MSP-EXP430FR5739 FRAM Experimenter Board

User's Guide

Literature Number: SLAU343B
May 2011–Revised February 2012

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Contents

1 Getting Started With the MSP-EXP430FR5739 FRAM Experimenter Board 5
- 1.1 Introduction 5
- 1.2 Kit Contents 6
- 1.3 MSP-EXP430FR5739 Board Overview 6
- 1.4 Connecting the Hardware 6
- 1.5 Starting the PC GUI 6

2 MSP-EXP430FR5739 User Experience Demo 7
- 2.1 Associated Zip Folder Contents 7
- 2.2 The User Experience Demo 7
- 2.3 View, Edit, or Recompile the User Experience Code Using an IDE 13

3 MSP-EXP430FR5739 Hardware 14
- 3.1 MSP430FR5739IRHA Device Pin Designation 14
- 3.2 Schematics 15
- 3.3 PCB Layout 18
- 3.4 Bill of Materials (BOM) 21

4 Suggested Reading 22

5 References 22

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List of Figures

1 MSP-EXP430FR5739 Overview 5
2 Comparing Write Speeds When Writing to Nonvolatile Memory (MSP430FR5739 FRAM vs MSP430F2274 Flash) 8
3 Comparing Average Power When Writing to Nonvolatile Memory at 13 kBps (MSP430FR5739 FRAM vs MSP430F2274 Flash) 10
4 On-Board Accelerometer 11
5 On-Board NTC Thermistor 12
6 MSP430FR5739 Pin Designation 14
7 Schematics (1 of 3) 15
8 Schematics (2 of 3) 16
9 Schematics (3 of 3) 17
10 MSP-EXP430FR5739 Top Layer 18
11 MSP-EXP430FR5739 Bottom Layer 19
12 MSP-EXP430FR5739 Silkscreen 20

List of Tables

1 User Experience Source Files 13
2 Bill of Materials (BOM) 21

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MSP-EXP430FR5739 FRAM Experimenter Board

1 Getting Started With the MSP-EXP430FR5739 FRAM Experimenter Board

1.1 Introduction

The MSP-EXP430FR5739 Experimenter Board introduces TI's first embedded ferro-electric random access memory (FRAM) based MCU, the MSP430FR5739. The experimenter board is an ideal platform for evaluating the latest in embedded memory technology while allowing the user to easily develop, debug, and implement prototypes in an efficient manner.

The MSP430FR5739 device is supported by both IAR Embedded Workbench and Code Compose Studio. It is recommended to download the latest version of the IDE from www.msp430.com.

The Quick Start Guide (SLAU341) is recommended for users who cannot wait to get started developing with the MSP430FR5739. For all others, this *MSP-EXP430FR5739 FRAM Experimenter Board User's Guide* provides detailed information on the hardware, the user experience firmware, and the MSP430FR5739 device.

The MSP-EXP430FR5739 Experimenter Board is available for purchase from the TI eStore at https://estore.ti.com/MSP-EXP430FR5739-MSP-EXP430FR5739-Experimenter-Board-P2430C42.aspx.

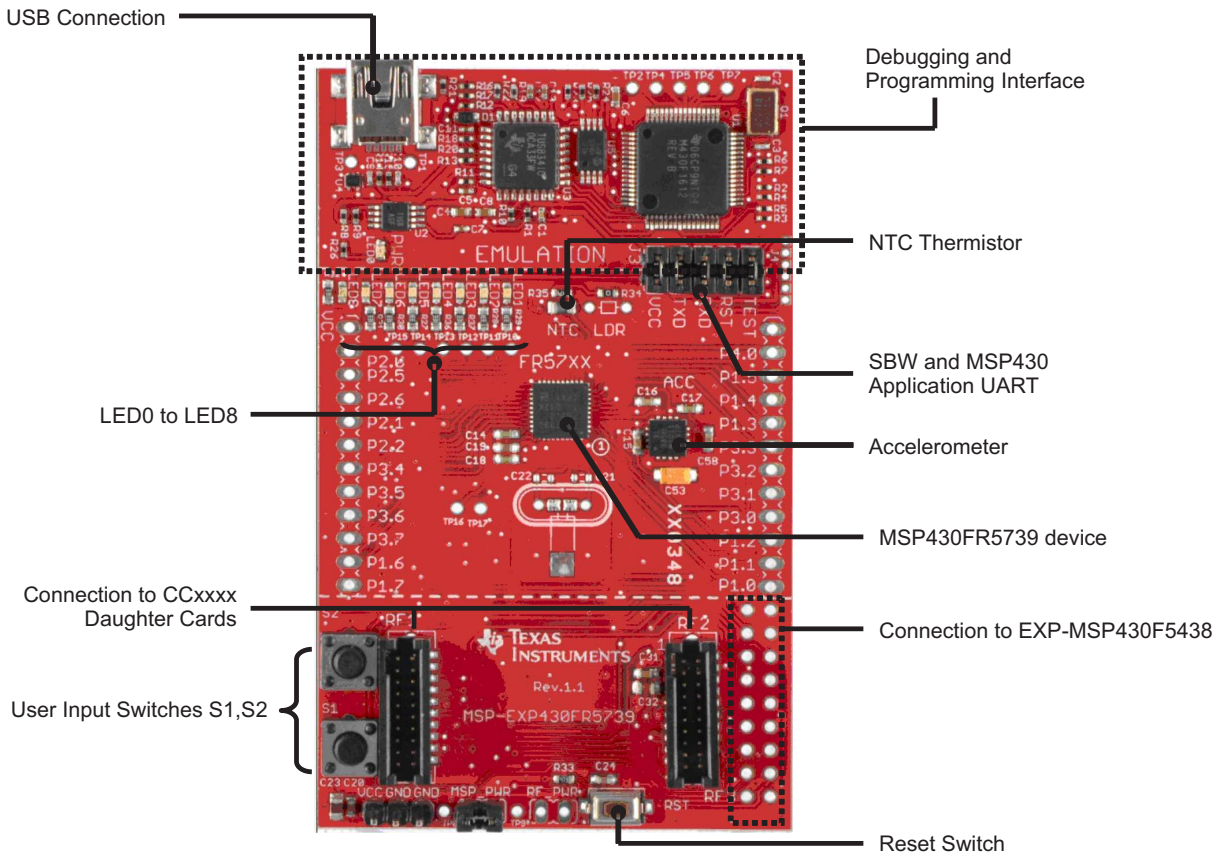

Figure 1. MSP-EXP430FR5739 Overview

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1.2 Kit Contents

The MSP-EXP430FR5739 FRAM Experimenter Board kit includes the following:

- The MSP-EXP430FR5739 board
- Mini USB-B cable, 0.5 m
- 12-pin PCB connectors (two male and two female)
- 32.768-kHz clock crystal from Microcrystal (www.microcrystal.com)

  The 32.768-kHz crystal can be used as the low-frequency XT oscillator. It is not required for the User Experience code and can be populated as needed.
- Quick start guide

See Section 2.1 for details on the associated software and source code.

1.3 MSP-EXP430FR5739 Board Overview

The experimenter board (see Figure 1) comes equipped with the following features:

- USB debugging and programming interface that uses a driverless installation and provides an application UART to communicate back to the PC
- On-board ADXL335 accelerometer
- NTC thermistor for temperature sensing
- Two user input switches and a reset switch
- Eight LEDs for output display
- Connectivity to the MSP-EXP430F5438 Experimenter Board
- Connectivity to CCxxx radio daughter cards
- Easily accessible device pins for debugging purposes or as socket for adding customized extension
- Separate power jumpers to measure power to the MSP430 and the RF daughter card.

1.4 Connecting the Hardware

Connect the MSP-EXP430FR5739 to the PC using the enclosed USB cable. If the PC has an MSP430 Integrated Development Environment (IDE) such as Code Composer Studio™ or IAR Embedded Workbench™ already installed, the driver files are automatically located and installed.

If there are no IDEs installed in the PC, unzip the folder associated with this user's guide (see Section 2.1) and point the installation to the [Install Path]\MSP-EXP430FR5739\Drivers folder.

After the drivers are installed, go to My Computer → Properties → Hardware → Device Manager to verify that the board is enumerated under Ports COM & LPT as MSP430 Application UART.

1.5 Starting the PC GUI

The Graphical User Interface (GUI) for the PC is located in the associated zip file (see Section 2.1) under [Install Path]\MSP-EXP430FR5739\Graphical User Interface.

Double click on FRAM_GUI.exe to load the PC application. More information on how to use this application is provided in Section 2.

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2 MSP-EXP430FR5739 User Experience Demo

2.1 Associated Zip Folder Contents

The zip file that contains the software and source code for the MSP-EXP430FR5739 can be downloaded from www.ti.com/lit/zip/slac492. The contents of the zip include:

- User Experience source code and project files
- Drivers that support the board installation
- PC GUI

The design files for the experimenter board are can be downloaded from www.ti.com/lit/zip/slac502.

2.2 The User Experience Demo

The User Experience demo is pre-loaded in the MSP-EXP430FR5739 board.

The user input to the demo is given using the switches S1 and S2. These switched allow the user to select the mode of operation and other options.

The output from the demo is displayed using the LEDs (LED1 to LED8) and is also sent via the back-channel UART that transmits information to the PC.

There are four modes of operation for the User Experience demo:

1. High-speed FRAM writes
2. Emulating the speed of flash writes
3. Sampling accelerometer data and writing to FRAM
4. Sampling thermistor data and writing to FRAM

2.2.1 Entering and Exiting the Demo Modes

Follow these steps to enter and exit the demo modes:

1. Press switch S1 for mode selection. After you press S1, LED8 through LED5 light up to show the corresponding mode.
2. Press switch S2 to enter the mode.
3. Press switch S2 when inside a mode to turn off the display (LED and UART output). This is useful when measuring power.
4. Press S1 to exit a mode and return to mode selection.

NOTE: Pressing S2 without selecting a mode causes LED8 to toggle rapidly, indicating an invalid sequence. To exit from this mode, press S1 to return to mode selection.

The MSP-EXP430FR5739 board is equipped with a reset switch. On reset, the device displays a short LED lighting sequence.

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2.2.2 Using Mode 1 – FRAM High Speed Writes

Mode 1 is entered by pressing S1 once, followed by S2. On entry, LED8 through LED1 light up sequentially to display the speed of FRAM writes.

Every time the LED1 through LED8 sequence is completed, 800KB are written to FRAM. In this mode, FRAM is bring written to at about 1.8MB per second. In comparison, a full-speed write to flash can achieve speeds of approximately 13kB per second.

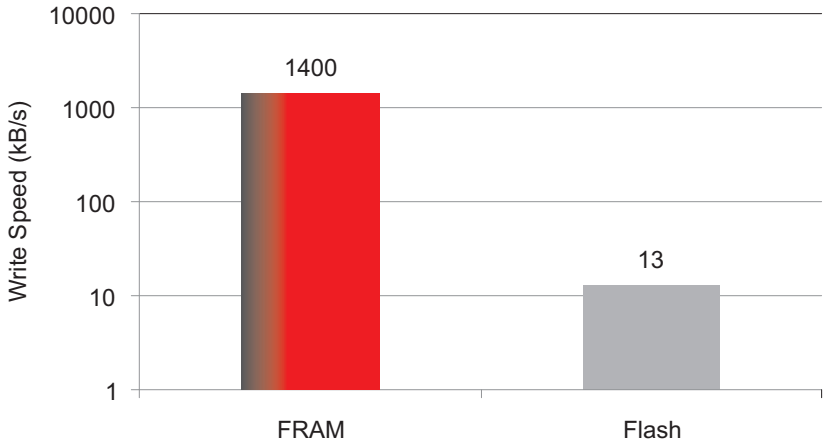

Figure 2. Comparing Write Speeds When Writing to Nonvolatile Memory (MSP430FR5739 FRAM vs MSP430F2274 Flash)

Note that the code is optimized for power and not speed. FRAM memory blocks can be written at speeds greater than 8MB per second depending on how the code is optimized. See the application report *Achieving High-Speed FRAM Writes Using the MSP430FR5739* for more details.

On entering Mode 1, the address of the FRAM scratchpad location is calculated. For the User Experience demo, the scratchpad location starts at 0xD400 and ends at 0xF000. This location can be modified in the header file FR_EXP.h. Note that when changing this location, it is important to first check the code space requirements in the map file to ensure that the FRAM scratchpad area does not overlap with the application code. Different compilers and optimization settings may impact the placement of the application code. If any overlap occurs, the application code may be overwritten in Mode 1, which can cause the demo to fail.

In Mode 1, the system main clock is configured to use the DCO set to 8 MHz. A function that performs long-word writes to FRAM is called continuously inside a while loop. Each time the FRAM_Write() function in FR_EXP.c is called, 512 bytes are written. This number was chosen arbitrarily to mimic flash segments, and there are no restrictions on the number of FRAM bytes that can be written at once. While in Mode 1, the LED sequence changes every time 100kB are written. For example, after the first 100KB are written, LED8 is turned on; after the next 100kB are written, LED8 and LED7 are turned on; and so on. The sequence completes when all eight LEDs are turned on, after which the process rolls over and starts again from LED8.

Also, after every 100kB, a UART data transmission occurs. This data is sent to the PC via a back-channel UART and is used to calculate the FRAM write speed and endurance information that is displayed in the PC GUI. The raw data can also be viewed directly using a PC application such as HyperTerminal.

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2.2.2.1 Measuring Current on the MSP-EXP430FR5739

While measuring the active power in a mode, the LEDs should be turned off and the UART transmissions should be halted. This is done by pressing switch S2 while inside the mode. Switch S2 toggles the display settings, turning them on or off as needed. Turning the display off allows the user to isolate and measure the current consumption of the MSP430 device when executing instructions at a clock speed of 8 MHz and writing to FRAM. In bench tests, the MSP430 I_{DVCC} was measured at approximately 800 µA.

Note that, because of the nature of the FRAM cache, the number of accesses to FRAM memory can greatly impact the active power consumption. Unoptimized code that performs a higher number of accesses to FRAM can cause an increase in the measured current. It is advisable to review the compiler settings when setting up a project using IDEs such as CCS or IAR to ensure the most efficient code and, hence, the least active power.

The project that accompanies this document (see Section 2.1) uses a level 1 optimization setting in both IAR and CCS that is one step higher than the default optimization levels.

As mentioned previously, when measuring the I_{CC} on the board, it is important to isolate the current consumption by the MSP430FR5739 only. The measurement can be done when the board is powered via USB or externally via a battery. When powering via the USB, it is recommended to disconnect the emulation portion from the MSP430FR5739 device. This can be done by removing jumpers TXD, RXD, Reset, and Test on J3. A multimeter can be used to measure the current into the MSP430FR5739 V_{CC} by removing the V_{CC} jumper and placing the multimeter leads in series.

An alternate approach requires powering the board externally via the V_{CC} and GND connection and disconnecting the USB cable from the board. In this case, the multimeter can be placed in series to V_{CC} by removing the MSP_PWR jumper.

These recommendations hold true when measuring I_{DVCC} in all four modes.

2.2.2.2 Displaying Results on the PC GUI

The GUI associated with this document provides details on the time elapsed in the mode, number of bytes written, speed of FRAM, and the endurance of FRAM emulated over a 512 byte FRAM block.

The endurance is calculated based on the 10^{14} program/erase cycles for the MSP430FR5739. Because the GUI updates every one minute, the scale of reduction of FRAM endurance is very small. A more obvious decline in endurance can be observed in Mode 2 when the endurance reduction when using flash is emulated.

2.2.3 Using Mode 2 – Emulating the Speed of Flash Writes

Mode 2 is entered by pressing S1 twice, followed by S2. In this mode, the maximum speed at which flash can be written to (at a 100% active duty cycle) is emulated on FRAM.

Similar to Mode 1, on entry into Mode 2, LED8 through LED1 light up sequentially to display the speed of emulated flash writes. Every time the LED1 through LED8 sequence is completed, an 800KB write to flash is emulated. In this mode, FRAM is written to at approximately 12 kBps. The entire sequence requires approximately 80 seconds, so the demo should be observed for more than one minute to see the LED sequence roll over.

NOTE: The time to run this sequence varies depending on the frequency source to the interval timer (that is, the VLO).

The test uses the same scratchpad FRAM memory as Mode 1 and the same system setup. In this mode, after every 2KB of memory is written, a UART packet is transmitted to the PC GUI to allow it to calculate speed and endurance information.

When measuring the average power the methodology described in Section 2.2.2.1 needs to be followed.

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2.2.3.1 The Math Behind Mode 2

The MSP430F2274 device was used as a benchmark device to calculate the maximum flash write speed. For a 512-byte block of flash, the following parameters were obtained from the MSP430F2274 data sheet:

Segment erase time = 4819 × t_{FTG} = 16 ms

Where, t_{FTG} = 1 / f_{FTG} ≈ 1 / 300 kHz

512 bytes write time ≈ 51.2 ms

Total time to write to 512 bytes ≈ 67.2 ms

Time to write to 100KB = 6.72 seconds, which calculates to 14.8 kBps

When measuring the speed of continuous flash writes on the bench, the observed speed is approximately 12 kBps, because the code execution overhead is added to the time calculated above.

This write speed is emulated with the FRAM device by maintaining a low active duty cycle and performing one 512 byte block write every 40 ms.

Number of writes per second = 1 / 40 ms = 25

Number of bytes written per second = 512 × 25 = 12.800 kBps

The timing of the FRAM write is controlled by the VLO clock.

From these bench tests, it can be seen that writing 12 kBps to flash requires nearly 100% duty cycle, while writing the same speed to FRAM requires less than 1% duty cycle. The rest of the time, the FRAM device is in shutdown mode (LPM4), which results in an average current of less than 10 µA. In comparison, for a similar write speed, flash-based MCUs can require average current up to 2.2 mA.

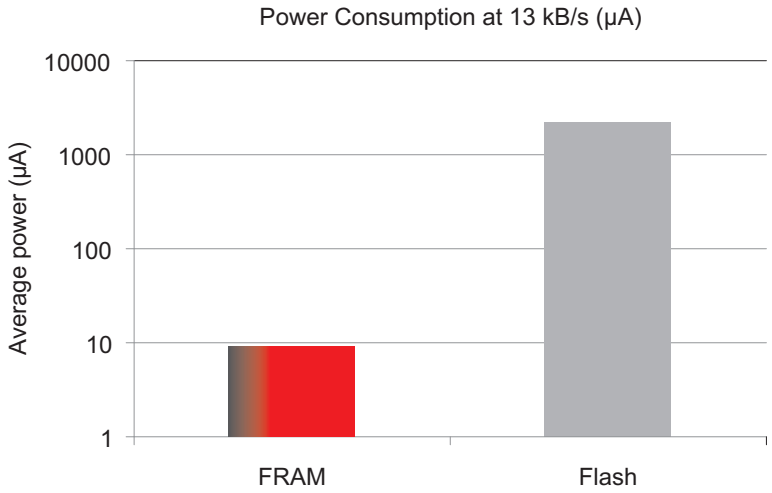

Figure 3. Comparing Average Power When Writing to Nonvolatile Memory at 13 kBps (MSP430FR5739 FRAM vs MSP430F2274 Flash)

2.2.3.2 Displaying Results on the PC GUI

When in Mode 2, the GUI provides details on the time elapsed in the mode, number of bytes written, speed of emulated flash writes, and the endurance emulated over a 512 byte flash block.

The endurance is calculated based on the 10^4 program/erase cycles (minimum) for the MSP430F2274. If a 512-byte block on a flash device were written to at a speed of 12.5 kBps (that is, 25 times per second), the endurance would exceed the minimum limit in 10000/25 or 6.6 minutes.

Note that the MSP-EXP430FR5739 board only emulates this test to demonstrate a comparison in speed and endurance between FRAM and flash; it does not perform the test on an actual flash device.

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2.2.4 Using Mode 3 – Accelerometer Demo

Mode 3 is entered by pressing switch S1 three times, followed by switch S2.

Upon entering this mode, the on-board accelerometer (see Figure 4) is calibrated. To aid this calibration process, it is recommended to place the board on a level surface before entering the mode.

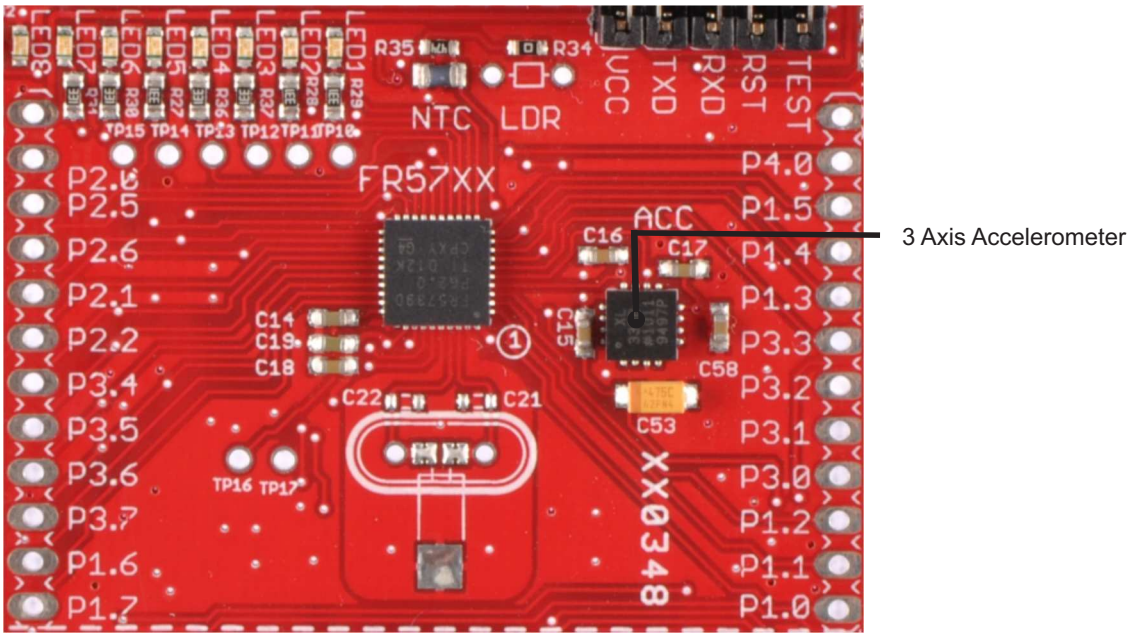

Figure 4. On-Board Accelerometer

After the calibration sequence is completed, LED4 and LED5 are turned on. When tilting the board in an upward or downward direction, the LEDs follow the direction of the tilt. S2 toggles the display on and off, similar to other modes.

Mode 3 also writes the sampled data from the ADC to the FRAM in real time with no wait states or extra cycles spent on setting up the FRAM. This can be observed in the ADC interrupt service routine. The sampling takes place at more than 15k samples per second. At this speed, flash devices require that the data be buffered in RAM before writing to flash. In FRAM devices, the only bottleneck is the speed at which the ADC can sample, not the writes to nonvolatile memory.

2.2.4.1 Displaying Results on the PC GUI

When in the accelerometer mode, the GUI mimics the LEDs that are lit up on the Experimenter Board and are a reflection of the tilt of the board.

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2.2.5 Using Mode 4 – Temperature Sensor Demo

Mode 4 is entered by pressing switch S1 four times, followed by switch S2.

Upon entering this mode, the on-board thermistor (see Figure 5) is calibrated.

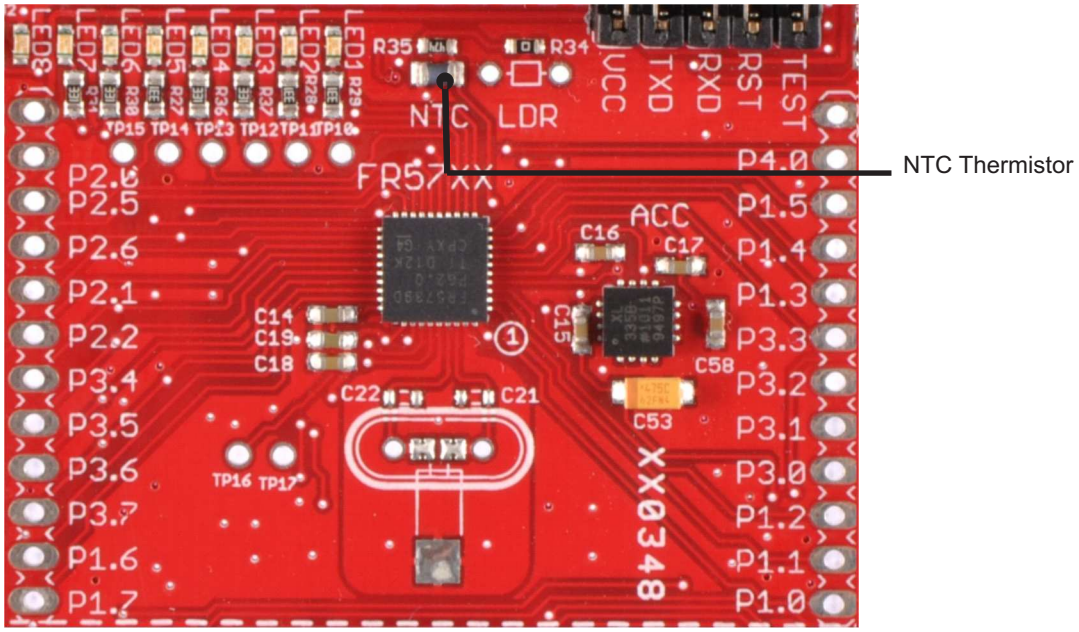

Figure 5. On-Board NTC Thermistor

After the calibration sequence is completed, LED4 and LED5 are turned on. When the NTC resistor is heated (for example, by placing a finger on it), LED3 through LED1 are turned on sequentially. When the NTC is cooled (for example, by using a freeze spay or a keyboard dust remover that uses compressed air) LED5 through LED8 are turned on sequentially.

Similar to Mode 3, Mode 4 also writes the sampled data from the ADC to the FRAM in real time with no wait states or extra cycles spent on setting up the FRAM. This can be observed in the ADC interrupt service routine. The sampling takes place at more than 15k samples per second. At this speed, flash devices require that the data be buffered in RAM before writing to flash. In FRAM devices, the only bottleneck is the speed at which the ADC can sample, not the writes to nonvolatile memory.

2.2.5.1 Displaying Results on the PC GUI

When in the temperature sense mode, the GUI mimics the LEDs that are lit up on the Experimenter Board and are a reflection of the thermistor's ambient temperature measurement.

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2.3 View, Edit, or Recompile the User Experience Code Using an IDE

There are different development software tools available for the MSP-EXP430FR5739 board. IAR Embedded Workbench™ KickStart™ and Code Composer Studio™ (CCS) IDEs are both available in a free limited version. IAR Embedded Workbench allows 4KB of C-code compilation. CCS is limited to a code size of 16KB. The software is available at www.ti.com/msp430.

To view, modify, or edit the User Experience code provided with the MSP-EXP430FR5739, an IDE installation is required. The associated software package (see Section 2.1) supports both IAR and CCS projects.

The User Experience source files and project folders are provided in the folder [Install Path]\MSP-EXP430FR5739\MSP-EXP430FR5739 User Experience.

2.3.1 Setting up the IAR Workspace for the User Experience Code

To set up the IAR workspace for the User Experience demo source code:

1. Double-click and open MSP-EXP430FR5739_Workspace.eww in IAR.
2. The Project is automatically included in the workspace.
3. Click Project → Download & Debug to download the code to the MSP-EXP430FR5739 Experimenter Board.
4. If multiple emulation tools are connected to your PC, click Project → Options → FET Debugger → Connection to explicitly select the experimenter board.

2.3.2 Importing the CCS Project for the User Experience Code

To import the CCS project for the User Experience demo source code:

1. Create a workspace folder.
2. Open CCS and point to the newly created workspace folder.
3. Click Project → Import Existing CCS/CCE Eclipse Project.
4. Browse to the folder [Install Path]\MSP-EXP430FR5739\MSP-EXP430FR5739 User Experience that was extracted from the associated zip file (see Section 2.1).
5. The project MSP-EXP430FR5739_UserExperience is automatically selected.
6. Click Finish to include the project in the current workspace.
7. Click the Debug icon to download the project

2.3.3 Source Files

Table 1 describes the source files for the User Experience demo.

Table 1. User Experience Source Files

Name	Description
Main.c	This file contains the user experience demo
Main.h	This file contains the definitions that are required for main.c
FR_EXP.c	This file contains the definitions of all C functions used by main.c
FR_EXP.h	This file contains all the function declarations needed by main.c and FR_EXP.c

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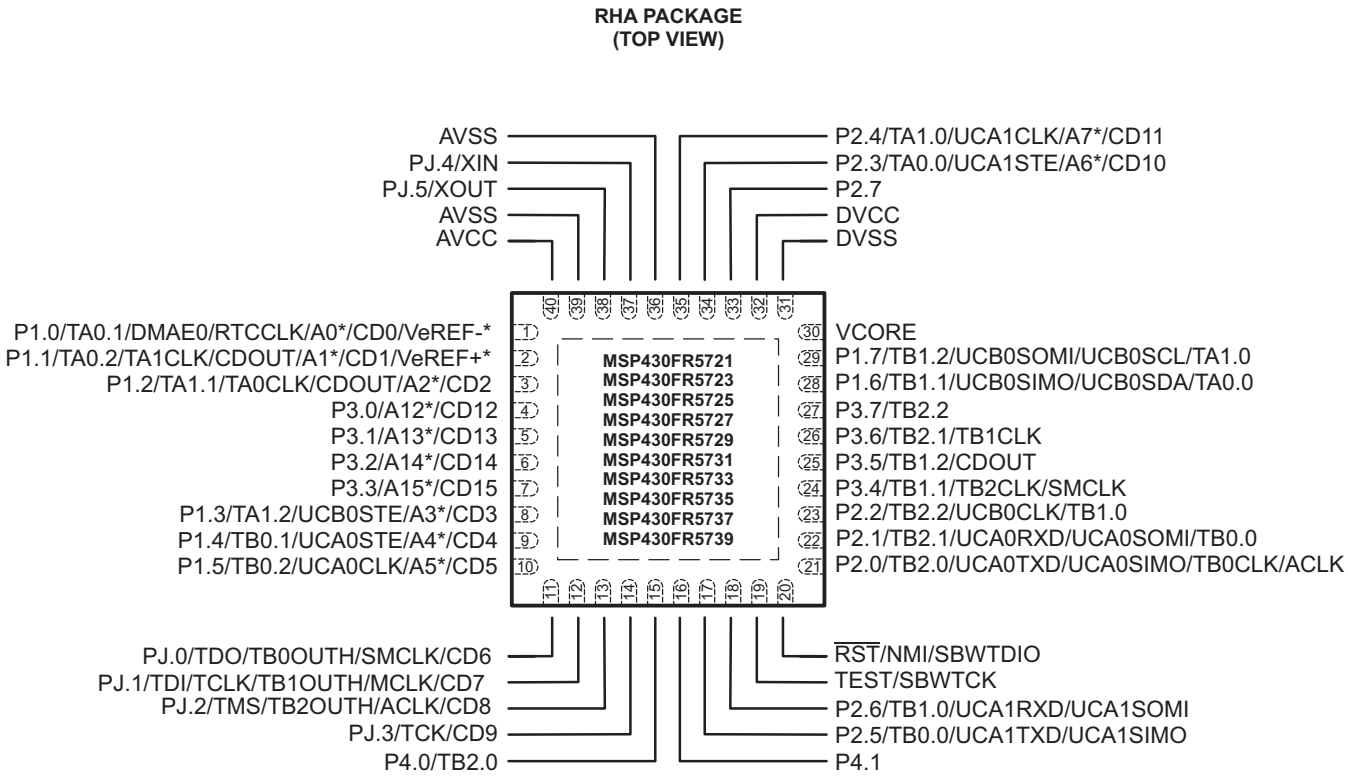
3 MSP-EXP430FR5739 Hardware

3.1 MSP430FR5739IRHA Device Pin Designation

See the MSP430FR5739 data sheet (SLAS639) for the latest information.



* Not available on MSP430FR5737, MSP430FR5733, MSP430FR5727, MSP430FR5723
Note: Power Pad connection to V_{SS} recommended.

Figure 6. MSP430FR5739 Pin Designation

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3.2 Schematics

The schematics and PCB layouts for the MSP-EXP430FR5739 are shown in the following pages.

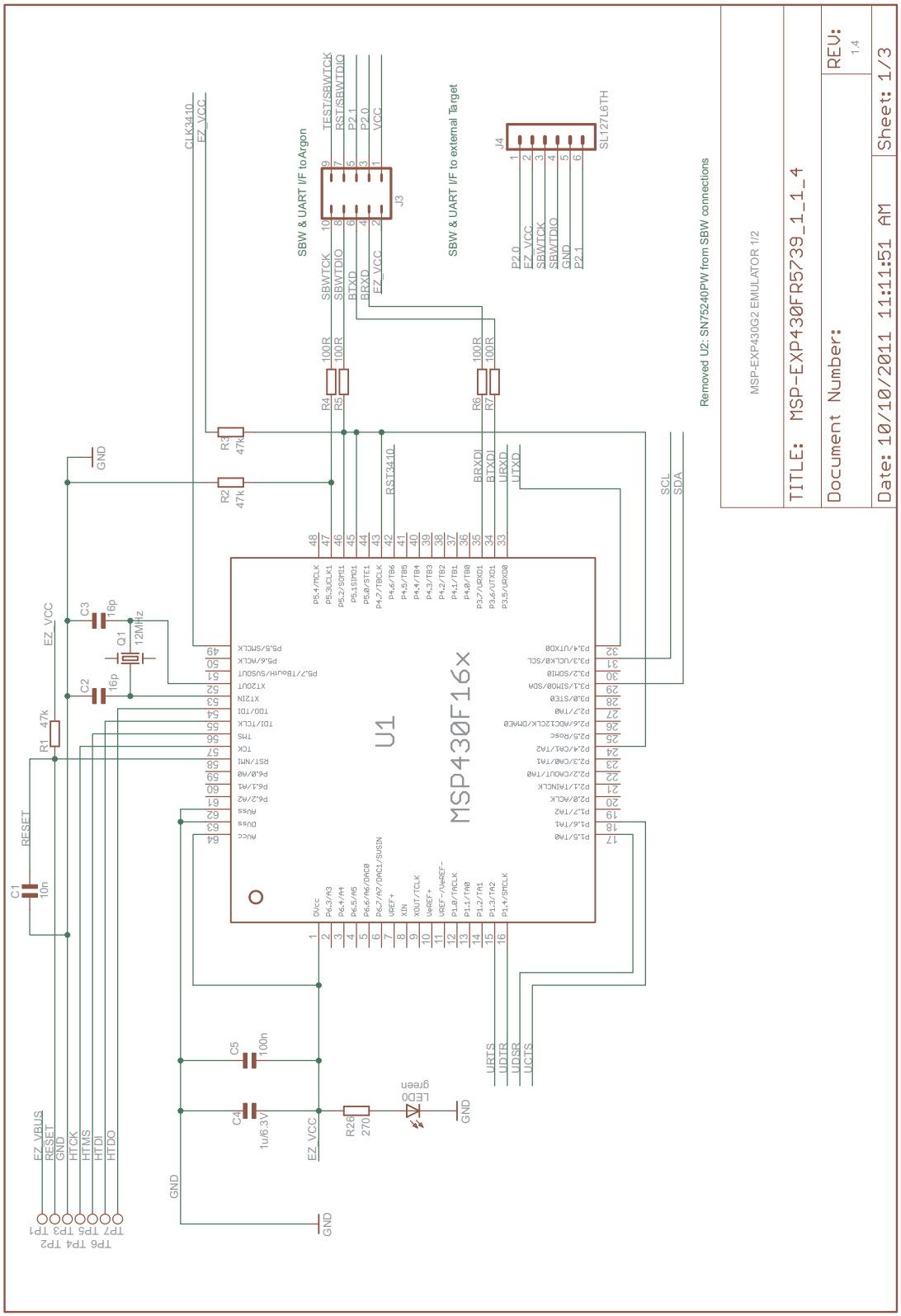

Figure 7. Schematics (1 of 3)

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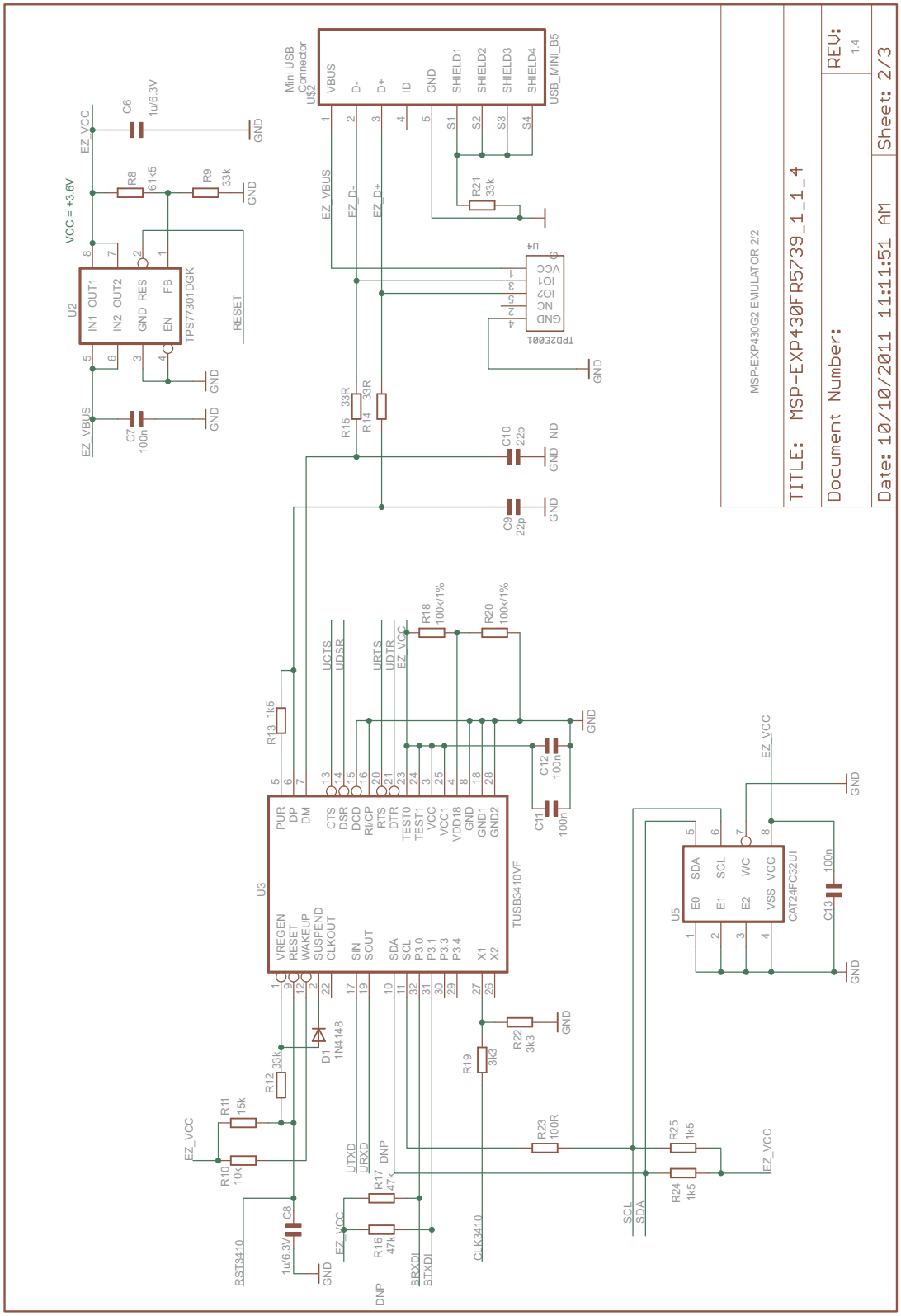

Figure 8. Schematics (2 of 3)

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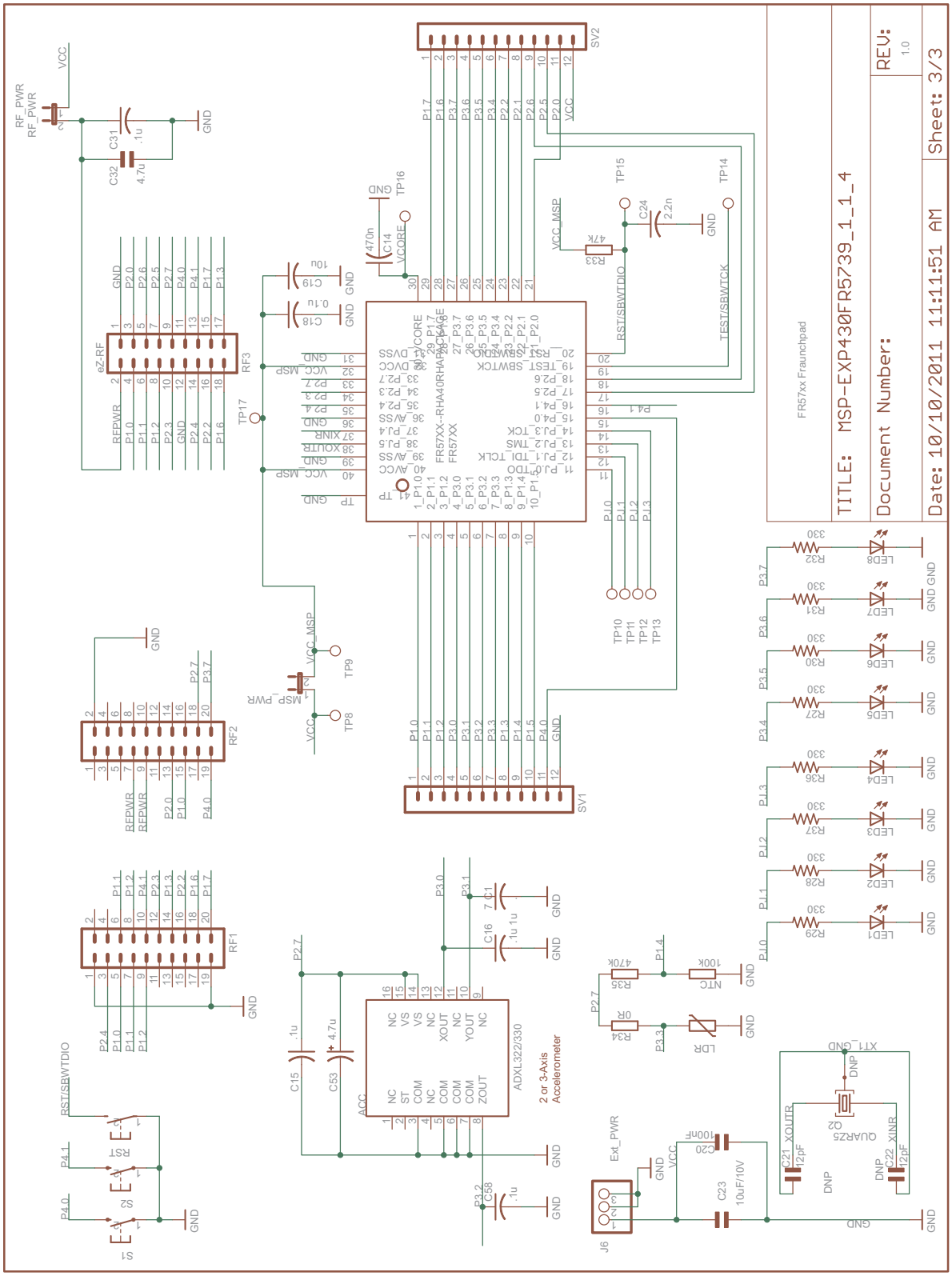

Figure 9. Schematics (3 of 3)

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3.3 PCB Layout

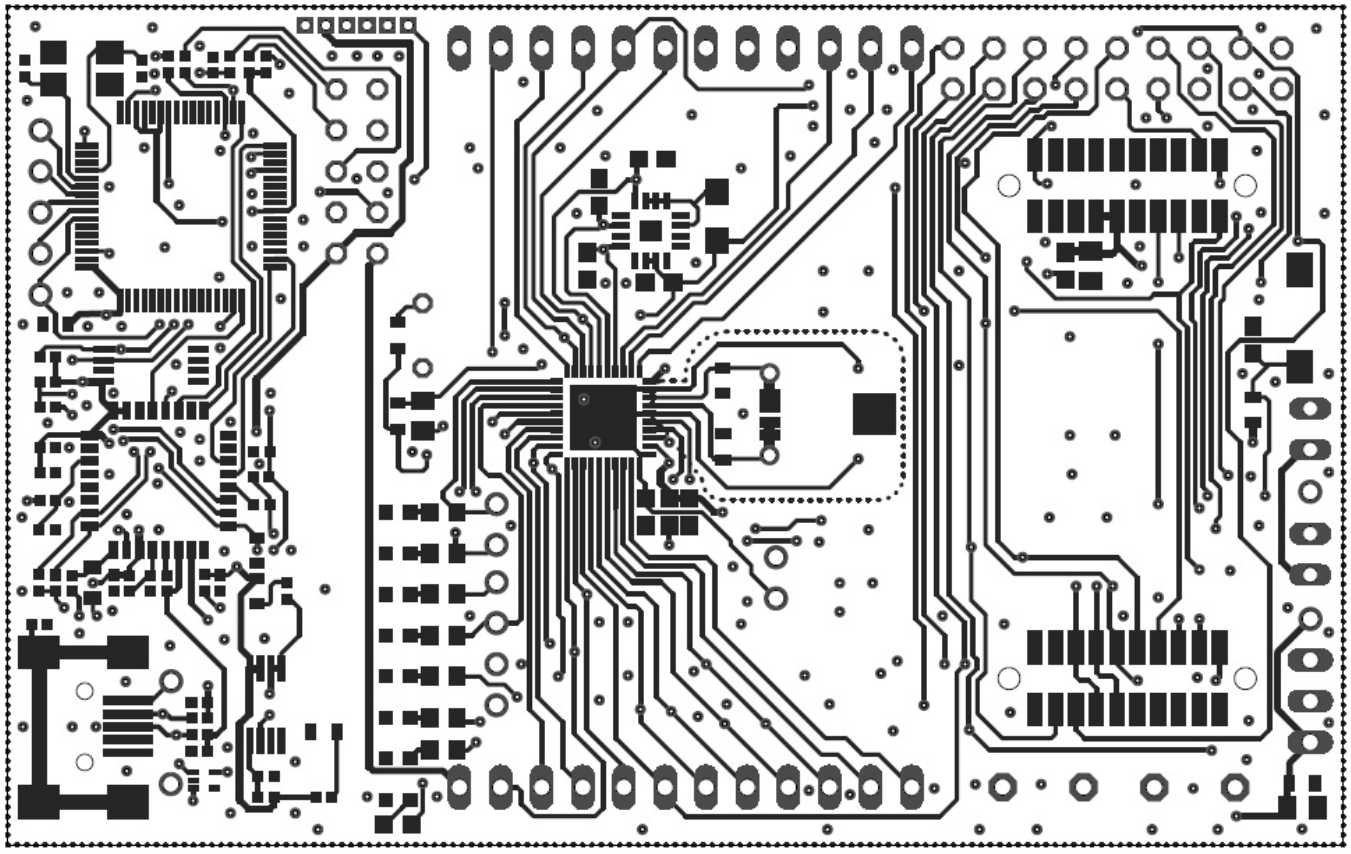

Figure 10. MSP-EXP430FR5739 Top Layer

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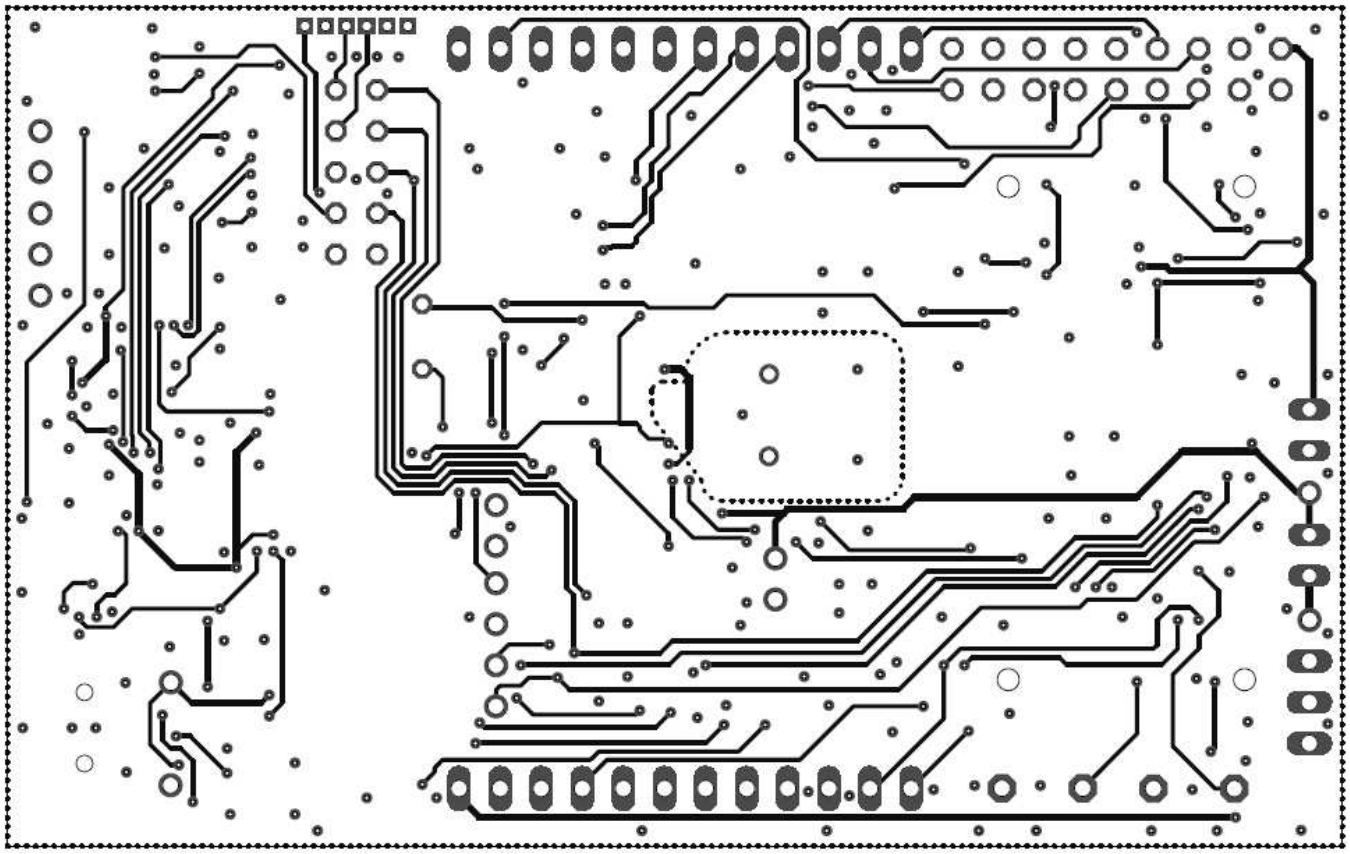

Figure 11. MSP-EXP430FR5739 Bottom Layer

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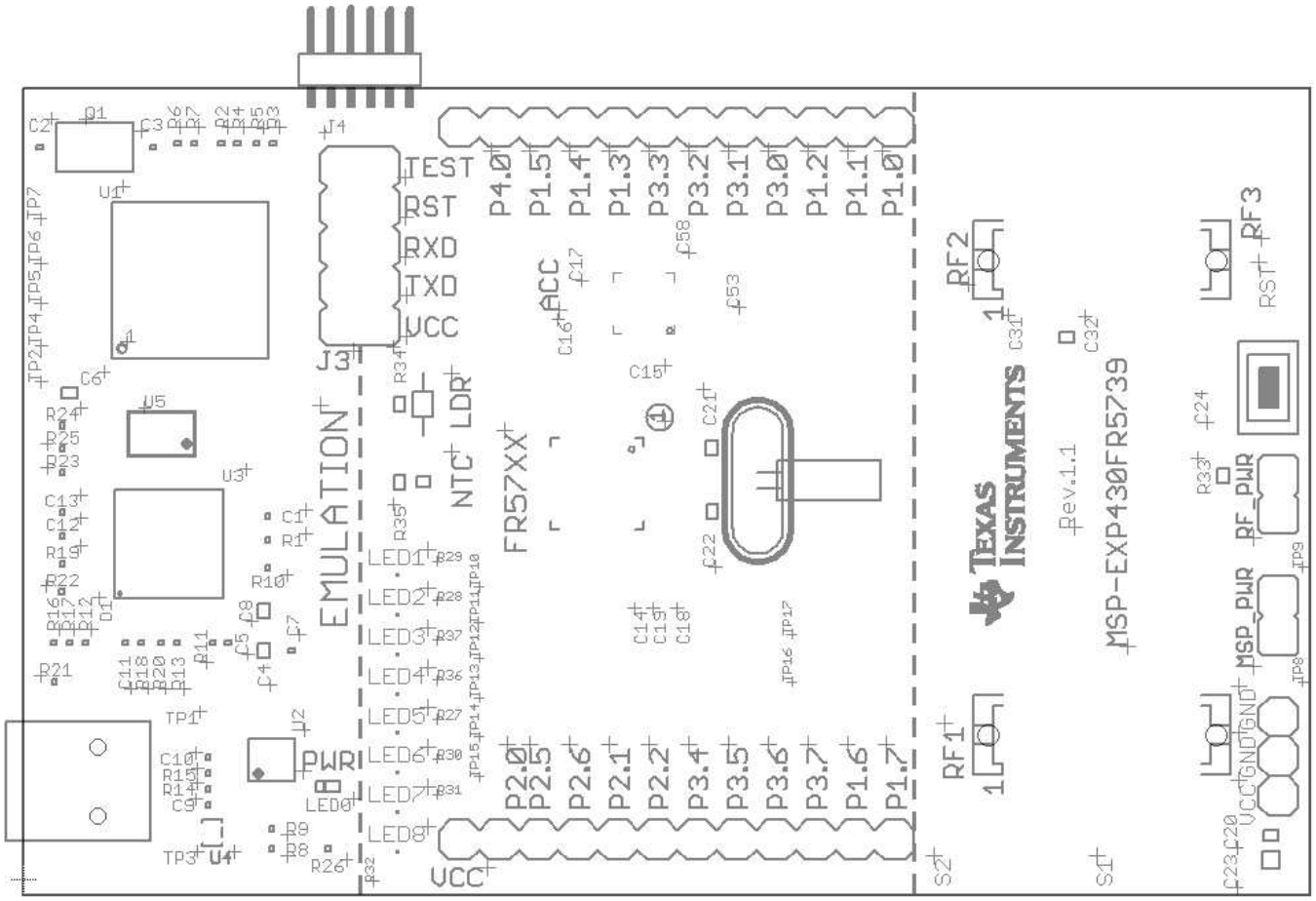

Figure 12. MSP-EXP430FR5739 Silkscreen

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3.4 Bill of Materials (BOM)

Table 2 shows the bill of materials for the MSP-EXP430FR5739 board.

Table 2. Bill of Materials (BOM)

Pos.	Ref Des	Number per Board	Description
1	C1	1	10n
2	C2,C3	2	16p
3	C4, C6, C8	3	1u/6.3V
4	C5, C7, C11, C12,C13	5	100n
5	C15, C16, C17, C18, C20, C31, C58	7	100n
6	C9, C10	2	22p
7	C14	1	470n
8	C19	1	10u
9	C21, C22	0	12pF
10	C23	1	10uF/10V
11	C24	1	2.2nF
12	C32, C53	2	4.7u
13	D1	1	1N4148
14	FR5739	1	FR5739-RHA40
15	J3	1	2x05 Pin Header Male
16	J4	[1]	SL127L6TH
17	J6	1	3-pin header, male, TH
18	LDR	0	Do not populate
19	LED0	1	LED GREEN 0603
20	LED1 - LED8	8	LED BLUE 470NM 0603 SMD
21	MSP_PWR	1	2-pin header, male, TH
22	NTC	1	100k
23	Q1	1	12MHz
24	Q2	1	Crystal
25	R1, R2, R3, R16, R17, R33	4	47k
26	R4, R5, R6, R7, R23	4	100R
27	R8	1	61k5
28	R12	1	33k
29	R9	1	30K
30	R10	1	10k
31	R11	1	15k
32	R13, R24, R25	3	1k5
33	R14, R15	2	33R
34			
35	R18, R20	2	100k/1%
36	R19, R22	2	3k3
37	R21	1	33k
39	R26	1	270

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

Pos.	Ref Des	Number per Board	Description
40	R27, R28, R29, R30, R31, R32, R36, R37	8	330
41	R34	0	0R
42	R35	1	470k
43	RF1, RF2	2	
44	RF3	0	eZ-RF connector for EXP-F5438 board
45	RF_PWR	1	RF_PWR
46	S1, S2	2	
47	RST	1	
48	SV1, SV2	2+[2]	12-pin header, TH
49	U$2	1	USB_MINI_B5
50	U1	1	F1612-PM64
51	U2	1	TPS77301DGK
52	U3	1	TUSB3410VF
53	U4	1	TPD2E001
54	U5	1	CAT24FC32UI
55	U6	1	ADXL335 accelerometer

4 Suggested Reading

The primary sources of MSP430 information are the device-specific data sheets and user's guides. The most up-to-date versions of those documents can be found at the Texas Instruments MSP430 page www.ti.com/msp430.

Visit www.ti.com/fram to find the latest information on TI's FRAM family.

To get an inside view of the CCS and IAR IDEs, download the latest version from the MSP430 page and read the included user's guides and documentation in the installation folder.

Documents describing the IAR tools (Workbench/C-SPY, the assembler, the C compiler, the linker, and the library) are located in common\doc and 430\doc. All necessary CCS documents can be found in msp430\doc inside the CCS installation path. The *Code Composer Studio v4.2 for MSP430™ User's Guide* (SLAU157) and *IAR Embedded Workbench Version 3+ for MSP430™ User's Guide* (SLAU138) include detailed information on how to set up a project for the MSP430 using CCS or IAR. They are included in most of the IDE releases and on the MSP430 page.

5 References

1. MSP430FR5739 data sheet (SLAS639)

2. MSP430F2274 data sheet (SLAS504)

3. *MSP430FR57xx Family User's Guide* (SLAU272)

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3.1 *United States*

3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

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3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

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