Using RF6505 Front End Module with CC2530 under FCC 15.247

By Jervais Seegars, RFMD

Features
- Low PA Harmonic Content
- 27 dBm of Output Power
- Excellent Sensitivity
- Antenna Diversity
- Flexible Design

Applications
- 802.15.4 Based Systems for Remote Monitoring and Control
- 2.4-2.5 GHz ISM Band Applications

Keywords
- Range Extender
- FCC Section 15.247
- External PA
- External LNA

1 Introduction

The RF6505 [1] integrates a complete solution in a single Front End Module (FEM) for WLAN and ZigBee applications in the 2.4 GHz unlicensed ISM band. This FEM integrates the PA plus the harmonic filter in the transmit path and the LNA with Bypass mode in the receive side. It provides a single balanced TDD access for RX and TX paths along with two ports on the output for connecting a diversity solution or a test port.

The CC2530 [2] is TI’s second generation ZigBee/IEEE 802.15.4 RF system-on-chip (SoC) for the 2.4 GHz unlicensed ISM band. This chip enables industrial grade applications by offering state-of-the-art selectivity/co-existence, excellent link budget, and low voltage operation.

The RF6505-CC2530 reference design [3] is a range extender design for the CC253x, CC2540-1 and CC85xx in the 2.4GHz ISM Bands. It increases the link budget by providing a power amplifier (PA) for increased output power, and a low-noise amplifier (LNA) with low noise figure for improved receiver sensitivity. In addition to these features it provides switches and integrated RF matching for design and high performance wireless systems.

This application note outlines the expected performance when using a RF6505-CC2530 design under FCC [4] Section 15.247 in the 2400-2483.5 MHz frequency band. This application note assumes the reader is familiar with the CC2530 and FCC 15.247 regulatory limits.

For additional information or further questions please contact, RFMD Technical Support at smartgrid@rfmd.com.
Table of Contents

KEYWORDS .............................................................................................................. 1
1 INTRODUCTION .................................................................................................. 1
2 ABBREVIATIONS ................................................................................................. 2
3 ABSOLUTE MAXIMUM RATINGS ........................................................................ 3
4 ELECTRICAL SPECIFICATIONS ......................................................................... 3
   4.1 OPERATING CONDITIONS ...................................................................... 3
   4.2 CURRENT CONSUMPTION ..................................................................... 3
      4.2.1 Supply current = 4.2 V ................................................................. 3
      4.2.2 Supply current = 3.6 V ................................................................. 3
      4.2.3 Supply current = 3.0 V ................................................................. 4
   4.3 TRANSMIT PARAMETERS .................................................................... 4
      4.3.1 Supply current = 4.2 V ................................................................. 5
      4.3.2 Supply current = 3.6 V ................................................................. 5
      4.3.3 Supply current = 3.0 V ................................................................. 6
   4.4 RECEIVE PARAMETERS ...................................................................... 8
5 SMARTRF STUDIO AND SMARTRF05EB .................................................. 8
6 REFERENCE DESIGN CONSIDERATIONS .................................................. 8
   6.1 POWER DECOUPLING ....................................................................... 8
   6.2 FILTERING ............................................................................................. 8
   6.3 PCB LAYOUT CONSIDERATIONS ..................................................... 8
   6.4 SHIELDING ............................................................................................ 9
   FIGURE 6-1 RF6505-CC2530 SCHEMATIC ............................................ 9
7 DISCLAIMER ..................................................................................................... 9
8 REFERENCE ........................................................................................................ 9
9 GENERAL INFORMATION ............................................................................... 10
   9.1 DOCUMENT HISTORY ...................................................................... 10
10 APPENDIX – PERFORMANCE VERIFICATION ....................................... 11
   10.1 EQUIPMENT ....................................................................................... 11
   10.2 GENERAL SETUP ............................................................................. 11
   10.3 TRANSMISSION .................................................................................. 12
      10.3.1 Continuous Transmission .......................................................... 12
      10.3.2 Packet Transmission ................................................................. 12
   10.4 RECEPTION ......................................................................................... 13
      10.4.1 Practical Sensitivity testing .......................................................... 13
      10.4.2 PER Test Setup ........................................................................... 14

2 Abbreviations

EB Evaluation Board
EM Evaluation Module
FCC Federal Communications Commission
FEM Front End Module
LNA Low Noise Amplifier
PA Power Amplifier
PCB Printed Circuit Board
PER Packet Error Rate
RX Receive, Receive Mode
TX Transmit, Transmit Mode
3 Absolute Maximum Ratings

The absolute maximum ratings and operating conditions listed in the CC2530 datasheet [2] and the RF6505 datasheet [1] must be followed at all times. Stress exceeding one or more of these limiting values may cause permanent damage to any of the devices.

4 Electrical Specifications

4.1 Operating Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>2394</td>
<td>2507</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>Operating Supply Voltage for 6505CC2530(1)</td>
<td>3.0</td>
<td>3.6</td>
<td>4.2</td>
<td>V</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-40</td>
<td>25</td>
<td>+85</td>
<td>°C</td>
</tr>
</tbody>
</table>

(1) The recommended maximum operational voltage level of CC2530 is 3.6V on the RF6505-CC2530 design the voltage level is regulated with a voltage regulator.

Table 4-1 Operating Conditions

4.2 Current Consumption

$T_c = 25°C$ and frequency = 2445 MHz. All parameters measured on the RF6505-CC2530 reference design [3][2] with a 50 Ω load.

4.2.1 Supply current = 4.2 V

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC supply Current, TX Mode</td>
<td>780</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Quiescent current (Idle)</td>
<td>140</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>RX Mode Supply Current</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
</tbody>
</table>

Table 4-2 Current Consumption at 4.2V Supply

4.2.2 Supply current = 3.6 V

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC supply Current, TX Mode</td>
<td>730</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Quiescent current (Idle)</td>
<td>130</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>RX Mode Supply Current (CW input signal at -20dBm)</td>
<td>32</td>
<td></td>
<td>mA</td>
</tr>
</tbody>
</table>
4.2.3 Supply current = 3.0 V

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Conditions</th>
<th>Typical</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmit current, VDD = 3.6V</td>
<td>TXPOWER 0= 0xF5</td>
<td>750</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xE5</td>
<td>685</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xD5</td>
<td>630</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xC5</td>
<td>595</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xB5</td>
<td>530</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xA5</td>
<td>475</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x95</td>
<td>410</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x85</td>
<td>375</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x75</td>
<td>330</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x65</td>
<td>285</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x55</td>
<td>240</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x45</td>
<td>205</td>
<td>mA</td>
</tr>
</tbody>
</table>

Table 4-3 Current Consumption at 3.6V Supply

4.3 Transmit Parameters

$T_c = 25^\circ C$ and frequency = 2445 MHz. All parameters measured on the RF6505-CC2530 reference design [3][2] with a 50 $\Omega$ load.
### 4.3.1 Supply current = 4.2 V

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Conditions</th>
<th>Typical</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>TXPOWER 0= 0xF5</td>
<td>28.5</td>
<td>dBm</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xE5</td>
<td>28.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xD5</td>
<td>27.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xC5</td>
<td>26.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xB5</td>
<td>26.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xA5</td>
<td>24.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x95</td>
<td>23.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x85</td>
<td>22.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x75</td>
<td>21.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x65</td>
<td>19.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x55</td>
<td>17.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x45</td>
<td>15.1</td>
<td></td>
</tr>
</tbody>
</table>

| Conducted 2\textsuperscript{nd} Harmonic Level |
| TXPOWER = 0xF5 | -46 dBm/MHz |

| Conducted 3\textsuperscript{rd} Harmonic Level |
| TXPOWER = 0xF5 | -48 dBm/MHz |

| Stability, Output VSWR |
| TXPOWER = 0xF5 All phase angles | >10:1 |

**Table 4-5 Transmit Parameters at 4.2V Supply**

### 4.3.2 Supply current = 3.6 V

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Conditions</th>
<th>Typical</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>TXPOWER 0= 0xF5</td>
<td>27.5</td>
<td>dBm</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xE5</td>
<td>27.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xD5</td>
<td>27.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xC5</td>
<td>26.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xB5</td>
<td>25.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xA5</td>
<td>24.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x95</td>
<td>23.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x85</td>
<td>22.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x75</td>
<td>21.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x65</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x55</td>
<td>17.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x45</td>
<td>15.2</td>
<td></td>
</tr>
</tbody>
</table>

| Conducted 2\textsuperscript{nd} Harmonic Level |
| TXPOWER = 0xF5 | -45 dBm/MHz |

| Conducted 3\textsuperscript{rd} Harmonic Level |
| TXPOWER = 0xF5 | -49 dBm/MHz |

| Stability, Output VSWR |
| TXPOWER = 0xF5 All phase angles | >10:1 |

**Table 4-6 Transmit Parameters at 3.6V Supply**
4.3.3 Supply current = 3.0 V

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Conditions</th>
<th>Typical</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>TXPOWER 0= 0xF5</td>
<td>25.9</td>
<td>dBm</td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xE5</td>
<td>25.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xD5</td>
<td>25.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xC5</td>
<td>25.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xB5</td>
<td>24.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0xA5</td>
<td>23.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x95</td>
<td>21.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x85</td>
<td>20.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x75</td>
<td>19.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TXPOWER 0= 0x65</td>
<td>17.7</td>
<td></td>
</tr>
</tbody>
</table>

Conducted 2\(^{nd}\) Harmonic Level
TXPOWER = 0xF5

-47 dBm/MHz

Conducted 3\(^{rd}\) Harmonic Level
TXPOWER = 0xF5

-48 dBm/MHz

Stability, Output VSWR
TXPOWER = 0xF5
All phase angles
>10:1

Table 4-7 Transmit Parameters at 3.0V Supply

Figure 4-1 Typical Current TX Consumption vs. CC2530 TXPOWER Setting over Voltage
Figure 4-2 Typical Output Power vs. CC2530 TXPOWER Setting over Voltage
4.4 Receive Parameters

$T_c = 25^\circ C$, $VDD = 3.3V$ and frequency = 2445 MHz. All parameters measured on the RF6505-CC2530 reference design [3] with a 50 $\Omega$ load.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Conditions</th>
<th>Typical</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Sensitivity</td>
<td>1 % PER, IEEE 802.15.4 [6] requires -85 dBm</td>
<td>-101</td>
<td>dBm</td>
</tr>
<tr>
<td>Saturation</td>
<td>IEEE 802.15.4 [6] requires -20 dBm</td>
<td>26</td>
<td>dBm</td>
</tr>
<tr>
<td>RSSI Offset$^{(1)}$</td>
<td></td>
<td>81</td>
<td></td>
</tr>
</tbody>
</table>

(1) Due to in the external LNA and the offset CC2530 the RSSI readouts from RF6505-CC2530 is different from RSSI offset values for a standalone CC2530 design.

Table 4-8 Receive Parameters at 3.3V Operation

5 SmartRF Studio and SmartRF05EB

The RF6505-CC2530 together with SmartRF™ Studio 7 software [5] and SmartRFEB can be used to evaluate performance and functionality. See Appendix – Performance Verification for details on how to evaluate performance and functionality. The RF6505-CC2530 can be configured using the SmartRF Studio 7 software. The SmartRF Studio software is highly recommended for obtaining optimum register settings.

6 Reference Design Considerations

The RF6505-CC2530 reference design includes schematic, gerber files and bill of materials [3]. It is highly recommended to follow the reference design for optimum performance. Error! Reference source not found. shows the RF6505-CC2530 schematic.

6.1 Power Decoupling

Proper power supply decoupling must be used for optimum performance. The capacitor C19 must be optimized to prevent RF leakage into the control lines of the RF6505 which may cause oscillations.

6.2 Filtering

The values of L5, L6, C11, C12 and C13 are for harmonics filtering purposes only. These components assist in the required filtering of harmonics to pass regulatory requirements.

6.3 PCB Layout Considerations

The top layer is used for components and signal routing, and the open areas are filled with metallization connected to ground using several vias. The areas under the two chips are used for grounding and must be well connected to the ground plane with multiple vias. Footprint recommendation for the RF6505 is given in the RF6505 datasheet [1].

Layer two is a complete ground plane and is not used for any routing. This is done to ensure short return current paths. The low impedance of the ground plane prevents any unwanted signal coupling between any of the nodes that are decoupled to it.

Layer three is a power plane. The power plane ensures low impedance traces at radio frequencies and prevents unwanted radiation from power traces.

Layer four is used for routing, and as for layer one, open areas are filled with metallization connected to ground using several vias.
6.4 Shielding
RF shielding may be necessary to keep the radiated harmonics below the regulatory limits.

Figure 6-1 RF6505-CC2530 Schematic

7 Disclaimer
The RF6505-CC2530 reference design board purpose and use is for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY and is not considered by TI or RFMD 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 has been tested against FCC regulations, but there has been no formal compliance testing at an external test house. It is the end user’s responsibility to ensure that their system complies with applicable regulations. For additional information or further questions please contact, RFMD Technical Support at smartgrid@rfmd.com.

8 Reference
[1] RF6505 Datasheet (RF6505DS)
[2] CC2530 Data Sheet (SWRS081)
[3] RF6505-CC2530 reference design (SWRR090)
[5] SmartRF™ Studio 7 (SWRR085)
9 General Information

9.1 Document History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Description/Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWRA385</td>
<td>2011.11.14</td>
<td>Initial release</td>
</tr>
</tbody>
</table>
10 Appendix – Performance Verification

10.1 Equipment
(1) SmartRF Studio 7 installed on each PC used, which can be downloaded at [5].
(2) An RF generator with packet option, or a CC253x, or RF6505-CC2530 connected to a SmartRFEB for packet transmission. Using the CC253xEM or RF6505-CC2530 as an RF generator will require a PC.
(1) A RF6505-CC2530 connected to a SmartRFEB and a PC for packet reception
(2) Attenuators and cable
(3) A 4.2V DC supply and a USB cable

10.2 General Setup
1) The firmware revision of the SmartRF Studio must be downloaded to the SmartRFEB
2) Place the RF6505-CC2530 board onto the SmartRFEB via the evaluation module connectors
3) Connect the USB cable from the PC to the SmartRFEB. Note: If the SmartRFEB is connected to a USB socket on a PC, it will draw power from the USB. The onboard voltage regulator supplies 3.3V to the board, but has limited current source capability and cannot supply the RF6505-CC2530 with the optimum supply of 4.0V to 4.2V. An external supply is therefore needed and shall be connected as shown in Connecting 4.2V Supply to the RF6505-CC2530 Figure 10-1.
4) Supply 4.2V DC to the SmartRFEB
5) The chip type will appear in the test box labeled “List of Connected Devices” at the bottom of the SmartRF Studio Interface. This should read “USB device ID = 0xxx, Firmware (revision = 00xx), CC2530”.
6) Double click on the chip type in the device list to open up the SmartRF Studio7 device control panel for user interface.
7) Once the user interface is open find the “Range Extender” option, click on the arrow and select CC2591. Now you’re ready to evaluate the RF6505-CC2530.

- To use an external power supply remove the jumper from Pins 2 & 3 in the Power Source Sections of the SmartRF05EB.
- Then place the supply lead to pin 2 and ground to a common ground plane on the SmartRF05EB board.

Figure 10-1 Connecting 4.2V Supply to the RF6505-CC2530
10.3 Transmission

10.3.1 Continuous Transmission

1) Complete steps 1 through 7 of the General Setup procedure.
2) Find the Continuous TX mode tab
3) Adjust your desired TX power setting for CC253 using “TX Power” box in the RF Parameters section or by modifying the TXPOWER register value in the Register view.
4) Select the center frequency, either by using the “Frequency” box or using the “IEEE 802.15.4 channel” box.
5) Select between modulated and un-modulated in the Continuous T tab.
6) Select the correct antenna path, the two antenna paths are controlled thorough GPIO P1.0 and P1.1, so to change the antenna path from ANT1 to ANT2 the following registers needs to be changed; PODIR=0x82 and PO=0x7D, see Figure 10-2.

![Figure 10-2 Continuous Transmission Tab, ANT2](image_url)

10.3.2 Packet Transmission

1) Complete steps 1 through 7 of the General Setup procedure.
2) Select the Packet TX mode tab
3) Adjust your desired TX power setting for CC253 using “TX Power” box in the RF Parameters section or by modifying the TXPOWER register value in the Register view.
4) Select the center frequency, either by using the “Frequency” box or using the “IEEE 802.15.4 channel” box.
5) Select the number of packets you want to send and the packet payload size.
6) Select the correct antenna path, the two antenna paths are controlled thorough GPIO P1.0 and P1.1, so to change the antenna path from ANT1 to ANT2 the following registers needs to be changed; PODIR=0x82 and PO=0x7D, see Figure 10-3.

![Figure 10-3 Packet TX Transmission Tab, ANT2](image)

10.4 Reception

10.4.1 Practical Sensitivity testing

To properly evaluate the receiver performance of the RF3858-CC1101 reference design, it is necessary to be able to find the sensitivity threshold, i.e. the lowest input signal the receiver can decode with acceptable signal quality. This Application Note describes how to test the sensitivity using a PER (Packet Error Rate) test. For questions on testing sensitivity with SmartRF Studio please refer to [6].
10.4.2 PER Test Setup

1) Setup the equipment as shown in the block diagram in Figure 10-5.
2) Complete steps 1 through 7 of the General Setup procedure.
3) If using a CC2530 or the RF6505-CC2530 as the packet transmitter, use the Packet transmission section in this application note to set up the module that will transmit packets. Otherwise, setup the RF generator to send 802.15.4 packets and configure it for the selected RF frequency.
4) Select the Packet TX mode tab as shown in Figure 10-4.
5) Set the number of packets expected to receive.
6) Verify the antenna is correct on the interface and the base frequency matches the frequency of the board or RF generator that will be transmitting the packets.
7) Set attenuation level near the expected result.
8) Press Start to begin listening for packets before beginning to transmit packets.
9) Adjust the attenuation level until a 1% PER is achieved.
10) The Packet RX will continue until the number of packets programmed has been reached, or until 100 consecutive packets have been lost.
Figure 10-5 Block Diagram of PER Test Setup
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 compliance with all legal and regulatory requirements in connection with such use. TI products are neither designed nor intended for use 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 | Audio | www.ti.com/audio
Amplifiers | www.amplifier.ti.com
Data Converters | www.dataconverter.ti.com
DLP® Products | www.dlp.com
DSP | www.dsp.ti.com
Clocks and Timers | www.ti.com/clocks
Interface | interface.ti.com
Logic | www.logic.ti.com
Power Mgmt | www.power.ti.com
Microcontrollers | www.microcontroller.ti.com
RFID | www.ti-rfid.com
OMAP Mobile Processors | www.ti.com/omap
Wireless Connectivity | www.ti.com/wirelessconnectivity

Applications | Communications and Telecom | www.ti.com/communications
Computers and Peripherals | www.ti.com/computers
Consumer Electronics | www.ti.com/consumer-apps
Energy and Lighting | www.ti.com/energy
Industrial | www.ti.com/industrial
Medical | www.ti.com/medical
Security | www.ti.com/security
Space, Avionics and Defense | www.ti.com/space-avionics-defense
Transportation and Automotive | www.ti.com/automotive
Video and Imaging | www.ti.com/video

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