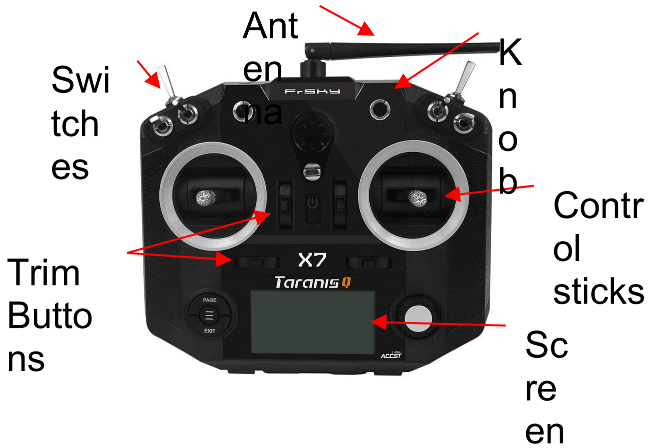
Transmitter and Receiver

- **Transmitter (TX):** The device used by the pilot to control the rc aircraft.
    - **Channels:** Refers to the number of inputs/outputs the transmitter can handle



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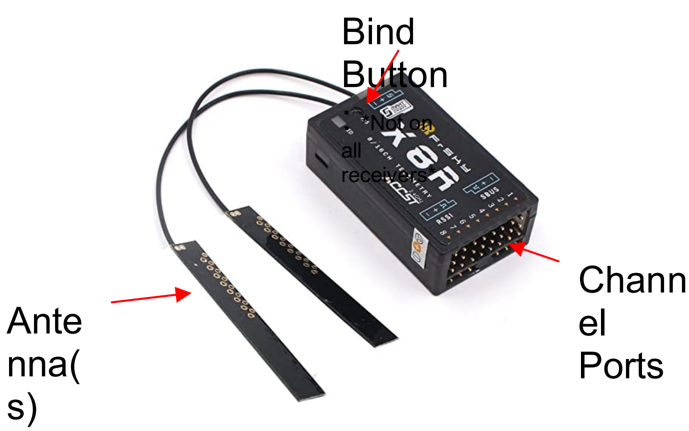
- **Receiver (RX):** The device on the remote control aircraft that receives radio signals from the transmitter and adjusts systems accordingly.
    - **Channels:** Refers to the number of systems the unit can control.
    - **Binding:** the process of ‘pairing’ a transmitter with a receiver.
        - Any two compatible transmitters and receivers (i.e. they use the same protocol) can be bound, although the number of useable channels will be dictated by the unit with the least channels

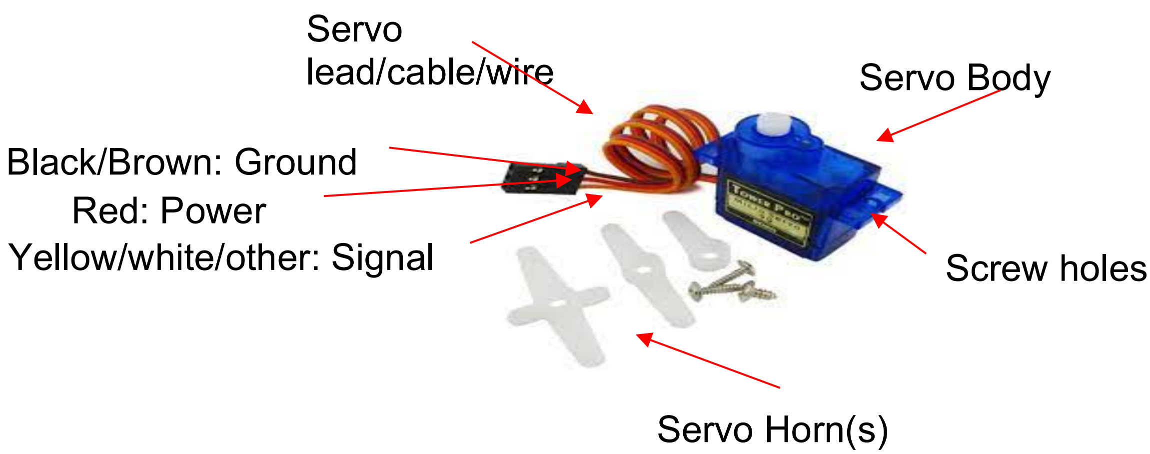


    - **Power:** Receivers typically require an external power source. This is usually provided by one of the channels (for example an esc) or by a dedicated receiver battery (RX battery)
        - Receivers typically require around 5-6V of power. They cannot handle above a certain voltage. Of note, typically servos have more strict power requirements and cannot handle the same maximum voltage that a receiver can handle.
            - A BEC is used to regulate the power accordingly. Many ESCs have built in BECs that enable them to power receivers

- You can also have a separate receiver (RX) battery. Typically NiMh or NiCd which supply around 4.8V.

Servo

- **Servo:** A precision motor unit that is used to control various functions on an rc aircraft such as primary/secondary control surfaces and special functions (e.g. landing gear, payload door).



- **Power:** Typically power is distributed to servo motors by the receiver. Typical voltage of ~4.8v.
- **Servo Throw:** The amount of distance/angle covered by a servo or an attachment.
    - This is dependent on the servo's build, limits imposed by the pilot, as well as which 'hole' is used on the servo horn
        - Holes farther away on the servo horn will give more throw but less torque.
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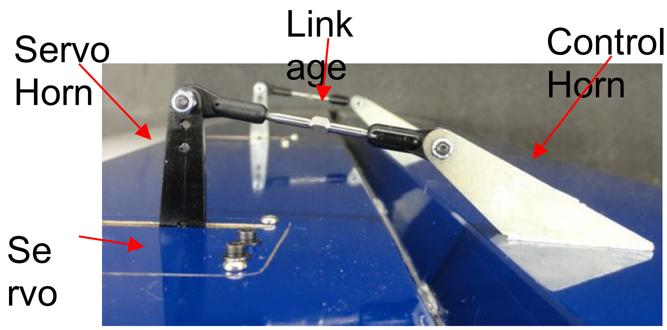
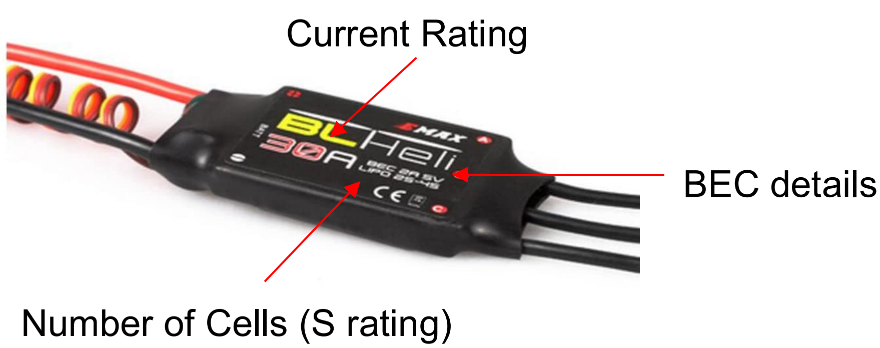
- **Typical uses on a remote control plane:**
    - Adjusting control surfaces: Ailerons, Elevator, Rudder



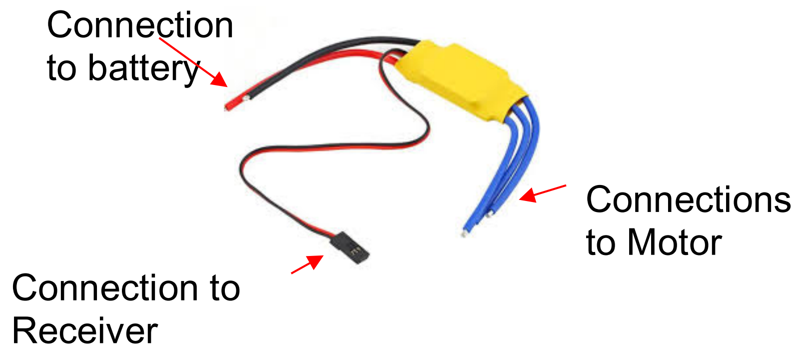
Electronic Speed Controller (ESC)

- **Electronic Speed Controller:** This unit regulates the speed of the motor based on input from the receiver.
  - **How they work:** In brief, ESCs work by alternating (turning on or off more or less) power to the motor and its different magnetic coils. This in turn causes the motor to rotate. By adjusting the frequency of these changes you can adjust the speed of the motor. This link provides more information.
    - **Brushed vs Brushless ESC:** ESCs for brushed and brushless motors are not compatible. Look in "motors" for more information on the differences.
  - **Picking an ESC:** First determine the maximum current that will be drawn from the motor. Next select an ESC that can handle *at least that current*. A bigger ESC won't matter as much as a smaller ESC will. Next, determine what type of battery you plan to use and how many cells that battery has (or 'S's, a 2 cell battery is a 2S, 3 cell 3S and so on). Make sure the ESC can handle *at least that number of cells*. While using a lower amperage rated ESC will destroy it relatively quickly, using a lower cell ESC will destroy it very quickly and with potentially hazardous results. Of note, the ESC, motor and battery are all dependent on each other for sizing.



  - **Connecting an ESC:** Start by connecting and testing the connections to the motor until you have the motor turning. If the connections are wrong, the motor will jerk back and forth. Swap two cables and try again. After the motor turns, make sure it is spinning the 'right' direction.

- Related: [Installation tips.]



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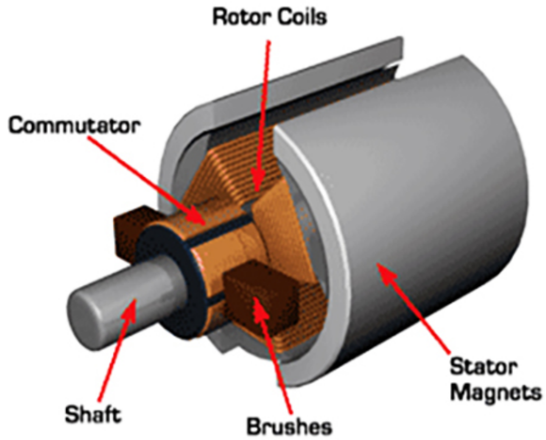
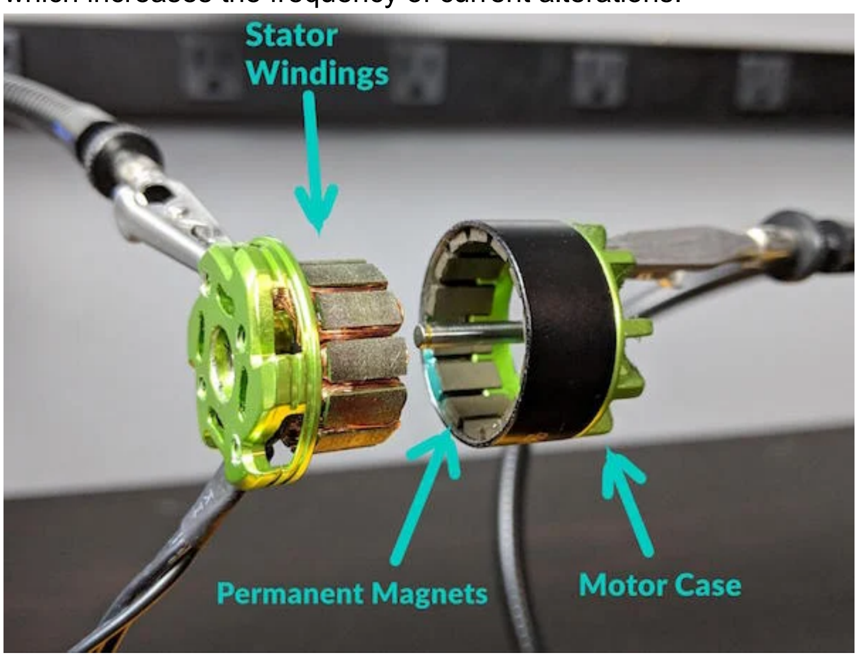
Electric Motors:

- **Terminology:**
    - **Kv Rating:** Gives the number of revolutions a motor without a load will do per volt. For instance a 1000Kv (always a lowercase v) will do 10,000 rpm at 10V. More information here.
    - **Sizing:** Represented a variety of ways but one common way is with a 4 digit number. The first two numbers represent the diameter (in mm) and the next two the length of the stator. For instance 2208 would mean a 22mm diameter motor that is 8mm tall more or less.
        - Generally speaking the larger the diameter and height, the more powerful the motor. A wider motor also tends to produce more torque although often spins slower as a result.
- **Brushed Electric Motors:**
    - **How they work:**
        - Within the motor there is a stationary stator and a rotating rotor. Both of them have either permanent or electro- magnets that interact with the magnets in the other section to produce a turning motion. At least one of the sections must be an electromagnet in order to control the motor. When current is applied to a wire it generates an electric and magnetic field. This field interacts with other sources of EM fields and produces a force. Within a motor this is a torque. This causes the motor to rotate. Reversing direction of the current reverses the magnetic field. Within a motor the current is reversed one or more times during a revolution to keep the motor spinning. In a brushed motor, this alternating is done by a commutator and brushes. As the commutator rotates the stationary brushes contact different pads to the motor windings, these are strategically situated to alternate the current at appropriate intervals and rotate the motor fully. This mechanical method is simple but can require regular cleaning and maintenance in a large system.

- 

- **Adjusting motor speed:** In a brushed motor the speed is adjusted by increasing or decreasing voltage. This can also be done by pulsing a constant voltage via PWM (pulse width modulation) or other techniques.

- **Brushless Electric Motors:**
  - **How they Work:** Brushless motors, as the name implies do not have brushes that mechanically alternate the current within the electromagnet. Instead, current is alternated by a (typically) separate controller (an ESC). The ESC relies on either sensors within the motor or analyzing the feedback from the motor to determine when to switch the current.
    - Brushless motors have more than 2 wires, usually 3. One for each set of coils within the motor. These wires must be connected in the correct order to the ESC (for more information look under the ESC section).
  - **Adjusting Motor Speed:** This is accomplished by the electronic speed controller which increases the frequency of current alterations.
  - 

    - Inside of a brushless motor for an RC plane or similar.

- Types:
    - **Outrunner (left and above):** The outer casing of the motor rotates and contains permanent magnets. The stator is within the motor housing.

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    - **Inrunner (Right):** The rotor is within the motor and therefore the outer casing does not rotate.
    - **Choosing a brushless motor:**
        1. Identify factors affecting aircraft propulsion requirements (Takeoff distance, max speed?)
        2. Outline power requirements (Max static thrust, thrust at top speed, etc.)
        3. Look for motors (with example props) that meet the requirements
        4. Look at props for the motor that better suit requirements.
    - **Factors to consider when choosing a motor:**
        - Motor temperature
        - Required amperage compared to maximum amperage
        - Required voltage (battery size)

- **Electric Ducted Fan (EDF):** These units are designed to replicate a turbine engine in looks. However, these units as the name suggests are electric powered and have an impeller within a shroud. More information here
        - EDF units typically use high Kv motors (They spin very fast in other words).
        - Typically the impellers have at least 5 blades. Larger EDFs can even have 12 blades.
    - **Uses**: High speed scale flight. Safety, the shrouded impeller design is more protected then the standard propeller. Typically EDFs are buried within a fuselage too.
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    - **Downsides:** EDFs require a lot of power and draw lots of current. For this reason, EDF RC aircraft typically have a short flying time and require good, high-performance batteries.

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Batteries:

- Most common types for RC planes are LiPo and NiMh. LiPos are becoming much more common, although NiMh and NiCd are still used for receiver batteries.
- LiPos:
    - Voltage: Average voltage varies the number of cells that the battery has as well as its charge. The ‘S’ rating gives the number of cells that a battery has. A 3S battery has three cells. The average voltage of each cell is 3.7v. Therefore a 3S battery has an average (at least for calculations) voltage of 11.1v. However, fully charged each cell actually has 4.2v. So a 3S battery at full charge will read 12.6v.
        - Try to not discharge a battery below 3.7v per cell and never below 3.3v per cell.
        - Discharging a battery too much can damage the battery.
    - Capacity: given by the mAh rating. mAh or milli-amps per hour is the amount of current that the battery can provide for one hour, at which point the battery will be completely exhausted.
        - Conversion to charge (coulombs): X * 3600s * 1A/1000mA = Y C
        - Conversion to energy: P = I*V. Multiply the amount of charge in the battery by the average voltage.

$$E\ [in\ joules]\ =\ (number\ of\ cells) * 3.7v * (number\ of\ mAh) * 3.6\ [A/(s * mAh)]$$

        - Flight time: divide the total energy by the (energy per time) used for flight: (Total Energy)/(Power consumption) = flight time
            - Ex. A plane that uses 125 watts at cruise with a 2200mAh 3S battery can fly for: 2200mah means that the battery holds 87,912J of charge. With a power consumption of 125 watts or J/s, the plane can fly for ~11.75 minutes.
    - Maximum discharge rate: The maximum discharge rate is related to the capacity and the C rating. The maximum discharge rate = (capacity) * (c rating)
        - Ex. a 1100mAh battery with a 30c rating can be safely discharged at 30c * 1100mA = 33A.
        - This is the recommended do not exceed value. Exceeding it for lengthy amounts of time decreases battery longevity
    - LiPo safety:

        - Never short or puncture a LiPo battery. It can catch fire.
        - Charge LiPos in flame resistant bags and never leave unattended.

Further Information:

- RC Airplane Glossary: https://www.rc-airplane-world.com/rc-flying-glossary.html
    - Provides definitions and further information to a wide variety of model aircraft terms.
- Electric Motors: http://learningrc.com/quadcopter-motors/
    - Gives information on both brushed and brushless motors, how they work, and how to pick one.
- A general guide to brushed vs brushless motors: https://www.arrow.com/en/research-and-events/articles/which-dc-motor-is-best-for-your-application
- What the numbers associated with batteries mean:
    - https://hobbyking.com/en_us/blog/cat/battery/post/reading-and-understanding-lipo-batteries?gclid=Cj0KCQjworiXBhDJARIsAMuzAuwnFpNZujXRov5gJQ8uasUoBvvlV_nE6qywkx-80qn45ly3gxskXtUaAg4-EALw_wcB
- Information on LiPo and NiMh batteries:
    - https://www.rccaraction.com/everything-need-know-rc-batteries/
- Scratchbuilding Community and Articles: https://www.flitetest.com/articles
    - Contains tons of articles are scratch building RC planes, primarily of foam board.