AN001 – Mach3 Sample Configuration with 3 Axis and PWM Spindle Speed Using a Single Parallel Port

1.0 Preface

This document is NOT a complete Mach3 tutorial. Users of this document should be familiar with how to run the Mach3 operation and configuration interfaces. We recommend that you review the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (see reference [1] below) first if you have not already do so.

The steps outlined in this document were tested with various Mach3 versions from 3.042.029 through 3.043.062, though this configuration should work with any newer version of Mach3. Note however that the Mach3 screen layout may change with newer releases. This document does not apply to Mach3 version 4, which is not yet publicly available and will likely have a completely different configuration structure.

NOTE: ***This application note and the accompanying Mach3 XML configuration file are designed for use with PMDX brand breakout boards and spindle speed controllers. PMDX does not support the use of this XML file with other brands of breakout boards or spindle controllers and we cannot help you debug your Mach3 configuration with non-PMDX boards.***

SAFETY WARNINGS:

The PMDX-122, PMDX-125, PMDX-126, PMDX-132 breakout boards and PMDX-106 and PMDX-107 spindle speed controllers are intended for integration by the purchaser into industrial control systems. It is solely the purchaser's responsibility to assure that the system is configured in a manner consistent with applicable safety requirements. Practical Micro Design, Inc. does not control how this board is integrated into the purchaser's system and cannot be responsible for guaranteeing the safety of your system.

The PMDX breakout boards and spindle speed controllers are not guaranteed to be fail-safe. Relays provided on PMDX boards are control relays and ARE NOT QUALIFIED AS SAFETY RELAYS. The system into which these boards are installed should provide fail-safe protection and emergency stop capability.

The PMDX-125, PMDX-126, PMDX-132, PMDX-106 and PMDX-107 contain circuitry that may be connected to dangerous voltages. Care must be taken that user cannot come in contact with these voltages. An enclosure that allows for modest ventilation, but prevents intrusion by operator's hands and foreign objects, especially conductive byproducts of machining operations, should be utilized with these boards. Interlock switches on power circuits should remove power when the enclosure is opened.

Automated machine tools, into which the PMDX products may be integrated, can cause injury. Precautions should be taken to assure that operators are trained in their proper operation and safety procedures, and that they are protected from moving parts that may be under remote control and may move unexpectedly.

2.0 References

[1] ***Mach3 CNC Controller Software Installation and Configuration Guide***, Version 3, downloaded from http://www.machsupport.com/documentation.php

[2] ***AN006: Connecting Limit and Home Switches to PMD Breakout Boards***, from support pages on the PMDX web site (http://www.pmdx.com)

3.0 Overview

This application note describes a sample Mach3 configuration for a 3-axis machine with PWM-based spindle speed control using a single PC parallel port. The accompanying Mach3 XML file (PMDX_3Axis_pp_02.xml) implements the configuration described here. This configuration can be used with any of the following PMDX breakout boards (PMDX-122, PMDX-125, PMDX-126 or PMDX-132). It can also be used with either of our spindle speed controllers (PMDX-106 or PMDX-107).

If you find any inaccuracies in this document, please let us know. See http://www.pmdx.com for our contact information.

4.0 Installing and Running the XML Configuration File

To install the XML configuration file, copy it into the directory in which you installed Mach3. Normally this would be "C:\Mach3". It is possible to change this directory during the install process. If you did change the install directory, then copy the XML file into the directory you specified during the install process.

You can rename the file to whatever name you like, as long as you keep the ".XML" file extension.

WARNING:	Please read this document before attempting to use the accompanying XML file. At the very least, read sections 5.1 through 5.7 as there are some basic configuration settings that you will need to verify and/or change before your system will function.

There are two ways that you can run this XML file: (1) via the "Mach3 Loader", or (2) by creating or modifying a desktop icon. These are described below. Note that you can verify which XML configuration file that Mach3 is using by looking in the lower right corner of the main Mach3 screen. There is a box labeled "Profile" that displays the name of the XML configuration file that Mach3 is using.

Running the XML using the "Mach3 Loader":
Some versions of the Mach3 install program put an icon for the "Mach3 Loader" on your desktop. If you have a "Mach3 Loader" icon, double-click on that. If not, you can access it through the Windows "Start" menu. Go to "Start", "Programs", "Mach3" and then select "Mach3 Loader". This will bring up a window showing all of the configuration files that Mach3 could find. Select your XML file and click on "OK".

If your XML file is not listed in theMach3 Loader screen then you either copied it to a different directory or the ".XML" extension was not found.

Note that using the Mach3 Loader to run Mach3 with your XML file does not create any links or shortcuts to that configuration. You will have the use the loader each time you want to run Mach3 with your configuration file. See below for the steps needed to create a shortcut for your XML file.

Running the XML from an icon on your desktop:
You can also put an icon on your desktop as a shortcut to your custom Mach3 configuration. There are two ways to do this, depending on whether you already have the standard Mach3 icons on your desktop (Mach3Mill, Mach3Turn, etc.).

If you ***do*** have existing Mach3 icons on your desktop:

(1) Copy the Mach3Mill icon - right click and drag the icon, release the mouse button and select "Copy Here"

(2) Right-click on the new icon and select "Rename" and give the icon a new name (other than "copy of Mach3Mill")

(3) Right-click again on the icon and select "Properties". In the dialog box you will see the "Target" line that looks something like this:

C:\Mach3\Mach3.exe /p ***Mach3Mill***

Change the "Mach3Mill" to the name of your custom XML file (without the ".XML" extension). Then click on "OK". For example, to use the default name for our XML file, you should change the "Target" line to:

C:\Mach3\Mach3.exe /p ***PMDX_3Axis_pp_02***

Note that the path to "Mach3.exe" may be different on your system if you did not choose the default installation directory. ***Do not change the path to "Mach3.exe" in your icon to match our example! Change only the text after the "/p" separator (shown in bold above).***

If you ***do not*** have existing Mach3 icons on your desktop:

(1) Run Windows Explorer (not Internet Explorer) or open "My Computer". Change into the directory into which you installed Mach3 (usually C:\Mach3). Scroll down until you see the file named "Mach3.exe".

(2) Right-click and drag the "Mach3.exe" file onto your desktop. Release the mouse button and select "Create Shortcut Here".

(3) Continue with step (2) under the "do have an existing icon" instructions above.

5.0 Machine Configuration in the XML File

The accompanying Mach3 XML configuration file (PMDX_3Axis_pp_02.xml) implements the following configuration and features:

- 3 axis of stepper or step-servo control
- Motor step and direction polarity configured for Gecko G203V stepper drivers
- Motor tuning set for low velocity and low acceleration for easy (and safer) testing
- PWM-based spindle speed control
- Limit switches for each axis (positive and negative directions on a shared input pin, active high)
- Charge Pump output
- Emergency Stop (E-Stop) input
- PC keyboard keys assigned to jog each axis
- Mach3 kernel speed set to 25 KHz
- One parallel port with port address 0x378 (the standard parallel port address)

The following table lists the parallel port pin numbers and the Mach3 functions that have been assigned to them in the XML configuration file:

Pin #	*Function*
1	Not used (available output signal)
2	X Axis Direction
3	X Axis Step
4	Y Axis Direction
5	Y Axis Step
6	Z Axis Direction
7	Z Axis Step
8	Not used (available output signal or optional A Axis Direction signal)

Pin #	*Function*
9	Not used (available output signal or optional A Axis Step signal)
10	Emergency Stop (E-Stop) input
11	X axis positive and negative limit switches
12	Y axis positive and negative limit switches
13	Z axis positive and negative limit switches
14	Spindle Direction
15	Not used (available input signal)
16	Spindle speed (PWM)
17	Charge Pump output

Table 1 – Parallel Port Pin Assignments

WARNING:

The descriptions below are not intended to be a complete tutorial on configuring and using Mach3. You will need to read the Mach3 CNC Controller Software Installation and Configuration Guide (reference [1]) in order to be able to make some of the configuration changes described below.

PMDX cannot provide support for Mach3 configuration items that do not directly pertain to the operation of the PMDX breakout or spindle controller boards. Please refer general Mach3 configuration questions to the Mach3 support forums or the Mach3 Yahoo email list. Both of these can be accessed from the Mach3 support web site (http://www.machsupport.com) under the "Support" menu.

5.1 General Mach3 Settings

The configuration in the XML file is based on several assumptions regarding your computer's hardware configuration and your CNC machine environment. For most machine configurations these settings will work without changes. These settings include:

- ***Parallel Port Address*** – the XML file is set for one parallel port, with the parallel port's address at 0x378. See section 5.2.1 in the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (reference [1]) if you need to change this setting.
- ***Mach3 Kernel Speed*** - the kernel speed is set to 25 KHz. This setting means that Mach3 can generate step pulses up to a maximum rate of 25,000 steps per second. If you need to generate higher step rates or have other reasons for running the kernel at a higher speed, please see section 5.2.2 in the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (reference [1]). Note that if you change the kernel frequency you must re-visit the motor tuning section and re-enter the tuning data.

5.2 Emergency Stop Input (pin 10)

The PMDX breakout boards have an "emergency stop" (E-Stop) input, and they pass the E-Stop signal to the PC on pin 10 of the parallel port. The E-Stop input on PMDX breakout boards is designed so that a floating input (or an input that is driven to +5V) is interpreted as an E-Stop condition. Having the E-Stop input pulled to ground is interpreted as a "not E-Stop" (or "system is OK") condition.

The XML file defines the E-Stop input to Mach3 on port 1, pin 10, with "Active Low" disabled (i.e. the E-Stop is active high). ***Do not change this setting!***

THINGS YOU NEED TO DO:

- You must have either a jumper wire or a normally-closed E-Stop switch circuit connected to the breakout board's E-Stop terminals. For testing purposes we recommend starting out with the jumper wire as this makes it easier to track down any problems you may have with Mach3 and the breakout board. Every PMDX breakout board except the PMDX-132 ships with a jumper wire installed on the E-Stop inputs. If you have a PMDX-132, install the pluggable terminal block on connector J10 as described in the PMDX-132 User's Manual and then install a jumper wire between the EStop input and GND (connector J10 pins 3 & 4).
- Verify that Mach3 sees the "no E-Stop" condition with the jumper wire installed, and sees an "E-Stop requested" condition when the jumper wire is removed (see section 11.0 for details). After you have verified the E-Stop operation with the jumper wire, install and test your E-Stop switch circuit.

5.3 Charge Pump Output (pin 17)

Mach3 can be configured to output a "charge pump" signal. This signal toggles as long as Mach3 is running and there is no error or E-Stop condition. The PMDX breakout boards can use this signal to enable their outputs so that the machine moves (or coolant flows, etc.) only while Mach3 is running and there is not error or E-Stop condition.

> ***WARNING:*** The "Charge Pump" signal is an important safety feature of Mach3 and the PMDX breakout boards. While it is not foolproof, PMDX recommends that you use the "charge pump" feature as part of your overall system safety scheme.

The XML file enables the charge pump signal on port 1 pin 17.

Background:
During the power-on boot process, the PC's BIOS and the Windows operating systems go through a "printer discovery" process whereby data is output on the parallel ports pins in order to determine if there is a printer attached and if so, what type of printer. If the PC is connected to a machine that is powered on, this discovery process can cause parts of the machine to turn on or move (for example, the spindle control relay could engage or some of the axis motors might move). This is generally recognized by machinists as a "bad thing" and should be avoided.

Also, it is possible for the PC to crash in such a manner that some of the output signals are active while other signals are inactive. For example, the axis motors are moving but the spindle is off.

The "charge pump" feature helps avoid both of these situations. When the "charge pump" feature is enabled on the PMDX breakout boards, the breakout boards will keep their outputs disabled (i.e. "inactive") until it sees a valid charge pump signal. The PC power-up sequence does not contain a valid charge pump signal, so it will not affect the machine. Likewise, if the PC crashes the charge pump signal will most likely halt and the breakout board will again disable its outputs thereby halting the machine.

THINGS YOU NEED TO DO:

- Configure the PMDX breakout board to enable the charge pump feature. See the User's Manual for your breakout board and sections 6.0, 7.0 and 8.0 in this document, whichever corresponds to your breakout board.

5.3.1 Mach3 "Charge Pump On in EStop" setting

There is a Mach3 configuration setting in the "Config", "General Config" dialog box called "Charge Pump On in EStop". This is located in the "General Configuration" section of the dialog box (near the center). ***This box must be left un-checked in order for the charge pump signal to have the desired effect on the PMDX breakout boards.***

5.3.2 Using Pin 17 as a General Purpose Output

Some systems require so many output signals that they need to use pin 17 as a general-purpose output instead of a "charge pump" signal. For safety reasons, PMDX recommends that you use pin 17 as the "charge pump" signal. However, if you find that you really do need one more general purpose output signal, ***and you have devised your own safety procedures to avoid spurious machine movements,*** then you can disable the "charge pump" signal and re-use pin 17 for some other function.

> ***NOTE:*** If you are using a PMDX-125 or PMDX-126, it is possible to gain an additional 4 general purpose outputs and 4 general purpose inputs than are normally available on a single parallel port by using the PMDX-125 Mach3 Plug-In and the special "Expanded" modes on the PMDX-125 or PMDX-126 board. This would allow you to keep the "charge pump" safety feature. Please see the ***PMDX-125 Plug-In Installation Guide*** (available on the "Software Downloads" page on our web site) for more information on the PMDX-125 and PMDX-126 expanded modes. This plug-in applies to both the PMDX-125 and PMDX-126 boards.

To disable the charge pump:

(1) Go to the Mach3 "Config", "Ports and Pins" menu. Click on the "Output Signals" tab. Scroll down until you see the "Charge Pump" line. Click on the green check mark in the "Enabled" column to change it to a red "X". Click on the "Apply" button.

(2) Scroll to the output that you wish to assign to pin 17 (for example, "Output #1"). Click on the red "X" in the "Enabled" column, the assign "1" in the "Port #" column and "17" in the "Pin #" column. Set the "Active Low" column as needed for your application. Click on the "Apply" button and then the "OK" button.

5.4 PC Keyboard Keys for Jogging Each Axis

The XML file configures the following keyboard keys to jog each axis:

- Right and left arrow keys jog the X axis (right arrow moves in the positive direction)
- Up and down arrow keys jog the Y axis (up arrow moves in the positive direction)
- ***PageUp*** and ***PageDown*** keys jog the Z axis (***PageUp*** moves in the positive direction)
- ***Insert*** and ***Delete*** keys jog the A axis, once you have enabled the A axis, see step (6) in section 5.5 (the ***Insert*** key moves in the positive direction)

Please see section 5.6.2 in the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (reference [1]) for more information on assigning "system hotkeys" to Mach3 functions.

5.5 Axis Motor Settings

The XML file is configured for a 3-axis machine (the spindle does not count as an axis). The step and direction signals for a 4th axis (the "A" axis) have been defined, but the axis is disabled. If you need to use a 4th axis, see step (6) in the ***Things You Need To Do*** section below.

Each axis is configured with the following settings:

- "step" signal active high, which means that the step occurs on rising edge, or ground to +5V transition of the step signal
- "direction" signal is active high, which means that Mach3 outputs ground for positive (clockwise) motion and +5V for negative (counter-clockwise) motion (yes, this may seem counter-intuitive, but that is the way Mach3 works)
- Step pulses are 5 microseconds wide
- Direction signal setup time is set to "5"
- Homing speed is set to 20% of maximum axis speed
- Initial homing direction is in the positive direction
- Homing "auto zero" is enabled, so that when an axis hits a home switch, the DRO (digital readout) for that axis is set to 0.000 (the DRO is the axis position that is displayed on the main Mach3 screen).

THINGS YOU NEED TO DO:

(1) Determine your motor driver's requirements for the step and direction "common" signal. This is usually either "ground" or +5V. The XML file is configured for Gecko G203V drivers, which use "ground" for the step and direction "common" signal. If you are using a different Geckodrive (or

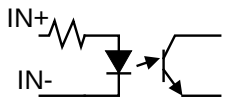
other brand of stepper driver) that requires a +5V common, you may need to change the polarity of the step and direction signals in Mach3 (see step (2) below).

Gecko Model	Step & Direction Common
G203V	Ground (terminal is labeled "Common")
G201X	Ground (terminal is labeled "Common"), **see note below
G320X	Ground (terminal is labeled "S/D Common"), **see note below

Table 2 – Step/Direction common signals for various Gecko motor drivers

*****NOTE:*** The G201X and G320X can accept either +5V or ground on the step and direction "common" pin. We recommend using ground since this makes the step signal "active high" (steps happen on the rising edge, or ground to +5V transition of the step pulse).

For all other Gecko stepper drivers and step-servo drivers please refer to the Gecko documentation. For other brands of motor drivers please refer to their documentation. Often you will see step and direction inputs documented like this:



For these cases we recommend that you tie the step and direction "IN-" signals together and connect them to a "ground" common on the breakout board. Then connect the step and direction signals from the breakout board to the individual "IN+" terminals on the motor drivers.

(2) If your stepper drivers use +5V for the step and direction "common" signal (see step [1] above), you may need to invert the step and direction signals in Mach3. Check with your motor driver documentation to determine whether a step happens on a positive or negative transition. To invert the step and direction signals, go to the Mach3 "Config" menu and select "Ports and Pins". Click on the "Motor Outputs" tab. You will see two columns labeled "Dir LowActive" and "Step Low Active", each with red "X"s for each axis. Click on these red "X" symbols to change them to green check marks. Then click on "Apply" and then "OK".

(3) Connect the step and direction signals from the breakout board to your stepper drivers or step-servo drivers according to Table 1 and the step and direction "common" requirements from step (1) above. Refer to the User's Manual for your breakout board for information on which connectors to use for these signals. See also sections 6.0, 7.0 or 8.0 for information on breakout board specific configuration.

(4) Determine "Native Units" – Mach3 is configured to use inches as the units for mapping motor steps to distance traveled and for motor tuning. If you want to use millimeters instead, go to the "Config" menu then select "Select Native Units". Click on "OK" in the first pop-up box then click on "MM" and "OK". Note that this does ***not*** change the units used in G-code commands. See section 5.4 in reference [1] for more information.

(5) Tune the motor performance – go to the "Config" menu and select "Motor Tuning". This will display the "Motor Tuning" dialog box. You will need to configure the parameters as appropriate for each axis of your machine. The first box is "number of steps per inch" (or per millimeter if you changed the native units as described above). The second box is the maximum velocity for that axis in inches per minute. The third box is acceleration, which can be set either by entering a number or by sliding the control just under the profile graph. Finally, there are two boxes for "Step Pulse" and "Dir" pulse setup time. We recommend leaving both of these at the default setting of "5" (5 microseconds). This will work for step rates up to 100 KHz (see step (7) below). Please refer to section 5.5 in the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (reference [1]) for more information on setting the motor tuning parameters.

(6) If you need to run a 4th axis, you need to enable that axis and then go through the motor tuning process for the 4th axis as described above. To enable the 4th axis, go to the "Config", "Ports and

Pins" menu. Click on the "Motor Outputs" tab. In the row for "A Axis", click on the red "X" in the "Enabled" column to change it to a green check mark. The step and direction signals are already configured.

(7) This XML file sets the default pulse timing parameters to 5us. If you need to generate step faster than 60,000 steps/second then you may need to change the step pulse width and direction setup parameters (to make them shorter). To do so, go to the Mach3 "Config", "Motor Tuning" menu. For each axis, click on the axis button along the right side. Along the bottom of the dialog box you will see a box labeled "Step Pulse 1-5us" and another labeled "Dir 0-5". The "Step pulse" box sets the step pulse width, in microseconds. The "Dir" box sets the direction signal setup time in TBD units. Please refer to section 5.5.2.1 in reference [1] (***Mach3 CNC Controller Software Installation and Configuration Guide***) and to the on-line Mach3 support forums for more information on setting these parameters. In rare instances you may encounter drivers that require more than 5us delays. If this is the canse, consult with Mach3 support for advice.

(8) If you need to change any of the homing parameters (homing speed, initial homing direction, auto-zero, etc.) go the Mach3 "Config", "Homing/Limits" menu. Also see section 5.6.1 in the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (reference [1]).

5.6 Limit Switches

The XML file configures positive and negative limit switches for the X, Y and Z axis as follows. Mach3's naming convention uses "++" to indicate the positive limit for an axis, and "--" to indicate the negative limit.

X++, X-- to pin 11, active high (i.e. a red "X" in "Active Low" column)
Y++, Y-- to pin 12, active high (i.e. a red "X" in "Active Low" column)
Z++, Z-- to pin 13, active high (i.e. a red "X" in "Active Low" column)

All limit switches are ***disabled*** by default in the XML file (i.e. a red "X" in the "Enabled" column). This allows you to test other aspects of your machine and XML configuration (like motor connections) before you have the limit switches connected. It also means that you don't have to worry about a mis-configured limit switch interfering with your motor testing.

To enable the limit switch inputs go to the "Config", "Ports and Pins" menu, then click on the "Input Signals" tab. For each limit switch that you intend to use, click on the red "X" in the "Enable" column to change it to a green check mark. When done changing the limit switch settings, click on the "Apply" button, then the "OK" button.

WARNING:	***We recommend that you leave your limit switch inputs DISABLED until you have tested other portions of your machine configuration. Please see the recommended testing sequence in section 11.0***

5.6.1 Active High Limit Switch Inputs

Active high limit switches signal an "at the limit" condition by outputting +5V or un-grounding (i.e. floating or open-circuit) the PMDX breakout board's input. A logic low voltage (i.e. ground) indicates "not at a limit".

One advantage of using active high limit switches is that a broken wire between the sensor and the breakout board (i.e. open circuit) is reported to Mach3 as an "at the limit" condition and the machine should stop.

Active high limit switches can be any one of the following:

- Mechanical switches between the breakout board input and ground. This can be either a single switch or multiple switches wired in series. The switch contacts should open when the machine is at a limit, and close otherwise.
- A single NPN sensor configured to detect the absence of a flag (i.e. it's output floats) when the machine is at a limit (NPN sensors cannot be paralleled for "active high" inputs)
- On a PMDX-126 only (NOT on a PMDX-125), a single PNP sensor powered by +24VDC configured to detect the absence of a flag (i.e. its output floats) when the machine is at a limit (PNP sensors cannot be paralleled for "active high" inputs)

For more information please see reference [2], ***AN006: Connecting Limit and Home Switches to PMD Breakout Boards***.

5.6.2 Active Low Limit Switch Inputs

Active low limit switches signal an "at the limit" condition by outputting a logic low voltage (i.e. ground). A logic high voltage (+5 volts) or open circuit indicates "not at a limit".

A possible disadvantage of using active low limit switches is that a broken wire between the limit switch and the breakout board will go undetected.

Active low limit switches can be any of the following:

- Mechanical switches between the breakout board input and ground. This can be either a single switch of multiple switches wires in parallel. The switch contacts should close when the machine is as a limit, and open otherwise.
- One or more NPN-style sensors wired in parallel between the breakout board input and ground. The sensor(s) should be configured to detect the presence of a flag (i.e. ground its output) when the machine is at a limit.
- On a PMDX-126 only (NOT on a PMDX-125), one or more PNP-style sensors wired in parallel between the breakout board input and +24VDC. The sensor(s) should be configured to detect the presence of a flag (i.e. connect to +24V) when the machine is at a limit. Yes, having +24V be "active low" may not make sense at first, but doing so makes the PNP "on" state match the NPN "on" state (and this is how the PMDX-126's inputs were designed).

For more information please see reference [2], ***AN006: Connecting Limit and Home Switches to PMD Breakout Boards***.

THINGS YOU NEED TO DO:

When you are ready to test your limit switches:

- If your limit switches are wired to be "active high" then you are ready to go. You do not need to change the "Active Low" setting in the Mach3 "Input Signals" tab.
- If your limit switches are wired to be "active low" then you must change the "Active Low" setting in Mach3. Go to the Mach3 "Config", "Ports and Pins" menu, then click on the "Input Signals" tab. For each active low limit switch, click on the red "X" in the "Active Low" column to change it to a green check mark. When you are done changing the limit switch settings click on the "Apply" button and then the "OK" button.

5.7 Spindle Speed Control

The XML file configures Mach3 to control a spindle speed using a PWM (pulse-width modulated) signal and the spindle direction with another output signal. This mode is compatible with both the PMDX-106 and PMDX-107 spindle speed controllers.

The PWM-based spindle control uses parallel port pin 14 to control the spindle direction and pin 16 for the PWM signal. The PWM frequency is set to 100 Hz and the minimum PWM setting is 5% duty cycle.

The spindle speed range is set for zero to 2000 RPM (though the 5% minimum PWM setting will limit this to 100 RPM).

> ***NOTE:*** The PMDX-125, PMDX-126 and PMDX-132 boards can be configured so that parallel port pin 14 controls one of their on-board relays. If you are using pin 14 to control the spindle direction via the PMDX-106 or PMDX-107 then make sure to ***disable the pin 14 relay*** on the PMDX-125, PMDX-126 or PMDX-132 boards. See sections 7.0, ***Configuring a PMDX-125*** or PMDX-126, and 8.0, ***Configuring a PMDX-132***, for more information. If you only need the spindle to run in a single direction and you need pin 14 as a general-purpose output then see section 5.7.1 below.

For more information on configuring the spindle, please see sections 5.3.6 and 5.5.5 in the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (reference [1]).

THINGS YOU NEED TO DO:

(1) To change the minimum and maximum spindle speeds, go to the "Config" menu and select "Spindle Pulleys". Change the "Min Speed" and "Max Speed" settings to match your machine. See section 5.5.5.1 in the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (reference [1]).

(2) If you do not need to control the spindle direction and want to use the "spindle direction" output (pin 14) for some other purport, see section 5.7.1.

(3) If you want to control your spindle using stepper motor signals (step and direction), see section 5.7.2. ***Note that this does not apply if you are using the PMDX-106 or PMDX-107.***

(4) If you do not need Mach3 to control the spindle speed at all (the spindle is either a fixed speed or under manual speed control), see section 5.7.3.

5.7.1 Configuring Spindle Controller to ignore pin 14

Some machines need to control the spindle speed using a PWM signal on parallel port pin 16, but need to use parallel port pin 14 for some purpose other than spindle direction. This means that they intend to always run the spindle in one direction. This can be done by making the following changes to the Mach3 configuration and to the PMDX-106 or PMDX-107 spindle controllers.

> ***NOTE:*** These instructions only apply to systems using the PMDX-106 or PMDX-107 spindle speed controllers.

(1) Go to the Mach3 "Config", "Ports and Pins" menu. Click on the "Motor Outputs" tab. In the "Spindle" row, change the "Dir Pin #" entry to "0" (zero). Click on the "Apply" button then the "OK" button.

(2) In Mach3, configure parallel port #1 pin 14 for whatever other purpose you need.

(3) Configure the PMDX-106 or PMDX-107 spindle controllers DIP switch settings to put them in "Run/Direction" mode. Please refer to the PMDX-106 and PMDX-107 User's Manuals for information on how to change the DIP switch settings.

(4) On the PMDX-106 or PMDX-107 spindle controllers, ***leave the "Reverse/Direction" relay terminals unconnected***. Connect the "Forward/Run" relay terminals to the "run" input on your spindle controller.

5.7.2 Configure Mach3 for Step & Direction Spindle Control

Some systems use a stepper motor (or step servo motor) to control the spindle. ***This does not apply to systems using the PMDX-106 or PMDX-107 (see section 5.7).*** To change the Mach3 configuration

to use step and direction signals to control the spindle motor, go to the "Config" menu and select "Ports and Pins". Click on the "Spindle Setup" tab. In the top center of the dialog box is a section labeled "Motor Control". Check the box labeled "Step/Dir Control". Click on the "Apply" button and then the "OK" button.

By default this will use parallel port pin 14 as the "direction" signal and pin 16 as the step signal. You can change these pin assignments by going to the "Config", "Ports and Pins" dialog box and clicking on the "Motor Outputs" tab. Change the Spindle step and direction pin numbers and "Active Low" settings to match your spindle stepper motor wiring and configuration.

Please see section 5.5.5.3 in the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (reference [1]) for more information on configuring the spindle to use step and direction signals.

5.7.3 Configure Mach3 for Manual Spindle Speed Control

Some systems do not require automated control of the spindle speed. The spindle speed is either fixed, or controlled manually. In this case you would not be using a PMDX-106 or PMDX-107 spindle speed controller. Mach3 will only be able to turn the spindle on and off, or optionally, turn the spindle on in the forward direction or turn it on in the reverse direction.

That is, the spindle direction will be controlled by two different outputs: one for "run spindle clockwise" and a second, optional output for "run spindle counter-clockwise".

PMDX breakout boards have one or more relays on them that may be used to control your spindle motor. The PMDX-122 has one relay driven by parallel port pin 1. The PMDX-125, PMDX-126 and PMDX-132 have two relays that can optionally be driven by parallel port pins 1 and 14. Please see the User's Manual for each board for relay specifications and information on enabling the relays.

To change the Mach3 configuration to support manual spindle speed control, make the following changes:

(1) Go to the Mach3 "Config", "Ports and Pins" menu. Click on the "Spindle Setup" tab.

(2) In the top center of the dialog box is a section labeled "Motor Control". Click on the "Use Spindle Motor Output" box (it should have been checked, and clicking on it will un-check the box). You should see a pop-up window that says "Spindle Motor has now been disabled". Click on "OK" to close the pop-up window.

(3) Still in the "Spindle Setup" tab, in the upper left corner of the dialog is a section labeled "Relay Control". Click on the "Disable Spindle Relays" box to un-check it.

(4) Look in the two lines below the "Disable Spindle Relays" box. These show the output signal numbers that are assigned to the "run spindle clockwise" command (the "M3" command in G&M code) and the "run spindle counter-clockwise" command (the "M4" command in G&M code). By default these are set to "output 2" and "output 1", respectively. You can change these to any output number 1 through 20, but we recommend that you keep them at their default setting. If you change these, you will need to substitute the new output numbers in the steps below.

(5) Click on the "Apply" button to save the changes to the "Spindle Setup" parameters.

(6) Click on the "Output Signals" tab.

(7) Configure the "run spindle" or "run spindle clockwise" output. "Output #2" is used for this purpose. In the "Output #2" line, click on the red "X" in the "Enabled" column to change it to a green check mark. Then change the "Port #" to "1" and the "Pin Number" to the desired parallel port pin number (we recommend using pin 1 for this signal). If you need an active low signal (i.e. the output goes low to turn on the spindle) then click on the red "X" in the "Active Low" column to change it to a green check mark.

(8) Configure the "run spindle counter-clockwise" output. If you only need to turn the spindle on and off and do not need to control the direction, then make sure there is a red "X" in the "Enabled"

column for "Output #1" (because you won't be using it). If you need to control the spindle direction, "Output #1" will be configured as the "run spindle counter-clockwise" output signal (controlled by the "M4" command in G&M code). In the "Output #1" line, click on the red "X" in the "Eanbled" column to change it to a green check mark. Then change the "Port #" to "1" and the "Pin Number" to the desired parallel port pin number (we recommend using pin 14 for this signal). If you need an active low signal (i.e. the output goes low to turn on the spindle) then click on the red "X" in the "Active Low" column to change it to a green check mark.

5.8 Spare Output Signals (pins 1, 8 and 9)

The XML file leaves parallel port pins 1, 8 and 9 as unused output pins.

On all of the PMDX breakout boards, pin 1 can drive an on-board relay. On some PMDX breakout boards the relay can be disabled so that pin 1 can be used as a general-purpose TTL output signal.

Pins 8 and 9 can be used as the direction and step signals for the 4th motor axis, or as general-purpose outputs, depending on which breakout board you use. The PMDX-132 dedicates these signals to the 4th motor axis. All other PMDX breakout boards allow you to use these signals as general-purpose TTL outputs.

THINGS YOU NEED TO DO:

- If you need to control some other device, such as a coolant pump, suction pump, etc., assign the desired pin number to one of the "Output #" signals in the Mach3 "Output Signals" tab of the "Config", "Ports and Pins" dialog box. Please see reference [1] (***Mach3 CNC Controller Software Installation and Configuration Guide***) for more information.

5.9 Spare Input Signal (pin 15)

The XML file leaves parallel port pin 15 as an unused input pin. It can be used for a touch probe input (also called a "digitizing probe"), vacuum good status, etc.

6.0 Configuring a PMDX-122

The following figure shows the jumper settings required for the PMDX-122 to operate with the XML configuration file. It also shows the necessary connections for motor drivers, limit switches, E-Stop switch and the optional PDMX-106 Spindle Speed Controller (the PMDX-122 does not support the PMDX-107).

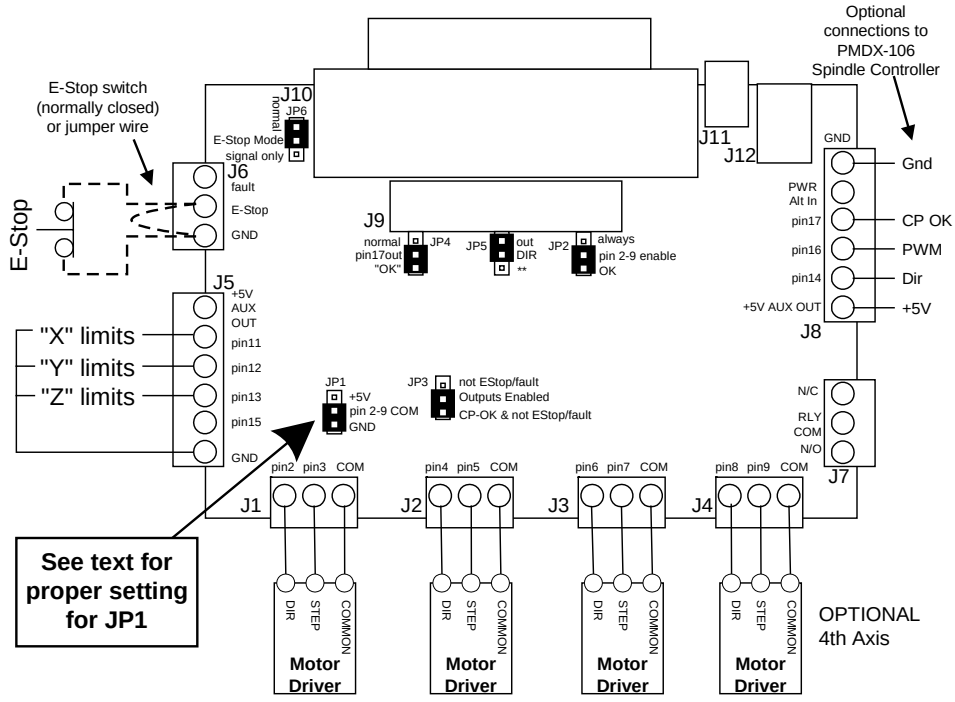


Figure 1 – PMDX-122 Jumper Settings & Connections

JP1 - Set according to the stepper drivers you are using. See item (1) in the "Things You Need to Do" section of section 5.5.
JP2 - Jumper set between the center pin ("pins 2-9 enable") and the bottom pin ("OK")
JP3 - Jumper set between the center pin ("Outputs Enabled") and the bottom pin ("CP-OK & not EStop/Fault")
JP4 - Jumper set between the center pin ("pin17out") and the bottom pin ("OK")
JP5 - Jumper set between the center pin ("DIR") and the top pin ("out")
JP6 - Jumper set between the center pin ("E-Stop mode") and the top pin ("normal")

For examples of limit and home switch wiring to the PMDX-122, please see reference [2], ***AN006: Connecting Limit and Home Switches to PMD Breakout Boards***.

7.0 Configuring a PMDX-125 or PMDX-126

DIP Switches "Config3", "Config2" and "Config1" must be set to "Run in Normal Mode with Charge Pump", see the ***PMDX-126 User's Manual*** for details. The "charge pump" signal is needed to prevent spurious machine movement during the PC or SmoothStepper power-on and configuration sequence. This document does not cover settings required to run the PMDX-126 or the PMDX-107 in "Expanded" mode.

If you are using a PMDX-106 or PMDX-107 spindle speed controller you will need to disconnect the K2 relay from parallel port pin 14. You will need to change jumper JP2 and/or DIP Switch "Config 8". Please see section 3.3 of the ***PMDX-126 User's Manual*** for more information.

For examples of limit and home switch wiring to the PMDX-126, please see reference [2], ***AN006: Connecting Limit and Home Switches to PMD Breakout Boards***.

8.0 Configuring a PMDX-132

The following figure shows the jumper settings required for the PMDX-132 to operate with the XML configuration file. It also shows the necessary connections for motor drivers, limit switches, E-Stop switch and the optional PDMX-106 or PMDX-107 Spindle Speed Controller. Please see

JP1 - Jumper set between the center pin ("output enable") and the top pin ("CP-OK") to enable the charge pump.
JP2 - Jumper set between the center pin ("pin 17 mode") and the top pin ("CP-OK") which makes the pin 17 output on connector J9 the "Charge Pump OK" signal
JP3 - Jumper set according to your configuration. Set the jumper between the center pin ("K1") and the bottom pin ("Pin 1") to control the K1 relay from parallel port pin 1. Set the jumper between the center pin ("K1") and the top pin ("disable") to disable the K1 relay.
JP4 - Jumper set according to your configuration. Set the jumper between the center pin ("K2") and the bottom pin ("Pin 14") to control the K2 relay from parallel port pin 14. Set the jumper between the center pin ("K2") and the top pin ("disable") to disable the K2 relay. Note that if you are using a PMDX-106 or PMDX-107 with the PMDX-132, you should disable the K2 relay unless you've configured the PMDX-106 or PMDX-107 to ignore the spindle direction signal (see section 5.7.1)
JP5 - Set according to your X axis stepper driver's step/direction common (see step (1) in section 5.5)
JP6 - Set according to your Y axis stepper driver's step/direction common (see step (1) in section 5.5)
JP7 - Set according to your Z axis stepper driver's step/direction common (see step (1) in section 5.5)
JP8 - Set according to your A axis stepper driver's step/direction common (see step (1) in section 5.5)

> ***NOTE:*** If you are using a PMDX-106 or PMDX-107 spindle speed controller, your should disable the K2 relay on the PMDX-132 board.

For examples of limit and home switch wiring to the PMDX-132, please see reference [2], ***AN006: Connecting Limit and Home Switches to PMD Breakout Boards***.

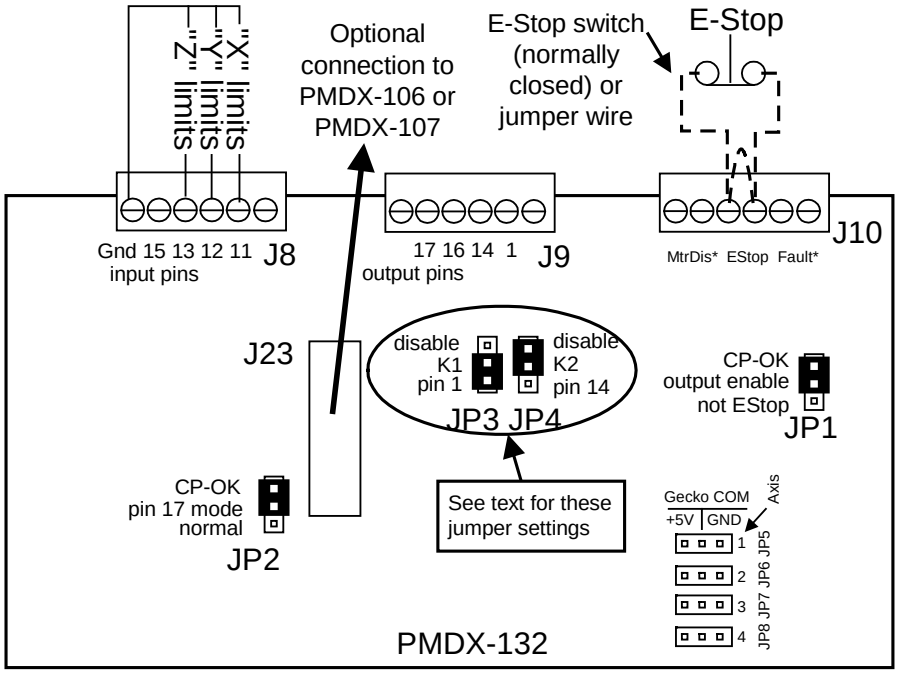


Figure 2 – PMDX-132 Jumper Settings & Connections

9.0 Configuring a PMDX-106

Configure your PMDX-106 as follows:

- DIP Switch 1 (labeled "Option Set") set to "off"
- DIP Switch 2 (labeled "F/R mode") set according to your VFD or spindle controller requirements (please refer to the ***PMDX-106 User's Manual*** for more information). If you want to configure the spindle speed controller to ignore pin 14 (the direction signal) as mentioned in section 5.7.1 then this DIP switch should be set to "on" to set for "Run/Direction" mode.
- DIP Switch 3 (labeled "Ignore PWM") set of "off" (PWM signal controls the spindle speed)
- DIP Switch 4 (labeled "Ignore CPOK") set to "off" (require the "charge pump OK" signal)
- DIP Switch 5 (labeled "Inboard POT") set according to your PMDX-106 configuration (please refer to the ***PMDX-106 User's Manual*** for more information)
- DIP Switch 6 (labeled "Filter Option") set according to your VFD or spindle controller requirements (please refer to the ***PMDX-106 User's Manual*** for more information)
- Set jumpers JP1 and JP2 according to your VFD or spindle controller requirements (please refer to the ***PMDX-106 User's Manual*** for more information)

Connect the PMDX-106 to your VFD or spindle controller as described in the PMDX-106 User's Manual. If you want to configure the spindle speed controller to ignore pin 14 (the direction signal), see section 5.7.1 for instructions on who to modify the PMDX-106 connections to your VFD or spindle controller.

10.0 Configuring a PMDX-107

Configure your PMDX-107 as follows:

- DIP Switches 1 and 2 (labeled "Config" and "Config2") set both to "off" (selects "Normal" mode)
- DIP Switch 3 (labeled "Config3") set according to your VFD or spindle controller requirements for the PMDX-107's relay signals (please refer to the ***PMDX-107 User's Manual*** for more information). If you want to configure the spindle speed controller to ignore pin 14 (the direction signal) as mentioned in section 5.7.1 then this DIP switch should be set to "on" to set for "Run/Direction" mode.
- DIP Switch 4 (labeled "Config4") set of "off" (require the "charge pump OK" signal)
- DIP Switch 5 (labeled "Slow"") set according to your VFD or spindle controller requirements (please refer to the ***PMDX-107 User's Manual*** for more information)
- DIP Switch 6 (labeled "5v/10v") set according to your VFD or spindle controller requirements (please refer to the ***PMDX-107 User's Manual*** for more information)

Connect the PMDX-107 to your VFD or spindle controller as described in the ***PMDX-107 User's Manual***. If you want to configure the spindle speed controller to ignore pin 14 (the direction signal), see section 5.7.1 for instructions on who to modify the PMDX-107 connections to your VFD or spindle controller.

11.0 Testing Your Configuration

The following sections describe how to test various portions of your Mach3 and machine setup.

> ***NOTE:*** If you will be using a PDMX-106 or PDMX-107 spindle speed controller, remove it or disconnect the spindle speed controller from the breakout board until you get to the ***Testing Your Spindle Control Interface*** step.

11.1 Testing the E-Stop Input

How to test E-Stop input:

- Install the E-Stop jumper wire between the breakout board's "EStop" input and the adjacent "GND" terminal. Power on the breakout board and verify that the "EStop" LED is off.

- Connect the breakout board to the PC's parallel port and start Mach3 using the sample XML file. Click on the RESET button on the Mach3 screen. It should stop flashing.
- Remove the E-Stop jumper wire from the breakout board (removing one end from the terminal block is sufficient). Mach3 should show "Emergency Stop Requested" and the RESET button on the Mach3 screen should be flashing.
- Click on the Mach3 RESET button. The Mach3 RESET button should continue to flash.
- Reconnect the jumper wire to the breakout board. Click on the Mach3 RESET button. It should stop flashing.

11.2 Testing the Charge Pump

PMDX breakout boards have an "Outputs Enabled" LED on them. This LED is lit ("on") when the breakout board's outputs are enabled (step and direction signals, spindle controls, etc.). If you have configured the breakout board according to the previous sections, this LED will only turn on when the breakout board sees a valid charge pump signal from Mach3.

To test the charge pump operation, do the following. Note that this test presumes that the E-Stop input has been tested and is working, and that the EStop jumper wire is installed. If you have not tested the E-Stop input, follow the steps in section 11.1 first, then come back and run this test.

(1) Power on the breakout board and start Mach3 using the sample XML file.
(2) Verify that your E-Stop circuit is "closed" (i.e. the E-Stop input on the breakout board is pulled to ground and the breakout board's E-Stop LED is turned off)
(3) On the Mach3 screen, the "RESET" button should be flashing.
(4) On the breakout board, the "Outputs Enabled" LED should be off.
(5) Click on the "RESET" button in Mach3. The "RESET" button should stop flashing and turn solid green. This will enable the charge pump signal from Mach3.
(6) The "Outputs Enabled" LED on the breakout board should turn on.
(7) Click the "RESET" button in Mach3 again. This will turn off the charge pump signal from Mach3. Verify that the Mach3 "RESET" button is flashing (again)
(8) Verify that the breakout board's "Outputs Enabled" LED is off.

11.3 Testing Motor Axis

Use the keyboard keys to jog each axis and observe the motor's response. The left and right arrow keys control the X axis. The up and down arrow keys control the Y axis. The "PageUp" and "PageDown" keys control the Z axis ("PageUp" moves in positive direction). The "Insert" and "Delete" keys control the A axis if you have that enabled ("Insert" moves in the positive direction).

- Jog each axis back and forth. If you observe no motion except for one step each time you reverse directions, then the step & direction signals are swapped. For example, the step signal from the breakout board is connected to the direction input of the motor driver, and the direction signal is connected to the step input.
- Jog an axis "forward". If the motor moves backwards then the direction polarity is incorrect. You can fix this in two ways: (1) change direction polarity in Mach3 (go to Config->Ports and Pins, click on the "Motor Outputs" tab and then change the "Dir Low Active" setting; or (2) remove power from your machine and swap the wires on one (and only one) of the stepper motor windings.

After you have verified that each motor axis is working properly, you should "tune" the motors. Tuning the motor tells Mach3 how fast it can accelerate and decelerate each axis, and what the maximum speed for that axis is. Tuning the motors is beyond the scope of this document. Please see section 5.5 in the ***Mach3 CNC Controller Software Installation and Configuration Guide*** (reference [1]).

11.4 Testing Your Limit Switches

Now that you have the E-Stop, Charge Pump and motor controls working, connect your limit switches to your breakout board and enable the limit switches in Mach3. See section 5.6 for more information on limit switch configuration.

To test the limit switches:

- Move each axis of your machine until it is off of all limit switches.
- In Mach3, go to the "Diagnostics" screen. To do so, you can press ALT-7 (not ALT-F7) or click on the "Diagnostics" button along the top right side of the Mach3 screen. Once in the diagnostics screen, look at the "Inputs Signals current state" section along the right-hand edge of the screen. You will see indicators for each limit switch input (as well as all the other inputs). The X axis limits are labeled "M1++ Limit" and "M1- - Limit", the "Y" axis limits are labeled "M2++ Limit" and "M2 - - Limit", and the "Z" axis limits are labeled "M3++ Limit" and "M3- - Limit". Each of these indicators should be "off" (i.e. a black or dark gray square). If any of them are lit up (yellow square), then either your wiring is incorrect or the polarity (active high or active low) is mis-configured in Mach3.

Then, for each axis, do the following:

- Jog the machine axis until it hits the negative limit switch. Verify that Mach3 shows the "- -" limit switch active (yellow box). If you have followed the sample XML configuration and have the positive and negative limit switches wired to the same input, Mach3 will show ***both*** the "++" and "- -" limit switches active at the same time. That is OK, and is the expected result.
- Now jog the machine in the positive direction until it moves off the limit switch. Verify that Mach3 shows the limit switches not active (black or dark gray boxes).
- Continue to jog the machine in the positive direction until it hits the positive limit switch. Verify that Mach3 shows the "++" limit switch active. Again, if you are using our sample XML configuration, Mach3 will show ***both*** the "++" and "- -" limit switches active.
- Jog the machine in the negative direction until it is off the limit switch. Verify that Mach3 shows the limit switches as not active.
- Repeat this sequence for each axis.

11.5 Testing Your Spindle Control Interface

The test steps below presume that you have not changed the maximum spindle speed, which we set to 2,000 RPM in the XML file. If you have changed the maximum spindle speed as outlined in section 5.7, then change the "S" command values below to match your spindle speed range (i.e. change the "S1000" command to whatever is 1/2 of your full speed).

(1) Remove power from your breakout board and install the PMDX-106 or PMDX-107 spindle speed controller.

(2) Disconnect the PMDX-106/PMDX-107 from your VFD or spindle controller.

(3) Apply power to the breakout board and PMDX-106/PMDX-107.

(4) In Mach3, click on the RESET button and make sure it stops flashing.

(5) Go to the "MDI" screen by clicking on the "MDI (Alt-2)" button near the upper left corner of the screen (just under the menu bar). Or you can press ALT-2 (the ALT key and the number "2" key at the same time).

(6) On the MDI screen, click on the long rectangular box near the bottom just to the right of the "Input" label. The box should turn light yellow in stead of gray. It is now ready for you to type commands.

(7) Type "S1000" then press the "Enter" key. This sets the spindle speed to 1,000 RPM (1/2 full speed). The "S" command does not start the spindle, it simply sets the target speed.

(8) Type "M3" then press the "Enter" key. This starts the spindle in the clock-wise direction. On the breakout board verify that the LED for the pin 14 terminal is off, and the LED for the pin 16 terminal is on, but not a full brightness.

(9) Verify on the PMDX-106/PMDX-107 that the "PWM" LED is on but not at full brightness, and that the "Fwd/Run" LED is on.

(10) In Mach3, type "M4" then press the "Enter" key. This changes the spindle direction to couter-clockwise. On the breakout board verify that the LED for the pin 14 terminal is now on, and the LED for the pin 16 terminal remains on, but not a full brightness.

(11) Verify on the PMDX-106/PMDX-107 that the "PWM" LED is on but not at full brightness, and that the "Rev/Dir" LED is on.

(12) In Mach3, type "S100" and press the "Enter" key. This sets the spindle speed to 100 RPM (the slowest allowed spindle speed). Verify that the pin 16 LED on the breakout board is on but very dim. Also verify that the "PWM" LED on the PMDX-106/PMDX-107 is also on but dim.

(13) In Mach3, type "S2000" and press the "Enter" key. This sets the spindle speed to 2,000 RPM (the maximum spindle speed). Verify that the pin 16 LED on the breakout board is on and bright. Also verify that the "PWM" LED on the PMDX-106/PMDX-107 is also on and bright.

(14) In Mach3 type "M5" and press the "Enter" key. This should turn off the spindle. Verify that the pin 16 LED on the breakout board turns off. Also verify on the PMDX-106/PMDX-107 board that the "PWM" LED is off, and that both the "Fwd/Run" and "Rev/Dir" LEDs are off.

(15) Remove power from the breakout board and PMDX-106/PMDX-107. Connect the PMDX-106/PMDX-107 to your VFD or spindle controller.

(16) Apply power to the breakout board and PMDX-106/PMDX-107. Also apply power to your VFD or spindle controller.

(17) Repeat the test sequence starting with step (4). Verify that your spindle moves in the direction and at the speed that you are commanding it to move.

12.0 Update History

Date / Rev	***Description***
13 Aug 2012 Rev 02	• Updated Mach3 versions covered by this app note. • Changed app note numbering scheme. • Added "PMDX-126". • Fixed/enhanced description of "active high" and "active low" limit switches (sections 5.6.1 and 5.6.2)