



### Tech Note #3: Setting up a Servo Axis For Closed Loop Position Control

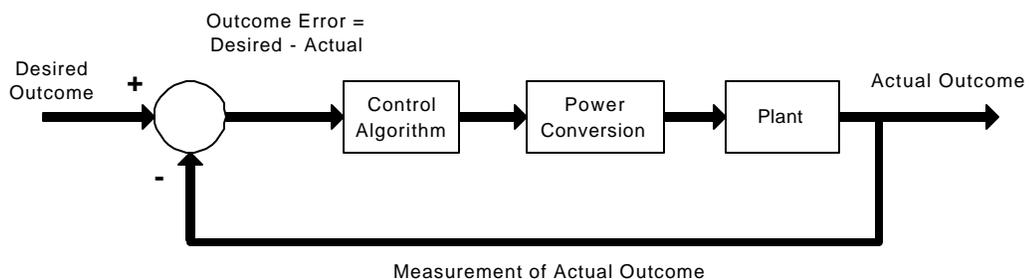
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September 10, 2001

#### Abstract:

In this Tech Note a procedure for setting up a servo axis for closed loop position control through an I<sup>2</sup>T Momentum motion module using the I<sup>2</sup>T Motion Controller Setup Software will be presented. This procedure assumes encoder feedback from the motor and the motor's drive setup as a torque amplifier. This document provides information on basic closed loop control in a servo system and setting an axis up, but does not walk the user through commissioning the axis with power. Refer to Tech notes 4 & 5 for commissioning and tuning a servo axis.

#### What is closed loop control?

Closed loop control is the act of producing a control signal that will reduce the difference between some desired outcome and the current outcome as derived from a measurement.

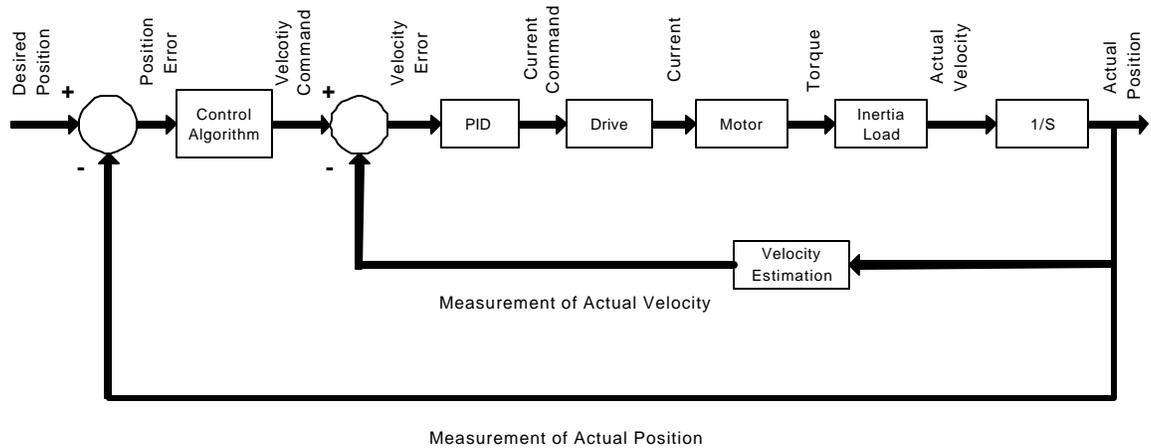


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For a servo axis the controller will close two loops with one wrapped around another. The inside loop regulates the velocity of the axis while the outside loop regulates the position of the axis. This configuration is referred to as cascaded control.



Defining the components in a closed loop servo axis

Control Variables:

For a servo system there are two outcomes, namely axis position and velocity. The velocity command is derived as the derivative of the position command.

Feedback:

The measurement of position comes from the incremental change in the axis's encoder from some defined starting point.

The velocity measurement comes from the difference of the current position and previous position divided by the sample time of the control loop.

Control Signal:

The produced control signal is an analog signal that is proportional to the required torque to reduce the difference in the control variables at a rate defined by the axis tuning.

What is the encoder?

The encoder provides a digital signal that indicates incremental movement and the direction of the movement. When the axis moves the encoder will produce a square wave pattern with each cycle of the square wave

indicating some defined incremental distance traveled by the axis and the frequency of the square wave indicating the speed of the axis.

What is a torque amplifier?

A motor's drive can be set to operate differently depending on the needs of the application. The most common methods are to set the drive to operate in either velocity or torque mode. In this application the drive should be set in Torque, or current mode, which means that the drive will produce a current that is proportional to the analog input, provided from the motion controller. This current will then produce a torque in the motor that is proportional to the motor's torque constant. Torque constant defines the amount of torque a motor will produce for a given current. So, from the perspective of the motion controller the analog output produces a proportional torque output from the motor.

## Setting the axis up on the motion controller

This section assumes that the motion control module has powered applied to it and that the I<sup>2</sup>T Motion Controller Setup Software has been installed. Run the I<sup>2</sup>T Motion Controller Setup Software and connect to a module.

### Set the Operational mode for the axis

The operational mode for the axis instructs the motion controller what type of control laws it will use to control the motor. Under the label *Setup Module* select the *PID* option. This will open a setup dialogue box titled **PID Setup – Axis 1**. To select Axis 2 click on the *Next Axis button*.

Available PID setup modes are dependent on the module that the software is connected to. For instance an IFC 220E allows an axis to be setup in either torque or velocity mode. The selection of these modes depends on how the motor's drive is configured to operate. In this application the drive should be configured to operate in Torque mode, therefore, select the *Motion Torque Mode* button, press the *SET button* and close the dialogues box. **Warning: If you are unsure of the mode that the drive is configured to operate in then refer to the drive's setup manual as improper setup can result in equipment damage or injury.**

### Limit the maximum torque output of the motor via an analog output clamp

Depending on the application and the mechanics it may be desirable to limit the maximum torque output that the drive and motor combination can produce. This can easily be accomplished by clamping the analog output from the motion controller to the drive, which acts as the torque reference. Under the label *Setup Module* select the *Analog Outputs* option. This will open a setup dialogue box titled **An. Out. Setup – Axis 1**. To select Axis 2 click on the *Next Axis button*.

This setup dialogue box provides the ability to clamp either the minimum or maximum torque reference from the controller. When the controller is in torque mode both zero offset and fault level should remain set at 8192 which corresponds to an analog output of 0 volts. Note that the values numbers used in this section apply to the Momentum IFC 220E motion controller and may be different on other controllers depending on analog output resolution.

To decrease the magnitude of the allowed negative torque increase the value next to *Minimum* up to a maximum of 8192. Setting this value to 8192 would result in the axis not having any negative torque while setting this value to 4096 would result in the axis having 50% of its available negative torque. Default value of 0 allows 100% negative torque.

To decrease the magnitude of the allowed positive torque decrease the value next to *Maximum* down to a minimum of 8192. Setting this value to 8192 would result in the axis not having any positive torque while setting this value to 12288 would result in the axis having 50% of its available positive torque. Default value of 16380 allows 100% positive torque.

**-\*SAFETY TIP\*-**

During initial power up of an axis it is, sometimes, desirable to clamp the allowed torque for the axis in both directions to a very low level, i.e. On an IFC 220E Setting minimum = 7373 and maximum = 9011 will allow only 10% maximum torque. This will minimize the potential for damage to equipment in the event of a wiring error resulting in a control logic polarity error. A control logic polarity error occurs when a position error produces a torque command that results in the position error growing rather than decreasing. The controller will quickly ramp the torque reference up to the clamp level until a position fault occurs. If this situation occurs then use the Reverse Output check box on the PID setup dialogues box or the Reverse Encoder check box on the axis setup dialogues box. These check boxes will reverse the control polarity resolving this issue.

**-\*CAUTION\*-**

Caution should be exercised when changing and/or checking the control polarity from the controller to the drive as enabling an axis with the incorrect control polarity will result in the motor producing 100% of its available torque, as defined by the analog clamp, immediately.

**Set the axis position user units**

The use of the Gear ratio command on the *AXIS setup dialogue box* sets a conversion factor for converting encoder counts to User units. These user units can be in any form that allows the displayed axis position and velocity to be more intuitive to the application. For example, a rotary application may want to display axis position in degrees, or a linear application may want to display position in thousands of an inch. The choice of the user units should be dependent on the application and the required resolution. Appendix A in the Module's *User's Guide* provides examples of how to set up the user units.

There are two steps to setting the axis position user units:

1. Enter the number of encoder pulses per revolution of the motor
2. Enter a conversion number in Gear Ratio to achieve the desired user units

Step 1 of this process requires that the number of quadrature encoder counts per motor revolution be entered under encoder settings. The

number of quadrature counts from an encoder is 4 times the line resolution of the encoder.

Step 2 of this process requires determination of the desired user units and display resolution. A Gear Ratio of 1 will produce a position feedback of 1.000 on the HMI, or a value of 1000 when read from a PLC.

Example:

If the axis is connected to a rotary load through a ratio 2:1 gearbox and the desired resolution is a hundredth of a degree then the gear ratio is calculated as follows:

User Units per Load revolution / Gear Ratio \* 1000, so

36,000 units per Load revolution / 2 \* 1000,

providing a Gear Ratio of 1.8. This indicates that for every full revolution of the motor the load will move 180 degrees with a value that can be read from the PLC of 18000. Appendix A in the Module's *User's Guide* provides examples of how to set up the user units.

### **Set the axis user unit's rollover position**

The use of the Rollover command on the *AXIS setup dialogue box* sets a positional value that will result in the displayed axis position resetting to zero. This can be very useful in applications where the angular position of the load must be known independent of the number of revolutions. For example, if the User Units produce 360.00 degrees per revolution, or as displayed on the HMI 36.000 user units per revolution then setting the rollover to 36 will result in the absolute position of the load always being displayed. An added benefit of the rollover function is that the displayed position will never be a negative number, because if the position drops below 0 the displayed position will wrap around to the rollover number.

Example:

If the rollover is set to a value of 36 and the axis moves 100 user units below zero then the displayed position will be 35.900 user units.

### **Set the Axis Speed Units**

The axis speed units allows axis velocity, that the PLC will read, to be converted to a form that is more intuitive based on the application. Only integer values are returned from this setting. This setting is located on the *AXIS setup dialogue box*.

Example:

From the above examples we set the user units to display degrees of the load position in hundredths of a degree resolution, as read from the PLC. On the HMI display 100 degrees would have the

following value displayed 10.000. So, setting the Speed Units to UU/min and running the load at 360 degrees per minute will produce an integer velocity of 36 UU/min. To maximized resolution is required then set this value to counts/sec, and perform any necessary conversions in the PLC.

### **Set a limit to the time a system will produce high torque**

Servo systems are rated to produce a continuous level of torque without overheating the motor and drive. However, this level is usually exceeded during acceleration of the load for short durations of time. In the event that a servo system is producing torque over its continuous rating for long periods of time this can result in the motor and drive overheating. To prevent this from happening the I2T controller provides the ability to set a specific current that the control will generate a fault on if exceeded for a set period of time. The settings for this are located on the *Tuning dialogue box* through *Current Limit (Avg)* and *Current Limit Time*.

The way these settings work is that the controller will also calculate an average current request to the drive. If this average exceeds the set *Current Limit (Avg)* for the set *Current Limit Time* a fault will be issued. Faults from these settings may indicate an undersized motor, a mechanical power transmission problem, a mechanical jam, or a drive fault.

This completes the setup procedure required to set an axis up for closed loop position control from the module. The final step in commissioning the axis prior to application programming is to tune the axis to achieve the desired performance level. I<sup>2</sup>T provides a tuning tech note that may provide some assistance into this procedure.