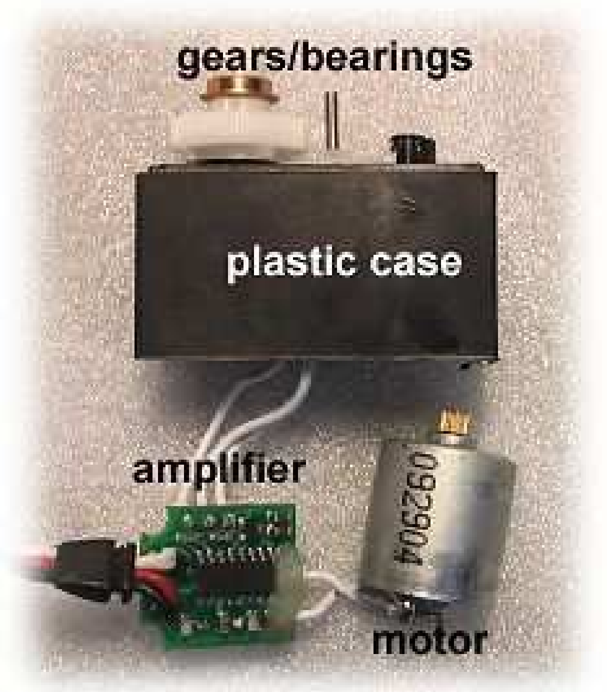
How do Servos Work?

THE BASICS OF SERVO OPERATION

RC servos come in an amazing range of sizes, speeds, strengths, weights, shapes colours and varieties but they all work on the same basic principles.

The job of an RC servo is to position its output arm to a position that exactly corresponds with the movement of the corresponding stick, switch or slider on the transmitter. What's more, it should do this as quickly as possible and provide a high level of accuracy regardless of the effects of aerodynamic loads or other factors.



Most servos, regardless of brand or type, consist of several main parts:

- **The mechanics**. These are the gears and the case.
- **The motor**. This provides the motive force to drive the output arm
- **The feedback pot**. This allows the servo to measure the actual position of the output arm
- **The amplifier**. This is the electronics that hook all those other bits together to make it work

Now let's take a look at those bits in more detail...

The Mechanics

Most RC servos have a plastic case, the top section of which contains a set of gears that can be either plastic or metal. The strength and rigidity of these mechanics play a significant role in determining the robustness and weight of the servo, with metal gears usually being significantly stronger (and heavier) than plastic.

The choice of gear material depends very much on the type and size of model in which the servo will be used. Generally speaking, plastic gears are only suited to models up to 5-6 lbs in weight.

Bearings

The output shaft and gear of a servo experiences significant side-loading during its operation and this means it needs some kind of support to stop it from moving out of mesh with the rest of the gears.

Cheap servos tend to simply rely on the plastic shaft rubbing against the plastic of the case and for small/slow models this isn't too much of a problem. These servos are often called 'bushed" and, because there has to be some clearance between the shaft and the case, usually demonstrate some side-to-side slop in the output shaft, which can appear as a degree of rocking up and down of the output arm.

However, precision and hi-torque servos really do benefit from the addition of a ball-bearing or two on the output shaft. This significantly reduces the friction, virtually eliminates wear and means there should be no slop at all in the output shaft.

Good servos have a single bearing (usually in the top of the case) while even better servos have two bearings -- one in the case and one at the bottom of the output shaft.

The Motor

There are basically three different types of motors used in model servos, the most common of which is a brushed motor with three or five-pole armature. The benefit of these motors is their low cost and robustness. The downside is that, because of their heavy iron armature, they tend to respond more slowly.

The second most common type is the coreless motor which, as the name suggests, does not have an iron-cored armature but instead has a lightweight plastic armature on which the field windings are formed. This has the advantage of being able to start and stop far more quickly (due to its low mass) and also produce more torque -- since the diameter of the windings is much greater than with a cored motor.

Because they cost more to manufacture, coreless motors are usually only found in expensive servos designed for very fast transit times (such as used on heli tailrotors).

The final motor type is the brushless variety being offered in just a few servo models from big-names like Futaba. The brushless motor can be designed to provide very high levels of torque and has no brushes to wear out. Servos with brushless motors are few and far-between right now though because of the costs involved.

Pots and Amplifiers

Inside every servo is a tiny circuit board that contains a bunch of components.

It is the job of this circuit (which is called an amplifier) to convert the signal from the receiver into a signal that drives the servo's motor to position the output arm to the requested position.

Way-back, when proportional RC gear was first developed, there was only one kind of servo amplifier: the analog amp, but today we also have digital versions.

Standard/analog Servo Amplifiers

Modern receivers send a series of pulses to each servo. Those pulses vary in width from about 1 thousandth of a second (1mS) to two thousandths of a second (2mS) -- with the center-point being around 1.5mS.

These pulses are sent at a rate of about 50 per second and every time a pulse arrives in a standard/analog servo, the amplifier checks to see if the servo's output arm needs to be moved one way or the other.

If the amplifier decides that the servo arm does need moving because the transmitter stick has been moved then it sends a short burst of power to the motor in order to rotate the gears and (ultimately) the output.

For most applications, this works just fine but since the servo motor isn't being driven continuously (only for a moment every time a new pulse is sent from the receiver), the full torque potential and speed of the servo isn't fully realized.

Another issue with standard servos is that the torque tends to drop off quite dramatically as the difference between the requested position and actual position of the output arm gets smaller. In fact, when this difference is very small, the torque of the servo be insufficient to move the arm against a slightly binding linkage and the result will be a buzzing noise.

Digital Servo Amplifiers

Since the standard/analog servo amp was designed, electronics have moved on significantly and now manufacturers can put tiny computer chips called microcontrollers in servos.

These little computers can provide significantly improved speed, torque and accuracy.

They do this by allowing the servo's motor to be driven far more frequently than was the case before.

Instead of only driving the motor each time a pulse arrives from the receiver (a mere 50 times per second), they effectively remember the length of the pulse and then drive the motor almost continuously (or at a much higher frequency).

The result is that the motor produces more torque and can accelerate/stop more quickly.

Digital servos are often easily identified when running because of the different sound they make as a result of this increased motor-drive. Hitec digitals will "sing" at a high frequency and some others like Futaba and JR will "growl".

Which is best?

Clearly, because of their greater torque, accuracy and speed, digital servos are usually superior to standard servos but in many cases, such as sport models, that extra performance might not be worth the extra price.

Feedback Pots

So how does a servo know exactly where its output arm is so that it can command the motor to move it to the position commanded by the transmitter stick?
Well that's the job of the feedback potentiometer ("pot" for short).

The pot is just a tiny version of the volume control knob on older-type radios and TV sets. It's a variable resistor which can be used to create a voltage that changes as the servo's output arm moves.

That voltage can then be used by the servo amp to work out the exact position of the arm and decide whether it needs moving and if so, which way to drive the motor.

Good servos use high quality pots, cheap servos tend to use inferior ones and the quality of the feedback pot is very important to the accuracy and reliability of a servo. When a pot becomes worn or dirty, the servo can jitter and become erratic in movement. Cheap pots may also be adversely affected by high-vibration environments.

Brand Wars

So who makes the best servos?

Well there's no easy answer to that question and asking it is likely to result in as many people as there are opinions offered.

The reality is that most of the big-name manufacturers produce perfectly good servos that, providing they're matched to the model properly, will provide long and useful service.

When it comes to the no-name servos, most of which originate from China then all bets are off.

Choosing The Right Servo

More important than choosing the right brand of servo is actually choosing the right servo for your model and flying style.

With modern servos spanning the range from featherweight 3g units with only a tiny amount of torque to mammoth heavyweights that can exert over a thousand ounce-inches of power there's really no excuse for using a servo that's not matched properly to your model.

For small models (foamies and the like) small, cheap 5-9g servos do the job just fine. Servos like the HXT900 are incredible value for money and are so cheap you can throw them away when/if they break.

Small heli-fliers can use these budget servos too but unless you're into just hovering around, there are some real benefits to be had from using digital servos instead. A number of companies make fast, strong digital servos that are well suited to small helis -- but you'll pay extra for that improved performance.

A sport/trainer model up to 5-6 lbs in weight will be ideal for the so-called "standard" servos such as the Futaba 3001/3003, Hitec 425 and a raft of others. While a ball-bearing servo will outlast a non-BB one, many people fly very low-cost (under R100) servos in these applications with no problems at all.

If you're into aerobatics or 3D flying then digital servos may offer you some benefits in terms of precision, speed and torque. It's also worth considering the use of metal-gears once models get above the 6lb mark as this will reduce the chance of stripping.

Larger helis are also a good candidate for stronger gears and digital amps since the force required (especially for collective/cyclic) can be very high.

Gas planes of 26cc and above really do need metal-geared servos due to the higher levels of vibration encountered and the size/weight of the control surfaces. Once you get into Giant Scale you should be looking at the top-end servos from the likes of Hitec, JR, Futaba, etc. From a performance and safety perspective, it makes no sense to try and save money by using anything less than the best you can afford.

Final Thoughts

It's important to remember that servos are just one link in a long chain of components that effectively connect your transmitter sticks to the control-surfaces on your model.

The failure of any one of the components in that chain can cause disaster.

One of the most common issues is not having enough battery or BEC capacity to handle the servos you're using.

Hi-torque and hi-speed servos (especially digital ones) can draw enormous amounts of current from your system and if your battery or BEC isn't up to the job, bad things will happen.

Originally, Futaba advised against using NiMH batteries with some of its hi-torque servos because the early nickel-metal batteries just weren't up to the task. Fortunately things are much better now and a good quality NiMH pack (of adequate size) will work just fine.

However, anyone who tries to drive a bunch of hi-torque digital servos using nothing more than an AA-sized receiver pack is going to be sorely disappointed with the performance (and wreckage) that results from such folly.

Also make sure that your extensions (if you're using any) are up to the task.

Always use heavy-duty extensions if you can afford to carry the extra weight as these will produce the least loss of torque in your servos. In fact some servos (notably the Futaba 3000 series) will behave very oddly (oscillating and hesitating) if your servo extensions are not up to the job.