Test Report: PMP23496

8kW Hot-Swap Reference Design For 48V Artificial Intelligence Servers

TEXAS INSTRUMENTS

Description

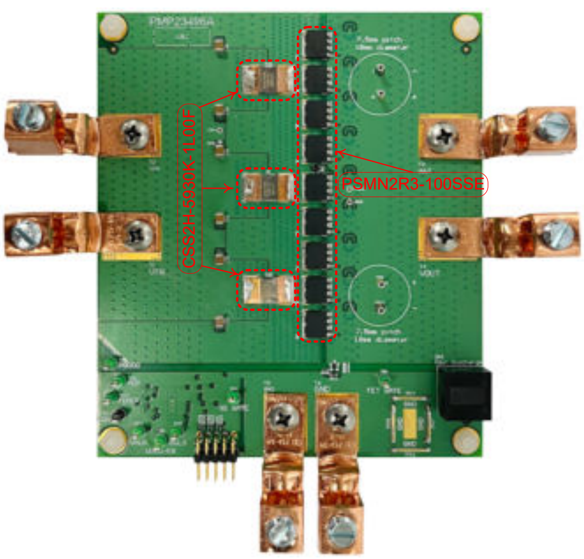
With the advancements in artificial intelligence (AI) and machine learning (ML), enterprise servers have become power-intensive as these servers simultaneously process a large amount of data and storage. The steady-state power rating of each server motherboard has gone up 5kW to 6kW, in contrast to 1kW to 2kW for general servers. However, the form factor remains the same, imposing system design challenges due to increased power density. The load amplitude, slew-rate, and frequency of transient loads on AI servers have increased by three to four times compared to general servers. Considering these requirements, this reference design is developed using the LM5066I hot-swap controller to provide a robust and reliable input power-path-protection design in high-power server backplane systems with a nominal input voltage of 54V.

Features

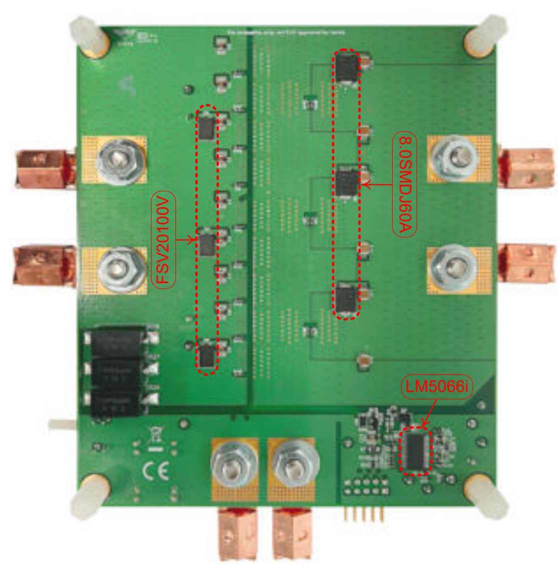
- Capable of carrying 150A of RMS load current at an ambient temperature of 70°C with a nominal input voltage of 54V (8.1kW design)
- Ability to safely turn off nine MOSFETs (effective C_{ISS} of 150nF) during an output hot-short event
- Supports high-frequency fast slew-rate load transients with large amplitudes
- Supports multiple hot insertions and removals

Applications

- 48V rack and server power
- High performance computing
- Rack server motherboard
- High availability server backplane systems



Top of Board



Bottom of Board

1 Test Prerequisites

1.1 Design Specifications of PMP23496 Reference Design

The PMP23496 reference design board is developed using the LM5066I hot-swap controller in conjunction with PSMN2R3-100SSE MOSFETs.

Table 1-1. Design Specifications of PMP23496 Reference Design

DESIGN PARAMETER	SPECIFICATIONS
Input voltage range	40V to 60V
Nominal input voltage	54V
Thermal design current	about 140A
Nominal current limit	150A at current limit threshold voltage (V_{CL}) of 50mV (typical)
Nominal short-circuit threshold	300A
Fault timer duration (typical)	520µs
Input cable inductance	about 900nH
Output capacitor	about 4mF
MOSFET $R_{θJA}$ (no forced air-flow)	about 40°C/W
Maximum ambient temperature	70°C

1.2 Equipment Used in the Experiments

- 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 multi-meters
- Fluke Ti480 PRO infrared camera
- MDO4000C mixed domain oscilloscope
- FTDI dongle
- PI-Commander EVM GUI

1.3 Dimensions

The board dimensions are 5.2in × 4.5in.

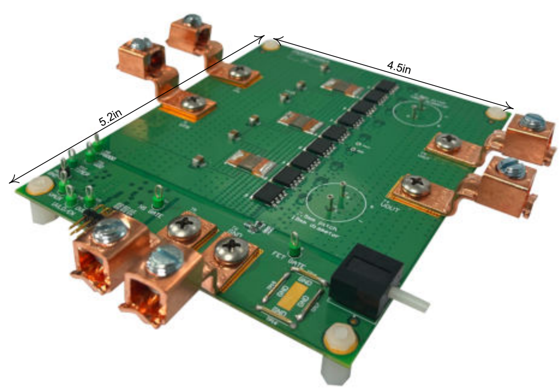


Figure 1-1. PMP23496 Reference Design Board

2 Testing and Results

2.1 Thermal Images

Figure 2-1 and Figure 2-2 show the thermal performance of the PMP23496 reference design at an ambient temperature of 25°C and 70°C, respectively.

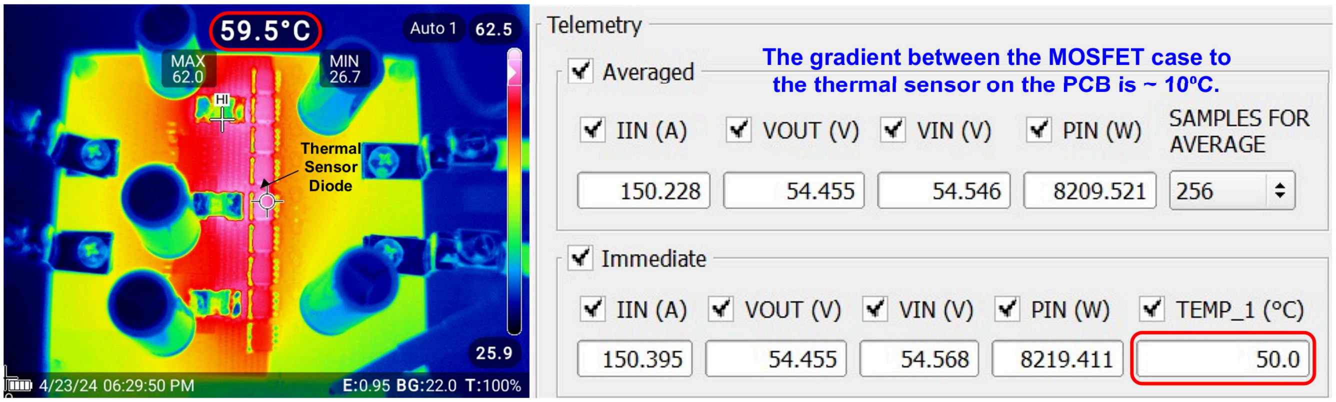


Figure 2-1. Thermal Performance: V_{IN} = 54V, I_{LOAD} = 150A, and T_A = 25°C

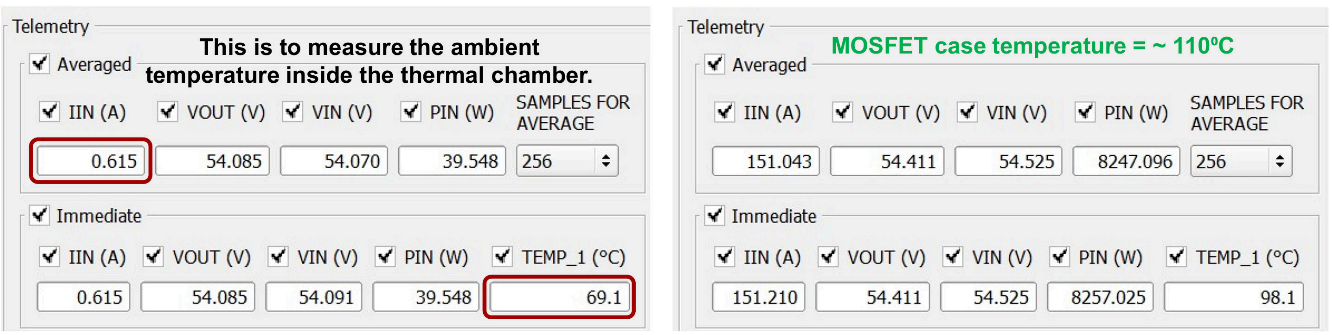


Figure 2-2. Thermal Performance: V_{IN} = 54V, I_{LOAD} = 150A, and T_A = 70°C

3 Waveforms

3.1 Hot-Plug Event

Figure 3-1 and Figure 3-2 show the waveform captured on the PMP23496 reference design during the hot-plug event.

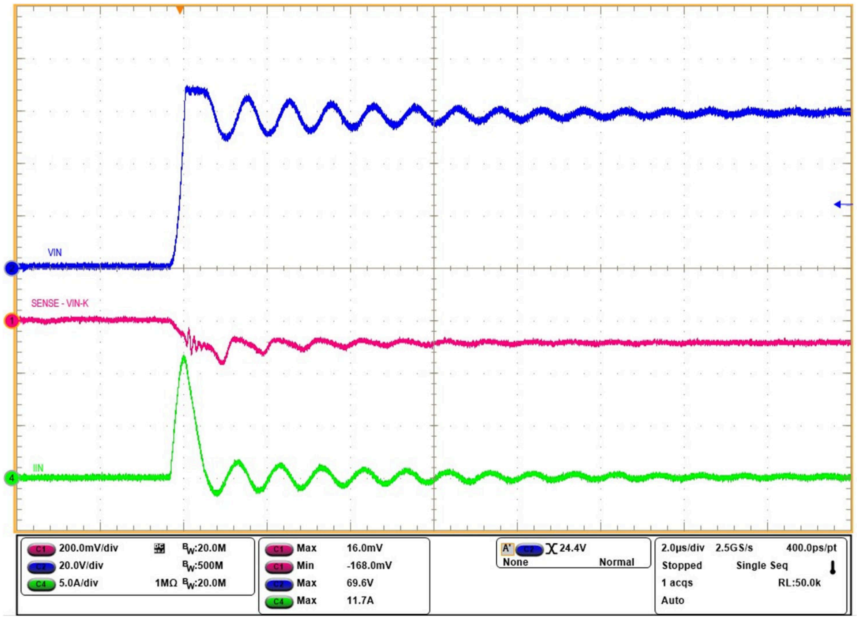


Figure 3-1. Hot-Plug Event: V_{IN} = 60V, C_{IN} = 1nF, and L_{IN} = About 900nH

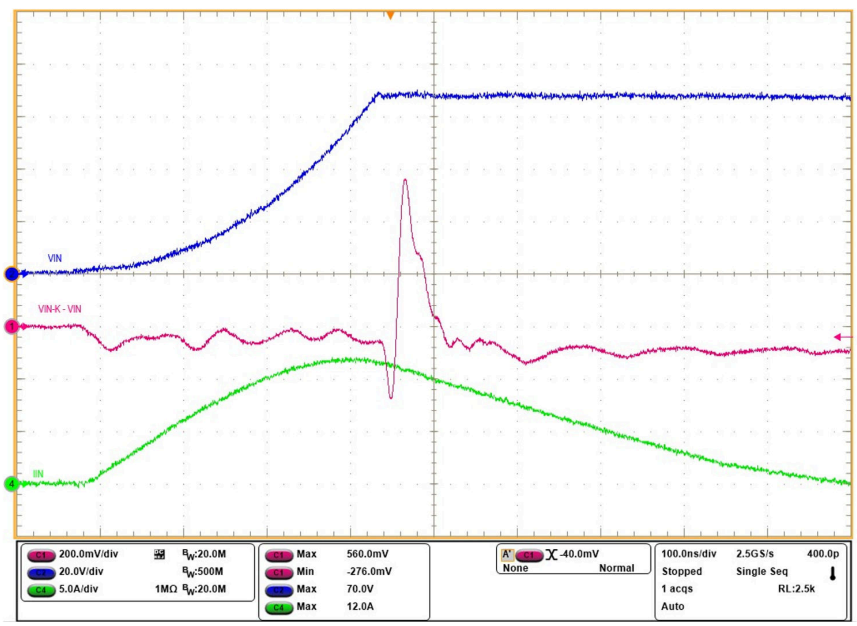


Figure 3-2. Hot-Plug Event: V_{IN} = 60V, C_{IN} = 1nF, and L_{IN} = About 900nH

Note

Transient peak differential voltages across SENSE to VIN-K and VIN-K to VIN are well below the specifications of ±1V for 1µs.

3.2 Power-Up

Figure 3-3 shows the start-up profile with ENABLE captured on the PMP23496 reference design.

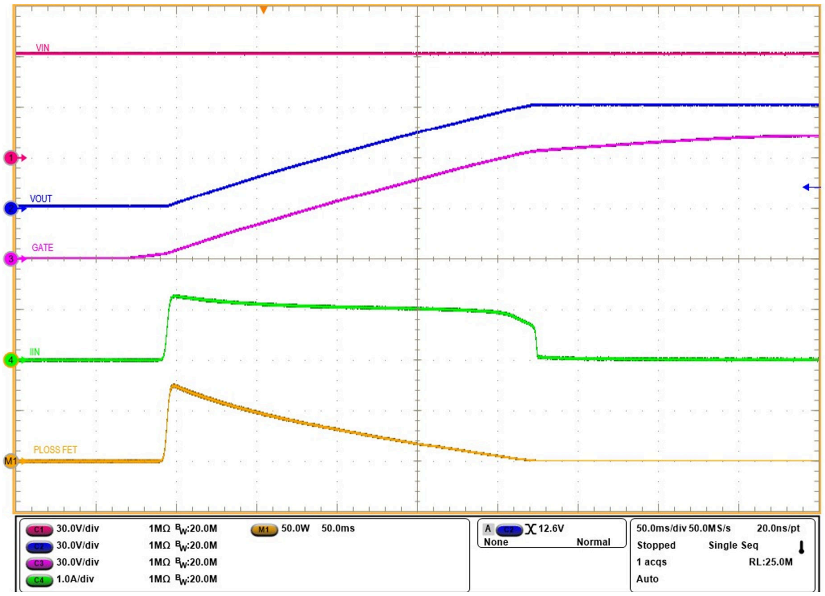


Figure 3-3. Start-Up: V_{IN} = 60V, C_{OUT} = 4.2mF, and C_{DVDT} = 47nF

3.3 Power-Up Into Output Short

Figure 3-4 and Figure 3-5 show the power-up into output short performance of LM5066I hot-swap controller on the PMP23496 reference design.

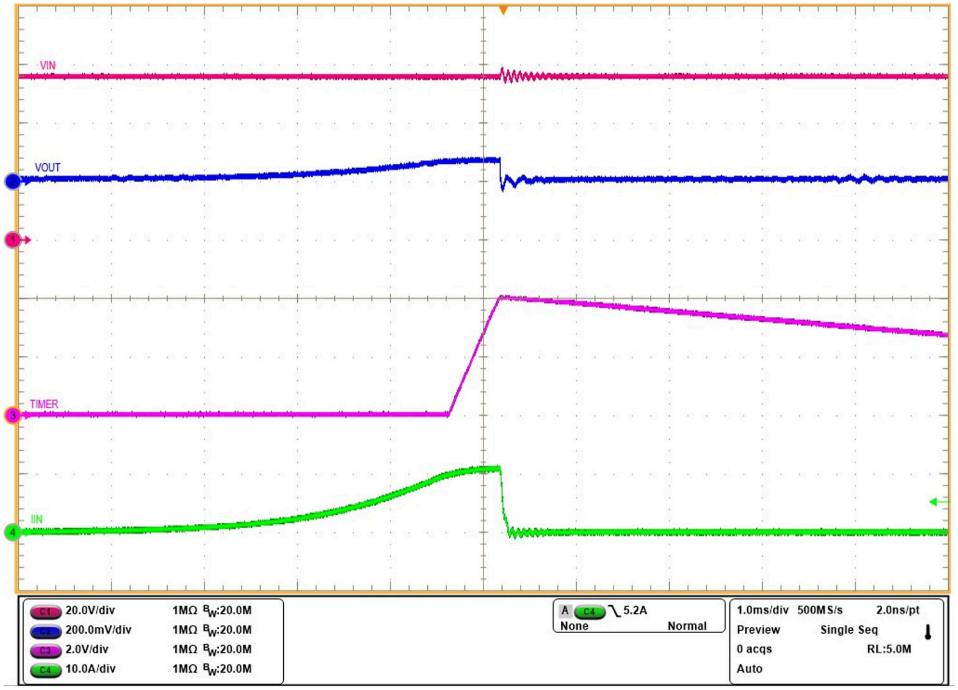


Figure 3-4. Start-up Into Short (Captured Signals: V_{IN}, V_{OUT}, TIMER, and I_{IN}): V_{IN} = 54V and C_{DVDT} = 47nF

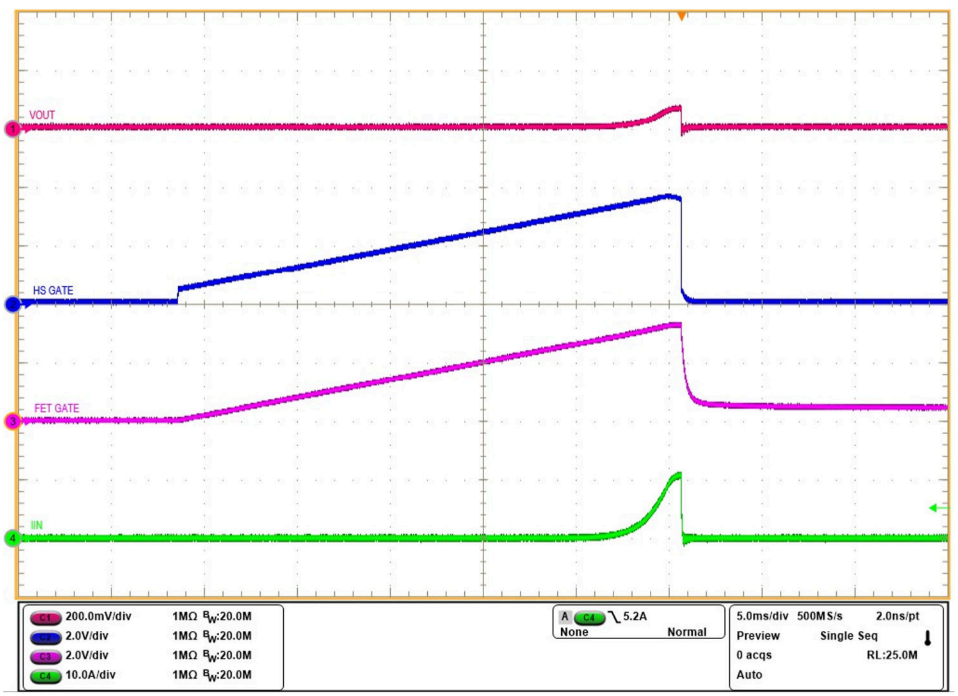


Figure 3-5. Start-up Into Short (Captured Signals: V_{OUT}, HS GATE, FET GATE, and I_{IN}): V_{IN} = 54V and C_{DVDT} = 47nF

3.4 Over-Current Event

Figure 3-6 and Figure 3-7 show the overcurrent response of LM5066I hot-swap controller captured on the PMP23496 reference design.

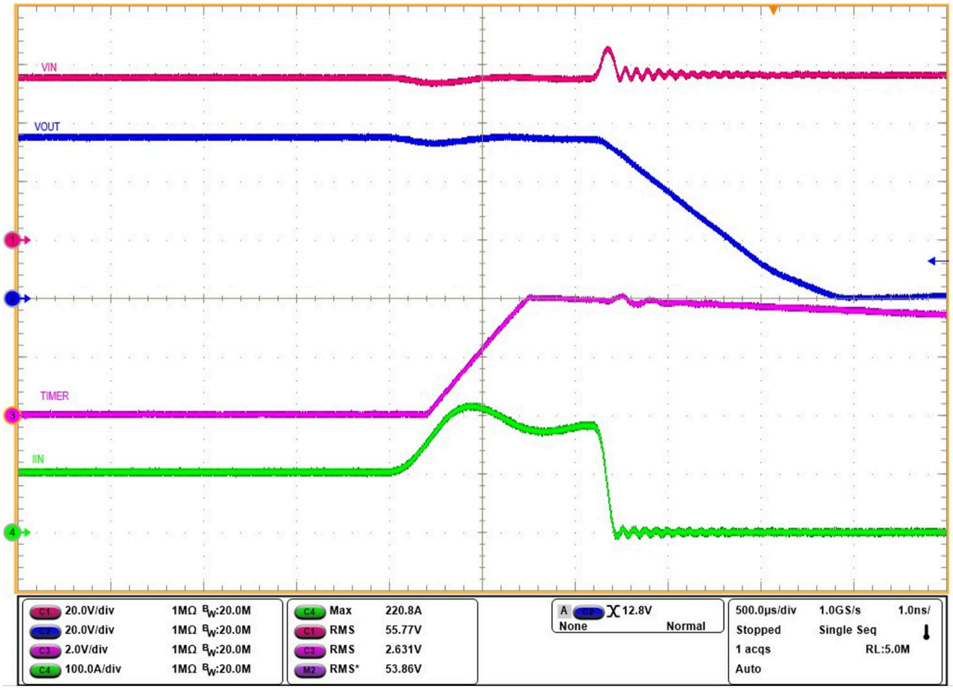


Figure 3-6. Over-Current Event (Captured Signals: V_{IN}, V_{OUT}, TIMER, and I_{IN}): V_{IN} = 54V, I_{LIM} = About 150A (Current limit threshold = 50mV and Effective R_{SNS} = 330µΩ), and T_{FLT} = 520µs

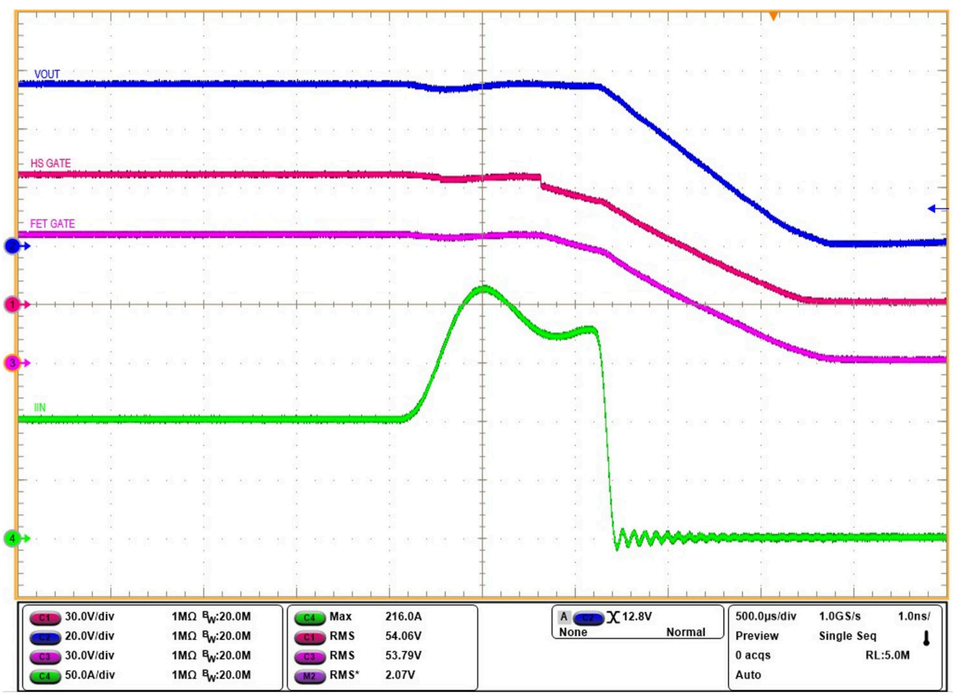


Figure 3-7. Over-Current Event (Captured Signals: V_{OUT}, HS GATE, FET GATE, and I_{IN}): V_{IN} = 54V, I_{LIM} = About 150A (Current limit threshold = 50mV and Effective R_{SNS} = 330µΩ), and T_{FLT} = 520µs

3.5 Load Transients

Figure 3-8 and Figure 3-9 show the high-frequency load transient performance of LM5066I hot-swap controller captured on the PMP23496 reference design.

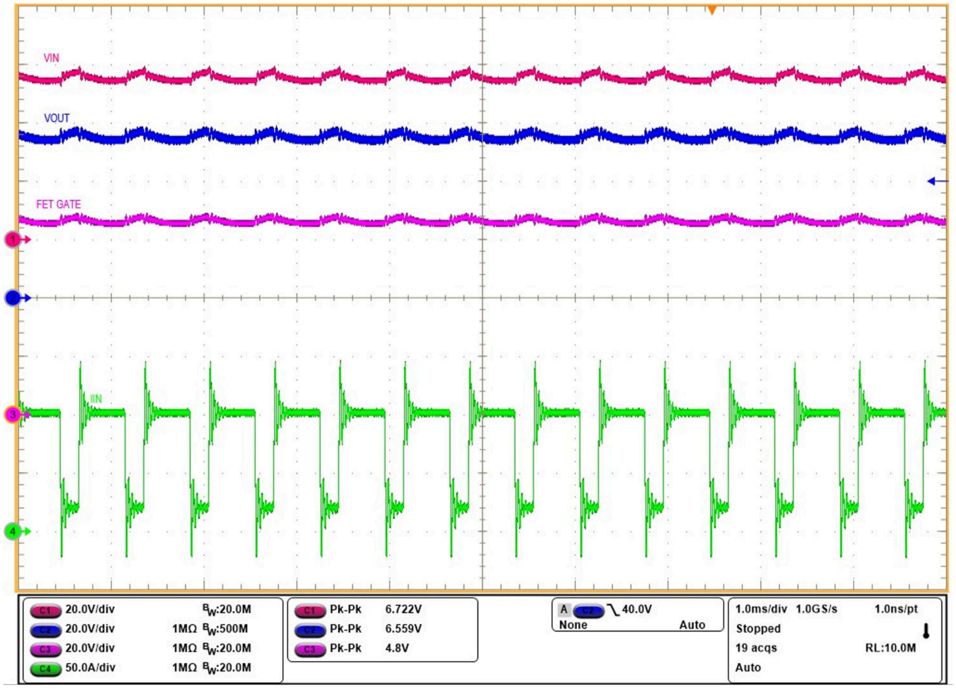


Figure 3-8. Load Transient Profile: V_{IN} = 54V, C_{OUT} = 4.2mF, and 20A for 200µs to 100A for 500µs

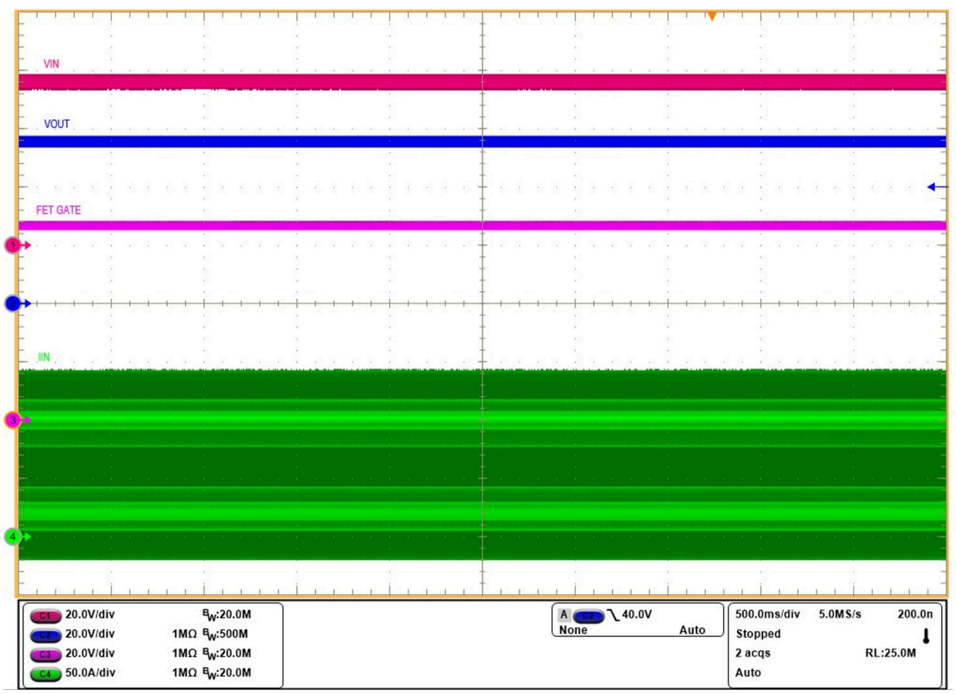


Figure 3-9. Load Transient Profile (Zoomed out): V_{IN} = 54V, C_{OUT} = 4.2mF, and 20A for 200µs to 100A for 500µs

3.6 Output Hot-Short Event

Figure 3-10 to Figure 3-15 show the output hot-short performance of LM5066I controller captured on the PMP23496 reference design.

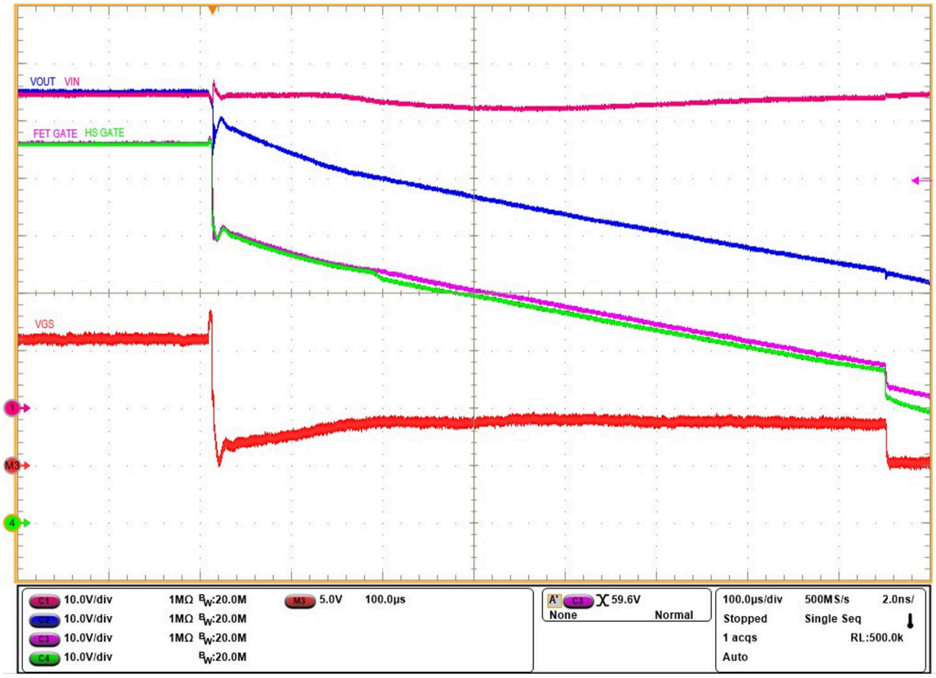


Figure 3-10. Output Hot-Short Event (Captured Signals: V_{IN}, V_{OUT}, HS GATE, FET GATE, and VGS): V_{IN} = 54V, C_{OUT} = 4.2mF, and Short-Circuit Threshold (I_{CB}) = About 300A

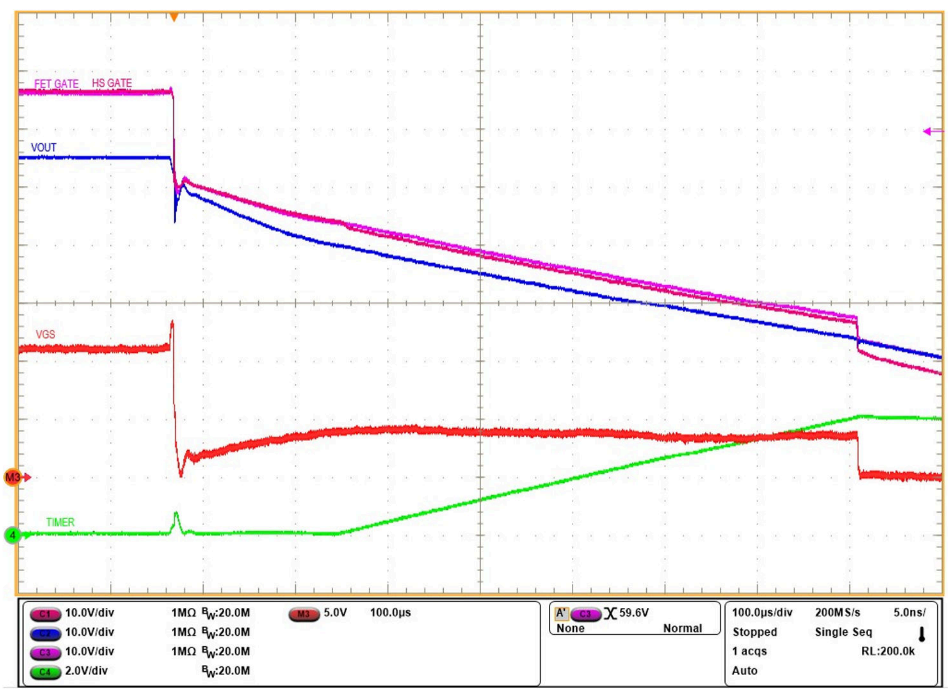


Figure 3-11. Output Hot-Short Event (Captured Signals: TIMER, V_{OUT}, HS GATE, FET GATE, and V_{GS}): V_{IN} = 54V, C_{OUT} = 4.2mF, and Short-Circuit Threshold (I_{CB}) = About 300A

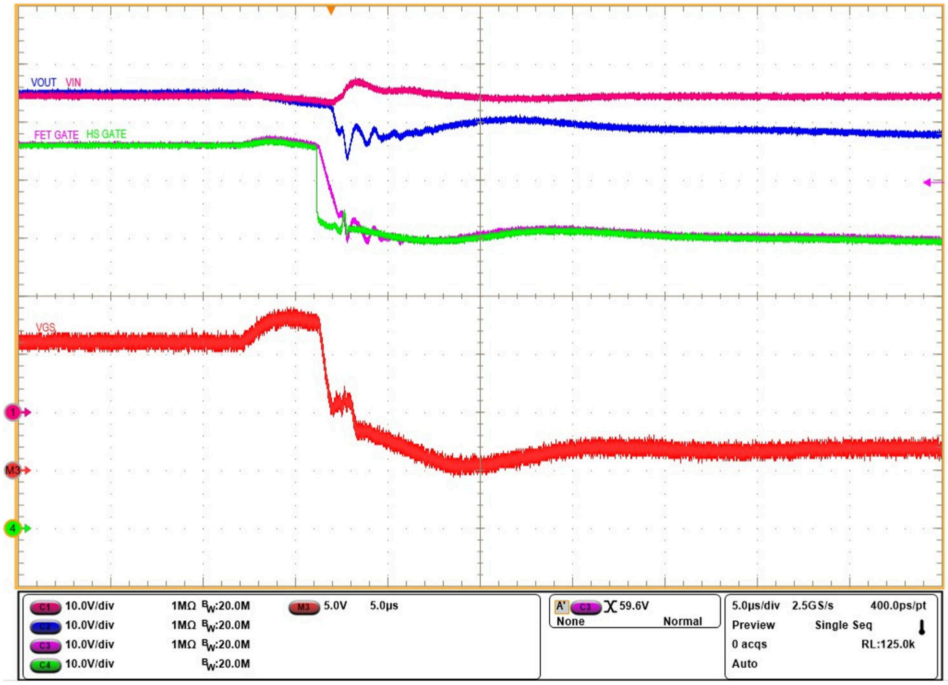


Figure 3-12. Output Hot-Short Event (Zoomed in, Captured Signals: V_{IN}, V_{OUT}, HS GATE, FET GATE, and V_{GS}): V_{IN} = 54V, C_{OUT} = 4.2mF, and Short-Circuit Threshold (I_{CB}) = About 300A

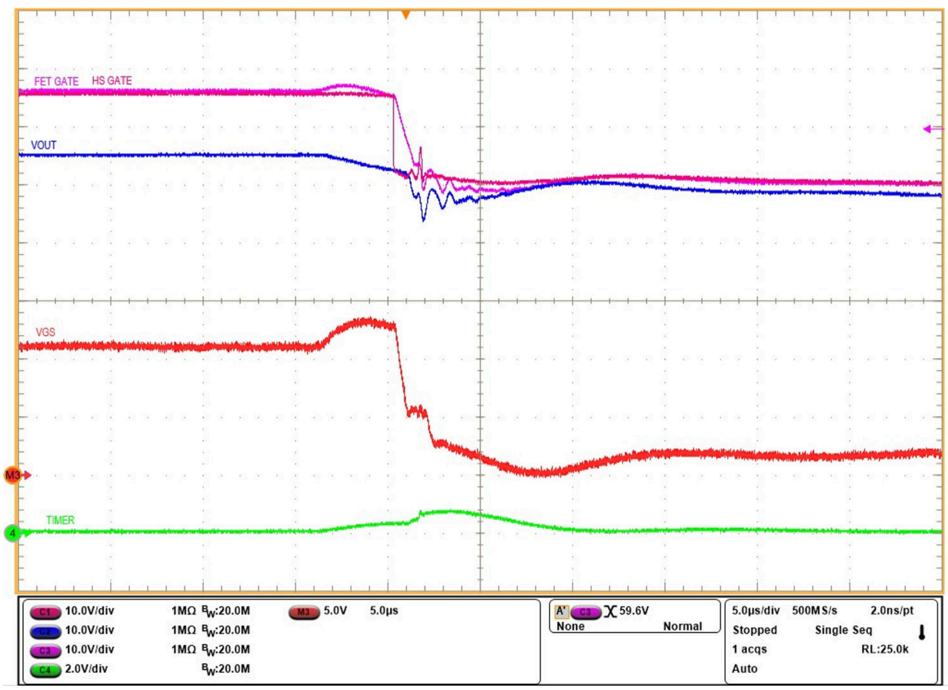


Figure 3-13. Output Hot-Short Event (Zoomed in, Captured Signals: TIMER, V_{OUT}, HS GATE, FET GATE, and V_{GS}): V_{IN} = 54V, C_{OUT} = 4.2mF, and Short-Circuit Threshold (I_{CB}) = About 300A

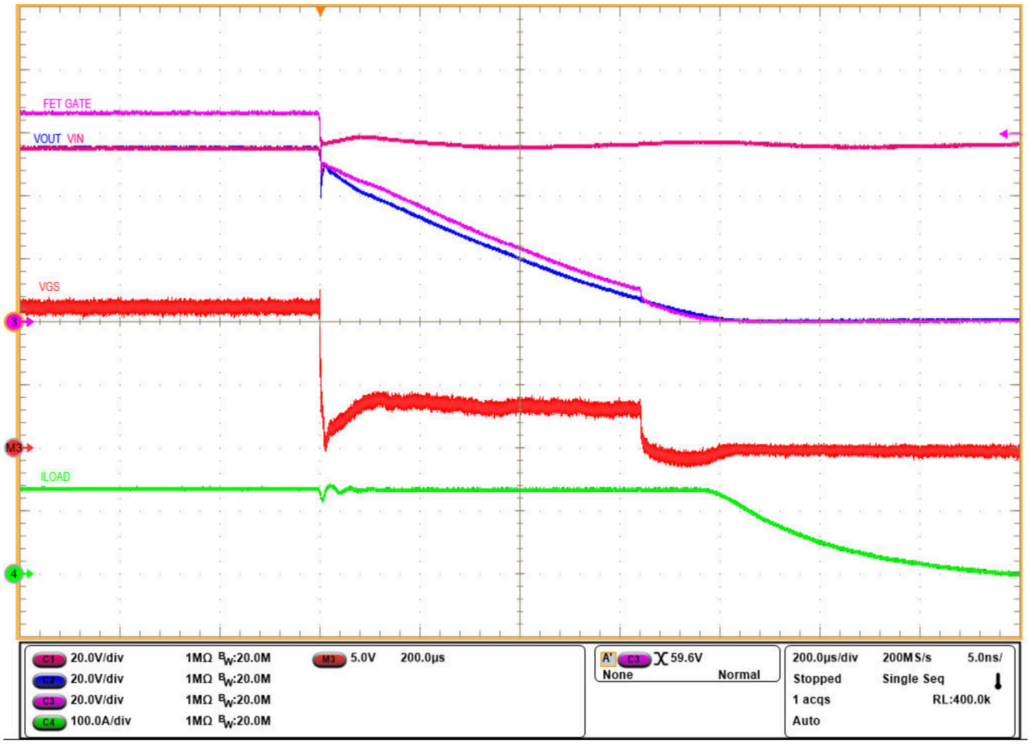


Figure 3-14. Output Hot-Short Event: V_{IN} = 54V, C_{OUT} = 4.2mF, I_{LOAD} = 150A, and Short-Circuit Threshold (I_{CB}) = About 300A

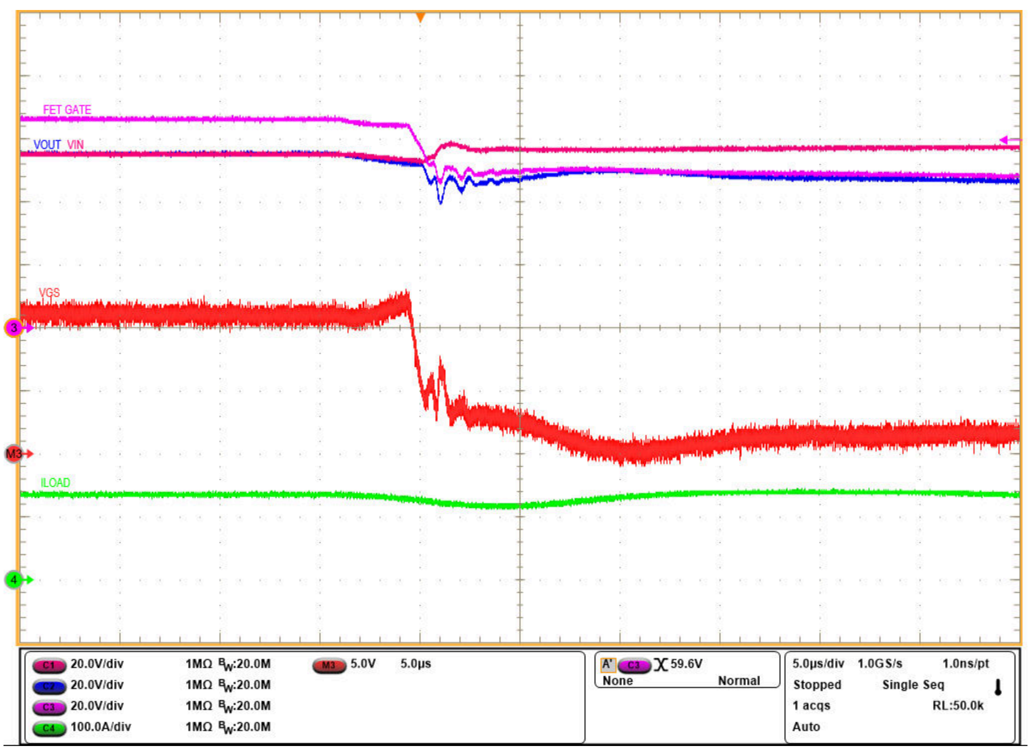


Figure 3-15. Output Hot-Short Event (Zoomed-In): V_{IN} = 54V, C_{OUT} = 4.2mF, I_{LOAD} = 150A, and Short-Circuit Threshold (I_{CB}) = About 300A

Trademarks

All trademarks are the property of their respective owners.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265