Interested in CNC?
Things to consider before buying a CNC machine

A CNC machine is a tool which can help you create items in wood, metal or plastics. The machine is simply a device that can carry tool bits in a router spindle or a laser cutter and mark, engrave, cut or shape different stock materials. The tool in use moves left and right, forward and back and up and down while the workpiece is fixed into position.

As CNC users we have made many many mistakes in buying our own machines, which we did without understanding what the requirements would or could be once we had got our machines up and running. The aim of these pages is to help you over that initial period where everything is new and makes no sense.

Should I buy a CNC machine?

- Is the machine going to be purchased as a part of a hobby for you?
- Do you know what size machining area you would like? (bigger is usually more expensive)
- Have you a space in mind for housing your CNC machine?
- If the space is a shed, will the shed be damp at any time?
- CNC machine routers can be very noisy so would this disturb your neighbours?
- CNC machines are heavy structures so do you have plans to support the weight?
- Would you use the CNC machine to support a business venture?
- Will anyone else be using the machine in your business?
- Have you considered regulations concerning employees, noise and guards?
- Have you considered regulations for dust extraction and particulate masks?
- What engineering knowledge do you have?
- Do you know how to read or write *G Code?*
- Do you understand the Cartesian Coordinate System?
- Have you ever worked with your hands and made things in wood or metal?
- Have you ever used a computer for any aspect of design work?
- What products do you wish to make and machine?

What is a CNC machine?

A CNC machine is used to machine parts using different manufacturing processes and machines. CNC is an abbreviation for **C**omputer **N**umerically **C**ontrolled and the use of a computer is vital to the operation. A CNC machine can be a lathe or a milling machine. It may also be a 3D printer or a laser engraving tool. It can be a drilling machine or a grinding machine and may be a plasma cutter or a water jet cutter. CNC machines may be routers or electrical discharge machines and they can all be named as having three, four or five axes.

The common ones have three axes which indicates that the tool can move in the X direction (left and right) and the Y direction (forward and backwards) and finally the Z direction (up and down). Cutting a line in a piece of wood on a flat surface only requires X and Y travel. Any degree of 3D cutting, where the tool moves up and down at the same time it is cutting left and right or front to back, requires the tool to travel in the Z direction. Some machines can change the tool bits automatically and this adds a further layer of complexity and control.

Some machines offer a further axis of travel. This axis is known as A. It is used when a machine has the ability to rotate the workpiece so that the tool can cut into a rotating workpiece. These machines will also be known as fourth axis machines. Fifth axis machines exist as well and they can tilt the table and/or the tool and can manage undercutting operations. Their use is mainly for 3D sculpted parts and they are beyond the needs and the smaller budget of most hobbyists. The fifth axis is known as B.

Running any CNC machine requires electricity, a computer and software for the design and control of the machine. The machine needs a means to carry and rotate the tool bit. This is usually provided by a router or a spindle. The machine will need a hardware controller to enable it to accept and interpret the software commands sent by the computer software.

Computer program software is generally of two kinds. These are known as open source and proprietary. Open source software is often available for free and is maintained by a group of enthusiasts. Proprietary software is usually paid for and may be supplied to work only with a particular machine. You would then have to change the software if you were to change your machine in the future.

The software for a CNC machine is often considered as three components. The first component is the design portion of the software. This allows the user to draw designs and create toolpaths that follow the designs and it turns the design into *GCode*. Sometimes this software may be referred to as CAD (**C**omputer **A**ided **D**esign). The GCode represents the steps required to create the design and these are coded in the order the tool must follow.

The second component to the required software is the program that takes the GCode and translates that into actual movement of the tool holding part of the machine. It tells the machine to move in X, Y or Z directions that are positive numbers or negative numbers. It follows the order in which the workpiece parts are to be cut, which was previously decided in the CAD part of the software. This is usually referred to as the CAM (**C**omputer **A**ided **M**anufacturing) section of the program.

The final part of the software is often hidden from the user but it makes the GCode work with your particular machine and its hardware interpreter and controller. This is referred to as a *Post Processor* and it will speak the exact dialect of GCode that your machine needs to operate.
Good CAD software will supply the post processors for many different machines so that you only need to design the part once.

You may hear the total software program referred to as CAD/CAM software. This tells you that you can use it from start to finish to create a design and get it machined by your own machine. Many designs can be created in design software for CAD alone or illustrations but the software cannot create and apply toolpaths. Further processing of the designs in a CAD software that can create toolpaths will be needed before passing the design to a CAM program.

What type of CNC machine should I buy?

Lasers

A laser engraver will use a single laser beam to burn a pattern onto wood. It can also burn paper or card and make patterns on slate or ceramic using special techniques and coatings. It may be a strong enough beam to burn lighter softwood such as plywood or balsa wood in such a way as to cut through it. There are several types of laser machine and they all use a computer and software to control the position of the laser head in both X and Y movement directions. Laser machines tend not to require movement in the Z axis.

Laser machines may be classified by wavelength and power. Laser output can be measured in milliwatts (mW) or Watts (W) while more powerful lasers can be measured in kilowatts (kW). As well as power output, a laser will have a frequency measured in nanometers (nm) which will determine the colour of the beam. This is important so that laser safety eyewear can be selected in the correct colour for the output frequency.

The frequency of the output from a laser will also determine its class. There are 4 classes of laser beam activity with some subdivisions for optically magnified output (1M and 2M). Classes 3R and 3B are harmful and need special conditions for viewing the beam. Class iv (4). is the most harmful and dangerous radiation level and can cause eye injuries, burns and skin burns, even from diffuse radiation. The type of laser that you will most likely buy will be class iv if its output exceeds 500mW. Typically, the lasers used by hobbyist are usually diode type lasers with an output below 10 Watts and they will produce a beam in the visible spectrum of 400 ~ 700 nanometers (nm). The most commonly available diode lasers are seen with an output at 445nm and 2 ~7 Watts.

A 445nm laser will require a dark green safety goggle lens and with an optical density (OD) of anywhere between 3 and 5, as calculated on the visible frequency of the beam. Signs that warn people of laser use and a laser machine that needs a key to switch it on are essential safety measures. The key should also lock the machine in the off position and be removable. A fire extinguisher is another sensible precaution because laser beams produce heat and may cause materials to be set on fire.

A step up in power output from diode laser beams is the CO_2 laser. Typically home users will have access to anything from 10 Watts to 50 Watts of power and 100 Watts is not unheard of. These laser beams will cut through metal. They need a lot of electricity to produce the laser effect through the gas and this will normally involve electricity at around 20Kv (kilovolts). Another highly dangerous factor in this type of laser is that unlike diode lasers which produce a beam in the visible spectrum, the CO_2 laser produces an invisible beam at the infra red end of the spectrum.

The very latest laser machines to become widely available are the much more powerful fibre lasers. They cost multiple thousands of pounds and the power outputs are currently in the 20 to 60 Watts range. These MOPA machines will engrave metal using a pulse duration of 2 ~ 500 nanoseconds. They can also mark metal to depth of 1mm at speeds of 7 milliseconds. This brief introduction to the subject of lasers cannot be left behind without mentioning that several manufacturers make laser attachments that are designed to fit onto CNC machines.

These are usually diode lasers and we have personal experience of such a 4.2W laser attachment. These devices work more than adequately for much of the work that one could wish to undertake. Being a high quality diode laser, it has a potential service life of up to 100,000 hours (11.4 years of continuous use).

3D Printers

These printers are all driven by a computer interpreting your design. There are a number of different processes which may be used to produce the 3D part. The part is often plastic but they can be created in metal too. The oldest type of 3D printing process is stereo-lithography and this is usually abbreviated to **SLA.** An ultra-violet light-sensitive resin is cured by the UV laser light source, which is directed by mirrors onto successive layers of resin. This process is known by the name photo-polymerisation.

An updated form of the SLA 3D printer carries the abbreviation **DLP**. This printer works by digital light processing and projects the digital image onto the resin surface. It is a faster method than SLA and the time savings are helpful, especially within industrial settings. The printers tend to be cheaper to buy than SLA printers.

Recently **LCD** printers have made an appearance and are usually smaller and cheaper than DLP printers. The printers use a series of LCDs to illuminate the image and shine it onto the resin. This technology (like DLP) also cures a whole page pf resin at once. A good general rule is that resin 3D printers are not usually recommended for users who are new to 3D printing.

The place where most beginners will start is with a 3D printer that works by Fused Deposition Modelling. **(FDM)** These printers are relatively cheap to purchase and they use reels of plastic filament to create the model. The filament travels through a heated nozzle and is laid down in individual layers of molten plastic. The filament can be obtained in many different grades including Poly Actide (**PLA**), Acrylonitrile Butadiene Styrene (**ABS**), Polyethylene Terephthalate Glycol (**PETG**) and many other materials including Nylon, Carbon Fibre, Metal and Glass fibre.

There are four types of FDM printer and the most common one is the **Cartesian** 3D printer. It will move the print nozzle in the three well know axes of X, Y and Z. The printing process can take a long time and a new variation on Cartesian printers is the **Delta** printer. Delta printers are tall cylindrical structures which can print faster than Cartesian 3D printers. They have a circular bed and three triangular points which can move up or down. They can print taller parts than a Cartesian printer.

Polar 3D printers use the polar coordinate system to locate the print nozzle. Every point on the print bed is compared with the central point in the middle of the print bed. The print beds rotate and move up and down. They are advantageous in using all of the print bed very efficiently and only need two engines rather than the three of Cartesian or Delta systems.

Scara (Selective Compliance Assembly Robotic Arm) printers are expensive and suited to industrial projects. The advantage is that the robotic arm system is not tied to producing parts on a bed of restricted size. There are many other 3D printer types but they are very costly to buy. They have little to no application application use for the hobbyist. All of the printers mentioned have to have filament or resin supplied to build anything. They all need software to run them and instruct their hardware controllers how to position the heated nozzle, which is often called the **'hot end'** and is fed by the extruder. Users supply the design files using the software of their choice. Design files are often in the .stl format.

CNC mill
The most usual type of CNC machine that users will want to buy is a mill. This machine will undertake all of the operations required to carve a shape from a piece of stock. The milling bits are usually referred to as endmills or cutters and they will have different diameters and different profile shapes from each other. They will also have a varying number of flutes.

The milling machine is the heart of most CNC machinery available to the hobbyist. It is less common to see machines that will only drill holes or only grind flat paths on metal. Some CNC machines are purely lathes. The user has many choices to make when first buying a CNC machine, apart from the ones previous listed. The machinery may be driven by **belts**, **lead screws** or **ball screws**. These various drive methods do bring mechanical advantages and disadvantages for each type of axis movement.

The machine may be enclosed or it may be left open. A number of the machines are available with quite a small footprint and they may even be described as 'desktop' machines. The limitations will be the working envelope size… which determines the maximum size of stock that can be machined without resorting to strategies such as tiling. When considering machine size, users should determine the available space by multiplying the X axis (width) by the Y axis (length) to arrive at the total area in square millimetres or inches that they will have available for machining. It is also important to calculate the available height for the Z axis.

The Z axis height specification is an important measurement to be aware of. It restricts the absolute height of the stock which can be placed on the machine. For example the Z height may be specified as being 100mm. This is describing the amount of movement that the Z height can make. The collet nut of the spindle when fixed into the bracket should not be below the bottom of the carriage. It should remembered that the Z height will be further reduced by several factors.

The baseboard, which is often supplied with the machine, will need protecting with a wasteboard (spoilboard). The spoilboard may reduce the Z height available by another 18mm if it is made from 18mm thick MDF. The stock may be clamped in modular vices and the height of the voice will have to be subtracted from the available Z height. The length of the endmill will also need subtracting from the available Z height.

Common Z hight dimensions on different machines are variable between 50mm and 200mm. The machines with a low Z height will restrict the amount and type of work that you can undertake. The higher the Z height the more rigid the fixation of the X and Y rails should be and the Z carriage will need to be prevent from transmitting the cutting forces to other parts of the machinery because it will affect measurements that are machined.

A well assembled and sorted CNC machine will have no difficulty in machining stock to tolerances such as plus or minus one thousandth of an inch. A badly assembled machine will be incapable of cutting a true circle. Nor will it be capable of machining two sides of material to the same length. Large surfaces will not be flat and machining marks will always be visible.

All machines should be assembled where they are going to be used. This is because any careful and accurate assembly by the user will be undone by moving the machine from one place to another. One solution to this problem is that the machine can be assembled onto a wheeled platform so that it may be moved without upsetting the accuracy. It is important to prepare the area where the machine is going to be placed. Remember that CNC machines are often quite heavy and weights of 40 ~ 70 kilograms are not unusual. Ensure that the place the machine will sit can support the weight and leave you enough room to work so that you can reach every part of the machine.

The CNC machine requires electricity to run and you should consider how many sockets may be needed to run associated machinery. The most important machine next to the CNC machine is the vacuum. It must suck up the waste material and keep the cutting head clear of the waste. If the cutter is continuously cutting the waste material it has produced, it will dull the cutter very quickly. It produces too much heat and the sharp edges of the cutter do not cut the stock but just file their way through the material. Cuts will be much slower and the finished item will not look good.

Industrial suction machines especially made for woodwork shops are the best option but they are noisy and expensive. It is possible to settle for an industrial vacuum cleaner that will not object to being run for several hours at a time. It needs a good capacity waste bag of at least 25 litres. Another useful refinement is to be wet and dry capable and a useful addition is if you can attach hand woodworking machines like an electric plane or a circular saw to the vacuum machine directly. These sorts of vacuum cleaner are sometimes referred to as 'shop vacs'.

Lighting is an important issue and you will do well to remember that daylight will not always be available in the winter months. Good lighting assists the operator to work well. Some bright LED lighting shining directly onto the baseboard in front of the X rail will help in setting up jobs correctly and measurement taking when it becomes necessary. The lighting may also use an extra wall socket so it is worth having a couple of pairs of sockets near the machine. In a shed it is worth installing a small 32A consumer unit and 6 or 8 socket outlets. The consumer unit will be properly fused and you can switch it off when not needed.

Cutters/Endmills are the working tools for a Router/Spindle based CNC machine. The profile of the cutters is chosen for the work to be done. A surfacing cutter will have about 25mm cutting area and this bit is one of the few essential bits that you will use to make a fait surface on a piece of stock that has not been trued up.

Depending on the collet size of the router/spindle, you will have a range of collet possibilities. Common imperial sizes are ⅛" and ¼" and endmills can be food in these sizes easily. Start with a square cut (flat at the end) endmill. Useful imperial sizes are ⅛" and ¼" and these bits will often have three or four flutes. They will work well generally for most woods unless you are cutting metal. Metal requires a single flat cutter. You can cut aluminium or brass with these endmills. Steel requires extremely rigid machines and special cutters as well as liquid cooling.

The other common size in collets is metric and you will be able to use 3, 4, 5 and 6mm cutters. Each cutter requires its own collet. Do not be tempted to put a 6mm cutter in a ¼" inch collet (6.35mm) because it does not fit and will come loose. A piece of metal flying around your workshop at 30,000 RPM is a very dangerous tool.

A diamond drag engraving bit is also available. With this bit you can engrave metal, ceramics, slate, stone and glass. The spindle or router is not switched on but the toolpath program is run. This causes the diamond bit to be dragged across the stock surface to engrave the image. These bits are available in 30°, 60°, 90°. And 120° angles so that lines may be thin or somewhat wider.

The CNC milling machine is a very versatile tool. It can machine many different types of stock using cutting bits, engraving bits, lasers and various carving tools. The machine can undertake all of the jobs it is given, very well. The most important caveat is that the machine must be set up perfectly and maintained regularly. The machine may run using steel belts, lead screws or ball screws. In every case it will need cleaning and adjustment every week so that screws do not become loose or parts that can wear are left to wear out.