Chipcon Products from Texas Instruments

Z-Stack User's Guide For CC2431ZDK

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1. Introduction

1.1. Scope

This document accompanies the Texas Instruments Z-Location Z-Stack™ Development kit and is essentially the same as the document that accompanies the basic Texas Instruments Z-Stack Development kit: The Z-Stack User's Guide – CC2430ZDK. The primary difference is that this document uses Z-Location as the sample application. Z-Location is a sophisticated radio location solution built on top of Z-Stack, conforming to ZigBee Alliance standards (www.zigbee.org).

1.2. Scope

The CC2430EM and the CC2431EM are interchangeable, except that a device intended to run as a Blind Node must be fitted with the CC2431EM.

2. Product Package Description

2.1. Installation Package Contents

The downloaded Z-Stack installation package contains all of the documentation and software required to install, configure, and develop applications using Z-Stack. The package employs a Microsoft Windows-based installation application which guides the installation process.

2.2. Development Boards

There are two Chipcon SmartRF04EB evaluation boards, each to be fitted with a CC243xEM evaluation module.

Figure 1: Chipcon SmartRF04EB with CC243xEM

There are ten compact Chipcon SOC_BB evaluation boards, each to be fitted with a CC243xEM.

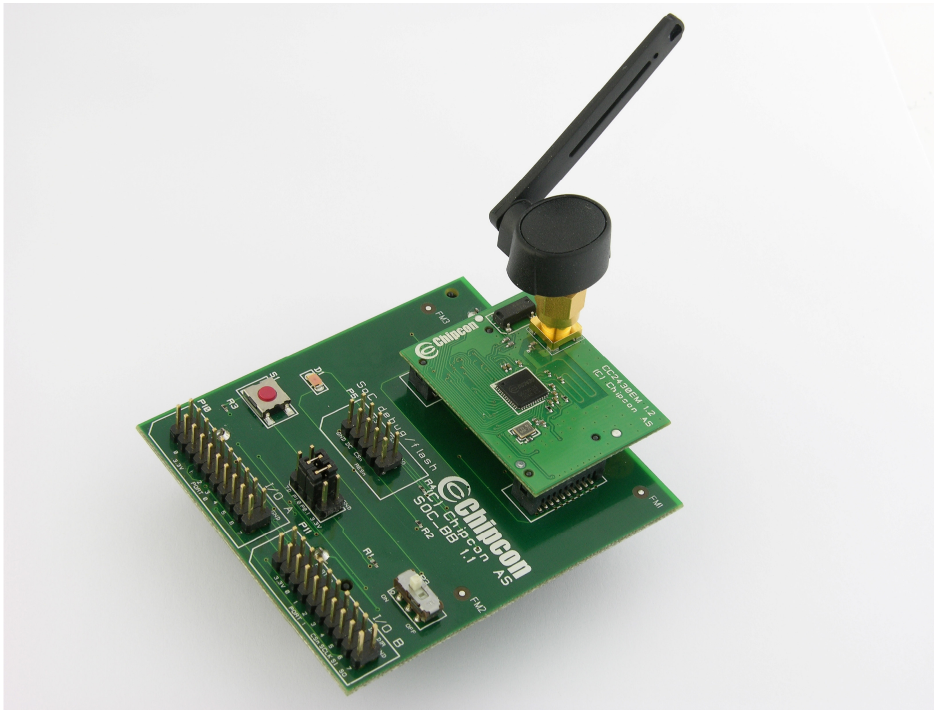


Figure 2: Chipcon SOC_BB Battery Board with CC243xEM

2.3. Cables

All necessary cabling has been included with the development kit. To support program download and debugging on the SmartRF04EB, a USB cable must be connected from the target board to the host PC. An RS232 cable may be connected between the serial port on the SmartRF04EB (9-pin connector) and the host PC to enable communication with the Z-Tool or Z-Location PC application included with the Z-Stack package.

3. Installation Requirements

3.1. Host Computer Requirements

Z-Stack and Z-Tool are designed for installation on a personal computer running Microsoft Windows XP Professional or Windows 2000. The following are the minimum requirements for the platform hosting Z-Stack and Z-Tool:

- .NET 1.1 Framework
- Windows XP Service Pack 1 (if using Windows XP)
- 1 serial port for Z-Tool communication with the SmartRF04EB board
- 1 USB port for download/debug of SmartRF04EB boards

3.2. Target Development System Requirements

Z-Stack provides a complementary offering to the IAR Embedded Workbench (EW8051) suite of software development tools. These tools support project management, compiling, assembling, linking, downloading, and debugging for various 8051-based processors, including the Chipcon CC243x family. The following is required support for the Z-Stack target development system:

- IAR EW8051 (http://www.iar.com/)

4. Product Installation Procedures

4.1. Install Z-Stack Package

Install the Texas Instruments Z-Stack files and programs from the downloaded package. Run the windows-based installation program, ***ZStack-CC2430-1.4.3-1.2.0.exe***, to create the required directory structure and load all software and documentation files. Review the README.txt file for a synopsis of new features and changes with this Z-Stack release.

4.2. Install IAR EW8051 Package

Install the Embedded Workbench for 8051 from IAR Systems: http://www.iar.com/. The project and library files included in this release of Z-Stack require the use of EW8051 version 7.30B or newer. When considering an upgrade to a newer version of EW8051, it is necessary to verify that installed project and library files are compatible with the newer development tools.

4.3. Device IEEE Addresses

Each CC243xEM board in the development kit has been pre-programmed with a unique 64-bit IEEE address. These addresses, assigned by Chipcon, are stored in *Little-Endian* format, located in the upper 8 bytes of FLASH memory on the CC243x processor. The IEEE address is displayed on a sticker affixed to the bottom of each CC243xEM.

This FLASH memory location would also be used for factory commissioning of IEEE addresses on devices that use Z-Stack. For CC243x-F128 devices, used on all boards in the development kit, the least significant byte of the IEEE address is located at “linear” FLASH memory address 0x1FFF8, corresponding to “banked” address 0x3FFF8.

Z-Stack treats the IEEE address area of FLASH as “write once” memory. When an attempt is made to write an IEEE address to that location (via Z-Tool, etc.), it will succeed only if the current contents are empty (0xFFFFFFFFFFFFFFFF). In other words, any 8-byte pattern other than all 0xFF values, is considered to be a valid IEEE address and won’t be modified.

5. Configuring and Using Z-Stack

5.1. Configuring Z-Stack

For the purposes of this release, the Logical Device Type and Profile are pre-configured. Details on configuring and programming the sample applications for the Z-Location are provided in the sections beginning with “Building the Sample Devices”.

5.2. Logical Device Types

Z-Stack can be configured in one of three ways:

- ZigBee Coordinator – This device is configured to start the IEEE 802.15.4 network and will serve as the PAN Coordinator in that network.
- ZigBee Router – This device is configured to join an existing network, associate to a Coordinator or Router, and then allow other devices to associate to it. It will route data packets in the network .
- ZigBee End Device – This device is configured to join an existing network and will associate with a Coordinator or Router.

5.3. Selecting the Application Profile

Once the Logical Device Type has been selected, devices can be configured for an application. Supported sample applications for this release of Z-Location include:

- Location Profile – Dongle
- Location Profile – Reference Node
- Location Profile – Blind Node

Multiple application profiles can be configured on a ZigBee device. Profiles are configured to operate overtop *Endpoints* which provide unique addressing for the application. By convention, *Endpoint 0* is reserved for the ZigBee Device Object, which performs device specific processing and implements functions required to support the selected *Logical Device Type.*

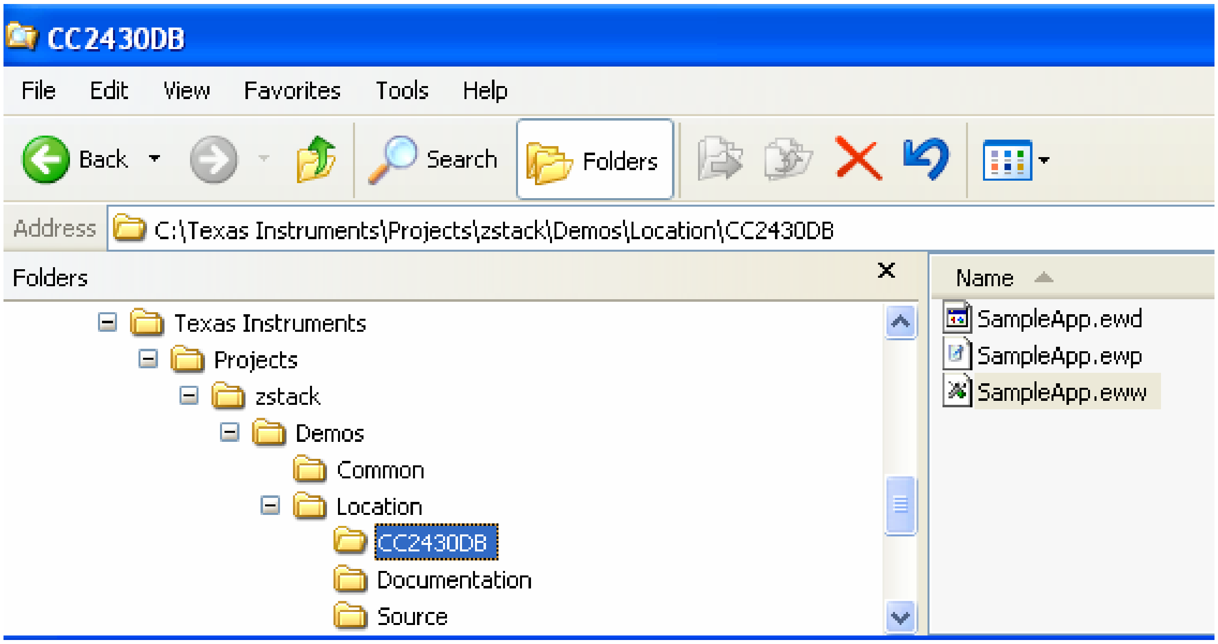
5.4. Building the Sample Devices

The remainder of this document describes setting up a network with 6 or more nodes: a Location Dongle as Coordinator, 4 or more Reference Node Routers, and 1 or more Blind Node Router(s). Notice that the procedures in Sections 5.5 thru 5.7 are identical, only folder names and filenames are different. Other Z-Location sample applications (e.g. a Blind Node End Device) can be built and loaded using the same general procedures.

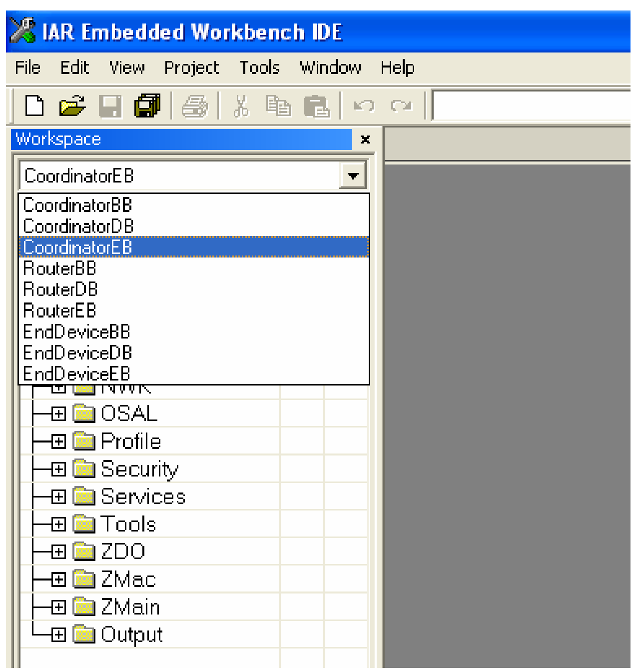
5.5. Building a Location Dongle Coordinator Device

- Make sure all tools have been installed (Sections 4.1 – 4.2)

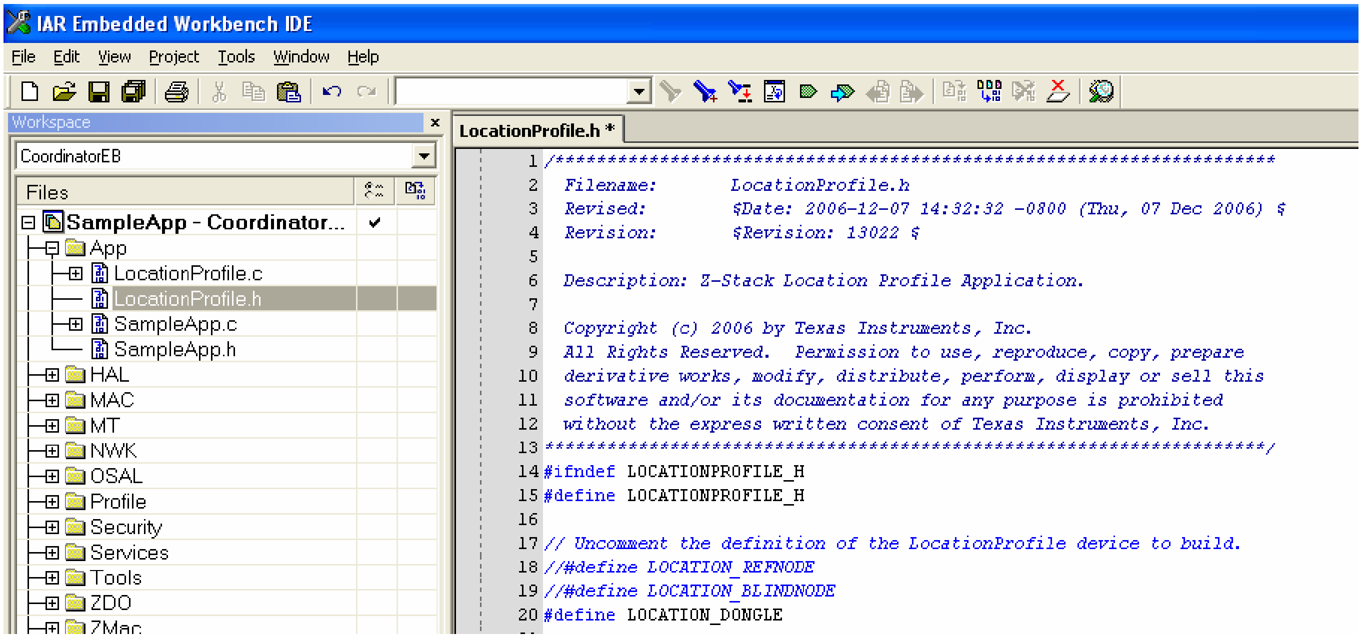
- Navigate to the SampleApp project directory and launch the IAR Embedded Workshop by double clicking on the ***SampleApp.eww*** file.



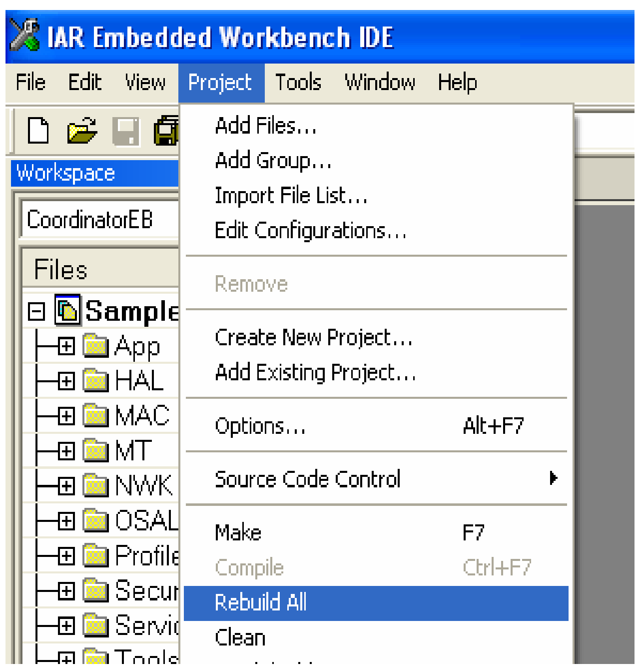
- Select the CoordinatorEB project from the ***Workspace*** pull-down menu:



- Open LocationProfile.h file by clicking the '+' next to the folder 'App' and then double-clicking on the file name. Uncomment only the line that defines the Location Dongle.

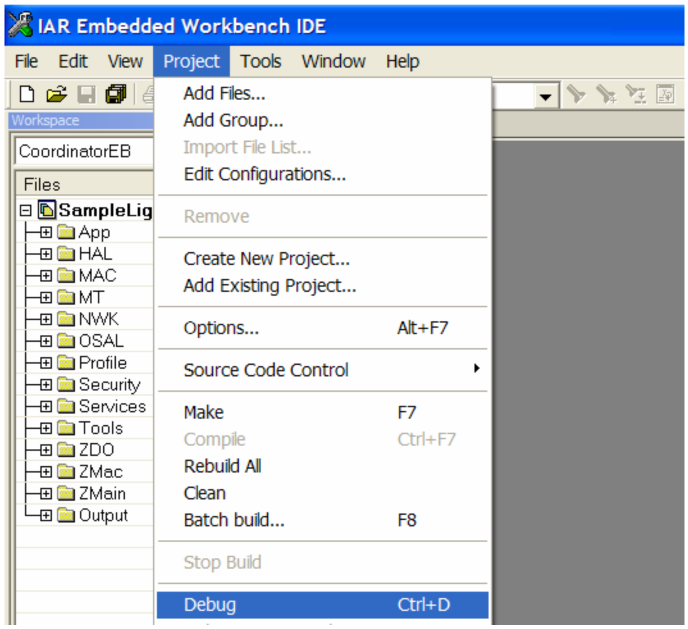


- Build the application by pulling down the ***Project*** menu and clicking on **Rebuild All**:

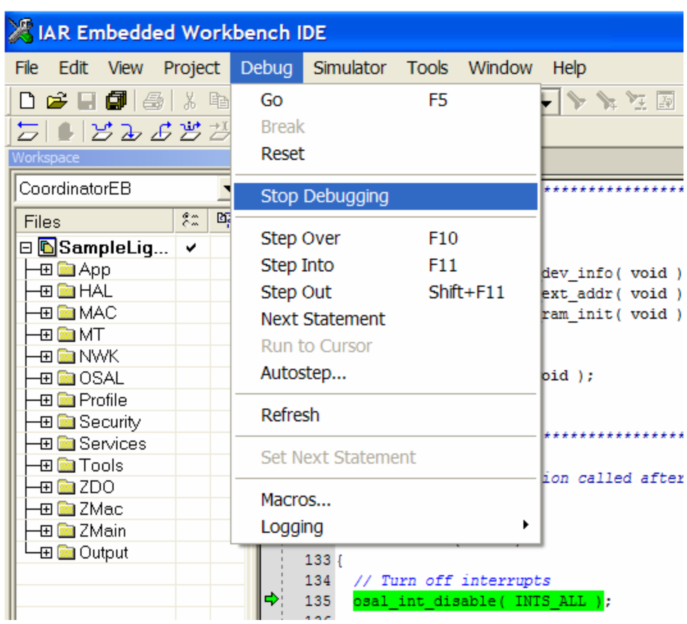


- Install a CC243xEM onto a SmartRF04EB and connect the SmartRF04EB to the development PC with a USB cable. Apply power by moving switch S3 toward the CC243xEM. If Windows needs to install a driver, browse to ***C:\Program Files\IAR Systems\Embedded Workbench 4.0\8051\drivers\Chipcon*** to locate the necessary files.

- Download the application by pulling down the ***Project*** menu and clicking on **Debug.**



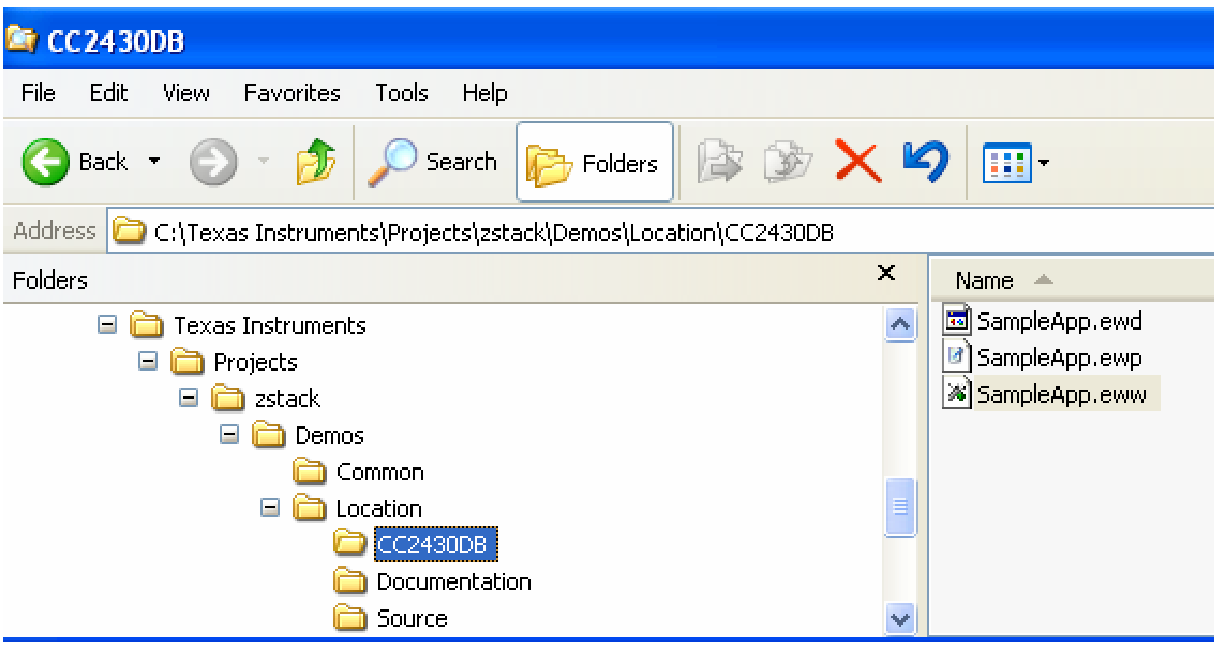
- After downloading to the SmartRF04EB is complete, exit the debugger by pulling down the ***Debug*** menu and clicking on **Stop Debugging**. Exit the Embedded Workbench IDE.



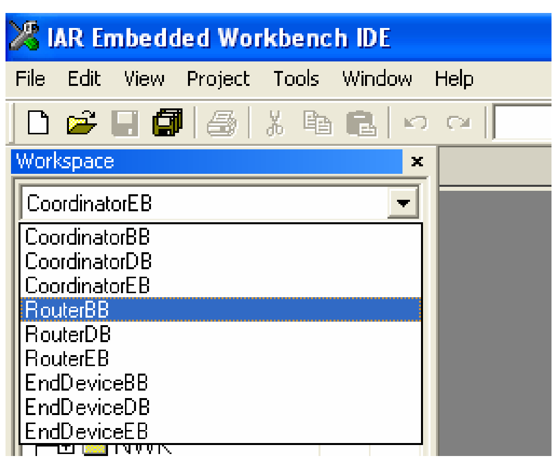
- Remove power from the CC2430EB by moving switch S3 away from the CC2430EM. Disconnect the board from the USB cable and set it aside.

5.6. Building a Reference Node Router Device

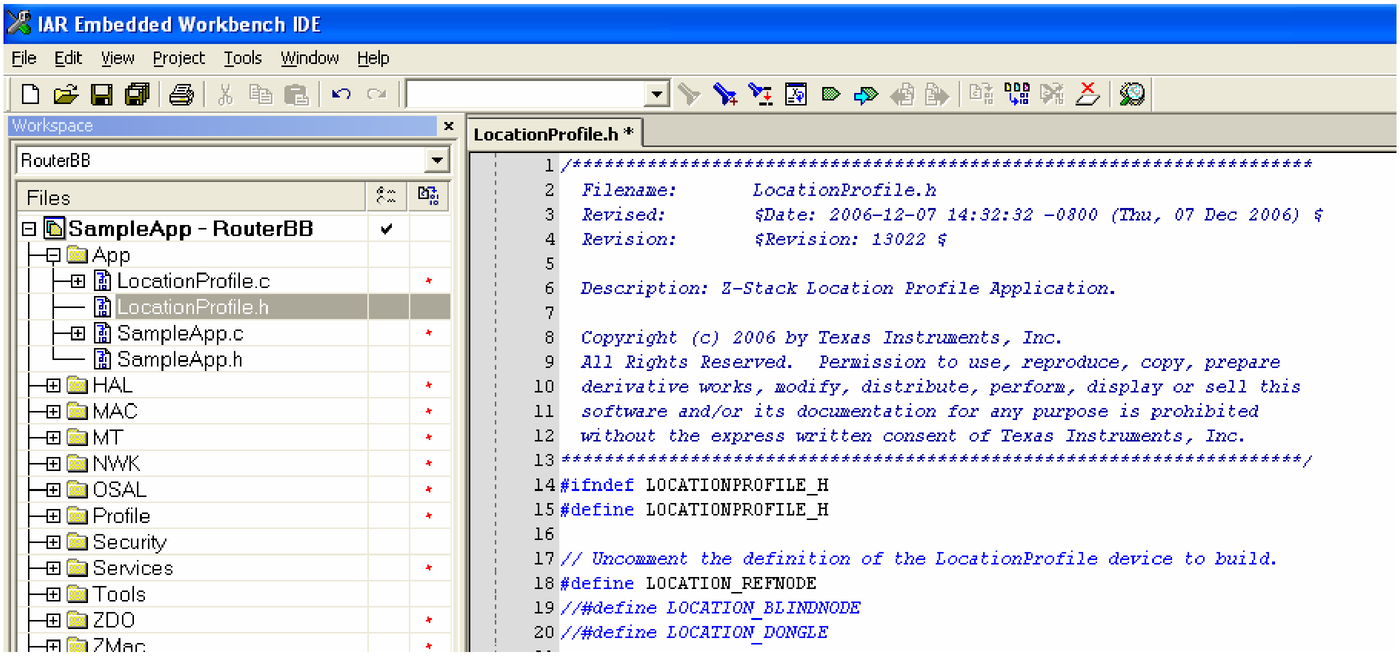
- Make sure all tools have been installed (Sections 4.1 – 4.2)
- Navigate to the SampleApp project directory and launch the IAR Embedded Workshop by double clicking on the ***SampleApp.eww*** file:



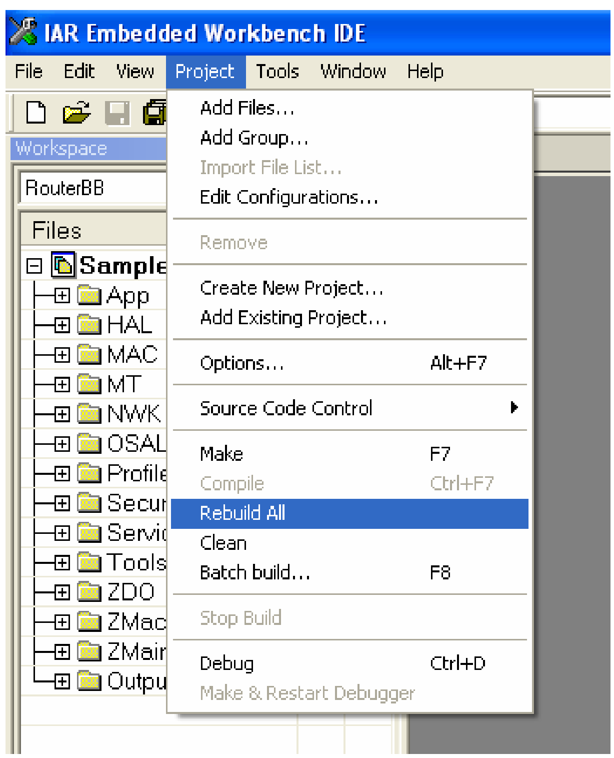
- Select the RouterBB project from the ***Workspace*** pull-down menu:



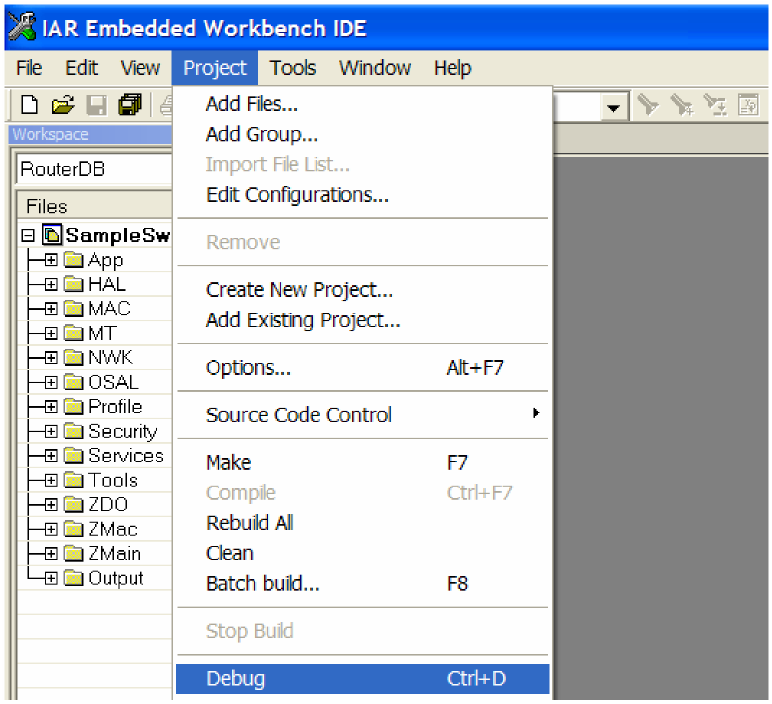
- Open the LocationProfile.h file by clicking the '+' next to the folder 'App' and then double-clicking on the file name. Uncomment only the line that defines the Reference Node.



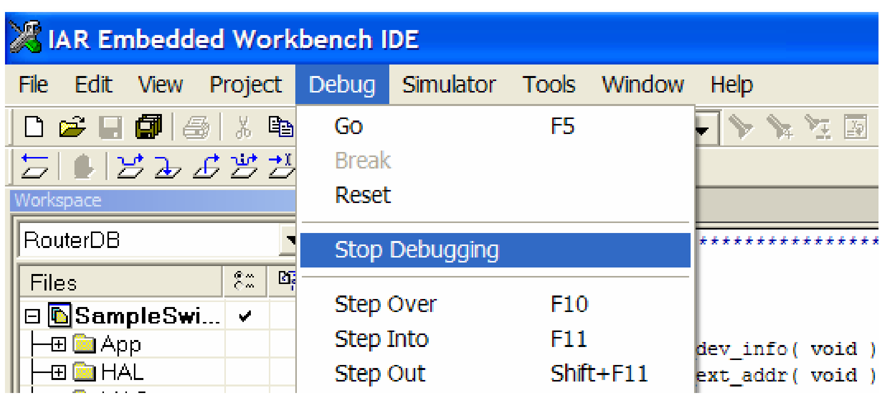
- Build the application by pulling down the ***Project*** menu and clicking on **Rebuild All**:



- Install a CC243xEM onto a SmartRF04EB and connect the SmartRF04EB to the development PC with a USB cable. Apply power by moving switch S3 toward the CC2431EM. If Windows needs to install a driver, browse to ***C:\Program Files\IAR Systems\Embedded Workbench 4.0\8051\drivers\Chipcon*** to locate the necessary files.
- Download the application by pulling down the ***Project*** menu and clicking on **Debug**:



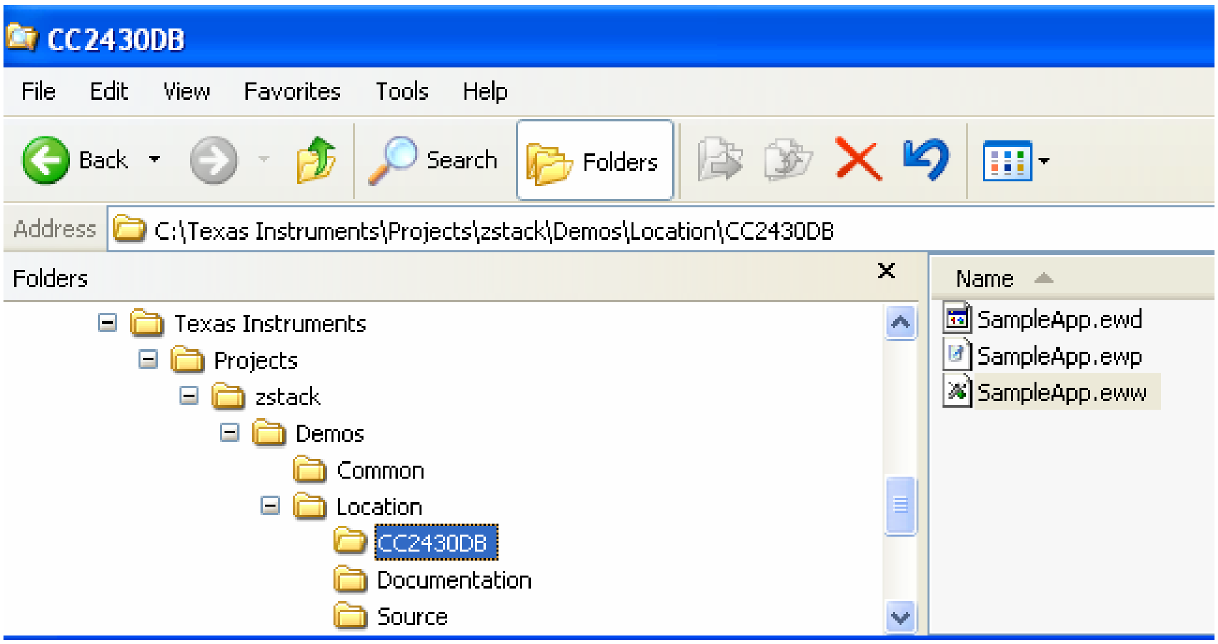
- After downloading to the CC2430EB is complete, exit the debugger by pulling down the ***Debug*** menu and clicking on **Stop Debugging**:



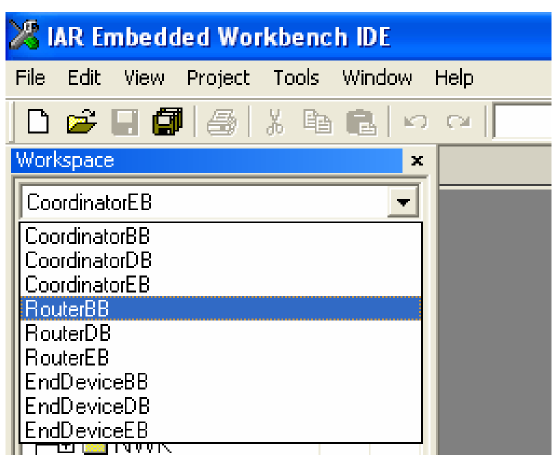
- If one or more additional Reference Node Router devices are to be programmed, repeat the previous three steps, starting with installation of a different CC243xEM onto the SmartRF04EB .

5.7. Building a Blind Node Router Device

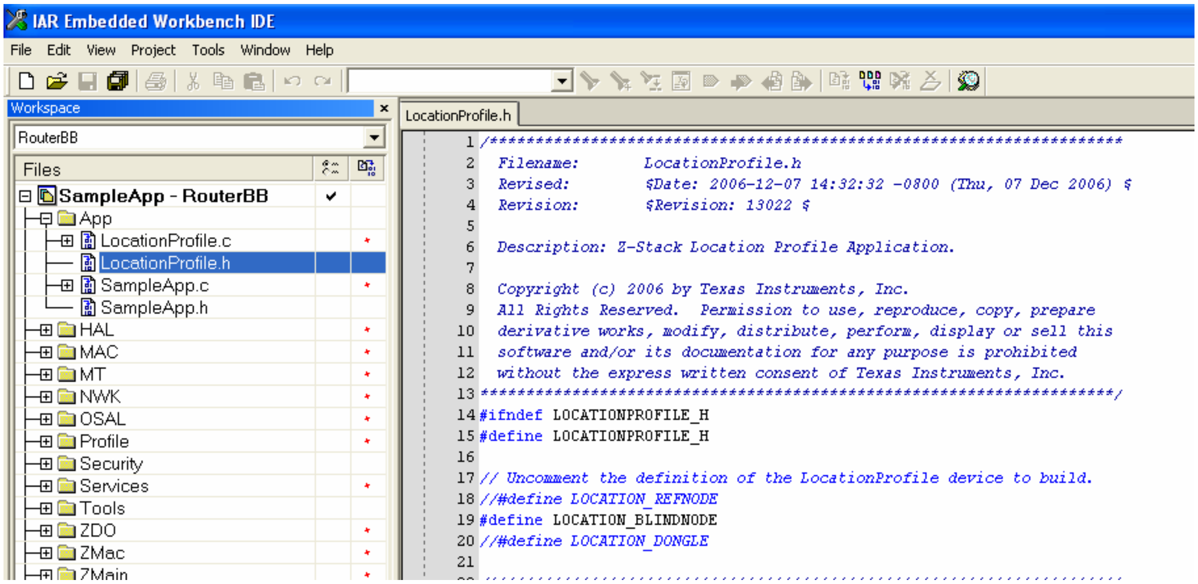
- Make sure all tools have been installed (Sections 4.1 – 4.2)
- Navigate to the SampleApp project directory and launch the IAR Embedded Workshop by double clicking on the ***SampleApp.eww*** file:



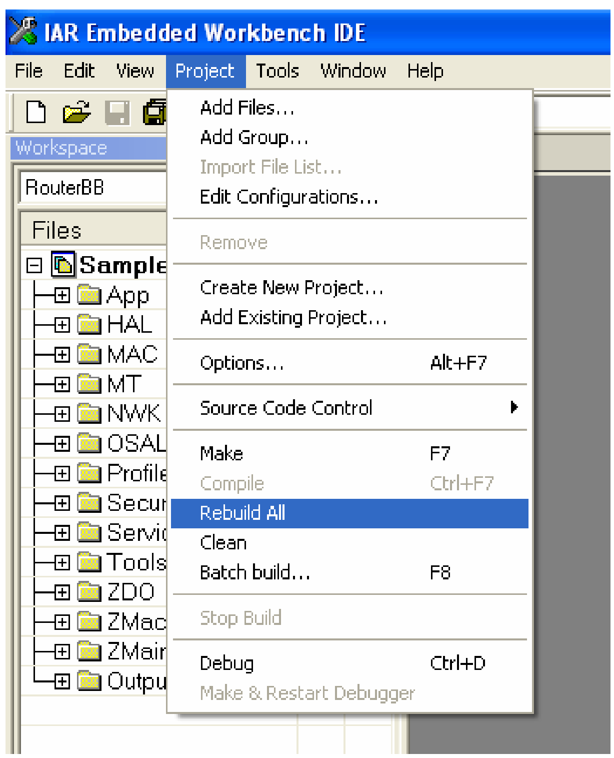
- Select the RouterBB project from the ***Workspace*** pull-down menu:



- Open the LocationProfile.h file by clicking the '+' next to the folder 'App' and then double-clicking on the file name. Uncomment only the line that defines the Blind Node.



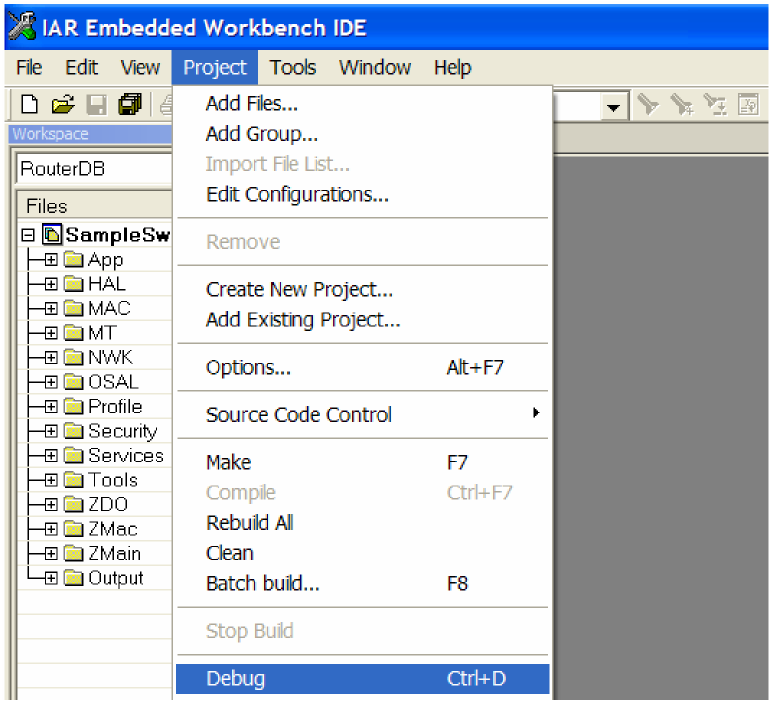
- Build the application by pulling down the ***Project*** menu and clicking on **Rebuild All**:



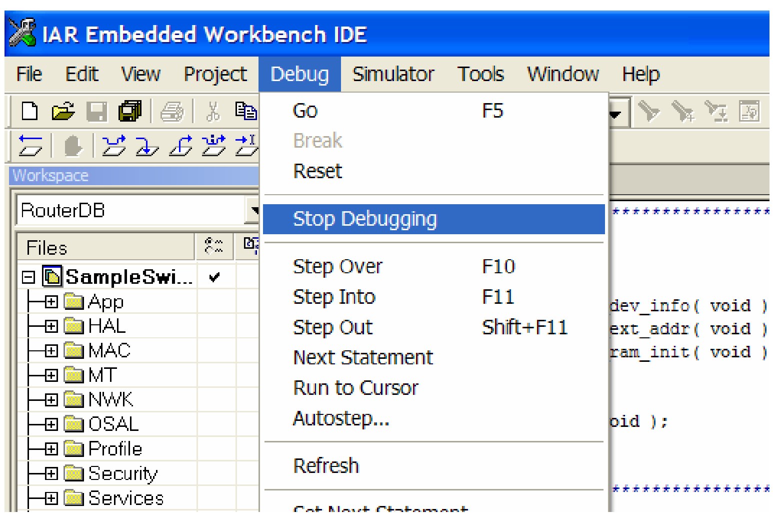
- Install a CC2431EM onto a SmartRF04EB and connect the SmartRF04EB to the development PC with a USB cable. Apply power by moving switch S3 toward the

CC2431EM. If Windows needs to install a driver, browse to ***C:\Program Files\IAR Systems\Embedded Workbench 4.0\8051\drivers\Chipcon*** to locate the necessary files.

- Download the application by pulling down the ***Project*** menu and clicking on **Debug**:



- After downloading to the CC2430EB is complete, exit the debugger by pulling down the ***Debug*** menu and clicking on **Stop Debugging**:



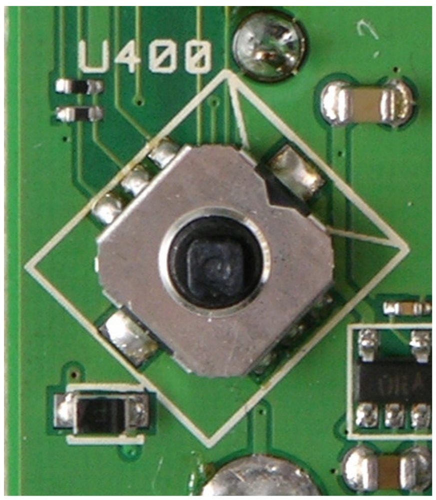
- If one or more additional Reference Node Router devices are to be programmed, repeat the previous three steps, starting with installation of a different CC2431EM onto the SmartRF04EB .
- When all devices have been programmed, exit the Embedded Workbench IDE.

6. Z-Location Demonstration

6.1. Switches and LEDs

In this, and other Z-Stack documents, references are made to switches and LEDs located on evaluation boards. These devices are used to control certain Z-Stack features and display status.

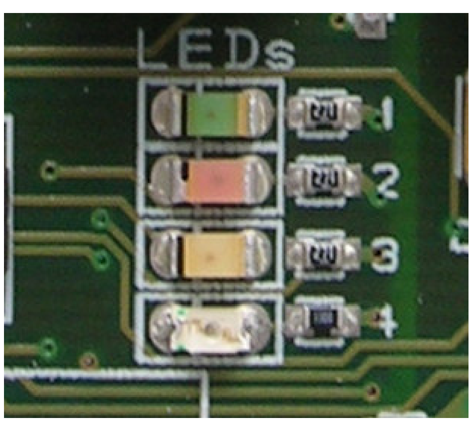
Certain procedures require user input via switches, commonly referred to as SW1 through SW5. The SmartRF04EB boards have a 5-position joystick, designated U400, which provides these switch inputs as shown in the table below. Pressing the joystick toward the U400 label (up position) activates the SW1 input. Switch inputs SW2 – SW4 result from pressing the joystick to the right, down (away from U400), and left positions, respectively. SW5 occurs when the joystick is pressed straight down when in the center position.



SWITCH	JOYSTICK
SW1	***U400*** position
SW2	right position
SW3	down position
SW4	left position
SW5	press down

Figure 3: SmartRF04EB Joystick

Z-Stack sample applications display various operational status LEDs, commonly referred to as LED1 through LED4. The SmartRF04EB has 4 colored LEDs, designated 1 - 4. The CC2430EM module does not have connections to the red LED (2) or the blue LED (4). Therefore, LEDs 1 and 3 are used to provide all LED indications from Z-Stack applications as shown in the table below.



LED	LABEL	COLOR
LED1	***D1***	Green
LED2	***D2***	Red
LED3	***D2***	Red
LED4	***D1***	Green

Figure 4: SmartRF04EB LEDs

The SOC BB's have a single button to press, labeled S1, in the lower left-hand corner of the board and a single red LED above it. The S1 button acts like the SW5 no the SmartRF04EB, and the single LED acts like the LED1.

6.2. Initial Loading of 64-Bit IEEE Address

Normally, Z-Stack loads the device's 64-bit IEEE address from FLASH upon power-up or reset. When the address has been reset (0xFFFFFFFFFFFFFFFF) by erasing the FLASH, the program waits in a loop during start-up, blinking LED1 (green). This prompts the user to establish a "temporary" address by pressing SW5 (joystick center). This temporary address allows Z-Stack to start normally so that the developer can later use Z-Tool to restore the proper 64-bit extended address, located on a sticker on the bottom surface of the circuit board.

6.3. Non-Volatile Memory

Z-Stack devices can be built to save certain operating state variables (PanID, 16-bit network address, etc.) in non-volatile (NV) memory. These variables will then be used when the device is restarted (reset or power on), to resume operation at its previous state. This feature is enabled by including *NV_RESTORE* in the list of compile flags in the IAR project files.

During program development and debugging, it is often convenient to disable saving/restoring NV parameters – remove or disable the *NV_RESTORE* compile flag. To bypass this feature in a device that was built with *NV_RESTORE*, press and hold the SW5 (or the S1 button on SOC_BB) while the device is rebooting. This will load the 64-bit IEEE address but skip restoration of other NV parameters.

6.4. Running the Sample Applications

Initially, place all the devices on the same table or work area. You will establish the network while the devices are all in view of each other. Later, you can experiment with various distances and different power-up sequences.

To begin execution of the programmed sample application, remove power from each programmed SmartRF04EB and SOC_BB board.

Start with the Dongle on the SmartRF04EB – while pressing and holding SW5, turn on power. Then turn on power to each Reference Node while pressing and holding the single S1 button. Finally, turn on power to the Blind Node while pressing and holding the single S1 button.

Once these devices have begun operation and joined the network, their Red LED will be turned on solid. Refer to the Z-Location PC Application guide for how to configure and control the nodes under the location profile.

The discussion above assumes each device has been programmed and disconnected from the development PC. When necessary, a target device can be controlled from the IAR IDE, providing for standard debugging features such as breakpoints, single-stepping, viewing of memory and register contents, etc.

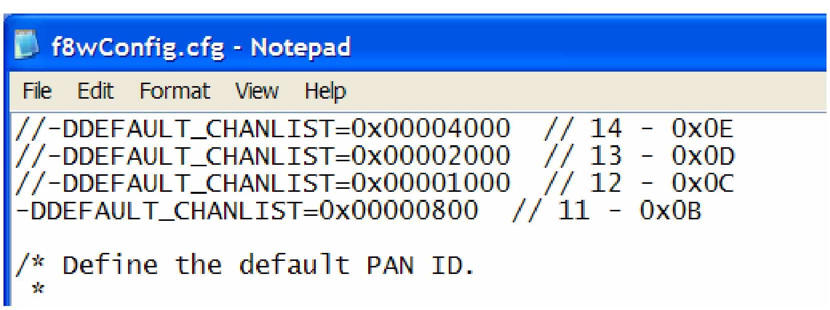
7. Channel Selection

The IEEE 802.15.4 specification defines 16 channels in the 2.4 GHz frequency range. These channels are assigned numbers 11 through 26. Z-Stack initially defaults to channel 11, but the user can select a different channel by changing *DEFAULT_CHANLIST*. This parameter is a bit map field, with each bit representing a single channel. As shown below, the initial default channel 11 (0xB) is represented by 0x00000800 (11^{th} bit in the field, starting from bit 0).

Channel Number	Bit Map Field
11	0x00000800
12	0x00001000
13	0x00002000
14	0x00004000
15	0x00008000
16	0x00010000
17	0x00020000
18	0x00040000
19	0x00080000
20	0x00100000
21	0x00200000
22	0x00400000
23	0x00800000
24	0x01000000
25	0x02000000
26	0x04000000

Table 1: Default Channel Select Bit Map

DEFAULT_CHANLIST is defined in the NLMEDE.h file. In addition, it can also be specified as a compile option in a project's configuration command file – this overrides the value in the NLMEDE.h file. Configuration command files are found in the …\Projects\Tools\CC2430DB folder. As shown below, a line in the *f8wConfig.cfg* file specifies the channel(s) that will be used when the Z-Stack devices start up. This is the recommended location for developers to establish specific channel settings for their projects. This feature allows developers set up a "personal" channel to avoid conflict with others. Multiple channels can be specified by including the appropriate bits in the *DEFAULT_CHANLIST* definition.



7.1. Energy Level

The coordinator will start a network on a selected channel only if the energy level on that channel is below a threshold value. The threshold value is set to -45dBm and can be modified by changing the MAX_SCAN_ENERGY definition in the *mac_scan.c* file (available only with TIMAC source file distribution). The value of this parameter minus 83 gives the maximum tolerated energy level in dBm. To ensure that the coordinator will always find a suitable channel to start the network on, it is recommended that more than one channel is selected.

Applicable Documents

Internal Documents

1. Serial Port Interface, F8W Document F8W-2003-0001
2. OSAL API, F8W Document F8W-2003-0002
3. Z-Stack API, F8W Document F8W-2006-0021

External Documents

4. Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs), IEEE Standard 802.15.4, 05/12/2003.

