

Digital Servos and BEC's (Scorpion ESC's)

This is an extremely important post, and I urge everyone to read it. It is quite long, but it contains VITAL information concerning motors, speed controller and servos

We have been having an above average rate of failures of ESC's lately, and as a result, I have taken a great deal of time investigating this issue to discover the root cause. From what I have been reading in other posts in other threads and on other sites, this is not an isolated incident, and is affecting all brands of speed controllers. These failures are occurring about 98% of the time in helicopters as compared to airplanes, so obviously, there is something inherent to helicopters that is the cause.

The conclusion that I have come up with is that the true cause of the ESC failures is the servos that are being used in models these days. With the advent of the newer Digital Servos, and the current availability of these servos at reasonable prices, just about everyone has switched to them.

A couple years ago, when the Scorpion ESC's were developed, hardly anyone used Digital Servos, because the only ones that were available were the larger full scale size models that are typically used in 600 class and larger helicopters. In the 400, 450 and 500 class machines, just about everyone was still using analog servos. In the larger 600 class heli's, due to the higher current demands on the radio gear, everyone used either a separate battery pack, or a separate high-current BEC to run the receiver and servos.

However, it was common for people to use the stock ESC with the built-in BEC for anything in the 400 to 550 range. To proceed with this discussion, a bit of education is necessary, so here it is. I will attempt to keep it as simple as I can, but there are some electronics terms that have to be used, so try to follow along as best you can.

For those of you that do not know how a servo actually works, here is a crash course. A servo consists of a motor, a set of gears that reduce the speed and increase the torque of the motor output, a feedback potentiometer, a feedback amplifier circuit and a drive circuit.

A servo receives a pulse from the radio receiver that tells the servo what position it should move to. In a typical radio system, the pulse has a width that varies from 1.0 milliseconds at one extreme to 2.0 milliseconds at the other extreme, with 1.5 milliseconds considered to be the center point.

The feedback potentiometer in the servo provides a variable resistance that is converted to a varying pulse signal inside the feedback amplifier. The feedback amplifier then compares the width of this signal to the one that is coming in from the radio receiver. If the width of the two pulses are the same, then the servo sits still at that position.

If you move the control stick a bit, the width of the pulse coming from the radio receiver will change and the feedback amplifier will now sense a difference between the two signals. The feedback amplifier will then send out a signal to the servo's drive circuit, and this causes the motor to spin in the proper direction to match the new signal input. As the motor turns, it spins the gears in the servo. These gears eventually attach to the output arm of the servo and to the feedback potentiometer. As the output arm turns the potentiometer, the resistance value changes until a point is reached where it matches the position of the control stick and the servo

stops at the new position.

This process repeats itself over and over again, hundreds of times per minute as we fly our models around, constantly matching the servo output position to match the control inputs that we give at the transmitter. Now that we know how the system works, we can take a look at the difference between the older analog servos versus the newer digital servos.

In analog servos, the transistors used in the driver circuit were normally traditional NPN and PNP bi-polar transistors. When these servos are set up in an amplifier circuit, there is a small range of operation on either side of neutral where the servos operate in a linear mode. What this means is that if you move your stick a tiny bit, the servo would react slowly at a lower power level. This would pull less current than normal, and the servo would move a little slower than normal. However, if you made a large stick movement, the servo would quickly ramp up to full power and full speed and move to the new position.

Since we are talking about current, I want to clarify a few things here about the different types of servo current. There are basically 3 different current levels you need to worry about. First is the "Idle Current". This is how much current the servo pulls when it is sitting still doing no work. In most cases, this value is very small, somewhere in the 5mA to 20mA range, which is very negligible.

The second current is the "Working Current". This is how much current the servo pulls when it is in the process of moving from one position to another, with normal flight loads applied to the output arm. Depending on the size of the servo, and the applied load, this value can range from around 200mA up to 1 amp or more.

The last current is the "Stall Current". This is how much current the servo draws if you hold the output arm from moving and apply a command to make the servo move. It is called Stall Current because the motor is stalled and cannot move. In this condition, the motor acts almost like a dead short and pulls a lot of current. Again, depending on the size of the servo, and primarily the size and quality of the motor in the servo, this value can be anywhere from 500mA to 2 amps or more.

Another current value that has become very important is the "Start Current" of the servos. When a servo is sitting still at a fixed position, it only pulls the Idle Current. However, whenever a control signal is given, the motor has to go from a dead stop and accelerate to full speed. At the instant that the control signal is given, the motor is not spinning, so for a very brief period of time, the motor draws the stall current, and then as the motor starts turning, this current level drops down to the Working Current value of the motor.

With the earlier analog type servos, this start-up was softened somewhat because of the slight linear region of the transistors, so it never really got up to the short circuit current. However, with the newer Digital Servos, this is not the case.

The new digital servos use FET type transistors in the drive circuit, and these have almost no linear range around neutral. They also send command signals to the motor much more quickly than the analog servos do, so they respond much more quickly. This change is what makes Digital Servos so popular with helicopter pilots. If you move the stick the smallest amount, the servo instantly reacts with full power to provide the desired control input. Helicopter pilots see this as a God-send, and use this power to perform amazing stunts with their helicopters.

The bad news is that this speed and responsiveness does not come without a very high cost. Unfortunately, very few pilots are aware of this, and it is this fact that has been the root cause of speed controller failures all over the world. (I am sure you were all wondering when I was going to get back to the speed controllers.)

Because of the insanely fast response of the new Digital Servos, and the fact that they instantly go to full power every time you move the stick, they pull HUGE amounts of current every time they move. The new digital servos basically pull the full stall current of the servo every single time you make any control movement on the sticks. Due to the fact that almost all of the helicopters made today use CCPM mixing, there are 3 servos attached directly to the swashplate.

Any time you make a collective pitch change, all 3 servos move together in unison, starting and stopping at exactly the same time. This means that every single time you move the collective stick, you are hitting full stall current on all three cyclic servos for a brief period of time. As I have said earlier, these new digital servos often pull 2 amps of current or more in a stall, so when you multiply that by 3 servos, you are pulling current spikes that are 6 amps or more every time the collective stick is moved.

As you know, any time you make a collective change, the torque from the head changes, and the gyro compensates with a rudder input to the tail rotor. This servo will also react, adding to the current. When you start adding all of this up, you can quickly see how the BEC circuit is getting constantly hammered with HUGE current surges.

Most of the on-board BEC circuits are rated for around 3 amps with a 4 amp surge. For a 400 or 450 size machine with 325mm blades, this is usually sufficient, even with the smaller digital servos. However, when you start getting into larger machines such as the Logo 400, Trex 500, and others with 400mm or larger blades, the current levels from the servos can quickly out-strip the ability of the BEC circuit to provide the required current without over-heating.

When the BEC circuit gets overloaded, they either go into an over-current or over temperature protection mode and shut down for a while, or just burn out all together. If you lose the BEC voltage, the microprocessor in the ESC can no longer function, and whatever phase was turned on in the ESC when the power goes out usually stays stuck on. This pulls full short circuit from the battery, through the ESC and into the motor. This current can be several hundred amps for a brief period of time, depending on the Rm value of the motor. Normally, the windings of the motor take several seconds to heat up and start to burn in this condition, but the FET transistors in the speed controller cannot handle that much current, so within about 2 seconds they start blowing out.

If you are lucky, the ESC burns "open" quickly and removes the load from the battery and motor and they survive the incident. In some cases though, the ESC welds shut from the current and takes out the motor and sometimes the battery as well.

The really sad thing is that the ESC itself is not at fault in this kind of failure. The complete fault for the incident lies in the current draw of the servos that exceeds the design specifications of the BEC. The worst part about it is that virtually none of the servo manufacturers out there give the full current specs for their servos, and some of them give absolutely no current specs at all. This places the blame for a huge number of speed controller failures squarely in the laps of the servo manufacturers.

What sucks about the whole situation is that the servos cause the problem, but they hardly ever see any damage as a result of it.

I went to several websites to pull the exact text from the specifications on several commonly used digital helicopter servos to see what they said. Here is what I found.

From the Futaba Website.

For the 9650 servo

SPECS: Dimensions: 1.4 x 0.6 x 1.1" (36 x 15 x 29mm)

Weight: .92oz (26g)

SPEED: 0.14 sec/60° @ 4.8V

0.11 sec/60° @ 6.0V

TORQUE: 50 oz-in (3.6 kg/cm) @ 4.8V

63 oz-in (4.5 kg/cm) @ 6.0V

How much current does it pull? 🤔

For the 9250 servo

SPECS: Speed: .11 sec/60° @ 4.8V

Torque: 76 oz-in (5.5 kg-cm) @ 4.8V

Weight: 1.9oz (54g)

Power Supply: 4.8V (Futaba does not recommend using 6V)

Length: 1.6 x 0.8 x 1.5" (41 x 20 x 38mm)

Current specs?

Ok, let's take a look over at the JR heli servos and see what they say.

From the www.jrradios.com website

DS9411 Digital Mid MG Servo

Specs

Size Category: Minis and Micros

Type: Digital

Torque: 82 oz/in @ 4.8V, 95 oz/in @ 6V

Speed: .15 sec/60° @ 4.8V, .12 sec/60° @ 6V

Dimensions (WxLxH): 0.71 x 1.41 x 1.03 in

Weight: 1.36 oz

Bushing Or Bearing: Bearing

Bearing: Dual

Motor Type: coreless

Gear Type: Metal

Gear Material: Metal

Um, How much current does this one draw? Idle current, Stall current, Working Current?
Inquiring minds want to know.

Let's try another

DS8231 Digital Ultra Precision Servo

Specs

Size Category: Standard

Type: Digital

Torque: 88 oz/in @ 4.8V, 113 oz/in @ 6V

Speed: .22 sec/60 @ 4.8V, .19 sec/60° @ 6V

Dimensions (WxLxH): 0.75" x 1.54" x 1.36"

Weight: 1.73 oz

Bushing Or Bearing: Bearing

Bearing: Dual

Motor Type: Coreless

Gear Type: Nylon

Application: precision pattern and jet airplanes, collective and rudder on helicopters

I looked further and found more information on this one.

Key Features

Outstanding holding torque that's 2-5 times greater than a conventional servo

Current draw is only 8% greater than a conventional servo

Ultra precise 5,900 step resolution for unmatched precision.

New wide-spaced output shaft dual ball bearings for minimal output shaft play

250MHz pulse rate for increased precision

OK, it pulls 8% more than a standard servo, so how much is that? 🤔

Well it seems we have struck out with Futaba and JR, let's try Hitec and see what they say. Info from the www.hitec.com site

HS-6975HB

Detailed Specifications

Motor Type: Coreless

Bearing Type: Dual Ball Bearing

Speed: 0.13 / 0.10 sec @ 60 deg.

English Metric

Torque: 119.42 / 144.42 oz.in (4.8v/6v) 8.6 / 10.4 kg.cm

Size: 1.57" x 0.78" x 1.45" 40.00 x 20.00 x 37.00mm

Weight: 1.83oz 52.00g

Again, no current specs on the site. I did notice that they had a downloadable PDF available with complete servo specs, so I downloaded that and finally got a current specification.

On this sheet I got the following information:

Idle Current - 3mA when stopped

Running Current - 200mA at 4.8 volts, 240mA at 6.0 volts (No load applied)

Stall Current - 2400mA at 4.8 volts, 3000mA at 6.0 volts

Finally! A real current spec for a servo. My hats off to Hitec! My only recommendation to them would be to add this data to the basic specs found on the front page of the site. This is EXTREMELY important information, and needs to be put in the standard servo specs.

I would strongly urge Futaba and JR, as well as every other servo manufacturer out there, to follow Hitec's lead here and publish your current specs for the servos you manufacture. I would also urge every single modeler out there to contact the servo manufacturers and obtain a copy of the current specifications for the servos. If they are not available, we all need to pressure the servo manufacturers to test their products and provide this critical information to us.

As you can see, this completely confirms what I was saying earlier about the current draw of these newer digital servos. The Scorpion Switching BEC circuits in the 6-cell ESC's are rated for 3 amps with a 4 amp surge, and put out 5.7 volts. Based on the above numbers for the Hitec 6975HB servo, I would estimate that they would pull about 2800mA of stall current at 5.7 volts. If you have 3 of these servos together on the swashplate of a helicopter, the total stall current is 8.4 amps!! 🤯 Are you starting to get scared now? I sure hope so, because this is what you are subjecting your BEC circuit to every time you move the collective stick.

Now granted, the 8.4 amp current surge is short lived, but when you consider the flying style of many of today's pilots and the maneuvers that they perform such as Tic-Tocks and hard shaking of the helicopter, the rapid pulsing of these currents really puts a beating on the BEC circuit. It probably will not fail right away, but I can guarantee that sometime in the future, maybe 10 flights, 15 flights or 20 flights into the heli's life, suddenly, out of nowhere, the BEC will fail and your heli will be coming down.

When you get to the helicopter you find that the ESC is smoked and get on the phone, all upset, to the ESC manufacturer to ask for a warranty replacement. Well, I can safely say that the ESC is not at fault here. It is the excessively high current draw of the servos that are the root cause of the problem.

It is for this reason that in ANY helicopter that uses 400mm blades or larger, I HIGHLY recommend the use of a separate power source for the receiver and servos in your machine, and disable the on-board BEC circuit. This power source can be a separate 4 or 5 cell Ni-Cad or Ni-MH battery pack, or a separate Higher-current switching BEC circuit rated for 5-8 amps running from the motor battery, or a dedicated separate 2-cell Li-Po battery with an appropriately sized linear or switching BEC. Failure to do this WILL lead to the eventual failure of your ESC.

I would urge everyone who has taken the time to read this to copy this text and paste it on every other site or forum that you go to. This is a serious educational issue that needs to be spread

around to every helicopter pilot in the world. This is one of the most important things that I have ever written, and I hope that everyone takes it to heart and makes the necessary modifications to their helicopters to provide the power needed to properly feed these very current hungry digital servos.

This is not "Someone crying Wolf" or running around saying that "The Sky is Falling", this is probably one of the most serious issues to come up in this hobby in many years, and needs to be addressed.

I know that many of you have probably run digital servos for some time in your helicopters, and have not seen any failures. The thing you all need to understand is that you have not seen any failures YET. I can guarantee that sometime in the future, when you least expect it, something WILL fail.

So getting back to Scorpion products, this is a huge issue for us. We have been getting a large number of ESC's back lately with people expecting us to cover them under warranty. We have always had one of the most generous return policies in the industry, and stand behind the product if there are any manufacturing defects.

In the future, we will be closely looking at the ESC's that do come back, and if the BEC circuits are blown out in them due to pulling too much current, we will not be covering this under warranty. The 50% crash warranty will be in effect for this type of failure, because it is the end users responsibility to ensure that the parameters of the ESC are not exceeded. This includes both the ESC current AND the BEC current. If you are running a helicopter with 400mm blades or larger, and you have digital servos in it, you really need to get a separate BEC system in there or you are going to lose your ESC eventually.

The purpose of this post is to shed some light on a very serious issue that is currently causing a huge amount of problems for modelers out there. I hope that everyone takes this information to heart, and takes the necessary actions to ensure the life of their ESC and helicopter.

Sincerely,

Lucien Miller

Innov8tive Designs