MACH 4-PMDX SHOPBOT OPERATION GUIDE

UVA Mechatronics

Purpose

This guide describes the operation of the Shopbot PRSAlpha when retrofitted with the PMDX-422 motion controller and Mach 4 interface, along with troubleshooting and additional information.
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1   Introduction

1.1   Basics of the Machine and the Retrofit

The ShopBot PRSAlpha is an entry-level CNC machine capable of cutting workpieces approximately 4'x8'. The machine is well-built mechanically and extremely cost-effective when compared against more traditional CNC machines. However, because it is entry-level, its target customers tend to be unfamiliar with CNC. Therefore, the software and interfaces have been significantly simplified.

For more experienced users who wish to gain greater control and further optimize their machines, this presents significant problems. Chief among them are a poor user interface, a failure to show the toolpath or G-code behind the cut, a lack of real-time adjustment of parameters such as feed rate and spindle speed, and an inability to recognize or manually input G-code commands.

Because of this, it was desirable to upgrade the system to a more standardized, flexible, and well-designed software. After much research, Mach 4 was chosen for its comprehensive features, flexibility, and ubiquity. To integrate Mach 4 with the ShopBot, however, the original motion controller which worked only with the proprietary ShopBot software had to be replaced. The PMDX-422 Smartbob-USB motion controller board was chosen, as it was well-integrated with the Mach 4 software.

After extensively rewiring the inside of the control box and variable frequency drive (VFD) to work with the PMDX and configuring Mach 4, the machine now runs as it did before but with added functionality and control. (Some issues, however, remain-see "Known Issues").

1.2   About the author

The author, Andy Cohen, is a mechanical engineering student at Virginia Tech. He undertook this project during the summer of 2015 under the supervision of UVA Professor Gavin Garner, and wrote the guide after its conclusion. To contact the author with questions or comments about this guide or the project in general, please use the email address posted on the title page of the document.

1.3   Intro to the Operation Manual

This manual assumes a basic familiarity with CNC machines, and has been written as such. As much documentation already exists for Mach 4 and the PMDX-422 motion controller, this manual will focus mainly on the features specific to this machine in conjunction with Mach 4 and the PMDX controller and a few primary operations. For further information, see the following resources:

- ❖ Mach Forums:
  http://www.machsupport.com/forum/
- ❖ Mach 4 Installation/Configuration Manual:
  http://www.machsupport.com/wp-content/uploads/2014/05/Mach4%20Installation%20Manual.pdf
- ❖ Mach 4 Operation Manual:
  http://www.machsupport.com/wp-content/uploads/2014/05/Mach4%20Operation%20Manual.pdf
- ❖ Mach 4 G-Code Reference:
  http://www.machsupport.com/wp-content/uploads/2014/05/Mach4%20Mill%20GCode%20Manual.pdf
- ❖ PMDX Quickstart Guide:
  http://www.pmdx.com/Doc/PMDX-422_Quick_Start_Rev0_3.pdf

❖ Installation manual/technical documentation for retrofitted system:
    Posted on acohen8.weebly.com under Projects -> ShopBot CNC Retrofit

2   Turning on the Machine

To turn on the machine, turn the black dial indicated in the figure at left clockwise so that the yellow arrow points to "on" as shown.

Additionally, make sure you have placed the key that is tethered to the wrench into the interlock engage on the outside of the control panel's door and have turned it clockwise. This allows the VFD to receive power.

Finally, press the blue "reset" on the three-button pendant to allow power to flow to the VFD and stepper drivers. You should see the lights on the drivers flash once and then turn a steady green.

3   Getting Started with Mach 4

3.1   Opening Mach 4

Once the machine has been turned on, the user should open the "Mach 4 GUI" program or follow the "Mach 4 Loader" shortcut. Select and open the third profile, "PMDX_ShopBot."

3.2   Enabling the machine

To interact with the PMDX and through it the machine, Mach 4 must be enabled. To do so, click the flashing green enable button in the lower-left corner.

3.3   Homing the machine

It is suggested that before doing anything else, the user click the large "Ref All Home" button next to the zeroing buttons in the "Program Run" screen. Mach 4 has been configured to home in place, meaning that the current location will become the machine's home, or zero location. This is a necessary step for many later operations and will prevent future errors.

3.4   Jogging the machine

After checking to make sure that the tool and gantry are clear to move, navigate to the "Jogging" tab in the operator controls pane.

By default, the machine is in continuous movement mode. To switch to incremental, click the "Jog Mode" button. The "Step" indicator light should turn on.

To adjust the step size, click "Cycle Jog Inc." These increments may be changed in Mach's configuration.
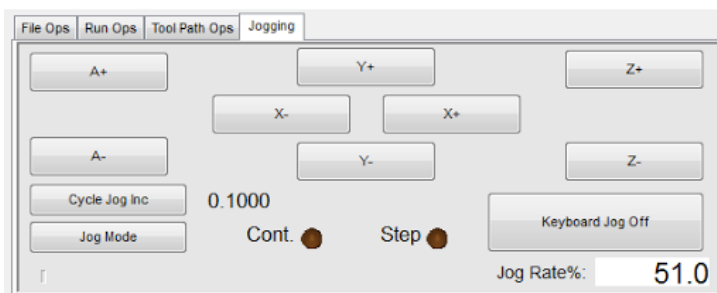
To revert to continuous movement, click "Jog Mode" twice. The first click will take it off of step mode and prevent the machine from jogging at all, and the second should turn on the "Cont." indicator light.

3.5   Inputting Commands

To run small snippets of G-code such as moving the machine to a specific location, navigate to the "MDI" tab at the top left of the screen. In this screen, type in G-code commands to the indicated box. Press cycle start to execute them. Pressing "Enter" will not execute, so multiple lines may be entered at once.

3.6   Zeroing the Z-axis

To zero the Z-axis, jog the machine to about 1-2 inches above the workpiece. The aluminum Z-zero plate mounted on the gantry underneath the tip of the tool. Hold this securely against the piece, and keep fingers out of the way. If you have a second person, have them navigate to the MDI screen, and type in "M11." This is a custom macro that will zero the z-axis. When you are ready, have them click "Cycle Start." The tool will descend slowly and, upon touching the plate (or moving 2 inches) will retract upwards. Once it has done so, check that the z-axis reads as about 1.122" (1" of movement + .122" for strike plate thickness). If not, try again until it does (See "Known Issues" about multiple attempts).

4   Post Processing

Once the toolpath is created within HSMWorks, click on "Post Process." A window will pop up asking for further input. Within this, under the section labeled "Post Configuration" lies a dropdown menu to select the correct post processor. Select the one called "mach3mill.cps – Generic Mach 3 Mill." It is made for Mach 3, but still works on Mach 4. Next, set the output folder to the desired location (likely a flash drive plugged into the computer), and click "Post." Save it to the desired location with the desired name and click "Save."

The code will then pop up. It is *highly advised* that you then comment out three lines of the code: Look for the line within the first section of code that begins with "G28," and comment it out by placing parentheses around the entire line, as follows: (G28 G91 Z0.). Do the same for the two G28 commands at the end of the code. For the reasoning behind this, see "Machine suddenly plunges…" within "Common Issues and Troubleshooting."

5   Running a Program

5.1   Executing the program

Within Mach, click File->Open Gcode File. Select the file you post processed. The G-code should now appear in the G Code pane in the upper left part of the screen. When the tool has been properly zeroed and positioned, press "Cycle Start" to execute the program. It is suggested that the user raise the tool above the workpiece and then press the "Goto Zero" button on the Axis Control Pane to check the correct positioning of the x and y axes before beginning the cut.

5.2   Monitoring the cut

You should carefully observe the machine for the first few movements, as this is where many errors such as the bit plunging into the workpiece will occur. To properly monitor the machine, use visual feedback, the G Code pane, and the Tool Path pane. The Tool Path pane has many options for viewing the machine's motion. By clicking within the pane and then dragging, the toolpath may be rotated, and by dragging while holding CTRL, the user may pan across the 3D environment. Zooming is done via

mouse wheel. To have the view follow the machine's movements, click on "Jog Follow." One thing in particular to look for in the first few layers is for any offset from the expected toolpath, usually visible within the Tool Path pane (See "machine movement is offset…" in "Common Issues").

5.3   Interventions and on-the-fly modifications

To pause a program temporarily, click the yellow "feed hold" button below "Cycle Start." This will stop movement, but allow for easy resumption via the "Cycle Start" button. Pressing feed hold *does not* turn off the spindle, however, and does not allow jogging out of position. If you turn off the spindle while the machine is paused, *make sure* to turn it back on before resuming the cut-failing to do so may break the bit. To stop the program entirely, use the "Stop" button. The program cannot be resumed after this, and the axes may need to be re-zeroed.

It is often helpful to change cutting parameters while the machine is in operation instead of going back and reprocessing the toolpath in HSMWorks. To do so, simply drag the sliders such as SRO and FR to the desired amount. SRO will adjust the programmed spindle speed to the percentage indicated, within the speed limits set within Mach's spindle configuration.

6   Common Issues and Troubleshooting

6.1   Cut face not parallel to bed

Because the current table is made of wood, when the clamps tighten the workpiece against the fence on the –Y edge, the fence will yield slightly and force the bottom of the piece upwards on a diagonal, causing the cut face to be skew with the bottom part of the piece when removed. One way to minimize this is to hold the piece against the bed as it is being clamped. As part of our future work, we intend to replace the bed with t-slotted aluminum, which should eliminate this issue.
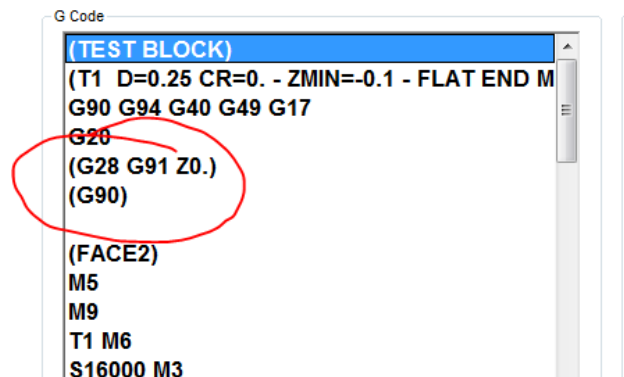
6.2   Toolpath on Mach does not match up with displayed machine movement/machine movement is offset from expected path
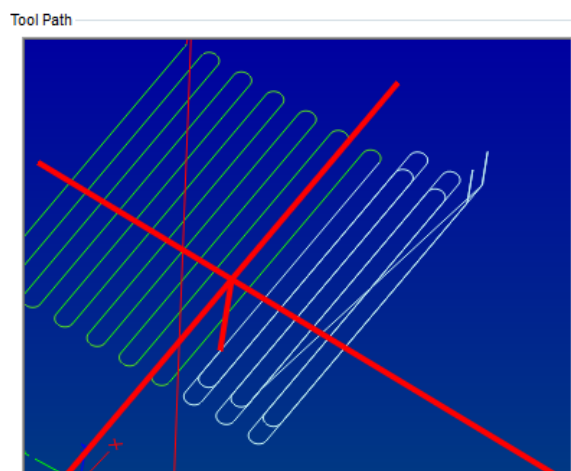
If the machine's toolpath is offset as in the figure at left, the issue is likely caused by the machine's axes becoming dereferenced. To fix this, simply press the "Ref All Home" button on the Axis Control panel of the main Program Run screen. Be aware, however: this will throw off your current coordinates, so it may be helpful to move the machine to a known location-X0 Y0 Z0, for example-and then home the machine so the axes' user coordinates are not lost.

6.3   Machine suddenly plunges or careens into workpiece before/after cut

This is an issue caused by the Mach3 post
processor for HSMWorks. When the program
begins and ends, the post processor inserts a G28
command to move the tool back to the home
position. Depending on where the machine's
home position is, this may cause it to run into the
workpiece. The workaround we have employed is
simply commenting out these lines at the
beginning and end of the program in either the
HSMWorks editor or the Mach 4 G-code editor.


```
G Code
(TEST BLOCK)
(T1  D=0.25 CR=0. - ZMIN=-0.1 - FLAT END M
G90 G94 G40 G49 G17
G20
(G28 G91 Z0.)
(G90)

(FACE2)
M5
M9
T1 M6
S16000 M3
```

6.4   The positive limit is hit, and the machine cannot be jogged off

The ShopBot only has one inductive proximity sensor per axis (though the z has only a hard mechanical
stop). This means that Mach 4 cannot distinguish between a positive and negative limit, and so in
configuring Mach, a choice had to be made on which signal would be read: positive or negative. The
negative X and Y limits were chosen as the signals read from the sensors, and so when the machine hits
its positive limit, it still thinks that it has hit a negative limit. Because of this, when the operator tries to
jog it back in the negative direction, Mach will not allow it. The limit must be overridden via the "Limit
Ovr." button located underneath the Axis Control pane.

6.5   "ERROR: Could not connect to the SmartBOBUSB device" on startup
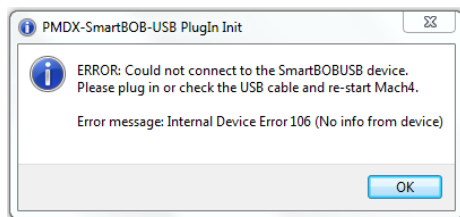
To fix this, make sure the power is on, the indicator lights on
the board are on, and the USB connection is good, then restart
Mach 4. This usually fixes the problem. If not, try unplugging
the USB cable from the computer and then plugging it back in.
If this does not work, turn the control box's power off and then
on again. Mach 4 will only connect to the SmartBOB upon
startup, so it must be restarted whenever the board is turned
off or otherwise disconnected.

7   Known Issues

7.1   Flat Spots on Circular Features

When cutting circular features, flat spots will sometimes appear at the positive and negative Y
quadrants of the circle. This is caused by backlash: The machine thinks it is switching direction and
moving, however because of about .016" of backlash in the y-motor assembly (measured with an
indicator dial) , it spins simply to take up that wiggle room, not moving in the y-direction and thus
producing a straight line at the quadrant.

While it is accounted for in Mach 4 in the motor configuration screen, according to Steve Stallings from
PMDX, "Backlash compensation must be implemented in the hardware device and its plugin.
The [PMDX] SmartBOB family does not yet support backlash compensation. Yes, it is on our list of things
to do. We are currently looking for the best way to do this." –Posted July 29, 2015

Readers are advised to check back on the PMDX plugin page (http://www.pmdx.com/PMDX-SmartBOB-USB-Plug-In) for updates on this issue and update the plugin once it supports backlash compensation.

7.2   Auto tool zero script (M11) must be run multiple times

The M11 script is a modified version of that provided by the Mach 4 forum user "poppabear." The checkprobe() function has been commented out to allow the script to run. The script, while effective, unfortunately does not usually zero the z axis correctly until it has been run multiple times. It should read ~1.122 when properly calibrated (1" of movement + .122" for strike plate thickness). It also will not zero correctly until the axes are referenced. This may be caused by an error in the PMDX's handling of the G31 probe command, and future updates to the driver may solve this issue.

7.3   Machine freezes during cut/communication errors during cut

Occasionally, we have found that the SmartBOB will suddenly cease communication with Mach 4, freezing the cut in the process and essentially ruining the cut. The exact cause of this has not yet been determined, and the only known solution is turning the power off and then restarting Mach 4 and the cut. The axes will likely have to be re-zeroed and re-referenced after doing so. Results have been replicated by unplugging the USB cable from the computer during operation, so cable connection issues may be a contributing factor. *Tested on Mach 4 build 2522, PMDX plugin version 29.128. Results consistent across different computers/OS (tested on Windows 7, 8.1 computers with same builds).*

7.4   Mach 4 program not responding during jogging/user control operations

Communication issues again are at least a part of this problem. Testing showed that unplugging the USB cable while the SmartBOB was enabled caused this same error to occur. Sometimes, restarting Mach after reconnecting the cable may be enough to fix this, but restarting the computer is so far the only consistent solution on the Dell T3500 running Mach on Windows 7 in our lab. Removing the cable on another computer running Windows 8 and the same builds of Mach and the PMDX plugin did not manifest the same issue, therefore it is thought the computer's connections or OS may be to blame.