Test Report: PMP23224

Universal Input, 220-W PFC, Active-Clamp, Flyback Battery Charger Reference Design

Description

This reference design is a 220-W, active clamp, flyback battery charger design with power factor correction (PFC) front end. The design takes a universal AC input (90 V to 264 V) and charges a battery with V_{OUT} range of 6 V to 22 V. There is an external constant current (CC), constant voltage (CV) loop on the board to accomplish the battery charging. The charge current is limited to 6 A for $V_{OUT} \leq 10$ V. If V_{OUT} is > 10 V, the charge current is 10 A.

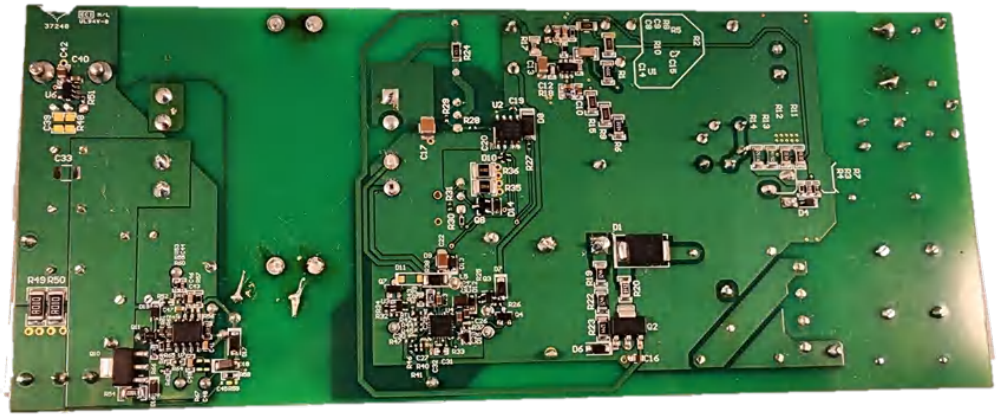
Features

- Universal Input
- PFC front end
- High efficiency; low power loss
- Passive cooling only – no fan needed
- Separate CC and CV loops to set the charge current and battery voltage
- Class B conducted EMI passed

Applications

- Mains powered tools

Top Board Photo



Bottom Board Photo

1 Test Prerequisites

1.1 Input Voltage Range and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage Range	90 VAC–264 VAC
Output Voltage, Current	6 V–22 V, 10 A

1.2 Required Equipment

- AC voltage source
- AC/DC power meter
- Electronic load
- Multimeters
- Oscilloscope

2 Testing and Results

2.1 Efficiency and Power Loss Graphs

Efficiency is shown in the following figures.

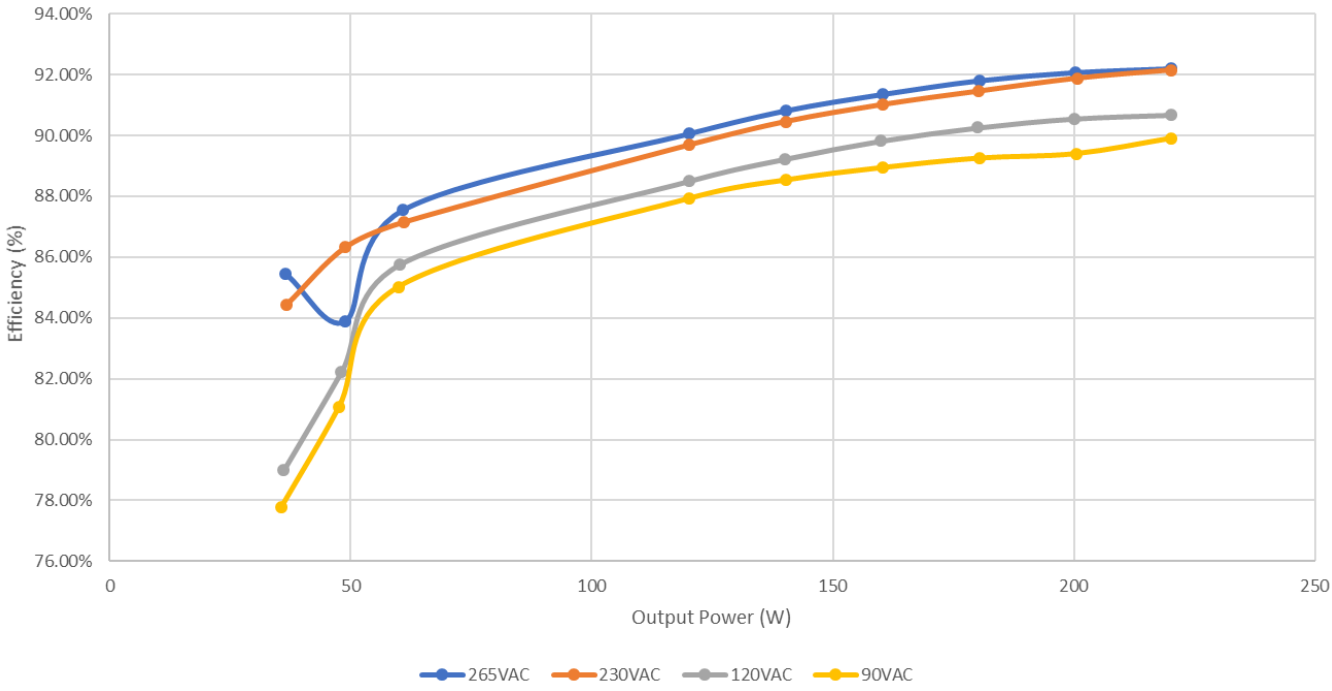


Figure 2-1. P_{OUT} vs Efficiency

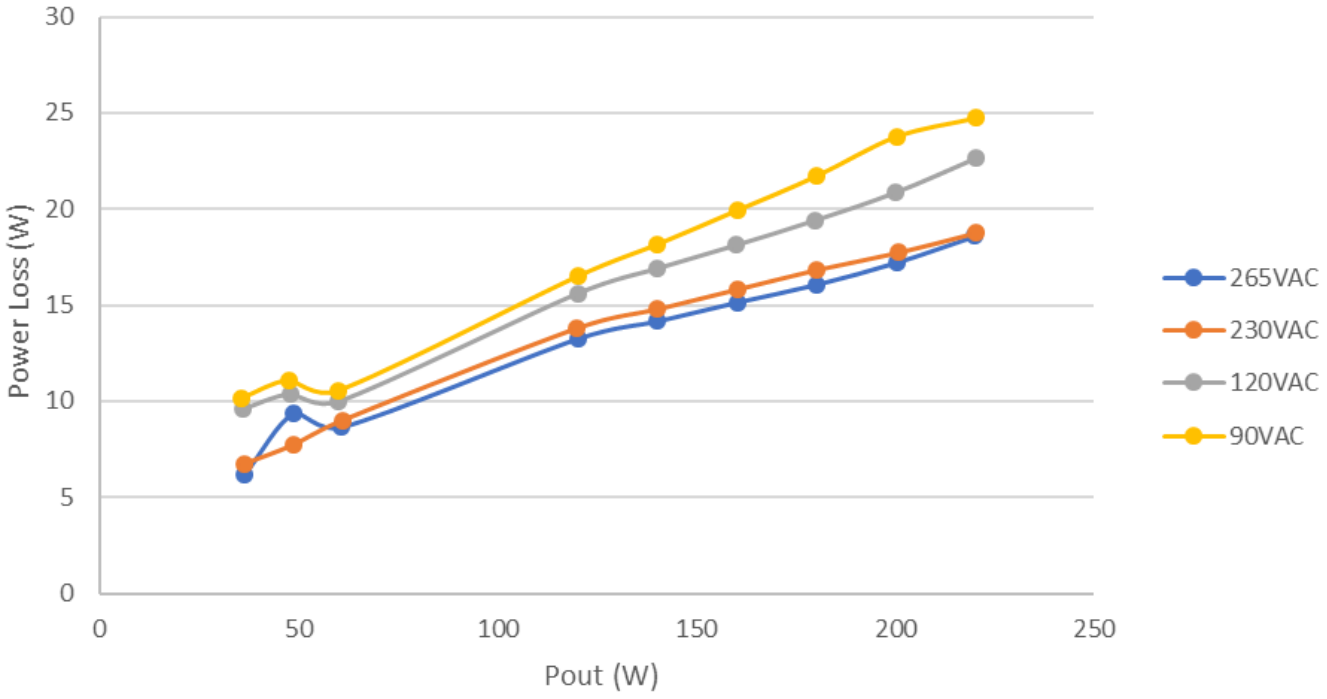


Figure 2-2. Power Loss

2.2 Efficiency Data

Efficiency data is shown in the following tables.

Table 2-1. Efficiency Data at V_{IN} = 90 V and V_{IN} = 95.5 V

V_{IN} (V)	P_{IN} (W)	PF	THD	V_{OUT} (V)	I_{OUT} (A)	P_{OUT} (W)	Efficiency (%)	P_{LOSS} (W)
90	45.65	0.979	9.8	6.002	5.915	35.502	77.77	10.148
90	58.63	0.984	9.356	8	5.942	47.536	81.08	11.094
90	70.44	0.987	9.658	10.012	5.982	59.892	85.03	10.548
90	136.7	0.986	15.39	11.992	10.023	120.196	87.93	16.504
90	158.43	0.989	12.04	13.998	10.02	140.26	88.53	18017
90	180.32	0.99	12.954	16.012	10.016	160.376	88.94	19.944
90	202.1	0.992	12.059	18.01	10.015	180.37	89.25	21.730
90	224.2	0.993	11.35	20.01	10.016	200.42	89.39	23.78
95.5	245	0.993	11.345	21.96	10.03	220.259	89.9	24.741

Table 2-2. Efficiency Data at V_{IN} = 120 V

V_{IN} (V)	P_{IN} (W)	PF	THD	VOUT(V)	I_{OUT} (A)	P_{OUT} (W)	Efficiency (%)	P_{LOSS} (W)
120	45.62	0.953	8.06	6.02	5.986	36.036	78.99	9.584
120	58.4	0.968	8.67	8.002	6.002	48.028	82.24	10.372
120	70.15	0.975	9.548	10.001	6.016	60.166	85.77	9.984
120	135.8	0.989	8.362	12.004	10.013	120.196	88.51	15.604
120	156.96	0.982	16.86	14.003	10.002	140.058	89.23	16.902
120	178.15	0.985	15.664	15.998	10.003	160.028	89.83	18.122
120	199.45	0.987	14.609	17.997	10.003	180.024	90.26	19.426
120	220.9	0.989	13.705	20	10.002	200.040	90.56	20.860
120	242.8	0.99	12.953	22.01	10.003	220.166	90.68	22.634

Table 2-3. Efficiency Data at V_{IN} = 230 V

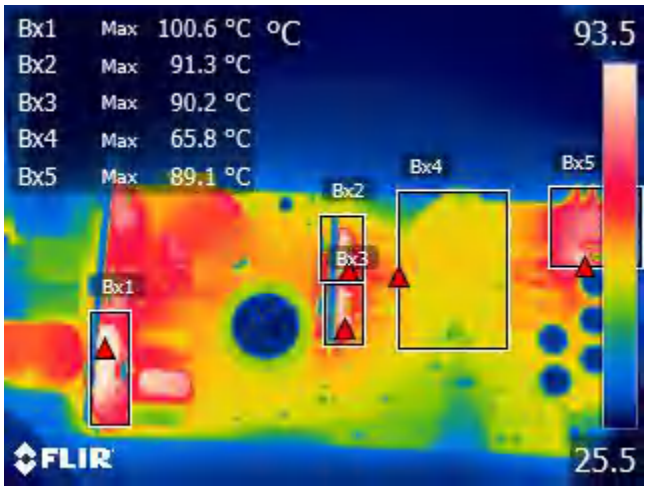
V_{IN} (V)	P_{IN} (W)	PF	THD	VOUT(V)	I_{OUT} (A)	P_{OUT} (W)	Efficiency (%)	P_{LOSS} (W)
230	43.3			6	6.093	36.558	84.43	6.742
230	56.52	.762	18.7	8.001	6.098	48.79	86.32	7.730
230	70.11	.825	15.402	10.008	6.106	61.109	87.16	9.001
230	133.93	.936	9.65	12.001	10.009	120.118	89.69	13.812
230	155.05	0.95	9.2	14.006	10.014	140.256	90.46	14.794
230	176.0	0.959	8.78	16	10.016	160.256	91.01	15.824
230	197.17	0.966	8.196	18	10.018	180.324	91.46	16.846
230	218.4	0.971	8.29	20.02	10.023	200.66	91.88	17.740
230	238.9	0.974	8.47	21.95	10.095	221.585	92.75	17.315

Table 2-4. Efficiency Data at V_{IN} = 265 V

V_{IN} (V)	P_{IN} (W)	PF	THD	VOUT(V)	I_{OUT} (A)	P_{OUT} (W)	Efficiency (%)	P_{LOSS} (W)
265	42.7			5.995	6.086	36.486	85.45	6.214
265	58.1	0.608	24	8.012	6.083	48.737	83.88	9.363
265	69.47	0.73	20.96	10.001	6.082	60.826	87.56	8.644
265	133.51	0.896	12.38	11.999	10.022	120.254	90.07	13.256
265	154.44	0.917	11.421	14.002	10.018	140.272	90.83	14.168
265	175.4	0.933	10.691	16.001	10.015	160.25	91.36	15.15
265	196.42	0.944	10.118	18.005	10.016	180.338	91.81	16.082
265	217.5	0.953	10.004	20.01	10.009	200.28	92.08	17.22
265	238.7	0.96	9.845	22.01	10	220.1	92.21	18.6

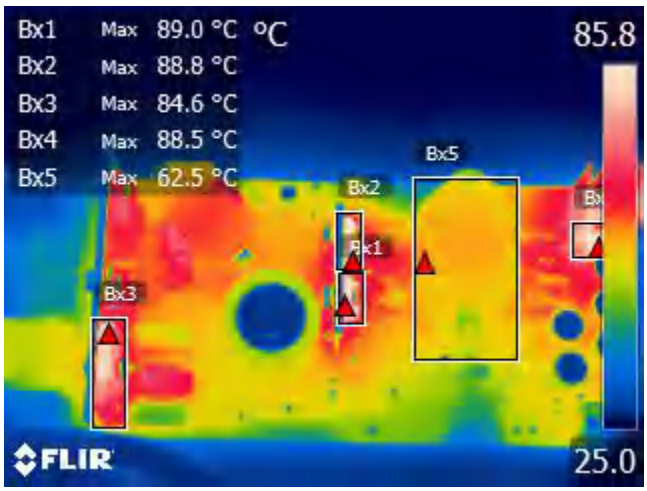
2.3 Thermal Images

Thermal images are shown in the following figures. All figures were taken after a 30 minute soak in a container with no external fan.



90 VAC full load, Bx1 = Diode bridge; Bx2 = Qclamp;
Bx3 = Qpri; Bx4 = XFMR; Bx5 = SR FET

Figure 2-3. Thermal Image



120 VAC full load, Bx3 = Diode bridge;
Bx2 = Qclamp; Bx1 = Qpri; Bx5 = XFMR; Bx4 = SR FET

Figure 2-4. Thermal Image

2.4 Bode Plots

The PMP23224 bode plots are shown in the following figures.

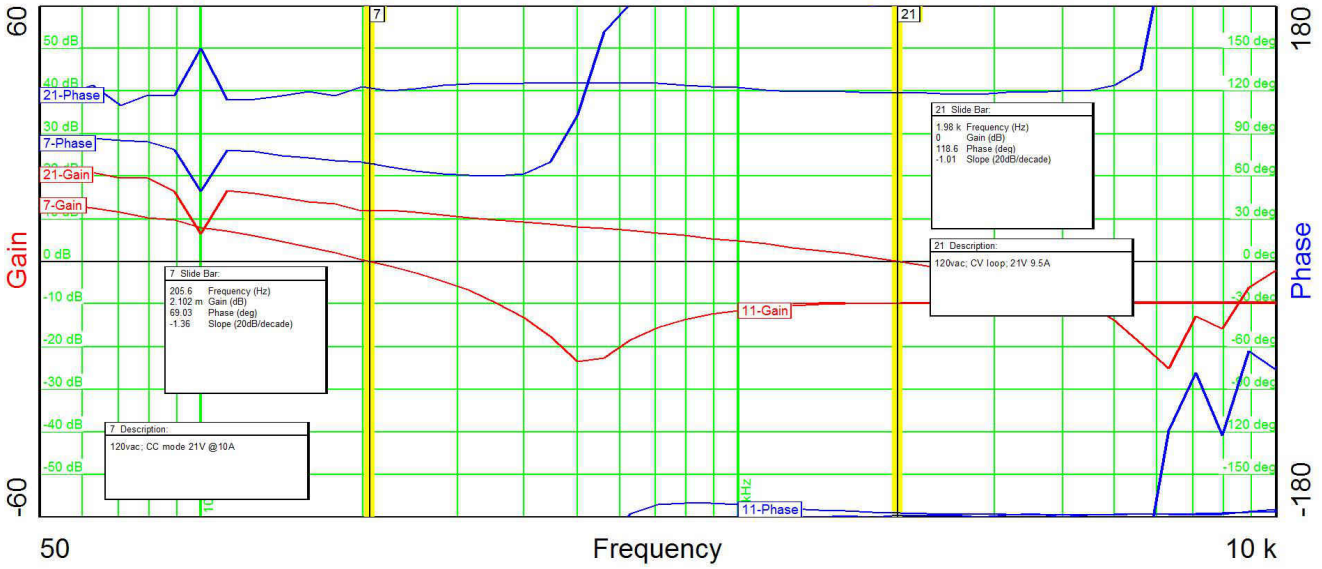


Figure 2-5. 120 VAC Input, Full Load Showing Both CC Loop and CV Loop Bode Plots

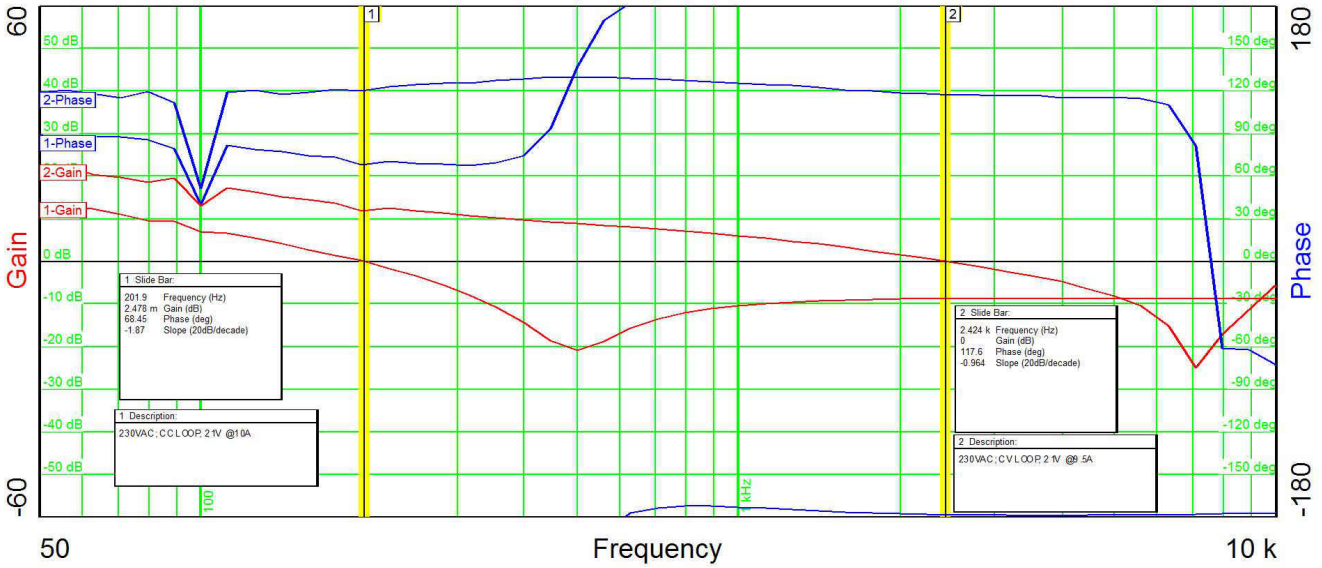


Figure 2-6. 230 VAC Input, Full Load Showing Both CC Loop and CV Loop Bode Plots

2.5 EMI

Conducted EMI results are shown in the following figures.

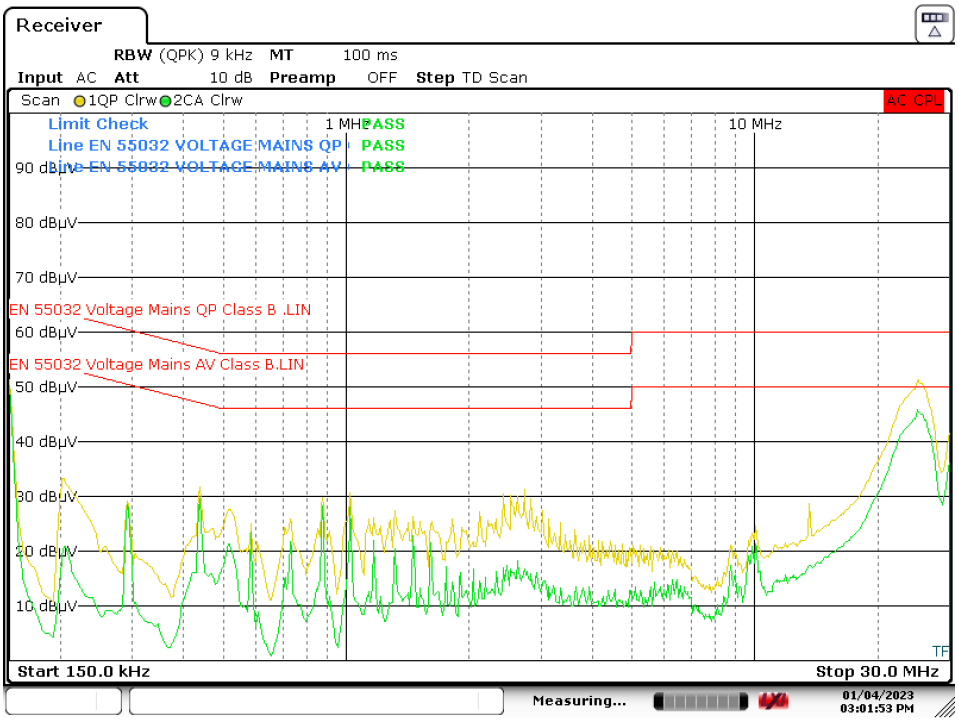


Figure 2-7. 115 VAC - LINE

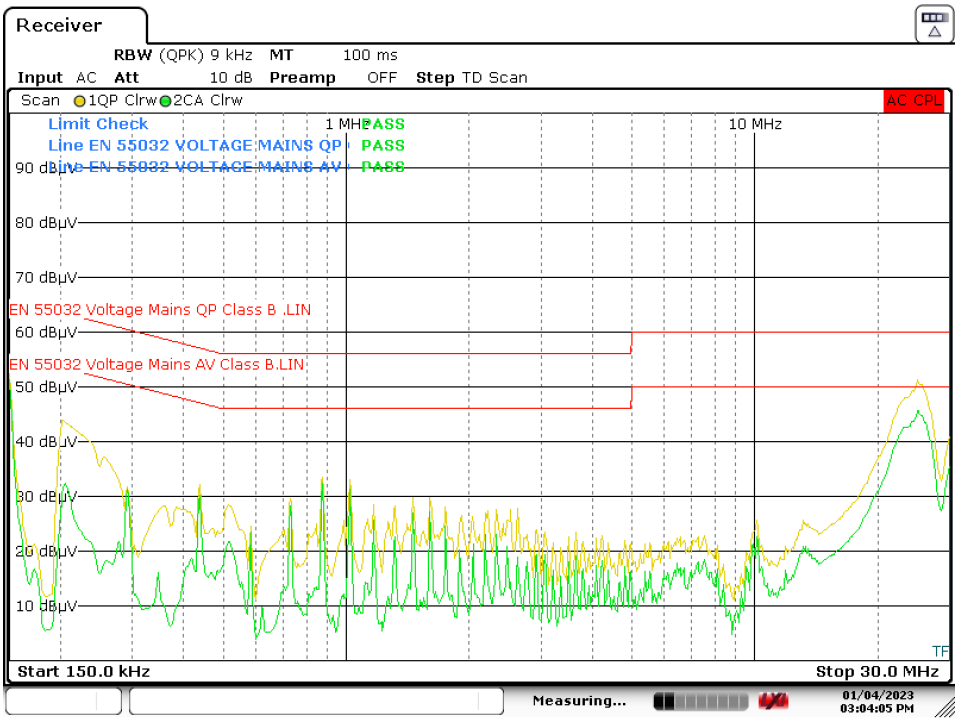


Figure 2-8. 115 VAC - NTRL

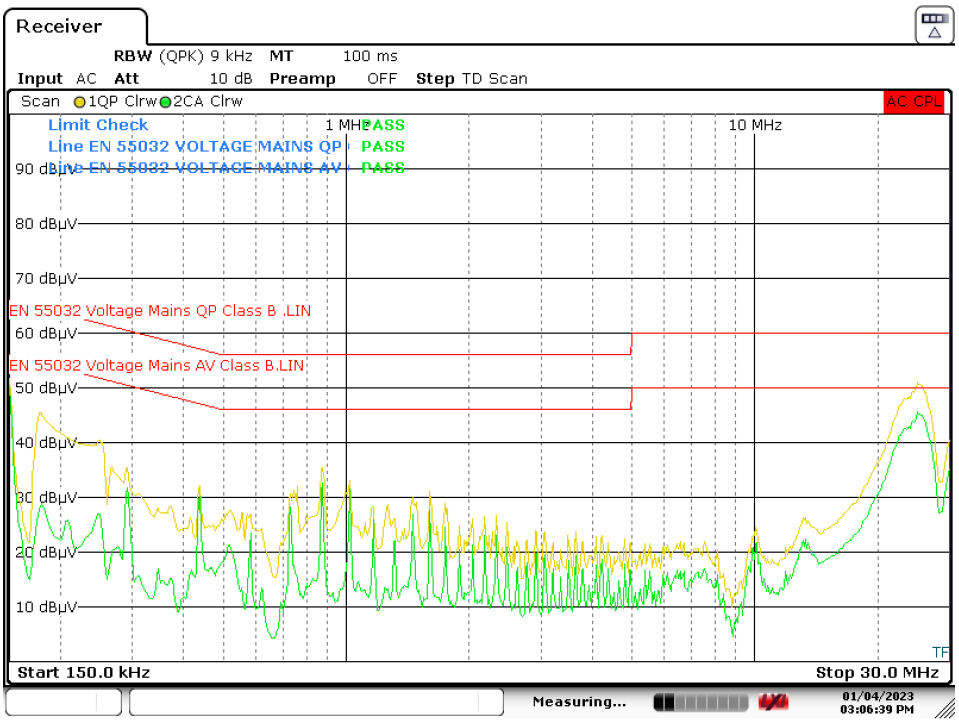


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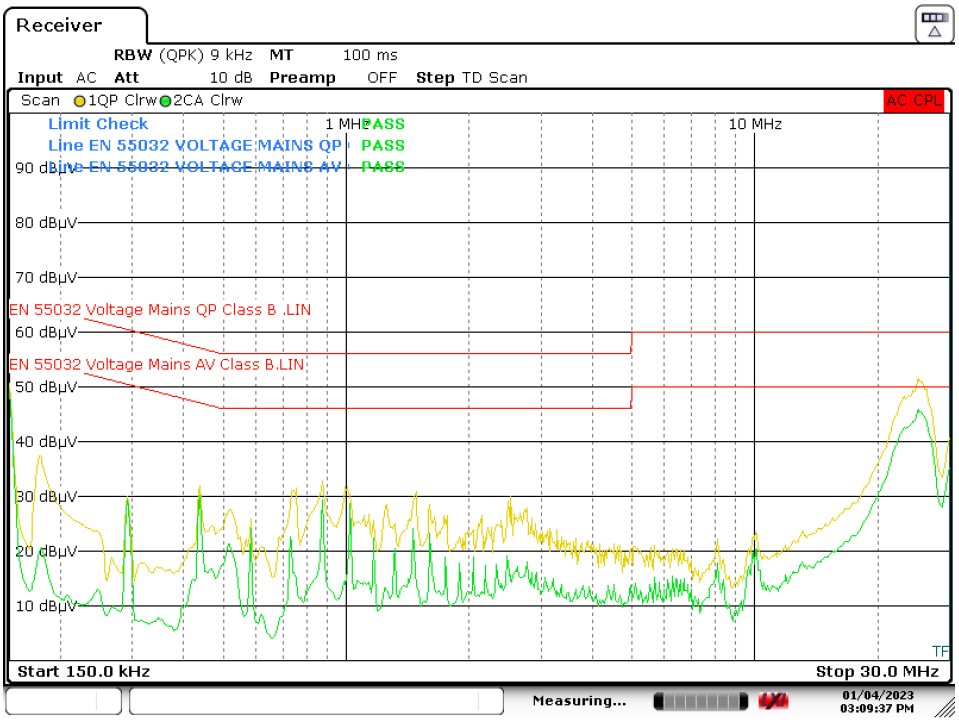
Figure 2-9. 230 VAC - LINE



Date: 4.JAN.2023 15:09:38

Figure 2-10. 230 VAC - NTRL

3 Waveforms

3.1 Switching

The primary and secondary switch nodes of the ACF are shown in the following images at various loads.

Figure 3-1 has the following parameters:

- Ch4 (Magenta): Q2 Switch node voltage (100 V/div), full bandwidth
- Ch1 (Blue): Q17 SR Switch node voltage (50 V/div), full bandwidth
- Timebase: 5 µs/div.

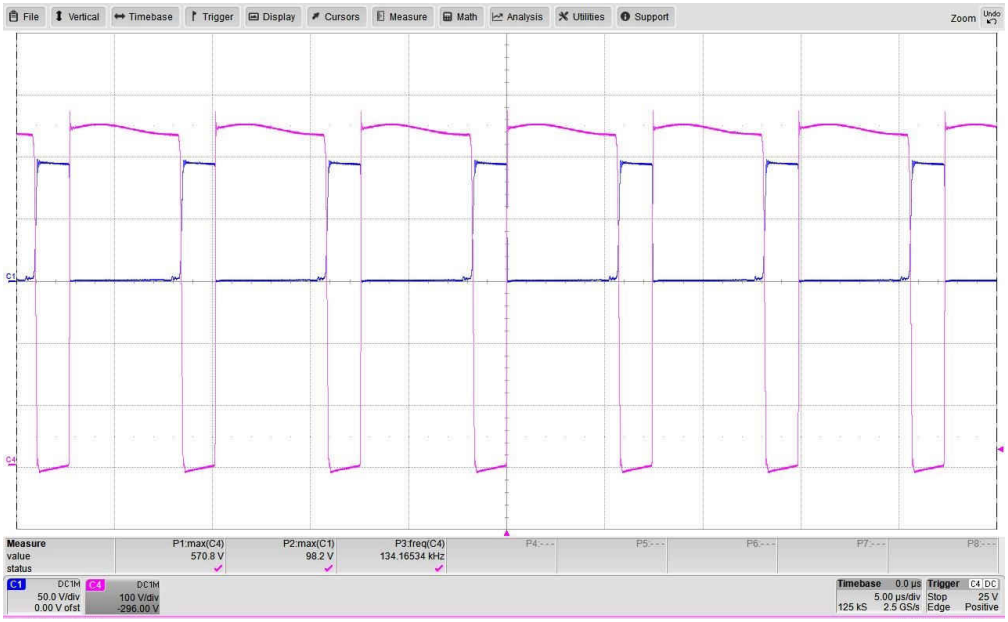


Figure 3-1. 265 VAC; 22 V at 9.5 A; f_{SW} = 134 kHz; Maximum Stress on: Q1 = 570.8 V; Q17 = 98.2 V

Figure 3-2 has the following parameters:

- Ch4 (Magenta): Q2 Switch node voltage (100 V/div), full bandwidth
- Timebase: 5 µs/div

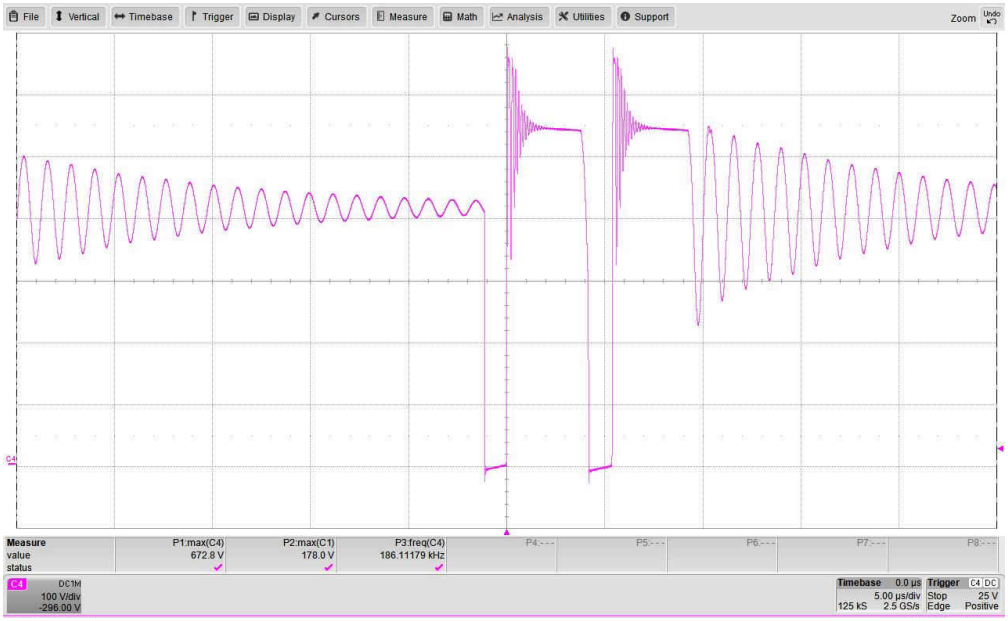


Figure 3-2. 265 VAC; 22 V at 2 A; (LPM to ABM); Maximum Stress on: Q1 = 672 V

Figure 3-3 has the following parameters:

- Ch1(blue): SR Switch node voltage (50 V/div) full bandwidth
- Timebase: 5 µs/div

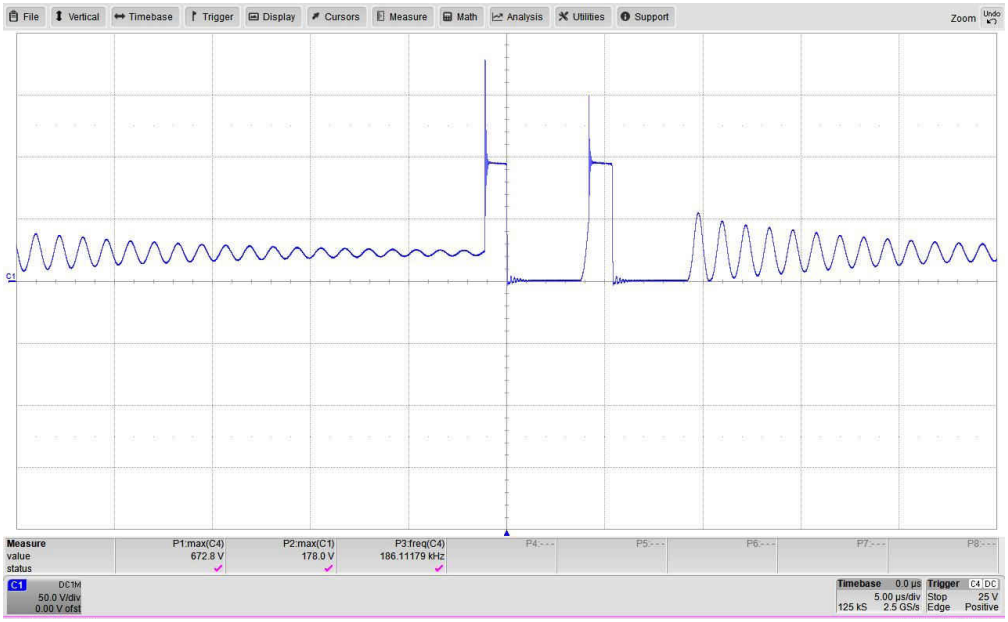
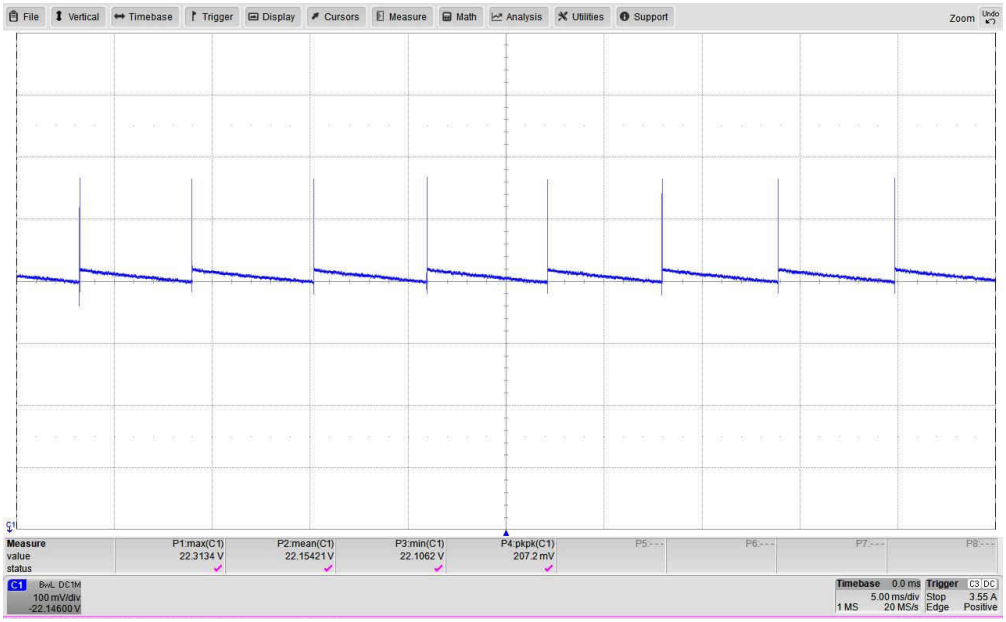


Figure 3-3. 265 VAC; 22 V at 2 A; (LPM to ABM); Maximum Stress on: Q17 = 178 V

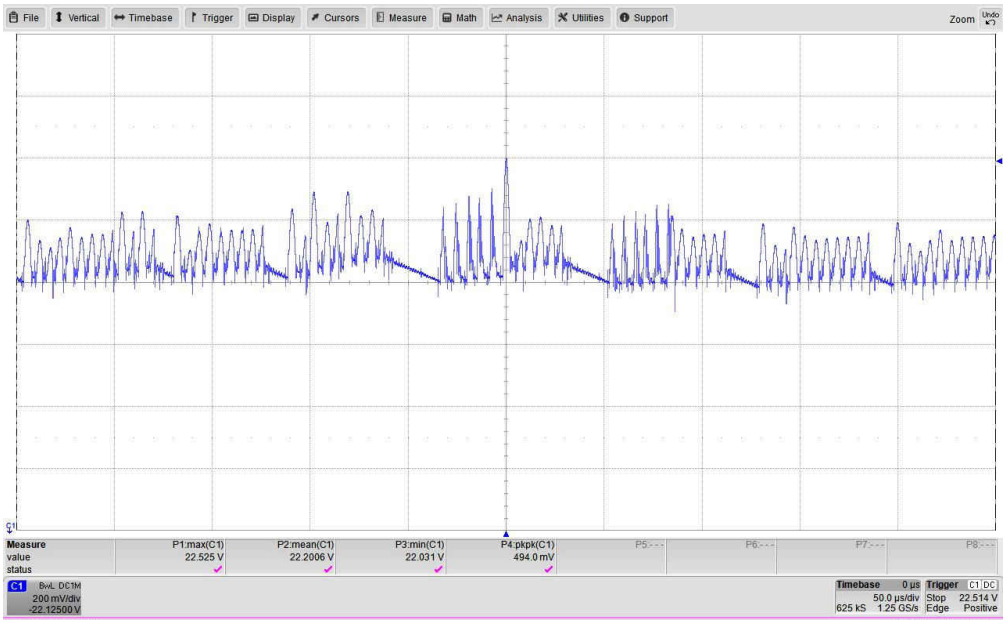
3.2 Output Voltage Ripple

The output voltage ripple waveforms are shown in the following figures.



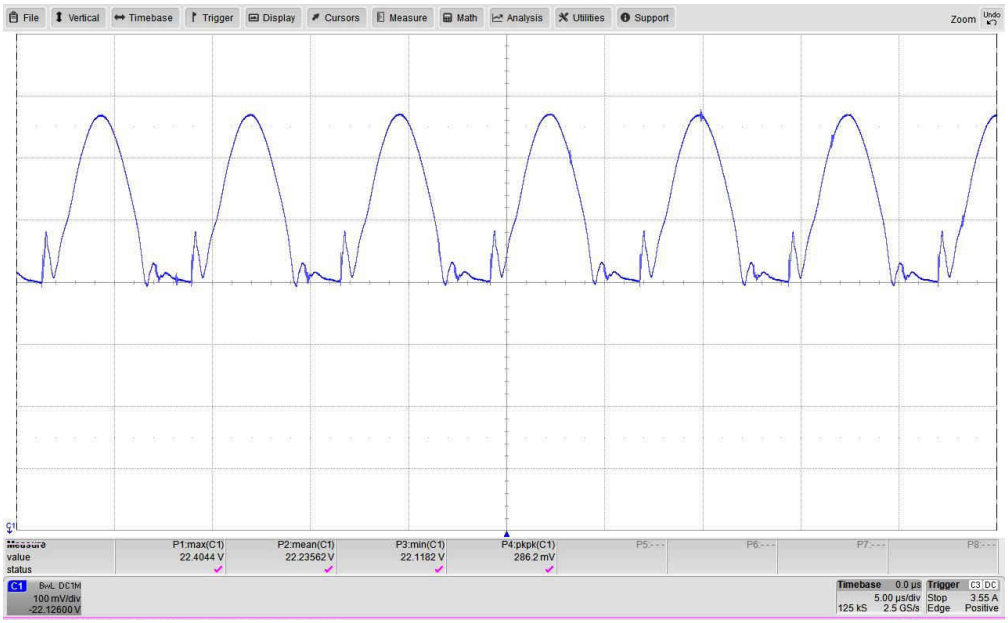
100 mV/div, 5.00 ms/div

Figure 3-4. Output Voltage Ripple, 120 VAC, No Load



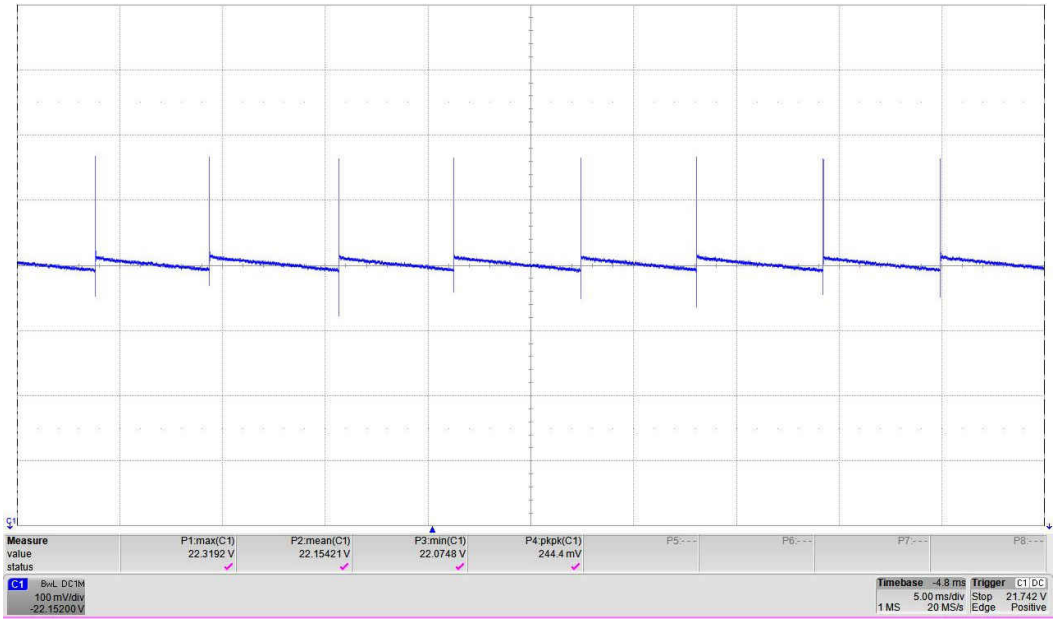
200 mV/div, 50.0 µs/div

Figure 3-5. Output Voltage Ripple, 120 VAC; 4-A Out



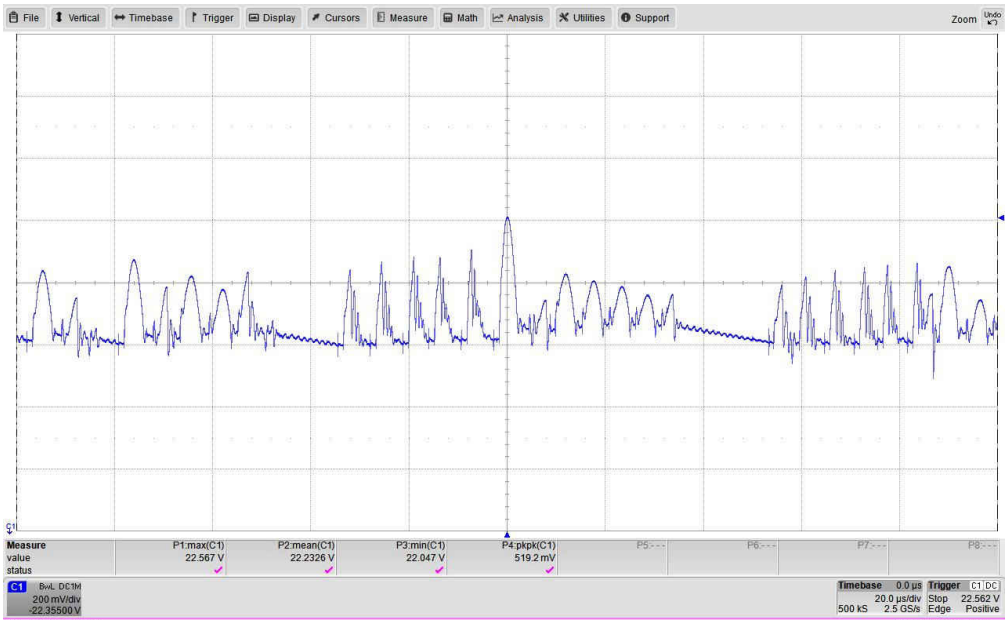
100 mV/div, 5.00 µs/div

Figure 3-6. Output Voltage Ripple, 120 VAC; Full Load



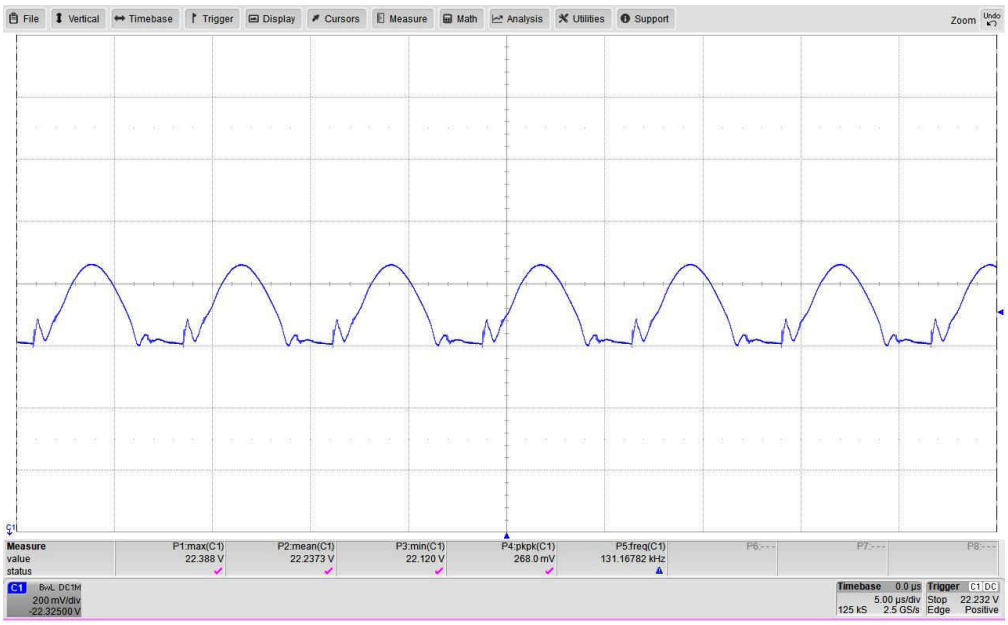
100 mV/div, 5.00 ms/div

Figure 3-7. Output Voltage Ripple, 230 VAC, No Load



200 mV/div, 20.00 µs/div

Figure 3-8. Output Voltage Ripple, 230 VAC, 4-A Out



200 mV/div, 5.00 µs/div

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

3.3 Load Transients

Load transient response waveforms are shown in the following figures.

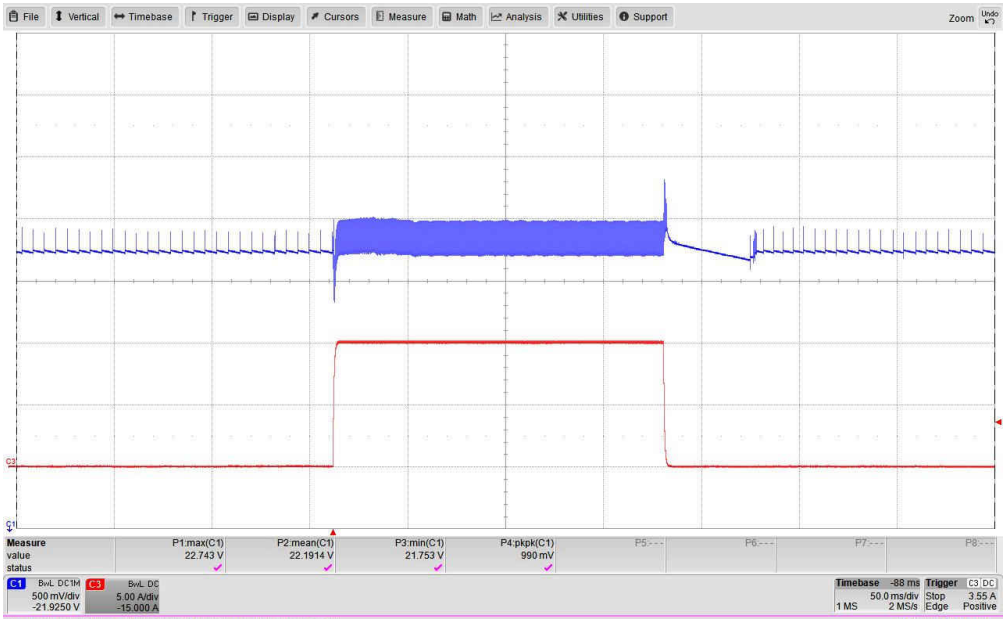


Figure 3-10. 120 VAC Input, I_{step} 0 A to 10 A; $V_{transient}$ = 990 mV_{PP}

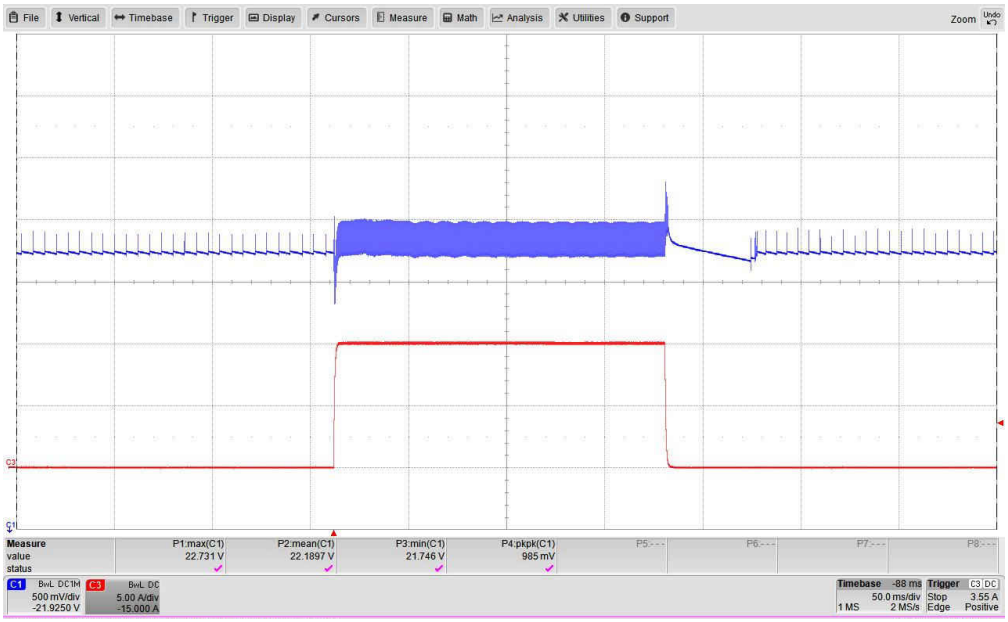


Figure 3-11. 230 VAC Input, I_{step} 0 A to 10 A; $V_{transient}$ = 985 mV_{PP}

3.4 Start-Up Sequence

Start-up behavior is shown in the following figure.

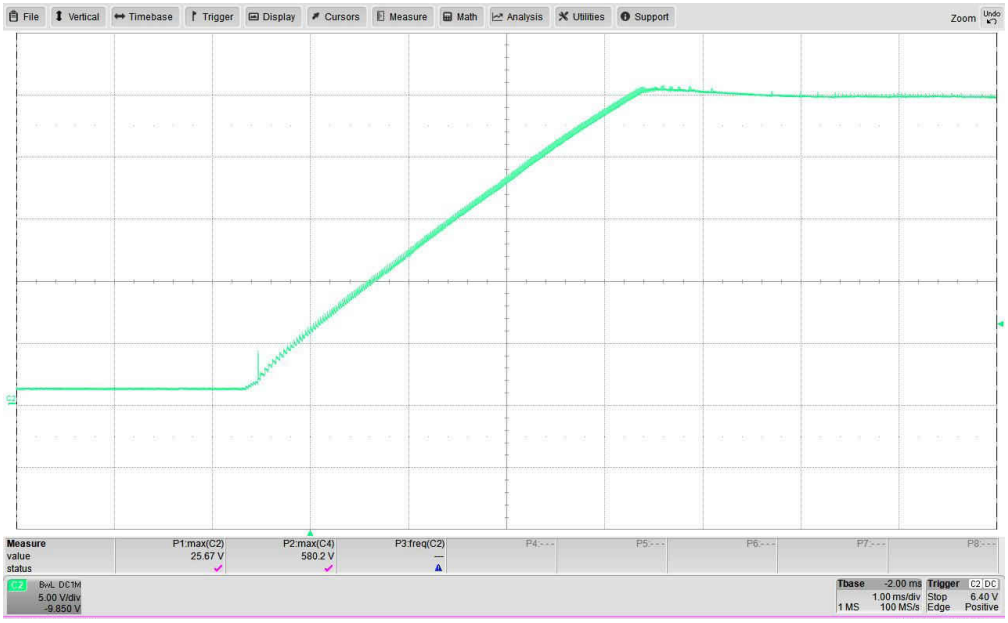


Figure 3-12. 120 VAC, No Load, CV Mode

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