Test Report: PMP23392

Dual-Phase Buck Converter Reference Design Using GaN FETs for 48V Automotive Applications

Description

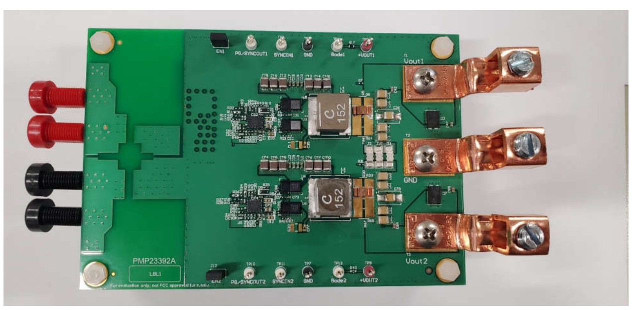
This reference design utilizes two LM5148-Q1 single-phase synchronous buck controllers and four LMG3100R017 GaN FETs configured as a dual-phase, interleaved, synchronous buck converter. The converter generates a regulated 5V output capable of delivering a nominal 30A of current to the load, with a peak current capability of 60A, accepting an input voltage of between 24Vin to 60Vin (48Vin nominal). The design is built on a 6-layer PCB with 2oz copper for each of the six layers. The evaluation board measures 5.0in × 3.4in (127.00mm × 86.36mm); however, the actual converter design size measures approximately 53.5mm × 52.0mm. This board is optimized for high efficiency across the entire load current range, which is achieved by configuring the converter to run in Pulse Frequency Modulation (PFM) mode at light loads.

Features

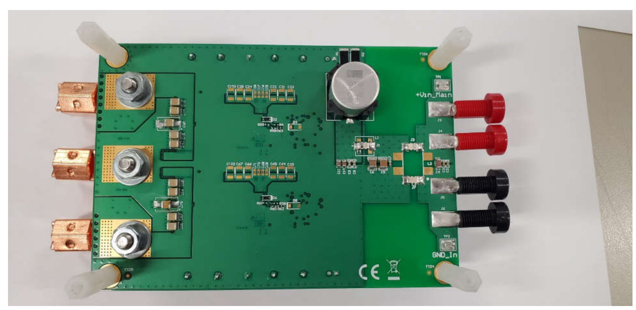
- Small design size
- High efficiency
- Spread-spectrum switching reduces EMI
- Interleaved two-phase operation reduces ripple voltages and RMS currents

Applications

- Surround view system ECU
- ADAS domain controller
- Conditionally automated drive controller



Top of Board



Bottom of Board

1 Test Prerequisites

1.1 Voltage and Current Requirements

Parameter	Specifications
V_{IN}	$48V_{DC}$ Nominal ($24V_{IN}$ minimum; $60V_{IN}$ maximum)
V_{OUT}	$5V_{DC}$
I_{OUT}	30A nominal (60A peak)
F_{sw}	300kHz per phase (600kHz effective interleaved)

1.2 Required Equipment

- Power Supply
- Electronic Load
- DMMs
- Oscilloscope

1.3 Considerations

Unless stated otherwise, the tests performed in this test report are taken at the nominal 48V input voltage and 30A load current and the device is configured to PFM mode.

2 Testing and Results

2.1 Efficiency, Power Loss, and Load Regulation Graphs

Figure 2-1 through Figure 2-12 show the buck converter efficiency, power loss, and load regulation, at 24V, 48V, and 60V input voltages.

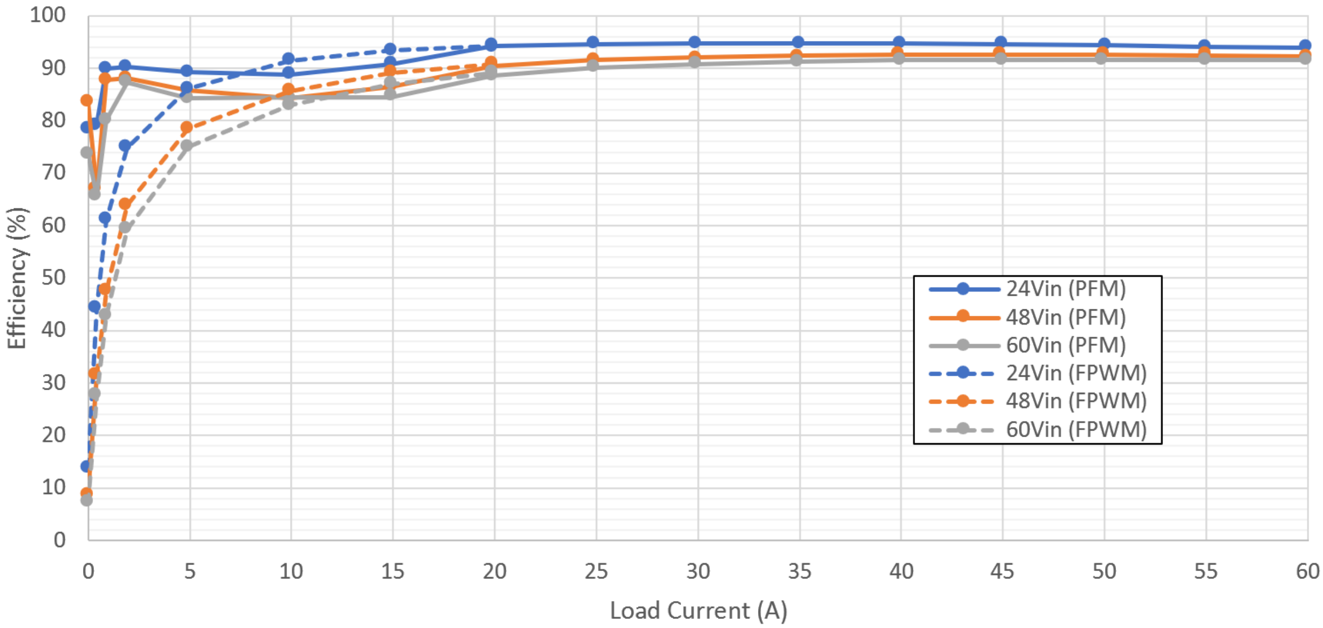


Figure 2-1. Efficiency (0A to 60A)

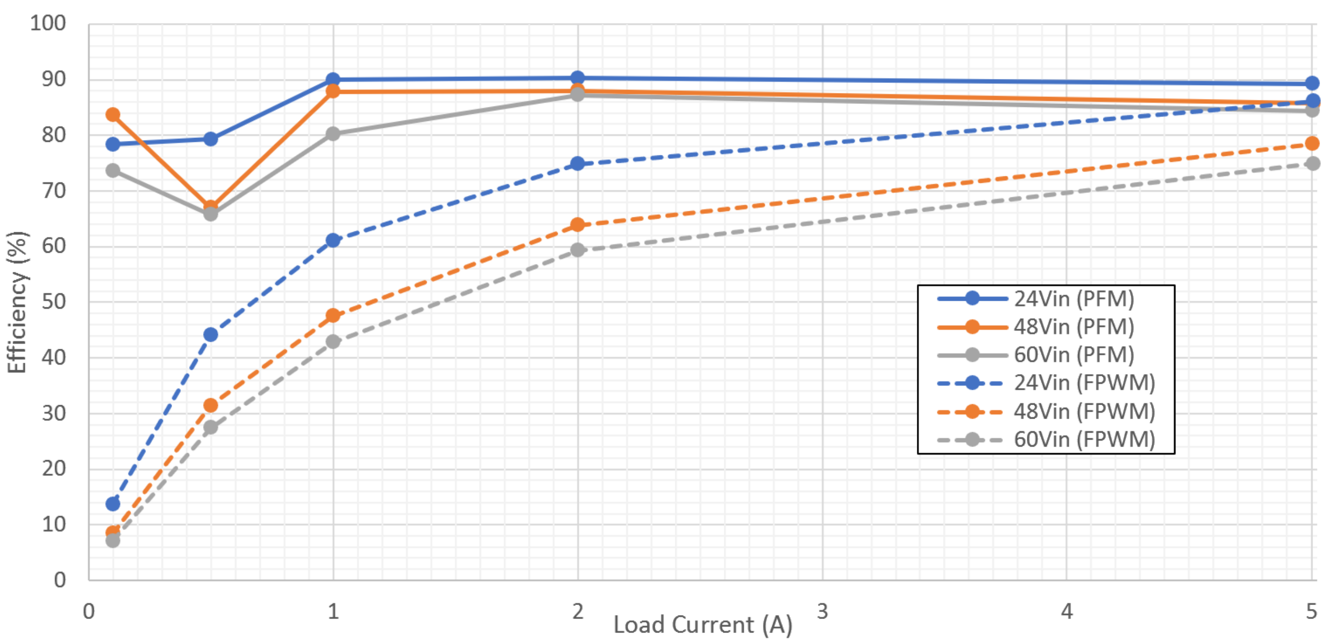


Figure 2-2. Efficiency (0A to 5A)

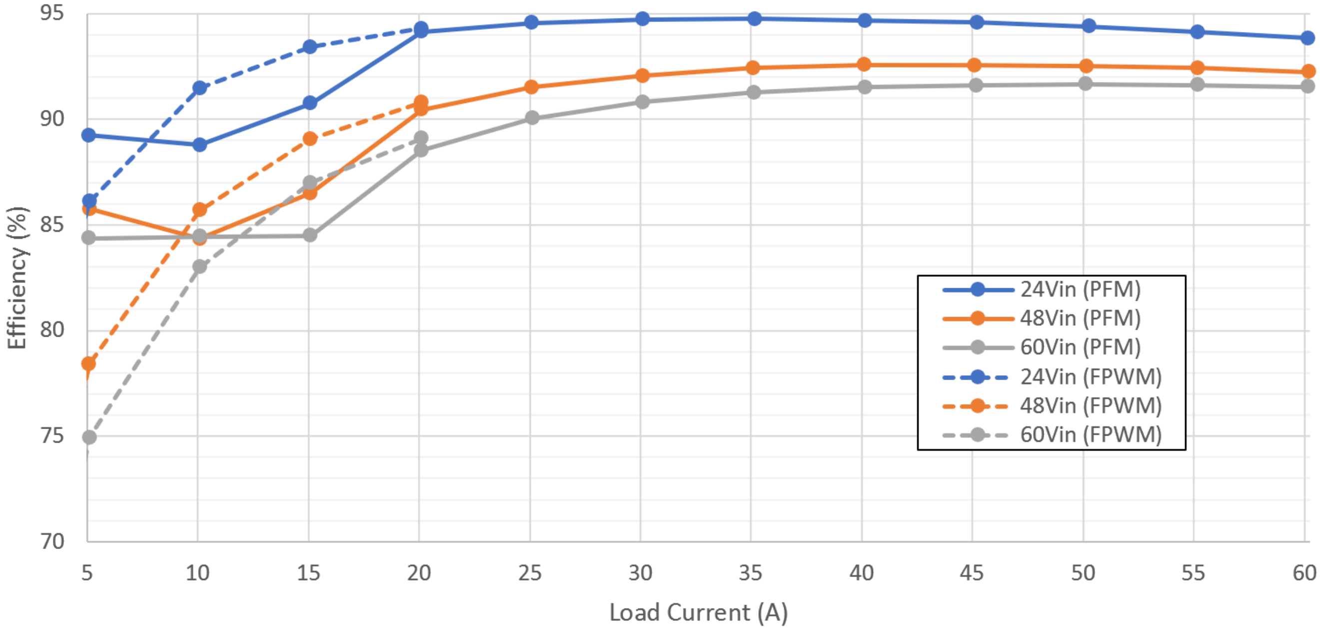


Figure 2-3. Efficiency (5A to 60A)

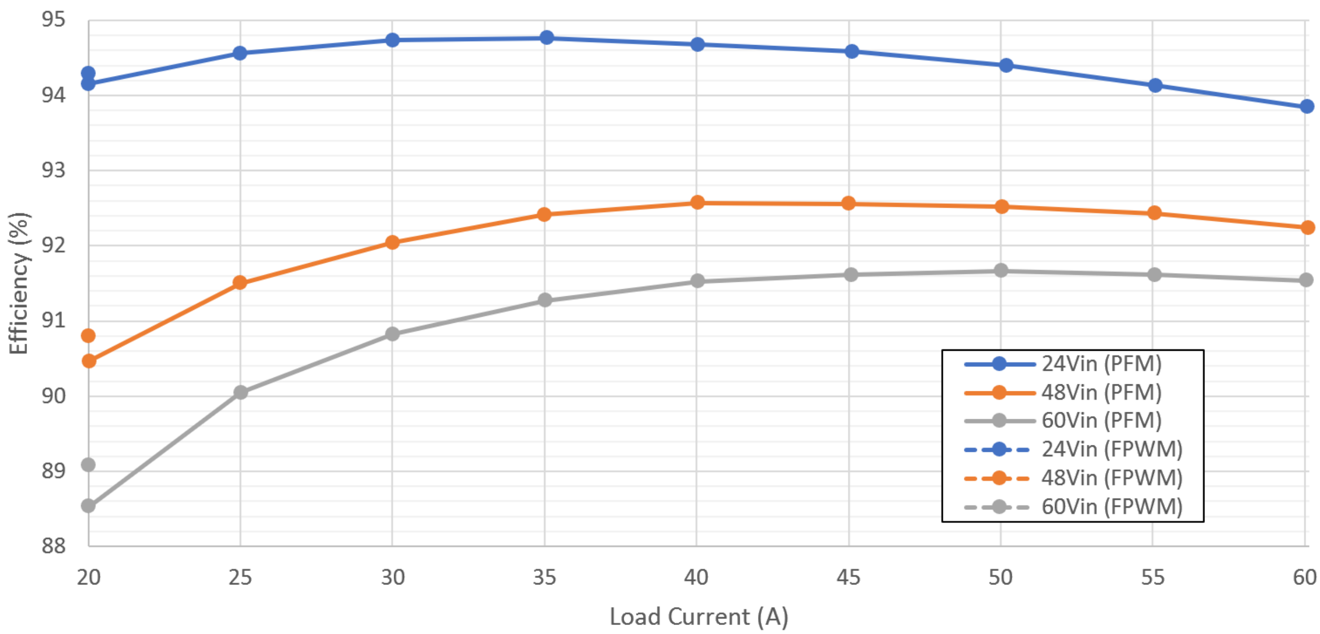


Figure 2-4. Efficiency (20A to 60A)

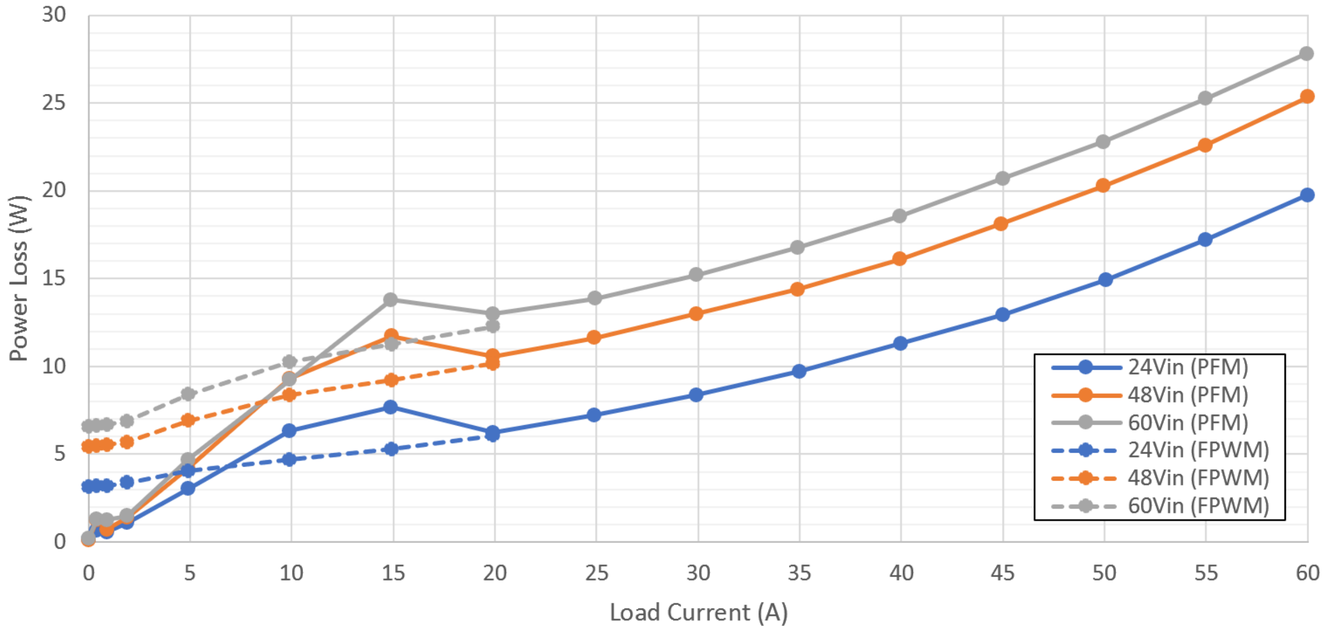


Figure 2-5. Power Loss (0A to 60A Load)

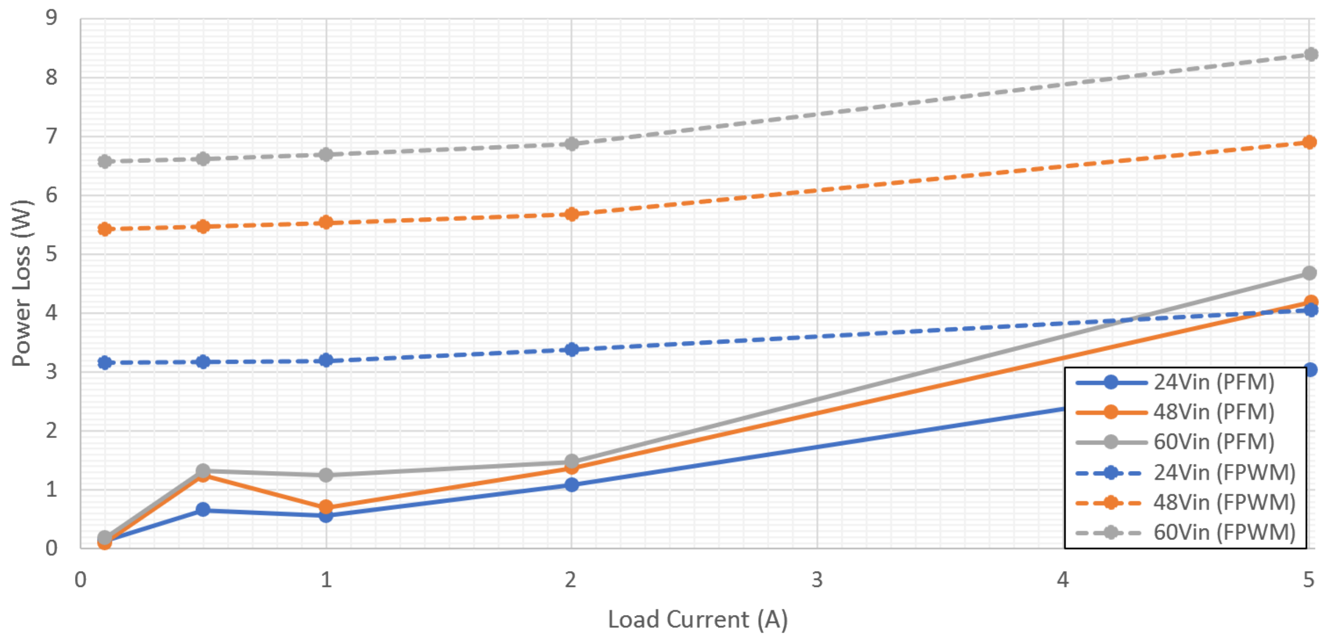


Figure 2-6. Power Loss (0A to 5A Load)

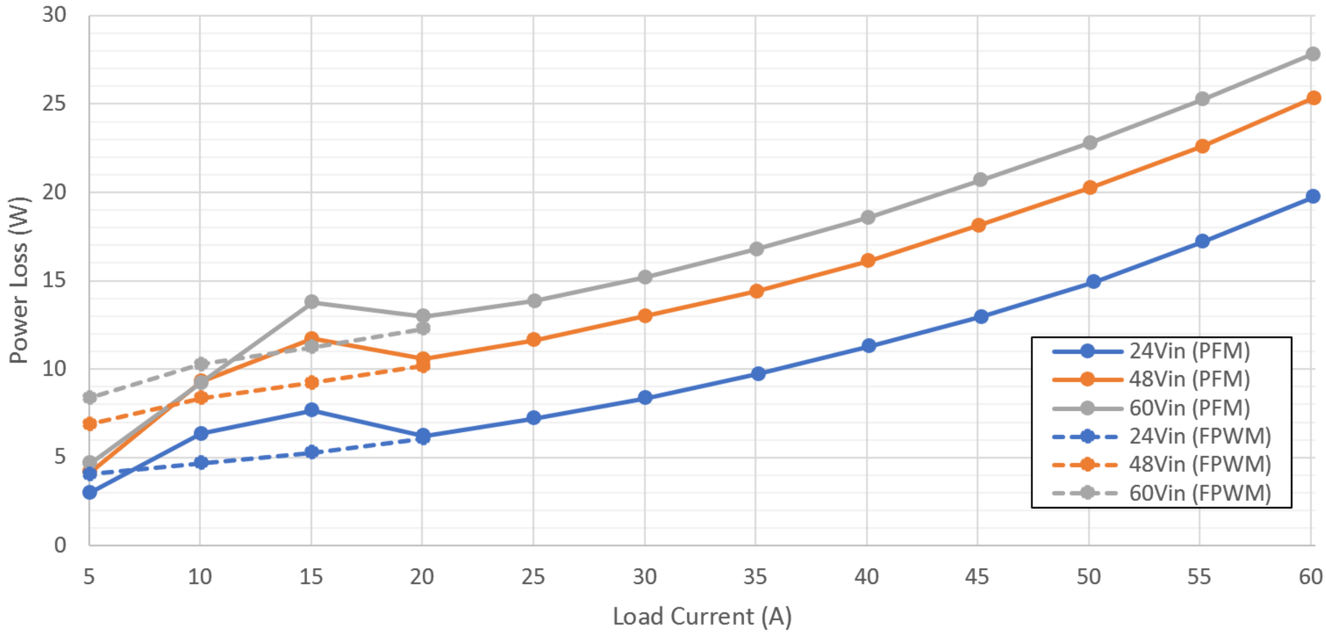


Figure 2-7. Power Loss (5A to 60A Load)

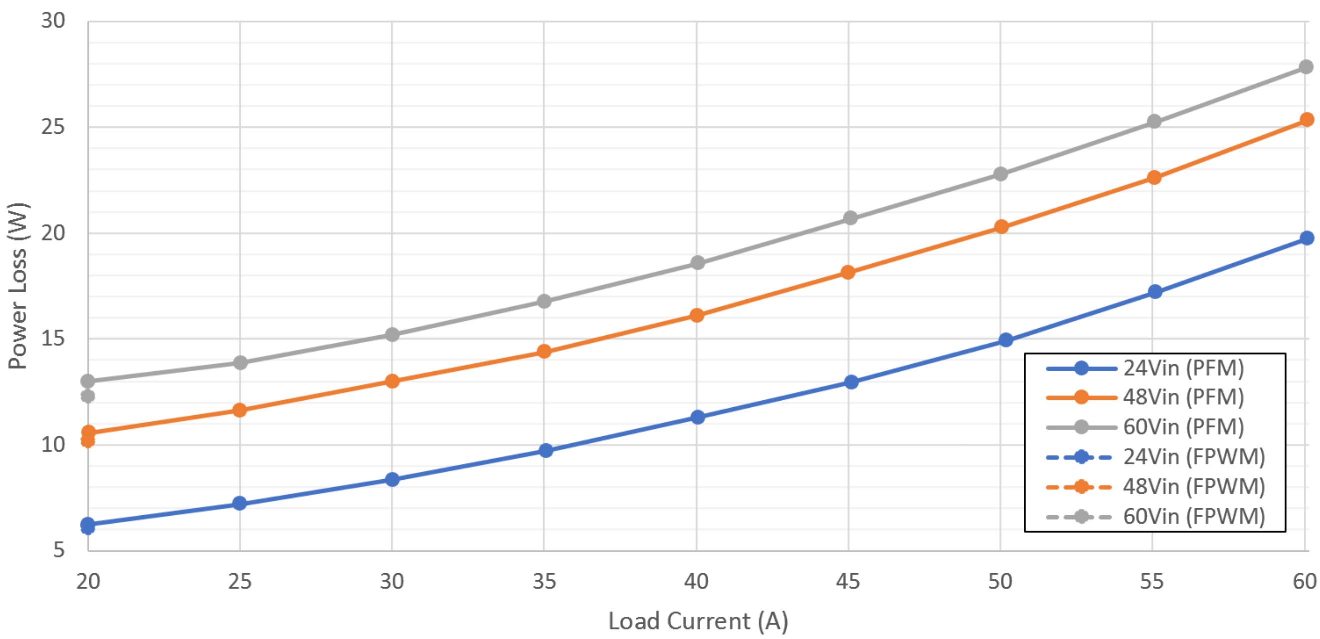


Figure 2-8. Power Loss (20A to 60A Load)

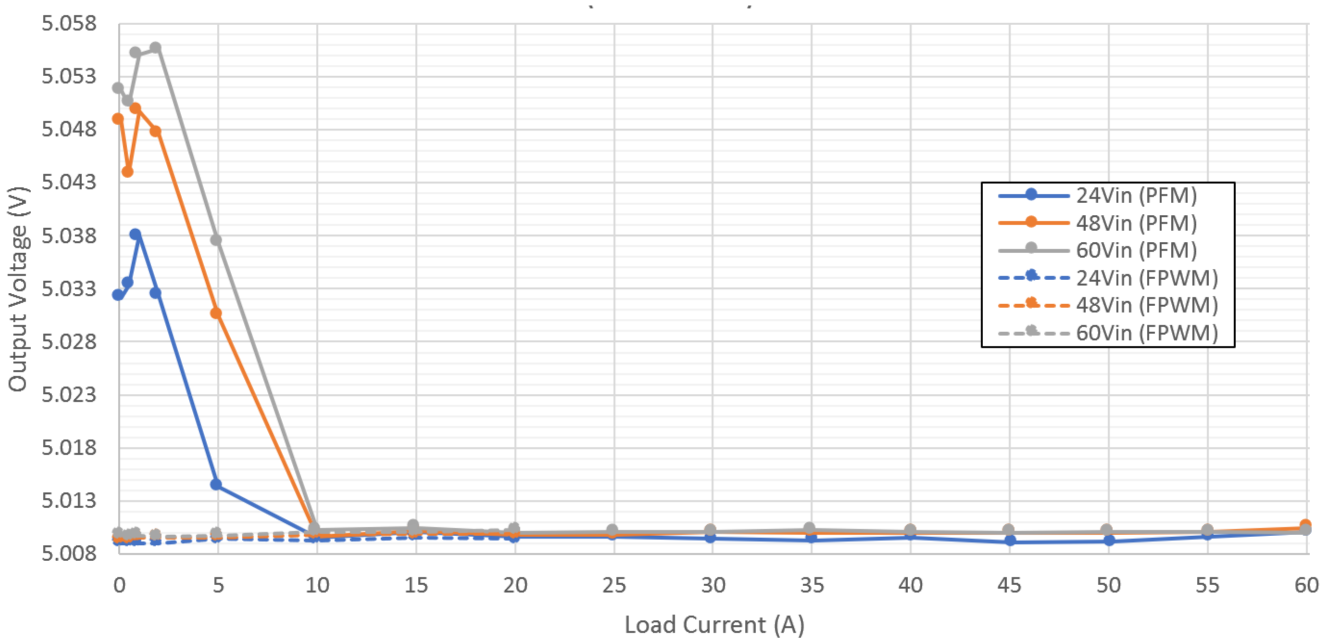


Figure 2-9. Load Regulation (0A to 60A Load)

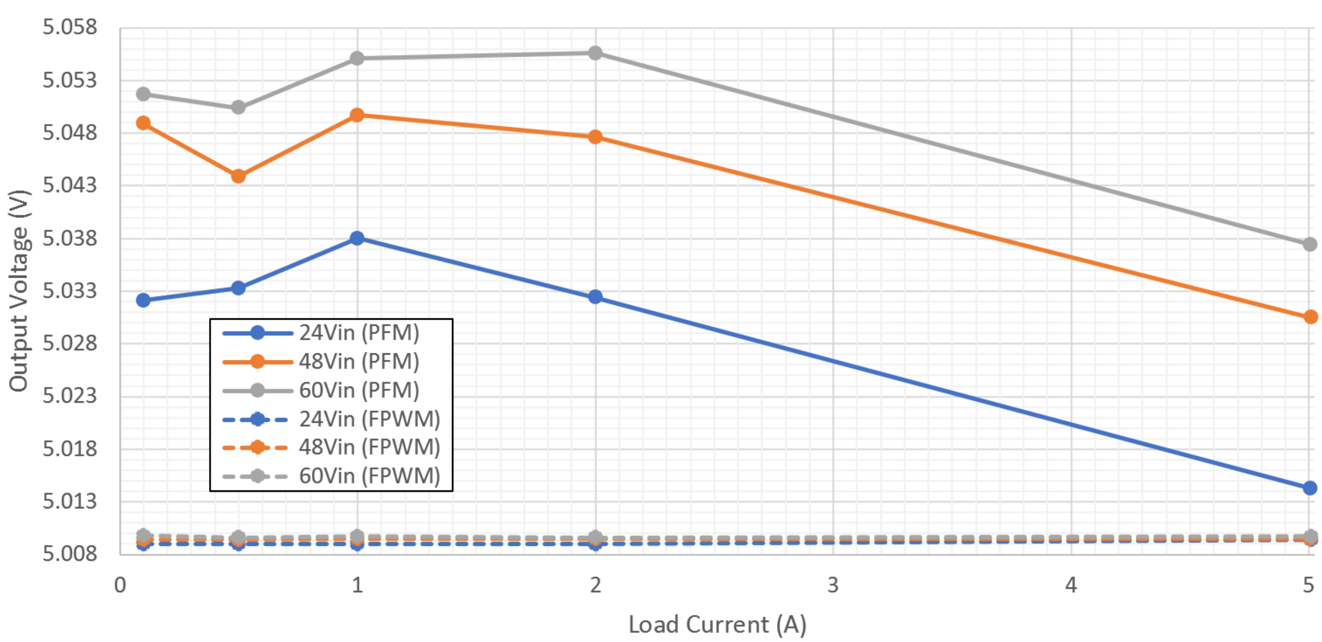


Figure 2-10. Load Regulation (0A to 5A Load)

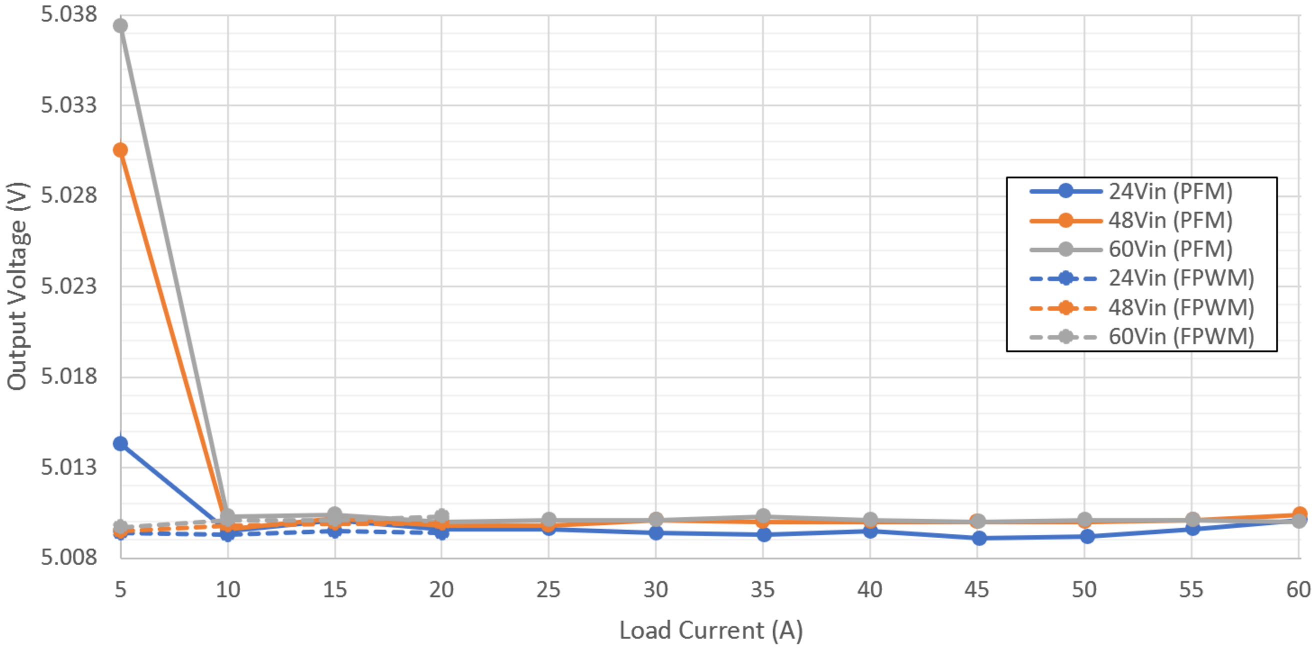


Figure 2-11. Load Regulation (5A to 60A Load)

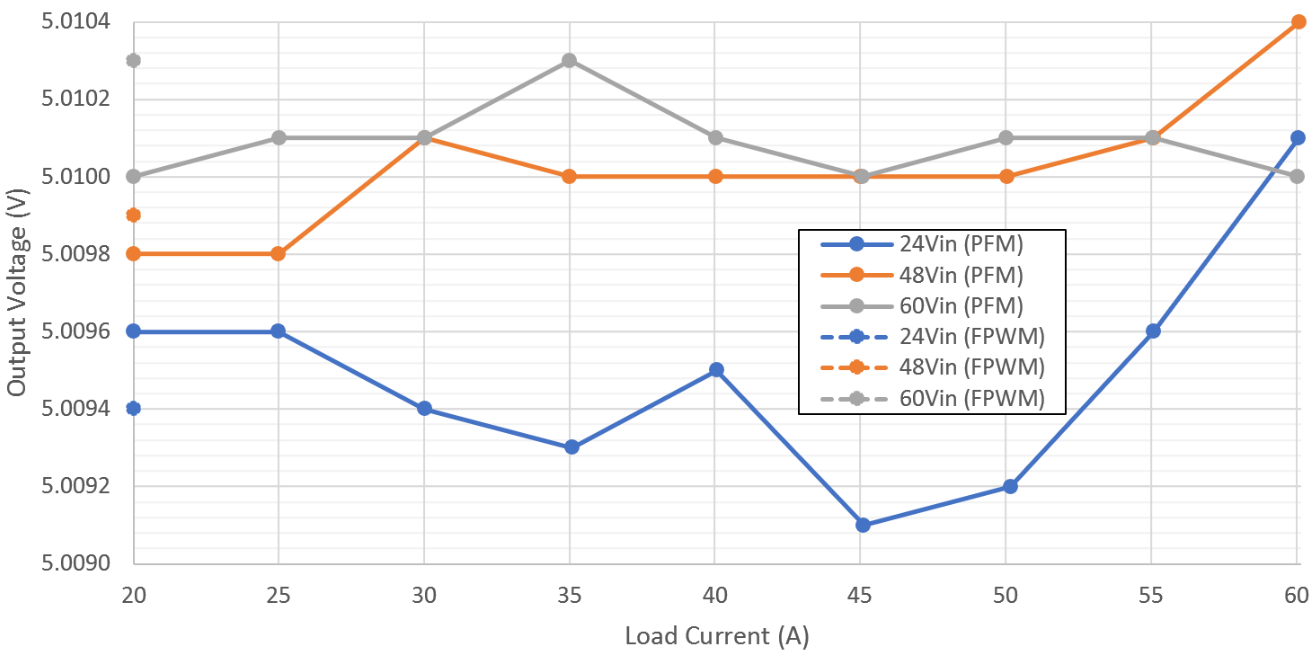
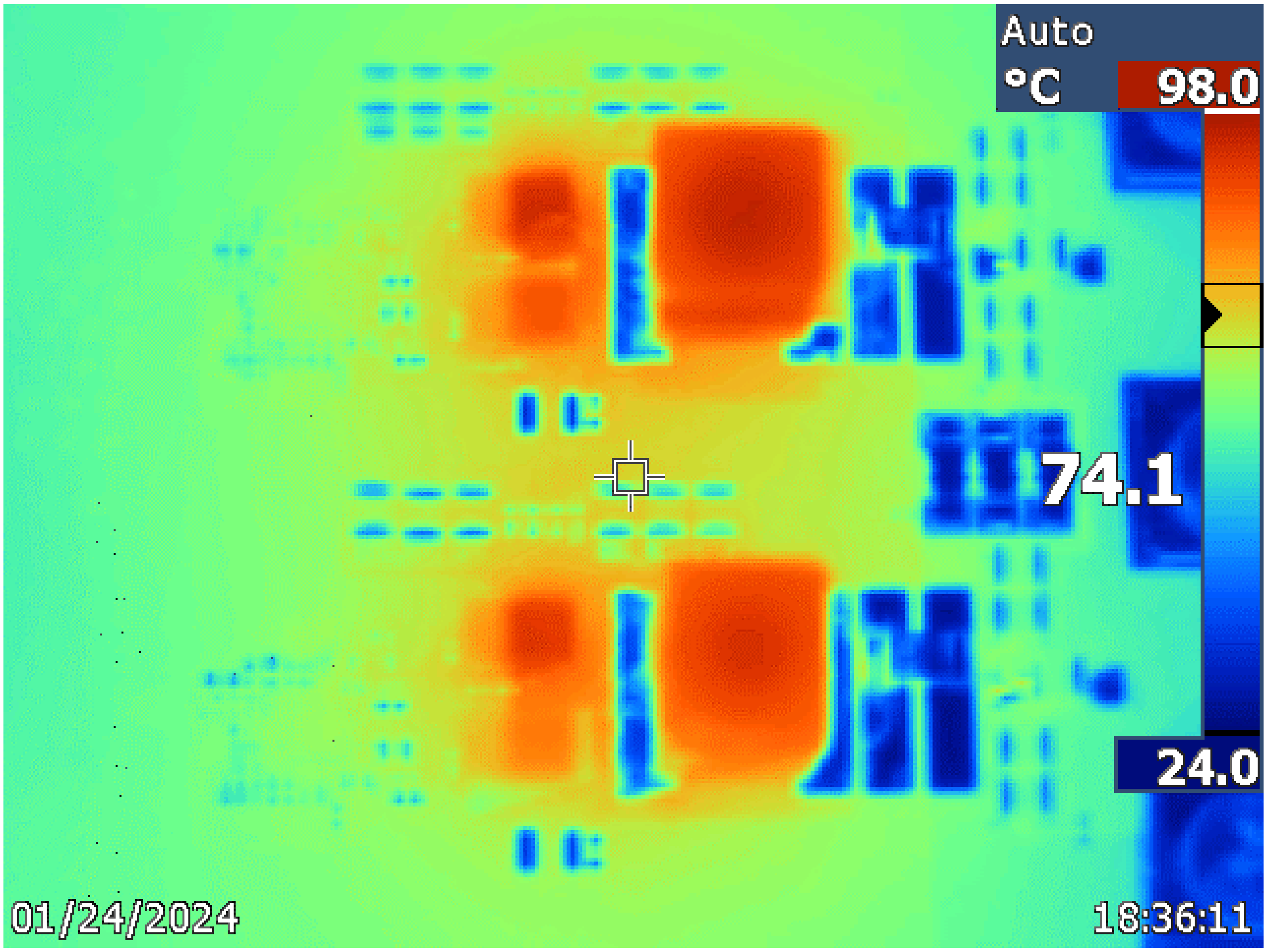


Figure 2-12. Load Regulation (20A to 60A Load)

2.2 Thermal Images

Figure 2-13 shows the buck converter thermal performance operating at 48V input and 30A load. The thermal test was conducted at room temperature with no airflow (natural convection), and the image was captured after thermal equilibrium was reached.



Natural convection (that is, no airflow); ambient at room temperature; thermal equilibrium reached

Figure 2-13. Thermal Image, 48V Input, 5V Output at 30A Load

2.3 Dimensions

Figure 2-14 and Figure 2-15 present the top and bottom photos of the PMP23392 board, respectively. The board dimensions are 5.0in × 3.4in (127.00mm × 86.36mm). Remember that this is an evaluation board and has plenty of unutilized space, for ease of testing. The final design size can be significantly reduced to approximately 53.5mm × 52.0mm (or smaller).

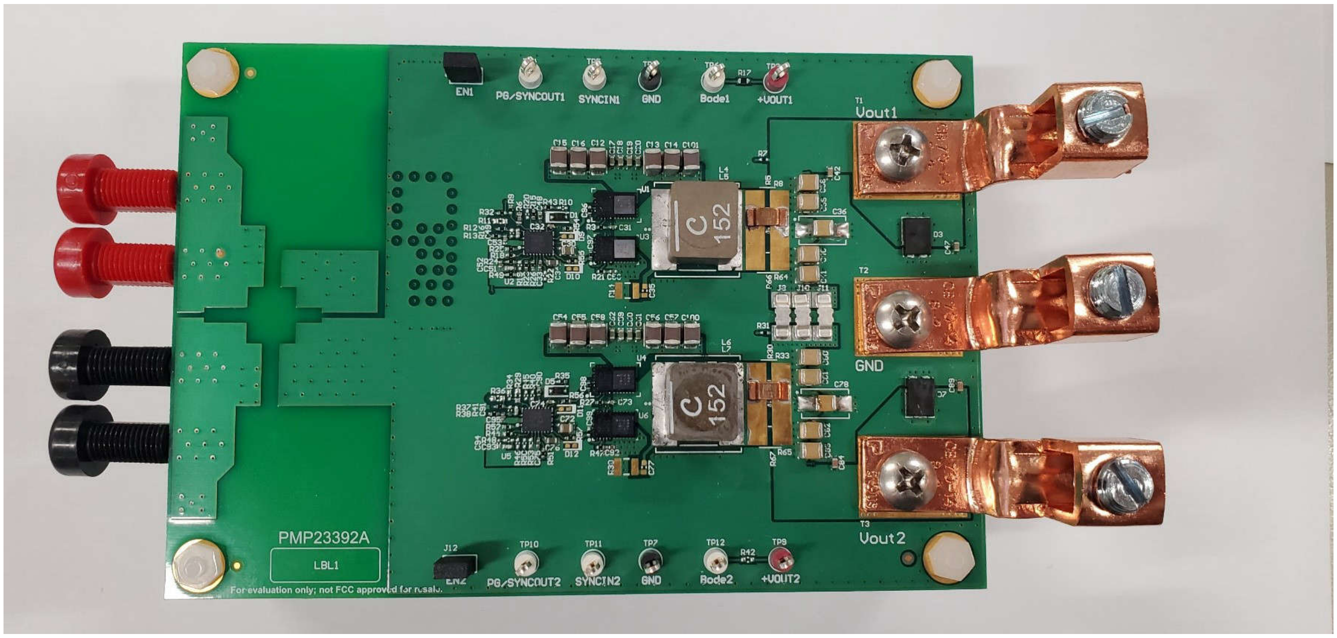


Figure 2-14. Top of PMP23392 Board

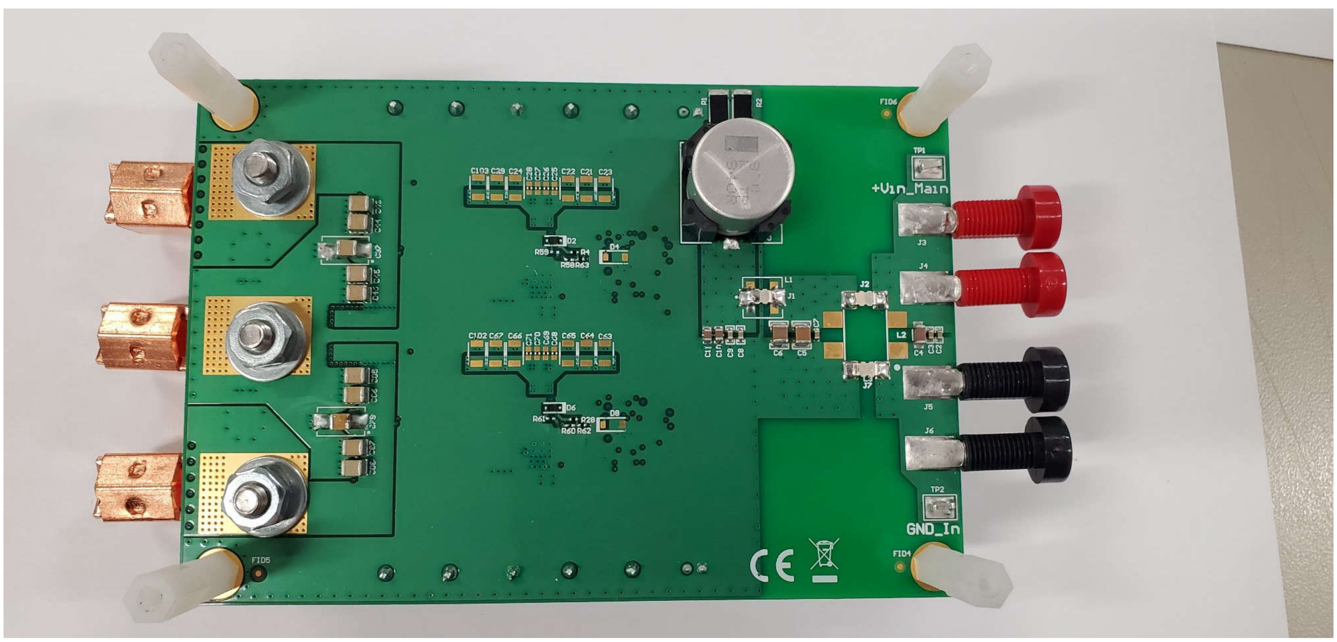


Figure 2-15. Bottom of PMP23392 Board

3 Waveforms

3.1 Switching

Figure 3-1 through Figure 3-9 show the switch node voltages of the buck converter at various operating conditions.

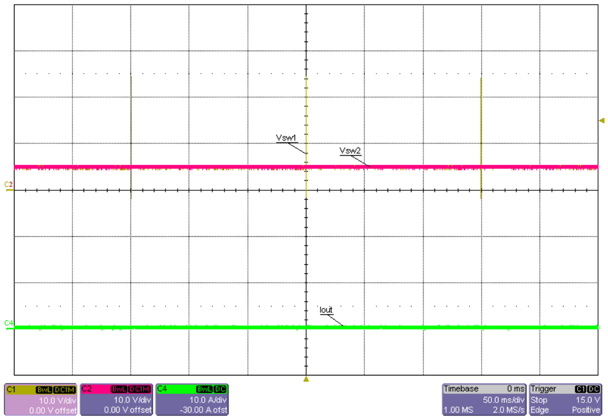


Figure 3-1. Switch Node Voltages, 24V Input, No Load, PFM Mode

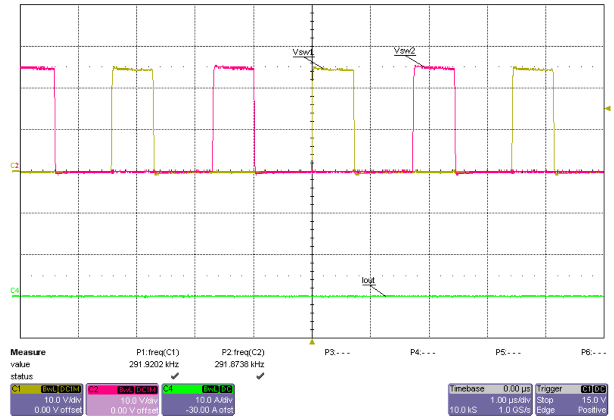


Figure 3-2. Switch Node Voltages, 24V Input, No Load, FPWM Mode

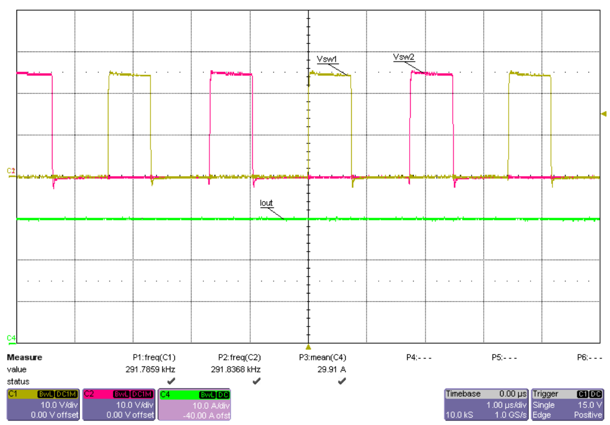


Figure 3-3. Switch Node Voltages, 24V Input, 30A Load

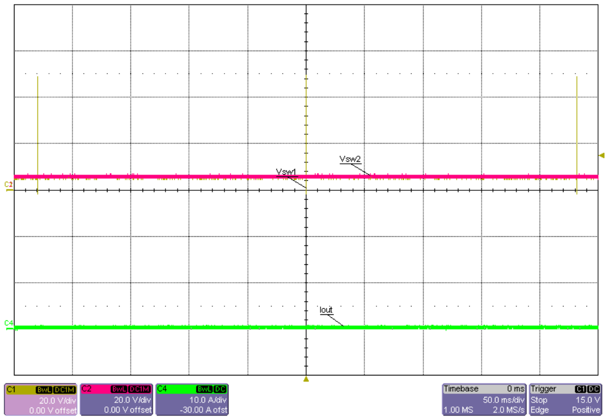


Figure 3-4. Switch Node Voltages, 48V Input, No Load, PFM Mode

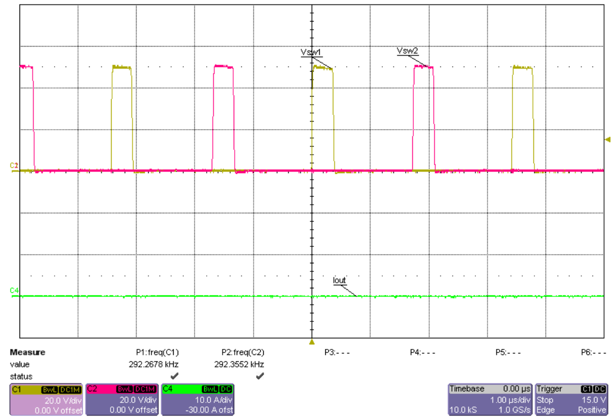


Figure 3-5. Switch Node Voltages, 48V Input, No Load, FPWM Mode

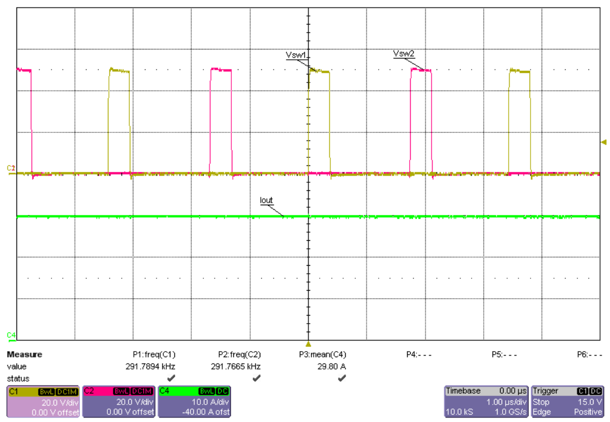


Figure 3-6. Switch Node Voltages, 48V Input, 30A Load

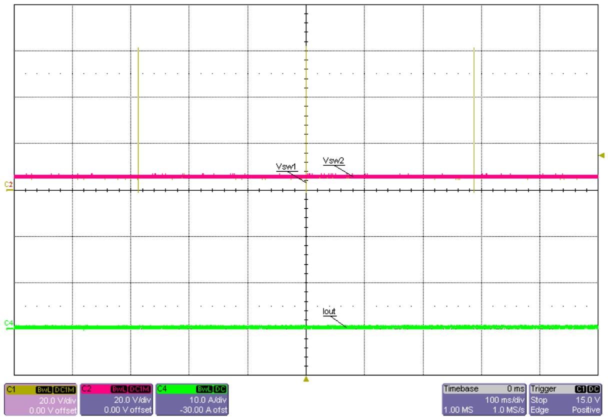


Figure 3-7. Switch Node Voltages, 60V Input, No Load, PFM Mode

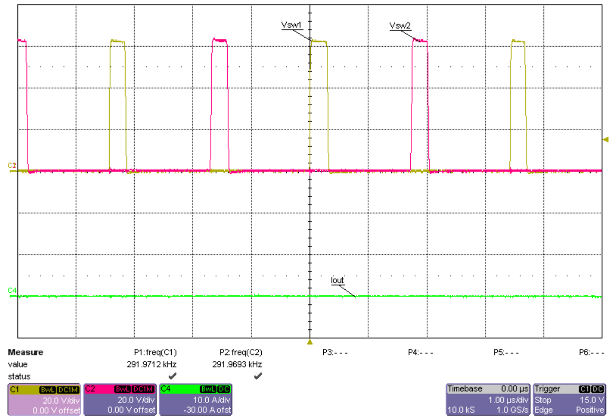


Figure 3-8. Switch Node Voltages, 60V Input, No Load, FPWM Mode

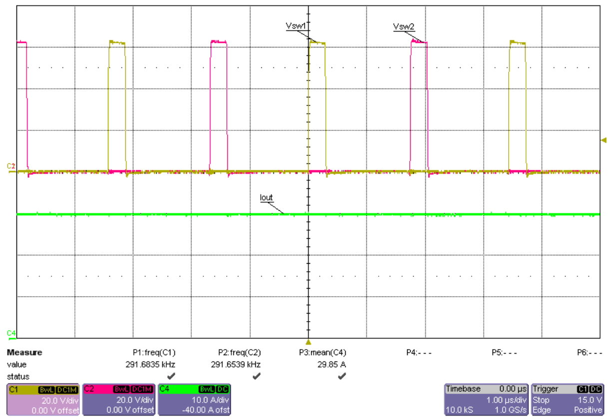


Figure 3-9. Switch Node Voltages, 60V Input, 30A Load

3.2 Output Voltage Ripple

Figure 3-10 through Figure 3-18 show the output voltage ripple at various operating conditions

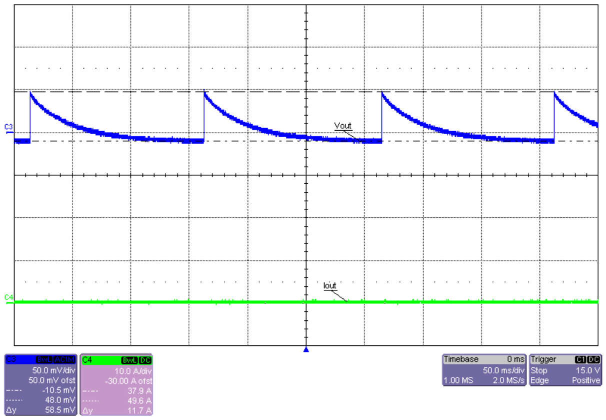


Figure 3-10. Output Voltage Ripple, 24V Input, No Load, PFM Mode

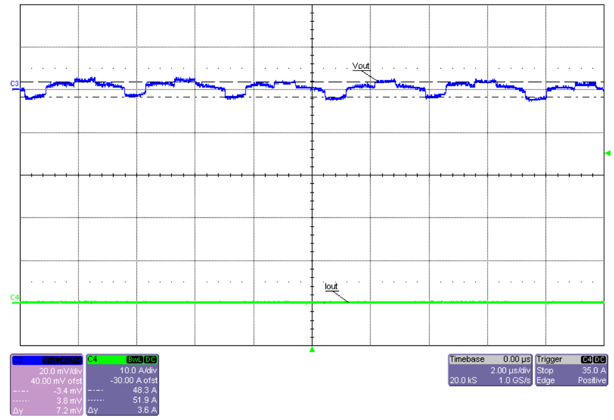


Figure 3-11. Output Voltage Ripple, 24V Input, No Load, FPWM Mode

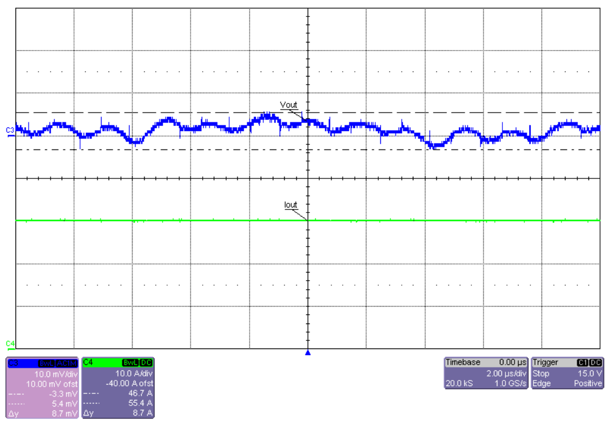


Figure 3-12. Output Voltage Ripple, 24V Input, 30A Load

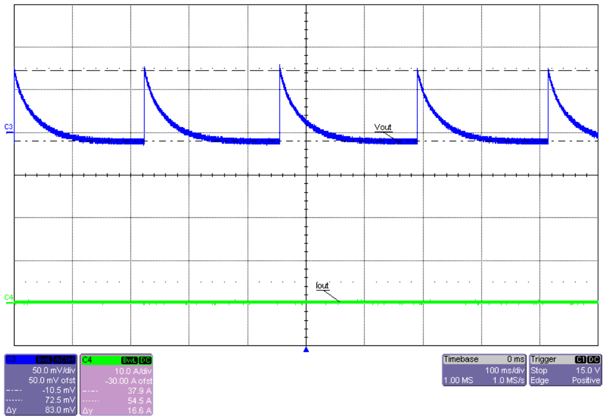


Figure 3-13. Output Voltage Ripple, 48V Input, No Load, PFM Mode

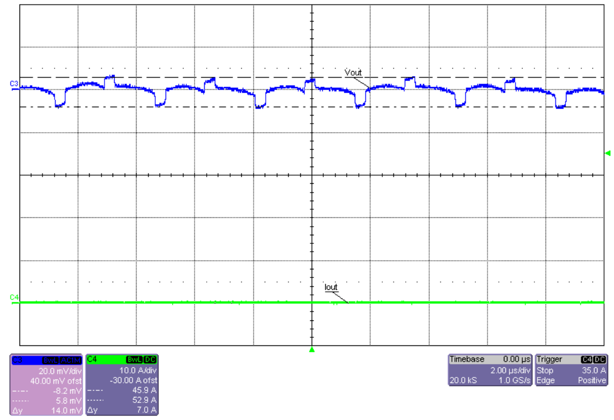


Figure 3-14. Output Voltage Ripple, 48V Input, No Load, FPWM Mode

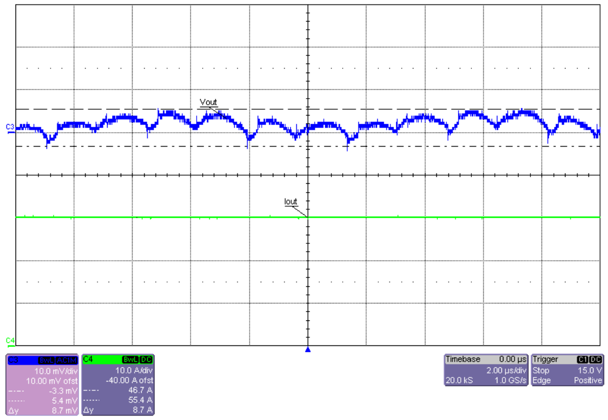


Figure 3-15. Output Voltage Ripple, 48V Input, 30A Load

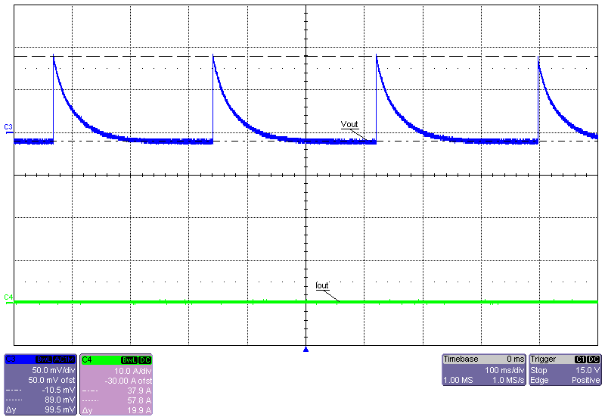


Figure 3-16. Output Voltage Ripple, 60V Input, No Load, PFM Mode

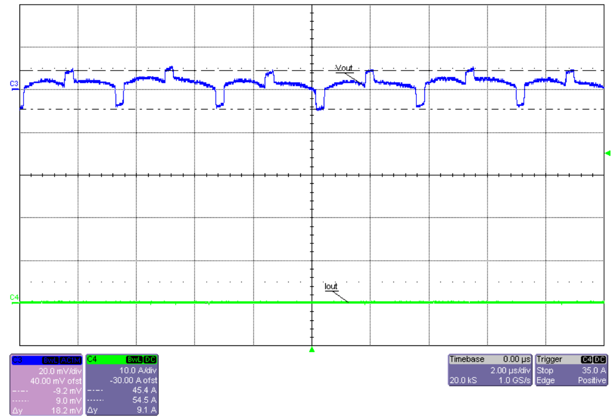


Figure 3-17. Output Voltage Ripple, 60V Input, No Load, FPWM Mode

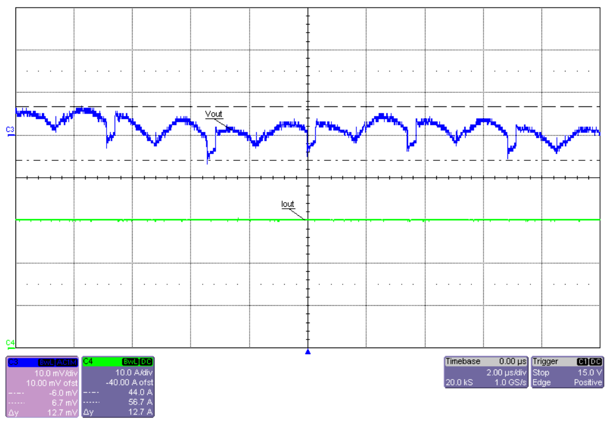


Figure 3-18. Output Voltage Ripple, 60V Input, 30A Load

3.3 Load Transient Response

Figure 3-19 through Figure 3-21 show the load transient waveforms of at various input voltages with the output undergoing a 30A-to-60A load step.

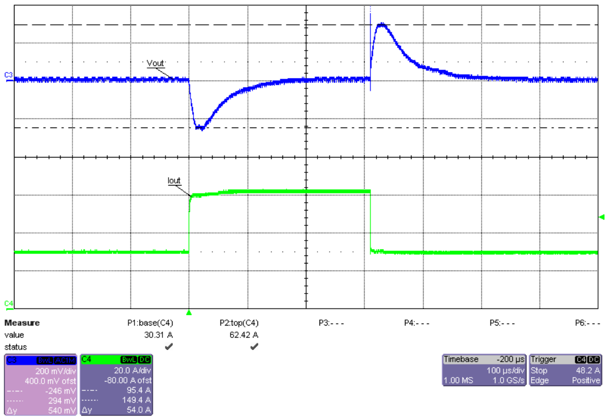


Figure 3-19. Load Transient Response, 24V Input, 30A-to-60A Load Step

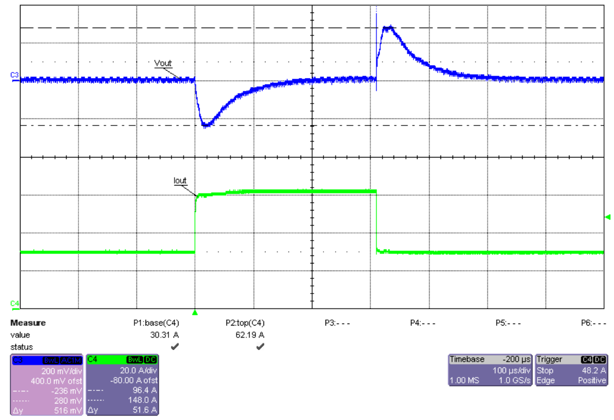


Figure 3-20. Load Transient Response, 48V Input, 30A-to-60A Load Step

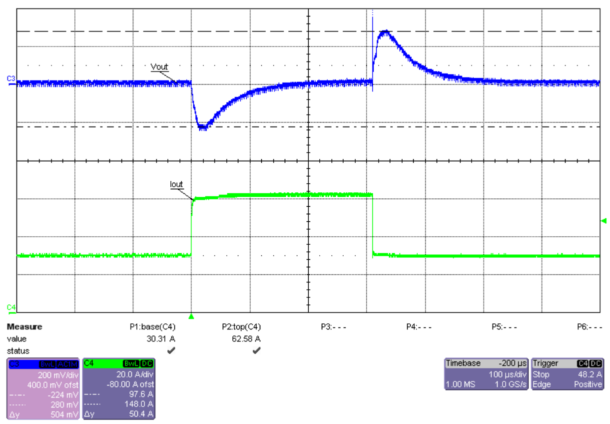


Figure 3-21. Load Transient Response, 60V Input, 30A-to-60A Load Step

3.4 Start-Up

Figure 3-22 through Figure 3-27 show the start-up waveforms of the converter at various operating conditions.

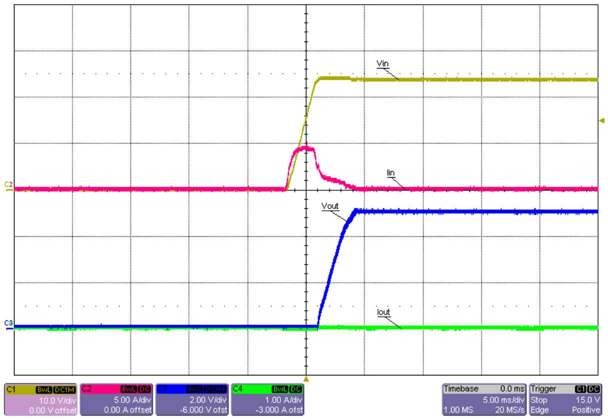


Figure 3-22. Start-Up Into No Load, 24V Input

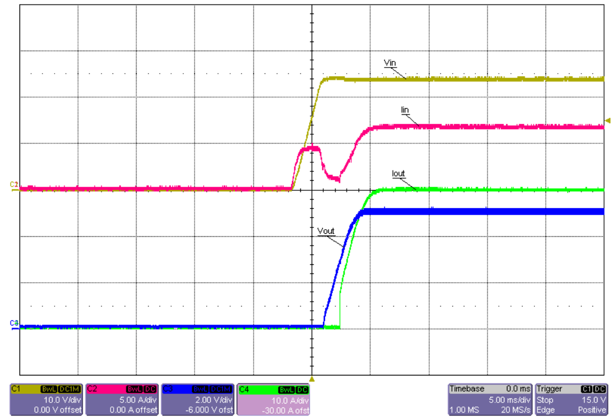


Figure 3-23. Start-Up Into 30A Constant-Resistance Load, 24V Input

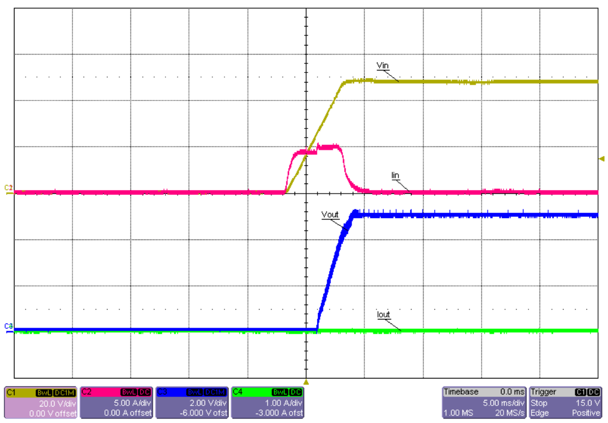


Figure 3-24. Start-Up Into No Load, 48V Input

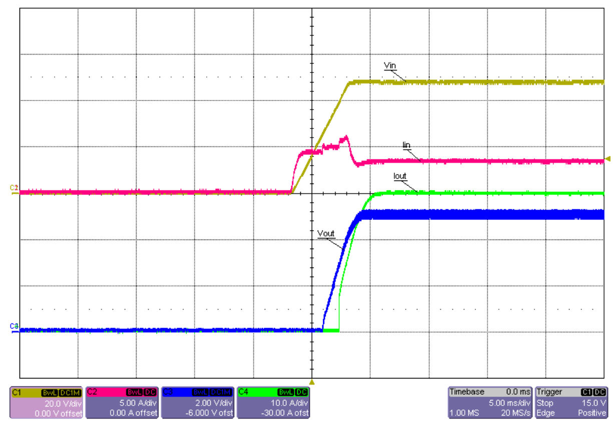


Figure 3-25. Start-Up Into 30A Constant-Resistance Load, 48V Input

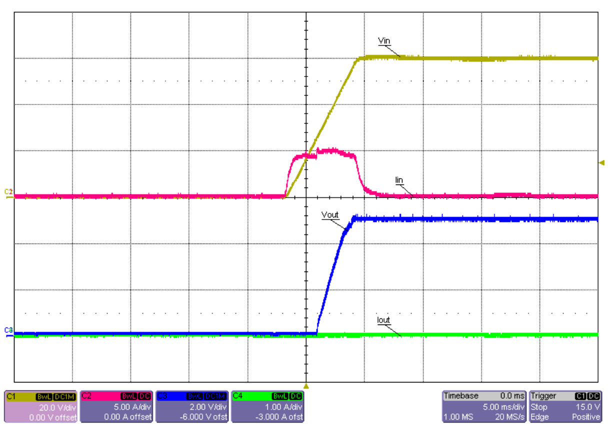


Figure 3-26. Start-Up Into No Load, 60V Input

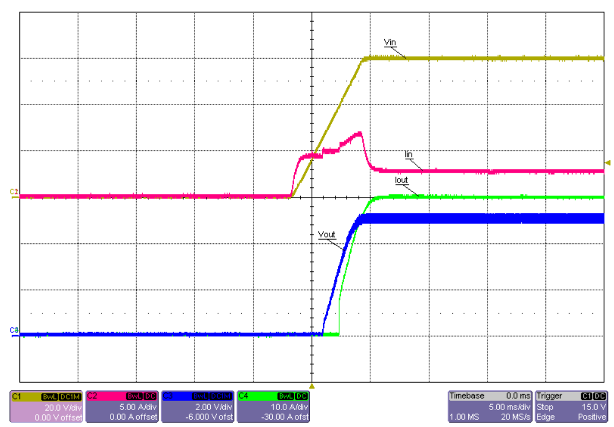


Figure 3-27. Start-Up Into 30A Constant-Resistance Load, 60V Input

3.5 Overcurrent Protection

Figure 3-28 shows the overcurrent protection (OCP) threshold of the buck converter at 48V input voltage.

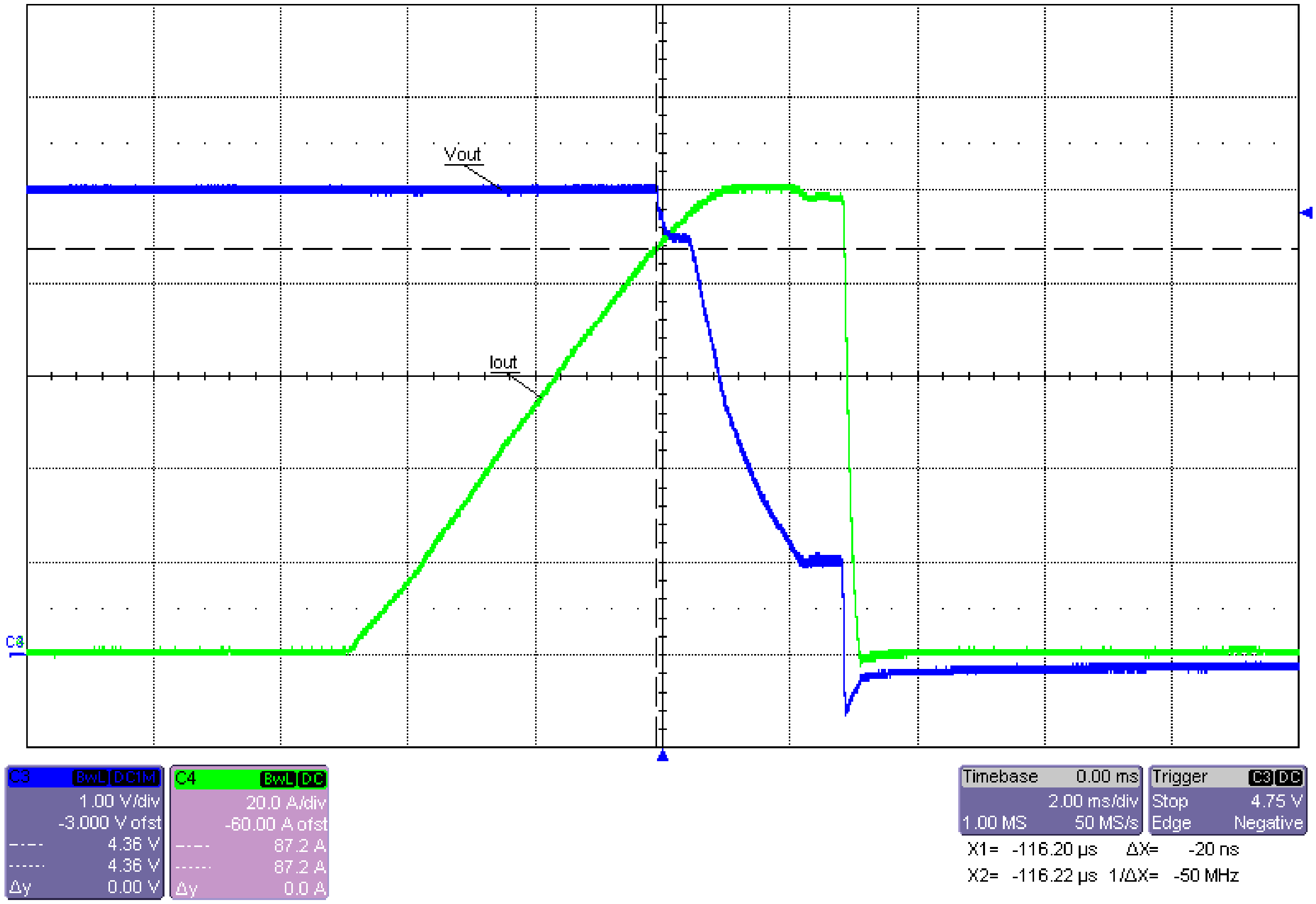


Figure 3-28. Overcurrent Protection at 48V Input

3.6 Efficiency and Power Loss Comparison of Varying Solutions

Figure 3-29 and Figure 3-30 show the difference in efficiency and power loss between Silicon FET and GaN FET designs operating at various switching frequencies. Results shown are taken at 48V input voltage.

The PMP23392 design uses LMG3100R017 GaN FETs switching at 300kHz / phase and XAL1010-152 inductors, exemplifying a small solution size. A variant of the PMP23392 design (using LMG3100R017 GaN FETs) except using ZE2652-AE inductors and switching at 150kHz / phase, exemplifies a high-efficiency solution.

PMP23420, a design equivalent to PMP23392, yet using Silicon FETs, ZE2652-AE inductors, and switching at 150kHz / phase, exemplifies a low-cost solution.

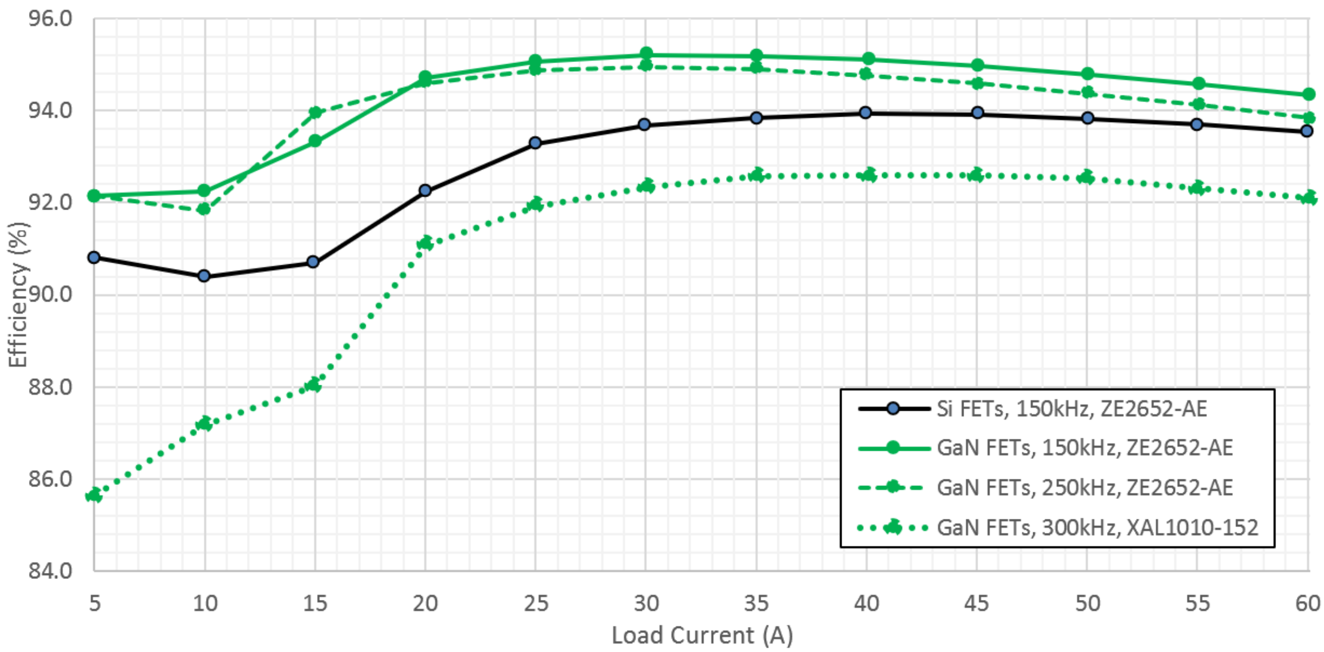


Figure 3-29. Efficiency Comparison Between Silicon and GaN FET Solutions at Varying Switching Frequencies (5A to 60A Load)

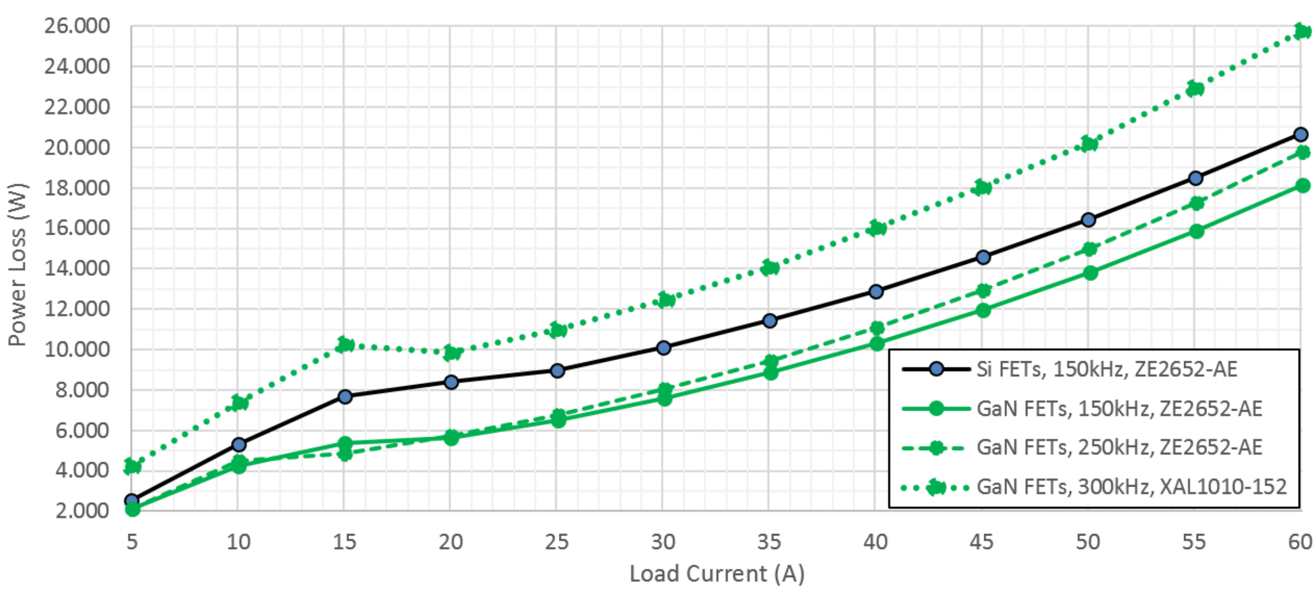


Figure 3-30. Power Loss Comparison Between Silicon and GaN FET Solutions at Varying Switching Frequencies (5A to 60A Load)

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