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SILICON LABS

August 5, 2012

120-4030-000E



EM35x Development Kit User Guide

New in this Revision

Chapter 4: Silicon Labs part number changes in Table 4-1.

Chapter 7: `usbaddr` command added.

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1 About This Guide

1.1 Purpose

This document describes the Ember EM35x Development Kit and explains how to set up its hardware and use the Ember InSight Adapter (ISA3). For information on developing and debugging applications with InSight Desktop, see its on-line HTML help.

For information on designing and debugging an application based on Silicon Labs' EmberZNet PRO software stack, refer to documents 120-3029-000, *Ember Application Development Fundamentals*, and 120-035X-000, the *EM35x Datasheet*. See section 2.7, Documentation, for a list of other EM35x documents of interest.

1.2 Audience

This document is intended for embedded software and hardware engineers who are responsible for developing wireless applications with the Ember Development Kit. This document assumes that the reader has a solid understanding of embedded systems design and programming in the C language. Experience with networking and radio frequency systems is useful but not expected.

1.3 Documentation Conventions

| Notation | Meaning | Example |
|------------------------|---|---|
| <i>Italics</i> | Identifies on-screen software menu options. | <i>Connect</i> |
| UPPERCASE | Identifies a keyboard key. | ENTER |
| Right-angle bracket | Delimits a series of software program menu options to be clicked. | <i>Open > Save</i> |
| Courier | Identifies software code and, in body text, variables. | <code>void Main(String[] argv) the buffer variable</code> |
| <i>Courier Italics</i> | Identifies a variable name. | <i>ipAddress</i> |

1.4 Getting Help

Development Kit customers are eligible for training and technical support. You can use the Silicon Labs web site [www.silabs.com/ zigbee](http://www.silabs.com/zigbee) to obtain information about all Ember products and services. You can also contact Customer Support at www.silabs.com/ zigbee-support.

If you have any questions about your Development Kit, contact your account representative at one of the following locations:

| | |
|----------------------|--|
| United States | 25 Thomson Place Boston, MA 02210 Telephone: 617-951-0200 Fax: 617-951-0999 |
| Asia/Pacific | HK Spinners Industrial Bldg, Phase 5 5/F Flat D 760-762 Cheung Sha Wan Rd Kowloon Hong Kong Telephone: +852-8120-5375 |
| Europe | Unit 300 Science Park Milton Road Cambridge CB4 0XL, UK Telephone: 44 (0) 1223 423322 Fax: 44 (0) 1223 423390 |

2 Introducing Ember Development Kits

2.1 Overview

The EM35x Development Kit is used for application design and development. The Development Kit contains a variety of hardware for quickly creating a prototype of the customer's hardware, EmberZNet PRO, Silicon Labs' implementation of the ZigBee Pro stack software specification, and various development tools which enable the development of the customer's application software.

EmberZNet PRO runs on top of an IEEE 802.15.4-compliant radio and link layer software. EmberZNet PRO is a self-organizing, self-healing mesh networking protocol stack. Combined with the powerful IEEE 802.15.4 compliant Ember radios, the EmberZNet network stack provides complete networking services from the physical layer up to a reliable application profile support layer. The stack produces networks that are reliable, flexible, secure, and easy to use.

EmberZNet PRO¹ provides a common Application Programming Interface (API) that utilizes the underlying layers. This API provides support for the following layers of the Open System Interconnection Reference Model (OSI Model):

- **PHY:** radio control
- **MAC:** medium access
- **LINK:** route discovery
- **NETWORK:** routing, association
- **APPLICATION:** Application Profile Support for reliable message delivery

The EmberZNet PRO stack can be used to build ZigBee-based applications. Applications that are built on this stack benefit from the following features:

- PHY and MAC layers comply with the IEEE 802.15.4-2003 standard
- LINK and NETWORK layers comply with the latest ZigBee specification
- The APS layer provides the interface to the application for data transfer and management, including reliable transport and binding.

The Development Kit includes InSight Desktop which facilitates application development and debugging. InSight Adapters (ISA3s) incorporate Power-over-Ethernet (PoE) capability, which can simplify node deployment in the test environment. Breakout Boards provide a direct connection for debugging customer-designed hardware. For detailed information about the Ember customer hardware debug interface, see document 120-2009-000, the *EM35x Breakout Board Technical Specification*.

¹ The release version of EmberZNet PRO at the time of this writing is 4.0.

2.2 Development Kit Contents

Table 2-1 summarizes the components and the specified count for each component in the EM35x Development Kit.

Table 2-1. EM35x Development Kit Components

| Component | EM35x Development Kit |
|---|-----------------------|
| InSight Adapter (ISA3) | 3 |
| EM357 Sample Chip | 10 |
| EM35x Breakout Board | 3 |
| EM35x Modules | 9 ² |
| Data Emulation Interface (DEI) Cable | 3 |
| Ember Happy Fun Ball | 1 |
| InSight Port (ISP) Cable | 3 |
| Radio Frequency Cable | 1 |
| Power-over-Ethernet Switch with Power Supply | 1 |
| USB Power Supply with Adapters | 3 |
| <i>EM35x Quick Start Guide</i> | 1 |
| InSight Desktop CD | 1 |
| IAR Embedded Workbench CD | 1 |
| US-to-multinational AC Plug Power Adapter Kit | 1 |
| AAA Battery Pack | 3 |
| Ethernet Cable | 3 |
| USB Cable | 3 |

2.3 Hardware Requirements

- PC with Ethernet connectivity
- Network hub with DHCP server

2.4 Software Requirements

- Microsoft Windows XP
- Java, version 1.5V6 or later
- Adobe Acrobat Reader (available free from <http://get.adobe.com/reader/>)

² Three EM35x modules are installed on EM35x Breakout Boards; six EM35x modules are included in the EM35x Module Box.

2.5 Hardware

- **Breakout Boards** serve as test beds for network hardware and applications. Each Breakout Board has an associated EM35x Module, which can be deployed as a node within a network application. Each Breakout Board connects with an InSight Adapter (ISA3) through two communication links: the InSight Port (ISP) and the DEI Port. This allows the Breakout Board's EM35x Module to interface with InSight Desktop (ISD) through the ISA's InSight Port and its wired Ethernet connection. These interconnections are described later in this chapter. The Breakout Boards also have a prototype breadboard area for application-specific hardware development.
- **EM35x modules** contain the Ember EM35x System-on-Chip (SoC) solution providing a complete radio and microcontroller solution. All modules are pin-compatible, and they can be directly attached to a Breakout Board.
- **InSight Adapters** (ISA3s) each connect a Breakout Board to the Ethernet. Each adapter transmits network data collected via its InSight Port and conveys it over its Ethernet connection to InSight Desktop. It also picks up any messages or new software that is addressed to this Breakout Board.

The InSight Port is a cabled communication link between the ISA3 and the EM35x Module mounted on the Breakout Board.

- **InSight Port Cables** connect each ISA3 to a Breakout Board.
- **AAA Battery Packs** that attach to a Breakout Board enable deployment of battery-operated nodes.
- **USB Power Supply with Adapters** power Breakout Boards and / or ISA3s from wall sockets.
- **Ethernet Cables** connect ISA3s to an Ethernet subnet.
- **Data Emulation Interface (DEI) cables** provide a peripheral interface connection between the ISA3 and Breakout Board. The DEI cable supports UART functionality.

2.6 Software

The Ember Development Kit contains two CDs for:

- InSight Desktop
- IAR Embedded Workbench

2.6.1 InSight Desktop

Installation components and associated documentation:

- EmberZNet PRO network stack library and APIs: debug and release builds (see Table 3-2)
- HAL library
- InSight Desktop
- Sample programs (see Table 3-3)

2.6.2 IAR Embedded Workbench

Licenses and support are provided separately and can be obtained from IAR Systems at <http://www.iar.com>.

2.7 Documentation

Document 120-4031-000, *EM35x Quick Start Guide*, is shipped with the EM35x Development Kit. All other documents listed below are available from Silicon Labs' Ember support page (www.silabs.com/zigbee-support) as Adobe PDF files or as on-line HTML help:

- EM35x Development Kit User's Guide (this document)
- *Application Development Fundamentals* (120-3029-000)

- *Testing and Debugging Applications* (120-3030-000)
- *Advanced Application Programming with the Stack and HAL APIs* (120-3031-000)
- *EmberZNet API Reference: For the EM350 SoC Platform* (120-3022-000)
- *EM35x Breakout Board Technical Specification* (120-2009-000)
- *InSight Adapter (ISA3) Technical Specification* (120-2010-000)
- *EM35x Module Technical Specification* (120-2011-000)
- *EM35x Datasheet* (120-035X-000)
- *InSight Desktop User's Guide* (120-4005-000 and on-line HTML help)
- Application notes (various)

2.8 Before You Begin

The EM35x Development Kit is designed only for the operating conditions and interfaces specified in Ember documents 120-2010-000, the *InSight Adapter (ISA3) Technical Specification*, and 120-2009-000, the *EM35x Breakout Board Technical Specification*. Any modifications or alterations to the hardware are liable to cause irreparable damage to the EM35x Development Kit, and shall render its warranty null and void.

If you wish to use the EM35x Development Kit in a non-standard fashion, consult with Ember Customer Support or Ember Sales before starting custom development. This is especially true if you are embarking on an aggressive development cycle, plan to use custom hardware, or wish to use alternate software configuration files, images, or hardware configurations. Contact us and describe your plan, so we can help you minimize the risk of delays in your development cycle.

3 Development Kit Components

3.1 Overview

Figure 3-1 shows the components in the EM35x Series Development Kit.

Figure 3-1. EM35x Series Development Kit



This chapter describes the hardware and software components in the EM35x Series Development Kit.

3.2 Hardware

The EM35x Series Development Kit development board set has three major hardware components:

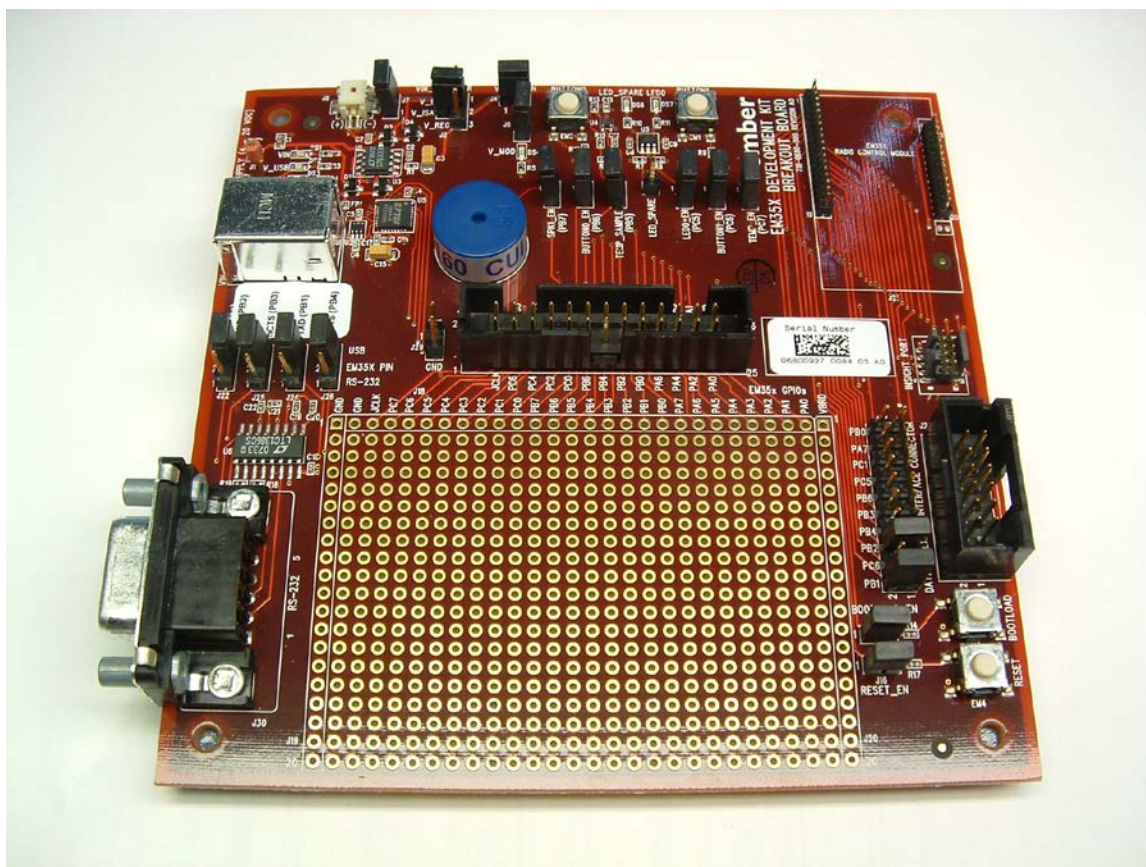
- Breakout Board
- EM35x Module
- InSight Adapter (ISA3)

The EM35x Series Development Kit also includes the following components:

- US-to-Multinational AC Plug Power Adapter Kit
- Power-Over-Ethernet (PoE) Switch
- USB Power Adapters
- Miscellaneous Cables (USB, DEI, InSight Port, and RF Coax)

3.2.1 EM35x Breakout Board

Figure 3-2. EM35x Breakout Board



The Breakout Board (Figure 3-2) has the following components:

- External power supply connectors
- One DB-9 serial port connector for RS-232 serial communication
- One header with TTL-compliant UART signals for SPI serial communication

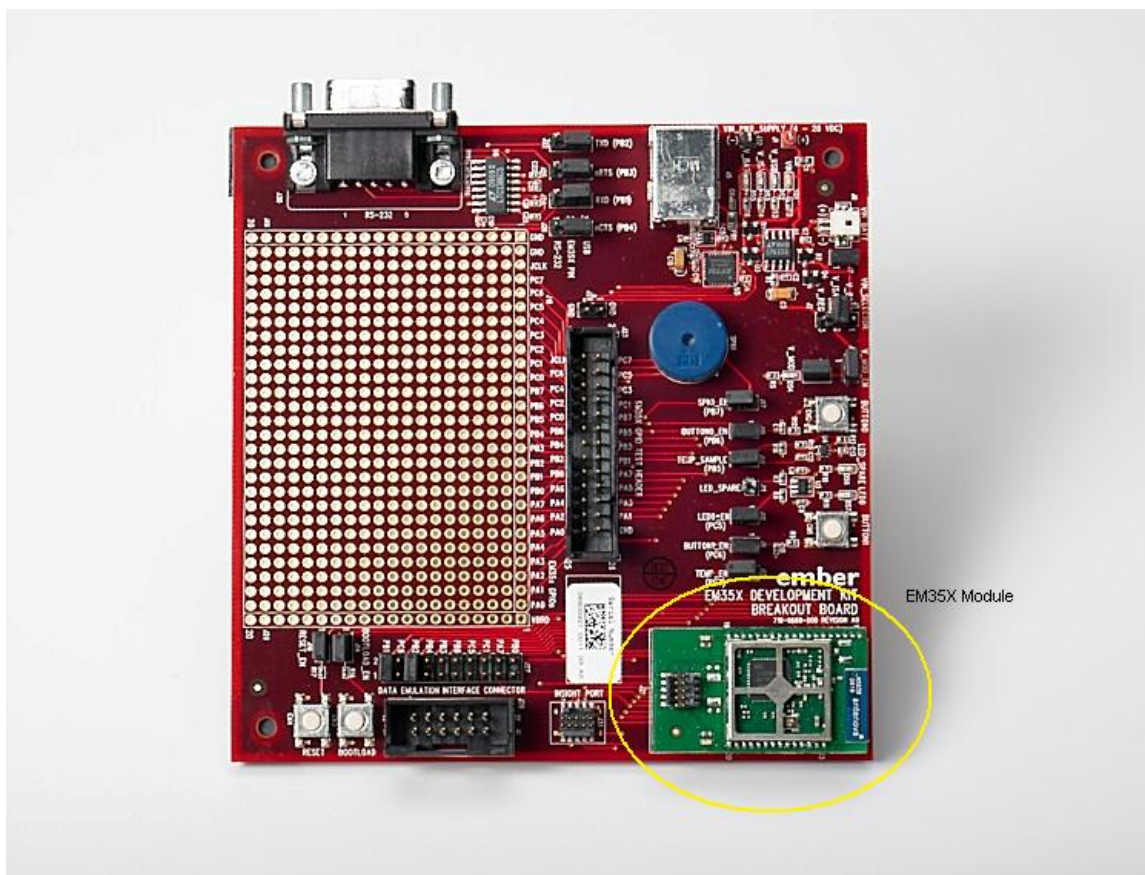
- A buzzer, two buttons, two LEDs, and a temperature sensor for application development purposes
- Hardware reset buttons for the EM35x module
- Prototype or breadboarding area (28 x 20, 0.1" pitch array) for application-specific hardware development
- One InSight data emulation interface connector

For detailed information about the Breakout Board, see document 120-2009-000, the *EM35x Breakout Board Technical Specification*.

3.2.2 EM35x Module

The EM35x Series Development Kit Module pictured in Figure 3-3 is used together with the Development Kit Breakout Board to prototype customer hardware, and to develop and debug application software. Its low-power design represents a good starting point for your own product design.

Figure 3-3. EM35x Breakout Board with EM35x Module installed



The EM35x Module includes these components:

- The Ember EM35x SoC (IEEE 802.15.4-compliant, 2.4 GHz radio transceiver with ARM[®] Cortex[™]-M3 microcontroller).
- All off-chip components required for optimum SoC performance
- Two LEDs
- InSight Port connector

For detailed information about the EM35x Module supplied with your kit, see document 120-2011-000, the *EM35x Module Technical Specification*.

Once you move away from the EM35x Module and toward application-specific hardware, refer to the extensive Ember reference design library at www.silabs.com/zigbee-support. Each reference design provides a schematic, Bill of Materials (BOM), characterization data, and layout files. They are designed and delivered in a manner that reduces both time to market and hardware implementation risk. For assistance in locating the best design for your needs, contact support at www.silabs.com/zigbee-support.

3.2.3 InSight Adapter (ISA3)

InSight Adapter (ISA3) provides an efficient and configurable Debug Interface to the Development Kit Breakout Board for processing emulation and debug commands. It also provides an interface to InSight Desktop for monitoring and managing network data.

The ISA3 has the following components:

- Debug Port interface to the Breakout Board's Extended Debug Interface Connector
- InSight Port interface to the radio communication module, providing programming and debugging services
- TCP/IP 10/ 100 Ethernet interface with Power-over-Ethernet functionality
- USB Interface

3.3 Acceptable Power Sources for Normal Operation

Table 3-1 lists all of the components and the acceptable combinations of power sources that yield normal operation. Potential power sources include the following:

- Power-Over-Ethernet (PoE) Switch
- AAA battery pack (3VDC)
- USB cable
 - Connected to PC
 - Connected to USB Power Supply with Adapters
- Power over Insight Port on ISA (the target power select switch on the front panel must be set to *Int (Internal)*).
- From RCM dedicated power
- External DC adapter (not supplied with the Development Kit)

Table 3-1. Safe combination of operating power

| | PoE | External DC | AAA Battery Pack | ISA3 InSight Port | USB | Breakout Board |
|------------------------|-----|----------------|------------------|-------------------|-----|----------------|
| InSight Adapter (ISA3) | X | N/A | N/A | N/A | X | N/A |
| EM35x Module | N/A | N/A | N/A | X ¹ | N/A | X |
| EM35x Breakout Board | N/A | X ² | X | X ³ | X | N/A |

3.3.1 Power-Over-Ethernet (PoE) Switch

The EM35x Series Development Kit contains a NETGEAR 8-port Power-over-Ethernet (PoE) switch that supplies power to an ISA3 over a standard TIA/ EIA-568 category 5 cable. The ISA3 can, in turn, supply power to an EM35x Breakout Board and the Module that is mounted on it. Thus, you can place Breakout Boards wherever an Ethernet cable connection is available.

The DC operating power for data terminal units is fed through unused pairs 7/ 8 and 4/ 5. For more information about the NETGEAR switch, see its online technical specifications.

The NETGEAR PoE Switch that is supplied in the EM35x Series Development Kit is certified by Silicon Labs. If you wish to use a different PoE switch, consult Customer Support at www.silabs.com/zigbee-support.

3.3.1.1 US-to-Multinational AC Plug Power Adapter Kit

The US-to-Multinational AC Plug Power Adapter Kit (Figure 3-4) is a set of 3 power adapters for use with the NETGEAR PoE Switch. These three interchangeable plugs are provided with various port configurations suitable for various locales: North America, Europe, United Kingdom, and Australia.

¹ Power is sourced from ISA3 to the RCM module using the InSight Port cable connected to the ISA3 with its target power select switch set to *Int* (Internal).

² External DC power between 4V and 20V can be connected to clip leads J1 (+) and J32 (-) on the EM35x Breakout Board.

³ Power is sourced from ISA3 to the EM35x Breakout Board using the InSight Port cable connected to the ISA3 with its target power select switch set to *Int* (Internal).

Figure 3-4. US-to-Multinational AC Plug Power Adapter Kit



3.3.2 USB Power Supply with Adapters

The USB power adapter (Figure 3-5) is a linear regulated wall plug power supply with 5V DC at 1A regulated output. It has a USB type-B connector for connecting power via a USB cable to the USB port of the ISA3 or Breakout Board. Four interchangeable snap-in input plugs are provided with various port configurations suitable for various locales: North America, Europe, United Kingdom, and Australia.

Figure 3-5. USB power supply with interchangeable AC adapters



3.4 Software

The EM35x Series Development Kit contains the following software components:

- Network Stack
- Hardware Abstraction Layer
- Sample Applications
- InSight Desktop

3.4.1 Network Stack

The EmberZNet PRO network stack is an advanced implementation of the ZigBee Pro wireless protocol stack which provides mesh routing algorithms for creating reliable, flexible, and secure networks. The stack's APS layer provides interfaces for delivering messages reliably. The network stack API is documented in documents 120-3009-000, *Advanced Application Programming with the Stack and HAL APIs*, and 120-3009-000, the *EZSP Reference Guide*, as well as 120-3022-000, *EmberZNet API Reference: For the EM35x SoC Platform*, also available in HTML.

The network stack is delivered as a collection of libraries that you can link to your applications. The libraries are available in both release and debug build versions:

- **Debug build** implements features that facilitate application debugging, such as error checking and an interface to InSight Desktop, which provides information about traffic flow, API traces, error conditions, and more.
- **Release build** omits debugging functionality, so it is smaller and runs more efficiently. Use this build in your application after it is fully debugged and ready for product release.

- **Stub library** is a library used for resolving references but which has no functionality. For those libraries which are not needed by the application, the stub library must be linked in order for the stack to build properly.

Table 3-2 lists the EmberZNet PRO stack and associated libraries.

Note: Table 3-2 shows the base library name, but it does not duplicate entries for the debug and stub libraries because they are self explanatory.

Table 3-2. EmberZNet PRO stack and associated libraries

| Library Name | Description |
|----------------------------------|---|
| alarm-library | Alarm library |
| binding-table-library | Binding table library |
| end-device-bind-library | End device bind library |
| security-library-core | Core security library |
| security-library-core-end-device | Core security library for end devices. This library is smaller than the full core security library. |
| security-library-link-keys | Library to handle optional link keys |
| zigbee-pro-stack | Core ZigBee Pro stack functionality |

3.4.2 Hardware Abstraction Layer

The hardware abstraction layer (HAL) acts as a conduit between the network stack and the node processor and radio. Separating network stack functionality from the specific hardware implementation enables easy portability. HAL code is provided as a library that you can alter in order to customize, extend, or reduce device functionality across various hardware platforms. The HAL API is documented in document 120-3022-000, the *EmberZNet API Reference: For the EM35x SoC Platform*.

3.4.3 Sample Applications

The EM35x Series Development Kit contains sample applications. These demonstrate aspects of the network stack that show the breadth of stack functionality. Silicon Labs provides an IAR project and workspace file for each application. Table 3-3 lists the sample applications that are in the current distribution. All applications are in the `app` directory.

Table 3-3. Development Kit Sample Applications

| Application name | Directory | Description |
|-----------------------------------|----------------------------|--|
| Smart Energy / Home Automation | ha | An Application Framework that can be set up to implement ZigBee Smart Energy devices or ZigBee Home Automation devices. This includes an implementation of the ZigBee Cluster Library that allows building of any of the SE or HA devices. |
| Nodetest | nodetest | A low-level test program meant for functional testing of RF modules. |
| Sensor & Sink | sensor | An example of a complete application that implements a distributed sensor network with one or more data collection points (called "sensors") and one or more data storage points (called "sinks"). |
| ZigBee Device Object (ZDO) Sample | zdo | An example of how to send ZDO messages using the ZDO library. |
| Manufacturing Library Sample | mfglib | An example of how to use the manufacturing library. |
| Standalone Bootloader Demo | standalone-bootloader-demo | An example of how to use the bootloader library utilities. |
| Application Bootloader Demo | app-bootloader-demo | An example of how to integrate the application bootloader utility library into an application. |

3.4.4 InSight Desktop

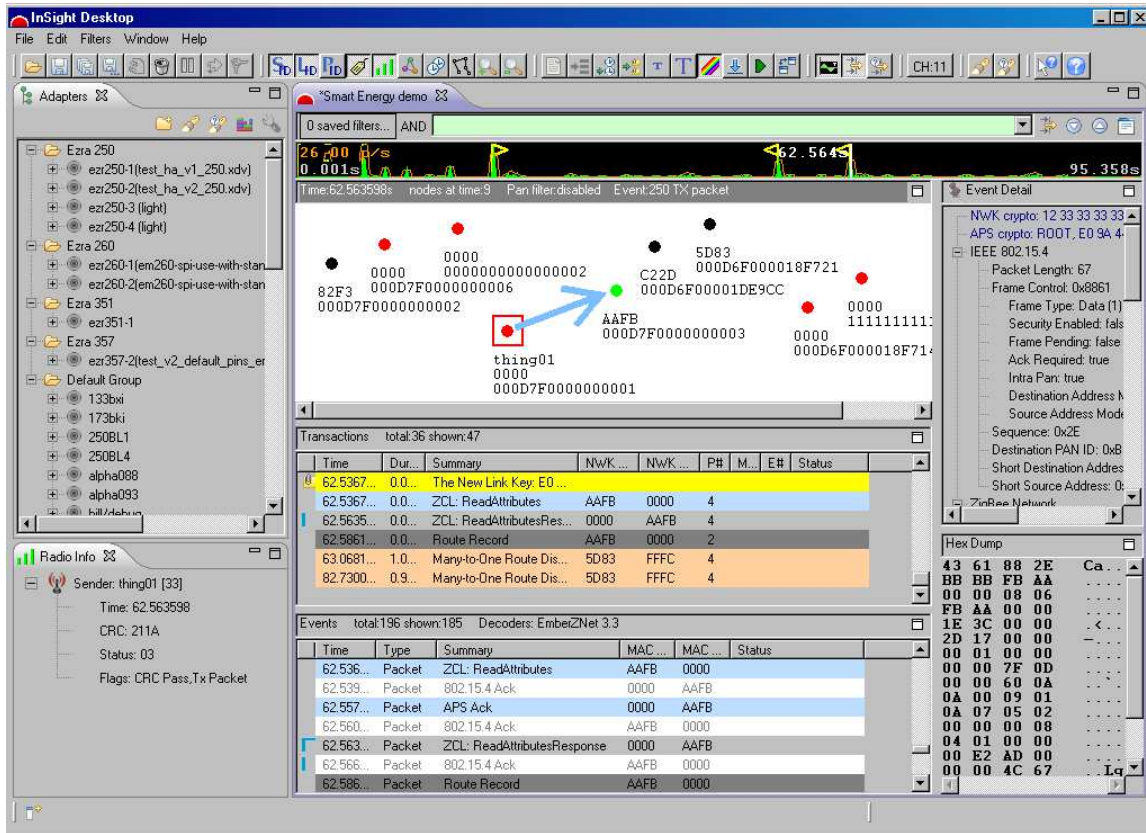
InSight Desktop (ISD) is a graphical tool that manages the Development Kit hardware and displays network and node activity in real time (see Figure 4-1). It provides a rich and flexible interface to Ember-embedded networks, which helps you develop and debug new network applications.

InSight Desktop includes these features:

- An Integrated Development Environment (IDE) with multiple editor panes that provide tiered views of network activity, letting you drill down from a high-level map of node interactions to the details of each packet.
- Customizable filters that let you specify exactly which network activities to display.
- Log files that save captured data, so you can step through transactions and events for detailed analysis.
- A file browser that lets you easily upload new applications to any connected node.

An Adapters view shown in Figure 3-6 allows you to interact with the ISA3s and RCM to download new firmware, reset, and manage each of the devices.

Figure 3-6. InSight Desktop



For detailed information about InSight Desktop, refer to document 120-4005-000, the *InSight Desktop User's Guide*, and InSight Desktop's on-line HTML help.

4 Setting Up Hardware Components

4.1 Overview

This chapter contains the following sections:

- ETRX3 Radio Communications Module (RCM)
- Hardware Connections
- Connecting the Breakout Board and RCM
- Breakout Board Power Configurations
- Breakout Board Serial Configurations
- Common Hardware Configurations
- Connecting the RF Cable to the RCM

4.2 ETRX3 Radio Communications Module (RCM)

The EM35x Series Development Kit contains various types of ETRX3 Radio Communications Modules (designed by Silicon Labs' partner, Telegesis). These modules contain either the EM357 or EM351 IC and are configured to use either the ceramic antenna or the on-board RF connector (U.FL). Some module variants also include a power amplifier. These configuration options are noted in the Module Product Label, as shown the example label in Figure 4-1. The top line contains the Silicon Labs Part Number, while the bottom line contains the Module Serial Number. The Module Serial Number is also listed in the Hardware Identification List attached to your *Quick Start Guide*. You can determine the EUI-64 of each module based on this list.

Figure 4-1. Module Product Serial Number Label



The modules shipped already installed on Breakout Boards are module variant EM357-MOD-ANT-T. All other module variants are contained in the Module Variety Pack. Refer to Table 4-1 for configuration comparisons of the modules included in your development kit. There are three additional EM351 module variants not included in the development kit that are available for purchase. Contact your sales representative or distributor for more details on these module variants.

Table 4-1. Module Product Variant Matrix

| Silicon Labs Part Number | Telegesis Part Number | Silicon Labs Product Number | IC | Antenna or Connector | PA or non-PA | Qty Included in Kit |
|--------------------------|-----------------------|-----------------------------|-------|----------------------|--------------|---------------------|
| EM357-MOD-ANT-T | ETRX357+CB | 0720 | EM357 | Antenna | Non-PA | 3 |
| EM357-MOD-RF-T | ETRX357-HR+CB | 0721 | EM357 | Connector | Non-PA | 1 |
| EM357-MOD-LR-RF-T | ETRX357-LRS-HR+CB | 0722 | EM357 | Connector | PA | 1 |
| EM357-MOD-LR-AN-T | ETRX357-LRS+CB | 0723 | EM357 | Antenna | PA | 2 |
| EM351-MOD-ANT-T | ETRX351+CB | 0724 | EM351 | Antenna | Non-PA | 2 |
| EM351-MOD-RF-T | ETRX351-HR+CB | 0725 | EM351 | Connector | Non-PA | 0 |
| EM351-MOD-LR-RF-T | ETRX351-LRS-HR+CB | 0726 | EM351 | Connector | PA | 0 |
| EM351-MOD-LR-AN-T | ETRX351-LRS+CB | 0727 | EM351 | Antenna | PA | 0 |

4.3 Hardware Connections

To avoid communication problems, verify that each radio communication module is firmly seated in its Breakout Board connector, and its InSight port cable is properly seated.

4.4 Connecting the Breakout Board and RCM

Refer to document 120-4031-000, *Quick Start Guide*, included in your development kit for detailed step-by-step instructions for setting up your hardware.

Two hardware modules attach to the EM35x Breakout Board:

- Radio Communication Module (RCM)
- InSight Adapter

Caution: Observe electrostatic discharge (ESD) precautions when removing, handling, or replacing RF communication modules.

To attach the radio communication module:

Align the radio communication module to its footprint outline on the Breakout Board, and then press it into place. Make sure that the RCM sits firmly in its mating connector.

To remove the radio communication module:

- Carefully pull the RCM away from the Breakout Board.

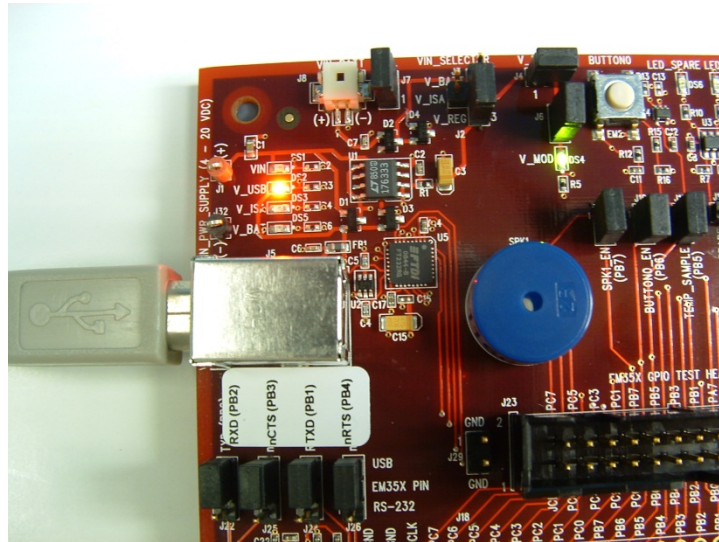
To attach the InSight Adapter:

- 1 Plug the InSight Port cable into the InSight Adapter.
- 2 Plug one end of the InSight Port cable into the 10 pin InSight Port (J31) on the Breakout Board, and the other end into the ISA. If desired, the InSight Port cable may be connected directly to the RCM instead of the Breakout Board, but the Breakout Board connector allows for straight cable paths and more convenient swapping of modules.
- 3 Verify that the InSight Adapter's Target Power Select switch is set to *Int* (Internal).

To remove the InSight Adapter:

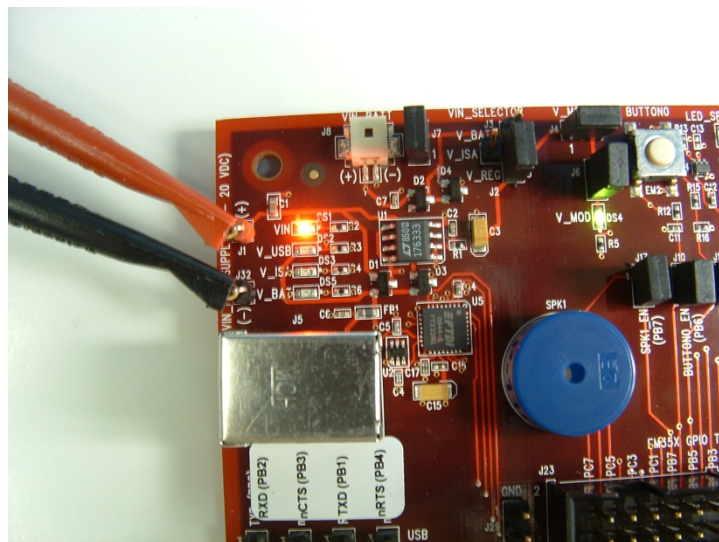
- 1 Unplug the InSight Port cable from the Breakout Board (or radio communication module).
- 2 Unplug the InSight Port cable from the InSight Adapter.

Figure 4-3. Breakout Board Power Supplied by USB



- Breakout Board Power Supplied by DC Jumpers** (Figure 4-4): The Breakout Board may also be powered by an external source that provides 4-20 volts DC. The power supply should be connected to jumpers J1 (+ supply) and J32 (ground). The power supply jumper on the Breakout Board should be in the lower vertical position, connecting V_REG to the center pin. The VIN LED will illuminate when power is applied. When powering the Breakout Board in this way, ensure the power switch on the InSight Adapter is in the EXT (External) position.

Figure 4-4. Breakout Board Power Supplied by DC Jumpers



- Breakout Board Power Supplied by Battery Connector** (Figure 4-5): Finally, the Breakout Board may also be powered via the battery connector, using the supplied battery packs and 2x AAA batteries. The power supply jumper should be in the upper vertical position, connecting V_BATT to the center pin. The V_BAT LED will illuminate when power is applied. When powering the Breakout Board in this way, ensure the power switch on the InSight Adapter is in the EXT (External) position.

