User's Guide
SLVU151–March 2006

TPS54550EVM-158 SWIFT™ Regulator Evaluation Module

Contents

List of Figures

List of Tables

1 Introduction

This user's guide contains background information for the TPS54550 as well as support documentation for the TPS54550EVM-158 evaluation module (HPA158). Also included are the performance specifications, the schematic, and the bill of materials for the TPS54550EVM-158.

1.1 Background

The TPS54550 dc/dc converter is designed to provide up to a 6-A output from an input voltage source of 4.5 V to 20 V. Rated input voltage and output current range for the evaluation module is given in Table 1. This evaluation module is designed to demonstrate the small printed-circuit-board areas that may be achieved when designing with the TPS54550 regulator. The maximum EVM input voltage of 17 V, is the result of the 3.3-V output voltage. The switching frequency is internally set at a nominal 700 kHz. The high-side MOSFET is incorporated inside the TPS54550 package along with the gate drive circuitry. The

SWIFT, PowerPAD are trademarks of Texas Instruments.

low drain-to-source on resistance of the MOSFET allows the TPS54550 to achieve high efficiencies and helps to keep the junction temperature low at high output currents. An external divider allows for an adjustable output voltage. External compensation components accommodate a wide range of output filter components. Additionally, the TPS54550 provides an enable input. The absolute maximum input voltage is 20 V.

Table 1. Input Voltage and Output Current Summary

EVM	INPUT VOLTAGE RANGE	OUTPUT CURRENT RANGE
TPS54550EVM-158	VIN = 6 V to 17 V	0 A to 5 A

1.2 Performance Specification Summary

A summary of the TPS54550EVM-158 performance specifications is provided in Table 2. Specifications are given for an input voltage of VIN = 12 V and an output voltage of 3.3 V, unless otherwise specified. The TPS54550EVM-158 is designed and tested for VIN = 6 V to 17 V. The ambient temperature is 25°C for all measurements, unless otherwise noted. Maximum input voltage for the TPS54550EVM-158 is 20 V.

Table 2. TPS54550EVM-158 Performance Specification Summary

SPECIFICATION		TEST CONDITIONS	MIN	TYP	MAX	UNIT
VIN voltage range			6	12 or 15	17	V
Output voltage set point				3.3		V
Output current range		V_{IN} = 10 V to 17 V	0		5	A
Line regulation		I_O = 0 2.5 A, VIN = 10 V - 17 V		+0.08 -0.03		%
Load regulation		VIN = 12 V, I_O = 0 A to 5 A		+0.07 -0.01		%
Load transient response	Voltage change	I_O = 1.25 A to 3.75 A		-72.5		mV
	Recovery time			450		µs
	Voltage change	I_O = 3.75 A to 1.25 A		+72.5		mV
	Recovery time			450		µs
Loop bandwidth		VIN = 12 V, I_O = 2.5 A		27		kHz
Phase margin		VIN = 12 V, I_O = 2.5 A		62		°
Input ripple voltage		VIN = 7 V, I_O = 5 A		276	300	mVpp
Output ripple voltage		VIN = 7 V, I_O = 5 A		7		mVpp
Output rise time				5		ms
Operating frequency				700		kHz
Max efficiency		VIN = 6 V, V_O = 3.3 V, I_O = 1.25 A		93.5%		

1.3 Modifications

The TPS54550EVM-158 is designed to demonstrate the small size that can be attained when designing with the TPS54550. A few changes can be made to this module.

1.3.1 Output Voltage Set Point

To change the output voltage of the EVM, it is necessary to change the value of resistor R2. Changing the value of R2 can change the output voltage above 0.891 V. The value of R2 for a specific output voltage can be calculated using Equation 1.

$$R2 = 10\ k\Omega \times \frac{0.891\ V}{V_O - 0.891\ V} \tag{1}$$

Table 3 lists the R2 values for some common output voltages. Note that VIN must be in a range so that the minimum on-time is greater than 220 ns, and the maximum duty cycle is less than 80%. The values given in Table 3 are standard values, not the exact value calculated using Equation 1.

Table 3. Output Voltages Available

Output Voltage (V)	R_2 Value (kΩ)
1.8	9.76
2.5	5.49
3.3	3.74
5	2.15

1.3.2 Input Voltage Range

The EVM is designed to operate from a nominal 12 V or 15 V with a working operating range of 6-V to 17-V input voltage. The TPS54550 is specified to operate over an input voltage range of 4.5 V to 20 V. The upper voltage limit of 17 V is due to minimum on time restrictions to guarantee 3.3-V output.

2 Test Setup and Results

This section describes how to properly connect, set up, and use the TPS54550EVM-158 evaluation module. The section also includes test results typical for the TPS54550EVM-158 and covers efficiency, output voltage regulation, load transients, loop response, output ripple, input ripple, and start-up.

2.1 Input / Output Connections

The TPS54550EVM-158 is provided with input/output connectors and test points as shown in Table 4. A power supply capable of supplying 3 A should be connected to J1 through a pair of 20 AWG wires. The load should be connected to J3 through a pair of 20 AWG wires. The maximum load current capability should be 5 A. Wire lengths should be minimized to reduce losses in the wires. Test-point TP1 provides a place to monitor the VIN input voltages with TP2 providing a convenient ground reference. TP3 is used to monitor the output voltage with TP4 as the ground reference.

Table 4. EVM Connectors and Test Points

Reference Designator	Function
J1	VIN, 12 V nominal, 6 V to 17 V
J2	OUT, 5 V at 5 A maximum
J3	2-pin header for bi-directional synchronization signal.
J4	2-pin header for enable. Connect EN to ground to disable, open to enable.
TP1	VIN test point at VIN connector
TP2	GND test point at VIN
TP3	Output voltage test point at OUT connector
TP4	GND test point at OUT connector
TP5	Test point between voltage divider network and R3. Used for loop response measurements.
TP6	Test point on power-good pullup resistor. Tie to 3.3 V or 5 V if power-good signal is used.
TP7	Test point for power good.
TP8	Test point for external UVLO.
TP9	Test point for timing resistor.

2.2 Efficiency

The TPS54550EVM-158 efficiency peaks at load current of about 1 A to 3 A, depending on input voltage, and then decreases as the load current increases towards full load. Figure 1 shows the efficiency for the TPS54550EVM-158 at an ambient temperature of 25°C. The efficiency is lower at higher ambient temperatures, due to temperature variation in the drain-to-source resistance of the MOSFETs.

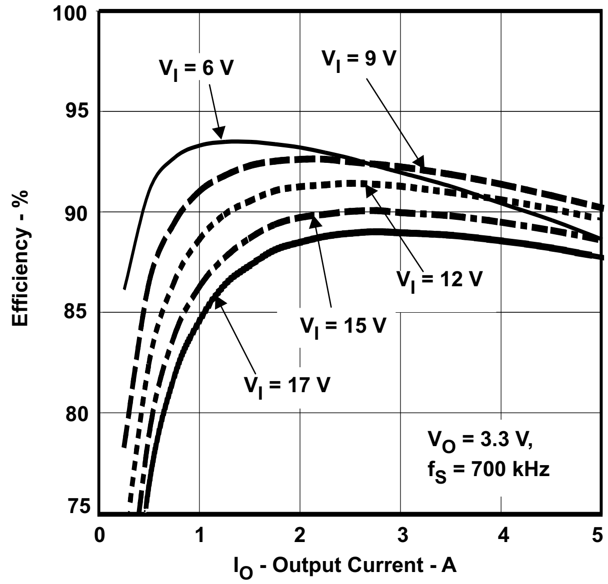


Figure 1. Measured Efficiency, TPS54550

2.3 Output Voltage Regulation

The output voltage load regulation of the TPS54550EVM-158 is shown in Figure 2; the output voltage line regulation is shown in Figure 3. Measurements are given for an ambient temperature of 25°C.

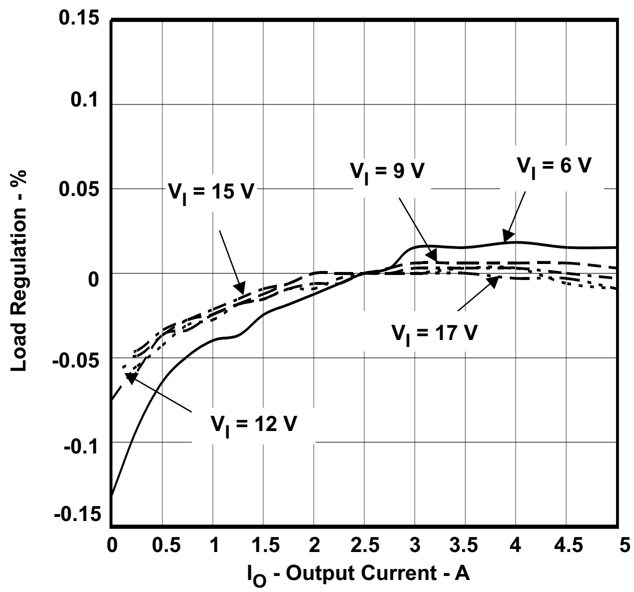


Figure 2. Load Regulation

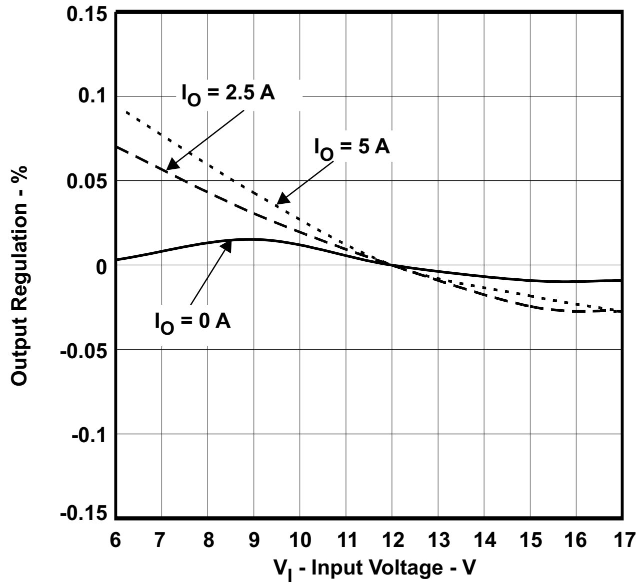


Figure 3. Line Regulation

2.4 Load Transients

The TPS54550EVM-158 response to load transients is shown in Figure 4. The current step is from 25% to 75% of maximum rated load. Total peak-to-peak voltage variation is as shown, including ripple and noise on the output.

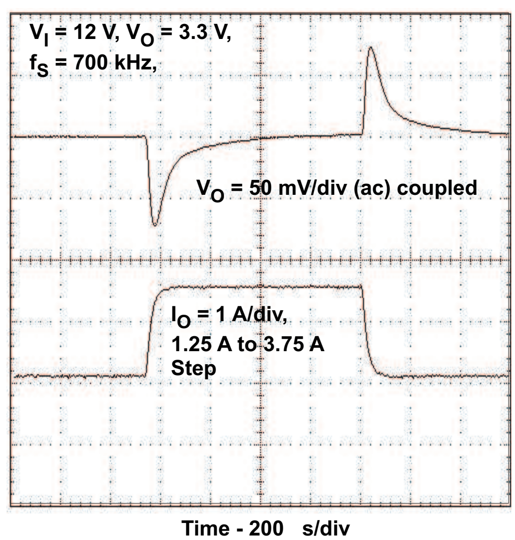


Figure 4. Load Transient Response, TPS54550

2.5 Loop Characteristics

The TPS54550EVM-158 loop-response characteristics are shown in Figure 5. Gain and phase plots are shown for VIN voltage of 12 V and load current of 2.5 A.

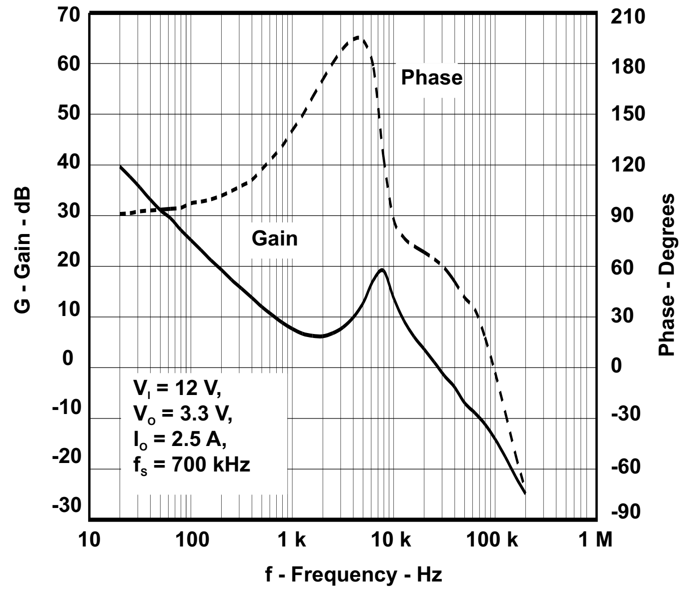
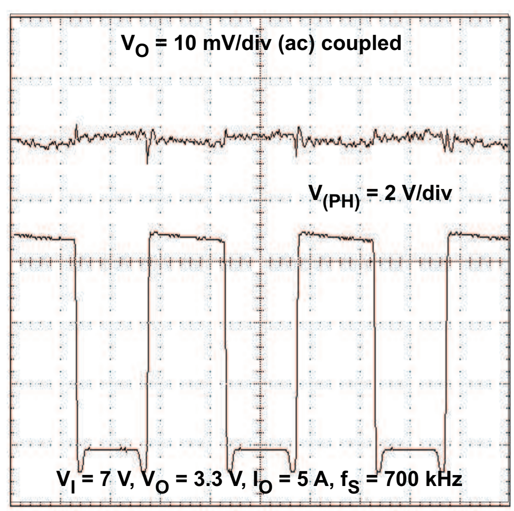


Figure 5. Measured Loop Response, TPS54550, VIN = 12 V

2.6 Output Voltage Ripple

The TPS54550EVM-158 output voltage ripple is shown in Figure 6. The input voltage is VIN = 12 V for the TPS54550. Output current is the rated full load of 5 A. Voltage is measured directly across output capacitors.



Time - 500 ns/div

Figure 6. Measured Output Voltage Ripple, TPS54550

2.7 Input Voltage Ripple

The input voltage ripple is shown in Figure 7. The input voltage is VIN = 12 V for the TPS54550. Output current for each device is at full rate TPS54550EVM-158 load of 5 A.

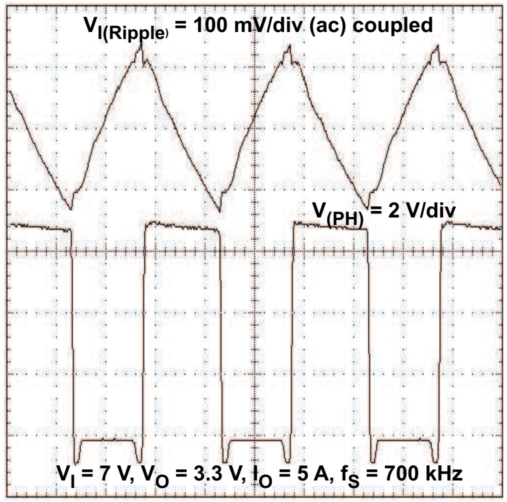


Figure 7. Input Voltage Ripple, TPS54550

2.8 Powering Up

The TPS54550EVM-158 start-up waveforms are shown in Figure 8. The top trace shows VIN whereas the bottom trace shows OUT. Vin charges up from 0 V toward 12 V. When the input voltage reaches the internally set UVLO threshold voltage, the slow-start sequence begins. After a delay, the internal reference begins to ramp up linearly at the internally set slow-start rate towards 0.891 V, and the output ramps up toward the set voltage of 5 V. The output may be inhibited by using a jumper at JP1 to tie EN to GND. When the jumper is removed, EN is released and the slow-start voltage begins to ramp up at the internally set rate. When the EN voltage reaches the enable-threshold voltage of 1.06 V, the start-up sequence begins as described previously.

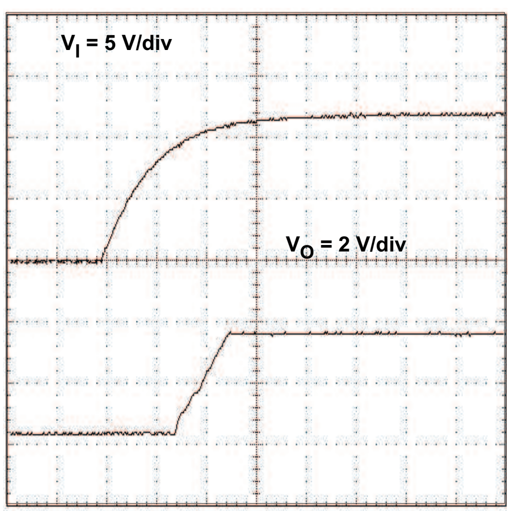


Figure 8. Power Up, OUT Relative to VIN

3 Board Layout

This section provides a description of the TPS54550EVM-158 board layout and layer illustrations.

3.1 Layout

The board layout for the TPS54550EVM-158 is shown in Figure 9 through Figure 11. The topside layer of the TPS54550EVM-158 is laid out in a manner typical of a user application. The top and bottom layers are 2-oz. copper.

The top layer contains the main power traces for VIN, OUT, and VPHASE. Also on the top layer are connections for the remaining pins of the TPS54550 and a large area filled with ground. The bottom layer contains ground and some signal routing. The top and bottom and internal ground traces are connected with multiple vias placed around the board including four vias directly under the TPS54550 device to provide a thermal path from the PowerPAD™ land to ground.

The input decoupling capacitor (C1) and bootstrap capacitor (C3) are all located as close to the IC as possible. In addition, the voltage set-point resistor divider components are also kept close to the IC. The voltage divider network ties to the output voltage at the point of regulation, adjacent to the output capacitor C3.

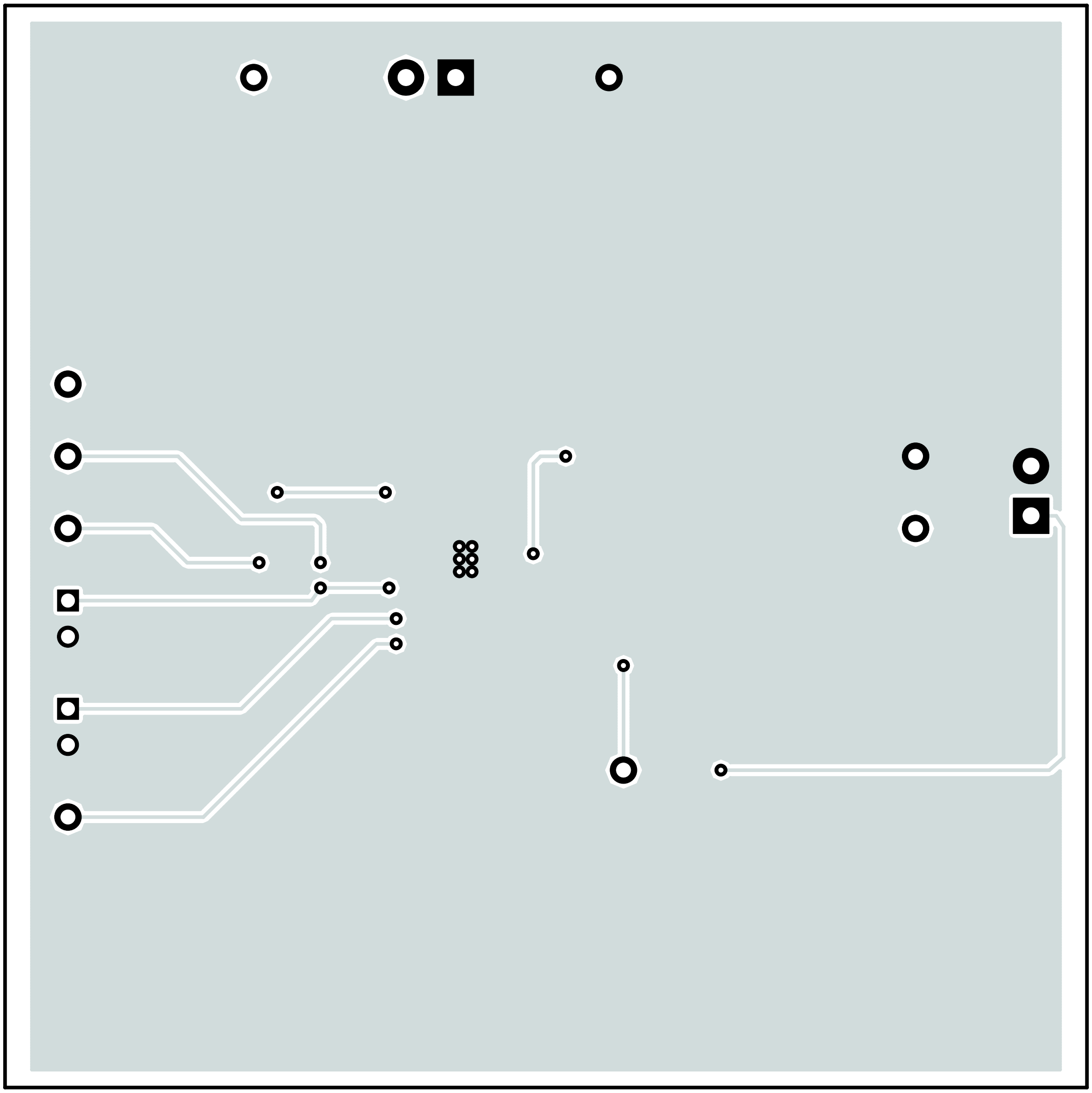


Figure 9. Top-Side Layout

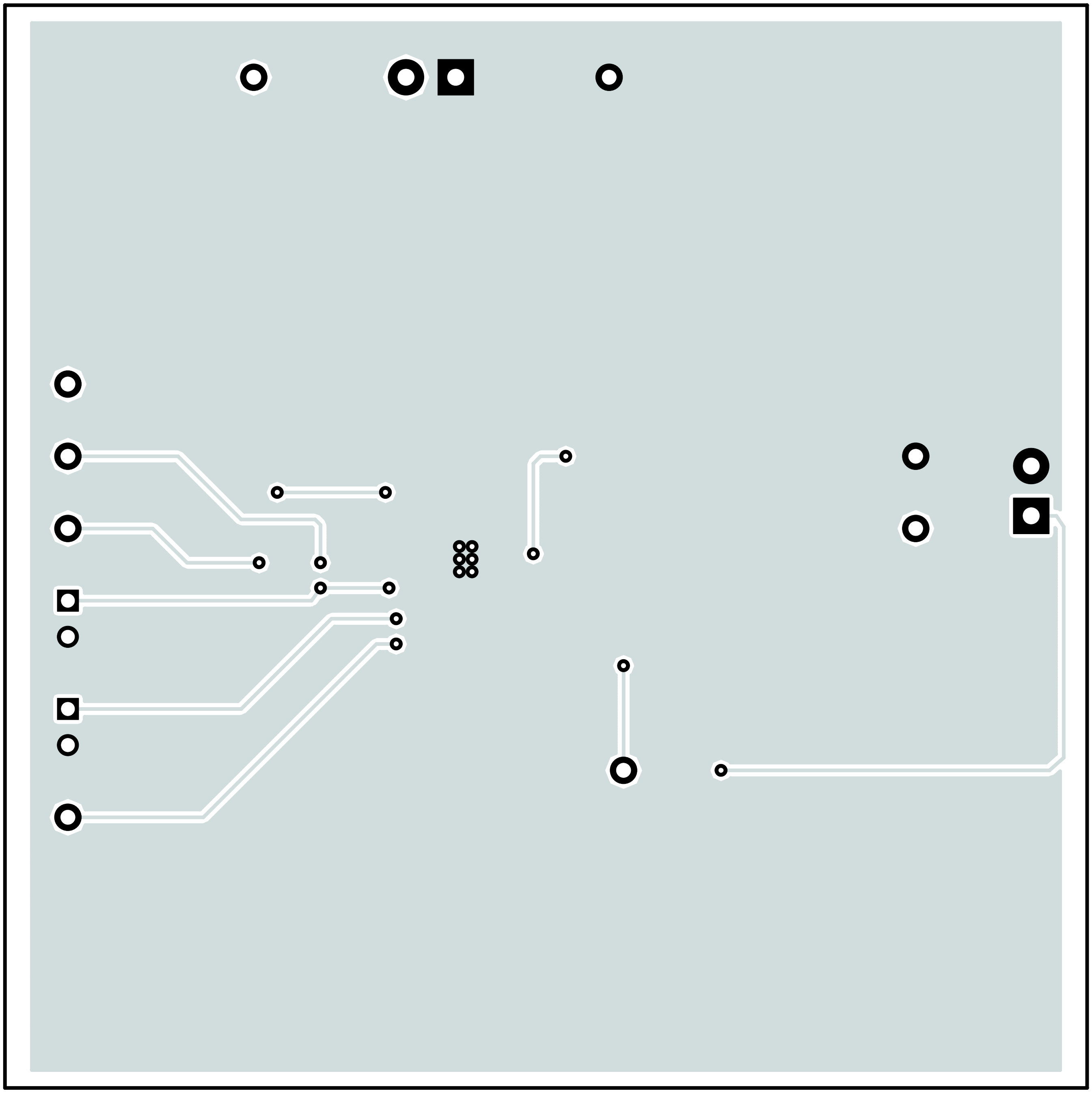


Figure 10. Bottom-Side Layout (Looking From Top Side)

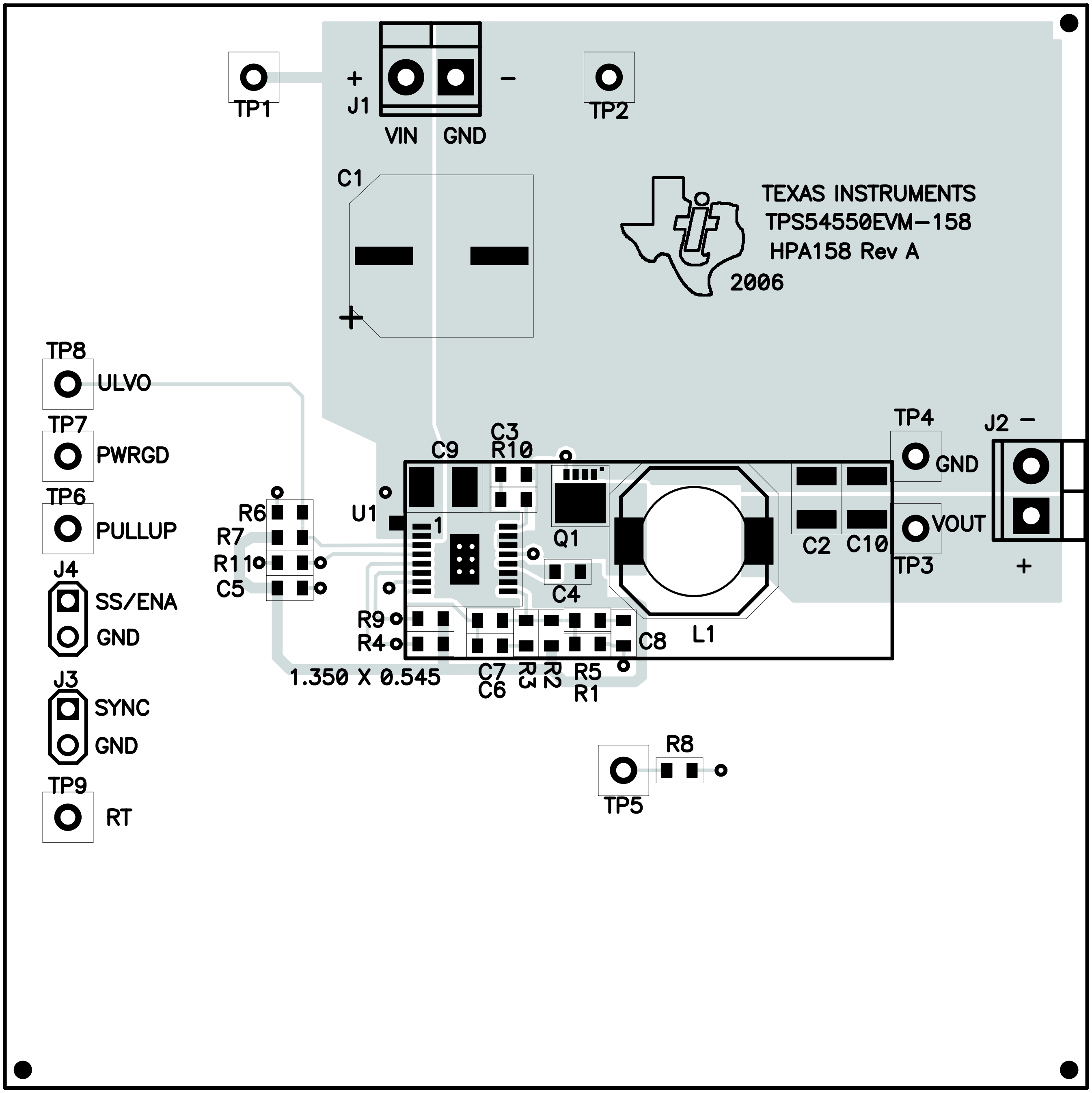


Figure 11. Top-Side Assembly

4 Schematic and Bill of Materials

The TPS54550EVM-158 schematic and bill of materials are presented in this section.

4.1 Schematic

The schematic for the TPS54550EVM-158 is shown in Figure 12.

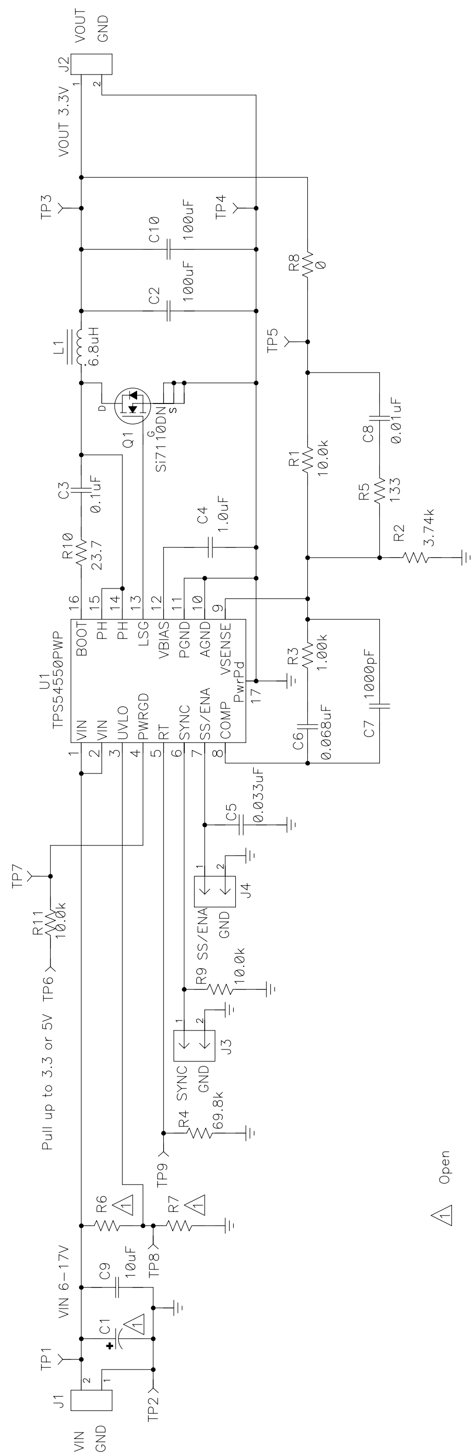


Figure 12. TPS54550EVM-158 Schematic

4.2 Bill of Materials

The bill of materials for the TPS54550EVM-158 is given by Table 5.

Table 5. TPS54550EVM-158 Bill of Materials

Count	REF DES	Value	Description	Size	Part Number	MFR
0	C1	Open	Capacitor, Aluminum, SM	10×12mm		
2	C2, C10	100 μF	Capacitor, Ceramic, 6.3V, X5R, 20%	1210	C3225X5R0J107M	TDK
1	C3	0.1 μF	Capacitor, Ceramic, 25V, X5R, 10%	0603	C1608X5R1E104KB	TDK
1	C4	1.0 μF	Capacitor, Ceramic, 25V, X5R, 10%	0603	C1608X5R1E105KB	TDK
1	C5	0.033 μF	Capacitor, Ceramic, 50V, X5R, 10%	0603	C1608X5R1H333KB	TDK
1	C6	0.068 μF	Capacitor, Ceramic, 50V, X5R, 10%	0603	C1608X5R1H683KT	TDK
1	C7	1000pF	Capacitor, Ceramic, 50V, C0G, 5%	0603	C1608C0G1H102JB	TDK
1	C8	0.01 μF	Capacitor, Ceramic, 50V, X5R, 10%	0603	C1608X5R1H103KB	TDK
1	C9	10 μF	Capacitor, Ceramic, 16V, X5R, 20%	1210	C3225X5R1C106M	TDK
2	J1, J2		Terminal Block, 2 pin, 6A, 3,5 mm	0.27 × 0.25	ED1514	OST
2	J3, J4		Header, 2 pin, 100 mil spacing, (36-pin strip)	0.100 × 2	PTC36SAAN	Sullins
1	L1	6.8 μH	Inductor, SMT, 5.4A, 14 mΩ	0.405 sq inch	CDRH105R-6R8	Sumida
1	Q1		MOSFET, Fast Switching, NChan, 20V, 21.1A, 5.3 mΩ	PWRPAK 1212	Si7110DN	Vishay
3	R1, R9, R11	10.0k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R10	23.7	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R2	3.74k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R3	1.00k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R4	69.8k	Resistor, Chip, 1/16W, 1%	0603	Std	Std
1	R5	133	Resistor, Chip, 1/16W, 1%	0603	Std	Std
0	R6, R7		Open Resistor, Chip, 1/16W, 1%	0603		
1	R8	0	Resistor, Chip, 1/16W, 1%	0603	Std	Std
7	TP1, TP3, TP5, TP6–TP9		Test Point, Red, Thru Hole Color Keyed	0.100 × 0.100	5000	Keystone
2	TP2, TP4		Test Point, Black, Thru Hole Color Keyed	0.100 × 0.100	5001	Keystone
1	U1		IC, 4.5 to 20V Input, 6A Step down converter with adjustable output voltage	PWP16	TPS54550PWP	TI
1	–		PCB, 3 In × 3 In × 0.062 In		HPA158	Any

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.

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.

EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 10.8 V to 19.8 V and the output voltage range of 1.3 V to 5 V.

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 55°C. The EVM is designed to operate properly with certain components above 60°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
Copyright © 2006, Texas Instruments Incorporated

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.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Telephony	www.ti.com/telephony
Low Power Wireless	www.ti.com/lpw	Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2007, Texas Instruments Incorporated