Test Report: PMP23475

GaN-Based 5kW Two-Phase Totem-Pole PFC Reference Design With Zero Current Detection

TEXAS INSTRUMENTS

Description

This reference design is a high-density and high-efficiency, 5kW power factor correction (PFC) converter implemented with TI high-performance Gallium Nitride (GaN) power switches. A peak system efficiency of 99.2% with an open-frame power density of 120W/in^3 was measured. The power stage uses a two-phase totem pole PFC in a brand new zero current detection (ZCD) based control mechanism. The new control method operates with variable frequency and maintains zero voltage switching (ZVS) over all operating conditions. The control is implemented with a TMS320F280039C high-performance micro-controller and the LMG3527R030 GaN field effect transistor (FET) with integrated ZCD sensing. The operating frequency range of the converter is approximately between 100kHz and 800kHz.

Resources

PMP23475	Design Folder
PMP40988	Design Folder
TMS320F280039C	Product Folder
LMG3527R030	High-Voltage GaN Switch

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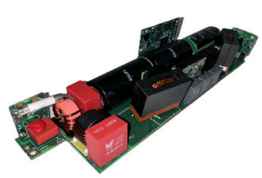
Features

- 99.2% efficiency
- Phase shedding
- 5kW
- Power density: 120W/in^3
- Density without hold up: 180W/in^3

Applications

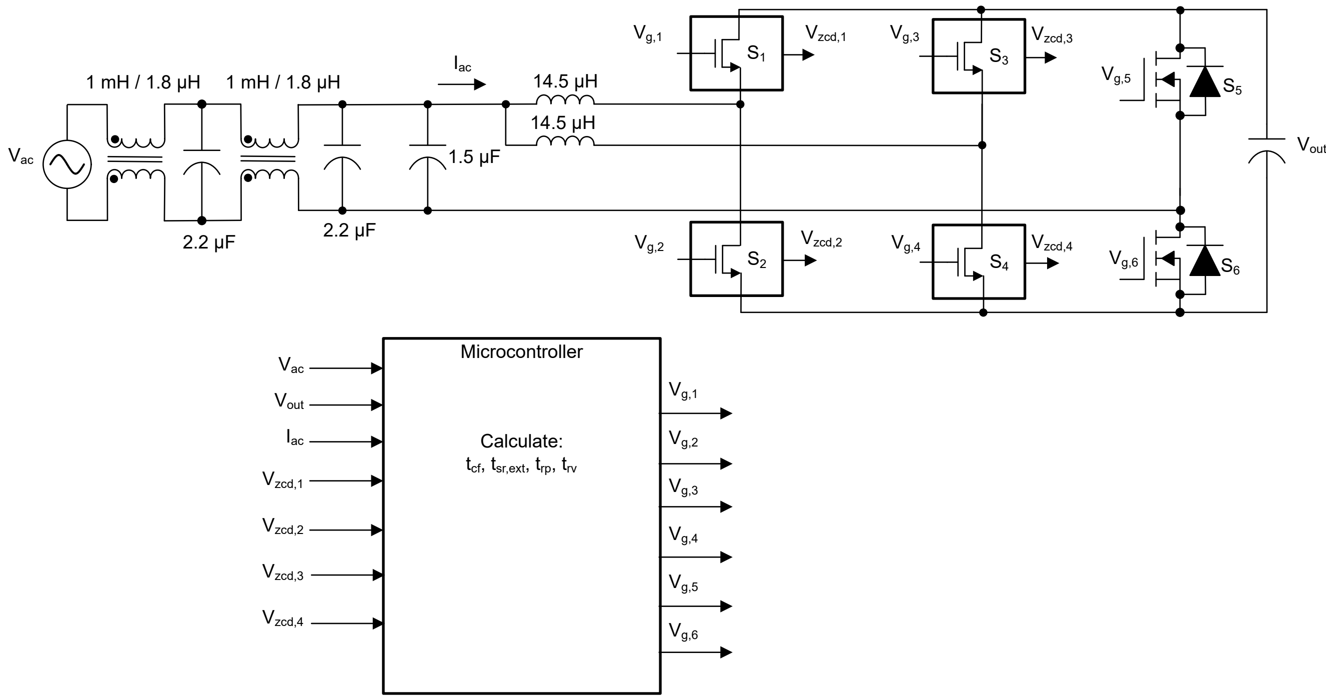
- Open rack server PSU
- Telecom rectifiers
- Industrial AC-DC



Angled View

Top View

Bottom View



Simplified Schematic

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

PARAMETER	SPECIFICATIONS
AC Input	180VAC to 265VAC
Output voltage	400V
Maximum Output Power	5kW

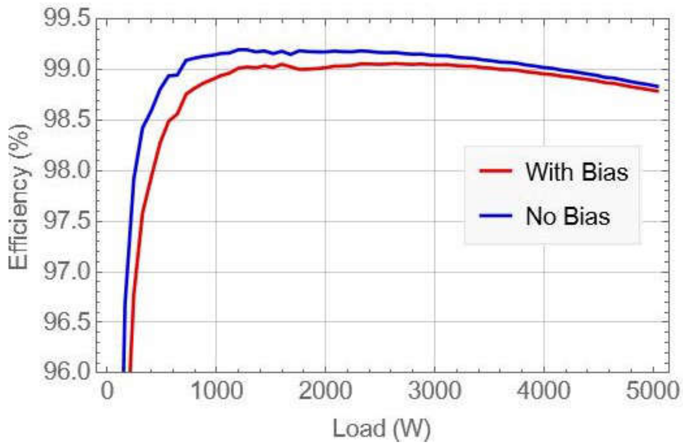
1.2 Dimensions

The dimensions of the PMP23475 board are 38mm × 65mm × 263mm.

2 Test Results

2.1 Efficiency Graphs

Figure 2-1 shows efficiency both with bias power and without bias power. Bias power includes power to the controller and drive circuitry. The enhanced efficiency at lighter loads is enhanced by turning off one of the phases. This, along with the high-efficiency enabled by the GaN switches and the ZVS control, enables a flat efficiency over a wide operating range.

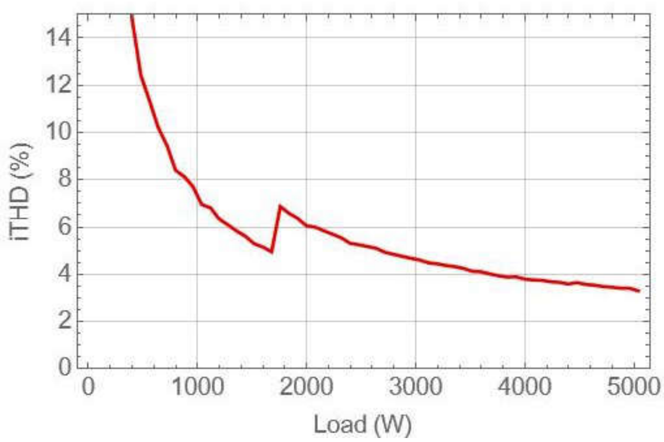


V_{IN} = 230V_{RMS}

V_{OUT} = 400V

Figure 2-1. Efficiency Graph

2.2 THD



V_{IN} = 230V_{RMS}

V_{OUT} = 400V

Figure 2-2. THD Graph

2.3 Data

Table 2-1 provides power, efficiency, and THD data.

Table 2-1. Power, Efficiency, and iTHD Data

$V_{in,ac,rms}$ (V)	$I_{in,ac,rms}$ (A)	P_{in} (W)	POWER FACTOR (%)	iTHD (%)	V_{out} (V)	I_{out} (A)	P_{out} (W)	V_{bias} (V)	I_{bias} (mA)	P_{bias} (W)	POWER STAGE LOSS (W)	BIAS LOSS (W)	EFFICIENCY, NO BIAS (%)	EFFICIENCY WITH BIAS (%)
230.2	0.8	8.3	4.5	79.3	400.1	0.0	0.2	11.9	14.7	3.4	8.1	11.4	2.8	2.0
230.1	1.9	407.1	94.4	14.8	399.3	1.0	401.3	12.0	11.8	2.7	5.7	8.5	98.6	97.9
229.9	3.6	806.6	98.4	8.4	399.3	2.0	799.5	12.0	10.5	2.4	7.1	9.6	99.1	98.8
229.8	5.3	1208.3	99.2	6.3	399.3	3.0	1198.7	12.0	9.7	2.2	9.7	11.9	99.2	99.0
229.7	7.0	1611.8	99.5	5.1	399.4	4.0	1598.6	12.0	9.1	2.1	13.2	15.3	99.2	99.1
229.6	8.8	2013.9	99.4	6.0	399.4	5.0	1997.3	11.9	13.9	3.2	16.6	19.8	99.2	99.0
229.4	10.6	2417.1	99.6	5.3	399.4	6.0	2397.3	12.0	13.1	3.0	19.8	22.8	99.2	99.1
229.4	12.3	2821.2	99.7	4.8	399.5	7.0	2797.4	12.0	12.5	2.9	23.9	26.8	99.2	99.1
229.3	14.1	3225.0	99.7	4.4	399.5	8.0	3196.8	12.0	12.0	2.8	28.2	31.0	99.1	99.0
229.2	15.9	3630.8	99.8	4.1	399.6	9.0	3597.2	12.0	11.5	2.7	33.5	36.2	99.1	99.0
229.1	17.7	4036.3	99.8	3.8	399.7	10.0	3996.8	12.0	11.2	2.6	39.5	42.0	99.0	99.0
229.0	19.4	4443.4	99.8	3.6	399.7	11.0	4397.2	12.0	10.9	2.5	46.2	48.7	99.0	98.9
228.9	21.2	4852.3	99.9	3.4	399.8	12.0	4798.1	12.0	10.7	2.5	54.2	56.7	98.9	98.8
228.8	22.3	5096.7	99.9	3.3	399.8	12.6	5037.4	12.0	10.6	2.4	59.3	61.7	98.8	98.8

3 Waveforms

3.1 Switching Waveforms

Figure 3-1 through Figure 3-4 show Switching behavior. Test conditions for these waveforms occur at:

- V_{IN}: 230V
- V_{OUT}: 400V
- I_{OUT}: 12.6A

Note

Several operating points are illustrated to demonstrate the topology and controls ability to maintain ZVS when the input voltage is both above and below ½V_{OUT}.

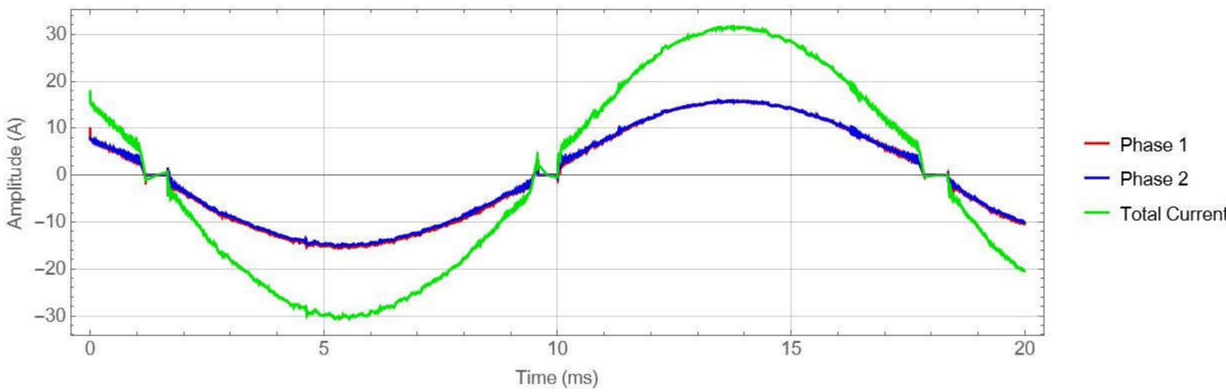


Figure 3-1. Average Inductor and Input Currents

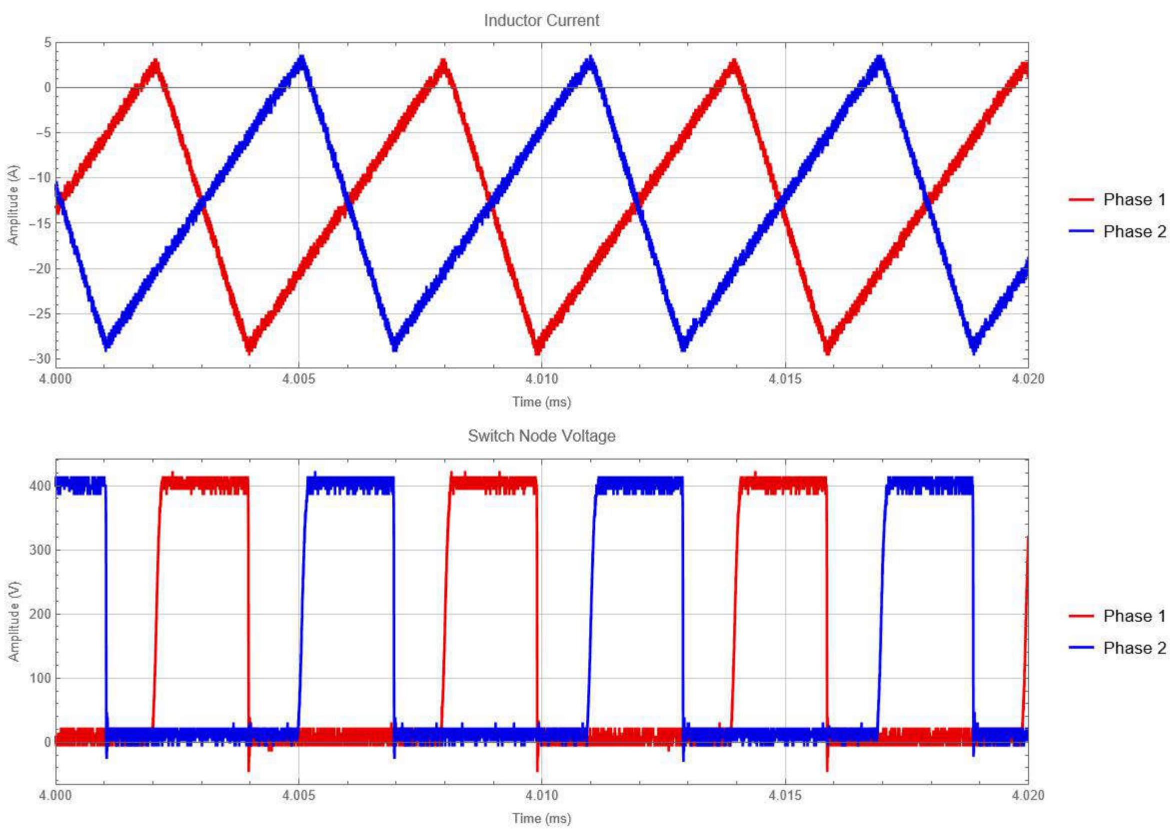


Figure 3-2. V_{IN} Less Than ½V_{OUT}

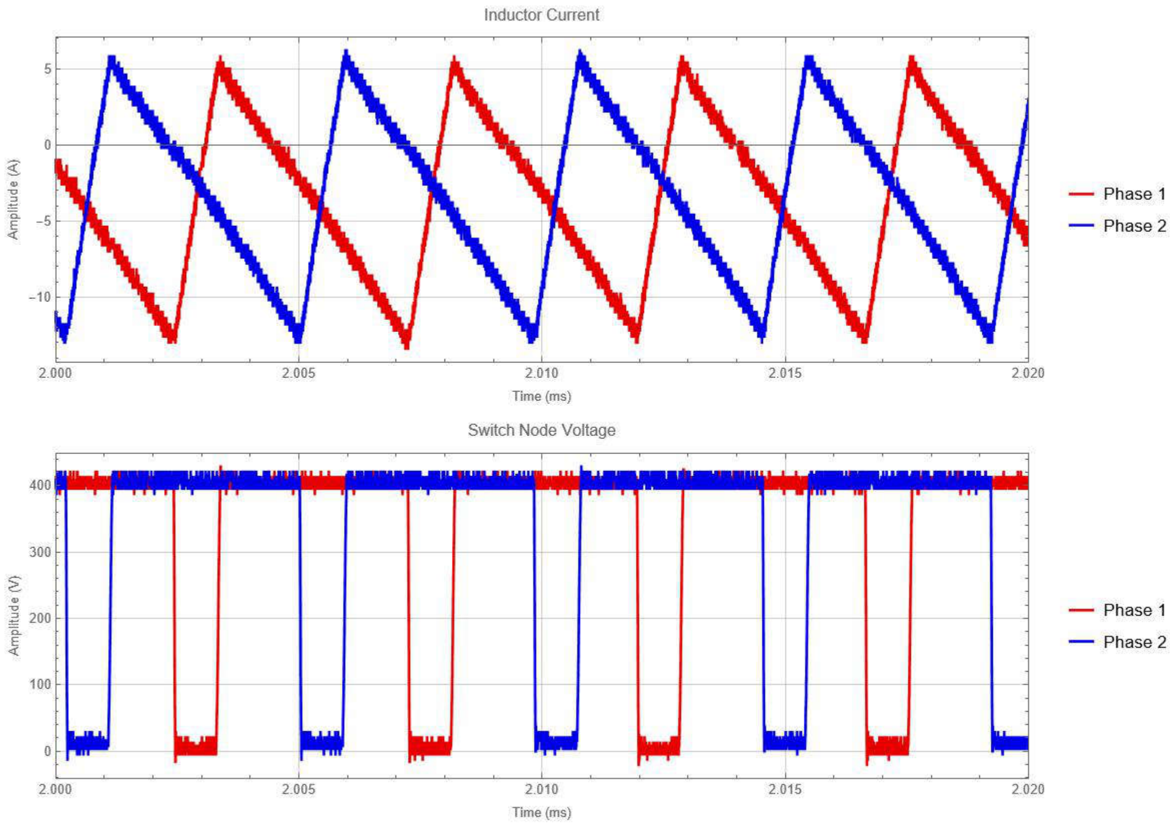


Figure 3-3. V_{IN} Greater Than ½V_{OUT}

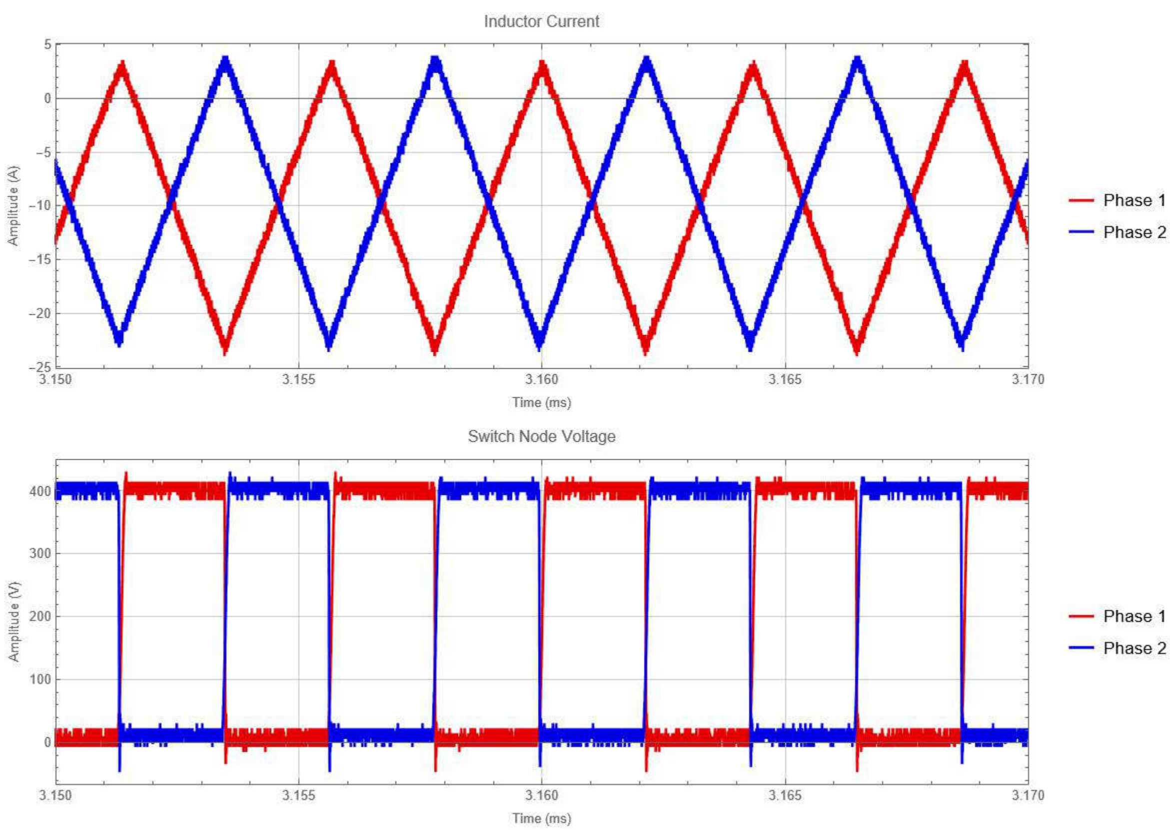


Figure 3-4. V_{IN} Equal to ½V_{OUT}

References

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