AeroQuad

Your Friendly Neighborhood Quadcopter Platform

A Build Tutorial

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Started: FEB152010
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1. INTRODUCTION

1.1 A WARM WELCOME

Welcome to AeroQuad! This particular tutorial will focus on providing most of the necessary information for the construction an Arduino-based quadcopter platform, referred to as an AeroQuad. Though a few suggestions of what a frame should have will be made, the construction of it will not be covered.

1.2 SAFETY WARNING

Though there are not many questions about this and it is not mentioned much until something goes wrong, I feel it is my duty to mention this. The motors and propellers used here are not something to be joked around with. They are dangerous moving parts that can do some serious cutting and chopping damage if you are not careful. **Under no circumstances are you to put the propellers on the motors until everything is checked out and tested to be working properly.** This is something that can turn a nice day into something horrible, such as an emergency room visit or worse, so please be aware, and please do all of the testing outside, **away from people as well.** The author of this tutorial will not be held responsible for any damage or injury done to or by the user. Please use safe engineering practices and common sense when working on such projects.

1.3 A SMALL NOTE

This tutorial was started on February 15, 2010 and was meant to help out the beginners in the AeroQuad community. Remember, in order to stay up to date, read and ask your questions in the AeroQuad support forum at www.aeroquad.com in the "Forum" link on the top left. Good luck, stay safe, and have fun with your build.

2. SHOPPING LIST

2.1 RECOMMENDED PARTS SUMMARY

Priority 1

Arduino Uno (x1)	**OR**	Arduino Mega (x1)
ITG-3200 triple axis gyro (x1)		ITG-3200 triple axis gyro (x1)
BMA180 triple axis accelerometer (x1)		BMA180 triple axis accelerometer (x1)
AeroQuad shield v1.8 (x1)		BMP085 barometric pressure sensor (x1)
Stackable female headers (Duem. pack) (x1)		HMC5843 triple axis magnetometer (x1)
Extra straight breakout pins		AeroQuad shield v2.0 (x1)
		Stackable female headers (Mega pack) (x1)
		Extra straight breakout pins

Priority 2
Motors (x4, plus spares)
ESCs (x4)
Battery (x1)
Counter rotating propellers (2 pairs, plus spares)
Radio system (x1)
Miscellaneous

Priority 3
Battery charger
Power supply
Battery voltage monitor/buzzer

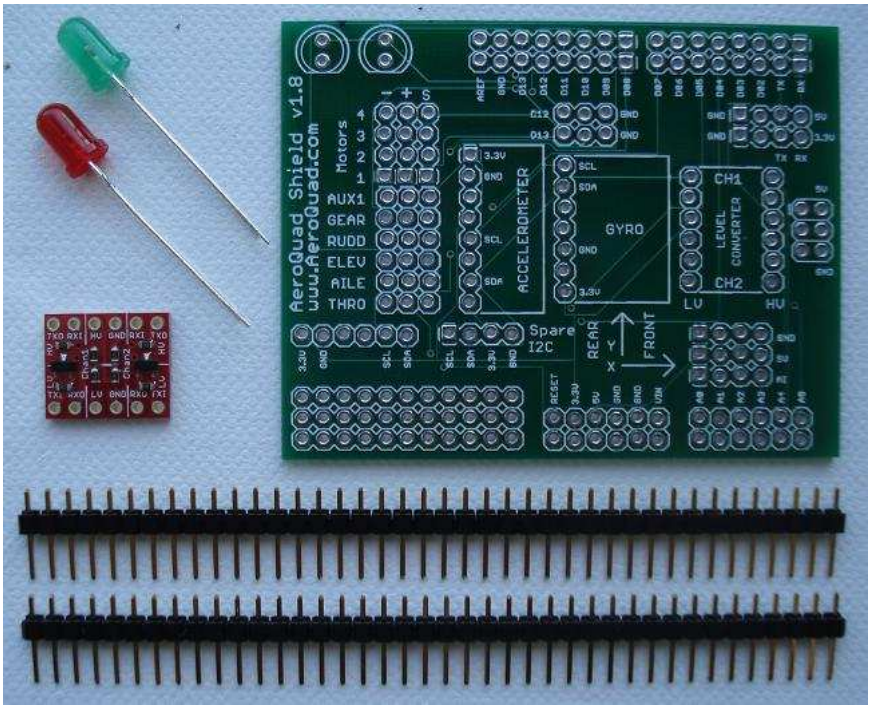
PRIORITY 1 – these parts comprise the command center of the quadcopter and are the Arduino (Duemilanove/Uno or Mega), the gyro, accelerometer, barometer, and magnetometer sensor boards, the AeroQuad shield, the stackable female headers, and the straight breakout pins. The Arduino is the computer controller which does all the calculations for stability and control. Both Arduino Duemilanove/Uno and Arduino Mega are capable of flying an AeroQuad. However, due to memory limitations on the Duemilanove/Uno, it will likely not be able to support more sensors beyond the gyros and accelerometers. Instead, the Arduino Mega with its v2.0 shield will provide those extra capabilities. A USB A-to-B cable is necessary for uploading the code to the Arduino from the PC. The gyros are for sensing rotational motion around the three axes (x y z), the accelerometers are for sensing linear acceleration about those same axes, the barometer measures air pressure for supporting the altitude hold feature, and the magnetometer provides an accurate heading measurement. The AeroQuad shield is a small green circuit board to which the sensors are soldered to and which then connects directly on top of the Arduino through pins. It eliminates the need to have a breadboard and lots of loose wiring. The headers and pins are necessary for the shield and the breakout pins are needed for the sensor boards.

Note: The new Arduino Duemilanove is now replaced by Arduino Uno, though both are basically identical. The Arduino Mega 1260 is also replaced with the new Arduino Mega 2560.

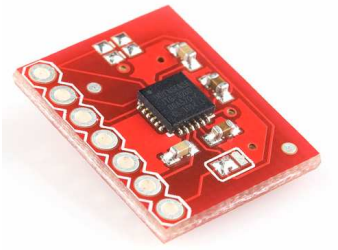
Arduino Mega 2560
Price: $65
Where: AeroQuad shop

Arduino Uno
Price: $30
Where: AeroQuad shop

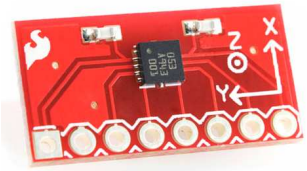
AeroQuad Shield v1.8 (comes with everything shown)
Price: $25
Where: AeroQuad shop



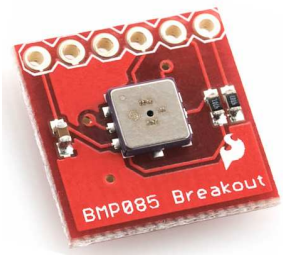
ITG-3200 triple axis gyro
Price: $50
Where: AeroQuad shop



BMA180 triple axis accelerometer
Price: $30
Where: AeroQuad shop

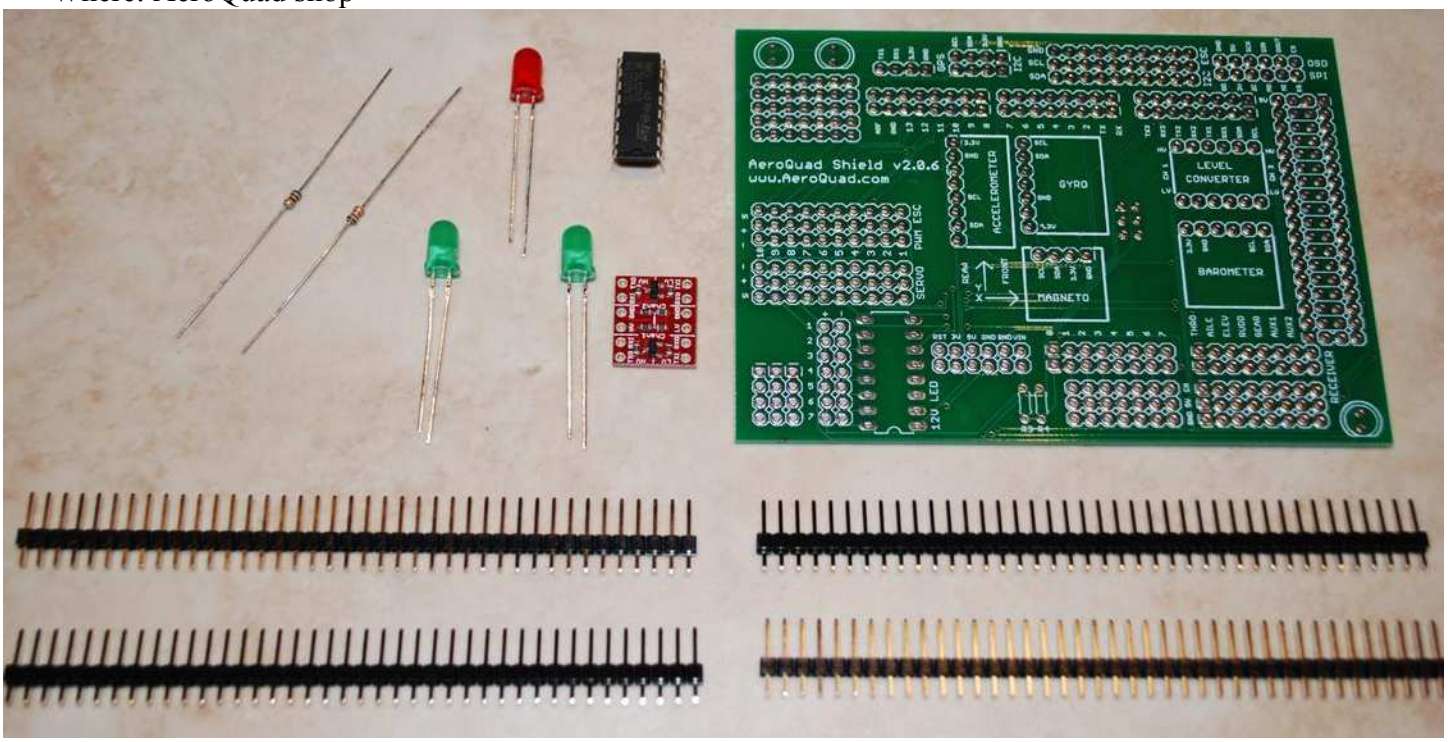


BMP085 barometric pressure sensor
Price: $20
Where: AeroQuad shop

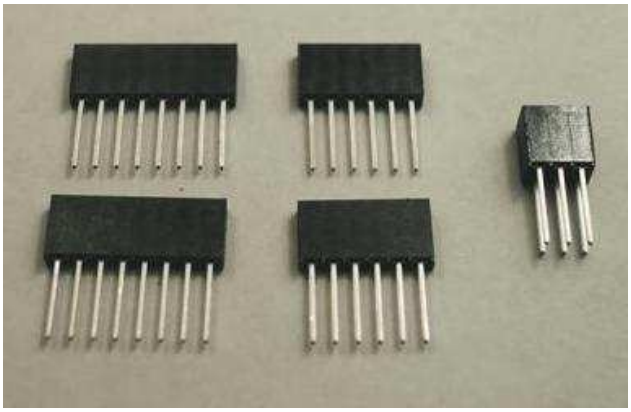


HMC5843 triple axis magnetometer
Price: $50
Where: AeroQuad shop

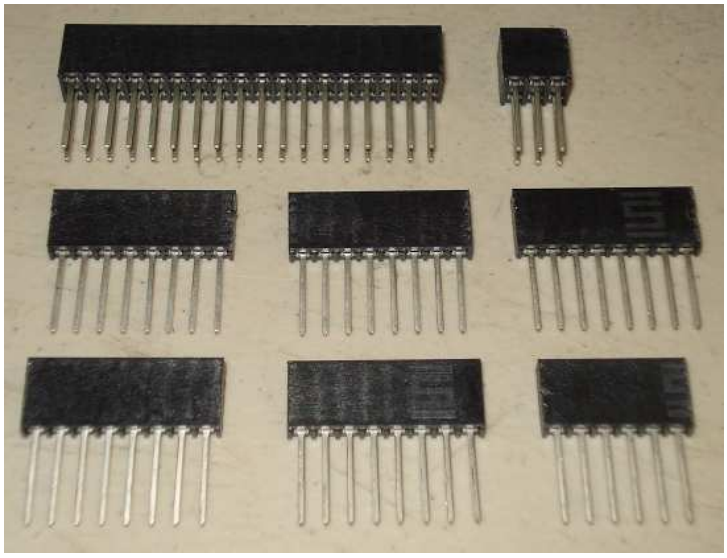
AeroQuad Shield v2.0 (comes with everything shown)
Price: $30
Where: AeroQuad shop



Stackable Female Headers (Duemilanove pack)
Price: $5
Where: AeroQuad shop



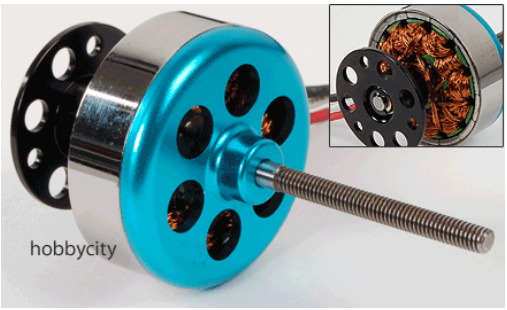
Stackable Female Headers (Mega pack)
Price: $12
Where: AeroQuad shop



Breakout Pins (straight)
Price: $2.50
Where: AeroQuad shop

PRIORITY 2 – these components include the motors, motor electronic speed controllers (ESCs), the main battery, the counter rotating propellers, the radio system and other, miscellaneous things. The ESCs control the brushless motors. The 10amp ESCs are recommended for lighter quads (under 1kg) and the higher amperage ones (18 or 25) are for heavier quads. The female-female servo extension cables are used to connect the radio receiver channels to the shield. The 3mm male/female bullet connectors are used to connect the ESCs to motors and also to the main power distribution line. Finally, the 18 gauge (no thicker than 16 as that will add unnecessary weight) wire is used to make the main power line, splitting the battery's output in a parallel fashion for the four motors/ESCs.

Hextronik DT750 motor (heavy duty)
Price: $9 ($36 for 4)
Where: HobbyKing



Hacker Style 20-22L motor (medium duty)
Price: $14 ($56 for 4)
Where: HobbyKing

Hextronik 24gram 1300kv motor (for quads under 800g)
Price: $8 ($32 for 4)
Where: HobbyKing

Turnigy 2217 16turn 1050kv motor (heavy duty)
Price: $14 ($56 for 4)
Where: HobbyKing

BP A2217-9 950kv motor (heavy duty)
Price: $21 ($84 for 4)
Where: TowerHobbies

Turnigy Plush 10 amp ESC
Price: $8.50 ($34 for 4)
Where: HobbyKing

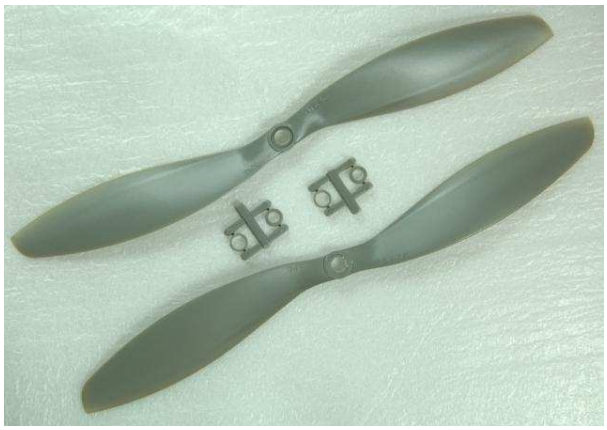
Turnigy Plush 18 amp ESC
Price: $11 ($44 for 4)
Where: HobbyKing

Turnigy Plush 25 amp ESC
Price: $12 ($48 for 4)
Where: HobbyKing

EPP1045 Counter Rotating Prop pairs OR **APC1047 Counter Rotating Prop pairs**

Price: $4.50 ($9 for two pairs)
Where: QuadroUFO.com

Price: $8.50 ($17 for two pairs)
Where: AeroQuad shop



Spektrum DX7 radio with AR6200 receiver (or the AR7000 shown)
Price: minimum new $280 w/AR6200 (eBay)
Where: online, local hobby shop

Zippy Flightmax 4000mAh 11.1v 20C lithium polymer battery pack
Price: $20
Where: HobbyKing

Servo Extension Cables (female to female)
Price: $13.45 (for 8)
Where: AeroQuad shop

3mm Bullet Connectors (for motors & ESCs)
Price: $4.50 ($9 for 2 packs, 20 pairs total)
Where: eBay (seller: *rctimer*)

18 gauge wire (2-3 ft)
Price: ~$6
Where: RadioShack, local hobby shop, online

PRIORITY 3 – These items include a good battery charger with a power supply and a battery voltage monitor or buzzer. They are not necessary for the flight of the quad, but obviously are needed for charging the battery and making sure that the battery is not discharged below recommended levels. Many different choices are available in this priority and the known and tested ones are shown. The HobbyKing battery monitor requires some minor soldering while the one on eBay comes ready to use.

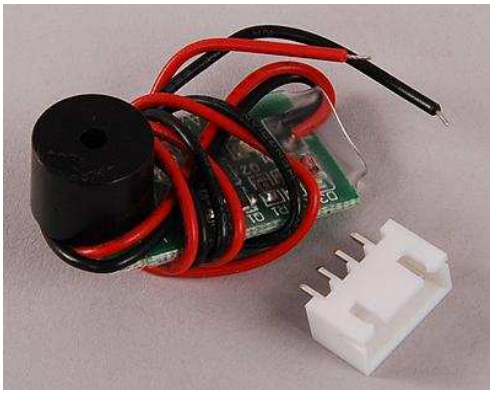
Turnigy Accucel-6 50W 5A Balancer/Charger
Price: $25
Where: HobbyKing

12v 5A Power Supply
Price: $10
Where: HobbyKing

Lipo Battery Low Voltage Buzzer Alarm OR **Hobby King Battery Monitor 3S**

Price: $4
Where: eBay (seller: *goodlucksell*)

Price: $4
Where: HobbyKing



2.2 TOOLS FOR THE JOB

Some of the tools necessary for the build include the soldering irons necessary for soldering of the sensors to the pins and to the shield, soldering female headers to the shield, and finally soldering all the bullet connectors to the motors, ESCs, and main power line. It is very important to use a low power soldering iron, such as a 15 watt iron (no higher) for all the sensor and shield soldering. The rest (connectors, etc) can be done with a higher power iron, such as a 30 watt one. An obvious necessity is then the solder. A 0.032" thick rosin core solder is ideal for the sensors job and a thicker one, such as 0.062" thick, is preferred for the other tasks.

15 watt soldering iron
Price: <$10
Where: RadioShack, online, other

30 watt soldering iron
Price: <$10
Where: RadioShack, online, other

0.032" rosin core solder
Price: <$10
Where: RadioShack, online, other

0.062" rosin core solder
Price: <$10
Where: RadioShack, online, other

3. THE BUILD

After obtaining all the necessary and recommended components, it is now time to start the build. This part of the tutorial covers the installation of the software, establishment of an Arduino to PC link, soldering tasks for the sensors and connectors, putting everything together, testing the radio and calibrating the ESCs, connecting and testing everything, and finally making the maiden flight.

3.1 DOWNLOADS

http://arduino.cc/en/Main/Software Download the **Arduino IDE** for your operating system. The latest version right now (October 22, 2010) is the 0021 version, which has support for the new Arduino Uno and Mega 2560. The Arduino IDE is an environment for developing and editing code, including the AeroQuad code. The IDE package should come with the necessary USB drivers. Install it.

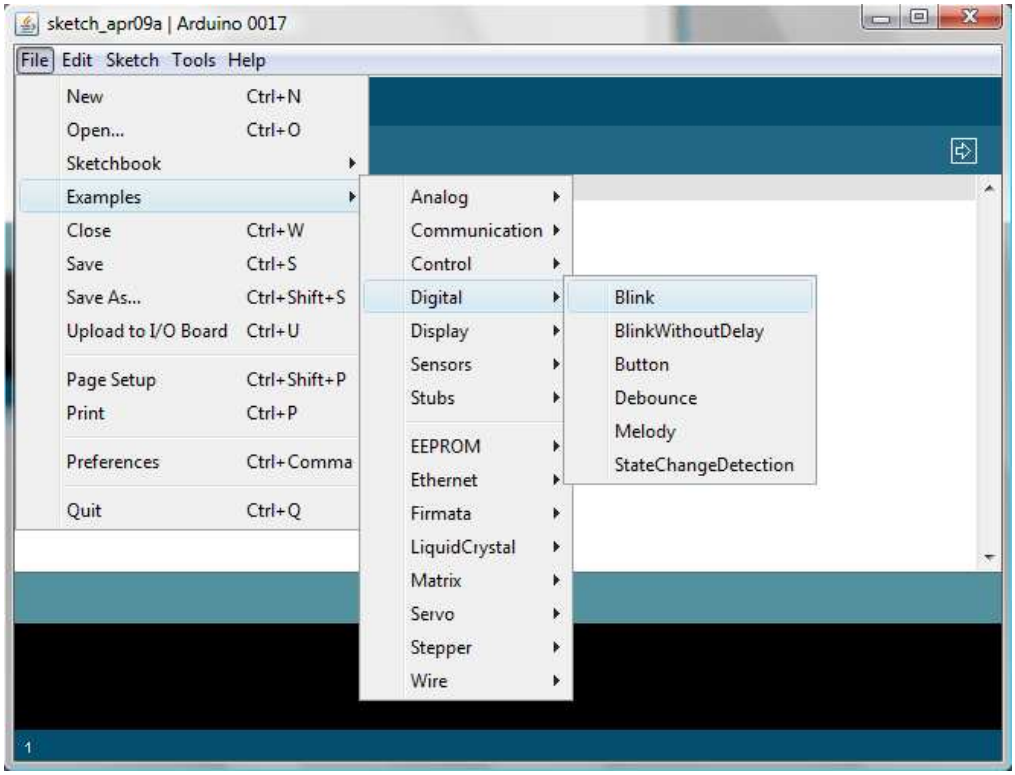
http://code.google.com/p/aeroquad/downloads/list Download the **AeroQuad code**. The AeroQuad code is the code which controls the quadrotor. It is uploaded into the Arduino through the Arduino IDE. Currently (October 22, 2010), the latest code available is the AeroQuad_v2.0.1 which is an upgraded version of the v1.7 and older codes and has some major architectural changes. Unzip it into a folder. (Later, when opening the AeroQuad code in the Arduino IDE, the file from the unzipped AeroQuad folder which needs to be opened is the AeroQuad.pde file.) **Note:** the unzipped AeroQuad folder with all the different files **must NOT be renamed.** It may be placed in another folder which may be named.

http://code.google.com/p/aeroquad/downloads/list Download the latest **AeroQuad Configurator.** The Configurator is a very useful tool when configuring and troubleshooting the quad. It has displays and commands for motors commands, sensor outputs, PID settings, transmitter/ESC calibration, and much more. Install the Configurator. More information regarding the Configurator is available at this http://aeroquad.com/content.php?116 dedicated page.

3.2 ARDUINO-PC INTERFACE

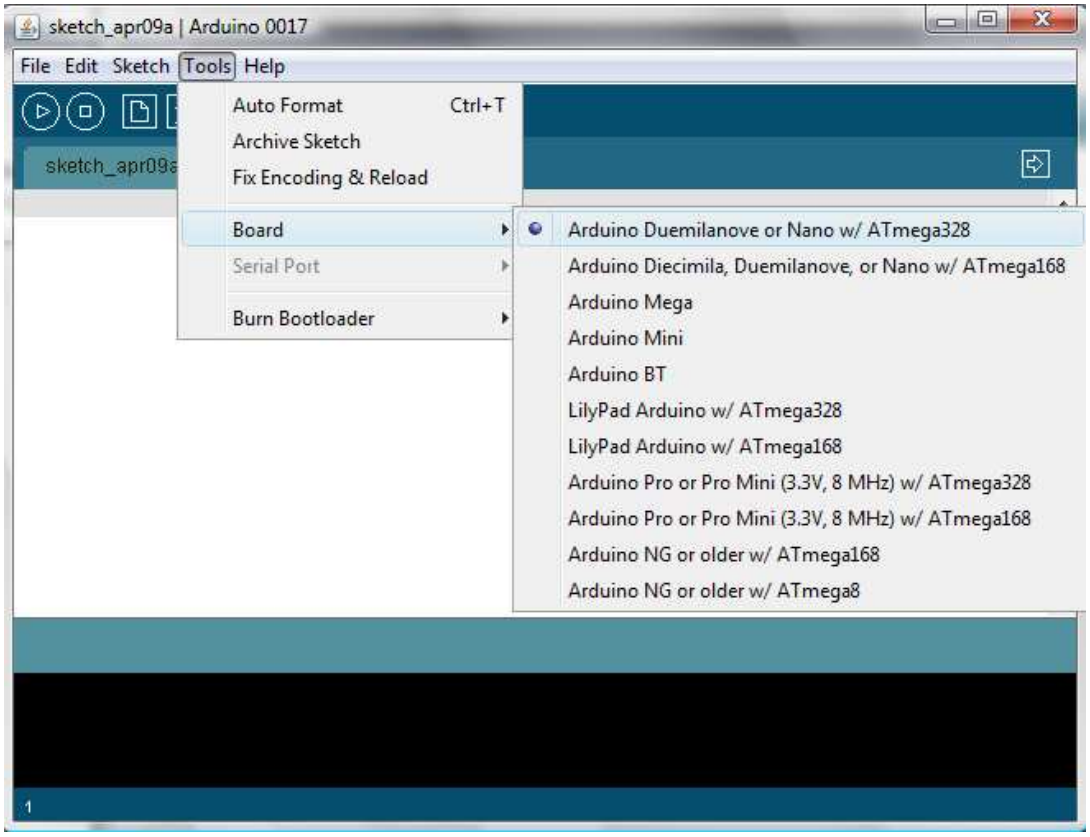
If you are completely unfamiliar with the Arduino, this part of the tutorial should provide information on how to establish a connection between the computer and the Arduino.

1. Open the Arduino IDE and then the Blink tutorial (IDE 0017 version shown) through **File>Examples>Digital>Blink**

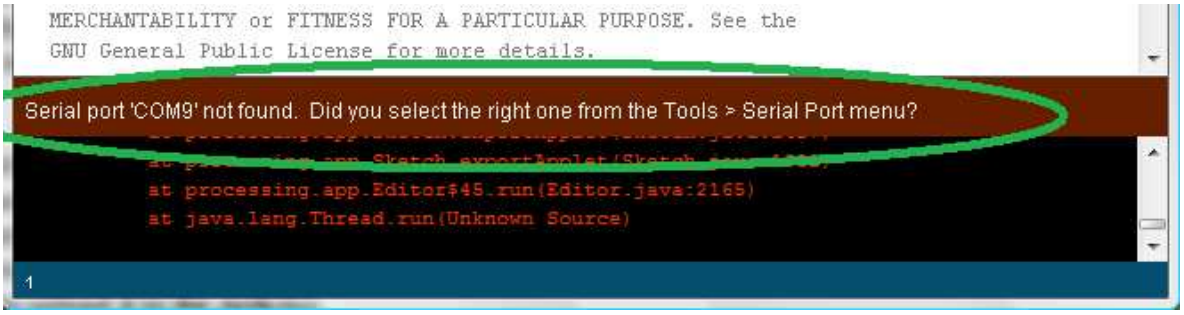


2. Connect the Arduino to the PC through the USB A-to-B cable. The USB provides power to the Arduino automatically and thus an external power is not required, but can be connected anyway.

3. Select the correct Arduino board through **Tools>Board> Arduino Duemilanove w/ATmega328** or **Arduino Mega** or **Arduino Uno** or **Arduino Mega 2560** (the latest IDE version should have support for all the latest Arduino boards).



4. Select the correct USB serial port through **Tools>Serial Port**. If uploading fails, then the wrong serial port (USB) was selected. Select another one if this message pops up during uploads.



5. Upload the Blink sketch (code) to the Arduino. Upon a successful upload, the message below should show "Done Uploading."

6. The Blink tutorial sketch makes the LED next to digital pin 13 on the Arduino blink in a loop, one second at a time by default. Congratulations, you've uploaded your first sketch to the Arduino.

Uploading the AeroQuad code

When satisfied with the LED, it is now time to upload the AeroQuad code in a similar manner.

1. Open the AeroQuad code through **File>Open**.
2. Find the previously extracted AeroQuad folder and select the **AeroQuad.pde** file. This will open the complete AeroQuad code with all the tabs. Upload the code.
3. After a successful upload, the Arduino may be disconnected from the computer.

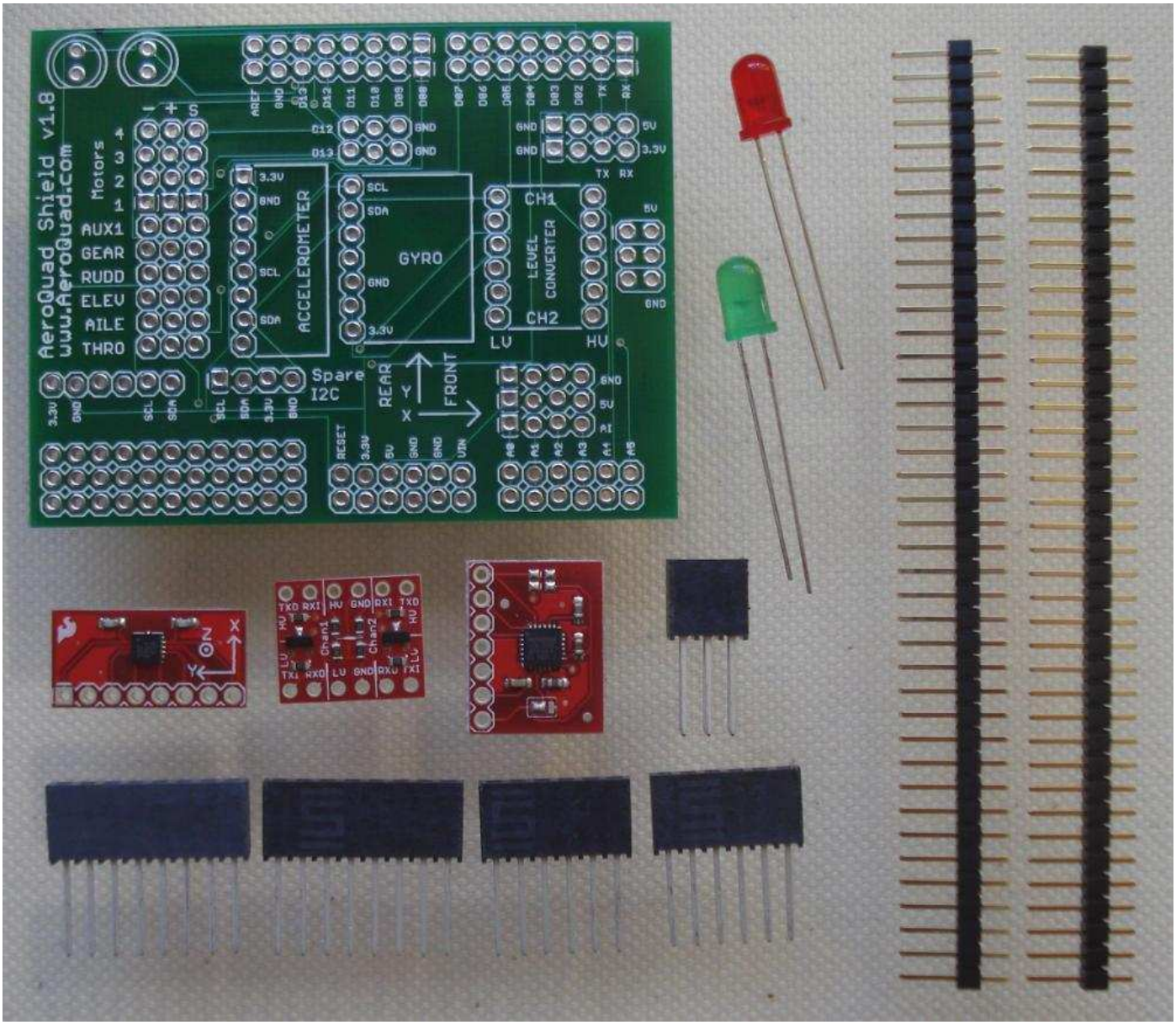
Also, before uploading the code to the Arduino, a section of the main AeroQuad.pde tab called "Hardware Configuration" needs to be edited. The user must uncomment the correct line based on the hardware that is being used in their quad. As an example, here's that section with the AeroQuad shield v1.8 and Arduino Duemilanove selected as the hardware.

```
************************ Hardware Configuration ***************************
*************************************************************************/

// Select which hardware you wish to use with the AeroQuad Flight Software

//#define AeroQuad_v1         // Arduino 2009 with AeroQuad Shield v1.7 and below
#define AeroQuad_v18        // Arduino 2009 with AeroQuad Shield v1.8
//#define AeroQuad_Wii        // Arduino 2009 with Wii Sensors (needs debug)
//#define AeroQuadMega_v1     // Arduino Mega with AeroQuad Shield v1.7 and below
//#define AeroQuadMega_v2     // Arduino Mega with AeroQuad Shield v2.x
//#define AeroQuadMega_Wii    // Arduino Mega with Wii Sensors (needs debug)
//#define APM                 // ArduPilot Mega (APM) with APM Sensor Board
//#define Multipilot          // Multipilot board with Lys344 and ADXL 610 Gyro
//#define MultipilotI2C       // Active Multipilot I2C and Mixertable
```

3.3 AEROQUAD SHIELD V1.8 SOLDERING PROCEDURES

The next step is to solder the sensors to the shield to make a single-piece six degrees of freedom inertial measurement unit (IMU). This requires some precise soldering which needs to be done carefully using the aforementioned 15 watt soldering iron and the 0.032" rosin core solder.

Before soldering, here's the complete set of components for the IMU version using the v1.8 shield for Arduino Duemilanove/Uno. Included in the picture is the AeroQuad shield v1.8 board, two indicator LEDs, the stackable female headers (Duemilanove/Uno pack), the breakout pins (57 total needed), the ITG-3200 triple axis gyro breakout board, the BMA180 triple axis accelerometer breakout board, and the logic level converter board.



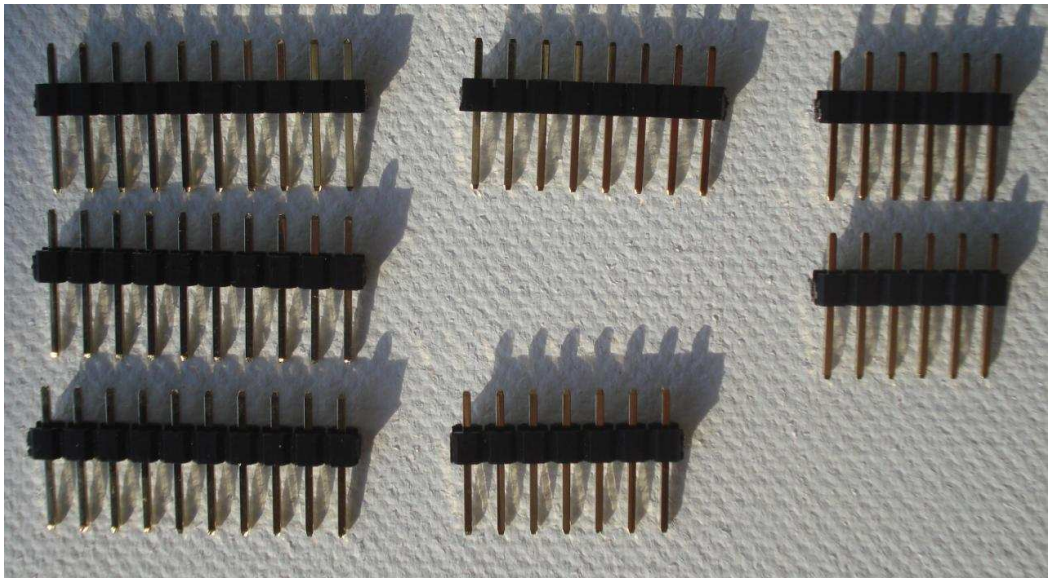
A note on electrostatic discharge (ESD)
It is important to take some care when working with the electronics (sensors and the Arduino) in order to prevent them from being damaged by ESD. Here are some recommendations:

- Ground yourself before touching the electronics. This can be done by touching a metal appliance which is plugged into an electrical socket.

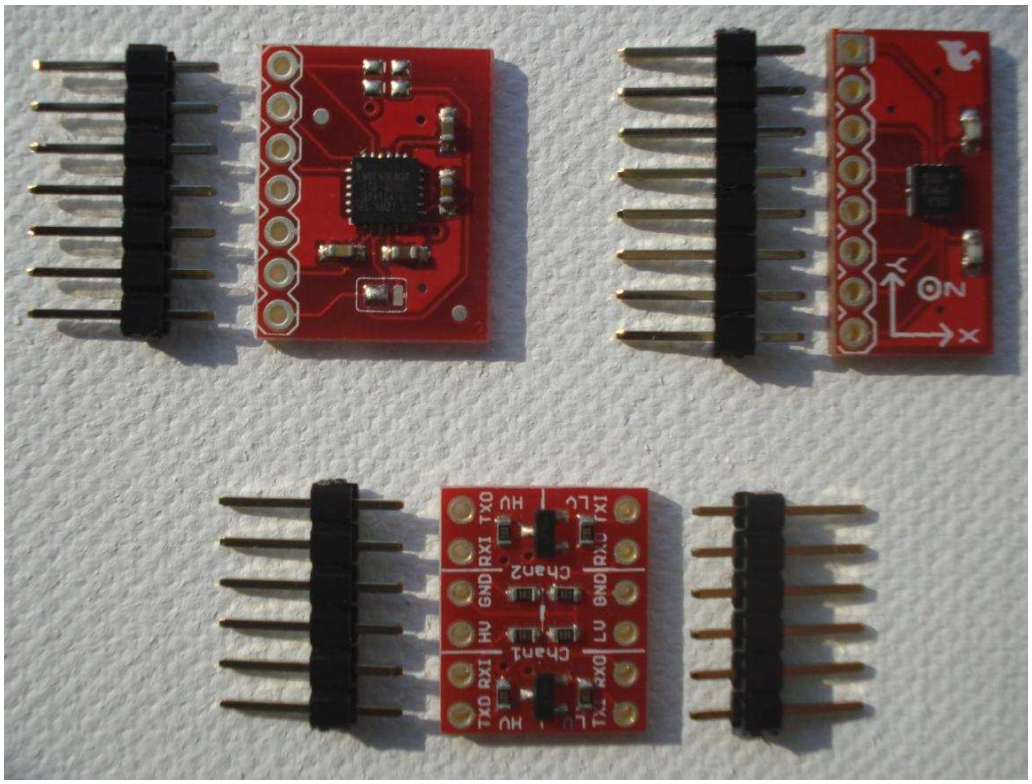
- Work in an environment where there is less chance of ESD developing, such as on a concrete floor of a garage. Avoid carpets and plastic tables
- When not in use, store the electronics in an ESD protective plastic bag.

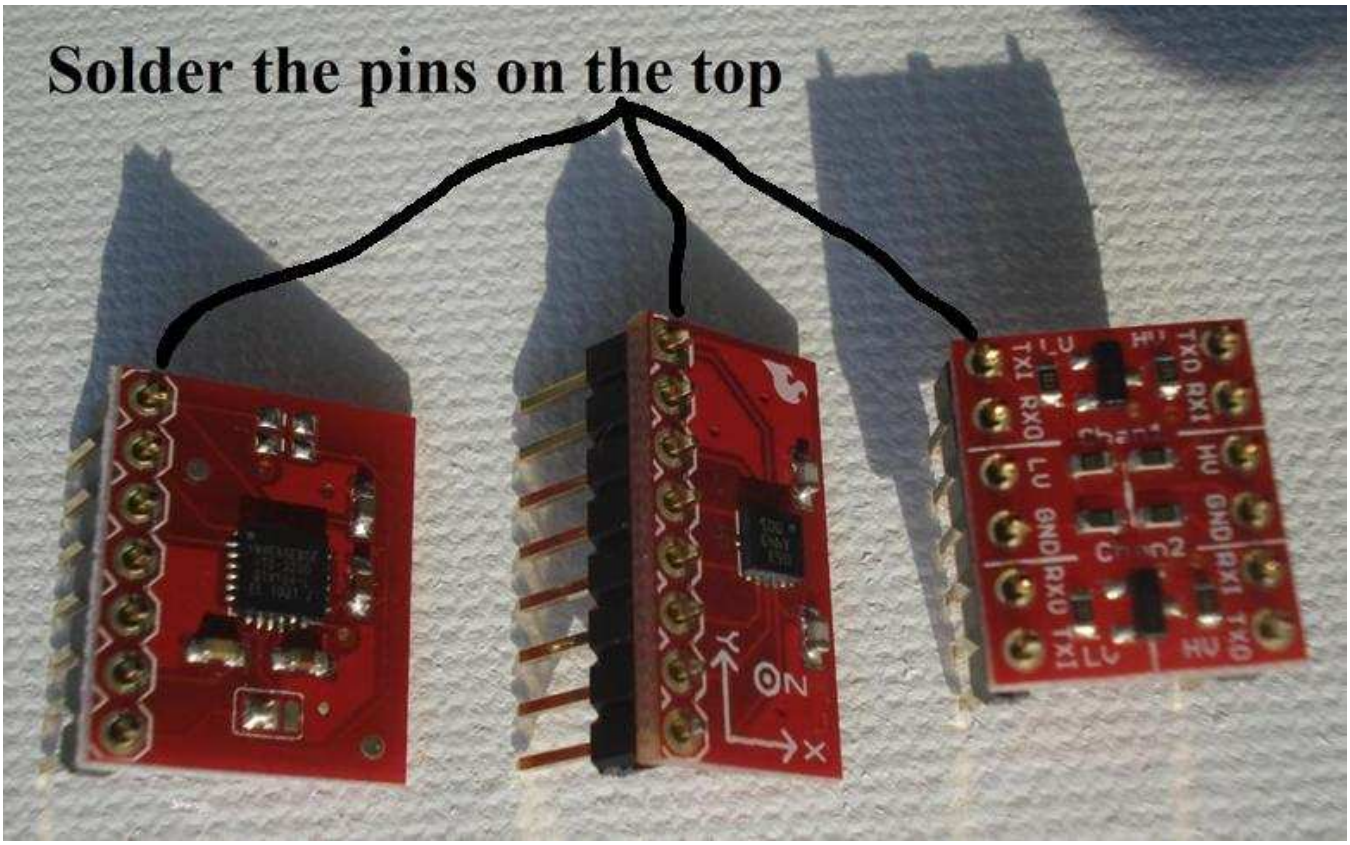
Breakout pins to the sensor boards

1. Break the pins into three 10-pin pieces, one 8-pin piece, one 7-pin piece, and two 6-pin pieces

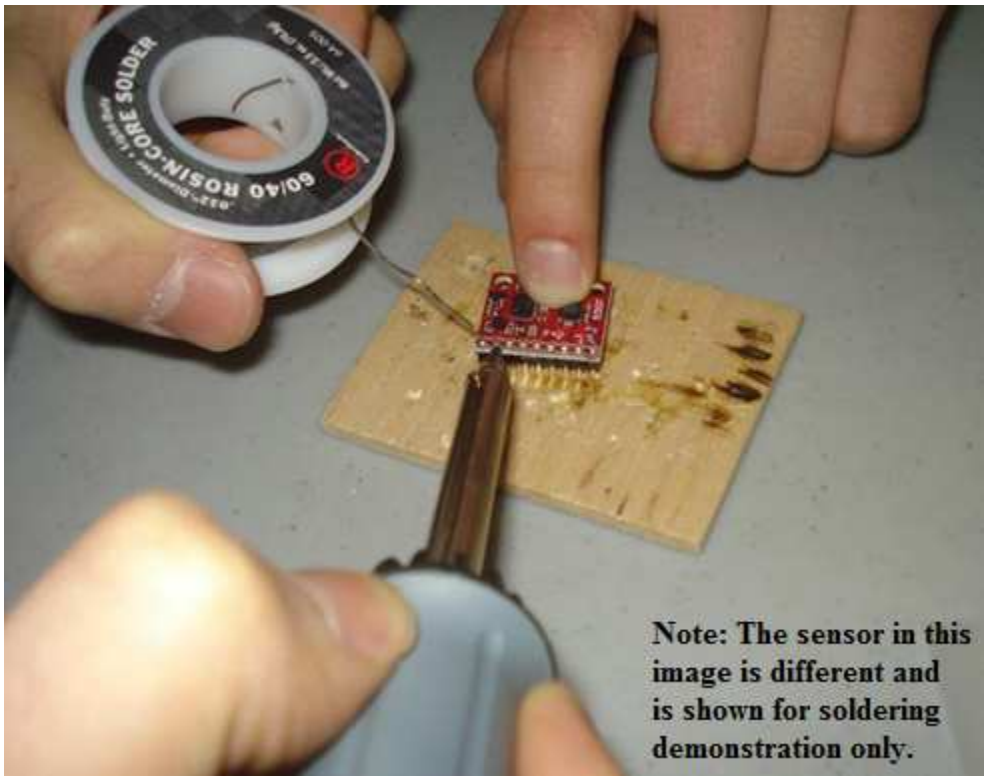


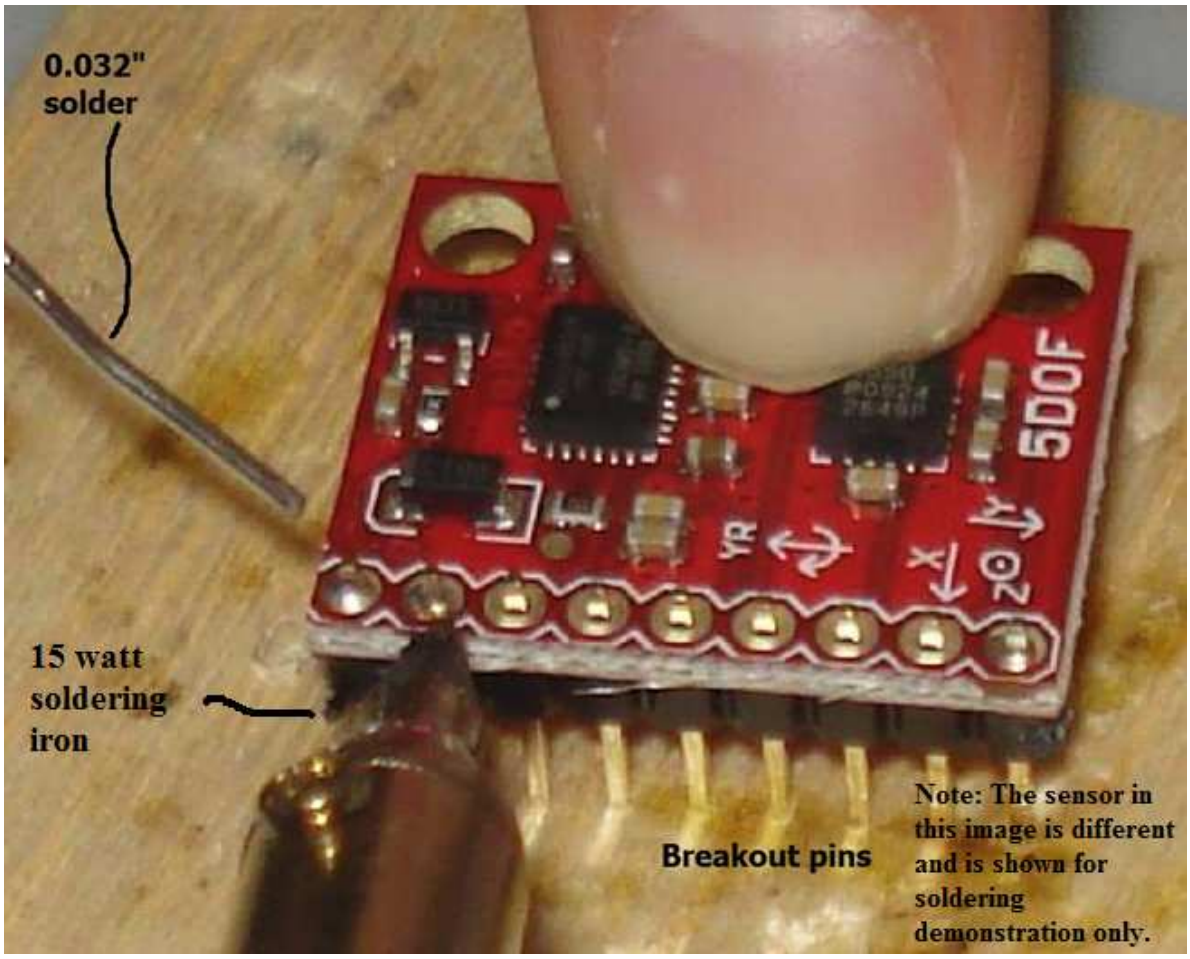
2. Insert the breakout pins to the hole slots of their respective sensor boards. Insert them **<u>from the bottom</u>** of the sensor boards (side with no circuitry) using the **<u>short end of the pins</u>**, like below.





3. Fix the pins to the sensor board so the pins are vertical to the board or have someone help.
4. Heat the 15 watt iron for at least 5 minutes
5. Solder the pins to the breakout board. Making sure that the pins and the board do not move, apply heat for about 1 second to both the round metal pad on the sensor board and the pin sticking out of it (simultaneously), then immediately apply the solder either onto the pad very close to the iron or onto the tip of the iron. Make sure not to touch the adjacent pads as that will short them and render the board useless. Also, after soldering the first pin, double check that the pins are vertical and flush with the board. If not, heat that first pin and carefully attempt to straighten out the pins.
6. Repeat this for all of the pins on the gyro, accelerometer, and the level converter boards.

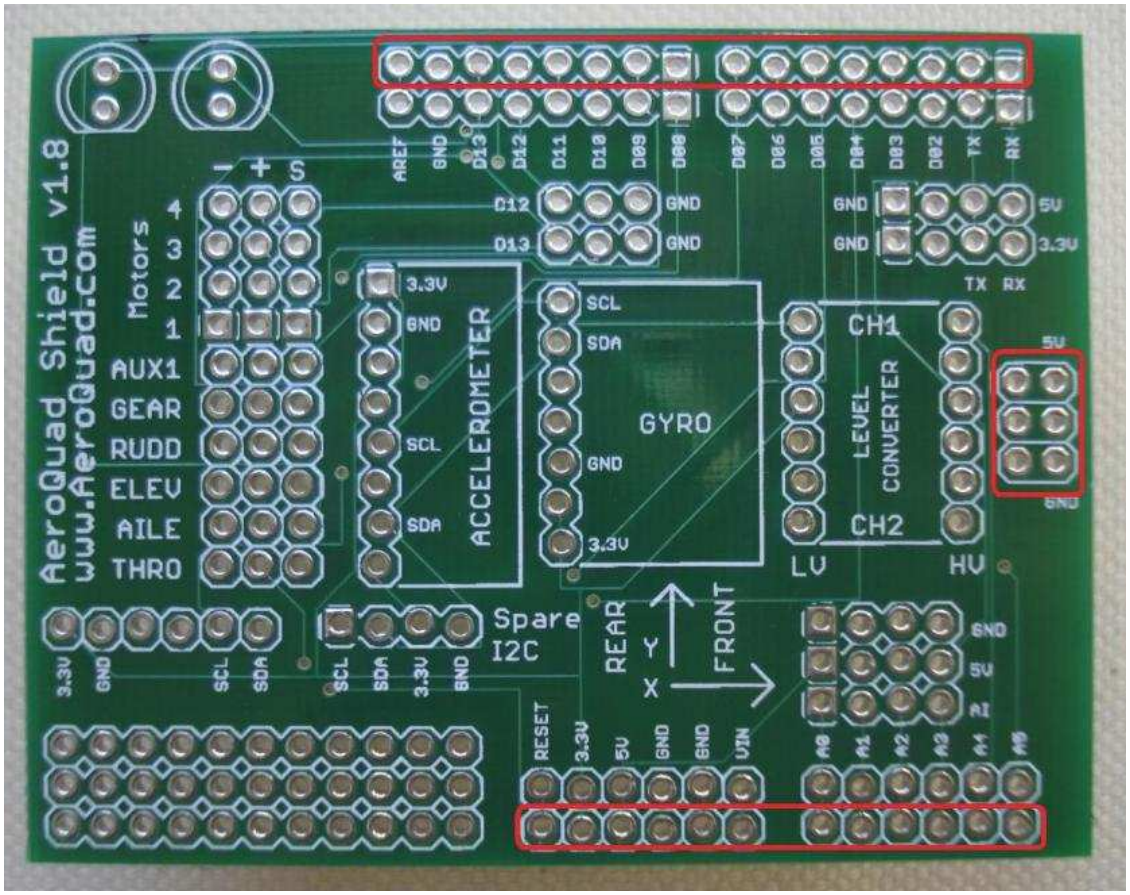


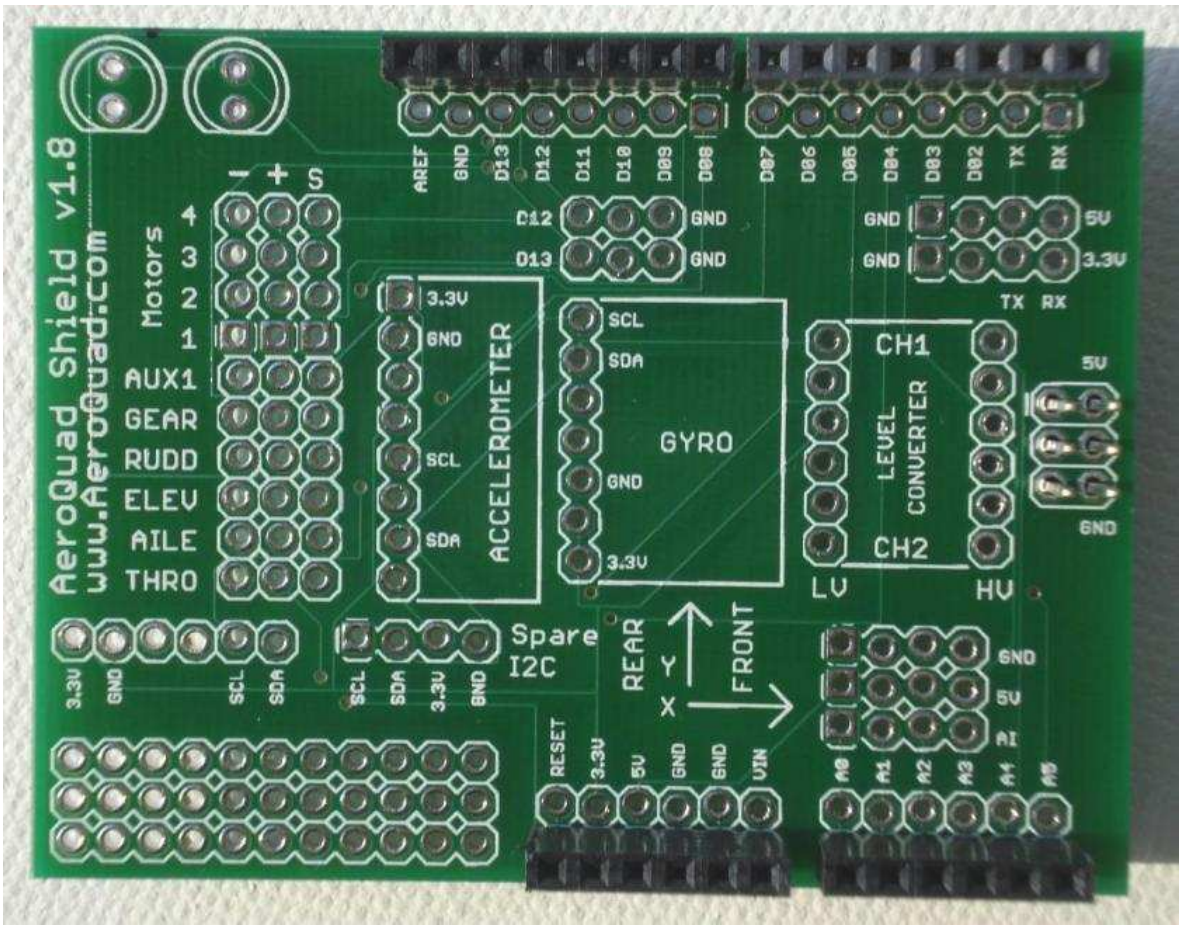


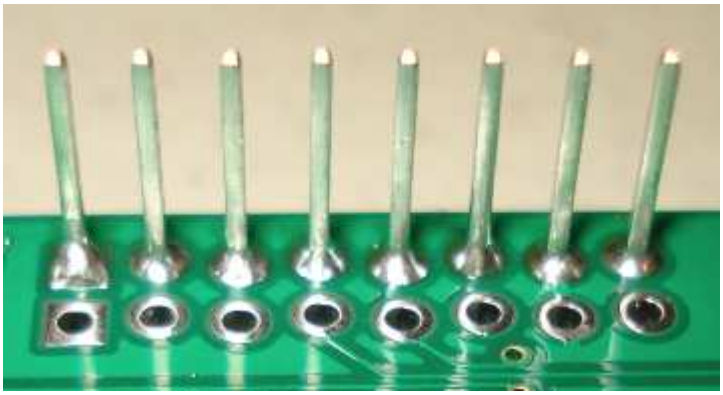
Stackable female headers (Duemilanove/Uno pack) to the shield

This step involves soldering the stackable headers (the ones bought separately from the shield) to the shield. This will allow the shield to be mated with the Arduino through the pins easily. There are a total of five pieces which need to be soldered, four on top and one from the bottom. Two are 6-pin, two are 8-pin, and one is a special piece having 2 rows of 3 pins.

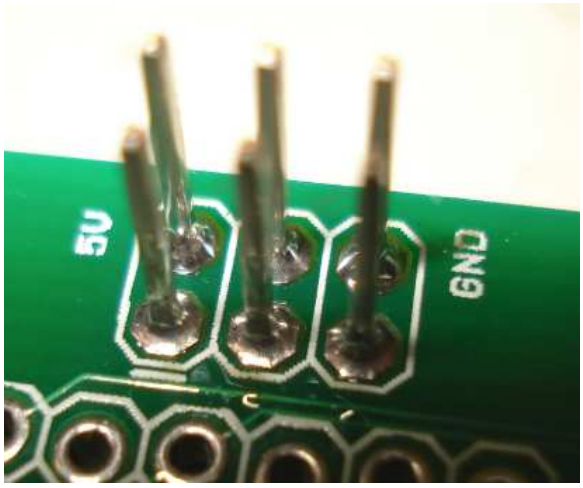
1. Start with the 6 or 8-pin pieces, soldering them with the same care as the sensor boards. Insert the 6 and 8 pin pieces **from the top** of the shield so as to have the black plastic headers on top and the pins sticking out from the bottom. They must be inserted into the outermost holes boxed in red (see picture) in order to fit the Arduino properly.
2. Solder the 6 and 8 pin pieces from the bottom, making sure they are all sticking out vertically
3. Insert the 2x3 piece **from the bottom** so as to have the metal pins coming out from the top side and the black headers being on the bottom side.
4. Solder the 2x3 piece to the shield


AeroQuad Shield v1.8
www.AeroQuad.com
Motors
4
3
2
1
AUX1
GEAR
RUDD
ELEV
AILE
THRO
ACCELEROMETER
GYRO
LEVEL CONVERTER
CH1
CH2
LV
HV
Spare I2C
REAR
FRONT
AREF
GND
D13
D12
D11
D10
D09
D08
D07
D06
D05
D04
D03
D02
TX
RX
5V
3.3V
SCL
SDA
RESET
VIN
A0
A1
A2
A3
A4
A5


AeroQuad Shield v1.8
www.AeroQuad.com
Motors
AUX1
GEAR
RUDD
ELEV
AILE
THRO
ACCELEROMETER
GYRO
LEVEL CONVERTER
CH1
CH2
LV
HV
Spare I2C
REAR
FRONT
AREF
GND
D13
D12
D11
D10
D09
D08
D07
D06
D05
D04
D03
D02
TX
RX
5V
3.3V
SCL
SDA
RESET
VIN



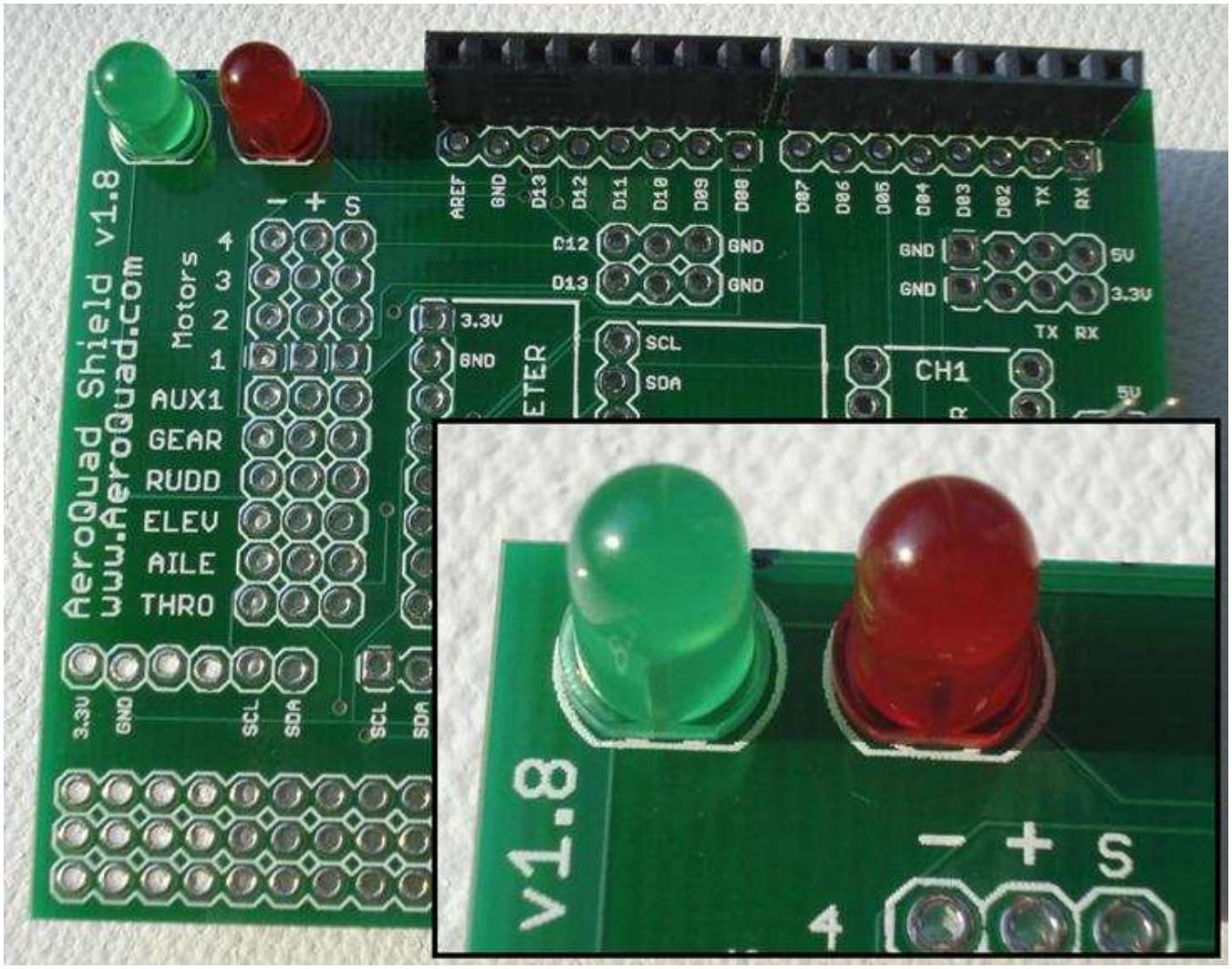
8-pin piece soldered from the bottom



2x3 pin piece soldered from the top

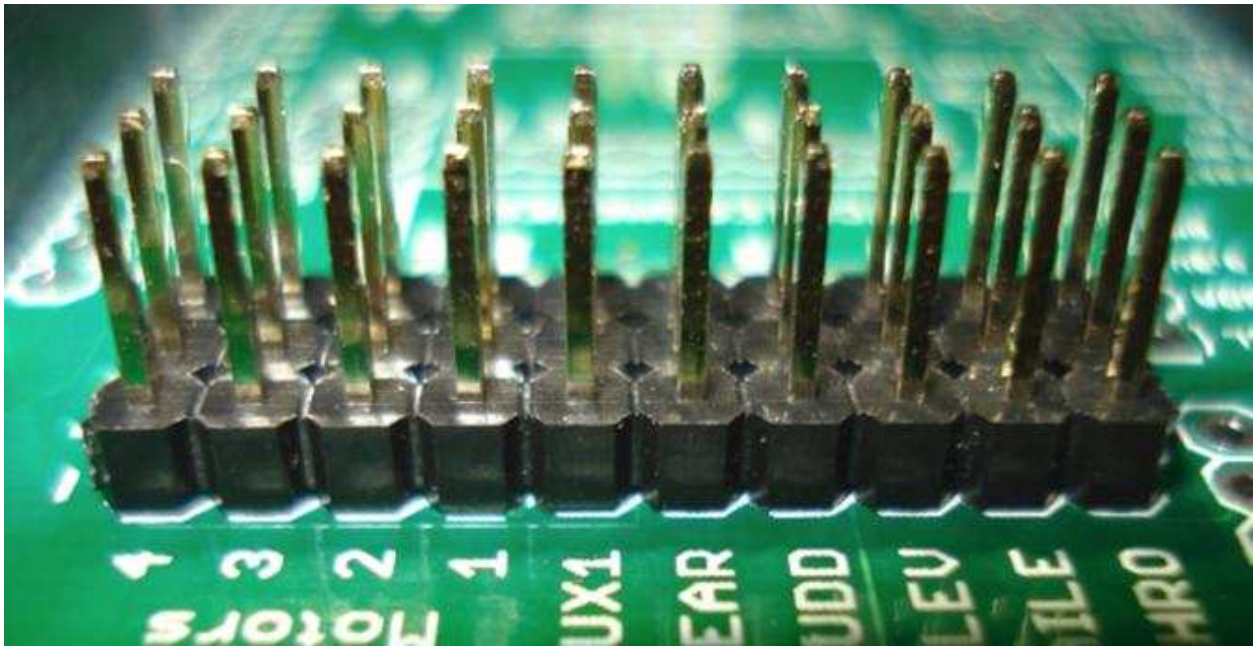
LEDs to the shield

These are simple to install and solder. First insert the LEDs, making sure that the polarity is respected. One side of the LEDs is flat and the spot on the shield for the LEDs has a round mark with one side being flat. After correctly inserting the LEDs, solder them from the bottom and trim off the extra wires.



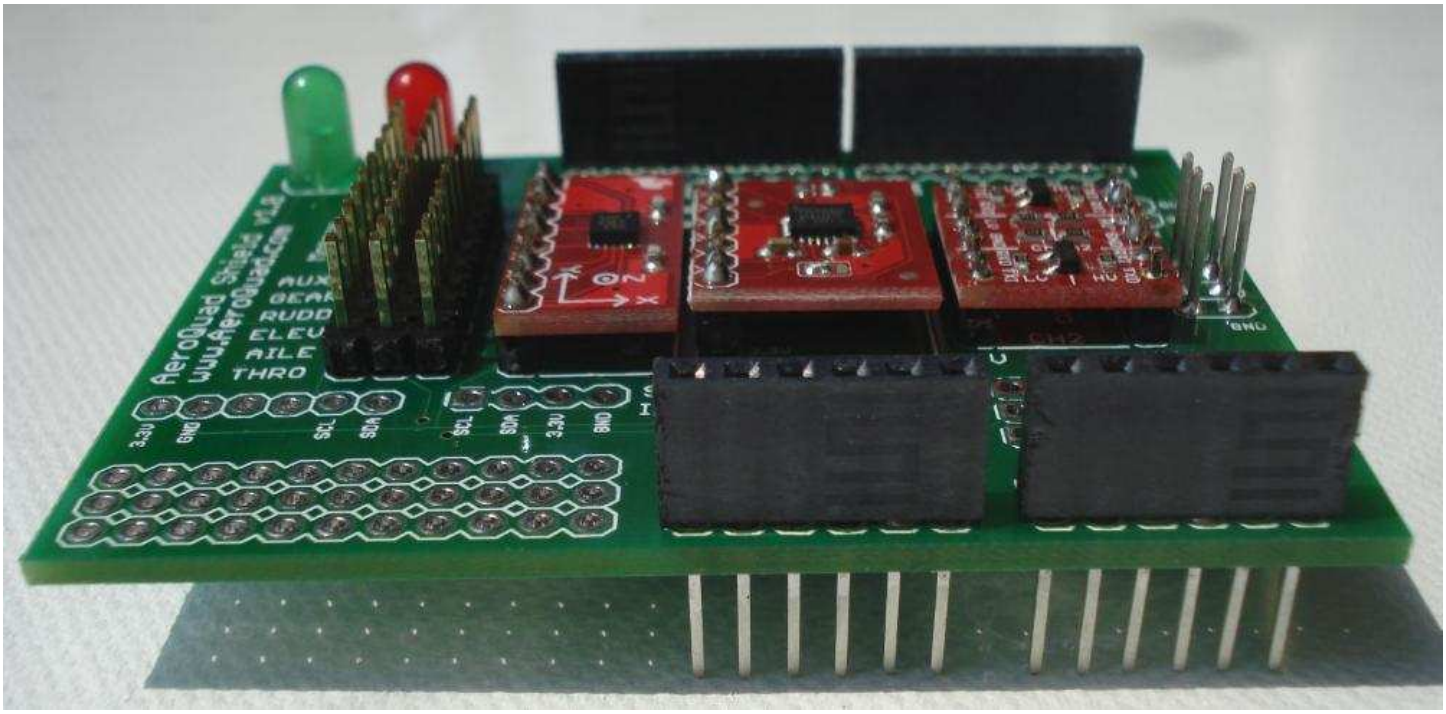
Motor and receiver pins to the shield

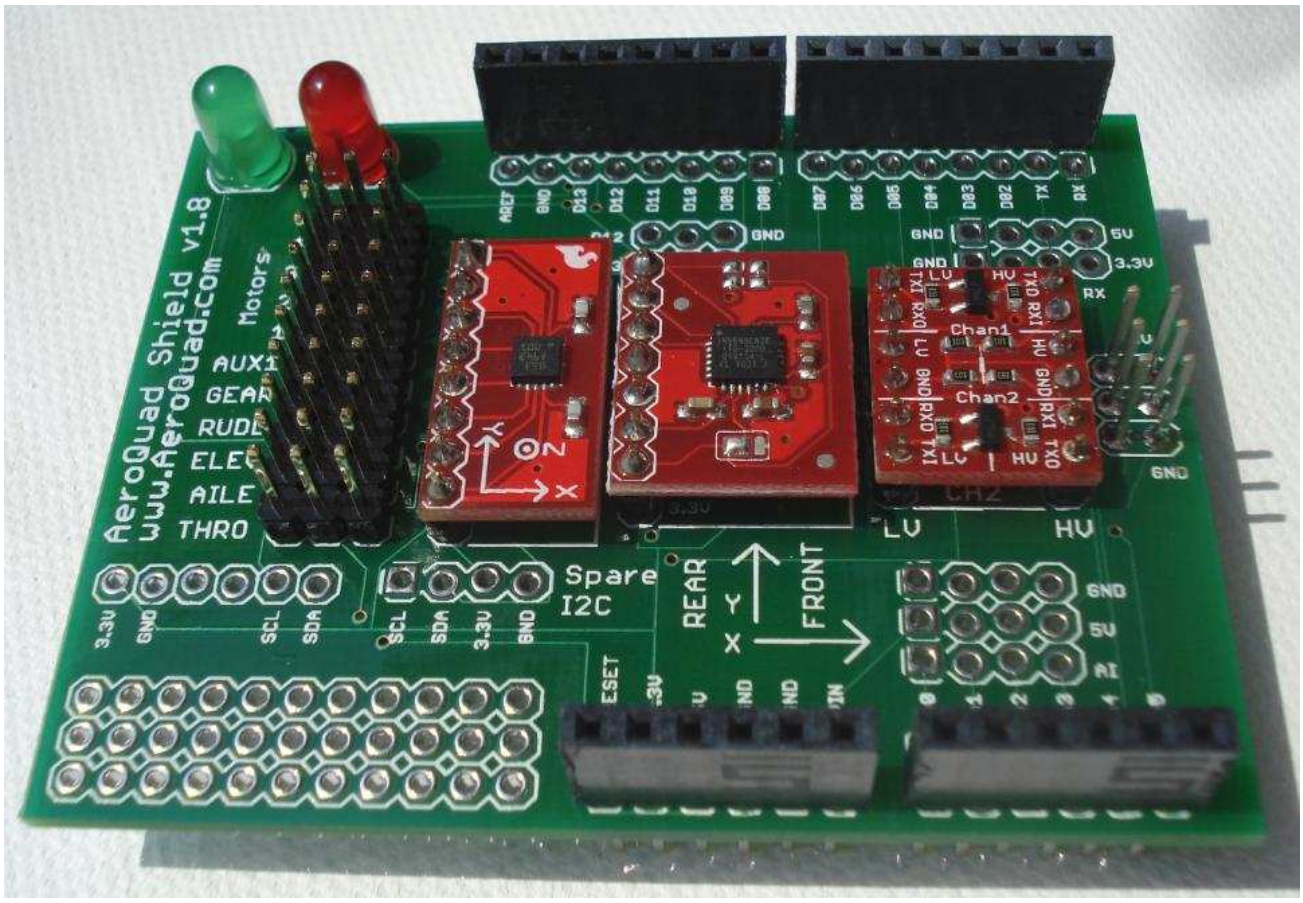
Insert the **short sides** of the three 10-pin pieces to the shield from the top and solder them from the bottom. These breakout pins will allow connections from the motor ESCs and the receiver channels to the shield.

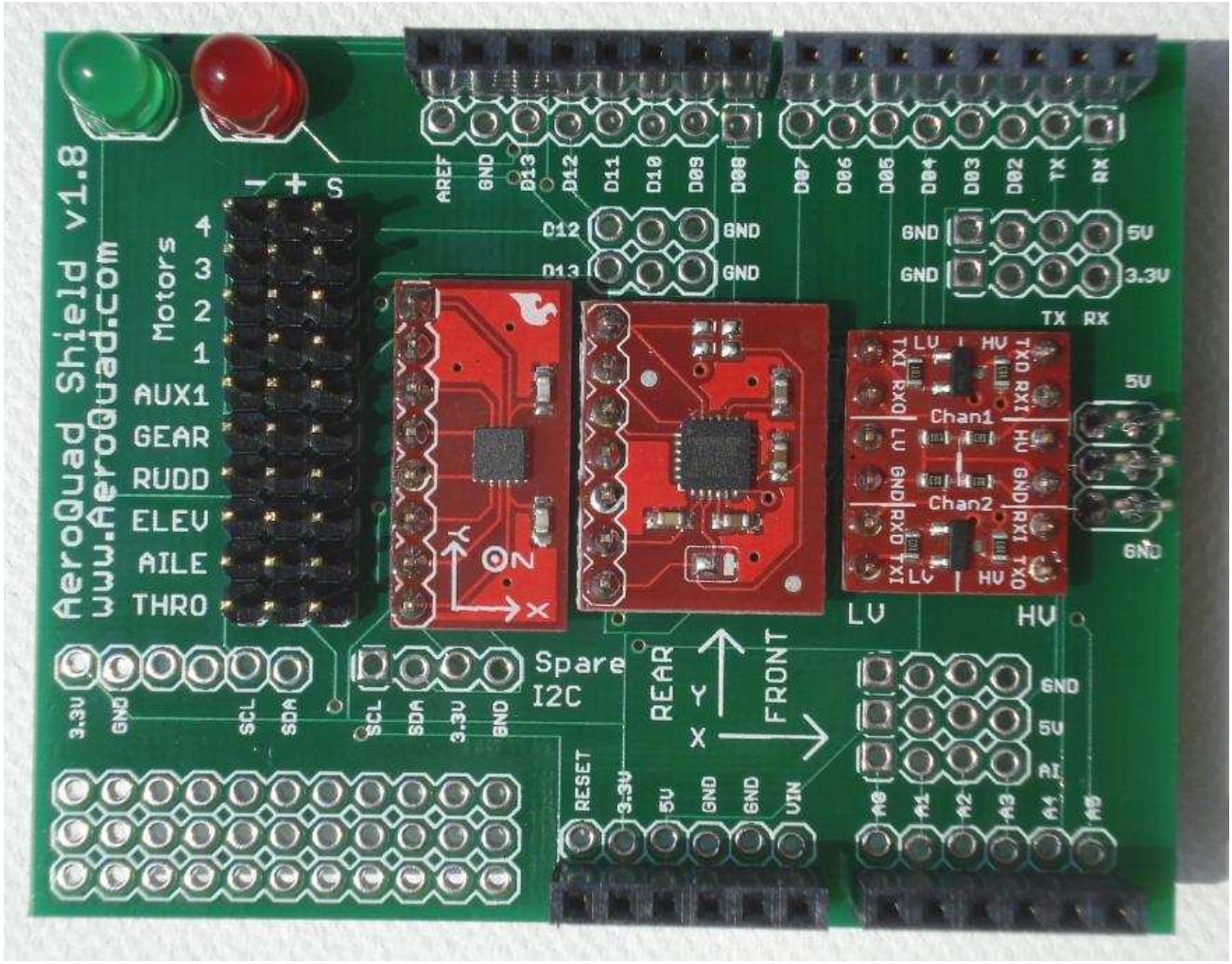


Sensors to the shield

The final step is to solder the two sensor boards as well as the level converter board (they should already have the breakout pins soldered to them) to the shield. After inserting the sensor boards and soldering one pin from the bottom, assure that the sensor board is horizontal to the shield and not at an angle as that will throw off readings of the sensors. Below is the completed shield.




AeroQuad Shield v1.8
www.AeroQuad.com
Motors
AUX1
GEAR
RUDD
ELEV
AILE
THRO
Spare I2C
REAR
FRONT
Chan1
Chan2
LV
HV
GND
5V
3.3V
RX
TX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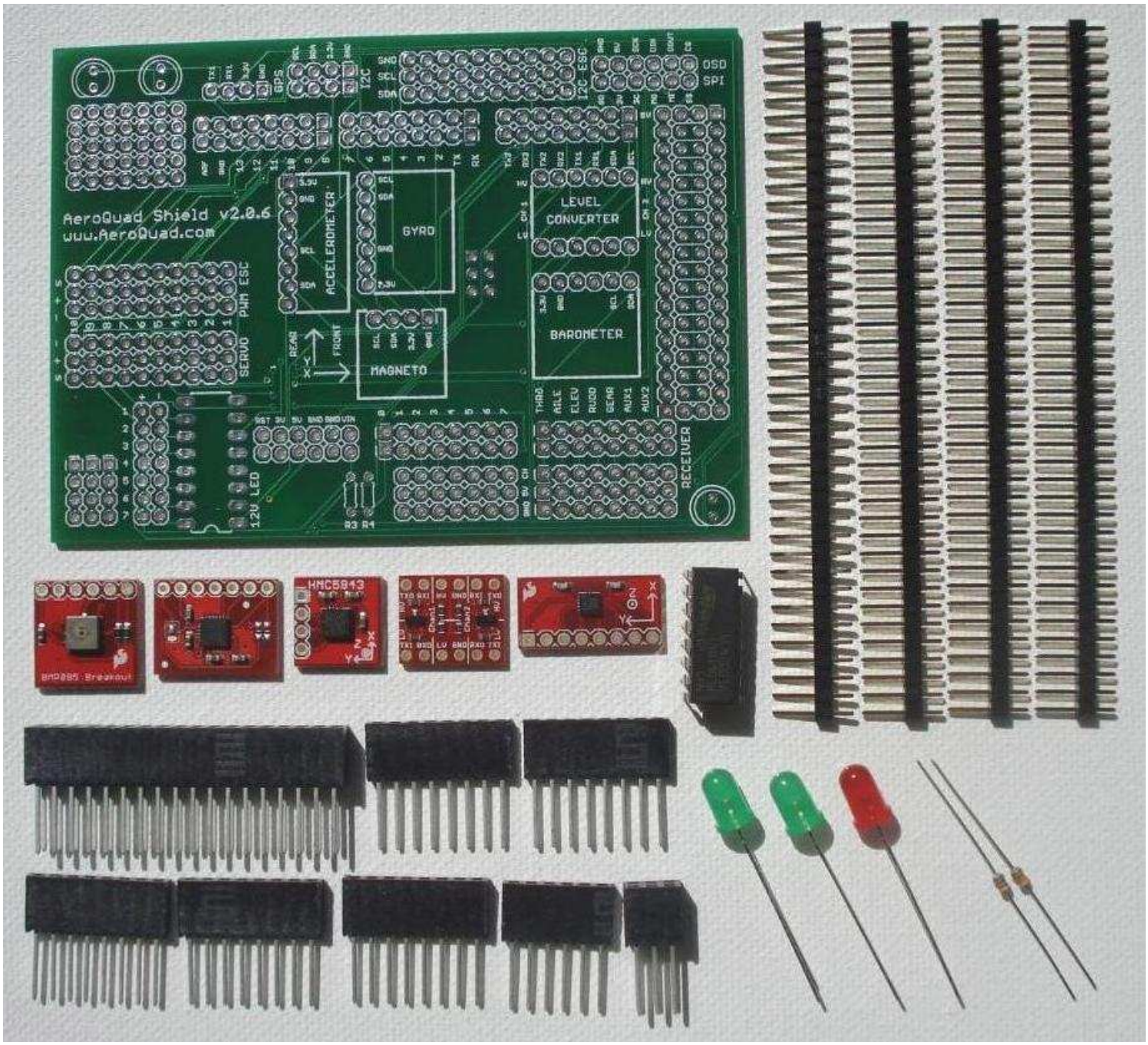
REAR
FRONT
Chan1
Chan2
LV
HV
GND
5V
3.3V
RX
TX

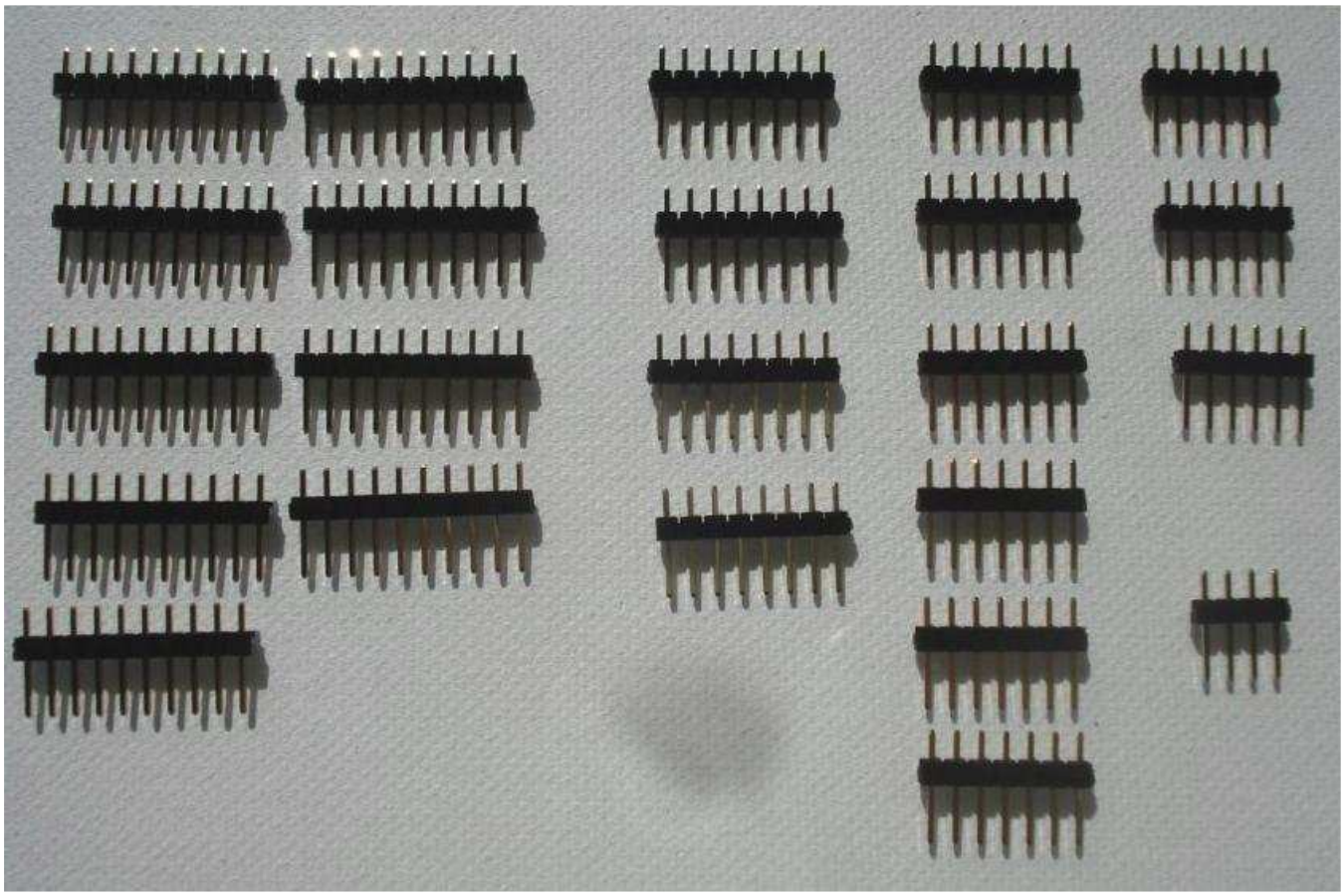
3.4 AEROQUAD SHIELD V2.0 SOLDERING PROCEDURES

Once again, here's the complete set of components for the IMU, this time the version using the v2.0 shield for Arduino Mega. Included in the picture is the AeroQuad shield v2.0 board, three indicator LEDs, the stackable female headers (Mega pack), the breakout pins (186 total needed), the ITG-3200 triple axis gyro breakout board, the BMA180 triple axis accelerometer breakout board, the BMP085 barometric pressure sensor breakout board, the HMC5843 triple axis magnetometer breakout board, the logic level converter board, two resistors (R3 = 15k and R4 = 7.5k), and a single integrated circuit chip.

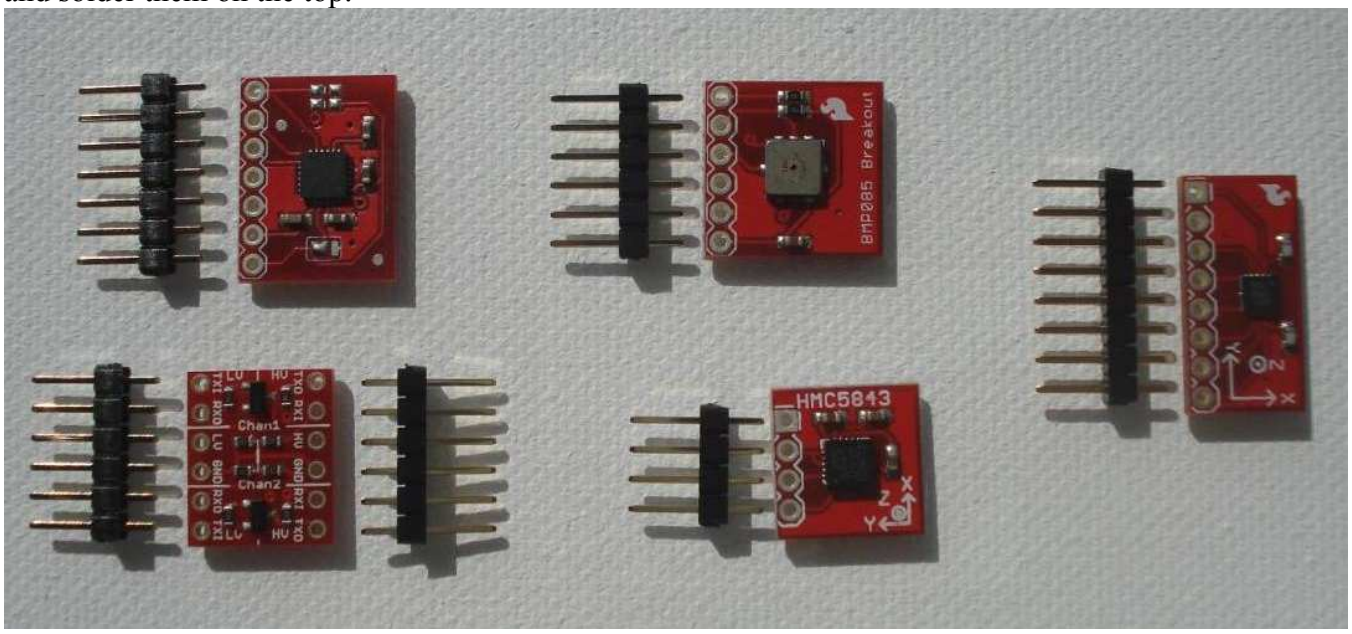


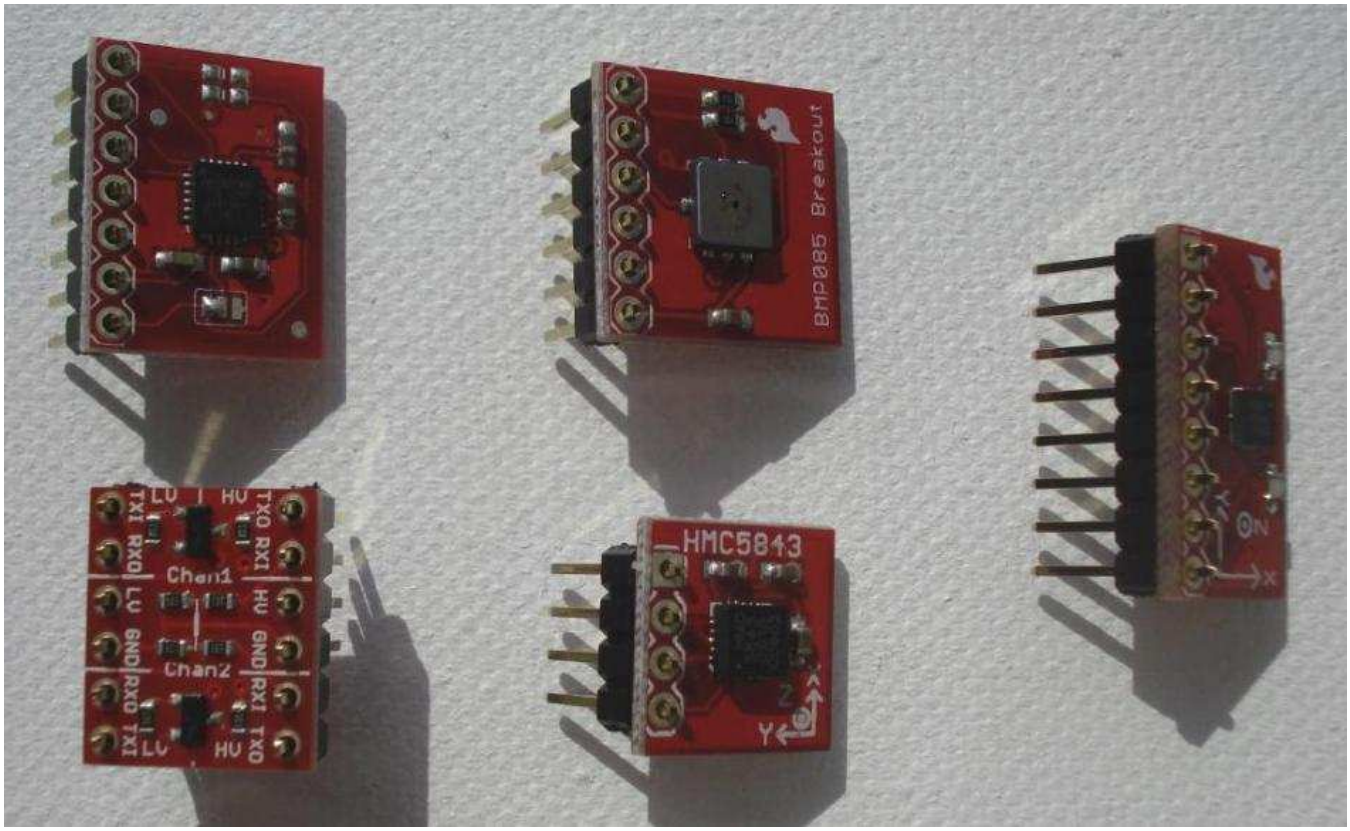
Breakout pins to the sensors boards

Break the breakout pins into nine 10-pin pieces, four 8-pin pieces, six 7-pin pieces, three 6-pin pieces, and one 4-pin piece.



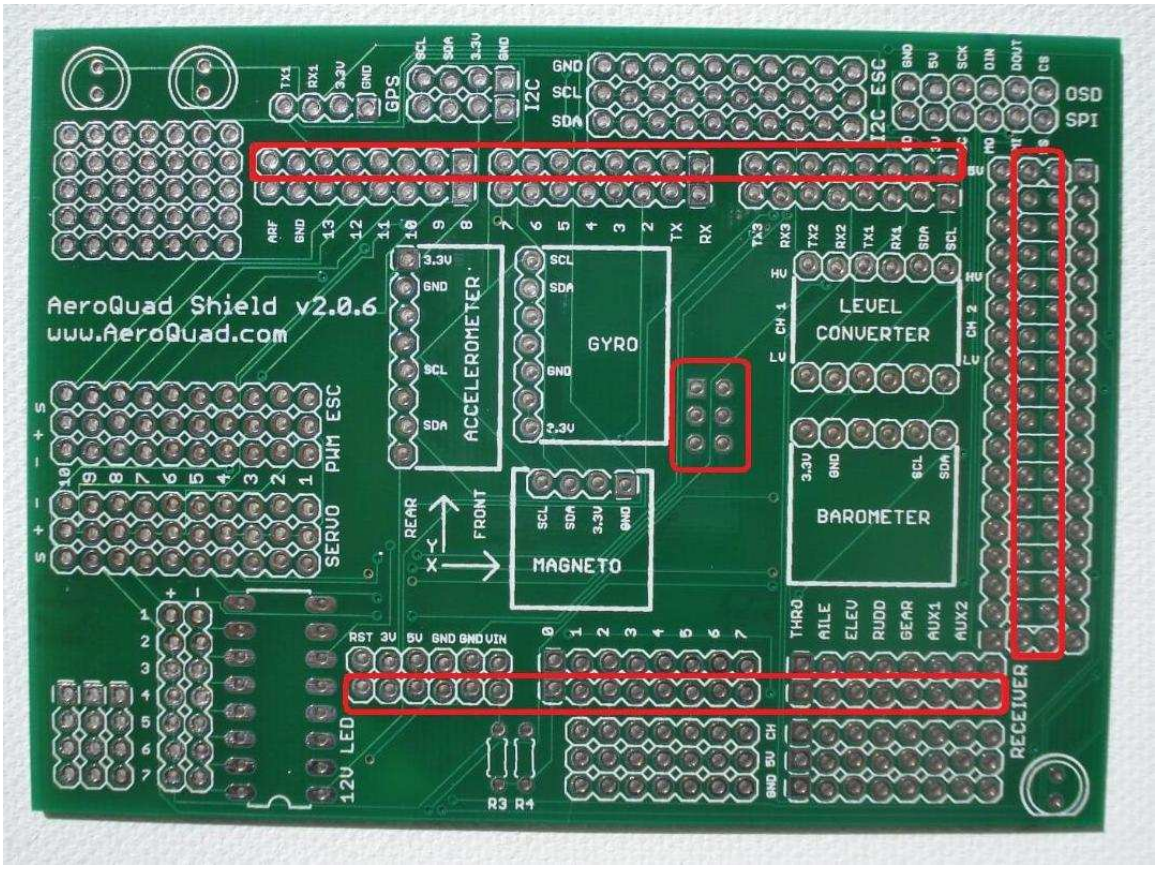
As before, insert the short ends of the breakout pins through the bottom of the sensor breakout boards and solder them on the top.

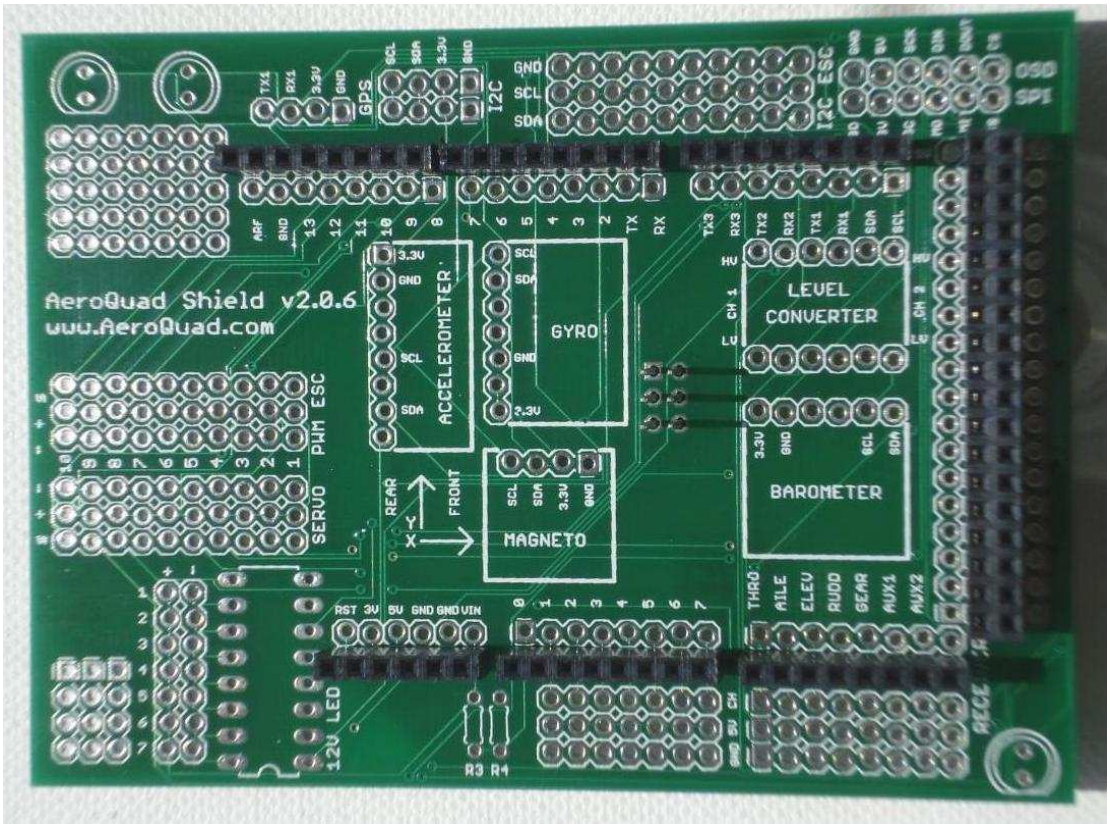




Stackable female headers (Mega pack) to the shield

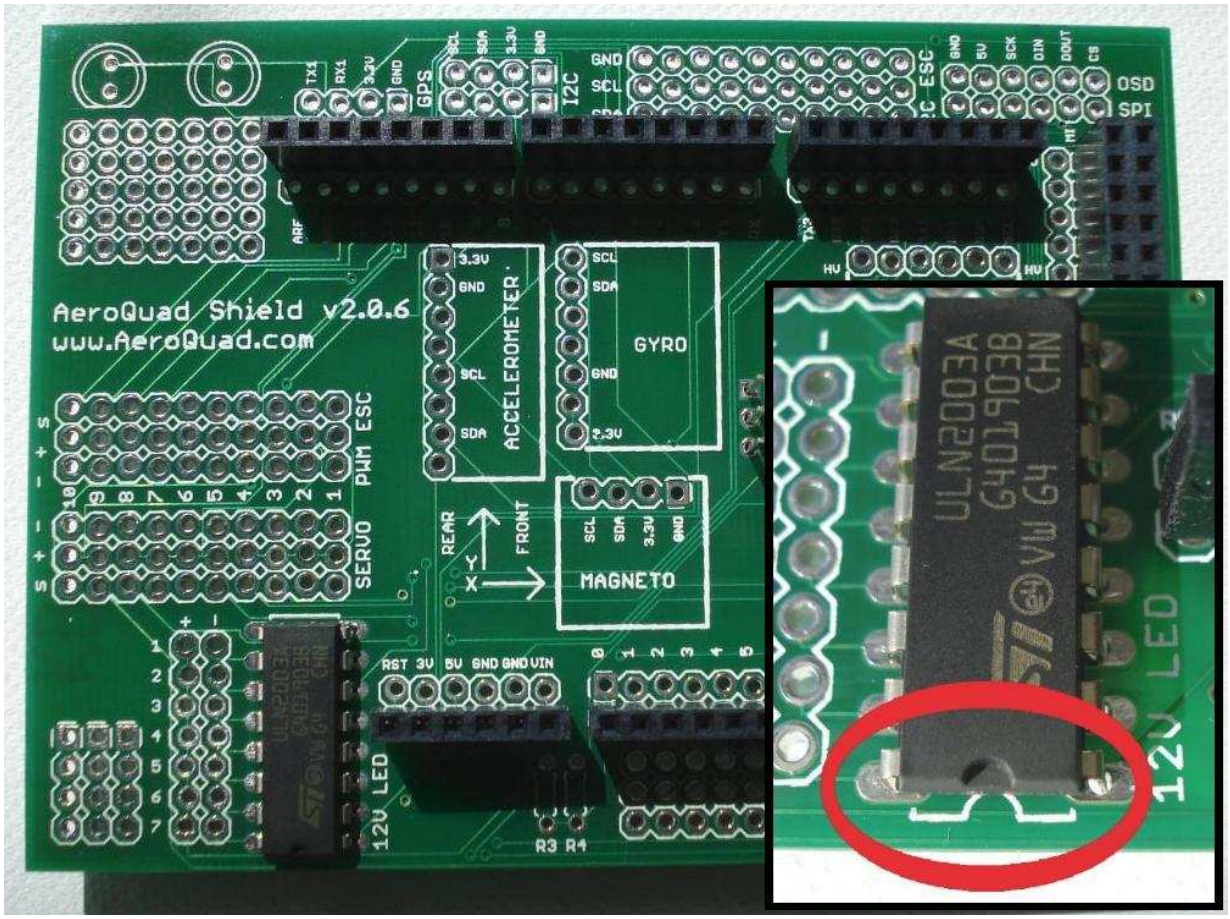
As in the v1.8 shield, these will be soldered to the shield in order to allow for an easy attachment and detachment of the shield to the Arduino. Insert the five 8-pin pieces, the one 6-pin piece, and the one 18x2-pin piece from the top of the shield into the slots shown in the picture below and solder them from the bottom of the shield. Then insert the 3x2-pin piece from the bottom and solder it from the top.



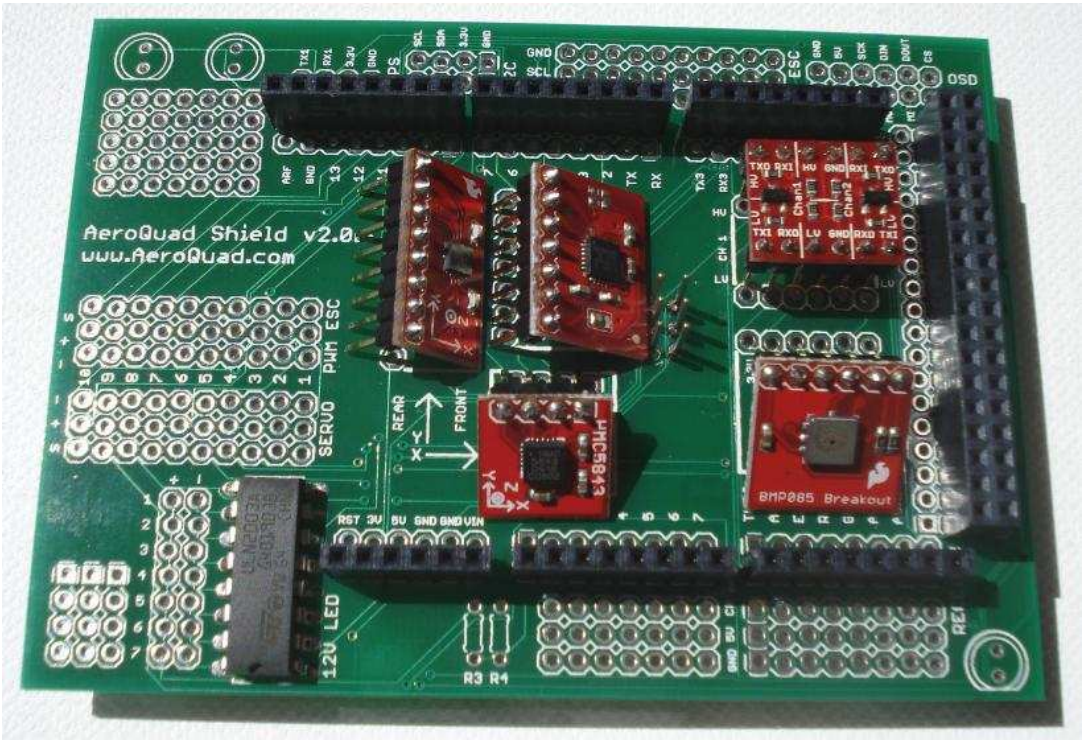


Integrated circuit chip to the shield

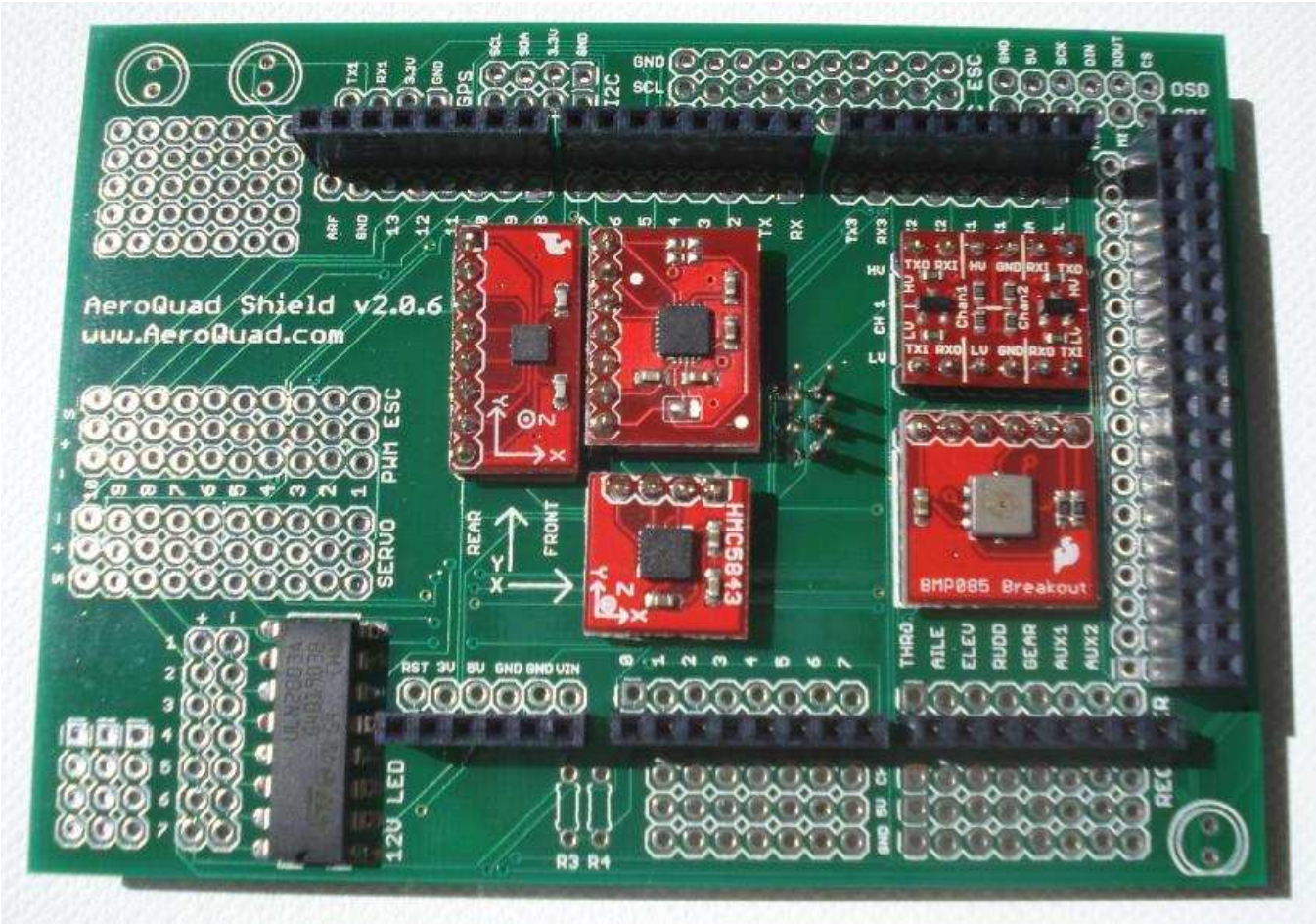
Insert the single piece integrated circuit chip into its appropriate spot, respecting the orientation. One side of the chip has a semi-circular cutout, as does the outline for the chip on the shield. Insert the chip accordingly from the top and solder its pins from the bottom.



Sensors to the shield
Insert the four sensor boards and the logic level converter board into the shield from the top and solder them from the bottom. The five breakout boards must already have the breakout pins soldered to them as explained earlier.

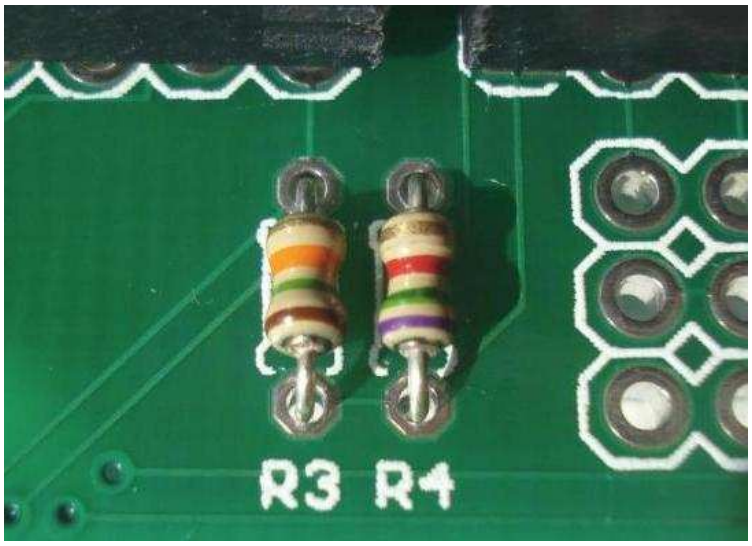


Note: The barometric pressure sensor board may also be inserted from the bottom of the shield and its pins soldered from the top. It's important to make sure though that the pin assignments are followed, meaning that each of the barometer board's pins is correctly in its hole in the shield. Installing the barometer under the shield will help reduce the aerodynamic effects from propellers which may give errors in pressure readings.

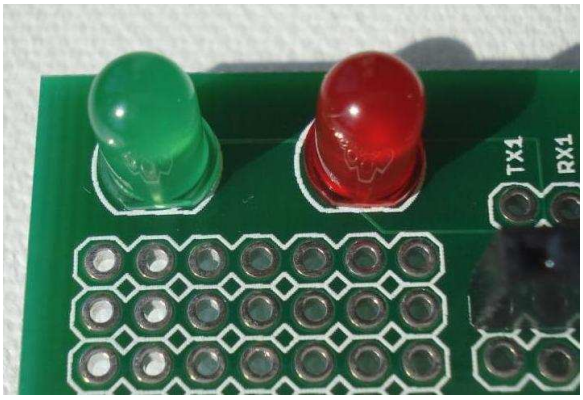


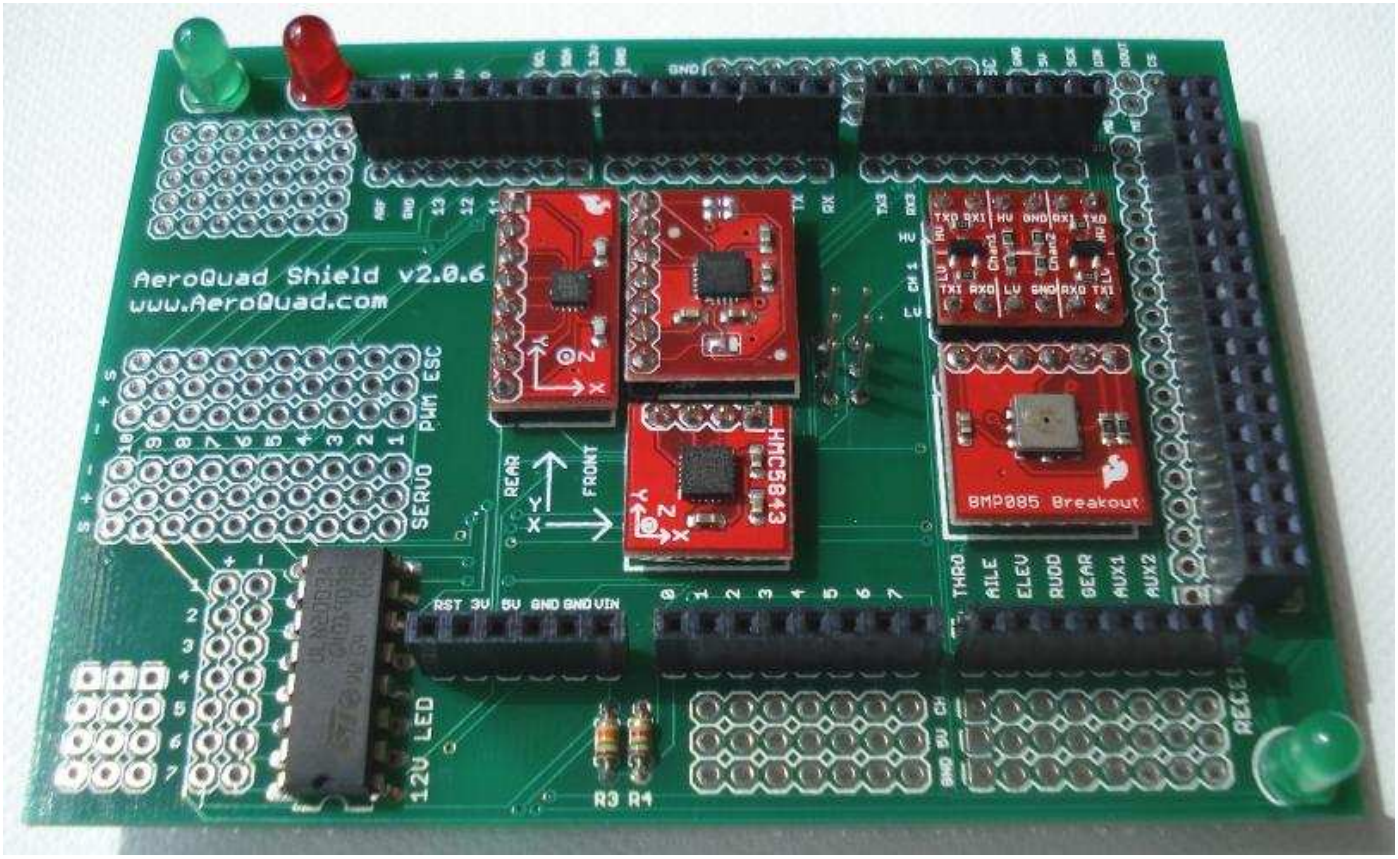
Resistors and LEDs to the shield

The two resistors that come with the shield are a R3=15kohm and R4=7.5kohm. R3 resistor has brown, green, orange, and gold stripes. R4 resistor has purple, green, red, and gold stripes. Place them into their respective spots, solder them from the bottom, and trim off the extra wires.



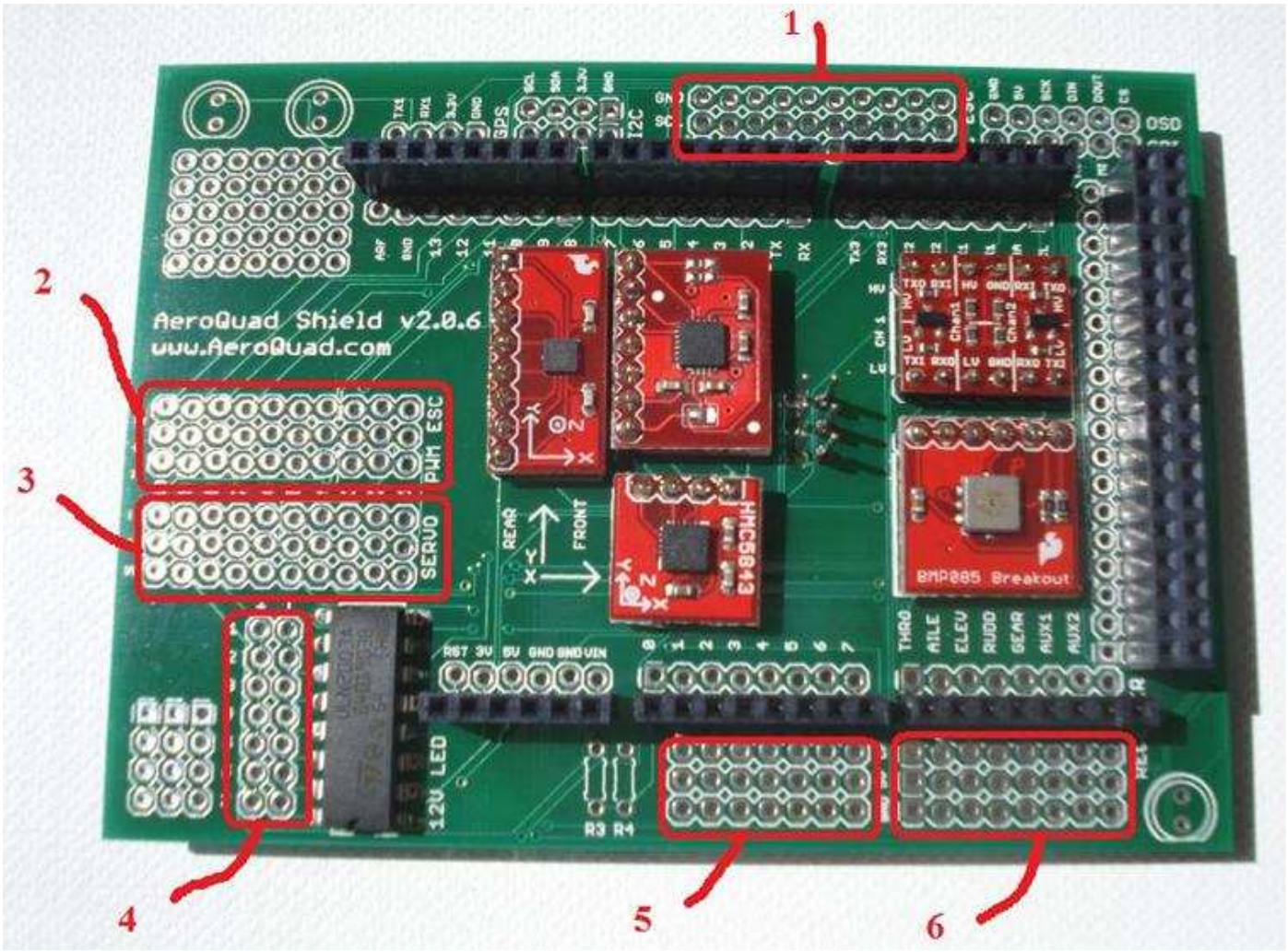
The three LEDs included in with the shield are to be inserted from the top and soldered from the bottom. The order is left to right on the top, green and then red and the third one on the bottom right is a green one as shown below.





Breakout pins to the shield

There are a total of 149 more breakout pins that need to be soldered to the shield. These will connect various things depicted below. The pins need to be inserted from the top of the shield using their short sides and soldered from the bottom.



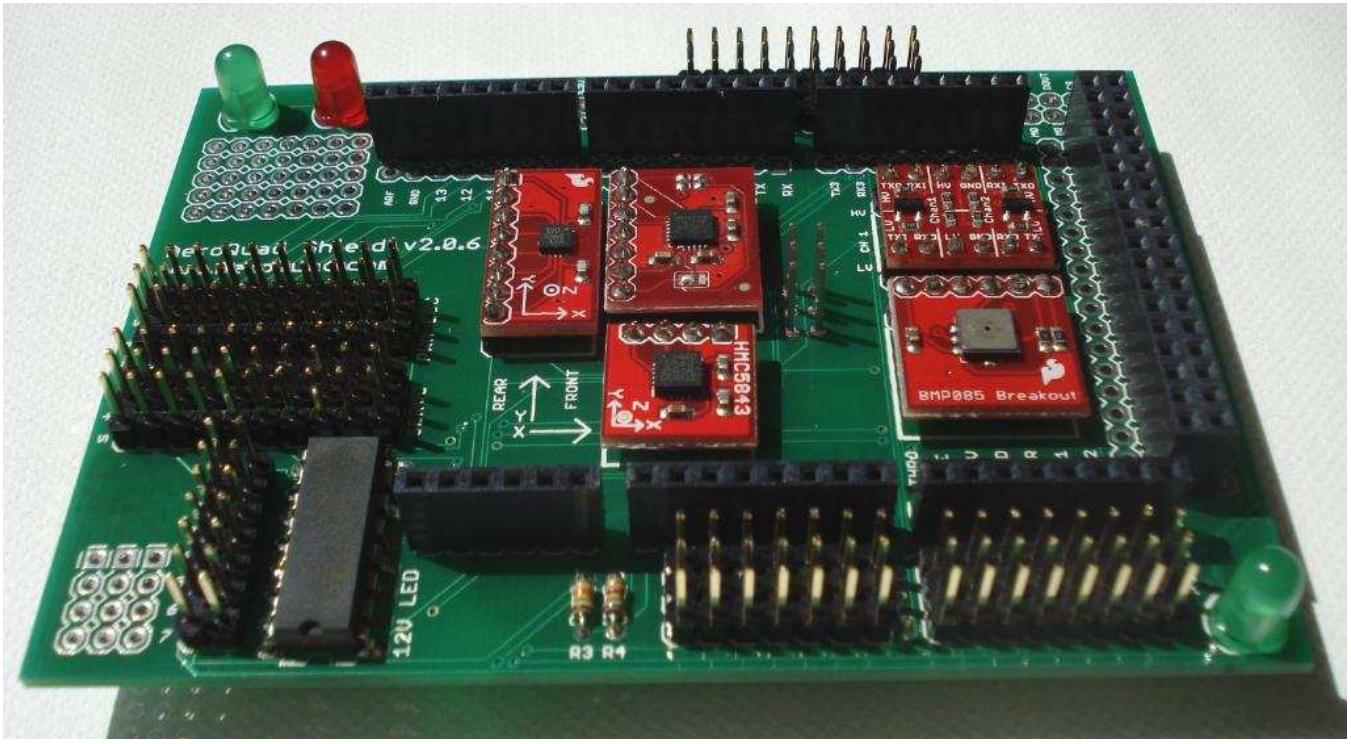
1- Outputs for the I2C based ESCs which will be supported in the near future. Users will have a choice between using the I2C and regular PWM ESCs.
2- Outputs for the regular PWM ESCs for the brushless motors.
3- Outputs for servo control. These will be useful for controlling camera stabilization servos or any other features requiring servo control.
4- 12-volt LED outputs. These will support custom user patterns through the Configurator.
5- Analog inputs for other sensors such as sonar.
6- Radio receiver channel inputs.

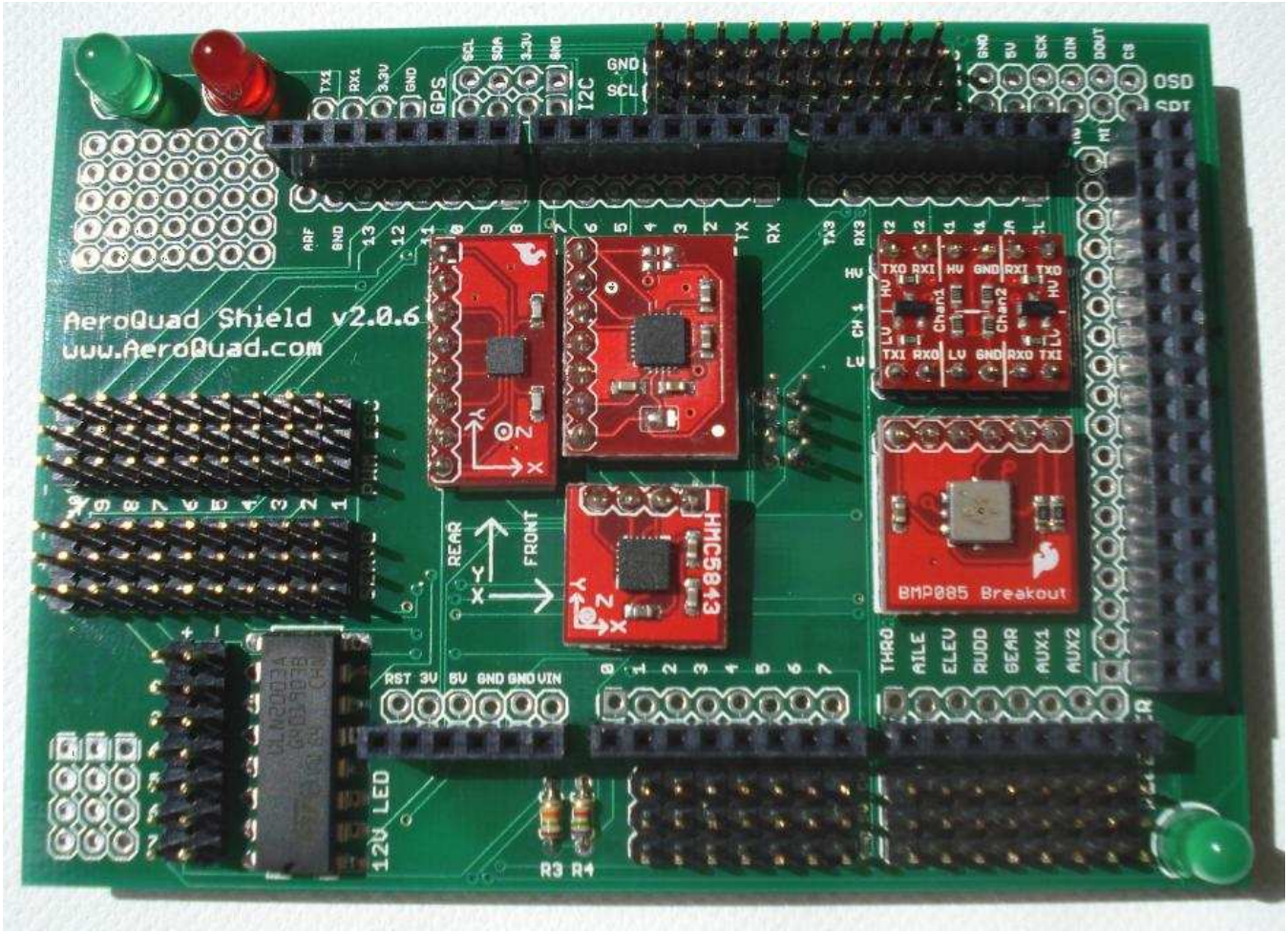
Arduino Mega PWM motor outputs

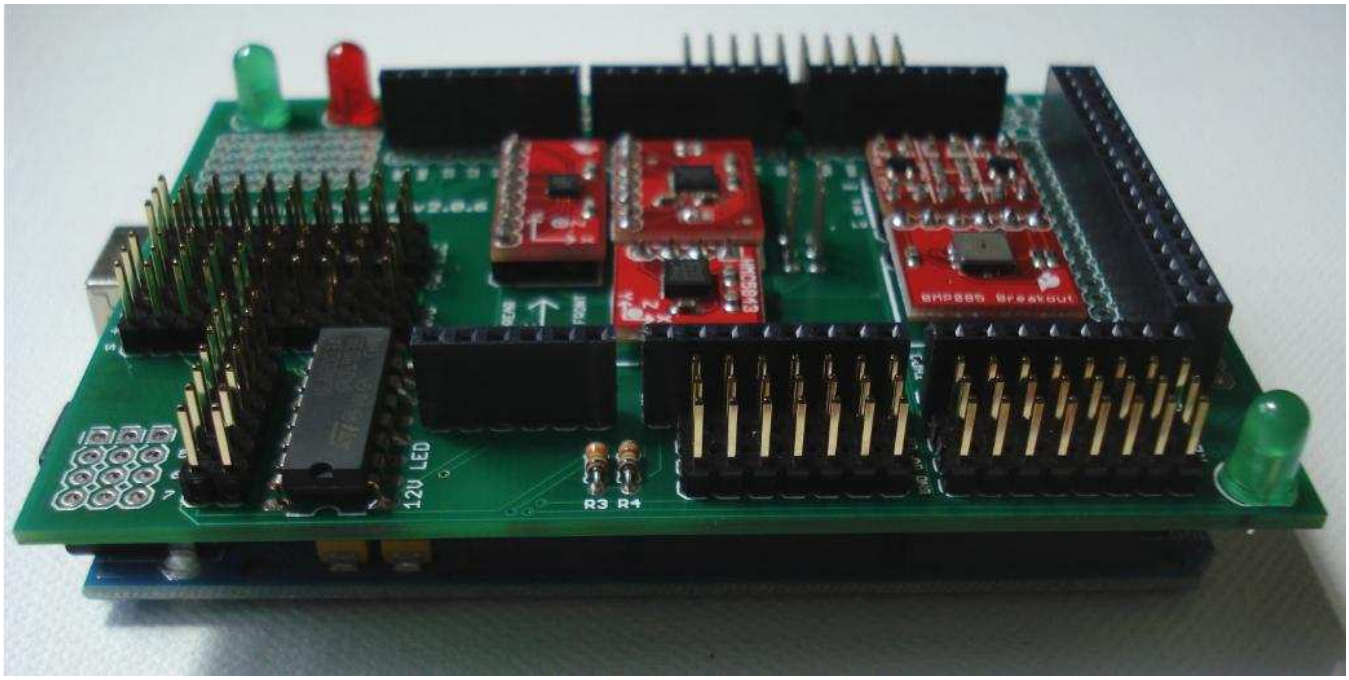
Plus Configuration	**X Configuration**
Front motor = 0	Front/left motor = 0
Back motor = 1	Back/right motor = 1
Right motor = 2	Right/front motor = 2
Left motor = 3	Back/left motor = 3

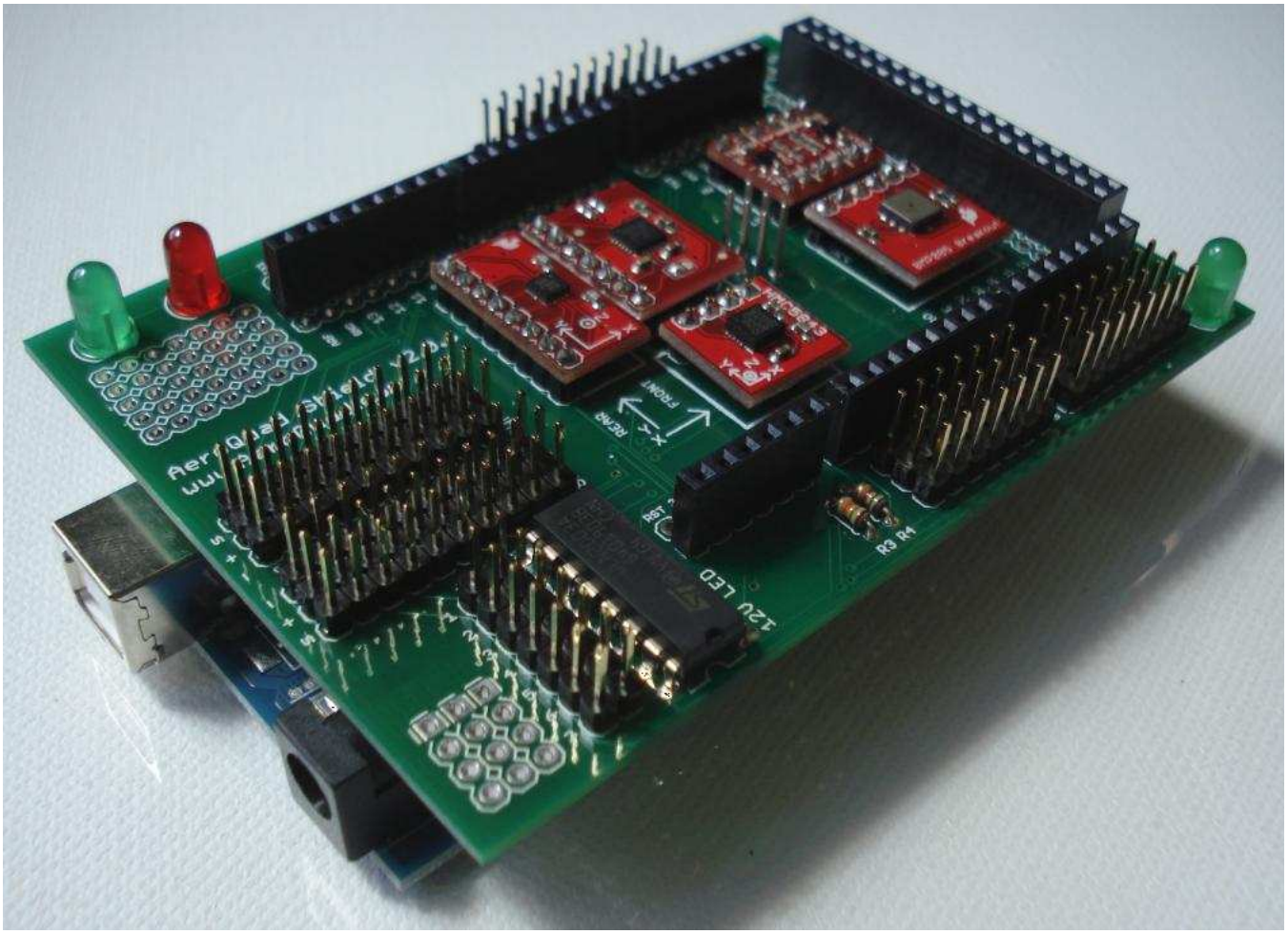
(refer to page 32 for flight Configuration modes)

The completed v2.0 shield





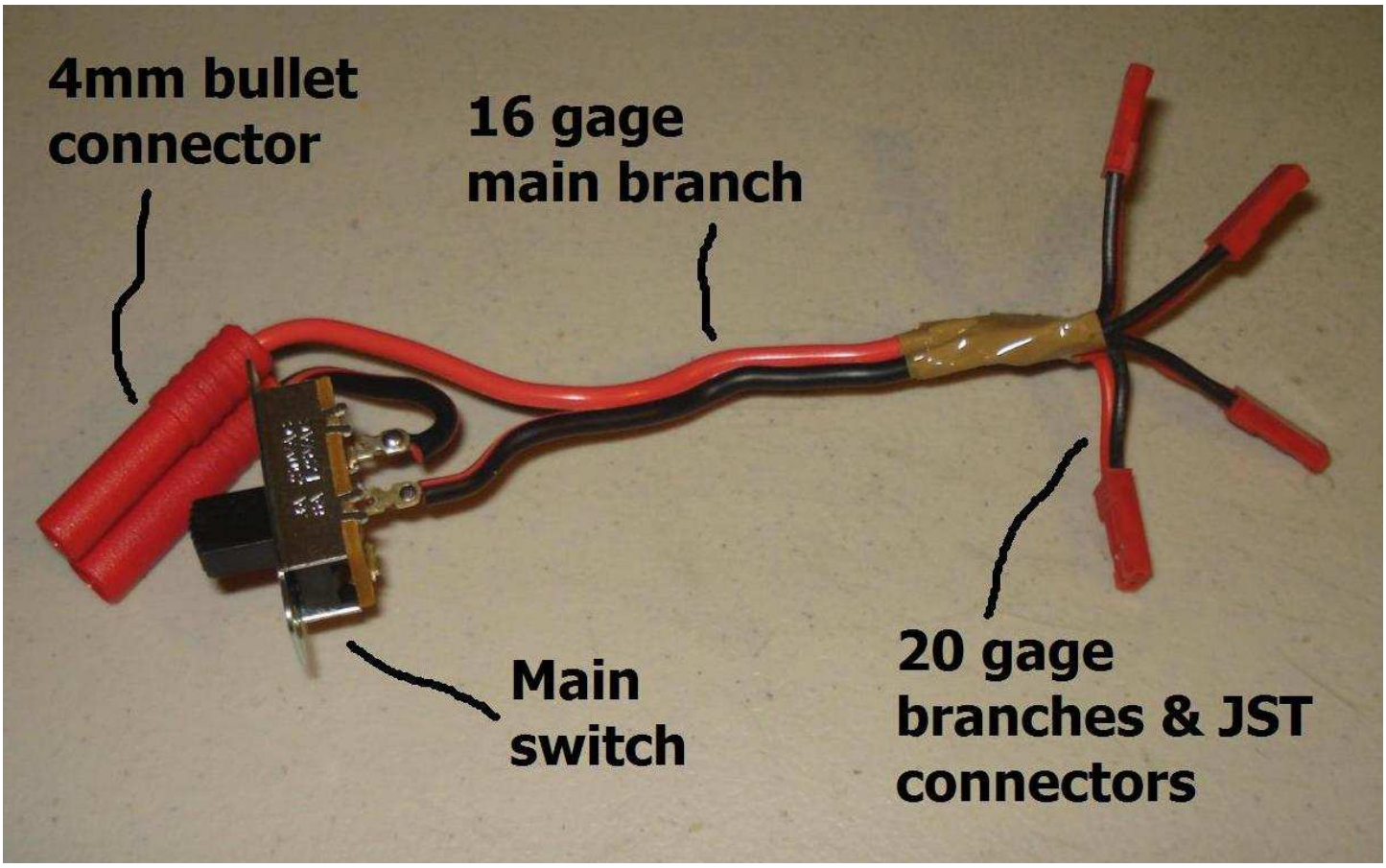

12V LED
R3 R4
BMP085 Breakout


FRONT
REAR
12V LED
R3 R4

3.5 POWER DISTRIBUTION GRID

This part of the quad includes the wiring which provides power to the motors. It is simple to construct such a power line using 18 and 16 gage wires, the 3mm bullet connectors, a connector compatible with the one on the battery, and an optional simple switch. The main branch which connects to the battery should be a little thicker, thus 16 gage, while the other 4 (or 5, if using main battery to power Arduino) branches can be thinner using the 18 gage wire. The main branch should have a 4mm bullet connector with protector (identical to the one on the battery). Solder all the 3mm bullet connectors to the motors, ESCs, and the power line wires. The motors and the battery side of the ESCs should have the bullet (male) connector. The motor side of the ESCs and the power line wires should have the female connector. The switch should be somewhere along the main branch so as to control all power at once. Once again, this soldering task can be done using the 30 watt iron and thicker solder.

Here's an example of a simple power line, although this particular one has JST connectors at the ends of the 4 branches instead of the female bullet connectors. This particular power line is for a light quad, using 20 gage wires, and will not take too much current on the individual branches.



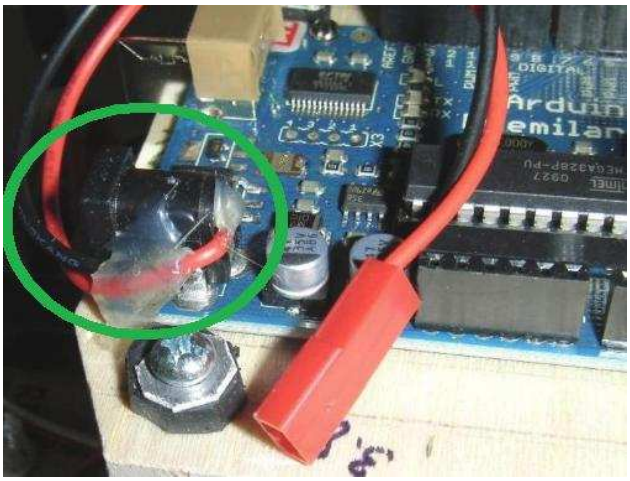
An important thing to remember when making the power line is to consider the frame and its dimensions in order to make the power line fit into the frame without any problems, such as interfering with other components.

Arduino power source

Although using the main battery for providing power to the Arduino is fine, it is recommended to use a separate battery, such as a small capacity 7.4v Lipo, to do so. This will ensure a clean power source for the Arduino and also reduce the heat generated by its onboard voltage regulator. A good such battery is the Rhino 610mAh or 460mAh 7.4v Lipo from HobbyKing, each costing around $4.

It is also highly recommended to solder a female JST connector directly into the Arduino power-in jack (or rather in the back of it). This will eliminate the need for using a 2.1mm center positive plug and will allow for a direct connection to a battery such as above.

The image on the right shows how a JST connector wire was soldered to the Arduino's power-in plug (respecting the polarity) and hot-glued for protection from shorts. That connector is directly compatible with the connector of the batteries displayed above.



3.6 TEST RADIO AND CALIBRATE ESCS

The next step is to test the radio. Some radio systems, such as the Spektrum 2.4GHz ones, require the binding of the receiver to the transmitter. Follow the instructions provided by the manufacturer and make sure that the radio system is working. This can be done by simply connecting a motor to an ESC and the ESC to the throttle channel of the receiver. If it is possible to run the motor, then the radio link is operational.

Note: Generally, any radio system with a receiver that outputs 1000-2000usec PWM pulses should work with the AeroQuad.

After making sure that the radio system is working properly, it is now time to calibrate the ESCs. The calibration is basically teaching the ESC the range of thrust (lowest and highest power to give the motors so to say). It will assure equal motor startup later on. **The ESC calibration must be done using the same radio system that will be used on the quadrotor and done individually for each ESC**. To do the calibration on the recommended Turnigy Plush 18 amp ESCs, follow the given steps (these are also provided in the Turnigy ESC instruction manual):

1. Connect the ESC to the throttle channel of the receiver. Have a motor connected to the ESC as the motor will provide beeps necessary to hear the calibration steps. **DO NOT** attach the propeller or anything else to the motor; simply have the motor connected to the ESC.

2. Turn on the radio and put the throttle stick to maximum position
3. Now connect the ESC to the battery
4. The motor should beep a 1 2 3 beep followed by two short beeps. Immediately after the two short beeps, put the throttle stick down all the way, the motors should make 3 short beeps (representing the 3 cells of the battery) and then finally make a 1 long beep, indicating that the throttle range has been set (calibrated).

"Calibrating all four ESCs together" method
There is also a second method for calibration of the ESCs (mentioned on page 26 in section 3.8, "Test and Configure Everything"). This method is done through the use of the Configurator by following its given instructions.

3.7 PUT EVERYTHING TOGETHER

This step is not discussed in detail as it involves the construction of a frame, which is completely up to the user. However, some recommendations regarding the construction of a frame are made. A ready to order frame known by many users at the AeroQuad forum is the "**Rusty's frame**" - it is not discussed here but simply mentioned for the sake of awareness.

A good frame should have the following:

- **Landing gear** – for medium to larger sized quads (1 kg and over) the T-Rex 600 helicopter landing gear set can be used. These can be obtained online or from a local hobby shop for around $15 for the complete set. For smaller quads, such as under 1kg, the smaller T-Rex 450 helicopter landing gear set can be used, costing around $10.
- **A housing for the electronics** – the electronics housing can be anything from an aluminum cage consisting of two strips of aluminum covering the electronics to a full pledged box of some sort. A good place to start is to use a styrofoam faucet cover, which provides a smooth, lightweight, and strong protective cover. The housing is there to protect the electronics from crash damage, such as flips and falls, as well as the elements when it is stored.
- **Battery compartment** – this part is a little trickier, but with some work, can be made very effectively. A recommended design is to use Velcro underneath the belly of the quad, incorporating it into the structure of the quad. This will provide a strong battery compartment while still allowing for an easy battery removal and replacement in the field.
- **Arm extensions** – these can be used to ensure safer operation of the quad, especially during first test flights or experiments. The arm extensions could simply extend beyond the propeller length or they can also protrude upwards, thereby providing protection for the motors and propellers during flips.

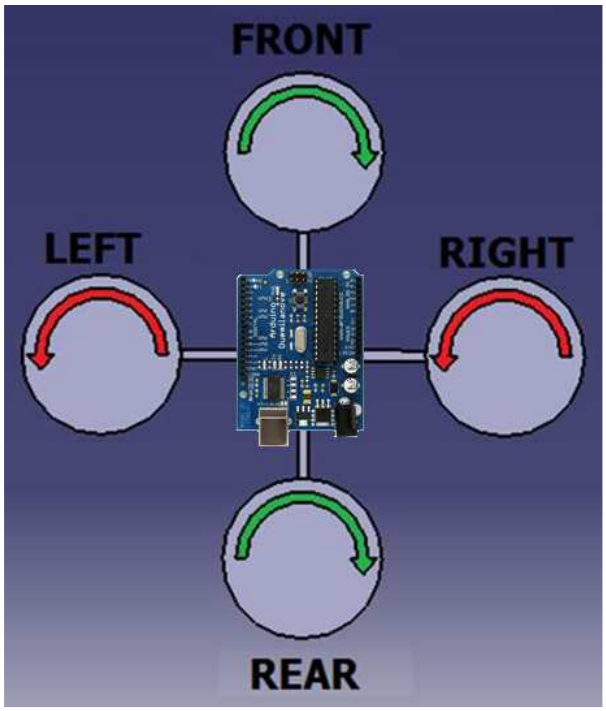
Motor-to-motor distances
Which motor to motor distance to pick is perhaps one of the most widely asked question in the quadrotor community. The simple answer is that there is no one best distance, unless talking about one particular quadrotor with all its dimensions and specifications known. Here's some information regarding the motor-to-motor distances:

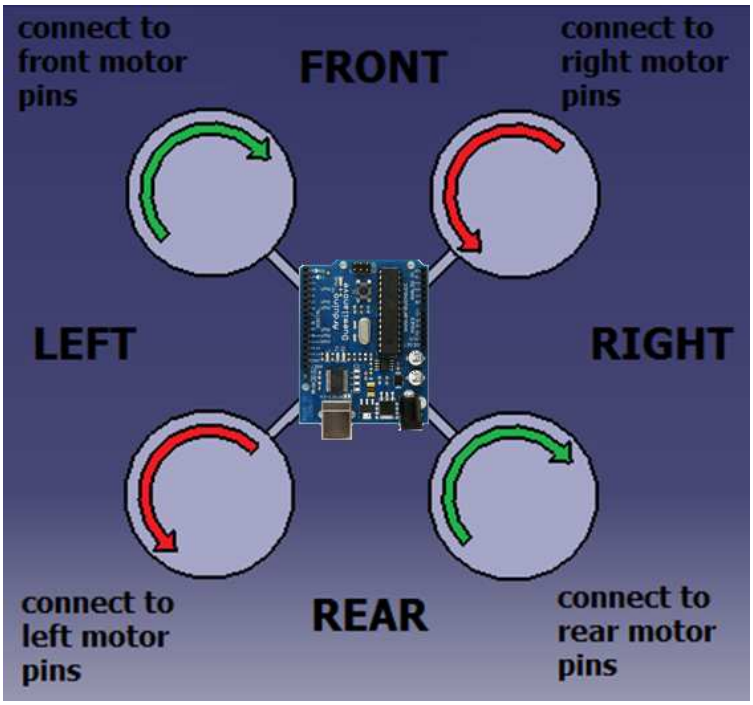
- Generally, the larger the distance between the motors, the more stable is the quad. The shorter is the distance, the quicker is the quad to respond. In other words, a larger armed quad will have slower response times to movements and a smaller armed one will be able to make agile movements and acrobatic maneuvers. Most aerial video and photography quads will tend to have larger distances than those for acrobatics.

- A good motor distance to start with is around 50-60cm. This however, depends totally on what the user wants.
- The motor distances should be made identical as accurately as possible

X versus + configuration

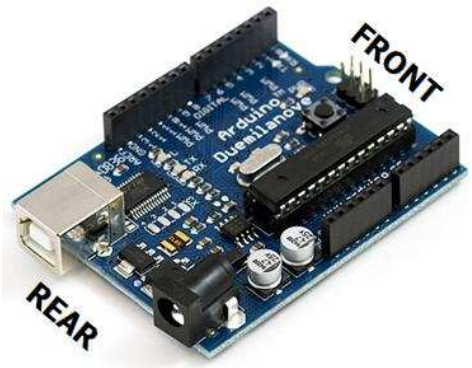
This refers to the configuration of the frame. In the **X configuration**, the quad has two motors on each of the four sides, while still having 4 motors total. Weird? Not really. This simply means that the front of the quad is between two of the front motors, the rear between two of the rear motors, and so on. In the **plus configuration**, the location of the front is simply the front motor, the rear is the rear motor, and so on. The plus configuration is generally the more common for beginners. The X configuration is more useful for aerial photography where the camera needs to be positioned as close to the center of the frame as possible while still having an open view.





The first image above shows the plus (+) configuration in which the motor ESCs are connected normally: the right motor ESC is connected to the "Right" motor pins on the shield, left motor ESC to the "Left" motor pins, and so on. The second image (on the right) shows the X configuration in which each of the four sides (front, rear, right, and left) have two motors and must be connected as depicted.

Arduino orientation



The correct way to secure the Arduino (which also has the shield and the sensors on top of it) is to have the USB connector side of it representing the rear side of the quad. The same is for Arduino Mega.

For the plus (+) flying mode, the front of the Arduino faces the front motor and the rear of the Arduino faces the rear motor. For the X flying mode, the Arduino must be mounted in such a way so as to have its front facing the two front motors and its rear facing the two rear motors. This is shown in the two images above.

3.8 CONNECT EVERYTHING TOGETHER

The next step is to simply connect all the electronics together, after mounting them to their respective locations of course. **DO NOT install the propellers yet.**

- Motors should be clamped, bolted, or otherwise secured to the arms.
- The ESCs should be connected to the motors and also secured either on the arms, inside the arms if large enough (though not recommended for head dissipation issues), or inside of the electronics housing/box. The ESCs should also be connected to the main power line.
- The Arduino and all its components (shield, sensors, etc) should be secured at the center of the frame. It is common for beginners to use mounting tape or even scotch tape to secure their electronics. This is not a good practice as all those things will loosen and induce vibrations and instability. A good thing to do is to use bolts and nuts.
- The shield should mate onto the Arduino and also have the receiver channels connected to it

3.9 TEST AND CONFIGURE EVERYTHING

These next steps are critical to ensure the correct operation of the quad. Once again, **still DO NOT install the propellers yet**.

1. Connect the now wired up AeroQuad to the Configurator on the PC. If using Windows Vista, run the configurator in Administrator mode. If connection does not work, select a different port.
2. In the rightmost flyout, select the Initial Setup option and then click on the blue "Initialize EEPROM" icon. This will write default values for PIDs and all the other factors into the Arduino EEPROM memory.
3. Then click the "Calibrate Transmitter" icon and follow the steps provided in the Configurator to do so. If using the recommended Spektrum DX7 radio with AR6200 receiver, then there should be no problems.
4. Using the "Calibrate ESCs," it is possible to calibrate all four ESCs together. Follow the instructions provided in the Configurator under the "Calibrate ESCs" icon. Using the ESC calibration feature of the Configurator is potentially dangerous unless all the steps are read and followed carefully. **Once again, DO NOT have the propellers installed yet.**
5. Next, follow the 13 steps of the Pre-Flight Checkout list (taken from AeroQuad website)

The Pre-Flight Checkout list (follow carefully)
In the Flight Configuration tab of the Configurator, select the Motor Bar Plot from the bottom most flyout and follow these steps:

1. Arm the motor output by moving the throttle stick to the lower right. Increase the throttle to 50%.
2. **By hand**, roll the AeroQuad to the left. The left motor command should increase. The right motor command should decrease.
3. **By hand**, roll the AeroQuad to the right. The right motor command should increase. The left motor command should decrease.
4. **By hand**, pitch the AeroQuad down (the front motor should be lower in position than the rear motor). The front motor command should increase. The rear motor command should decrease.
5. **By hand**, pitch the AeroQuad up (the front motor should be higher than the rear motor). The rear motor command should increase. The front motor command should decrease.

6. **By hand**, rotate the AeroQuad clockwise. The front and rear motor commands should increase (assuming the motors are wired to rotate in the clockwise direction).
7. **By hand**, rotate the AeroQuad counter-clockwise. The left and right motor commands should increase in value (assuming the motors are wired to rotate in the counter-clockwise direction).
8. **Using the transmitter**, move the roll stick to the left. The right motor command should increase. The left motor command should decrease.
9. **Using the transmitter**, move the roll stick to the right. The left motor command should increase. The right motor command should decrease.
10. **Using the transmitter**, move the pitch stick forward. The rear motor command should increase. The front motor command should decrease.
11. **Using the transmitter**, move the pitch stick back. The front motor command should increase. The rear motor command should decrease.
12. **Using the transmitter**, move the yaw stick to the left. The front and rear motor commands should increase.
13. **Using the transmitter**, move the yaw stick to the right. The left and right motor commands should increase.

Finally, repeat the above steps, but this time check the responses of the actual motors and cross-check them with the responses of the motors in the Configurator. The virtual motors in the Configurator and the actual motors should have the same (correct) responses.

Note: If the automatic ESC calibration was used ("Calibrate ESCs" button in the Configurator), then when armed (throttle stick to the lower right), the motors would spin at a low rate indicating that they are armed. Also, when zeroing all the sensors out through the transmitter (left stick to the lower left and right stick to the lower right), the motors should spin up at a low rate three times and then stop.

3.10 MAIDEN FLIGHT

After completing the quad and double and triple checking that everything works, it is now time to test it out. To assure safety, it is wise to test fly the quad in an open field, as far away from people as possible, the operator included.

It is now time to put on the propellers. Remember, the front and rear motors spin clockwise when looking from above, thus they need the clockwise propellers and the right and left spin counterclockwise when looking from above. If any of the motors are spinning the wrong way, then the only thing that needs to be done is to **swap any two of the three motor/ESC wires of those particular motors**. From this point on, the quad is potentially a very dangerous machine and must be handled with extreme caution.

After attaching the propellers, turn on the Arduino and the main power. The motors are armed by bringing the throttle stick to the lower right and disarmed when on lower left. Step back, arm the motors, and apply thrust slowly. Be cautious and apply thrust slowly at first to assure that all the motors are spinning equally. Take off, hover, and learn to fly. Good luck!

4. LINKS TO PARTS

Arduino Duemilanove/Uno
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=ARDUINO-03 (AeroQuad shop)

Arduino Mega
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=ARDUINO-04 (AeroQuad shop)

Triple-axis digital-output gyro breakout ITG-3200
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=SEN-09801 (AeroQuad shop)

Triple-axis accelerometer breakout BMA180
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=SEN-09723 (AeroQuad shop)

Triple-axis magnetometer breakout HMC5843
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=SEN-09371 (AeroQuad shop)

Barometric pressure sensor BMP085
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=SEN-09694 (AeroQuad shop)

AeroQuad shield v1.8
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=AQ1-008 (AeroQuad shop)

AeroQuad shield v2.0
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=AQ2-000 (AeroQuad shop)

Stackable female headers (Duemilanove/Uno pack)
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=CONN-001 (AeroQuad shop)

Stackable female headers (Mega pack)
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=CONN-010 (AeroQuad shop)

Breakout pins (straight)
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=CONN-002 (AeroQuad shop)

Hextronik DT750 motors
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=6247 (HobbyKing)

Hacker Style 20-22L motors
http://hobbyking.com/hobbyking/store/uh_viewItem.asp?idproduct=4700 (HobbyKing)

Hextronik 24gram 1300kv motors
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=2069 (HobbyKing)

Turnigy 2217 16turn 1050kv motors
http://www.hobbycity.com/hobbyking/store/uh_viewItem.asp?idProduct=5690 (HobbyKing)

TowerHobbies BP A2217-9 950kv motor
http://www.bphobbies.com/view.asp?id=V450327&pid=B2632605 (TowerHobbies)

Turnigy Plush 10 amp ESCs
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=4204 (HobbyKing)

Turnigy Plush 18 amp ESCs
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=4312 (HobbyKing)

Turnigy Plush 25 amp ESCs
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=2163 (HobbyKing)

Zippy Flightmax 4000mAh 11.1v 20C battery
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=7634 (HobbyKing)

EPP1045 counter-rotating propellers set
www.quadroUFO.com (QuadroUFO)

APC1047 counter-rotating propellers set
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=LP10047 (AeroQuad shop)
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=LP10047SFP (AeroQuad shop)

Female-female servo extension cables
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=RCVR-001 (AeroQuad shop)

USB Cable A to B - 6 Foot
https://www.aeroquadstore.com/ProductDetails.asp?ProductCode=CAB-00512 (AeroQuad shop)

Spektrum DX7 Mode 2 radio with AR6200 receiver
eBay (seller: gotheli) or local hobby shop or http://www.toddsmodels.com/default.asp (Todd's Models)

3mm bullet connectors
eBay (seller: rctimer)

18 and 16 gage wire
RadioShack, other

Turnigy Accucel-6 balancer/charger
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=7028 (HobbyKing)

12v 5A power supply
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idProduct=6256 (HobbyKing)

Battery voltage alarm
eBay (seller: goodlucksell)
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=7223 (HobbyKing)

15 watt soldering iron
RadioShack, other

30 watt soldering iron

RadioShack, other

0.032" solder
RadioShack, other

0.062" solder
RadioShack, other

610mAh Arduino battery
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=7305 (HobbyKing)

JST male/female connectors w/cables
http://www.dealextreme.com/details.dx/sku.15234 (DealExtreme)

Square carbon fiber 10x10x750mm tubes
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=9012 (HobbyKing)

4mm bullet connectors w/ protector
http://hobbycity.com/hobbycity/store/uh_viewItem.asp?idproduct=9283 (HobbyKing)

Updates:

- Added the Uno and Mega 2560 boards in the IDE board selection (pg 10)
- Updated the latest IDE and code versions (pg 9)
- Noted that the barometer may be soldered on the bottom of the v2.0 shield (pg 24)
- Updated links to the AeroQuad shop parts (pg 35)
- Noted the new Arduinos (Uno and Mega 2560) (pg 2)