The Magic of Electric Flying

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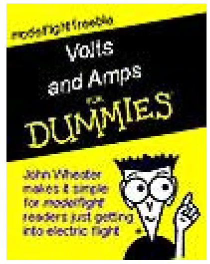


Volts and Amps for Dummies

By John Wheater

IT SEEMS there are many who are confused with what goes where and why and what motor and prop should be used on what battery and so on. When you find a web site that will explain volts and amps and watts it serves only to confuse by analogies to water and taps and pressure and stuff like that which confuses me as well as the next man. My father was an electronics engineer, he made a television from scratch in 1936 and received signals from Alexander Palace in London but none of his knowledge, absolutely none, has rubbed off on to me. So, if I can fly electric successfully without an in-depth knowledge so can you.

I shall describe only the 'brushless' motor set up as that is the way of things these days and I am hoping to do it in words of one syllable that even I can understand.

1. The basics

An ESC

The Brushless Motor is effectively a three phase AC motor. Current through any two connections will create a magnetic field, making the rotor turn a partial revolution. It will not work without a 'controller'.

The Controller, 'ESC' which stands for electronic speed control "commutates" a brushless motor by turning dc into ac and switching the two wires which are being energized in a sequence using a DC source, i.e. a battery.

What you NEED to know:
MOTOR + ESC + FLIGHT BATTERY = MOTIVE POWER

The speed of the motor is controlled by the ESC and to do this we need a radio receiver 'Rx' which is controlled by the radio transmitter 'Tx'

What you NEED to know:
MOTOR + ESC + FLIGHT BATTERY + Rx (controlled by Tx) = CONTOLLABLE MOTIVE POWER

2. Choosing a motor

"Thumper" 4250

There are hundreds of them. How can you hope to choose which one you need to power your specific model?

Let's look at the data for a typical motor then take each aspect in turn in an attempt to assist our selection:

"Thumper" 4250

a) 10.8v - 25.9v
b) 600 kv
c) 7 winds
d) 45amps max
e) 720 watts max
f) Total length 70mm, l w/o axle 50mm, dia 42.5mm
g) shaft 5mm
h) weight 210g
i) Recommended props from 12 x 6
j) Models up to 3kg
k) Recommended controller 45amp constant

a) The operating voltage. I don't have to explain that the motor will go faster by increasing the voltage do I?
b) The first item of motor data we need to consider is Kv. This is the number of rpm per volt that the motor will provide. Let's look at two *in extremis:*
   i) 600 Kv
   ii) 4,500 Kv

   What you NEED to know:
   A low Kv motor will turn a larger propeller and provide more torque.
   A high Kv motor is more suited to small propellers and provides less torque.

The first thing to remember is that the published figures are a guide as it is impossible for a manufacturer to state what will be the Kv on your set up as they don't know what size prop you will be using. The stated Kv is, therefore, the shaft speed without a load.

Basically, a larger propeller is more efficient than a small one and generally speaking the larger the model the larger the prop required. A small propeller will turn faster on similar power because it offers less resistance to the air so think of a smaller prop for faster models.

You will understand readily if I tell you that a large prop will need more power to turn it than a small one. It therefore follows that the larger the prop the larger the motor required.

Let's assume all the way from now on that we are using a 3S Lithium Polymer Battery, the 'Lipo'. 3S is simply a way of stating that the battery has **three** cells in **S**eries (the number of cells we are concerned with). A single Lipo cell has 3.7 volts so a 3S has 11.1 volts (3 x 3.7v = 11.1v)

So back to our two motors, how fast are they going to turn on a 3S Lipo?
i) 600 x 11.1 = 6,660 rpm
ii) 4,500 x 11.1 = 49,950 rpm
Don't forget they are NO LOAD figures.

Particularly if you have been a glow motor flier you will be able to accept 6,660 rpm but 49,950 rpm? The simple answer is that ii) is suitable only for a high speed, small diameter fan in EDF (electric ducted fan) jet type models.

c) The number of winds on the motor's armature.

What you NEED to know:
The lower the number of winds the faster the motor will turn for a given voltage and the lower the torque.

d) The motor's maximum current draw.

What you NEED to know:
The higher the number of amps the more power the motor will provide.

e) The maximum rate of electrical power the motor will consume before it generates too much heat and lets the smoke out. Don't panic, this is a very simple mathematical formula to determine how many watts an electrical circuit can carry or how many watts an electrical device will require: **Watts = Volts x Amps**.

What you NEED to know:
The higher the wattage the higher the power the motor is capable of producing.

Incidentally, to give you some idea, 1 horsepower = 745.699872 watts

f) These are
g) simply
h) motor dimensions

i) Now there is a useful figure. You must have some idea what size prop you want!
j) And you must know what your model weighs.
k) This is a reference to the ESC you should choose, always err on the large size. If your motor is going to consume 45 amps, choose a 60 amp controller so it will not have to work at its capacity.

What you NEED to know:
Choose your ESC by taking the maximum current draw of the motor and going for the next size up.

So, what sort of model is the Thumper 4250 capable of flying?
We will assume it will draw a steady 35 amps at 11.1v on its 12 x 6 prop.

Question: How many watts is it producing?
Answer as at e) above.

35 amps x 11.1v = 388.5 watts

As a general rule of thumb the power requirements of the four basic type of model are as follows:

Powered Gliders 50 watts per pound
General sport model around 75 watts per pound
Mild aerobatic model 100 watts per pound
EDF and 3D in excess of 150 watts per pound

That means that the Thumper 4250 will fly:

A powered glider weighing 7.77 lbs, that's a biggie;
A general sport model (which includes scale types like the Piper Cub and Beaver) of around 5lbs;
A mild aerobatic model (or scale low winger like a Mustang) of up to 4 lbs;
Or
A 3D model of 2.5 lbs.
THIS MOTOR IS NOT SUITABLE AT ALL FOR EDF, it simply does not turn fast enough.

3. Testing for power

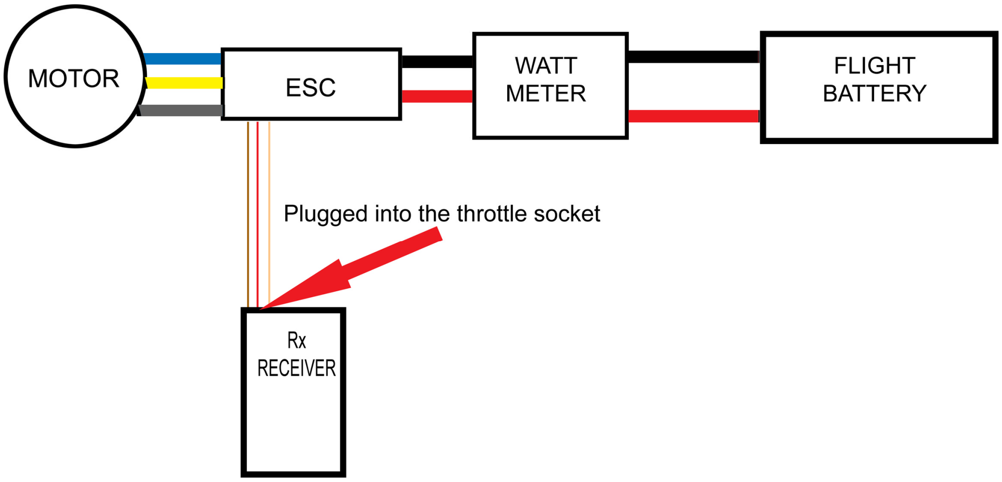
Wattmeter

What you NEED to know:
How do we measure the current draw? That's how many amps.

Answer: We use a WATTMETER.

Wattmeters vary with the readings they give but even the most basic will provide at least the current 'amps' drawn and the voltage of the battery at that current. Better ones will also multiply the two for you and give you the units of power that is 'watts'. Generally about £30 from most model shops.

A wattmeter is installed in the electrical circuit for testing purposes only between the battery and the ESC like this:



With a propeller attached and following the instructions for the ESC gently fully open the throttle and note the readings on the watt meter. The current drain will increase as you advance the throttle.

Repeat the experiment with a variety of propellers and note the difference they make to the current drain.

What you should aim for is the power to fly the aircraft as you intend, motors are more efficient at a lower power than designed maximum and you will achieve a longer flight time.

Let’s look at an actual test:

E-Flite 25 Motor Test					
			Current		
Battery	**Propeller**	**Volts**	**AMPS**	**Watts**	**RPM**
3S 1P	**11 x 8**	**11.1**	**31**	**344.1**	**7860**
3300					
mAh	**11 x 10**	**10.4**	**36.3**	**377.52**	**7200**
20-30C	**12 x 8**	**10.6**	**36**	**381.6**	**7200**
	12 x 10	**10**	**40.2**	**402**	**6680**

Whilst this isn’t the Thumper we have already discussed, it is a similar motor.

But wait a cotton picking minute, what’s that 3300 Mah under the battery type? And what the heck is 20-30C?

OK, now is as good a time as any I suppose.

What you NEED to know:

All batteries carry a figure which states the amount of current they are able to deliver shown as Milliamp (mA) Hours. A milliamp is 1/1000th of an amp so 3300 mAh is 3.3 Ah (Amp/hours).

But we are drawing 31 amps at the minimum, how does that figure?

What you NEED to know:

All model Lipo batteries carry a figure which is the C (for charge) rating. It is, in fact, the maximum current that the battery will allow itself to be discharged at. Therefore a 20C 3300 mAh battery (3.3 Amps) can be discharged safely at 66 Amps.

The second figure is the very maximum the battery can be discharged for in a short burst; 99 amps.

The greater capacity the battery (in Amps) the longer will be your flight time, all other things being equal.

And the RPM figure has sneaked in too but I will come back to that later. The difference in the RPM on this test you will notice doesn't alter dramatically.

So what's the best prop for this motor for a sport model? Looks like an 11 x 10 or a 12 x 8 doesn't it? There is virtually no difference in the figures. A 12 x 10 is offering only 5% more power (watts) but at a higher required current (Amps) so the flight time is likely to be slightly less.

What is the advantage of using a higher voltage battery?

Here's a reduced test sheet to show you the very basic of data.

Ultrafly H12/09 Motor Test				
Battery	**Propeller**	**Volts**	**Current Amps**	**Watts**
3S	**12 x 6**	**11.1**	**23**	**255.3**
4S	**12 x 6**	**14.8**	**43**	**636.4**

From this you will see that the current draw increases dramatically and the power output is more than doubled.

Don't run away with the idea that you must have as much power as possible, you could fit a V8 into a Mini but there isn't much point. Mind you, better too much power than too little, you can always throttle back.

This does show, however, that, assuming the motor's specification will allow it, you can find a great deal more power just by changing the battery or fitting a bigger prop, a little understood concept. It also serves to show how flexible the electric motor is.

4. Motor speed

Tachometer

Let's go back the RPM data from the previous chapter.

To calculate the RPM you need a digital tachometer available from most model shops for less than £20

With it, it's possible to gauge a theoretical speed for your airframe by calculating the ***pitch speed*** of the propeller using the following formula;

$$\frac{\text{RPM x PITCH = INCHES PER MINUTE x 60 = INCHES PER HOUR}}{\text{63,360 (The number of inches in a mile)}} = \text{MPH}$$

So given the E-Flite 25 above on a 12 x 8 we would have

$$\frac{7{,}200 \times 8 \times 60}{63{,}360} = 54.55 \text{ MPH}$$

5. Flight duration

You can also get an approximation of your flight time;

Let's say the battery is 3,300 Milliamp Hours and you are pulling 30 Amps as an average for the flight. Convert the MaH to Amp Hours so that's 3.3, then divide by your discharge rate. Multiply the answer by 60 (minutes) and you will have your theoretical maximum duration on full throttle:

$$\frac{3.3}{30} = 0.11 \times 60 = 6.6 \text{ minutes}$$ (Volts don't enter into this equation at all.)

That's it in a nutshell.

modelflight

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