Crossbow

M2110 Hardware Reference Manual

Revision B, January, 2008

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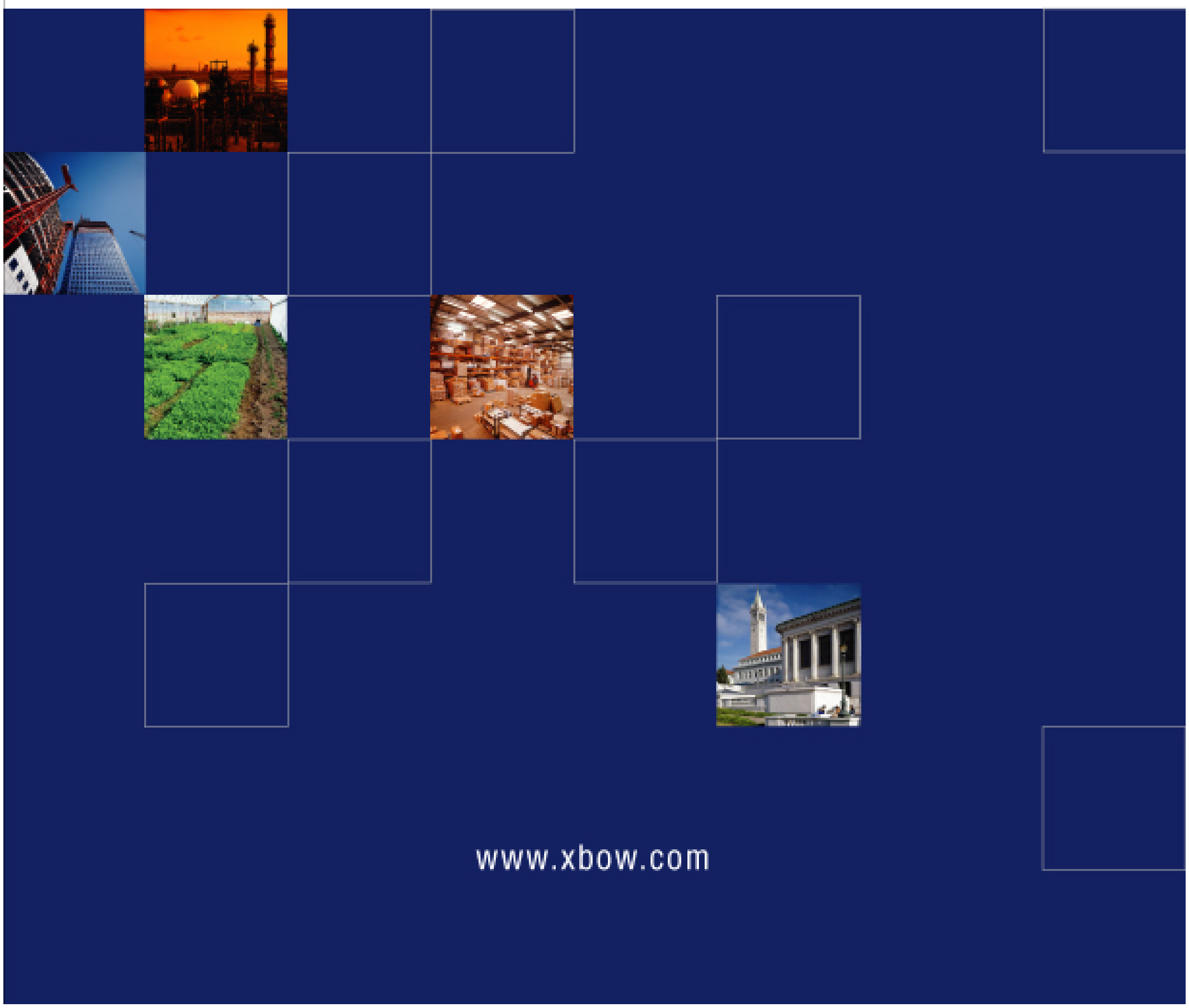

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About This Document

The following annotations have been used to provide additional information.

NOTE

Note provides additional information about the topic.

☑ EXAMPLE

Examples are given throughout the manual to help the reader understand the terminology.

IMPORTANT

This symbol defines items that have significant meaning to the user

⚠ WARNING

The user should pay particular attention to this symbol. It means there is a chance that physical harm could happen to either the person or the equipment.

The following paragraph heading formatting is used in this manual:

1 Heading 1

1.1 Heading 2

1.1.1 Heading 3

This document also uses different body text fonts (listed in Table 0-1) to help you distinguish between names of files, commands to be typed, and output coming from the computer.

Table 0-1. Font types used in this document.

Font Type	Usage
`Courier New Normal`	Sample code and screen output
`Courier New Bold`	Commands to be typed by the user
Times New Roman Italic	TinyOS files names, directory names
Franklin Medium Condensed	Text labels in GUIs

1 Introduction

This *User's Manual* describes the hardware features of the OEM Edition M2110 modules.

Table 1-1 below lists the models covered in this Manual.

Table 1-1. OEM Edition Models covered in the Reference Manual

Model Number	Description
M2110	2.4GHz IRIS OEM module

This *Manual* is **not** a software guide to programming the Motes using *MoteWorks*, nor is it a guide to pre-built software packages that run on top of the Motes. The following resources are available regarding software:

- *MoteWorks Getting Started Guide* by Crossbow Technology, Inc.
- *XMesh User's Manual* by Crossbow Technology, Inc.
- *MoteView User's Manual* by Crossbow Technology, Inc.
- *MoteConfig User's Manual* by Crossbow Technology, Inc.

2 Quick Start for the OEM Kit Users

IMPORTANT: This section is intended for the Standard OEM Edition module kit users only. If you did not purchase the complete pre-programmed kit, but only stand-alone boards then skip to Chapter 3.

2.1 Out-of-the-Box Demo

This section will step you through the process of setting up a simple Mote sensor network demonstration. The four main steps are to

1. Install *MoteView* on your Windows PC
2. Install the USB drivers for the MIB520 programming pod
3. Set up OEM reference Motes with the MDA300 sensor boards
4. Start *MoteView* and log sensor data from the wireless network

2.1.1 Installing MoteView on a Windows PC

Before you can use *MoteView* you have to install it on a PC. The requirements necessary to properly install *MoteView* are below:

1. A PC with one of the following operating systems
   - Windows XP Home/Professional
   - Windows 2000 with SP4
2. An NTFS file system
3. Screen resolution must be at least 800 × 600 or the interface will require scrollbars
4. Administrative privileges to write to Windows registry

NOTE: Prior to installing *MoteView*, it is highly recommended that you shut down all the programs running on your computer.

Follow these installation steps:

1. Insert the WSN Kit CDROM into the computer's CD drive.
2. Double-click on MoteViewSetup_<version>.exe from "**MoteView**" folder.
3. Select the desired installation directory (the default installation directory is **C:\Program Files\Crossbow\MoteView**)
4. Select all available installation tasks
5. InstallShield will guide you through the rest of the process and install the following:
   - MoteView application
   - PostgreSQL 8.0 database service
   - PostgreSQL ODBC driver
   - Microsoft .NET framework

2.1.2 Installing the USB drivers for the MIB520 Programming Pod

When you plug an MIB520 into your PC for the first time, Windows detects and reports it as new hardware. Do the following steps.

1. Connect one end of the USB extension cable to an available USB port on your PC. Connect the other to the MIB520's USB connector. In a few moments your PC will identify the MIB520 as a new hardware.
2. When the PC directs you to search for a suitable driver select "Install from a list or specific location (Advanced)."
3. Browse to "**MIB520 Drivers**" folder of the *MoteWorks* Support Tools CDROM.
4. Follow the FTDI InstallShield Wizard through the rest of the installation process. Up to four different installations will take place.

When the drivers are installed, you will see two serial ports associated with the MIB520. Before programming or listening to Motes using the MIB520, you need to see which ports were assigned to the MIB520. To find out do the following:

5. Click on **Start > Control Panel > System > Hardware > Device Manager > Ports (COM & LPT)**.
6. Make a note of the assigned COM port numbers.

> **NOTE:** The two virtual serial ports for MIB520 are com<x> and com<x+1>
>
> com<x> is for Mote programming, and
>
> com<x+1> is for Mote communication.

2.1.3 Setting up the OEM Reference Motes with the XMDA300 Board

1. The OEM reference Motes are numbered from 0 to 3. Identify the Motes labeled one ("1") through three ("3"). Attach the MDA300 boards to each of these to Motes via the mating 51-pin connectors. Turn the Motes on by putting the switch at SW2 to "ON." (Remember to install two of the AA alkaline batteries included in your kit.)
2. Identify the OEM reference Mote labeled as number zero ("0") and attach it to the MIB520 programming pod via the mating 51-pin adapter.

2.1.4 Setting up MoteView

All the visualization tools in *MoteView* require being connected to a database. The database is in your PC ("localhost"), but can also be a remote PC/server. Instructions for logging and viewing data locally are described next.

1. Start *MoteView* by double-clicking the icon on the desktop.
2. Open the Connection Wizard window from the menu **File > Connect > Connect to WSN**.
3. Select the **Mode** tab, check on **Acquire Live Data** as operation mode and **Local** as acquisition type and click on **Next >>**.
4. In the **Gateway** tab, select MIB520 as the interface board, and change the Serial Port port to the higher of the two com numbers assigned to the MIB520 during the driver installation. For example if the COM ports on the MIB520 are COM8 and COM9, then select in COM9 from the Serial Port drop-down box. Select the "**57600**" for the Baud rate from drop-down box and click on **Next >>**.

5. In the **Sensor Board** tab, for the Application Name, select "**XMDA300**" from the pull-down menu.
6. Click on the **DONE** button.

Soon after that it should display incoming data. Click on the *MoteView* window to view data, time plots of sensor values, and topology of the Mote network.

2.1.5 User Interfaces

You should see nodes one, two and three appear in the node list on the left hand side of the *MoteView* window. *MoteView* has four main user interface sections which you can browse and use.

- **Toolbar / Menus:** Allows the user to specify actions and initiate command dialogs.
- **Node List:** Shows all known nodes in a deployment and health status summary.
- **Visualization Tabs:** Enables the user to view the sensor data in various ways.
- **Server Messages:** Displays a log of server events and incoming messages.

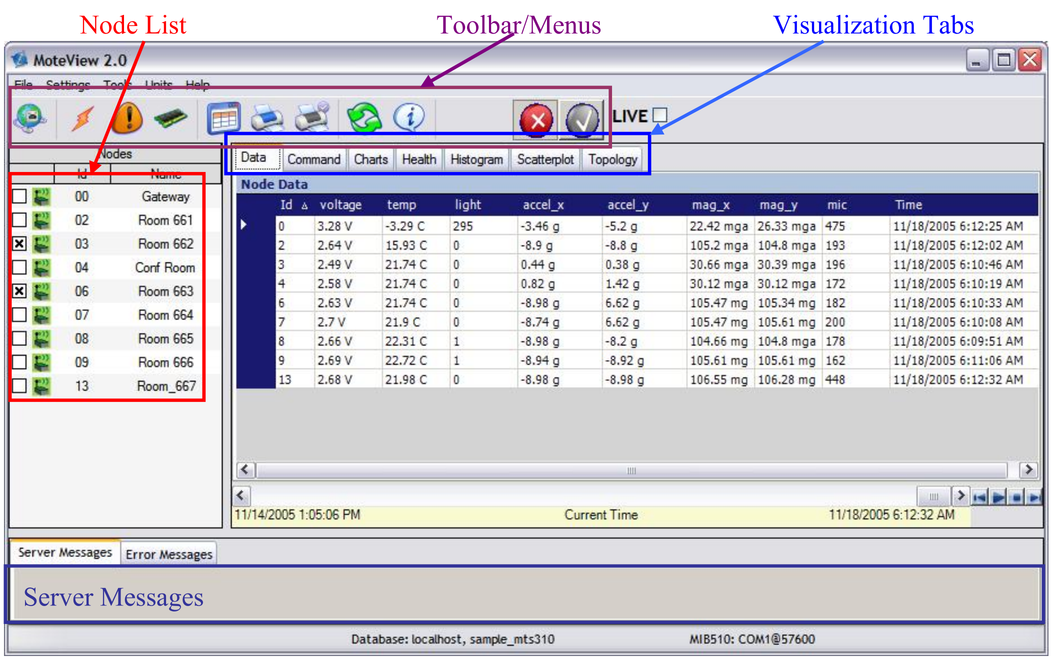


Figure 2-1. Screenshot of the MoteView GUI

More information about *MoteView* and its features can be found in the *MoteView* User's manual.

3 Product Overview

Crossbow's M2110 OEM Edition module provides users with high level functional integration designed to optimize the addition of wireless mesh networking technology to a wide variety of both new and existing custom sensing applications. Powerful new design features include:

- Optimized processor/radio module integration based on Crossbow's extensive Mote development and deployment.
- Flexible onboard hardware interface for both standard and custom sensing devices.
- Comprehensive software support, including sensor board drivers and algorithms, via Crossbow's industry leading *MoteWorks* software platform.

The M2110 OEM Edition module is the functional equivalent of Crossbow's newest generation IRIS family Mote in a postage stamp form factor. This inherent design continuity makes the OEM Edition module an ideal solution for next-generation mesh networking products and designs.

By utilizing open-platform, standards based interfaces the OEM Edition module offers users an attractive value proposition consisting of easily differentiated, low-power radio/processor modules that can be rapidly designed and built.

Figure 3-1. Photo of the OEM Edition Module

The Table 3-1 below summarizes the main features of OEM Edition modules.

Table 3-1. OEM Edition Module Product Summary

Mote Hardware Platform		M2110
MCU	Chip	ATMegal1281V
	Type	7.37 MHz, 8 bit
	Program Memory (kB)	128
	SRAM (kB)	8
Sensor Board Interface	10-Bit ADC	0 V to 3 V input
	UART	2
	Other interfaces	DIO, I2C

RF Transceiver (Radio)	Chip	AT86RF230
	Radio Frequency (MHz)	2400
	TMax. Data Rate (kbits/sec)T	250
Flash Data Logger Memory	Chip	AT45DB041D
	Connection Type	SPI
	Size (kB)	512

3.1 Block Diagram and Schematics for the OEM Edition Module

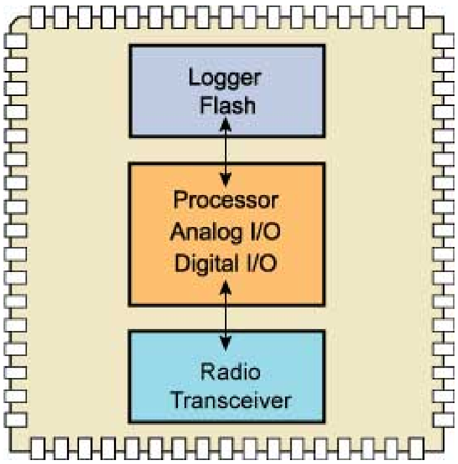


Figure 3-2. Block Diagram for the OEM Edition Module

3.2 Electrical Specifications

The electrical specifications for the OEM Edition module are provided in Table 3-2.

Table 3-2. M2110 Electrical Specifications

Parameter	Operating Value
Power supply	2.7 to 3.6 Volts
I/O	See Table 3-4
GPIO levels	0 - VCC
GPIO current (source/sink)	10 mA max
UART levels	0 - VCC
UART data rate	Up to 115kB
I2C rate	100 kbps max
I2C levels	0 - VCC
Interrupt levels	0 - VCC
RF port	50 ohm

3.3 Environmental Specifications

The environmental specifications for the OEM Edition module are provided in Table 3-3.

Table 3-3. M2110 Environmental Specifications

Parameter	Operating Value
Storage Temperature	-40 deg. C to + 85 deg. C
Operating Temperature	-40 deg. C to + 85 deg. C
Shock	6g any axis
Vibration	2g random any axis
Humidity	0 to 90 % RH

3.4 Mechanical Dimensions

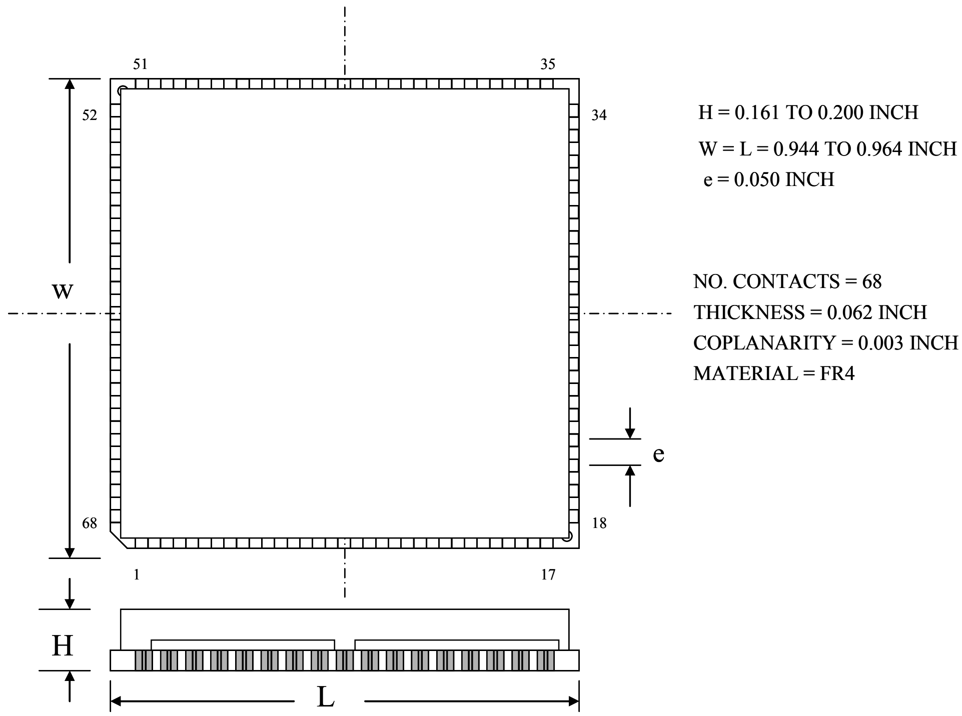


Figure 3-3. Mechanical Outline Drawing of OEM Edition Module

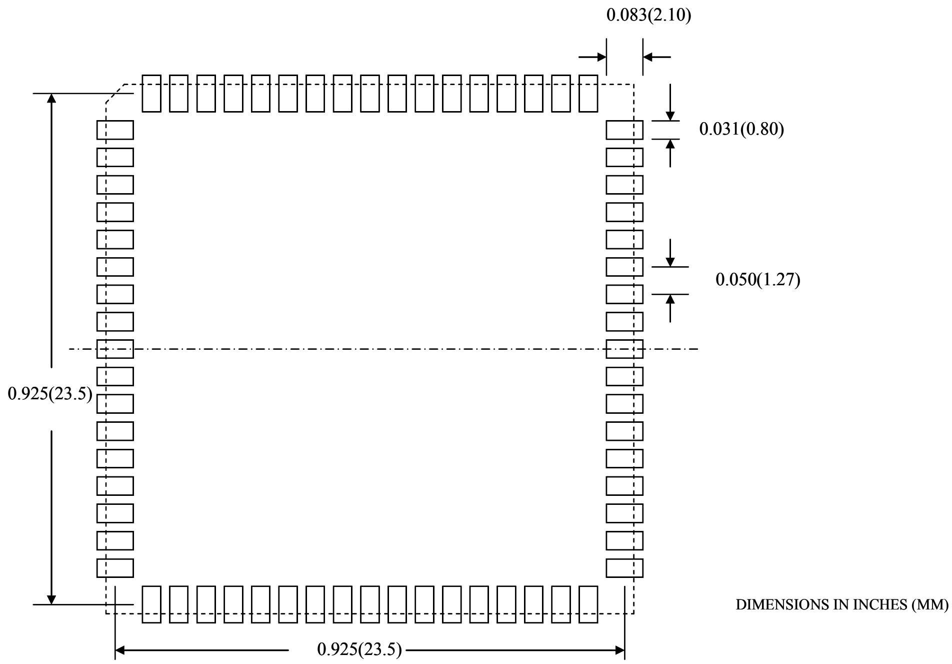


Figure 3-4. Recommended Land Pattern for OEM Edition Module

3.5 Pin-out Description

The 68-pin interface provides a user interface for power and ground, power control of peripheral sensors, ADC inputs for reading sensor outputs, a UART interface, and I2C interface, general purpose digital IO, and others.

Table 3-4. Pin-out description for OEM Edition Module

Pin	Name	Description	Pin	Name	Description
1	GND	Ground	35	GND	Ground
2	PG0	GPIO	36	FLASH_RSTN	Flash Reset
3	PG1	GPIO	37	FLASH_CS	Flash Chip Select
4	PG2	GPIO	38	TC2	GPIO
5	XLT2	External Crystal	39	PG5	GPIO
6	XLT1	External Crystal	40	NC	Not Connected
7	I2C_CLK	I2C Bus Clock	41	NC	Not Connected
8	I2C_DATA	I2C Bus Data	42	GND	RF Ground
9	ONE_WIRE	One Wire	43	RF_OUT	RF Output
10	UART0_RX	UART0 Receive	44	GND	RF Ground
11	UART0_TX	UART0 Transmit	45	TR	NC
12	SPI_CK	SPI Serial Clock	46	NC	Not Connected
13	RSTN	Reset	47	NC	Not Connected
14	USART1_TX	UART1 Transmit	48	NC	Not Connected
15	USART1_RX	UART1 Receive	49	NC	Not Connected
16	USART1_CK	UART1 Clock	50	NC	Not Connected
17	DVCC	Digital Supply	51	AVCC	Analog Supply
18	GND	Ground	52	GND	Ground
19	PW0	GPIO/PWM	53	LED3	Yellow LED
20	PW1	GPIO/PWM	54	LED2	Green LED
21	PW2	GPIO/PWM	55	LED1	Red LED
22	PW3	GPIO/PWM	56	INT7	GPIO
23	PW4	GPIO/PWM	57	INT6	GPIO
24	PW5	GPIO/PWM	58	INT5	GPIO
25	PW6	GPIO/PWM	59	INT4	GPIO
26	PW7	GPIO/PWM	60	ADC7	ADC Channel 7
27	PB4	PWM0	61	ADC6	ADC Channel 6
28	PB5	PWM1A	62	ADC5	ADC Channel 5
29	PB6	PWM1B	63	ADC4	ADC Channel 4
30	PE2	GPIO	64	ADC3	ADC Channel 3
31	PE3	GPIO	65	ADC2	ADC Channel 2
32	PA7	GPIO	66	ADC1	ADC Channel 1
33	PB7	NC	67	ADC0	ADC Channel 0
34	AVCC	Analog Supply	68	DVCC	Digital Supply

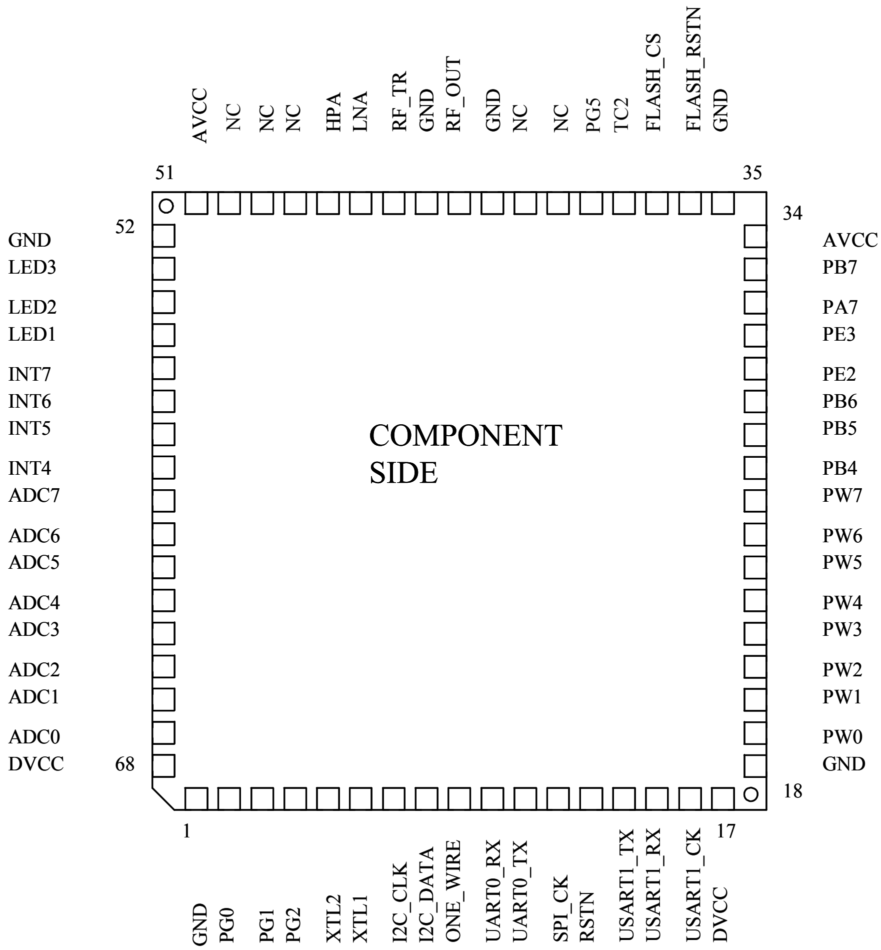


Figure 3-5. Pin-out Diagram for OEM Edition Module

4 IRIS OEM Reference Board

The IRIS OEM reference board is a carrier PCB with the same form factor and functionality as the IRIS family product. It consists of a surface mount module consisting of a processor core and a two-way radio, high density digital interface connector, RF coaxial antenna connector, power supply connection, battery pack connection, power switch, and mounting holes.

4.1 Block Diagram

The block diagram for OEM reference board is provided in Figure 4-1. The detailed schematics and Gerber files are provided in the CD-ROM.

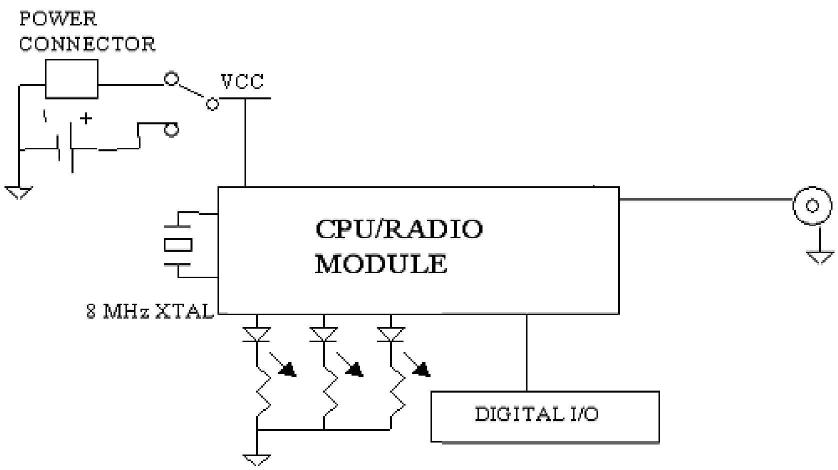


Figure 4-1. Block diagram of the OEM Reference Board

4.2 Layout Considerations

The reference design requires specific support for the module. I/O pins used for communication with peripherals will require pull-up resistors (10kΩ), such as the UART transmit and receive pins. The RF out port must be connected to a 50 ohm trace to the antenna terminal. A ground plane and proper impedance control must be observed for optimum function. No additional RF filtering is necessary for the reference design.

A typical design should include a ground plane under the STAMP to provide a good transition between the 50 ohm RF port and the mating board. Connecting the grounds on both sides of the RF pad is strongly recommended. Using a trace that has almost the same width as the RF pin will also help to minimize impedance mismatch as the RF connection transitions from the module to the board. Provide a ground flood on the surface of the board from the RF ground terminals to the antenna connector where possible, using regularly spaced vias to the ground plane in the area of the copper flood. Provide a clearance region between the flood and the 50 ohm trace that is at least equal to the width of the trace. A good value for the trace width is 37 mils with a dielectric thickness of 20 mils between the trace and the ground plane for FR4 material.

The RF output port is 50 ohm and can be connected directly to a 50 ohm microstrip or 50 ohm coaxial cable. A PI-Matching network is recommended for antenna matching especially when using inner antennas. If the antenna's input impedance is not 50 ohm, please contact antenna vendor and ask for matching network value.

An example of a typical layout is shown in Figure 4-2.

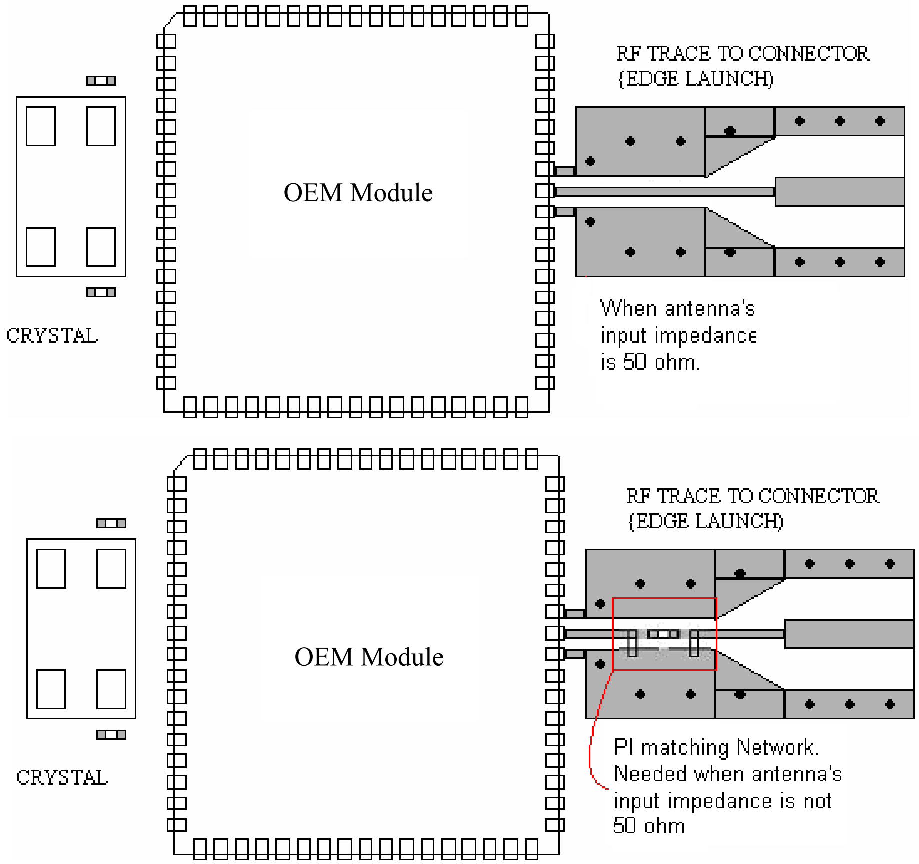


Figure 4-2. An example layout for OEM Edition Module

4.3 Circuit Design Considerations

An external crystal is not required. The unit can be configured to run on the internal RC oscillator, leaving the crystal connections open. If an external crystal is to be used, place the crystal as close to the input pins as possible to reduce parasitics. When selecting capacitors for the crystal, take into account the stray capacitance from the board to the module and adjust accordingly. If an external clock is used, XTL1 (PIN 6) should be used, and XTL2 (PIN 5) should be left open. For proper operation, correct selection of clock fuse options is required.

XTAL1 and XTAL2 are input and output, respectively, of an inverting amplifier which can be configured for use as an On-chip Oscillator, as shown in Figure 4-3. Either a quartz crystal or a ceramic resonator may be used. Normally, a 7.3728 MHz crystal is used for units requiring serial communication. The CKOPT fuse selects between two different Oscillator Amplifier modes.

When CKOPT is programmed, the Oscillator output will oscillate will a full rail-to-rail swing on the output. This mode is suitable when operating in a very noisy environment or when the output from XTAL2 drives a second clock buffer. This mode has a wide frequency range. When CKOPT is unprogrammed, the Oscillator has a smaller output swing. This reduces power consumption considerably. This mode has a limited frequency range and it can not be used to drive other clock buffers.

C1 and C2 should always be equal for both crystals and resonators. The optimal value of the capacitors depends on the crystal or resonator in use, the amount of stray capacitance, and the electromagnetic noise of the environment.

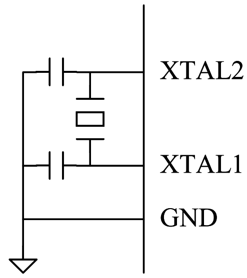


Figure 4-3. Crystal Oscillator Connections

The device has the following clock source options, selectable by Flash fuse bits as shown in Table 4-1. The clock from the selected source is input to the AVR clock generator, and routed to the appropriate modules.

Table 4-1. Device Clocking Options Selection

Device Clocking Option	CKSEL[3..0]
Low Power Crystal Oscillator	1111—1000
Full Swing Crystal Oscillator	0111—0110
Low-Frequency Crystal Oscillator	0101-0100
Internal 128kHz RC Oscillator	0011
Calibrated Internal RC Oscillator	0010
External Clock	0000

Some initial guidelines for choosing capacitors for use with crystals are given in Table 4-2. For ceramic resonators, the capacitor values given by the manufacturer should be used.

Table 4-2. Low Power Crystal Oscillator Operating Modes

CKSEL[3..1]	Freq Range (MHz)	Capacitor Range
100†	0.4 - 0.9	-
101	0.9 – 3.0	12 – 22 pF
110	3.0 – 8.0	12 – 22 pF
111	8.0 – 16.0	12 – 22 pF

† ceramic resonators only

4.3.1 Internal RC Oscillator

The Calibrated Internal RC Oscillator provides a default 8.0 MHz clock. All frequencies are nominal values at 3V and 25°C. This clock may be selected as the system clock by programming the CKSEL fuses as shown in Table 4-3. If selected, it will operate with no external components.

Table 4-3. Internal Calibrated RC Oscillator Operating Modes

CKSEL[3..0]	Nominal Freq Range (MHz)
0010	7.3 – 8.1

4.3.2 System Clock Prescaler

The processor has a system clock prescaler, and the system clock can be divided by setting the "Clock Prescale Register - CLKPR" as shown in Table 4-4. This feature can be used to reduce the system frequency and the power consumption when the requirement for processing power is minimized.

Table 4-4.Clock Prescaler Select

CLKPS[3..0]	Clock Division Factor
0000	1
0001	2
0010	4
0011	8
0100	16
0101	32
0110	64
0111	128
1000	256
1001 – 1111	Reserved

4.3.3 128 kHz Internal Oscillator

The 128 kHz internal Oscillator is a low power Oscillator providing a clock of 128 kHz. The frequency is nominal at 3V and 25℃. This clock maybe selected as the system clock by programming the CKSEL fuses to "11" as show in Table 4-6.

Table 4-5 128 kHz Internal Oscilator Operating Modes

CKSEL[3..0]	Nominal Freq (kHz)
0011	128

More information is available in the datasheet for Atmel's ATmega1281 processor.

4.4 Solder Profile

4.4.1 Hand-soldering

Instructions for Hand Soldering of Crossbow OEM Module are provided below.

Method 1:

1) Pre-tin the surface mount pads on the board the OEM module will be soldered to. Be careful to use an equal amount of solder on each pad.

2) Apply a small amount of flux to the tinned pads.
3) Place the OEM module on the pads, making sure to have the pin one reference markings aligned. Inspect the placement to make sure the OEM module edge contacts are centered on the pads on all four sides.
4) While applying mild pressure to the top of the OEM module (to hold it in position), apply heat from a fine soldering tip to the area of the pre-tinned pad that is exposed at the edge of the OEM module. Reflow only one corner pad first, and verify the OEM module is still positioned correctly on the remaining pads.
5) Using a fine solder tip, reflow each of the pre-tinned pads until the solder flows and makes contact with the pad on the underside of the OEM module.

Method 2:

1) Pre-tin the surface mount pads on the board the OEM module will be soldered to. Be careful to use an equal amount of solder on each pad.
2) Apply a small amount of flux to the tinned pads.
3) Place the OEM module on the pads, making sure to have the pin one reference markings aligned. Inspect the placement to make sure the OEM module edge contacts are centered on the pads on all four sides.
4) While applying mild pressure to the top of the OEM module (to hold it in position), apply heat from a thermal heat gun to the edges of the OEM module until the exposed solder on the pre-tinned pads melts.

4.4.2 Machine Soldering

The recommended solder profile for OEM module is shown in Figure 4-4.

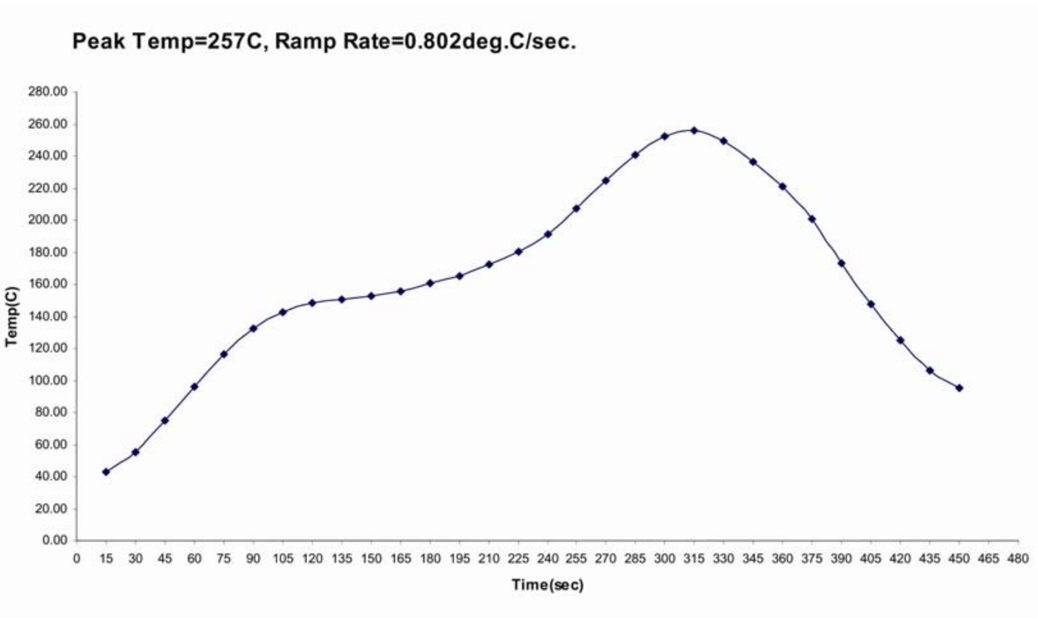


Figure 4-4. Recommended Temperature Profile for OEM Edition Module

4.5 Peripheral Interfaces on OEM Edition Module

The ports available on the OEM Edition module consist of the following:

- UART0
- USART1
- I2C bus
- SPI bus
- ONE-WIRE
- ADC ports
- GPIO

4.5.1 UART0

The UART0 port is a dual function port. It is used in conjunction with the RSTN (active LOW) and SPI_CK lines to program the CPU. The CPU is in program mode if the RSTN line is low, and data is clocked in using the UART0_RX and SPI_CK lines. The RSTN line has an internal 10K pull-up to bring it out of reset when power is applied. When the device is not being programmed, the UART0 port serves as the main communication port to a system controller. An external 10k pull-up resistor is recommended on the UART0_RX and UART0_RX ports to hold the lines in a known state during power-up and reset. The rates supported are a function of the system clock chosen.

☑ EXAMPLE

For standard crystal and resonator frequencies, the most commonly used baud rates for asynchronous operation can be generated by using the UBRR settings as shown in Table 4-4. UBRR values which yield an actual baud rate differing less than 0.5% from the target baud rate, are bold in the table. Higher error ratings are acceptable, but the receiver will have less noise resistance when the error ratings are high, especially for large serial frames. The error values are calculated using the following equation:

$$Error(\%) = \left(\frac{BaudRate_{ClosestMatch}}{BaudRate} - 1 \right) * 100$$

Table 4-4. Oscillator frequency = 7.32826 MHz

Baud Rate (bps)	U2X = 0 UBRR	U2X = 0 ERROR	U2X = 1 UBRR	U2X = 1 ERROR
2400	191	0.0%	383	0.0%
4800	95	0.0%	191	0.0%
9600	47	0.0%	95	0.0%
14.4k	31	0.0%	63	0.0%
19.2k	23	0.0%	47	0.0%
28.8k	15	0.0%	31	0.0%
38.4k	11	0.0%	23	0.0%
57.6k	7	0.0%	15	0.0%
76.8k	5	0.0%	11	0.0%
115.2k	3	0.0%	7	0.0%

4.5.2 UART1

USART1 is a shared interface, used for communication with the on-board serial flash, as well as external serial peripherals. Proper management of the chip select lines (FLASH_CS) is required to avoid port contention. The serial flash also has a reset line (FLASH_RSTN) that can be asserted externally to place the serial flash in a known state. The flash reset line has an internal 10K pull-up resistor to enable the device after power-on. Additional pull-up resistors may be required on the USART1_TX, USART1_RX, and USART_CK lines to avoid unintentional communication with external peripherals during reset or power-on.

4.5.3 I2C

The I2C bus is a two-wire interface that is meant to control I2C peripherals. I2C peripherals usually require an external 5K pull-up to supply power to the port, and use an addressing scheme that is internal to the I2C peripheral. Many of the I2C peripherals have an internal hard-wired portion of their address along with some external address decode lines in the event multiple devices of the same kind are attached to the bus. See the individual vendor datasheets for details.

4.5.4 SPI

The SPI bus is a bidirectional synchronous bus common to many devices available. As it is applied in the OEM Edition module, the SPI bus is dedicated to the radio data interface, and cannot be used for other peripherals. The SPI_CK line is made available to facilitate reprogramming the processor, and should be left in a high impedance state when not in programming mode.

4.5.5 One-Wire

The One-Wire bus is a single wire bidirectional bus used to communicate with the Dallas/Maxim series of One-Wire peripherals. These devices require a 5k resistor to VCC to bias the pin, and accurate timing of signals on the bus for proper communication.

⚠ **WARNING**: The choice of system clock is critical to making this interface work.

4.5.6 ADC Ports

The OEM Edition module features 10-bit successive approximation ADC. The ADC is connected to an 8-channel Analog Multiplexer which allows 8 single-ended voltage inputs. The single ended voltage inputs are reference to 0V (GND). The ADC ports are high impedance inputs to the ADC, used for voltage sampling. The uppermost bits (ADC[4..7]) also support the JTAG interface. The JTAG port can be enabled by choosing that option in the fuse bits for the processor. Choosing the JTAG active option will cause approximately 50k ohms to be applied from the ADC pin to VCC. This setting can affect the accuracy of ADC readings from weak sources.

Table 4-5. JTAG Pin Definitions

PIN	PORT
ADC4	TCK
ADC5	TMS
ADC6	TDO
ADC7	TDI
RSTN	RSTN

The JTAG programming capability supports:

- Flash programming and verifying
- EEPROM programming and verifying
- Fuse programming and verifying
- Lock bit programming and verifying

4.5.7 GPIO

The remainder of the I/O pins is available as GPIO under processor configuration control. All GPIO ports have true Read-Modify-Write functionality when used as general digital I/O ports. This means that the direction of one port pin can be changed without unintentionally changing the direction of any other pin with the SBI and CBI instructions. The same applies when changing drive value (if configured as output) or enabling/disabling of pull-up resistors (if configured as input). They can be left floating if not used, or can be set as inputs with a weak pull-up, outputs set high, or outputs set low.

5 Power

5.1 Battery Power

M2110 is designed for battery power. Any battery combination (AA, AAA, C, D, etc., cells) can be used provided that the output is between 2.7 VDC to 3.6 VDC.

Care should be used in selecting the battery and its capacity to match the energy needs of the motes and their required operating span. Also make sure that the temperature range and associated capacity degradation are looked at prior to deployment.

Table 5-1 below provides some useful guidance on current consumption of various system components.

Table 5-1. Current Requirements for the Motes under Various Operation

Operating Mode	M2110 Current (mA)
ATMega1281V, full operation	6 (7.37 MHz)
ATMega1281V, sleep	0.010
Radio, receive	16
Radio, transmit (1 mW power)	17
Radio, sleep	0.001
Serial flash memory, write	15
Serial flash memory, read	4
Serial flash memory, sleep	0.002

The Table 5-2 below provides some useful guidance on how to predict battery life.

Table 5-2. Estimate of battery life operation for OEM Edition Module

SYSTEM SPECIFICATIONS			
Currents			**Example Duty Cycle**
Processor			
Current (full operation)	6	**mA**	1
Current sleep	10	µA	99
Radio			
Current in receive	16	mA	0.75
Current transmit	17	mA	0.25
Current sleep	1	µA	99
Logger Memory			
Write	15	mA	0
Read	4	mA	0
Sleep	2	µA	100
Sensor Board			
Current (full operation)	5	mA	1
Current sleep	5	µA	99
Computed mA-hr used each hour			
Processor			0.0699
Radio			0.1635
Logger Memory			0.0020
Sensor Board			0.0550
Total current (mA-hr) used			**0.2904**
Computed battery life vs. battery size			
Battery Capacity (mA-hr)			Battery Life (months)
250			1.20
1000			4.78
3000			14.35

NOTE: In most applications, the processor and radio run for a brief period of time, followed by a sleep cycle. During sleep, current consumption is in the micro-amps as opposed to milli-amps. This results in very low-current draw the majority of the time, and short duration spikes while processing, receiving, and transmitting data. This method extends battery life; however, due to the current surges, it reduces specified battery capacity. Battery capacity is typically specified by the manufacturer for a constant nominal current drawn.

6 Radios

6.1 M2110

The radio used by the M2110 is an IEEE 802.15.4 compliant RF transceiver designed for low-power and low-voltage wireless applications. It uses Atmel's AT86RF230 radio that employs O-QPSK ("Offset Quadrature Phase Shift Keying") with half sine pulse shaping. The 802.15.4 radio includes a DSSS (digital direct sequence spread spectrum) baseband modem providing a spreading gain of 9 dB and an effective data rate of 250 kbps. The radio is a highly integrated solution for wireless communication in the 2.4 GHz unlicensed ISM band. It complies with worldwide regulations covered by ETSI EN 300 328 and EN 300 440 class 2 (Europe), FCC CFR47 Part 15 (US) and ARIB STD-T66 (Japan).

6.1.1 Radio RF Channel Selection

The M2110's Atmel radio can be tuned within the IEEE 802.15.4 channels that are numbered from 11 (2.405 GHz) to 26 (2.480 GHz) each separated by 5 MHz.

6.1.2 Radio Transmission Power

RF transmission power is programmable from 3 dBm to –17.2 dBm. Lower transmission power can be advantageous by reducing interference and dropping radio power consumption.

Table 6-1. Atmel® AT86RF230 Output Power Settings

RF Power (dBm)	Power Register (code)
3.0	0
2.6	1
2.1	2
1.6	3
1.1	4
0.5	5
-0.2	6
-1.2	7
-2.2	8
-3.2	9
-4.2	10
-5.2	11
-7.2	12
-9.2	13
-12.2	14
-17.2	15

The RF received signal strength indication (RSSI) is read directly from the AT86RF230 Radio and sent with every radio packet received.

7 Antennas

7.1 Radio/Antenna Considerations

An antenna facilitates the transfer the reception of RF energy to and from free space. Care should be taken in the antenna choice or design so it provides proper coverage for the environment expected. Good antenna design is the most critical factor in obtaining good range and stable throughput in a wireless application. This is especially true in *low power RF transceivers* and *compact antenna* designs, where antenna space is less than optimal. However, several compact, cost efficient, and very effective options exist for implementing integrated antennas.

To obtain the desired performance, it is required that users have at least a basic knowledge about how antennas function, and the design parameters involved. These parameters include selecting the correct antenna, antenna tuning, matching, gain/loss, and knowing the required radiation pattern. Refer to the "*Antenna Design Considerations*" application note to understand antenna basics, and aid in selecting the right compact antenna solution for the application.

Care should be taken to provide an antenna that provides proper coverage for the environment expected. Range and performance are strongly affected by choice of antenna and antenna placement within the environment. In addition, care must be taken to ensure compliance with FCC article 15 regulations for intentional radiators. Because of its small physical size, the usual antenna chosen is a length of insulated wire one-quarter wavelength long for the frequency of interest. This type of antenna is often called a *monopole* antenna, and its gain is ground plane dependent.

There are literally hundreds of antenna designs, but to simplify the default antenna for the OEM reference board, an insulated wire attached to a right handed MMCX RF connector is used. The length of the wire is one-quarter wavelength of an RF signal 2.4 GHz. This type of antenna is often called a quarter wave whip monopole. Antenna lengths for the different radio frequencies are provided in Table 7-1**.**

Table 7-1. Antenna lengths for quarter wavelength whip antennas

Model	Whip Antenna Length (inches)
M2110 (2.4 GHz)	1.2

Third-party or custom made antennas can also be used by attaching them to the MMCX connector. For making your own antenna, the part numbers of the MMCX mating connectors are shown in Table 7-2 and Table 7-3. These can be purchased from Digi-Key. There are two manufacturers—Johnson Components and Hirose Electric Ltd. The mating connectors come in straight and right angle. They also support two different standard varieties of coaxial cable—RG178 /U and RG 316/U. There are also other vendors who sell MMCX to SMA conversion cables.

Table 7-2. Hirose MMCX connectors

Type	Coax	Digi-Key PN	Hirose PN
Straight Plug	RG178/U	H3224-ND	MMCX-J-178B/U
Right Angle	RG178/U	H3221-ND	MMCX-LP-178B/U
Right Angle	RG316/U	H3222-ND	MMCX-LP-316/U

Table 7-3. Johnson Components' MMCX mating connectors*

Type	Coax	Digi-Key PN	Johnson PN
Straight Plug	RG178/U	J589-ND	135-3402-001
Straight Plug	RG316/U	J590-ND	135-3403-001
Right Angle	RG178/U	J593-ND	135-3402-101
Right Angle	RG316/U	J594-ND	135-3403-101
Right Angle	RG 316 DS	J595-ND	135-3404-101

*These connectors require the following hand crimp and die set (Digi-Key part # / Johnson part #): a) Hand crimp (J572-ND / 140-0000-952), b) Die (JD604-ND / 140-0000-953).

There are literally hundreds of antenna options offered by different vendors and some references are provided below:

- Linx Technologies: http://www.linxtechnologies.com/
- Nearson: http://www.nearson.com/

These antennas are terminated in a coax pigtail, and must have an appropriate connector installed. They also function best with a ground plane installed, as shown in Figure 7-1. . The ground plane can be a layer of aluminum or copper tape attached to the lid of a plastic enclosure, or the lid of a metal enclosure.

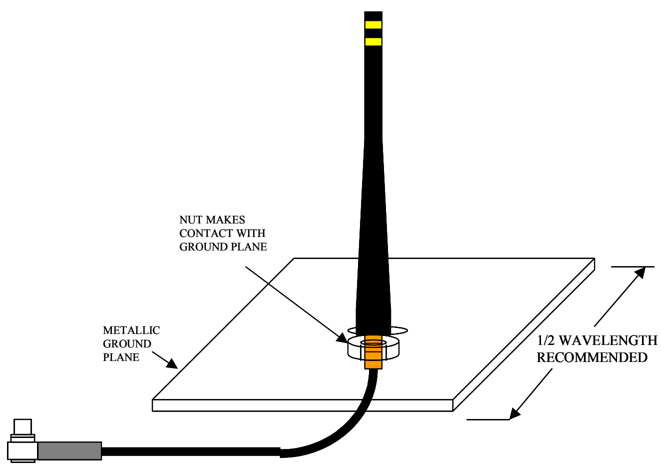


Figure 7-1. Illustration of an antenna option for the motes using a Linx antenna and ground plane

The OEM Edition module is well suited for embedded antenna designs. Proper care must be taken in the design phase to account for packaging effects due to the enclosure, metallic parts adjacent to the antenna, and placement on the PCB. In addition, the final application and expected performance should be evaluated for suitable antenna choice. For an example of embedded antenna design, Refer to the application note on "*Antenna Design Considerations*".

8 Flash Data Logger and Serial ID Chip

All OEM Edition Modules feature a 512 k serial flash for storing data, measurements, and other user-defined information. It is connected to one of the USART on the ATmega1281V. This chip is supported in *MoteWorks* which uses this chip as micro file system. The serial flash device supports over 100,000 measurement readings. This chip is also used for *XOtap* (Over the Air Programming) services available in *MoteWorks*.

> **NOTE:** This device consumes 15 mA of current when writing data.

The OEM Edition modules also have a 64-bit serial ID chip.

9 Atmega1281 Fuses

The ATMega1281V processor on the OEM edition modules has many programmable fuses to control various parameters. Refer to Atmel's technical information for the ATMega1281V for a complete discussion of the fuses. There are two fuses that *MoteWorks* users should be aware of as setting these fuses incorrectly will cause the unit to not operate correctly.

9.1 JTAG fuse

This fuse enables users to use the Atmel JTAG pod for in-circuit code debugging. Units are shipped with JTAG enabled. As discussed in the previous section on battery voltage monitoring, if JTAG is enabled, it will cause inaccurate measurements on ADC channel 7.

9.2 Using UISP to set fuses

The UISP utility used to download code to the OEM edition modules via a programming board can also be used to set and unset fuses of the Atmel® ATMega1281.

Table 9-1. UISP Commands for Setting the ATMega1281's Fuses

Action	Command
Disable JTAG fuse	**uisp -dprog=<*programmer*> --wr_fuse_h=0xd9**
Enable JTAG fuse	**uisp -dprog=<*programmer*> --wr_fuse_h=0x19**
Enable native 128 mode	**uisp -dprog=<*programmer*> --wr_fuse_e=0xff**
Use internal clock	**uisp -dprog=<*programmer*> --wr_fuse_l=0xc2**
Use external clock	**uisp -dprog=<*programmer*> --wr_fuse_l=0xff**

<*programmer*> is the device you are using to interface to the Mote from a computer. The current options are **dapa** (for an MIB500), **mib510** for a MIB510; and **EPRB** for a MIB600.

Users can also edit the file called *profile* in the ***cygwin/etc/*** directory and enter an alias. One example is this alias to disable the JTAG fuse:

```
alias fuse_dis="uisp -dprog=<programmer> --wr_fuse_h=0xd9"
```

Therefore, when `fuse_dis` and is entered into a Cygwin command line, the script will be executed.

10 Sensor Boards & Expansion Connectors

Crossbow supplies a variety of sensor and data acquisition boards for the Motes. This Chapter describes the connectors and the functions of the pins for the MICA family sensor boards.

10.1 Sensor Board Compatibility via Expansion Connector

Connection to the MICA family sensor boards is made by a 51-pin connector (see Figure 10-1 below).

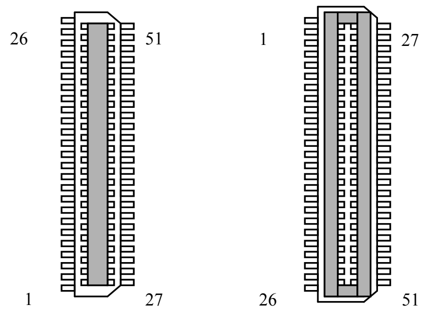


Figure 10-1.The 51-pin connector used on the MICA family sensor boards;

(Left: Female; Right: Male)

The expansion connector provides a user interface for sensor boards and base stations. The connector includes interfaces for power and ground, power control of peripheral sensors, ADC inputs for reading sensor outputs, UART interfaces, and I2C interface, general-purpose digital IO, and others. The part numbers of the expansion connectors are shown in Table 10-1. These can be purchased from Digi-Key.

Table 10-1. 51-pin expansion connectors

Type	Digi-Key PN	Hirose PN
Female	H2175-ND	DF-51P-1V(54)
Male	H2163-ND	DF9-51S-1V(54)

11 USB Programming Pod

The MIB520 based programming pod provides USB connectivity to the OEM Edition modules for communication and in-system programming. It supplies power to the devices through USB bus of the PC.

Figure 11-1. Picture of Programming Pod

11.1 ISP

The MIB520 programming pod has an on-board in-system processor (ISP) to program the Motes. Code is downloaded to the ISP through the USB port. Next the ISP programs the code into the Mote.

11.2 Mote Programming Using the MIB520

Programming the Motes requires having *MoteWorks* environment installed in your host PC. The OEM Edition modules connect to the MIB520 via the 10-pin adapter that connects to USB port of the host PC.

11.3 MIB520 USB Drivers

MIB520 uses FTDI FT2232C to use USB port as virtual COM port. Hence you need to install FT2232C VCP drivers. These drivers are available in the *MoteWorks* CD and instructions are provided in Section 2.1.2.

11.4 Power

The MIB520 is powered by the USB bus of the host.

11.5 USB Interface

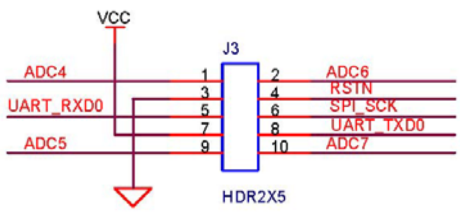
The MIB520 offers two separate ports: one dedicated to in-system Mote programming and a second for data communication over USB.

Table 11-1. Pin outs for USB Connection

Pin No.	Name	Description
1	VBUS	Powered Supply Pin
2	USBDM	USB Data Signal Minus
3	USBDP	USB Data Signal Plus
4	GND	Ground Supply Pin

11.6 Programming Interface

The programming interface provided by MIB520 debug pod is via 10-pin connector. The pin-out details for this connector are provided in Table 11-2.



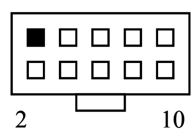


Table 11-2. Pin outs for programming connector

Pin No.	Name
1	ADC4
2	ADC6
3	GND
4	RSTN
5	UART_RXD0
6	SPI_SCK
7	VCC
8	UART_TXD0
9	ADC5
10	ADC7

When OEM customers layout their boards, it is a good idea to provide this 10-pin mating interface to facilitate the programming of OEM edition modules. The part numbers for the mating header/receptacle are shown in Table 11-3. These can be purchased from Digi-Key.

Table 11-3. 10-pin mating header/receptacle

Type	Digi-Key PN	AMP PN
Male	A26267-ND	103308-1

The MIB520 debug pod is also provided with 10-pin to 51-pin adapter to facilitate the connectivity to Crossbow's MICA family processor/radio and sensor boards.

12 Appendix A. Warranty and Support Information

12.1 Customer Service

As a Crossbow Technology customer you have access to product support services, which include:

- Single-point return service
- Web-based support service
- Same day troubleshooting assistance
- Worldwide Crossbow representation
- Onsite and factory training available
- Preventative maintenance and repair programs
- Installation assistance available

12.2 Contact Directory

United States: Phone: 1-408-965-3300 (8 AM to 5 PM PST)

Fax: 1-408-324-4840 (24 hours)

Email: techsupport@xbow.com

Non-U.S.: refer to website www.xbow.com

12.3 Return Procedure

12.3.1 Authorization

Before returning any equipment, please contact Crossbow to obtain a Returned Material Authorization number (RMA).

Be ready to provide the following information when requesting a RMA:

- Name
- Address
- Telephone, Fax, Email
- Equipment Model Number
- Equipment Serial Number
- Installation Date
- Failure Date
- Fault Description

12.3.2 Identification and Protection

If the equipment is to be shipped to Crossbow for service or repair, please attach a tag TO THE EQUIPMENT, as well as the shipping container(s), identifying the owner. Also indicate the service or repair required, the problems encountered and other information considered valuable to the service facility such as the list of information provided to request the RMA number.

Place the equipment in the original shipping container(s), making sure there is adequate packing around all sides of the equipment. If the original shipping containers were discarded, use heavy boxes with adequate padding and protection.

12.3.3 Sealing the Container

Seal the shipping container(s) with heavy tape or metal bands strong enough to handle the weight of the equipment and the container.

12.3.4 Marking

Please write the words, "***FRAGILE, DELICATE INSTRUMENT***" in several places on the outside of the shipping container(s). In all correspondence, please refer to the equipment by the model number, the serial number, and the RMA number.

12.3.5 Return Shipping Address

Use the following address for all returned products:

Crossbow Technology, Inc.
4145 N. First Street
San Jose, CA 95134
Attn: RMA Number (XXXXXX)

12.4 Warranty

The Crossbow product warranty is one year from date of shipment.

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FCC COMPLIANCE STATEMENT:

The following statement applies to M2110 OEM module:

To ensure compliance with FCC RF exposure requirements, the antenna used for this device must be installed to provide a separation distance of at least 20cm from all persons and must not be co-located or operating in conjunction with any other antenna or radio transmitter. Installers and end-users must follow the installation instructions provided in this user guide.

The device complies with part 15 of the FCC rules and RSS-210. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

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

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

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

This device has been designed to operate with the antennas listed below: Pulse Tecnitrol company, OMNI 2dBi antenna (Model: W1030) and Crossbow, Whip 0dBi antenna (Model: Whip). and having a maximum gain of 2 dB. Antennas not included in this list or having a gain greater than 2 dB are strictly prohibited for use with this device. The required antenna impedance is 50 ohms.

This Class B digital apparatus complies with Canadian ICES-003

Cet appareil numérique de la classe B est conforme à la norme NMB-003 du Canada.

Crossbow Technology, Inc.
4145 N. First Street
San Jose, CA 95134
Phone: 408.965.3300
Fax: 408.324.4840
Email: info@xbow.com