



# ZigBit™



## ZigBit™ Development Kit 1.3 User's Guide

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# 1. Introduction

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## Intended Audience and Purpose

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This document is intended for engineers and software developers working with the ZigBit™ Development Kit (ZDK). The Kit is used to evaluate the performance and features of ZigBit modules and the eZeeNet software, and to implement custom applications on top of eZeeNet API or with AT-commands (SerialNet).

## Safety and Precautions

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The product contains electronics, which are electrically sensitive. Please take necessary precautions when using such devices. MeshNetics does its best to protect the product components from electrostatic discharge phenomena, but we encourage our users to follow common guidelines to avoid electrostatics by using proper grounding etc.

The product complies with the FCC (Part 15), IC and ETSI (CE) rules applicable to the devices radiating in the uncontrolled environment. Please find out if the product complies with your local regulations.

Any modifications of the hardware, its components or improper use of the product can cause an uncontrolled violation of the in-band or out-band radiation levels. It can result in progressing violation of emission level limits, thus causing harmful interference.

### Precautions

The product radiates power in the microwave band. Although the levels are considered to be low (less than 2 mW), it is reasonable to protect the operating personnel from possible harmful impact of the electromagnetic field. When the parts of the product are turned on, an operator should avoid touching the PCB antenna and the board itself. The recommended distance between an operator and antenna should be more than 20 centimeters.

AC/DC adapters which can be used with the product contain high voltage circuits. General precautions should be taken against electric shock before the product hardware is mains powered.

The ZigBit Development Kit contains fragile components. Please handle with care.

## Related documents

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- [1] ZigBit™ OEM Modules. Product Datasheet. MeshNetics Doc. M-251~01
- [2] eZeeNet™ IEEE802.15.4/ZigBee Software. Product Datasheet. MeshNetics Doc. M-251~02
- [3] eZeeNet™ Software 1.7. SerialNet. Reference Manual. AT-Command Set. MeshNetics Doc. P-EZN-452~01
- [4] eZeeNet™ Software 1.7. eZeeNet™ API. Reference Manual. MeshNetics Doc. P-EZN-452~02
- [5] eZeeNet™ Software 1.7. WSN Demo Messaging Protocol Description. MeshNetics Doc. P-EZN-452~03.
- [6] ZigBit™ OEM Module. Application Note. ZigBit Power Consumption Testing. MeshNetics Doc. AN-481~01

- [7] ZigBit™ OEM Module. Application Note. Serial Bootloader.  
MeshNetics Doc. AN-481~04
- [8] ZigBit™ OEM Module. Application Note. Using ZigBit Module with Analog Sensors.  
MeshNetics Doc. AN-481~06
- [9] eZeeNet™ Software 1.7. Range Measurement Application. User's Manual.  
MeshNetics Doc. P-EZN-451
- [10] ZigBee Document 053474r14, November 03, 2006
- [11] Serial asynchronous automatic dialing and control. ITU-T Recommendation V.250,  
05/99
- [12] IEEE Std 802.15.4-2003 IEEE Standard for Information technology – Part 15.4  
Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications  
for Low-Rate Wireless Personal Area Networks (LR-WPANs)
- [13] TSL2550 Ambient Light Sensor With Smbus Interface. TAOS Datasheet  
TAOS029E. February 2006  
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- [14] LM73 2.7V, SOT-23, 11-to-14 Bit Digital Temperature Sensor with 2-Wire Interface.  
National Semiconductor Corporation Datasheet DS201478. July 2006  
<http://www.national.com/pf/LM/LM73.html#Datasheet>
- [15] CP2102, Single-Chip USB to UART Bridge, Rev. 1.1 9/05. [www.silabs.com](http://www.silabs.com)
- [16] AVR Studio. User Guide. Available in HTML Help with the product.
- [17] JTAGICE mkII Quick Start Guide.  
[http://www.atmel.com/dyn/resources/prod\\_documents/doc2562.pdf](http://www.atmel.com/dyn/resources/prod_documents/doc2562.pdf)
- [18] avr-libc Reference Manual 1.4.3
- [19] WinAVR User Manual – 20060125/ By Eric B. Weddington
- [20] Using the GNU Compiler Collection/ By Richard M. Stallman and the GCC  
Developer Community

## Abbreviations and Acronyms

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API	Application Programming Interface
BOM	Bill of Materials
Channel Mask	Channel mask is a number that defines the set of working channels.
Coordinator	Within ZigBee networks, the ZigBee coordinator is responsible for starting the network and for choosing certain key network parameters. The network may be extended through the use of ZigBee router.
DIP	Dual In-line Package
EEPROM	Electrically Erasable Programmable Read-Only Memory
End-device	In ZigBee networks, the ZigBee end-device provides sensor data sent to a router. End-device is often subject to power management restrictions, so it may be in sleeping mode most of the time.

API	Application Programming Interface
ESD	Electrostatic Discharge
GUI	Graphical User Interface
HAL	Hardware Abstraction Layer
IDE	Integrated Development Environment
JTAG	Digital interface for debugging of embedded devices, also known as IEEE 1149.1 standard interface
LED	Light Emitting Diode
LQI	Link Quality Indicator
MAC	Medium Access Control layer
MCU	Microcontroller Unit. In this document, it also means the processor, which is the core of ZigBit module
MIPS	Million Instructions per Second
NWK	Network layer
PAN ID	Personal Area Network Identifier. In ZigBee, it is 16-bit number which must be unique for each one of multiple networks working on the same frequency channel
PCB	Printed Circuit Board
PHY	Physical layer
RF	Radio Frequency
Router	In ZigBee networks, routers transfer data and control messages through the network using a hierarchical routing strategy. The ZigBee coordinator is also responsible for routing.
RS-232	Serial binary data interconnection interface, which is commonly used in computer serial ports
RSSI	Received Signal Strength Indicator
SMA	Surface Mount Assembly
TOS	Open-source operating system TinyOS
UID	Unique Identifier
USB	Universal Serial Bus
VCP	Virtual Com Port
WSN	Wireless Sensor Network
ZDK	ZigBit Development Kit
ZigBee	Wireless networking standard targeted at low-power sensor applications [10]
802.15.4	The IEEE 802.15.4-2003 standard applicable to low-rate wireless Personal Area Networks [12]

## 2. Development Kit Overview

ZigBit™ Development Kit (ZDK) is a simple, out-of-the-box solution designed for WSN prototyping and development. It provides MeshBean2 boards containing the ZigBit OEM modules to test the wireless network features and develop customized wireless solutions based on eZeeNet Software.

ZigBit Development Kit includes:

1. MeshBean2 board (1 piece) with integrated PCB antenna
2. MeshBean2 board (1 piece) with external antenna connector
3. MeshBean2 board (1 piece) with dual chip antenna integrated into ZigBit module
4. USB 2.0 A/mini-B cable (3 pieces)
5. External interface cable – a ribbon cable with single-side IDC-20 pin socket connector (2 pieces)
6. Swivel antenna (1/2 wave antenna)
7. Software & Documentation Distribution CD (1 piece).

See the ZigBit Development Kit in Figure 1.



**Figure 1. The Development Kit delivery set**

The ZigBit Development Kit is offered with **2 support packages** (see Table 1):

- **ZigBit Development Kit Lite** offers access to standard evaluation and development tools and comes with 45 days of complimentary support. This option is good for product demonstration, platform evaluation and quick application prototyping.
- **ZigBit Development Kit Complete** comes with 1 year of professional support which provides users with continuous software updates, dedicated design-in support, and RF design assistance. It's ideal for customers engaged in a full cycle of developing, prototyping, and launching innovative products made possible by MeshNetics ZigBit wireless platform.

**Table 1. The ZDK support packages**

ZDK Edition	Lite	Complete
Part Number	ZDK-A1281-LTE	ZDK-A1281-CPT
Support Duration	45 days	1 year
Hardware design support	+	+
RF design support	+	+
Software development support	+	+
Early software release access	-	+
Access to Gerber Files	-	+
Additional sample applications	-	+
Response time	72 h, workdays	72 h, workdays
Support channel	E-mail	E-mail

## 2.1. Hardware General Specifications

MeshBean2 board is intended to evaluate the operation performance of ZigBit OEM module. ZigBit module with the embedded eZeeNet Software provides wireless connectivity for MeshBean2 board being a node in a ZigBee network.

The MeshBean2 board can be configured to operate as a network coordinator, a router or an end-device, by means of setting DIP-switches (see Section 2.3.2) and/or sending AT-commands. The node's role is defined by the embedded applications.

The boards are delivered with ZigBit preprogrammed with Serial Bootloader and SerialNet application firmware. For full list of demo applications see Section 2.4.

Gerber files are available with Complete Support Package only.

The MeshBean2 basic parameters are presented in Table 2.

**Table 2. MeshBean2 Board Specifications**

Parameter	Value
<b>RF</b>	
Compliance	2.4 GHz IEEE 802.15.4-2003 [12]
Operating Band	2400–2483.5 MHz
TX Output Power	from -17 dBm to +3 dBm
RF Transceiver	AT86RF230
Antenna versions	2.4 GHz (PCB on-board antenna, external 50 Ohm unbalanced antenna or dual chip antenna)
<b>MCU</b>	

Parameter	Value
Microcontroller	ATmega1281V
RAM	8K Bytes
Flash Memory	128K Bytes
EEPROM	4K Bytes
Performance	Up to 4 MIPS throughput at 4 MHz Clock
<b>Power</b>	
Power Supply	Dual AA type Battery, automatically switched to USB or AC/DC adapter
Over-Voltage Protection	Yes
Reverse Polarity Protection	Yes
Operating Voltage Range	1.8...3.6 V
Voltage Supervisor	Yes
<b>Miscellaneous</b>	
Sensors	Digital: Ambient Light/ Ambient Air Temperature
LED Indicators	3 programmable color status LEDs external power supply status LED
Switches	3 DIP switches
Buttons	2 programmable buttons
Size	60 x 63 x 24 mm
Operating Temperature Range	-40°C to 85°C. Minor degradation of clock stability may occur beyond the -20°C to +70°C range.

## 2.2. MeshBean2 Featured Components

### 2.2.1. ZigBit Module

ZigBit module is an ultra-compact, low-power, high sensitivity 2.4GHz 802.15.4/ZigBee OEM module from MeshNetics. ZigBit module is based on Atmel's Z-Link 2.4GHz platform. It includes ATmega1281V Microcontroller and AT86RF230 RF Transceiver.

In ZDK, the ZigBit module is delivered installed on MeshBean2 board.

Two different versions of ZigBit modules are available [1]: a version with balanced RF port for applications where the benefits of PCB or external antenna can be utilized, and a version with dual chip antenna satisfying the needs of size-sensitive applications.

Detailed specifications of the ZigBit module, including the module interfaces, voltage levels, power consumption, are available in the ZigBit datasheet [1].

## 2.2.2. Sensors

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The board incorporates light sensor TSL2550T from TAOS and temperature sensor LM73CIMK from National Semiconductors. Both sensors are connected in parallel to the I<sup>2</sup>C bus. For more information on the sensors see their datasheets [13], [14] available from the corresponding manufacturers' websites.

**NOTE:**

In addition to the built-in, onboard sensors, external sensors selected by developer can be used. An external sensor can be connected to the terminals of External interface cable leading to the onboard Expansion slot. See the corresponding pinout in Table 2. As an example, connection of an external sensor is illustrated in Application Note [7].

## 2.2.3. USB to UART Bridge

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CP2102, the USB to UART Bridge controller from Silicon Labs [15], is installed on the board. It provides seamless USB interface to any RS-232 legacy device. If the controller's driver has been installed on PC during the deployment of the whole Development Kit (see Section 3.3) the onboard USB port is visible on the PC as generic COM port with a particular number.

## 2.2.4. Silicon Serial for UID storage

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UID (Unique Identifier) is HEX value, 8 bytes long. UID is used for setting unique MAC address of the node.

UID is hardware defined value. It is programmed into a chip (Silicon Serial Number DS2411R+ by Maxim/Dallas) at the factory.

UID is unique, and cannot be overwritten. In order to ensure the presence of UID on the board it is required to execute Hardware Test application (see section 3.6 for details).

## 2.3. MeshBean2 Board Design

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The MeshBean2 board contains the ZigBit module, which operates as ZigBee/802.15.4 transceiver. It also includes sensors, buttons, DIP-switches, and a set of interfaces.

The board provides the following interfaces:

- USB 2.0 port
- Light and temperature sensors
- 2 push buttons controlling the software
- Reset button
- 3 DIP switches
- 3 software-controlled LEDs
- Symmetrical dipole PCB antenna (only for MeshBean2 with PCB antenna)
- SMA connector (only for MeshBean2 with external antenna)
- JTAG connector for software upload and debugging
- Power connector (3 V) to use an AC/DC adapter (not supplied with ZDK)
- 20-pin Expansion slot containing external ZigBit's interfaces (see Table 3), including:
  - Serial port interface (RS-232)
  - USART
  - Buffered I<sup>2</sup>C interface with ESD protection and voltage level translation
  - ADC/GPIO
- Battery compartment for AA-size batteries
- 3 configuration jumpers
- 3 clamps for power consumption measurements.

Also, the board contains an internal voltage regulator to supply most of the components with 3.6 V. This is needed if ZigBit's MCU is to be run at 8 MHz<sup>1</sup>.

**NOTE:**

Normally ZigBit module is powered directly by the batteries, USB or AC/DC adapter (via protection circuitry); however, Jumper J2 (see Table 6) can switch ZigBit to 3.6 V supply.

See Figure 2 for the layout of MeshBean2 version with integrated PCB antenna. See also Figure 3 for the board's functional diagram. Note the upward sidebar for external antenna case.

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<sup>1</sup> 8MHz requires changes in the eZeeNet Software that normally runs at 4 MHz in order to extend the voltage range and decrease power consumption.

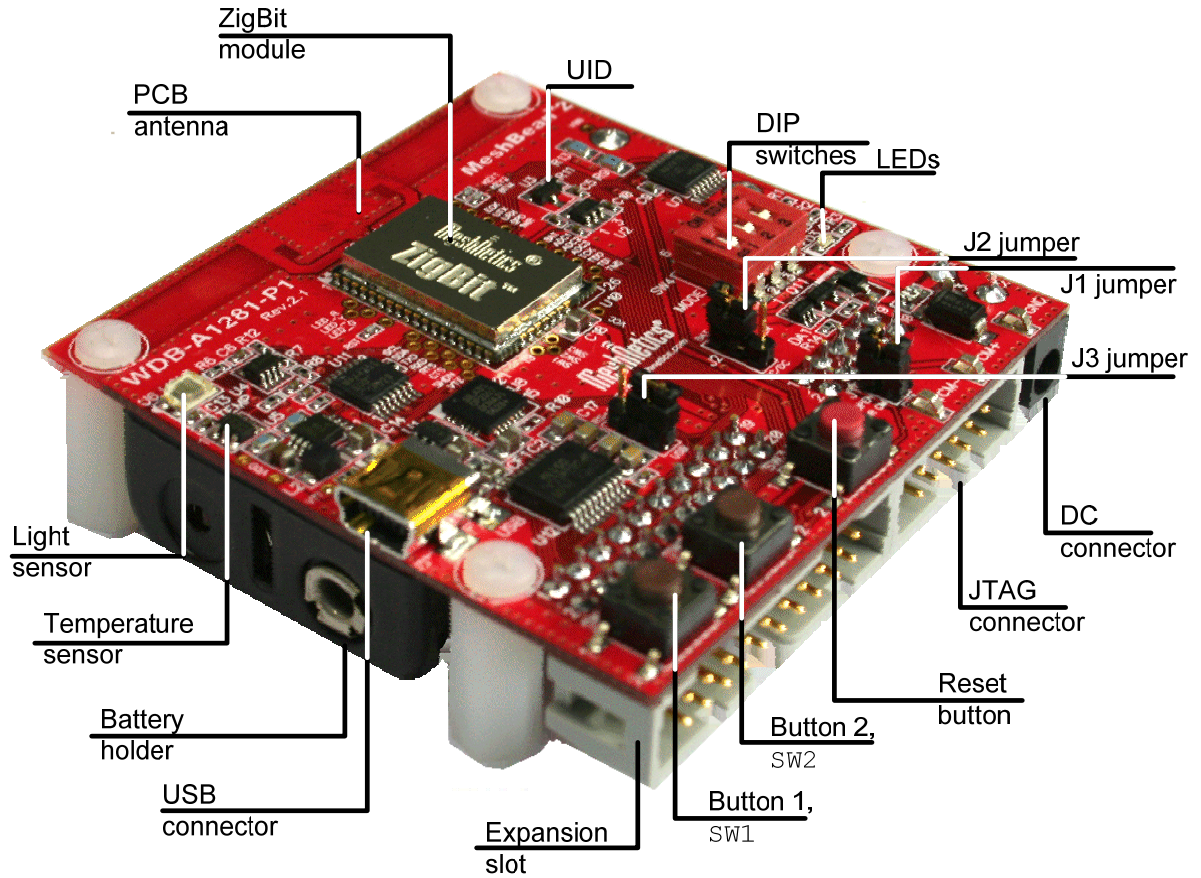


Figure 2. MeshBean2 with integrated PCB antenna and UID Silicon Serial

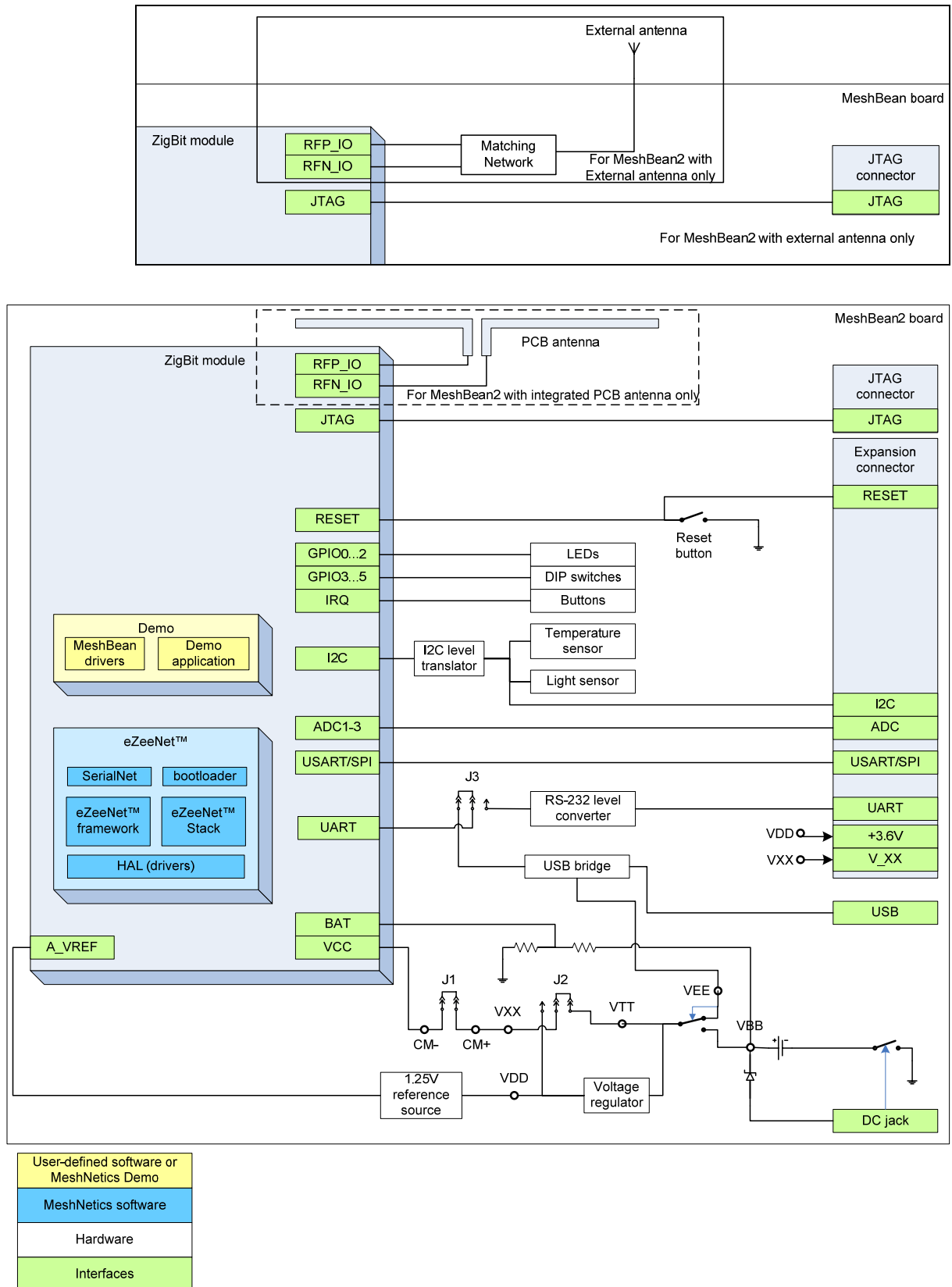


Figure 3. MeshBean2 functional diagram

### 2.3.1. Connectors and Jumpers

The board connector pinouts and jumper settings are presented in Table 3 through Table 8.

#### IMPORTANT NOTE:

All manipulations with connectors or jumpers should be done when the board is not powered!

**Table 3. Expansion slot pinout**

Pin	Name	I/O	Description
1	UART_RTS	Input	Request to Send Pin. RS-232 level.
2	UART_TXD	Input	Transmit Data Pin (meaning that the host device will transmit data to this line). RS-232 level.
3	UART_CTS	Output	Clear To Send signal from the module. Active low. RS-232 level.
4	UART_RXD	Output	Receive Data Pin (meaning that the host device will receive data from this line). RS-232 level.
5	GND		Digital/analog ground
6	GND		Digital/analog ground
7	I2C_CLK	Input	I <sup>2</sup> C clock. It is connected to the I2C_CLK pin of the module via low-voltage level translators. For details, refer to ZigBit datasheet [1].
8	I2C_DATA	Bidirectional	I <sup>2</sup> C data. It is connected to the I2C_DATA pin of the module via low-voltage level translators. For details, refer to ZigBit datasheet [1].
9	+3.6V	Output	Output of internal voltage regulator. Normally, the voltage is 3.6 V.
10	V_XX	Output	ZigBit supply voltage
11	RESET	Input	Reset Pin. Active low. This pin is connected in parallel to the RESET button on the board.
12	USART_TXD	Output	This is Transmit Data Pin for USART0 interface of the ZigBit module. It is connected directly to the USART0_TXD pin of the module. Digital logic level. For details, refer to ZigBit datasheet [1].
13	USART_RXD	Input	This is Receive Data Pin for USART0 interface of the ZigBit module. It is connected directly to the USART0_RXD pin of the module. Digital logic level. For details, refer to ZigBit datasheet [1].

Pin	Name	I/O	Description
14	USART_CLK	Input	This is Clock Data Pin for USART0 interface of the ZigBit module. It is connected directly to the USART0_EXTCLK pin of the module. Digital logic level. For details, refer to ZigBit datasheet [1].
15	GND		Digital/analog ground
16	ADC_INPUT1	Input	ADC input. This pin is connected directly to the ADC_INPUT_1 pin of the module. For details, refer to ZigBit datasheet [1].
17	ADC_INPUT2	Input	ADC input. This pin is connected directly to the ADC_INPUT_2 pin of the module. For details, refer to ZigBit datasheet [1].
18	ADC_INPUT3	Input	ADC input. This pin is connected directly to the ADC_INPUT_3 pin of the module. For details, refer to ZigBit datasheet [1].
19	GND		Digital/analog ground
20	GND		Digital/analog ground

**GENERAL NOTES:**

Pins 12, 13, 14, 16, 17, 18 are not buffered and driven by the MCU pins directly. Thus this interface should be used with precautions at the low supply voltages to avoid damaging the module.

Pins 7 and 8 are connected via voltage level translators with ESD protection. Thus these pins can be used easily to connect extra I<sup>2</sup>C sensors without extra logic.

Voltage on the V<sub>XX</sub> pin does not depend on the state of jumper J1 or ammeter connection between clamps CM+, CM-.

**Table 4. JTAG connector pinout**

Pin	Name	Description
1	JTAG_TCK	Scan clock
2	JTAG_GND	Digital ground
3	JTAG_TDO	Test data output
4	JTAG_VCC	Controller supply voltage
5	JTAG_TMS	Test mode select
6	JTAG_RST	Reset controller; active low
7	N_Cont	Not connected
8	N_Cont	Not connected
9	JTAG_TDI	Test data input
10	JTAG_GND	Digital ground

**NOTE:**

JTAG connector pinout is compatible with ATmega JTAGICE mkII in-circuit emulator connector.

**Table 5. J1 jumper settings: current measurement**

Jumper position	Description
J1 is mounted	This position is used for normal operation.
J1 is not mounted	In this position, the ZigBit module is not powered while remaining parts of the board are powered. This position is used to measure current consumption of the ZigBit module (see Section 3.8).

**Table 6. J2 jumper settings: ZigBit power source**

Jumper position	Description
J2 bridges POWER pin and BAT pin	ZigBit is powered by primary source (battery, USB or AC/DC adapter).
J2 bridges POWER pin and DC/DC pin	ZigBit is powered by 3.6 V internal voltage regulator.

**Table 7. J3 jumper settings: Serial/USB selection**

Jumper position	Description
J3 bridges central pin and RS-232 pin	The board will use serial port (available in the Expansion slot) for connection to the host.
J3 bridges central pin and USB pin	The board will use USB for connection to the host.

**IMPORTANT NOTES:**

Any other position of jumpers J2 and J3 or their omission may cause permanent damage of the hardware.

Powering the board without J1 jumper and ammeter connection between clamps CM+ and CM- may cause a permanent damage of the hardware.

When making connection to the PC's serial port through the Expansion slot consider the pinout as indicated below in Table 8.

**Table 8. Serial interface pinout**

Signal	Expansion slot pins	Serial port pins (PC side)
RXD	4: UART_RXD	2
TXD	2: UART_TXD	3
CTS	3: UART_CTS	8
RTS	1: UART_RTS	7
GND	5, 6, 15, 19, 20: GND	5

### 2.3.2. Buttons, Switches and LEDs

The board includes 2 buttons, 3 DIP switches, one Reset button that generates hardware reset signal, 3 software-defined LEDs (green, yellow and red) and one blue LED indicating powering the board from the USB. Any of onboard buttons, DIP-switches and LEDs can be controlled with the application running on the ZigBit.

For instance, the status of any DIP-switch will be ignored when running SerialNet (see Section 5). DIP switches can be tested when running the Hardware Test application (see Section 3.6).

### 2.3.3. External Antenna

Among the MeshBean2 boards delivered with ZDK, one particular board is equipped with SMA connector to attach external antenna. The specifications of external antenna supplied with the Development Kit are presented below in Table 9.

**Table 9. External antenna specifications**

Part Number	Manufacturer & Description	Gain, dBi	Impedance, Ohm	Min. Separation, cm
17010.10	WiMo, swivel antenna (1/2 wave antenna) with SMA connector, frequency range 2.35-2.5 GHz	2.1	50	20

**IMPORTANT NOTE:**

Only the Non-RP SMA Connector antennas can be used for a custom design!

Attach the external antenna through SMA connector before using the board. Match the antenna's female coaxial thread with the connector's male thread.

## 2.4. eZeeNet Software

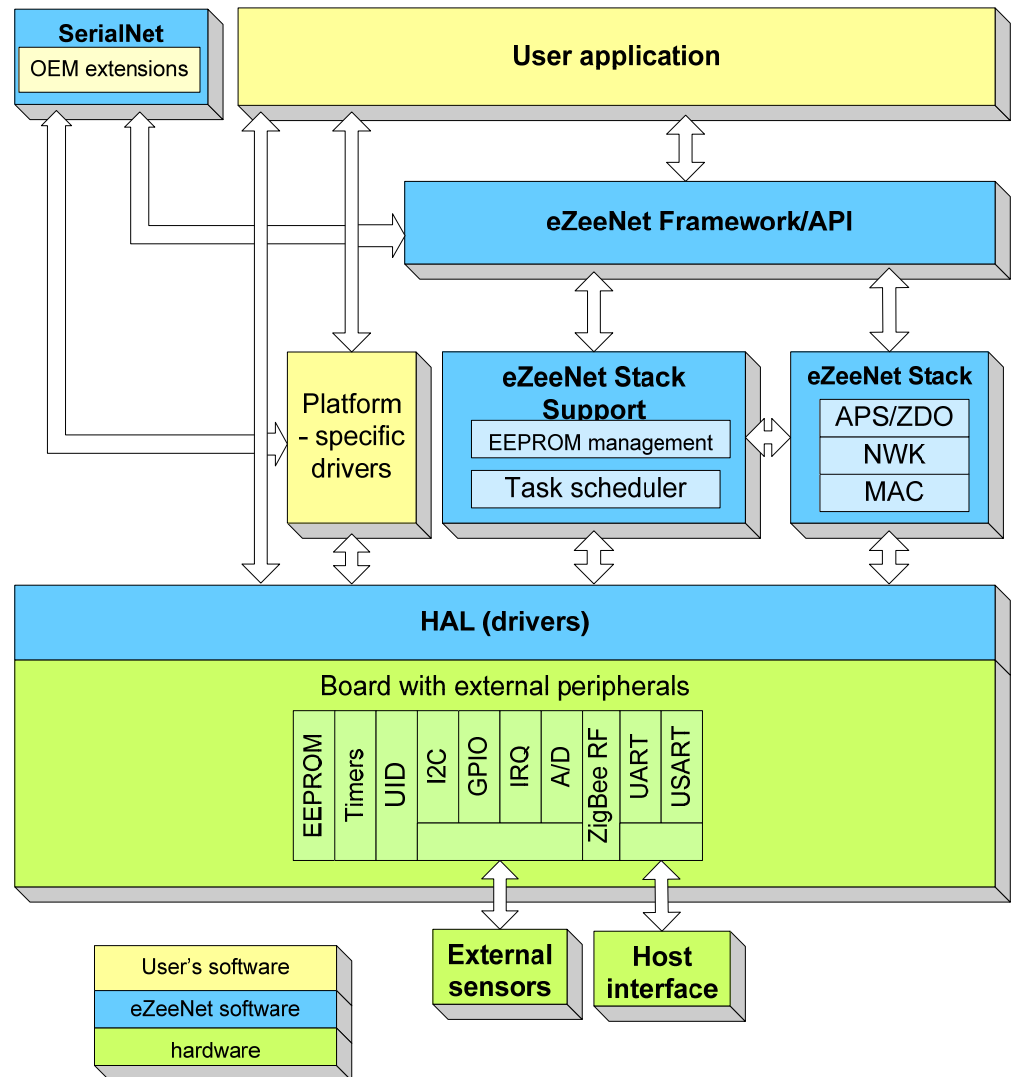
eZeeNet Software from MeshNetics is a robust IEEE802.15.4/ZigBee software that runs on ZigBit modules and organizes a self-healing, self-organizing mesh network. It is specifically tailored for easy-to-use networking in sensing, control, monitoring and data acquisition applications. It provides easy to use networking, with a routing mechanism that optimizes network traffic and reduces power consumption.

eZeeNet Software offers a user-friendly API for network and smart power management, including data exchange, network formation/node join, PAN ID management, channel selection, TX power control etc. The eZeeNet provides a wide range of software interfaces for standard peripherals. The eZeeNet comes with the Framework layer which eases application development and simplifies integration.

ZDK offers opportunity to develop user's custom applications based on the eZeeNet API [4]. API-based demos are provided in source code which can be modified and extended. In the ZigBit Development Kit, using the API makes it possible to develop WSN applications for a variety of networking scenarios. For example, an end-device can be configured to communicate with a router between the periods of sleep thus saving power.

Another configuration of eZeeNet Software, SerialNet, enables a user to implement customized WSN scenarios without developing any WSN application code. In this case WSN nodes are controlled through AT-commands (see Section 5).

The structure of eZeeNet Software is presented in Figure 4. It is detailed in datasheet [2].



**Figure 4. eZeeNet Block Diagram**

The Development Kit includes two kinds of applications (see Appendix A). Evaluation tools are delivered in binary format. Sample applications are available in source code.

The following evaluation tools are delivered:

- SerialNet application
- Hardware Test
- Range Measurement Tool
- WSN Demo with WSN Monitor
- Serial Bootloader utility.

SerialNet is intended to control WSN nodes via serial AT-commands (see Section 5). eZeeNet Software lets AT-commands be interpreted locally or forwarded for execution on remote nodes.

Hardware Test (see Section 3.6) is a simple application which tests major MeshBean2 board components for correct operation.

Range Measurement Tool is an application intended to measure radio performance of ZigBit-based devices and/or to make comparison with platforms of other manufacturers. Usage essential information and guiding instructions are given in [9].

Serial Bootloader is a software utility designed to program an application code into WSN nodes through USB or serial port, without using JTAG. See the description of Serial Bootloader in Section 6.

The following sample applications are delivered (referenced as given in brackets):

- WSN Demo (`WSNDemo`)
- Low Power Networking (`Lowpower`)
- Ping-Pong (`Pingpong`)
- Peer-To-Peer Data Exchange (`Peer2peer`)
- Blink minimal sample application (`Blink`).

The WSN Demo application is a ZDK feature program demonstrating the WSN performance. It is presented in details in Section 4. The source code for `WSNDemo` is available with Complete Support Package only.

The rest of programs are sample implementations triggering common eZeeNet APIs. `Blink` is a minimal application (see Section 7.3). Low Power, Ping-Pong and Peer-To-Peer applications are introduced in Section 7.4.

## 3. Getting Started

### 3.1. Overview

This section describes the system requirements and ZDK deployment. It also provides how-to instructions on handling the boards, testing WSN functionality and performing local hardware tests.

### 3.2. System Requirements

Before employing the Kit, a user should become aware of the minimum system requirements (see Table 10).

**Table 10. System requirements**

Parameter	Value	Note
<b>PC</b>		
CPU	Intel Pentium III or higher, 800 MHz	
RAM	128 MB	
Hard disk free space	50 MB	
JTAG emulator	JTAGICE mkII emulator with cable	Necessary to upload firmware onto the MeshBean2 board through JTAG (see Appendix B).
<b>Software</b>		
Operating system	Windows2000/XP	
USB driver	CP210x USB to UART Bridge VCP Driver	Necessary to connect MeshBean2 to PC via USB port (see Section 3.4)
IDE	AVR Studio 4.12 + Service Pack + WinAVR	Necessary to upload firmware image through JTAG (see Appendix B), and to develop applications using API (see Section 7)
Serial Bootloader utility		Necessary to upload firmware image without using JTAG (see Section 6)
Java machine	Java Runtime Environment (JRE) 5 Update 8, or more recent	Necessary to run the WSN Monitor application (see Section 4.5)

### 3.3. Installing the Development Kit

In order to install the Development Kit open the ZDK Software and Documentation CD on your PC and make sure that ZDK installation wizard is automatically starting. Specify the installation path and follow the upcoming instructions.

As a result the ZDK file structure under the selected path will be generated on the PC, which is described in Appendix A.

During the ZDK deployment the following auxiliary software can be optionally installed:

- USB to UART Bridge VCP driver for Windows platform
- Java Runtime Environment (JRE).

To complete the installation of VCP driver before use of the ZDK do the following:

- connect MeshBean2 board to the USB port. Windows should detect the new hardware. Follow the instructions provided by the driver installation wizard.
- make sure that the driver is installed successfully and the new COM port is present in the device list. Open the Device Manager window shown in Figure 5: Start/Control Panel/System/Hardware/Device Manager.

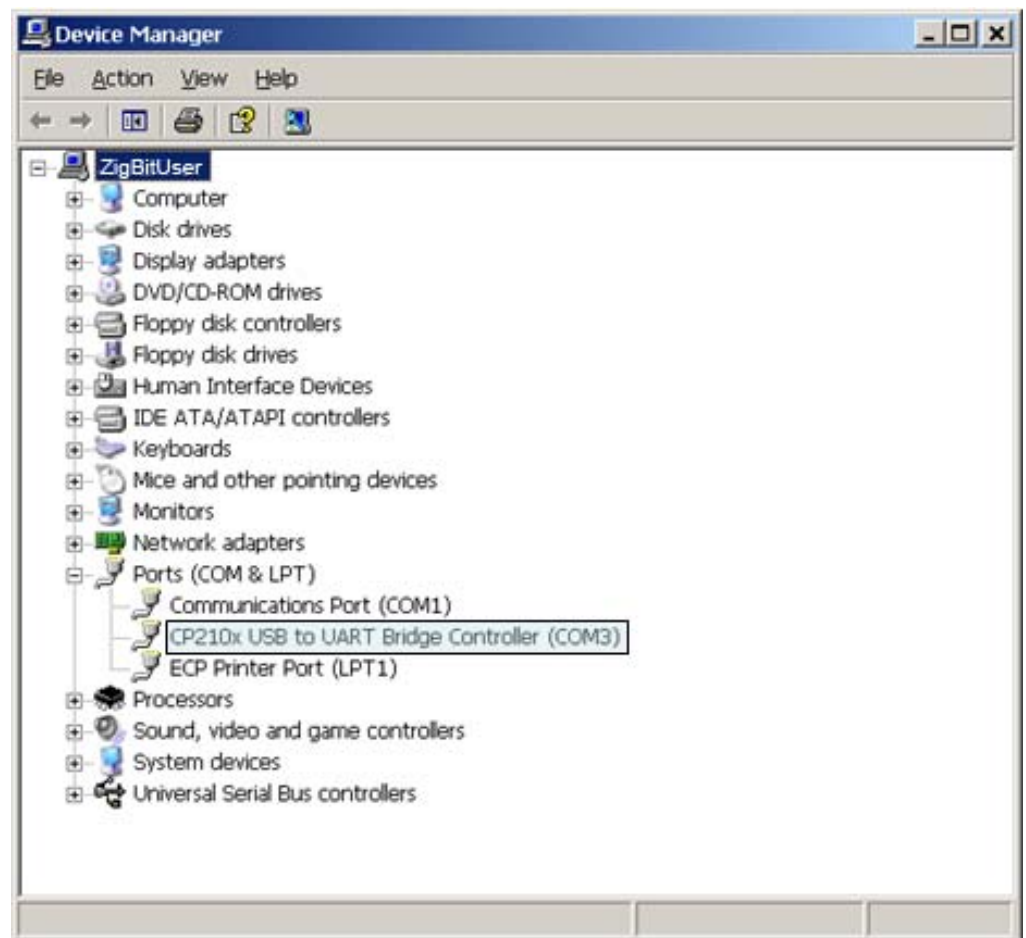


Figure 5. COM port drivers in the Windows Device Manager window

To resolve possible problems see Section 3.4.

**NOTE:**

USB to UART Bridge VCP driver for Windows platform is also available from the manufacturer's site:

[http://www.silabs.com/tgwWebApp/public/web\\_content/products/Microcontrollers/USB/en/mcu\\_vcp.htm](http://www.silabs.com/tgwWebApp/public/web_content/products/Microcontrollers/USB/en/mcu_vcp.htm).

Java Runtime Environment (JRE) is also available from

<http://java.sun.com/javase/downloads/index.jsp>.

There may be other Java instances occasionally installed on your computer before use of ZDK. To avoid confusion, edit `start.bat` file in `./Evaluation Tools/WSNDemo (WSN Monitor)` subdirectory containing the WSN Monitor. Make sure to provide full path to the Java executable file, specify its file name extension (`.exe`) explicitly.

Current version of the AVR Studio [16] with Service Pack can be freely downloaded from the Atmel's website (<http://www.atmel.com>). Simply launch the downloaded installer programs and follow the setup instructions.

The WinAVR suite of development tools can be downloaded from <http://sourceforge.net/projects/winavr>. To install WinAVR follow the setup instructions.

## 3.4. Connecting the Board to PC

The board can be connected to host PC via USB port, using USB 2.0 A/mini-B cable supplied within the Kit. USB is typical connection. Furthermore, it provides the convenient possibility to link multiple boards to a single PC. Besides, no battery is required once a board is powered via USB.

Because wireless applications usually employ host connection through COM port, linking the onboard USB to UART Bridge controller to PC requires installation of the USB to UART Bridge VCP driver (see details in Section 3.3, Section 2.2.3). As a result, generic COM port can be used to access a board via USB.

**IMPORTANT NOTES:**

When USB connection is used, the COM port number would be changed by the Windows operating system if the board has been reconnected. To avoid confusion use Windows Control Panel to check on the actual port number.

Under some circumstances, the boards can conflict with other USB devices recently installed. In such cases, the Windows Device Manager would show a problem occurred during the plug-and-play procedure or it would not detect the USB to UART Bridge controller at all. Possible solution is to change the USB ID for the board, using special utility available from the controller's manufacturer. See Section 8 for details.

Alternatively, the board can be connected to host PC via serial port, using a serial cable (not provided with ZDK). Serial port pinout is presented in Table 8.

**IMPORTANT NOTE:**

USB and serial port (RS-232) share the same physical port on the board. They cannot be used at the same time.

Take in mind that the connection mode is controlled by setting of jumper J3 (see Table 7).

## 3.5. Powering the Boards

The boards can be powered by a pair of AA-size batteries, via the USB port, once connected for data transfer, or via AC/DC adaptor. The nominal voltage is 3 V. Using AC/DC adaptor is disconnecting AA batteries automatically. Using USB port is disconnecting the AC/DC adaptor.

In order to make accurate measurements of sensor parameters, battery powering is recommended. USB powering is not stable enough, which can affect transmission of power level or RF parameters.

### IMPORTANT NOTES:

It is strongly recommended to check up the power supply voltage before programming the boards by Serial Bootloader or by JTAG. Power drops happened during the programming process could result in an inoperable state of the ZigBit or its permanent damage.

Using the discharged batteries (when the voltage is below the specified limit) may cause damage of flash memory or EEPROM as well. If that happened, programming by means of Serial Bootloader would fail. In this case the only option becoming available would be using of JTAG emulator (see Appendix B).

Using nickel-cadmium rechargeable batteries is allowed but with certain precautions. Nominally, their cell potential is 1.2 V. Although a pair gives 2.4 V thus fitting the operating voltage range (see Section 2.1), it is still lower than 3 V level, which a pair of the most popular alkaline cells give. Hence, nickel-cadmium rechargeable batteries could not be a proper alternative of the alkaline cells for all applications.

## 3.6. Testing WSN Functionality Using SerialNet

All the boards are delivered preprogrammed with the SerialNet firmware (see Section 5).

Connect the board to PC (see Section 3.4).

Run standard Hyper Terminal utility which is a part of Windows 2000/XP:

Start/All Programs/ Accessories/ Communications/ Hyper Terminal.

Select logical value for COM port provided by the system (see Section 3.4). COM port parameters should be set to the values given in Table 11.

**Table 11. COM-port settings for hardware testing**

Option	Value
Data Rate	38 400 bps
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	None

Type the "AT" command and press `Enter` key.

The board responds to Hyper Terminal with "OK".

Now, a user can play various networking scenarios by sending AT commands, without reprogramming any of the boards. Full description of AT commands is contained in [3].

A simple networking scenario for building WSN, transmitting data between the WSN nodes and accessing the nodes' interfaces is presented in the [Examples](#) Section of the document [3].

### 3.7. Testing the Board Controls and Sensors

To check the onboard controls and sensors the Hardware Test application can be used.

Connect the board to the PC.

Upload Hardware Test image onto the boards. The Hardware Test image files are listed in Appendix A.

Run Hyper Terminal utility in the same manner as described above (see Section 3.6).

While the Hardware Test is running, all the board LEDs are blinking. Reports are generated each 5 sec (see Figure 6), including the status of buttons, DIP switches, the UID chip number and sensor readings. To test the hardware, you can perform simple manipulations with the board: press the buttons, move the DIP-switches, manually hide the light sensor from light, finger the temperature sensor and so on. You should see the changes in parameters reported through Hyper Terminal (see Figure 6).

#### NOTE:

During the test, if you reconnect the board to USB or power off the board, the operating system would arbitrarily switch this particular USB connection to another COM port. Apparently, Hyper Terminal does not recognize such changes. If this happens, you have to reconnect Hyper Terminal to a proper port. Simply select **File/New Connection** menu item and repeat the recent procedure which you were performing before the accident.

```
File Edit View Call Transfer Help
Hardware test version 1.3
Button 1          OFF NOT PRESSED
Button 2          OFF NOT PRESSED
Dip switch 1     OFF NOT MOVED
Dip switch 2     OFF NOT MOVED
Dip switch 3     OFF NOT MOVED
Unique ID chip number 000100001090e4ad
Temperature sensor 27
Light sensor      280
=====

Hardware test version 1.3
Button 1          OFF NOT PRESSED
Button 2          OFF OK
Dip switch 1     OFF NOT MOVED
Dip switch 2     OFF NOT MOVED
Dip switch 3     OFF NOT MOVED
Unique ID chip number 000100001090e4ad
Temperature sensor 27
Light sensor      154
=====
Connected 0:16:46 Auto detect 38400 8-N-1 SCROLL CAPS NUM
```

Figure 6. Hyper Terminal Hardware Test report

### 3.8. Measuring Power Consumption

---

The board allows measuring power consumption of the ZigBit module . To perform the measurements, simply connect ammeter to the clamps denoted as CM+ and CM- and remove jumper J1. Make sure that the board is powered by batteries only. However, such measurement would not be absolutely correct, because power is consumed by the interfaces and the peripherals connected to ZigBit. To make it correctly, all interfaces should be disconnected from ZigBit module, excluding RF ports. Refer to the Application Note [5] for details.

### 3.9. Antenna Precautions

---

Each type of antenna – namely, PCB antenna, dual chip antenna and external antenna – were matched and tuned, with taking into account all adjacent components, including the ZigBit module shield, battery compartment and plastic legs. Any object approached or put closely next to antenna affects its performance. Do not put the module into enclosure. Do not mount the board on metal surface. Do not use metal screws over 5 mm long to fasten the board legs. These factors would affect antenna performance.

Mount plastic legs from bottom side only, next to the battery compartment). Use plastic screws to fasten the legs. Do not use the legs made of different plastic composite. Omitting these plastic legs would significantly affect antenna performance.

The pattern of antenna is wide. The following facts should be considered. In far-field zone, it is a horizontal plane normal to the dipoles where electromagnetic radiation appears stronger. Contrarily, at distances of several centimeters the pattern is more complex. . Approximate field patterns are given in the ZigBit datasheet [1].

Handle the external antenna with care to avoid mechanical damage.

## 4. WSN Demo Application

### 4.1. Overview

The networking performance of ZigBit platform is demonstrated with the WSN Demo application which is based on the eZeeNet Software API. This application comprises embedded firmware, which supports functions for coordinator, router and end device, and the GUI part – the WSN Monitor which is run on PC.

Thanks to the WSN Demo application embedded, the MeshBean2 boards are organized into a set of nodes constituting a wireless network. The LEDs of a board indicate the board current state and activities. In duty cycle, end-devices and routers read from the onboard sensors and send the readings to coordinator in packets. That data is displayed on WSN Monitor panes as temperature, light and battery level measurements.

End-device is mostly sleeping, consuming very low power, and it wakes up shortly each 10 seconds for activities. During the sleep period, you can force end-device for waking up by pressing the SW1 button.

Router sends data each 1 second. Using UART, the coordinator transmits the received packets, along with its own sensor data, to the GUI application (WSN Monitor).

In real time, the WSN Monitor visualizes the network topology in a form of tree. It also displays the node parameters like node addresses, node sensor information and node link quality data.

Measured in dBm, RSSI indicates link's current condition. The RSSI resolution is 3 dBm. LQI is a certain numeric value defined within the 0...255 range to measure the link quality. Larger values mean better link, while values close to zero indicate poor connection.

Using WSN Monitor controls, you can change the network channel mask, node timeouts and you can reset any node remotely.

**NOTE:**

The WSN Demo is extended to support both ZigBit and other platform devices [2]. Heterogeneous configurations can be implemented. For instance, a set of AVR RZ502/STK500/STK501 modules, RZ200 RCBs from Atmel and MeshNetics' Meshbean2 boards can operate as a single WSN. Network information can be visualized on the connected PC by means of WSN Monitor.

In regard to the WSN Demo, Section 4.3 describes how to use the boards. GUI is described in Section 4.5. Operation instructions are given in Section 4.6.

The application is delivered with source code included (see Appendix A). It is implemented on top of the eZeeNet API and it can be rebuilt as described in Section 7.

With WSN Demo, you can use as many routers and/or end-devices as it is limited by network parameters (see Section 7.4).

## 4.2. Programming the Boards

---

Upload WSN Demo image onto the board. The WSN Demo image files are listed in Appendix A.

WSN Demo image file can be uploaded into the boards in two ways: either you can use Serial Bootloader utility (see Section 4.2.1) or you can do it under AVR Studio, using JTAG emulator. For instance, JTAGICE mkII from Atmel [17]<sup>2</sup> (see Section 4.2.2) is employed.

### IMPORTANT NOTE:

Be careful selecting the method of the node programming. Each of MeshBean2 boards come with the bootstrap uploaded onto the ZigBit's MCU, which is needed to run Serial Bootloader. If JTAG had been used, this would make Serial Bootloader useless until bootstrap is reloaded to the board.

To be connected with WSN network each node should be identified with a unique MAC address. Once MAC address is not defined by hardware, the address of the node should be programmed. Programming a MeshBean2 board with MAC address can be performed in four ways.

1. MAC address can be uploaded to a board by means of Serial Bootloader running with the key specified within command line (see [7]).
2. It can be specified in Makefile when defining the compilation for an application (see details in Section 7.4). The resulting image file containing the unique MAC address can be uploaded to the board either by JTAG or using Serial Bootloader.
3. Otherwise, MAC address can be programmed sending SerialNet AT-commands, as described in [3].
4. Value stored in UID is used as MAC address.

MAC address is utilized for identification of the node within the network. Default value of MAC address is zero. The module would not join the network unless MAC address is set to any non-zero value which is not equal to `0xFFFFFFFFFFFFFFFF`.

Notice: Using UID number, you can design the network with "random" MAC addresses as UID number is a random value.

eZeeNet Software detects MAC address the next way. At startup, eZeeNet Software tries to load MAC address from EEPROM. If there is 0 or `0xFFFFFFFFFFFFFFFF` value in EEPROM, eZeeNet attempts to load MAC address from UID.

If there is no UID, the node cannot join the network (the subsequent actions depend upon application). Commonly, the node's is staying in the network-searching mode.

In order to get MAC address value during the application duty-cycle the specific function is called: `fw_getParam(FW_Param_t *param)`. Refer to the eZeeNet API Reference Manual [4].

---

<sup>2</sup> Another JTAG programmer may be also used but it should be compatible with the Atmel 1281 MCU.

### 4.2.1. Using Serial Bootloader

To program a board using Serial Bootloader do the following steps:

1. Connect MeshBean2 to the PC via USB or serial port, depending on the position of jumper J3 (see Table 7).
2. Run Serial Bootloader. In command line, specify the image file as `wsndemo.srec` (see Appendix A), the COM port and the optional keys. See [7] for details.
3. Press reset button on the board.
4. Release reset button on the board. Serial Bootloader expects that the button will be released within approximately 30 seconds. If this does not happen, the booting process would stop.

**NOTE:**

If a node has been configured as end-device and it is currently controlled by application, the node should be powered off before reprogramming.

Make sure that J3 position corresponds to the actual connection of the board, either it is Serial or USB.

Serial Bootloader indicates the operation progress. Once upload was successful, the board would restart automatically. If uploading failed, Serial Bootloader would indicate the reason. In rare cases, booting process can fail due to the communication errors between the board and the PC. If this happened, attempt booting again or try using conventional serial port, instead of USB. If booting fails, the program written to the board recently would be corrupted, but the board can be reprogrammed again.

### 4.2.2. Using JTAG

Link JTAG emulator to the MeshBean2's on-board JTAG connector (see Figure 2). Start uploading process under AVR Studio, following the instructions from [16] and [17]. Select the image file as `wsndemo.hex` (see Appendix A) to upload.

Check ON the following options in Fuses Tab before uploading the image through JTAG:

```
Brown-out detection disabled; [BODLEVEL=111]

JTAG Interface Enabled; [JTAGEN=0]

Serial program downloading (SPI) enabled; [SPIEN=0]

Boot Flash section size=1024 words Boot start
address=$FE00; [BOOTSZ=10]

Divide clock by 8 internally; [CKDIV8=0]

Int. RC Osc.; Start-up time: 6 CK + 65 ms; [CKSEL=0010
SUT=01]
```

Uncheck the rest of options. Make sure the following hex value string appears in the bottom part of Fuses Tab:

```
0xFF, 0x9D, 0x62.
```

Additionally, check ON the following option if the nodes will be programmed with Serial Bootloader:

```
Boot Reset vector Enabled (default address=$0000);  
[BOOTRST=0]
```

Make sure the following hex value string appears at the bottom of Fuses Tab:

```
0xFF, 0x9C, 0x62.
```

By default, each of the boards (MCU) is preprogrammed this way.

Besides, JTAG can be used to restore the device's ability to respond to Serial Bootloader commands. Serial Bootloader code can be reprogrammed with JTAG by selecting `bootloader.hex` image taken from your ZDK Distribution CD and transferring it to the device.

### 4.3. Using the Boards

At node startup, current channel mask is regularly read from EEPROM. If channel mask has been uploaded to EEPROM using Serial Bootloader, then no special action described below is needed before starting WSN Demo. Nevertheless, if you need to upload channel mask to EEPROM from flash (from an image file) then startup initialization of the node must be performed as follows.

Press and hold the on-board SW1 button first (see Figure 2). Power ON the board with holding the button pressed for at least 1 second. LED2 will get flashing 3 times. Next, all LEDs will start flashing to indicate the node's role: they will flash once on router, twice on end-device and three times on coordinator.

LED1, LED2 and LED3 will start blinking for 2 sec to indicate the acceptance of channel mask in EEPROM.

**NOTE:**

When the operation described above is completed, the channel mask preloaded to EEPROM is lost.

Starting the WSN Demo, do the following:

1. Configure one single node as a coordinator, and make the others be routers and end-devices (see Table 12). Any of the boards provided can be configured with any role.
2. Connect the coordinator node to the PC, using USB port on the coordinator board
3. Power on the coordinator node
4. Run WSN Monitor (see Section 4.6.1)
5. Power ON and reset the rest of the nodes.

**NOTE:**

While WSN Demo is running, channel mask can be changed anytime by sending the command through WSN Monitor (see Section 4.6.4). The channel mask which has been issued from WSN Monitor and received by a node is permanently stored in the node's EEPROM, regardless of power-offs. To restore the default channel mask in EEPROM repeat a node reinitializing procedure described above in this section or use Serial Bootloader.

**Table 12. DIP-switch configurations used in WSN Demo**

DIP-switches			Description
1	2	3	
ON	ON	X	Board is configured to be a coordinator.
ON	OFF	X	Board is configured to be a router.
OFF	OFF	X	Board is configured to be an end-device.

Coordinator organizes the wireless network automatically. Upon starting, any node informs the network on its role. At that moment, LED1, LED2 and LED3 are flashing once on router, they are flashing twice on end-device and they are flashing three times on coordinator.

After joining the network, a node starts sending data to the coordinator, which is indicated by LEDs.

WSN activity is observed in two ways:

- controlling the onboard LEDs (see LED indication described in Table 13)
- controlling the network information through the WSN Monitor installed on PC.

**Table 13. LED indication used in WSN Demo**

Node State	LED state		
	LED1 (Red)	LED2(Yellow)	LED3(Green)
Network searching	OFF	OFF	blinking
Having joined to network			ON
Message receiving		flashing	ON
Message transmitting	flashing		ON
Changing channel mask	blinking	blinking	blinking
Sleeping (for end-device only)	OFF	OFF	OFF
Accepting channel mask in EEPROM (at startup)		blinking	
Role indication (at startup)	All LEDs are flashing once on router, twice on end-device and three times on coordinator		
Idle (invalid DIP switch configuration)		ON	
MAC address missed	ON		

If you power ON the coordinator, it switches to an active state, even though no child node is present. This is normal, it means that the coordinator is ready and child nodes can join the network with coordinator's PAN ID.

By default, coordinator uses predefined PAN ID valued as D170, which is recognized by all routers. Changing PAN ID is not allowed.

**NOTES:**

The predefined value of D170 originates from eZeeNet version V. 1.7.

If coordinator is absent or it has not been turned on, the routers are staying in the network search mode. In this mode, routers are scanning the selected frequency channels in search for a network with the selected PAN ID.

In rare cases, if radio channel is busy on the selected frequency the coordinator node is staying in the network searching mode. If this happens, you should switch it to other channel by changing the channel mask in WSN Monitor.

## 4.4. Sensors Data and Battery Level Indication

Each of the boards measures temperature, light and its own battery level. They send the data values to coordinator and, further to the PC. The WSN Monitor displays the readings from onboard sensor's next to a node icon along with visualization (see Section 4.5).

Temperature sensor measures ambient temperature. The sensor data is depicted in the WSN Monitor charts with resolution of 1 °C .but the actual sensor accuracy is better.

Light sensor measures ambient illumination in Lux.

The battery voltage is indicated with typical accuracy of about 0.1 V, which is enough for most applications and self-monitoring tasks.

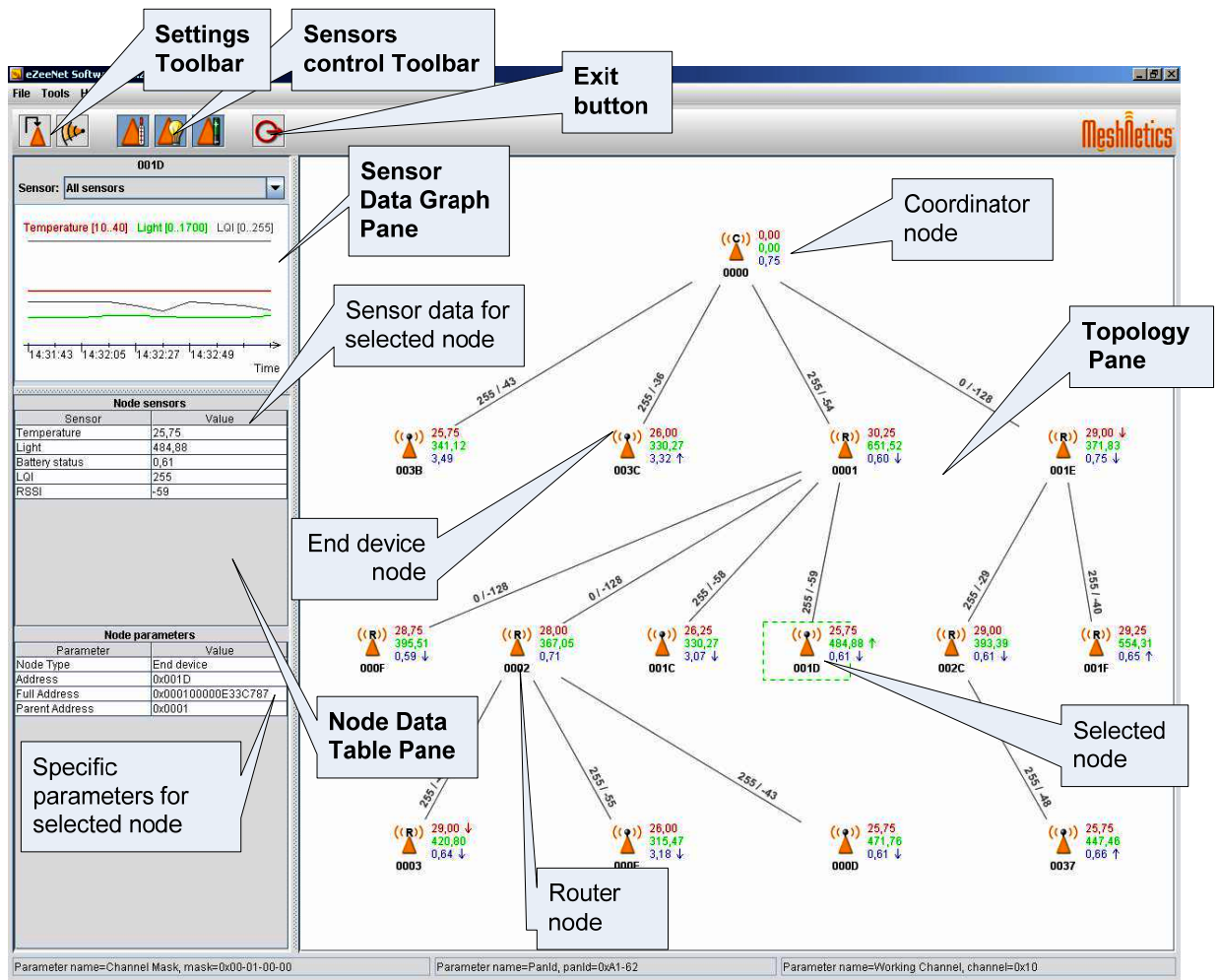
### NOTES:

In case the board is powered via USB port, the battery level might be shown improperly. Typically, it is shown as 0.6 V due to power protection circuitry. However, if batteries had been installed into the battery compartment, when the board is connected to the USB, the battery level indication is correct.

In case the board is powered via USB port, the heating voltage regulator, which is located next to the temperature sensor, can distort the sensor readings. Use battery-powered boards for more accurate measurements.

## 4.5. WSN Monitor

WSN Monitor is a PC-based GUI application for WSN Demo that is used to display WSN topology and other information about WSN network. See WSN Monitor screen in Figure 7. It contains the Network Topology Pane, Sensor Data Graph Pane, Node Data Table Pane and Toolbars.



**Figure 7. WSN Monitor GUI**

Network Topology Pane displays the networking tree in real time. That helps to control the formation and evolution of the network while the nodes join, send data or leave. The Network Topology Pane updates automatically while the nodes are discovered and while they join through coordinator. The networking tree is displayed in form of parent/child links which are tipped with RSSI and LQI values. Each of the nodes displayed is depicted by icon captured by name, and tipped with the node's data.

Node Data Pane displays the data coming from onboard sensor's of each of the nodes (see Section 4.4). It is presented in graphs and in table form. Other parameters can be also observed for each node in table form. Node Data Pane includes a Sensor Selection combo-box used to switch between sensor types.

Use text menu upside and toolbars controlling visualization.

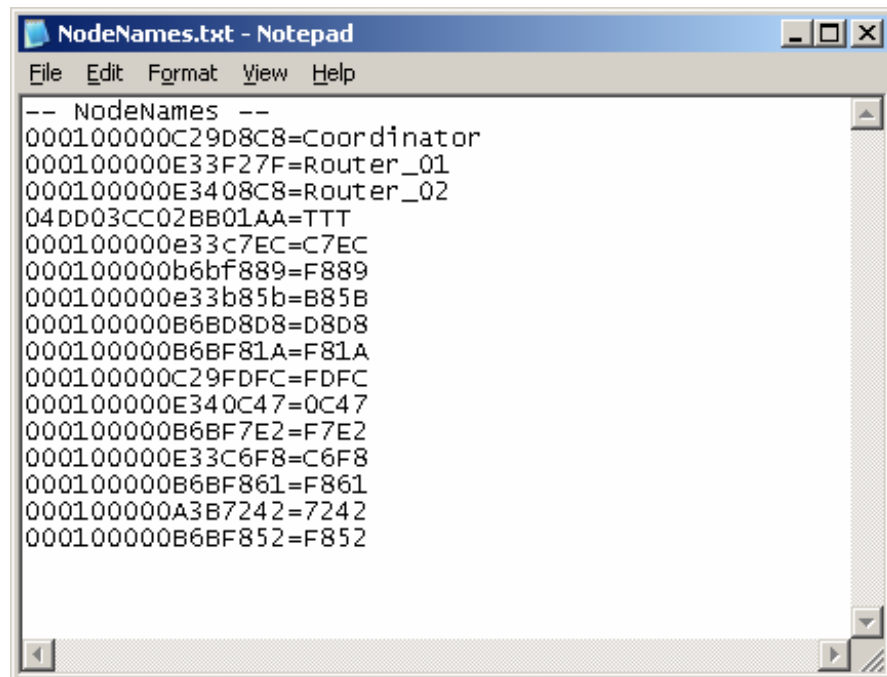
Node titles are defined in the `NodeNames.txt` file. By default, it is located in the following subdirectory:

"/Evaluation Tools/WSNDemo (WSN Monitor)/resources/  
configuration/".

Notice: the full path to the file depends on the root directory which has been specified during installation of the Development Kit (see Section 3.3).

NodeNames.txt contains one "-- NodeNames --" header string which is followed by a number of strings each of which contains 64-bit MAC address and the title of each node. For example, see Figure 8.

If the NodeNames.txt file is not found or its format is not recognized, the WSN Monitor designates the titles named by default.



```
-- NodeNames --
000100000C29D8C8=Coordinator
000100000E33F27F=Router_01
000100000E3408C8=Router_02
04DD03CC02BB01AA=TTT
000100000e33c7EC=C7EC
000100000b6bf889=F889
000100000e33b85b=B85B
000100000B6BD8D8=D8D8
000100000B6BF81A=F81A
000100000C29FDFC=FDFC
000100000E340C47=0C47
000100000B6BF7E2=F7E2
000100000E33C6F8=C6F8
000100000B6BF861=F861
000100000A3B7242=7242
000100000B6BF852=F852
```

Figure 8. Example of file containing the node titles

## 4.6. Operating the WSN Demo

### 4.6.1. Starting WSN Demo on MeshBean2 nodes

First, connect the coordinator node to the USB or to serial port, in accordance with the J3 jumper setting (see Table 7). Next, run the WSN Monitor application on your PC. At startup, WSN Monitor will attempt using the default COM port to connect to coordinator. The WSN Monitor screen pops up but the coordinator node icon would not yet appear on the Network Topology Pane (see Figure 7). You have to set a proper COM port via Tools/Settings menu (see Figure 9). Restart the program if the icon would not appear.

### 4.6.2. Setting up node timeouts

The Tools/Settings menu contains a number of parameters. Timeouts are used to tune up visualization for coordinator, routers and end-devices because they disappear from the network each time when link drop, power down, or reset occur. A node timeout means the waiting period, during which the WSN Monitor is expecting to receive data packet from that node, which would update the network Topology tree. To get it smooth for any changes in topology picture, setting timeouts to 3 sec is recommended for

coordinator and router and 30 sec is recommended for end-device. Those timeouts cover 3 periods between packet sending.

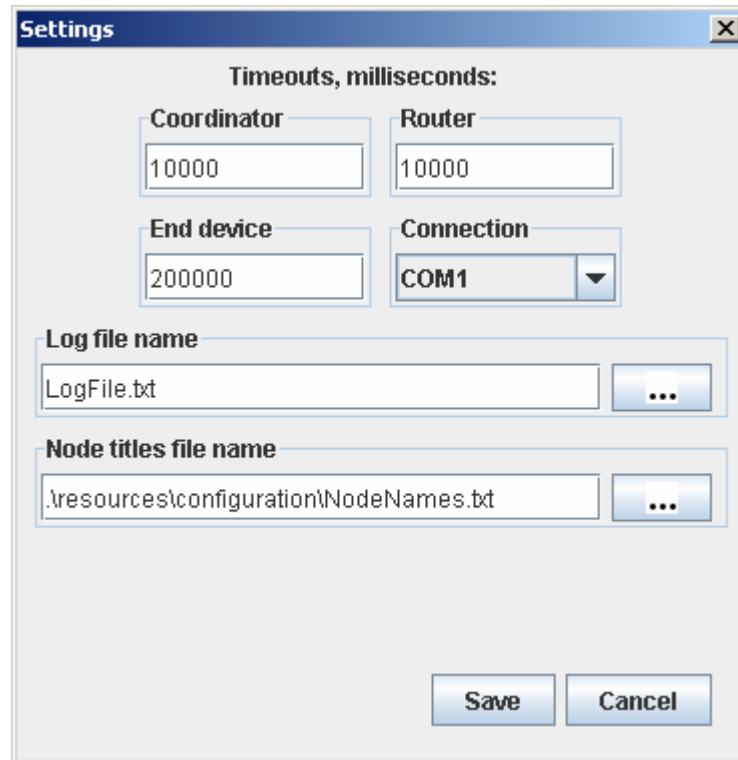


Figure 9. WSN Monitor Tools/Settings menu

#### 4.6.3. Node Reset

A node can be reset by means of the WSN Monitor using the **Tools/Send Command** menu (see Figure 10). A node can be identified by its MAC address or it can be selected from the list of the nodes (using the combo-box) which are currently present in the Network Topology Pane.

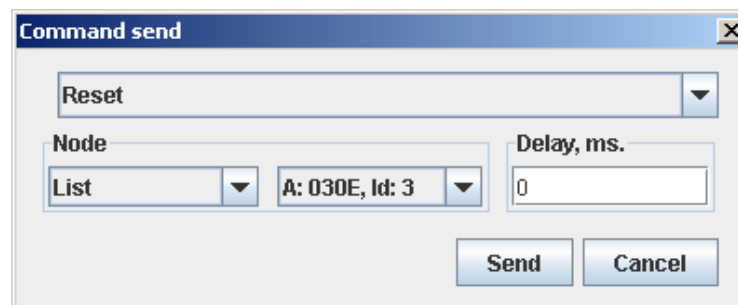


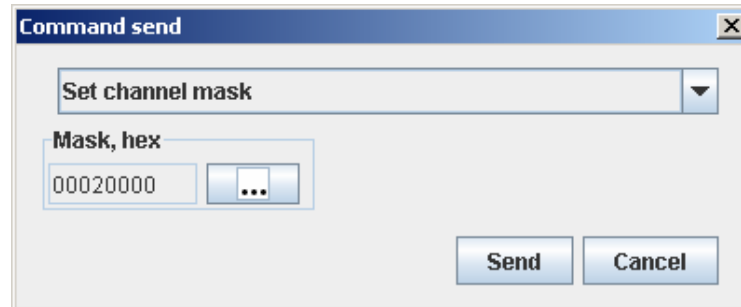
Figure 10. Resetting the node

#### 4.6.4. Changing Frequency Channels

The network operation is supported on 16 upper channels in 2.4 GHz band, which are numbered from 11 (0x0B) through 26 (0x1A). Use **Tools/Send Command** dialog box to set channel mask. By default, current channel mask is displayed there (see Figure 10). Enter mask directly in hex format or click "... " button.

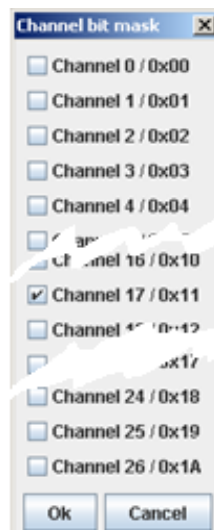
**NOTE:**

Channel mask is a bit field which defines the channels available. The 5 most significant bits ( $b_{27}, \dots, b_{31}$ ) of channel mask should be set to 0. The rest 27 least significant bits ( $b_0, b_1, \dots, b_{26}$ ) indicate availability status for each of the 27 valid channels (1 = available, 0 = unavailable).



**Figure 11. Setting channel mask dialog box**

Otherwise you can open the next dialog box by clicking the “...” button. Use checkboxes to select the channels thus setting some of them ON (see Figure 12).



**Figure 12. Setting the channel mask using checkboxes**

When changing channel mask, coordinator sends the command to all of the nodes and waits for 1 minute more after having received the last packet using old channel mask. Next, coordinator forms the network on the new channel.

When channel mask command is being accepted by router or by end-device the node stops sending packets for 1 minute, and the LED1, LED2 and LED3 start blinking. Next, it leaves the network and proceeds joining, using new channel mask.

When router is rejoining, the network indication LED, namely LED3, is blinking. Upon having router joined, LED3 is ON.

When end-device is rejoining, the network indication LED, LED3, is blinking. Upon having end-device joined, LED3 turns ON. LED1 flashes shortly to indicate sending a packet, LED1 flashes shortly to indicate having received acknowledgement. Next, all LEDs get turned OFF when end-device is falling to sleep.

When channel mask is being changed, the Topology Pane might display the Topology tree unrealistically. After changing channel mask, the network Topology tree is updated.

#### 4.6.5. Visualization of the Sensor Data

---

Observing the Topology tree and operating the GUI controls, user can select any node to monitor the node activity and see the node data in three different forms:

- Text table
- Chart
- The onboard sensor's data on the Topology Diagram. These values are tipped with arrows indicating relative increase or decrease.

Topology Pane displays temperature and light readings as well as battery level for any selected node (which icon appears in dashed frame). Also, these data values are shown on the Sensor Data Graph Pane. You can easily check how they evolve over time.

The Sensor Data Graph Pane includes a Sensor Selection combo-box. Use the button on the Sensor Control Toolbar to display the desired types of sensor data.

## 5. SerialNet

SerialNet is a configuration of eZeeNet Software which allows control over the most of the ZigBit/eZeeNet functionality through any communication interface using standardized Hayes-like AT-command set.

The commands come from Serial/USB interface in simple text form. The language principles are described in ITU-T V.250 recommendation (see [11]).

### NOTES:

Strictly, the SerialNet is an application developed “on top” of eZeeNet API.

Before running SerialNet application make sure that the corresponding image file (see Appendix A) is uploaded to each of the board properly by means of Serial Bootloader or JTAG.

See the set of supported AT-commands, their syntax and detailed description in the Reference Manual [3]. Chapter “Examples” of that document shows how to use the commands to do the following:

- to control LED and DIP switches
- to create a network (to set the node roles and addresses)
- to transmit data between the nodes
- to manage PAN ID and frequency channels
- to forward commands for remote execution
- to control power consumption for end-device.

Thanks to flexibility of AT-commands, you can create your own scenarios of communications that meet your needs and comply with particular applications.. The examples will provide you with a good toolset for your network evaluation.

A variety of terminal programs provide capability to type AT-command scripts and to analyze the responses from a board. This extends your capability of remote control over MeshBean2 boards. For example, you can simulate the sensor readings which should be sent periodically to the coordinator node, or implement other scenarios.

Before running the application, check the connection between the board and the PC and provide the following parameters of the COM-port set in the terminal software (see Table 14).

**Table 14. COM-port settings for SerialNet application**

Option	Value
Data Rate	38 400 bps
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	none

Running the SerialNet application, follow step-by-step instructions from the *Examples* section of the document [3]. Use AT-command samples to control your network conditions and to manage data transmission.

**NOTE:**

The +IFC command and the +IPR command both change the rate and flow control parameters of Serial/USB port. If any of these commands are used, the COM-port settings on the terminal program running on the PC should be properly changed.

## 6. Serial Bootloader

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Serial Bootloader is software intended to burn firmware images in SREC format into WSN nodes without using JTAG (see Appendix B). It also provides the possibility to set up the network parameters for each node without affecting its firmware.

Serial Bootloader consists of two parts: a PC console application for Windows platforms and bootstrap code residing in the MCU. In ZigBit Development Kit, each MeshBean2 board is delivered with fuse bits set up and the bootstrap preloaded to ZigBit MCU. Bootstrap itself can be recovered using JTAG when necessary. It is supplied in form of `bootloader.hex` image file (see Appendix A).

Exhaustive information on using Serial Bootloader is contained in document [7].

## 7. Using eZeeNet API

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### 7.1. Overview

---

With the eZeeNet Software API the WSN functionalities can be programmed. The following interfaces are distinguished within the eZeeNet API:

- eZeeNet Framework
- eZeeNet Stack
- Hardware Abstraction Layer (HAL)
- MeshBean2 board drivers.

eZeeNet API is fully described in [4].

Through the Framework interface, the user's HAL and the user's application are initialized, the user's loop is called, system time, EEPROM and eZeeNet parameters are managed.

Stack interface is applied to manage the network and to control data transmission.

Data can be transmitted in two ways: using either logical or network addressing. As advantage, logical address of a node is not fixed. Logical addressing is preferable when the address of each node is known in advance, or the addresses can be preset during the commissioning procedure. As disadvantage, address conflict is possible and it should be resolved manually or by dedicated software running on coordinator node.

NWK addresses are allocated and changed dynamically. NWK addressing scheme is only recommended for initial network addressing setup, when application receives data from some unknown node, or when several nodes in the network have to use the same logical address. This would be the way to resolve address duplication or provide plug-and-play node installation. NWK addressing scheme can be also used in wireless network where data is collected at a single central point (sink) and no data should be transmitted back. In that case logical addressing is not required, because NWK address is known for coordinator and it equals zero.

HAL interface supplied in source code can be modified to implement user-defined drivers and to manage specific peripherals. The particularly configured HAL API, the MeshBean2 board interface provides reading the DIP-switches, LED manipulation, button control, sensor management, battery voltage measurement. It can be a starting point for modifications targeting custom board different from the MeshBean2.

### 7.2. Using AVR Programming Tools

---

We recommend the Atmel's AVR Studio [16] to develop custom applications based on eZeeNet API. This multiplatform Integrated Development Environment (IDE) provides the options for editing source code, compilation, linking object modules with libraries, debugging, making executable file automatically, and more. See Section 3.3 for the IDE installation instructions. Refer to the AVR Studio User's manual delivered with that product.

AVR Studio can be integrated with WinAVR – a suite of software development tools for the Atmel AVR series of RISC microprocessors hosted on the Windows platform [19]. WinAVR contains a set of utilities including AVR GCC compiler, linker, automatic Makefile generator, system libraries etc. Installing the AVR GCC plug-in lets these tools working automatically in AVR Studio. GCC compiler is designed to be executed on the Windows platform, and is configured to compile C or C++ codes. For description of GCC compiler see WinAVR documentation. You can find command options for compilation and linking specified in [20].

In AVR Studio, the development of an application is organized under particular project. All the necessary information about a project is kept in project file. Such files assigned to the AVR Studio have an \*.aps extension, so they become opened automatically if double-clicked.

The easiest way to configure an AVR project is to use Makefile that is a plain text file which name has no extension. Makefile specifies compilation and linking flags. Makefile also specifies corresponding directories in order to include header files and to link the system object libraries.

The required eZeeNet Software is allocated in ZDK Distribution CD in the "eZeeNet" structured subdirectory as presented in Appendix A. It should be copied to user's hard drive with keeping the whole structure of subdirectories containing source files, header files, Makefiles and libraries.

## 7.3. How to Build Minimum Application

---

For quick start in programming, a user's sample application is designed to show the required structure of minimum code. This application (somewhat like the "Hello World!" demo) implements blinking of the MeshBean2's LED. In user's loop, the GPIO-0 pin state is toggled, using the GPIO interface. The source code for minimum application is given in Appendix C, along with the Makefile corresponding to the file structure specified in Appendix A. They are allocated in the ". /Sample Applications/Blink/" subdirectory. The resulting image files are also delivered. You can rebuild them any time as described below.

Open blink.aps file from the ". /Sample Applications/Blink/" subdirectory and just execute Build/Rebuild All item from the main menu. The blink.hex and blink.srec image files will be generated. No \*.eep image file will be produced as EEPROM is not involved for Blink. To test the minimum application, upload any of the image files into a MeshBean2 board, following the instructions which are given in Section 6 or in Appendix B, correspondingly.

You can modify the minimum code to upgraded the application using other eZeeNet API functions. Make sure that your application code satisfies the programming conventions specified in [4].

Play with the other API demos (see Section 7.4), building them similarly to enhance your network with new functionalities. Make sure your applications are uploaded into the boards before use.

## 7.4. API Sample Applications

---

ZDK is supplied with the set of eZeeNet API sample applications in source code. These are named as given in brackets:

- WSN Demo application (WSNDemo)
- Low-Power Networking application (Lowpower)
- Peer-to-Peer Data Exchange application (Peer2peer)
- Ping-Pong application (Pingpong).

WSN Demo is a ZDK featured application demonstrating the formation of network based on eZeeNet software and MeshBean2 hardware. In WSN Demo, the nodes communicate based on a proprietary messaging protocol described in [5]. WSN Demo is presented in details in Section 4.

The source codes for WSN Demo application can be found inside the ". /Sample Applications/WSNDemo" subdirectory (see Appendix A), once the Development Kit is installed to user's PC (see Section 3.3).

Network parameters and their default values are defined in Makefile as below:

```
# Network parameters
DEFINES = \
  WSN_DEFAULT_CHANNEL_MASK=0x100000 \
  ADE_SOFTWARE_VERSION=0x01060200 \
  DEFAULT_PAN_ID=0xD162 \
  NWK_MAX_END_DEVICES=2 \
  NWK_MAX_ROUTER_NEIB_NUMBER=2 \
  NWK_MAX_DEPTH=4 \
  MAX_PAN_DESCRIPTOR=5 \
```

Also, MAC address can be defined in Makefile to be uploaded to a node along with the application image. Varying the IEEEADDR value you can prepare image files for individual nodes:

```
#default IEEE address
IEEEADDR = 1
```

To compile WSN demo application use `make` utility. Otherwise, open the `WSNDemo.aps` file from the `./Sample Applications/WSNDemo/` subdirectory with AVR Studio and just execute `Build/Rebuild All` item from the main menu. The `WSNDemo.hex`, `WSNDemo.eep` and `WSNDemo.srec` image files will be then generated.

Low-Power, Peer-to-peer and Ping-Pong applications are described in details in [4].

## 8. Troubleshooting

In case of any operational problem with your system please check the power first, and make sure that all of your equipment is properly connected.

Check if your PC conforms to the minimum system requirements (see Section 3.2). Check if the PC interfaces (COM, USB) are present and drivers are installed.

Check on LED indication of a node if it is not responding or behaving unusually. Make sure the DIP switches are set according to the application running on the board.

You can retest the particular node as described in Section 3.7, if needed.

You may be required to reset the node.

The following list represents some typical problems that you may encounter while working with the Development Kit and possible solutions.

**Table 15. Typical problems and solutions**

Problem	Solution
The board does not indicate its activity with LEDs.	Make sure that either WSN Demo image or Hardware Test image is loaded. For SerialNet, the LED status is controlled by AT-commands.
The board does not respond to outer commands (in case of external antenna)	Make sure the external antenna is not broken and it is properly connected to the board.
In effort to connect several boards to the same PC their detection fails due to ID recognition conflict.	Detect ID for any single connected board using the USBView.exe utility from Silicon Laboratories. It can be downloaded from <a href="http://www.silabs.com/tgw/WebApp/public/web_content/products/Microcontrollers/USB/en/USBXpress.htm">http://www.silabs.com/tgw/WebApp/public/web_content/products/Microcontrollers/USB/en/USBXpress.htm</a> . You can use the CP210xSetIDs.exe utility from Silicon Laboratories which is included in AN144SW. It is described at <a href="http://www.silabs.com/public/documents/tpub_doc/anote/Microcontrollers/Interface/en/an144.pdf">http://www.silabs.com/public/documents/tpub_doc/anote/Microcontrollers/Interface/en/an144.pdf</a> and it can be downloaded from <a href="http://www.silabs.com/public/documents/software_doc/othersoftware/Microcontrollers/Interface/en/an144sw.zip">http://www.silabs.com/public/documents/software_doc/othersoftware/Microcontrollers/Interface/en/an144sw.zip</a> .
WSN Monitor fails to start.	Make sure Java machine is properly installed on your PC. Java Runtime Environment installation program can be found in <code>./Third Party Software/</code> directory as <code>jre-6u3-windows-i586-p-s.exe</code> file (see Appendix A)
No node is shown on the Topology Pane in the WSN Monitor	Check if the WSN Monitor uses proper COM port and if not, change it and restart the program.
WSN Monitor shows NO DATA in the Sensor Data Graph Pane.	No node is selected. Select the required node by mouse-clicking on it.
Node titles displayed on the Topology Pane do not show node destinations.	The displayed titles do not necessarily relate to the node functions but they can be redefined by user anytime. These names are stored in the node title file (see Section 4.5) along with MAC addresses mapped to the nodes.

Problem	Solution
At WSN Monitor startup, all node's LEDs are blinking, or none of them is flashing.	The WSN Demo application was not uploaded into the node. Upload this application to the node.
Neither Serial Bootloader nor other application work with a node, except for the Hardware Test.	Make sure that J3 is set on the board properly to correspond to the actual connection type (either Serial or USB).  Make sure the microcontroller flash memory was not erased before, and the bootstrap was not lost there after having the node programmed through JTAG.

# Appendices

## Appendix A. ZDK File Structure

The installation of ZDK to the user's PC is performed from the ZDK Software and Documentation CD (see Section 3.3). As the result the following file structure will be generated under the user defined destination (see Table 16).

**Table 16. The ZDK file structure**

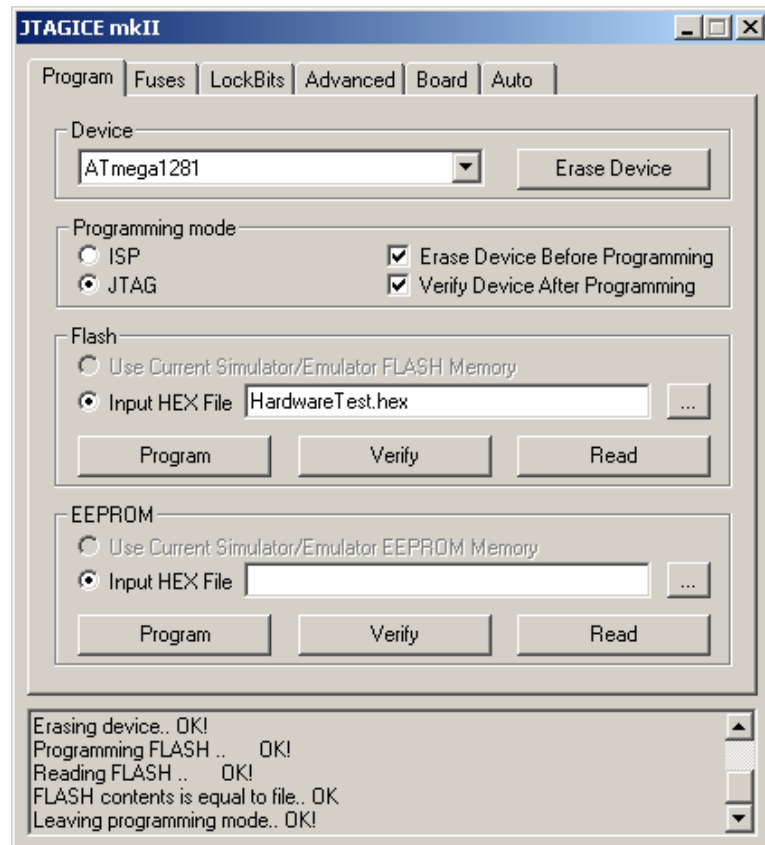
Directory/File	Description
Readme.html	Introductory document containing the links to the documentation files
ZigBit Development Kit Release Notes.txt	The ZDK release notes
EULA.txt	End User License Agreement
SLA.txt	Support Level Agreement
./Documentation	Documentation on hardware and software, datasheets, application notes
./Product Information	Getting Started document, product briefs and case study documents
./Bootloader/Bootloader.exe ./Bootloader/bootloader.hex	Serial Bootloader executable file  Binary image file containing bootstrap code
./Evaluation Tools/Hardware Test/ HardwareTest.srec ./Evaluation Tools/Hardware Test/ HardwareTest.hex	Hardware Test image files
./Evaluation Tools/WSNDemo (Embedded)/wsndemo.srec ./Evaluation Tools/WSNDemo (Embedded)/wsndemo.hex	WSN Demo image files
./Evaluation Tools/WSNDemo (WSN Monitor)/Start.exe	WSN Monitor executable with all the resource files
./Evaluation Tools/SerialNet/ serialnet.srec ./Evaluation Tools/SerialNet/ serialnet.hex	SerialNet image files
./eZeeNet/Framework ./eZeeNet/Stack ./eZeeNet/StackSupport	Header and library files for eZeeNet Framework, Stack and Stack Support
./eZeeNet/HAL/HAL_R6	Source, header and library files for eZeeNet HAL
./eZeeNet/TOSLib	Source, header and library files for TOS

Directory/File	Description
./Sample Applications/WSNDemo	Source and image files for WSN Demo application. Source code is available with Complete Support Package only.
./Sample Applications/Blink	Source and image files for Blink application
./Sample Applications/Lowpower	Source and image files for Low Power sample application
./Sample Applications/Peer2peer	Source and image files for Peer-to-Peer sample application
./Sample Applications/Pingpong	Source and image files for Ping-Pong sample application
./Evaluation Tools/Range Measurement Tool/range_tool.vi ./Evaluation Tools/Range Measurement Tool/receiver.hex ./Evaluation Tools/Range Measurement Tool/receiver.srec ./Evaluation Tools/Range Measurement Tool/transmitter.hex ./Evaluation Tools/Range Measurement Tool/transmitter.srec	Range Measurement Tool application's GUI  Range Measurement Tool image files
./Third Party Software/ CP210x_VCP_Win2K_XP_S2K3.exe	USB to UART Bridge VCP driver installation program
./Third Party Software/ jre-6u3-windows-i586-p-s.exe	Java Runtime Environment installation program

## Appendix B. Using JTAG Emulator

Programming with JTAG gives more flexibility in managing the loading process, but requires special hardware. For Windows environment we recommend using the AVR Studio 4.12 + Service Pack. AVaRICE 2.40 may be used for Linux. In both cases, the recommended JTAG emulator is JTAGICE mkII from Atmel. Other programming devices can be utilized as well, but make sure before use that the particular model supports programming an Atmega1281 MCU.

Using AVR Studio both flash memory and EEPROM of a board can be separately programmed with images having Intel HEX format. EEPROM image has `.eep` extension while flash image has `.hex` extension. To upload firmware, follow the instructions from the device manufacturer's manuals [16], [17], [18]. A sample pop-up window is shown in Figure 13.



**Figure 13. AVR Studio dialog box for firmware upload using JTAG**

The well-known command line utility, `avrdude`, which is a part of WinAVR environment (<http://sourceforge.net/projects/winavr>) can be used for upload as well. This utility recognizes both Intel HEX and Motorola SREC formats.

**IMPORTANT NOTES:**

To avoid corruption of the bootstrap code required for serial booting, do not erase device when using JTAG.

For JTAG programming, the `Boot Reset vector` fuse bit should be disabled. To enable serial booting this fuse bit should be enabled.

## Appendix C. Minimum Application

### Source Code

```
/*
 * LED Blinking Implementation Project: C source
 */
#include "framework.h"
#include "gpio.h"
#include "apptimer.h"
#define LED GPIO_0 // Pin connected to LED.
// Functions' declarations.
void mainLoop(); // Main loop.
void timerFired(); // Blink timer handler.
/*
 * Users entry.
 */
void fw_userEntry(FW_ResetReason_t resetReason)
{
    // Initialize the pin connected to the LED.
    gpio_setConfig(LED, GPIO_OUTPUT);
    // Open and start blink timer.
    {
        int handle;
        handle = appTimer_open(timerFired);
        appTimer_start(handle, TIMER_REPEAT_MODE, 1000);
    }
    // Start main loop.
    fw_setUserLoop(20, mainLoop);
}
/*
 * Main loop.
 */
void mainLoop()
{
    // Additional user's activities.
}
/*
 * Blink timer handler.
 */
void timerFired()
{
    static bool on=0;
    gpio_setState(LED, on);
    on = on ? 0:1; // Toggle.
}
// eof blink.c
```

## Makefile

```
#####  
# LED Blinking Implementation Project: Makefile  
#####  
## General Flags  
PROJECT = blink  
MCU = atmega1281  
TARGET = blink.elf  
CC = avr-gcc  
  
## Options common to compile, link and assembly rules  
COMMON = -mmcu=$(MCU)  
  
## Compile options common for all C compilation units.  
CFLAGS = $(COMMON)  
CFLAGS += -Wall -D_WDM1281_ -Os -g -fsigned-char  
  
## Assembly specific flags  
ASMFLAGS = $(COMMON)  
ASMFLAGS += -x assembler-with-cpp -Wa,-g  
  
## Linker flags  
LDFLAGS = $(COMMON)  
  
## Intel Hex file production flags  
HEX_FLASH_FLAGS = -R .eeprom  
  
HEX_EEPROM_FLAGS = -j .eeprom  
HEX_EEPROM_FLAGS += --set-section-flags=.eeprom="alloc,load"  
HEX_EEPROM_FLAGS += --change-section-lma .eeprom=0  
  
## Framework defines.  
  
## Path to Stack, StackSupport, HAL, TOSLib  
#SUPPORT_DIR = ../../..  
SUPPORT_DIR = ../../eZeeNet  
#SUPPORT_DIR = ../../API  
  
## Modules directories paths.  
APP_DIR = ./  
STACK_DIR = $(SUPPORT_DIR)/Stack  
STACK_SUPPORT_DIR = $(SUPPORT_DIR)/StackSupport  
TOSLIB_DIR = $(SUPPORT_DIR)/TOSLib  
HAL_DIR = $(SUPPORT_DIR)/HAL/HAL_R6  
FRAMEWORK_DIR = $(SUPPORT_DIR)/Framework  
  
## Include Directories.  
INCLUDES = -I"$(APP_DIR)/include" \
```

```
-I"$(STACK_DIR)/include" \
-I"$(TOSLIB_DIR)/include" \
-I"$(HAL_DIR)/base/include" \
-I"$(HAL_DIR)/eZeeNet/include" \
-I"$(STACK_SUPPORT_DIR)/include" \
-I"$(STACK_SUPPORT_DIR)/include/stack" \
-I"$(FRAMEWORK_DIR)/include"

## Library Directories
LIBDIRS = -L"$(HAL_DIR)/lib" \
-L"$(TOSLIB_DIR)/lib" \
-L"$(FRAMEWORK_DIR)/lib" \
-L"$(STACK_SUPPORT_DIR)/lib"

## Libraries
LIBS = -ltos \
-lFW \
-lZigBitInt \
-lstackSupport \
-lc

SRC = $(APP_DIR)/blink.c \
$(STACK_SUPPORT_DIR)/src/ConfigServer.c \

## Objects explicitly added by the user
LINKONLYOBJECTS = $(STACK_DIR)/lib/NWKMACLibA.o \
$(STACK_DIR)/lib/APLLibA.o \
$(HAL_DIR)/lib/wdtinit.o

## Build
all: $(TARGET) blink.srec blink.hex

##Link
$(TARGET): $(SRC)
$(CC) $(CFLAGS) $(INCLUDES) $(LINKONLYOBJECTS) $(SRC) -o
$(TARGET) $(LIBDIRS) $(LIBS)
avr-size $(TARGET)

%.srec: $(TARGET)
avr-objcopy -O srec $(HEX_FLASH_FLAGS) $< $@

%.hex: $(TARGET)
avr-objcopy -O ihex $(HEX_FLASH_FLAGS) $< $@

%.lss: $(TARGET)
avr-objdump -h -S $< > $@

## Clean target
clean:
-rm -rf $(TARGET) $(PROJECT).srec $(PROJECT).hex
```

