

# **TRF4903 With MSP430 Demonstration and Development Evaluation Kit**

---



---



---

This document presents the contents of the TRF4903 demonstration and development tool kit. The user manual provides information on how to operate the MSP-TRF4903-DEMO kit and describes its hardware and software. Users should understand the MSP430F449, TRF6903, and the TRF4903 to obtain the full benefit of this user manual.

Different topics covered in this manual may require different levels of expertise. The first two chapters are focused on how the kit operates.

If you want to build your own prototype, review the third chapter on how to load firmware. The later chapters cover hardware and software topics that may require some additional expertise.

Other related Texas Instruments information includes the following that may be helpful:

|                       |                         |
|-----------------------|-------------------------|
| TRF4903 data sheet    | <a href="#">SWRS023</a> |
| TRF6903 data sheet    | <a href="#">SWRS022</a> |
| MSP430F449 data sheet | <a href="#">SLAS344</a> |
| TRF6903 Design Guide  | <a href="#">SWRU009</a> |
| TRF6901 FAQ           | <a href="#">SLAD008</a> |

For design and product information related to the TRF6903, MSP430, and similar products, go to:

<http://www.ti.com/ismrf>  
<http://www.msp430.com>

PDF documents and zip files may be located on Texas Instruments' website by typing in the literature number in the *Search* text box; for example, typing in SWRS022 will locate the TRF6903 data sheet.

### Contents

|   |   |    |
|---|---|----|
| 1 | TRF4903 Demonstration and Evaluation Kit Overview ..... | 2  |
| 2 | Demonstrating a Wireless Link.....                      | 2  |
| 3 | Prototyping.....  | 7  |
| 4 | PCB Hardware Overview .....                             | 9  |
| 5 | Software Overview .....                                 | 14 |
| 6 | SCHEMATICS .....  | 22 |

### List of Figures

|   |  |   |
|---|--|---|
| 1 | Top-Side, Back-Side of the TRF4903 Demonstration Board ..... | 4 |
| 2 | JTAG Connector .....   | 8 |
| 3 | TRF4903 RF Block Diagram .....                               | 9 |

|    |   |    |
|----|---|----|
| 4  | Block Diagram of the MSP430F44x .....                   | 10 |
| 5  | Top-Side Silk Screen .....                              | 10 |
| 6  | Bottom-Side Silk Screen .....                           | 11 |
| 7  | JP1 Pin-Out Configuration .....                         | 13 |
| 8  | Game Application FLOW Chart – Transmit Mode .....       | 15 |
| 9  | Game Application FLOW Chart – Receive Mode .....        | 16 |
| 10 | Communication Protocol .....                            | 17 |
| 11 | TRF4903 Graphical User Interface for RF Evaluation..... | 21 |
| 12 | Schematic (Page 1) .....                                | 22 |
| 13 | Schematic (Page 2) .....                                | 23 |
| 14 | Schematic (Page 3) .....                                | 24 |

#### List of Tables

|   |  |    |
|---|--|----|
| 1 | 4-Bit DIP Switch (SW1) Settings and Transmit Frequencies ..... | 5  |
| 2 | Bill of Materials .....  | 11 |
| 3 | Antenna Suppliers.....   | 13 |
| 4 | 6-Byte Transmission Data Packet.....                           | 18 |
| 5 | TRF4903 Game Application Register Values .....                 | 18 |

## 1 TRF4903 Demonstration and Evaluation Kit Overview

This chapter provides an overview of the TRF4903 demonstration and development kit.

### 1.1 Description

The MSP-TRF4903-DEMO kit is used to demonstrate a unidirectional radio frequency (RF) data link without the need of an external computer, and for prototyping by downloading new software code to the MSP430F449 through the JTAG connector. This kit is used to evaluate the Texas Instruments TRF4903, a single-chip multiband RF transmitter. The schematics and layout of the board can be used as a reference design if desired, limited by the software system parameters of the demonstration firmware.

### 1.2 Contents

The TRF4903 demonstration and development kit contains:

- One TRF4903 demonstration board (transmitter)
- One TRF6903 demonstration board (receiver)
- User's manual (this document)

Software is not included in the kit. Software and hardware documentation related to this kit can be downloaded at <http://www.ti.com/ismrf>.

### 1.3 Equipment Requirement

The following equipment is not included in this kit and is required to operate the MSP-TRF4903-DEMO kit:

- Four AAA batteries
- MSP430 bus expansion cable for the JTAG connector, required only for prototyping purposes.

## 2 Demonstrating a Wireless Link

This chapter explains how to operate the MSP-TRF4903-DEMO kit to demonstrate a RF bidirectional link.

## **2.1 Board Description**

The demo kit has two circuit boards. The first circuit board (unit) is the transmitter and consists of a TRF4903 RF transmitter and a MSP430F449 microcontroller. The second circuit board in the kit is a receiver and consists of a TRF6903 RF transceiver and a MSP430F449 microcontroller. The TRF6903 board is capable of sending and receiving half-duplex wireless data on the European and North American/US ISM bands. However, for demo purposes, the TRF6903 board is used as a receiver for the TRF4903 transmitter.

The microcontroller firmware is configured by default to use the 902-MHz to 928-MHz ISM frequency band. Additional firmware has been developed to operate the TRF4903 demo kit in the European 868-MHz ISM band. See the *Operating the TRF4903 Demo Kit in the 868-MHz EU ISM Band* application note (SWRA047) for further information. The firmware for the 868-MHz EU band can be downloaded from the <http://www.ti.com/ismrf> website. [Figure 1](#) shows top-side and back-side views of the transmit TRF4903 circuit board.

Demonstrating a Wireless Link

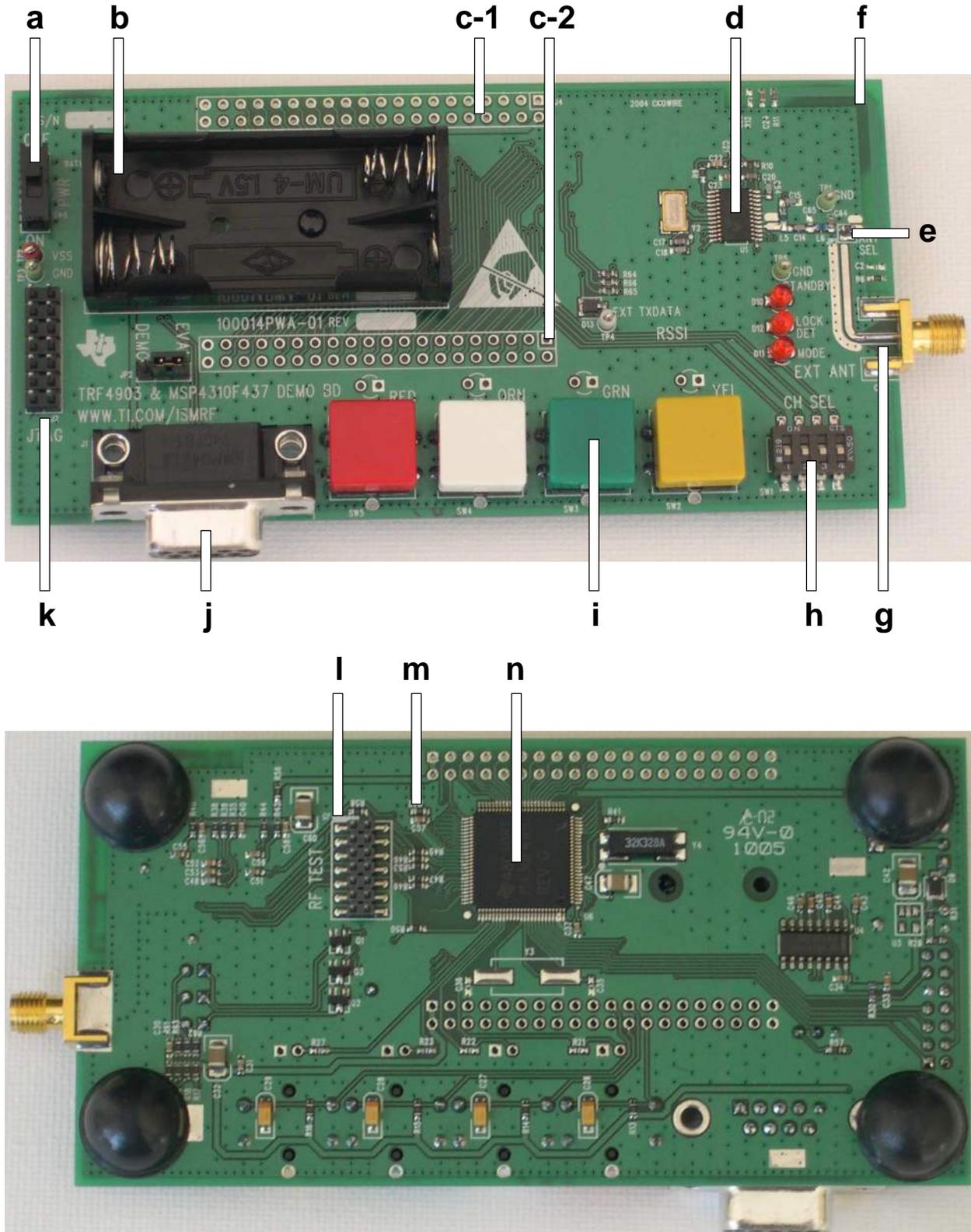


Figure 1. Top-Side, Back-Side of the TRF4903 Demonstration Board

Circuit board features:

- a On/Off switch
- b Battery holder for two AAA batteries in series (batteries not included).
- c-1, c-2 Headers used to access the MSP430F449 I/O ports.
- d TRF4903 RF transmitter
- e Antenna jumper (0- $\Omega$  resistor) used to select either the SMA connector or PCB antenna (selecting both not recommended).
- f On-board PCB antenna (default configuration). The antenna has modest gain and radiates in the direction of the bend in the long arm.
- g SMA connector footprint for an external antenna or test equipment (SMA connector not included).
- h Four-bit DIP switch used in the link demonstration mode to change the transmit/receive frequencies. The switch is connected to MSP430 I/O ports P3.0, P3.1, P3.2, and P3.3.
- i Four buttons used for the demonstration game application, connected to MSP430 I/O ports P1.0 through P1.3.
- j RS-232C connector
- k JTAG connector
- l TRF4903 I/O header used to monitor or control the TRF4903.
- m Zero- $\Omega$  resistor R42, remove to disable the MSP430F449 (or short reset to ground at JTAG connector).
- n MSP430F449 microcontroller

## 2.2 Operation

A simple game is implemented in the firmware to demonstrate unidirectional RF communication between the TRF4903 transmit board and the TRF6903 configured in the receive mode. The user starts the game by pushing any sequence of four colored buttons. The corresponding colored LED's light up on the receive board in the same sequence.

- Successful packet reception: The LED's light up in same sequence as the transmit button sequence.
- Communication error: NO LED's illuminate on the receiving board if there was a communication error.

### 2.2.1 Preparing for Operation

Before operating the units as a demonstration, make sure that you have done the following:

- Slide the on/off switch to ON
- Place two AAA batteries on each demonstration board
- Have the same 4-bit DIP switch (SW1) configuration on both boards

Table 1 shows the transmit and receive frequencies selected with the 4-bit DIP switch (SW1). Both circuit boards must have the same channel switch settings in order for the demonstration game to operate correctly.

**Table 1. 4-Bit DIP Switch (SW1) Settings and Transmit Frequencies**

| 1234 SW1 Setting<br>(1=On, 0=Off) | TX Frequency (MHz)<br>4903 TX Board | RX Frequency (MHz)<br>6903 RX Board |
|-----------------------------------|-------------------------------------|-------------------------------------|
| 0000                              | 902.3988                            | 891.6992                            |

**Table 1. 4-Bit DIP Switch (SW1) Settings and Transmit Frequencies  
(continued)**

| 1234 SW1 Setting<br>(1=On, 0=Off) | TX Frequency (MHz)<br>4903 TX Board | RX Frequency (MHz)<br>6903 RX Board |
|-----------------------------------|-------------------------------------|-------------------------------------|
| 0001                              | 903.218                             | 892.5184                            |
| 0010                              | 904.4468                            | 893.7472                            |
| 0011                              | 905.266                             | 894.5664                            |
| 0100                              | 906.0852                            | 895.3856                            |
| 0101                              | 907.7236                            | 897.024                             |
| 0110                              | 909.362                             | 898.6624                            |
| 0111                              | 910.1812                            | 899.4816                            |
| 1000                              | 911.8196                            | 901.12                              |
| 1001                              | 912.6388                            | 901.9392                            |
| 1010                              | 913.458                             | 902.7584                            |
| 1011                              | 914.2772                            | 903.5776                            |
| 1100                              | 915.506                             | 904.8064                            |
| 1101                              | 916.3252                            | 905.6256                            |
| 1110                              | 917.554                             | 906.8544                            |
| 1111                              | 918.3732                            | 907.6736                            |

## 2.2.2 Power Up

Slide the power switch to ON. The STANDBY, MODE, and LOCK DETECT LED's blink to indicate power up condition. After the power-up initialization, the TRF4903 based transmit unit goes into Standby Mode (IDLE\_STATE) and Mode 0 and waits for a button press. This turns off all the LED's.

---

### Note:

The LOCK LED on the transmit board is connected to the multiplexed pin 16 of the TRF4903. Initially, the TRF4903 is programmed to obtain a lock detect signal on the multiplexed pin 16. This turns on the LOCK DETECT LED on the transmit board.

Once the TRF4903 is ready to transmit data, the multiplexed pin 16 is programmed for the DCLK mode and the recovered data clock at 38.4 kbps is output at terminal 16. This blinks the LOCK LED at 38.4 kbps. Once the transmission is complete, the TRF4903 goes back to Standby (IDLE\_STATE) and the LOCK LED is turned off again.

---

The TRF6903 based receive board goes into the receive mode to monitor for any transmit activity. The RSSI indicator LED is lighted to indicate the signal strength in the frequency channel of operation. Red indicates the lowest signal strength and green indicates the highest.

## 2.2.3 Wireless Demonstration

Only the TRF4903 transmit board is configured to initiate wireless communication. Assume that Board A is the transmit board and transmits the first four-button transmitted sequence and Board B receives the transmission.

Use Board A to start the wireless demonstration by pressing the four colored buttons in any sequence with about 1/2 second between successive buttons. Once the four buttons are pushed, Board A initiates the transmission.

Once the transmission is received by Board B and if the response sequence matches, the LEDs are turned on in the same sequence as the buttons were pushed at the transmitter side.

If there are errors due to poor or lost transmission, NO LED lights up on the Board B. This concludes the basic demonstration of the one-way RF communication.

On completion, the transmit board waits for another button press and the receive board goes back to receive mode to listen for a new button sequence.

#### 2.2.4 RSSI Indicator

Since the TRF4903 is a transmitter, it does not have an RSSI feature. The TRF6903 receive board is equipped with a receive signal strength indicator (RSSI) that illustrates the signal strength on the receiver. Four levels are used to indicate signal strength. Red is the lowest and means no signal was received, while green indicates the highest level of signal strength. The RSSI shows transmission activity when the other board is transmitting a data stream on the same DIP switch configuration or when there is another external RF source broadcasting at that channel frequency. For the best results, the two boards should be in the same plane of orientation, with the bend in the long antenna arm pointed towards each other.

#### 2.2.5 Error Conditions

Cycle the system power to reinitialize the hardware if you get error conditions that persist. Error conditions are defined as lost communication, mismatch in response sequences, or response time outs. In some cases, antenna orientation, signal multipath, or another interfering signal can increase errors.

### 3 Prototyping

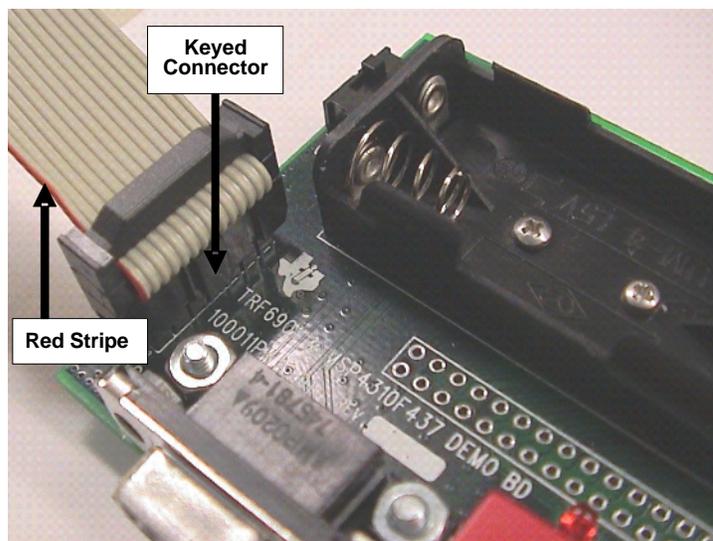
This chapter explains how to operate the MSP-TRF4903-DEMO kit to prototype new applications.

#### 3.1 Connecting to the MSP430 JTAG

The MSP-TRF4903-DEMO is designed for rapid application development. The MSP430 MCU flash memory can repeatedly be erased and reprogrammed. The on-chip emulation logic allows real-time debugging and fast code development. The MSP-TRF4903-DEMO and the MSP430 flash emulation tool provide everything that is required to develop an entire firmware project.

For information go to <http://www.msp430.com>

Connector J2 provides access to the JTAG port of the MSP430 microcontroller on the MSP-TRF4903-DEMO circuit board. The MSP-FET430 flash emulation tool (FET) interface board MSP-FETP430IF (not included in this kit) connects to J2 and allows real-time in-system emulation. Programming the MSP430, assembler/C source-level debugging, single stepping, multiple hardware breakpoints, full-speed operation, and peripheral access are fully supported in-system using the JTAG connector. [Figure 2](#) shows the connections of the MSP-TRF4903-DEMO to the JTAG cable provided by the MSP430 FET interface board.



**Figure 2. JTAG Connector**

### **3.2 Loading the MSP430 With the Firmware**

The MSP-TRF4903-DEMO comes with source code installed on the MSP430 to run the demo program. The user can develop new application software that can be downloaded to the MSP430 MCU through the JTAG connector. Since the Compiled C code size is greater than 4 kB, only unrestricted versions of the IAR development environment (not the Kickstart version) must be used for downloading and modifying the code.

The workspace file for compiling the demo source code is TRF4903\_Demo\_US.eww, developed with IAR compiler version 3.20a.

The following steps show how to open the project file and program the MSP430.

- Step 1. Insert the two AAA batteries and slide the on/off switch to ON.
- Step 2. Start the Workbench (START->PROGRAMS->IAR SYSTEMS->IAR EMBEDDED WORKBENCH)
- Step 3. Use FILE->OPEN WORKSPACE to open the workspace file at: <Installation root>\...\TRF4903\_Demo\_US.eww
- Step 4. Use PROJECT->BUILD ALL to compile and link the source code. You can view the source code by double-clicking Common Sources, and then double-clicking on the source files in the workspace window
- Step 5. Ensure that the C-SPY Debugger is properly configured for the Parallel Port used. (Choose PROJECT->OPTIONS->FET DEBUGGER and select ->LPT1 (default) or LPT2 or LPT3 for the Parallel Port Configuration).
- Step 6. Use PROJECT->DEBUG to start C-SPY. C-SPY erases the device Flash and downloads the application object file
- Step 7. In C-SPY, use DEBUG->GO to start the application
- Step 8. In C-SPY, use DEBUG->STOP DEBUGGING to exit C-SPY
- Step 9. In Workbench, use FILE->EXIT to exit Workbench

The MSP430 is now programmed with the game demonstration code and ready to operate.

## 4 PCB Hardware Overview

This chapter provides the default PCB hardware documentation in detail and provides alternate configurations that the user may want to implement.

### 4.1 Hardware Overview

The TRF4903 ISM-band transmitter IC operates from 315 MHz to 950 MHz. It has low power consumption and an operating voltage of 2.2 V to 3.6 V. It features an integer-N PLL synthesizer and supports FSK and OOK operation. Other features include on-chip clock recovery, brownout detector, and XTAL frequency trimming in software. See the TRF4903 data sheet ([SWRS023](#)) for detailed information on the TRF4903 features.

The TRF4903 demonstration and development kit (MSP-TRF4903-DEMO) provide a stand-alone demonstration of a unidirectional link using the MSP430F449, the TRF4903 RF transmitter and the TRF6903 RF transceiver configured as a receiver.

### 4.2 TRF4903 RF Block Diagram

Figure 3 shows the block diagram of the TRF4903 ISM transceiver IC.

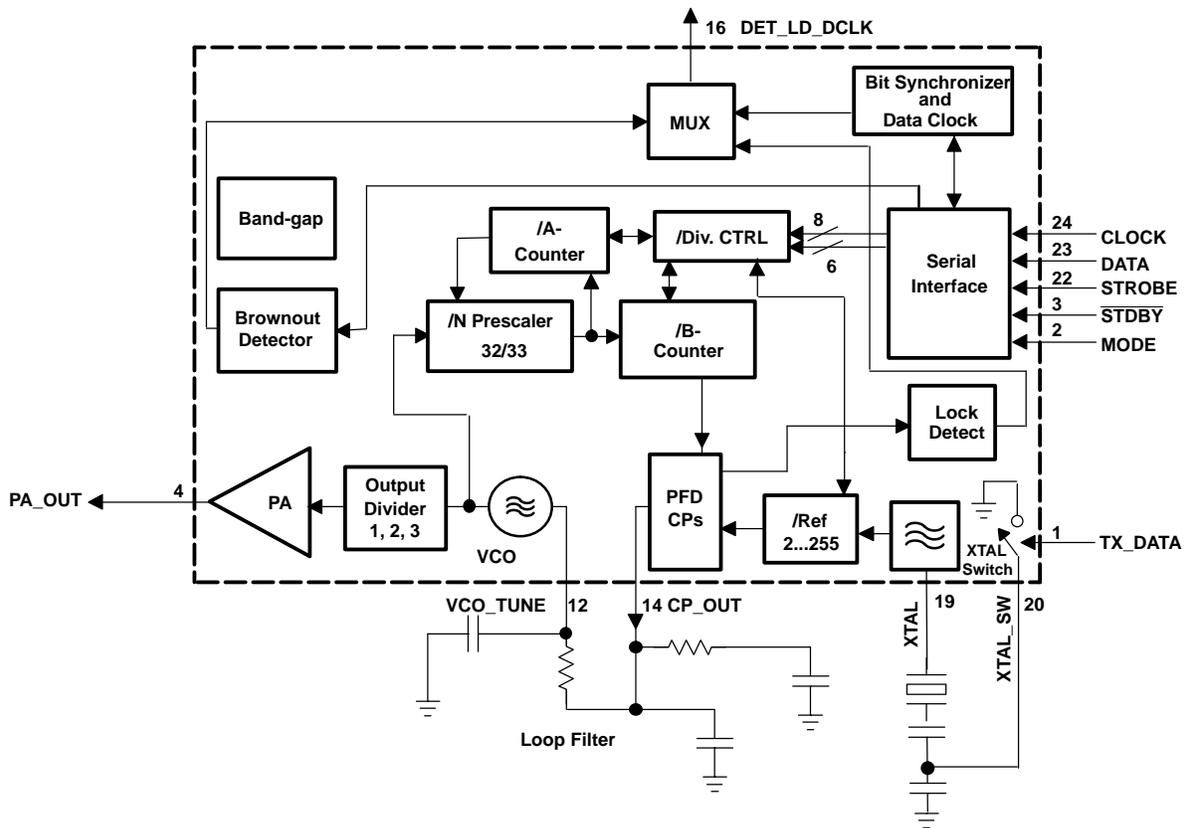


Figure 3. TRF4903 RF Block Diagram

### 4.3 MSP430F449 Block Diagram

Figure 4 shows the block diagram of the MSP430F449 microcontroller IC.

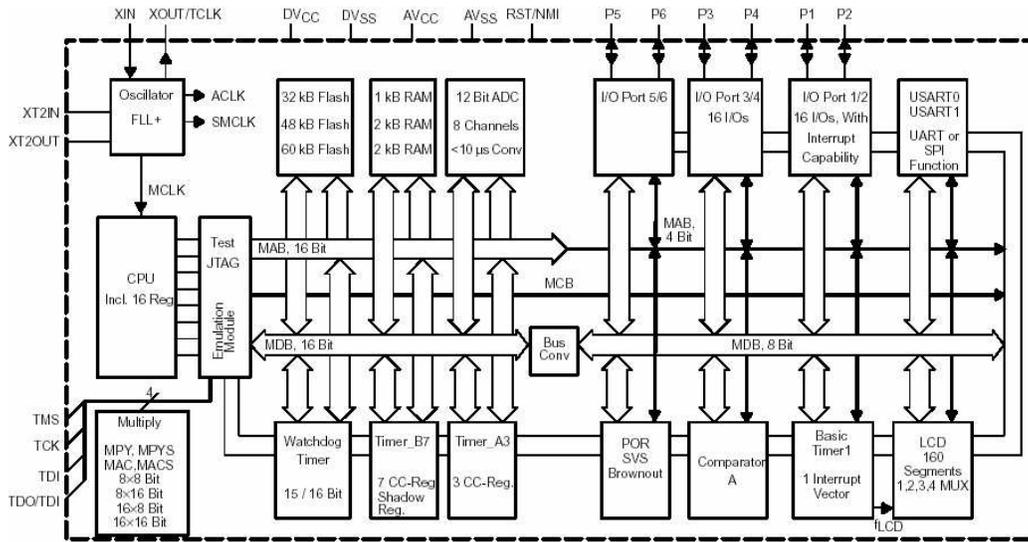


Figure 4. Block Diagram of the MSP430F44x

### 4.4 Demo Board Schematics

See SWRR009 for the TRF4903 transmit side schematics and SWRR001 for the TRF6903 receiver side schematics. All the schematics for the demonstration boards can be found at <http://www.ti.com/ismrf>.

### 4.5 Top and Bottom Silk Screen and Drawing

Figure 5 and Figure 6 show the top-side and bottom-side TRF4903 circuit board silkscreen.

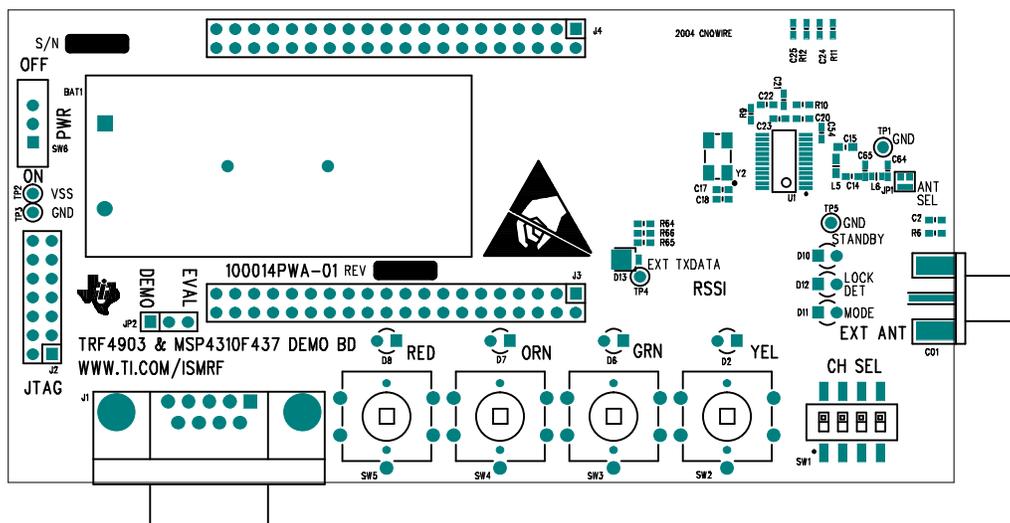


Figure 5. Top-Side Silk Screen

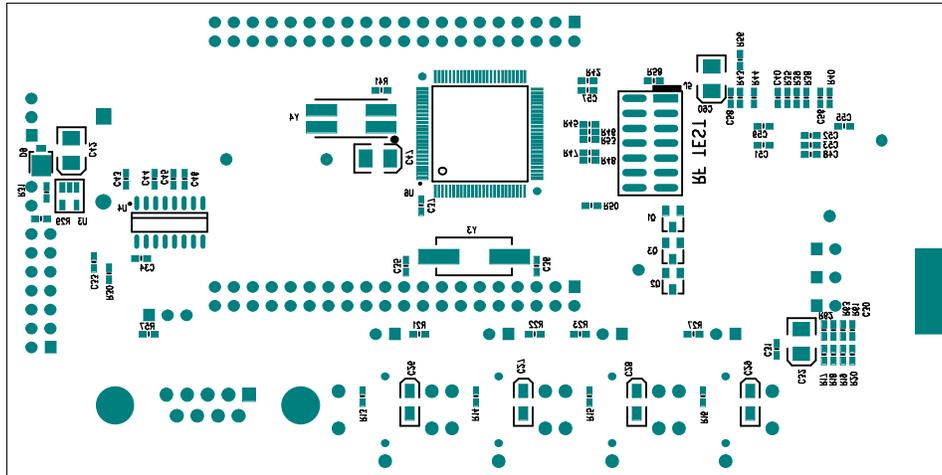


Figure 6. Bottom-Side Silk Screen

#### 4.6 Parts List

Table 2. Bill of Materials

| QTY | VALUE          | MFG          | MFG NO.          | DESCRIPTION  | REFERENCE   |
|-----|----------------|--------------|------------------|--|---|
| 1   | 0.5 pF         | AVX          | 06035A0R5CAT2A   | CAP, CER, 0603, 50 V, $\pm 0.25$ pF, 0.5 pF                    | C24   |
| 1   | 1.5 pF         | AVX          | 06035A0R5CAT2A   | CAP, CER, 0603, 50 V, $\pm 0.25$ pF, 1.5 pF                    | C64   |
| 1   | 22 pF          | AVX          | 06035A220FAT2A   | CAP, CER, 0603, 50 V, 1%, 22 pF                                | C18   |
| 1   | 27 pF          | AVX          | 06035A270FAT2A   | CAP, CER, 0603, 50 V, 1%, 27 pF                                | C17   |
| 2   | 33 pF          | AVX          | 06035A330FAT2A   | CAP, CER, 0603, 50 V, 1%, 33 pF                                | C15, C48  |
| 1   | 43 pF          | AVX          | 06035A430FAT2A   | CAP, CER, 0603, 50 V, 1%, 43 pF                                | C14   |
| 1   | 100 pF         | AVX          | 06035A101FAT2A   | CAP, CER, 0603, 50 V, 1%, 100 pF                               | C54   |
| 1   | 120 pF         | AVX          | 06035A121FAT2A   | CAP, CER, 0603, 50 V, 1%, 120 pF                               | C21   |
| 1   | 75 pF          | AVX          | 06035A820JAT2A   | CAP, CER, 0603, 50 V, 5%, 75 pF                                | C20   |
| 1   | 5600 pF        | AVX          | 06035A562JAT2A   | CAP, CER, 0603, 50 V, 5%, 5600 pF                              | C22   |
| 19  | 0.1 $\mu$ F    | AVX          | 0603YC104KAT2A   | CAP, CER, 0603, 16 V, 10%, 0.1 $\mu$ F                         | C23, C30, C31, C33, C34, C37, C40, C43, C44, C45, C46, C51, C52, C53, C55, C56, C57, C58, C59 |
| 4   | 1 $\mu$ F      | AVX          | TAJA105K016R     | CAP, TANT, 3216, 16 V, 10%, 1 $\mu$ F                          | C26, C27, C28, C29  |
| 4   | 22 $\mu$ F     | CAL CHIP     | GMC32Y5V226Z16NT | CAP, CER, 1210, 16 V, -20 +80%, 22 $\mu$ F                     | C32, C42, C47, C60  |
| 3   | RED            | KingBrite    | W934-IT          | DIODE, LED, T1, RED, 12.5 MCD at 20 mA                         | D10, D11, D12   |
| 2   | MBRM120LT      | Motorola     | MBRM120LT1 or 3  | DIODE, SCHOTTKY, 20PIV, 1A, DO-216AA                           | D9, D13   |
| 3   | FMMT2222A      | Central Semi | CMPT2222A        | XSTR, NPN, GenPurp, 75hfe, 40 V <sub>ceo</sub> , 600 mA, SOT23 | Q1, Q2, Q3  |
| 1   | 15 nH          | Murata       | LQW1608A15ND00   | IND, SMD, 0603, $\pm 0.5$ nH, 650 mA, 15 nH                    | L6  |
| 1   | 270 nH         | Murata       | LQW1608A270ND00  | IND, SMD, 0603, $\pm 0.5$ nH, 650 mA, 270 nH                   | L5  |
| 8   | 0 $\Omega$     | AVX          | CJ10-000-T       | RES, 0603, 5%, 0 $\Omega$                                      | JP1, R6, R29, R31, R41, R42, R56  |
| 6   | 10 $\Omega$    |              |                  | RES, 0603, 5%, 10 $\Omega$                                     | R35, R38, R39, R40, R43, R44  |
| 6   | 100 $\Omega$   |              |                  | RES, 0603, 5%, 100 $\Omega$                                    | R45, R46, R47, R48, R50, R58  |
| 3   | 200 $\Omega$   |              |                  | RES, 0603, 5%, 200 $\Omega$                                    | R61, R62, R63   |
| 1   | 1 k $\Omega$   |              |                  | RES, 0603, 5%, 1 k $\Omega$                                    | R11   |
| 1   | 7.5 k $\Omega$ |              |                  | RES, 0603, 5%, 7.5 k $\Omega$                                  | R9  |

**Table 2. Bill of Materials (continued)**

| QTY | VALUE               | MFG                | MFG NO.                        | DESCRIPTION   | REFERENCE   |
|-----|---------------------|--------------------|--------------------------------|---|---|
| 13  | 10 kΩ               |                    |                                | RES, 0603, 5%, 10 kΩ                                  | R13, R14, R15, R16, R17, R18, R19, R20, R53, R57, R64, R65, R66 |
| 1   | 15 kΩ               |                    |                                | RES, 0603, 5%, 15 kΩ                                  | R10   |
| 1   | 82 kΩ               |                    |                                | RES, 0603, 5%, 82 kΩ                                  | R30   |
| 1   | Header 7 x 2 mm     | SAMTEC             | TSW-107-07-T-D                 | CONN, HDR, P, 14, 7 x 2 x 0.1, TTH                    | J2  |
| 1   | Header 7 x 2 x 2 mm | SAMTEC             | TMM-107-01-T-D-SM              | CONN, HDR, P, 14, 7 x 2 x 2 mm, SMT                   | J5  |
| 1   | Header 3            | MOLEX              | 22-28-4030                     | CONN, HDR, P, 3, 3 x 1x 0.1, TTH                      | JP2   |
| 1   | CONN DB-9           | AMP                | 745781-4                       | CONN, PCB, DB9, F, RT                                 | J1  |
| 1   | SMA EDGE            | Johnson Components | 142-0701-801 (-801 = Au Plate) | CONN, Coax, SMA, Edge, SMT, 0.062 Thk PCB             | CO1   |
| 1   | 4 x SPST            | CTS                | 219-4MST                       | SW, Slide, 4 X SPST, 20 V at 100 mA, SMT, Sealed      | SW1   |
| 4   | PB SPST, NO         | OMRON              | B3W-4050                       | SW, PB-SPST, NO, 50 mA, 24 V, TTH                     | SW2, SW3, SW4, SW5  |
| 1   | SS12SDP2            | NKK                | SS12SDP2                       | SW, SLIDE SPDT, PCB, 30 V at 0.2 A                    | SW6   |
| 1   | 12 mm Switch Cap    | OMRON              | B32-1320                       | Cap, SW, 12 mm sq, fits B3W-4050, Orange              | See sample  |
| 1   | 12 mm Switch Cap    | OMRON              | B32-1330                       | Cap, SW, 12 mm sq, fits B3W-4050, Yellow              | See sample  |
| 1   | 12 mm Switch Cap    | OMRON              | B32-1350                       | Cap, SW, 12 mm sq, fits B3W-4050, Green               | See sample  |
| 1   | 12 mm Switch Cap    | OMRON              | B32-1380                       | Cap, SW, 12 mm sq, fits B3W-4050, Red                 | See sample  |
| 1   | 2468                | MemProtectionDev   | BC2AAAPC                       | Battery holder, 2 X AAA, PCB Mount                    | BAT1  |
| 1   | TP Red              | Kobiconn           | 41-77B4                        | Test Point, RED, 0.037 TTH                            | TP2   |
| 3   | TP Green            | Kobiconn           | 42-23F8                        | Test Point, GRN, 0.037 TTH                            | TP1, TP3, TP 5  |
| 1   | TP White            | Kobiconn           | 33-85B4                        | Test Point, WHT, 0.037 TTH                            | TP4   |
| 1   | TRF4903PW           | Texas Instruments  | TRF4903PW                      | IC, RF XMIT, 315-930 MHZ, FQFP48                      | U1  |
| 1   | MSP430F449          | Texas Instruments  | MSP430F449IPZ                  | IC, MicroP, MixSig, 16-Bit RISC, 32 kb Flash, FQFP100 | U6  |
| 0   | TPS76330DBV         | Texas Instruments  | TPS76330DBVT                   | IC, PS LDO Regulator, 30 V at 150 mA, SOT32-5         | U3  |
| 1   | MAX3232-SOIC16      | Texas Instruments  | MAX3232CD                      | IC, RS232 Driver, 2 Driver, 2 Receiver, SOIC16        | U4  |
| 1   | 19.6608 MHz         | CRYSTEK Corp       | 017119                         | XTAL, SMT, 19.6608 MHz, LCC-5X7                       | Y2  |
| 1   | 32.768 kHz          | Seiko              | 628-SPT1A-0368                 | XTAL, SMT, 32.768 kHz, CM202                          | Y4  |

#### 4.7 Alternate Hardware Configurations

The MSP-TRF4903-DEMO kit is preconfigured to function under the following assumptions:

- North American ISM frequency band, 902-928 MHz
- NRZ (non-return to zero) coding
- FSK (frequency shift keying)
- 38.4 Kbps
- On-board PCB antenna

The kit can be reconfigured to a limited extent. These options are covered in this section.

#### 4.7.1 European ISM Frequency Band

The European 868-MHz to 870-MHz ISM band is not covered in the preconfigured system, but it can be modified by changing software variables; download new software configurations through the JTAG connector. No hardware changes are needed, but the antenna matching is not optimized for this band. See the *Operating the TRF4903 Demo Kit in the 868-MHz EU ISM Band* application note (SWRA047) for further information. The firmware for the 868-MHz EU band can be downloaded from the <http://www.ti.com/ismrf> website.

#### 4.7.2 External Antenna

Significant range performance may be achieved when an external antenna is used. The actual performance improvement will depend on the antenna design and proper impedance matching. A solder pad for a SMA connector is provided on the circuit board. The antenna can be mounted onto the SMA connector. Jumper (JP1) setting must be moved to connect the external antenna to the rest of the RF front end. Shorting pins 2 and 3 of JP1 with a 0- $\Omega$  resistor connects the circuit board antenna. To connect an external antenna, open pins 2 and 3 and short pins 1 and 2 with a 0- $\Omega$  resistor. Figure 7 shows the pin-out configuration at the silk screen. Table 3 lists information for some antenna suppliers. If the PCB antenna is not used, leave it unconnected, remove the matching components from each end, and substitute one 100- $\Omega$  resistor at each end; this will prevent unwanted coupling between the PCB antenna and the RF signal.

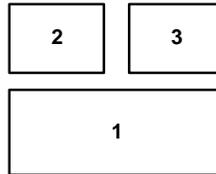


Figure 7. JP1 Pin-Out Configuration

Table 3. Antenna Suppliers

| Supplier        | Web Site   | Part Number                 | ISM Band       |
|-----------------|--|-----------------------------|----------------|
| Nearson         | <a href="http://www.nearson.com">www.nearson.com</a>             | S467AM-915S<br>S467AH-868S  | US<br>European |
| MaxRad          | <a href="http://www.maxrad.com">www.maxrad.com</a>               | MEXR902SM                   | US             |
| Mobilemark      | <a href="http://www.mobilemark.com">www.mobilemark.com</a>       | PSWN3-925S<br>PSTNS-900S    | US<br>European |
| W. Badland Ltd. | <a href="http://www.badland.co.uk">www.badland.co.uk</a>         | Various models              | US/ European   |
| Radiall/Larsen  | <a href="http://www.radialllarsen.com">www.radialllarsen.com</a> | Various models<br>SPDA24832 | US<br>European |

#### 4.7.3 RS-232C Port

The circuit board is designed for communication to the MSP430 microcontroller through the RS232 serial port. The UART driver is implemented in firmware and is used in the RF evaluation mode.

#### 4.7.4 On-Board LDO Voltage Regulator

In normal operation, the battery is connected directly to the circuit board power through R31. There is a footprint for a low dropout (LDO) regulator for cases where a higher-voltage power supply is used instead of the on-board batteries. To add an LDO regulator, remove R31 and install Texas Instruments regulator TPS76330DBV at the U3 footprint.

#### 4.7.5 High-Frequency Crystal

The board has a footprint for a high-frequency (4 MHz) microprocessor crystal (Y3) as well as the low-frequency crystal. The factory board configuration uses the 32-kHz watch crystal (Y4). An internal frequency multiplier generates the 2.4576-MHz system clock.

#### 4.7.6 Discrete LC Filter or SAW Filter

A SAW filter is typically used to band-limit the received RF signal and reduce RF interference outside the ISM band. The SAW filter from Murata (SAFC915MA70N-TC11) gives a pass band typical of 902 MHz to 928 MHz, while providing about 30-dB attenuation in the stop band. Insertion loss in the pass band is about 4.5 dB. This causes a corresponding loss in operational range due to signal attenuation. The SAW filter is not normally installed at the factory in order to maximize range rather than noise immunity.

There are other hardware configurations for attenuating transmitter harmonics and filtering out-of-band received noise. It is recommended that discrete LC filters be used for this purpose. See the TRF6903 Design Guide ([SWRU009](#)) for a detailed discussion on the design of discrete LC filters.

#### 4.7.7 Disabling the MSP430

In normal operation, the MSP430 microprocessor controls the TRF4903 transmitter and the game user interface. The RF section can also be controlled directly with external computer software. To disable the microcontroller, either short the MSP430 reset pin (RST) to ground at the JTAG connector (preferred method), or remove R42, which disables the voltage supply to the MSP430. The TRF4903 can then be controlled directly through J5, the 14-pin surface-mount header.

#### 4.7.8 Game and RF Operational Modes (Jumper JP2)

The TRF4903 circuit board comes with jumper JP2 set in the position for the game (demonstration link) mode, where two circuit boards communicate with each other in game mode to demonstrate a wireless link. In the other jumper position (RF evaluation mode), the TRF4903 is controlled from external software run on a PC and the commands are passed through the MSP430. This software can be downloaded from the <http://www.ti.com/ismrf> website.

## 5 Software Overview

This chapter describes the link demonstration firmware that has been flashed to the microcontroller and external control software for RF test and evaluation.

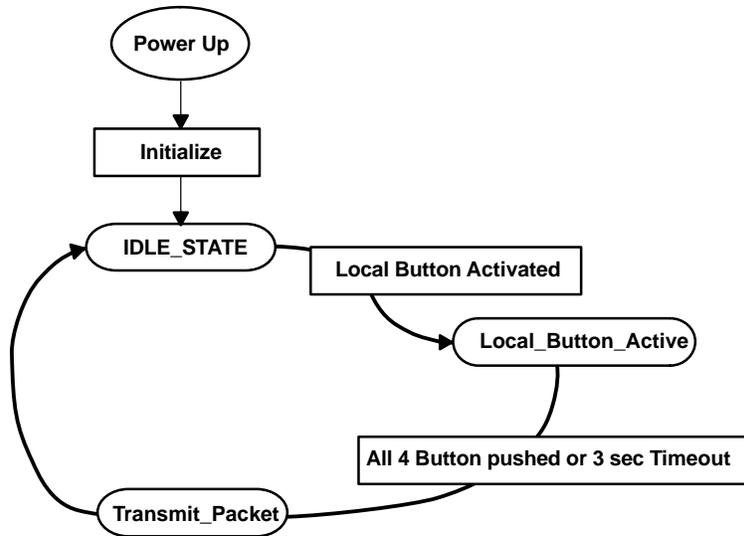
### 5.1 Software Description

The demonstration software implements a simple one-way game application utilizing a half-duplex unidirectional wireless link. The transmit board and receive board have different software. The 4903-based transmit side software routines are discussed in this section. The software was developed using IAR's Embedded Workbench, version 3.20a ([www.iar.com](http://www.iar.com)). The software files are:

- trf4903\_demo\_us.ewp – Project file
- trf4903\_main.c – Main body of the program written in C language. All subroutines are called from this program
- rf\_reg.c – C file to configure the TRF4903 registers
- api\_4903.c – C file for UART interface
- trf4903.s43 – Assembly subroutine to program the TRF4903 registers
- radio49.s43 – Assembly subroutines that execute wireless transmission commands
- setdco.s43 – Assembly routine that sets the baseband clock.

## 5.2 Flowchart

After power up initialization, the controller is configured as a state machine to run the link demonstration. [Figure 8](#) illustrates the state machine flowchart for the TRF4903 transmit board and the TRF6903 receive board. Buttons and timer functions are handled through interrupt subroutines.



**Figure 8. Game Application FLOW Chart – Transmit Mode**

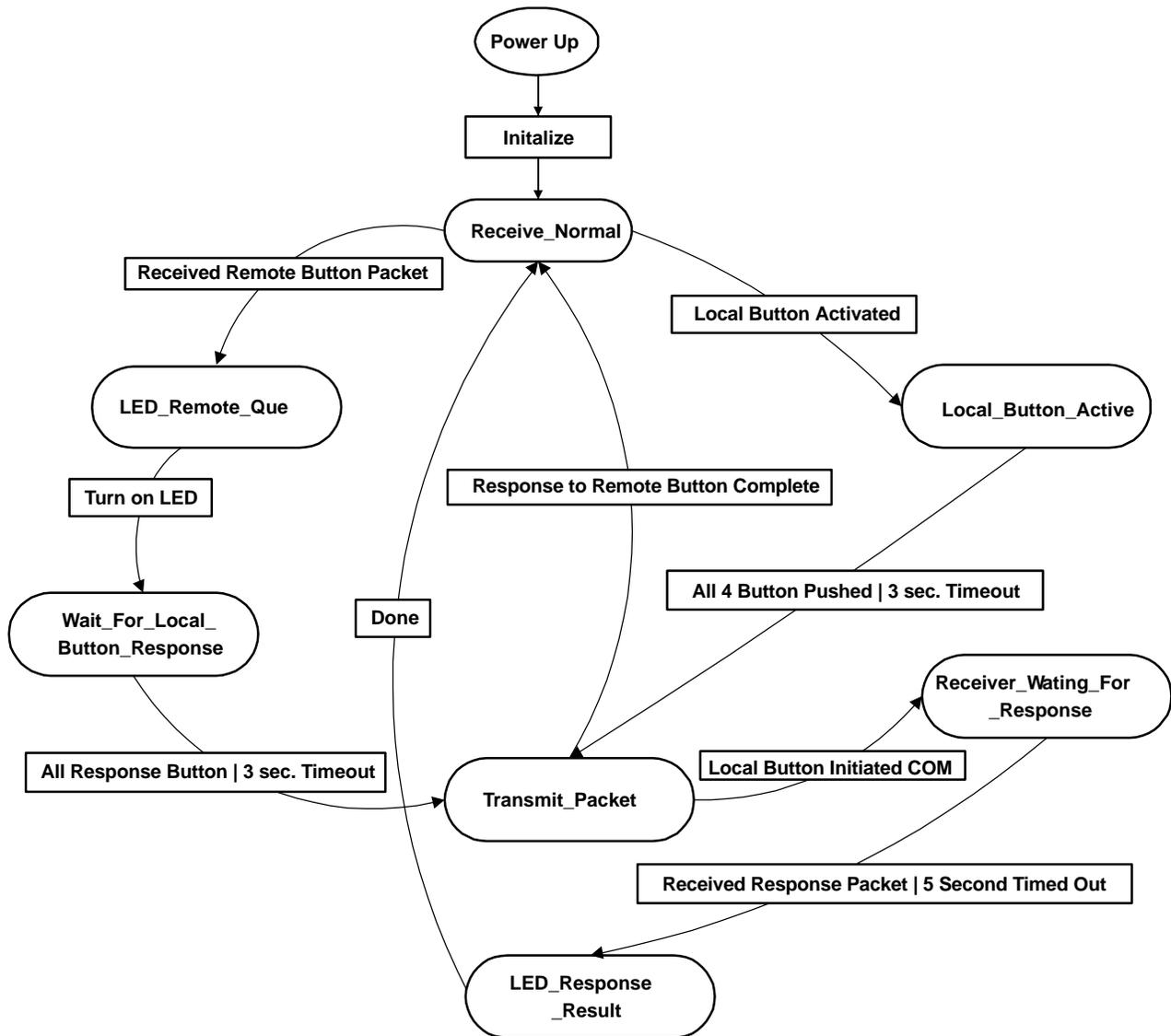
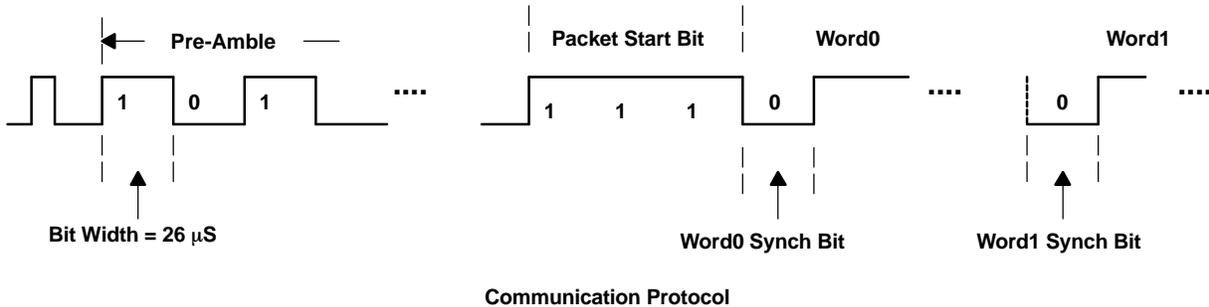


Figure 9. Game Application FLOW Chart – Receive Mode

### 5.3 Wireless Protocol

The wireless data communication protocol is digital FSK at 38,400 bits per second with NRZ coding. The communication protocol used for the demonstration board includes preamble, packet start bit, and word-sync bit as illustrated in [Figure 10](#).



**Figure 10. Communication Protocol**

#### Preamble

The function of the preamble is to train the receive hardware to set the proper reference voltage threshold to extract 1 and 0 data. The preamble consists of a train of alternating ones and zeros. A longer preamble may give better performance at a cost of more time to deliver an equivalent data packet. The current design has a preamble 100 bits long, or 2.6 ms in duration. Shorter lengths may be used for more time-critical applications.

#### 5.3.1 Packet Start and Word-Sync Bits

The packet start bit and the word sync bit are used by the receive routine to adjust microprocessor timing for sampling the incoming data stream. The packet start bit occurs once at the beginning of the data packet to indicate the end of the preamble and the start of data. The sync bit is used to resynchronize the bit stream and the data sampling timer. Over time the receive timing could shift in phase relative to transmit timing due to the small variation in component tolerances and performance. This shows up as an error in sampled data. The problem gets worse as the packet size increases. Resynchronization minimizes this drift over time.

Although resynchronization can be done at byte boundaries, word boundary resynchronization is slightly more efficient.

The data clock recovery feature of the TRF4903 and the TRF6903 provides a convenient way to synchronize data.

#### 5.3.2 Wireless Data Stream

The wireless data stream for the game application is implemented as follows:

- User initiates an RF transmission on **Board A** (TRF4903 demo board) by pushing four buttons in any sequence.
- User sequence is sent to **Board B** (TRF6903 demo board) using the transmission data packet described in [Table 4](#), embedded in the communication protocol described in [Figure 10](#). The transmission packet includes a unique header, four bytes with the button IDs and a checksum.
- **Board A** then goes to the IDLE\_STATE and waits for further button pushes.
- **Board B** receives the 6 data bytes, calculates the checksum and compares it with the received checksum. If checksums match, it lights up the LED's on the receive board in the same order in which the transmit buttons were pressed. The **Board B** then goes into the receive mode and listens for transmissions.

**Table 4. 6-Byte Transmission Data Packet**

| Header Byte | Button 1 | Button 2 | Button 3 | Button 4 | Checksum Byte |
|-------------|----------|----------|----------|----------|---------------|
| OxFa        | ID Byte  | ID Byte  | ID BYte  | ID BYTe  |               |

### 5.3.3 Checksum Byte

Each packet has a checksum byte at the end of the data packet (see [Table 4](#)). The checksum byte is calculated by summing the first 5 bytes of the packet and ignoring overflow.

## 5.4 TRF4903 Registers

The TRF4903 has five control registers (A through E) that are initialized using an on-chip serial port interface (SPI). [Table 5](#) shows the values loaded into the registers by the microprocessor during demo program initialization.

**Table 5. TRF4903 Game Application Register Values**

| Register | Parameter   | Value   |
|----------|---|---|
| A        | PA attenuation<br>Mode 0<br>Charge Pump<br>Frequency Band<br>TX Frequency                               | 0 dB<br>TX<br>0.5 mA<br>915 MHz<br>902.3488 MHz             |
| B        | PA attenuation<br>PA<br>Mode 1<br>Modulation<br>Brownout threshold<br>Brownout detector<br>TX Frequency | 0 dB<br>Enabled<br>TX<br>FSK<br>2.2 V<br>On<br>902.3488 MHz |
| C        | Reference divider<br>Reference frequency  | 48<br>409.6 kHz   |
| D        | Crystal Tune<br>Reset Signal for PFD<br>Crystal Switch during OOK                                       | 20.23 pF<br>Derived From Prescaler<br>Open                  |
| E        | Transmit Capture Mode (TXM)<br>Dividers D1 D2 D3<br>Terminal 16 Multiplex function                      | High<br>38.4 kbps<br>Lock Detect                            |

## 5.5 Transmit-Side Wireless Subroutines

The game application uses a combination of C and MSP430 assembly language functions to implement different communication tasks that are required to receive and send data. Brief descriptions of these subroutines follow.

### 5.5.1 program\_TRF4903\_word()

This function configures one of the five registers of the TRF4903 transceiver. Here is a sample code on how to use this function so that you can program all five registers:

```

struct REGA_BITS{
unsigned long BND:2;          //1-0 Band of operation
unsigned long CP_Acc:2;      //3-2 speed up time for the CP
unsigned long reserved0:1
    unsigned long TX:1;       //5
    unsigned long PA0:2;      //7-6
        unsigned long B_DIV_M0:9; //16-8 Mode 0 = Transmit
        unsigned long A_DIV_M0:5; //21-17
        unsigned long ADDR:2;   //23-22
};
union TRF_REGA{
    unsigned long all;
    struct REGA_BITS bit;
};
struct TRF_REG{
    union TRF_REGA a;
    union TRF_REGB b;
    union TRF_REGC c;
    union TRF_REGD d;
    union TRF_REGE e;
};
void configure_trf4903(void)
{
    int pointer;
    P4OUT&=0xfe;
    pointer=(int)f_sel;   trf4903.a.bit.B_DIV_M0=MAIN_B_T[pointer];
    trf4903.a.bit.A_DIV_M0=MAIN_A_T[pointer];
    program_TRF4903_word(trf4903.a.all);
    trf4903.b.bit.B_DIV_M1=MAIN_B_R[pointer];
    trf4903.b.bit.A_DIV_M1=MAIN_A_R[pointer];
    program_TRF4903_word(trf4903.b.all);
    program_TRF4903_word(trf4903.c.all);
    trf4903.d.bit.XTAL_Tune = XTAL_OFFSET;
    program_TRF4903_word(trf4903.d.all);
    program_TRF4903_word(trf4903.e.all);
}

```

### 5.5.2 send\_RF(unsigned int, unsigned int\*)

This function is used to transmit a packet of wireless data stream. Here is an example of how it is used:

```

union RF_XMIT_PACKET{
    unsigned int w[MAXWORD];
    unsigned char b[MAXBYTE];
}xmit;
void SendRFWithModeSelect(unsigned int ByteCnt)
{
    switch(trf4903.e.bit.TXM){
    case 0:
        send_RF(ByteCnt,xmit.w);
        break;
    case 1:
        trf4903.e.bit.MUX = 1; //set to DCLK mode
        program_TRF4903_word(trf4903.e.all);
        send_RF_DCLK(ByteCnt,xmit.w);
        break;
    }
}

```

## 5.6 External Control Software for RF Evaluation Mode

In the RF evaluation mode, the TRF4903 transmitter is controlled by external software run on a PC rather than by the game/demo firmware installed on the MSP430. There is no operational link in RF evaluation mode; the transmitter is set to one operational state at a time. Jumper JP2 sets the board operation mode to game/demo or RF evaluation.

The RF control software has a graphical user interface (GUI) for the user to set the transmitter frequency, power, etc. In the RF evaluation mode, the external software GUI controls the TRF4903 by passing control register words through the computer COM1 serial port, RS232 driver IC (MAX3232), and finally through the MSP430 microcontroller to the transmitter.

Figure 11 shows the graphical user interface that communicates with the circuit board through the COM1 RS232 serial port. The user must click on the adjacent COM1 button if its caption reads *Com1 Closed* in order to open the serial port. The RF evaluation GUI is written in Borland C++ Builder, version 6, and integrates utilities from Winsoft Ltd. to write to the serial port (Comport). In RF evaluation mode, the serial port COM1 is used to control the TRF4903.

An example GUI setup for the TRF4903 (transmit mode) is shown in Figure 11. Several boxes and pick lists have to be filled out by the user before clicking the *Send All* button to configure the RF transceiver. Some of the boxes will toggle state when the cursor is placed over the box contents and double-clicked (power amplifier).

The crystal frequency should be set to 19.6608 MHz. Set the reference divider to 48 (enter value and click the *Set* button). The crystal tune capacitance should be set to an intermediate value like 17, 20, or 22 pF. The charge pump current is 0.5 mA. In the *Mode Select* box, Either *A-Word* or *B Word* can be selected for transmit mode. The phase-frequency detector reset should be set to *Prescaler*. Enter the power amp output frequency and click the *Set Freq* button; the software rounds off the output frequency to an integer multiple of the reference frequency. The *Band Select List* box can be used to select for the ISM band of operation. The Modulation box should be set to FSK. For initial evaluation, set TXM=0 and TXDATA to *Low*. The *Multiplex Terminal List* box can be used to define the output at terminal 16 of the TRF4903.

Other communication utilities such as HyperTerminal or ProComm can be used in place of the external software GUI to control the TRF4903 in pass-through mode. Set the transmission raw data rate to 38.4 kbps, 8 bits data, no parity, 1 stop bit, no flow control or handshake. Send the 24-bit control words for registers A through E in ASCII hex with a leading asterisk (hex 2A) and trailing carriage return (hex 0D), i.e., “\*[A][B][C][D][E]<CR>”.

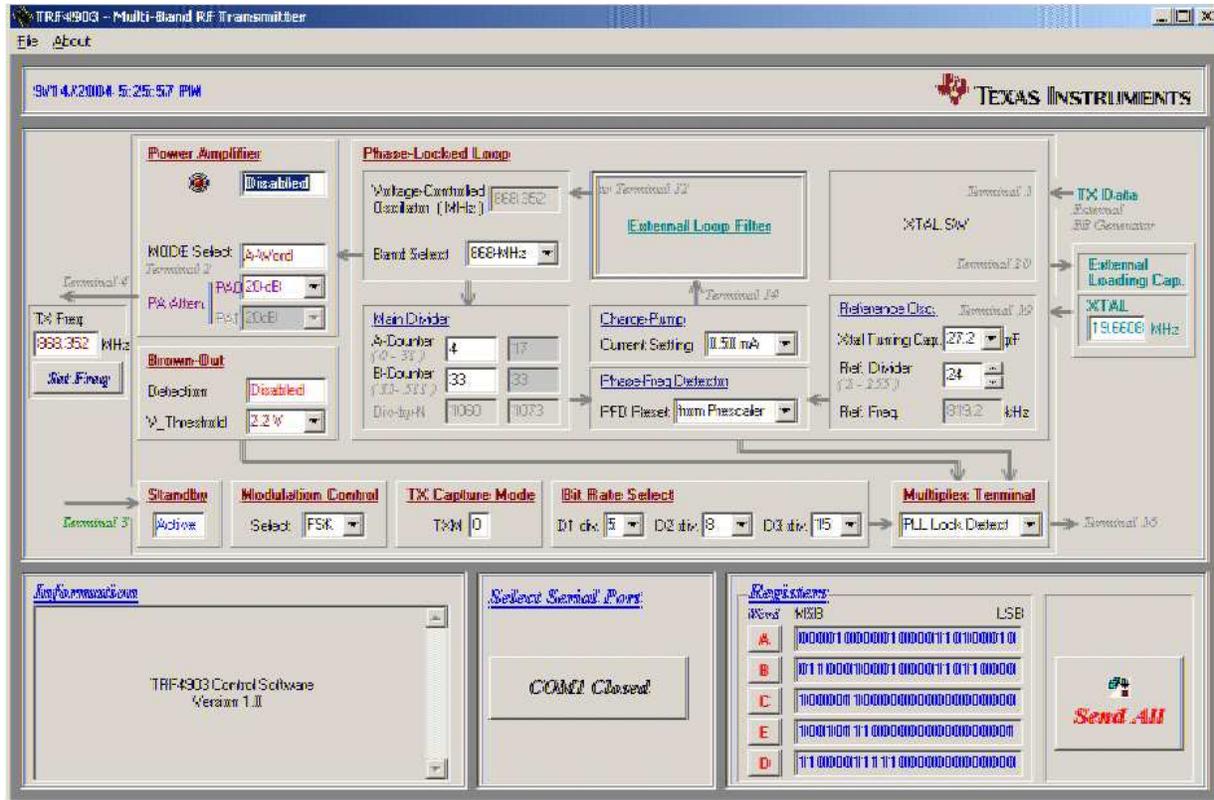


Figure 11. TRF4903 Graphical User Interface for RF Evaluation

### 5.7 Operation of the TRF4903 Evaluation Kit in the European ISM Band

The European ISM band covers the frequency band from 868 MHz to 870 MHz. A different set of firmware needs to be downloaded to operate the evaluation kit at the EU band. The firmware can be downloaded from the [www.ti.com/ismrf](http://www.ti.com/ismrf) website. See the *Operating the TRF4903 With MSP430 Evaluation Kit in the 868 MHz European ISM Band* application report (SWRA047) for detailed information on the 868-MHz EU operation Mode.

SCHEMATICS

6 SCHEMATICS

The following figures are the schematics for the TRF4903.

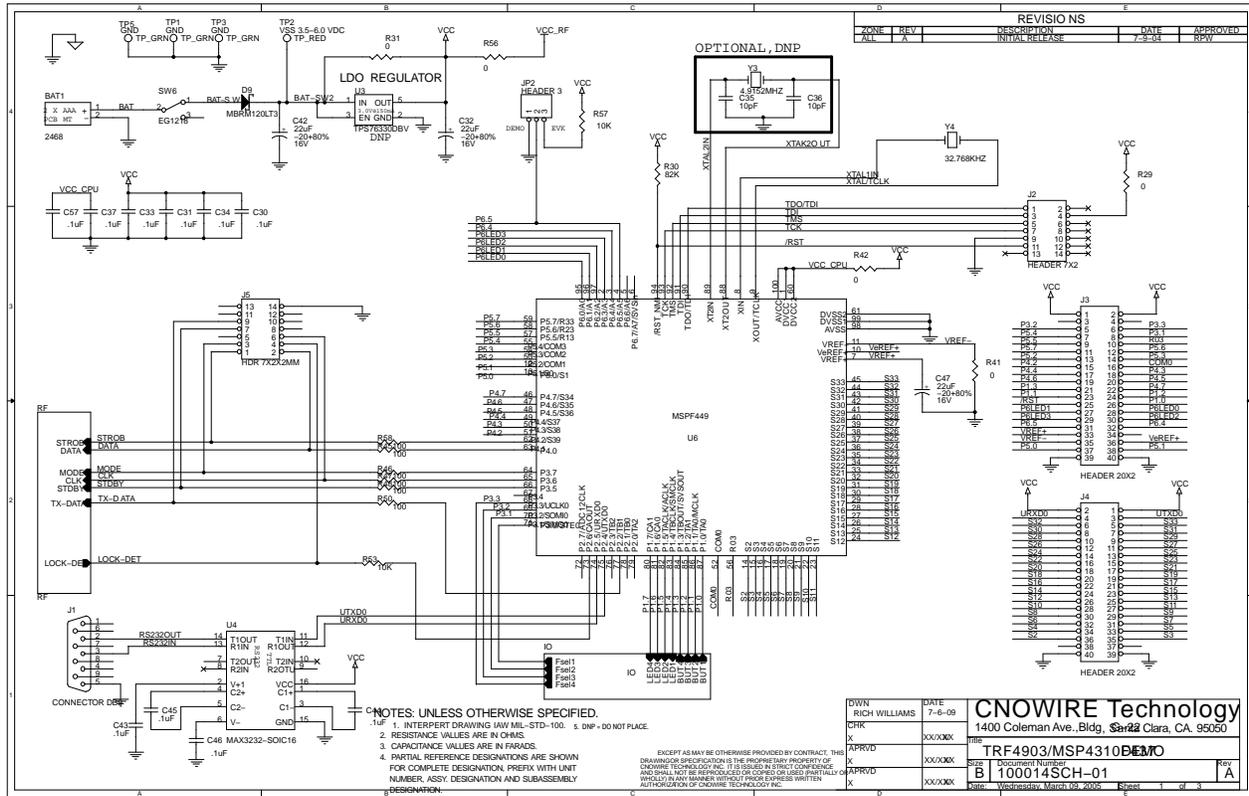


Figure 12. Schematic (Page 1)

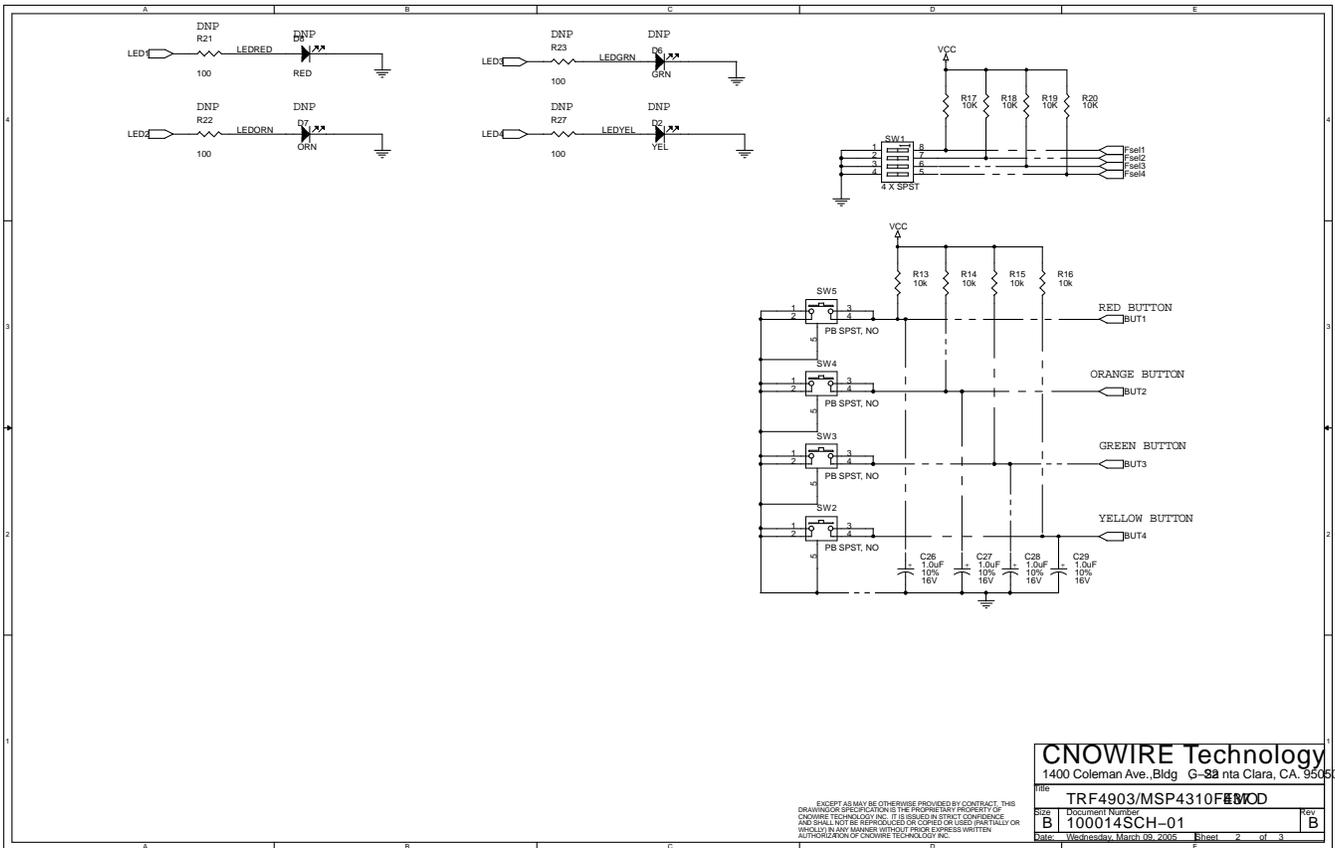
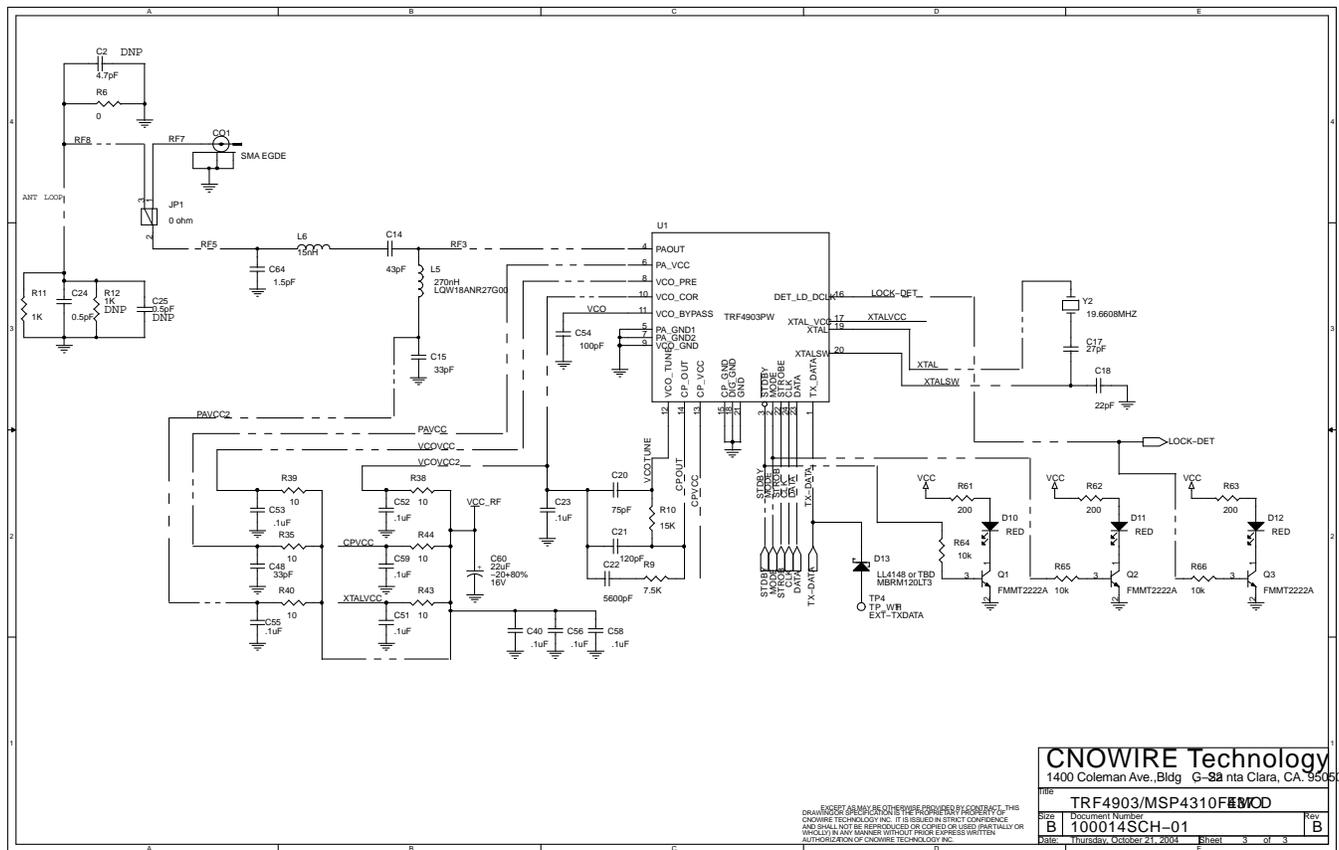


Figure 13. Schematic (Page 2)

**SCHEMATICS**



**Figure 14. Schematic (Page 3)**

## 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.

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

| <b>Products</b>  |  | <b>Applications</b> |  |
|------------------|--|---------------------|--|
| Amplifiers       | <a href="http://amplifier.ti.com">amplifier.ti.com</a>             | Audio               | <a href="http://www.ti.com/audio">www.ti.com/audio</a>                   |
| Data Converters  | <a href="http://dataconverter.ti.com">dataconverter.ti.com</a>     | Automotive          | <a href="http://www.ti.com/automotive">www.ti.com/automotive</a>         |
| DSP              | <a href="http://dsp.ti.com">dsp.ti.com</a>                         | Broadband           | <a href="http://www.ti.com/broadband">www.ti.com/broadband</a>           |
| Interface        | <a href="http://interface.ti.com">interface.ti.com</a>             | Digital Control     | <a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a> |
| Logic            | <a href="http://logic.ti.com">logic.ti.com</a>                     | Military            | <a href="http://www.ti.com/military">www.ti.com/military</a>             |
| Power Mgmt       | <a href="http://power.ti.com">power.ti.com</a>                     | Optical Networking  | <a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a> |
| Microcontrollers | <a href="http://microcontroller.ti.com">microcontroller.ti.com</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