Test Report: PMP23537

3.6kW CCM-TCM Multimode Controlled Totem-Pole Bridgeless PFC Reference Design

Description

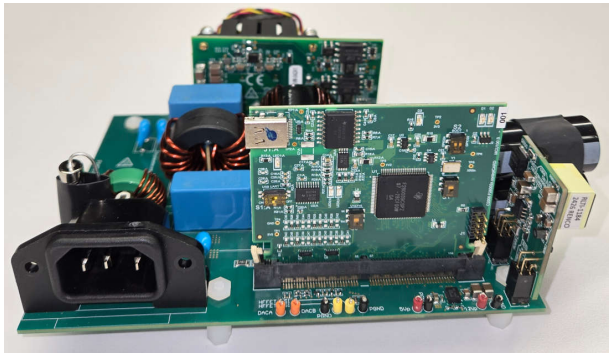
This reference design is a 3.6kW, single-phase, totem-pole bridgeless power factor correction (PFC) converter targeting modular hardware system common redundant power supply (M-CRPS) servers. The PFC operates at continuous conduction mode (CCM) at AC peak where inductor current is high, and operates at triangular conduction mode (TCM) with zero voltage switching (ZVS) at AC low area where the inductor current is low, achieving both high efficiency and high power density. The power stage is followed by a baby boost converter, which helps to greatly reduce the size of the bulk capacitor. This design also includes e-meter functionality with 0.5% accuracy using AMC1306 as a current sensing device, eliminating the need for external power metering ICs. An alternative low-cost current sensing option using TMCS1133 is also provided in this design. This design works with the LMG3427R30 gallium nitride (GaN) device, which has an integrated zero-current detection (ZCD) circuit for TCM control. The F28003x C2000™ real-time microcontroller is used for all the advanced controls including PFC control and e-metering.

Features

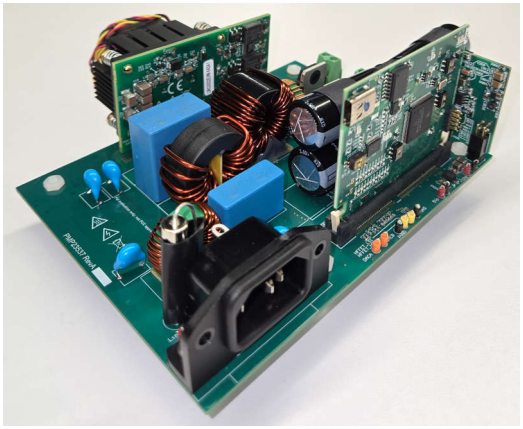
- CCM-TCM multimode control in each AC half cycle. Light load efficiency is improved up to 2%
- TI GaN with integrated zero current sensing
- Single current sensor for both PFC control and e-metering with < 0.5% accuracy
- Includes baby boost to extend holdup time and reduce bulk capacitor
- Re-rush current control when AC comes back from dropout

Applications

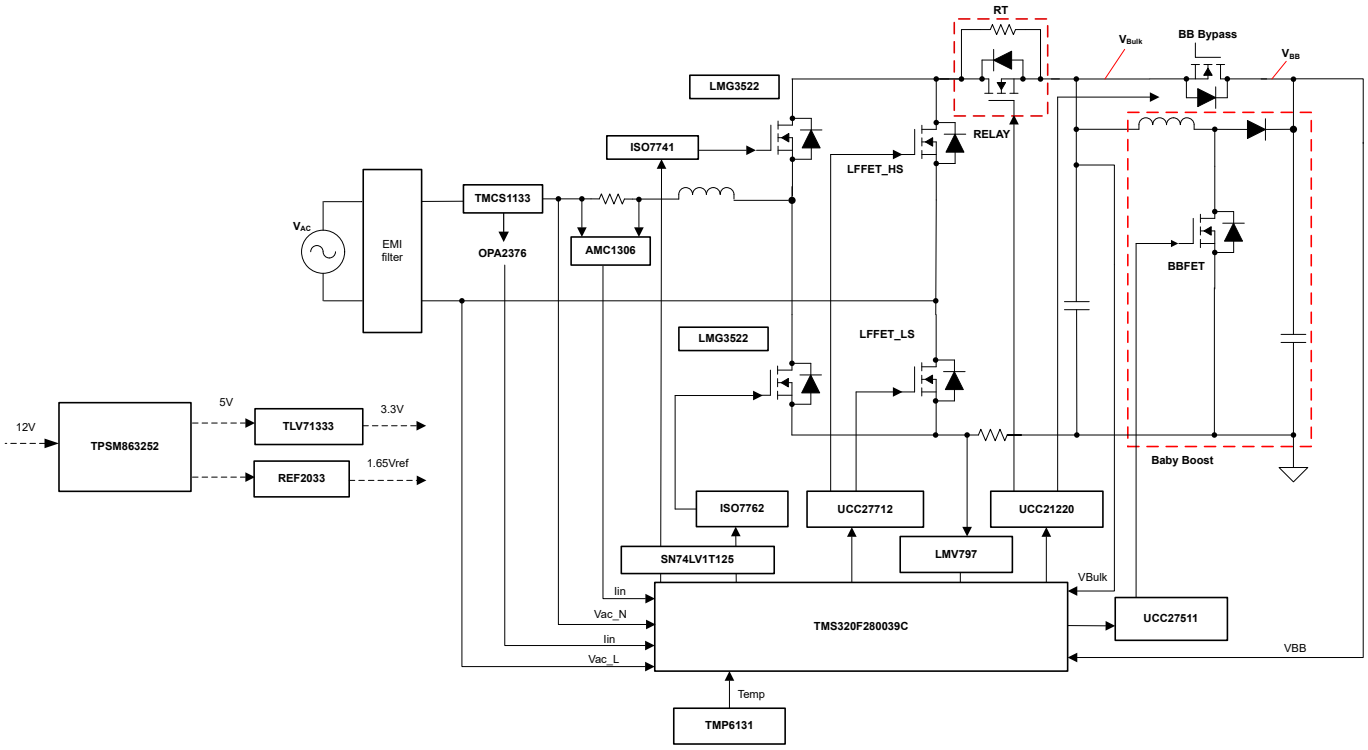
- Rack and server power
- Industrial AC-DC
- Telecom rectifiers
- UPS - single phase online



Board Top Photo



Board Side Photo



Block Diagram

1 Test Prerequisites

1.1 Key System Specifications

Table 1-1. Key System Specifications

Parameter	Specifications	Unit
Input Voltage	90–265	V_{RMS}
Line Frequency	50 or 60	Hz
Input Current (Max)	16	A
Output Voltage	385	V
Output power at 230VAC	3.6	kW
Output power at 115VAC	1.8	kW

1.2 Required Equipment

- AC source: 300VAC, 20A
- Electronic load
- Digital power meter
- Isolated voltage probes
- Current probe

1.3 Considerations

- This PFC needs to be used together with the C2000 control card TMDSCNCD280039C, PMP20306 isolated bias supply reference design and LMG3522EVM-042 EVM. The LMG3522EVM-042 EVM needs some modification: replace LMG3522R030 with LMG3427R30, change R20 to 0Ω, remove C39.
- Due to the totem-pole topology, the PFC ground (PGND) is floating. This can lead to common-mode current issues with improper test equipment setups. Always use isolated differential voltage probes when measuring voltage signals.

1.4 Test Setup

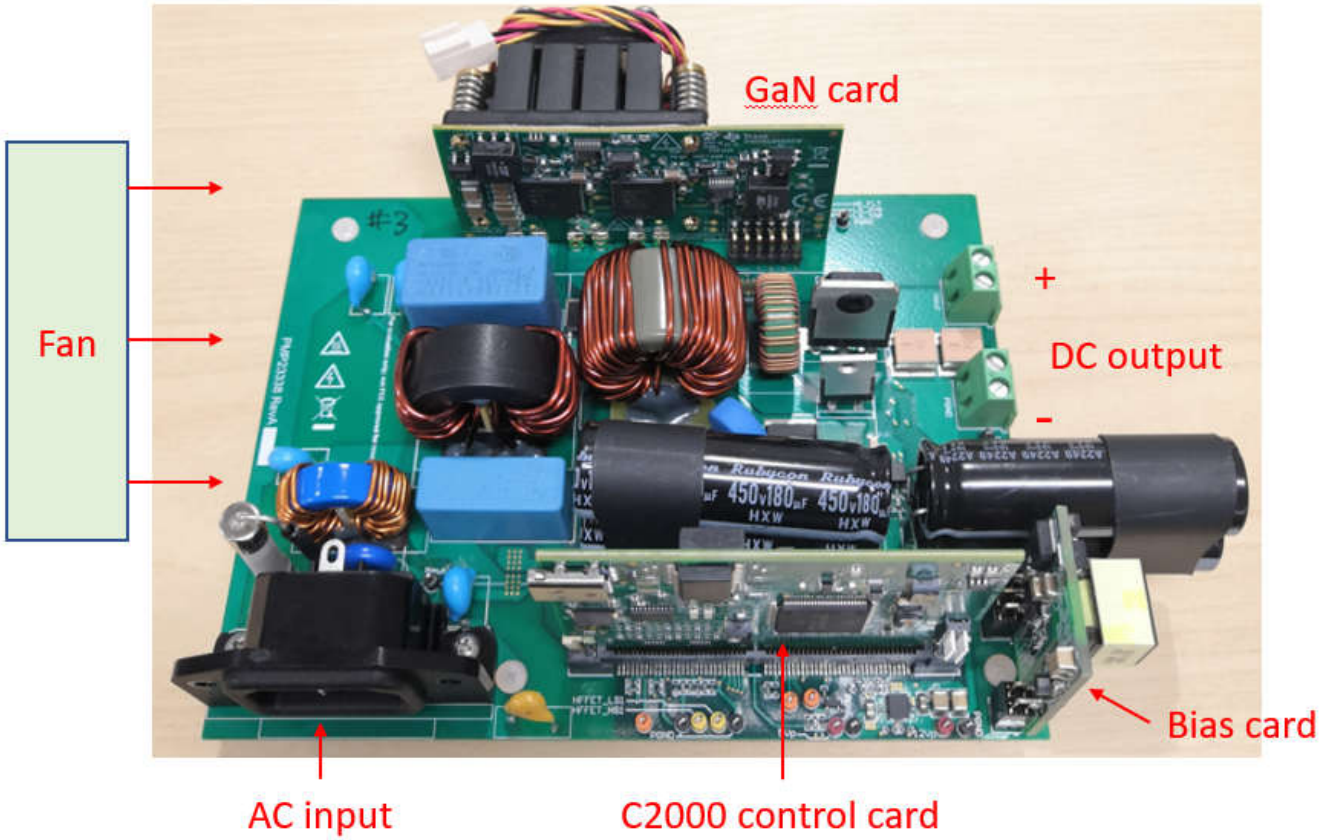


Figure 1-1. Test Setup

1.5 Power Up Procedure

1. Check that GaN card, C2000 control card and bias card are plugged in correctly and tightly.
2. Use an external fan for cooling during test.
3. Use current probe to monitor AC input current. Use voltage meter to measure DC output voltage.
4. Connect a high voltage load to DC output. Set load to 0.1A. Turn on load.
5. Connect AC source to AC input.
6. Set AC output at 115V-60Hz, or 230V-50Hz. Turn on AC. DC output voltage is regulated at about 385V.
7. Gradually increase load. Full load: 1.8kW at 115VAC, 3.6kW at 230VAC.

2 Testing and Results

2.1 Efficiency Graphs

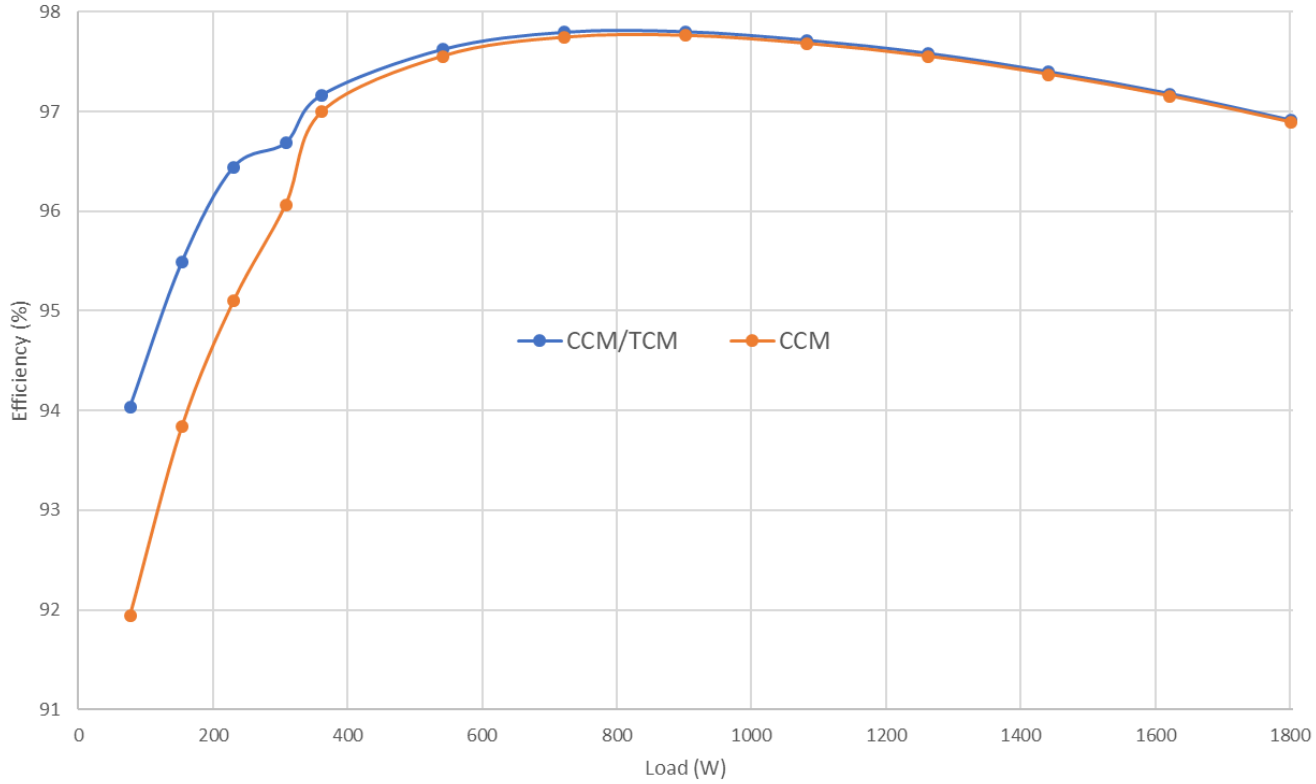


Figure 2-1. Efficiency at 115VAC-60Hz

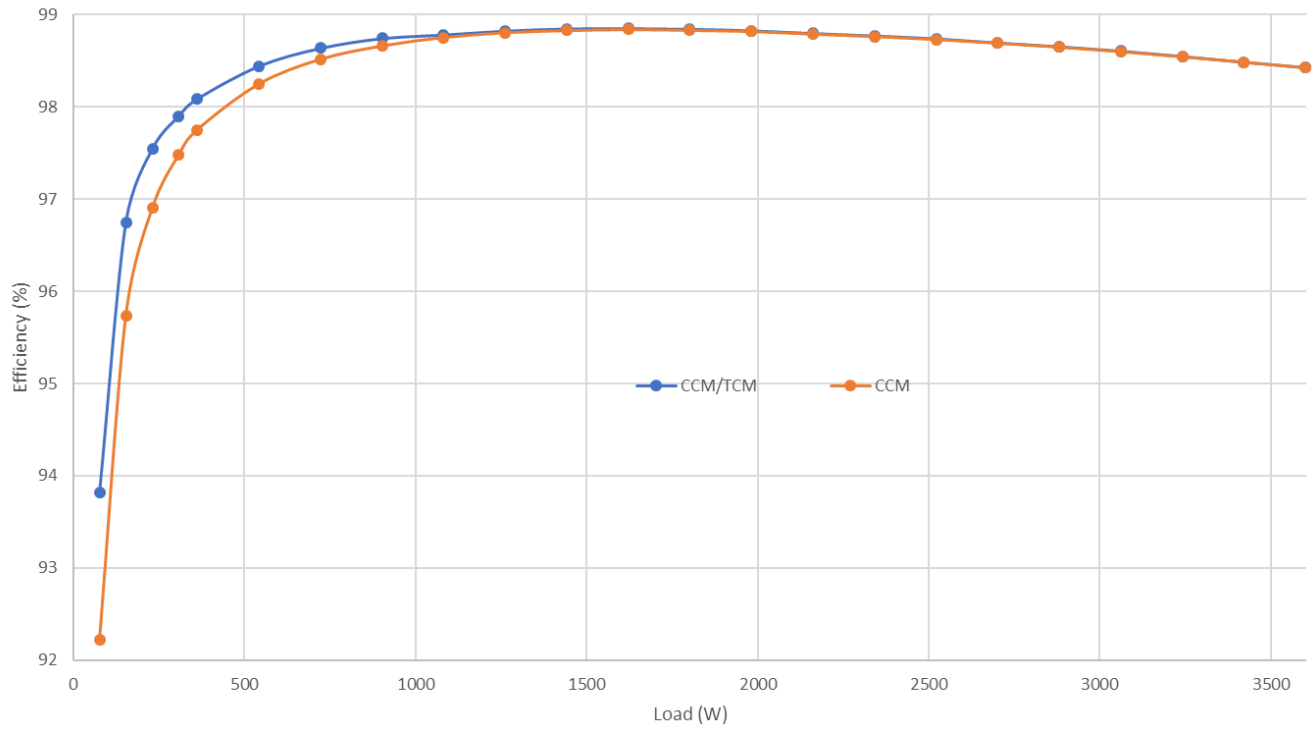


Figure 2-2. Efficiency at 230VAC-50Hz

2.2 Efficiency Data

Efficiency data is shown in Table 2-1.

Table 2-1. Efficiency Data at 115VAC-60Hz

P_{OUT} (W)	EFFICIENCY (%)	
	CCM/TCM	CCM
77	94.04	91.95
154	95.49	93.84
231	96.44	95.10
308	96.68	96.06
362	97.16	97.00
542	97.62	97.55
722	97.79	97.74
902	97.80	97.76
1082	97.71	97.68
1262	97.58	97.55
1442	97.40	97.37
1622	97.18	97.15
1802	96.91	96.89

Table 2-2. Efficiency Data at 230VAC-50Hz

P_{OUT} (W)	EFFICIENCY (%)	
	CCM/TCM	CCM
77	93.81	92.22
154	96.75	95.74
231	97.54	96.90
308	97.90	97.48
362	98.09	97.75
542	98.44	98.25
722	98.64	98.52
902	98.74	98.66
1082	98.78	98.75
1262	98.83	98.81
1442	98.85	98.83
1622	98.85	98.84
1802	98.85	98.83
1982	98.83	98.82
2162	98.80	98.79
2342	98.77	98.77
2522	98.74	98.73
2702	98.70	98.69
2882	98.66	98.65
3062	98.61	98.60
3242	98.55	98.54
3422	98.49	98.49
3602	98.43	98.43

2.3 Thermal Images

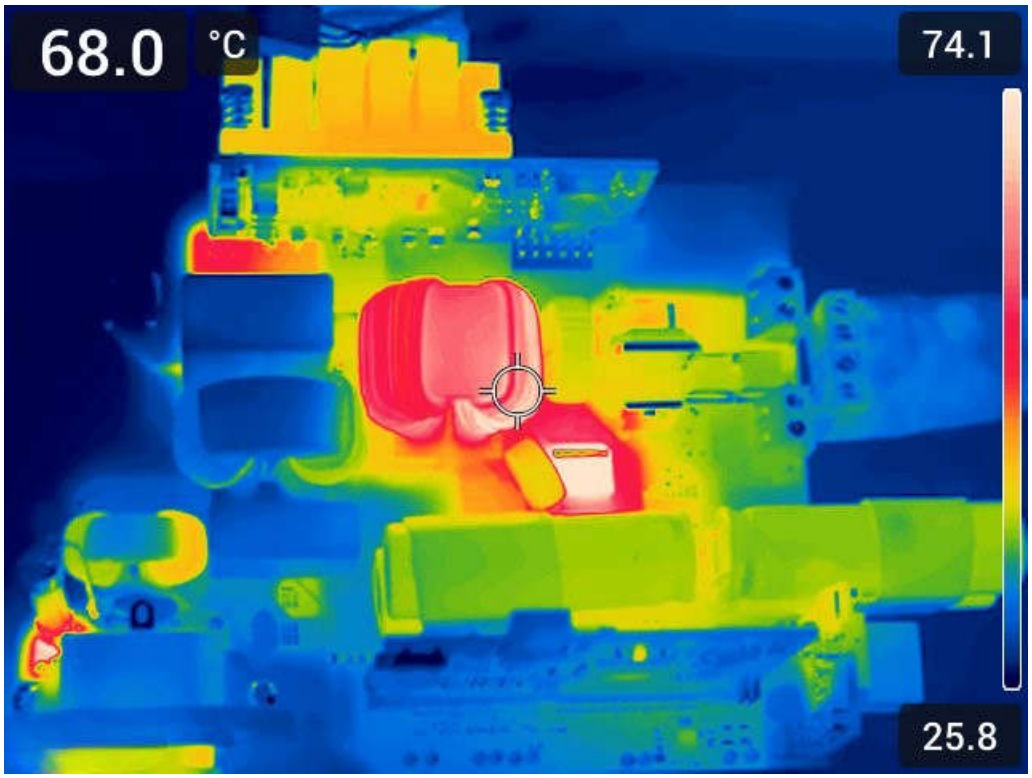


Figure 2-3. Thermal Image

Figure 2-4. Thermal Image

3 Waveforms

3.1 Start-up Waveform

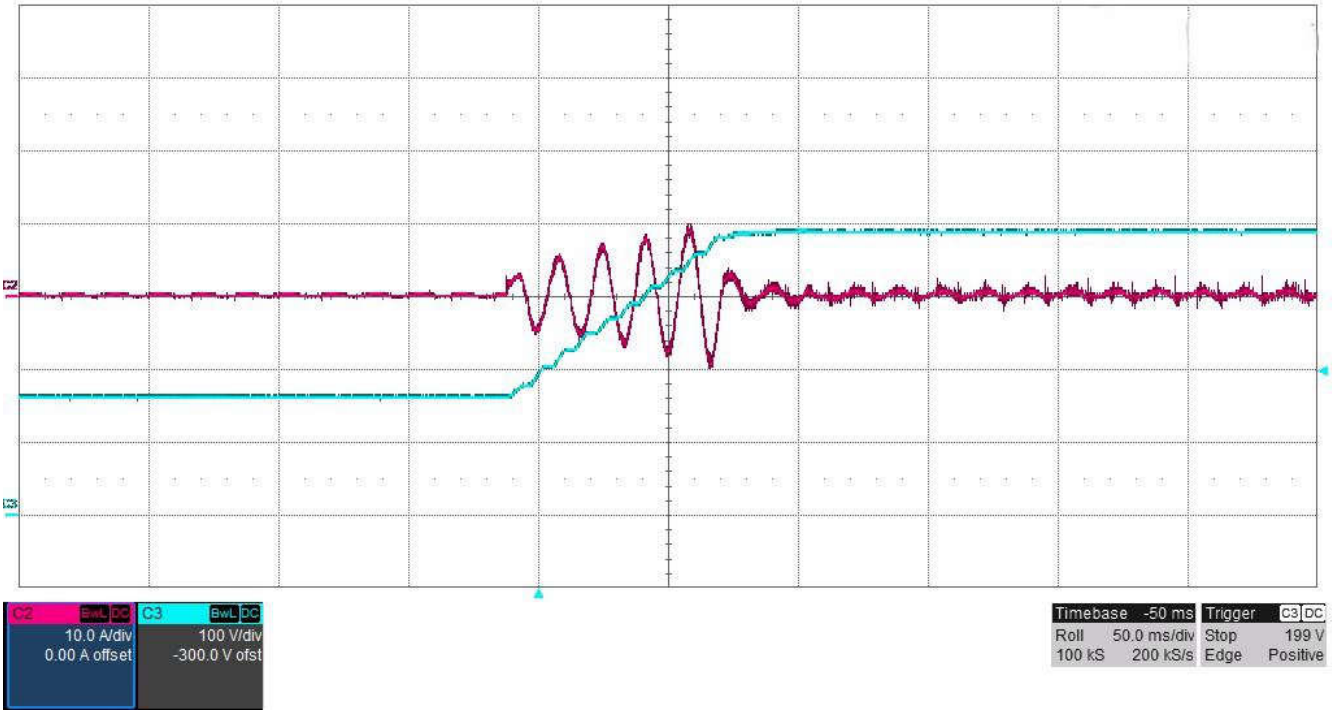


Figure 3-1. 115VAC, 0 Load, Pink: I_{in}, Blue: V_{out}

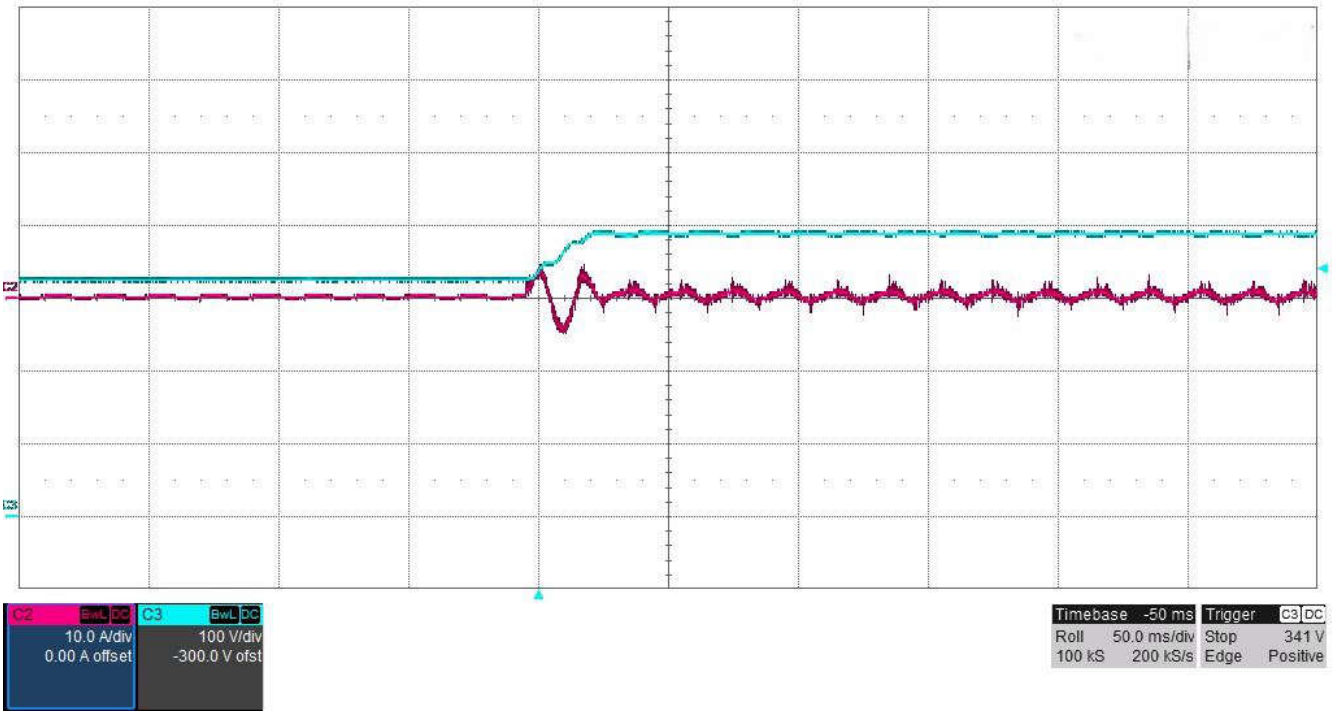


Figure 3-2. 230VAC, 0 Load, Pink: I_{in}, Blue: V_{out}

3.2 Input Current Waveform

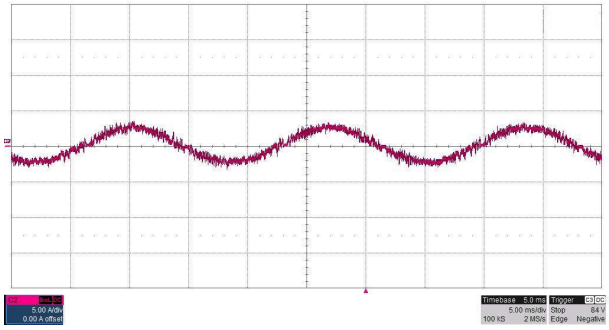


Figure 3-3. 115VAC, 10% Load

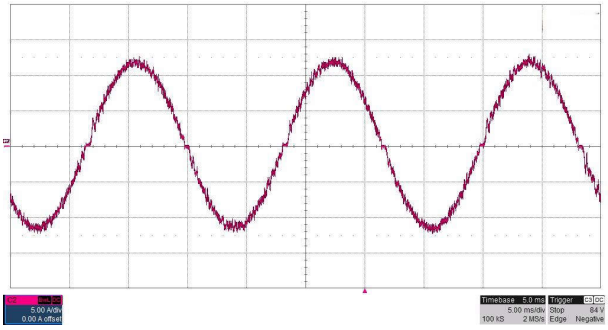


Figure 3-4. 115VAC, 50% Load

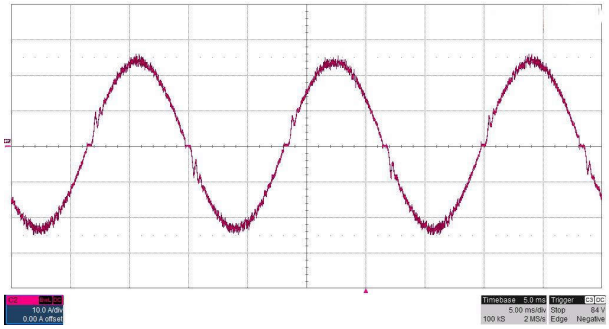


Figure 3-5. 115VAC, 100% Load

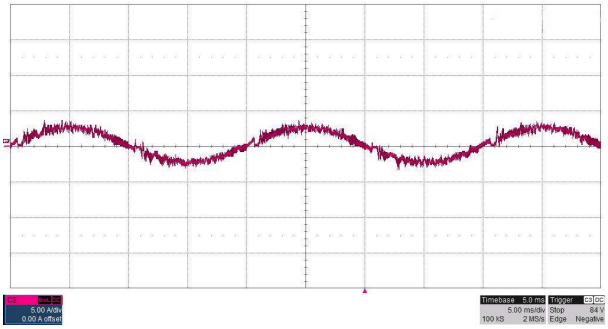


Figure 3-6. 230VAC, 10% Load

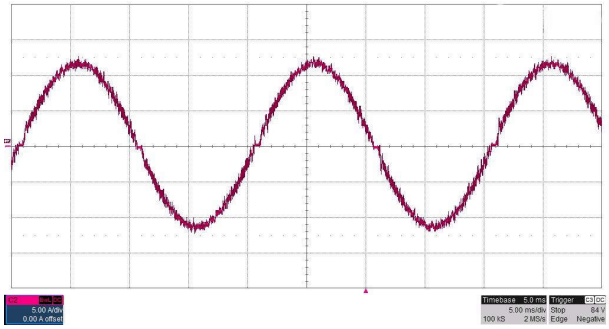


Figure 3-7. 230VAC, 50% Load

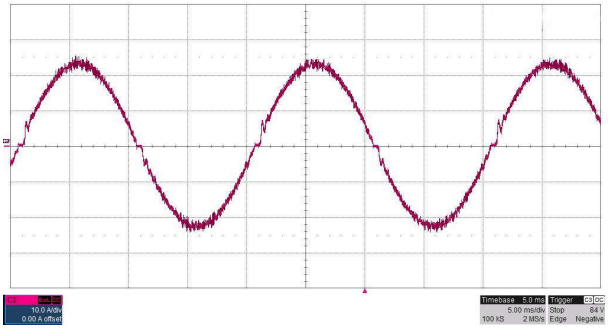


Figure 3-8. 230VAC, 100% Load

3.3 Load Transients

In Figure 3-9 through Figure 3-16: Blue: V_{out}, Pink: I_{in}, Yellow: I_{out}.

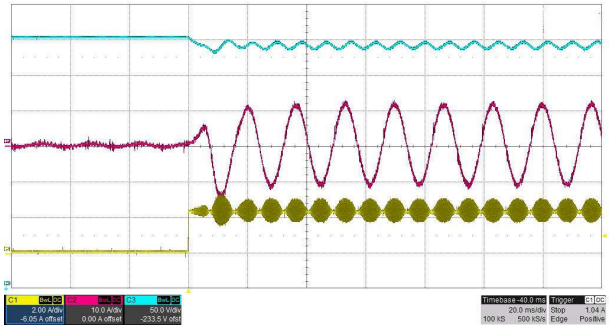


Figure 3-9. 115VAC, 0% to 50% Load

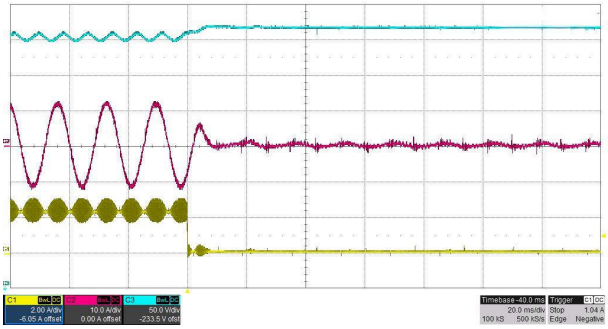


Figure 3-10. 115VAC, 50% to 0% Load

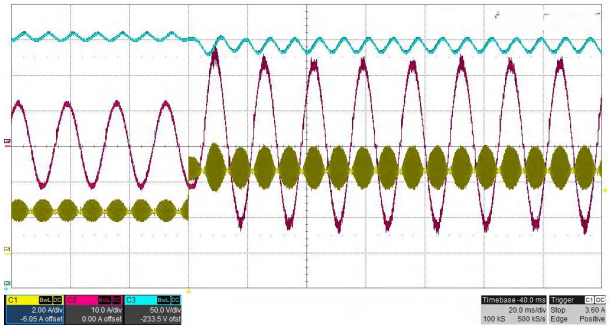


Figure 3-11. 115VAC, 50% to 100% Load

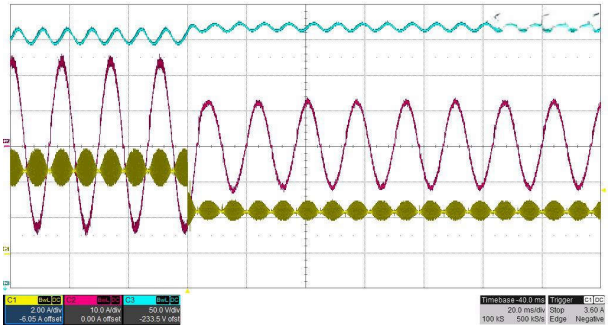


Figure 3-12. 115VAC, 100% to 50% Load

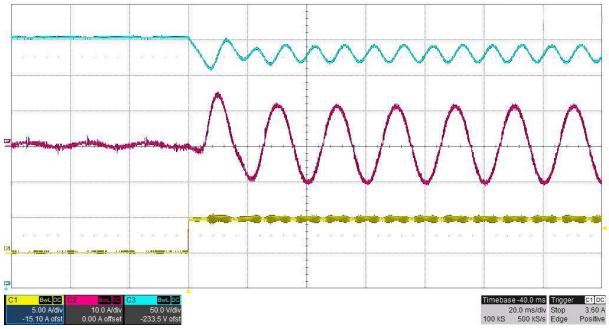


Figure 3-13. 230VAC, 0% to 50% Load

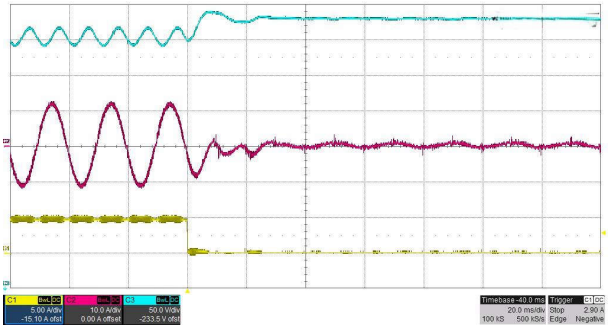


Figure 3-14. 230VAC, 50% to 0% Load

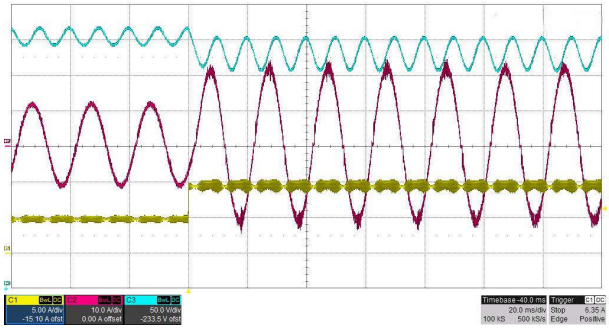


Figure 3-15. 230VAC, 50% to 100% Load

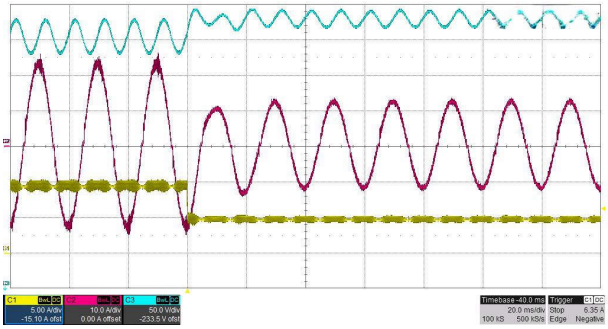


Figure 3-16. 230VAC, 100% to 50% Load

3.4 AC Drop Test

In Figure 3-17 and Figure 3-18: Blue: V_{out}, Pink: I_{in}.

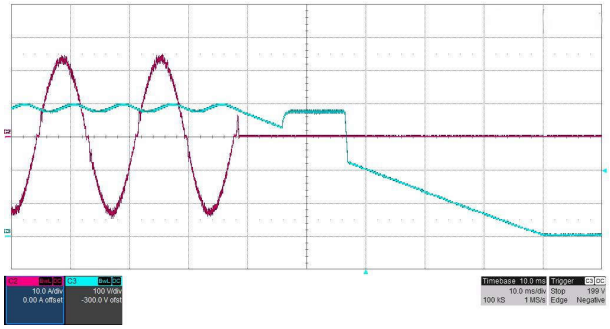


Figure 3-17. 115VAC, 100% Load

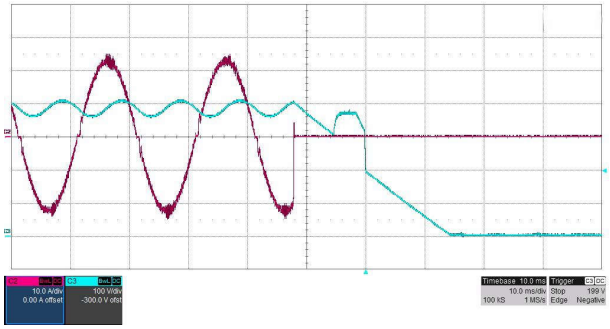


Figure 3-18. 230VAC, 100% Load

3.5 THD and PF

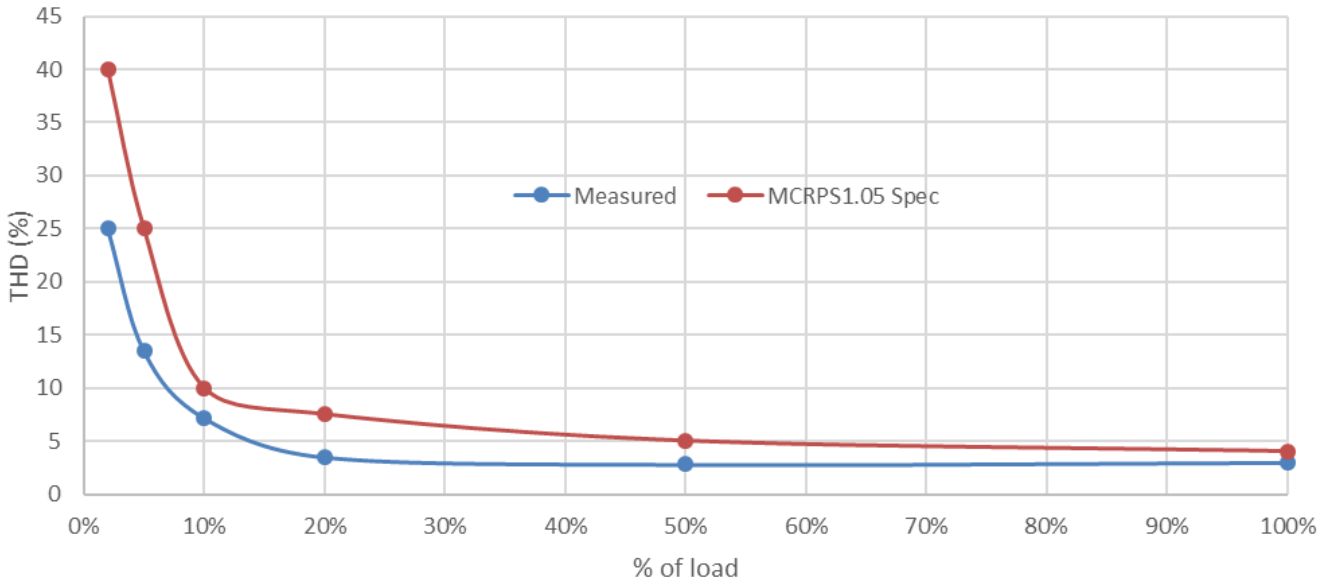


Figure 3-19. THD at 120VAC-60Hz

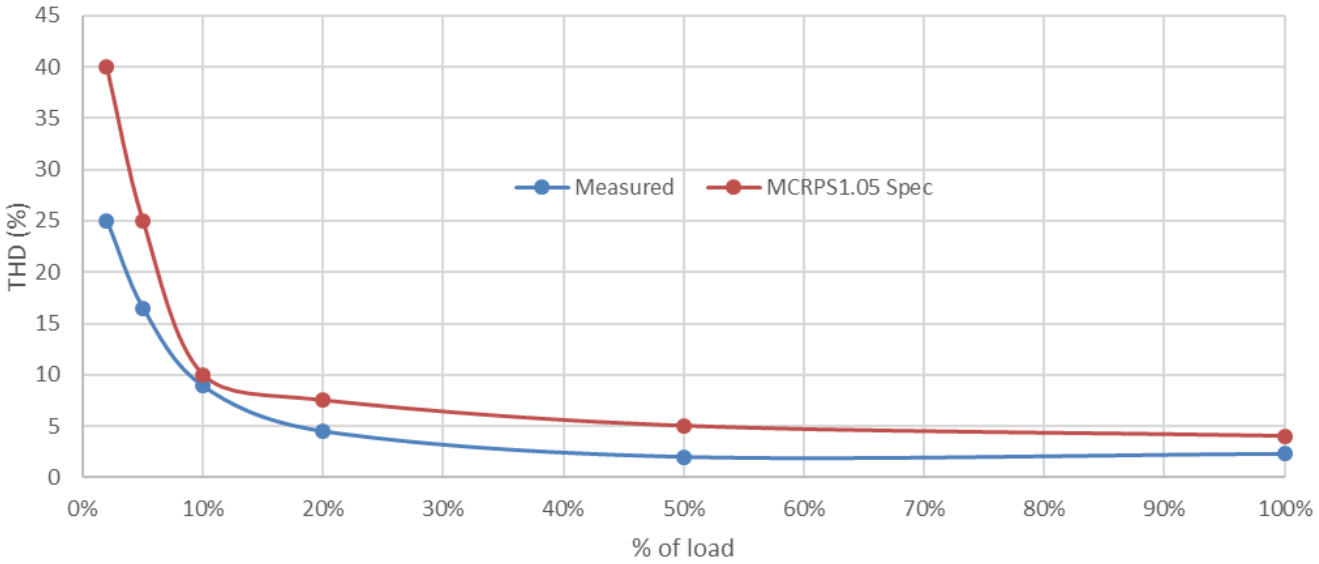


Figure 3-20. THD at 240VAC-50Hz

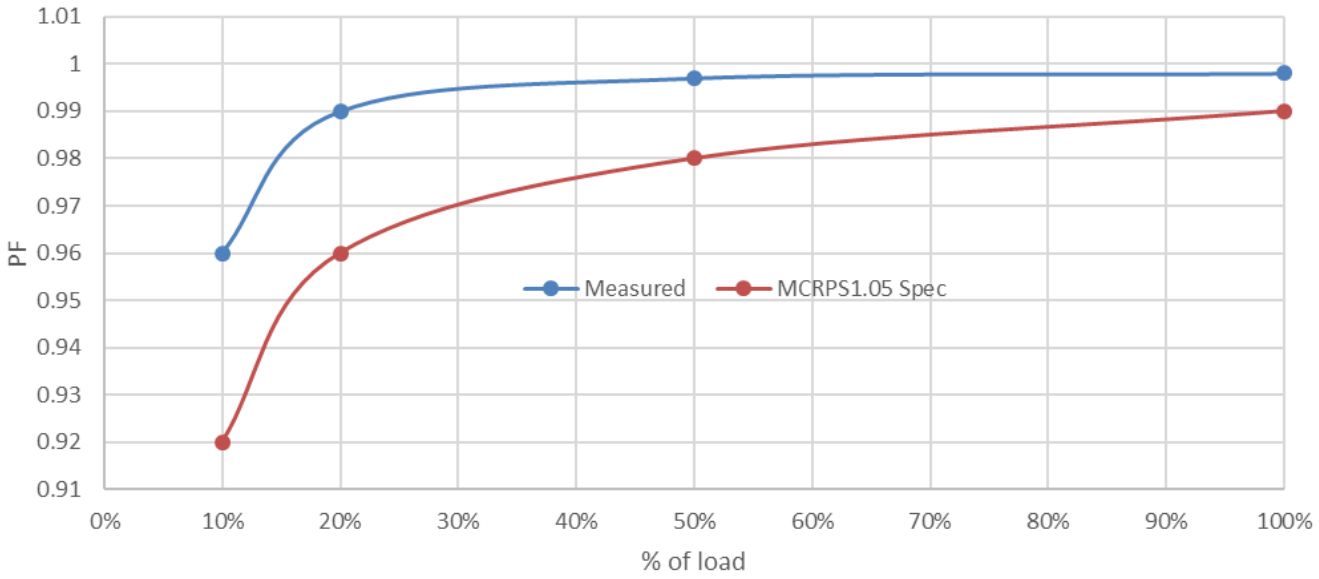


Figure 3-21. PF at 120VAC-60Hz

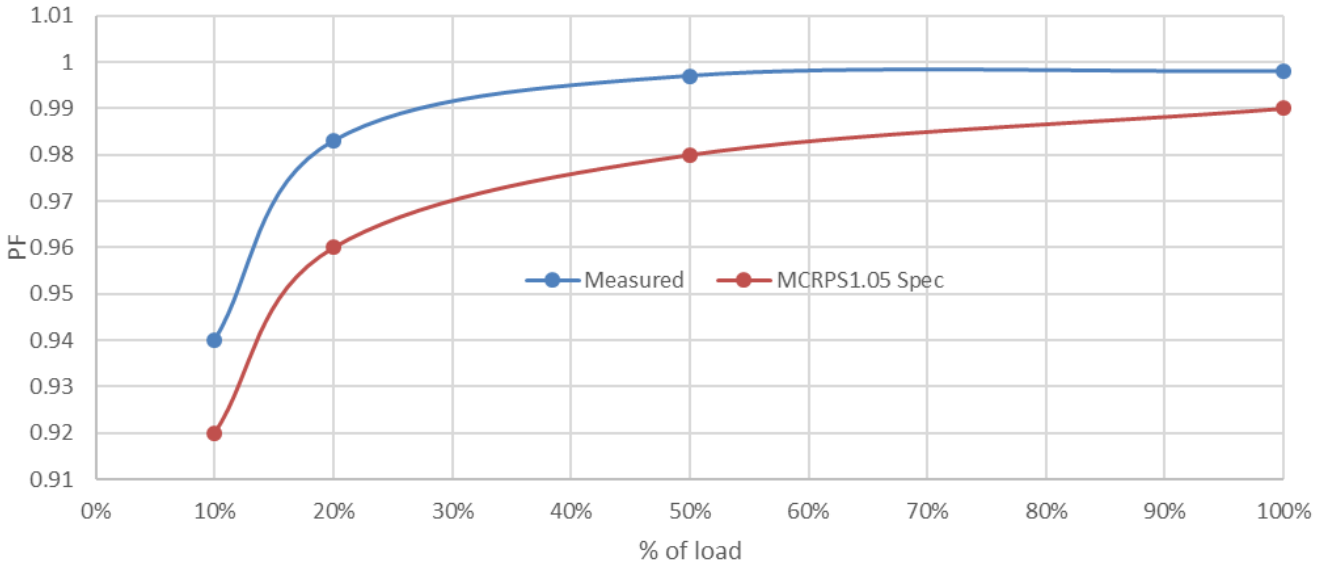


Figure 3-22. PF at 240VAC-50Hz

3.6 E-Meter Performance

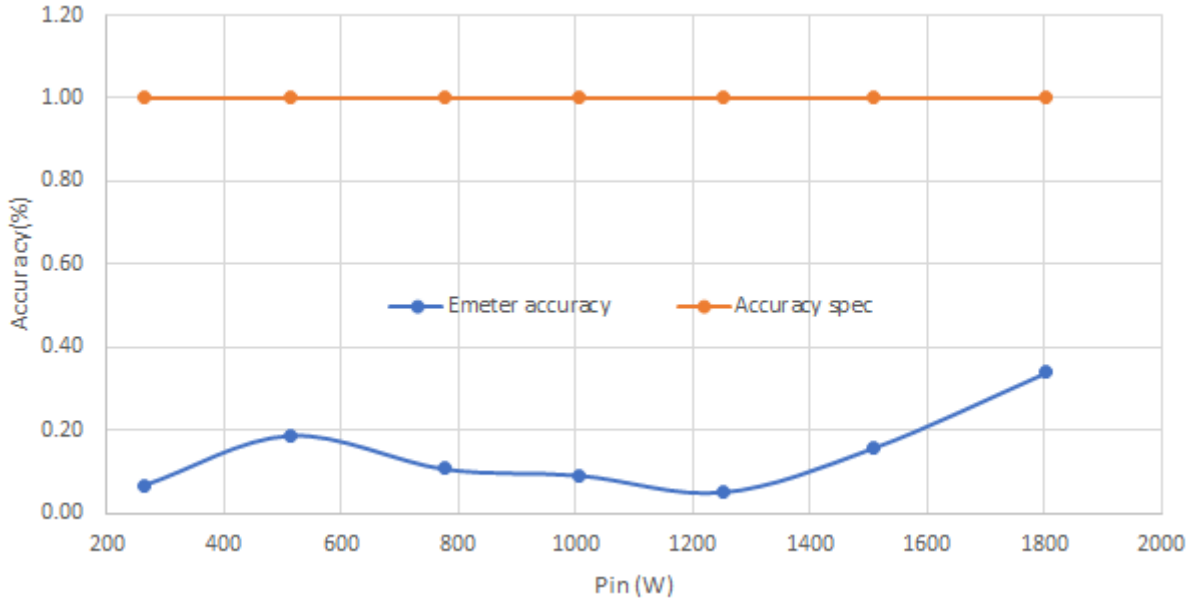


Figure 3-23. E-Meter Graph at 115VAC

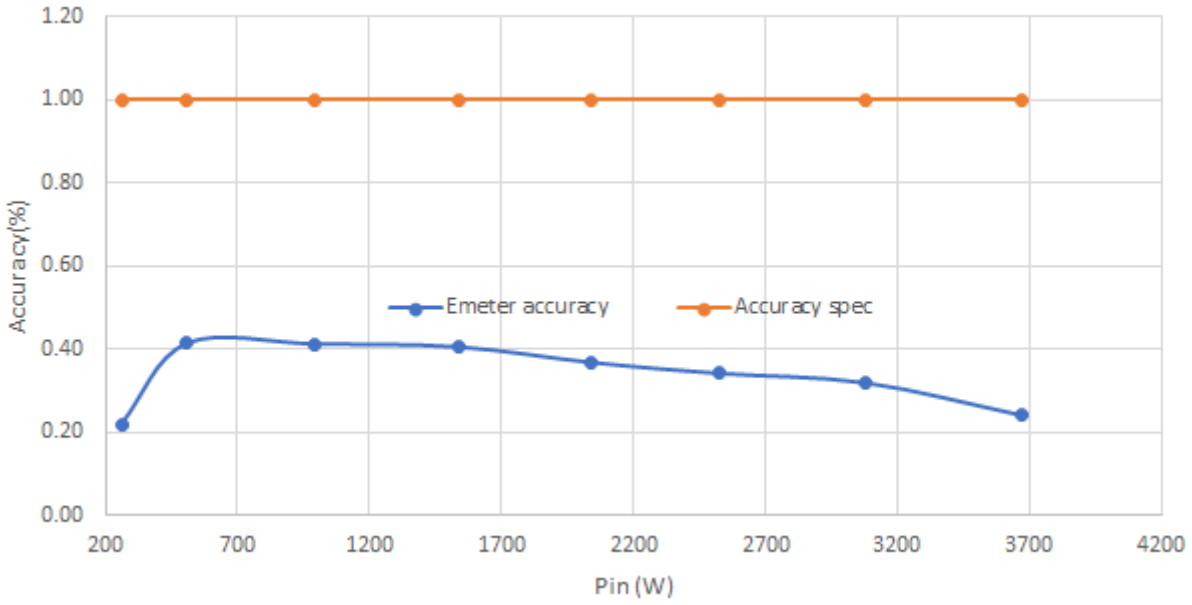


Figure 3-24. E-Meter Graph at 230VAC

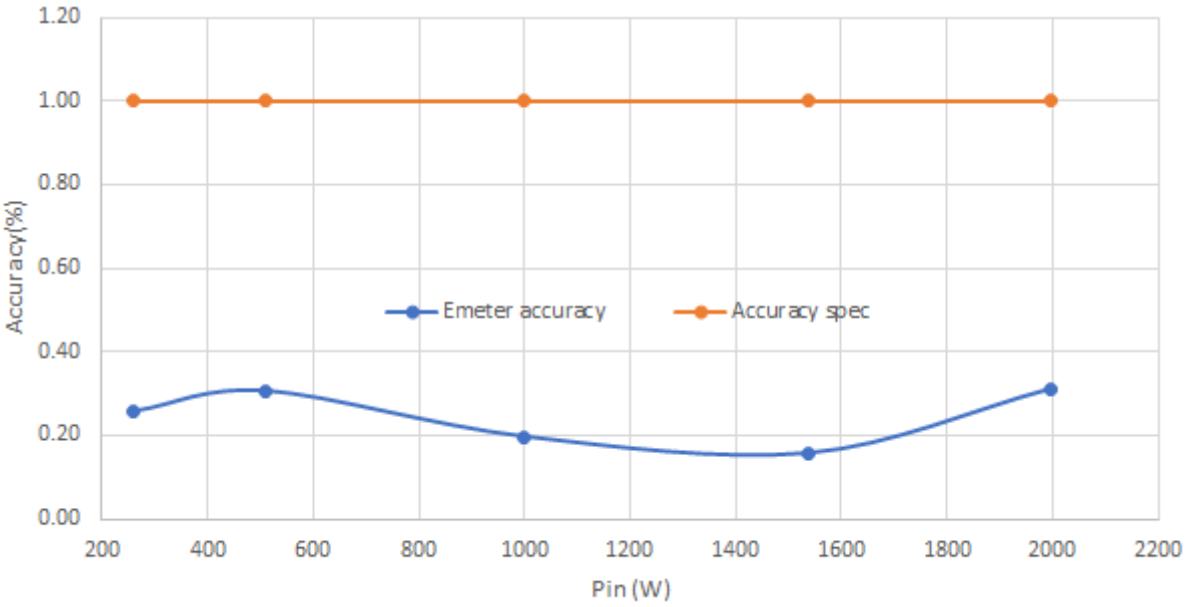


Figure 3-25. E-Meter Graph at 240VDC

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