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- Hand movement
- Hardware Implementation
- Quad-copter components
- Wireless hand gesture components:

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- Quad-copter
- Wireless hand gesture
- Testing
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quad-copter

The quad-copter is one of the most complex flying machines due to its versatility to perform many types of tasks. Classical quad-copters are usually equipped with a four rotors. Quad-copters are symmetrical vehicles with four equally sized rotors at the end of four equal length rods.

Abstract

The objective of this project is to build a quad-copter that can be controlled by hand gesture wirelessly. User is able to control motions of the quad-copter in three dimension.

Quad-Copter Movement

Yaw Rotation

Each of the rotors on the quad-copter produces both thrust and torque. Given that the front-left and rear-right motors both rotate counter-clockwise and the other two rotate clockwise, the net aerodynamic torque will be zero.

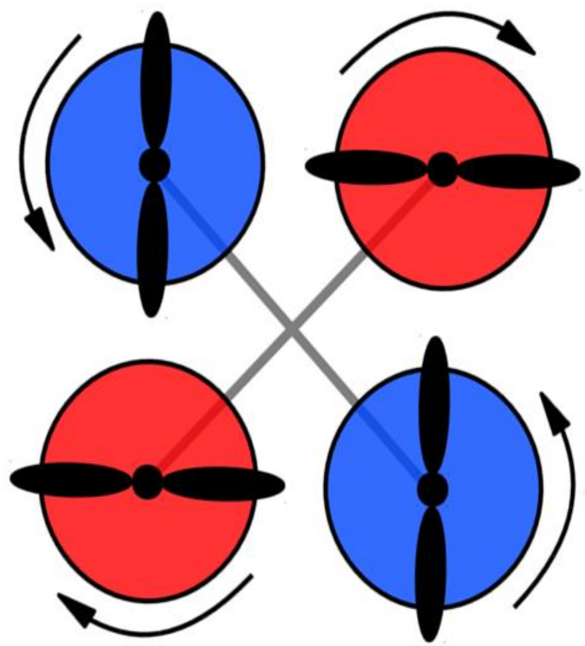
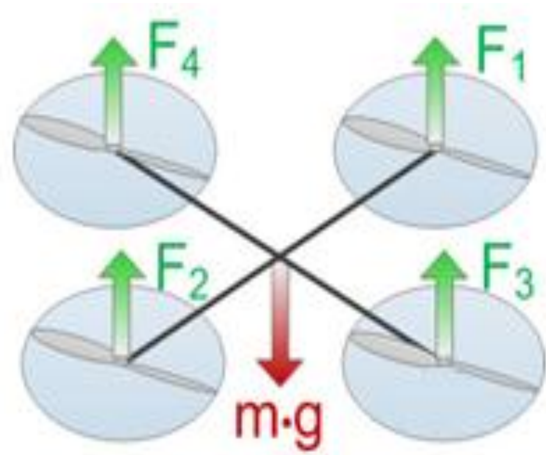


Figure 1: Torque patterns and related motion.

Hovering

For hovering a balance of forces is needed. If we want the quad-copter to hover, SUM(Fi) must be equal m•g. To move the quad-copter climb/decline the speed of every motor is increased/decreased .

SUM(Fi) > m•g <=> climb
SUM(Fi) = m•g <=> hover
SUM(Fi) < m•g <=> decline



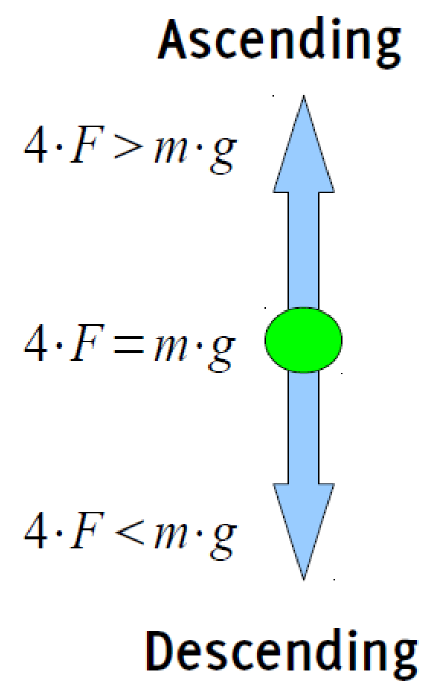


Figure 8: Balance of power while hovering.

Tilting

Now let us take a look on what is happening when we tilt the quad-copter. For simplification only two of the four rotors are shown. We see that the force is divided in two different parts. FL1 and FL2 are the part of the force used to lift the quad-copter. FT1and FT2 represents the part used for the translation. It is obvious that the lift part becomes smaller with increasing ϕ.

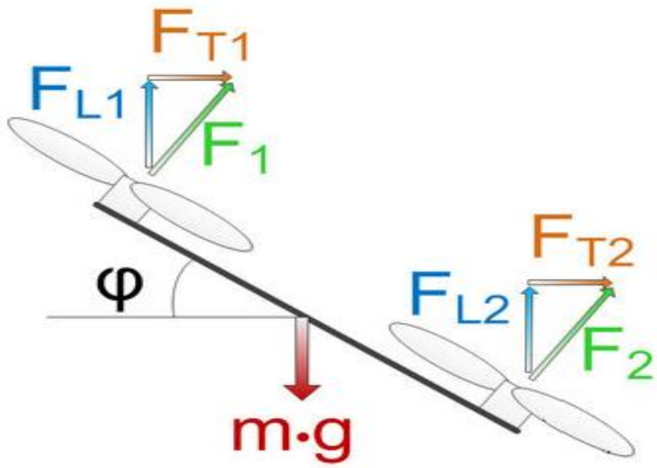


Figure 9: Force distribution for tilting.

Hand movement

* control the roll of quad-copter : rotate the hand left and right

- control the pitch : rotate the hand up and down
- control the speed : fingers motion change the speed (throttle).

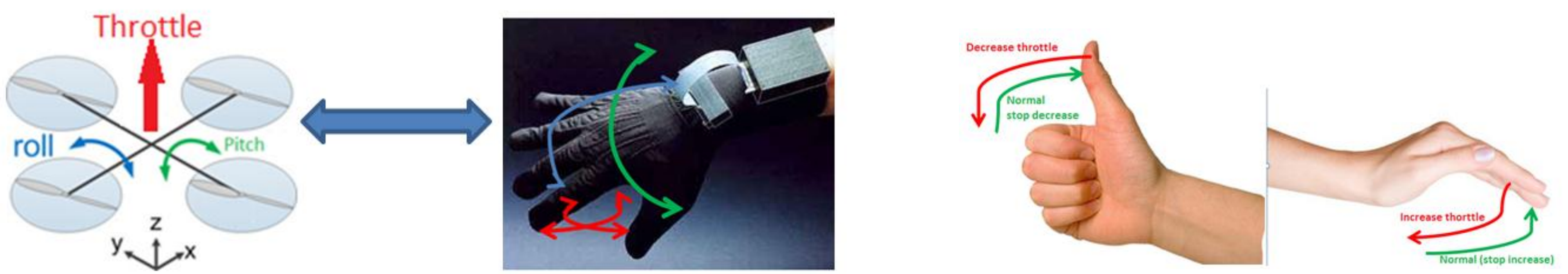
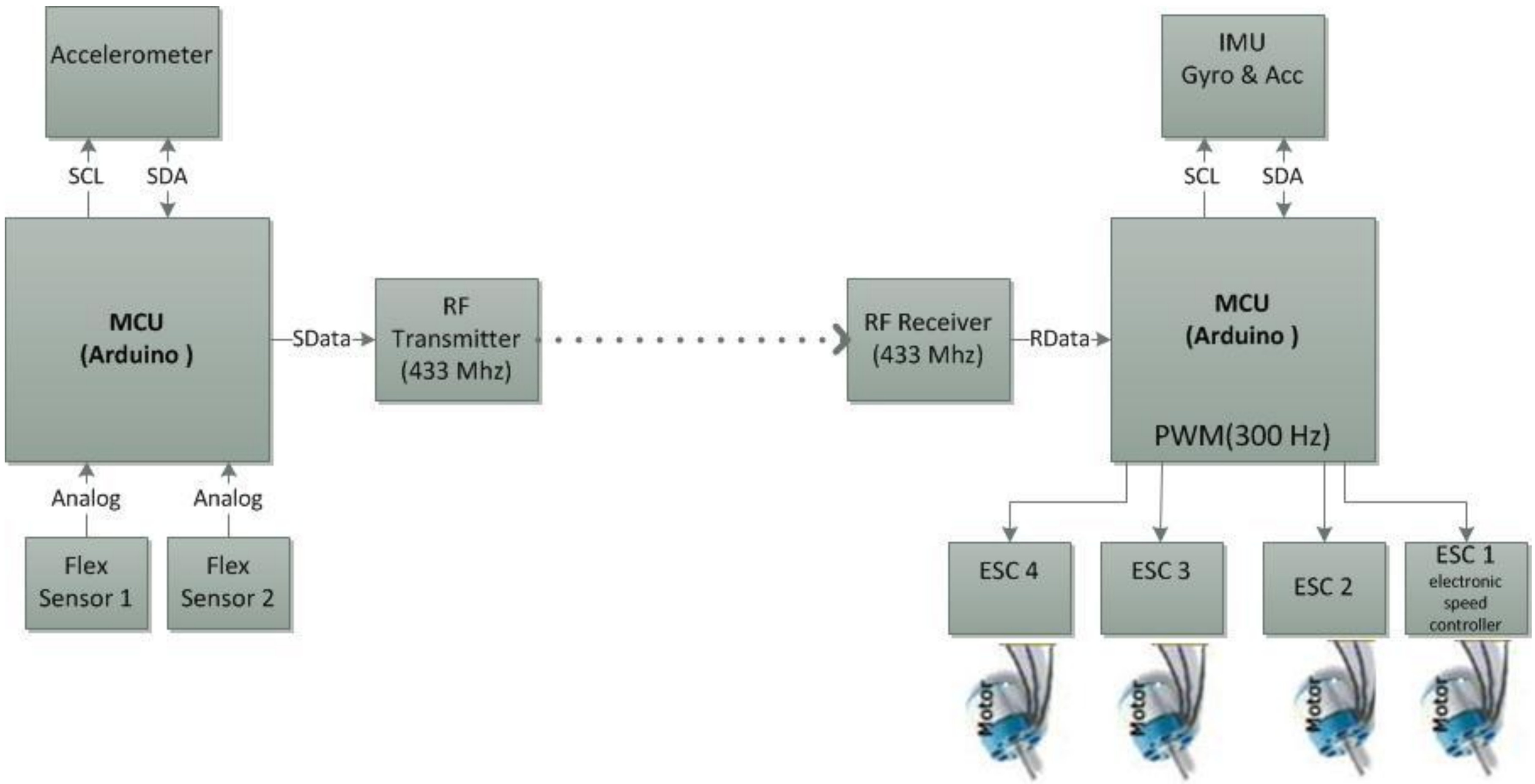


Figure 5: Movement of quad-copter and the way of control.

Hardware Implementation



Hardware Implementation

Quad-copter components:

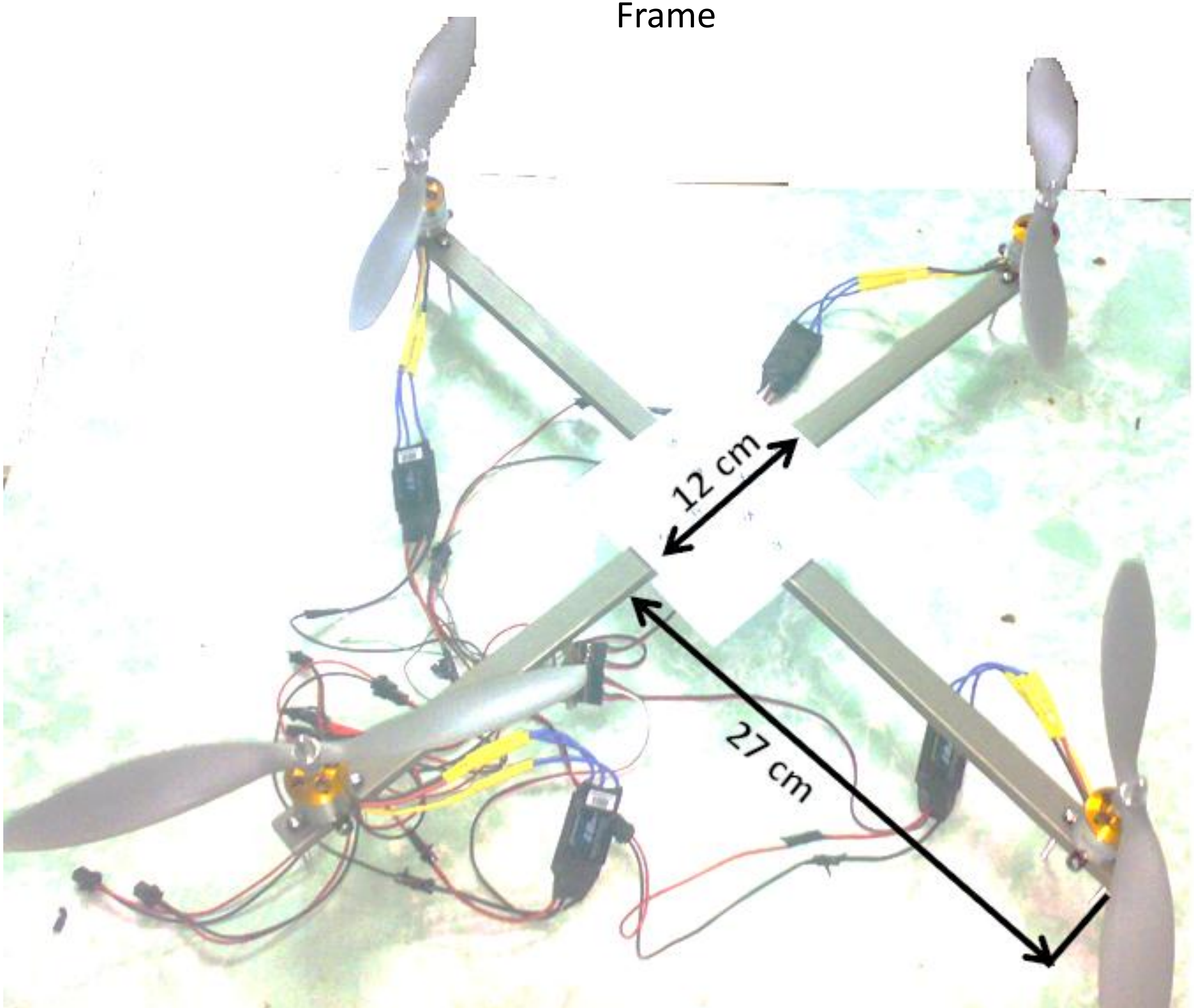
1- Frame.
2- Microcontroller (Arduino Uno).
3- Motors (A2217-9 Brushless Outrunner Motor).
4- Electronic Speed Controller (ESC).
5- Lithium Polymer Battery.
6- Propeller.
7- Inertial Measurement Unit (IMU Digital Combo Board).
8- RF receiver.

Wireless hand gesture components:

1- Microcontroller (Arduino Uno).
2- Accelerometer (ADXL 335).
3- Flex sensors.
4- RF transmitter.

Quad-copter components

Frame



Quad-copter components

Frame

* The first consideration is the material to be used. It must be lightweight, sturdy, and affordable. The forces which act on the quad-copter primarily will be gravity and air pressure.

* We chose plastic which is less weight from the other material.

* We designed a prototype frame with a 12cm X 12cm square plastic central plate with four rods 27cm.

Quad-copter components

Microcontroller

Quad-copter components

Microcontroller

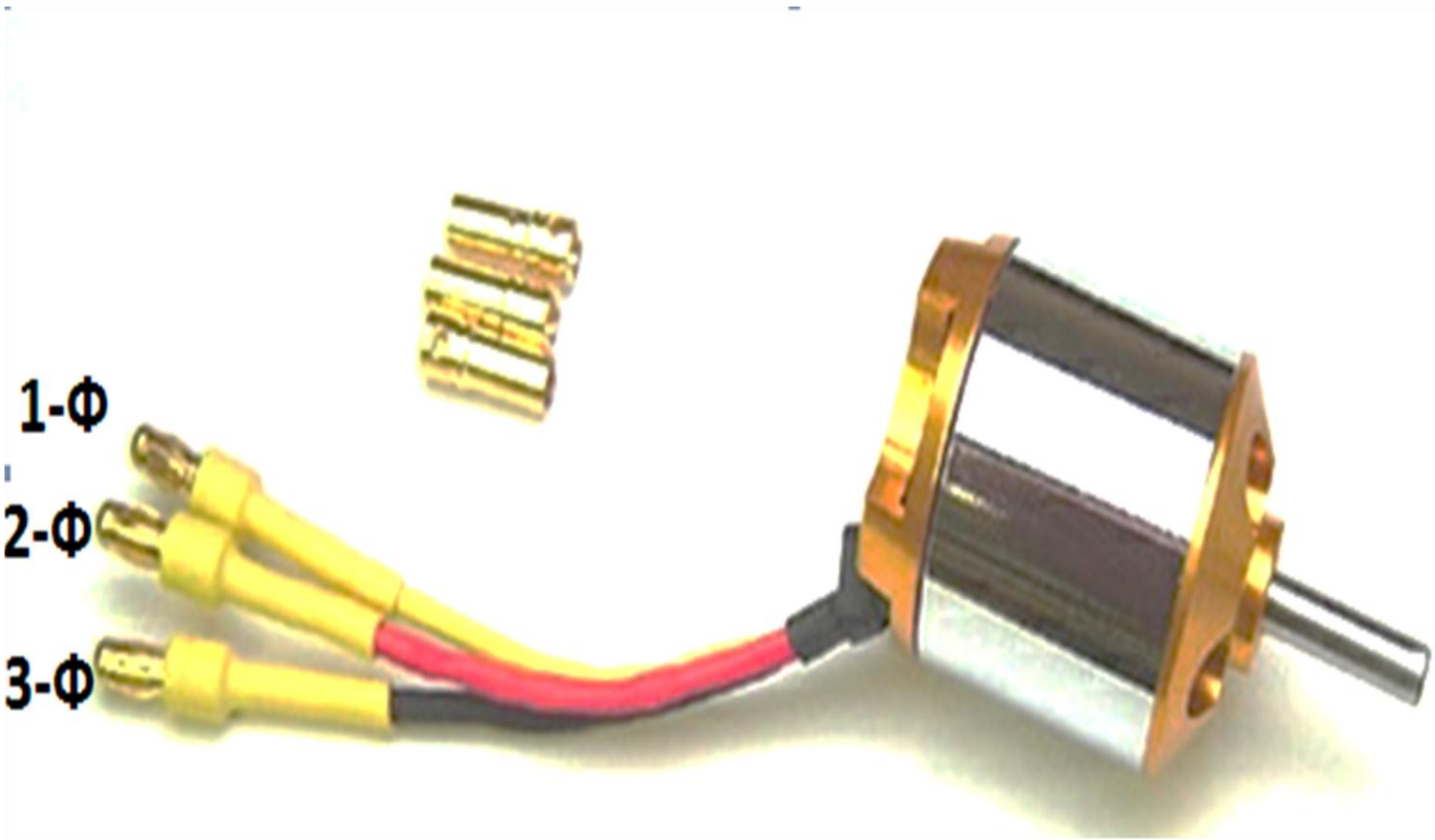
* Collects sensor data
- Receives control commands
- Calculates orientation .
- Control motor speed .

We use Arduino which have the following specifications:

Parameter	Value
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Quad-copter components

Motor

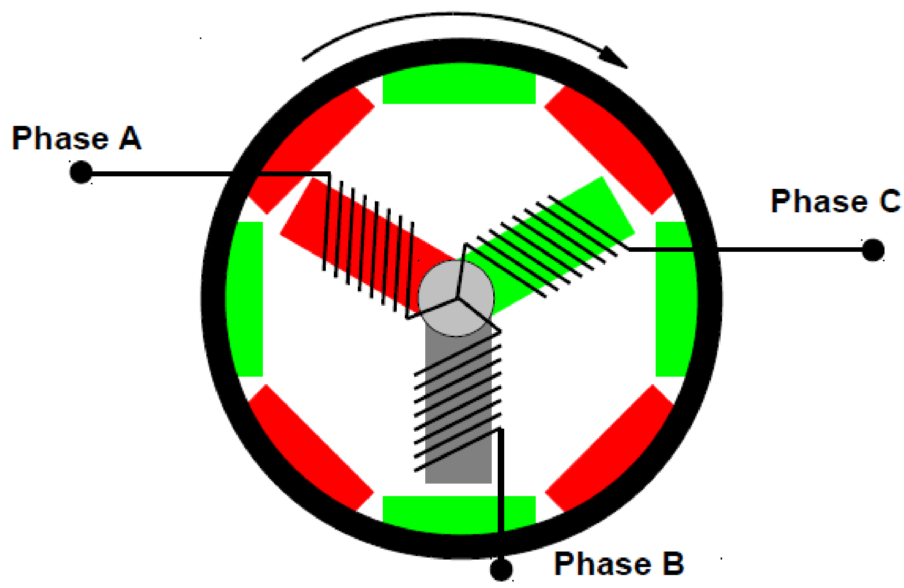


* starting point when calculating flight stability and control.

The motors chosen should meet the following specifications:
- Lightweight.
- High speed and torque.
- PWM speed controlled.

We chose BL-2217/9 brushless Outrunner motor

* Brushless
- Outrunner .
- Requires special controller



Motor specification

Parameter	Value
Kv	950 RPM/V
Max Efficiency	80%
Max Efficiency Current	5 - 15A (>75%)
No Load Current	0.9A @10V
Resistance	0.095 ohms
Max Current	18A for 60S
Max Watts	200W
Weight	73.4 g / 2.59 oz
Size	27.8 mm x 34 mm
Shaft Diameter	4mm
Poles	14

Quad-copter components

Electronic Speed Controller (ESC)

*Converts the battery pack DC voltage to a three phase alternating signal which is synchronized to the rotation of the rotor and applied to the armature windings.

*The motor speed is set by the ESC in response to a pulse width modulated control signal.

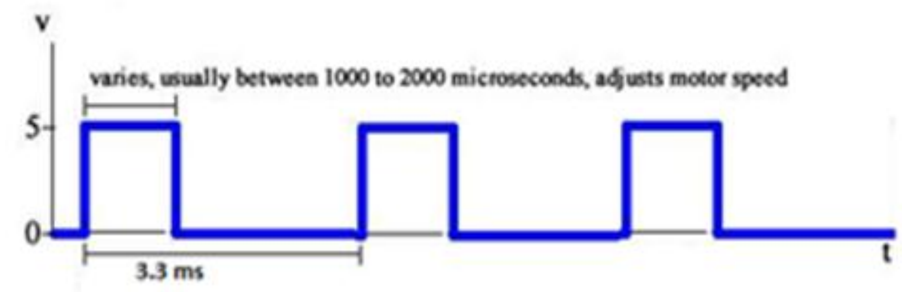
● The motor speed is then proportional to the root-mean-square (RMS) value of the armature voltage.

Parameter	Value
Output	Continuous 18A, Burst 22A up to 10 Secs
Input Voltage	2-4 cells lithium battery or 5-12 cells NiCd/NIMh battery
BEC	2A / 5V (Linear mode)
Max Speed	210,000rpm for 2 Poles BLM, 70,000rpm for 6 poles BLM, 35,000rpm for 12 poles Brushless Motors
Size	45mm (L) * 24mm (W) * 11mm (H)
Weight	18g

Quad-copter components

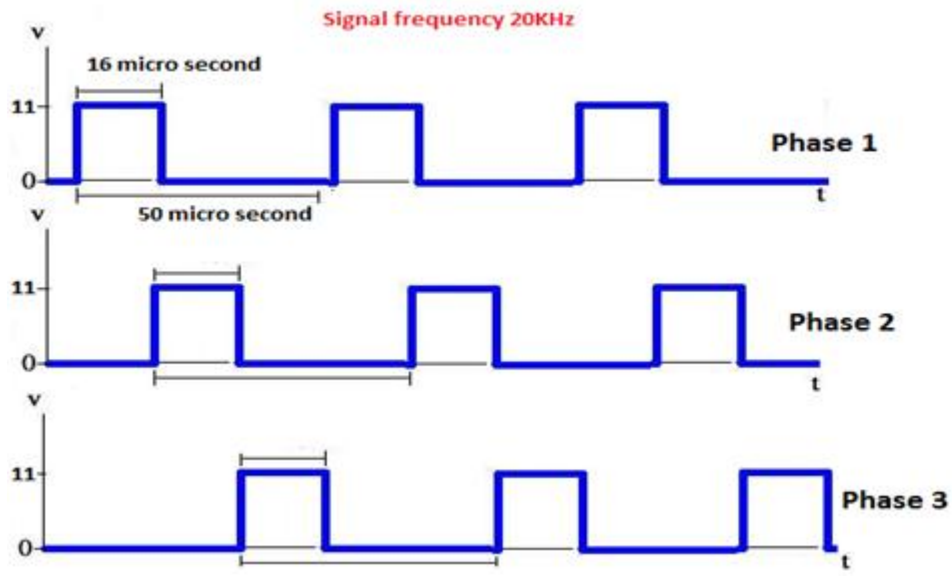
Electronic Speed Controller (ESC)

Signal output from MCU to ESC
ESC handle (1-2 ms) pulse width but we use output signal frequency 300Hz not 500Hz .



Signal output from ESC to motor

The frequency of output signal from ESC to motors 10-30KHz.



Quad-copter components

Battery

Quad-copter components

Battery

- Lightweight
- High discharging current and capacity
- low internal resistance .

* long working time .

We select Lithium Polymer (LiPo) to achieve these characteristics

Max current can be calculated by using the following equation:

Max current=Ah*C = 5A *30 =150A

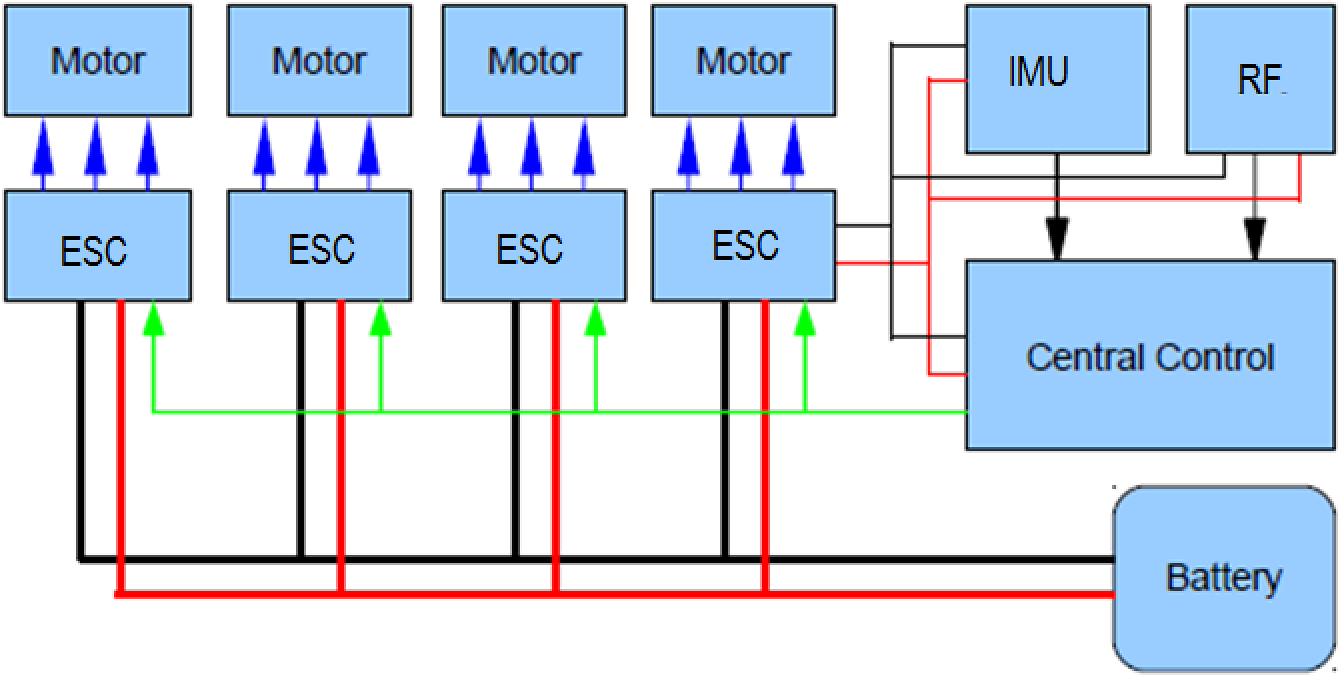
In average, all four motors consume 40A.

We can calculate the flight period using the following equation:

flight period= Ah/Acc=5A/40A*60=7.5 minutes

Parameter	Value
Voltage	11.1 V
Nominal capacity	5000 mAh
Continuous discharge current	30 C
Dimension	131*41*21 mm

Power Distribution



Quad-copter components

Propeller

Quad-copter components

Propeller

* Dimension: 10X4.7 inch
● 2 blades
● Directly attached to motor
● 2 each rotating CW and CCW (a "pusher" and a "puller").
● Properller balance reduces vibrations .

Quad-copter components

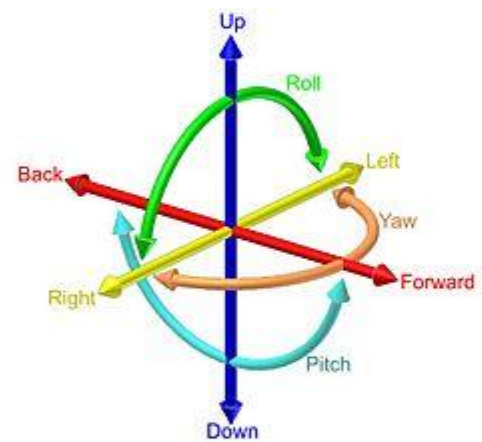
Inertial Measurement Unit (IMU Digital Combo Board)

Quad-copter components

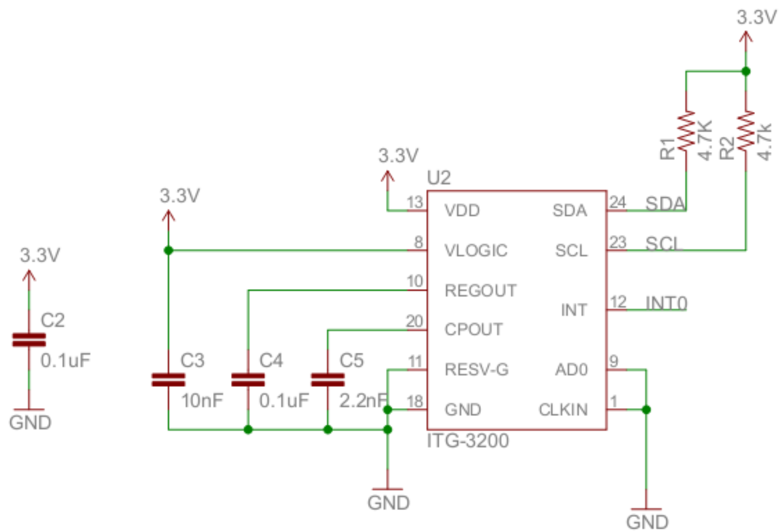
Inertial Measurement Unit (IMU Digital Combo Board)

This is a simple breakout board for the ADXL345 accelerometer and the ITG-3200 gyro.

With this board, we get a full 6 degrees of freedom

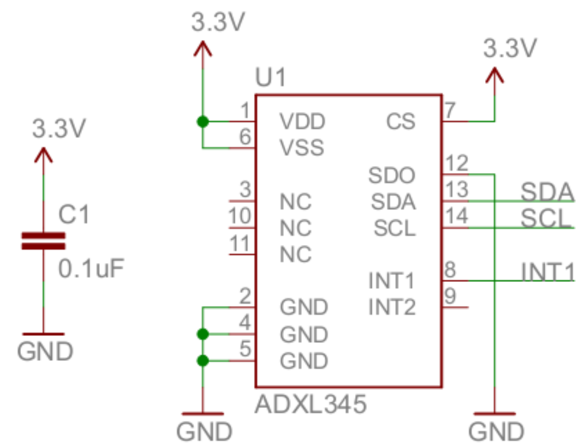


* combination of accelerometers and gyroscopes is a common approach used to measure the stability of quad-copters.



0xD0 for write, 0xD1 for read

Gyro



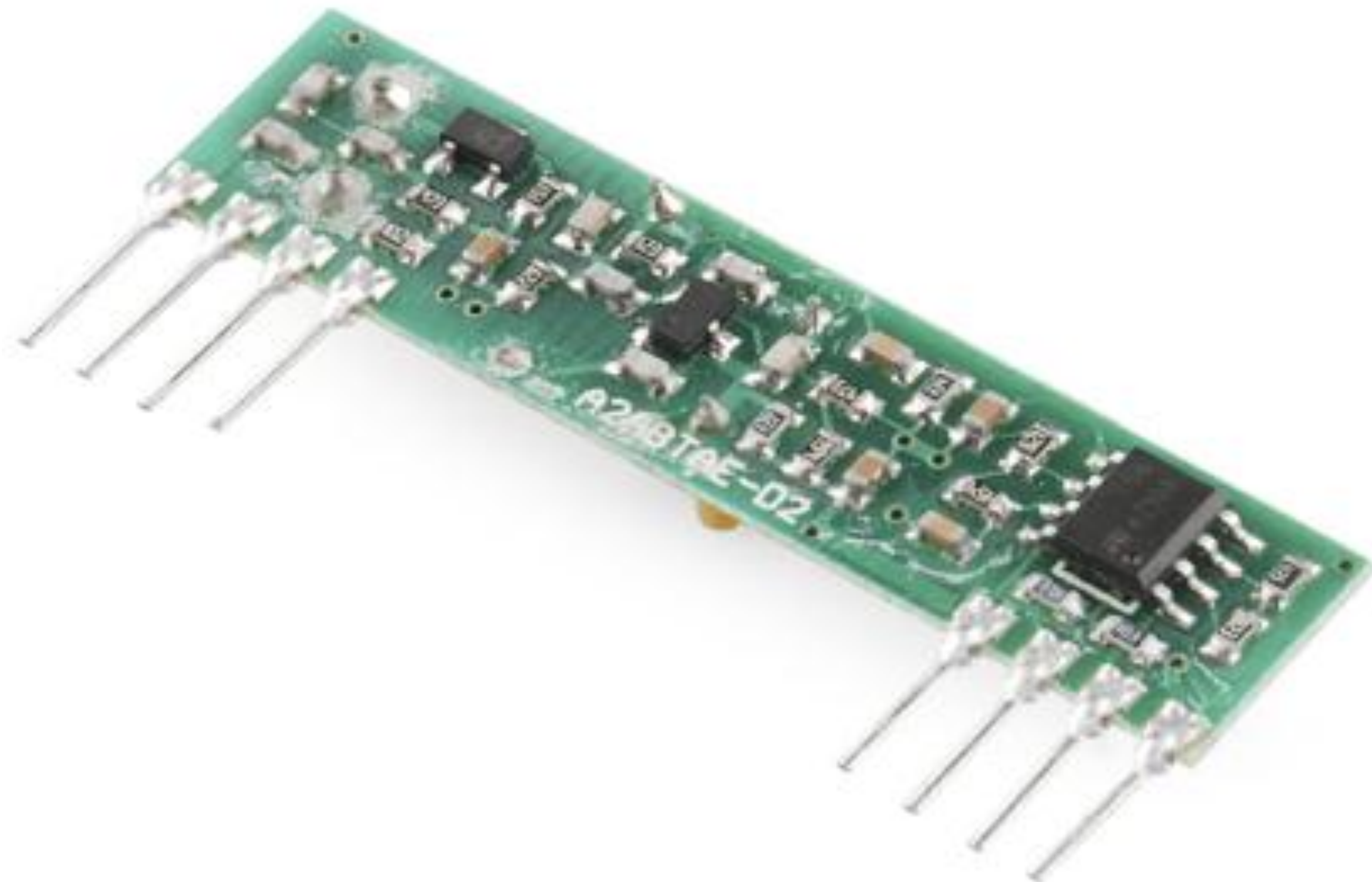
0xA6 for write ,0xA7 for read

Accelerometer

The sensors communicate over I2C

Quad-copter components

Radio Frequency Receiver – 434 MHz

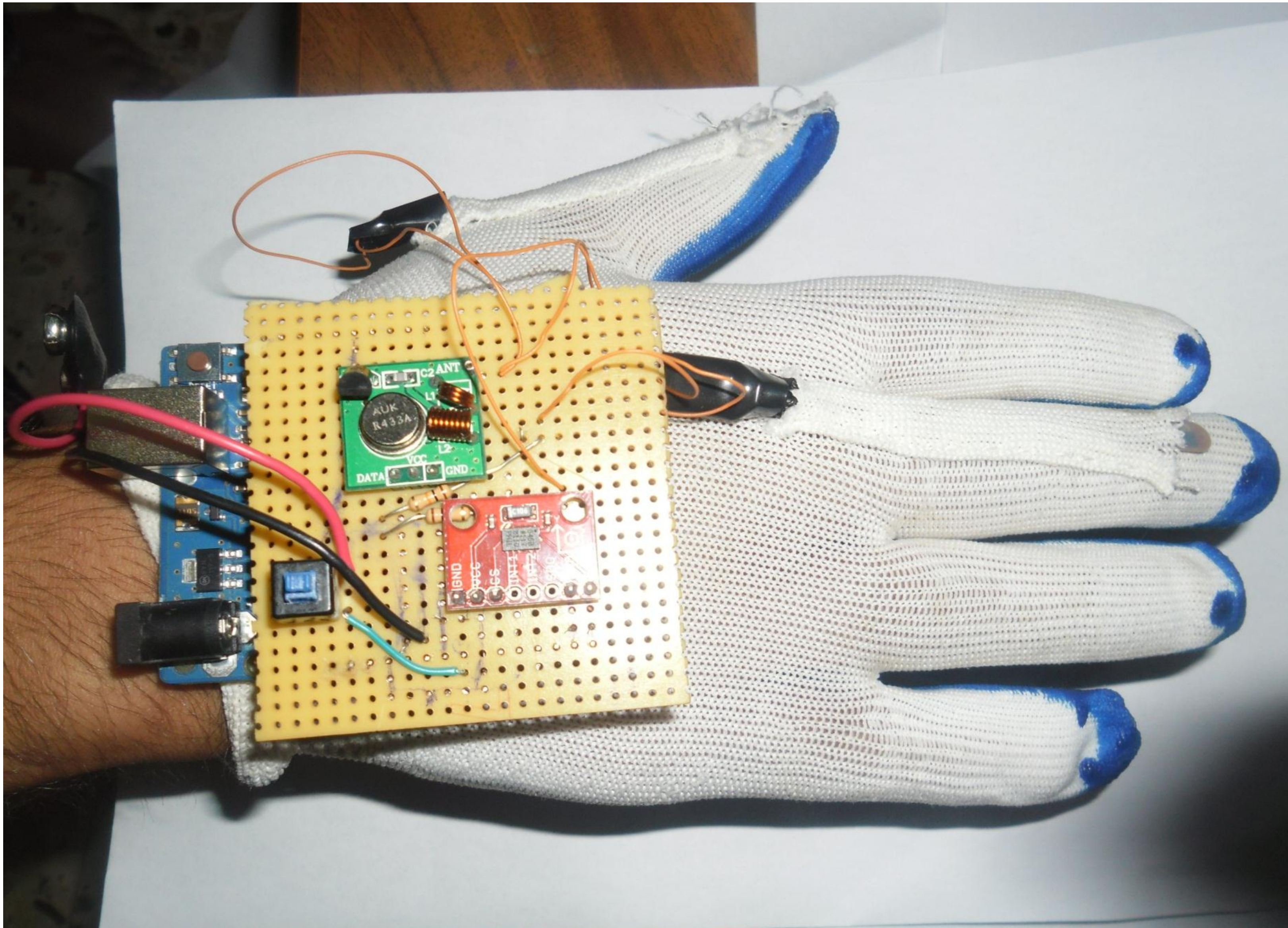


Radio Frequency Receiver - 434MHz

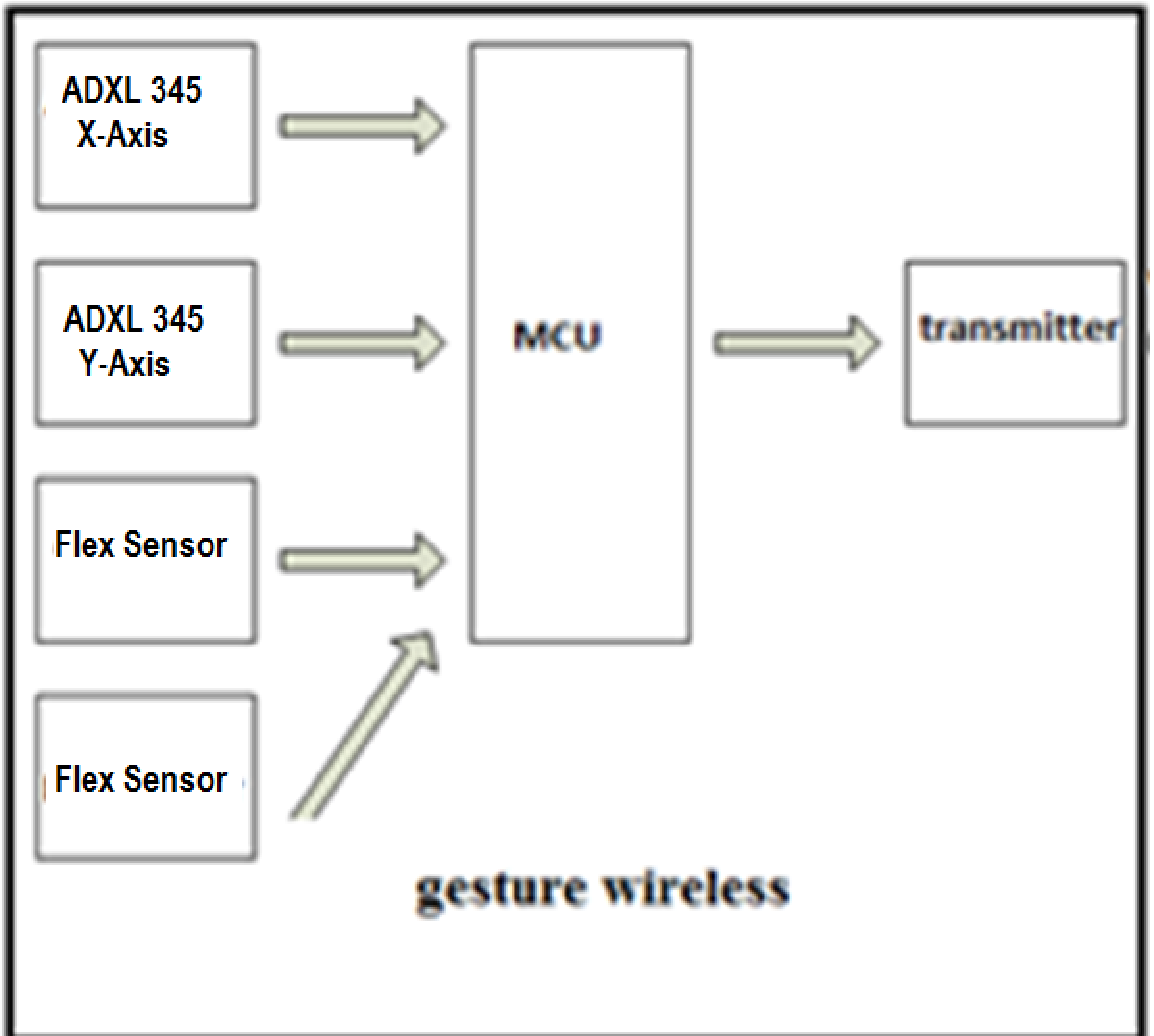
This wireless receiver provides a simple, straight-forward receiver for all of low-cost wireless project.

Features:
- 434 MHz.
- 150m range.
- 4800bps data rate.

Wireless hand Gesture Components

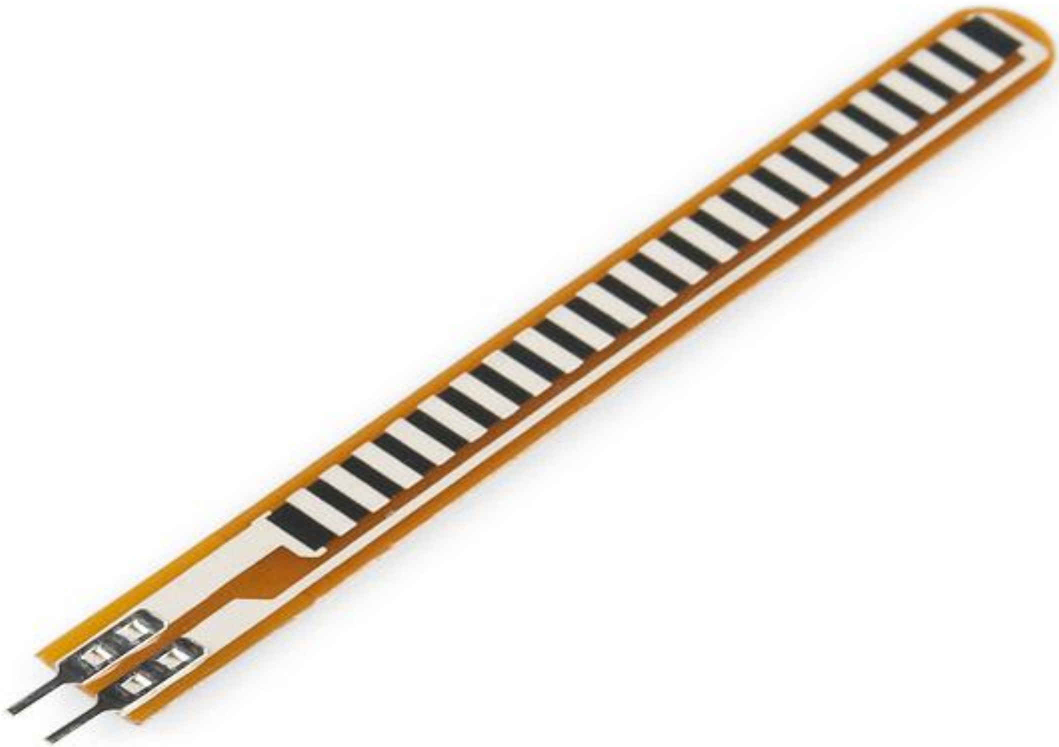


Wireless hand Gesture Components

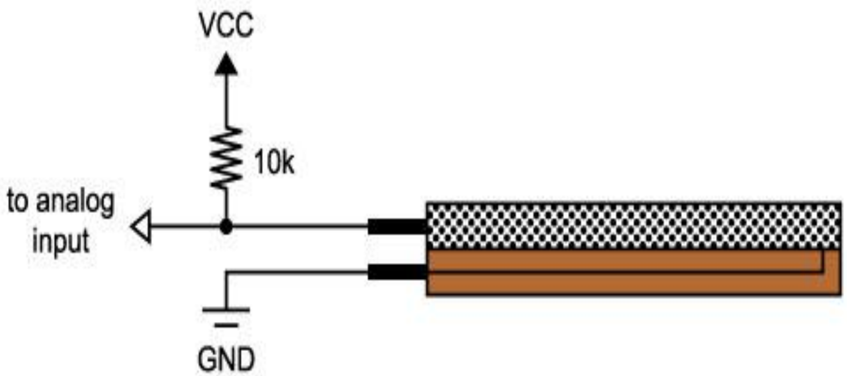


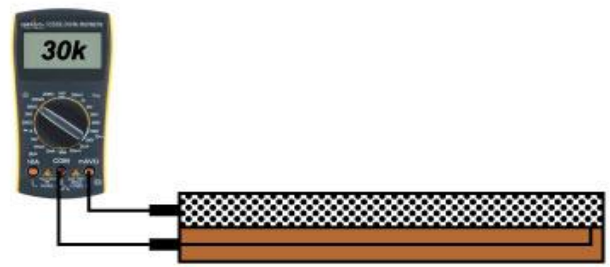
Triple Axis Accelerometer Breakout (ADXL345)

Flex sensor

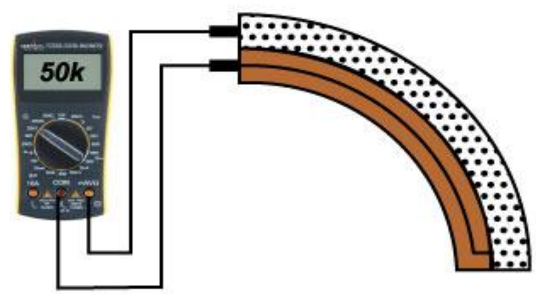


When the sensor is bent, the conductive particles move farther apart, increasing this resistance.



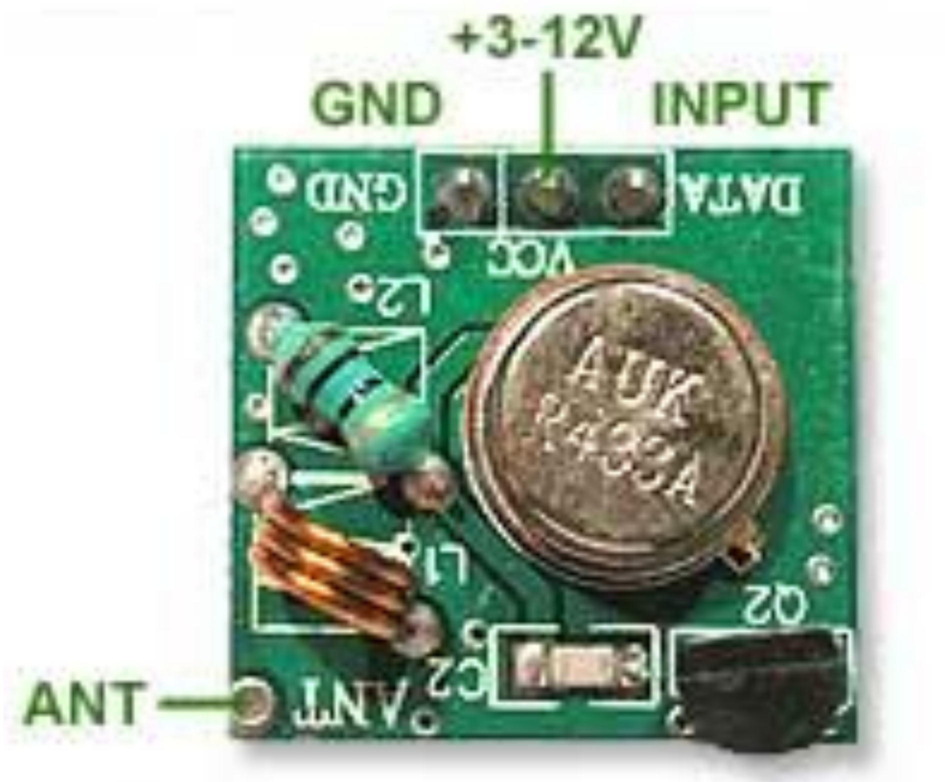


Conductive particles close together - 30K Ohms



Conductive particles further apart - 50K Ohms

RF Link Transmitter - 434MHz



RF Link Transmitter - 434MHz

This wireless transmitter, provides a simple, straight-forward transmitter for all of low-cost wireless project and work with the 434MHz receivers

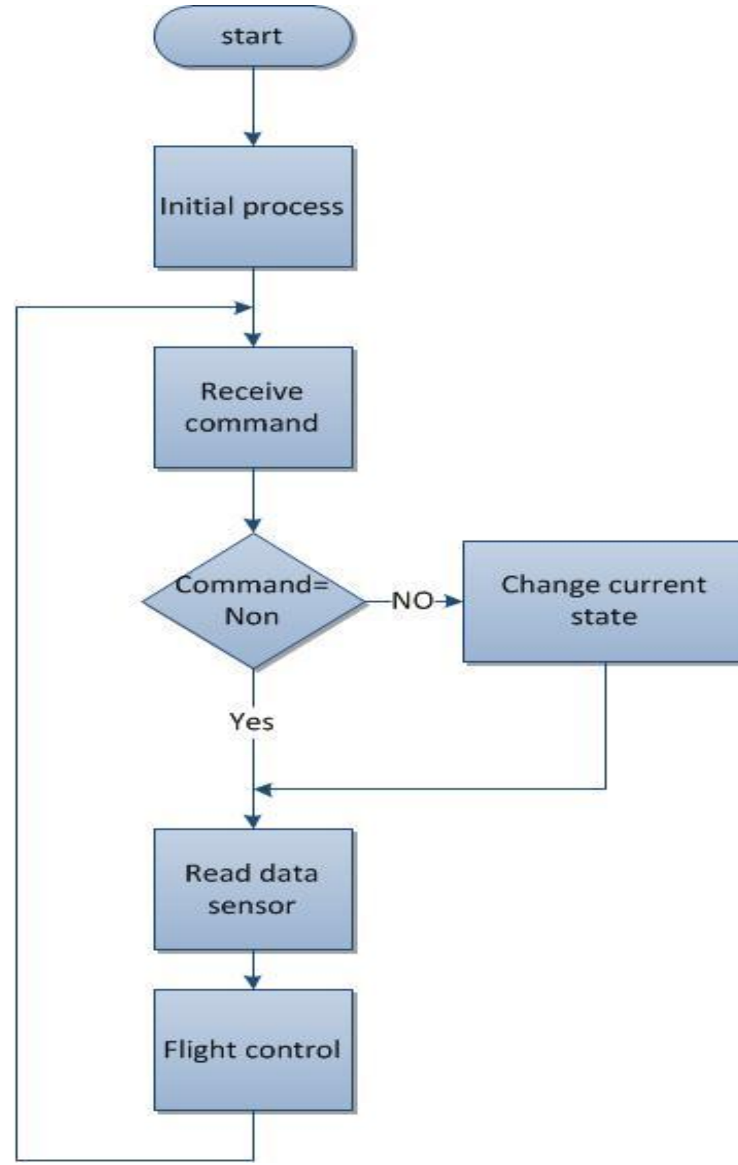
Features:

- 434 MHz.
- 150m range .
- 4800bps data rate.

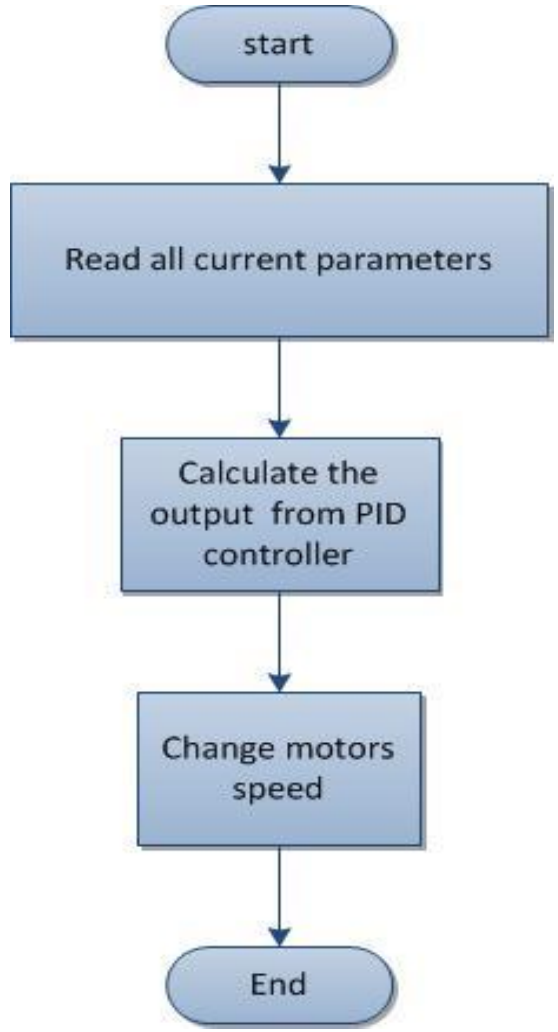
Software Implementation

Quad-copter processes

To maintain the stability and response to control command from transmitter,



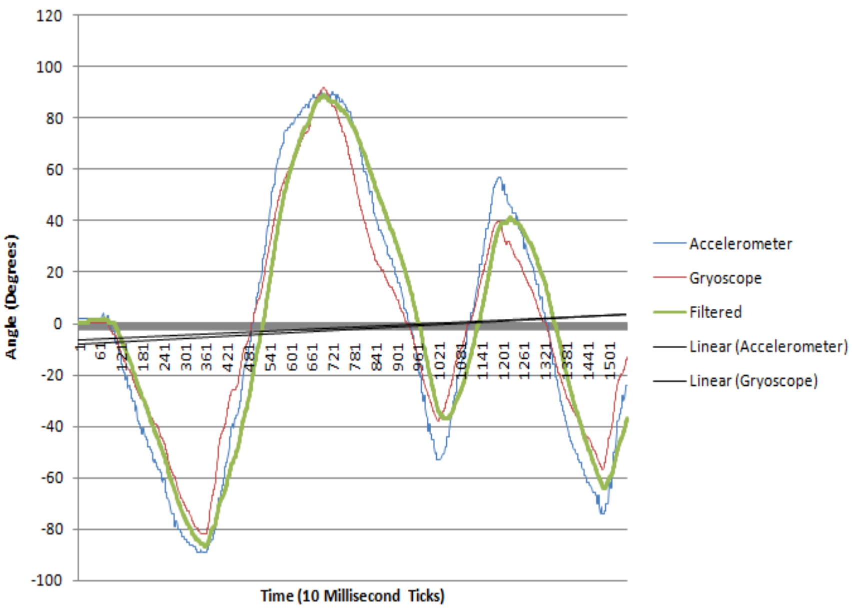
Flight control process:



Flight control process:

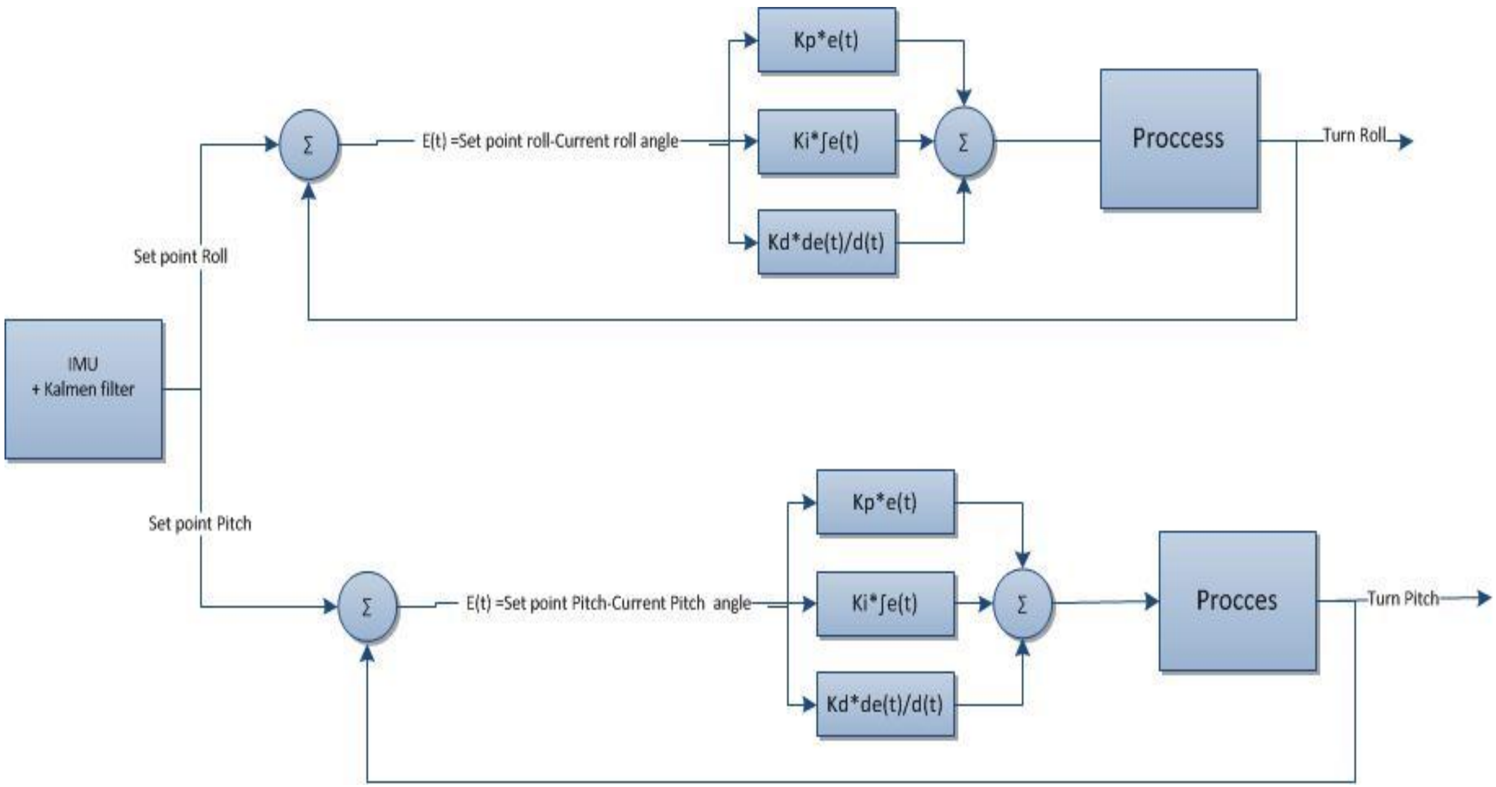
Our challenge is the combination both of the gyro and accelerometer values .

We used Kalman filter which is the most commonly approach to make combining of these sensors by filtering out noise from both sensors and derived angles for both in a range between -90 and 90 degrees.



Flight control process:

To keep quad-copter self-stable automatically it should use specific algorithm, the best algorithm for this task is PID controller.



Flight control process:

PID controller

The quad rotor will use a Proportional-Integral-Derivative control which a closed-loop feedback system, it will be tuned to determine the optimum response and settling time.

The controller calculated the difference between the desired orientation and the current orientation and adjusts output value(U) accordingly.

The equations for a PID controller is as follows:

$$u = P + I + D$$

$$e(t) = ed(t) - ea(t)$$

$$P = Kp * e(t) \qquad I = Ki\int_0^t e(t)dt \qquad D = Kd\frac{de}{dt}$$

Change motor speed control

We use the correction value from PID, to change the motor speed through changing the duty cycle of PWM to each motor.

The next equations show how to change the motors speed.

$$\text{motor[font\_right]} = \text{throttle} + \text{turn\_roll} + \text{turn\_pitch}$$

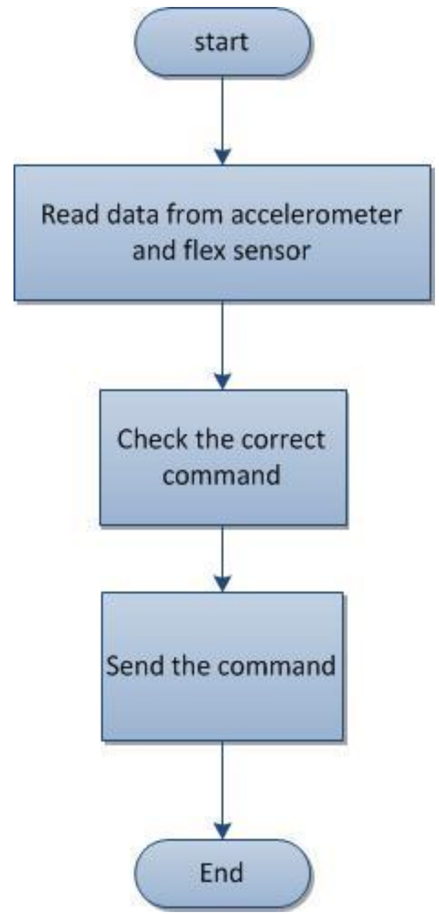
$$\text{motor[font\_left]} = \text{throttle} - \text{turn\_roll} + \text{turn\_pitch}$$

$$\text{motor[rear\_right]} = \text{throttle} + \text{turn\_roll} - \text{turn\_pitch}$$

$$\text{motor[rear\_left]} = \text{throttle} - \text{turn\_roll} - \text{turn\_pitch}$$

Gesture Wireless Processes

We use accelerometer and flex sensors to detect the correct hand motion. The bellow flowchart shows the sequence of process.



Testing

- Video

Budget

Component	Count	Price	Total
Arduino	2	180	360
Motor	4	250	1000
ESC	4	100	400
Propeller	4	20	80
IMU	1	300	300
Accelerometer	1	150	150
RF pair	1	120	120
Flex	2	60	120
battery	1	300	300
Total (NIS)			2830

- DIMO