UCC2540 Secondary Side Post Regulator Evaluation Module With the UCC38083

User's Guide

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DYNAMIC WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the maximum input voltage ranges specified in section 5.

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 50°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

UCC2540 Secondary-Side Post Regulator Evaluation Module With the UCC38083

Lisa Dinwoodie
Power Supply Control Products

ABSTRACT

The UCC2540 is a voltage-mode secondary-side synchronous-buck PWM controller for high current and low output voltage applications.

Contents

1 Introduction

The UCC2540 is a voltage-mode secondary-side synchronous-buck PWM controller for high current and low output voltage applications. It can be used as either a secondary-side post regulator (SSPR) for generating additional auxiliary outputs for multiple output power supplies or as a local secondary side controller for isolated dc-to-dc converters in cascaded topologies. The input is synchronized to a pulsed signal derived from either the secondary winding of the main transformer or from a pulse transformer from the primary side. In SSPR applications, the primary side control for the main output can be generated by any buck derived topology such as forward, push-pull, half-bridge, or full-bridge. The UCC2540 is a high efficiency controller that provides tight regulation, fast transient response, and is a cost effective solution for multiple output power supplies and cascaded converters.

2 Description

This UCC2540 secondary side post regulator evaluation module adds an auxiliary output to an existing current-mode controlled converter. The leading edge modulation of the UCC2540 makes it easily compatible with either voltage-mode or current-mode control primary stages used in topologies such as forward, half-bridge, or push-pull. This evaluation module takes the UCC38083 push-pull 3.3-V output converter and adds a 1.5-V, 7.5-A output. The UCC38083 gate drive transformer, used to drive the push-pull synchronous rectifiers, provides an ideal synchronization pulse for the UCC2540. Bias to the device is provided by the existing rectified bias used to power the discrete driver circuit on the secondary side and the power stage for the UCC2540 synchronous buck is directly tapped off of the secondary side winding of the main transformer, minimizing the size of the main converter’s inductor and output capacitors. If more outputs are desired for a given design, additional synchronously rectified and independently regulated outputs can easily be added using the same method shown here, each controlled with a UCC2540 benefiting from their own soft start, current limit, and on/off control.

The UCC2540/UCC38083EVM highlights the many benefits of using the UCC2540 secondary side synchronous buck PWM controller in conjunction with the UCC38083 current mode control PWM controller. The following user guide provides the schematic, component list, assembly drawing, artwork, and test set up necessary to evaluate the UCC2540 and UCC38083 in a typical multiple output application.

3 Applications

- Secondary-side post regulation (SSPR) for multiple output power supplies
- Cascaded buck converters
- Can replace magnetic amplifiers and other inefficient solutions for high current multiple output power supplies
- Post processing converters for bus converter and dc transformer architectures
- Can be used in telecommunication and data communication equipment, industrial and computer power supplies, test and medical instrumentation, as well as for merchant power supplies

4 Features

- Voltage mode control
- 24-V typical input voltage
- 3.3-V, 7.5-A output
- 1.5-V, 7.5-A output
- 400-kHz secondary-side switching frequency, 200-kHz primary-side switching frequency
- User programmable shutdown for the auxiliary output
- Parallel average current mode control loop for two levels of overcurrent protection: constant current limit and overcurrent reset/retry
- On-Chip Predictive Gate Drive™ for high efficiency synchronous buck operation by minimizing body diode conduction and reverse recovery losses in the synchronous rectifier
- Dual ±3-A TrueDrive™ outputs suitable for high current applications
- Leading edge modulation
- High bandwidth error amplifiers
- Thermally enhanced HTSSOP 20-pin PowerPAD™ package which is housed in a standard 20-pin TSSOP footprint but has a drastically lower thermal impedance of 2°C/W θ_{JC} to accommodate the dual high-current on-board drivers
- Tracking pin for output sequencing using sequential, ratiometric, or simultaneous methods

5 Electrical Performance Specification

Table 1. Electrical Performance Specifications

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
Input voltage range	V_{IN}		18.5	24	35	V
Output voltage regulation	V_{OUT1}	0 A < I_{OUT1} < 7.5 A	3.24		3.36	
	V_{OUT2}	0 A < I_{OUT2} < 7.5 A	1.47		1.53	
Output voltage ripple	$V_{RIPPLE1}$	V_{IN} = 35 V, I_{OUT1} = 7.5 A			66	mV_{p-p}
	$V_{RIPPLE2}$	V_{IN} = 35 V, I_{OUT2} = 7.5 A			30	
Output load current	I_{OUT1}	V_{OUT1} = 3.3 V	0		7.5	A
	I_{OUT2}	V_{OUT2} = 1.5 V	0		7.5	
Efficiency		V_{IN} = 19 V I_{OUT1} = 4.5 A I_{OUT2} = 4.5 A		86		%

6 Schematic

A schematic of the UCC2540/UCC38083EVM is shown in Figure 1. The primary-side consists of the current-mode UCC38083 pulse-width modulator configured for 200-kHz switching frequency in a push-pull configuration to generate a 3.3-V output. The output signals of the UCC38083 are fed into a TPS2812 driver to turn on and off the main switches and are also sent across the isolation boundary using a pulse edge transformer to the secondary side to control the discrete driver circuit for the synchronous rectifiers. The voltage feedback from the 3.3-V output is transferred across the isolation boundary with an optocoupler. This circuit is identical to the UCC38083 reference design found in the UCC38083 product folder.[3]

The same pulse edge signal that controls the 3.3-V secondary-side synchronous rectifiers is used as the synchronization signal to the UCC2540 to control the auxiliary 1.5-V output. The synchronization signal switches at 400 kHz. The 1.5-V output is generated with a synchronous buck circuit controlled by the UCC2540 in a mode 2 biasing configuration. The pulse train output of the main transformer is connected to the drain of the high-side FET. Bias to the UCC2540 is provided by the same bias circuit used by the discrete drive components on the 3.3-V secondary side and is approximately 6 V which determines mode 2 operation, as detailed in the UCC2540 data sheet.[1] Charging currents for the closed loop soft start, PWM ramp generator, and the maximum on-time duration of the synchronous rectifier are all established with the RSET resistor. The REF pin is decoupled as close to the device as possible with a good quality ceramic capacitor as is the VDD and VDRV pins. Type III compensation closes the voltage mode control loop as well as the over current protection loop. A charge pump is used to drive the high-side FET. The sense pins for the SW node and the low side FET gate drive, SWS and G2S, must be connected as close as possible to the drain and gate, respectively, of the low side switch. Do not connect them directly at the device pins as the sense signals are crucial to optimum Predictive Gate Drive™ functionality. To shut down the auxiliary output, a 3-V signal can be applied to J5. Test points are provided on the EVM for the user. Always use a differential probe from TP24, referenced to TP26 when looking at the high-side FET gate drive signal.

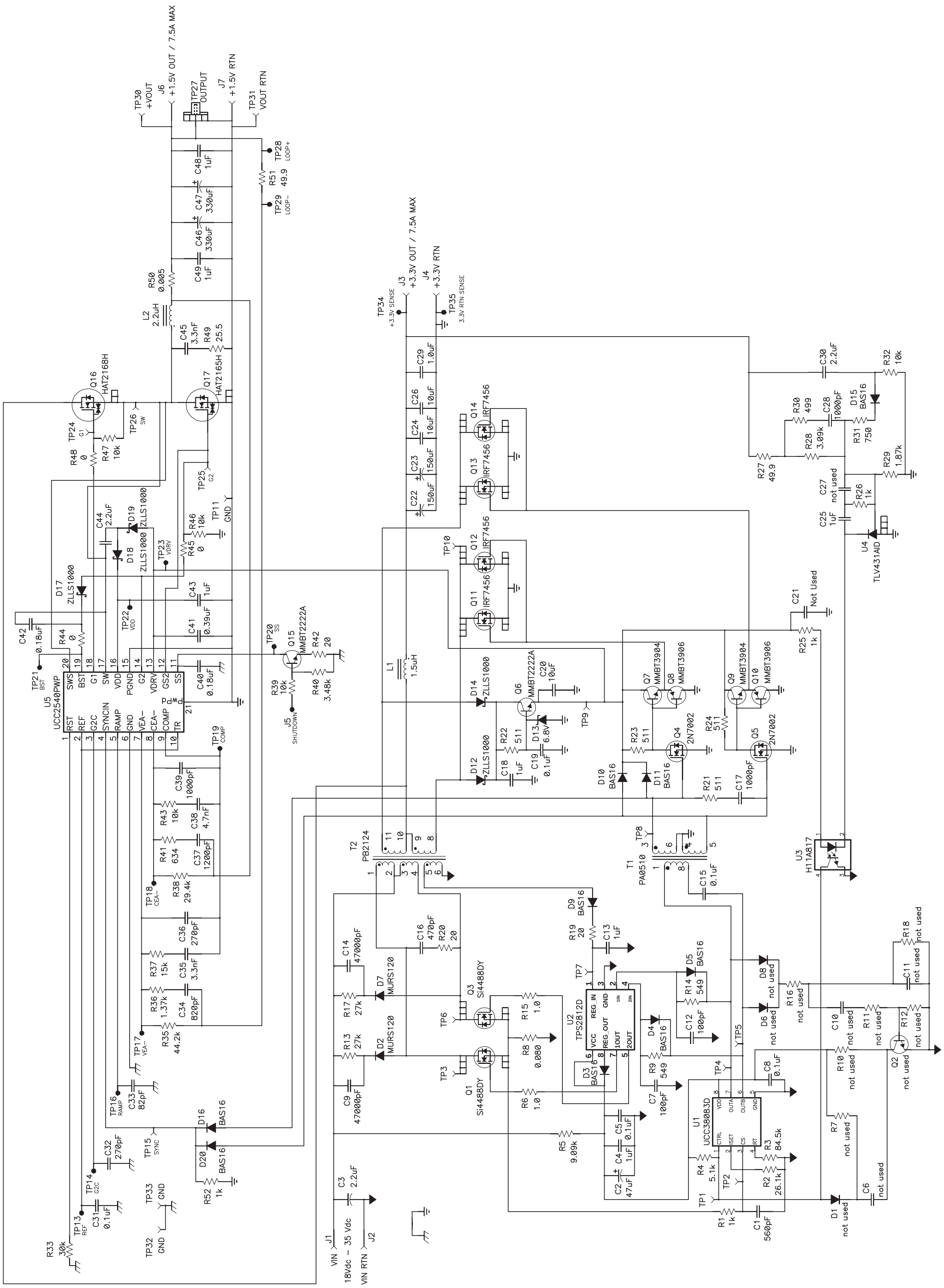

Figure 1. Schematic of the UCC2540/UCC38083 Evaluation Module

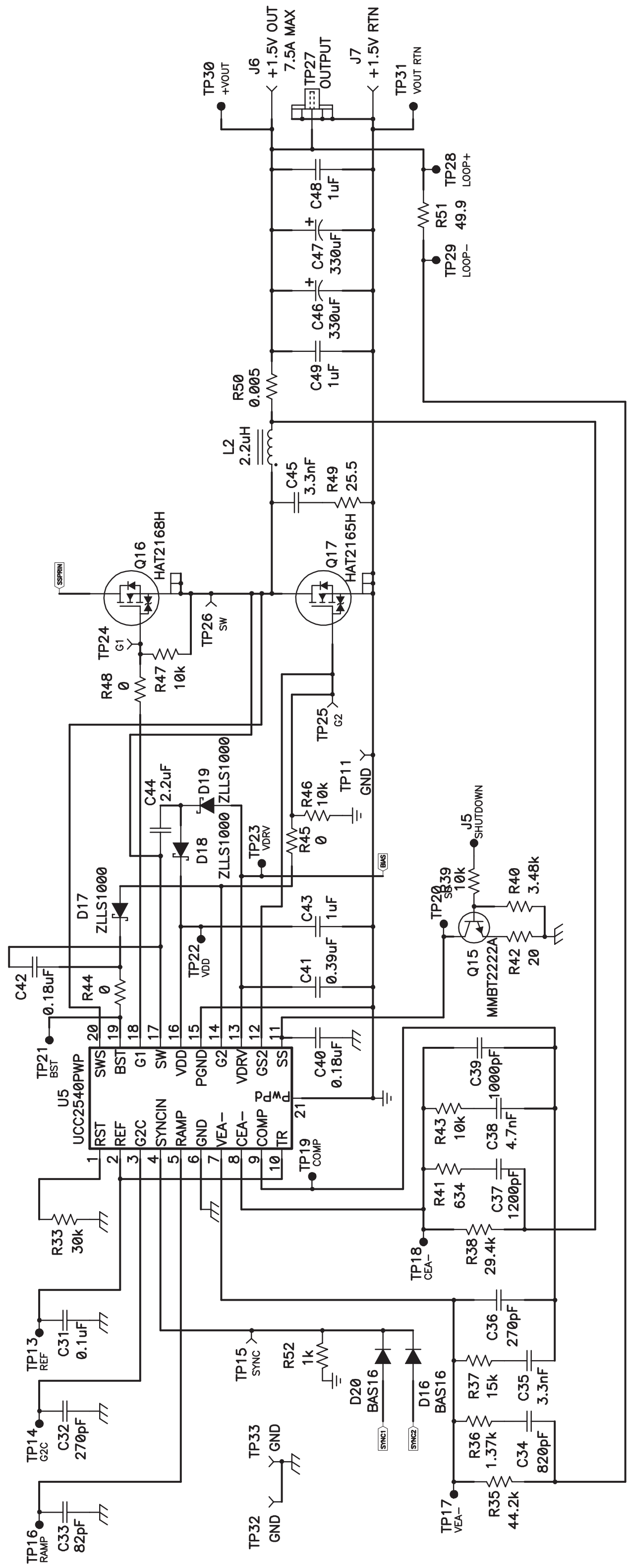

Figure 2. Schematic of the UCC2540 Section of the EVM

7 Test Setup

Shown below in Figure 3 is the basic test set up recommended to evaluate the UCC2540/UCC38083EVM.

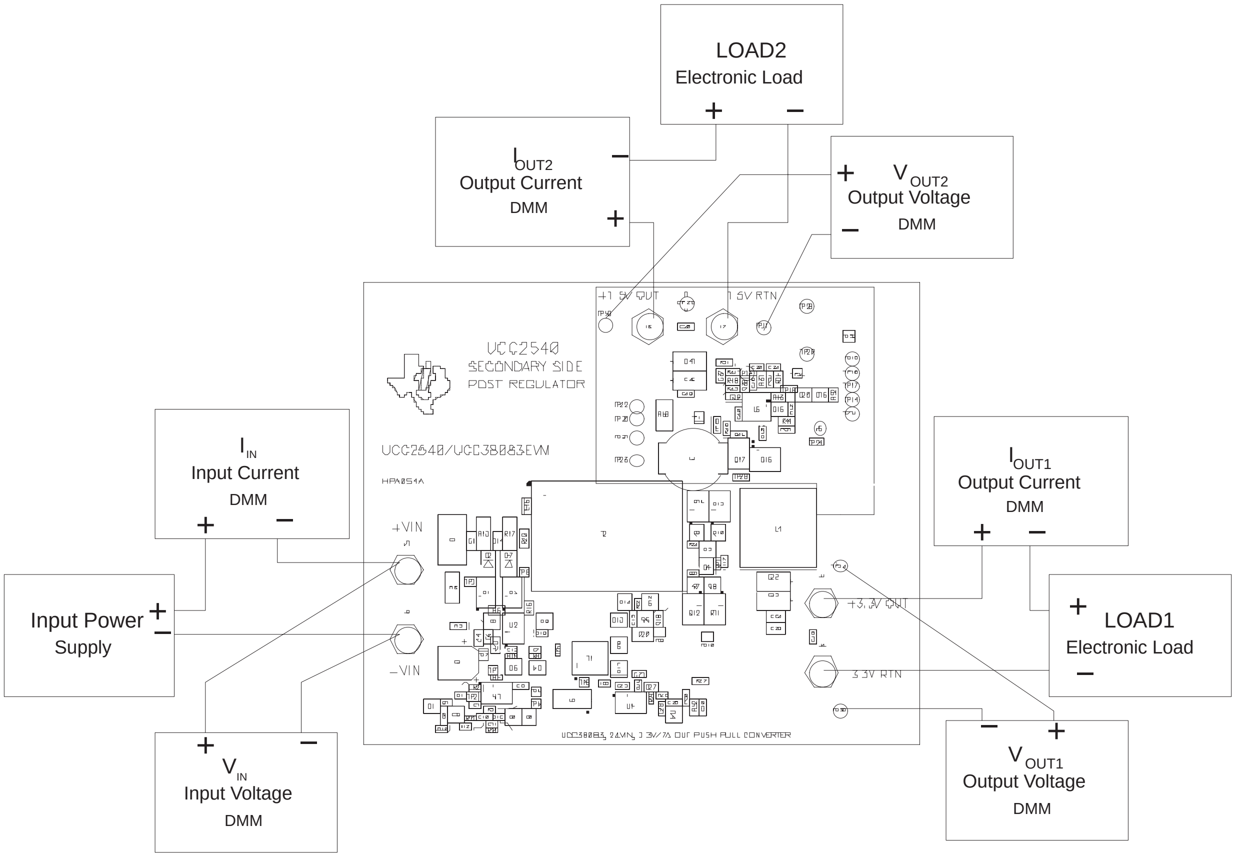

Figure 3. Recommended EVM Test Configuration

7.1 Output Loads (LOAD1 and LOAD2)

For the output loads to V_{OUT1} and V_{OUT2}, programmable electronic loads, LOAD1 and LOAD2, set to constant current mode and capable of sinking 7.5 A at 3.3 V and 1.5 V, respectively, are used. Using a dc voltmeter, measure the output voltages, V_{OUT1} and V_{OUT2}, directly at the test points provided. Avoid measuring the output voltages at the J3/J4 and J6/J7 output terminals, especially at higher load currents due to finite voltage drops across the connectors. Measure each of the output currents, I_{OUT1} and I_{OUT2}, with a dc ammeter connected in series with the loads.

7.2 Input Power Supply (V_{IN})

The input voltage source shall be a variable dc source capable of supplying between 0 V_{DC} and 35 V_{DC}, measured with a dc voltmeter, V_{IN}, at no less than 4 A_{DC} and connected across the input terminals as shown. For fault protection to the EVM, limit the source current to not more than 3 A_{DC}. A dc ammeter, used to measure I_{IN}, should be placed in series with the input source supply as shown.

7.3 Network Analyzer (not shown)

To measure the closed loop response of the auxiliary output, a network analyzer can be connected directly across TP28 and TP29. The 49.9-Ω resistor (R51) between the output load and the voltage feedback allows for non-invasive measurement of the control to output loop response.

8 Power Up/Down Sequence

The following procedure is recommended primarily for powering up and shutting down the UCC2540/UCC38083EVM. Never walk away from a powered evaluation module for extended periods of time.

8.1 Power Up Sequence

- Turn on the electronic load, LOAD1. Set the electronic load to 1.5 A.
- Turn on the electronic load, LOAD2. Set the electronic load to 1.5 A.
- Turn on the input power supply. Starting with the input dc power supply at the zero volt setting, slowly increase the voltage to the EVM operating range, 18.5 V to 35 V.
- The converter will begin operating when the input voltage is at or before 16.5 V maximum, measured on the V_{IN} DMM.

8.2 Power Down Sequence

- Decrease the input power supply to 0 V and turn it off.
- Turn off both electronic loads.

9 Performance Data and Characteristic Curves

TYPICAL WAVEFORMS

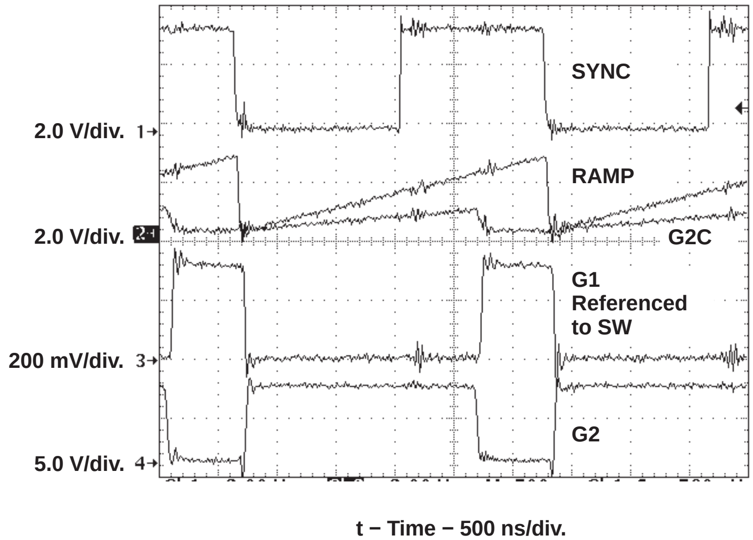

Figure 4.

TURN ON TRAJECTORY

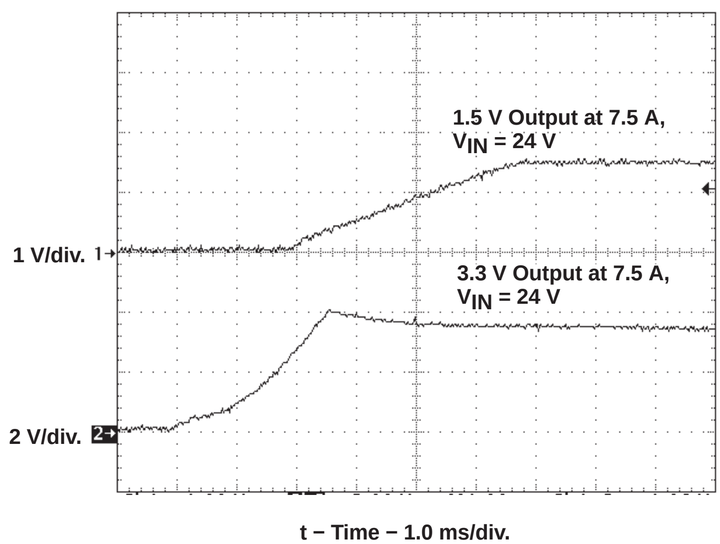

Figure 5.

OUTPUT VOLTAGE RIPPLE AT 35-V_{IN}, FULL LOAD

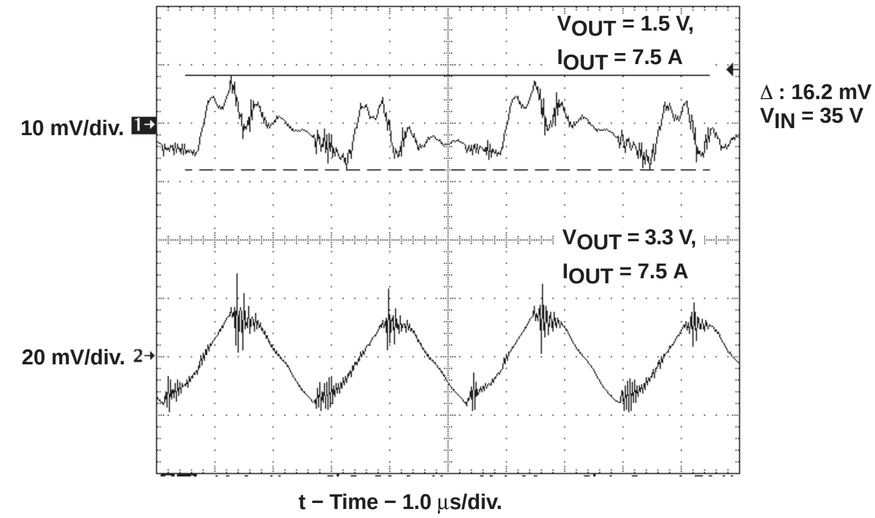

Figure 6.

1.5-V OUTPUT LOAD TRANSIENT RESPONSE

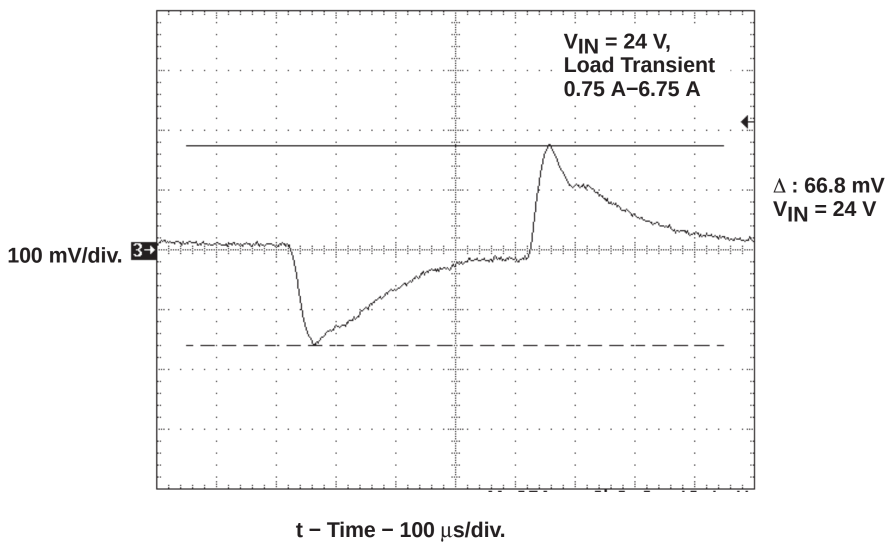

Figure 7.

PREDICTIVE GATE DRIVE

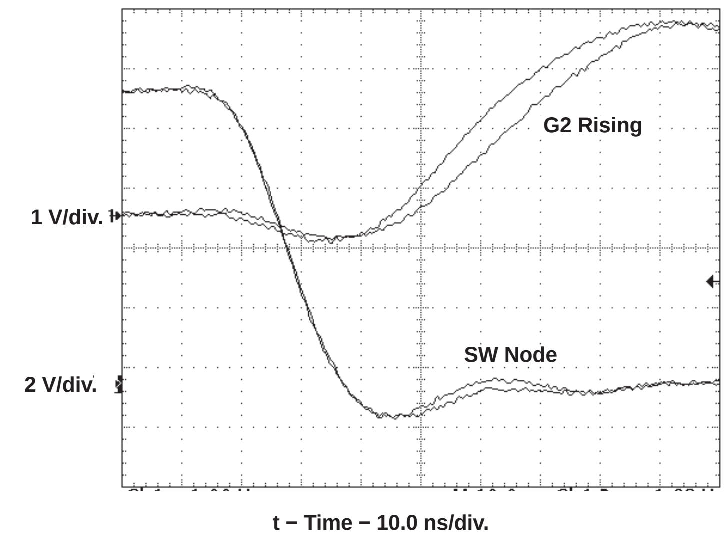

Figure 8.

PREDICTIVE GATE DRIVE

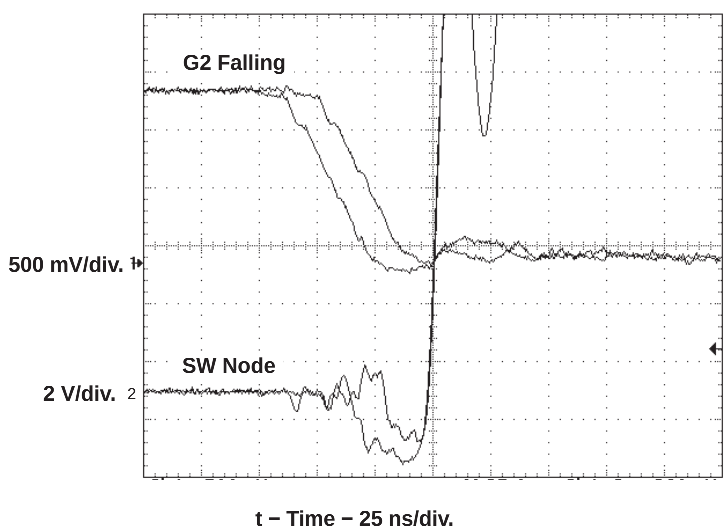

Figure 9.

CONVERTER SHUTDOWN

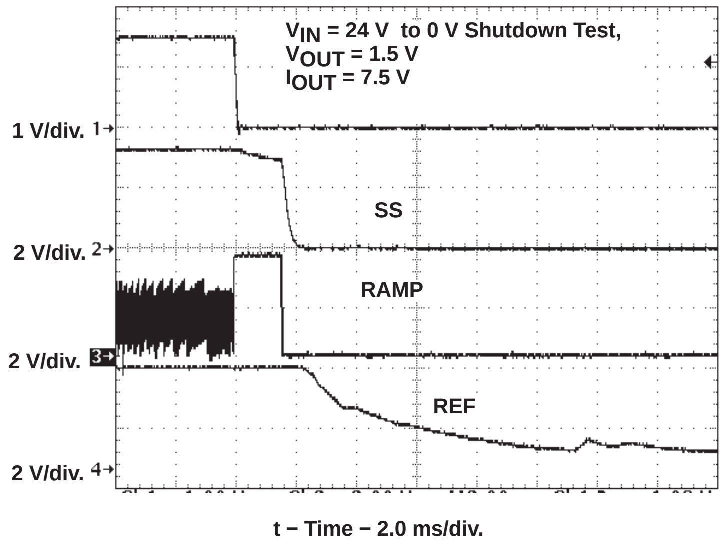

Figure 10.

OVERCURRENT PROTECTION

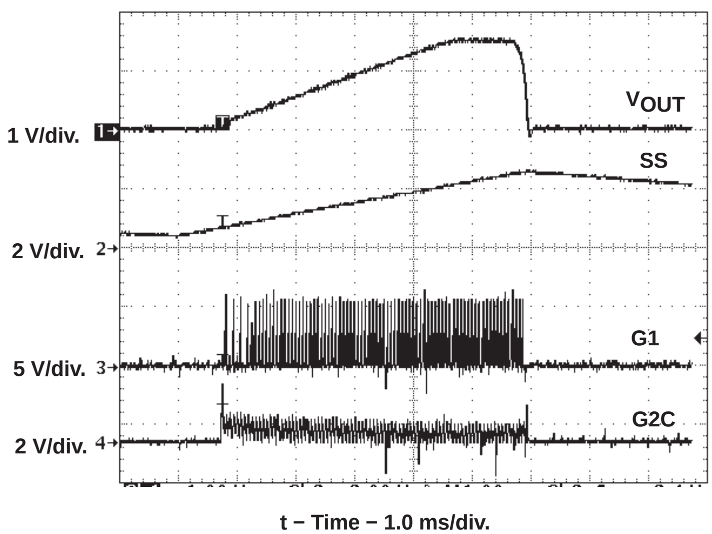

Figure 11.

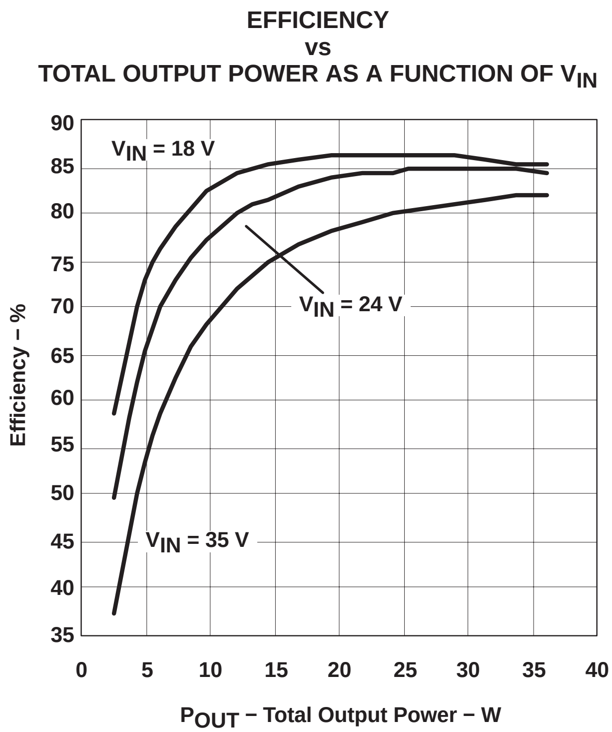

Figure 12.

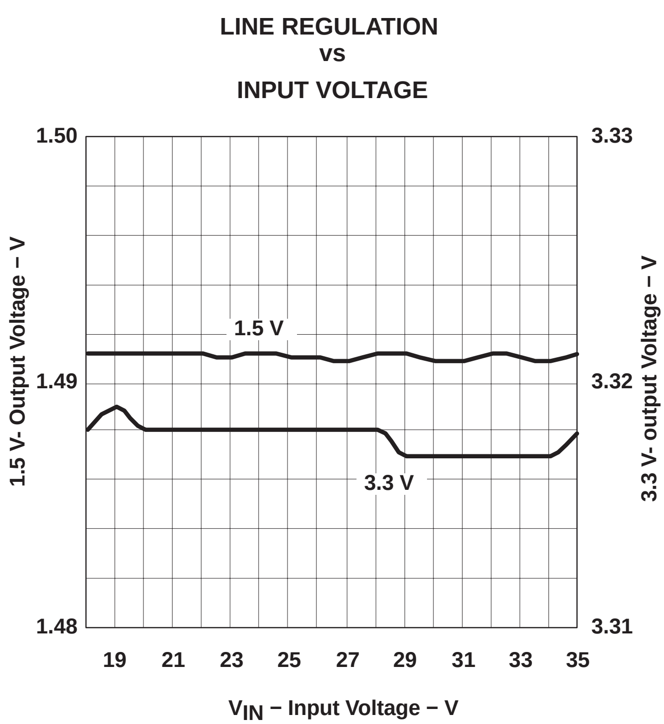

Figure 13.

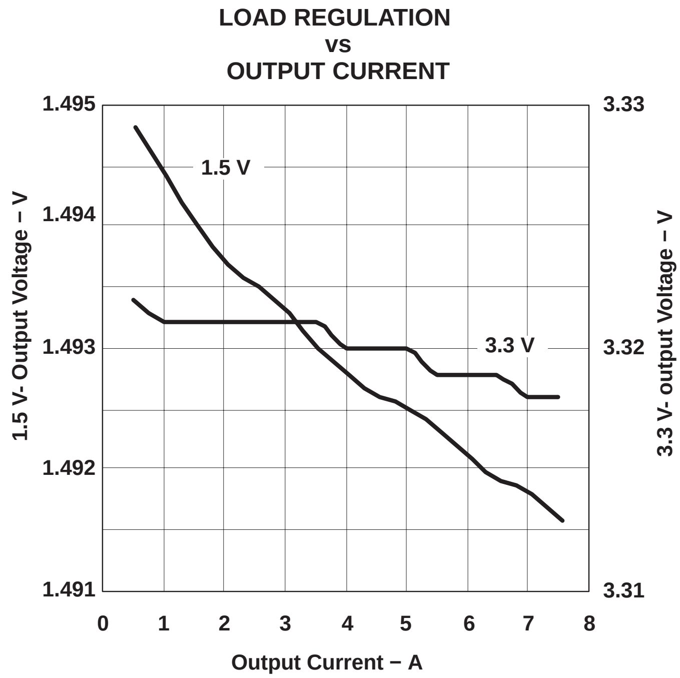

Figure 14.

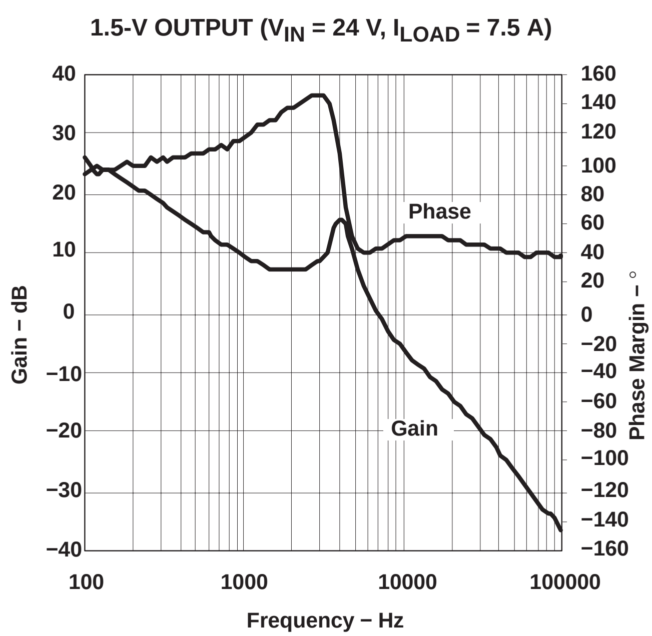

Figure 15.

10 EVM Assembly Drawing and PCB Layout

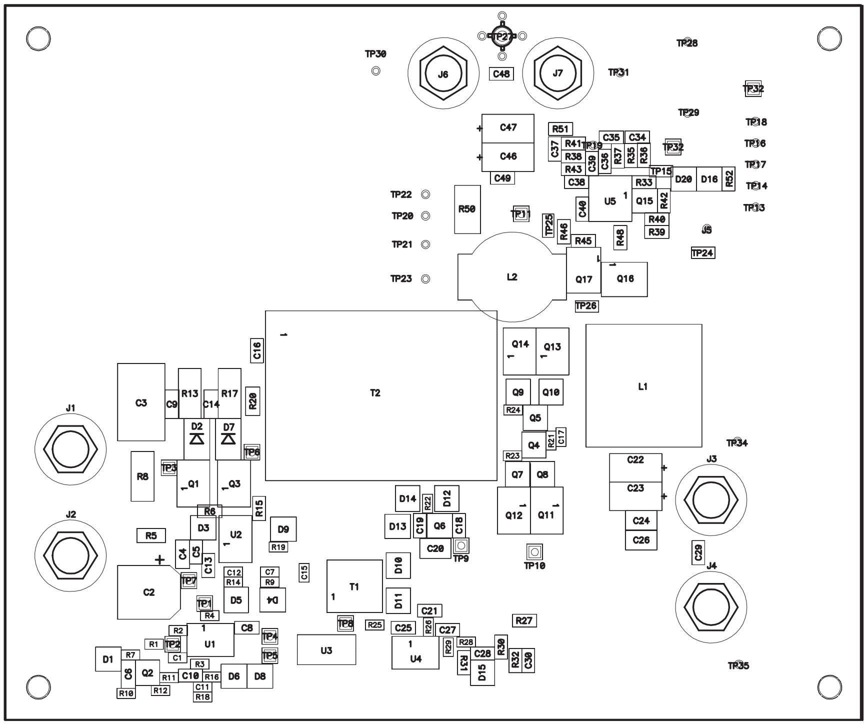

Figure 16. Top Assembly

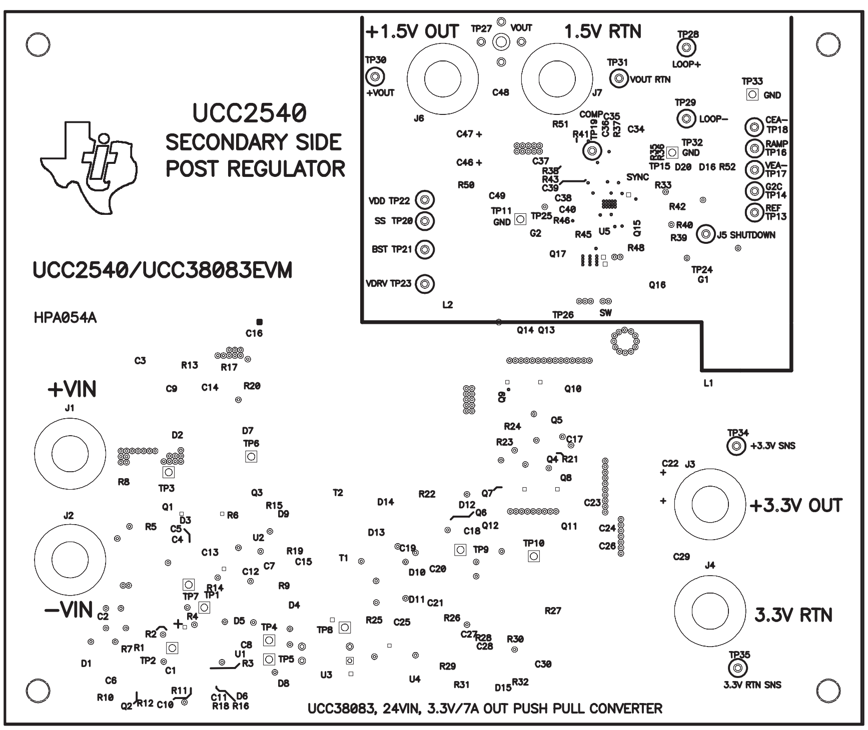

Figure 17. Top Silk

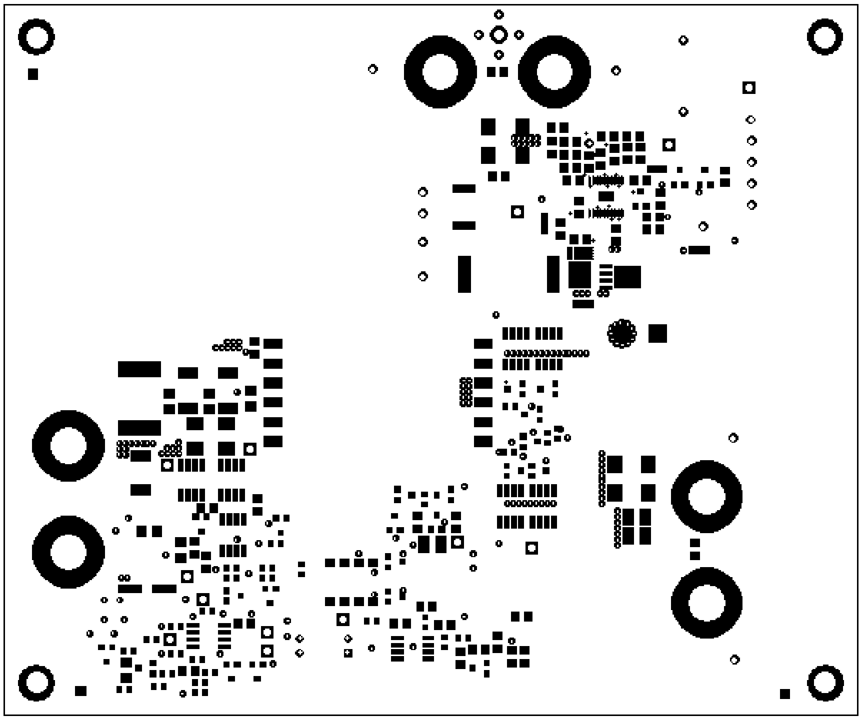

Figure 18. Top Mask

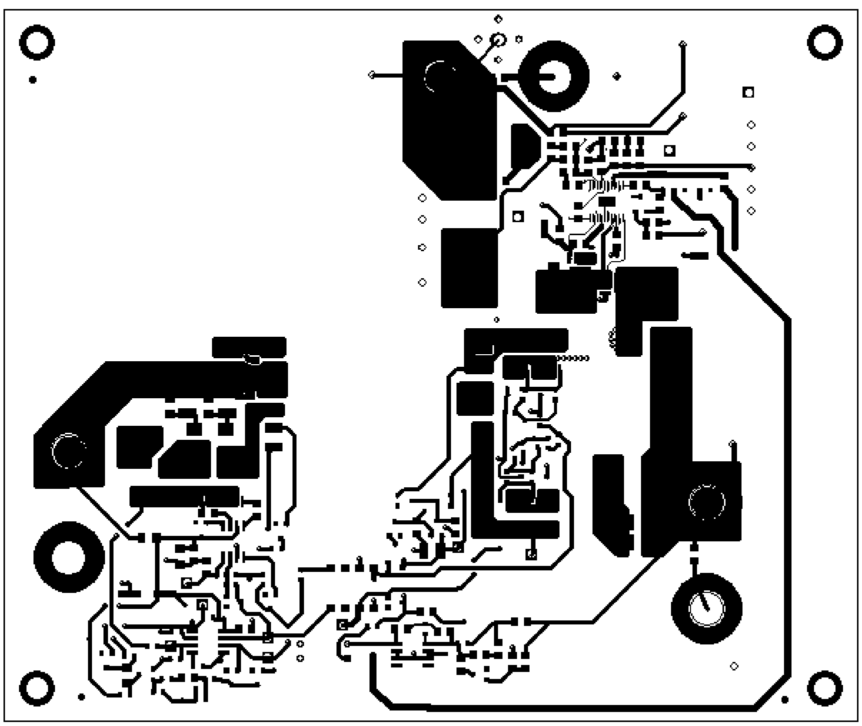

Figure 19. Top Route

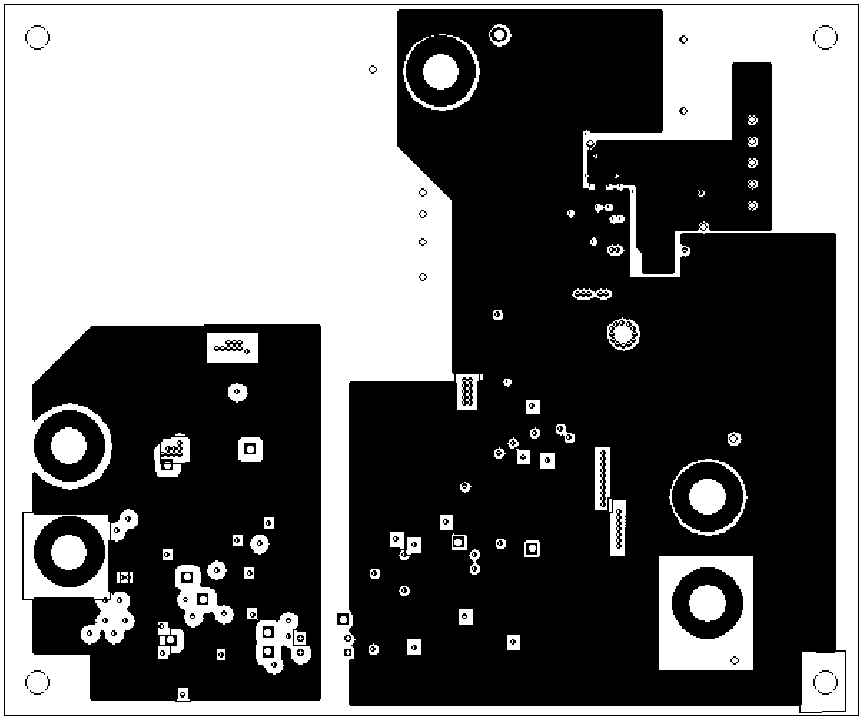

Figure 20. Layer 2 Route

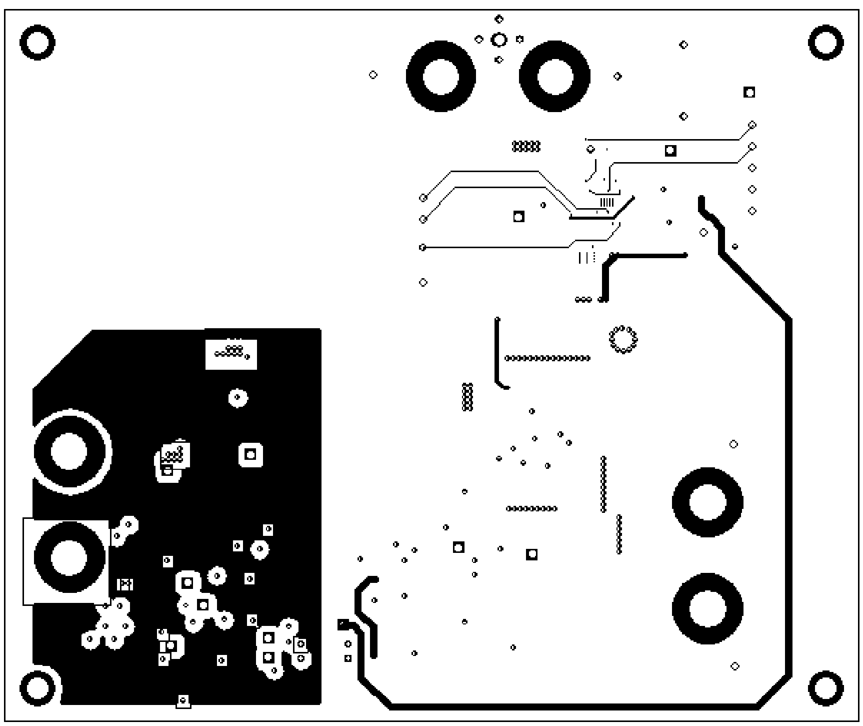

Figure 21. Layer 3 Route

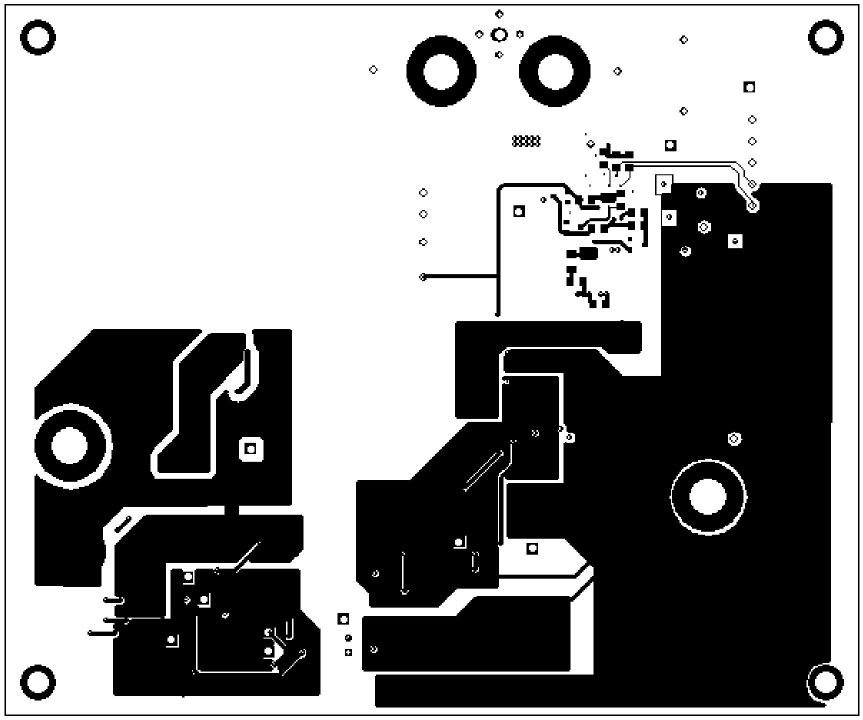

Figure 22. Bottom Route

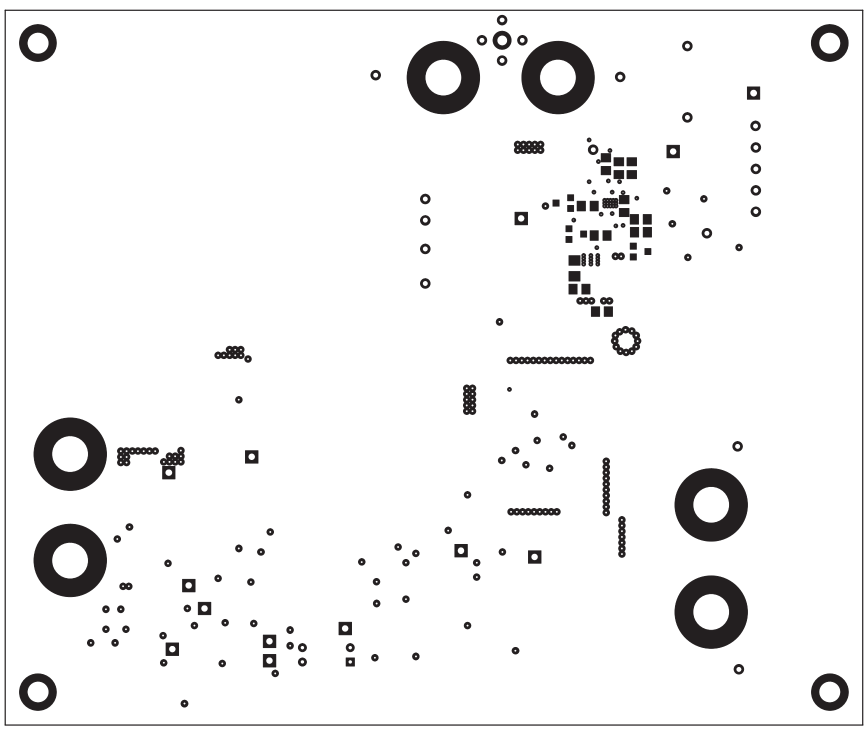

Figure 23. Bottom Mask

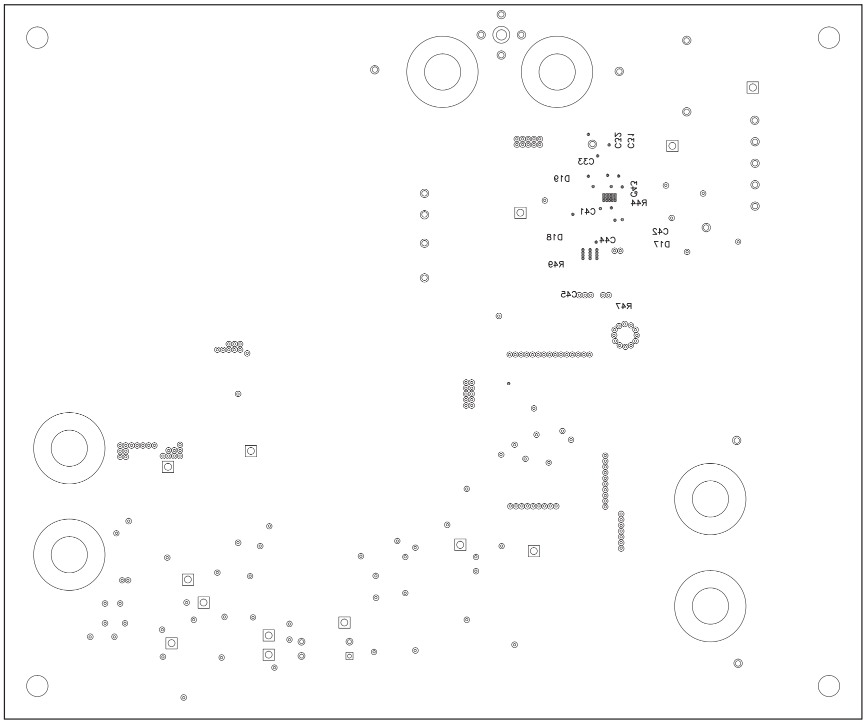

Figure 24. Bottom Silk

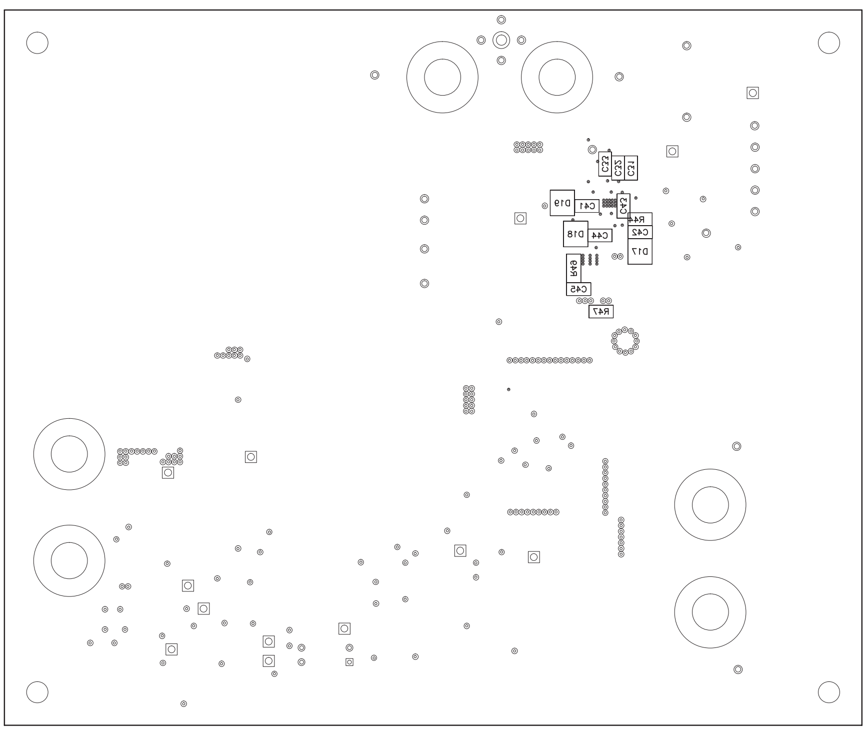

Figure 25. Bottom Assembly

11 List of Materials

REF DES	QTY	DESCRIPTION	MFR	PART NUMBER
C1	1	Capacitor, ceramic, 560 pF, 50 V, X7R, ±10%, 0603	Std	Std
C2	1	Capacitor, aluminum, 47 µF, 16 V, ±20%, HA series, 0.335 x 0.374	Panasonic	EEV−HA1C470P
C3	1	Capacitor, film, 2.2 µF, 100 V, ±10%, ST3827	ITW PAKTON	225K100ST3827
C4	1	Capacitor, ceramic, 1 µF, 16 V, X7R, ±10%, 1206	Std	Std
C5, C8, C19, C31	4	Capacitor, ceramic, 0.1 µF, 50 V, X7R, ±10%, 0805	Std	Std
C6	not used	not used, 1206		
C7, C12	2	Capacitor, ceramic, 100 pF, 50 V, NP0, ±5%, 0603	Std	Std
C9, C14	2	Capacitor, ceramic, 47000 pF, 50 V, X7R, ±10%, 1206	Std	Std
C10, C21, C27	not used	not used, 0805		
C11	not used	not used, 0603		
C13, C18, C25, C29, C43, C48, C49	7	Capacitor, ceramic, 1 µF, 16 V, X7R, ±10%, 0805	Std	Std
C15	1	Capacitor, ceramic, 0.1 µF, 16 V, X7R, ±10%, 0603	Std	Std
C16	1	Capacitor, ceramic, 470 pF, 200 V, X7R, ±10%, 0805	Std	Std
C17	1	Capacitor, ceramic, 1000 pF, 50 V, X7R, ±10%, 0603	Std	Std
C20, C24, C26	3	Capacitor, ceramic, 10 µF, 16 V, X5R, ±10%, 1210	Std	Std
C22, C23	2	Capacitor, POSCAP, 150 µF, 6.3 V, 55 mΩ, ±20%, 7343(D)	Sanyo	6TPB150ML
C28	1	Capacitor, ceramic, 1000 pF, 50 V, C0G, ±5%, 0805	Std	Std
C30	1	Capacitor, ceramic, 2.2 µF, 6.3 V, X5R, ±10%, 0805	Std	Std
C32	1	Capacitor, ceramic, 270 pF, 50 V, NP0, ±5%, 0805	Std	Std
C33	1	Capacitor, ceramic, 82 pF, 50 V, NP0, ±5%, 0805	Std	Std
C34	1	Capacitor, ceramic, 820 pF, 50 V, X7R, ±10%, 0805	Std	Std
C35, C45	2	Capacitor, ceramic, 3.3 nF, 50 V, X7R, ±10%, 0805	Std	Std
C36	1	Capacitor, ceramic, 270 pF, 50 V, X7R, ±10%, 0805	Std	Std
C37	1	Capacitor, ceramic, 1200 pF, 50 V, C0G, ±5%, 0805	Std	Std
C38	1	Capacitor, ceramic, 4.7 nF, 50 V, X7R, ±10%, 0805	Std	Std
C39	1	Capacitor, ceramic, 1000 pF, 50 V, NP0, ±5%, 0805	Std	Std
C40	1	Capacitor, ceramic, 0.18 µF, 16 V, X7R, ±10%, 0805	Std	Std
C41	1	Capacitor, ceramic, 0.39 µF, 25 V, X7R, ±10%, 0805	Std	Std
C42	1	Capacitor, ceramic, 0.18 µF, 25 V, X7R, ±10%, 0805	Std	Std
C44	1	Capacitor, ceramic, 2.2 µF, 25 V, X5R, ±10%, 0805	Std	Std
C46, C47	2	Capacitor, POSCAP, 330 µF, 4 V, 12 mΩ, ±20%, 7343 (D)	Sanyo	4TPD330M
D1, D6, D8	not used	not used, SOT−23		
D2, D7	2	Diode, ultrafast rectifier, 1 A, 200 V, SMB	On Semiconductor	MURS120T3
D3, D4, D5, D9, D10, D11, D15, D16, D20	9	Diode, switching, 600 mA, 85 V, 350 mW, SOT−23	Fairchild Semiconductor	BAS16
D12, D14, D17, D18, D19	5	Diode, schottky, 1.16 A, 40 V, SOT−23	Zetex	ZLLS1000
D13	1	Diode, zener, 6.8 V, 350 mW, SOT−23	Diodes Inc.	BZX84C6V8−7
L1	1	Inductor, SMT, 1.5 µH, 21A, 0.78 mΩ, 0.770 x 0.780	Pulse	PA1292.152
L2	1	Inductor, SMT, 2.2 µH, 12 A, 6.1 mΩ, 0.730 x 0.600	Coilcraft	DO5010P−222HC
Q1, Q3	2	MOSFET, N-channel, 150 V, 5 A, 50 mΩ, SO−8	Vishay−Siliconix	Si4488DY
Q2	not used	not used,		

Q4, Q5	2	MOSFET, N-channel, 60 V, 115 mA, SOT−23	Std	2N7002
Q6, Q15	2	Transistor, NPN, 40 V, 1 A, SOT−23	Fairchild Semi-conductor	MMBT2222A
Q7, Q9	2	Bipolar, NPN, 40 V, 200 mA, 350 mW, SOT−23	Std	MMBT3904
Q8, Q10	2	Bipolar, PNP, −40 V, 200 mA, SOT−23	Std	MMBT3906
Q11, Q12, Q13, Q14	4	MOSFET, N-channel, 20 V, 16 A, 6.5 mΩ, SO−8	International Rectifier	IRF7456
Q16	1	MOSFET, N-channel, V_{DS} 30 V, R_{DS} 13.9 mΩ, Id 30 A, LFPAK	Hitachi	HAT2168H
Q17	1	MOSFET, N-channel, V_{DS} 30 V, R_{DS} 3.3 mΩ, Id 55 A, LFPAK	Hitachi	HAT2165H
R1, R25, R26	3	Resistor, chip, 1 kΩ, 1/16 W, ±1%, 0603	Std	Std
R2	1	Resistor, chip, 26.1 kΩ, 1/16 W, ±1%, 0603	Std	Std
R3	1	Resistor, chip, 84.5 kΩ, 1/16 W, ±1%, 0603	Std	Std
R4	1	Resistor, chip, 5.1 kΩ, 1/16 W, ±1%, 0805	Std	Std
R5	1	Resistor, chip, 9.09 kΩ, 1/8 W, ±1%, 1206	Std	Std
R6, R15	2	Resistor, chip, 1 Ω, 1/10 W, ±1%, 0805	Std	Std
R7, R10, R11, R12, R16, R18	not used	not used, 0603		
R8	1	Resistor, chip, 0.08 Ω, 1W, ±1%, 2512	Dale	WSL−2512−0.08 1%
R9, R14	2	Resistor, chip, 549 Ω, 1/16 W, ±1%, 0603	Std	Std
R13, R17	2	Resistor, chip, 27 kΩ, 1 W, ±1%, 2512	Dale	CRCW25122672F
R19	1	Resistor, chip, 20 Ω, 1/16 W, ±1%, 0603	Std	Std
R20	2	Resistor, chip, 20 Ω, 1/8 W, ±1%, 1206	Std	Std
R21, R22, R23, R24	4	Resistor, chip, 511 Ω, 1/16 W, ±1%, 0603	Std	Std
R27, R51	2	Resistor, chip, 49.9 Ω, 1/10 W, ±1%, 0805	Std	Std
R28	1	Resistor, chip, 3.09 kΩ, 1/16 W, ±1%, 0603	Std	Std
R29	1	Resistor, chip, 1.87 kΩ, 1/16 W, ±1%, 0603	Std	Std
R30	1	Resistor, chip, 499 Ω, 1/10 W, ±1%, 0805	Std	Std
R31	1	Resistor, chip, 750 Ω, 1/10 W, ±1%, 0805	Std	Std
R32, R39, R43, R46, R47	5	Resistor, chip, 10 kΩ, 1/10 W, ±1%, 0805	Std	Std
R33	1	Resistor, chip, 30 kΩ, 1/10 W, ±1%, 0805	Std	Std
R35	1	Resistor, chip, 44.2 kΩ, 1/10 W, ±1%, 0805	Std	Std
R36	1	Resistor, chip, 1.37 kΩ, 1/10 W, ±1%, 0805	Std	Std
R37	1	Resistor, chip, 15 kΩ, 1/10 W, ±1%, 0805	Std	Std
R38	1	Resistor, chip, 29.4 kΩ, 1/10 W, ±1%, 0805	Std	Std
R40	1	Resistor, chip, 3.48 kΩ, 1/10 W, ±1%, 0805	Std	Std
R41	1	Resistor, chip, 634 Ω, 1/10 W, ±1%, 0805	Std	Std
R42	1	Resistor, chip, 20 Ω, 1/10 W, ±1%, 0805	Std	Std
R44, R45, R48	3	Resistor, chip, 0 Ω, 1/10 W, ±1%, 0805	Std	Std
R49	1	Resistor, chip, 25.5 Ω, 1/4 W, ±1%, 1206	Std	Std
R50	1	Resistor, metal strip, 0.005 Ω, 1 W, ±1%, 2512	Vishay Dale	WSL−2512 0.005 ±1%
R52	1	Resistor, chip, 1 kΩ, 1/10 W, ±1%, 0805	Std	Std
T1	1	Transformer, gate drive, 3950 µH, 1500 V_{DC} isolation, 0.340 x 0355	Pulse	PA0510
T2	1	Transformer, 3 Primary, 2 Secondary, push pull , 1160 x 1524	Pulse	PB2124

U1**	1	IC, Current Mode Push-Pull PWM Controller, SO−8	Texas Instru-ments	UCC38083D
U2**	1	IC, MOSFET Driver, Dual Channel Buffer w/Regulator, SO−8	Texas Instru-ments	TPS2812D
U3	1	IC, Optocoupler, 5300 V, 50 to 600% CTR, 0.380 x 0.180	QT Optoelectro-nics	H11A817
U4	1	IC, Adj Shunt Regulator, 100 mA, 36 V, SO−8	Texas Instru-ments	TLV431AID
U5**	1	IC, High-Efficiency Secondary-Side Synchronous Buck PWM Controller, PWP20	Texas Instru-ments	UCC2540PWP
−−		PCB, 6 In x 5 In x 0.062 In,	Any	HPA054A
J1, J2, J3, J4, J6, J7	6	Connector, banana jack, uninsulated, 0.500 dia	Pomona	3267
J5	1	Miniature Thru-hole mount test point, white, 0.040	Keystone	5002
TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP32, TP33	14	Thru-hole mount test point, O.043 hole, 0.043 dia	Mill−Max	3103−1−00−15−00 −00−0X−0
TP13, TP14, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP28, TP29, TP30, TP31, TP34, TP35	16	Miniature Thru-hole mount test point, white, 0.040 dia.	Keystone	5002
TP15, TP24, TP25, TP26	4	Test point, SMT, 0.105 x 0.040	Keystone	5015
TP27	1	Adaptor, 3.5-mm probe clip (or 131−5031−00), 0.2	Tektronix	131−4244−00

NOTES: 1. These assemblies are ESD sensitive, ESD precautions shall be observed.
2. These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.
3. These assemblies must comply with workmanship standards IPC−A−610 Class 2.
4. Ref designators marked with an asterisk ('**') cannot be substituted. All other components can be substituted with equivalent MFG's components.

12 References

1. Data Sheet, *UCC2540 High-Efficiency Secondary-Side Synchronous Buck PWM Controller,* Texas Instruments Literature Number SLUS539
2. Data Sheet, *UCC38083 8-Pin Current Mode Push-Pull PWM Controllers With Programmable Slope Compensation*, Texas Instruments Literature Number SLUS488B
3. Bottrill, John, *50-W Push-Pull Converter Reference Design Using the UCC38083*, Texas Instruments Literature Number SLUU135A

IMPORTANT NOTICE

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