

# High Power Density 65-W, USB Type-C® Charger Using Active Clamp Flyback Reference Design



## Description

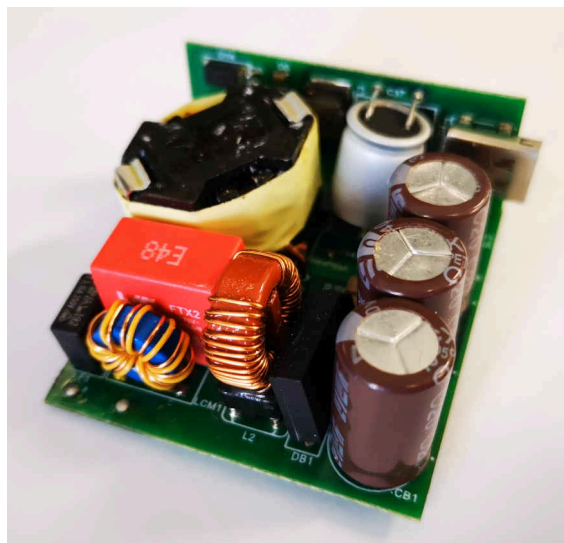
This reference design is a 65-W, high-power density USB charger using the UCC28782 active-clamp flyback controller achieving 30-W/in power density. The maximum power rating is 65 W at 20 V  $V_{OUT}$  across a universal AC input range.  $V_{OUT}$  is also adjustable to 20-, 15-, 9-, and 5-V output voltage and 3 A. The design reaches a peak efficiency of 94%. The average efficiency and standby power levels are designed to meet DoE Level VI and CoC Tier 2 limits.

## Features

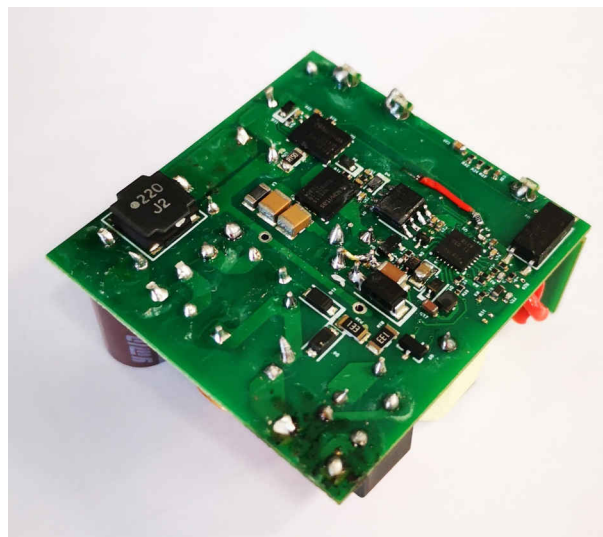
- High-efficiency 94% peak
- High-power density 30 W/in<sup>3</sup>
- Meets DoE Level VI and CoC Tier 2 efficiency regulation
- Fully compatible with USB PD 3.0 Standard
- Compact size: 44 mm × 42.5 mm × 19 mm

## Applications

- [Mobile wall charger design](#)
- [Notebook PC power adapter design](#)
- [Other AC/DC adapters and PSU](#)
- [USB wall power outlet](#)



Angle View of Assembly



Bottom View of Assembly

## 1 Test Prerequisites

### 1.1 Voltage and Current Requirements

Table 1-1 shows the specification of 65-W USB PD charger design.

**Table 1-1. 65-W USB PD Charger Specifications**

Parameter	Specifications
Input voltage range	90 V <sub>AC</sub> to 265 V <sub>AC</sub> , 50 Hz, 60 Hz
Output voltage range	5 V to 20 V
Maximum output current	3.25 A
Maximum output power	65 W

### 1.2 Dimensions

PCB board size: 44mm\*42.5mm\*19mm (L × W × H).

## 2 Testing and Results

The output cable was unplugged and input power was measured for standby power consumption. Table 2-1 details the standby power consumption.

**Table 2-1. Standby Power Consumption**

V <sub>IN</sub> (VAC)	Line Frequency (Hz)	V <sub>OUT</sub>	P <sub>IN</sub> (mW)
115	60	5.03	41
230	50	5.04	54

Output was set to 20 V and loaded with 200 mW, input power was measured.

**Table 2-2. Tiny Load Power Consumption**

V <sub>IN</sub> (VAC)	Line Frequency (Hz)	V <sub>OUT</sub> (V)	P <sub>OUT</sub> (mW)	P <sub>IN</sub> (mW)	Efficiency
115	60	20	200	270	74.1%
230	50	20	200	304	65.8%

## 2.1 Efficiency Graphs

### Average and 10% Load Efficiency

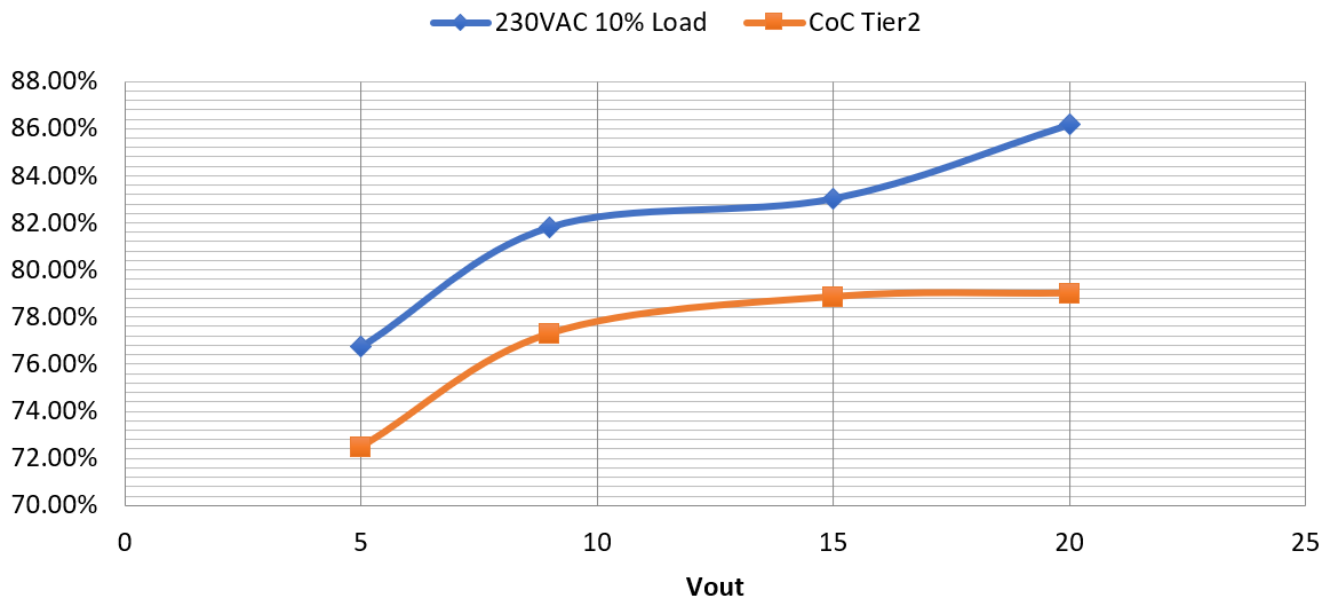


Figure 2-1. 10% Load Efficiency

Average efficiency testing was performed at four rated load percentages of 25%, 50%, 75%, 100%.

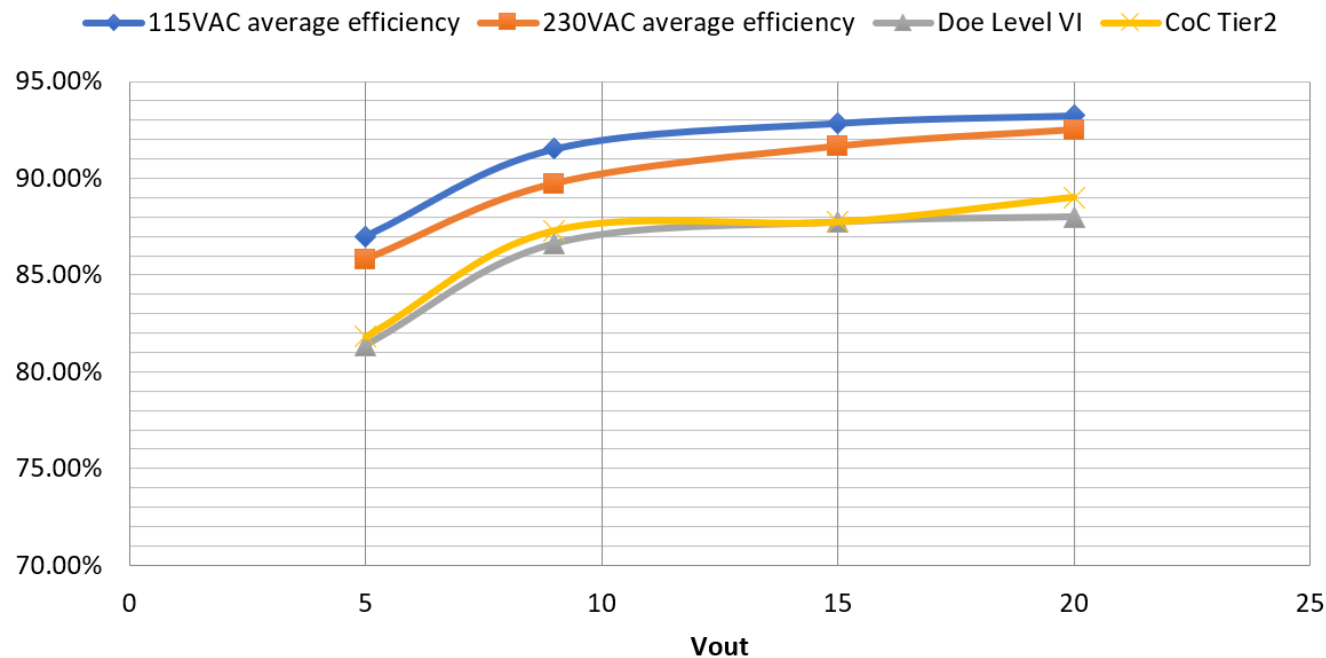
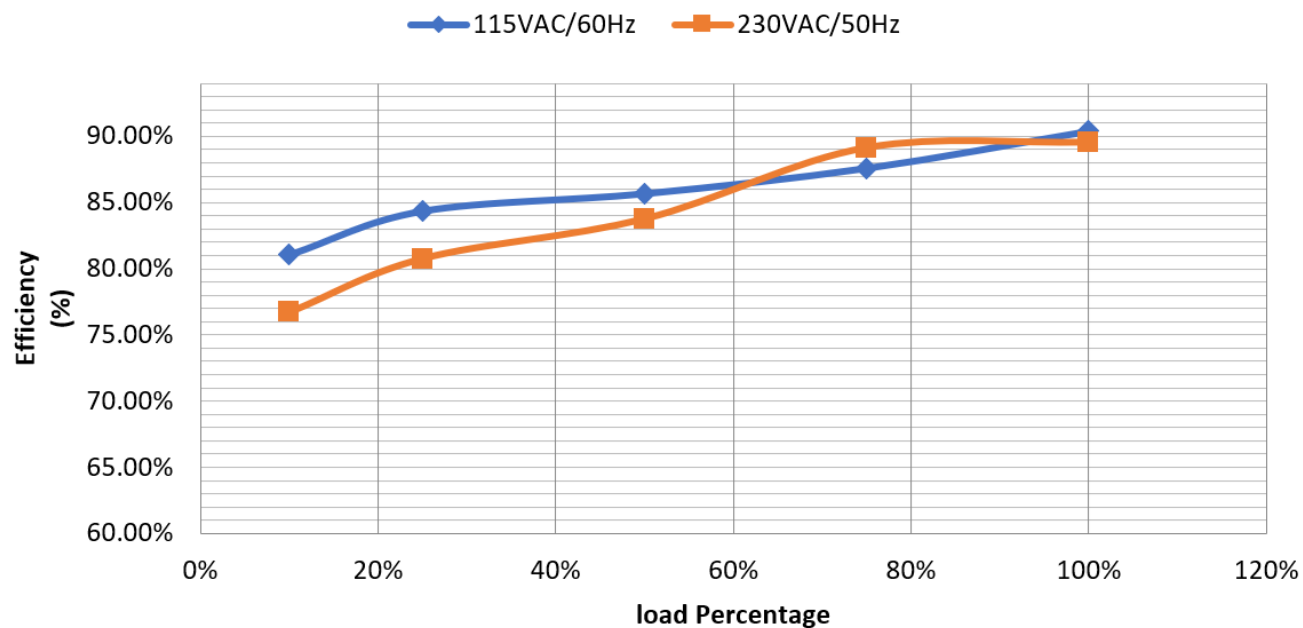
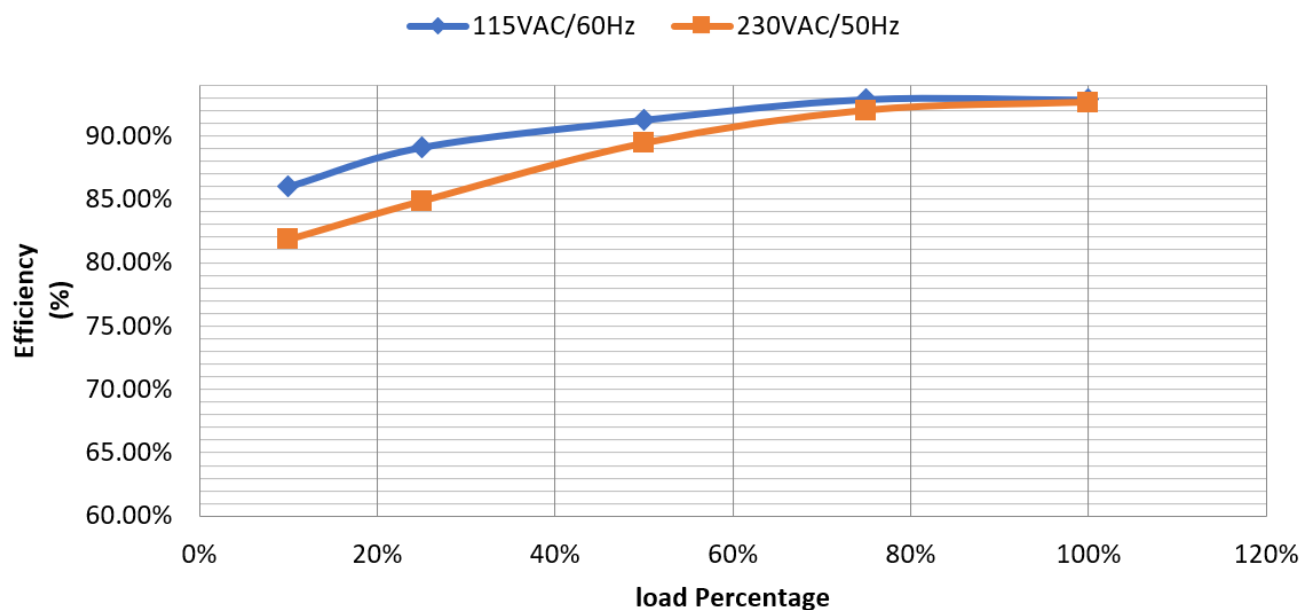


Figure 2-2. Average Efficiency for 5 V, 9 V, 15 V, and 20 V

Figure 2-3 through Figure 2-6 show efficiency as measured at different output voltages.



**Figure 2-3. 5-V Output Efficiency**



**Figure 2-4. 9-V Output Efficiency**

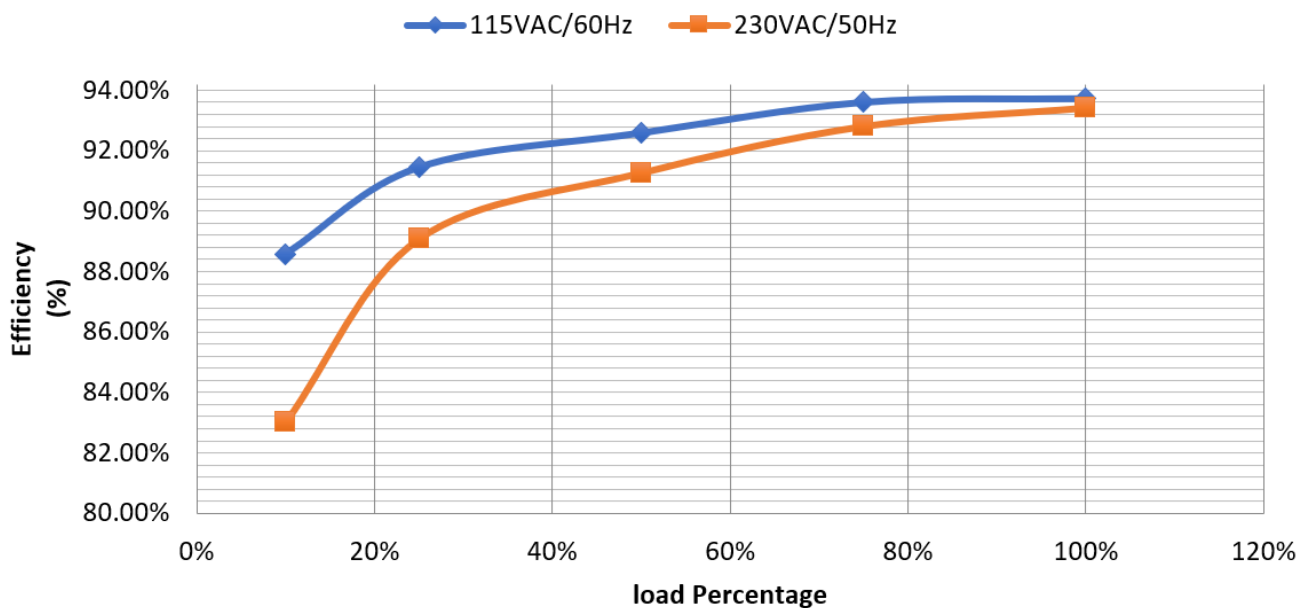


Figure 2-5. 15-V Output Efficiency

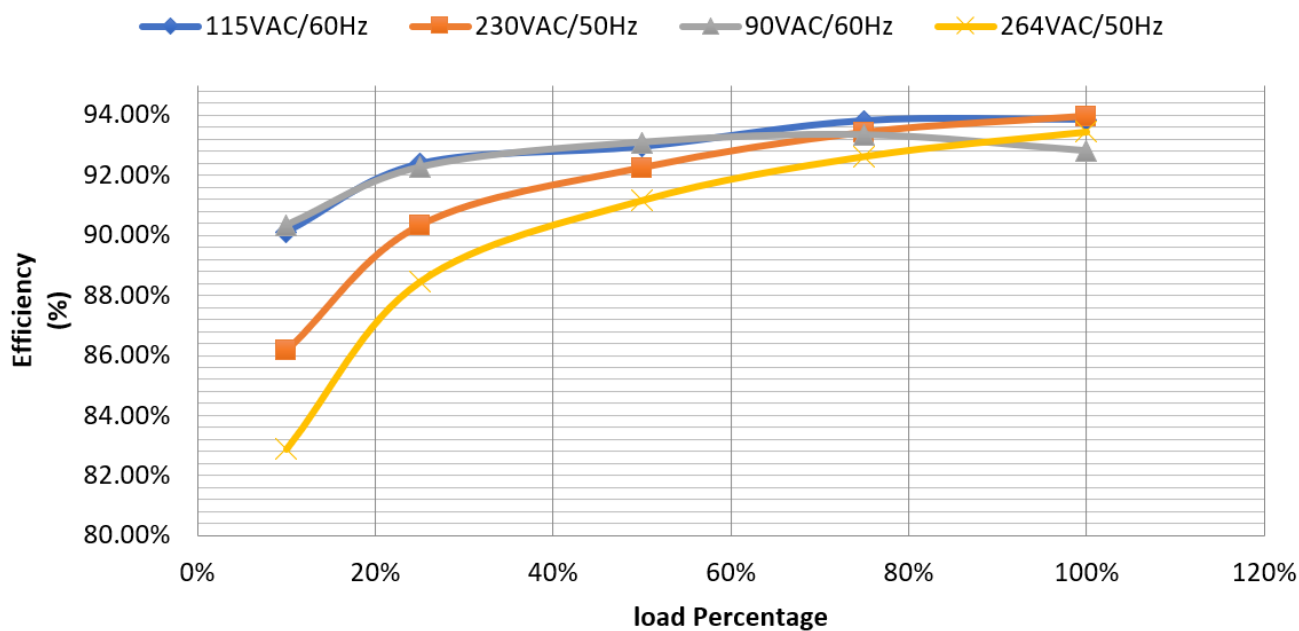


Figure 2-6. 20-V Output Efficiency

## 2.2 Thermal Images

All images were captured with the UUT enclosed in a 30-cm × 45-cm × 20-cm plexiglass box, 25°C ambient temperature, after a 30-minute warm up. The output was set to 20 V and loaded with 3.25 A.

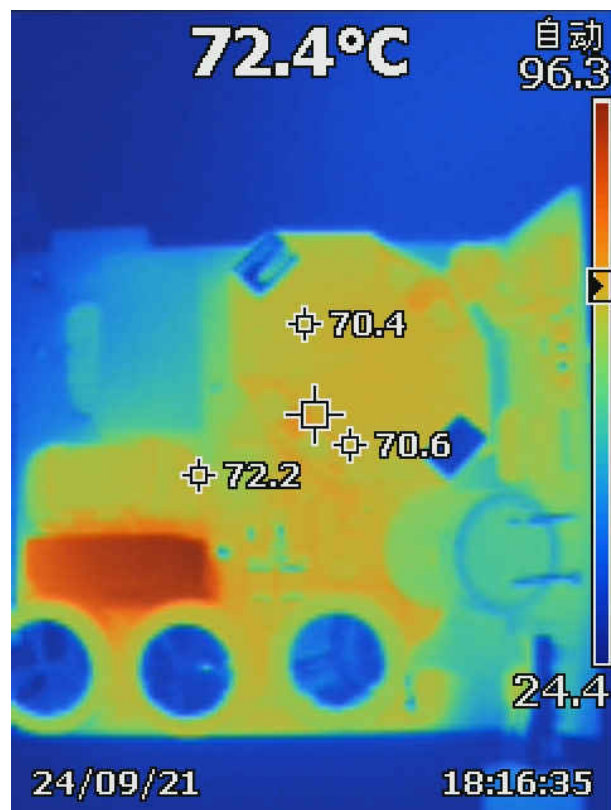


Figure 2-7. 90 V<sub>AC</sub> Full Load Top View

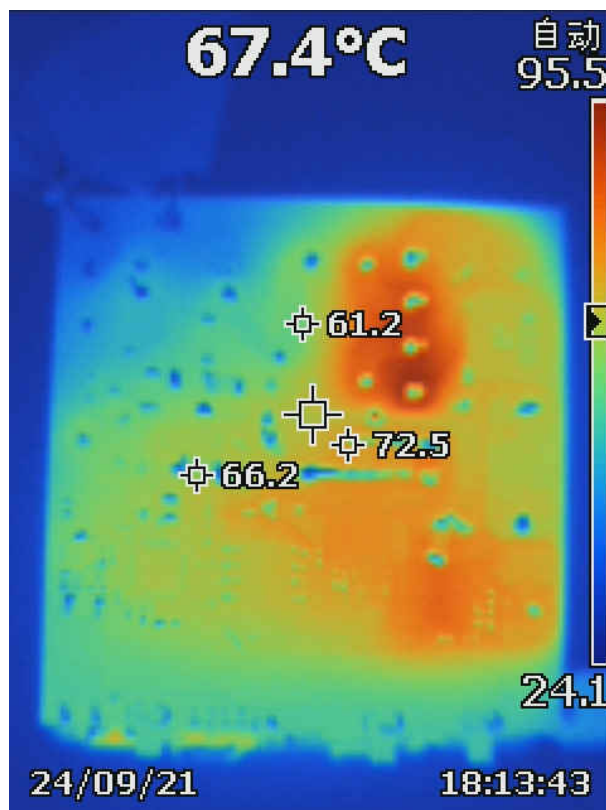


Figure 2-8. 90 V<sub>AC</sub> Full Load Bottom View



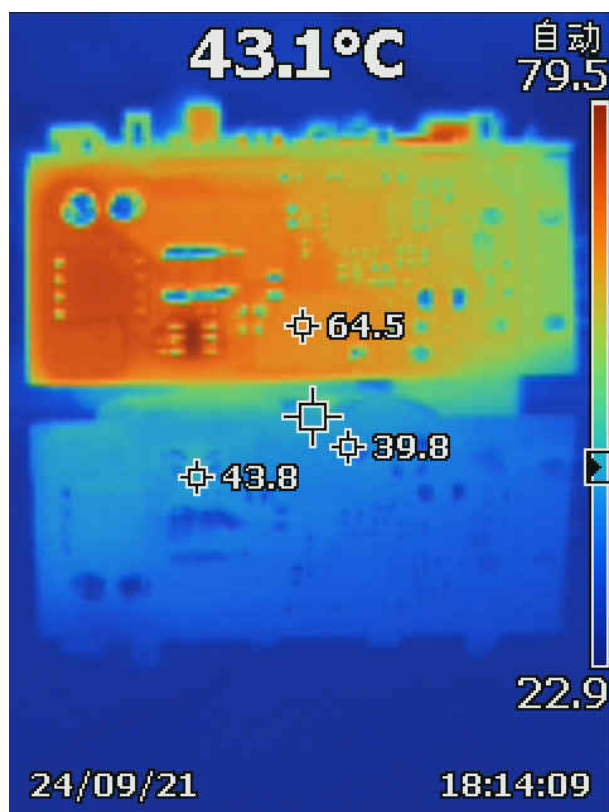


Figure 2-9. 90 V<sub>AC</sub> Full Load Side View

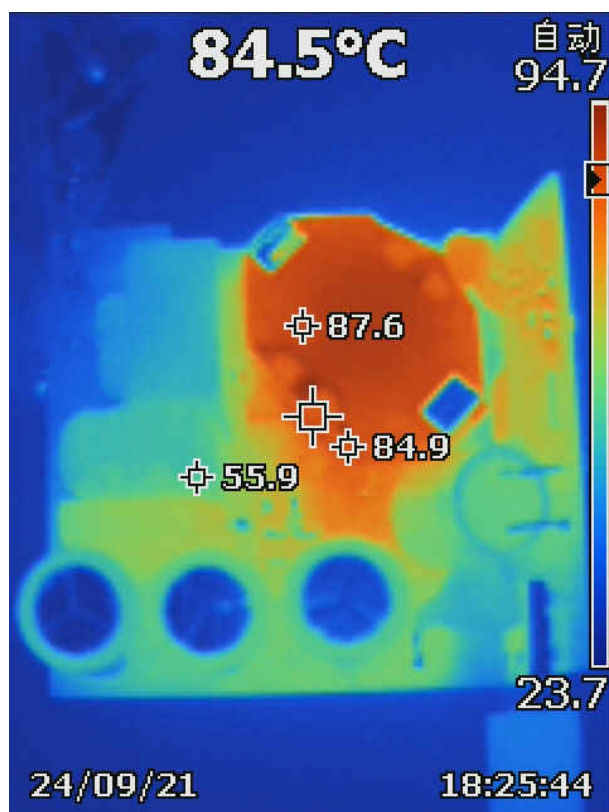


Figure 2-10. 264 V<sub>AC</sub> Full Load Top View

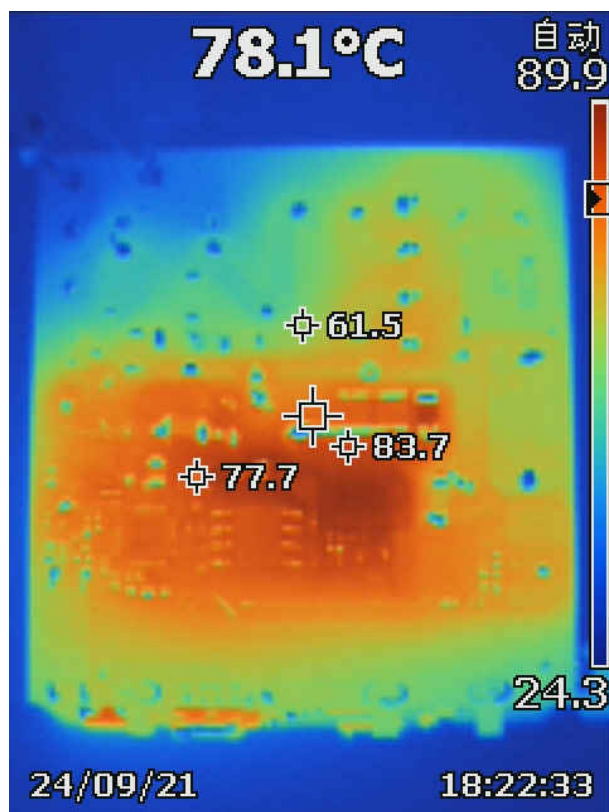


Figure 2-11. 264 V<sub>AC</sub> Full Load Bottom View

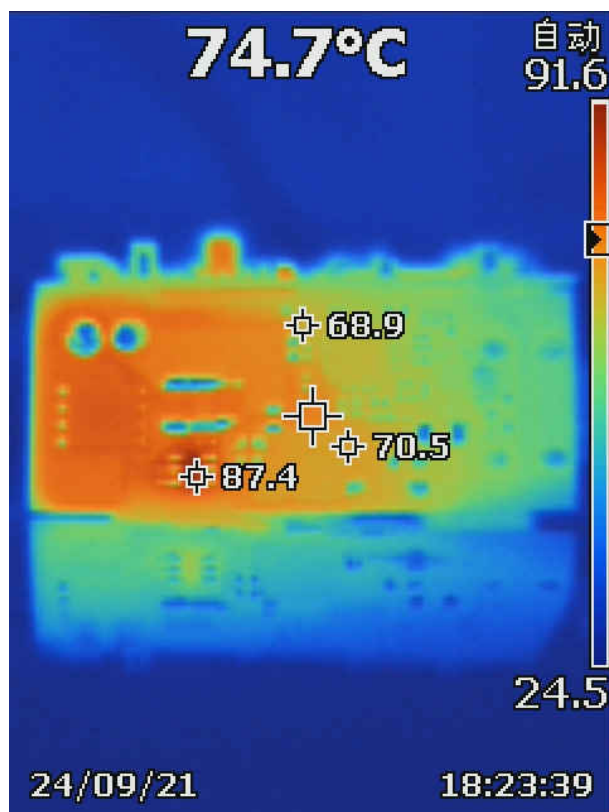


Figure 2-12. 264 V<sub>AC</sub> Full Load Side View

## 2.3 EMI

Conducted EMI was measured at full load conditions at 115 V<sub>AC</sub> and 230 V<sub>AC</sub>, respectively.

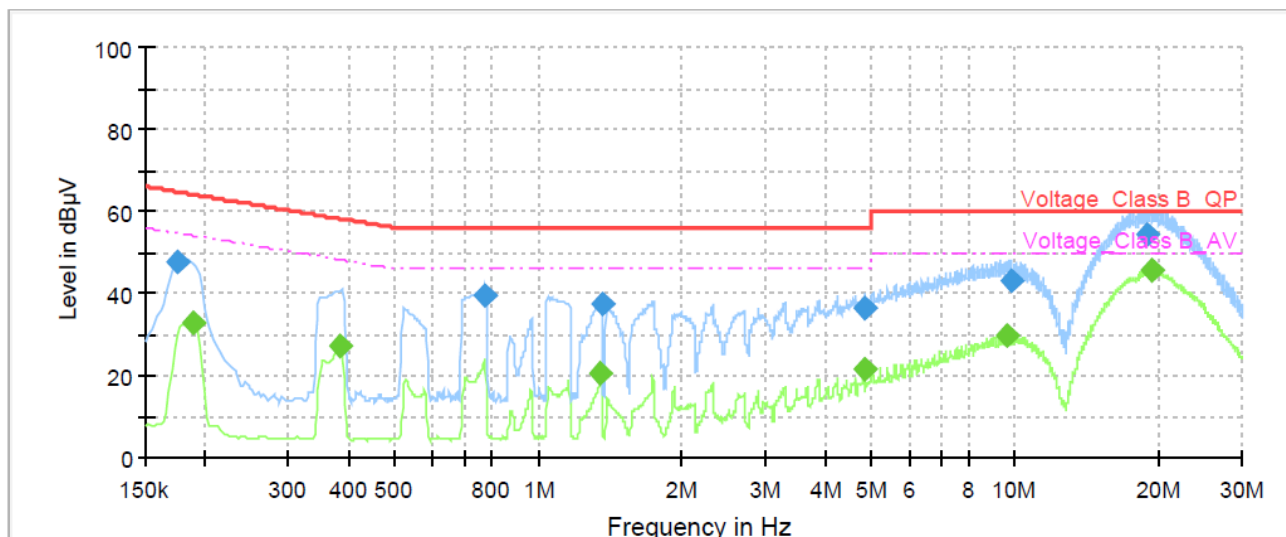


Figure 2-13. 20 V Full Load 115 VAC\_L

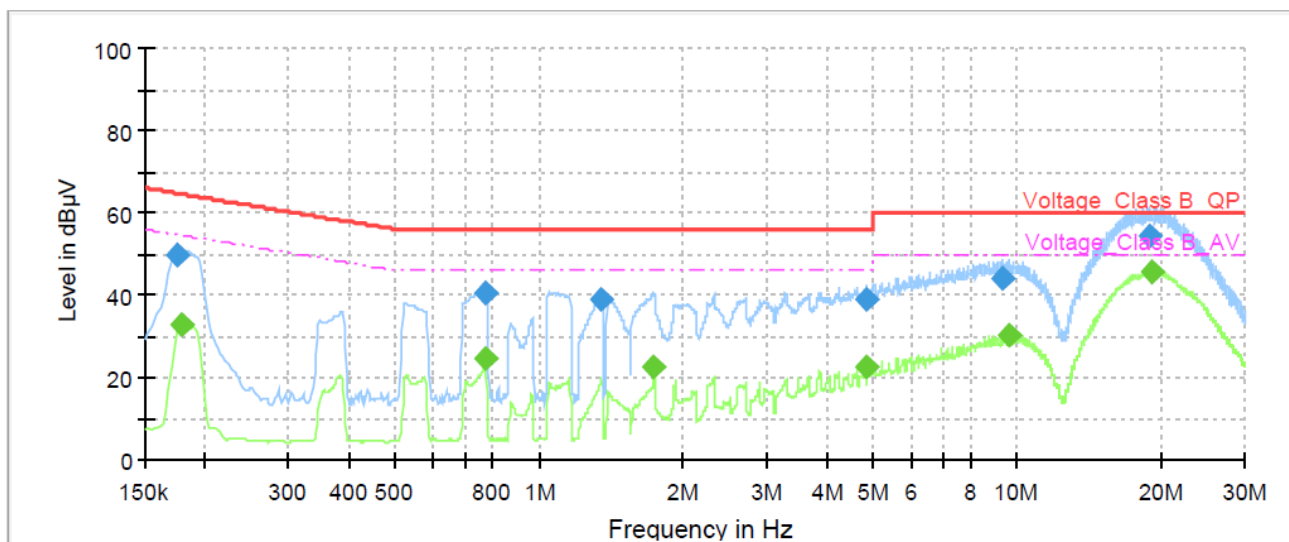


Figure 2-14. 20 V Full Load 115 VAC\_N



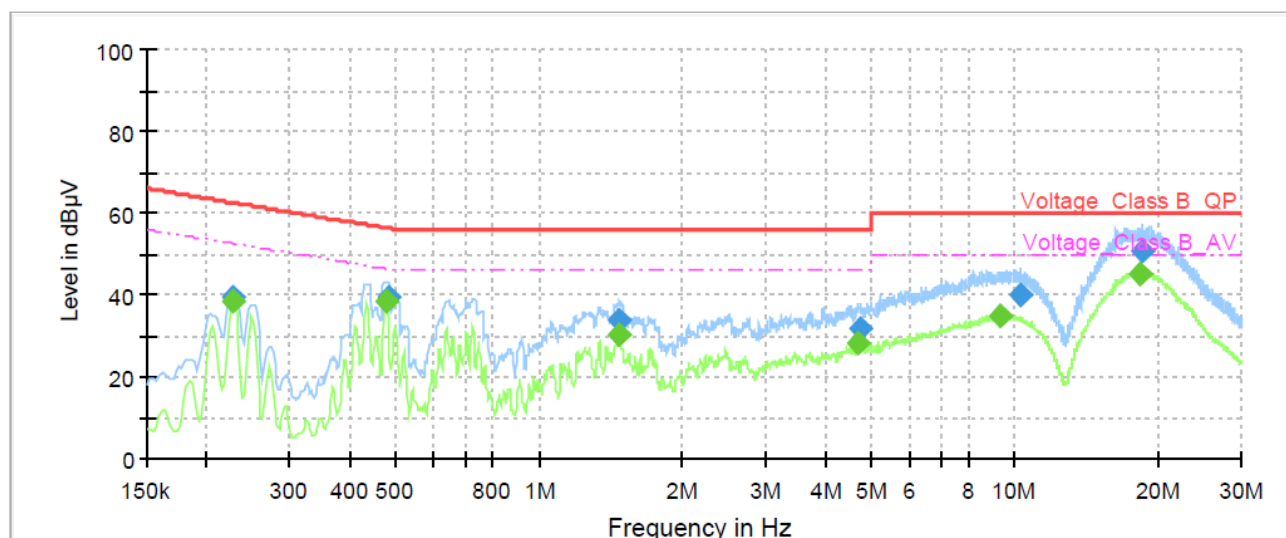


Figure 2-15. 20 V Full Load 230 VAC\_L

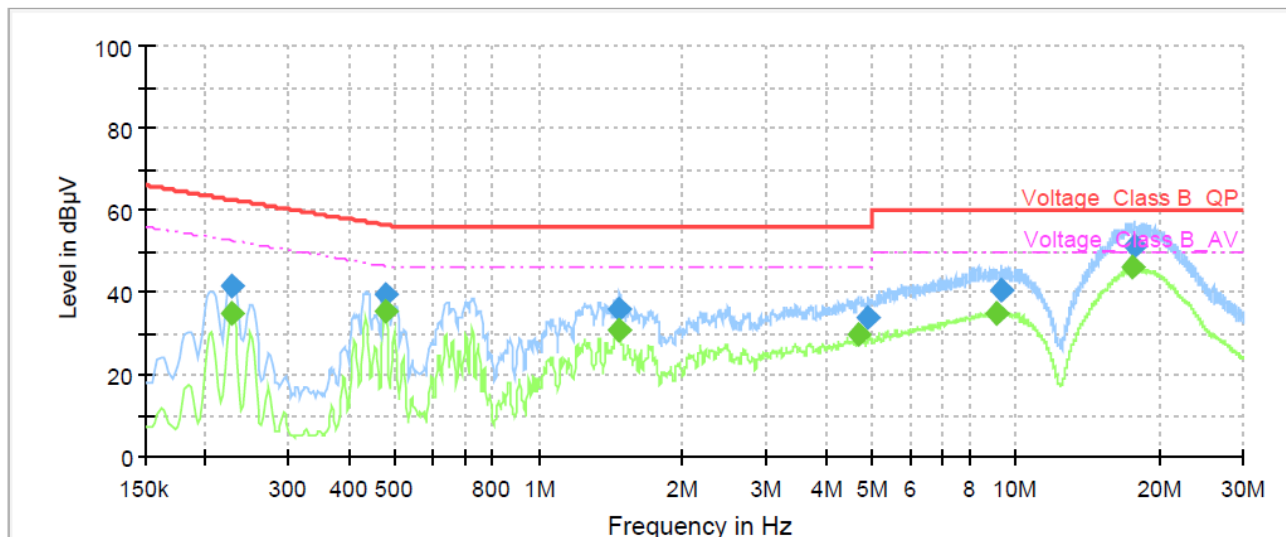
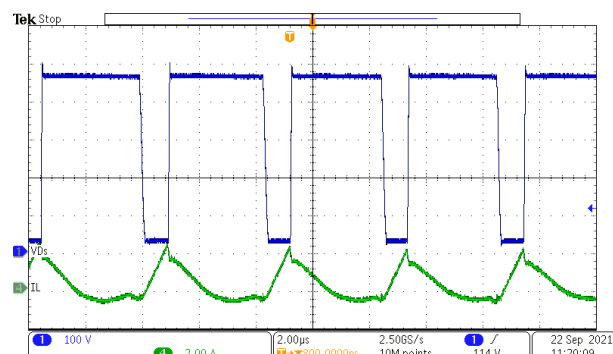


Figure 2-16. 20 V Full Load 230 VAC\_N

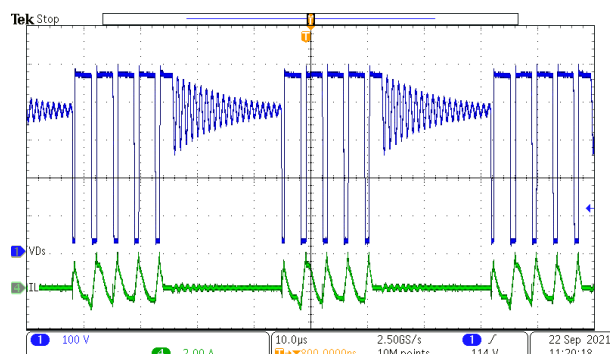
## 3 Waveforms

### 3.1 Switching

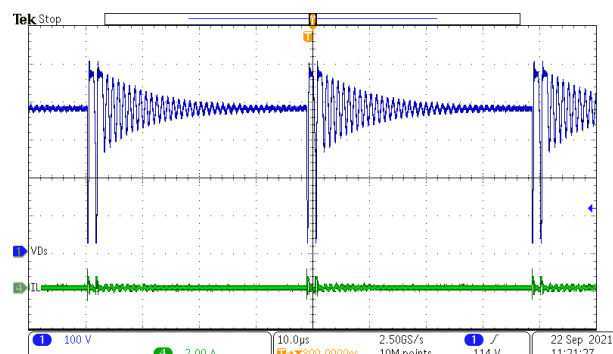
Switching waveforms of primary switch voltage stress as well as secondary side rectifier voltage stress were recorded at 264 V<sub>AC</sub> line and load conditions.



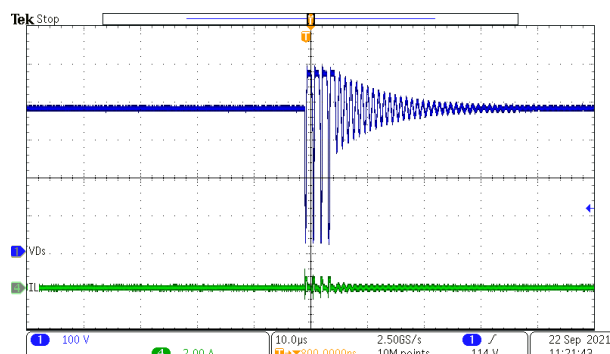
**Figure 3-1. Primary MOSFET Drain Source Voltage at 20 V, 3.25-A Output 264 V<sub>AC</sub>**



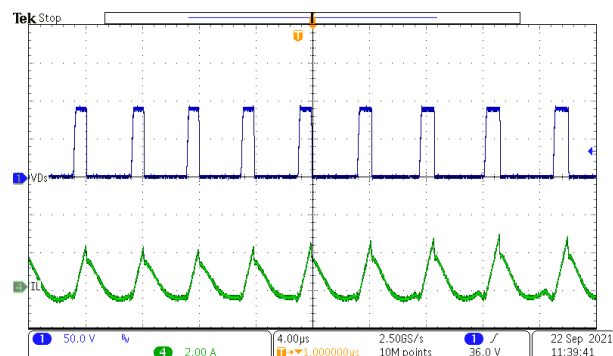
**Figure 3-2. Primary MOSFET Drain Source Voltage at 20 V, 1-A Output, 264 V<sub>AC</sub>**



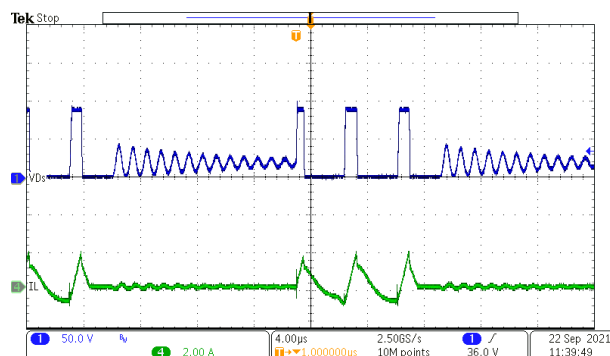
**Figure 3-3. Primary MOSFET Drain Source Voltage at 20 V, 0.1 A-Output, 264 V<sub>AC</sub>**



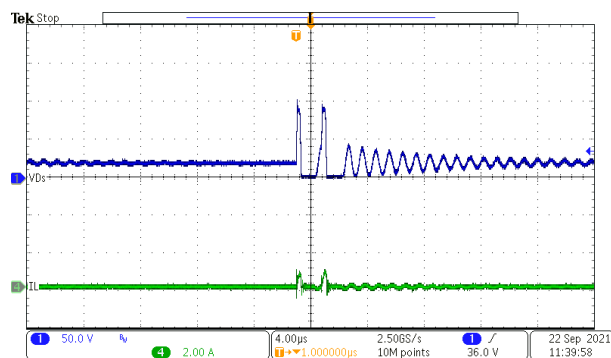
**Figure 3-4. Primary MOSFET Drain Source Voltage at 20V, Open Output, 264 V<sub>AC</sub>**



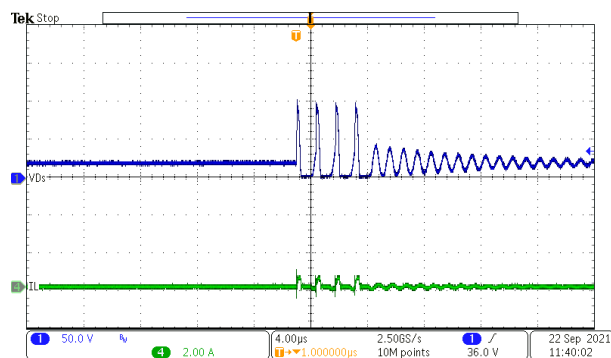
**Figure 3-5. Synchronous Rectifier MOSFET Voltage Stress at 20 V, 3.25-A Output, 264 V<sub>AC</sub>**



**Figure 3-6. Synchronous Rectifier MOSFET Voltage Stress at 20 V, 1-A Output, 264 V<sub>AC</sub>**

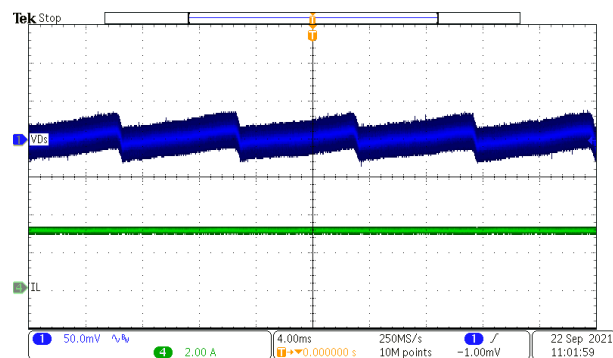


**Figure 3-7. Synchronous Rectifier MOSFET Voltage Stress at 20 V, 0.1-A Output, 264 V<sub>AC</sub>**

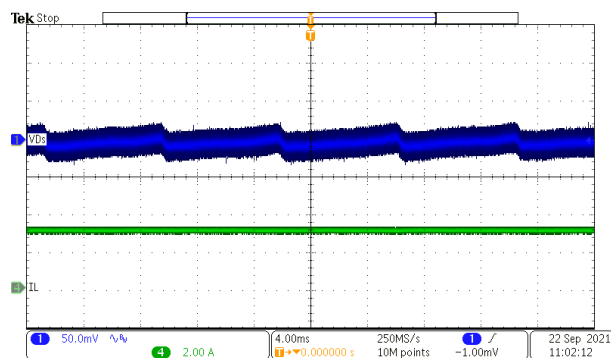


**Figure 3-8. Synchronous Rectifier MOSFET Voltage Stress at 20 V, Open Output, 264 V<sub>AC</sub>**

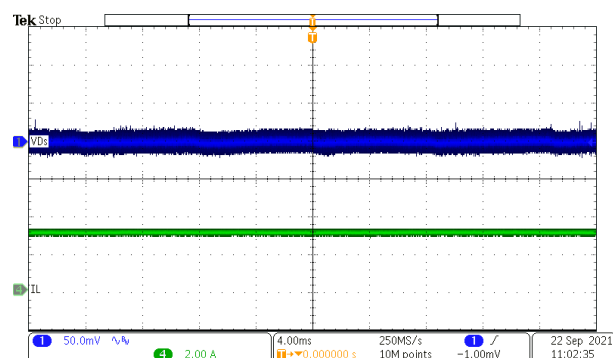
## 3.2 Output Voltage Ripple



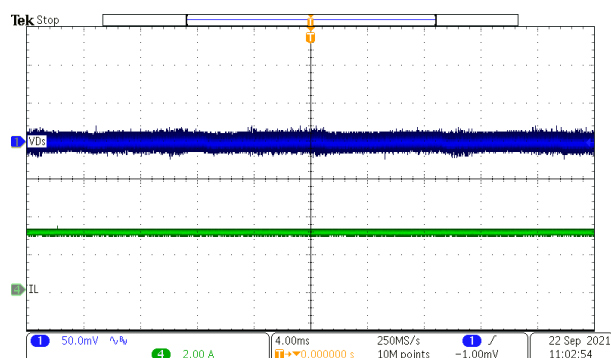
**Figure 3-9. 115 V<sub>AC</sub>, 20 V, 3.25 A Voltage Ripple**



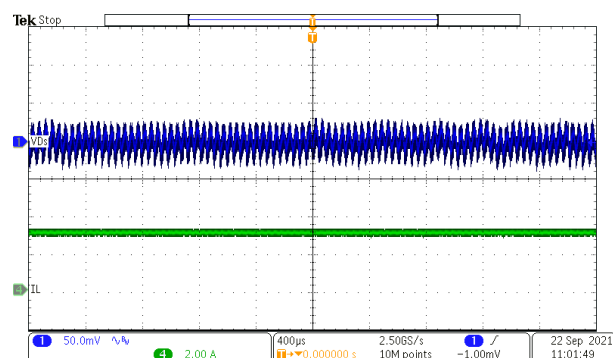
**Figure 3-10. 115 V<sub>AC</sub>, 15 V, 3 A Voltage Ripple**



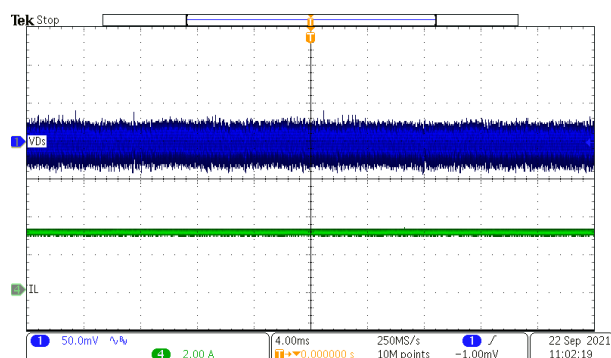
**Figure 3-11. 115 V<sub>AC</sub>, 9 V, 3 A Voltage Ripple**



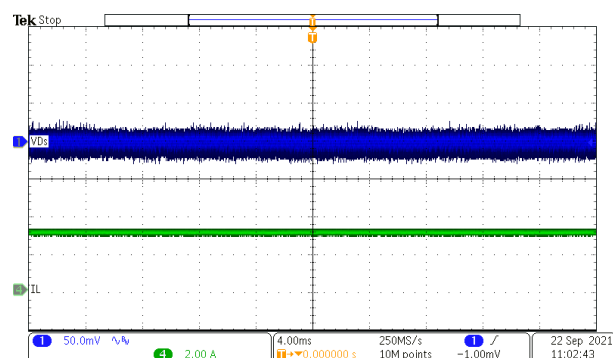
**Figure 3-12. 115 V<sub>AC</sub>, 5 V, 3 A Voltage Ripple**



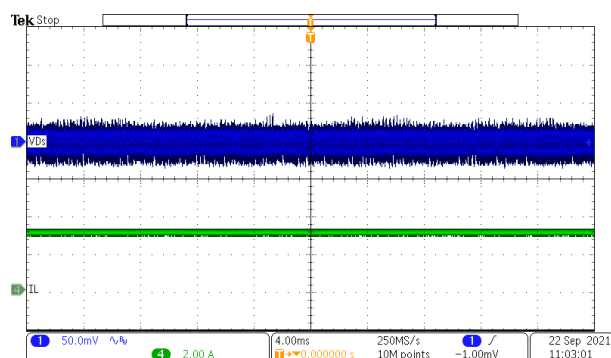
**Figure 3-13. 230 V<sub>AC</sub>, 20 V, 3.25 A Voltage Ripple**



**Figure 3-14. 230 V<sub>AC</sub>, 15 V, 3 A Voltage Ripple**

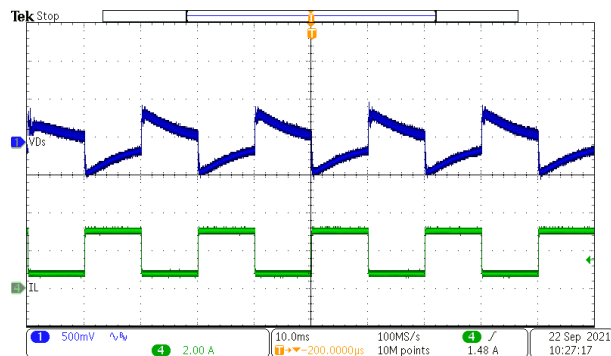


**Figure 3-15. 230 V<sub>AC</sub>, 9 V, 3 A Voltage Ripple**

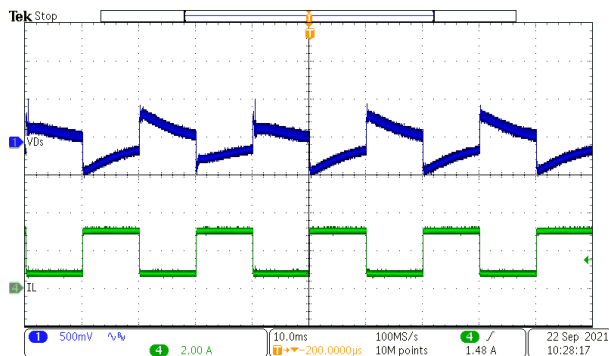


**Figure 3-16. 230 V<sub>AC</sub>, 5 V, 3 A Voltage Ripple**

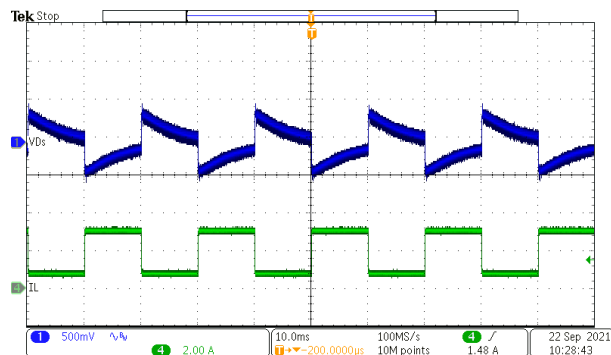
### 3.3 Load Transients



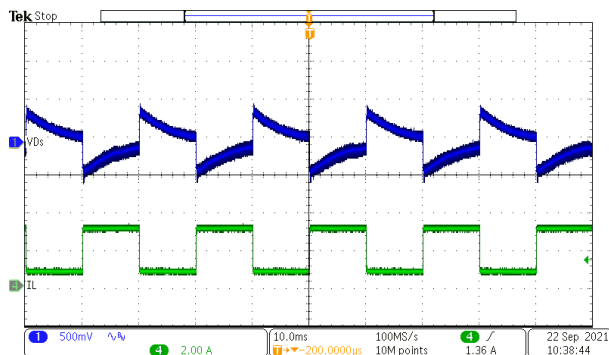
**Figure 3-17. 115 V<sub>AC</sub>, 5 V, 0.75-A to 3-A Load Dynamic**



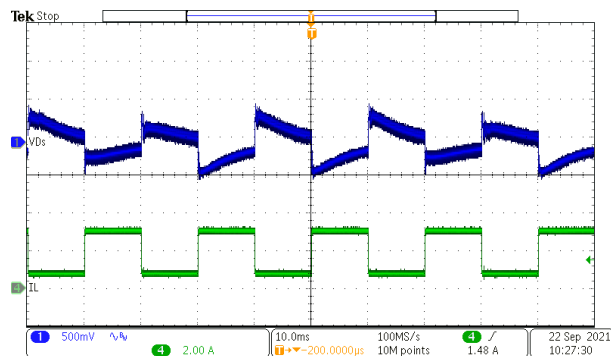
**Figure 3-18. 115 V<sub>AC</sub>, 9 V, 0.75-A to 3-A Load Dynamic**



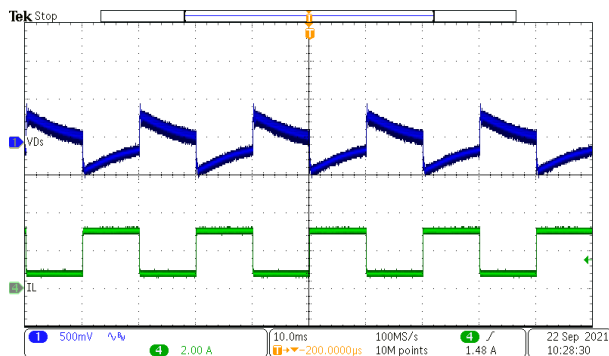
**Figure 3-19. 115 V<sub>AC</sub>, 15 V, 0.75-A to 3-A Load Dynamic**



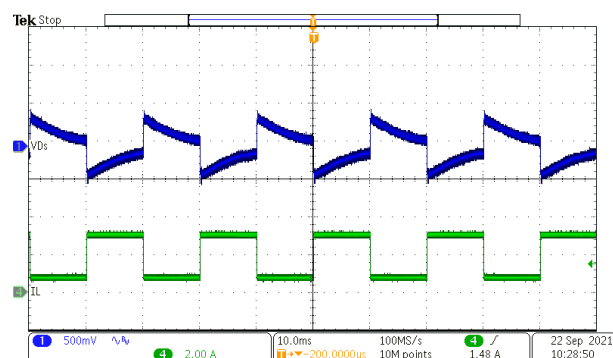
**Figure 3-20. 115 V<sub>AC</sub>, 20 V, 0.75-A to 3.25-A Load Dynamic**



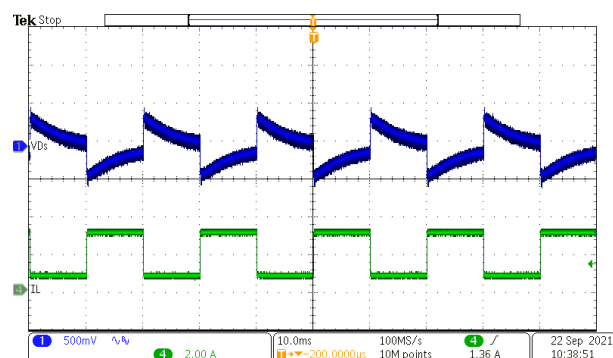
**Figure 3-21. 230 V<sub>AC</sub>, 5 V, 0.75-A to 3-A Load Dynamic**



**Figure 3-22. 230 V<sub>AC</sub>, 9 V, 0.75-A to 3-A Load Dynamic**



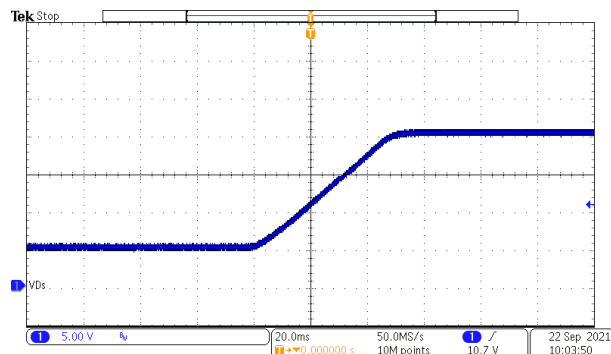
**Figure 3-23. 230 V<sub>AC</sub>, 15 V, 0.75-A to 3-A Load Dynamic**



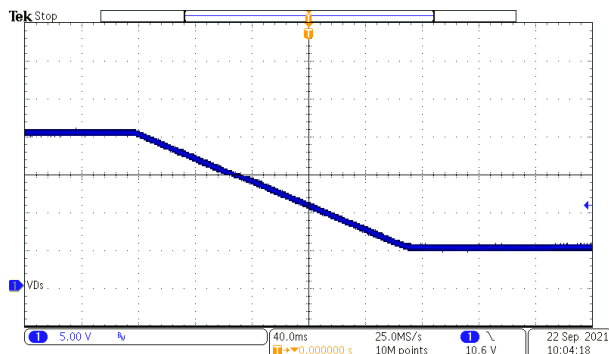
**Figure 3-24. 230 V<sub>AC</sub>, 20 V, 0.75-A to 3.25-A Load Dynamic**

### 3.4 Voltage Transition

Figure 3-25 and Figure 3-26 show the output voltage during USB Type-C voltage transitions. The input was 115 V<sub>AC</sub>, 60 Hz, and output was set to full-load condition. This behavior is not dependent on the input voltage.



**Figure 3-25. 5 V to 20 V, Full-Load Voltage Transition**



**Figure 3-26. 20 V to 5 V, Full-Load Voltage Transition**



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