TEXAS INSTRUMENTS

UCC3580EVM Flyback Converters, Active Clamp vs Hard-Switched Evaluation Board and List of Materials

User's Guide

EVM IMPORTANT NOTICE

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

This evaluation kit being sold by TI is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not considered by TI to be fit for commercial use. As such, the goods being provided may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety measures typically found in the end product incorporating the goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may not meet the technical requirements of the directive.

Should this evaluation kit not meet the specifications indicated in the EVM User's Guide, the 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. Please be aware that the products received may not be regulatory compliant or agency certified (FCC, UL, CE, etc.). 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 EVM User's Guide and, specifically, the EVM Warnings and Restrictions notice in the EVM User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact the TI application engineer.

Persons handling the product must have electronics training and observe good laboratory practice standards.

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.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 0 VAC to 135 VAC and the output voltage of 0 VDC to 14 VDC.

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 60°C. The EVM is designed to operate properly with certain components above 125°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

TEXAS INSTRUMENTS

UCC3580EVM
Flyback Converters, Active Clamp vs Hard-Switched Evaluation Board and List of Materials

Power Supply Control Products

Contents

Figures

Tables

1 Introduction

This user's guide describes the UCC3580EVM flyback converter evaluation board for comparing an active-clamp configuration with a hard-switched configuration. The UCC3580EVM is originally configured as an active-clamp flyback converter. Instructions and parts list are included in order to reconfigure the UCC3580EVM as a hard-switched flyback converter. Both configurations use the UCC3580 PWM controller. The active clamp configuration operates noticeably more efficiently than the hard switched configuration. Most of the efficiency differences will be seen in the primary-side components.

2 Features

- Provides auxiliary-switch activation complementary to main-power switch drive

- Programmable dead time (turnon delay) between activation of each switch

- Voltage mode control with feedforward operation

- Programmable limits for both transformer volt-second product and PWM duty cycle

- High-current gate driver for both main and auxiliary outputs

- Multiple protection features with latched shutdown and soft restart

- Low supply current (160-μA startup, 2.5-mA operation)

3 Description

3.1 Operating Guidelines

WARNING:

DANGER: HIGH VOLTAGE! *This evaluation board is intended for professional use only. It has exposed high voltages. Do not operate this board without proper isolation and high-voltage/high-current safety practices.*

Refer to the recommended test setup, as shown in Figure 1, and the test points in Table 1. Connect the UCC3580EVM, configured for either active clamp operation or hard-switched operation, as shown in Figure 1. Close the ac line switch and verify that the UCC3580EVM is operating correctly (12 V should be measured by the hand-held DVM on the converter output). Using the appropriate oscilloscope probes, observe the main transistor drain source voltage (TP14 to TP13) and the cathode to anode voltage of the output rectifier (TP6 to TP8). The active clamp implementation will have crisp, clamped voltages and no overshoot on the output rectifier. Converter dynamics can be observed [1] using TP3, 4 and 5.

Other test points are included to observe voltages and currents that are of interest for a specific application. Table 1 describes the intended purpose of the test points that are installed in the board and how they should be used.

3.2 Added Features

Flyback converters require a voltage clamp in order to limit the main switch voltage at turnoff. The effect is due to energy that is stored in the primary leakage inductance of the power transformer. Older hard-switched technology captures the excess leakage inductance energy at turnoff and merely dissipates it in a resistor. In contrast, the active clamp uses the leakage inductance energy to facilitate zero voltage transitions. Efficient ZVS transitions occur at turnon of both the main MOSFET and the auxiliary MOSFET.

Active-clamp technology is made possible here with the UCC3580 single ended active clamp/reset PWM controller. Essentially, this controller is a voltage mode PWM controller with complementary outputs and programmable delay between output transitions. The controller also includes over-current protection, volt-seconds protection and a soft-start feature. The programmable delay is set to be long enough for the leakage inductance energy to forward bias the power MOSFETs before their respective turnon, thus achieving zero voltage switching.

The schematic for the active clamp configuration is shown in Figure 2 and its parts list is in Table 2. The schematic for the hard-switched configuration is shown in Figure 3. Both configurations operate with the same input voltage (110 VAC $\pm$ 10%) and produce the same output voltage (12 V) and current (10 A). Heat sink HS1 is selected to accommodate the hard-switched configuration and it is thus over-sized for active clamp operation. The thermal resistance of HS1 is 6.5°C/W, which is required for hard-switched operation. In contrast, heat sink HS1 only needs a thermal resistance of 10°C/W for active-clamp operation, which was verified in the laboratory. Thus transistor QM operates more efficiently, and it requires a smaller heat sink in the active-clamp configuration. Also, notice that the active-clamp configuration does not require secondary rectifier snubber components (R31 and C30). These features are the result of efficient active clamp technology.

For more information, pin descriptions and specifications for the UCC3580 single ended active clamp/reset PWM, please refer to the UCC3580 data sheet.

3.3 Re-Configuration Instructions

WARNING:

Danger: *Remove power from the UCC3580EVM before removing or installing components.*

These instructions describe how to reconfigure the UCC3580EVM from the active clamp configuration to the hard switched configuration. This section requires components, de-soldering, soldering, and assembly equipment and skills. The components are listed in Table 4.

Begin with an UCC3580EVM in the active-clamp configuration (original configuration). Refer to Table 3 and Table 4 for the components to remove and add, respectively in order for the UCC3580EVM to match the schematic in Figure 3. The additional components in Table 4 are supplied in the kit that is included with the UCC3580EVM.

De-solder the components listed in Table 3. Solder the components listed in Table 4.

Conversion is now complete and comparisons can be made using the test setup in Figure 1 and the test points in Table 1.
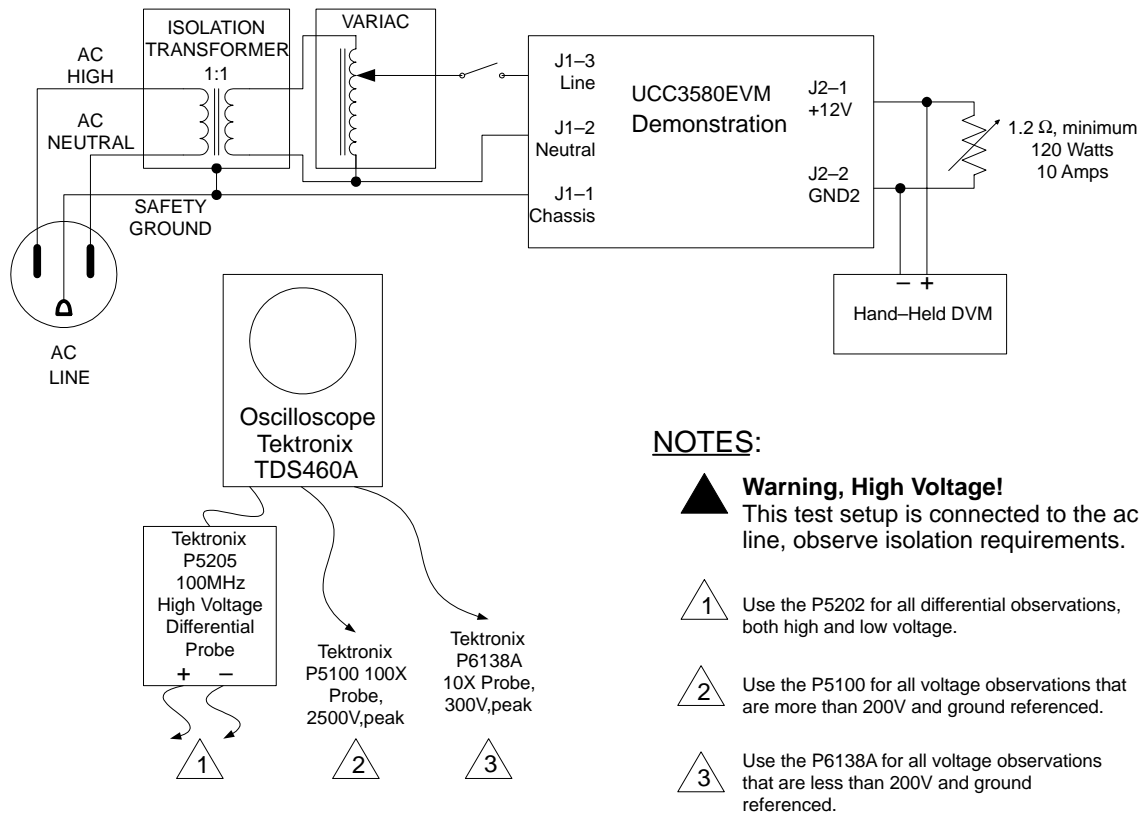
4 Test Setup and Test Points

Figure 1. Recommended Test Setup for the UCC3580EVM

Table 1. List of Test Points

Test Point	Signal Name	Voltage Range	GND REF	Measurement
TP1	GND2		SEC	Secondary ground
TP2	12 V	12 V	SEC	12 V, observe relative to TP1
TP3 TP4 TP5		12 V, 0.1 VAC	SEC	Injection and observation points for control loop. Refer to [1]
TP6 TP7 TP8		12 V 50 V 50 V	SEC	Differentially observe V(D17) between TP6 and TP8. Differentially observe snubber power between TP6 and TP7.
TP9	PRI GND		PRI	Primary ground for controller observations
TP10	OUT1	12 V	PRI	Main MOSFET (QM) gate control signal
TP11	OUT2	12 V	PRI	Auxiliary MOSFET (QA) gate control signal
TP12	EAOUT	5 V	PRI	Error amplifier output to PWM comparator
TP13	PRI GND		PRI	PRI GND reference for QM and CSENSE observations
TP14	DRAIN	300 V	PRI	Observe QM drain voltage relative to PRI GND
TP15	CSENSE	1 V	PRI	Observe drain current of QM
TP16 TP17 TP18	SOURCE BULK DRAIN	300 V 300 V 300 V	PRI	Differentially observe QA drain–source voltage between TP18 and TP16 Differentially observe clamp voltage, V(C25) between TP18 and TP17
TP19 TP20	PRI GND BULK	200 V	PRI	Observe bulk capacitor voltage (the dc input voltage to the converter)

TEXAS
INSTRUMENTS

5 Application Drawings and Parts List

5.1 Active Clamp Configuration
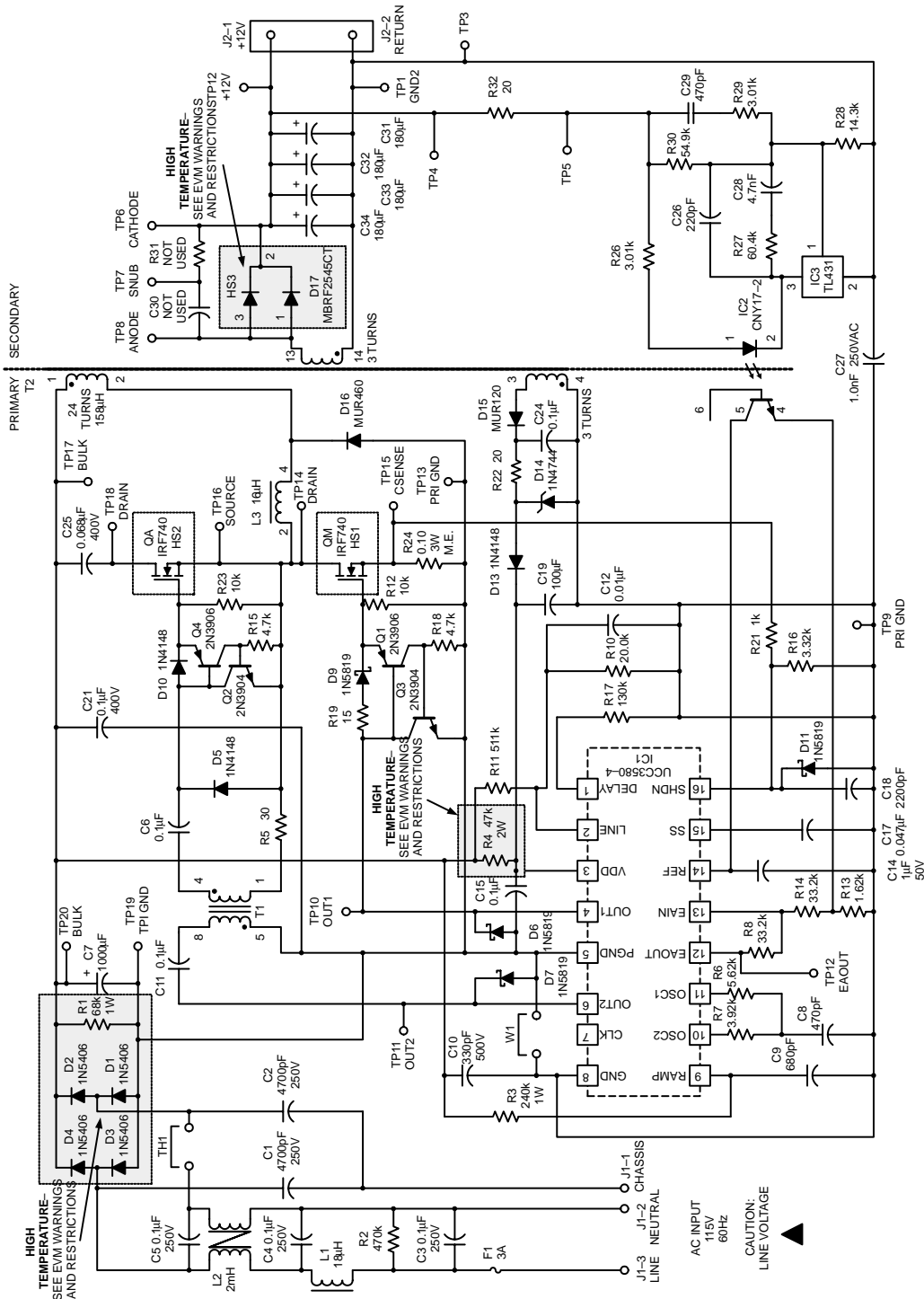
UDG–00014

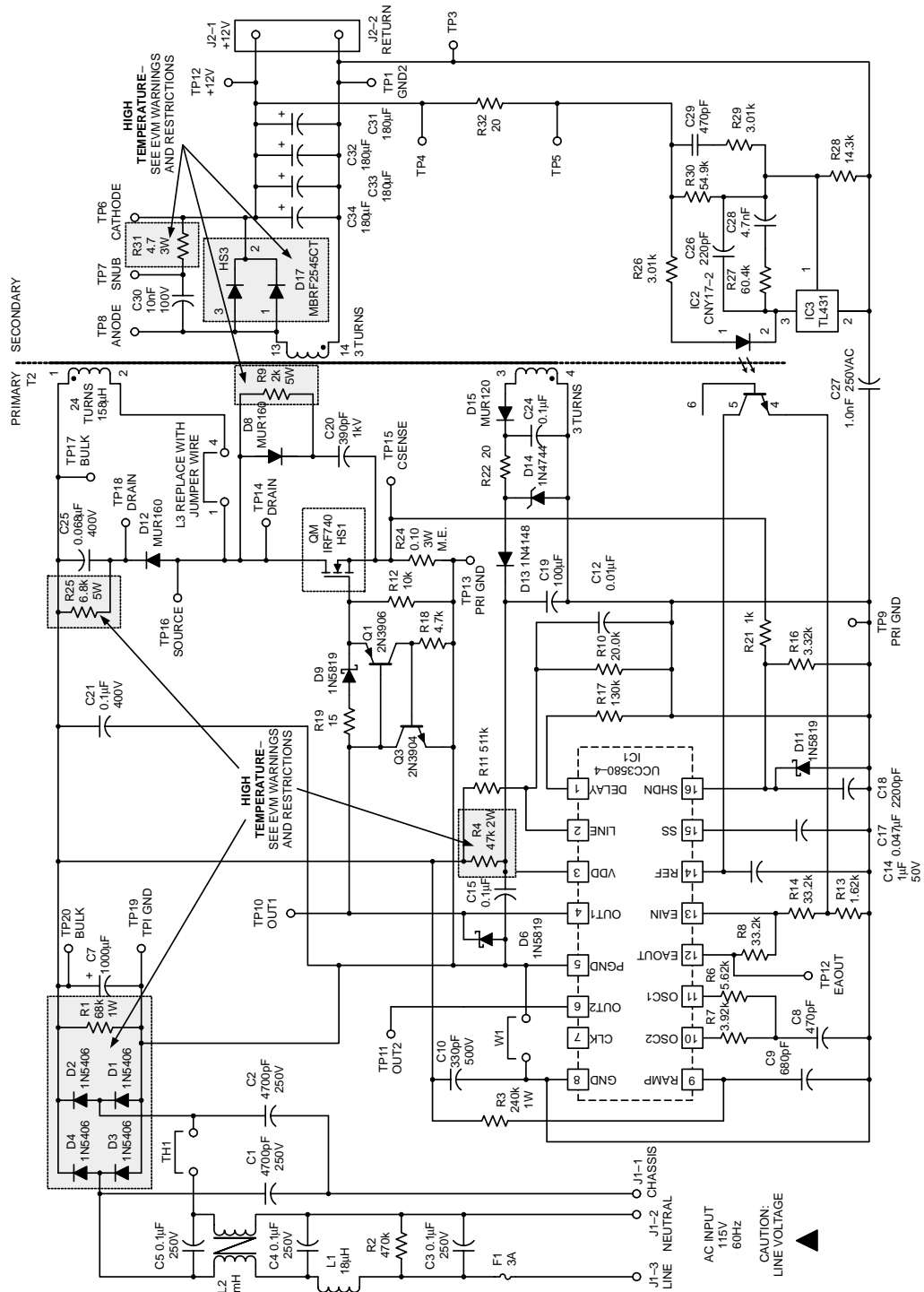Note: High-temperature component. See EVM Warnings and Restrictions at the front of this document.

Figure 2. Flyback Converter Populated for Active Clamp Operation

Table 2. Parts List for Active Clamp Configuration

	Ref Des	Qty	Description	MFG	Size	Part Number
Capacitor	C1,2	2	Y Cap, 4700 pF, 250 Vac	Sprague	6.5 mm	5GAD47
	C3 – C5	3	X Film Cap, 0.1 µF, 250 Vac	Philips	15 mm	222 330 40104
	C6, C11, C15, C24	4	Ceramic, 0.1 µF, 50 V	Panasonic	5 mm	ECU–S1H104KBB
	C7	1	Aluminum electrolytic, 1000 µF, 200 V	United Chemi–con	10 mm	KMH200VN102M35X35 T2
	C8	1	Ceramic, 470 pF, 50 V	Panasonic	2.5 mm	ECU–S1H471JCA
	C9	1	Ceramic, 680 pF, 50 V	Panasonic	2.5 mm	ECK–F1H681KB
	C10	1	Ceramic Disk, 330 pF, 500 V	Philips	5 mm	D331K20Y5PLAAEU
	C12	1	Ceramic, 0.01 µF, 50 V	Panasonic	2.5 mm	ECU–S1H103KBA
	C14	1	Ceramic, 1 µF, 50 V	Panasonic	5 mm	ECU–S1H105MEB
	C17	1	Ceramic, 47 nF, 50 V	Panasonic	2.5 mm	ECU–S1H473MEA
	C18	1	Ceramic, 2200 pF, 50 V	Panasonic	2.5 mm	ECK–F1H222KB
	C19	1	Aluminum Electrolytic, 100 µF, 25 V	Panasonic	2 mm	ECE–A1EU101
	C21	1	Foil, 0.1 µF, 400 V	Panasonic	20 mm	ECQ–P4104JU
	C25	1	Foil, 0.068 µF, 400 V	Panasonic	20 mm	ECQ–P4683JU
	C26	1	Ceramic, 220 pF, 50 V	Panasonic	2.5 mm	ECU–S1H221JCA
	C27	1	Y1 Ceramic, 1000 pF, 250 Vac	Panasonic	10 mm	ECK–DNA102MB
	C28	1	Ceramic, 4.7 nF, 50 V	Panasonic	2.5 mm	ECU–S1H472KBA
	C29	1	Ceramic, 470 pF, 50 V	Panasonic	7.5 mm	ECU–S1H471JCA
	C31 – C34	4	Os–Con, 180 µF, 20 V	Sanyo	5 mm	20SP180M
Diode	D1 – D4	4	General Purpose, 3 A, 600 V		DO–201AD	1N5406
	D5, D10, D13	3	Switching, 75 mA, 75 V		DO–35	1N4148
	D6, D7, D9, D11	4	Schottky, 1 A, 40 V		DO–41	1N5819
	D14	1	Zener, 15 V, 1 W		DO–41	1N4744A
	D15	1	Ultra Fast, 1 A, 200 V		DO–41	MUR120
	D16	1	Ultra Fast, 4 A, 400 V		DO–201AD	MUR460
	D17	1	Schottky, Dual, 25 A, 45 V		ITO–220AB	MBRF2545CT
Fuse	F1	1	3 A, AGC3A Buss, 3 A	Buss	31.75 mm	AGC3A
Fuse clips	FCa,b	2	2 required, spacing per dwg	Keystone	7.62 mm	3510
Heatsink	HS1	1	For QM, 6.5 C/W	Thermalloy	50.44 mm	7022B–MT
	HS2	1	For QA, 13 C/W	Thermalloy	24.38 mm	6021PB
	HS3	1	For D53, 4.4 C/W	Thermalloy	27.94 mm	7023B–MT
PWM	IC1	1	IC control	TI–Unitrode	DIL–16	UCC3580N–4
Optocoupler	IC2	1	CNY17–2		DIL–6	CNY17–2
Voltage Reference	IC3	1	2.495 V	TI	TO–226AA	TL431CLP
Connector	J2	1	2 pos, 5.08 mm spacing	Phoenix Contact	5.08 mm	1730612
Choke	L1	1	Toroid, 18 µH	Magnetek	12.06 mm	FIT68–7
	L2	1	Common mode, 2 mH	Panasonic	10X16.5 mm	ELF–18N032A
	L3	1	E25/10/6–3F3 core, 10-pins, 16 µH	Century Magnetics	5.1X15.6 mm	CMI–2408
MOSFET	QA, QM	2	400 V, 0.55 Ω, 10 A	IR	TO–220AB	IRF740

	Ref Des	Qty	Description	MFG	Size	Part Number
Screw		3	#4–40 x 3/8" round head, philips, for QA, QM & D17			
Nut		3	#4–40 hex for QA, QM & D17			
Washer		3	#4, flat for QA, QM & D17			
Washer		3	#4, split lock, for QA, QM & D17			
Heat sink pad		2	TO220, for QA, QM	Bergquist	3.18 mm hole	SP600–58
Shoulder washer		2	Hi temp plastic, for QA, QM & D17	Bivar	for #4 screw	SW–031–145
Transistor	Q1, Q4	2	PNP, 40 V, 200 mA		TO–226AA	2N3906
	Q2, Q3	2	NPN, 40 V, 200 mA		TO–226AA	2N3904
Resistor	R1	1	1 W, Metal Oxide, 68 kΩ, 5%	Panasonic	20 mm	P68kW–1BK–ND
	R2	1	1/4 W, carbon comp, 470 kΩ, 5%	Multicomp	15.24 mm	RC1/4G474JT
	R3	1	1 W, Metal Oxide, 240 kΩ, 5%	Panasonic	20 mm	P240kW–1BK–ND
	R4	1	2 W, 47 kΩ, 5%	Panasonic	25.4 mm	P47kW–2BK–ND
	R5	1	1/4 W, 30 Ω, 5%		10.16 mm	
	R6	1	1/4 W, 5.62 kΩ, 1%		10.16 mm	
	R7	1	1/4 W, 3.92 kΩ, 1%		10.16 mm	
	R8	1	1/4 W, 33.2 kΩ, 1%		10.16 mm	
	R10	1	1/4 W, 20.0 kΩ, 1%		10.16 mm	
	R11	1	1/4 W, 511 kΩ, 1%		10.16 mm	
	R12, R23	2	1/4 W, 10 kΩ, 5%		10.16 mm	
	R13	1	1/4 W, 1.62 kΩ, 1%		10.16 mm	
	R14	1	1/4 W, 33.2 kΩ, 1%		10.16 mm	
	R15	1	1/4 W, 4.7 kΩ, 5%		10.16 mm	
	R16	1	1/4 W, 3.32 kΩ, 1%		10.16 mm	
	R17	1	1/4 W, 130 kΩ, 1%		10.16 mm	
	R18	1	1/4 W, 4.7 kΩ, 5%		10.16 mm	
	R19	1	1/4 W, 15 Ω, 5%		10.16 mm	
	R21	1	1/4 W, 1 kΩ, 1%		10.16 mm	
	R22, R32	2	1/4 W, 20 Ω, 5%		10.16 mm	
	R24	1	3 W, Metal Element, 0.1 Ω, 1%	IRC	20 mm	LOB–3–0.10 Ω
	R26, R29	2	1/4 W, 3.01 kΩ, 1%		10.16 mm	
	R27	1	1/4 W, 60.4 kΩ, 1%		10.16 mm	
	R28	1	1/4 W, 14.3 kΩ, 1%		10.16 mm	
	R30	1	1/4 W, 54.9 kΩ, 1%		10.16 mm	
Transformer	T1	1	Gate drive, 8-pins	Coiltronics	2.5X8 mm	CTX08–14086–X1
	T2	1	PC40EER35 core, 12-pins, 158 μH pri, 24:3	Century Magnetics	5X22.5 mm	CMI–2409
Thermistor	TH1	1	Jumper, insulated, 20AWG		10.16 mm	
Test Point	TP1 to TP20	20	White, 0.063 inch dia.	Keystone	1.6 mm	5012
Jumper	W1	1	2 holes		7.62 mm	
Support Post		4	Nylon, in PWB corner holes	Richco	156"hole, 15.9 mm	SP3–10–01
PCB	—	1	2-Layer, 2 oz, 9.00"(L) x 6.00"(W) x 0.062"(T)			SLUP054

5.2   Hard-Switched Configuration

UDG–00015

Note: High-temperature component. See EVM Warnings and Restrictions at the front of this document.

Figure 3. Flyback Converter Populated for Hard-Switched Operation

Table 3. Conversion From Active Clamp to Hard-Switched Configuration: Remove List

	Ref Des	Qty	Description	MFG	Size	Part Number
Capacitor	C6, C11	2	Ceramic, 0.1 µF, 50 V	Panasonic	5 mm	ECU–S1H104KBB
Diode	D5, D10	2	Switching, 75 mA, 75 V		DO–35	1N4148
	D7, D11	2	Schottky, 1 A, 40 V		DO–41	1N5819
	D16	1	Ultra Fast, 4 A, 400 V		DO–201AD	MUR460
Heatsink	HS2	1	For QA, 13 C/W. Remove as an assembly with QA and all of the mounting hardware attached to HS2.	Thermalloy	24.38 mm	6021PB
Choke	L3	1	E25/10/6–3F3 core, 10-pins, 16 µH	Century Magnetics	5.1X15.6 mm	CMI–2408
MOSFET	QA	1	400 V, 0.55 Ω, 10 A (removed with HS2)	IR	TO–220AB	IRF740
Transistor	Q2	1	NPN, 40 V, 200 mA		TO–226AA	2N3904
	Q4	1	PNP, 40 V, 200 mA		TO–226AA	2N3906
Resistor	R5	1	30 Ω, 1/4 w, 5%		10.16 mm	
	R15	1	1/4 W, 4.7 kΩ, 5%		10.16 mm	
	R23	1	1/4 W, 10 kΩ, 5%		10.16 mm	
Gate	T1	1	xfmr, 8-pins	Coiltronics	2.5X8 mm	CTX08–14086–X1

Table 4. Conversion From Active Clamp to Hard-Switched Configuration: Add List

	Ref Des	Qty	Description	MFG	Size	Part Number
Capacitor	C20	1	Ceramic disk, 390 pF, 1 kV	Panasonic	5 mm	ECK–D3A391KBN
	C30	1	Polyester, 0.01 µF, 100 V	Panasonic	5 mm	ECQ–E1103KF
Diode	D8, D12	2	Ultra fast, 1 A, 600 V		DO–41	MUR160
Jumper	L3	1	Pin 1 to pin 4, 20AWG, insulated		14 mm	
Resistor	R9	1	5 W, wire, vertical, 1 kΩ, 5%	Ohmite	5 mm	TWM–5J1K0
	R25	1	5 W, wire, vertical, 6.8 kΩ, 5%	Ohmite	5 mm	TWM–5J6K8
	R31	1	5 W, wire, vertical, 4.7 Ω, 5%	Ohmite	5 mm	TWM–5J4R7

6 Traces and silkscreen

Figures 4, 5, and 6 show the traces and silkscreen for the UCC3580EVM.
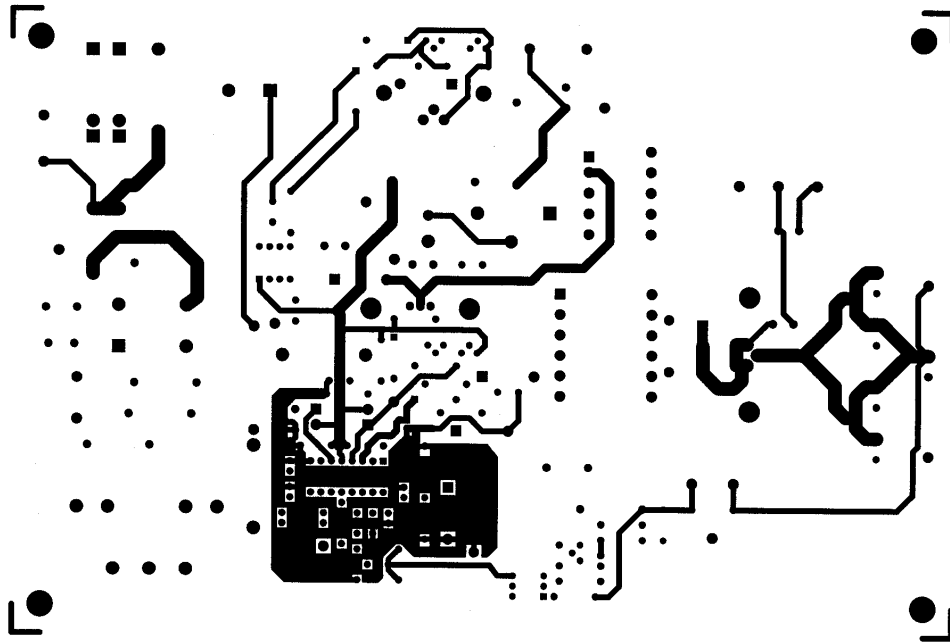
6.1 Traces

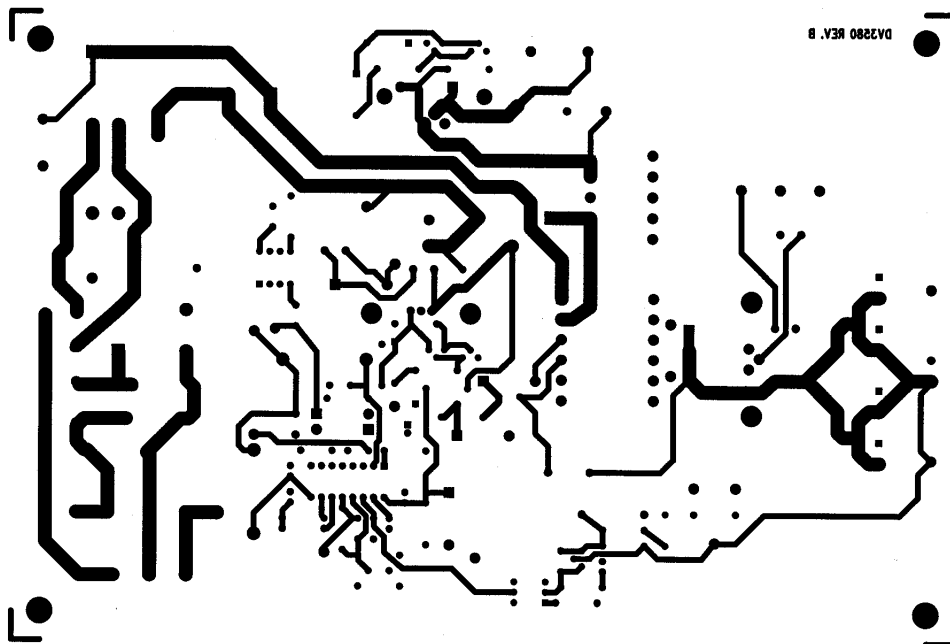**Figure 4. UCC3580EVM Layout, Top Traces**

Figure 5. UCC3580EVM Layout, Bottom Traces
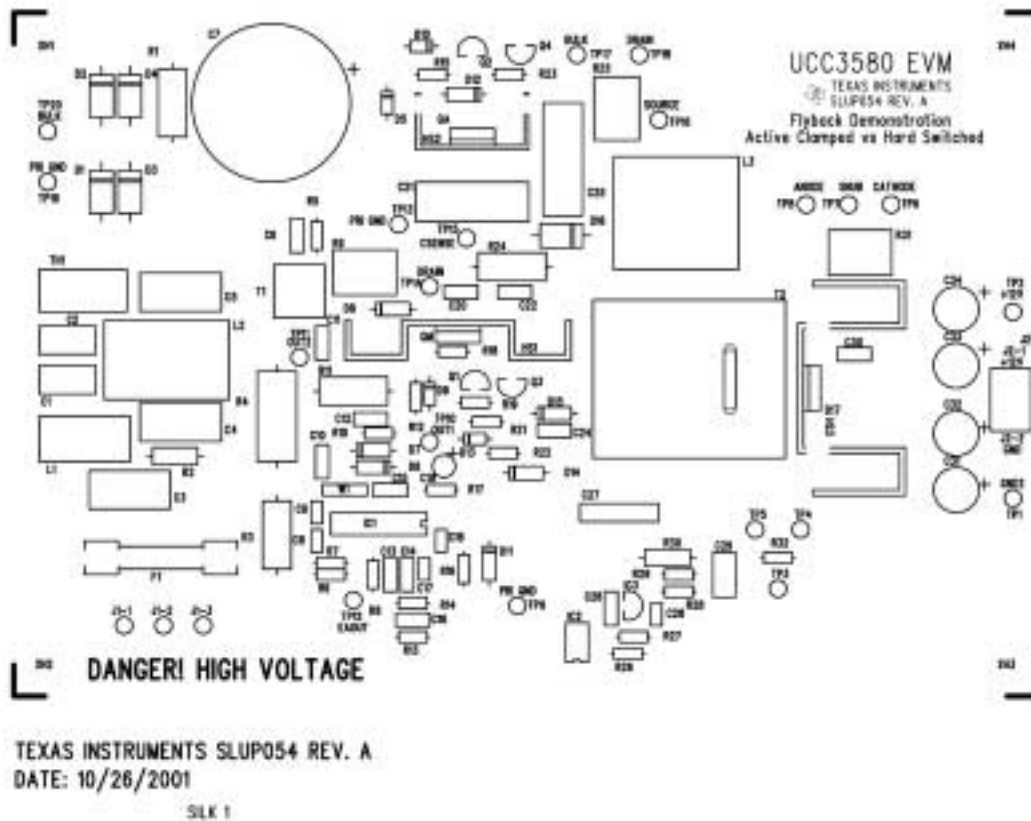
6.2 Silkscreen

Figure 6. UCC3580EVM Silk Screen (only top layer has a silk screen)

7   Reference

[1] R.B. Ridley, Switching power supply design information, design tips, frequency response analyzers, and educational material for power supplies. See web site located at http://www.ridleyengineering.com.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third–party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

Copyright © 2002, Texas Instruments Incorporated