Wireless Communication

GT Off-Road Racing | Data Acquisition

Andrew Hellrigel

10/05/2021

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# 1.0 Overview

## 1.1 Introduction

The purpose of this documentation is to serve as an introduction in to the setup that we use for wireless communication and how to configure and test the XBEE’s.

# 2.0 XBEE Configuration

## 2.1 XBEE Types

### 2.1.1 XBEE 3 Pro

<https://www.digi.com/products/embedded-systems/digi-xbee/rf-modules/2-4-ghz-rf-modules/xbee3-zigbee-3>

A close-up of a computer chip

Description automatically generated with medium confidence

The XBEE 3 Pro was the first XBEE that we used on our team for wireless communication. Through our tests we found that we could get about a half a mile range before we started having problems with packet loss (Although we don’t have much experience in RF so this could probably be optimized).

### 2.1.2 XBEE Pro S3B

<https://www.digi.com/products/embedded-systems/digi-xbee/rf-modules/sub-1-ghz-rf-modules/xbee-pro-xsc>

**A picture containing text, electronics, circuit

Description automatically generated**

The XBEE Pro S3B is a more advanced RF radio module. It theoretically can operate up to 9 miles, but we really only need it to work at a range of about a mile without packet loss. It uses 1W of power which is more than the XBEE 3 Pro, but that is how it is able to reach such long ranges.

### 2.1.3 Antenna Selection

The most important thing in choosing an antenna is to make sure that it matches the frequency of the XBEE. For the XBEE Pro S3B this means that the antenna should be rated for 900MHz. The other important factor in choosing an antenna is the dBi rating of the antenna. More research needs to be done on what this number actually means for our application but a higher number doesn’t necessarily mean that it is a better antenna.

## 2.2 XBEE Wiring

### 2.2.1 XBEE Pinout

The pinout for each device can be found in the respective datasheet.

XBEE 3 Pro: <https://www.digi.com/resources/documentation/digidocs/pdfs/90001543.pdf>

XBEE Pro S3B: <https://www.digi.com/resources/documentation/digidocs/pdfs/90002173.pdf>

### 2.2.2 XBEE Important Connections

There are only 4 pins that need to be connected for the XBEE communication to work.

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 1.** XBEE pin connections | | | |
| Pin Name | Pin # | [Teensy 4.x Pin #](https://www.pjrc.com/store/teensy40_pins.html) | Connection |
| VCC | 1 | 3.3V | Connect this to 3.3V (The XBEE is **not** 5V compatible) |
| DOUT | 2 | 7 (RX2) | Connect this to a Teensy’s RX pin |
| DIN | 3 | 8 (TX2) | Connect this to a Teensy’s TX pin |
| GND | 10 | GND | Connect this to GND |

Diagram, schematic

Description automatically generated

### 2.2.3 Connection Standards

It is standard to put the XBEE on Serial2 so that the embedded software for wireless communication can be consistent between designs. These connections can be seen in table 1. Note that some older designs may have the XBEE connection on Serial1.

### 2.2.4 PCB Layout

When designing the PCB layout for an XBEE it is important to remember that there will be an antenna or antenna wire coming out of the top of the XBEE. Also, in general, it is a good idea to use female headers so that the XBEE can be unplugged and plugged back in. XBEEs aren’t cheap (~$30 for XBEE 3 Pro and ~$50 for XBEE Pro S3B) so it is convenient to be able to reuse them for newer designs. Note that the pitch spacing is not the same as standard headers. In the past our team has used these headers: <https://www.digikey.com/en/products/detail/sullins-connector-solutions/NPPN101BFCN-RC/804812>.

## 2.3 XCTU

### 2.3.1 XCTU Installation and XBEE Connection

XCTU is the software that is used to update firmware for the XBEE’s and set the configuration of the XBEEs.

The installation for XCTU can be found here: <https://hub.digi.com/support/products/xctu/>

More information about XCTU can be found in this Sparkfun tutorial for configuring XBEE’s. <https://learn.sparkfun.com/tutorials/exploring-xbees-and-xctu/all>

Graphical user interface, text, application

Description automatically generated

This is the first page of the XCTU software. To connect to an XBEE, select the “Add Devices” button in the top left corner of the application. For this software to be able to find the XBEE, it has to be plugged into your computer through an XBEE explorer. <https://www.sparkfun.com/products/11812?_ga=2.31523646.1807256704.1633483130-1997756260.1628974791>

You will need to select the COM port that the XBEE is connected to and you will need to select the baud rate to be able to talk to the XBEE. If the XBEE has been configured previously, the baud rate will most likely be set at “230400”. Otherwise, it will probably be set at “9600”.

The XBEE explorer uses and FTDI chip so if you can’t find the XBEE for some reason you may need to install an FTDI driver. <https://learn.sparkfun.com/tutorials/how-to-install-ftdi-drivers>

### 2.3.2 XBEE 3 Pro Firmware

Once the XBEE shows up in the left pane, you can click on it to access the settings for that XBEE. If it doesn’t have the correct firmware on it or it needs a firmware update, that can be done by clicking the “Update” button.

Graphical user interface

Description automatically generated

We have been using the 802.15.4 TH protocol for communications which has been good for point-to-point communication. If we need something more advanced, we may need to look into a different protocol such as Zigbee. Select this protocol after hitting the “update” button, and then select the most recent version to be uploaded to the XBEE. This process might take a couple of minutes to complete.

### 2.3.3 XBEE 3 Pro Settings

Below are the settings that need to be changed for the XBEE’s to be able to communicate with each other. I will give example settings for two XBEE’s that will be able to talk to each other.

|  |  |  |
| --- | --- | --- |
| **Table 2.** XBEE 1 Settings | | |
| Parameter | Value | Notes |
| ID | 1998 | This tells the XBEE what network to communicate on. This number must be the same for all XBEE’s that want to communicate with each other. 1998 is an arbitrary value that we have chosen as the standard for our team. |
| MY | 1 | This is the individual ID of the XBEE. The XBEE will receive all messages sent to this address and it should probably be unique for each XBEE. |
| DL | 2 | This is the address of the ID that the XBEE will send message to. |
| BD | 115200 | This sets the baud rate for the XBEE. |

|  |  |  |
| --- | --- | --- |
| **Table 3.** XBEE 2 Settings | | |
| Parameter | Value | Notes |
| ID | 1998 | This tells the XBEE what network to communicate on. This number must be the same for all XBEE’s that want to communicate with each other. 1998 is an arbitrary value that we have chosen as the standard for our team. |
| MY | 2 | This is the individual ID of the XBEE. The XBEE will receive all messages sent to this address and it should probably be unique for each XBEE. |
| DL | 1 | This is the address of the ID that the XBEE will send message to. |
| BD | 115200 | This sets the baud rate for the XBEE. |

Once these settings have been changed, make sure to click the “Write” button so that the changes get saved to the XBEE.

### 2.3.4 XBEE Pro S3B Firmware and Settings

Unlike the XBEE 3 Pro, the XBEE Pro S3B should come with the correct firmware, however the settings will need to be changed so that they can communicate with each other.

Edit: For achieving longer ranges, the firmware can be changed to a lower sending frequency (goes from 200kbps to 10kbps but should get about double the range. This can be done by clicking the update button, selecting XBP9B as the product family, and choosing the newest version. In 10kbps mode, the data coming in is delayed significantly and comes in staggered, so it’s not ideal if enough range can be achieved in 200kbps mode.

|  |  |  |
| --- | --- | --- |
| **Table 4.** XBEE 1 Settings | | |
| Parameter | Value | Notes |
| ID | 1998 | This tells the XBEE what network to communicate on. This number must be the same for all XBEE’s that want to communicate with each other. 1998 is an arbitrary value that we have chosen as the standard for our team. |
| DH | 13A200 | This should match the serial number high (SH) of the XBEE that this device wants to communicate with. All XBEE Pro S3B devices should have the same SH so this number should be the same on all of them. |
| DL | xxxxxxxx | This should match the serial number low (SL) of the XBEE that this device wants to communicate with. All XBEE Pro S3B devices should have a different SL so this number should be unique for all of them. |
| BD | 230400 (or 9600 in 10kbps mode) | This sets the baud rate for the XBEE. |

|  |  |  |
| --- | --- | --- |
| **Table 5.** XBEE 2 Settings | | |
| Parameter | Value | Notes |
| ID | 1998 | This tells the XBEE what network to communicate on. This number must be the same for all XBEE’s that want to communicate with each other. 1998 is an arbitrary value that we have chosen as the standard for our team. |
| DH | 13A200 | This should match the serial number high (SH) of the XBEE that this device wants to communicate with. All XBEE Pro S3B devices should have the same SH so this number should be the same on all of them. |
| DL | xxxxxxxx | This should match the serial number low (SL) of the XBEE that this device wants to communicate with. All XBEE Pro S3B devices should have a different SL so this number should be unique for all of them. |
| BD | 230400 (or 9600 in 10kbps mode) | This sets the baud rate for the XBEE. |

# 3.0 Testing

## 3.1 Testing with XCTU

Graphical user interface, text

Description automatically generated

Graphical user interface

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To test if the XBEE’s are working, the terminal function on XCTU can be used. The two pictures above show how to access the terminal. Once the terminal, anything can be typed into the console log to send it out over the RF link to the other XBEE. Anything that gets received by the XBEE will also show up on the console log. Two people can use the terminal function with XCTU to test if the communication is set up properly, or a simple Arduino test that passes through UART data to the serial monitor will also work.

## 3.2 Wireless Comms Chatter

## 3.3 Ping / Latency Test

# 4.0 Recommended Parts

|  |  |  |
| --- | --- | --- |
| Part Description | Link | Cost |
| XBEE 3 Pro | <https://www.sparkfun.com/products/15131> | $28.95 |
| XBEE Pro S3B | <https://www.digikey.com/en/products/detail/digi/XBP9B-DMST-002/3594157?WT.z_cid=ref_neda_dkc_buynow_digiintl&utm_source=ecia&utm_medium=aggregator&utm_campaign=digiintl> | $51.30 |
| 10 pos XBEE female headers | <https://www.digikey.com/en/products/detail/sullins-connector-solutions/NPPN101BFCN-RC/804812> | $0.98 |
| XBEE Explorer (for programming) | <https://www.sparkfun.com/products/11812?_ga=2.31523646.1807256704.1633483130-1997756260.1628974791> | $25.95 |
| XBEE Breakout Board | <https://www.sparkfun.com/products/8276> | $2.95 |
| Antenna Extension Wire | <https://www.amazon.com/Nisaea-Extension-Connecting-Extender-Equipment/dp/B07FZZS55F/ref=sr_1_1_sspa?gclid=Cj0KCQjwjOrtBRCcARIsAEq4rW4JC4wVKCsRs-09NLoCoQTOHUcMIC7AiQ2UsJ7xYFBj9IRwFUftkb8aAu-YEALw_wcB&hvadid=174224730184&hvdev=c&hvlocphy=9010932&hvnetw=g&hvpos=1t3&hvqmt=e&hvrand=4207401236651672309&hvtargid=kwd-5269083698&hydadcr=19133_9441234&keywords=rp-sma+extension+cable&qid=1572567489&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExTk9GUDA5NjFWTjNXJmVuY3J5cHRlZElkPUEwMTg0NjA0WEJITVBITlczSVRNJmVuY3J5cHRlZEFkSWQ9QTA0ODYyMTgxMk1TNE9LWjBJSDgyJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==> | $5.59 |
| 915 MHz Antenna | <https://www.amazon.com/dp/B07WC75PNZ/ref=sspa_dk_detail_0?psc=1&pd_rd_i=B07WC75PNZ&pd_rd_w=o0cho&pf_rd_p=887084a2-5c34-4113-a4f8-b7947847c308&pd_rd_wg=bwHJD&pf_rd_r=9904HW42C811R2MREC0W&pd_rd_r=a8da8e88-bcec-4e44-ad89-39f7fda186da&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUE3T0lSVk1PRzBPQ1gmZW5jcnlwdGVkSWQ9QTAyNjU1OTMzOVBGVEtIUDNNRUpQJmVuY3J5cHRlZEFkSWQ9QTA4MzkxMjgzUFI4QlpNN1MxNFRPJndpZGdldE5hbWU9c3BfZGV0YWlsJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==> | $9.99 |

# 5.0 Revision History

10/05/2021 (Andrew Hellrigel) – Created the documentation for our wireless communication standards.

11/05/2021 (Andrew Hellrigel) – Added settings and configuration for the XBEE Pro S3B.

06/04/2022 (Andrew Hellrigel) – Added settings for XBEE Pro S3B 10kbps mode.