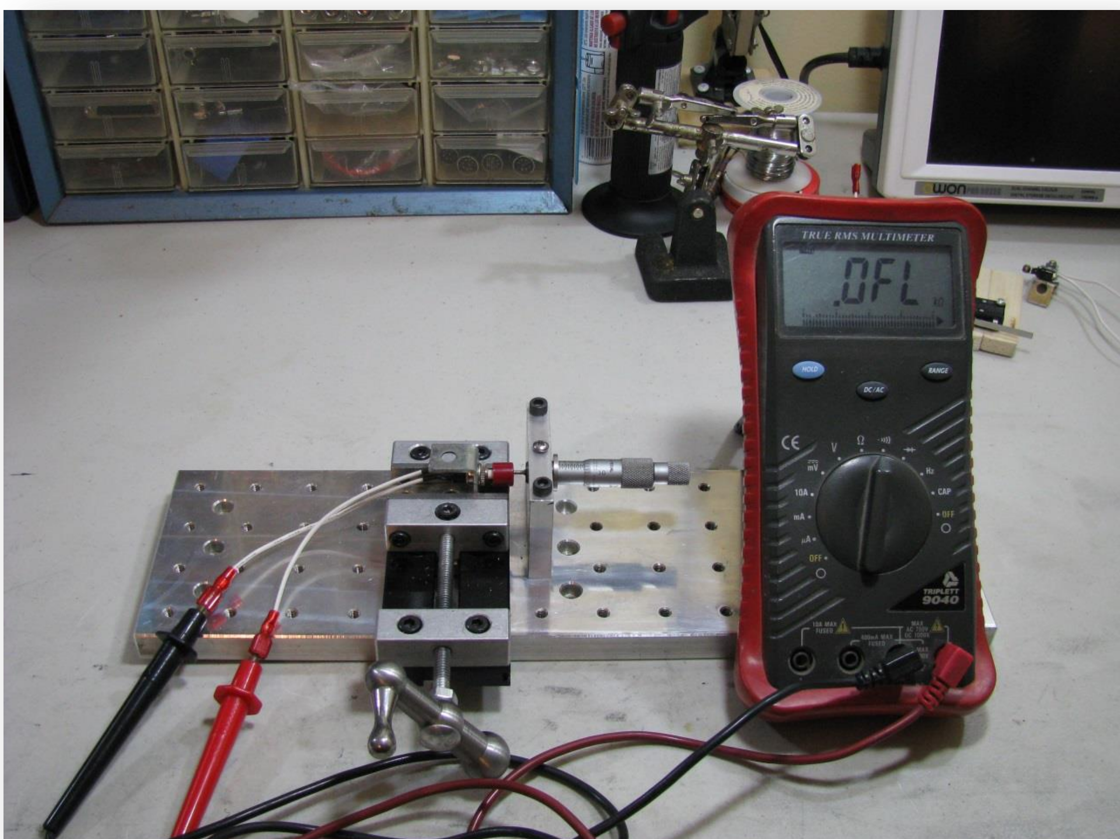
Soigeneris Application Note 2

Mechanical Limit Switch Tips

V1.1



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Knowing your limits…

It is quite common to use a mechanical switch for limit or home sensors on a CNC machine. They are relatively inexpensive, simple in concept and can be wired up easily. While mechanical switches are simple devices they do have some peculiar traits that can lead to some surprising behavior if you are not aware of them.

In this article we will take a look at these mechanical switches and attempt to discover their quirks and find methods to work around them. Let's get started…

A little bounce in your ~~step~~ switch…

The first odd trait that you have to wrap your head around is that a mechanical switch does not change from OFF to ON, or ON to OFF instantly or cleanly. When the contacts in the switch open and close they 'bounce', that is they make and break contact several times before settling into a steady state. If we look at the switch signal with an oscilloscope we would see something like Figure 1 below.

Figure 1, Switch Bounce

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You can see after the switch turns ON the contact bounce causes dips (noise) in the signal. The first dip, from the left, starts at about 50us from switch closure and is about 100us in length; it drops from 5V to just under 4V. The second dip starts about 200us from switch closure and is about 200us in length and drops to nearly 2V. These dips in the signal may be sufficient to cause the controller to 'see' the switch as turning ON, OFF, ON, OFF and finally back ON again.

When you 'Home' an axis the controller (Mach3) will move the axis until it contacts the switch and then reverse the axis until the switch is released. This is considered the 'Home' position. If you were using the mechanical switch shown above, your controller might interpret the bounce in the switch signal as the machine moving onto the switch and back off again; it would appear to the controller that the axis had homed when it had not. If this switch was also used as a limit switch the controller would see that the Limit switch was triggered and show a Limit fault condition.

Noise filtering

To prevent the switch bounce from causing errant operation it is common to use some form of noise filtering. Noise filtering can be done in hardware, that is hardware components on the circuit board of your Break Out Board or Motion Control board that form a low pass filter.

A noise filter can also be done in software by the motion control device, whether that motion control device is Mach3's parallel port driver or an external device such as the SmoothStepper. A software based noise filter works by starting a timer when the switch signal is first seen on the input line. The switch signal must stay ON for a certain period of time before the controller will recognize it. This minimum ON time can typically be configured by the user.

Hardware noise filtering

A type of hardware filter may be present on your Break Out Board or Motion Control board. Take a look at your board's documentation to find out. This filter may consist of a simple RC network (resistor and capacitor) or it could be more advanced. It should also be noted that an optically isolated input also works as a low pass filter. This is yet one of the advantages of isolated inputs.

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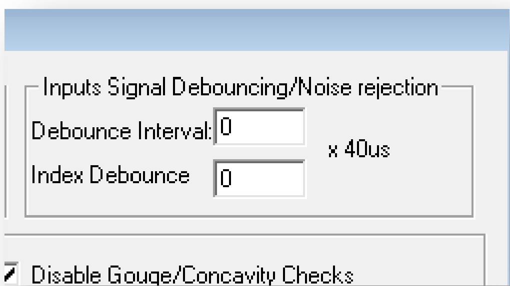
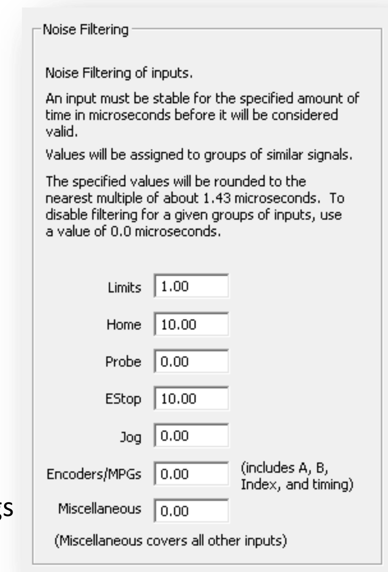
Software noise filtering

If you are familiar with Mach3 or a motion device like the SmoothStepper settings you may recall seeing settings called something like 'Debounce' or 'Noise Filtering'. These settings give you control of how the software noise filtering works. The switch shown in Figure 1 settles into a steady state after about 400us, so if we set a noise filtering value of 500us the filtering will block the switch bounce so controller will not get confused.



Mach3 parallel port settings



SmoothStepper settings

Figure 2, noise filter settings

Noise filtering not only helps with switch bounce but also serves to help filter out electrical noise that the switch wiring may pick up. The noise filtering setting in Mach3's parallel port driver is global – one setting is used for all input types, and is units of 40 microseconds. The noise filtering for the SmoothStepper allows you to set the noise filter values for different types of inputs differently. The values you enter are in microseconds. Other motion control boards may differ; refer to your manual to be sure.

It should also be noted that any form of filtering, electronic or software, will cause a signal delay. While this delay is typically very small it should be kept in mind.

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Accuracy of mechanical switch triggering

A mechanical switch does not always turn ON (or OFF) at the exact same position every time. This is due to construction of the switch, dirt/debris that might foul the switch and/or switch actuator, etc. This limits the accuracy of a switch used for Homing purposes.

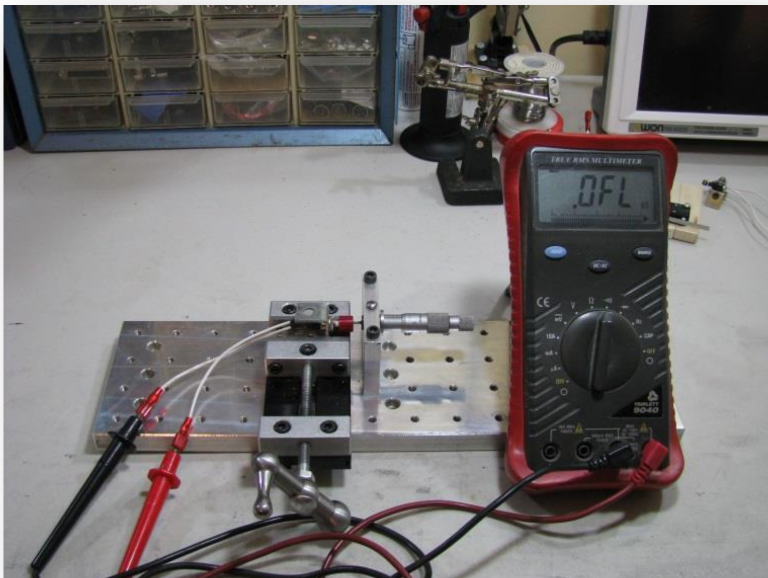

Figure 3, the Test Rig

Details of test rig

To demonstrate the test rig shown in Figure 3 was constructed. A Taig 2010 tooling plate was used as it provided a nice solid base with an array of 10-32 tapped holes. A Taig 2225 vise, with mounting hole spacing that conveniently matches the tooling plate, was fixed into position and was used to hold the various switches in place for testing. A small piece of 3/8" thick aluminum was fabricated to hold a small micrometer head.

The micrometer head allowed for precisely actuating the switch under test. A mounting bracket was created for each type of switch to allow the vise to hold it into position in front of the micrometer head. A digital multi-meter was used to monitor the conductivity of the switch. The conductivity 'beep' feature of the meter was use to provide an auditory confirmation of switch state as well as the resistance reading (ohms).

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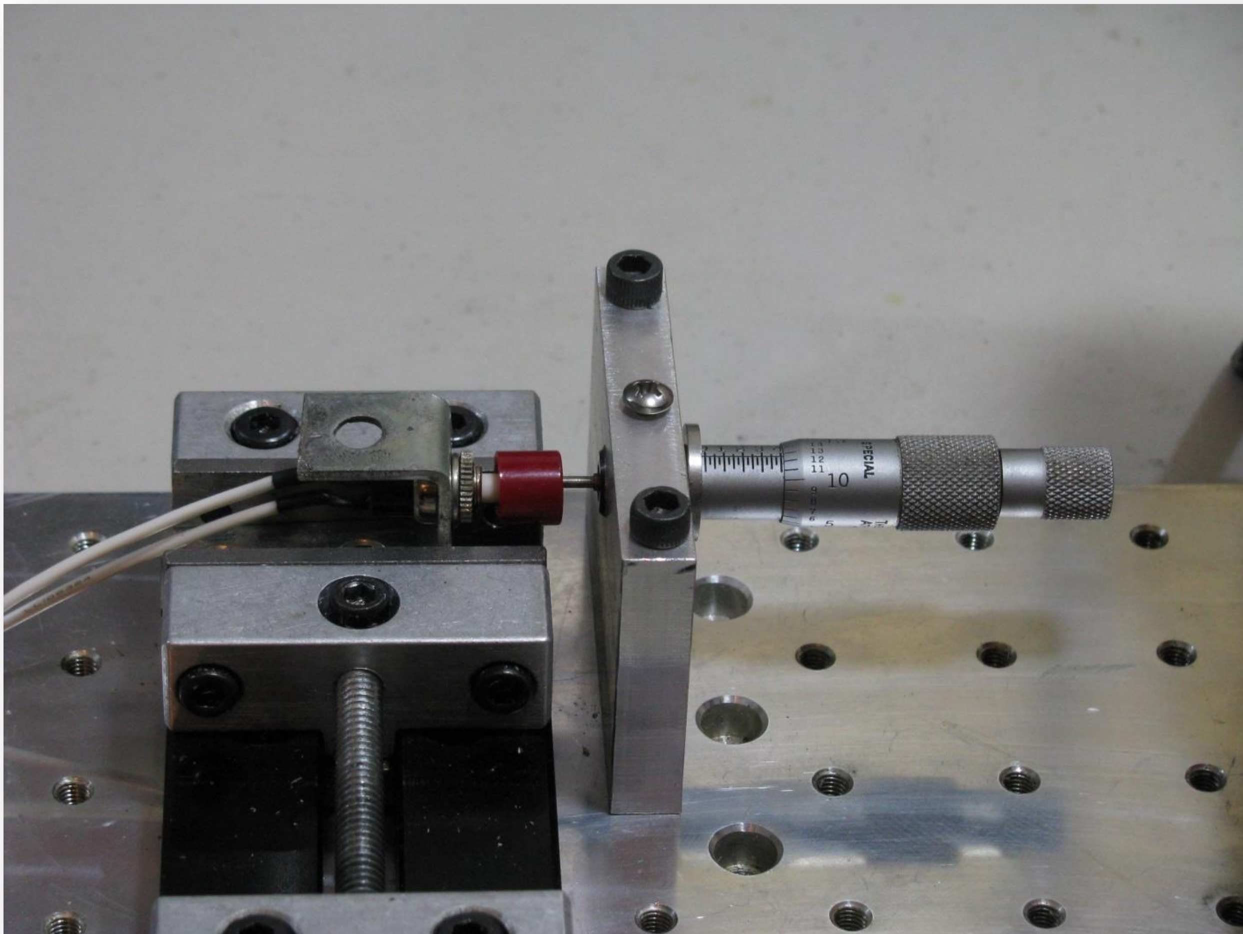

Figure 4, Micrometer Head and Test Rig

Three different types of switches were tested. Two small lever-action micro switches and a small push butting switch. All are of common size and construction as those used on small CNC machines.

The lever-action micro switches were of the type that makes a 'clicking' sound when activated. They are often referred to as 'snap action' switches. The push button switch was not a snap action type.

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Data

Each switch was tested to determine the position at which it first turned ON, the position at which it turned on solidly and the position at which it turned OFF solidly. By solidly I am referring to the switch being ON or OFF without any intermittent behavior. Positions were reported when the switched was touched, when it first turned on, when it was on solidly and when it turned off solidly. The results are shown in Table 1, all values are in inches.

Table 1, Switch Data

Switch Num	Touch Pos	Click Pos	Click Pos Ohms MAX	Click Pos Ohms MIN	ON Pos First	ON Pos Solid	ON Pos Ohms MAX	ON Pos Ohms MIN	OFF Pos
1	0.397	0.327	700	92	0.326	0.318	9	7	0.325
2	0.524	0.472	2	3	0.472	0.468	2	2	0.482
3	0.475	n/a	n/a	n/a	0.407	0.39	2	0	0.405

Notes: Click position: is the audible click of the switch; switch may click but not turn ON.
On Pos MAX is the first position where the switch registered as ON.
On Pos MIN: position where switch was on solidly; before this switch was intermittent.
OFF Pos: is the position at when the switch turned solidly OFF.

Since the micrometer head being used read 'backwards', (i.e. the further the pin protrudes toward the switch the lower the reading), you will find that the ON position reading is lower than the 'Click' and 'Touch' positions. For example for Switch 1 the Touch Position is 0.397" and the Click Position is 0.327"; the difference of 0.070" gives us the travel of the switch that is needed before it clicks. However the switch had to be depressed another 0.001" before it first turned ON, and it had to be depressed another 0.008" before it is solidly ON.

As you can see there is a difference of 0.004" to 0.008" between the switch first turns ON and when it is solidly ON. This has to do with things like the irregularity of the switch contracts and manufacturing irregularities in the moving components. This can lead to situations where the switch causes erratic operation of the machine. This can occur when a switch is on the edge of solid operation and the machine wiggle/shakes just enough to change the switch state.

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When homing a machine with a slaved axis the machine will move both the master and slaved sides until either switch is triggered, then the triggered side is backed off to release the switch. Then the other side is moved separately until its switch is triggered and then it too is backed off until the switch is released. This serves to automatically square the gantry. If the master side switch stops in the 'not solidly ON or OFF zone' the movement of the gantry when the slave side is homing can cause the master side switch to trigger in error.

To try and avoid these problems you can adjust your switch actuators to ensure that the switch is depressed past the first point when it triggers; typically an additional 0.020" will be enough. Having the machine travel further on and off the switch is desirable although we don't have direct control of this. If you set the noise filtering to a relatively high value you get the effect of increased travel after the switch is triggered. This may have negative consequences with Mach3s parallel port driver as the setting is global with the SmoothStepper you can set separate values of noise filtering for the home sensors so it works quite well.

The effects of the type of switch used

If you take a look at the data sheet for a switch, two of the specifications you will see are the current and voltage ratings. A lot of folks think that a switch with higher ratings is more desirable but that may not be the case.

When the switch opens, an electrical arc will be formed across the contacts. The contact materials used in the switch are chosen based on how much current they are expected to handle and to take advantage of the arc to automatically clean the contacts of oxidation and carbon buildups. In our CNC machines we will be typically be switching 5V (up to 24V) and a very small amount of current. Using a switch rated for high current/voltage results in the contacts not being cleaned properly and the switch will degrade over time. You can obtain switches designed for low voltage/low current operation which will provide better service.

It should be noted that industrial systems use 24V I/O. This is not only because 24V is a common voltage for industrial devices but also because it helps prevent problems with electrical noise. A bit of electrical noise that would induce 3V spike on a limit switch signal, would likely cause problems on a 5V system as it would be high enough to be seen as an ON condition. With a 24V system it would not be high enough to cause a problem.