Kamloops Model Airplane Society

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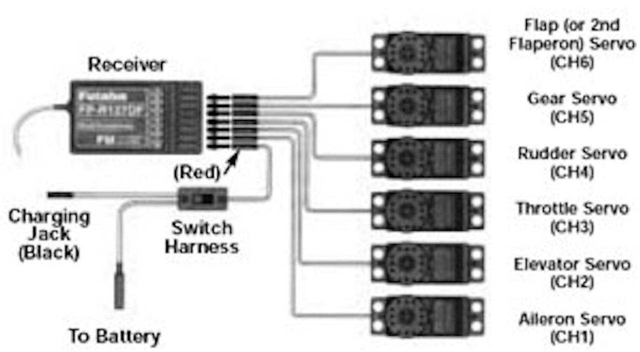
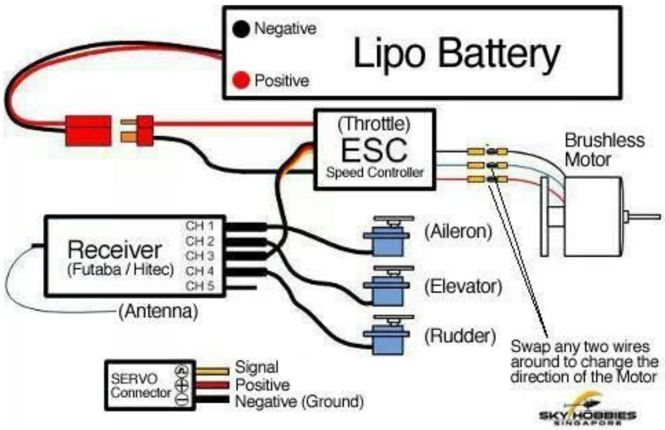
Radios, Receivers & Speed Controllers

As in shapes of Pasta, there are numerous Manufacturers and in turn, models of Radios (Tx), Receivers (Rx) and Electric Speed Controls (ESC). Due to the support for new pilots with "AS3X" and "Safe", I will be referring mainly about Spektrum Radios and Receivers. The wiring in a Internal Combustion (IC) and an Electric Powered (EP) RC plane are very similar. As shown in the images below, the IC plane doesn't need a ESC and the battery plugs into a Hub or Harness to provide power to the Receiver. The EP plane, because it has an electric motor, needs the ESC to control the speed of that motor. The ESC also provides power to the Receiver. In both cases, the Radio sends the command to the receiver which in turn, sends the command to the appropriate servo or motor. In the case of the IC plane, there is a servo on the throttle of the engine. The EP plane motor just receives the command to decrease or increase the power from the ESC.



Wiring for IC RC Plane



Wiring for EP RC Plane

There are two components in either of the two types of planes, that will control or restrict the number of options your plane can have. The number of channels your radio and receiver support, will determine the number of options that can be operated on your plane. If you have an 8 channel radio, but the receiver only has 4, then 4 is the maximum number of channels supported. And the reverse is also the case. Lets look at a basic plane that has Ailerons, rudder, elevator and throttle. The channels needed would be (this is not an indication of what surface/device is on what channel):

Channel #1 - ailerons
Channel #2 - elevator
Channel #3 - rudder
Channel #4 - throttle

So, you purchased a basic 4 channel radio and plane with a 4 channel receiver when you started out. 6 Months later you are loving the hobby and have decided to upgrade to a plane with flaps and retractable landing gear. Hmmmmm, seems to be a problem! You can fly it , but you can't use flaps or retract your landing gear! Well, the reason would be that your radio only supports 4 channels, despite the plane having a 6 channel receiver. Oh, and that plane you are saving up for that drops bombs too, because you want to enter into the National Bomb Dropping competition? Get the idea? So, what I am says is, while you may be in a hurry to get out flying and have bought a Ready to Fly package with an entry level radio, you now will join the ranks (myself included) that have gone out and bought at least an 8 channel radio.

Radios

The transmitter converts the pilot's movements into a radio signal in a process called modulation. The transmitter then broadcasts this signal to the receiver. The receiver inside the airplane picks up this signal the same way the radio in your car picks up the local radio station. The receiver pulls the information from the radio waves and relays this information to each servo. Each Servo has a horn that is attached to its shaft. This horn is attached to a control surface, or engine throttle, via a push rod. The rotation of the horn translates into a linear movement at the control surfaces.

Servo Push Rod Horn

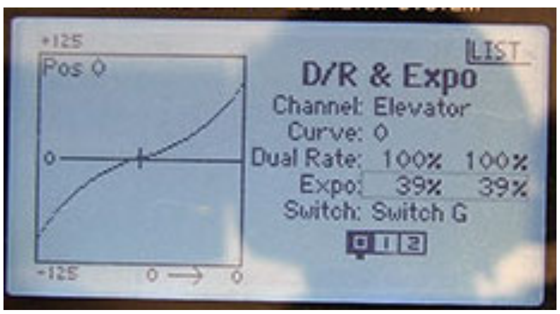
The movement of the servo is directly proportional to the movement of the control sticks on the radio. In other words, the control surfaces on the airplane move exactly the way you move the stick on the radio. The servos and receiver power source simply plug into the receiver. Some people add a switch between the battery and receiver which is mounted to the side of the airplane. Some manufactures of large scale planes (i.e. Cessna 150) install a switch as standard equipment. The switch allows you to turn the receiver off without removing the battery when you're not flying or waiting to fly. If you wish to install a switch, install it between the ESC/Hub and Receiver.

The basic "Stick" movements on your radio as displayed below, correspond to the appropriate servo control via the receiver. The more you move any one stick, the more the receiver tells the servo to move. While the picture may be a bit intimidating, unless you are a 10 year old who has spent the last 8 years with a game controller in your hands, there are aids such as Safe to help you. As most things, it is also a matter of time spent on the field going through the movements and practicing.

Function of radio sticks

I will not spend a lot of time talking about the switches on your radio, but there are three that are important to you as a new pilot. Keep in mind that all the switches are programmable and you can setup the function for each, that best suits you. I will refer to a specific switch such as "A". If you look beside each switch on your radio, there should be a small label with what switch it is. When you accumulate planes, each is a separate setup for each plane, on your radio. When you want to fly a different plane, you simply go to the plane selection on your radio and select it. All settings for each plane on your radio are for that particular plane and are kept separate. It is highly recommended that when you acquire new planes, you setup the same switches for each with the same function. That way you don't have to remember what switch does what as you change plane selections.

The first switch (I use switch "A") that is important, is the one you use to turn Safe off and on, if your plane receiver has it. The second switch is called the "Rate" or Dual Rate" Switch, that controls the sensitivity of each stick. "Dual Rates" refer to altering the rate of servo travel for a control surface on RC aircraft (e.g. Ailerons, Elevator, and sometimes Rudder). Dual Rates consist of Low, Medium and High Rates. Low Rates make the aircraft less responsive (i.e. easier to control), and High Rates make the aircraft more responsive (i.e. harder to control). Dual Rates are typically controlled by a three position toggle switch (I use switch "C") on a radio. There are three settings, Low, Medium and High for each of the aileron, rudder and elevator. When you look at the radio display screen while setting the Dual Rates, you first select the switch. Further on the screen you select the control surface you want to set for i.e. aileron. If you move the switch through the three positions, you will see it highlight each from 0, 1 and 2. You can set the percent (%) of response for each, i.e. 55% for 0, 75% for 1 and 100% for 2. You would then go back and select the control surface you want to set for, make the changes and then repeat for the third surface. This may sound complicated, but once our instructors show you the screen and assist you in setting it up, you will have a clear understanding of how it works. Below is an example of a radio's D/R & Expo screen.



Expo (exponential):

This setting alters how sensitive the sticks are around the center point. It does not alter the total throw of the servo movement. It alters the default linear curve to one that either is less sensitive (positive expo) or more sensitive (negative expo) around the middle point. You can see the curve line in the picture above. Typically, I start with 30% for all my aircraft on all surfaces, and then alter as deemed necessary. This allows for a little more stick movement around the middle for more precise flying. Typically 25-40% expo on control surfaces is typical for beginners.

Now when you add in the Safe switch, you can see six different levels of control with the Rate switch. Three setting with Safe and three settings without Safe. When you have Safe on and use the Rate switch, you not only have the ability to slow down the reactions of the plane to your stick movements, you have Safe's ability in obtaining level flight after a turn. When you are first starting your lessons, your instructor is going to have your Rate switch in the Low position. This means you have to move the stick a lot more than Medium or High for the control surface to move. This means your plane is not going to make any fast movements such as turns and elevation changes. You learn to make smoother movements and become confident with your flying. As you improve, you can switch to a higher setting. A good example would be doing your takeoff and landing at low with Safe and once you gain some height, switch to a higher rate setting and practice smaller stick movements.

The third important switch, is the Throttle Cut switch. This is a two position switch you assign to cutting power to the motor. Your throttle must be cut until you have moved your plane to your pilot station at the runway. You then do your surface movement and motor run-up tests. The propeller on any plane is capable of causing serious body damage and has to be treated as such. When you have finished your flight, you once again cut the throttle before picking up your plane.

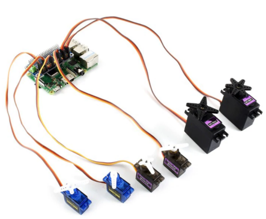
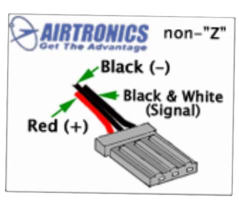
Receivers

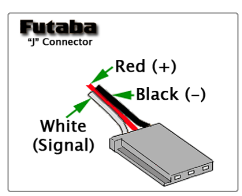
Receivers could be called the Brains of your RC Plane. They come in a wide variety of configurations and in a lot of cases, are dependent on what type of plane you are installing them into and what features such as the number of channels, AS3X or Safe are desired. Most receivers use a Bind plug for Binding, but we are seeing new receivers that have a Bind button right on the receiver. One of these types would be the Spektrum AR637T 6 Channel Safe and AS3X Telemetry Receiver which can be found here. A complete chart of Spektrum Receivers can be found here.

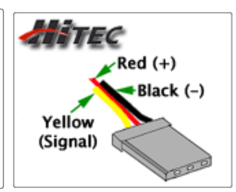
When you purchase a RTF or BNF plane, the receiver will have been installed. Take a close look at that receivers and what is coming out of it.

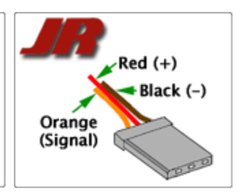
Servos

Servos, as mentioned, control the movement of control surfaces and motor. On EP planes, the motor is controlled from the receiver through the ESC to the motor. On IC planes, the throttle on the motor is controlled from the receiver to a servo on the throttle. Like all plane parts, there are numerous makers and models of servos. The picture below shows some of the different sizes available.



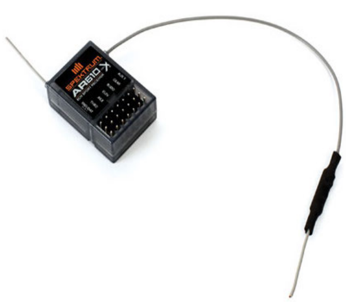




Servos have one thing in common. They each have three wires attached which plug into the appropriate slot on the receiver. As shown in the pictures above, there isn't any uniformity in the colours used for the wires. What they do have in common is that one wire is for power, one for signal and one for ground. Usually the brown or black is the ground wire. Now, once again look at the receiver and in all cases, the wire colours are all in the same order. As you are installing batteries or making connections to the wing from the receiver, one of these connectors can come out of the receiver. Simply plug it back in, in the same colour order as the rest. If you are doing your check at the flight like and one control surface isn't working, it is because that plug has come out, or is partly out and not making a connection. If you are installing a receiver and aren't sure which way the colours should go, try with all black or brown at the bottom. If they are backwards, the servos will not work. Just reverse all the plugs and it should be fine.

Antennas

The receiver has two antennas coming out of it. One is quite short and the other longer with an amplifier for greater signal clarity. For optimum RF link performance, mount the antennas for best possible signal reception for the aircraft in all possible attitudes and positions. Orient the antennas perpendicular to each other—one vertical and one horizontal Mount the long antenna at least 2 inches away from and perpendicular to the short antenna using tape. Experienced pilots will use clear fuel line over the short antenna and tape it so it is pointing straight towards the side of the plane. The long antenna should be taped securely straight out towards the back or front of the plane, avoiding laying it over any other electrical wires or devices. Prior to carrying your plane to the flight line, the first time that day you fly it, you will do a radio range check. This involves turning on your radio, installing a battery in the plane, turning on the switch to power the receiver if you have one and walking a given distance (32-36 steps) away from the plane with your receiver. You should be able to clearly see all control surfaces on your plane as you try each of them in turn. Your throttle cut should be engaged and do NOT test the motor at this stage. If you are having problems seeing if everything is moving properly, ask a fellow member to stand by the plane and watch for you as you cycle each surface. Some smaller planes that are white, can be hard to see movement.

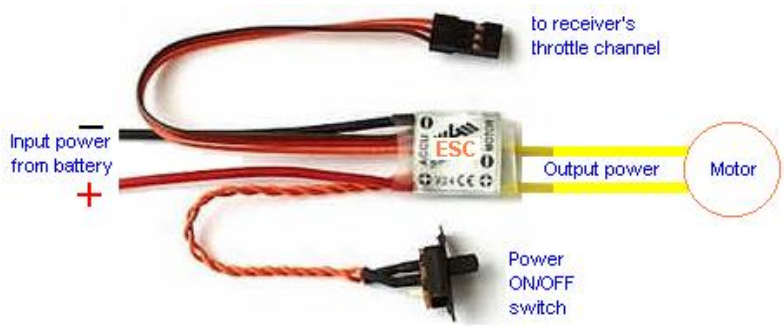


A Typical receiver with Antennas

Electronic Speed Control (ESC)

While we can refer to the receiver as the Brains of your RC plane, the ESC would be the Heart. ESC's designed for RC airplanes usually contain a few safety features. If the power coming from the battery is insufficient to continue running the electric motor, the ESC will reduce or cut off power to the motor while allowing continued use of ailerons, rudder and elevator function. This allows the pilot to retain control of the airplane to glide or fly on low power to safety. As you probably know, an electronic speed controller (or ESC) controls how fast your airplane's motor spins. It serves the same purpose as the throttle servo of a glow powered airplane. It's an interface between the airplane's radio receiver and the power plant.

An ESC will have three sets of wires. One lead will plug into your airplane's main battery. The second lead will have a standard servo wire that plugs into the throttle channel of your receiver. And finally, the third set of wires actually power the motor.



A Sample connection of an ESC

An ESC follows a speed reference signal (derived from a throttle lever) and varies the switching rate of a network of field effect transistors . By adjusting the duty cycle or switching frequency of the transistors, the speed of the motor is changed. The rapid switching of the transistors is what causes the motor itself to emit its characteristic high-pitched whine, especially noticeable at lower speeds.

Different types of speed controls are required for brushed DC motors and brush-less DC motors. A brushed motor can have its speed controlled by varying the voltage on its armature. A brush-less motor requires a different operating principle. The speed of the motor is varied by adjusting the timing of pulses of current delivered to the several windings of the motor.

Brush-less ESC systems basically create three-phase AC power, like a VFD (variable frequency drive), to run brush-less motors. Brush-less motors are popular with radio controlled airplane hobbyists because of their efficiency, power, longevity and light weight in comparison to traditional brushed motors. Brush-less DC motor controllers are much more complicated than brushed motor controllers.

The correct phase varies with the motor rotation, which is to be taken into account by the ESC: Usually, back EMF from the motor is used to detect this rotation, but variations exist that use magnetic (Hall effect) or optical detectors. Computer-programmable speed controls generally have user-specified options which allow setting low voltage cut-off limits, timing, acceleration, braking and direction of rotation. Reversing the motor's direction may also be accomplished by switching any two of the three leads from the ESC to the motor.

ESC's are normally rated according to maximum current, for example, 25 amperes or 25 A. Generally the higher the rating, the larger and heavier the ESC tends to be which is a factor when calculating mass and balance in airplanes. Many modern ESC's support nickel metal hydride, lithium ion polymer and lithium iron phosphate batteries with a range of input and cut-off voltages. The type of battery and number of cells connected is an important consideration when choosing a battery eliminate circuit (BEC), whether built into the controller or as a stand-alone unit. A higher number of cells connected will result in a reduced power rating and therefore a lower number of servos supported by an integrated BEC, if it uses a linear voltage regulator. A well designed BEC using a switching regulator should not have a similar limitation.

ESC's are rated for a maximum current. The more current an ESC is rated for, the more expensive and heavier it will be. Choose an electronic speed controller that is rated for slightly more than what your motor will pull at full throttle. Too much current will damaged an electronic speed controller very quickly! On the same token, too big of an ESC is dead weight that will adversely affect the performance and balance of your airplane.

LiPo batteries will be permanently damaged if the voltage of any cell drops below 3.0 volts. For this reason, Li-Po batteries require an electronic speed controller with a low voltage cutoff (LVC). The LVC will cut the power to the motor when the voltage reached 3.2V, or whatever you set the LVC to be. You will also need to choose an ESC that can handle the voltage of the battery pack you plan to use. The voltage rating for each ESC is clearly stated in the specifications.

ESC firmware

Most modern ESC contain a micro-controller interpreting the input signal and appropriately controlling the motor using a built-in program, or firmware. In some cases it is possible to change the factory built-in firmware for an alternate, publicly available, open source firmware. This is done generally to adapt the ESC to a particular application. Some ESC'sESCs are factory built with the capability of user up-gradable firmware. Others require soldering to connect a programmer. ESC are usually sold as black boxes with proprietary firmware. As of 2014, a Swedish engineer named Benjamin Vedder started an open source ESC project later called VESC. The VESC project has since attracted attention for its advanced customization options and relatively reasonable build price compared to other high end ESC's.