Test Report: PMP41006

1-kW Reference Design With CCM TotemPole PFC and Current Mode LLC Realized by C2000 and GaN

Description

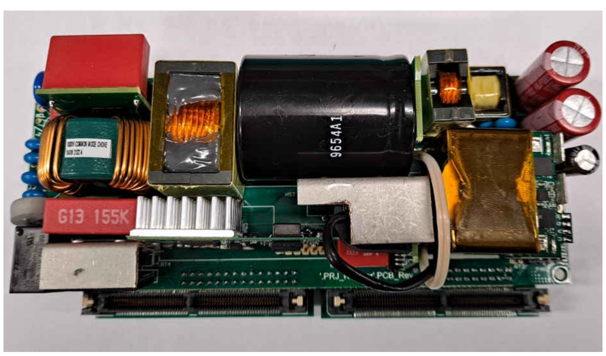
This reference design demonstrates a hybrid hysteresis control (HHC) method, a kind of current-mode control method, on half-bridge LLC stage with a C2000 F28004x microcontroller. The hardware is based on TIDA-010062, which is 1-kW, 80 Plus titanium, GaN CCM totem pole bridgeless PFC and half-bridge LLC reference design. A separated sensing card is added for hybrid hysteresis control, which recreates the voltage on the resonant capacitor. This test result shows better transient response and ease-of-control loop design, compared with the single-loop voltage mode control method (VMC).

Features

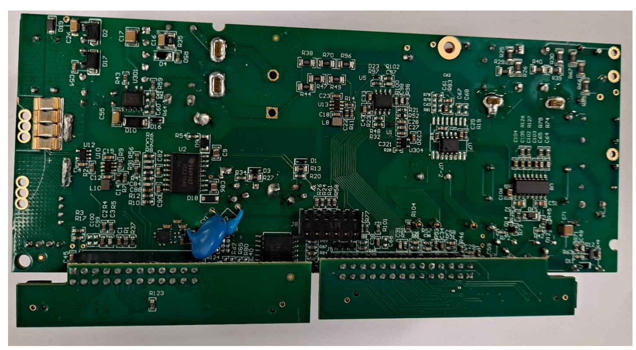
- 80 plus titanium efficiency, η = > 95% at 20%–100% load
- Fast load transient, V_O change within 300 mV at 2.5-A/µs slew rate
- CCM GaN based totem-pole bridgeless PFC stage with > 99% peak efficiency, enabled by LMG341x GaN FET with integrated driver
- Half-bridge Si MOSFET LLC stage with > 98% peak efficiency
- Power density 39 W/in_3, 38 mm × 66 mm × 165 m

Applications

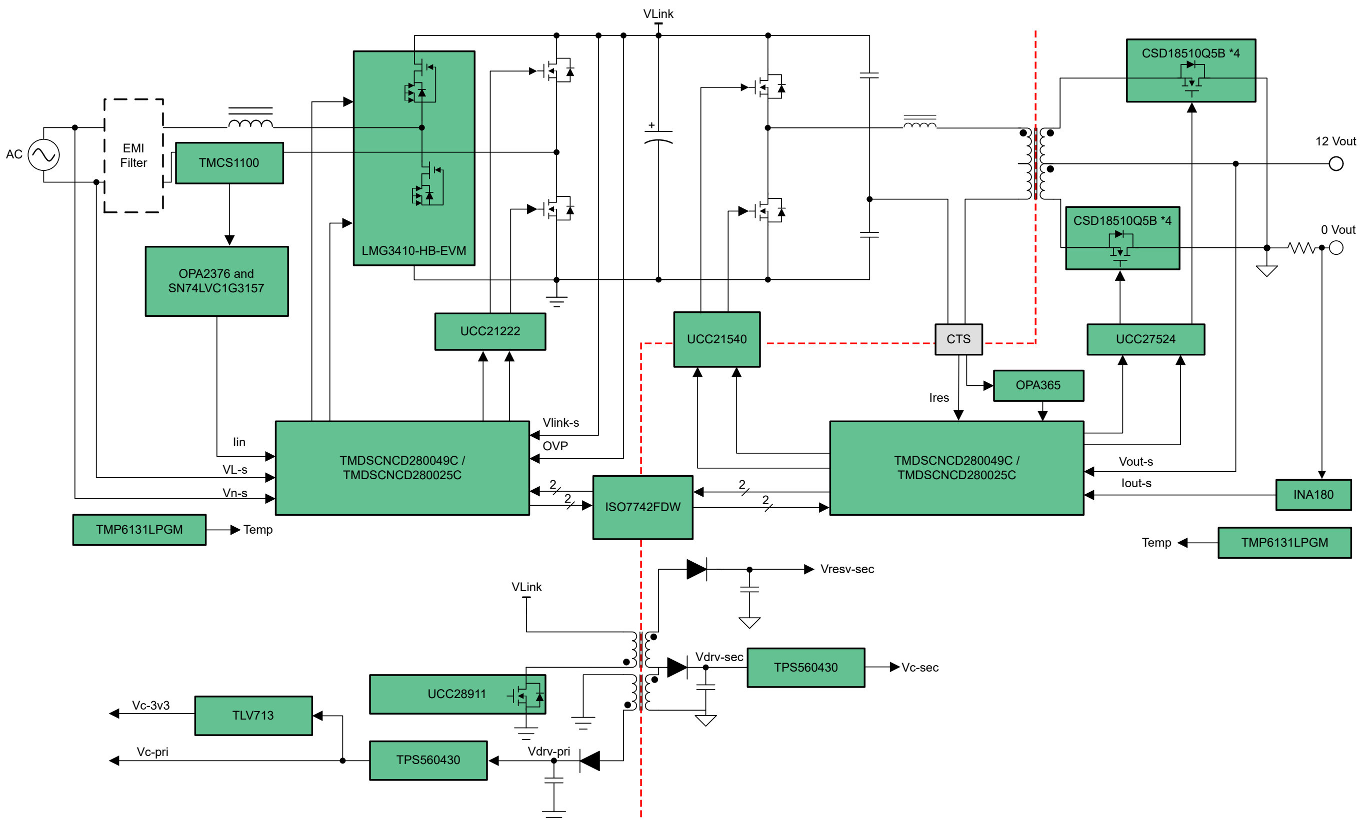
- Merchant network and server PSU
- Merchant telecom rectifiers
- Industrial AC-DC



Top View



Bottom View



Block Diagram or Simplified Schematic

1 Test Prerequisites

1.1 Key System Requirements

Key System Specifications

Parameter	Test Condition	MIN	NOM	MAX	Units
AC Input voltage (Low line)		100	115	132	V
AC Input voltage (High line)		180	230	264	V
Line Frequency		47		63	Hz
Output voltage	All line and load conditions (±5%)	11.4	12	12.6	V
Output Current				84	A
PF	230Vin, 100% load		0.99		
iTHD	10% load			<10%	
	100% load			<2%	
Ripple and noise	12V main output			±120mV	mV
AC holdup time	@ 100% load, within Vout regulation	8	10		mS
Dynamic loading and transient response	50% of Iout-max, 2.5A/uS, 3300uF Capacitive load		±5%		%
Operating ambient		0	25	50	°C
OCP of 12-V output	Shut-down, latch-off	110		130	% of Iomax
OVP of 12-V output	Shut-down, latch-off	13		14.5	V
Dimension (mm)	Without shell and golden finger		165*66*38		mm
Power density			39		W/in3

2 Testing and Results

Since this design is generated from TIDA-010062, its power stage performance is the same as the TIDA-010062. This document only highlights the performance related to the HHC LLC control.

2.1 Sensed VCR and Output Voltage Ripple Under Different Loads

The following parameters apply to Figure 2-1 and Figure 2-2.

- CH1: output current
- CH2: VCR feedback signal
- CH3: output voltage
- CH4: PWM1A output

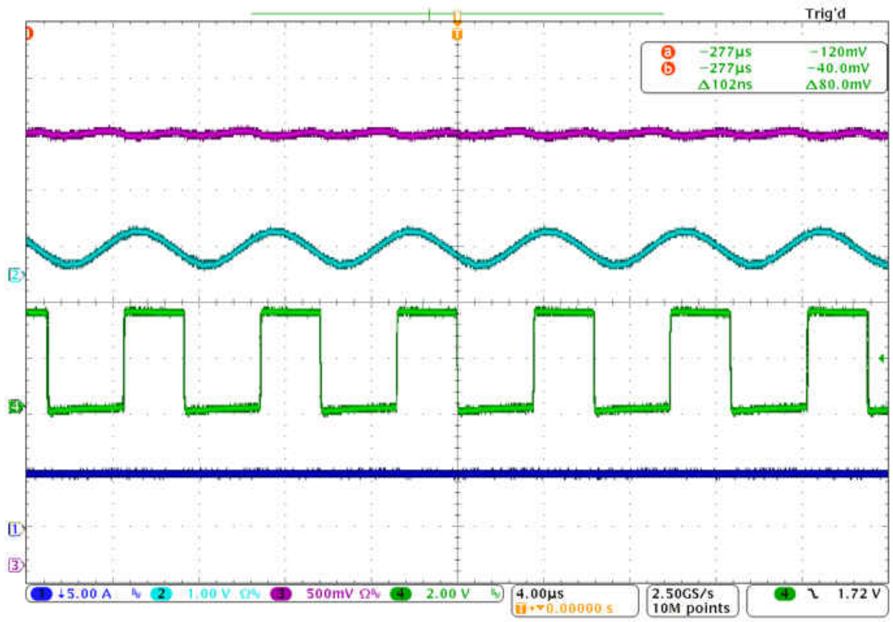


Figure 2-1. Load Current Equals 20 A (24% Load)

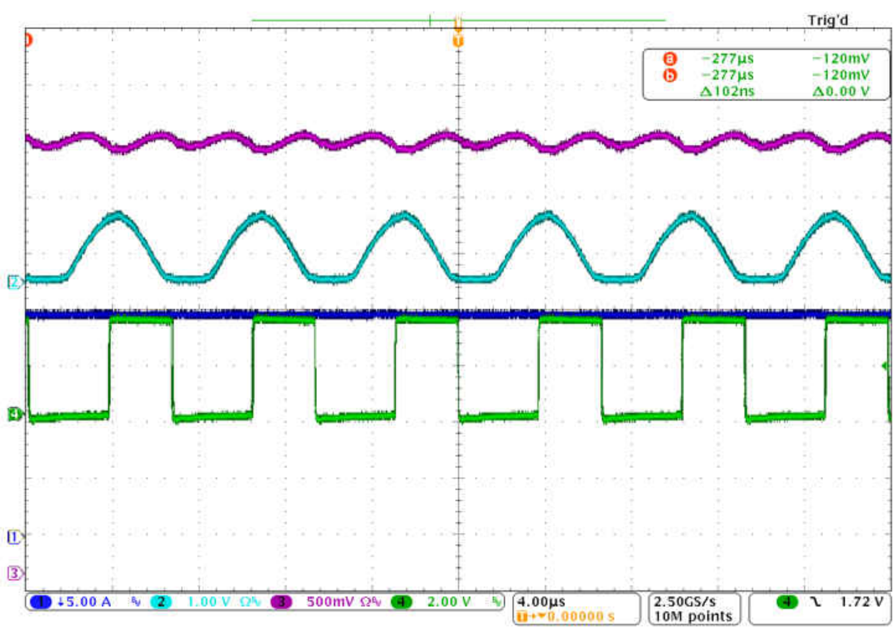


Figure 2-2. Load Current Equals 50 A (60% Load)

2.2 Control Loop Bode Plot Comparison

The voltage control loop bode plot is measured using SFRA (Software Frequency Response Analyzer) based on the C2000 MCU.

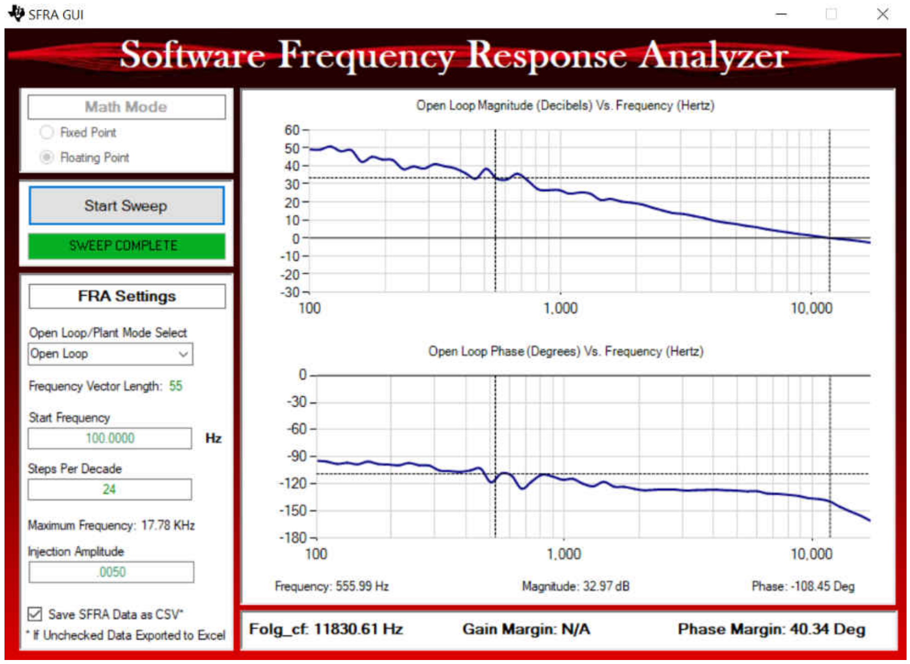


Figure 2-3. HHC Voltage Loop Bode Plot

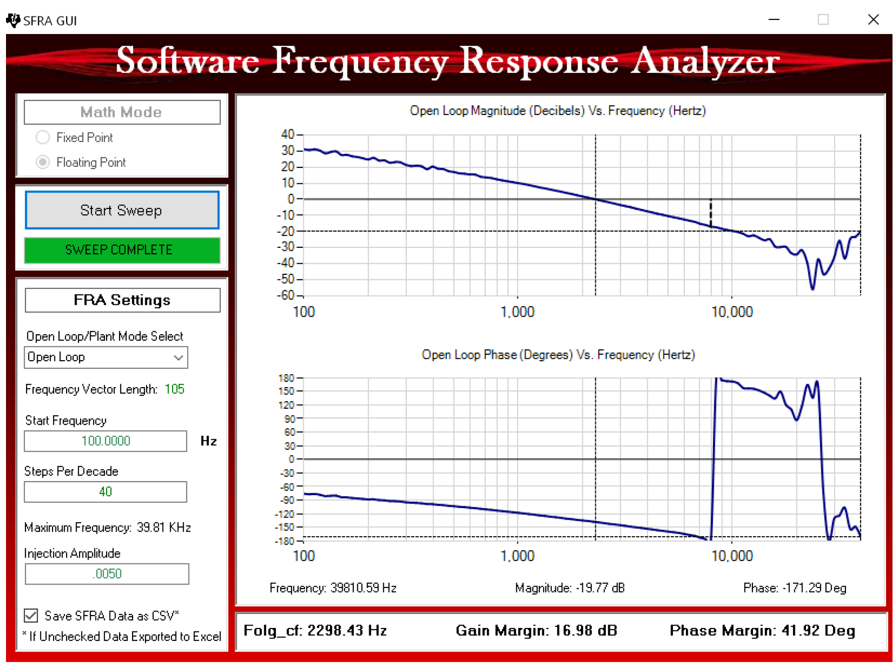


Figure 2-4. VMC Voltage Loop Bode Plot

2.3 Transient Response Test

The following tables present load transient comparisons between HHC and VMC:

Table 2-1. V_{OUT} Deviation Comparison Between HHC and VMC

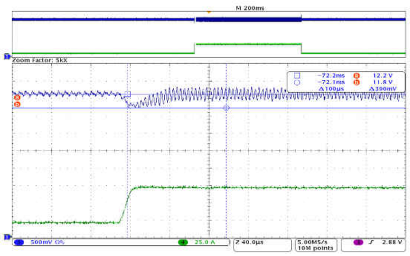
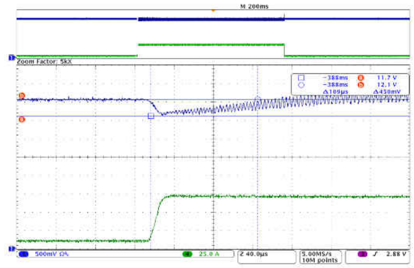
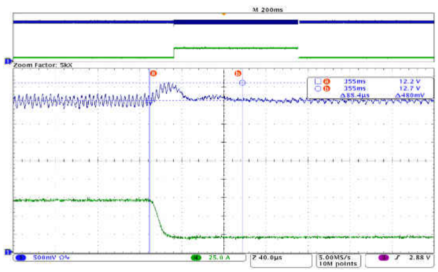
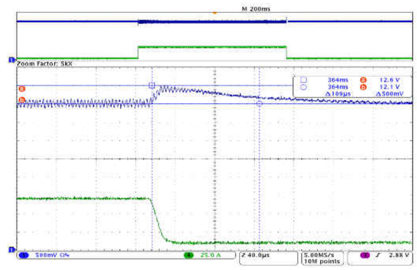
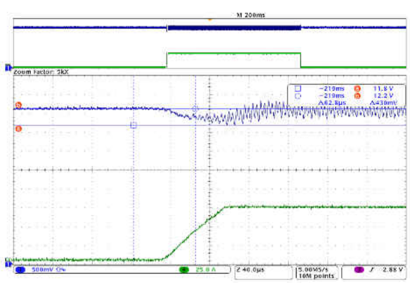
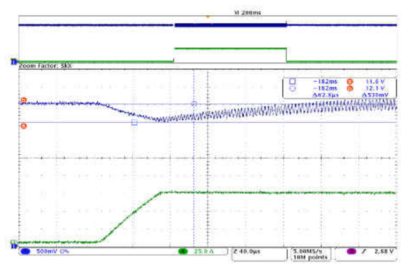
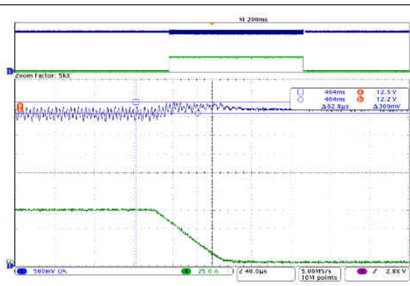
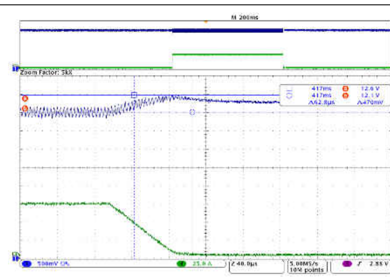
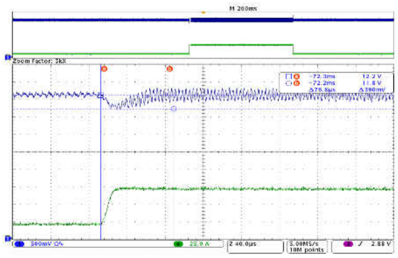
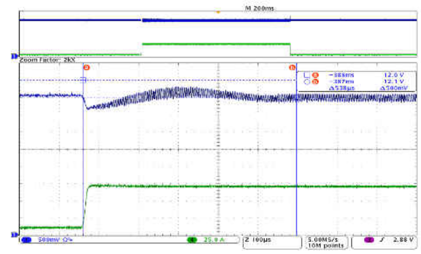
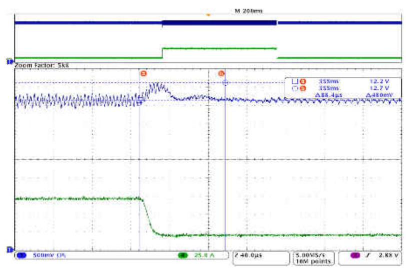
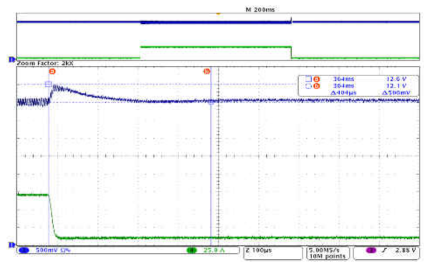
Load Transient Parameters	HHC	VMC	Output Capacitance: 3300 µF × 2
25% → 85% Load Transient (4 A/µs) Transition: 10 µs			HHC: 390 mV vs VMC: 450 mV
85% → 25% Load Transient (4 A/µs) Transition: 10 µs			HHC: 480 mV vs VMC: 500 mV
1 A → 70 A Load Transient (1 A/µs) Transition: 60 µs			HHC: 430 mV vs VMC: 530 mV
70 A → 1 A Load Transient (1 A/µs) Transition: 60 µs			HHC: 300 mV vs VMC: 470 mV

Table 2-2. Settling Time Comparison Between HHC and VMC

Load Transient Parameters	**HHC**	**VMC**	**Output Capacitance: 3300 µF × 2**
25% → 85% Load Transient (4 A/µs) Transition: 10 µs			HHC: 76.8 µs vs VMC: 538 µs
85% → 25% Load Transient (4 A/µs) Transition: 10 µs			HHC: 88.4 µs vs VMC: 404 µs

2.4 References

- Texas Instruments, *1-kW, 80 Plus Titanium, GaN CCM Totem Pole Bridgeless PFC and Half-Bridge LLC* reference design guide

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