Blacksheep RC Modelers

Danville, IN AMA #3032

Squadron News March 2022

An AMA Gold Club

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Newsletter Editor.

Hello everyone, I'm John Lawyer and I am going to be taking over as the newsletter editor. I will admit I am terrible with names, so if I get your name wrong in the newsletter I apologize beforehand. If I get other facts wrong, I apologize. If you send me an email or hand me a note on any corrections, I will be glad to get it into the next newsletter. Besides, that will help me to take up space in the newsletter also. ☺ You can contact me at jlawyer41@att.net or 765-918-7229

I will always be happy to take input from anyone for the newsletter.

P.S. Pictures of your latest bird or project are always welcome

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Upcoming Club Events

April 6 - monthly club meeting, 7:00 pm at the field.

May 4 - monthly club meeting, 7:30 pm at the field

June 1 - monthly club meeting, 7:30 pm at the field.

July 6 - monthly club meeting, 7:30 pm at the field.

August 3 - monthly club meeting, 7:30 pm at the field.

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Upcoming Area Events

April 29 & 30 - Dayton Modelrama RC Swap Meet and Auction. Click here for event details.

June 24 thru 26 - AMA National Fun Fly Intl Aero Center, Muncie, IN.

August 13 - NMAD event

August 25 thru 27 - Hoosier Dawn Patrol, AMA Natl Site, Muncie, IN.

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March 2022 Meeting Minutes

Recorded by Tom Carlyle, Secretary

The March 2022 club meeting was held on March 2, 2022 at the flying field and via Zoom. Vice-President John Louden called the meeting to order at 7:00 PM. Twenty-six (26) club members were in attendance at the flying field and two (2) club members attended via Zoom.

President's Report

- No report.

Vice President's Report

- No report.

Treasurer's Report

- Richard reported on the club's bank account balances and transactions.

Secretary's Report

- No report.

Field Marshall's Report

- Bryan talked to Waste Management last fall about getting the new drainage tile installed along both sides of the runway. Work is likely to begin later this year when the ground dries out enough to get equipment on the field. It was noted during the meeting that Waste Management should engineer the drainage plan since they own the land. There could be some disruption in the pit area as the drainage tile is installed at the east end of the runway.

- Waste Management will apply weed killer to the field. We'll ask them to put down some crabgrass killer, too.
- Bryan Baumer told us he will be traveling a lot this summer, so someone else needs to coordinate the mowing. Terry Hatfield volunteered to coordinate the mowing.
- If we need to water the runway this summer, we can go to the water company and get a meter to put on the hydrant. As for now, we'll just wait to see if we need to water.
- There was a brief discussion of putting a bench and a shelter on the west end of the pit area. No decisions.

Safety Coordinator's Report

- No report.

New Members/Visitors

- Brett Myers from Brownsburg joined the club. Brett has flown but might need some assistance. Nguyen Nguyen from Brownsburg joined the club. Nguyen has flown helicopters and is transitioning to airplanes. Doug Gifford from Brownsburg joined the club. Doug has been flying since 1975 and is a contest director and likes to train new RC pilots.

Old Business

- No old business.

New Business

- Tom Carlyle checked AMA's website, again, to fill out the Gold Leader Club renewal form but AMA has still not updated the form to 2022 (still shows 2021 at the top of the form).
- We might have a warbird day in the spring (May).
- Jon Derringer would like to have a trainer night this summer.

Show and Tell

- Tom Carlyle showed us his new FMS A-10 Thunderbolt II, Version 2. It has dual 70mm EDFs and is powered by a single 6S 5000 mAh battery or by parallel 6S 3500 mAh batteries. Control will be with a Spektrum 6 channel receiver bound to a Spektrum DX7S transmitter. The maiden flight will be after the weather warms and the field dries.

Raffle

- No raffle was conducted.

With no further club business, the meeting was adjourned.

The April club meeting will be held on Wednesday, April 6th. The meeting will begin at 7:00 p.m. The meeting will be held at the club flying site.

One last reminder, please support your local hobby stores. Special thanks go out to HobbyTown USA in Castleton for extending a discount to our club for our monthly and year end raffle prizes.

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Message from the President.

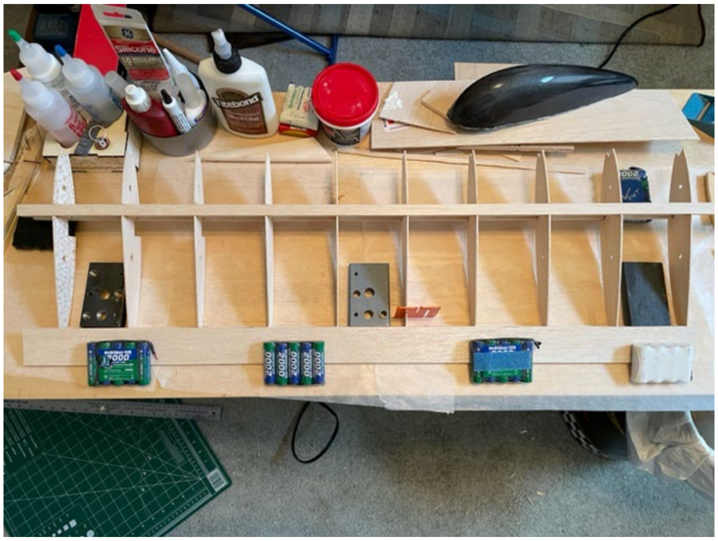
President's message:

March went out like a lion, or at least a cold lion, what strange weather we have seen this year so far. If nothing else the field has received much moisture to go with the grass seed recently put down. I want to send a big thank you to Bryan Paris and Rick Gilmore for getting our mower back into better condition than new. Also, thanks to Warren, Bryan, Bryan, Harold and Greg for keeping the clubhouse on field in great shape. The retiree team has been getting quite a bit of flying in lately, and we had a really nice Saturday and a nice Wednesday not too long ago. Finally, I was able to maiden my Christmas plane, a Flex Innovations 6S RV-8, larger in person than it looked on the website, nice flyer.

The April meeting is this Wednesday evening at the field, bring a show n tell to share what you have been working on over the long off season. My latest project is getting started on a Hawk 60 electric version. Parker gave me a powerful Scorpion motor and Avion ESC for Christmas to power it. I included a couple photos of the building process. A little slower than I used to be and doing as much building as I can with wood glue as opposed to CA glue. My other recent project started is a JMB Jets MB339 in Italian Air Force airshow team colors, 71" wingspan / 73" length. I plan to power it with a KT85G4 and Spektrum guidance. Made the purchase from Ryan Jones' Nova-Jets.com, need a jet or EDF part, check his website out.

As we get much closer to nice flying weather, please take an opportunity to check everything over, batteries, hinges etc. On a final note of this message, Tom Carlyle completed our AMA Gold status application, and we are Gold again! Rege

Wanted - A good friend and former Blacksheep Mike Girdley picked up a Hangar 9 F4U Corsair. Unfortunately, it is missing the radiator inlets. If anyone has a set, or from a wrecked wing or know who might have a set, please let me know and we can contact Mike.



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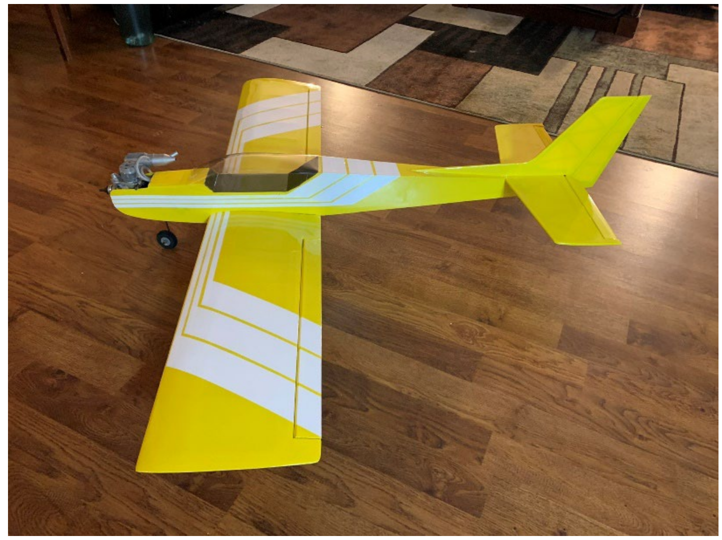
John Lawyer's Latest Projects

Over the winter I farmed out my services to a gentleman that wanted a Tiger 60 finished that his dad had started and could no longer finish. I was happy with how it turned out but not something I wish to do a lot as it cut into my building time.



I did pick up two Gliders at the swap meet down at Franklin earlier this year. One was a Sagitta 600 that was already covered and I just added a receiver and battery.

The other glider was an older design called a Super Eye Soar. I had to finish it up and then cover. Should be ready to fly by this weekend if the weather is good.

I decided to do it up in John Deere Colors when I saw some transparent green that looked good.

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Tips and Tricks.

While covering the Glider, I had my covering Iron give up the ghost. When I went online I could not find a new covering iron. I did find a good replacement, though it was a little more expensive. I purchased a Veneer Edge Banding Sealing iron. It has a digital display for the temperature and push buttons for temperature control and on/off. I have been very happy with it. I can turn it off and it isn't sitting there constantly hot and I can adjust the temperature by one degree at a time.

[O'SKOOL LCD Display Veneer Edge Banding Sealing Iron]

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amazon smile reminder

This is the quarterly notification to inform you that AmazonSmile has made a charitable donation to the charity you've selected, **Academy of Model Aeronautics Foundation**, in the amount of **$816.79** as a result of qualifying purchases made by you and other customers who have selected this charity.

Thanks to customers shopping at smile.amazon.com or using the Amazon app with AmazonSmile ON, everyday purchases make an impact. So far, AmazonSmile has donated:

- **$9,116.96** to Academy of Model Aeronautics Foundation*
- **Over $334 million** to US charities
- **Over $377 million** to charities worldwide

Visit your AmazonSmile impact page to track donations generated or change your charity.

From Rege.

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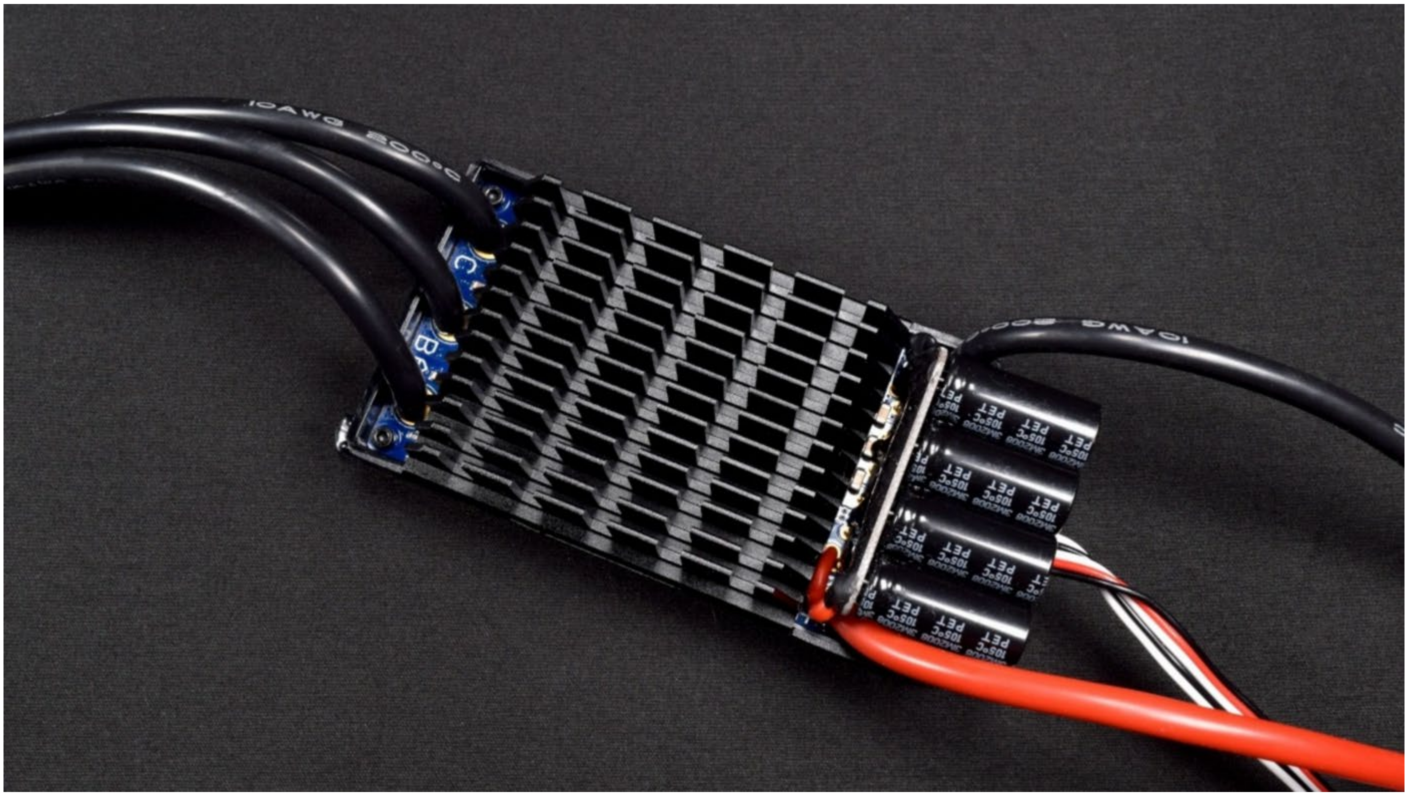

(credit: Aloft Hobbies)

Electricity for Model Flyers

Part V: A Technical Explanation of Electronic Speed Controllers (ESC)

This is an attempt to explain how electronic speed controllers (ESC) work using the Feynmann Method which is to write it down in language simple enough for an eight-year old. He asserted that if you can't do that then you don't yet understand it yourself.

All electric motors rely on one magnet pulling or pushing on another so the motor shaft goes round. The motors we use in model aircraft have two types of magnet. One is a permanent magnet which can move round. The other is a coil of wire that is fixed. When you make an electric current go through a coil of wire it makes it into a magnet. Our motors have fixed coils that can be switched on to make them into magnets and then off again so they stop.

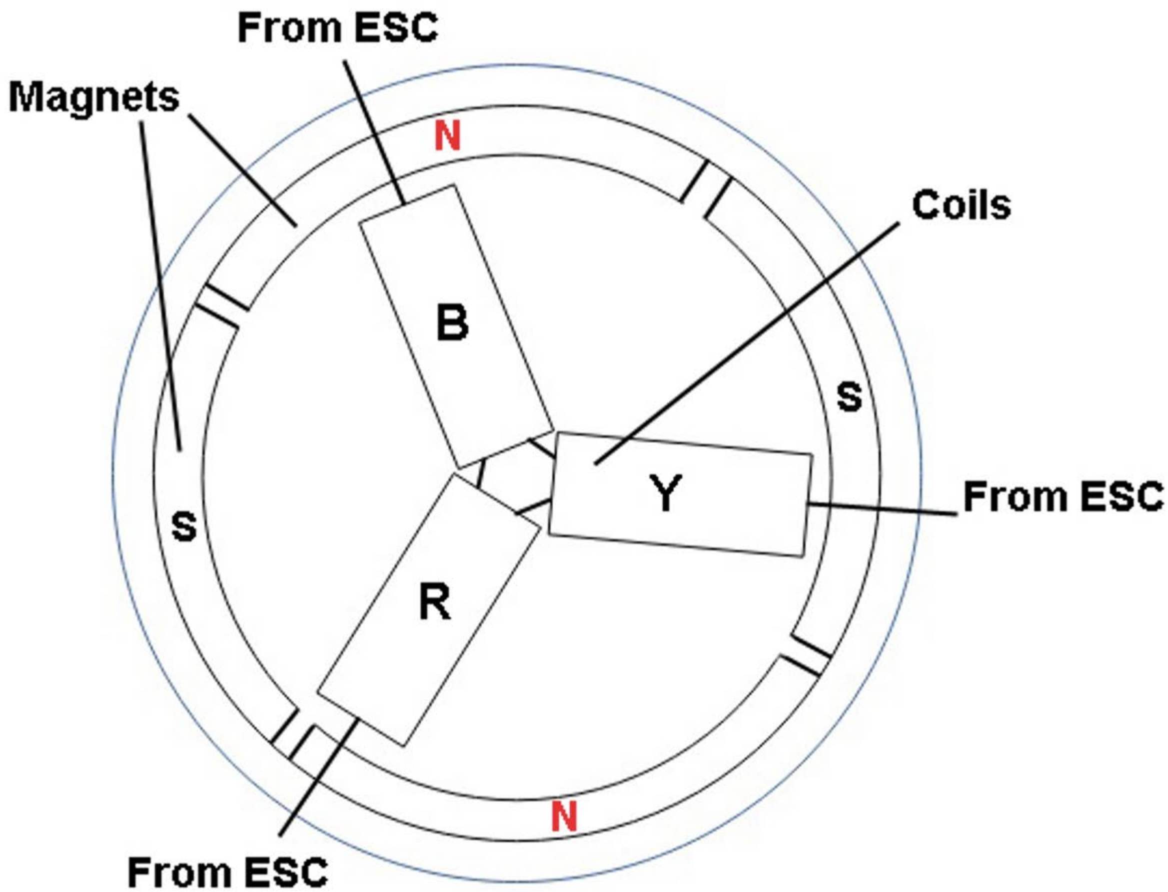

Figure 1 (credit: author)

The coils are fixed so are called the stator (static). In Figure 1 they are labelled R (red), B (black) and Y (yellow). These are the colours of the wires on the motor and possibly the ESC.

Look at the circular bit labelled NSNS. This the outer case of the motor onto which permanent magnets are fixed. The N and S are the poles that face inwards. They are made using a rare earth metal, usually neodymium (Nd). The case rotates and drives the propellor so it is called the ‘rotor’ (turning). If the red R coil is switched on so it becomes a south pole it will pull the magnet labelled N (north) round to line up with it.

If at the same time the black coil B is made a north pole it will push the nearby N magnet.

The rotor has started to turn. If B stays north it will pull the south magnet. If Y is made south it will pull the north magnet.

Why not use all three coils? The ESC needs to know the position of the rotor. The turning rotor creates (induces) a voltage in the now unpowered R coil and the ESC can read it to work out the position and speed.

The ESC sends constantly changing currents through a pair of coils. It moves on from one pair to the next. The effect is that the magnetic field effectively rotates and drags and pushes the permanent magnets with it. No electric current has to be fed to the rotor through brushes. This makes our motors simpler and more reliable and is why they are called ‘brushless’. Remember all those sparks you used to get from brushed motors? Our motors use tens of amps or even over a hundred. You can imagine the sparks you would get. This could not easily be done with light brushes.

How Is All This Switching Done?

We have to use a device called an electronic speed controller (ESC). These have electronic switches called field-effect transistors (FET) that can switch on and off in very short times and a circuit board that makes them switch.

Have a look at the following circuit diagram Figure 2, even if you are not used to reading them. On the left are the sets of U, V and W coils. These are the standard letters used for the coils I labelled red, black and yellow. On the right are the switches in the power circuit. They are labelled Tr1 to Tr6 as they are transistors.

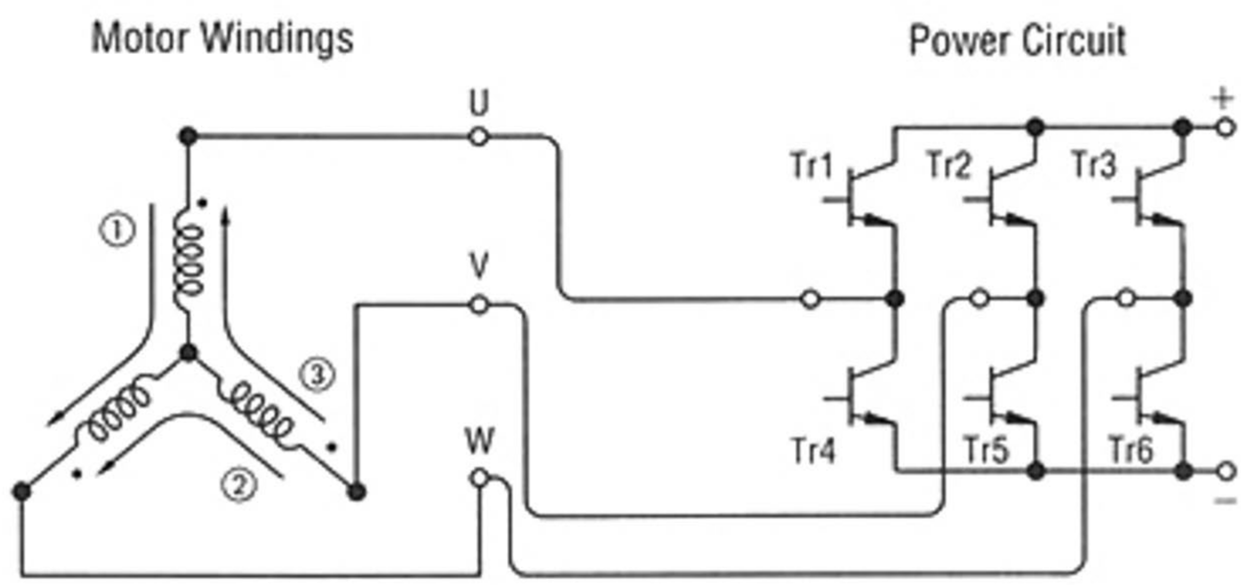

Figure 2 (credit: Oriental Motor)

Figure 3 shows one of the transistors. As you see there is some variation in the symbols used. In Figure 3 I have drawn the most common one.

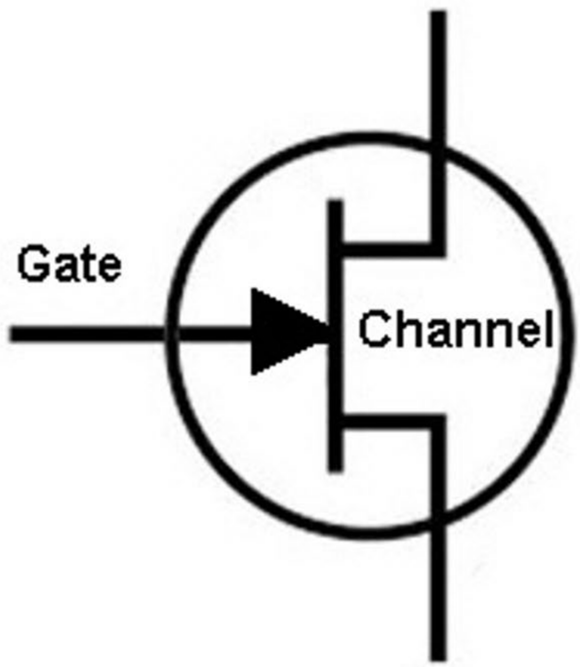

Figure 3 (credit: author)

Electric current can travel through the transistor channel from top to bottom but only when the correct voltage is connected to the small spike sticking out to the left, which is called a ‘gate’. The electric field the voltage creates allows the current to flow or not. That is why it is called a field-effect transistor (FET). It acts like the switch you use on your house lights and indeed FETs are used in light dimmers. They switch the bulbs on and off rapidly with different amounts of on and off, so changing the brightness.

Why are there six FETs, not three? There are only three coils to switch on. Look at the connection to coil U. If TR1 switches on, the coil is connected to the plus +. If TR4 is on, U connects to the minus -. So depending on which is switched the coil can be made north or south.

Transistor \ Step	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬
Tr1	ON					ON	ON					ON	ON
Tr2		ON	ON					ON	ON				
Tr3				ON	ON					ON	ON		
Tr4			ON	ON					ON	ON			
Tr5					ON	ON					ON	ON	
Tr6	ON	ON					ON	ON					ON
Phase U	N	—	S	S	—	N	N	—	S	S	—	N	N
Phase V	—	N	N	—	S	S	—	N	N	—	S	S	—
Phase W	S	S	—	N	N	—	S	S	—	N	N	—	S

Table 1 (credit: Oriental Motor)

If you have followed this so far you now know how the motors work. As the coils magnetise in turn they produce a magnetic field that turns round continuously pulling the rotor with it. Almost all electric motors used in cars and industrial machines work like this. They are also called ‘synchronous’ motors.

Factors to Consider Choosing an ESC

The compactness, rotational speed and power of brushless motors is impressive. When I started electric flying it took me a while to realise that they were small versions of the three-phase motors I had come across in industry. I was puzzled where the driving waves came from, so that sparked my interest in electronic speed controllers. You now know that they produce the three phases at large currents, but they can be programmed for braking the motor, reversing the motor, throttle response speed and other things. You can even change the sounds they make.

My favourite simple ESCs are Turnigy *Plush*. They are quite cheap, compact and very robust and they can be programmed using a cheap card rather than struggling with beeps from a transmitter.

My favourite ESCs of all are the FrSky *Neuron* range, so-called no doubt because they are ‘brainy’. They are available in 40A, 60A and 80A versions with a +50% burst capacity. I use the word brainy because they provide a range of telemetry data for FrSky radio equipment, including RPM, temperature, current and lipo voltage, from which you can also derive milliampere hours (mAh) used and power. They produce up to 7A for the receiver and servos and as a final bonus they are small. The only downside is that they are expensive, starting at around £45 ($60).

But What's the Right ESC For Me?

There are several factors you should take into consideration when making a decision about ESCs:

- **Current Capacity** It is best to choose one that can produce a current at least 20% more than the maximum for the motor.
- **Number of Cells** Most ESCs can handle lipos of between two and six cells. For larger numbers of cells, for example when you use two lipos in series, you need to find a suitable ESC, which is likely to be expensive.
- **Battery Equivalent Circuit (BEC)** That is, whether the ESC can produce the voltage for the receiver and servos. Make sure it can pass enough current for the receiver and servos. If not, fit a separate receiver battery or find out about power boxes.
- **Failsafe Cutoff** Whether it will switch off power to the motor if the lipo voltage drops low. This ensures that it can still supply power to the receiver and servos so you can safely land deadstick.
- **Programming Card** Whether or not there is a programming card available. As noted above, one is for the *Plush* but not for the for *Neurons*)

And last, but not least:

- **Size and Weight** (of course)

The more I learn about ESCs the more clever I think they are, or at least the people who design them. I like to know how things work. By that I don't mean what they do, but what are the underlying principles. These will be a combination of science, engineering and computer code.

Let us suppose that the throttle lever is at maximum. The ESC starts to energise the coils and the motor turns. What determines the speed at which it turns? For a given voltage and motor there is a speed determined by the propellor. If the propellor match is good the motor will turn at roughly its kV rating multiplied by the voltage. For a 3S battery of 12.6 volts and a motor of 1000kV this will be 12,600 RPM. In practice it will be lower as the battery voltage will be lower than its maximum value.

So How Do They Work?

We have now covered the physical arrangement. This does not explain how the ESC sends the correct pulse of current to the correct coil at the correct moment. This diagram shows the control loop. Note that there are boxes for detection of position and speed. The speed setting is the signal from the throttle.

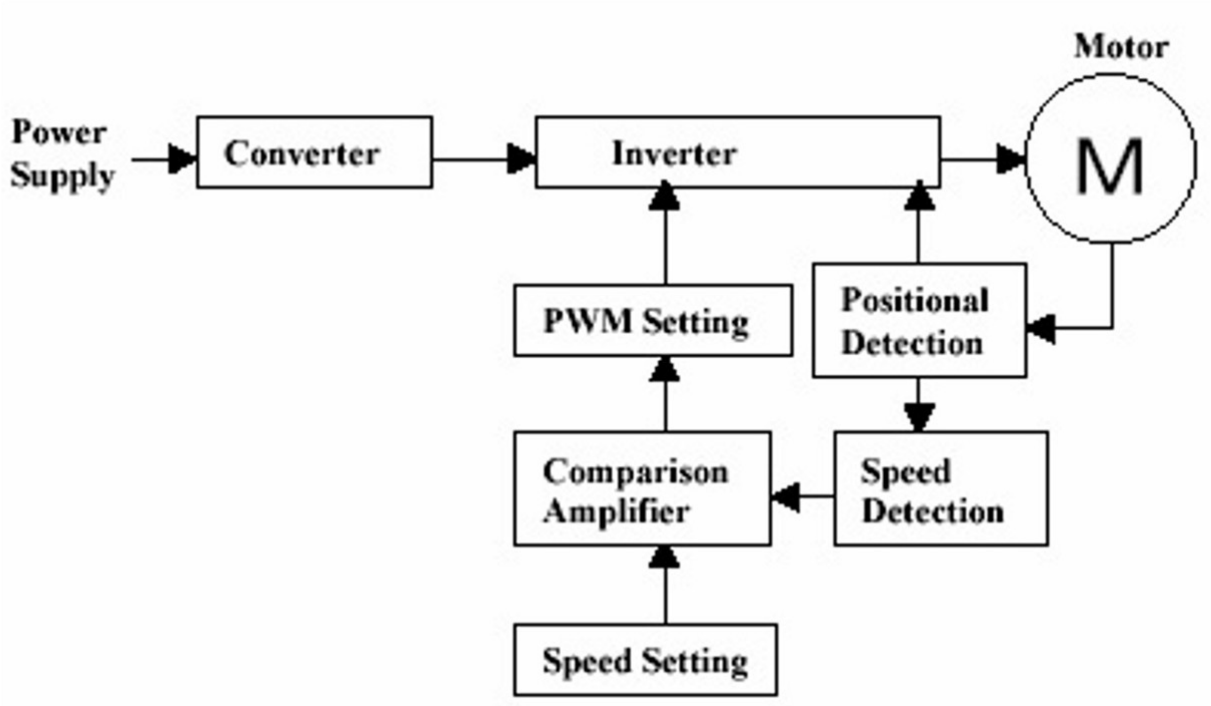

Figure 4 (credit: Oriental Motor)

The inverter produces and switches the power to the coils on and off as decided by the pulse width modulation (PWM) setting. This varies the power as you will see later.

Detecting Position and Speed

As we saw earlier the ESC powers two coils at a time. That leaves the third coil and wire unused. To see how it is used we need to understand a scientific principle called induction. Coils are made of windings of wires. If a wire moves through a magnetic field, or a stationary wire is in a varying field, a voltage is created in the wire. The rate at which the magnetic flux 'lines' are cut by the wire decides the voltage. As a rotor magnet passes the third coil it creates a voltage in it by induction. The ESC circuitry notes this voltage by reading the third wire and uses it to calculate the rotor position and hence how fast it is turning. It uses this data to vary the speed at which the coils are switched.

Throttle Positions Less than Maximum

To send reduced power, the FETs that drive the coils are switched on and off during each power pulse (that is as noted above, pulse width modulation or PWM) or the ‘duty cycle’. At full throttle both of the coils are on all or most of the time. They are most efficient at full throttle as each switching operation causes a small energy loss.

Calibrating an ESC Before Use

Many ESCs do not need this. If yours does, however, this is how to do it when connecting up for the first time or when changing transmitters.

1. Ideally remove the propellor or at least tie the model down.
2. Switch your transmitter on and set the throttle stick to maximum position.
3. Power up your receiver
4. Connect the battery pack to the ESC.
5. In a short while the ESC will beep.
6. Then pull the throttle stick to the zero power position.
7. The ESC will beep again, which indicates that your ESC has got the signal range of the throttle from your transmitter.
8. The throttle is now calibrated and your ESC is ready for operation.

What Programs Do They Run?

Hard as I looked I could not find any information on how the ESC reads and processes the data. This is not surprising. Companies making ESCs will be jealous of the commercial value of the program code.

So I thought it might be an idea to work out how I would set about writing the program code for an ESC and it might help you understand how they work. I might not get it right of course and I hope someone will correct me if I don’t. Or maybe my method is correct but there are other ways of doing it.

We start with the data. Of the three wires to the motor, two will be carrying current depending on throttle setting. What will we ‘see’ on the third wire? As it is pushed at speed past a magnet, a pulse of voltage will be induced in the coil to which it is connected. The height of the pulse will tell us the speed and the centre of the pulse tells us the position.

How Does That Work?

Now the science bit. The strength of a magnetic field is called flux density and is represented by the Greek letter Φ (phi). When you played with iron filings and magnets they were tighter packed where Φ was greatest, near to the magnet. When a wire moves through magnetic flux a voltage is created (that is, induced) in it. This works with a fixed magnet and a moving wire, a moving magnet and a fixed wire or where wire and magnet are both moving. Just for completeness, though not relevant here, a fixed wire in a magnetic field that is changing, such as a field made by a coil of wire with a varying current, will also have a voltage induced in it. That is how transformers work.

So induced voltage = rate of change of the magnetic flux linked with the wire.

Physicists write that $d\Phi/dt$ pronounced ‘dee-fy by dee-tee’.

So the induced voltage tells us the speed of the coils of wire and hence rotor.

However we can also find the speed from the time between this pulse and the one from when the next set of coils is switched on. We could use either, or perhaps both. The midpoint of the pulse will show when the magnet and coil are exactly lined up so will show us the position of the magnet.

All computers (and an ESC is one) have a ‘timebase’, which is effectively a ticking clock that keeps everything in step.

A First Try at the Program Code

Here is my pseudo code that can be converted into any computer language. Note that it produces speed data in the two different ways. This code is for a situation where brake is on as it would be for folding props.

```
Repeat the following
    If throttle is more than zero
    Then do the following lines of code (start loop)
        Move to the next set of coils
        Identify the third wire by checking which has no signal going to it
        Read its voltage
        Read the clock time as a voltage appears above a threshold
        Sample the voltage repeatedly and rapidly and record values
        Read the clock time when it drops to the threshold value again
        Calculate the mid-point time
        Select the maximum value for the voltage
        Convert the maximum voltage into a speed value
        Convert the mid-point time into an angular position value
        Calculate a suitable delay
        Calculate the lengths of the drive current signals for wires 1 and 2 from throttle setting
        After the delay send the drive signals to the FETs for the relevant coils
        Calculate the speed from the current and last angular positions and the times
        Compare the mid-point time with the mid-point time of the drive signals
            If it is lagging or leading change the delay timing for the drive signals
    End loop
    Else (i.e. throttle zero) short out all coils to put brake on
    Read the throttle setting again ready for next loop
End of repeat (i.e. jump back to the start)
```

In a Neuron ESC there will be additional code for sending rpm and time, plus current and lipo voltage from other internal sensors, as telemetry data to the receiver.

In a twelve coil motor the above code would be repeated twelve times for each revolution. If the motor was turning at 10,000 RPM that would mean 120,000 loops each second. Is that even possible? To see why it is, you need to understand two things — machine code and clock speed.

First — Machine Code

Computer programmers (coders) usually write the programs in a language that is a bit like English. For example

```
printline("Hello");
```

That makes it easier to write and understand the program. Then a program, called a compiler, reads each line and checks that it makes sense, a process called ‘parsing’. If it does it turns it into a machine code instructions. These are compact and efficient being just a string of binary digits (1 or 0). It stores them all in a file. You can spot these files on a computer as they usually have the file extension .exe, standing for ‘executable code’. They are what a computer — the ESC in this case — runs as a program (application).

In the case of the ESC, and similar things like receivers, phones and washing machines, the machine code is stored permanently in a chip inside, called firmware, so does not have to be loaded like a normal application. It is usually erasable so the programs can be changed by updates. Firmware binary code does not have a file name. It starts automatically as soon as the device is switched on.

Some programmers write directly in machine code. I have occasionally. A good programmer might write machine code better than a compiler can, but it is a lengthy and brain-boiling process. Early computers could not even start themselves up. The startup code had to be put in line by line by setting a row of toggle switches to one or zero and then pressing a button. This was called ‘toggling it in’ and allowed the computer to start, in effect by pulling itself up by its own bootstraps. Hence the term that we still use for starting up, to ‘boot’ the computer.

Clock

The clock in a computer processor ticks at a speed that we find difficult to imagine. Even the simple Arduino runs at 8 or 16MHz and it’s possible that those in ESCs run faster than that. There are roughly 30 million seconds in a year. At 16MHz a processor divides a second as a second divides six months. On average a machine code instruction takes two machine clock cycles (ticks). That’s plenty of room for lots of lines of code that each take a few microseconds to run. Incidentally the speeds at which modern computers work are measured in gigahertz (GHz or a thousand million ticks per second). For example a 3GHz computer processor divides a second as a second divides 100 years and most computers have several processors.

Is That It?

Er, no. ESCs can do all kinds of clever things such as braking the motor on zero throttle by shorting the ESC wires, reversing the motor for getting out of reeds when flying on lakes (or playing in the air when flying a Durafly Tundra), changing the pulse timings for different type of motor, deciding what noises the ESC makes, calibrating for maximum and minimum throttle values, changing how rapidly the motor speed changes as the throttle changes, and so on. This would need another article. You have suffered enough for now.

Resources

- ***Inside the Electronic Speed Control*** — From *Model Aviation* magazine: "Mysterious events are often attributed to mystical causes, and brushless power systems are about as mysterious as things get in RC. Some systems work and others don't…"

- ***Speed Control Methods of Various Types of Speed Control Motors*** — From Oriental Motor: "A large number of motors are being used for general purposes in our surroundings from house-hold equipment to machine tools in industrial facilities. The electric motor is now a necessary and indispensable source of power…"

- ***Turnigy Plush*** — From HobbyKing: "They have a broad range of programming features coupled with smooth throttle response making them the go-to ESC for those in the know. "

- ***FrSky Neuron*** — From Aloft Hobbies: "smaller and lighter the new Neuron S is compared to the original Neuron (Neuron 59 grams / Neuron S 60A 39grams). Thats all well and good but we are here for the telemetry so let's dive in…"

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Editor: John Lawyer

****** Till next month may all your landings be wheels down. ******

P.S. I am always open to people sending me pictures of their latest projects. Special thanks to Rege Hall for helping with input for these newsletter.