Test Report: PMP41166

3.6kW 3-Level Flying Cap Totem-Pole Bridgeless PFC Reference Design

TEXAS INSTRUMENTS

Description

This reference design is a 3.6kW, single-phase, 3-level flying cap 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) with peak efficiency of 99%. 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. The LMG3522 top-side cooled GaN device with integrated driver and protection, enables higher efficiency and reduces power supply size and complexity. The TMDSCNCD28P55X C2000™ real-time microcontroller is used for all the advanced controls including PFC control and e-metering.

Resources

- TMS320F28P55X
- LMG3522R030
- AMC1306M05
- TMCS1133
- 3.6KW CCM 2-level totem-pole PFC PMP23338
- 3.6KW CCM/TCM multi-mode totem-pole PFC PMP23537

Features

- High efficiency (99% peak efficiency) and high power density
- New flying cap voltage method balancing method
- 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
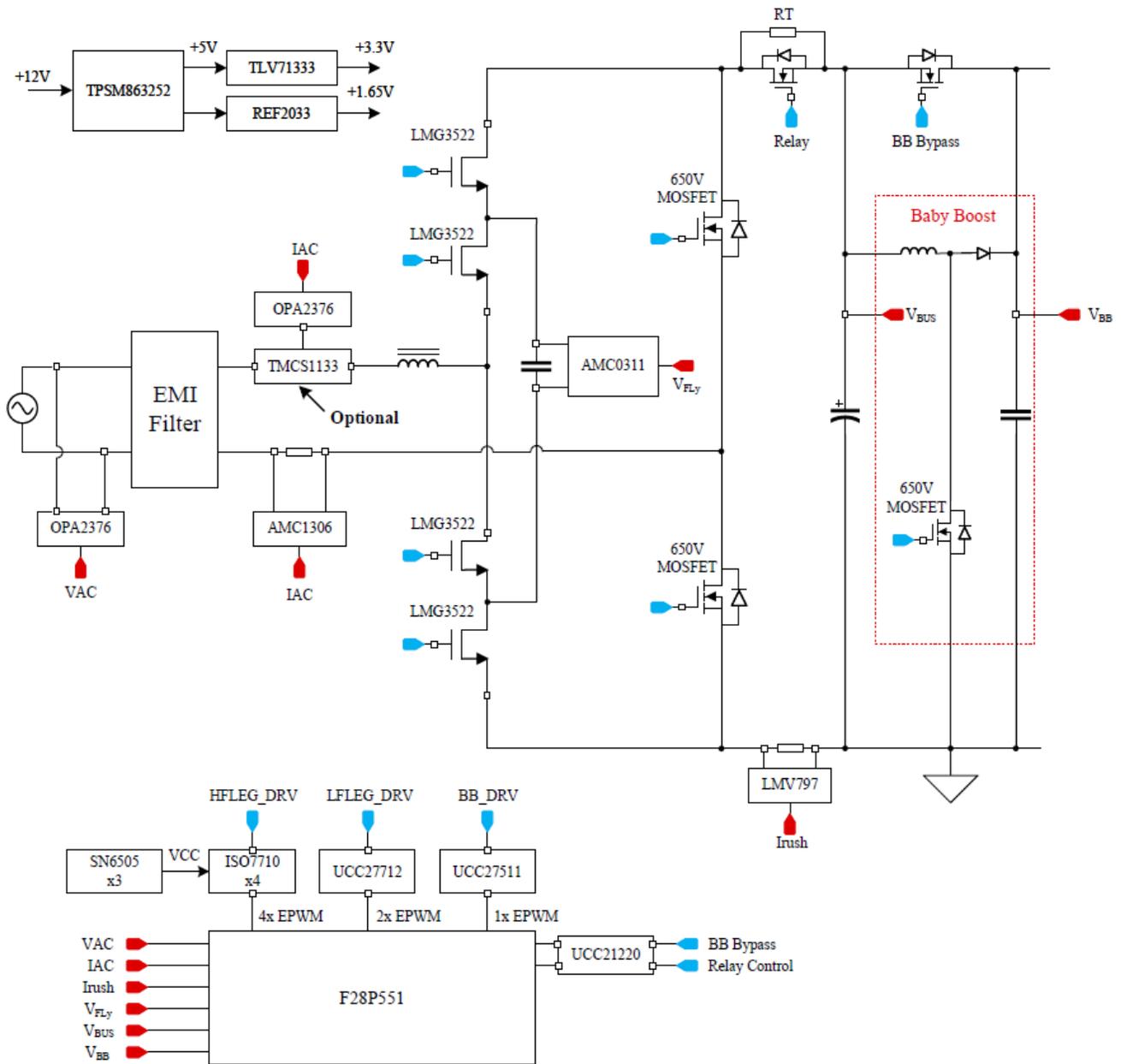
Applications

- Rack and server power
- Industrial AC-DC
- Telecom rectifiers
- Uninterruptible power supply

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 TMDSCNCD28P55X and PMP20306 isolated bias supply reference design.
- 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.
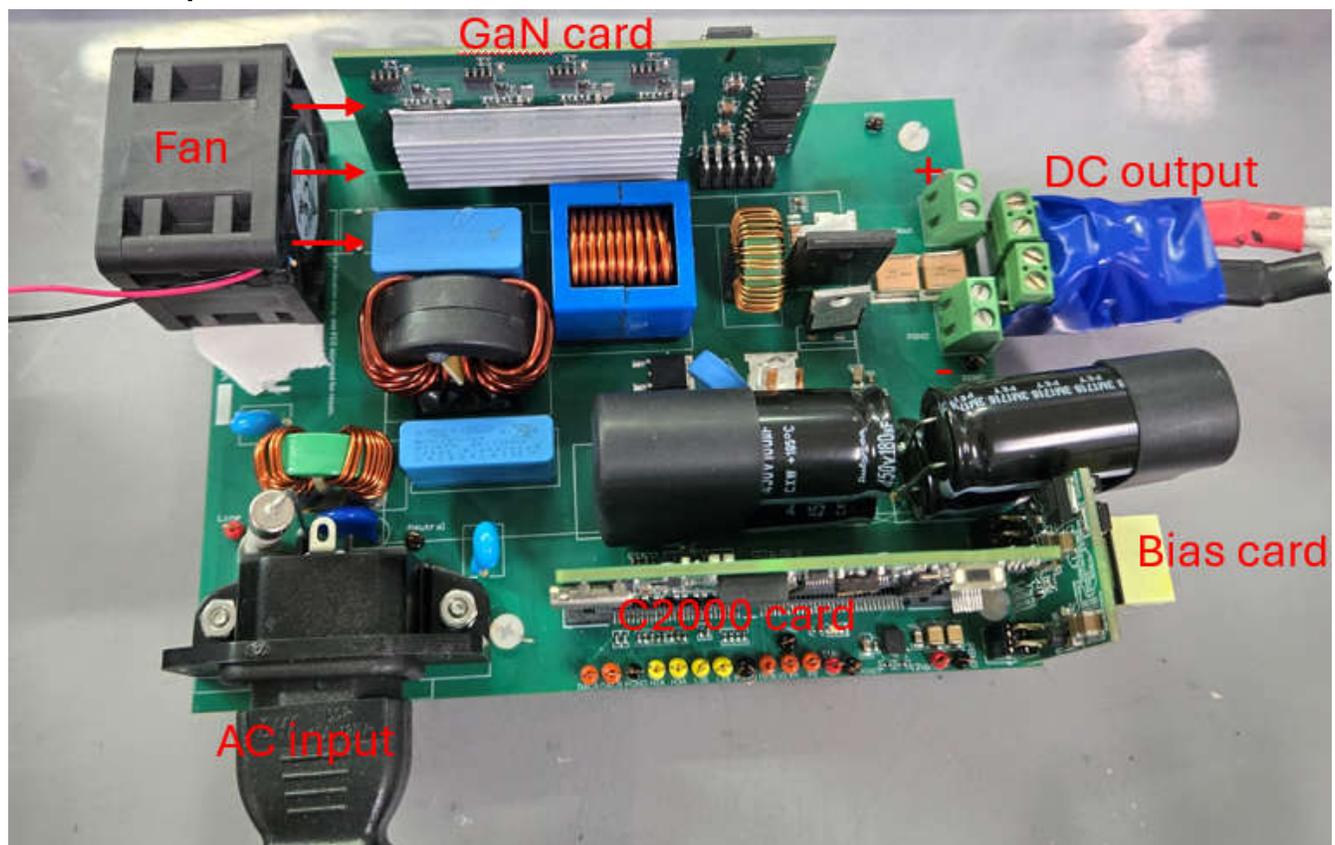
1.4 Test Setup

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 (recommended fan part number:FFB0412EN-00Y2E, run at 13V) put close to the board 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 Graph

Conditions:

- Switching Frequency: 65kHz
- GaN Slew Rate: 50V/ns
- Output: 385V
- Relay and BB bypass FETs shorted
- Auxiliary supply not included

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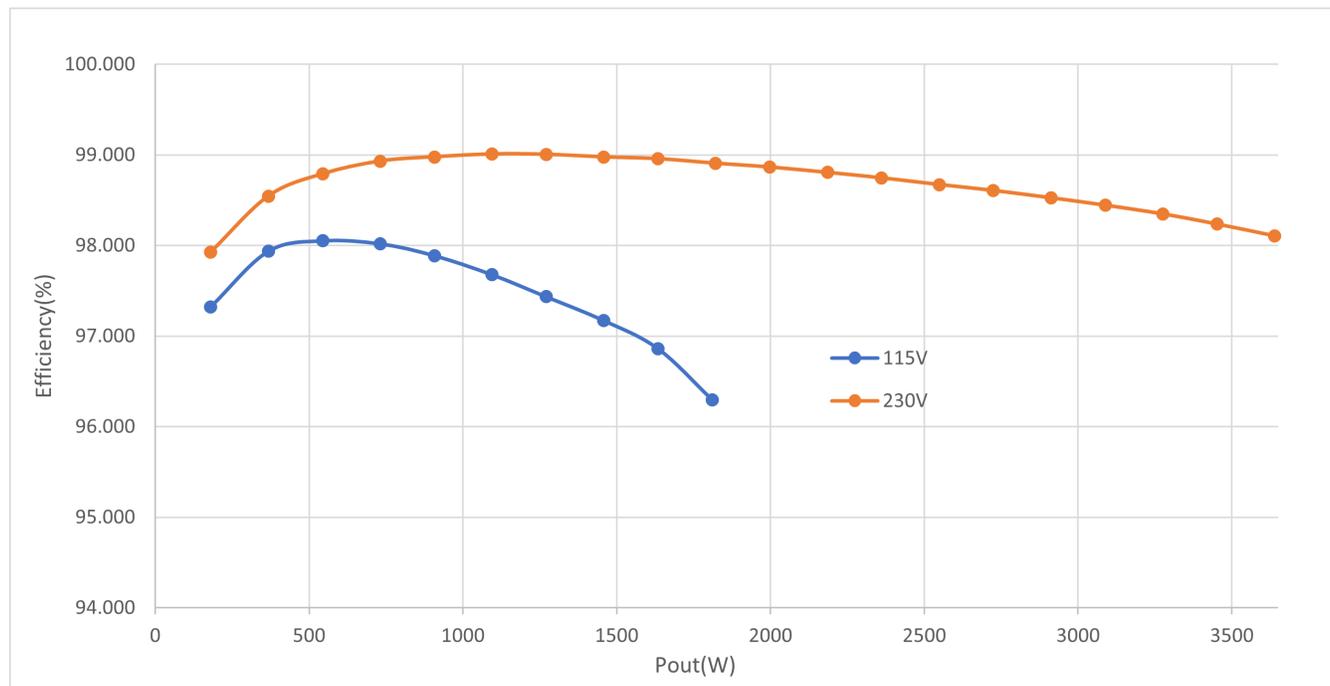
2.2 Efficiency Data

Efficiency data is shown in Table 2-1.

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

P$_{IN}$ (W)	P$_{OUT}$ (W)	efficiency(%)
185.486	180.519	97.322
375.74	367.99	97.937
554.86	544.06	98.054
746.22	731.45	98.021
927.19	907.62	97.889
1121.01	1094.99	97.679
1304.52	1271.05	97.434
1500.42	1457.98	97.171
1687.37	1634.39	96.860
1880.49	1810.8	96.294

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

P$_{IN}$ (W)	P$_{OUT}$ (W)	efficiency(%)
184.185	180.365	97.926
373.249	367.82	98.545
550.83	544.17	98.791
739.55	731.65	98.932
916.81	907.44	98.978
1105.97	1095.01	99.009
1283.98	1271.21	99.005
1473.02	1457.95	98.977
1651.64	1634.42	98.957
1841.88	1821.76	98.908
2020.78	1997.85	98.865
2211.61	2185.21	98.806
2391.3	2361.31	98.746
2582.64	2548.36	98.673
2762.93	2724.44	98.607
2955.65	2912.09	98.526
3136.87	3088.08	98.445
3330.71	3275.7	98.348
3513.8	3451.83	98.236
3709.53	3639.31	98.107

2.3 Thermal Images
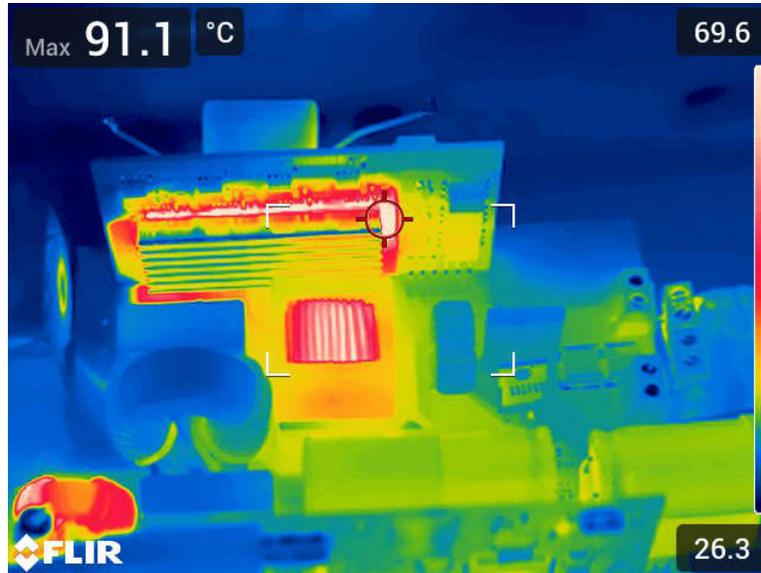
Figure 2-1. Thermal Image at 115V/1800W

Figure 2-2. Thermal Image at 230V/3600W

3 Waveforms

3.1 Start-up Waveform
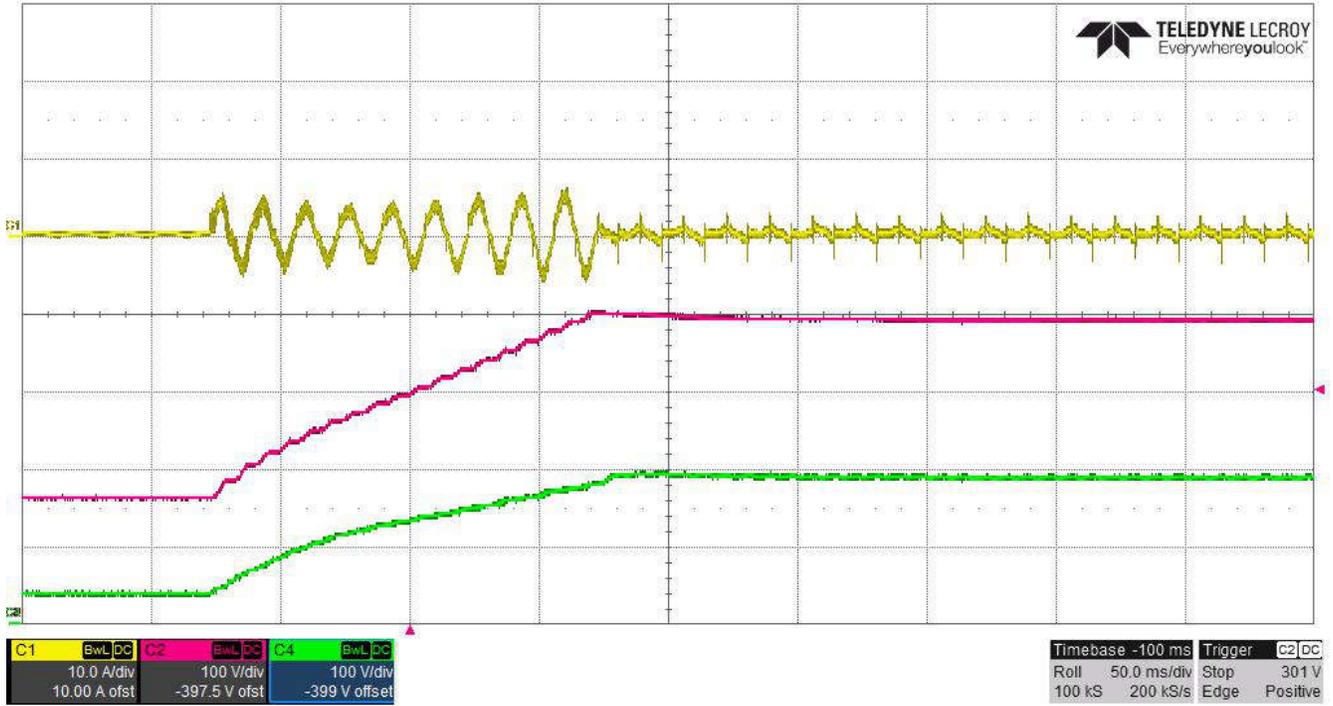
Figure 3-1. 115VAC, 0 Load, Yellow: I$_{in}$, Pink: V$_{out}$, Green: V$_{FLY}$
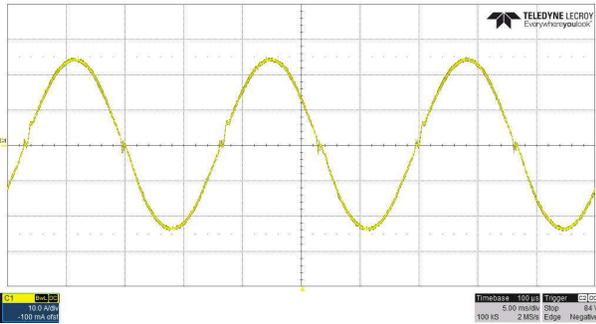
3.2 Input Current Waveform
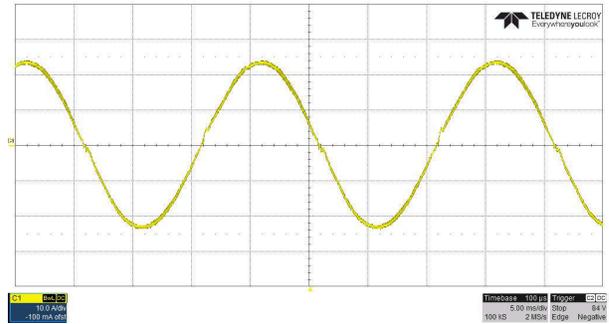

Figure 3-2. 115VAC, 100% Load

Figure 3-3. 230VAC, 100% Load

3.3 AC Drop Test

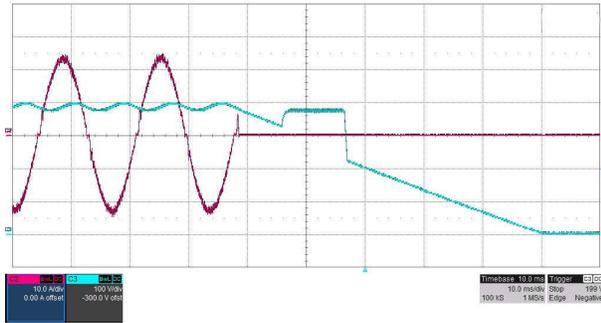In Figure 3-4 and Figure 3-5: Blue: V_{out}, Pink: I_{in}.
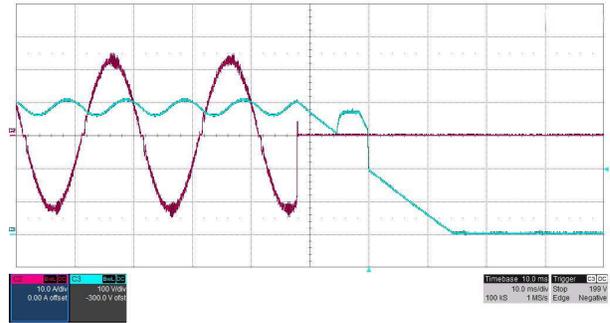

Figure 3-4. 115VAC, 100% Load

Figure 3-5. 230VAC, 100% Load

3.4 Fly Cap Voltage Balancing

	Iout(A)	0.1	0.5	1	1.5	2	2.5	3	3.5	4
	Vout(V)	385	385	385	385	385	385	385	385	385
	Vout/2(V)	192.5	192.5	192.5	192.5	192.5	192.5	192.5	192.5	192.5
No compensation	Vfly(V)	188	183	183	184	184	184	183	183	183
With compensation	Vfly(V)	191	190	191	192	192	192	191	191	191

3.5 E-Meter Performance
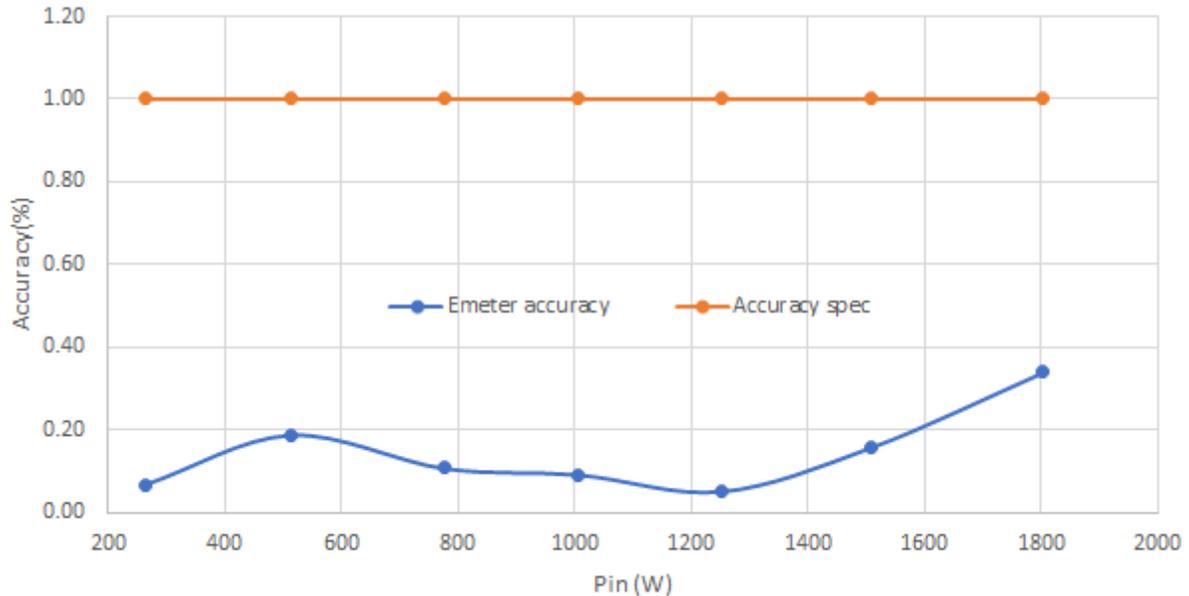
Figure 3-6. E-Meter Graph at 115VAC
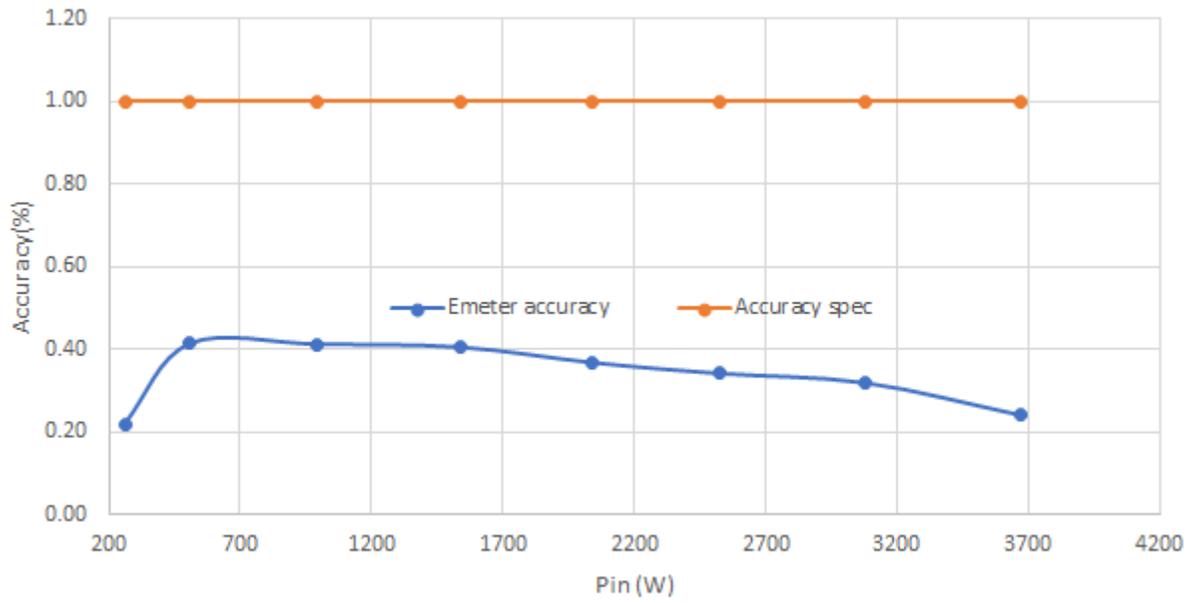
Figure 3-7. E-Meter Graph at 230VAC
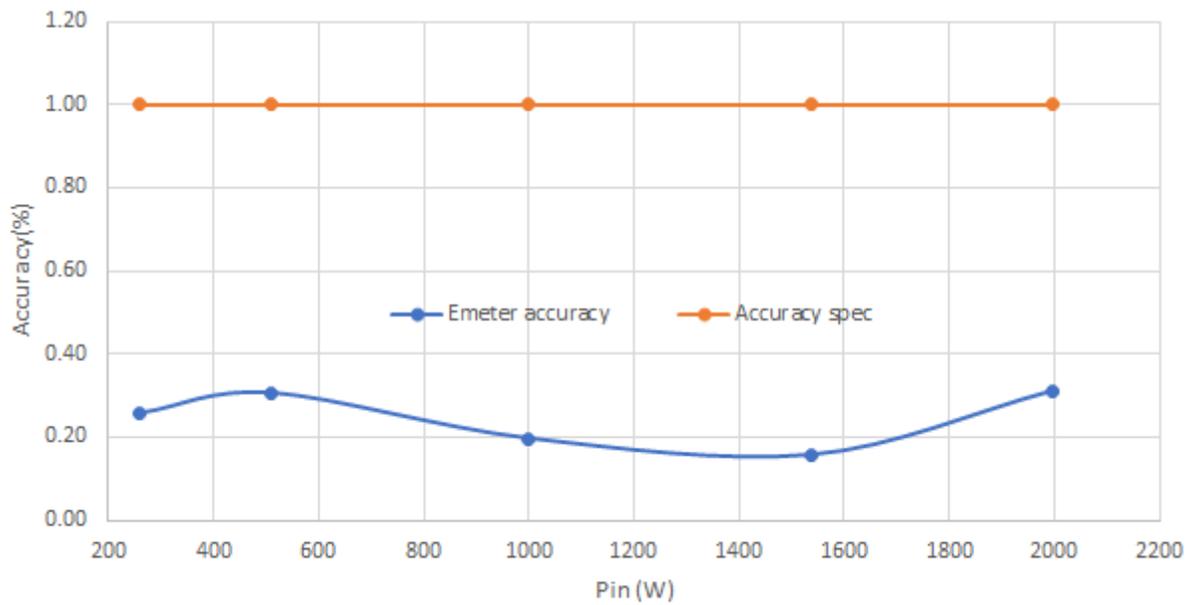
Figure 3-8. E-Meter Graph at 240VDC

3.6 References

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