Test Report: PMP22829

Synchronous Buck Converter Reference Design for Infotainment Applications

Description

This reference design is a Synchronous Buck Converter circuit using the LM63625-Q1 controller integrated circuit (IC). The design accepts an input voltage of 9.8 V_{IN} to 16 V_{IN} and provides a regulated output voltage of 9.3 V_{OUT} capable of delivering up to 2.1 A of current. The design is built on a 4-layer FR-4 PCB, with 1 oz copper for each of the four layers. The board is 29.2 mm × 12.5 mm. See *LM636xx-Q1 Functional Safety FIT Rate, FMD, and Pin FMA* for any safety concerns.

Features

- Very small design size with single-sided component assembly
- Regulator includes integrated FETs
- High efficiency
- Optimized for automotive applications
- Regulator features spread-spectrum switching (dithering) for improved EMI performance

Applications

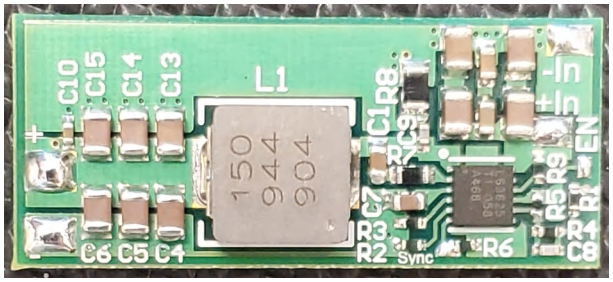
- Aftermarket head unit
- Automotive head unit

Note

Waveforms gathered for Section 3.4 (Start-up and Shutdown) were performed with 6 × 22-µF output capacitors installed and with a 100-kΩ top feedback divider resistor and 12.1-kΩ bottom feedback divider resistor. All other tests were performed using the 2 × 22-µF output capacitors and 24.9-kΩ top feedback divider resistor and 3.01-kΩ bottom feedback divider resistor.

No significant change is anticipated during start-up, except for a lower input current during the soft-start period when using 2 × 22-µF output capacitors.

No significant change is anticipated during shutdown, except for a faster output voltage decay when using 2 × 22-µF output capacitors.



Top Photo

Bottom Photo

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
V_{IN}	9.8 VDC to 16 VDC, 13.2 VDC nominal
V_{OUT}	9.3 VDC
I_{OUT}	1.8 A nominal, 2.1 A maximum
Switching Frequency	About 500 kHz

2 Testing and Results

2.1 Voltage Regulation

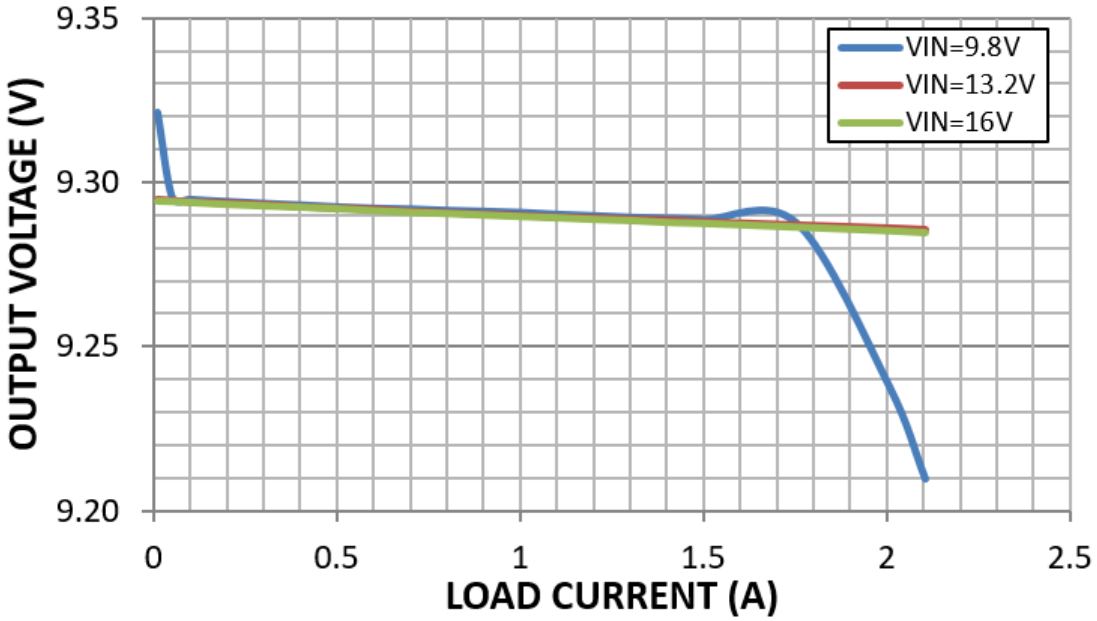


Figure 2-1. FPWM Line and Load Regulation, V_{OUT} = 9.32 V, Ta = 25°C

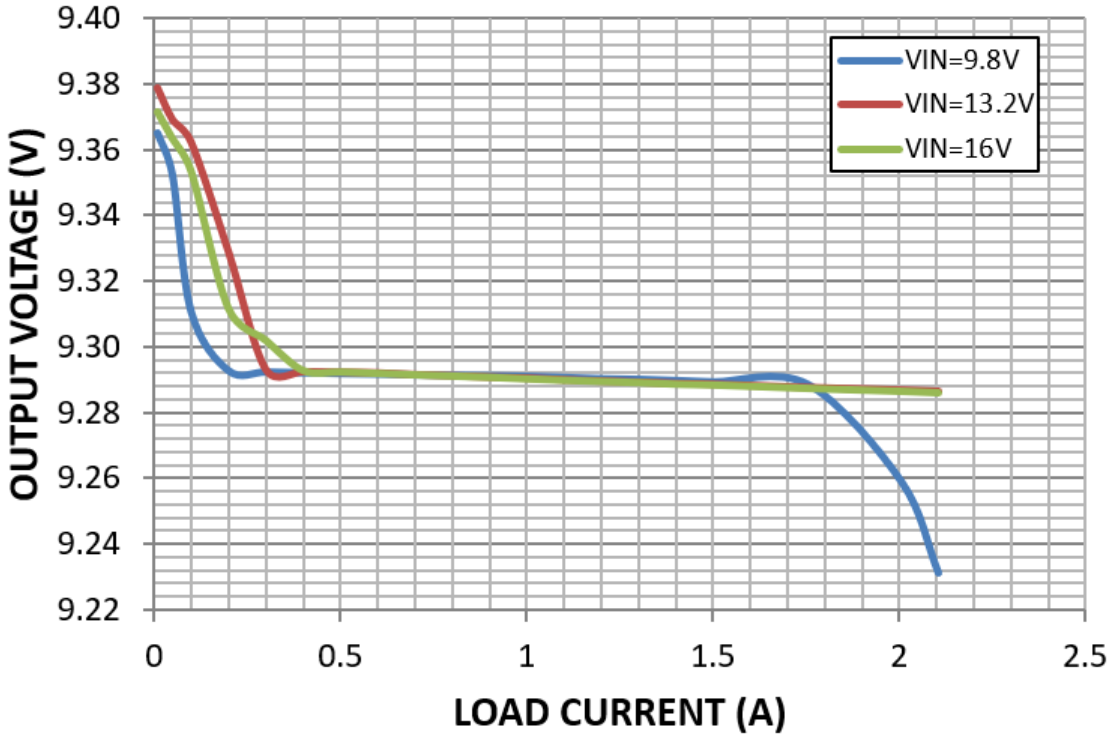


Figure 2-2. PFM Line and Load Regulation, V_{OUT} = 9.36 V, Ta = 25°C

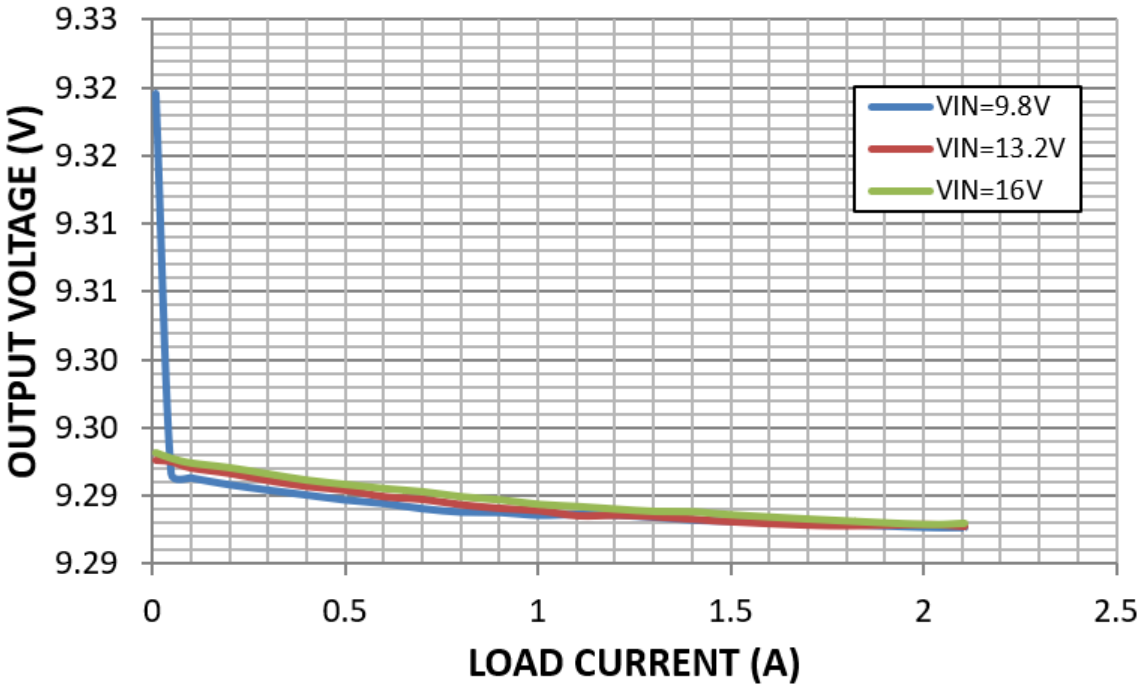


Figure 2-3. FPWM Line and Load Regulation, V_{OUT} = 9.32 V, Ta = –30°C

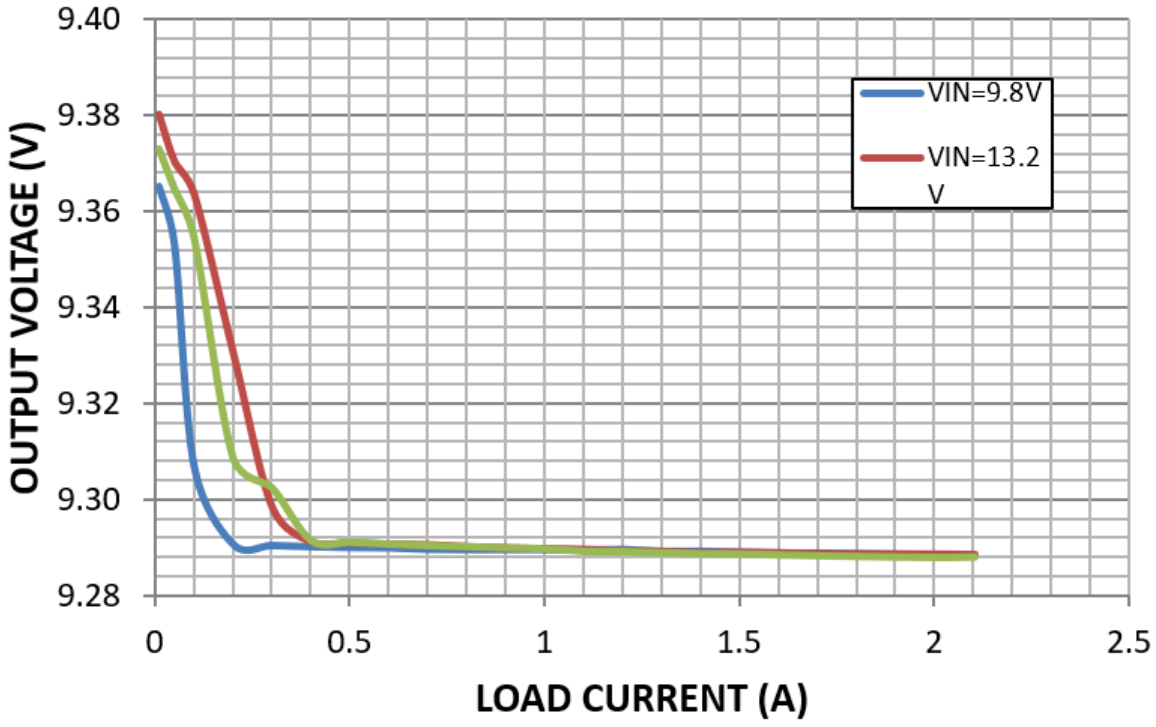


Figure 2-4. PFM Line and Load Regulation, V_{OUT} = 9.37 V, Ta = –30°C

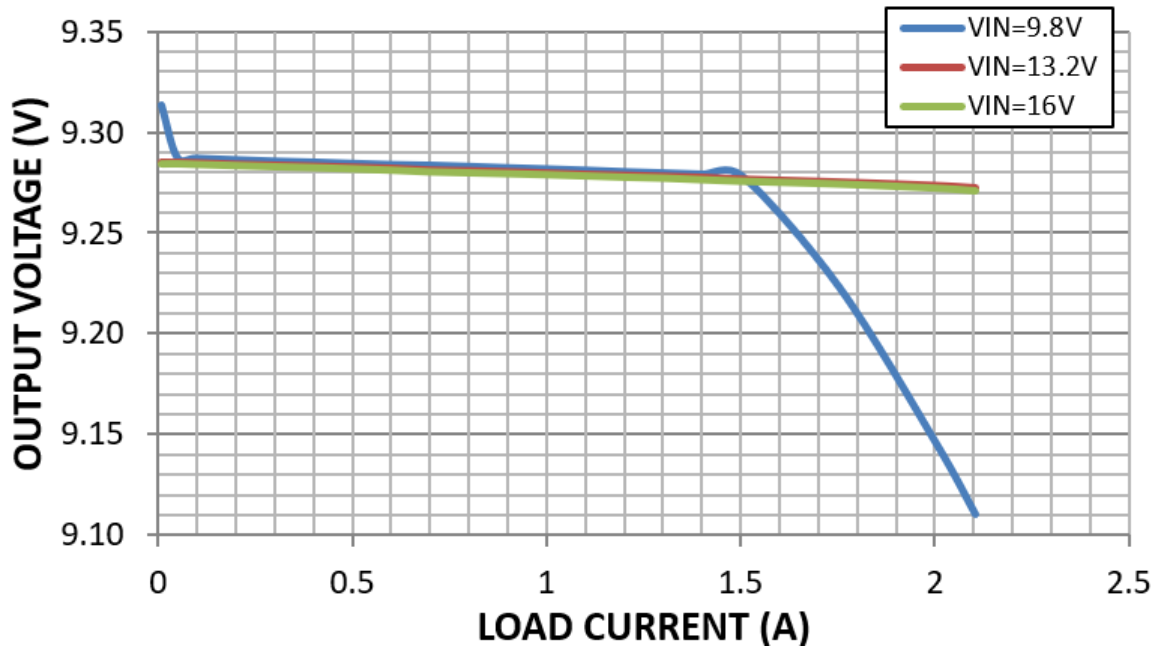


Figure 2-5. FPWM Line and Load Regulation, V_{OUT} = 9.31 V, Ta = 85°C

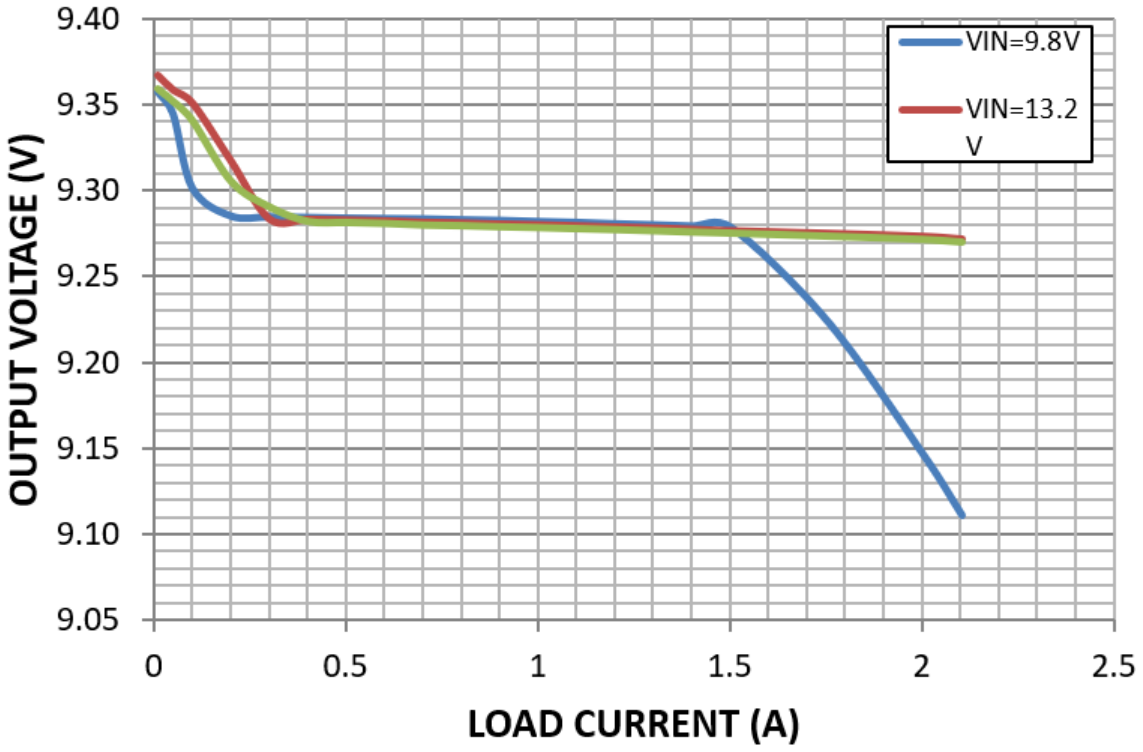


Figure 2-6. PFM Line and Load Regulation, V_{OUT} = 9.22 V, Ta = 85°C

2.2 Efficiency Graphs

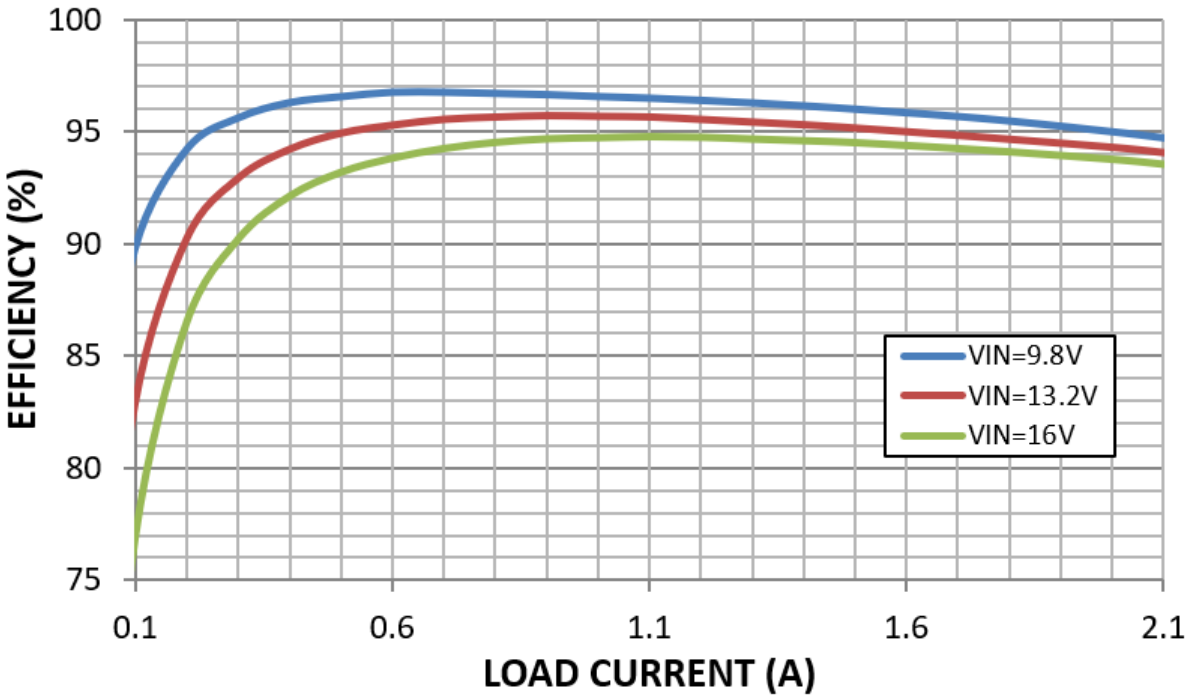


Figure 2-7. FPWM Efficiency, V_{OUT} = 9.32 V, Ta = 25°C

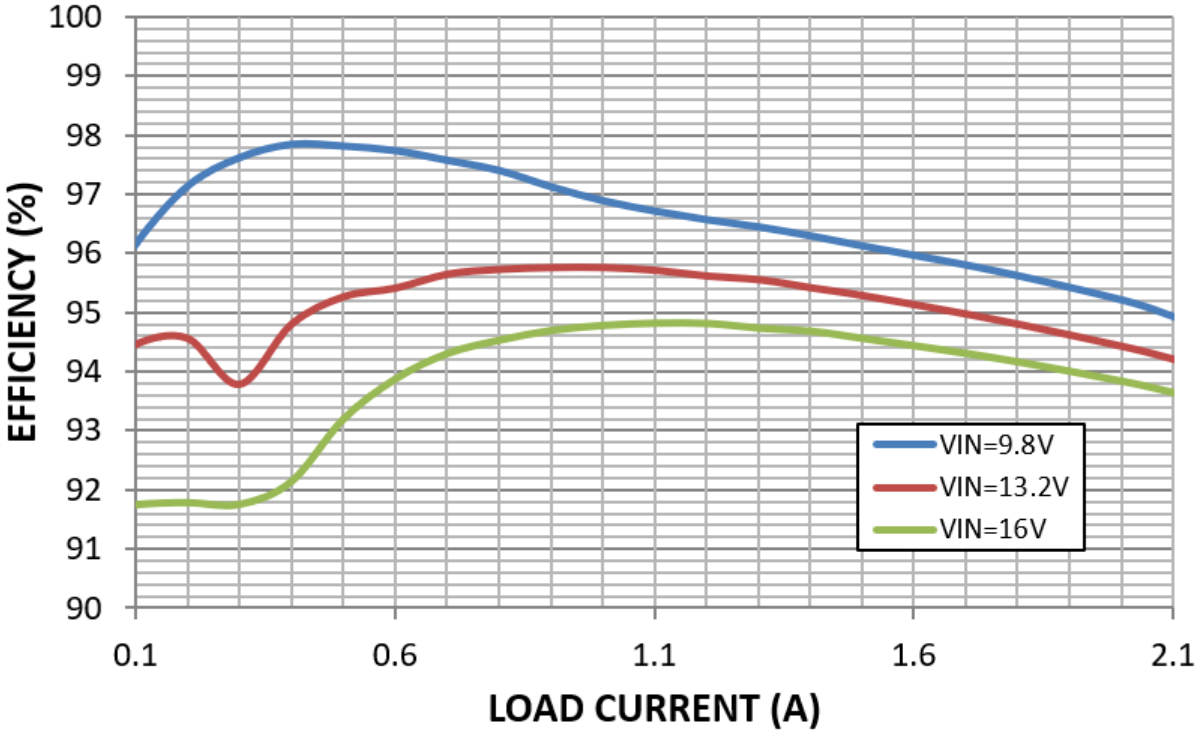


Figure 2-8. PFM Efficiency, V_{OUT} = 9.36 V, Ta = 25°C

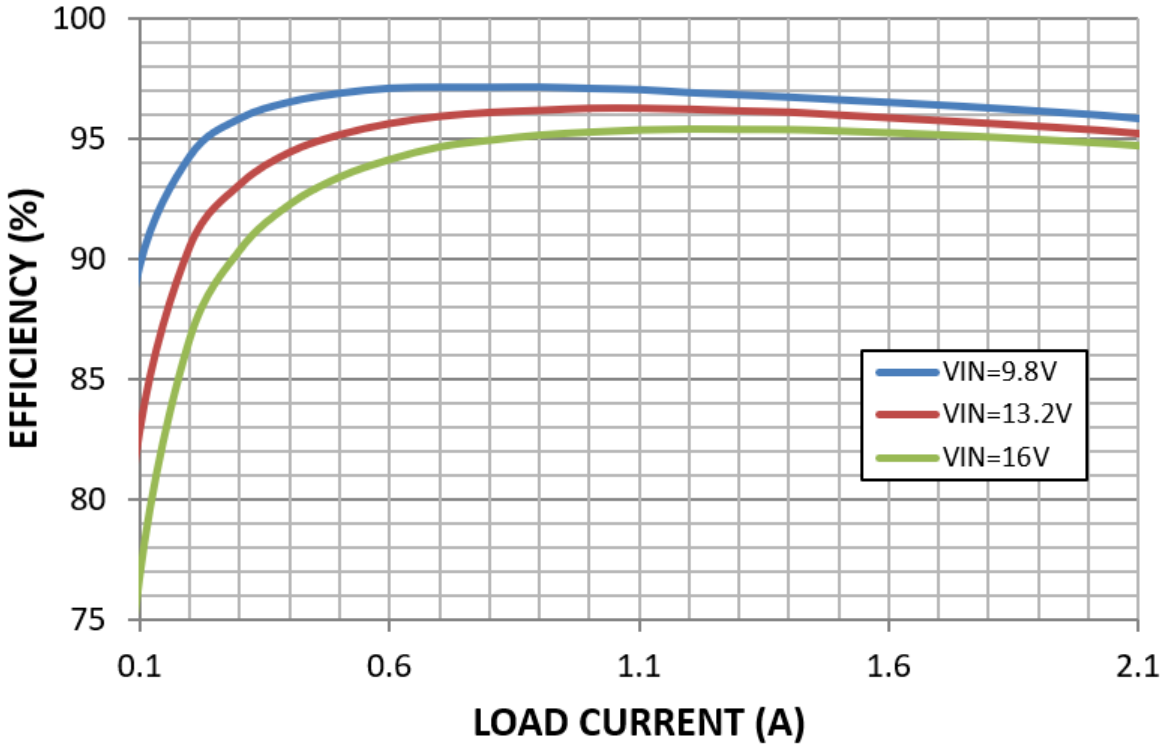


Figure 2-9. FPWM Efficiency, V_{OUT} = 9.32 V, Ta = –30°C

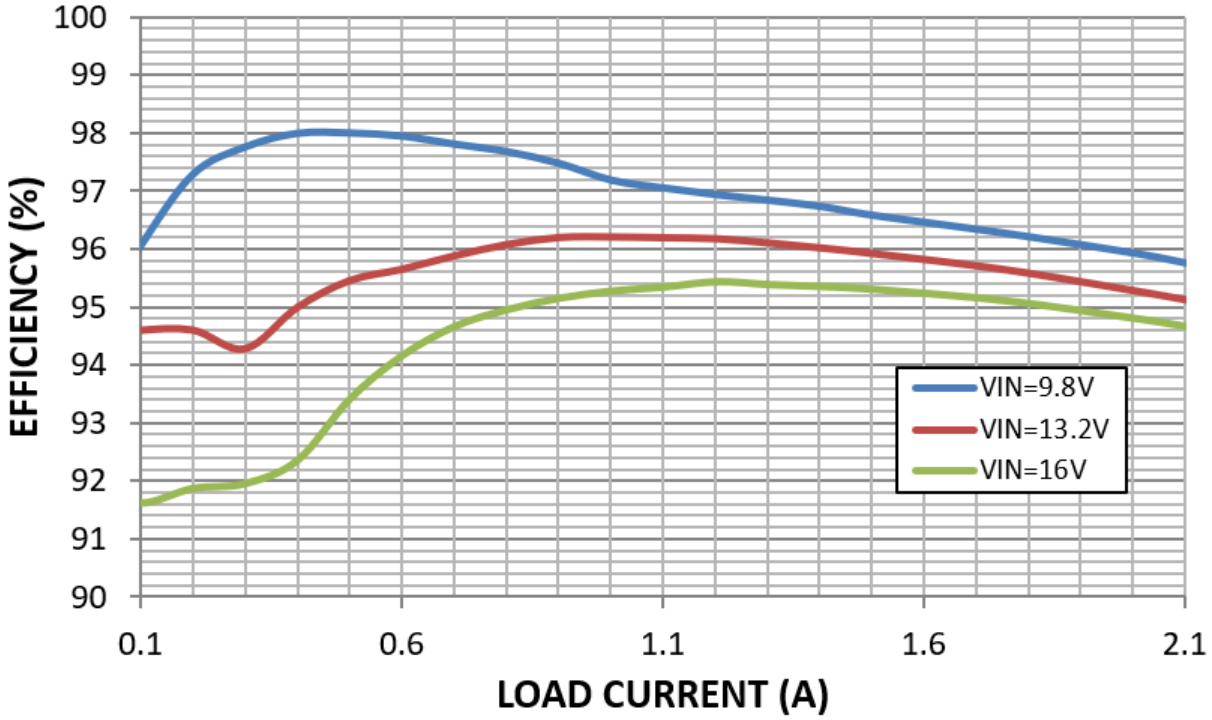


Figure 2-10. PFM Efficiency, V_{OUT} = 9.37 V, Ta = –30°C

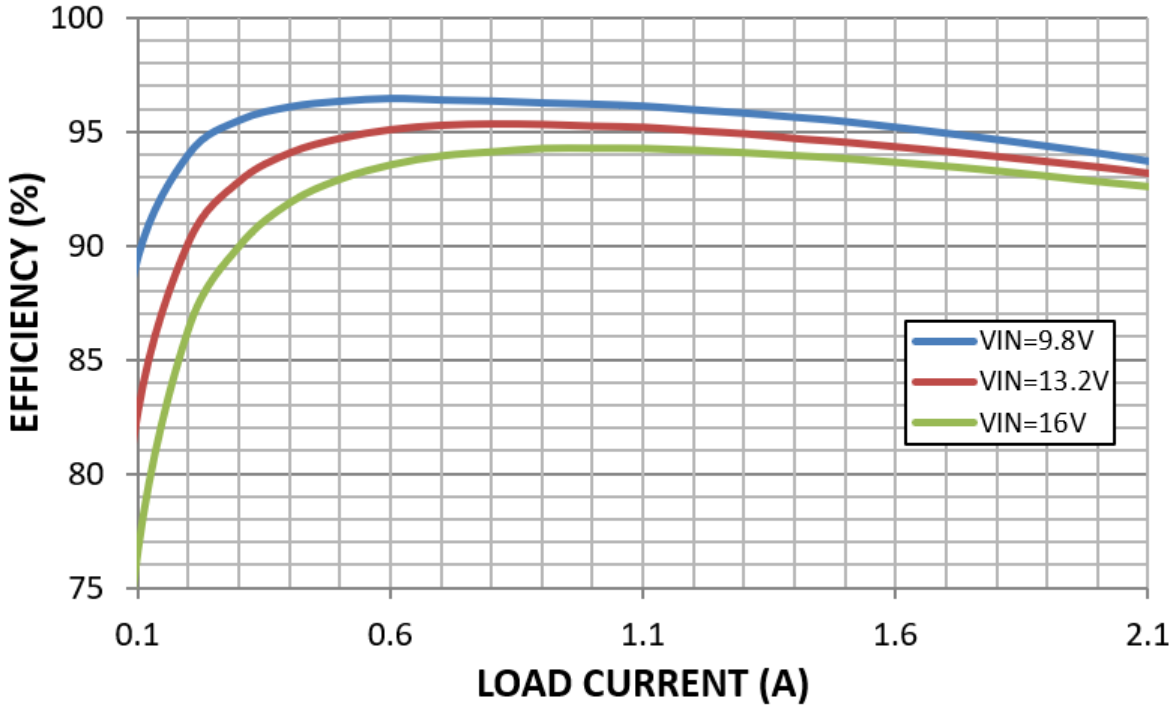


Figure 2-11. FPWM Efficiency, V_{OUT} = 9.31 V, Ta = 85°C

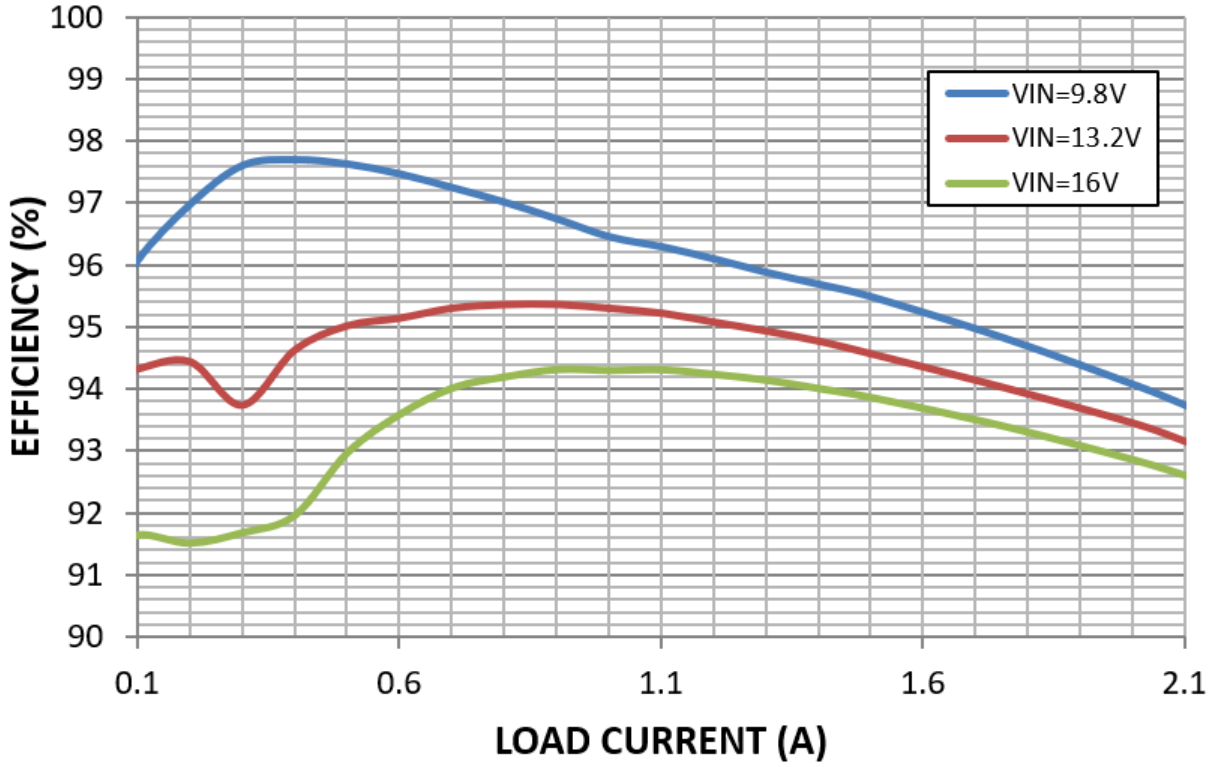


Figure 2-12. PFM Efficiency, V_{OUT} = 9.22 V, Ta = 85°C

2.3 Thermal Images

The following thermal images are at steady state with an input voltage of 16 V and a load of 2.1 A. There is no airflow and ambient is at room temperature.

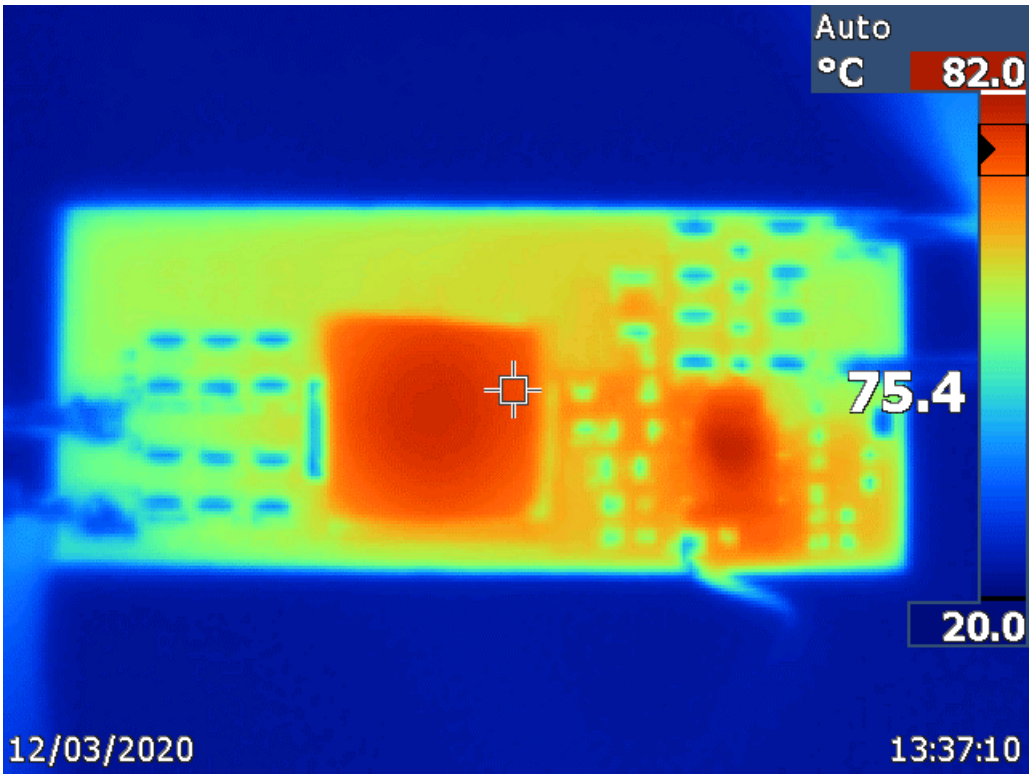


Figure 2-13. Full Board

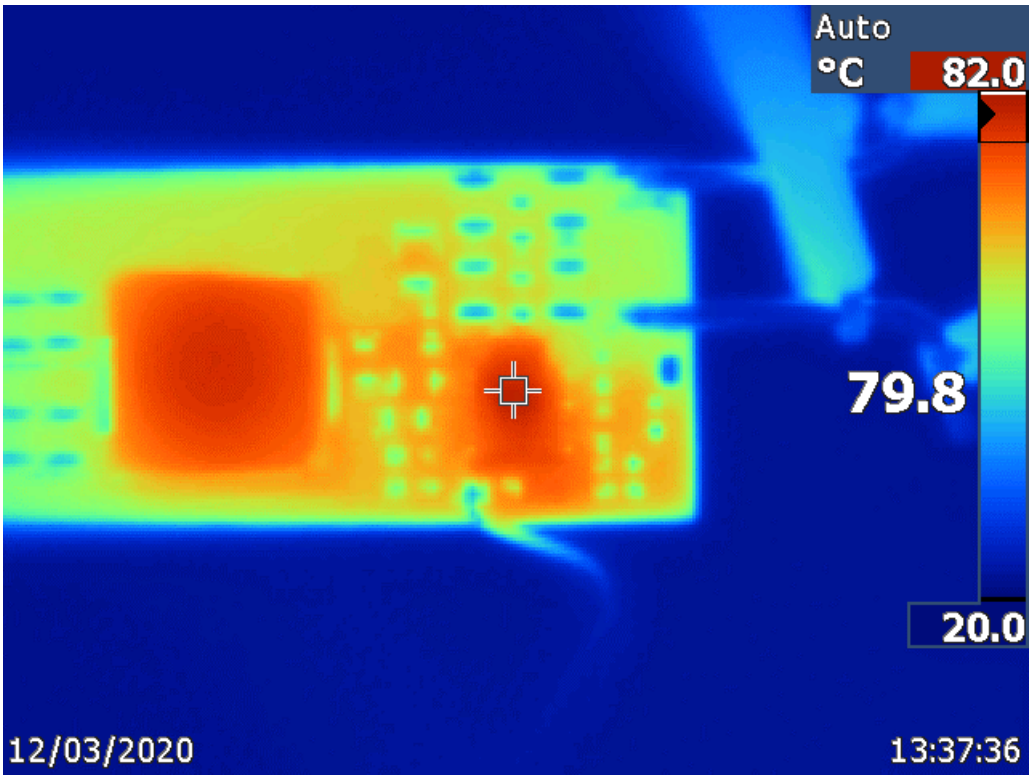


Figure 2-14. IC Peak Temperature (79.8°C)

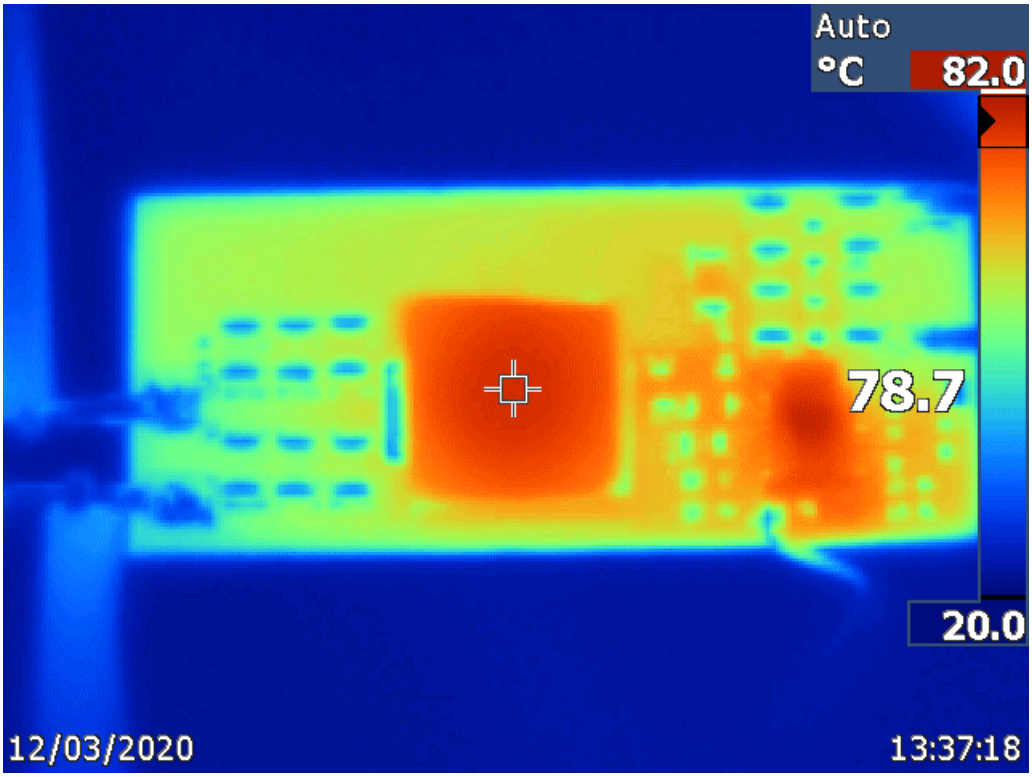


Figure 2-15. Inductor Peak Temperature (78.7°C)

2.4 Bode Plots

The following plots are measured with an input voltage of 13.2 V.

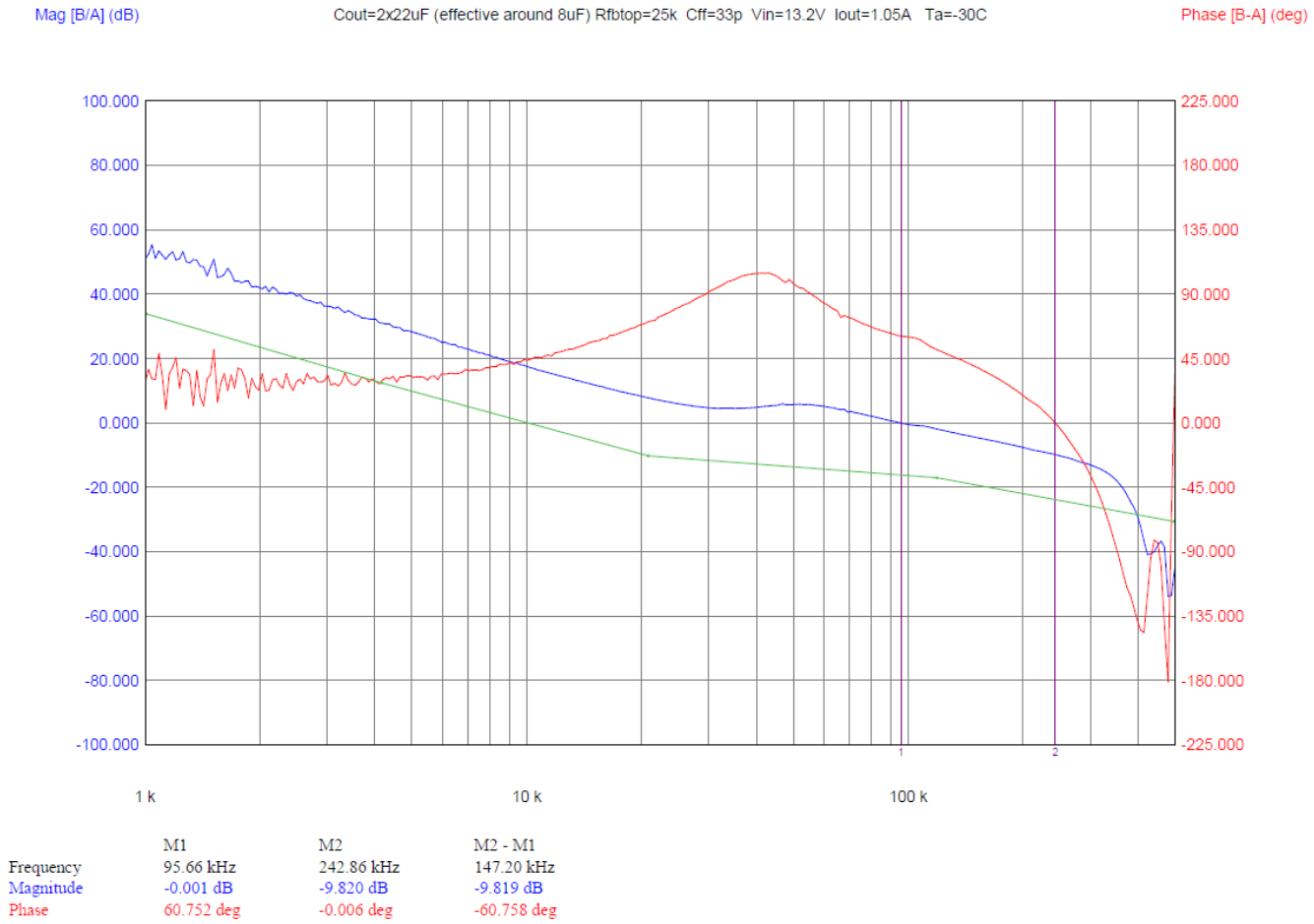


Figure 2-16. Bode Plot, Load: 1.05 A, Temperature: –30°C

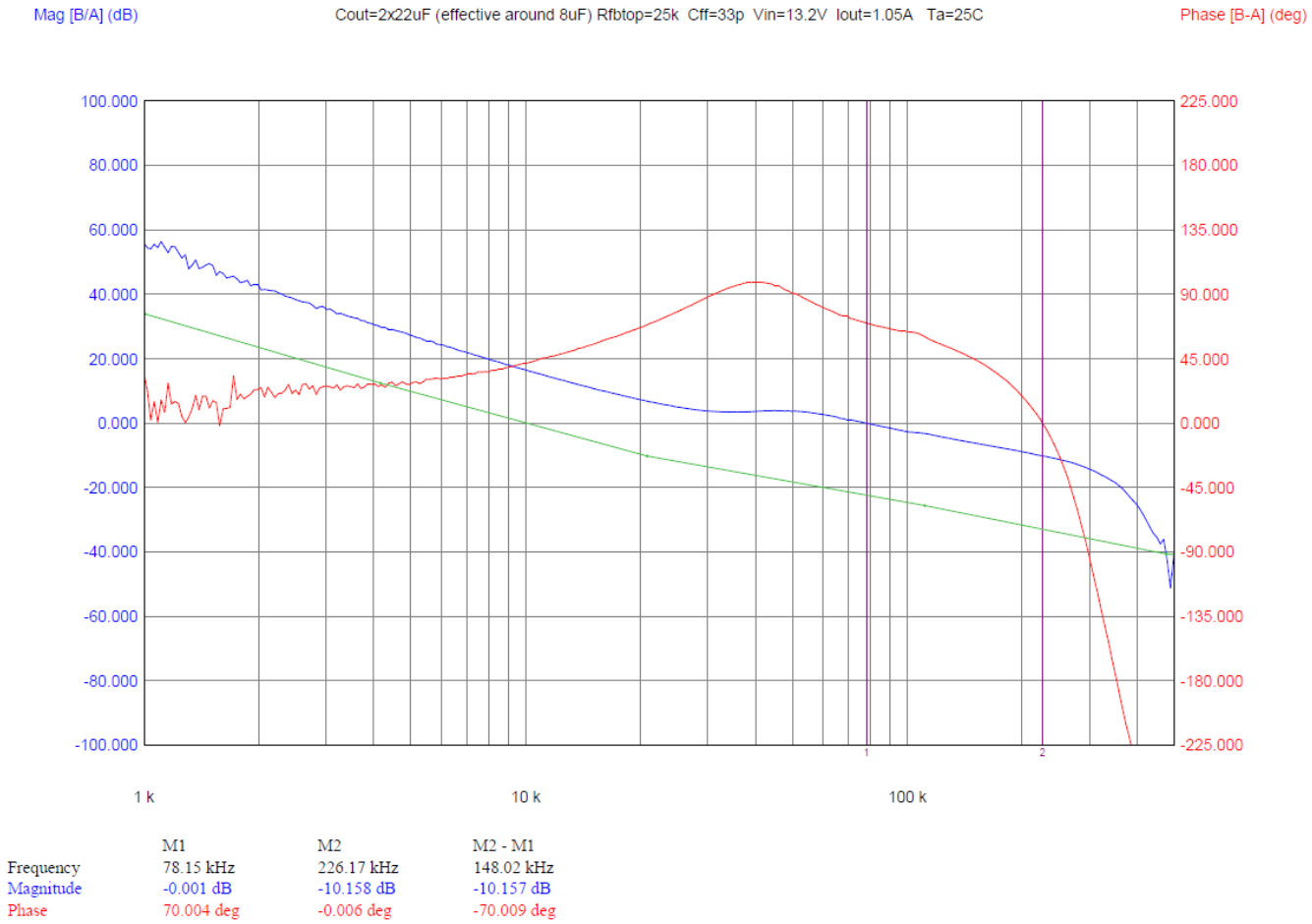


Figure 2-17. Bode Plot, Load: 1.05 A, Temperature: 25°C

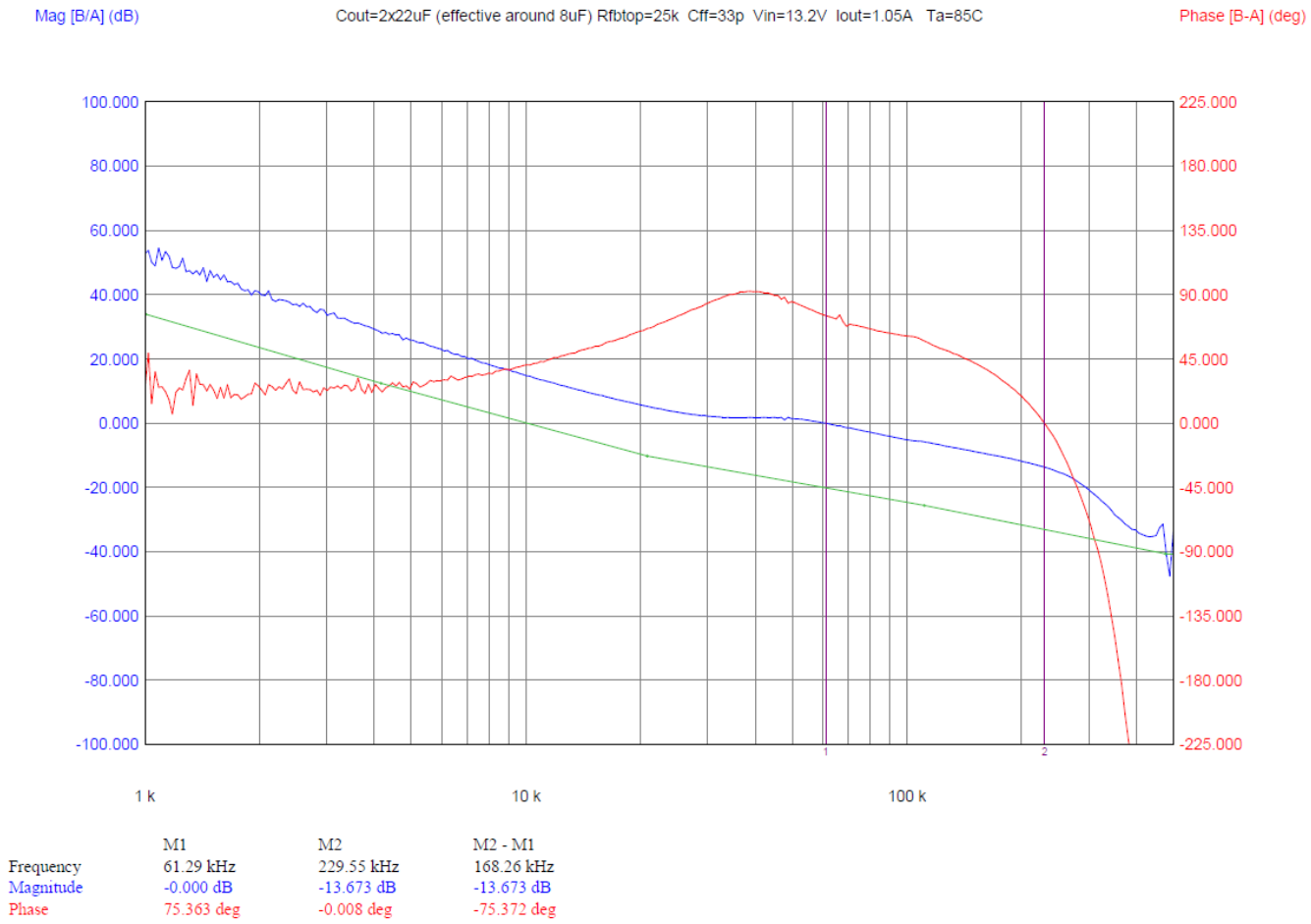


Figure 2-18. Bode Plot, Load: 1.05 A, Temperature: 85°C

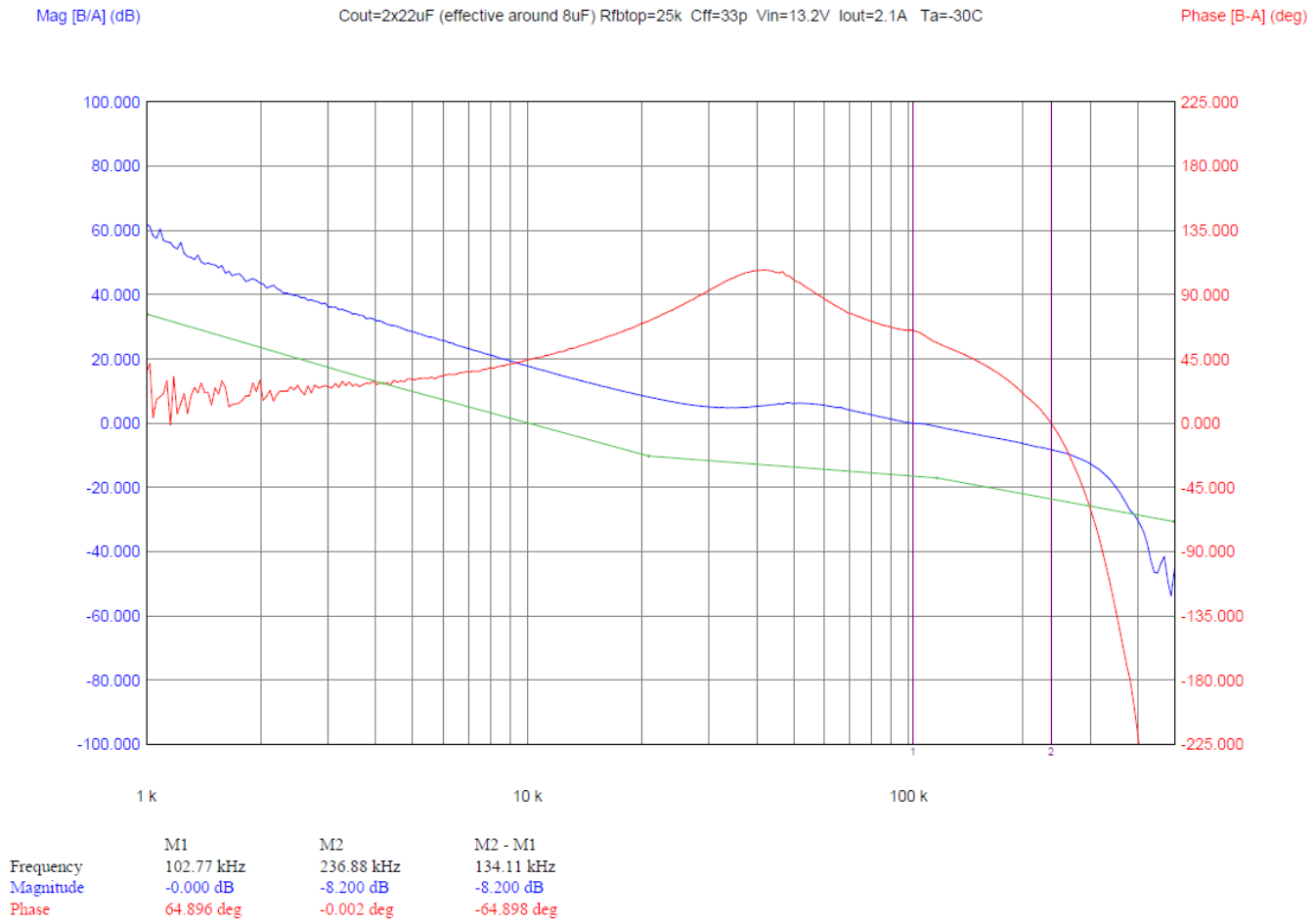


Figure 2-19. Bode Plot, Load: 2.1 A, Temperature: –30°C

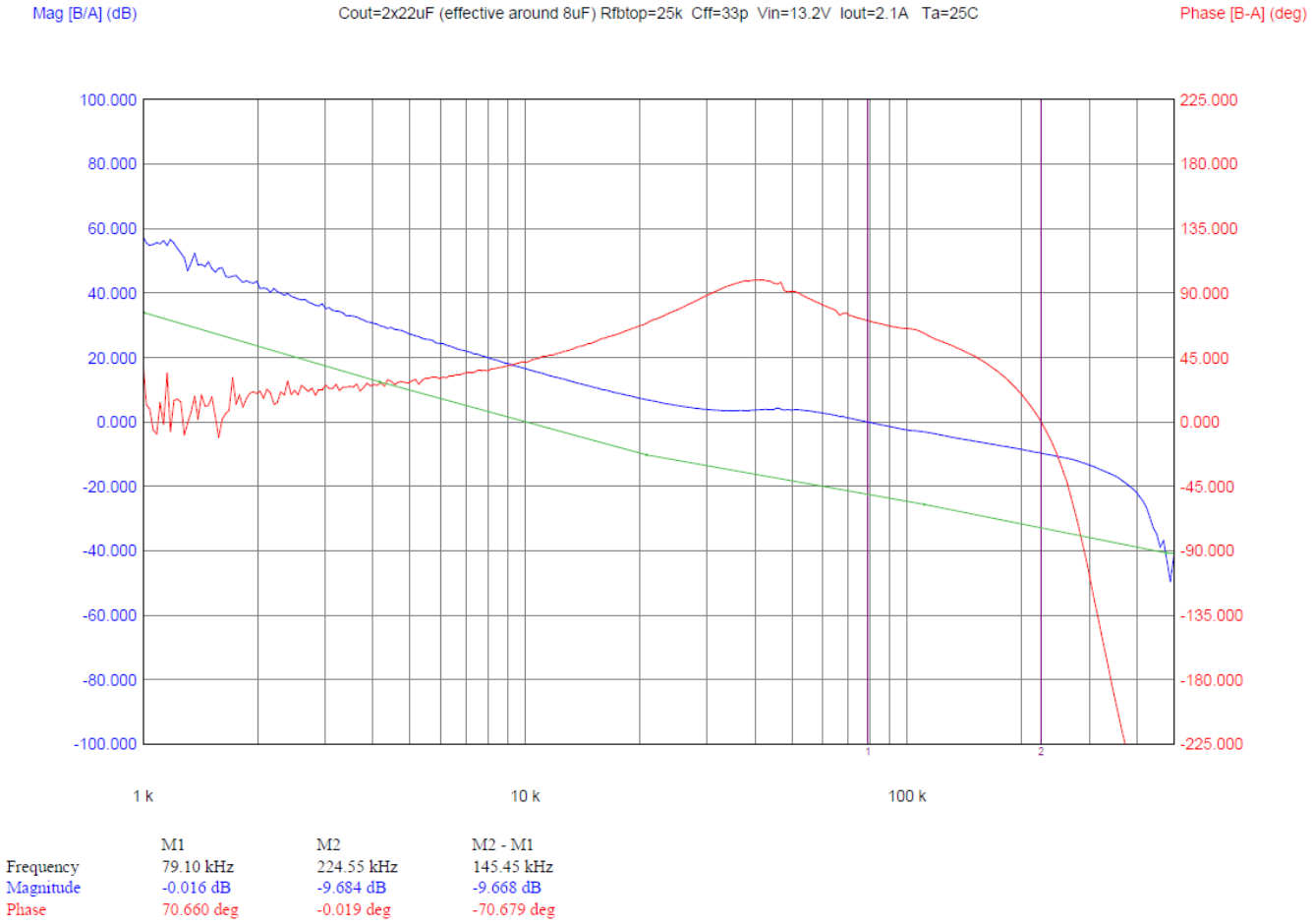


Figure 2-20. Bode Plot, Load: 2.1 A, Temperature: 25°C

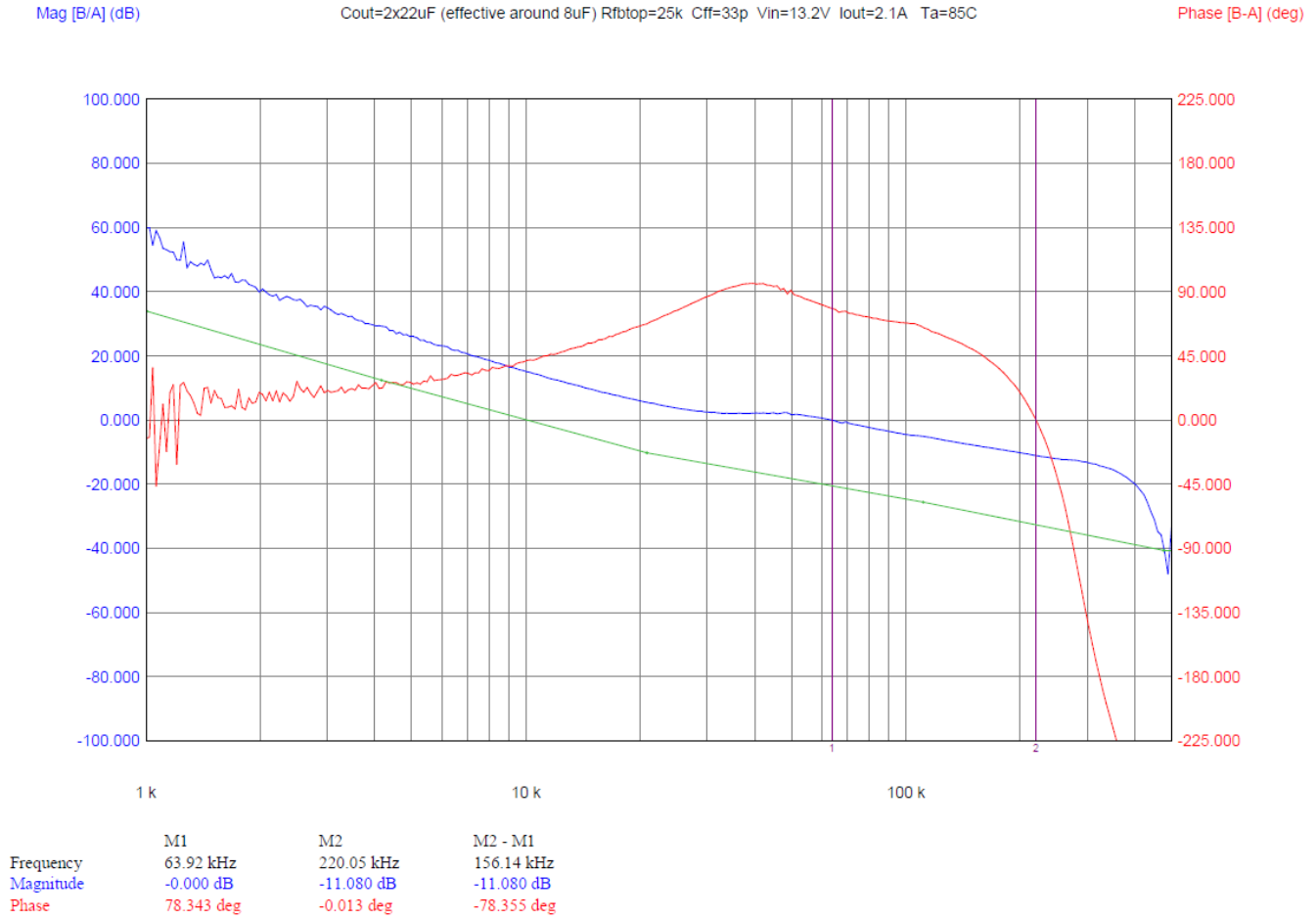


Figure 2-21. Bode Plot, Load: 2.1 A, Temperature: 85°C

3 Waveforms

3.1 Output Voltage Ripple

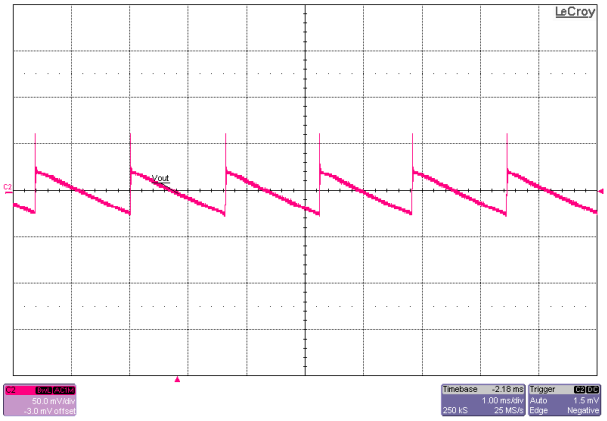


Figure 3-1. Output Voltage Ripple at 9.8 V_{IN}, 0-A Load, PFM, –30°C

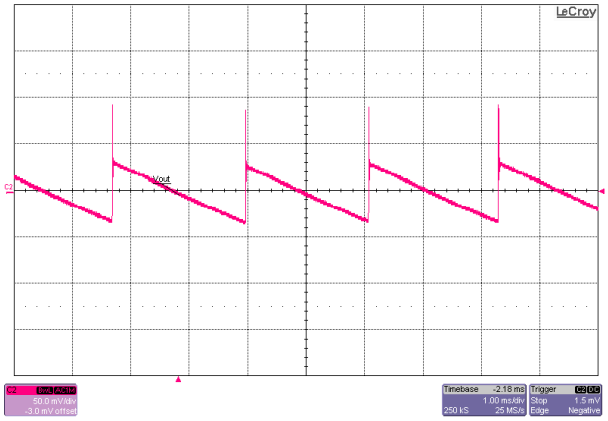


Figure 3-2. Output Voltage Ripple at 13.2 V_{IN}, 0-A Load, PFM, –30°C

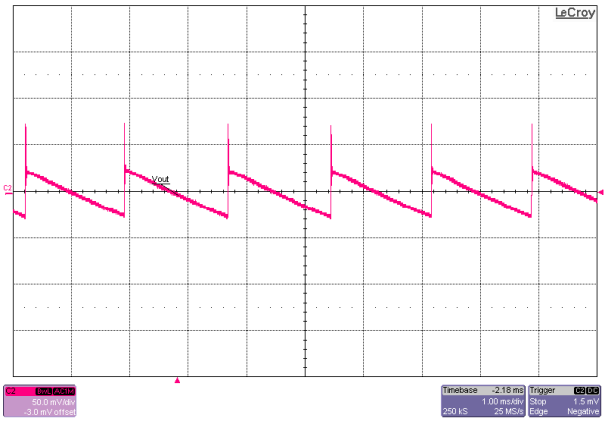


Figure 3-3. Output Voltage Ripple at 16 V_{IN}, 0-A Load, PFM, –30°C

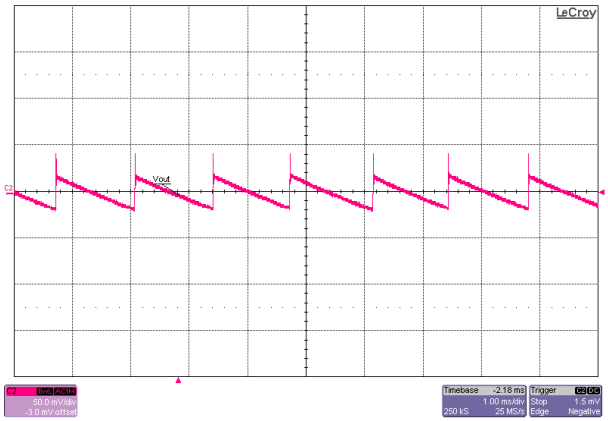


Figure 3-4. Output Voltage Ripple at 9.8 V_{IN}, 0-A Load, PFM, 25°C

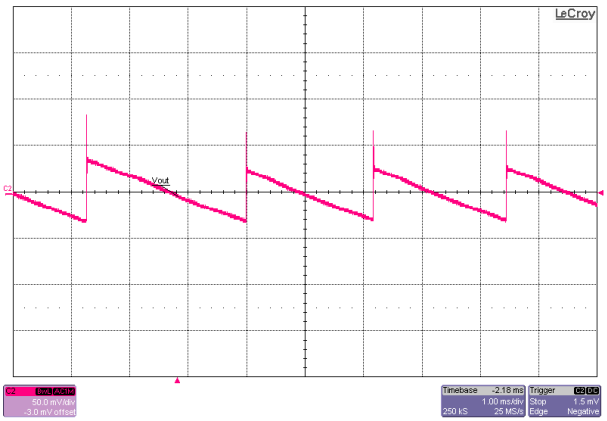


Figure 3-5. Output Voltage Ripple at 13.2 V_{IN}, 0-A Load, PFM, 25°C

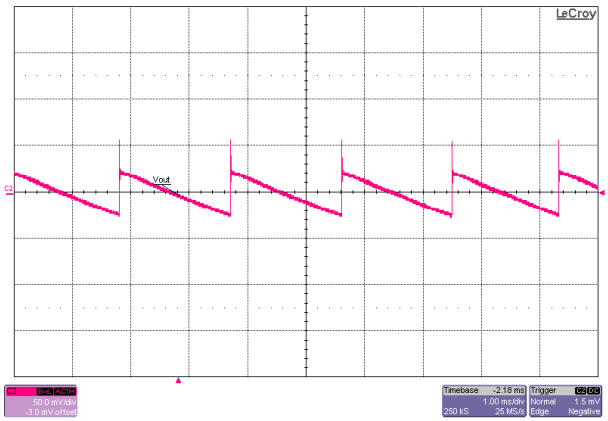


Figure 3-6. Output Voltage Ripple at 16 V_{IN}, 0-A Load, PFM, 25°C

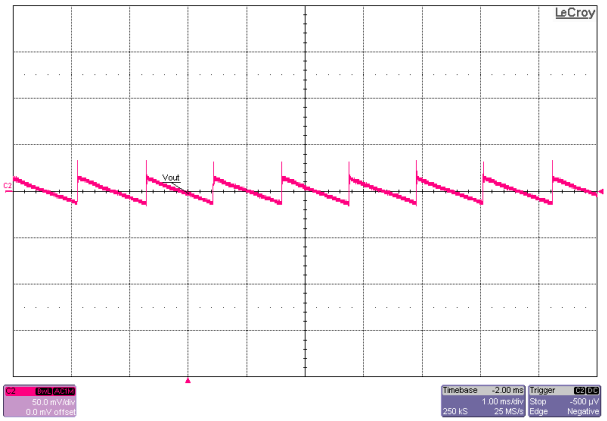


Figure 3-7. Output Voltage Ripple at 9.8 V_{IN}, 0-A Load, PFM, 85°C

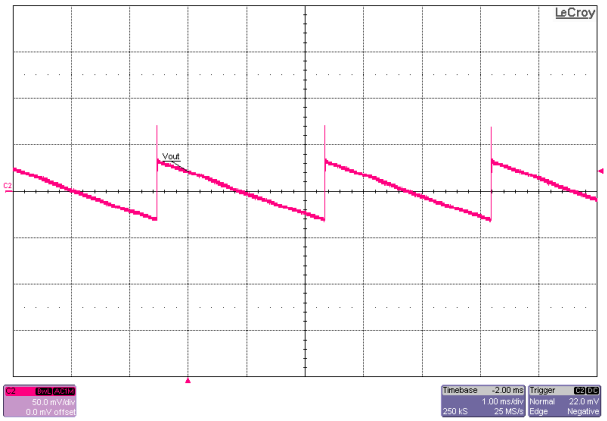


Figure 3-8. Output Voltage Ripple at 13.2 V_{IN}, 0-A Load, PFM, 85°C

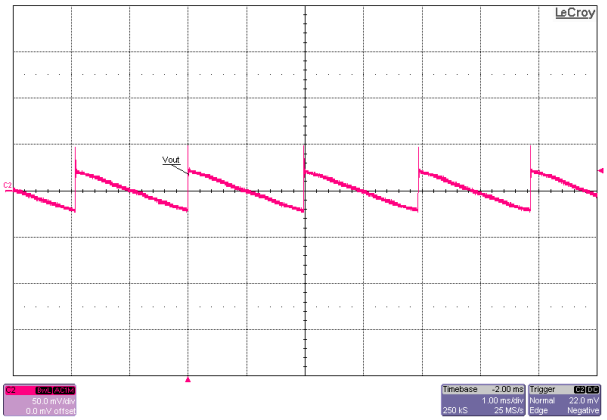


Figure 3-9. Output Voltage Ripple at 16 V_{IN}, 0-A Load, PFM, 85°C

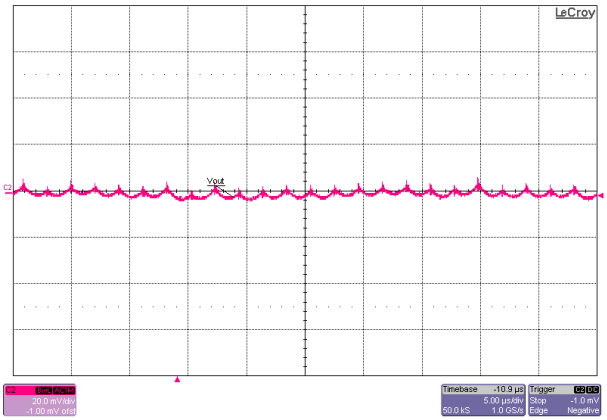


Figure 3-10. Output Voltage Ripple at 9.8 V_{IN}, 0-A Load, FPWM, –30°C

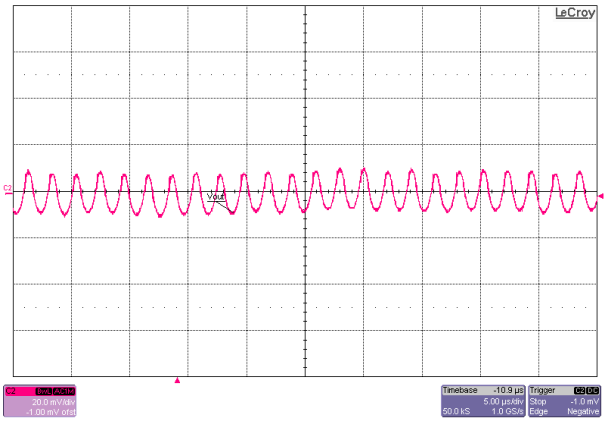


Figure 3-11. Output Voltage Ripple at 13.2 V_{IN}, 0-A Load, FPWM, –30°C

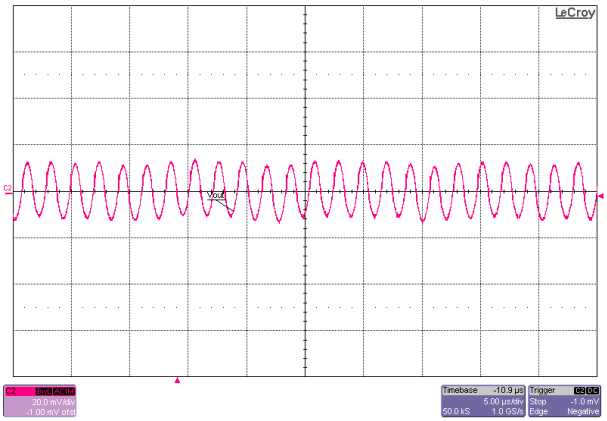


Figure 3-12. Output Voltage Ripple at 16 V_{IN}, 0-A Load, FPWM, –30°C

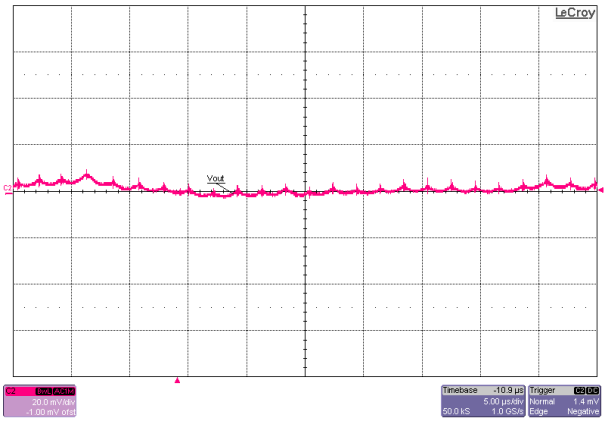


Figure 3-13. Output Voltage Ripple at 9.8 V_{IN}, 0-A Load, FPWM, 25°C

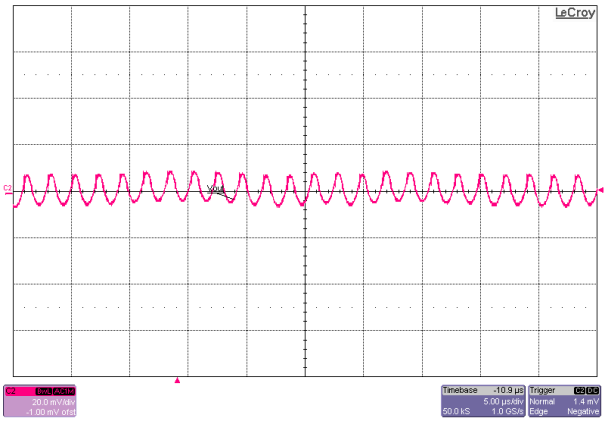


Figure 3-14. Output Voltage Ripple at 13.2 V_{IN}, 0-A Load, FPWM, 25°C

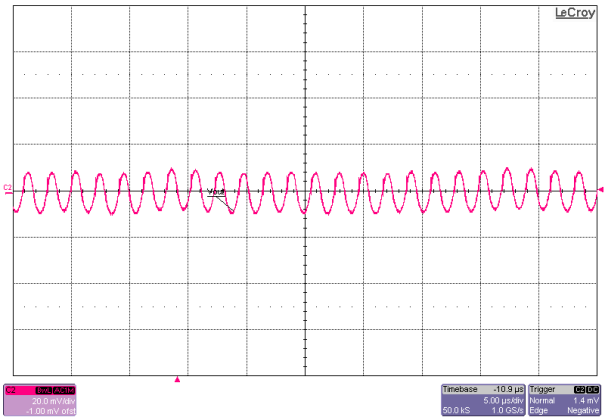


Figure 3-15. Output Voltage Ripple at 16 V_{IN}, 0-A Load, FPWM, 25°C

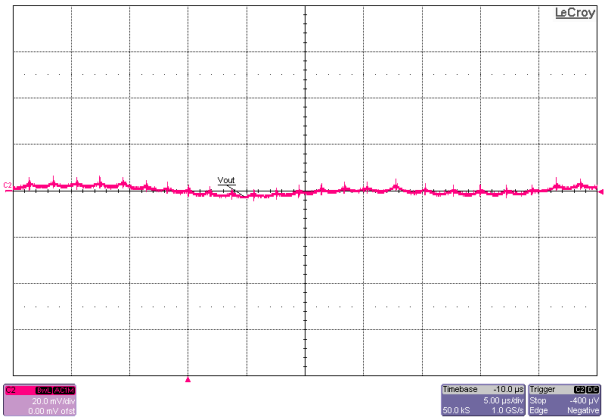


Figure 3-16. Output Voltage Ripple at 9.8 V_{IN}, 0-A Load, FPWM, 85°C

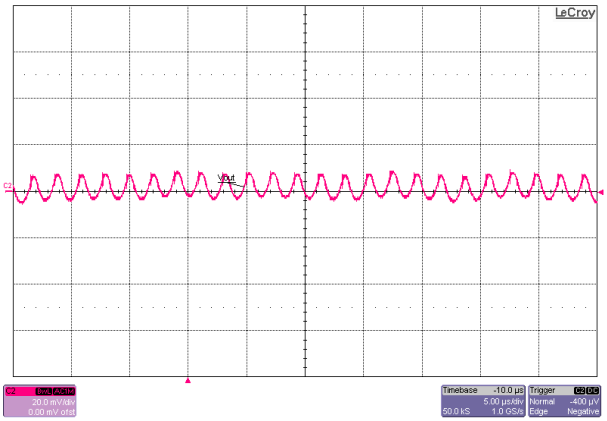


Figure 3-17. Output Voltage Ripple at 13.2 V_{IN}, 0-A Load, FPWM, 85°C

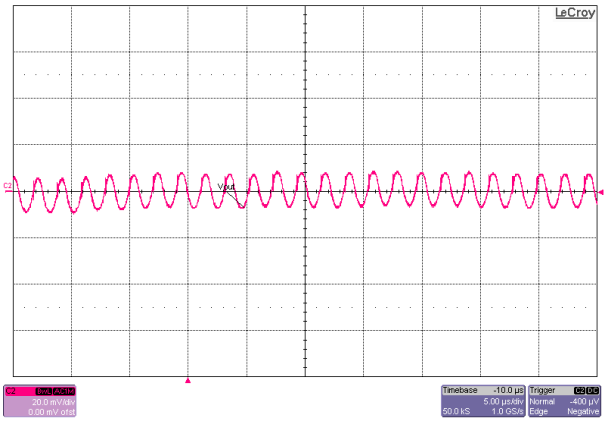


Figure 3-18. Output Voltage Ripple at 16 V_{IN}, 0-A Load, FPWM, 85°C

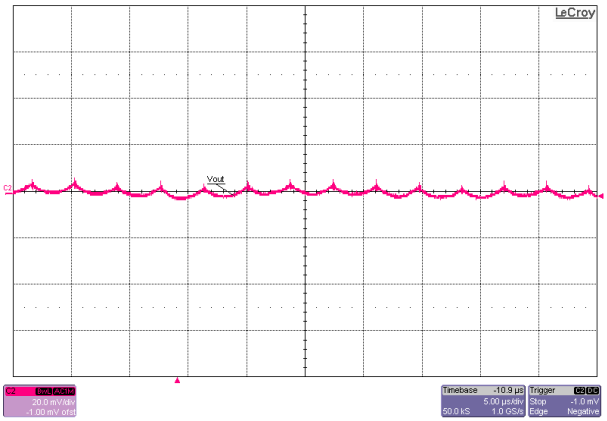


Figure 3-19. Output Voltage Ripple at 9.8 V_{IN}, 1.8-A Load, FPWM, –30°C

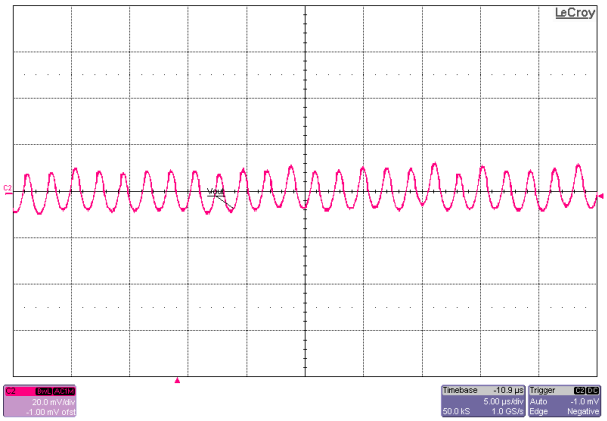


Figure 3-20. Output Voltage Ripple at 13.2 V_{IN}, 1.8-A Load, FPWM, –30°C

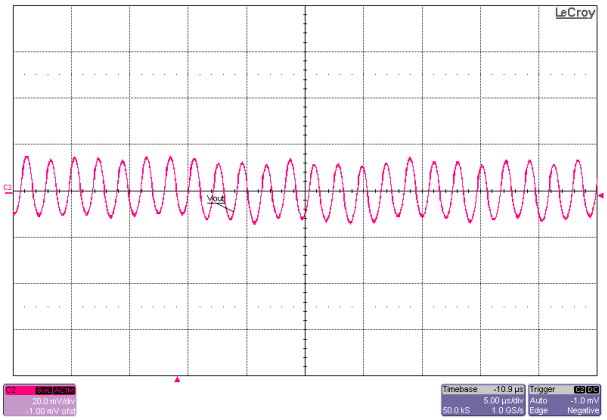


Figure 3-21. Output Voltage Ripple at 16 V_{IN}, 1.8-A Load, FPWM, –30°C

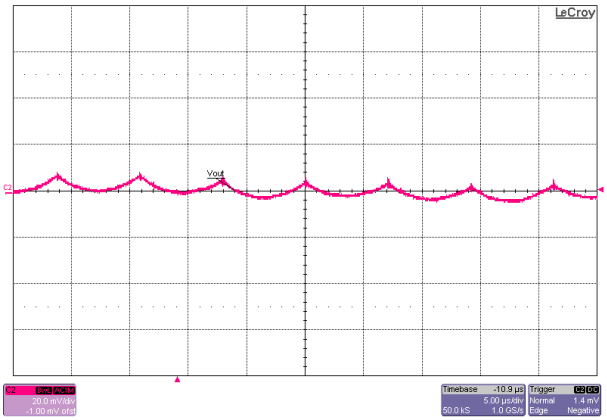


Figure 3-22. Output Voltage Ripple at 9.8 V_{IN}, 1.8-A Load, FPWM, 25°C

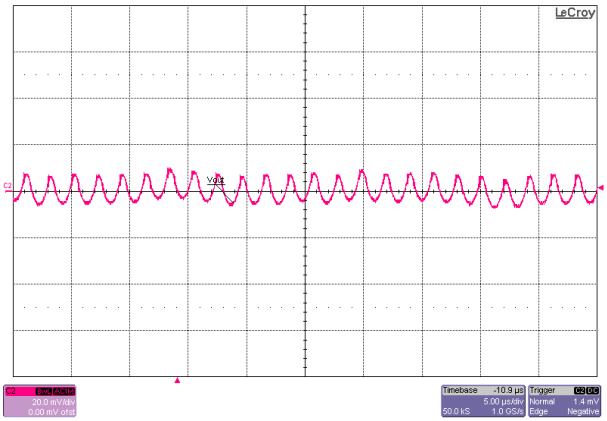


Figure 3-23. Output Voltage Ripple at 13.2 V_{IN}, 1.8-A Load, FPWM, 25°C

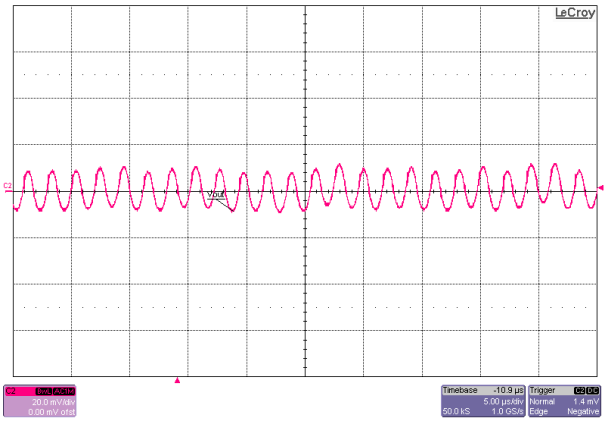


Figure 3-24. Output Voltage Ripple at 16 V_{IN}, 1.8-A Load, FPWM, 25°C

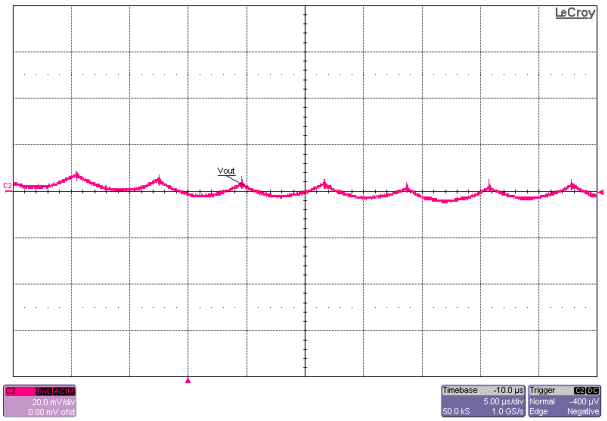


Figure 3-25. Output Voltage Ripple at 9.8 V_{IN}, 1.8-A Load, FPWM, 85°C

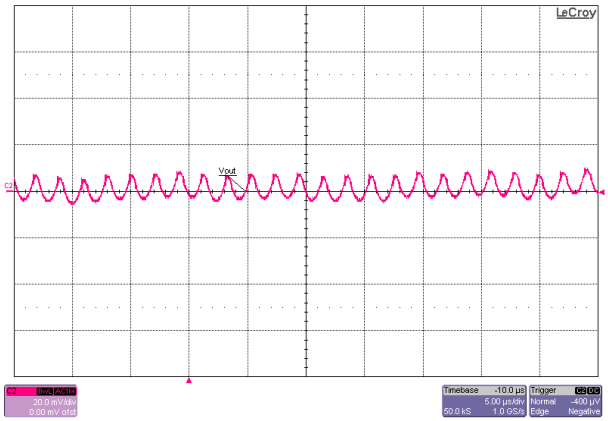


Figure 3-26. Output Voltage Ripple at 13.2 V_{IN}, 1.8-A Load, FPWM, 85°C

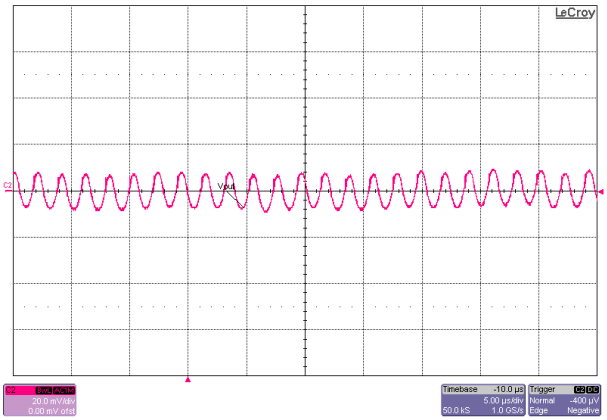


Figure 3-27. Output Voltage Ripple at 16 V_{IN}, 1.8-A Load, FPWM, 85°C

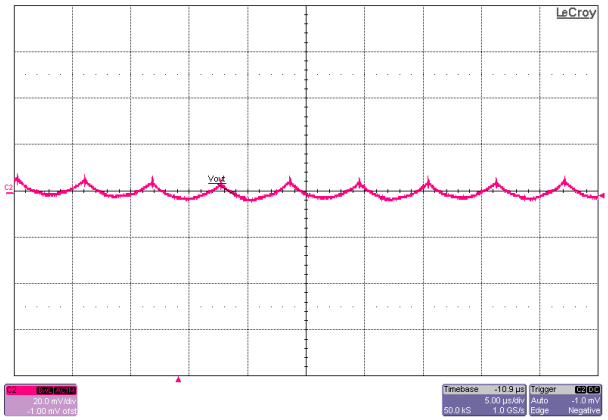


Figure 3-28. Output Voltage Ripple at 9.8 V_{IN}, 2.1-A Load, FPWM, –30°C

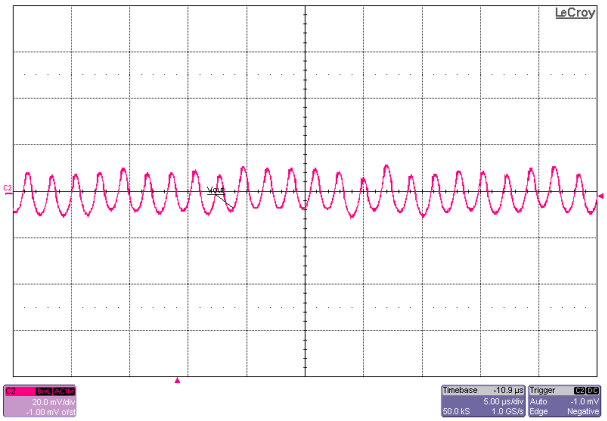


Figure 3-29. Output Voltage Ripple at 13.2 V_{IN}, 2.1-A Load, FPWM, –30°C

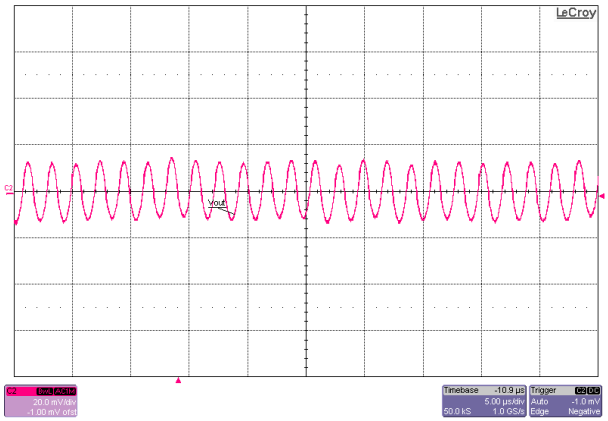


Figure 3-30. Output Voltage Ripple at 16 V_{IN}, 2.1-A Load, FPWM, –30°C

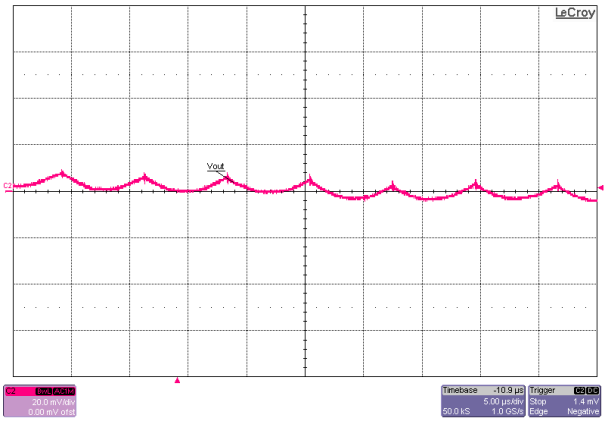


Figure 3-31. Output Voltage Ripple at 9.8 V_{IN}, 2.1-A Load, FPWM, 25°C

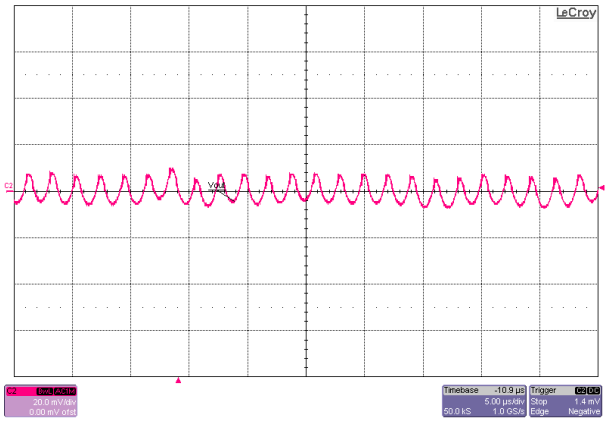


Figure 3-32. Output Voltage Ripple at 13.2 V_{IN}, 2.1-A Load, FPWM, 25°C

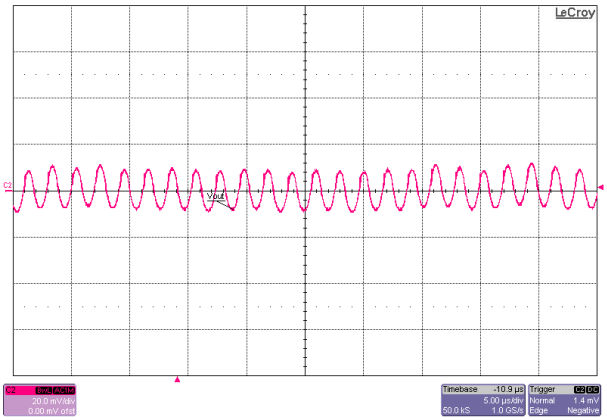


Figure 3-33. Output Voltage Ripple at 16 V_{IN}, 2.1-A Load, FPWM, 25°C

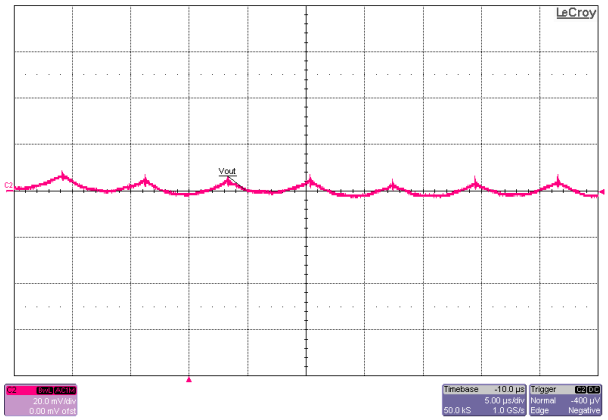


Figure 3-34. Output Voltage Ripple at 9.8 V_{IN}, 2.1-A Load, FPWM, 85°C

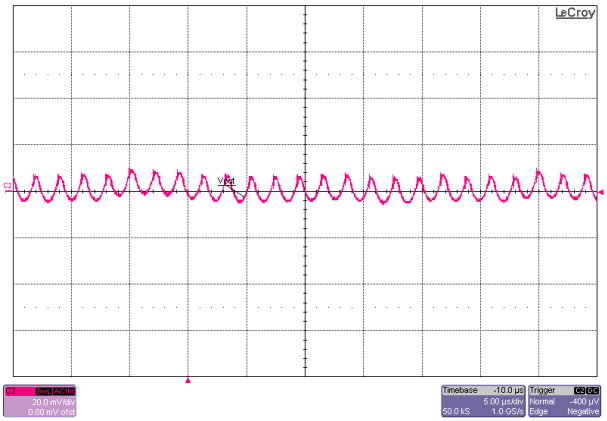


Figure 3-35. Output Voltage Ripple at 13.2 V_{IN}, 2.1-A Load, FPWM, 85°C

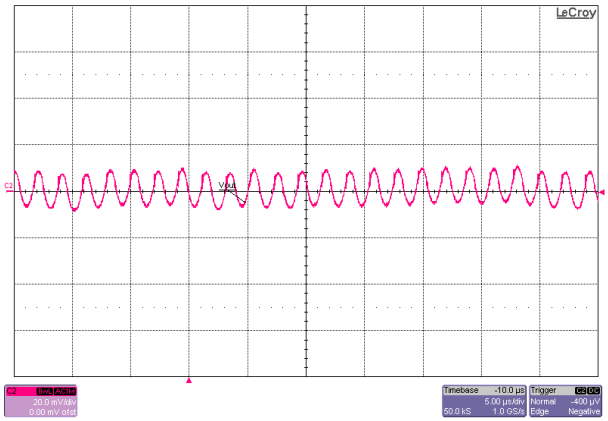


Figure 3-36. Output Voltage Ripple at 16 V_{IN}, 2.1-A Load, FPWM, 85°C

3.2 Current Limit

The following figures show a load step being applied from 2.1 A to 3.5 A. The current ramps up, hits current limit, and output drops followed by hiccup mode. Once the load step goes down to 2.1 A the output recovers with soft start.

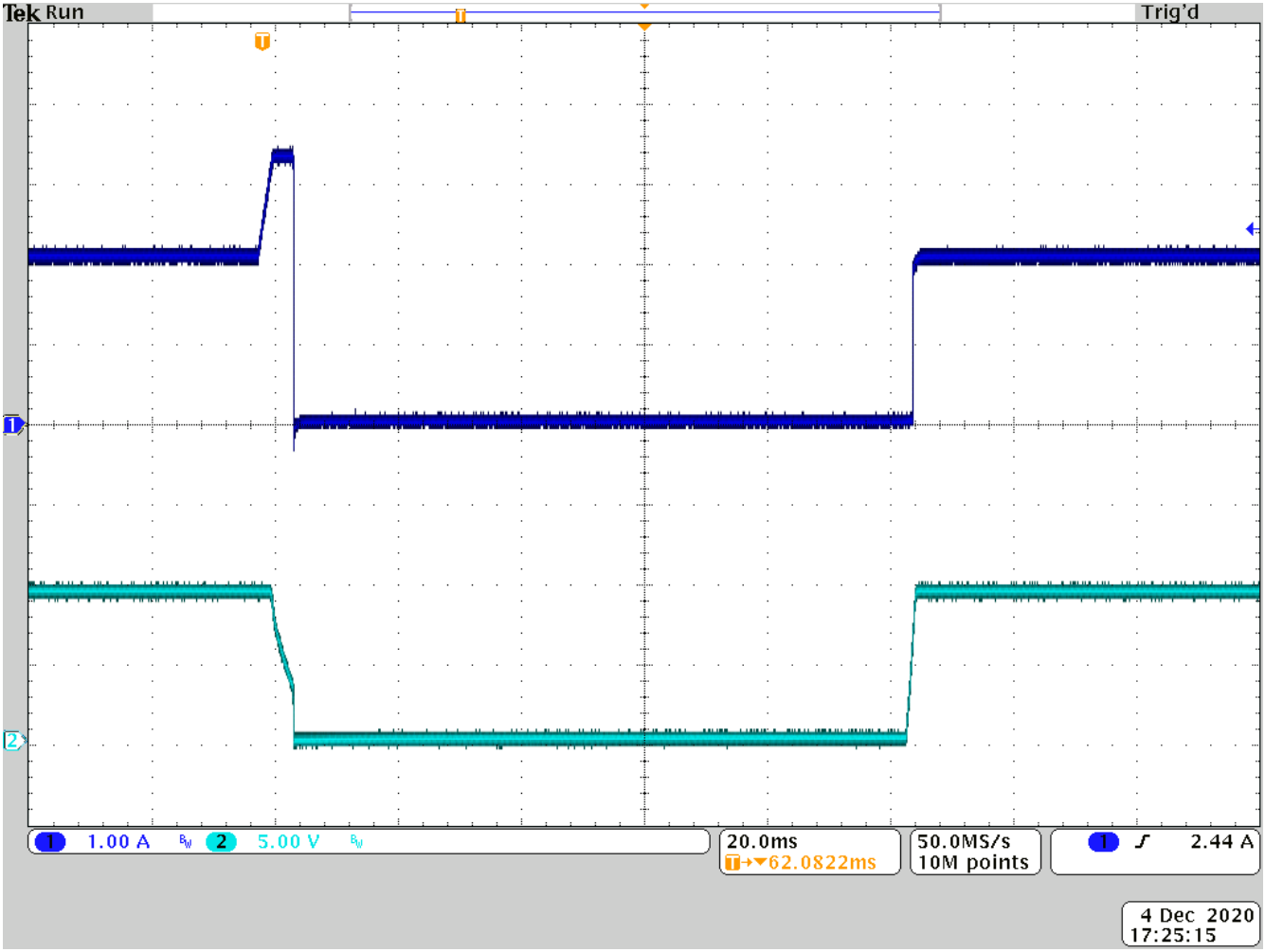


Figure 3-37. Load Step, 13.2 V_{IN}, 25°C

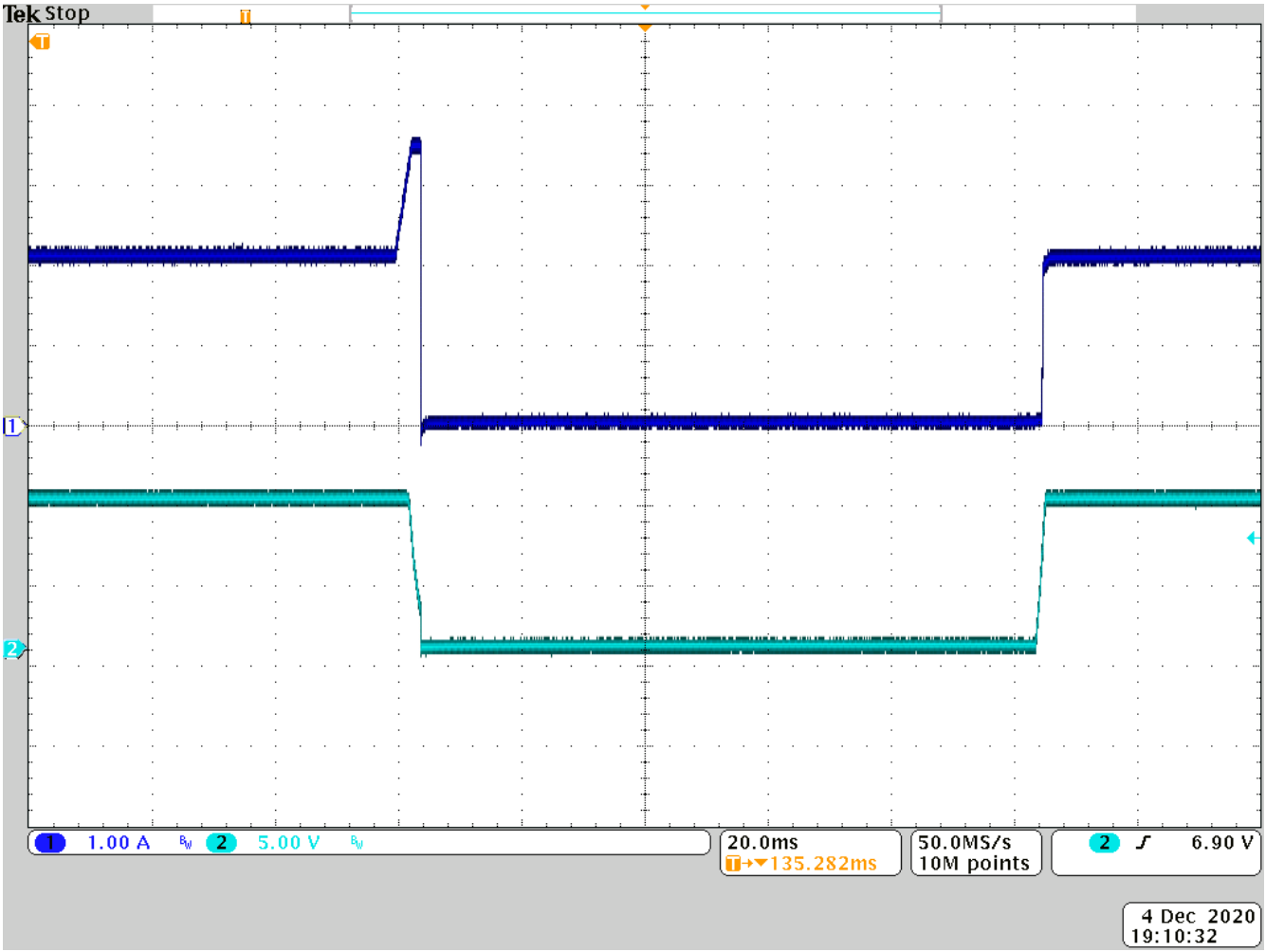


Figure 3-38. Load Step, 13.2 V_{IN}, –30°C

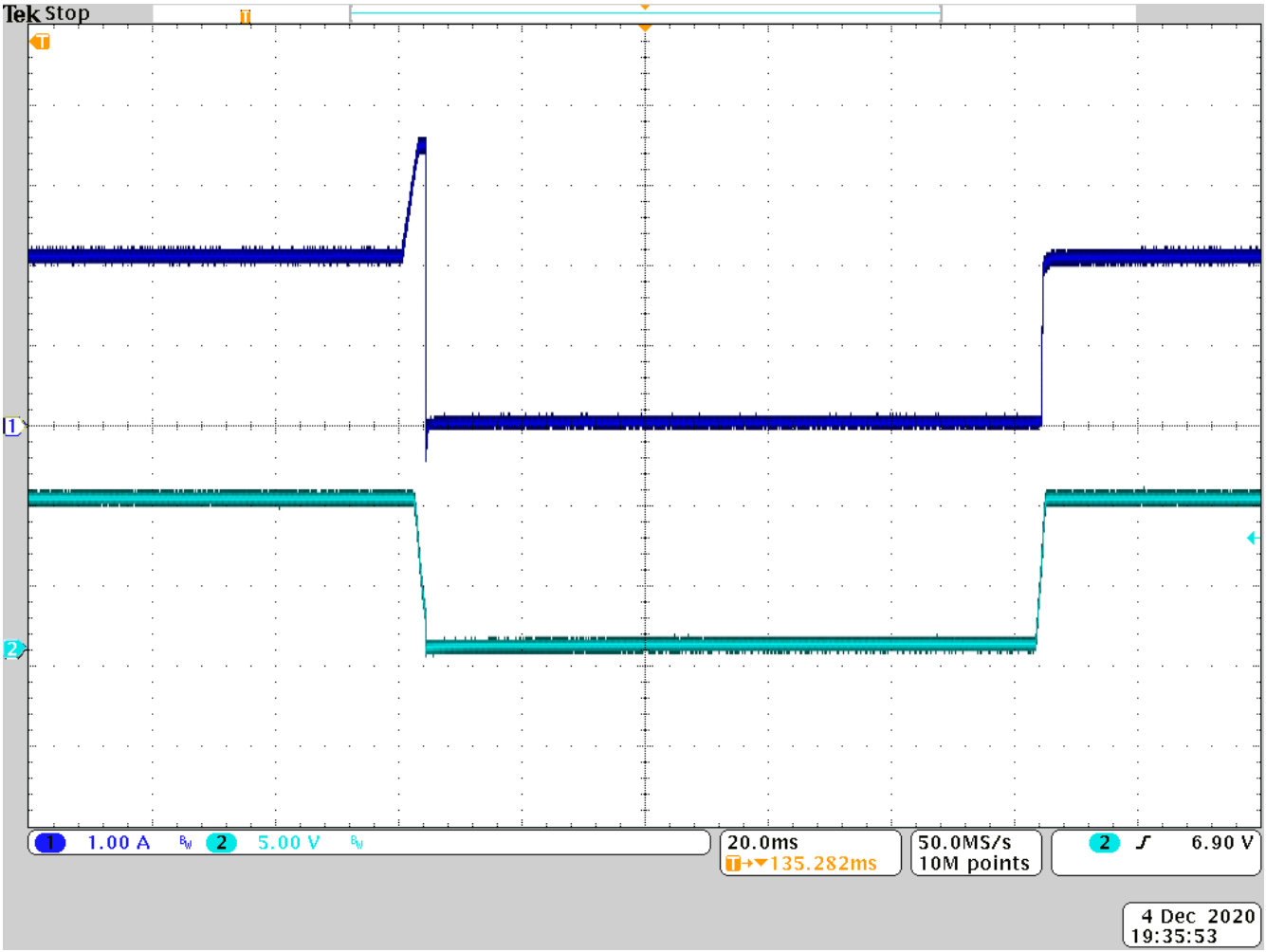


Figure 3-39. Load Step, 13.2 V_{IN}, 85°C

In Figure 3-40 through Figure 3-42, the current limit trip point shifts as the load is increased to above the limit.

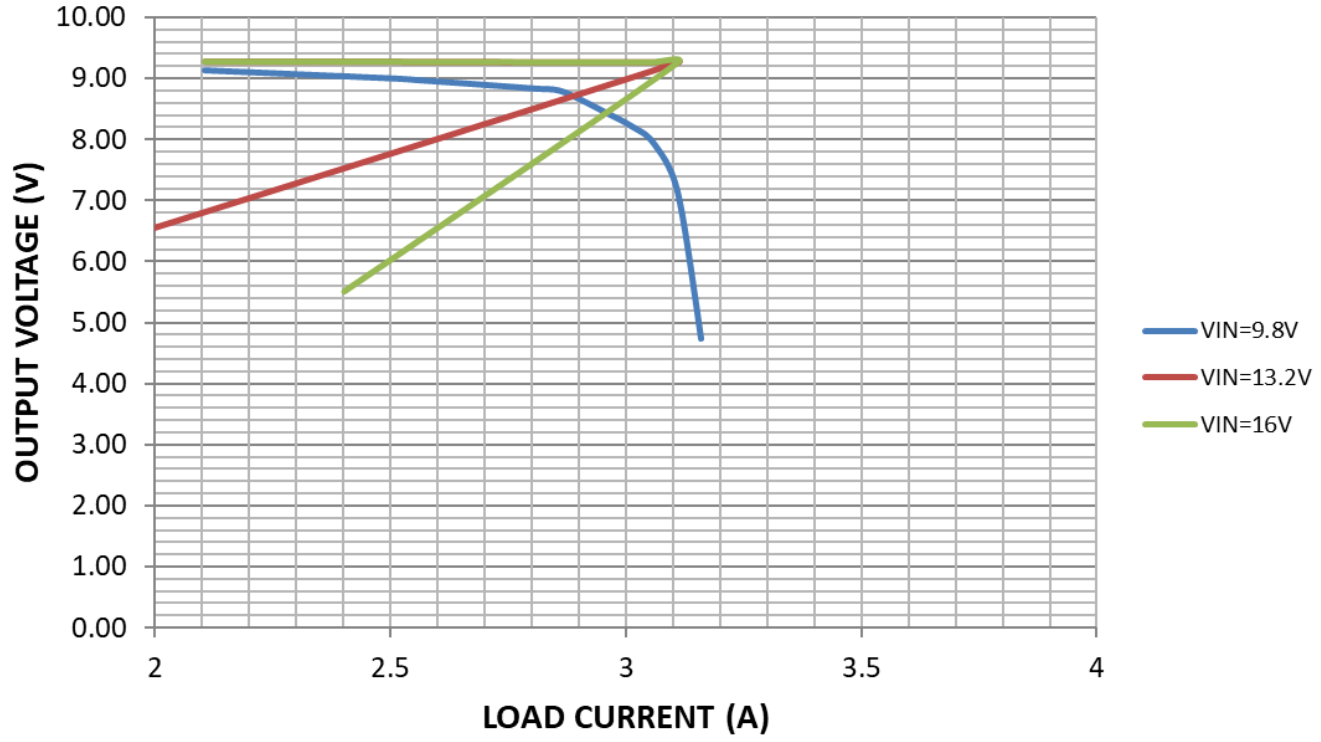


Figure 3-40. LM63625 Output Voltage vs Load Current, V_{OUT} = 9.3 V, Ta = 85°C

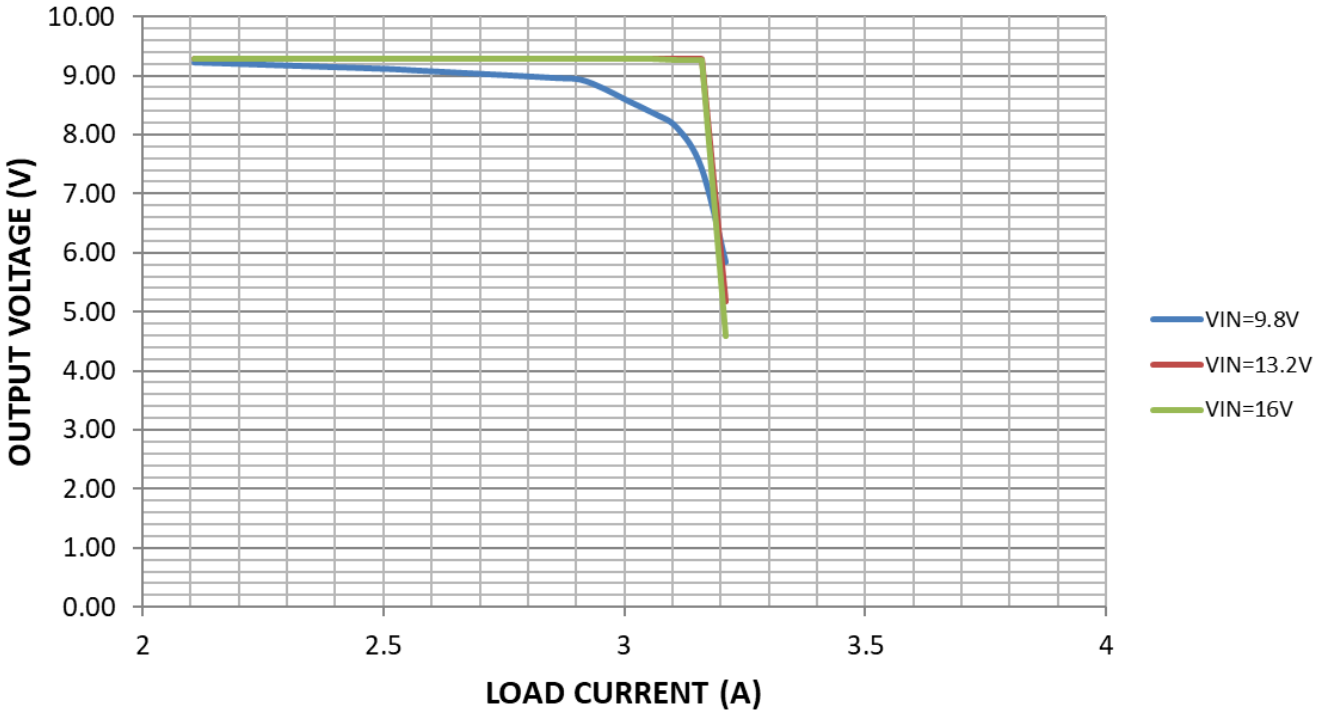


Figure 3-41. LM63625 Output Voltage vs Load Current, V_{OUT} = 9.3 V, Ta = 25°C

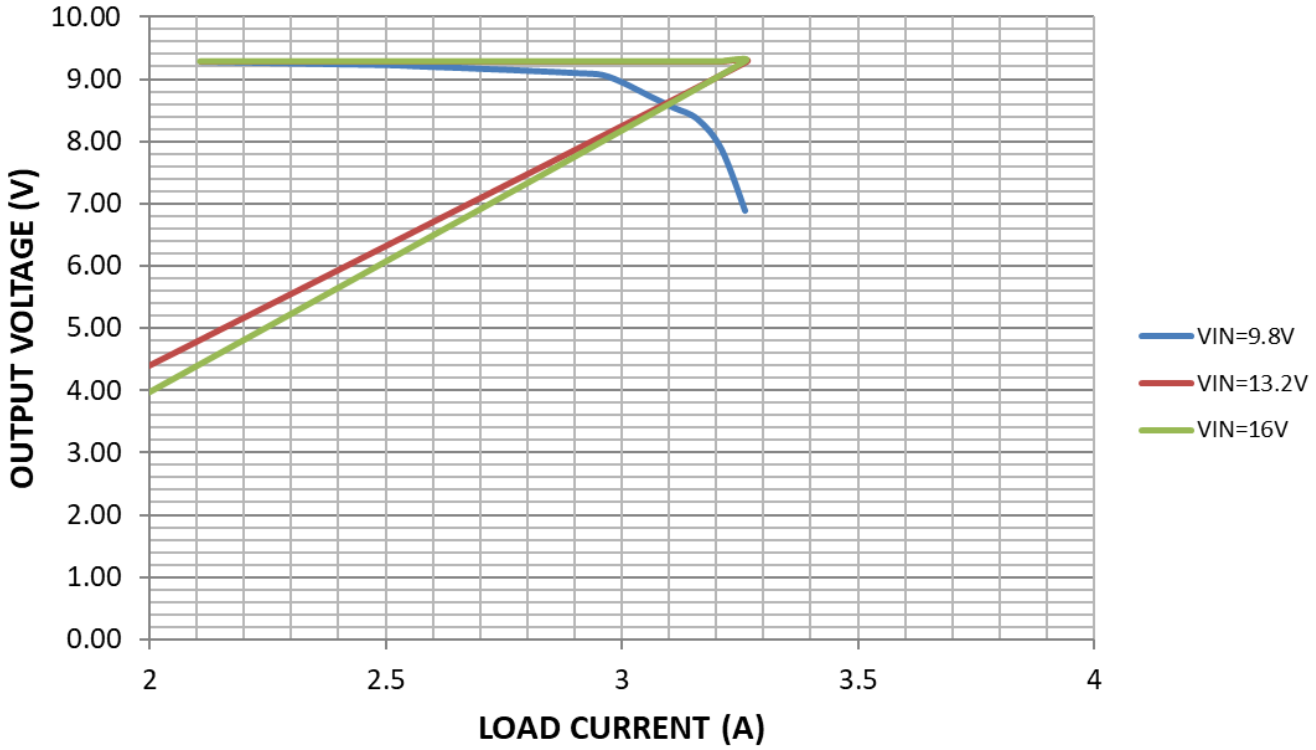


Figure 3-42. LM63625 Output Voltage vs Load Current, V_{OUT} = 9.3 V, Ta = –30°C

3.3 Load Transients

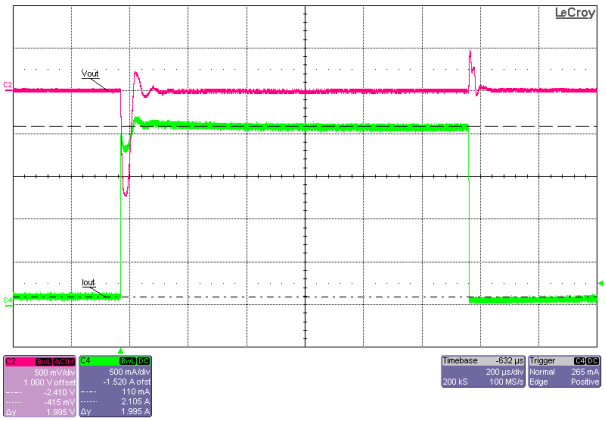


Figure 3-43. Load Transient Response at 9.8 V_{IN} and 0.1-A to 2.1-A Load Step at –30°C

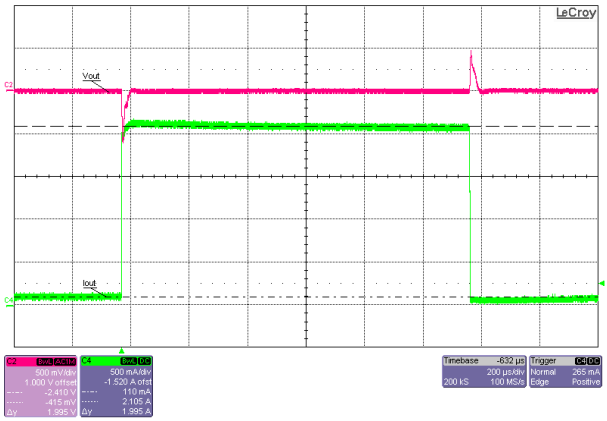


Figure 3-44. Load Transient Response at 13.2 V_{IN} and 0.1-A to 2.1-A Load Step at –30°C

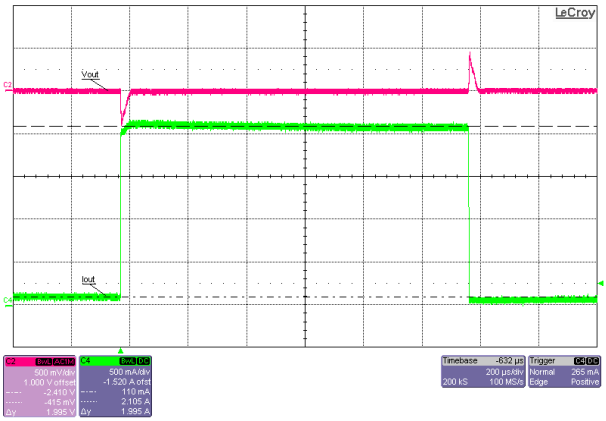


Figure 3-45. Load Transient Response at 16 V_{IN} and 0.1-A to 2.1-A Load Step at –30°C

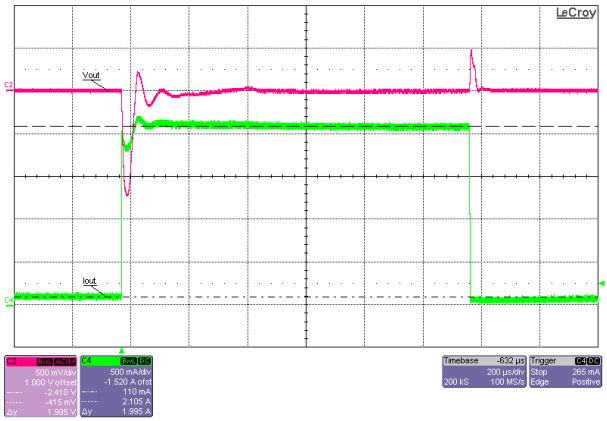


Figure 3-46. Load Transient Response at 9.8 V_{IN} and 0.1-A to 2.1-A Load Step at 25°C

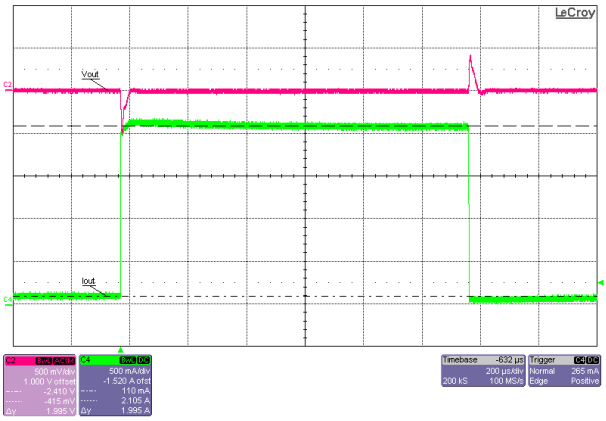


Figure 3-47. Load Transient Response at 13.2 V_{IN} and 0.1-A to 2.1-A Load Step at 25°C

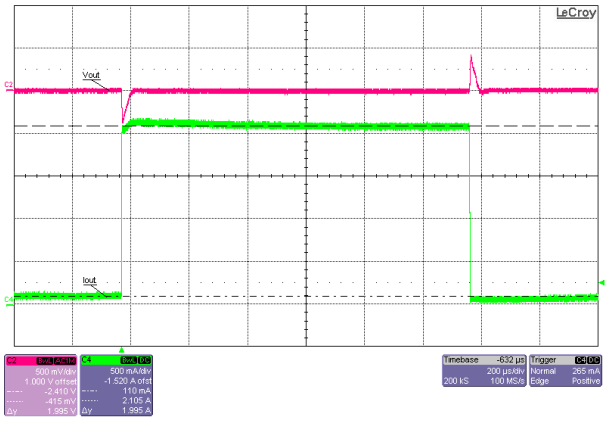


Figure 3-48. Load Transient Response at 16 V_{IN} and 0.1-A to 2.1-A Load Step at 25°C

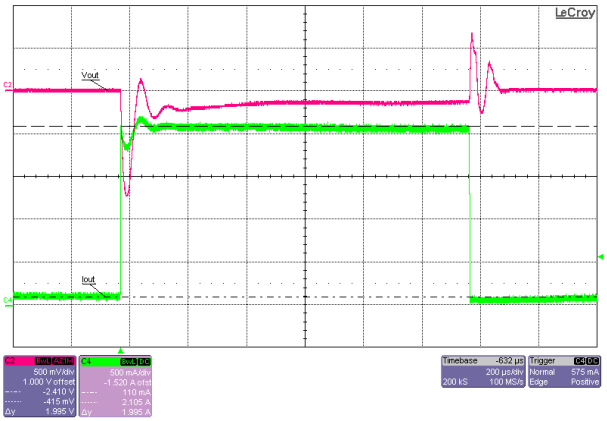


Figure 3-49. Load Transient Response at 9.8 V_{IN} and 0.1-A to 2.1-A Load Step at 85°C

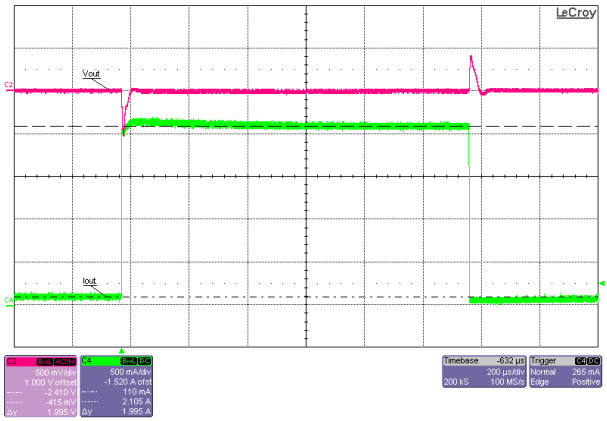


Figure 3-50. Load Transient Response at 13.2 V_{IN} and 0.1-A to 2.1-A Load Step at 85°C

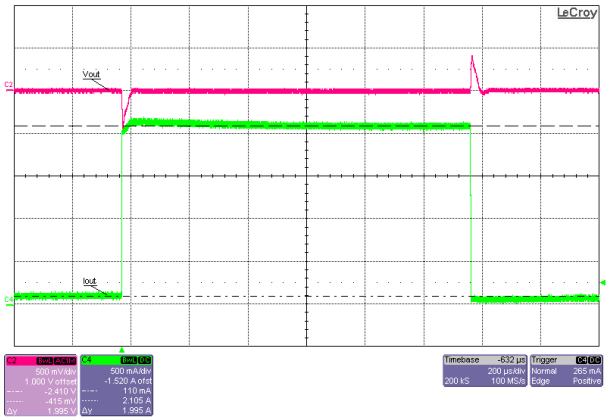


Figure 3-51. Load Transient Response at 16 V_{IN} and 0.1-A to 2.1-A Load Step at 85°C

3.4 Start-up and Shutdown

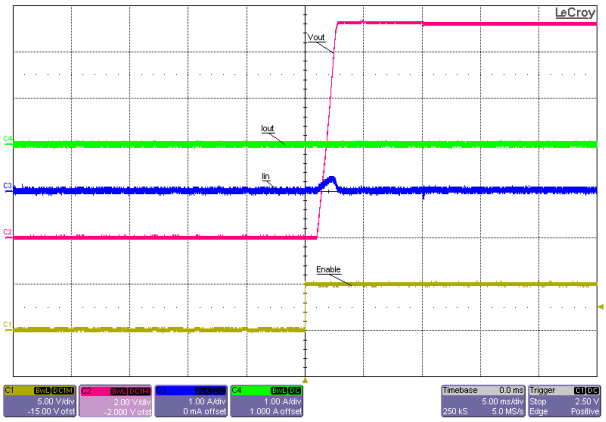


Figure 3-52. Start-up Into No Load at 9.8 V_{IN} and 25°C

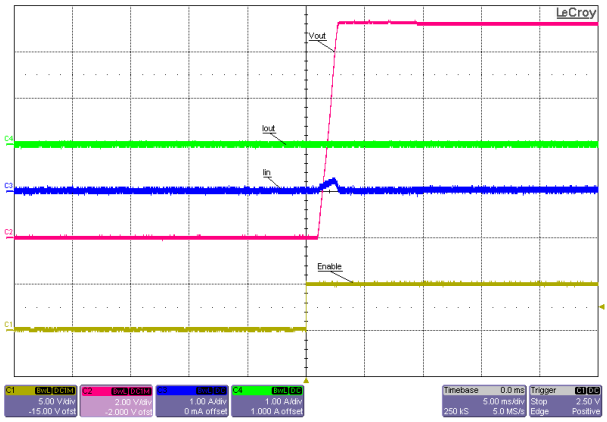


Figure 3-53. Start-up Into No Load at 13.2 V_{IN} and 25°C

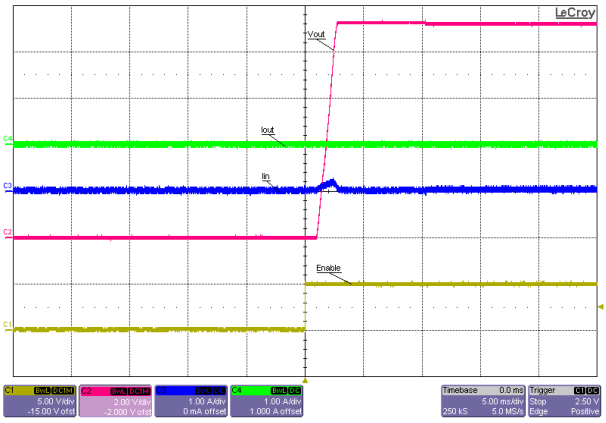


Figure 3-54. Start-up Into No Load at 16 V_{IN} and 25°C

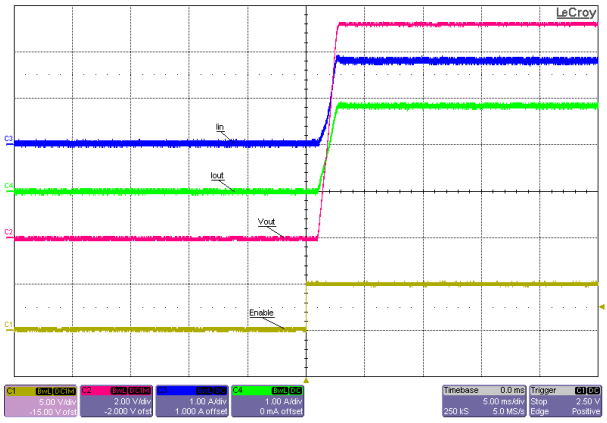


Figure 3-55. Start-up Into 1.8-A Resistor Load at 9.8 V_{IN} and 25°C

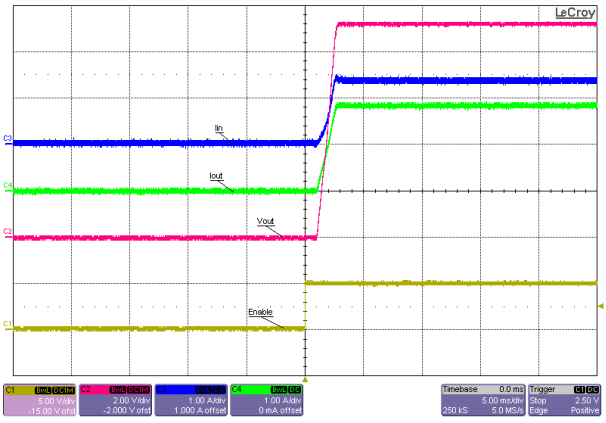


Figure 3-56. Start-up Into 1.8-A Resistor Load at 13.2 V_{IN} and 25°C

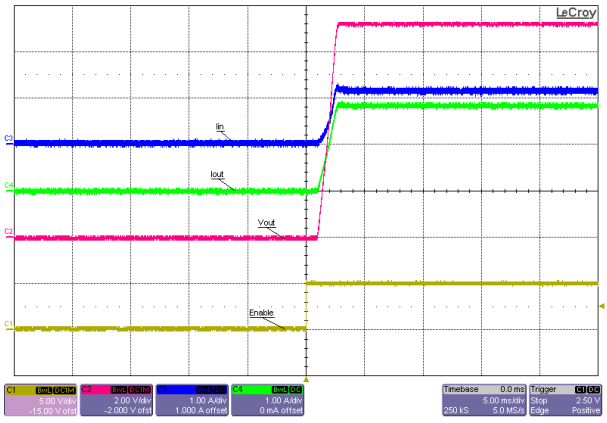


Figure 3-57. Start-up Into 1.8-A Resistor Load at 16 V_{IN} and 25°C

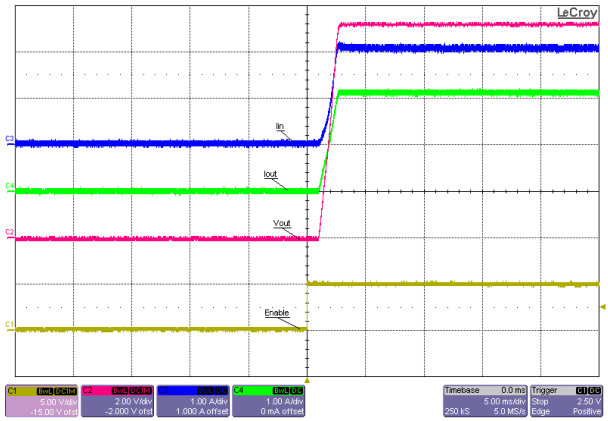


Figure 3-58. Start-up Into 2.1-A Resistor Load at 9.8 V_{IN} and 25°C

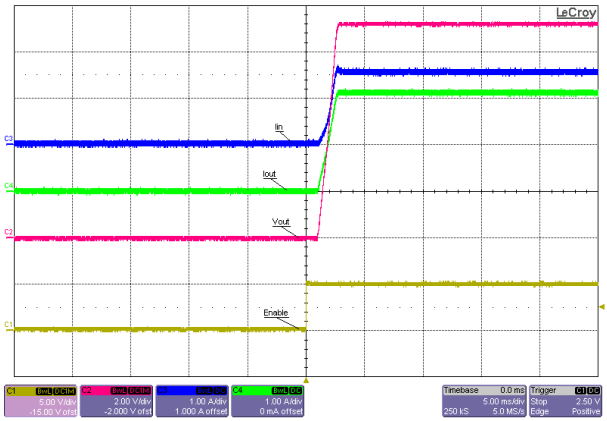


Figure 3-59. Start-up Into 2.1-A Resistor Load at 13.2 V_{IN} and 25°C

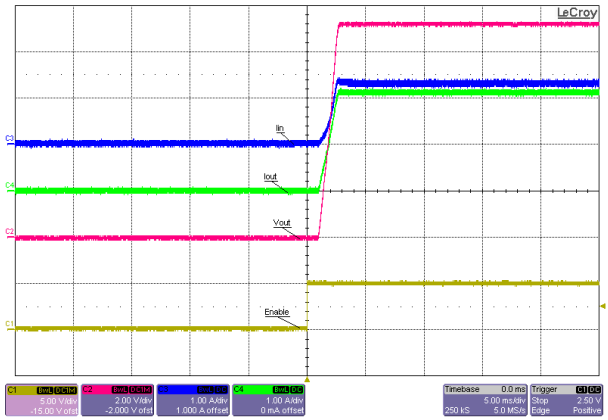


Figure 3-60. Start-up Into 2.1-A Resistor Load at 16 V_{IN} and 25°C

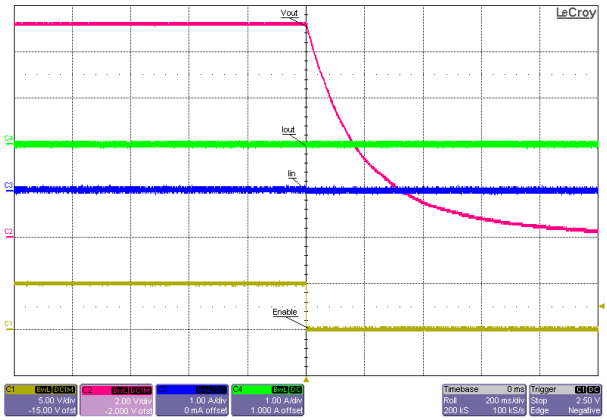


Figure 3-61. Shutdown From No Load at 9.8 V_{IN} and 25°C

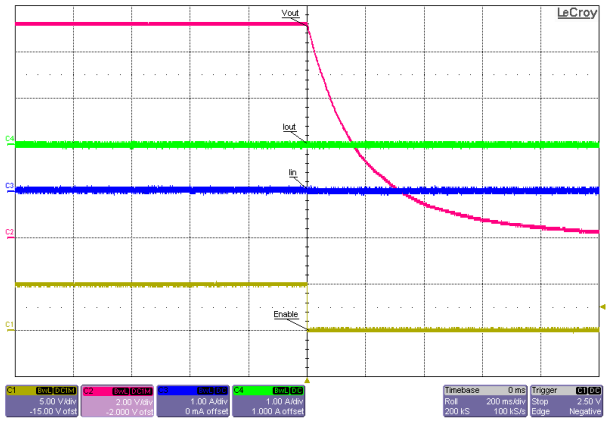


Figure 3-62. Shutdown From No Load at 13.2 V_{IN} and 25°C

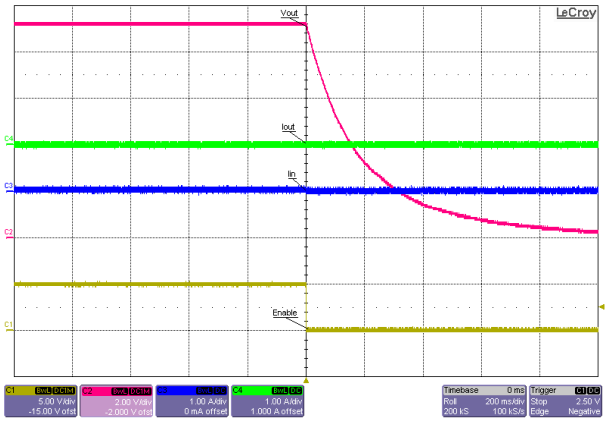


Figure 3-63. Shutdown From No Load at 16 V_{IN} and 25°C

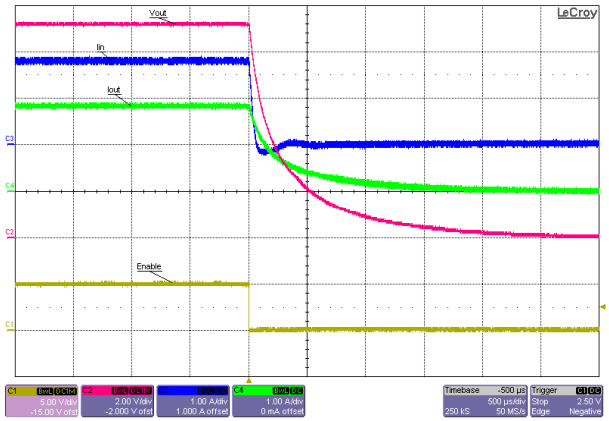


Figure 3-64. Shutdown From 1.8-A Resistor Load at 9.8 V_{IN} and 25°C

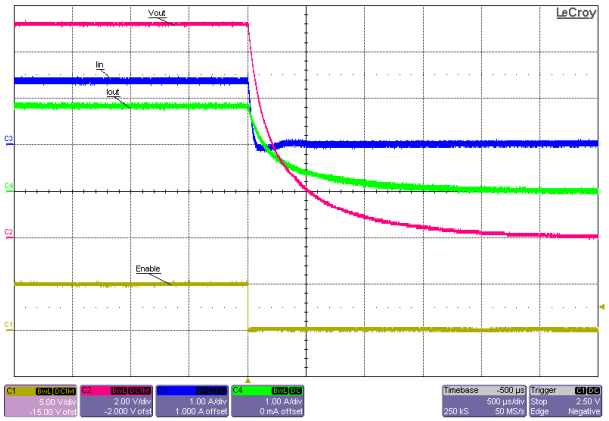


Figure 3-65. Shutdown From 1.8-A Resistor Load at 13.2 V_{IN} and 25°C

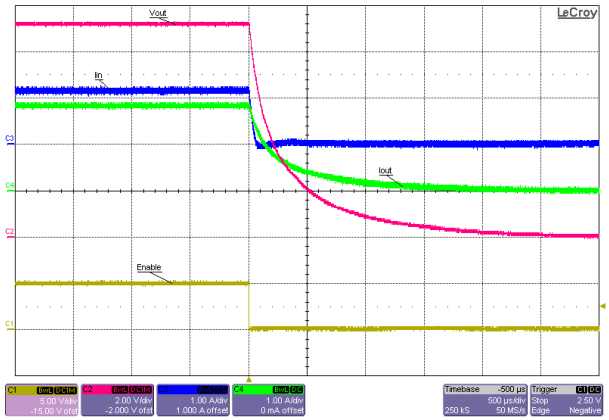


Figure 3-66. Shutdown From 1.8-A Resistor Load at 16 V_{IN} and 25°C

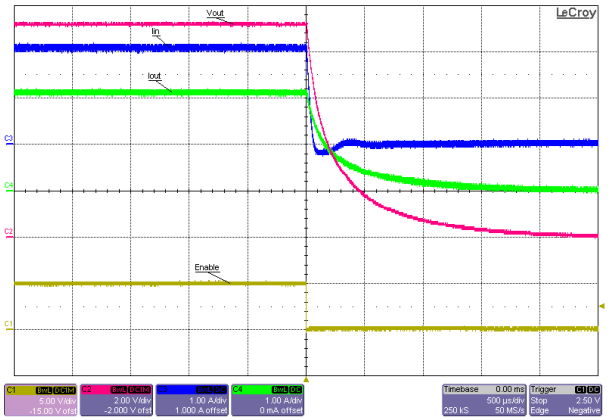


Figure 3-67. Shutdown From 2.1-A Resistor Load at 9.8 V_{IN} and 25°C

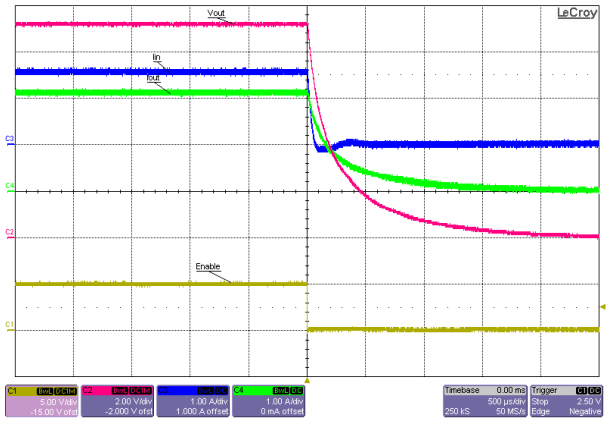


Figure 3-68. Shutdown From 2.1-A Resistor Load at 13.2 V_{IN} and 25°C

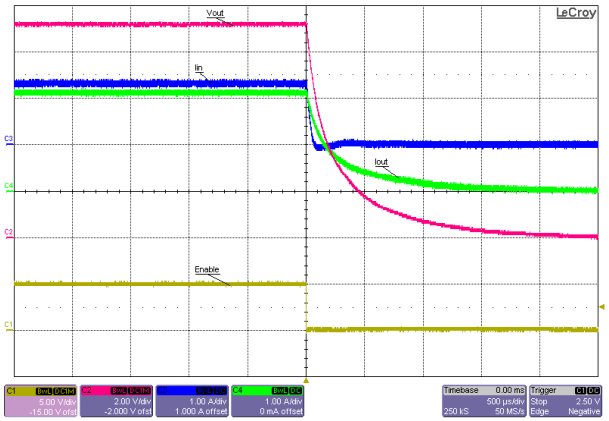


Figure 3-69. Shutdown From 2.1-A Resistor Load at 16 V_{IN} and 25°C

3.5 Thermal Shutdown

The following figures show thermal shutdown and recovery as the output voltage collapses and resets.

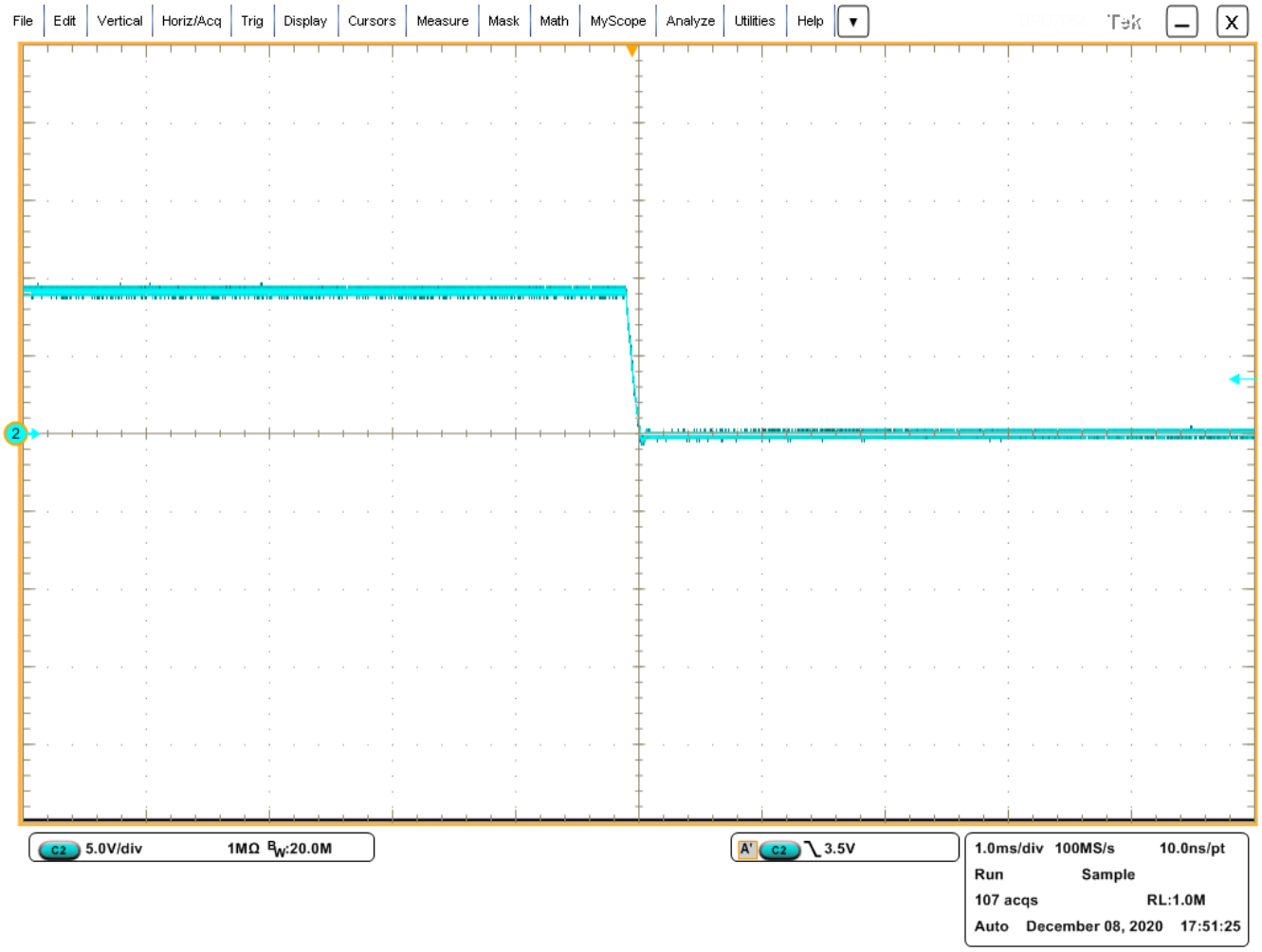


Figure 3-70. Thermal Shutdown (Case Temperature = 151°C)

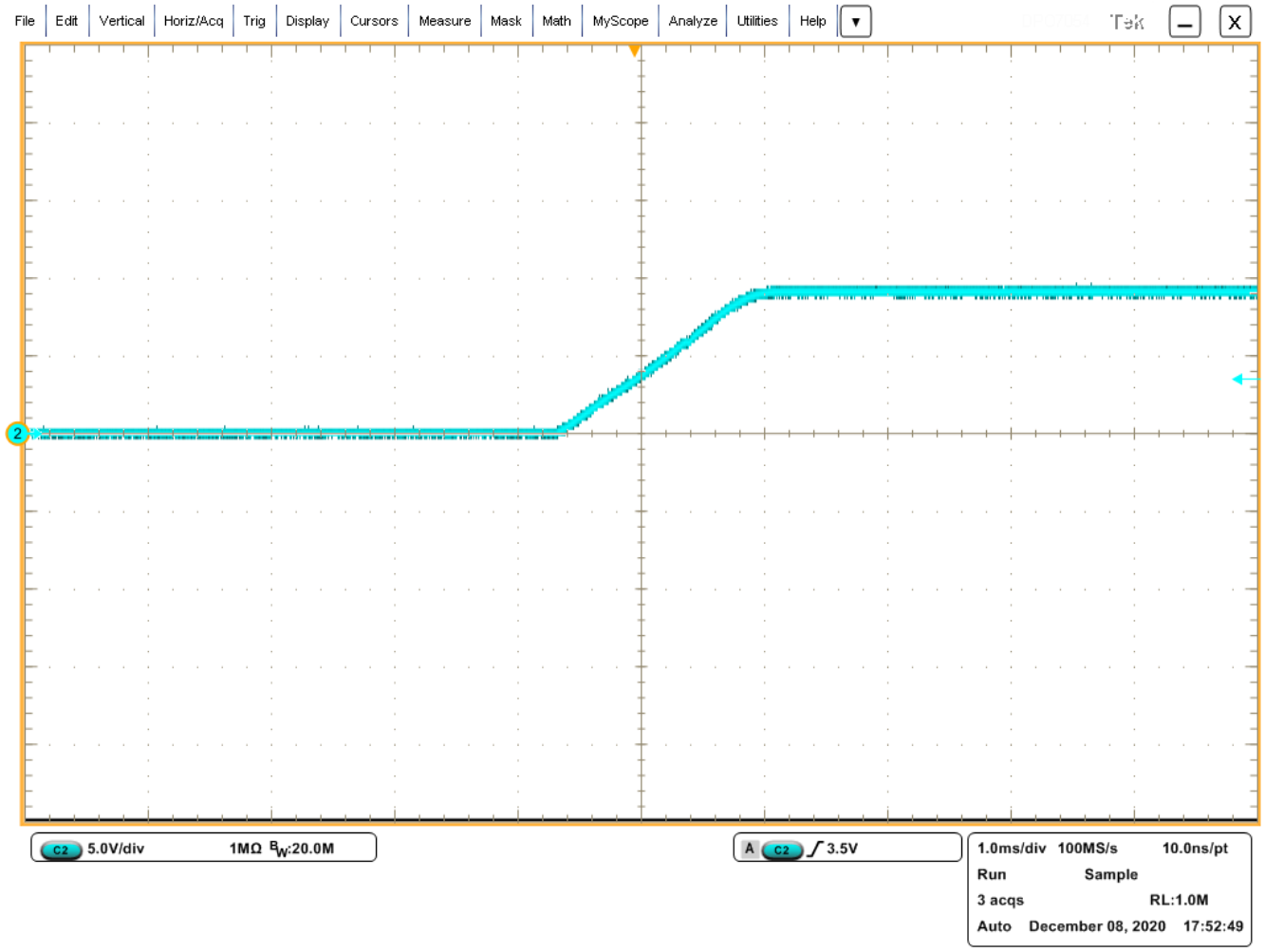


Figure 3-71. Thermal Recovery

Thermal shutdown occurred at 162.6°C and recovery occurred at 151°C.

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