Test Report: PMP41145

Universal AC Input 65W 20V, 3.25A Flyback With Integrated GaN Reference Design

Description

This reference design is a 65W, 20V fixed output voltage AC-DC power supply design with integrated flyback and Gallium nitride (GaN). This design can deliver 65W full rated power across 90VAC to 264VAC and achieve 93% efficiency at 90VAC. The design can meet efficiency standards and regulations such as DoE Level VII and CoC V5 Tier 2 efficiency standard for average efficiency across 25%, 50%, 75%, 100% and standby power consumption. The design can achieve 2.3W per cubic centimeters and eliminate auxiliary winding as well as associated VCC rectifier circuity. The design can also support a 100W peak power capability for 4ms.

Features

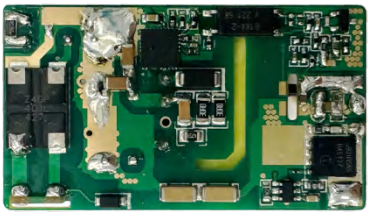
- Achieve 93% efficiency at 90VAC
- 2.3W per cubic centimeter. Power density based on PCB size
- Meet DoE Level VII and CoC V5 Tier 2 efficiency standards
- No load power consumption 18mW at 115VAC, 28mW at 230VAC
- Provide 100W peak power capability

Applications

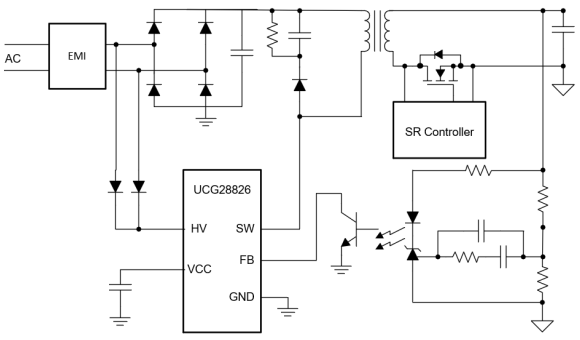
- Industrial AC-DC
- USB AC/DC adapter
- USB wall power outlet
- Battery charger

Top view

Angle view



Bottom View



Block Diagram

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input voltage range	90VAC to 264VAC
Output voltage	20VDC
Output current	3.25A
Rated Power	65W
Peak Power	100W, 4ms

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: 27mm × 48mm × 22mm (open frame)

2 Testing and Results

2.1 Efficiency Graphs

Efficiency is shown in Figure 2-1 through Figure 2-3.

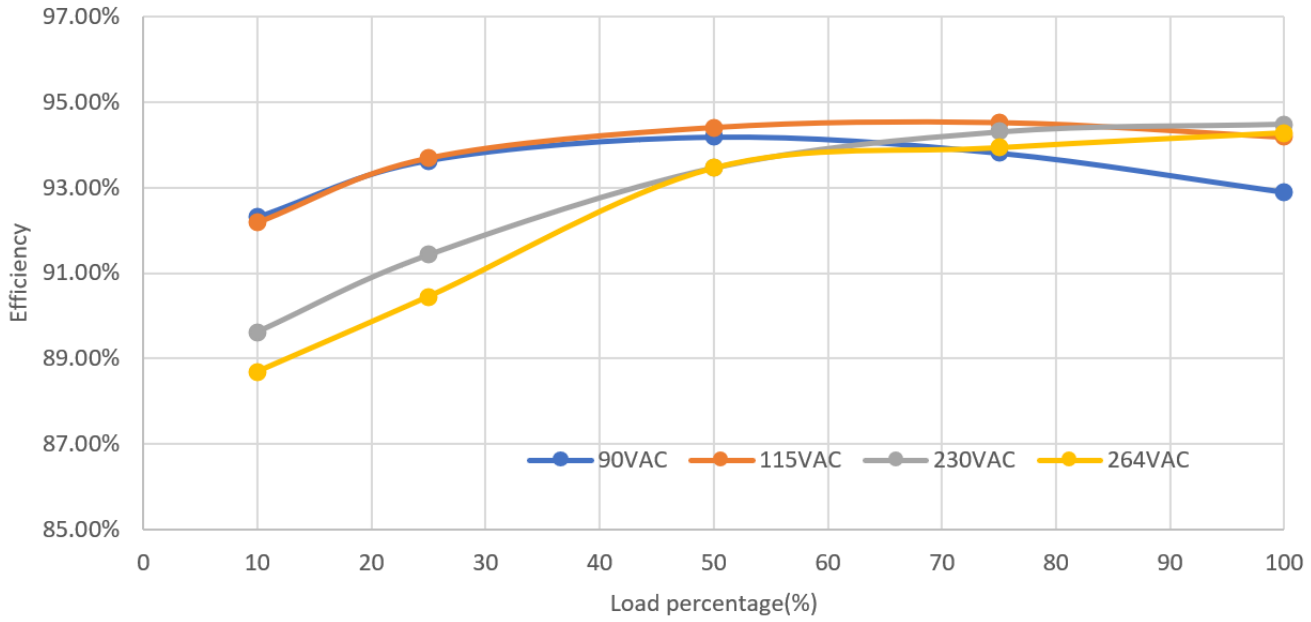


Figure 2-1. Efficiency Versus AC Input and Load

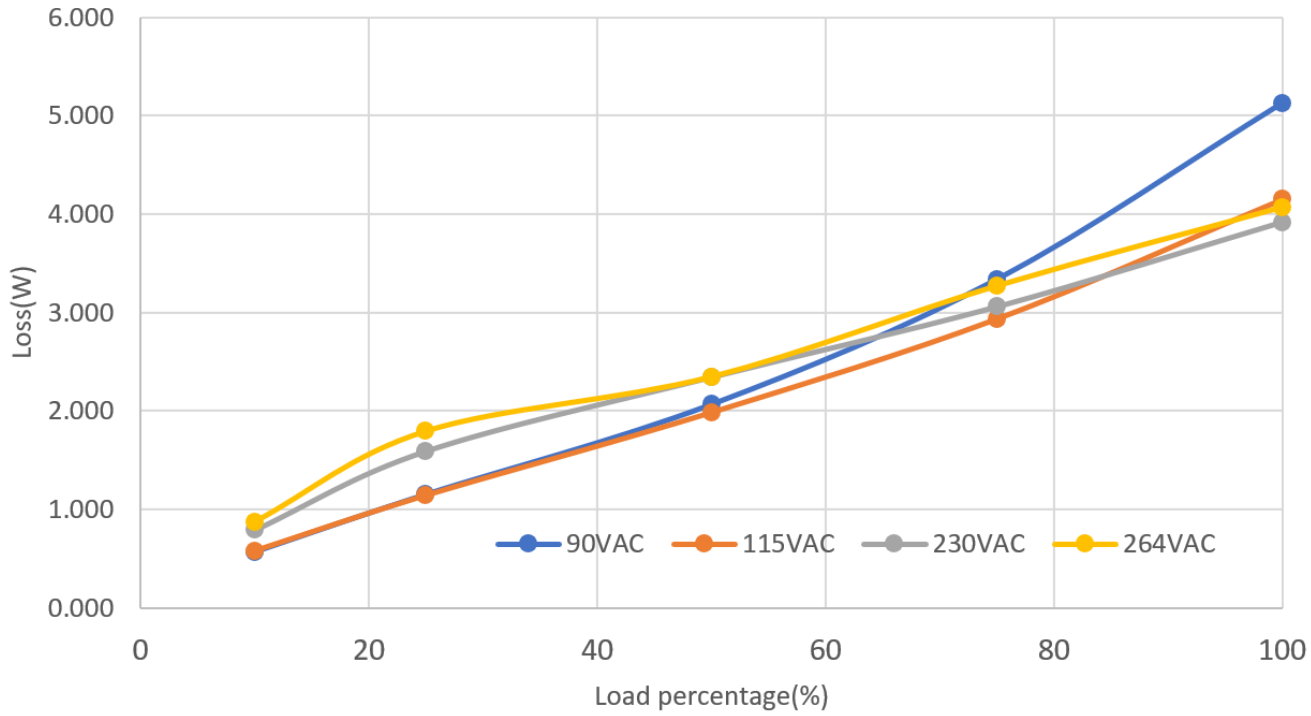


Figure 2-2. Power Loss Versus AC Input and Load

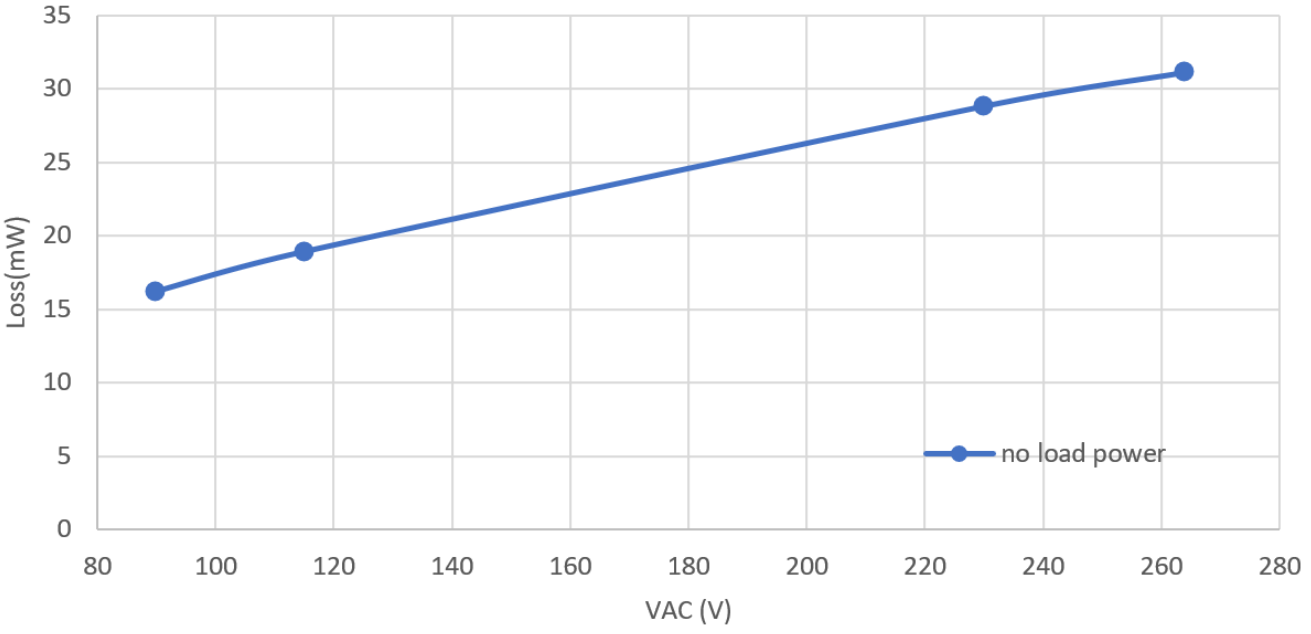


Figure 2-3. No Load Input Power Consumption Versus AC Input Voltage

2.2 Voltage Regulation

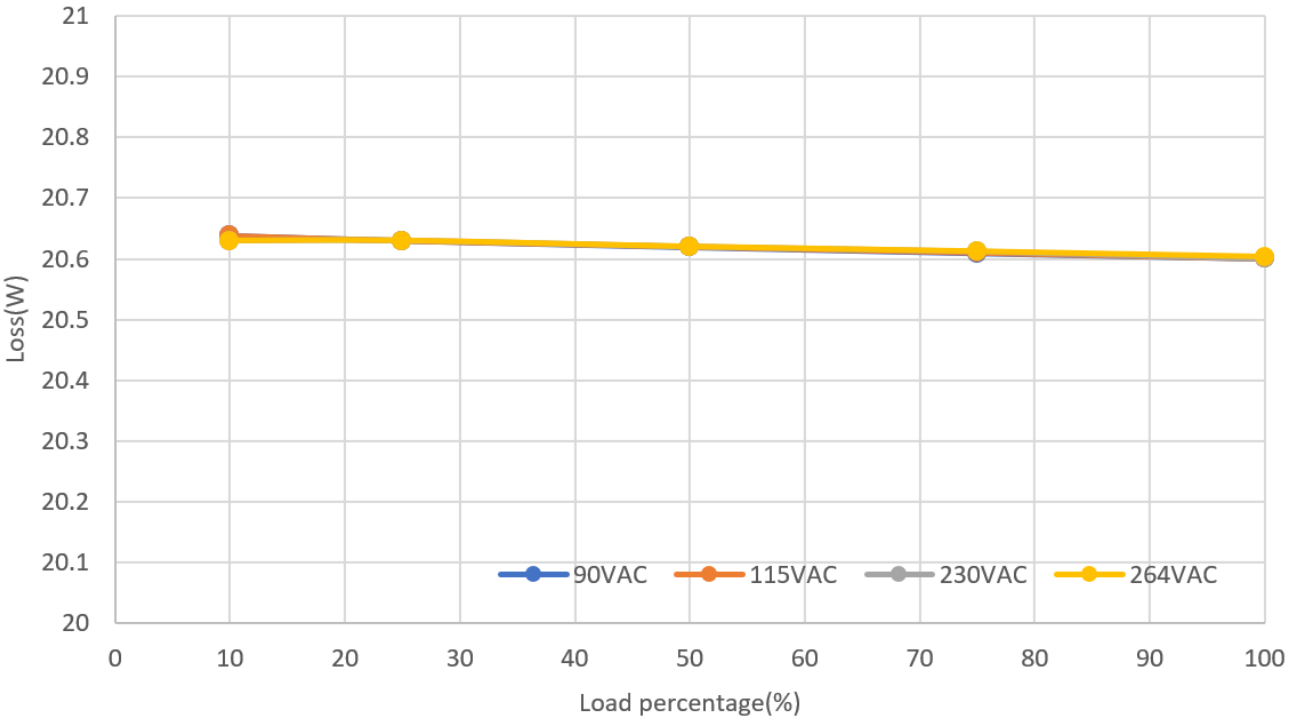


Figure 2-4. V_{out} Voltage Regulation Versus AC Input and Load

2.3 Efficiency Data

Efficiency data is shown in Table 2-1.

Table 2-1. Efficiency Data

$V_{AC\ IN}$(V)	P_{IN}(A)	V_{OUT} (V)	I_{OUT} (A)	P_{OUT} (W)	P_{LOSS} (W)	P_{OUT} (%)	Efficiency (%)	Average Efficiency at Four Point (%)
90	72.036	20.61	3.255	67.053	4.983	100	93.08	93.82
90	53.802	20.609	2.454	50.574	3.228	75	94.00	
90	35.459	20.619	1.623	33.465	1.994	50	94.38	
90	18.074	20.63	0.822	16.958	1.116	25	93.83	
90	7.385	20.638	0.331	6.831	0.554	10	92.50	
115	71.058	20.61	3.255	67.053	4.005	100	94.36	94.39
115	53.403	20.61	2.454	50.577	2.826	75	94.71	
115	35.379	20.62	1.623	33.466	1.913	50	94.59	
115	18.064	20.63	0.822	16.958	1.106	25	93.88	
115	7.395	20.638	0.331	6.831	0.564	10	92.37	
230	70.828	20.61	3.255	67.053	3.755	100	94.67	93.60
230	53.533	20.612	2.454	50.582	2.951	75	94.49	
230	35.738	20.62	1.623	33.466	2.272	50	93.64	
230	18.513	20.63	0.822	16.958	1.555	25	91.60	
230	7.605	20.63	0.331	6.829	0.776	10	89.79	

Table 2-1. Efficiency Data (continued)

VAC $_{IN}$(V)	P $_{IN}$(A)	V_{OUT} (V)	I_{OUT} (A)	P_{OUT} (W)	P_{LOSS} (W)	P_{OUT} (%)	Efficiency (%)	Average Efficiency at Four Point (%)
264	70.988	20.603	3.255	67.063	3.925	100	94.47	93.21
264	53.742	20.612	2.454	50.582	3.160	75	94.12	
264	35.738	20.62	1.623	33.466	2.272	50	93.64	
264	18.713	20.63	0.822	16.958	1.755	25	90.62	
264	7.685	20.63	0.331	6.829	0.856	10	88.86	

2.4 Thermal Images

Thermal image is shown in Figure 2-5 through Figure 2-8.

Table 2-2. Thermal Test Result

Parts	90VAC	115VAC	230VAC	264VAC	
	Temperature(°C)	Temperature(°C)	Temperature(°C)	Temperature(°C)	Room temperature(°C)
AC Bridge	105	90	75	73	25
UCG28826	84	76	79	83	25
Transformer	75	75	76	77	25
SR MOSFET	68	66	67	66	25
RCD Snubber	91	83	80	79	25

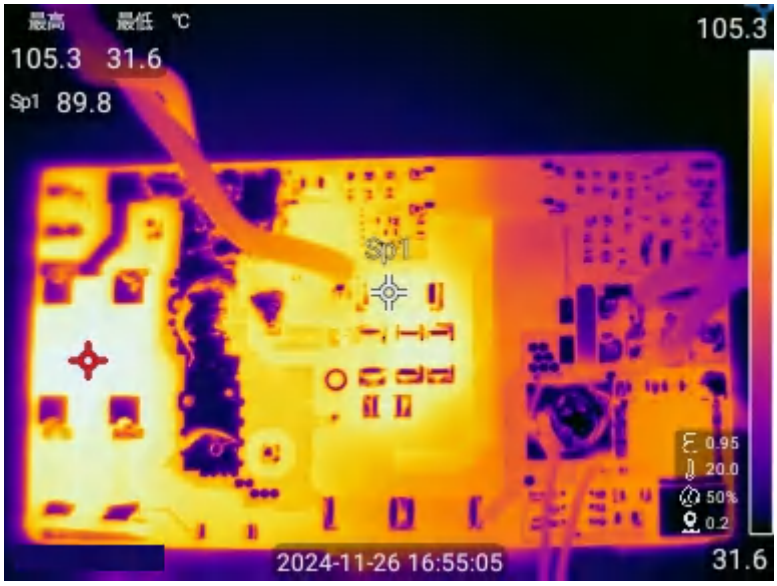


Figure 2-5. Thermal, 90VAC, Full Load

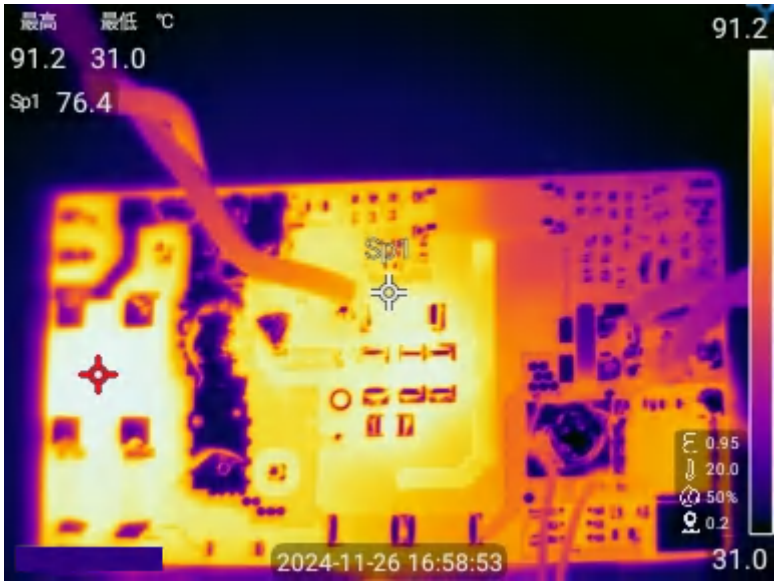


Figure 2-6. Thermal, 115VAC, Full Load

Figure 2-7. Thermal, 230VAC, Full Load

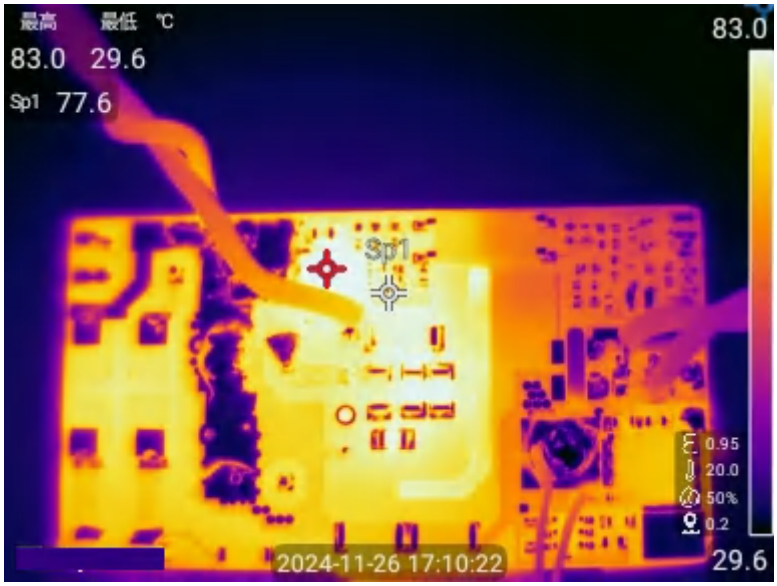


Figure 2-8. Thermal, 264VAC, Full Load

2.5 EMI

EMI is shown in Figure 2-9 through Figure 2-12.

EMI TEST REPORT

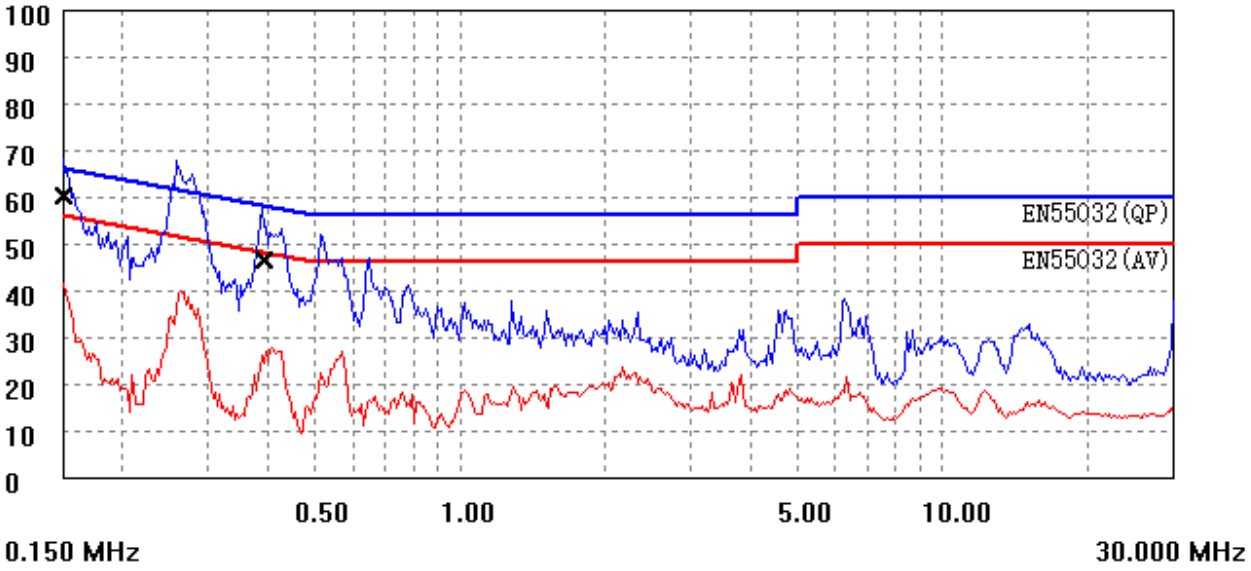
parameter

Organization:		Operator:		EUT:	
Place:		Time:	2024/12/4/12:58	Test equipment:	KH3932
Detector:	PK+AV	Test-time(ms):	30	SN:	320684
Limit:	EN55032	Transductor(PK/AV):	PK / AV	JZ:	2,15,1031
Remark:					

freq, step

Start(MHz)	End(MHz)	Step(MHz)
0.150	2.000	0.002
2.000	10.000	0.010
10.000	30.000	0.025

scan result



final test

[QP]	freq(MHz)	lev(dBuV)	Lim(dBuV)	Δ(lev-Lim)
	0.150	60.4	66.0	-5.6
	0.391	46.5	59.1	-12.6

Figure 2-9. 115VAC, Full Load, Resistive Load, Unearthed, L phase

EMI TEST REPORT

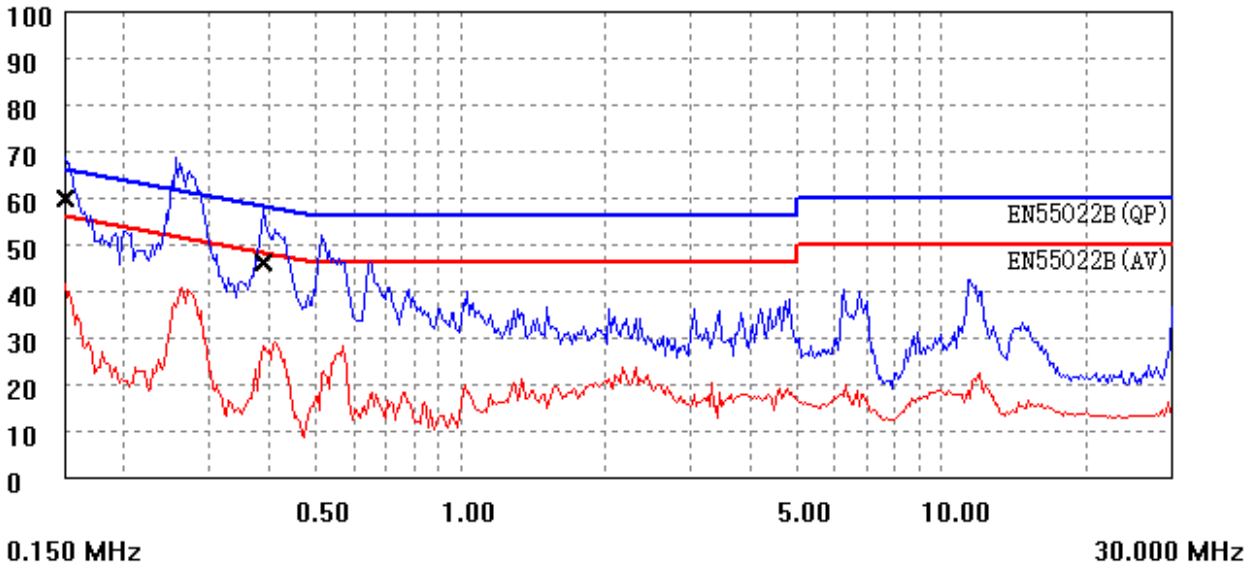
parameter

Organization:		Operator:		EUT:	
Place:		Time:	2024/12/4/14:23	Test equipment:	KH3932
Detector:	PK+AV	Test-time(ms):	30	SN:	320684
Limit:	EN55022B	Transductor(PK/AV):	PK / AV	JZ:	2,15,1039
Remark:					

freq, step

Start(MHz)	End(MHz)	Step(MHz)
0.150	2.000	0.002
2.000	10.000	0.010
10.000	30.000	0.025

scan result



final test

[QP]	freq(MHz)	lev(dBuV)	Lim(dBuV)	Δ(lev-Lim)
	0.150	60.0	66.0	-6.0
	0.390	46.0	59.1	-13.1

Figure 2-10. 115VAC, Full Load, Resistive Load, Unearthed, N phase

EMI TEST REPORT

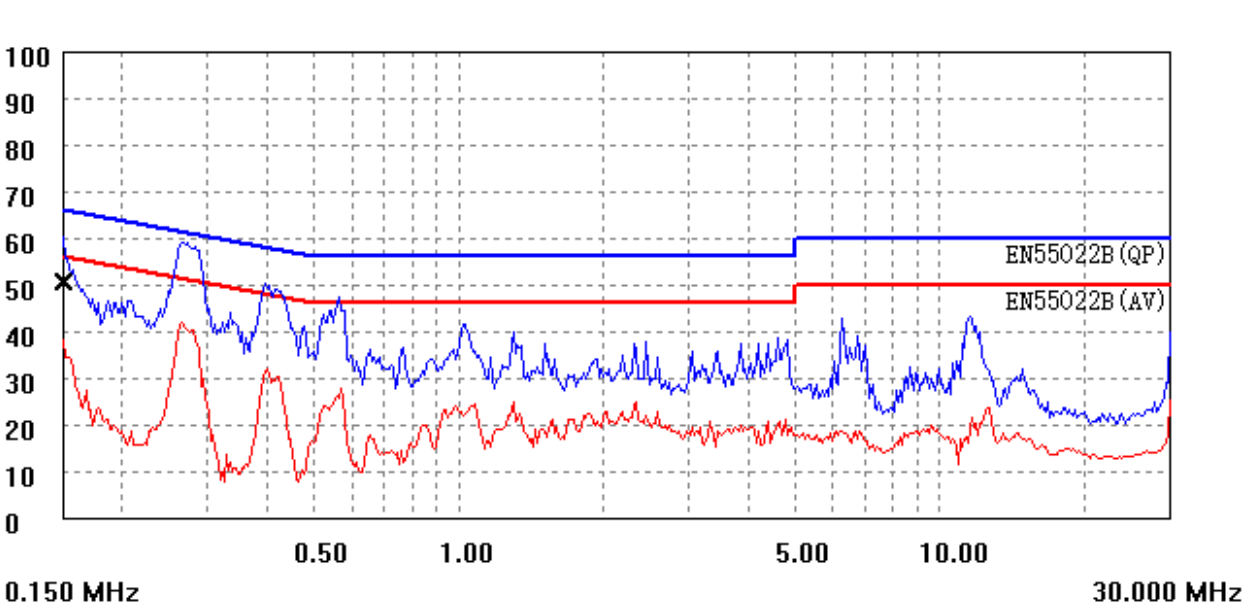
parameter

Organization:		Operator:		EUT:	
Place:		Time:	2024/12/4/14:13	Test equipment:	KH3932
Detector:	PK+AV	Test-time(ms):	30	SN:	320684
Limit:	EN55022B	Transductor(PK/AV):	PK / AV	JZ:	2,15,1044
Remark:					

freq, step

Start(MHz)	End(MHz)	Step(MHz)
0.150	2.000	0.002
2.000	10.000	0.010
10.000	30.000	0.025

scan result



final test

[QP]	freq(MHz)	lev(dBuV)	Lim(dBuV)	Δ(lev-Lim)
	0.150	50.7	66.0	-15.3

Figure 2-11. 230VAC, Full Load, Resistive Load, Unearthed, L phase

EMI TEST REPORT

parameter

Organization:		Operator:		EUT:	
Place:		Time:	2024/12/4/14:18	Test equipment:	KH3932
Detector:	PK+AV	Test-time(ms):	30	SN:	320684
Limit:	EN55022B	Transductor(PK/AV):	PK / AV	JZ:	2,15,1040
Remark:					

freq, step

Start(MHz)	End(MHz)	Step(MHz)
0.150	2.000	0.002
2.000	10.000	0.010
10.000	30.000	0.025

scan result

dBuV

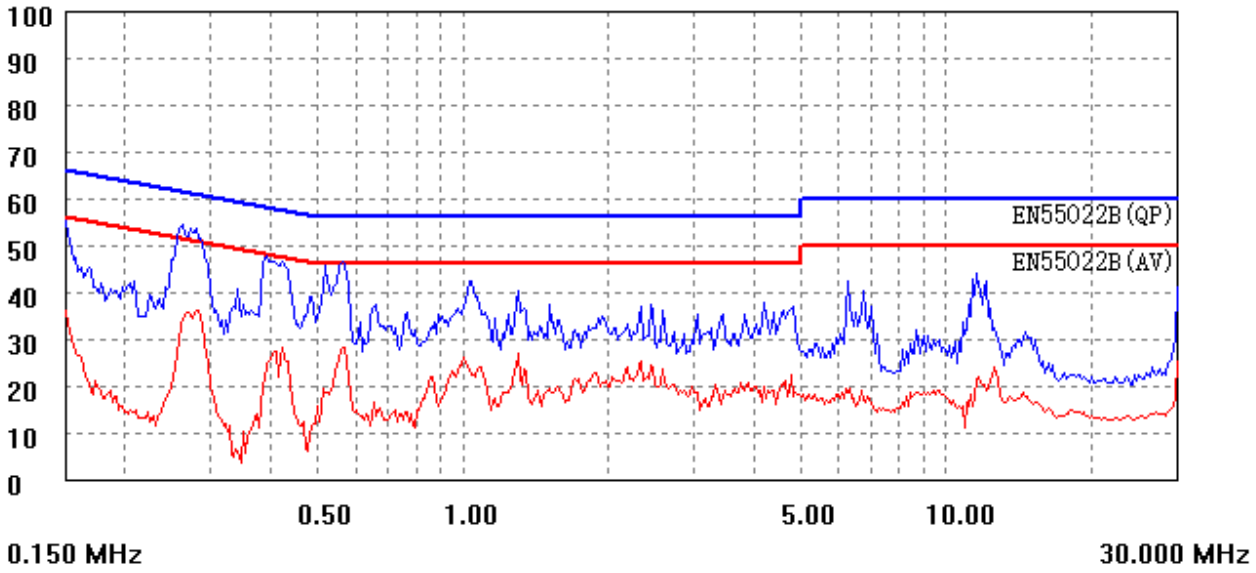


Figure 2-12. 230VAC, Full Load, Resistive Load, Unearthed, N phase

3 Waveforms

3.1 Start-up and Shut Down Waveform

Start-up behavior is shown in Figure 3-1 through Figure 3-4.

CH1: VAC, CH2:VOUT, CH4: Iout

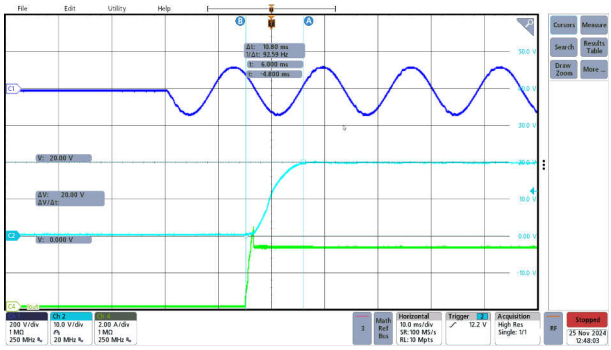


Figure 3-1. 90VAC, Soft Start-Up Time 6ms

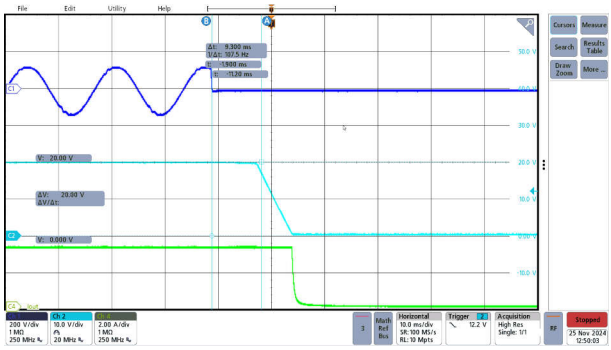


Figure 3-2. 90VAC, Shut Down, Hold Up Time 9.3ms

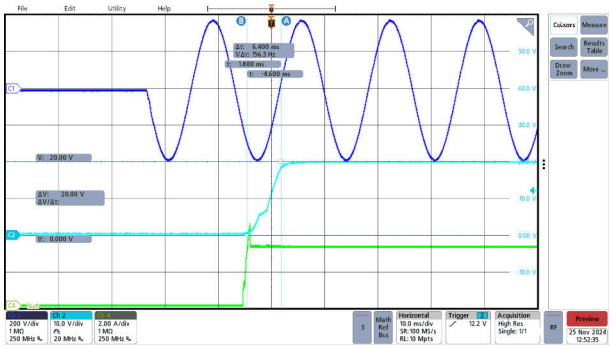


Figure 3-3. 264VAC, Soft Start-Up Time 6ms

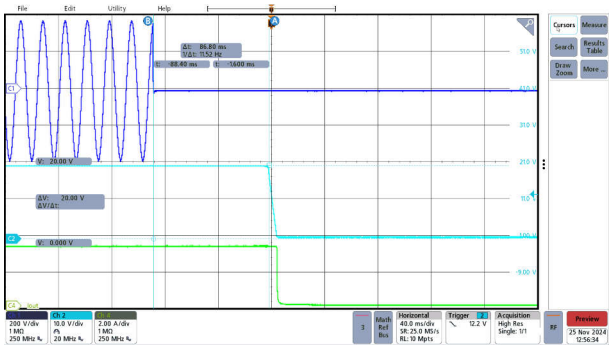


Figure 3-4. 264VAC, Shut Down, Hold-Up Time 87ms

3.2 Switching

Switching behavior is shown in Figure 3-5 through Figure 3-21.

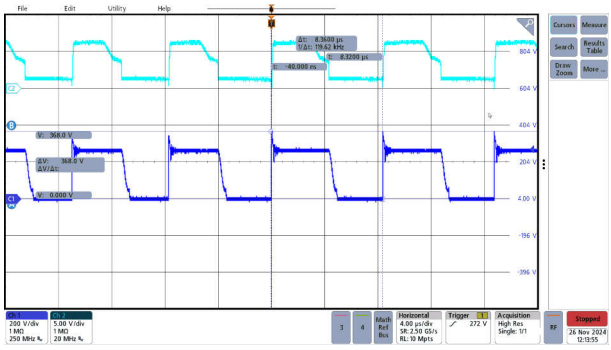


Figure 3-5. 115VAC, Vds_pri, Vsr_gate, Full Load

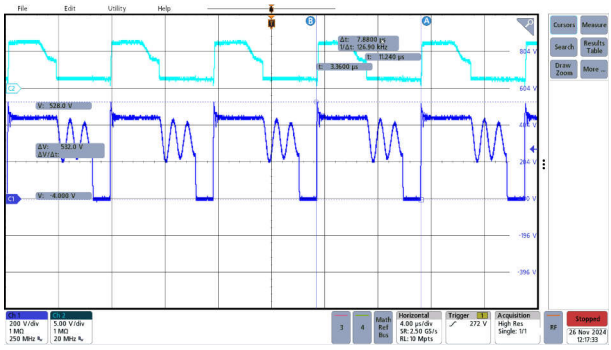


Figure 3-6. 230VAC, Vds_pri, Vsr_gate, Full Load

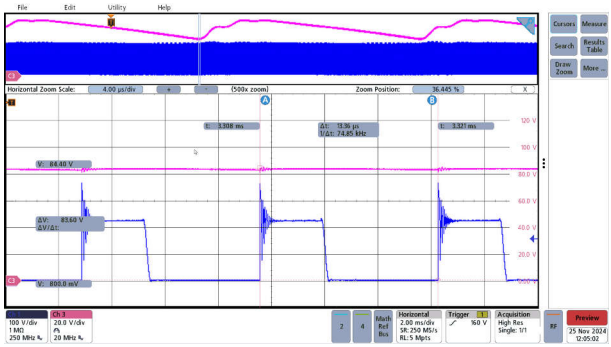


Figure 3-7. 90VAC, Full Load, Vds_pri, Vbus Valley 83V

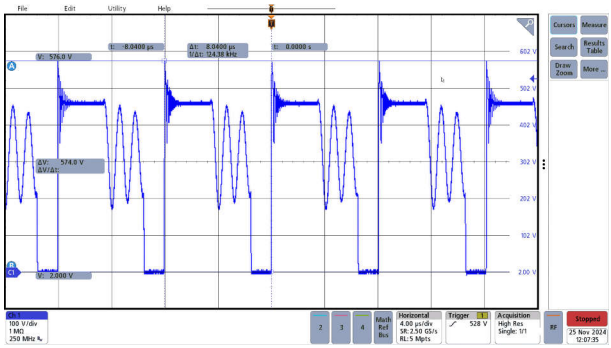


Figure 3-8. 230VAC, Full Load, 3.25A, fsw = 125kHz

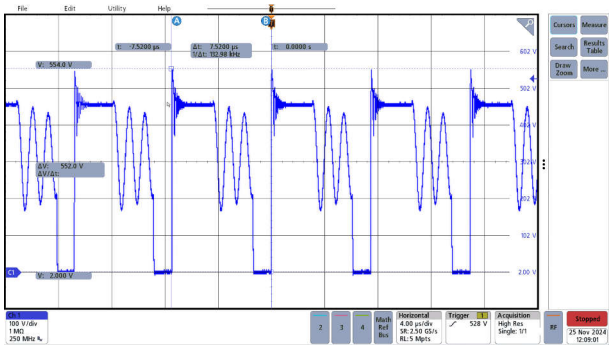


Figure 3-9. 230VAC, 75% Load, 2.45A, fsw = 133kHz

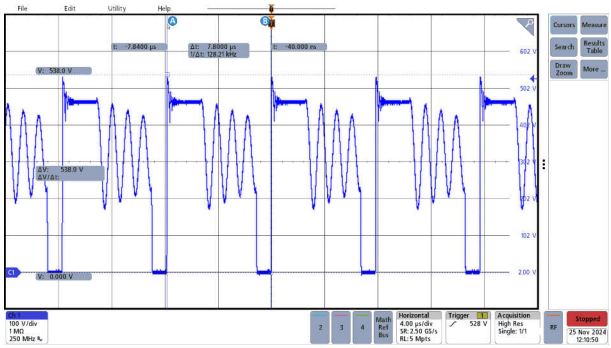


Figure 3-10. 230VAC, 50% Load, 1.6A, fsw = 128kHz

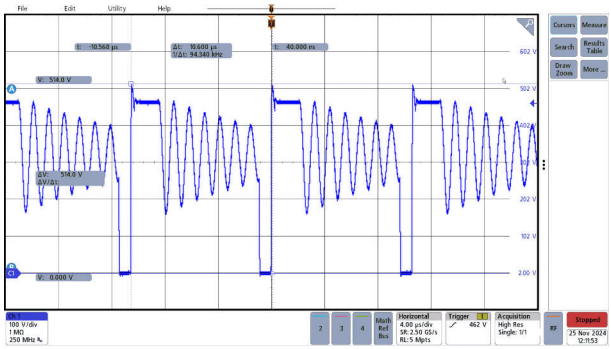


Figure 3-11. 230VAC, 25% Load 0.82A, fsw = 94kHz

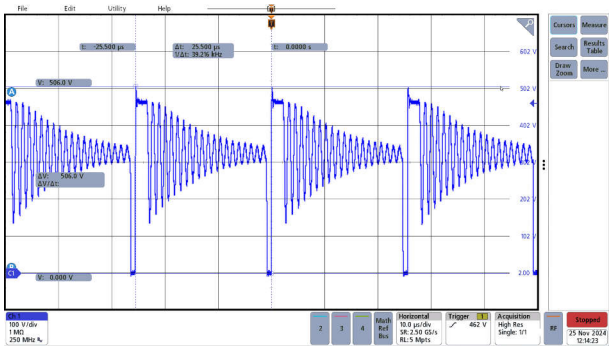


Figure 3-12. 230VAC, 10% Load 0.32A, fsw=39kHz

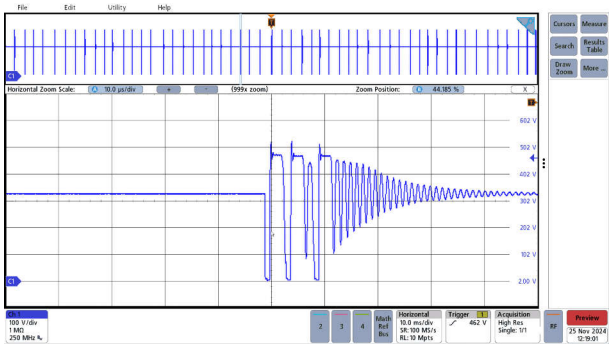


Figure 3-13. 230VAC, 20V, 200mW Load, Vds_pri

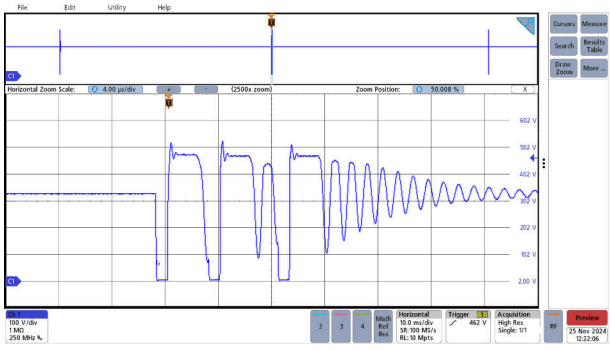


Figure 3-14. 230VAC, 20V, Open Load, Vds_pri

Figure 3-15 through Figure 3-21 are 115VAC input switching waveforms.

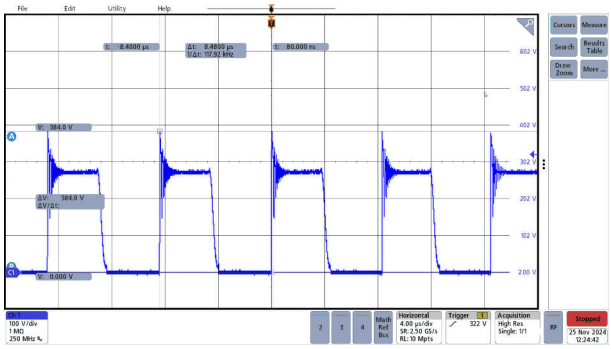


Figure 3-15. 115VAC, 20V, 3.25A Full Load, Vds_pri, fsw = 118kHz

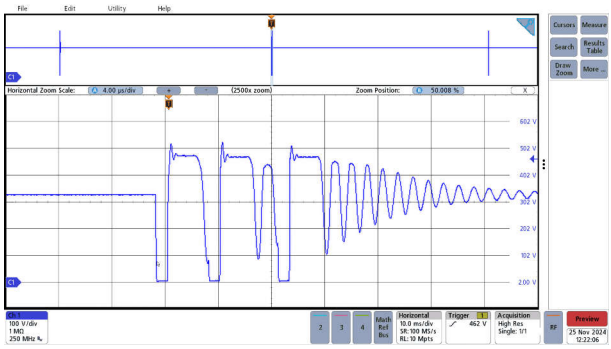


Figure 3-16. 115VAC, 20V, 2.45A 75% Load, Vds_pri, fsw = 127kHz

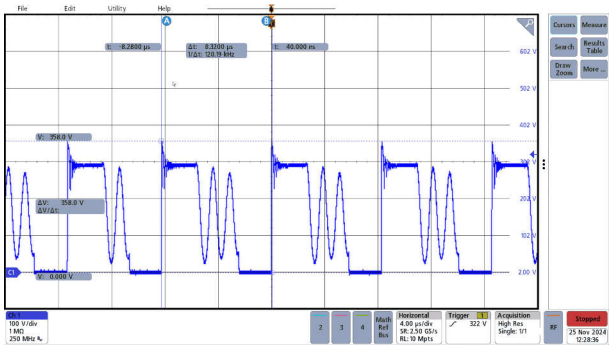


Figure 3-17. 115VAC, 20V, 1.8A 50% Load, Vds_pri, fsw = 120kHz

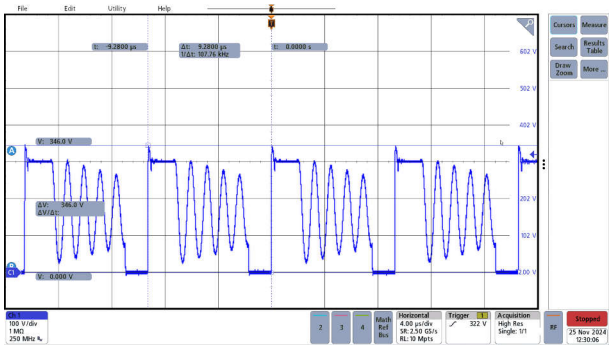


Figure 3-18. 115VAC, 20V, 0.82A 25% Load, Vds_pri, fsw = 107kHz

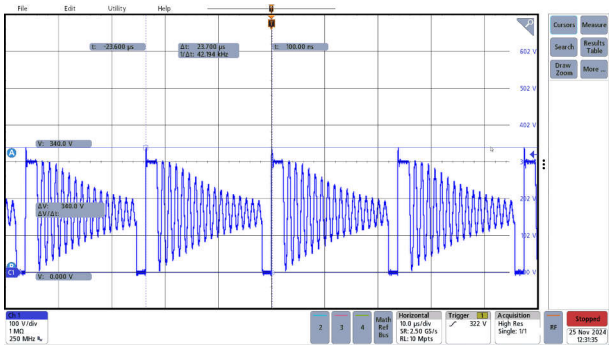


Figure 3-19. 115VAC, 20V, 0.32A 10% Load, Vds_pri, fsw = 42kHz

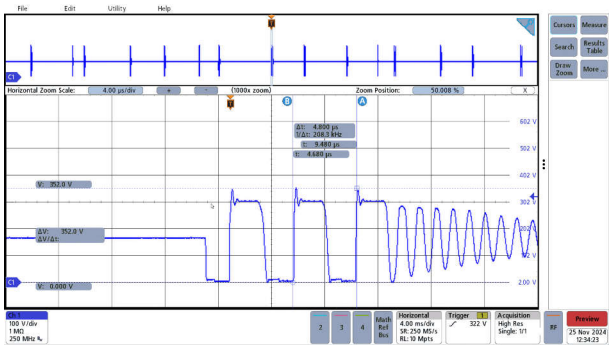


Figure 3-20. 115VAC, 20V, 200mW Load, Vds_pri

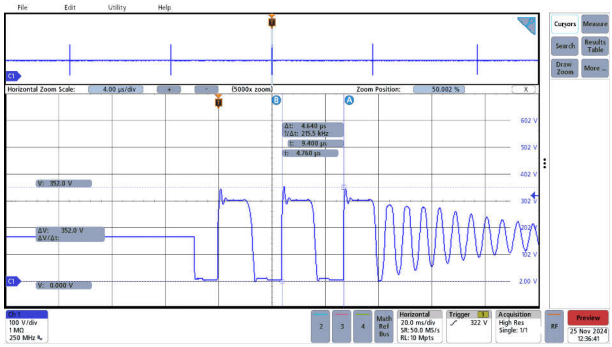


Figure 3-21. 115VAC, 20V, Open Load, Vds_pri, 3 Consecutive Switching Cycles to Achieve First Valley Switching

3.2.1 Voltage Stress

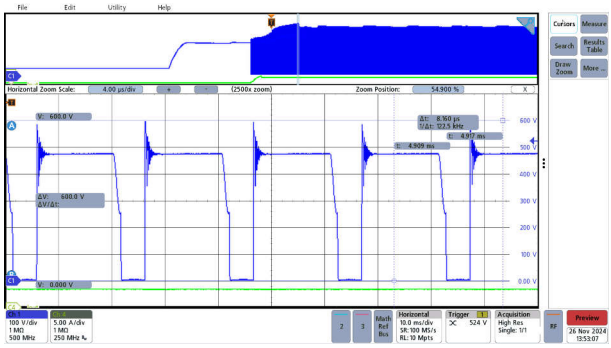


Figure 3-22. 264VAC, Full Load, Vds Peak = 600V

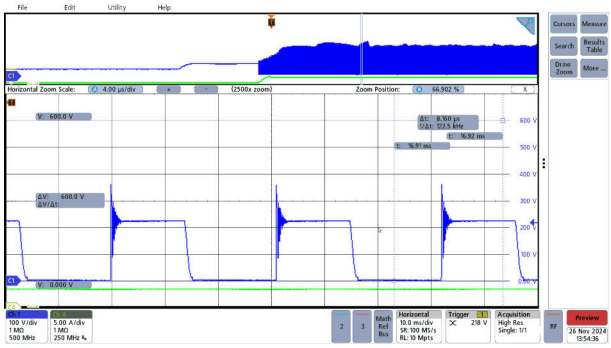


Figure 3-23. 90VAC, Full Load, Vds Peak = 360V

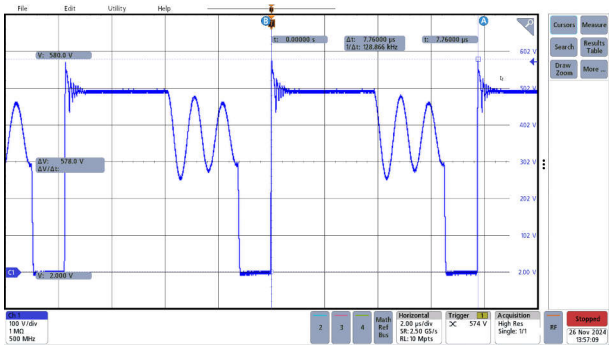


Figure 3-24. 264VAC, Full Load, Steady State Vds Primary 580V

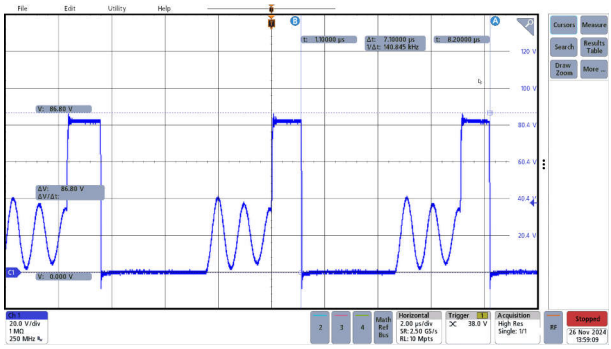


Figure 3-25. 264VAC, Full Load, Vds on Synchronous Rectifier 86.8V

3.3 VCC Self Bias

VCC was regulated across AC input and load condition. Figure 3-26 through Figure 3-31 show VCC waveforms.

CH1: Vds, CH2: VCC, CH3: HV Pin, CH4: I_{out}

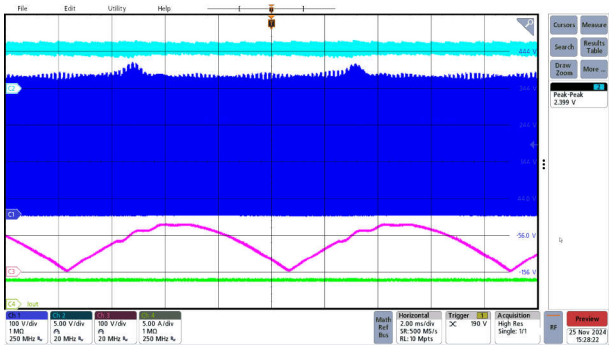


Figure 3-26. VCC Voltage, 90VAC, Full Load

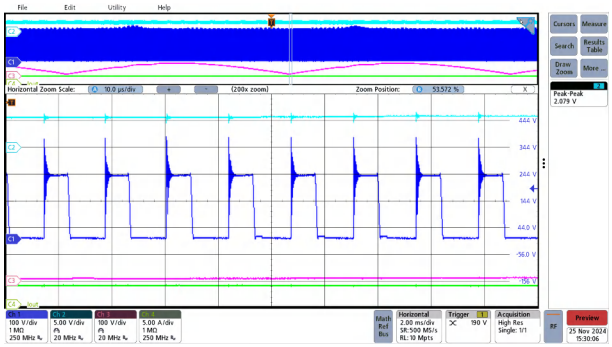


Figure 3-27. VCC Voltage, 90VAC, Full Load, Zoom in at VBUS Valley

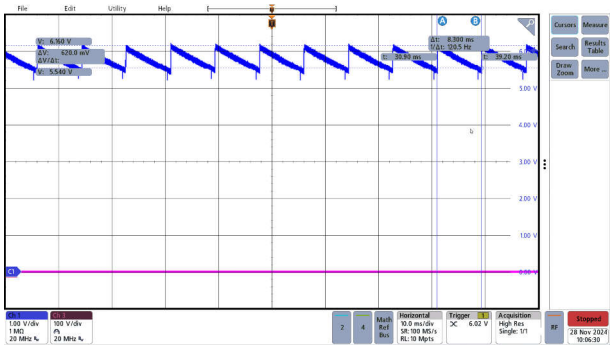


Figure 3-28. VCC Voltage, 115VAC, Open Load, VCC Charging at Around 120Hz Frequency

Figure 3-29 through Figure 3-31 shows VCC at 230VAC input.

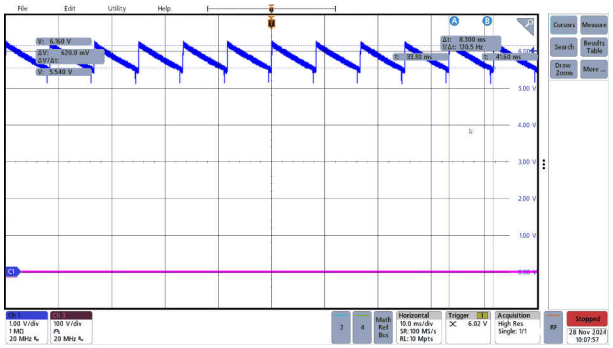


Figure 3-29. VCC Voltage, 230VAC, Open Load, VCC Charging at Around 120Hz Frequency

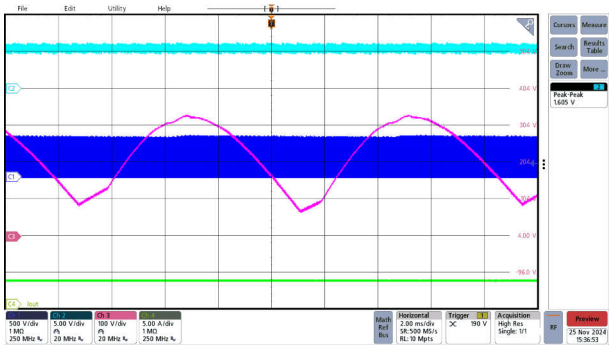


Figure 3-30. VCC Voltage, 230VAC, Full Load

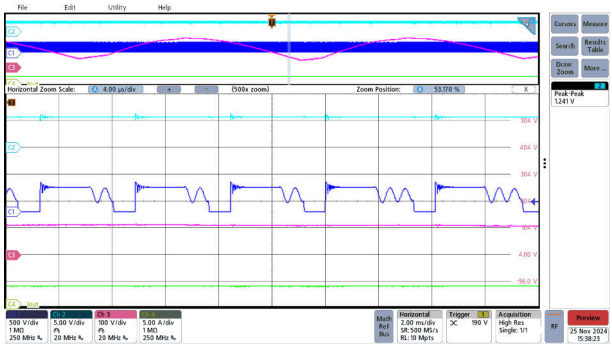


Figure 3-31. VCC Voltage, 230VAC, Full Load, Zoom-In

3.4 Output Voltage Ripple

Output voltage ripple is shown in Figure 3-32 through Figure 3-39.

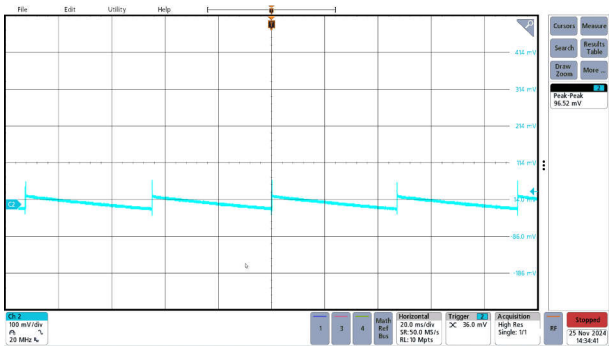


Figure 3-32. Output Voltage Ripple, 115VAC, Open Load

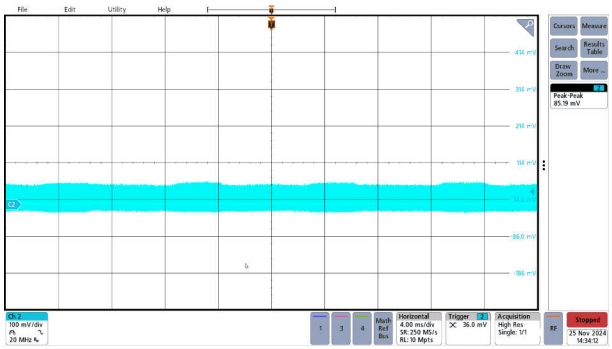


Figure 3-33. Output Voltage Ripple, 115VAC, 10% Load 0.33A

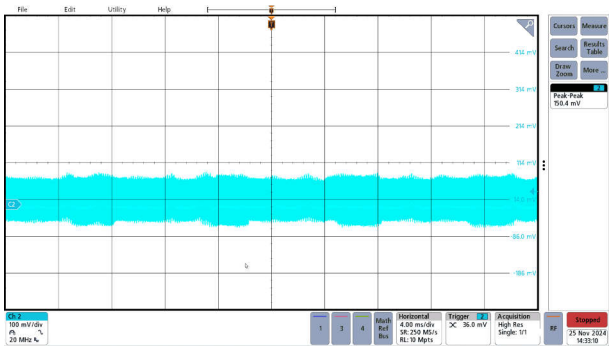


Figure 3-34. Output Voltage Ripple, 115VAC, 50% Load 1.62A

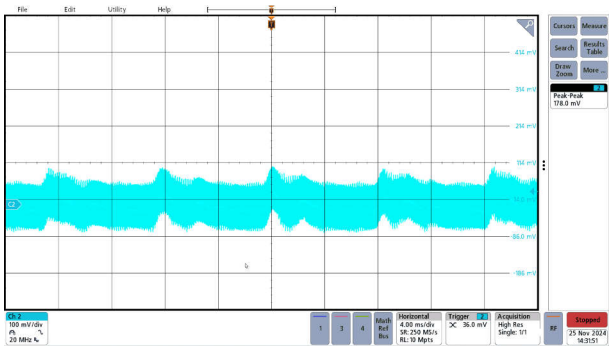


Figure 3-35. Output Voltage Ripple, 115VAC, 100% Load, 3.25A

Figure 3-36 through Figure 3-39 are tested at 230VAC.

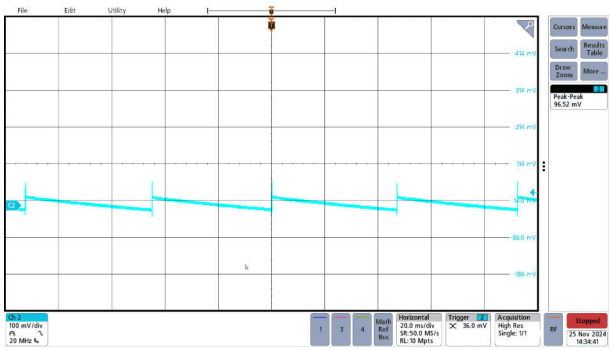


Figure 3-36. Output Voltage Ripple, 230VAC, Open Load

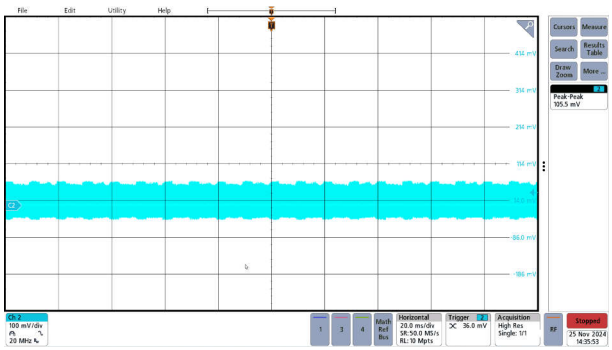


Figure 3-37. Output Voltage Ripple, 230VAC, 10% Load 0.33A

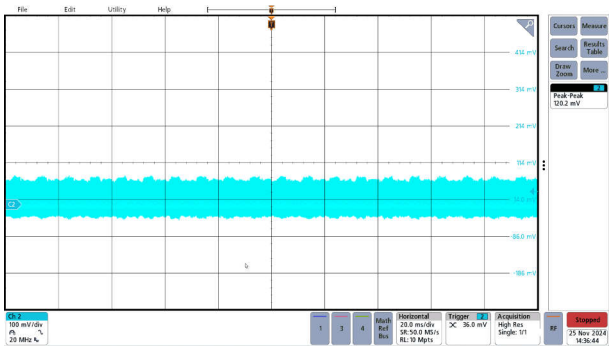


Figure 3-38. Output Voltage Ripple, 230VAC, 50% Load 1.6A

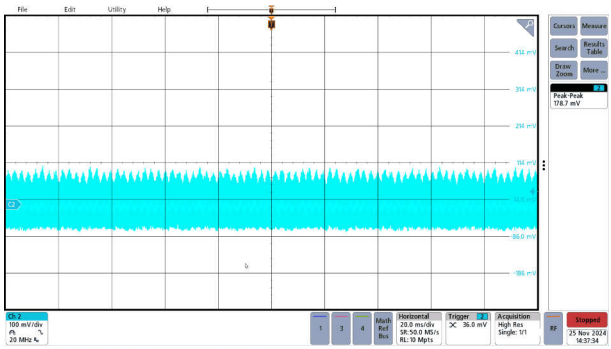


Figure 3-39. Output Voltage Ripple, 230VAC, 100% Load 3.25A

3.5 Load Dynamic Response

The load dynamic test was performed from 0.1A to full load, 3.25A. Output voltage was measured at the PCB end.

CH2: V_{out}, CH4: I_{out}

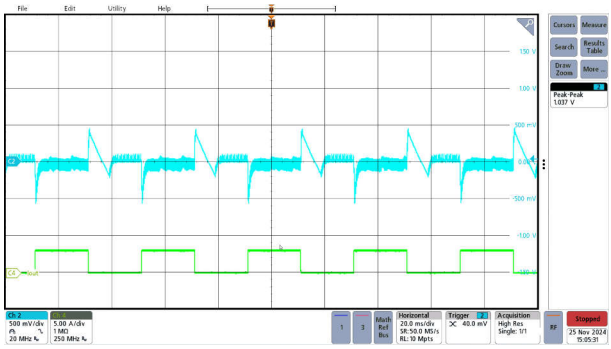


Figure 3-40. Load Transient, 115VAC, 0.1A to 3.25A Full Load

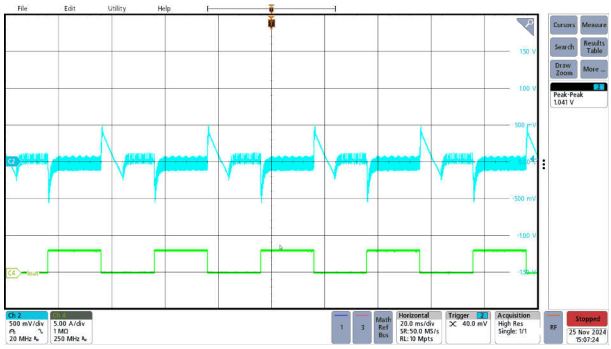


Figure 3-41. Load Transient, 230VAC, 0.1A to 3.25A Full Load

3.6 Peak Power

Peak power test was performed by setting the peak power to 1.5 times rated power (100W) for 4ms followed by 36ms 0.9 times rated power (58W).

CH1: Vds_pri, CH2: V_{out}, C4:I_{out}

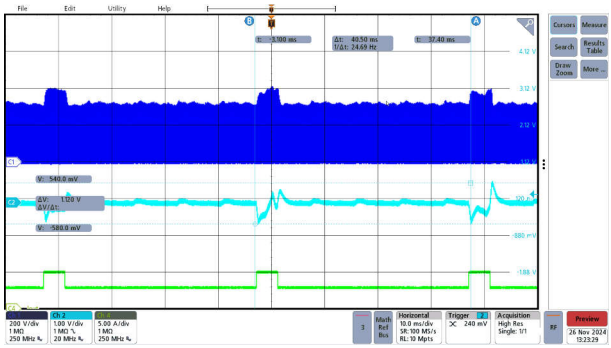


Figure 3-42. Peak Power, 90VAC, 100W Peak Power 4ms, 58W 36ms, V_{out} Drop 0.58V

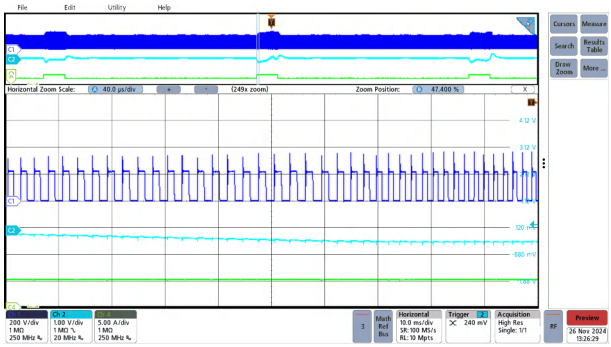


Figure 3-43. Peak Power, 90VAC, 100W Peak Power 4ms, 58W 36ms, Zoom In, fsw Increase to Provide Peak Power

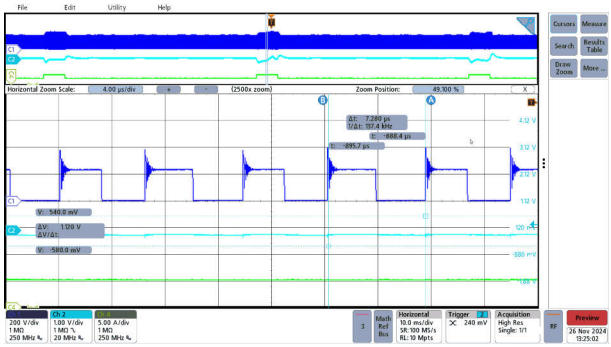


Figure 3-44. Peak Power, 90VAC, 100W Peak Power 4ms, 58W 36ms, Zoom In, CCM Mode to Provide Peak Power With fsw Increased to 137KHz

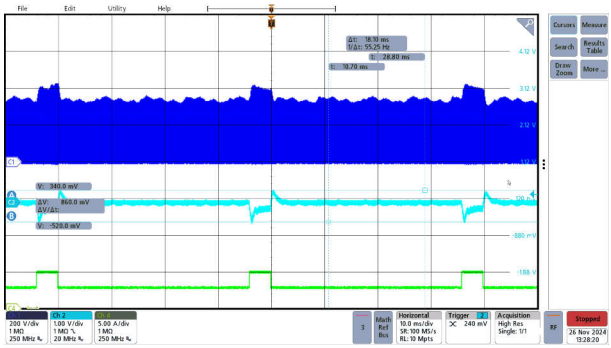


Figure 3-45. Peak Power, 115VAC, 100W Peak Power 4ms, 58W 36ms, V_{out} Drop 520mV

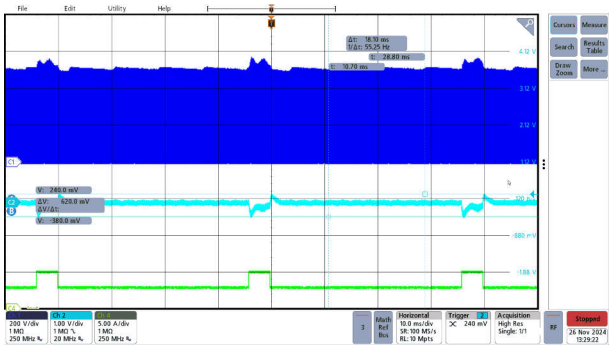


Figure 3-46. Peak Power, 230VAC, 100W Peak Power 4ms, 58W 36ms, V_{out} Drop 380mV

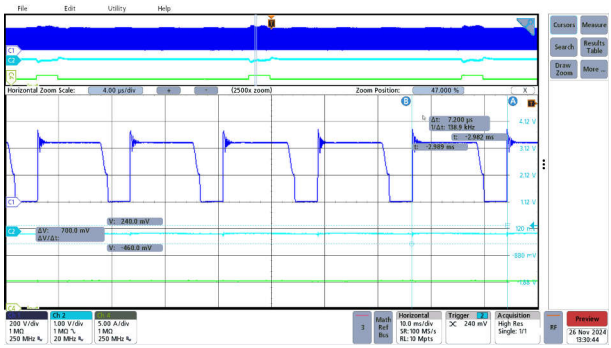


Figure 3-47. Peak Power, 230VAC, 100W Peak Power 4ms, 58W 36ms, V_{out} Drop 380mV, Zoom In

3.7 Short-Circuit Protection

Short-circuit protection was performed at PCB board end. Auto recovery after short was removed.

CH1: Vds primary, CH2:VCC, CH3: V_{out}, CH4: I_{out}

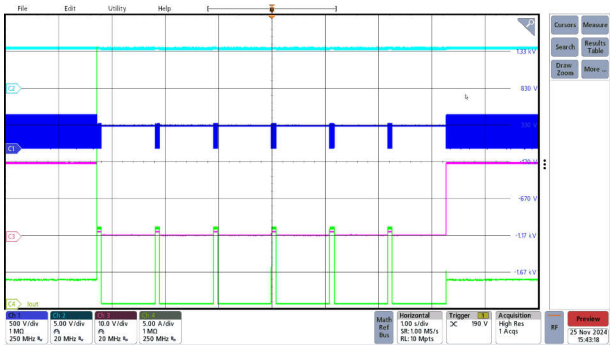


Figure 3-48. Short Circuit at PCB End and Recovery When Short Circuit Removed, 264VAC

3.8 Output Over Voltage 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.

CH2: Vout, CH4: Vds primary switching

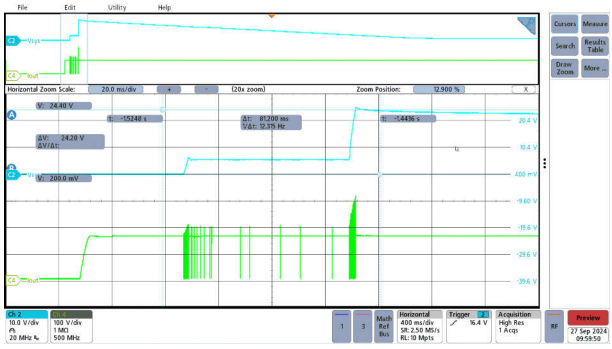


Figure 3-49. 264VAC, OVP, Open Load

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265