# Working Out the Power Train for Direct Drive Brushless Electric Aircraft

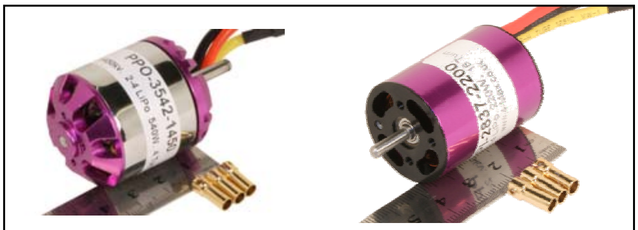
This is the question I get asked the most. Well this is how I work out the power train for brushless direct drive model aeroplanes. It's a simple way with a few 'Rule of Thumb' tables. There are other ways, there are more complicated ways, but this is my simple way.
It's best to work through an example. In this case let's work with the Hangar 9 P-47D Thunderbolt (.60 Size).

## What sort of aircraft is it?

Simple Question, but this is where your choice starts

Q. Small fast pusher or tractor plane?
A. Yes, then you'll need an Inrunner

Q. EDF (Electric Ducted Fan)?
A. Yes, then you'll need an Inrunner



Outrunner Inrunner

In this example the answer is 'no' to both of the above questions, so we'll need an 'Outrunner'

## How heavy is it?

Do you know the expected flying weight? If not, then weigh the kit bits and add 40% to get an estimated flying weight

The Hangar 9 has an advised flying weight of 8.0lbs – 9.5lbs for an IC version. Flying weights are roughly the same for IC and Electric (brushless motors and LiPo batteries). For this example we'll assume 9lbs.

***Rule of Thumb Guide for Performance for Prop Driven Aircraft***

| | |
|---|---|
| Slow High Wing | 60-80 Watts/lbs |
| Sport/Warbird | 80-130 Watts/lbs |
| Aerobatic | 130-180 Watts/lbs |
| Extreme 3D | 200+ Watts/lbs |

***Rule of Thumb Guide for Performance for EDF Powered Aircraft***

| | |
|---|---|
| Acceptable | 120 Watts/lbs |
| Good | 150 Watts/lbs |
| Very Good | 180 Watts/lbs |
| Excellent | 200+ Watts/lbs |

## Let's recap what we know so far

- We know what type of aircraft it is, (medium sized warbird) so we now know we need an Outrunner
- We know the estimated flying weight (9lbs)
- We know the sort of performance we require (Warbird)
- We also now know how many watts we require (9lbs x 130W/lbs =1,170W)

## How Many LiPo Cells Do I Need?

| Model Size | Number of LiPo's | Volts Under Load |
|---|---|---|
| Indoor Models | 2-3S LiPo | 6.7-10V |
| Up to .30 Size | 3S LiPo | 10.0V |
| .40 Size IC | 4S LiPo | 13.3V |
| .50 Size IC | 5S LiPo | 16.6V |
| .60 Size IC | 6S LiPo | 20.0V |
| .90 Size IC | 8S LiPo | 26.6V |
| 1.20 Size IC | 10S LiPo | 33.3V |
| 1.60 Size IC | 12S LiPo | 40.0V |

## Still not sure how many LiPo cells you need?

Then another good rule of thumb is to keep the Amps below 60A at full throttle.
Smaller the model = smaller amps. Hence a bigger model requires will require more Amps.
One thing to remember is that larger props are more efficient then smaller props. So always try to select a motor that throws a largest propeller that the model will allow.

Watts = Amps x Volts      Therefore      Amps = Watts/Volts

***Example 1 (6S).***
Amps = 1,170W/20V (20V = 6S LiPo Voltage under load) = 58.5A

***Example 2 (8S).***
Amps = 1,170W/26.6V (26.6V = 8S LiPo Voltage under load) = 44.0A

## What Capacity (mAh) of LiPo is Needed?

***Example 1 (6S LiPo).***
Say we want an 8 minute flight at 70% throttle….
(70% throttle position roughly halves the full throttle current)

$$\text{Capacity of battery needed} = \frac{\text{Time x Current}}{60} = \frac{8\text{ (minutes) x }29.25\text{ (Amps)}}{60} = 3.9\text{Ah} = 3{,}900\text{mAh}$$

To maximise the life of your LiPo battery packs you should aim to put back 80% or less of the packs capacity. Therefore we need to divide the capacity needed by 0.8

$$\frac{3.9\text{Ah}}{0.8} = 4.875\text{Ah}$$ which is the same 4,875mAh

The nearest battery sizes are either 4,100mAh or 5,000mAh

***Example 2 (8S LiPo).***
Again working on an 8 minute flight at 70% throttle….
(70% throttle position roughly halves the full throttle current)

$$\text{Capacity of battery needed} = \frac{\text{Time x Current}}{60} = \frac{\text{8 (minutes) x 22 (Amps}}{60} = 2.9\text{Ah} = 2{,}900\text{mAh}$$

To maximise the life of our LiPo battery packs you should aim to put back 80% or less of the packs capacity. Therefore we need to divide the capacity needed by 0.8

$$\frac{2.9\text{Ah}}{0.8} = 3.625\text{Ah which is the same } 3{,}625\text{mAh}$$

The nearest battery sizes are either 3,300mAh or 4,100mAh

## So what's best? 6S or 8S LiPo? Let's look at weights and costs

| Battery | Weight | 4-Max List Price |
|---|---|---|
| 6S – 4,100mAh | 650g | £133.98 |
| 6S – 5,000mAh | 820g | £159.98 |
| 8S – 3,300mAh | 750g | £147.98 |
| 8S – 4,100mAh | 1,080g | £177.98 |

In my opinion it's better to sacrifice a little flight time for a lighter aircraft.
Lighter aircraft, need less power, are easier to fly, harder to tip stall and can take off and land slower.
In conclusion I would choose the 6S 4,100mAh as I am quite gentle on the throttle.
If you like flying with more power then I would recommend the 6S 5,000mAh.

My recommendation is to purchase 2 packs of 3S and connect them together in series to get 6S.
Why? If one pack gets damaged in a crash then you only need to replace one of the packs.
Another reason is that you might be able to use the 3S packs in smaller models.

## How Hard Am I pushing the LiPo's?

Another point to consider is…. How hard are you pushing your LiPo packs? Why do we need to consider how hard we are pushing our LiPo? Well….. The harder you push them, the shorter the life.
To work out how hard you are working your packs, take the full throttle current (in this example 58.5A) and divide it by the capacity of the battery (4.1Ah) = 14C which is about right for a 20C rated battery.

A good range is 10-15C (full throttle) for a 20C rated battery. Remember that 70% throttle is roughly equal to half the full throttle current, therefore our example is 29.25A / 4.1Ah = 7C

## So What Motor Do We Need?

We know how much power we need (1,170W) and we know how many cells we intend to use (6S – 4,100mAh) so we just look up the table and choose a motor that can handle this power and is suitable to be used on 6S LiPo's. Click here for the list of all the Purple Power Motors

| Part Number | kv (RPM/V) | Power (W) | Turns | Coil Resistance (mΩ) | No Load Current (I) | Recommended ESC (A) | Cells Ni-Cd/ Ni-MH | Cells LiPo | Diameter (mm) | Length (mm) | Weight (g) | Shaft (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PPO-5055-400 | 400 | 1300 | 8 | 31 | 1.6 | 70 | 9-24 | 3-8 | 50 | 55 | 315 | 8.000 |
| PPO-5055-580 | 580 | 1280 | 6 | 20 | 2.3 | 70 | 9-24 | 3-8 | 50 | 55 | 315 | 8.000 |
| PPO-5065-270 | 270 | 1600 | 9 | 42 | 1.5 | 70 | 9-24 | 3-8 | 50 | 65 | 410 | 8.000 |
| PPO-5065-320 | 320 | 1600 | 8 | 34 | 1.9 | 70 | 9-24 | 3-8 | 50 | 65 | 410 | 8.000 |
| PPO-5065-380 | 380 | 1400 | 7 | 27 | 2.0 | 70 | 9-24 | 3-8 | 50 | 65 | 410 | 8.000 |
| PPO-5065-410 | 410 | 1400 | 6 | 20 | 2.0 | 70 | 9-24 | 3-8 | 50 | 65 | 410 | 8.000 |

There are 6 motors that initially meet our requirements. So which one do we use? We need to look at the kv rating of the motor. What is kv rating? Very simply it's an indication of the RPM per volt with no load on the motor.
Warbirds are generally medium to fast flying and therefore we need to pick a motor with a medium to high kv rating. I would therefore pick the PPO-5065-380 as it can handle a bit more power, so we are not pushing it to the limit.

## What Prop Should We Use?

Again we need to consider how fast we want to fly. Warbirds are medium to fast flying and therefore we need to pick a prop with medium to high pitch to keep the flying speed up. Again check the manufacturers recommended prop.

| Part Number | RPM/ Volt | Winds | Batt | Power | ESC | Model Weight | Prop | Price | Quantity |
|---|---|---|---|---|---|---|---|---|---|
| PPO-5065-380 | 380 | 7 | 3-8 LiPo | 1400W | 80A | 3000-4500g | 6LiPo 18x12<br>8LiPo 16x10 | £54.90 | |

As we don't need 1,400W we can choose a slightly smaller diameter prop, say a 16x10 or 17x10

## What Size ESC Do I Need?

Another good rule of thumb is to get an ESC (Electronic Speed Controller) with around 20% spare capacity. From our previous calculations we know we have a full throttle current of 58.5A.

Therefore 58.5A/0.8 = 73A so a 70A or 80A ESC would be suitable.

Make sure the ESC can take the voltage of batteries you plan to use.
In this case 6S. 4-Max P/N = PP-ESC70A

## BEC or not BEC? That is The Question

Most ESC's that have a built in BEC, (**B**attery **E**liminating **C**ircuit) but normally they only work on a supply up to 3S LiPo.
For batteries of 4S and above, the BEC has to be disabled by removing the red wire from the plug that goes into your throttle channel in your receiver.
A separate power supply for your receiver and servos is needed. You can power them via a traditional Rx pack as you would in an IC powered plane or you can use a UBEC (**U**niversal **B**attery **E**liminating **C**ircuit).
For example the 4-Max UBEC can accept input DC voltages from 8.4V - 42V (3S-10S) and convert it to 6VDC at 3 Amps.

## Aren't Electric Aircraft Heavier?

They used to be, but not any more.

***IC Powered Hangar 9 P-47D Thunderbolt***

| | | | |
|---|---|---|---|
| Engine | OS 91FS Surpass II | 640g | £189.99 |
| Engine Mount | Std Engine Mount | 100g | £3.50 |
| Fuel Tank | 8 oz | 80g | £2.69 |
| Fuel | 8 oz | 226g | £ |
| Throttle Servo & Linkage | Futaba S148 | 55g | £7.00 |
| Rx Battery Pack | (GP) 4.8V 1,700mAh | 112g | £12.99 |
| Prop | APC Pattern 16 x 10 | 107g | £13.99 |
| Totals | | 1,320g | £230.16 |

***Electrified Powered Hangar 9 P-47D Thunderbolt***

| | | | |
|---|---|---|---|
| Motor | PPO-5065-380 | 410g | £54.90 |
| Battery | 2 x 3S 4,100mAh | 650g | £133.98 |
| Motor Mount | PP-MOUNTSET50 | 68g | £8.00 |
| ESC | PP-ESC70A | 45g | £43.95 |
| UBEC | PP-UBEC3A | 11g | £8.99 |
| Prop | APCE 16 x 10 | 55g | £8.25 |
| Totals | | 1,239g | £258.07 |

| | | |
|---|---|---|
| 4-Max Electric Power | 1,239g (Includes LiPo's) | £258.07 (Includes LiPo's) |
| OS 91FS IC Power | 1,320g (Full Tank of Fuel) | £230.16 (No Fuel Included) |
| Difference using Electric Power | 81g / 2.85oz lighter | £27.91 more expensive but includes fuel |

## In Conclusion

We worked out…

- What type of motor we needed (Outrunner).
- The amount of power we need for our required performance (1,170W).
- We calculated the size and capacity of the LiPo's needed to give us the performance and duration required.
- We decided on the motor for the job from looking at the manufacturers charts.
- The propeller was selected, again from the manufactures information.
- We calculated the ESC needed and discovered that we needed a separate power source for our Rx and servos.