

MSP-EXP430FR5739 FRAM Experimenter Board

User's Guide



Literature Number: SLAU343B
May 2011 – Revised February 2012

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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 Composer Studio. It is recommended to download the latest version of the IDE from www.msp430.com.

The Quick Start Guide ([SLAU341](http://www.ti.com/lit/ug/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>.

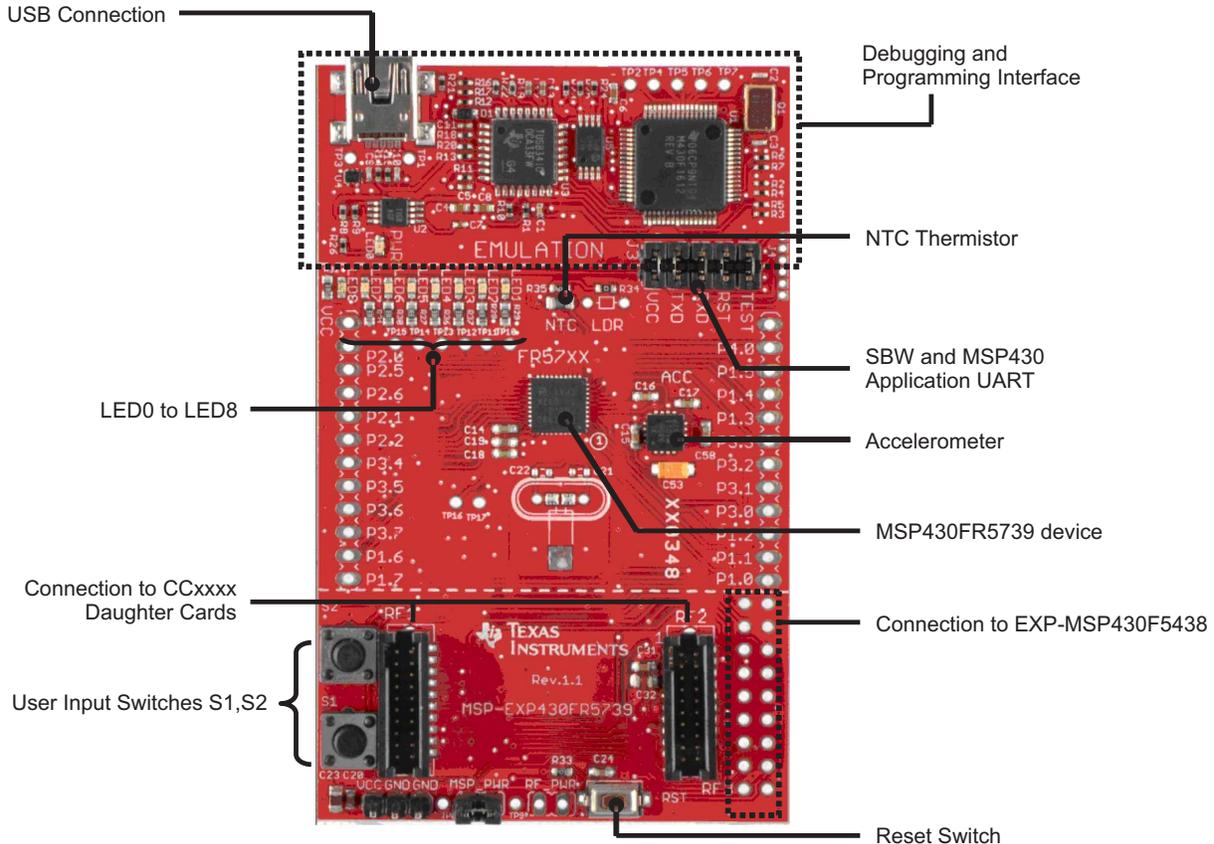


Figure 1. MSP-EXP430FR5739 Overview

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](#).

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.

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 being written to at about 1.8MB per second. In comparison, a full-speed write to flash can achieve speeds of approximately 13kB per second.

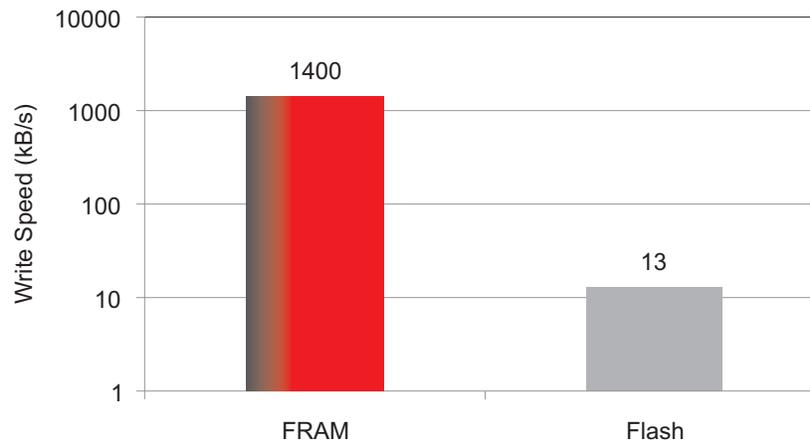


Figure 2. Comparing Write Speeds When Writing to Nonvolatile Memory (MSP430FR5739 FRAM vs MSP430F2274 Flash)

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.

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 μ A.

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.

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 = $4819 \times t_{FTG} = 16 \text{ ms}$

Where, $t_{FTG} = 1 / f_{FTG} \approx 1 / 300 \text{ kHz}$

512 bytes write time $\approx 51.2 \text{ ms}$

Total time to write to 512 bytes $\approx 67.2 \text{ ms}$

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 = $1 / 40 \text{ ms} = 25$

Number of bytes written per second = $512 \times 25 = 12.800 \text{ kBps}$

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.

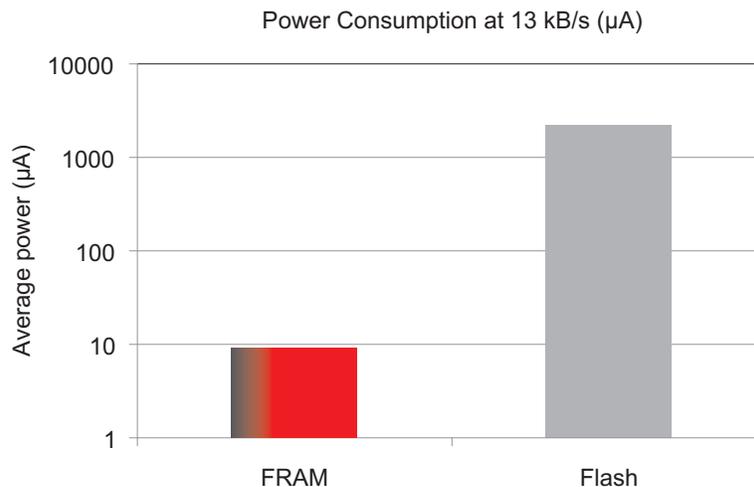


Figure 3. Comparing Average Power When Writing to Nonvolatile Memory at 13 kBps (MSP430FR5739 FRAM vs MSP430F2274 Flash)

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.

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.

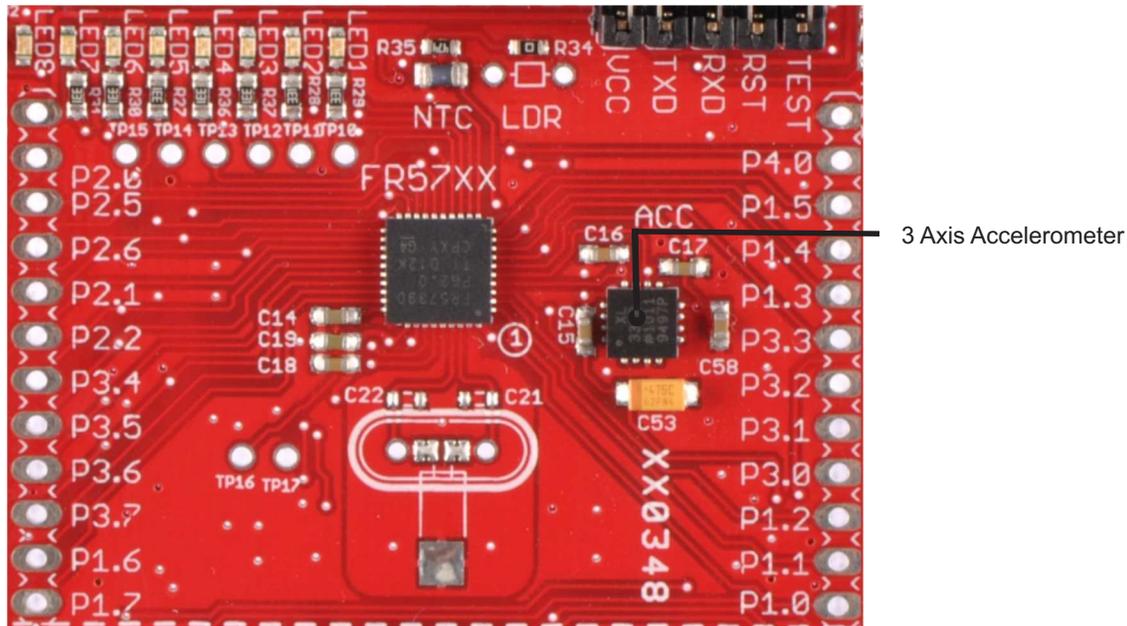


Figure 4. On-Board Accelerometer

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.

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.

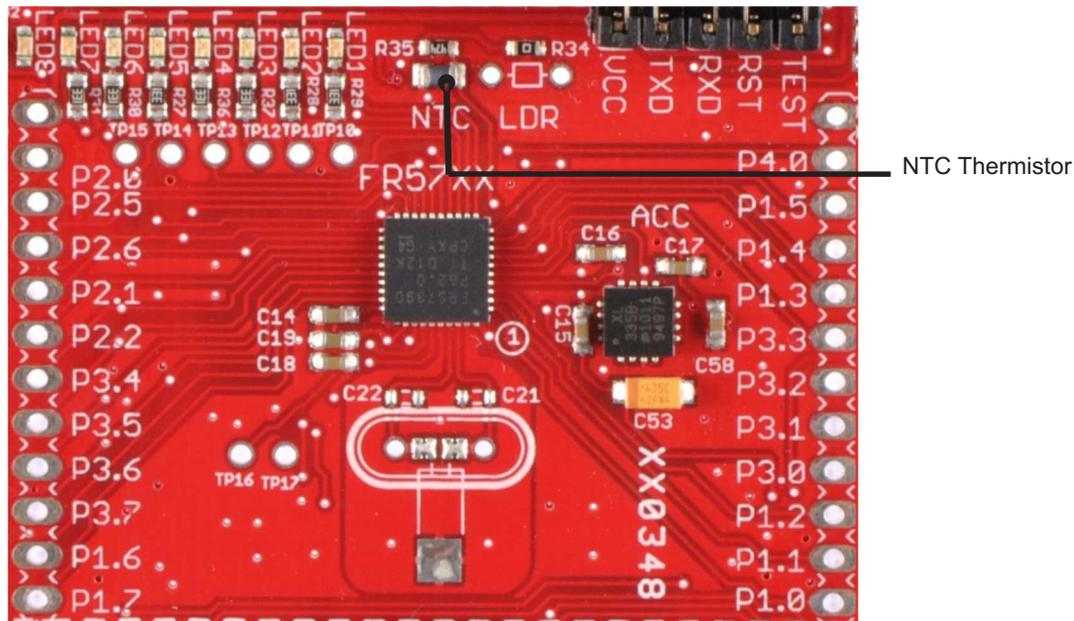


Figure 5. On-Board NTC Thermistor

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 spray 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.

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.

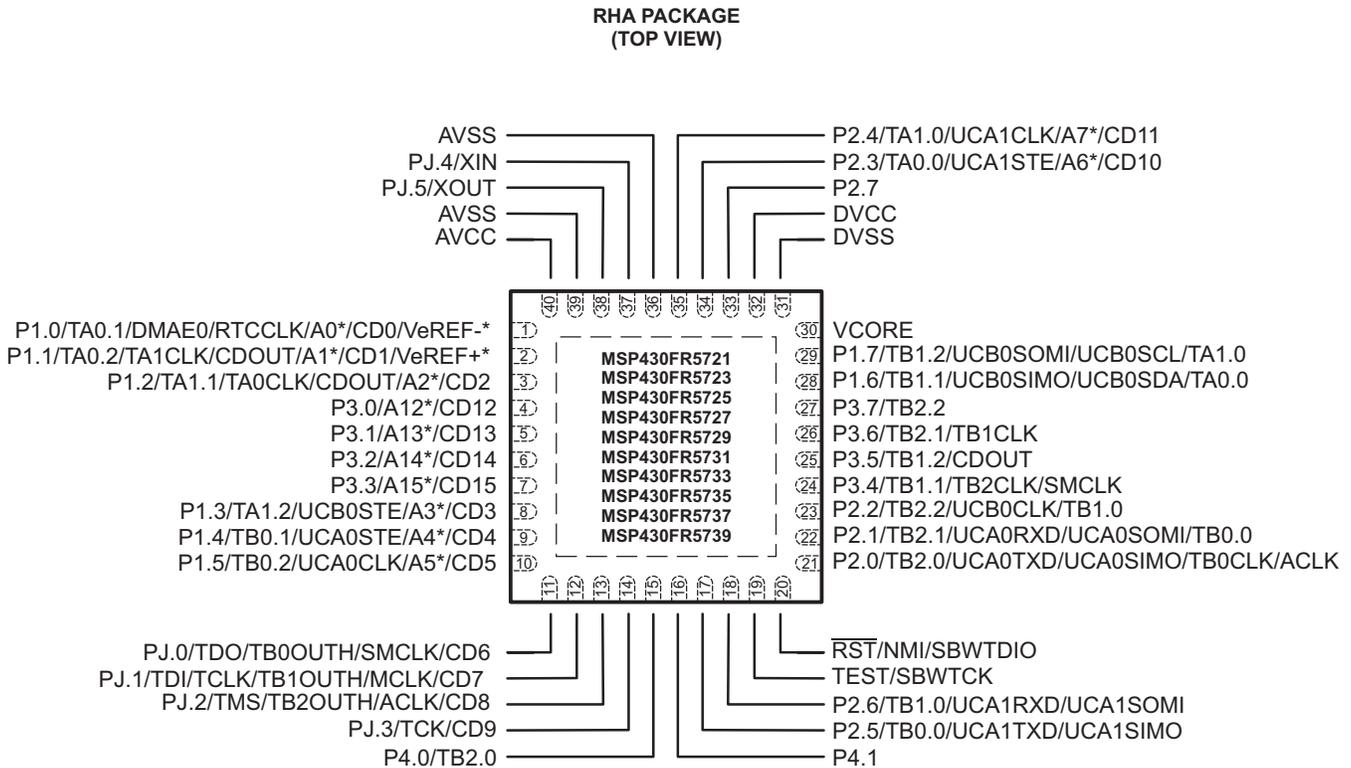
Table 1. User Experience Source Files

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

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

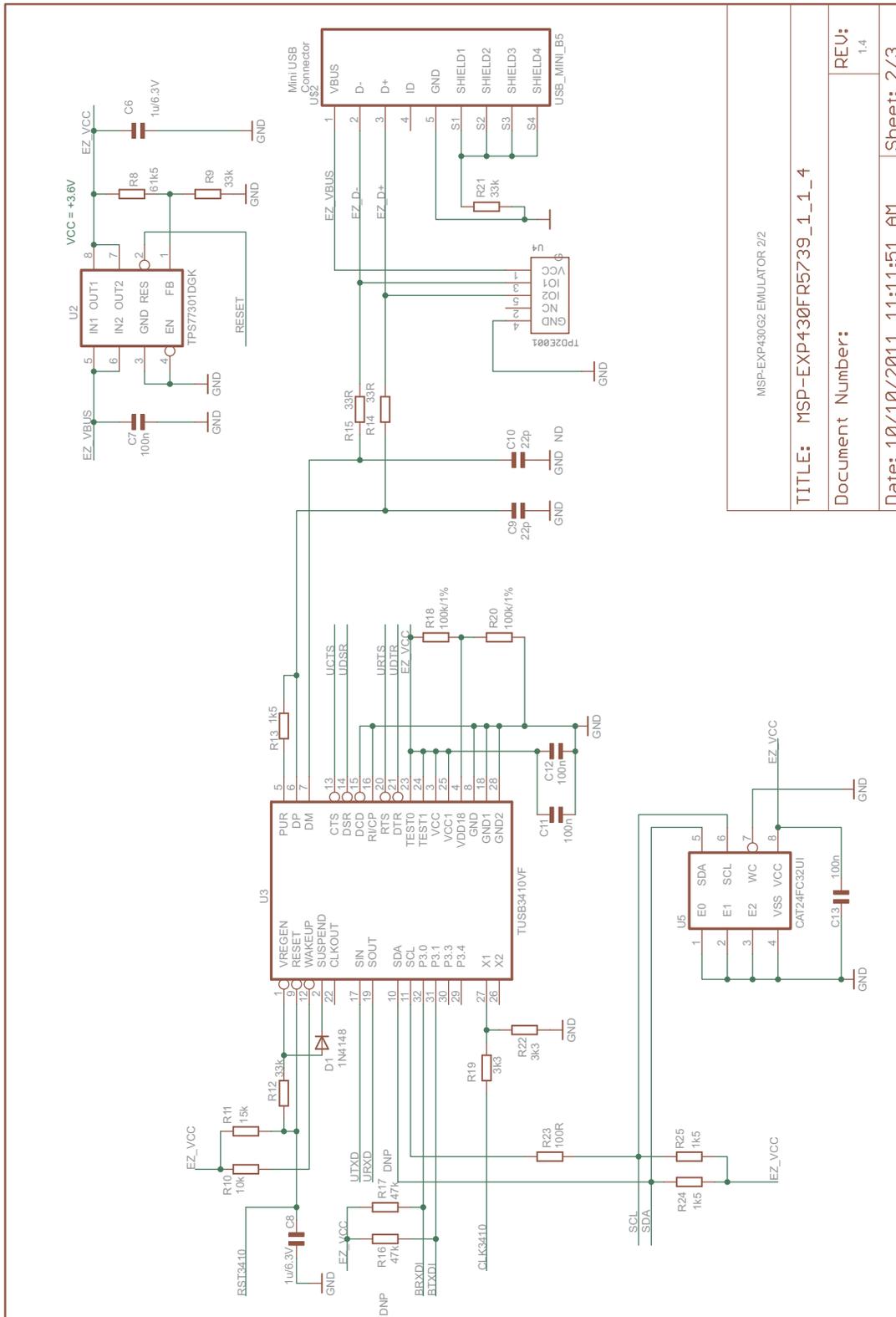


Figure 8. Schematics (2 of 3)

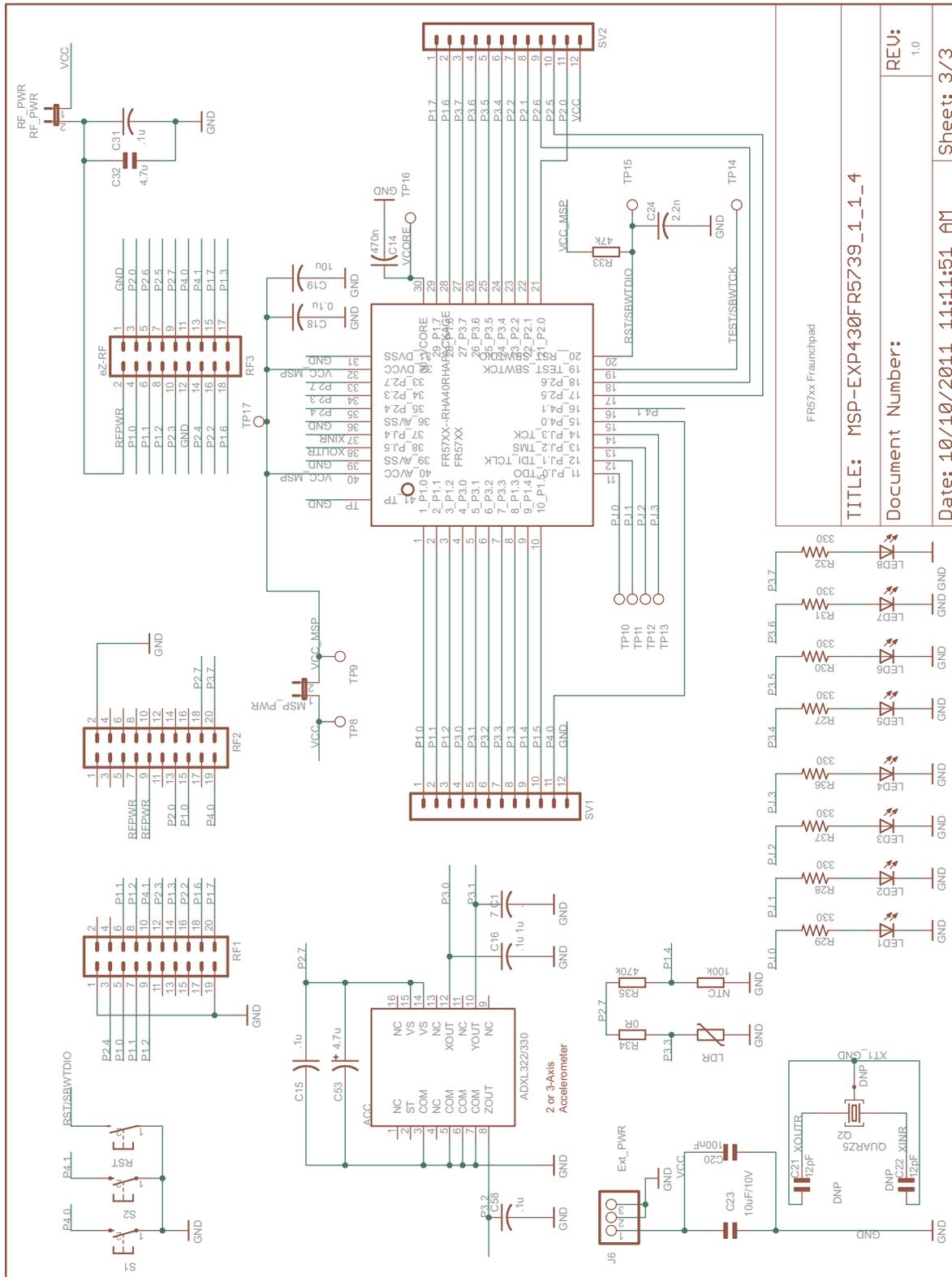


Figure 9. Schematics (3 of 3)

3.3 PCB Layout

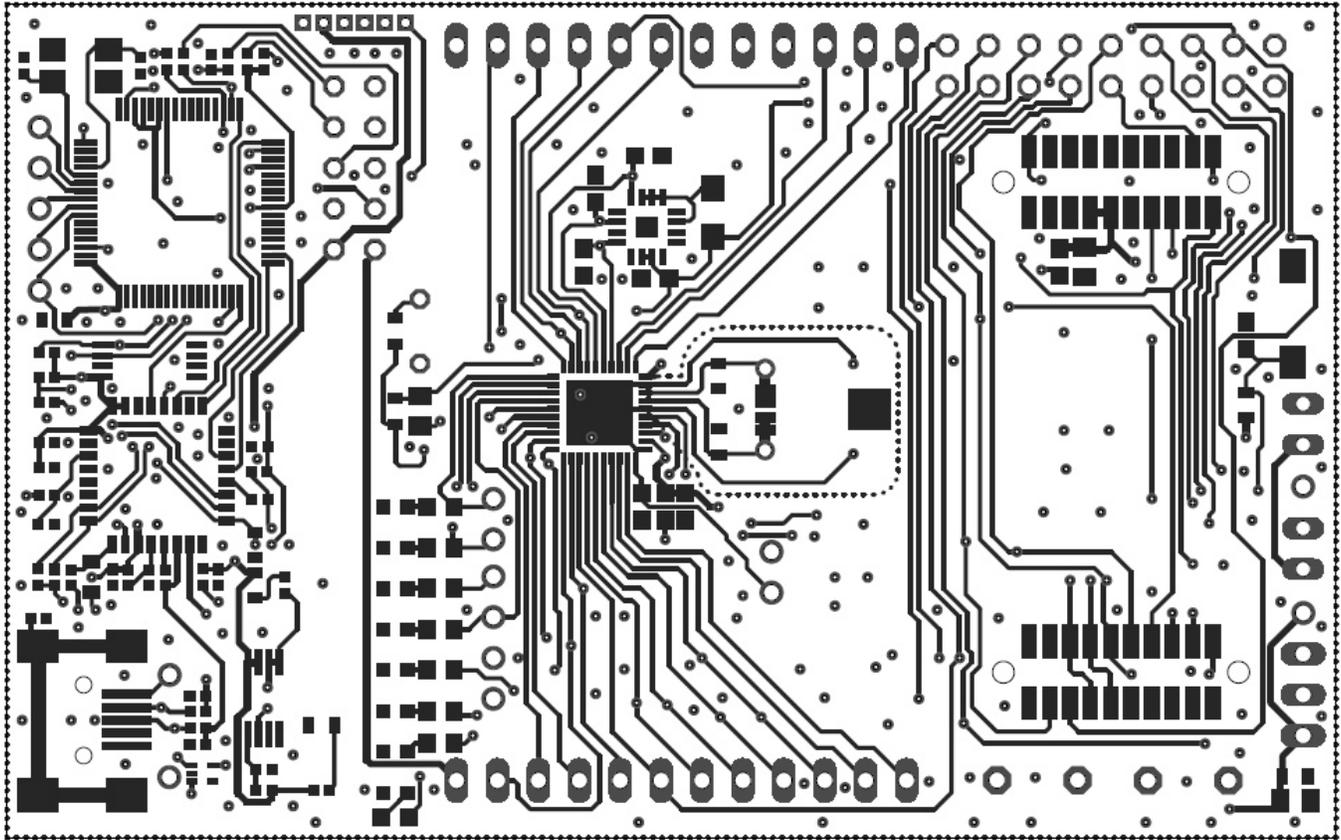


Figure 10. MSP-EXP430FR5739 Top Layer

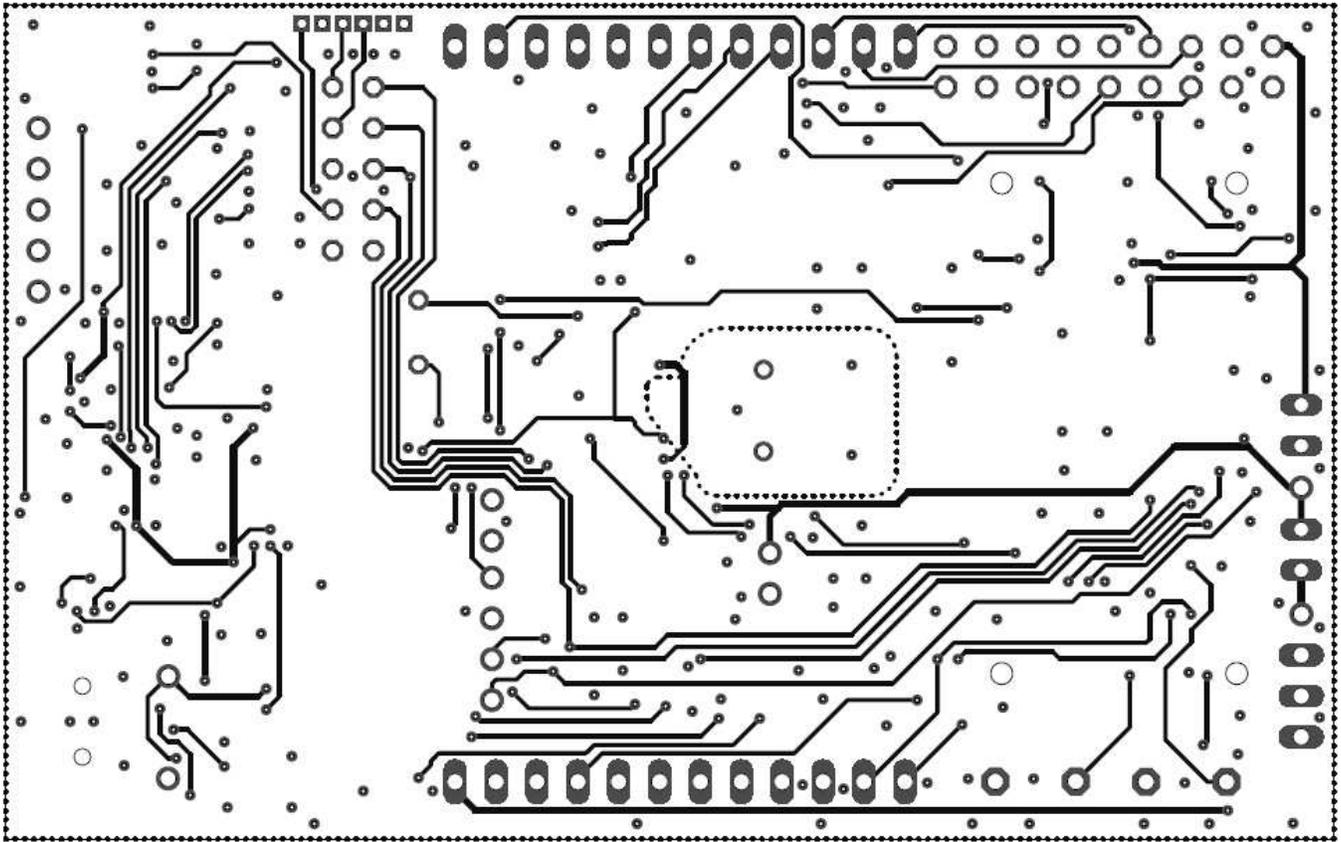


Figure 11. MSP-EXP430FR5739 Bottom Layer

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

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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