

Electric flying for beginners

This article does not attempt to cover the enormous range of issues that come up when you want to look at flying electric rather than IC powered planes. It is based on my experiences as a total beginner at Suncoast Model Flyers, and is restricted to offering advice on setting up to build or assemble an electric trainer, and to get it into the air. This advice tries to cover all of the things that I had to learn along the way.

Back two years ago when I started to get involved with model planes again after a sixty-year break, I became fascinated with the possibilities of electric flight. This was partly because of the technology now available, but also because it can be as technical as you want it to be, or as straightforward as buying an ARF trainer plane with a recommended power pack.

Flying electric has some advantages over fuel powered flying, mainly in the convenience of setting up and maintaining the plane. You don't have to deal with the sundry problems that arise with starting and adjusting IC engines – you just assemble the plane, turn it on, and go. Flying electric also gives you access to the world of small planes and indoor flying, as well as to an extremely wide range of commercially available models and freely available plans for models to build and experiment with. Pretty much all planes smaller than about 1 metre wingspan are now electric, and there are a lot of electric ducted fan jet replicas if you want to fly fast. Many of these come with all of the components ready installed – just add the receiver and go!

The extras required to fly an electric trainer are, in total, more expensive than the equipment required for flying IC trainers. While you don't need the engine, the fuel, the radio/servo battery and the starter, you will need one or more flight batteries, a battery charger, a motor and an electronic speed control or ESC. The radio transmitter and receiver and the servos are the same for both, and the ESC replaces the throttle servo required for an IC plane.

I had some good advice at the time I started that gave me an initial window into the world of electrics, and I have continued from there. I have designed and built a number of corflute (corrugated plastic board) deltas and flying wings, built and flown an electric trainer (a Rainbow), and converted three glow engine trainers (a Boomerang and two Classics) to electric power.

Planes designed specifically for electric flight, usually denoted as EP models, are lighter and less robust than IC or glow powered planes, because the general approach is that it is easier to set up and fly an electric plane if it is lighter. As a beginner, you will have your crashes and hard and untidy landings, which is why I have persisted with electric conversions of IC trainers of the 40 or 46 size. IC planes are built more robustly than their electric equivalents, but can still be set up electrically to provide performance that is definitely equivalent to that of the IC versions.

The reason that I have two Classics is that I bought the second one to provide spare components for the first: in the meantime my flying improved to the point where I no longer needed the spares sitting on the shelf, and so it was worth while building the second one. That gave me the opportunity to experiment with motor and battery choices.

Choosing a trainer

I assume that as a beginner you will be following the recommended path into learning to fly, by building your own trainer. If you want to get started as quickly as possible, one of the best sources of information would be an Australian model plane magazine. I subscribe to "Airborne" magazine, but it is not the only one available. There are reviews and build logs based on a wide range of ARF kits, and many advertisements from model suppliers that list a wide range of electric trainers. Your local hobby store can also help with some advice and kits off the shelf. I would advise a high wing trainer with a wingspan of 1.5m or thereabouts. There are lots of them, and they are all more or less equivalent in their construction and ease of operation. A trainer of this size is big enough to see at a safe height (two mistakes high) and it flies slowly enough to be easy to control. These models are designated as 40 or 46 size models, which refers to the recommended IC engine size of 0.40 cubic inch or 0.46 cubic inch (1 cubic inch is about 16 cc). There are also 60 (or 0.60 cubic inch) size trainers that can certainly be converted to electric, but I haven't done one of these. There are a lot of 1m wingspan electric models, but they get small very quickly if you get into trouble, and they are not all that useful as trainers.

The internet is an amazing source of information on all aspects of electric flight. There are some excellent on-line stores that can supply pretty much any component you need at prices that are more than competitive.

An excellent site that covers all of the more technical topics I outline below, but in more detail and with experimentally measured comparisons of the different components, is www.bungymania.com It is in French, but Google will supply an English translation if you click the British flag icon. The translation is odd in places, but you can get the idea very easily. This article is intended to summarise one approach to learning to fly in Coolum using an electric powered trainer, with enough detail about the components for it all to make some sense. It is based on my own adventures, investigations and conclusions.

Batteries and chargers

There are some technical issues that you need to understand before you can confidently choose the batteries, charger and motor that you need with a trainer ARF, unless you buy the power pack that the dealer recommends for it.

The battery chemistry of choice for electric flight is the lithium polymer battery, or LiPo. It comes in a huge variety of sizes and capacities, so it can be confusing working your way through it all.

LiPo batteries are based on individual cells that are produced as a flat pack made up of layers of cells. The thickness and area of the cell determine its capacity in milliamp hours, and the number of these cells that are stacked and then joined in series determine the output voltage of the battery. Each cell has a voltage of 4.2 volts when fully charged, but this drops off as the battery is discharged, down to a cut-off voltage of about 3 volts per cell. If you discharge it lower than this, you can do permanent damage to the cells.

C ratings

Each battery also has a "C" rating (10C, 15C, 20C etc) that defines the maximum current that can be drawn from the battery. For instance, a 4000mAh (milliamphour) battery has a basic capacity of 4 amp-hours or 4 amps for one hour, and this current is designated as 1C. LiPo batteries can be charged at 1C, so this one can be charged at 4 amps, at which current it takes an hour to be charged fully.

The maximum discharge current that the battery can supply is then given by the C rating. If the battery is rated at 20C, then it can supply 20x4 or 80 amps, which is a lot of current. Not only this, but ratings can be given as (say) 20C/30C, where the second number (30C) is the burst current (30x4 amps) that can be sustained for a short time (say 20 seconds). When you get into currents of this magnitude, then components such as speed controls have to be sized accordingly, and rapidly become very expensive. The other downside of running at high currents is that operating LiPo batteries at more than 10C compromises their life in terms of the maximum number of charge/discharge cycles they can withstand.

So, if we have a 4000 mAh battery, it can operate comfortably at 10C or 40 amps, and nominally do this for 1/10 of an hour, or six minutes. Of course, you don't operate at full throttle all the time, and so the expected flight time is probably twice the full throttle time. An average voltage from a 4S battery is about 15 volts, so you would have 15x40 or 600 watts of installed power. One rule of thumb suggests that good sports performance requires 100 watts per pound weight, so a 3 kg plane should perform well with 600 installed watts. My first Classic uses a 3750 mAh battery, an installed power of 560 watts, a mass of 2.8 kg, and it can keep up with a 46 IC powered trainer, which has about the same mass.

Battery cell arrangements

If our notional 4000mAh battery has four LiPo cells connected in series (so that the voltages of each cell add) then it is designated as a 4S1P battery. The capacity in milliamp hours does not increase as you interconnect the individual cells positive to negative, but the voltage does. The energy stored is the product of the capacity and

the voltage of the battery, so a 4000mAh 4S1P battery stores 4x 4.2 or 16.8 watt hours of energy. If you connected two of these batteries in parallel so that positive is connected to positive, and negative to negative, the capacity is doubled to 8000mAh while the voltage remains the same, and it would be designated as 4S2P.

Choosing a battery

Choosing a battery for an electric trainer is a matter of optimising capacity, voltage or number of cells, physical dimensions and cost. Remember that while a battery powered flight of twelve or fifteen minutes is possible, it will take an hour or so to recharge the battery at the field. Hence a second battery may be a good idea if you want to achieve as many flights as possible. Higher voltage (or more cells) will make the motor run faster, so that you can use a smaller propeller and reduce the current while achieving the same thrust. Motor choice, battery capacity and voltage, propeller size, thrust and run duration are all inter-related. If you want to play with these parameters, then free drive calculation software such as DriveCalc (www.drivecalc.com) can be very useful. Alternatively, you can follow the recommendations of the plane or motor manufacturer, if you can find the information. Fortunately there is a number of internet sites where motor data are available, usually provided by enthusiasts who just love measuring and reporting motor and propeller performance as a public good.

The physical dimensions of the battery are more important if you are converting a glow trainer, where the space left by removing the fuel tank may be restricted, and that is where you have to put the battery. Electric trainers tend to have more space available. A good idea is to locate and pack the battery with EPP (expanded polypropylene) foam, which is flexible, strong, and recovers from distortion. It is occasionally used to pack electronic goods, so you can source it by haunting the bins at electrical stores. It is a good idea to protect your battery from damage in a crash, because the battery can be the most expensive component in the plane. LiPo batteries will happily deform to some extent, but if their covering is punctured or broken they have to be retired.

Battery charging

Battery charging arrangements also have to be planned. LiPo batteries are notorious for causing problems such as overheating and possibly catching fire during charging. Their cell chemistry has no inbuilt control over the maximum cell voltage achieved during charging, so an individual cell can run away and overheat, causing problems. The latest balance chargers are computer controlled and monitor the entire charging process, reducing the risk as much as possible. You are recommended to charge these batteries on a fireproof surface, and not leave them unattended.

LiPo batteries have to be charged so that each cell has the same voltage within close limits. They are constructed with balance leads that connect to the connections between the cells. Balance chargers not only charge the complete battery, but they also

monitor the voltage across each cell during charging, and adjust it as necessary. The battery balance leads plug directly into the charger so that this monitoring can be done.

The standard charging rate for LiPo batteries is 1C, which means that they can be fully charged in one hour: charging a 4000 mAh battery at 4 amps for one hour will completely charge the battery. This means that you have to have a charger that can supply 4 amps at the voltage (or cell count) of your battery.

This is where there can be problems. A typical mid-range charger can charge up to 6 cells, but its output is typically limited to 50 watts. Watts are the product of amps and volts: for our 4000 mAh 4S1P battery, the voltage after a flight may be 4×3.7 or 14.8 volts, so the charging current is limited to about 3 amps by the power capacity of the charger. The battery may need only 3000mAh to replace the charge used in the flight, but at 3 amps this will still take an hour. So to enjoy as many flights as possible, do you buy more batteries or a larger charger that can charge at 4 amps and 15 volts?

If you want to charge a 5000 mAh 6S battery in one hour, you will need a charger with a current capacity of 5 amps, but a power capacity of $(6 \times 3.7 \text{ volts}) \times (5 \text{ amps})$ or 110 watts. Battery technology keeps improving, so that LiPo batteries are now available with a 2C charge capacity, which means that they can be charged in half an hour. This charge capacity that halves recharge times can only be utilised if the charger capacity is doubled, and chargers of this sort of capacity in terms of both amps and power are very expensive.

As a beginner, and if you can see yourself continuing to fly electric planes larger than say one metre wing span, then the general advice applies - set yourself up with equipment that has a future. A 50watt charger will handle up to 4000mAh 4S1P batteries without the charger itself becoming the limitation on re-charging times. A battery of this capacity can power an electric trainer of 1.5 metre wing span and give flight times of between ten and fifteen minutes. Two batteries will enable a flight every 40 minutes or so, allowing for changeover, setup and flight times, and this is a comfortable and convenient way to learn.

Battery charger/balancers are usually powered from a 12V battery so that they can be used in the field, but there are some that also have the 240V AC input option. This is useful and convenient for charging at home. Alternatively, you could also purchase a 14V DC power supply that plugs into the 240 V supply, but make certain that it has a power rating greater than the rating of your charger.

Choosing a motor

The default position here is just to buy the motor recommended by the plane manufacturer, and install it.

There are thousands of motors of all sizes available, and choosing one from this multitude can be very confusing. There are also significant questions of cost, and you may want to look further than the recommended motor to minimise your expenditures.

There are some options, but you need to know about the numbers and specifications used in describing motors. Here I am talking about "outrunner" motors, which are more powerful and more efficient than their "inrunner" predecessors. Electric motors have a ring of permanent magnets surrounding an armature made up of radial arms, each one of which has windings that are activated in sequence to create a localised magnetic pole, which moves from one arm to the next as the current is switched from one arm to the next. As the magnetic poles move around the armature due to their activation in sequence, they interact with the permanent magnets to cause rotation of the output shaft.

In an inrunner motor, the magnet ring or outer casing is fixed, and the armature rotates with the shaft. In an outrunner motor, the armature is fixed, and the outer casing with the permanent magnets rotates, carrying the shaft with it. In both cases, the Electronic Speed Control, or ESC, (of which more later), controls the speed at which the sequential switching of current from arm to arm occurs.

Motor sizing

The accepted method for designating the size of an outrunner motor is to specify two pairs of numbers and a second number separated by a dash. The first pair is the diameter of the stator or armature, and the second pair is its length. So a 3026 motor has a 30mm diameter stator, and its length is 26mm. The second number denotes the number of turns in each armature or stator winding. A smaller number denotes a faster motor, and a 3026-10 motor has 10 turns in each winding. This standard method of sizing allows you to find pretty much equivalent motors across a range of manufacturers.

Not all motor manufacturers adhere to this method. For example one major manufacturer makes a 4250 motor that is actually a 3625 motor in the standard notation, and the same sort of difference exists for all the motors it makes.

The other number used to specify motors is the kV number, which is the number of rpm per input volt at no load. It can be used as an alternative to specifying the number of turns. The 4250 motor mentioned above is fully specified as a 4250-650, which means that it would give 13000 rpm at no load with an input voltage of 20 volts, not that it has 650 turns on each armature winding.

Finding a motor

This is where the choices that you have made to this point come together. You have a plane of a particular mass ready to fly and a battery of a particular capacity and voltage. You have now to choose a motor and propeller combination that will provide a thrust somewhere near the weight of the plane while operating from that battery and drawing a current of around 10C.

DriveCalc is one option for searching for a suitable combination, and there are other free calculators available as well. For direct recommendations, I would suggest www.bungymaniaman.com again because it provides very thorough motor and plane reviews.

Once you have identified a suitable motor, it will be worthwhile looking for it on the internet, because shopping in online stores can save you a lot of money.

One very useful piece of equipment is a meter for measuring watts and amps so that you can check the current draw of your motor/prop combination, and avoid smoky incidents.

Propellers

Propellers are designated by their diameter and their pitch. A 10x5 propeller has a 10 inch diameter, and in one revolution it would advance 5 inches if there were no slip between the prop and the surrounding air. Larger diameters give more thrust and are more efficient, while larger pitches allow the prop to fly at a higher speed with maximum efficiency.

Electric motors have smooth shafts, unlike IC engine shafts that are threaded. They therefore require some form of adapter between the shaft and the prop. This may be a grubscrew type, but the collet type is much preferred. It has an outer conical surface that causes the collet to tighten on the shaft as the prop nut is tightened.

Electric propellers differ from propellers suited to IC engines in that they are much lighter and have narrower hubs. IC props may not fit within the length of an electric motor prop adapter because their hub is too wide. Electric props are usually designated by having the suffix E, as in 10x5E.

Electronic Speed Control or ESC

The ESC accepts the motor voltage as an input, and supplies a three phase output to the motor. This output creates the magnetic field that rotates around the armature or stator, and drags the magnet ring with it.

An ESC is rated by the continual current that it can provide, and it may also have a burst current rating that it can sustain for a short time, such as ten seconds. It is probably sensible to buy an ESC with a higher rating than you need, because the increment in price is not too significant compared with the additional peace of mind. I have seen many ESCs turn to smoke, flames and melted plastic due to over-propping or other misadventures. For the suggested 40 amp system we have been discussing, a 60 amp ESC gives a nice margin.

Again, it is worthwhile to shop around. Prices can vary by a factor of two or three for a similarly rated ESC.

Most ESCs also provide a regulated voltage of 5 or 6 volts to power the receiver and the servos, by way of a BEC, or "battery elimination circuit". The ESC is connected to the "throttle" input of the receiver, delivering the regulated voltage to the receiver, as well as transmitting the throttle signal back to the ESC. The current capacity of the BEC should be 3 amps to enable it to operate all the servos as well as the receiver.

Some ESCs do not have a BEC, or it is not available for battery cell counts (or battery voltage) above some limit, or its current capacity is low. In this case, you have to install a UBEC or "universal battery elimination circuit" which is a separate component powered at one end by the battery and connected at the other to the "battery" input of the receiver. Part of the installation procedure requires that the positive (red) lead from the ESC should be disconnected from the receiver by snipping out a section of it near the receiver plug end.

ESCs can be programmed to set various parameters that control its interface between the motor and the battery. These parameters are typically the brake setting, the battery type, the cutoff mode when the minimum voltage is reached (reduce power or shut down), the cutoff voltage, the startup mode (soft start or normal) and the timing of the pulses to the motor. This programming is performed using the transmitter throttle stick, following the instructions provided with the ESC or available from the manufacturer's website. More conveniently, some ESCs also have provision for programming via a multi-button card, an infrared link or a USB connection to a PC.

More advice

This summary of the major issues involved in setting up to fly electric is hopefully enough to help you decide whether or not, and to what degree, you want to get involved. It is more technical than IC flying, but that may also appeal to you if you want to get more deeply implicated. It is also possible to just buy an ARF electric trainer with a manufacturer's or hobby store's recommended power pack, and enjoy the convenience of "plug and go" flying.

There are a number of electric flyers in the club who will be only too happy to provide further advice and other information on other sources of components and useful websites.