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Navigator®-PCI
User's Guide



Performance Motion Devices, Inc.
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Lincoln, MA 01773

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Related Documents

Navigator Motion Processor User's Guide (MC2000UG)
How to use all members of the Navigator motion processor family.

Navigator Motion Processor Programmer's Command Reference (MC2000PR)
Descriptions of all Navigator motion processor commands, with coding syntax and examples, listed alphabetically for quick reference.

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1.0 Installation

In This Section

- Software
- Accessory Products
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- Installation Sequence
- Required Hardware
- Preparing the Card for Installation
- Connection Summary for Navigator-PCI Cards
- Applying Power
- Software Installation
- First Time System Verification

The PMD Navigator-PCI cards are high performance PCI-bus cards that provide motion control for DC brush, brushless DC, and step motors. These cards are based on PMD Navigator motion processors which perform motion command interpretation and many other real time functions.

The following product selector table shows the relationship between card part numbers (P/N), Navigator motion processor part numbers (P/N), the number of axes supported, and the type of motors supported.

Navigator-PCI card P/N	Navigator P/N	Number of axes	Motor type
MB902140	MC2140	4	DC brush
MB902120	MC2120	2	DC brush
MB902110	MC2110	1	DC brush
MB902340	MC2340	4	Brushless DC
MB902320	MC2320	2	Brushless DC
MB902310	MC2310	1	Brushless DC
MB902540	MC2540	4	Pulse & direction step motor
MB902520	MC2520	2	Pulse & direction step motor
MB902510	MC2510	1	Pulse & direction step motor
MB902440	MC2440	4	Picrostepping step motor
MB902420	MC2420	2	Microstepping step motor
MB902410	MC2410	1	Microstepping step motor
MB902840	MC2840	4	Mixed motor - DC brush and brushless DC
MB902820	MC2820	2	Mixed motor - DC brush and brushless DC

DC Brush cards output a single-phase motor command, either in PWM (pulse width modulated) or analog (+/- 10V) output format. They are intended to control DC-brush motors, or brushless-DC motors using an amplifier which performs commutation.

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Brushless DC cards provide multi-phase motor command signals, using Hall-based or sinusoidal commutation located on the Navigator-PCI card. These cards are intended to interface with brushless DC amplifiers and motors, although they can also control other 3-phase devices such as AC Induction motors.

Pulse & direction cards output standard pulse & direction signals, and are intended to interface with amplifiers which accept that command format.

Microstepping cards output multi-phase analog (+/- 10V) or PWM (pulse width modulation) waveforms. They are designed to control 2 or 3-phase step motors using amplifiers that accept this command format.

Mixed motor cards provide the ability to control both DC-Brush and Brushless DC motors within the same card. The output formats are software programmable, allowing various combinations of motor types and axis number to be configured.

For complete information on motor output formats and other information see the *Navigator Motion Processor User's Guide.*

1.1 Software

Two major software packages are provided with the Navigator-PCI cards: Pro-Motion, an interactive Windows-based exerciser program and C-Motion, a C-language library which simplifies the development of motion applications for Navigator-PCI cards.

Pro-Motion is a sophisticated, easy to use exerciser program that allows you to set and view all card parameters, and exercise all card features. Pro-Motion features include:

- Motion oscilloscope graphically displays processor parameters in real-time
- Interactive servo tuning
- Project window for accessing card parameters
- Ability to save and load current settings
- Distance and time units conversion
- Motor-specific parameter setup
- Axis shuttle performs continuous back and forth motion between two positions
- Command window for direct text command entry. It also serves as a communications monitor that echoes all commands sent by Pro-Motion to the card.

C-Motion provides a convenient set of callable routines that comprise all of the code required for controlling your Navigator-PCI card. C-Motion includes the following features:

- Axis virtualization
- The ability to communicate to multiple Navigator-PCI cards
- Can be easily linked to any "C/C++" application

Pro-Motion is described in *section 3, Using Pro-Motion, page 35,* C-Motion is described in detail in *section 4, Developing Your Own Applications with C-Motion, page 41.*

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1.2 Accessory Products

The Navigator-PCI cards can be enhanced by a number of hardware accessory products, listed below:

Component part number	Description
Cable-1003	100 position, 3-foot long, shielded round cable with locking connectors (amp) to connect Navigator-PCI card to IM-1000 interconnect module.
Cable-1006	100 position, 12-foot long, shielded round cable with locking connectors (amp) to connect Navigator-PCI card to IM-1000 interconnect module.
IM-1000	Breakout interconnect module that provides convenient jack-screw type terminators for the 100 pin cable. Used with cable-1003 or cable-1006.
DC-1000	Parallel encoder input adaptor. This daughter card module allows parallel-word and other encoders which use the SSI interface format to be directly connected.
Cable-3003	Interface cables used with 68-pin connector. This connector is generally only used with the brushless DC, microstepping, and mixed motor card versions.
Cable-4003	3-foot long serial port cable which connects to a serial I/F connector. This cable allows serial communication to the PCI card. Only used if serial port communications are desired.

For information on ordering these accessory products, please contact your PMD representative.

1.3 Documentation

There are three manuals specifically associated with the Navigator-PCI cards. A brief description of each is listed below.

Component part number	Name	Description
MB90XUG	Navigator-PCI User's Guide	This is the first document you will turn to to get started, make connections, and exercise the card. This document will answer questions such as "How do I connect my amplifiers and motors to the card?" and "What jumper options do I set to use the card?" This document also provides a complete electrical description of the card, and a description of the associated software products C-Motion and Pro-Motion.
MC2000UG	Navigator Motion Processor User's Guide	This is a functional description of the Navigator motion processor, which is the chipset that is at the heart of the Navigator-PCI cards. This document will answer questions such as, "How do I make a trapezoidal move?" or "How do I load servo parameters."
MC2000PR	Navigator Motion Processor Programmer's Command Reference	This document provides a complete listing of all motion commands supported by the Navigator motion processors.

To download these documents, or request that they be sent to you, you can visit the PMD website at www.pmdcorp.com or contact your PMD representative.

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1.4 Installation Sequence

For a normal installation of a Navigator-PCI card, you will need to configure your card for the PC system and motor hardware that you will connect it to. Configuration of the Navigator-PCI cards is described in detail in *section 1.6, Preparing the Card for Installation, see page 11*.

Next you will need to connect your system's motors, encoders, amplifiers, and sensors as desired to operate your motion hardware. A description of the connections that are made for the various Navigator-PCI cards is found in *section 1.7, Connection Summary for Navigator-PCI Cards, see page 12*.

Once this hardware configuration is complete, you should then install the software. Installation of the software is described in *section 1.9, Software Installation, see page 15*.

The final step to finish the installation is to perform a functional test of the finished system. This is described in *section 1.10, First Time System Verification, see page 15*.

Once all of the above has been accomplished installation is complete, and you are ready to operate the card.

1.5 Required Hardware

To install a Navigator-PCI card you will need the following hardware:

1. The recommended platform is an Intel (or compatible) processor, Pentium or better, one available PCI slot, 5MB of available disk space, 32MB of available RAM, and a CDROM drive. The PC operating system required is Windows 9X/ME/NT/2000/XP.
2. 1 to 4 pulse and direction, PWM, or analog-input amplifiers. The type of amplifier depends on the card type you are using.
3. 1 to 4 step motors or servo motors. These motors may or may not provide encoder position feedback signals depending on the type of card being used. Servo motors must have encoder feedback, while step motors can optionally do so.
4. Additional connectors as required to connect the Navigator-PCI card to the amplifiers and the motors. A single 100-pin header-type connector will be needed to interface to all cards, while the brushless DC cards, microstepping, and mixed motors cards will additionally require a 68 pin SCSI connector. *See section 5.3, Connections Summary, page 52,* for more information on setting up your connections.

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1.6 Preparing the Card for Installation

The board has minimal jumper settings. It is almost entirely software configurable. To prepare your card for installation the following user-settable hardware option should be checked:

Item	How to set	Description
Resistor packs - RS1, RS2, RS3	Installed *this is the default setting of resistor packs RS1-RS3*	If you are using differential connections leave these resistor packs installed.
	Removed	If you are using single-ended encoder connections, remove the resistor packs.
Mode jumper	1-2 *this is the default setting of mode*	Sets PCI bus to be main communications channel. Serial port, if used, can be used in diagnostic mode only
	2-3	PCI bus is disabled, serial port is primary communication channel

The following diagram shows the location of the resistor packs RS1, RS2, RS3 and the mode jumper, along with other components such as connectors.

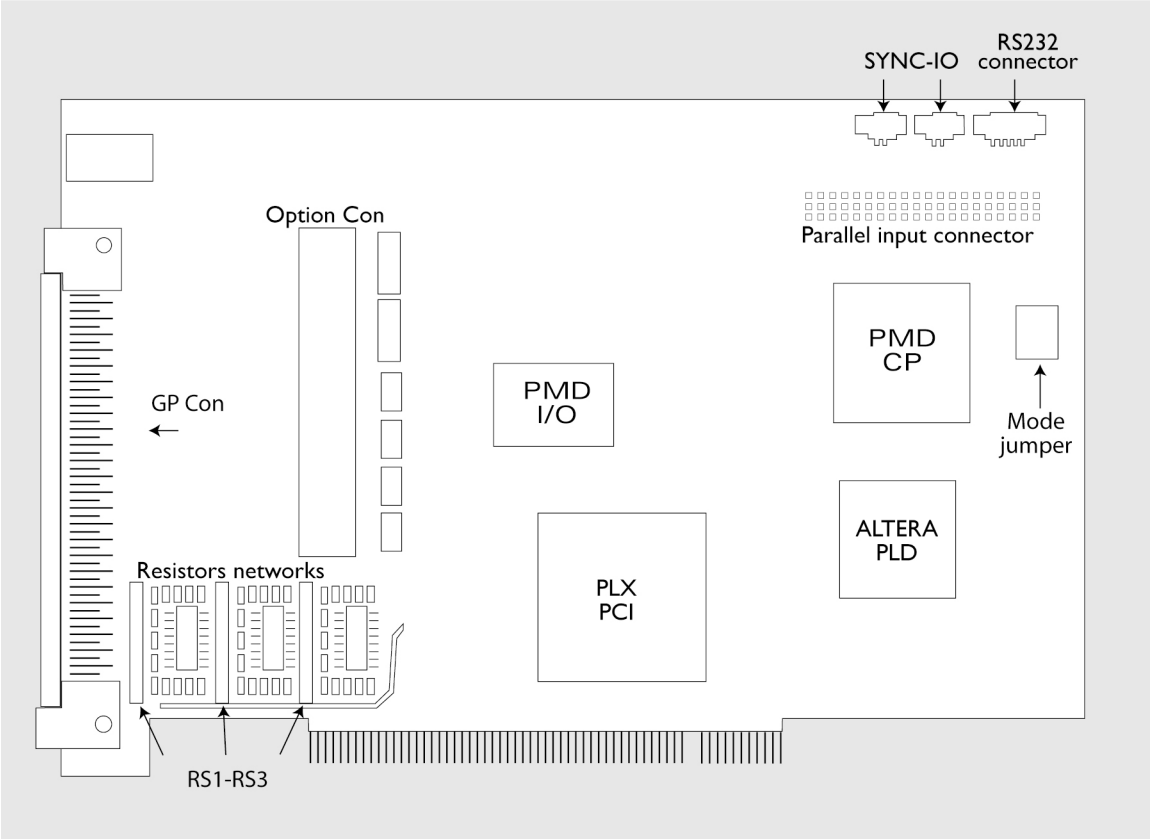


Figure 1-1. Location of various board elements

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1.7 Connection Summary for Navigator-PCI Cards

The following sections summarize the connections you should make for various motor types. Generally, the motor type you will install is specified by the card type purchased. *See table, page 7.* However with the mixed-motor cards (part number MB902840, MB902820) brushless DC, DC brush and microstepping motors can be connected to the same card.

1.7.1 DC Brush Motors

The following table summarizes connections to the Navigator-PCI card when DC-brush motors are used.

Depending on the specific card that you ordered, between 1 and 4 axes should be connected. All connections are made through connector GP Con, the primary 100-pin connector indicated in *figure 1.1, page 11*. For a detailed list of connections, *see section 5, Navigator-PCI Electrical Reference, page 45*.

Signal category	Signal description
Encoder input signals: *(per axis)*	A quadrature channel input B quadrature channel input Index pulse channel input
Amplifier output signals: *(per axis, if PWM sign, magnitude used)*	PWM direction PWM magnitude
Amplifier output signals: *(per axis, if PWM 50/50 used)*	PWM magnitude
Amplifier output signals: *(per axis, if analog output used)*	Analog out (DAC output)
Other control signals: *(optional, per axis)*	Home signal input Limit switch inputs AxisIn input AxisOut output
Miscellaneous signals:	Digital GND +5 V (for encoder power)

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1.7.2 Brushless DC Motors

The following table summarizes connections to the Navigator-PCI card when brushless DC motors are used. Depending on the specific card that you ordered, between 1 and 4 axes should be connected. Note that some of these connections are made through connector GP Con, the primary 100-pin connector, and some are made through Option Con, the 68-pin connector. For detailed signal descriptions *see section 5, Navigator-PCI Electrical Reference, page 45*.

Signal category	Signal description
Encoder input signals: (per axis)	A quadrature channel input B quadrature channel input Index pulse channel input
Amplifier output signals: (per axis, if PWM 50/50 used)	PWM magnitude (phase A) PWM magnitude (phase B) PWM magnitude (phase C)
Amplifier output signals: (per axis, if analog output used)	Analog out (phase A) Analog out (phase B)
Hall inputs:	Hall (phase A) Hall (phase B) Hall (phase C)
Other control signals: (optional, per axis)	Home signal channel input Positive limit switch input Negative limit switch input AxisIn input AxisOut output
Miscellaneous signals:	GND +5 V (for encoder power)

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1.7.3 Pulse & Direction Motors

The following table summarizes connections to the Navigator-PCI card when pulse & direction interface step motors are used. Depending on the specific card that you ordered, between 1 and 4 axes should be connected. All connections are made through connector GP Con, the primary 100-pin connector, indicated on *figure 1-1, see page 11*. For detailed signal descriptions see *section 5, Navigator-PCI Electrical Reference, page 45*.

Signal category	Signal description
Encoder input signals: (optional, per axis)	A quadrature channel input B quadrature channel input Index pulse channel input
Amplifier output signals:	Pulse Direction
Other control signals: (optional, per axis)	AtRest signal output Home signal channel input Positive limit switch input Negative limit switch input AxisIn input AxisOut output
Miscellaneous signals:	GND +5 V (for encoder power)

1.7.4 Microstepping Motors

The following table summarizes connections to the Navigator-PCI card when microstepping-interface step motors are used. Depending on the specific card that you ordered, between 1 and 4 axes should be connected. Note that some of these connections are made through connector GP Con, the primary 100-pin connector, and some are made through Option Con, the 68-pin connector. For detailed signal descriptions *see section 5, Navigator-PCI Electrical Reference, page 45*.

Signal category	Signal description
Encoder input signals: (per axis)	A quadrature channel input B quadrature channel input Index pulse channel input
Amplifier output signals: (per axis, if PWM sign, magnitude used)	PWM magnitude (phase A) PWM magnitude (phase B) PWM direction (phase A PWM direction (phase B)
Amplifier output signals: (per axis, if PWM 50/50 used)	PWM magnitude (phase A) PWM magnitude (phase B)
Amplifier output signals: (per axis, if analog output used)	Analog out (phase A) Analog out (phase B)
Other control signals: (optional, per axis)	Home signal channel input Positive limit switch input Negative limit switch input AxisIn input AxisOut output
Miscellaneous signals:	GND +5 V (for encoder power)

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1.8 Applying Power

Once you have installed the Navigator-PCI card in your PC and made the necessary connections to your external amplifiers and motor encoders, hardware installation is complete and the board is ready for operation.

Upon power up, the card will be in a reset condition. In this condition no motor output will be applied. Therefore, the motors should remain stationary. If the motors do move or jump, power down the card and check the amplifier and encoder connections. If anomalous behavior is still observed, call PMD for application assistance.

1.9 Software Installation

Locate the CDROM which contains C-Motion and Pro-Motion software. This CD contains software to exercise your board, and source code that will enable you to develop your own motion applications. The exercise software is designed to work with Windows 95/98/ME or Windows NT/2000/XP.

If you have autorun enabled, the installation process will start when you insert the CDROM. The installation program will guide you through installing the software. Upon completion of the installation process, the following components will be installed:

1. Pro-Motion – an application for communicating to and exercising the installed card. Refer to *section 3, Using Pro-Motion*, *page 35* for operating instructions.
2. PMD Board Setup – used to set the base address for communication with ISA-based cards. This application is not used with the Navigator-PCI cards.
3. C-Motion – source code that can be used for developing your own motion applications based on the Navigator motion processor. Refer to *section 4, Developing Your Own Applications with C-Motion, page 41,* for further information. These files are installed in the "C-Motion" folder, a sub-folder of the installation folder.
4. "PDF" versions of the Navigator-PCI Users Guide, Navigator Motion Processor Programmer's Command Reference and Navigator Motion Processor User's Guide. The Adobe Acrobat Viewer is required for viewing these files. If the Adobe Acrobat Viewer is not installed on your computer, you can download it from http://www.adobe.com.

1.10 First Time System Verification

To verify that the Navigator-PCI card and Pro-Motion software program have been properly installed, it is useful to have each axis of the system perform a short move. The instructions shown on the following pages are a summary. Before executing these commands you may want to refer to the section of the *Navigator Motion Processor User's Guide* to familiarize yourself with operation of the card's motion processor.

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The following table summarizes what is required for each motor type. Note that the step numbers reference specific steps that are detailed in the next section. Perform only the setup step sequences for the card/motor type installed in your system.

Motor type	Step #	Operation
DC brush	1	Set amplifier type (PWM sign/mag, PWM 50/50, DAC)
	4	Set filter parameters
	6	Make a trajectory move
Brushless DC	1	Set amplifier type (PWM 50/50, DAC)
	2	Initialize commutation*
	3	Check commutation
	4	Set filter parameters
	6	Make a trajectory move
Microstep step motor	1	Set amplifier type (PWM 50/50, DAC)
	5	Set the motor output power
	6	Make a trajectory move
Pulse and direction step motor	6	Make a trajectory move

* Contact PMD for the "Phase Initialization" application note.

It is assumed that you will check out each axis of your system one at a time. This being the case, after executing Pro-Motion, type one of the axis setting commands (#axis 1, #axis 2, #axis 3, or #axis 4) in the command window and go through the whole checkout for that axis. Then to check out other axes enter a new axis number and check that axis out entirely, etc.

1.10.1 Step #1: Set the Motor Amplifier Type

The motion processor must be told what type of motor output mode to use, PWM sign/mag, PWM 50/50, or DAC. This can be set using the command **SetOutputMode**. Assuming the axis you want to exercise is #1, you would type in the command "**SetOutputMode**" followed by the output mode; 0 for DAC, 1 for PWM sign/mag, and 2 for PWM 50/50. For example, to specify the output mode as PWM 50/50 the following sequence would be typed in:

SetOutputMode 2

And this would be followed by an <ENTER> to process the command. Upon successfully accepting this command Pro-Motion will return a prompt ">". If there is some problem with the command, Pro-Motion will indicate the nature of the error, then will be followed with a ">" prompt.

For more information on Pro-Motion, refer to *section 3, Using Pro-Motion, page 35*.

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1.10.2 Step #2: Initialize the Commutation

NOTE: THIS SECTION APPLIES TO BRUSHLESS OR MIXED MOTOR CARDS ONLY

For the motor to be controlled properly, the motion processor must select and possibly initialize the commutation phasing. If you will be using Hall-based commutation then no initialization is necessary. Simply specify this to the motion processor using the command:

SetCommutationMode 1

No other commands are necessary and you may proceed to step #3.
If you are controlling a brushed type motor, set the number of phases to 1 as follows:

SetNumberPhases 1

No other commands are necessary and you may proceed to step #3.

If you will be commutating using a sinusoidal technique you must initialize the commutation phasing.. There are two ways this can be done. You will need to decide whether to initialize using Hall-based or algorithmic methods. *See the Navigator Motion Processor User's Guide* for more information on this.

Each of these two-phase initialization methods requires a separate sequence, as follows (note that // indicates a comment and should not be typed in):

Hall-based initialization command sequence:

```
SetNumberPhases x          // where x is 2 or 3 depending on type of motor
SetPhaseCounts yyyy        // yyyy is # of encoder counts per electrical cycle
SetPhaseInitializeMode 1   // set phase initialize mode to 'Hall-based'
InitializePhase
```

Algorithmic-based initialization command sequence:

```
SetNumberPhases x          // x is 2 or 3 depending on type of motor
SetPhaseCounts yyyy        // yyyy is # of encoder counts per electrical cycle
SetPhaseInitializeMode 0   // set phase initialize mode to 'algorithmic'
SetMotorMode 0             // places axis in open loop mode, required for algorithmic initialization.
SetPhaseInitializeTime zzzz // zzzz is # of motion processor cycles to initialize for
SetMotorCommand wwww       // wwww is motor command
InitializePhase
```

To determine the values of x, yyyy, zzzz, and wwww you should refer to the *Navigator Motion Processor User's Guide - Commutation Section.*

For more information on Pro-Motion, refer to *section 3, Using Pro-Motion, page 35*.

If your system has one or more of the following conditions present then the above sequence will need to be expanded. To handle such systems you will need to use the **SetSignalSense** command as well as the **SetPhasePrescale** command. Refer to the commutation section of the *Navigator Motion Processor User's Guide* for more information.

1. One or more Hall signals must be inverted to commutate or initialize the commutation correctly
2. Number of encoder counts per electrical cycle exceeds 32,767

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1.10.3 Step #3: Check Commutation

NOTE: THIS SECTION APPLIES TO BRUSHLESS MOTOR CARDS AND MIXED MOTOR CARDS.

After phase initialization has been completed it is useful to check the smoothness of the motor rotation in open loop mode to verify that the motor phasing initialization and commutation is correct. To do this use the following command sequence:

```
SetMotorMode 0              // set axis for open loop operation
SetMotorCommand xxxx        // xxxx is the motor command from 0 to 32,767 to output
Update
```

The xxxx value represents the fraction of the value 32,768 of total power that will be applied to the motor. For example a value of 1000 sends roughly 3% (1000/32,768) of the total power to the motor.



When the motor mode is set to off (**SetMotorMode 0**) the motor is not under servo control. Be aware that the motor may spin rapidly after a motor command value is applied. Use small values and increase slowly.

After this command sequence the motor should smoothly spin in one direction or the other. The motor command is a signed number and the sign controls the rotation direction. When a positive motor command is given the motor should rotate in the positive (increasing encoder counts) direction. If the motor spins roughly, in the wrong direction, or if it moves a short distance and then abruptly stops there may be a problem with the commutation. Check your wiring and re-test. Once the motor is spinning smoothly in both directions under open loop control, re-enable closed-loop servo control by executing the following command:

```
SetMotorMode 1
```


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1.10.4 Step #4: Set Filter Parameters

For motion to occur, some amount of feedback gain must be specified. Initially use just a proportional gain with a very low value between 1 and 25. Later you can add integral or derivative gains as well as feedforward gains if desired. The following sequence shows how to set the P, I, and D terms of the filter and how to 'update' them, making them active.

SetKp xxxx	// xxxx is the desired proportional gain
SetKd yyyy	// yyyy is the desired derivative gain
SetKi zzzz	// zzzz is the desired integral gain
SetIntegrationLimit aaaa	// aaaa is the desired integration limit
Update	// make the values active

It is not necessary to specify all 3 gains. Just Kp, followed by an **Update** can be specified, just a Kd, etc.



When exercising the motor use extreme caution. It is the responsibility of the user to observe safety precautions at all times.

1.10.5 Step #5: Set the Motor Command

NOTE: THIS SECTION APPLIES TO THE MICROSTEPPING STEP MOTOR CARDS ONLY.

In order for motion to occur, the magnitude of the output must be set. Refer to the *Navigator Motion Processor User's Guide* for more information. A value between 0 and 32,767 represents an amplitude of 0 – 100%. A value of around 5000 should be satisfactory to start with.
Here is the command sequence to use:

SetMotorCommand xxxx	// Sets the motor output level
Update	// execute the move

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1.10.6 Step #6: Make a Trajectory Move

To test that the motor is being driven properly, set up and execute a small trapezoidal move. Specify a small distance of (for example) 5000 counts, and a low velocity and acceleration of (for example) 10,000, and 10 respectively. With a cycle time of 400 µSec, these values correspond to roughly 381 counts/sec, and 954 counts/sec2, respectively.



Whatever profile values you use, be sure that they are safe for your system.

Here is the command sequence to use:

```
SetProfileMode 0          // set current profile mode to trapezoidal
SetPosition 5000          // 5000 is the desired destination position
SetVelocity 10000         // 10,000 is the desired maximum velocity
SetAcceleration 10        // 10 is the desired acceleration
SetDeceleration 10        // 10 is the desired deceleration
Update                    // execute the move
```

After entering this sequence of commands you should see the axis smoothly move for about 15 seconds (if the suggested values are used and the cycle time of the motion processor is 400 µsec) If you do not see the axis moving, or if the axis jumps rapidly in one direction or the other, there may be a problem with the board or software settings. Re-check and review the board setup procedures, as well as the exerciser parameter settings.

If you are still having problems after re-checking your system, call PMD for applications assistance.

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2.0 Operation

2

In This Section

- Card Function Overview
- Navigator Motion Processor
- Card Specific Functions
- Signal Processing and Hardware Functions

The PMD Navigator-PCI cards are high performance PCI-bus cards that provide motion control for DC brush, brushless DC, and step motors. These cards are based on Navigator PMD motion processors which perform motion command interpretation and other real time functions.

The overall card function is divided amongst a number of modules. These modules are indicated in the block diagram below:

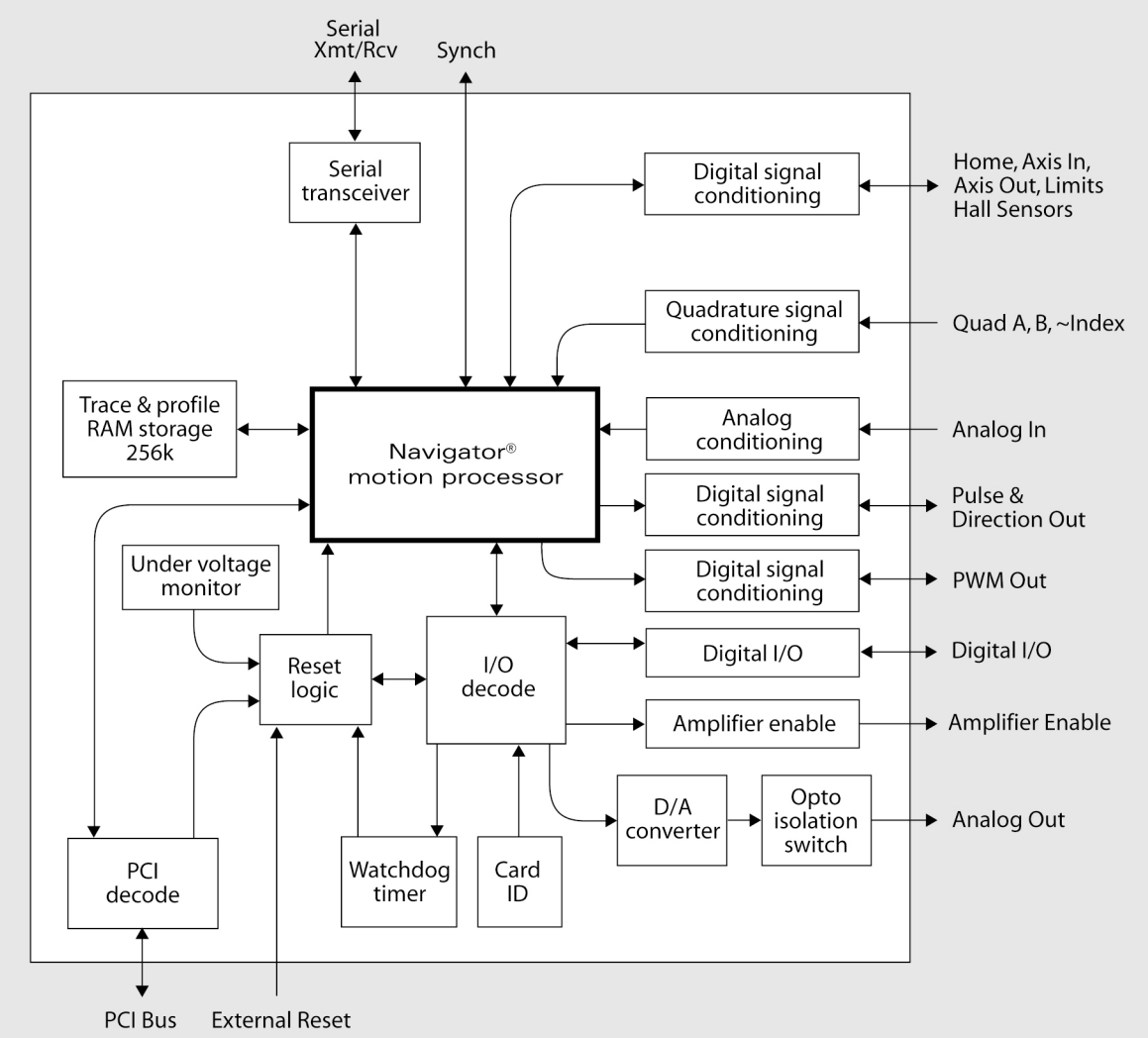


Figure 2-1. Navigator-PCI Internal Block Diagram

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2.1 Card Function Overview

Navigator-PCI card resources can be broken into three overall categories:

Navigator motion processor functions - These are programmable functions which reside in the motion processor such as profile generation, servo loop closure, and much more. These functions are accessed using Navigator motion processor commands, of which there are roughly 150 in total, to allow sophisticated control of the card's overall behavior.

Card-specific functions - These are programmable functions which are controlled by the motion processor using commands **ReadIO** and **WriteIO**, but which reside in various portions of the card circuitry. These functions include general purpose digital I/O, and other card-specific capabilities.

Signal processing & hardware functions - A substantial portion of the card provides signal conditioning and other functions associated with non-programmable, signal-related processing.

2.2 Navigator Motion Processor

The Navigator motion processor pictured in *figure 2.1, the Internal Block Diagram, page 21,* is comprised of 2 ICs, a CP (command processor) and an I/O (input/output) IC. A summary list of the functions provided by the motion processor is as follows:

- Profile generation
- Motor output signal generation (PWM and analog)
- Quadrature counting, index capture
- Servo loop closure (for DC Brush or Brushless DC motors only)
- Breakpoint processing
- PLC-function processing (AxisIn and AxisOut signals)
- Trace
- Motion error detection, tracking windows, and at-settled indicator
- Limit switches

Access to the Navigator-PCI card may occur through the PCI port, or through the serial port. In either case, a complete set of C-Motion function calls, one for each Navigator command, is used to communicate to the card. For a complete list of Navigator commands see the *Navigator Motion Processor Programmer's Command Reference*.

The system on which the Navigator-PCI card is installed can control the card through the pre-compiled program Pro-Motion, or through a program of your own construction, using C-Motion calls as the basic interface. During axis setup (see *section 4, Developing Your Own Applications with C-Motion, page 41* for more details) the communications method (PCI-bus or serial port), and other parameters, are specified which allow C-motion to create a virtualized axis handle, that from then on is the reference for all C-motion commands.

Available C-Motion commands correspond one-for-one with those listed in the *Navigator Motion Processor Programmer's Command Reference*. All C-Motion commands preface the Navigator command with the letters 'PMD', so the Navigator command (for example) **SetPosition** becomes the C-callable routine

PMDSetPosition

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Example

The Navigator instruction set is very flexible and powerful. The following simple example, to set up and execute a simple trapezoidal profile, illustrates just a small part of the overall command set.

PMDSetProfileMode(axis_handle, trapezoidal);
PMDSetPosition(axis_handle, position_value);
PMDSetVelocity(axis_handle, velocity_value);
PMDSetAcceleration(axis_handle, acceleration_value);
PMDSetDeceleration(axis_handle, deceleration_value);
PMDUpdate(axis_handle);

Two separate manuals describe how the Navigator motion processor operates and how it is programmed, the *Navigator Motion Processor User's Guide,* and the *Navigator Motion Processor Programmer's Command Reference.*

2.3 Card Specific Functions

Card -specific functions are those functions that are mapped through the motion processor's ReadIO and WriteIO facility, but are implemented in the card circuitry.

Card-specific functions are detailed in this document, the *Navigator-PCI's User's Guide,* rather than the *Navigator Motion Processor User's Guide*, or the *Navigator Motion Processor Programmer's Command Reference.*

2.3.1 General Purpose Digital I/O

In addition to numerous special-purpose digital signals that are input or output to the card such as ***AxisIn, AxisOut, Home, QuadA,*** etc., the Navigator-PCI cards support 8 general-purpose inputs, and 8 general-purpose outputs. These signals provide a convenient way of accessing additional general purpose digital I/O. Although access to these signals occurs through the motion processor's **ReadIO** and **WriteIO** command, the signals present at these various connections do not directly affect the motion processor's behavior. Thus the motion processor simply passes them through.

ReadIO and WriteIO commands
The 8 inputs and outputs are read using the **ReadIO** command and **WriteIO** command, with an I/O address of 0. The table below shows this, along with the bit locations of the input and output signals.

I/O address	Bit location	Signals
+0	0-7	***DigitalOut0-7***
	8-15	***DigitalIn0-7***

To read the 8 general purpose digital I/Os, a **ReadIO** command is performed at address offset 0. The 16 bit read word returns the current output values (set using the **WriteIO** command) in bits 0-7, while bits 8-15 hold the digital values corresponding to the signal levels at the connector for those inputs. To write new signal values to the 8 digital outputs, a **WriteIO** command to address offset 0 is sent, and the values on bits 0-7 will be output to the signal connections. The value of bits 8-15 are ignored.

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Example

To write a sequence 0xaa to bits 0-7, the C-Motion command (*see section 4, Developing Your Own Applications with C-Motion, page 41,* for more information on C-Motion commands) **PMDWriteIO**(axis_handle, 0, 0xaa) is used. Assuming that the signal pattern 0x55 is present on the 8 input connections, if the command **PMDReadIO**(axis_handle, 0, &load_reg) is used, load_reg will contain 0x55aa. The upper 8 bits reflect the present value of the output signals, while the lower 8 bits reflect the 8-bit value being input.

C-Motion commands

In addition to accessing these signals using the C-Motion commands **PMDReadIO** and **PMDWriteIO**, you can use card-specific C-Motion functions for this purpose. Card specific functions have a 'MB' after the letters PMD. The available card specific functions for this feature are:

C-Motion command	Arguments	Function description
PMDMBWriteDigitalOutput	axis handle, write_value	This function writes to the 8 general-purpose digital I/O signals (digitalOut0-7). Write_value holds the 8 signals in its low order 8 bits.
PMDMBReadDigitalInput	axis_handle, read_value	This function reads the value of the signals DigitalIn0-7 and returns them in the low order 8 bits of read_value.
PMDMBReadDigitalOutput	axis_handle, read_value	This function reads the value of the signals DigitalOut0-7 and returns them in the low order 8 bits of read_value.

Connections & associated signals

The general-purpose I/O signals are direct single-signal digital inputs and outputs. There are no associated connections that need to be made for these signals to function properly, however one or more of the digital grounds must be connected. The default value, upon powerup, for all general-purpose digital outputs is low.

For a complete description of the pinout connections to/from the card, *see section 5, Navigator-PCI Electrical Reference, page 45.*

2.3.2 Amplifier Enable

The signals ***AmpEnable1-4*** provide up to four digital outputs which, if desired, can be used as amplifier enable signals, although they can also be used as general-purpose digital outputs. Similar to the general-purpose digital inputs and outputs (*section 2.3.1, page 23*), these signals are not directly affected by the motion processor's behavior, however they can be read or written through the motion processor's **ReadIO** and **WriteIO** commands.

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ReadIO and WriteIO commands

These outputs are read using the **ReadIO** command, and written to using the **WriteIO** command, using an I/O address of +1. The table below shows this.

I/O address	Bit location	Signals
+1	0-3	Amplifier enable outputs (0-3)
	4-6	Unused
	7	DAC enable status (1 = enabled, 0 = disabled)
	8-11	Change mask for bits 0-3 - amplifier enable outputs (1 = change, 0 = don't change)
	12-14	Unused
	15	Change mask for DAC enable (1 = change, 0 = don't change)

To read the status of the amplifier enable outputs the command **ReadIO** is used at address +1. The values currently being output will appear in bits 0-3. To write values to the amplifier enable output signals, the **WriteIO** command is used with an address of +1, and the change mask bits corresponding to the signals that will be changed must be loaded at bits 8-11 and the value(s) to be loaded must be loaded in bits 0-3.

Example



To set the amplifier enable outputs to high (1) for axes 1 & 3, the C-Motion command **PMDWriteIO**(axis_handle, +1, 0x505) is used. To then disable the output only for axis 3, the command **PMDWriteIO**(axis_handle, +1, 0x400) is used, and to then disable the output for axis 1, the command **PMDWriteIO**(axis_handle, +1, 0x100) is used.

C-Motion commands

In addition to accessing these signals using the C-Motion commands **PMDReadIO** and **PMDWriteIO**, you can use card-specific C-Motion functions for this purpose. The available card specific functions for this feature are:

C-Motion command	Arguments	Function description
PMDMBSetAmplifierEnable	axis handle, mask, write_value	This function writes to the 4 amplifier enable signals (AmpEnable1-4) using mask and write_value. When a 1 appears in mask, the corresponding bit position in write_value is written to the corresponding signal. The values for mask and write_value are all 0- shifted, that is they are stored in the lowest order 4 bits.
PMDMBGetAmplifierEnable	axis_handle, read_value	This function reads the value of the AmpEnable1-4 and returns them in the low order 4 bits of read_value.

Connections & associated signals

AmpEnable1-4 are direct single-signal digital outputs. There are no associated connections that need to be made for these signals to function properly; however, one or more of the digital grounds must be connected. The default value, upon powerup, for all amplifier enable signals is low. In addition, these signals are driven low upon a hard reset, which is a reset via the PCI bus, or via the external ***Reset*** signal. *See section 2.3.7, Reset, page 29,* for more information.

For a complete description of the pinout connections to/from the card, *see section 5, Navigator-PCI Electrical Reference, page 45.*

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2.3.3 DAC Output Enable

In addition to the amplifier enable outputs described above, there is a dedicated card function which allows the DAC output signals to be shunted to 0 volts for safety purposes (DAC disabled) or allowed to be set by the motion processor (DAC enabled). This 'shunting' occurs at a hardware level outside the motion processor itself, and represents an additional safety layer to control the motor command.

ReadIO and WriteIO commands

The status of the DAC output enable function can be read using the **ReadIO** command, and the DAC output enable status can be set using the **WriteIO** command, with an I/O address of +1. See *the table in section 2.3.2 on the previous page* for a summary of the bit functions for I/O address word +1.

To read the status of the DAC output enable function, **ReadIO** is used with address +1. The value currently in use will appear in bit 7. A 1 value indicates DAC output is enabled, which means the voltage being output by the DACs is programmed by the motion processor, while a 0 value indicates it is disabled, which means the voltage being output by the DAC is forced to 0.0 volts.

To enable or disable the DAC enable function, the **WriteIO** command is used with an address of +1. The change mask bit at bit 15 must be loaded with a 1, and bit 8 must be loaded with the desired value of 0 to disable, and 1 to enable output.

The default value, upon powerup, for DAC Output Enable is disabled. In addition, the DAC Output Enable is disabled upon a hard reset, which is a reset via the PCI bus, or via the external ***Reset*** signal. *See section 2.3.7, Reset, page 29,* for more information.



Since, for safety reasons, the default condition of DAC Output Enable is disabled, the DAC Output Enable must be enabled by the user for proper DAC-based operation to occur.



Example

To set the DAC output enable function to enabled, the C-Motion command **PMDWriteIO**(axis_handle, +1, 0x4040) is used. To disable the DAC output the command **PMDWriteIO**(axis_handle, +1, 0x4000) is used.

C-Motion commands

In addition to accessing these signals using the C-Motion commands **PMDReadIO** and **PMDWriteIO**, you can use card-specific C-Motion functions for this purpose. The available card specific functions for this feature are:

C-Motion command	Arguments	Function description
PMDMBSetDACOutputEnable	axis handle, write_value	This function sets the DACOutputEnable status. A 1 value written enables DAC output, while a 0 disables it.
PMDMBGetDACOutputEnable	axis_handle, read_value	This function reads the value of the DACOutputEnable function. A 1 indicates enabled, a 0 indicates not enabled.

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Connections & associated signals
DAC output enable is an internal function of the card. Thus there are no signals directly associated with this function.

2.3.4 Serial Transceiver

This module and associated signals provides the capability to operate the Navigator-PCI card using an asynchronous serial port, or to allow certain monitoring operations to be performed through the serial port, even while the PCI bus is used to command motion sequences.

To operate the serial port as the primary communication channel to the card and disable the PCI interface, jumper mode should be set to the 2-3 position. To use the PCI bus for primary communications, and allow the serial port to be used for certain diagnostic operations, mode should be set to 1-2 configuration. For a complete description of primary and diagnostic communication modes, *see Navigator Motion Processor User's Guide*. The following table shows the jumper options for mode:

Jumper	Jumper location	Description
Mode	1-2	PCI bus is main communications channel, serial port can be used in diagnostic mode. *this is the default setting of mode*
	2-3	PCI bus is disabled, serial port is primary communication channel.

The serial port can be operated at various baud rates from 1,200 to 416,667, and different configurations of stop, start, and parity codes. In addition, three connection modes are provided, point-to-point, multi-drop (address bit mode), and multi drop (idle line mode). The Navigator commands **SetSerialPortMode** and **GetSerialPortMode** are used to set, and read back, the serial port communication parameters. A complete description of the serial port, and its usage modes is provided in the *Navigator Motion Processor User's Guide*. A complete description of Navigator commands can be found in the *Navigator Motion Processor Programmer's Command Reference*.

When operated in the serial-only mode (mode set to 2-3) the card will power-up with a default serial communications parameters set of 9600 baud, no parity, one stop bit, and point to point mode. To alter these parameters in serial-only mode, the user should set new desired serial port parameters using the **SetSerialPortMode** command, while communicating at the default parameters, and then switch to the new communications parameters.

Connections & associated signals
A special 5-pin connector is used to connect to the serial port. It is also possible to order a convenient cable with this connector installed. *See section 1.2, Accessory Products, page 9. Section 5.2.7, Serial I/F Connector, page 52,* provides a detailed signal description of the serial I/F connector.

For a complete description of the pinout connections to/from the card, *see section 5, Navigator-PCI Electrical Reference, page 45*.

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2.3.5 Watch Dog Timer

To enhance the overall safety of the card a watch dog function has been included, allowing the motion processor to be automatically reset if communications to/from the host, for whatever reason, should be lost. Resetting the motion processor will have the result of setting all motor command outputs to zero, thereby letting the motors come to a safe stop.

ReadIO and WriteIO commands
To enable the watchdog timer, a **WriteIO** command is sent to address +4, with a specific value of 0x5562. Once enabled, the watchdog timer will time out, causing a motion processor reset, if another write to address +4 with a value of 0x5562 is not received within 104 milliseconds. As long as a watch-dog value is written to the +4 address within a 104 milliseconds interval, no reset will occur, and motion operations will proceed normally.

If no command is sent to the +4 location, then watchdog will remain disabled. Thus watchdog disabled is the default condition upon power-up.

C-Motion commands
In addition to accessing these signals using the C-Motion command **PMDWriteIO**, you can use card-specific C-Motion functions for this purpose. The available card specific functions for this feature are:

C-Motion command	Arguments	Function description
PMDMBSetWatchDog	axis handle, mask	This function writes to the correct value to the watchdog register, so that for the next 104 milliseconds the card will not be reset by the watchdog circuitry.

Connections & associated signals
The Watchdog timer is an internal function of the card. Thus there are no signals directly associated with this function.

2.3.6 Under Voltage Monitor

To enhance reliability under a variety of electrical conditions, a special under voltage detection circuit triggers a motion processor reset when the voltage has dropped to an unsafe level. Resetting the motion processor will have the result of setting all motor command outputs to zero, thereby letting the motors come to a safe stop.

An under voltage condition is detected when the 5V supply to the card, provided through the PCI bus, drops below a specific voltage specified by an under voltage supervisory device. The typical under voltage threshold is 4.625V, while the min. and the max. values are 4.50V, and 4.75V, respectively.

Connections & associated signals
The under voltage detector is an internal function of the card. Thus there are no signals directly associated with this function.

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2.3.7 Reset

Although a reset occurs automatically during power up, it is sometimes desirable to reset the motion processor explicitly, through a user-initiated command or action.

There are several methods by which you can explicitly reset the motion processor. They are summarized in the table below:

Method	Type of reset	Description
External reset	Hard reset	When external signal ***Reset*** on GP Con is brought low, a reset occurs. Normally this signal is pulled high by the card. This type of reset is a 'hard' reset, which resets both the card circuitry and the motion processor. *See table below for more information.*
Reset through motion processor	Soft reset	The C-Motion command **PMDReset** sends the command **Reset** to the motion processor, which causes a 'soft' reset of the motion processor only. *See table below for more information.*
Reset through PCI bus	Hard reset	The C-Motion command **PMDHardReset** uses the PCI bus to perform a 'hard' reset of both the card circuitry and the motion processor. *See table below for more information.*

After a reset occurs, the motion processor and other related output signals will be driven to known states, depending on the type of reset performed. These are summarized in the table below:

Signal name	Soft reset	Hard reset
AxisOut1-4	High	High
PWMMag1A-4C	For DC-brush or mixed motor cards: low	For DC-brush or mixed motor cards: low
	For brushless-DC cards: 50/50 high/low	For brushless-DC cards: 50/50 high/low
	For microstepping cards: low	For microstepping cards: low
PWMSign1A-4B	Low	Low
DAC1A-DAC4B	0.0 volts	0.0 volts
DigitalOut0-7	No change	Low
AmpEnable1-4	No change	Low
Dac On/Off	No change	Off

C-Motion commands

The available C-Motion callable functions for this feature are:

C-Motion command	Arguments	Function description
PMDHardReset	axis_handle	This function causes a 'hard' reset of the motion processor. Unlike all other card-specific commands, this command is processed directly through the PCI card interface.

Connections & associated signals

The reset feature has an external signal input, ***Reset***, associated with it.

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2.3.8 Reset Monitor

In addition to resets which are explictly requested by the user (detailed in the previous section), some reset conditions can occur automatically. During normal operations the motion processor is only reset during power-up. A reset serves the purpose of initializing values and bringing the motion processor to a known and consistent state. On occasion though, the motion processor will be reset due to one of a few anomalous conditions.

ReadIO and WriteIO commands

To determine the source of a card reset special instructions to read the reset source have been provided. The command **ReadIO** with an address of +2 should be used. The following table shows the encoding of this I/O address word:

I/O address	Bit location	Signals
+2	0-11	Reserved
	12	Software command: a 1 value in this bit indicates reset caused by a software command by the user.
	13	Under voltage detection: a 1 value in this bit indicates reset caused by under voltage detection.
	14	External signal: a 1 value in this bit indicates reset caused by external signal. Such a reset originates from the GP Con connector on the connector 'Reset'. When this signal is brought low, a reset condition occurs.
	15	Watch dog timeout: a 1 value in this bit indicates reset caused by watch dog timeout.

Once a reset condition has occurred, the reset status stored in location +2 described above can be cleared by a **WriteIO** command to address +2 with a value of 0.



Example

To determine that a reset has occurred, and to determine what the reset condition is, the C-Motion command **PMDReadIO**(axis_handle, 2, &reset_value) is used. Assuming that a watchdog timer event has occurred, the value returned would be 0x8000. To reset the reset monitor word, the command **PMDWriteIO**(axis_handle, 2.0) is sent.

C-Motion commands

In addition to accessing these signals using the C-Motion commands **PMDReadIO** and **PMDWriteIO**, you can use card-specific C-Motion functions for this purpose. The available card specific functions for this feature are:

C-Motion command	Arguments	Function description
PMDMBGetResetCause	axis handle, reset_cause,	This function returns the reset cause in the variable reset_cause and also clears the reset condition.

Connections & associated signals

The Reset monitor is an internal function of the card. Thus there are no signals directly associated with this function.

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2.3.9 Card ID

This module allows the user to query the card for a card ID. This may be useful for verifying the type of card in situations where different types of cards are employed.

ReadIO and WriteIO Commands
To read this value the **ReadIO** command is used with an address of 0xff. The following table shows the encoding of the bits returned when this function is called:

Address	Bit location	Signals
+0xff	0-3	Major PLD revision: binary coded 4-bit word encoding the major PLD revision. This value can range from 0 to 15.
	4-7	Minor PLD revision: binary-coded 4-bit word encoding the minor PLD revision. This value can range from 0 to 15.
	8-11	Board revision: binary-coded 4-bit word encoding the board revision. This value can range from 0 to 15.
	12-15	Board type: binary-coded 4-bit word encoding the board type. This value can have one of the following values: 0 - Navigator-ISA family card 1 - Navigator-PCI family card 2 - Unused 3 - Navigator-PC/104 family card 4-15 - Unused

Example

To read the card ID the C-Motion command **ReadIO**(axis_handle, +0xff, &card_id) is used. Assuming the value returned is 0x1005, this can be interpreted as:

Navigator-PCI card, board revision 0, PLD revision 5.0

C-Motion commands
In addition to accessing these signals using the C-Motion command **PMDReadIO**, you can use card-specific C-Motion functions for this purpose. The available card specific functions for this feature are:

C-Motion command	Arguments	Function description
PMDMBReadCardID	axis handle, card_ID	This function returns the card ID, encoded as defined in the table above.

Connections & associated signals
The Card ID is an internal function of the card. Thus there are no signals directly associated with this function.

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2.4 Signal Processing and Hardware Functions

Signal processing and hardware functions are card functions which are not directly user-programmable. These are card characteristics which are encoded in hardware. Primarily this consists of various types of signals. The following sections lists these related groups of signals and provides information that may be helpful when connecting your motion system.

2.4.1 Home, AxisIn, AxisOut, Limits, Hall Sensors

These signals are conditioned by the card, but are output or input directly to the motion processor. The *Navigator Motion Processor User's Guide* explains the functions provided in connection with these various signals. Most of the signals are optional, and are connected depending on the nature of the application being used.

These signals are named ***Home1-4, AxisIn1-4, AxisOut1-4, PosLim1-4*** (positive direction limit input), ***NegLim1-4*** (negative direction limit input), and ***Hall1A-4C*** (12 signals in all).

Connections & associated signals
This group of signals are direct single-signal digital inputs to the card, with the exception of ***AxisOut*** which is a single-ended output. There are no associated connections that need to be made for these signals to function properly, however one or more of the digital grounds must be connected. The default value, upon powerup, for all ***AxisOut*** signals, is high.

For a complete description of the pinout connections to/from the card, *see section 5, Navigator-PCI Electrical Reference, page 45*.

2.4.2 QuadA, QuadB, Index

Quad A, B, Index
This group of signals provides position feedback to the controller which is used to track motor position, and for servo motors, to generate a motor command. For DC brush and brushless DC motors, they are required for proper operation. For microstepping or pulse and direction motors, they are optional.

The encoder-processing circuitry provides a multi-pass digital filter of the ***QuadA, QuadB***, and ***Index*** signals for each axis. This provides additional protection against erroneous noise spikes, thereby improving reliability and motion integrity.

These signals are named ***quadA1+*** through ***quadB4-*** (16 signals), and ***Index 1+*** through ***Index4-*** (8 signals).

Connections & associated signals
This group of signals are connected in one of two ways. Single-ended termination means that only one wire per signal is used, while differential (dual) mode means two wires encode each signal (labeled + and -). Differential encoding is generally recommended for the highest level of reliability because it provides greater noise immunity than a single-ended connection scheme.

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If single-ended connections are used only the + signal is connected, and the - signal should be left floating. For example, in connecting to the A quadrature input, QuadA1+ connects to the signal, and QuadA1- is left floating. If differential connections are used, both the + and - signals are used. Differential or single-ended termination must be selected through resistor pack installation. *See table in section 1.6, page 11, for details.* Note that all Quadrature and index connections should be in either single-ended or differential mode. It is not possible to mix on a signal-by-signal basis.

When using the system with differential connections, if desired, the polarity of the differential signal can be reversed by swapping the + and - connections. This may be useful for altering the motor and/or encoder direction, however this same function can also be accomplished through commands to the motion processor. *See Navigator Motion Processor User's Guide,* for more information.

Associated connections that are supported by the card are the +5V output signals. These are provided as a convenience, as they are generally connected to a corresponding input on the encoder, to power its LEDs or other circuitry. As was the case for the digital input signals, one or more of the digital grounds must also be connected.

For a complete description of the pinout connections to/from the card, *see section 5, Navigator-PCI Electrical Reference, page 45.*

2.4.3 Analog Input

The ***Analog1-8*** signals provide general purpose input of 8 analog signals. If connected, the voltages present at these various connections do not directly affect the motion processor's behavior. However they can be read through the motion processor, and thus provide a convenient way of bringing in analog signal levels that may be acted upon by the user's application code located on the PC. These signals are read using the Navigator command **ReadAnalog**. For more information on reading the value of these analog inputs, *see Navigator Motion Processor User's Guide.*

These signals are named ***Analog1-8***

The minimum allowed input voltage is 0.0V, and the maximum allowed input voltage is 4.096V. To determine the numerical value that will be read by the motion processor given a specific voltage, the following formula is used:

ReadValue = AnalogVoltage * 65,472 / 4.096V

Conversely, given a read value, the voltage at the connection is calculated as:

AnalogVoltage = ReadValue * 4.096V / 65,472

Connections & associated signals
For analog voltages to be read correctly, in addition to the analog signal itself, ***AnalogGND*** (Analog ground) must be connected.

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2.4.4 Pulse and Direction

For pulse & direction motors these signals provide a stream of pulse and direction data, compatible with a wide variety of off-the-shelf step motor amplifiers. These signals are directly generated by the Navigator motion processor. For more information on output waveforms, pulse rates, and related information, *see Navigator Motion Processor User's Guide.*

These signals are named ***pulse1-4, direction1-4***.

The default value, upon powerup, for all pulse & direction output signals is high.

Connections & associated signals
This group of signals are direct single-signal digital outputs. There are no associated connections that need to be made for these signals to function properly, however one or more of the digital grounds must be connected.

For a complete description of the pinout connections to/from the card, *see section 5, Navigator-PCI Electrical Reference, page 45.*

2.4.5 PWM Out

For servo or microstepping motors these signals provide PWM (pulse width modulated) motor command signals when the motor output mode is set to **PWMSignMagnitude** or **PWM5050Magnitude**. *See the Navigator Motion Processor User's Guide* for complete information. The number of signals per axis varies depending on the motor type being connected to, the number of phases that the motor has, and the motor drive method (sign/magnitude or 50/50). *Section 5, Navigator-PCI Electrical Reference, page 45,* has complete connection tables for various motor configurations.

These signals are named ***PWMMag1A-4C*** (12 signals) and ***PWMSign1A-4B*** (8 signals).

Connections & associated signals
This group of signals are direct single-signal digital outputs. There are no associated connections that need to be made for these signals to function properly, however one or more of the digital grounds must be connected.

For a complete description of the pinout connections to/from the card, *see section 5, Navigator-PCI Electrical Reference, page 45.*

2.4.6 Motor Command

For servo or microstepping motors, these signals contain the analog motor command when the motor output mode is set to DAC (digital to analog converter). These signals vary between -10V and +10V. S*ee Navigator Motion Processor User's Guide* for more information. The number of signals per axis varies depending on the motor type being connected to.

These signals are named ***DAC1A - DAC4B*** (8 signals)

Connections & associated signals
For analog voltages to be output correctly, ***AGND*** (motor command ground) must be connected.

For a complete description of the pinout connections to/from the card, *see section 5, Navigator-PCI Electrical Reference, page 45.*

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3.0 Using Pro-Motion

3

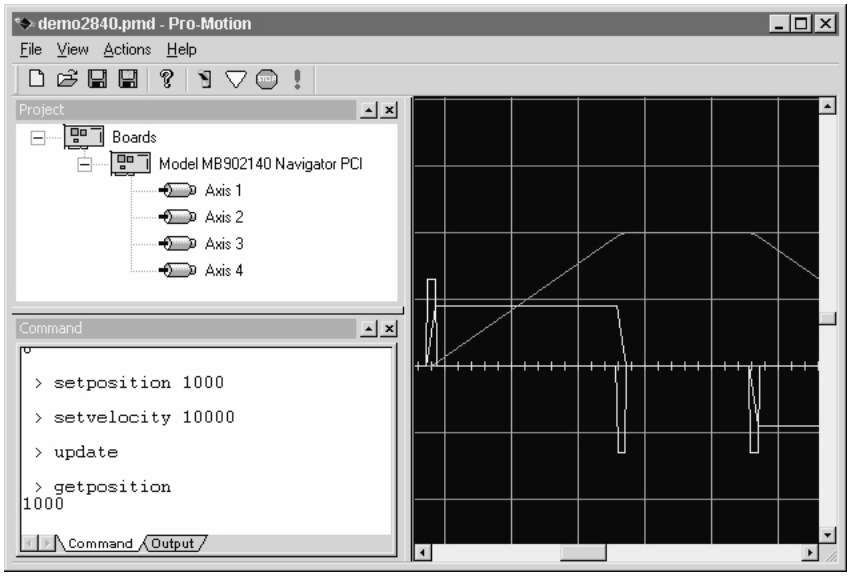
In This Section

- Communication
- Motion
- Command Window

The Pro-Motion program facilitates the exercising of the Navigator-PCI card. All card parameters can be viewed and modified via standard Windows controls, and all card functions may be exercised.

Pro-Motion features:

- Project window for accessing processor parameters.
- Command window for direct text command entry. It also serves as a communications monitor that echoes all commands sent by Pro-Motion to the card.
- Axis shuttle performs continuous back and forth motion between two positions.
- Oscilloscope graphically displays processor parameters in real-time.



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3.1 Communication

When Pro-Motion is started (or file/new is selected) the Navigator-PCI card is interrogated by first attempting to connect via the parallel interface (PCI slot). If successful, Pro-Motion will display the processor version and the number of axes in the project window. If no axes are displayed under the 'card' item in the project window, then there is a communication problem with the card.

3.2 Motion

Once communications has been established with the Navigator-PCI card, motion may be performed to the connected motors by setting the appropriate axis parameters and running the motion shuttle. Right clicking on an axis icon in the project window accesses these dialogs.

The following table summarizes the steps necessary to obtain motion depending on the card used.

Card part number	Step#	Operation
DC brush (MB902140, MB902120, MB902110)	1	Set amplifier type (PWM sign/mag, PWM 50/50, DAC)
	4	Set filter parameters
	6	Start motion
Brushless DC & mixed motor (MB902340, MB902320, MB902310, MB902840, MB902820)	1	Set amplifier type (PWM sign/mag, PWM 50/50, DAC)
	2	Initialize commutation
	3	Check commutation
	4	Set filter parameters
	6	Start motion
Microstepping step motor (MB902440, MB902420, MB902410)	1	Set amplifier type (PWM 50/50, DAC)
	5	Set the motor output power
	6	Start motion
Pulse & direction (MB902540, NB902520, MB902510)	6	Start motion

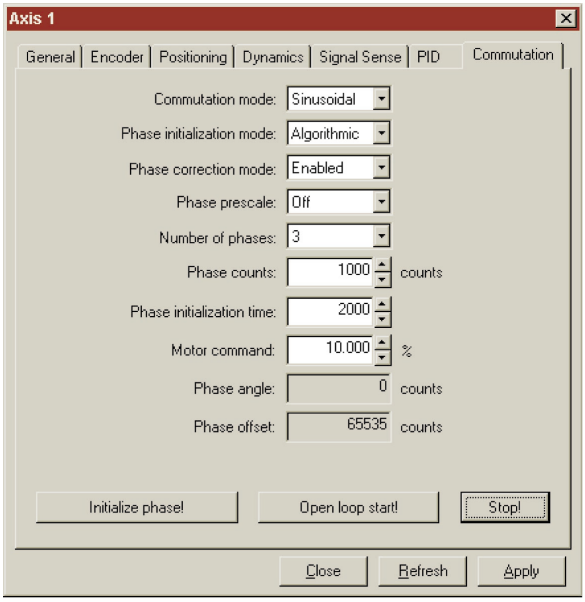
3.2.1 Step #1 Amplifier Type

Select the general page of the axis properties dialog and set the motor output mode. Make sure the motor mode is set to on and the axis enabled button is checked. Click the apply button to send the changes.

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3.2.2 Step #2 Initialize Commutation

Select the commutation page of the axis properties dialog and set the commutation parameters to the desired values. If the commutation mode is set to sinusoidal, then the initialize phase button should be clicked after all the parameters have been correctly set and before any motion is attempted or the open loop start button is pressed.



3.2.3 Step #3 Check Commutation

The commutation may be verified by running the motor in open loop mode. Set the motor command parameter to a low value between 1% and 15%, keeping in mind the motor will start to move at a rate proportional to the motor command setting. Click the open loop start button. If the motor is commutating properly, the motor should spin smoothly. Click the stop button to stop motion.

3.2.4 Step #4 Set Filter Parameters

Select the PID page of the axis properties dialog and set the Kp parameter to a low value between 1 and 25 initially to prevent any oscillations. Click the apply button.

3.2.5 Step #5 Motor Output Power

Set the motor command parameter to a low value between 10% and 20% to start with. Click the open loop start button to send this value because the apply button does not send this particular value. If an attempt to start a trajectory move does not move the motor, try increasing this value.

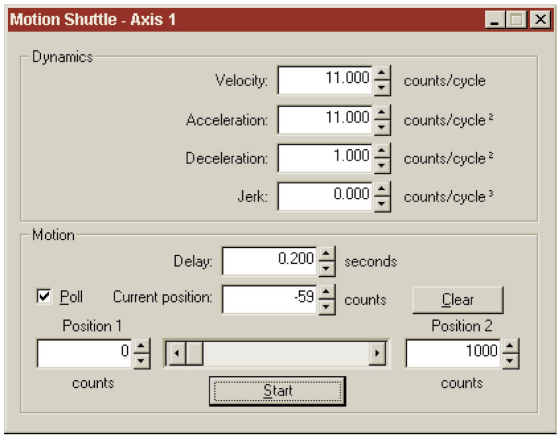
3.2.6 Step #6 Start Motion

Select the page of the axis properties dialog and set the profile mode to trapezoidal. Set the velocity to a low value between 1 and 10 counts/cycle. Set the acceleration and deceleration parameters to a

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low value between 0.01 and 1 counts/cycle. Click the apply button.

Right click on the desired axis and select shuttle to display the motion shuttle dialog if it is not already displayed for the desired axis.

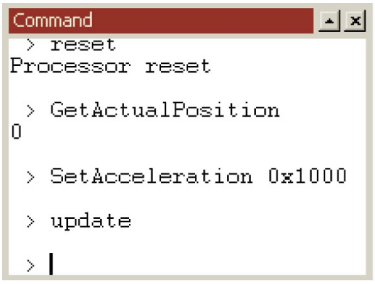


The dynamics parameters should be set to the values previously set in the dynamics page of the axis properties dialog. Click the start button. The motor should start moving back and forth between position 1 and position 2. If the motor does not begin to move return to step 1. If the motor starts moving, but does not look like it's shuttling between the two points, verify that it is moving in the right direction and the current position is between the 2 position values. If it is not moving in the right direction, try changing the signal sense of one of the encoder signals if applicable. If the motor's current position was not between the two positions, it will move to position 1 before shuttling will occur.

The motion can be monitored using the oscilloscope.

The commands that Pro-Motion sends to the processor can be monitored by selecting the view/monitor output menu item.

3.3 Command Window



The command window in Pro-Motion allows you to issue commands directly to the PMD motion processor installed in your Navigator-PCI card. The window has a command line style interface that accepts all of the motion processor commands. The *Navigator Motion Processor Programmer's Command Reference* contains a full list of commands along with their required parameters. The command window presents you with the command prompt '>'. The sequence on the facing page shows a typical command session.

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```
> Reset
Processor reset
> SetKp 25
> Update
> SetProfileMode 0
> SetVelocity 200000
> SetAcceration 256
> SetDeceleration 256
> SetPosition 123456
> Update
```

This sequence of commands:

1. Resets the Navigator motion processor;
2. Sets the Kp PID filter parameter;
3. Sets up and executes a trapezoidal move.

The command window is not case sensitive so commands can be entered in any combination of upper and lower case characters. As shown above, commands are entered as a sequence of command name followed by up to 2 numeric parameters. Parameters can represent a single 16-bit word of data or a 32-bit double word of data depending on what is required by the particular command.

```
> SetBreakpointValue 0 1000
```

In this example the first parameter represents a 16-bit word that contains the selected breakpoint number (0 or 1), and the second parameter represents a 32-bit word that contains the breakpoint value.

All of the "Get" commands display the value returned by the chipset.

```
> GetEventStatus
0x0309
```

Some "Get" commands require a parameter for selecting the desired value.

```
> GetBreakpointValue 0
0
```

In this example, 0 selects the breakpoint number for which the value is retrieved. The command window accepts numeric parameters in either decimal or hexadecimal format. Pre-fixing a numeric parameter with "0x" enters that number using hexadecimal format. For example,

```
> SetKp 0xA
```

sets the Kp to 10 (decimal). When a numeric parameter is entered without any prefix it is assumed to be in decimal format.

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The command window automatically inserts the axis number into the command word before sending it to the Navigator motion processor. At startup, the axis number is set to 1. For motion processors that support more than one axis, you can select the axis number using the following commands:

```
> #axis 1          // selects axis # 1
> #axis 2          // selects axis # 2
> #axis 3          // selects axis # 3
> #axis 4          // selects axis # 4
```

The command window is capable of executing sequences of commands stored in external files using the file-input command "<" followed by the name of the file to execute.

```
> <setup.txt
```

As an example, the file "setup.txt" could have the following command sequence that initializes DAC output mode and sets the servo parameters for the attached hardware.

```
Reset
SetOutputMode 0
SetKp 25
SetKd 200
Update
```

This file can then be used any time the system needs to be re-started. Any sequence of valid commands can be contained within the script file.

The tilde symbol '~' can be prefixed to any line to make that line a comment which will not be executed.

3.3.1 Commands Available within the Command Window

CTRL-R:	Repeat the last command entered.
TAB:	Automatic command name completion. Press this key after having entered the first few characters of the command you wish to execute. If more than one command begins with these characters, a window containing a list of commands that match the starting characters will appear. Select the correct command using the keyboard or mouse.
UP-ARROW:	Sequentially scrolls back through previously entered commands.
DOWN-ARROW:	Sequentially scrolls forward through previously entered commands.
ESC:	Clears the command line.
#axis *number:*	Selects the current axis (e.g., #axis 3 selects axis number 3.) All future commands will be executed on the selected axis.
<filename	Script file-input command. Executes the commands contained in the specified file.
TraceDownload *filename:*	Reads trace data from the external memory and stores it to the specified *filename*. Prior to executing this command, an actual trace must have been started as described in section 7 of the *Navigator Motion Processor User's Guide*.

For more information click on *Help* in *Pro-Motion*.

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4.0 Developing Your Own Applications with C-Motion

4

In This Section

- Overview
- Using C-Motion

4.1 Overview

C-Motion is a "C" source code library that contains all the code required for communicating to your Navigator-PCI card.

C-Motion includes the following features:

- Axis virtualization
- The ability to communicate to multiple Navigator-PCI cards
- Can be easily linked to any "C/C++" application

C-Motion callable functions are broken into two groups, those callable functions that encapsulate direct motion processor commands, and those callable functions that encapsulate card-specific capabilities.

Motion Processor Commands
The motion processor specific commands are detailed in the *Navigator Motion Processor Programmer's Command Reference*. They are the primary commands that you will use to control the major motion features including profile generation, servo loop closure, motor output signal generation (PWM and analog), breakpoint processing, trace operations, and many other functions.

Each Navigator motion processor command listed in the *Navigator Motion Processor Programmer's Command Reference* has a C-Motion command of the identical name, but prefaced by the letters 'PMD'. For example the Navigator command **SetPosition**, is called **PMDSetPosition**.

Card-Specific Commands
The card-specific C-Motion commands are detailed in *section 5.5, "Command Summary: Card-Specific Functions", page 56*. These functions provide access to features that are located in the card, as opposed to in the motion processor. This is a much smaller set of features, and includes:

General Purpose Digital I/O function
Amplifier enable outputs
DAC output enable
Watchdog timer
Reset monitor
Card ID

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4.2 Using C-Motion

The following files make up the C-Motion distribution:

C-Motion.h/C-Motion.c	Definition/declaration of the PMD Navigator command set
PMDpar.h/PMDpar.c	Parallel interface functions
PMDW32ser.h/PMDW32ser.c	Windows serial communication interface functions
PMDdrv.h/PMDdrv.c	Windows ISA driver communication interface functions
PMDpci.h/PMDpci.c	Windows PCI driver communication interface functions*
PMDutil.h/PMDutil.c	General utility functions
PMDtrans.h/PMDtrans.c	Generic transport (interface) functions
PMDecode.h	Defines the PMD Navigator and C-Motion error codes
PMDocode.h	Defines the control codes for Navigator commands
PMDtypes.h	Defines the basic types required by C-Motion
PMDdiag.h	Defines a string structure for each command code that can be used for debugging or diagnostics

**The PMDpci.c file cannot be compiled without the PLX source which can be purchased separately from PLX Technology. In order to build a PCI program without the PLX source, the PMDpci.obj and PlxApi.lib files must be linked in. These files are located in the \Debug and \Release subdirectories.*



If you use Visual Studio 6.0 or later, it may be advantageous to use the pre-made Visual Studio Project MB900.dsp in the C-Motion Examples folder.

C-Motion can be linked to your application code by including the above "C" source files in your application. Then, for any application source file that requires access to the motion processor #include "C-Motion.h". In addition, the required interfaces need to be #defined as shown below. Only the required interfaces need to be included.

```
#define PMD_PARALLEL_INTERFACE      // use this for a standard parallel interface under DOS or Win9x
#define PMD_W32SERIAL_INTERFACE     // use this for a standard serial interface under Win9x/NT/2000/XP
#define PMD_DRIVER_INTERFACE        // use this for a standard parallel interface under Win9x/NT/2000/XP
#define PMD_PCI_INTERFACE           // use this for a standard PCI parallel interface under Win9x/NT/2000/XP
```

By customizing the base interface functions, C-Motion can be ported to virtually any hardware platform. An example would be a memory-mapped IO scheme that uses the parallel interface. This would be built using the PMDPar.c/.h source files as a basis.

The Navigator-PCI board uses the PCI interface chip provided by PLX Technology. To fully understand the interface mechanism, or to write your own interface software you can purchase the PLX SDK. More information on the price and features can be found on the PLX website – http://www.plxtech.com/ in the products, tools, software development kits area.

C-Motion is a set of functions that encapsulate the motion processor command set. Every command has as its first parameter an "axis handle." The axis handle is a structure containing information

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about the interface to the motion processor and the axis number that the handle represents. Before communicating to the motion processor, the axis handle must be initialized using the following sequence of commands:

```
    // the axis handles
PMDAxisHandle hAxis1, hAxis2;
     // open interface to PMD processor and initialize handle to axis one
PMDSetupAxisInterface_PCI( &hAxis1, PMDAxis1, 0 );
    // initialize handle to the second axis
PMDCopyAxisInterface( &hAxis2, &hAxis1, PMDAxis2 );
```

The above is an example of initializing communication using the parallel communication interface. Each interface .c source file contains an example of initializing the interface.

Once the axis handle has been initialized, any of the motion processor commands can be executed. C-Motion.h includes the prototypes for all motion processor commands as implemented in C-Motion. Refer to this file for the required parameters for each command. *The Navigator Motion Processor Programmer's Command Reference* is the primary source for information about the operation and purpose of each command.

As part of a normal startup procedure, the motion processor is often reset. This command only needs to be executed ONCE for each motion processor, and not for every axis. The following code demonstrates a chip reset using C-Motion.

```
PMDuint16 result;
PMDuint16 status;
    // reset the PMD chip that this axis resides on
    // if more than one chip(set) is present, all of them should be
    // reset here
result = PMDReset(handle);
    // in the serial interface mode if an error occured it is returned
    // immediately with no need to call GetHostIOError, so in this
    // code we check for any error before continuing.
    // with the parallel interface the result code will always be
    // PMD_ERR_CommandError since that bit is set whenever a reset
    // occurs.  If it ISN'T set then there is some other error
if ( (result != PMD_ERR_ChipsetReset) && (result != PMD_ERR_CommandError))
{
    printf("Error: %s\n", PMDGetErrorMessage(result));
    return 0;
}

    // after the reset the chip will be in the PMDChipsetReset state
result = PMDGetHostIOError(handle, &status);

    // the above command should execute without error but we need to check
if ( (result != PMD_ERR_OK) || (status != PMD_ERR_ChipsetReset) )
{
    printf("Error: %s\n", PMDGetErrorMessage(result));
    printf("Status: %s\n", PMDGetErrorMessage(status));
    return 0;
}
return 1;
```


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An example of the reset procedure is also included in the PMDutil.c source file. Every motion processor command returns a status code of type PMDuint16. The return code for every command executed should be checked before attempting to execute more commands.

```
PMDuint16 result,status;
result = PMDUpdate(&hXAxis);
if (result != PMD_ERR_OK)
{
    status = result;
    if (result == PMD_ERR_CommandError)
    PMDGetHostIOError( &hXAxis, &status );
    printf("Error: %s\n", PMDGetErrorMessage(status));
    return;
}
```

Internally, C-Motion checks the status of the HostIOError bit after issuing a command. If this bit is set it will return **PMD_ERR_CommandError**. The application should then call **PMDGetHostIOError** to clear the error bit and determine the cause of the error.

Many commands require additional parameters. Some standard values are defined by C-Motion and can be used with the appropriate commands. Refer to PMDtypes.h for a complete list of defined types. An example of calling one of the C-Motion functions with the pre-defined types is shown below.

```
PMDSetBreakpoint(&hXAxis, PMDBreakpoint1, PMDAxis2, PMDBreakpointActionAbruptStop,
PMDBreakpointActualPositionCrossed);
```

The following functions are provided by C-Motion in addition to the standard chip command set:

C-Motion command	Arguments	Function description
PMDuint16 PMDGetStatus	axis_handle	Returns the result of executing an IO status read operation. Only returns a valid result when the interface is parallel.
PMDuint16 PMDHasError	axis_handle	Returns 1 if the error bit is set in the IO status word and returns 0 if it is not set. Only returns a valid result when the interface is parallel.
PMDuint16 PMDIsReady	axis_handle	Returns 1 if the ready bit is set in the IO status word and returns 0 if it is not set. Only returns a valid result when the interface is parallel.
PMDuint16 PMDHasInterrupt	axis_handle	Returns 1 if the interrupt bit is set in the IO status word and returns 0 if it is not set. Only returns a valid result when the interface is parallel.
void PMDCloseAxisInterface	axis_handle	Should be called to terminate an interface connection.
char *PMDGetErrorMessage	errorCode	Returns a character string representation of the corresponding PMD chip or C-Motion error code.
void GetCMotionVersion	MajorVersion MinorVersion	Returns the major and minor version number of C-Motion.

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5.0 Navigator-PCI Electrical Reference

5

In This Section

- User-Settable Components
- Connectors
- Connections Summary - Motor Amplifiers
- Command Summary - ReadIO, WriteIO
- Environmental and Electrical Ratings

5.1 User-Settable Components

The figure below shows the locations of the principal components of the Navigator-PCI cards. The component side of the board is shown, with the PCI slot connector at the bottom. All component locations in this manual refer to this orientation.

The important user-accessable components of the card are:

- Resistor packs RS1, RS2, and RS3 set the encoder termination
- Mode jumper allows the serial communication port mode to be selected

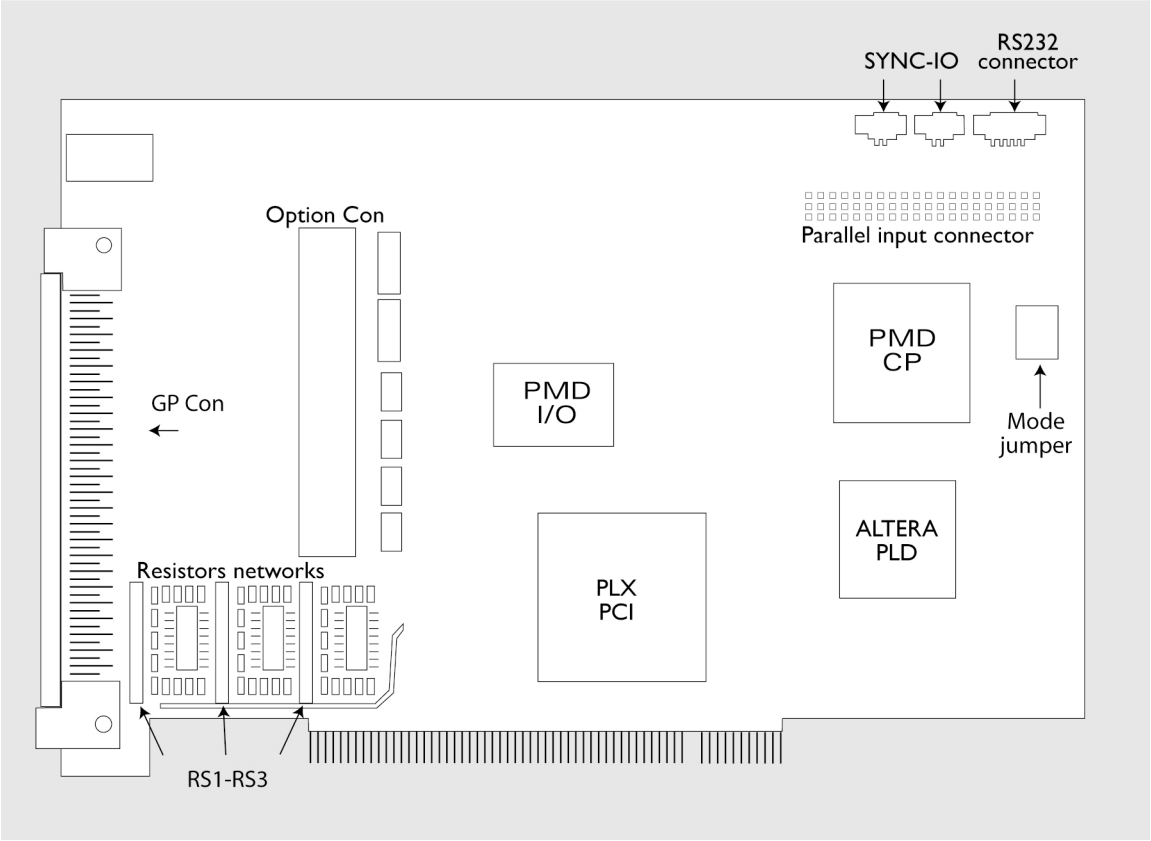


Figure 5-1. Location of various board elements

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5.1.1 Resistor Packs RS1, RS2, RS3

The following table shows the function of the RS1-RS3 resistor packs

Item	What to set	Description
Resistor packs - RS1, RS2, RS3	Remove RS1, RS2, RS3 if you are not using differential encoders *the default condition is resistor packs installed*	Encoder input can be connected differentially, with two wires for A, B, and Index signals, or with just one wire per signal. If you are using differential connections leave these resistor packs installed. Otherwise remove the resistor packs using *figure 5.1* as a guide.

5.1.2 Mode Jumper

The following table shows the function of the mode jumper

Jumper	Jumper location	Description
Mode	1-2	PCI bus is main communications channel, serial port can be used in diagnostic mode. *this is the default setting of mode*
	2-3	PCI bus is disabled, serial port is primary communication channel.

5.2 Connectors

There are three user-accessable connectors on the Navigator-PCI card

- Connector GP Con provides connections to external amplifier and motor elements
- For brushless, microstepping, and mixed motor cards, connector Option Con provides additional connections to external amplifier and motor elements
- Connector Serial I/F allows the card to be controlled via a serial port, or to allow monitoring over a separate serial port to occur

5.2.1 GP Con Connector

The GP Con connector is used to connect to various motion peripherals such as encoders, amplifiers, etc. It is a 100-position high density connector. The following table provides ordering information for those users wishing to develop their own cables to this connector:

Part description	Vendors and part numbers
Straight connector	AMP: 2-175887-9 (Champ)
	3M: 102A0-6212VC (Mini D-ribbon)
Right angle connector	AMP: 2-178238-9 (Champ)
	3M: N102A0-52E2VC
Shielded cable connector	AMP: 1-176793-9 champ (shell) AMP: 2-175677-9 champ (plug)
	3M: 103A0-A200-00 (shell) 3M: 101A0-6000EL (plug)

Depending on what type card is used, various configurations of GP Con pin connections apply.

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5.2.2 GP Con using DC Brush Cards

(part numbers MB902140, MB902120, MB902110)

This table shows connections to the GP Con connector when the card type is DC brush. Unless otherwise noted, 1 indicates axis 1, 2 indicates axis 2, etc.

Pin	Connection	Description	Pin	Connection	Description
1	QuadA1+	Quadrature A+ encoder input (axis 1)	51	QuadA3+	Quadrature A+ encoder input (axis 3)
2	QuadA1-	Quadrature A- encoder input (axis 1)	52	QuadA3-	Quadrature A- encoder input (axis 3)
3	QuadB1+	Quadrature B+ encoder input (axis 1)	53	QuadB3+	Quadrature B+ encoder input (axis 3)
4	QuadB1-	Quadrature B- encoder input (axis 1)	54	QuadB3-	Quadrature B- encoder input (axis 3)
5	Index1+	Index+ input (axis 1)	55	Index3+	Index+ input (axis 3)
6	Index1-	Index- input (axis 1)	56	Index3-	Index- input (axis 3)
7	Vcc	+5V	57	Vcc	+5V
8	GND	Ground	58	GND	Ground
9	PosLim1	Pos. direction limit switch input (axis 1)	59	PosLim3	Pos. direction limit switch input (axis 3)
10	NegLim1	Neg. direction limit switch input (axis 1)	60	NegLim3	Neg. direction limit switch input (axis 3)
11	Home1	Home input (axis 1)	61	Home3	Home input (axis 3)
12	GND	Ground	62	GND	Ground
13	AxisOut1	AxisOut output (axis 1)	63	AxisOut3	AxisOut output (axis 3)
14	PWMMag1A	PWM magnitude output (axis 1)	64	PWMMag3A	PWM magnitude output (axis 3)
15	PWMSign1A	PWM sign output (axis 1)	65	PWMSign3A	PWM sign output (axis 3)
16	AxisIn1	AxisIn input (axis 1)	66	AxisIn3	AxisIn input (axis 3)
17	DAC1A	Analog mtr cmd output (axis 1), ±10V	67	DAC3A	Analog mtr cmd output (axis 3), ±10V
18	AGND	Ground for analog motor command	68	AGND	Ground for analog motor command
19	QuadA2+	Quadrature A+ encoder input (axis 2)	69	QuadA4+	Quadrature A+ encoder input (axis 4)
20	QuadA2-	Quadrature A- encoder input (axis 2)	70	QuadA4-	Quadrature A- encoder input (axis 4)
21	QuadB2+	Quadrature B+ encoder input (axis 2)	71	QuadB4+	Quadrature B+ encoder input (axis 4)
22	QuadB2-	Quadrature B- encoder input (axis 2)	72	QuadB4-	Quadrature B- encoder input (axis 4)
23	Index2+	Index+ input (axis 2)	73	Index4+	Index+ input (axis 4)
24	Index2-	Index- input (axis 2)	74	Index4-	Index- input (axis 4)
25	Vcc	+5V	75	Vcc	+5V
26	GND	Ground	76	GND	Ground
27	PosLim2	Pos. direction limit switch input (axis 2)	77	PosLim4	Pos. direction limit switch input (axis 4)
28	NegLim2	Neg. direction limit switch input (axis 2)	78	NegLim4	Neg. direction limit switch input (axis 4)
29	Home2	Home input (axis 2)	79	Home4	Home input (axis 4)
30	AxisOut2	AxisOut output (axis 2)	80	AxisOut4	AxisOut output (axis 4)
31	PWMMag2A	PWM magnitude output (axis 2)	81	PWMMag4A	PWM magnitude output (axis 4)
32	PWMSign2A	PWM sign output (axis 2)	82	PWMSign4A	PWM sign output (axis 4)
33	AxisIn2	AxisIn input (axis 2)	83	AxisIn4	AxisIn input (axis 4)
34	DAC2A	Analog mtr cmd output (axis 2), ±10V	84	DAC4A	Analog mtr cmd output (axis 4), ±10V
35	AGND	Ground for analog motor command	85	AGND	Ground for analog motor command
36	DigitalIn0	General purpose digital input 0	86	DigitalIn4	General purpose digital input 4
37	DigitalIn1	General purpose digital input 1	87	DigitalIn5	General purpose digital input 5
38	DigitalIn2	General purpose digital input 2	88	DigitalIn6	General purpose digital input 6
39	DigitalIn3	General purpose digital input 3	89	DigitalIn7	General purpose digital input 7
40	AmpEnable1	Amplifier enable signal (axis 1)	90	AmpEnable3	Amplifier enable signal (axis 3)
41	DigitalOut0	General purpose digital output 0	91	DigitalOut4	General purpose digital output 4
42	DigitalOut1	General purpose digital output 1	92	DigitalOut5	General purpose digital output 5
43	DigitalOut2	General purpose digital output 2	93	DigitalOut6	General purpose digital output 6
44	DigitalOut3	General purpose digital output 3	94	DigitalOut7	General purpose digital output 7
45	AmpEnable2	Amplifier enable signal (axis 2)	95	AmpEnable4	Amplifier enable signal (axis 4)
46	Reset	Hardware reset input	96	AnalogGND	Gnd for general purpose analog inputs
47	Analog1	General purpose analog input 1	97	Analog5	General purpose analog input 5
48	Analog2	General purpose analog input 2	98	Analog6	General purpose analog input 6
49	Analog3	General purpose analog input 3	99	Analog7	General purpose analog input 7
50	Analog4	General purpose analog input 4	100	Analog8	General purpose analog input 8

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5.2.3 GP Con using Brushless DC Cards, Microstepping Cards, or Mixed Motor Cards

(part numbers MB902340, MB902320, MB902310, MB902440, MB902420, MB902410, MB902840, MB902820)

The following table shows connections to the GP Con connector when the card type is brushless DC, microstepping, or mixed motor. Unless otherwise noted, 1 indicates axis 1, 2 indicates axis 2, etc. Note that in addition to the GP Con connector detailed below, proper operation of the brushless DC, microstepping, or mixed motors cards also requires connections to the Option Con connector. See *section 5.2.6, page 51,* for a detailed list of Option Con connections.

Pin	Connection	Description	Pin	Connection	Description
1	QuadA1+	Quadrature A+ encoder input (axis 1)	51	QuadA3+	Quadrature A+ encoder input (axis 3)
2	QuadA1-	Quadrature A- encoder input (axis 1)	52	QuadA3-	Quadrature A- encoder input (axis 3)
3	QuadB1+	Quadrature B+ encoder input (axis 1)	53	QuadB3+	Quadrature B+ encoder input (axis 3)
4	QuadB1-	Quadrature B- encoder input (axis 1)	54	QuadB3-	Quadrature B- encoder input (axis 3)
5	Index1+	Index+ input (axis 1)	55	Index3+	Index+ input (axis 3)
6	Index1-	Index- input (axis 1)	56	Index3-	Index- input (axis 3)
7	Vcc	+5V	57	Vcc	+5V
8	GND	Ground	58	GND	Ground
9	PosLim1	Pos. direction limit switch input (axis 1)	59	PosLim3	Pos. direction limit switch input (axis 3)
10	NegLim1	Neg. direction limit switch input (axis 1)	60	NegLim3	Neg. direction limit switch input (axis 3)
11	Home1	Home input (axis 1)	61	Home3	Home input (axis 3)
12	GND	Ground	62	GND	Ground
13	AxisOut1	AxisOut output (axis 1)	63	AxisOut3	AxisOut output (axis 3)
14	n.c.	No connection	64	n.c.	No connection
15	n.c.	No connection	65	n.c.	No connection
16	AxisIn1	AxisIn input (axis 1)	66	AxisIn3	AxisIn input (axis 3)
17	DAC1A	Phase A analog mtr cmd output (axis 1), ±10V	67	DAC3A	Phase A analog mtr cmd output (axis 3), ±10V
18	AGND	Ground for analog motor command	68	AGND	Ground for analog motor command
19	QuadA2+	Quadrature A+ encoder input (axis 2)	69	QuadA4+	Quadrature A+ encoder input (axis 4)
20	QuadA2-	Quadrature A- encoder input (axis 2)	70	QuadA4-	Quadrature A- encoder input (axis 4)
21	QuadB2+	Quadrature B+ encoder input (axis 2)	71	QuadB4+	Quadrature B+ encoder input (axis 4)
22	QuadB2-	Quadrature B- encoder input (axis 2)	72	QuadB4-	Quadrature B- encoder input (axis 4)
23	Index2+	Index+ input (axis 2)	73	Index4+	Index+ input (axis 4)
24	Index2-	Index- input (axis 2)	74	Index4-	Index- input (axis 4)
25	Vcc	+5V	75	Vcc	+5V
26	GND	Ground	76	GND	Ground
27	PosLim2	Pos. direction limit switch input (axis 2)	77	PosLim4	Pos. direction limit switch input (axis 4)
28	NegLim2	Neg. direction limit switch input (axis 2)	78	NegLim4	Neg. direction limit switch input (axis 4)
29	Home2	Home input (axis 2)	79	Home4	Home input (axis 4)
30	AxisOut2	AxisOut output (axis 2)	80	AxisOut4	AxisOut output (axis 4)
31	n.c.	No connection	81	n.c.	No connection
32	n.c.	No connection	82	n.c.	No connection
33	AxisIn2	AxisIn input (axis 2)	83	AxisIn4	AxisIn input (axis 4)
34	DAC2A	Phase A analog mtr cmd output (axis 2), ±10V	84	DAC4A	Phase A analog mtr cmd output (axis 4), ±10V
35	AGND	Ground for analog motor command	85	AGND	Ground for analog motor command
36	DigitalIn0	General purpose digital input 0	86	DigitalIn4	General purpose digital input 4
37	DigitalIn1	General purpose digital input 1	87	DigitalIn5	General purpose digital input 5
38	DigitalIn2	General purpose digital input 2	88	DigitalIn6	General purpose digital input 6
39	DigitalIn3	General purpose digital input 3	89	DigitalIn7	General purpose digital input 7
40	AmpEnable1	Amplifier enable signal (axis 1)	90	AmpEnable3	Amplifier enable signal (axis 3)
41	DigitalOut0	General purpose digital output 0	91	DigitalOut4	General purpose digital output 4
42	DigitalOut1	General purpose digital output 1	92	DigitalOut5	General purpose digital output 5
43	DigitalOut2	General purpose digital output 2	93	DigitalOut6	General purpose digital output 6
44	DigitalOut3	General purpose digital output 3	94	DigitalOut7	General purpose digital output 7
45	AmpEnable2	Amplifier enable signal (axis 2)	95	AmpEnable4	Amplifier enable signal (axis 4)
46	Reset	Hardware reset input	96	AnalogGND	Gnd for general purpose analog inputs
47	Analog1	General purpose analog input 1	97	Analog5	General purpose analog input 5
48	Analog2	General purpose analog input 2	98	Analog6	General purpose analog input 6
49	Analog3	General purpose analog input 3	99	Analog7	General purpose analog input 7
50	Analog4	General purpose analog input 4	100	Analog8	General purpose analog input 8

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5.2.4 GP Con using Pulse & Direction Cards

(part numbers MB902540, MB902520, MB902510)

The following table shows connections to the GP Con connector when the card type is pulse & direction. Unless otherwise noted, 1 indicates axis 1, 2 indicates axis 2, etc.

Pin	Connection	Description	Pin	Connection	Description
1	QuadA1+	Quadrature A+ encoder input (axis 1)	51	QuadA3+	Quadrature A+ encoder input (axis 3)
2	QuadA1-	Quadrature A- encoder input (axis 1)	52	QuadA3-	Quadrature A- encoder input (axis 3)
3	QuadB1+	Quadrature B+ encoder input (axis 1)	53	QuadB3+	Quadrature B+ encoder input (axis 3)
4	QuadB1-	Quadrature B- encoder input (axis 1)	54	QuadB3-	Quadrature B- encoder input (axis 3)
5	Index1+	Index+ input (axis 1)	55	Index3+	Index+ input (axis 3)
6	Index1-	Index- input (axis 1)	56	Index3-	Index- input (axis 3)
7	Vcc	+5V	57	Vcc	+5V
8	GND	Ground	58	GND	Ground
9	PosLim1	Pos. direction limit switch input (axis 1)	59	PosLim3	Pos. direction limit switch input (axis 3)
10	NegLim1	Neg. direction limit switch input (axis 1)	60	NegLim3	Neg. direction limit switch input (axis 3)
11	Home1	Home input (axis 1)	61	Home3	Home input (axis 3)
12	GND	Ground	62	GND	Ground
13	AxisOut1	AxisOut output (axis 1)	63	AxisOut3	AxisOut output (axis 3)
14	Pulse1	Pulse output (axis 1)	64	Pulse3	Pulse output (axis 3)
15	Direction1	Direction output (axis 1)	65	Direction3	Direction output (axis 4)
16	AxisIn1	AxisIn input (axis 1)	66	AxisIn3	AxisIn input (axis 3)
17	AtRest1	Atrest indicator output (axis 1)	67	AtRest3	Atrest indicator output (axis 1)
18	GND	Ground	68	GND	Ground
19	QuadA2+	Quadrature A+ encoder input (axis 2)	69	QuadA4+	Quadrature A+ encoder input (axis 4)
20	QuadA2-	Quadrature A- encoder input (axis 2)	70	QuadA4-	Quadrature A- encoder input (axis 4)
21	QuadB2+	Quadrature B+ encoder input (axis 2)	71	QuadB4+	Quadrature B+ encoder input (axis 4)
22	QuadB2-	Quadrature B- encoder input (axis 2)	72	QuadB4-	Quadrature B- encoder input (axis 4)
23	Index2+	Index+ input (axis 2)	73	Index4+	Index+ input (axis 4)
24	Index2-	Index- input (axis 2)	74	Index4-	Index- input (axis 4)
25	Vcc	+5V	75	Vcc	+5V
26	GND	Ground	76	GND	Ground
27	PosLim2	Pos. direction limit switch input (axis 2)	77	PosLim4	Pos. direction limit switch input (axis 4)
28	NegLim2	Neg. direction limit switch input (axis 2)	78	NegLim4	Neg. direction limit switch input (axis 4)
29	Home2	Home input (axis 2)	79	Home4	Home input (axis 4)
30	AxisOut2	AxisOut output (axis 2)	80	AxisOut4	AxisOut output (axis 4)
31	Pulse2	Pulse output (axis 1)	81	Pulse4	Pulse output (axis 4)
32	Direction2	Direction output (axis 1)	82	Direction4	Direction output (axis 4)
33	AxisIn2	AxisIn input (axis 2)	83	AxisIn4	AxisIn input (axis 4)
34	AtRest2	Atrest indicator output (axis 1)	67	AtRest4	Atrest indicator output (axis 1)
35	GND	Ground	85	GND	Ground
36	DigitalIn0	General purpose digital input 0	86	DigitalIn4	General purpose digital input 4
37	DigitalIn1	General purpose digital input 1	87	DigitalIn5	General purpose digital input 5
38	DigitalIn2	General purpose digital input 2	88	DigitalIn6	General purpose digital input 6
39	DigitalIn3	General purpose digital input 3	89	DigitalIn7	General purpose digital input 7
40	AmpEnable1	Amplifier enable signal (axis 1)	90	AmpEnable3	Amplifier enable signal (axis 3)
41	DigitalOut0	General purpose digital output 0	91	DigitalOut4	General purpose digital output 4
42	DigitalOut1	General purpose digital output 1	92	DigitalOut5	General purpose digital output 5
43	DigitalOut2	General purpose digital output 2	93	DigitalOut6	General purpose digital output 6
44	DigitalOut3	General purpose digital output 3	94	DigitalOut7	General purpose digital output 7
45	AmpEnable2	Amplifer enable signal (axis 2)	95	AmpEnable4	Amplifer enable signal (axis 4)
46	Reset	Hardware reset input	96	AnalogGND	Gnd for general purpose analog inputs
47	Analog1	General purpose analog input 1	97	Analog5	General purpose analog input 5
48	Analog2	General purpose analog input 2	98	Analog6	General purpose analog input 6
49	Analog3	General purpose analog input 3	99	Analog7	General purpose analog input 7
50	Analog4	General purpose analog input 4	100	Analog8	General purpose analog input 8

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5.2.5 Option Con Connector

When either the brushless DC, microstepping, or mixed motor cards are used, the Option Con connector provides additional signals for multi-phase motor output and input of signals such as Hall sensors.

The Option Con connector is a 68-pin SCSI-style connector. The following table provides ordering information for those users wishing to develop their own cables to this connector:

Part description	Vendors and part numbers
For flat ribbon	Harting: 60 06 068 5440 (for AWG 30, 0.635mm flat ribbon)
Plug	Harting: 60 03 068 52 (for solder connections)
Shell	Harting: 60 03 068 0155

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5.2.6 Option Con using Brushless DC, Microstepping or Mixed Motor Cards

(part numbers MB902340, MB902320, MB902310, MB902440, MB902420, MB902410, MB902840, MB902820)

The following table shows connections to the Option Con connector when the card type is brushless DC, microstepping, or mixed motor. Unless otherwise noted, 1 indicates axis 1, 2 indicates axis 2, etc., and A indicates phase A, B indicates phase C, etc.

Pin	Connection	Description	Pin	Connection	Description
1	PWMMag1A	Phase A PWM magnitude output (axis 1)	35	PWMMag1B	Phase B PWM magnitude output (axis 1)
2	PWMMag1C	Phase C PWM magnitude output (axis 1)	36	GND	Ground
3	PWMSign1B	Phase B PWM sign output (axis 1)	37	GND	Ground
4	PWMMag2A	Phase A PWM magnitude output (axis 2)	38	PWMMag2B	Phase B PWM magnitude output (axis 2)
5	PWMMag2C	Phase C PWM magnitude output (axis 2)	39	GND	Ground
6	PWMSign2B	Phase B PWM sign output (axis 2)	40	GND	Ground
7	PWMMag3A	Phase A PWM magnitude output (axis 3)	41	PWMMag3B	Phase B PWM magnitude output (axis 3)
8	PWMMag3C	Phase C PWM magnitude output (axis 3)	42	GND	Ground
9	PWMSign3B	Phase B PWM sign output (axis 3)	43	GND	Ground
10	PWMMag4A	Phase A PWM magnitude output (axis 4)	44	PWMMag4B	Phase B PWM magnitude output (axis 4)
11	PWMMag4C	Phase C PWM magnitude output (axis 4)	45	GND	Ground
12	PWMSign4B	Phase B PWM sign output (axis 4)	46	GND	Ground
13	Hall1A	Phase A hall sensor input (axis 1)	47	Hall1B	Phase Bhall sensor input (axis 1)
14	Hall1C	Phase Chall sensor input (axis 1)	48	GND	Ground
15	Hall2A	Phase Ahall sensor input (axis 2)	49	Hall2B	Phase Bhall sensor input (axis 1)
16	Hall2C	Phase Chall sensor input (axis 2)	50	GND	Ground
17	Hall3A	Phase A hall sensor input (axis 3)	51	Hall3B	Phase Bhall sensor input (axis 1)
18	Hall3C	Phase Chall sensor input (axis 3)	52	GND	Ground
19	Hall4A	Phase A hall sensor input (axis 4)	53	Hall4B	Phase Bhall sensor input (axis 1)
20	Hall4C	Phase Chall sensor input (axis 4)	54	GND	Ground
21	n.c.	No connection	55	n.c	No connection
22	n.c	No connection	56	n.c	No connection
23	n.c	No connection	57	n.c	No connection
24	n.c	No connection	58	n.c	No connection
25	n.c	No connection	59	n.c	No connection
26	n.c	No connection	60	n.c	No connection
27	n.c	No connection	61	n.c	No connection
28	n.c	No connection	62	n.c	No connection
29	VCC	+5V	63	VCC	+5V
30	GND	Ground	64	GND	Ground
31	DAC1B	Phase B analog mtr cmd output (axis 1), ±10V	65	AGND	Ground for analog motor command
32	DAC2B	Phase B analog mtr cmd output (axis 2), ±10V	66	AGND	Ground for analog motor command
33	DAC3B	Phase B analog mtr cmd output (axis 3), ±10V	67	AGND	Ground for analog motor command
34	DAC4B	Phase B analog mtr cmd output (axis 4), ±10V	68	AGND	Ground for analog motor command

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5.2.7 Serial I/F Connector

The following connector is used during serial communications. The Serial I/F connector is a 5-position Molex MLX Micro-4-SMD style connector.

Pin	Connection	Description
1	SrlEnable	Serial enable (only used for RS422/485)
2	SrlXmt	Serial transmit output
3	SrlRcv	Serial receive input
4	GND	Ground
5	Vcc	+5V

For more information on communicating to the card by serial port, *see the Navigator Motion Processor User's Guide.*

5.3 Connections Summary - Motor Amplifiers

The Navigator card supports three methods of output to motor amplifiers:

DAC	Analog signals from the on-board D/A converters
PWM sign-magnitude	Pulse-width modulated signals with separate magnitude and sign signals per output phase
PWM 50/50	Pulse-width modulated square-wave signals with a single PWM signal per output phase

In addition, each motor axis may have 1, 2, or 3 output phases associated with it. For DC brush motors, the number of phases is one, while for multi-phase motors such as brushless DC or microstepping motors, the number of phases can be 2 or 3, depending on the output waveform programmed into the Navigator motion processor. For more information, *see the Navigator Motion Processor User's Guide.*

The following tables provide convenient summaries of amplifier connections for various configurations of motor output method and motor type. These outputs should be connected from the designated connector pins to the appropriate amplifier inputs. Note that the names of the pins may vary among amplifiers. Common names are shown.

5.3.1 DC Brush Motor Connections

			Connection			
Motor output method	**Navigator-PCI connection name**	**Amplifier input connection name***	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
DAC	DAC1-4A	Ref+ or V+	GP 17	GP 34	GP 67	GP 84
	AGND	Ref- or Gnd	GP 18	GP 35	GP 68	GP 85
PWM sign/magnitude	PWMMag1-4A	PWM magnitude	GP 14	GP 31	GP 64	GP 81
	PWMSign1-4A	PWM direction	GP 15	GP 32	GP 65	GP 82
	GND	Ground	GP 8	GP 26	GP 58	GP 76
PWM 50/50	Unused					

** Names of amplifier connections may vary. Common names are shown.*

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5.3.2 Brushless DC Motor Connections

			Connection			
Motor output method	**Navigator-PCI connection name**	**Amplifier input connection name***	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
DAC	DAC1-4A	Ref1+ or V1+	GP 17	GP 34	GP 67	GP 84
	DAC1-4B	Ref2+ or V2+	option 31	option 32	option 33	option 34
	AGND	Ref- or Gnd	GP 18	GP 35	option 65	option 66
PWM sign/magnitude	Unused					
PWM 50/50	PWMMag1-4A	PWM phase 1	option 1	option 4	option 7	option 10
	PWMMag1-4B	PWM phase 2	option 35	option 38	option 41	option 44
	PWMMag1-4C	PWM phase 3	option 2	option 5	option 8	option 11
	GND	Ground	option 36	option 37	option 39	option 40

** Names of amplifier connections may vary. Common names are shown.*

5.3.3 Microstepping Motor Connections

			Connection			
Motor output method	**Navigator-PCI connection name**	**Amplifier input connection name***	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
DAC	DAC1-4A	Ref1+ or V1+	GP 17	GP 34	GP 67	GP 84
	DAC1-4B	Ref2+ or V2+	option 31	option 32	option 33	option 34
	AGND	Ref- or Gnd	GP 18	GP 35	option 65	option 66
PWM sign/magnitude	PWMMag1-4A	PWM magnitude	option 1	option 4	option 7	option 10
	PWMSign1-4A	PWM direction	GP 14	GP 31	GP 64	GP 81
	PWMMag1-4B	PWM magnitude	option 35	option 38	option 41	option 44
	PWMSign1-4B	PWM direction	option 3	option 6	option 9	option 12
	GND	Ground	GP 8	GP 26	option 65	option 66
PWM 50/50	Unused					

** Names of amplifier connections may vary. Common names are shown.*

5.3.4 Pulse & Direction Motor Connections

			Connection			
Motor output method	**Navigator-PCI connection name**	**Amplifier input connection name***	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
Pulse & direction	Pulse1-4	Pulse or step	GP 14	GP 31	GP 64	GP 81
	Direction1-4	Direction	GP 15	GP 32	GP 65	GP 82
	GND	Ground	GP 8	GP 26	GP 58	GP 76

** Names of amplifier connections may vary. Common names are shown.*

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5.4 Command Summary - ReadIO, WriteIO

Card-specific features are accessed through the Navigator's general-purpose I/O addressing scheme. These card-specific functions can be accessed using the **ReadIO** and **WriteIO** commands, or through convenient 'packaged' board-specific C-Motion commands *(see section 4, Developing Your Own Applications with C-Motion, page 41,* for more information*)*.

The following table shows the overall address map for the ReadIO and WriteIO functions supported by the Navigator-PCI cards.

I/O space address offset	Register	Description
+0	Digital I/O	Register which allows 8 general purpose digital input and output signals to be read from and written to.
+1	Amplifier & DAC enable	Register which allows AmpEnable1-4 output signals (which can also be used as a general purpose outputs to be written to and verified, and which allows DAC enable output function to be written to and verified).
+2	Reset monitor	Register which allows reset monitor to be checked and reset.
+3	Unused	
+4	Watchdog	Register which allows watchdog function be activated and updated.
+0xff	Card ID	Register which allows Card ID word to be read.

5.4.1 General Purpose Digital I/O Control Register (I/O Space Address +0)

The following table details the +0 address digital I/O control register

I/O address	Bit location	Signals
+0	0-7	Digital input signals
	8-15	Digital output signals

5.4.2 Amplifier & DAC Enable Control Register (I/O Space Address +1)

The following table details the +1 address amplifier & DAC enable register

I/O address	Bit location	Signals
+1	0-3	Amplifier enable outputs (0-3)
	4-6	Unused
	7	DAC enable status (1 = enabled, 0 = disabled)
	8-11	Change mask for bits 0-3 - amplifier enable outputs (1 = change, 0 = don't change)
	12-14	Unused
	15	Change mask for DAC enable (1 = change, 0 = don't change)

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5.4.3 Reset Monitor Control Register (I/O Space Address +2)

The following table details the +2 address reset monitor register

I/O address	Bit location	Signals
+2	0-11	Reserved
	12	Software command: a 1 value in this bit indicates reset caused by a software command by the user.
	13	Under voltage detection: a 1 value in this bit indicates reset caused by under voltage detection.
	14	External signal: a 1 value in this bit indicates reset caused by external signal. Such a reset originates from the GP Con connector on the connector 'Reset'. When this signal is brought low, a reset condition occurs.
	15	Watch dog timeout: a 1 value in this bit indicates reset caused by watch dog timeout.

5.4.4 Card ID register (I/O Space Address +0xff)

The following table details the +0xff address card ID register

Address	Bit location	Signals
+0xff	0-3	Major PLD revision: binary coded 4-bit word encoding the major PLD revision. This value can range from 0 to 15.
	4-7	Minor PLD revision: binary-coded 4-bit word encoding the minor PLD revision. This value can range from 0 to 15.
	8-11	Board revision: binary-coded 4-bit word encoding the board revision. This value can range from 0 to 15.
	12-15	Board type: binary-coded 4-bit word encoding the board type. This value can have one of the following values: 0 - Navigator-ISA family card 1 - Navigator-PCI family card 2 - Unused 3 - Navigator-PC/104 family card 4-15 - Unused

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5.5 Command Summary - Card-Specific Functions

The following tables provide convenient summaries for card-specific C-Motion commands. The much larger list of Navigator motion processor commands is detailed in *Navigator Motion Processor Programmer's Command Reference*.

C-Motion command	Arguments	Function description
PMDMBWriteDigitalOutput	axis handle, write_value	This function writes to the 8 general-purpose digital I/O signals (digitalOut0-7). Write_value holds the 8 signals in its low order 8 bits.
PMDMBReadDigitalInput	axis_handle, read_value	This function reads the value of the signals DigitalIn0-7 and returns them in the low order 8 bits of read_value
PMDMBReadDigitalOutput	axis_handle, read_value	This function reads the value of the signals DigitalOut0-7 and returns them in the low order 8 bits of read_value
PMDMBSetAmplifierEnable	axis handle, mask, write_value	This function writes to the 4 amplifier enable signals (AmpEnable1-4) using mask and write_value. When a 1 appears in mask, the corresponding bit position in write_value is written to the corresponding signal. The values for mask and write_value are all 0-shifted, that is they are stored in the lowest order 4 bits.
PMDMBGetAmplifierEnable	axis_handle, read_value	This function reads the value of the AmpEnable1-4 and returns them in the low order 4 bits of read_value
PMDMBSetDACOutputEnable	axis handle, write_value	This function sets the DACOutputEnable status. A 1 value written enables DAC output, while a 0 disables it.
PMDMBGetDACOutputEnable	axis_handle, read_value	This function reads the value of the DACOutputEnable function. A 1indicates enabled, a 0 indicates not enabled.
PMDMBSetWatchDog	axis handle, mask	This function writes to the correct value to the watchdog register, so that for the next 104 milliseconds the card will not be reset by the watchdog circuitry.
PMDHardReset	axis_handle	This function causes a 'hard' reset of the motion processor. Unlike all other card-specific commands, this command is processed directly through the PCI card interface
PMDMBGetResetCause	axis handle, reset_cause	This function returns the reset cause in the variable reset_cause, and also clears the reset condition.
PMDMBReadCardID	axis handle, card_ID	This function returns the card ID, encoded as defined in the table above.

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5.6 Environmental and Electrical Ratings

Dimensions:	175 mm x 112 mm (6.89" x 4.41")
Storage temperature:	-40 to +125 degrees C
Operating temperature:	0 to +70 degrees C (standard commercial version)
Power requirement:	4.8 V to 5.25 V operating range, 1 Amp no load current: 0.6 A (no outputs on)
Supply voltage limits:	-0.3 V to +7 V
Analog output range:	-10.0 .0 V to +10.0 V, ±5 mA/axis, ±20 mA max./axis
Analog input range:	0 - 4.096 V
Digital outputs drive capacity:	DC output source or sink current: +/- 50 mA
Under voltage detection:	The under voltage supervisory device used is a MCP120T-475I. Under voltage specs are Min: 4.50 V, Max: 4.75 V, Typical: 4.625 V.

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