Application Note #5424

Connecting a Copley Controls Digital Servo Amplifier to a Galil Controller

This application note discusses connection and control of a Galil motion controller with the Copley Controls digital servo drive and brushless motor. The Galil used for this note was a DMC-1780 controller with the ICM-1900 interconnect module, although any Galil controller would work for this application. The specific drive used for this application note is the Model 7228AC digital drive with the brushless motor CBL232BE-001. Copley Controls Corp. may be reached at (781) 329-8200 (www.copleycontrols.com).

The Copley Motion Explorer software was used for setting up the drive parameters. This software is used to select the operation mode of the drive, as well as to set tuning and safety parameters for your system. The drive may be configured for one of four control modes: torque, position, velocity or digital position. The torque mode closes a current loop around an external +/-10V analog reference signal. The position mode again closes a positional loop but this mode is based on an internal command signal or through the Copley 7XX8 Pendant. The velocity mode closes a velocity and current loop around a +/-10V analog reference signal. The digital position mode accepts an external pulse/direction or encoder input to command the internal Copley positional loop. The Galil controller can control this drive in three of these configurations; torque mode, velocity mode and digital position mode. This application note outlines the hardware connections necessary for these modes of control, as well as giving some technical tips for proper operation. The assumption is made that the Copley amplifier has been properly configured for the necessary safety and protection parameters, as well as for proper set up of phase initialization.

Torque Mode Control connections:
In this mode, the controller provides a +/-10V signal to the amplifier and closes a servo loop around the motor encoder. The Copley Motion Explorer software should be used to set the drive into torque mode. Under the heading Operating Mode, select "+/-10V->Torque" for the external reference torque mode. The single ended +/-10V analog output (MOCMDX) from the controller will connect directly to the - Reference of the Copley. The + Reference signal is then connected to the Signal Ground (GND) of the amplifier. The Motion Explorer software allows the user to select either a high or low TTL enable signal. If you are using a standard ICM-1900 or ICM-2900 with the 7407 high enable IC, select the appropriate high enable box in the Motion Explorer software. A schematic of the hardware connections is found below. In this torque mode, the PI current loop of the amplifier will have to be tuned in addition to the PID loop of the controller. Notes on this may be found in the Performance section of this application note.

Velocity Mode Control connections:

Hardware connections in this mode are identical to the torque mode. The only differences in setting up the system for the external reference velocity mode is in the Motion Explorer software. In this software under the heading Operating Mode, select "+/-10V[Pos->Torque]" for the external reference velocity signal. Next, under the Profiles heading in the Motion Profile section, select the "Velocity" option. In this velocity mode, both the PI current loop and the PID positional loop are active. Once these loops are properly tuned, the PID loop of the controller must also be tuned. Notes on the velocity loop tuning may be found in the Performance section of this application note. Hardware connections for this mode are found below.

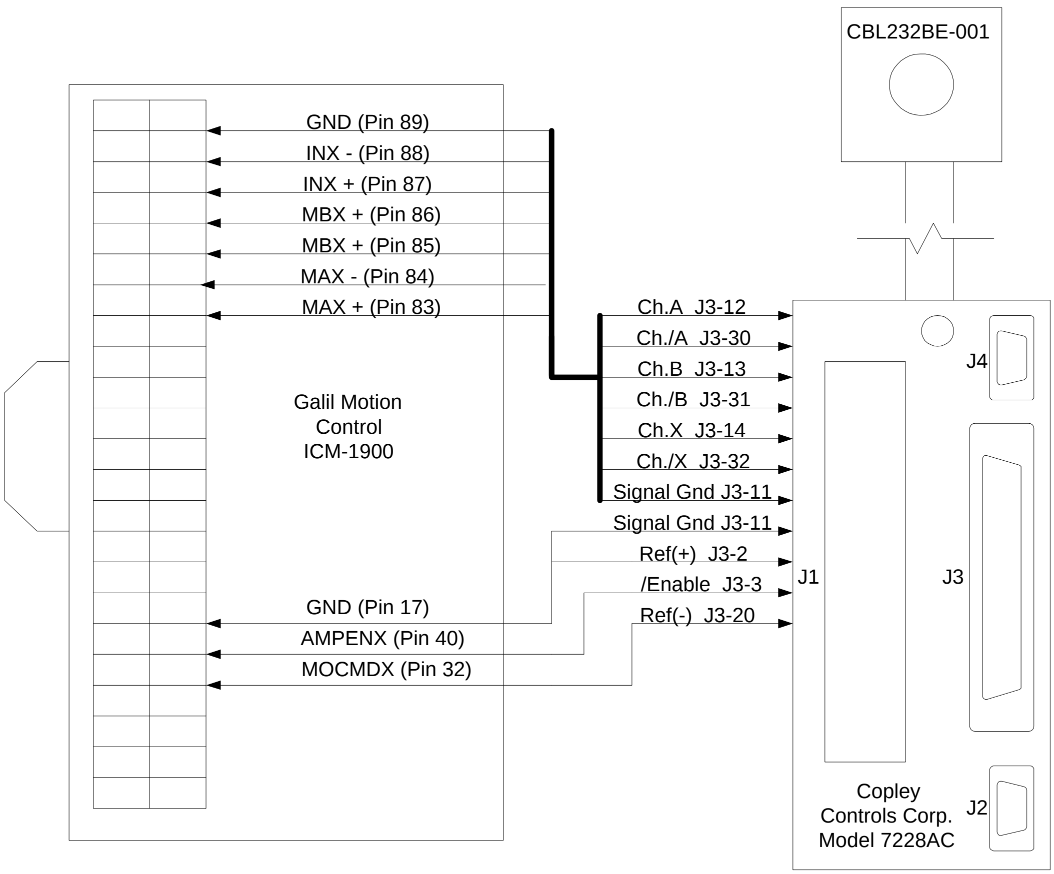

Figure 1: Basic hardware configuration for torque and velocity modes

Position Mode Control connections:

In this mode, the controller provides step and direction signals to the amplifier, allowing the amplifier to close its own PID position loop and PI current loop. The Galil controller must be set up in the stepper mode, with the appropriate SM jumpers and MT command issued through software. For hardware connections, the single-ended Step output from the controller connects to the Ch.A input (J3-17), while the single-ended Direction output from controller connects to the Ch.B input (J3-18). The enable setup is identical to the torque and velocity modes. The encoder output may still be connected to the main encoder input on the Galil, but this is not necessary for operation. A connection diagram may be found following this section.

There are three changes that must be made to the Motion Explorer software in order to set the Copley up for digital position mode. First, the “Pos->Torque” option must be selected from the Operating Mode section of the software. Next, under the Motion Profile section, you must also select “Gear” from the Profile heading. And finally, from the Digital Position Input section, select “Pls/Dir” as the input source. For initial testing, the Gear Ratio was set to 1, although this may be changed to best suit the specific application.

The digital position mode is similar to the velocity loop in that both the PI current loop must be tuned on the drive, as well as the PID positional loop. Since the controller is running in an open loop stepper mode, no tuning of the controller is necessary. Contact Copley Controls for assistance in tuning these two loops.

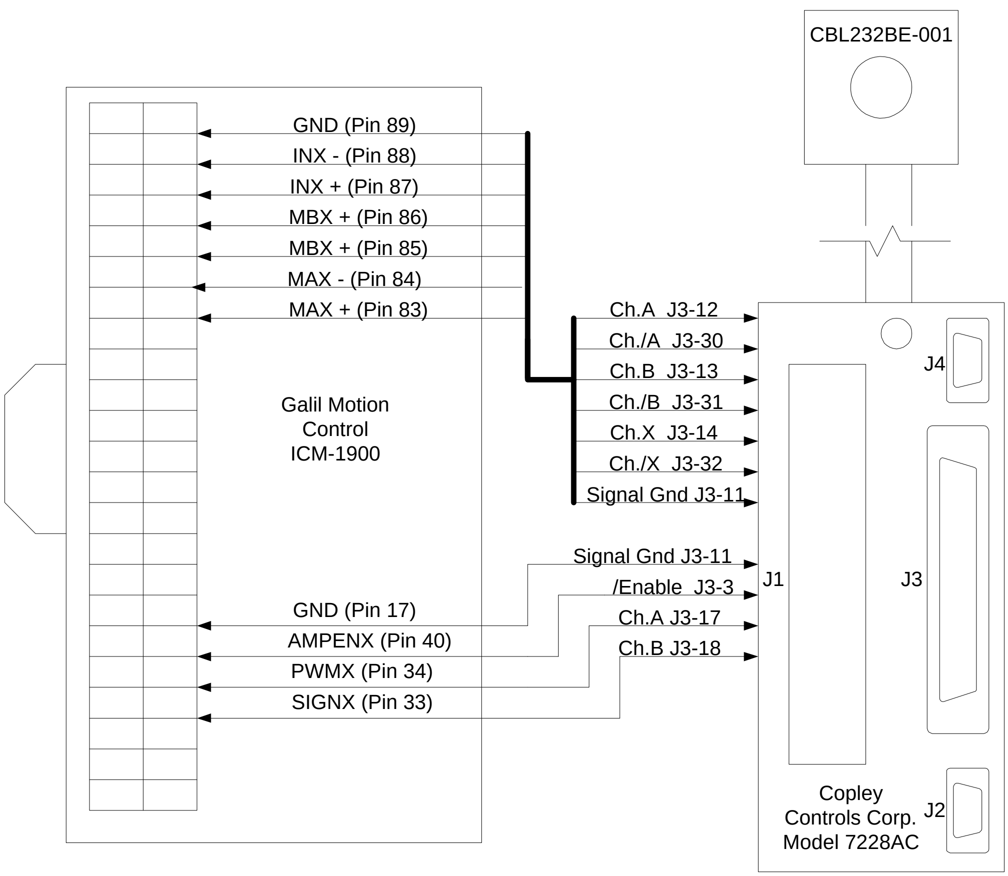

Figure 2: Basic hardware configuration for digital position mode

Hardware Notes
All connections to the Galil controller may be made through the single J3 37-Pin D connector of the Copley digital drive. For other connections to the Copley drive, please refer to the Advanced Digital documentation. These schematics were based on an Optima series controller using the ICM-1900 interconnect module. If your setup differs from this, please consult your Galil Product Manual for the actual interconnect pin connections.

Performance Notes
The Copley Controls 7228AC has two filter loops that may be adjusted, a PI current loop and a PID positional loop. In addition to these loop gains are velocity feedforward, acceleration feedforward and integration limits. Which gains are active depends on the mode in which the drive is currently operating.

In the torque mode, the Copley digital drive has a single PI current loop for tuning. This loop is tuned for the specific motor and load combination. For this application note, the default PI drive gains were used. The Copley manual is helpful if these need to be adjusted for your system. In addition, the Motion Explorer software has a storage scope display that can be used to help tune the PI values of the drive. With these gains set, the Galil WSDK software was used to tune the PID loop of the controller. The best tuning parameters were found by simply using the Auto-Crossover Tuning test. This gave a fairly typical range of PID parameters, with the KD term about 10X larger than the KP, and the KP slightly larger than the KI. In addition, the sample period of the controller was lowered to a TM of 500 usec, which gave much better system responsiveness than the TM 1000 default. The General Tuning test also gave consistent results, with slightly more conservative values for the PID. Your specific system will determine which test should be used for optimum system performance. Contact an application engineer at Galil for assistance in tuning the Galil filter.

With the drive set to the velocity mode, the PI gains of the current loop as well as the PID gains of the positional loop are active. The PI gains were left at their default and again should be tuned to match the motor and load combo in your specific system. Once tuned, this velocity loop provided the best response of the three modes when connected with Galil. The PID could be adjusted in one of two ways; either with the Motion Explorer storage scope software or with the WSDK storage scope utility. For this application note, the testing and tuning were performed with the WSDK software.

The first step in tuning this system was to set the velocity reference for the drive, which is similar to a velocity gain. Under the Motion Profile section of the Motion Explorer software, the gain is set in the RPM Velocity box. This value scales the velocity of the motor to the voltage input from the +/-10V analog reference. There are also acceleration and deceleration times which can be adjusted and act as filters to the responsiveness of the command input. The velocity feedforward and acceleration feedforward gains were left to the Copley default.

The method used for tuning the velocity loop was to set controller PID gains to zero and issue an open loop voltage step response. Using the Storage Scopes, the velocity response of the motor could then be monitored. The PID gain of the Copley digital drive was then adjusted to provide a smooth, damped square wave output. With these amplifier gains set, the WSDK General or Auto-Tuning could then be used to tune the system for optimum performance. PID values in this configuration were typical of velocity loop systems, with zero-to-very low KD gains, and then standard KP and KI gains. Again, once tuned, this provided the best system response.

In the digital position mode, the controller is set up as a stepper, so there is no Galil tuning necessary. The Copley setup is nearly identical to the velocity loop, in that both the PI current loop and the PID positional loop are active. This filter could either be tuned with the Motion Explorer software and storage scopes, or with the WSDK software. In order to tune the system with the WSDK, the encoder output of the drive must be connected to the Galil ICM-1900. Using the WSDK for tuning, the best results in this mode were found by examining the results of a step response test. A very short step profile with high acceleration, deceleration and velocity will give a good idea of the stability of the motor. By viewing this actual encoder profile with the Storage Scope while adjusting the PID parameters of the drive through the Motion Explorer software, the correct, stable motor parameters can be determined.