Bob’s RC Electric Motor Basics

Motor:

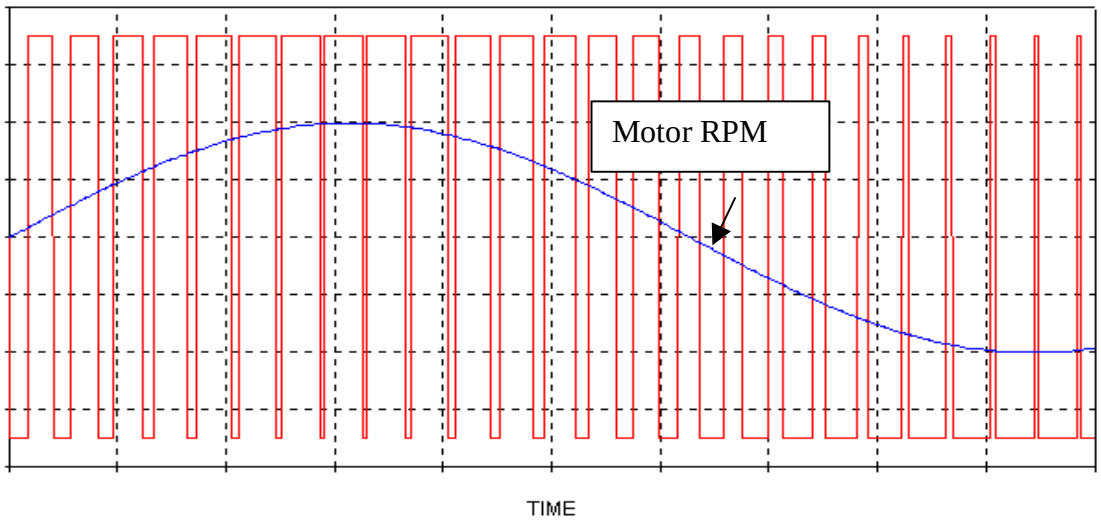
A motor operates by a principle called the Lorentz Force. A force will be produced on a wire if a current is passed through it and it is in a magnetic field. The inverse is also true; a current will be induced in the wire if it is moved by an external force through a magnetic field. A motor will become a generator if we turn it with an external force. This effect is how braking is performed with an electric motor.

In order for a motor powered by DC current to rotate, the current direction must be alternated. A brushed motor accomplishes this by switching the current in the armature mechanically using brushes riding on a conductive commutator. Brushless motors use special controllers which electronically switch the current through the motor so it will rotate. Brushless motors (and their controllers) are more expensive than brushed types, but they offer higher efficiency and are typically built to high mechanical and electrical standards.

Motors have several electrical characteristics that allow us to compare them. Winding resistance (ohms), Back EMF or Kv (RPM/Volt), maximum power dissipation (Watts), and efficiency. DC motors may also have a nominal voltage rating, but this is really an attempt to summarize the other characteristics into a single number. Motors can operate over a wide voltage range, you just can’t exceed their electrical or mechanical limit, or you have to be willing to put up with short motor life.

Speed controller:

Speed Controllers give us proportional control of the motor by varying the power supplied to the motor. Modern controllers vary the power by switching the full battery voltage on and off very quickly and varying how long the power is on or off. Technically this is called Pulse Width Modulation or PWM. Many controllers now offer user adjustable pulse frequencies. I’m not sure how the casual consumer would know how to set the frequency so I would use the default unless you have good information to change it.

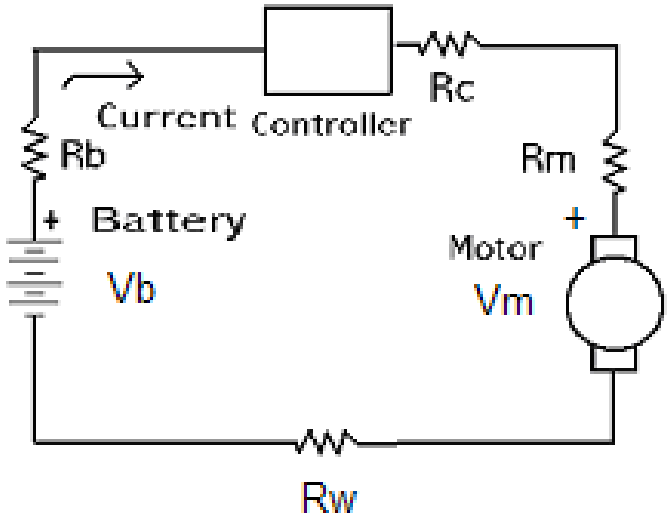


Most controllers will shut down power to the motor when the battery voltage drops to pre-determined voltage. This maintains power to the radio (if you are using the battery eliminator circuit) so you can safely land your plane. Other features include brake and failsafe.

The main electrical characteristics we need to concern ourselves with are the controller's resistance and current capacity.

Now let's put everything together and see how it works. This diagram is simplified

Simplified motor circuit:



Rc represents the internal resistance of the battery, Rc represents the internal resistance of the controller, and Rm represents the internal resistance of the motor and losses due to friction, and Rw is the resistance of the wire, Vb is the voltage of the battery, and Vm is the voltage of the motor.

If we apply a voltage to the motor, current will flow and the motor will spin. In a perfect world, the motor voltage (Vm) would rise to match the input voltage and no current would flow. In the real world, mechanical and electrical resistance will cause a small amount of current to be drawn to overcome these losses. As we load the motor down with a prop, it will draw more current in an attempt to keep the motor voltage the same as the input voltage. This current manifests itself as heat in the motor, controller, and battery. Too much heat, and one or more of those will be cooked. For the motor, the magnets are the most sensitive to heat and will lose their magnetism if they get too hot. A loss of magnetic force will cause the motor to lose its ability to create the motor voltage, and it will become more of a wire-wound resistor and just get hotter, which in turn demagnetizes the magnets more, which cause more current to be drawn, until something becomes a fuse and burns out.

The safe thing to do is to choose a motor with enough power capacity to pull whatever you are flying through the air without getting too hot. Also be careful with your propeller selection. Use what is recommended, and don’t go bigger unless you also have an inline ammeter to keep the max current at a safe limit.

How do you select the right motor, controller, battery pack, and propeller combination?

A safe and reliable method is to go with the manufacturer's recommendations.
The next reliable method is to copy somebody else's setup
The third is to experiment.

The recommended power for flight goes something like this:

Trainer & Sport Performance: 75-100 Watts Per Pound
Aerobatic & High Speed Performance: 100-150 Watts Per Pound
3D & Extreme Performance: Over 150 Watts Per Pound

So for a Pattern aircraft weight between 10 and 11 pounds we need 1650 watts of power available. I chose the Great Planes Rimfire 63-62-250 Out-Runner Brushless motor. Its specifications are as follows:

Can Diameter: 2.48" (63mm)
Can Length: 2.44" (62mm)
Shaft Diameter: .32" (8mm)
Shaft Length: .98" (25mm)
RPM/V (kV Rating): 250
Input Voltage: 29.6-44.4V
Max. Constant Current: 45A
Max. Surge Current: 72A
Max. Constant Watts: 1665W
No Load Current: 1.5A
Weight: 22.4oz (635g)

I wanted a direct drive motor to eliminate the need for a gearbox. The out runner design allows this motor to turn large propellers without a gearbox.

Controller. I chose the Castle Creations HV-85 controller because it had the maximum voltage and current ratings needed for this application and Patrick Castillo has been in the business for a while, knows his stuff and as a nice guy with great customer focus. (I was not paid to say that and I am not sponsored)

Choosing the battery. Here I went with what others are using and picked the

Choosing the prop. This is the tricky part. With 42 volts and a 250 kV rating, this motor will turn 42*250 or 10500 RPM at full throttle. Chances are the voltage will sag a little due to in circuit resistance, but the number is close. So, you need to prop the motor so it will not draw any more than the maximum current at full throttle, and remember not to use full throttle all the time.

If you put a prop too big for the application, the motor will draw more current in an attempt to meet its kV rating for the given input voltage and will likely burn up or break something (I have first hand experience). Something WILL become a fuse. You must have a reliable way to measure current when experimenting with props. I use the Astro Flight Wattmeter in between the battery and the controller to monitor current as I test the propeller.