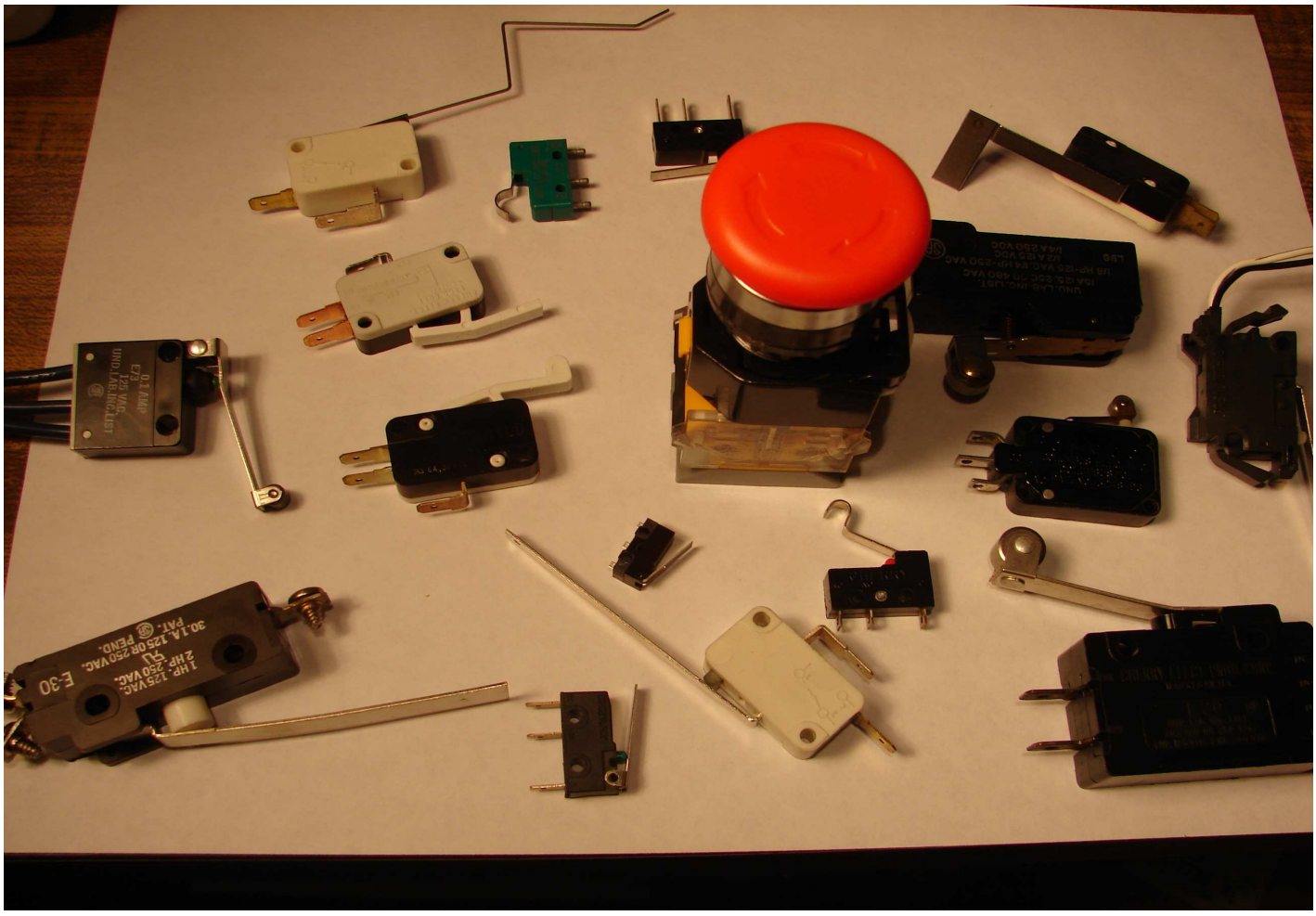
CNC STEPPER MOTOR DRIVE SYSTEMS

LIMIT SWITCHES FOR "BEGINNERS"

WRITTEN BY A DUMMIE, SO YOU CAN UNDERSTAND IT

ALSO INCLUDES "HOME SWITCHES", EMERGENCY STOP SWITCHES, AND RELAY CONTROLS



ALSO INCLUDES A SECTION ON COORDINATES AND HOMEING

OR HOME REFERENCING YOUR SYSTEM

THE ROOTS OF ALL LIMIT SWITCHES, AND HOME SWITCHES START RIGHT HERE AT THE PARALLEL PORT OF YOUR CNC COMPUTER

ONCE YOU UNDERSTAND THE FOUR POINTS A, B, C, AND D BELOW, YOU WILL BE WILL BE 90 PERCENT OF THE WAY ALONG THE CURVE OF UNDERSTANDING THE OPERATION OF LIMIT AND HOME SWITCHES IN CNC STEPPER MOTOR SYSTEMS.
(*Hopefully only a few minutes from right now, after reading the points A, B, C, and D.)*

THIS IS THE PARALLEL PORT LOOKING IN AT THE BACK OF YOUR COMPUTER

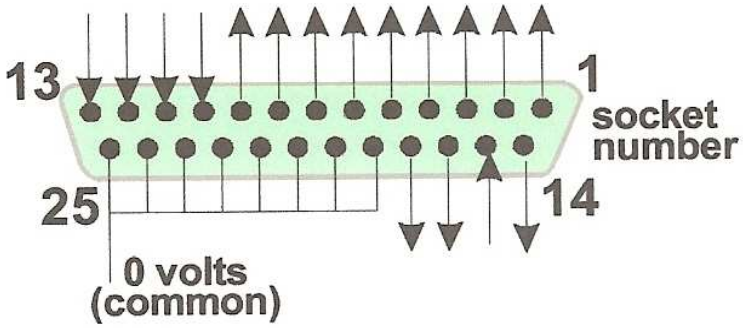


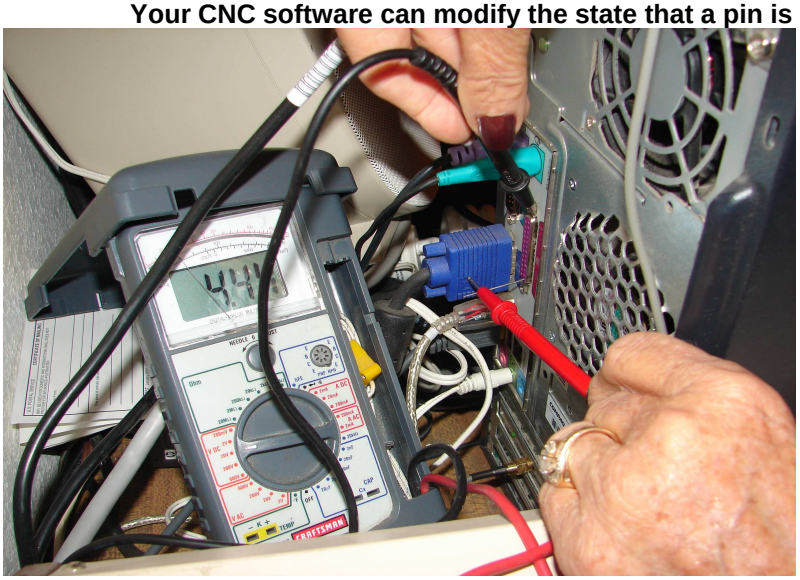
Figure 1.

Pins "one to seventeen" are the pins used by your CNC software to achieve CNC control. Pins eighteen to twenty five are the "common", "signal ground", or 0 volt reference pins.

THE IMPORTANT POINTS:

Important Point A. **The VOLTAGE state of any pin (1-17) can only be Zero volts, or +5 volts at any time, this is called binary operation, and is sometimes referred to as logic 1, or logic 0, or at other times called low, or high. High or Low are the only two states that the pins are allowed (actually, low is 0 volts to 0.8 volts and high is +2.5 volts to +5 volts.**

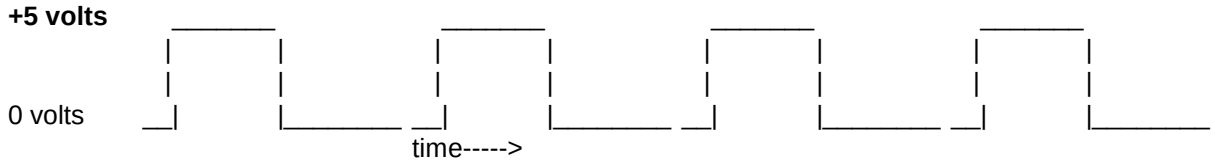
When your computer starts up, all the operating pins (1-17) are put into high state. Your CNC software can modify the state that a pin is in. Shown below is pin 1 startup.



Note the paper clip stuck into pin one where the red + probe is measuring and the black probe contacting the grounded "D" ring of the purple printer port. the pin is measuring +4.44 volts.

Important
Point B. Your computer CNC software has the ability to modify the state of any pin (1-17). Your software can change a pin state at your will, by you manually clicking a setup button, or by command lines in your G-code Program. Your CNC software can send a fast sequence of state changes from low state to high state, at any number of varible frequency rates, commonly called step pulse signals. Your CNC software can leave a pin waiting in any state that it desires, low or high.

Below is a representation over time of a CNC step pulse signal.



Important
Point C. Five of the pins on the printer port are specially configured to be able to take signals in from outside the computer, to allow EXTERNAL signals to modify the binary (high or low) state of that pin. The specially configured pins are called input pins, and are shown on the Fig 1. diagram with arrows pointing in-to the computer, these are pins numbered: 10, 11, 12, 13, and 15. The other active pins with the arrows pointing away from the pin are called output pins, and their function is to send signals out of the computer to perform functions like turn on relays, change the direction of step motors, or to send pulse signals to your stepper motor driver boards to rotate motors, etc.

Important
Point D. Your CNC software "monitors" the "state" of the "input" pins, (and other pins) and can react to a state change in a manner designated by you apon that pin's change of state. In simplified terms, you can tell the computer software to do things that you want it to do, like stop running your G-code, or turn on a limit led, when it sees a state change (high to low, or low to high) on an input pin. This powerfull feature gives you control of the software from outside the computer, like EMERGENCY STOPS, etc.

Please read and re-read the four points; A, B, C, and D until you are quite clear on what the principle of binary operation, and state change, and outside control possibilities are before proceeding.

THE PRACTICAL" LIMITS" OF WHAT WE WANT TO ACCOMPLISH

The real truth is that we never want our machine cutting tool to go outside of its designated cut area. The real truth is that we are human, and we make errors in scale, length of travel, etc., etc., etc., and we want the computer to know when to stop the machine from damaging itself or YOU when things go out of limits. To accomplish limit control, we install various kinds of switches on our system to keep the cutting tool within its boundrys. Below is some practical discussion on switches and "how-to" in CNC.

Fortunately there is a computer involved, so that we don't have to take the blame for an error in travel, or size, or position. All of these errors are lumped under the term "computer error", but the computer can redeem itself by detecting a "limit-trip" and stop things before damage occurs.

Next we will discuss switches before going on to "How to Connect them"

SWITCHES

Almost infinite is the term that describes the number of kinds of switches that are available to use.

First I want to discuss the very "basics" of switches for us beginners in the crowd (me included) Skip past this section if you are a veteran electronics buff.

A basic switch simply connects two conductors (wires) to each other, or disconnects two conductors, from each other. When the switch is ON, or "CLOSED" the wires can conduct electricity, and when the switch is OFF or "OPEN" the wires cannot conduct electricity. Below is a "schematic" diagram of an "open" switch, and one of a "closed" switch. This switch would be called a single pole single throw switch, (spst) much like a light switch in your house, one contact point, one direction for ON.

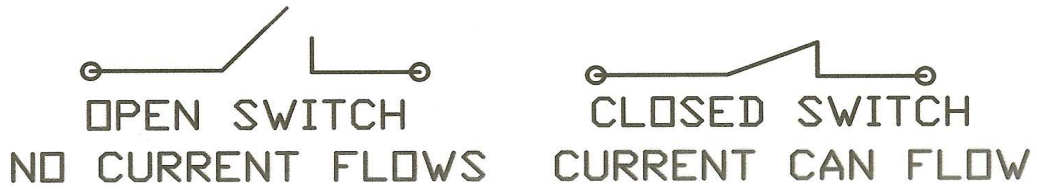


Figure 2.

SELECTING A SWITCH FOR YOUR APPLICATION

MANY MANY CONSIDERATIONS HERE TO LOOK AT

SOME DON'TS

Don't choose a switch that will be disabled by your process.

Examples:

Don't choose magnetic switches if your process creates metal particles that will collect on the magnet and disable the switch.

Don't choose Light activated switches for a process that creates a lot of dust that will collect and disable the light activated switching.

Don't choose non explosion proof switches for a process that generates explosive fumes.

Don't position open type switches where coolant can splash on them and disable them

Don't use switches that will be damaged by over-travel of your axis. Example, non lever arm types of switches.

SOME DO-S

Do choose a switch that matches the application.

Examples:

Do choose switches with lever arms that reach into the machine and trip on some out of the way machine component.

Do choose switches that can be mounted under the machine and out of harms way.

Do choose switches that are amp rated for the load that they will carry.

Do choose switches where practical that have a roller mechanism as a traveling component to prevent wear.

Do choose switches that have reasonable repeatable accuracy in switching position.

Do choose a switch with the proper starting contact position for your application. Example a normally closed switch when you need normally open. Many switches can be wired either way, normally the kind that have three connection terminals. The center to one side is normally open, and the center terminal to the other side is normally closed.

CONNECTING LIMIT SWITCHES TO YOUR CNC SYSTEM

YOU MUST HAVE WIRE ACCESS TO THE COMPUTER PRINTER PORT VIA SCREW LUGS ON YOUR DRIVER BOARD, OR A BREAKOUT BOARD THAT DISTRIBUTES SIGNALS TO YOUR DRIVER BOARDS. ACCESS LUGS GIVE YOU A PLACE TO CONNECT WIRES FROM YOUR LIMIT SWITCH INTO YOUR COMPUTER, WHERE YOUR CNC SOFTWARE CAN ACT AND REACT TO SWITCH TRIPS.
ACCESS TO PINS 10, 11, 12, 13, AND 15 IN PARTICULAR.

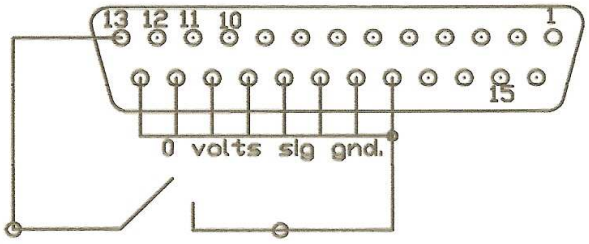
THERE ARE A NUMBER OF WAYS TO CONNECT A LIMIT SWITCH TO AN INPUT PIN.

FIRST: THE STATE OF THE INPUT PIN IS ALL IMPORTANT IN SETTING UP A LIMIT. WE WILL DISCUSS CONNECTION POSSIBILITIES FOR BOTH BINARY STATES OF AN INPUT PIN. THE SAME DISCUSSION WILL APPLY TO ALL 5 INPUT PINS.

If you set the default state of the input pin to high (+5 volts), then you will want to tell your software to perform some action when that pin drops to low (0 volts). This setup is called "active low" in many CNC software manuals. How do you get that pin to drop to 0 volts with a limit switch? Simple, have the normally open limit switch connect the +5 volt input pin directly to ground (pin 18) when the limit is tripped by your axis. This setup is shown schematically below. Normally you will tell your software to stop the execution of any G-code, and to turn on a limit LED to let you know of the limit trip.

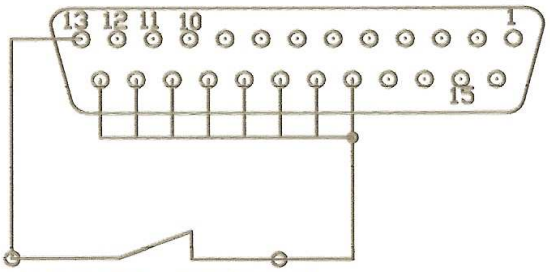
THE "ACTIVE LOW" METHOD OF CONNECTING YOUR LIMIT SWITCH.

CONDITION-NORMAL RUN, LIMIT IS NOT TRIPPED
PIN 13 IS AT +5 VOLTS, SOFTWARE IS RUNNING



OPEN SWITCH
NO CURRENT FLOWS

CONDITION-LIMIT IS TRIPPED, SOFTWARE IS STOPPED
RED ON SCREEN LED FOR LIMIT TRIP IS ON
PIN 13 HAS BEEN SHORTED TO GROUND, AND IS AT 0 VOLTS.



CLOSED SWITCH
CURRENT CAN FLOW

Keep in mind that I am only using pin 13 as an illustration because it is conveniently on the corner of the db25 connector, I could just as easily have used any of the other input pins; 10, 11, 12, or 15 for this illustration.

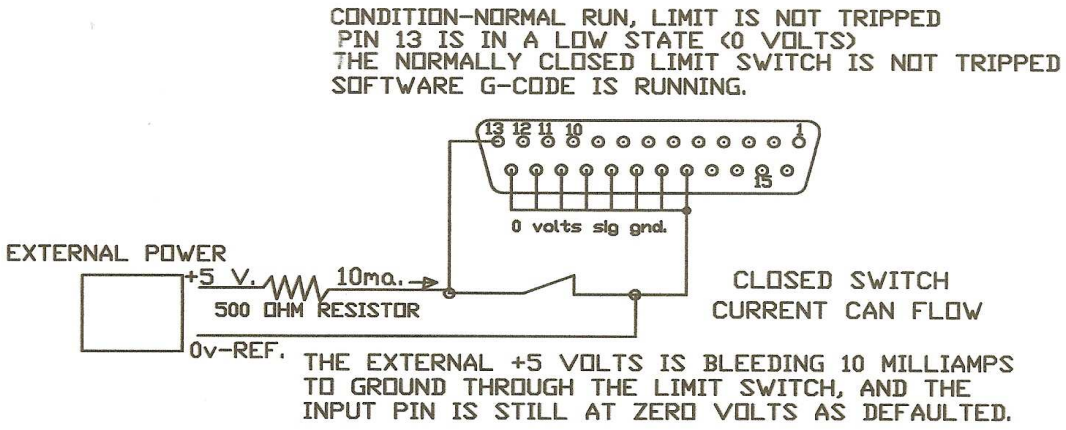
THIS IS ONLY ONE METHOD OF MAKING A LIMIT SWITCH WORK WITH AN INPUT PIN. ABOVE METHOD MAY NOT BE AS RELIABLE AS THE ACTIVE HIGH METHOD SHOWN BELOW BECAUSE OF RESISTANCE IN THE LONG CABLES REQUIRED TO CONNECT THE LIMIT SWITCH TO THE COMPUTER, THAT MAY KEEP THE VOLTAGE ON THE INPUT PIN (13 IN THIS ILLUSTRATION) TOO HIGH FOR PRACTICAL USE. ALWAYS USE SHIELDED WIRE TO CONNECT LIMITS TO THE COMPUTER WHENEVER PRACTICAL. NEVER COMBINE LIMIT WIRES WITH MOTOR POWER CABLE WIRES, KEEP THEM APART.

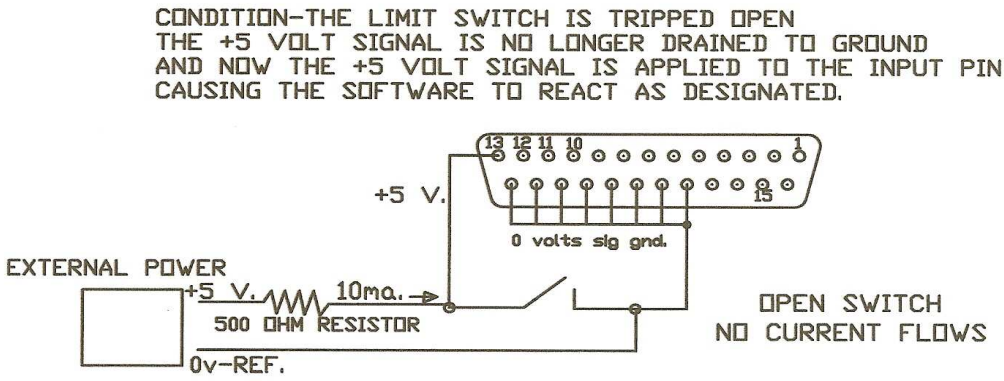
WITH THE ABOVE METHOD, YOU COULD CONNECT ALL OF YOUR LIMIT SWITCHES TO ONE INPUT PIN. ALL THE SWITCHES WOULD HAVE TO BE THE NORMALLY OPEN TYPE WITH SEPARATE CABLES ALL COMING TO THE PIN CONNECTION LUG. THIS IS CALLED PARALLELING THE SWITCHES. ANY ONE CLOSING NOTIFYS THE SOFTWARE OF A LIMIT TRIP. THIS MAY BE NECESSARY BECAUSE YOU ONLY HAVE 5 INPUT PINS.

THE ACTIVE HIGH METHOD OF CONNECTING A LIMIT SWITCH

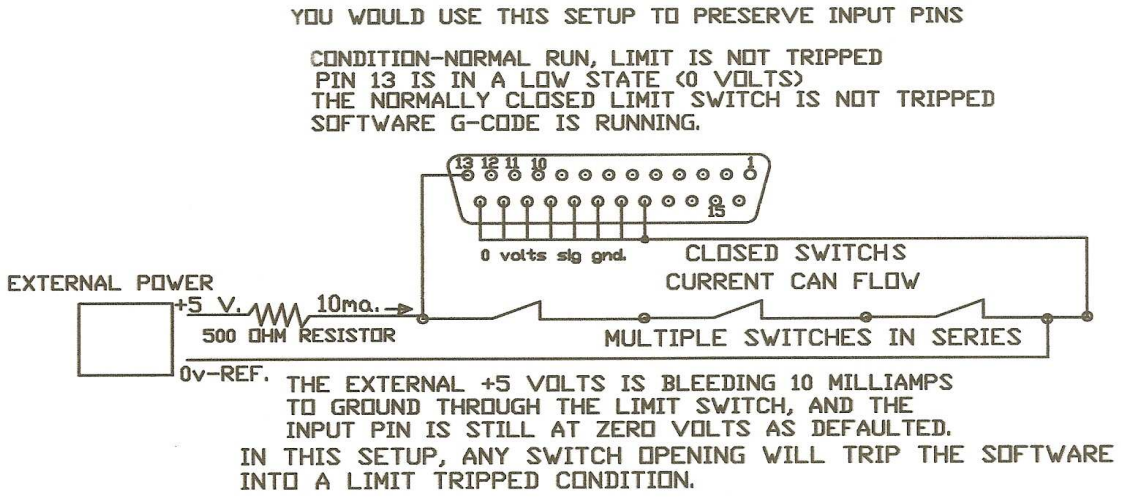
The input pin that you choose to use in this method, is set to default in the low (0 volts) state, and the software is told that when the pin rises to a high state (+5 volts) that it should react, by stopping G-code software execution, and turning on a limit LED to notify you that a limit has been tripped.

Note: In this method of operation, a +5 volt external voltage is needed to bring the input pin to a high state. Many breakout boards and specialty boards have a built in +5 volt source just for this application, but you can use a connection from your computer power supply, or a small wall plug type power supply to give you this voltage source. Just make sure it does not exceed 5.0 volts, or the magic smoke appears, they compress smoke into the printer port at the computer factory, and if you let that smoke out, it is very very hard to get it back in.





With this "active high" method of limit switch inputs, you can also put all of your limit switches on one pin, simply by putting them all in series as shown in the next Figure.



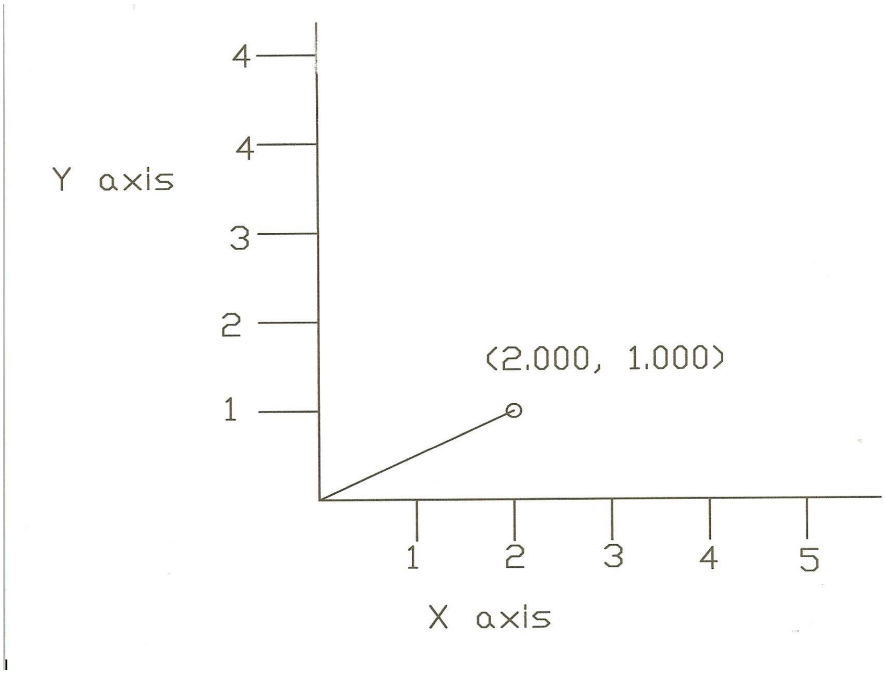
HOME SWITCHES AND EMERGENCY STOP SWITCHES

HOME SWITCHES AND LIMIT SWITCHES ARE VERY SIMILAR INSTALLATIONS, BUT ARE HANDLED SOMEWHAT DIFFERENTLY BY YOUR CNC SOFTWARE. TO TALK A LITTLE MORE INTELLIGENTLY ABOUT HOME SWITCHES, I WANT TO FIRST DISCUSS COORDINATE SYSTEMS. IT IS NECESSARY TO HAVE A BASIC KNOWLEDGE OF COORDINATES TO UNDERSTAND THE FUNCTION OF A HOME SWITCH.

COORDINATE SYSTEM DISCUSSION

Lets say you want to operate a two dimensional "Engraving Table". For the sake of discussion, the table is 3' long and 2' tall. This table will be much like an "etch-a-stetch" that the kids play with, but instead of being operated by dials for it's two directions, the pen, pointer, will be moved by the computer. On an "etch-a-sketch" one dial will move the pen up or down, and the other dial will move the pen right or left. Unlike the "etch a sketch", the computer wants to know exactly what you want it to do in "Mathematical" terms. To satisfy the computer's need for mathematical preciseness, a mathematical term for any point on your X-Y engraving table was developed. Straignt right hand movements are called plus (+) X movements, (relative to the left edge of the table), straight leftward movements are called minus (-) X movements. The left edge of the table can be called the zero X position. When your pen is at the left edge, it is called x=0, or your pen is at the zero X position. If your pen is moved to the right by one inch, the X position is now called x=1.000 (three decimal places if you are working in thousants of an inch. If your pen was moved all of the way to the right of your 3' table, it would be called x=36.000. The Up and Down movements are called "Y" movements. The bottom edge can be defined as the zero position, or y=0.000. Up movements, are called positive or + Y movements. Down movements are called negative or -Y movements. The lower left corner is now definde as x=0, y=0.

Calling the lower left corner the zero x, zero y position is totally arbitrary, but is convenient. The mathematical coordinate term for the lower left position defined in this fashion is (x=0.000, y=0.000) or simplified (0.000, 0.000), or 0.000, 0.000. If you move the pen 2" to the right, and up 1", the mathamatical coordinate would (2.000, 1.000). The computer can understand terms like these. Just a note, if you tell your CNC software to draw a line from 0.000, 0.000 to 2.000, 1.000, it will draw a diagonal line, like the one shown below.



The lower left corner is called absolute zero in this example. You could install a home switch on the x axis at absolute zero, and a home switch on the y axis at absolute zero, and when you tell your CNC software to home x and y, then the pen would move to home, and also be at absolute zero at the same time, this is not wise, but can be done. Typically home position is chosen away from the absolute zero position to allow space for axis limit switches to operate without allowing the pen to get near it's absolute end of travel.

Ok, lets install our theoretical home switches on this engraving table. On the X axis we install a limit switch at x=1.000, and our HOME switch at x=2.000. On the Y axis we do the same, limit switch at y=1.000, and HOMEswitch at y=2.000. This installation will loose us some of our working surface, but is safe.

Now lets examine what happens when we use the home switches. First of all When you ask your CNC software to home the x axis,(called referenceing), it is presumed that your pen is somewhere to the "right" or positive direction from where the home switch is located. The CNC homeing process starts moving the x axis in the minus direction at a rate of speed that is selectable in many CNC software packages. When the x axis home switch is tripped and sensed by the CNC software, the motor

will shut off and coast to a stop, (the limit switch must be set to allow for coast down). Once the motor has stopped, your CNC software will turn the motor back on in the positive direction until it just moves off of the home switch and it will stop there, and call this position the X home. The software will now re-set the on screen Digital-Readout to a value selected by you in many CNC packages. You can tell the software to set the readout to +2.000, and maintain absolute coordinates, or you can call home as a new zero position, (not absolute zero, but a new "reference zero that all future moves of the pen are relative to), or you can call it any position number you desire.

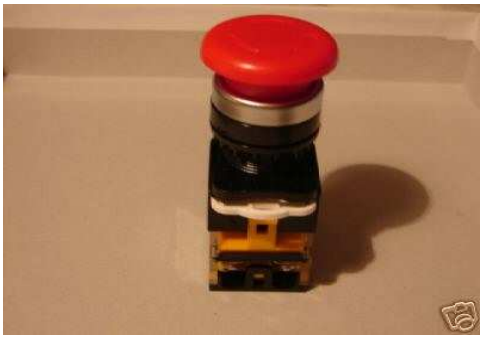
Y axis home operates just the same as X.

HOME AND LIMIT COMBO SWITCHES

One switch can be set up to act as a limit switch and a home switch. You can wire the switch to two pins, one to act as a limit sensing input, and the other to act as a home sensing input, or with some CNC software, the same pin can sense it as a limit or a home switch, depending on which function mode you are in. Many CNC software packages will turn OFF limit sensing while in homeing mode.

EMERGENCY STOP SWITCHES

Emergency stop switches can be wired just like limit switches, to tell the software to shut things down, BUT, relying on slow, busy, unresponsive software, can be dangerous to you and your machine. Emergency stop is best accomplished outside the computer to give a positive stop to the actual operating hardware, and then send a signal back to the software that an emergency stop has been activated, and that the software should stop G-code execution, and notify the operator via on-screen notification. Methods of shutting down machine components that have been used are various, some are not good, like shutting off the power supply to the motors, because charge capacity inside the power supply sometimes keeps the motors moving until the charge drops. Interrupting the power to the stepper motor coils is also dangerous, because it can damage the motor, and it allows the motor to continue spinning. One of the best methods is to create an absolute stoppage pf the step pulse signals going to the driver board while keeping the power to the driver board ON, this method puts on the electric brakes to the stepper motors, and stops them dead in their tracks. There are boards available in my ebay store that will accomplish this task, as well as shutting down spindle motors and torches.



EMERGENCY STOP SWITCHES should be of the latching type, that once tripped remain tripped until you re-set them. E-stop switches should be bright in color and easy to see. The system you use should allow for many E-stop switches to be positioned around your machine, so there is one available wherever you are around your machine when the need occurs.

RELAY CONTROL SETUP ON YOUR CNC MACHINE

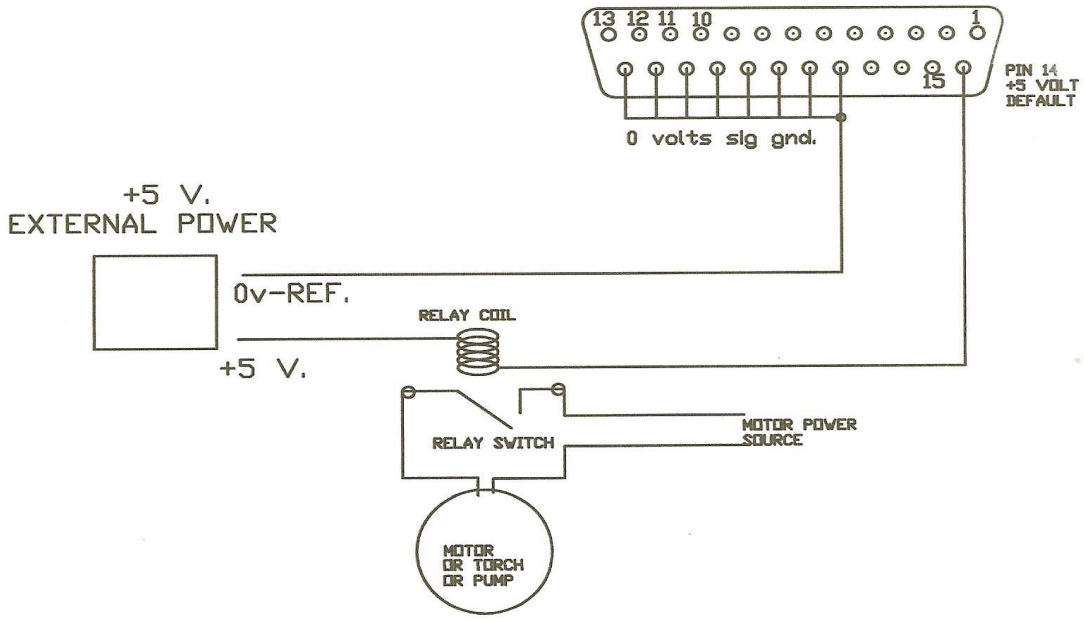
IN THIS FINAL SECTION WE DISCUSS CONTROLLING OTHER OUTSIDE DEVICES.

IT IS DESIREABLE AND OFTEN NECESSARY TO HAVE YOUR CNC SOFTWARE BE ABLE TO TURN ON/OFF OTHER DEVICES BESIDES STEPPER MOTORS. THIS TASK IS ACCOMPLISHED WITH THE USE OF RELAYS. A RELAY IS SIMPLY A SWITCH THAT IS ELECTRICALLY TURNED ON AND OFF BY PASSING A SMALL CURRENT THROUGH A MAGNETIC COIL THAT ACTIVATES THE SWITCH.

The pins on a printer port typically do not put out enough amps to trip a relay coil. An output pin can only put out about 0.0004 amps, not enough to trip most relays with the possible exception of solid state relays. Even with solid state relays, the following method works well. A print port pin can accept more amps "in", than it can put out, roughly 20 times more current can be pumped IN as opposed to output.

With this method, you are not limited to only input pins, you can also use output pins. Typically you would use one of the following pins with this setup: pin 1, pin 14, 16, and 17.

For this setup, you will tell your CNC software to set the pin to high (+5 volts), then one side of your relay coil is connected to the pin. The other side of the coil is connected to a +5 volt external power source. With both sides of the coil sitting at +5 volts, no current will flow and the relay will not be tripped. As soon as you tell your CNC software or G-code program to drop that control pin to low, the pin goes low and allows current to flow through the coil of the relay, thus activating the relay and turning on your spindle or torch. A picture of setup is shown below, with +5v on one side of the coil, and the +5v pin 14 on the other side of the coil.



End, thank you