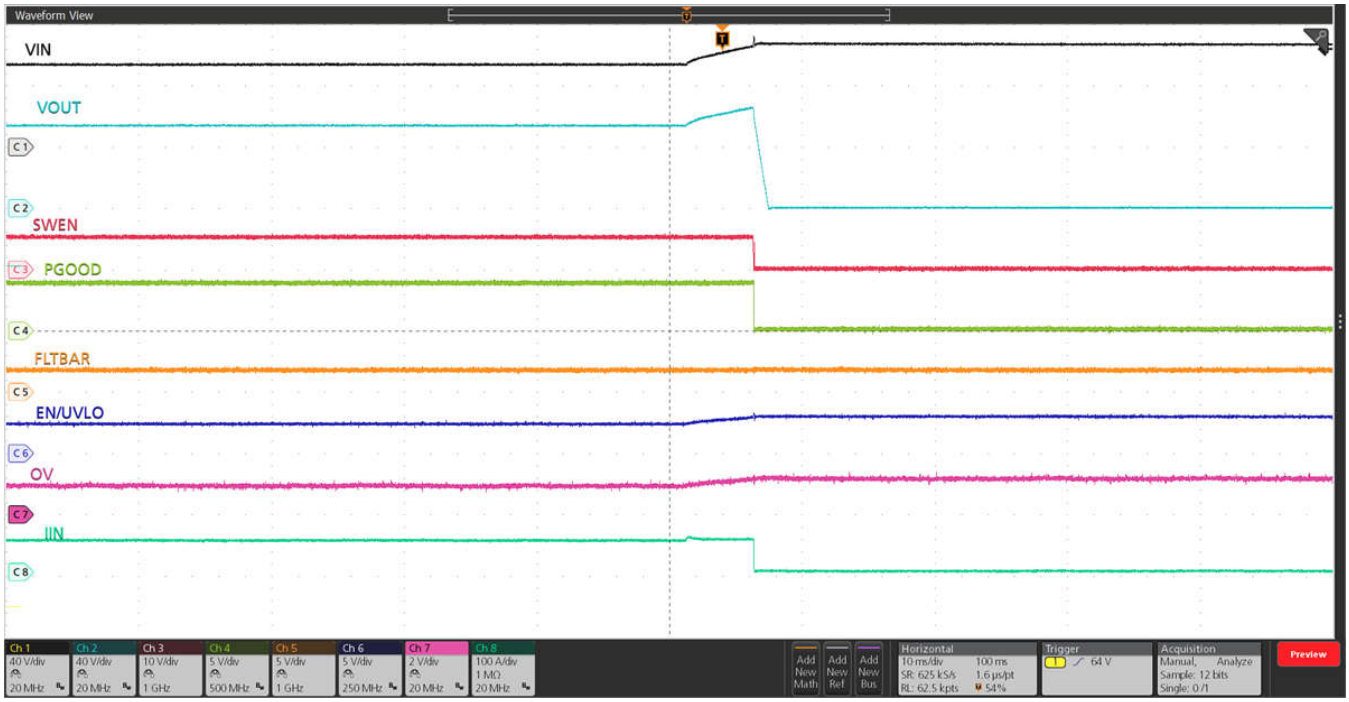
V_{IN} = 54V, OUT shorted to GND, EN stepped up from 0V to 3V, C_{OUT} = 6mF, and C_{DVDT} = 68nF

Figure 3-10. Power-Up Into Output Short Response With Six Devices in Parallel



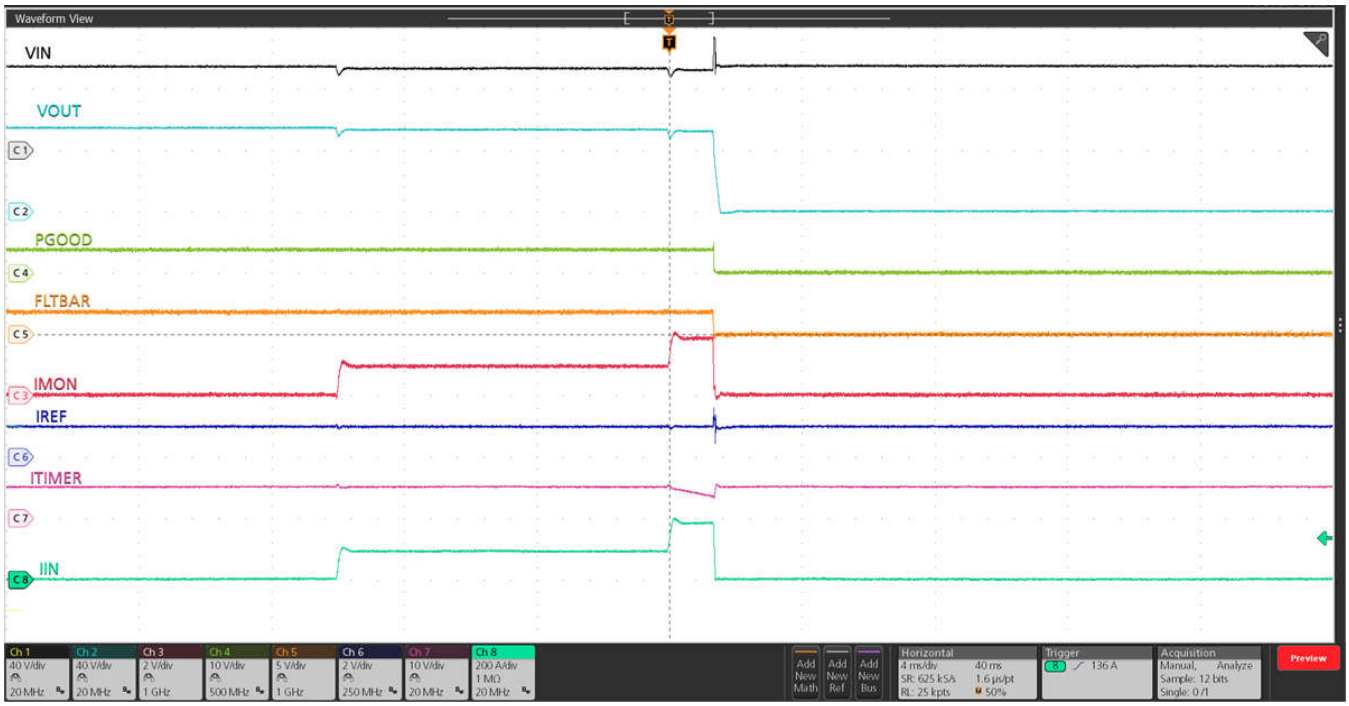
V_{IN} stepped down from 54V to 25V, UVLO Threshold = 30V, and I_{LOAD} = 60A

Figure 3-11. Undervoltage Lockout Response With Six Devices in Parallel



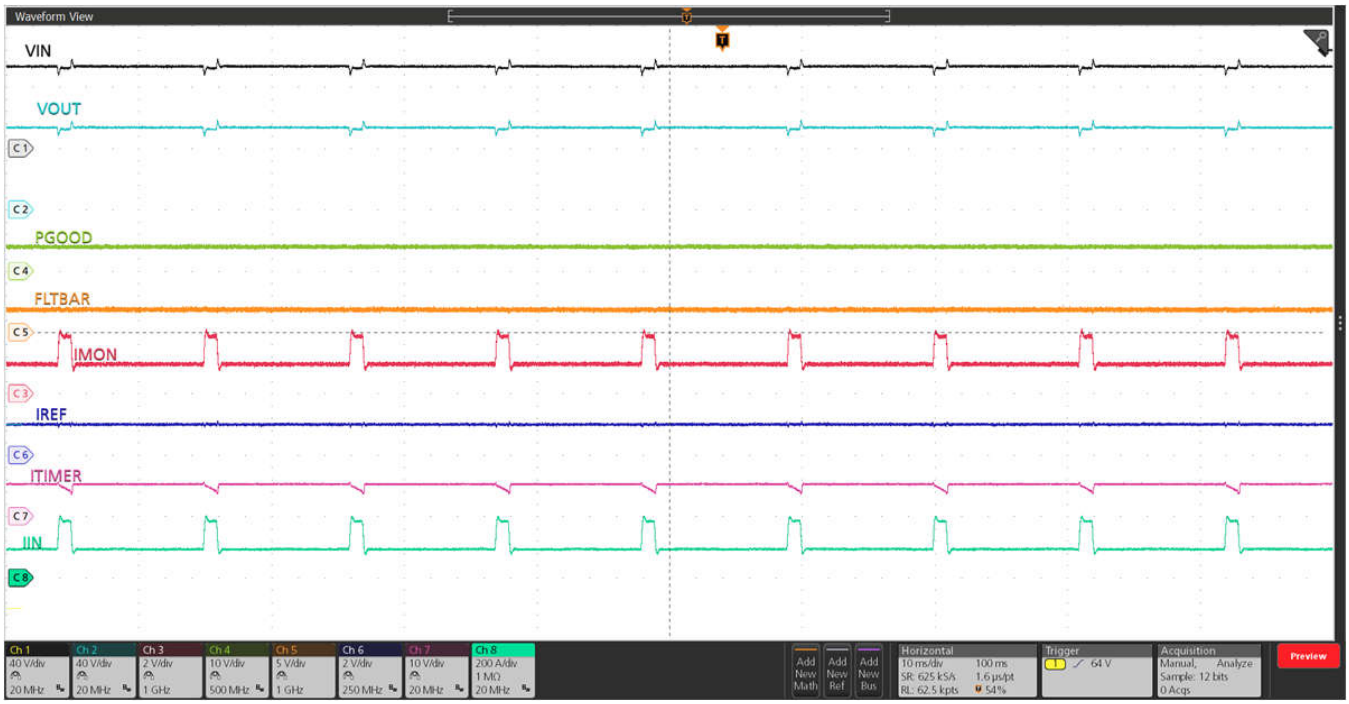
V_{IN} stepped up from 54V to 65V, UVLO Threshold = 60V, and I_{LOAD} = 60A

Figure 3-12. Overvoltage Lockout Response With Six Devices in Parallel



V_{IN} = 54V, t_{ITIMER} = 1.5ms, R_{IMON} = 549Ω, V_{IREF} = 1V, and I_{LOAD} ramped from 90A to 180A for 5ms

Figure 3-13. Overcurrent Performance With Six Devices in Parallel



V_{IN} = 54V, t_{ITIMER} = 1.5ms, R_{IMON} = 549Ω, V_{IREF} = 1V, and I_{LOAD} ramped from 90A to 180A for 1.2ms, and then 90A for 10ms

Figure 3-14. Transient Overload Performance With Six Devices in Parallel

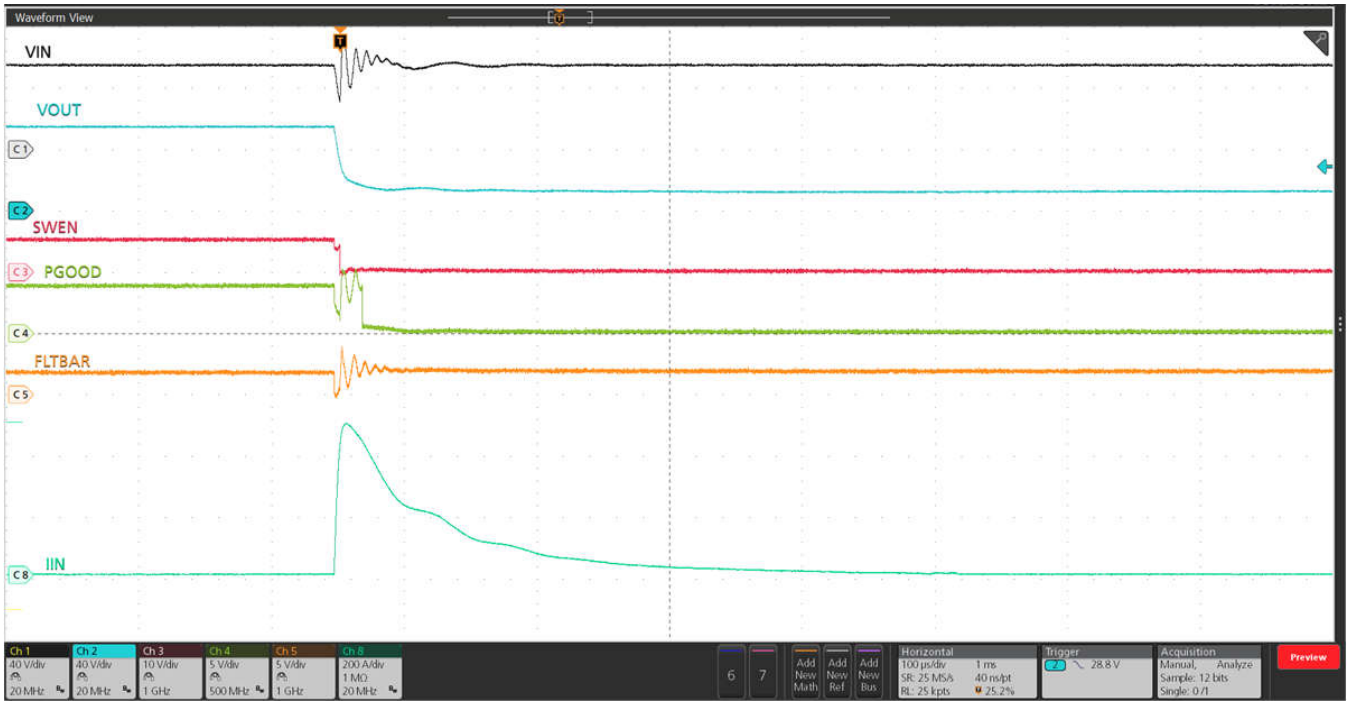


Figure 3-15. Output Hot-Short Response With Six Devices in Parallel

Figure 3-16 shows the thermal performance of the TIDA-050090 reference design under the given conditions.

V_{IN} = 54V, I_{OUT} = 100A, and no external airflow

Figure 3-16. Thermal Performance With Six Devices in Parallel

4 Design and Documentation Support

4.1 Design Files

4.1.1 Schematics

To download the schematics, see the design files at TIDA-050090.

4.1.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-050090.

4.1.3 Altium Project

To download the Altium project files, see the design files at TIDA-050090.

4.1.4 Gerber Files

To download the Gerber files, see the design files at TIDA-050090.

4.2 Tools

Design Calculator	TPS1689 Design Calculator
Design Calculator	TPS1685 Design Calculator
TVS-RECOMMENDATION-CALC	TVS diode recommendation tool
PSPICE-FOR-TI	PSpice® for TI design and simulation tool

4.3 Documentation Support

1. Texas Instruments, *TPS1685x 9V–80V, 3.5mΩ, 20A Stackable Integrated Hotswap (eFuse) With Accurate and Fast Current Monitor Datasheet*
2. Texas Instruments, *TPS16890 9V–80V, 3.65mΩ, 20A Stackable Integrated Hotswap (eFuse) With PMBus® Digital Telemetry Datasheet*
3. Texas Instruments, *TPS7A4001 100-V Input Voltage, 50-mA, Very High Voltage Linear Regulator Datasheet*

4.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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