## Motor Tuning Instructions

<u>Before you begin tuning:</u>
1. Make sure Pro-Motion is installed.
2. Hook up motor drive, motor, and computer.
    -   Connect motor drive to computer using a USB to Serial Com Port. Make sure there is power to   the motor drive.
    -   Install motor so that it is tuned using the same load as during normal operation.
    -   Plug motor drive cables into connectors on motor, encoder, and brake.
3. Apply 24V DC to defeat the brake. When the brake is defeated, the knob on the front will turn freely.
4. Open Pro-Motion
    -   If the Interface Dialogue box (below) appears, select COM port and the corresponding port number.
        o   Port number can be determined through Control Panel ->System ->Hardware tab -> Device Manager -> Ports
        o   If Pro-Motion cannot establish a connection to the port and the device is working properly, try a different USB port.
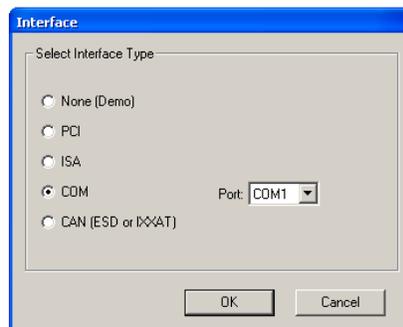
    -   Clicking OK will bring up the Serial port dialogue box. Correct settings are Baud: 57600, Parity: None, Stop bits: 1, Protocol: Point to point, and Address: 0.
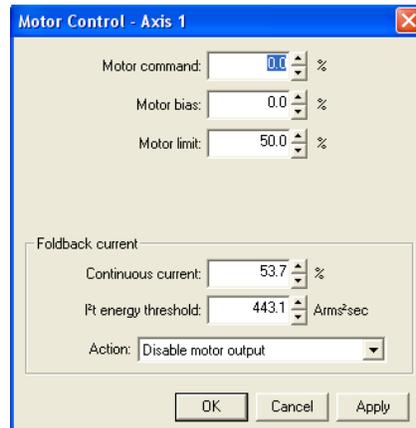

5. Turn off limit switches.
    -   In the Control window, click Limit Switches.
    -   Check the Invert box next to both limits. Click Apply.
   -   The circles next to Positive and Negative should be open/white. Click OK.

6. Limit maximum motor power to 50%.
   - Click Motor Control.
   - Set Motor Limit to 50.0%. Click Apply.
   - Click OK.

Tuning using the Axis Wizard
1. If an error occurs or the emergency stop is initiated at any point during tuning, the axis wizard will be interrupted. You may need to start from the beginning of the Axis Wizard.
   - Check that the break is defeated, limit switches are disabled, and the motor power is set to 50.0%.
   - Begin again at step 2 in Tuning using the Axis Wizard.
2. In Pro-Motion, select Axis1 in the Project window. Click on AXIS WIZARD in the toolbar at the top of the Pro-Motion window.
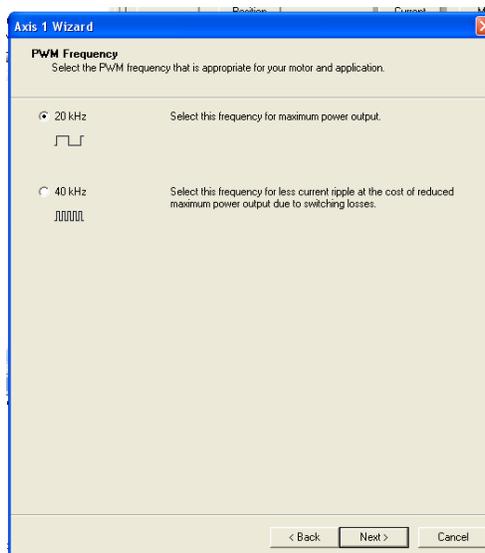3. Click Next to continue.
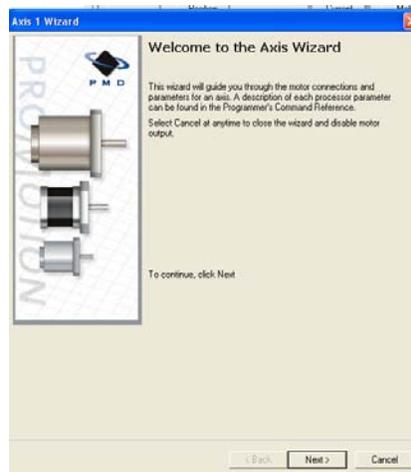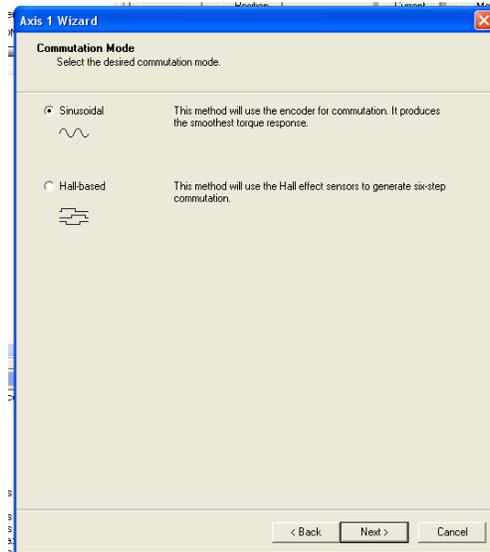
4. Select Incremental. Click Next.
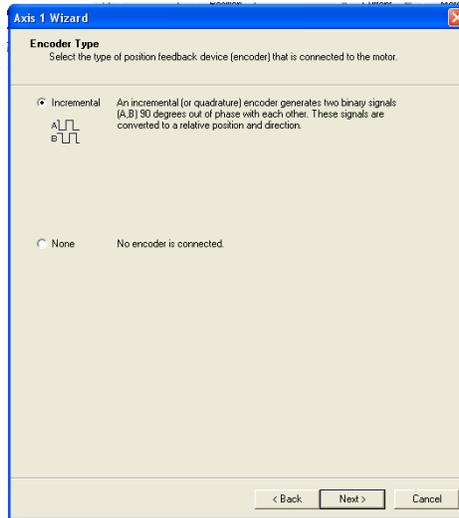
5. Do not invert the signal. Test that the motor is connected properly by turning the knob on the front of the motor clockwise and counterclockwise.
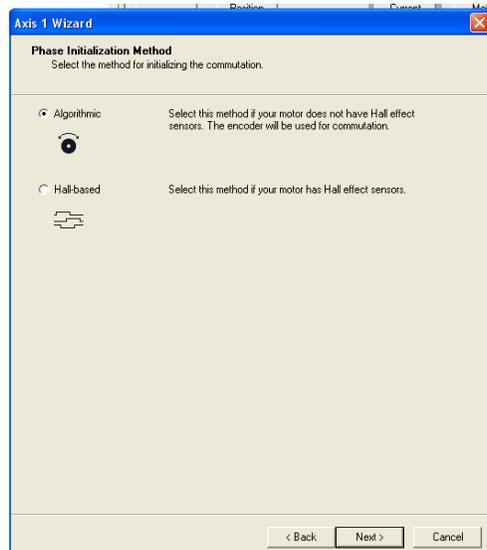   - The Actual position counts in the window should change. Click Next.
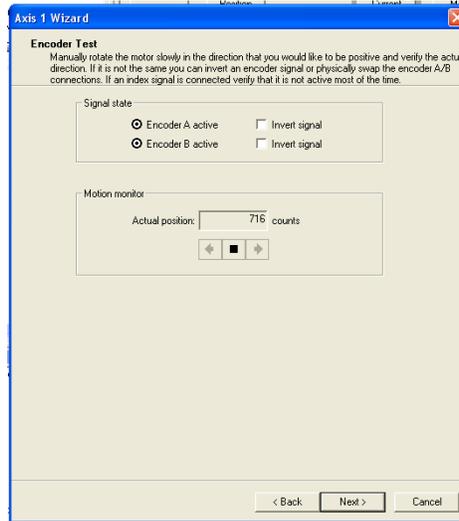
6. Select 20 kHz. Click Next.

7. Select Sinusoidal. Click Next.


8. Select Algorithmic. Click Next.

9. Set Motor output level to 10-15%, Phase initialization time to 10.0 sec, and Phase counts to 1200 counts. Click Initialize phasing!.
   - The wheel on the motor should move slightly in one direction, pause, and return to its initial position. If the wheel does not move, try increasing the motor output level.
   - When Status is Completed*, click Next.
     o *Note: Status will be Completed when the time runs out even if the wheel never moved. Only click Next if the wheel moved.
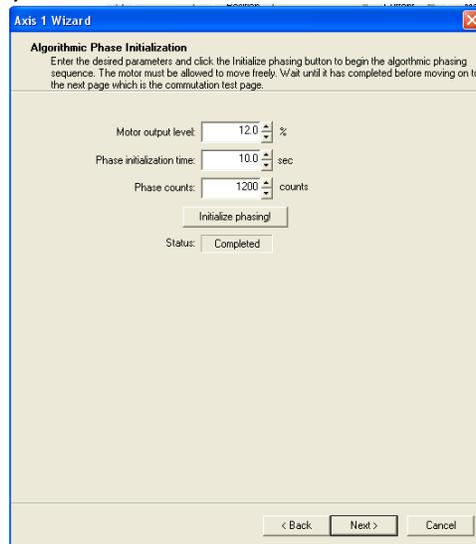
10. Check Enable and Invert index signal in the Phase correction box. Click the forward arrow, stop button, back arrow, and the stop button again. Be careful to click the stop button before the motion axis extends beyond its limit.
    - The motion axis should move in one direction, stop and reverse its direction. The wheel on the motor should spin quickly.
    - If the axis does not move, or the wheel spins slowly, increase motor output level up to 15%.
    - Click Next.
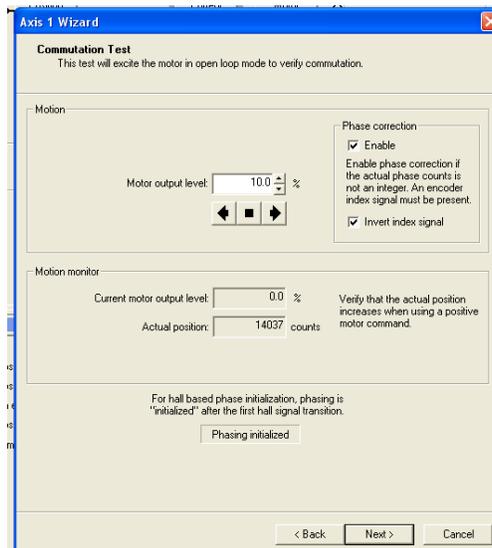
11. Select Field-oriented control. Click Next.
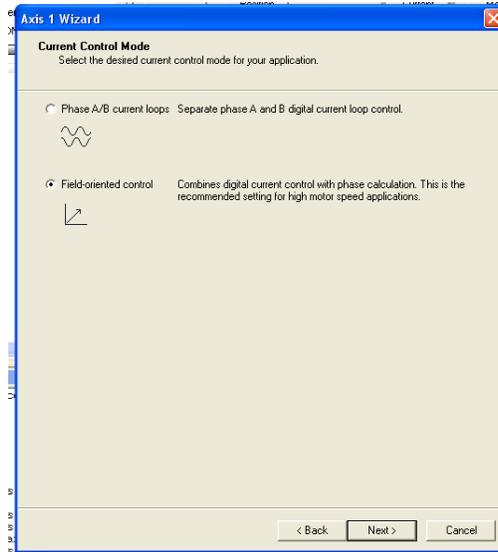

12. Change Rated motor continuous current to 8.0 Amps, Phase margin to 1.0 Radians, and Constraint on Kp to 2000. Click Start!.
    - The motor will emit high-pitched tones and beeps as it tunes. Repeat the tuning process (by clicking Start!) several times until a consistent set of Kp and Ki is produced.
    - Every motor will give a slightly different set of numbers. Click Next to continue.
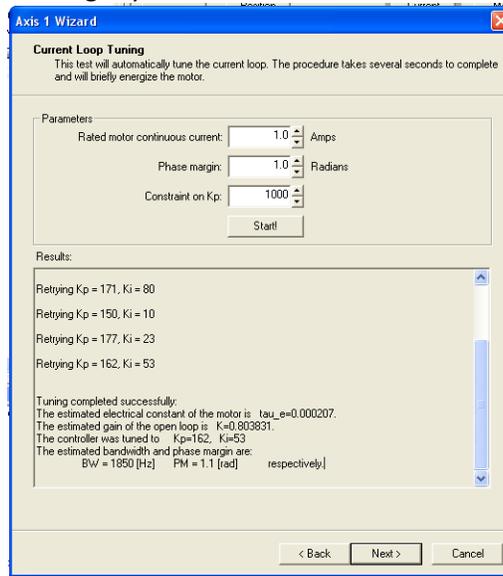
13. Step 1: Analyze system response. Set step distance to 1700-3600 counts. (One loop is ~3600 counts). Click Start.
    - The motion axis will move and then oscillate back and forth. It is completed when the motion axis stops moving and it says 'Analysis completed successfully'.
    - If the analysis is interrupted or aborted try it again or go back and repeat earlier steps in the wizard.
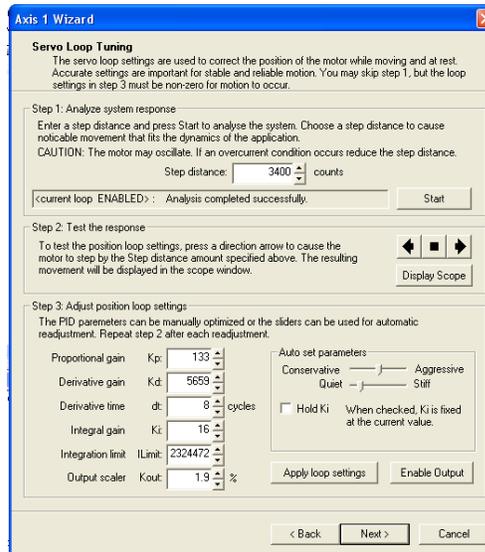
14. Step 2: Test the response. Click Display Scope. Click the forward arrow.
    - It may take awhile for the position to "settle" or the position may oscillate. It is ok to click the stop button to end the test.
    - Stiff is how resistant the motor is to change in motion. Aggressive is how much force the motor uses (less aggressive is likely to result in under damped motion, highly aggressive will result in ringing.)
    - The integration limit sets the allowable accumulated error. When the integration limit is reached, the motor tries to find the target again.
    - Otherwise, if the motor is within +/- 50 counts of the target position for longer than 0.5 second, it is considered "settled" and in position.
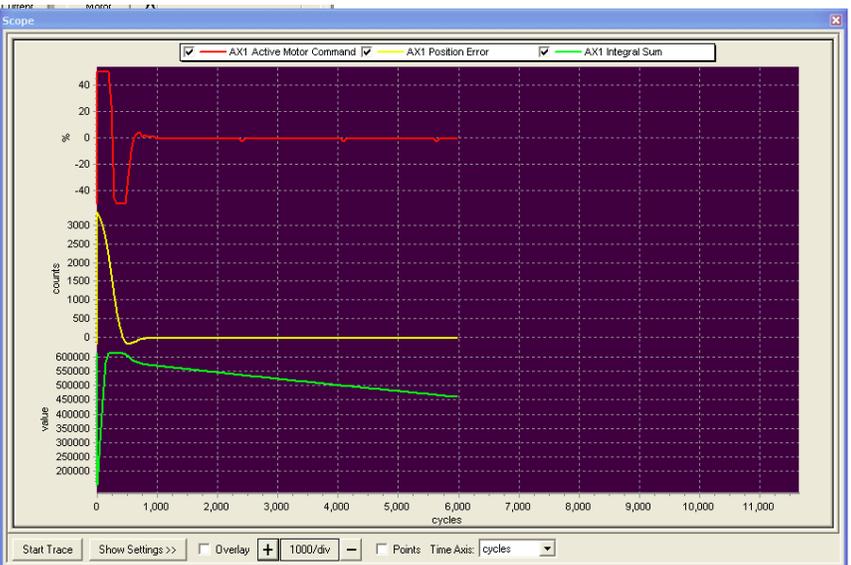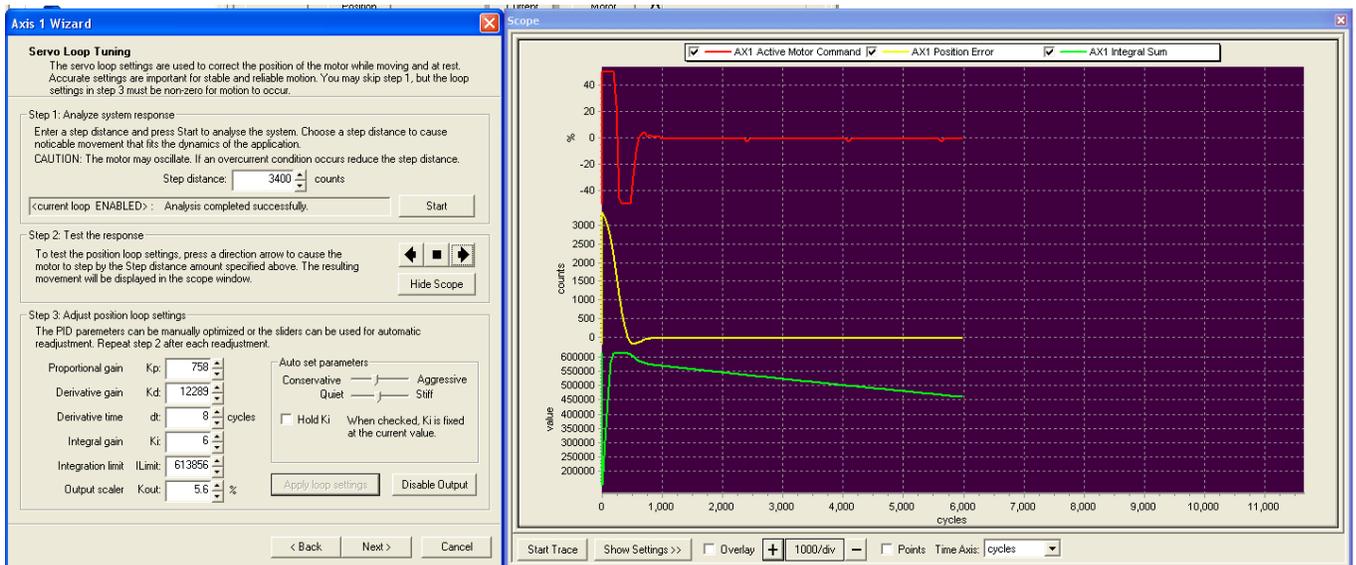
15. Step 3: Adjust position loop settings.
    - It is easiest to adjust position loop settings using the sliding bars in the Auto set parameters box.
    - This step requires slowly adjusting and testing parameters to find smooth, quick motion. See the image below for an example of good motion.
        o Achieving the target quickly (<1000 counts), over-shooting slightly, settling quickly, and a relatively horizontal integral sum are all qualities that should be achieved before moving on.
   o The Active Motor Command may saturate at some points. Brief saturation is ok. If it saturates longer than the image above, reduce aggressiveness.
        o On the next page is a zoomed-in look at good, smooth motion.
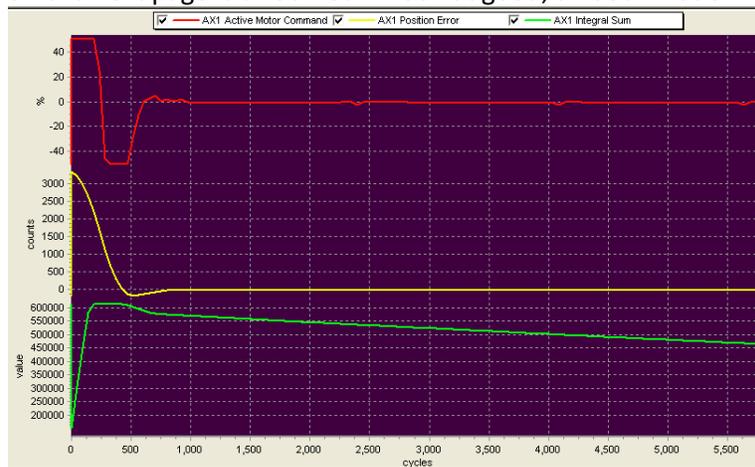
16. A note about under-damped, over-damped and critically damped motion.
    - Under damped is most useful in situations where milliseconds variation in speed make a difference.
    - Over damped is useful in situations when you are not allowed to overshoot or go past the target. Greatly under damped motion can result in 'ringing' or oscillation around the target.
    - Critically damped motion reaches the target without over-shooting but does not reach the target (within allowable error) as quickly as under-damped motion.
    - For RSS-NIR, the motion needs to be accurate, but it does not need to be exceedingly fast.
    -
17. Select Index. Click Next.
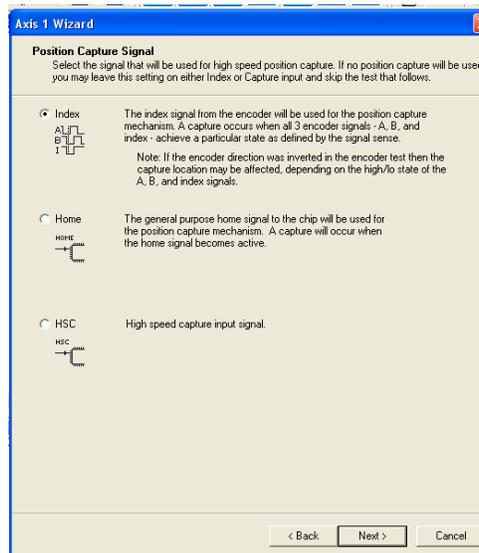
18. Encoder index signal test.
    - Check Invert signal.
    - Change Velocity to 100 counts/sec. Click forward arrow.
    - Capture received will appear in black when the motor has made one full revolution (~3600 counts). Click reset and check that a capture is received every full revolution.
    - Reverse the motion and check that a capture is received at the same locations as during forward motion.
        o The Encoder Index Signal Test is completed when the Capture events are consistent and repeatable.
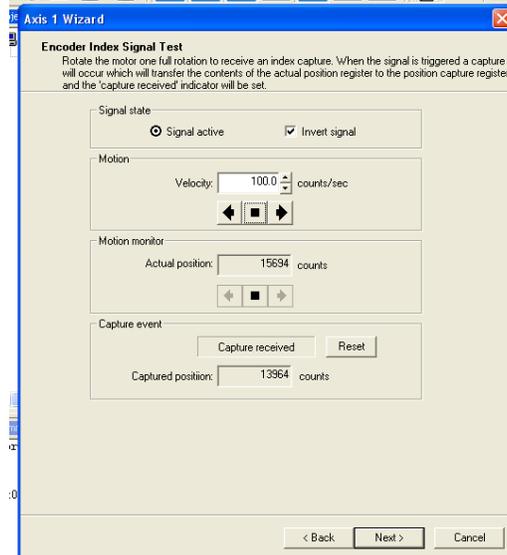
19. Skip Positive Limit Switch Test. Click Next to continue.
20. Skip Negative Limit Switch Test. Click Next to continue.
21. You've completed the Axis Wizard. Click Finish to exit the wizard.
    - Go on to the next section: Test the Trajectory.
    - Whenever you stop tuning and step away from the test area, be sure to un-defeat the brake, and disable the motor and/or turn off the motor drive.
        o The motor can be disabled by clicking Operating Mode in the Control window in Pro-Motion.
        o Click Disable All. Click Apply.
22. Save your current project so that all numbers can be retrieved.
    - The necessary numbers can be obtained by clicking on Position Loop and Current Loop in the Control window in Pro-Motion.

<u>Testing the Trajectory</u>
1. Click Trajectory in the Control window of the main screen of Pro-Motion.
2. Move axis to the beginning of its trajectory.
   - In the Profile mode drop-down menu, select S-curve.
   - Set Jerk to 10^6, Acceleration to 10^5, and Velocity to 5^4
   - In the Shuffle mode, select Single move. Adjust Position 1 and click Go to move the axis to a good starting position.

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Trajectory - ION 500 :  Axis 1

                    Profile mode:  S-curve          ▼
   ┌ Trajectory parameters ─────────────────────────────┐
   │                         Jerk:    1000000 ▲  counts/sec³ │
   │                 Acceleration:     100000 ▲  counts/sec² │
   │                     Velocity:     50000.0 ▲  counts/sec │
   │                                                    │
   └────────────────────────────────────────────────┘
   ┌ Motion ───────────────────────────────────────────┐
   │ ┌ Shuttle mode ─┐                                  │
   │ │ ⦿ Single move │  Position 1:    -24000 ▲  counts  │
   │ │ ○ Manual      │   ⟮▭⟯-        Go               │
   │ │ ○ Automatic   │                                  │
   │ └───────────────┘                                  │
   └────────────────────────────────────────────────┘
                                          Close
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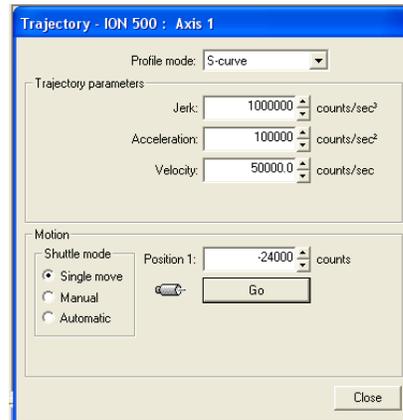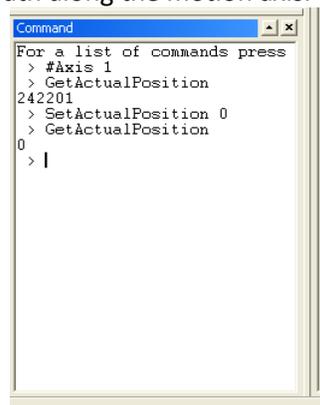
3. Use the command line to change the Current Actual Position [counts].
   - Click on the CMD button on the toolbar in the top of Pro-Motion to get the command window.
   - Use the commands GetActualPosition and SetActualPosition *pos*, where *pos* is a number, to help set up a repeatable path along the motion axis.

```
Command                        ▲ ×
For a list of commands press
 > #Axis 1
 > GetActualPosition
242201
 > SetActualPosition 0
 > GetActualPosition
0
 > |
```

4. Find a long trajectory for the axis to traverse.
   - In the Trajectory window, select Manual.
   - Position 1 is *pos* determined in step 3. Position 2 can be positive or negative depending on which direction you would like the axis to move. Be careful not to command the axis to move beyond the axis' allowed range of motion; the limit switches are turned off.
   - Try to make the motion as long as possible/reasonable.
5. Set up an automatic, repeated trajectory.
   - Select Automatic in the Trajectory window.
   - Increase the pause to 1.0 sec.
   - Click Go.
   - Motion should be smooth, fluid, and stiff, i.e. insensitive to pushing/pulling/additional loads.
6. Analyze the position error, motor output, and velocity smoothness.
   - Click Scope in the toolbar at the top of Pro-Motion.
   - Click Show settings. Choose the fourth data-line to be Actual Velocity. Make the graph continuously buffered. Adjust the sample rate to be 2-15 counts.

- Push/pull on the motion axis (NOT on the motor wheel or motor itself). You should feel the motor adjust and push back. Active Motor Command will increase slightly; it should not increase significantly.
- Position error should be +/- 30 during normal operation and +/- 50 to +/-100 when being pushed.
   o If position error is too large, try increasing Kp and Ki (through clicking Position Loop in the Control window).
- The integral sum should be smooth. See below for examples of desirable results.
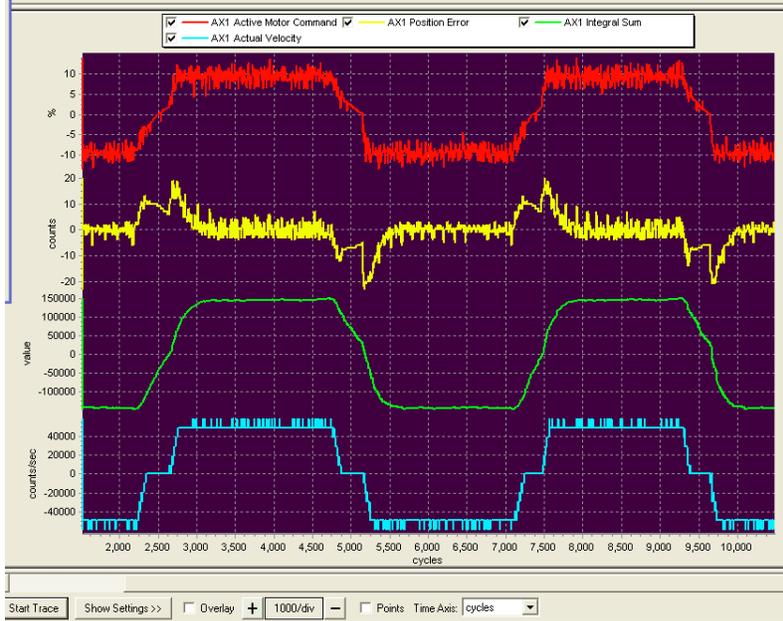
(Above) Normal Operation.
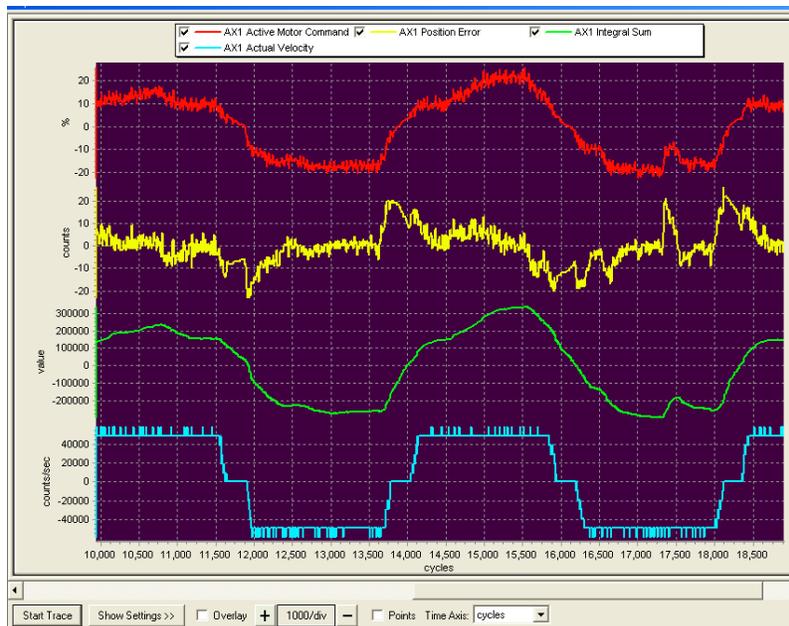
(Above) Operation under added stress.

7. Save any new changes made to the project.