Antelope Valley Tailwinds Technical Info

Subject	ESC and BEC Operation		
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How do these things work:

In all modern electric radio control aircraft and cars, there is usually an Electronic Speed Control controlling the throttle of the motor. Additionally, for weight minimalization and onboard simplicity, there is a Battery Eliminator Circuit, or BEC. I in this technical publication, I will cover both separately.

ESCs have humble beginnings, early brushed speed controls were nothing more than a giant rheostat or a wire wound variable resistor. Obviously, this type is very in-efficient due to the high loss of energy in the form of heat. Rheostat speed controls also were prone to getting dirty causing variations in the voltage outputs. Another problem was the size of the speed control; as current requirements went up, the size increased exponentially.

Transistorized ESCs are the norm today. Both brushed and brushless ESCs use the same types of transistors. The advantage of these types of ESCs is efficiency size, and low cost.

Modern brushed and brushless ESCs use Field Effect Transistors or FETs to control the speed of a motor. FETs are a type of transistor that uses an electrical field to vary the flow of electrons to the motor. You can visualize this by thinking of a hose with your thumb on the end of it. The hose represents the battery or power source, your thumb would be the “gate” in the transistor and the resulting spray is the output to the motor. With the water at full on and your thumb is controlling the water flow, you could shut it off completely, or spray as needed or take your thumb off and have full output. That is exactly what the FET is doing in our ESCs. If one is astute, you may have noticed while you are merely spraying with your hose for a while, your thumb will start to strain against the pressure of the water. This “resistance” is the reason why ESCs run the hottest at partial throttle settings. Additionally, this is the least efficient operating area of the ESCs, there is a lot of resistance when the gate is partially open which will result in wasted energy in the form of heat.

Brushed ESCs are considerably simpler in the operation, the FETs just control the overall output. But, we all use brushless motors in our aircraft. Brushless ESCs have to be able to turn the motor so the ESC needs to know the rotor position relative to the stator. There are two methods used, sensor or sensor-less. Sensor equipped motors, which are used mainly in ground vehicle applications uses small sensors to determine the position of the rotor. The advantage of these motors is a very smooth start, disadvantage is the requirement of an extra motor control lead. Sensor-less motors, which we use in our airplanes and helicopters use back Electro-Magnetic Field induction to determine the position of the rotor. The three wires connect to the stator, as the rotor turns (magnets) an electrical current is induced and fed into the ESC. The ESC samples this, modulates the gates (thumbs on the hose) to match the polarity of the magnets thus pushing and pulling the rotor producing power.

For the ESC to “discover” where the rotor is in relation to the stator, the rotor must be turning. This is the reason when our brushless motors on our airplanes jump when they initially start-up.

With all of these great advantages there are some limitations. FETs are sensitive to voltage ripple. For maximum performance, a constant voltage is needed. ESC manufactures ensures this by placing capacitors on the source end of the ESC. The capacitors are used as temporary storage to fill in any voltage ripple. The capacitor dumps voltage to maintain a constant input voltage to the FETs. You are taking your shower and your better half turns on the hot water to wash her hands, the sudden lack of hot water is felt by you in the shower, this is voltage ripple. Now, we add a pressurized hot water reservoir (capacitor) between the shower and the sink, when your better half turns on the hot water, the reservoir dumps its own stored hot water to make up for the loss. Also, we could just use a larger pipe, this too would solve the lack of hot water issue. This is the reason why the wires are so large between the battery and the ESC. If long wires are required, large diameter and more capacitance is necessary to reduce voltage ripple.

Application:

ESCs today are generally rated by amps. Amps by itself is an arbitrary number, 10 amps at 1 volt is different from 10 amps at 100 volts. Watts represents the power or work produced, P(in Watts)=Volts X Amps. So using the previous numbers, 1 volt X 10 Amps = 10 Watts, 100 volts x 10 Amps = 1000 watts. You could picture this by thinking of 10 psi from a garden hose to 10psi from a fire hydrant. Watts would represent by the amount of water.

Based on the above, one would notice that depending on the application, if you use a lower voltage, you could get away with higher current spikes on a given ESC. To find out maximum output wattage, take the max current and multiply it with the max input voltage.

Motor Timing is where the ESC will output relative to the rotor position. Advance or high timing will situate the pulse to lead the rotor, while low timing is closer to the sync of the rotor. Advance timing will give you more power output but is inefficient and can damage your motor due to the higher heat produced.

For maximum performance of your ESC, ensure the following:

1. Use the shortest possible battery to ESC lead length
2. Ensure proper cooling for your ESC, this is more important in lower throttle applications
3. Do not fly your aircraft to the low voltage cut-off, this is more important in higher voltage/current applications

BECs:

Battery Elimination Circuits are usually standard on ESCs today. When electrics first started coming on the scene in the 1980’s, weight was critical. Generally the early models were under powered with heavy electrical storage systems. “Elimination” of the onboard receiver battery was less flying weight. The term BEC has remained with us today.

A BEC is merely an onboard voltage regulator. Depending on the application, most onboard BECs on quality ESCs are fine. There are some limitations though.

Most manufactures market there ESCs with a max output in amps, this also is how the BEC spec is presented. The problem with most BECs, the excess voltage is dissipated as heat. A BEC is merely a small linear voltage regulator. These are used due to the low cost and small foot print. There disadvantage is the straight DC-DC conversion is in-efficient. Linear regulators require a higher voltage than its own output voltage. The excess voltage needs to be dissipated as heat. Assuming a peak output of 4 amps at 6 volts, you have an input voltage of 22.2 volts from a 6s lipo. The extra voltage (22.2 - 6= 18volts), 18 volts x 4 amps = 72 watts. The regulator circuit will need to dissipate 72 watts in the form of heat. Depending on the design, there may be several linear regulators in parallel which would share the load. One could see how this becomes a problem with higher input voltages.

Another problem with linear regulators is the inability to handle large current spikes (Usually sudden servo motor reversal associated with 3-d flying). The current spikes will result in a voltage ripple that could be low enough to reset the onboard receiver. Either disadvantage could result in a crash.. To minimize these disadvantages, in high performance or multi servo applications, a separate BEC/Regulator is recommended. If the onboard is used, it is imperative to have proper cooling.