

## **TPS68000EVM-161**

This user's guide describes the characteristics, operation, and use of the TPS68000EVM evaluation module (EVM). This EVM is designed to help the user easily evaluate and test the operation and functionality of the TPS68000. This document includes setup instructions for the hardware, a schematic diagram, a bill of materials (BOM), and PCB layout drawings for the EVM.

### **Contents**

1	Introduction .....	1
2	Setup and Results .....	2
3	Board Layout .....	7
4	Schematic and Bill of Materials .....	10

### **List of Figures**

1	Turn ON Into 330-mm Lamp, Voltage at 500 V/div .....	4
2	Output Voltage and Vsen Test Point 14, Divide Ratio 1:820 .....	5
3	Output Current and Csen Test Point 13, Divide Ratio 1 V:2.55 mA .....	6
4	Burst Dimming Current at 50% Duty Cycle .....	7
5	Assembly Layer .....	8
6	Top Layer Routing .....	9
7	Bottom Layer Routing .....	10
8	TPS68000EVM-161, U1 Schematic .....	11
9	TPS68000EVM-161, U2 Schematic .....	12

### **List of Tables**

1	Performance Specification Summary .....	2
2	U1 With 300-mm Lamp .....	6
3	U2 With 360-mm Lamp .....	6
4	TPS68000EVM-161 Bill of Materials .....	13

## **1 Introduction**

The Texas Instruments TPS68000EVM-161 evaluation module (EVM) helps designers evaluate the operation and performance of the TPS68000 cold cathode fluorescent lamp (CCFL) controller. The TPS68000EVM-161 EVM is a fully functional DC/AC inverter module used to drive a single CCFL lamp. The upper section demonstrates a small layout whereas the larger lower section allows access to all features of the TPS68000. This EVM operates from an input supply of 8 V to 22 V and generates up to 600 Vrms at 6 mArms. Lamp current is fixed at 6 mArms by resistor value, and output voltage is determined by CCFL. This output is typical of a 300-mm length CCFL, reference JKL Components BF3300-208.

---

**Note:** As with all CCFL inverters, high AC voltages are present on outputs, and care should be taken to avoid shock hazards and equipment damage.

---

## 1.1 Background

The TPS68000EVM-161 uses the TPS68000 version. Other versions with additional features are available; consult the data sheet. The input voltage range of the TPS68000 is greater than the limits of this EVM. Additional lower input voltage configurations are also possible. Output voltage and current are a function of transformer and circuit design

## 1.2 Performance Specification

**Table 1** provides a summary of the TPS68000EVM-161 performance specifications. All specifications are given for an ambient temperature of 25°C.

**Table 1. Performance Specification Summary**

SPECIFICATION	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage		8		22	V
Input current		200		500	mA
Output current			6		mArms
Output voltage			665		Vrms
Efficiency			80%		
Strike voltage			1500		Vrms
Open-lamp delay			1.6		s
Operating frequency			56		kHz
Burst dimming frequency			100		Hz
Burst dimming range		0		2	V
Analog dimming range		0		2.3	V

## 1.3 Modifications

The U2 lower section has the option for two additional outputs at TP21 and TP22. These outputs do not have voltage applied until C31 and C30 are installed. TP21 and TP22 are used to demonstrate a dual-lamp configuration with a common return at TP12.

Typical values for C31 and C30 are 33 pF to 15 pF, respectively. Input voltage range of the IC is 8 V to 30 V but is limited to a Vin of 22 V due to the voltage ratings of input capacitors and switch FETs.

### 1.3.1 Burst Dimming Adjustment

R7 adjusts the burst dimming of U2 to increase or decrease brightness. On-time of the lamp is changed at a fixed frequency to vary brightness. C17 sets the frequency at 100 Hz. Full counter-clockwise setting of R7 is maximum brightness and full clockwise is minimum brightness. Voltage can be monitored at J5. Dimming voltage range is 2 V to 0 V. Note that at low settings of the lamp, on-time flicker may appear due to lamp strike characteristics.

### 1.3.2 Analog Dimming Adjustment

R8 adjusts the analog dimming of U2 to increase or decrease brightness. The lamp current regulation point is changed to vary brightness. R16 sets the lamp current is to normally 6 mArms. A full counter-clockwise setting of R8 is maximum brightness and full clockwise setting of R8 is minimum brightness. Voltage can be monitored at J6. The dimming voltage range is 3.3 V to 0 V. Note that typically when the lamp current is reduced to less than 3 mArms, performance is degraded.

## 2 Setup and Results

This section describes how to properly use the TPS68000EVM-161.

## 2.1 Input/Output Connector and Header Descriptions

J1–Vin	Power supply positive input for U1
J2 – GND	Power supply return input for U1
TP3–HV	High-voltage AC output to lamp, U1
TP4–HV	RTN high-voltage lamp return from lamp, U1
TP1–BC	Burst dimming input, U1
TP2–FAULT	Fault output open-collector signal, U1
JP1–EN	Enable input, OFF and ON setting, no jumper is ON, U1
TP15–OCP	Overcurrent protection test point, transformer primary current, U1
TP17–VSEN	Voltage-sense test point, output voltage divider sample voltage, U1
TP16–CSEN	Current-sense test point, lamp return current-sense resistor, U1
TP20–GND	Ground test point for TP15, TP16, and TP17, U1
J3–Vin	Power supply positive input for U2
J4–GND	Power supply return input for U2
TP11–HV	High-voltage AC output to lamp, U2
TP12–HV	RTN high-voltage lamp return from lamp, U2
J5–BBR	Burst dimming voltage set by R7 or input, U2
J6–ABR	Analog burst dimming voltage set by R8 or input, U2
TP6–BC	Burst dimming input, U2
TP5–GND	Ground located near TP6, U2
TP9–SYNC	Synchronous output from U2
TP8–GND	Ground located near TP9, U2
JP7–FAULT	Fault output open-collector signal, U2
JP2–EN	Enable input, OFF and ON setting, no jumper is ON, U2
TP10–OCP	Overcurrent protection test point, transformer primary current, U2
TP14–VSEN	Voltage-sense test point, output voltage divider sample voltage, U2
TP13–CSEN	Current-sense test point, lamp return current-sense resistor, U2
TP7–GND	Ground test point for TP10, TP14, and TP13, U2
TP18–SA	Transformer primary, U2
TP19–SC	Transformer primary, U2
TP21–HV	HV to lamp if C31 is installed, U2
TP22–HV	HV to lamp if C30 is installed, U2

## 2.2 Setup

### CAUTION

High AC voltage is present at the output terminals when input voltage is applied; all connections should be made with the input supply off.

## Setup and Results

Do not place the EVM or the lamp on a conductive surface. Do not run output leads across the EVM or input voltage leads.

The power supply input should be at J1/J2 for U1 top section. The lower section U2 power input is J3/J4.

Each section is power-independent of the other. The minimum setup requires an input power supply and load. The input supply range is 10 V to 20 V. Lamp loads can be as short as 100 mm or up to 300 mm.

JP1 or JP2 EN can be used to turn the unit ON or OFF.

## 2.3 Power Up

During power up, the lamp will strike, then go into a current regulation mode. During lamp strike, the lamp has a high resistance because there is no ionization of gas. The voltage required to strike the lamp is 2X normal operation. Once current is flowing in the lamp, the TPS68000 transitions to a current regulation mode.

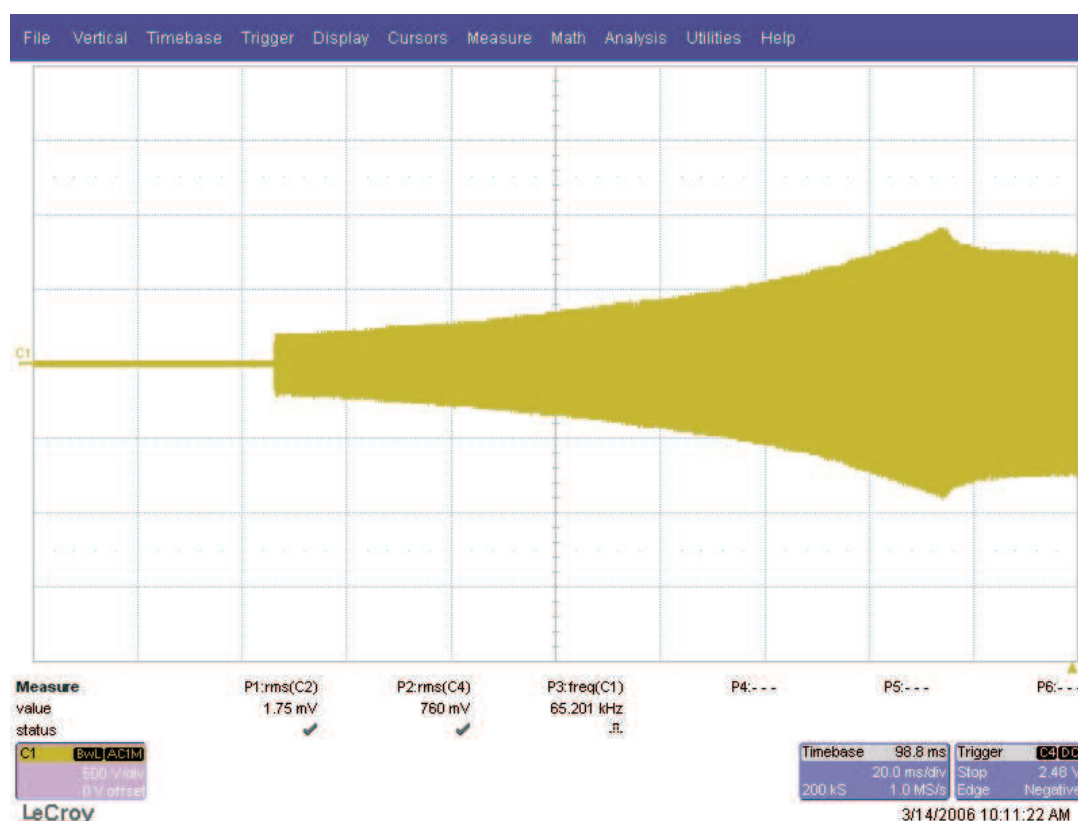


Figure 1. Turn ON Into 330-mm Lamp, Voltage at 500 V/div

## 2.4 Output Current and Voltage

Output current and voltage during normal operation see from the lamp. Also from Vsen and Csen test points.

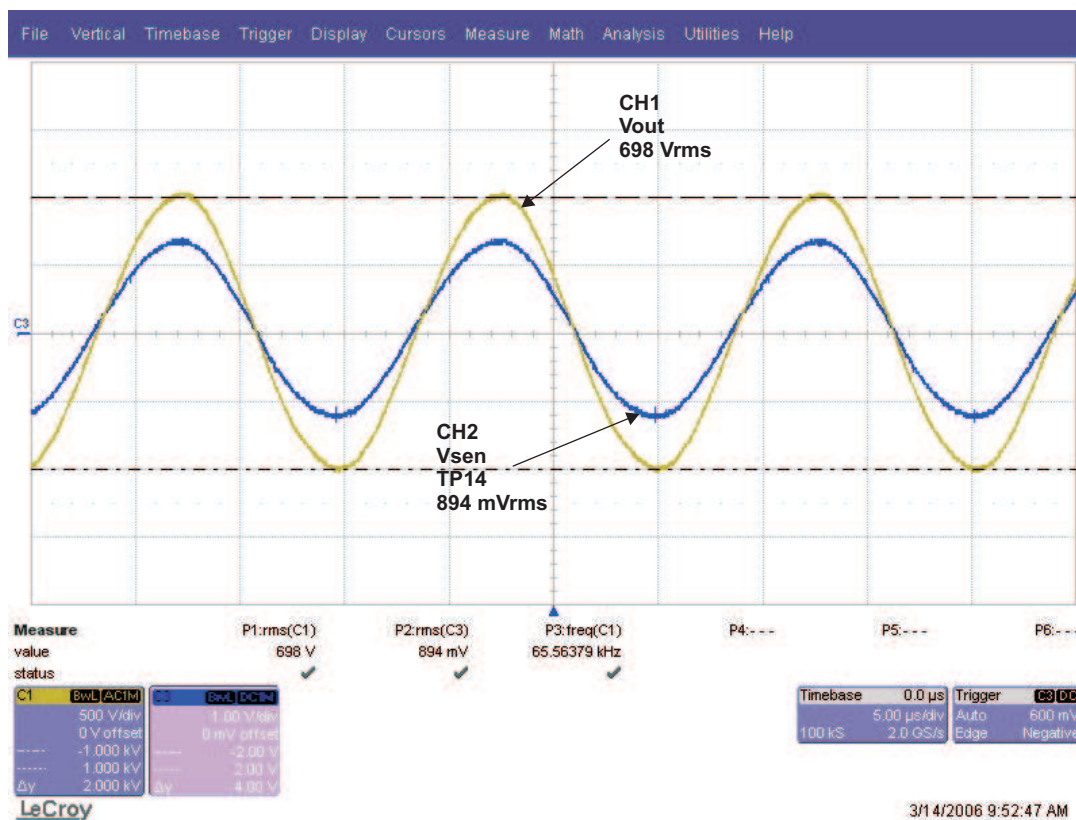


Figure 2. Output Voltage and Vsen Test Point 14, Divide Ratio 1:820

## Setup and Results

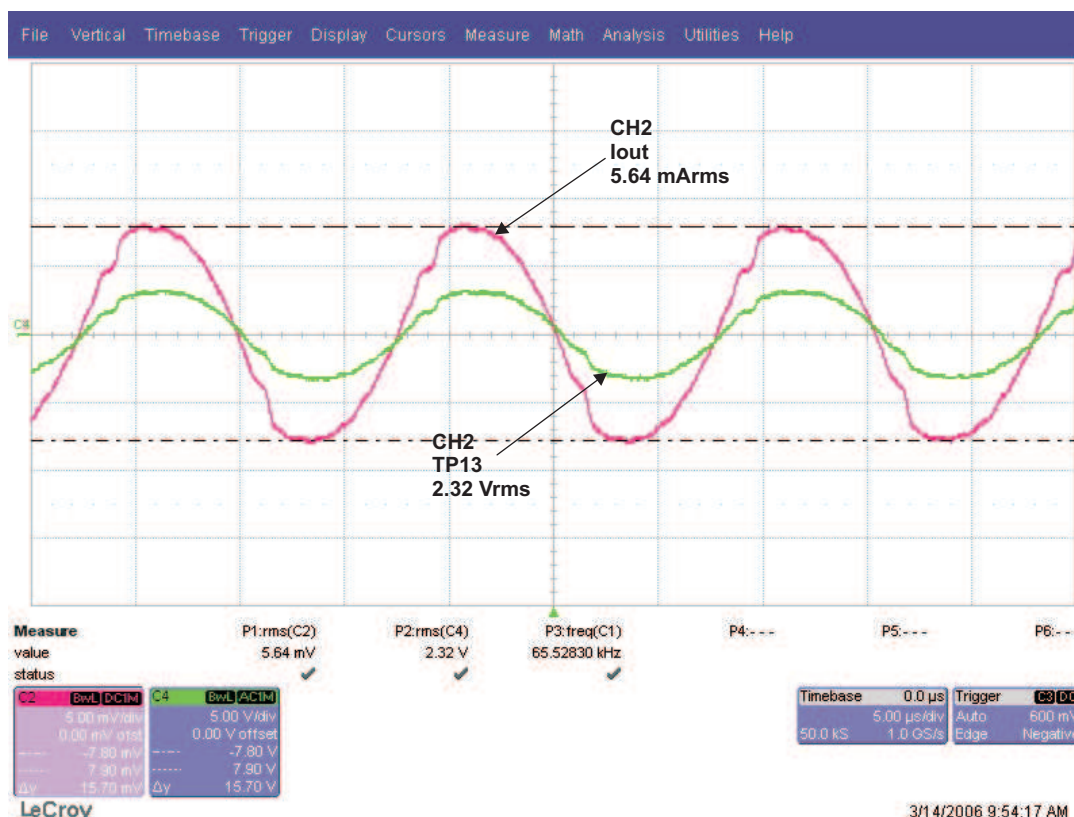


Figure 3. Output Current and Csen Test Point 13, Divide Ratio 1 V:2.55 mA

## 2.5 Efficiency/Power Dissipation

With high efficiency, the power to be dissipated is low.

Table 2. U1 With 300-mm Lamp

Vin	Iin	Vout	Iout	PWR IN	PWR OUT	Efficiency
12	0.364	609	5.63	4.37	3.43	78.50
8	0.545	607	5.63	4.36	3.42	78.38
22	0.202	607	5.68	4.44	3.45	77.58

Table 3. U2 With 360-mm Lamp

Vin	Iin	Vout	Iout	PWR IN	PWR OUT	Efficiency
12	0.432	721	5.63	5.18	4.06	78.30
18	0.285	722	5.62	5.13	4.06	79.10
22	0.234	720	5.62	5.15	4.05	78.60

## 2.6 Burst Dimming

R7 controls burst dimming. Adjustment range is 2 V to 0 V. Below setting is 1 V for 50% duty cycle. Note the reduced soft start at turn on.

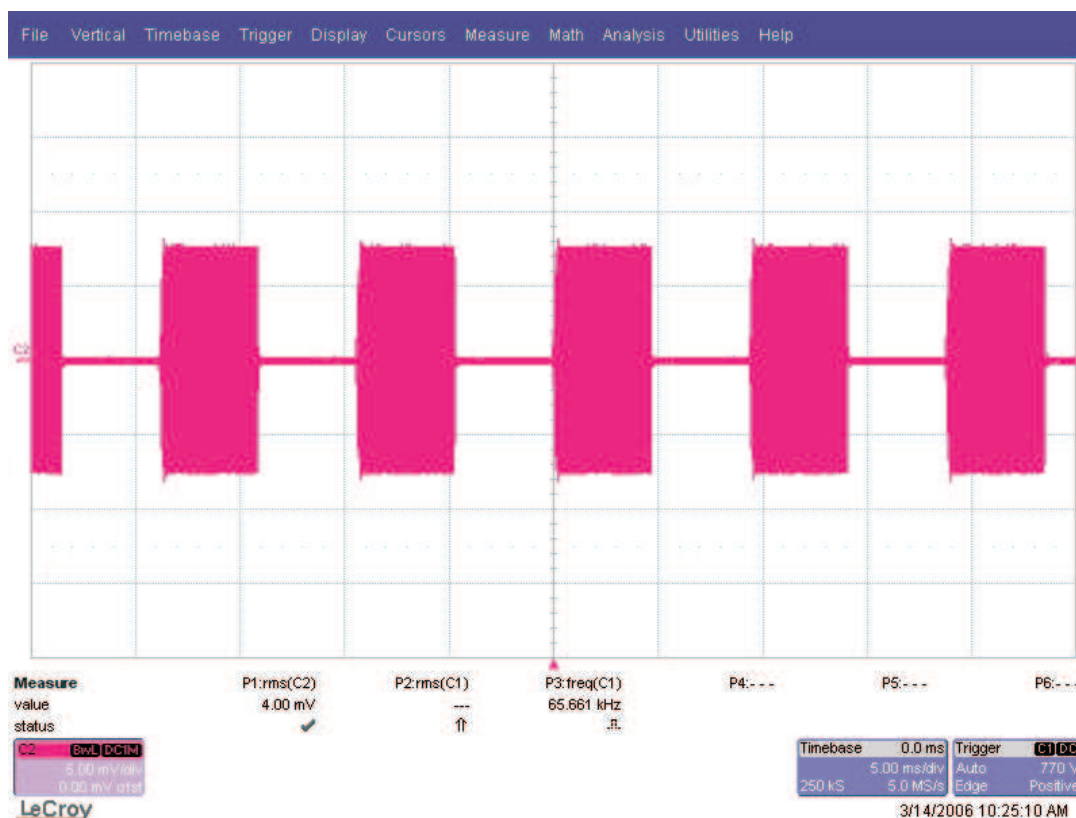


Figure 4. Burst Dimming Current at 50% Duty Cycle

## 3 Board Layout

This section provides the TPS68000EVM-161 board layout and illustrations.



### 3.1 Layout

Figure 5, Figure 6, and Figure 7 show the board layout for the TPS68000EVM-161 PCB.

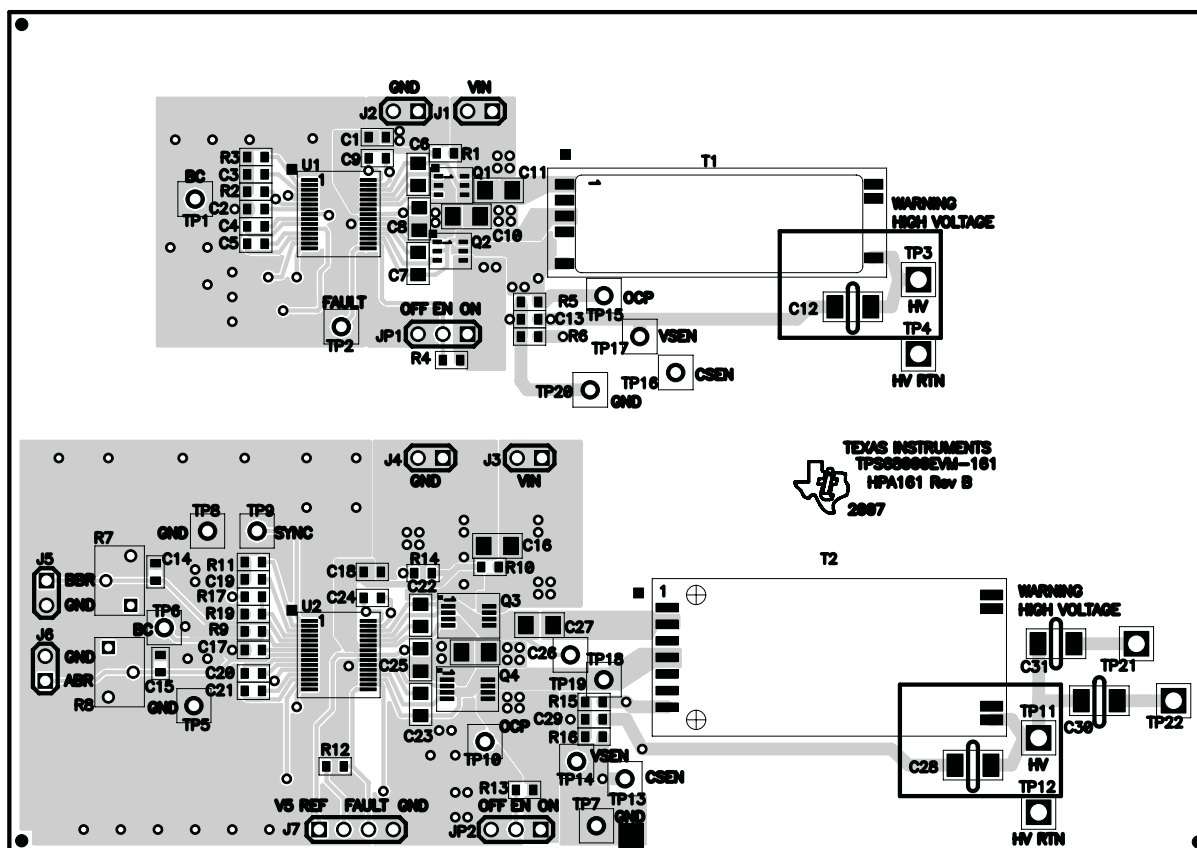


Figure 5. Assembly Layer



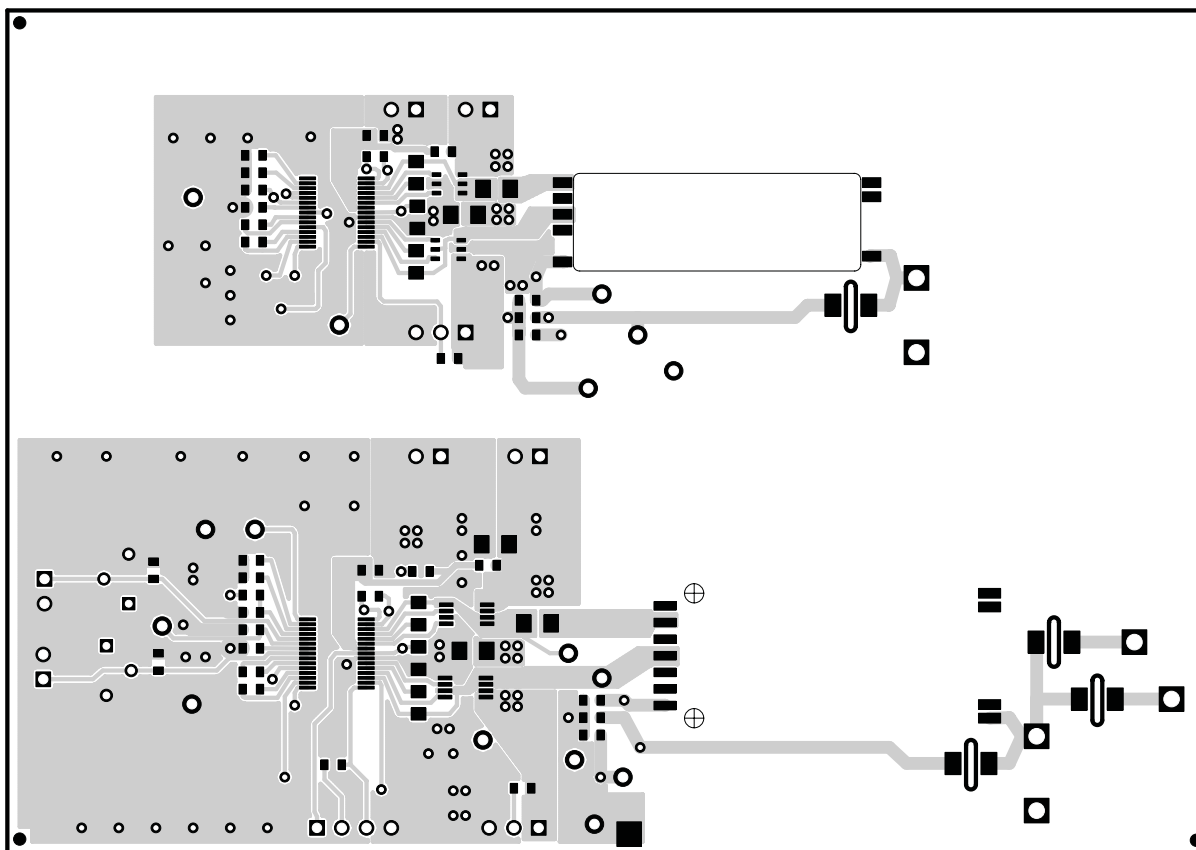
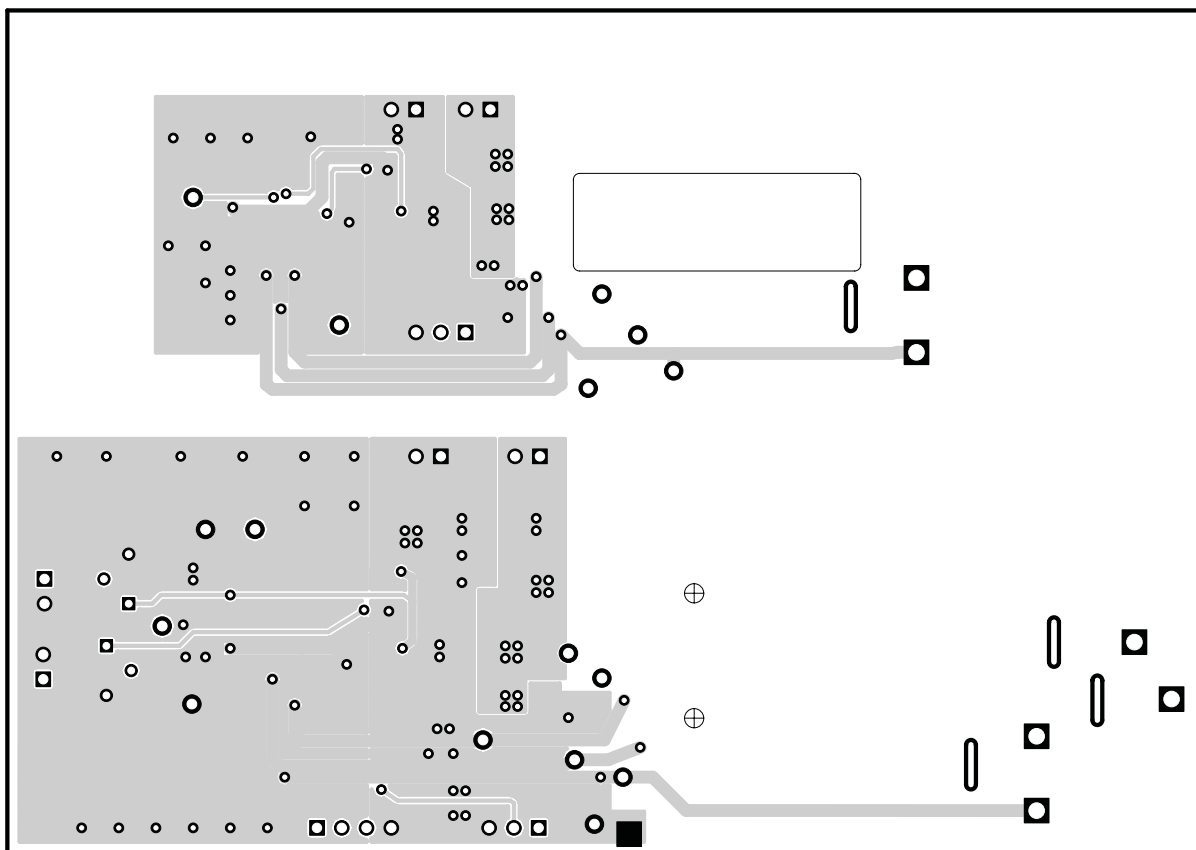


Figure 6. Top Layer Routing



**Figure 7. Bottom Layer Routing**

#### **4 Schematic and Bill of Materials**

This section provides the TPS68000EVM-161 schematic and bill of materials.

## 4.1 Schematic

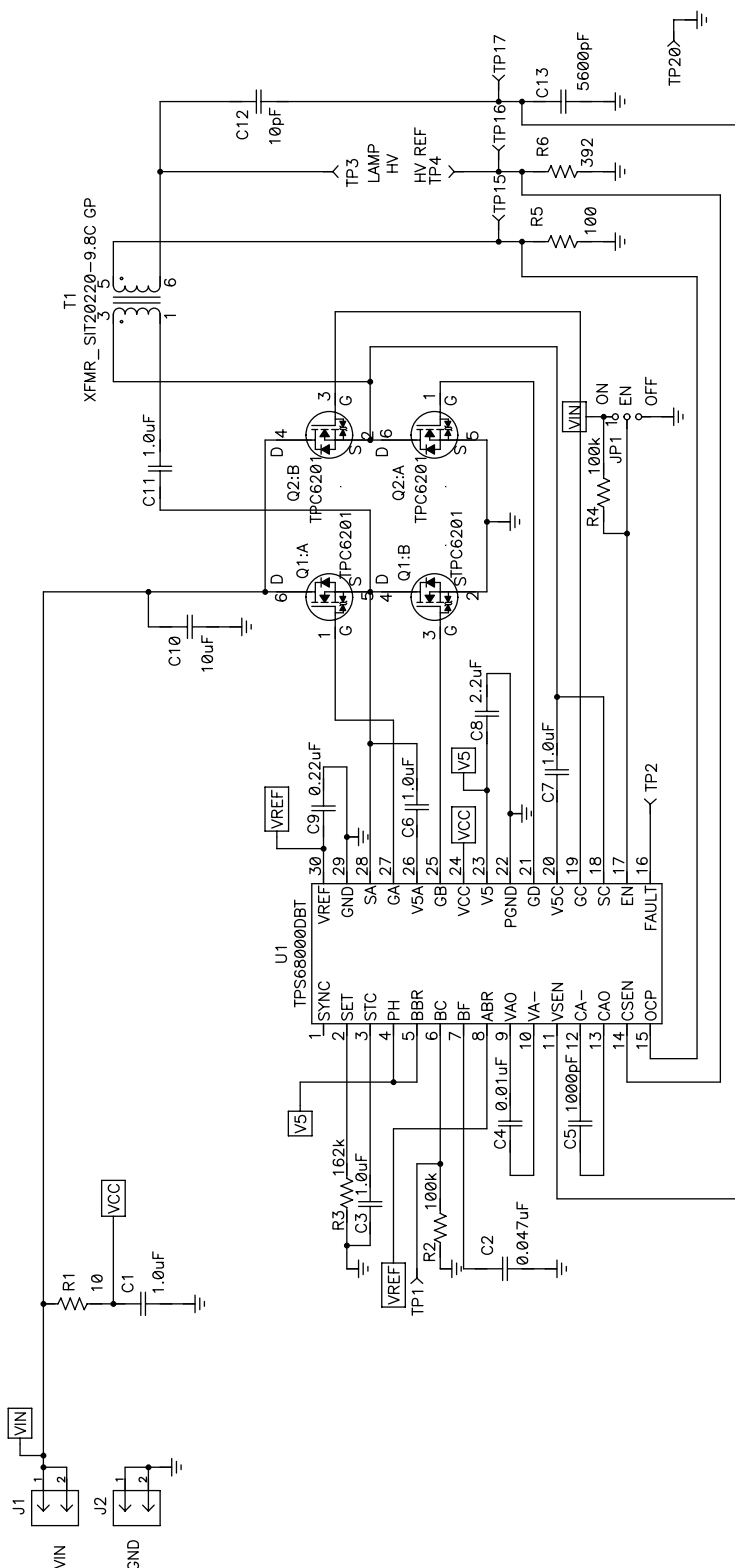


Figure 8. TPS68000EVM-161, U1 Schematic

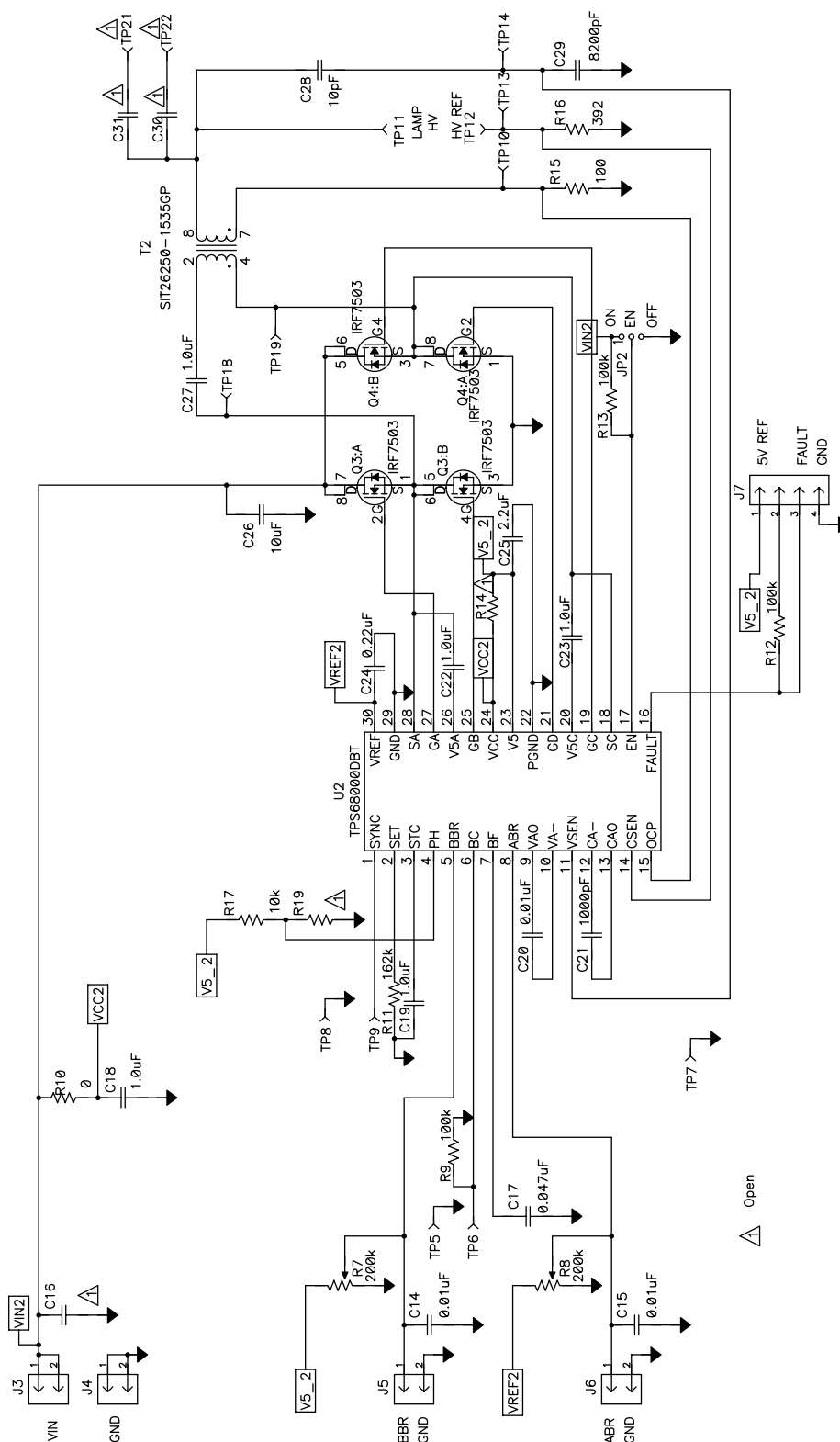


Figure 9. TPS68000EVM-161, U2 Schematic

## 4.2 Bill of Materials

**Table 4. TPS68000EVM-161 Bill of Materials**

Count	Ref Des	Value	Description	Size	Part Number	MFR
4	C1, C3, C18, C19	1 $\mu$ F	Capacitor, ceramic, 25-V, X5R, 10%	0603	C1608X5R1E105K	TDK
2	C10, C26	10 $\mu$ F	Capacitor, ceramic, 25-V, X5R, 10%	1206	C3216X5R1E106K	TDK
2	C11, C27	1 $\mu$ F	Capacitor, ceramic, 50-V, X7R, 10%	1206	C3216X7R1H105K	TDK
2	C12, C28	10 pF	Capacitor, 3-kV, C0G, $\pm$ 1 pF		C4520C0G3F100F	TDK
1	C13	5600 pF	Capacitor, ceramic, 50-V, X7R, 10%	0603	GRM188R71H562KA01	Murata
4	C4, C14, C15, C20	0.01 $\mu$ F	Capacitor, ceramic, 25-V, X5R, 10%	0603	C1608X5R1E103KB	TDK
0	C16	Open	Capacitor, ceramic, vvV	1206		
2	C2, C17	0.047 $\mu$ F	Capacitor, ceramic, 50-V, X7R, 10%	0603	C1608X7R1H473KB	TDK
1	C29	8200 pF	Capacitor, ceramic, 50-V, X7R, 10%	0603	GRM188R71H822KA01	Murata
0	C30, C31		Capacitor			
2	C9, C24	0.22 $\mu$ F	Capacitor, ceramic, 16-V, X5R, 10%	0603	C1608X5R1C224KB	TDK
2	C5, C21	1000 pF	Capacitor, ceramic, 50-V, X5R, 10%	0603	C1608X5R1H102KB	TDK
4	C6, C7, C22, C23	1 $\mu$ F	Capacitor, ceramic, 25-V, X7R, 10%	0805	C2012X7R1E105K	TDK
2	C8, C25	2.2 $\mu$ F	Capacitor, ceramic, 25-V, X5R, 10%	0805	C2012X5R1E225K	TDK
6	J–J6		Header, 2-pin, 100-mil spacing, (36-pin strip)		PTC36SAAN	Sullins
1	J7		Header, 4 pin, 100-mil spacing, (36-pin strip)		PTC36SAAN	Sullins
2	JP1, JP2		Header, 3 pin, 100-mil spacing, (36-pin strip)		PTC36SAAN	Sullins
2	Q1, Q2		MOSFET, N-Ch, 30-V, 2.5-A	2-3T1B	TPC6201	Toshiba
2	Q3, Q4		XSTR, MOSFET, N-Ch, 30-V, 2.4-A, Rds 0.135- $\Omega$	TSSOP8-MICRO8	IRF7503	IR
1	R1	10 $\Omega$	Resistor, chip, 1/16-W, 1%	0603	Std	Std
1	R10	0 $\Omega$	Resistor, chip, 1/16-W, 1%	0603	Std	Std
0	R14, R19	Open	Resistor, chip, 1/16-W, 1%	0603		
1	R17	10 k $\Omega$	Resistor, chip, 1/16-W, 1%	0603	Std	Std
5	R2, R4, R9, R12, R13	100 k $\Omega$	Resistor, chip, 1/16-W, 1%	0603	Std	Std
2	R3, R11	162 k $\Omega$	Resistor, chip, 1/16-W, 1%	0603	Std	Std
2	R5, R15	100 $\Omega$	Resistor, chip, 1/16-W, 1%	0603	Std	Std
2	R6, R16	392 $\Omega$	Resistor, chip, 1/16-W, 1%	0603	Std	Std
2	R7, R8	200 k $\Omega$	Potentiometer, 1/4 cermet	12-turn	3266W-1-204	Bourns
1	T1		Transformer, inverter LCD backlight		SIT20220-9.8C GP or G064199LF	Taipei Multipower or GCI Technologies
1	T2		Transformer, EFDL15 inverter		SIT26250-1535 GP or G064200LF	Taipei Multipower or GCI Technologies
12	TP1, TP2, TP6, TP9, TP10, TP13–TP19		Test point, red, thru-hole, color-keyed		5000	Keystone
0	TP21, TP22		Test point			
2	TP3, TP11		Test point, red, thru-hole, compact style		5005	Keystone
2	TP4, TP12		Test point, black, thru-hole, compact style		5006	Keystone
4	TP5, TP7, TP8, TP20		Test point, black, thru-hole, color keyed		5001	Keystone
2	U1, U2		IC, high efficient phase shift full bridge CCFL controller	TSSOP-30	TPS68000DBT	TI
1			PCB, 4.85-in. $\times$ 3.4-in. $\times$ 0.062-in. (12.32 cm $\times$ 8.64 cm $\times$ 1.58 mm)		HPA161	Any
2			Shunt, 100-mil (2.54-mm), black		929950-00	3M
4			Bump on, transparent		SJ5303	3M

## 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](http://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 8 V to 22 V and the output voltage range of 500 V to 1500 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 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  
Copyright © 2007, 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

Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
Low Power Wireless	<a href="http://www.ti.com/lpw">www.ti.com/lpw</a>

### Applications

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Broadband	<a href="http://www.ti.com/broadband">www.ti.com/broadband</a>
Digital Control	<a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a>
Military	<a href="http://www.ti.com/military">www.ti.com/military</a>
Optical Networking	<a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Telephony	<a href="http://www.ti.com/telephony">www.ti.com/telephony</a>
Video & Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>
Wireless	<a href="http://www.ti.com/wireless">www.ti.com/wireless</a>

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