Test Report: PMP41015

40W AC-DC Isolated Power Supply Reference Design for Industrial PLC Application

Description

This reference design provides 40W isolated 24V and 5V output with flyback topology. The power supply can be powered from 85VAC to 264VAC input. This design uses the UCC28740 valley-switching, flyback controller. A peak efficiency of 84.99% is reached and the device supports a 2400µF capacitive load with a start-up time of less than 611ms. The board is a single-side component placement PCB design which reduces manufacturing costs.

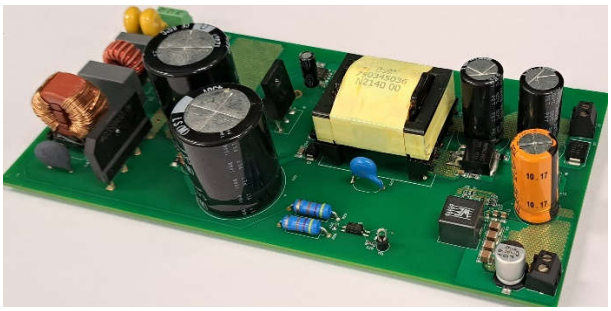
Features

- Universal AC input range: 85VAC to 264VAC
- 84.99% Efficiency at full load
- Start-up time < 611ms at 2400µF output capacitive full-load condition
- Provides AC zero-crossing signal
- Single-sided mounting PCB design
- Verified EMI performance

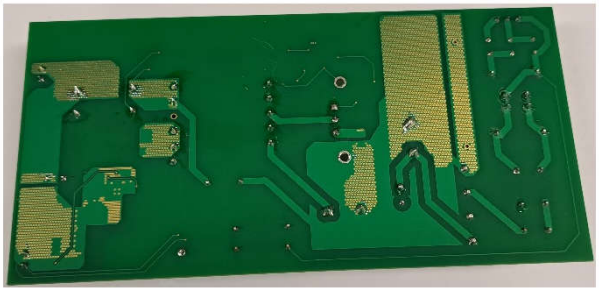
Applications

- CPU (PLC Controller)
- Industrial AC-DC
- Refrigerator and freezer

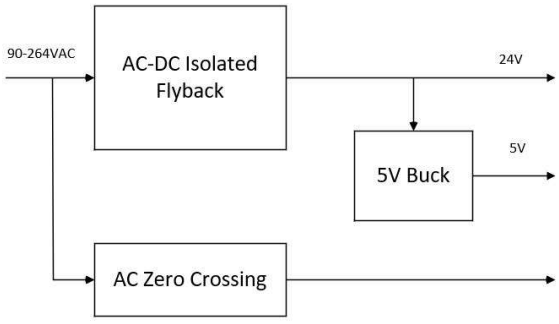
Top View



Angle View



Bottom View



System Block Diagram

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1 shows the voltage and current specification of this reference design.

Table 1-1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input voltage range	85V to 264Vac
Output voltage, Current	24V at 1.5A, 5V at 1.1A
Maximum power	40W
Switching frequency	70kHz at full load

1.2 Required Equipment

- DC Source: IT-M3906D-1500-12
- Chroma DC Source: 62024P-600-8
- Electronic load: Chroma, 6314A
- Oscilloscope: Tektronix, DPO 3054
- Infrared Thermal Camera: Fluke, TiS55
- Ture-RMS-Multimeter: Fluke, 287C
- Digital Power Meter: Yokogawa WT310

1.3 Considerations

The reference design shows an example of an isolated AC/DC transformer that converts 85VAC–264VAC to 24VDC and 5VDC with AC zero crossing. This design can be used in CPU (PLC Controller), Industrial AC-DC ,and Refrigerator and freezer designs as well as various other electronic systems. This design provides overcurrent protection (OCP) and short-circuit protection (SCP) to improve the reliability.

1.4 Dimensions

Board size: 173mm × 85mm × 33mm (open frame).

1.5 Test Setup

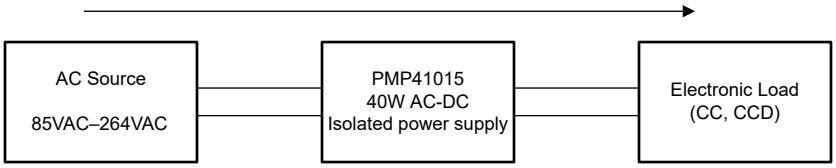


Figure 1-1. Test Setup

2 Testing and Results

2.1 Efficiency Graphs

Figure 2-1 shows the efficiency across different load and input voltage.

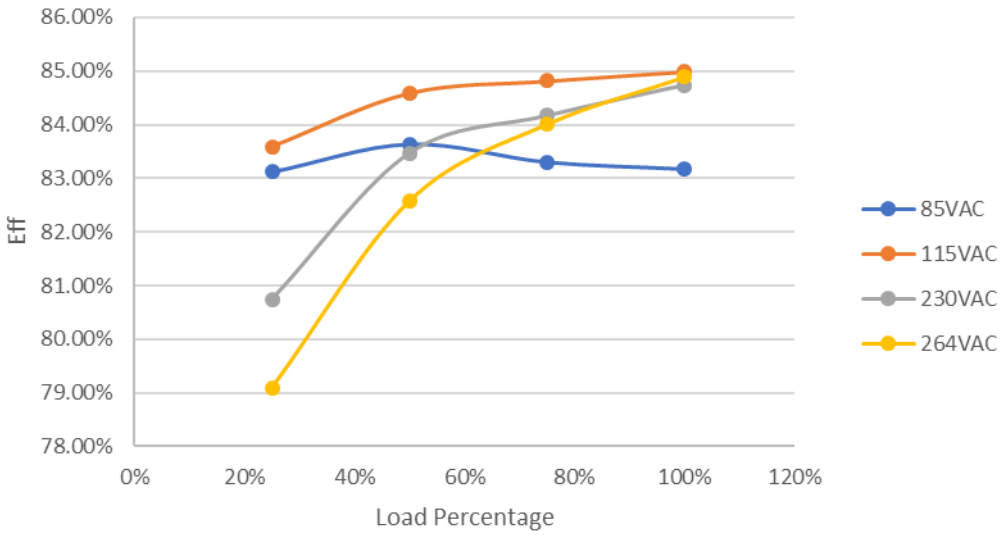


Figure 2-1. Efficiency Across Load At 85VAC, 115VAC, 230VAC, and 264VAC

2.2 Efficiency Data

Table 2-1 through Table 2-4 show the efficiency data at 85VAC, 115VAC, 230VAC, and 264VAC.

Table 2-1. Efficiency Data at 85VAC

V_{IN} (V)	I_{IN} (A)	V_{OUT_24V} (V)	I_{OUT_24V} (A)	V_{OUT_5V} (V)	I_{OUT_5V} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
85	0.0626	24.09	0	5.2450	0	0.14	0	0.14	0
85	0.3085	24.08	0.375	5.2025	0.2662	12.53	10.41	2.12	83.12
85	0.5616	24.06	0.75	5.1875	0.5362	24.90	20.83	4.07	83.64
85	0.8291	24.06	1.125	5.1775	0.8025	37.48	31.22	6.26	83.30
85	1.1013	24.06	1.5	5.1675	1.0687	50.03	41.61	8.42	83.18

Table 2-2. Efficiency Data at 115VAC

V_{IN} (V)	I_{IN} (A)	V_{OUT_24V} (V)	I_{OUT_24V} (A)	V_{OUT_5V} (V)	I_{OUT_5V} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
115	0.0797	24.09	0	5.2450	0	0.21	0	0.21	0
115	0.2554	24.08	0.376	5.2050	0.2662	12.49	10.44	2.05	83.58
115	0.4445	24.06	0.75	5.1875	0.5362	24.62	20.83	3.79	84.59
115	0.6355	24.06	1.126	5.1775	0.8025	36.84	31.25	5.59	84.82
115	0.8361	24.06	1.5	5.1675	1.0687	48.96	41.61	7.35	84.99

Table 2-3. Efficiency Data at 230VAC

V_{IN} (V)	I_{IN} (A)	V_{OUT_24V} (V)	I_{OUT_24V} (A)	V_{OUT_5V} (V)	I_{OUT_5V} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
230	0.1190	24.09	0	5.2450	0	0.68	0	0.68	0
230	0.1909	24.08	0.377	5.2050	0.2662	12.96	10.46	2.50	80.74
230	0.2935	24.05	0.75	5.1850	0.5362	24.94	20.82	4.12	83.47
230	0.4022	24.05	1.126	5.1775	0.8025	37.11	31.24	5.87	84.17
230	0.5074	24.04	1.5	5.1675	1.0687	49.07	41.58	7.49	84.74

Table 2-4. Efficiency Data at 264VAC

V_{IN} (V)	I_{IN} (A)	V_{OUT_24V} (V)	I_{OUT_24V} (A)	V_{OUT_5V} (V)	I_{OUT_5V} (A)	P_{IN} (W)	P_{OUT} (W)	P_{LOSS} (W)	Efficiency (%)
264	0.1215	24.09	0	5.2450	0	0.88	0	0.88	0
264	0.1826	24.08	0.377	5.2050	0.2662	13.23	10.46	2.77	79.09
264	0.2742	24.05	0.75	5.1875	0.5362	25.21	20.82	4.39	82.58
264	0.3703	24.05	1.126	5.1775	0.8025	37.18	31.24	5.94	84.01
264	0.4636	24.04	1.5	5.1650	1.0687	48.98	41.58	7.40	84.89

2.3 Output Voltage Regulation Graphs

Figure 2-2 and Figure 2-3 show output voltage across different loads and input voltages.

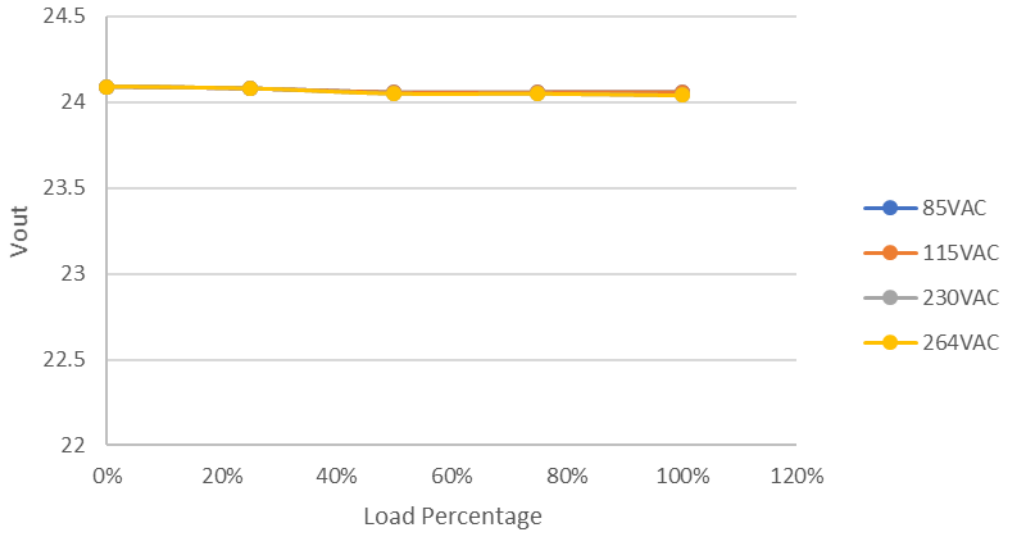


Figure 2-2. Output Voltage 24V Across Load at 85VAC, 115VAC, 230VAC, and 264 VAC

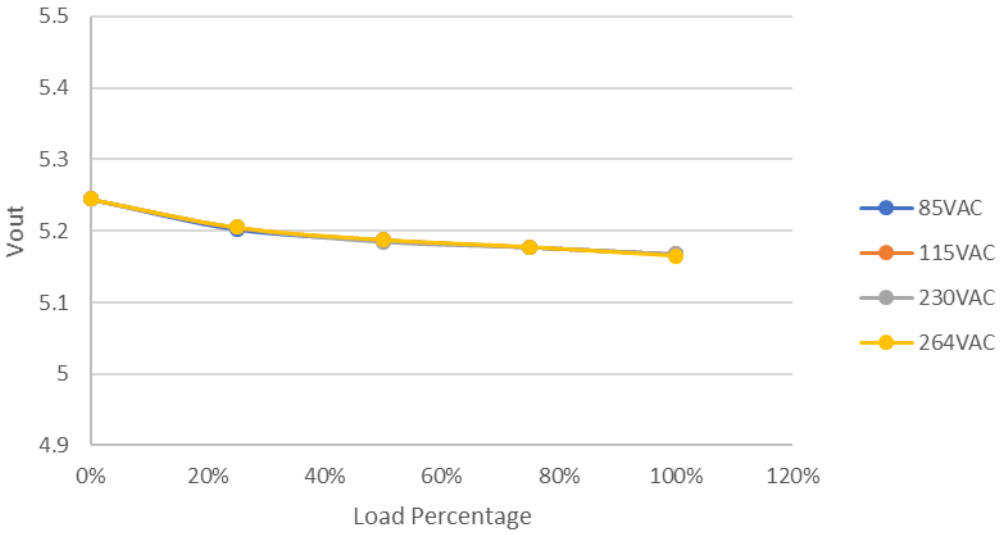


Figure 2-3. Output Voltage 5V Across Load at 85VAC, 115VAC, 230VAC, and 264VAC

2.4 Thermal Images

Table 2-5 shows the temperature data with 25ºC ambient after a 30-minute warm up.

Table 2-5. Temperature Data

TEMPERATURE (°C)	TEST CONDITION FULL LOAD	
	115VAC	230VAC
Primary switch	90.5	87.8
Secondary diode	59	60
Transformer	62.2	60.3
Bridge	50	49
UCC28740	36	36
LMR33620ADDAR	76	75

Figure 2-4 and Figure 2-5 show the thermal images, all images were captured with 25ºC ambient, after a 30-minute warm up.

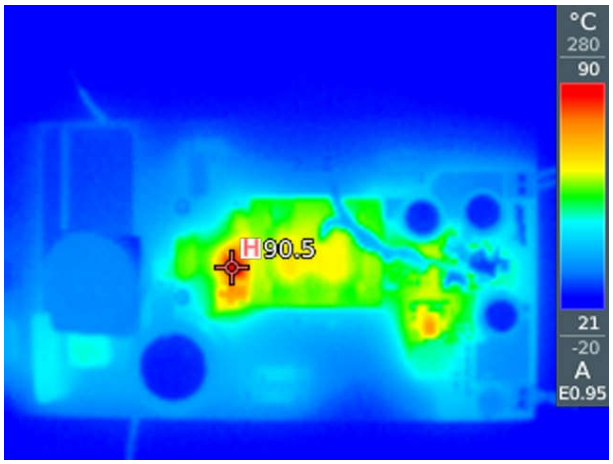


Figure 2-4. Thermal Image at 115VAC, Full Load

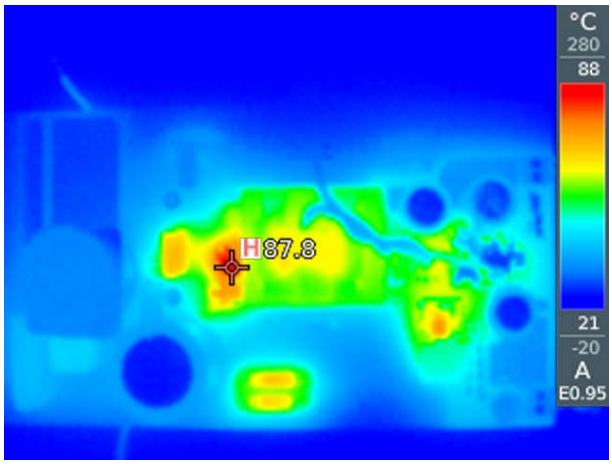


Figure 2-5. Thermal Image at 230VAC, Full Load

2.5 EMI

Figure 2-6 and Figure 2-7 show the conducted EMI results.

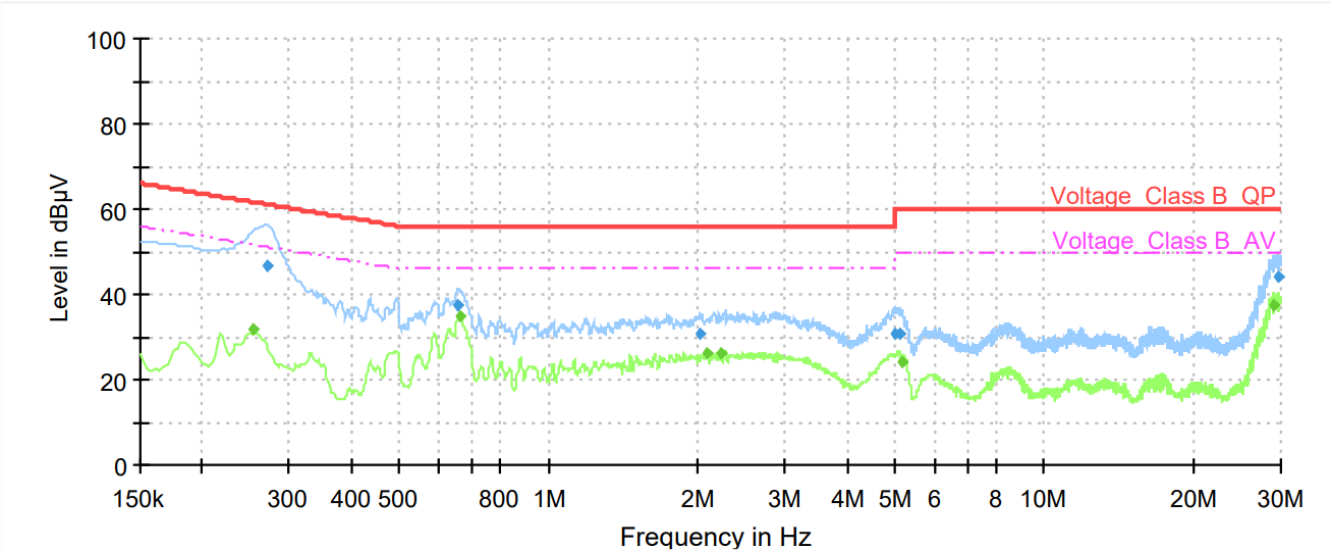


Figure 2-6. 115VAC, Full Load

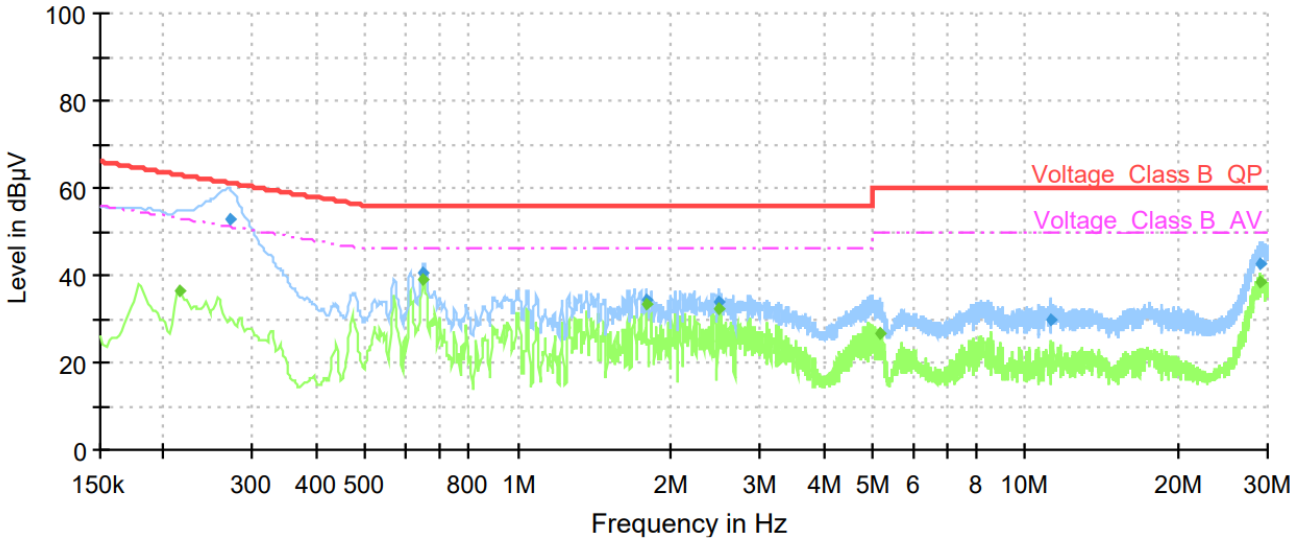


Figure 2-7. 230VAC, Full Load

3 Waveforms

3.1 Switching

Figure 3-1 through Figure 3-4 show the V_{ds} (drain and source) switching waveform at 85VAC and 264VAC, full load.

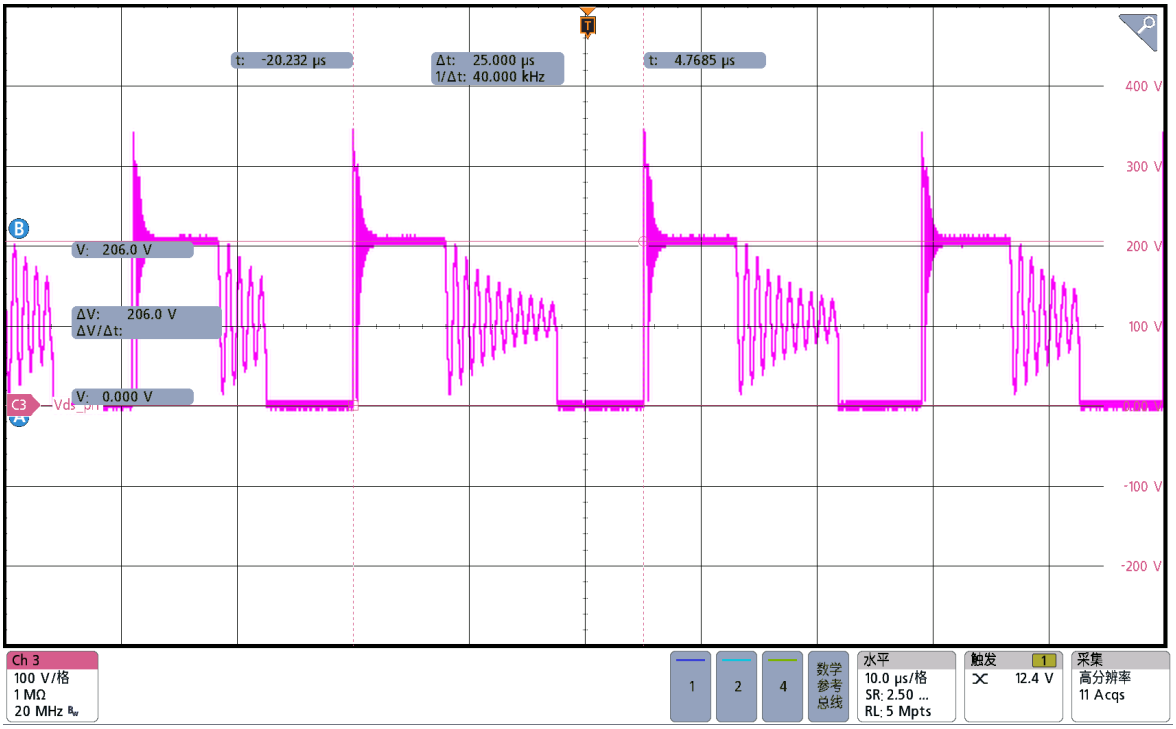


Figure 3-1. V_{ds_pri} Waveform, 85VAC, Full Load

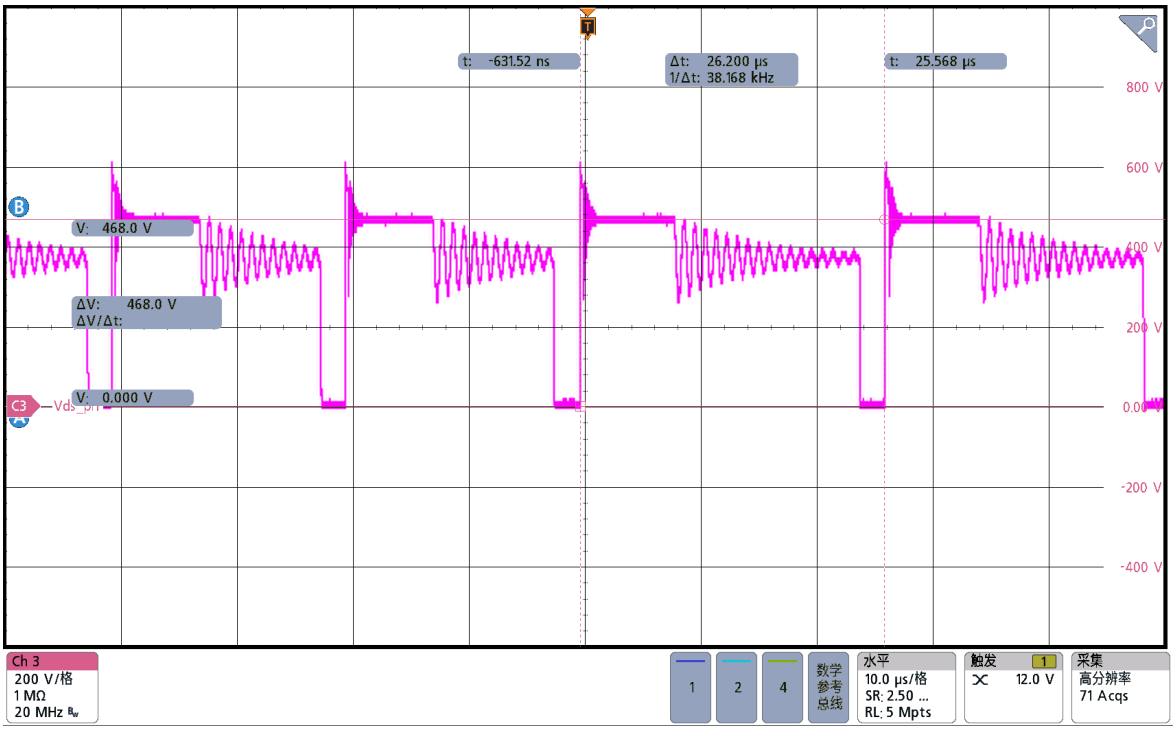


Figure 3-2. V_{ds_pri} Waveform, 264VAC, Full Load

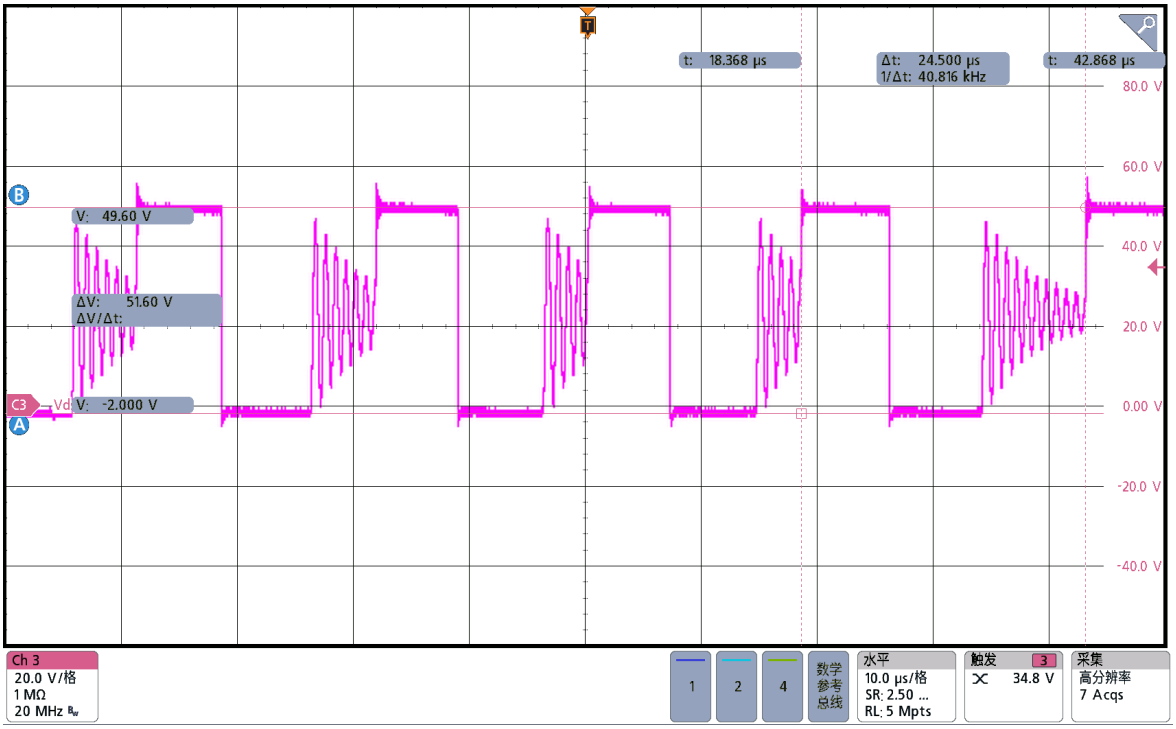


Figure 3-3. V_{ds_sec} Waveform, 85VAC, Full Load

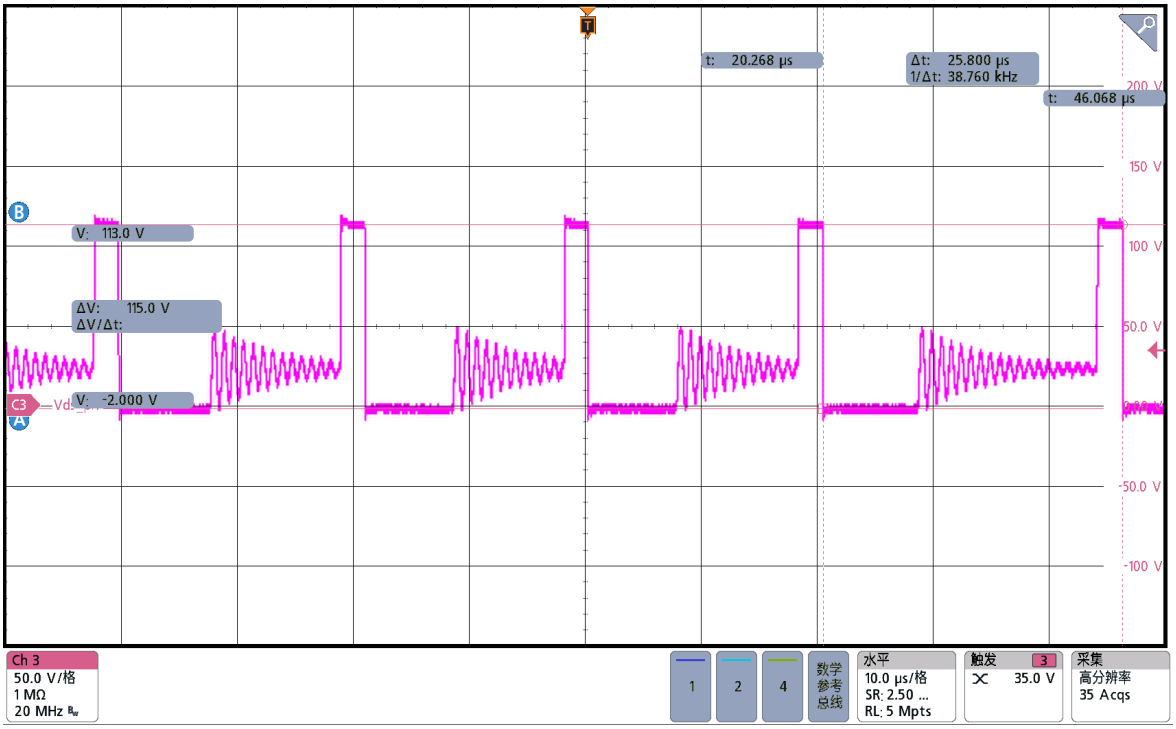


Figure 3-4. V_{ds_sec} Waveform, 264VAC, Full Load

3.2 Output Voltage Ripple

Figure 3-5 through Figure 3-12 show output voltage Ripple waveform at different input voltage and load.

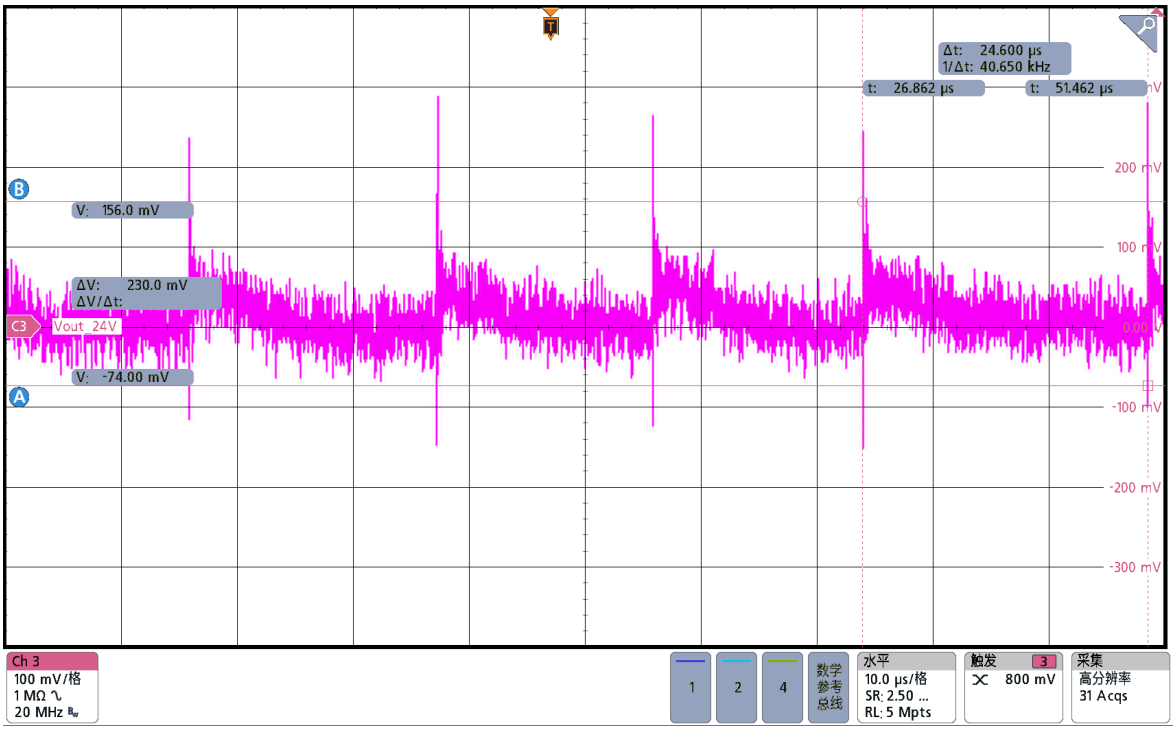


Figure 3-5. Output Voltage Ripple Waveform, 24VDC, 115VAC, Full Load

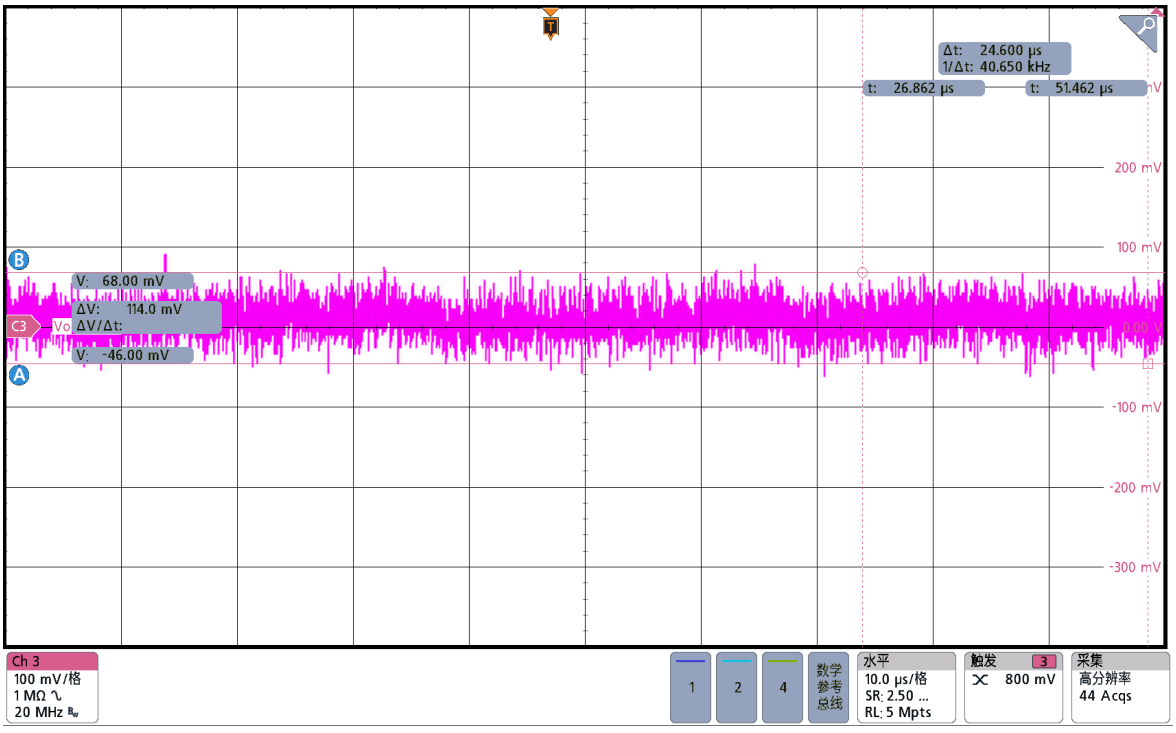


Figure 3-6. Output Voltage Ripple Waveform, 24VDC, 115VAC, Open Load

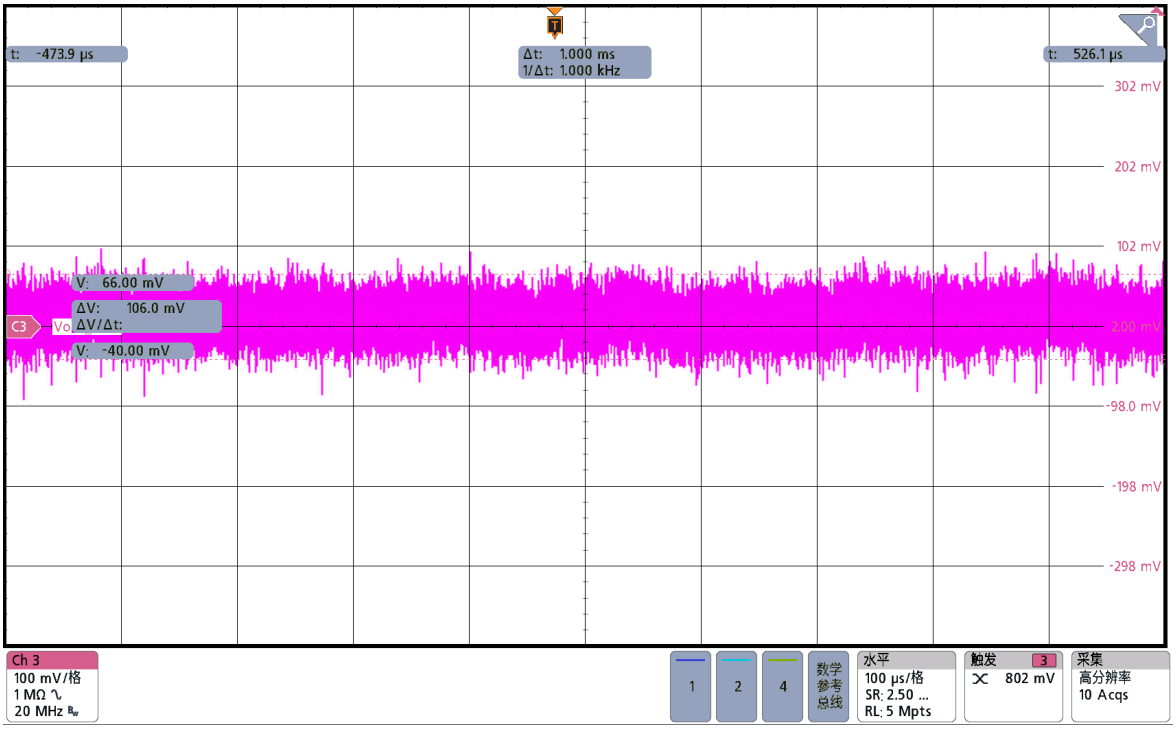


Figure 3-7. Output Voltage Ripple Waveform, 5VDC, 115VAC, Full Load

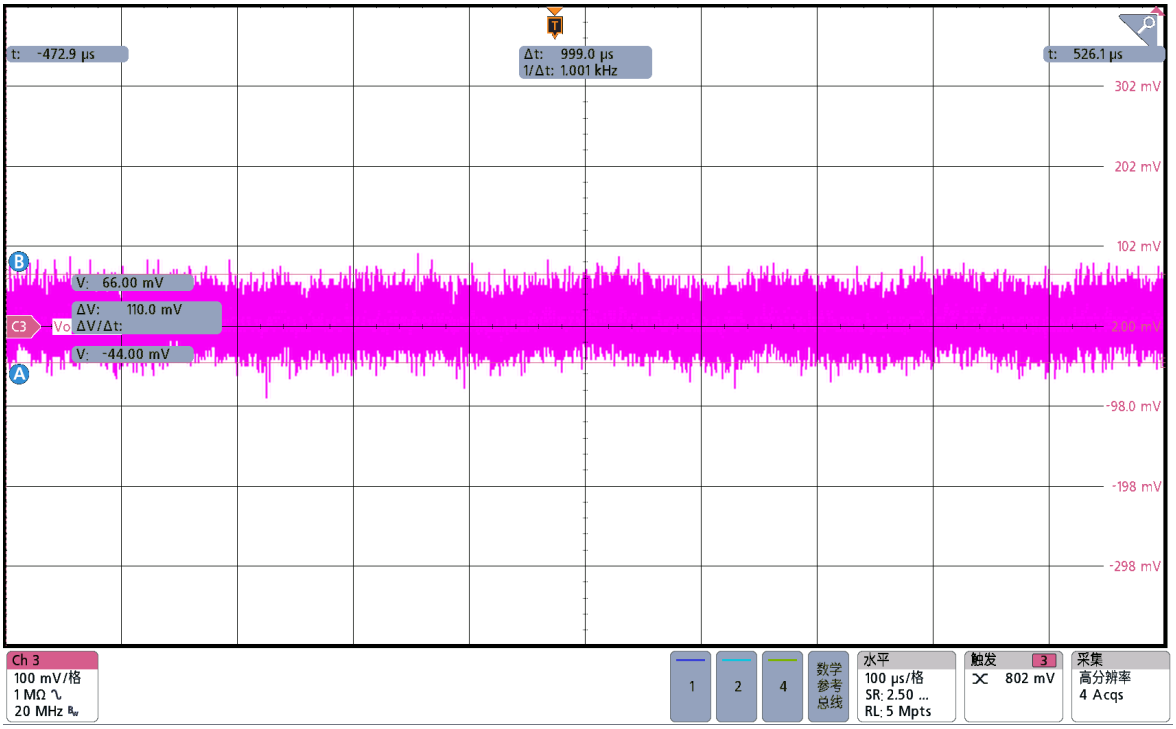


Figure 3-8. Output Voltage Ripple Waveform, 5VDC, 115VAC, Open Load

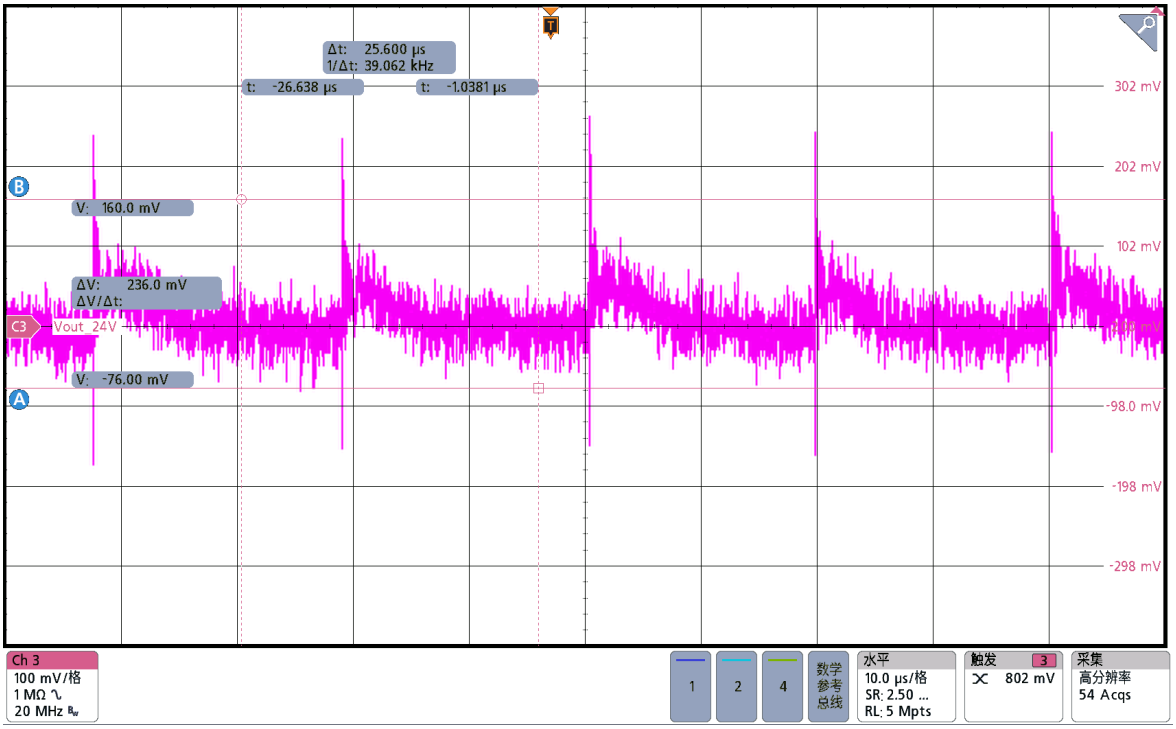


Figure 3-9. Output Voltage Ripple Waveform, 24VDC, 230VAC, Full Load

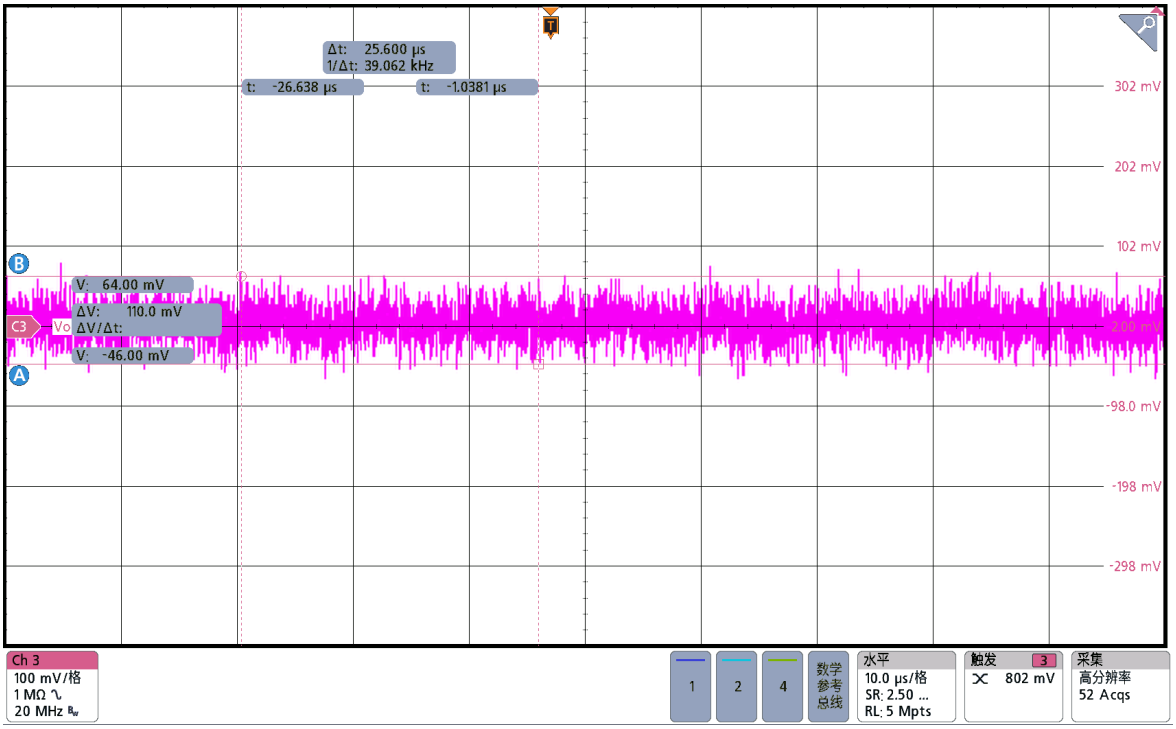


Figure 3-10. Output Voltage Ripple Waveform, 24VDC, 230VAC, Open Load

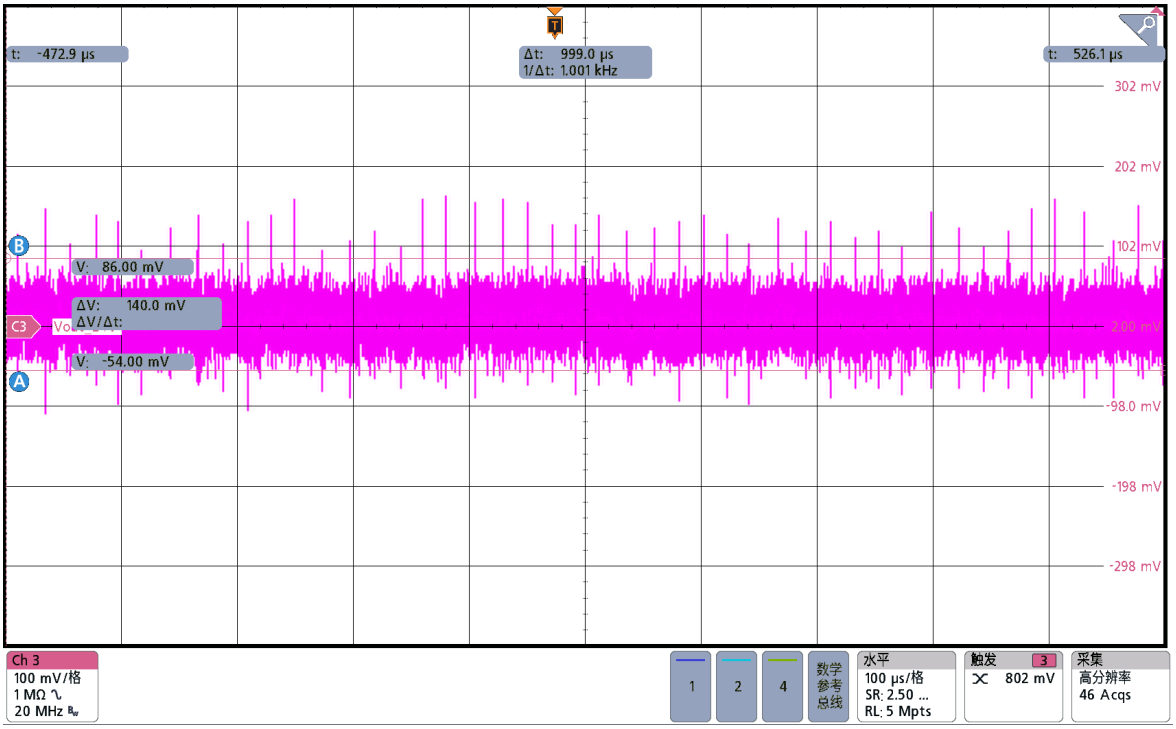


Figure 3-11. Output Voltage Ripple Waveform, 5VDC, 230VAC, Full Load

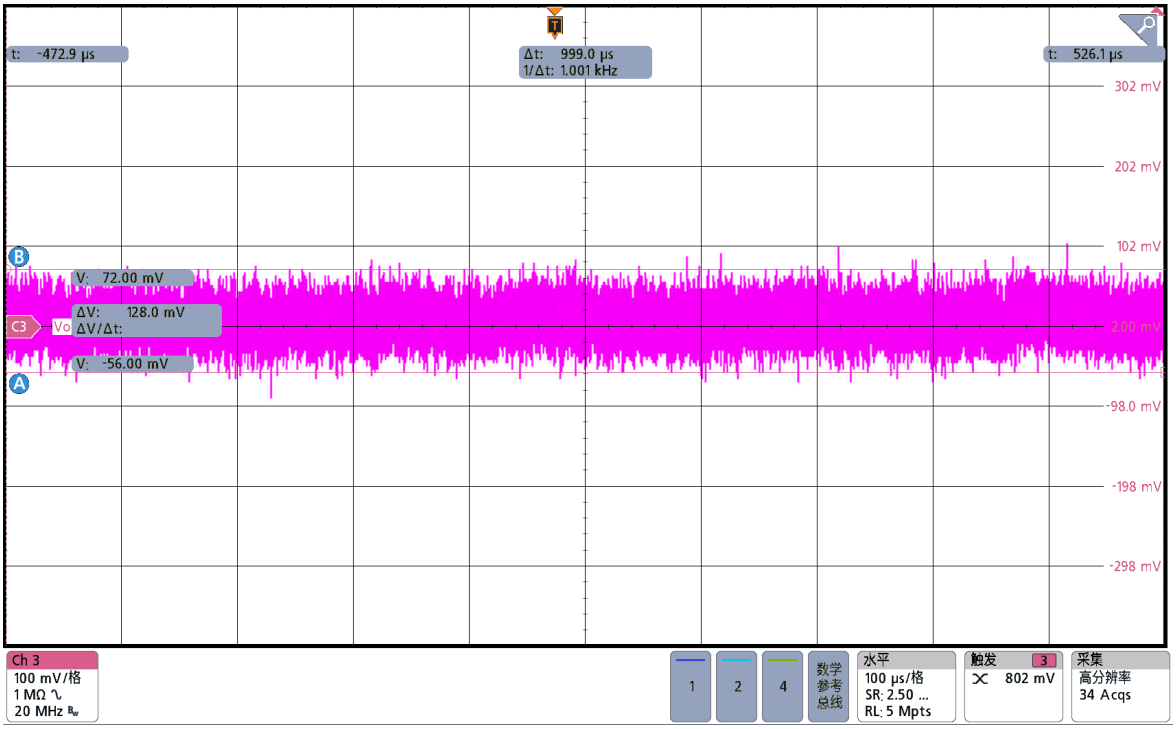


Figure 3-12. Output Voltage Ripple Waveform, 5VDC, 230VAC, Full Load

3.3 Load Transients

Figure 3-13 and Figure 3-14 show load transient waveforms between 0% and 100% at 115VAC and 230VAC.

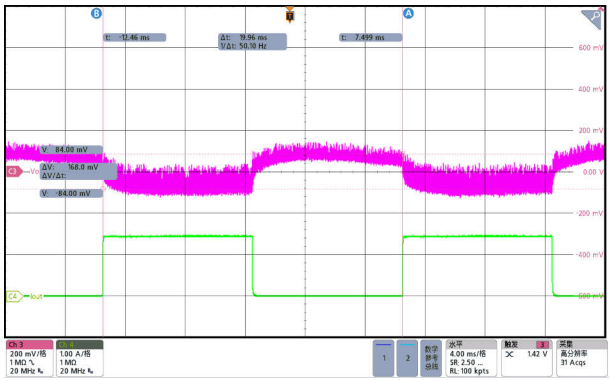


Figure 3-13. Output Voltage Start-Up Waveform at 85VAC, Full Load

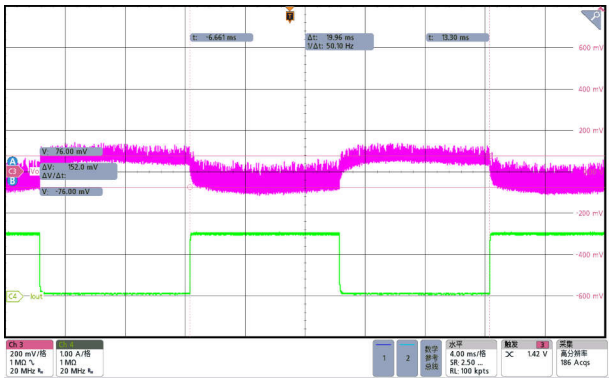


Figure 3-14. Output Voltage V_{OUT} and Output Current I_{OUT} Waveform at Load Transient, 230VAC

3.4 Output Voltage Start-Up Sequence

Figure 3-15 through Figure 3-18 show the output voltage start-up waveform with different loads and input voltages.

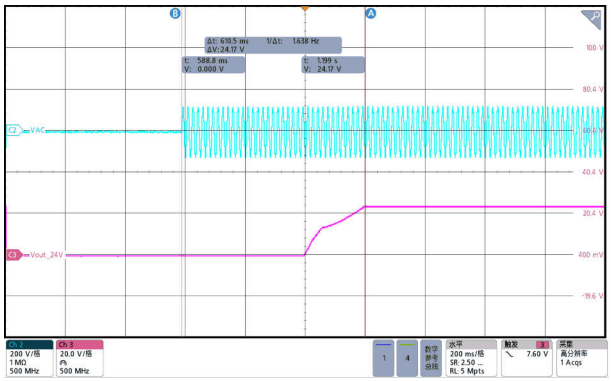


Figure 3-15. Output Voltage Start-Up Waveform at 85VAC, Full Load

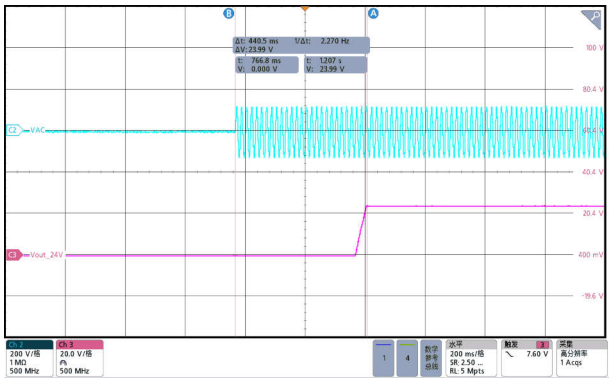


Figure 3-16. Output Voltage Start-Up Waveform at 85VAC, Open Load

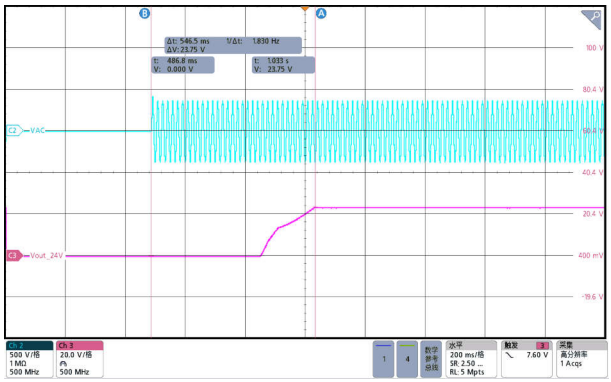


Figure 3-17. Output Voltage Start-Up Waveform at 264VAC, Full Load

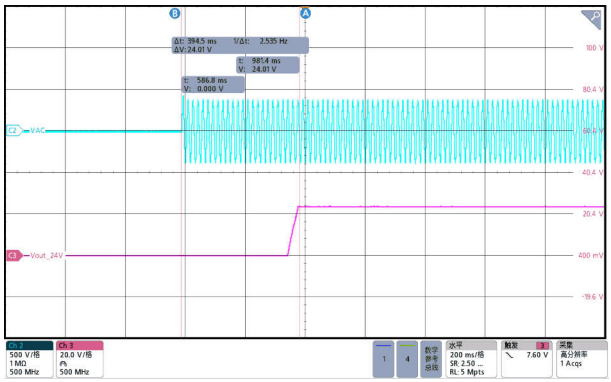


Figure 3-18. Output Voltage Start-Up Waveform at 264VAC, Open Load

3.5 Overcurrent Protection (OCP)

Figure 3-19 and Figure 3-20 show the overcurrent protection waveform at 115VAC and 230VAC.

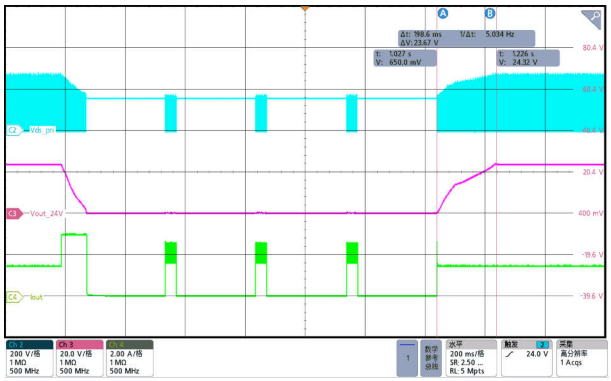


Figure 3-19. Overcurrent Waveform at 115VAC

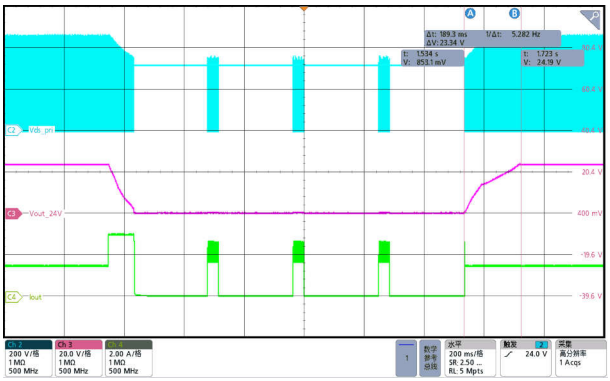


Figure 3-20. Overcurrent Waveform at 230VAC

3.6 Short-Circuit Protection (SCP)

Figure 3-21 and Figure 3-22 show the short-circuit protection waveform at 115VAC and 230VAC.

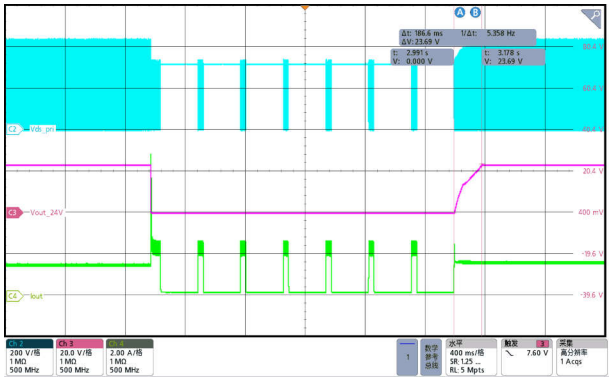


Figure 3-21. Short Circuit Waveform at 115VAC

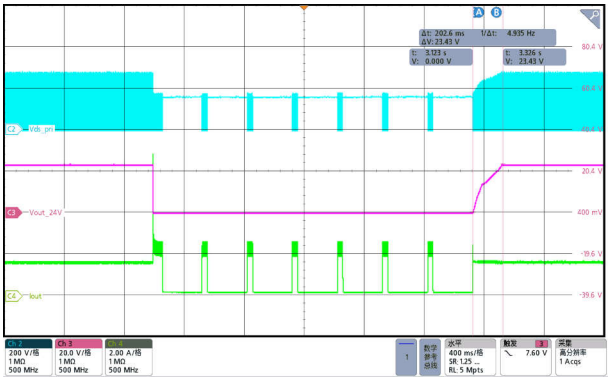


Figure 3-22. Short Circuit Waveform at 230VAC

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