Using the UCC25600EVM

User's Guide

Literature Number: SLUU361
April 2009

User's Guide
SLUU361 – April 2009

LLC Resonant Half-Bridge Converter, 300-W Evaluation Module

1 Introduction

The UCC25600 evaluation module, EVM (HPA341), is a 300-W LLC resonant half-bridge converter, providing a regulated output voltage nominally at 12 V at maximum 300 W of load power with reinforced isolation of AC-DC off-line application between the primary and the secondary, operating from a DC source of 390 V. The EVM uses the UCC25600 resonant half-bridge controller which integrates built-in state of the art efficiency boost features with high level protection features to provide cost effective solutions for LLC resonant half-bridge converter applications. The secondary side uses two daughter cards, HPA410, with diodes to make rectification.

Proper precautions must be taken when working with the EVM. High voltage levels, over 390 V, and temperature higher than 70C are present on the EVM when it is powered on and after power off for a short time as well. Forced air cooling is required when the EVM is powered on.

2 Description

2.1 Typical Applications

LLC resonant half-bridge converters are seen in applications such as TVs. The converters produce higher power conversion efficiency from their zero-voltage switching. Such converters are intended to extend to low-voltage applications such as ATX12 power supplies for computers and servers to obtain better energy conservation and savings. The EVM provides a platform to evaluate UCC25600 LLC resonant controller from a PFC input voltage and 12-V output rated at 300-W output power.

2.2 Features

The UCC25600EVM, HPA341, features:

- 300-W Output Power Rating
- High Efficiency 92% Peak and Over 91% at Full Load
- Regulated Output Nominal of 12 V
- Input DC Voltage of 390 V
- Plenty of Test Points to Facilitate the Device Evaluation
- Over-Current Protection
- Output Over-Voltage Protection
- Burst Operation at Light Load

3 Electrical Performance Specifications

Table 1. UCC25600EVM Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage range	V_{IN}	375	390	405	V_{DC}
Maximum input current	V_{IN} = 390 V_{DC} , I_{OUT} = 25A			0.88	A
Switching frequency	V_{IN} = 390 V_{DC} , I_{OUT} = 25A		110		kHz
Output Characteristics					
Output voltage V_{OUT}	V_{IN}: 390 V_{DC} , I_{OUT}: 1A	11.9	12	12.2	V_{DC}
Load current1[(1)]	V_{IN}: 390 V_{DC}	0		25	A
Continuous output power	V_{IN}: 390 V_{DC}			300	W
Line regulation	V_{IN}: 375 V_{DC} to 405 V_{DC} , I_{OUT} = 1.0A			5	mV
Load regulation	V_{IN}: 390 V_{DC} , I_{OUT}: 1 - 25A			50	
Load starting burst[(1)]	V_{IN}: 390 V_{DC}		0.5		A
Ripple and noise (20 MHz BW)	V_{IN}: 390 V_{DC} , I_{OUT} = 25A			120	mVpk-pk
Over current threshold, I_{o_ocp}	V_{IN}: 390 V_{DC}		30		A
Max power limit	V_{IN}: 390 V_{DC}		350		W
Efficiency					
Peak	V_{IN} = 390 V_{DC} , I_{OUT} = 15 A		92.5%		
Full load	V_{IN} = 390 V_{DC} , I_{OUT} = 25 A		91%		
Operation ambient temperature	Full load, forced air cooling 400 LFM			45	C

(1) The EVM output may present saw-tooth waveforms or a voltage higher than the regulation point typically about 13.1 V depending on load levels and the speed when the load is reduced. The saw-tooth waveform is caused by UCC25600 burst operation. The output voltage of 13.1 V is caused by output over voltage protection.

4 Schematic

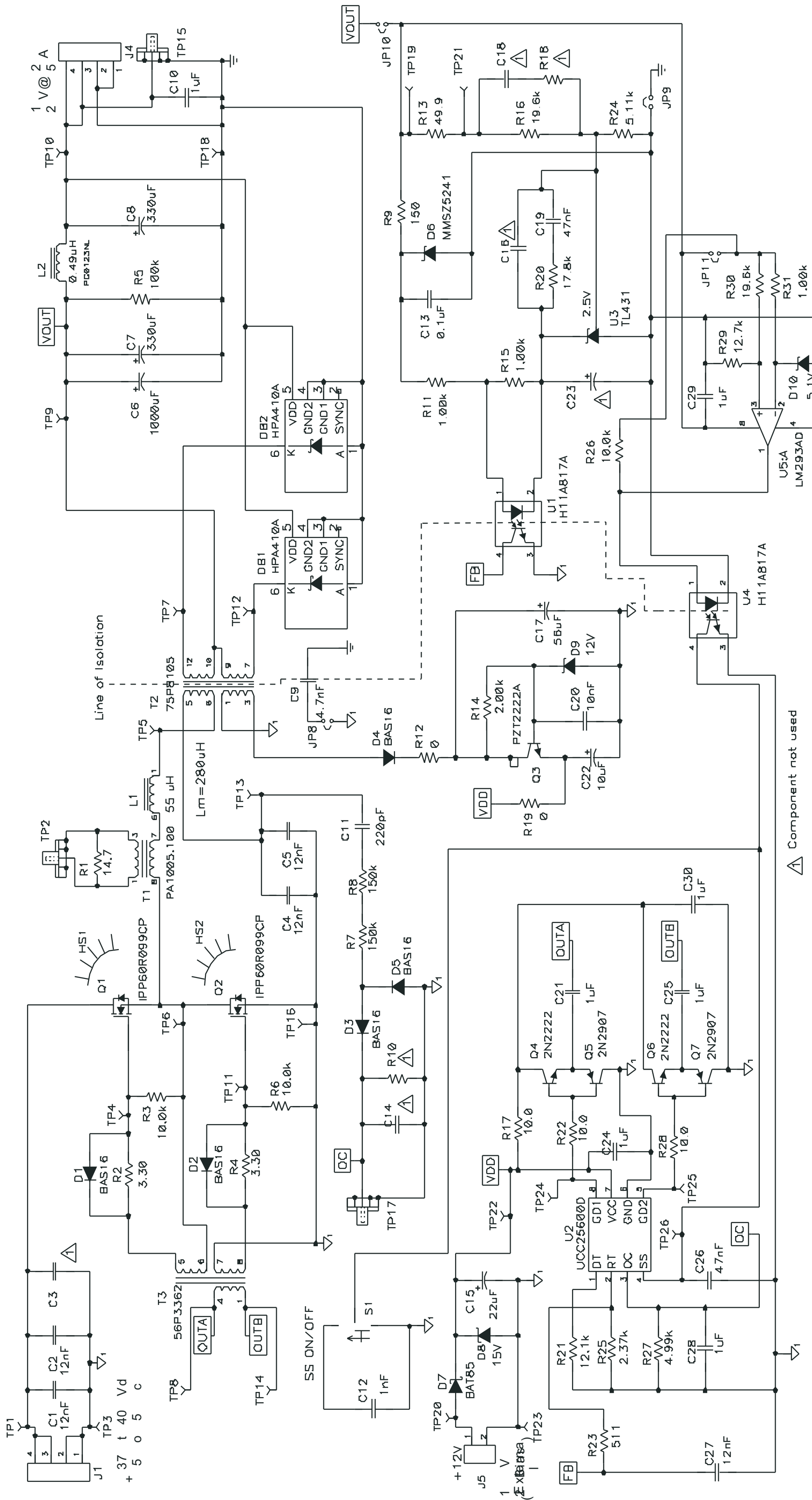

Figure 1. UCC25600EVM Schematic

5 Test Setup

5.1 List of Test Points

The EVM provides plenty of test points to facilitate the device's evaluation work. All test points are divided into two major groups – primary test points and secondary test points. Their locations are shown in Figure 2. The list below helps users to identify the functions of each test point.

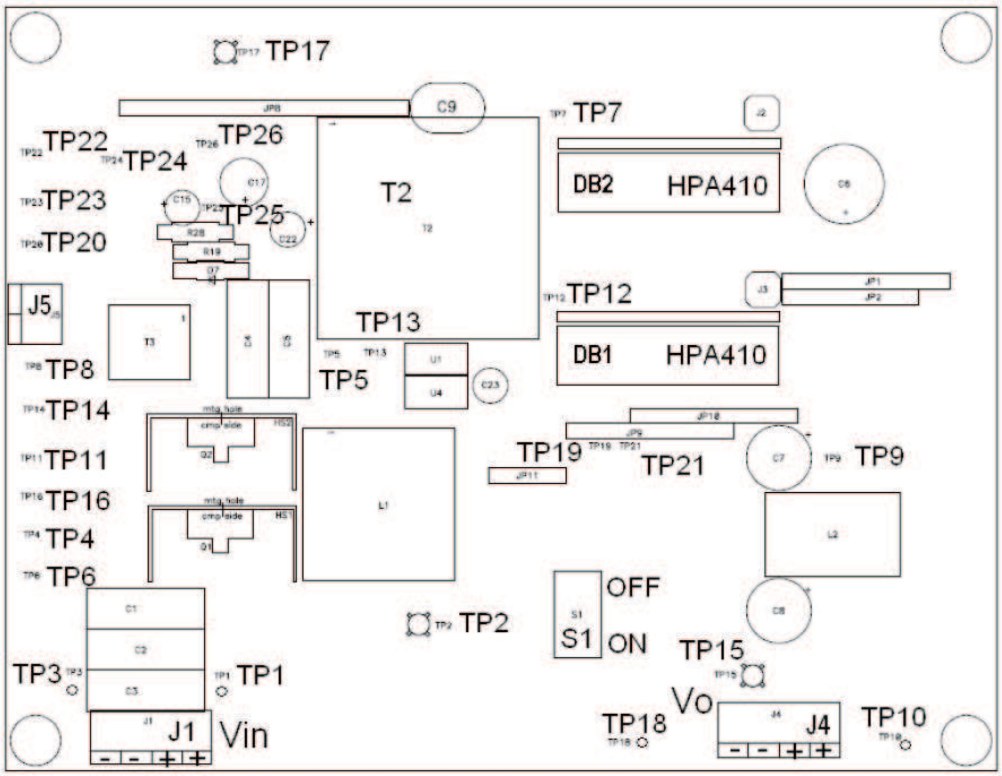

Figure 2. Test Point Location

Table 2 shown below lists the functions of each test point.

Table 2. UCC25600EVM Test Points

PRIMARY TEST POINTS			SECONDARY TEST POINTS		
NAME	**REF DES**	**CONNECTION**	**NAME**	**REF DES**	**CONNECTION**
Vin	TP1	Module input voltage +	Vxm	TP7	T2 pin 12
PGND	TP3	Module input voltage -	Vxm	TP12	T2 pin 7
Vbias	TP20	Primary Bias 12V +	VOUT	TP9	T2 pin 9 & 10
GND	TP23	Primary Bias 12V -	VO+	TP10	Output +
SS	TP26	UCC25600 SS-pin	VO-	TP18	Output -
VDD	TP22	UCC25600 VCC-pin	Loop+	TP19	Loop measure +
GD1	TP24	UCC25600 pin 8	Loop-	TP21	Loop measure -
GD2	TP25	UCC25600 pin 5	VOripple	TP15	Output ripple
VG5	TP4	Q5 gate			
OC	TP17	UCC25600 pin 3			
VG6	TP11	Q6 gate			
SW1	TP6	Switch node of Q5 and Q6			
PGND	TP16	Power GND			
Icr	TP2	Resonant tank current			
Vxm	TP5	T2 pin 6			
Vcr	TP13	Resonant capacitor voltage			
OUTB	TP14	T3 pin 1			
OUTA	TP8	T3 pin 4			

5.2 *Test Equipment*

Voltage Source: The input source shall be a constant DC source capable of supplying 390 V_{DC} with minimum 1.0 A_{DC} current rating.

Multimeters: Multimeters are used to measure the output voltage (DMM1), the input voltage (DMM3), the output current (DMM2) and the input load current (DMM4).

Output Load: A programmable electronic load is recommended, configurable for constant current mode and capable of sinking 0 A_{DC} to 25 A_{DC} from 12 V_{DC}. The output voltage can be monitored by connecting a DC voltmeter, DMM1 to sense pins (TP10 and TP18) shown in Figure 3. A DC current meter, DMM2, may be inserted in series with the electronic load for accurate output current measurements. Similarly, the input voltage can be monitored by connecting a DC voltage meter to sense pins (TP1 and TP3). The input current can be monitored by a DC current meter too. These are shown in Figure 3.

Oscilloscope: Set the oscilloscope channel to AC coupling with 20-MHz bandwidth.

5.3 Notes on Power Up and Power Down

The following steps are guidelines for power up and power down of the EVM.

1. An ESD workstation is recommended. Make sure that an ionizer is on before the EVM is removed from the protective packaging and power is applied to the EVM. Electrostatic smock and safety glasses should also be worn.
2. Power Up
   a. Set up an air cooling fan with minimum 400 LFM or 2.0 m/s forced airflow. This airflow direction should point to the middle of DB1 and DB2 and towards transformer T2. The cooling fan should be on throughout the test.
   b. Prior to connecting the DC input source, limit the source current 1.0 A maximum. Make sure the DC source is initially set at 390 V_{DC} prior to turning on. Connect the DC source to the EVM as shown in Figure 3.
   c. Connect the current meters DMM2 and DMM4 as shown in Figure 3.
   d. Connect the volt meter DMM1 and DMM3 as shown in Figure 3.
   e. For operation with a load, connect the electronic load to the EVM as shown in Figure 3. Set the LOAD to constant current mode with initial value of 1.0 A. Note: if the load less than 1.0 A, the UCC25600 may be in burst operation and the EVM output voltage may start hiccup.
   f. Turn on the DC source and observe the output voltage. Its output voltage should be at nominal 12 V_{DC}.
   g. Varying the load between 1.0 A and 25 A.
3. Power Down
   a. Turn off the DC source.
   b. Turn off the load.

5.4 Recommended Test Setup

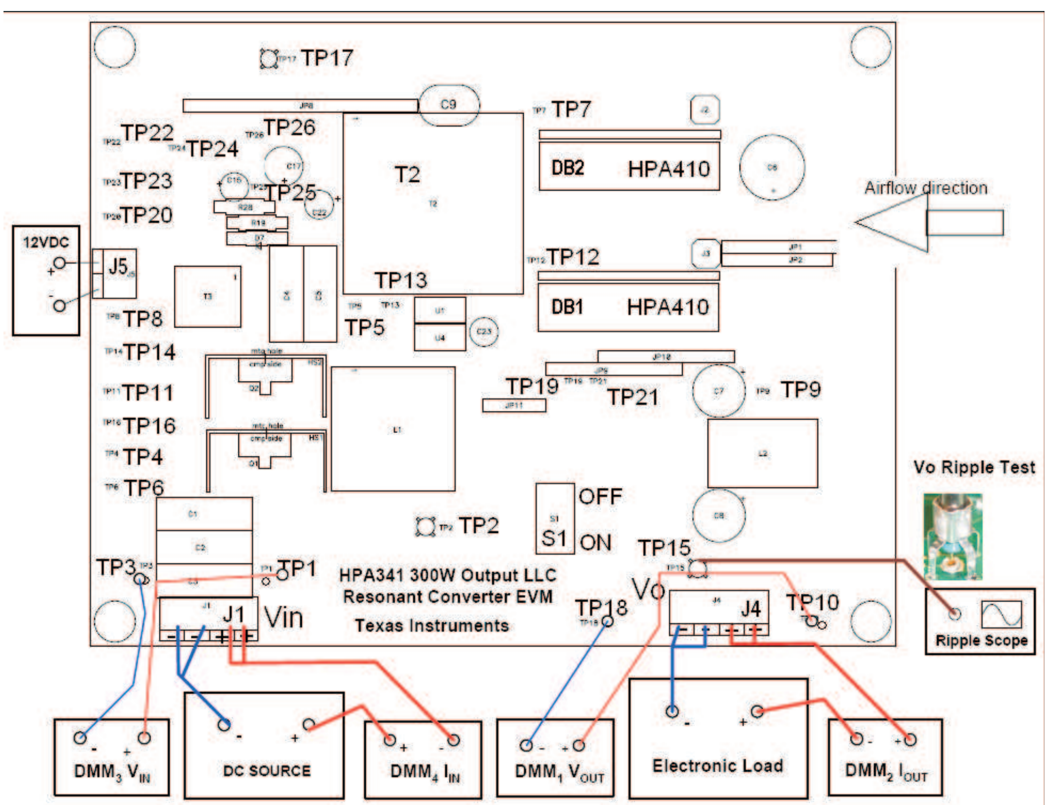

Figure 3. Recommended Test Set Up

6 Test Procedure

Setup the EVM with equipment as shown in Figure 3 and following the test set up directions described in Section 5.

6.1 Line/Load Regulation and Efficiency Measurement Procedure

Set up the load to 1.0 A and input voltage between 375 V_{DC} and 405 V_{DC}. Prior to turning on the power, set up the input source current limit to 1.0 A to avoid potential damage, although the EVM has its power limit typical 350 W. Turn on the input source. Reference test results of line and load regulation can be found from Section 7

6.2 Output Ripple

Along with the measurement of line and load regulation, the output voltage ripple can be measured at the same time. The method of tip-and-barrel should be used for the output voltage ripple measurement. The EVM provides such type of test point to facilitate the measurement for the type of oscilloscopes from Tektronix as shown in Figure 3. Reference test results of the output voltage ripple can be found in Section 7.

6.3 Efficiency

The efficiency may be calculated based on the test data obtained from Section 6.1. To correctly measure input and output voltage for the efficiency calculation, test points TP1 and TP2 should be used for input voltage measurement, and test points TP10 and TP18 should be used for output voltage measurement. Reference results of efficiency can be found in Section 7.

6.4 Bode Plots

To measure loop compensation bode plots, a sweep signal may be injected through test points TP19 and TP21. The full system bode plots is measured with TP19 and TP21. The controller bode plots is measured with TP21 and U3 pin 4. The modulator bode plots is measured with U3 pin4 and TP19.

6.5 Others

The EVM provides plenty of test points to facilitate the device's evaluation work. Table 2 presents a list of test points. Users can use these test points to make measurement to the functions of their interest. The test points are divided into two groups, namely primary side group and secondary side group. During the measurement setup, be aware of the setup especially for different ground pick up. The EVM is designed with 3500-V reinforced insulation between the primary and the secondary. As such there is no common ground as reference point for the measurement to be made on both sides. In other words, each side has its own ground to be used for measurement reference point.

7 Performance Data and Typical Characteristic Curves

Figure 4 through Figure 17 present typical performance curves for UCC25600EVM.

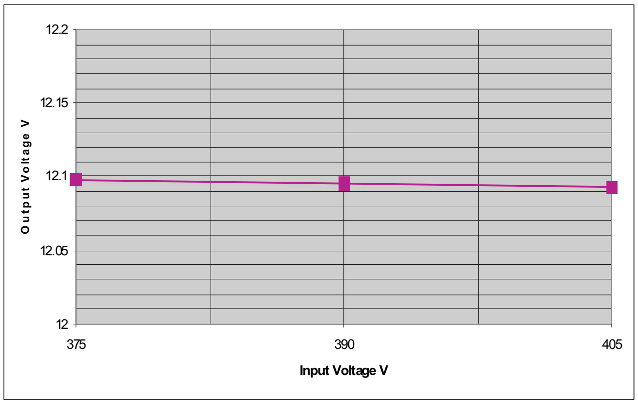

Figure 4. Line Regulation, I_O = 1 A

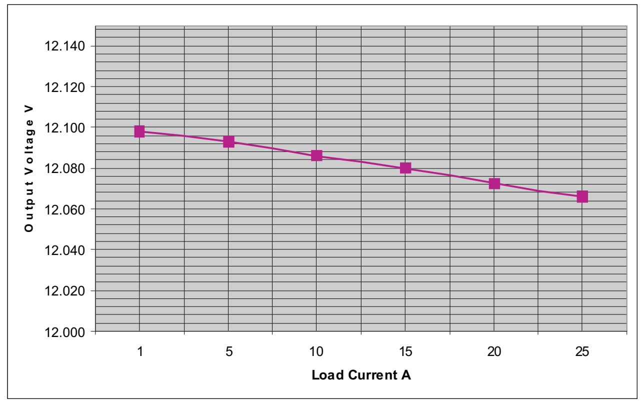

Figure 5. Load Regulation, V_{IN} = 390 V_{DC}

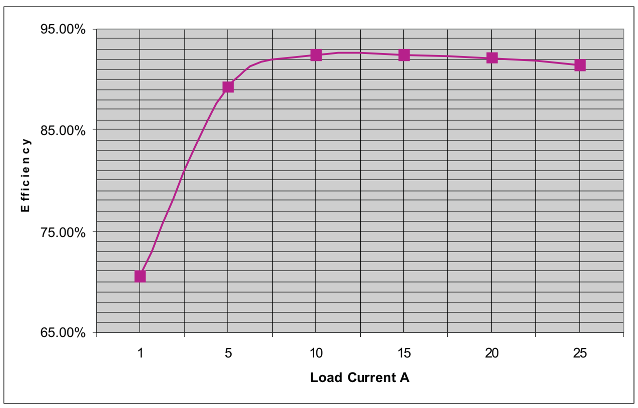

Figure 6. Typical Efficiency at V_{IN} = 390 V_{DC}

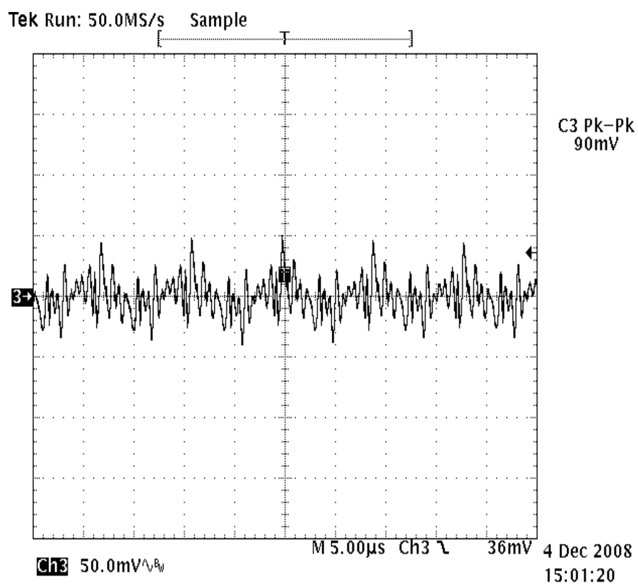

Figure 7. Typical Output Voltage Ripple Waveform at V_{IN} = 390 V and I_O = 15 A (TP15)

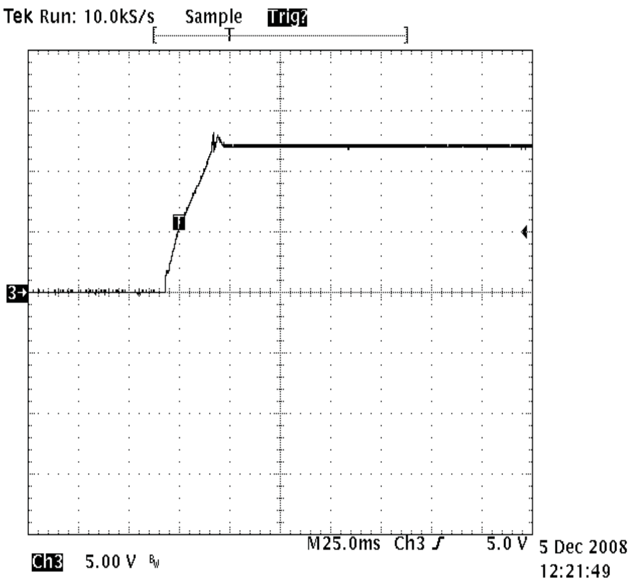

Figure 8. Typical Output Voltage Turn On (TP15)

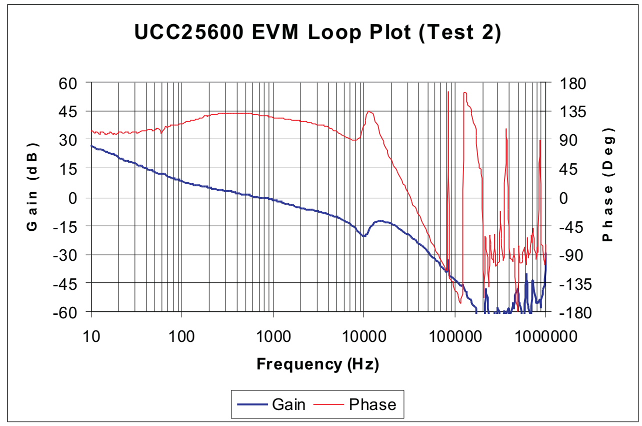

Figure 9. Full System Loop Compensation (TP19 and TP21)

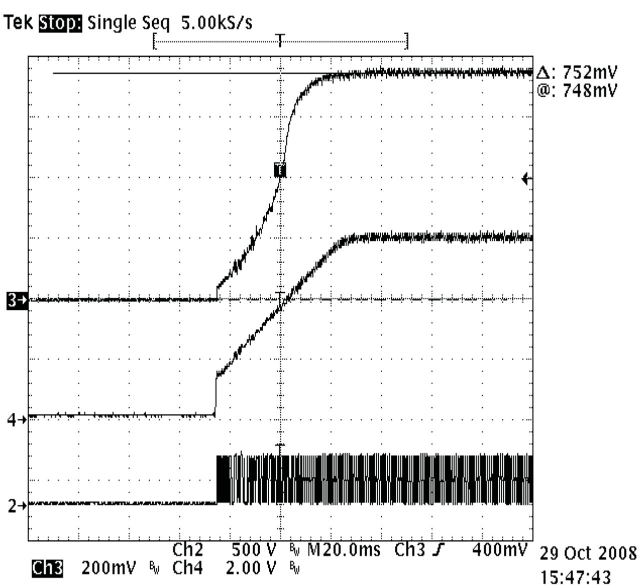

Figure 10. Typical Soft-Start Waveform

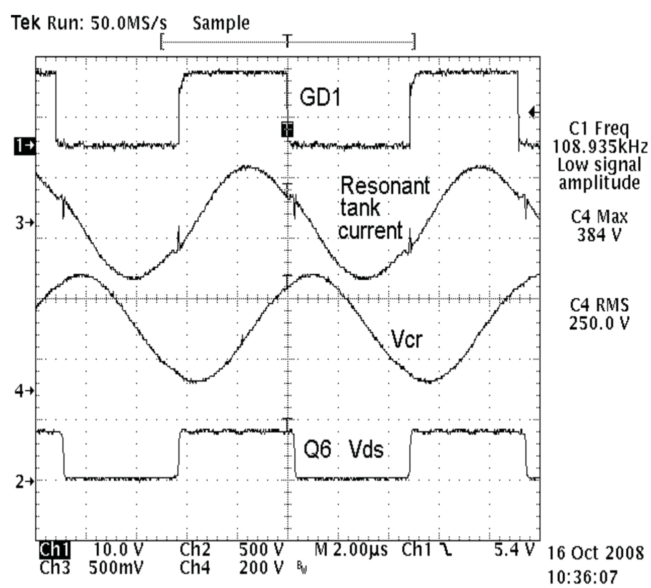

Figure 11. Typical Resonant Tank Current and Resonant Capacitor Voltage

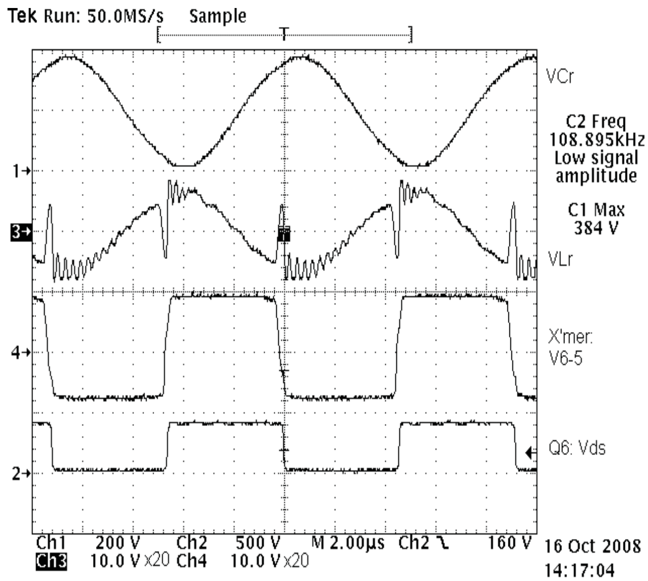

Figure 12. Typical Voltage of the Resonant Circuit

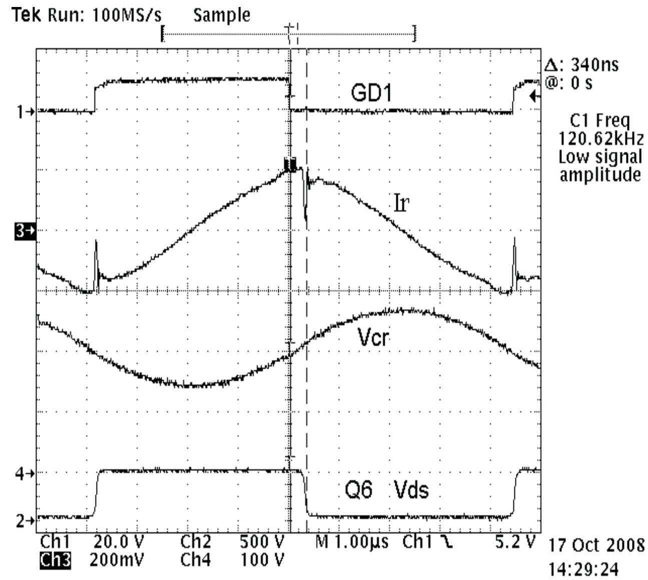

Figure 13. Typical Resonant Voltage and Current at Light Load

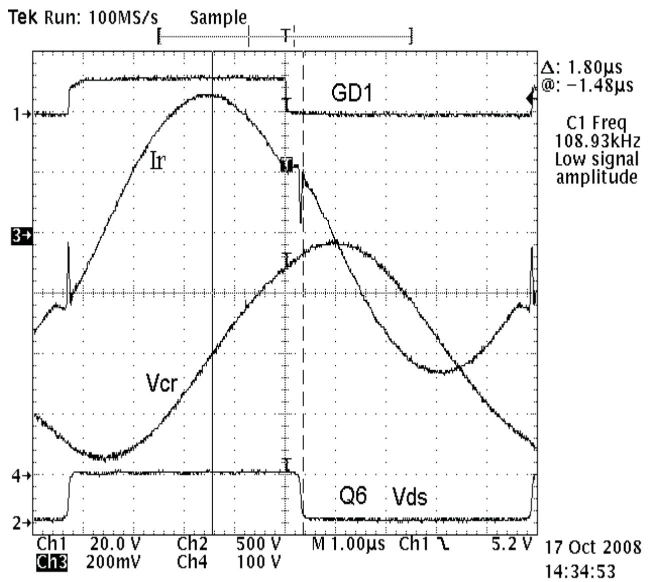

Figure 14. Typical Resonant Voltage and Current at Heavy Load

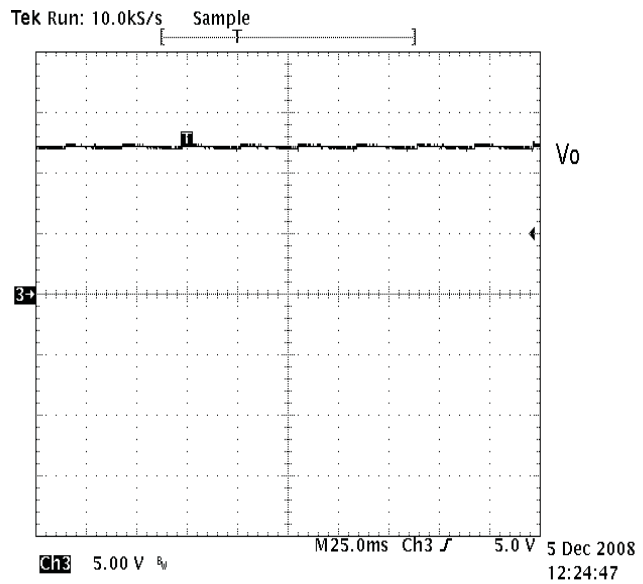

Figure 15. Typical Output Voltage in Burst Operation (TP15)

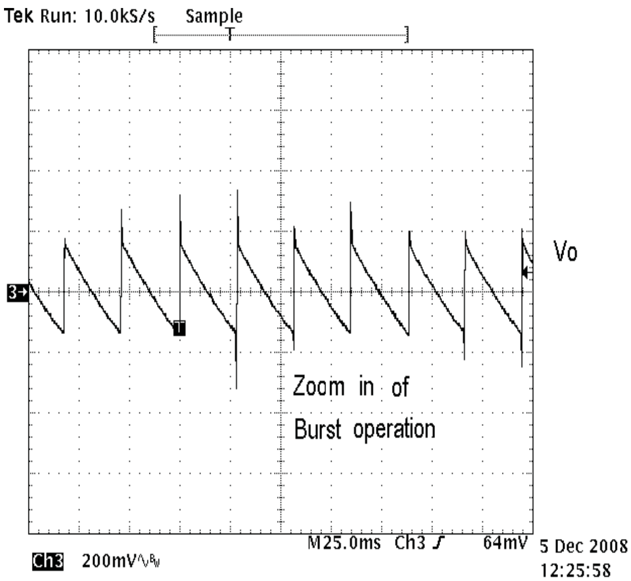

Figure 16. Typical Output Voltage in Burst Operation (TP15)

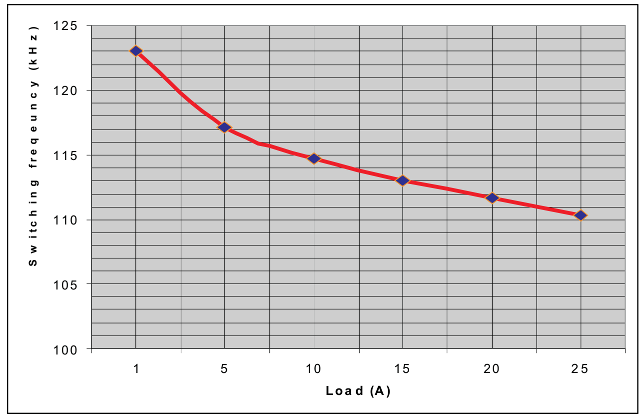

Figure 17. Switching Frequency Variation with Respect to Load (TP24)

8 EVM Assembly Drawing and PCB Layout

Figure 18 through Figure 26 shows the layout of the four-layer printed circuit board used for the EVM.

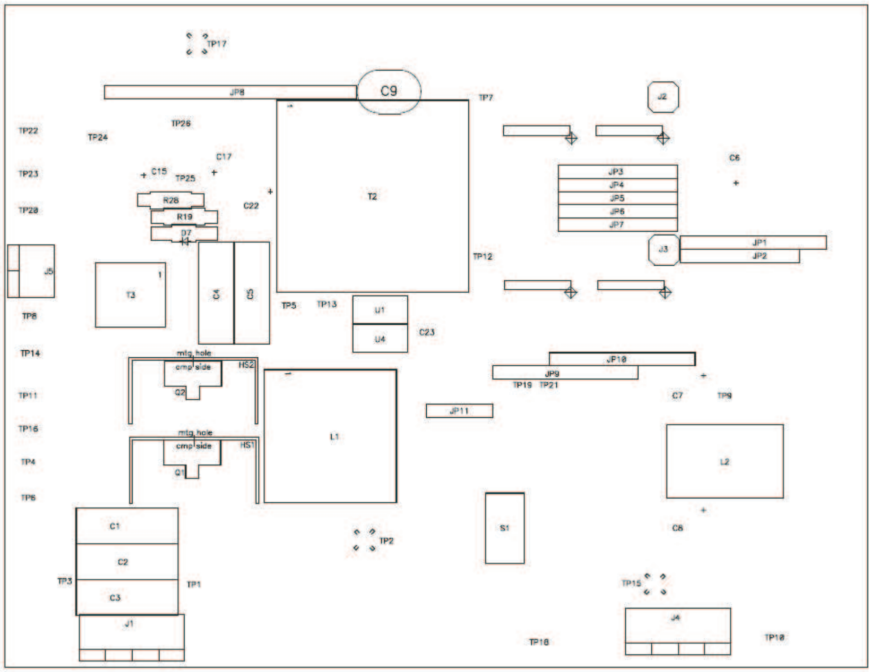

Figure 18. Top Assemblies

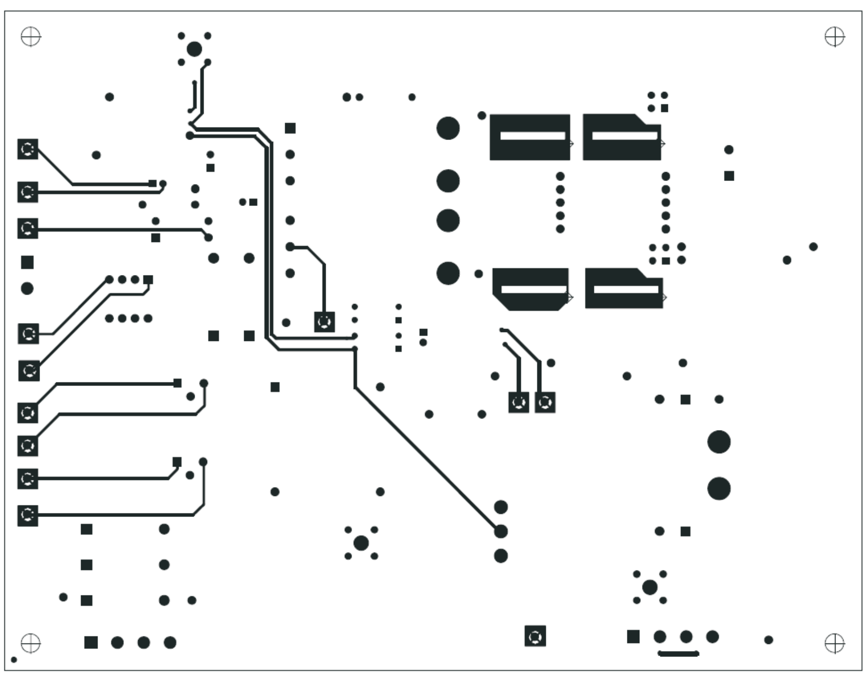

Figure 19. Top Copper

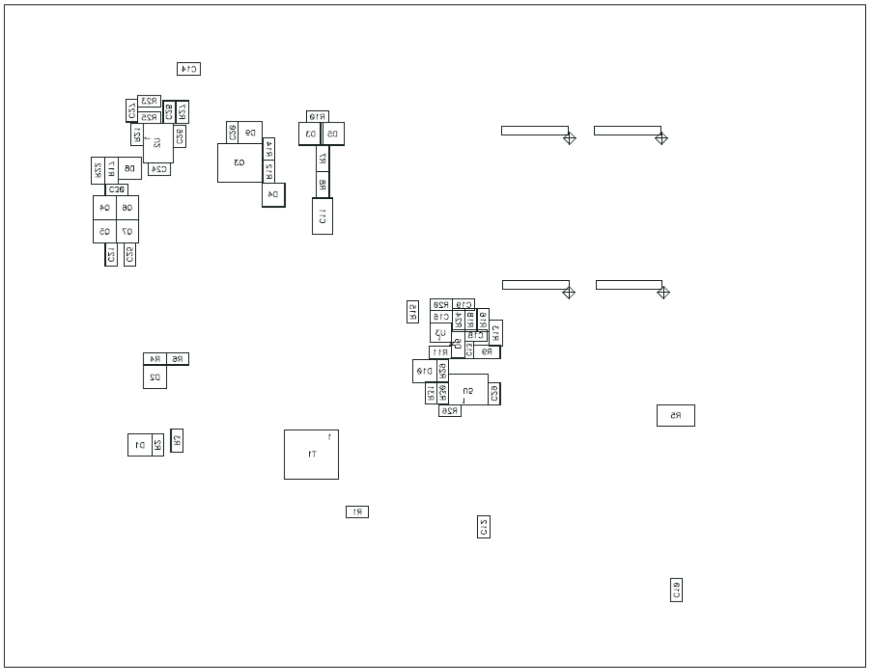

Figure 20. Bottom Assemblies

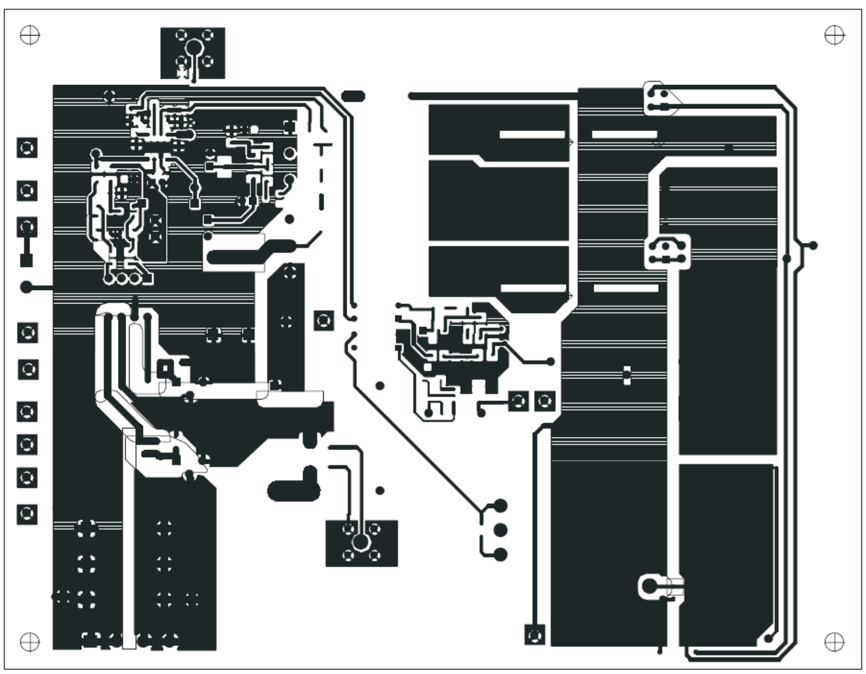

Figure 21. Bottom Copper

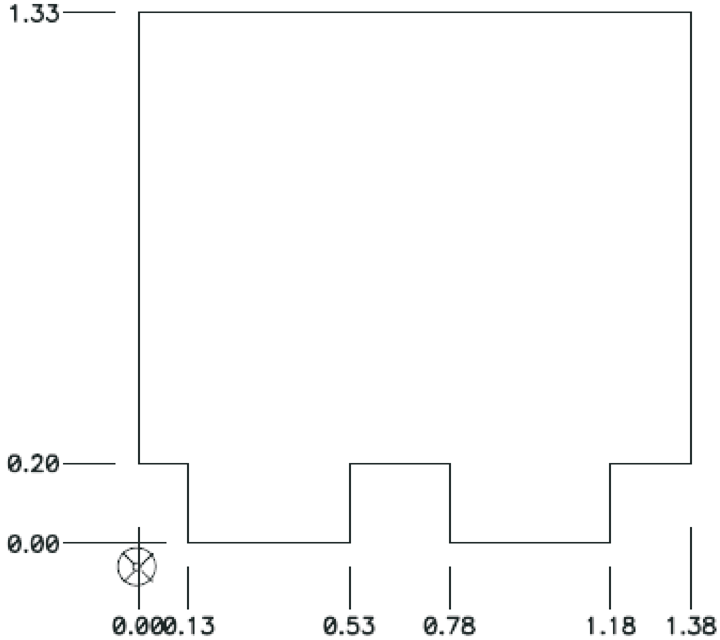

Figure 22. Top Assemblies

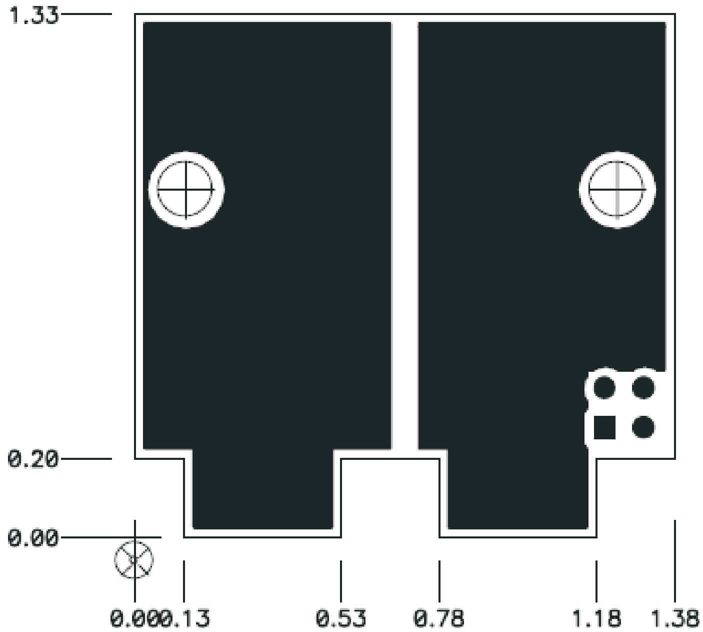

Figure 23. Top Copper

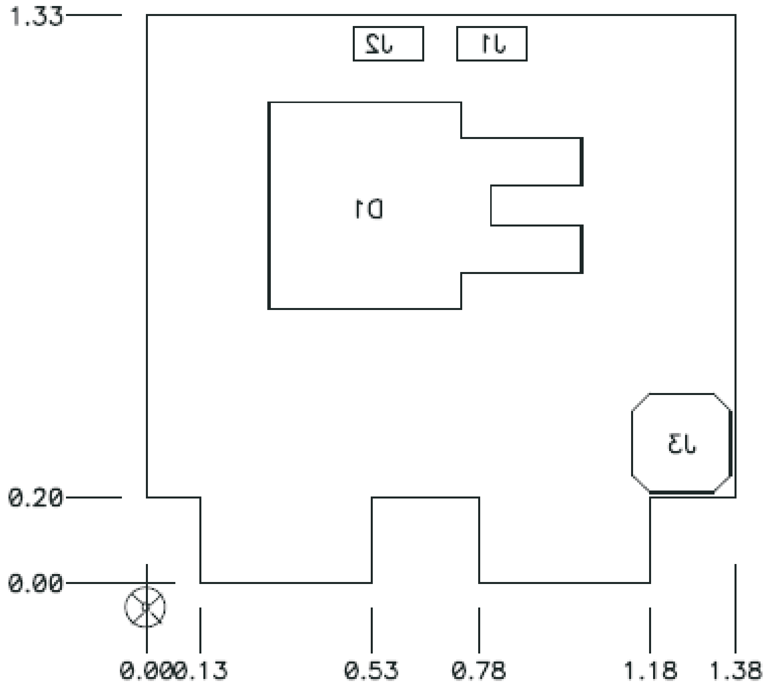

Figure 24. Bottom Assemblies

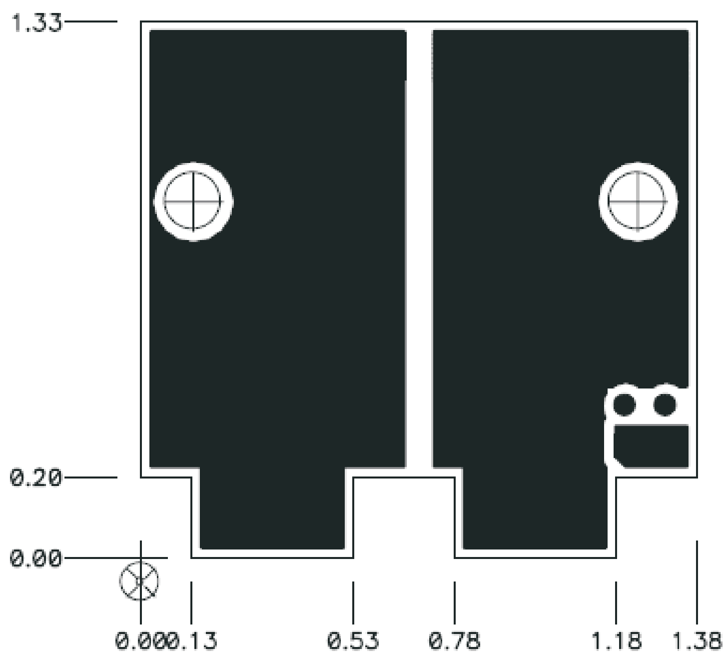

Figure 25. Bottom Copper

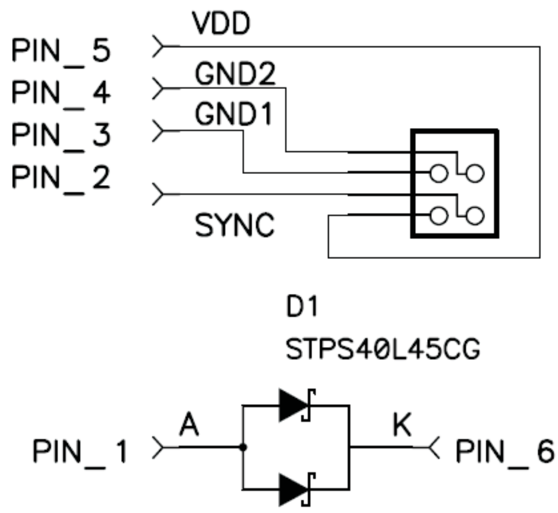

Figure 26. Schematics

9 List of Materials

The EVM components list according to the schematic shown in Figure 1 is shown below.

Table 3. UCC25600 List of Materials

QTY	REF DES	DESCRIPTION	MFR	PART NUMBER
4	C1, C2, C4, C5	Capacitor, metallized polypropylene film, 12nF, 630VDC, 400VAC	Vishay	2222 383 30123
7	C10, C21, C24, C25, C28, C29, C30	Capacitor, ceramic, 1 µF, 16 V, X5R, 10%, 0805	std	std
1	C11	Capacitor, ceramic, 220 pF, 1 kV, X5R, 10%, 1808	std	std
1	C12	Capacitor, ceramic, 1 nF, 16 V, X5R, 10%, 0805	std	std
1	C13	Capacitor, ceramic, 0.1 µF, 16 V, X7R, 10%, 0603	std	std
1	C15	Capacitor, aluminum, 22 µF, 50 V, 20%	Panasonic	EEU-FC1H220
1	C17	Capacitor, aluminum, 56 µF, 50 V, 20%	Panasonic	EEU-FC1H560
2	C19, C26	Capacitor, ceramic, 47 nF, 50 V, X7R, 10%, 0805	std	std
1	C20	Capacitor, ceramic, 10 nF, 50 V, X7R, 10%, 0805	std	std
1	C22	Capacitor, aluminum, 10 µF, 50 V, 20%	Panasonic	EEU-FC1H100
1	C27	Capacitor, ceramic, 12 nF, 50 V, X7R, 10%, 0805	std	std
1	C6	Capacitor, aluminum electrolytic, 1000 µF, 16V	Panasonic	ECE-A1CN102U
2	C7, C8	Capacitor, aluminum polymer, 330 µF, 16 V, 20%	Chemi-Con	APS-160ELL331MJC5S
1	C9	Capacitor, cer. disc, 4.7 nF, 250 V, 20%	Panasonic	ECK-ANA472ME
5	D1, D2, D3, D4, D5	Diode, switching, 75 V, 200 mA, SOT23	Onsemi	BAS16LT1G
1	D10	Diode, Zener, 5.1 V, 225 mW, 5%	Onsemi	BZX84C5V1LT1G
2	D11, D12	Diode, dual Schottky, 2 x 20 A, 45 V	STM	STPS40L45CG
1	D6	Diode, Zener, 11 V, 500 mW	Onsemi	MMSZ5241BT1G
1	D7	Diode, Schottky, 200 mA, 30 V	Philips	BAT85
1	D8	Diode, Zener, 15 V, 225 mW	Onsemi	BZX84C15LT1G
1	D9	Diode, Zener, 12 V, 225 mW	Onsemi	BZX84C12LT1G
1	L1	Inductor, 55 µH	Vitec	75P8106

Table 3. UCC25600 List of Materials (continued)

QTY	REF DES	DESCRIPTION	MFR	PART NUMBER
1	L2	Inductor, 48 A, 0.49 µH	Pulse	PG0123NL
2	Q1, Q2	MOSFET, N-channel, 650 V, 31 A	Infineon	IPP60R099CP
1	Q3	Transistor, NPN, 40 V, 1 A	Fairchild	PZT2222A
2	Q4, Q6	Transistor, NPN, 30 V, 0.1 A	Infineon	2N2222
2	Q5, Q7	MOSFET, P-channel, 65 V, 0.1 A	Philips	2N2907
1	R1	Resistor, chip, 14.7 Ω,1/8 W, 1%, 0805	std	std
3	R11, R15, R31	Resistor, chip, 1.00 kΩ, 1/8 W, 1%, 0805	std	std
1	R12	Resistor, chip, 0 Ω, 1/8 W, 1%, 0805	std	std
1	R13	Resistor, chip, 49.9 Ω, 1/4 W, 1%, 1206	std	std
1	R14	Resistor, chip, 2.00 kΩ, 1/8 W, 1%, 0805	std	std
2	R16, R30	Resistor, chip, 19.6 kΩ, 1/8 W, 1%, 0805	std	std
2	R17, R22	Resistor, chip, 10.0 Ω, 1/4 W, 1%, 1206	std	std
1	R19	Resistor, film, 0 Ω, 1/4 W, 1%, RN55	std	std
2	R2, R4	Resistor, chip, 3.30 Ω, 1/8 W, 1%, 0805	std	std
1	R20	Resistor, chip, 17.8 kΩ, 1/8 W, 1%, 0805	std	std
1	R21	Resistor, chip, 12.1 kΩ, 1/8 W, 1%, 0805	std	std
1	R23	Resistor, chip, 511 Ω, 1/8 W, 1%, 0805	std	std
1	R24	Resistor, chip, 5.11 kΩ, 1/8 W, 1%, 0805	std	std
1	R25	Resistor, chip, 2.37 kΩ, 1/8 W, 1%, 0805	std	std
1	R27	Resistor, chip, 4.99 kΩ, 1/8 W, 1%, 0805	std	std
1	R28	Resistor, film, 10.0 Ω, 1/4 W, 1%, RN55	std	std
1	R29	Resistor, chip, 12.7 kΩ, 1/8 W, 1%, 0805	std	std
3	R3, R6, R26	Resistor, chip, 10.0 kΩ, 1/8 W, 1%, 0805	std	std
1	R5	Resistor, chip, 100 kΩ, 1/8 W, 1%, 0805	std	std
2	R7, R8	Resistor, chip, 150 kΩ, 1/4 W, 1%, 1206	std	std
1	R9	Resistor, chip, 150 Ω, 1/4 W, 1%, 1206	std	std
1	S1	Switch, actuator SPDT	C & K	1101M2S3CQE2
1	T1	Transformer, current sense, 20 A, 1:100	Pulse	P1005.100
1	T2	Xfmr, half-bridge	Vitec	75P8105
1	T3	Transformer, gate drive	Vitec Electronics	56P3362
2	U1, U4	IC, optocoupler	Fairchild	H11A817A300
1	U2	Resonant mode controller	TI	UCC25600D
1	U3	2.5V precision adjustable shunt regulator	TI	TL431ACDBVR
1	U5	Dual differential comparators	TI	LM293AD
2	DB1, DB2	Rectifier daughter card	TI	HPA410A
1	D1	Diode, dual Schottky, 2 x 20 A, 45 V, D2PAK	STM	STPS40L45CG

10 References

1. *UCC25600 8-Pin High-Performance Resonant Mode Controller*, datasheet, SLUS846, September 2008.

Table 4. EVALUATION BOARD/KIT IMPORTANT NOTICE

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

TI currently deals with a variety of customers for products, and therefore our arrangement with the user **is not exclusive.**

TI assumes **no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.**

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please contact the TI application engineer or visit www.ti.com/esh.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used.

Table 5. FCC Warning

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment in other environments may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

Table 6. EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 375VDC to 405VDC and the output voltage range of 0ADC to 25ADC.

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 100°C. The EVM is designed to operate properly with certain components above 100°C 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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265