LM20323

Application Note 1790 LM20323 Evaluation Board



Literature Number: SNVA324A

LM20323 Evaluation Board

National Semiconductor Application Note 1790 Dennis Hudgins October 1, 2008

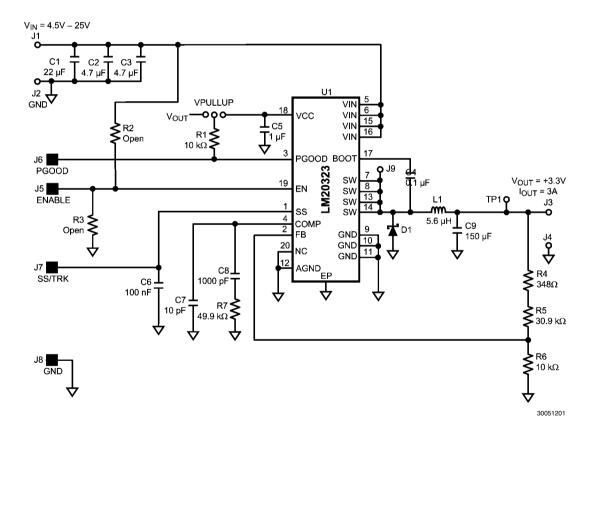


Introduction

This evaluation board provides a solution to examine the full featured LM20323 buck switching regulator that is capable of driving up to 3A of load current. This device features a 500 kHz fixed oscillator allowing the device to reach a good compromise between switching losses and inductor size. The LM20323 is capable of down converting from an input voltage between 4.5V and 36V. Fault protection features include cycle-by-cycle current limit, output power good, and output overvoltage protection. The dual function soft-start/tracking pin can be used to control the startup response of the LM20323, and the precision enable pin can be used to easily sequence the LM20323 in applications with sequencing requirements.

Evaluation Board Schematic

The LM20323 evaluation board has been optimized to work from 4.5V to 25V achieving a balance between overall solution size with the efficiency of the regulator. The evaluation board measures just under 2" x 2" on a four layer PCB, and exhibits a thermal characteristic of 27 °C/W with no air flow. The power stage and compensation components of the LM20323 evaluation board have been optimized for an input voltage of 12V, but for testing purposes, the input can be varied across the entire operating range. The output voltage of the evaluation board is nominally 3.3V, but this voltage can be easily changed by replacing one of the feedback resistors (R5 or R6).



AN-1790

Powering and Loading Considerations

Read this entire page prior to attempting to power the evaluation board.

QUICK SETUP PROCEDURE

Step 1: Set the input source current limit to 3A. Turn off the input source. Connect the positive output of the input source to J1 and the negative output to J2.

Step 2: Connect the load, with 3A capability, to J3 for the positive connection and J4 for the negative connection.

Step 3: The ENABLE pin, J5, should be left open for normal operation.

Step 4: Set the input source voltage to 12V and the load to 0.1A. The load voltage should be in regulation with a nominal 3.3V output.

Step 5: Slowly increase the load while monitoring the load voltage at J3 and J4. It should remain in regulation with a nominal 3.3V output as the load is increased up to 3 Amp.

Step 6: Slowly sweep the input source voltage from 4.5V to 25V. The load voltage should remain in regulation with a nominal 3.3V output. If desired the output of the device can be disabled by connecting the ENABLE pin (J5) to GND (J8)

Step 7: The pull-up voltage for PGOOD can be selected by using the JP1 shunt to connect VPULLUP to VOUT or VCC.

Powering Up

It is suggested that the load power be kept low during the first power up. Set the current limit of the input source to provide about 1.5 times the anticipated wattage of the load. Once the device is powered up, immediately check for 3.3 volts at the output.

A quick efficiency check is the best way to confirm that everything is operating properly. If something is amiss you can be reasonably sure that it will affect the efficiency adversely. Few parameters can be incorrect in a switching power supply without creating losses and potentially damaging heat.

Over Current Protection

The evaluation board is configured with cycle-by-cycle overcurrent protection. This function is completely contained in the LM20323. The peak current is limited to approximately 5.2A.

Connection Descriptions

Terminal Silkscreen	Description		
VIN	This terminal is the input voltage to the device. The evaluation board will operation over the input voltage range of 4.5V to 25V. This voltage is limited due to the voltage rating of the input capacitors.		
GND	These terminals are the ground connections to the device. There are three different GND connections on the PCB. J2 should be used for the input supply, J4 should be used for the load, and J8 should be used for low power signal connections such as ENABLE.		
VOUT	This terminal connects to the output voltage of the power supply and should be connected to the load.		
ENABLE	This terminal connects to the enable pin of the device. This terminal can be left floating or driven externally. If driven externally, a voltage typically less than 1.2V will disable the device. The operating voltage for this pin should not exceed 5.5V. The absolute maximum voltage rating on this pin is 6V.		
SS/TRK	This terminal provides access to the SS/TRK pin of the device. Connections to this terminal are not needed for most applications. The feedback pin of the device will track the voltage on the SS/TRK pin if it is driven with an external voltage source that is below the 0.8V reference. The voltage on this pin should not exceed 5.5V during normal operation. The absolute maximum voltage rating on this pin is 6V.		
PGOOD	This terminal connects to the power good output of the device. There is an option to connect this pin to VOUT or VCC through a 10 k Ω pull-up resistor. The voltage on this pin should not exceed 5.5V during normal operation and has an absolute maximum voltage rating of 6V.		
JP1	This terminal block selects the pull-up voltage for the PGOOD pin to be either VCC or VOUT. An external voltage source for PGOOD may be supplied by connecting to the center terminal. The voltage applied to PGOOD should not exceed 5.5V during normal operation and has an absolute maximum voltage rating of 6V.		
SW	This terminal allows easy probing of the switch node. Do not apply any external voltage source to this pin.		
TP1 (VOUT)	This is a oscilloscope probe connector point used to measure the output ripple and transient response. It is design to work with most Tektronix oscilloscope probes and is the recommended measurement point for evaluating AC performance.		

AN-1790

Performance Characteristics

EFFICIENCY PLOTS

Figure 1 shows the conversion efficiency versus output current for a 5V and 12V input voltage.

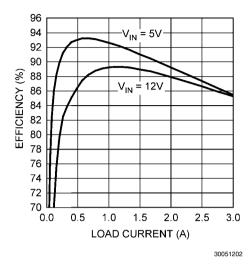


FIGURE 1.

TURN-ON WAVEFORM

When applying power to the LM20323 evaluation board a soft-start sequence occurs. Figure 2 shows the output voltage during a typical start-up sequence.

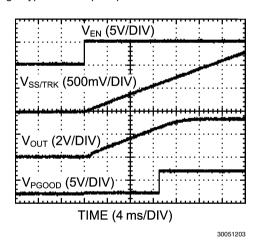
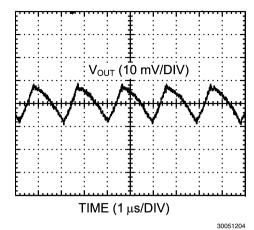


FIGURE 2.

OUTPUT RIPPLE WAVEFORM

Figure 3 shows the output voltage ripple. This measurement was taken with the scope probe tip placed on the J3 load terminal and the scope probe ground "barrel" pushed against the J4 load terminal. The scope bandwidth is set to 20 MHz.



Bandwidth Limit = 20 MHZ



OUTPUT TRANSIENT RESPONSE

FIGURE 4 shows the output transient response durning a 300mA to 3A transient.

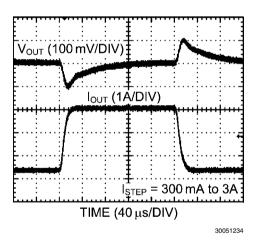


FIGURE 4.

Bill of Materials

The Bill of Materials is shown below, including the manufacturer and part number.

TABLE 1.

DESIGNATOR	QTY	PART NUMBER	DESCRIPTION	VALUE
C1	1	GRM32ER61E226KE15	CAPACITOR, 1210 X5R CER, MURATA	22 µF, 25V
C2, C3	2	GRM21BR61E475KA12L	CAPACITOR, 0805 X5R CER, MURATA	4.7 μF, 25V
C5	1	GRM188R71A105KA61D	CAPACITOR, 0603 X7R CER, MURATA	1 µF, 10V
C4, C6	2	C1608X7R1H104K	CAPACITOR, 0603 X7R CER, TDK	0.1 µF, 50V
C7	1	C1608C0G1H100J	CAPACITOR, 0603 COG CER, TDK	10 pF, 50V
C8	1	C1608C0G1H102J	CAPACITOR, 0603 COG CER, TDK	1000 pF, 50V
C9	1	6TPB150MAZB	CAPACITOR, POSCAP B, SANYO	150 µF, 6.3V
D1	1	CMMSH1-40-NST	DIODE, SCHOTTKY, CENTRAL SEMI	1A, 40V
L1	1	IHLP4040DZER5R6M01	INDUCTOR, VISHAY	5.6 µH, 16A
R1, R6	2	CRCW06031002F	RESISTOR, 0603, VISHAY	10 kΩ
R7	1	CRCW06034992F	RESISTOR, 0603, VISHAY	49.9 kΩ
R2, R3	0	OPEN	-	-
R4	1	CRCW0603348RF	RESISTOR, 0603, VISHAY	348Ω
R5	1	CRCW06033092F	RESISTOR, 0603, VISHAY	30.9 kΩ
U1	1	LM20323MH	SWITCHING REGULATOR, NATIONAL SEMI	
J1 - J4	4	160-1026-02-01-00	TURRET TERMINAL, CAMBION	TERMINAL, TURRET
J6, J7, J9	3	5002	TERMINAL, SINGLE PIN, KEYSTONE	TESTPOINT, LOOP
J5	1	5000	TERMINAL, SINGLE PIN, KEYSTONE	TESTPOINT, LOOP
J8	1	5001	TERMINAL, SINGLE PIN, KEYSTONE	TESTPOINT, LOOP
TP1	1	131503100	TEKTRONIX SCOPE PROBE TESTPOINT	PROBE TESTPOINT

Component Selection

This section provides a walk-through of the design process of the LM20323 evaluation board. Unless otherwise indicated all equations assume units of amps (A) for current, farads (F) for capacitance, henries (H) for inductance, and volts (V) for voltages.

INPUT CAPACITORS: C1, C2, C3

The required RMS current rating of the input capacitor for a buck regulator can be estimated by the following equation:

$$I_{CIN(RMS)} = I_{OUT} \sqrt{D(1 - D)}$$

The variable D refers to the duty cycle, and can be approximated by:

$$D = \frac{V_{OUT}}{V_{IN}}$$

From this equation, it follows that the maximum I_{CIN(RMS)} requirement will occur at a full 3A load current with the system operating at 50% duty cycle. Under this condition, the maximum I_{CIN(RMS)} is given by:

$$I_{CIN(RMS)} = 3A \sqrt{0.5 \times 0.5} = 1.5A$$

Ceramic capacitors feature a very large I_{RMS} rating in a small footprint, making a ceramic capacitor ideal for this application. A two 4.7 μ F, X5R, 25V ceramic capacitor(C2, C3) from Murata are used to provide the necessary input capacitance for the evaluation board. An additional 22 μ F, X5R, 25V capacitor is used to provide additional input capacitance to counter cabling inductance to the input.

INDUCTOR: L1

The value of the inductor was selected to allow the device to achieve a 12V to 3.3V conversion at 500kHz to provide a peak to peak ripple current 854mA, which is about 28.5% of the maximum output current. To have an optimized design, generally the peak to peak inductor ripple current should be kept to within 20% to 40% of the rated output current for a given input voltage, output voltage and operating frequency. The peak to peak inductor ripple current can be calculated by the equation:

$$\Delta I_{P-P} = \frac{(V_{IN} - V_{OUT}) \times D}{L \times f_{SW}}$$

Once an inductance value is calculated, an actual inductor needs to be selected based on a trade-off between physical size, efficiency, and current carrying capability. For the LM20323 evaluation board, a Vishay IHLP4040DZ-ER5R6M01 inductor offers a good balance between efficiency (18 m Ω DCR), size, and saturation current rating (16A I_{SAT} rating).

OUTPUT CAPACITOR: C9

The value of the output capacitor in a buck regulator influences the voltage ripple that will be present on the output voltage, as well as the large signal output voltage response to a load transient. Given the peak-to-peak inductor current ripple ($\Delta I_{\text{P},\text{P}})$ the output voltage ripple can be approximated by the equation:

$$\Delta V_{OUT} = \Delta I_{P-P} x \left[R_{ESR} + \frac{1}{8 x f_{SW} x C_{OUT}} \right]$$

The variable R_{ESR} above refers to the ESR of the output capacitor. As can be seen in the above equation, the ripple voltage on the output can be divided into two parts, one of which is attributed to the AC ripple current flowing through the ESR of the output capacitor and another due to the AC ripple current actually charging and discharging the output capacitor. The output capacitor also has an effect on the amount of droop that is seen on the output voltage in response to a load transient event.

For the evaluation board, a Sanyo 150 μ F POSCAP output capacitor was selected to provide good transient and DC performance in a relatively small package. From the technical specifications of this capacitor, the ESR is roughly 35 m Ω , and RMS ripple current rating is 1.4A. With these values, the worst case peak to peak voltage ripple on the output when operating from a 12V input can be calculated to be 31 mV.

SOFT-START CAPACITOR: C6

A soft-start capacitor can be used to control the startup time of the LM20323 voltage regulator. The startup time of the regulator when using a soft-start capacitor can be estimated by the following equation:

$$t_{\rm SS} = \frac{0.8V \times C6}{I_{\rm SS}}$$

For the LM20323, $I_{\rm SS}$ is nominally 5 $\mu A.$ For the evaluation board, the soft-start time has been designed to be roughly 15 ms, resulting in a C_{\rm SS} capacitor value of 100 nF.

VCC BYPASS: C5

The capacitor C5 is used to bypass the internal 4.5V sub-regulator. A value of 1 μ F is sufficient for most applications.

BOOT CAPACITOR: C4

C4 is the boot capacitor which is used to provide the charge needed to drive the high-side FET. An optimal value for this capacitor is 0.1 $\mu F.$

COMPENSATION CAPACITOR: C8

The capacitor C8 is used to set the crossover frequency of the LM20323 control loop. Since this board was optimized to be stable over the full input and output voltage range, the value of C8 was selected to be 1 nF. Once the operating conditions for the device are known, the transient response can be optimized by reducing the value of C8 and calculating the value for R7 as outlined in the next section.

COMPENSATION RESISTOR: R7

Once the value of C8 is known, resistor R7 is used to place a zero in the control loop to cancel the output filter pole. This resistor can be sized according to the equation:

$$R7 = \left[\frac{C8}{C9} \times \left[\frac{I_{OUT}}{V_{OUT}} + \frac{2 \times D}{f_{SW} \times L1}\right]\right]^{-1}$$

For stability purposes the device should be compensated for the maximum output current expected in the application.

OPTIONAL COMPENSATION CAPACITOR: C7

A second compensation capacitor C7 can be used in some designs to improve noise immunity for low duty cycle conversions, as well as, provide a high frequency pole, useful for cancelling a possible zero introduced by the ESR of the output capacitor. For the LM20323 evaluation board, a 10pF capacitor is populated for C7. Higher value capacitors can be used to improve low duty cycle performance at the expense of phase margin.

FEEDBACK RESISTORS: R4, R5, and R6

The resistors labeled R5 and R6 create a voltage divider from V_{OUT} to the feedback pin that is used to set the output of the voltage regulator. Nominally, the output of the LM20323 evaluation board is set to 3.3V, giving resistor values of R5 = 30.9 k Ω and R6 = 10 k Ω . If a different output voltage is required, the value of R5 can be adjusted according to the equation:

$$R5 = \left(\frac{V_{OUT}}{0.8} - 1\right) \times R6$$

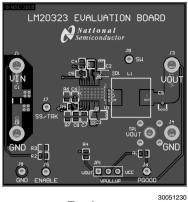
R6 does not need to be changed from its value of 10 k Ω . Resistor R4 has a value of 348 Ω and is provided as an injection point for loop stability measurements, as well as, a way to further tweak the output voltage accuracy to account for resistor tolerance values differing from ideal calculated values.

PROGRAMMABLE UVLO: R2 and R3

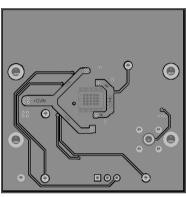
The resistors labeled R2 and R3 create a voltage divider from $V_{\rm IN}$ to the enable pin that can be used to set the turn-on threshold or UVLO of the voltage regulator. To allow evaluation of the device down to 4.5V these components are not installed. To change the turn-on threshold of the device a 10 k Ω resistor is recommended for R3 and the value of R2 can be calculated using the equation:

$$R2 = \left(\frac{V_{TO}}{1.25} - 1\right) \times R3$$

PCB Layout

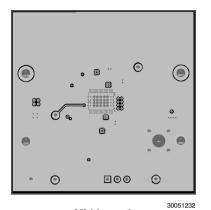


Top Layer

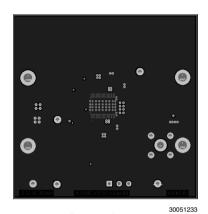


Mid Layer1

30051231



Mid Layer2



Bottom Layer

AN-1790

Products		Design Support	
Amplifiers	www.national.com/amplifiers	WEBENCH	www.national.com/webench
Audio	www.national.com/audio	Analog University	www.national.com/AU
Clock Conditioners	www.national.com/timing	App Notes	www.national.com/appnotes
Data Converters	www.national.com/adc	Distributors	www.national.com/contacts
Displays	www.national.com/displays	Green Compliance	www.national.com/quality/green
Ethernet	www.national.com/ethernet	Packaging	www.national.com/packaging
Interface	www.national.com/interface	Quality and Reliability	www.national.com/quality
LVDS	www.national.com/lvds	Reference Designs	www.national.com/refdesigns
Power Management	www.national.com/power	Feedback	www.national.com/feedback
Switching Regulators	www.national.com/switchers		
LDOs	www.national.com/ldo		
LED Lighting	www.national.com/led		
PowerWise	www.national.com/powerwise		
Serial Digital Interface (SDI)	www.national.com/sdi		
Temperature Sensors	www.national.com/tempsensors		
Wireless (PLL/VCO)	www.national.com/wireless		

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2008 National Semiconductor Corporation

For the most current product information visit us at www.national.com

AN-1790

National Semiconductor Americas Technical Support Center Email: support@nsc.com Tel: 1-800-272-9959 National Semiconductor Europe Technical Support Center Email: europe.support@nsc.com German Tel: +49 (0) 180 5010 771 English Tel: +44 (0) 870 850 4288 National Semiconductor Asia Pacific Technical Support Center Email: ap.support@nsc.com National Semiconductor Japan Technical Support Center Email: jpn.feedback@nsc.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 TI 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. Information of third parties may be subject to additional restrictions.

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	
	Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
	Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
	Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
	DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
	DSP	dsp.ti.com	Industrial	www.ti.com/industrial
	Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
	Interface	interface.ti.com	Security	www.ti.com/security
	Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
	Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
	Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
	RFID	www.ti-rfid.com		
	OMAP Mobile Processors	www.ti.com/omap		
	Wireless Connectivity	www.ti.com/wirelessconnectivity		
			u Hama Dawa	a O a Al a a m

TI E2E Community Home Page

e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265 Copyright © 2011, Texas Instruments Incorporated