

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?

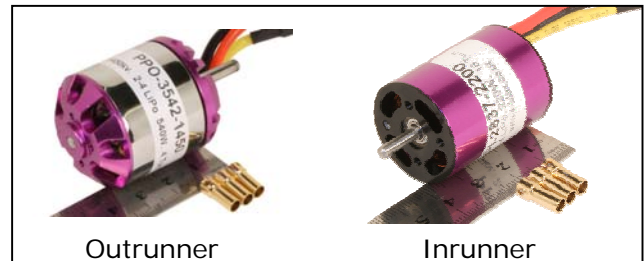
Simple Question, but this is where your choice starts

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



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)

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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)

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

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

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

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

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Example 2 (8S LiPo).

Again working on an 8 minute flight at 70% throttle...
(70% throttle position roughly halves the full throttle current)

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

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

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

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

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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 8LiPo 16x10	£54.90	<input type="text"/>

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

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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

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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.