The Farad

A Supercap Powered Model for the Wide Outdoors.

Bob Lee's experiments with supercapacitors and electric motors has culminated in a power train that will fly this robust 55cm span model suitable for outdoors as well as indoors.

Most supercap powered models have a performance limitation when flown outdoors due to the low voltages that supercaps can handle. Typically they are rated for 2.7V, but this voltage falls steadily drops as soon as they are discharged into a motor. This is fine for indoor flying, where a slow rate of climb is required to avoid the ceiling, but not very exciting for the outdoors. Some people overcome this by overcharging the supercaps to a higher voltage. This seems to work but is taking the supercaps a long way outside of their datasheet limits and still isn't as high a voltage as even a single lithium cell can provide.

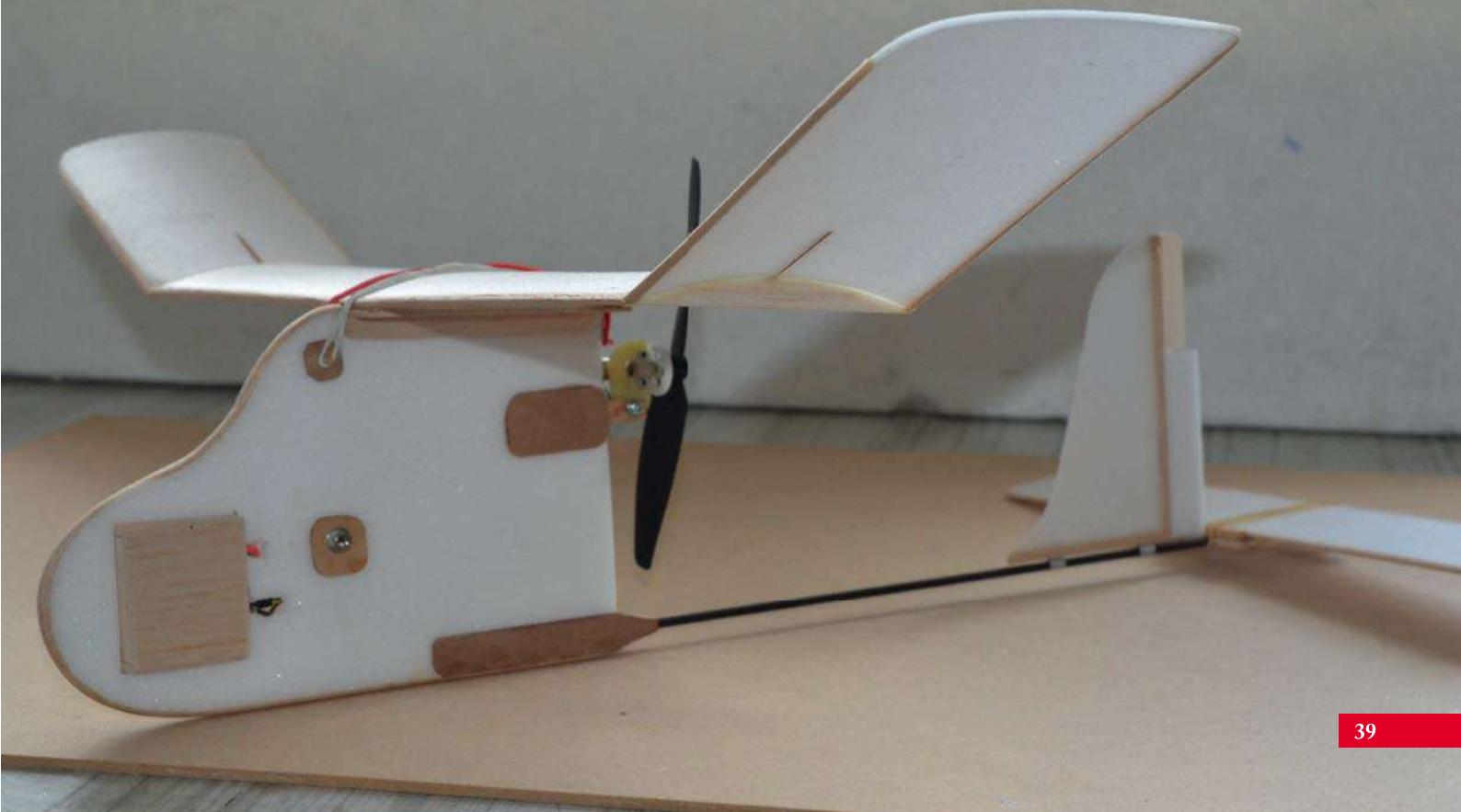
A better method of increasing performance is to use two supercaps connected in series. A convenient method of charging series supercaps is four AA batteries, in the correct configuration (see later), which can charge two series connected supercaps to a total of 6V. This is a small level of overcharge (3V each supercap) but I feel acceptable given the simplicity of the charging arrangement. The Farad was designed as an easy to build model that would test this concept and has proved the point that such a model can indeed have a very good outdoor performance. The pusher configuration was chosen to save broken props and damaged motors.

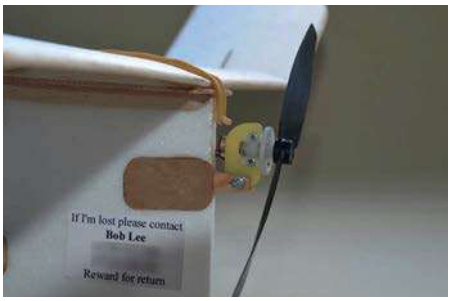
The Farad is my first venture into the world of mechanical CAD. I have used many different design tools over the years but until now not used any 2D CAD. I downloaded the free copy of DraftSight and was helped by some recent AeroModeller articles on the subject and encouraged by fellow club member Laurence Marks.

Materials

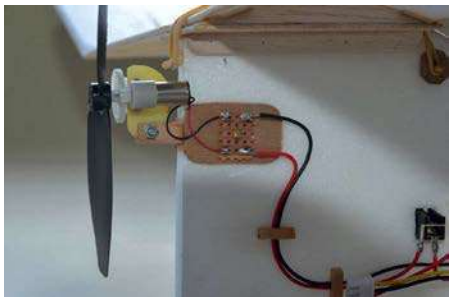
The Farad uses low cost, easy to obtain components for the powertrain. The motor is the ESP-7 from HobbyKing and the supercaps are each 25F. Mine came from

The 55cm span Farad is designed purposely for outdoors flying with supercapacitor power.

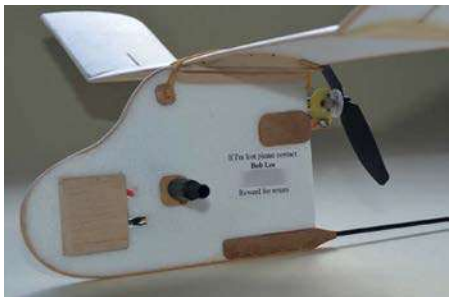




Close up of motor mounting, LH side



Close up on motor mounting, RH side. Note the stripboard used to connect the motor to the wiring. The alternative would be an 'air wired' joint, then sleeved.



LH side detail - note the jack plug inserted so the model is clearly safe. Also note the address label as your model could fly away…

Maplin, part number N50QQ. At the time of writing it seems that Maplin is no more and an alternative source would be RS Components, part number 763-7772.

You will need a carbon fibre tube for the fuselage boom, this is 3mm OD and 1.5mm ID. I got mine from the Model Shop Leeds. You will also need 6mm and 2mm Depron, some 0.5mm ply and some small amounts of 3mm, 1.5mm and 0.8mm balsa sheet. The motor stick is 6 mm sq. spruce.

Fuselage

The fuselage pod is made from 6mm Depron. When cutting Depron I like to make a card template first. Most home printers have a 'copy' function and this can be used to make a copy of the part of the plan containing the fuselage pod. Cut this out with a margin and glue it to some stiff card. When dry, cut out the outline of the fuselage pod. To make it clear, this is marked on the plan with some small arrows. Be sure to include the slots for the boom and motor stick, and the hole for the supercap box. The template can now be used to cut out the fuselage pod but DON'T cut out the slots or hole as yet, just use the template to mark the positions.

To add rigidity and make it less prone to damage, the fuselage pod is edged with two strips of balsa, so first cut these, 6mm wide and of suitable length, from a sheet of medium 0.8mm balsa. Put these in a bowl of warm water to soak for 10 minutes or so. Meanwhile, cover a building board with Clingfilm and pin the Depron fuselage pod flat on the board. You can avoid unsightly pin holes by pinning where the slots and supercap box will be.

Remove the balsa strips from the water and wipe off the excess. Coat both sides of one of the strips with PVA, this strip is formed around the edge of the Depron pod first, followed immediately by the second strip. Pins placed around the edges of the strips will hold them in place and ensure that they follow the curves. Leave to dry overnight. When dry, the pod can be removed from the building board and the edging strips sanded flush and rounded off. Take care not to sand the Depron, this will spoil the surface finish.

The next job is to add the carbon fibre boom, this should be cut to a length of 340mm (don't measure from the plan!). The carbon fibre can be cut with a junior hacksaw, or better, a Dremel fitted with a cutting disk. (Do NOT breathe the dust.)

The 3mm boom now needs to be attached centrally to the 6mm pod and accurately aligned with it. Start by cutting the slot in the pod such that the boom is a good fit. Now cut a piece of 1.5mm balsa to fit the slot and glue in place such that it is flush with the RH side.

Back to the covered building board, pin or weight down the pod, flat on the board, RH side down. The boom can then be epoxied in place with its length supported by scrap pieces of 1.5mm balsa to ensure its correct alignment with the pod. While the epoxy is still fluid, add a piece of 1.5mm balsa to the slot, this should then be flush with the upper surface of the pod. When all of this is dry, add the 0.5mm ply doublers to both sides and fill out the ends of the doublers with scrap balsa.

Next is the motor mounting. Cut out the motor mount but don't drill the hole at this stage. I made my motor mount from 1.5mm epoxy glass board. I bought mine at the same time as the carbon fibre tube. A suitable alternative should be 1.5mm ply.

Drill a 1.5mm diameter hole in each of the motor mounting lugs. Position the motor on the motor mount and mark the centres of those holes on the mount. Drill the mount with a 1.2mm drill. The motor can then be secured with size 0 self-tapping screws. When happy with the motor fit, remove it from the motor mount for now.

The motor stick is 6mm square spruce. Cut this to length, then cut a slot in the end to take the motor mount. This needs to be a firm fit but don't force it in, this may split the spruce. When happy with the fit, position the motor mount and drill through the stick and the mount with a 2mm drill. A 2mm bolt and nut can then be used to secure the mount to the stick but should allow for some thrust line adjustment.

When happy with the motor mounting, the motor stick can be epoxied to the fuselage pod in much the same way as the boom, with the pod flat on a covered building board. Add the ply doublers either side. When its dry, fit the motor mount and motor.

The wing seat is cut from hard 1.5mm balsa. I couldn't work out which grain direction was best, so set mine on a diagonal. Cut out the two ribs, R2 from 3mm balsa and cyano these to the wing seat. Use PVA to glue the wing seat to the fuselage pod, pinning it in place and taking great clear that seat is at right angles to the fuselage. Add the two fillets under the wing seat, these are 6mm sq. soft balsa, sanded to a triangular section.

The wing dowels are cut from cocktail sticks. Drill the fuselage for the forward dowel, glue in place and add 0.5mm ply doublers either side. Leave a pointed end on the rear dowel and it can be pushed into place and glued.

The switch is a 2.5mm, mono jack socket and plug. The socket has three connections. Use a multimeter to find the two that are connected together with no plug in place. Put the plug in, and check that they are no longer connected, these are the two connections you need. Cut the other one off (no mistakes later then). Cut a hole in the fuselage to take the socket and make the 1.5mm ply mounting plate,

with the correct sized hole for the socket. Screw the socket to the doubler, then glue the doubler in place. The fuselage can then be set aside for a while.

Wing

The wing is made from 2mm Depron and formed to a curve by a technique, from an AM article in June 2016, using boiling water. Start by cutting a rectangle 320 x 76mm (again, don't measure off the plan), this is the centre section. Make a template for the tips and cut two of these.

I formed the curve in the wings using a length of 200mm diameter HVAC ducting (bought from eBay). Lay the centre section along the length of the ducting and secure it with lengths of cohesive bandage. You now need to go into the kitchen and put several large pans of water on to boil. The ducting was too long to lay flat in the kitchen sink, so I it set it diagonally across it. When the water has boiled, very, very, carefully and slowly, pour the water over the Depron. You may want to wear protective gloves and eye protection in case of splashes. When it has all cooled, remove the bandage and the Depron. It will spring back a bit, but retain most of the curve. Repeat for the two wing tips taking care that you make a LH and a RH pair.

If all of that seems too much bother then the curve can probably be formed by rolling the Depron around the rounded edge of a kitchen worktop.

The leading and trailing edges are 3 x 2 mm, cut from a sheet of medium, 3mm balsa. In order to glue these in place such that they follow the curve of the Depron, position the edge of the building board along the edge of the workbench. Pin the edge of the wing centre section close to the edge of the building board such that most of the Depron is hanging over the edge. The leading edge can then be placed flat on the building board and be glued to the edge of the Depron using PVA and held in place with pins. When dry, repeat for the trailing edge and then the wing tip sections. Round off all of the leading and trailing edges. All of the wing sections should then be straight and true with no warps or twists.

Cut three wing ribs, R1, from 1.5mm balsa and glue in place on the wing centre section. I used Uhu Por for this, used as a contact adhesive. Apply to both surfaces and leave to dry for 10 minutes before bringing the surfaces together. Used this way the joint is dry almost immediately. Place a steel straight edge along the bottom of the wing and cut off the bottom part of the ribs.

The dihedral is 50mm under each tip, so make up a suitable support of some kind. Also cut the dihedral braces from 1.5mm ply, ensuring that they are the same depth as the thickness of the Depron. Secure the wing centre section to the building board with scraps of balsa and pins. Test fit the tip section, supported at the correct height. The curve in the end of the tip should be correct to match up with the end of the centre section, if not, it will need to be 'tweaked'. When happy, apply Uhu Por to the ends of the centre section and the tip, leave 10 minutes and then bring then carefully together. With the wing tip still supported, cut the slots in the centre section and tip for the dihedral brace. Cutting the slots at this stage rather than earlier ensures that they are aligned. Glue in the brace with PVA or epoxy. Repeat the above procedure for the other wing tip. Remove from the building board and finish the dihedral joints with a small fillet of epoxy between the ribs and the underside of the wing tips.

Keys added to the underside of the wing centre section ensure that it always goes on in the same place. These are made from short lengths of bamboo skewers, split lengthways with the split faces sanded flat, and attached with Uhu Por.

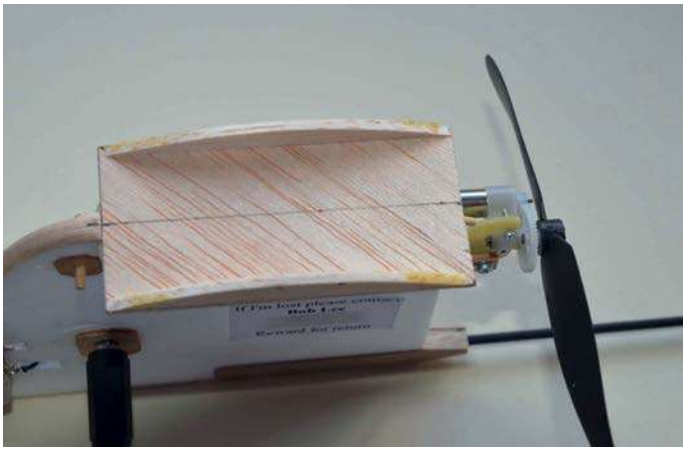
Fin and Tailplane

The fin and tailplane are both made from 2mm Depron, with spars from 3x2mm balsa strip. They are both assembled flat on a covered building board. The fin has a rudder trim tab, made from 1.5mm balsa and attached with fuse wire hinges.

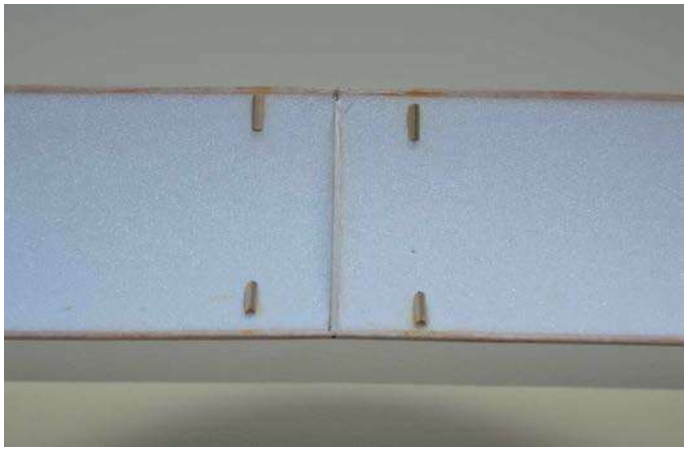
To attach the fin to the fuselage boom, cut some strips about 3mm wide from a soft drinks can. Wrap one of these around an offcut from the carbon fibre, bring the ends together and clamp tight with a pair of pliers. Remove from the carbon fibre, cyano the ends together and trim these to about 4mm long. The result should be a clip that is a sliding, but firm grip on the boom. This may take several attempts to get right. You need two of these.

Cut slots in the bottom fin spar to take the clips and secure with small drops of cyano, keeping the cyano well away from the Depron. The fin should then slide onto the boom. To aid alignment, band on the wing. Position the fin at the correct distance from the end of the boom and rotate it so that it is at right angles to the wing. Check everything several times and when happy, secure the clips to the boom with small drops of cyano.

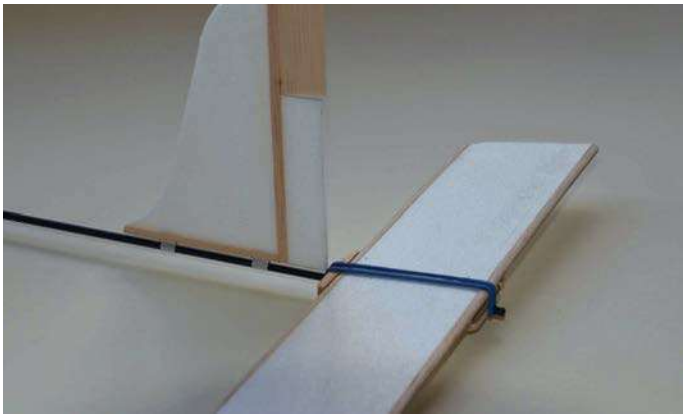
To make the tailplane seats, cut these from 0.5mm ply and then cyano them to some 3mm balsa. You can then cut the balsa to the ply outline. Cut or file a full depth slot in the balsa (all the way to the ply) such that it is a firm fit on the boom. The front seat has a piece of hard 3mm sq



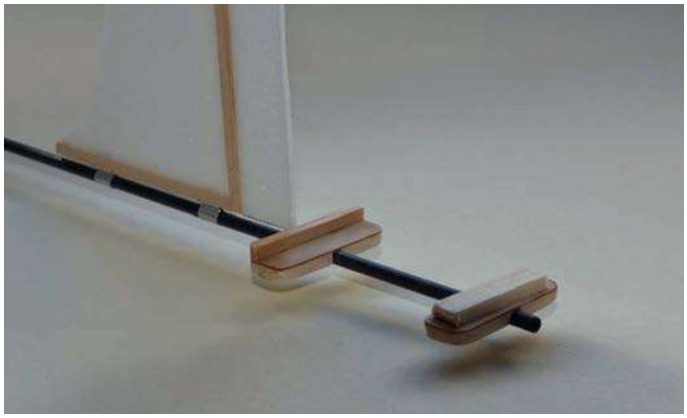
Wing mount (note grain direction) and top view of motor mounting.



Underside of centre of wing – note the keys to ensure consistent location.



Fin (note the clamps that secure it to the boom) and tailplane banded in place.



Tailplane mount detail.

balsa on top to act as a front stop for the tailplane. The rear seat has a piece of 3mm balsa packing on top, which is what I found I needed for a flat glide.

Position the tailplane seats on the boom, then band on the tailplane. Adjust everything such that the tailplane is at right angles to the fin and parallel to the wing. When you are happy, secure the tailplane seats with small amounts of cyano. Add keys to the underside of the tailplane, similar to the ones used on the wing.

Supercaps and Wiring

The next task is the supercap box. Cut the top and bottom lids from 1.5mm balsa and the four sides from 3mm balsa. One of the sides needs slots to accommodate the supercap leads. Cyano, the four sides to one lid and then check the fit of the supercaps. Adjust as required to ensure a good fit. Position the supercaps, one of them with the positive connection uppermost and the other with the negative uppermost. The next stage is very important. Mark the +ve and-ve connections on the outside of the box while you can still see the supercaps. The other lid can now be added. Given that the supercaps aren't being abused in any way, they should outlast the model, so there is no need to access them again. However, just to play safe, when adding the lid, spot glue it in place so it can be removed if need be. Cut the supercap leads down to a few mm and round off all the edges of the box.

The hole in the fuselage pod can now be cut to match the size of the supercap box (you will also need two slots as well for the leads). Don't glue the box in place yet since it's easier to make the solder connections first.

You will need a charging lead on the model with a 3 pin connector fitted. For this I used a 2S balance extension lead which uses the JST XH connector, so buy a couple of these leads. For the wiring to the switch and motor I used 7/0.2mm stranded wire. The wiring diagram is shown in Fig 1 and reflects the layout in my model.

Start by making the series connection between the two supercaps, i.e. +ve on one of them to –ve on the other. You now have, in effect three connections to the supercaps, +ve, -ve and mid. One end of the balance extension lead will have a plug fitted (the other end will have a socket), this is the end to use. Cut the lead about 70mm from the plug and strip back the ends of the wires. This will be the charging lead on the model. Prepare two lengths of the 7/0.2mm wire for the motor connections (leave these overlong for now) and strip them back. You now need to connect two wires to the +ve supercap connection, the balance lead and the motor lead, so twist the two together and solder to the supercap. Repeat for the –ve supercap connection. Connect the other wire from the balance lead to the supercap mid. Lengths of heat shrink sleeving make the joints look neat.

Test fit the supercap box in the fuselage pod. The charging lead should lie alongside the fuselage during flight. Adjust if need be to achieve this. When you are happy, glue the supercap box in place.

The +ve lead from the supercaps goes to the motor via the switch, the –ve lead goes directly. Before connecting the motor however, you have a decision to make. The prop is a GWS 5 x 3 and you can either use a tractor (normal) prop or a pusher (reverse prop). If you use a tractor then you have to reverse the motor connections (motor red wire to the supercap –ve), for a pusher, then wire it normally. Either way, the prop needs to go on 'backwards', i.e. the lettering facing the front of the model. I think there may be a bit of a taper in the hole in the prop, I had to tease it out a little with a drill to make it fit this way round.

I used a scrap of stripboard to make the connections to the motor (see photo), which is neat and makes the motor easy to change. Otherwise, just air wire and sleeve the connections. Small pieces of 3mm sq balsa serve as clamps to keep the wiring neat and against the fuselage side.

Charging

In earlier AeroModellers (April & May 2018) I discussed supercap charging and described a simple charger using a diode to drop the battery voltage. Since then I have had some printed circuit boards made up and can supply a limited number of assembled chargers. If you wish to purchase a charger then contact me on lee_bob2@yahoo.co.uk

The charger above does have a number of advantages in that it's 'kind' to the batteries and supercaps and has LED's to indicate progress. However Fig 2 shows a simpler charging arrangement that can be used. You will need two battery holders, to take two AA batteries each. You need two (rather than a single 4 x AA holder), since you need easy access to the mid-point. The lead from the batteries to the JST socket can be the other end of the balance lead that you cut for the model charging lead. Be sure to wire this such that all the polarities are correct, as in Fig 2.

There are a couple of 1ohm resistors shown in Fig 2, these are optional, but adding them limits the very high currents that can otherwise flow and is kinder to the batteries. The resistors will get warm during charging, this is expected. From the flying notes that follow shortly, you will see that it's unlikely that you will be charging the supercaps to the full 6v total that would

be the case if you just left it to fully charge. The model produces long flights on a partial charge and doesn't need the full charge. For this reason it is very useful to be able to monitor the voltage during charging. If you have a multimeter then you can modify the second balance lead that you bought, as shown in Fig 3, to go between the charger and the model and connect to the multimeter. The alternative to monitoring the voltage is to time the charge.

Flying

The model should balance on, or close to the point shown on the plan, if not then add nose or tailweight as appropriate. The flying surfaces should be true to each other, correct if not the case. The motor thrust line should be parallel to the fuselage boom.

Start with a test glide with the rudder tab set centrally. I did the test glides with the prop removed. You should get a fairly flat, straight glide, if not add packing at TE of the tailplane to correct a dive (unlikely) or remove the packing to correct a stall. When happy with the straight line glide, add some right rudder until you have a glide with a lazy turn to the right.

Time to add power. To avoid a flyaway, I suggest you don't start with a full charge. Make sure that the jack plug is inserted (to switch the motor off), connect the charger and charge to 3V. Remove the charger and when ready remove the jack plug and launch. The result will probably be a powered glide to the ground. Try again with a 3.5V charge. This should give a short climb with a long decent. Move up in 0.5V steps. On my model, a 4.5V charge gives flights of 1 ½ mins. If you are timing the charge then I suggest starting with a 30 second charge and move up in 15 second steps.

Due to the nature of the supercap discharge curve, you get a long cruise after the initial climb so it may take longer to descend from height than you expect. For longer flights I suggest adding a DT. As the charge is increased you may have to adjust the thrust line.

The Farad has proved the point that series connected supercaps can power an outdoor model with a good level of performance. It's easy to build and fun to fly. ■

FIG. 1. *Wiring for the Farad.*

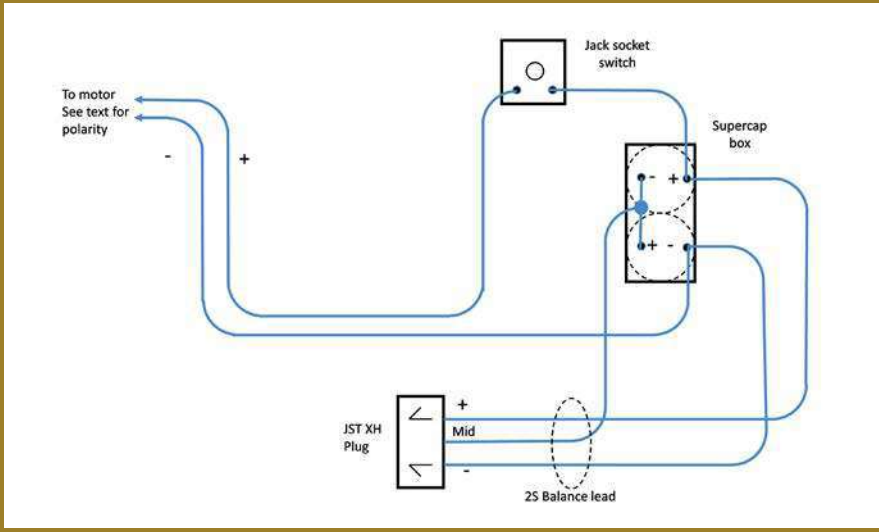


FIG. 2. *Simple charger use two of AA x 2 battery boxes.*

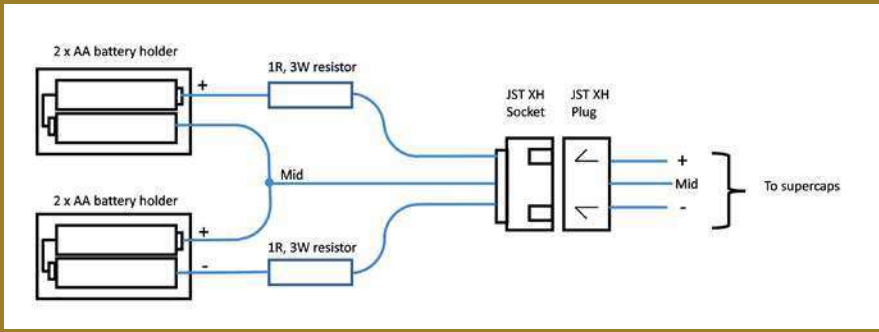
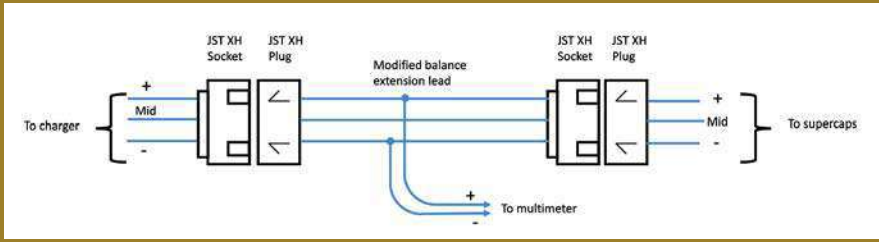
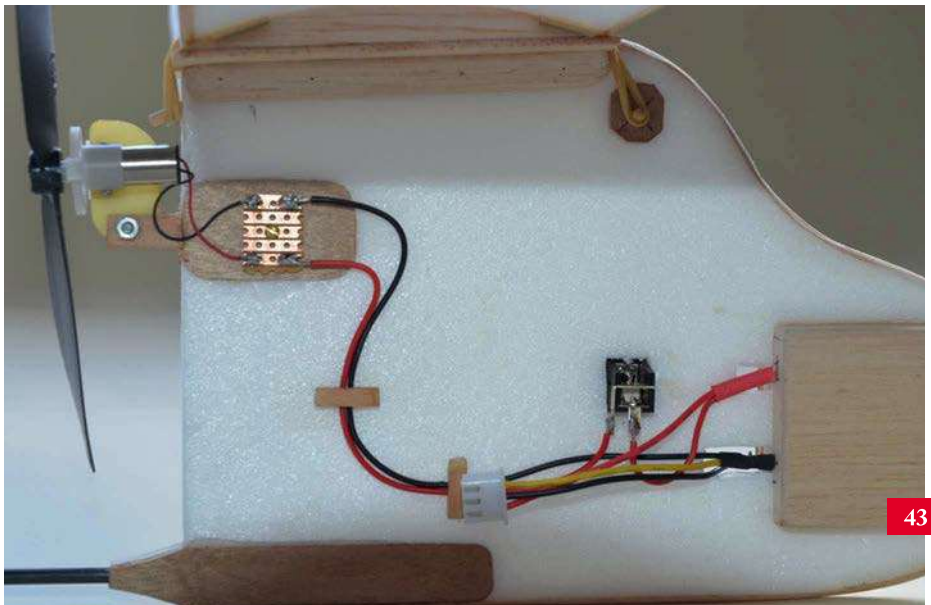


FIG. 3. *Using a balance lead and multimeter to monitor the charge voltage.*





General view of the wiring. Note the charging lead and the simple balsa clamps to keep it all tidy, and the stripboard used for motor connections.