Using the UCC28070EVM

User's Guide

Texas Instruments

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UCC28070 300-W Interleaved PFC Pre-Regulator User's Guide

1 Introduction

The UCC28070 evaluation module is a 300-W, two phase interleaved, PFC pre-regulator that uses average current mode control techniques to achieve near unity power factor. The pre-regulator was designed to operate off a universal ac line input of 85 V to 265 V and provides a regulated 390-V dc output. This evaluation module demonstrates TI's interleaved PFC control technology.

2 Description

The pre-regulator uses the UCC28070 PFC interleaved controller to shape the input current wave form to provide power factor correction.

3 Thermal Requirements

- The evaluation module works up to 300 W without external cooling in ambient temperature of 25°C.

4 Electrical Specifications

Table 1. Specification Table

DEFINITION	MINIMUM	TYPICAL	MAXIMUM	UNITS
RMS Input Voltage (ac line)	85		265	V
Output Voltage (V_{OUT})		390		
Line Frequency	47		63	Hz
Power Factor (PF) at Maximum Load	0.9			
Output Power			300	W
Full Load Efficiency	90			%

5 Schematics

To evaluate inductor ripple currents jumpers JP1 and JP2 can be removed and replaced with current loops.

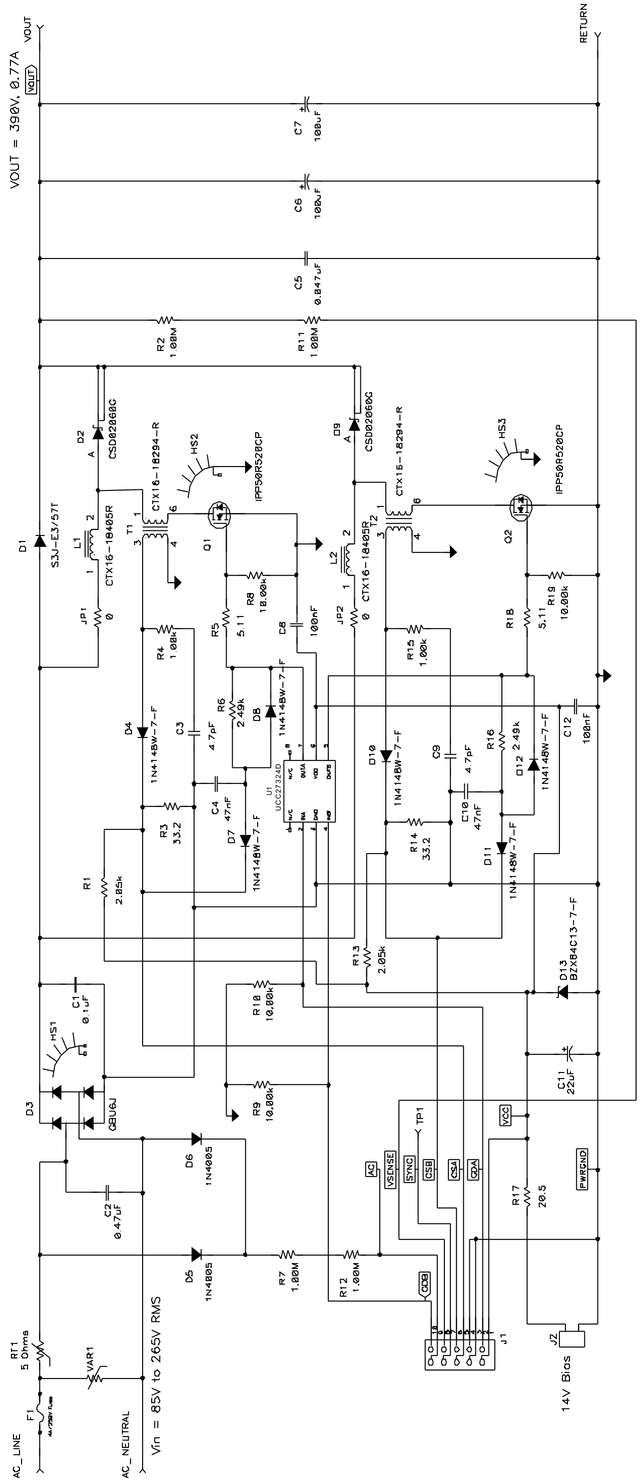

Figure 1. Interleaved PFC Power Stage (Mother Board HPA225)

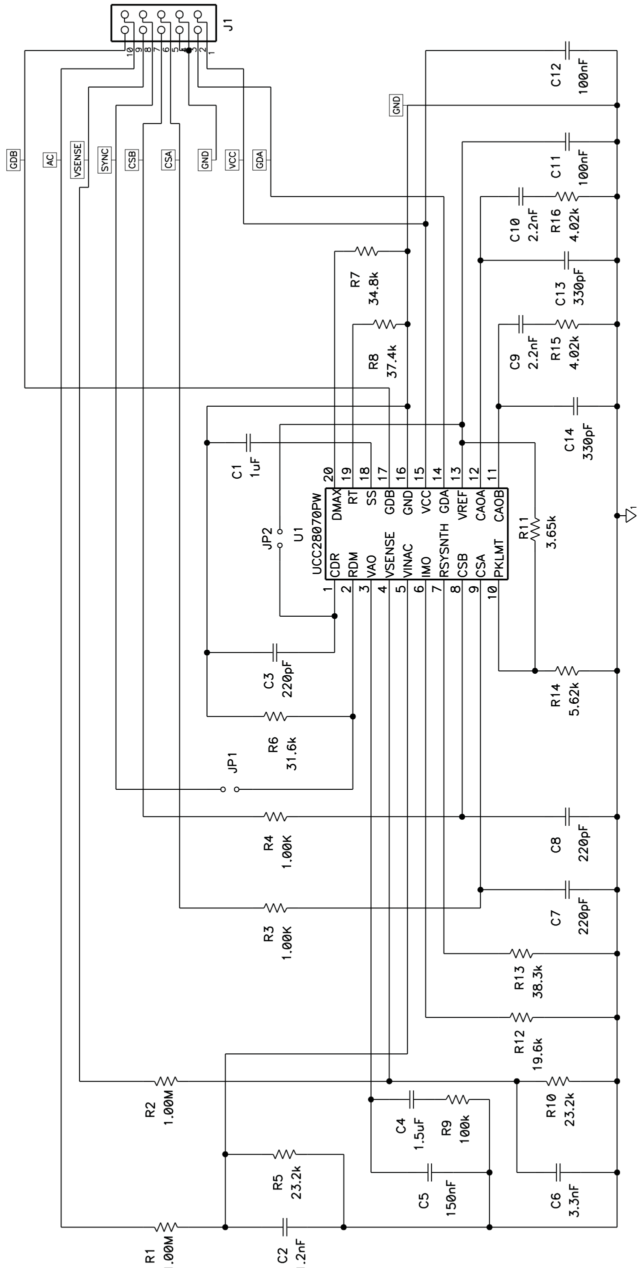

Figure 2. Controller Circuitry (Daughter Board HPA284)

6 Warning

There are high voltages present on the pre-regulator and it should only be handled by experienced power supply professionals. To evaluate this board as safely as possible the following test set up should be used. An isolation transformer should be connected between the source and unit. Before power is supplied a voltmeter and a resistive or electronic load should be attached to the unit's output.

7 Test Setup and Power Up/Power Down Instructions

A separate 14-V bias supply is required to power the UCC28070 control circuitry. The unit will start up under no load conditions. However, for safety, a load should be connected to the output of the device before it is powered up. It is advised that resistive loads be used. Constant current or constant power loads could damage the evaluation board. The unit should also never be handled when power is applied to it or the output voltage is above 50-V dc. Please refer to Figure 3 for the test setup diagram.

Note: There are very high voltages on the board and components can and will reach temperatures above 100 °C, so caution must be taken in handling the board.

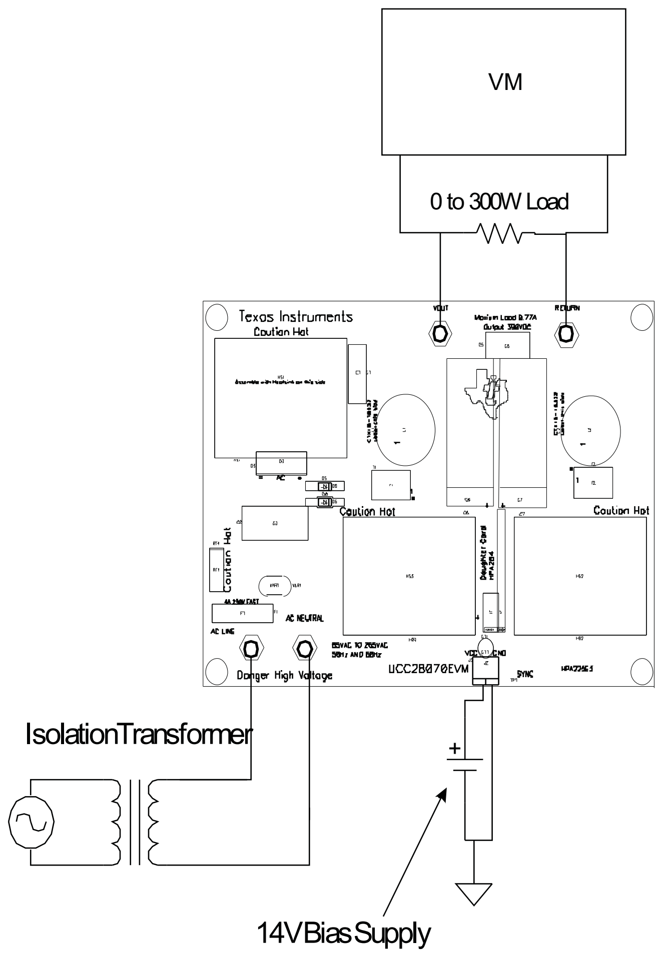

Figure 3. Test Setup

8 Performance Data

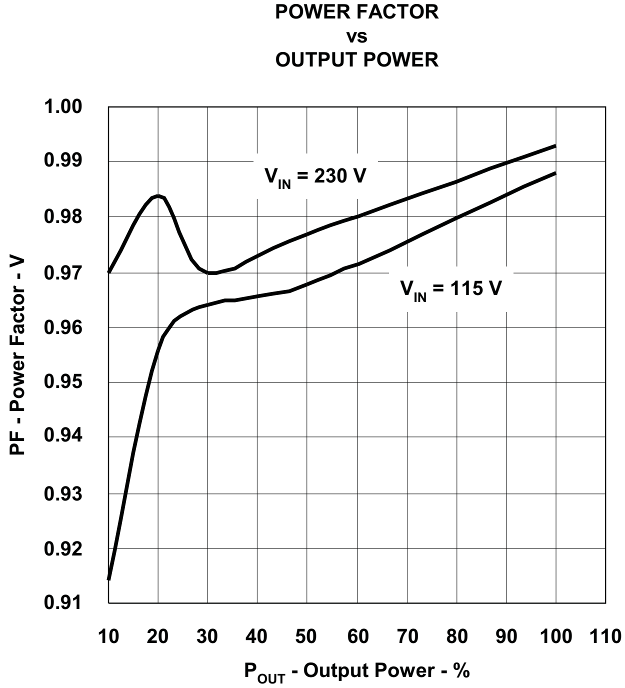

Figure 4. Power Factor at V_{IN} = 115 V and 230 V RMS

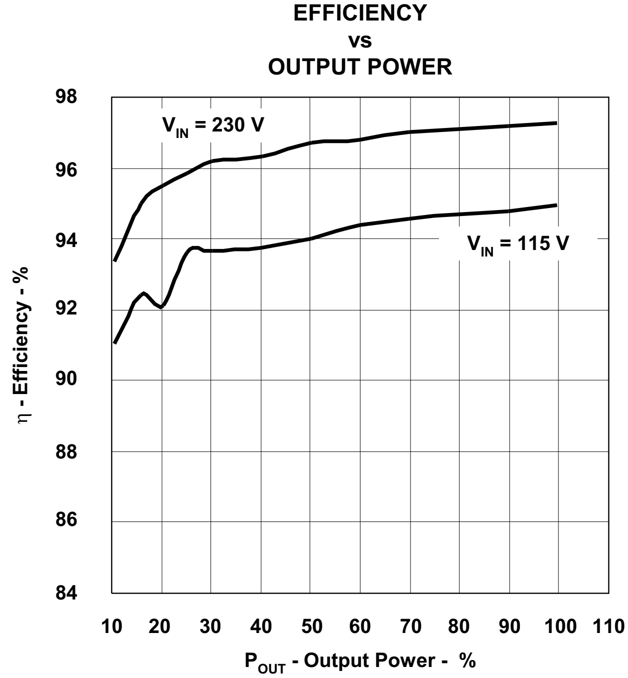

Figure 5. Efficiency at V_{IN} = 115 V and 230 V RMS

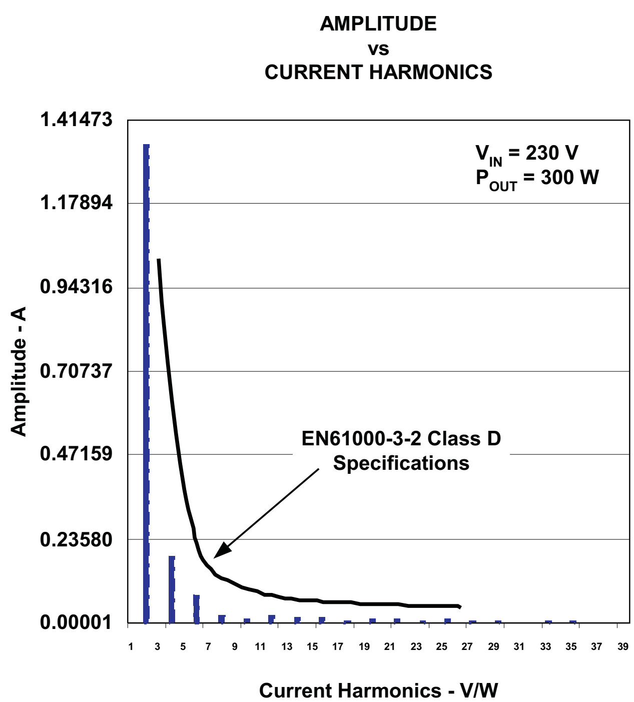

Figure 6. Input Current Harmonics at V_{IN} = 230 V, P_{OUT} = 300 W

8.1 Input Current and Output Ripple Voltage at Full Load

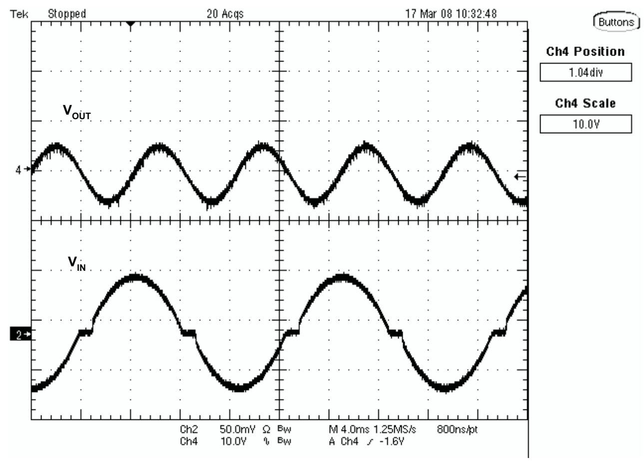

Figure 7. Input Ripple Current (I_{IN}), Output Ripple Voltage (V_{OUT}), V_{IN} = 85 V RMS, P_{OUT} = 300 W

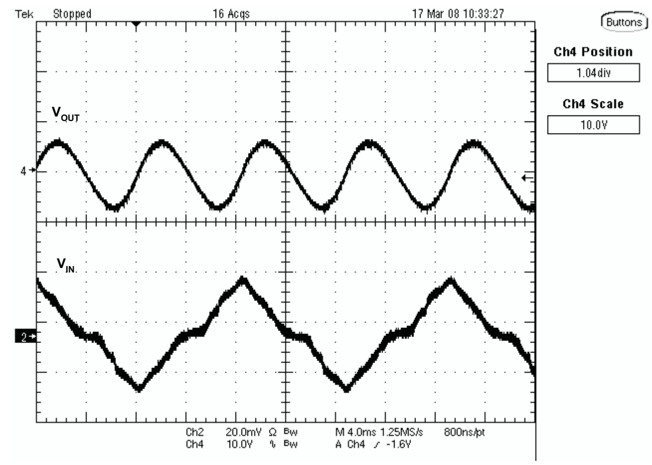

Figure 8. Input Ripple Current (I_{IN}), Output Ripple Voltage (V_{OUT}), V_{IN} = 265 V RMS, P_{OUT} = 300 W

8.2 Input Ripple Current Cancellation

The following waveforms show input current (M1 = I_{L1}+I_{L2}), Inductor Ripple Current (I_{L1}, I_{L2}) verses rectified line voltage. From these curves it can be observed that interleaving reduces the magnitude of input ripple current caused by the inductor ripple current.

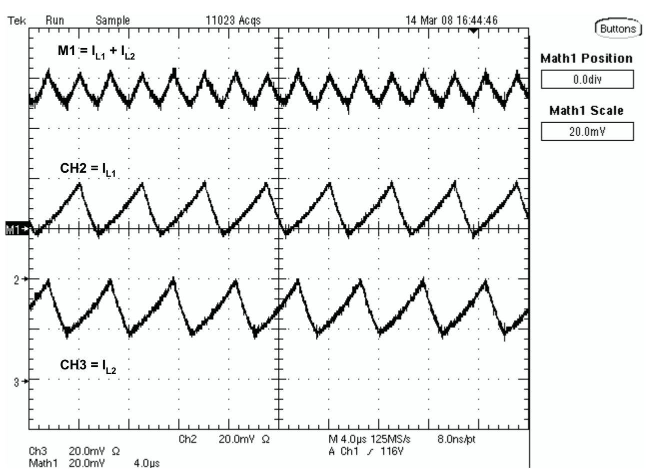

Figure 9. Inductor and Input Ripple Current at V_{IN} = 85 V RMS at the Peak of Line

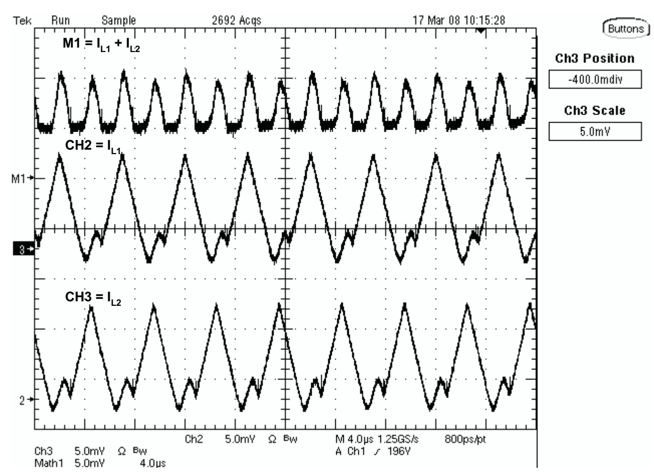

Figure 10. Inductor and Input Ripple Current at 265 V RMS Input at the Half Output Voltage

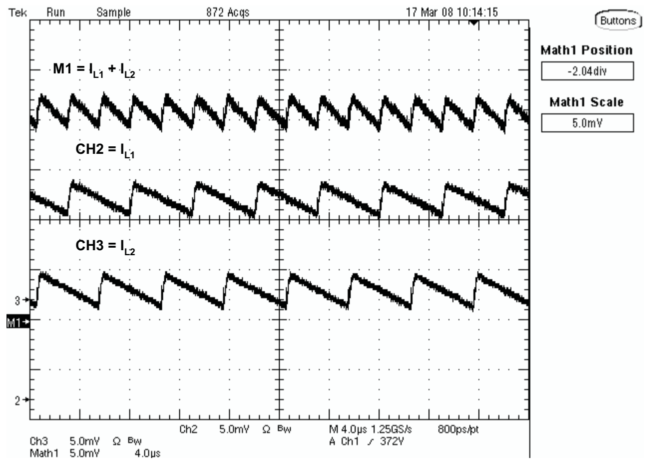

Figure 11. Inductor and Input Ripple Current at 265 V RMS Input at Peak of the Line Voltage

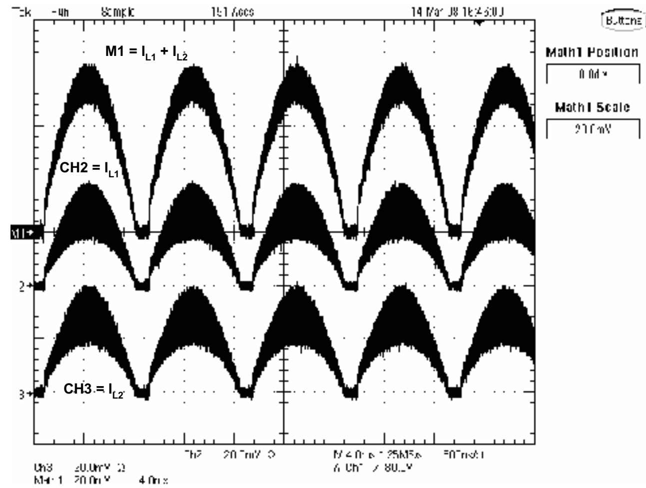

Figure 12. Input and Inductor Ripple Current at V_{IN} = 85 V RMS, P_{OUT} = 300 W

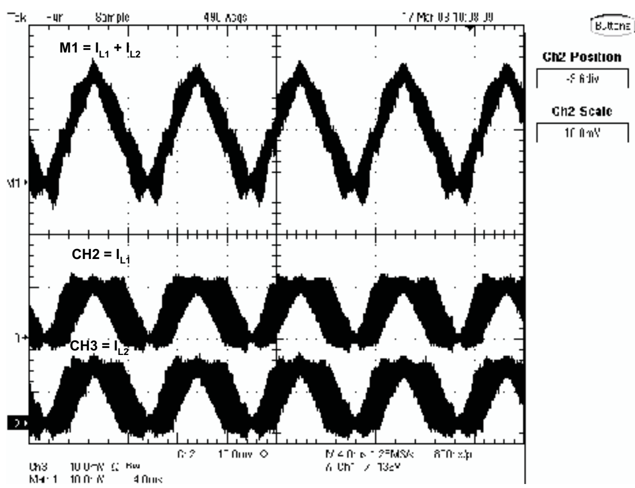

Figure 13. Input and Inductor Ripple Current at V_{IN} = 265 V RMS, P_{OUT} = 300 W

8.3 Startup Characteristics

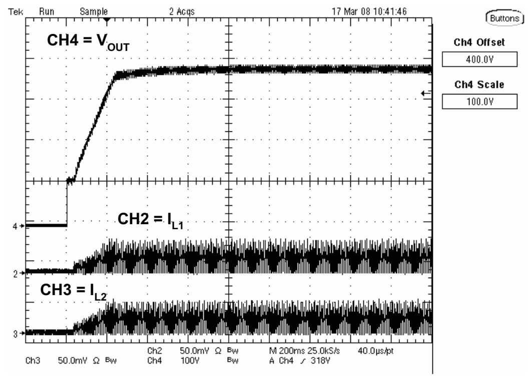

Figure 14. Start Up at V_{IN} = 85 V, P_{OUT} = 300 W

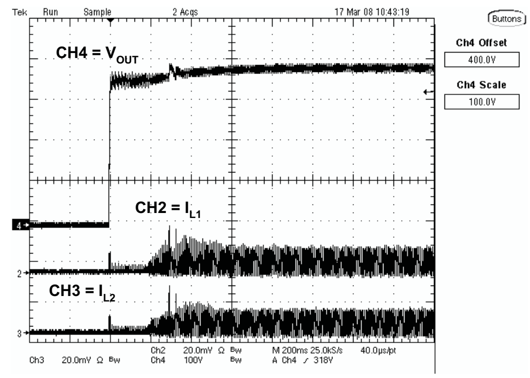

Figure 15. Start Up at V_{IN} = 265 V, P_{OUT} = 300 W

8.4 Line Dropout

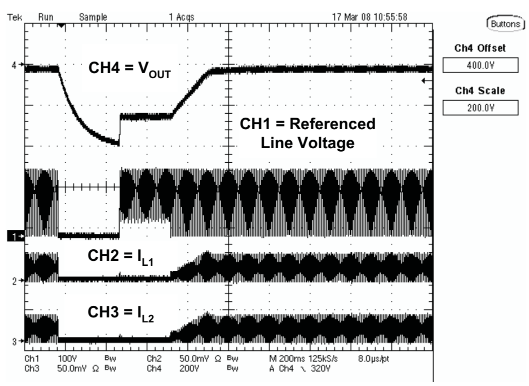

Figure 16. Line Dropout at 115 V RMS

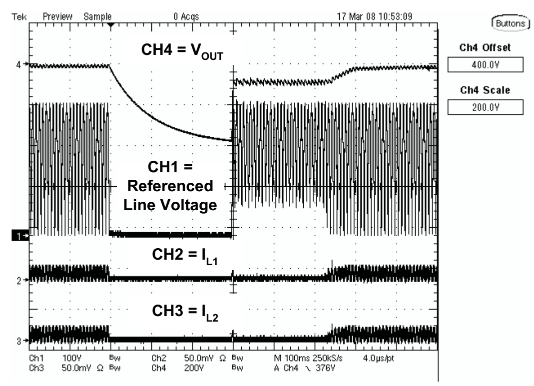

Figure 17. Line Dropout at 230 V RMS

8.5 Frequency Dithering

Frequency dithering has shown to reduce EMI. The UCC28070 EVM was design to operate in frequency dithering mode and none frequency dithering mode. When the JP1 and JP2 jumpers on the daughter board are shorted the PWM is operating in a fix frequency mode. The fixed frequency was set to 200 kHz per phase. When Jumpers JP1 and JP2 are open the converter is running in frequency dither mode. The single phases switching frequency was set to vary from roughly 190 kHz per phase to 210 kHz per phase.

When frequency dithering was applied to the EVM a 4.35 dBuV reduction in the Quasi Peak (QP) EMI measurement was observed.

Note: A filter was added to the front end of the EVM to clean up some of the noise to take EMI data. Depending on the filter the amount of EMI will vary. Also, this filter was not setup to pass EMI requirements but to show frequency dithering can reduced EMI.

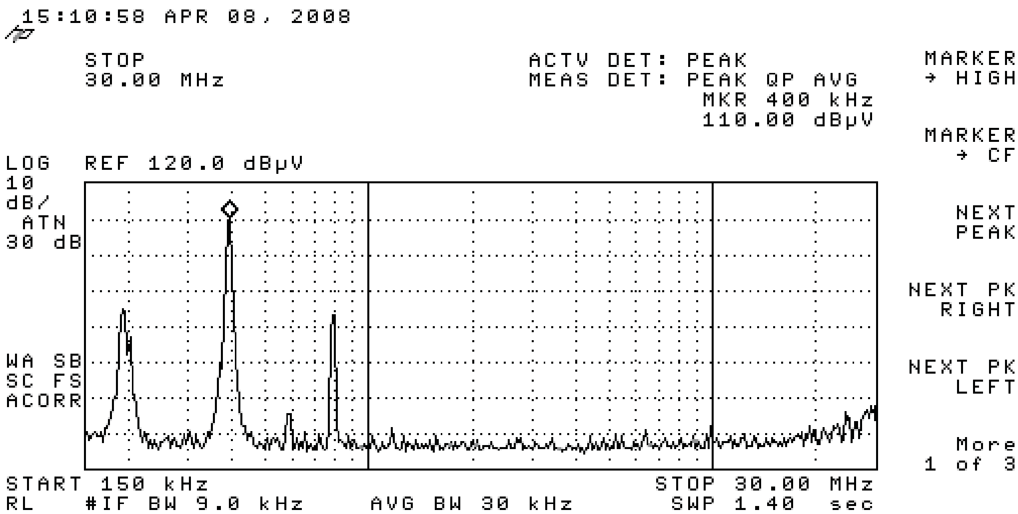

Figure 18. EMI Quasi Peak (QP) Measurement Without Frequency Dithering, No EMI Filter Present

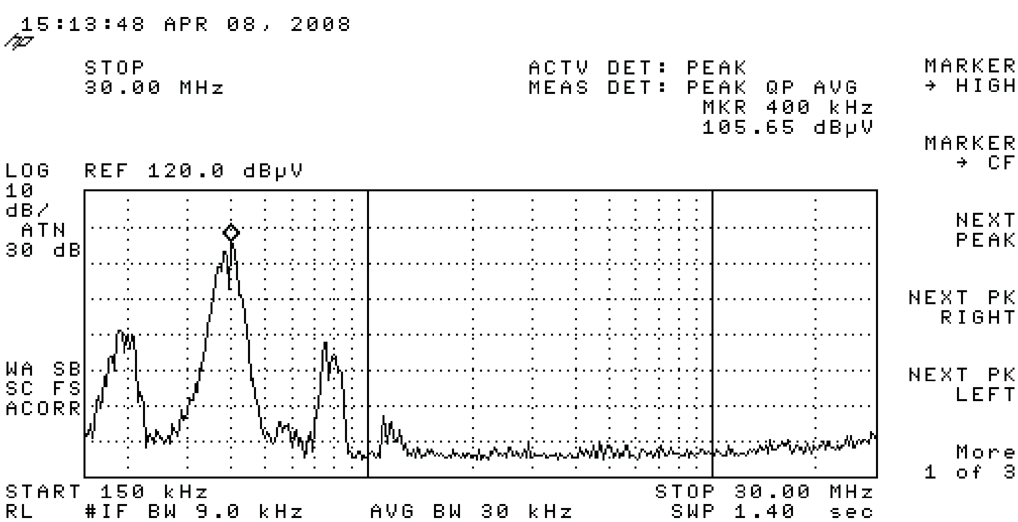

Figure 19. EMI Quasi Peak (QP) Measurement With Frequency Dithering, No EMI Filter Present

9 Reference Design Assembly Drawing

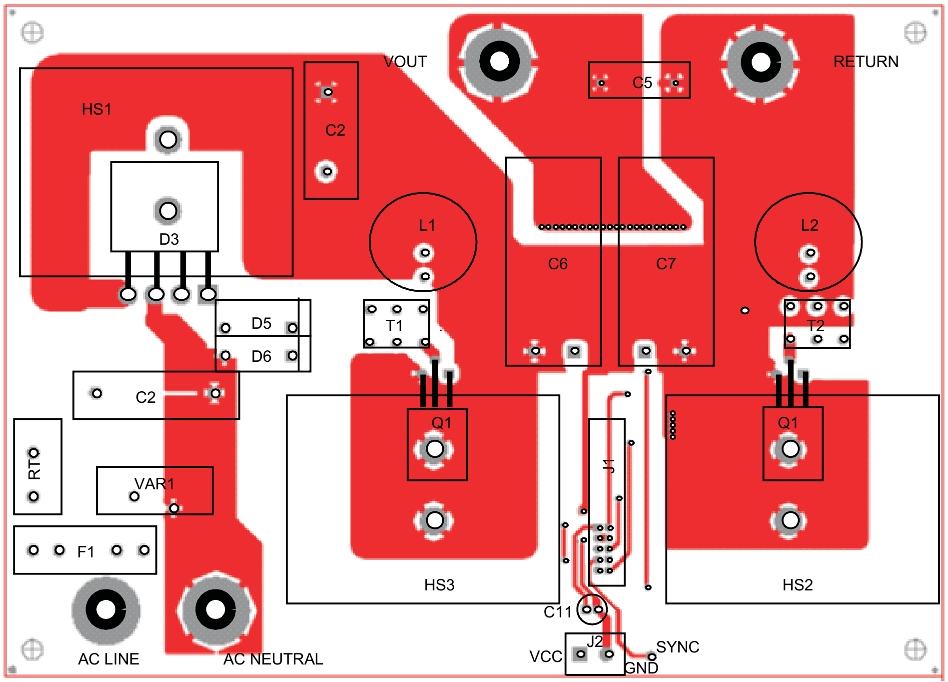

Figure 20. Mother Board, Top Assembly and Copper Layer

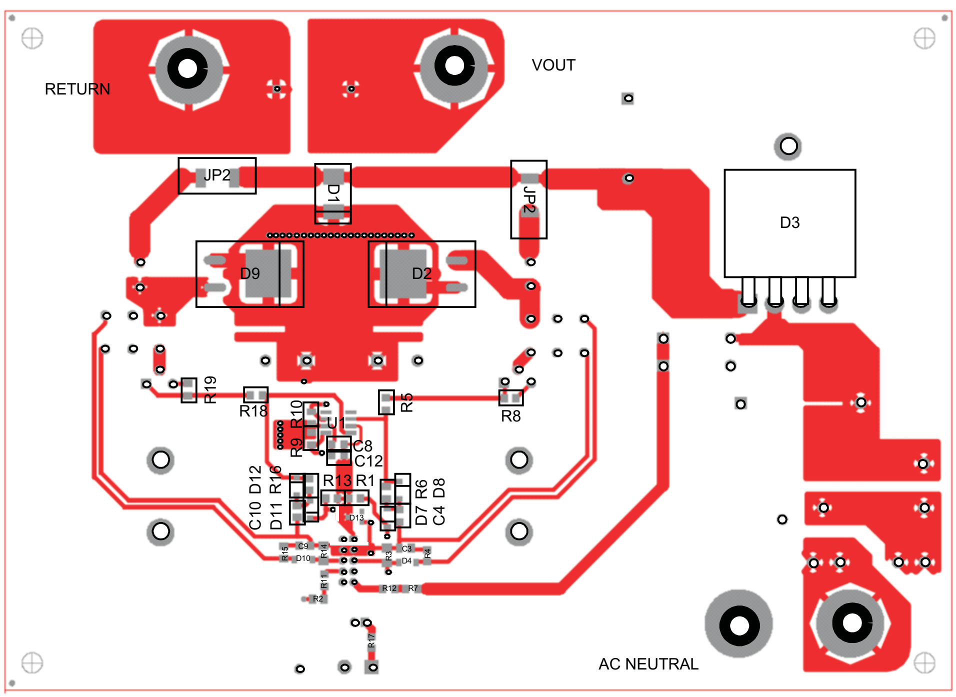

Figure 21. Mother Bottom, Assembly and Copper Layer

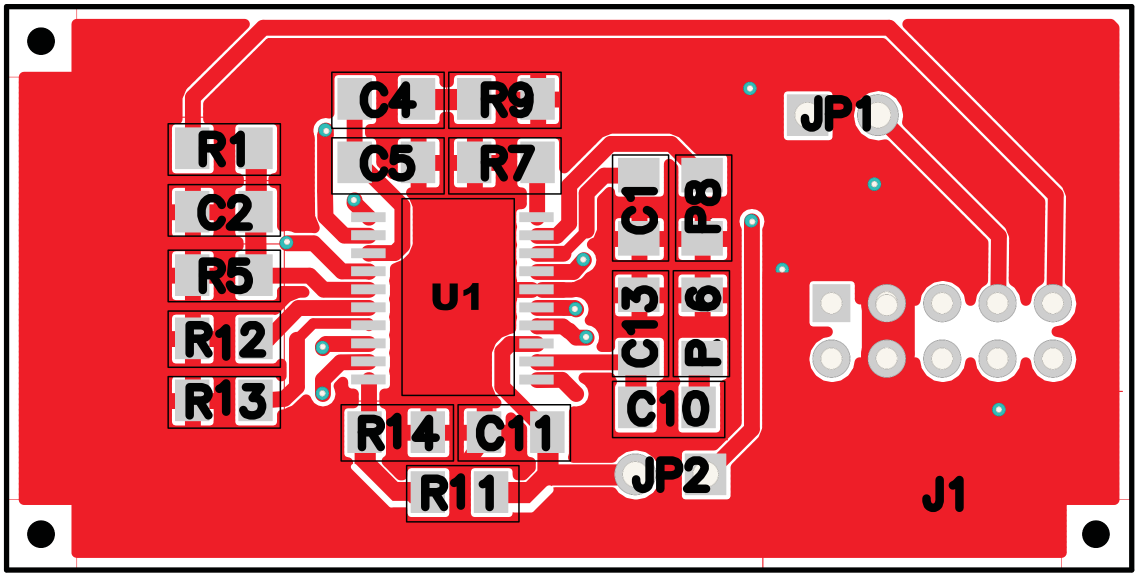

Figure 22. Daughter Board, Top Assembly and Copper Layer

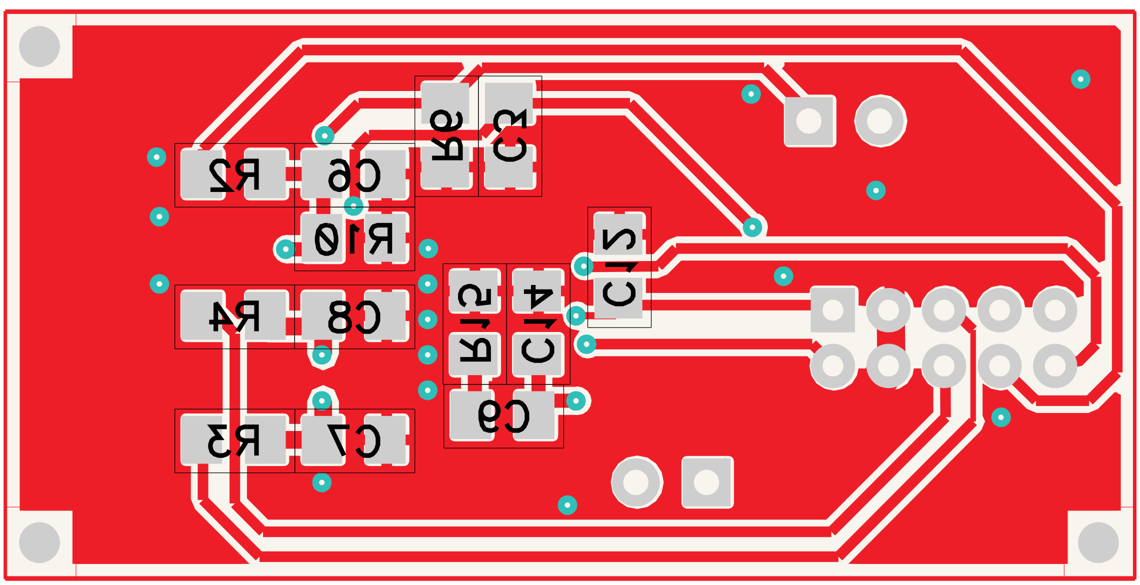

Figure 23. Daughter Board, Top Assembly and Copper Layer

10 List of Materials

10.1 Mother Board List of Materials

Table 2. Mother Board

COUNT	REF DES	DESCRIPTION	MFR	PART NUMBER
4	AC_LINE, AC_NEUTRAL, RETURN, VOUT	Connector, banana jack, uninsulated, 3267, 0.500 dia. inch	Pomona	3267
1	C1	Capacitor, film, 275 VAC, 20%, 0.1 µF, 0.689 x 0.236 inch	Panasonic	ECQU2A104BC1
1	C11	Capacitor, aluminum, 35 V, 20%, 22 µF, 0.200 * 0.435 inch	Panasonic	ECA-1VM220
1	C2	Capacitor, film, 275 VAC, 20%, 0.47 µF, 0.236 X 0.591	Panasonic	ECQ-U2A474MG
2	C3, C9	Capacitor, ceramic, 25 V, X7R, 10%, 4.7 pF, 805	Std	Std
2	C4, C10	Capacitor, ceramic, 25 V, X7R, 10%, 47 nF, 805	Std	Std
1	C5	Capacitor, polyester, 630 V, 10%, 0.047 µF, 0.256 x 0.650 inch	Panasonic	ECQ-E6473KZ
2	C6, C7	Capacitor, aluminum, 450 VDC, 20%, 100 µF, 18 x 40 mm	Nippon Chemi-con	EKXG451ELL101MM40S
2	C8, C12	Capacitor, ceramic, 25 V, X7R, 10%, 100 nF, 805	Std	Std
1	D1	Diode, 3000 mA, 600 V, SMC	Vishay	S3J-E3/57T
1	D13	Diode, zener, 13 V, 300 mW, SOT-23	Diodes	BZX84C13-7-F
2	D2, D9	Diode, Schottky Rectifier, 2 A, 600 V, TO-263-2	CREE	CSD02060G
1	D3	Diode, bridge, 6 A, 600 V, BU6	Vishay	GBU6J
6	D4, D7, D8, D10, D11, D12	Diode, signal, 200 mA, 100 V, 350 mW, SOD-123	Diodes	1N4148W-7-F
2	D5, D6	Diode, signal, 600 V, 1 A , DO-41	Diodes	1N4005
1	F1	Fuse clip, 5x20 mm, 4 A/250 V fuse, 0.205 x 0.220 inch x2	Wickmann	0100056H
3	HS1, HS2, HS3	Heat sink, universal-mount TO-220, 1.500 x 2.000 inch	Aavid Thermalloy	600703U01500G
1	J1	Receptacle, 10 pins, 0.200 x 0.472 inch	HRS	DF11-10DS-2DSA(05)
1	J1	Assembled daughter board controller, HPA284	Std	Std
1	J2	Terminal block, 2 pin, 15 A, 5.1 mm, 0.40 x 0.35 inch	OST	ED1609
2	JP1, JP2	Resistor, chip, 1 W, 5%, 0, 2512	Std	Std
2	L1, L2	Inductor, 140 µH at 3.2 A pk, 0.828 dia. inch	Cooper	CTX16-18405R
1	PCB	Printed circuit board, HPA225	Std	Std
2	Q1, Q2	MOSFET, N-channel, 500 V, 7.1 A, 520 mΩ, TO-220V	Infineon	IPP50R520CP
2	R1, R13	Resistor, chip, 1/10 W, 1%, 2.05 kΩ, 805	Std	Std
1	R17	Resistor, chip, 1/10 W, 1%, 20.5 Ω, 805	Std	Std
4	R2, R7, R11, R12	Resistor, chip, 1/10 W, 1%, 1.00 MΩ, 805	Std	Std
2	R3, R14	Resistor, chip, 1/8 W, 1%, 33.2 Ω, 1206	Std	Std
2	R4, R15	Resistor, chip, 1/10 W, 1%, 1.00 kΩ, 805	Std	Std
2	R5, R18	Resistor, chip, 1/10 W, 1%, 5.11 Ω, 805	Std	Std
2	R6, R16	Resistor, chip, 1/10 W, 1%, 2.49 kΩ, 805	Std	Std
4	R8, R9, R10, R19	Resistor, chip, 1/10 W, 1%, 10.0 kΩ, 805	Std	Std
1	RT1	Thermistor, NTC, 5 Ω, 6 A, 5 Ω, 0.180 X 0.550 inch	Thermometrics	CL-40

Table 2. Mother Board (continued)

COUNT	REF DES	DESCRIPTION	MFR	PART NUMBER
2	T1, T2	Inductor, 140 µH at 3.2 A PK, 0.360 X 0.520 inch	Cooper	CTX16-18294-R
1	U1	Device, High Speed Low Side Power MOSFET Driver, SO8	TI	UCC27324D
1	VAR1	Varistor 275 V RMS, 0.472 x 0.213 inch	Epcos	S10K275E2
Additional Hardware				
1	X1 @ F1	4 A, fast acting fuse, 5 mm X 20 mm	Cooper/Bussman	BK/S501-4-R
6	X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2	Nut #4-40 (steel)	Std	Std
6	X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2	Pan head screw #4-40X3/8 (steel)	Std	Std
1	X1 D3 and HS1	Thermal grease	Std	Std
6	X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2	Split lock washer #4(steel)	Std	Std
4	X1 @ HS1 and D3, HS2 and Q1, HS3 and Q2	Nylon shoulder washer #4	Keystone Electronics	3049
2	X1 @ HS2 and Q1, HS3 and Q2	Thermal pad silicon TO220	BERQUIST	3223-07FR-51
4	X1 @ HS2, HS3 None FET Side, Top and Bottom	External tooth washer #4	Std	Std

10.2 Daughter Board List of Materials

Table 3. Daughter Board

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
1	C1	Capacitor, ceramic, 25 V, X7R, 10%, 1 µF, 805	Std	Std
2	C11, C12	Capacitor, ceramic, 25 V, X7R, 10%, 100 nF, 805	Std	Std
2	C13, C14	Capacitor, ceramic, 25 V, X7R, 10%, 330 pF, 805	Std	Std
1	C2	Capacitor, ceramic, 25 V, X7R, 10%, 1.2 nF, 805	Std	Std
1	C3	Capacitor, ceramic, 25 V, X7R, 10%, 150 pF, 805	Std	Std
1	C4	Capacitor, ceramic, 25 V, X7R, 10%, 1.5 µF, 805	Std	Std
1	C5	Capacitor, ceramic, 25 V, X7R, 10%, 150 nF, 805	Std	Std
1	C6	Capacitor, ceramic, 25 V, X7R, 10%, 3.3 nF, 805	Std	Std
2	C7, C8	Capacitor, ceramic, 25 V, X7R, 10%, 220 pF, 805	Std	Std
2	C9, C10	Capacitor, ceramic, 25 V, X7R, 10%, 2.2 nF, 805	Std	Std
1	J1	Header, right angle 10 pins, DF11-10DP-2DSxx, 0.394 x 0.472 inch	DF11-10DP-2DSxx	HRS
2	JP1, JP2	Header, 2 pin, 100 mil spacing, (36-pin strip), 0.100 inch x 2	PTC36SAAN	Sullins
2	JP1, JP2	Sockets jumper closed black	151-8010	Kobiconn
1	PCB	Daughter board PCB, HPA284	Std	Std
2	R1, R2	Resistor, chip, 1/10 W, 1%, 1.00 MΩ, 805	Std	Std
1	R11	Resistor, chip, 1/10 W, 1%, 3.65 kΩ, 805	Std	Std
1	R12	Resistor, chip, 1/10 W, 1%, 19.6 kΩ, 805	Std	Std
1	R13	Resistor, chip, 1/10 W, 1%, 38.30 kΩ, 805	Std	Std
1	R14	Resistor, chip, 1/10 W, 1%, 5.62 kΩ, 805	Std	Std
2	R15, R16	Resistor, chip, 1/10 W, 1%, 4.02 kΩ, 805	Std	Std
2	R3, R4	Resistor, chip, 1/10 W, 1%, 1.00 kΩ, 805	Std	Std
2	R5, R10	Resistor, chip, 1/10 W, 1%, 23.20 kΩ, 805	Std	Std
1	R6	Resistor, chip, 1/10 W, 1%, 46.40 kΩ, 805	Std	Std
1	R7	Resistor, chip, 1/10 W, 1%, 34.80 kΩ, 805	Std	Std
1	R8	Resistor, chip, 1/10 W, 1%, 37.40 kΩ, 805	Std	Std
1	R9	Resistor, chip, 1/10 W, 1%, 100.00 kΩ, 805	Std	Std
1	U1	Device, Two- Phases Interleaved CCM PFC Controller, TSSOP-20	UCC28070PW	TI

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 85 to 265 VRMS and the output voltage range of 390 V ±15% .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 50°C. The EVM is designed to operate properly with certain components above as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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