Test Report: PMP41106

Universal Input, 500W Constant Current and Constant Voltage E-Bike Charger Reference Design

Description

This reference design is a universal input, 48V, 10.4A constant current (CC), constant voltage (CV) charger for e-bike applications. The reference design achieves 91.5% end-to-end peak efficiency with a 110Vac input, and 93.50% end-to-end peak efficiency with a 230Vac input. This design includes fan control and charging status indication based on output current. This reference design uses the UCC28180, UCC256603, UCC28910, and TL103W devices.

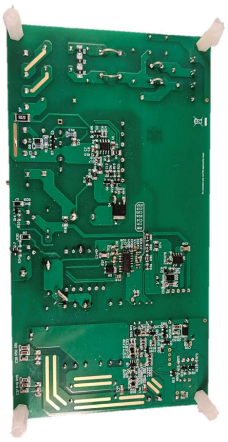
Features

- 93.5% peak efficiency
- Power factor of greater than 0.9 for output power larger than 100W
- Charging status indication
- Automatic fan control
- 190mm × 100mm × 40mm

Applications

- Battery charger

Top



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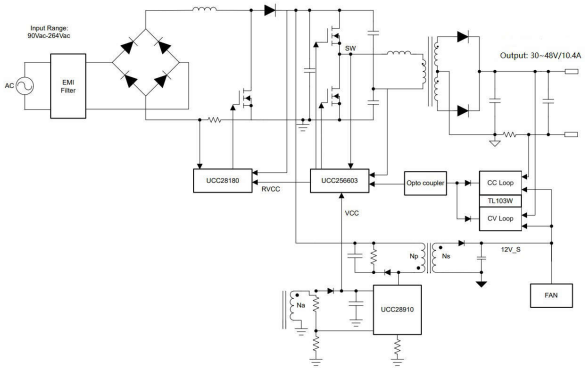

Block Diagram

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1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
Input Voltage	90Vac to 264Vac
Input Frequency	50Hz to 60Hz
Output Voltage	30Vdc to 48Vdc
Output Current	10.4A

1.2 Required Equipment

- AC Source: Chroma 6590
- E-Load: Chroma 63203A-600-210
- Oscilloscope: Tektronix MDO3024
- Mulitmeter: YOKOGAWA WT500

2 Testing and Results

2.1 Load Regulation

Load regulation is shown in Figure 2-1.

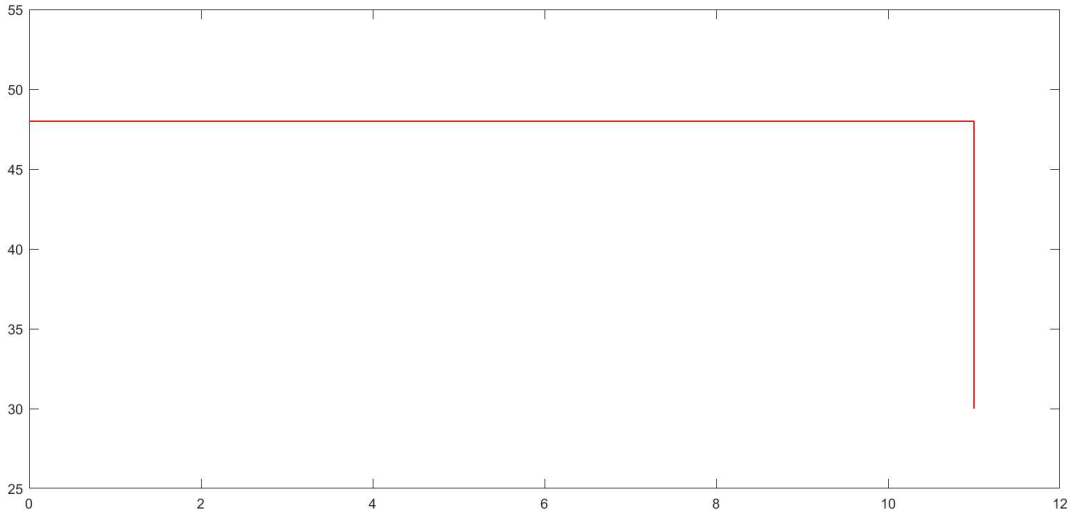

Figure 2-1. Load Regulation

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2.2 Efficiency Graphs

Efficiency is shown in Figure 2-2 and Figure 2-3.

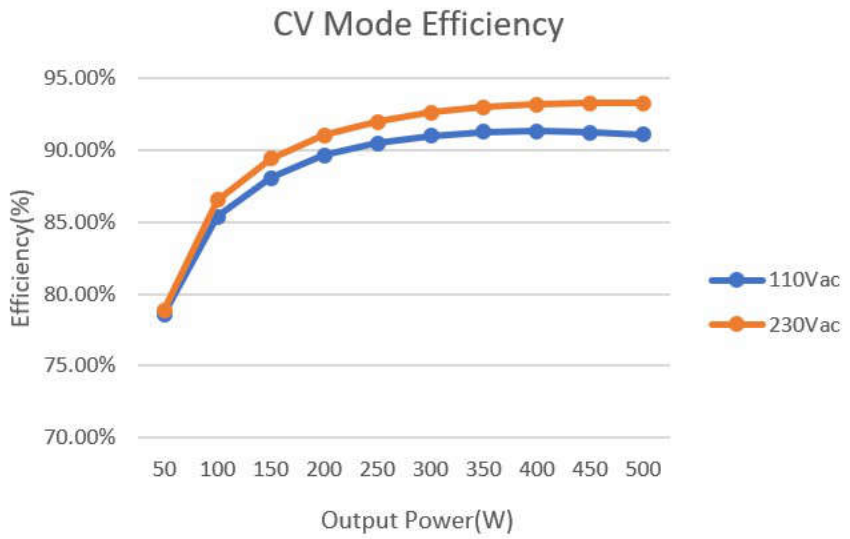

Figure 2-2. CV Mode Efficiency Graph

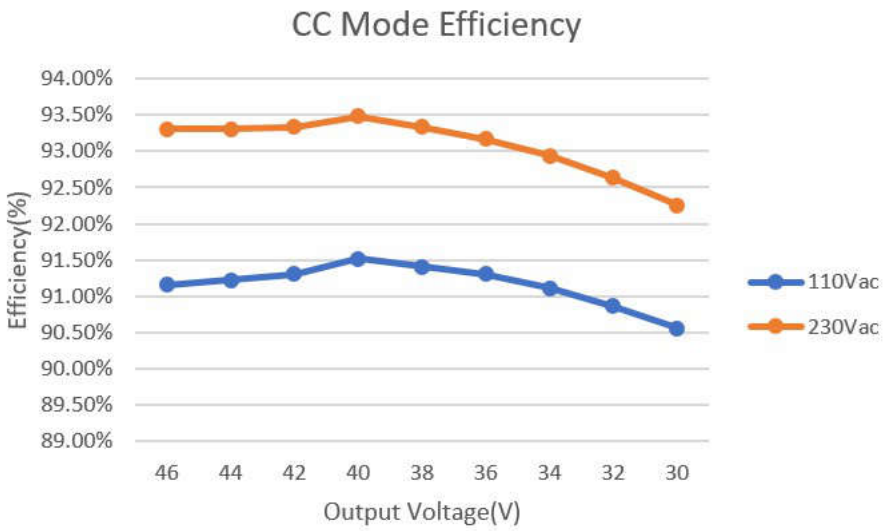

Figure 2-3. CC Mode Efficiency Graph

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2.2.1 Power Factor (PF) and Input Current Total Harmonic Distortion (iTHD)

Graphs of PF and iTHD are shown in Figure 2-4 and Figure 2-5.

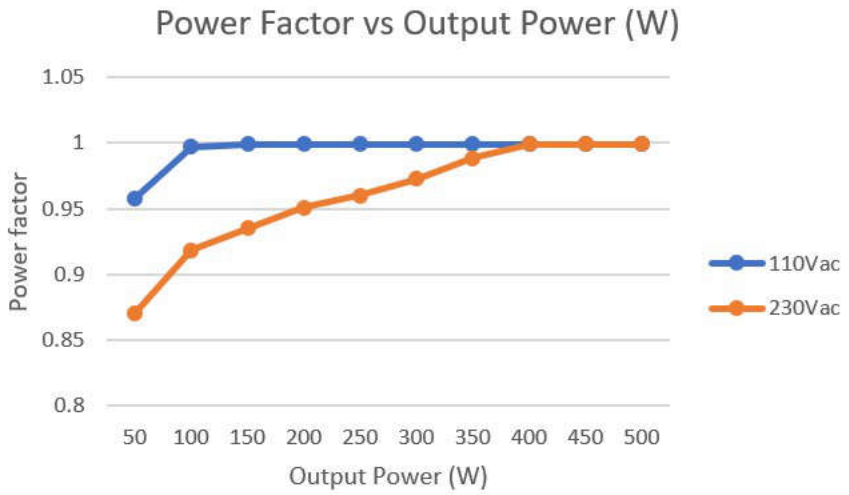

Figure 2-4. Graph of PF

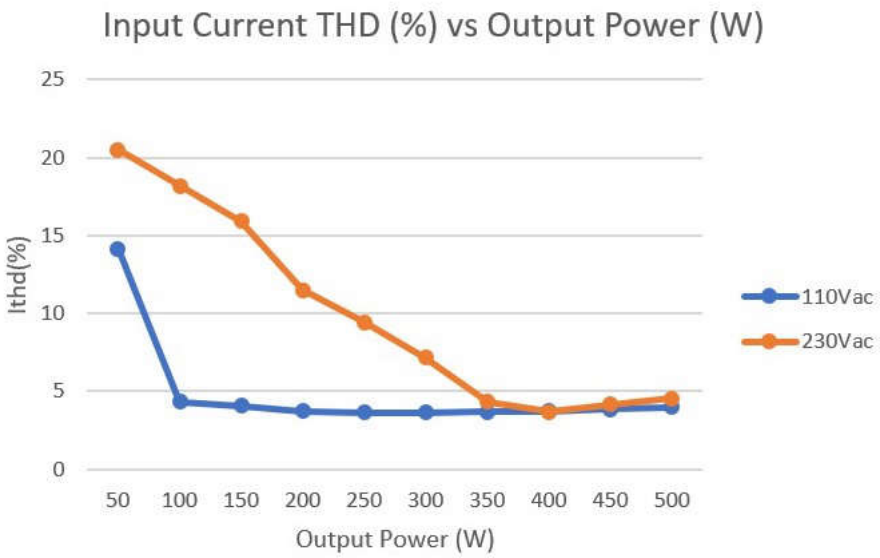

Figure 2-5. Graph of iTHD

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2.3 Efficiency Data

Efficiency data, power factor and input current THD data is shown in Table 2-1.

Table 2-1. Efficiency, PF, and THD Data

V_{IN} (V)	I_{IN} (A)	PF	iTHD	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	Efficiency (%)
109.88	0.5708	0.9579	14.15%	48.468	1	61.5	48.5	78.86%
109.75	1.0391	0.997	4.32%	48.466	1.998	113.4	96.85	85.41%
109.62	1.5088	0.999	4.06%	48.461	2.992	164.8	145	87.99%
109.48	1.9884	0.999	3.75%	48.456	4.013	216.9	194.45	89.65%
109.34	2.4537	0.999	3.63%	48.452	5.003	267.8	242.33	90.49%
109.2	2.9311	0.999	3.63%	48.446	6.01	320	291.16	90.99%
109.02	3.4148	0.999	3.67%	48.43	7.001	371.8	339.1	91.2%
108.88	3.9	0.999	3.75%	48.425	8	424.2	387.42	91.33%
108.74	4.402	0.999	3.85%	48.42	9.01	478	436.3	91.28%
108.54	5.071	0.999	4%	48.412	10.34	549.5	500.6	91.1%
108.66	4.8166	0.999	3.975%	46.06	10.347	522.7	476.57	91.17%
108.77	4.383	0.999	3.885%	42.018	10.347	476.1	434.8	91.33%
108.92	3.9618	0.999	3.8%	38.087	10.348	430.9	394.12	91.46%
109.03	3.5496	0.999	3.72%	34.052	10.348	386.5	352.4	91.18%
109.14	3.1577	0.999	3.67%	30.122	10.348	344	311.793	90.64%
230.03	0.3117	0.8708	20.5%	48.45	1.009	61.7	48.9	79.25%
229.96	0.5192	0.9182	18.18%	48.445	2.013	112.5	97.53	86.69%
229.9	0.7312	0.935	15.92%	48.441	3	162.4	145.3	89.47%
229.83	0.9488	0.9511	11.5%	48.436	4.02	213.6	194.7	91.15%
229.77	1.167	0.96	9.43%	48.431	5.02	264.2	243.1	92.01%
229.71	1.3829	0.9725	7.15%	48.426	6.016	314.4	291.33	92.66%
229.64	1.5981	0.9882	4.33%	48.422	7	364.4	338.86	92.99%
229.54	1.8228	0.999	3.7%	48.418	8.004	415.8	387.52	93.2%
229.48	2.0476	0.999	4.16%	48.414	9	467	435.72	93.3%
229.4	2.3531	0.999	4.55%	48.408	10.344	536.6	500.73	93.32%
229.42	2.2397	0.99	4.5%	46.055	10.35	510.8	476.7	93.32%
229.48	2.0427	0.98	4.2%	42.013	10.351	465.9	434.87	93.34%
229.57	1.8504	0.98	3.8%	38.082	10.351	422.2	394.18	93.36%
229.63	1.6617	0.98	3.96%	34.046	10.352	379	352.44	92.99%
229.67	1.4822	0.98	5.73%	30.117	10.353	337.6	311.78	92.35%

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2.4 Thermal Images

Thermal image is shown in Table 2-2.

Table 2-2. Component Temperature, 230V, 50Hz Input, Full Load

LLC Inductor	52℃
LLC Transformer	55℃
LLC Rectifier Diodes	51.3℃
Rectifier Bridge	50℃
PFC Choke	36℃

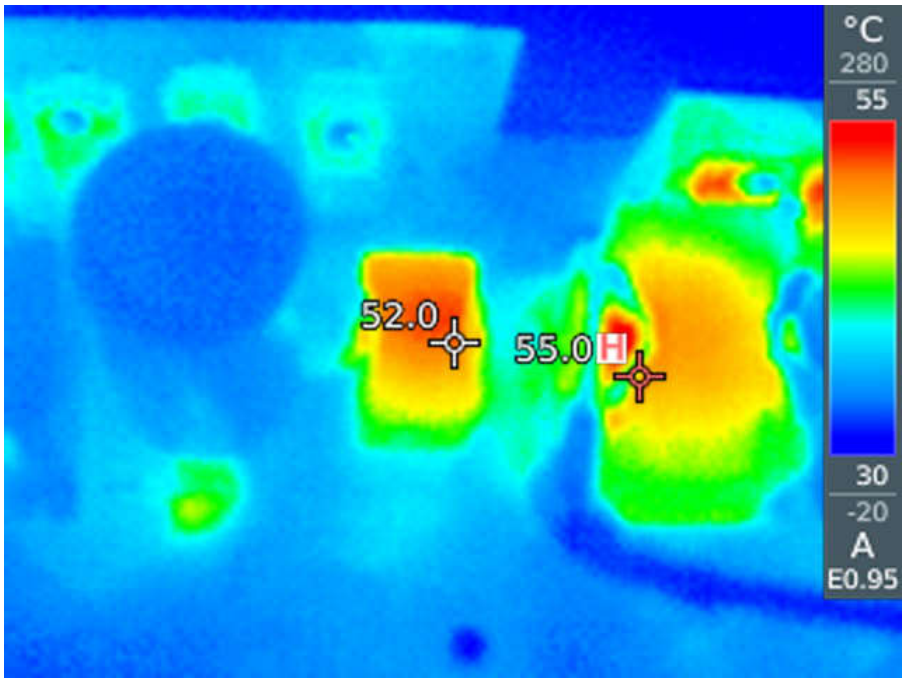

Figure 2-6. Thermal Image at 230Vac

Note

TA = 25.0°C, 230V, 50Hz Input, Full Load

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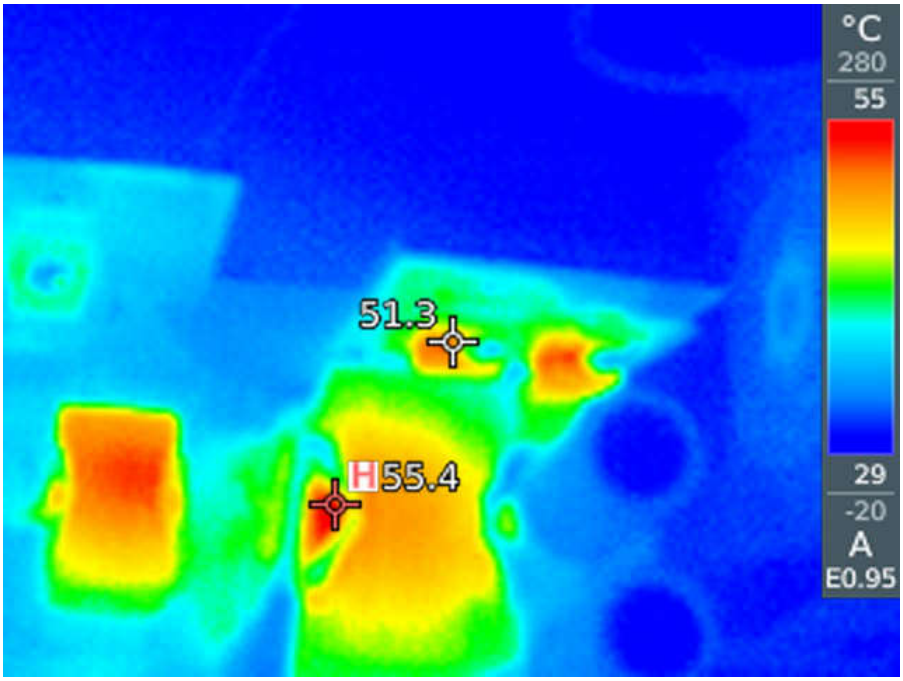

Figure 2-7. Thermal Image at 230Vac

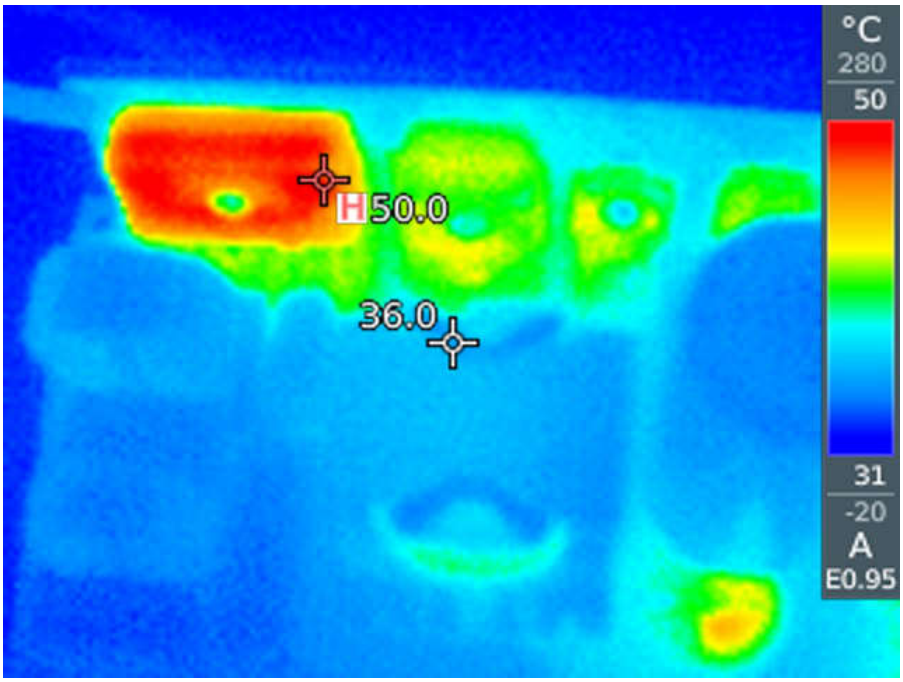

Figure 2-8. Thermal Image at 230Vac

Table 2-3. Component Temperature, 110V, 50Hz Input, Full Load

LLC Inductor	52.6℃
LLC Transformer	55.4℃
LLC Rectifier Diodes	51.3℃
Rectifier Bridge	67.9℃
PFC MOSFET	45.9℃

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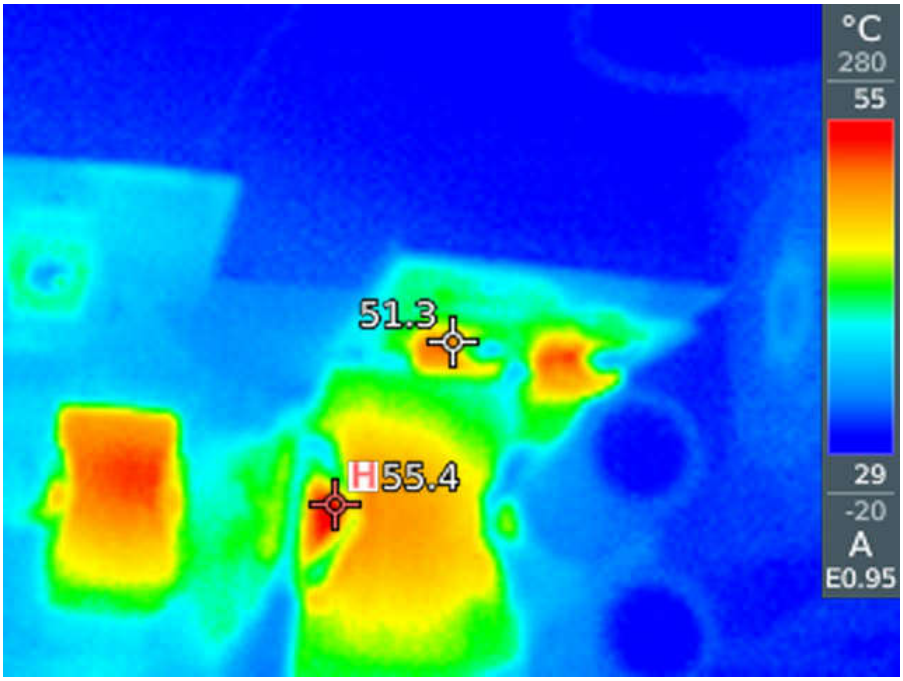

Figure 2-9. Thermal Image at 110Vac

Note

TA = 25.0°C, 110V, 50Hz Input, Full Load

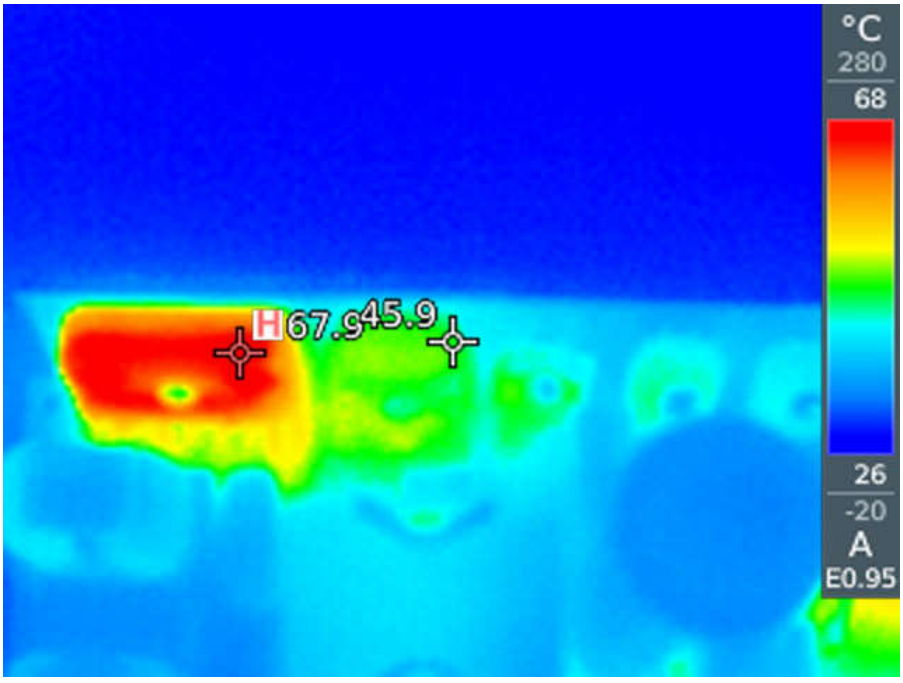

Figure 2-10. Thermal Image at 110Vac

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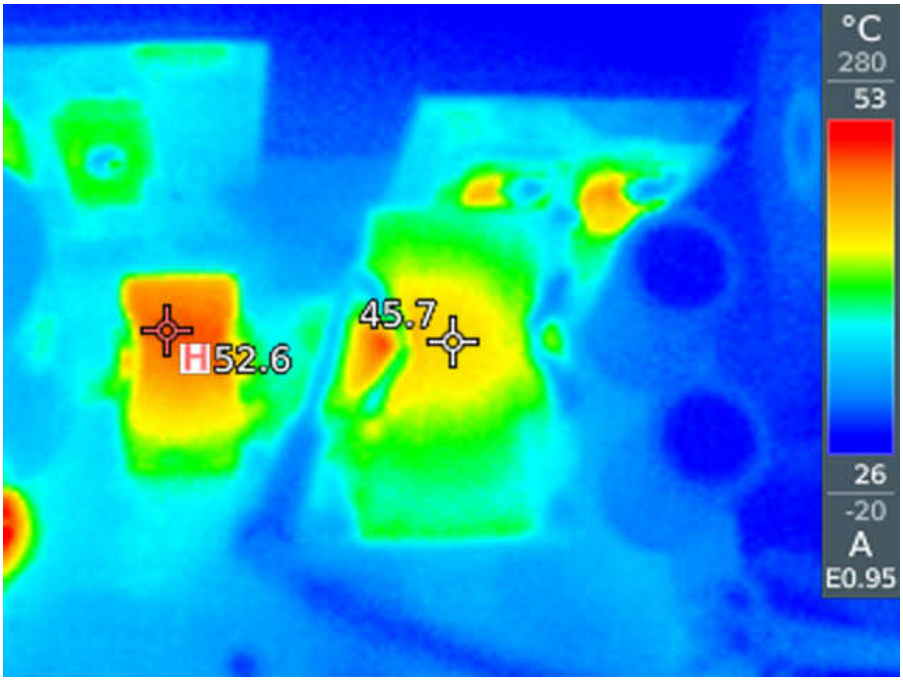

Figure 2-11. Thermal Image at 110Vac

Note

Tested after 30 minutes operation, with 12V, 0.5A fan cooling

3 Waveforms

3.1 Switching

Switching behavior is shown in Figure 3-1 through Figure 3-10.

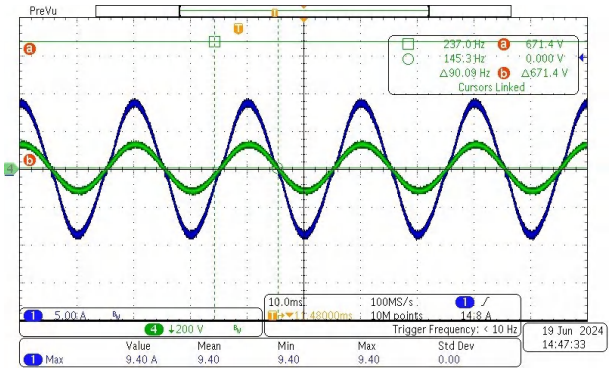

Figure 3-1. PFC, 90Vac Input, Full Load

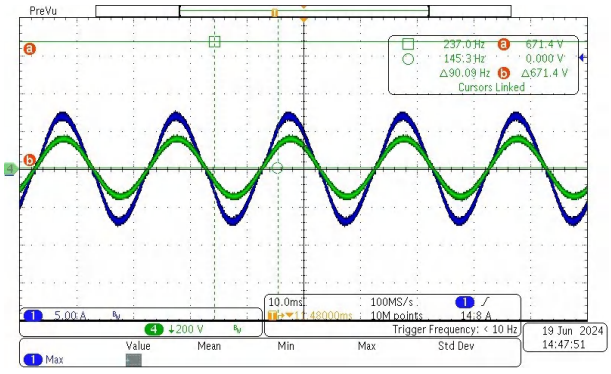

Figure 3-2. PFC, 110Vac Input, Full Load

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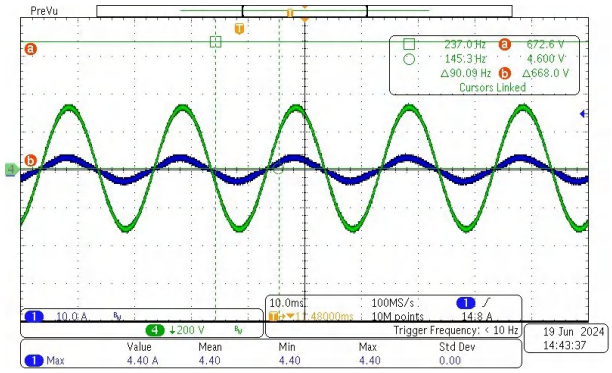

Figure 3-3. PFC, 230Vac Input, Full Load

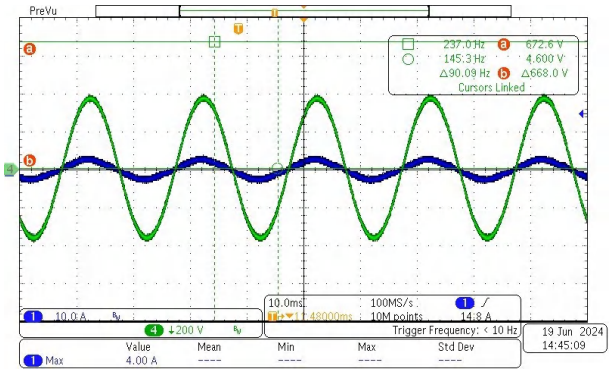

Figure 3-4. PFC, 264Vac Input, Full Load

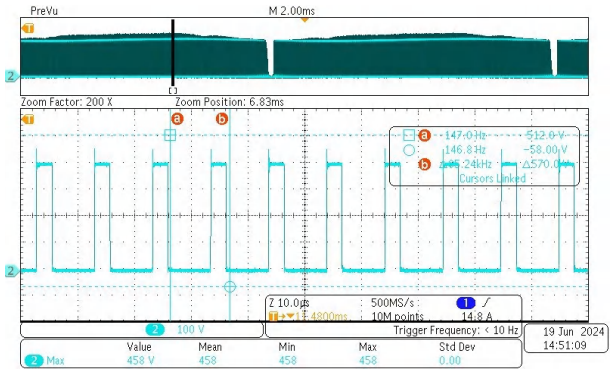

Figure 3-5. PFC, 90Vac Input, Full Load, Switch Node Waveform

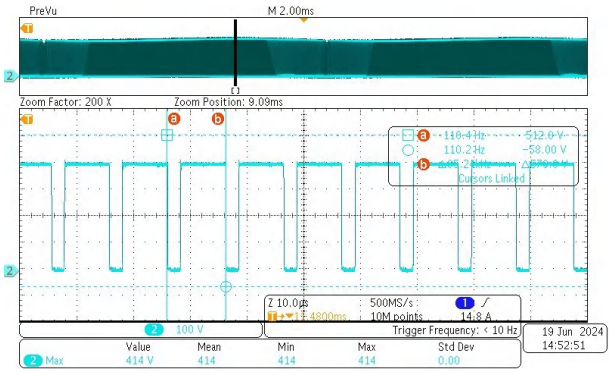

Figure 3-6. PFC, 264Vac Input, Full Load, Switch Node Waveform

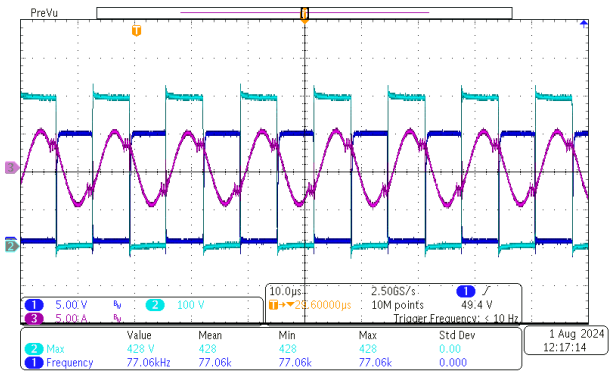

Figure 3-7. LLC, 48V, 10.4A Load

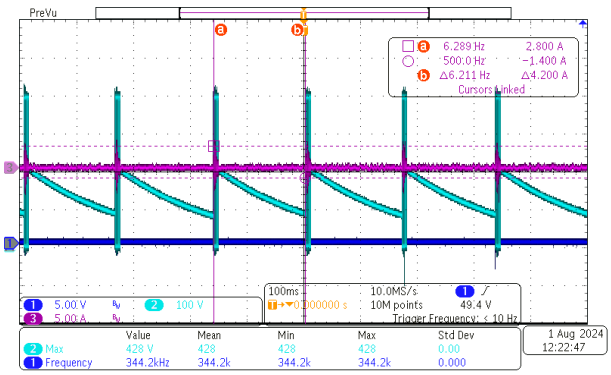

Figure 3-8. LLC, 48V, 0A Load

Note

CH1: Vgs CH2: Vds CH3: Resonant tank current

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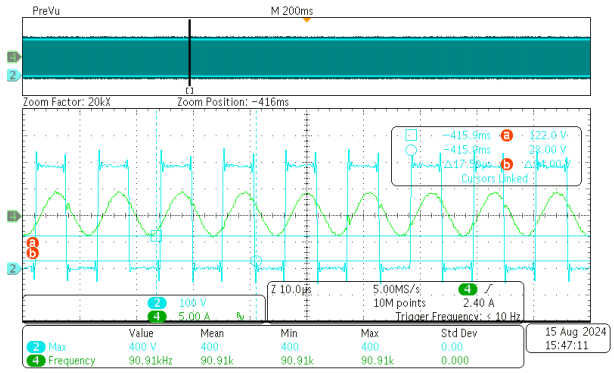

Figure 3-9. LLC, 40V, 10.4A Load

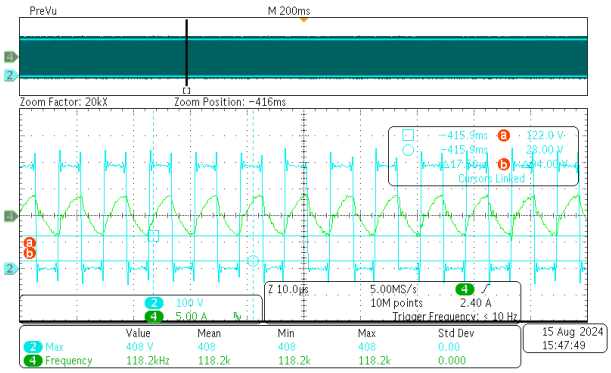

Figure 3-10. LLC, 30V, 10.4A Load

Note

CH2: Vds CH4: Resonant tank current

3.2 Output Voltage Ripple

Output voltage ripple is shown in Figure 3-11 and Figure 3-12.

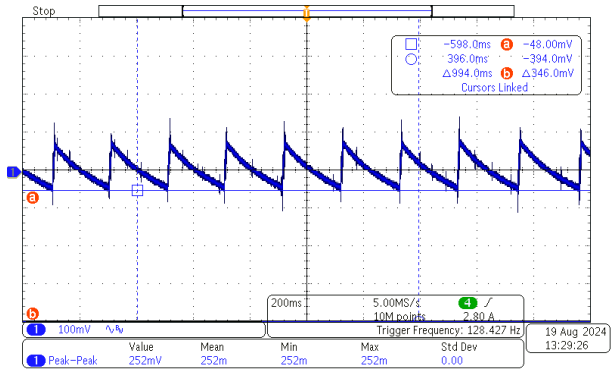

Figure 3-11. 48V, No Load

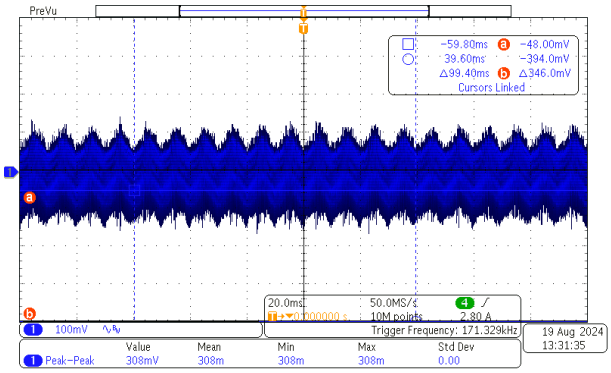

Figure 3-12. 48V, 10.4A Load

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3.3 Start-up Sequence

Start-up behavior is shown in Figure 3-13 and Figure 3-14.

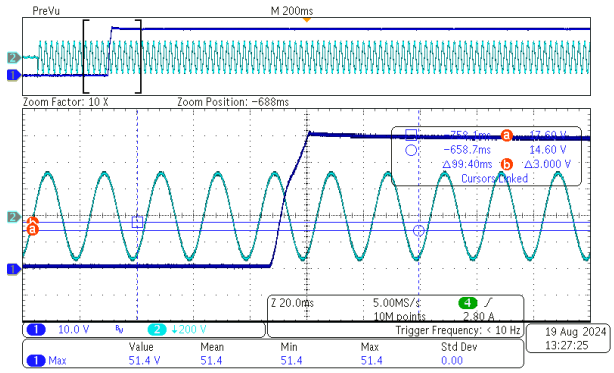

Figure 3-13. 110Vac Input, No Load

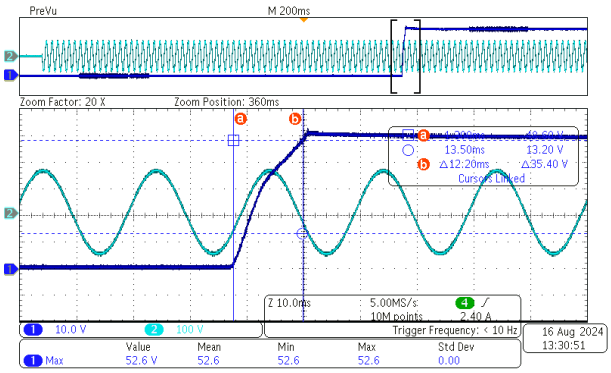

Figure 3-14. 230Vac Input, No Load

Note

CH1: Output voltage, CH2: Input voltage

3.4 Dynamic Response

Dynamic response is shown in Figure 3-15 and Figure 3-16.

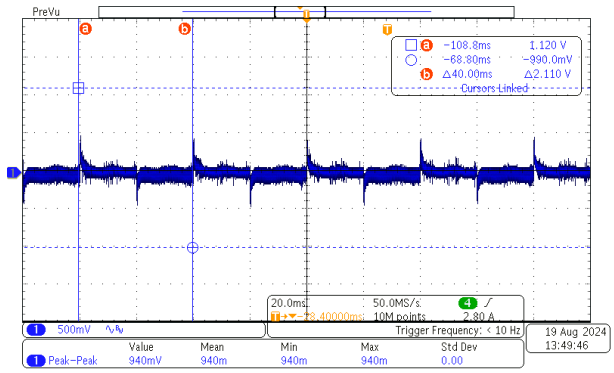

Figure 3-15. 110Vac Input, 48V, 5.2A to 10.4A

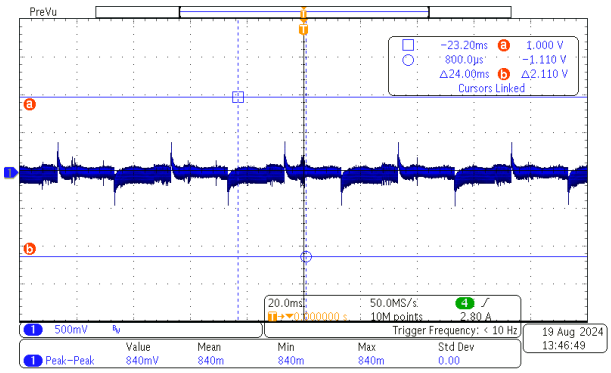

Figure 3-16. 230Vac Input, 48V, 5.2A to 10.4A

Note

The high-current level is full load for 20ms. The low-current level is ½ load for 20ms, with a slew rate of 2.5A/µs

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