Building a Long-Bed Inverted Scanner for Digitizing Biological Collections

… being an adventure in hardware hacking

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Motivation

We are faced with scanning approx. 10k adult Odonate samples once we finish transferring them to modern transparent envelopes with the collection data. Doing this with the scanner we had, a standard letter sized model, would mean scanning 4 insects at time. Even large herbarium scanners would only accommodate about 10 insects. This project will show you how to create a scanner that scans approx. 9" x 48" (if it works). There are third-party software drivers that will allow you to set any length of scan, so the problem boils down to hardware.

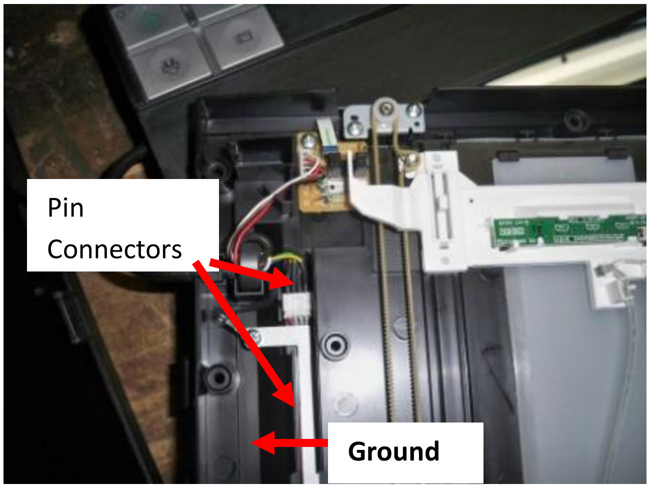
Step 1: Voiding the Warranty.

In this step I remove the lid and integral film scanner, open the case, and see what's inside. Get a large work area cleared and assemble: small flat head screwdriver, medium sized Phillips screwdriver, sealable containers that you can write on for miscellaneous screws and parts (no, you will absolutely not remember where all these parts obviously go).

Slide the white plastic sheet off the bottom of the lid. This will expose a total of 11 Phillips screws holding the lid together.

Unscrew all of these and slowly lift the lid pieces apart. The lid will still be attached to the base by the hinge, unlike in the photo.

You will now be able to see the electrical connections to the film scanner—this is what you need to disconnect. There is a black ground wire connected with a screw and two pin connectors.



A small flat-head screwdriver can be used to carefully pry the pin connectors loose. If you don't want to lose screws, put them back in place right away, starting with the ground wire screw.

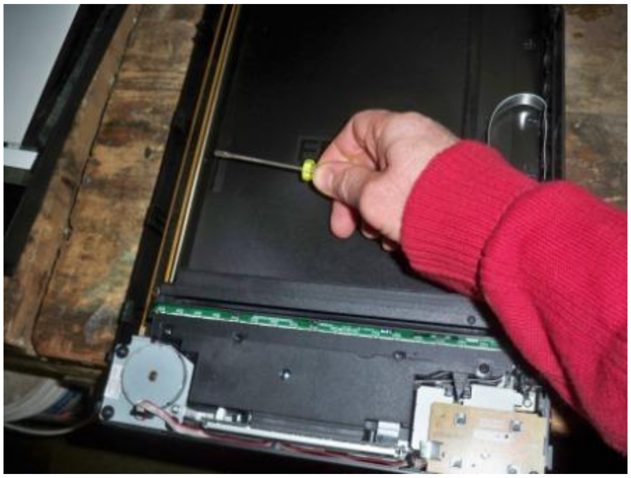
Have a quick look at the mechanism used to move the scanner head. There is a stepper motor running the gears. This is similar to what we will face in the main body of the scanner as well. One challenge is going to be to find a belt the correct size.

At any time, you can remove the hinge from the lid by extending it all the way out, opening the lid all the way, and pressing the lid and body towards each other. There are two screws holding the body together. Once these are undone you can pry the body apart a bit and slide the hinge out.

The only other things holding the two parts of the body together are two plastic taps on the side of the body opposite the two screws. If you’re careful you may be able to separate the halves without breaking them. I was not.

Now you can see all the important parts we need to salvage: the stepper motor and gears (lower left), the circuits and connections (lower right), and the scanner head (left-to-right bar).

We will replace this metal bar with one much longer. First we need to get a very precise diameter measurement. You can remove the drive belt by unscrewing the gear housing at the far end, but be careful to note how it is threaded through all the gears and tensioner first.



You have now gained access to the parts you will salvage from the original scanner, and have some idea of how it works.

Step 2: Building the New Housing

We in West Lafayette, Indiana, USA, are fortunate to have an excellent plastic supply and fabrication company (Meyer Plastics) with a great staff this is always ready to help out with strange orders. They took the time to help me think through the materials for the body, and even demonstrated how to best glue up the parts.

Take careful measurements of the inside of the case depth, width, and desired length, give yourself a bit of extra room to these dimensions, and work outwards from there. You will need some extra depth for the glass attachments. I went with thick plastic to have strength and inertia. Most of the body is built with black plastic. Any color is fine but you want it to be opaque to reduce light getting in. I left one side part and the top cover clear so that I can see what's going on while doing initial testing. This can always be made opaque with Crylon Fusion spray paint.

My initial parts list, based on starting with an Epson Perfection V300 Photo scanner:

3/8" clear acrylic:

50_1/2"	x	1_9/16"	x1	main body, front
10_9/16"	x	1_9/16"	x4	main body, inner supports
51_1/4"	x	11_5/16"	x1	main body, top

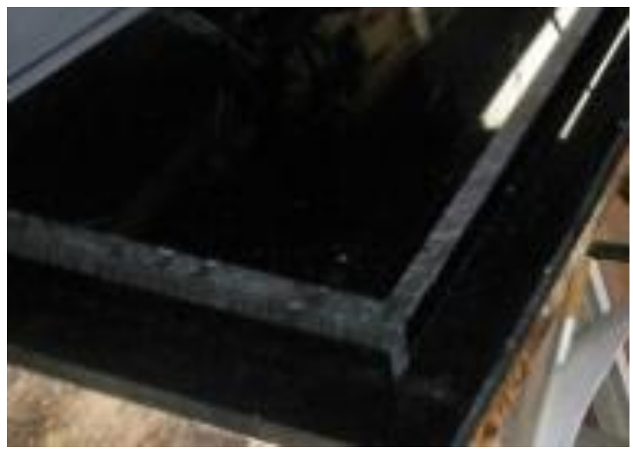
3/8" black acrylic:

50_1/2"	x	1_9/16"	x1	main body, back
11_5/16"	x	1_9/16"	x2	main body, sides
53_1/4"	x	13_5/16"	x1	base, bottom
50_1/2"	x	7/16"	x2	base, front and back
11_5/16"	x	7/16"	x2	base, outer ends
10_9/16"	x	7/16"	x4	base, inner supports

It is possible to brace the new longer guide bar into the housing so it will not move. I had one made that had the same small groove around the circumference near one end to slot into a metal bracket to reduce movement. This should be either stainless steel, or keep it oiled to prevent rust. The diameter must be exactly the same as the old bar or the scanner head will wobble.

Dry-assemble the pieces for the base and ensure measurements are correct. Use a large carpenter's square to ensure all angles are 90°. Use a scribe to score position guides into the bottom piece. Glue pieces one at a time using a fine-tipped syringe to add glue to the corners of pieces sitting on the base; the glue will wick into the join. As 3/8" is a good distance, I did this on both sides. Only do this with the lower piece horizontal to ensure the glue doesn't flow downhill.

I used a larger base than necessary, with a 1" lip around the outside, to allow the final scanner to be easily clamped to a table top. For some designs this will not be necessary, but with the heavier upper piece swinging up and back, I wanted a rock-solid base. The base is quite thin, so that biological specimens up to approximately 7/16" can be put into it and not be crushed when the main scanner body is lowered onto them. Adjust this for thicker/deeper specimens, but be aware of the scanning range of the scanner head you are using. This will be a trade-off between the size range of specimens it is possible to scan, and the depth at which the scanner is not able to get sharp images.



I also used a double wall in the base design at both ends to add some additional strength. This may not be necessary with plastic this thick, but it will keep those joints bomb-proof, and create a very strong base to build upon.

The frame for the upper scanner body is glued together in a similar manner. Be sure to do this on a very flat surface and again check all corners for square before and during gluing.

You can see here the one side that I left clear to observe test runs.

The next step is to very carefully measure the inside dimensions of the main scanner body and order a sheet of glass to fit into it. It should be about 1/16" smaller in each dimension, and be free of any scratches. While you are waiting for this to be cut, prepare the brackets that will hold the glass in place. At the corners of the main body, on only one side (which will become the lower side) use a Forstner bit in a drill press to drill out some shallow pits that do not quite reach the outside. You will be adding a metal plate between these.

Using an appropriately sized drill bit, drill partway through the sides of the main body in approximately the center of each pit, but closer to the middle of the plastic wall. Decide what sized machine screw you want to use (do not use wood screws). This will determine the bit used to cut the threads, and also the drill bit size. Use a drill press, observe the proper speed setting, and be sure the other end of the long piece body is secure.

Use a tap set to tap out threads in all holes. If your holes are near the center of the plastic, it should be possible to do this without breaking through the plastic. Go slowly, and reverse direction to clear out the removed plastic whenever the force necessary increases. Check the threads with machine screws. Do not use countersunk head screws; pan head work well. Robertson screws prevent slipping if you can find them in the size you use.

Drill or route out a 12” or so channel in the middle of the two long sides of the main body to hold metal glass supports. I made these from the inner wall to about ¾ of the way to the outer wall. These and the previous round pits near the corners are all about 1/32” deep, just enough to offset the metal brackets. Drill 4 holes spaced along the removed channel in the middle of the plastic wall. Tap them as with the corner bracket holes.

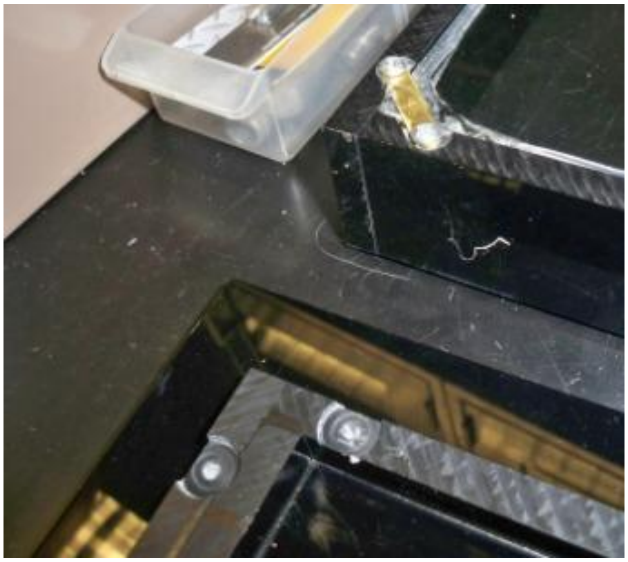
You will need four metal brackets as pictured here. Each may be a little different, so it is best to make them separately for each corner. I used brass plate 1/64” thick and ¼” wide for the corners and ½” wide for the side brackets.

Line up the holes needed and drill them out. Doing this one bracket at a time and cutting the piece off at the final end after drilling will keep the pieces manageable and safer to drill. Drill through into block of plywood or hardwood to reduce deformation. Round off the corners by filing or snipping.

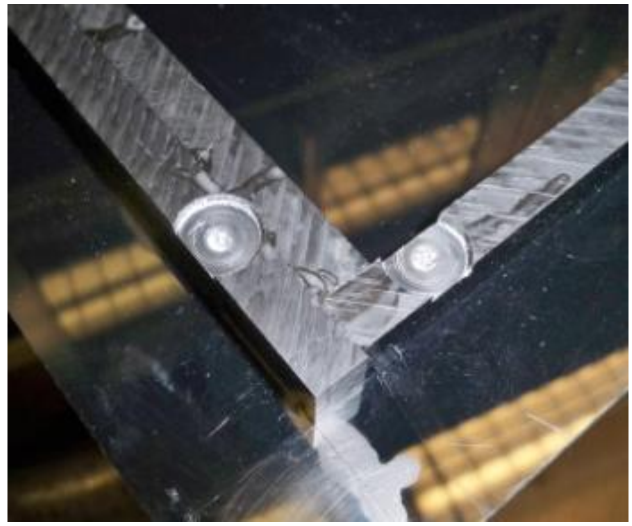
Smooth out any burs on edges and around holes with a file or grindstone. Use ### screws to attach the brackets to the main body. Apply clear silicone sealant to the upper surface of the brackets (inside the main body) and slowly lower the cleaned glass into place on the brackets.

Allow the silicone to dry. Apply a small bead of clear silicone around the inner body and glass interface and allow to dry. Carefully trim off any excess silicone with a sharp, flat blade. It's main purpose to help seal the body, and apply some small amount of adhesion between the plastic and glass. Excess more than 1/64" or so will interfere with the moving scanner head.

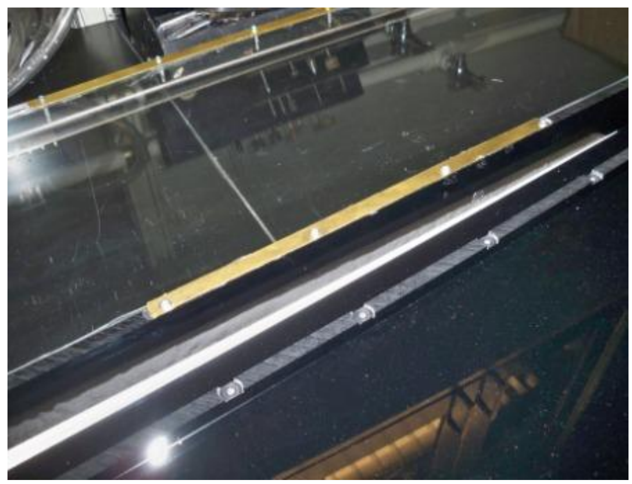
The heads of the screws holding the brackets to the bottom of the main body will hit the upright rectangular box on the base, allowing a lot of light to get in, and raising the scanner head further from the specimens. Use a Forstner bit to drill out some gaps in the base for the screws to settle into when the scanner is closed. These can be sealed later. This is not ideal, but is better than raising the glass further with deeper pits for the brackets, because this would further separate the scanner head and specimens. This photo shows one finished corner bracket holding the glass and the corresponding gaps in the base for the screw heads.



This is close-up of a corner of the base after drilling gaps to receive the screw heads. Note also how the pieces come together to increase strength.



This image shows the finished side brackets holding the glass in place from the bottom (upper), and the corresponding gaps in the base (lower) for the screw heads.

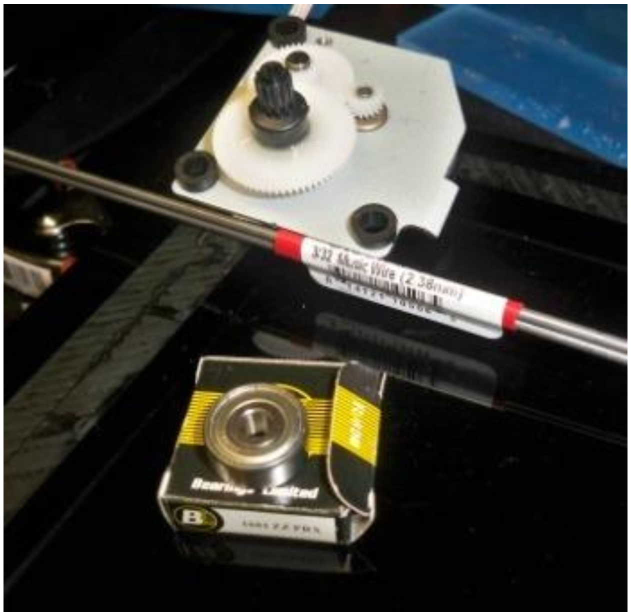


The base and main body are connected together with a 4 foot piano hinge on the back. A standard hinge will be almost exactly the 7/16" depth I used to the center of the hinge. Center the hinge on the base, mark the first two holes very carefully, and drill these out. Be very careful to not hit the glass with the bit! Keep the holes in exactly the correct place and keep them perpendicular. A carpenters square clamped to a drill press surface works very well for this. You will also need another pairs of hands for when you begin the outer holes. I wanted to use machine screws of size #10-32, so I got a tap to match this diameter and tooth pattern, and used a #21 drill bit. In hindsight, a #8-32 may have been a better choice so that the countersunk heads would have sat better in the countersunk holes of the hinge. After the first pair of holes, you will be able to drill through the hinge holes, and thus you will have a built-in guide. When doing this, ensure that the hinge is straight and that the base and main body are tight together. You will not get a second chance on any of these holes.

Step 3: Reassembling the Electronics and Mechanical Drive

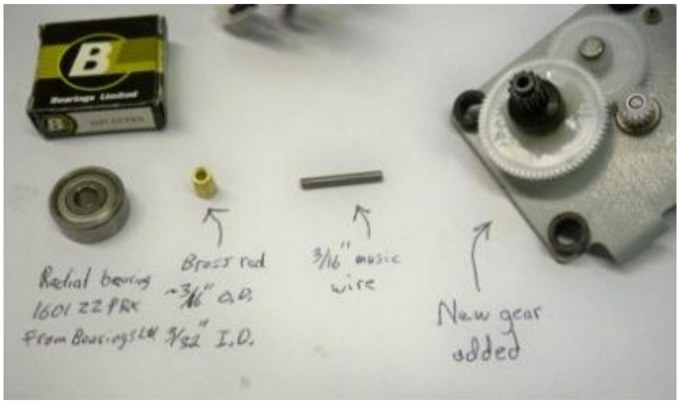
I was not able to find a belt with the same tooth pattern and width that was long enough to run in the longer scanner. I had to increase the width in order to get a belt long enough. This lead to a necessary change in the tooth pitch (length between teeth centers). This lead to the need to add another gear onto the gear assembly to drive the new belt. The important thing is that the diameter of the new gear exactly match the diameter of the old gear, so that when the controls tell the stepper motor to turn the main gear by x amount, this still translates into the same linear distance in the belt moving the scanner head. I found a long belt (96.12") and matching gear of the correct tooth diameter, but had to drill out the base of the gear so that I could attach it to the gear assembly. This hole must be exactly the correct size to slip over the existing gear, be exactly plumb, and be perfectly centered. I added some grooves for glue traction to the base of the gear with a hack saw. Not knowing what kind of plastic was in the existing gear (and it was unlikely to get the two plastics the same), I opted to use 5 minute epoxy to attach the gear. Hold this firmly in place for at least 5 minutes, and ensure it stays straight upright.

The parts I ordered from SDP/SI:
A 6Z 16-B89018   drive belt, 1-sided, 96.12" long, 3/16" wide (0.1875"), 0.080" pitch
A 6M 16-012SF2503 drive gear, plastic, 0.080" pitch

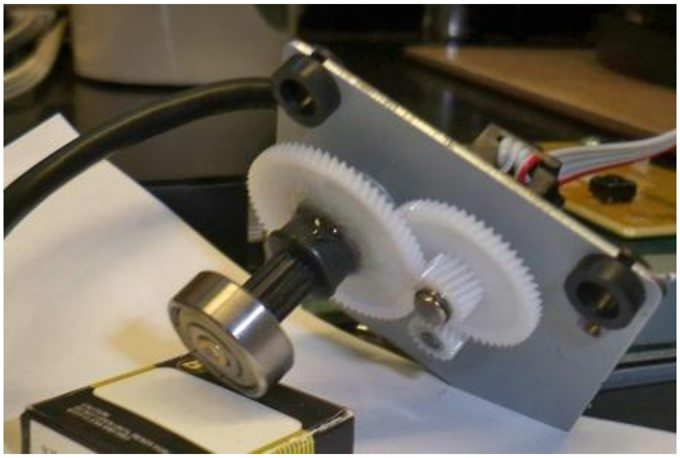


To support the far end of the new gear and thus prevent lateral strain from the belt from pulling it off at the base, I inserted a steel rod into the central hole and inserted this into a radial bearing. The rod is a short section of 3/32" music wire.

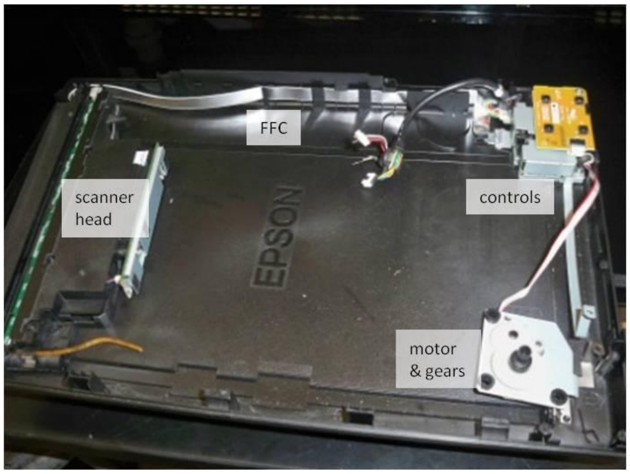
The radial bearing with the smallest center hole was still larger than the rod, just under 1/16” inner diameter. I very slightly tapered the end of a 1/16” brass rod to fit into the bearing, and used a drill press to drill out a 3/32” hole in the exact center. The necessary piece of brass (now a hollow cylindrical adapter sleeve) was cut off and used to attach the drive belt gear to the radial bearing.



Here is the gear, radial bearing, brass sleeve, and wire rod assembled and ready to insert into the scanner. I will drill out an appropriately sized hole in the supports later to hold the bearing steady and thus take the sideways strain of the drive belt.



The remaining problem with extending the scanner by several feet is that the flexible flat cable (FFC) that connects the controls with the scanner head needs to be lengthened. I was not successful in finding a replacement part, and so ordered 4 of these that were 18 inches long and 2 that were 12 inches. After several failed attempts at soldering these together I made 4 very small circuit boards that each consisted of 2 FFC—PCB connectors and straight conductors between them. There are many good sets of instructions online for circuit board etching. This involves corrosive

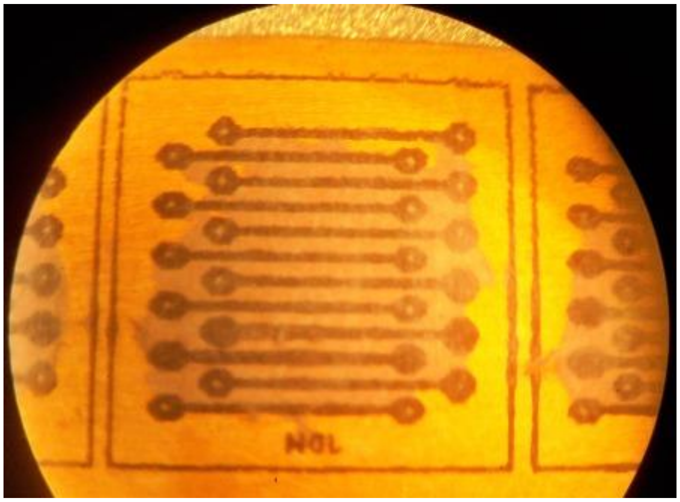


chemicals and poisonous fumes, so follow all safety instructions.

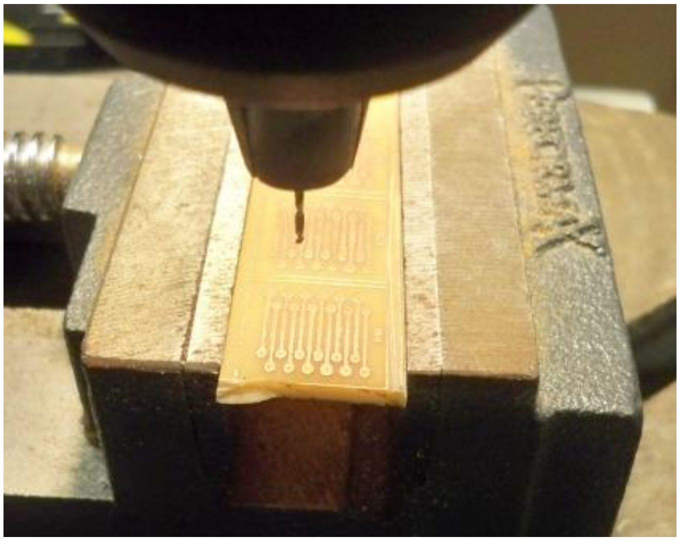
The part numbers at Digi-Key:
HF12U-18-ND, FFC, 18”, 12 cond’s, 1 mm
HF12U-12-ND, FFC 12”
A100303-ND, FFC—PCB connector, 12 cond

I used the toner transfer method and made my own etching fluid with H_2O_2 and hydrochloric acid. I do not recommend doing this. You can see the pattern I used here. This must be printed out at 200 dpi to work, therefore do not use anything in MS Office, as this messes with the resolution. I recommend using GIMP. Contact me for the original file.

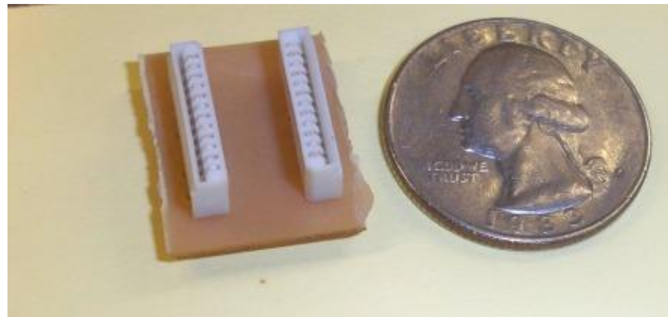
Note that my initials are backwards – a reminder that things will be reversed upon transferring. However, the pins on the FFC—PCB connectors go in from the opposite side, so in this case two wrongs makes a good connection.



I used a drill press to drill out the holes for the pins. This really makes fine control possible. Use as small a bit as possible; larger holes will make soldering more difficult. I used a #60 and they still could have been smaller. Cut out the individual PCB with a hacksaw or similar tool after drilling. If available, solder with the board held securely under a dissecting microscope or similar magnifier. Of course, ensure that connections remain isolated from each other (remember these are 1 mm apart!).

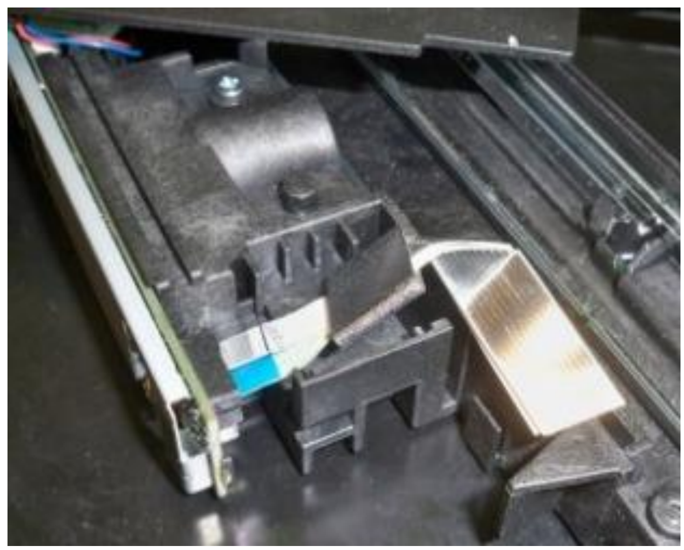


The individual boards will look like this. Four of these are necessary to connect 6 FFC into two 4 foot cables. You may want to use 3 18” cables as some of the length will be used up inside the scanner head, making the connection.

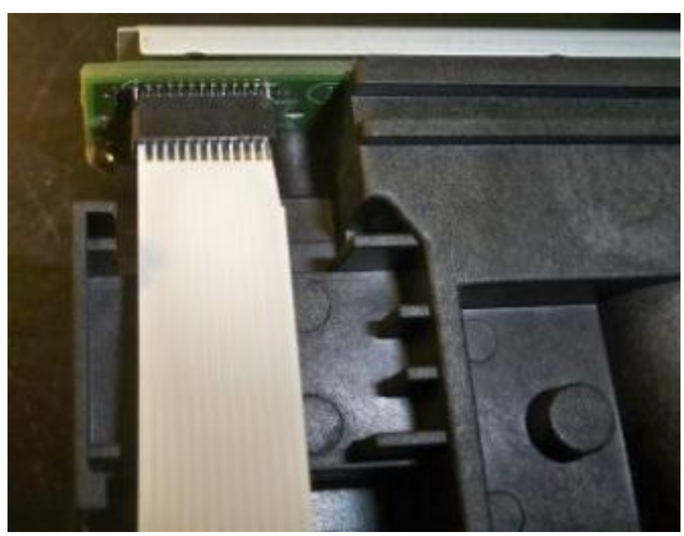


Use electrical or other tape to ensure the cable connections are not strained by being pulled at a tight angle at the connector during use. If there is insufficient room along the side of the scanner as it goes by for this, you will need to carefully kink the FFC at 90 degrees.

Remove the screws holding the case of the scanner head together. Remove the FFC cables and replace with the ends of the long ones you have just created.

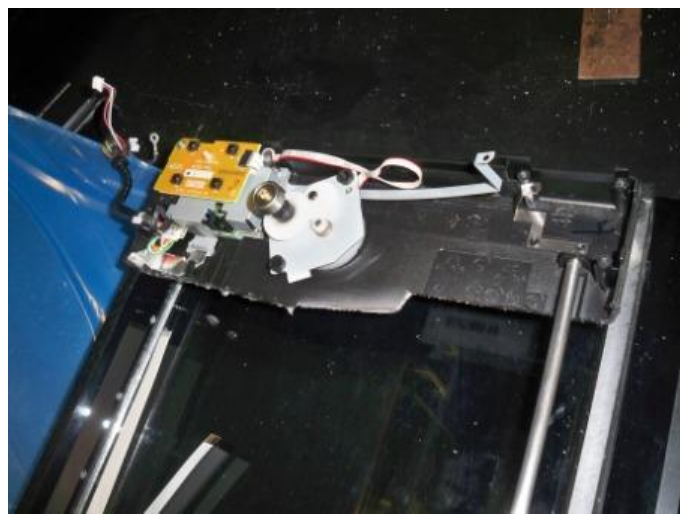


The scanner I used had cables with 11 conductors, which apparently don’t exist elsewhere in the known universe, so I had to clip the side of the cables at the end to fit into the connectors. Be careful to use the cable routing guides on the side of the scanner head case. When you clip the other end, be sure you do this to the same conductor! Do not clip cables for the small connecting PCBs you made, only at the very ends. Clean all mirrors and optics while you’re in there, and then put case back together.



You can now begin to lay out all the parts you will need in assembling the scanner (it is beginning to look like something now!)

You can simplify some of the layout of individual parts by salvaging the ends of the original scanner case. I saved both ends by cutting them out with a hacksaw. Note the motor and gear assembly is not in position in this photograph; it is simply sitting loose.



The next step is to figure out how the drive belt needs to move to pull the scanner head, as this will determine whether the vertical orientation of the gear assembly (radial gear up or down).