SM72238,SM72240,SM72295,SM72375,SM72442, SM72480,SM72485

Application Note 2122 SM3320-RF-EV Reference Design



Literature Number: SNOSB82D

SM3320-RF-EV Reference Design

National Semiconductor Application Note 2122 Arief Hernadi October 12, 2011





Introduction

The SolarMagic[™] SM3320-RF-EV reference design integrates a power optimizer and a low-cost 2.4GHz radio to add a remote shutdown feature to a PV system. The remote shutdown feature can be used during installation, maintenance, or emergency situations to de-energize the PV system.

Although its principal purpose is to communicate shutdown intent, this RF system is 2-way and can be used for a wide variety of communication applications, including monitoring, security and identification.

The SolarMagic[™] SM3320-RF-EV is based off of the SM3320-1A1 power optimizer, and shares all of its best-inclass power optimization features. This includes its ability to mitigate real-world mismatch, its 99.5% peak efficiency, and its Panel-Mode operation. In addition, the same ultra-low profile form factor of the original SM3320-1A1 is maintained so that it can be integrated into the same junction box designs. This evaluation board should work as a power optimizer even without a transmitter

The wireless RF communications in the SM3320-RF-EV is implemented using a low-cost Nordic nRF24LE1 chip. This is a low-cost, 2.4GHz radio and 8051 microcontroller on a single chip. The 2.4GHz radio uses narrow band modulation (as opposed to direct sequence spread spectrum), which can be used either with or without frequency hopping. Example software is provided that implements the remote shutdown feature on the 8051 microcontroller in the nRF24LE1.

One of the unique features of the SM3320-RF-EV is its use of the DC power lines as an RF antenna and transmission

line. This enables the SM3320-RF-EV to maintain radio communication even when it is mounted in the junction box of the module. This antenna design can be used with other 2.4GHz radio chipsets besides the nRF24LE1 by straightforward modification of the provided design files.

The SM3320-RF-EV reference design provides a flexible platform for developing value added features in firmware with no additional hardware development. Examples of these features include module-level monitoring, security (theft-detection and theft-deterrence), and identification. Similarly, firmware development on this platform can be used to customize the SM3320-RF-EV to be compatible with an existing monitoring system or inverter communication protocol if a customer desires.

SolarMagic[™] technology is an overall solution that works in existing and new installations, residential, commercial, and utility scale projects. National Semiconductor's 50 years of experience in the electronics industry delivers unsurpassed manufacturing, design, and development technology.

System Overview

Figure 1 depicts how the SM3320-RF-EV design would be implemented in its intended application. In this example, every module is connected to an SM3320-RF-EV power optimizer. Under normal conditions, the central transmitter sends a signal to each SM3320-RF-EV power optimizer indicating that it is ok to operate and output power. When an emergency condition occurs, the central transmitter will send a signal command to all the SM3320-RF-EV to shutdown. This denergizes the output of each SM3320-RF-EV, and in doing so brings down the voltage of the DC bus and all DC wiring to a safe voltage level.

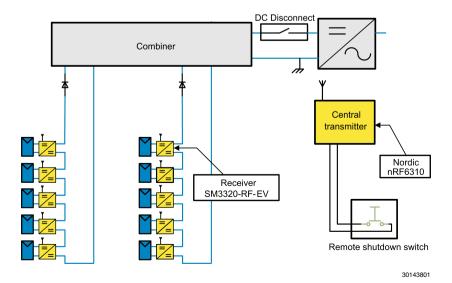


FIGURE 1. System Overview Showing Intended Application of SM3320-RF-EV Board in a PV System

SM3320-RF-EV Design Specification

Symbol	Parameter	Min	Тур	Max
V _{MPP}	PV Module MPP Voltage	15 Vdc		40Vdc
P _{MPP}	PV Module Power	10 W		350 W
V _{oc}	PV Module Open Circuit Voltage			50 Vdc
I _{SC}	PV Module Short-Circuit Current			11A
V _{OUT}	Output Voltage	0 Vdc		43 Vdc
I _{OUT}	Output Current			12.5A
OVP	Overvoltage Protection Threshold		45V	
ОТР	Overtemperature Protection Threshold		125°C	
MPP _{EFF}	MPP Efficiency		98.5%	
PM _{EFF}	Panel-Mode Efficiency		99.5%	

1) SM3320 RF-EV KIT

Included in the SM3320-RF-EV are the following items:

- 1. SM3320-RF-EV PCB
- Software for the Receiver (SM3320-RF-EV) compiled and source code
- 3. Software for the Central Transmitter (nRF6310) compiled and source code
- 4. Design files Schematic, BOM and Gerbers

In order to get started as quickly as possible with this kit, users are recommended to purchase a Nordic nRF6310 mother-board. Using the included Central Transmitter sample code will enable users to test the enable/disable and Panel-Mode functionality.

2) FEATURES

- Wireless shutdown for SM3320-1A1
- Wireless Panel-Mode operation for SM3320-1A1
- · MPPT for Photovoltaic Panel
- · 2.4 GHz ISM band operation
- Enhanced 8 bit 8051 compatible microcontroller
- Power line antenna

3) DESIGN DESCRIPTION

The Sirius RF evaluation board shares the same power specifications as the SolarMagic SM3320-1A1 Power Optimizer. The controller for the power optimizer consists of an SM72442 programmable MPPT controller for PV panels and a Nordic nRF24LE1 low power system-on-chip wireless solution. The nRF24LE1 has a built in 2.4GHz transceiver (250kbps, 1Mbps and 2Mbps air data rates) and an 8051 compatible microcontroller. Operation at 250kbps is recommended.

Receiver

The nRF24LE1 IC will be located in the SM3320-RF-EV board and used as a receiver that controls the forced shutdown and Panel-Mode operation.

By utilizing these two ICs (SM72442 and nRF24LE1),the evaluation board is capable of tracking the maximum power point of PV panels during normal operation as well as controlling a shutdown during emergency conditions. Two of the GPIO outputs (P0.0 and P0.1) from the microcontroller are used to send a shutdown or Panel-Mode signal into the SM72442. The shutdown signal will pull the RESET pin low in order to deactivate the PWM signals that are coming out from SM72442. Panel-Mode operation can be forced on the SM72442 by pulling the PM pin of the SM72442 low.

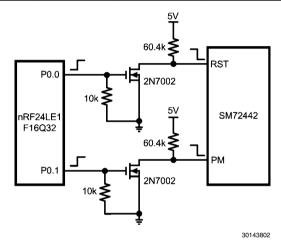


FIGURE 2. Forced Panel-Mode and Reset using nRF24LE1

Figure 2 shows one sample application where the GPIO outputs of nRF24LE1 are used to force a reset or Panel-Mode condition on the SM72442. The nRF24LE1 radio uses the power line as an antenna by coupling into the output wire of the SM3320-RF-EV. This implementation is shown on Figure 3. In order to not short the output of the radio to ground, an air wound inductor (L104 in schematic) is placed between the OUT (-) terminal and the actual string wire. The inductor, together with the capacitors to ground at the DC power feed (C116) and the series capacitor between it and the RF transceiver device (C113), create an LC Network to couple RF in and out of the string wire terminal without shorting it to the DC power feed, and at the same time carrying the DC from the power feed to the string wire. The other string wire has a capacitor (C117) to ground to provide a return for the RF through the ground planes to the RF transceiver device. The dimensions for the air wound inductor are attached in Figure 4. This inductor introduces approximately 10 dB loss at 2.4 GHz. For better manufacturability, the inductor can be redesigned with a core so it is smaller. It still needs to carry the full string current

www.national.com 2

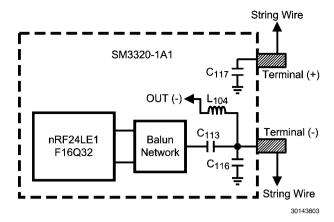


FIGURE 3. Power Line Antenna Implementation

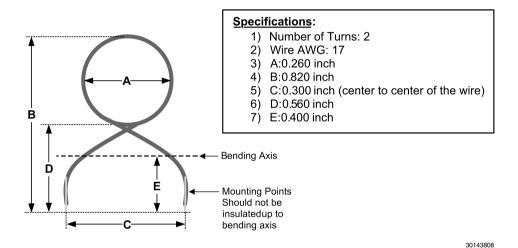


FIGURE 4. Inductor Dimension

3

Central Transmitter

For this evaluation board, a Nordic module (nRF2723) is used as a transmitter. In general, any Nordic RF module with an nRF24xx IC and external antenna connection can be used as a transmitter, however additional software development could be required. To minimize programming and hardware development time, the transmitter can be made of a Nordic RF module with nRF24xxIC along with Nordic Motherboard (nRF6310) which are included in the Nordic starter kit nRF6700. The user can download the transmitter.hex file included in this kit onto the Nordic module in order to use it as a transmitter to send a shutdown or Panel-Mode signal towards the receiver. The motherboard has buttons that can be manually connected to the GPIO pins from the module. By doing this, the transmitter module will receive button input from the user and send an appropriate signal towards the receiver located on the SM3320-RF-EV board.

Both sample codes and hex files for the receiver and transmitter are provided in the .zip file.

4) FLASH PROGRAMMING

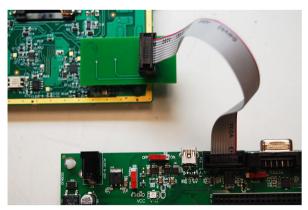
A Nordic Motherboard (nRF6310) is required to program the transmitter and receiver ICs. The sample code and hex files provided can be used as a start to program both ICs. Please remove R101 and R102 from the board before downloading the .hex file into the receiver. The receiver IC in the SM3320-RF-EV board is pre-programmed with functions to enter a reset condition or to operate into a forced Panel-Mode condition. Logic high will appear on P0.0 and P0.1 of the receiver IC once an appropriate signal command is received from the transmitter. The user also has the flexibility to program the flash memory in the receiver IC by using the 10 pin connector (J101 on schematic) located in the board. These 10 pins should be connected with the external ISP interface on the Nordic Motherboard (nRF6310) to enable the in-circuit programming. Below is the table of pinouts for the 10 pin header on SM3320-Rf-EV board and an external ISP interface from the Nordic Motherboard.

TABLE 1. Pinouts for 10 Pin Headers and Nordic
Motherboard

Pin	10 Pin Headers	Nordic Motherboard (nRF6310)
1	P0.4	RF_VDD
2	PROG	Not Used
3	SCK	PROG
4	GND	CSN
5	MOSI	MOSI
6	GND	RESET
7	MISO	MISO
8	3.3VDC	SCK
9	CSN	Not Used
10	RESET	GND

Each of the pins of the 10 pin header should be connected to the appropriate pin on the Nordic Motherboard. Pin 1 of the 10 Pin Header can either be connected to pin 2 of the Nordic Motherboard or it can be left floating during programming. All of the other pins on the header should be connected to its appropriate pin on the Nordic nRF6310 external interface. For example pin 2 on the header should be connected to pin 3 of the Nordic nRF6310. The SM3320-RF-EV kit also comes a schematic and gerber file for a connector board which will aid in the programming between the receiver IC and the Nordic nRF6310 motherboard, as shown in *Figure 5*. The user can then download his or her own hex file into the flash memory of nRF24LE1 that is located on the SM3320-RF-EV board.

The RF_VDD (pin 1 of nRF6310) should be connected to the 3.3VDC (pin 8 on SM3320–RF-EV). Since the RF_VDD pin is used as a signal level shifter on the Nordic Motherboard, the power supply voltage from the motherboard does not need to match the power supply voltage from the application board (SM3320-RF-EV in this case). However, an input voltage of minimum 15V should be applied to the SM3320-RF-EV in order to provide a 3.3VDC voltage on pin 8 of the header.



30143809

FIGURE 5. Connector Board interface

In order to start programming on the nRF radio IC, the following software has to be downloaded:

- 1. μVision IDE from Keil
- 2. nRFgo Studio

The nRFgo Studio is provided on the nRFgo Starter Kit (nRF 6700). The nRFgo Studio will download the .hex file generat-

ed by μ Vision IDE into the flash memory on the receiver. To program the flash using the external ISP interface from the motherboard, an nRF ISP interface has to be manually selected in the nRFgo Studio. A complete download of the hex file into the IC is indicated by a successful verification of the flash memory. Please note that both R101 and R102 (refer to the schematic) on the SM3320-RF-EV board have to be removed during the programming.

5) I2C INTERFACE

Using a connector board that is supplied in this kit, the user has the ability to access the SCL and SDA pins on the SM72442 as well as W2SCL (P0.4) and W2SDA (P0.5) on the 32 pin nRF24LE1. Pin 1 and 3 on the 10 Pin Header are connected to P0.4 and P0.5 respectively through R101 and R102 (refer to the schematic). Please make sure that both resistors are assembled on the SM3320-RF-EV board. The SM72442 and nRF24LE1 are configured as a slave. A master can be used to communicate to SM72442. External pull-up resistor of $2k\Omega$ to 3.3V is required. The address for SM72442 is 1 whereas the address for the nRF24LE1 can be configured using setting the address W2SADR on the SFR register (Please refer to nRF24LE1 datasheet for more information). The I2C protocol for communicating with SM72442 can be found on the SM72442 datasheet.

6) LAYOUT CONSIDERATION

- RF IC layout assumes an adjacent ground plane. If the adjacent layer is a power plane, a bypass capacitor should be added between ground and power plane in the vicinity of the RF IC. In our case, three 0.01µF and three 100pF capacitors are connected between ground and the power plane, and are placed near nRF24LE1.
- The distance from an RF trace and a plane around it should be at least two times the width of the RF trace to avoid co-planar coupling that lowers the line impedance, unless co-planar ground flood is included in the calculation.
- 3. The trace going into the crystal oscillator should be wide enough (~15 mils in our case) to reduce the line inductance for more reliable starting at low temperature. On the other hand, increasing these traces should also increase the line capacitance to ground which can affect starting as well. However, this effect can be counteracted by reducing the value of C105 and C106.

7) HEATSINKING

SM3320-RF-EV evaluation board does not come with a heatsink. Therefore, in order to run the evaluation board at elevated power ratings, an appropriate heatsink should be added on Q1, Q2, Q3 and Q4 as well as diode D1. Care must be taken prevent electrical contact between the drains of the MOSFETs in the process of proper heatsinking. At elevated power operation please note the increase in temperature across these semiconductor devices.

8) TEST SETUP

To perform an evaluation on a single SM3320-RF-EV, it is suggested that the user connect the input to a SAS (Solar Array Simulator) and the output to a load bank.

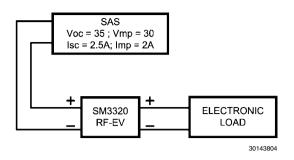


FIGURE 6. Test Setup for SM3320-RF-EV

Listed below are example settings for the SAS and electronic load:

SAS:

Voc = 35V; Vmp = 30V; Isc = 2.5A; Imp = 2A. Electronic Load: Constant Current Mode (CC) at 1.5A

Test Results

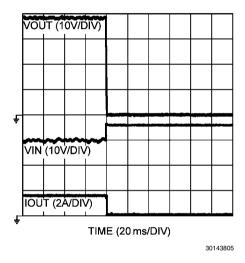


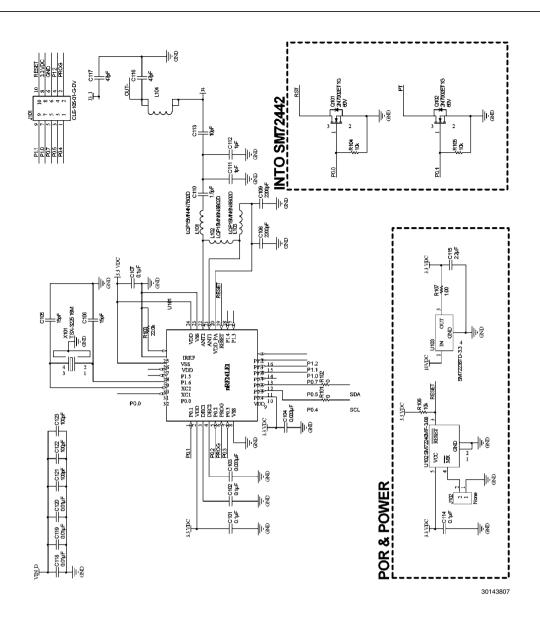
FIGURE 7. RF Shutdown

When the electronic load is turned on at 1.5A load current, SM3320-RF-EV will operate in Panel Mode for at least 128 seconds. After this period, the MPPT mode is then entered. During MPPT, the output voltage is at 38V with an input voltage of 30V. Once the shutdown signal is received by the receiver, one of the Nordic GPIO output will pull the reset line down causing the SM3320-RF-EV to stop switching and resulting the output voltage will go down (*Figure 7*).

5 www.national.com

Schematic 製業 **Σ**ξ Net Class - HV_NETS 728 C50 3

www.national.com



7

Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:

Pro	oducts	Design Support	
Amplifiers	www.national.com/amplifiers	WEBENCH® Tools	www.national.com/webench
Audio	www.national.com/audio	App Notes	www.national.com/appnotes
Clock and Timing	www.national.com/timing	Reference Designs	www.national.com/refdesigns
Data Converters	www.national.com/adc	Samples	www.national.com/samples
Interface	www.national.com/interface	Eval Boards	www.national.com/evalboards
LVDS	www.national.com/lvds	Packaging	www.national.com/packaging
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
Voltage References	www.national.com/vref	Design Made Easy	www.national.com/easy
PowerWise® Solutions	www.national.com/powerwise	Applications & Markets	www.national.com/solutions
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempsensors	SolarMagic™	www.national.com/solarmagic
PLL/VCO	www.national.com/wireless	PowerWise® Design University	www.national.com/training

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© 2011 National Semiconductor Corporation

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



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 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 dataconverter.ti.com Consumer Electronics www.ti.com/consumer-apps **Data Converters 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 <u>www.ti-rfid.com</u>
OMAP Mobile Processors www.ti.com/omap

Wireless Connectivity <u>www.ti.com/wirelessconnectivity</u>

TI E2E Community Home Page <u>e2e.ti.com</u>