Using the UCC27714EVM-551

User's Guide

Literature Number: SLUUB02A
July 2015–Revised September 2015

600-W Phase-Shifted Full-Bridge (PHSB) Converter Based on the 600-W PHSB UCC28950 Converter

Cautions and Warnings

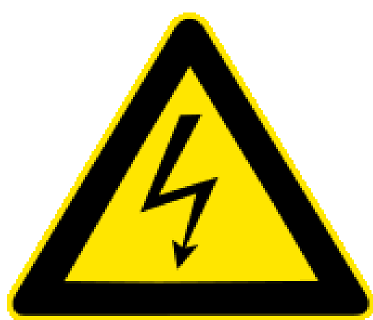
CAUTION:

Caution! Do not leave EVM powered when unattended.

HOT SURFACE:

Caution Hot Surface! Contact may cause burns. Do not touch. Please take the proper precautions when operating.

HIGH VOLTAGE:



Danger High Voltage! Electric shock possible when connecting board to live wire. Board should be handled with care by a professional. For safety, use of isolated test equipment with overvoltage/overcurrent protection is highly recommended.

General Texas Instruments High Voltage Evaluation (TI HV EMV) User Safety Guidelines

WARNING

Always follow TI's set-up and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and those working around you. Contact TI's Product Information Center http://ti.com/support for further information.

Save all warnings and instructions for future reference.

> **WARNING**
>
> **Failure to follow warnings and instructions may result in personal injury, property damage or death due to electrical shock and burn hazards.**

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is *intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise and knowledge of electrical safety risks in development and application of high voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments.* If you are not suitable qualified, you should immediately stop from further use of the HV EVM.

1. Work Area Safety:
   (a) Keep work area clean and orderly.
   (b) Qualified observer(s) must be present anytime circuits are energized.
   (c) Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.
   (d) All interface circuits, power supplies, evaluation modules, instruments, meters, scopes, and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.
   (e) Use stable and non-conductive work surface.
   (f) Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
2. Electrical Safety:
   As a precautionary measure, it is always good engineering practice to assume that the entire EVM may have fully accessible and active high voltages.
   (a) De-energize the TI HV EVM and all its inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   (b) With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment hook-ups and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
   (c) Once EVM readiness is complete, energize the EVM as intended.

WARNING

While the EVM is energized, never touch the EVM or its electrical circuits, as they could be at high voltages capable of causing electrical shock hazard.

3. Personal Safety
   (a) Wear personal protective equipment e.g. latex gloves or safety glasses with side shields or protect EVM in an adequate lucent plastic box with interlocks from accidental touch.

Limitation for safe use:

EVMs are not to be used as all or part of a production unit.

1 Introduction

This 600-W EVM was designed to demonstrate how the UCC28950 control device, UCC27524A and UCC27714 gate drivers could be used in high-efficiency applications by achieving ZVS from 50% to 100% load. To achieve this high efficiency the UCC28950 was designed to drive synchronous rectifiers on the secondary side of the full-bridge converter. The UCC28950 also incorporates a burst mode and DCM function to improve no-load efficiency. Please see UCC28950 data sheet for details.

The UCC277714 is a high-speed, high-voltage, high-side/low-side gate driver optimized for driving MOSFETs in high-frequency, switch-mode power supplies that are based on bridge-type topologies. It enables users to eliminate bulky gate-drive transformers in offline power supplies and achieve fast switching of power MOSFETs by virtue of its low propagation delay and high-peak-drive current.

2 Description

The UCC27714EVM-551 is a 600-W phase-shifted, full-bridge converter that converts a 370-V_{DC} to 410-V_{DC} input to a regulated 12-V output. This converter was designed to maintain ZVS down to 50% load.

2.1 Features

- ZVS from 50% to 100% load
- Higher Efficiency for 80-plus Applications
- Burst Mode/DCM Function (reduces no-load power dissipation to meet green mode requirements)
- Features UCC28950 controller, UCC27714 High-Voltage, High-Side/Low-Side Gate Driver, UCC27524A Dual-Channel Low-Side Gate Driver and CSD19506KCS MOSFETs

2.2 Typical Applications for Phase-Shifted Full Bridge

- Server, Telecom Power Supplies
- Industrial Power Systems
- High-Density Power Architectures

3 Electrical Performance Specifications

Table 1. UCC27714EVM-551 Electrical Specifications[1]

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics					
DC input voltage range		370	390	410	V
Maximum input current	V_{IN} = 370 V_{DC} to 410 V_{DC}			2	A
Output Characteristics					
Output voltage (V_{OUT})	V_{IN} = 370 V_{DC} to 410 V_{DC}	11.4	12	12.6	V
Output current (I_{OUT})	V_{IN} = 370 V_{DC} to 410 V_{DC}			50	A
Continuous output power (P_{OUT})	V_{IN} = 370 V_{DC} to 410 V_{DC}			600	W
Load regulation	V_{IN} = 370 V_{DC} to 410 V_{DC} I_{OUT}= 5 A to 50 A			150	mV
Line regulation	V_{IN} = 370 V_{DC} to 410 V_{DC} I_{OUT}= 5 A to 50 A			150	mV
Output ripple voltage	V_{IN} = 370 V_{DC} to 410 V_{DC} I_{OUT}= 5 A to 50 A			200	mV
Holdup time	V_{IN} stepped from 390 V_{DC} to 0 V_{DC} P_{OUT} = 500 W		17		ms
System					
Full load efficiency	V_{IN} 370 V to 390 V, P_{OUT} = 500 W	93%	94%		

(1) Operation ambient temperature full load, forced-air cooling 400 LFM at 25°C.

4 Schematic

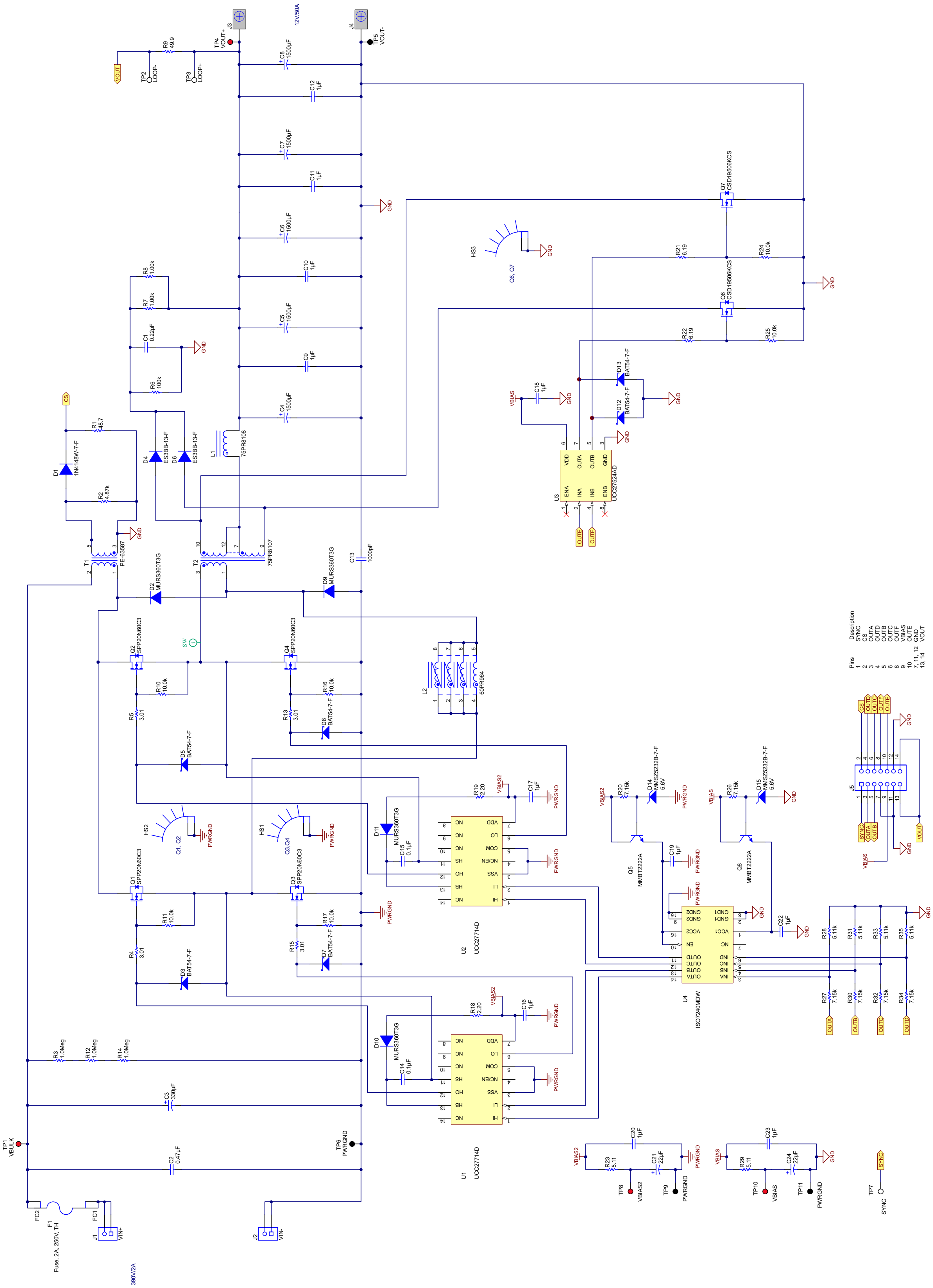


Figure 1. UCC27714EVM-551 Power Stage Schematic

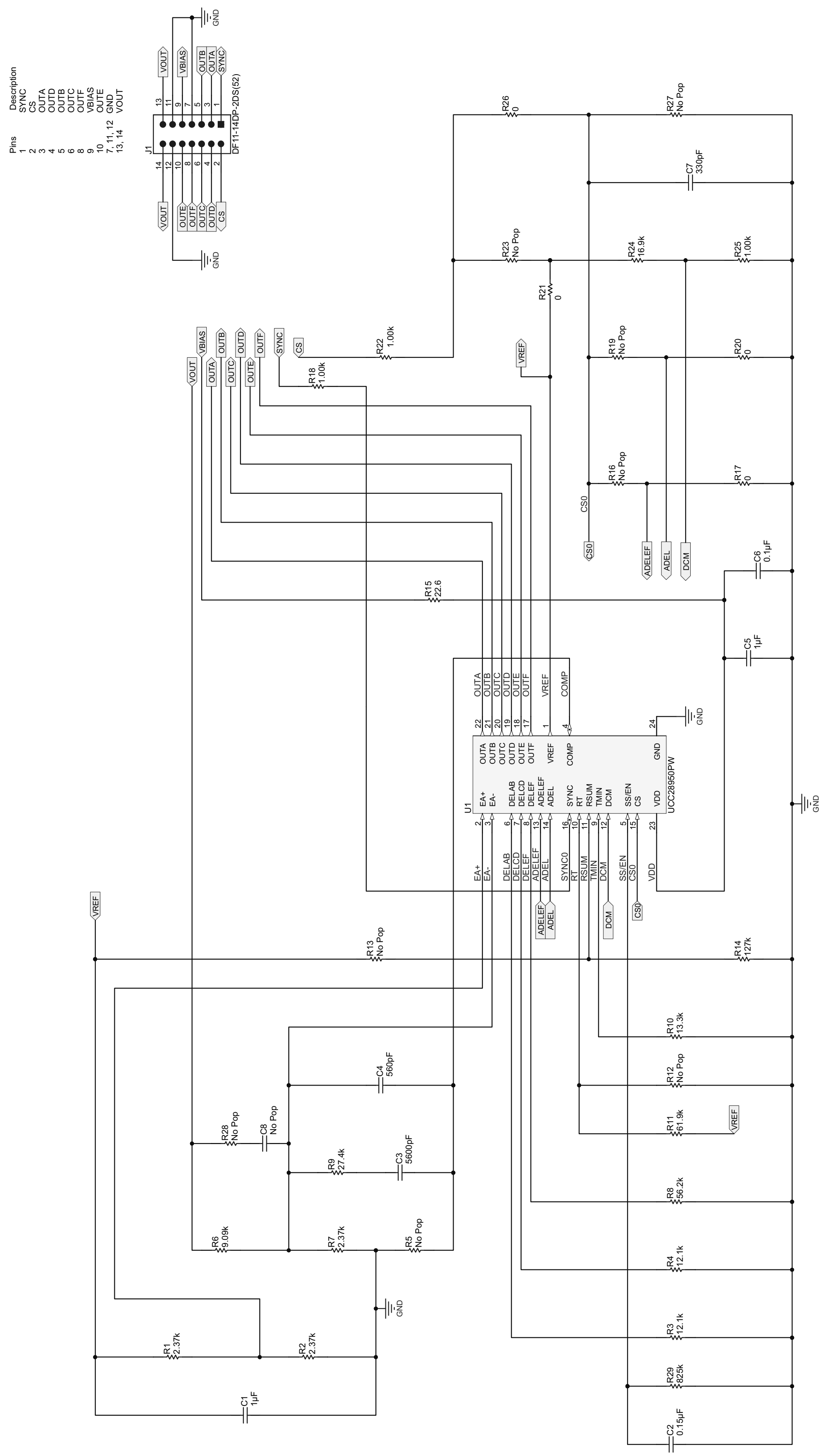


Figure 2. UCC27714EVM-551 Daughter Card Controller Schematic

5 Recommended Basic Test Equipment

Voltage Sources:

- 500-V_{DC} Source Capable of 750 W
- Two DC Power Supply Capable of 20 V

Volt Meters: 4-V Meters

Output Load: 25-V/750-W Load

Precision Shunt Resistors for Measuring Efficiency:

- R_{SHUNT1} = 5 A/100 mV
- R_{SHUNT2} = 50 A/50 mV

Fan: 400 LFM

Recommended Wire Gauge:

- 18 AWG at V_{IN}, V_{IN} – to Source
- 8 AWG at V_{OUT}, V_{OUT} – to Electronic/Resistive Loads

6 Recommended Test Setup

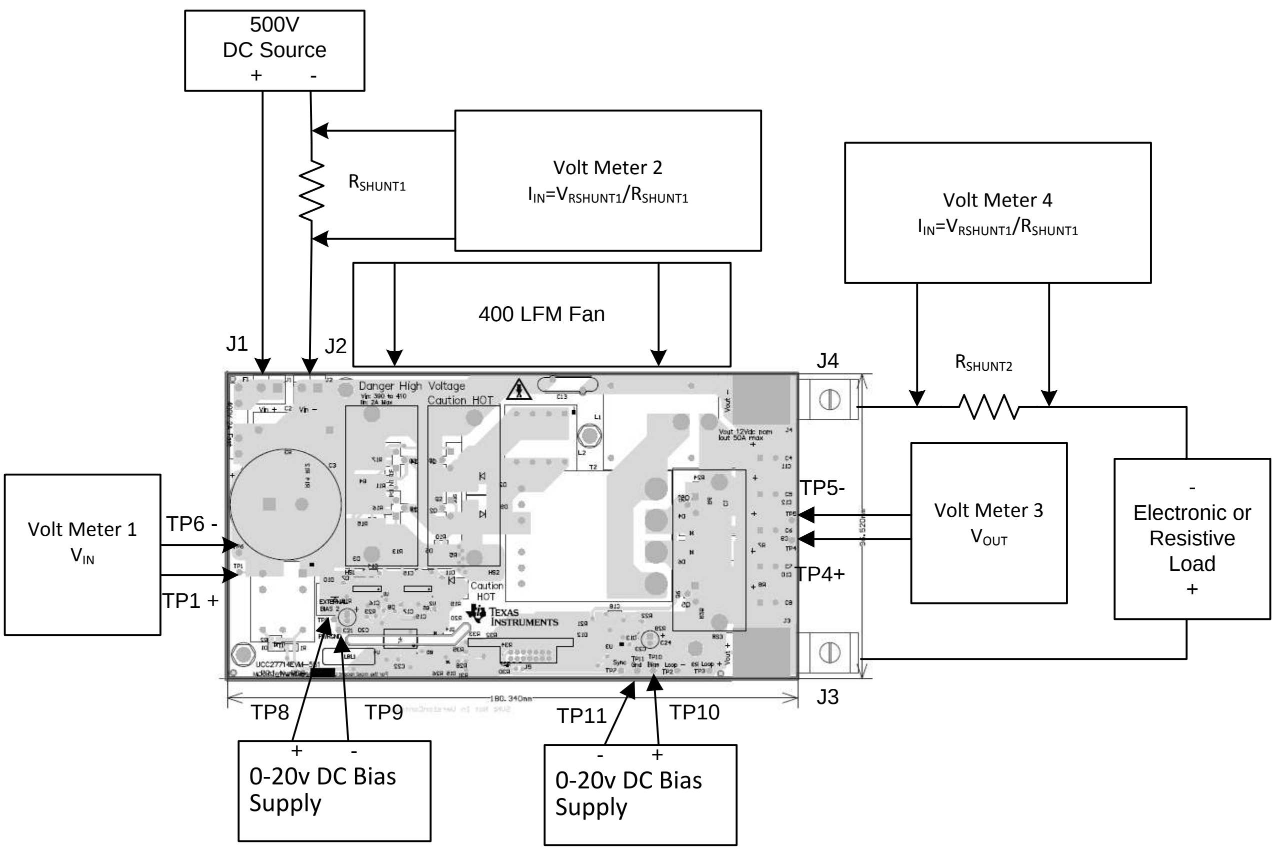


Figure 3. Test Setup to Measure Efficiency

6.1 List of Test Points

Table 2. Test Points

TEST POINTS	NAME	DESCRIPTION
TP1	VBULK	Input voltage positive (VIN+)
TP2	N/A	Voltage loop injection point 1
TP3	N/A	Voltage loop injection point 2
TP4	VOUT+	Output voltage positive
TP5	VOUT–	Output voltage negative
TP6	PWRGND	Input voltage ground (VIN–)
TP7	SYNC	Synchronization input
TP8	VBIAS2	Bias 2 positive
TP9	GND2	Bias 2 negative
TP10	VBIAS	Bias positive
TP11	GND1	Bias negative

7 Power On/Off Procedure

NOTE: It is important to follow the power up and power down procedure to ensure the EVM does not get damaged.

This EVM was designed to show the performance of the UCC28950, UCC27714 and UCC27524A in a phase-shifted, full-bridge and is not a standalone power supply. This EVM does not included input under voltage lockout (UVLO) circuitry that would be present in a standalone power supply.

1. The EVM was not designed to startup from 0-V input voltage. Please make sure the input voltage is in-between 370 V and 410 V before applying the bias voltages.
2. Connect test setup similar to Figure 3 before applying power to the EVM.
3. Apply 370 V_{DC} to 410 V_{DC} to the input of the power converter with the 500-V_{DC} source.
4. Set the 0-V to 20-V bias power supplies to 11 V, 12 V Maximum, (This powers the UCC28950 PWM Controller).
5. When powering down the unit set the 0-V to 20-V DC supply to 0 V.
6. For safety before handling the EVM make sure there are not voltages present on the EVM greater than 50 V (Volt Meter 1).

8 Test Data

8.1 Line/Load Regulation and Efficiency Test Data

Table 3. Line/Load Regulations and Efficiency Test Data

SET V_{IN}	MEASURED V_{IN}	I_{IN}	V_{OUT}	I_{OUT}	EFFICIENCY
370	370.3	0.202	12.124	5.02	81%
370	370.0	0.302	12.123	8.02	87%
370	370.2	0.351	12.123	10.02	93%
370	370.2	0.857	12.123	25.03	96%
370	369.9	1.743	12.12	50.02	94%
390	390.4	0.192	12.123	5.02	81%
390	390.4	0.288	12.123	8.03	87%
390	390.3	0.334	12.123	10.03	93%
390	390.3	0.814	12.123	25.03	96%
390	390.0	1.654	12.120	50.07	94%
410	410.1	0.184	12.123	5.02	81%
410	410.1	0.276	12.123	8.02	86%
410	410.1	0.320	12.123	10.03	93%
410	410.0	0.776	12.122	25.04	95%
410	410.0	1.575	12.12	50.07	94%

8.2 Efficiency Test Data

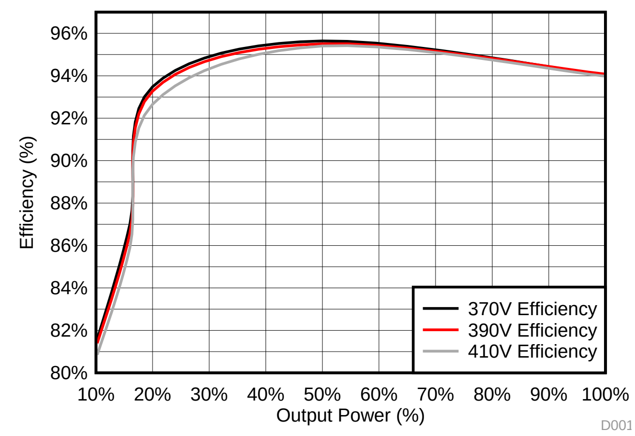


Figure 4. Efficiency 10% to 100% Load

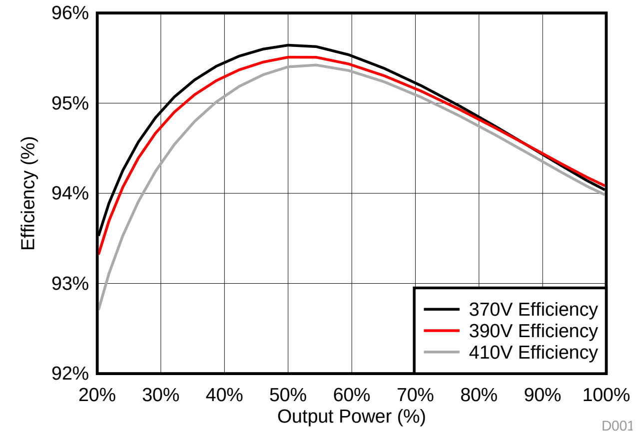


Figure 5. Efficiency 20% to 100% Load

8.3 Control Loop Gain and Phase Measurement

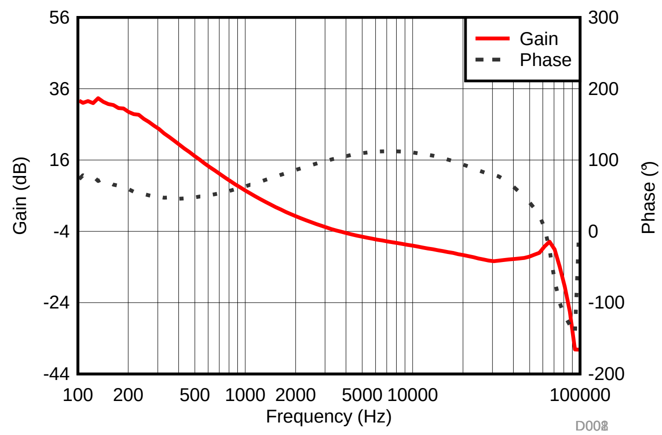


Figure 6. Loop Gain/Phase at 50 A, f_c = 2 kHz, PM = 90 Degrees

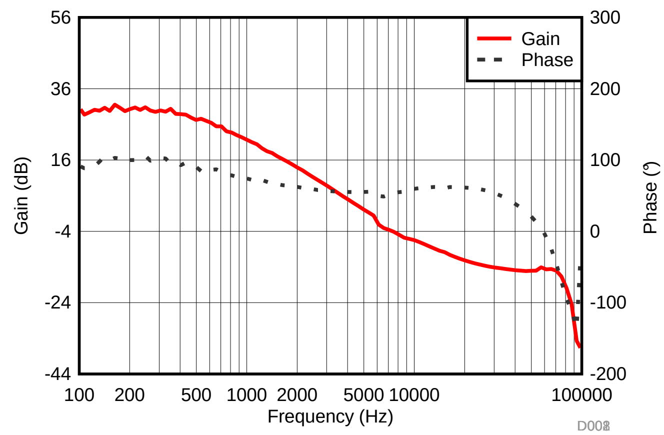


Figure 7. Loop Gain/Phase at 5 A, f_c = 6 kHz, PM = 45 Degrees

8.4 Transient Response

Startup CH3 = V_{OUT}.

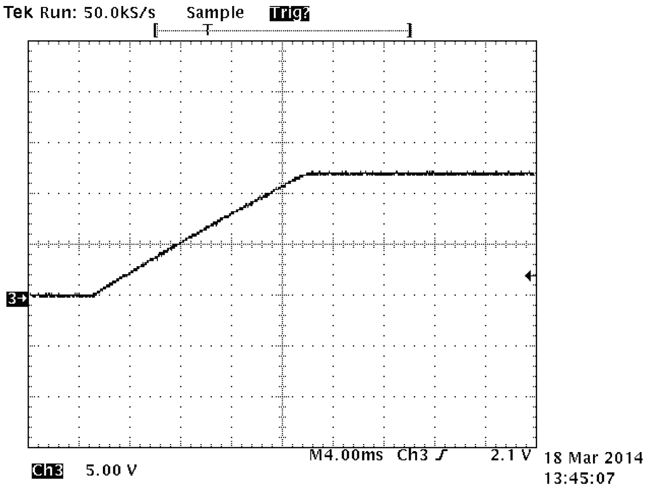


Figure 8. V_{IN} = 390 V, I_{OUT} = 0 A

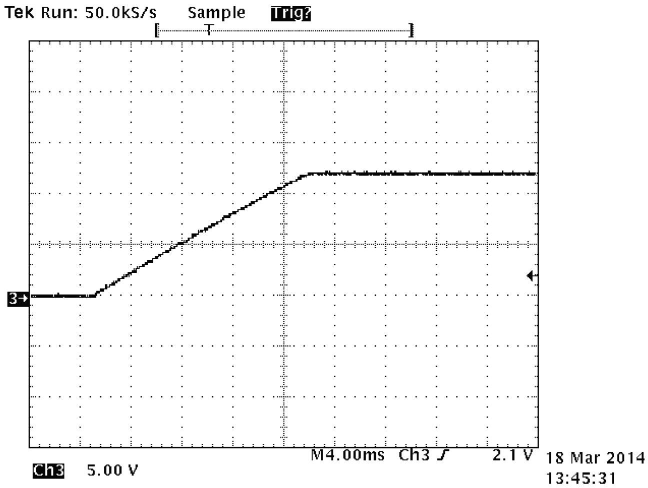


Figure 9. V_{IN} = 390 V, I_{OUT} = 5 A

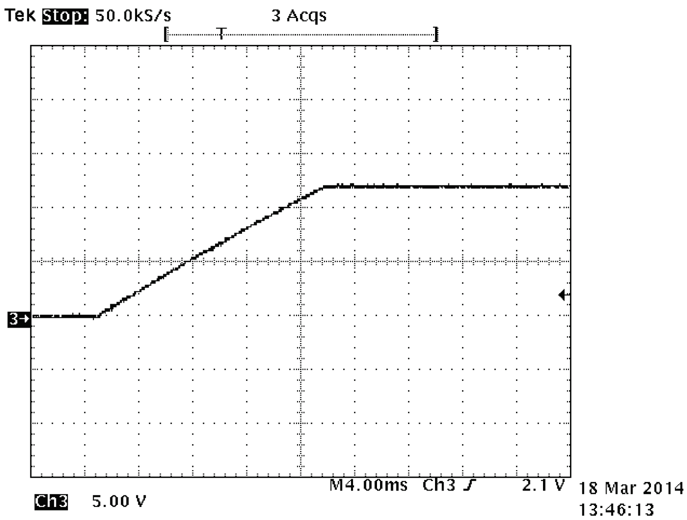


Figure 10. V_{IN} = 390 V, I_{OUT} = 50 A

8.5 Load Transient Response

CH4 = I_{OUT}, CH3 = V_{OUT} with 10-V_{DC} Offset

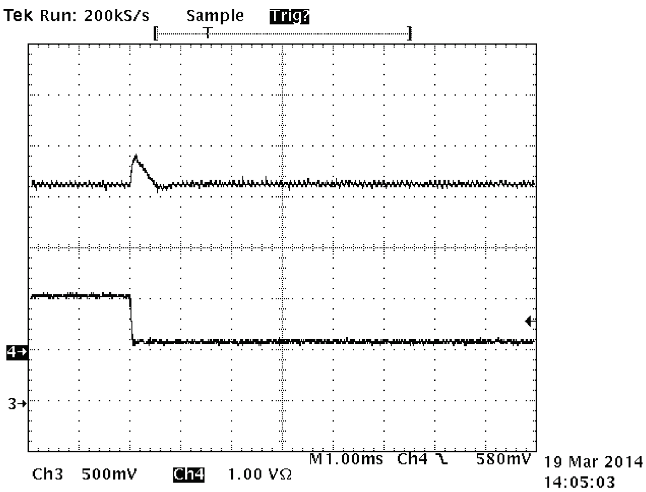


Figure 11. V_{IN} = 390 V I_{OUT} = 50 A to 5 A

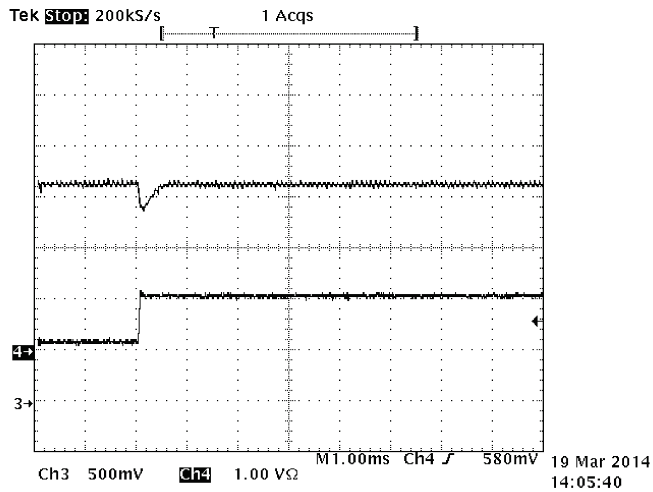


Figure 12. V_{IN} = 390 V, I_{OUT} = Stepped from 5 A to 50 A

8.6 Output Ripple Voltage

CH3 = V_{OUT}

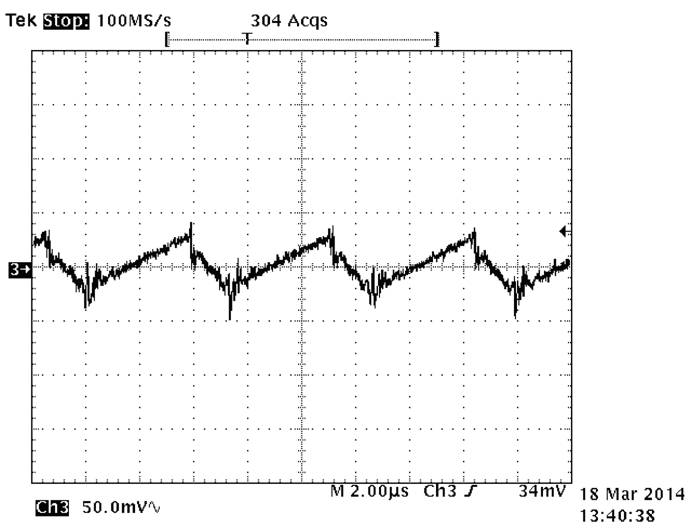


Figure 13. V_{IN} = 390 V, I_{OUT} = 50 A

8.7 Valley Switching

Loads Lower than 25 A, switch nodes valley switch

(CH1 = Q3g, CH2 = Q4g)

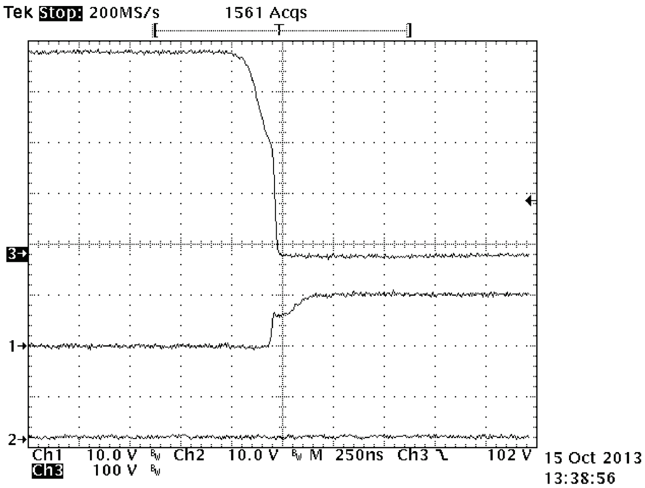


Figure 14. V_{IN} = 390 V, I_{OUT} = 5 A
(V_{IN} = 390 V, I_{OUT} = 5 A AB Valley Switching (Q3d = CH1))

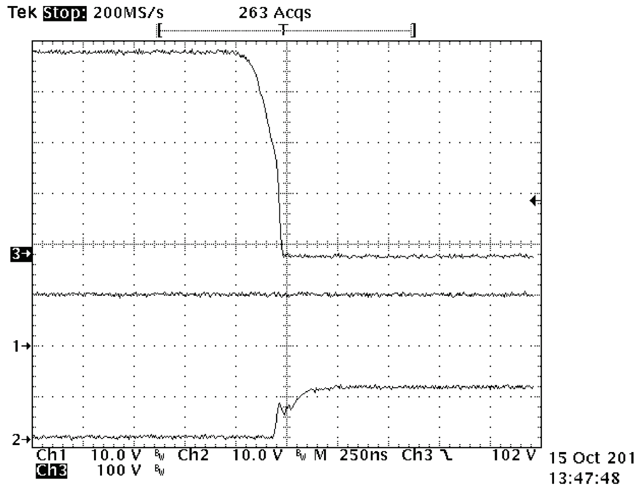


Figure 15. V_{IN} = 390 V, I_{OUT} = 5 A
(V_{IN} = 390 V, I_{OUT} = 5A CD Valley Switching (Q4d = CH3))

Loads Greater than 25 A, the switch nodes ZVS

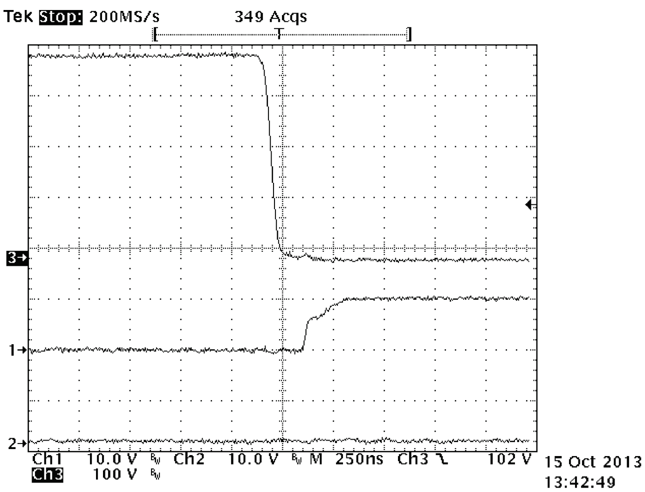


Figure 16. V_{IN} = 390 V, I_{OUT} = 25 A
(V_{IN} = 390 V, I_{OUT} = 5 A AB Valley Switching (Q3d=CH1))

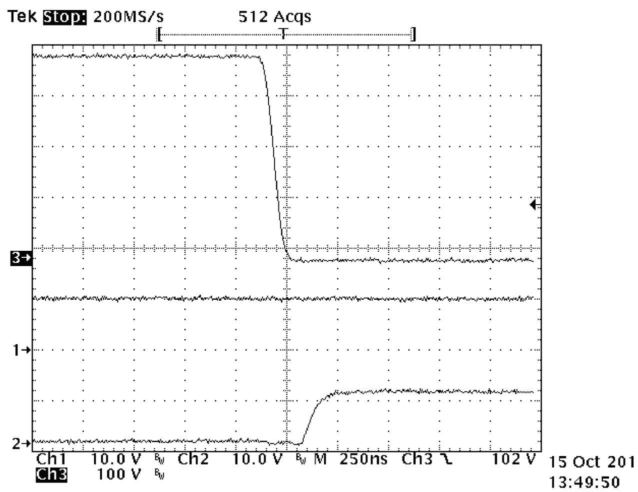


Figure 17. V_{IN} = 390 V, I_{OUT} = 25 A
(V_{IN} = 390 V, I_{OUT} = 5 A CD Valley Switching (Q4d=CH3))

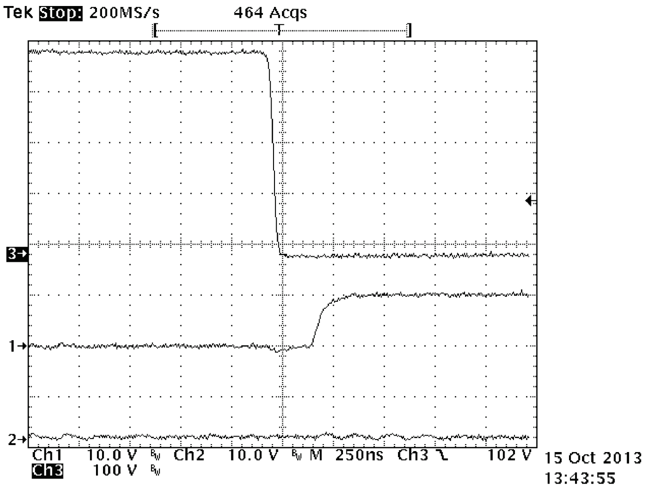


Figure 18. V_{IN} = 390 V, I_{OUT} = 50 A (V_{IN} = 390 V, I_{OUT} = 5 A AB Valley Switching (Q3d=CH1))

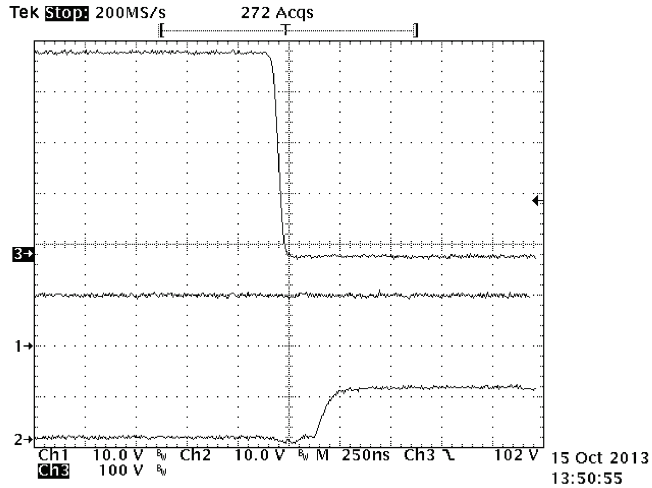


Figure 19. V_{IN} = 390 V, I_{OUT} = 50 A (V_{IN} = 390 V, I_{OUT} = 5 A CD Valley Switching (Q4d = CH3))

8.8 *UCC27714 Gate Drive Performance*

8.8.1 LI, LO propagation delay CH1 (VDD), CH2(LO), CH3(LI)

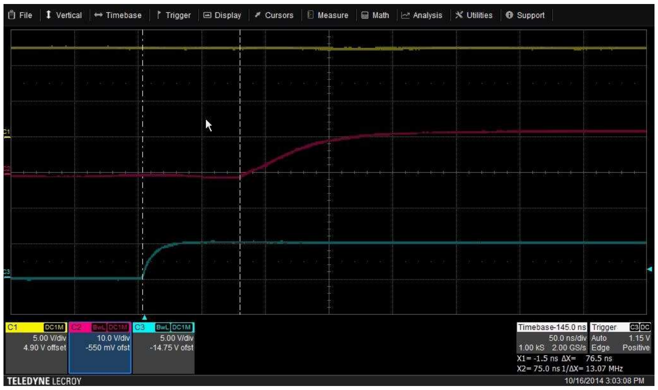


Figure 20. LI, LO Turn-On Propagation Delay

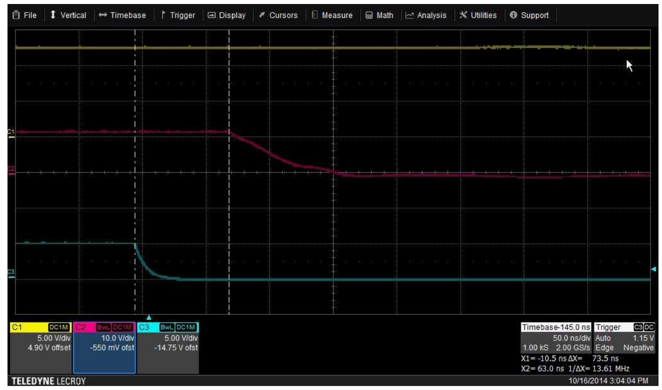


Figure 21. LI, LO Turn-Off Propagation Delay

8.8.2 First LI LO Pulse at Power Up

(CH1 (VDD), CH2(LO), CH3(LI),

Drop in VDD at first LO pulse due to charging HB capacitor)

Figure 22. VDD Drop On First Bootstrap Capacitor Charging

8.8.3 HI HO Propagation Delay

(CH2 (LO), CH1(HI), CH3(HO), CH4(VDD)

HO was measured with a 1:20 differential probe)

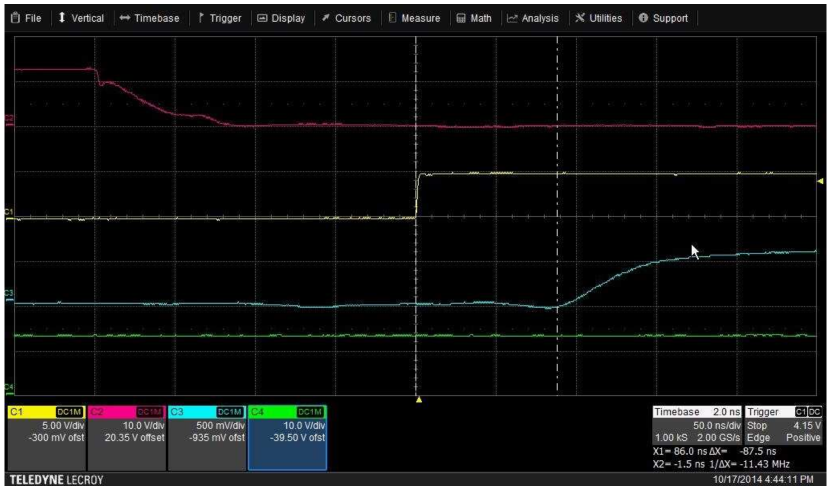


Figure 23. HI, HO Turn-On Propagation Delay

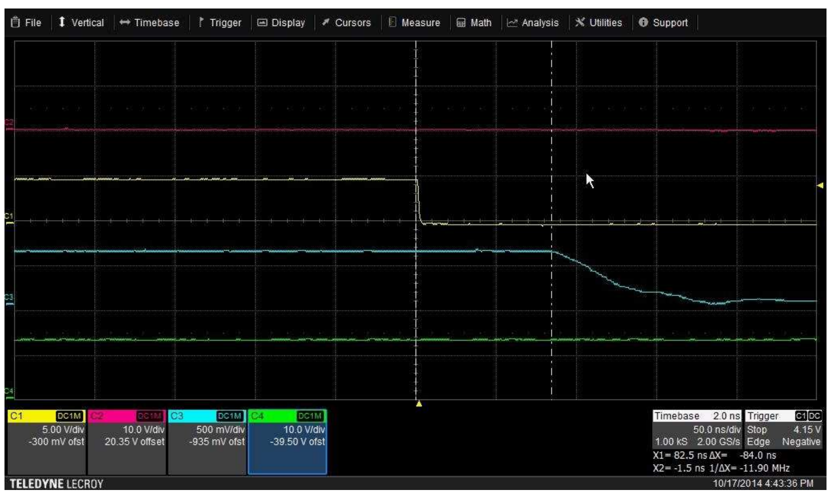


Figure 24. HI, HO Turn-Off Propagation Delay

8.8.4 HB (CH2), HI(CH1), HO(CH3), LO(CH4) During Power Up

1. HB and HO were measured with 1:20 differential probes.
2. HB charges up on first LO pulse.
3. HO will not become active on the first HI pulse.
   • Includes a built-in fixed delay, please refer to the UCC27714 data sheet for details.

Figure 25. HB and HO Measurement During Start Up

8.8.5 Q3g(CH1), Q1g(CH3), Q4g(Ch2), Q2g(Ch4) During Soft-Start Power Up

1. VBIAS1 and VBIAS2 set at 11 V.
2. UCC28950 soft start capacitor C2 pulled to ground and then released to activate soft start.
3. Q1g and Q2g measured with 1:20 differential probes.
4. Q1g and Q2g are driven with HO pins from the UCC27714 U1 and U2.
   There is roughly a 90us delay before the HO outputs become active.
   This is a combination of the UCC28950's burst mode function and UCC27714 built-in delay check the device data sheets for delay details.

Figure 26. Q_g Measurement During Startup

UCC28950 during soft start enters burst mode.

Please refer to the UCC28950 data sheet for details.

Figure 27. UCC28950 Burst-Mode Function

Q3g (CH1), Q1g (CH3), Q4g (Ch2), Q2g (V_{OUT}) during soft-start startup.

Ch1 = 1:20 differential probe.

Figure 28. UCC28950 Burst-Mode Function During Soft Start

9 Assembly Drawings and Layout

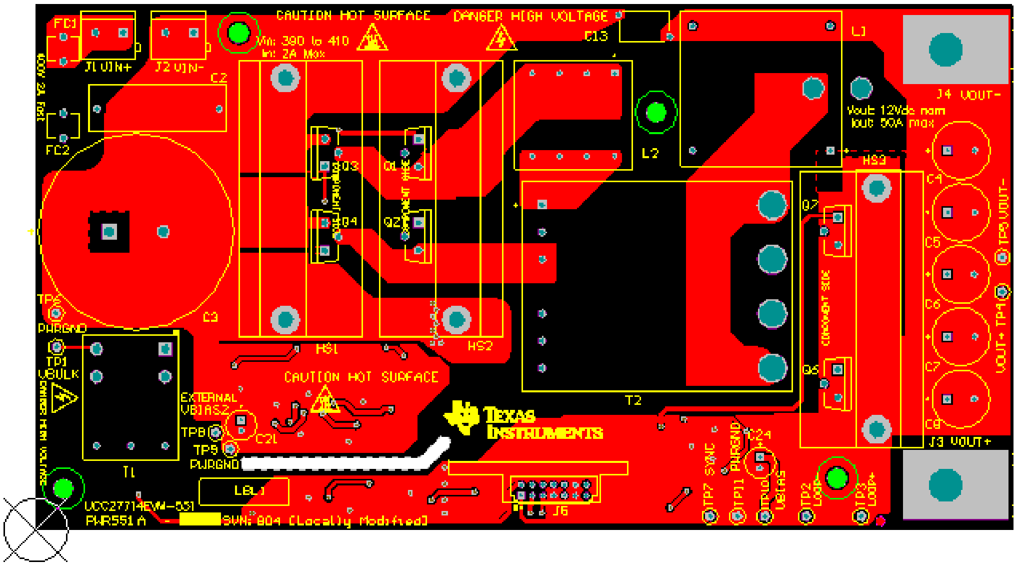


Figure 29. UCC27714EVM-551 Power Stage Top Layer Assembly Drawing (top view)

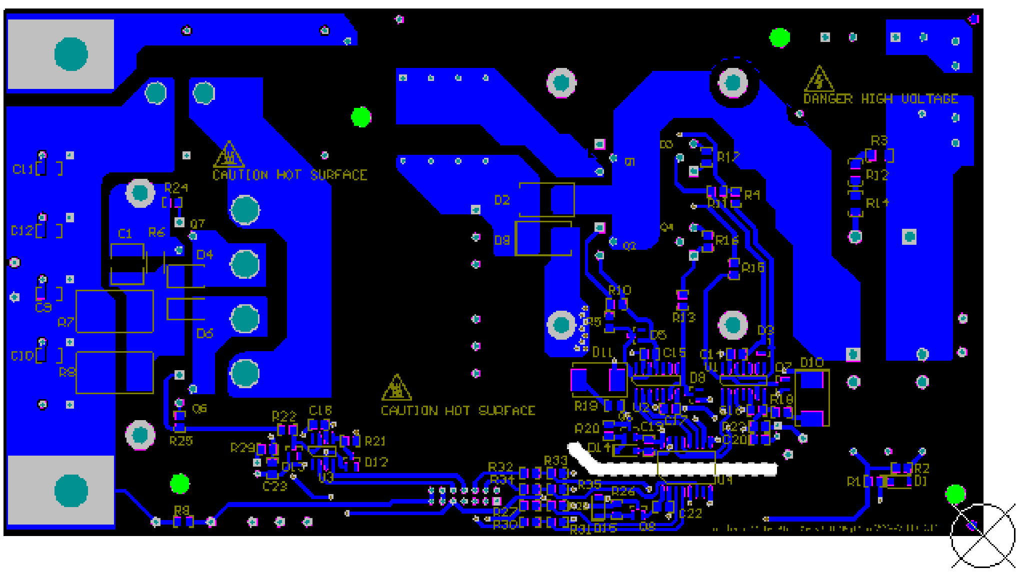


Figure 30. UCC27714EVM-551 Power Stage Bottom Layer Assembly Drawing (bottom view)

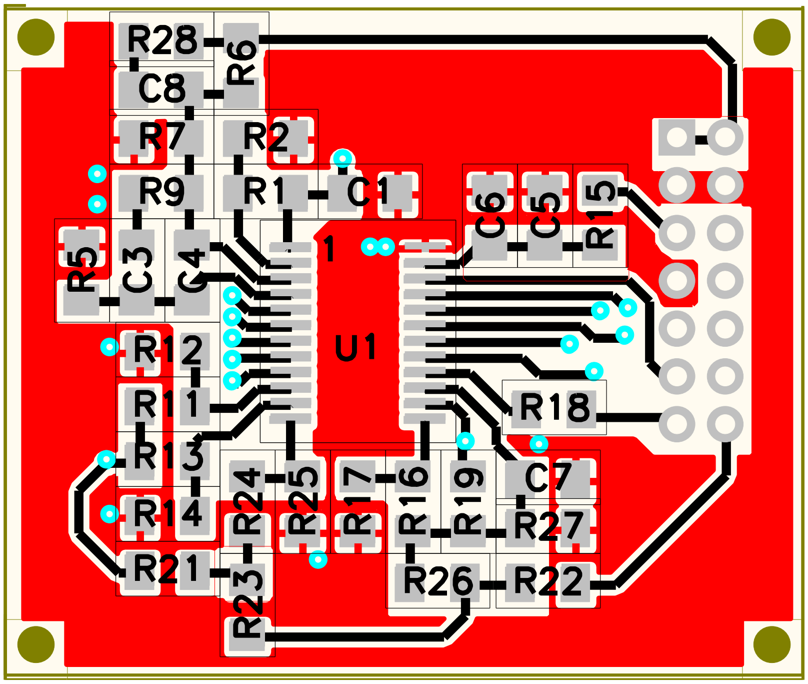


Figure 31. UCC27714EVM-551 Daughter Controller Card Top Layer Assembly Drawing (top view)

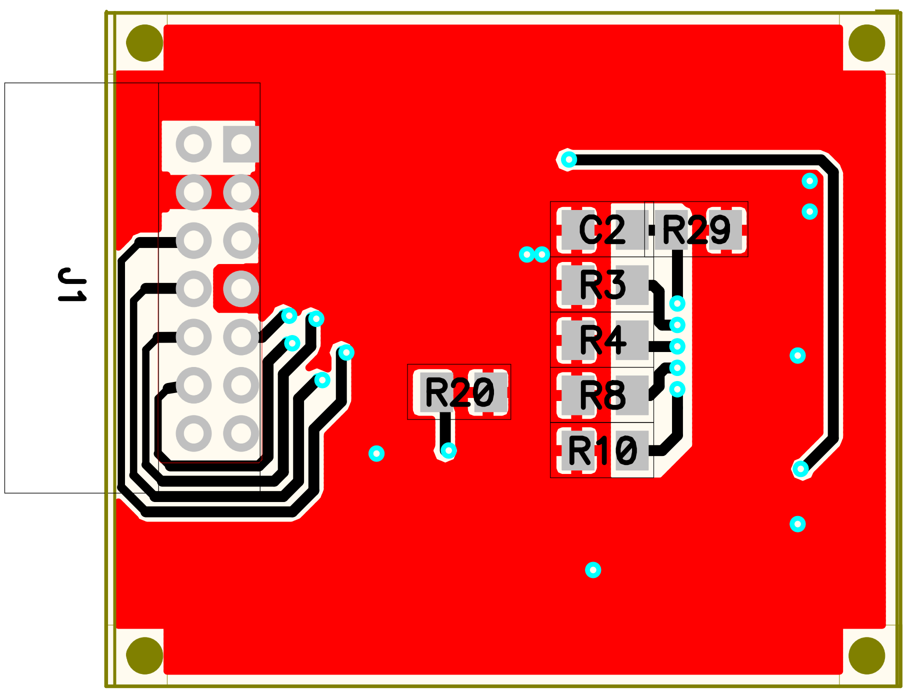


Figure 32. UCC27714EVM-551 Daughter Controller Card Bottom Layer Assembly Drawing (bottom view)

10 List of Materials

Table 4. UCC27714EVM-551 Power Stage Components List of Materials (list according to the schematic in Figure 1)

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
1	PCB	Printed circuit board	PWR551	Any
1	C1	Capacitor, ceramic, 220 nF, 100 V X7R, ±10%, 2220	C2220C224J1GACTU	Kemet
1	C2	Capacitor, film, 0.47 µF, 275 V_{AC}, ±20%	ECQ-U2A474MG	Panasonic
1	C3	Capacitor, 450 V, 330 µF, temperature –255 to 105°C, ±20%	EETHC2W331EA	Panasonic
5	C4, C5, C6, C7, C8	Capacitor, low impedance, 16 V, 1500 µF, ±20%	EKY-160ELL152MJ30S	Nippon
4	C9, C10, C11, C12	Capacitor, ceramic, 25 V, 1 µF, X7R, ±10%,1206	C3216X7R1E105K085A A	TDK
1	C13	Capacitor, ceramic disk, 1000 pF, 500 V_{AC}	440LD10	Vishay-Sprague
2	C14, C15	Capacitor, ceramic, 50 V, 100 nF, X7R, ±10%,0805	C1608X7R1H104K080A A	TDK
7	C16, C17, C18, C19, C20, C22, C23	Capacitor, ceramic, 50 V, 1 µF, X7R, ±10%,0805	C2012X7R1H105K125A B	TDK
2	C21, C24	Capacitor, aluminum, 35 V, 22 µF, ±20%	ECA-1VM220-R	Panasonic
1	D1	Diode, signal, 200 mA, 100 V, 350 mW, SOD123	1N4148W-7-F	Diodes
4	D2, D9, D10, D11	Diode, 3000 mA, 600 V,SMC	MURS360T3G	ON Semiconductor
6	D3, D5, D7, D8, D12, D13	Diode, Schottky, 200 mA, 30 V,SOT23	BAT54	Vishay-Liteon
2	D4, D6	Diode, 3000 mA, 100 V, SMB	ES3BB-13-F	Diodes Inc
2	D14, D15	Diode, Zener, 5.6 V, 20 mA, SOD-123	MMSZ5232B-V-GS08	Vishay
2	F1	Fuse clip	0100056H	Wickmann
4	H1, H2, H3, H4	Machine screw, round, #4-40 x 1/4, nylon, Philips panhead, screw	NY PMS 440 0025 PH	B&F Fastener Supply
4	H5, H6, H7, H8	Standoff, hex, 0.5"L #4-40 nylon, standoff	1902C	Keystone
3	HS1, HS2, HS3	$H_{EATSINK}$	782653B02000	Aavid
2	J1, J2	Terminal block, 2 pin, 15 A, 5.1 mm	ED120/2DS	OST
2	J3, J4	Copper, single barrel, one-hole, straight tongue (fixed) lug, #14 - #4 AWG wire, 1/4 stud hole."	CX70-14-CY	Panduit
1	J5	Conn receipt 14 pos 2mm PCB tin female	DF11-14DS-2DSA(05)	HRS
1	L1	Inductor, 2.0 µH	75PR8108	Vitec Electronics Corp
1	L2	Inductor, 26 µH	60PR964	Vitec Electronics Corp.
4	Q1, Q2, Q3, Q4	MOSFET, N-channel, 650 V, 20 A, 220 mΩ, TO-220V	SPP20N60CFD	Infineon
2	Q5, Q8	Transistor, NPN, high performance, 500 mA, SOT-23	MMBT2222A	Fairchild
2	Q6, Q7	MOSFET, N-channel, 80 V, 273 A, 2.0 mΩ, TO-220 V	CSD19506KCS	TI
1	R1	Resistor, chip, 48.7 Ω, 1/10 W, 1%, 0805	ERJ-2RKF48R7X	Panasonic
1	R2	Resistor, chip, 4.87 kΩ, 1/10 W, 1%, 0805	ERJ-6ENF4871V	Panasonic
3	R3, R12, R14	Resistor, chip, 1.00 MΩ, 1/10 W, 5%, 0805	ERJ-6GEYJ105V	Panasonic
4	R4, R5, R13, R15,	Resistor, chip, 3.01 Ω, 1/10 W, 1%, 0805	CRCW08053R01FKEA	Vishay
2	R21, R22	Resistor, chip, 6.19 Ω, 1/10 W, 1%, 0805	CRCW08056R19FKEA	Vishay

Table 4. UCC27714EVM-551 Power Stage Components List of Materials (list according to the schematic in Figure 1) (continued)

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
1	R6	Resistor, chip, 100 kΩ, 1 W, 1%, 2512	CRCW2512100KFKEG	Vishay
2	R7, R8	Power metal strip, 1.00 kΩ, 2 W, ±5%, 4527	WSC45271K000FEA	Vishay
1	R9	Resistor, chip, 49.9 Ω, 1/10 W, 1%, 0805	ERJ-6ENF1001V	Panasonic
6	R10, R11, R16, R17, R24, R25	Resistor, chip, 10.0 kΩ, 1/10 W, 1%, 0805	ERJ-6ENF1002V	Panasonic
2	R18, R19	Resistor, chip, 2.2 Ω, 1/10 W, 1%, 0805	ERJ-6GEYJ105V	Panasonic
6	R20, R26, R27, R30, R32, R34	Resistor, chip, 7.15 kΩ, 1/10 W, 1%, 0805	ERJ-6ENF7151V	Panasonic
2	R23, R29	Resistor, chip, 5.11 Ω, 1/10 W, 1%, 0805	ERJ-6GEY0R00V	Panasonic
4	R28, R31, R33, R35	Resistor, Chip, 5.11 kΩ, 1/10 W, 1%, 0805	ERJ-6ENF5111V	Panasonic
1	T1	XFMR, current sense	PE63587	Pulse
1	T2	Transformer	75PR8107	Vitec Electronics
11	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11	Pin, thru hole, tin plate, for 0.062 PCB's	K24A/M	Vector
2	U1, U2	High-Speed Low-side Gate Driver Device, D0014A	UCC27714D14	Texas Instruments
1	U3	High Speed Low Side Power MOSFET driver, SO8	UCC27324AD	TI
1	U4	Low-Power Quad-Channel Digital Isolator, SOIC-16	SI8640BD-B-IS	Silicon Laboratories
ADDITIONAL HARDWARE				
1	X1 at F1	2-A, fast acting fuse	BK/S501-2-R	Cooper/Bussman
6	X1 at HS1, HS2, HS3	Screw steel M3 THR 6 mm	29311	Keystone Electronics
6	X1 at HS1, HS2, HS3	Washer lock metric M 3 ZINC	MLWZ 003	B&F Fastener Supply
6	X1 at HS1,HS2, HS3, Q1, Q2 Q3, Q4, Q5, Q6	Thermal pad tube, needs to be cut to 22 mm	BER156-ND	Bergquist
6	X1 at HS1, HS2, HS3, Q1, Q2, Q3, Q4, Q5, Q6	MAX clip	MAX01G	Aavid
1	X2 at J5	UCC28950 daughter card assembly	HPA471	Any
4	At PCB	Standoff hex .500/6-32THR nylon, mount on bottom of PCB	1903C	Keystone Electronics
4	At PCB	Nut, mount to top of PCB	4824	Keystone Electronics

Table 5. UCC27714EVM-551 Daughter Controller Card Power Stage List of Materials (list according to the schematic in Figure 2)

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
2	C1, C5	Capacitor, ceramic, 25 V, 1 µF, X7R, ±10%, 0805	Std	Std
1	C2	Capacitor, ceramic, 50 V, 150 nF, X7R, ±10%, 0805	Std	Std
1	C3	Capacitor, ceramic, 50 V, 5.6 nF, X7R, ±10%, 0805	Std	Std
1	C4	Capacitor, ceramic, 25 V, 560 pF, X7R, ±10%, 0805	Std	Std
1	C6	Capacitor, ceramic, 25 V, 0.1 µF, X7R, ±10%, 0805	Std	Std
1	C7	Capacitor, ceramic, 25 V, 330 pF, X7R, ±10%, 0805	Std	Std
0	C8	Capacitor, ceramic, 25 V, no pop, X7R, ±10%, 0805	Std	Std
1	J1	Conn header 14 pos 2 mm R/A gold, male, right angle	DF11-14DP-2DS(52)	HRS
1		EVM daughter board PCB	HPA471	Any
3	R1, R2, R7	Resistor, chip, 2.37 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R10	Resistor, chip, 13.3 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R11	Resistor, chip, 61.9 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R14	Resistor, chip, 127 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R15	Resistor, chip, 22.6 Ω, 1/10 W, 1%, 0805	Std	Std
4	R17, R20, R21, R26	Resistor, chip, 0 Ω, 1/10 W, 1%, 0805	Std	Std
3	R18, R22, R25	Resistor, chip, 1.00 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R24	Resistor, chip, 16.9 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R29	Resistor, chip, 825 V, 1/10 W, 1%, 0805	Std	Std
2	R3, R4	Resistor, chip, 12.1 kΩ, 1/10 W, 1%, 0805	Std	Std
0	R5, R12, R13, R16, R19, R23, R27, R28	Resistor, chip, no pop, 1/10 W, 1%, 0805	Std	Std
1	R6	Resistor, chip, 9.09 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R8	Resistor, chip, 56.2 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R9	Resistor, chip, 27.4 kΩ, 1/10 W, 1%, 0805	Std	Std
1	U1	Advanced Phase-Shifted PWM Controller, TSSOP-24	UCC28950PW	TI

Revision History

Changes from Original (July 2015) to A Revision **Page**

- Added High Voltage warning notices. 2

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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   3.1 *United States*

   3.1.1 *Notice applicable to EVMs not FCC-Approved:*

   This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

   3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

   CAUTION

   This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

   Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

   FCC Interference Statement for Class A EVM devices

   NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

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- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

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Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

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http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

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2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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