Test Report: PMP41043

1.6-kW Reference Design With CCM Totem Pole PFC and Current-Mode LLC Realized by C2000 and GaN

Description

This reference design is a digitally controlled, compact 1.6-kW AC/DC power supply design for server power supply unit (PSU) and telecom rectifier applications. The highly-efficient design supports two main power stages, including a front-end continuous conduction mode (CCM) totem-pole bridgeless power factor correction (PFC) stage. The PFC stage features TI's LMG341x GaN FET with integrated driver to provide enhanced efficiency across a wide load range. The design also supports a half-bridge LLC isolated DC/DC stage using LMG342x GaN FET to achieve a +12-V DC output at 1.6 kW. Two control cards use C2000™ Piccolo™ microcontrollers to control both power stages

Features

- CCM GaN based totem-pole bridgeless PFC stage with > 98% peak efficiency, enabled by LMG341x GaN FET with integrated driver
- Half-bridge LLC stage with > 98% peak efficiency, enabled by LMG342x GaN FET with integrated driver
- Power density 41 W/in^3 , 38 mm × 66 mm × 160 mm
- Fast serial interface (FSI) based PFC, DC/DC communication

Applications

- Merchant network and server PSU
- Industrial AC/DC

Top of Board

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage Range	100 V_{AC} to 265 V_{AC}
Output Voltage	12 V_{DC}
Output Current	0 A to 133 A

1.2 Required Equipment

- Isolated AC source
- Digital oscilloscope
- Current probe
- Multimeters
- Power meter
- Electronic load
- High voltage probe (> 600 V)
- Cooling fan

1.3 Test Setup

Figure 1-1 shows the test setup with air flow.

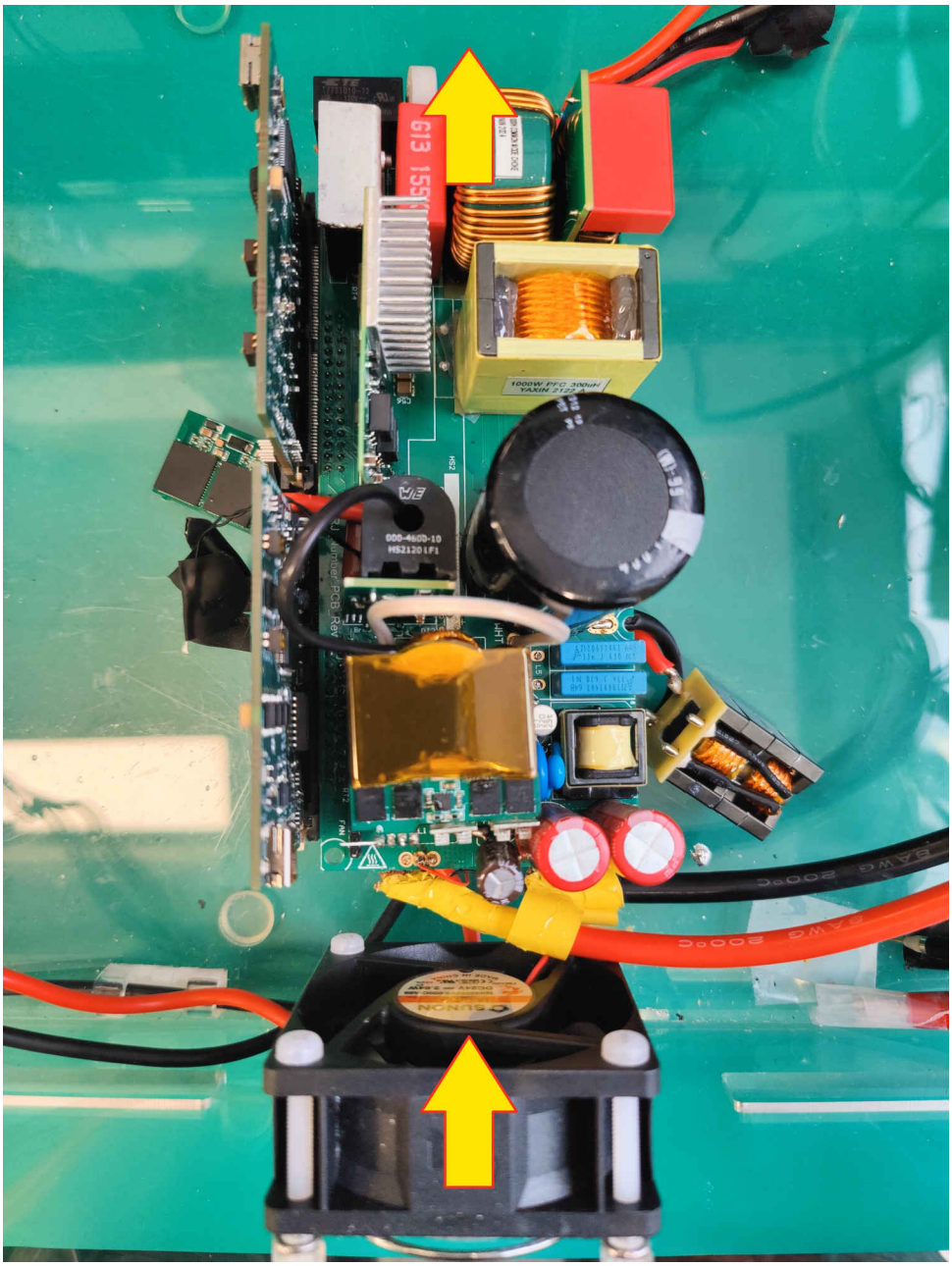


Figure 1-1. PMP41043 Test Setup

2 Testing and Results

2.1 Efficiency Graphs of PFC Stage

Efficiency is shown in the following figure.

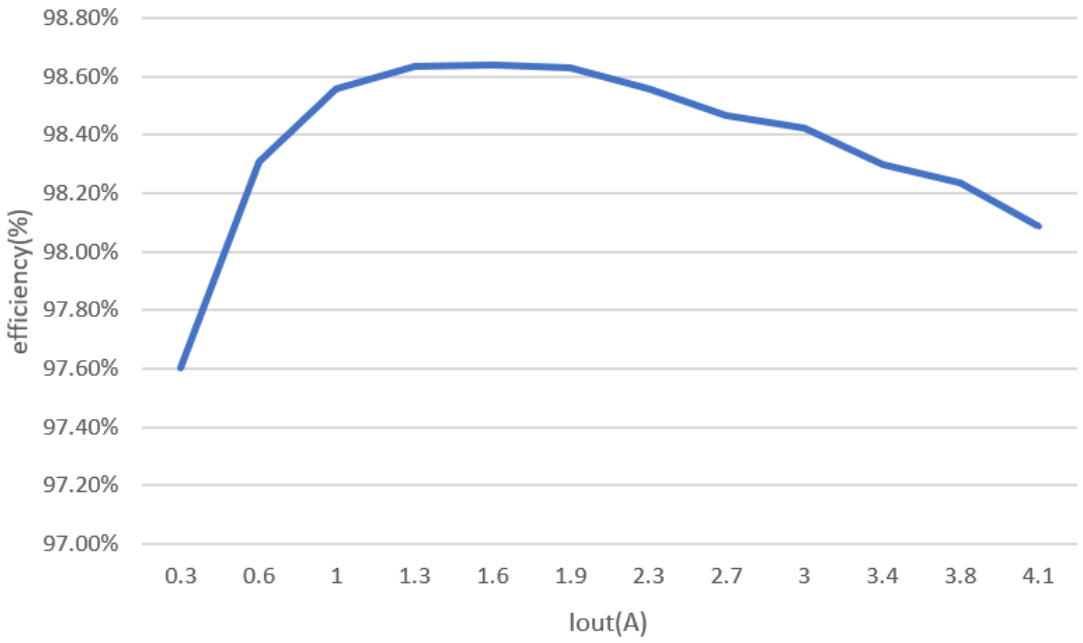


Figure 2-1. PFC Efficiency Graph

2.2 Efficiency Data of PFC Stage

PFC efficiency data is shown in the following table.

Table 2-1. PFC Efficiency Data

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	Efficiency (%)	PF
229.95	0.57	388.4	0.285	112.7	110	97.6	0.86
229.9	1.054	388.4	0.585	230.7	226.8	98.31	0.954
229.83	1.73	388.41	0.9852	388.2	382.6	98.56	0.977
229.77	2.233	388.4	1.2842	505.7	498.78	98.63	0.9857
229.71	2.742	388.39	1.5845	623.9	615.4	98.64	0.99
229.65	3.254	388.39	1.8845	742.1	731.92	98.63	0.993
229.57	3.941	388.39	2.2849	900.4	887.43	98.56	0.995
229.49	4.632	388.4	2.6852	1059	1042.93	98.48	0.996
229.43	5.149	388.4	2.9852	1178	1159.45	98.43	0.9967
229.35	5.846	388.4	3.3843	1337.2	1314.46	98.3	0.9974
229.26	6.541	388.4	3.7845	1496.3	1469.9	98.24	0.9977
229.19	7.063	388.4	4.0811	1616	1585.1	98.09	0.998

2.3 Efficiency Graphs of LLC Stage

Efficiency is shown in the following figure.

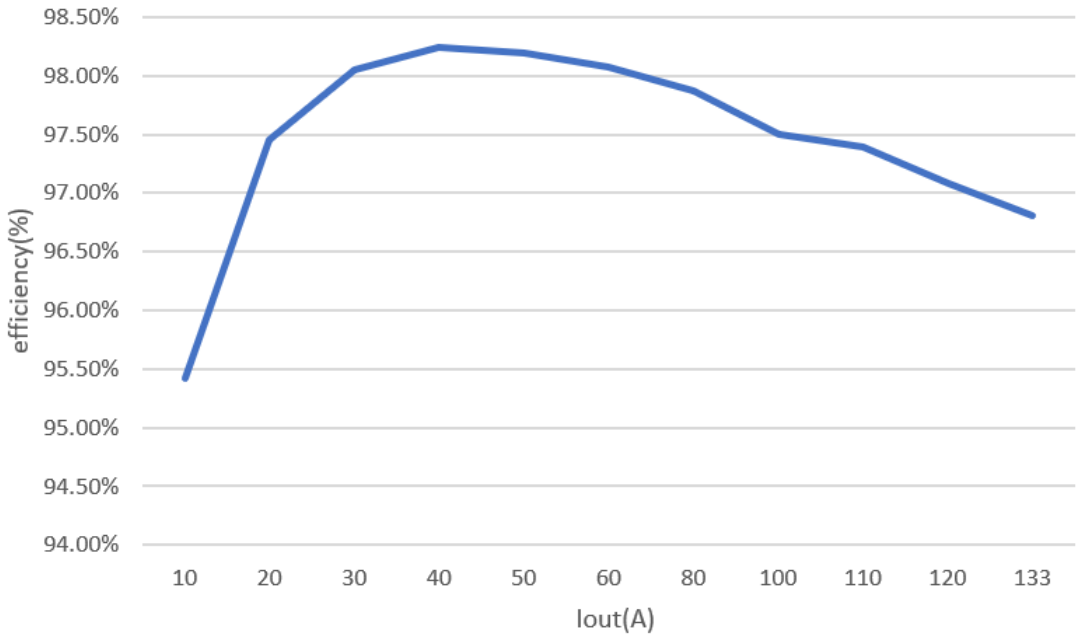


Figure 2-2. LLC Efficiency Graph

2.4 Efficiency Data of LLC Stage

LLC efficiency data is shown in the following table.

Table 2-2. LLC Efficiency Data

V_{IN} (V)	I_{IN} (A)	V_{OUT} (V)	I_{OUT} (A)	P_{IN} (W)	P_{OUT} (W)	Efficiency (%)
384.88	0.326	11.98	10	125.45	119.7	95.42
384.88	0.6387	11.98	20	245.86	239.6	97.45
384.81	0.9534	11.99	30	366.84	359.7	98.05
384.77	1.2677	11.98	40	487.8	479.2	98.24
384.72	1.5855	11.98	50	610	599	98.2
384.71	1.9018	11.96	60	731.7	717.6	98.07
384.68	2.535	11.93	80	975.2	954.4	97.87
384.64	3.173	11.9	100	1220.5	1190	97.5
384.62	3.494	11.9	110	1344.1	1309	97.39
384.6	3.828	11.91	120	1472.2	1429.2	97.08
384.6	4.243	11.89	133	1631.2	1581.37	96.95

2.5 Thermal Images

Thermal images are shown in the following figures under the following conditions:

- V_{IN} = 385 V
- P_{OUT} = 1.6 kW
- Ambient temperature: 25°C
- Fan: MB60252VX-000C-A99(SUNON)

Figure 2-3. SR MOSFET

Figure 2-4. Core of Transformer

Figure 2-5. Resonant Inductor

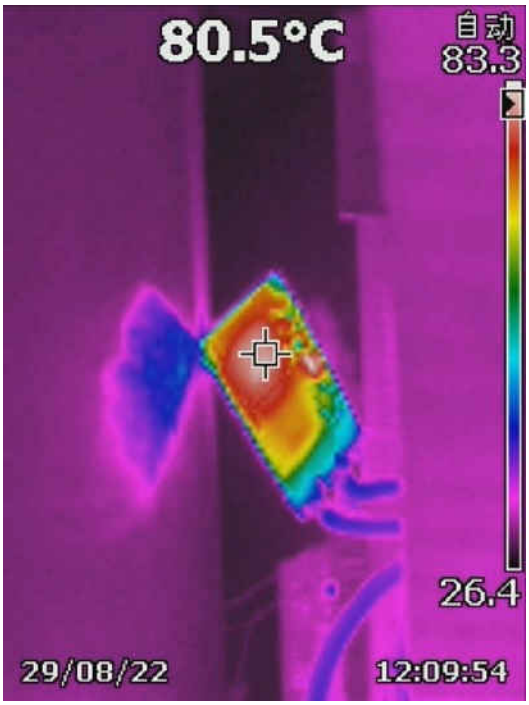
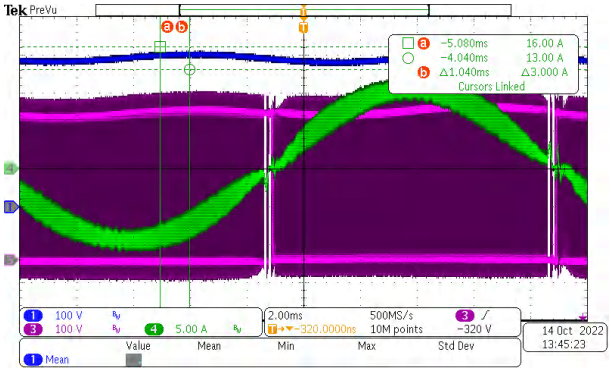


Figure 2-6. Primary GaN FET of LLC Stage

3 Waveforms

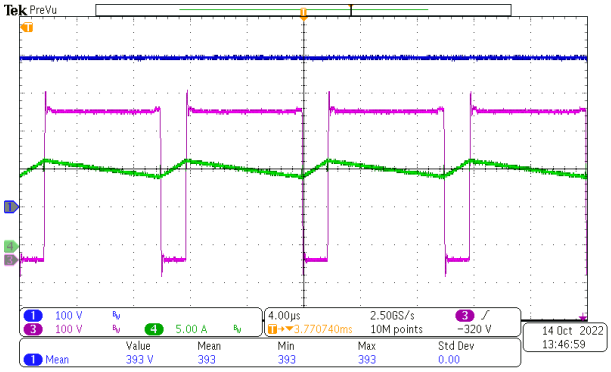
3.1 Steady State

Steady state waveforms are shown in the following images.



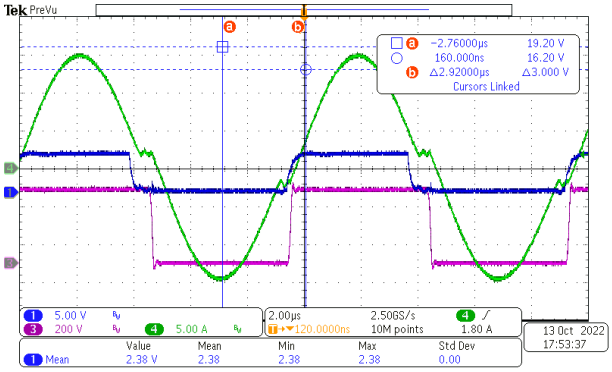
CH1: VBUS, CH3: VDS, CH4: Inductor Current

Figure 3-1. PFC Stage – 230 V_{AC}, 1.6 kW



CH1: VBUS, CH3: VDS, CH4: Inductor Current

Figure 3-2. Zoom-in PFC Stage– 230 V_{AC}, 1.6 kW

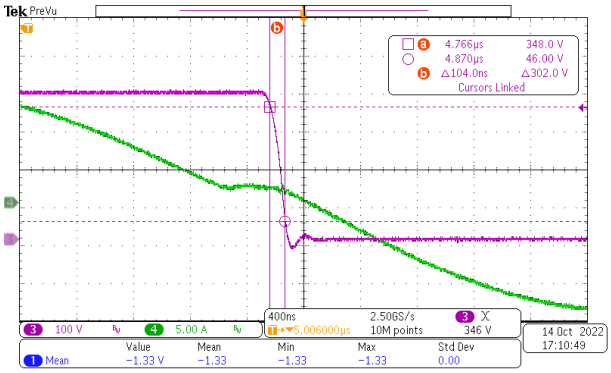


CH1: SR VGS, CH3: PRI MOS VDS, CH4: Resonant Tank Current

Figure 3-3. LLC Stage – 1.6 kW

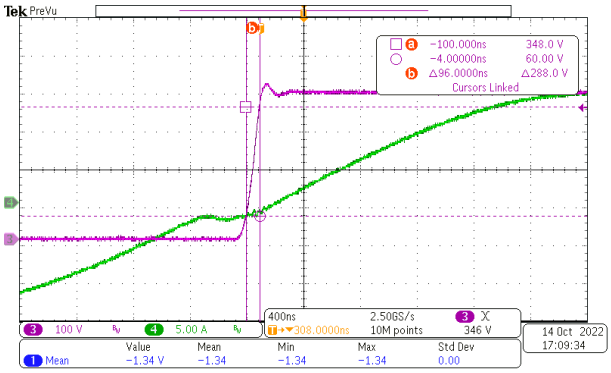
3.2 Switching

Switching behavior is shown in the following figures.



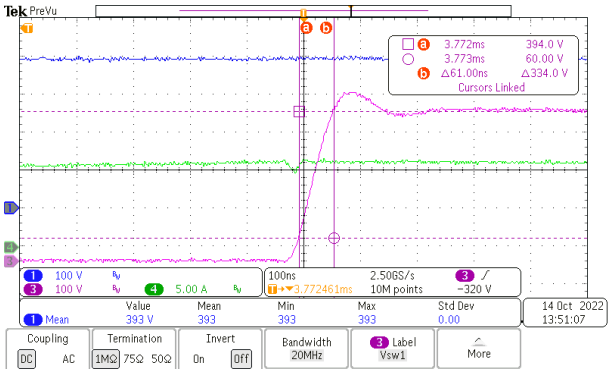
CH3: VDS, CH4: Resonant Current

Figure 3-4. Falling Edge Behavior of LLC Stage



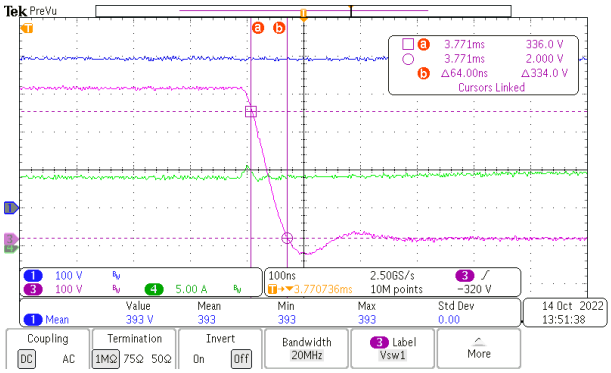
CH3: VDS, CH4: Resonant Current

Figure 3-5. Rising Edge Behavior of LLC Stage



CH1: VBUS, CH3: VDS, CH4: Inductor Current

Figure 3-6. Rising Edge Behavior of PFC Stage

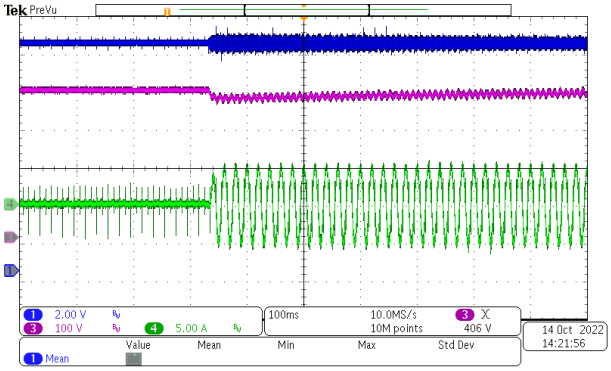


CH1: VBUS, CH3: VDS, CH4: Inductor Current

Figure 3-7. Falling Edge Behavior of PFC Stage

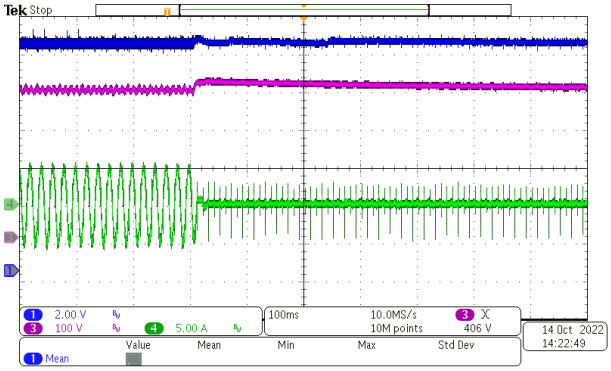
3.3 Load Transients

The load transient waveforms were captured at 230 V_{AC}.



CH1: Output Voltage, CH3: VBUS, CH4: Input Current

Figure 3-8. 0% Load to 50% Load



CH1: Output Voltage, CH3: VBUS, CH4: Input Current

Figure 3-9. 50% Load to 0% Load

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