

# LAB: Using Digi International's XBee Modules

## Data Acquisition

### Acknowledgements

Subject Matter Expert: Jesus Casas, Austin Community College:

### Purpose

The purpose of this resource is to introduce the instructor to Digi International's XBee wireless modules; and to provide the instructor with several working examples of data being transmitted and received using these modules.

### Systems Rationale

In years past, data was transmitted wirelessly through simple schemes such as On-Off-Keying (OOK) or Frequency Shift Keying (FSK). And the frequencies employed then were in the KHz and MHz range which required sizeable hardware. Today, wireless data is transmitted using protocols which ensures data is received completely and error free. Current wireless modules operate in the MHz and GHz range making their hardware footprints smaller than ever before. The size reduction and their construction require that these modules be looked at as a system instead of discrete components working together to make a transmitter/receiver.

### System Concepts

This system covers the following system concepts (signified by an X):

- S1. A system can be defined in terms of its functional blocks i.e., a "structured functional unit."
- S2. A system has a purpose, transforms inputs into outputs to achieve a goal.
- S3. A system is defined by the flow of materials, energy and information, between its functional units.
- S4. A system may be open or closed. In an open system additional inputs are accepted from the environment.
- S5. A system is more than the sum of its parts. Individual components can never constitute a system.
- S6. A system provides feedback to the operator and services to the user. Some system functions may involve operator action.
- S7. Systems have unique problems.

### Learning Outcomes

Appropriate SLOs for the lab activity are below. For a complete list of course SLOs visit: [http://www.esyst.org/Courses/Communications/\\_delivery/index.php](http://www.esyst.org/Courses/Communications/_delivery/index.php)

### Electronics Communications

2. Identify the electromagnetic frequency spectrum and name the major frequency bands and examples of applications in each.
5. Explain the relationship between the serial data rate and the bandwidth needed to pass it without error. Define the Shannon theory.

15. Name the most common short range wireless technologies (Bluetooth, Wi-Fi, ZigBee/802.15.4, UWB, ISM band, etc.) and state a common application for each.
18. Define WAN, MAN, LAN and PAN and give an example of each.

## LABORATORY

5. Demonstrate the use of at least one short range radio technology.

## Prerequisite Knowledge & Skills

The instructor should have a general understanding of digital IO, modems using the Hayes AT command set, and the RS232 protocol.

## Learning Objectives

Relevant knowledge (K) or skill (S) student learning outcomes include:

- K1.** Familiarity with the 802.15.4 standard and an application thereof.
- K2.** Familiarity with RF module parameters and configuration.
- S1.** To identify specific data from a transmission packet.

## Process Overview

This instructor resource consists of three goals:

1. Set up two XBee modules to communicate with each other via two PCs.
2. Configure an XBee module to transmit the status of several input pins and configure another XBee module to receive their status.
3. Configure an XBee module to perform A/D conversion on one of its analog inputs and transmit the data to a receiving XBee module that is connected to a PC. The PC will use National Instruments LabView to view the A/D data.

## Instructional Setting

This lab has been designed to take place in an electronics lab which has PCs running Windows XP.

## Time Needed

### Instructor Setup/Cleanup:

The instructor classroom setup time is minimal. Ten minutes should be enough time to set out the modules and cables.

### Student Lab Performance:

It should take students approximately one and a half hours to work through the steps found in this guide.

### Student Lab Deliverables:

The student deliverables are to demonstrate the XBees communicating with each other.

## Materials, Equipment, & Supplies Needed

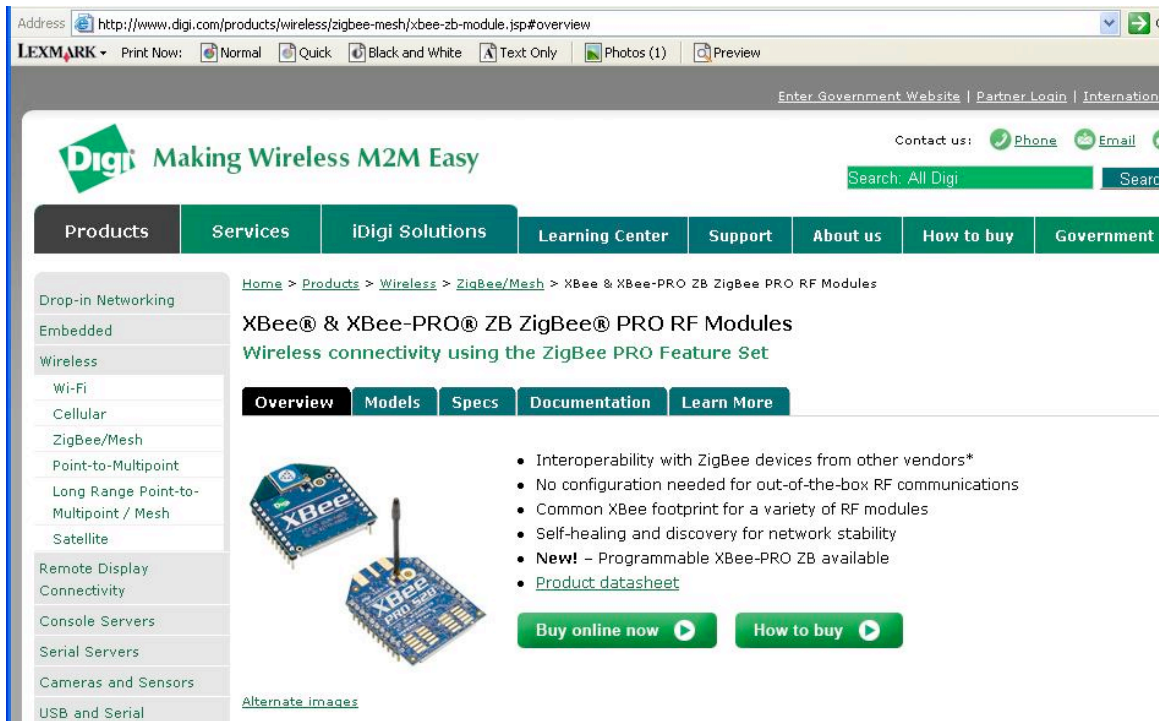
Item	Quantity
XBee Explorer Regulated sku: WRL-09132 (www.sparkfun.com)	2
XBee Explorer USB sku: WRL-08687 (www.sparkfun.com)	2
XBee 1mW Chip Antenna sku: WRL-08664 or XBee Pro 60mW Chip Antenna sku: WRL-08690 (www.sparkfun.com)	2
USB miniB Cable - 6 Foot sku: CAB-00598 (www.sparkfun.com)	2
PC running Windows XP (with Internet access)	2
National Instruments LabView (version 7.1 or higher)	1
100 KOhm Potentiometer	1
220 Ohm Resistor	4
Momentary Normally-Open Switches	4
LED	4

## Special Safety Requirements

There are no special safety requirements.

## Lab Preparation

1. Download and read the documentation for the XBee modules. These can be found at [www.digi.com](http://www.digi.com). The following is a picture of the webpage where they can be found:



2. Download the X-CTU software from [www.sparkfun.com](http://www.sparkfun.com). The following picture is of the webpage containing the link. This software can also be downloaded from

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### XBee Explorer USB

sku: WRL-08687

**Description:** This is a simple to use, USB to serial base unit for the XBee line. This unit works with all XBee modules including the Series 1 and Series 2.5, standard and Pro version. Plug the unit into the XBee Explorer, attach a mini USB cable, and you will have direct access to the serial and programming pins on the XBee unit.

You get the red board only. XBee modules and USB cable sold below.

Add a couple **XBees**, and a **Regulated Explorer** and you've got a great gift for that special electronics geek! For more gift ideas check out our **SparkFun Gift Guide!**

**Documents:**

- [Schematic](#)
- [X-CTU Software](#)
- [USB FTDI Drivers for Windows, Linux, Mac](#)


**\$24.95** price

\$22.46 10-99 (10% off)


\$19.96 100+ (20% off)

1 quantity

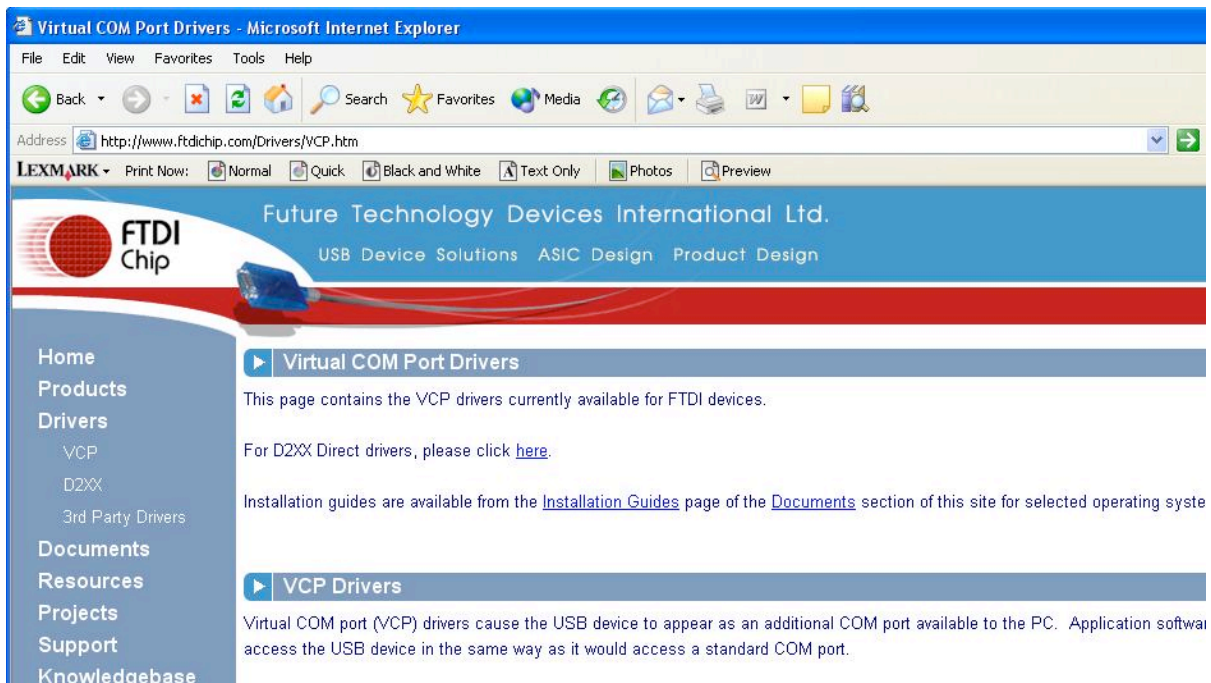
**add to cart**



click on image to enlarge



- Download the USB FTDI drivers for Windows. Use the link in the above picture to get to the FTDI webpage. Download the Microsoft WHQL certified Virtual Com Port driver (ver 2.06.00). The following picture is of the FTDI website:



## Overview

The XBee Series 1 and XBee Pro are very popular 2.4 GHz modules from Digi International (formally Maxstream). These modules employ the 802.15.4 stack (the basis for Zigbee). The modules are configured using a simple serial command set such

as that used on modems. The interface is an asynchronous serial port. As such, parameters such as baud rate, parity, and number of bits must be set between two communicating modules. The modules also have the added functionality of being assigned individual addresses such that they will only communicate as a matched pair, for example. Point-to-point and multi-point communications are supported.

The XBee modules come in different antenna configurations and strength. The modules (XBee Series 1 and XBee Pro) are interchangeable, meaning that they can be swapped out for one another without having to change any code.

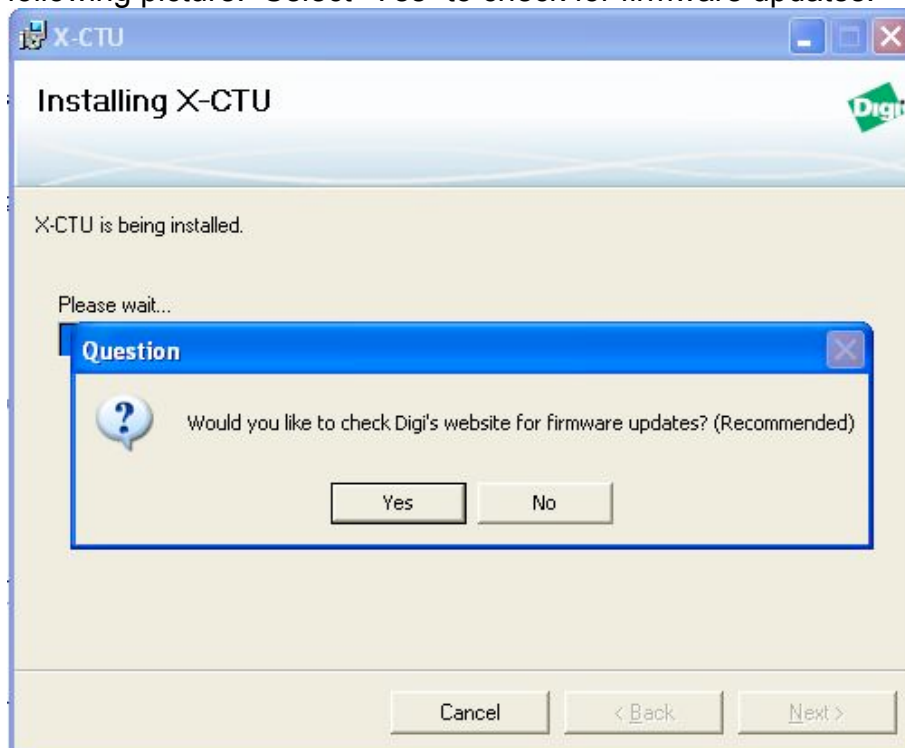
Depending on the module, up to a one mile range line-of-sight can be had. The modules offer a maximum data rate of 250 kbps, six 10-bit ADC inputs, eight digital IO pins, and include 128-bit encryption.

### Quick Tips

Do not upgrade the firmware unless you absolutely have to. If the XBee module works fine for your application, do not get tempted to upgrade the firmware just for the sake of it. Making a mistake in selecting the correct firmware version may render your XBee module useless.

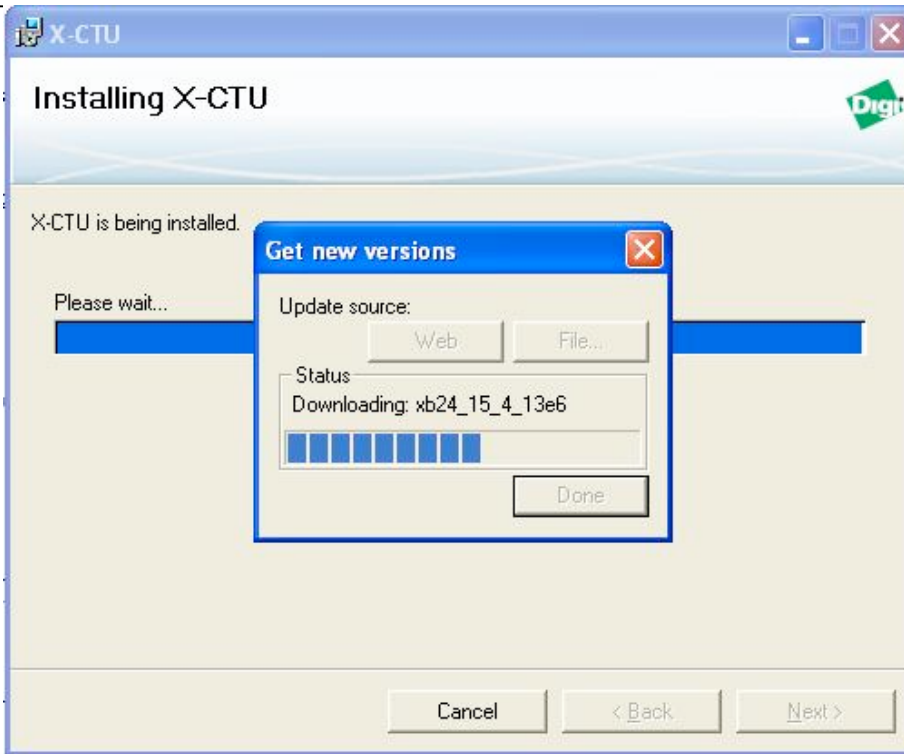
### Installing X-CTU

1. Run the X-CTU install executable. Soon you will be prompted as shown in the following picture. Select “Yes” to check for firmware updates.

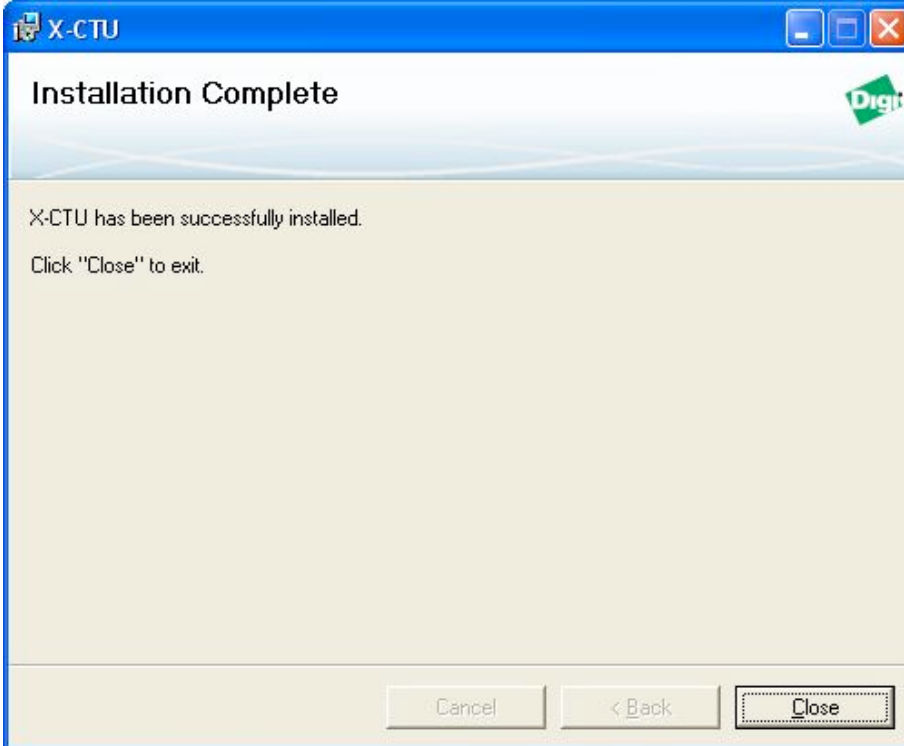


2. The downloading of the firmware updates will commence as shown in the following picture:





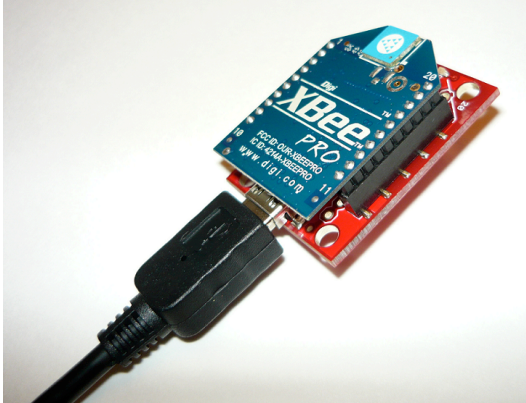
3. Once the install is complete the following screen should be shown:



4. Install X-CTU on the other Windows PC.

## Connecting the Hardware and Installing the USB Drivers

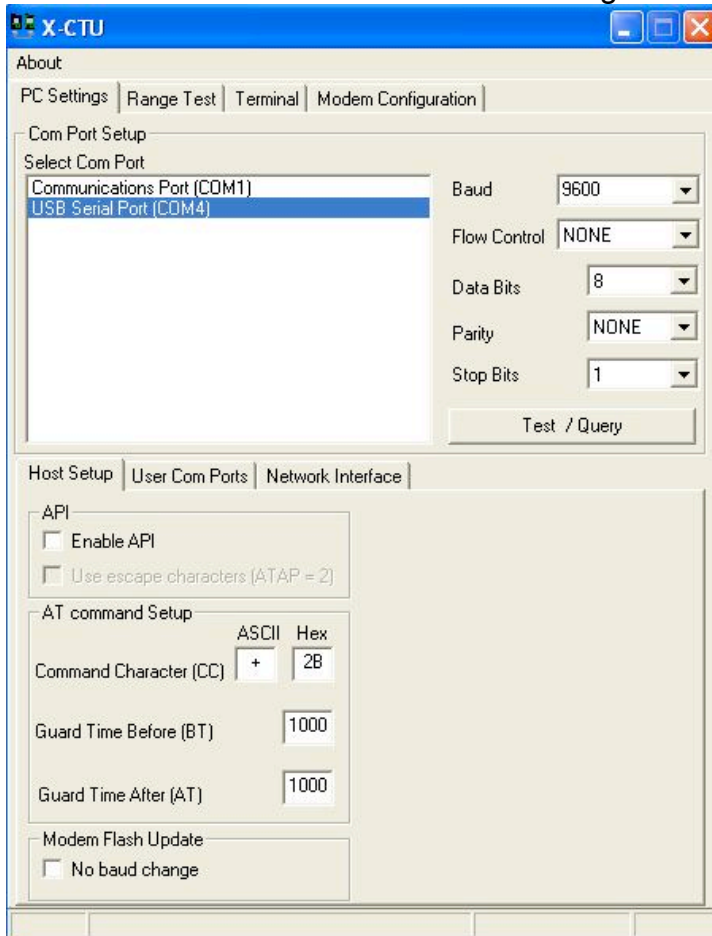
1. Insert the XBee module onto the USB Explorer. Then connect the USB cable to the USB Explorer and the other end to an available USB port on one of the PCs. The following is a picture of an XBee Pro module installed on a USB Explorer.



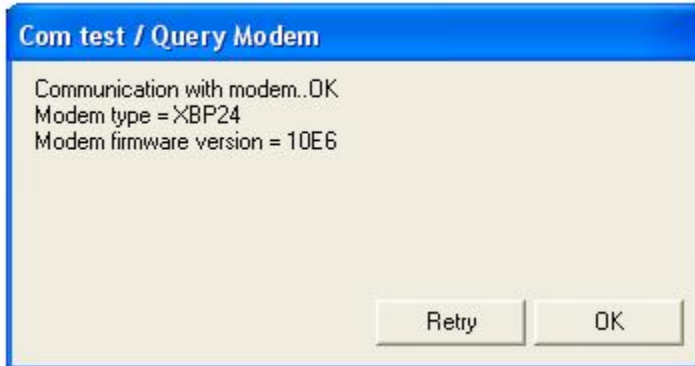
2. When the USB Explorer is connected to the PC, the Windows OS will “ask” for the Virtual Com Port drivers. Install them at this time.

## Using X-CTU to View/Change/Restore the Configuration Settings

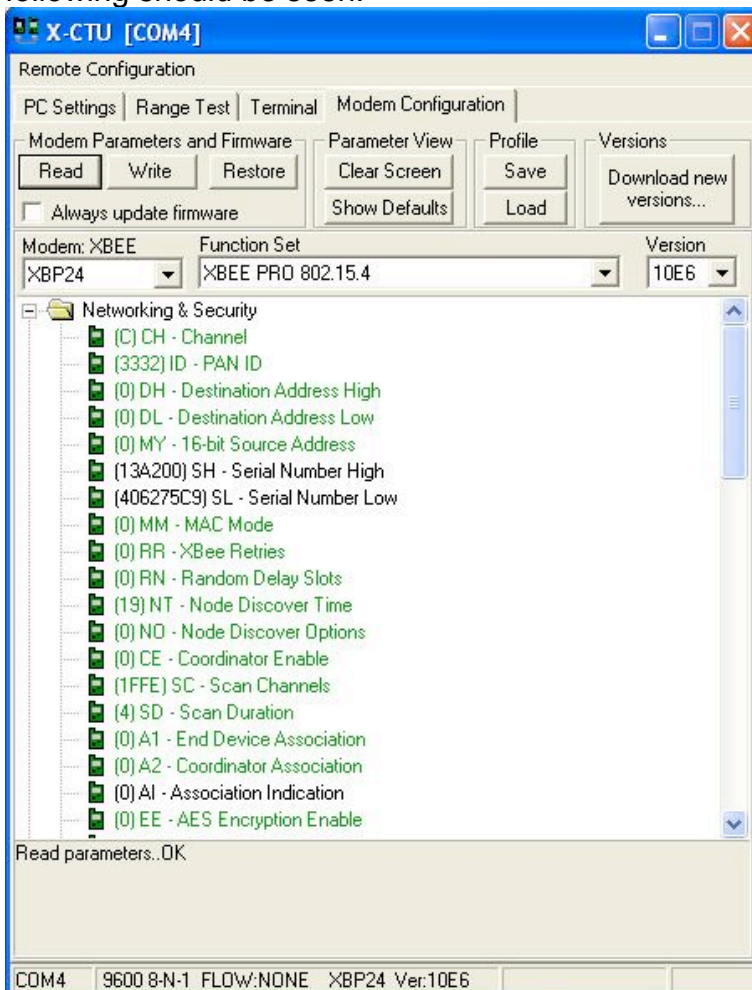
1. Run the X-CTU software. The following window should appear:



2. Select the Virtual Com Port which the USB Explorer is using. Since the default communication settings of the XBee modules is 9600 Baud, Flow Control is None, 8 data bits, no parity, and 1 stop bit; ensure that X-CTU settings are the same. Then “click” on Test/Query button. If there is success in communication between the PC and the XBee module, a window stating this success will be display. This window will also provide the modem type and firmware version.



3. Next, click on the Modem Configuration tab; and then under the Modem Parameters and Firmware, click on the Read button. This discovers the attached XBee module and displays its current configuration. A window such as the following should be seen:





From this window the XBee module's settings can be changed and also restored to default condition. Since the XBee modules are new and are factory configured to operate right out of the box, there should be no need to restore or make any changes. This default configuration allows communication between all and any XBee series 1 and XBee Pro 802.15.4 modules.

### Using X-CTU and the XBee Modules to Communicate Between Two PCs

1. Set up two PCs each with one XBee module.
2. Run X-CTU on both PCs.
3. Ensure that both XBee modules are on the same settings. If the modules are still in their defaults settings, they should communicate without any changes. Click on the Terminal tab. Anything typed into the terminal should be received at the other PC and vice versa. The following window shows data transmitted in blue and data received in red.

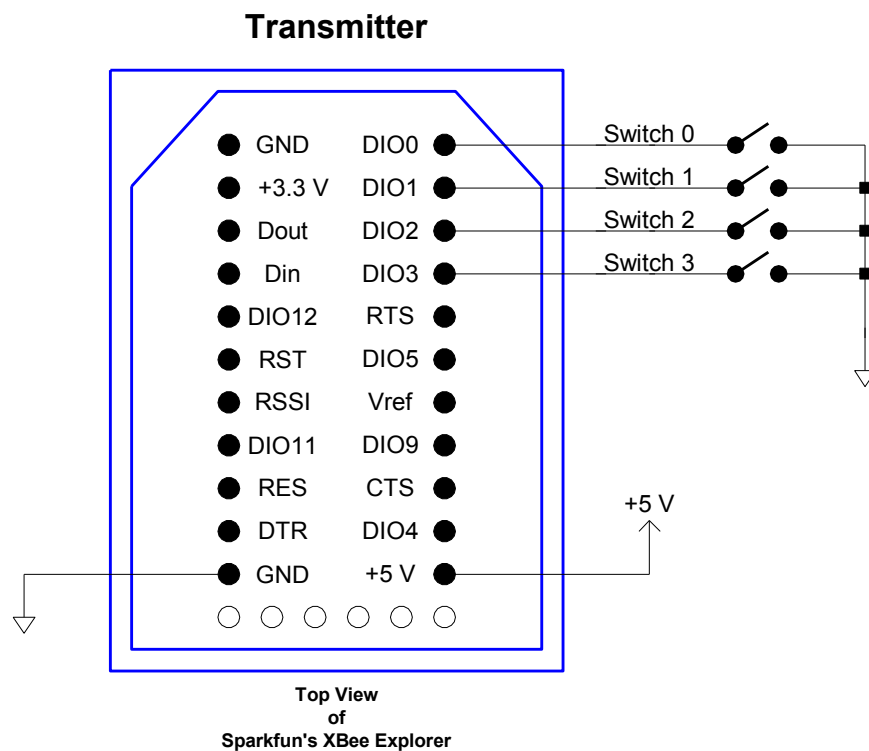


4. Communication between the two PCs can also be performed using Windows HyperTerminal.

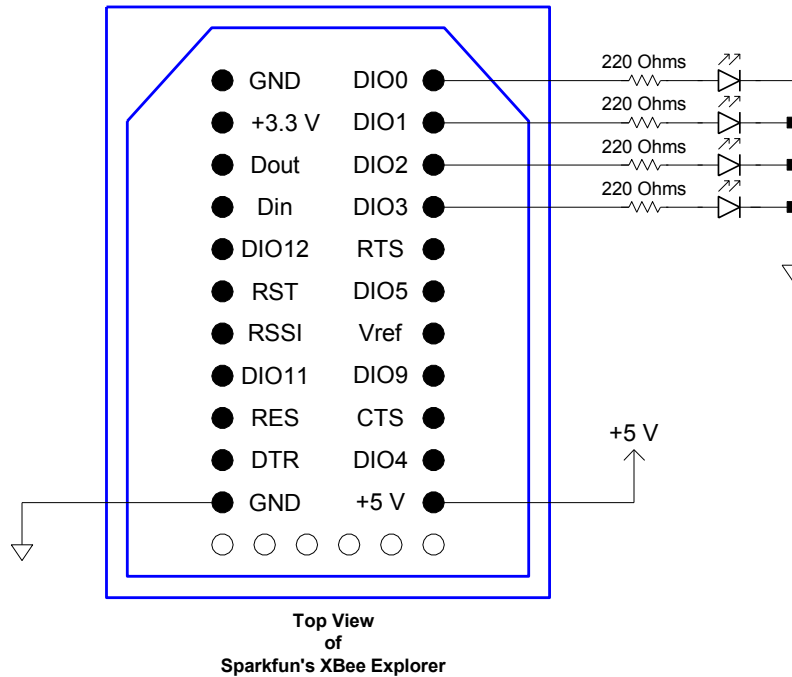
### Performing Digital Input/Output Line Passing

In addition to transmitting serial UART data, XBee Series 1 modules have the ability to pass individual digital signals on its DIO pins. The XBee has eight usable DIO lines that can be used to pass digital signals between two XBee modules without additional hardware. The input lines on the transmitter module are mapped to the output lines on the receiver module. For example, if DIO1 is used to transfer digital data, DIO1 on the transmitter would be configured as an input; and on the receiver DIO1 would be configured as an output.

The following hardware diagrams (transmitter and receiver) are for a simple 4-line digital transfer system. The transmitter uses the XBee’s DIO internal pull-up resistors to allow a simple switch to send either a “high” or “low”. On the receiver, LED indicators are placed at the associated output pins.



### Receiver



### XBee Configuration for a Simple 4-line Digital Transfer System

To set up a digital input/output line passing system, two XBee modules need to be configured. One module needs to be configured to accept the digital signal input and then transmit it; while the other module needs to be configured to receive the signal and output it.

Using the X-CTU software, restore both units to their default settings. Even if the units are new, restoring them will ensure your units are at their default settings. This can be done under the Modem Configuration tab by clicking on “Restore” in the Modem Parameters and Firmware box. Once restored, the configuration can begin. After the configuration for a module has been done, click on “Write” in the Modem Parameters and Firmware box to program the module with the new settings.

Designate one of the XBee modules as the transmitter and make the following changes to its configuration:

#### Transmitter

1. Change the power to the lowest setting. This should be adequate for transmissions within the same room and draws approximately 65mA.
2. DIO3 needs to be set as an input (3-DI).
3. DIO2 needs to be set as an input (3-DI).
4. DIO1 needs to be set as an input (3-DI).
5. DIO0 needs to be set as an input (3-DI).
6. I/O Output Enable needs to be disabled. This turns off the UARTs output since it is not needed to do line passing.
7. DIO Change Detect needs to be changed from 0 to FF. This configures the transmitter to transmit if a change is detected on any of its DIO pins.

Designate another XBee module as the receiver and make the following changes to its configuration:

### **Receiver**

1. Change the power to the lowest setting. Even though this module is designated as a receiver, it still transmits to communicate with other XBees. This should be adequate for communications within the same room.
2. Pull-up Resistor Enable needs to be set to E1. This disables the pull-up resistors from being used on DIO0, DIO1, DIO2, and DIO3 since they will be used as outputs to drive the LEDs.
3. DIO3 needs to be set at either DO Low or DO High. Which one to choose depends on what the default output state should be before data is received.
4. DIO2 needs to be set at either DO Low or DO High. Which one to choose depends on what the default output state should be before data is received.
5. DIO1 needs to be set at either DO Low or DO High. Which one to choose depends on what the default output state should be before data is received.
6. DIO0 needs to be set at either DO Low or DO High. Which one to choose depends on what the default output state should be before data is received.
7. I/O Output Enable needs to be disabled. This turns off the UARTs output since it is not needed to do line passing.
8. IA-I/O Input Address needs to be changed to FFFF. This configures the XBee to receive transmission from any other XBee. Since only two XBees are being used, this setting is adequate.

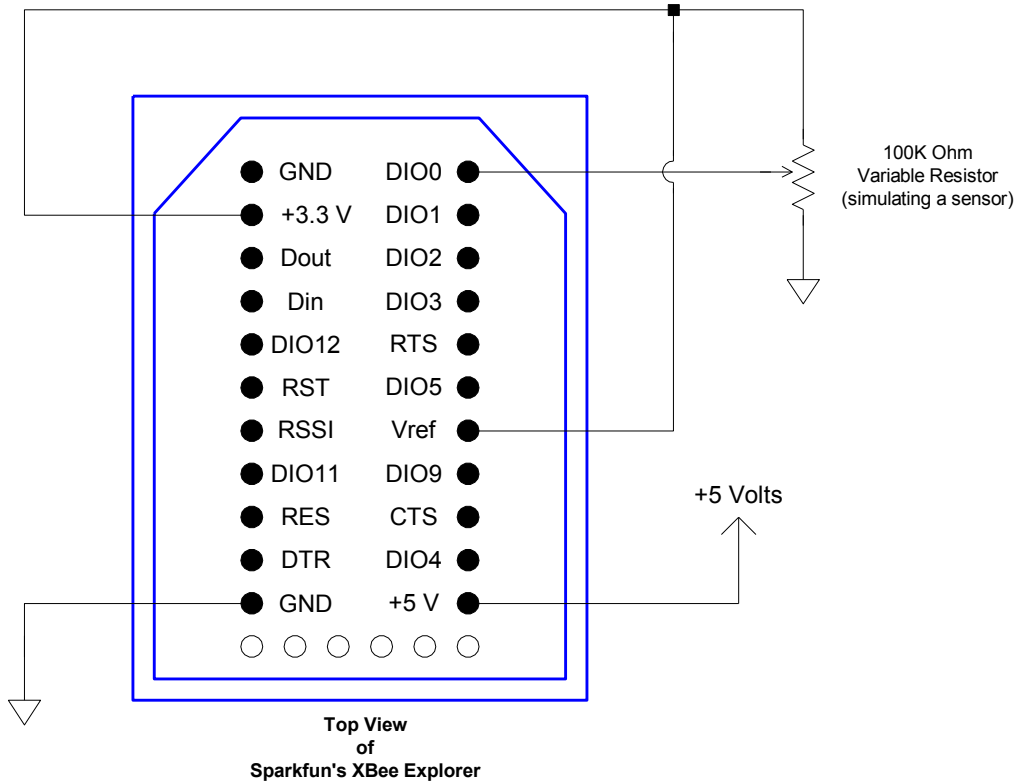
Assemble the transmitter and receiver pair and verify that the I/O transfer system is working as specified.

### **A/D Conversion using XBee Modules**

XBee modules have on-board A/D functionality. The A/D features 10-bit resolution and a sampling rate up to 1000 samples per second. Input analog voltage should not exceed 3.3 Volts. A/D conversion can be done on the following pins: AD0, AD1, AD2, AD3, AD4, and AD5. The A/D channel data is presented as an unsigned 10-bit value right-justified on a 16-bit boundary.

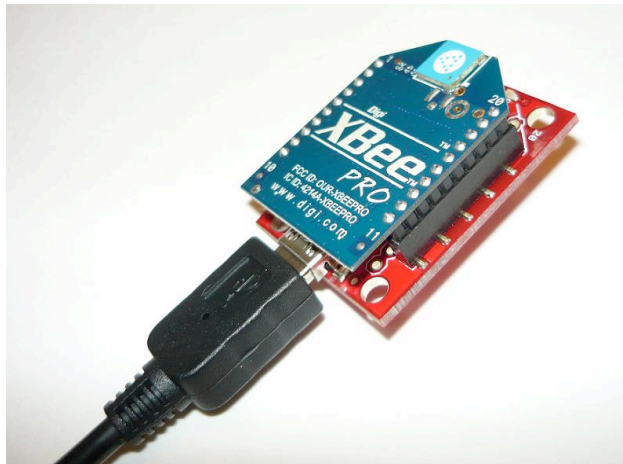
The objective for this section is to configure an XBee module for A/D conversion on AD0 at a sampling rate of 2 samples per second. The A/D data will then be inserted into a transmission packet and transmitted. The receiving XBee module will then receive the packet and output it over its UART. The outputted packet will then be viewed on a PC using National Instruments LabView.

### The Transmitter A/D Circuit



Sparkfun's XBee Explorer has an on-board 3.3 Volt voltage regulator which supplies power to the XBee module itself and also supplies the 3.3 Volts needed for the Vref of the A/D. A 100K Ohm potentiometer will provide the analog sample voltage and is able to be varied between 0 Volts and 3.3 Volts. A sensor configured to output a signal of 0 thru 3.3 Volts can be substituted for the 100K Ohm potentiometer.

### The Receiver Circuit



The receiver circuit is an XBee module plugged into a Sparkfun USB Explorer which is connected to a PC running National Instruments' LabView data acquisition software.



## **XBee Configuration for A/D Conversion**

To set up an A/D transmission system, two XBee modules need to be configured. One XBee module needs to be configured to perform A/D conversions at one of its inputs and then transmit the results; while another XBee module needs to be configured to receive the transmitted data and output it.

Using the X-CTU software, restore both units to their default settings. This can be done under the Modem Configuration tab by clicking on “Restore” in the Modem Parameters and Firmware box. Once restored, the configuration can begin. After the configuration for a module has been done, click on “Write” in the Modem Parameters and Firmware box to program the module with the new settings.

Designate one of the XBee modules as the transmitter and make the following changes to its configuration:

### **Transmitter**

1. Power Level to Lowest. This is done because most likely the transmitter and receiver XBee modules will be in the same room, therefore full RF power is not needed for this short distance.
2. DIO0 to ADC. The analog sampling will be done at DIO0.
3. IR-Sample Rate to 1F4. The hexadecimal value placed here will be the number of milliseconds between samples. 1F4 hex is 500 in decimal. Therefore a sample will be taken every 500 ms for a sample rate of 2 samples per second.

Designate another XBee module as the receiver and make the following changes to its configuration:

### **Receiver**

1. Power Level to Lowest.

## **Viewing the A/D Results using LabView**

The A/D results are transmitted in a 14 byte packet. The receiver module receives the packet and sends it out in its entirety through its UART. The A/D results are bytes 12 and 13, with the 12<sup>th</sup> being the Most Significant Byte (MSB) and the 13<sup>th</sup> being the Least Significant Byte (LSB). The XBee’s UART is connected to the PC via an FTDI USB converter chip which can be accessed through the virtual com port driver.

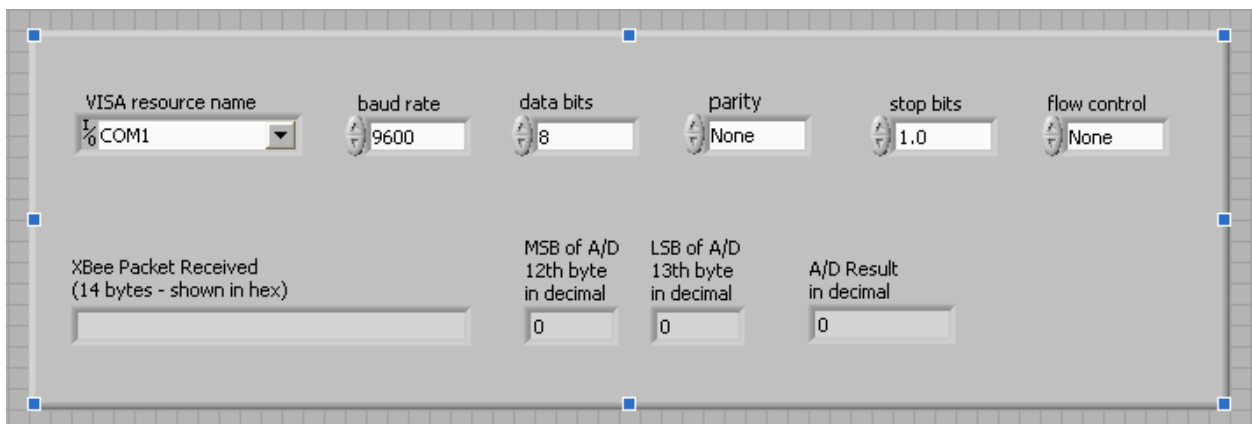
Included with this resource are three LabView VI programs.

The first program (XBee\_string\_view.vi) allows the viewing of the entire 14 byte packet being received. The following is a view of the front panel:

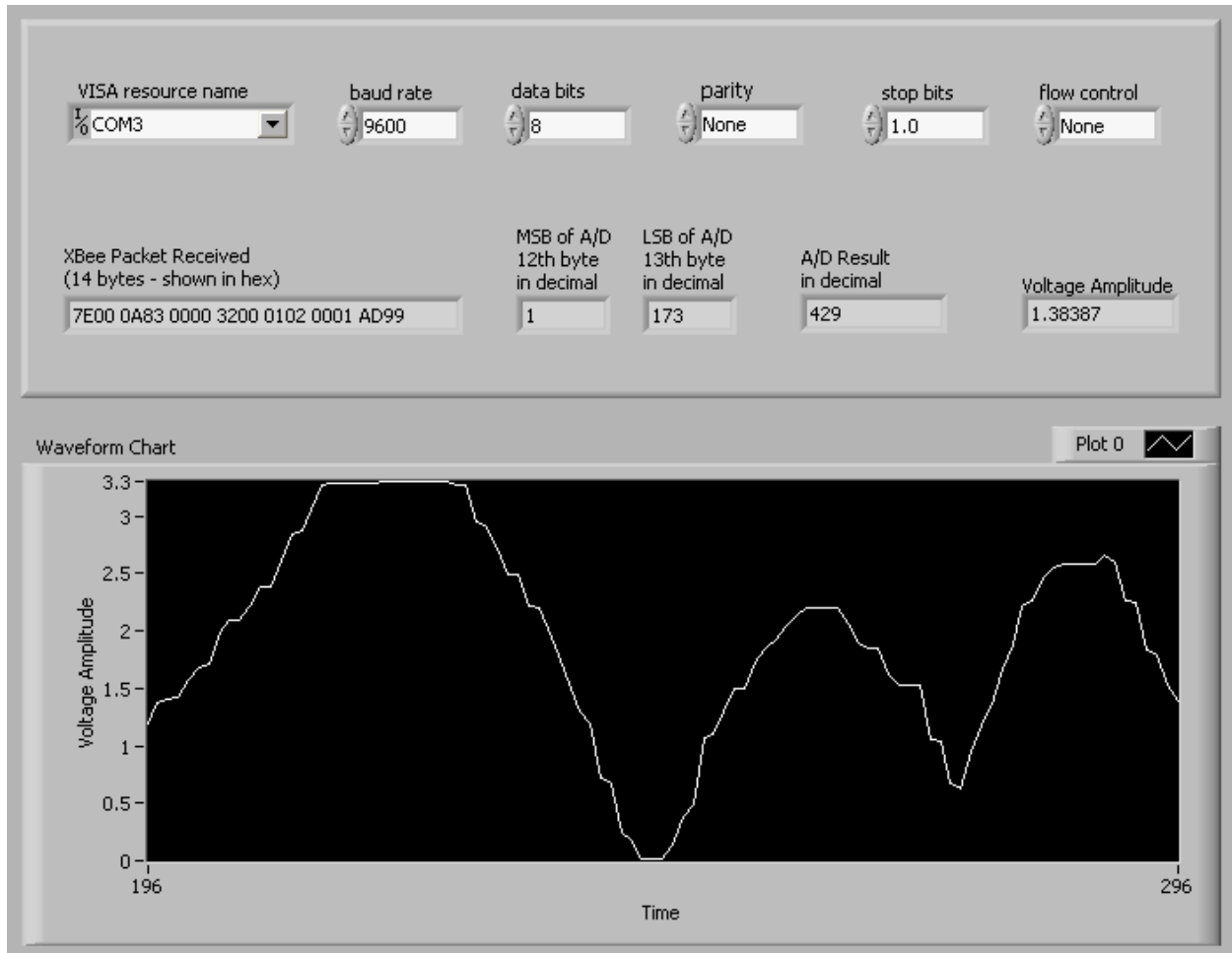


Use this program to identify the bytes that comprise the A/D results.

The second program (XBee\_msb\_lsb.vi) extracts the bytes that make up the A/D results and displays them separately and also as a decimal value. The range of the decimal value is from 0 to 1023. The following is a view of the front panel:



The third and last program (XBee\_voltage\_graphical.vi) adds a graphical view to the voltage amplitude represented by the A/D date. Since the A/D has 10 bits of resolution and the input voltage span is 0 thru 3.3 Volts, each bit therefore represents a voltage of 3.225806 milliVolts. The following is a view of the front panel:



### Summary

This instructor resource is provided as a means to reduce development time for labs employing the XBee modules.

### Assessment & Grading

It is left up to the instructor to decide as to how students' learning will be assessed and how this activity is graded.