CNC Router Project

A low cost, but useful tool

Over the last few years I have built several CNC Routing/Milling Machines
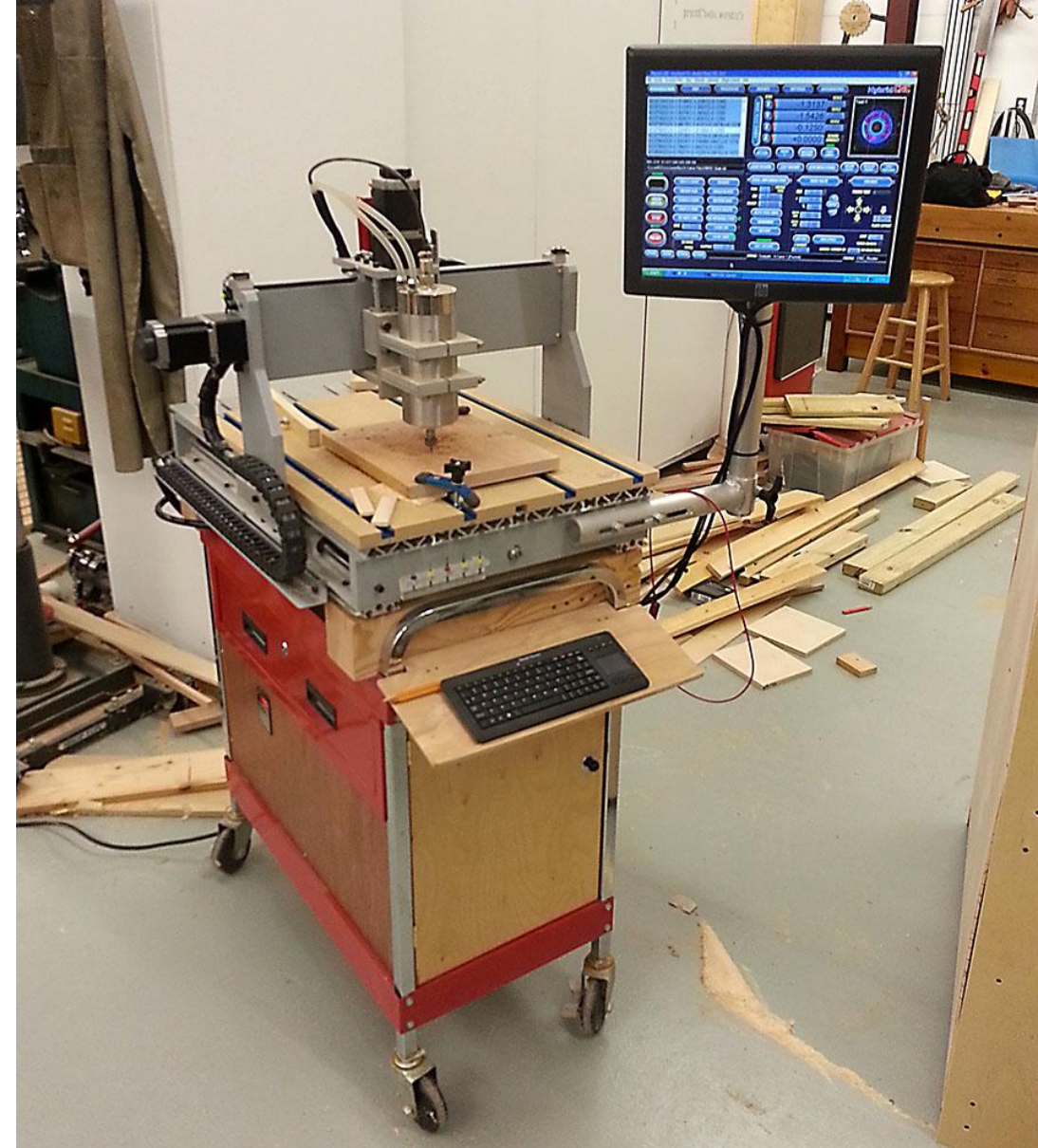
All machines use stepper motors controlled by Mach3 software.

This machine is a modified Chinese 6040 type CNC Router.

It uses a 1.5KW (2HP) water cooled spindle. The spindle is driven by a VFD for speeds from 6,000 to 24,000 RPM.

The original electronics were replaced with a Gecko G540 stepper controller.

The unit is self-contained and very easy to use.

Although the 6040 machine functioned well, I decided to build a larger machine from scratch. The plan was for a machine designed mostly for woodworking, but capable for fine work such as milling printed circuit boards.

The new machine has a working area of 27x48x5". It uses a 3HP water cooled spindle with an ER20 collet. This allows cutter shank diameters up to ½"

A special vertical bed on the end of the machine allows work pieces to be mounted vertically for end machining dovetail joints.

This machine was designed by a friend who is here from Germany. I assisted in the design and did most of the machine work.

It is a very stout machine well designed for cutting wood of aluminum.

It has a work are of about 20x30x5".

The machine I brought today is a modified Chinese 2030 type machine. This machine was design specifically for milling printed circuit boards and other thin flat work.

More about this machine later.

This is my latest machine.

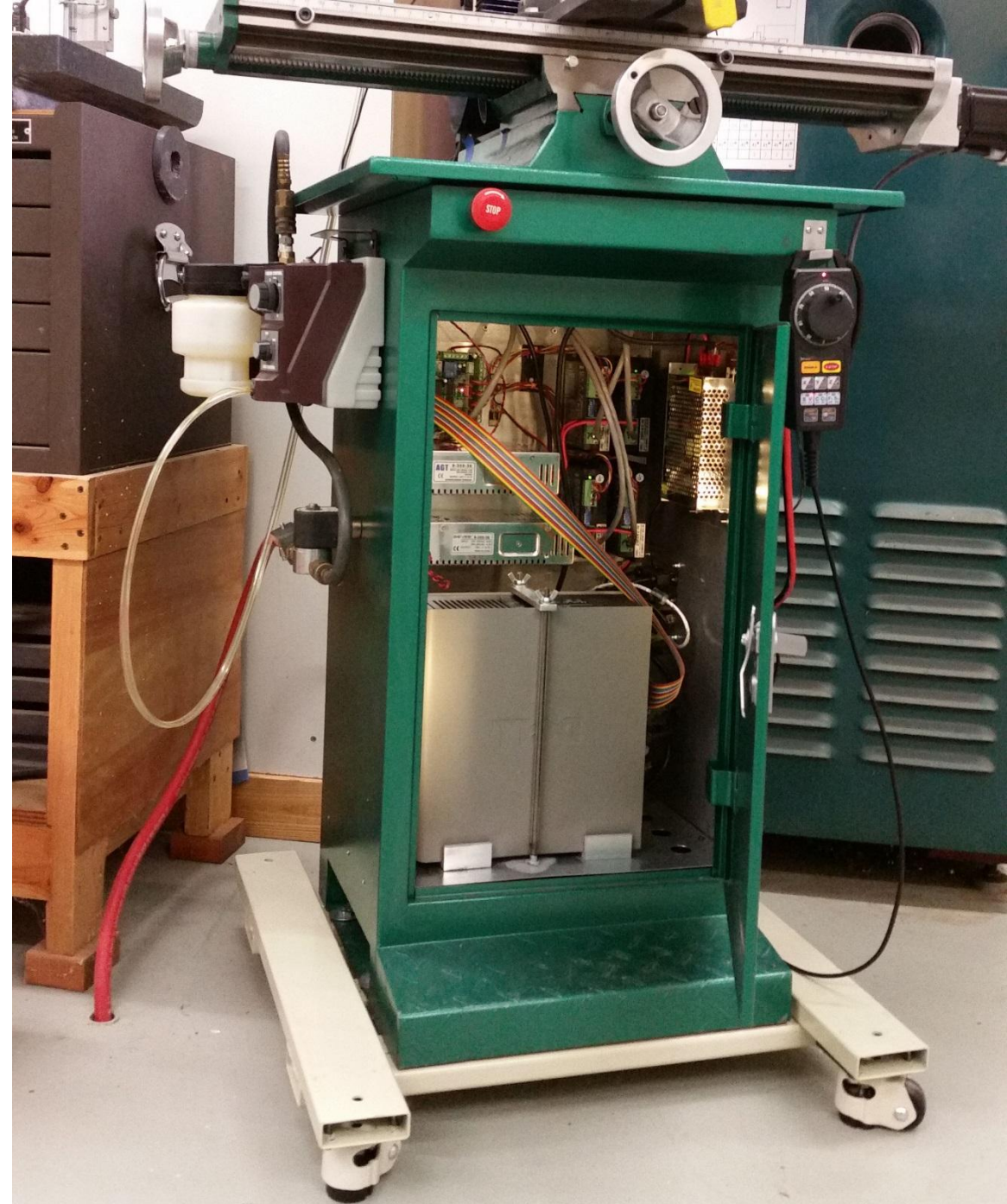It is a Grizzly G0704 milling machine that has been converted to CNC operation.

Lead-screws were replaced with ball-screws. All electronics, including the computer, are located inside the base.

It is fully capable of machining most metals including steel.

Locating the electronics inside the cabinet-stand makes for a compact and robust design.

The cabinet is cooled using a fan in the base blowing air through a automotive air filter/ The fan and filter are under the computer.

The mill has automatic control of the mist coolant system, but does not have automatic spindle motor control (yet).

What is involved in the design and building of a CNC Mill/Router?

There are three main sections to any CNC Machine.

1. The mechanical components
2. The electronics
3. The software

Mechanical Considerations

1. Basic machine layout
2. Lead screws vs ball screws
   a. Lead screw/Ball screw mounting
   b. Isolation from drive motor
3. Stepper motors vs Servo motors
   a. Stepper motor size
   b. Torque, current, and inductance
   c. Four, six, or eight leads?
4. Spindle motor
   a. Trim router
   b. Air cooled DC spindle
   c. Water Cooled 3 phase spindle

Lead-screws, sometimes referred to as Tangential or Acme screws are inexpensive but present backlash and friction problems.
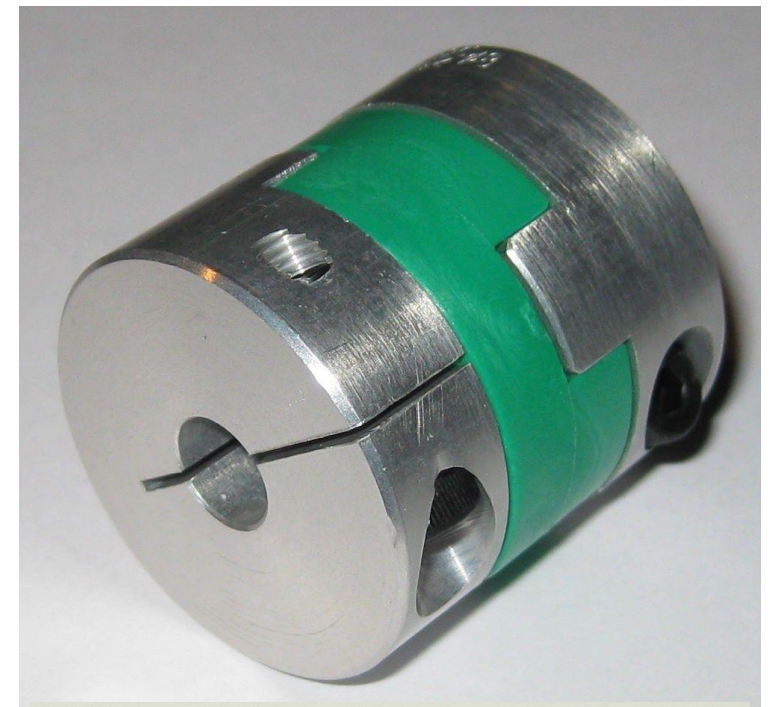
Ball-screws have almost no backlash and very low friction. They can be expensive, but the Chinese made screws are good quality and affordable, fine for hobby/light use.

Some type of flexible coupling should be used between the Ball-screw and drive motor.
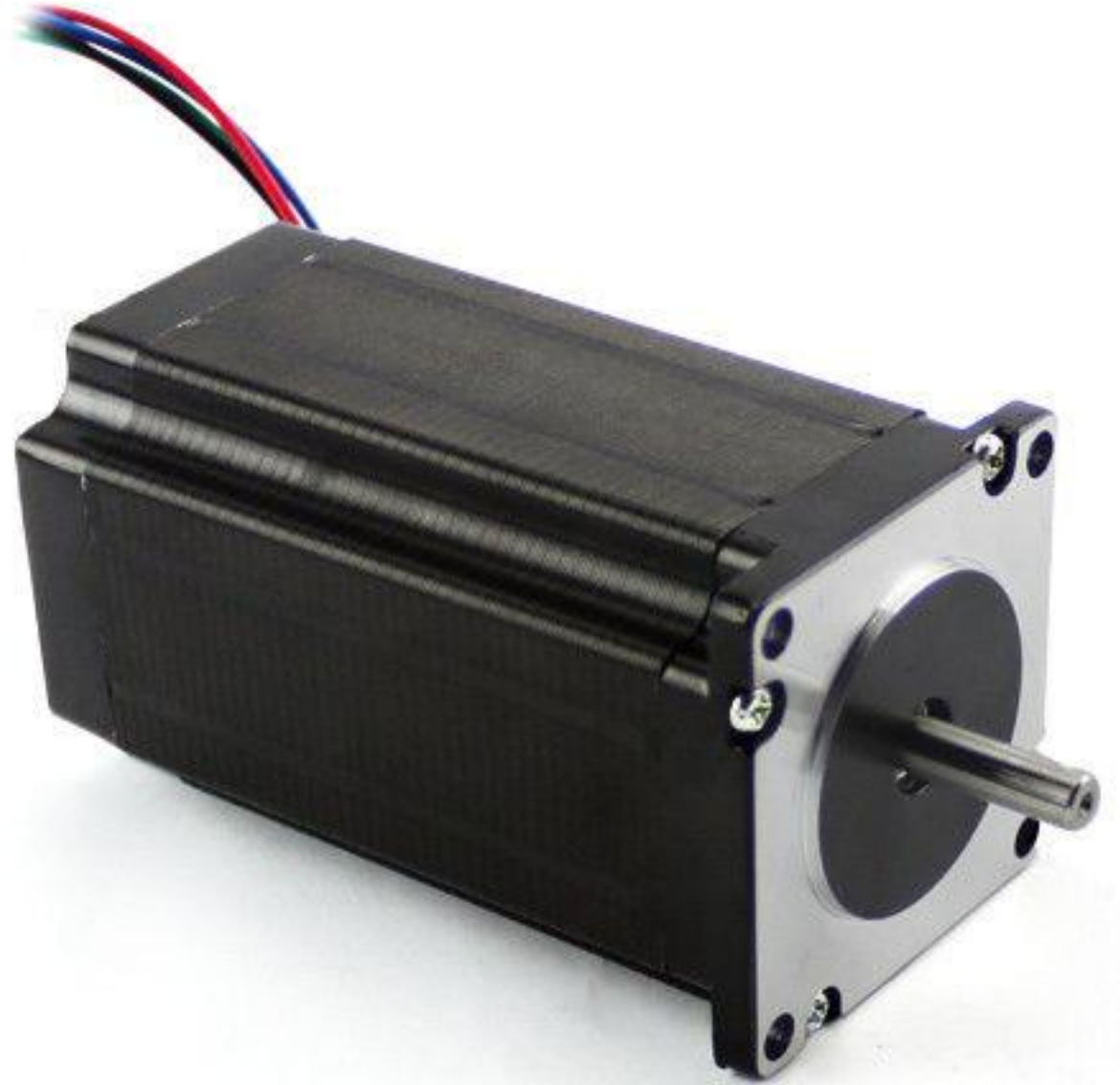
Oldham couplings work well and handle high torque. As they wear, backlash may start to appear.

Spiral cut couplings have no backlash. I prefer the compression type shaft locking over the set screw as shown in the photo. For high torque, a roll pin should be used.

This is a NEMA 23 motor. It is 2.3" across the face. Smaller motors, such as the NEMA 17 are used for low torque applications such as 3D printers.

For high torque applications, such as converting a Bridgport type machine, NEMA 34 motors may be required.

Stepper motors are sold by torque, but there are other specifications you should be aware of.

The torque curve shows the motor's torque at various speeds. This curve below shows a motor with high static torque, but its torque falls off quickly at higher speeds.

To avoid this problem, also look at current and inductance. A low inductance motor has higher current, for the same torque, but can achieve much higher speeds.

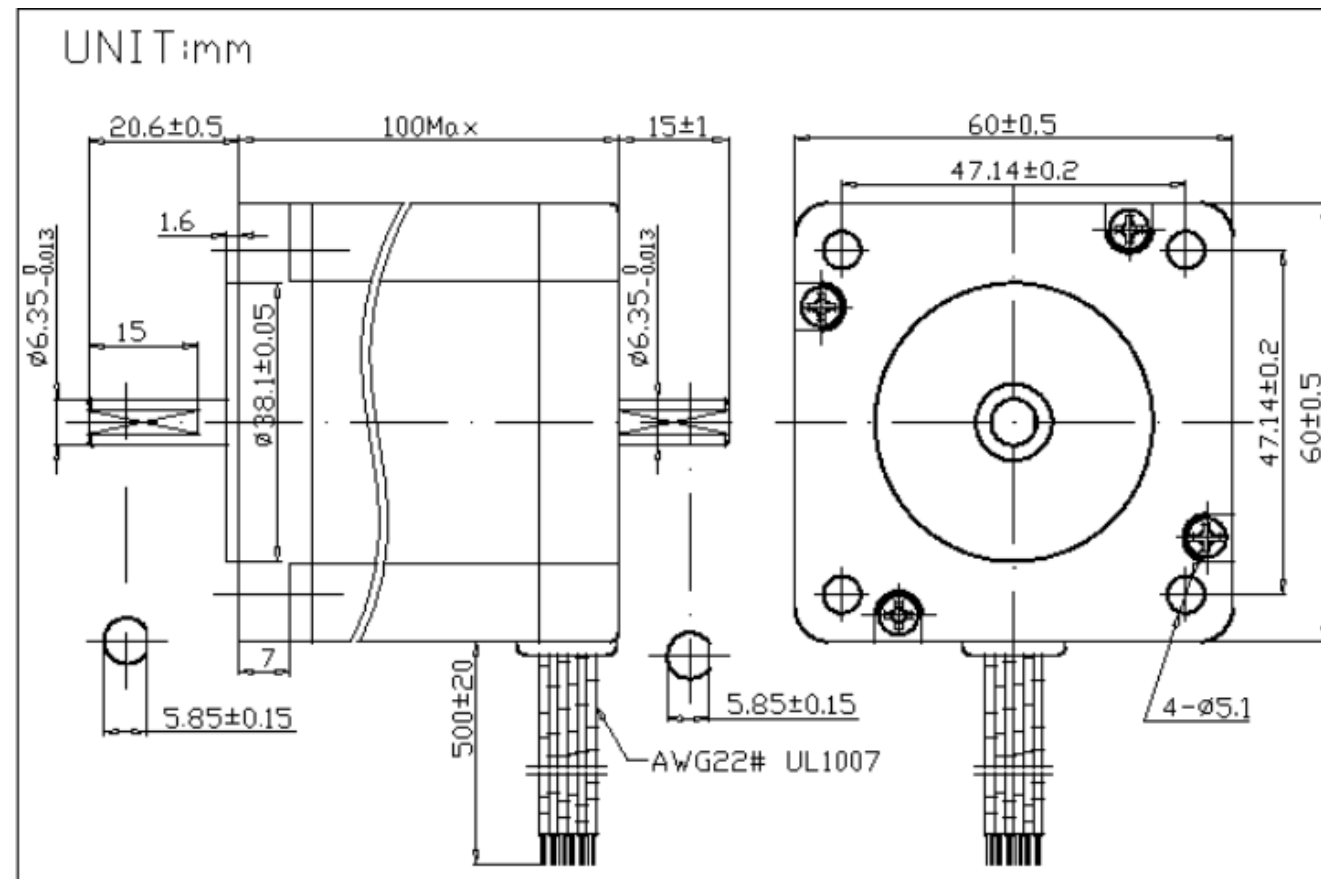A four lead motor has two coils and is simple to connect. A six wire motor has two center-tapped coils, the center taps are usually left unconnected with modern driver modules.

This motor has 8 leads, which means it has two pairs of coils and can be used in several ways. Generally you would want to operate the motor in parallel.

UNIT:mm

	Holding Tourque (2 phases on) N. cm ± 10%	Rated Current/Phase (Amps DC)	Resistance/Phase (ohms) ± 10%	Voltage/Phase (V DC)	Inductance/Phase (mH) ± 20% Typical (1kHz)
Unipolar	420	3.5	1.2	4.2	2.7
Bipoar (Series)	570	2.5	2.4	3.0	10
Bipoar (Parallel)	570	5.0	0.6	3.0	2.7

CNC routers must be able to operate for extended time periods. When 3D carvings are done, the spindle may have to runs many hours without stopping. For this reason a water-cooled 3phase spindle is an excellent choice. These spindle will operate from 6000 to 24000RPM under control of a VFD. The VFD can be controlled by the computer.

Unfortunately, these motors do not operate well below 6000RPM.

Electrical Considerations

1. Stepper motor drivers
2. Power Supplies
3. Breakout board or smooth stepper
4. Limit switches
5. Touch pad
6. Computer
   a. Touch display
   b. Keyboard, mouse
   c. G-Code import
      1. On machine generation
      2. Thumb drive
      3. Network
7. Pendant
   a. X-Box controller
   b. Vista CNC
   c. Wireless Pendant

Stepper Motor Drivers

Drivers come in various voltages and current ratings. Choose a driver that handles the current required by your motor.

Higher voltages allow faster operation of the motor, but quickly become expensive.

Modern stepper drivers use micro-stepping and PWN current control.

After the size and number of motors is determined, you can determine the power requirements.

Most NEMA 23 systems use either 24 or 36 volts. Smaller motors can generally get by with 24 volts. If your motors are larger, and have more inductance, 36, or even 48 volts may be necessary.

Using multiple power supplies for multiple driver modules works well. Do not connect power supply outputs in parallel.

Breakout boards organize the parallel port signals from the computer.

Output signals such as Step and Direction are connected to the stepper drivers. Input signals from limit switches and touch sensors are read through the breakout board.

The breakout board also provides opto-isolation of signals to prevent damage to the PC.

Machine Sensors

Limit switches are optional, but can be very handy. Limits switches can stop the machine in some goes haywire, but they can also be used to determine a machine "Zero"

A touch pad is a simple piece of conductive material (a piece of copper clad fiberglass works well) that is placed on to of the work-piece. The machine can lower the tool until it touches the pad to precisely determine Z axis zero. A real time and tool saver.

Computer selection

For Mach3 control software, the computer speed should be at least 1.5GHz. It is best to dedicate the computer to only Mach3 operation. Other programs operating in the background will cause problems.

The small chassis Dell computers work well and can be purchased used for around $50. Look on Craigslist or eBay for good deals on used machines.

The computer must have a parallel port (this rules out new computers). Also Windows XP or a 32bit Version of Windows 7 must be installed.

Computer Accessories

A touch display allows control of the system without using a delicate keyboard and mouse. Most touch displays are impervious to dirt and oil. A used ELO 15" display can be found on eBay for $50-$75.

There are times when a keyboard and/or mouse are needed. Get a wireless keyboard with a touch pad instead of a mouse. Keep the keyboard hidden away when not required.

G-Code should always be generated on another computer. Programs can be transferred using thumb-drives, or better, through a WiFi network link.

Pendants

A Pendant, or MPG, allows remote jogging of the machines axes.

A wireless X-Box controller can be used with a USB adapter.

The VistaCNC pendants are very reliable and connect through a USB.
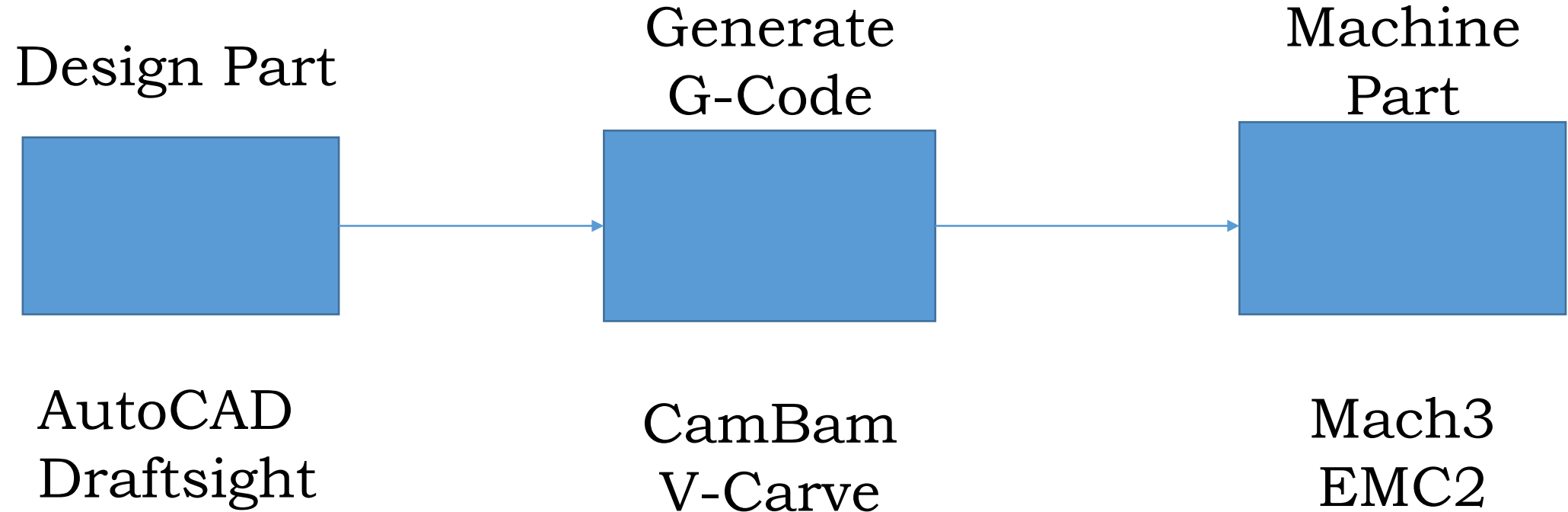
The Chinese wireless units tend to be unreliable in my experience.

Software Considerations

1. Linux based systems
2. Windows based systems
3. Design Software
   - a. AutoCAD / Draftsight
   - b. PCB CAD packages
   - c. Other design packages
4. CAM Software
   - a. CamBam
   - b. V-Carve / Aspire
   - c. Other Cam packages

Software Flow

Operating Systems

Linux (Ubuntu) systems use LinuxCNC (EMC2) as the G-Code interpreter. Linux and LinuxCNC are free, but not as universal as the Windows/Mach3 systems.

Windows XP or 32bit Windows 7 and Mach3 are the most popular combination. Mach3 is a very versatile program. It allows custom operations written in Visual Basic, and simple I/O operations written as Brains. There are many aftermarket support products for Mach3

Design Software

There are many CAD and drawing programs that can be used for 2D design. Since most of the work done on CNC Routers is 2D, these work fine.

AutoCAD, DraftSight, Adobe Illustrator, Corel Draw, and Inkscape all product DXF files that can be used G-Code generation.

Cam programs such as CamBam and V-Carve also have built-in design capability.

CAM Software, G-Code generators

CamBam is a low cost program that provides extensive control of the CNC machine. CamBam can also be used for reading the Gerber files produced by printed circuit design programs. CamBam should be in all CNC toolboxes.

V-Carve does not provide the detailed control of G-Code that CamBam provides, but it main strength is the generation of 3D V-Carve toolpaths. In these toolpaths, line width is controlled with control of the Z-Axis (depth) of the V-type toolbit. This producing extremely fine details and square corners using a round toolbit. Aspire provides all the power of V-Carve plus extensive 3D carving capability.

Mini-Chop High Precision CNC Router

Chinese CNC Router with ball-screws, 800W water cooled spindle, control electronics, and 4th Axis rotary adapter and tailstock.

Price of basic machine:	$865
Vacuum platten and pump:	75
VistaCNC pendant:	100
Touchscreen Display:	100
Computer, Keyboard etc:	125
Total system cost:	$ 1265