Everything You Need to Know About Electronic Speed Controllers (ESC)

This entry was posted on February 8, 2018 by Gozarian.

We take the humble speed controller for granted but it hasn't always been this easy. Speed controllers have been around since Adam, however, they were nowhere near as sophisticated as today's modern Electronic Speed Controllers.

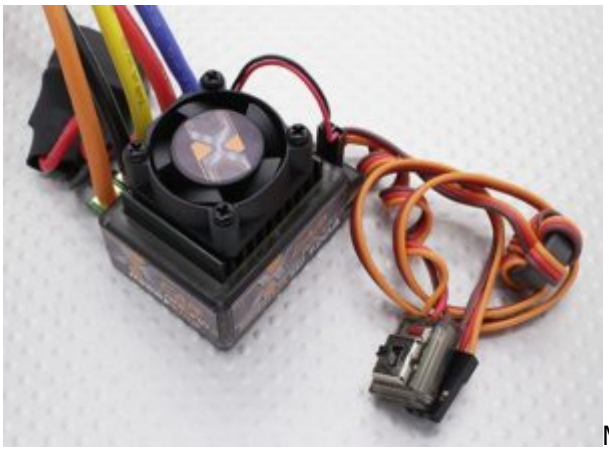
What Is An ESC?

An electronic speed controller or (ESC) is a device used to control an electric motors speed and direction. ESCs can be commonly found radio controlled models with the most common type being used for brushless three-phase motors. An ESC generally plugs into the receiver's throttle control channel where it is controlled by pulse width modulated signals.

What Is The Best Brand Of ESC

Choose a well-known reputable ESC and spend a little more to ensure you have a quality unit. You can skimp on many different areas of a build, however, an ESC services many critical functions so you want something you can trust. Turnigy, Plush, YEP are all brands that I trust to get the job done.

How Does An ESC Work



Much like a servo, an ESC is controlled via a PWM signal. Depending on the throttle position, a microprocessor rapidly drives a set of FETs (field-effect transistor) to create 3 phase AC current to drive your Brushless motor. The rapid switching of the transistors is what causes the motor itself to emit its characteristic high-pitched whine, especially noticeable at lower speeds. It also allows much smoother and more precise variation of motor speed in a far more efficient manner than the mechanical type with a resistive coil and moving arm once in common use.

What Is A BEC

A Battery Eliminator Circuit is typically part of the electronic speed controller (ESC) and its sole function is to provide 5~6v to the electrical system. A BEC negates the need to carry an additional

battery pack but rather uses the main motive power battery pack. A BEC regulates a higher voltage to 5-6v and sustains between 1-5amps depending on the ESC specifications. R/C BECs in their simplest form use a linear fixed voltage regulator however it is more common to find, switching regulated types of BEC.

It is not uncommon to need more power than the integrated BEC can supply. In this case, you will need to use either a separate receiver pack or a separate stand-alone BEC. Many companies make stand-alone BECs that can handle higher voltages and higher servo loads. Keep in mind if you do decide to power the receiver with another source besides the BEC that is built into an ESC, that BEC must be disabled. Disabling the integrated BEC is as simple as cutting only the positive line of the receiver wire. Although permanently disabling the BEC is not very favourable since it may work well in another application later. So there are other options to disabling the positive wire and one is to use a servo extension between the BEC plug and receiver, then cutting the positive wire on the extension.

Low Voltage Cut-Off (LVC)

Most ESC incorporates a low-voltage-cutoff (LVC) circuit that monitors the voltage of the battery pack and when the voltage has reached a predetermined level, power is either reduced or cut completely to the drive motor(s) in order to get you home, hopefully in one piece. If this happens whilst you're flying an aircraft, the power to the propeller would be cut but the operation of the control surfaces would be the only system maintained

in order to perform a dead-stick landing. Without this feature, all control would be lost when the battery expired, probably resulting in the destruction of the model.
LVC should be avoided because you have likely reduced the serviceable life of your battery and tempted fate with a dead-stick landing. There are ways to avoid this, such as timing your flight or using a telemetry system. FrSky, as well as Turnigy, have some great systems that allow you to easily and simply monitor your flight battery. Some are even capable of talking to you in flight.

Regenerative Braking

Some ESC controllers have a function known as regenerative braking. You can see some examples of this in a range of e-bikes. When traveling downhill, the motor can act as a generator and the ESC circuit is set up in a way that excess current can be put back into the battery system. This concept is known as during dynamic braking. On full-sized vehicles, regenerative braking is used in electric and dynamic braking is used in diesel-electric locomotives to help slow trains on long downgrades.

ESC Motor Timing. What Setting Should I Choose?

It’s all about the number of poles in your motor. To determine the motor pole count simply count the number of magnets you have on the bell of the motor. For inn runners, this is usually 4 poles unless otherwise stated.

Low Timing

- Motor Poles – 2 to 6
- Expected Performance – Good balance of power and efficiency

Medium Timing

- Motor Poles – 6 to 14
- Expected Performance – Good balance of power and efficiency

High Timing Advance

- Motor Poles – 12 or more
- Expected Performance – Highest power, less efficiency

Will Long Wires Damage My ESC Or Battery?

Long battery wires will damage your ESC over time so try to avoid it. Instead, you can lengthen the ESC to the motor wire as this is not as critical. All ESC manufactures agree on these points. You can reduce the risk damage by adding capacitors in parallel. For every 10cm of additional length you should add 220uF extra capacitance near the ESC. The voltage of the additional caps should be the same as those already installed on the ESC. Using thicker wire will not help, it's a wire inductance problem, not a resistance problem.

So What Is The Solution?

Keep battery wires short, lengthen the ESC-motor wires.That's hardly critical because there's already a lot of wire in the coils in the motor itself. If the motor-ESC wire eventually gets too long, it will not harm motor and/or controller. May cause interference though, give the motor-ESC wires a twist. Always a good idea to do that anyway.

And on the motor-side wire-inductance is a good thing, together with flyback diodes it smoothes the current thus reducing noise/interference.

ESC PWM Setting - What KHZ Should I Chose?

I find this formula works well and has served me well.

- Kv x Volts (nominal you are using) x Pole count / 20
- e.g. 1000kv motor + 3s battery + 14 pole
- 1000 x 11.1 = 11,100 x 14 = 155,400 / 20 = 7,7000

So in this example you would choose 8khz.

The Motor Squeals And Stops Working If I Move The Throttle Quickly To Full

You may have the wrong timing selected or you may be using a prop that is too large. Try using a smaller prop and adjusting your motor timing.

Powering The ESC Leads To Beeping

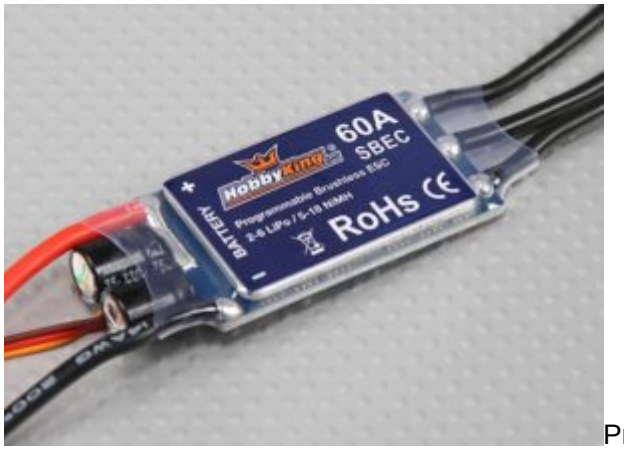
1. Remove your prop
2. Turn the radio on
3. Move the throttle to full
4. Power on the ESC
5. As soon as the beeping starts, move throttle to off
6. Power off the ESC and Radio
7. Repeat for all ESC
8. Use the system
9. If it is still not working try moving the throttle trim all the way down to see if that arms the ESC

ESC Cooling

It’s important to keep your ESC as cool as possible so be sure to position the ESC where it will get plenty of cool air. If your ESC runs hot then it’s a good idea to select a higher rated unit. For

example, if you were using a 40, select a 50 or 60amp. Remember, amps are pulled not pushed, so, using a 60 instead of a 40 is fine.

Programming Cards



Programming cards make life super easy and are quite handy to have in the pit box. They will save you the frustration of transmitter programming and give you something visual to reference. You generally need to use the vendors own card, so that is to say a Turnigy programming card will not work with a HobbyKing programming card and vice versa.

Choosing The Right Connectors

My preference for ESC to motor connectors have always been either a 3.5 or 4mm gold bullet connector. I use 3.5 for anything up to 60amps and 4mm bullets on anything up to 100amps, beyond that I use 6mm bullets. Some people will just solder the ESC leads to the motor leads, however, this makes it difficult if you need to swap out components. This works great and in high current applications and it's one less failure point. You should absolutely take connector sizing seriously as I have seen the solder in the connectors melt and disconnect in the air.

ESC To Battery Connector Selection

A connector is always used because the battery must be removed for charging and storage. Whatever battery or motor connector you decide to use, make sure it's rated for a current/amperage larger than what the motor is likely to pull. If the connector can't handle the flow, it will heat up and

potentially be damaged. Also, using connectors not rated for the task will act as a resistor and the motor will never develop full power.

Try to stick to a standard where possible, as it's easier. I use xt60 for applications up to 60amp and an XT90 for applications above this. There are others out there too that work well, just decide which ones you like and stick with it.

How The ESC Controls The Motor

An ESC is not a variable resistor that adjusts the voltage to the motor but rather an extremely fast switch that pulses power to the motor. You might remember earlier we touched on how to choose the most appropriate Khz setting, this is related to how fast the ESC can pulse power to the motor.

You can think of this as a duty cycle control. How long will the ESC power on each phase last before it turns it off? Then, how long will it be off before it turns it back on? There is no need for you to know this cycle time, only that with every ‘on’ cycle, the motor is getting the full voltage of the battery for a brief moment in time. When full throttle is selected, power on pulses are drawn much closer to the point where you could almost consider it constantly on. Also note that since the ESC is switching power on and off it is also producing electromagnetic pulses or radio waves. The electronics in the ESC will typically be designed to reduce or shield some of this radio wave noise, but it can’t block it all. This is why it is recommended to keep the ESC as far away from the receiver as possible.

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