Test Report: PMP41131

Universal AC-Input 45W Low-Profile USB Power Delivery Charger Reference Design With Integrated GaN

TEXAS INSTRUMENTS

Description

This reference design is a 45W, low-profile AC/DC USB Power Delivery (PD) charger reference design with integrated flyback controller and gallium nitride (GaN) power switch. This design can achieve less than 10mm height by using a low-profile planar PCB transformer. The flyback converter UCG28826 features V_{CC} self-bias and simplifies the planar transformer PCB winding by eliminating auxiliary winding as well as associated V_{CC} rectifier circuity. The design can meet efficiency standards and regulations such as Department of Energy (DOE) Level VI and Code of Conduct (CoC) Version 5 (V5) Tier 2 standards. The design achieves less than 75mW standby power consumption at 230VAC.

Features

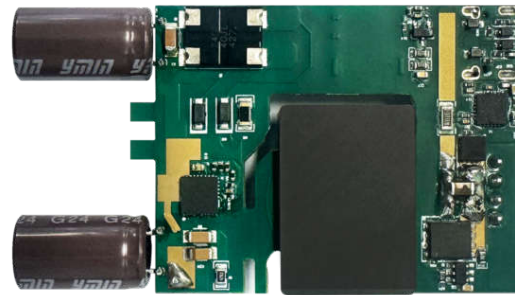- <10mm height, low profile design with PCB planar transformer
- Achieves >92% efficiency at 90VAC
- Simplified PCB winding design with V_{CC} self-bias feature
- Meets DoE Level VI and CoC V5 Tier 2 efficiency standards
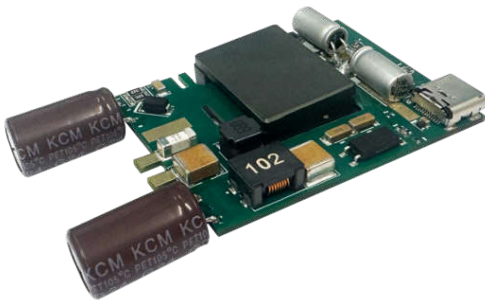- No load power consumption, <75mW at 230VAC

Applications

- USB AC/DC adapter
- USB wall power outlet
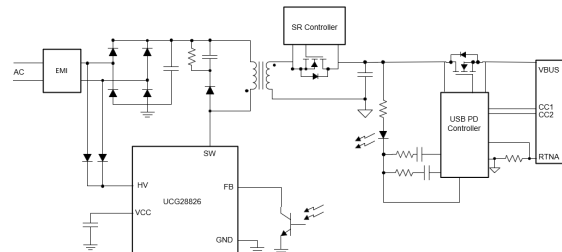- Battery charger
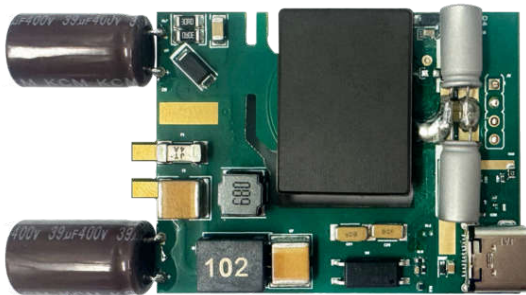
Top View Photo

Bottom View Photo

Angle View Photo

Block Diagram

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input voltage range	90VAC - 264VAC
Input voltage frequency	47HZ - 60Hz
Output power profile	5V, 3A, 9V, 3A, 15V, 3A, 20V, 2.25A

1.2 Required Equipment

- AC Source: Chroma Model 61601
- Digital Power Meter: Yokogawa WT310
- Power-Z P240 Bidirectional Multi-protocol Power Supply
- DC source: GWinstek, GPS-3303C
- Bidirectional Power Source: IT6010C-80-300
- Electronic load: Chroma, 6314A
- Oscilloscope: Tektronix, DPO 3054
- Infrared Thermal Camera: Fluke, TiS55
- Ture-RMS-Multimeter: Fluke, 287C

1.3 Dimensions

PCB board size: 39mm × 50.4mm × 10mm

1.4 Test Setup
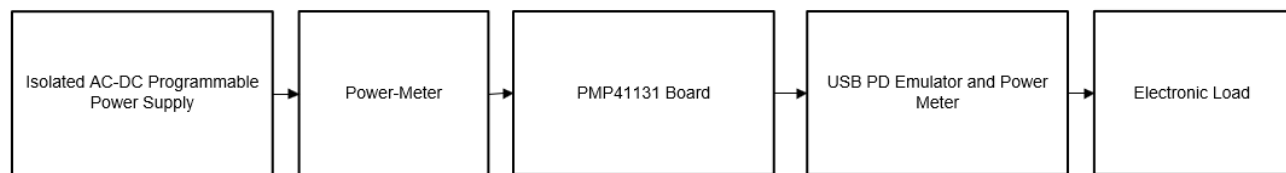
Figure 1-1. Test Setup

2 Testing and Results

2.1 Efficiency Graphs

Efficiency is shown in Figure 2-1 through Figure 2-7.
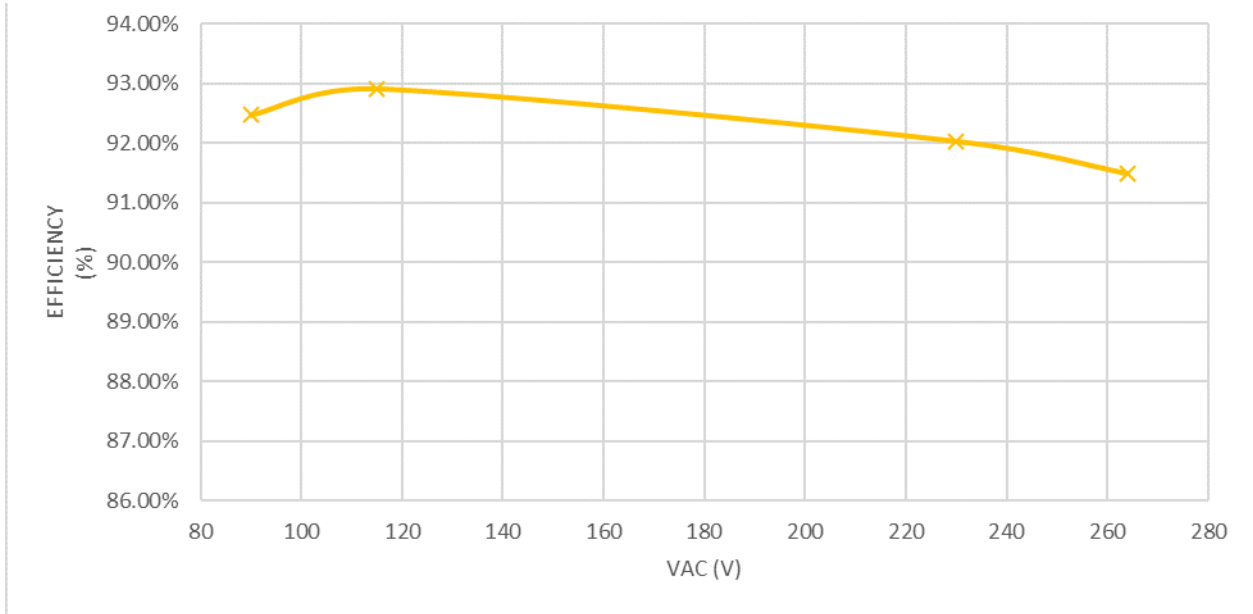
Figure 2-1. 20V Full-Load Efficiency Versus AC Input Voltage
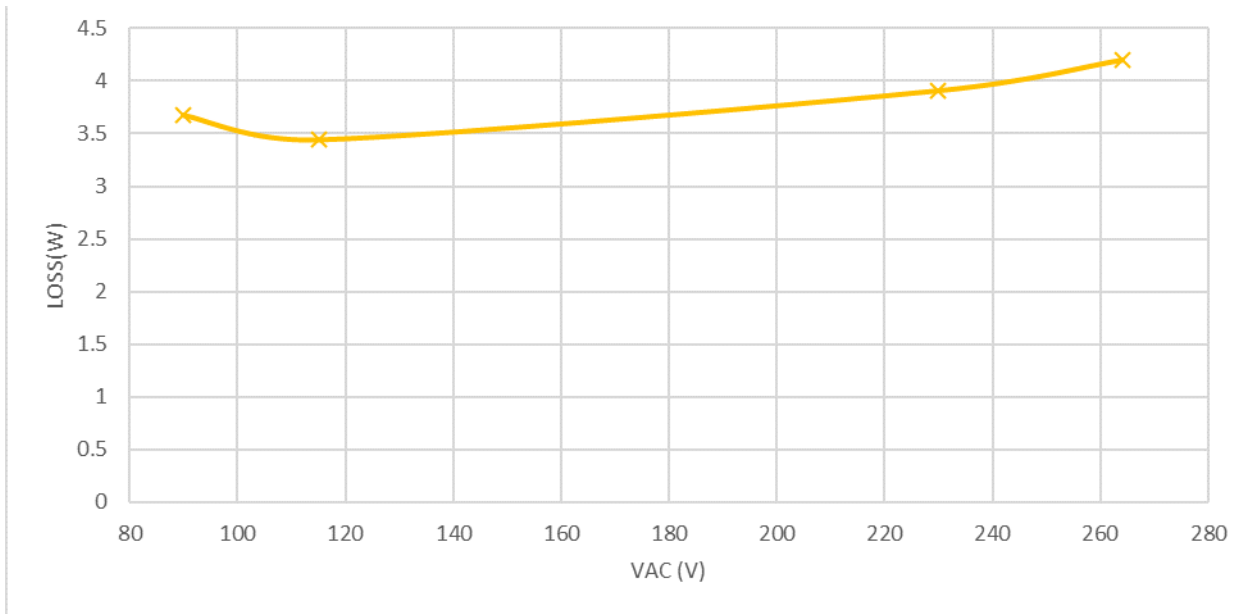

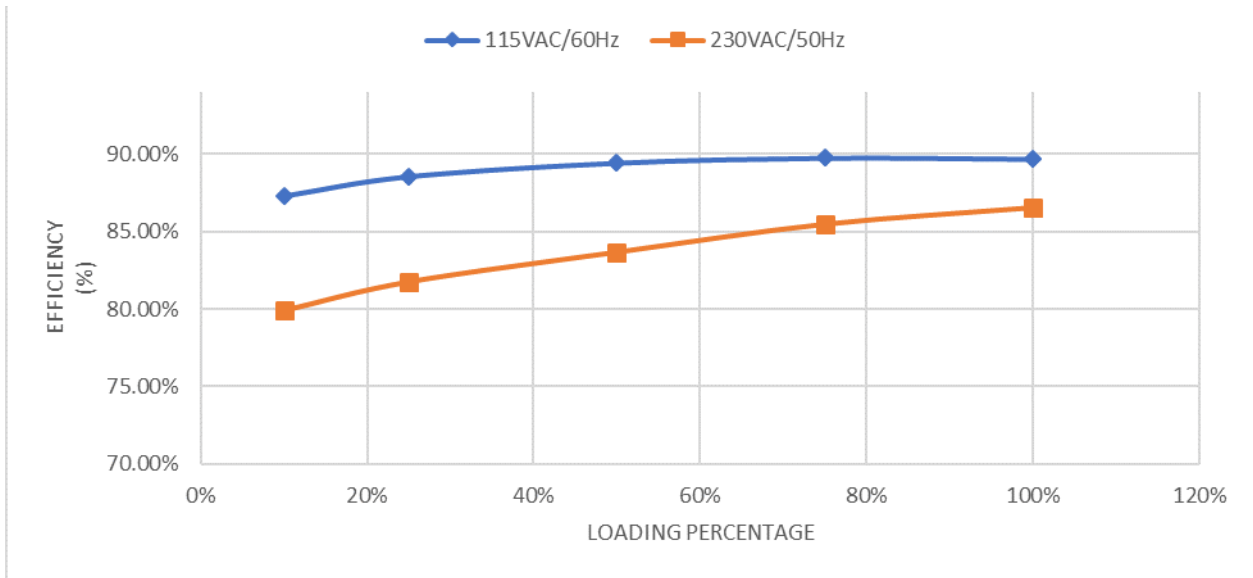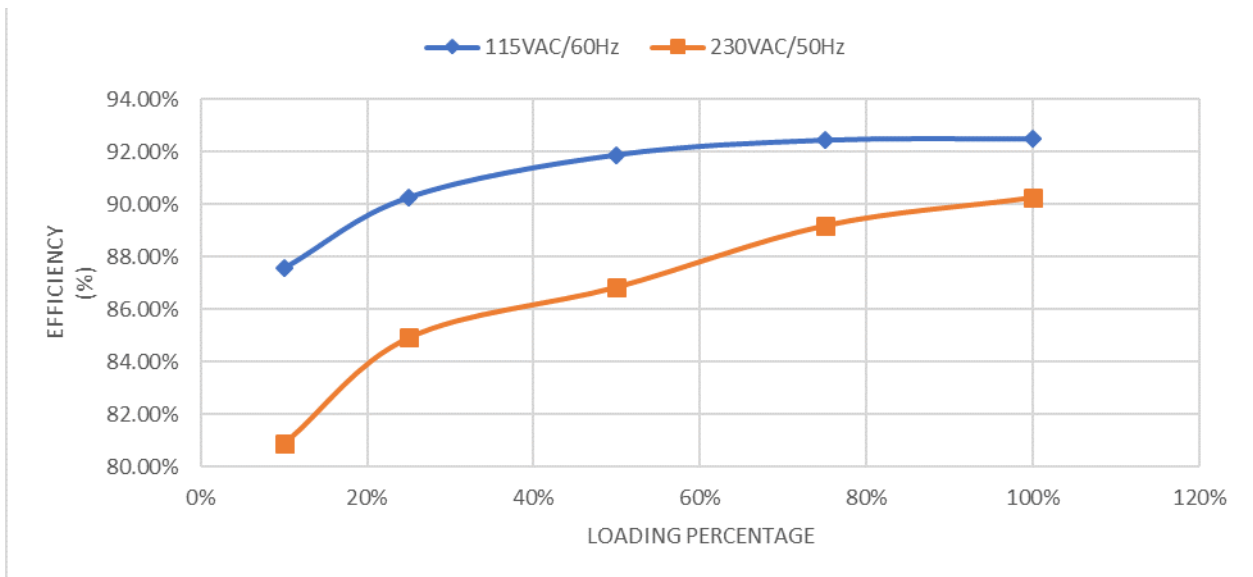**Figure 2-2. 20V Full-Load Power Loss Versus AC Input Voltage**

Figure 2-3. 5V, 3A
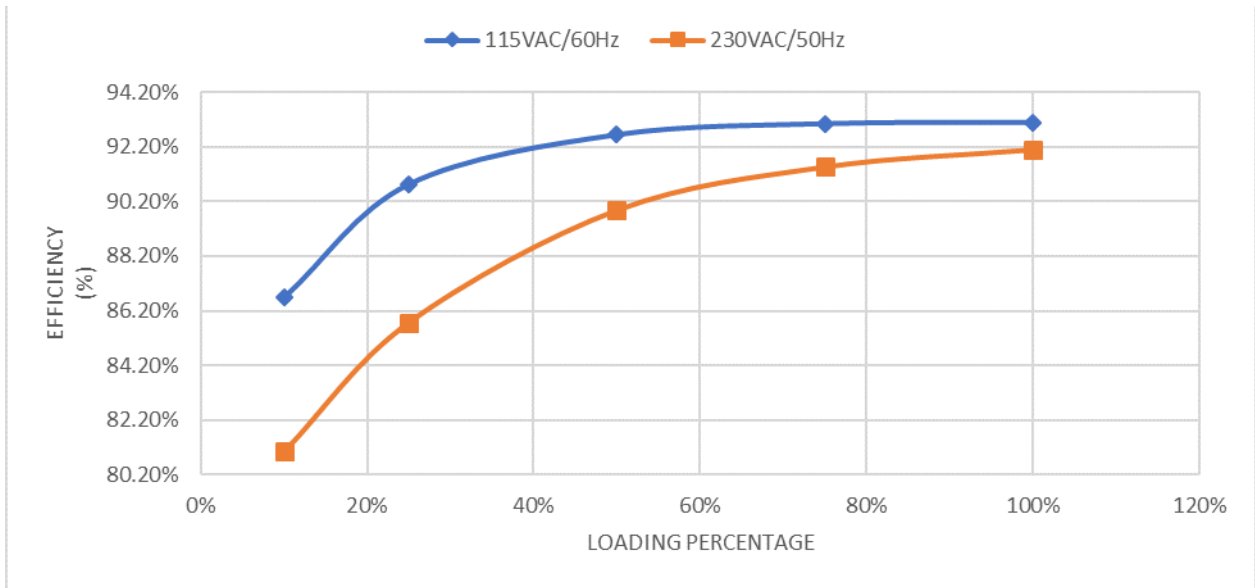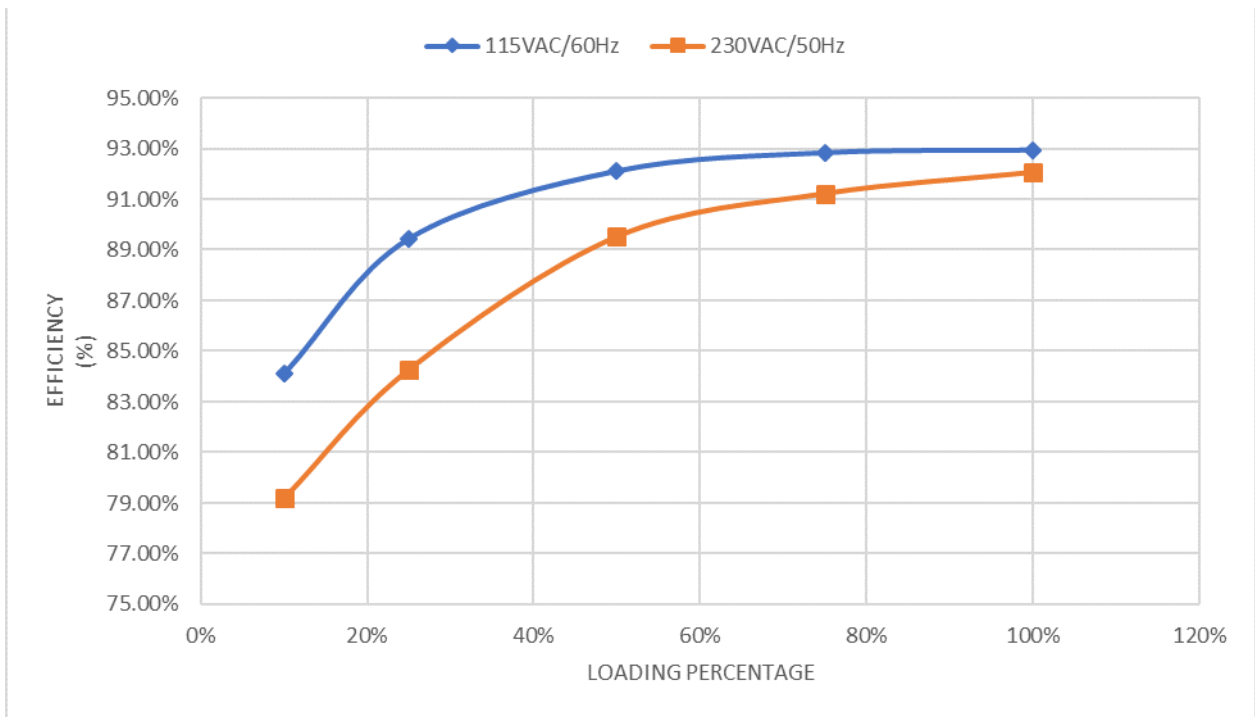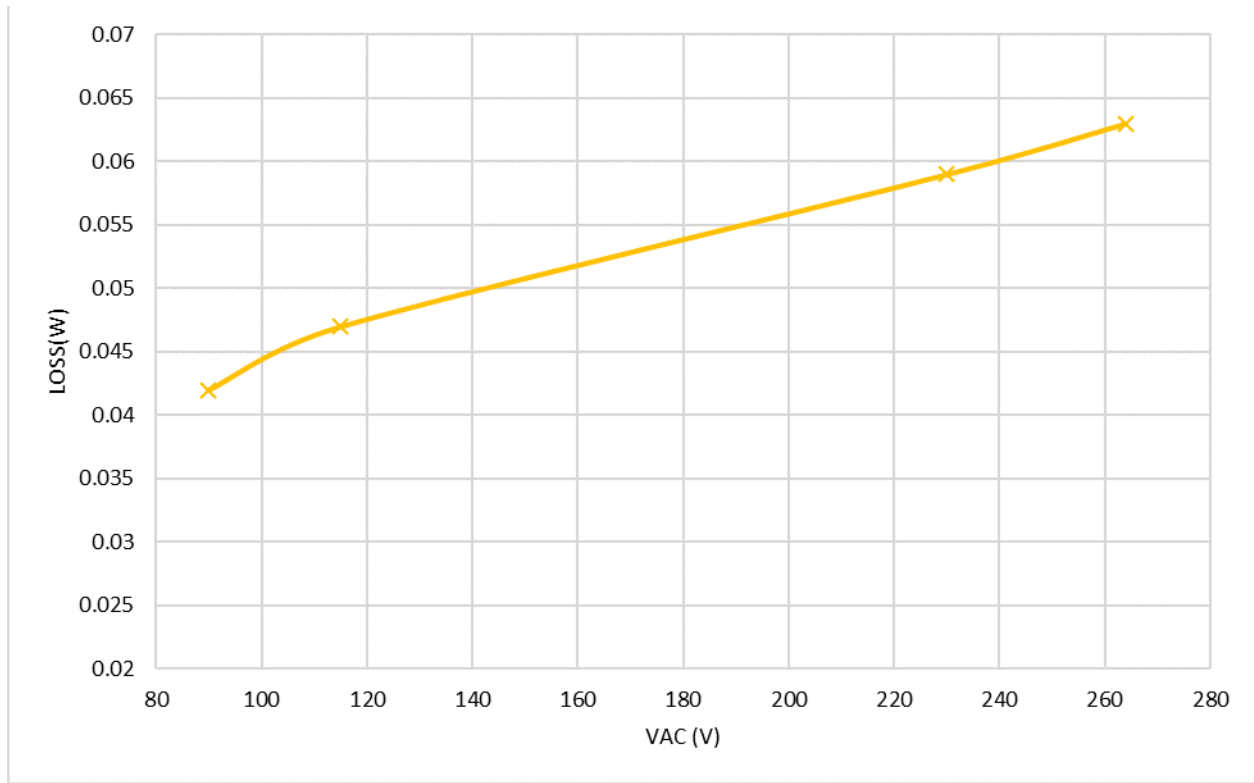

Figure 2-4. 9V, 3A

Figure 2-5. 15V, 3A

Figure 2-6. 20V, 2.25A

Figure 2-7. No Load Power Consumption

2.2 Voltage Regulation
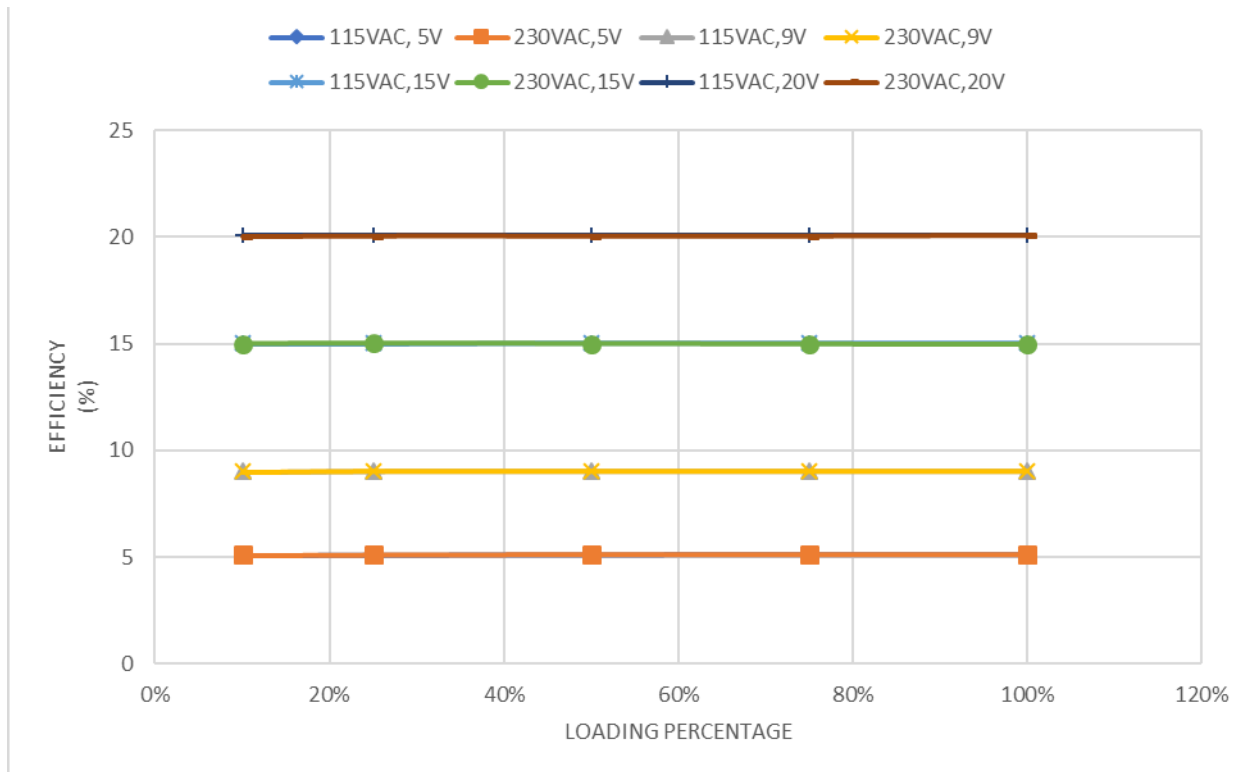
Figure 2-8. Voltage Regulation

2.3 Efficiency Data

Efficiency data is shown in Table 2-1 through Table 2-3.

Table 2-1. Efficiency Data

V_{IN}(V)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (A)	P_{OUT} (W)	Efficiency (%)
115	1.79	5.136	0.304	1.563	87.32
115	4.40	5.143	0.758	3.897	88.57
115	8.71	5.148	1.513	7.790	89.44
115	13.02	5.151	2.269	11.687	89.76
115	17.38	5.153	3.025	15.588	89.69
230	1.96	5.136	0.301	1.566	79.9
230	4.77	5.144	0.751	3.899	81.74
230	9.32	5.149	1.501	7.797	83.66
230	13.69	5.150	2.252	11.70	85.46
230	18.03	5.151	3.002	15.602	86.53
115	3.13	9.021	0.304	2.741	87.57
115	7.56	9.045	0.754	6.824	90.26
115	14.85	9.05	1.508	13.644	91.88
115	22.14	9.053	2.261	20.465	92.43
115	29.5	9.054	3.031	27.284	92.49
230	3.39	9.019	0.304	2.743	80.91
230	8.04	9.049	0.755	6.829	84.94
230	15.72	9.052	1.508	13.654	86.86
230	22.96	9.054	2.262	20.478	89.19
230	30.26	9.056	3.016	27.31	90.25
115	5.26	15.018	0.304	4.561	86.71
115	12.49	15.018	0.755	11.346	90.84
115	24.44	15.025	1.507	22.642	92.64
115	36.44	15.025	2.257	33.905	93.04
115	48.46	15.025	3.003	45.114	93.10
230	5.63	14.993	0.304	4.563	81.05
230	13.23	15.021	0.755	11.348	85.77
230	25.19	15.001	1.509	22.642	89.88
230	37.07	14.978	2.264	33.908	91.47
230	48.99	14.952	3.018	45.12	92.10
115	5.43	20.05	0.228	4.566	84.09
115	12.70	20.05	0.566	11.357	89.43
115	24.58	20.05	1.129	22.637	92.10
115	36.38	20.05	1.684	33.767	92.82
115	48.62	20.05	2.253	45.18	92.92
230	6.39	19.997	0.253	5.062	79.22
230	13.53	20.025	0.569	11.403	84.28

Table 2-1. Efficiency Data (continued)

V$_{IN}$(V)	P$_{IN}$ (W)	V$_{OUT}$ (V)	I$_{OUT}$ (A)	P$_{OUT}$ (W)	Efficiency (%)
230	25.30	20.025	1.131	22.646	89.51
230	37.04	20.025	1.687	33.782	91.20
230	49.10	20.026	2.257	45.19	92.04

Note: Variation of ±0.3% in 4-point average efficiency and ±0.5% in 10% efficiency can be observed.

Table 2-2. Full-Load Efficiency

V$_{IN}$(V)	P$_{IN}$(W)	V$_{OUT}$(V)	I$_{OUT}$(A)	P$_{OUT}$(W)	Power Loss(W)	Efficiency(%)
90	48.86	20.05	2.253	45.18	3.676	92.48
115	48.62	20.05	2.253	45.18	3.442	92.92
230	49.10	20.03	2.257	45.19	3.909	92.04
264	49.38	20.05	2.253	45.18	4.200	91.49

Table 2-3. No Load Power Consumption

Vac(V)	90	115	230	264
Standby power(mW)	45	47	59	63

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2.4 Thermal Images

Thermal images are shown in Figure 2-9 through Figure 2-12. Thermal test was performed at room temperature, open frame, with 30-minute warm up.

Table 2-4. Thermal Test at 20V, Full-Load Condition

Temperature(ºC)	90VAC	115VAC	230VAC	264VAC
AC Bridge	77.5	70.1	65.3	64.9
UCG28826	69.2	66.2	75.2	82.2
Transformer	83.4	80.8	85.5	86.5
SR MOSFET	73.5	74.1	74.8	76.2
SR Controller	80.4	80.2	81.3	82.2
RCD Snubber	67.8	66.2	64.2	63.5
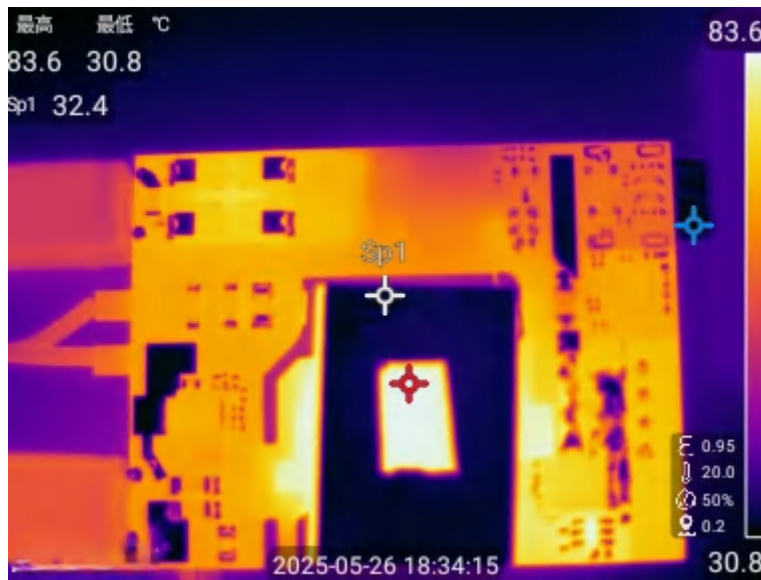
Figure 2-9. 90VAC, 20V, 2.25A

Figure 2-10. 115VAC, 20V, 2.25A
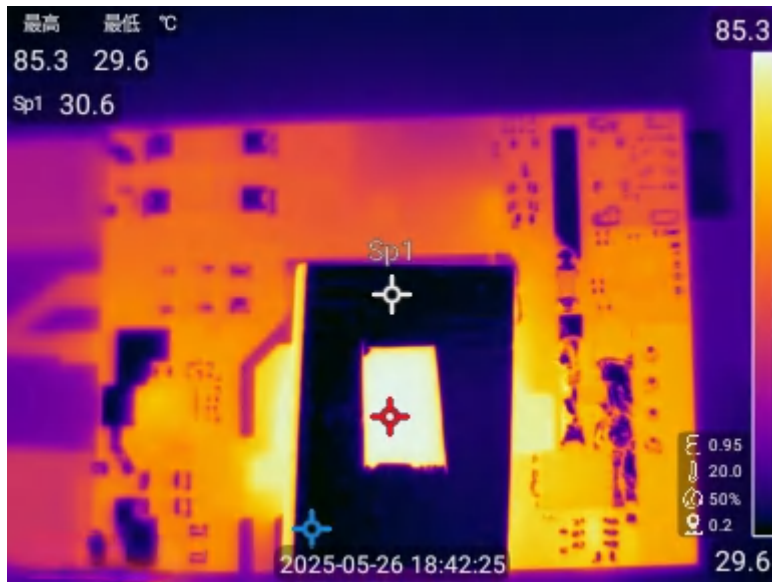
Figure 2-11. 230VAC, 20V, 2.25A
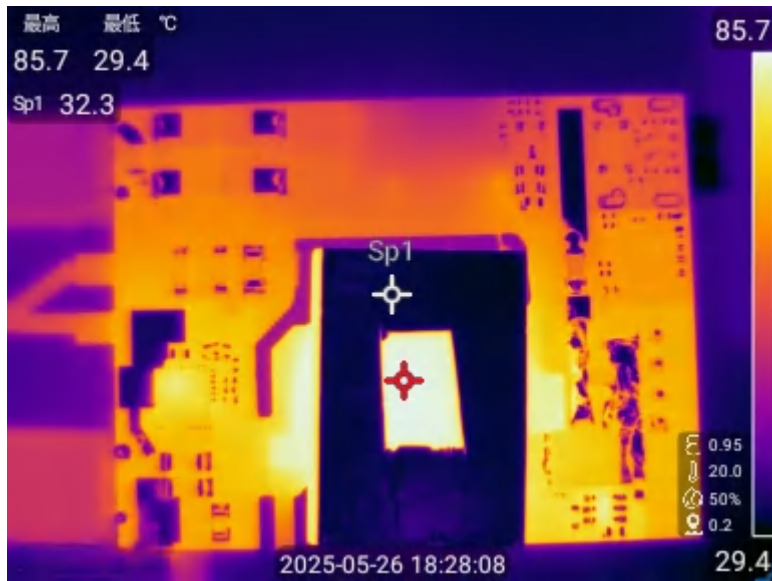
Figure 2-12. 264VAC, 20V, 2.25A

2.5 EMI

EMI is shown in Figure 2-13 and Figure 2-14.

Figure 2-13. EMI at 115VAC, Full Load

EMI TEST REPORT

Figure 2-14. EMI at 230VAC, Full Load

3 Waveforms

3.1 AC Brown In and Brown Out
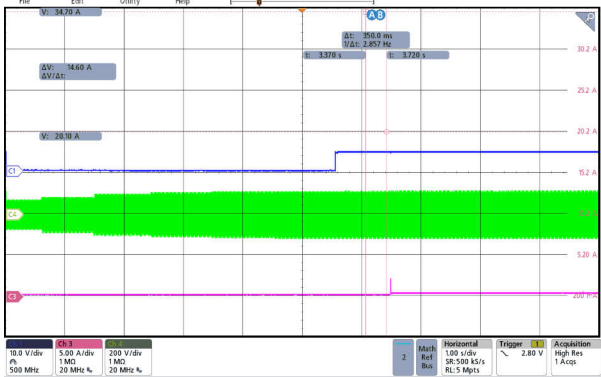
Figure 3-1. AC Brown In
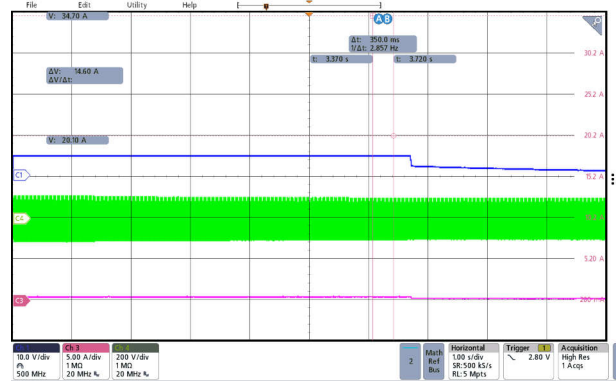
Figure 3-2. AC Brown Out

3.2 AC Start Up and Shut Down
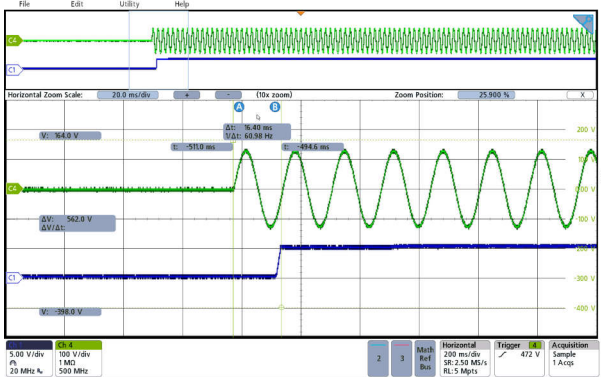
Figure 3-3. 90VAC, Start-Up
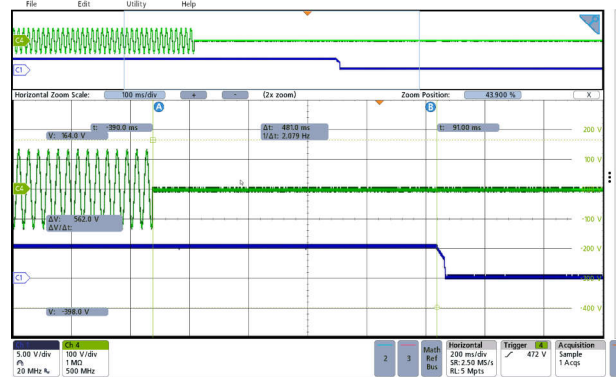
Figure 3-4. 90VAC, Shut-Down
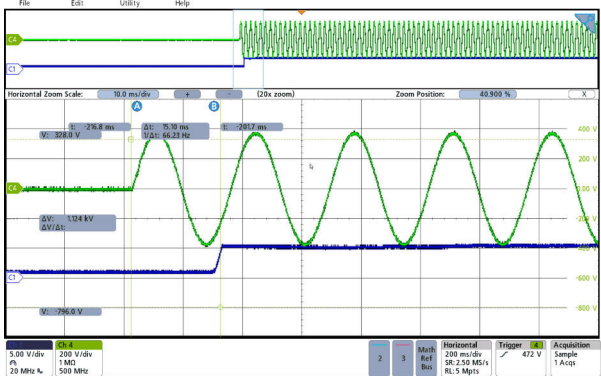
Figure 3-5. 264VAC, Start-Up
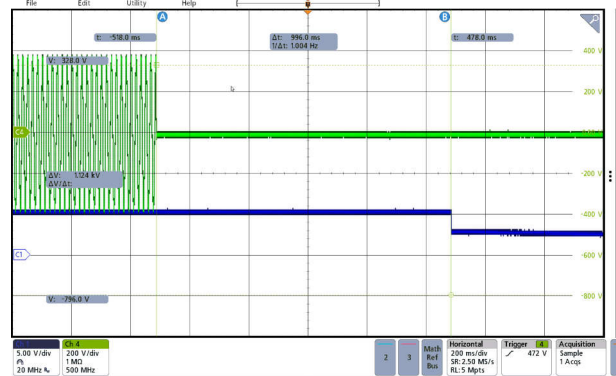
Figure 3-6. 264VAC, Shut-Down

3.3 Voltage Transition
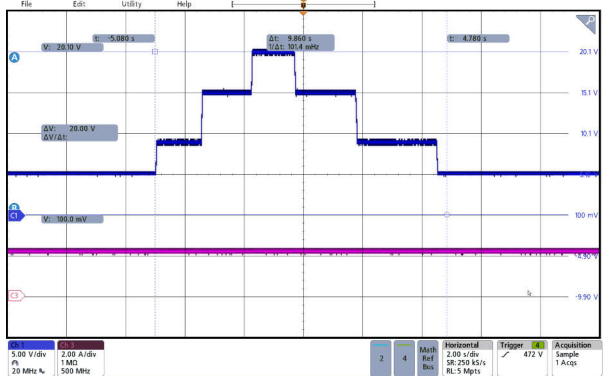
Figure 3-7. 115VAC, 20V to 5V Voltage Transition at 2.25A Load
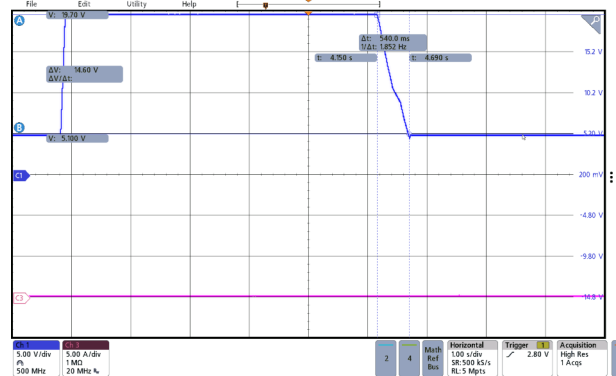
Figure 3-8. 115VAC, Voltage Transition from 20V to 5V at Open Load

3.4 Switching

Switching behavior is shown in Figure 3-9 and Figure 3-20.
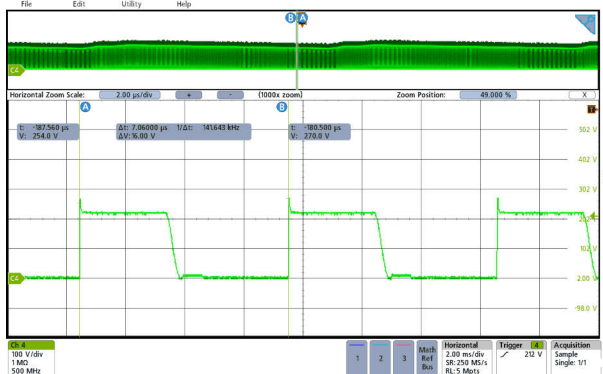
Figure 3-9. 90VAC, 20V, 2.25A, Vsw
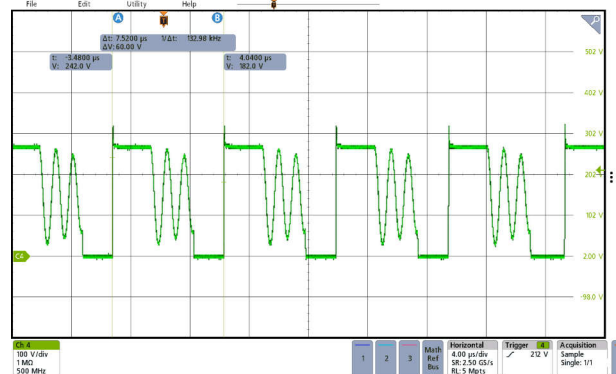
Figure 3-10. 110VAC, 20V, 2.25A, Vsw
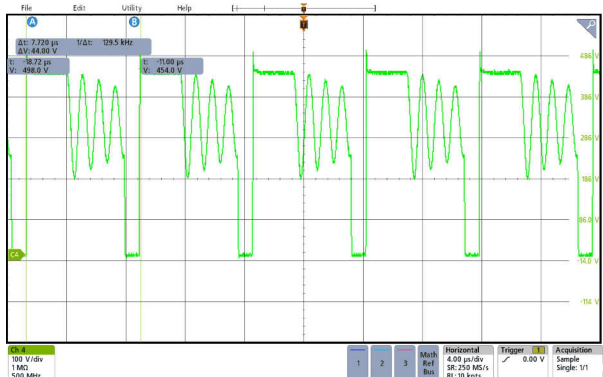
Figure 3-11. 230VAC, 20V, 2.25A, Vsw
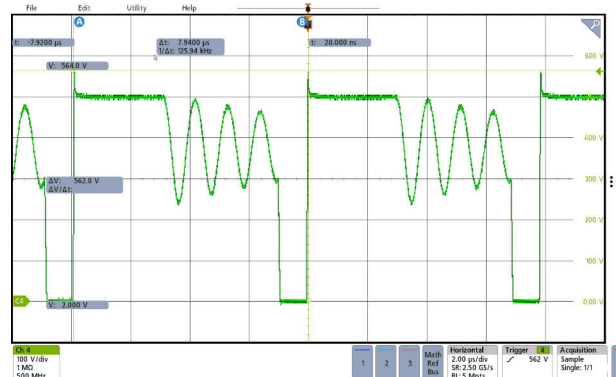
Figure 3-12. 264VAC, 20V, 2.25A, Vsw
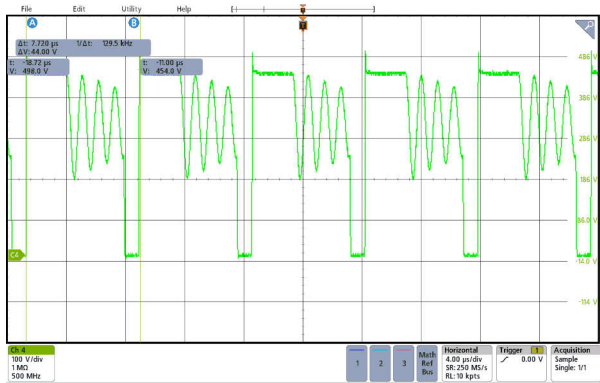
Figure 3-13. 230VAC, 20V, 2.25A, Vsw
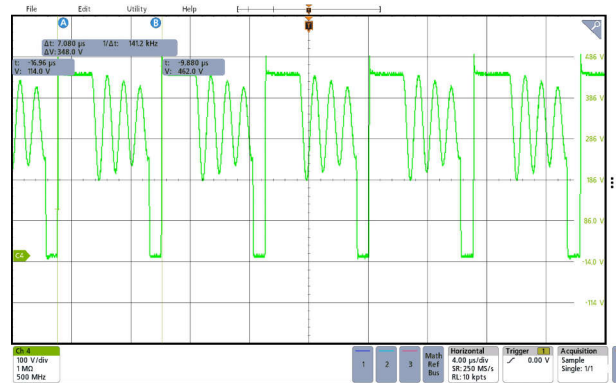
Figure 3-14. 230VAC, 20V, 1.68A, Vsw
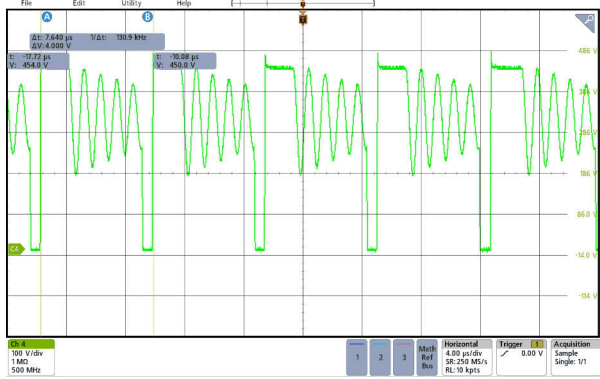
Figure 3-15. 230VAC, 20V, 1.125A, Vsw
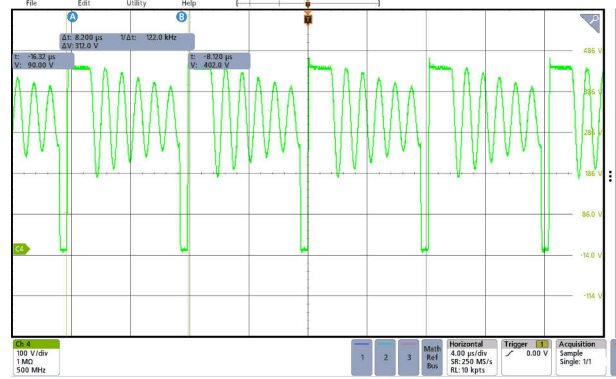
Figure 3-16. 230VAC, 20V, 0.565A, Vsw
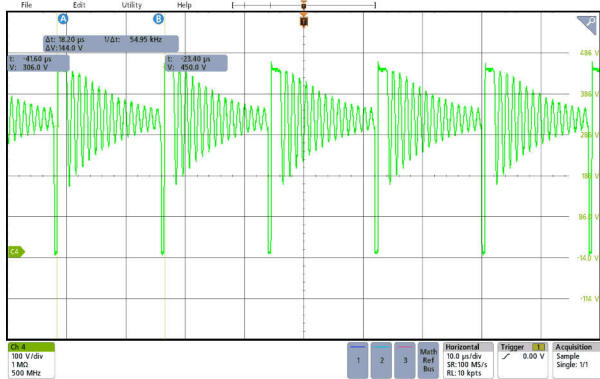
Figure 3-17. 230VAC, 20V, 0.225A, Vsw
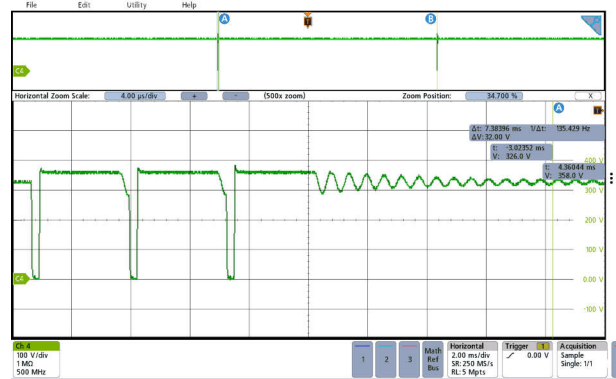
Figure 3-18. 230VAC, 5V Open Load, Vsw
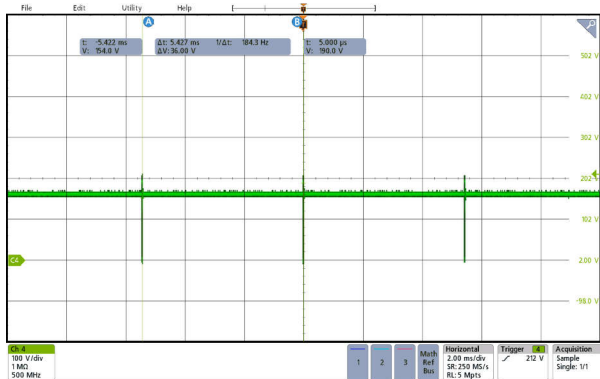
Figure 3-19. 115VAC, 5V Open Load, Vsw
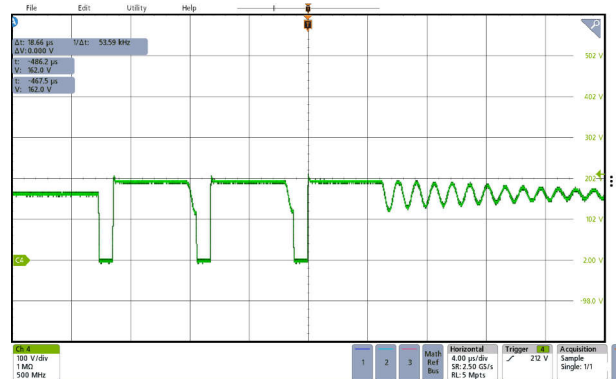
Figure 3-20. 115VAC, 5V Open Load, Vsw, Zoom

3.5 Output Voltage Ripple

Output voltage ripple is shown in Figure 3-21 through Figure 3-39.
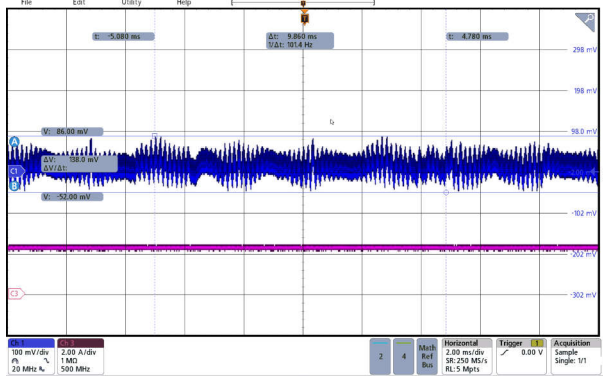
Figure 3-21. 90VAC, 20V, 45W Full Load, Output Ripple
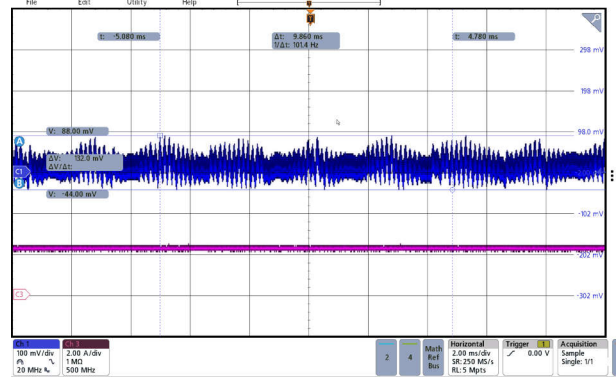
Figure 3-22. 115VAC, 20V, 45W Full Load, Output Ripple
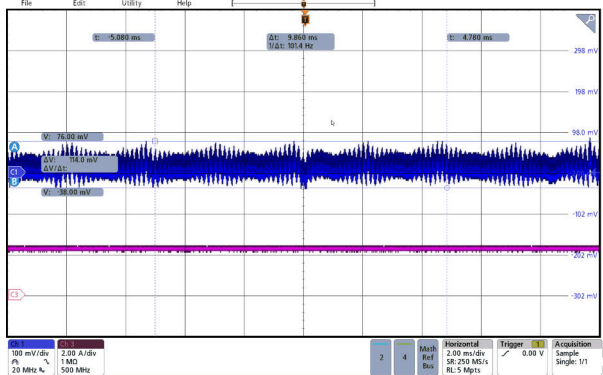
Figure 3-23. 230VAC, 20V, 45W Full Load, Output Ripple
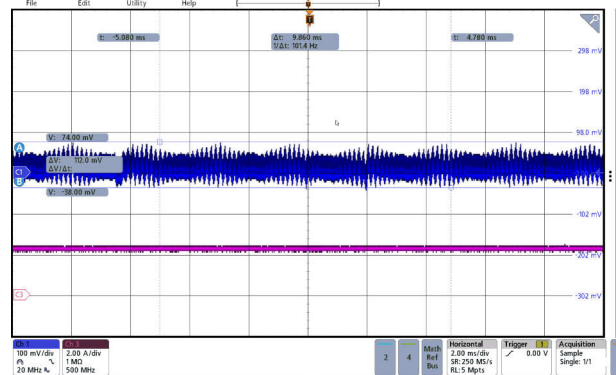
Figure 3-24. 264VAC, 20V, 45W Full Load, Output Ripple
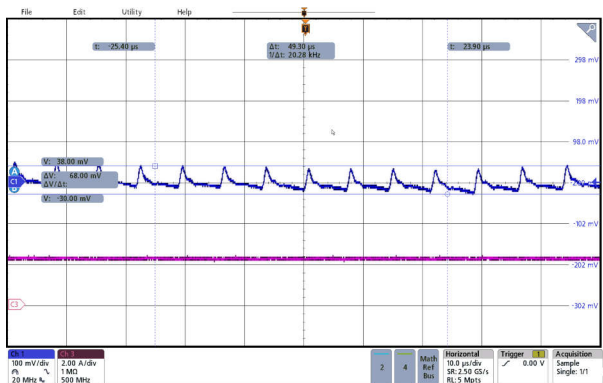
Figure 3-25. 264VAC, 20V, 45W Full Load, Output Ripple, Zoom
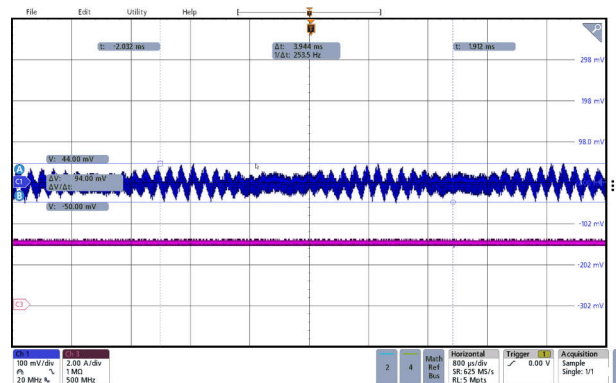
Figure 3-26. 115VAC, 5V,3A, Output Ripple
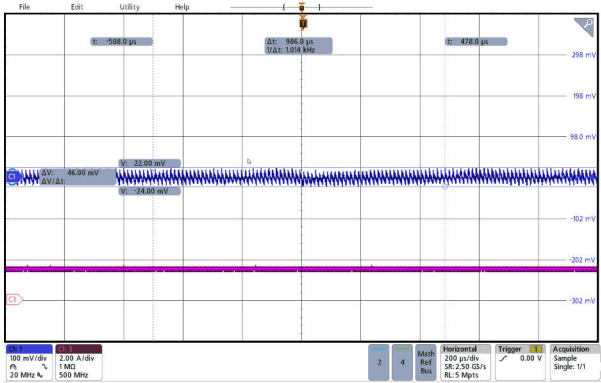
Figure 3-27. 115VAC, 5V, 1.5A, Output Ripple
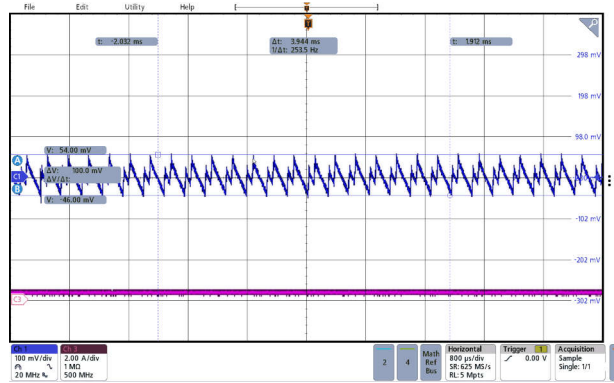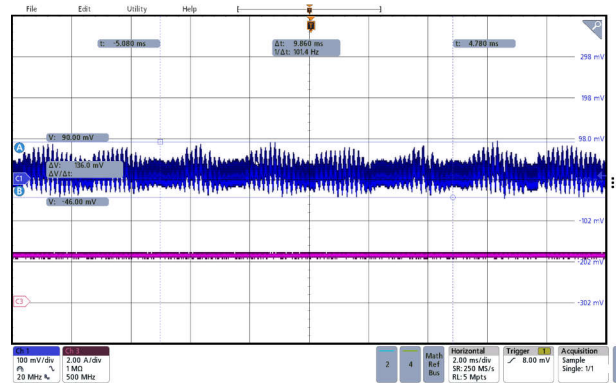

Figure 3-28. 115VAC, 5V, 0.3A, Output Ripple
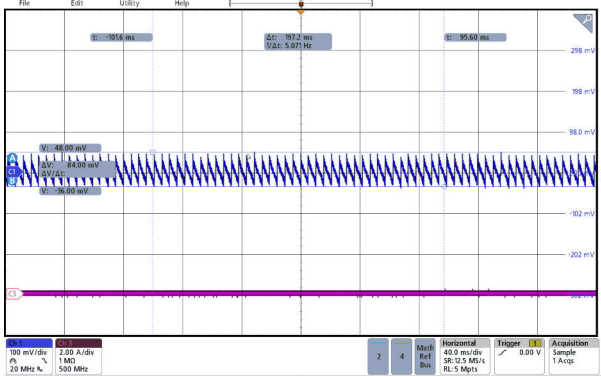
Figure 3-29. 115VAC, 5V, Open Load, Output Ripple
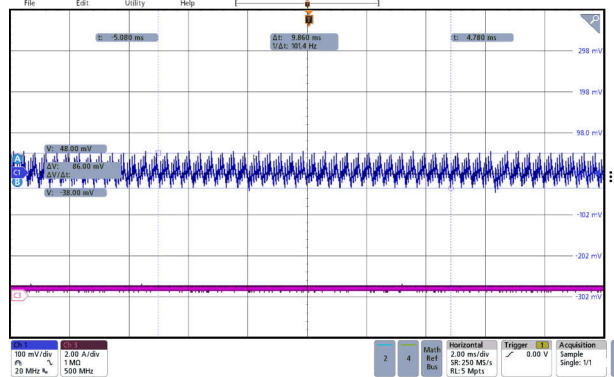
Figure 3-30. 115VAC, 9V, 0.3A, Output Ripple
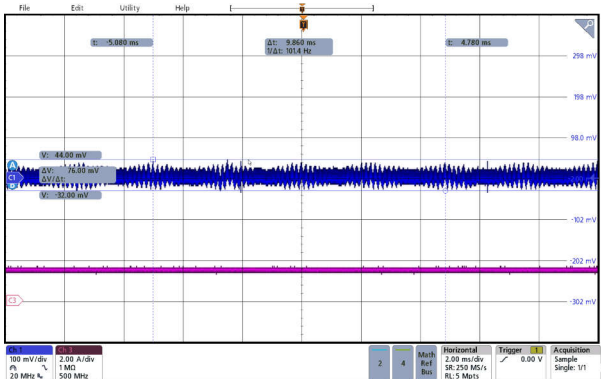
Figure 3-31. 115VAC, 9V, 1.5A, Output Ripple
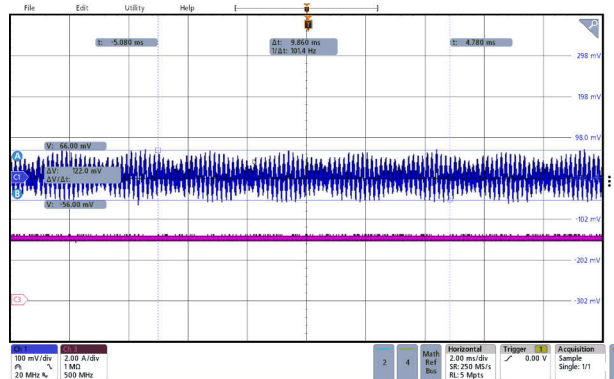
Figure 3-32. 115VAC, 9V, 3A, Output Ripple
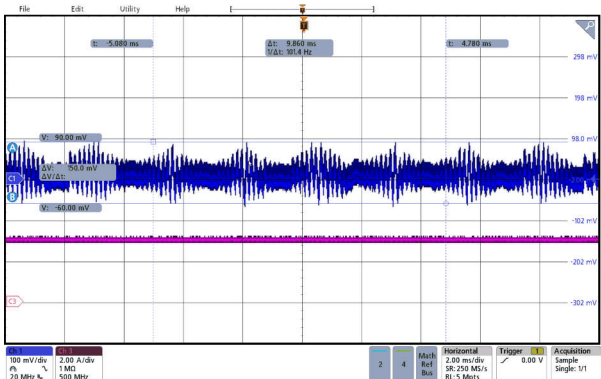
Figure 3-33. 115VAC, 15V, 3A, Output Ripple
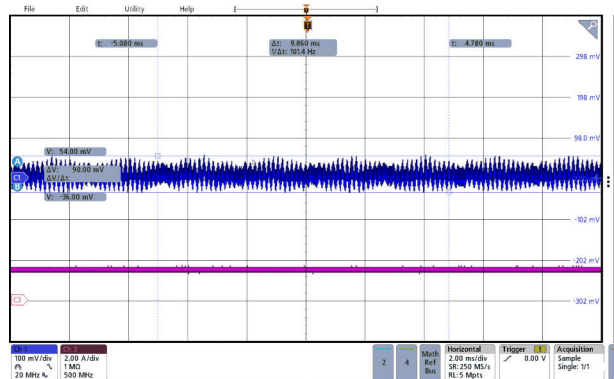
Figure 3-34. 115VAC, 15V, 1.5A, Output Ripple
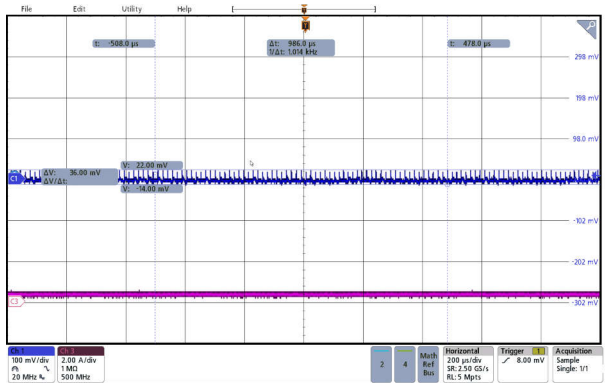
Figure 3-35. 115VAC, 15V, 0.3A, Output Ripple

Figure 3-36. 115VAC, 20V, 2.25A, Output Ripple
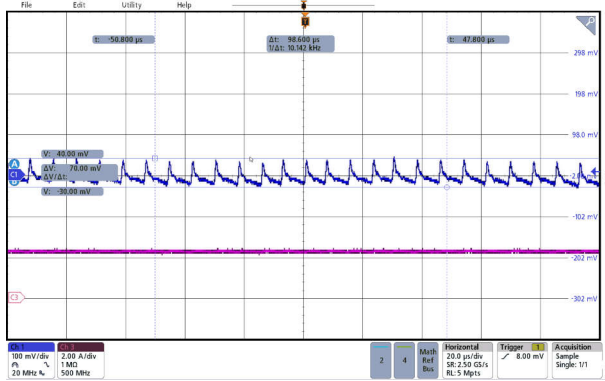
Figure 3-37. 115VAC, 20V, 2.25A, Zoom, Output Ripple, Zoom
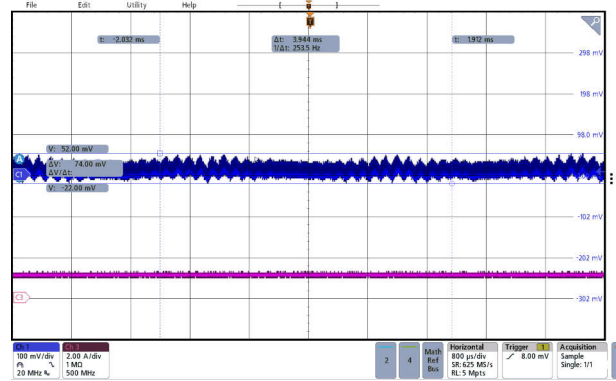
Figure 3-38. 115VAC, 20V, 1.12A, Output Ripple
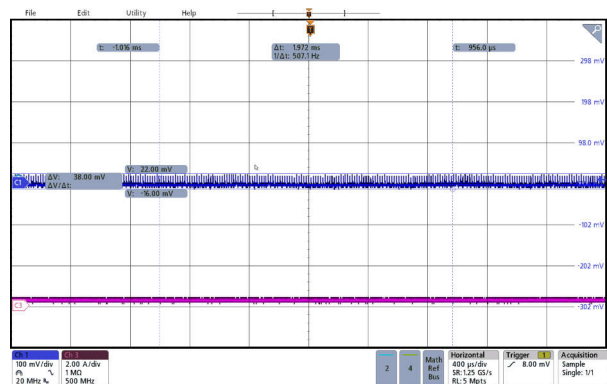
Figure 3-39. 115VAC, 20V, 0.225A, Output Ripple

3.6 Load Transient

Load transient waveform is shown in Figure 3-40 through Figure 3-44.

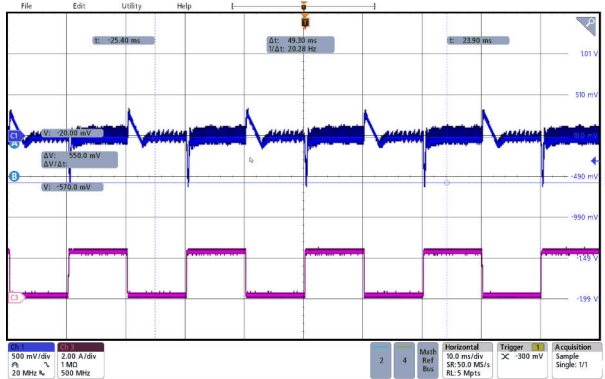The load dynamic test was performed from 0.1A to full load. Output voltage was measured at the PCB end.

Figure 3-40. 115VAC, 20V, 0.1A to 2.25A Load Dynamic
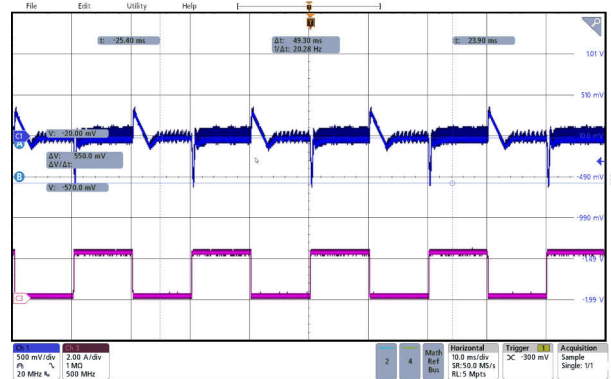
Figure 3-41. 230VAC, 20V, 0.1A to 2.25A Load Dynamic
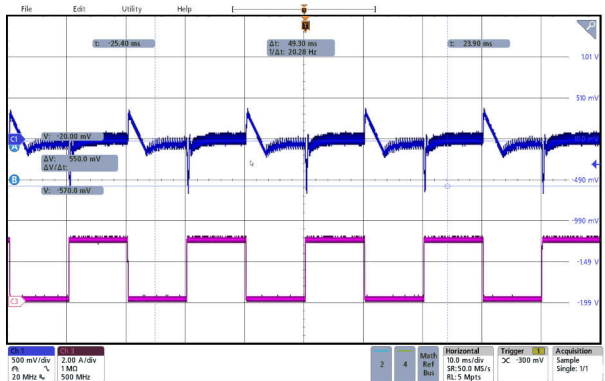
Figure 3-42. 115VAC, 5V, 0.1A to 3A Load Dynamic
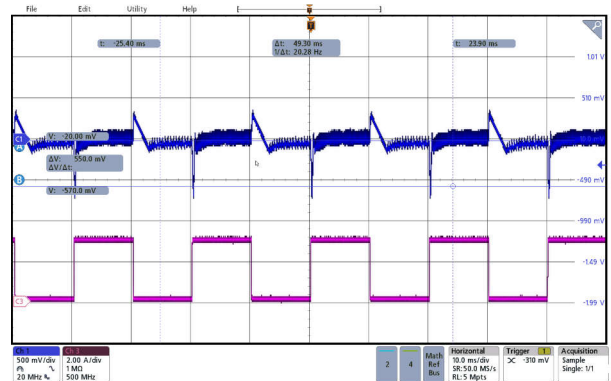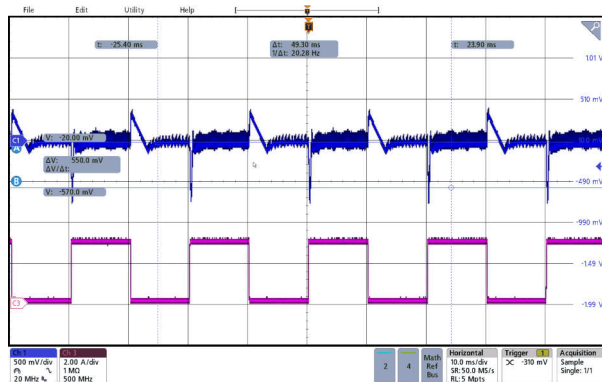

Figure 3-43. 115VAC, 9V, 0.1A to 3A Load Dynamic

Figure 3-44. 115VAC, 15V, 0.1A to 3A Load Dynamic

3.7 Short-Circuit Protection

Short circuit protection was performed at PCB board end and goes to auto recovery after short is removed. CH1: V_{out}, CH3: I_{out}, CH4: Vsw
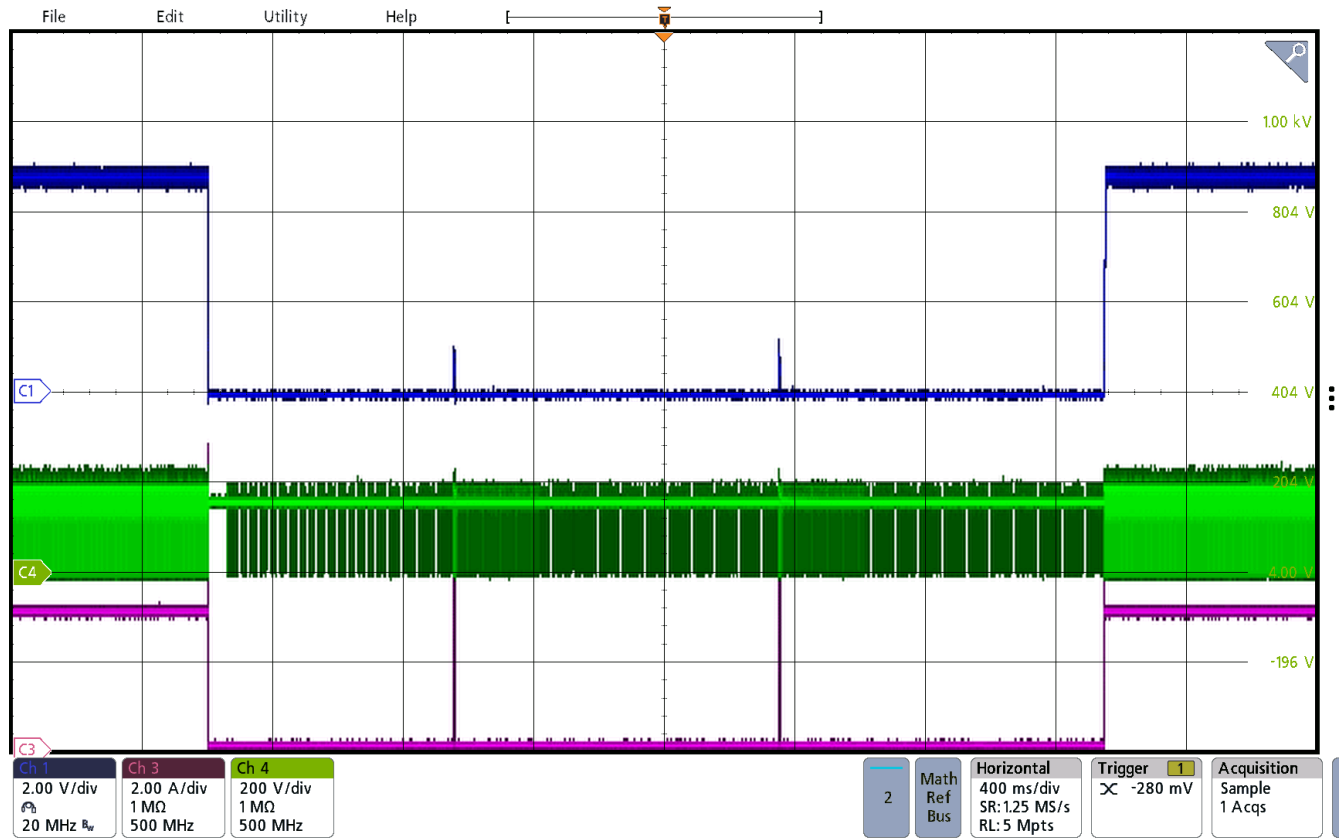
Figure 3-45. Short Circuit Protection at PCB End and Recovery After Short Removed

3.8 Feedback Loop Open Protection

By disconnecting output feedback, V_{out} ramps up and UCG28826 SW pin senses the output voltage. Once the sensed voltage triggers the OVP threshold, the OVP protection is triggered. The OVP set is latch protection.

CH2: V_{out}, CH4: Primary switching node
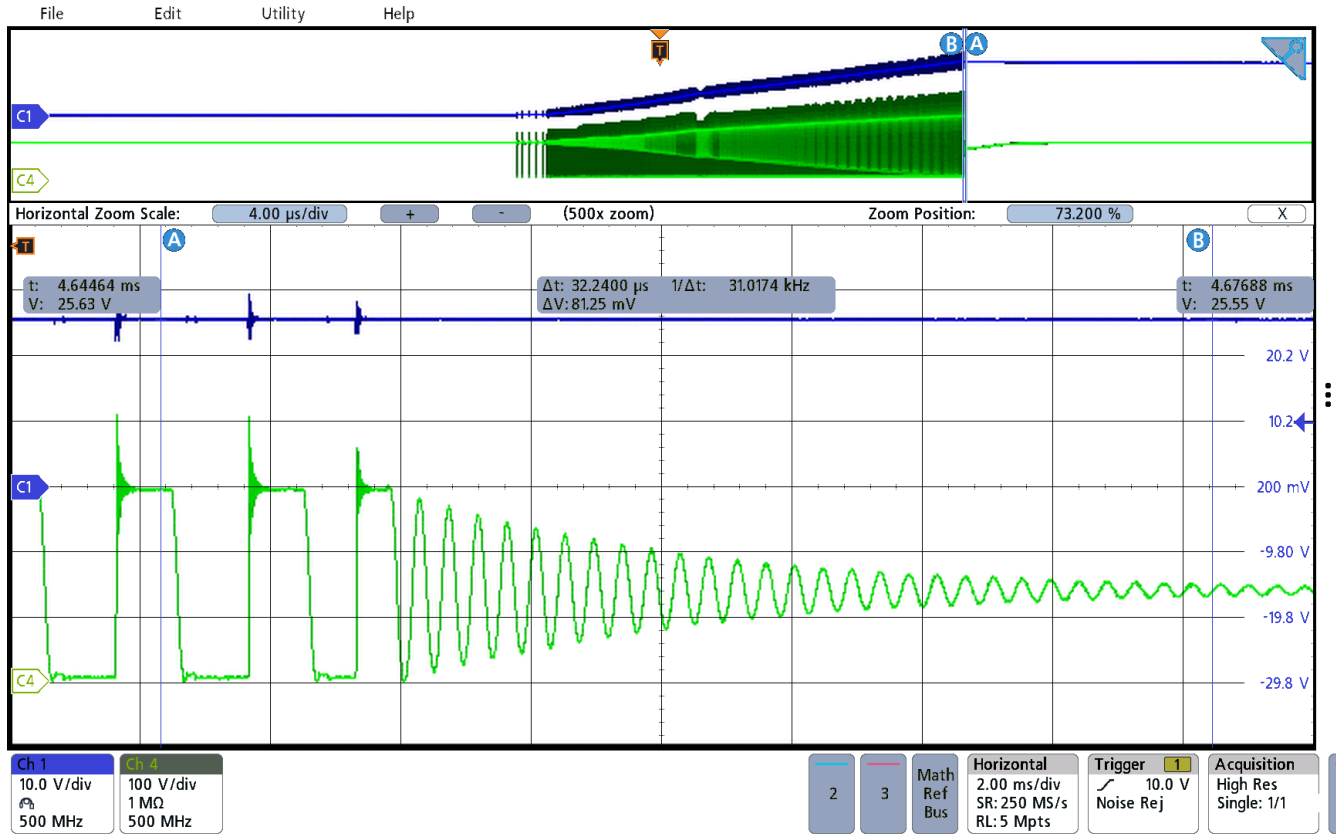
Figure 3-46. Feedback Loop Open, Output Over-Voltage Protection 25.6V

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