Servos: analogue, digital and coreless

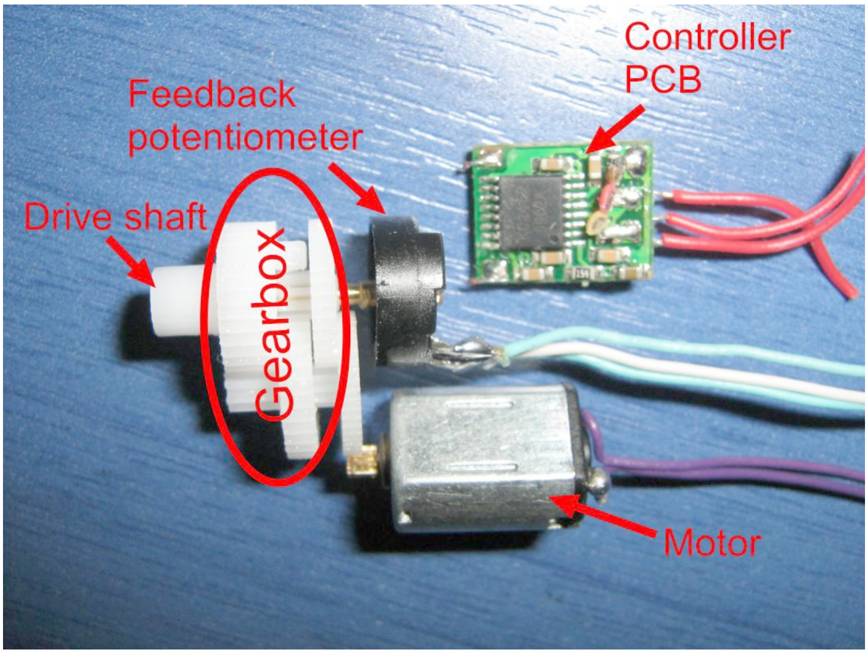
All rotary model aircraft servos work the same way. Unless coreless, the only difference between analogue and digital ones is one small piece of electronics.

Servos use pulse width modulation (PWM) and feedback.The receiver (Rx) splits each second into fifty ‘windows’ of 20 thousandths of a second (milliseconds ms) each. Inside each window the Rx sends a pulse of voltage, between 3.3 and 5 V, down the signal wire (yellow or white) to each servo, evenly spaced out. These pulses are nearly rectangular in shape and vary in length between 1.0 and 2.0 ms. The length is determined by the position of the transmitter stick, rotary/slider control or switch position for that channel. So full up elevator might be 1.0 ms and full down 2.0. Neutral will be 1.5, with small changes to it being set by trim or offset. A two-position switch will change the width from one extreme to another. A three-position switch will add a 1.5 ms mid-point. Transmitter-based adjustments to throw or weight will increase the 1 ms or reduce the 2 ms pulses. Most servos don’t use all of their possible movement so you can send signals outside the normal range and get more movement. However this is risky as you don’t know how much more is safe for a particular servo. Taranis users have to be careful as the amount of movement can be set in at least three ways and they multiply. A good head for arithmetic is needed or a stock of spare servos.

That explains the words **pulse** and **width**. **Modulation** means a change that carries information, in this case a move from 0 to 5V that starts the pulse or 5 to 0 that ends it.

Inside the servo case there are four things – a motor, some gears, some electronics and a variable resistor called a feedback potentiometer (pot). I don’t need to explain what the motor does. The gears do two things. They slow down the rotation and they increase its turning force (torque). Torque is measured as a force times a distance. For servos the measurement unit is usually kg cm. A 10 kg cm servo can make a force of 10 kg at the end of a 1 cm arm, 2 kg at the end of a 5cm one and so on. The pot is turned by the final drive from the gears. Because it is a variable resistor, as it turns it produces a varying voltage, so the position of the servo output shaft is turned into a voltage that can be read by the electronics.

The servo electronics controller PCB measures the control pulse from the receiver and turns it into a desired position for the servo. It reads the voltage from the pot. If the pot voltage shows that the servo is already in that position it does not send a voltage to the motor. It the servo is out of position it sends a voltage to move it one way or the other until it is in the right position. This is known as feedback. It means that the servo can only move once every 20 ms. Rapid small movements of the stick can get confused. The effect can be that the response feels sluggish or weak.



Picture: pcbheaven.com

What's different about digital?

The electronics is where digital servos are different. The PWM pulses from the Rx are the same. However digital electronics 'remembers' the pulse size and produces voltage pulses at a greater rate than fifty per second, in fact 300 or more, so they are effectively continuous. This means that the motor starts sooner and produces more torque. It also means that the servo responds instantly to any external force on the control surface that moves it from the correct position. If you push the working servo it feels 'solid' rather than mushy. I am not clear why such servos are called 'digital'. They are no more so than analogue ones, but I suppose it sounds modern and there is no better alternative. High-speed or high-pulse-rate could be misleading.

Analogue servos switch off when they get no signal so can be moved by external forces. Some digital servos hold their last position and firmly lock it. The only downside to digital is that the servos use more power so you must use a bigger capacity battery to drive them.

One last word to explain is 'deadband'. Its true meaning is the amount of signal change needed before a servo reacts. For example in a car it is how far you need to move the wheel before the steering takes effect. However it is used loosely in RC servo descriptions to mean sluggishness.
When I started using digital servos I noticed that some buzzed slightly. Being used to analogue servos this worried me, as buzzing often indicates a fault, meaning that I wouldn't fly. I was assured that slight buzzing is normal with some digital servos.

Coreless digital servos

If you watch a highly aerobatic model the speed of the control surface movement is impressive. It can be less than 0.1 second to 60° servo arm deflection. To achieve this, coreless servos have very light moving parts. There is no moving iron core, hence the name, just a light wire cage of windings shown copper-red in the picture.


Picture: rchelicopterfun.com

A conventional servo motor has an iron core armature wrapped in wire that spins inside magnet. In a coreless servo, the armature is a cylindrical thin wire mesh that spins round outside a magnet. Ordinary servo motors have three or five magnets. When the coil is between two of these the force drops. There are no gaps in a coreless motor magnet, so they are smoother, more constant, and stronger.

Current consumption

A word of warning. Digital servos use more current than analogue ones, because they are working all the time. If they also produce a lot of torque, and are high speed coreless types, they might need more current than your receiver channel can provide, especially if there are two on a Y-lead. For digital servos above say 10 kg cm torque, try to find out what current it uses and what your receiver can provide. The manufacturers don't tell you. To be safe (and I broke a receiver finding this out) use a power distribution board. I will be trying out a new servo tester soon that measures current draw.

Good and bad points of digital servos

Good

Fast reaction to control and deflection
Smaller deadband
Probably lock in position rather than switch off

Bad

Use much more energy so use larger, or twin, batteries or replace them regularly as you do flight batteries
Likely to need a power distribution board

For further information and some excellent pictures by Jan see
https://www.pololu.com/blog/17/servo-control-interface-in-detail