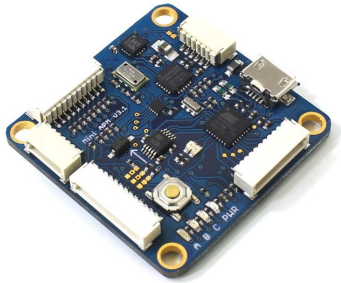
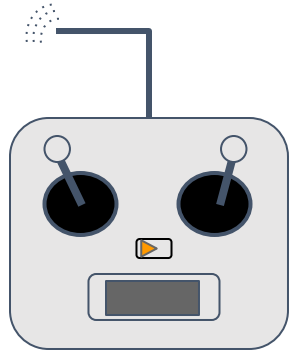
CMSC 828T
Vision, Planning And Control In Aerial Robotics

Quadrotor HW

Bare Minimum - Quads/Quadrotor/Quadcopter

Frame





Radio Transmitter

Propellers

Brushless DC Motors

M2

ESC

RF

Radio Receiver

IMU

Core Distributor

M1

ESC

ESC

M3

Electronic Speed Controller

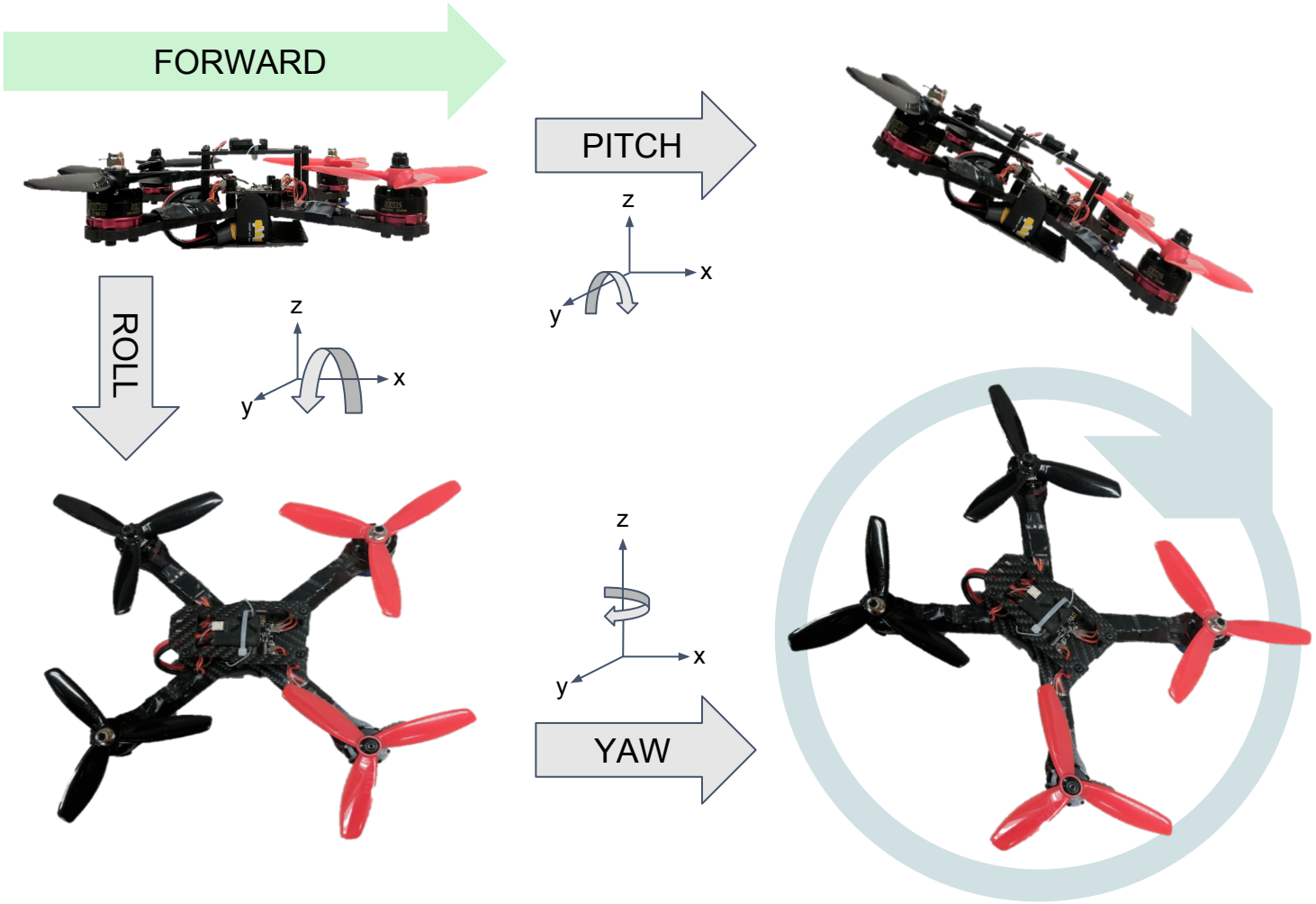
LiPo Battery

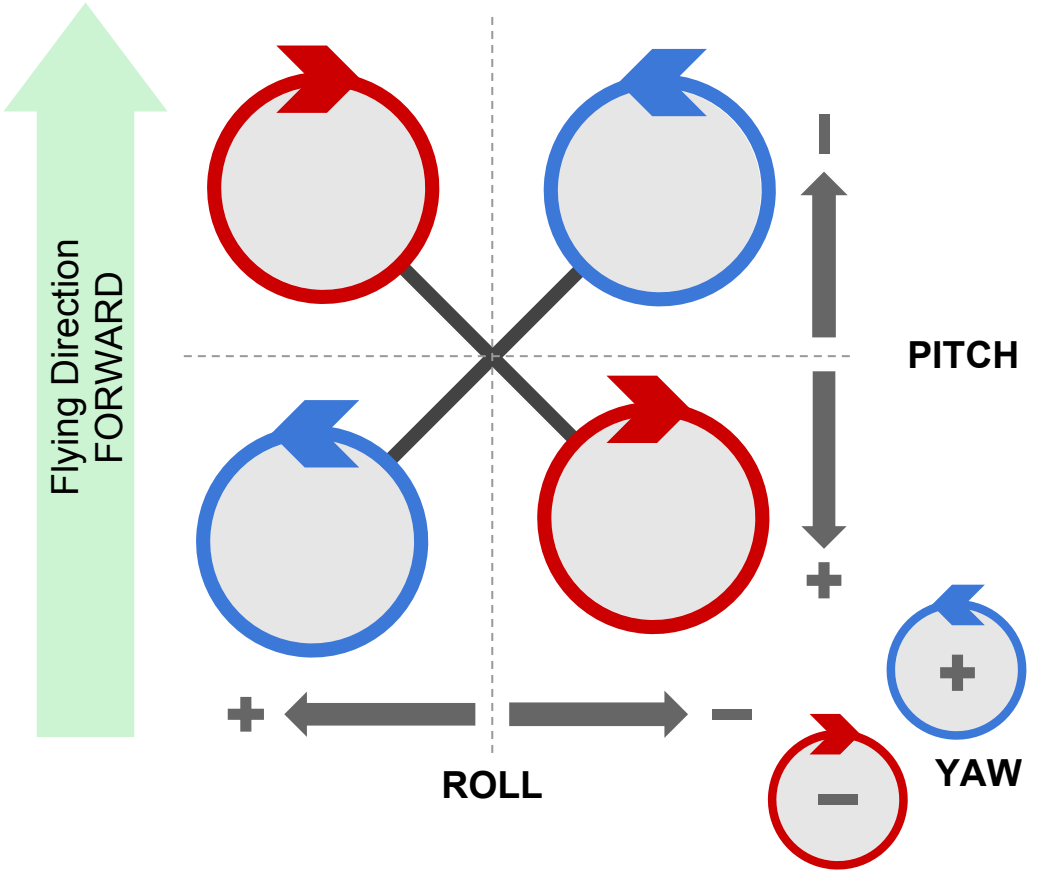
Power Supply

ESC

M4

<Recall> Quadrotor Dynamics

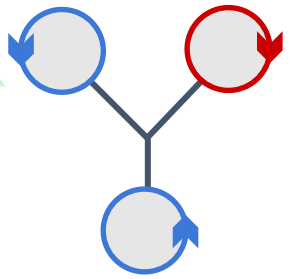




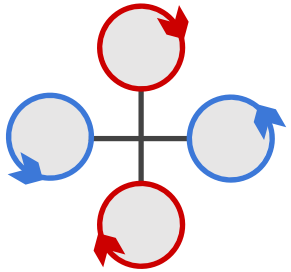
Frames

1. Degrees of freedom
   a. Translation (X-Y-Z)
   b. Rotation (Roll, Pitch, & Yaw)
2. Frames types and configurations
3. Frame Materials
   a. Wood
   b. Plastic
   c. Aluminum
   d. Carbon Fiber
4. Choosing frames considerations
   a. Dimensions
   b. Configuration
   c. Weight
   d. Strength
   e. Material
   f. Price
   g. Appearance

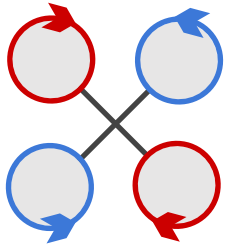
Flying Direction FORWARD



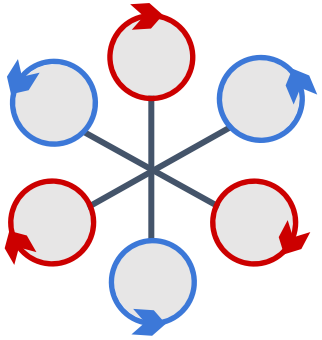
Tri-*copter*



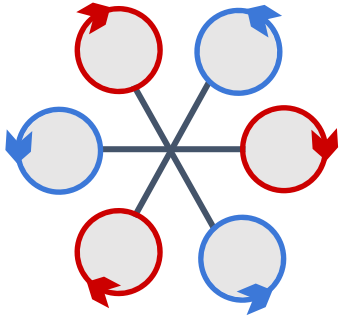
Quad Plus



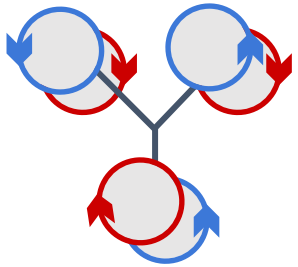
Quad **X**



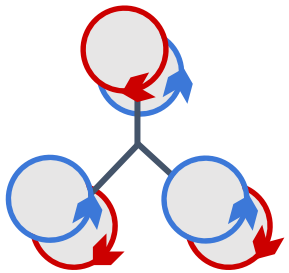
Hexa Plus



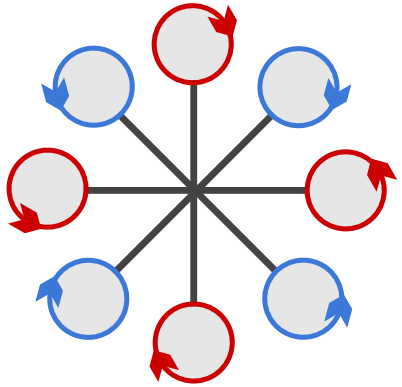
Hexa X



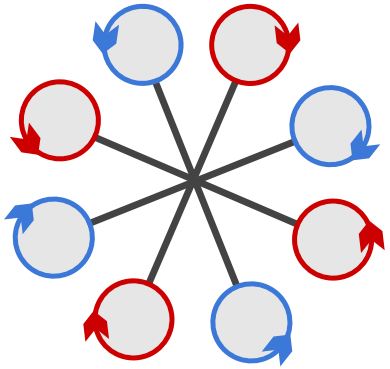
Hexa Coax Y (**Y6**)



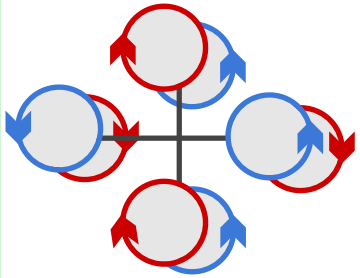
Hexa Coax Y **Reversed**



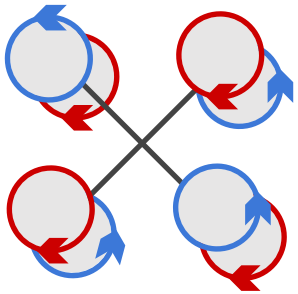
Octo Plus



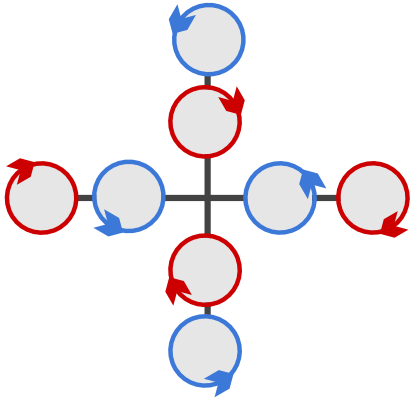
Octo X



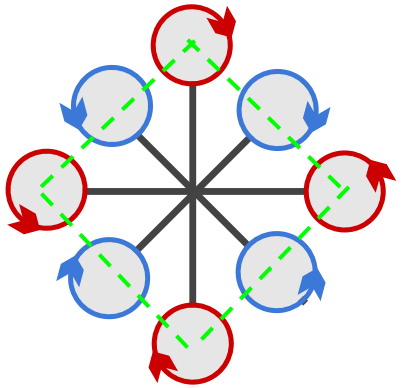
Octo **Coax** Plus



Octo Coax X (**X8**)



Octo **Collinear** Plus



Octo **Square** Plus

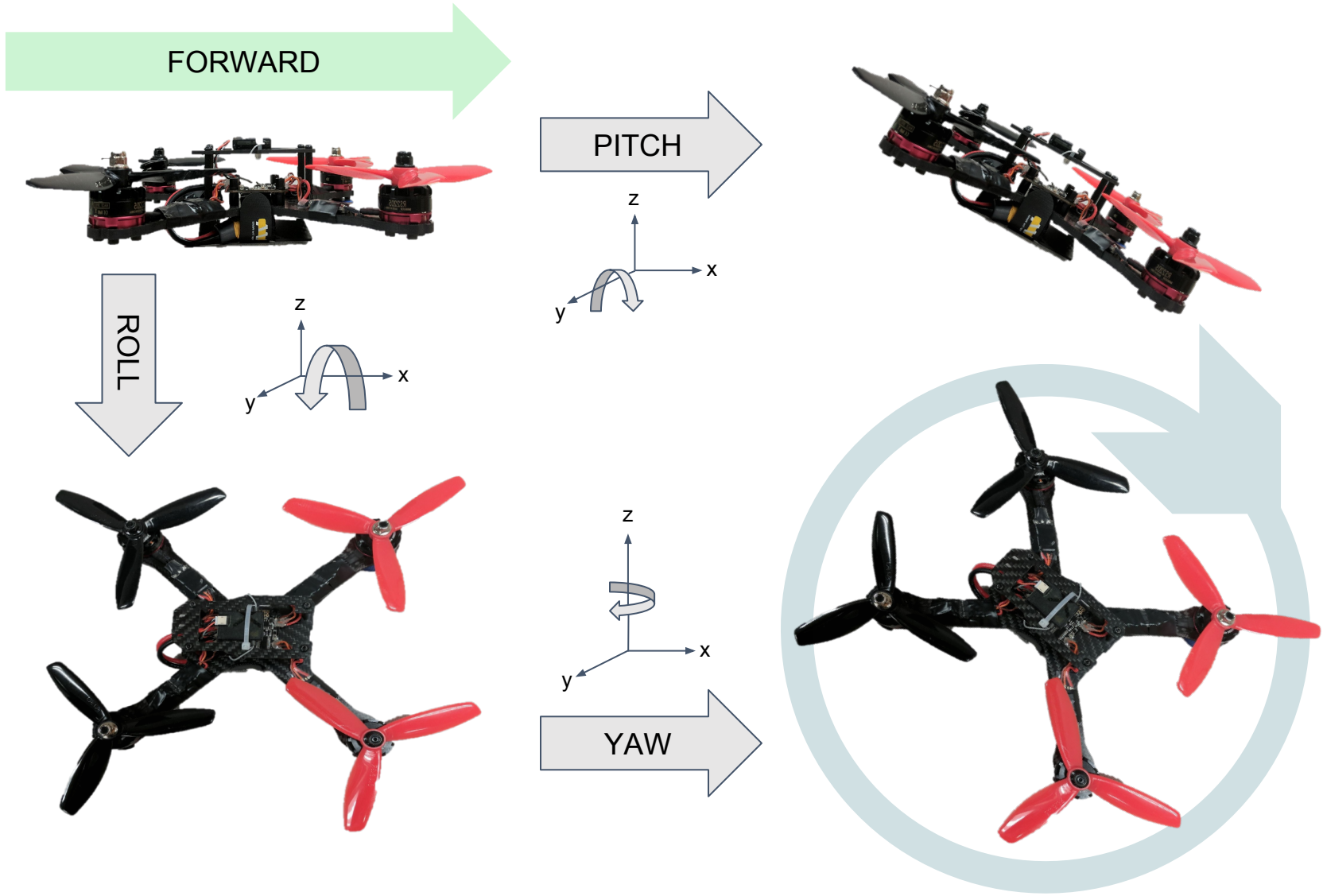
Inertial **M**easurement **U**nit (IMU)

1. Gyroscope (3-DOF, IMU 3-DOF)
   a. Measures: Angular Rate
   b. Provides: Roll, Pitch, & Yaw

2. Accelerometer (3-DOF, IMU 6-DOF)
   a. Measures: Linear Accelerations
   b. Altitude change Z-axis
   c. Movement change XY-plane

3. Magnetometer (3-DOF, IMU 9-DOF)
   a. Measures: Magnetism
   b. Provides: Orientation

4. Barometer (1-DOF, IMU 10-DOF)
   a. Measures: Air Pressure
   b. Provides: Altitude



Inertial **M**easurement **U**nit (IMU)

1. Understanding specs
2. Bias of IMU

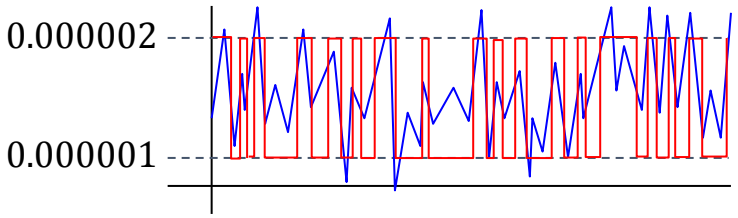
$$\text{At Rest} \quad \underbrace{\begin{bmatrix} 0 \\ 0 \\ -g \end{bmatrix}}_{\text{Ideal}} + \underbrace{\begin{bmatrix} a \\ b \\ c \end{bmatrix}}_{\text{Bias}} \quad \text{Reality}$$

3. Random Walk

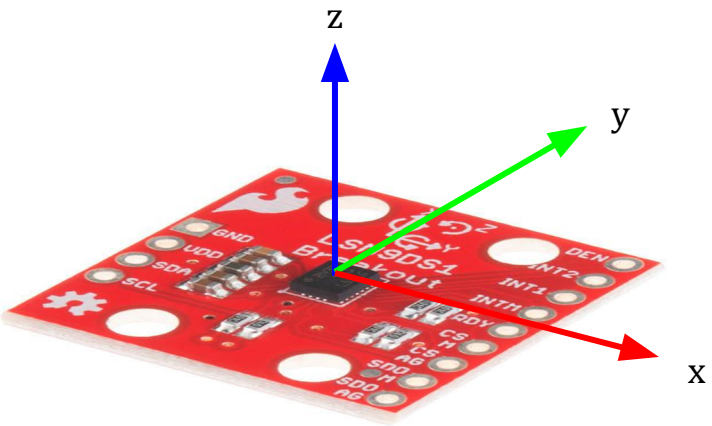
$$\begin{bmatrix} 0 \\ 0 \\ -g \end{bmatrix} \pm \begin{bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \end{bmatrix}$$

Rounding
Significant Bits
Error

4. IMU data plots



Example: iNEMO inertial module:3D accelerometer, 3D gyroscope, 3D magnetometer
http://www.st.com/content/st_com/en/products/mems-and-sensors/inemo-inertial-modules/lsm9ds1.html



Example of how orientation can be achieved using IMU
https://youtu.be/6ijArKE8vKU?t=10s

Motors (BLDC)

Brushless Direct Current Motors (BLDC)

1. More Efficient & Reliable, Longer lasting, and Less Noisy

2. Parts
   a. Rotor - Permanent Magnet
   b. Stator (Electromagnet Coil Sets)

3. Good reference for BLDC working principle:
   https://www.youtube.com/watch?v=bCEiOnuODac

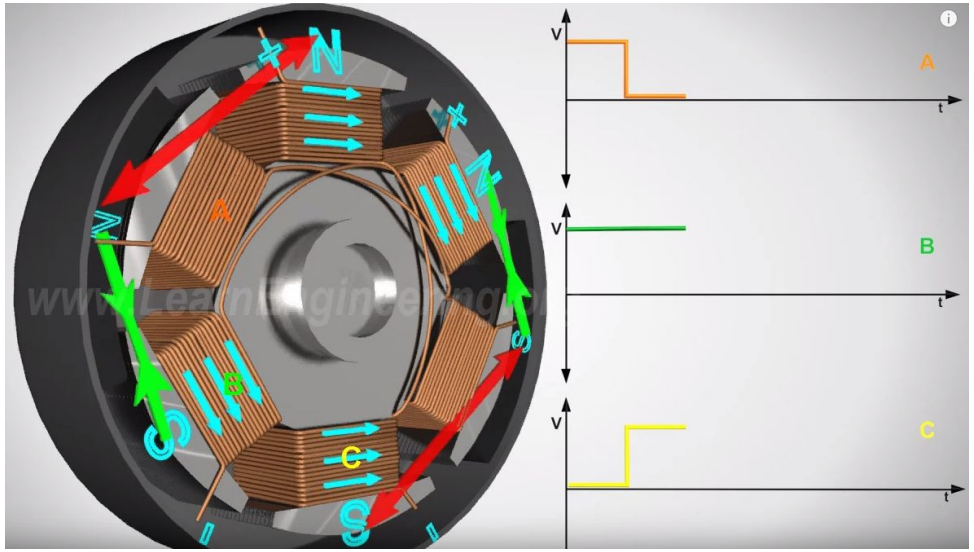
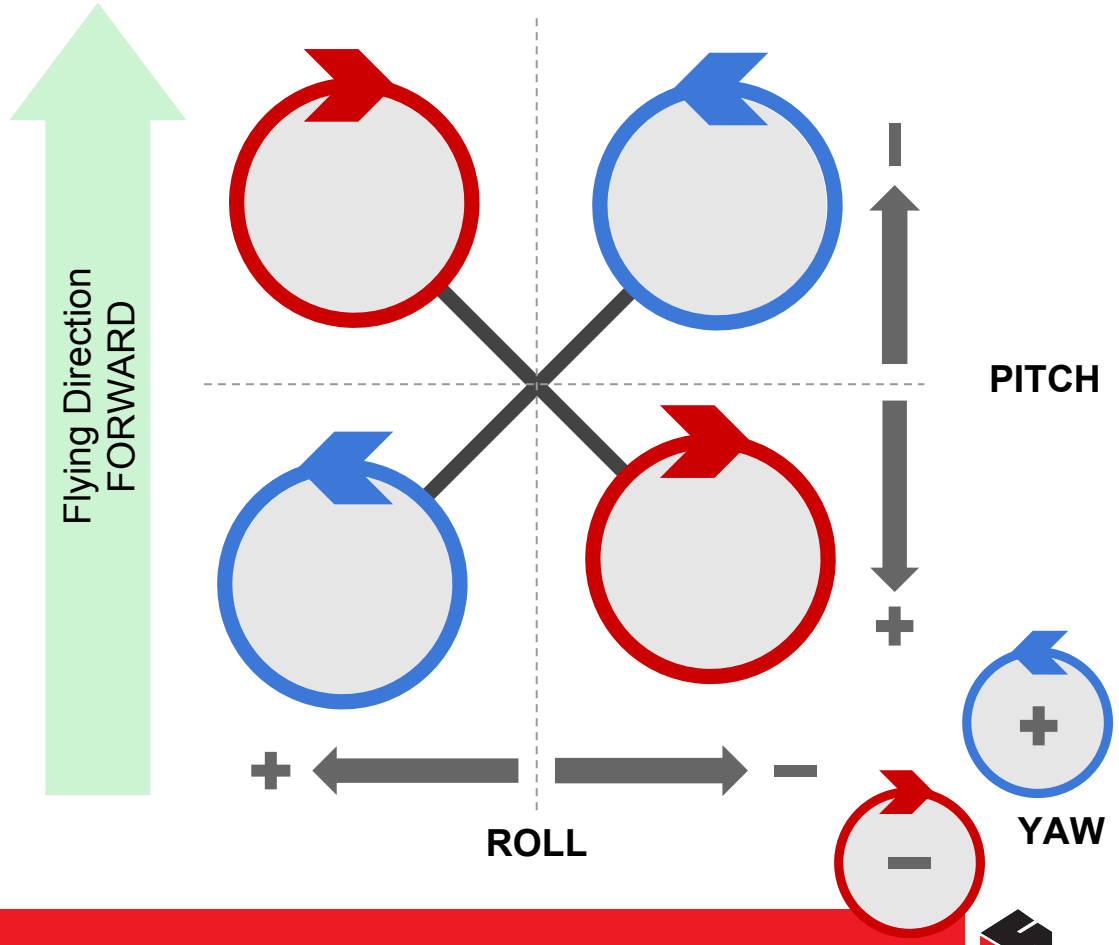


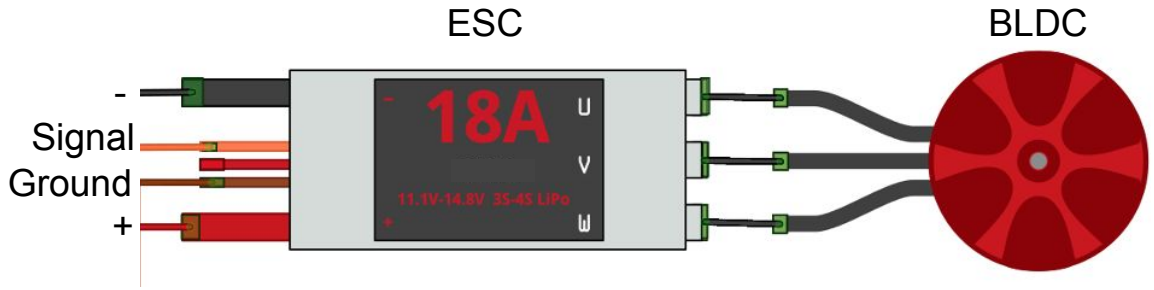
Image Source: https://www.patreon.com/LearnEngineering

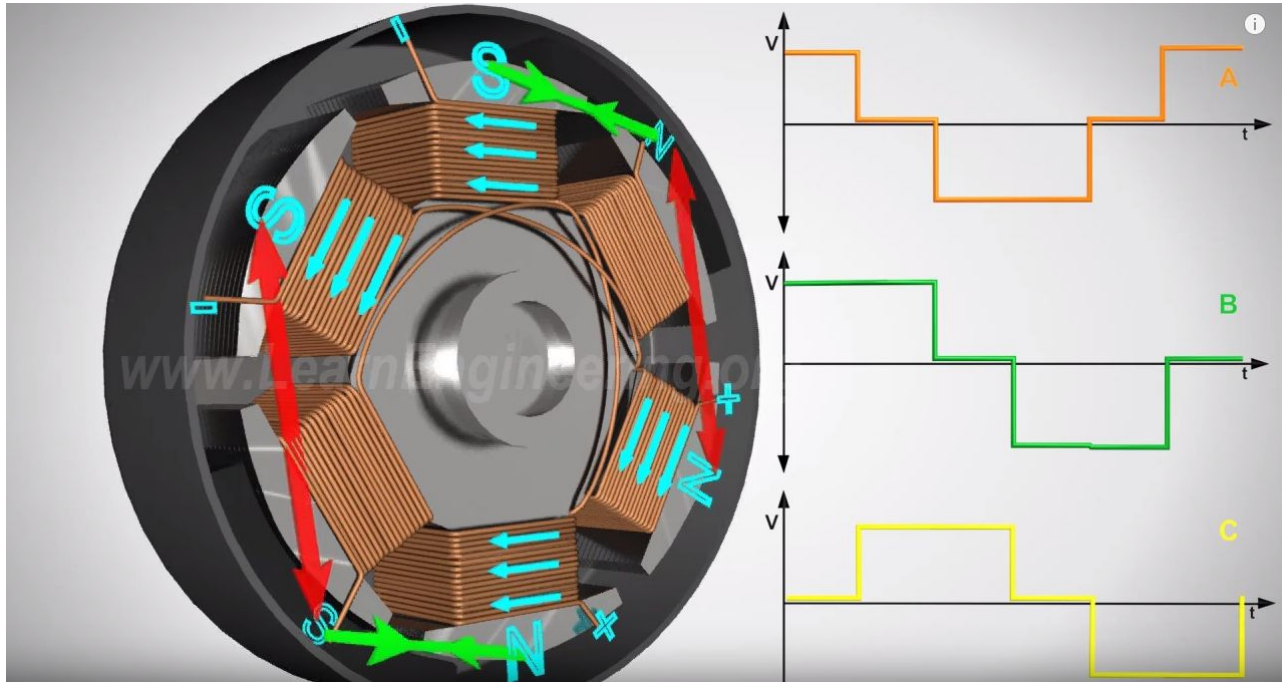


Electronic Speed Controllers (ESC)

1. How it works
   a. Three phase motor
   b. For jerk free, continuous rotation:
      i. Which coil to energize?
      ii. When to energize?
   c. This is the job of the ESCs

2. Wiring
   a. Battery to ESC
   b. Ground and Signal from the Flight controller
   c. Three state connectors from ESC to BLDC





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Batteries - Lithium Polymer (LiPO)

1. Eg. of types: Alkaline, Pb, NiCd, NMh, **LiPo**, etc.

2. Understanding the battery specifications:
   a. 4S -- 4 Cells of 3.7V in series (S=Series, P=Parallel)
   b. 14.8V -- Fully Charged Voltage Level
   c. 3300mAh -- Power capacity
   d. 48.8Wh -- Power capacity (14.8*3.3 = 48.8 Wh)
   e. 50C Max Cont. Discharge -- 50*3.3 =165 Amps
   f. 5C Max Charge Rate -- 5*3.3 =16.5 Amps

3. Charging
   a. Never discharge to too low voltage levels
   b. Set the appropriate cell type
   c. Set the appropriate charge rate

4. Safety
   a. Flexible
   b. Flammable/ Explosive
   c. Prone to puncture
   d. Overheat/ Overcharge

5. Storing
   a. Should be stored in lipo bags
   b. Voltage level should be charged to storing mode ~3.7V per cell, not higher

Radios

1. Most Popular Ones
   a. Spectrum
   b. FrSky
   c. Futaba

2. Considerations
   a. Number of Channels
   b. Binding
   c. Connection to Simulators
   d. Price

3. Wiring Protocols to the receiver
   PWM, PPM, PCM, DSM2, DSMX, UART, SBUS, IBUS

4. Pairing -- Will be covered in the lab session

Beyond Bare Minimum

INPUT (SENSORS)

1. Ultrasonic Range Sensor
2. LIDAR
3. GPS
4. FLIR
5. Light sensor
6. Sound sensor
7. Gas Sensor
8. Temperature Sensor
9. Humidity Sensor
10. Vibration Sensor
11. Buttons/ Switch
12. **Camera (The Swiss Army Knife)**
    a. OF,
    b. VIO
    c. SFM
    d. SLAM etc
    e. The reason why we focus on vision on this course

OUTPUT

1. LEDs
2. Buzzer
3. Display
4. Servo Release

COMMUNICATION

1. Wifi
2. Bluetooth/ BLE
3. Zigbee
4. LTE
5. ...

Safety and FAA Regulations: In & outside the lab

1. **Safely Tips**
   a. Must calibrate IMU
   b. Check communications antennas are secure
   c. Test it out without propellers
   d. Check your battery charge levels
   e. Know how to Arm, Disarm, Emergency land, Home button (Drones with GPS)
   f. When working in groups, loudly and clearly communicate
   g. Safety gears
      i. Gloves
      ii. Goggles
      iii. Fly behind a net when flying indoors

2. **FAA Regulations and Registration**
   More Details can be found: http://www.faa.gov/uas/registration
   a. Flying outdoors, drones between 0.5 to 55 lbs must be registered. More than 55 lbs drones are not legal without a special permission
   b. Stick the registration number on the drone and carry your certificate when flying
   c. Always use B4UFLY mobile app to check FAA requirements based on your GPS location
   d. Further than 5 miles from any airports, unless otherwise authorized
   e. Fly below 400 ft
   f. Don't fly above people (Has to be higher than 50 ft)
   g. Has to be without visual line of sight (FPV does not quality for visual line of sight)
   h. Must fly during the day light
   i. Must fly at less than 100 mph