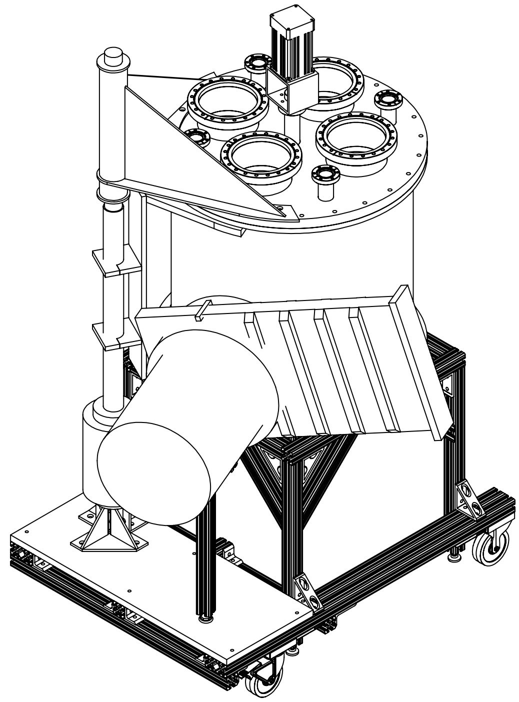
Automated Multilayer Fabrication

Hardware and Software Users Guide



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Cambridge, Massachusetts November 12, 2010

Abstract

This document will present information relating to the assembly, configuration and operation of the hardware and software systems necessary to successfully produce a variety of single and multilayer coatings on prototype and flight optics for use in X-ray observatories. The optics are produced using a technique called DC magnetron sputtering. The implementation of this technique is carried out inside three vacuum chambers present in Dr. Suzanne Romaine's Multilayer Fabrication Laboratory at the Harvard-Smithsonian Center for Astrophysics.

A WORK IN PROGRESS

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Ch. 1: Introduction

As with any piece of scientific equipment, an X-ray telescope is only as good as its worst component. Ideally, every component would be an exact physical reproduction of its theoretical design, and the instrument would be perfect. However, as the required tolerances for these components become smaller and smaller, it becomes easier to introduce error in the manufacturing process.

This manual shall concern itself with information and instructions relating to the correct assembly, configuration and operation of the hardware and software systems necessary to produce a telescope optic. The software and hardware systems developed and used in the Multilayer Lab exist to manufacture these optics while ensuring any error incurred during the process can be discounted as negligible.

When manufacturing an optic, the controlled deposition of materials on the surface of the optic is critical for minimizing and eliminating error. This is done through correct assembly, configuration and operation of the hardware and software systems outlined here. Material is deposited on the surface of an optic using a technique called DC magnetron sputtering, which is carried out inside three different vacuum chambers present in Dr. Suzanne Romaine's Multilayer Fabrication Laboratory at the Harvard-Smithsonian Center for Astrophysics.

The setup of the three vacuum chambers in the multilayer lab can produce many different shapes and types of optics. For instance, they can handle coatings done on a rat mandrel, on cylindrical hyperboloid shells, or simply on flat wafers of silicon commonly used in the semiconductor industry. Additionally, through the use of multiple cathodes, it is possible to control the deposition of many different types of material to achieve different optic characteristics. Due to the various shapes and sizes of these optics, many different algorithms are at work to make sure the substrate in the chamber is moved correctly to produce the expected coating.

1.1 Intro to DC magnetron sputtering

The core of this document will not deal with the underlying principles that explain why a multilayer or single layer coating on an optic is a good way of focusing X-rays. Instead, it will deal with the actions and operations necessary to produce an optic. It is therefore worth going over the high level technique being employed to precisely control deposition of material on to the surface of the optic. This technique is called DC magnetron sputtering.

DC magnetron sputtering starts out by utilizing a magnetron (an RF oscillator, similar to one found in a common microwave) to excite a material into a plasma state. The ultimate goal is to deposit the material on to the surface of a substrate (a substrate, once properly coated, becomes an optic). If the plasma were generated in open air, it would collide with air molecules and never get anywhere near the substrate and therefore never coat it. For this reason, the entire process is conducted inside of a vacuum chamber pumped down to several milli-torr.

By placing the material to be deposited at the cathode of the magnetron inside of the chamber under vacuum, it effectively creates a stream of plasma when the magnetron is turned on. This flow of plasma can then be used to coat an optic at a very precise and reliable deposition rate. Since it is not easy to adjust this rate or repeatedly turn on / off the cathode, mechanical shutters are used to block the flow of material, ultimately controlling whether or not deposition occurs. The shutters are simply pieces of stainless steel that exist in binary states of open or closed.

With the process outlined above, it is possible to control the deposition of material well enough to be accurate down to the angstrom level. With a controlled deposition process established, the next item of concern (and indeed why the software even exists) is controlling the movement of a substrate in and out of the plasma stream(s) to produce a particular style of coating useful for X-ray astronomy.

1.2 Hardware and Motion Control

The plasma stream out of the cathode has a fixed flux and therefore deposition rate that remain constant throughout the production of a single optic. The desired characteristics of an optic are such that it would be impossible to produce it simply by inserting it into the plasma stream, leaving it there for a certain amount of time, and then taking it out. Discrepancies such as the surface area of the optic being larger than the what the flux of the cathode can cover, desired material thicknesses not matching up exactly with deposition rates, and optic geometry in general mandate that some form of motion control be employed to ensure an even and accurate coating is produced on the surface of that substrate no matter what kind of characteristics are desired of the optic.

Typically, the rotary stage (also called a platen), and in some cases a rat mandrel are used to sweep or rotate the substrate around under the cathode to create a desired thickness as evenly as possible over the surface of an optic. The actual movements themselves are carried out by a motion controller, stepper drivers, and finally stepper motors attached to the platen or mandrel which in turn have substrates affixed to them. The exact nature of how both pieces of equipment move are governed by algorithms in the software.

1.3 LabVIEW and Software

The entirety of the software is written in the LabVIEW programming environment provided by National Instruments. LabVIEW is unique in that it is an entirely graphical language. Graphical programming offers several advantages, as well as disadvantages over traditional text based languages (C++, python, java, etc), but it has been tested throughly and is in suitable and working order for this particular application.

The software's ultimate function is to translate various parameters specified by the user into correct instructions to issue to the stepper motors. It is modularized into various sub-programs (VI's in LabVIEW terminology) to facilitate easy troubleshooting, maintenance, efficiency as well as making it very easy to additional functionality. It has sophisticated hardware abstraction, motion control algorithms, an easy and intuitive user interface, error checking, and features that make it easy for people unfamiliar with the nitty gritty details of the software to execute a run.

The latest iteration of the software is version 5.7, which is universal for all coating types and can be run on any chamber. Previous incarnations of the software only worked on a specific vacuum chamber or for a specific type of run. This was a nightmare any time a bug was discovered because a bug present in one version would often be present in another version, making it necessary to do the same fix over and over for each version to just to fix one bug. Now with version 5.7, the integration and code is much tighter. When version 5.7 was written, it was necessary to separate the application control VI's and hardware control VI's into discrete entities so they could be troubleshooted on their own, yet still function as part of a greater whole without the need for duplicate code.

Ch. 2: Hardware

The hardware portion of this manual will detail in depth the physical subsystems relevant to running the software to produce an optic. Many parts of the hardware architecture and even individual components, are custom. Most of the sections here deal entirely with electrical hardware. Information about structural related hardware (things like brackets, plates, clamps, etc.) is not presented here. Instead, information such as detailed engineering drawings can be found in the appendices.

2.1 Hardware Overview

All hardware instructions originate on the computer running the Automated Multilayer Fabrication software. Since the software is written in LabVIEW, this necessitates that the computer be running some version of the Windows operating system no older than Windows XP. For familiarity's sake, the computer in the lab set up to run this software is called 'Spectre', so the term 'Spectre' is synonymous with PC from here on out.

For the purposes of this application, any time a hardware instruction is issued from LabVIEW, it can go to either a motion controller or a shutter controller. The simpler of the two is the shutter controller, which is a custom component that uses a micro controller to open and close shutters on a chamber. The shutter controller actually fires solenoids, which then use compressed air to move rotary actuators on the chamber that rotate the shutters. There is one shutter controller for every vacuum chamber, and all are connected to Spectre through a USB hub.

The motion controller on the other hand is much more complicated. Essentially, the motion controller is an FPGA that sits on a PCI card inside of the computer. It can control four axes of stepper drivers, and is sufficient to control all chambers. When an instruction arrives from LabVIEW, the motion controller generates pulse trains that can be understood by the stepper drivers.

The stepper drivers are what send high current electricity to the phases of a stepper motor in the correct sequence to rotate it correctly based on signals coming from the motion controller. Each stepper drive controls one stepper motor. Since the pulse train coming from the motion controller is only for reference (one pulse represents one step) and therefore does not contain any significant power, the actual wattage to drive the motor is taken from an external DC power supply. Additionally, all of the drives can bypass the motion controller entirely and connect directly to the computer through a custom cable for configuration / troubleshooting purposes.

The stepper motors themselves vary quite a bit. In general, their purpose is to translate electrical energy supplied from the drives into mechanical actuation. They contain two phases and magnetic teeth that can be used to move the motor in tiny increments called steps in a very precise manner. They are coupled to hardware that physically moves the substrate inside the chamber.

To more clearly understand the role and connections between all the pieces of hardware mentioned here, check out the hardware flowchart on the next page as well as the hardware list on the page after that.

Figure 2.1: Electrical Hardware Flowchart

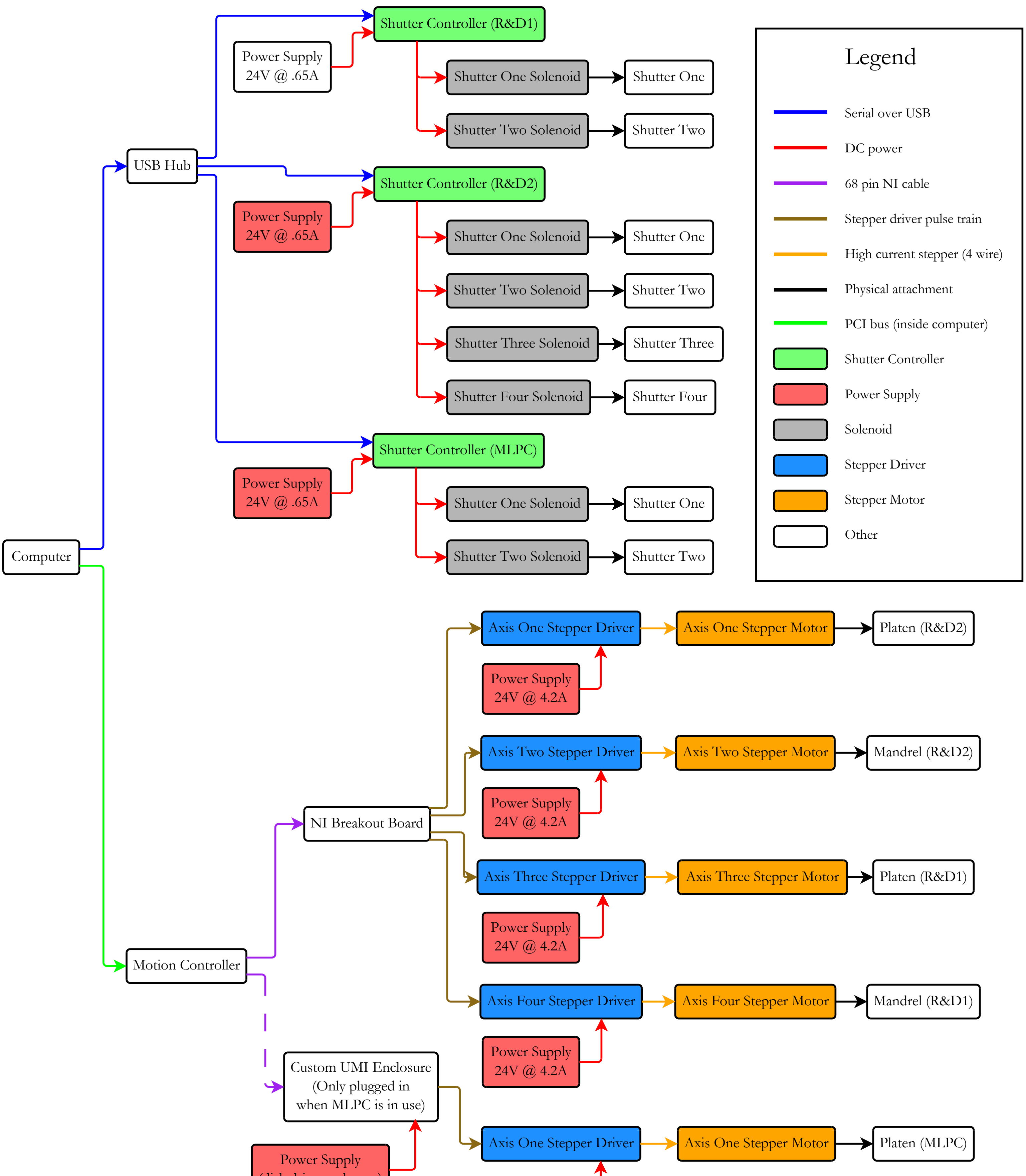


Figure 2.2: Electrical Hardware Components List

Quantity	Device Name	Model	Manufacturer	Vendor	Notes
1	Computer	Optiplex 755	Dell	???	Obtained through CfA
1	Motion controller	PCI-7330	National Instruments	National Instruments	
5	Stepper driver	P70530 -SDN	Pacific Scientific	Minarik	Minarik is the cheapest place for these
1	68 pin breakout board	CB-68LP	National Instruments	National Instruments	Used for both R&D chambers. Functions exactly like UMI except cheaper
1	UMI	UMI-7764	National Instruments	National Instruments	Housed inside custom enclosure. Used only for MLPC.
1	Stepper motor R&D2 platen	AM34-419-1	Advanced Micro Systems	Advanced Micro Systems	Fantastic price and quality
3	Shutter controller	N/A	Lucas Doyle	Custom made	See shutter controller section
3	Power supply 24V @ .65A	Various	Various	Various	Misc power supplies already owned to power shutter controllers
4	Power supply 24V @ 4.2A	Z2494-ND	Omicron Electronics Inc	Digi-key	Power for stepper drivers
1	Stepper motor R&D1 platen	Slo-syn ???	Superior Electric?	Danaher / Kollmorgen	Old motor on R&D1, can be replaced by one from AMS (see platen motor for R&D2)
1	Stepper motor Mandrel	???	???	???	Vacuum compatible, one Mandrel switches between chambers
1	Stepper Motor MLPC platen	???	???	???	Origins of this motor is unknown
7	Solenoids	SYJ3140	SMC	???	2 used for R&D1, 4 for R&D2, 1 spare
2	Solenoids	???	???	???	Unknown solenoids for MLPC

2.2 Stepper Motors and Power Transmission

Stepper motors are attached to end effectors inside the vacuum chamber and are ultimately what move the sample in the appropriate manner under the cathode. There are several different sizes of stepper motors in use throughout the lab. In most cases, the stepper motors on the chambers have 200 steps per rotation, but using a technique called micro stepping on the stepper drivers, it is possible to achieve 50,000 steps per revolution (as is the case on R&D2's platen). Using a gearbox can further improve how precise the motor is, but may introduce backlash (as is the case on MLPC and R&D1).

The expected torque of a stepper motor is related to the current going through it at a given moment. All of the steppers in the lab are two phase bipolar motors. Bipolar motors tend to be powerful than an equivalently sized unipolar motor, but this comes at the price of increased thermal output. Excessive heat in or around the vacuum chamber is not desirable. Consequently, most of the motors are either not being driven at their full current capacity, or the drivers are configured to reduce current going to the motor after a certain duration of inactivity. For reference, most of the stepper motors in the lab operate in the 1-5 Amp range, which provide more than enough torque for the application.

On their own, the only thing you can really control about a motor is which way it normally turns when pulses are sent to the phase. To reverse a motor, simply swap the polarity going to any one phase. For example, for a stepper motor with inputs going to A, A', B and B', swapping the wires that go to A and A' or B and B' would reverse the motor. Other than that, there is not much else to say about the stepper motors. Their performance is almost completely dictated by whatever drive it is connected to.

2.3 Stepper Drivers

Nothing here yet

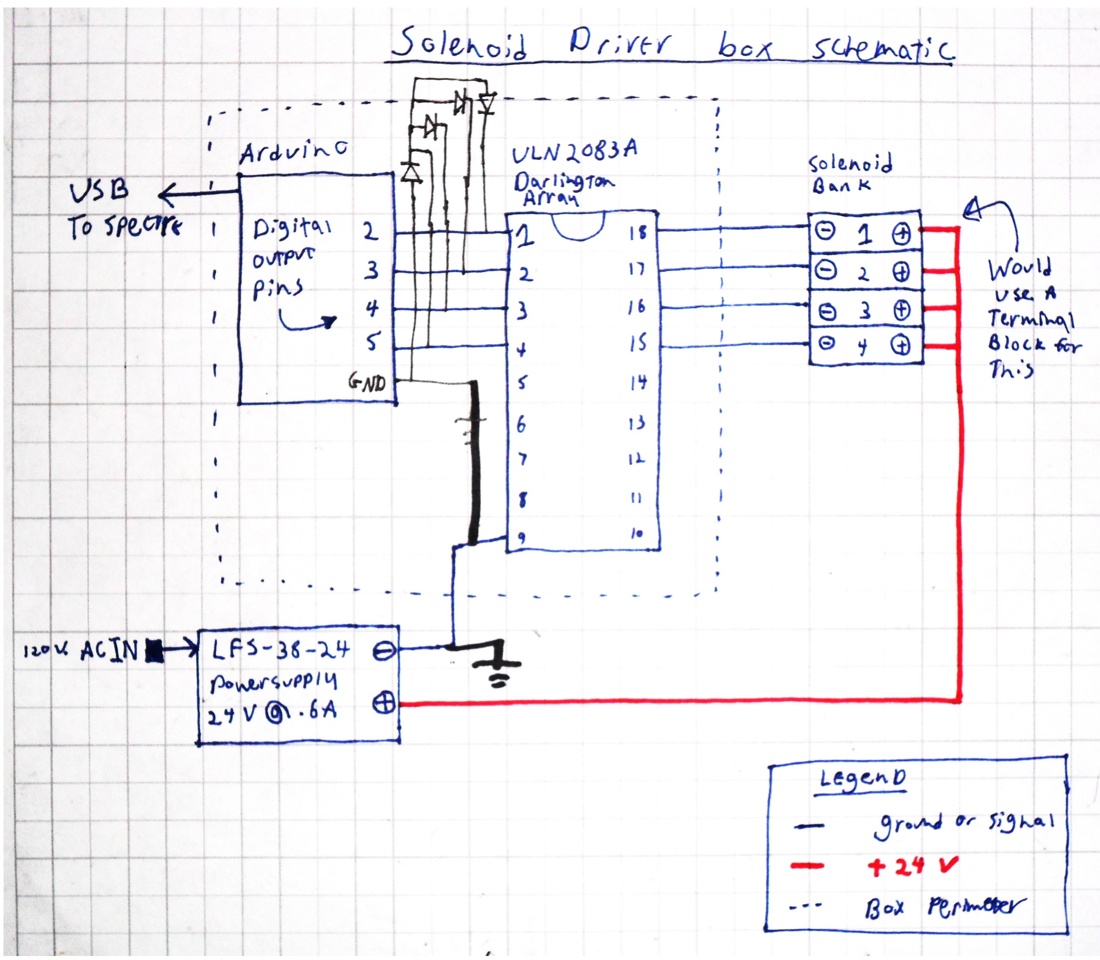
2.4 Motion Controller

Nothing here yet

2.5 Arduino and Shutter Drivers

Nothing here yet, but here is a diagram of the component

Figure 2.3: Shutter Controller Schematic



Ch. 3: Software

3.1 High Level Software Overview

Nothing here yet

3.2 Notes on LabVIEW

Nothing here yet

3.3 Explanation of Core Algorithms

Nothing here yet

3.4 File Handling

Nothing here yet

3.5 Error Handling

Nothing here yet

3.6 Control Loops

Nothing here yet

3.7 Motion Control Algorithms

Nothing here yet

Ch. 4: Operation

4.1 Explanation of interface

Figure 4.1: Main Run Window

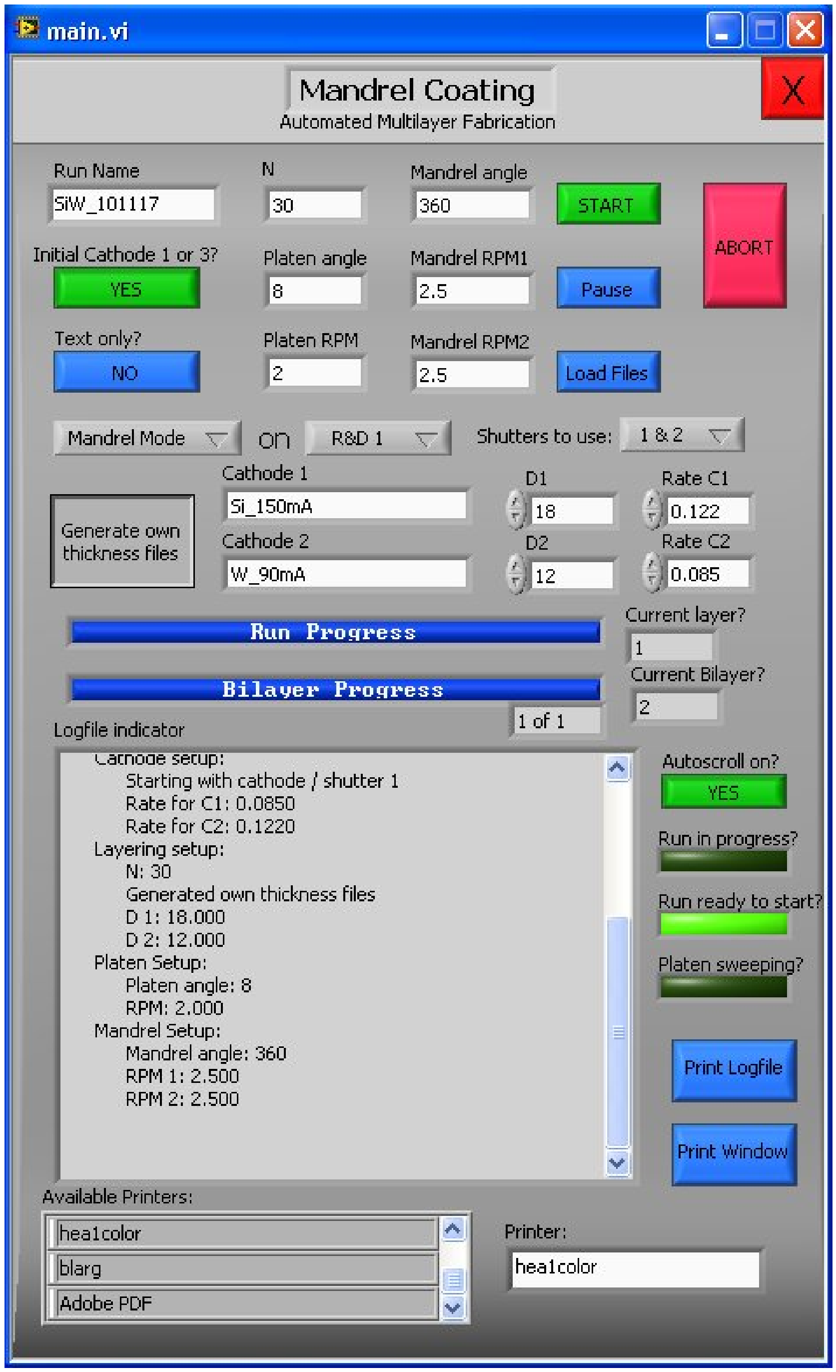


Figure 4.2: Manual Control Window

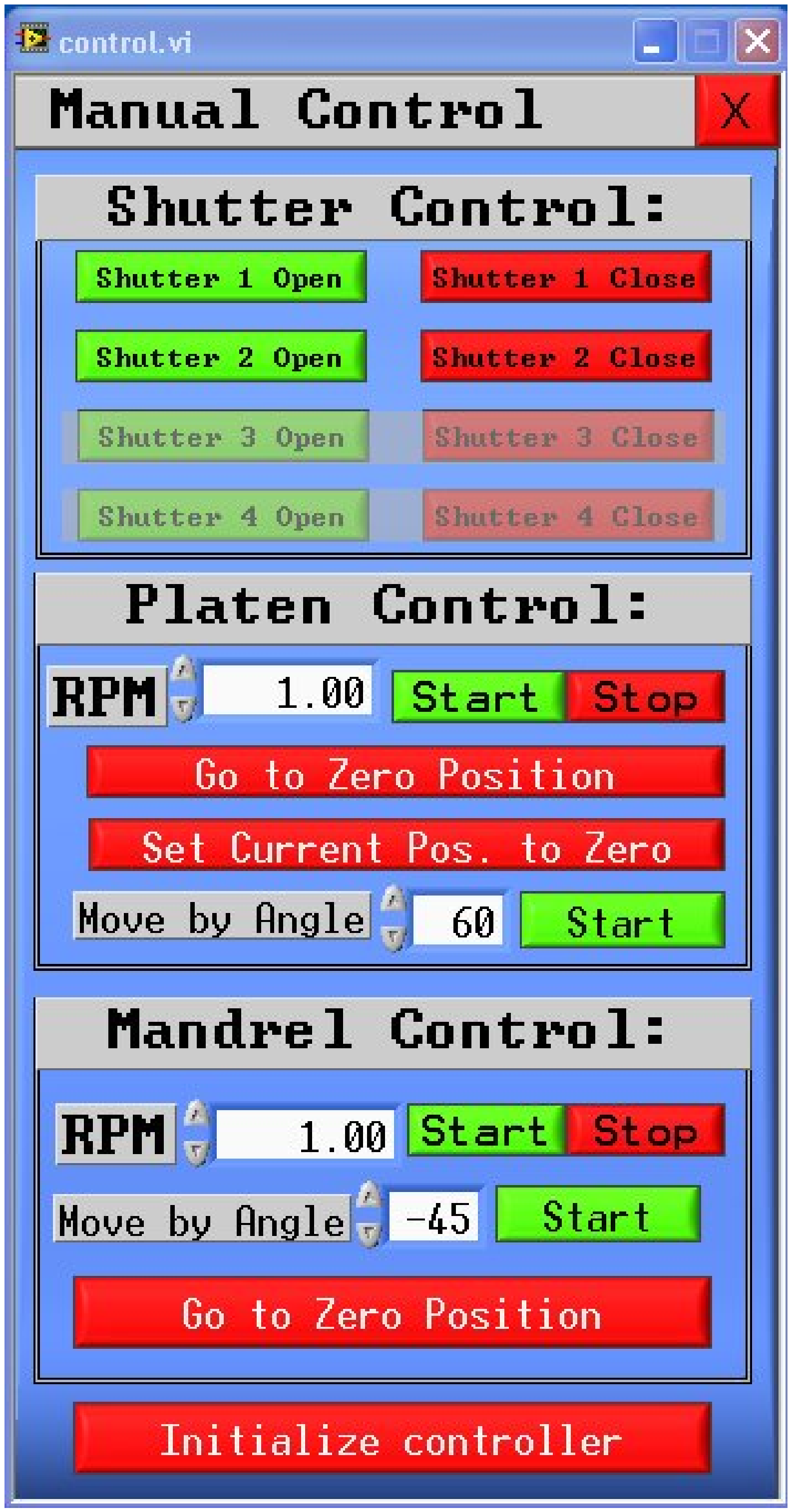
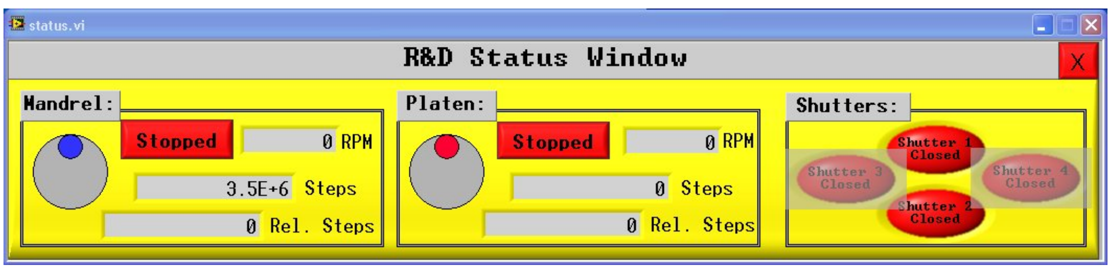


Figure 4.3: Status Window



4.2 Hardware Checks

Nothing here yet

4.3 Software Checks

Nothing here yet

4.4 Runtime operations

Nothing here yet

Ch. 5: Troubleshooting

5.1 General info about the chambers

Nothing here yet

Ch. 6: Appendicies

6.1 Engineering Drawings

6.1.1 Stepper - FFF Bracket

Stepper - FFF Bracket

Purpose: bracket will mount a NEMA 34 size stepper motor to the ferrofluidic feedthrough at top of the chamber.

Material: mild steel, 0.25 thick unless otherwise noted

All measurements in inches

Do not scale drawing

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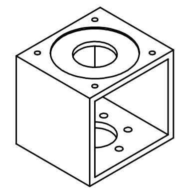
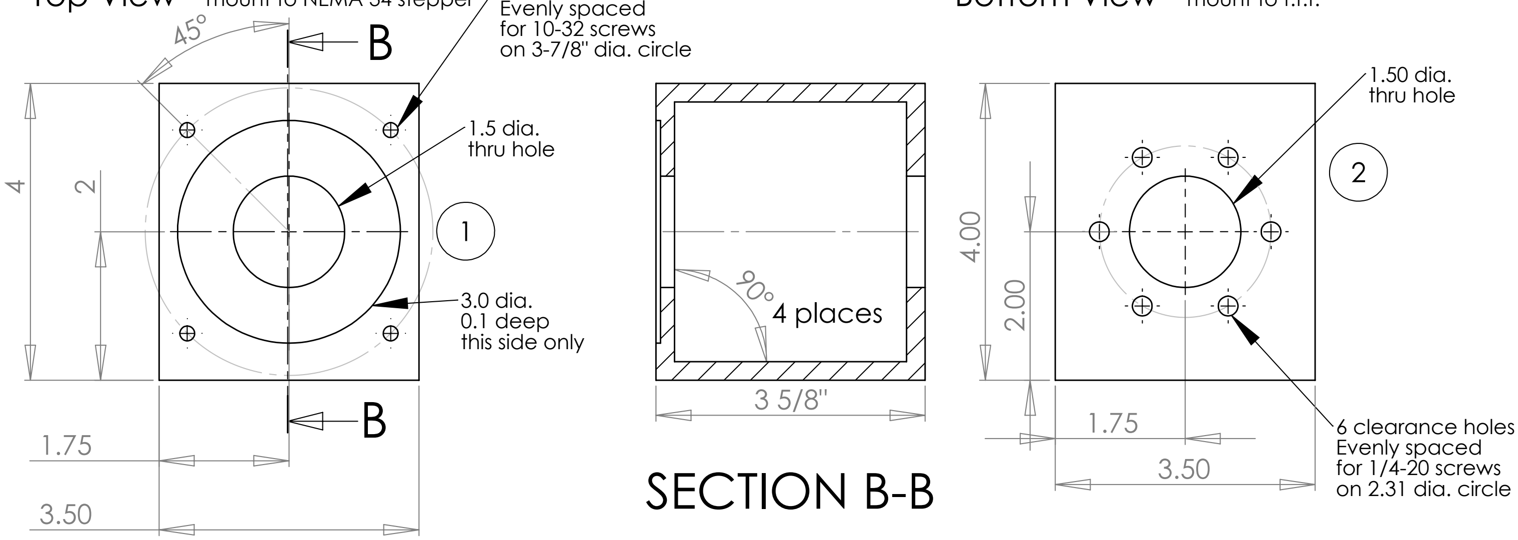


Top View - mount to NEMA 34 stepper

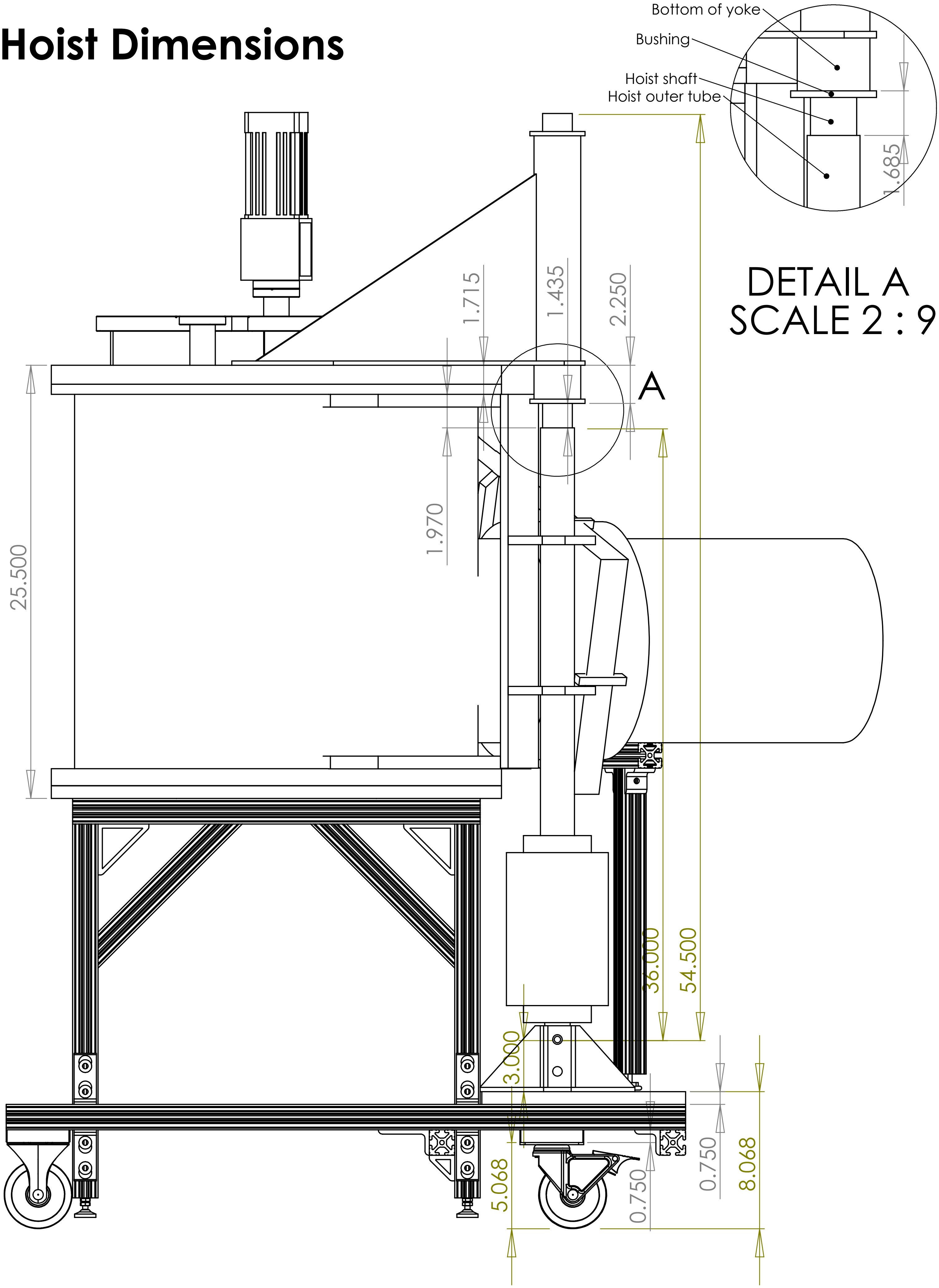
Bottom View - mount to f.f.f.



NOTES:
Drill through centerline
of 1 and 2 colinear to ± .005"
All angles ±1 degree

6.1.2 Hoist

Hoist Dimensions

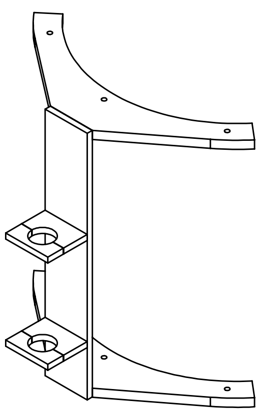


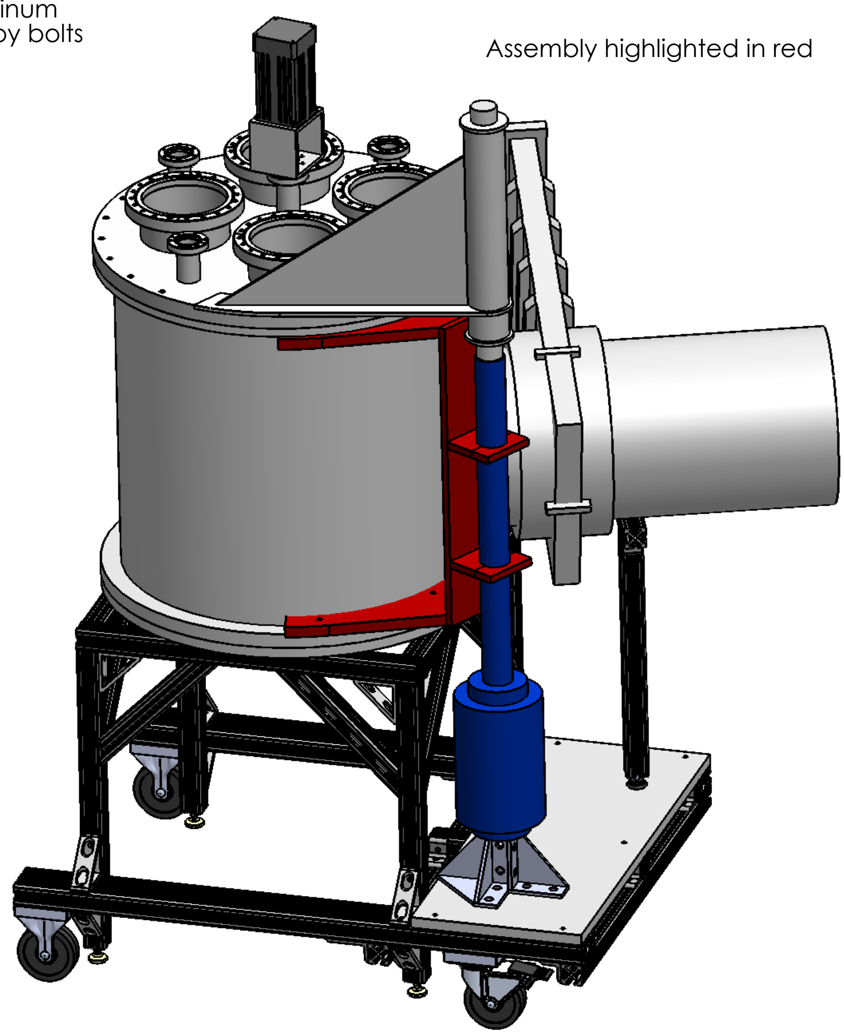
6.1.3 Hoist Support

Vertical Support for Hoist

Proposed construction consists of aluminum
plate/blocks which are held todether by bolts

Assembly highlighted in red





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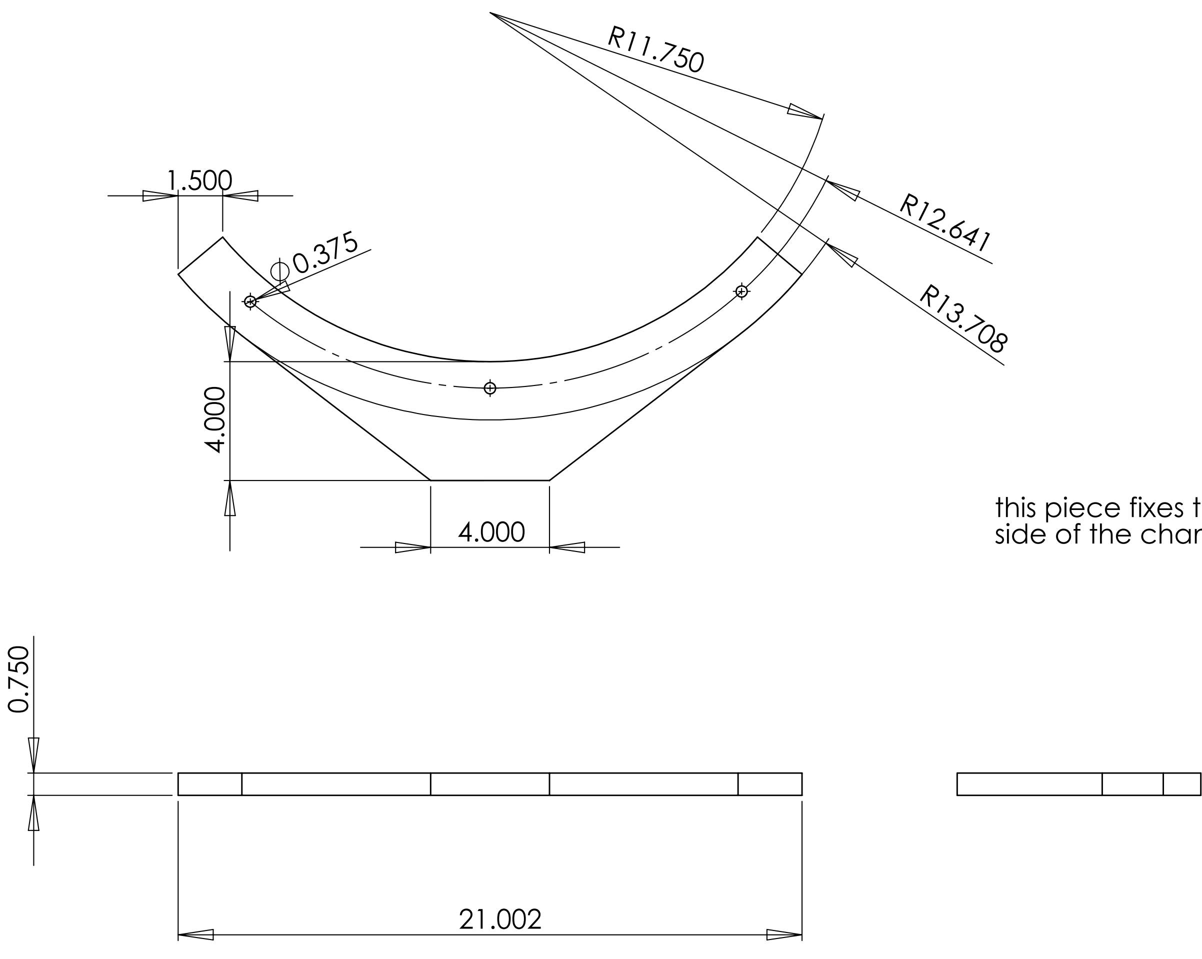
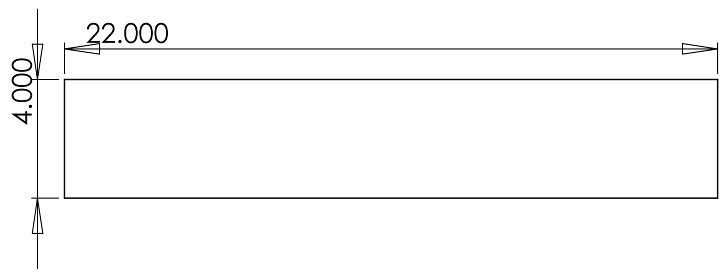
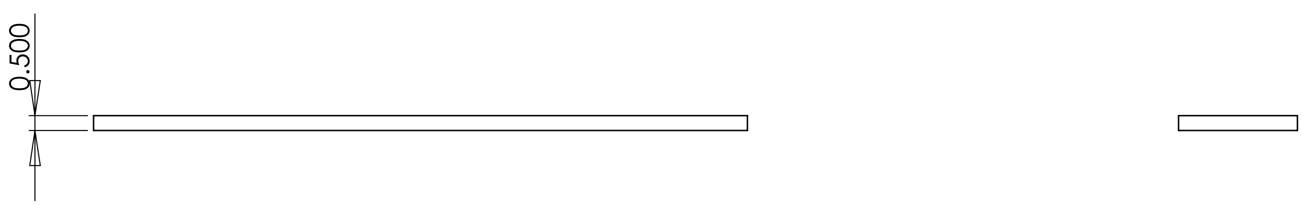
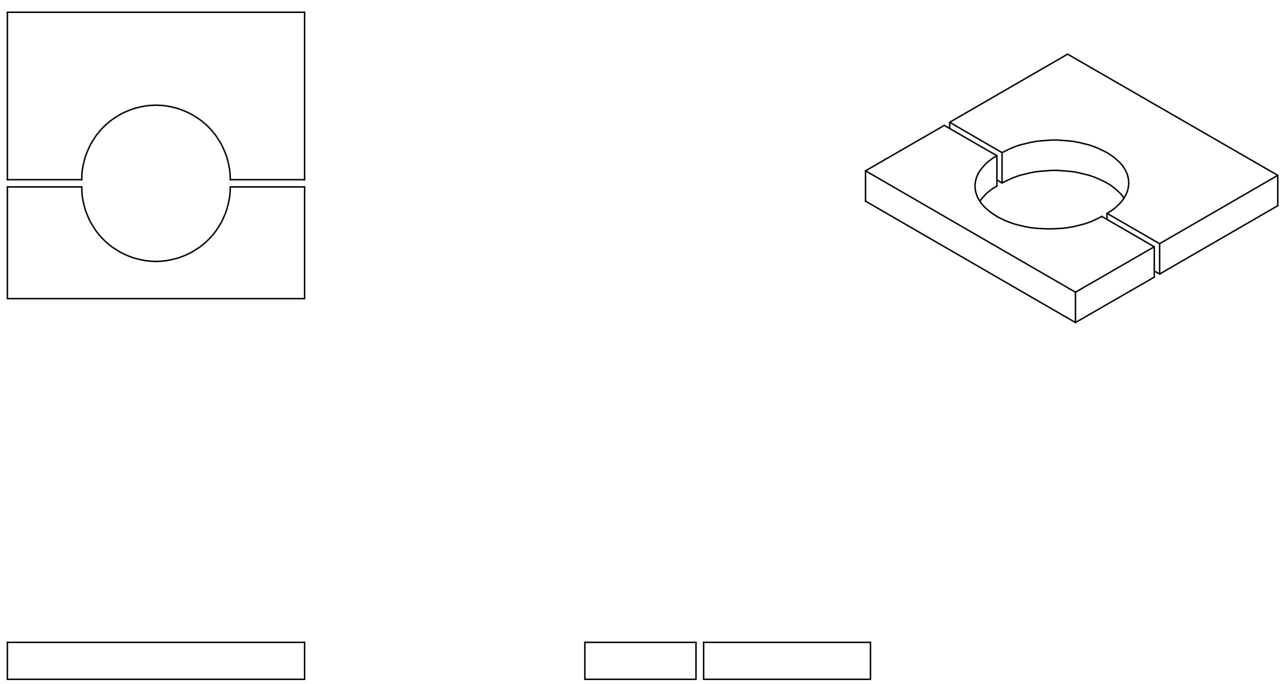


this piece fixes the plate to the side of the chamber



This is the vertical hoist mounting plate
the clamps that go around the hoist bolt
to this which in turn bolts to the blocks
that grab the chamber





6.1.4 Mounting plate

Hoist mount plate

Material: 3/4" aluminum plate
All dims. in inches
Do not scale drawing

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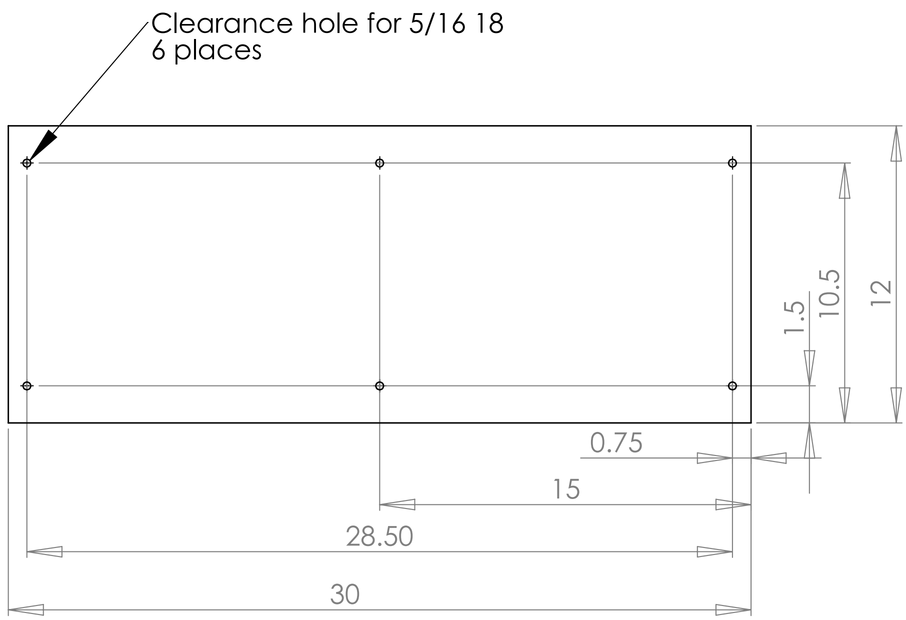
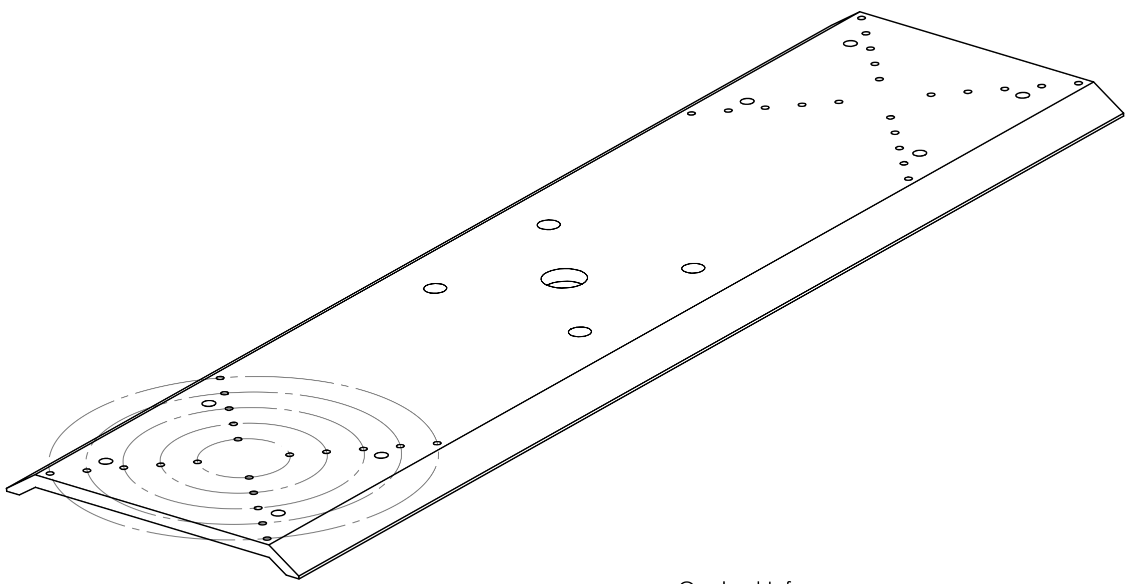


6.1.5 Platen

New Chamber Platen

Material: 304 Stainless steel plate - 0.060" thick
All dims. in inches
Do not scale drawing



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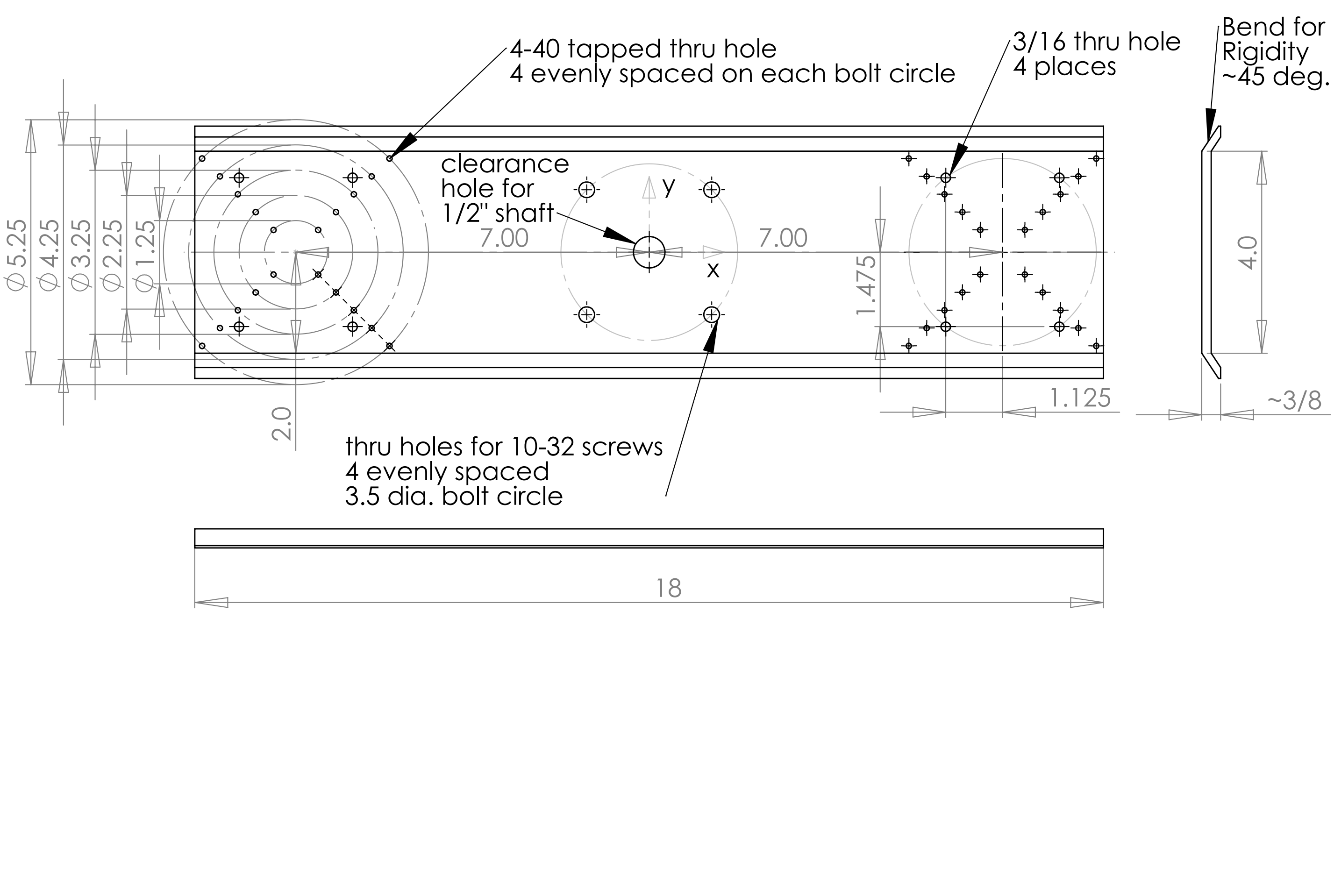
New Chamber Platen

NOTES:
Part should be symmetrical about the YZ plane



6.2 Equipment Documentation

6.2.1 Motion Controller Documentation

Motion Control

National Instruments 7330 User Manual

October 2003 Edition
Part Number 370837A-01

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ni.com

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For further support information, refer to the *Technical Support and Professional Services* appendix. To comment on the documentation, send email to techpubs@ni.com.

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Compliance

FCC/Canada Radio Frequency Interference Compliance

Determining FCC Class

The Federal Communications Commission (FCC) has rules to protect wireless communications from interference. The FCC places digital electronics into two classes. These classes are known as Class A (for use in industrial-commercial locations only) or Class B (for use in residential or commercial locations). All National Instruments (NI) products are FCC Class A products.

Depending on where it is operated, this Class A product could be subject to restrictions in the FCC rules. (In Canada, the Department of Communications (DOC), of Industry Canada, regulates wireless interference in much the same way.) Digital electronics emit weak signals during normal operation that can affect radio, television, or other wireless products.

All Class A products display a simple warning statement of one paragraph in length regarding interference and undesired operation. The FCC rules have restrictions regarding the locations where FCC Class A products can be operated.

Consult the FCC Web site at www.fcc.gov for more information.

FCC/DOC Warnings

This equipment generates and uses radio frequency energy and, if not installed and used in strict accordance with the instructions in this manual and the CE marking Declaration of Conformity*, may cause interference to radio and television reception. Classification requirements are the same for the Federal Communications Commission (FCC) and the Canadian Department of Communications (DOC).

Changes or modifications not expressly approved by NI could void the user's authority to operate the equipment under the FCC Rules.

Class A

Federal Communications Commission

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user is required to correct the interference at their own expense.

Canadian Department of Communications

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de la classe A respecte toutes les exigences du Règlement sur le matériel brouilleur du Canada.

Compliance to EU Directives

Users in the European Union (EU) should refer to the Declaration of Conformity (DoC) for information pertaining to the CE marking. Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit ni.com/hardref.nsf, search by model number or product line, and click the appropriate link in the Certification column.

* The CE marking Declaration of Conformity contains important supplementary information and instructions for the user or installer.

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About This Manual

This manual describes the electrical and mechanical aspects of the PXI/PCI-7330 and contains information about how to operate and program the device.

The 7330 is designed for PXI, compact PCI, and PCI bus computers.

Conventions

The following conventions appear in this manual:

<> — Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, DIO<3..0>.

» — The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.

♦ — The ♦ symbol indicates that the following text applies only to a specific product, a specific operating system, or a specific software version.

This icon denotes a tip, which alerts you to advisory information.

This icon denotes a note, which alerts you to important information.

This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash. When this symbol is marked on a product, refer to the *Safety Information* section of Chapter 2, *Configuration and Installation*, for information about precautions to take.

bold — Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names.

italic	Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font also denotes text that is a placeholder for a word or value that you must supply.
`monospace`	Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames and extensions, and code excerpts.

Related Documentation

The following documents contain information you might find helpful as you read this manual:

- *NI-Motion User Manual*
- *NI-Motion C Reference Help*
- *NI-Motion VI Reference Help*

1 Introduction

This chapter includes information about the features of the National Instruments PXI/PCI-7330 controller and information about operating the device.

About the 7330 Controller

The 7330 controller features advanced motion control with easy-to-use software tools and add-on motion VI libraries for use with LabVIEW.

Features

The 7330 controller is a stepper motor controller for PXI and PCI. The 7330 provides fully programmable motion control for up to four independent or coordinated axes of motion, with dedicated motion I/O for limit and home switches and additional I/O for general-purpose functions.

You can use the 7330 motion controller for point-to-point and straight-line vector moves for stepper motor applications. The 7330 controller adds the ability to perform arbitrary and complex motion trajectories using stepper motors.

Stepper axes can operate in open or closed-loop mode. In closed-loop mode, stepper axes use quadrature encoders or analog inputs for position and velocity feedback (closed-loop only), and provide step/direction or clockwise (CW) /counter-clockwise (CCW) digital command outputs. All stepper axes support full, half, and microstepping applications.

Hardware

The 7330 uses an advanced dual-processor architecture that uses a 32-bit CPU, combined with a digital signal processor (DSP) and custom field programmable gate arrays (FPGAs), making the controller a high-performance device. The first-in, first-out (FIFO) bus interface and powerful function set provide high-speed communications while off-loading complex motion functions from the host PC for optimum command throughput and system performance.

Each axis of the 7330 has motion I/O for end-of-travel limit and home switch inputs, breakpoint output, trigger input, and encoder feedback. Refer to Appendix A, *Specifications*, for information about the encoder feedback rates. The 7330 also has non-dedicated user I/O including 32 bits of digital I/O and four analog inputs for ±10 V signals, joystick inputs, or monitoring of analog sensors. Additionally, the 7330 analog inputs can provide feedback for loop closure.

RTSI

The 7330 supports the National Instruments Real-Time System Integration (RTSI) bus. The RTSI bus provides high-speed connectivity between National Instruments products, including image acquisition (IMAQ) and data acquisition (DAQ) products. Using the RTSI bus, you can easily synchronize several functions to a common trigger or timing event across multiple motion, IMAQ, or DAQ devices.

What You Need to Get Started

To set up and use the 7330 controller, you must have the following items:

- ❑ NI PXI-7330 or PCI-7330 motion controller
- ❑ This manual
- ❑ NI-Motion 6.1 or later driver software and documentation
- ❑ One of the following software packages and documentation:
  - LabVIEW 6.0 or later
  - LabWindows™/CVI™
  - Measurement Studio
  - C/C++
  - Microsoft Visual Basic
- ❑ A computer with an available PXI or PCI slot

Software Programming Choices

NI-Motion is a simple but powerful high-level application programming interface (API) that makes programming the 7330 easy. All setup and motion control functions are easily executed by calling into a dynamically-linked library (DLL). You can call these libraries from C, Microsoft Visual Basic, and other high-level languages. Full function sets are available for LabVIEW, LabWindows/CVI, and other industry-standard software programs.

National Instruments Application Software

LabVIEW is based on the graphical programming language, G, and features interactive graphics and a state-of-the-art user interface. In LabVIEW, you can create 32-bit compiled programs and stand-alone executables for custom automation, data acquisition, test, measurement, and control solutions. National Instruments offers NI-Motion driver software support for LabVIEW, which includes a series of virtual instruments (VIs) for using LabVIEW with National Instruments motion control hardware. The NI-Motion VI library implements the full NI-Motion API and a powerful set of demo functions; example programs; and fully operational, high-level application routines.

ANSI C-based LabWindows/CVI also features interactive graphics and a state-of-the-art user interface. Using LabWindows/CVI, you can generate C code for custom data acquisition, test, and measurement and automation solutions. NI-Motion includes a series of sample programs for using LabWindows/CVI with National Instruments motion control hardware.

Optional Equipment

National Instruments offers a variety of products for use with the 7330 controller, including the following accessories:

- Cables and cable assemblies for motion and digital I/O
- Universal Motion Interface (UMI) wiring connectivity blocks with integrated motion signal conditioning and motion inhibit functionality
- Stepper compatible drive amplifier units with integrated power supply and wiring connectivity
- Connector blocks and shielded and unshielded 68-pin screw terminal wiring aids

For more specific information about these products, refer to the National Instruments catalog, the National Instruments Web site at `ni.com`, or call your National Instruments sales representative.

Motion I/O Connections

The external motion and digital I/O connectors on the 7330 are high-density, 68-pin female VHDCI connectors.

For custom cables, use the AMP mating connector (part number 787801-1).

2

Configuration and Installation

This chapter describes how to configure and install the PXI/PCI-7330.

Software Installation

Before installing the 7330, install the NI-Motion driver software. Refer to the *Getting Started with NI Motion Control* manual, which is included with the controller, for specific installation instructions.

Note If you do not install the NI-Motion driver software before attempting to use the 7330, the system does not recognize the 7330 and you are unable to configure or use the device.

Controller Configuration

Because motion I/O-related configuration of the 7330 is performed entirely with software, it is not necessary to set jumpers for motion I/O configuration.

The PXI-7330 and PCI-7330 controllers are fully compatible with the industry standard *PXI Specification*, Revision 2.0 and the *PCI Local Bus Specification*, Revision 2.2, respectively. This compatibility allows the PXI or PCI system to automatically perform all bus-related configuration and requires no user interaction. It is not necessary to configure jumpers for bus-related configuration, including setting the device base memory and interrupt channel.

Safety Information

Caution The following paragraphs contain important safety information you *must* follow when installing and operating the 7330 and all devices connecting to the 7330.

Do not operate the device in a manner not specified in this document. Misuse of the device can result in a hazard. You can compromise the safety protection built into the device if the device is damaged in any way. If the device is damaged, return it to National Instruments (NI) for repair.

Do not substitute parts or modify the device except as described in this document. Use the device only with the chassis, modules, accessories, and cables specified in the installation instructions. You must have all covers and filler panels installed during operation of the device.

Do not operate the device in an explosive atmosphere or where there may be flammable gases or fumes. If you must operate the device in such an environment, it must be in a suitably rated enclosure.

If you need to clean the device, use a soft, nonmetallic brush. Make sure that the device is completely dry and free from contaminants before returning it to service.

Operate the device only at or below Pollution Degree 2. Pollution is foreign matter in a solid, liquid, or gaseous state that can reduce dielectric strength or surface resistivity. The following is a description of pollution degrees:

- Pollution Degree 1 means no pollution or only dry, nonconductive pollution occurs. The pollution has no influence.
- Pollution Degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Pollution Degree 3 means that conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation.

Note The 7330 is intended for indoor use only.

You must insulate signal connections for the maximum voltage for which the device is rated. Do not exceed the maximum ratings for the device. Do not install wiring while the device is live with electrical signals. Do not remove or add connector blocks when power is connected to the system. Remove power from signal lines before connecting them to or disconnecting them from the device.

Operate the device at or below the installation category[1] marked on the hardware label. Measurement circuits are subjected to working voltages[2] and transient stresses (overvoltage) from the circuit to which they are connected during measurement or test. Installation categories establish standard impulse withstand voltage levels that commonly occur in electrical distribution systems. The following is a description of installation categories:

- Installation Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS[3] voltage. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.
- Installation Category II is for measurements performed on circuits directly connected to the electrical distribution system. This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (for example, 115 AC voltage for U.S. or 230 AC voltage for Europe). Examples of Installation Category II are measurements performed on household appliances, portable tools, and similar devices/modules.
- Installation Category III is for measurements performed in the building installation at the distribution level. This category refers to measurements on hard-wired equipment such as equipment in fixed installations, distribution boards, and circuit breakers. Other examples are wiring, including cables, bus bars, junction boxes, switches, socket outlets in the fixed installation, and stationary motors with permanent connections to fixed installations.
- Installation Category IV is for measurements performed at the primary electrical supply installation (<1,000 V). Examples include electricity meters and measurements on primary overcurrent protection devices and on ripple control units.

[1] Installation categories, also referred to as *measurement categories*, are defined in electrical safety standard IEC 61010-1.

[2] Working voltage is the highest rms value of an AC or DC voltage that can occur across any particular insulation.

[3] MAINS is defined as a hazardous live electrical supply system that powers equipment. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

Hardware Installation

Install the 7330 in any open compatible expansion slot in the PXI or PCI system. Appendix A, *Specifications*, lists the typical power required for each controller.

The following instructions are for general installation. Consult the computer user manual or technical reference manual for specific instructions and warnings.

Caution The 7330 is a sensitive electronic device shipped in an antistatic bag. Open only at an approved workstation and observe precautions for handling electrostatic-sensitive devices.

Note When adding or removing a controller from a Windows 2000/NT/XP system, you must be logged on with administrator-level access. After you have restarted the system, you may need to refresh Measurement & Automation Explorer (MAX) to view the new controller.

- PXI-7330

1. Power off and unplug the chassis.

Caution To protect yourself and the computer from electrical hazards, the computer must remain unplugged until the installation is complete.

2. Choose an unused +3.3 V or +5 V peripheral slot and remove the filler panel.
3. Touch a metal part on the chassis to discharge any static electricity that might be on your clothes or body. Static electricity can damage the controller.
4. Insert the PXI controller into the chosen slot. Use the injector/ejector handle to fully inject the device into place.
5. Screw the front panel of the PXI controller to the front panel mounting rails of the chassis.
6. Visually verify the installation.
7. Plug in and power on the chassis.

- PCI-7330

1. Power off and unplug the computer.

Caution To protect yourself and the computer from electrical hazards, the computer must remain unplugged until the installation is complete.

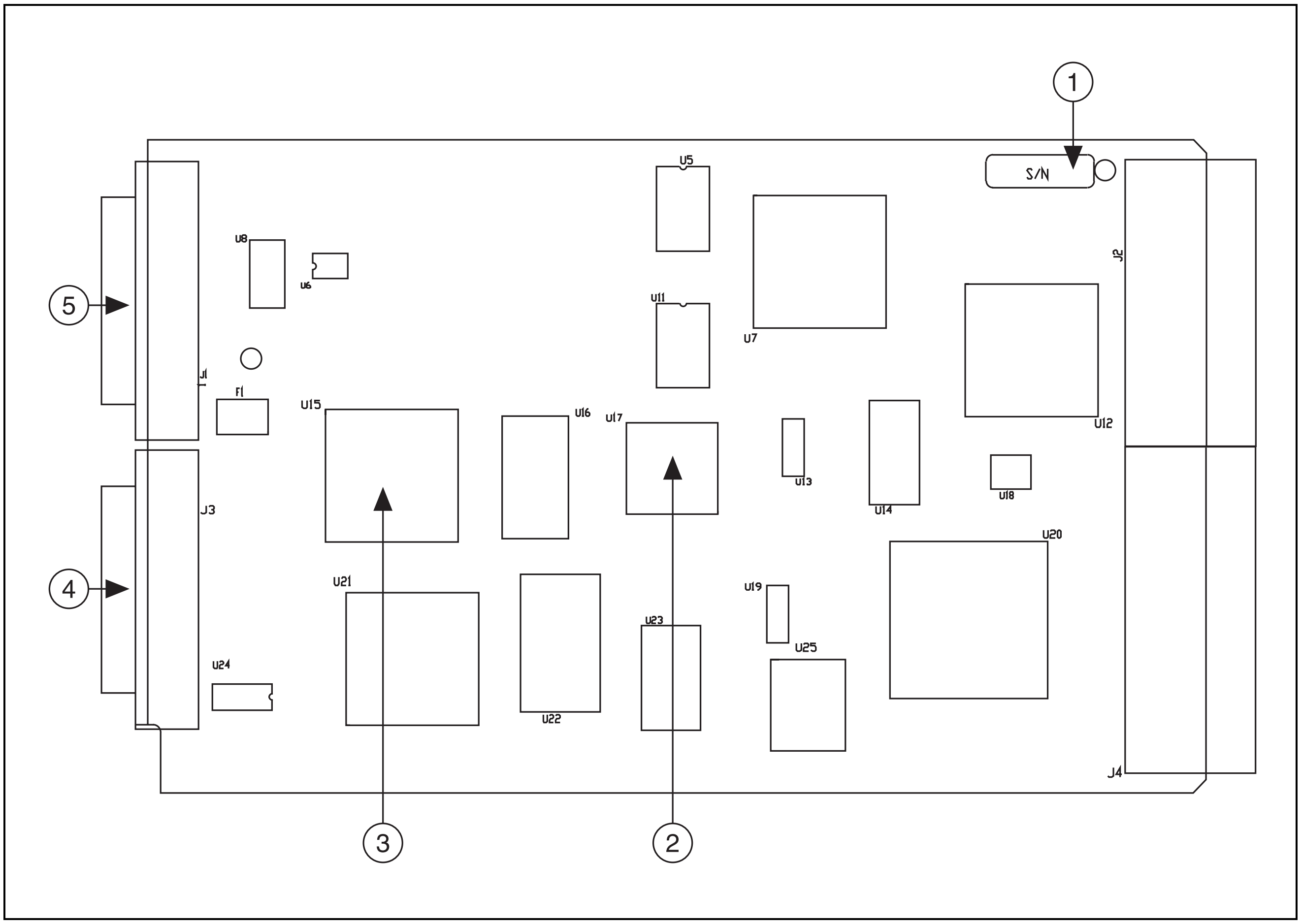
2. Remove the cover to expose access to the PCI expansion slots.
3. Choose an unused 5 V PCI slot, and remove the corresponding expansion slot cover on the back panel of the computer.
4. Touch a metal part on the computer case to discharge any static electricity that might be on your clothes or body before handling the controller. Static electricity can damage the controller.
5. Gently rock the controller into the slot. The connection may be tight, but *do not force* the controller into place.
6. If required, screw the mounting bracket of the controller to the back panel rail of the computer.
7. Replace the cover.
8. Plug in and power on the computer.

3

Hardware Overview

This chapter presents an overview of the PXI/PCI-7330 functionality.

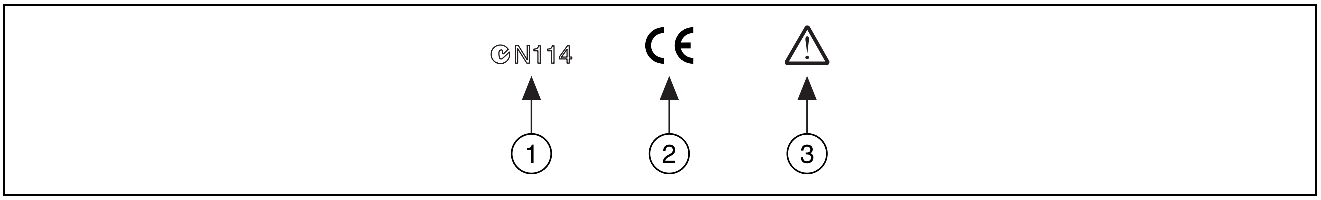
Figures 3-1 and 3-3 show the PXI-7330 and PCI-7330 parts locator diagrams, respectively.



1	Serial Number Label	4	68-Pin Digital I/O Connector
2	DSP	5	68-Pin Motion I/O Connector
3	CPU		

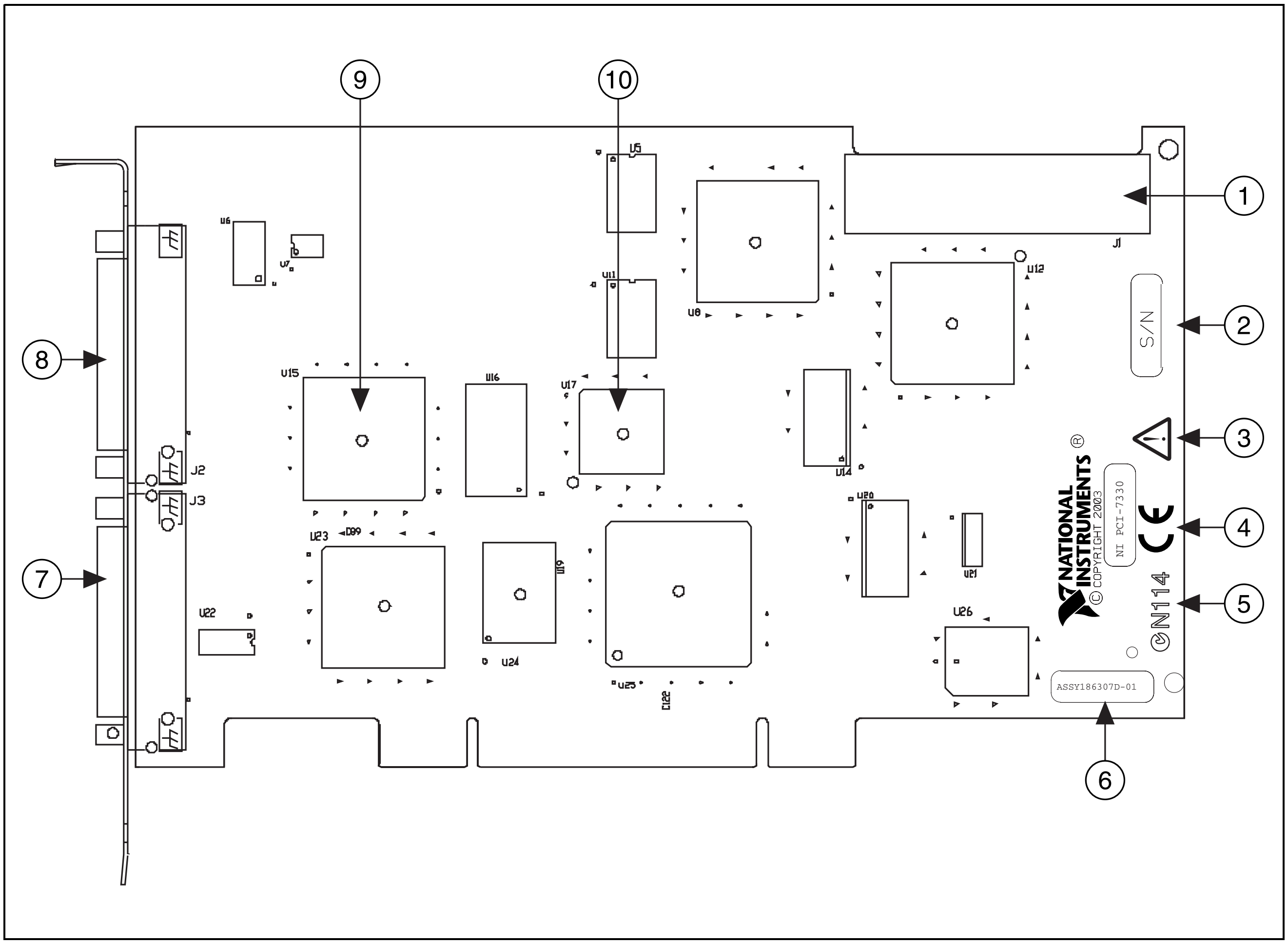
Figure 3-1. PXI-7330 Parts Locator Diagram

Note The PXI-7330 assembly number is located on the back of the PXI module.



1	Identification Number Used in Australia	3	Symbol to Alert User to Read the Manual
2	Symbol Indicating FFC Compliance		

Figure 3-2. Symbols on the Back of the PXI-7330



1	RTSI Connector	6	Assembly Number Label
2	Serial Number Label	7	68-Pin Digital I/O Connector
3	Symbol to Alert User to Read the Manual	8	68-Pin Motion I/O Connector
4	Symbol Indicating FFC Compliance	9	CPU
5	Identification Number Used in Australia	10	DSP

Figure 3-3. PCI-7330 Parts Locator Diagram

User Connectors

The 68-pin motion I/O connector provides all the signals for four axes of closed-loop motion control, including encoder feedback, limit and home inputs, breakpoint outputs, trigger inputs, and analog-to-digital (A/D) converter signals. Refer to Chapter 5, *Signal Connections*, for details about the signals in the motion I/O connector.

The 68-pin digital I/O connector provides 32 bits of user-configurable digital I/O. Refer to Chapter 5, *Signal Connections*, for details about the signals in the digital I/O connector.

The PCI-7330 RTSI connector provides up to eight triggers to facilitate synchronization between multiple National Instruments products. The PXI-7330 RTSI-enabled connection provides up to eight triggers and one PXI star trigger to facilitate synchronization between multiple National Instruments PXI-enabled products. Typical applications of the RTSI bus include triggering an image acquisition or DAQ measurement based on motion events, or capturing current motion positions based on events external to the motion controller. You also can use the RTSI bus for general hardware-based communication between RTSI devices.

The RTSI bus also can be used for general-purpose I/O. Refer to Chapter 5, *Signal Connections*, for details about RTSI connector signals.

4

Functional Overview

This chapter provides an overview of the motion control algorithms and the PXI/PCI-7330 capabilities.

Dual Processor Architecture

With the 7330, you can perform up to four axes of simultaneous, coordinated motion control in a preemptive, multitasking, real-time environment.

An advanced dual-processor architecture that uses a real-time 32-bit CPU combined with a digital signal processor (DSP) and custom FPGAs give the 7330 controllers high-performance capabilities. The FIFO bus interface and powerful function set provide high-speed communications while off-loading complex motion functions from the host PC for optimized system performance.

The 7330 uses the DSP for all closed-loop control and motion trajectory generation. The DSP chip is supported by custom FPGAs that perform the high-speed encoder interfacing, position capture and breakpoint functions, motion I/O processing, and stepper pulse generation for hard real-time functionality.

The embedded, multitasking real-time CPU handles host communications, command processing, multi-axis interpolation, error handling, general-purpose digital I/O, and overall motion system integration functions.

Embedded Real-Time Operating System (RTOS)

The embedded firmware is based upon an embedded RTOS kernel and provides optimum system performance in varying motion applications. Motion tasks are prioritized. Task execution order depends on the priority of each task, the state of the entire motion system, I/O or other system events, and the real-time clock.

The DSP chip is a separate processor that operates independently from the CPU but is closely synchronized. The 7330 is a true multiprocessing and multitasking embedded controller.

Refer to the *NI-Motion User Manual* for more information about the features available on the 7330.

Trajectory Generators

The 7330 controller trajectory generators calculate the instantaneous position command that controls acceleration and velocity while it moves the axis to its target position. This command is then sent to the stepper pulse generator.

To implement infinite trajectory control, the 7330 controller has eight trajectory generators implemented in the DSP chip (two per axis). Each generator calculates an instantaneous position for each update period. While simple point-to-point moves require only one trajectory generator, two simultaneous generators are required for blended moves and infinite trajectory control processing.

Analog Feedback

The 7330 controllers have an 8-channel multiplexed, 12-bit ADC. The converted analog values are broadcast to both the DSP and CPU through a dedicated internal high-speed serial bus. The multiplexer provides the high sampling rates required for feedback loop closure, joystick inputs, or monitoring analog sensors. Refer to Appendix A, *Specifications*, for the multiplexer scan rate. Four of these channels are intended for calibration, leaving the other four available for analog feedback.

Flash Memory

Nonvolatile memory on the 7330 controller is implemented with flash ROM, which means that the controllers can electrically erase and reprogram their own ROM. Because all the 7330 embedded firmware, including the RTOS and DSP code, is stored in flash memory, you can upgrade the onboard firmware contents in the field.

It is possible to save the entire parameter state of the controller to the flash memory. On the next power cycle, the controller automatically loads and returns the configuration to these new saved default values.

The FPGA configuration programs are also stored in the flash ROM. At power-up, the FPGAs are booted with these programs, which means that updates to the FPGA programs can be performed in the field.

A flash memory download utility is included with the NI-Motion software that ships with the controller.

Axes and Motion Resources

The 7330 controller can control up to four axes of motion. The axes can be completely independent, simultaneously coordinated, or mapped in multidimensional groups called coordinate spaces. You also can synchronize coordinate spaces for multi-vector space coordinated motion control.

Axes

At a minimum, an axis consists of a trajectory generator, a stepper control block, and a stepper pulse generator output. Closed-loop stepper axes require a feedback resource, while open-loop stepper axes do not. Figure 4-1 shows this axis configuration.

With the 7330 controller, you can map one feedback resource and one or two output resources to the axis.

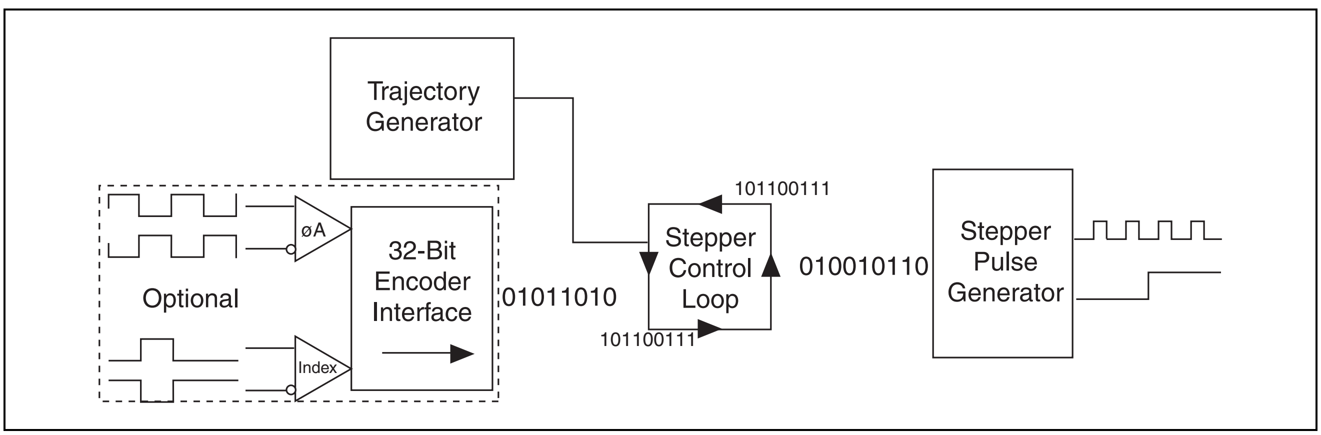


Figure 4-1. Stepper Axis Resources

The 7330 supports axes with secondary output resources. Defining two output resources is useful when controlling axes with multiple motors.

Note Refer to the *NI-Motion User Manual* for more information about configuring axes.

Motion Resources

Encoder, ADC, and motion I/O resources that are not used by an axis are available for non-axis or nonmotion-specific applications. You can directly control an unmapped ADC as a general-purpose analog input (±10 V) to measure potentiometers or other analog sensors.

If an encoder resource is not needed for axis control, you can use it for any number of other functions, including position or velocity monitoring, as a digital potentiometer encoder input, or as a master encoder input for master/slave (electronic gearing) applications.

Each axis also has an associated forward and reverse limit input, a home input, a high-speed capture trigger input, a breakpoint output, and an inhibit output. These signals can be used for general-purpose digital I/O when they are not being used for their motion-specific purpose.

Host Communications

The host computer communicates with the controller through a number of memory port addresses on the host bus. The host bus can be either PXI or PCI.

The primary bidirectional data transfer port supports FIFO data passing in both send and readback directions. The 7330 controller has both a command buffer for incoming commands and a return data buffer (RDB) for returning data.

The communications status register (CSR) provides bits for communications handshaking as well as real-time error reporting and general status feedback to the host PC. The move complete status (MCS) register provides instantaneous motion status of all axes.

5

Signal Connections

This chapter includes instructions on how to make input and output signal connections directly to the PXI/PCI-7330 as well as general information about the associated I/O circuitry.

The 7330 has three connectors that handle all signals to and from the external motion system:

- 68-pin motion I/O connector
- 68-pin digital I/O connector
- RTSI connector

You can connect to your motion system with cables and accessories, varying from simple screw terminal blocks to enhanced Universal Motion Interface (UMI) units and drives.

Note The 7330 does not provide isolation between circuits.

Caution Power off all devices when connecting or disconnecting the 7330 controller motion I/O and auxiliary digital I/O cables. Failure to do so may damage the controller.

Motion I/O Connector

The motion I/O connector contains all of the signals required to control up to four axes of stepper motion, including the following features:

- Motor command stepper outputs
- Encoder feedback inputs
- Forward, home, and reverse limit inputs
- Breakpoint outputs
- Trigger inputs
- Inhibit outputs

The motion I/O connector also contains four channels of 12-bit A/D inputs for analog feedback or general-purpose analog input.

Figure 5-1 shows the pin assignments for the 68-pin motion I/O connector on the 7330. Table 5-1 includes descriptions for each of the signals. A line above a signal name indicates that the signal is active-low.

Axis 1 Dir (CCW)	1	35	Axis 1 Step (CW)
Digital Ground	2	36	Axis 1 Encoder Phase A
Digital Ground	3	37	Axis 1 Encoder Phase B
Axis 1 Home Switch	4	38	Axis 1 Encoder $\overline{\text{Index}}$
Trigger 1	5	39	Axis 1 Forward Limit Switch
Axis 1 $\overline{\text{Inhibit}}$	6	40	Axis 1 Reverse Limit Switch
Axis 2 Dir (CCW)	7	41	Axis 2 Step (CW)
Digital Ground	8	42	Axis 2 Encoder Phase A
Digital Ground	9	43	Axis 2 Encoder Phase B
Axis 2 Home Switch	10	44	Axis 2 Encoder $\overline{\text{Index}}$
Trigger 2	11	45	Axis 2 Forward Limit Switch
Axis 2 $\overline{\text{Inhibit}}$	12	46	Axis 2 Reverse Limit Switch
Axis 3 Dir (CCW)	13	47	Axis 3 Step (CW)
Digital Ground	14	48	Axis 3 Encoder Phase A
Digital Ground	15	49	Axis 3 Encoder Phase B
Axis 3 Home Switch	16	50	Axis 3 Encoder $\overline{\text{Index}}$
Trigger 3	17	51	Axis 3 Forward Limit Switch
Axis 3 $\overline{\text{Inhibit}}$	18	52	Axis 3 Reverse Limit Switch
Axis 4 Dir (CCW)	19	53	Axis 4 Step (CW)
Digital Ground	20	54	Axis 4 Encoder Phase A
Digital Ground	21	55	Axis 4 Encoder Phase B
Axis 4 Home Switch	22	56	Axis 4 Encoder $\overline{\text{Index}}$
Trigger 4	23	57	Axis 4 Forward Limit Switch
Axis 4 $\overline{\text{Inhibit}}$	24	58	Axis 4 Reverse Limit Switch
Digital Ground	25	59	Host +5 V
Breakpoint 1	26	60	Breakpoint 2
Breakpoint 3	27	61	Breakpoint 4
Digital Ground	28	62	Shutdown
Reserved	29	63	Reserved
Reserved	30	64	Reserved
Reserved	31	65	Reserved
Analog Input 1	32	66	Analog Input 2
Analog Input 3	33	67	Analog Input 4
Analog Reference (Output)	34	68	Analog Input Ground

Figure 5-1. 68-Pin Motion I/O Connector Pin Assignments

Table 5-1. Motion I/O Signal Connections

Signal Name	Reference	Direction	Description
Axis <1..4> Dir (CCW)	Digital Ground	Output	Motor direction or counter-clockwise control
Axis <1..4> Step (CW)	Digital Ground	Output	Motor step or clockwise control
Axis <1..4> Encoder Phase A	Digital Ground	Input	Closed-loop only—phase A encoder input
Axis <1..4> Encoder Phase B	Digital Ground	Input	Closed-loop only—phase B encoder input
Axis <1..4> Encoder $\overline{\text{Index}}$	Digital Ground	Input	Closed-loop only—index encoder input
Axis <1..4> Home Switch	Digital Ground	Input	Home switch
Axis <1..4> Forward Limit Switch	Digital Ground	Input	Forward/clockwise limit switch
Axis <1..4> Reverse Limit Switch	Digital Ground	Input	Reverse/counter-clockwise limit switch
Axis <1..4> $\overline{\text{Inhibit}}$	Digital Ground	Output	Drive inhibit
Trigger <1..4>	Digital Ground	Input	High-speed position capture trigger input <1..4>
Breakpoint <1..4>	Digital Ground	Output	Breakpoint output <1..4>
Host +5 V	Digital Ground	Output	+5 V—host computer +5 V supply
Analog Input Ground	—	—	Reference for analog inputs
Analog Input <1..4>	Analog Input Ground	Input	12-bit analog input
Shutdown	Digital Ground	Input	Controlled device shutdown
Analog Reference (output)	Analog Input Ground	Output	+7.5 V—analog reference level
Digital Ground	—	—	Reference for digital I/O

Motion Axis Signals

The following signals control the stepper driver:

- Axis <1..4> Step (CW) and Dir (CCW)—These open-collector signals are the stepper command outputs for each axis. The 7330 supports both major industry standards for stepper command signals: step and direction, or independent CW and CCW pulse outputs.

The output configuration and signal polarity is software programmable for compatibility with various third-party drives, as follows:

- When step and direction mode is configured, each commanded step (or microstep) produces a pulse on the step output. The direction output signal level indicates the command direction of motion, either forward or reverse.
- CW and CCW mode produces pulses (steps) on the CW output for forward-commanded motion and pulses on the CCW output for reverse-commanded motion.

In either case, you can set the active polarity of both outputs to active-low (inverting) or active-high (non-inverting). For example, with step and direction, you can make a logic high correspond to either forward or reverse direction.

The Step (CW) and Dir (CCW) outputs are driven by high-speed open-collector TTL buffers that feature 64 mA sink current capability and built-in 3.3 kΩ pull-up resistors to +5 V.

Caution Do *not* connect these outputs to anything other than a +5 V circuit. The output buffers will fail if subjected to voltages in excess of +5.5 V.

- Axis <1..4> Inhibit—Use the inhibit output signals to control the enable/inhibit function of a stepper driver. When properly connected and configured, the inhibit function causes the connected motor to be de-energized and its shaft turns freely. These open-collector inhibit signals feature 64 mA current sink capability with built-in 3.3 kΩ pull-up resistors to +5 V, and can directly drive most driver/amplifier inhibit input circuits.

  While the industry standard for inhibits is active-low (inverting), these outputs have programmable polarity and can be set to active-high (non-inverting) for increased flexibility and unique drive compatibility.

  Inhibit output signals can be activated automatically upon a shutdown condition, a Kill Motion command, or any motion error that causes a kill motion condition, such as following error trip. You also can directly control the inhibit output signals to enable or disable a driver or amplifier.

Limit and Home Inputs

The following signals control limit and home inputs:

- Axis <1..4> Forward Limit Input
- Axis <1..4> Home Input
- Axis <1..4> Reverse Limit Input

These inputs are typically connected to limit switches located at physical ends of travel and/or at a specific home position. Limit and home inputs can be software enabled or disabled at any time. When enabled, an active transition on a limit or home input causes a full torque halt stop of the associated motor axis. In addition, an active forward or reverse limit input impedes future commanded motion in that direction for as long as the signal is active.

Note By default, limit and home inputs are digitally filtered and must remain active for at least 1 ms to be recognized. You can use MAX to disable digital filtering for limit and home inputs. Active signals should remain active to prevent motion from proceeding further into the limit. Pulsed limit signals stop motion, but they do not prevent further motion in that direction if another move is started.

The input polarity of these signals is software programmable for active-low (inverting) or active-high (non-inverting).

You can use software disabled limit and home inputs as general-purpose inputs. You can read the status of these inputs at any time and set and change their polarity as required.

Limit and home inputs are a per axis enhancement on the 7330 controller and are not required for basic motion control. These inputs are part of a system solution for complete motion control.

Caution National Instruments recommends using limits for personal safety, as well as to protect the motion system.

Wiring Concerns

For the end of travel limits to function correctly, the forward limit must be located at the forward or positive end of travel, and the reverse limit at the negative end of travel.

Caution Failure to follow these guidelines may result in motion that stops at, but then travels through, a limit, potentially damaging the motion system. Miswired limits may prevent motion from occurring at all.

Keep limit and home switch signals and their ground connections wired separately from the motor driver/amplifier signal and encoder signal connections.

Caution Wiring these signals near each other can cause faulty motion system operation due to signal noise and crosstalk.

Limit and Home Input Circuit

By default, all limit and home inputs are digitally filtered and must be active for at least 1 ms. You can use MAX to disable digital filtering for limit and home inputs. Figure 5-2 shows a simplified schematic diagram of the circuit used by the limit and home switch inputs for input signal buffering and detection.

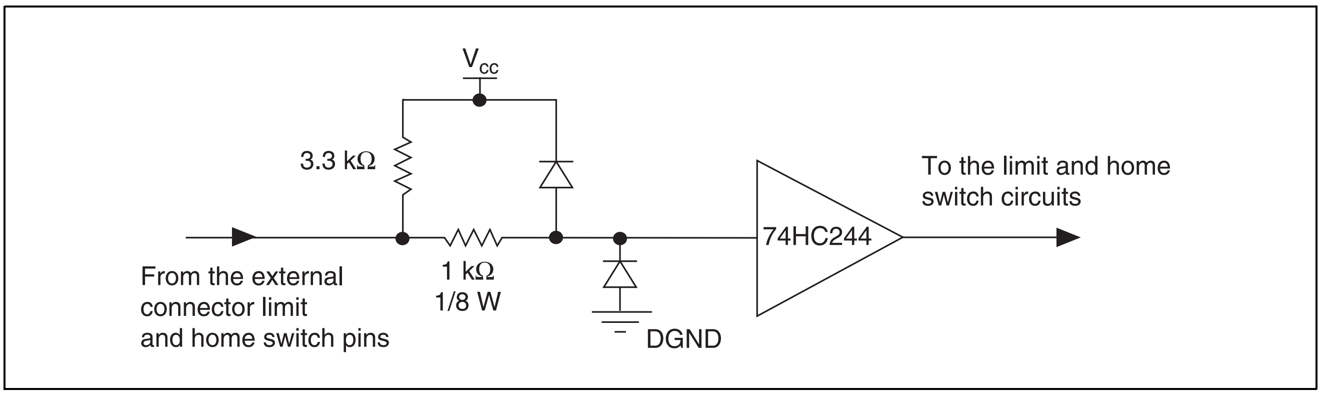


Figure 5-2. Limit and Home Input Circuit

Caution Excessive input voltages can cause erroneous operation and/or component failure. Verify that your input voltage is within the specification range.

Encoder Signals

The 7330 offers four channels of single-ended quadrature encoder inputs. All National Instruments power drives and UMI accessories provide built-in circuitry that converts differential encoder signals to single-ended encoder signals. Each channel consists of a Phase A, Phase B, and Index input, as described in the following sections.

Encoder <1..4> Phase A/Phase B

The encoder inputs provide position and velocity feedback for absolute and relative positioning of axes in any motion system configuration.

If an encoder resource is not needed for axis control, it is available for other functions, including position or velocity monitoring, digital potentiometer encoder inputs, or as a master encoder input for master/slave electronic gearing applications.

The encoder channels (Encoder <1..4>) are implemented in an FPGA and are high performance with extended input frequency response and advanced features, such as high-speed position capture inputs and breakpoint outputs. The encoders have a maximum count frequency of 20 MHz.

An encoder input channel converts quadrature signals on Phase A and Phase B into 32-bit up/down counter values. Quadrature signals are generated by optical, magnetic, laser, or electronic devices that provide two signals, Phase A and Phase B, that are 90° out of phase. The leading phase, A or B, determines the direction of motion. The four transition states of the relative signal phases provide distinct pulse edges that cause count up or count down pulses in the direction determined by the leading phase.

A typical encoder with a specification of N (N = number) lines per unit of measure, which can be revolutions or linear distance, produces $4 \times N$ quadrature counts per unit of measure. The count is the basic increment of position in NI-Motion systems.

Tip Determine quadrature counts by multiplying the encoder resolution in encoder lines by four. The encoder resolution is the number of encoder lines between consecutive encoder marker or Z-bit indexes. If the encoder does not have an index output, the resolution is referred to as lines per revolution, or lines per unit of measure, such as inch, centimeter, millimeter, and so on.

Encoder <1..4> Index

The Index input is primarily used to establish a reference position. This function uses the number of counts per revolution or the linear distance to initiate a search move that locates the index position. When a valid Index signal transition occurs during a Find Reference routine, the position of the Index signal is captured accurately. Use this captured position to establish a reference zero position for absolute position control or any other motion system position reference required.

The default MAX settings guarantee that the Find Index routine completes successfully if the encoder generates a high index pulse when phases A and B are low and the encoder is connected through an NI UMI or drive accessory. Figure 5-3 shows the default encoder phasing diagram at the inputs to the controller.

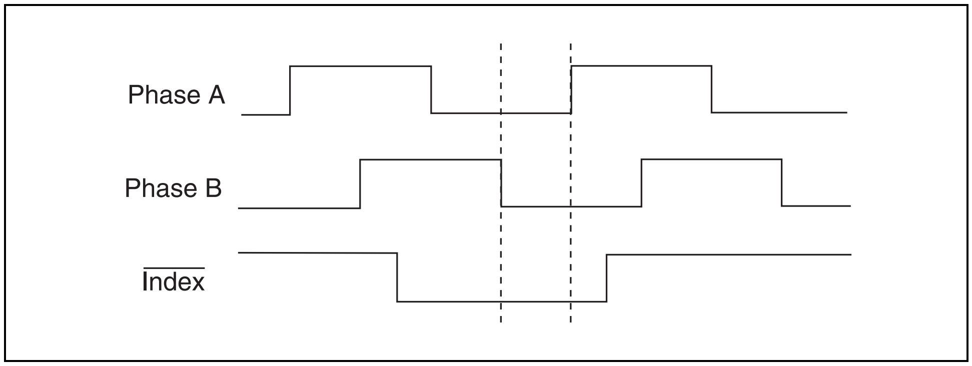


Figure 5-3. Quadrature Encoder Phasing Diagram

You can set the index reference criteria in MAX to change the pattern of phases A and B for the index search. You also can set the encoder polarity for phases A, B, and I in MAX.

Wiring Concerns

The encoder inputs are connected to quadrature decoder/counter circuits. It is very important to minimize noise at this interface. Excessive noise on these encoder input signals may result in loss of counts or extra counts and erroneous closed-loop motion operation. Verify the encoder connections before powering up the system.

Caution Wire encoder signals and their ground connections separately from all other connections. Wiring these signals near the motor drive/amplifier or other signals can cause positioning errors and faulty operation.

Encoders with differential line driver outputs are strongly recommended for all applications and must be used if the encoder cable length is longer than 3.05 m (10 ft). Shielded, 24 AWG wire is the minimum recommended size for the encoder cable. Cables with twisted pairs and an overall shield are recommended for optimized noise immunity.

All National Instruments power drives and UMI accessories provide built-in circuitry that converts differential encoder signals to single-ended encoder signals.

Caution Unshielded cable can cause noise to corrupt the encoder signals, resulting in lost counts and reduced motion system accuracy.

Encoder Input Circuit

Figure 5-4 shows a simplified schematic diagram of the circuit used for the Phase A, Phase B, and Index encoder inputs. Both phases A and B are required for proper encoder counter operation, and the signals must support the 90° phase difference within system tolerance. The encoder and Index signals are conditioned by a software-programmable digital filter inside the FPGA. The Index signal is optional but highly recommended and required for initialization functionality with the Find Index function.

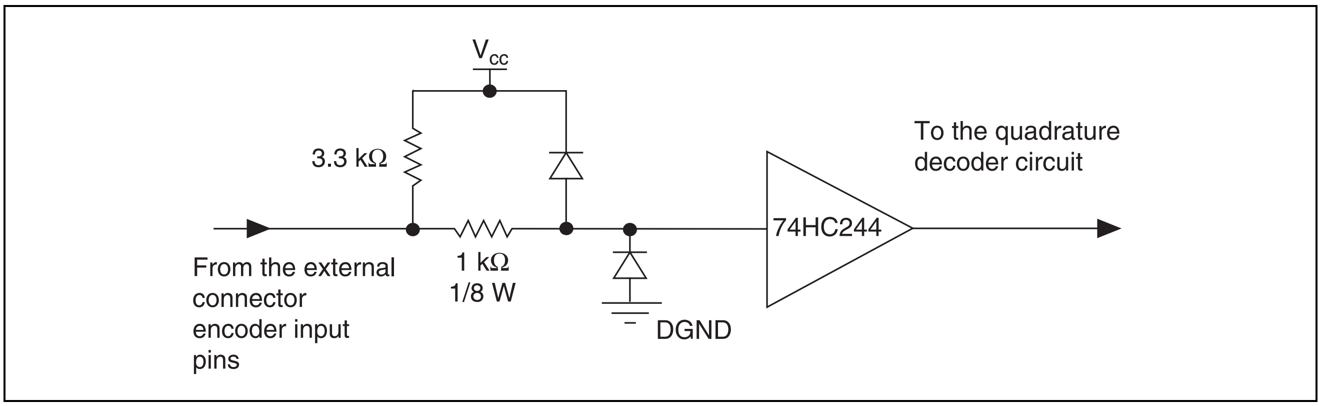


Figure 5-4. Encoder Input Circuit

Trigger Inputs, Shutdown Input, and Breakpoint Outputs

The 7330 offers additional high-performance features in the encoder FPGA. The encoder channels have high-speed position capture trigger inputs and breakpoint outputs. These signals are useful for high-speed synchronization of motion with actuators, sensors, and other parts of the complete motion system:

- Trigger Input <1..4>—When enabled, an active transition on a high-speed position capture input causes instantaneous position capture (<100 ns latency) of the corresponding encoder count value. You can use this high-speed position capture functionality for applications ranging from simple position tagging of sensor data to complex camming systems with advance/retard positioning and registration. An available 7330 position mode is to move an axis Relative to Captured Position.

The polarity of the trigger input is programmable in software as active-low (inverting), active-high (non-inverting), rising, or falling edge. You also can use a trigger input as a latching general-purpose digital input by simply ignoring the captured position.

- Shutdown Input—When enabled in software, the shutdown input signal can be used to kill all motion by asserting the controller inhibits, setting the analog outputs to 0 V, and stopping any stepper pulse generation. To activate shutdown, the signal must transition from a low to a high state, or rising edge.
- Breakpoint Output <1..4>—A breakpoint output can be programmed to transition when the associated encoder value equals the breakpoint position. You can use a breakpoint output to directly control actuators or as a trigger to synchronize data acquisition or other functions in the motion control system.

  You can program breakpoints as either *absolute*, *modulo*, or *relative* position. Breakpoint outputs can be preset to a known state so that the transition when the breakpoint occurs can be low to high, high to low, or toggle.

  The breakpoint outputs are driven by open-collector TTL buffers that feature 64 mA sink current capability and built in 3.3 kΩ pull-up resistors to +5 V.

  You can directly set and reset breakpoint outputs to use them as general-purpose digital outputs.

Wiring Concerns

Caution Keep trigger input, shutdown input, and breakpoint output signals and their ground connections wired separately from the motor driver/amplifier signal and encoder signal connections. Wiring these signals near each other can cause faulty operation.

Caution Excessive input voltages can cause erroneous operation and/or component failure.

Trigger Input, Shutdown Input, and Breakpoint Output Circuits

Figures 5-5, 5-6, and 5-7 show a simplified schematic diagram of the circuits used by the trigger inputs, shutdown inputs, and breakpoint outputs for signal buffering.

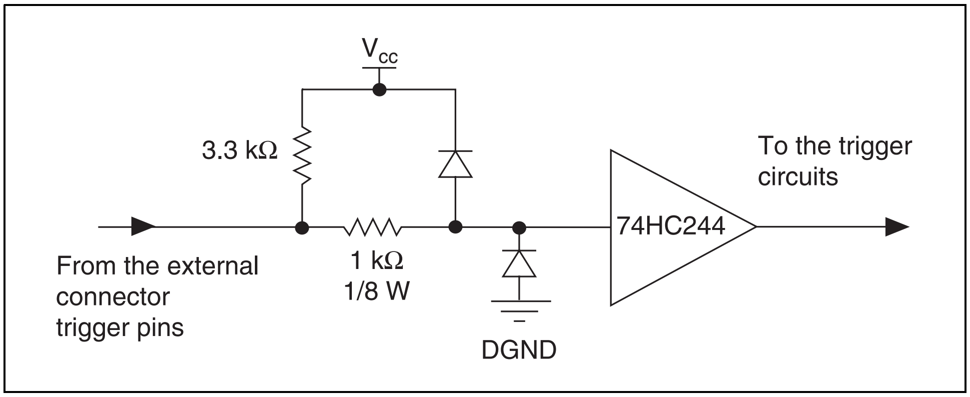


Figure 5-5. Trigger Input Circuit

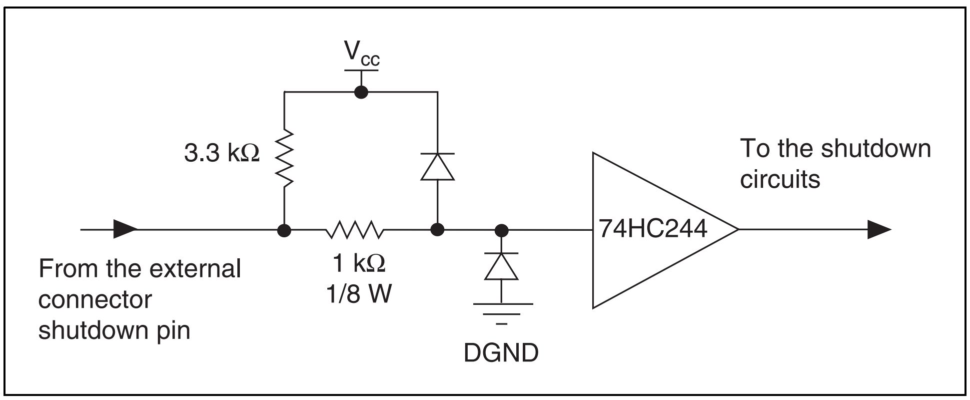


Figure 5-6. Shutdown Input Circuit

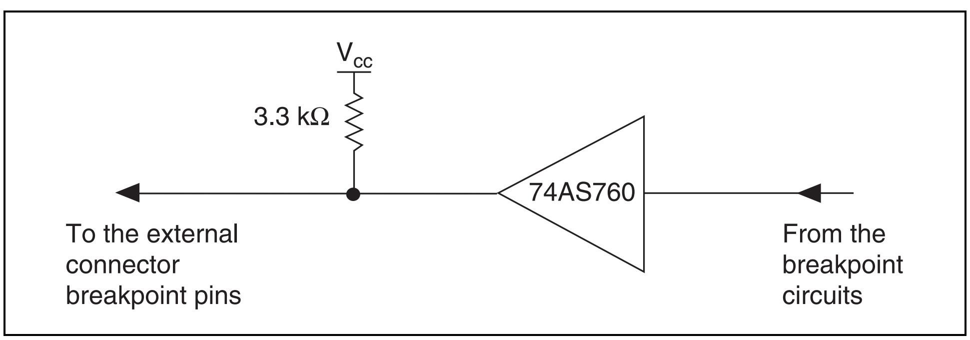


Figure 5-7. Breakpoint Output Circuit

Analog Inputs

The 7330 has the following ADC input signals:

- Analog Input <1..4>—The 7330 includes an eight-channel multiplexed, 12-bit ADC capable of measuring ±10 V, ±5 V, 0–10 V, and 0–5 V inputs. ADC channels 1 through 4 are brought out externally on the 68-pin motion I/O connector. ADC channels 5 through 8 are connected internally, as shown in Table 5-2. These signals can be used for ADC test and system diagnostics.

Table 5-2. Internal ADC Channels

ADC Input	Signal
5	Filtered +5 V
6	Floating (NC)
7	Analog Reference (7.5 V)
8	Analog Input Ground

You can configure each ADC channel for motion feedback, simple analog-to-digital conversion, or both.

You can read the digital value of analog voltage on any of the eight ADC channels of the controller. Table 5-3 shows the range of values read back and the voltage resolution for each setting. The voltage resolution is in volts per least significant bit (V/LSB).

Table 5-3. Analog Input Voltage Ranges

Input Range	Binary Values	Resolution
±10 V	–2,048 to 2,047	0.0049 V/LSB
±5 V	–2,048 to 2,047	0.0024 V/LSB
0–10 V	0 to 4,095	0.0024 V/LSB
0–5 V	0 to 4,095	0.0012 V/LSB

As indicated in Figure 5-3, when configured as analog feedback, an analog sensor acts like a limited range absolute position device with a full-scale position range. You can map any ADC channel as feedback to any axis.

You can enable and disable individual ADC channels in software. Disable unused ADC channels for the highest multiplexer scan rate performance. When the ADC channels are properly enabled, the scan rate is high enough to support analog feedback at the highest PID sample rate.

- Analog Reference—For convenience, 7.5 V (nominal) analog reference voltage is available. You can use this output as a low-current supply to sensors that require a stable reference. Refer to Appendix A, *Specifications*, for analog reference voltage specifications.
- Analog Input Ground—To help keep digital noise out of the analog input, a separate return connection is available. Use this reference ground connection and not Digital Ground (digital I/O reference) as the reference for the analog inputs.

Wiring Concerns

For proper use of each ADC input channel, the analog signal to be measured should be connected to the channel input and its ground reference connected to the Analog Input Ground.

Note The analog reference output is an output signal only and must not connect to an external reference voltage. Connect the common of the external reference to the Analog Input Ground pin for proper A/D reference and improved voltage measurement.

Other Motion I/O Connection

The 7330 provides the following other motion I/O connection:

- Host +5 V—This signal is the internal +5 V supply of the host computer. It is typically used to detect when the host computer is powered on and to shut down external motion system components when the host computer is powered off or disconnected from the motion accessory.

Caution The host +5 V signal is limited to <100 mA and should not be used to power any external devices, except those intended in the host bus monitor circuits on the UMI and drive products.

Digital I/O Connector

All the general-purpose digital I/O lines on the 7330 are available on a separate 68-pin digital I/O connector. Figure 5-8 shows the pin assignments for this connector.

+5 V	1	35	Digital Ground
PCLK	2	36	Digital Ground
Reserved	3	37	Digital Ground
Reserved	4	38	DPull
PWM1	5	39	Digital Ground
Reserved	6	40	Reserved
Reserved	7	41	Digital Ground
Reserved	8	42	Digital Ground
PWM2	9	43	Digital Ground
Port 1:bit 0	10	44	Port 1:bit 1
Digital Ground	11	45	Port 1:bit 2
Port 1:bit 3	12	46	Digital Ground
Port 1:bit 4	13	47	Port 1:bit 5
Digital Ground	14	48	Port 1:bit 6
Port 1:bit 7	15	49	Digital Ground
Port 2:bit 0	16	50	Digital Ground
Port 2:bit 1	17	51	Port 2:bit 2
Digital Ground	18	52	Port 2:bit 3
Digital Ground	19	53	Port 2:bit 4
Digital Ground	20	54	Port 2:bit 5
Port 2:bit 6	21	55	Digital Ground
Port 2:bit 7	22	56	Digital Ground
Port 3:bit 0	23	57	Port 3:bit 1
Digital Ground	24	58	Port 3:bit 2
Port 3:bit 3	25	59	Digital Ground
Port 3:bit 4	26	60	Port 3:bit 5
Digital Ground	27	61	Port 3:bit 6
Port 3:bit 7	28	62	Digital Ground
Port 4:bit 0	29	63	Port 4:bit 1
Digital Ground	30	64	Port 4:bit 2
Port 4:bit 3	31	65	Digital Ground
Port 4:bit 4	32	66	Port 4:bit 5
Digital Ground	33	67	Port 4:bit 6
Port 4:bit 7	34	68	Digital Ground

Figure 5-8. 68-Pin Digital I/O Connector Pin Assignments

The 32-bit digital I/O port is configured in hardware as four 8-bit digital I/O ports. The bits in a port are typically controlled and read with byte-wide bitmapped commands.

All digital I/O lines have programmable direction and polarity. Each output circuit can sink and source 24 mA.

The DPull pin controls the state of the input pins at power-up. Connecting DPull to +5 V or leaving it unconnected configures all pins in all ports for 100 kΩ pull-ups. Connecting DPull to ground configures the ports for 100 kΩ pull-downs.

PWM Features

The 7330 provides two pulse width modulation (PWM) outputs on the digital I/O connector. The PWM outputs generate periodic waveforms whose period and duty cycles can be independently controlled through software commands. The PWM is comparable to a digital representation of an analog value because the duty cycle is directly proportional to the desired output value. PWM outputs are typically used for transmitting an analog value through an optocoupler. A simple lowpass filter turns a PWM signal back into its corresponding analog value. If desired, you can use the PCLK input instead of the internal source as the clock for the PWM generators.

RTSI Connector

The physical RTSI bus interface varies depending on the type of 7330 controller.

The PXI-7330 uses the PXI chassis backplane to connect to other RTSI-capable devices.

The PCI-7330 uses a ribbon cable to connect to other RTSI-capable PCI devices.

RTSI Signal Considerations

The 7330 motion controller allows you to use up to eight RTSI trigger lines as sources for trigger inputs, or as destinations for breakpoint outputs and encoder signals. The RTSI trigger lines also can serve as a generic digital I/O port. The RTSI star trigger line can be used only for a trigger input. Breakpoint outputs are output-only signals that generate an active-high pulse of 200 ns duration, as shown in Figure 5-9.

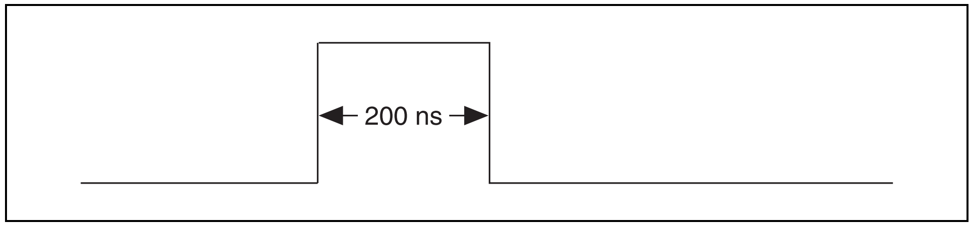


Figure 5-9. Breakpoint across RTSI

Encoder and Index signals are output-only signals across RTSI that are the digitally-filtered versions of the raw signals coming into the controller. If you are using the RTSI bus for trigger inputs or generic digital I/O, all signals are passed through unaltered.

A

Specifications

This appendix lists the hardware and software performance specifications for the PXI/PCI-7330. Hardware specifications are typical at 25 °C, unless otherwise stated.

Stepper Performance

Trajectory update rate range .... 62.5 to 500 µs/sample

- Maximum update rate .... 62.5 µs/axis
- 4-axis update rate .... 250 µs total

Multi-axis synchronization .... <1 update sample

Position accuracy

- Open-loop stepper........................... 1 full, half, or microstep
- Encoder feedback............................ ±1 quadrature count
- Analog feedback .... ±1 LSB

Double-buffered trajectory parameters

- Position range .... $\pm 2^{31}$ steps
- Maximum relative move size.......... $\pm 2^{31}$ steps
- Velocity range................................ 1 to 4,000,000 steps/s
- Acceleration/deceleration[1] .... ±512,000,000 counts/s^2
- S-curve time range.......................... 1 to 32,767 samples
- Following error range .... 0 to 32,767 counts
- Gear ratio .... ±32,767:1 to ±1:32,767

Stepper outputs

- Maximum pulse rate .... 4 MHz (full, half, and microstep)
- Minimum pulse width..................... 120 ns at 4 MHz
- Step output mode .... Step and direction or CW/CCW

[1] Assumes a PID update rate of 250 µs and a 2,000-count encoder.

Voltage range..................................0 to 5 V
  Output low voltage ....<0.6 V at 64 mA sink
  Output high voltage ....Open collector with built-in 3.3 kΩ pull-up to +5 V
Polarity ....Programmable, active-high or active-low

System Safety

Watchdog timer function ....Resets board to startup state
  Watchdog timeout ....63 ms

Shutdown input
  Voltage range..................................0 to 5 V
    Input low voltage......................0.8 V
    Input high voltage.....................2 V
    Polarity ....Rising edge
  Control ....Disable all axes and command outputs

Motion I/O

Encoder inputs ....Quadrature, incremental, single-ended
  Maximum count rate........................20 MHz
  Minimum pulse width......................Programmable; depends on digital filter settings
  Voltage range..................................0 to 5 V
    Input low voltage......................0.8 V
    Input high voltage.....................2 V
  Minimum index pulse width............Programmable; depends on digital filter settings

Forward, reverse, and home inputs
  Number of inputs.............................12 (3 per axis)
  Voltage range..................................0 to 5 V
    Input low voltage......................0.8 V
    Input high voltage.....................2 V
  Polarity ....Programmable, active-high or active-low

Minimum pulse width	1 ms with filter enabled; 60 ns without filter enabled
Control	Individual enable/disable, stop on input, prevent motion, Find Home

Trigger inputs

Number of inputs	4 (Encoders 1 through 4)
Voltage range	0 to 5 V
Input low voltage	0.8 V
Input high voltage	2 V
Polarity	Programmable, active-high or active-low
Minimum pulse width	100 ns
Capture latency	<100 ns
Capture accuracy	1 count
Maximum repetitive capture rate	100 Hz

Breakpoint outputs

Number of outputs	4 (Encoders 1 through 4)
Voltage range	0 to 5 V
Output low voltage	<0.6 V at 64 mA sink
Output high voltage	Open collector with built-in 3.3 kΩ pull-up to +5 V
Polarity	Programmable, active-high or active-low
Maximum repetitive breakpoint rate	100 Hz

Inhibit/enable output

Number of outputs	4 (1 per axis)
Voltage range	0 to 5 V
Output low voltage	<0.6 V at 64 mA sink
Output high voltage	Open collector with built-in 3.3 kΩ pull-up to +5 V
Polarity	Programmable, active-high or active-low
Control	MustOn/MustOff or automatic when axis off

Analog inputs

- Number of inputs .... 8 multiplexed, single ended
  - Number for user signals 4
  - Number for system diagnostics ... 4
- Voltage range (programmable)........ ±10 V, ±5 V, 0–10 V, 0–5 V
- Input resistance .... 10 kΩ min
- Input coupling .... DC
- Resolution .... 12 bits, no missing codes
- Monotonic .... Guaranteed
- Multiplexor scan rate .... 25 μs/enabled channel

Analog reference output .... 7.5 V (nominal) @ 5 mA

Digital I/O

Ports .... 4, 8-bit ports

- Line direction .... Individual bit programmable

Inputs

- Voltage range .... 0 to 5 V
  - Input low voltage .... 0.8 V
  - Input high voltage .... 2.0 V
- Polarity .... Programmable, active-high or active-low

Outputs

- Voltage range .... 0 to 5 V
  - Output low voltage .... <0.45 V at 24 mA sink
  - Output high voltage .... >2.4 V at 24 mA source
- Polarity .... Programmable, active-high or active-low
- PWM outputs
  - Number of PWM outputs 2
  - Maximum PWM frequency ...... 50 kHz
  - Resolution 8-bit
  - Duty cycle range .... 0 to (255/256)%
  - Clock sources .... Internal or external

RTSI

Trigger lines 7

Maximum Power Requirements

+5 V (±3%) .... 1 A

+12 V (±3%) .... 30 mA

–12 V (±3%).. 30 mA

Power consumption................................ 5.7 W

Physical

Dimensions (Not Including Connectors)

PXI-7330... 16 × 10 cm (6.3 × 3.9 in.)

PCI-7330 .... 17.5 × 9.9 cm (6.9 × 3.9 in.)

Connectors

Motion I/O connector............................ 68-pin female high-density VHDCI type

32-bit digital I/O connector.................... 68-pin female high-density VHDCI type

Weight

PCI-7330 .... 113 g (4 oz)

PXI-7330.. 170 g (6 oz)

Maximum Working Voltage

Channel-to-earth ....12 V, Installation Category 1 (signal voltage plus common-mode voltage)

Channel-to-channel................................22 V, Installation Category 1 (signal voltage plus common-mode voltage)

Caution These values represent the maximum allowable voltage between any accessible signals on the controller. To determine the acceptable voltage range for a particular signal, refer to the individual signal specifications.

Environment

Operating temperature ....0 to 55 °C

Storage temperature ....–20 to 70 °C

Humidity ....10 to 90% RH, noncondensing

Maximum altitude..................................2,000 m

Pollution Degree 2

Safety

This product is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 3111-1, UL 61010B-1
- CAN/CSA C22.2 No. 1010.1

Note For UL and other safety certifications, refer to the product label or visit `ni.com/hardref.nsf`, search by model number or product line, and click the appropriate link in the Certification column.

Electromagnetic Compatibility

Emissions .... EN 55011 Class A at 10 m
FCC Part 15A above 1 GHz

Immunity .... EN 61326:1997 + A2:2001,
Table 1

CE, C-Tick, and FCC Part 15 (Class A) Compliant

Note For EMC compliance, you *must* operate this device with shielded cabling.

CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

Low-Voltage Directive (safety) 73/23/EEC

Electromagnetic Compatibility
Directive (EMC) 89/336/EEC

Note Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit `ni.com/hardref.nsf`, search by model number or product line, and click the appropriate link in the Certification column.

B Cable Connector Descriptions

This appendix describes the connector pinout for the cables that connect to the PXI/PCI-7330.

Figure B-1 shows the pin assignments for the stepper 50-pin motion connectors. These connectors are available when you use the SH68-C68-S shielded cable assembly and the 68M-50F step/servo bulkhead cable adapter.

Axis 1 Dir (CCW)	1	2	Axis 1 Step (CW)
Digital Ground	3	4	Axis 1 Encoder Phase A
Digital Ground	5	6	Axis 1 Encoder Phase B
Axis 1 Home Switch	7	8	Axis 1 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 1	9	10	Axis 1 Forward Limit Switch
Axis 1 $\overline{\text{Inhibit}}$	11	12	Axis 1 Reverse Limit Switch
Axis 2 Dir (CCW)	13	14	Axis 2 Step (CW)
Digital Ground	15	16	Axis 2 Encoder Phase A
Digital Ground	17	18	Axis 2 Encoder Phase B
Axis 2 Home Switch	19	20	Axis 2 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 2	21	22	Axis 2 Forward Limit Switch
Axis 2 $\overline{\text{Inhibit}}$	23	24	Axis 2 Reverse Limit Switch
Axis 3 Dir (CCW)	25	26	Axis 3 Step (CW)
Digital Ground	27	28	Axis 3 Encoder Phase A
Digital Ground	29	30	Axis 3 Encoder Phase B
Axis 3 Home Switch	31	32	Axis 3 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 3	33	34	Axis 3 Forward Limit Switch
Axis 3 $\overline{\text{Inhibit}}$	35	36	Axis 3 Reverse Limit Switch
Axis 4 Dir (CCW)	37	38	Axis 4 Step (CW)
Digital Ground	39	40	Axis 4 Encoder Phase A
Digital Ground	41	42	Axis 4 Encoder Phase B
Axis 4 Home Switch	43	44	Axis 4 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 4	45	46	Axis 4 Forward Limit Switch
Axis 4 $\overline{\text{Inhibit}}$	47	48	Axis 4 Reverse Limit Switch
Digital Ground	49	50	Host +5 V

Figure B-1. 50-Pin Stepper Connector Pin Assignment

C

Technical Support and Professional Services

Visit the following sections of the National Instruments Web site at `ni.com` for technical support and professional services:

- **Support**—Online technical support resources include the following:
  - **Self-Help Resources**—For immediate answers and solutions, visit our extensive library of technical support resources available in English, Japanese, and Spanish at `ni.com/support`. These resources are available for most products at no cost to registered users and include software drivers and updates, a KnowledgeBase, product manuals, step-by-step troubleshooting wizards, conformity documentation, example code, tutorials and application notes, instrument drivers, discussion forums, a measurement glossary, and so on.
  - **Assisted Support Options—**Contact NI engineers and other measurement and automation professionals by visiting `ni.com/support`. Our online system helps you define your question and connects you to the experts by phone, discussion forum, or email.
- **Training—**Visit `ni.com/training` for self-paced tutorials, videos, and interactive CDs. You also can register for instructor-led, hands-on courses at locations around the world.
- **System Integration—**If you have time constraints, limited in-house technical resources, or other project challenges, NI Alliance Program members can help. To learn more, call your local NI office or visit `ni.com/alliance`.
- **Declaration of Conformity (DoC)—**A DoC is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electronic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting `ni.com/hardref.nsf`.

If you searched `ni.com` and could not find the answers you need, contact your local office or NI corporate headquarters. Phone numbers for our worldwide offices are listed at the front of this manual. You also can visit the Worldwide Offices section of `ni.com/niglobal` to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

Glossary

Symbol	Prefix	Value
μ	micro	10^{-6}
m	milli	10^{-3}
M	mega	10^{6}

Numbers/Symbols

/	per
%	percent
±	plus or minus
+5 V	+5 VDC source signal

A

A	amperes
A/D	analog-to-digital
absolute mode	treat the target position loaded as position relative to zero (0) while making a move
absolute position	position relative to zero
acceleration/ deceleration	a measurement of the change in velocity as a function of time. Acceleration and deceleration describes the period when velocity is changing from one value to another.
active-high	a signal is active when its value goes high (1)
active-low	a signal is active when its value goes low (0)
ADC	analog-to-digital converter

address	character code that identifies a specific location (or series of locations) in memory or on a host PC bus system
amplifier	the drive that delivers power to operate the motor in response to low level control signals. In general, the amplifier is designed to operate with a particular motor type—you cannot use a stepper drive to operate a DC brush motor, for instance
Analog Input <1..4>	12-bit analog ADC input
API	application programming interface
axis	unit that controls a motor or any similar motion or control device
Axis <1..4> Forward Limit Input	axis 1 through 4 forward/clockwise limit switch
Axis <1.4> Home Input	axis 1 through 4 home input
Axis <1..4> $\overline{\text{Inhibit}}$	axis 1 through 4 inhibit output
Axis <1..4> Reverse Limit Input	axis 1 through 4 reverse/counter-clockwise limit input

B

b	bit—one binary digit, either 0 or 1
base address	memory address that serves as the starting address for programmable or I/O bus registers. All other addresses are located by adding to the base address.
binary	a number system with a base of 2
buffer	temporary storage for acquired or generated data (software)
bus	the group of conductors that interconnect individual circuitry in a computer. Typically, a bus is the expansion vehicle to which I/O or other devices are connected.
byte	eight related bits of data, an eight-bit binary number. Also used to denote the amount of memory required to store one byte of data.

C

CCW	counter-clockwise—implies direction of rotation of the motor
closed-loop	a motion system that uses a feedback device to provide position and velocity data for status reporting and accurately controlling position and velocity
common	reference signal for digital I/O
CPU	central processing unit
crosstalk	an unwanted signal on one channel due to an input on a different channel
CSR	Communications Status Register
CW	clockwise—implies direction of motor rotation

D

DC	direct current
dedicated	assigned to a particular function
DGND	digital ground signal
digital I/O port	a group of digital input/output signals
DLL	dynamically-linked library—provides the API for the motion control boards
drivers	software that communicates commands to control a specific motion control board
DSP	Digital Signal Processor

E

encoder	device that translates mechanical motion into electrical signals; used for monitoring position or velocity in a closed-loop system
encoder resolution	the number of encoder lines between consecutive encoder indexes (marker or Z-bit). If the encoder does not have an index output the encoder resolution can be referred to as lines per revolution.

F

f	farad
FIFO	First-In, First-Out
filter parameters	indicates the control loop parameter gains (PID gains) for a given axis
filtering	a type of signal conditioning that filters unwanted signals from the signal being measured
flash ROM	a type of electrically reprogrammable read-only memory
following error trip point	the difference between the instantaneous commanded trajectory position and the feedback position
FPGA	Field Programmable Gate Array
freewheel	the condition of a motor when power is de-energized and the motor shaft is free to turn with only frictional forces to impede it
full-step	full-step mode of a stepper motor—for a two phase motor this is done by energizing both windings or phases simultaneously

G

Gnd	ground
GND	ground

H

half-step	mode of a stepper motor—for a two phase motor this is done by alternately energizing two windings and then only one. In half step mode, alternate steps are strong and weak but there is significant improvement in low-speed smoothness over the full-step mode.
hex	hexadecimal
home switch (input)	A physical position determined by the mechanical system or designer as the reference location for system initialization. Frequently, the home position also is regarded as the zero position in an absolute position frame of reference.
host computer	computer into which the motion control board is plugged

I

I/O	input/output—the transfer of data to and from a computer system involving communications channels, operator interface devices, and/or motion control interfaces
ID	identification
in.	inches
index	marker between consecutive encoder revolutions
inverting	the polarity of a switch (limit switch, home switch, and so on) in *active* state. If these switches are active-low they are said to have inverting polarity.
IRQ	interrupt request

K

k	kilo—the standard metric prefix for 1,000, or 10^3, used with units of measure such as volts, hertz, and meters
K	kilo—the prefix for 1,024, or 2^{10}, used with B in quantifying data or computer memory

L

LIFO	Last-In, First-Out
limit switch/ end-of-travel position (input)	sensors that alert the control electronics that physical end of travel is being approached and that the motion should stop

M

m	meters
MCS	Move Complete Status
microstep	The proportional control of energy in the coils of a Stepper Motor that allow the motor to move to or stop at locations other than the fixed magnetic/mechanical pole positions determined by the motor specifications. This capability facilitates the subdivision of full mechanical steps on a stepper motor into finer microstep locations that greatly smooth motor running operation and increase the resolution or number of discrete positions that a stepper motor can attain in each revolution.
modulo position	treat the position as within the range of total quadrature counts per revolution for an axis

N

noise	an undesirable electrical signal—noise comes from external sources such as the AC power line, motors, generators, transformers, fluorescent lights, soldering irons, CRT displays, computers, electrical storms, welders, radio transmitters, and internal sources such as semiconductors, resistors, and capacitors. Noise corrupts signals you are trying to send or receive.
noninverting	the polarity of a switch (limit switch, home switch, etc.) in *active* state. If these switches are active-high, they are said to have non-inverting polarity.

O

open-loop	refers to a motion control system where no external sensors (feedback devices) are used to provide position or velocity correction signals

P

PCI	Peripheral Component Interconnect—a high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA. It is achieving widespread acceptance as a standard for PCs and workstations; it offers a theoretical maximum transfer rate of 132 MB/s.
port	(1) a communications connection on a computer or a remote controller (2) a digital port, consisting of eight lines of digital input and/or output
position breakpoint	position breakpoint for an encoder can be set in absolute or relative quadrature counts. When the encoder reaches a position breakpoint, the associated breakpoint output immediately transitions.
power cycling	turning the host computer off and then back on, which causes a reset of the motion control board
PWM	Pulse Width Modulation—a method of controlling the average current in a motor phase winding by varying the on-time (duty cycle) of transistor switches
PXI	PCI eXtensions for Instrumentation

Q

quadrature counts	the encoder line resolution times four

R

RAM	random-access memory
relative breakpoint	sets the position breakpoint for an encoder in relative quadrature counts
relative position	destination or target position for motion specified with respect to the current location regardless of its value
relative position mode	position relative to current position
ribbon cable	a flat cable in which the conductors are side by side
RPM	revolutions per minute—units for velocity

RPSPS or RPS/S	revolutions per second squared—units for acceleration and deceleration
RTR	Ready to Receive

S

s	seconds
servo	specifies an axis that controls a servo motor
stepper	specifies an axis that controls a stepper motor
stepper <1..4> Dir (CCW)	direction output or counter-clockwise direction control
stepper <1..4> Step (CW)	stepper pulse output or clockwise direction control

T

toggle	changing state from high to low, back to high, and so on
torque	force tending to produce rotation
trapezoidal profile	a typical motion trajectory, where a motor accelerates up to the programmed velocity using the programmed acceleration, traverses at the programmed velocity, then decelerates at the programmed acceleration to the target position
trigger	any event that causes or starts some form of data capture
TTL	transistor-transistor logic

V

V	volts
V_{CC}	positive voltage supply
velocity mode	move the axis continuously at the specified velocity

W

watchdog	a timer task that shuts down (resets) the motion control board if any serious error occurs
word	the standard number of bits that a processor or memory manipulates at one time, typically 8-, 16-, or 32-bit

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6.2.2 Stepper Driver Documentation

P70530 (DC) High Performance Micro-stepping Drive

Reference Guide
Part # M-SD-7DC-01
Rev A January 10, 2007

Keep all product manuals as a product component during the life span of the stepper drive.
Pass all product manuals to future users/owners of the stepper drive.

DANAHER MOTION
Helping you build a better machine faster.

Record of Manual Revisions

Revision	Date	Description of Revision
1	04/2006	Initial Release

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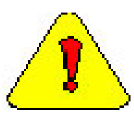
Danaher Motion reserves the right to make engineering refinements on all its products. Such refinements may affect information in instructions. **USE ONLY THE INSTRUCTIONS PACKED WITH THE PRODUCT.**

Safety-alert symbols used in this document are:

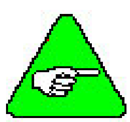
WARNING

Alerts users to potential physical danger or harm. Failure to follow warning notices could result in personal injury or death.



CAUTION

Directs attention to general precautions, which if not followed, could result in personal injury and/or equipment damage.



NOTE

Highlights information critical to your understanding or use of the product.

Table of Contents

1. GETTING STARTED

WARNING

Read this reference guide before you apply power to the drive. Mis-wiring of the drive may result in damage to the unit voiding the warranty. Improper grounding of the drive may cause serious injury to the operator.

Only qualified personnel are permitted to transport, assemble, commission, and maintain this equipment. Properly qualified personnel are persons who are familiar with the transport, assembly, installation, commissioning and operation of motors, and who have the appropriate qualifications for their jobs.

Read all available documentation before assembling and using. Incorrect handling of products in this manual can result in injury and damage to persons and machinery. Strictly adhere to the technical information regarding installation requirements.

CAUTION

Keep all covers and cabinet doors shut during operation.

CAUTION

Be aware that during operation, the product has electrically charged components and hot surfaces. Control and power cables can carry a high voltage, even when the motor is not rotating.

CAUTION

Never disconnect or connect the product while the power source is energized.

CAUTION

After removing the power source from the equipment, wait at least 2 minutes before touching or disconnecting sections of the equipment that normally carry electrical charges (e.g., capacitors, contacts, screw connections). To be safe, measure the electrical contact points with a meter before touching the equipment.

1.1 UNPACKING AND INSPECTING

Open the box and remove all the contents. Check to ensure there is no visible damage to any of the equipment.

CAUTION ***Use proper procedures when handling electronic components to avoid damage to equipment.***

CAUTION ***Remove all packing material and equipment from the shipping container. Be aware that some connector kits and other equipment pieces may be quite small and can be accidentally discarded. Do not dispose of shipping materials until the packing list has been checked.***

NOTE ***Upon receipt of the equipment, inspect components to ensure that no damage has occurred in shipment. If damage is detected, notify the carrier immediately. Check all shipping material for connector kits and documentation.***

1.2 PART NUMBER

P7 NN N 0 XX N - NNN

Family
P7 - P7000 Series

Current Rating
03 - 2.5 A_{RMS} continuous, 3.5 A_{RMS} peak (***AC only***)
05 - 5 A_{RMS} continuous, 7.1 A_{RMS} peak (***DC only***)

Voltage
3 - 20 - 75 VDC
6 - 120/240 VAC

Electrical Option
0 - no option

Functionality
PN - Motion Node Indexing
SD - Step/Direction Base Drive
R4 - RS485 ***AC only***

Feedback
N - None

Customization
Omitted for standard units

1.3 ACCESSORIES

768-026902-01	26-pin D-Sub connector to terminal block adapter
P7S2-232-9D	RS-232 Serial cable RJ12 to 9 pin D-Sub connector 6 feet

1.4 SPECIFICATIONS

NOTE

Unless otherwise specified, specifications are worse-case limits and apply over the specified operating ambient temperature and over the specified operating line voltage.

1.4.1 DRIVE POWER

Specification	P70530
Max Output Current (0-40° C)	5 A_{RMS}
Max Output Power at 5 A max average	350 W at 72 V 240 W at 48 V 120 W at 24 V
Power Dissipation at 3.5 A	9 W max at 5 A_{RMS}/motor phase 5 W max at 3 A_{RMS}/motor phase 1.8 W typ. at disabled
Motor Inductance Range	2-15 mH nom.
Maximum Motor Cable Length (24 AWG)	20 m
Power Supply 20 - 75 VDC recommended design center isolated unregulated type (or regulated + bus cap)	20 – 75 VDC 5 A average (max)
Cbus cap min scale as ratio of (motor current/5A) scale as ratio of (72 V/supply voltage) for multiple drives on supply scales as (number of drives) locate within 10 ft. of drive (#16 AWG twisted)	6,000 µf at 5 A motor, 72 V
Bus Under Voltage Fault	18 VDC
Bus Over Voltage Fault	91 VDC
Inrush Current & Fusing	
Peak Current	15 A
Inrush Pulse Width	4 ms
Recommended Fusing	10 A Slow Blow
5 VDC Internal Supply	50 mA
Time delay for "reduced idle current" to return to the system's "full current"	< 1 ms (typ)

NOTE

See Appendix A for information on power supply bus capacitance.

1.4.2 I/O SPECIFICATIONS

Step, Direction, & Enable Inputs	
Step/Dir J4-1-J4-6	
Step Input Voltage & Current Range	3 V - 6 V, 16 mA at 5 V (See Note below)
Direction Input Voltage & Current Range	3 V - 6 V, 16 mA at 5 V (See Note below)
Enable Input Voltage & Current Range	3 V - 6 V, 3-6 mA at 5 V (See Note below)
Step Minimum on/off time	800 ns
Step Input Max Frequency	2 MHz
Direction minimum set up Time	50 µs

General Purpose I/O	
DIN1-DIN9 (J4-10-J4-18)	
Input Voltage Range	4 - 6 VDC (See Note below)
Input Current Range (Internally Controlled)	1 mA at 5 VDC 5.3 mA at 24 VDC
Response Time	<= 250 µs
GPO J4-7, J4-8, J4-21, J4-22	
Maximum Output Voltage	30 VDC
Clamp Voltage	30 VDC
Maximum Output Current	5 mA
On Voltage	0.4 VDC
Response Time	<= 250 µs

NOTE

Higher voltages may also be used if an appropriately sized current limit resistor is installed external to the drive (Reference sections 2.2.2.2, 2.2.2.3, and 2.2.2.4).

1.4.3 ENVIRONMENTAL

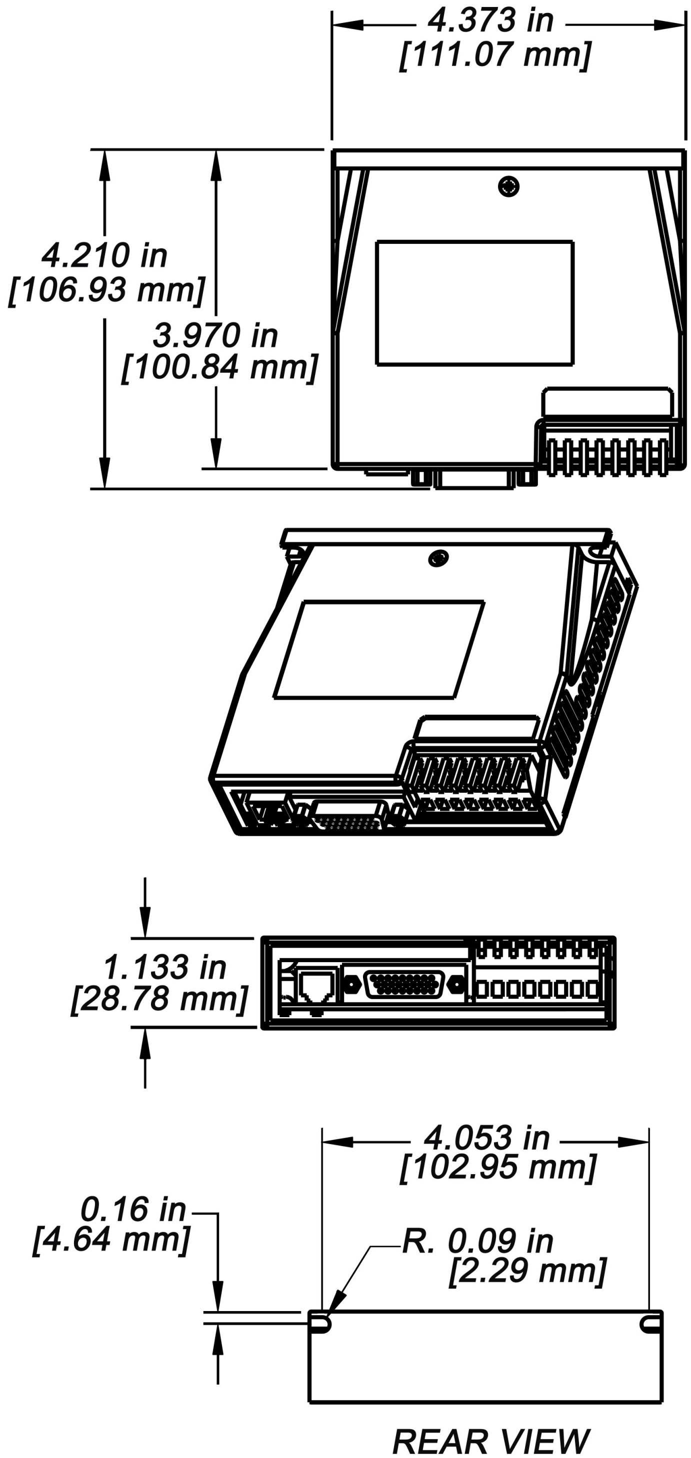
Operating Temperature	0 - 45° C unmounted 0 - 55° C Typ. cabinet mount
Pollution Degree	II
Storage Temperature °C	0 - 70° C
Humidity (% non-condensing)	10-90%
Altitude	<1500 m (5000 ft)
Weight	0.26 kg (0.562 Lbs)

1.5 *DC MOUNTING*

Mount the P70530 to a cold plate using either 8x32 or M4 screws. This drive can be mounted either vertically or horizontally.

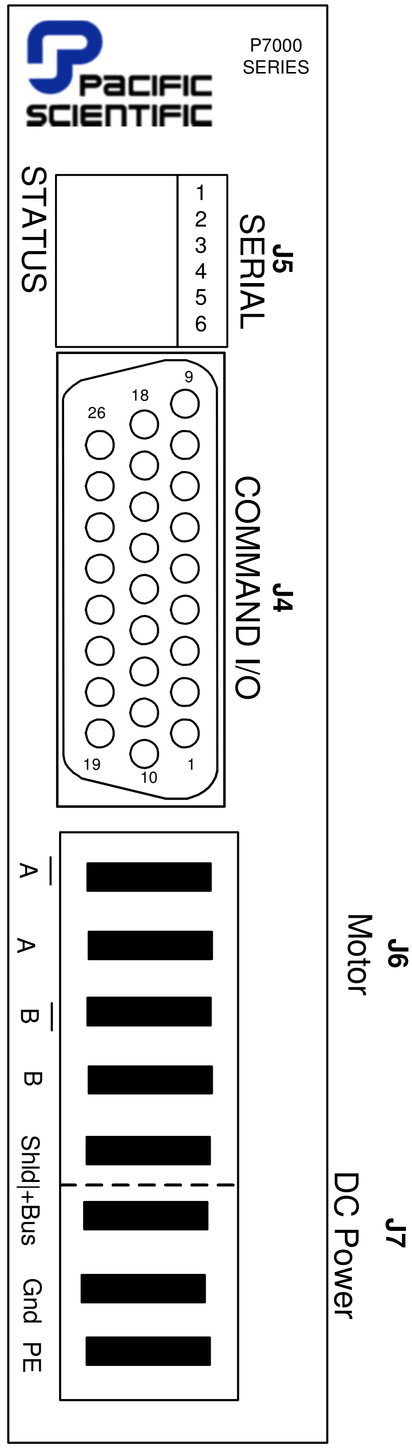
1. For convection cooling allow a minimum of 1 in (25.4 mm) of space around all sides.
2. It the heat sink temperature exceeds 70 °C the drive shuts down due to overheating. Fan cooling or a lower ambient temperature may be required to allow the drive to run properly.

1.5.1 DC BASE DRIVE MOUNTING DIMENSIONS



2. WIRING

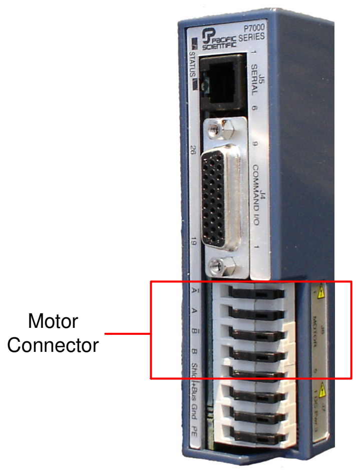
2.1 CONNECTOR LOCATIONS



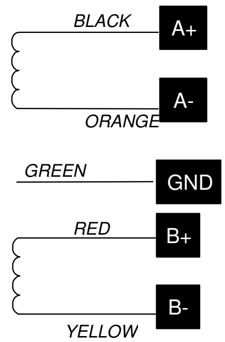
2.2 FUNCTIONS BY CONNECTOR

2.2.1.1. Connecting A Motor

Danaher Motion offers a number of standard stepper motors designed to provide optimum performance when matched with the P70530. The motors are offered with a 4-flying lead configuration. If your motor has 6 or 8 leads, you should consult your distributor or the factory for assistance.



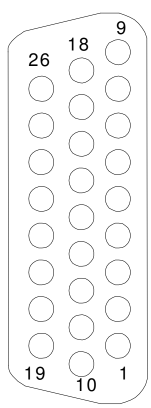
Danaher Motion's Pacific Scientific
Flying Lead Motor Wiring
For T2x, N3x, K3x, N4x, and K4x Series Motors.



CAUTION

Do not hot-plug the motor connector.
Avoid "whiskers" from stranded phase leads protruding from the motor plug.

2.2.2 J4 CONNECTOR – COMMAND I/O



J4 is a 26-Position High Density D subminiature female connector. (Connector is shown as viewed from the front of the drive.

Pin	Description
J4-1	STEP +
J4-2	STEP -
J4-3	DIR +
J4-4	DIR -
J4-5	ENABLE +
J4-6	ENABLE -
J4-7	FAULT +
J4-8	FAULT -
J4-9	Gnd
J4-10	DIN1 (MVSEL 1)*
J4-11	DIN2 (MVSEL 2)*
J4-12	DIN3 (MVSEL 3)*
J4-13	DIN4 (MVSEL 4)*

Pin	Description
J4-14	DIN5 (Jog +)*
J4-15	DIN6 (Jog -)*
J4-16	DIN7 (EOT +)*
J4-17	DIN8 (EOT -)*
J4-18	DIN9 (Fault Reset)*
J4-19	+ 5 V
J4-20	Pull Up/Dn
J4-21	OUT + (Motion Node Active)*
J4-22	OUT – (Motion Node Active)*
J4-23	NC
J4-24	RS-232 RX
J4-25	Gnd
J4-26	RS-232 TX

*Default I/O Assignments

NOTE

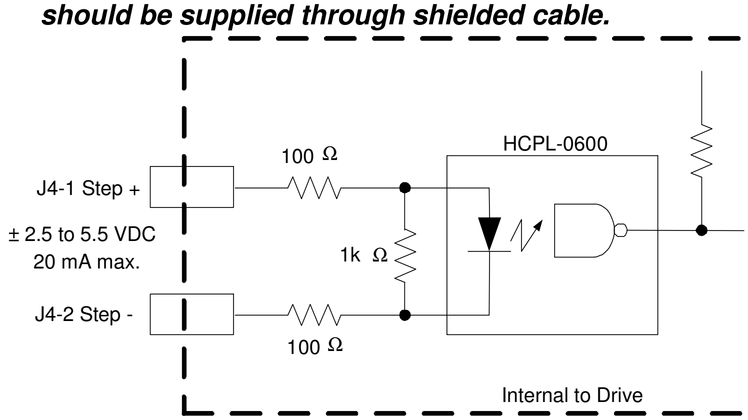
MVSEL (Move Select) is available in –PNN (Motion Node) units only. The same is true for MOTION NODE ACTIVE outputs.

2.2.2.1. Step, Direction, and Enable Inputs

Step Input

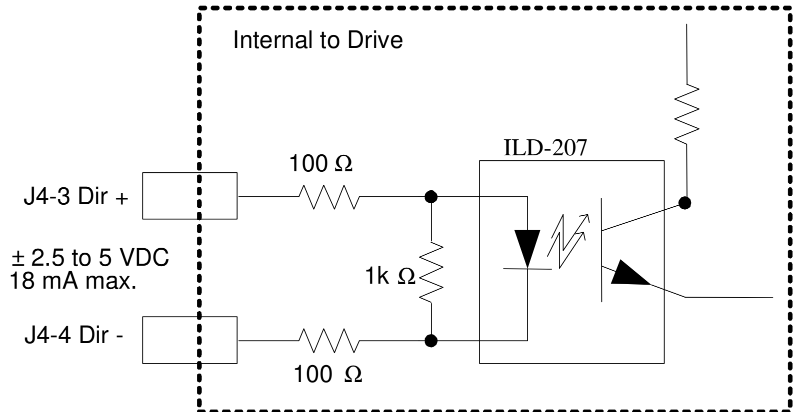
J4 1, 2 The P70530 increments its internal step counter on the ON-to-OFF transition of the LED in an opto isolator. Minimum ON and minimum OFF times are both 250 ns. This results in a maximum step input frequency of 2 MHz. Pulses that do not meet minimum times may be ignored by the drive's electronics. ***The input circuitry is suitable for use with 5-volt logic (single ended or differential). It is best to drive the input to both logic states rather than utilize open collector transistors***

The STEP input is sensitive to high frequency noise and should be supplied through shielded cable.



Direction Input

J4 3, 4 The DIRECTION input is similar to the step input except that it employs a slower opto isolator. Allow for a 55 µs setup time from changes at the DIR input prior to transition of the STEP input. Failure to meet setup time can result in the drive misinterpreting the intended direction of a step.



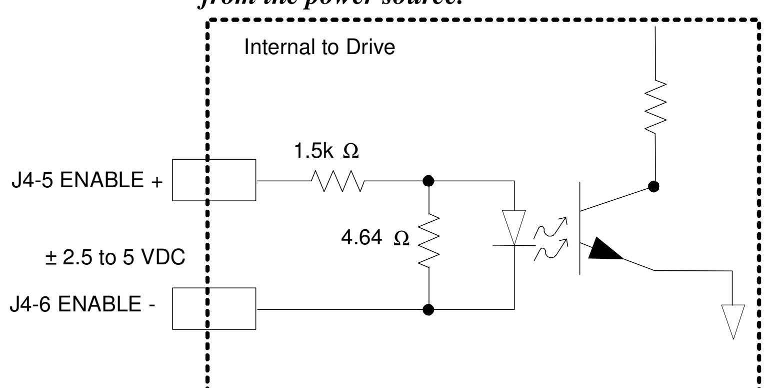
Enable Input

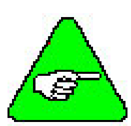
J4 5, 6 The ENABLE input removes current from the motor windings so the axis can be externally moved. The polarity of the ENABLE logic is configurable using P7000Tools. Factory default is ENABLE = ACTIVE OPEN. If the inputs are left open, the drive is enabled.

The input is enabled with 5 mA of current. It is suitable for use with 3 to 5 volt logic. The ENABLE input is digitally filtered and internally de-bounced.

WARNING

Do not depend on the ENABLE input as a safety or E-STOP mechanism. Internal drive failure could result in motion. When disabled, the winding terminals are not at safe potential. The power output from the drive is electrically safe only when the drive is disconnected from the power source.

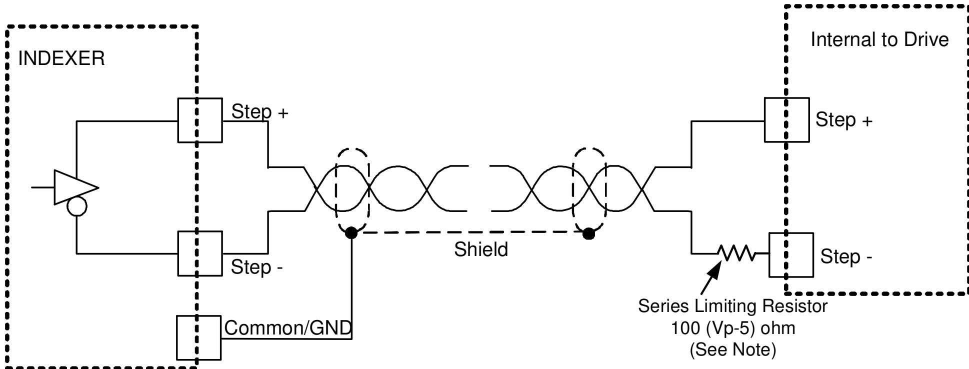




NOTE

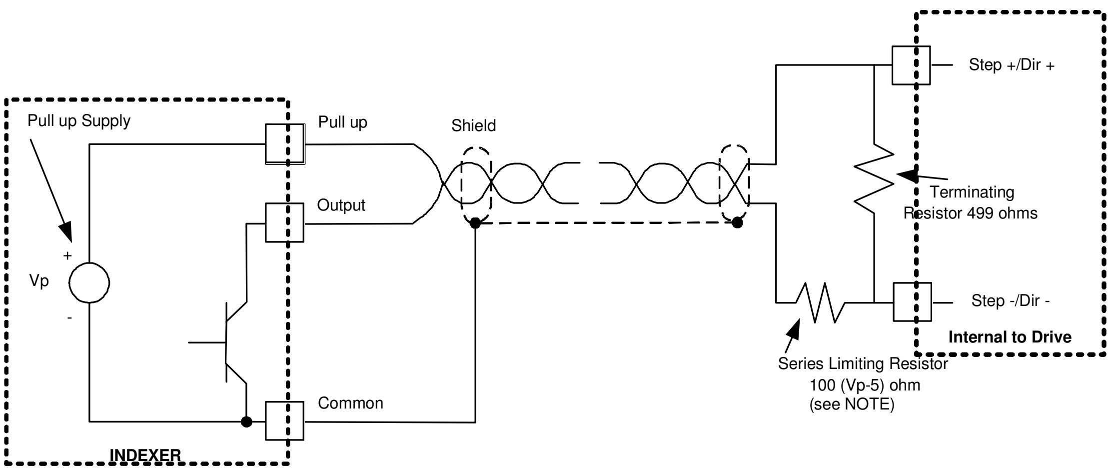
For step and direction inputs, refer to Section 1.4.2, I/O Specifications.

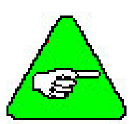
2.2.2.2. *Connection Scheme for Differential Step and Direction Signals*



Always use shielded, twisted-pair cable for step and direction signals.
Route away from motor leads.

2.2.2.3. *Connection Scheme for Open-Collector Single-Ended Step and Direction Signals*





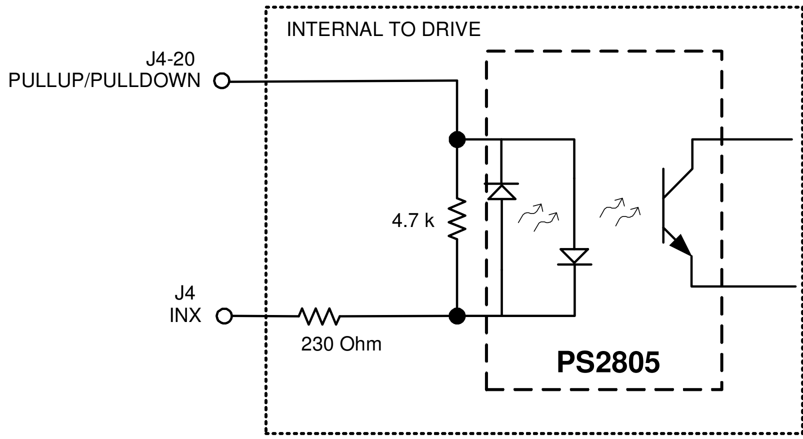
NOTE

Use series limiting resistor for pull-up voltages greater than 5 volts. Always use shielded, twisted pair cable to step and direction signals. Route away from motor leads.

2.2.2.4. *General Purpose Inputs*

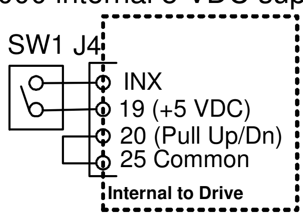
There are nine configurable General Purpose Inputs (GPI's) on the P70530 drive. All the inputs share a common optically isolated bus (Pull Up/Down). The common bus simplifies the wiring allowing a common point to connect either sinking or sourcing input devices.

Typical Input Schematic

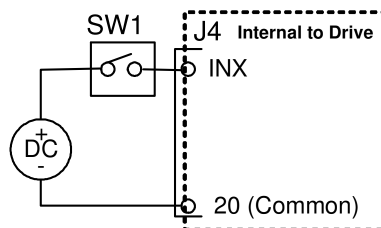


Configuration Examples

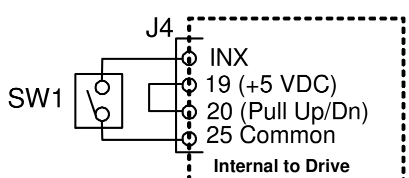
Sourcing input device using
P7000 internal 5 VDC supply



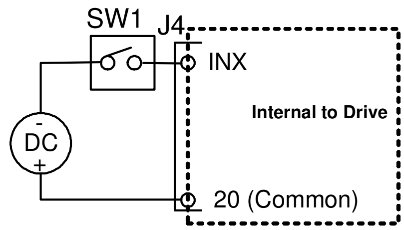
Sourcing input device using
external supply (+5 VDC)



Sinking input device using
P7000 internal 5 VDC supply



Sinking input device using
external supply (+5 VDC)



SW1 Input device is shown as NORMALLY OPEN. It may also be configured via the user interface as NORMALLY CLOSED.

For voltages greater than 5 VDC (24 VDC max), install a current limiting resistor in series with the input.

Size according to: R_{CL} = (V_S-5) 100

NOTE

2.2.2.5. Fault Output (J4-7, 8)

NOTE

This output is from an optoisolator able to support no more than 5 mA before increasing V_{CESAT}.

Dedicated Fault Output indicates that the drive has sustained a latched condition. Whenever the fault output is asserted, the front panel LED blinks a Fault Code repeatedly. FAULT+ and FAULT- are the isolated (collector-emitter) terminals of an optocoupler. They must be attached to a pull-up and signal common of the machine control system. The output pair is normally conducting and becomes and open circuit during a fault.

Faults are cleared in three ways:

1. Power cycle – Power must remain disconnected for approximately 10 seconds to effect reset.
2. Software reset – Use the Reset button on the toolbar.
3. I/O pin – Any of the nine I/O pins may be configured as a Fault Reset. (See schematic in section 2.2.2.6)

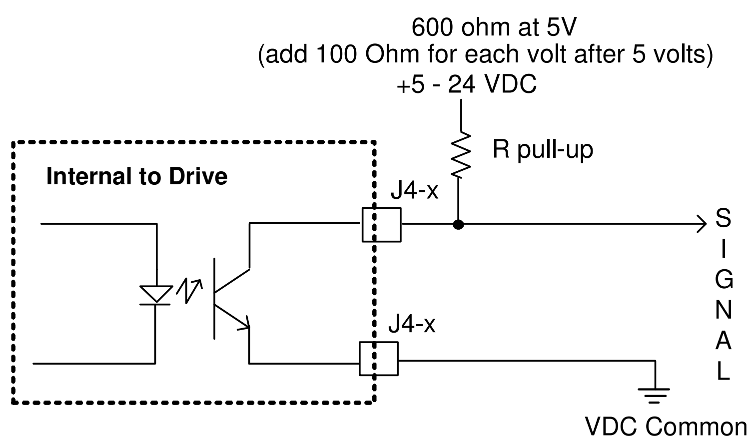
2.2.2.6. General Purpose Output (J4-21, 22)

NOTE

This output is from an optoisolator able to support no more than 5 mA before increasing V_{CESAT}.

The P70530 includes one optically isolated output that can be configured to indicate:
— EOT latched
— Motor Moving
— Motion Node Active
— No Function
— Stalled

The input may be powered by the on-board 5 VDC logic supply (J4-19) or from a remote supply ranging from 5 - 24 VDC.



2.2.3 J5 SERIAL CONNECTOR (RS-232)

RJ12/RJ11 Phone Style
Standard RJ12/RJ11 Plug

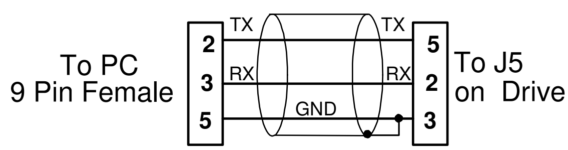
RJ12/RJ11 Phone Style	
Pin	**Description**
J5-1	No Connection
J5-2	RX232
J5-3	I/O RTN
J5-4	No Connection
J5-5	TX232
J5-6	No Connection

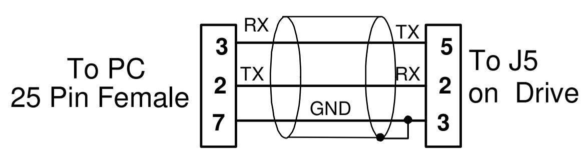
Parameter	Specification
Baud rate	19,200
Electrical interface	RS-232, Full duplex
Transfer format	UART, 1 start bit (mark), 8 data bits, even parity bit and 1 stop bit (space), no flow control.

Cable wiring diagrams for connecting to either 9 or 25 pin serial ports of most computers are also shown below.

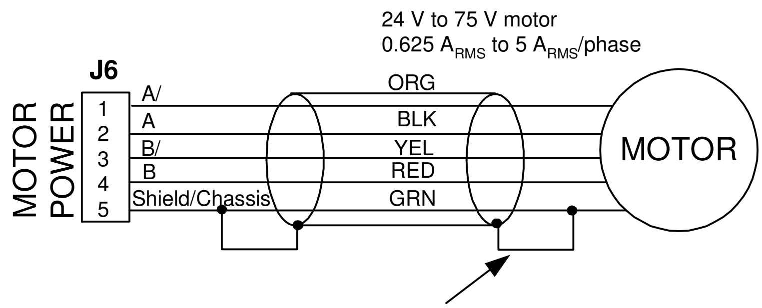
NOTE

Pinouts vary among computer manufacturers. Check the hardware reference manual for your machine before wiring.





2.2.4 J6 MOTOR



To avoid electrical shock, motor ground must be connected to protective earth.

Typical Pacific Scientific stepper wire color code:

A- A+	Orange Black	Motor Phase A (twisted pair)
B- B+	Yellow Red	Motor Phase B (twisted pair)
PE	Green/Yellow Stripe	Cable Shield/Motor Case (J6-5 connects to J7-3 inside drive)

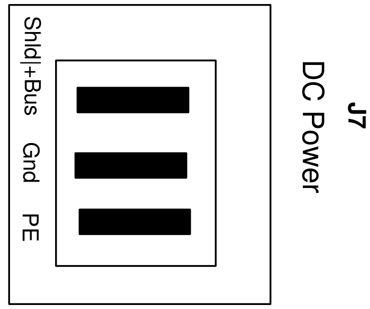
NOTE

To reverse direction of motor rotation:
Switch A- with A
OR
Switch B- with B
OR
Switch A-,A with B-,B
OR
Switch rotation polarity in the user interface

NOTE

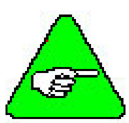
Danaher Motion recommends the use of insulated wire ferrels to prevent shorting and add strain relief.

2.2.5 J7 DC POWER



(Connector view from front of drive)

<table>
<tr><th>Pin</th><th colspan="2">Description</th></tr>
<tr><td>J7-1</td><td>Plus power supply terminal</td><td rowspan="2">20 V – 75 V
5 A av max
isolated, unregulated (or regulated) power supply</td></tr>
<tr><td>J7-2</td><td>Negative power supply terminal
Negative power supply terminal/ Bus Gnd is normally earthed
Maximum allowable voltage between Bus Gnd (J7-2) and Chassis (J7-3) is 100 V peak.</td></tr>
<tr><td>J7-3</td><td colspan="2">Connect to PE (Protective Earth)
(J7-3) connects to J6-5 inside drive</td></tr>
</table>



NOTE

Danaher Motion recommends the use of insulated wire ferrels to prevent shorting and add strain relief.

3. CONFIGURE THE DRIVE WITH SWITCHES

NOTE

The drive is configured by either using P7000Tools or the switches on the top of the drive. The instructions that follow detail how to configure the drive using the switches.

3.1 *MOTOR SELECTION*

Configure the drive for a motor type via switch settings on the top of the drive. Valid settings are:

MOTOR	S1	S2	MOTOR	S1	S2
GUI Select	0	OFF	M21…C (series)	E	OFF
T2H…H (parallel)	1	OFF	M22…C (parallel)	F	OFF
T21H…H (parallel)	2	OFF	M22…C (series)	1	ON
T22…G (parallel)	3	OFF	N32…J (parallel)	2	ON
T23…H (parallel)	4	OFF	N33…J (parallel)	3	ON
P2H…B (parallel)	5	OFF	N34…J (parallel)	4	ON
P2H…B (series)	6	OFF	K31…J (parallel)	5	ON
P2H…C (parallel)	7	OFF	K32…J (parallel)	6	ON
P2H…C (series)	8	OFF	K33…J (parallel)	7	ON
P21…C (parallel)	9	OFF	K34…J (parallel)	8	ON
P21…C (series)	A	OFF	N41…J (parallel)	9	ON
P22…C (parallel)	B	OFF	N42…K (parallel)	A	ON
P22…C (series)	C	OFF	K41…J (parallel)	B	ON
M21…C (parallel)	D	OFF	K41…K (parallel)	C	ON

NOTE

For non-system motors, configure the drive with the P7000Tools GUI Wizard. The motor inductance range is 2 – 15 mH.

Motor type zero is used for non-system motors.

Using incorrect settings results in zero current (motor will not operate).

If you change the motor type, you MUST cycle power to the drive for the changes to take effect.

3.2 STEP RESOLUTION

Step Resolution			
Resolution	**S2-2**	**S2-3**	**S2-4**
200	ON	ON	ON
400	OFF	ON	ON
5,000	ON	OFF	ON
10,000	OFF	OFF	ON
18,000	ON	ON	OFF
25,000	OFF	OFF	OFF
25,400	OFF	ON	OFF
50,000	ON	OFF	OFF

3.3 LOAD INERTIA

The P7000 eliminates resonance, typical of step motors, with high-speed, digital processing of motor electrical activity. To use this feature, you must set three switches based on the load-to-rotor inertia ratio. These switches select the gain parameter for the drive to use to stabilize the motor.

Load Inertia Ratio			
Load-Rotor	**S2-5**	**S2-6**	**S2-7**
0-1	OFF	OFF	OFF
1-1.5	ON	OFF	OFF
1.5-2.5	OFF	ON	OFF
2.5-5.0	ON	ON	OFF
5.0-7.0	OFF	OFF	ON
7.0-12.0	ON	OFF	ON
12.0-20.0	OFF	ON	ON
20.0-32.0	ON	ON	ON

3.4 DYNAMIC SMOOTHING™

Dynamic smoothing is a temporal filter (2nd- Order, Low-pass) applied to the command sequence to reduce jerk. It helps reduce overshoot and lessens the excitation of mechanical resonance in the system. It filters from slightly below the resonant frequency up to well above resonance to remove spectral content would be misrepresented in the motor output and may also excite other parts of the machine.

Dynamic Smoothing		
Smoothing	S2-8	S2-9
Minimal	OFF	OFF
Moderate	ON	OFF
Heavy	OFF	ON
Aggressive	ON	ON

3.5 CURRENT REDUCTION

Reduces drive and motor heating by invoking standby current reduction via Switch S2-10. When enabled, the reduction mode cuts motor current to 75% of its commanded value 100 ms after receipt of the last step pulse or the end of a stored move. The reduction proportion and the delay can be set to other values using P7000Tools.

Current Reduction	S2-10	ON=Disabled

3.6 MULTI-STEPPING™

Multi-Stepping™ is similar to dynamic smoothing™ except that it is a much more aggressive use of the filter. Typically, it results in a filter that begins to roll off a couple octaves below the resonant frequency. This is intended for use with course resolution (full/half step input pulses) to smooth out the big steps into a continuous train of microsteps.

Multi-Stepping	S2-11	ON=Enabled

3.7 ENCODERLESS STALL DETECTION™

The P70530 drive is uniquely designed to sense the motor shaft position at all times. The drive monitors the commanded position and compares it to the actual position. As with any two-phase step motor, when the shaft position and commanded position are greater than two full steps apart a stall will be detected and the drive will fault.

Stall Detection	S2-12	ON=Enabled

Encoderless stall detection uses an internal motor model for stall detection. Motors in the *P7000 Data Publication* work well. Other motors may not work as well as the algorythm is subject to constraints. No guarantees of reliability of this feature are made when using other motors.

4. USING P7000TOOLS

4.1 *INSTALLING P7000TOOLS*

When you install P7000Tools, the Installation Wizard will check to see if you have a previous version of P7000Tools on your system. If found, it will uninstall it. After this, you will need to run the installation again to install the new version on your system.

If you do not have a previous version of P7000Tools on your system, you only need to run the installation once.

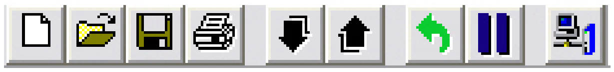
4.2 *SET-UP WIZARD*

Start **P7000Tools.** Follow the **Setup Wizard.** You will go through a series of screens to set up the motor, drive I/O, command structure and mechanical configuration.

When you successfully finish this set up, the front panel **LED** indicator is **Solid Green**. The motor has holding torque.

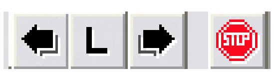
4.3 TOOLBARS

Utilities Toolbar



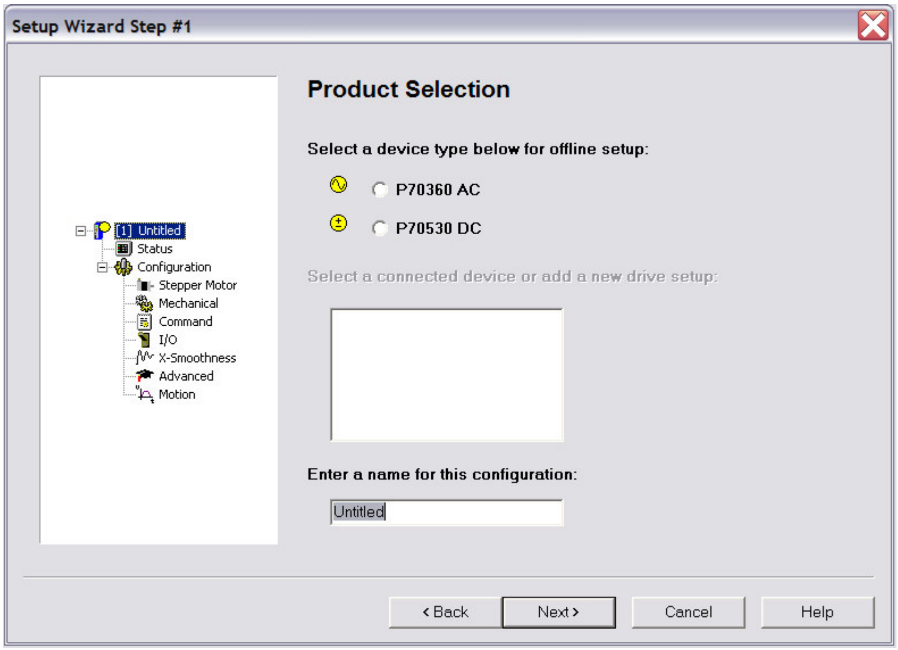
New Project	Creates a new project file in P7000 Tools
Open Project	Opens an existing project file in P7000 Tools
Save Project	Saves the current project to a file
Print Configuration	Prints the selected drive configuration (active only when the Configuration view is selected)
Send All	Sends the entire configuration to the currently connected drive
Retrieve All	Retrieves the entire configuration from the currently connected drive
Reset Drive	Performs a soft drive reset equivalent to a power cycle (used for clearing fault conditions)
Soft Disable Amplifier	Disables amplifier
Scan for Connected	Scans the selected serial port for connected drives

Motion Toolbar



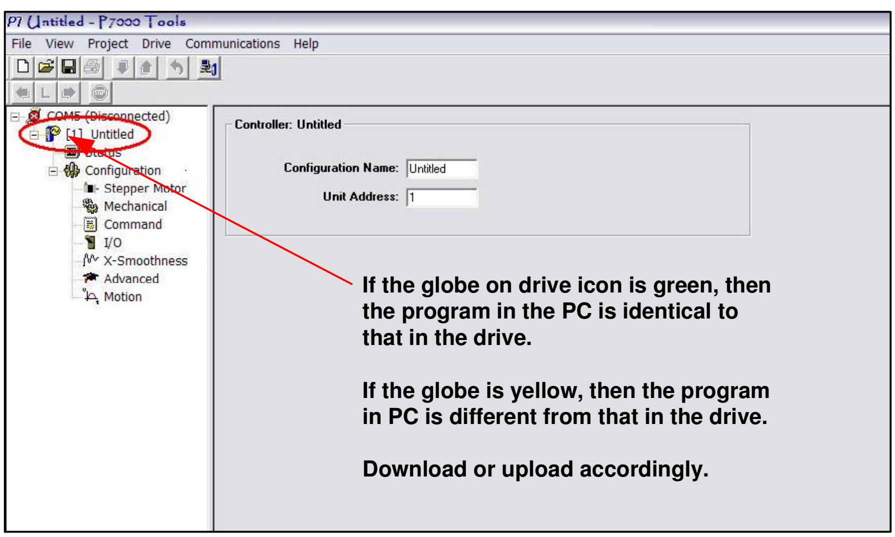
	Jog Motor Negative	Jogs the motor in the negative direction at the selected velocity
L	Jog Velocity Toggle	Selects the active jog velocity for the Jog arrow buttons (L designates Low Speed, H designates High speed)
	Jog Motor Positive	Jogs the motor in the positive direction at the selected velocity
	Stop Motion	Stops all Motion Node generated motion and breaks any active move sequence

4.4 PRODUCT SELECTION

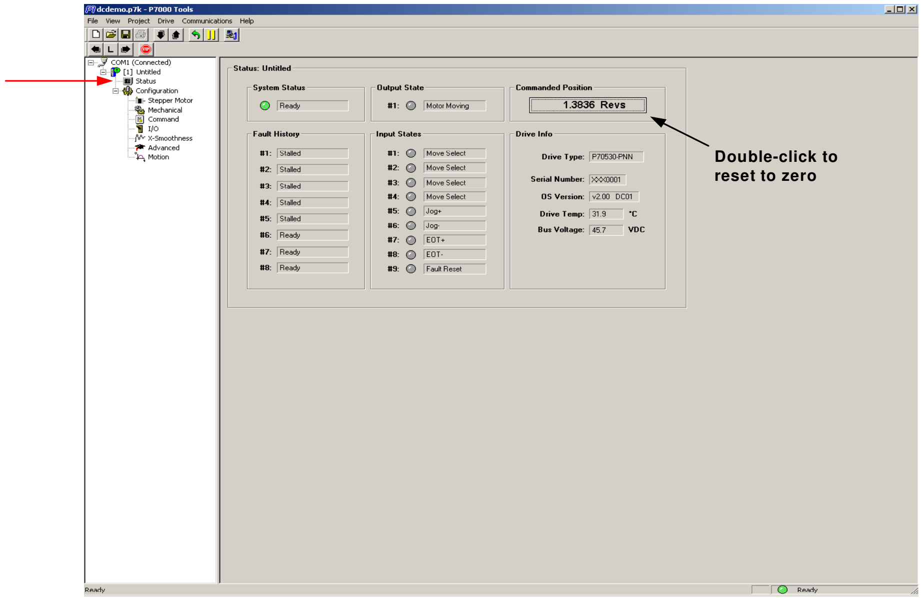


- Select either P70360 AC or P70530 DC unit.
- Add New Drive
  Add additional units.
- Enter a Name for this configuration
  This is the name for the unit or axis.

4.5 CONFIGURATION AND UNIT ADDRESS



4.5.1 STATUS SCREEN



System Status

Disconnected	Not online with the drive. Indicator off.
Disabled	Drive blinking green indicates online, but not enabled.
Ready	Drive online and enabled. Solid green indicator.

Output State

Offline	Not connected to a drive. Indicator gray.
Online	Indicator is green when programmed output condition is met.

Fault History List of the last nine drive faults. #1 being the most recent, #8 is the oldest.

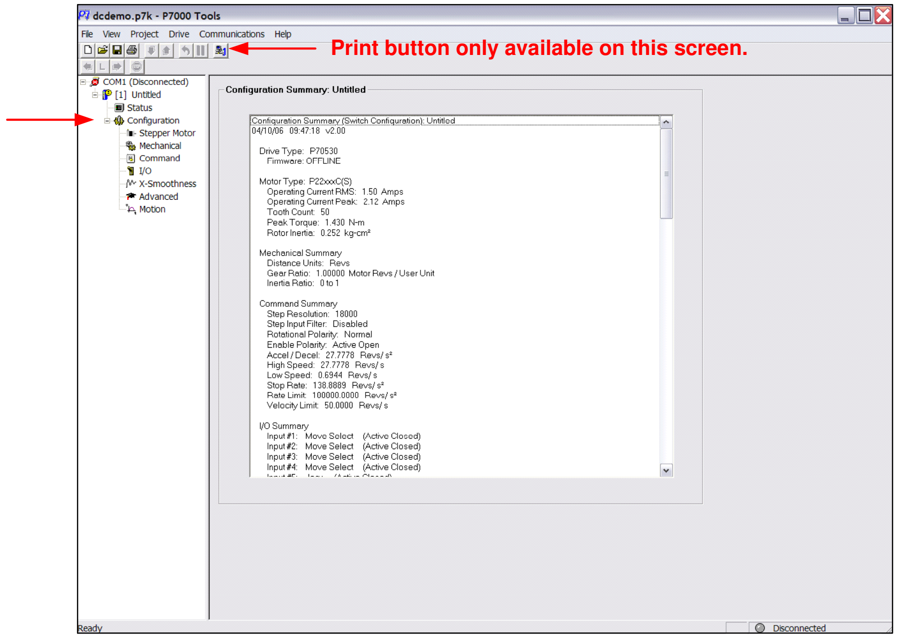
Input States Indicator is green if the input is true, gray if false.

Commanded Position Actual motor position in user units (double-click in box to reset to zero).

Drive Information

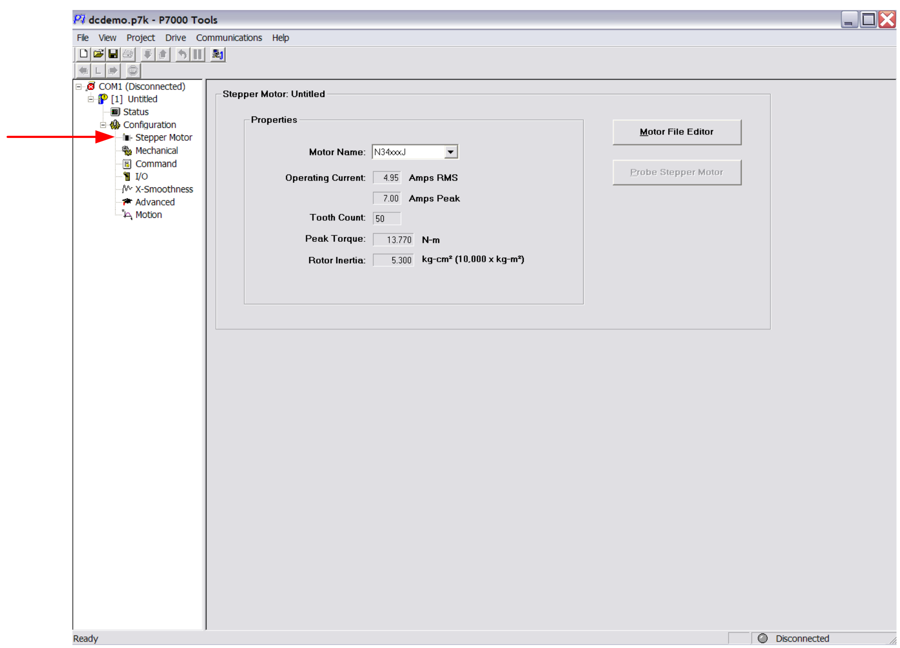
Drive Type	Model number for this drive.
Serial Number	Serial number for this drive.
OS Version	Current firmware revision level.
Drive Temp	Drive temperature in degrees Celsius.
Bus Voltage	DC Bus voltage

4.5.2 CONFIGURATION SUMMARY



The configuration summary is displayed.

4.5.3 STEPPER MOTOR SCREEN



Motor Name Select from the list or create a custom file using Motor File Editor (see next section for details).

Operating Current

A

- **A_{RMS}** Continuous current rating for the selected motor.
- **A_{PEAK}** Peak current rating for the selected motor. (Calculated by GUI based on continuous current rating.

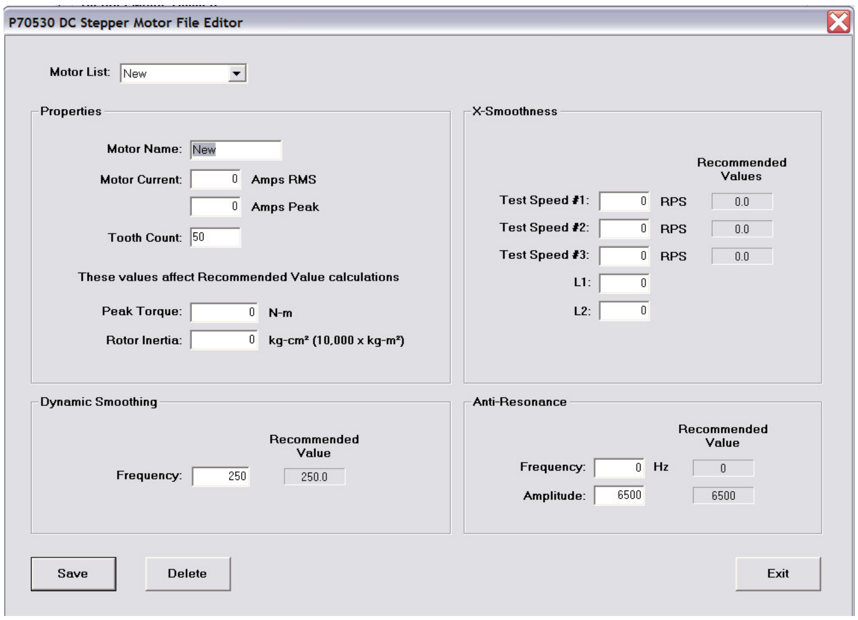
Tooth Count Number of magnetic poles on the stator.

Peak Torque Peak torque capability of the motor.

Rotor Inertia Rotor inertia of the motor.

Probe Stepper Motor When a new motor is selected, you are prompted to allow a PROBE. This is similar to what an inductance meter does to measure inductance. The P7000 uses a more powerful test signal, which makes an audible tone in the motor. The probe action takes 10 to 20 seconds, during which time, the drive is gathering information needed to operate state observers. It may be desirable to manually start a probe using the PROBE STEPPER MOTOR button. This would be done if a motor were replaced by a unit of the same type.

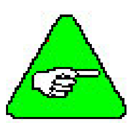
4.5.3.1. Motor File Editor



Motor List List box that contains all of the motor file configurations available in the database on this PC. Select a motor from this list to edit or select NEW to configure a new motor.

This screen is where you will enter custom motor parameters. The steps to define a custom motor are:

Properties:



The Properties box must be populated with values from a motor data sheet. All other values are calculated by the GUI software.

NOTE

Motor Name Enter an appropriate motor name.

Motor Current: Continuous current rating of the motor (A_{RMS}). A_{PEAK} is automatically calculated by the GUI software.

Tooth Count Total number of magnetic poles on the motor stator. The default is 50.

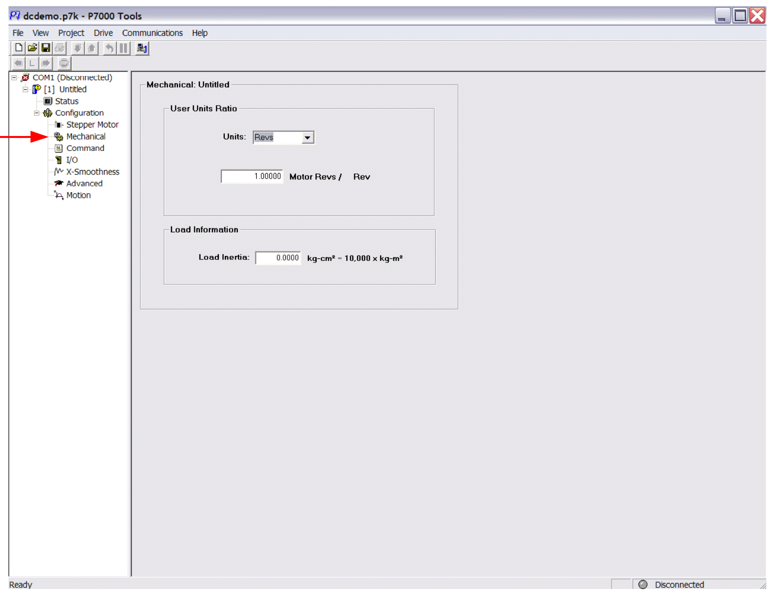
Peak Torque Peak output torque of motor in N-m.

Rotor Inertia Inertia of motor rotor in kg cm^2.

NOTE

Frequency equations illustrated later use rotor inertia in units of kg m^2

4.5.4 MECHANICAL



4.5.4.1. User Units Ratio

NOTE

These values are used as parameters by the Move Profile Editor.

Units Can be set to one of the following:
- Steps
- Revolutions
- Millimeters
- Inches

Motor revs/rev This is a scaling function used in the Motion Node to accommodate a gearbox.

Example:
- — 2:1 Gearbox
- — Enter 2 motor revs/rev
- — Enter a Distance of 1 rev in a given motion profile

Result:

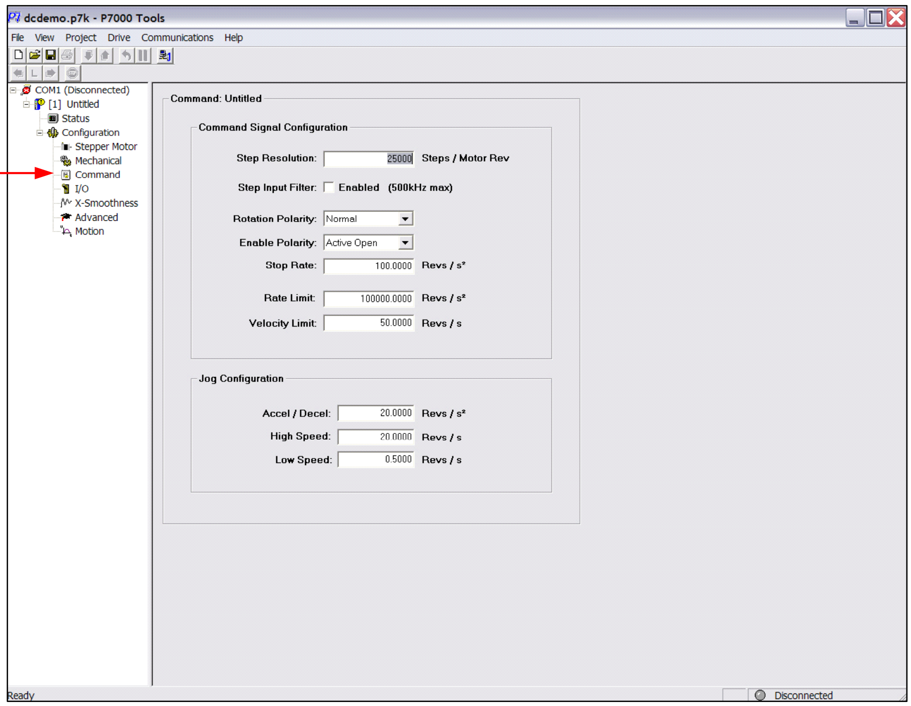
The motor advances 2 revolutions to obtain 1 revolution of the gearbox.

4.5.4.2. Load Information

The anti-resonance, stall detect, and dynamic smoothing features require the adjustment of various parameters, depending upon the ratio of Load-to-Rotor inertia. If the ratio is unknown, use an educated guess. The drive easily tolerates a 30% - 40% error.

If the selection is set unrealistically high, the anti-resonance damping may be ineffective. If set too low, dynamic performance may be somewhat reduced.

4.5.5 COMMAND CONFIGURATION



Command Signal Configuration

Here you can check the Step Resolution, Rotation Polarity, Enable Polarity, Stop Rate, Rate Limit, and Velocity Limit.

Step Resolution 200 to 50,000 steps per motor revolution.

NOTE

When using a controller, set the drive resolution equal to the controller resolution. This is particularly important if there is position feedback to the controller.

Step Input Filter Check to enable low pass cutoff filter at 500 kHz to reduce response to high frequency noise.

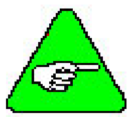
Rotation Polarity Changes direction of motor rotation for a given input command.

Enable Polarity

Active Open	Drive is enabled upon power up or external switch must ***OPEN*** to ENABLE drive.
Active Closed	External switch must ***CLOSE*** to ENABLE drive.
Stop Rate	Used by Motion Profile Generator to terminate a programmed move.
Rate Limit	Global limit on ACCEL/DECEL in programmed moves.
Velocity Limit	Global limit on the velocity of programmed moves and jog speeds.

Jog Configuration

Here you can set the Acceleration/Deceleration, High and Low speeds.

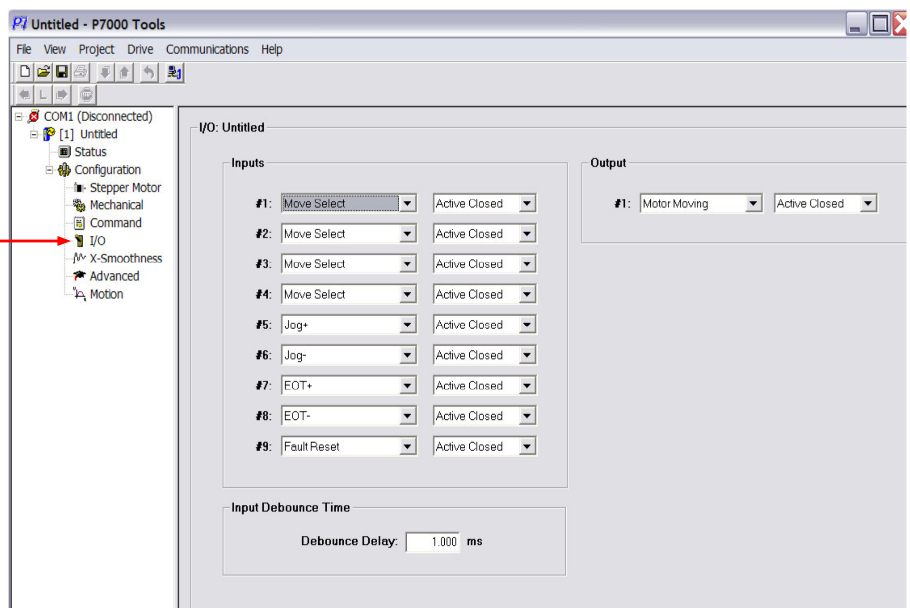


NOTE

These parameters control ACCEL/DECEL and jog speeds that are generated by jog commands from within the user interface or the I/O.

ACCEL/DECEL	Global limit on jog acceleration/deceleration.
High Speed	High jog.
Low Speed	Low jog.

4.5.6 I/O CONFIGURATION



4.5.6.1. INPUTS

The P7000 drive has nine general-purpose user configurable inputs. Most functions like Jog or Fault Reset can be assigned to any input number. There are some assumptions about the use of these inputs when using them for Move Select that must be understood. Only the first six inputs may be configured as Move Select Inputs with DINP1 being the LSB (Least Significant Bit).

These nine configurable inputs can be configured as a group as either sinking or sourcing. Individually, they can be configured as either Active Closed or Active Open. All inputs, regardless of function, are subjected to digital debouncing and the Debounce Delay is applied globally. Debounce logic requires an input state to persist for the programmed time before being recognized.

Input Funtion	Description
EOT+	Stops motion in a positive direction when transitioned from inactive to active.
EOT-	Stops motion in a negative direction when transitioned from inactive to active.
Home	A home input is used by the internal move engine during a Home maneuver.
Jog+	Jogs the motor in a positive direction.
Jog-	Jogs the motor in a negative direction
Jog Speed	Selects high or low jog speed.
Fault Reset	Clears latched fault condition and resets the position counter.
Move Select	Functions as one bit of a binary number (up to 6 bits) for selecting pre-programmed moves. The combination of states on the assigned Move Select inputs serves to define a SELECTED MOVE.
Start Move	Transition to active triggers the move engine to begin the selected move. If a Start Move input has not been assigned, moves are triggered by the appearance of a non-zero value at the Move Select inputs.
Start/Stop Move	Similar to Start Move except that this type of input automatically becomes a Stop input once motion is begun.
Stop Move	Transition to active causes the move engine to decelerate to a controlled stop.
Stop Move on Edge	Move stops on leading edge of input transition.
No Function	Input has no effect.

4.5.6.2. *Input Debounce Time*

Requires an input state to persist for the programmed time before being recognized.

4.5.6.3. *Output*

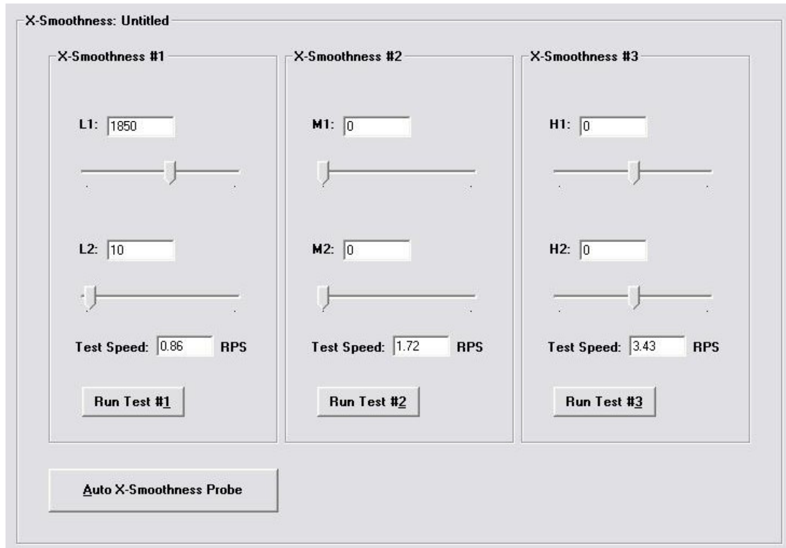
This output can be configured as Active Closed or Active Open.

Output Function	Description
EOT Latched	Indicates that an EOT has been encountered and the motor has not been moved back off the sensor.
Motor Moving	Motor is rotating.
Motion Node Active	Motion Node is still processing a move, including any programmed time delay.
Stalled	Indicates that the drive has detected a stall.
No Function	Output will not be asserted.

The GPO+ and GPO- are the isolated (collector – emitter) terminals of an optocoupler. They must be attached to a pull-up and signal common of the machine control system (see General Purpose Output (J4-21, 22) – section 2.2.2.6).

4.5.7 X-SMOOTHNESS

Adjusting your Motor for Maximum Smoothness with the X-Smoothness Feature



The X-Smoothness feature helps eliminate undesirable motor vibration effects due to the 3 major resonance frequency responses: Fundamental, 2nd Harmonic and 4th Harmonic. The X-Smoothness settings allow you to enter compensation values, which cancel these resonance responses.

X-Smoothness #1:

L1 Amplitude adjustment for 4th harmonic
L2 Phase adjustment for 4th harmonic

NOTE

All Danaher Motion's standard Pacific Scientific motors, which have been characterized for use with the P7000 drive, have nominal values for L1 & L2 stored in the motor files. Variances in the materials and magnets of two-step motors of the same type can affect comparable motor performance by as much as ±10%. Due to these variances, the nominal settings may not be the best possible settings for a given motor.

X-Smoothness #2:

M1 Amplitude adjustment for 2nd harmonic
M2 Phase adjustment for 2nd harmonic

X-Smoothness #3

H1 DC offset adjustment for phase A
H2 DC offset adjustment for phase B

Procedure for Achieving Optimum Performance

Step 1: Run the Auto X-Smoothness Probe. The X-Smoothness Probe typically comes within 95% of the best adjustment values and finds the exact test speeds for the given motor.

Step 2: Run each X-Smoothness group at the given test speed and verify the motor smoothness. You may find a better smoothing value by slightly moving the slider bars back and forth.

It is very important to make the X-Smoothness adjustments at the proper test speeds with an unloaded motor. Running at an incorrect test speed will not excite the motor at its peak resonance, making it more difficult to find proper adjustment values. Running the tests with a loaded motor moves the resonance frequency and the calculated tests speeds no longer apply.

Test Speed #1 Test speed which generates the excitation frequency for the X-Smoothness #1 compensation adjustment

$$\text{Test Speed \#1} = \sqrt{\frac{T_{\max\ N\cdot M}}{16 \bullet \text{Toothcount} \bullet J_{\text{Rotor}\ kg\cdot m^2}}}$$

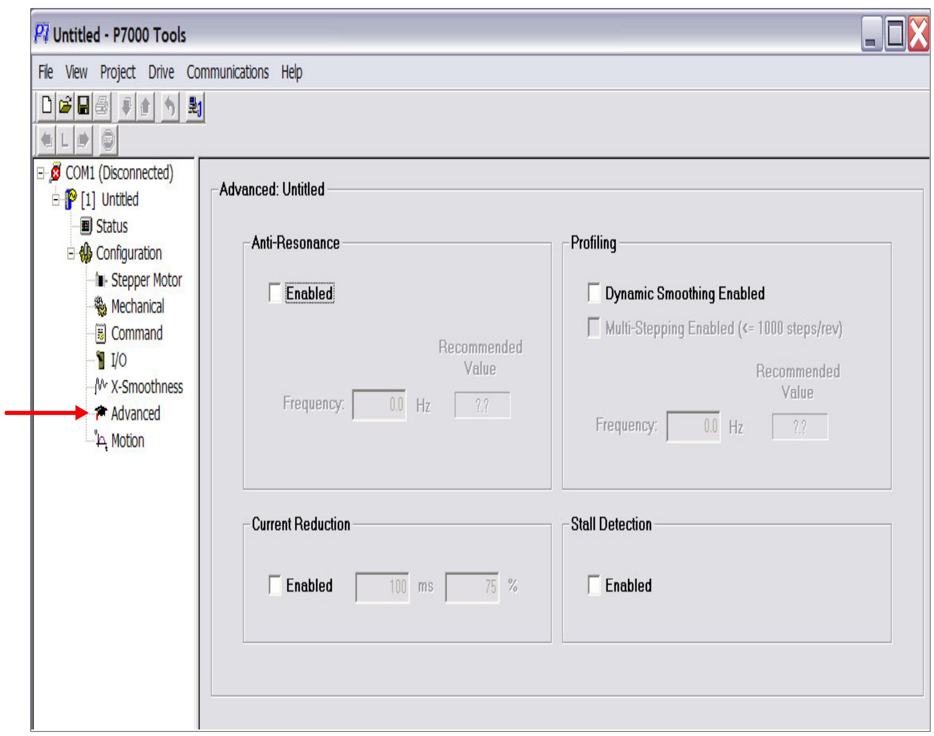
Test Speed #2 Test speed which generates the excitation frequency for the X-Smoothness #2 compensation adjustment

$$\text{Test Speed \#2} = \sqrt{\frac{T_{\max\ N\cdot M}}{4 \bullet \text{Toothcount} \bullet J_{\text{Rotor}\ kg\cdot m^2}}}$$

Test Speed #3 Test speed which generates the excitation frequency for the X-Smoothness #3 compensation adjustment

$$\text{Test Speed \#3} = \sqrt{\frac{T_{\max\ N\cdot M}}{\text{Toothcount} \bullet J_{\text{Rotor}\ kg\cdot m^2}}}$$

4.5.8 ADVANCED SETUP



4.5.8.1. *Anti-Resonance*

Step motors are highly resonant, which results in vibration and ringing. The ringing utilizes a large fraction of the motor's available torque – thereby wasting performance. Furthermore, at mid-range velocities, the resonance can become so severe that the motor looses synchronism and stalls. The P7000 drives provide robust anti-resonance control to stop the vibrations and maintain equilibrium. This feature requires that the drive be configured with respect to the total inertia in the system. The rotor inertia and the Load-to-Rotor inertia ratio are set in the Mechanical screen. If set improperly, the effectiveness of the feature may be diminished.

The anti-resonance check box is used to invoke or disable the feature. It should be enabled unless the system configuration either does not need it or cannot tolerate it. A system with lossy couplings or viscous loading generally does not need this feature. If a system has compliant (springy) coupling and is absent appreciably viscosity, it may not respond well to the active, anti-resonant loop in the drive. The anti-resonant feature is not designed to damp such a 4th order system. If the application of anti-resonance results in degradation or instability, it should be disabled (unchecked).

Frequency Break frequency of anti-resonance tuning filter. Typically set to 1/10 the resonant frequency of the motor.

$$\text{ARes Frequency} = \sqrt{\frac{\text{ToothCount} \bullet T_{\max\,\text{N}\cdot\text{M}}}{100 \bullet J_{\text{Rotor kg}\cdot\text{m}^2}}}$$

Amplitude Set to 6500 nominal. Do not alter this value unless advised by technical support.

4.5.8.2. *Current Reduction*

Unlike a servo system, the step motor is left energized – even at rest. This leaves full torque available to oppose external disturbing influences and hold position precisely. However, many applications encounter vanishingly small load effects at rest and may benefit from the reduction of current when not moving. The reduced level is programmed as a percent of full current and the time delay is entered in milliseconds (ms). The drive will gently reduce the current to the programmed value after the motor has been at rest for a specified time. If the box is left unchecked, the numeric entries have no effect and full current is maintained at rest.

Motor heating is proportional to the square of the current. Thus, a reduction of 70% current represents a reduction to 50% power. Current reduction has little effect as long as the resting motor is not opposing a continuous torque as in lifting applications. If a disturbing torque is present, the current reduction will result in a small amount of movement. The current vector is restored to full value the instant an incoming step is received or the move engine begins a move.

4.5.8.3. *Profiling*

Profiling (Multi-stepping) refers to the process of altering the acceleration in the command sequence to reduce Jerk. Acceleration transients jar the application and may cause unwanted vibrations. When Dynamic Smoothing is enabled, the moment-to-moment move profile is passed through digital filters to smooth out the acceleration/deceleration transients. If the feature is enabled, a value is recommended for the frequency of the filters. This recommendation is based on the moment of inertia of the motor, the load-to-rotor inertia ratio, and torque production specified in the configuration. That recommendation should be accepted, unless it is desired to filter more aggressively. If the application uses course resolution such as 200 or 400 steps/rev, it may be quite helpful to invoke Multistepping (checkbox). This is a very aggressive use of the smoothing filter, which will make full stepping appear almost as smooth as microstepping.

Heavy filtering is accompanied by a small delay of the command sequence. All causal low-pass filters have group delay, which is inversely proportional to the bandwidth. In this case, the delay is 0.22/BW. Multistepping cuts the bandwidth to 1/10 the value shown in the frequency box.

Dynamic Smoothing is the process whereby the incoming pulse train or move profile is filtered in such a way as to sharply reduce Jerk. This results in a more quiet system and reduces the excitation of mechanical resonances.

The more heavily the filtering is applied, the smoother the commanded motion becomes. Heavy filtering is necessarily accompanied by group delay.

The drive uses information about load-to-rotor inertia ratio to predict the resonant frequency fr of the system. The various levels of filtering introduce a second-order, low-pass filter into the command sequence, according to the following table.

Dynamic Smoothing:

Frequency: Break frequency of a second order command input filter. Typically set to 1/3 the natural frequency of the motor.

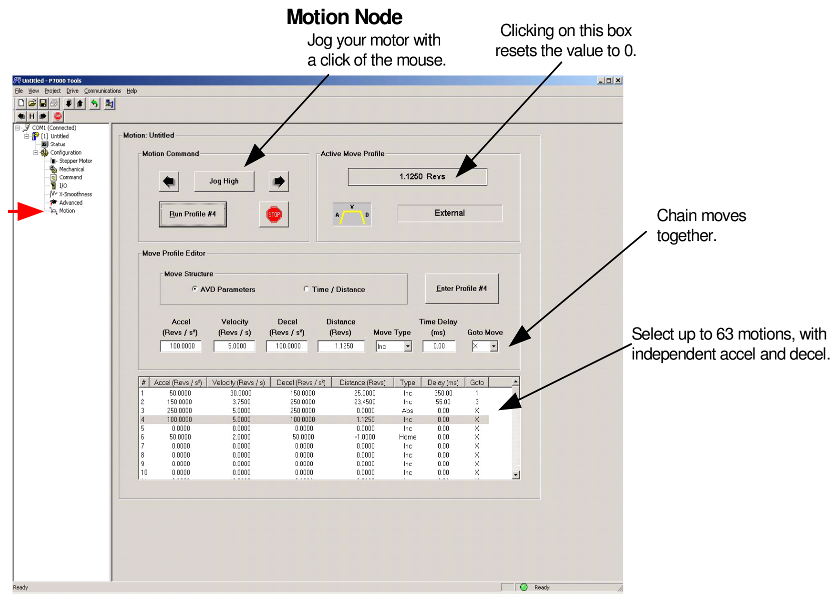
$$\text{Smoothing Frequency} = \sqrt{\frac{\text{ToothCount} \bullet T_{\text{max N}\cdot\text{M}}}{9 \bullet J_{\text{Rotor kg}\cdot\text{m}^2}}}$$

4.5.8.4. *Stall Detection*

Stall Detection is enabled and disabled using the check box. Stall detection would be disabled if it failed to operate correctly and rendered nuisance stall indications. This may occur with non-standard motors from other vendors. If an application is suspected of causing nuisance stall indications, try disabling the feature and running the move sequence. If the system makes the move without losing synchronism, then it is likely that nuisance trips have occurred.

4.5.9 MOTION PROFILE GENERATOR

Once the system is configured you can select Motion Generator by double clicking on the motion folder.



The Motion Profile Generator selects the Move Structure (Acceleration-Velocity-Distance [AVD] or Time-Distance [T/D]), and enters the parameters for a stored move. Once a move has been composed, it must be entered using the Enter Profile button.

Moves may be entered in any order and edited at will. A move profile is brought to the edit line by clicking on it in the move list. To enter a new move, click on it in the list and select a structure (AVD or T/D). Enter the various parameters represented in user unites as defined in the Mechanical screen.

NOTE

If the Enter Profile button is not clicked, the move is not stored and is lost. Once a move is stored, its parameters appear in the move list.

The most popular move structure is AVD. The programmer must specify both acceleration and deceleration rates along with velocity, distance, move type, time delay, and GoTo index, if needed.

For convenience, a move may be copied, pasted, or deleted by right-clicking on the target in the move list. Moves are anchored to the index at which they are entered. Deleting a move does not cause the others to shift up to fill the gap. The only way to relocate a move is to copy, paste, and then delete from the original position.

It is impossible to enter a set of move parameters that are inconsistent. For instance, it may be impossible to reach the target velocity using the specified acceleration in the programmed distance. If the programmed parameters do not define an attainable trapezoidal move, the Generator offers to collapse the move into a triangular profile by adjusting the velocity. The move engine cannot execute moves that have inconsistent parameters.

Individual Motion Profiles are executed in the following manner:

Up to six of the digital inputs may be programmed as Move Select. These inputs now function as binary coded decimal bits. Inputs must be programmed for this function, starting with the LSB-Input #1 and proceeding sequentially until the desired number of inputs are programmed for Move Select.

Input	Binary	Decimal
1	2^0	1
2	2^1	2
3	2^2	4
4	2^3	8
5	2^4	16
6	2^5	32

Initiating a programmed move from a controller works by one of the following methods:

METHOD 1:

1. Assert a logic signal on the appropriate MOVE SELECT inputs. For example, to execute Move #3, assert a logic signal on MOVE SELECT inputs 1 and 2.
2. Assert a logic signal on START MOVE. The drive scans the MOVE SELECT inputs and executes the selected move. This input is edge triggered.
3. MOVE SELECT input signals may now be terminated along with the START MOVE input.

METHOD 2: You may initiate a move without using START MOVE. You are limited to the following moves: 1, 2, 4, 8, 16, 32. To do this, configure as many MOVE SELECT inputs as required and ***DO NOT*** configure an input as START MOVE. Triggering the appropriate MOVE SELECT input initiates the selected move.

NOTE

Method 1 requires that one input be programmed as Start Move. Method 2 does not.

NOTE

You need not configure more inputs for Move Select than you actually need. For example, if you have only four programmed moves, configure only Inputs 1, 2, and 3 for Move Select.

NOTE

Move Select inputs must be consecutive. It is suggested to start with input 1 and work down.

5. TROUBLESHOOTING

5.1 COMMON PROBLEMS

Problems	Possible Fixes
Motor spins in wrong direction	Reverse wires on one phase. Change direction polarity using P7000Tools
Motion Profiles in table will not execute	The P7000 Drive is the SDN version not the PNN version,
Drive Overheats	Lower ambient temperature. Provide fan cooling. Reduce system throughput.

5.2 STATUS DISPLAY

There are 7 faults that may occur with the P7000 drive. The fault output latches when they occur. Determine the type of fault by viewing the front panel or through the serial port. The front panel LED turns red and blinks according to the table below.

LED Color	Blinks	Description	Cause	Solution
Green	Solid	System OK	NA	NA
Green	1	Amplifier is disabled	The enable input (J4-5 & J4-6) is not asserted if ENABLE is configured ACTIVE CLOSED or the enable input is asserted if ENABLE is configured ACTIVE OPEN.	De-assert the enable input or disable the soft shutdown from P7000Tools.
Red	Solid	FLASH memory fault	A FLASH memory checksum validation has failed indicating corruption of the operating system. This typically occurs during firmware download.	Without attempting to connect to the drive, download the most current firmware file from the P7000Tools menu option Drive->Update Operating System…. If the FLASH download utility fails, contact technical support.
Red	1	Stall Fault	The Encoderless Stall Detection feature has detected that the motor has slipped or stalled.	Reduce move profile acceleration, velocity, deceleration or load inertia. Power cycle or reset drive via Fault Reset input or P7000Tools.
Red	2	Over-current Fault	An event has occurred which caused the amplifier output current to exceed 5.6 amps.	Check motor wiring for shorts. Power cycle or reset drive via Fault Reset input or P7000Tools.
Red	3	Over-voltage Fault	A regenerative event has occurred which forced the bus voltage above 440 VDC. Incoming AC line voltage too high.	Reduce deceleration, load inertia, or reduce deceleration duty cycle to allow enough time for the power dump circuit to recover. Power cycle or reset drive via Fault Reset input or P7000Tools.
Red	4	Drive Over-temp Fault	The temperature of the heatsink has exceeded 70° C.	Reduce ambient temperature or system duty cycle. Power cycle or reset drive via Fault Reset input or P7000Tools.

LED Color	Blinks	Description	Cause	Solution
Red	5	System Fault	An error occurred while attempting to converge on a solution while running the Motor Probe or Auto X-Smoothness Probe.	Power cycle or reset drive via Fault Reset input or P7000Tools.
Red	6	Under-voltage Fault	Attempting to operate the unit at a bus voltage below 10 VDC. Incoming AC line voltage too low.	Power cycle or reset drive via Fault Reset input or P7000Tools.
Red	7	EEPROM Checksum Fault	User non-volatile memory checksum validation has failed indicating user setup corruption.	Restore default configuration from the P7000Tools menu option Drive->Restore Default Configuration…
Red	8	Open Phase Fault	A motor phase is open	Check continuity of motor cable and motor windings.
Red	Constant Blinking	Processor Fault	Illegal Address	Contact technical support.
Alternating Red & Amber	Multi	Processor Fault	Internal system error.	Contact technical support.
Alternating Red & Green	Fast	Motor being probed	Part of setup process.	
Alternating Red & Green	Slow	End of Travel	An End of Travel input has been activated	Determine cause of activation.

The blinking continues until the drive is reset by one of the following methods:

- Power Cycle
- GUI Control
- Fault Reset (Configurable General Purpose Input)

5.3 SAFETY

As the user or person applying this unit, you are responsible for determining the suitability of this product for the application. In no event will Danaher Motion be responsible or liable for indirect or consequential damage resulting from the misuse of this product.

Read this manual completely to effectively and safely operate the P7000.

Comply with the applicable European standards and Directives.

In Germany, these include:

- DIN VDE 0100 (instructions for setting up power installations with rated voltages below 1000 V).
- DIN - EN 60204 - Part 1, (VDE 0113, part 1) instructions relative to electric equipment in machines for industrial use.
- DIN EN 50178, (VDE 0160) instructions relative to electronic equipment for use in power installations.

Insure that the motor’s case is connected to PE ground. The fifth wire in the motor cable connecting J6,5 to the motor case accomplishes this.

Motor case grounding

CAUTION

If the motor is not properly grounded, dangerous voltages can be present on the motor case due to capacitive coupling between the motor windings and case.

Requirements for Safe Operation of the Drive

It is the machine builder's responsibility to insure that the complete machine complies with the Machine Directive (EN60204). The following requirements relate directly to the stepper controller:

Emergency Stop

CAUTION

If personal injury can result from motor motion, the user must provide an external hardwired emergency stop circuit outside the drive. This circuit must simultaneously remove power from the drive's motor power terminal J6-12, J6-2, J6-3, and J6-4. Note: The motor will coast under this condition with no braking torque.

Avoiding Unexpected Motion

CAUTION

Always remove power from J7 and wait 2 minutes before working on the machine or working anywhere where injury can occur due to machine motion.

Avoiding Electrical Shock

CAUTION

Never power the stepper drive with the cover removed or with anything attached to circuitry inside the cover.

If the drive must be removed from the cabinet, wait at least five minutes after turning off power before removing any cables from the drive or removing the drive from the mounting panel. To be safe, measure the electrical contact points with a meter before touching the equipment.

Never connect or disconnect any wiring to the drive while power is applied. Always power down and wait two minutes before connecting or disconnecting any wires to the terminals.

Avoiding Burns

CAUTION

The temperature of the drive's heat sink and housing may exceed 70°C. Therefore, there is a danger of severe burns if these regions are touched.

Preventing Damage to the Drive

Follow these guidelines to prevent damage to the stepper drive during operation:

- Never plug or unplug connectors with power applied.
- Never connect or disconnect any wires to terminals with power applied
- If the drive indicates a fault condition, find the cause of the fault and fix it prior to resetting the fault or power-cycling the drive.

APPENDIX A

A.1 POWER SUPPLY MINIMUM BUS CAPACITANCE

The power supply MUST have an output capacitor that meets the drive minimum requirements. In an unregulated supply the Cbus min requirements are normally met by the output filter capacitor built into the power supply. If a regulated power supply is used, Cbus min should be added across the output of the supply.

The DC P7000 drive has a small internal bus capacitor of 200 µf. This absorbs most of the high frequency PWM ripple current, but it is not large enough to handle the peak power demands of the motor during rapid acceleration and deceleration.

WARNING

➔**Do not skimp on Bus Capacitance.**

Drives are difficult loads for supplies. Drives can have high peak power flows in and out as the load accelerates and decelerates. The DC P7000 does not have any internal means to dissipate regenerated motor energy. Energy regenerated back to the supply must be absorbed capacitively with a limited increase in bus voltage.

For a single drive load related energy flows in the bus are approximately proportional to motor current and bus voltage, so the minimum bus capacitor is selected so that capacitive energy storage scales with motor current and bus voltage. Capacitance rises as bus voltage drops to compensate for the fact that energy storage in a capacitor goes down as the square of voltage.

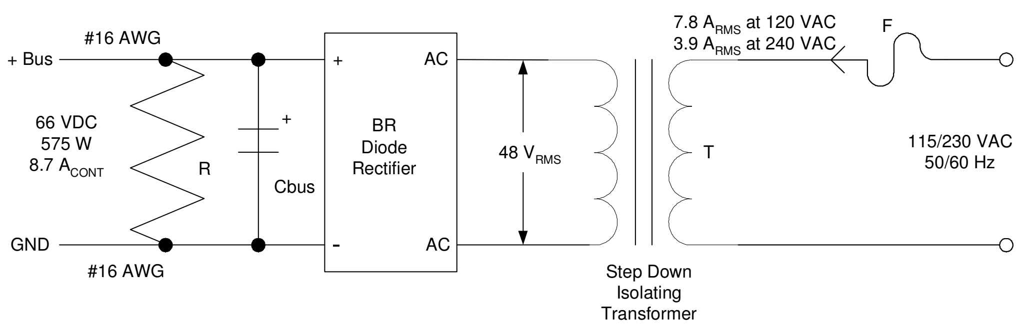
A.2 CBUS MIN FOR A SINGLE DRIVE

Motor Current	Bus Voltage		
(rms per phase)	24 V nom	48 V nom	75 V nom
5 A	18,000 µf	9,000 µf	6,000 µf
3 A	10,800 µf	5,4000 µf	3,600 µf
1.5 A	5,400 µf	2,700 µf	1,800 µf

Capacitor type is a general purpose, 85C, aluminum electrolytic, screw terminal, can. For 75 V bus select a 100 V rated capacitor; for a 48 V bus select a 63 V or 75 V rated capacitor; for a 24 V bus select a 35 V or 40 V rated capacitor. For example, Cornell Dubilier DCMC, 85C, High Capacitance, Computer Grade, Aluminum.

6,000 µf, 100 V	DCMC602U100EA2B	1.75 in dia x 2.125 in

Example of a Simple, Unregulated, Isolated Offline DC Power



Vbus Spec

79 VDC at 0 W load, 264/132 VAC line

69 VDC at 0 W load, 230/115 VAC line

66 VDC at 575 W load, 230/115 VAC line

56 VDC at 489 W load, 195/98 VAC line

Materials

T — 115/230 VAC to 24/48 VAC step down transformer, 900 VA, 4,000 V Isolation
5.25 x 5.2 x 4.8, ht 20 lb, Signal MPI-900-48

BR — 25 A, 200 V, single phase bridge rectifier, 1.14 x 1.14
General Semiconductor GBPC2502

Cbus — 20,000 µf, 100 V aluminum capacitor, computer grade, 85C, 2 dia x 4.125 ht
Cornell Dubilier DCMC203U100BC2B

F — 250 VAC, Type 3AB, slo-blo fuse, 1.25 x 0.25
115 VAC line: 15 A rated, Littlefuse 326015
230 VAC line: 7 A rated, Littlefuse 326007

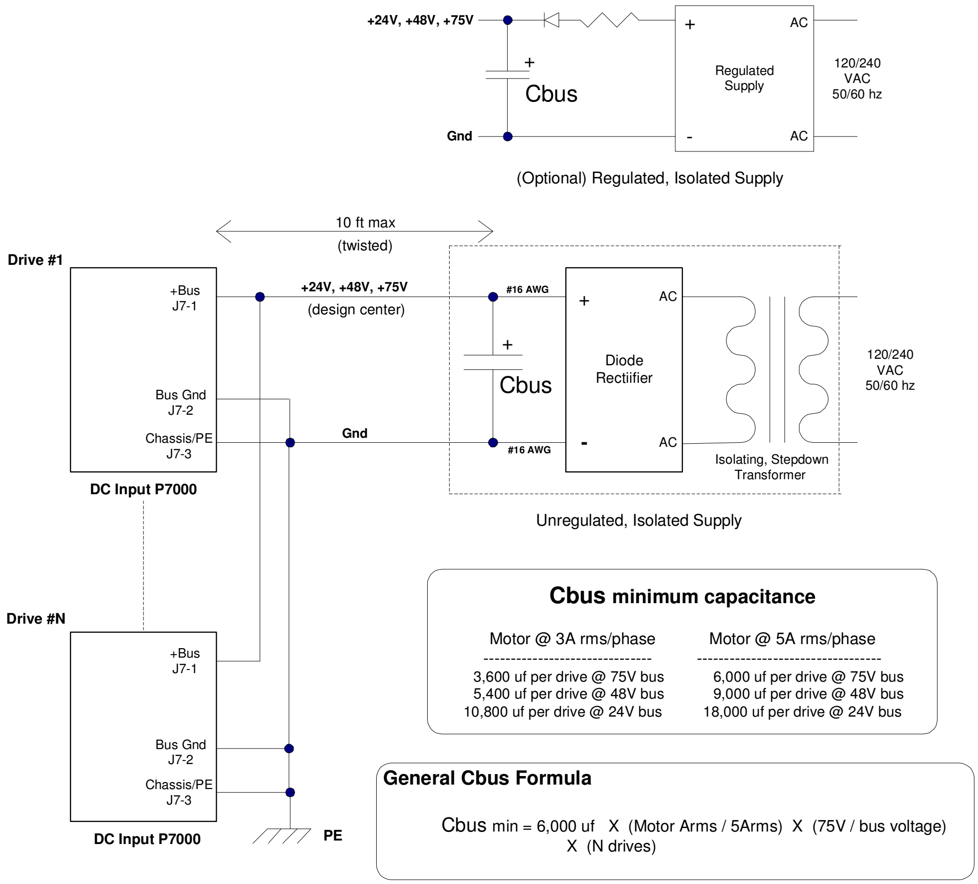
R — 1 k, 10 W, wirewound, aluminum housed chassis mount resistor, 1.42 x 0.62
Huntington Electric TMC-10-1-0K

A.2.1 GENERAL CBUS MIN FORMULA FOR MULTIPLE DRIVES

For multiple drives on the same supply a conservative rule is to scale up the capacitance by the number of drives on the supply. For a large number of drives on the same supply with moves that are uncorrelated it may be adequate to increase the minimum capacitance by the square root of the number of drives.

$$\text{Cbus min} = 6{,}000\ \mu f \ \text{X (motor } A_{RMS}/5A_{RMS}) \text{ X (75 V/bus voltage) X (\# of Drives)}$$

The recommended minimum capacitance will handle matched inertias with most motors, but if the application has high regenerated energy, then more bus capacitor than the minimum may be needed.



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Danaher Motion is committed to quality customer service. Our products are available world-wide through an extensive authorized distributor network. To serve in the most effective way, please contact your local sales representative for assistance. If you are unaware of your local sales representative, please contact us.

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