*Test Report: PMP22244*

# *60-W USB Type-C High-Density Active Clamp Flyback With GaN Reference Design*

## Description

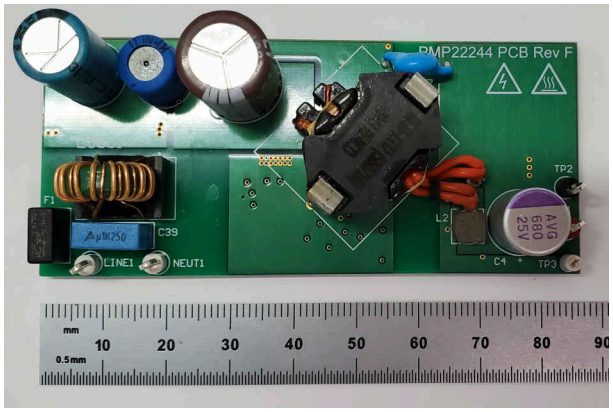
This reference design is a high-density 60-W, 115-$V_{AC}$ input power supply for USB Type-C® applications. The typical application is a single-stage, USB Type-C charger that can support two ports which simultaneously provide the same output voltage. The maximum power rating is 60 W at 20-V or 15-V output, 54 W at 9-V output, and 30 W at 5-V output. This power supply is designed to minimize power loss at all output voltage configurations. The LMG2610 GaN half-bridge simplifies the power stage with the included integrated gate drivers, current sense emulation, and high-side level shifter. These integrated features eliminate the need for external gate-drive circuitry, current-sense transformer (and associated losses), and high-side isolator. The UCC28782 active clamp flyback controller and UCC24612 synchronous rectifier driver allow this design to achieve a peak efficiency of 94.8% within the compact dimensions of 1.5 in × 3.35 in × 1 in (37.5 mm × 85 mm × 25 mm) and minimize temperature rise.

## Features

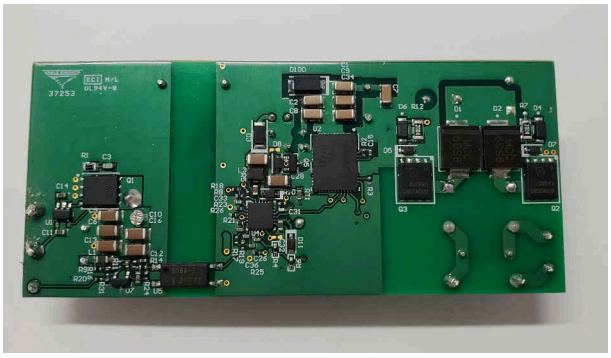
- AC-DC power supply design for 60-W single-stage, dual-port USB Type-C
- Supports 20 V | 3 A, 15 V | 4 A, 9 V | 6 A, and 5 V | 6 A outputs
- 94.8% maximum efficiency, maximum power loss of 3.5 W
- Compact dimensions of 1.5 in × 3.35 in × 1 in

## Applications

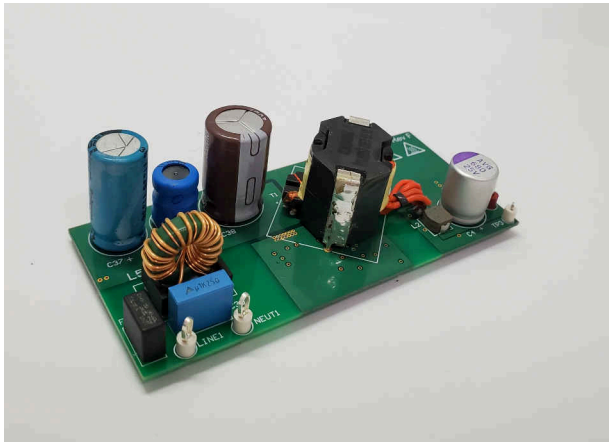
- USB wall outlets
- High-density USB Type-C power delivery (PD) adapters for laptop, tablet, TV, set-top box, and printer
- LED lighting



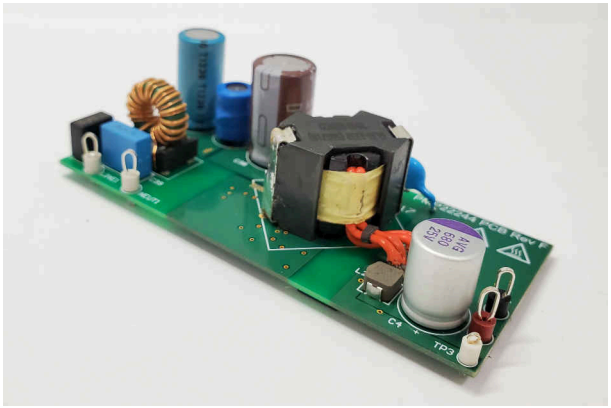

**Assembly Top View**



**Assembly Bottom View**



Angle View of Assembly



Assembly Angle View

# 1 Specifications

## 1.1 Voltage and Current Requirements

**Table 1-1. Voltage and Current Requirements**

| Parameter | Specifications |
|---|---|
| Input Voltage Range | 108 $V_{AC}$–132 $V_{AC}$ \| 60 Hz |
| Output Voltage Range | 5 V–20 V |
| Maximum Output Current | 6 A |
| Maximum Output Power | 60 W |

## 1.2 Dimensions

1.5 in × 3.35 in × 1 in (37.5 mm × 85 mm × 25 mm)

# 2 Testing and Results

## 2.1 Standby Power Consumption

For standby mode, the output voltage was set at 5 V with no load applied, and the input power was measured.

| $V_{IN}$ ($V_{RMS}$) | Line Frequency (Hz) | $P_{IN}$ (mW) |
|---|---|---|
| 115 | 60 | 56 |

## 2.2 Efficiency Graphs

Efficiency and power loss for different output voltages is shown in the following images.

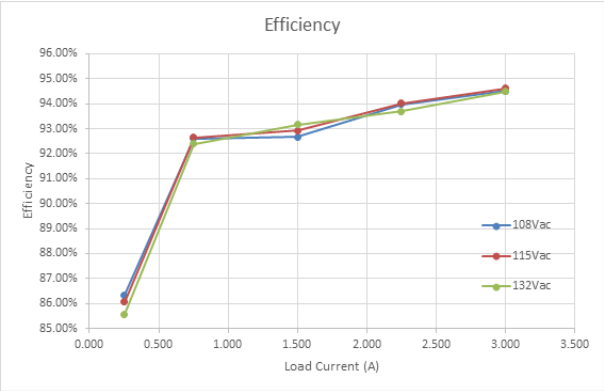



**Figure 2-1. 20-V Output Efficiency**

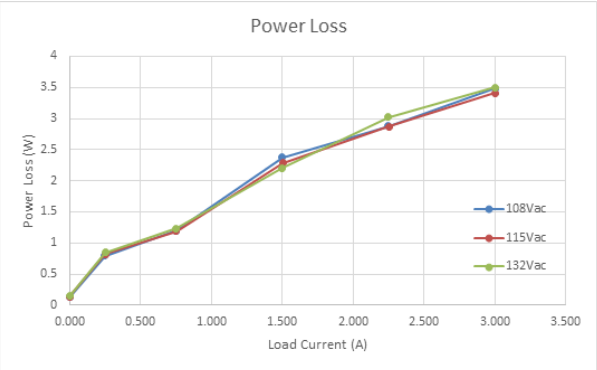



**Figure 2-2. 20-V Output Power Loss**

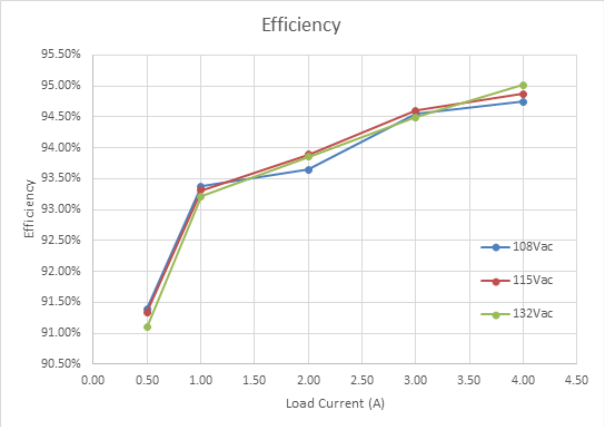



**Figure 2-3. 15-V Output Efficiency**

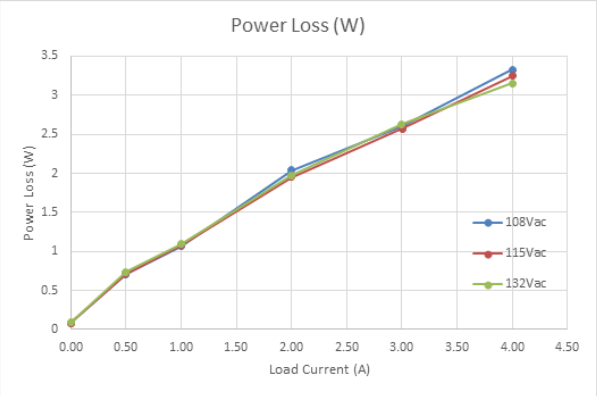



**Figure 2-4. 15-V Output Power Loss**

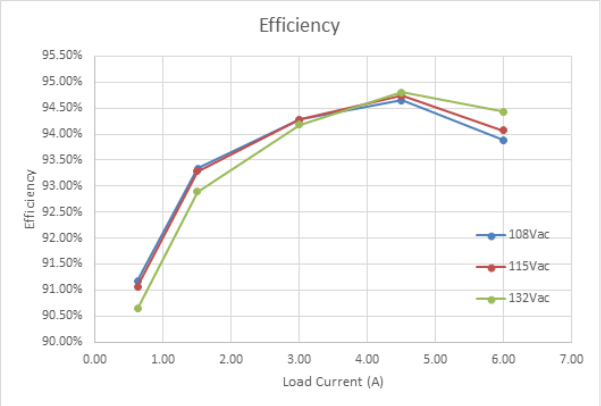



**Figure 2-5. 9-V Output Efficiency**

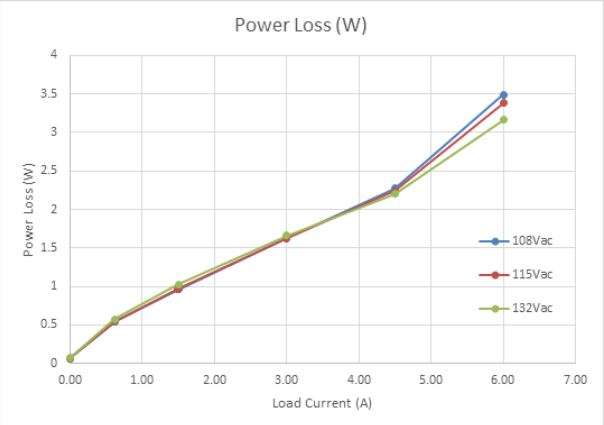



**Figure 2-6. 9-V Output Power Loss**

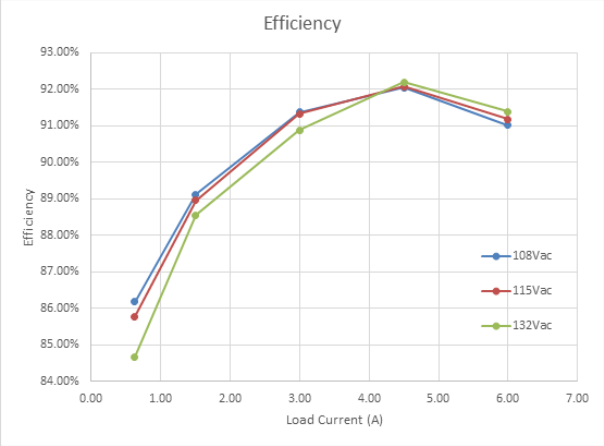



**Figure 2-7. 5-V Output Efficiency**


**Figure 2-8. 5-V Output Power Loss**

## 2.3 Thermal Images

All images captured with the unit under test (UUT) were enclosed in a 30 cm × 45 cm × 20 cm plexiglass box, 25ºC ambient, after a 30-minute warm up. The input voltage was 115 $V_{AC}$, 60 Hz.

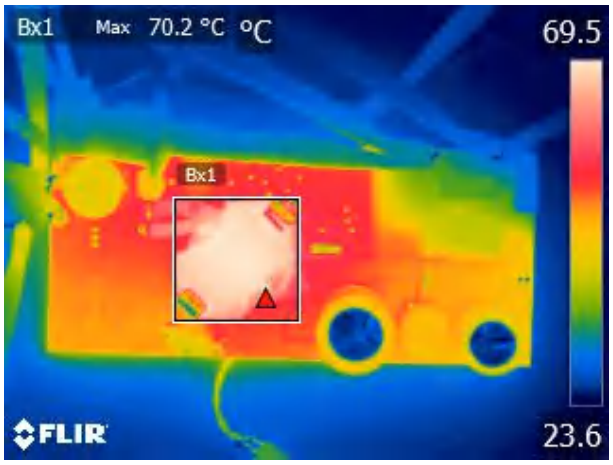



**Figure 2-9. 20-V Output With 3-A Load, Top View**

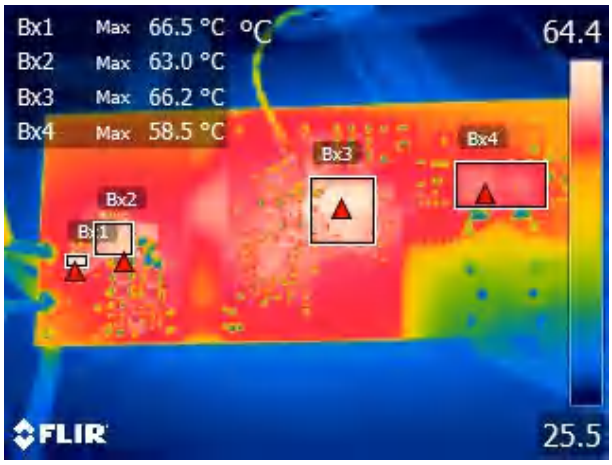



**Figure 2-10. 20-V Output With 3-A Load, Bottom View**

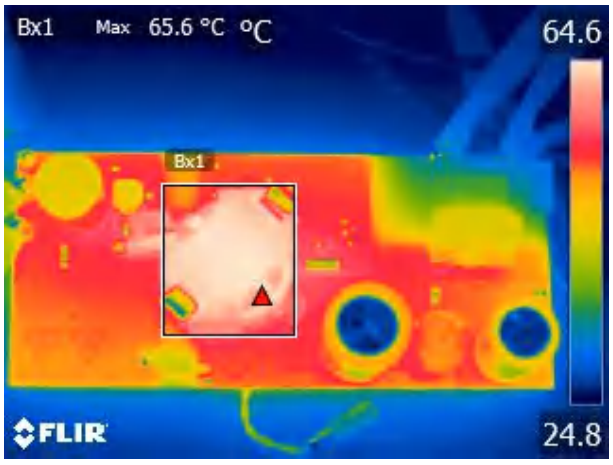



**Figure 2-11. 15-V Output With 4-A Load, Top View**

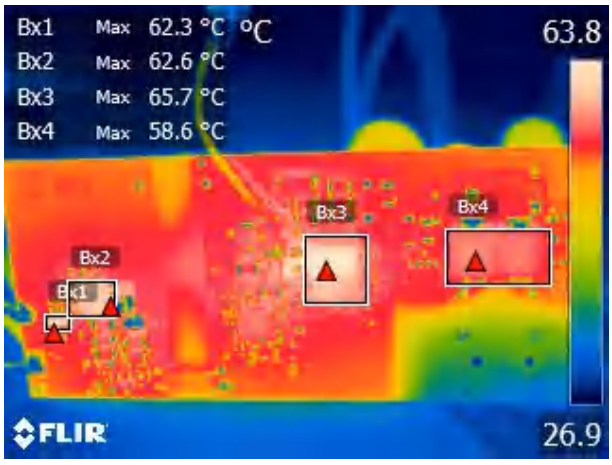



**Figure 2-12. 15-V Output With 4-A Load, Bottom View**

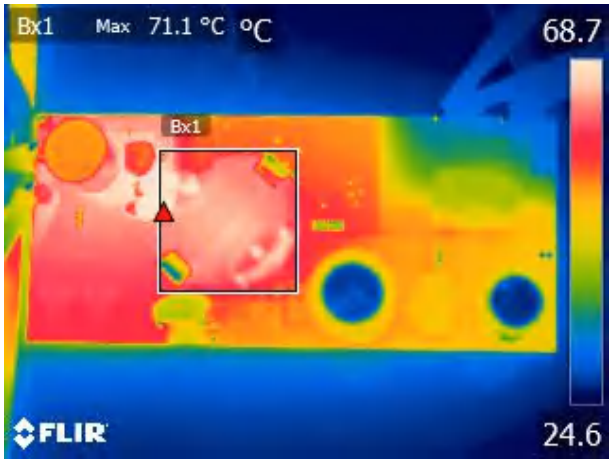



**Figure 2-13. 9-V Output With 6-A Load, Top View**

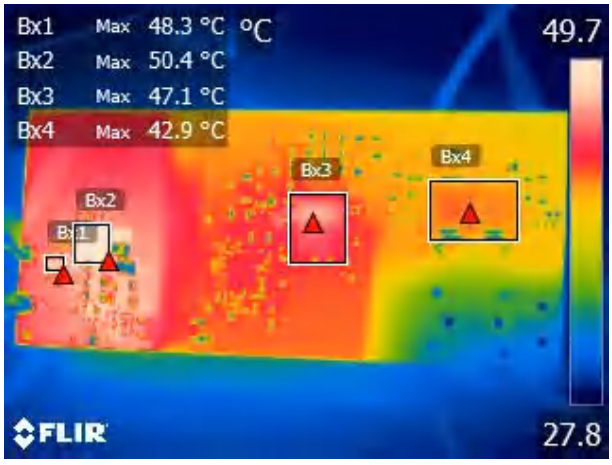



**Figure 2-14. 9-V Output With 6-A Load, Bottom View**

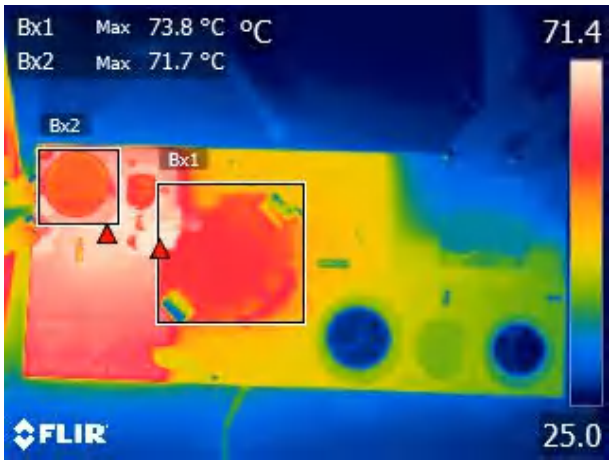



**Figure 2-15. 5-V Output With 6-A Load, Top View**

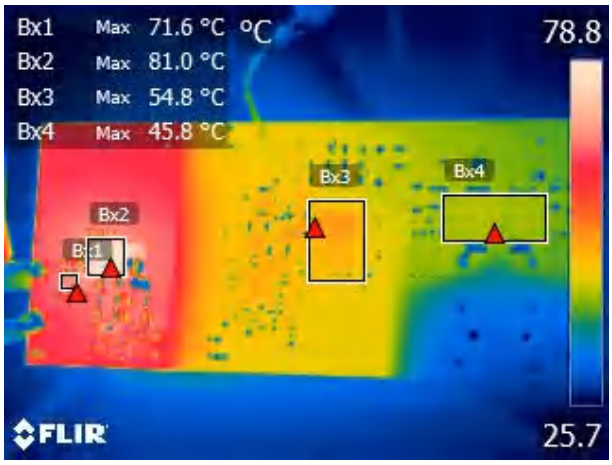
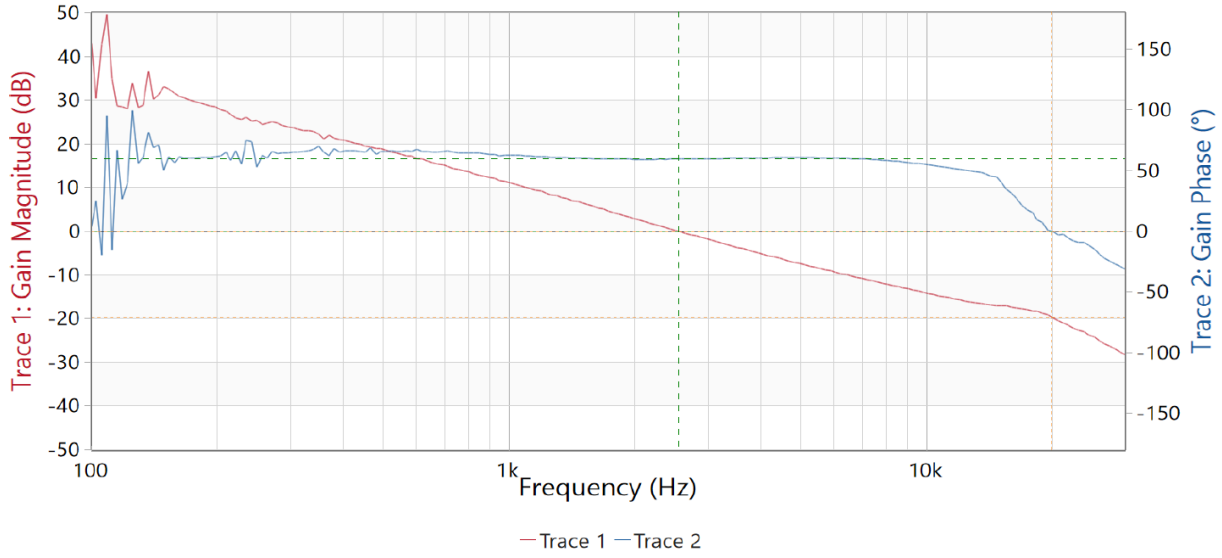



**Figure 2-16. 5-V Output With 6-A Load, Bottom View**

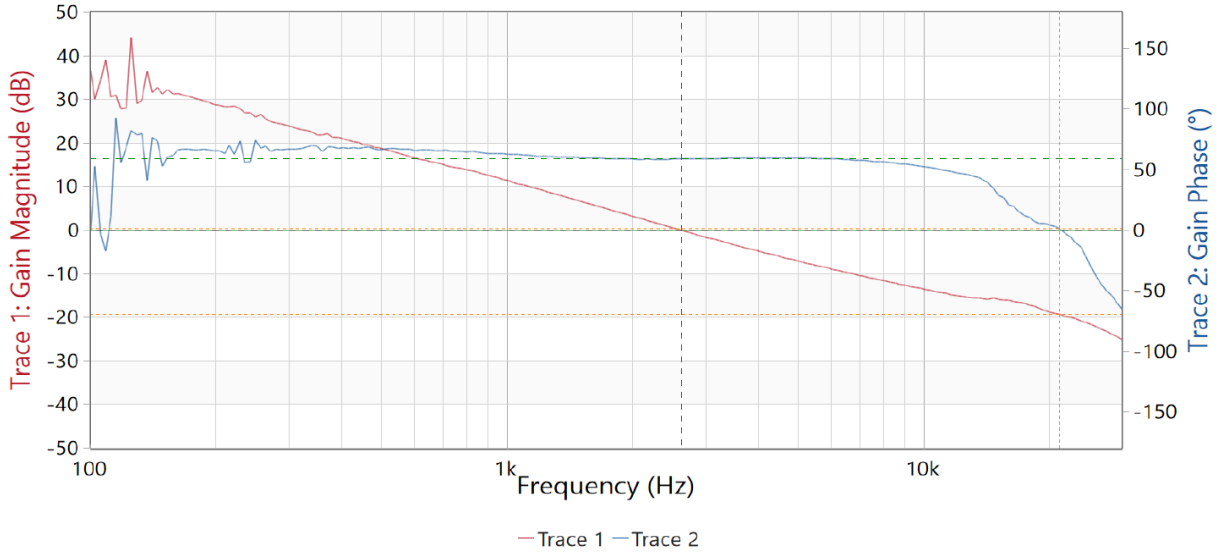
## 2.4 Bode Plots

The following frequency responses were measured with a 115 $V_{AC}$, 60-Hz input voltage. Data was taken on the revision D2 board.



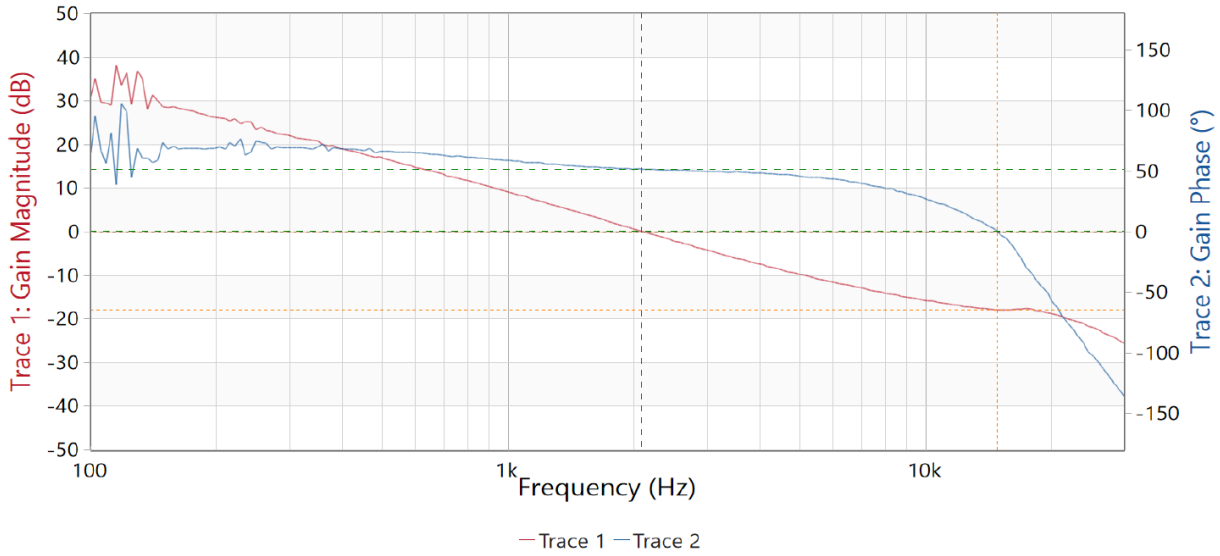

| | Cursor 1 | Cursor 2 | |
|---|---|---|---|
| Frequency | 2.555 kHz | 20.037 kHz | |
| **Trace 1** | **Magnitude (dB)** | **Magnitude (dB)** | |
| Measurement | 5.174 mdB | -19.673 dB | |
| **Trace 2** | **Phase (°)** | **Phase (°)** | |
| Measurement | 59.385 ° | 107.523 m° | |

**Figure 2-17. 20-V Output With 3-A Load**



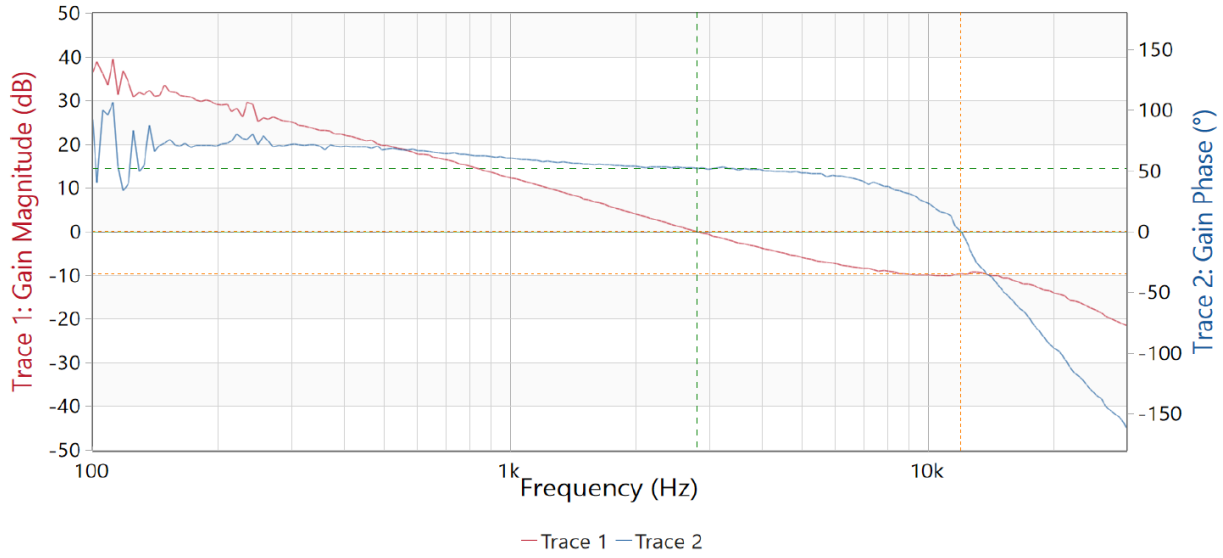

| | Cursor 1 | Cursor 2 | |
|---|---|---|---|
| Frequency | 2.632 kHz | 21.19 kHz | |
| **Trace 1** | **Magnitude (dB)** | **Magnitude (dB)** | |
| Measurement | -39.605 mdB | -19.315 dB | |
| **Trace 2** | **Phase (°)** | **Phase (°)** | |
| Measurement | 58.799 ° | 1.135 ° | |

**Figure 2-18. 15-V Output With 4-A Load**




| | Cursor 1 | Cursor 2 | |
|---|---|---|---|
| Frequency | 2.091 kHz | 14.88 kHz | |
| **Trace 1** | **Magnitude (dB)** | **Magnitude (dB)** | |
| Measurement | 121.331 mdB | -17.951 dB | |
| **Trace 2** | **Phase (°)** | **Phase (°)** | |
| Measurement | 51.747 ° | 185.35 m° | |

**Figure 2-19. 9-V Output With 6-A Load**




| | Cursor 1 | Cursor 2 | |
|---|---|---|---|
| Frequency | 2.8 kHz | 12 kHz | |
| **Trace 1** | **Magnitude (dB)** | **Magnitude (dB)** | |
| Measurement | -19.157 mdB | -9.634 dB | |
| **Trace 2** | **Phase (°)** | **Phase (°)** | |
| Measurement | 52.478 ° | 614.247 m° | |

**Figure 2-20. 5-V Output With 6-A Load**

## 2.5 Conducted EMI

Conducted EMI measurement with a 115 $V_{AC}$, 60-Hz input are shown in the following figures. The output was not tied to Earth ground.

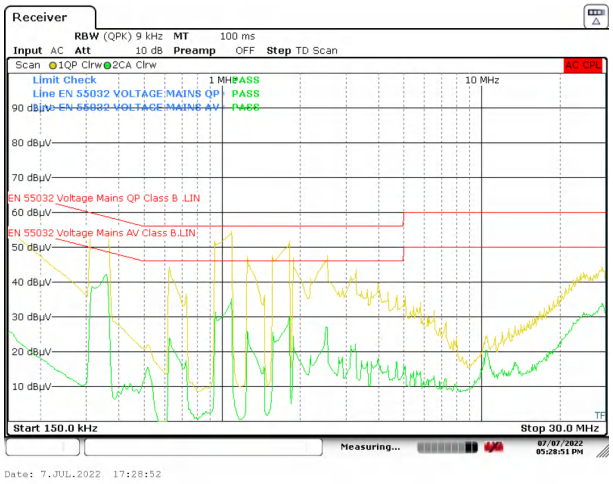



**Figure 2-21. 20-V Output With 3-A Load**

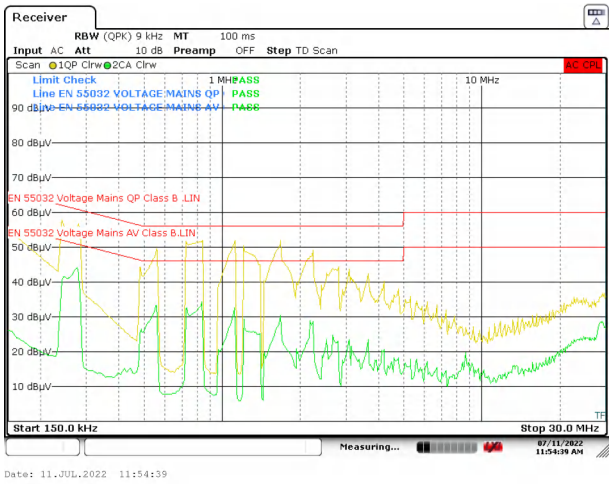



**Figure 2-22. 15-V Output With 4-A Load**

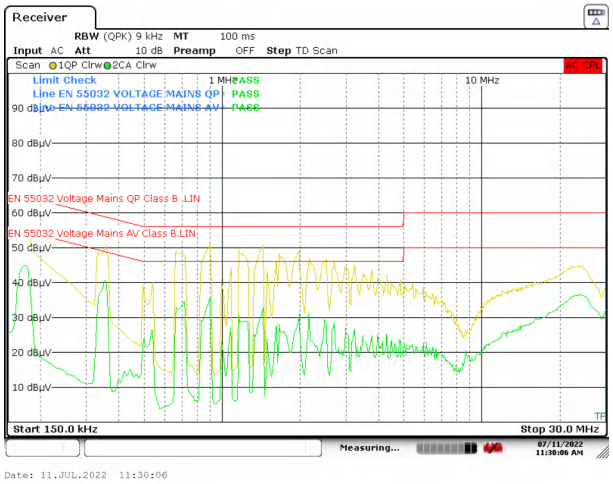



**Figure 2-23. 9-V Output With 6-A Load**

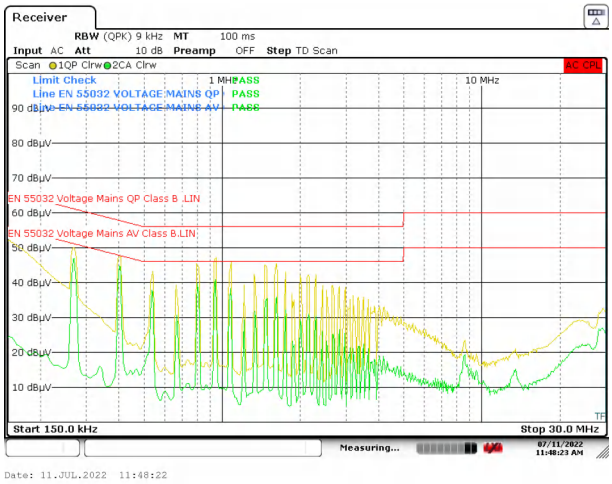



**Figure 2-24. 5-V Output With 6-A Load**

# 3 Waveforms

## 3.1 Switching

Switching behavior at 132 $V_{AC}$, 60-Hz input is shown in the following figures. The highest voltage stress on both primary and secondary FETs occurs at highest input voltage and highest output voltage conditions. The voltage stress is highest on the primary FET during *Low Power Mode* operation of the UCC28782. At this condition, the high-side FET is disabled to conserve power dissipation, resulting in a leakage spike on the primary FET.

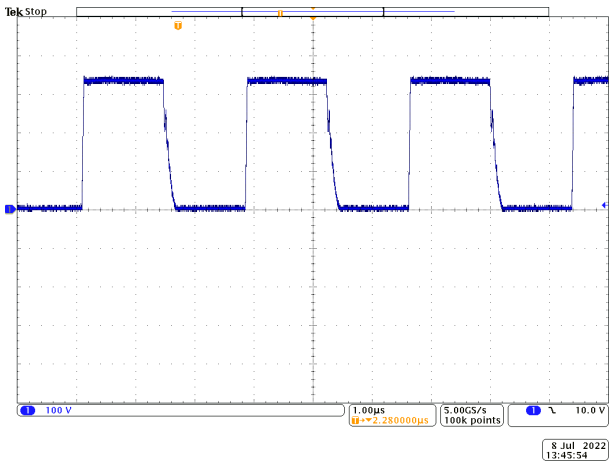



**Figure 3-1. Primary FET (U2) Drain-Source Voltage at 20-V Output and 3-A Load**

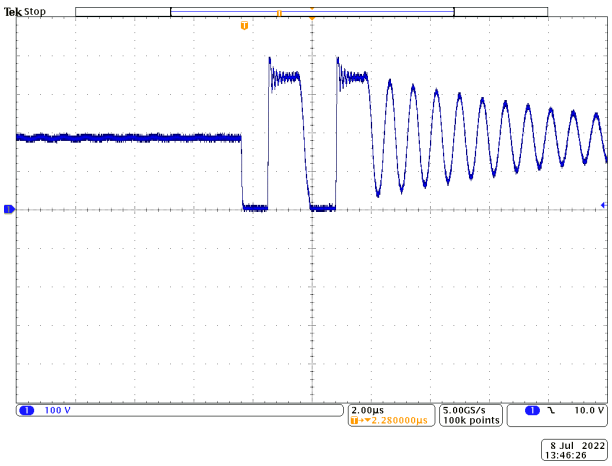



**Figure 3-2. Primary FET (U2) Drain-Source Voltage at 20-V Output and 250-mA Load**

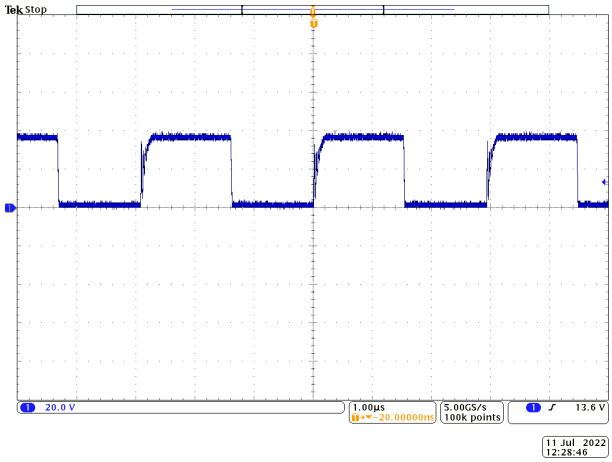



**Figure 3-3. Secondary FET (Q1) Drain-Source Voltage at 20-V Output and 3-A Load**

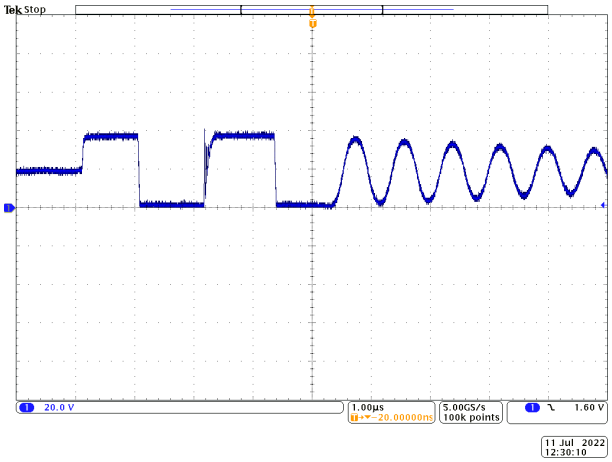



**Figure 3-4. Secondary FET (Q1) Drain-Source Voltage at 20-V Output and 250-mA Load**

## 3.2 Output Voltage Ripple

Output voltage ripple at 115VAC, 60Hz input is shown in the following figures. The output ripple voltage is sub-modulated by the burst frequency at lighter loads.

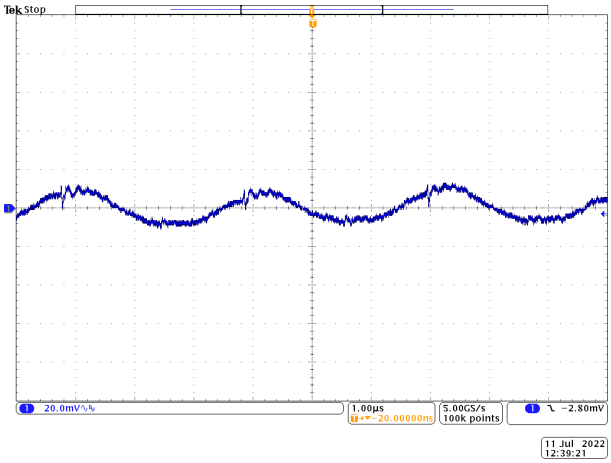



**Figure 3-5. 20-V Output With 3-A Load**

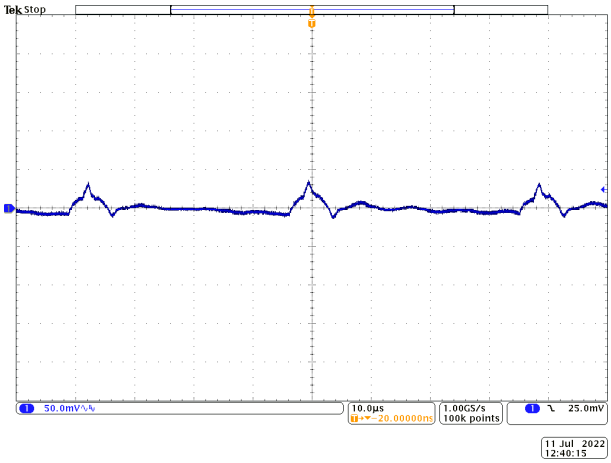



**Figure 3-6. 20-V Output With 250-mA Load**

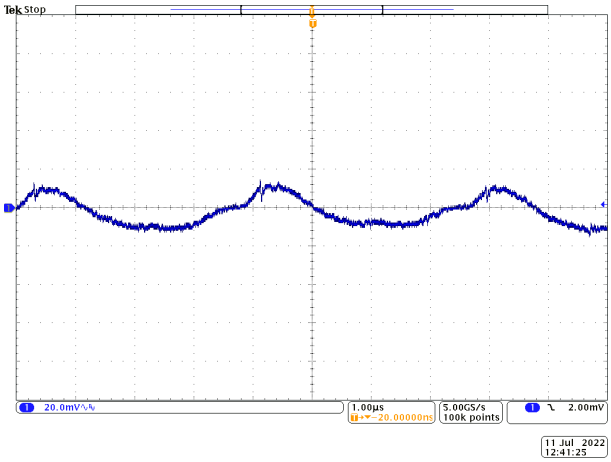



**Figure 3-7. 15-V Output With 4-A Load**

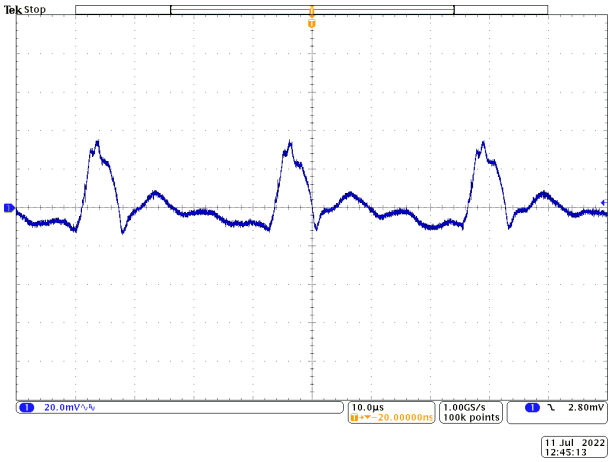



**Figure 3-8. 15-V Output With 400-mA Load**

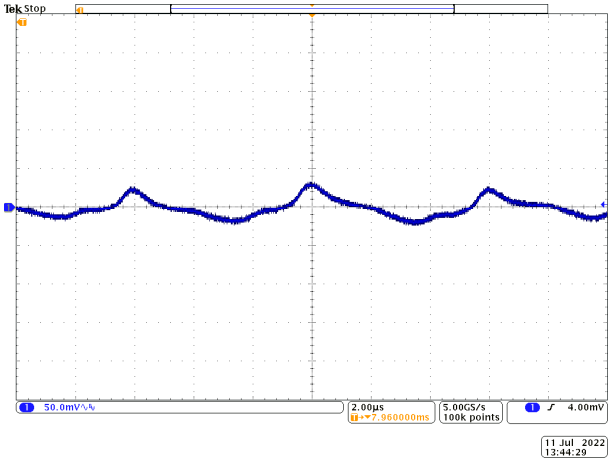



**Figure 3-9. 9-V Output With 6-A Load**

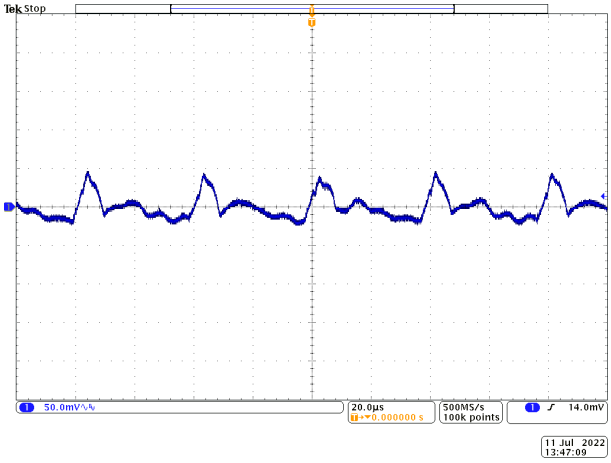



**Figure 3-10. 9-V Output With 600-mA Load**

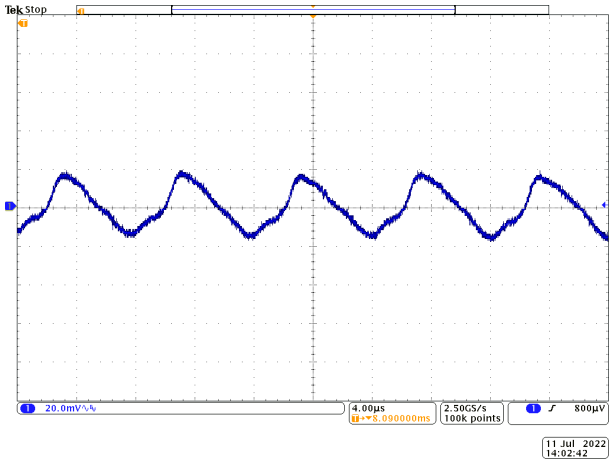



**Figure 3-11. 5-V Output With 6-A Load**

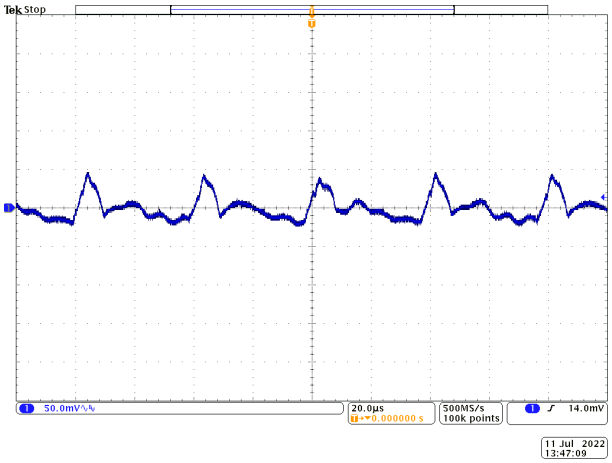



**Figure 3-12. 5-V Output With 1-A Load**

## 3.3 Load Transients

Load transient responses with a 115 $V_{AC}$, 60-Hz input are shown in the following figures. Channel 1 shows the output voltage, AC-coupled, and Channel 4 shows the load current.

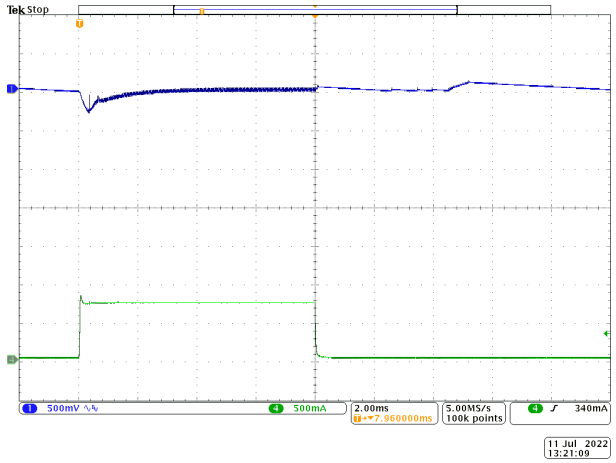



**Figure 3-13. 20-V Output With 0-A to 750-mA Step**

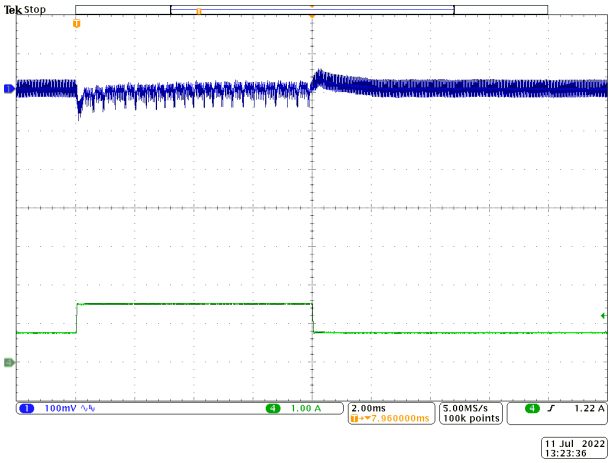



**Figure 3-14. 20-V Output With 750-mA to 1.5-A Step**

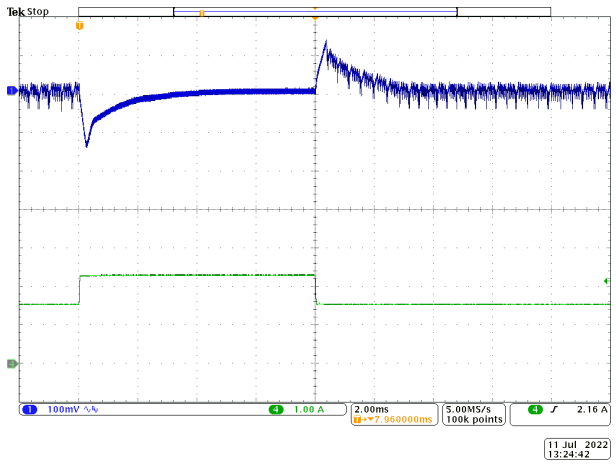



**Figure 3-15. 20-V Output With 1.5-A to 2.25-A Step**

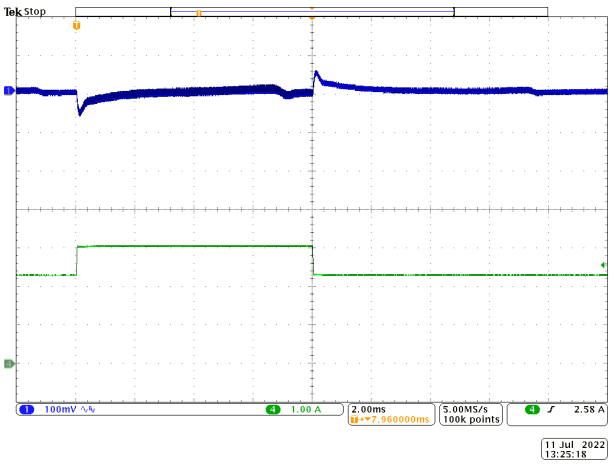



**Figure 3-16. 20-V Output With 2.25-A to 3-A Step**

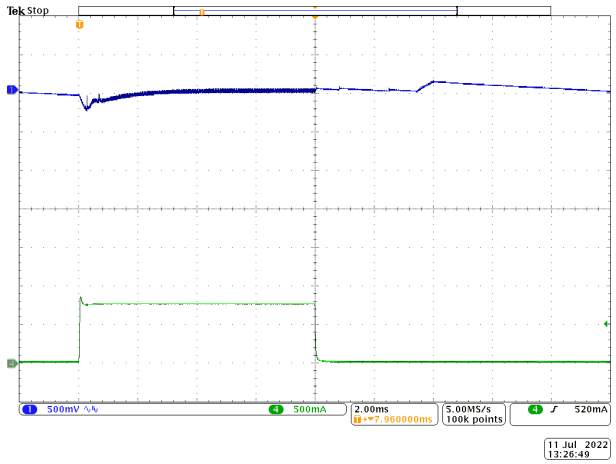



**Figure 3-17. 15-V Output With 0-A to 750-mA Step**

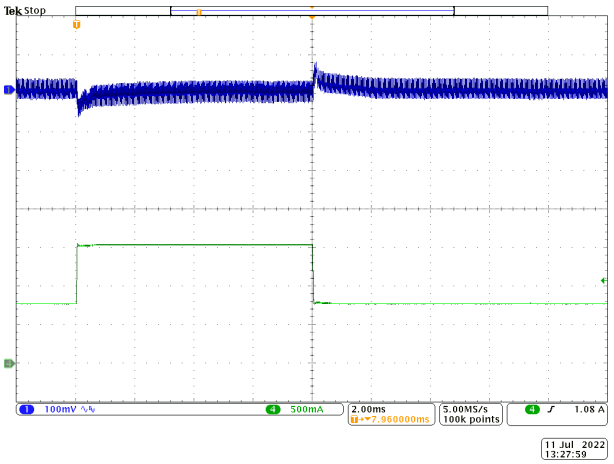



**Figure 3-18. 15-V Output With 750-mA to 1.5-A Step**

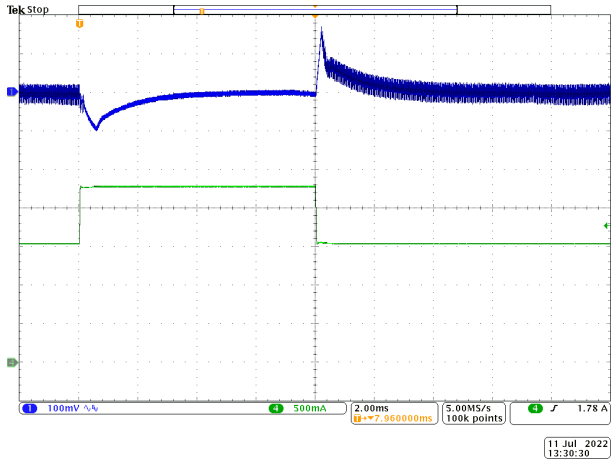



Figure 3-19. 15-V Output With 1.5-A to 2.25-A Step

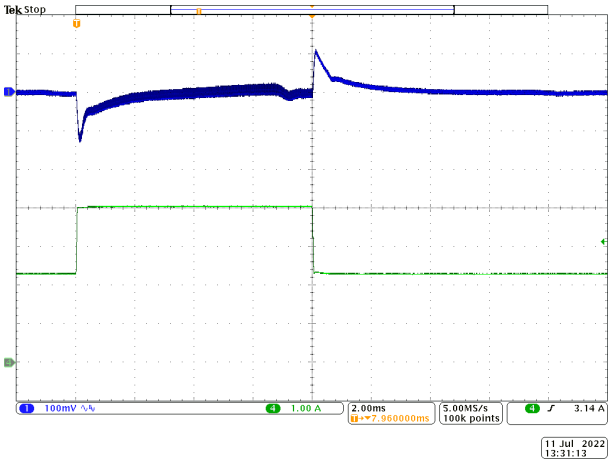



Figure 3-20. 15-V Output With 2.25-A to 4-A Step

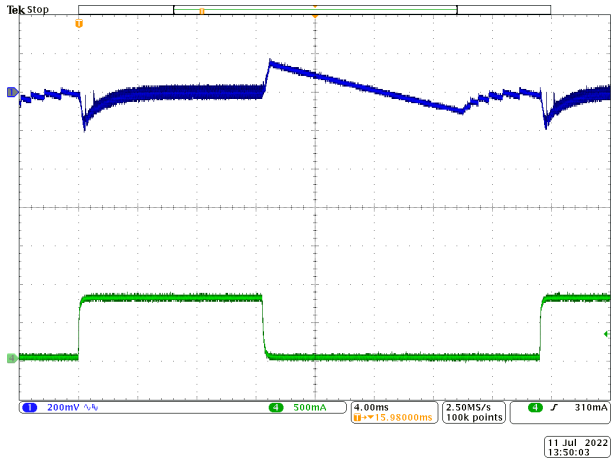



Figure 3-21. 9-V Output With 0-A to 750-mA Step

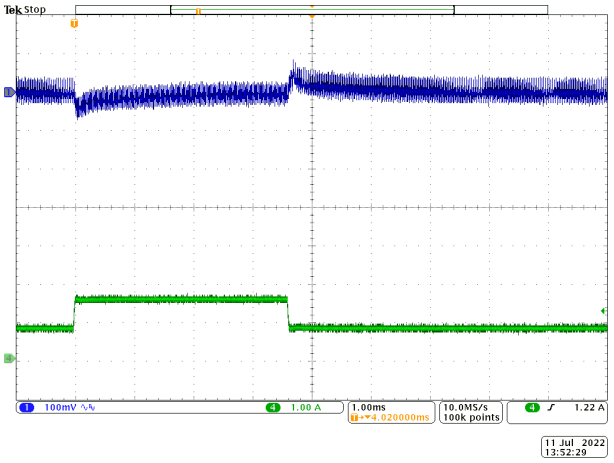



Figure 3-22. 9-V Output With 750-mA to 1.5-A Step

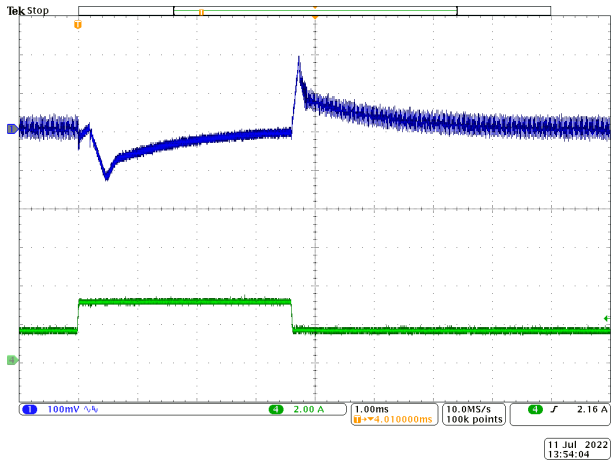



Figure 3-23. 9-V Output With 1.5-A to 3-A Step

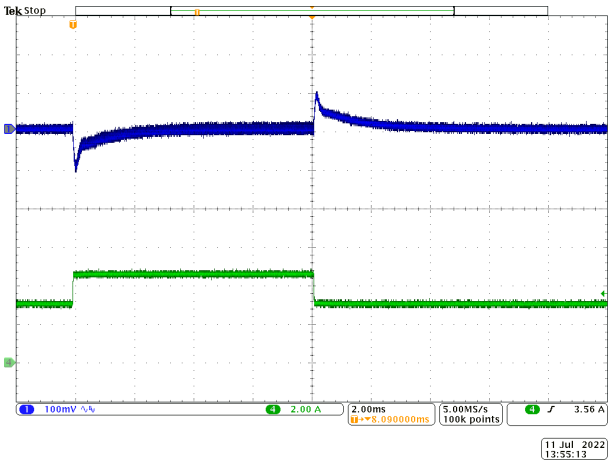



Figure 3-24. 9-V Output With 3-A to 4.5-A Step

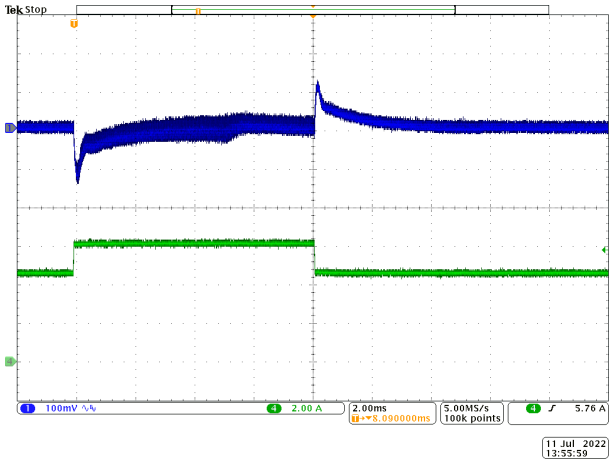



**Figure 3-25. 9-V Output With 4.5-A to 6-A Step**

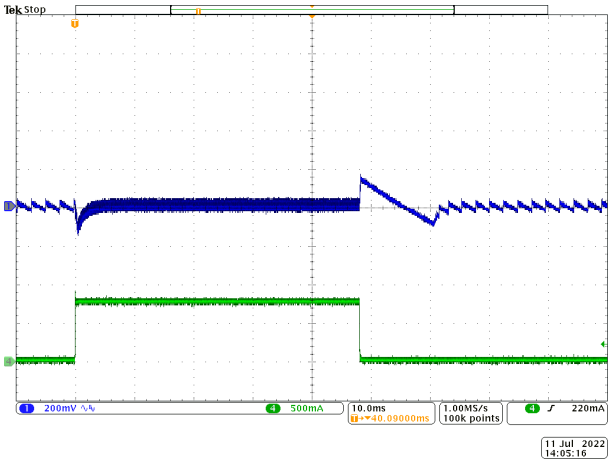



**Figure 3-26. 5-V Output With 0-A to 750-mA Step**

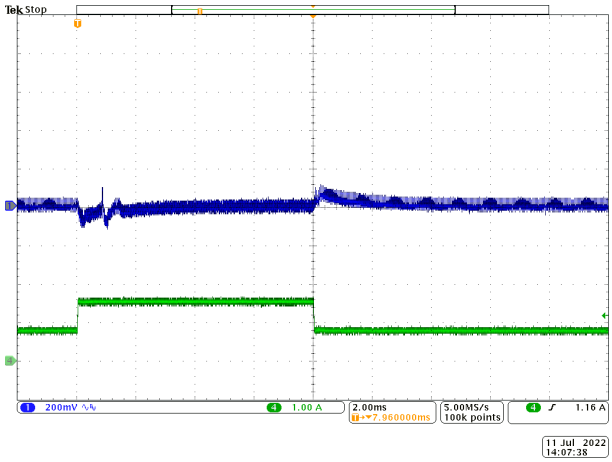



**Figure 3-27. 5-V Output With 750-mA to 1.5-A Step**

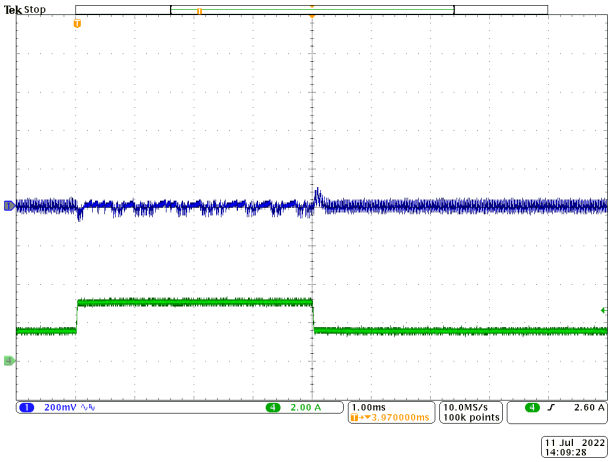



**Figure 3-28. 5-V Output With 1.5-A to 3-A Step**

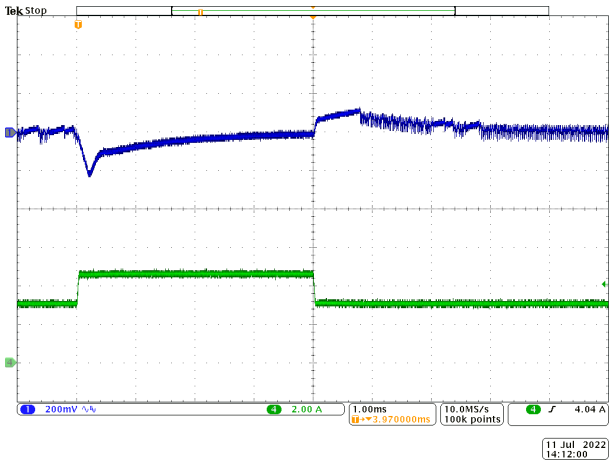



**Figure 3-29. 5-V Output With 3-A to 4.5-A Step**

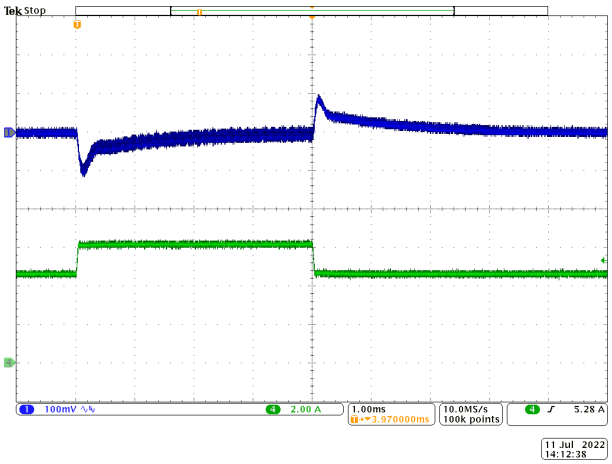



**Figure 3-30. 5-V Output With 4.5-A to 6-A Step**

## 3.4 Start-Up

Start-up behavior at 115 $V_{AC}$, 60-Hz input is shown in the following figure. The output was unloaded and input voltage was applied.

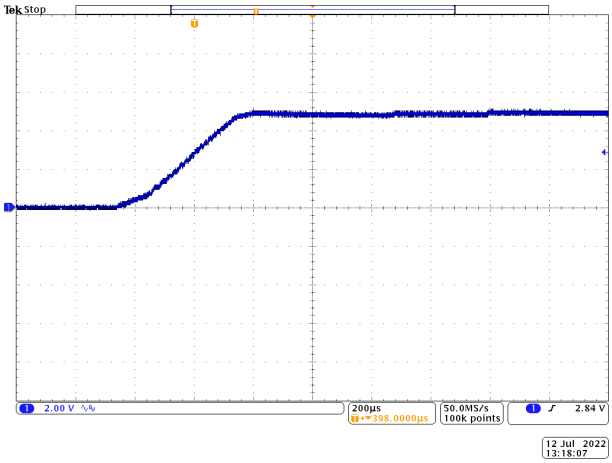



**Figure 3-31. Start-Up With No Load**

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