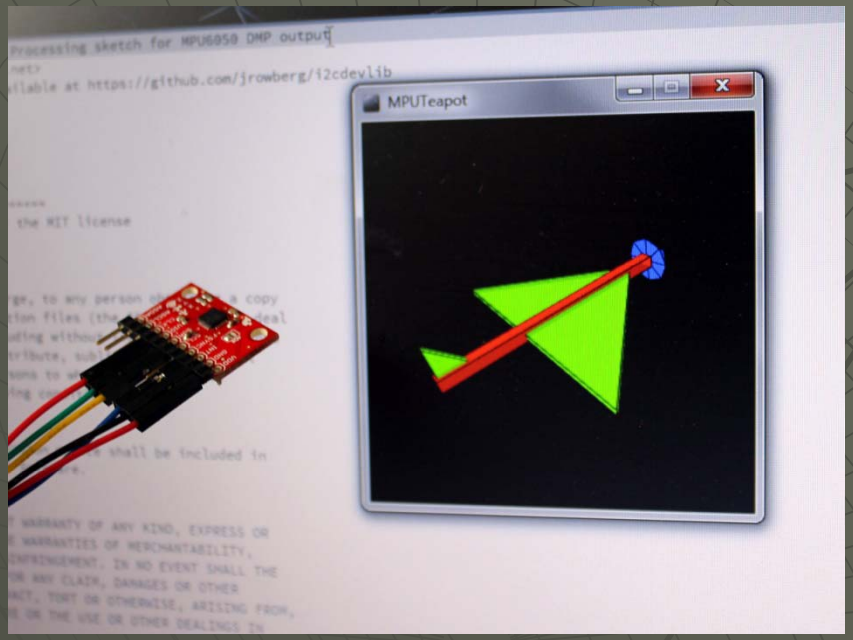
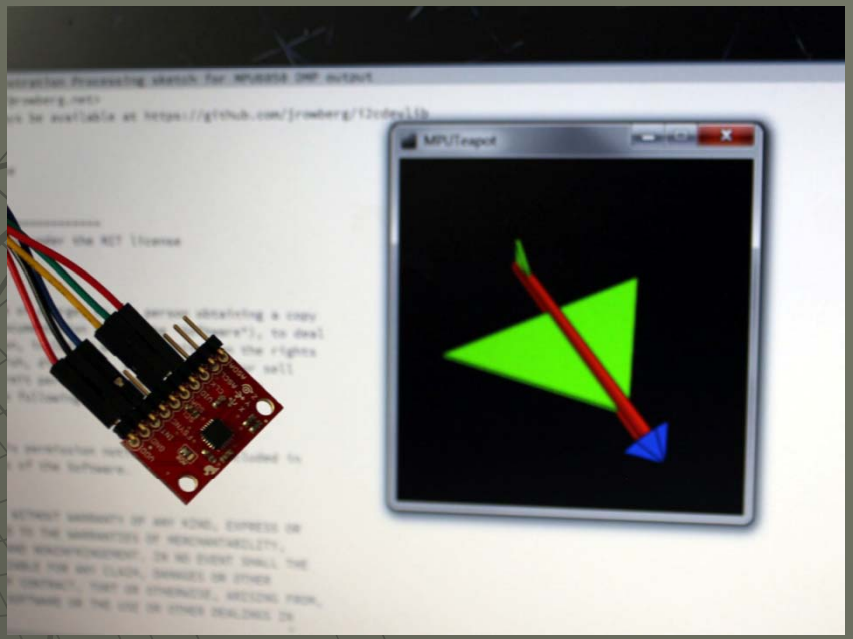
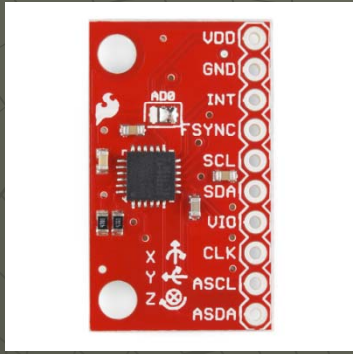
Triple Axis Accelerometer-Gyro with Arduino Uno

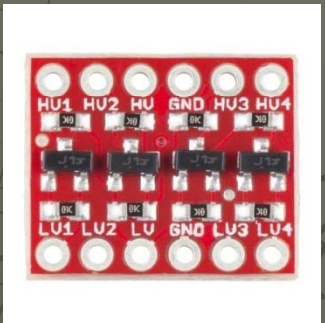




This tutorial uses the MPU-6050 triple axis accelerometer-gyro (6 degrees of freedom) connected to the Arduino Uno to continuously measure the attitude of a vehicle (pitch, yaw, and roll of your rocket). This data can be recorded on an SD card or radioed back to a ground station

Hardware Required





- Three Axis MPU-6050 Accelerometer-Gyro: From Sparkfun, Sainsmart, Robotshop and many more

- Purchase: https://www.sparkfun.com/products/11028
- Schematic: http://dlnmh9ip6v2uc.cloudfront.net/datasheets/Sensors/IMU/Triple_Axis_Accelerometer_-_Gyro_Breakout_-_MPU-6050-v12.pdf

-Bidirectional Level Shifter (converter) 3.3V to 5V from Sparkfun. Adafruit, and others

- Purchase: https://www.sparkfun.com/products/12009
- Schematic: http://dlnmh9ip6v2uc.cloudfront.net/datasheets/BreakoutBoards/Logic_Level_Bidirectional.pdf

Arduino Uno: From Arduino, Amazon, Sparkfun, MP3Cars, many more:

- Purchase: http://www.amazon.com/Arduino-UNO-board-DIP-ATmega328P/dp/B006H06TVG
- Schematic: http://arduino.cc/en/uploads/Main/Arduino_Uno_Rev3-schematic.pdf

- A PC or laptop

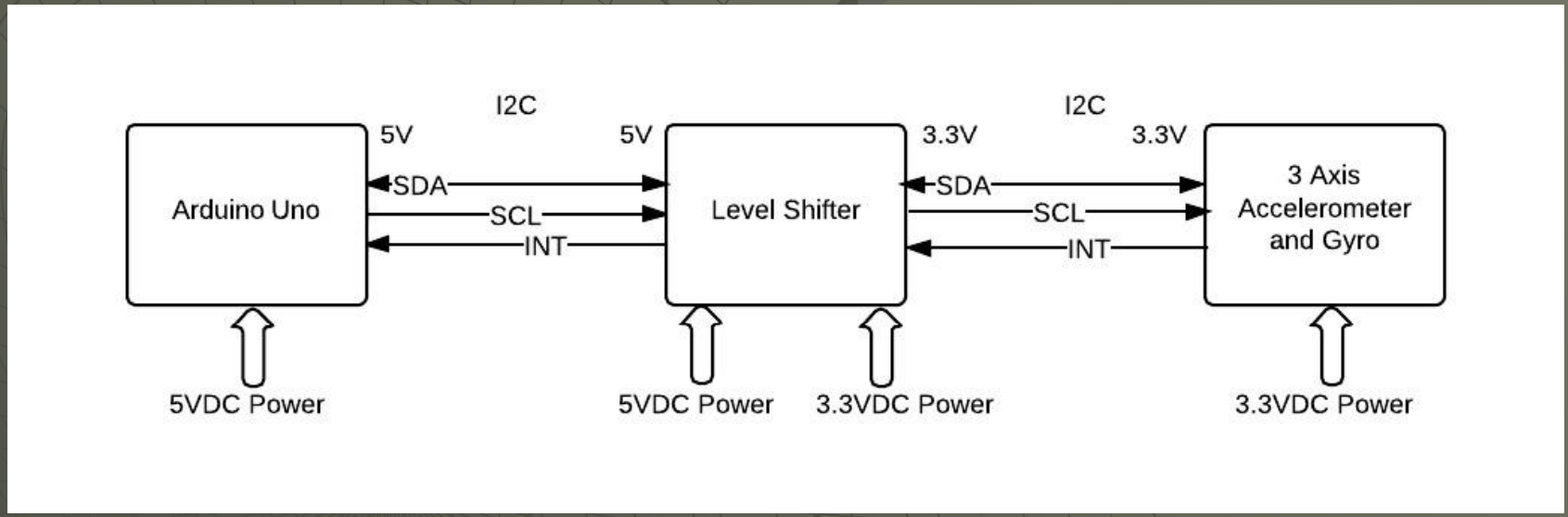
Data Sheets

- Arduino Uno uses the ATmega328 microcontroller
  - Datasheet: http://www.atmel.com/Images/Atmel-8271-8-bit-AVR-Microcontroller-ATmega48A-48PA-88A-88PA-168A-168PA-328-328P_datasheet.pdf
    - Although the ATmega328 can run at lower voltage, the Arduino Uno uses V_{CC} = at 5V
    - From the data sheet, at V_{CC} = 5VDC, V_{OH} is a minimum of 4.2V
    - From the data sheet, VIH is a minimum of $0.7V_{CC}$ – 3.5V
- The Triple Axis Accelerometer and Gyro uses an Invensense MPU-6050
  - Datasheet: http://www.invensense.com/mems/gyro/documents/PS-MPU-6000A-00v3.4.pdf
    - V_{DD} is 2.375V – 3.46V – since we have 3V available on the Uno we'll use that
    - VLOGIC input is a maximum of V_{DD} + 0.5V or 3.5V

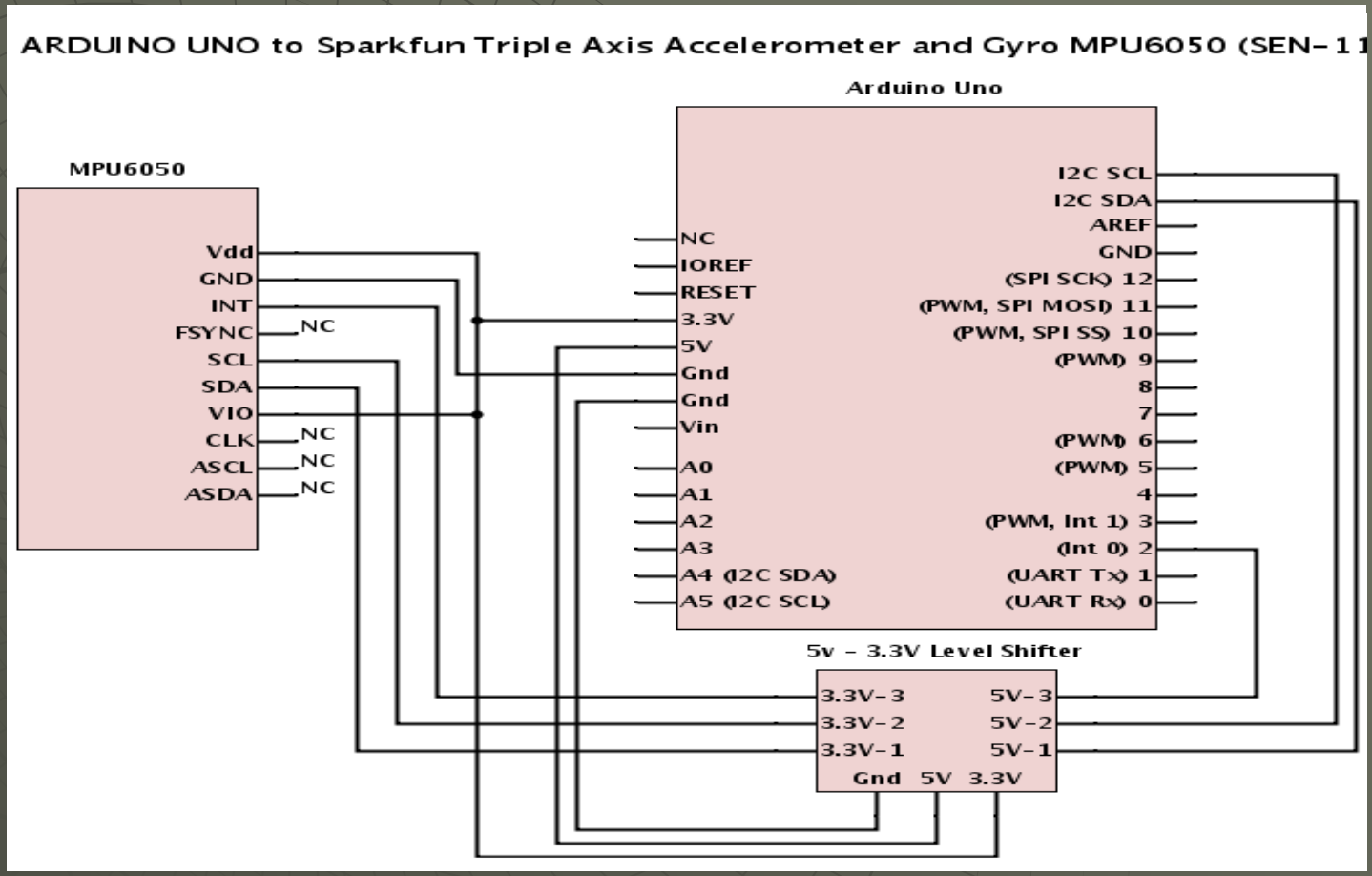
Since the output from the Arduino Uno is higher than the allowed input to the accelerometer, and the minimum High input to the Arduino Uno is less than the maximum HIGH output from the accelerometer, we will need a level shifter. It may work for a while without it, but not reliably and the accelerometer will probably be damaged from overvoltage

- Datasheet: http://www.fairchildsemi.com/ds/BS/BSS138.pdf

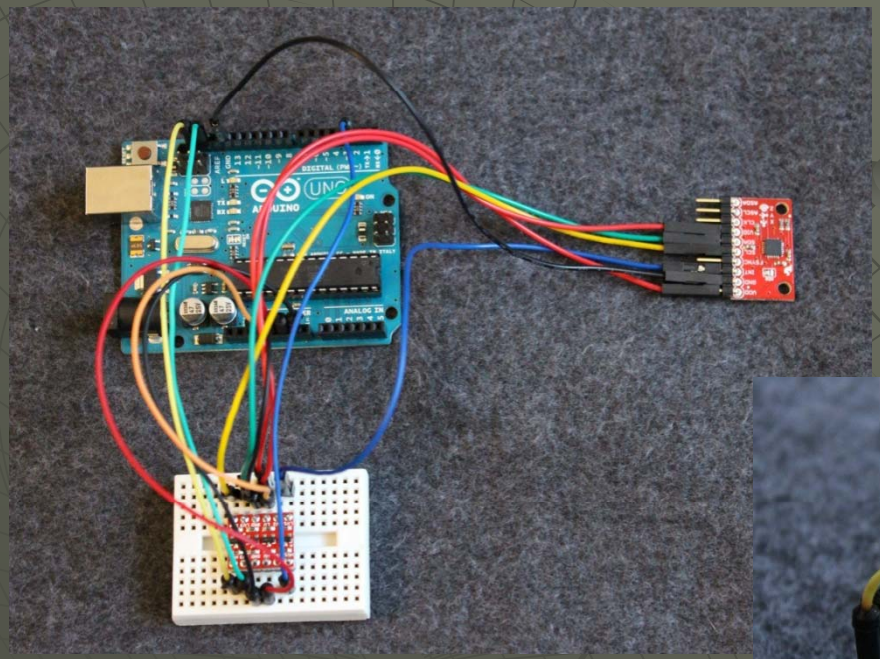
Connecting the Uno and 3-Axis Accel-Gyro Block Diagram

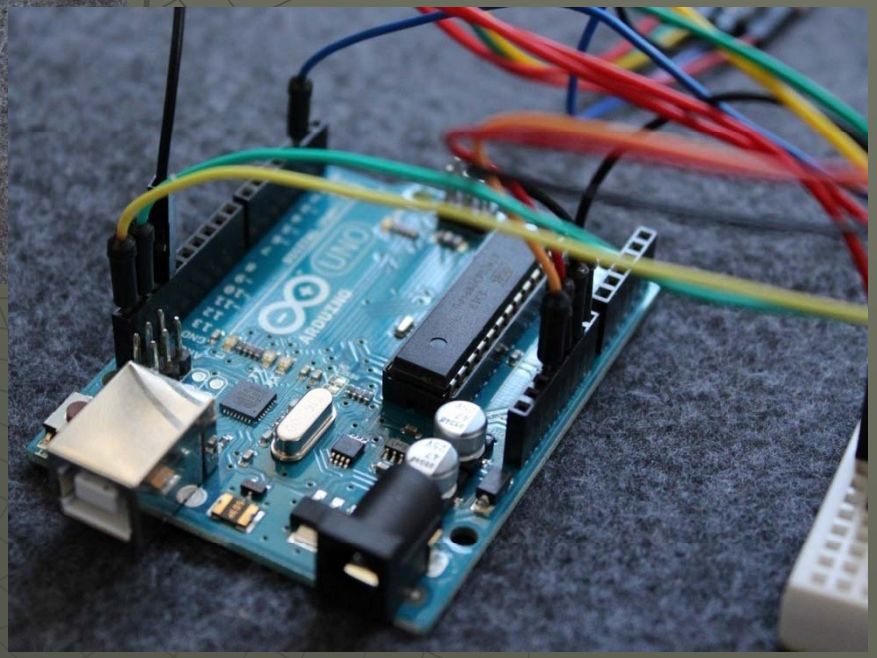


Connecting the Uno and 3-Axis Accel-Gyro Schematic

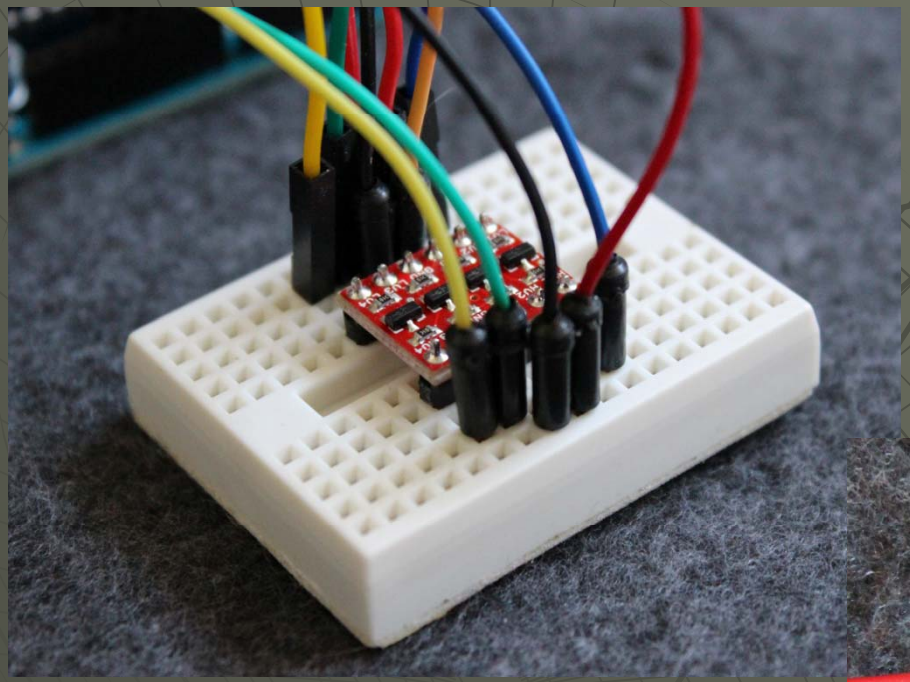


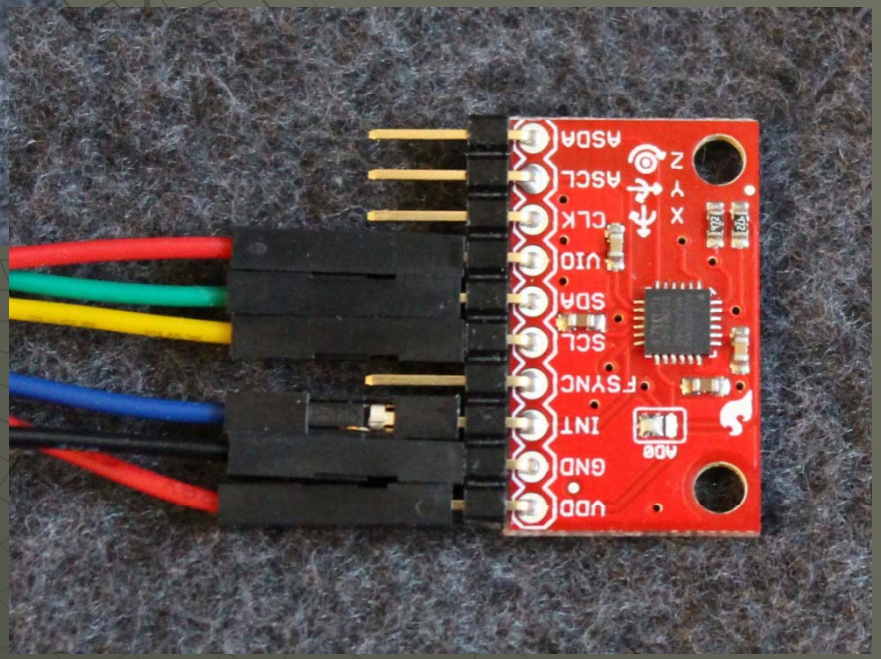
Connecting the Uno and 3-Axis Accel-Gyro

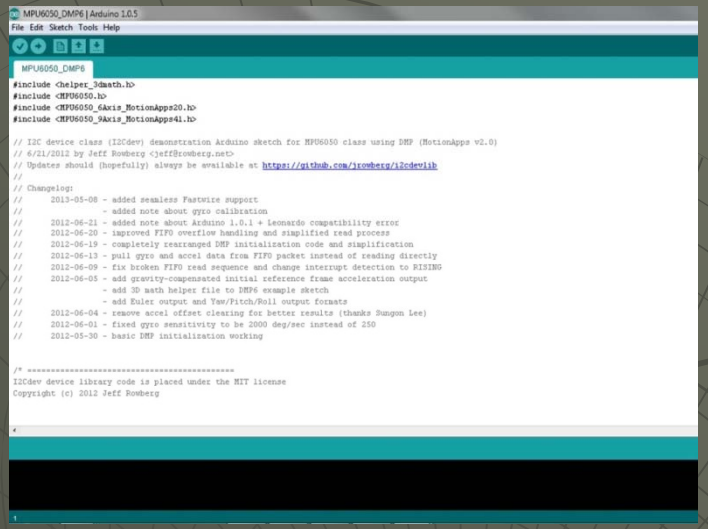




Connecting the Uno and 3-Axis Accel-Gyro







Arduino Software Required

Arduino Integrated Development Environment (IDE):
http://arduino.cc/en/main/software#.Uy4WgU1OUpA

Arduino Sketch MPU6050_DMP.ino and I2Cdev Library and MPU6050 Library:
https://github.com/jrowberg/i2cdevlib (select “Download .zip” on the right below the list of files)

- MPU6050_DMP.ino is in i2cdevlib-master->Arduino->mpu6050->Examples->MPU6050_DMP6
- I2Cdev library is in i2cdevlib-master->Arduino->I2Cdev
- MPU6050 library is in i2cdevlib-master->Arduino->MPU6050

Arduino Calibration Sketch MPU6050_calibration.ino:
http://www.i2cdevlib.com/forums/topic/112-another-auto-offset-calibration-sketch/?hl=calibration

MU6050 Library Documentation (optional download):
http://www.i2cdevlib.com/docs/html/class_m_p_u6050.html

Install Arduino IDE and Libraries

Working Directory Tree:
(My) Documents
Arduino
libraries
I2CDev
MPU6050
sketchbook
MPU6050

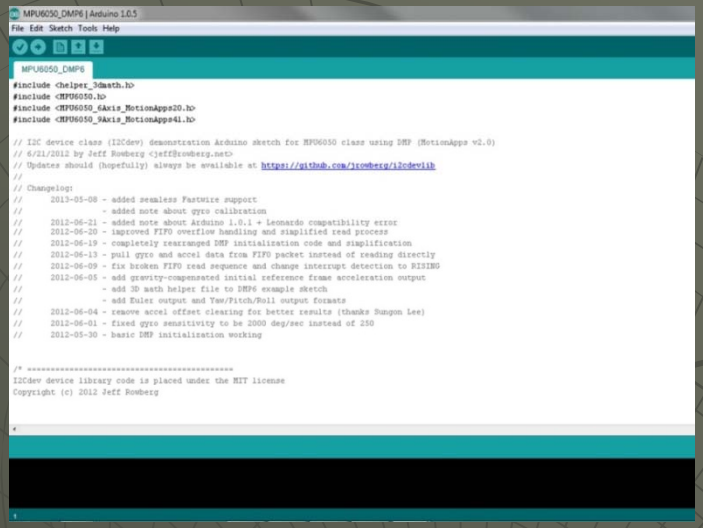
Note: You can skip this step if you have already installed the IDE

STEP 1: INSTALL THE ARDUINO IDE
- Download the IDE (currently named "arduino-1.0.5-r2-windows.exe") and click on it to install
- It will be installed in the Program Files directory
- Your sketches and libraries will go in the Arduino folder in (my) Documents
- Also allow the installation of the device driver software

STEP 2: INSTALL THE TWO LIBRARIES
- Library install instructions are here: http://arduino.cc/en/Guide/Libraries#.Uy4bYU1OUpA

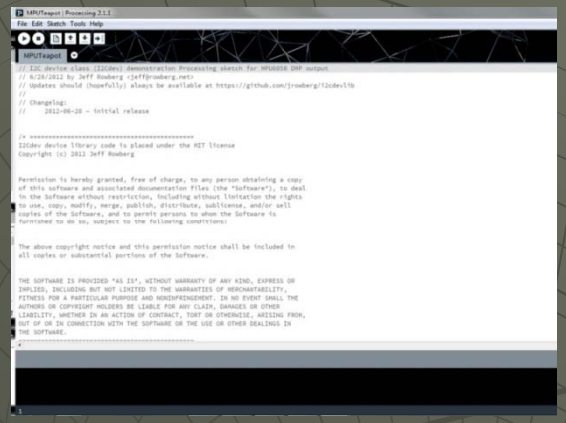
- To automatically install a downloaded .zip file library, start the Arduino IDE and click on: SKETCH->IMPORT LIBRARY->ADD LIBRARY then navigate to where the libraries were downloaded and click on the library (.zip file or folder) – check that the library has been added under "contributed" in the list under SKETCH->IMPORT LIBRARY->ADD LIBRARY

- To manually install a downloaded library, unzip it and move the folder containing all files into the "libraries" folder in the (My) Documents\Arduino\libraries, then restart the IDE



Arduino Sketch Required

1. Find the folder containing the Arduino Sketch named “MPU6050_DMP.ino” . You will find it in the i2cdevlib-master .zip file you previously downloaded at:
   i2cdevlib-master->Arduino->mpu6050->Examples->MPU6050_DMP6
2. Copy the MPU6050 FOLDER into the “sketchbook” folder at (My)Documents->Arduino->Sketchbook (the folder contains the MPU6050_DMP6.ino sketch
3. Important: You may need to make two changes to the sketch as downloaded (more instructions on this later):
   1. The sketch defaults to an I2c address of 0x68 – the default for Sparkfun. You may need 0x69 for other devices, or if you have modified the board
   2. There is a section in the code with several output options: “#define OUTPUT_READABLE_YAWPITCHROLL” is the default. To use with the teapot sketch comment (add “//” at the beginning of that line) and uncomment (remove the “//”) on the line that reads “#define OUTPUT_TEAPOT



PC Software Required

Any decent Serial Communications Program or terminal emulator OR use the Serial Monitor built into the Arduino IDE

Processing Integrated Development Environment (Processing is a programming environment much like the one we have for Arduino – and was developed originally for the visual arts):
https://processing.org/download/

MPU Teapot Sketch (called the teapot sketch as earlier versions showed a teapot):
https://github.com/jrowberg/i2cdevlib/tree/master/Arduino/MPU6050/Examples/MPU6050_DMP6/Processing
Requires Toxi Library:
http://hg.postspectacular.com/toxiclibs/downloads/

More information about this project:
http://www.i2cdevlib.com/

Install the Processing IDE and Libraries

Working Directory Tree:
(My) Documents
Processing
libraries
toxiclibs_p5
toxiclibscore
sketchbook
MPUTeapot

STEP 1: INSTALL THE PROCESSING IDE
- Download the IDE (currently named "processing-2.2-windows64.zip or processing-2.2-windows32.zip" depending upon your system)
- Unzip the file
- Start processing by clicking on the processing.exe file – it needs no formal installation
- It is more convenient if you manually add a link on your desktop

STEP 2: INSTALL THE TOXI LIBRARIES
- Library install instructions are here: http://wiki.processing.org/w/How_to_Install_a_Contributed_Library

- To manually install a downloaded library, unzip it and move the folder containing all files into the "libraries" folder in the (My) Documents\Processing\libraries, then restart the Processing IDE

Running the Arduino Sketch

1 - Use the Arduino IDE to open the MPU6050_DMP6.ino sketch
2 – Make certain you have selected the Arduino Uno (Tools->Board)
3 – Make certain you have selected the correct serial port (Tools->Serial Port)
4 - Verify that your MPU 6050 breakout board I2C address is set to 0x68
5 - If the AD0 jumper looks like the picture you are set to 0x68


```
// class default I2C address is 0x68
// specific I2C addresses may be passed as a parameter here
// AD0 low = 0x68 (default for SparkFun breakout board)
// AD0 high = 0x69
MPU6050 mpu;
//MPU6050 mpu(0x69); // <-- use for AD0 high
```

6 – Find the section that changes the form of the output:

"uncomment "OUTPUT_READABLE_QUATERNION" if you want to see the actual quaternion…
"//#define OUTPUT_READABLE_QUATERNION"
"uncomment "OUTPUT_READABLE_EULER" if you want to see Euler angles (in degrees)
"//#define OUTPUT_READABLE_EULER"
etc….

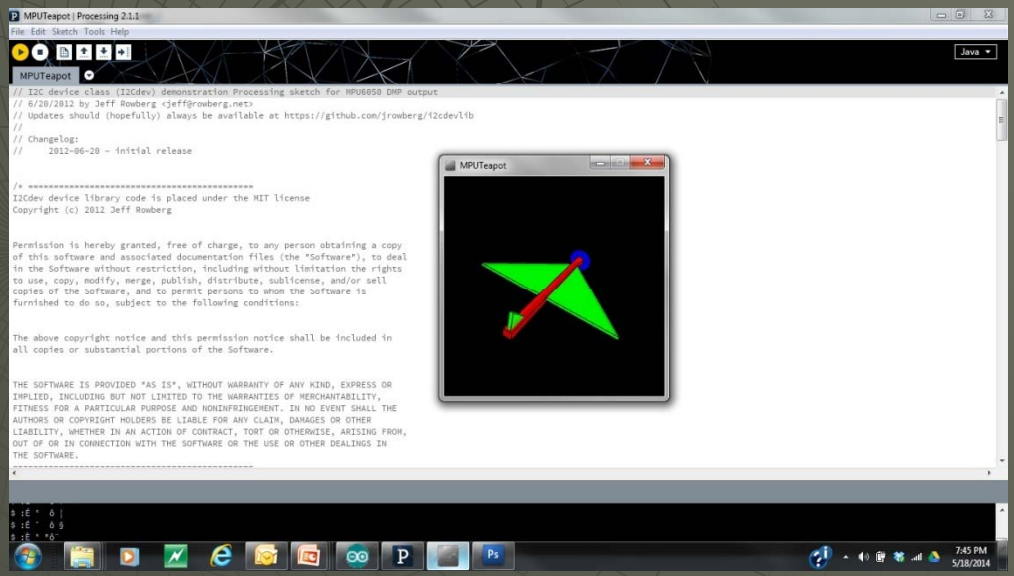
7 - The only one of these that should be uncommented (remove the "//" at the beginning of the line with the #define) is the one that reads:

```
// uncomment "OUTPUT_TEAPOT" if you want output that matches the
// format used for the InvenSense teapot demo
#define OUTPUT_TEAPOT
```

8 - Connect your circuit to your PC via the USB cable
9 - Compile and upload the sketch (click the right facing arrow at the top)

Running the Processing Sketch

1 – Move the MPUTeapot folder containing the MPUTeapot.pde sketch into the sketchbook folder under Processing ((my)documents->Processing->sketchbook)
2 - Start the Processing (processing.exe in the folder where you unzipped the downloaded Processing program) program to open the MPUTeapot.pde sketch
3 - Compile and start the sketch (the right arrow in the upper left)
4 – You should see the small screen with a simple image of an airplane (there is no teapot – there was a previous version that did show a teapot)
5 – The airplane image will probably slowly wander in one direction – you will need to calibrate your MPU6050



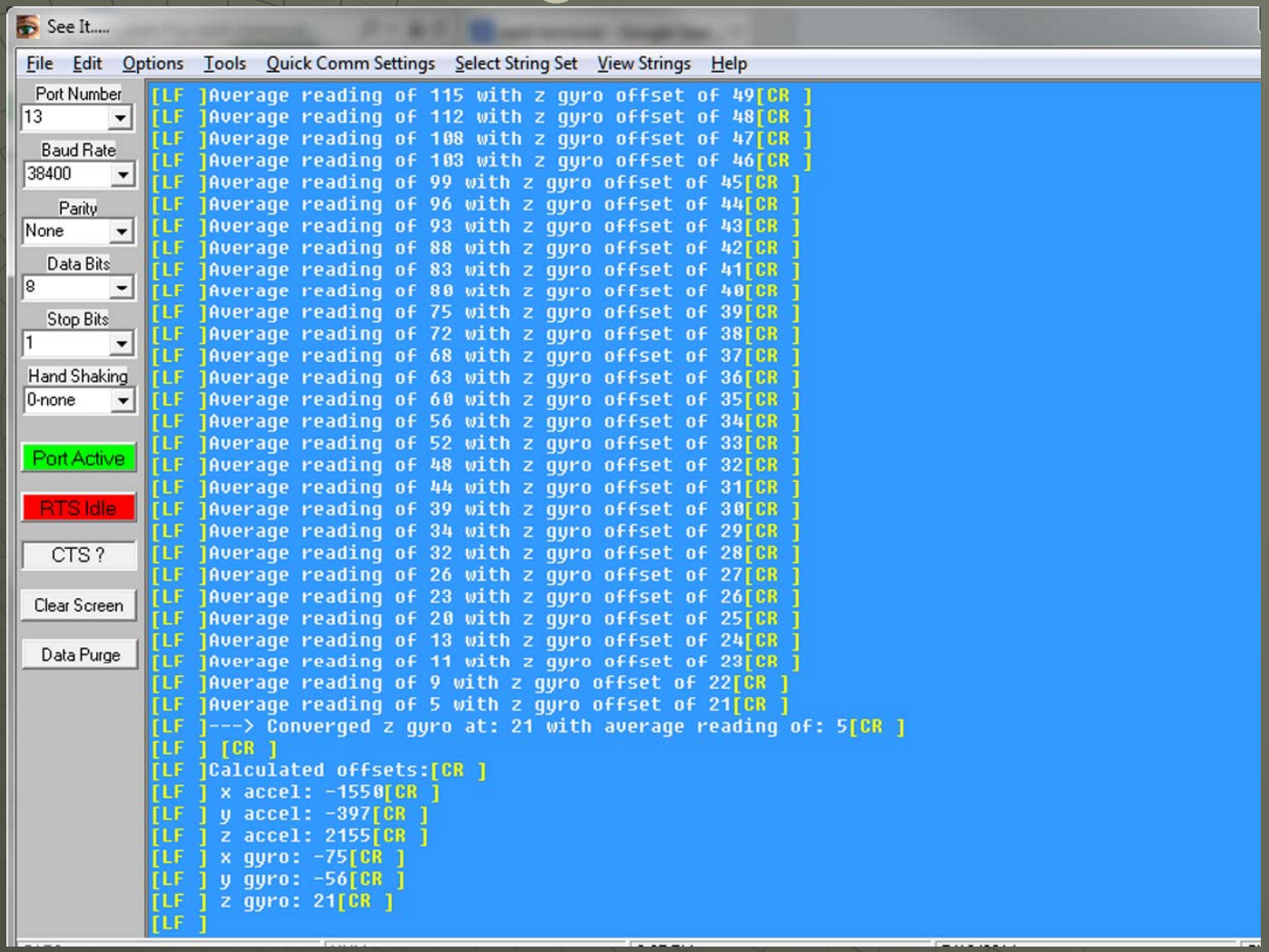
Calibrating the MPU 6050

1 - Use the Arduino IDE to open the MPU6050_calibration.ino sketch
2 - Verify that your MPU 6050 breakout board I2C address is set to 0x68 (you should have already done this in a previous step)
3 - If the AD0 jumper looks like the picture you are set to 0x68

```
// class default I2C address is 0x68
// specific I2C addresses may be passed as a parameter here
// AD0 low = 0x68 (default for SparkFun breakout board)
// AD0 high = 0x69
MPU6050 mpu;
//MPU6050 mpu(0x69); // <-- use for AD0 high
```

4 - Connect your circuit to your PC via the USB cable
5 - Start your RS-232 communications program (or the Arduino Serial Monitor) and set to 38.4K Baud and the correct port
6 - Compile and upload the sketch (click the right facing arrow at the top)
7 - The program will start to run after it is loaded and find the proper values to configure YOUR MPU 6050 (these values will be different for every chip)
8 - Record the values listed in the “Calculated Offsets” when the program stops (see next slide- x gyro = -75, y gyro = -56, z gyro = 21, z accel = 2155)

Calibrating the MPU 6050



Calibrating the MPU 6050

1 - Use the Arduino IDE to open the MPU6050_DMP6.ino sketch

2 - Find the section labeled “supply your own gyro offsets here…”:

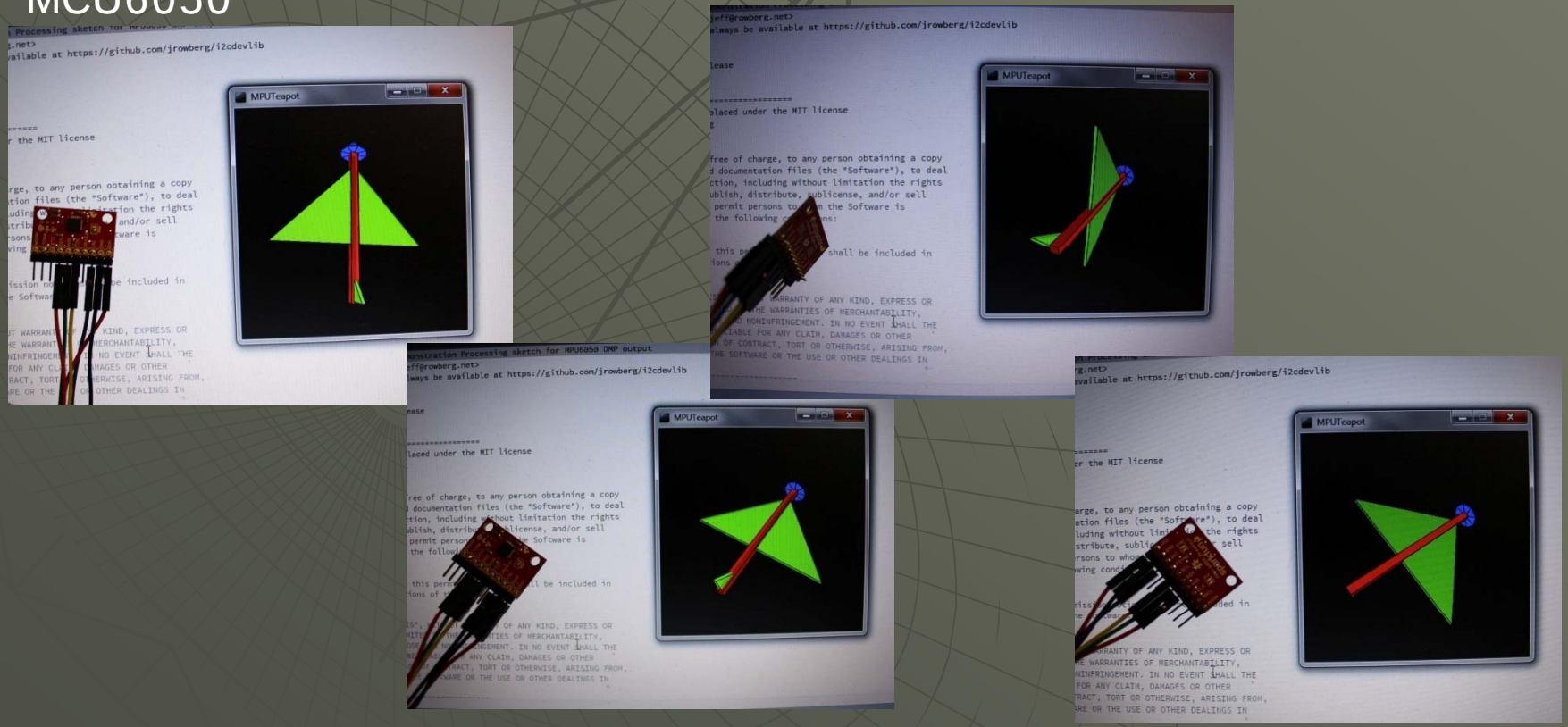
```
// supply your own gyro offsets here, scaled for min sensitivity
mpu.setXGyroOffset(220);
mpu.setYGyroOffset(76);
mpu.setZGyroOffset(-85);
mpu.setZAccelOffset(1788); // 1688 factory default for my test chip
```

3 - And change them to match the values that you recorded from the configuration program (x and y acceleration values are not used)

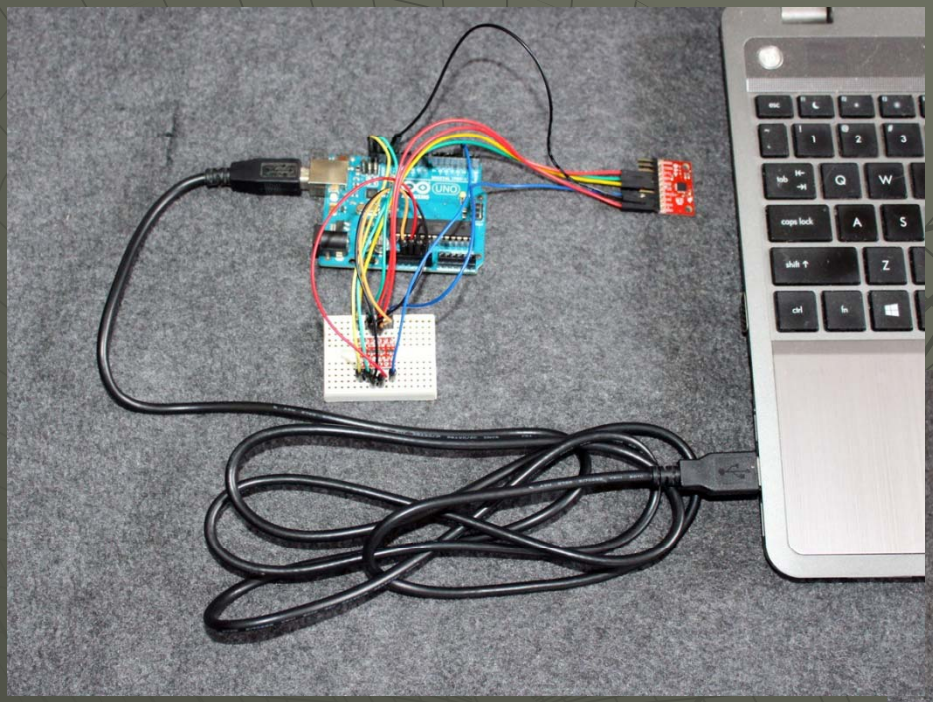
```
// supply your own gyro offsets here, scaled for min sensitivity
mpu.setXGyroOffset(-75);
mpu.setYGyroOffset(-56);
mpu.setZGyroOffset(21);
mpu.setZAccelOffset(2155); // 1688 factory default for my test chip
```

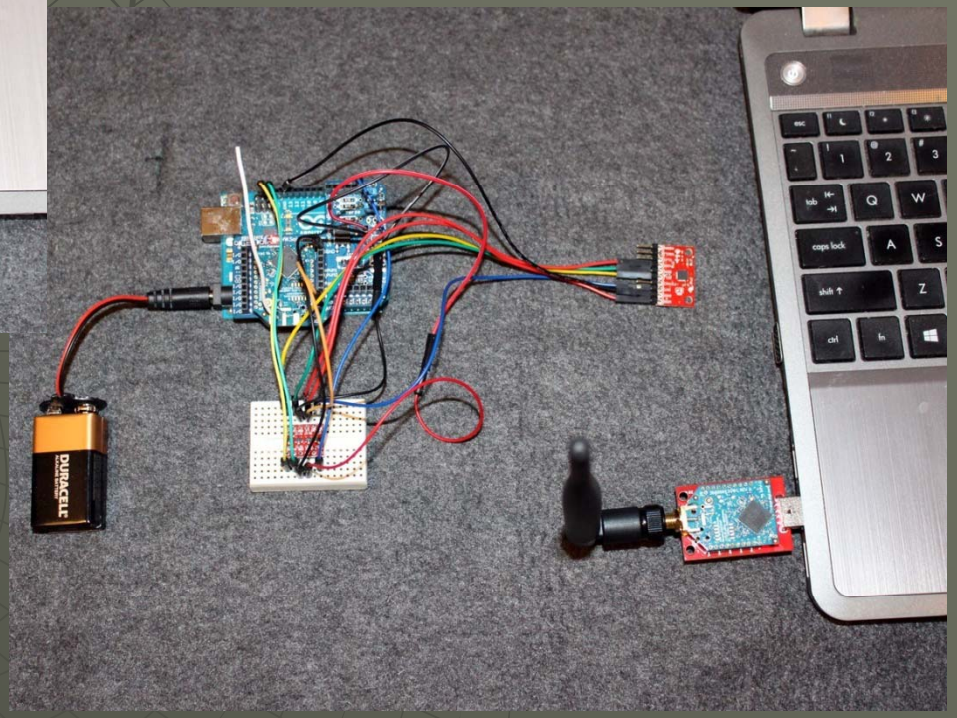
Rerun both Sketches

1 - With the changes in place and saved, recompile and run the Arduino Sketch
2 – Recompile and run the Processing sketch
3 – The image should now be stable and follow the movement of the MCU6050

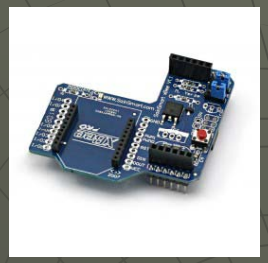


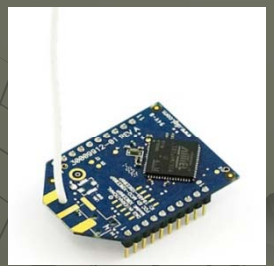
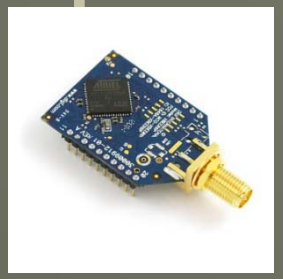
Wired or Wireless





Hardware Required




-XBee Shield for Arduino Uno

- Purchase: http://www.sainsmart.com/sainsmart-xbee-shield-module-for-zigbee-arduino-uno-duemilanove-mega-1280-2560.html
- Schematic: http://www.sainsmart.com/zen/documents/20-011-902/Libelium-Xbee-Shield.pdf

-XBee USB Explorer Dongle

- Purchase: https://www.sparkfun.com/products/9819
- Schematic: http://dlnmh9ip6v2uc.cloudfront.net/datasheets/Wireless/Zigbee/XBee-Explorer-DongleV12.pdf

-XBee Pro 60mW Wire Antenna Series 1

- 900 MHz Purchase: https://www.sparkfun.com/products/9097
- 2.4GHz Purchase: https://www.sparkfun.com/products/8742

-XBee Pro 60mW RPSMA connector

- 900MHz Purchase: https://www.sparkfun.com/products/9099
- 2.4GHz Purchase (U.FL Connector): https://www.sparkfun.com/products/8710

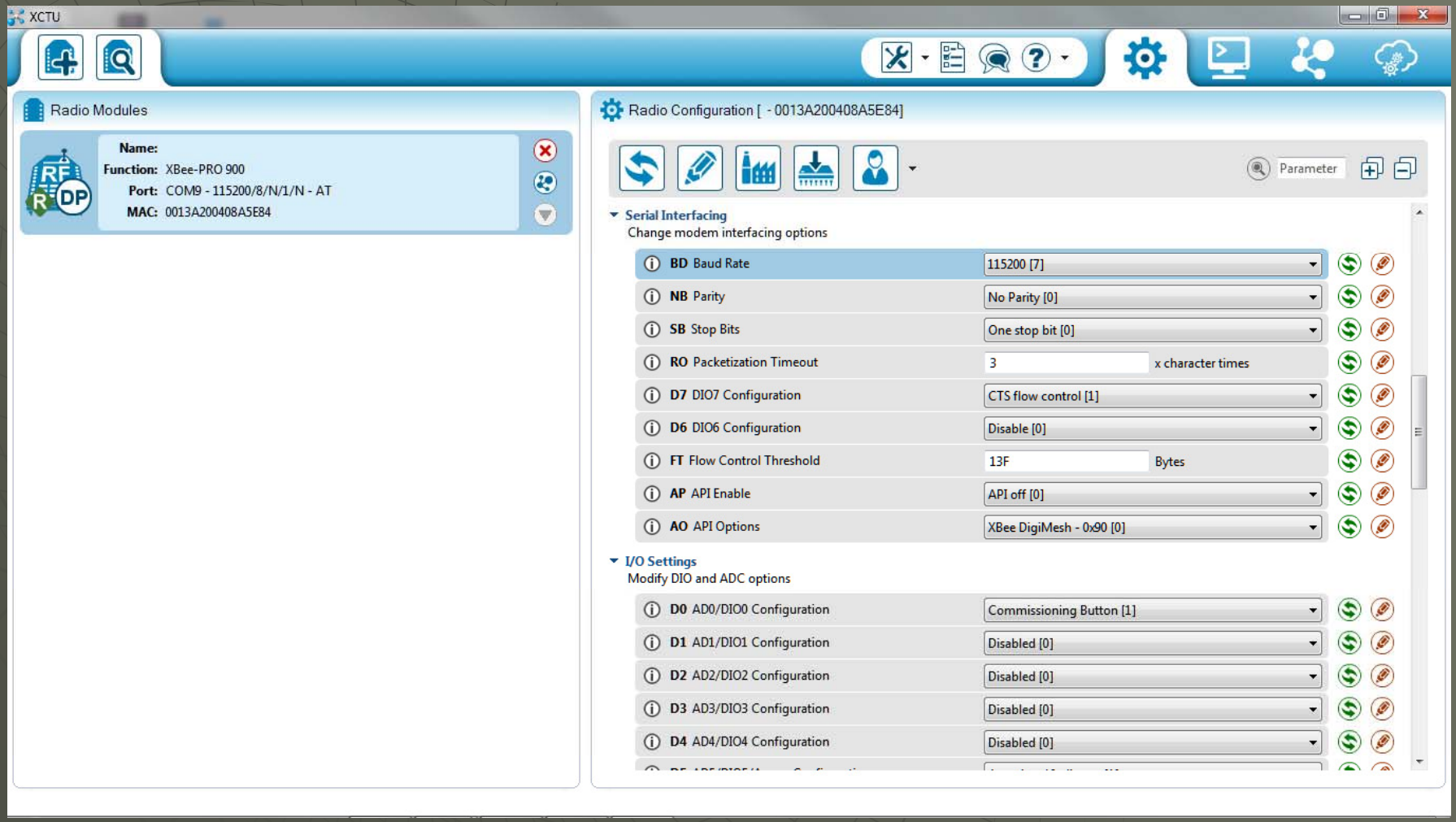
-Rubber Duck Antenna

- Purchase: https://www.sparkfun.com/products/9143
- Purchase (Cable U.FL to RPSMA connector): https://www.sparkfun.com/products/662

XBee Series 1 Setup

1 – Download the XCTU Next Generation Software and install
http://www.digi.com/support/productdetail?pid=3352&osvid=57&type=utilities
2 – Plug one of the XBee modules into the USB Explorer dongle and plug that into the PC
3 - Set up the XBee modules for 115.2K Baud
    A – Start the XCTU Software
    B – Click on the search Icon to find your module (you will need to specify the COM port and BAUD rate
    C – Click on “Add Selected Device”
    D – After the module is found click on the module name (the configuration tab should already be selected)
    E – Set the module BAUD rate to 115.2K Baud
    F – Click on the write icon to write to the module
    G – Verify that the BAUD rate changed in the description block that originally appeared when you discovered the module
4 - Repeat for the second module

XBee XCTU Configuration

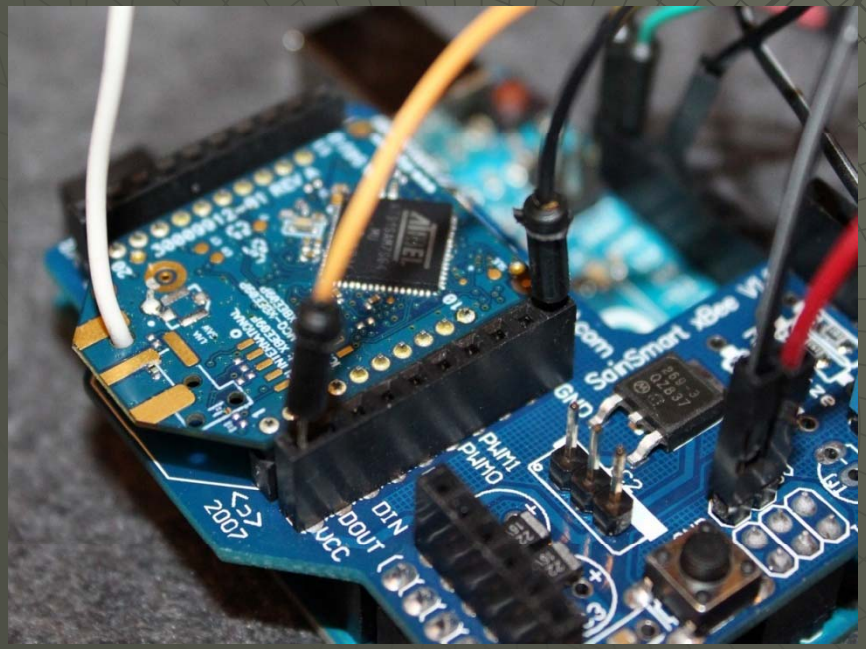


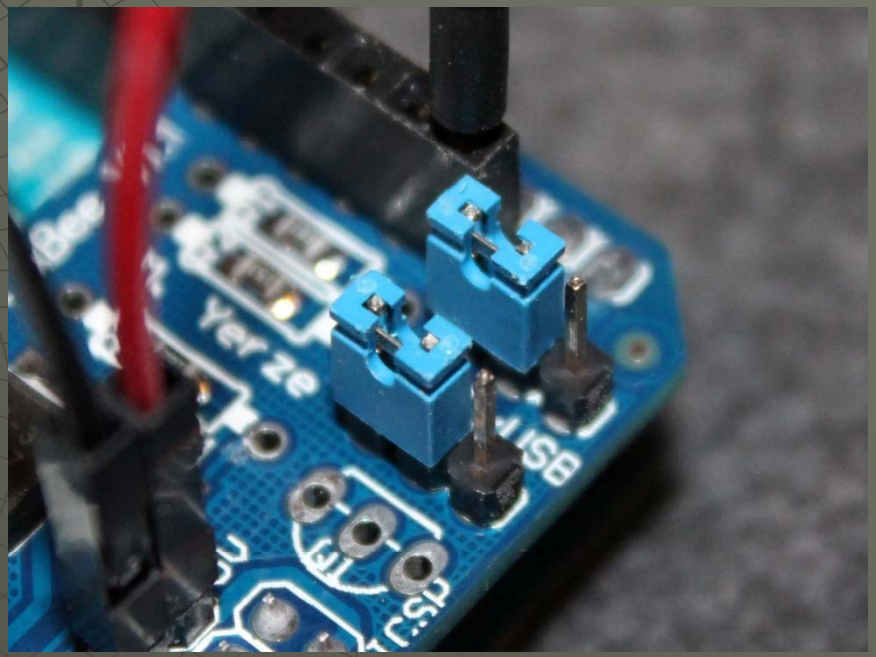
Xbee/Arduino Hardware Setup

The schematic remains the same as for the wired version – the XBee replaces the USB wire with an equivalent wireless RF connection

You can still access all of the pins on the Arduino Uno, but most of them will be connected to the XBee shield instead of directly to the Uno. It helps to solder a female header to the shield on either side of the XBee socket

The two jumpers should be in the XBEE position (not the USB position)





Xbee/Arduino Operation

1 - Apply power to the Arduino Uno with the XBee Shield with the same program loaded as with USB connected (MPU6050_DMP.ino)
2 – Start the Processing IDE and load and compile the same program as with USB connected (MPUTeapot.pde)
3 – The program should function the same as before, but you will notice a slight delay in response on the PC screen