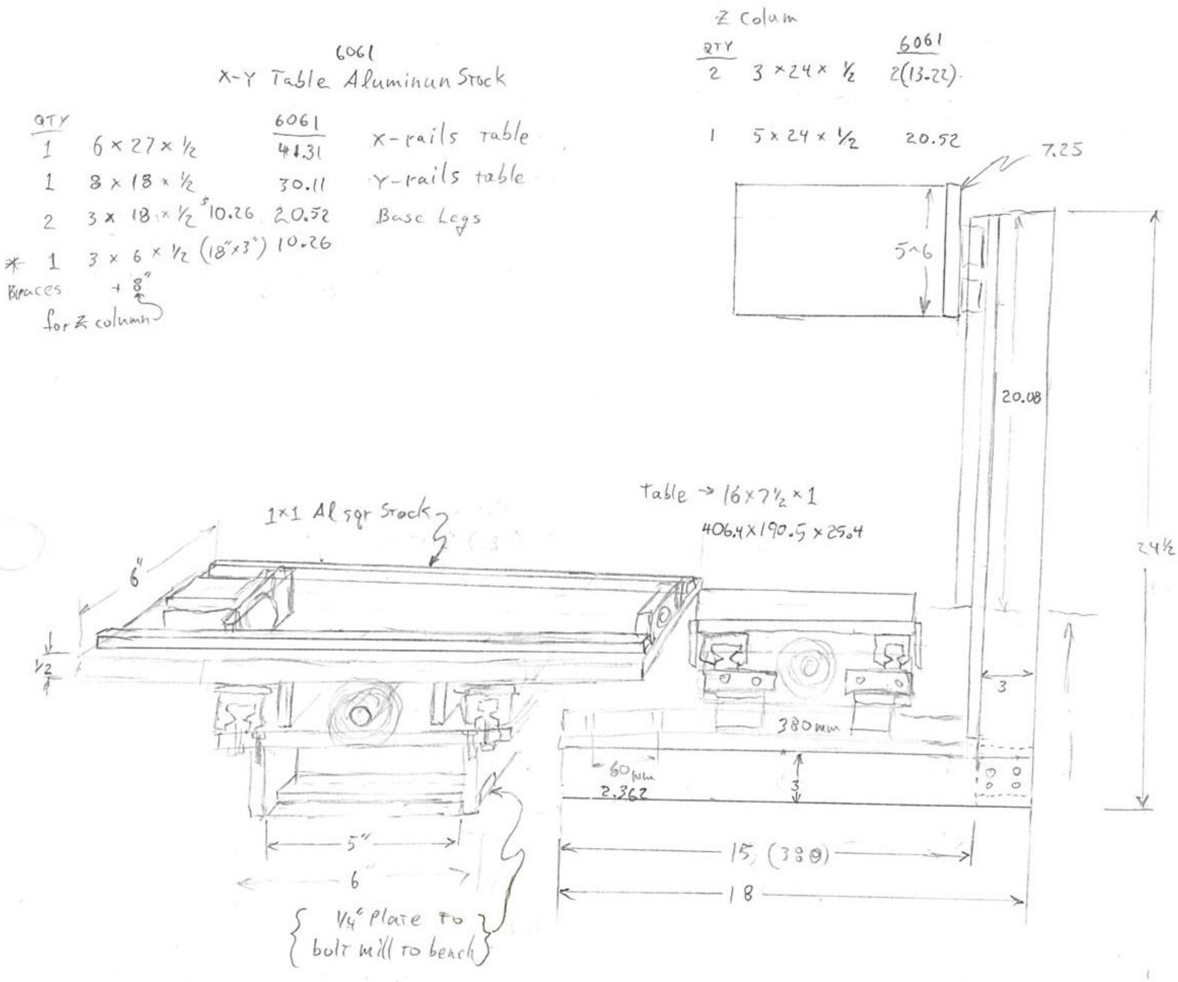
DIY CNC Milling Machine

Several years ago I made a decision that I wanted to design and build at least one and most likely several steam turbines. After much research I decided that this goal was something within my capabilities, but that I would either need to gain access to a CNC milling machine or build my own in order to mill the curved blades on each turbine disk. I was living and working in Silicon Valley California during this time, so it didn't take long to query a few of the many high tech machine shops in the area to learn that having anything made on a CNC would cost me much more than I wanted to pay, and besides, I was entering into this endeavor to build a steam turbine as a fun hobby project, so why not make building a CNC mill just another step towards that goal. After just a bit of "googling" I found an entire on-line community of like-minded people at www.cnczone.com. After a little more research, I was convinced that I could build my own DIY CNC Milling machine using my Harbor Freight 9" x 20" lathe and my Grizzly G0704 (BF20) manual milling machine.

Below is a view of the final machine.

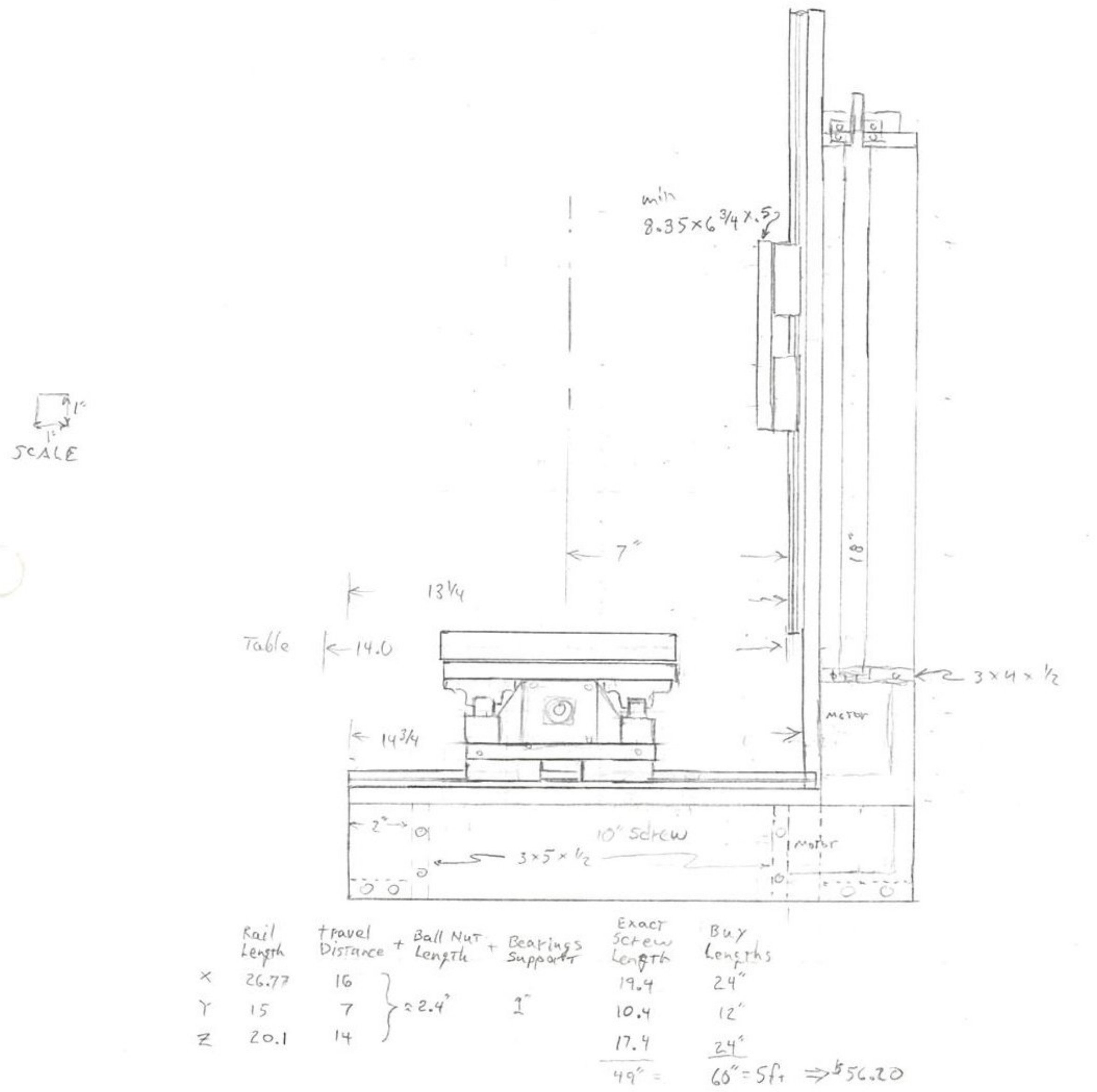
Before I go any further, I think it important to note that all CNC machines consist of 3 main parts; the metal machine itself, the motors and electronic hardware to make the machine move, and the software needed to control the electronics and motors. This article will focus on the first two parts; the metal machine and the electronics.

After researching what others on CNCzone had built, I had a good idea of what I wanted, and started making a few rough sketches, making decisions about what materials to use, and pricing those materials. I chose to use aluminum for as much of the construction as possible; with a machine as small as I was planning to build I didn't believe that I would lose any significant degree of stiffness by using aluminum over the use of steel, and besides, I really wanted to keep the weight down to make moving it around the shop as easy as possible,…I'm not as young as I used to be, and know how hard it is to move my Grizzly Mill.



The aluminum frame is mostly ½" 6061 extruded flat pieces either purchased from "Speedy Metals" (an on-line US company) or a local metal dealer in the San Francisco Bay area. I chose to use machine screws to assemble all the pieces, and to avoid welding, as the welding heat always warps the metal and removes much of the hardening from the aluminum alloy. A big unknown for me was whether or not machine screw fasteners would provide adequate stiffness.

Rough sketches were refined into to scale sketches which I use to for final fabrication. These sketches ar e far from detailed CAD drawings, but they're plenty good enough for me.



I drew everything in pencil and made lots of changes as I went….not exactly an ISO 9000 approved manufacturing method, but again, it works for me.

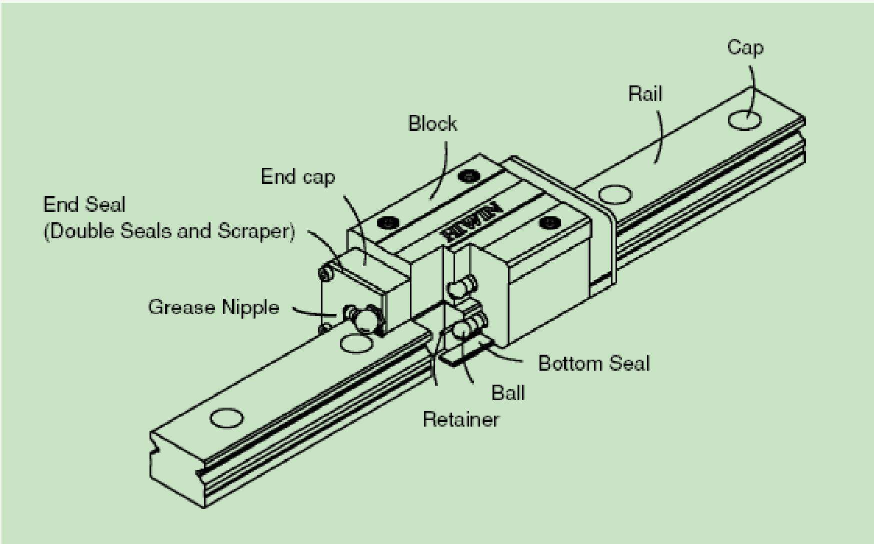
My design attempts to hide the motors and lead screws as much as possible so as to keep them away from mill shavings. Those parts which couldn't be hidden are covered with flexible cloth covers.

I used HIWIN linear guideways as they are designed for heavy loading and had been successfully used by others. Below is a brief description and a picture:-

2-1-1 Features of The LG Series Linear Guideway

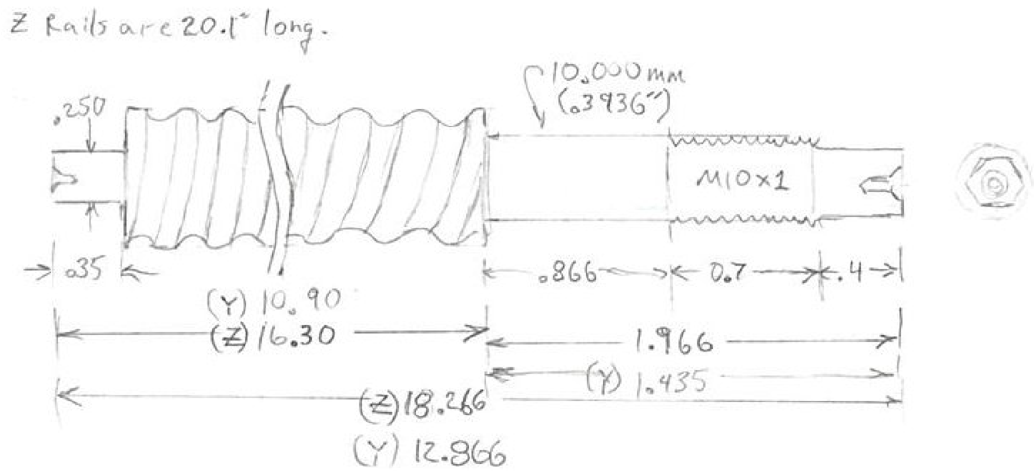
The enlarged ball diameter design has increased the stiffness and the loading capacity, and this makes the LG series guideway especially suitable for the application with heavy working load. Besides, the optimum design of circulating system makes the movement smooth.The retainer is designed for avoiding the balls fall out, even if the blocks are removed from the rail while installing.

2-1-2 Construction of LG Series

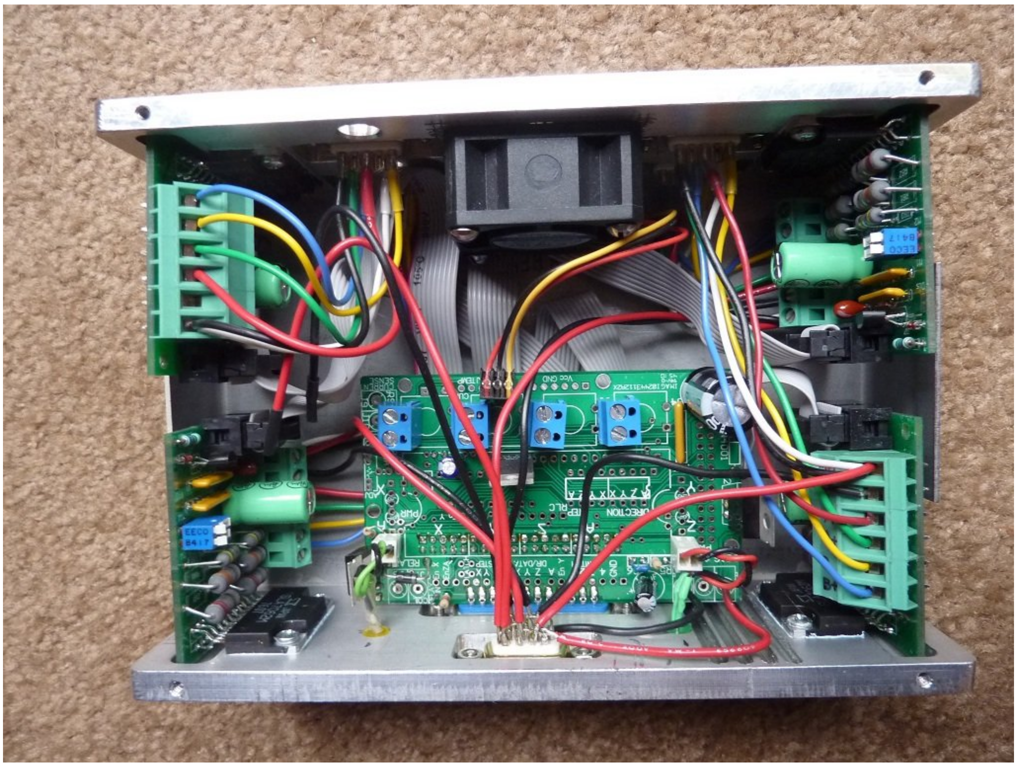


- Rolling Circulation System ➡Block, rail, end plate and retainer.
- Lubrication System ➡Grease nipple and piping joint.
- Dust Protection System ➡End seal, bottom seal, cap, double seals and scraper.

To keep friction low, I used 5/8" x .2 Ball Screws and Ball Nuts from www.Roton.com. Machining the ends of the hardened Ball Screws for the bearings and lock-nuts was a learning experience, but with a little patience and the right technique, it can be done.



All three axis's are driven by stepper motors which are in turn, all driven by individual stepper controller boards. The CNC hobby world is rather mature and all the printed circuit boards and electronic parts you see in the photo below were purchased from one of many on-line suppliers. I re-used an old electronic box I had laying around in my spare parts to put all the boards in. Most of the hobby CNC world uses the older Centronix, or parallel printer port found on older computers, to control their machines.

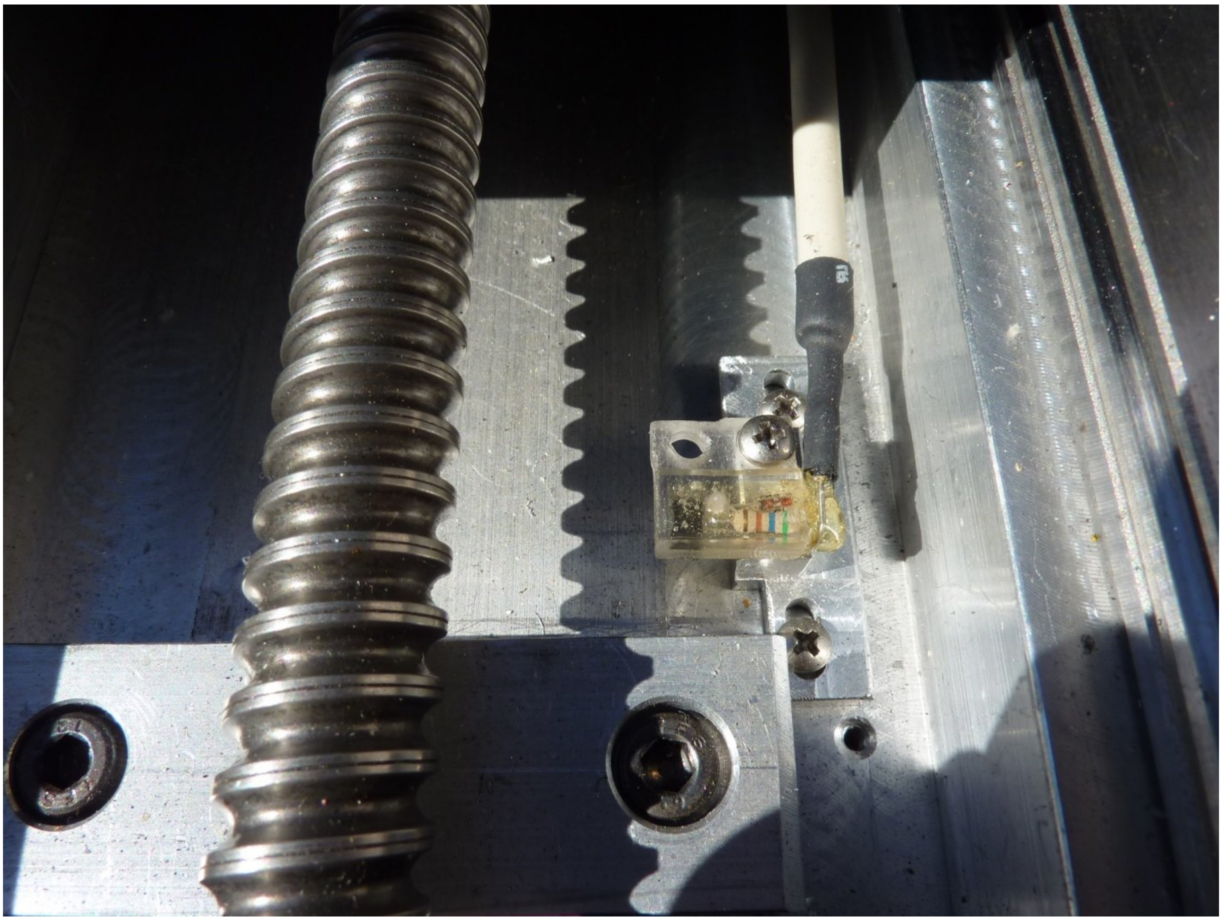


Stepper Motor Controller

I use only three of the four stepper driver boards shown in the photo, leaving the 4th for future use. The larger board in the middle is called a Break Out Board, and connects the 4 motor control boards to the printer port.

Below is view of the front of controller box showing the parallel printer port connector, DC power supply connector, and the electronic stops connector.

The little black box on top of the stepper controller is used to distribute all 3 axis's of electronic stops. We humans know when we've reached the end of travel on our milling machines, we can feel it in the turn-handle. But machines need to be told when they've reached the end of travel, or they just keep trying to "turn the handle" forever. I chose to use an electronic device called a Hall Effect sensor to accomplish this. The next picture shows one of six Hall Effect sensor modules I built.



Hall effect sensor module

Each sensor module consists of 4 electronic components epoxied in place inside a hollowed out piece of Lexan which is mounted on an adjustable aluminum block that allows the electronic stop to be set to “trip” just a few hundredths of an inch before the hard mechanical stop, which gives the software and motors enough time to gently stop instead of crashing full speed into the end of travel.

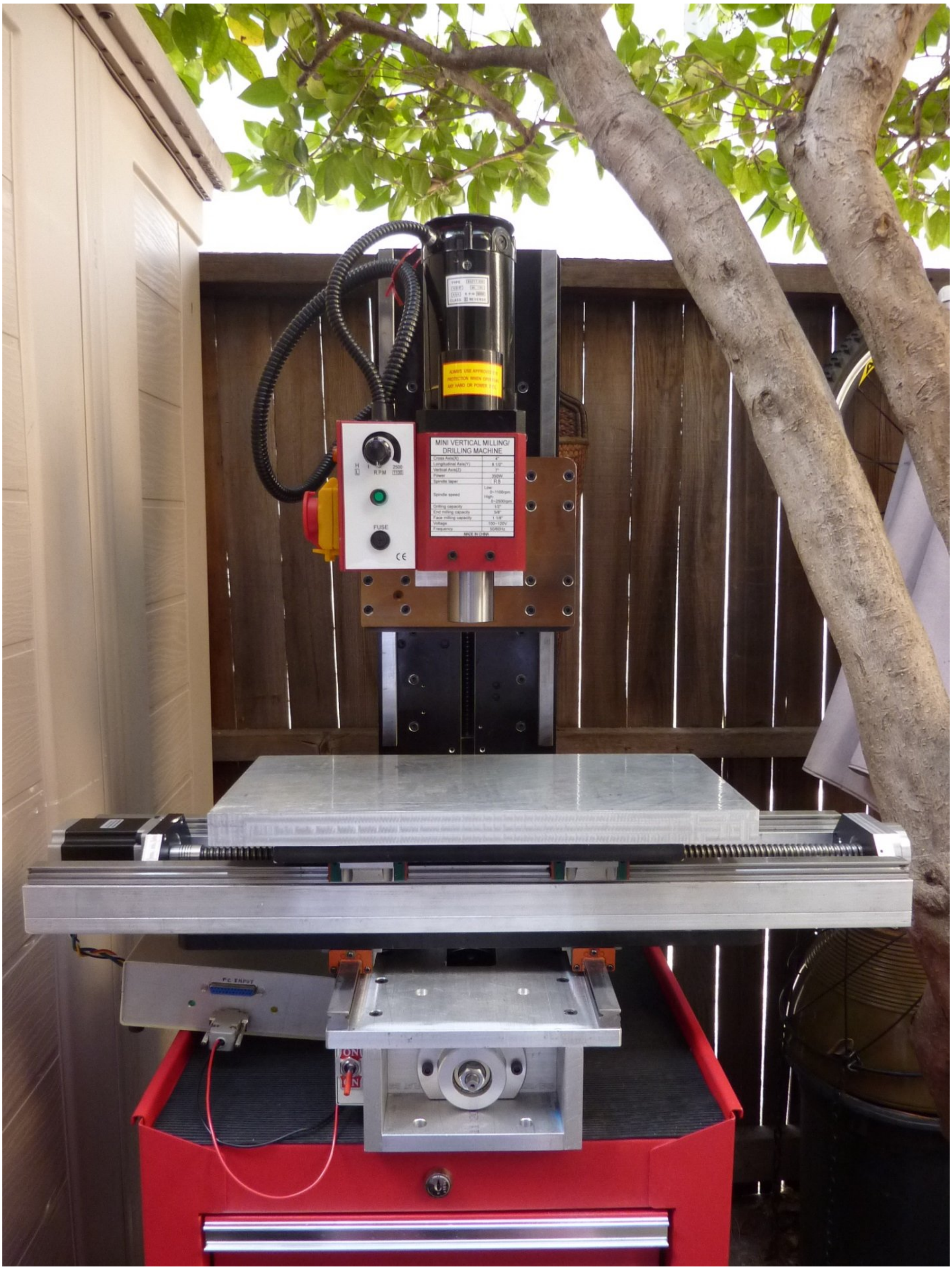
Getting back to the machine itself, the next photo shows an early stage of construction, before the mini mill head assembly was attached.

Partly to add rigidity and partly because I wanted to try out using a “fixture table” and a more traditional T-Slot table, I designed the mill such that either table can be easily bolted onto the carriage plate. I also selected this quick change attachment method just in case my idea of using an aluminum table didn’t work out, I could always remove it and replace it with a steel table.

Early construction phase

The next photo shows the T-Slot table before it was slotted and type 3 black anodized.

I considered making the milling head assembly myself but it turned out that buying the Mini Mill assembly which included the spindle motor speed controller and R8 spindle was cheaper than I could buy an R8 spindle by itself.



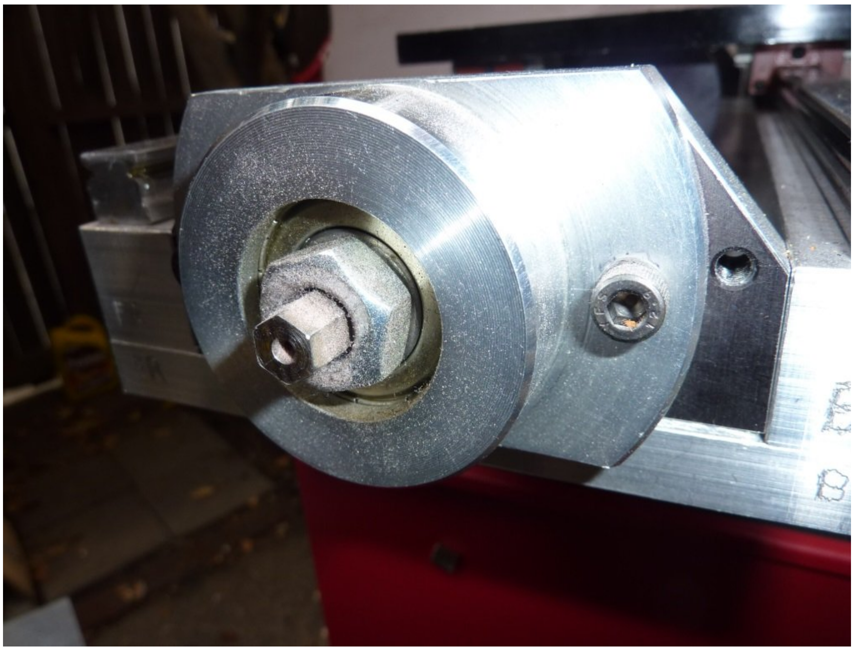
Unfinished T-Slot table

Counter weight spring assembly

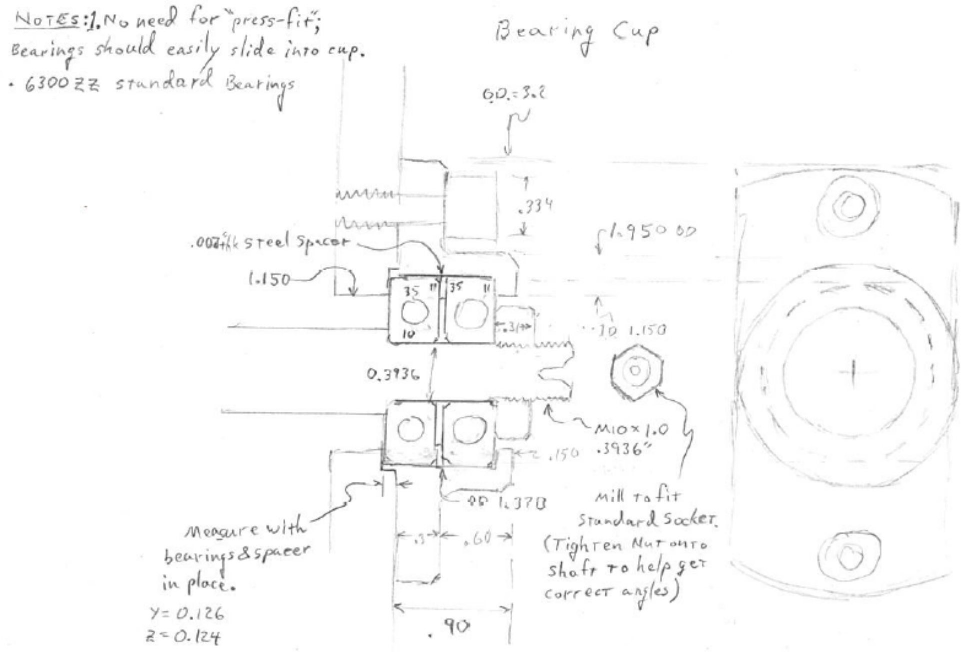
I had originally planned to use a single pulley & cable assembly attached to a simple lead weight to help offset the weight of the milling head assembly, but I came up with the above “block and tackle” idea as it reduces the overall machine weight and accomplishes the counterweight goal.

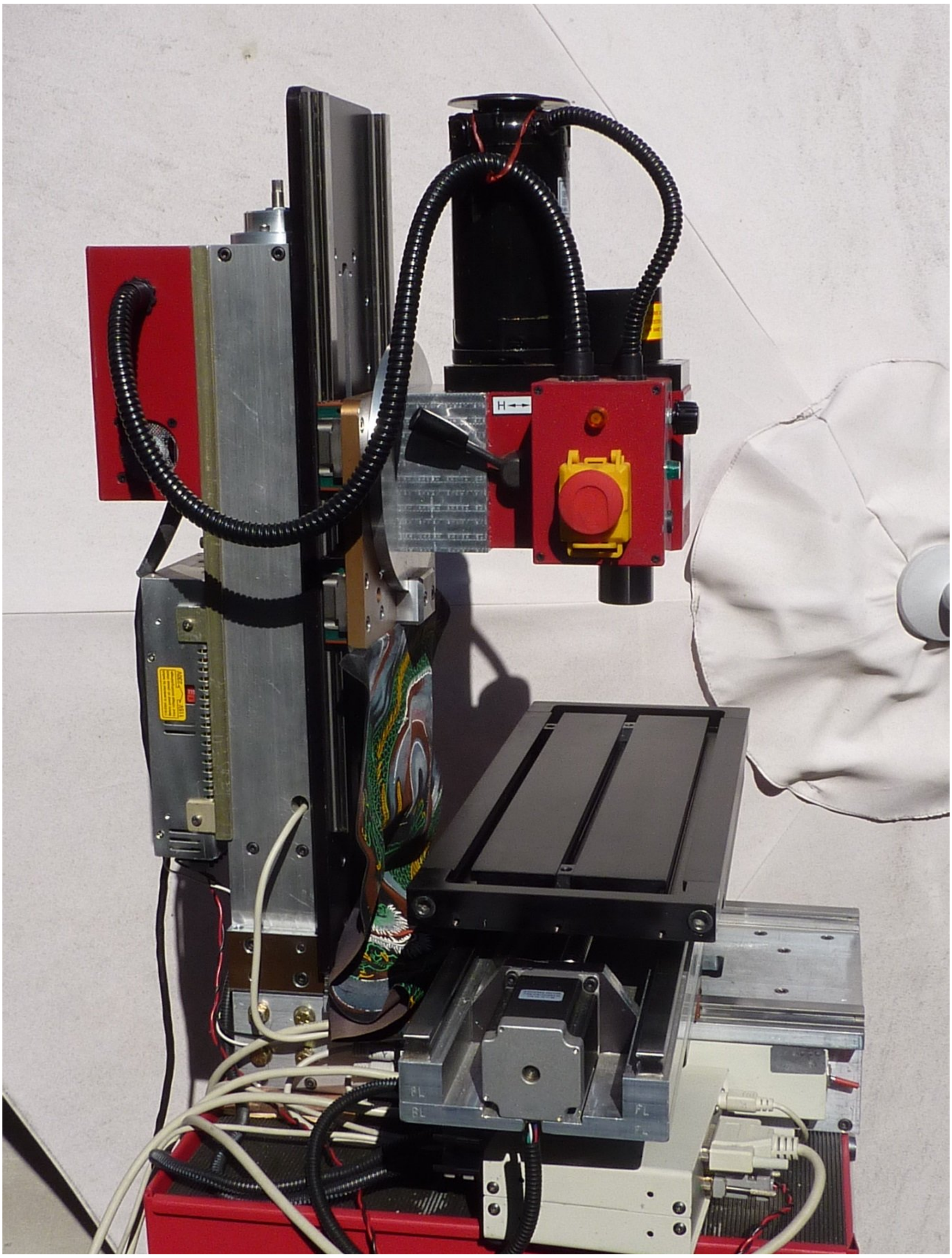
At roughly this point in the construction phase, I discovered that the use of a single ball nut, as is shown in the above counter weight photo, was inadequate as it allowed approximately 0.012” play or “slop”; my design goal was always to have “0” slop. I would need to redesign and refit all three axis with two ball nuts capable of adjusting out all slop.

Each lead screw is rigidly held in place by two ball bearings retained on their O.D. within an aluminum cup. All slop is removed by tightening the nut on the lead screw which pulls the two bearing I.D.s together. I also machined one end of each lead screw with a standard hex nut profile which allows me to manually move each screw, and thereby each axis, when needed.



Close up of “X” axis ball bearing cup and lead screw with tightening nut.


NOTES: 1. No need for "press-fit"; Bearings should easily slide into cup.
• 6300ZZ standard Bearings
Bearing Cup
O.D. = 3.2
.334
1.950 OD
.007 thk steel Spacer
1.150
0.3936
M10×1.0 .3936"
Mill to fit Standard Socket. (Tighten Nut onto shaft to help get correct angles)
Measure with bearings & spacer in place.
Y = 0.126
Z = 0.124
.60
.90



Side View

Red box upper left is the spindle variable speed controller which was purchased as part of the Mini Mill Head assembly. The silver box with the yellow label (located just below the red box) is a 36 volt DC power supply which provides power for the stepper motors.

Cloth covers protect lead screw and rails from milling chips.

Each white cover is gently pulled down by the addition of a steel rod inside the seam at the bottom of each cloth cover. The covers are easily replaced when they inevitably wear out.

Now it's on to the next phase: testing. I had hoped to have the time to fully test and check my newly created little toy before I needed to partially disassembled it and pack it up for shipping to Thailand, but I ran short of time. So at present time my mill sits in a box here in Thailand awaiting re-assembly. I still need to fully check the mill for trueness, that is, if I were to mill out a square box, will it be a perfectly rectangular box with perfect 90° angles all around? How stiff is the final assembly? These are questions I still need answered.