PCB Drilling Machine (4)

Part 4: mechanical construction

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Now we come to the mechanical assembly of the PCB drilling machine. The components come ready-made: all that is needed is a little care in fitting them together.

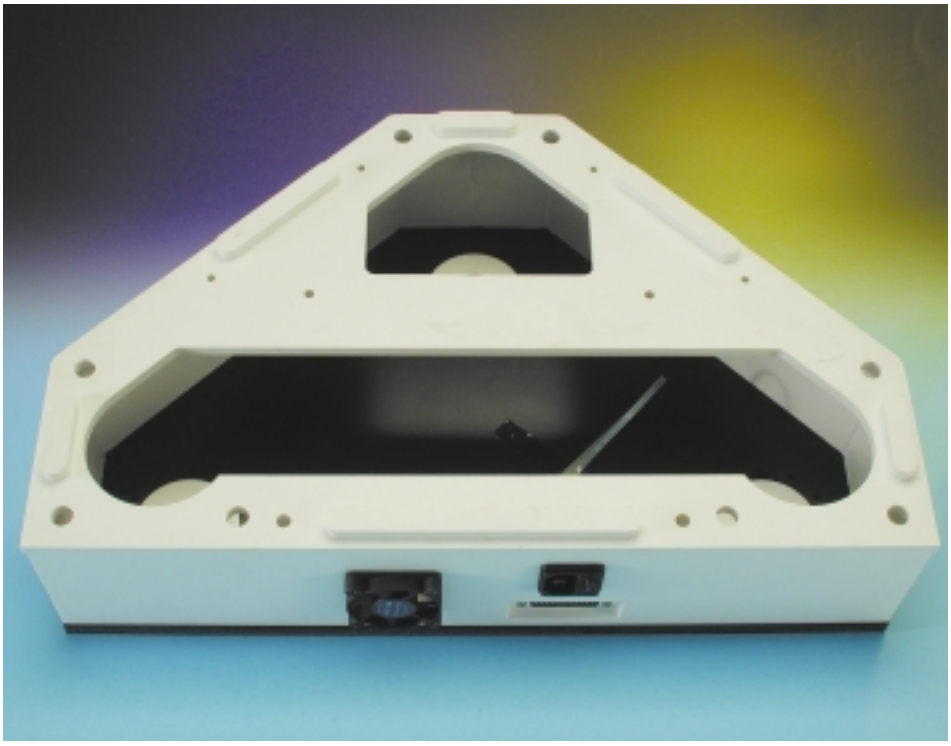


Figure 1. The machine enclosure, with some parts already fitted.

The kit of mechanical parts for the PCB drilling machine consists of ready-drilled and machined parts that simply have to be fitted together. All the parts required to build a machine with one tool arm are included in the kit, even down to the necessary screws and glue. Not included, however, are any drills or milling tools that you may want to fit to the machine.

A toolkit suitable for constructing the machine can be ordered from Radix. It contains all the required tools in the correct sizes: slotted and cross-head screwdrivers, box spanners, open-ended spanners, Allen keys, brushes for removing swarf, cleaning cloths, side cutters, blades etc. All the tools are of the highest quality. By purchasing the complete set you can be sure that you will always have the correct tool to hand during construction.

All the components - except those that are glued together, of course - can be subsequently disassembled, and so the exact order of assembly is unimportant. However, the sequence suggested below has been found to be the simplest.

Preparation

All the components which are to be glued together are either slotted or have milled tongues that fit into the slots. All the parts are supplied perfectly free of dirt and grease, and therefore need not be cleaned. Unnecessary handling of the areas to be joined attracts dirt and grease which make the glue much less effective.

After milling a certain amount of swarf and other material may remain on some edges and corners, which must be removed. Vigorous brushing will quickly remove the unwanted material. Alternatively, you can use compressed air at at least 8 bar, but only if you are absolutely certain that the air is perfectly free of oil. If you do get oil on the parts, you will find it impossible to clean them adequately, and there is no point in even trying to glue them together: you will have to order a new kit of components. The best way to remove unwanted material from the parts is with an ordinary stiff toothbrush (although not one with a flexible head!). Thoroughly brush the corners and joints until all the swarf is removed. Mould flash may remain around some parts: this can be cut away using a craft knife.

You will need an absolutely flat, perfectly clean working surface at least 50 cm square. A useful tip is to use an (undamaged) offcut of plain-coloured plastic-coated kitchen worktop, which can be bought at the DIY store for a pound or so, or perhaps even for free. Offcuts of fibreboard, for example, are generally not suitable, because they are generally warped.

Step 1: Gluing the machine enclosure

We start by gluing the white machine base plate to the three side cheeks. These parts are large and thick, so we can use them as a gentle introduction to the technique of gluing a concealed joint. All the other parts are glued in exactly the same way. After this gentle warm-up, we will be able to move on to the rather fiddlier job of gluing the drilling arms.

Clear away all the drinks and greasy foods from the working area. Put away everything that is not needed for the gluing operation and anything that might distract you while working. Your hands should be clean and as free of grease as possible. Best (although somewhat uncomfortable) is to wear light working gloves made for exactly this purpose, which keep dirt and grease from the objects being glued.

As a trial, bring together the three

All about glue

The degree of rigidity and stability that can be obtained with a glued construction is significantly higher than can be obtained with screws. The assembly is as strong as if it were made from a single piece of material. All joints must be left to dry for at least 24 hours to ensure a rigid construction. Assembly proceeds in two stages: gluing and then screwing, and should therefore take at least two days.

'Gluing' is not really the correct term here: it would be nearer the mark to say that the plastic components are 'welded' together. The process can only work if the glue and the plastic are perfectly compatible with one another.

Some chemicals in glues tend to dissolve certain plastics. Often this effect is not desirable: if you have ever accidentally tried to clean a plastic surface with an inappropriate solvent, you will know what we mean. Acetone, although excellent for removing grease, dissolves many plastics including Plexiglas (a.k.a. perspex).

Acetone alone is not viscous enough to be a satisfactory glue, and it evaporates too quickly. Neither, unfortunately, does it dissolve PVC (polyvinyl chloride).

The plastics we wish to bond are polystyrene (PS) and various polyvinyl chlorides. Gluing PS to PS or PVC to PVC presents no difficulties, as specialised glues are available for each. However it is difficult to bond one to the other: PVC was developed to be resistant to practically all chemicals, including those used for gluing. After hundreds of experiments with fourteen different types of glue we finally came to the conclusion that there was no single suitable glue for our application.

However, we did find a glue composed of seven chemicals that can bond PS to PVC. If the truth be told, it is a rather unpleasant mixture and we were rather surprised that it wasn't an explosive! Delivering such a mixture creates some problems since there is practically no type of plastic suitable for making a container for it.

Fortunately our problems were solved when a company brought out a new glue which meets our requirements in terms of viscosity, spreading characteristics and tendency not to drip or form filaments, and which can bond PS to PS as well as PS to PVC.

More than enough of this glue is included in the kit to build a drilling machine with one tool arm. Be generous with the glue, since using too much will not do any harm. To reiterate: use only the supplied glue, even if you see some cheap-looking alternative 'suitable for most plastics' in the model shop or DIY store. Other glues are simply nowhere near as strong.

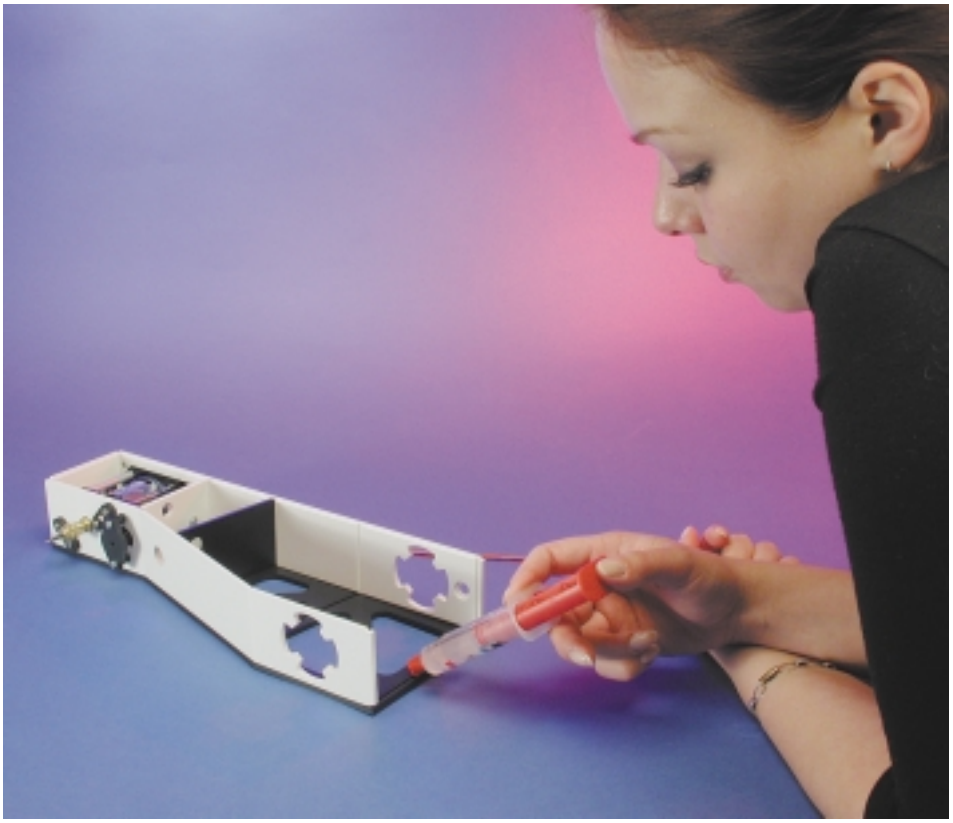


Figure 2. In a single motion, draw out a line of glue along the full length of the joint.

Figure 3. Partially-glued tool arm with drill motor and solenoid already fitted.

side panels, the white base plate and the black top plate (**Figure 1**). First put the base plate down on the working surface with the joints facing upwards and then guide the rear panel into its slot. Hold the first side panel at a slight angle and fit it first to the slot in the rear panel and then into the slot in the base plate. The side panel is now held at two points. Repeat the procedure with the second side panel.

Now fit the black top plate to the three side panels. With a little toing and froing the top plate will seat on the side panels. Check with a ruler that the enclosure is the same height everywhere and hence that the top plate is indeed properly seated.

Now pick up the whole enclosure, holding together the base plate and top plate and inspect it all around and from inside. It should feel solid and stable.

Before reaching the point of no return, go through the following checklist:

– Have you removed all unwanted material and are the joints clean?
– Do the parts fit together smoothly without jamming?
– Do the side panels fit cleanly without fouling the rear panel?
– Imagine that there is already glue in the joints and look at where your hands are. How far are your fingers from where the glue will be?

When you are convinced that the parts fit as well as possible, you can begin gluing. Otherwise, take the assembly apart and try again, until everything can be fitted together smoothly.

So much for practice; now for the real thing. Lay the five parts on the working surface. In a single motion, apply a line of glue along the full length of the joint in the rear panel, as shown in **Figure 2**. Fit the rear panel LOOSELY and without force onto the joint in the base plate. It is better if the rear panel does not stand perfectly upright but rather leans slightly backwards. Apply glue also to the groove in the first side panel and to the groove which will fit with the rear panel. Fit the side panel along these joints, again starting at the rear panel. Proceed in the same way with the other side panel.

Offer up the top panel, **without** glue, until it seats properly. This is just to hold the assembly square: it will be glued later. Before finally gluing the lid to the white parts of the machine enclosure, we will fit some of the parts inside. In principle this could be done after the enclosure is finished, but the job is easier without the lid fitted.

Leave the assembly for at least an hour without moving it, so that the glue can set.

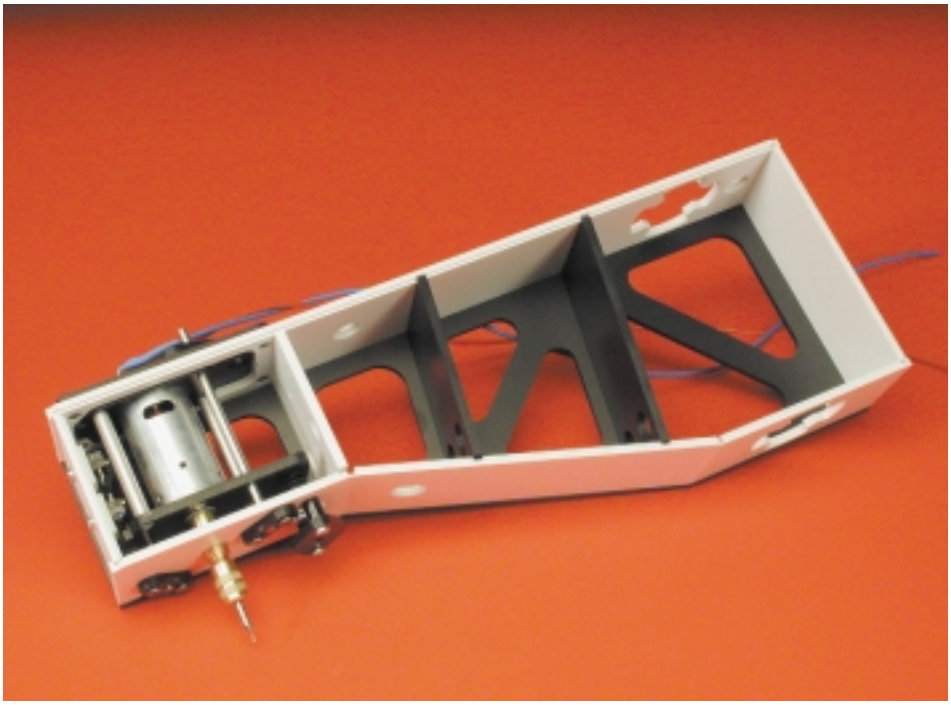


Figure 4. Tool arm, immediately before gluing of second side panel.

STEP 2: GLUING THE TOOL ARM

Take the nine parts for the tool arm

out of their packaging: two black side pieces, a white base plate and a white top plate, and three white and two black reinforcing side pieces. As before, clean the parts with a brush. Before putting the parts together, ten M3 nuts should be fitted into the holes provided. It is easiest to put the nuts on the table and push the plastic sheet down on them. The photograph (**Figure 3**) shows how these are used later to attach the spindle/magnet unit; in the procedure we are following here, we fit only the nuts, leaving the drilling head to be fitted afterwards.

Place one of the black side panels in front of you, preferably with the straight edge at the back. Fit the white top plate. All the joints here use the same tongue-and-groove arrangement with the other panels as the rear panel in the machine enclosure. Fit the two small external side pieces, again beginning with the joint with the top plate, proceeding to the side plate and finally with the three interior panels. Fitting the base plate, which is fixed at two points, begins at one side: then follow around the side panel. Ignoring the drilling head for the moment, the arm should now appear as shown in **Figure 4**.

Now — surprise, surprise — fit the other side panel and seat it firmly by pushing it gently to and fro. Even without gluing, the arm is surprisingly stiff. If you are happy that everything is fitting smoothly, proceed to gluing; otherwise, take it apart and try again.

Try not to get glue on your fingers, or else you will leave fingerprints all over the arm enclosure. If this does happen, the best thing to do is let the glue dry and then scrape it away with the craft knife.

When all nine parts of the arm are glued together, it must immediately be checked for squareness. Lay it on each side in turn on the flat working surface. If it is not true, push down hard on the assembly to force the parts together.

As we shall see later, the construction of the arm includes a means of ensuring that the tip of the tool (and that, after all, is the only point that matters) can move in a straight vertical line. Faults in the gluing which make the arm out of true can be compensated for, but of course this is best not relied upon.

Construction of the arm will take a good hour or so; it is a good idea to take a break at this point. Next we shall turn our attention back to the black top plate of the machine enclosure, which is sitting, unglued, on top of the side pieces. We lift the top plate carefully off and put the glued parts to one side.

Step 3: Fitting the mechanical parts to the enclosure lid

Take the pack containing the four cone bearings and the two packs labelled `Mechanik 1' and `Mechanik 2' out of the packaging. These comprise a complete set of mechanical parts for one axle (**Figure 5**). The cone bearings consist of two separate parts, an outer race and an interior part with the rollers. The bearings are rather oily: this oil should be cleaned away except on the race and on the inner part, so that only the moving parts are lubricated. Push two of the races into the holes in the enclosure top plate, one for the turntable and one for an arm. Push the bearing some distance through the hole so that about half a millimetre protrudes on the other side.

Fit the long M4 countersunk screws in the four 4 mm holes in each race, each with a precision washer. Now turn the top plate over. As long as the screws do not fall out, you should now see the ends of eight screws, onto which you should fit the 10 mm thick cable supports. This is where the connecting cables for the tool arm will be run.

Press both remaining races into the two remaining black bearing flanges and as before push them through so that about half a millimetre protrudes. The bearing flanges are fitted over the top of the cable supports. Now fit a precision washer and an M4 nut on the end of each screw. As the nuts are tightened each race will be lifted slightly and brought into exact alignment, flush and square in its hole. Now slacken the nuts by a quarter to half a turn. The nuts should not rattle, but the components should now be able to move slightly from side to side. The whole assembly is shown in **Figure 6**.

Figure 5. The cone bearing consists of two components: an outer race and an interior part with rollers.

Now take the pack with the short aluminium shaft out of the packaging. Here you will also find a neoprene ring, three curved black securing pieces, a white plastic securing washer, and a large plastic sheet, with three M6 screws, to which the turntable will later be fixed.

Screw the large plastic sheet loosely to the aluminium shaft so that it has about 1 mm of play vertically.

From the other end of the shaft fit the interior part of a cone bearing and pass the shaft from the top side of the enclosure top plate into the race.

Fit the second interior part of the cone bearing to the end of the shaft now protruding under the top plate, and the neoprene ring immediately behind it. Behind the neoprene ring fit the white plastic securing washer, and the three black plastic securing pieces will fit exactly in the groove in the aluminium shaft. Now fully tighten the three screws in the large plastic sheet and check that the securing pieces are not bending the securing washer (**Figure 8**).

The parts in the pack with the long alu-

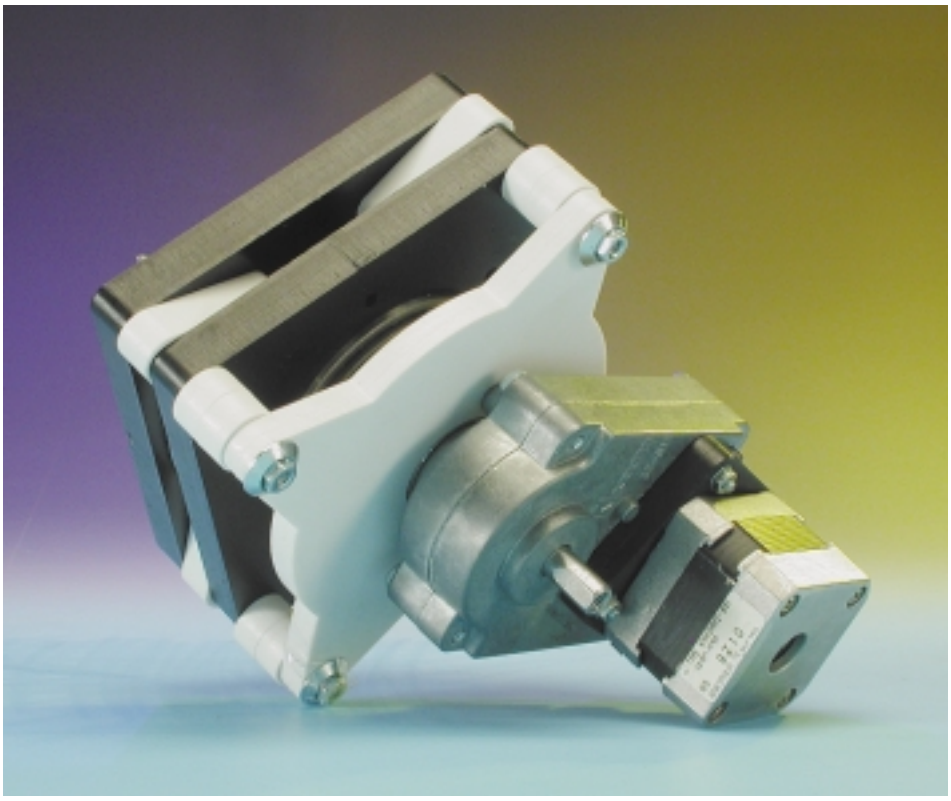


Figure 6. The motor is connected to the gearbox via a flange screwed to each, and the star-shaped drive fixing is screwed to the output of the gearbox.

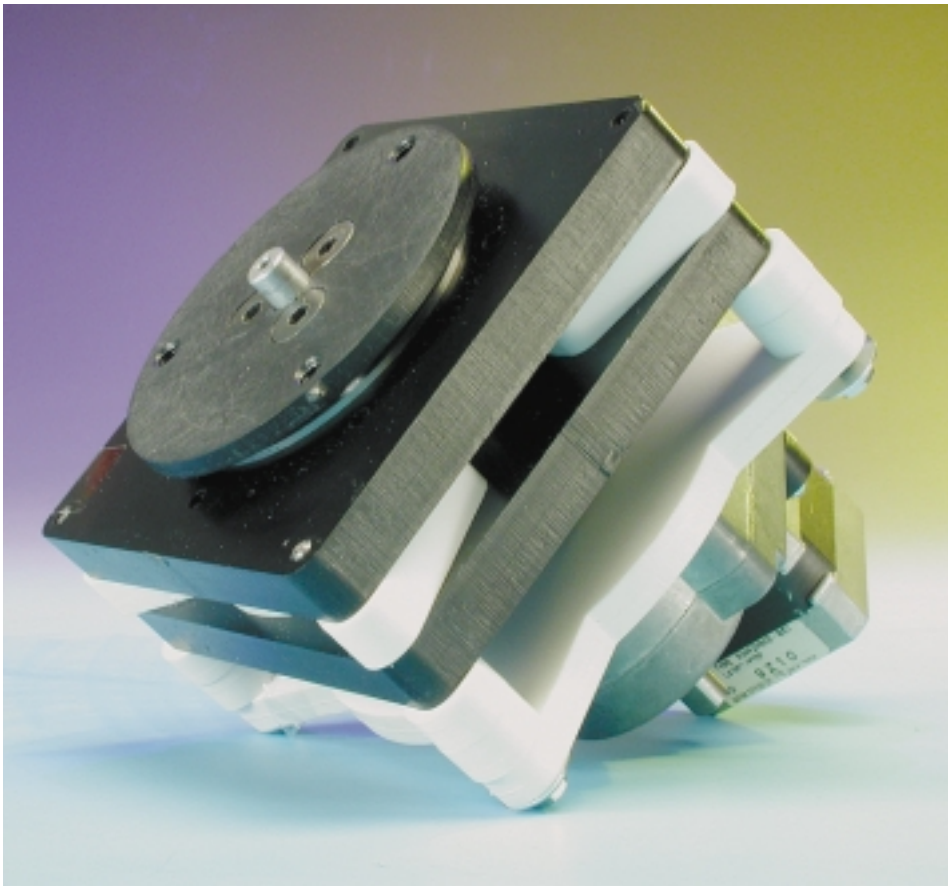


Figure 7. Completed drive unit viewed from the opposite side.

minium shaft are assembled in exactly the same way, except that here there is no large plastic sheet or attached screws.

Turn the two shafts gently to and fro until they move smoothly. In this way the bearing flanges, which are still loose, will settle into their optimal positions. You can also push gently on the bearing flanges themselves and then, by turning the shafts, find the best position. The flanges can then be fully tightened using a spanner.

Looking down on the bearings you can see four open holes, in each of which an M4 bolt (from pack 3) should be fitted. The nuts and washers from this pack will be used later for fixing the drive unit.

All the above work can of course be carried out with the top plate fixed to the rest of the enclosure. However, it is much easier with the enclosure open, and so it is only now that we glue the lid to the enclosure. Apply glue to the joints on the side pieces of the enclosure and fit the lid, ensuring it is properly seated.

All the gluing has now been done. Leave the enclosure and tool arm assemblies to dry for a day.

Step 4: Building the motor drives

The two drives are built identically. They consist of a stepper motor and a gearbox, which is sealed against ingress of dirt: the gearbox should not be dismantled. To connect the motor and the gearbox we use a coupling (in pack 4) which is fixed to the motor with four M3 screws and to the gearbox with two M3 screws (**Figure 9**). Screw the star-shaped drive fixing firmly to the output of the gearbox with four M4 screws. The now complete drive unit can be fitted from below into the machine enclosure, the four bolts protruding from the bearing flange fitting exactly into the holes in the drive fixing. The whole assembly is now firmly screwed together using the nuts and washers from pack 3.

Assembly of the drive is now complete.

Step 5: Building the drill lift unit

We now turn to the Z-axis drive, i.e. the lift unit for the drill. All the required components are in pack 5. First the drill motor is fixed to the longer of the two black plastic plates from the shaft side using two M3 screws. On the motor side the two long pillars are fixed to the plastic plate with M3 screws. The second black plastic plate is fitted over the motor housing from behind the motor and fixed firmly using the pillars. The two precision machined hardened steel shafts are fitted through the 4 mm holes drilled in the plastic plates and positioned so that they protrude equally above and below (**Figure 10**, here shown with drill motor but without lifting solenoid).

Before the unit can be fitted in the arm, the solenoid and the two limit switches must be screwed on. Then the unit can be lowered into the arm so that the drive shaft of the motor protrudes from under the arm. The arm assembly can now be closed off by fitting the top plate. The screws on the top plate must be tightened fully so that they do not shake loose in operation. Although the unit looks finished, the lift mechanism will wobble alarmingly in the arm. This play is reduced by fitting bearing blocks (to be found in pack 6) above and below the shafts now protruding from the arm assembly: fix these loosely at first using two M3 screws with washers (see **Figure 11**). A spring (from pack 6) is now fitted in the hole provided in the underside of the arm, and the hole closed off by fitting the cover with two spacers and screws. Check that the spring is seated properly in its recess, and push it into position if not. With the chuck attached to the motor shaft the arm assembly is complete (**Figure 12**).

Step 6: Fixing the arm and turntable

Fit the arm to the long 30 mm aluminium shaft and turn it until the 10 mm transverse hole in the shaft points in the direction of the motor spindle on the arm. The wiring will pass through this hole down into the machine enclosure. The arm is fixed to the shaft using a tapered grip, which will hold the arm absolutely rigidly to the shaft when the shaft top plate is screwed down.

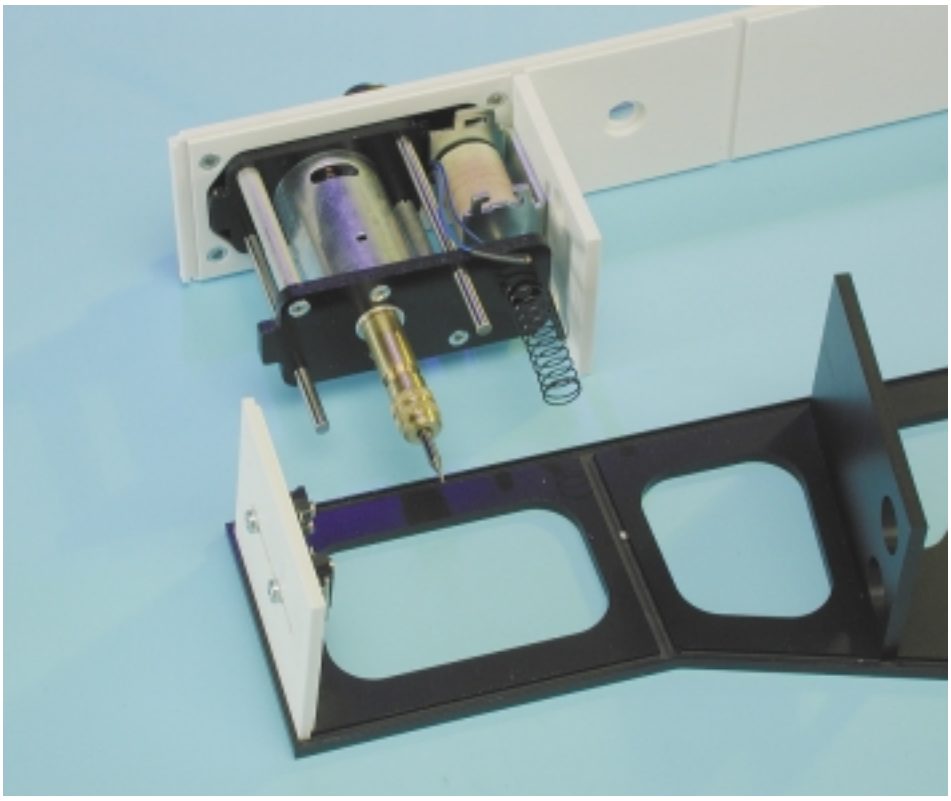


Figure 8. Fitting the drill lift assembly.

The last major component, the turntable, must be carefully and evenly pressed down over the centring peg found at the end of the aluminium shaft onto the circular plastic plate and screwed down firmly using M6 screws. The small white reg-

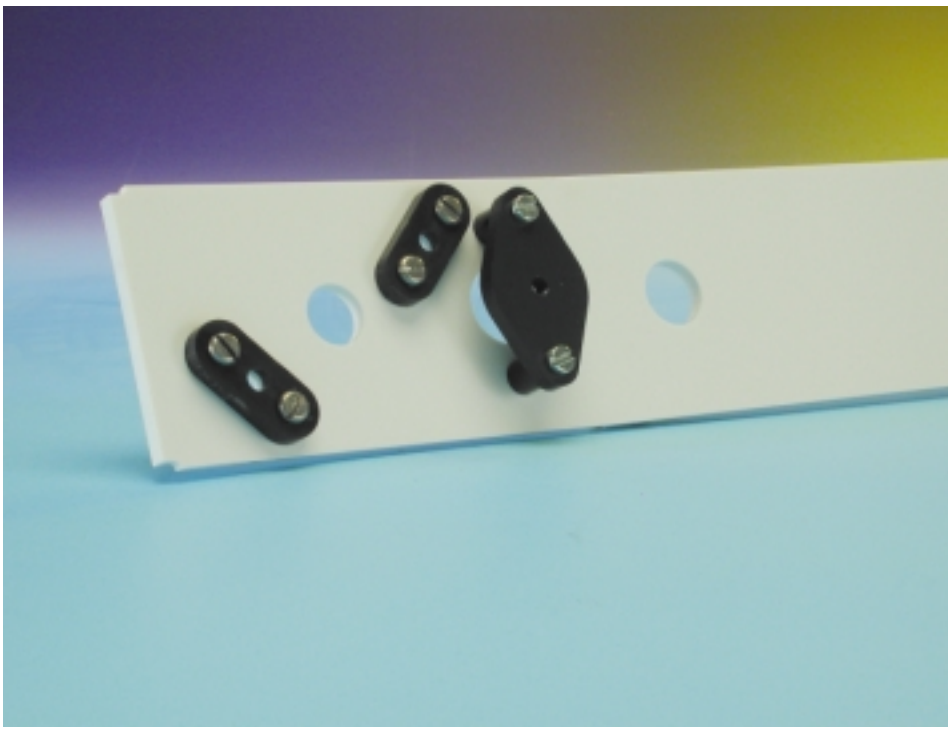


Figure 9. Bearing blocks and spring hole cover on the underside of the arm. There are two identical bearing blocks on the upper side.

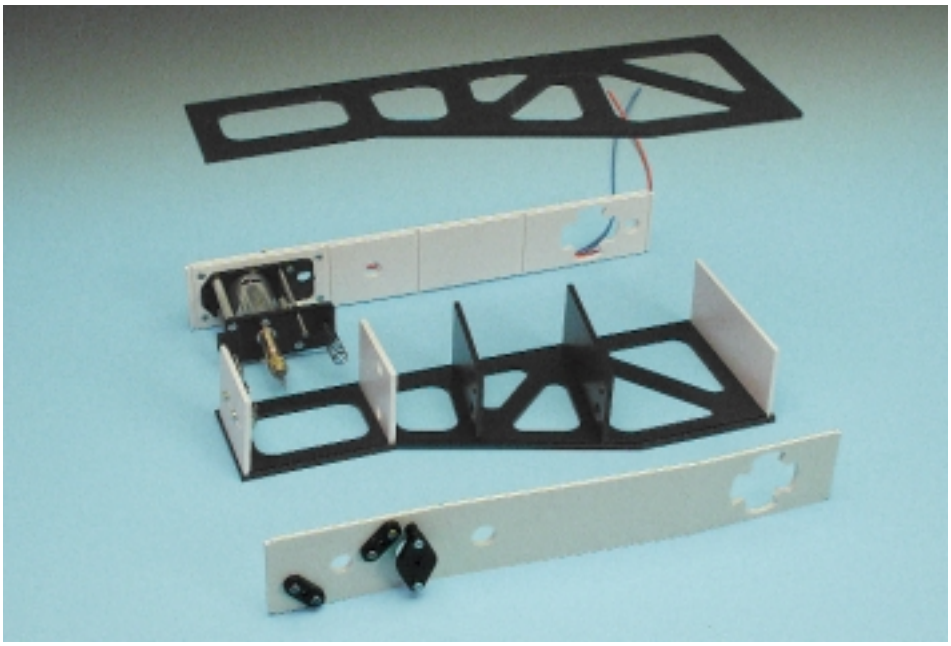


Figure 10. The parts of the arm laid out as they are to be glued. The lifting solenoid is not shown.

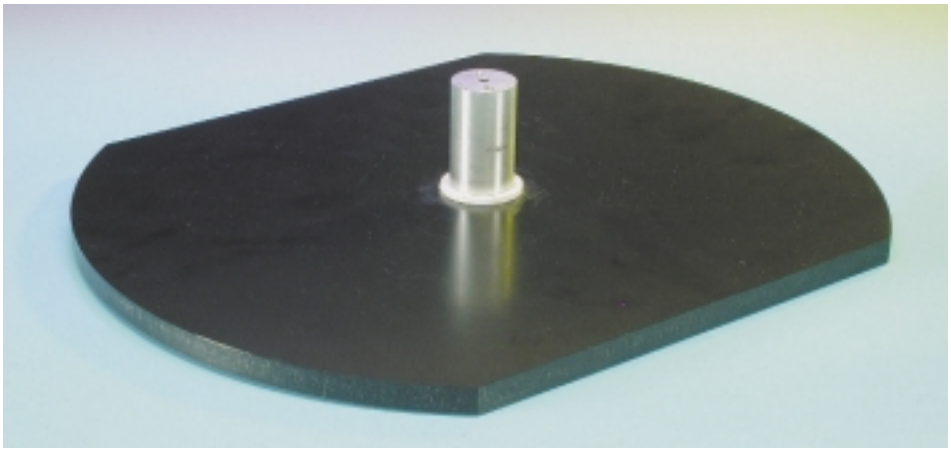
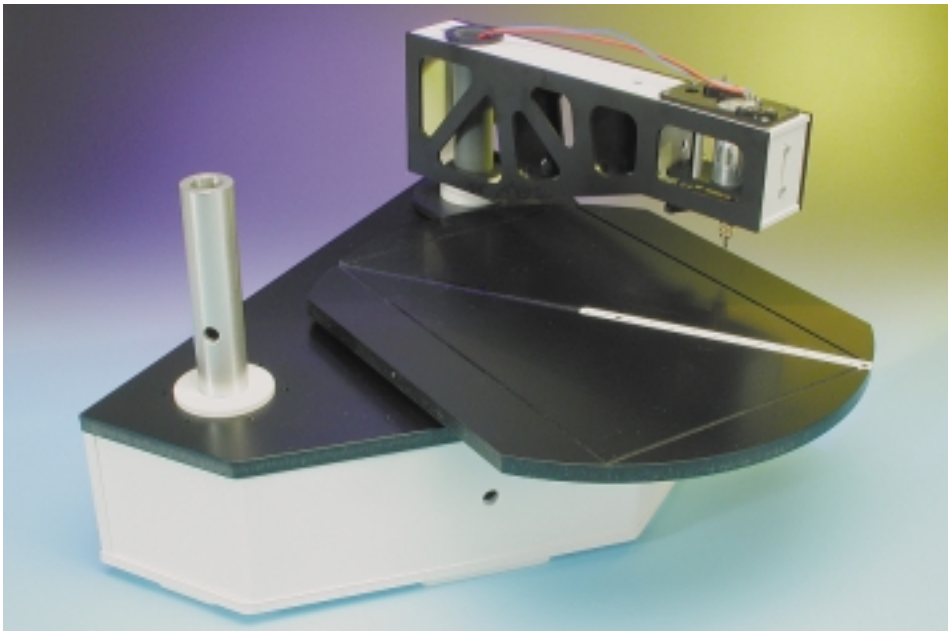


Figure 11. Turntable and axle.



istration guide, with 13 holes, is pressed down into the long slot in the table until the edge is flush with its surface.

The relative position of arm and turntable is not important as all the components are moved to the correct positions by software during commissioning of the machine: at this point the (still loosely-fitted) drill lift mechanism is also adjusted.

Step 7: Wiring

Now we come to the point where the arm wiring must be installed. A two-conductor cable is soldered to each of the two limit switches, the drill motor and to the solenoid, and the wires are run back to the hole in the shaft. Feed the cables down the shaft until they appear in the machine enclosure directly next to the cable supports. The cables, already cut to length, are of course included in the kit of parts.

Now you can fit the connectors to the end of the cables (it is rather harder to feed the cables through the shaft with the connectors already attached!) There is no need to install the electronics in the enclosure yet: place the controller board to one side next to the enclosure while commissioning the machine. This makes things much easier if there is a fault in the circuit. When the electronics are proven to work, the board can be screwed into the machine enclosure. The PCB drilling machine is now finished and should look just like the final photograph.

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All that remains is to discuss the commissioning of the machine and to describe the software. We will conclude the series by describing the process for getting from PCB layout program to finished drilled circuit board.