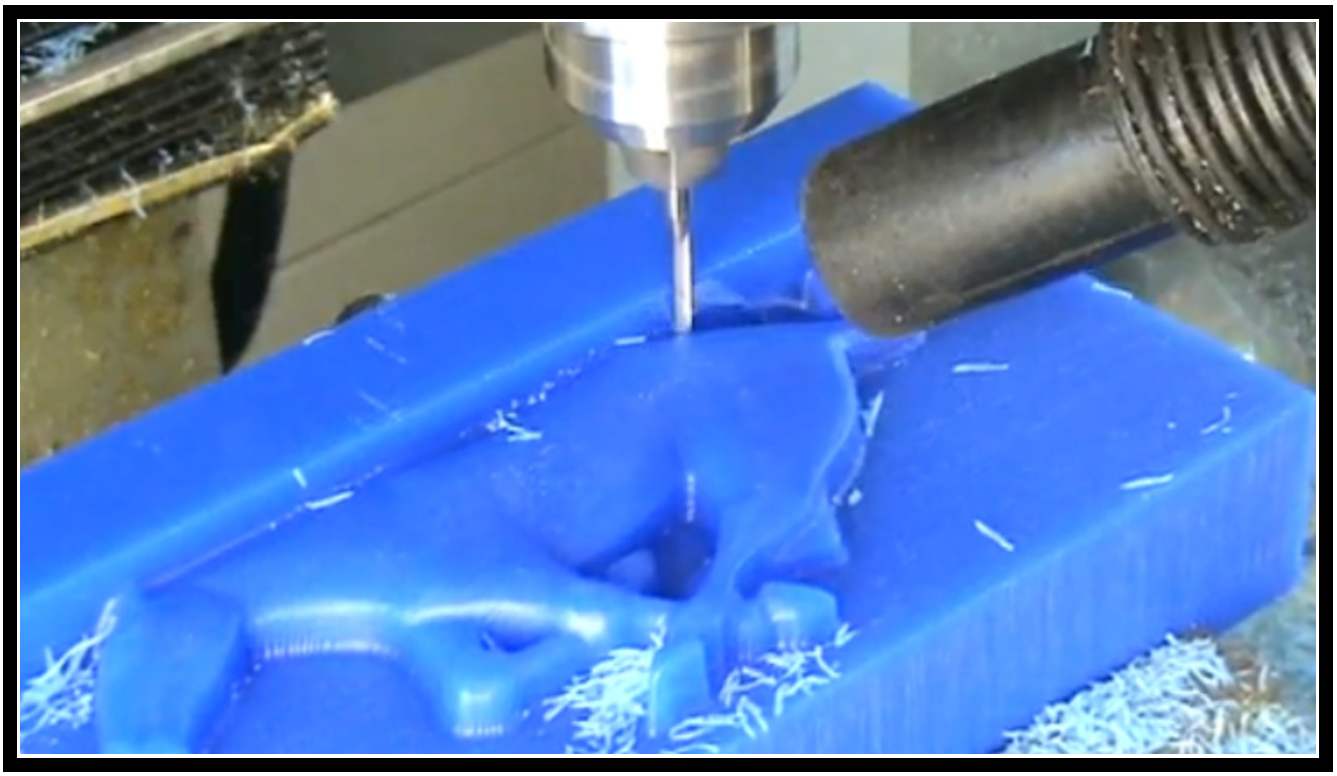
Ajax Mach3 Based CNC Kit



Operator's Manual
Version 1.12 for DC3IOB

(Mach3 is a trademark of Newfangled Solutions, LLC)

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AjaxCNC
P.O. Box 9012
Milesburg, PA 16853

Tel. 814-360-0279
Fax. 413-793-4886
www.ajaxcnc.com

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I have read, understand and accept the above terms and conditions:

_____

Name (print)

_____ _____

Signature *Date*

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1 Introduction

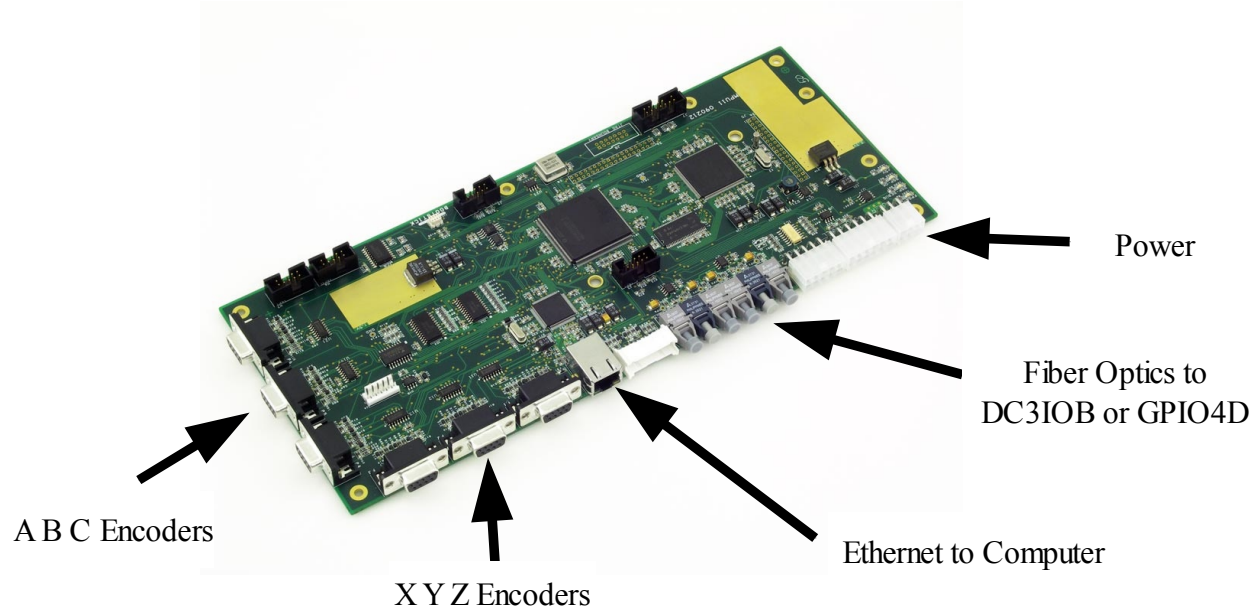
The Mach Ajax Plugin is designed as a simple way to run a CNC machine at high speeds and low headaches. Instead of driving stepper motors over the parallel port, the plugin allows Mach3 to smoothly command the motion of servo motors over a direct Ethernet connection. G Code programs consisting of many small moves (digitized shapes for example) can be run at full speed without problem.

2 Hardware Setup

The kit you purchased should contain two printed circuit boards – an Ajax MPU11 board and a DC3IOB.

2.1 Ajax MPU11

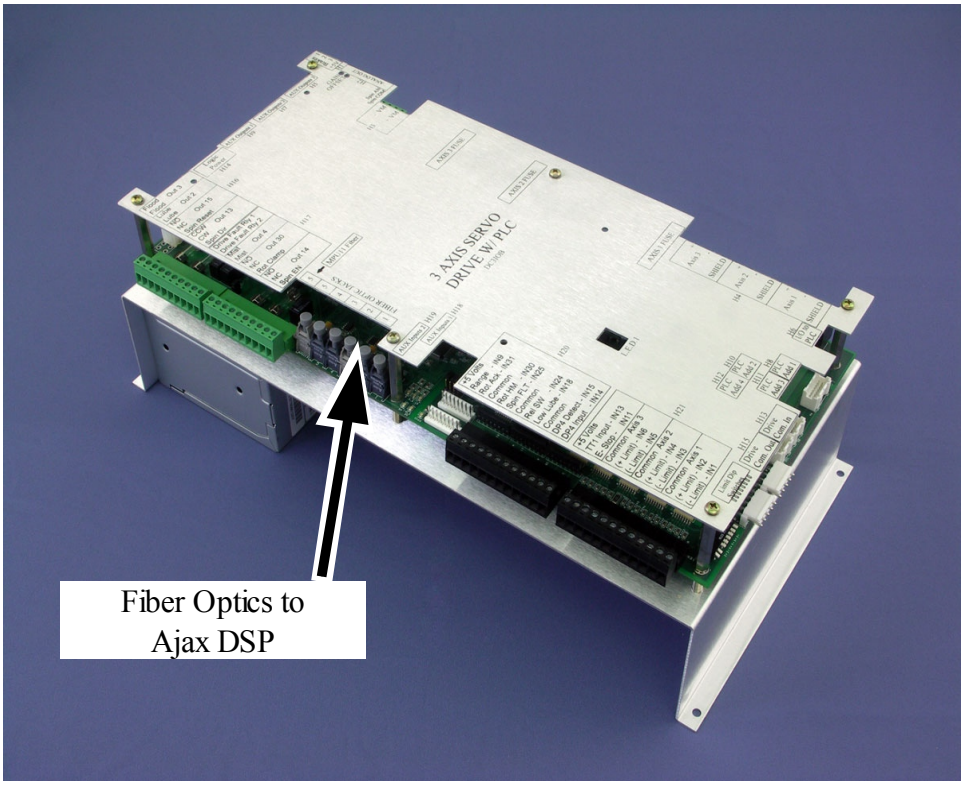
The Ajax MPU11 board connects to your computer with a standard ethernet cable. Your computer will need to have at least one network adapter card installed, though two are recommended if you intend to use your computer for anything other than CNC operation. It looks like this...



2.2 DC3IOB

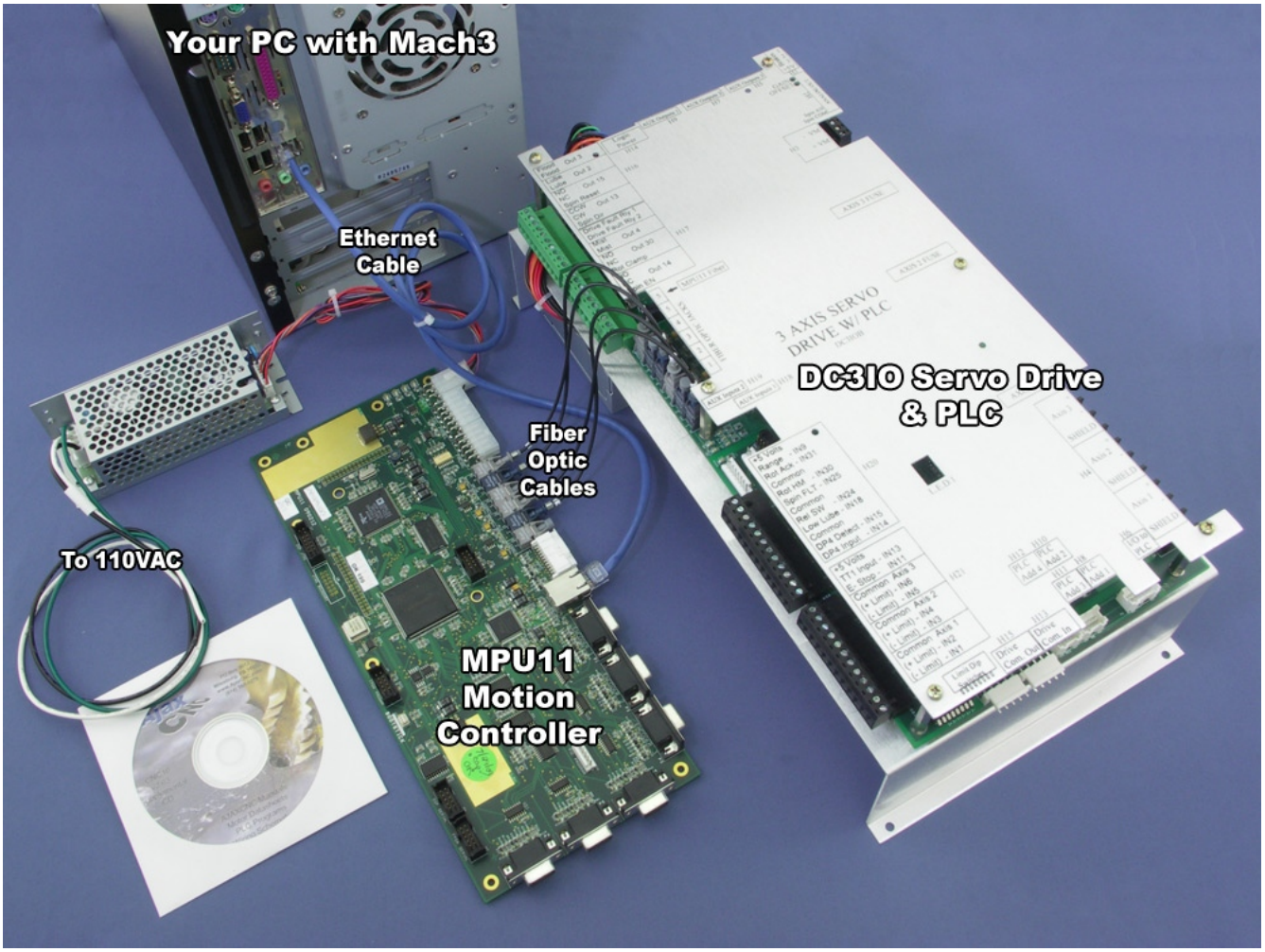
The DC3IOB connects to your Ajax MPU11 board with 4 fiber optic cables (to isolate your computer from any electrical feedback that could otherwise cause damage). Only fiber ports 1, 3, 4 and "MPU11 5" are used – the other 2 ports should be capped.

Port 1 on the DC3IOB should connect to port 1 on the Ajax MPU11.
Port 3 on the DC3IOB should connect to port 3 on the Ajax MPU11.
Port 4 on the DC3IOB should connect to port 4 Drive on the Ajax MPU11.
The Port labeled "MPU11 5" on the DC3IOB should connect to port 5 Drive on the Ajax MPU11 (not port 5 Legacy)



2.3 Image of Connections

Your major connections should look something like the image below (servos, encoders, and I/O wires are not shown)



2.4 Encoder Basics

Encoder Type:

- Ajax MPU11 hardware requires quadrature, differential encoders which operate on 5VDC. This is the most common type of encoder. Encoders labeled "TTL type" (non differential) are unsuitable, and fortunately are quite rare.

Encoder Signals:

- The following signals must be present and wired: A, /A, B, /B, Z, /Z, +5VDC and ground. Note: The Z channel is sometimes labeled as I, C or "marker". The "/" symbol may also be expressed as "-", "NOT" or "!" or a line over the letter, it means the signal is the complement (opposite) of the channel specified.
- Signal levels:
  The "low" signal level must be less than 0.5 VDC and the "high" signal level must be at least 3.5 VDC.

Encoder Resolution:

- Typical Machine tool applications (milling machines, lathes and routers) require at least 1000 line (4000 counts per rev) encoders. We recommend and sell 2000 line (8000 counts per rev) encoders. To achieve reasonable accuracy and smooth motion, the encoder/motor/ballscrew configuration must achieve a minimum resolution of 20,000 encoder counts per inch of travel (787 counts/mm). For a typical knee mill which uses a 5tpi (turns per inch) ballscrew and has the motors belted at a 1:1 ratio, a 1000 line encoder just meets the minimum counts per inch. Which is 20,000 for smooth motion. The 1000 line encoder will work. However, a 2000 line encoder (8000 counts per rev) would be a better choice. Older 250 and 500 line encoders will not work to satisfaction.

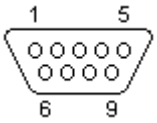
Some Examples:

- 5 turns per inch ballscrew belted at 2:1 with the servo motor = 10 turns of the servo motor per inch of axis travel
- 10 turns per inch x 4000 counts per rev (1000 line) = 40,000 counts per inch
- 10 turns per inch x 8000 counts per rev (2000 line) = 80,000 counts per inch.
- 5 turns per inch ballscrew belted at 1:1 with the servo motor = 5 turns of the servo motor per inch of axis travel
- 5 turns per inch x 8000 counts per rev = 40,000 counts per inch of axis travel.

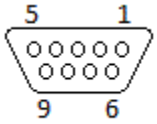
Encoder wiring

- MUST be shielded, twisted pair cabling.
- **Encoder wiring at MPU11:**
  DB9 Body = Cable Shield

  Pin Function
  1 No Connection
  2 GND
  3 Z\
  4 A\
  5 B\
  6 Z
  7 A
  8 B
  9 +5 VDC



Pin Side



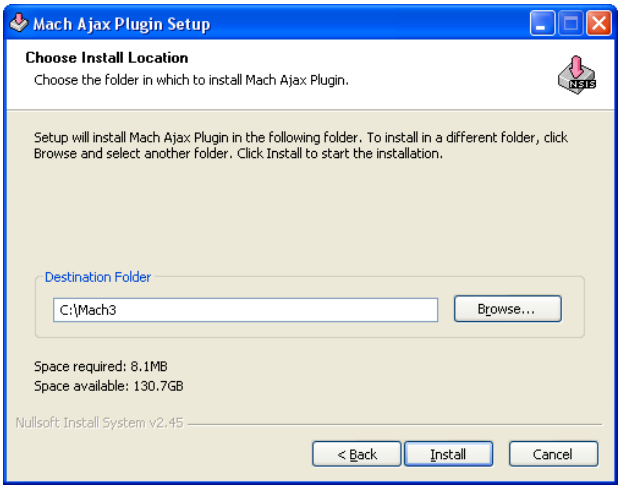
Solder Side

Encoder Errors:

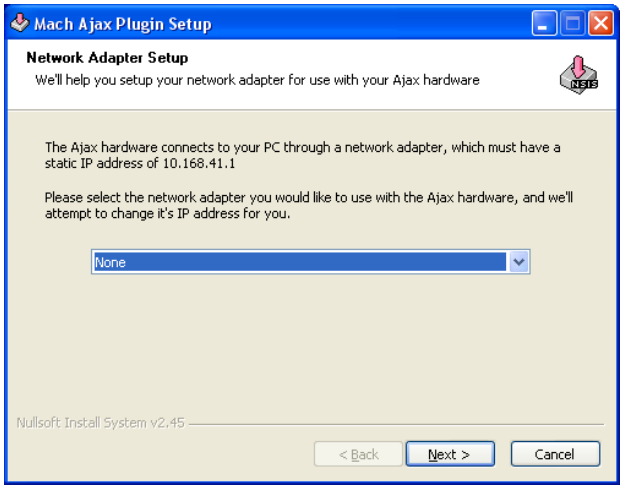
- The MPU11 has built in encoder error checking. It will try to cause a fault if your encoder connections become loose, disconnected, or subject to noise.
- If your encoders do not meet the above specifications, you may encounter encoder error faults.
- For this reason, the plugin configuration utility allows you to disable the encoder error checking. **WARNING: This will prevent the MPU11 from detecting any encoder errors. It will no longer fault if the encoder is disconnected. If the encoder becomes disconnected, it may cause a motor run-away situation which will only fault after an axis position error or a full power without motion fault.**

3 Software Installation

Before beginning this step, you should have already installed the Mach3 software from Newfangled Solutions, LLC.



Insert the CD that came with your kit into your computer's CD Rom drive, and your computer should automatically start the setup program for you. Follow the onscreen prompts, and make sure you install the Ajax software into the same directory as your Mach3 software (typically C:\Mach3).



After the software has been installed, the Setup program will help you configure your computer so it can communicate with the Ajax MPU11. In order to do so, you should select the network adapter you wish to use with the Ajax MPU11 from the list provided. The IP address of the selected adapter will be changed to 10.168.41.1, which is the only address that the Ajax MPU11 recognizes.

NOTE: Two network adapters must be installed in your computer if you intend to use your computer to connect to the internet and to the Ajax MPU11 at the same time. That is to say, the Ajax MPU11 requires a dedicated network adapter.

4 Mach3 Setup

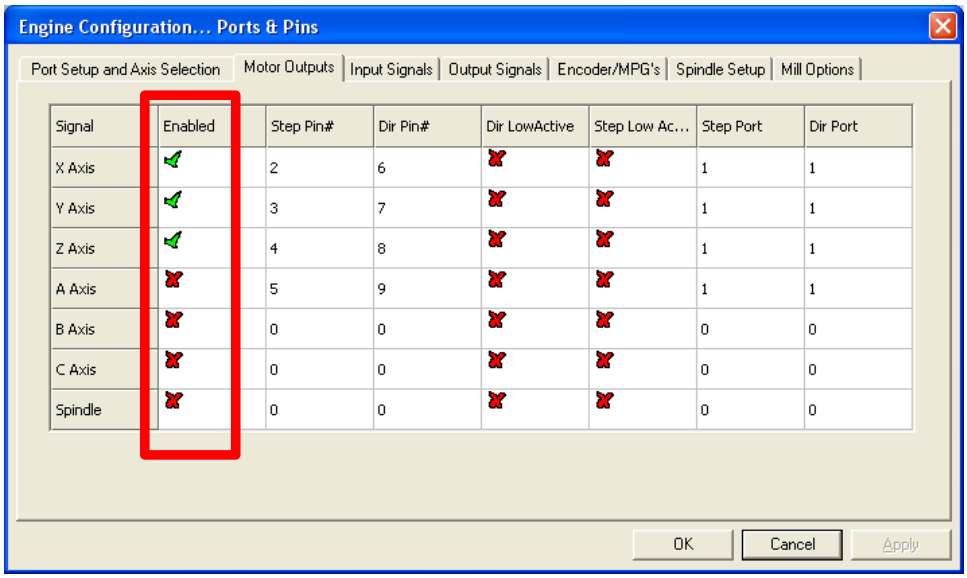
The setup program should create a shortcut on your desktop labeled “Mach Ajax Plugin”. Clicking on this shortcut will start Mach3 using our default settings, which will help you get running faster. The steps below should also help – but please see the full Mach3 Operator's manual for detailed instructions.

The values shown in the following screen shots are the default values that the setup program establishes when it is run. You will likely need to deviate from these values, depending on the actual machine you are setting up.

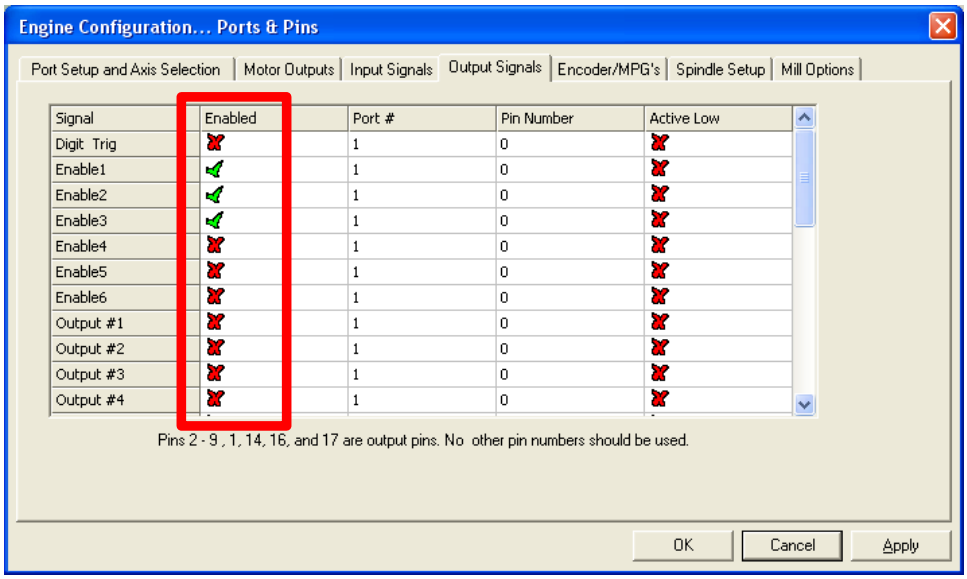
4.1 Axis Setup

By default, three motor axes (X, Y, and Z) are setup.

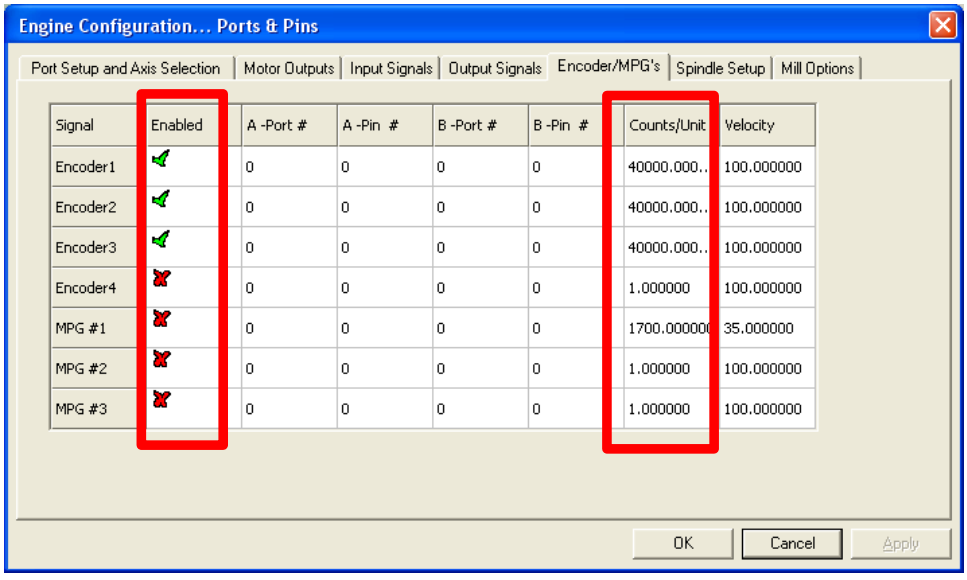
In order to change the configuration, go to Config → Ports and Pins in Mach3's menu bar. From here, click the Motor Outputs tab. Each motor that you intend to use must have a green check mark in the Enabled column (otherwise it will not be recognized). All other settings on this tab are ignored by the Mach Ajax Plugin.



In addition, each axis motor must also have a green check mark in the Enabled column on the Output Signals tab (Enable1 is for the X axis, Enable2 is for the Y axis, and so on). This will cause an output signal to be sent (via Brains) which will in turn cause power to flow to the motor. All other settings on this tab are ignored by the Mach Ajax plugin.

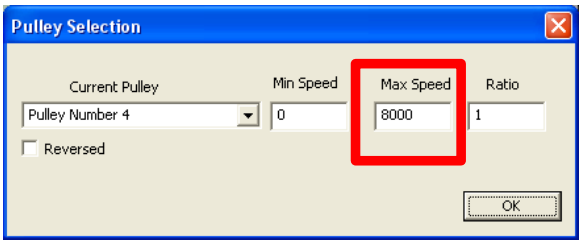


Also, because the Mach Ajax Plugin is a closed loop system, each axis motor should have an encoder setup on the Encoder/MPG's tab. Again, a green check mark is needed in the Enabled column, but Counts/Unit must also be set for each axis.



4.2 Spindle Setup

To setup the maximum spindle speed for your mill, select Config → Spindle Setup from Mach3's menu bar. This max speed value is the value at which full power is delivered to the spindle motor. So, if the maximum is set to 8000, and the commanded spindle speed is 4000 (“M3 S4000”), half power will be delivered to the spindle motor.

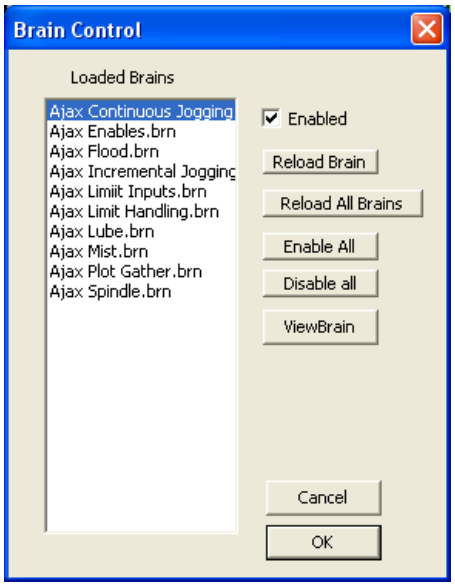


4.3 Axis Reversal

If you find that the axes of your machine move in the opposite direction of what they should, go to the Config → Homing/Limits menu and set a green check mark in the Reversed column for any axis you wish to reverse.

4.4 General Brain Setup

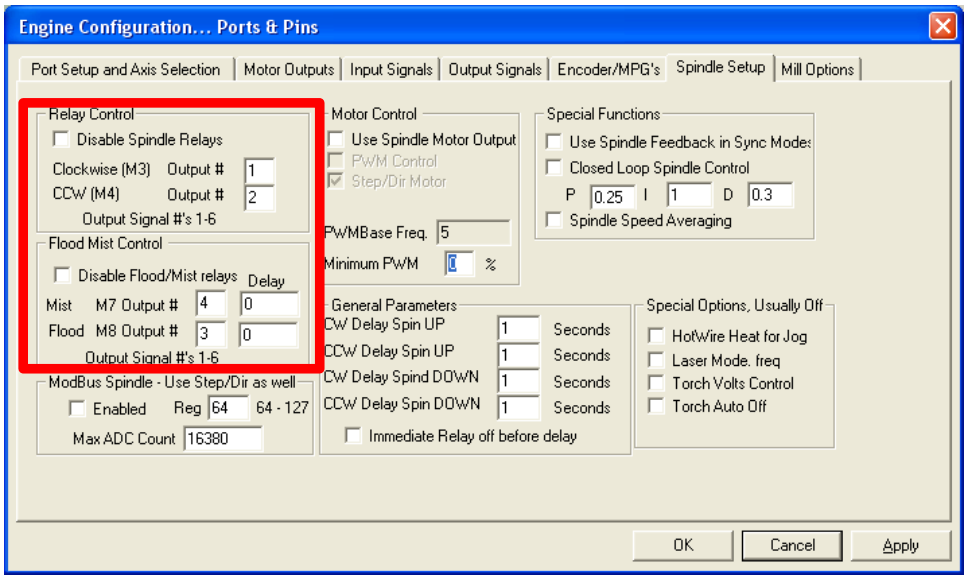
Mach3 has a built in programmable control system (Brains) that allows certain outputs to be set when certain conditions are met. Your kit comes with several default brains, which can be enabled or disabled from Mach3's Operator → Brain Control menu.



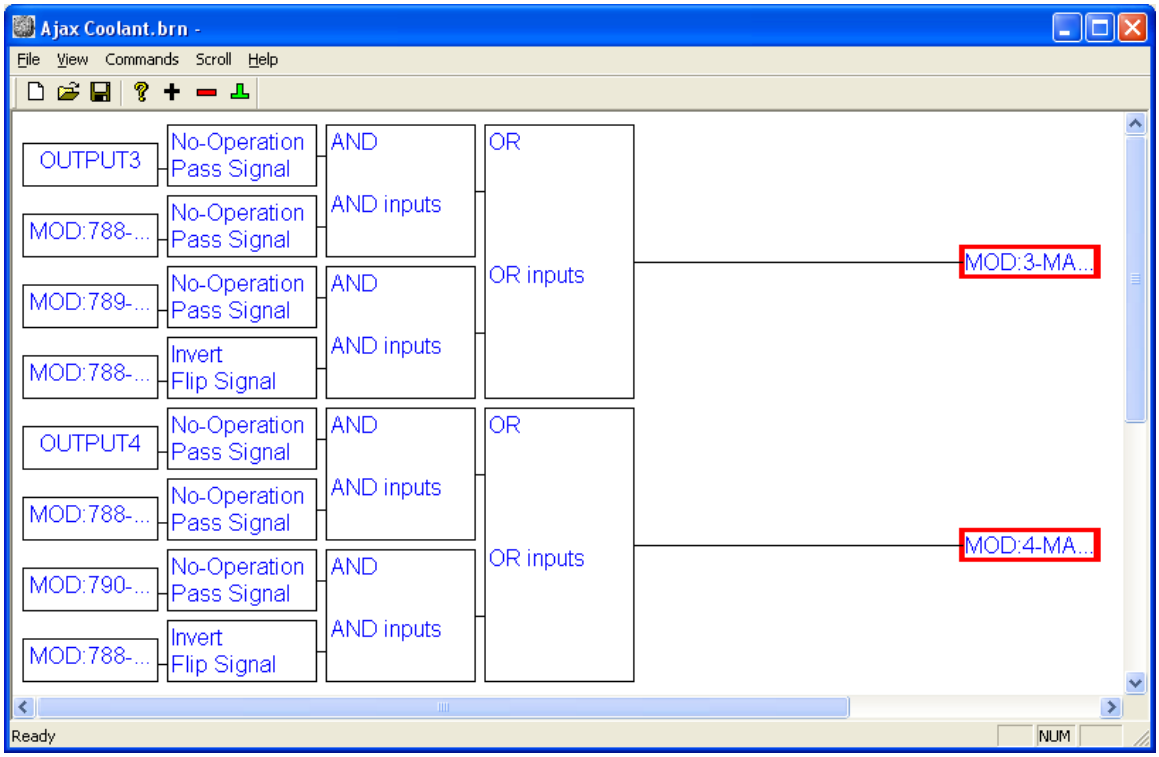
Of particular interest are the use of OEM Triggers 1 through 6 to control the Jogging brains and the use of Input 1 through 3 to control the Plot Gather brain. Also note that ModBus registers are used in brains to indicate Ajax MPU11 inputs and outputs (in order to provide a full range of inputs and outputs). The ModBus protocol isn't actually used.

If you are controlling more or less than the default of 3 axes, you will also want to review the Ajax Enable brains that you are using. You may also have to add brains of your own to control jogging on the additional axes.

Also, the Ajax Spindle brain assumes that Output 1 and Output 2 will be used to control the spindle direction and enable state. These are located on the Spindle Setup tab of the Config → Ports and Pins menu within Mach3. Likewise, the Flood and Mist brains assume the use of Output 4 and 3. These values are already set, and you shouldn't change these values unless you make corresponding changes to the spindle control brain.

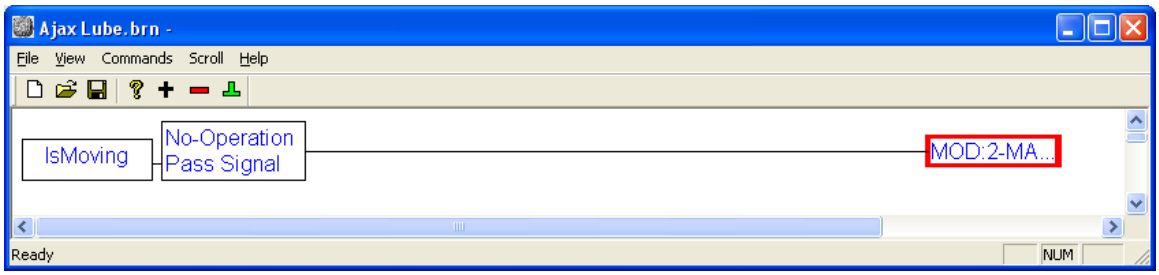


4.5 Ajax Coolant Brain



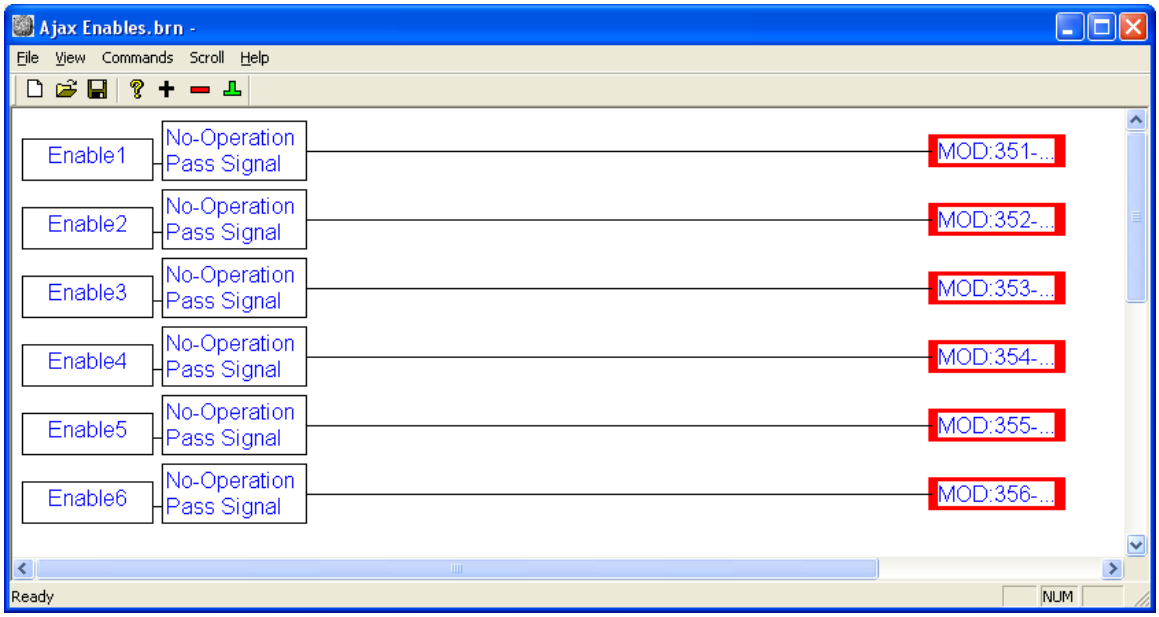
Mach3 will normally turn on Outputs 3 and 4 to indicate that Mist and Flood coolant relays should be active – this brain passes those signals along to the MPU11 (using ModBus outputs 3 and 4). However, the control pendant (which is optional add-on hardware) allows the user to manually control coolant. The state of ModBus output 788 indicates whether automatic or manual coolant mode is selected (1 for automatic, 0 for manual) – and if manual coolant mode is selected, the coolant values from the pendant are passed along instead (789 and 790).

4.6 Ajax Lube Brain



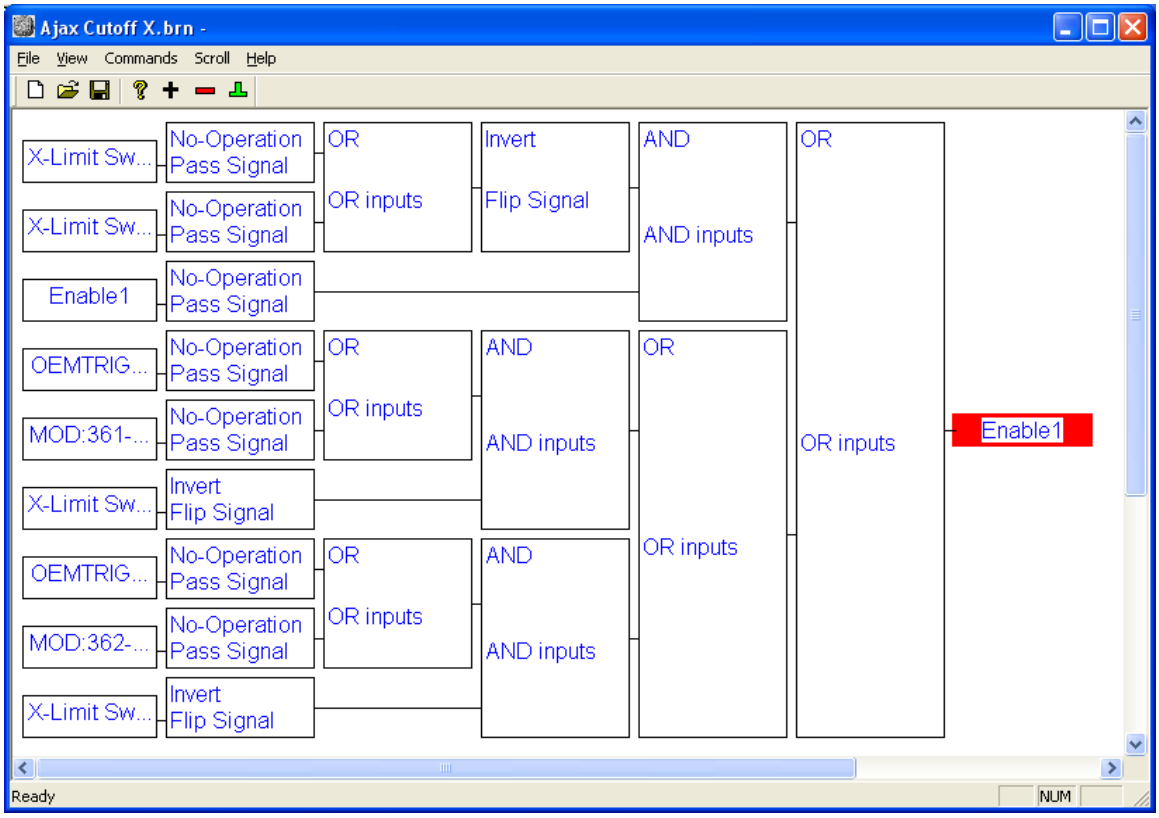
The Ajax Lube Brain turns on ModBus Output 2 whenever the machine is moving, which then gets passed along to the Ajax MPU11. This should cause your Lube relay to trip on your control board.

4.7 Ajax Enables Brain



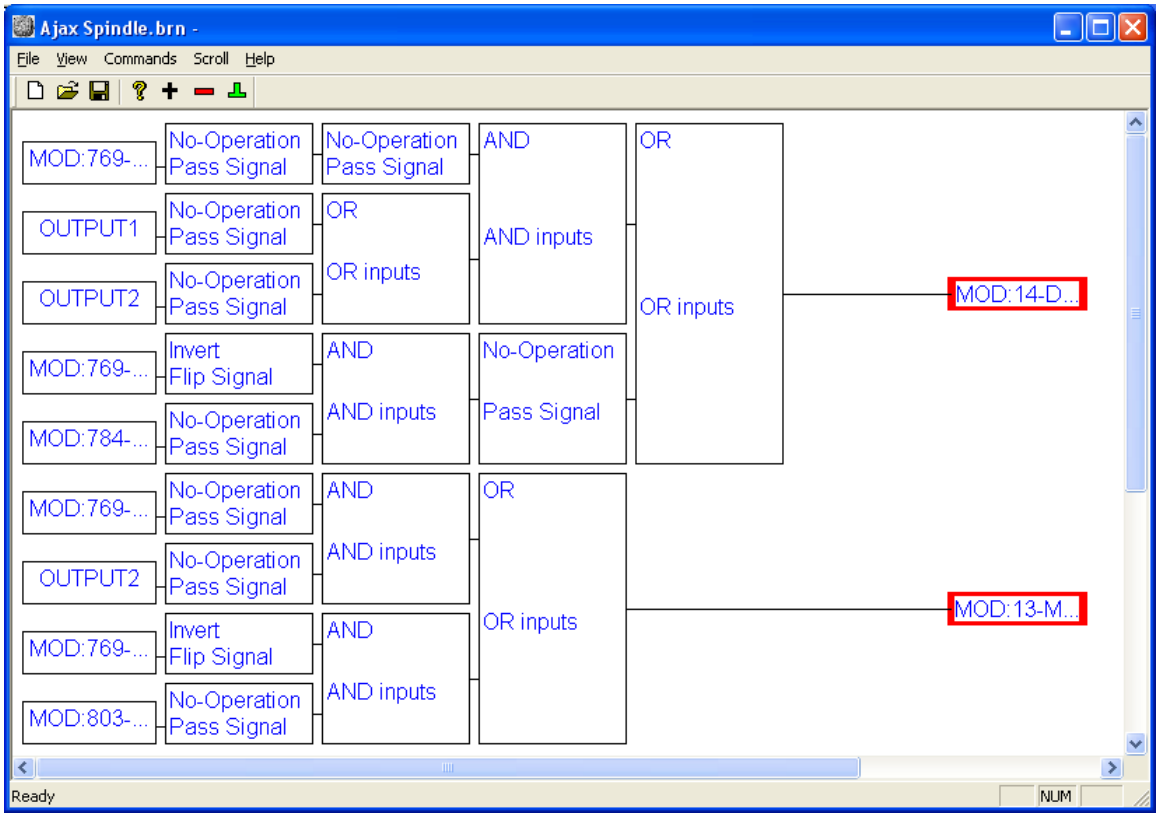
In order for each of your motors to get power, the corresponding ModBus Output (351 to 356) needs to be set. Mach3 makes the determination of which motors are Enabled, and this brain simply passes that information along to the Ajax MPU11.

4.8 Ajax Cutoff Brains (X, Y and Z)



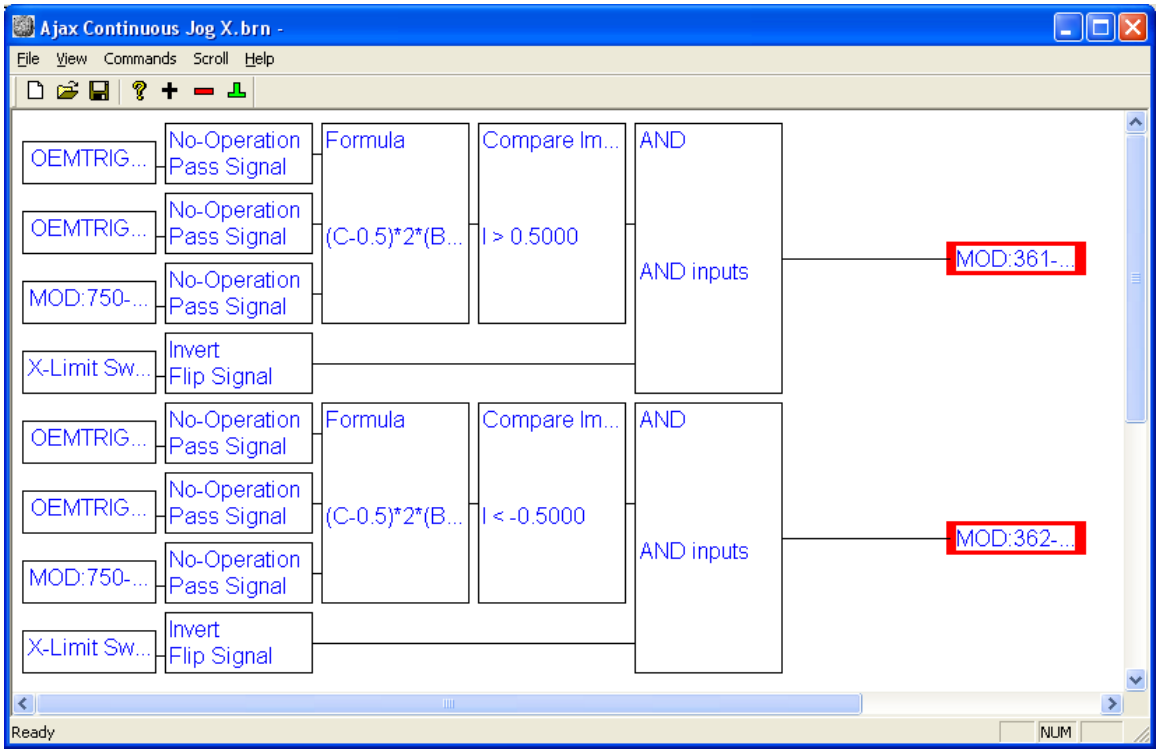
These three brains cause the motor enables to turn off in Mach3, whenever a limit switch is tripped. This is a safety feature to help prevent your machine from crashing into its hard stops should it overrun its limits. These brains also re-enable power to the motor whenever jogging is attempted and the corresponding limit switch is not tripped (which allows you to jog your machine off of the limit switch should you hit it).

4.9 Ajax Spindle Brain



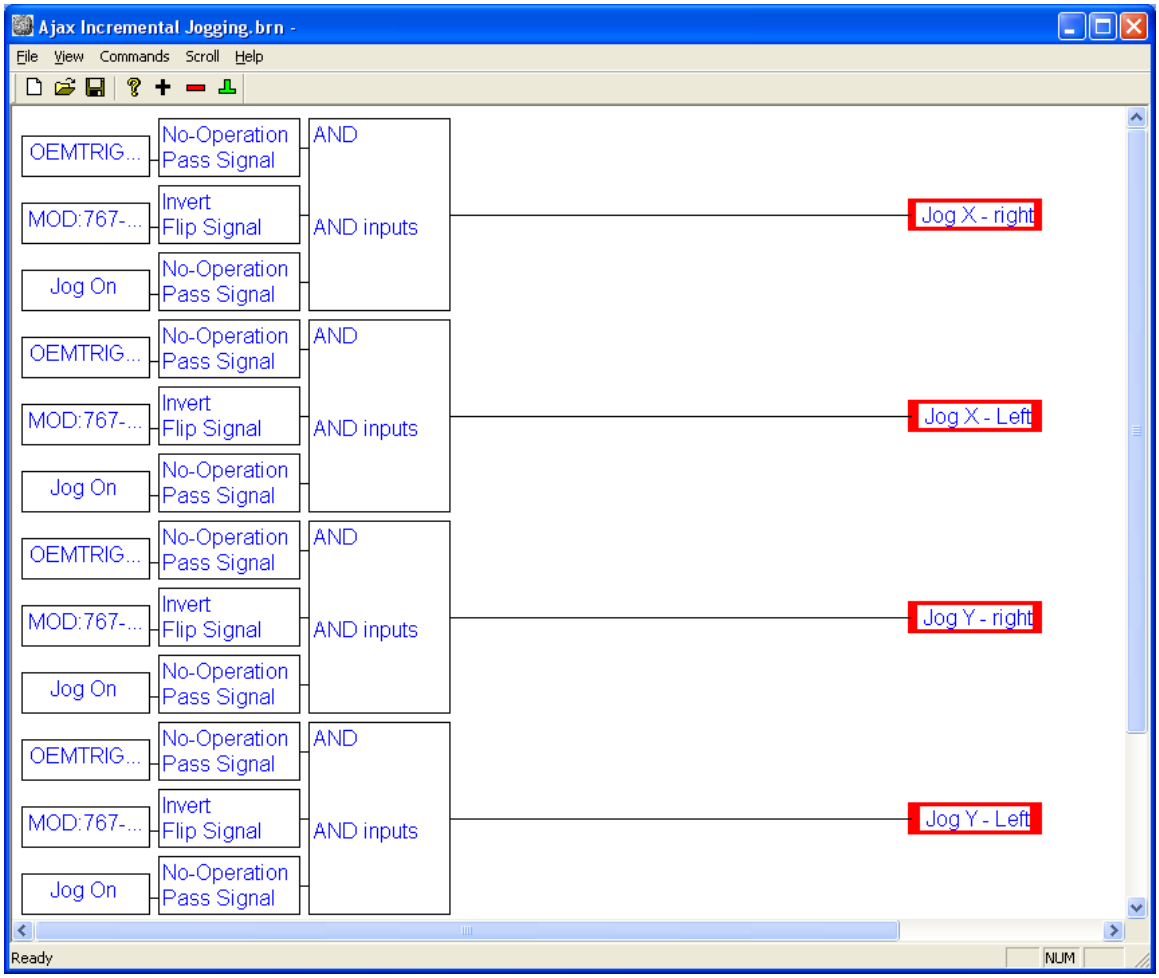
The Ajax Spindle Brain determines whether or not the Spindle Enable output (ModBus 14) and the Spindle Direction output (ModBus 13) should be set – which in turn cause two relays on your control board to respond. The state of ModBus output 769 is used to indicate whether the optional control pendant is in automatic spindle control mode (a value of 1) or manual spindle mode (a value of 0). In automatic mode, Mach's Outputs 1 and 2 are used to determine the values for the Spindle Enable and Spindle Direction outputs. In manual mode, ModBus output 784 is used to determine whether the spindle is enabled, and ModBus output 803 is used to indicate its direction (0 for clockwise, 1 for counterclockwise).

4.10 Ajax Continuous Jog Brains (X, Y and Z)



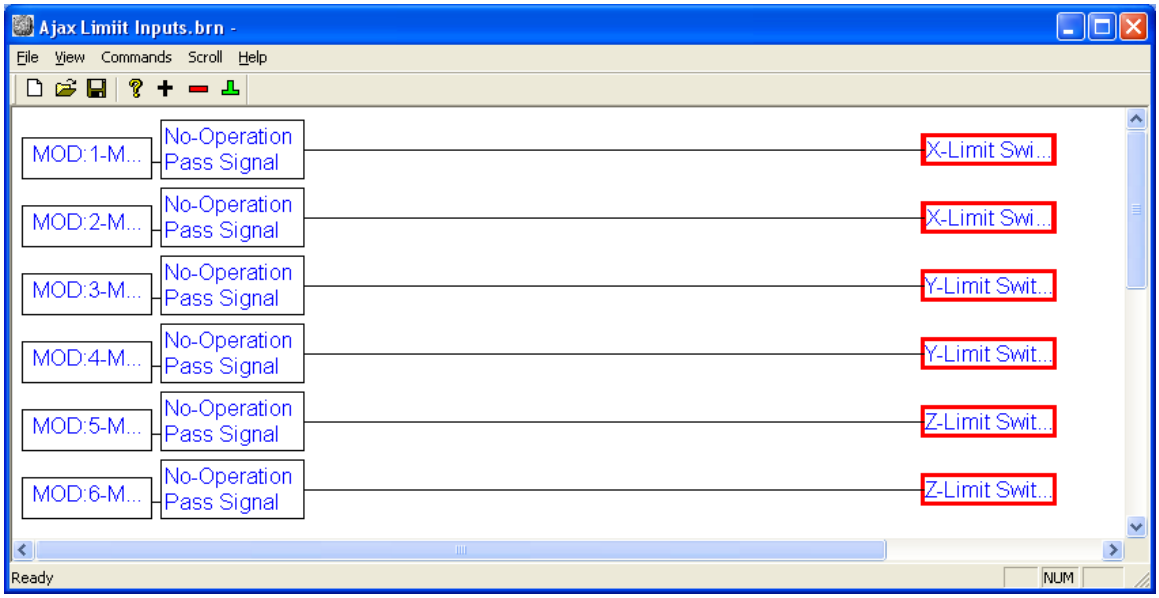
These three brains control continuous jogging, by sending signals to the Ajax MPU11. The signals are arranged in pairs, and tell the Ajax MPU11 to turn each motor one direction or the other. ModBus Outputs 361 and 362 control the X axis, for example. So basically, the OEM Trigger values are used to determine if each axis should be jogged in the positive or negative direction, or not at all (1, -1 or 0). ModBus Input 750, 751, and 752 are also used to determine if each axis is reversed – and if so, the sign of the formula is reversed. The limit switch values are also used to prevent continuous jogging toward a tripped limit switch.

4.11 Ajax Incremental Jogging Brain



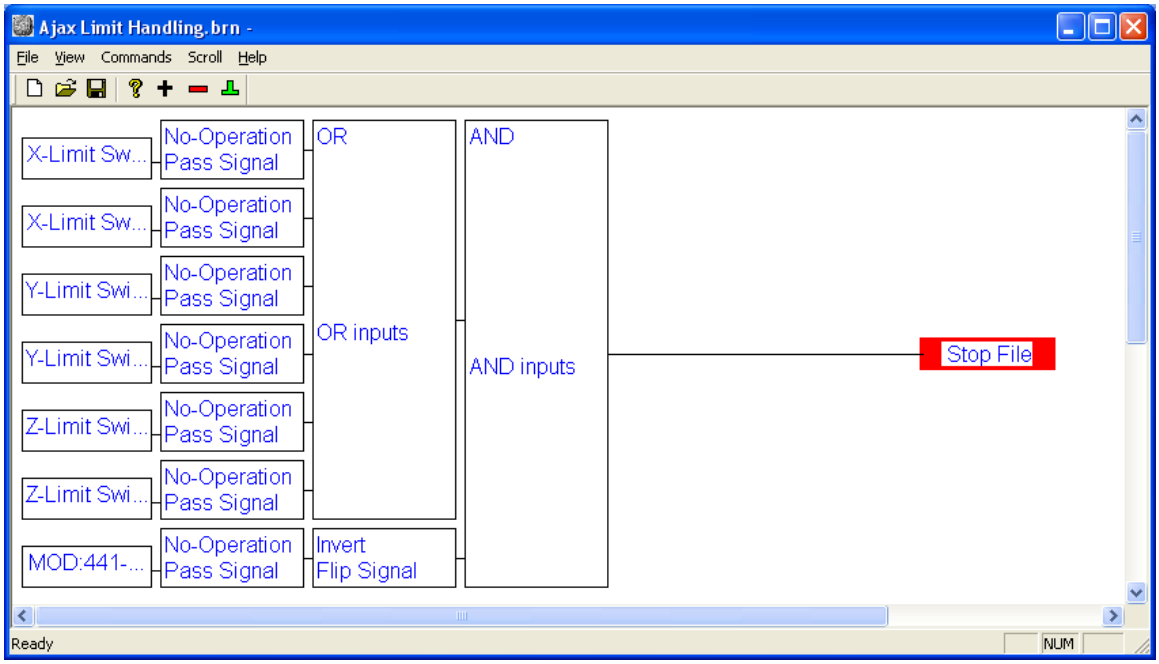
This brain passes the OEM Trigger presses that control jogging to Jog Button presses in Mach3, but only if Jogging is allowed. It also prevents movement if the MDI line has cursor focus, by checking the value of ModBus Input 767.

4.12 Ajax Limit Inputs Brain



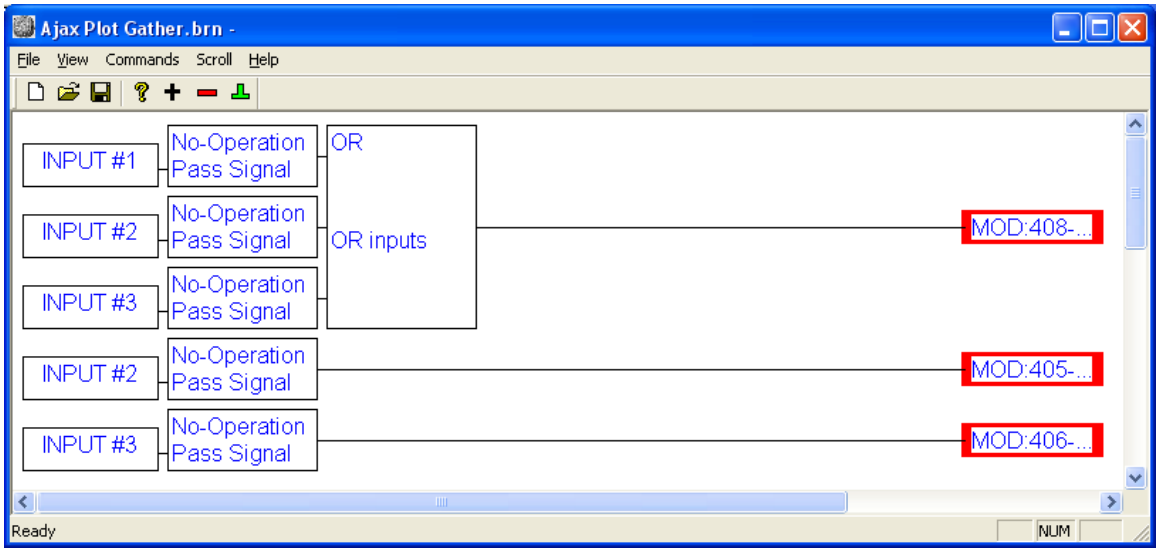
This brain simply passes the limit switch inputs supplied by the Ajax MPU11 into Mach3's limit switch inputs.

4.13 Ajax Limit Handling Brain



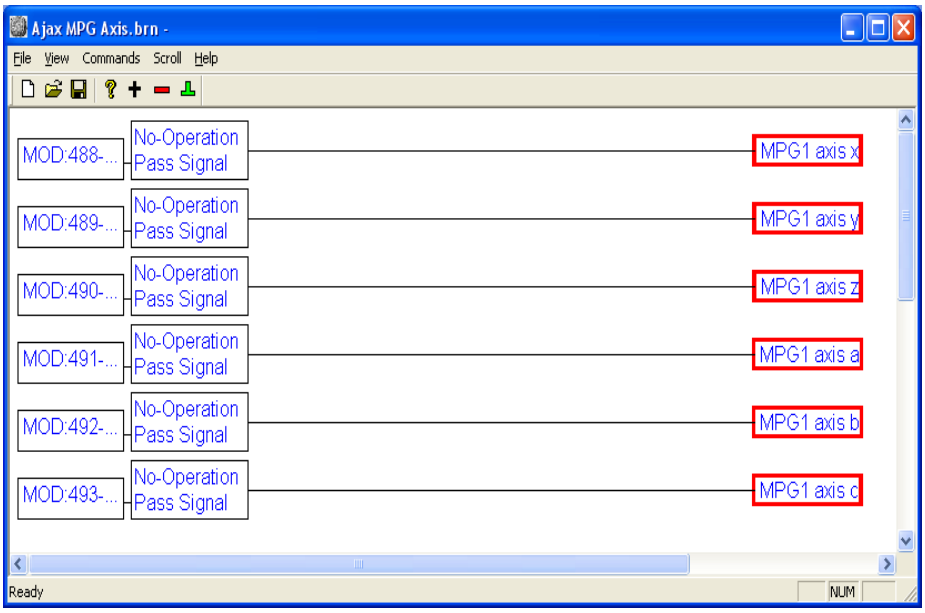
This brain determines what to do when a limit switch is tripped, and by default it will act as if the Stop button was pressed. The only exception is if ModBus Output 441 (the ignore errors flag) is set, in which case no action is taken when the limit switch is tripped (used in the M92 homing macro).

4.14 Ajax Plot Gather Brain



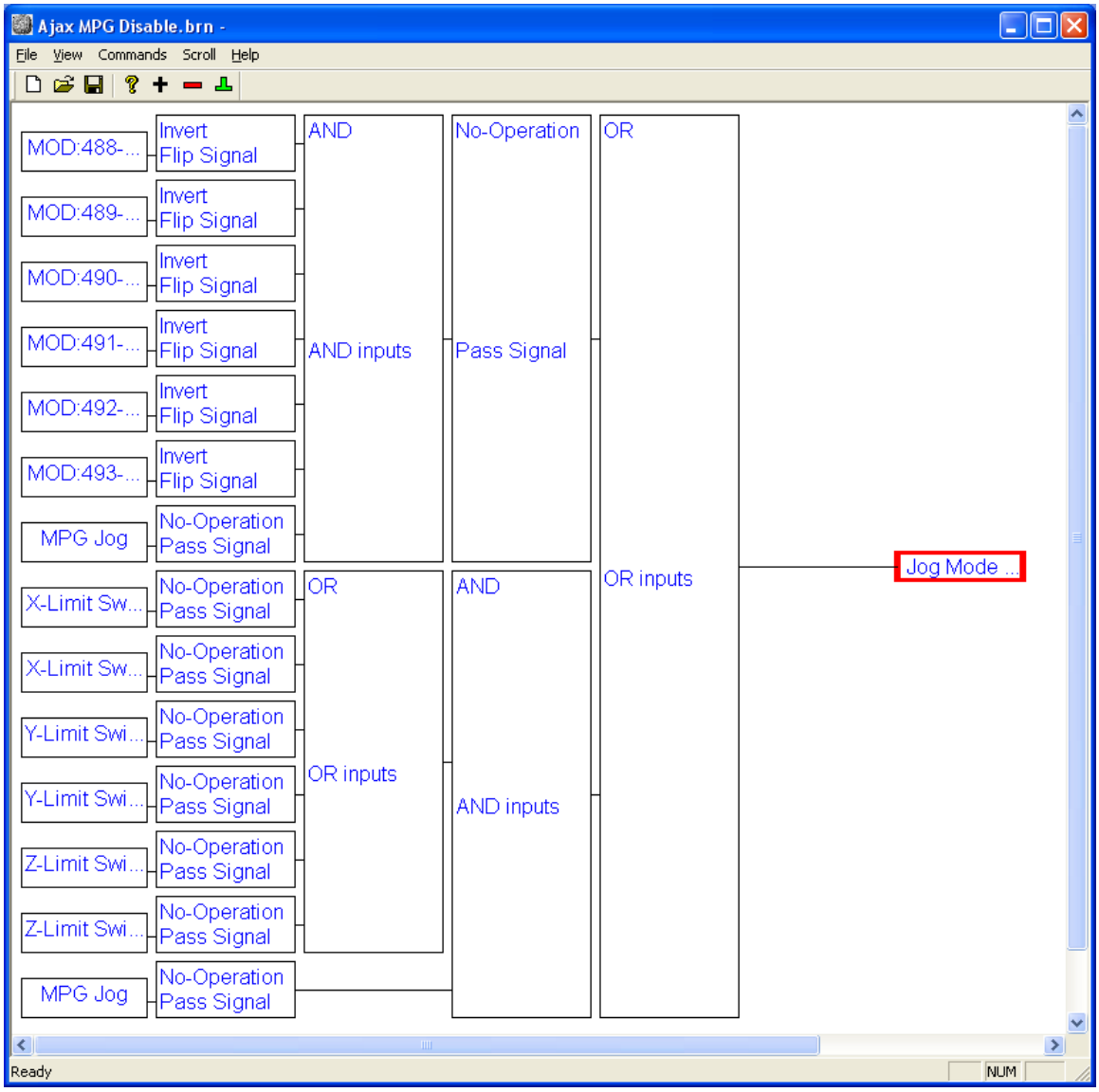
This brain checks Inputs 1, 2, and 3 (normally F1, F2, and F3) – and sends a corresponding plot request to the Ajax MPU11. The Diagnostics and Tuning section below provides more information on how to use this brain.

4.15 Ajax MPG Axis Brain



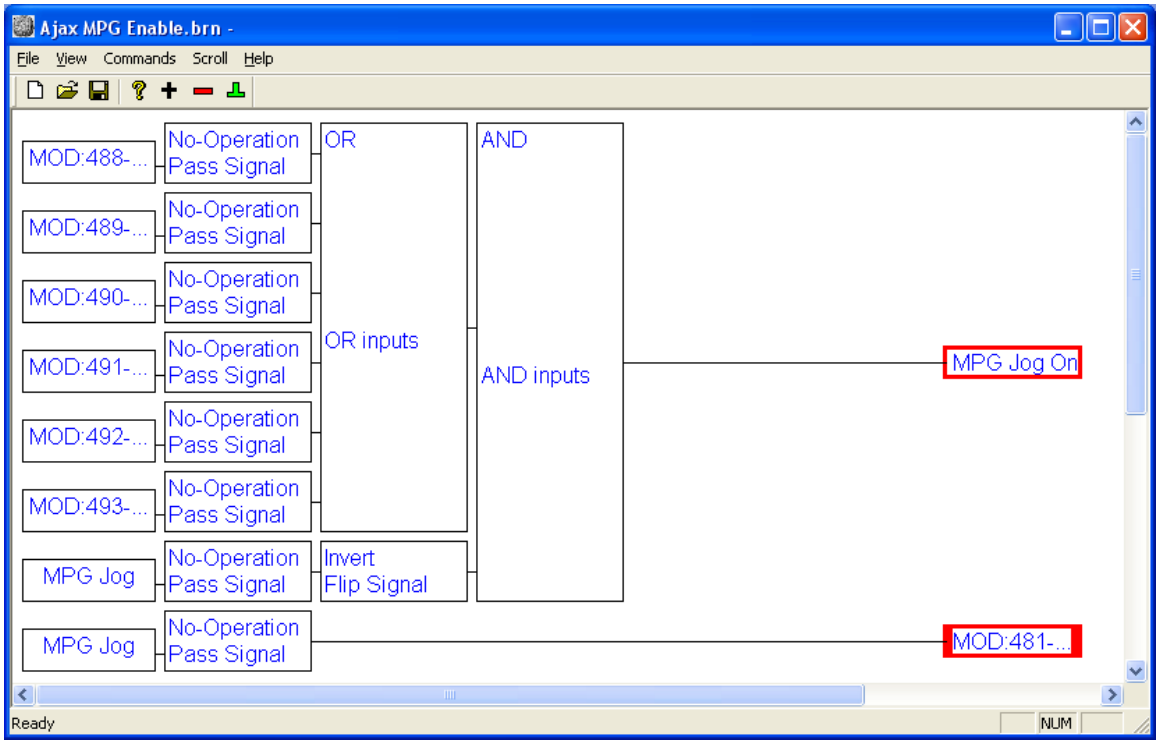
The 100 step MPG offered by Ajax CNC has an Axis selection knob, and this brain uses the state of that knob to tell Mach3 which axis is selected.

4.16 Ajax MPG Disable Brain



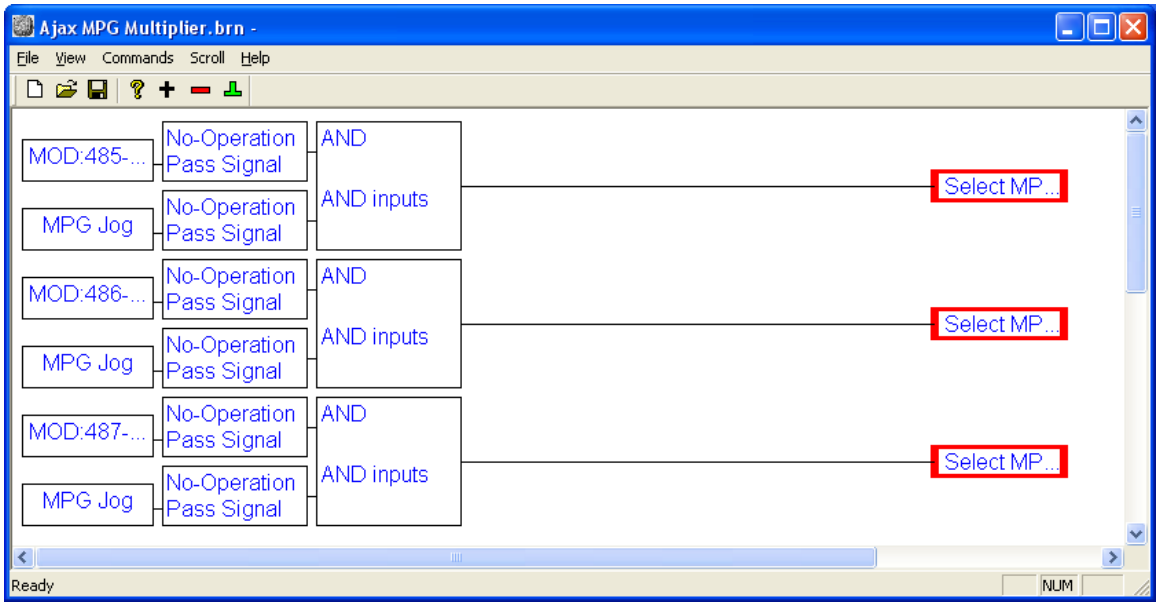
The axis selection knob on the Ajax MPG also has an “Off” setting. This brain tells Mach3 to disable the MPG (and return to continuous jog mode) if “Off” is selected. It also disables MPG mode if any of the limit switches are tripped. NOTE: If you are using a non-Ajax MPG (for example an encoder plugged into the Encoder 6 port on the Ajax MPU11), this brain will continually disable your MPG unless the brain itself is disabled.

4.17 Ajax MPG Enable Brain



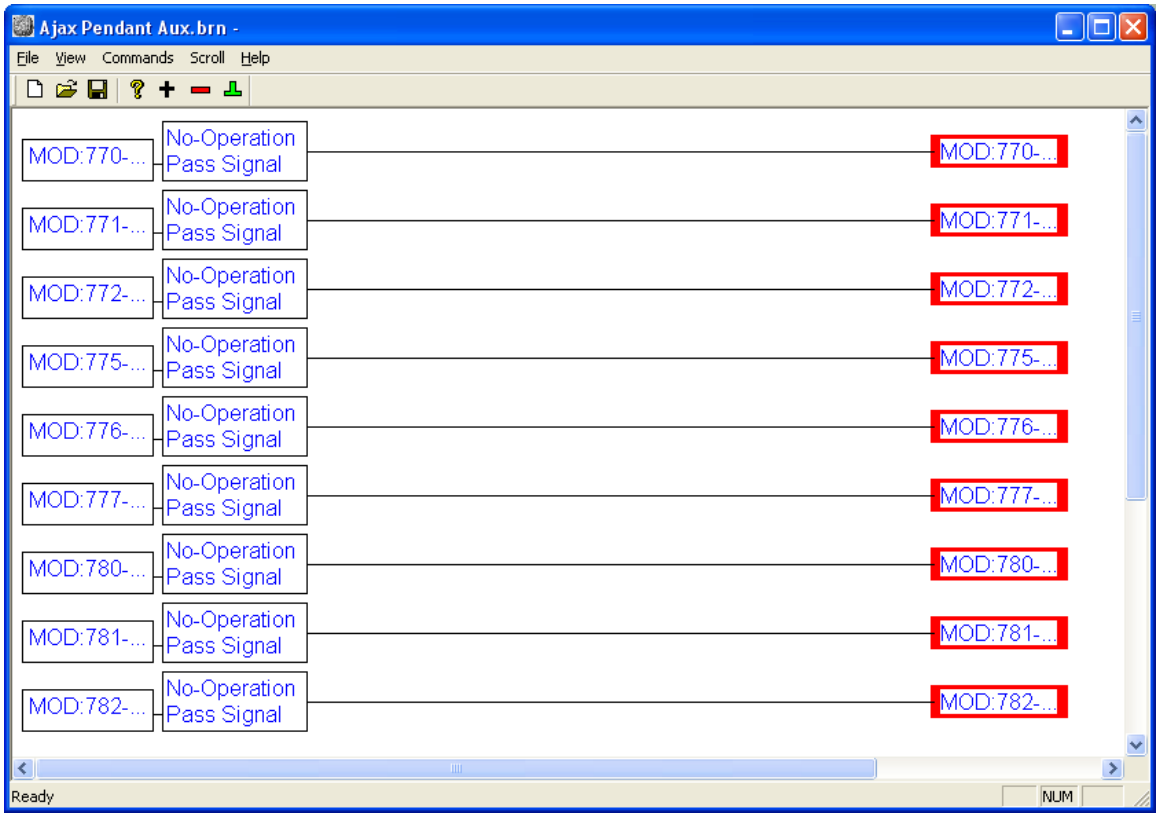
This brain causes the axis selection knob of the Ajax MPG to automatically turn MPG mode on, whenever the knob is not turned to the “Off” position. It also causes the LED on the MPG to light up (ModBus output 481) if Mach3 is in MPG mode.

4.18 Ajax MPG Multiplier Brain



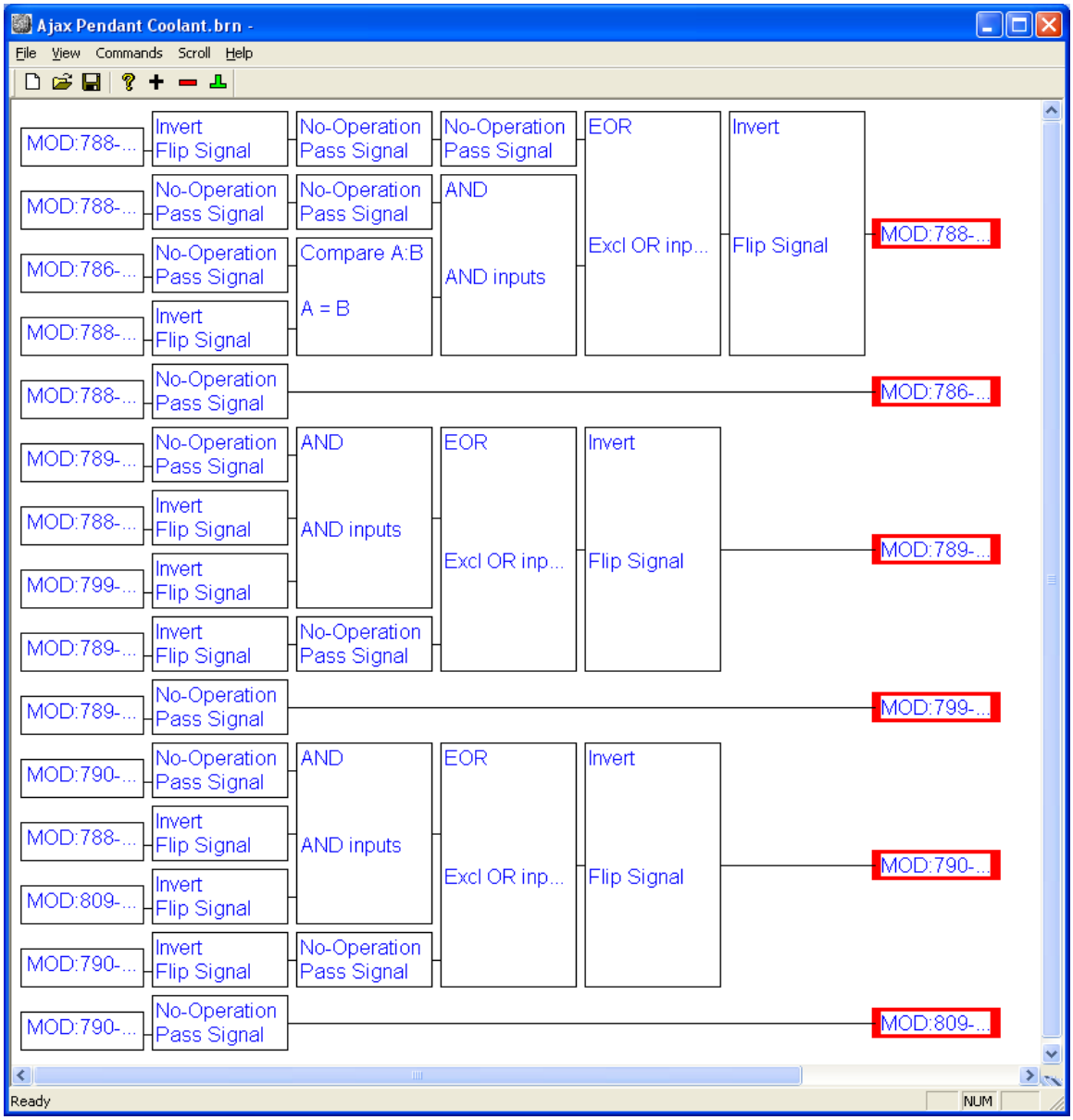
This brain causes the multiplier knob (x1, x10, x100) on the Ajax MPG to select the jog increment to use. These are setup by default to 0.001, 0.01, and 0.1 respectively. These values can be configured in Mach3's Config → General Config menu.

4.19 Ajax Pendant Aux Brain



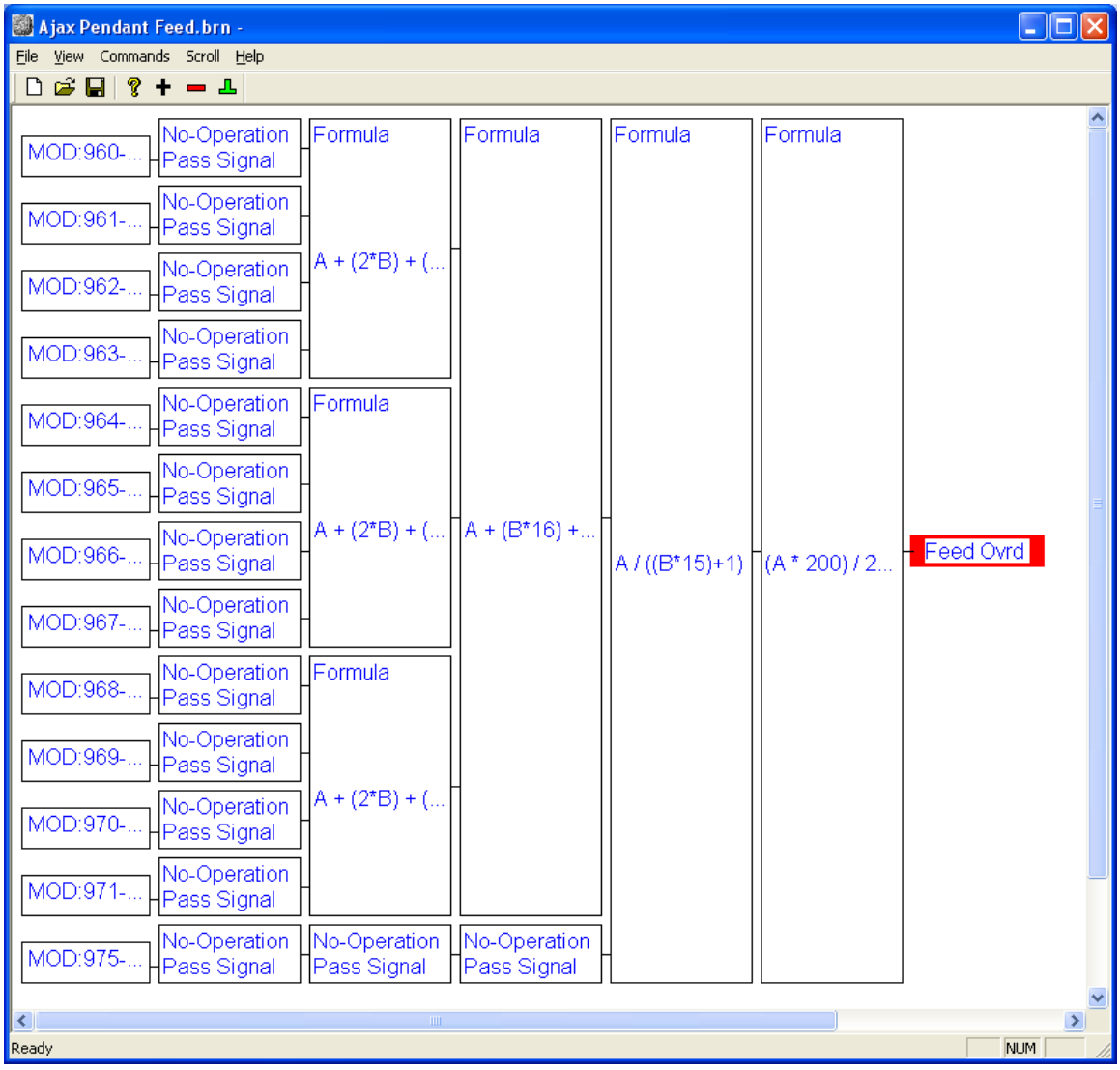
Ajax CNC offers an operator's control pendant, and this brain simply shows how to use the Aux inputs to light up the LEDs of the associated keys.

4.20 Ajax Pendant Coolant Brain



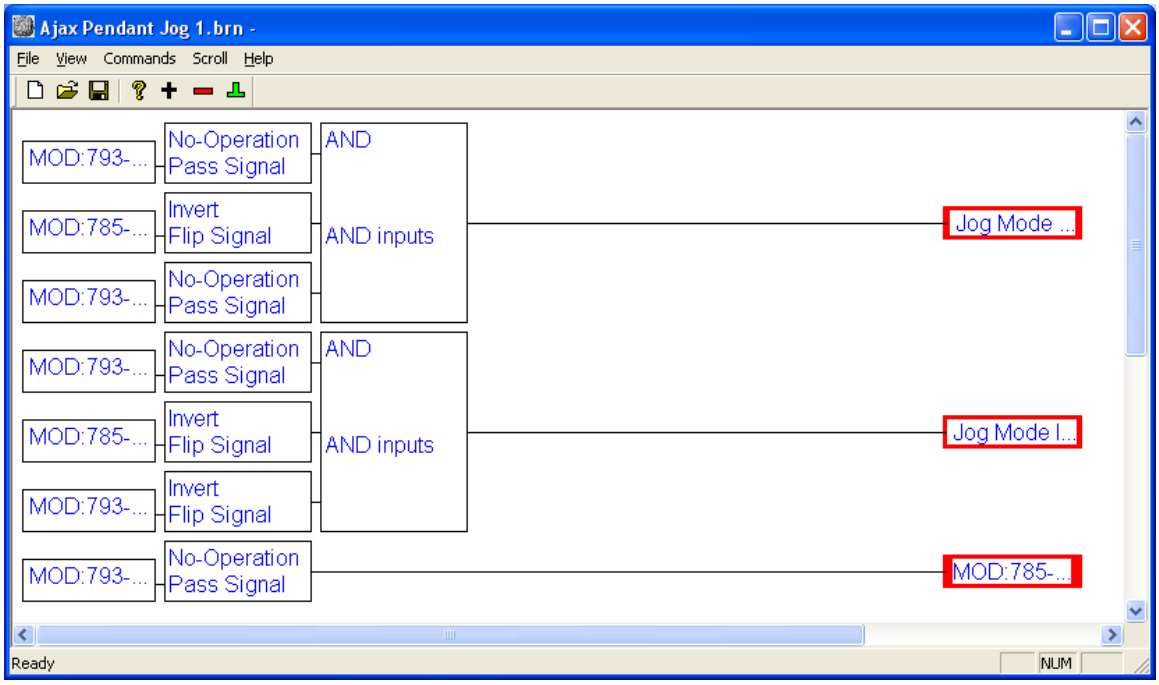
This brain allows the user of a control pendant to manually control the Flood and Mist relays.

4.21 Ajax Pendant Feed Brain



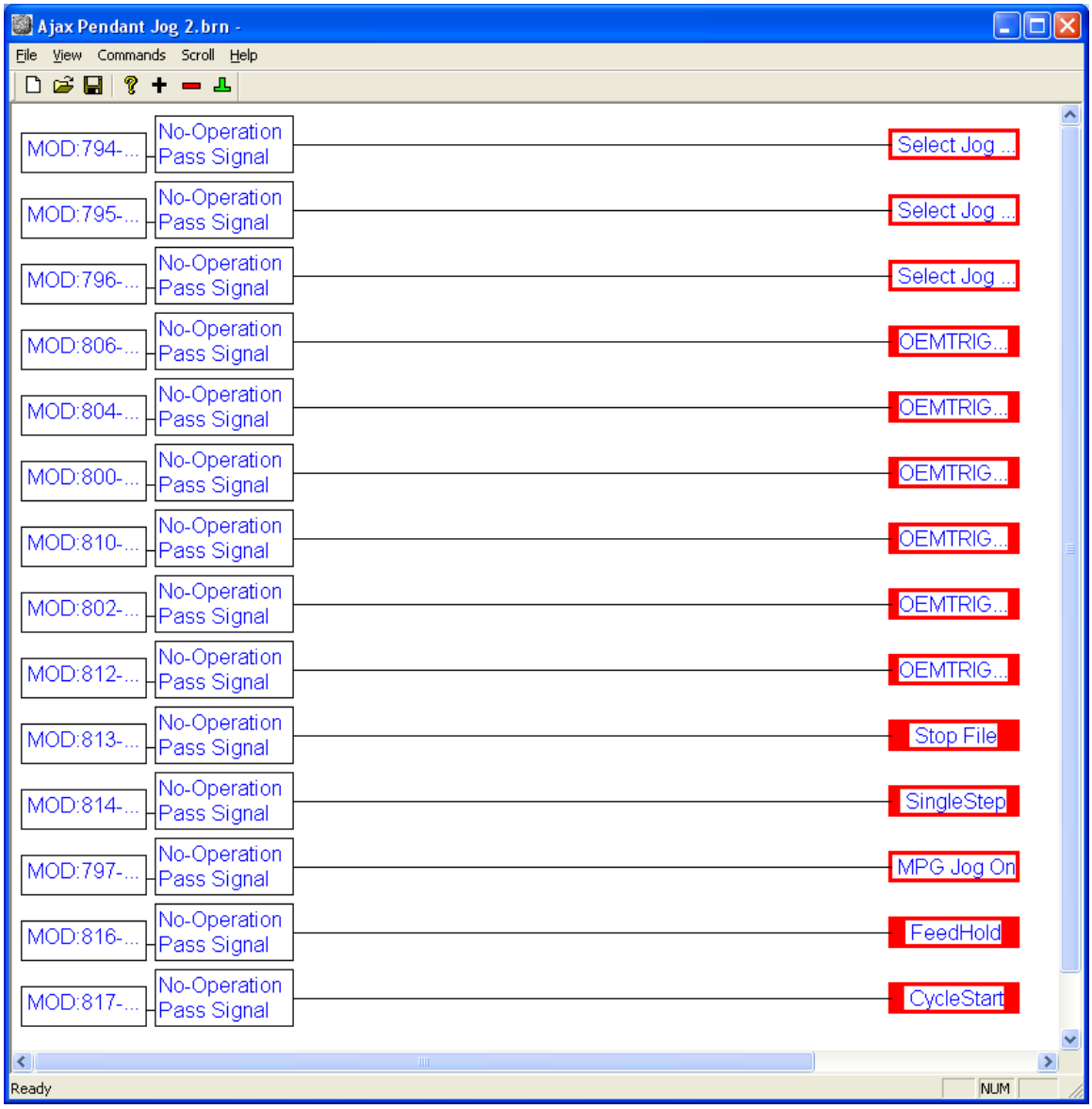
This brain converts the (8 or 12) output bits generated by the Feedrate Override knob on the Ajax control pendant into a number that Mach3 can use for its feedrate.

4.22 Ajax Pendant Jog 1 Brain



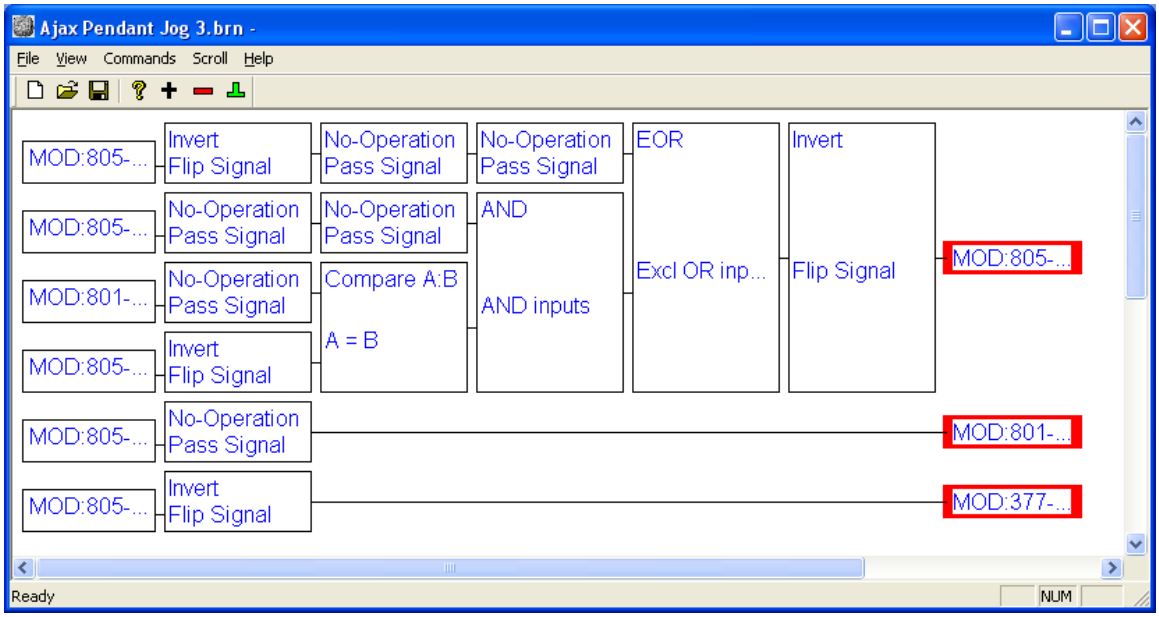
This brain makes the Incremental / Continuous jog mode selection button on the Ajax control pendant function.

4.23 Ajax Pendant Jog 2 Brain



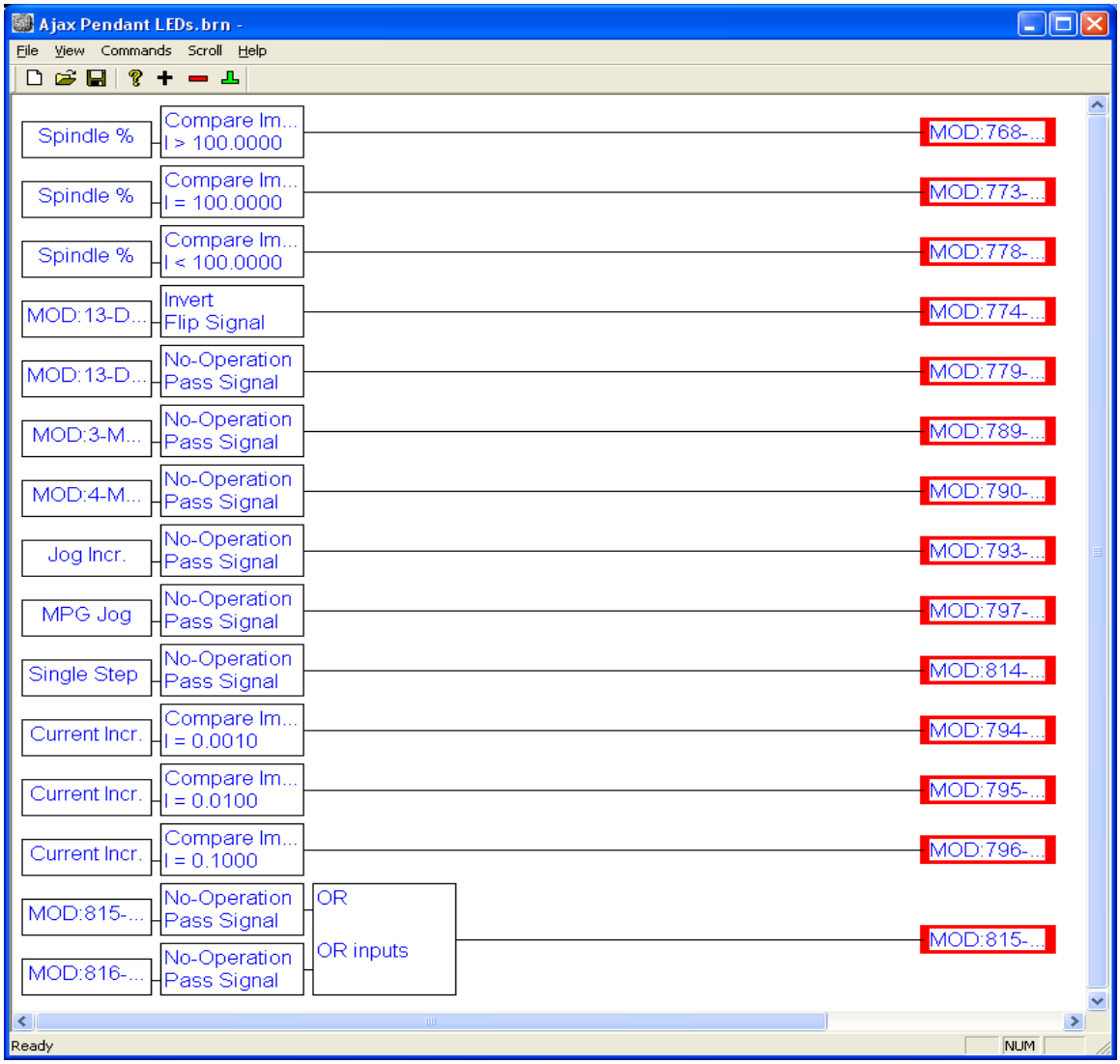
This brain makes most of the other jog-related keys on the Ajax control pendant function, simply passing the input values through to Mach3 as the corresponding button presses. NOTE: This brain overrides the OEM Trigger values. If you are using a control pendant, you should change your settings in the Config → Ports and Pins → Input Signals menu such that the OEM Trigger values are not emulated by the keyboard.

4.24 Ajax Pendant Jog 3 Brain



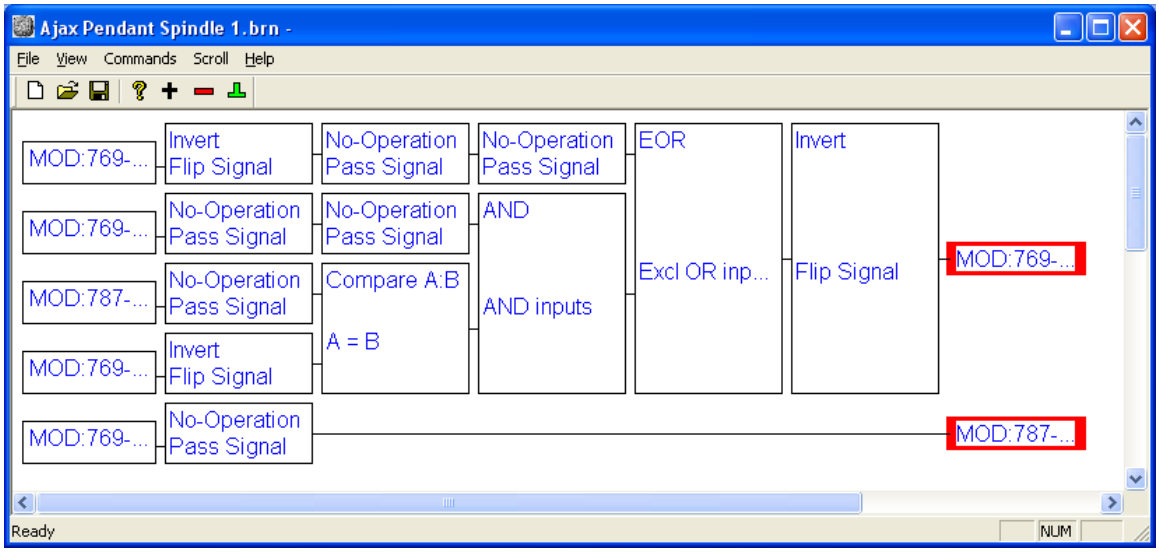
This brain controls the Fast/Slow button on the Ajax control pendant (the turtle / rabbit button). It also sends the state of that button to ModBus output 377, so the Ajax MPU11 knows whether it should perform a fast or slow jog.

4.25 Ajax Pendant LEDs Brain



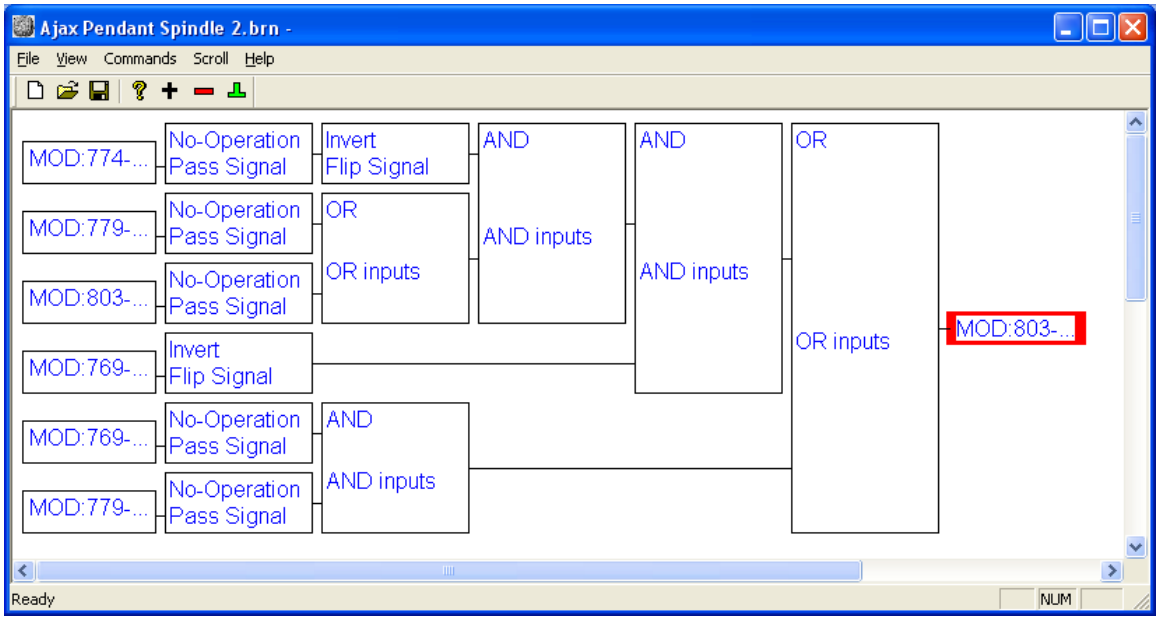
This brain determines which of the Ajax control pendant LEDs should be lit, and which should be dark. Some LEDs are controlled by other brains, but this is where most of the simple ones are located.

4.26 Ajax Pendant Spindle 1 Brain



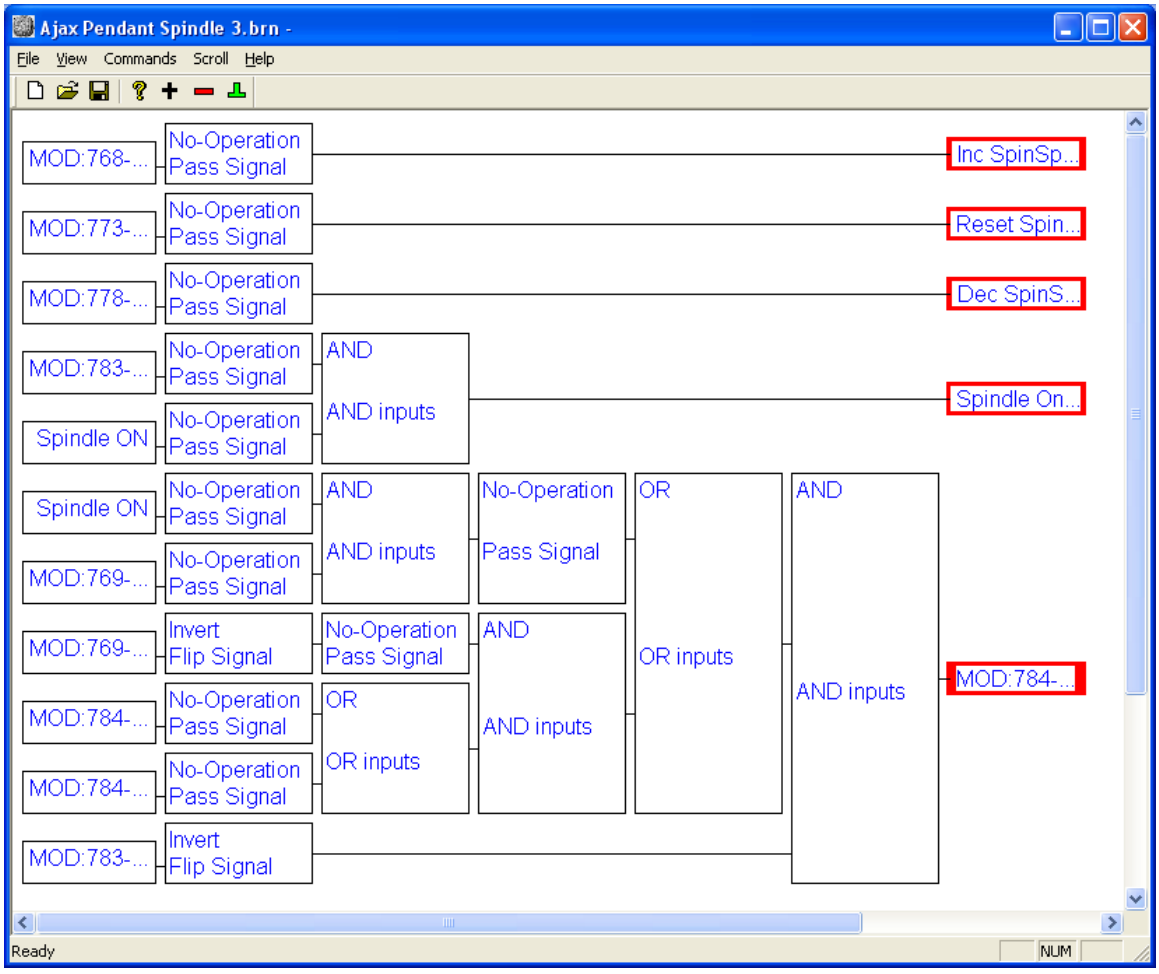
This brain controls the state of the Automatic/Manual spindle setting on the Ajax control pendant.

4.27 Ajax Pendant Spindle 2 Brain



This brain causes the Clockwise/Counter-Clockwise spindle setting on the Ajax control pendant to function. The setting itself is stored in ModBus output 803 – with a 0 indicating clockwise and a 1 indicating counter clockwise.

4.28 Ajax Pendant Spindle 3 Brain



This brain allows the Spindle +, 100%, -, Stop and Start keys on the Ajax control pendant to function.

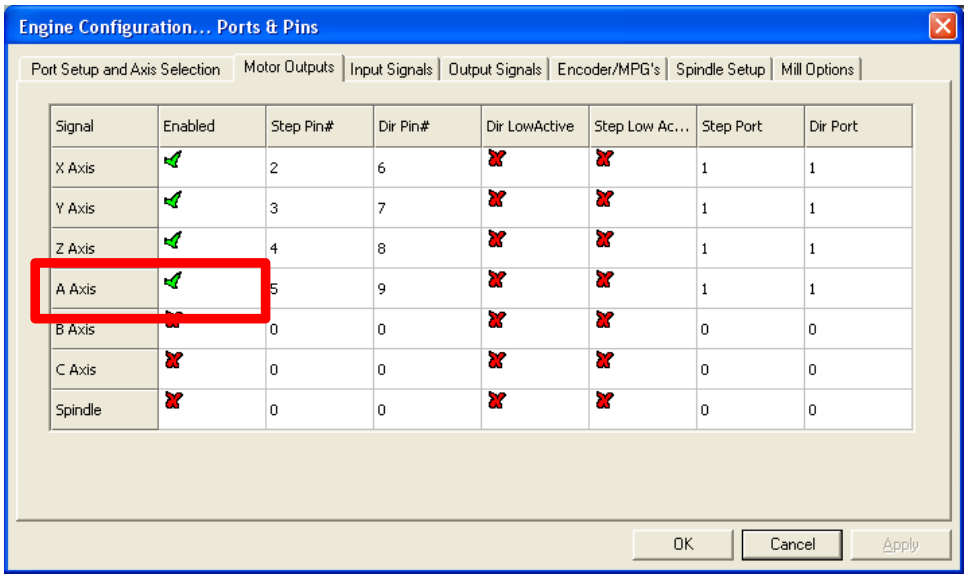
4.29 Add On Boards

If you have purchased a PLCADD1616 or other expansion board, the ajaxlog.txt file can assist you in determining the correct IO range to use for your particular board.

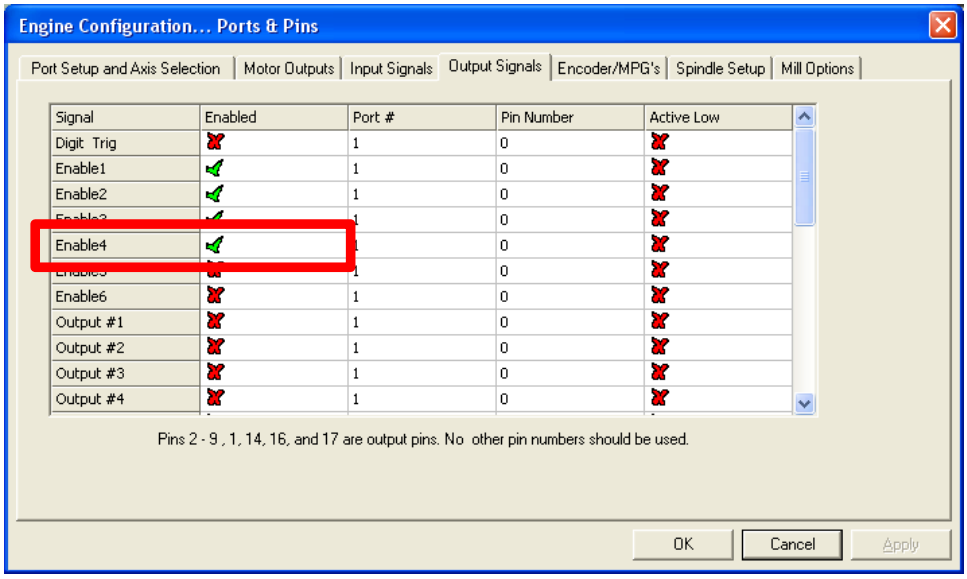
4.30 Fourth Axis Setup

If you would like to setup a fourth axis with your Ajax system, you will need to alter your settings in several different places...

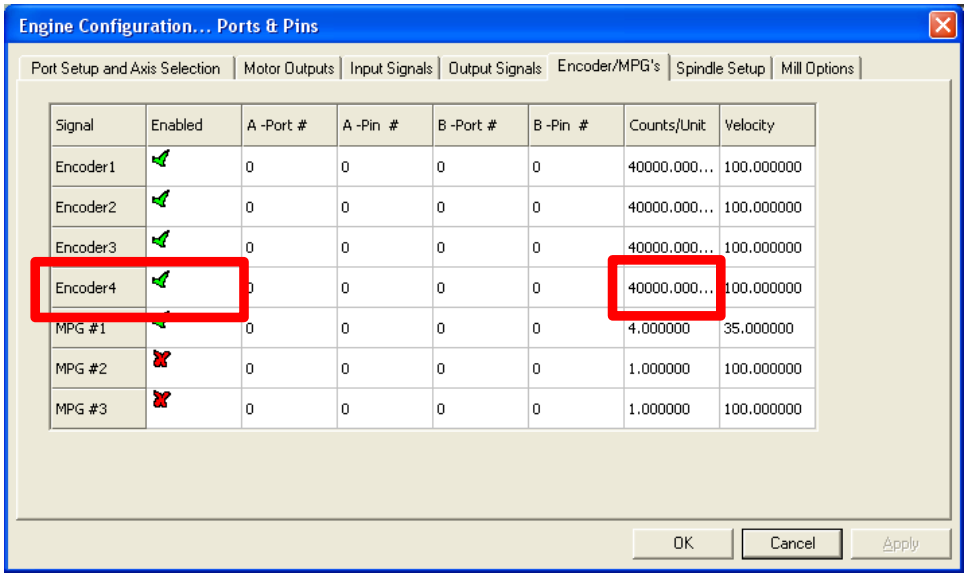
First, go to the Config → Ports and Pins menu. Select the Motor Outputs tab and mark the fourth axis (A Axis) as enabled. This will allow Mach3 to recognize your fourth axis.



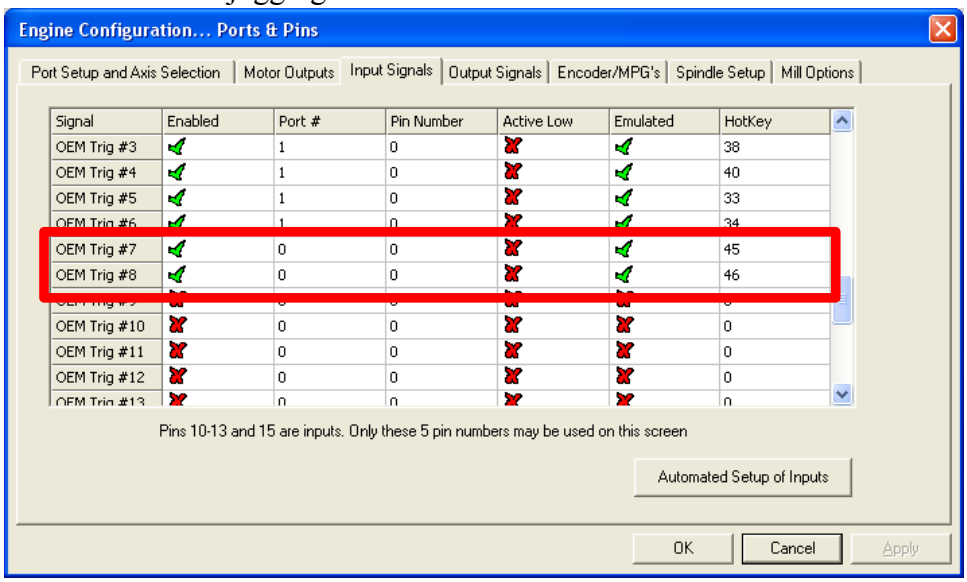
Next, go to the Output Signals tab, and mark Enable4 as Enabled. This allows your fourth axis to get power.



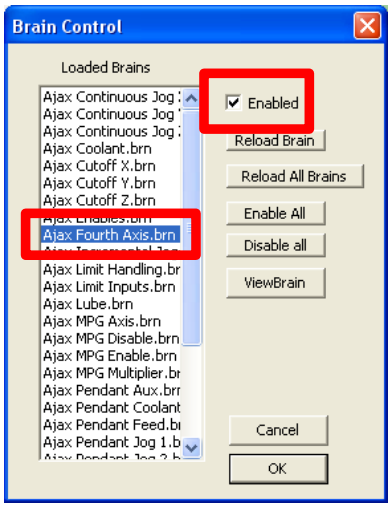
Then, click on the Encoder/MPG's tab and set Encoder4 as Enabled – and also fill in the appropriate value for Counts/Unit. This allows your fourth axis to measure angles (or distances) accurately.



Following that, go to the Input Signals tab. Setup OEM Trigger 7 and 8 to be emulated with the keypresses you'd like to use for jogging the fourth axis.

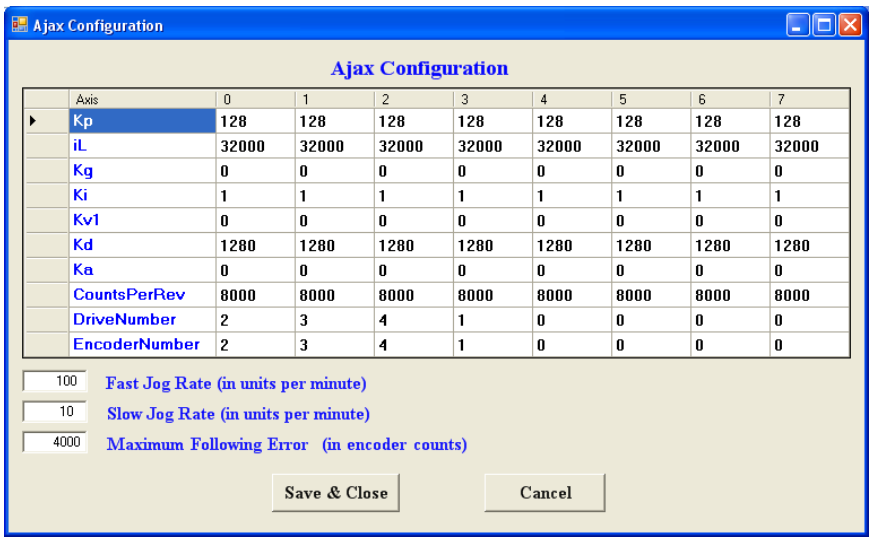


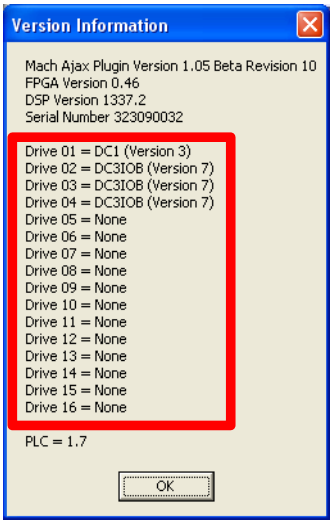
Next click on the Operator → Brain Control menu and mark the Ajax Fourth Axis.brn brain as being Enabled. This brain converts the OEM trigger signals into actual jog commands on the fourth axis.



At this point, your fourth axis should be somewhat functional – however, the fourth axis motor may be controlled by the X axis, rather than the A axis as expected (for a DC3IOB kit and a DC1 add on board – GP4IOD users can probably ignore this step). This is because the DC3IOB/MPU11 hardware detects drives in reverse order. While it's possible to setup your machine so it works like this, it will make more sense if we remap each of the axes to control the motor we expect it to control.

To do this, use the Config → Config Plugins → AjaxPlugin menu, and modify the DriveNumber and EncoderNumber settings for each axis. The PlugIn Control → Mach Ajax Plugin menu can help you determine the correct drives to use, though it will typically be 2, 3, 4, 1 (as shown below).





NOTE: You may also need to modify the M92 macro if you use an input other than 30 for rotary axis home.

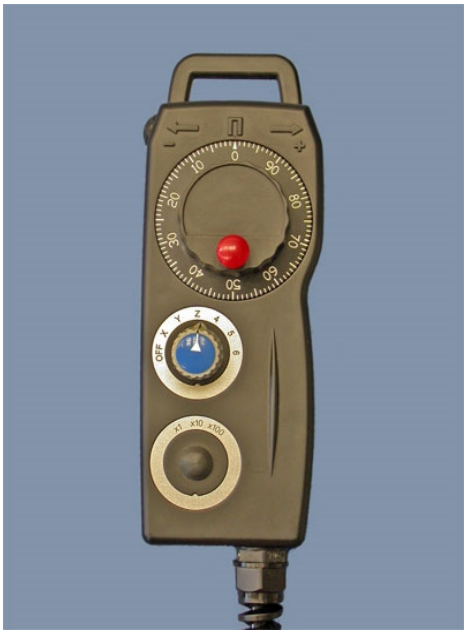
Drive Number Chart

Drive Number	Location	Description
1	Drive Bus Channel 1	Drive types are DC3IOB, DC1, ACSingle, and OPTIC4. Other drive types may be added in the future. The drive which is on drive channel one will normally display a 1 on the LED display. Drive channel 1 gets assigned by the FPGA to the last drive on the Drive bus chain and sequential numbers are added back to the device with the fiber optic cable connected to the MPU11. A DC3IOB will take 3 drive channels, one for each axis output, and an OPTIC4 will take 4 drive channels.
2	Drive Bus Channel 2	
3	Drive Bus Channel 3	
4	Drive Bus Channel 4	
5	Drive Bus Channel 5	
6	Drive Bus Channel 6	
7	Drive Bus Channel 7	
8	Drive Bus Channel 8	
9	GPIO4D Drive Out 1	Implemented through outputs on the plc bus which are written to at 4000hz. It is possible to have a GPIO4D connected to the PLC bus and a drive to connected to the drive bus at the same time.
10	GPIO4D Drive Out 2	
11	GPIO4D Drive Out 3	
12	GPIO4D Drive Out 4	
13	Legacy DC 1	Legacy DC drives (DC3IO) are not compatible with the above drive bus drives.
14	Legacy DC 2	
15	Legacy DC 3	
16	Legacy DC 4	
Future: Drive numbers could be expanded to support other drive types such as SD1		

Encoder Index Chart

Encoder Index	Location	Description
1	MPU11 onboard Encoder 1	The encoder inputs that are on the MPU11. Labeled Encoder 1- Encoder 6
2	MPU11 onboard Encoder 2	
3	MPU11 onboard Encoder 3	
4	MPU11 onboard Encoder 4	
5	MPU11 onboard Encoder 5	
6	MPU11 onboard Encoder 6	
7	Drive Bus Channel 1 Encoder	An encoder connected to a drive bus device. An Optic4 has 1 encoder per channel.
8	Drive Bus Channel 2 Encoder	
9	Drive Bus Channel 3 Encoder	
10	Drive Bus Channel 4 Encoder	
11	Drive Bus Channel 5 Encoder	
12	Drive Bus Channel 6 Encoder	
13	Drive Bus Channel 7 Encoder	
14	Drive Bus Channel 8 Encoder	
15	MPU11 onboard MPG Encoder Input	MPG connector, which has no index pulse signal

4.31 MPG Setup (MPU11 Based)



The Ajax MPU11 and Plugin have built in support for an MPG with a 5 volt differential encoder. The Ajax Plugin comes with several brains which work with a single Ajax supplied MPG (as shown on right). If you have a different MPG, the brains will work as long as you follow the MPG wiring diagram in MPU11_AND_CABLES.pdf. The brains control the axis selection, multiplier, and MPG enable/disable. They also control the LED indicator light on the MPG. It is not necessary to have the supplied brains working, as long as you can specify the axis selection and multiplier in Mach.

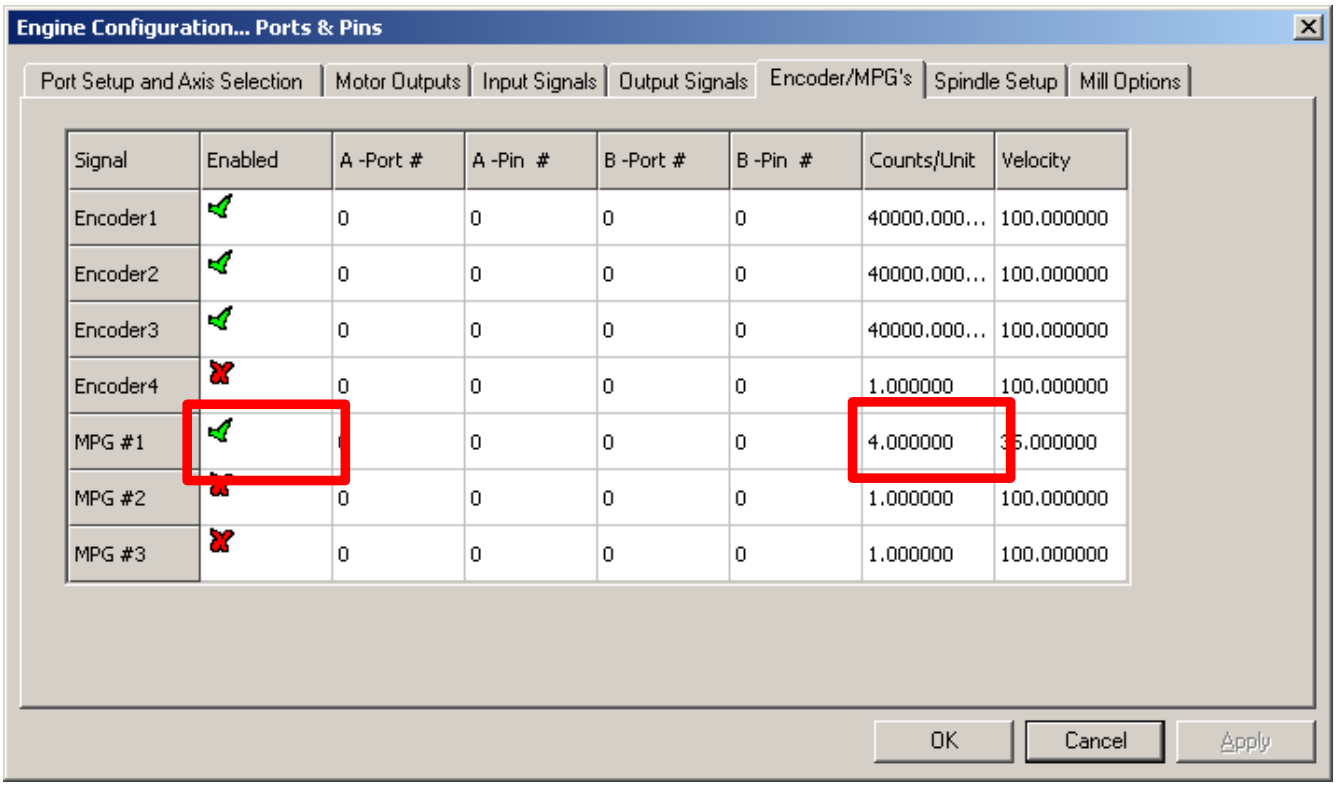
- **Detents**: The marks on the MPG handwheel. They provide tactile feedback and cause the encoder to stop exactly on a detent. The MPG to the right has 100 detents per revolution.

- **Windup Mode**: The MPU11 MPG has two modes of operation. If Windup Mode is on the MPG will move the exact number of steps that the user commanded. If Windup Mode is off, the MPG will stop short if the user cranks the MPG faster than the motor can handle. The Ajax Plugin automatically turns off Windup Mode for jog-steps greater than .01 inches or greater than .2 mm in metric mode. Windup mode is turned on for smaller jog-increments.

- **MPG Feedrate**: It is recommended that you set this value to the the highest maximum velocities for all of your axes. The MPG will try to move the motors as fast as the user cranks the hand wheel. However, it is limited by the **MPG Feedrate,** shown to the right, and the maximum velocity of the selected axis. It is also effected by the acceleration rate for the selected axis. If your MPG is moving slower than you expect, check your MPG Feedrate which is in Mach's MPG Mode window. (Press Tab from the main screen)

- **Counts/Detent:** The MPG needs to know how many encoder counts per detent there are. The MPG provided by Ajax has 4 encoder counts per detent. In order to change this value, go to Config → Ports and Pins in Mach3's menu bar. From here, click the Encoder/MPG's tab. The Counts per Detent are set in the Counts per Units column. If your MPG doesn't have detents, that's ok. The MPU11 needs to know how many encoder counts cause 1 jog-increment of movement (in x1 mode).
- **Enabled:** The enabled column must be checked in the Encoder/MPG's tab for the MPG to work.

MPG Enable and Counts/Detent Configuration



NOTE: The Velocity column in this window has NO effect for the MPG row. (When using an MPU11 based MPG)

- **Multiple MPGs:** The MPU11 supports up to 3 MPG's which can be connected to any available encoder input.

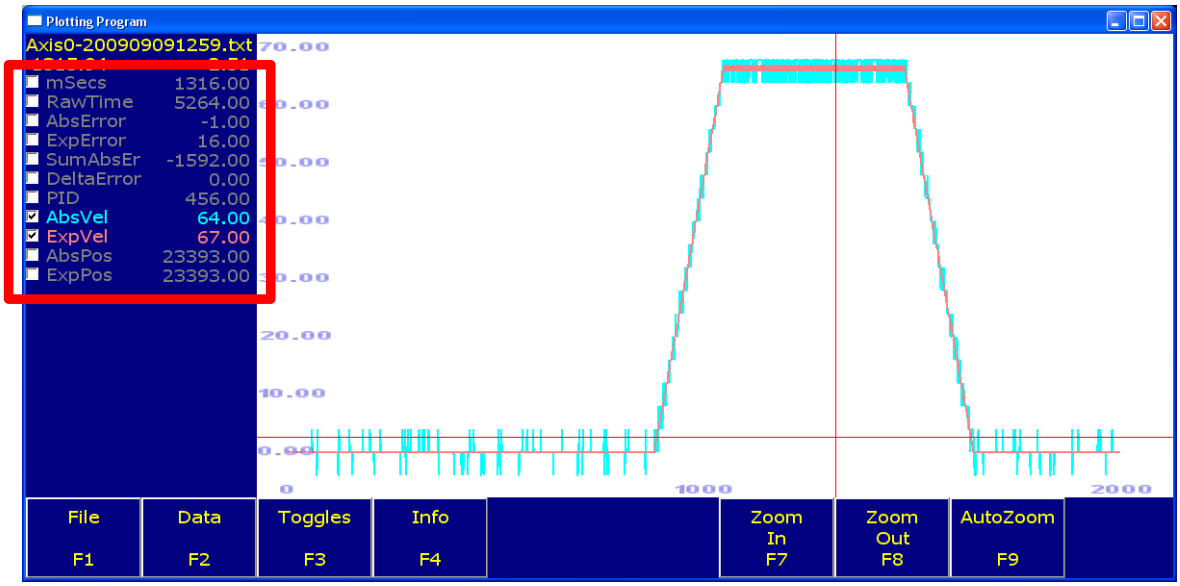
- **MPG Encoder Inputs**: The MPG encoder indexes tell the MPU11 which encoder to read as an mpg. The MPG header is the default encoder input for the first MPG. This can be changed in the mach_ajax.xml configuration file. You can also specify encoder inputs for the other two mpgs. See the Encoder Index chart above in section 4.30.

5 Diagnostics and Tuning

The Mach Ajax Plugin has several features to assist you in diagnosing and resolving problems you may encounter with your machine.

5.1 Axis Plot

To perform an axis plot, the Ajax Plot Gather brain must be enabled. This brain will ask the Ajax MPU11 to record its position, velocity, acceleration and error values for a 2 second period of time, for a given axis. These values are then sent to your computer where they are displayed in an graphical form. Input 1 (X axis), Input 2 (Y axis) and Input 3 (Z axis) are used to select which axis to plot, and are by default bound to the F1, F2, and F3 keys. Each plot will also be saved to your computer's hard drive for later reference (C:\Mach3\Ajax directory by default).



mSecs The time at which the sample was taken in milliseconds

AbsError The absolute error, which is the difference (in encoder counts) between where the machine should be and where it actually is.

SumAbsError The sum of absolute error, which is a running total of the absolute error value. This number is often quite large, so a Y Scaling factor of 0.01 can be useful.

AbsVel The absolute velocity, as measured in encoder counts per millisecond. This value tells you how fast your motor is actually spinning at any given time.

ExpVel The expected velocity, as measured in encoder counts per millisecond. This value tells you how fast your motor is trying to spin.

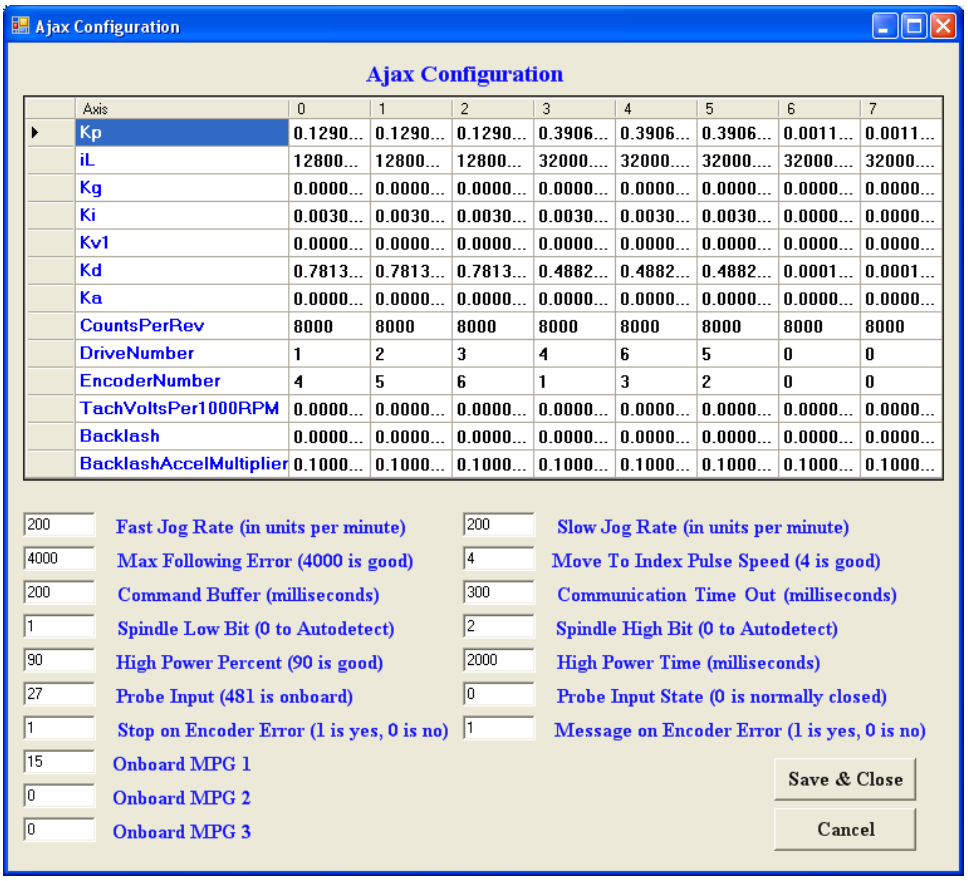
AbsPos The absolute position, as measured in encoder counts. This value tells you where the machine is at any given time.

ExpPos The expected position, as measured in encoder counts. This value tells you where the machine is supposed to be at any given time.

5.2 Ajax Configuration Utility

The Mach Ajax Plugin comes with its own configuration utility that allows the setup of several additional parameters specific to your servo motors – or specific to the Ajax MPU11. To access this utility, select Config → Config Plugins from Mach3's menu bar, then click the yellow Config square.

NOTE: You may need to install Microsoft's .NET framework for this configuration menu to function.



Kp, iL, Kg, Ki, Kv1, Kd, and Ka are used to calculate the amount of power each motor should receive, in order for the machine to follow its intended path as best as possible. The default values will probably be pretty close to what you want for your motors, but the steps below will help you tweak the numbers to reduce errors and oscillations. In general, you should not alter Ki, Ka, iL or Kg.

CountsPerRev is the number of encoder counts in a single rotation of the motor

Drive Number is used to determine which motor should get power when an axis is commanded to move. In most cases, these should be set to 0 – which will cause the MPU11 to autodetect.

Encoder Number is used to determine which encoder should be used to determine the actual position of each axis. Again, these should probably be set to 0 for autodetection.

Backlash is used to counteract mechanical play in your machine (where the motor moves slightly before the table itself)

Backlash Accel Multiplier is used to determine how quickly backlash is taken up, and the default value of 0.1 should work well in most cases. Unless you have access to a sophisticated testing system, you probably shouldn't change this.

Fast Jog Rate and **Slow Jog Rate** are used for continuous jogging. Which is in use, depends on the state of ModBus output 377.

Max Following Error is used to trigger a critical error if the Ajax MPU11 is missing its intended position by too great a distance, for too long a time period. The length of that time period is equal to the amount of time it takes for a motor to accelerate from a stop to full speed.

Move To Index Pulse Speed is 4. Leave it that way. It controls how quickly the MPU11 performs the most critical portion of the homing sequence, and modifying it could cause the MPU11 to home inconsistently.

Command Buffer is the number of milliseconds that the MPU11 will hold movement commands before executing them. If this number is too low, the MPU11 is more prone to communication errors and vector starvation. As the number gets higher and higher, there will be a longer and longer delay before the MPU11 responds.

Communication Time Out determines how long the Ajax plugin can go without hearing from the MPU11, before entering an EStop state.

Spindle Low Bit and **Spindle High Bit** are used to tell the plugin where it should write the spindle speed value. These are usually set to 0 to allow the MPU11 to autodetect.

High Power Percent and **High Power Time** are used to cause an EStop if any single motor is being driven too hard for too long, in order to prevent damage to the motors due to overheating. The default values should work well.

Probe Input and **Probe Input State** are used when doing a G31 probing movement to determine when the probe has tripped.

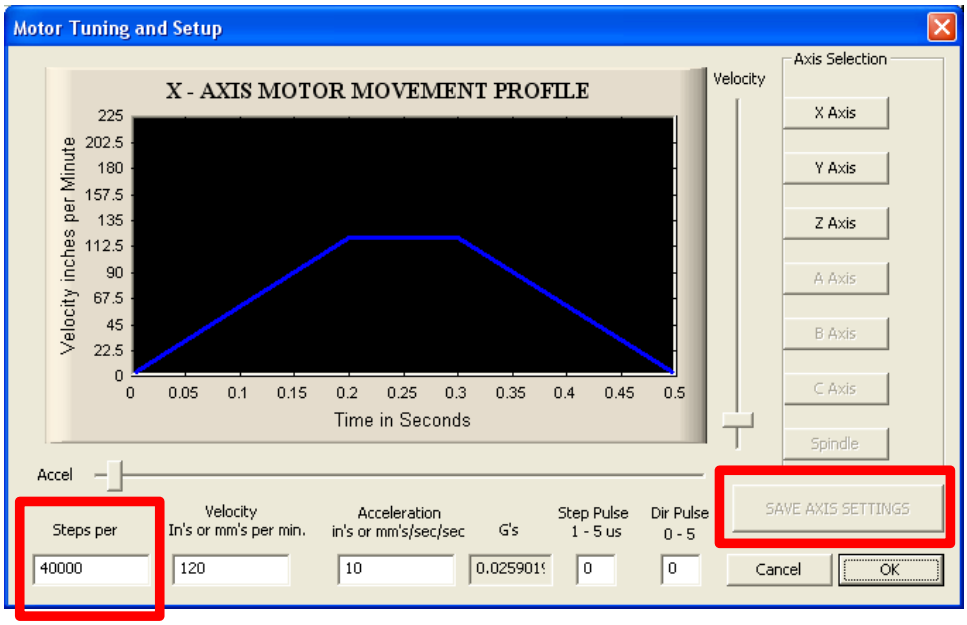
Stop on Encoder Error and **Message on Encoder Error** should both be set to 1. However, some encoders may constantly trigger an encoder error if the are under-voltage, despite working well otherwise. In that case, these values can be used to suppress the encoder error – however doing so could cause a dangerous situation if an encoder ever becomes disconnected.

Onboard MPG 1, 2 and 3 are used to specify which encoders control the MPU11's hardware MPGs (handwheels).

5.3 Preliminary Motor Tuning

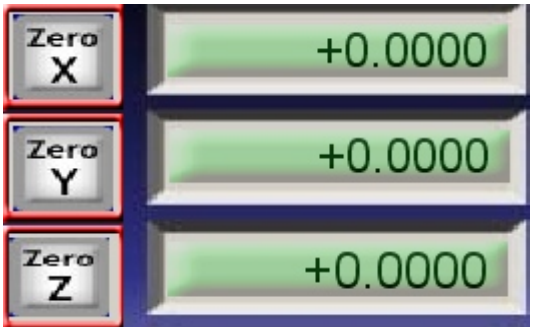
Go to Mach3's Config → Motor Tuning menu, and set the “Steps Per” value (usually the same as the Counts/Unit setting from the Encoder/MPG tab) for each axis. Then click Save Axis Settings and repeat for each axis that you intend to use.

At this point, leave Velocity at the default of 120 inches per minute and Acceleration at 10 inches per second per second. The “Step Pulse” and “Dir Pulse” are not used by the Mach Ajax plugin at all.



5.4 Initial Positioning

Position your machine such that the tool has ample clearance on all sides (centered on the table and z raised midway). Zero the position at this point. This will help prevent damage to your machine in the following instructions, and you should return to this position after each tuning movement. Also be sure to keep a hand on EStop, as heavy oscillations could cause damage.



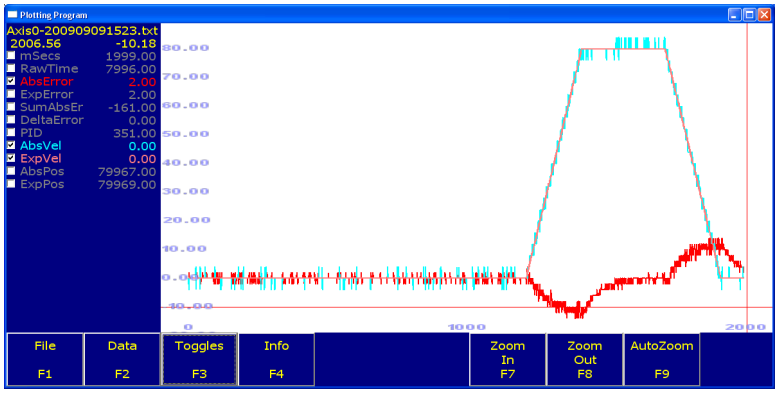
Another note – when doing these tuning movements on the Z axis, do the movement away from the table and return to your initial position with a slow movement. That will help prevent running the tool into the table.

5.5 Tuning Kp

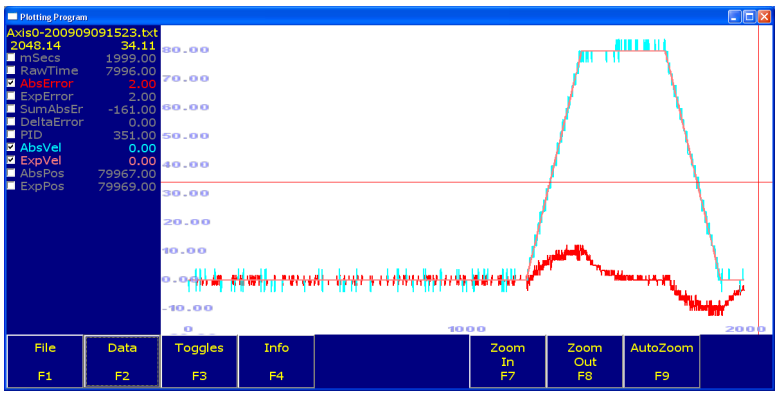
Kp is the first value you should adjust, and it should range from 0.2 to 2.34. From your initial location, perform a 1 inch movement at 120 inches per minute (ie “G1 X1.0 F120”), and generate a plot after the movement has finished (Press F1).

When looking at the plot, hide all lines except AbsError, AbsVel and ExpVel – then click AutoZoom to fit the plot to the screen.

If Kp is too high, the motor will run ahead of where it should be from the start of the move. If your plot looks like this sample below (where AbsError dips at the start of a move), your Kp should be reduced by 0.05 and the test should be run again from the initial position (also press the Reset button in Mach3 a few times to make sure the new value is taken).



If Kp is too low, the motor will trail behind of where it should be. If your plot looks like the plot below (with AbsError rising at the start of the move), your Kp should be increased by 0.05 and the test repeated (from the initial location).

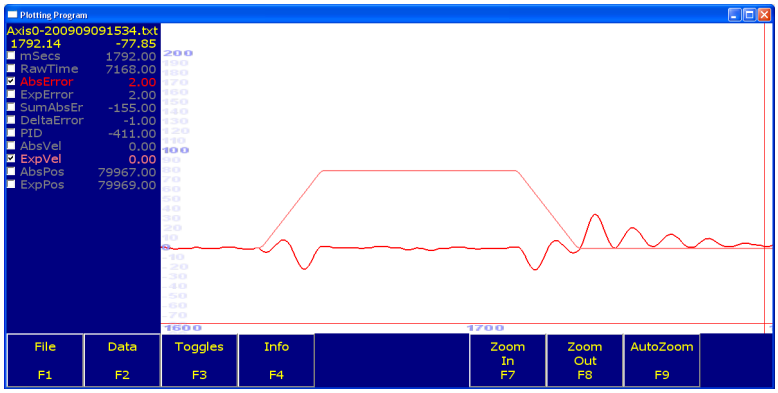


5.6 Tuning Kd

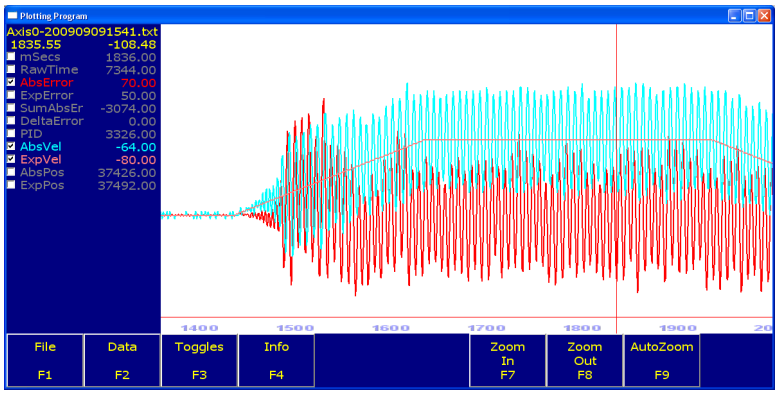
Kd is the next value you should adjust, and it should range from 0.2 to 1.5. Return to your center point and perform a 1 inch movement at 120 inches per minute, and generate a plot.

Again, hide all lines except AbsError, AbsVel and ExpVel.

If Kd is too low, you will get low frequency oscillations, primarily at the end of the move. If your plot looks similar to the one below, try increasing Kd by 0.05 and running the test again.



If Kd is too high, you will get a high frequency oscillation resulting in instability and motor whining. If your motor whines loudly, hit EStop immediately and reduce Kd by 0.05. Do not perform a movement if your motor is whining – as the small initial error that causes the whining will quickly build into a larger and larger error, causing a larger and larger oscillation (your machine will shake violently).

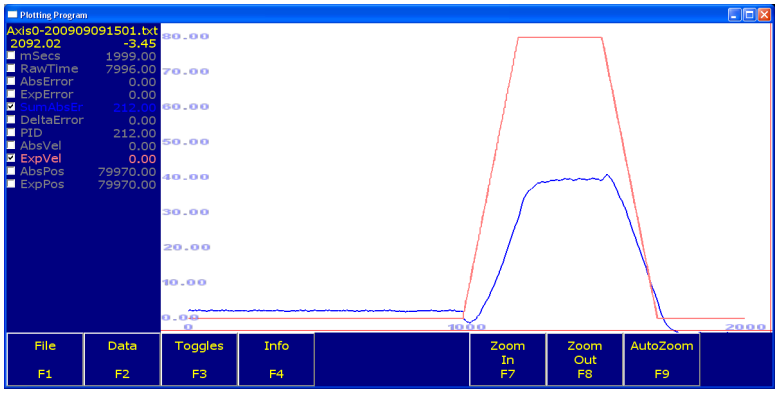


5.7 Tuning Kv1

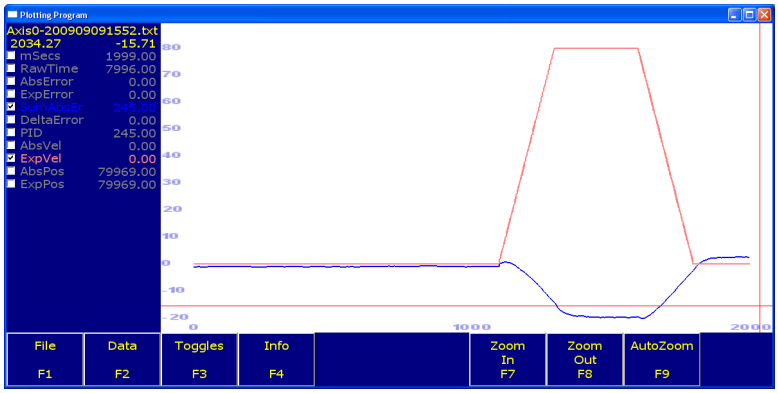
Kv1 is used for making long term adjustments, and its effects are most noticeable on the sum of absolute error. Common values for Kv1 are 7.8 to 15.6 on the X axis, 9.4 – 17.2 on the Y axis (higher because it carries the weight of the X) and 2.3 – 7.8 on the Z axis.

Return to your center point and perform a 1 inch movement at 120 inches per minute, and generate a plot. This time, hide all lines except SumAbsError, AbsVel and ExpVel. You may also want to scale SumAbsError by 0.01 so it fits on your screen better.

If Kv1 is too low, the plot will look something like this. Try increasing Kv1 by 3 and running the test again.



If Kv1 is too high, the plot will look something like this. Try decreasing Kv1 by 3 and running the test again.



5.8 Adjusting Kg

In general, you should not have to adjust Kg. It is the Gravity constant, and is used to counteract an unbalanced axis. Typical ranges for Kg are -4 to 4 on the X and Y axes and -8 to 8 on the Z axis.

Situations where a Kg value may be needed are as follow...

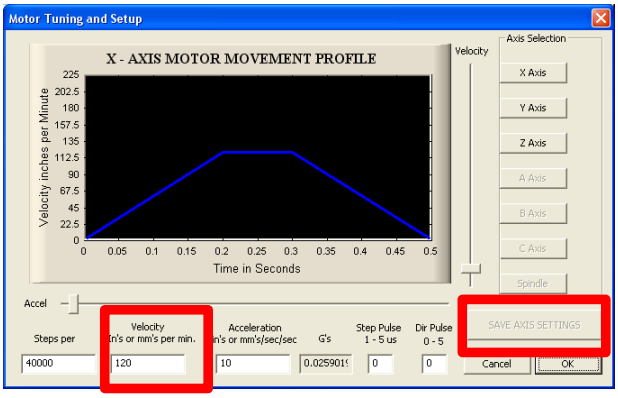
•A bed mill with an incorrect weight on the counter balance.

•A loose gib.

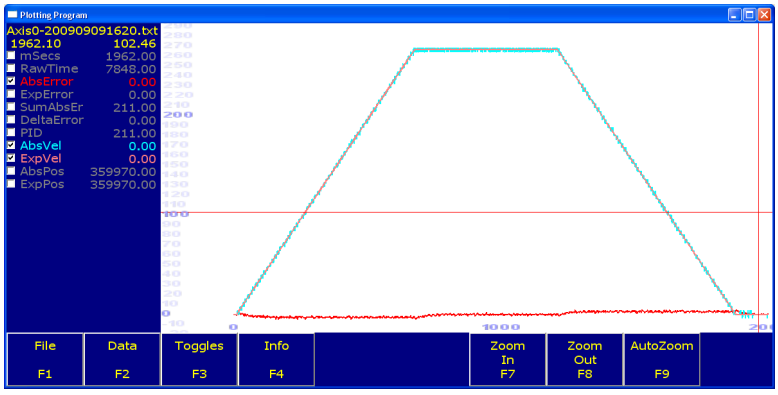
•A failing support bearing.

5.9 Adjusting Maximum Velocity

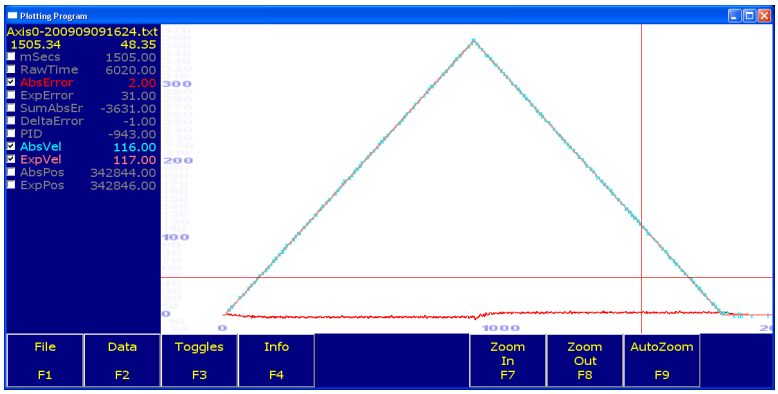
At this point, your motor should be moving with very little error – and now it is time to determine the maximum velocity of the motor. Return to Mach3's Config → Motor Tuning menu, and increase the velocity by 50 inches per minute (this velocity setting determines the maximum feedrate your motor will attain). Remember to Save the Axis settings as well.



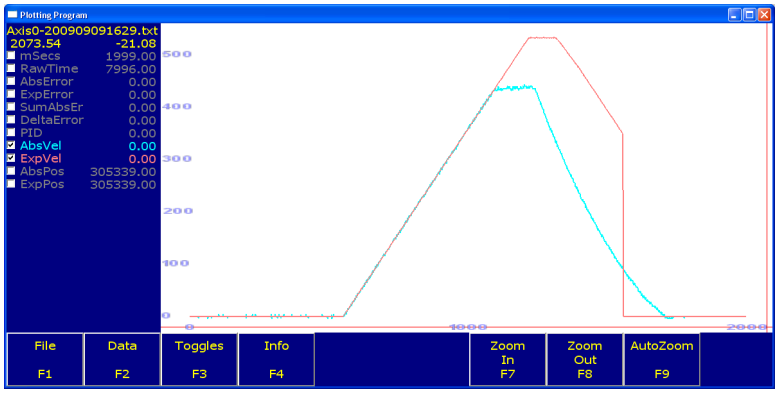
Return to your initial position and run an 4 inch move (make sure you have clearance) at the new feedrate (ie “G1 X4.0 F170”). Plot the result and ensure that the actual velocity and expected velocities are very closely matched (like the image below).

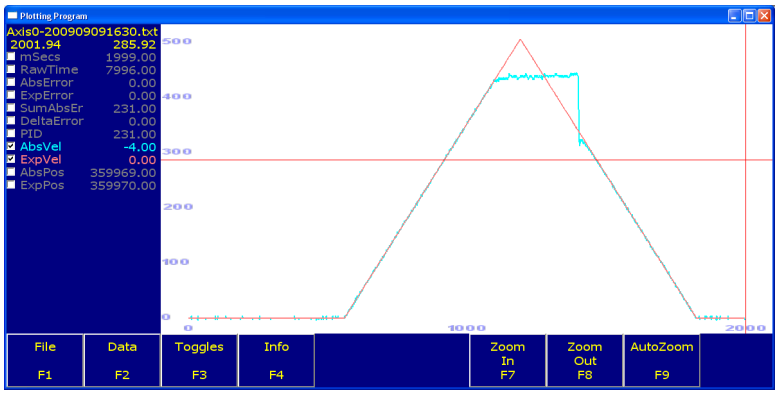


If your plot is triangle shaped (with no flat area on the top), your motor did not attain the maximum velocity you set – but only because the distance you moved was too short. Increase the length of your movement and try the movement again (make sure there's ample clearance so the machine doesn't crash into itself).



Repeat this process until the actual velocity fails to keep up with the expected velocity (like one of the images below). This may also cause a position error. Reduce your velocity to the last known good value.



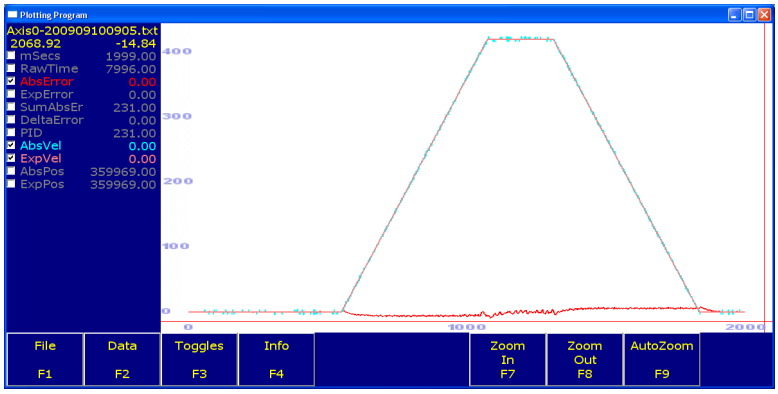


The following formula may also help – but stay 10-20% below the actual maximum attained.
VelocityInchesPerMinute = AbsVel * 1000 * 60 / EncoderCountsPerInch

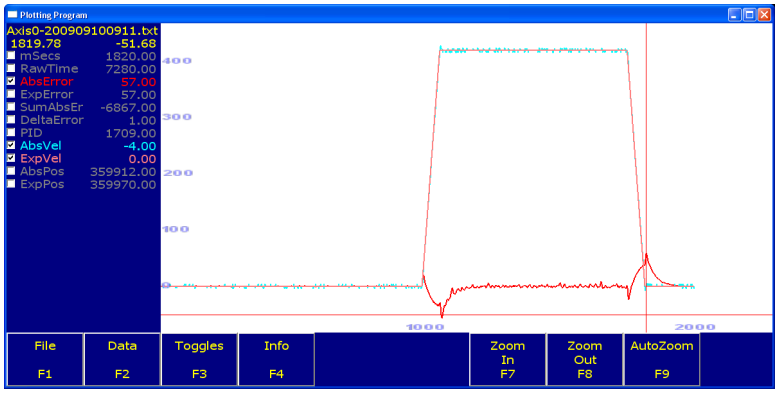
5.10 Adjusting Acceleration

Now that the motor is reaching its maximum velocity, we can adjust the rate of acceleration. Return to Mach3's Config → Motor Tuning menu, and increase the acceleration by 2 inches per second per second, then click the Save Axis Settings button.

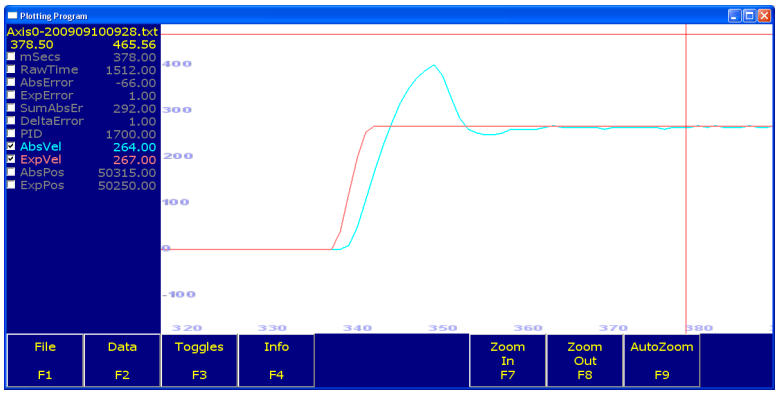
Now, return to your initial position and run another test movement (again make sure you have adequate clearance). The length of the movement should be sufficient for the motor to reach its maximum velocity (as in the previous step) – and should look something like the plot below



As you gradually increase the acceleration rate, the plot will look more and more like the following image. Notice the Absolute Error values at the start and end of the movement – this tells you how many encoder counts the tool is off its desired position. If this value becomes too great, you may wish to back the acceleration down a bit. (In the image, we are off by 57 counts maximum – at 40,000 counts per inch, which translates into 0.001425 inches which may or may not be acceptable)

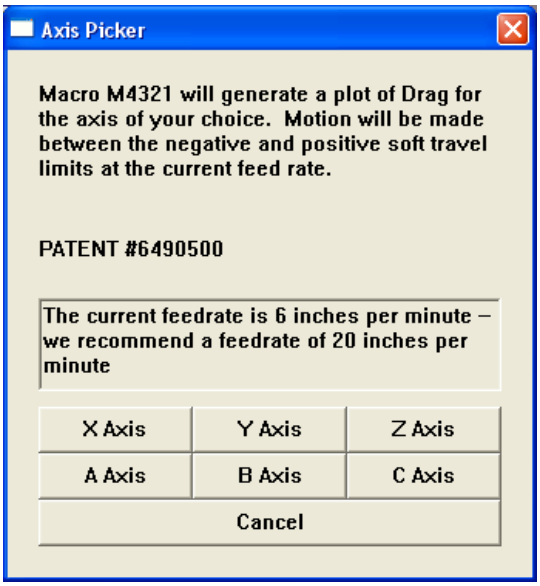


You will definitely want to reduce the acceleration rate if the absolute velocity fails to keep pace with the expected velocity, or if it overshoots. The following image shows both of these conditions (you may need to zoom in to see this – shift and the right mouse button will allow a non-proportional zoom, which may also be helpful).



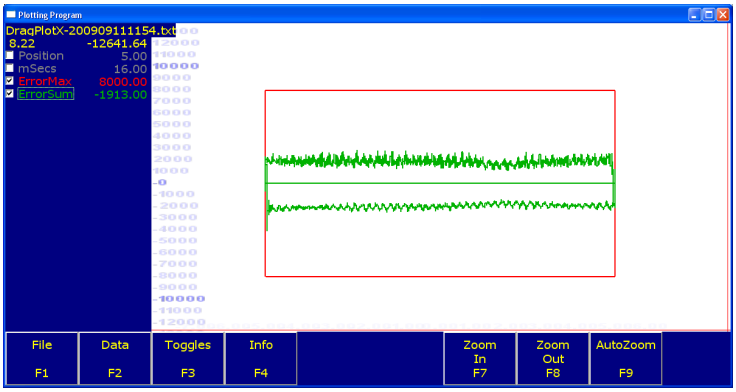
5.11 Drag Plot Macro

Typing M4321 on Mach3's MDI line will cause the Drag Plot Macro to run. This macro can help you visualize the amount of friction your machine experiences as it moves between the soft travel limits for any axis.

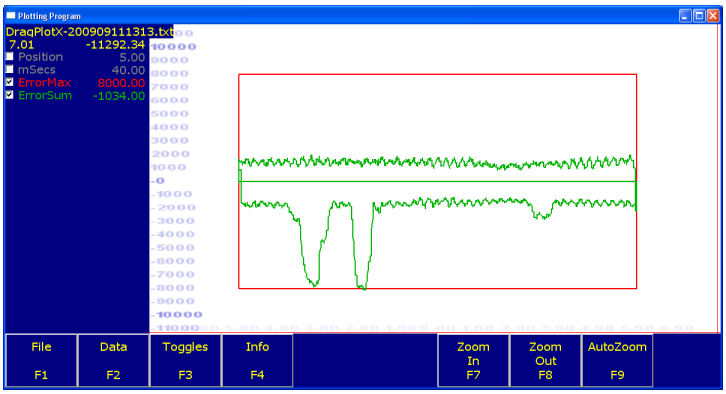


Before running this macro, setup your Soft Travel limits for each axis (in Config → Homing / Limits).

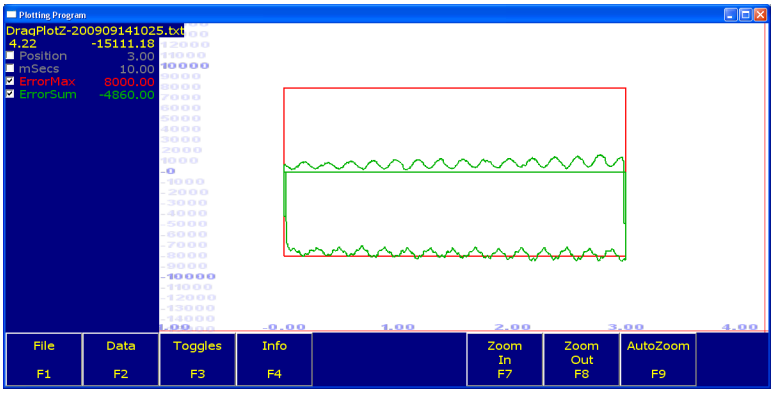
In general, if the green lines are outside of the red box (and all other settings are correct for the motor), the drag is excessive for that axis. It can also help you determine where along its track your machine is binding. The image below shows a typical drag plot, with acceptable levels of drag throughout the course of the machine's movement on the X axis.



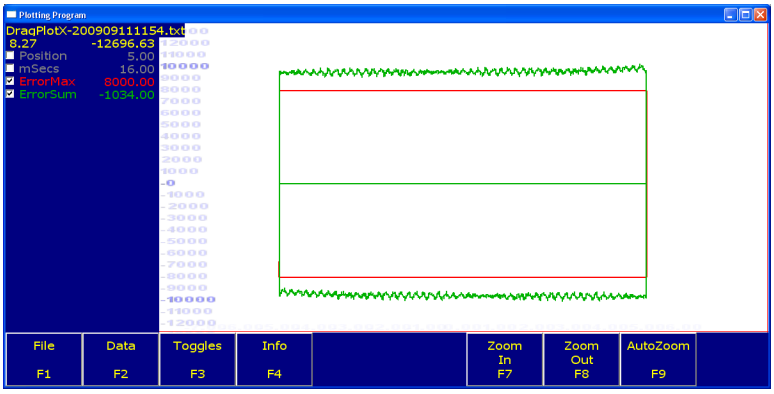
The next image shows a plot with heavy resistance (two men pushing against the table at three different points), as the machine made its movement. If the cause was unknown, a plot like this would indicate major trouble spots at two spots along the axis of travel (-3 and -2), and a minor trouble spot (at 2.5).



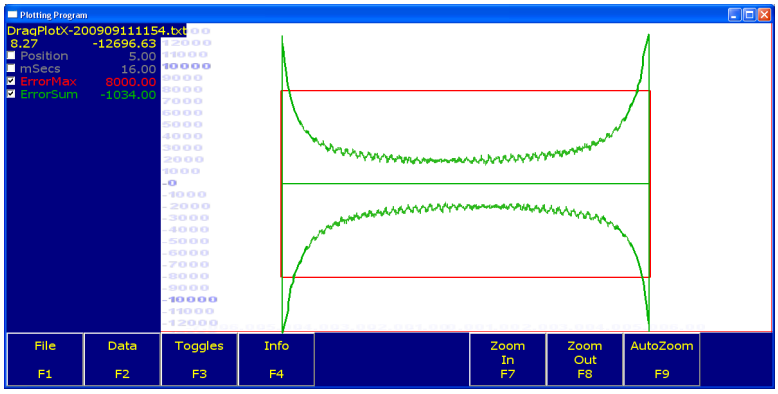
The image below shows a drag plot for an unbalanced Z axis.



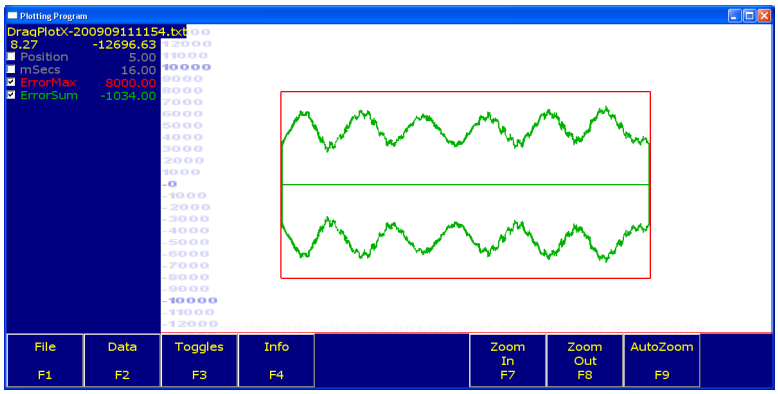
The next image shows an example drag plot with all around too much drag, which could be due to inadequate lubrication, chips and debris, rust, or tight gibs.



The next example shows a drag plot of an axis that has a misaligned ball screw. The axis is tight near the ends of travel since the ballscrew is not concentric with the support bearings.



The next example shows a drag plot of a stick-slip type of action, which could be the result of inadequate lubrication, rust, dirt/debris on the way, or an incorrectly installed gib. If the axis is controlled with a pulley system, it could also be off center.

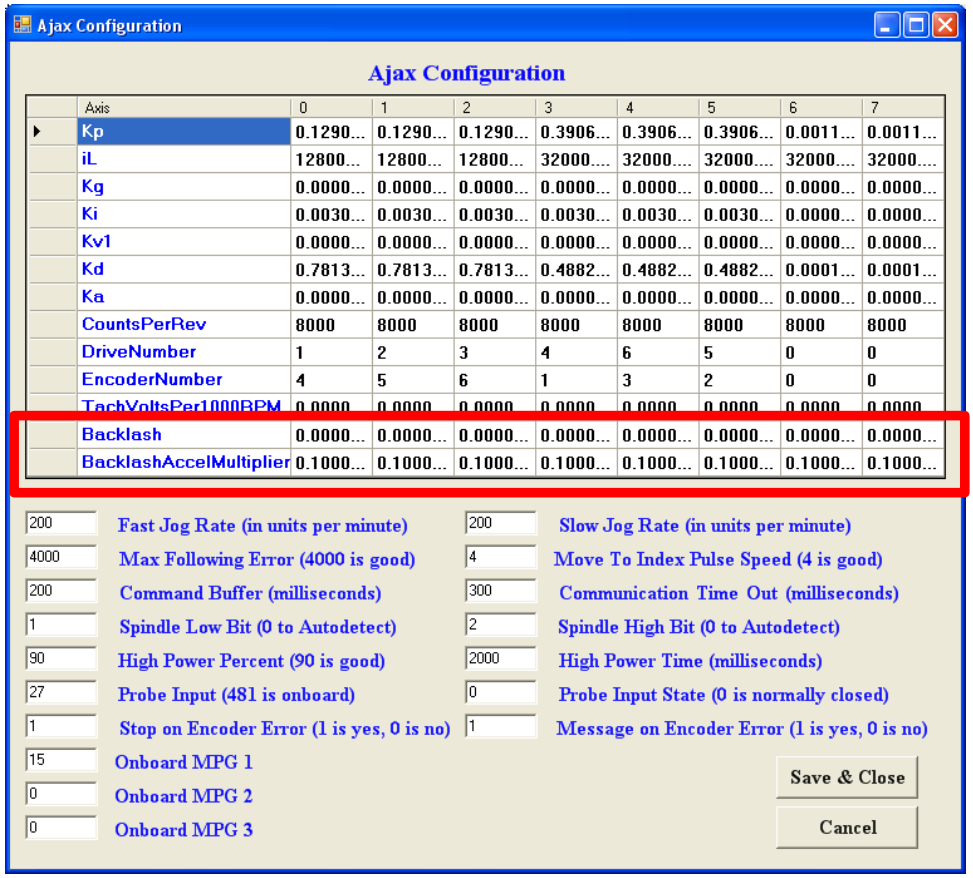


5.12 Backlash Compensation

When a motor is turning one direction – then reverses and goes the other direction, your machine may hesitate slightly before moving in that opposite direction. This is a normal occurrence caused by looseness or wear, and is called backlash.

If you measure the amount of backlash, the Ajax MPU11 can be instructed to compensate for it. Use the Ajax Configuration Utility to enter the values you measured (Config → Config Plugins → yellow Config square). Enter the amount of backlash on the Backlash row. The BacklashAccelMultiplier row is used to determine how quickly the backlash should be taken up – a value of 0.1 is usually sufficient (meaning that backlash will be taken up at one tenth the maximum acceleration rate of that axis).

NOTE: It is required that the machine is rehomed after changing Backlash Compensation.



6 Mach3 Operation

This section is intended as a brief overview of how to operate Mach3 with the Mach Ajax Plugin. Please refer to the full Mach3 user's manual for more detailed instructions.

6.1 Homing

Homing can be performed by typing “M92 P#” on Mach3's MDI line. This will cause the axis specified by the # sign (1 for X, 2 for Y, 3 for Z) to do a positive homing movement until it hits the limit switch, then it will back off until it reaches the index pulse of the encoder.

Multiple axes can be homed simultaneously by specifying Q and R values as well. For example, “M92 P1 Q2 R3” will cause the X, Y and Z axes to home in the positive direction. Homing can be performed in the negative direction by adding 10 to the numbers – for example “M92 P11 Q12 R13”. The M92.m1s file in the Macros directory is the script that handles this behavior.

6.2 Jogging

By default jogging can be performed using the Left and Right cursor keys for X movement, the Up and Down cursor keys for Y movement, and the Page Up and Page Down keys for Z movement. These can be reconfigured by changing OEM Trigger 1 through 6 in the Input Signals tab of the Config → Ports and Pins menu, or by creating a custom brain to set the appropriate values.

Continuous jogging is performed at the slow jog rate specified in the Ajax Configuration Utility.

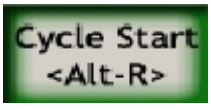
6.3 Running a Job

The 

ton will allow you to load a text file that contains G-Code movements to control your machine. Before running the job, read through the code so you know what size and type of tool to use and where to set your part zeroes. Check the ToolPath screen in Mach3 to verify that your Program Limits are acceptable (upper right hand corner). Also be wary of any G54, G55, G56, G57, G58 and G59 codes that may be present (an unexpected coordinate system change can ruin your day).

When starting out, set the Feed Rate Override to a low percentage, so you have time to react if something unexpected does happen. Cutting in the air is also a good idea.

When you're all ready, the Cycle Start button will start the job running.



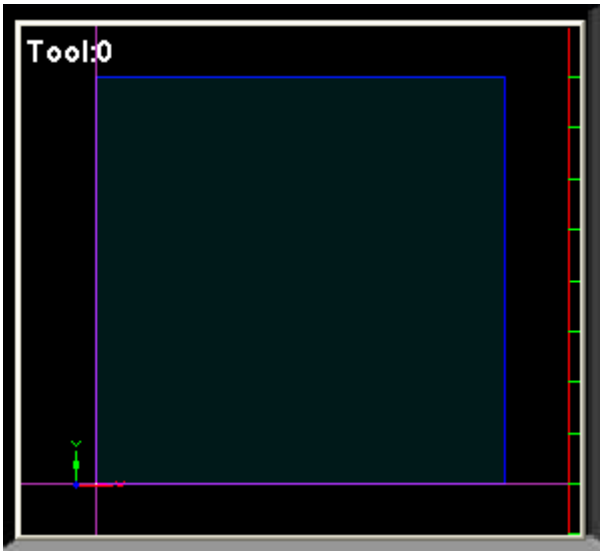
6.4 A Note About Feed Hold

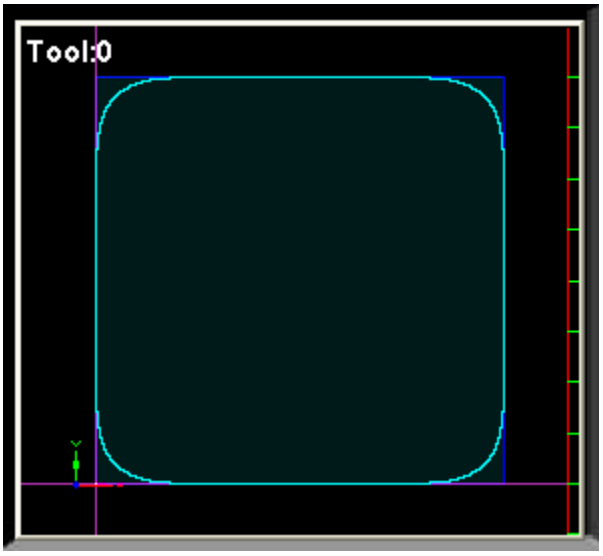
As of this time, Feed Hold does not work perfectly with the Mach Ajax Plugin. Specifically, jogging and MDI commands should not be used when Feed Hold is active as unintentional or delayed motion may occur.

6.5 Rounded Corners

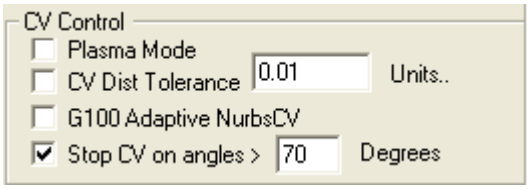
Mach3 can either operate in Constant Velocity mode (CV mode) or Exact Stop mode. CV mode is enabled by default, and has the advantage of stringing movements together into one long continuous motion – keeping the specified feedrate as best as possible. Exact Stop mode causes the machine to stop motion after each G Code command is issued.

CV mode has a tendency to cause your machine to round tight corners (an effect which is more pronounced at higher feedrates). The images below show a box shaped movement on the left, and the actual path taken by the machine on the right.





In order to combat that tendency of CV mode and to give you greater control over your machine's behavior, Mach3's Config → General Config menu can be used to set several additional parameters (in the CV Control section). "Stop CV on angles >" is set to 70 by default, and will cause an exact stop in the case shown above (so the final cut comes out as a square) – a hexagon (with 60 degree angles) would still exhibit this rounding behavior, unless the setting was further reduced.



Another option that works well is the CV Dist Tolerance option, which limits the maximum amount of rounding that occurs to the value specified.

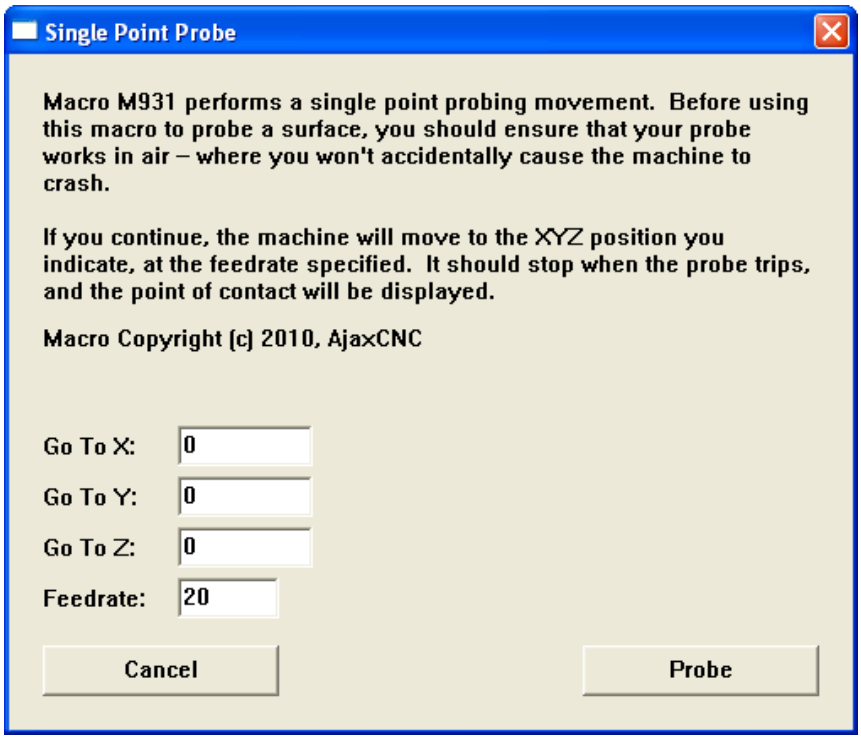
6.6 Probing and Digitization

The Ajax MPU11 supports high speed probing through the use of the G31 command – however the current implementation differs slightly from the normal Mach3 implementation. In particular, the point of contact is written to OEM DROs 2000 through 2007, and OEM DRO 1999 is used to indicate whether or not a contact has occurred. Also, when using G31 within a macro to digitize an object, all output should be explicitly written to a file (rather than relying on the OpenDigFile and CloseDigFile functions) – the macro should also wait until the G31 is complete before issuing any further commands.

The G31 operates much like a G1, and moves at the current feedrate to the specified position. What feedrate to use will depend on the probe you are using, but in general, slower probing will give more accurate results. If the feedrate is too high, it is possible to damage the probe or part – since the machine will need time to decelerate after registering a probe hit.

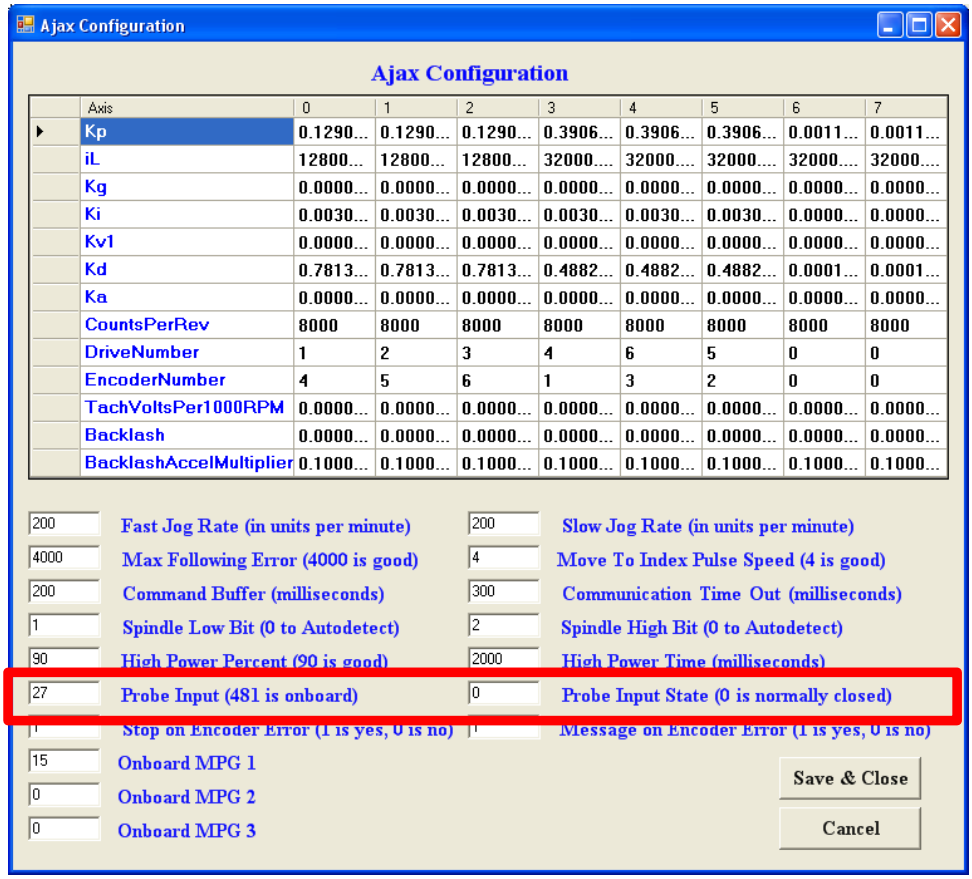
The M931 macro (which is provided with your kit) shows a simple example of how to perform a single point probing movement with the Ajax hardware. This example could be improved upon in several ways – however it shows the basic techniques which should be employed.

WARNING Do not turn on the spindle when a probe is inserted – doing so can cause the probe to fly out and embed itself in a nearby wall/person.



In order to use the G31 probing command, you will first need to attach your probe to one of the hardware inputs. The Ajax MPU11 has a high speed probe input channel (input 481) that allows the probe to be sampled at 4000 times per second (which yields greater accuracy), however any normal input on your DC3IOB / GPIO4D can be used.

Next, use the Ajax Configuration Utility (Config → Config Plugins → yellow Config square) to tell the Ajax Plugin which input the Probe is using, and whether the probe is normally open or normally closed.



Make sure you test the G31 command in air to ensure that your probe works correctly and consistently.

7 Appendices

7.1 Input Reference

The values in this section can be read by Brains by using ModBus inputs.

Stall: Position Error	Input 351
Stall: Full Power without Motion	Input 352
Stall: Encoder Error or Encoder Warning	Input 353
Stall: Communication Error	Input 354
Jogging: Travel Limit reached Does not require a Clear Stop Reason. Will clear whenever the Jogging output goes low.	Input 355
Stall: Following Error	Input 356
Stall: Vector Starvation	Input 357
Drive Fault	Input 358
PLC Fault	Input 359
Axis Error Bit 0	Input 361
Axis Error Bit 1	Input 362
Axis Error Bit 2	Input 363
PLC Type bit 0	Input 364
PLC Type bit 1	Input 365
PLC Type bit 2	Input 366
Operation Complete	Input 367 Homing: (reset when index pulse move starts set when index pulse move is finished)
Mpg still moving Error	Input 368
Probed Tripped	Input 369 (set when the mpu11 detects a probe trip, Reset on the Rising edge of the Enable Probe Detection bit)
Local Inputs (Mpu11 Onboard Inputs)	481-512
Axis 0 Reversed	Input 750 (set to 1 if the axis is reversed, so the continuous jogging brains can determine which direction to move)
Axis 1 Reversed	Input 751
Axis 2 Reversed	Input 752
Axis 3 Reversed	Input 753
Axis 4 Reversed	Input 754

Drive Type bits: DC3IOB = 0, GP4IOD = 1

7.2 Output Reference

Most of the values in this section can be written to by Brains by using ModBus outputs. Some (such as Output 380) are controlled directly by the Mach Ajax Plugin.

Axis Enable 1	Output 351
Axis Enable 2	Output 352
Axis Enable 3	Output 353
Axis Enable 4	Output 354
Axis Enable 5	Output 355
Axis Enable 6	Output 356
Axis Enable 7	Output 357
Axis Enable 8	Output 358
Master Enable	Output 351 or Output 352 or Output 353 or Output 354 or Output 355 or Output 356 or Output 357 or Output 358
Start Plot Dump (Ethernet debug packets)	Output 359
Clear Stop Reason	Output 360
Axis 1 Jog Positive	Output 361
Axis 1 Jog Negative	Output 362
Axis 2 Jog Positive	Output 363
Axis 2 Jog Negative	Output 364
Axis 3 Jog Positive	Output 365
Axis 3 Jog Negative	Output 366
Axis 4 Jog Positive	Output 367
Axis 4 Jog Negative	Output 368
Axis 5 Jog Positive	Output 369
Axis 5 Jog Negative	Output 370
Axis 6 Jog Positive	Output 371
Axis 6 Jog Negative	Output 372
Axis 7 Jog Positive	Output 373
Axis 7 Jog Negative	Output 374
Axis 8 Jog Positive	Output 375
Axis 8 Jog Negative	Output 376
Fast Jog	Output 377 low = slow jog, high = fast jog
Decel Bit	Output 378 cause mpu11 to decel and purge buffers until Clear Stall Error is set.
Enable Jogging	Output 380
Move Axis 1 to index pulse positive	Output 381

Move Axis 1 to index pulse negative	Output 382
Move Axis 2 to index pulse positive	Output 383
Move Axis 2 to index pulse negative	Output 384
Move Axis 3 to index pulse positive	Output 385
Move Axis 3 to index pulse negative	Output 386
Move Axis 4 to index pulse positive	Output 387
Move Axis 4 to index pulse negative	Output 388
Move Axis 5 to index pulse positive	Output 389
Move Axis 5 to index pulse negative	Output 390
Move Axis 6 to index pulse positive	Output 391
Move Axis 6 to index pulse negative	Output 392
Move Axis 7 to index pulse positive	Output 393
Move Axis 7 to index pulse negative	Output 394
Move Axis 8 to index pulse positive	Output 395
Move Axis 8 to index pulse negative	Output 396
Set Axis 1 Home	Output 397
Set Axis 2 Home	Output 398
Set Axis 3 Home	Output 399
Set Axis 4 Home	Output 400
Set Axis 5 Home	Output 401
Set Axis 6 Home	Output 402
Set Axis 7 Home	Output 403
Set Axis 8 Home	Output 404
Gather/Drag Axis Bit 0	Output 405 These 3 bits define the axis number (0-7)
Gather/Drag Axis Bit 1	Output 406 for the gather.
Gather/Drag Axis Bit 2	Output 407 Bit 0 is the least significant bit
Start Gather Dump	Output 408 (starts a Binary dump of data)
Allow jogging even if MDI window has focus (special for homing and other macros)	Output 440
Ignore Following and Full Power w/o Motion Errors. This also causes the Ajax Limit Handling brain to ignore limit switches.	Output 441
Enable Probe Detection / Position Event Capture	Output 442 (Plugin Resets after receiving captured positions)
Local Outputs (Mpu11 Onboard Outputs)	481-512
Jog Panel Outputs	768-1023

7.3 Ajax Mpu11 On-board I/O Reference

The Ajax Mpu11 board has built in inputs and outputs which are mapped to the following ModBus I/O. The first four inputs are probing inputs which are connected via the probe connector. The MPG I/O are connected via the mpg encoder connector. Any I/0 not shown in this chart is unimplemented.

Input Specification			Input Location	
ModBus Input Number	Function	Type	Connector	Pin
481	Mechanical Probe	12VDC Opto	H3	6
482	DSP Probe	12VDC Opto	H3	4
483	Probe Detect	12VDC Opto	H3	8
484	Probe Auxiliary	12VDC Opto	H3	10
485	MPG x1	5VDC	H4	9
486	MPG x10	5VDC	H4	11
487	MPG x100	5VDC	H4	13
488	MPG Axis 1	5VDC	H4	4
489	MPG Axis 2	5VDC	H4	6
490	MPG Axis 3	5VDC	H4	8
491	MPG Axis 4	5VDC	H4	10
492	MPG Axis 5	5VDC	H4	12
493	MPG Axis 6	5VDC	H4	14
494	MPG Axis 7	5VDC	H4	16
495	MPG Axis 8	5VDC	H4	18
496	MPG Aux 1	5VDC	H4	15
497	MPG Aux 2	5VDC	H4	20
498	MPG Aux 3	5VDC	H4	22

Output Specification			Output Location	
ModBus Output Number	Function	Type	Connector	Pin
481	MPG LED	Open Collector	H4	17
482	MPG Aux 1	Open Collector	H4	19
483	MPG Aux 2	Open Collector	H4	21

*Open Collector outputs are pulled up to 5V

*5 VDC inputs are not isolated

7.4 Debounce Settings

Starting in version 1.10, All inputs, on all PLC bus devices and add on boards, the jog pendent, and the on-board Ajax Mpu11 inputs have a 1.5 millisecond debounce time, except the DSP Probe input, input 482. Input 482 has a debounce time of 0 milliseconds. In other words, there is no debounce time for input 482.

7.5 Control Pendant Reference

The control pendant offered by Ajax CNC interfaces with Mach3 through the following ModBus Input and Output values.

768 **Spindle+**	**769** **Spindle Auto/Man**	**770** **Aux 1**	**771** **Aux 2**	**772** **Aux 3**
773 **Spindle 100%**	**774** **Spindle CW**	**775** **Aux 4**	**776** **Aux 5**	**777** **Aux 6**
778 **Spindle -**	**779** **Spindle CCW**	**780** **Aux 7**	**781** **Aux 8**	**782** **Aux 9**
783 **Spindle Stop**	**784** **Spindle Start**	**785**	**786**	**787**
788 **Coolant Auto/Man**	**789** **Flood**	**790** **Mist**	**791**	**792**
793 **Incr/Cont**	**794** **x1**	**795** **x10**	**796** **x100**	**797** **MPG**
798 **4th +**	**799**	**800** **Y +**	**801**	**802** **Z +**
803	**804** **X -**	**805** **Slow/Fast**	**806** **X +**	**807**
808 **4th -**	**809**	**810** **Y -**	**811**	**812** **Z -**
813 **Cycle Cancel**	**814** **Single Block**	**815** **Tool Check**	**816** **Feed Hold**	**817** **Cycle Start**

NOTE: The default brains for the control pendant use outputs 785, 786, 787, 799, 801, 803 and 809 to hold temporary state values.