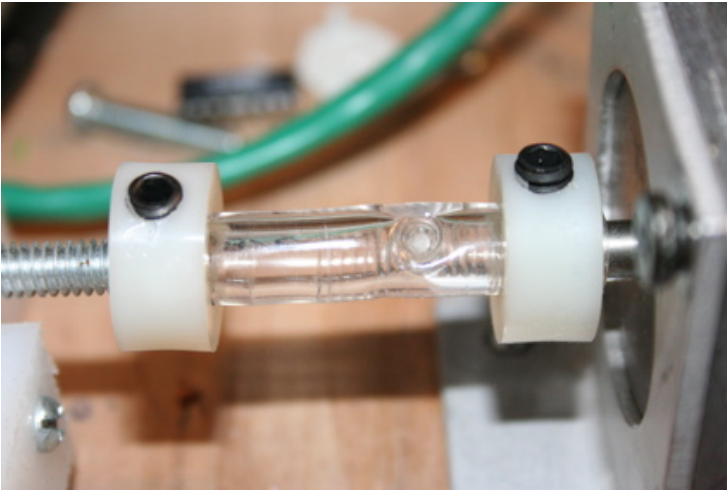


engadget

How-To: Build your own CNC machine (Part 1)

Posted Jun 29th 2006 6:21PM by [Will O'Brien](#) Filed under: [Features](#), [Misc. Gadgets](#)



Ready for some hard core gadget creation? If you thought your dremel tool was handy before, in today's How-To we'll start building our own CNC machine. Aside from the geek factor, it can be handy for making things like PC boards without chemicals or maybe some little styrofoam voodoo heads of all your enemies, uh friends.

Gentlemen, start your soldering irons.



Computer controlled mills have been around for a long time. If you just want to buy one, [Sherline](#) makes mills that are ready to go (pictured is their CNC ready model -- just add your own motors and controller). But then again, if you wanted to buy one, you probably wouldn't be reading this, now would you? A CNC machine is a lot like a precision drill press with a table that moves in two directions -- seeing a commercial unit like the one above should help you visualize the end goal. We'll be making ours from scrounged, recycled, and adapted parts; today we'll be going over the basic parts we'll need to build our own.

[Update: If you're not quite sure what a CNC machine is, check out the [Wikipedia article](#), mkey.]

Parts Hunting

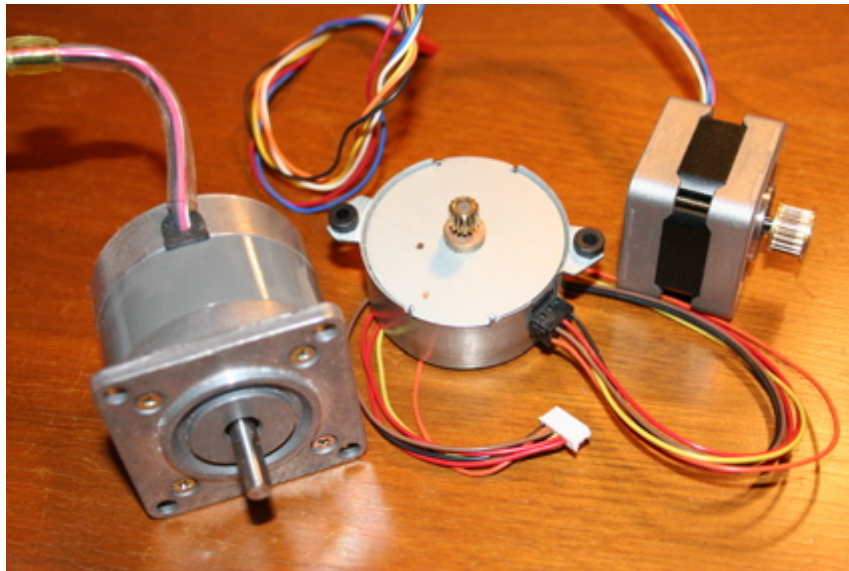
For Part 1 of the How-To, we'll go over all the major components of the project and get started with the controller.

The major components of the DIY CNC machine:

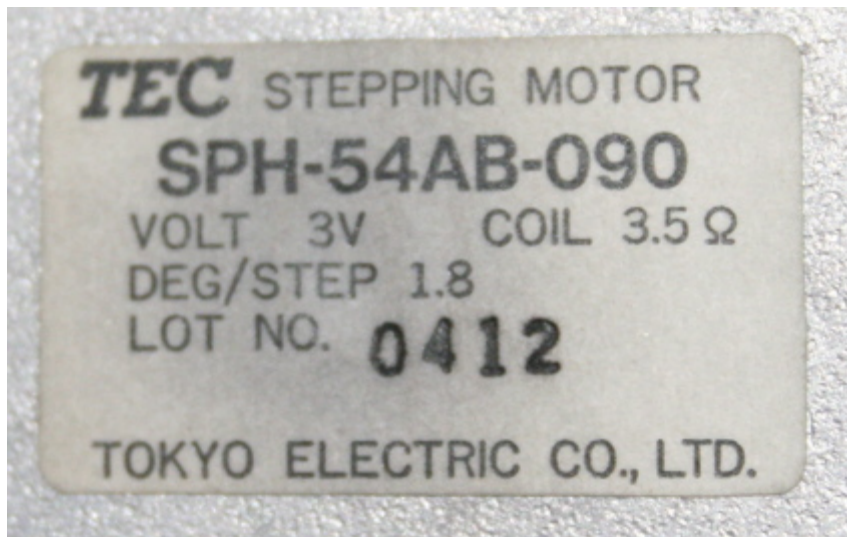
- Stepper motors
- drive positioning screw
- 3 Axis stepper motor controller
- Linear slides



The most important component to determine the construction of your milling machine is the motor. Motors can be purchased from surplus houses, but the cheapest place to get them is from old dot matrix printers. Apple Imagewriters are one of our favorite sources. They contain multiple stepper motors, and the primary is pretty beefy. As a bonus, just about every dot matrix printer has a hardened steel rod that can be useful for our nefarious goals.



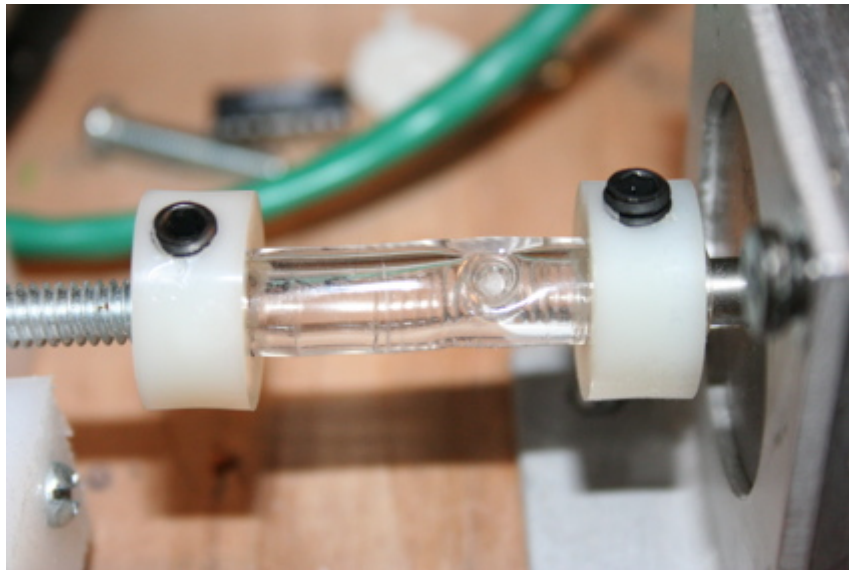
A stepper motor is an odd beast. Most motors spin when power is applied, stepper motors contain multiple coils. If the coils are energized in the proper order, the motor will rotate a small amount (a step). We'll take full advantage of the nature of stepper motors with this project. To simplify your life later on, you'll want to find stepper motors with more than four wires. Four wire motors are usually Bipolar motors. They produce more torque, but end up complicating the control circuit. The preferred type of motor for the frugal hobbist is Unipolar. These usually have five or six wires, and they're pretty easy to work with.



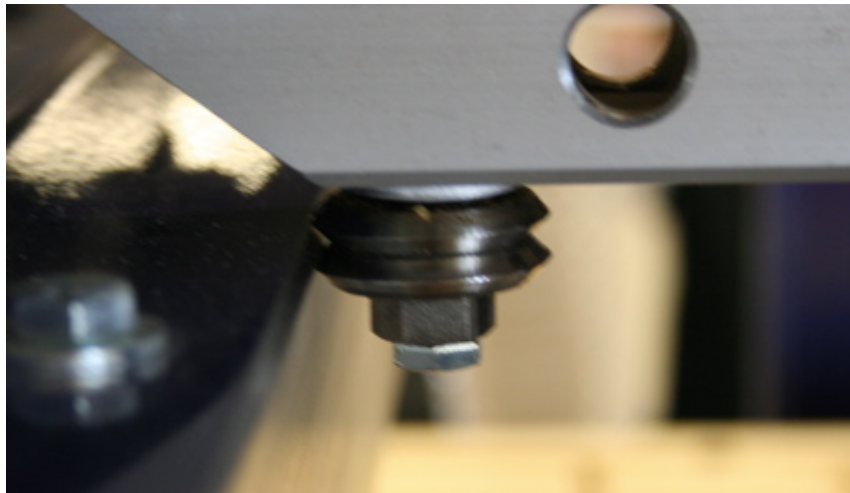
Most stepper motors are labeled. The major points of interest include the voltage, resistance and the number of degrees per step. Knowing the number of degrees per step is vital for configuring the software to properly control the machine later on. For a three axis machine, at the very least you'll want the X and Y axis to both have identical motors. It's not the end of the world if they don't match, but it's more of a pain later on.



The drive screw is the next piece of our project. Commercial units use linear ball screws or linear gears. The commercial parts aren't cheap, but you can get away with some 1/4-inch threaded rod from the hardware store. Instead of anti-backlash nuts, we'll use these handy 1-inch long 1/4-inch nuts. Just about every hardware store has them, and they produce very little play. Try out the hardware at the store because defects in the nut or rod will produce drag that's easily noticeable by spinning the nut on the rod.



To couple the rod to the motor shaft, we'll use vinyl tubing with a pair of collars. The tubing is 1/4-inch inner diameter and prevents binding by allowing some play between the rod and the motor. You can get suitable collars from a model airplane store (The hardware store had some, but they were overpriced). Alternatively, you can make your own like we did from nylon bushings and hex screws.



Finally, we'll need some linear slides. One easy out is to purchase a used or surplus XY table that's built just for this purpose. Custom designs can be built using ball bearings. Above is the linear rail that [ShopBot](#) uses. They machine the edge of a piece of steel and use this cool angled roller bearing.



We built this linear slide from a 1/2-inch steel rod and multiple bearing surfaces. It works, but we don't recommend building it if you value your sanity.



Once you've bought or salvaged a set of motors, you'll need a controller. The controller provides the interface to the computer, drives the motors and can provide some simple feedback to the computer. The stepper controller has to be powerful enough to drive the motors you've selected. We sifted through lots of stepper controller designs looking for one that presented the best value.

In the end we found [this design](#) for a relatively simple parallel port interface that originally appeared in a 1994 issue of Nuts and Volts. Today, the expensive UCN5804B is only available as a surplus item, but now the entire controller can be built for about \$22-\$30 in parts. (If you use a heavier motor like the ones from the Imagewriter, you might need to add some separate power transistors.)

The parts list at the link is a bit outdated, here's our updated shopping list.

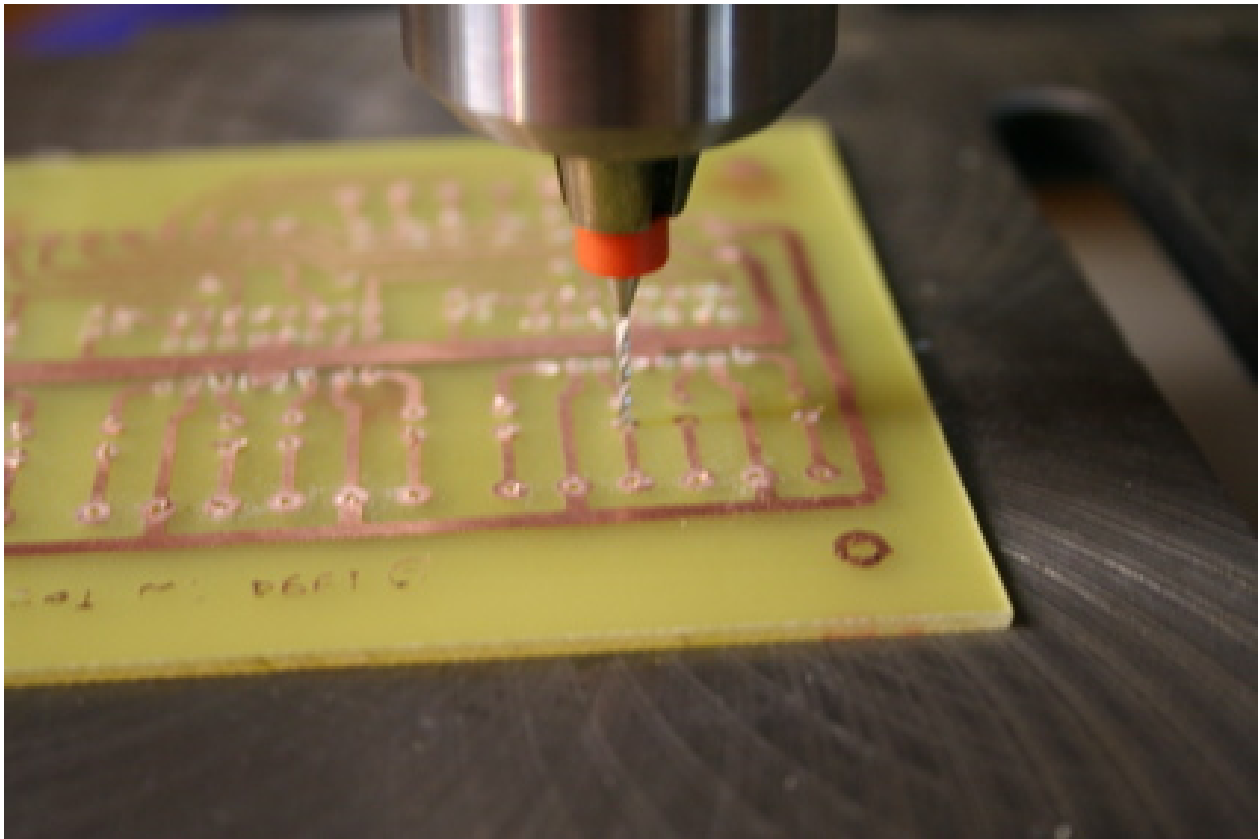
- 3 - UCN5804B - alltronics.com
- 12 - 1N4935 Diodes - Part 625-1N4935 from Mouser.com
- 2 - .01uF Capacitors - Part 581-SR155C103KAT from Mouser.com
- 1 - 10uF Capacitor - Part 140-HTRL25V10-TB from Mouser.com
- 3 - 4.7k Resistor Network 652-4608X-101-4.7K from Mouser.com (Has an extra resistor, but works fine)
- 1 - D-Sub 25 pin Male - Mouser, RadioShack, etc.
- 1 - Barrel power connector - Whatever works for your power supply. (We used a spare 12V power brick)
- Stranded Cat-5 is sufficient for wiring
- Terminals and male headers are optional, see the page for the circuit.
- Heat sinks for the 5804Bs are needed. We used some aluminum channel.
- Copper clad PC board (We stock up on ebay every so often)
- Etching solution - Ferric Chloride, etc.



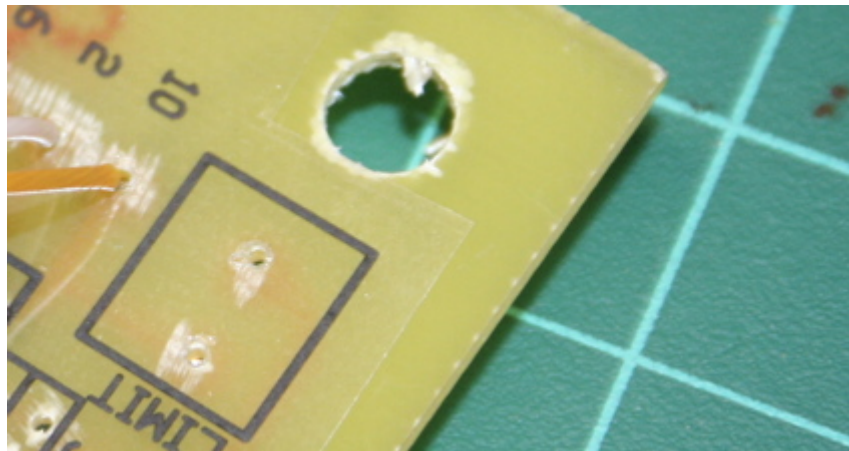
We made our own board using the template from the web page. We used similar techniques to the one in part 4 of our [iPod Superdock How-To](#). We reversed the pdf image using Gimp, and printed it onto a laserprinter transparency. This method doesn't create as nice of a trace as the paper, but it's speedier. Clean the board, and keep the paper backing between the plastic and the iron. Once the toner is ironed, just cool it with water and peel.



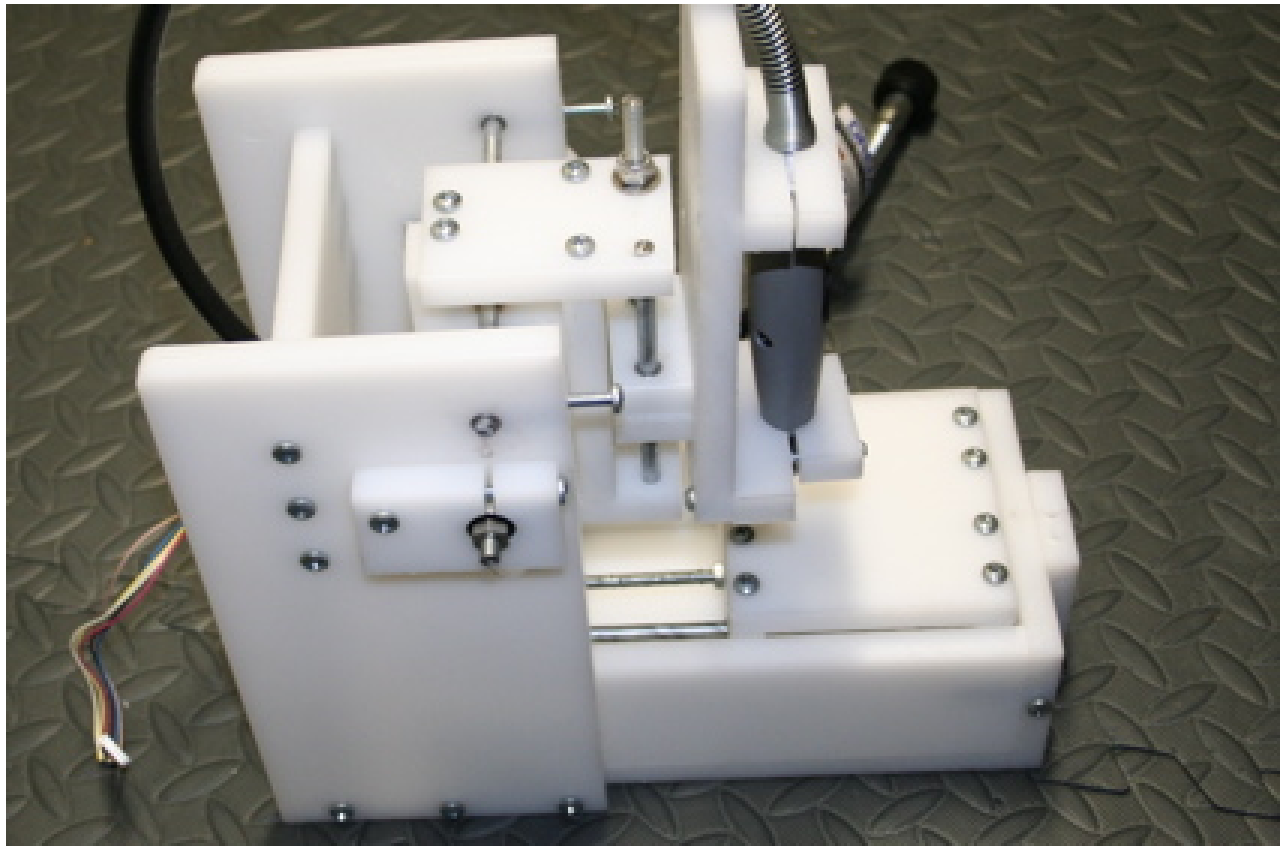
We etched the board using Ferric Chloride from RadioShack in a disposable Zip-Lock container. It needs to be warm and agitated to work well. The acid and hydrogen peroxide solution etches way faster.



We drilled the board with our drill press and tungsten carbide bits from Drill Bit City. We had to refer to the placement schematic several times to make sure we drilled everything right. Getting the pins holes aligned for the 5804s is a challenge!



If you want to do a toner transfer of the placement mask, do it before drilling the holes. Otherwise the surface is too uneven to allow a good transfer. If you screw it up like we did, you can cheat. Just print the mask onto a transparency and burn holes for the components with a soldering iron. It works surprisingly well.

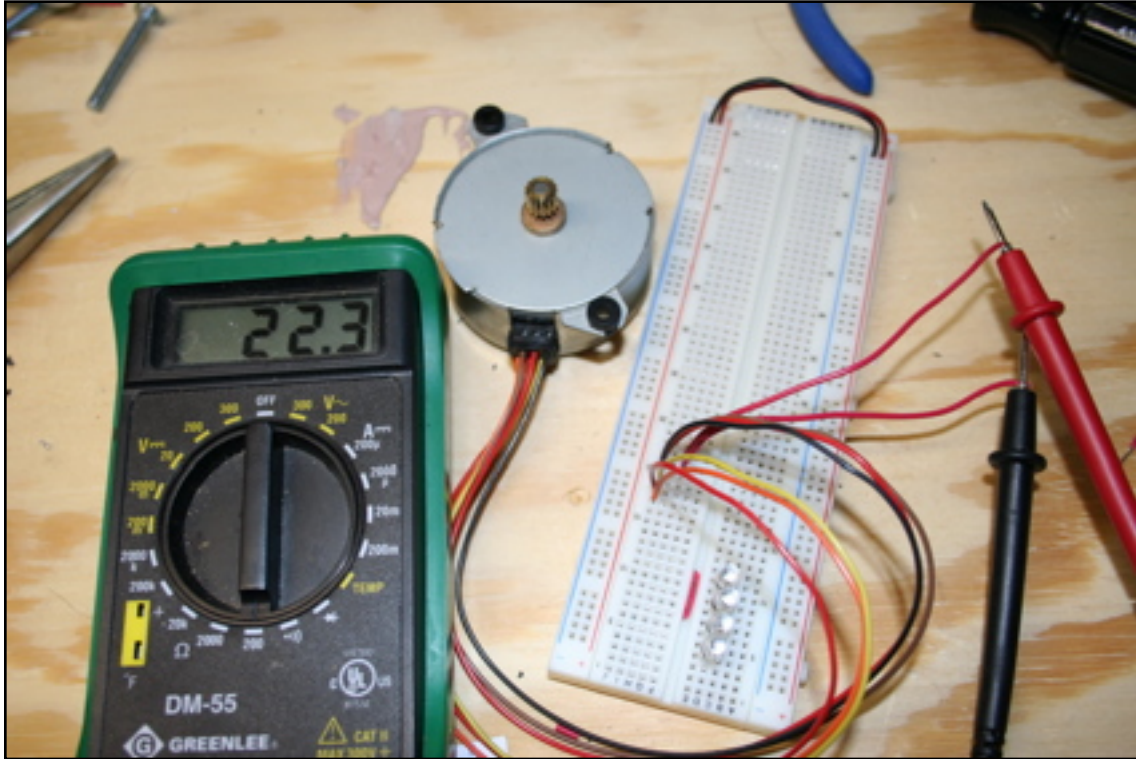


Next time we'll start building the actual machine and show you how to build some simple and effective slide systems. For now, here's a teaser of what's coming! Good luck!

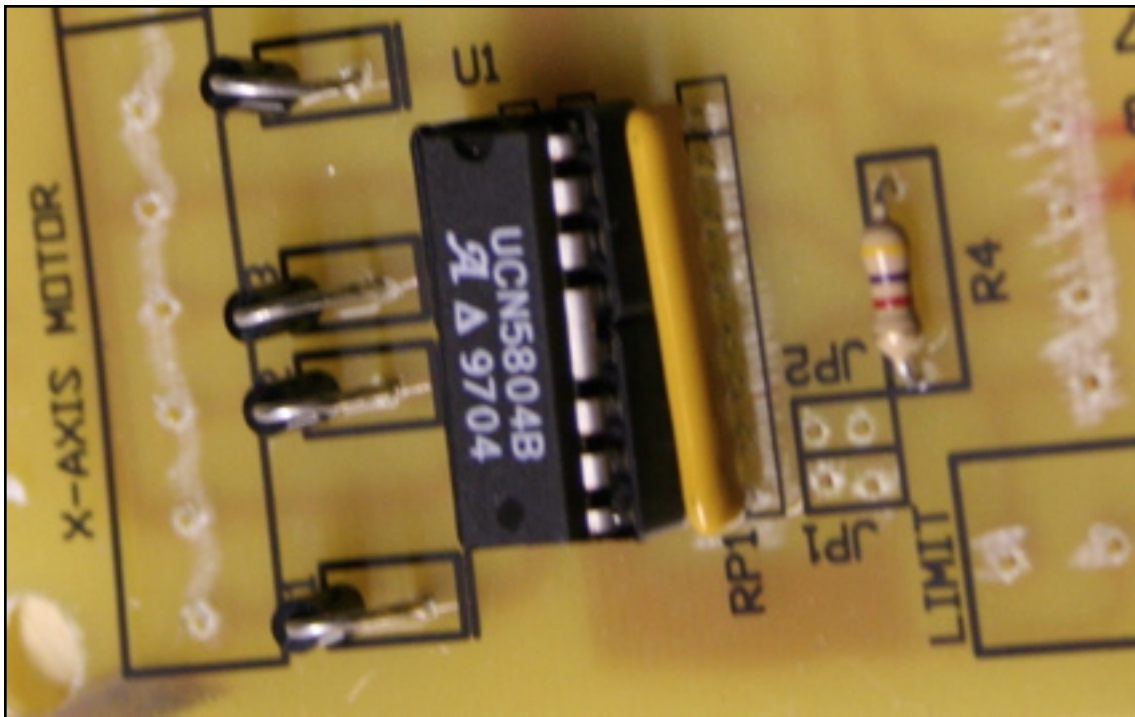
How-To: Build your own CNC machine (Part 2)

Posted Jul 4th 2006 9:37PM by [Will O'Brien](#)

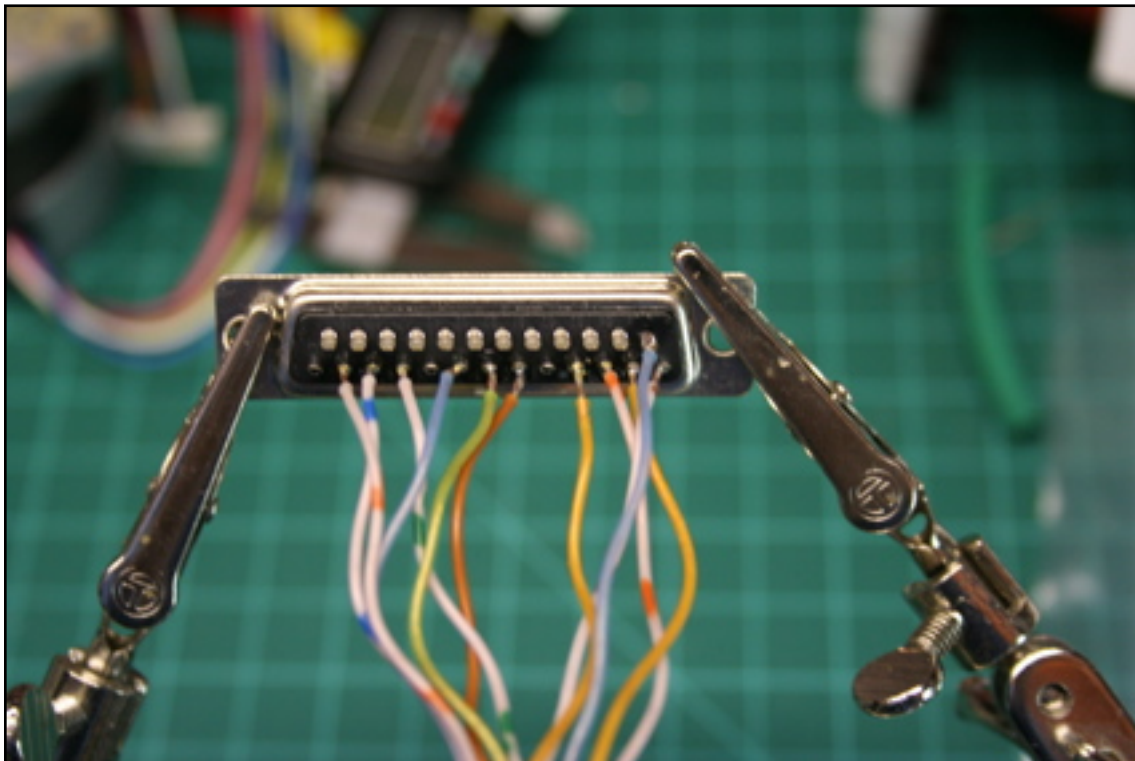
Filed under: [Features](#), [Misc. Gadgets](#)



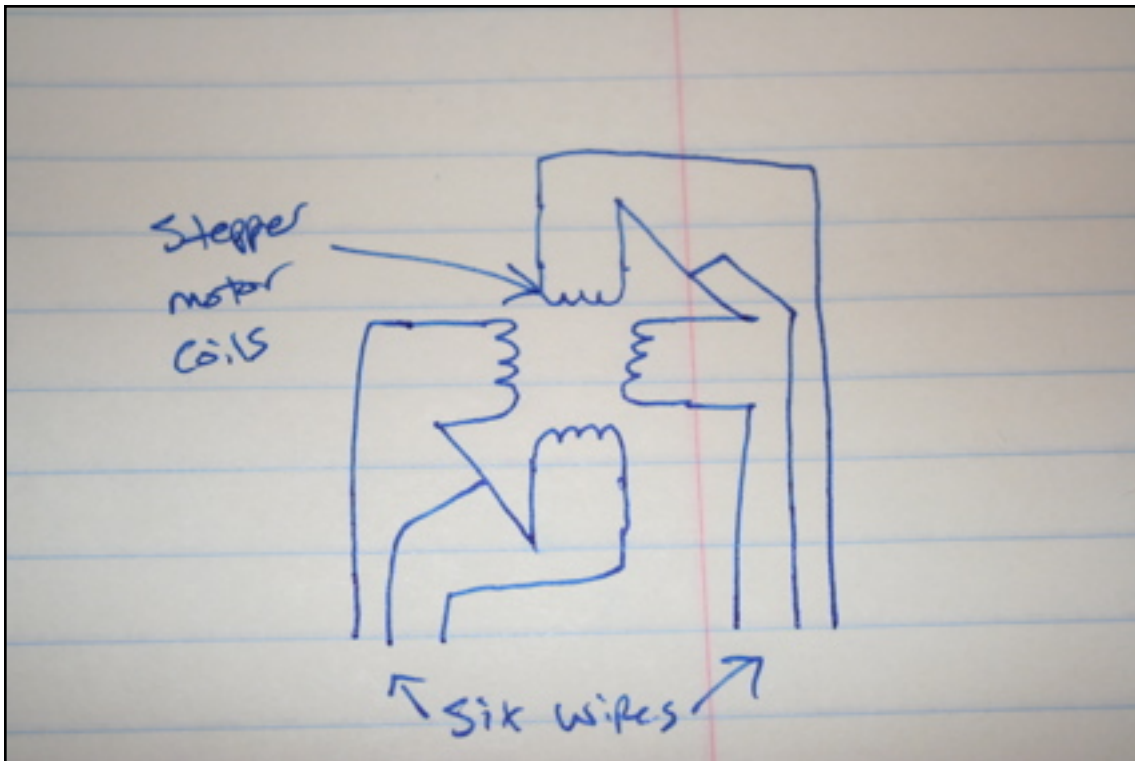
In today's How-To, we're still pimping out our dremel tool with parts from old printers. In [Part 1](#) we got started with the controller and covered all the basics. Today we'll get into the details and get busy with the power tools. And that, of course, is always the best part.



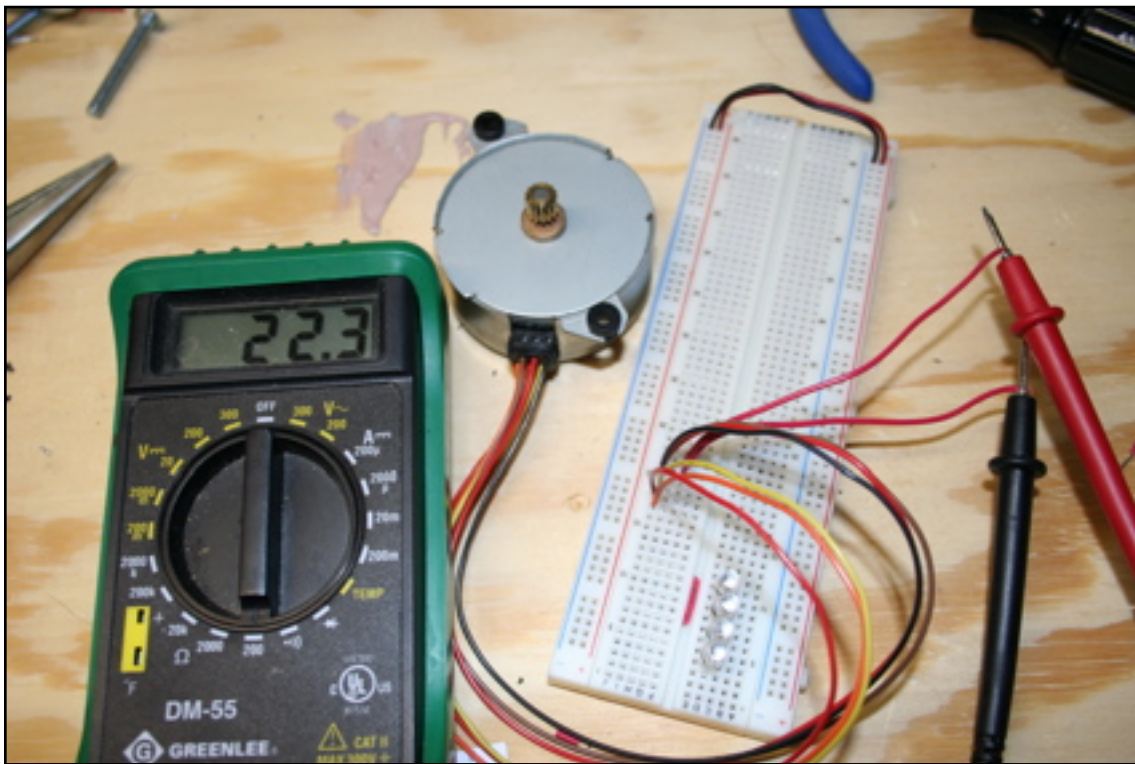
Once the board is finished, building the controller is pretty easy. We highly recommend using sockets for mounting the 5804 chips. The thin, flexible legs are much easier to fit into a hand-drilled board. (We were out of 16 pin sockets, so we used pairs of 8 pin sockets.) The rest of the board is standard fare.



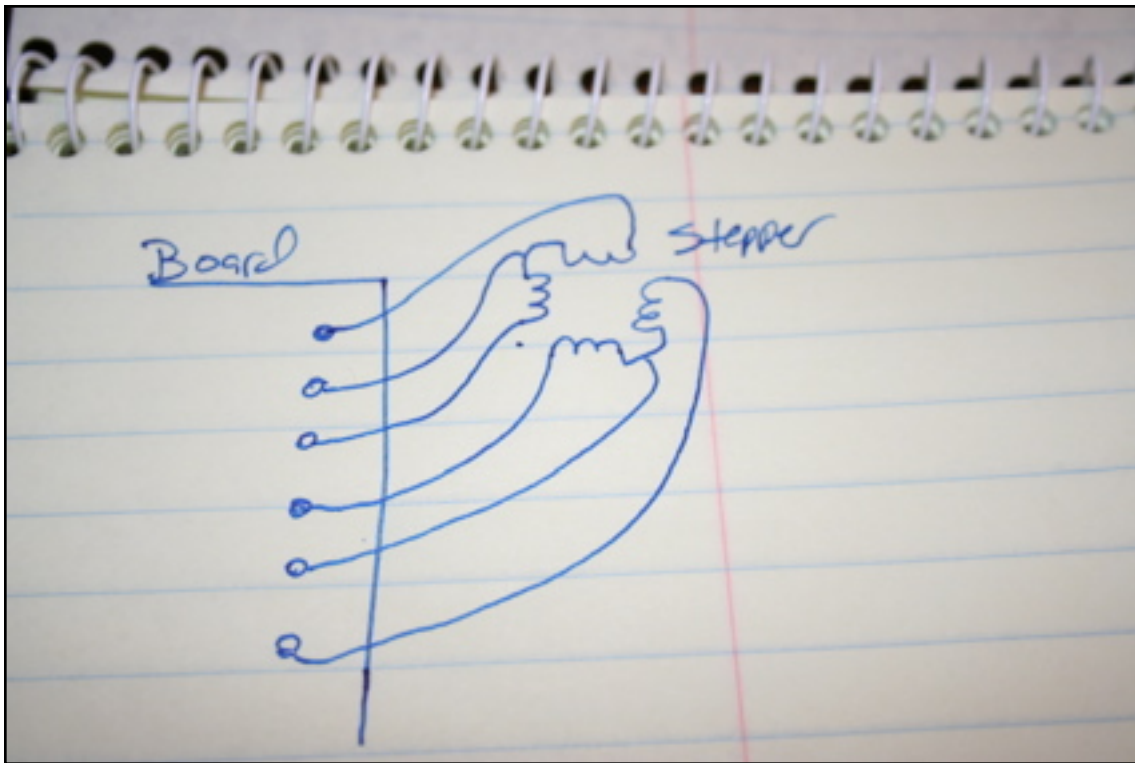
The controller is designed to connect to the parallel port, and each connection is helpfully labeled with the pin of the Sub-D 25 connector. We prefer the solder type connectors. Assembly is quick and easy if you have a set of "helping hands" alligator clips.



Electrically, unipolar stepper motors have four coils inside. Every motor we've salvaged has had six wires, so we'll go over that type. To have six connections, each pair of coils has a common lead, while the opposite end has a dedicated lead.



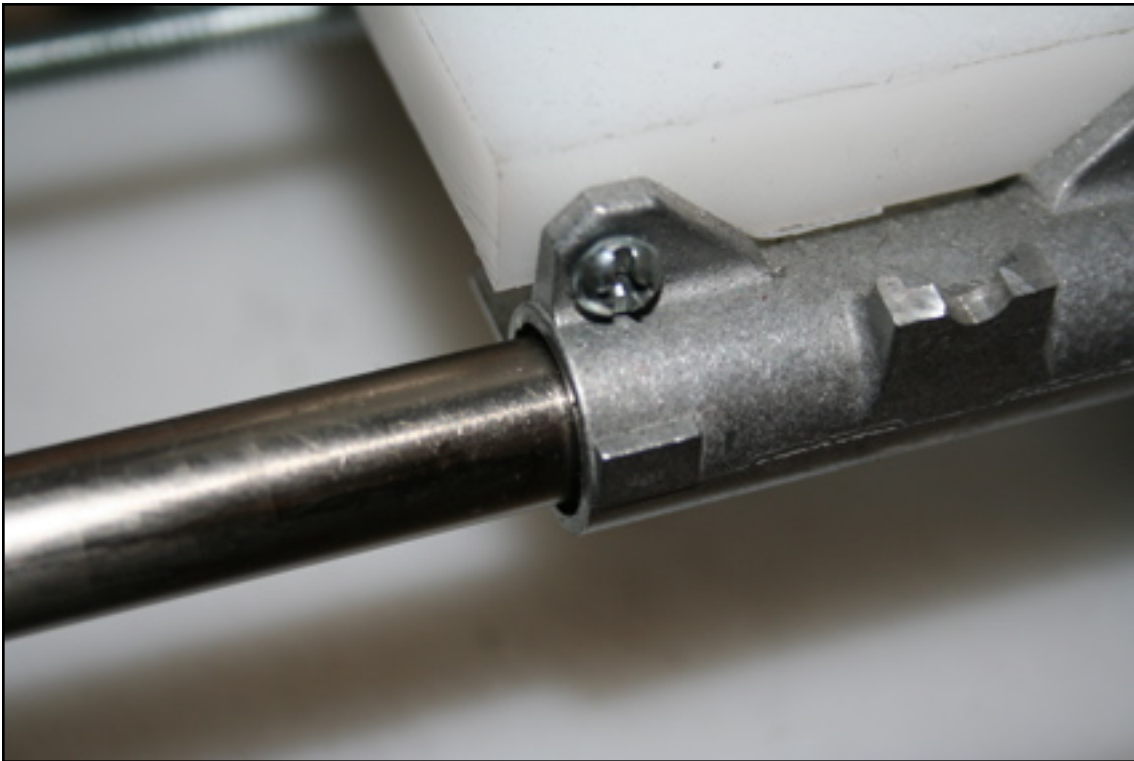
Identify the wires by measuring the resistance between the leads with a multi-meter. If the wire are connected to separate sets of coils, the resistance will be very high. Resistance across two coils will be double the resistance of just one coil. On some motors, the common leads are connected.



Each axis of the stepper controller has six output connections. Each group of three wires connects to a pair of coils.



Linear slides are key to the design of a functional machine. These slides are a half successful experiment. We used 1/4-inch steel rod from the hardware store and some brass and steel bushings. The brass material slides easier, but ultimately we think the smaller size and unfinished rod is too prone to binding. Alignment is critical, but they can work well for very short travel.



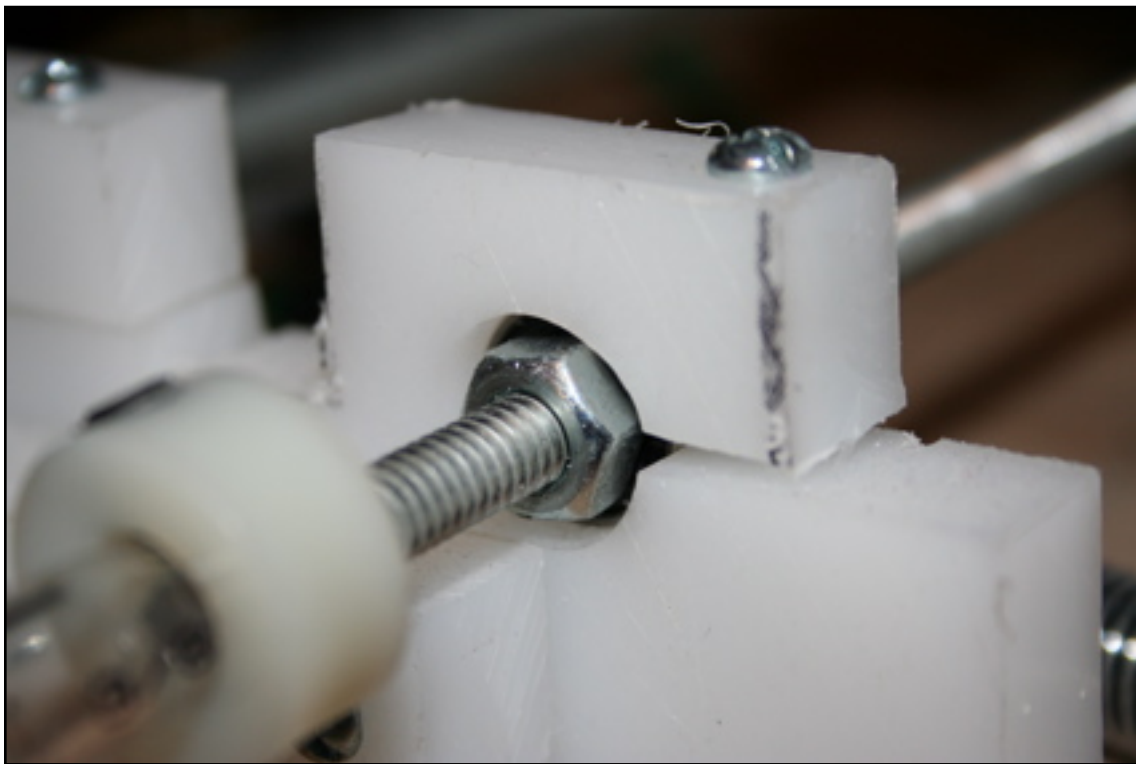
Salvaging matching rods from old printers is more optimal. Imagewriter IIs have metal carriages with pressed in brass bearings. The cast material is on the brittle side, but some careful dremel work can really pay off.



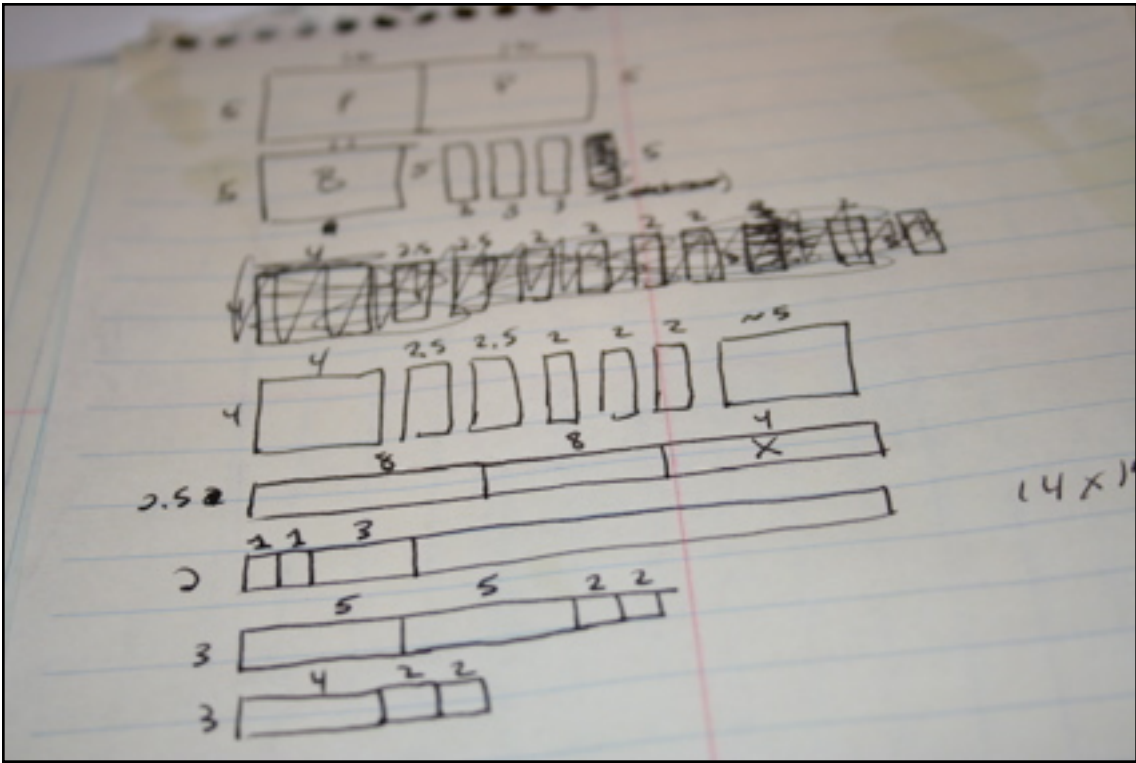
Getting appropriate materials for the project can be a challenge. In this case, we're using two of these handy half inch thick cutting boards from [Sam's Club](http://www.samscub.com). They're about \$10 each. Higher quality plastics like delrin can be obtained from suppliers like [McMaster-Carr](http://www.mcmaster-carr.com).



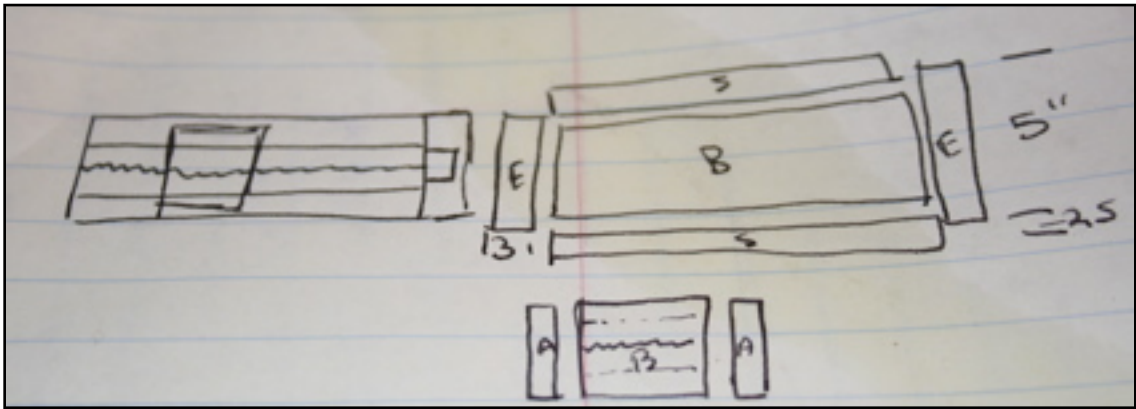
The threaded rod needs to spin freely with the motor, but still needs to be anchored. We picked up a 1/4-inch inner diameter ball bearings off of ebay. We drilled a hole the same size as the bearing, then cut a slot in the piece with a miter saw. Finally, we drilled a hole for a machine screw.



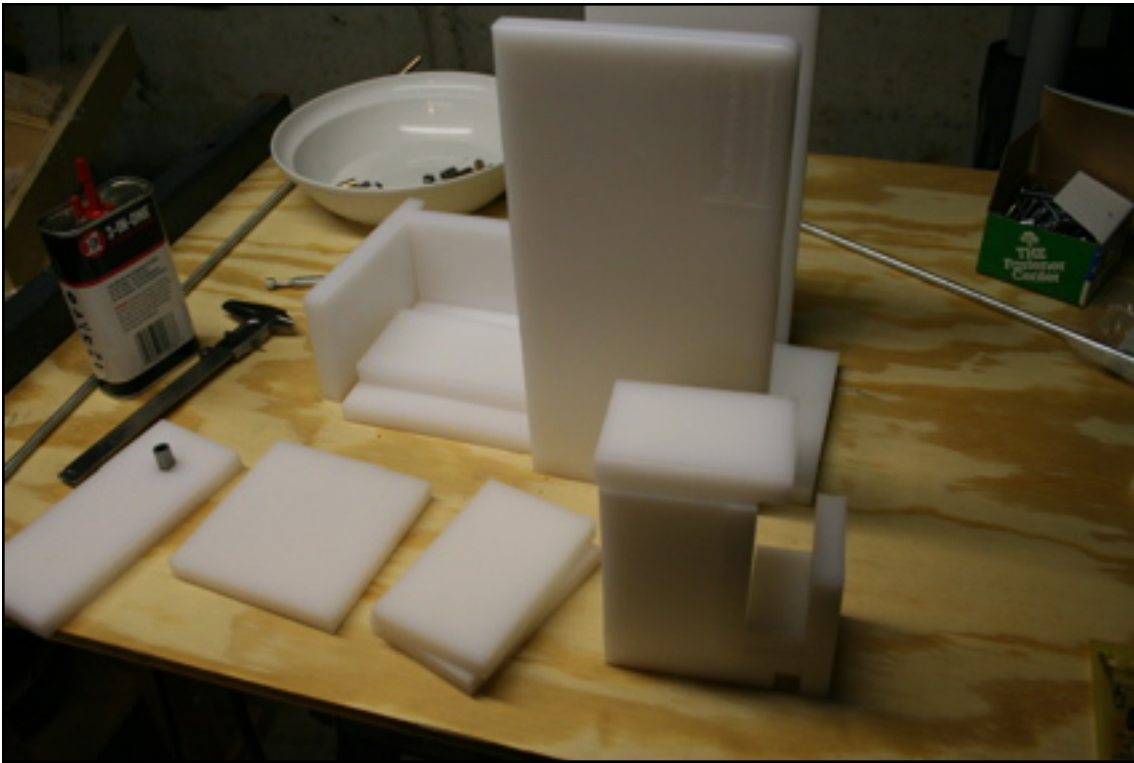
The bearing is sandwiched between two nuts on the threaded rod. They are tightened with two wrenches. Then the bearing is inserted into the block and the machine screw is tightened down. It's a simple and effective design. We usually put one at each end of the threaded rod.



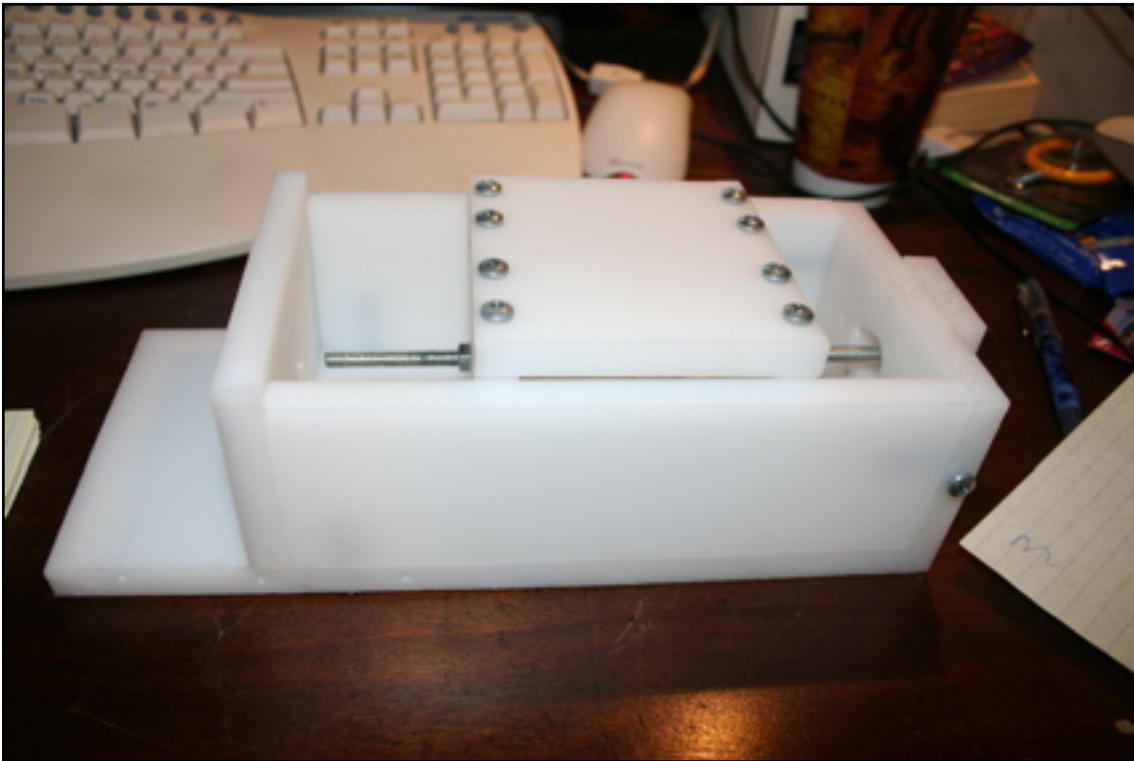
To build the mechanical base of the machine, it's important to put in some design time. Determine how much material you have, draw out your design and estimate how much material you'll need to achieve the size of machine you're going for.



Spend time laying out each axis. Then break it into its components so you can begin laying out your cut sheets. This was our original layout for the first axis of our machine.



We cut our cutting boards using a standard table saw and a circular miter saw. If the blade is sharp, you'll end up with some very nicely finished edges.



The first axis for this table is simple. The base acts as a large channel for the table. We've found that the plastic is soft enough that it doesn't have to be tapped for threads. Just drill the hole with the same bit you'd use if you were tapping threads (like a #21 for 3/16 threads) and bevel the outer edge a bit. Machine screws will thread right into the plastic, and the threads will hold surprisingly well. However, tapping the threads for extra precision isn't a bad idea.

Originally we wanted to use two 1/4-inch rods to maintain alignment, but thanks to the channel design, just one was sufficient. The second rod was a source of binding. We suggest incorporating a larger rod or two from a printer.



The holes for the rods and screw were drilled at one time on the drill press before assembly. The bearing block was added once the screw was aligned. The locknut isn't necessary. If you want to hand align the machine, This is a good place to add a knob or wheel to spin.

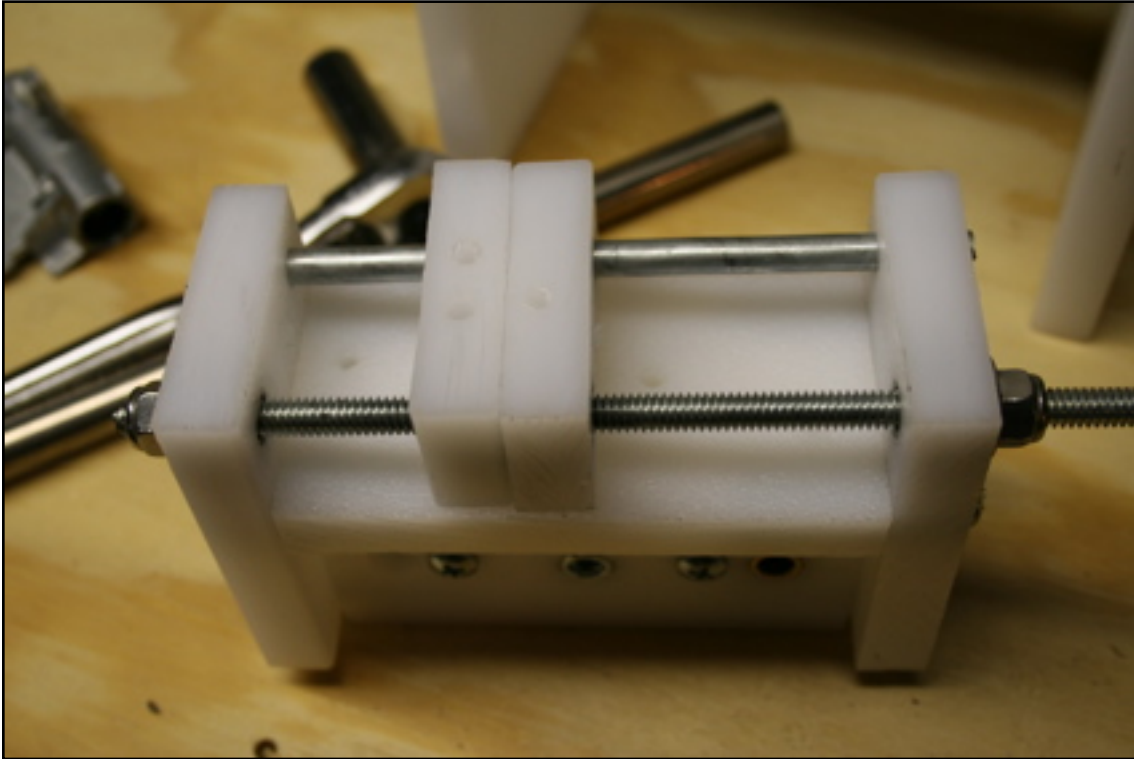
Next week we'll build the rest of the machine, mount the tooling and finish the job. See you then!

Tags: [CNC Machine](#), [CncMachine](#), [How To](#), [HowTo](#), [Stepper Motor](#), [StepperMotor](#)

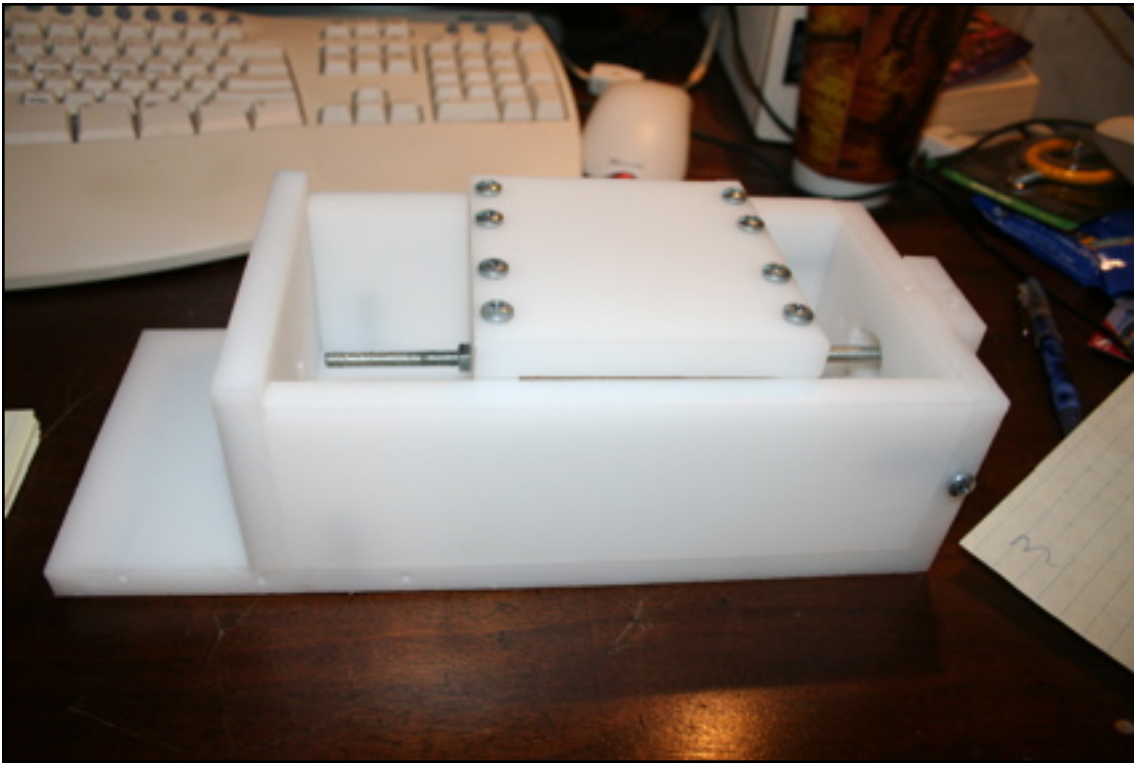
How-To: Build your own CNC machine (Part 3)

Posted Jul 11th 2006 9:45PM by [Will O'Brien](#)

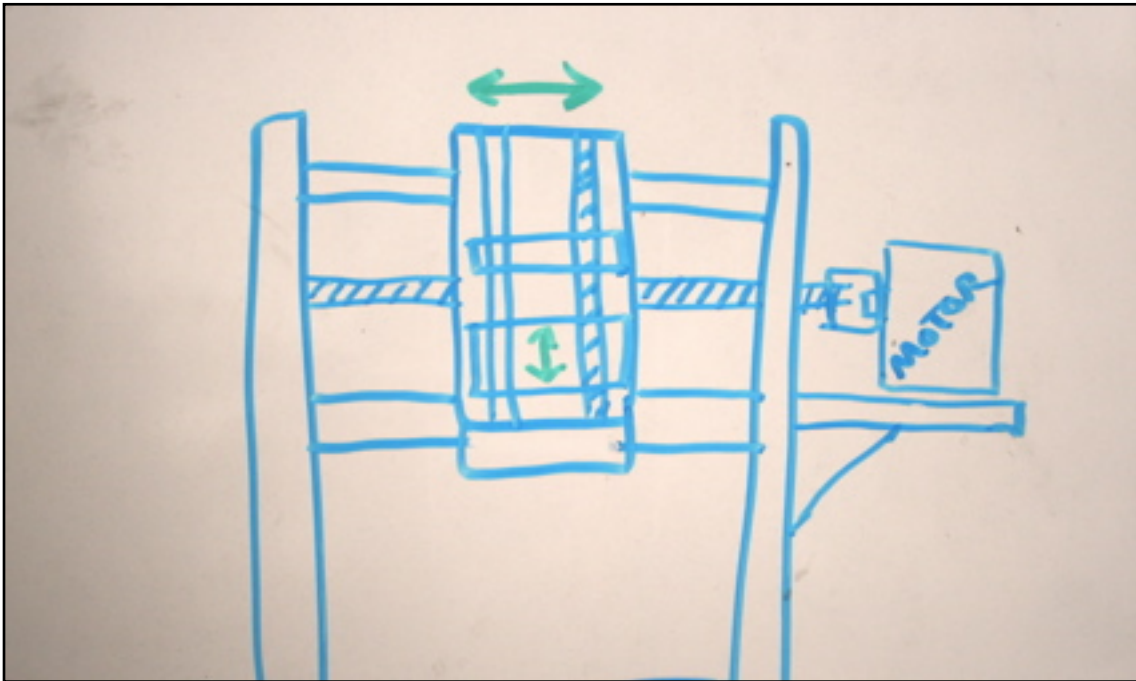
Filed under: [Features](#), [Misc. Gadgets](#)



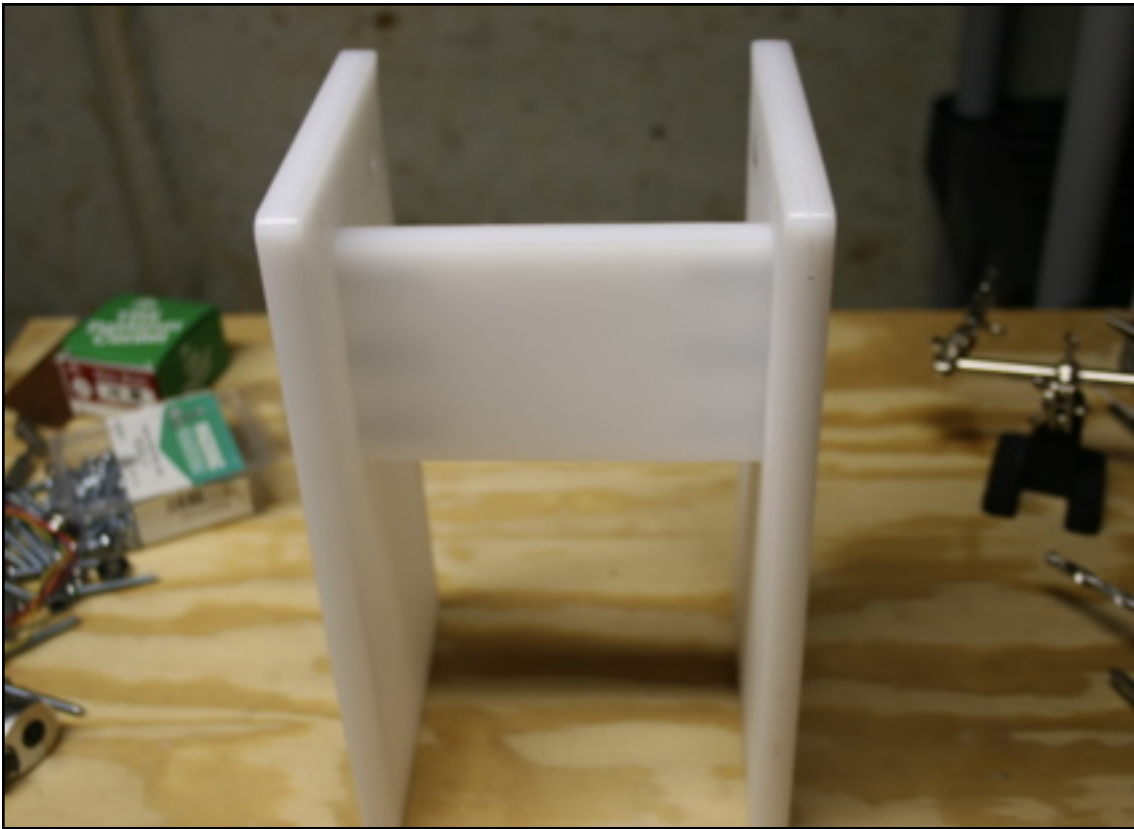
Back in [Part 1](#), we introduced the basics and started building the electronics. In [Part 2](#), we finished up the controller and started building our machine. Today we complete our unholy marriage of cutting boards and dot matrix printers in Part 3 of How-To: Build your own CNC machine. Good luck.



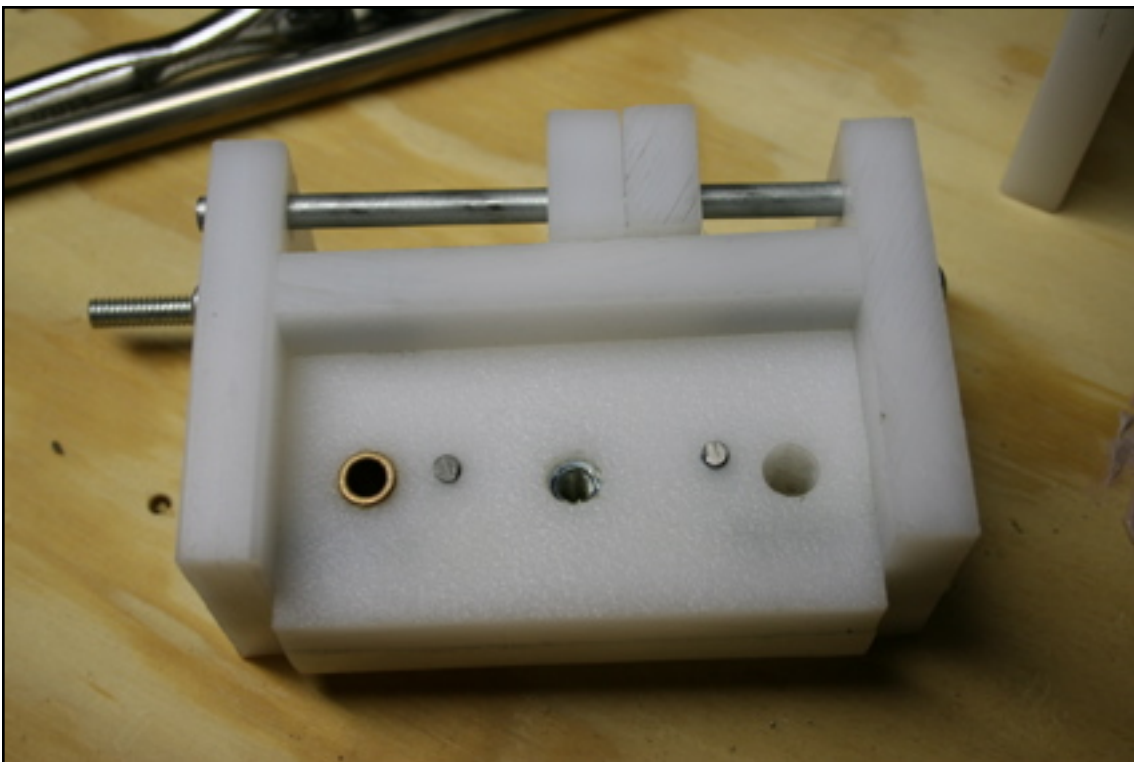
Last time we showed you the completed base, with the first axis. The screw drive turns easily and there's very little play in the motion of the table.



The design of the upper axis is simple, but is the most difficult to execute. Originally we hoped to use a pair of the small sliders, but binding was an issue so we redesigned it to use a large printer slider at the base. Ultimately, the binding was caused by the nut and threaded rod we were using. Swapping them out solved our problems.



A simple tower constructed of three pieces forms the basis for the rest of the machine. The tower will be mounted to the outer edges of the base. This allows greater side to side movement to maximize the usable area on the table. The center piece is from the same cut as the bottom of the base. To drill the two sides evenly, we screwed them together and drill the mounting holes with the drill press. Once the first screw was in, we drilled the rest one at a time.



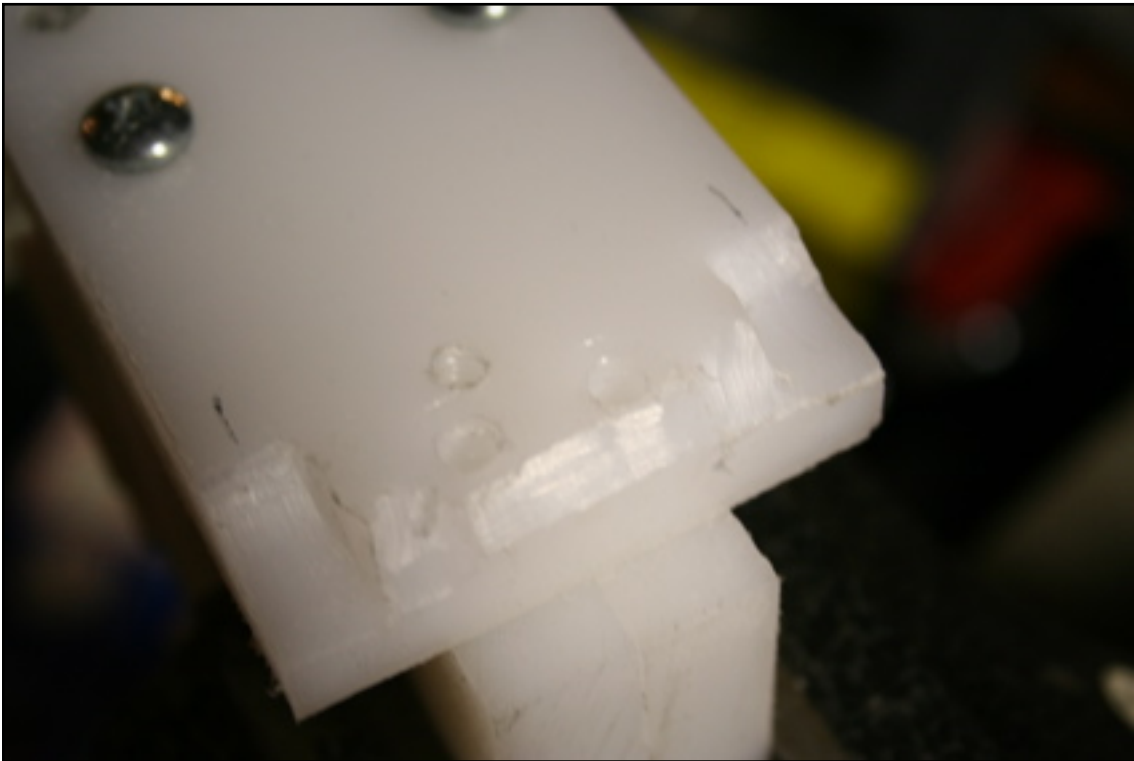
The center slider is the most complex to build. Each piece is visible here. We used our usual trick of screwing the opposite pieces together in order to align the holes for the slide and the threaded rod. The brass slider and long hex nut were pressed into the plastic with our bench vise. This technique seems to work well, but alignment is critical!



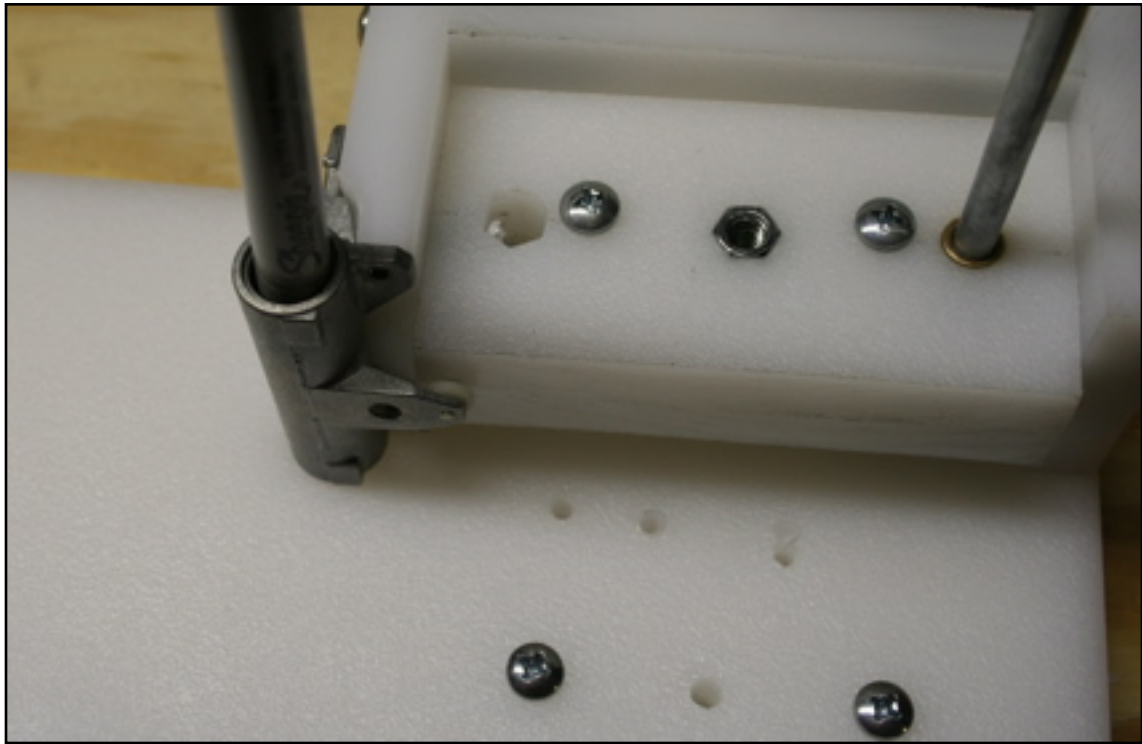
To effectively deal with the minimum space, we had to get tricky. There just isn't enough room in the carrier to mount bearings for the Z axis. Instead, we pressed bushings into the plastic with our vise. Then we added a washer and a lock nut to the threaded rod at the top and bottom of the carrier. Careful tweaking with a pair of wrenches made for very little play. Just how long this setup will stay tight is in question so we'll have to keep an eye on it as we break in the machine.



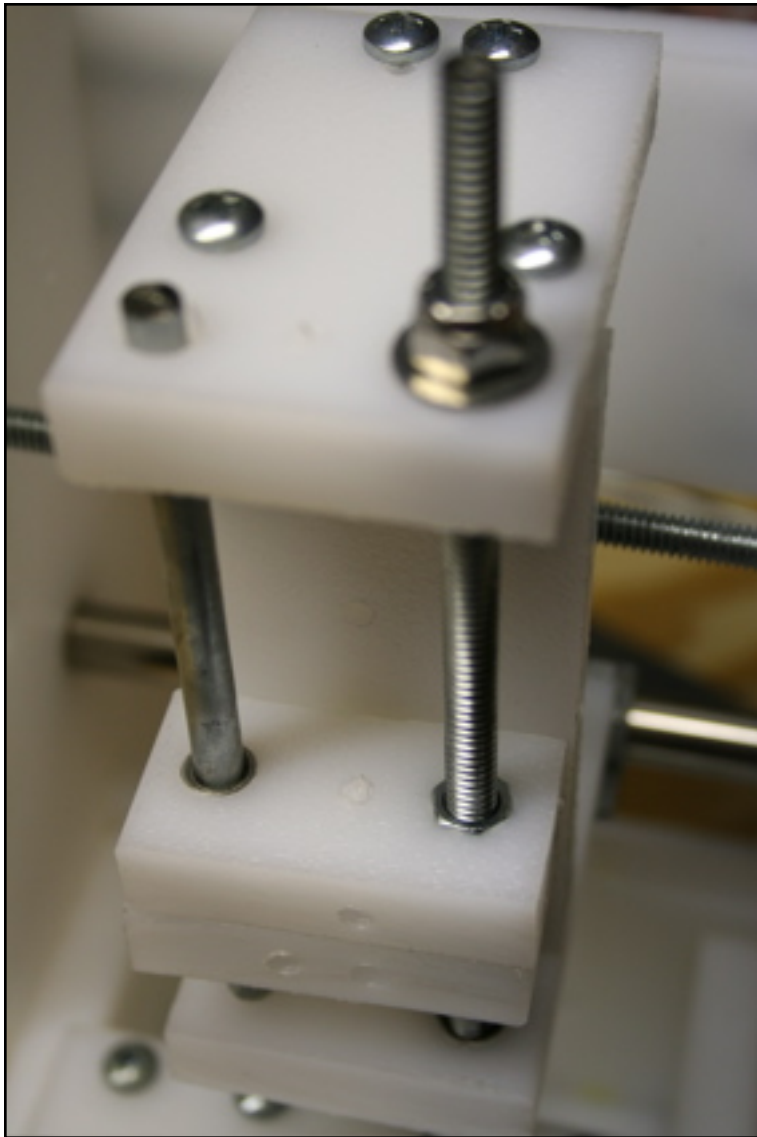
This slide and carrier were salvaged from an old Okidata printer. We decided to use it to smooth out the action for the Y axis.



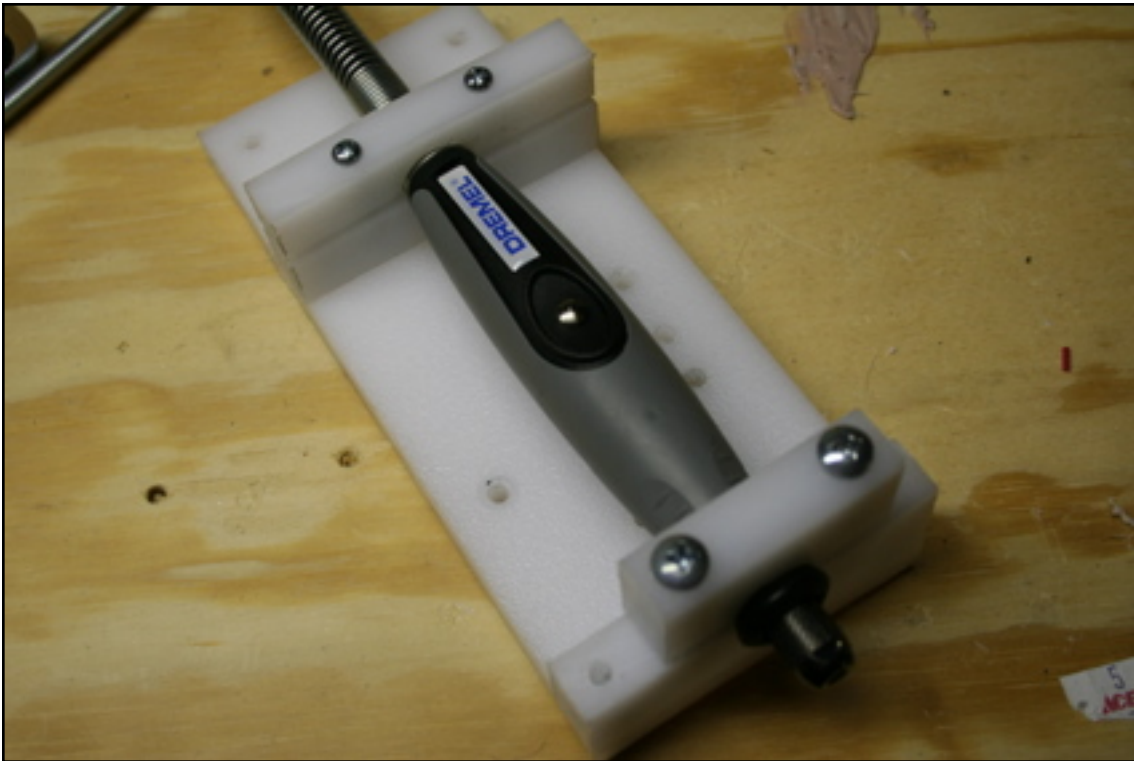
We whipped out the drum sander attachment on our dremel tool and contoured the plastic on the bottom so we could mount the printer slide without compromising the integrity of the cast metal.



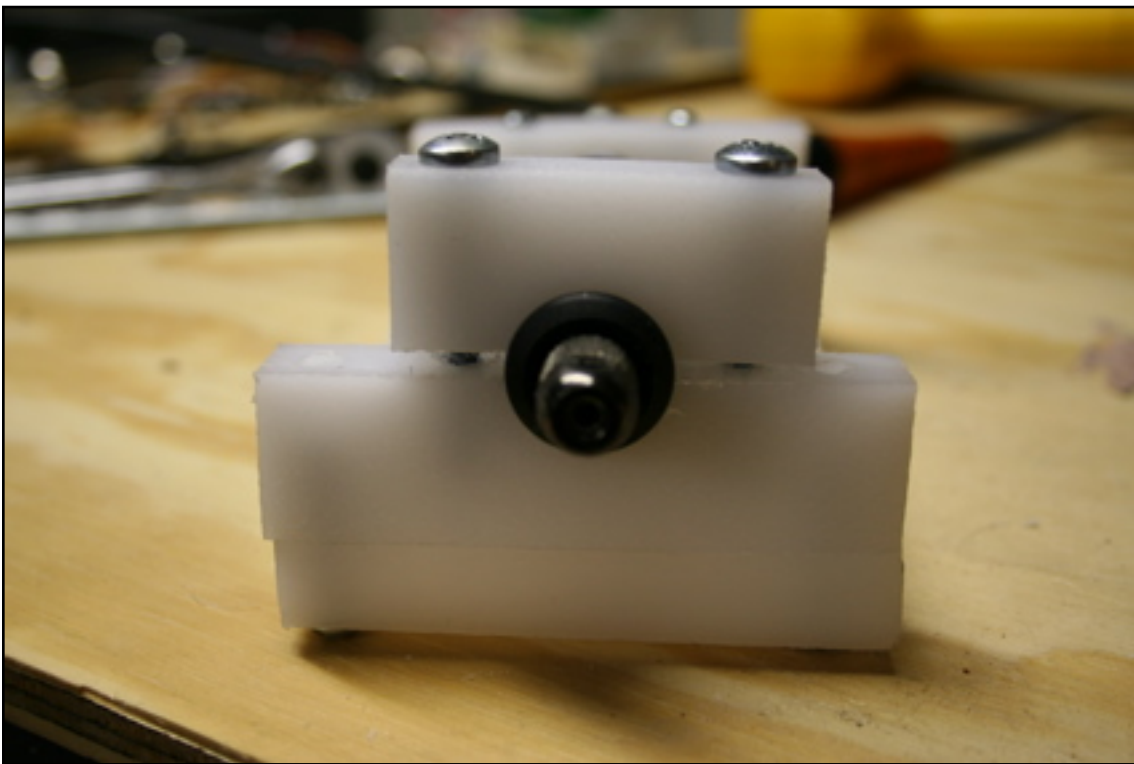
Once the slide was mounted, we marked and drilled the mounting holes for each axis. Once the slides are set up, we'll use some screws to lock them in place.



Once things start coming together, they'll get extra frustrating as you begin aligning the slides and drive screws. I took us a while to narrow down that the source of binding was the drive screw and nut combination. We'd overlooked them initially because they worked very, very well in the other cases.



Once each axis has been constructed, we needed a carrier for the rotating tool. We picked up a flexible dremel shaft and created a simple mount for it. The flexible shaft will reduce vibration. The dremel version has the nice button for locking rotation -- far less frustrating to use than the off-brand tools.



We used a couple of tricks to achieve a nice fit. The strips were cut first, then screwed together with some space to spare. Then we drilled the plastic with a starter hole and used the dremel tool to taper and round out the holes until the fit was perfect.



Motor mounts are dependent on the motors you've ended up with. If you're lucky, you'll salvage some motor mount brackets. Creative mounting can be achieved by using new or salvaged pulley systems.



Limit switches are very helpful for keeping your machine from self destructing. A switch is placed at the limit of each axis and wired in parallel. When the carrier or table contacts one, the circuit is closed and the controller signals the computer. Lever switches like these are ideal, or you can salvage some of the exposed contact switches from printers. The main danger of either switch is fouling caused by debris from your work project. Covering the switch with a bit of latex glove or balloon can help prevent problems later on.

Now that you've got all the bits of information you'll need to build your machine, lets get into some actual software to make the machine work.

[KCam](#) - Probably the easiest software to set up and configure, KCam is great for testing out your machine. It ran just fine on our Windows XP laptop. The drawback has to do with the method that Windows uses to access the parallel port. Because of this limitation, the machine won't run as smoothly as it really can.

[EMC Linux](#) - Some dedicated individuals maintain EMC and actually produce a stripped down, brain dead install of Linux just for running EMC. It doesn't take much of a machine to run, so it's great for dedicating an old machine just to run your CNC machine. Add a network card and you can operate and send jobs to the machine remotely. It's not too bad to install, but expect to spend some time figuring out the quirks.



Now, what you've all been waiting for... the machine in action! The bit is another tungsten carbide bit from [Drill Bit City](#). (Oh, how we love them.)

If you've gotten this far, congratulations are an order! Oh, and then you should already expect to spend some time troubleshooting your creation. Don't be upset if everything doesn't work perfectly! (Or if you end up ripping all apart and starting all over...)

Tags: [cnc machine](#), [CncMachine](#), [how to](#), [how-to](#), [HowTo](#)