Nick’s Notes

Sailboat Servo Basics

I keep getting asked questions about servos, mostly digital versus analog. So I wrote up the following to help all of you make your own decisions about what to do to your boat. I’m going to start at the beginning so as not to make any assumptions about what you know or don’t know.

TYPICAL PARTS OF A SERVO — LOTS OF GEARS, HUH?

All RC-servos have a three wire connector. One wire supplies positive DC voltage – usually 6.6 volts. The second wire is for voltage ground, and the third wire is the signal wire. The receiver “talks” to the servo through this wire by means of a simple on/off pulsed signal.

Speed and Torque Ratings

Speed is a measurement of the time it takes the servo to rotate a certain number of degrees. This has been standardized in most specifications to the time it takes for the servo to turn 60°.The smaller the number, the faster the servo.

For example a 0.12 sec/60° servo rating means it will take 0.12 seconds to rotate the servo arm or wheel 60°. This would be twice as fast as a standard speed servo that is rated in the 0.24 sec/60° range.

Torque determines the maximum amount of rotational force the servo can apply at a right angle to a servo arm. This torque force specification is measured and listed in the servo specifications as ounce inches (oz-in). The larger the number, the more force the servo can exert

So what exactly does 100 ounce-inches mean?

Well if you had a servo arm that was one inch long on your servo it would be able to produce 100 ounces of pull or push force to a right angle at the end of the servo arm before stalling. If you had a two inch servo arm what do you think the force would be? Yup, 50 ounces of force. Half the lever length and you double the torque, double the leaver length and you half the torque. Those of you who are clever with math have already figured out that our (mostly) six inch arms (three inches on each side of the servo shaft) will reduce the servo torque to ⅓ of the spec value (Yes! One-third!). Most airplane servos, by the way, are in the 30-50 oz-in range.

Digital RC Servos vs. Analog RC Servos

To answer the question – let's look at how each type works and like everything in boating it's a trade-off

First off, there is no physical or main component difference between a digital servo or analog servo. The servo case, motor, gears, and even the feed back potentiometer all have the same functions and operations in both types.

The difference between the two is in how the signal from the receiver is processed and how this information is used to send power to the servo motor.

Analog Servo Operation

An analog RC servo controls the speed of the motor by applying on and off voltage signals or pulses to the motor. This voltage is constant. This on-off frequency is standardized to 50 cycles/second. The longer each on pulse is, the faster the motor turns and the more torque it produces.

This is the same way the speeds of most motors are controlled. For instance, if you have a ceiling or exhaust fan in your house that is controlled with a variable rotary dial speed switch; the fan motor is not given lower and higher voltages to adjust the speed.

The speed switch simply cycles the 120 volts to the fan motor on and off many times a second. The longer each on pulse is, the faster the fan runs.

Now back to our analog RC servo. At rest, there is no voltage going to the motor. If a small transmitter command (sail in-out) is given or some external pressure (the wind) is applied to the servo horn forcing it off neutral, a short duration voltage pulse will be sent to the motor.

The larger the sail movement, the longer this "on" pulse will be in order to move the servo quickly to the desired position.

Again, in one second, there are 50 windows that last 20 milliseconds each (50x20 = 1000 ms = 1 second). The longer each “on” voltage pulse is in each of these fifty 20 millisecond windows, the faster the servo motor turns and the more torque it produces.

You don’t have to understand all this tech stuff, however, as long as you understand that during small amounts of sail movement or when wind forces are applied forcing the servo off its neutral or holding position; only a short duration voltage pulse will be sent to the servo motor every 20 milliseconds. With large sail movements, a long voltage pulse will be sent every 20 milliseconds to the servo motor.

As you can imagine, a short power pulse every 20 milliseconds doesn’t get the motor turning that quickly or allow it enough time to produce much torque. This is the problem with all analog servos; they don’t react fast or produce much torque when given small sail commands or when wind forces are trying to push them off their holding position. This area of slow or sluggish response and torque is called dead-band.

While airplane and helicopter control movement actually happens within the dead-band area of an analog servo, I’m not sure it applies very much to sailboats. However, I could be wrong. I’m happy to admit it, if someone can prove it applies to sailboats.

Digital RC Servo Operation

A digital servo has all the same parts as an analog servo, even the three wire plug that plugs into the receiver is the same. The difference is in how the pulsed signals are sent to the servo motor.

A small microprocessor inside the servo analyzes the receiver signals and processes these into very high frequency voltage pulses to the servo motor.

Instead of 50 pulses per second, the motor will now receive upwards of 300 pulses per second. The pulses will be shorter in length of course, but with so many voltage pulses occurring, the motor will speed up much more quickly and provide a constant torque.

Incidentally, if you have ever wondered why digital servos "sing" when very light force loads are placed on them, what you are hearing is the short high frequency voltage pulses acting on the motor.

The result is a servo that has a much smaller dead-band, faster response, quicker and smoother acceleration, and better holding power. You can test this very easily by plugging in a digital servo and an analog servo to your receiver. Try to turn the servo wheel off centre on the analog RC servo.

Notice how you will be able to move it slightly before the servo starts to respond and resist the force - it feels a bit spongy.

Now do the same thing with the digital RC servo. It feels like the servo wheel and shaft are glued to the case – it responds that fast and holds that well.

Now nothing is perfect and this increase in speed, torque, and holding power does come with a disadvantage. Power Consumption!

Yup, digital servos are power hungry. All those hundreds of power pulses per second use up more battery power than an analog servo would.

Size and weight

Digital servos are generally smaller and lighter, but as mentioned above, use more power. How much more? Around a little more than twice.

Gears

With today's high torque and speedy digital servos, metal gears and output shafts are getting more and more common. They are a popular choice for several reasons, but strength is the obvious one. There are two downsides to metal gears, however. They weight a little more than plastic or nylon gears and they wear out a little faster. Most servos have replaceable gear sets so you can easily replace the gears for not much money. The best metal gear servo's on the market these days are using titanium gear sets and this drops the weight down quite a bit.

Real Servos

First off, let me say that I only use HiTec servos. They appear to be a good company that will talk to you (phone or email). I've had many conversations with them. They also offer excellent warranties (in that they honor their warranty). The data presented below is about HiTec servos. However, you pays your money and gets to choose your own servos.

I'm not going to deal with rudder servos, as I've never had one fail. They usually don't get worked hard like sail servos are. If they were, you'd be going around in a circle — teehee. Actually, I think Trevor never uses his rudder – HOW DOES HE DO THAT?

Anyway, my boat is all analog. I use a HiTec HS-425BB for the rudder and a HS-815BB for the sail. Lots of the digital boats seem to use an HS-7954 or the newer HS-7950.

Here's the specs (at 6 volts):

Model	**Circuitry**	**Gears**	**Speed**	**Torque oz-in**	**Size in**	**Wt oz**
7950	Gen 2 Digital	Titanium	0.17	403	1.6x.8x1.5	2.29
7954	Gen 2 Digital	Steel	0.15	333	1.6x.8x1.5	2.40
815BB	Analog	Nylon	0.19	275	2.6x1.2x2.3	5.36

Also, note that HiTec recommends only a few of their servos for sailboat racing. The HS-7954 is NOT one of them. The other two above are recommended. This is probably because the 815 doesn't get as hot and the 7950 has a large heat sink (like the entire case — see photo at end).

Cost: HS-815BB $44, HS-7954 $83, HS-7950 $130. No surprises here. All prices from Amazon.

Power consumption

It's hard to find this data in specifications from the manufacturers. I've found the following by searching various RC blogs. In a couple of sources, they performed actual measurements:

815BB 0.83 amps (under load)

7950 1.9 amps (inder load)

This is a factor of 2.3 times. This is why lots of sailors change their batteries at half time. Assume an average of one amp per hour (?) that would be like 1,000 mAhr, kinda the size of many batteries. I think that's right. If not I'm sure someone will correct me. In any event, the voltage would be down after an hour and funny things will start to happen.

The following photos sort of show the relative size of a digital versus analog servo.


HS-7950TH
HIGH VOLTAGE TORQUE
Hitec


Hitec
HS-815BB