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PREFACE

pcControl - 4 Axis Servo Motor Control Board

pcControl is a 4 Axis Servo Motor Control board providing high-performance motion control for ISA Bus based IBM® compatible computer systems. It provides fully programmable motion control for four independent axes utilizing quadrature encoders for position and velocity feedback. The pcControl board has powerful indexer and controller functionality including programmable limit switch and home switch inputs as well as programmable I/O bits for additional system configuration and control.

This pcControl User Manual describes the programming, electrical and mechanical aspects of the pcControl board. It includes examples of setup and control routines to aid in the implementation of systems designed using this product.

The information contained in this User Manual is believed to be correct and complete. However, no responsibility is assumed for potential inaccuracies or omitted information.

READ THIS BEFORE INSTALLING OR POWERING THE pcControl™ BOARD.

Caution: Special care should be taken in system wide power cycling of motion control hardware and subsystems. Never power up the drives or motors until the pcControl board and its host computer have been fully powered up and initialized in a known stable state. Failure to properly sequence component power may result in unpredictable motor motion. During system power down, the same care should be taken to properly remove power from the drives and motors prior to shutting down the pcControl board and its host computer. Unpredictable motor motion may occur if proper power down sequencing is not followed.

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1.0 INTRODUCTION TO pcControl.

1.1 Overview.

pcControl provides complete 4 Axis Servo Motor control with powerful, intelligent functions for all ISA Bus based motion control applications. Drive output is available in two standard formats: +/-10 volt analog, or Pulse Width Modulated (PWM) output with an independent direction line. Quadrature encoder inputs provide position feedback information for accurate closed loop control and limit switch /home switch inputs allow for enhanced application specific position control.

pcControl is fully programmable for velocity, acceleration and position control in both continuous and point to point motion algorithms. Closed loop servo performance is implemented via a time sampled digital filter control loop. Dynamic loop tuning can be utilized to optimize system performance for varying motor and load conditions.

Programming the pcControl board is very straightforward using a simple but powerful high level command set. All setup and motion control functions are easily executed through register level communications or may be implemented using device driver level commands, callable from assembly language, C, or other high level languages. Full command set implementations are available for LabVIEW®, LabWindows®, Visual Basic® and other industry standard software programs.

pcControl offers the advanced feature of event based motion profiling. By preloading motion control commands into special command buffers on the pcControl board, a sequence of stored motion parameters can be set up for later or repetitive execution by a trigger event. Triggers can be external I/O events or manual trigger commands sent by the user. This mode is very powerful for motion sequences coordinated by external events recognized by the board's flexible digital I/O port.

1.2 Functional Modes.

Trapezoidal Profile Position Control

Trapezoidal profile control provides point to point motion based on the difference between the current position and the target position, utilizing preprogrammed acceleration and velocity values. The trapezoidal motion profile is calculated based on the move duration, maximum velocity, and desired acceleration. Motion occurs first with a programmable acceleration, then for a period at a constant velocity, and finally with a programmable deceleration to the desired target position. Motion may be interrupted via a limit or home switch input or the execution of a stop or kill command.

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Velocity Control

Velocity control provides continuous motion at a preprogrammed velocity until a limit or home switch is encountered or until a stop or kill command is executed.

Velocity Profiling

Velocity profiling provides for preprogrammed acceleration to a desired velocity which is maintained until a new velocity value is loaded. New velocity values may be loaded at any time. The system will execute the most recent commands and attain the new programmed values. Motion is continuous until a limit or home switch is encountered or until a stop or kill command is executed. This mode is used for circular interpolation and continuous contouring applications.

Event Based Motion Profiling

pcControl offers the advanced feature of event based motion profiling. By preloading motion control commands into special trigger buffers, single or multiple move sequences can be set up for later execution by trigger events. Triggers can be external I/O events or manual trigger commands sent by the host computer. This mode can be used for semi-autonomous operation or for precise coordination with external events recognized by the pcControl's flexible digital I/O port.

1.3 Trajectory Parameters.

Motion control utilizing the pcControl board requires parameter loading in conjunction with command level programming of the motion trajectory. All motion control parameters used by the pcControl board are expressed in terms of quadrature counts.

Closed loop position and velocity control is obtained by the use of an incremental encoder. All position data is referred to in quadrature counts. Quadrature counts are determined by multiplying the number of encoder lines per index period times four. The encoder resolution is the number of encoder lines between consecutive encoder indexes (marker or Z-Bit) . If the encoder does not have an index output, then the resolution would be referred to as lines per revolution.

Position Value Loading:

Position values are loaded in quadrature counts as a signed 32 bit hexadecimal number.

Position (in quadrature counts) = (4)*(Desired Position In Encoder Lines)

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Velocity Value Loading:

Velocity values are determined and loaded as COUNTS PER SAMPLE PERIOD. The calculation of velocity to be loaded requires that the base filter sample period used by the digital filter loop also be used in the determination of loaded velocity values. The following formula may be used to calculate velocity values to be loaded. Please note, the formula shown includes a scale factor of 65,536. This scale factor is utilized to convert fractional decimal values for hexadecimal value loading. The resulting velocity to be loaded is converted into a 32 bit hexadecimal number, where, the upper 16 bits are the integer portion and the lower 16 bits are the fractional portion.

Velocity (loaded) = (Encoder Lines)*(4)*(341E-6)*(Velocity in RPM)*(1/60)*(65,536)

Continued on next page...

For Example:

If the desired Velocity in RPM = 250 RPM

and the Encoder Resolution = 500 Lines Per Revolution

and the Base Sample Period = 341 E -6

Then, the Velocity value to be loaded into the pcControl board would be:

Velocity (loaded) = (500)*(4)*(341 E -6)*(250)*(1/60)*(65,536)

Velocity (loaded) = (2000)*(341 E -6)*(273066.67)

Velocity (loaded) = 186,231 scaled counts per sample period (rounded)

The actual value transferred to the pcControl board must be a 32 bit hexadecimal number, therefore the loaded Velocity value would be:

Velocity (loaded in hex) = 0x0002 D777 (186,231 converted into hex.)

This value corresponds to 250 RPM for a system having an encoder resolution of 500 lines.

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Acceleration Value Loading:

Acceleration values are loaded for motion trajectory as scaled COUNTS PER SAMPLE PERIOD PER SAMPLE PERIOD. The calculation of acceleration to be loaded requires that the digital filter loop base sample period be used. The following formula is used to calculate acceleration values to be loaded. Please note, the formula shown includes a scale factor of 65,536. This scale factor is utilized to convert fractional decimal values for 32 bit hexadecimal value loading.

Acceleration = (Encoder Lines) * (4) * (341E-6) * (341E-6) * (Acceleration in RPSPS) (65,536)

(RPSPS = Revolutions / Second / Second)

Acceleration (loaded) = (500)*(4)*(341 E -6)*(341 E -6)*(1.5 RPS/S)*(65,536)

Acceleration (loaded) = (2000)*(1.163 E -7)*(1.5 RPS/S)*(65,536)

Acceleration (loaded) = 23 scaled counts per sample per sample (rounded)

Continued on next page...

The actual value transferred to the pcControl board must be a hexadecimal number, therefore the loaded Acceleration value would be:

Acceleration (loaded in hex) = 0x0000 0017 (23 converted into hex.)

This value corresponds to 1.5 RPS/S for a system having an encoder resolution of 500 lines.

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2.0 SETTING UP & INSTALLING THE pcControl BOARD.

2.1 External Connector Type.

The external connector used on the pcControl board is a 50 Pin Male Right Angle Box Header connector (AMPHENOL #821-A050P-AFD00.) This is a very common connector type.

Any compatible female mating connector may be used. Mating connector types include insulation displacement ribbon cable connectors and discrete wire 50 pin female mating connectors. The box header connector includes polarity guides to help prevent improper connector placement.

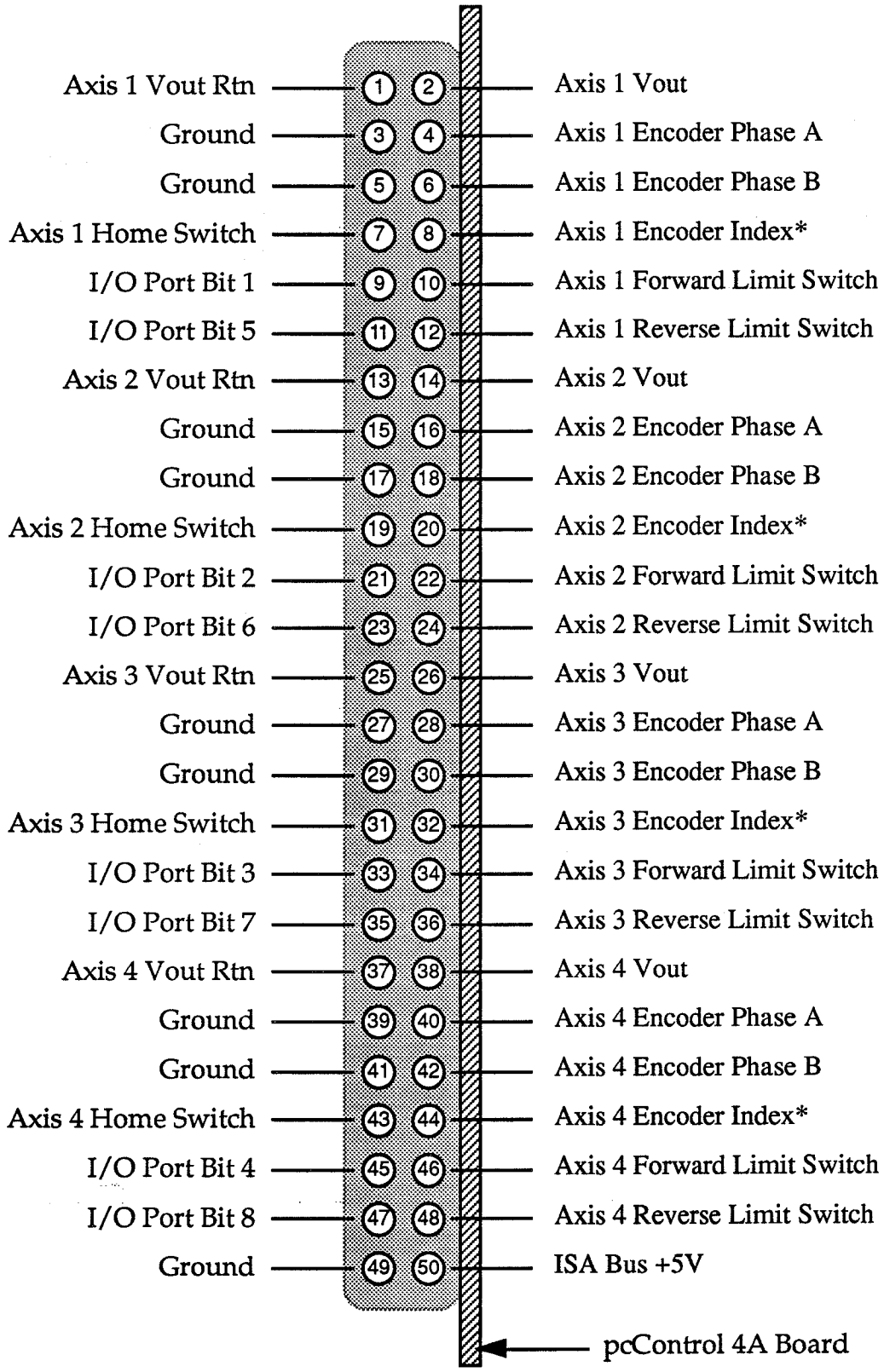
2.2 External Connector Pinout.

The external connector pinout diagram is shown in Figure 1 viewed from the rear panel of the host computer. The computer is oriented horizontally.

Please turn to the next page for the External Connector Pinout Diagram (Figure 1)...

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REAR PANEL VIEW OF THE 50 PIN EXTERNAL CONNECTOR

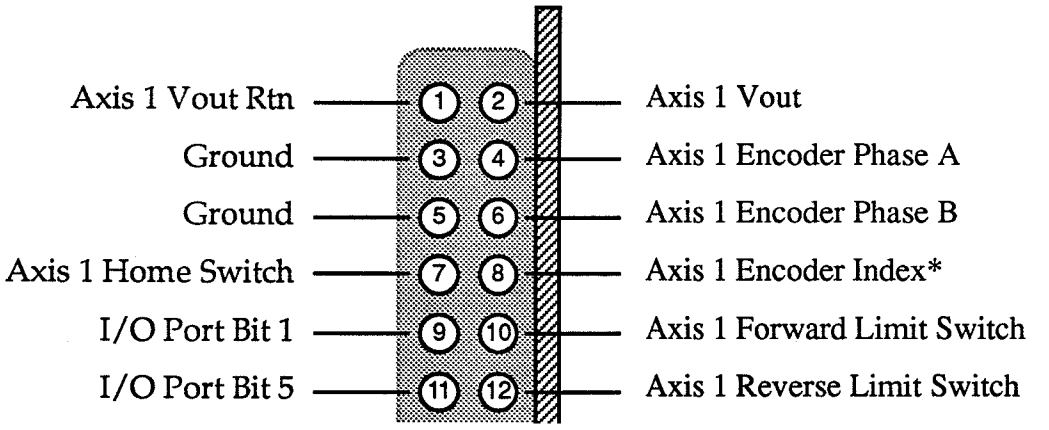
FIGURE #1

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2.3 External Connector Wiring Recommendations.

The external connector may be broken up into five separate sections for the purpose of wiring descriptions. Four of the sections are identical in pinout and format. Each of these four identical sections corresponds to an individual axis controller circuit. The fifth section is the Bus Power Interlock section.



PER AXIS CONNECTOR SECTION VIEW
Axis 1 Example

FIGURE #2

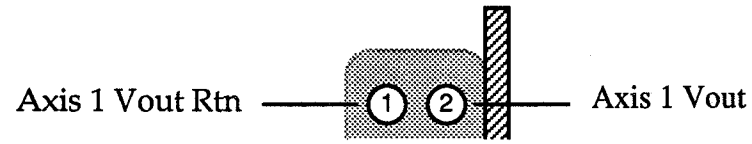
Each per axis connector section is broken down into three subsections:

1) Motor Drive Outputs.
2) Encoder Feedback Inputs.
3) Limit & Home Switch Inputs.
4) Related I/O Port Bits

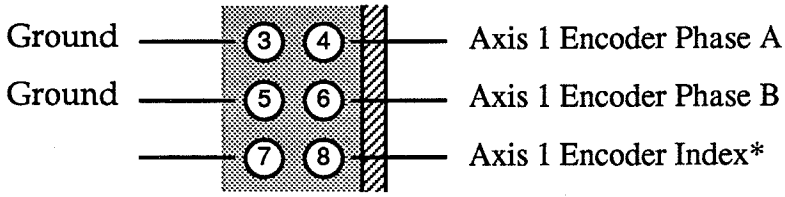
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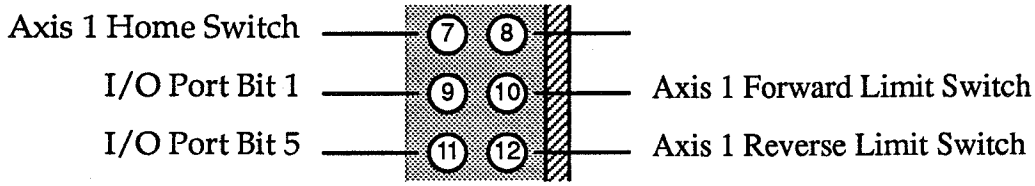
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MOTOR DRIVE OUTPUT SIGNALS
FIGURE #3



ENCODER FEEDBACK INPUT SIGNALS
FIGURE #4



LIMIT, HOME AND I/O PORT SIGNALS
FIGURE #5

These three groups must be wired separately from each other in order to prevent unwanted noise or signal crosstalk from affecting adjacent signal groups. Failure to take these simple precautions may cause faulty operation.

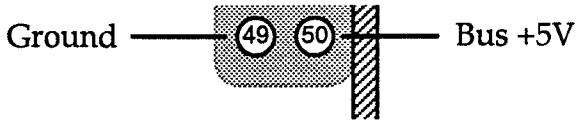
It is important to note that numerous ground connections have been provided in the pcControl backplane connector. Proper use of these ground connections will help to prevent unwanted signal disturbance and noise. These ground connections may be used as ground current return paths or as shield connections for proper signal grounding applications.

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Bus Power Signal

The Bus power +5 V signal has been made available for bus monitoring and interlock purposes. It is not intended to power external circuitry or components. Current draw should not exceed 100 mA maximum.



EXTERNAL CONNECTOR BUS POWER MONITORING SIGNALS

FIGURE #6

2.4 I/O Port Signals.

The following section describes hardware jumper selection and the specifications for I/O Port signal interconnection. Proper motion system setup including I/O port software initialization must be executed using the pcControl commands prior to use of the I/O port for correct operation.

2.4.1 Input Signals.

Input signals to the I/O port may be active high or active low. Proper operation will depend upon correct setup and programming of I/O polarity & direction. Improper setup and programming may cause faulty operation. (See Section #3.7.5, I/O Port Configuration.)

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2.4.2 Output Signals.

I/O Port signals configured as outputs are single ended TTL with internally pulled up open collector drive outputs.

2.4.3 Wiring Concerns.

Warning: Keep I/O Port signals and I/O Port grounds wired separately from the motor drive signals. Wiring these signals near each other may cause faulty operation. Be sure to utilize adequate ground signal connections in conjunction with I/O Port bit signal connections.

2.4.4 Jumper Configuration.

There are two hardware jumper locations available for each I/O Port bit on the pcControl board. One of these connections is for input signal configuration and the other is for output signal configuration. The jumpers must be properly installed and correspond to the direction programmed in order to ensure correct operation of the I/O Port bits.

Warning: Never install both input and output jumpers for the same I/O Port bit locations.

The Jumpers are utilized in conjunction with I/O Port configuration programming to properly setup the I/O Port function.

The following table shows the I/O Port bit assignments and the corresponding hardware jumpers.

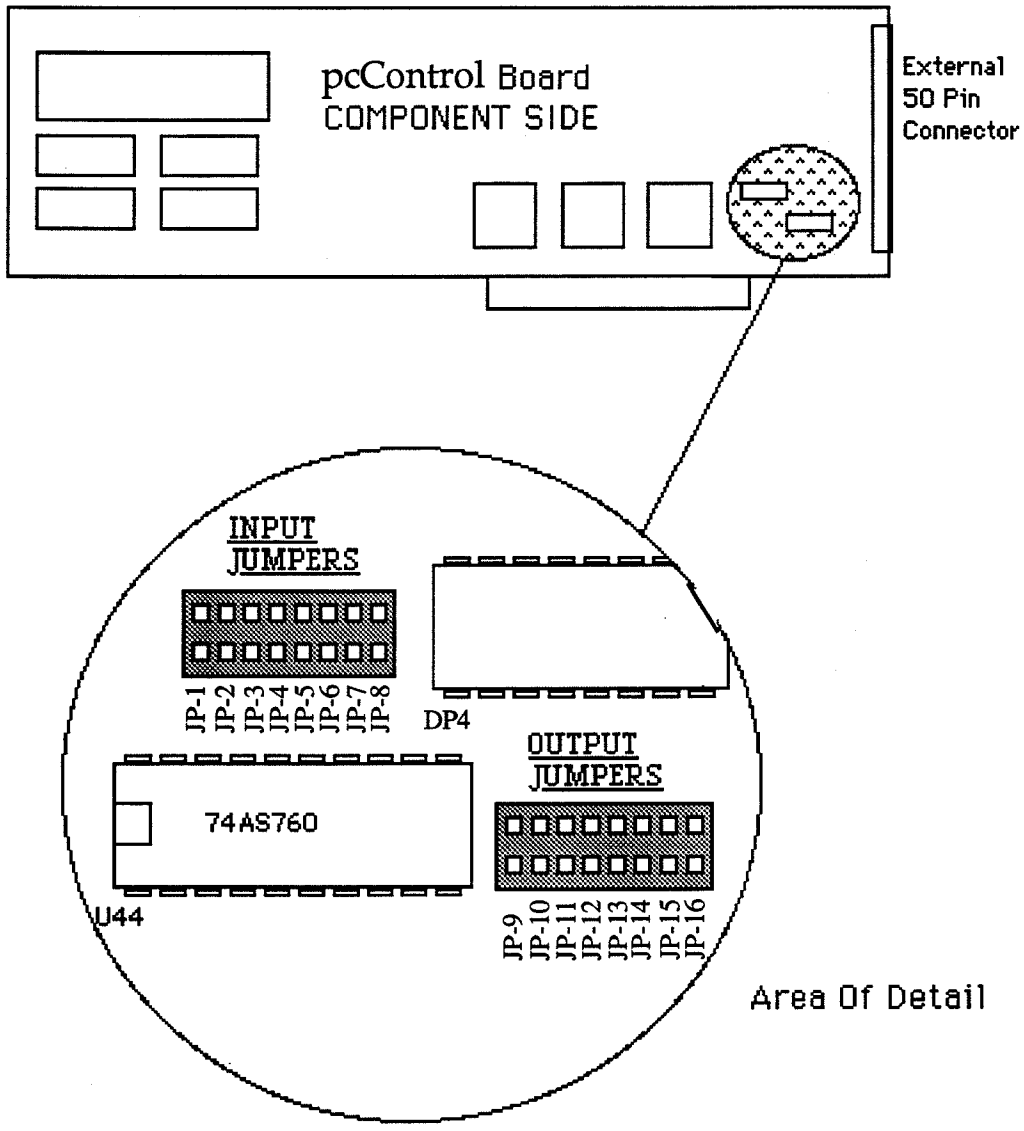
I/O Port Bit #	Input Jumper #	Output Jumper #
1	JP-1	JP-9
2	JP-2	JP-10
3	JP-3	JP-11
4	JP-4	JP-12
5	JP-5	JP-13
6	JP-6	JP-14
7	JP-7	JP-15
8	JP-8	JP-16

JUMPER PIN TO I/O PORT BIT CORRESPONDENCE.
FIGURE #7

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The following diagram shows the I/O Port jumper locations on the pcControl board. Please refer to this diagram when setting the I/O port hardware jumpers. The pcControl board is shipped with eight jumpers, all located on the input pins JP1 - JP8.



JUMPER BLOCK LOCATION FOR THE I/O PORT CONFIGURATION JUMPERS.

FIGURE #8

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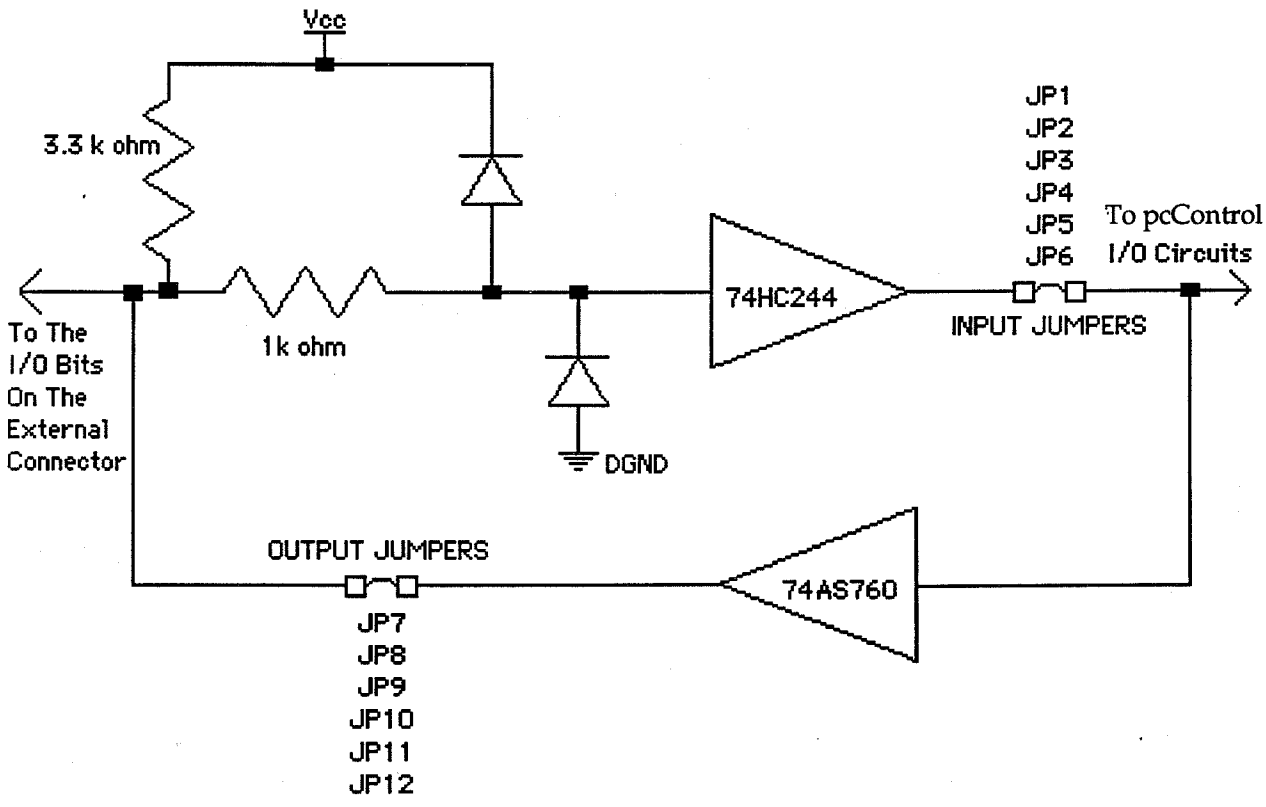
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2.4.5 I/O Port Hardware Circuit.

Figure 9 shows a simplified schematic diagram of the hardware circuitry utilized by the I/O Ports for input signal buffering and output signal drive, as well as the jumper locations.

Protection is provided for input signal over-voltage and misconnection of the I/O Port bits. However, care must be taken when making these and any other hardware wiring connections. The inputs are clamped between 0 - 5 volts through a 1 kOhm, 1/4 Watt resistor. 12 V input signals can be interfaced directly but higher voltages should be avoided. The 3.3 kOhm pull-up resistor facilitates interfacing to open collector signals.

Warning: Excessive input voltages may cause component failure.



I/O PORT INPUT & OUTPUT HARDWARE CIRCUITRY.
(Note: Do Not Connect Both Input & Output Jumpers For The Same I/O Port!)

FIGURE #9

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2.5 Limit and Home Switches.

Limit and Home switch inputs can be active high or active low single ended signals. Input signal polarity may be programmed using the Set Limit Switch Polarity command. Limit and Home switch inputs may be enabled and disabled using the Enable Limits Command.

An active input signal on an enabled limit or home switch input will cause motion to halt stop on the corresponding axis. Limit and Home Switch input signals perform special motion control functions during the Find Home Command. (See the Find Home command in the command description section #4.3)

Note: The pcControl board expects latching limit switch input signals. Active inputs should remain active as the motion proceeds into the limit. Transient or pulse limit signals will cause motion to stop but they will not prevent further motion profiles that are started beyond the limit active position.

Limit switch inputs are a per axis system level enhancement on the pcControl board and are not required for basic motion control. These inputs are provided as part of a system solution for position control. All motion control functions may be operated without limit switches (except the Find Home command).

2.5.1 Wiring Concerns.

Warning: Keep limit and home switch signals and their ground connections wired separately from the motor driver/amplifier signal connections. Wiring these signals near each other may cause faulty operation.

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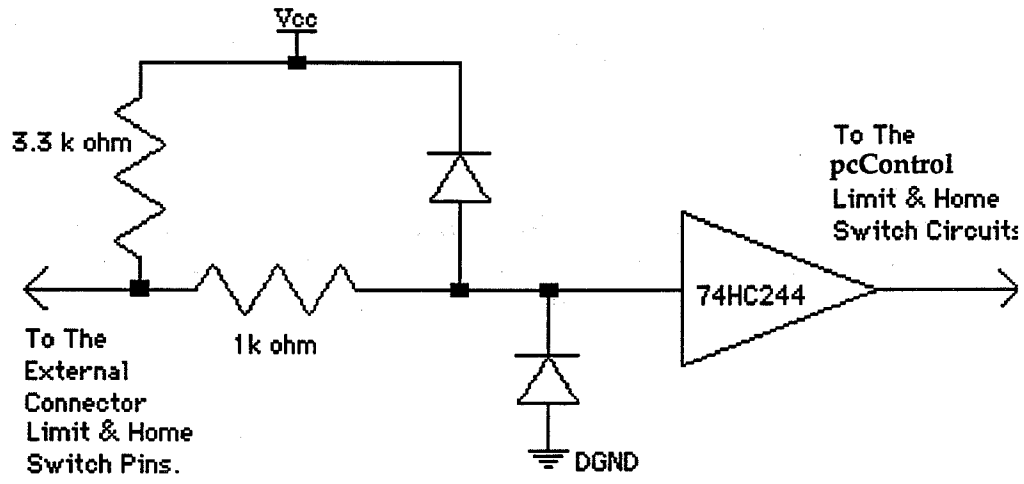
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2.5.2 Limit & Home Switch Input Circuit.

Figure 10 shows a simplified schematic diagram of the hardware circuit used by the Limit and Home Switch inputs for input signal buffering.

Protection is provided for over-voltage inputs and misconnection of the Limit and Home Switch Input signals. However, care must be taken when making these and any other hardware wiring connections. The inputs are clamped between 0 - 5 volts through a 1 kOhm, 1/4 Watt resistor. 12 V input signals can be interfaced directly but higher voltages should be avoided. The 3.3 kOhm pull-up resistor facilitates interfacing to open collector signals.

Warning: Excessive input voltages may cause component failure.



LIMIT SWITCH & HOME SWITCH INPUT HARDWARE CIRCUITRY.

FIGURE #10

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2.6 Encoder Connections

Encoder signal inputs can be active high or active low single ended TTL signals. Special care must be take to observe the phasing of the Phase A and Phase B encoder quadrature signals in order to ensure that the direction of motor motion and encoder feedback signals are correctly related. See Figure 11 below.

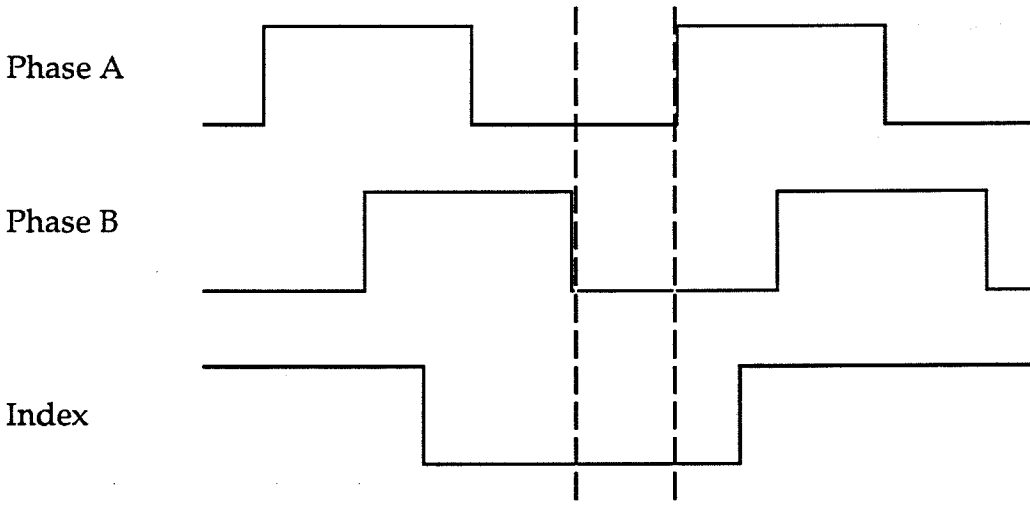
2.6.1 Wiring Concerns.

The encoder inputs are connected to quadrature decoder/counter circuits. Care must be taken to minimize noise at this interface. Excessive noise may overwhelm the digital noise filters resulting in lost or extra counts and erroneous closed loop operation. Verify these connections before powering up the system.

Warning: Keep encoder signals and their ground connections wired separately from the motor driver signal connections. Wiring these signals near each other may cause faulty operation.

2.6.2 Encoder Signals.

The pcControl board expects quadrature encoder input (feedback) signals (90 degrees out of phase from each other). Any deviation from this signal type, or excessive noise on the encoder signals will cause faulty operation and lost quadrature counts.



QUADRATURE ENCODER PHASING DIAGRAM

FIGURE #11

Note: Quadrature counts are determined by multiplying the encoder resolution times four (4). The encoder resolution is the number of encoder lines between consecutive encoder indexes (marker or Z-Bit) . If the encoder does not have an index output, then the resolution would be referred to as lines per revolution, or lines per unit of measure (inches, mm, cm, etc..).

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2.6.3 Encoder Index Pulse Signal.

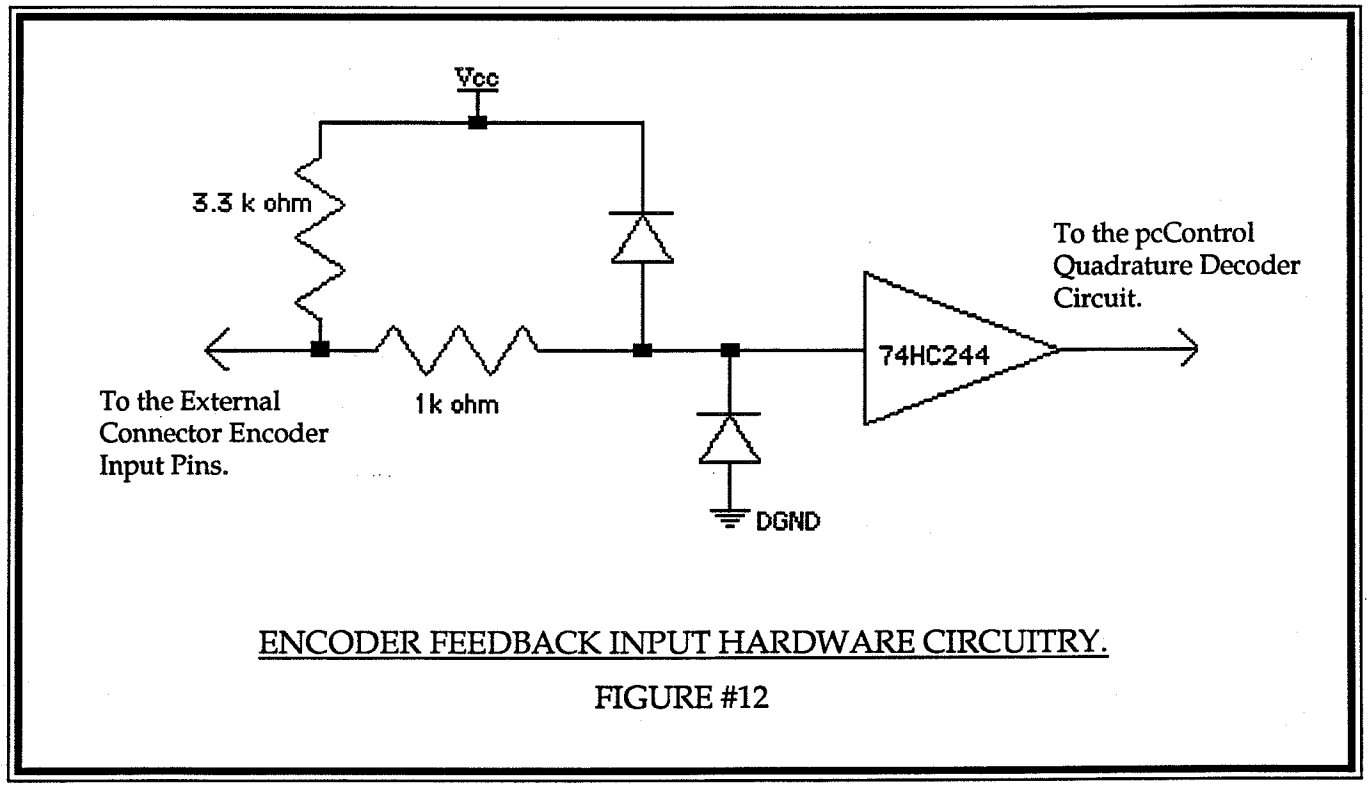
The pcControl board (Closed Loop Version) may be used with an active low index (marker or Z-bit) input. This signal must be single ended, TTL compatible and properly phased with respect to the Phase A and Phase B input signals. (See Figure 11.) The index state is defined when all three signals are low. To avoid redundancy, the Index signal must be less than 360°. Improper index signal connection and configuration may cause faulty operation during the Find Index command. If this command is not functioning properly, check the encoder index signal connection.

2.6.4 Encoder Signal Input Circuit.

Figure 12 shows a simplified schematic diagram of the hardware circuit used by the Encoder Inputs for input signal buffering.

Protection is provided for over-voltage inputs and misconnection of the Encoder Input signals. However, care must be taken when making these and any other hardware wiring connections. The inputs are clamped between 0 - 5 volts through a 1 kOhm, 1/4 Watt resistor. 12 V input signals can be interfaced directly but higher voltages should be avoided. The 3.3 kOhm pull-up resistor facilitates interfacing to open collector signals.

<u>Warning:</u> Excessive input voltages may cause component failure.



ENCODER FEEDBACK INPUT HARDWARE CIRCUITRY.

FIGURE #12

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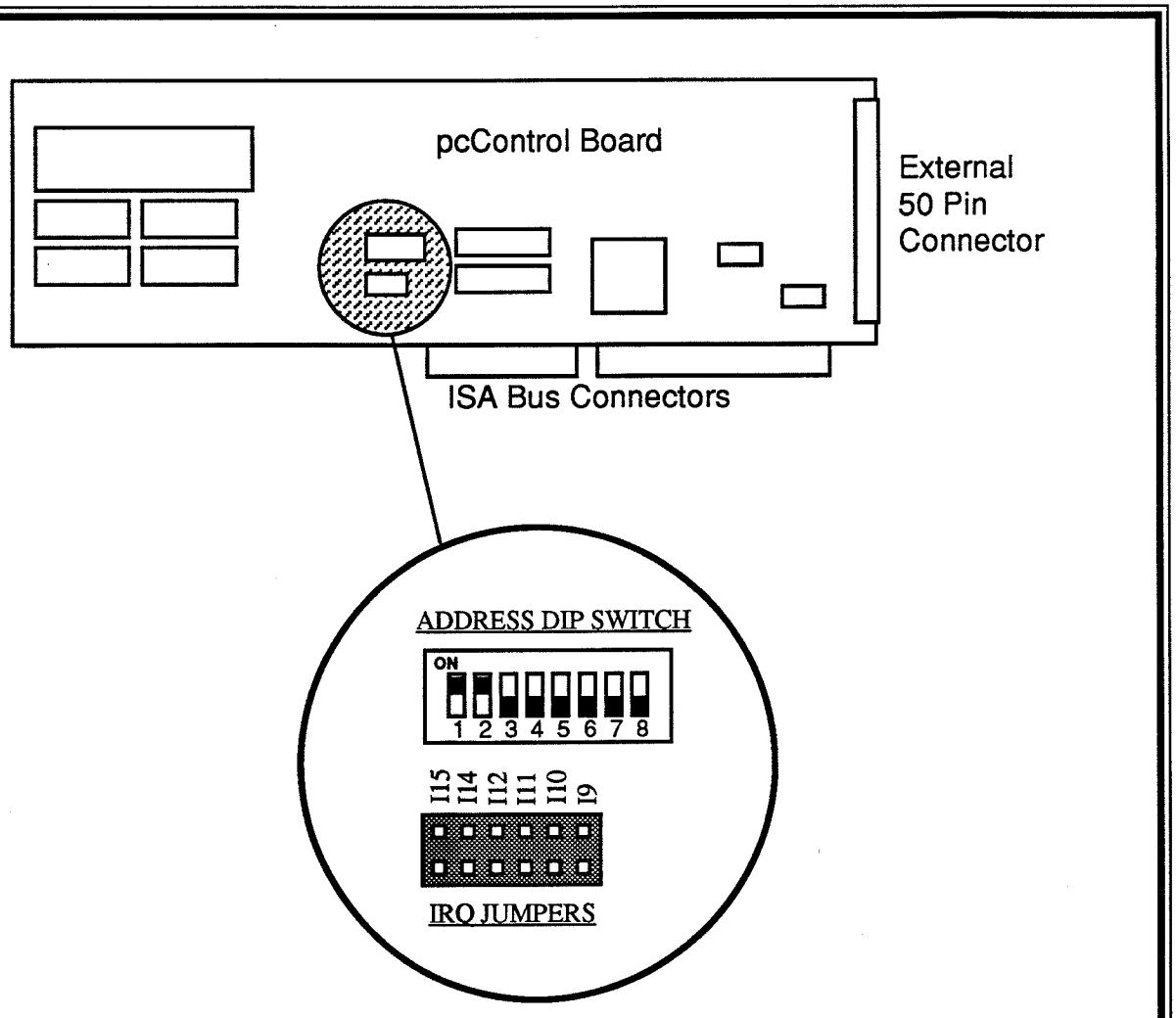
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2.7 Selecting an ISA Bus Address for the pcControl Board.

The pcControl board may occupy any available ISA Bus (16 Bit) slot in the host computer. The bus communications address of the pcControl board is set with the DIP Switch as shown in Figure 13. See Section # 3.1 for more information on selecting an appropriate bus address. Multiple pcControl boards with different addresses may be installed in the host computer.

NOTE: IRQ (Interrupt Request) Jumpers are provided for future expansion and are not presently used on the pcControl. All six jumper locations should be left empty.

Consideration should be given to the power available for expansion boards in the ISA Bus backplane. Check your system power supply capability to determine the per slot power budget and the power required by all of the boards presently installed in the backplane. The power required by each pcControl board is shown in the specifications section. (See Section #5.0)



ADDRESS SELECTOR DIP SWITCH LOCATION

FIGURE #13

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3.0 PROGRAMMING THE pcControl BOARD.

3.1 Board Addressing.

When programming pcControl board, two address locations are utilized within the available Host I/O Address Space. These two address locations are for the Communications Status Register (always available for reading regardless of board function) and for the Command & Data I/O Register.

3.1.1 Command & Data I/O Register

The Command & Data I/O Register is located at the base address set by the Address DIP Switch on the pcControl board. It is a 16 bit read / write address location providing separate internal registers for read and write. These separate internal registers allow read and write operations to be interleaved without crossover data corruption. Both registers utilize the same address location. Commands are written to and return data is read from this address location as word wide (16 bit) values.

3.1.2 Communications Status Register

The Communications Status Register is a 16 bit wide read-only register located at (base address + 6.) The base address is set by the Address Selector DIP Switch on the pcControl board. The Communications Status Register can be read as either a byte or a word from this address. Reading a byte returns all necessary communications handshaking information while reading a word returns additional information on the status of the board.

Prior to any read or write operations to the Command & Data I/O Register, the Communications Status Register must be read and the status bits tested to determine if the Command & Data I/O Register is available for communications or if it is busy. The Communications Status Register contains, in addition to other status bits, Ready To Receive and Return Data Pending status indicator bits which correspond to data reading and writing control for the pcControl - ISA Bus communications interface. These handshaking bits provide complete control for all pcControl read/write communications.

All communications with the pcControl board is accomplished by the use of command and read packet formats. There are specific communication packet format requirements (See the Send Command and Return Data Packet Format sections for more details, Sections #3.4. & #3.5.) Incorrect communications formats will cause command error conditions. Be sure to follow the packet format configuration. (See Status Register Error Bit description in Section #3.2.)

NOTE: A command error condition may be cleared by writing a packet terminator word to the write data register after checking for a valid Ready To Receive Data status bit.

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3.1.3 Address Table.

The following is a list of possible base addresses for pcControl along with the corresponding settings for the Address Selector DIP Switch. All addresses in this table are hexadecimal.

NOTE: Certain addresses that are typically used for host computer functions such as serial and parallel I/O ports and display adaptors are indicated. However, since not all manufacturers follow these standards, please verify that an address is truly not used before setting pcControl to that address.

Base Address	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	Typical Use
200	ON	ON	ON	ON	ON	ON	OFF	OFF	Game I/O
208	OFF	ON	ON	ON	ON	ON	OFF	OFF	
210	ON	OFF	ON	ON	ON	ON	OFF	OFF	
218	OFF	OFF	ON	ON	ON	ON	OFF	OFF	
220	ON	ON	OFF	ON	ON	ON	OFF	OFF	
228	OFF	ON	OFF	ON	ON	ON	OFF	OFF	
230	ON	OFF	OFF	ON	ON	ON	OFF	OFF	
238	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	
240	ON	ON	ON	OFF	ON	ON	OFF	OFF	
248	OFF	ON	ON	OFF	ON	ON	OFF	OFF	
250	ON	OFF	ON	OFF	ON	ON	OFF	OFF	
258	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	
260	ON	ON	OFF	OFF	ON	ON	OFF	OFF	
268	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	
270	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	
278	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	Parallel Port 2
280	ON	ON	ON	ON	OFF	ON	OFF	OFF	
288	OFF	ON	ON	ON	OFF	ON	OFF	OFF	
290	ON	OFF	ON	ON	OFF	ON	OFF	OFF	
298	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	
2A0	ON	ON	OFF	ON	OFF	ON	OFF	OFF	
2A8	OFF	ON	OFF	ON	OFF	ON	OFF	OFF	
2B0	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	
2B8	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	
2C0	ON	ON	ON	OFF	OFF	ON	OFF	OFF	
2C8	OFF	ON	ON	OFF	OFF	ON	OFF	OFF	
2D0	ON	OFF	ON	OFF	OFF	ON	OFF	OFF	

ISA BUS ADDRESS MAP

FIGURE #14

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Base Address	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	Typical Use
2D8	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	
2E0	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	
2E8	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	Serial Port 4
2F0	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	
2F8	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	Serial Port 2
300	ON	ON	ON	ON	ON	OFF	OFF	OFF	Prototype Card
308	OFF	ON	ON	ON	ON	OFF	OFF	OFF	Prototype Card
310	ON	OFF	ON	ON	ON	OFF	OFF	OFF	Prototype Card
318	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	Prototype Card
320	ON	ON	OFF	ON	ON	OFF	OFF	OFF	
328	OFF	ON	OFF	ON	ON	OFF	OFF	OFF	
330	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	
338	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	
340	ON	ON	ON	OFF	ON	OFF	OFF	OFF	
348	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	
350	ON	OFF	ON	OFF	ON	OFF	OFF	OFF	
358	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	
360	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	PC Network
368	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	PC Network
370	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	
378	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	Parallel Port 1
380	ON	ON	ON	ON	OFF	OFF	OFF	OFF	SDLC/Bisynchronous
388	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	SDLC/Bisynchronous
390	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	
398	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	
3A0	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	Bisynchronous 1
3A8	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	Bisynchronous 1
3B0	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	Monochrome/Printer
3B8	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	Monochrome/Printer
3C0	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	EGA/VGA Adapter
3C8	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	EGA/VGA Adapter
3D0	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	CGA/MCGA Adapter
3D8	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	CGA/MCGA Adapter
3E0	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	
3E8	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	Serial Port 3
3F0	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	Diskette Controller
3F8	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	Serial Port 1

ISA BUS ADDRESS MAP

FIGURE #14

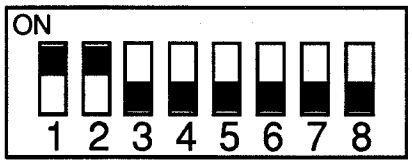
(cont.)

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Example:

Hex address 0x3E0 is not being used by the host computer or any add-in board. It is free to be used as the base address for a pcControl board. Referring to Figure #14, the Address selector DIP switch should be set as follows:



The address of the Command & Data I/O Register is equal to the base address = 0x3E0.

The address of the Communications Status Register is equal to the base address + 6 = 0x3E6.

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3.2 Communications Status.

The Communications Status Register is a word wide (16 bit) read only register. It may be read as either a byte or a word from the status register address for the pcControl board Slot ID. number selected. The status register readback bit values are a necessary aspect of communications with the pcControl board. They also provide extremely useful and powerful status information for system control.

The data contained in the status register may be read back at any time, regardless of the pcControl board function. The status data is updated in real time for all aspects of the board including, NuBus communications control and Per Axis Status Information. A byte read of the status register data byte has the following per bit format.

D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	X	X	X	X

D7 - Command Execution Status Bit (1 = Last Command Not Executed / 0 = OK)

D6 - Hardware Failure Status Bit (1 = Failure / 0 = OK)

D5 - Watchdog / Reset Status Bit (1 = Occurred / 0 = OK)

D4 - Command Error Status Bit (1 = Command Error / 0 = OK)

D3 - Command In Process Status Bit (1 = In Process / 0 = Finished)

D2 - Not Used

D1 - Return Data Pending Status Bit (1 = Data Pending / 0 = No Data)

D0 - Ready To Receive Status Bit (1 = Ready / 0 = Busy)

COMMUNICATIONS STATUS REGISTER - BYTE READ
FIGURE #15A

For additional information, a complete word may also be read from the Communications Status Register. The per bit format for a word read is shown in Figure #14B. Note that a word wide read of the Communications Status Register returns the same information returned by the Read Communications Status command (Cmd Id 0x41) except that the order of the bytes are swapped. (See the Command Description Section #4.3.)

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D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

D15 - Command Execution Status Bit (1 = Last Command Not Executed / 0 = OK)

D14 - Hardware Failure Status Bit (1 = Failure / 0 = OK)

D13 - Watchdog / Reset Status Bit (1 = Occurred / 0 = OK)

D12 - Command Error Status Bit (1 = Command Error / 0 = OK)

D11 - Command In Process Status Bit (1 = In Process / 0 = Finished)

D10 - Not Used

D9 - Return Data Pending Status Bit (1 = Data Pending / 0 = No Data)

D8 - Ready To Receive Status Bit (1 = Ready / 0 = Busy)

D7 - Axis #4 Move Status Bit (1 = Complete / 0 = In Process)

D6 - Axis #3 Move Status Bit (1 = Complete / 0 = In Process)

D5 - Axis #2 Move Status Bit (1 = Complete / 0 = In Process)

D4 - Axis #1 Move Status Bit (1 = Complete / 0 = In Process)

D3 - Axis #4 Run / Stop Status Bit (1 = Running / 0 = Stopped)

D2 - Axis #3 Run / Stop Status Bit (1 = Running / 0 = Stopped)

D1 - Axis #2 Run / Stop Status Bit (1 = Running / 0 = Stopped)

D0 - Axis #1 Run / Stop Status Bit (1 = Running / 0 = Stopped)

COMMUNICATIONS STATUS REGISTER - WORD READ
FIGURE #15B

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Further detailed status information relating to the individual axis functionality may be obtained by executing the Read Per Axis Hardware Status command (Cmd Id 0x49). The per axis hardware status word read will provide detailed status information on the present function of each axis and its associated limit inputs. Additional commands are available for use in obtaining detailed status information on all aspects of the pcControl board. (See Section #4.3, for a description of all of these command capabilities.)

3.3 Communications.

Command writing, data read and status read functions are accomplished via ISA Bus communications with the pcControl board. All communications must occur at the addresses shown in the board addressing Section #3.1. All write data and read data communication with the pcControl board must utilize 16 bit transfers.

Prior to each read or write of a word to/from the Command & Data I/O Register, the Communications Status Register bits must be tested for valid Ready To Receive or Return Data Pending status.

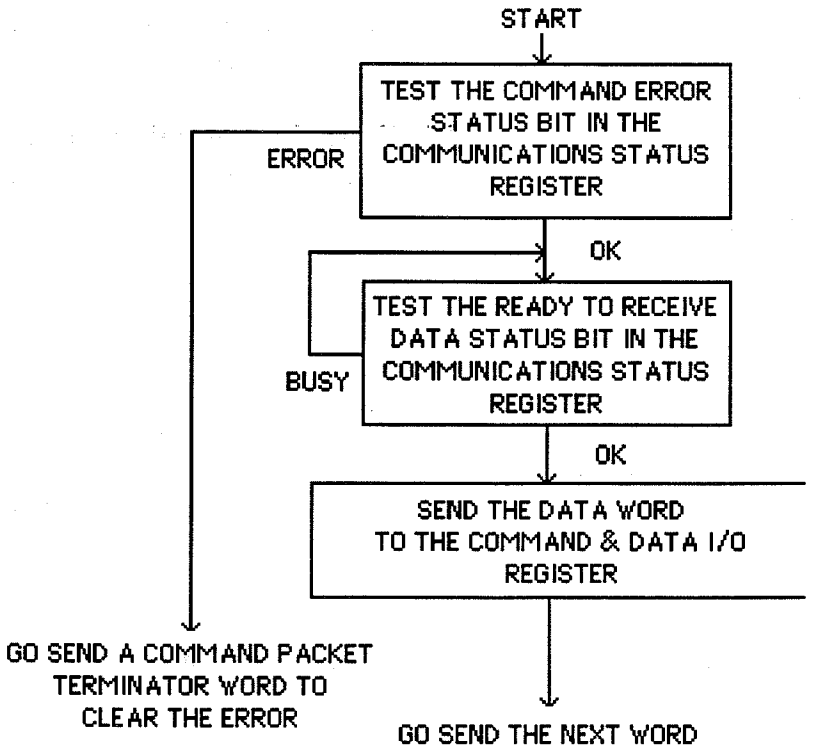
The status register may be read at any time to check for communications status bit validity or for other board level status information. (See Communications Status Register description, Section #3.2.)

All data transfers via the Command & Data I/O Register must follow the communications packet formats for sending commands and reading data. The details of packet configuration are described later in this section.

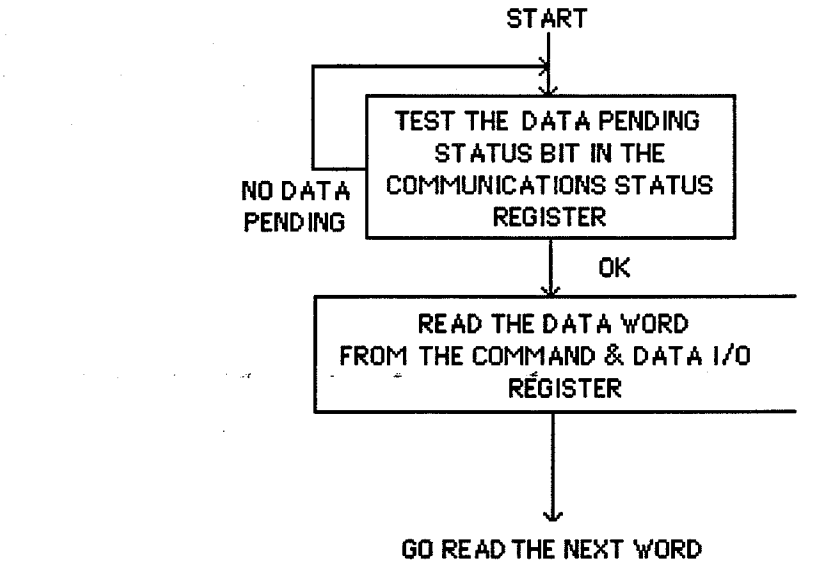
The following flowcharts present a brief overview of single word communications control for reading or writing the pcControl card, as a subset of full packet communications. Only single word transfers are covered in the flow charts. Complete send command and read data packet communications flowcharts are included later in this section.

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COMMAND & DATA I/O REGISTER WRITE FLOWCHART
1 Word Transfer
FIGURE #16



COMMAND & DATA I/O REGISTER READ FLOWCHART
1 Word Transfer
FIGURE #17

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The communication packet formats have been optimized for higher level language and assembly language programming of the pcControl board command set. Packet configuration and status bit result testing can be setup and accomplished using simple and straightforward programming techniques. Command packets are designed to be axis independent and easily configurable. Command packet sending and return packet data read may be accomplished via a minimum of word transfers and status byte tests by direct memory addressing to specific register addresses. Multiple pcControl board programming for greater than 4 Axis capability may be implemented with only a slight variation in register addressing. Only the address and Axis Id # would need to be changed in order to use the same control programs.

All communications with the pcControl board is accomplished via packet transfers. There are two types of packets. A Send Command Packet and a Read Data Packet. Both packet types have a similar Packet ID word. **The primary difference between send and read packets is that send command packets must end in a command packet terminator word.** Read data packets do not end with a terminator word value.

3.4 Send Command Packets.

In order to send commands to the pcControl board, the Send Command Packet format must be utilized. The following is a description of the send command packet format.

Please note that the number of words in a command packet is dependent upon the specific command type and its input data requirement. Therefore, send command packet size will vary with command type. The word size data referred to in packet communications is a 16 bit unsigned value. Hexadecimal words are represented in this document by either of the following formats: 0x???? or ???? (hex) where ???? is a 16 bit hexadecimal value.

3.4.1 Send Command Packet Format.

0x????	1st Word Sent	-	Command Packet ID Word
0x????	2nd Word Sent	-	Most Significant Word Of Long Word (32 bit) data value. [optional]
0x????	3rd Word Sent	-	Least Significant Word Of Long Word (32 bit) data value. [optional]
0x????	Last Word Sent	-	Command Packet Terminator Word.

SEND COMMAND PACKET FORMAT OVERVIEW

FIGURE #18

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The inclusion of data words indicated as [optional] depends upon the individual command requirement and the corresponding data size.

There are three possible sizes for send command packets: 2,3 or 4 words total. Please refer to the Command Listing (See Section # 4.1) for the packet sizes of individual commands.

2 Word Command Packet Format.

A 2 word command packet consists of a command packet ID word and a command packet terminator word.

0x????	1st word sent	-	Command Packet ID Word
0x????	Last word sent	-	Command Packet Terminator Word.

3 Word Command Packet Format.

A 3 word command packet consists of a command packet ID word, data word and a command packet terminator word. The data word may be either a data input value or a control word for setup and configuration. The actual value of the data word is command type dependent.

0x????	1st word sent	-	Command Packet ID Word
0x????	2nd word sent	-	Data Word
0x????	Last word sent	-	Command Packet Terminator Word.

4 Word Command Packet Format.

A 4 word command packet consists of a command packet ID. word, a most significant data word (upper 16 bits of a 32 bit data value), a least significant data word (lower 16 bits of a 32 bit data value) and a command packet terminator word. The data to be sent in this packet type is 32 bits. This 32 bit value (Long Word) is sent as two 16 bit values in the 2nd and 3rd word positions of the 4 word command packet.

The second word sent is always the most significant word (16 bits) of the long word data value and the third word sent is the least significant word (16 bits) of the long word data value. The 32 bit data word may be a signed or unsigned value depending upon the individual command requirement.

0x???? ????	32 bit Long Word data value. (hex)

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The data word may be either a data input or a control word for setup and configuration. The actual value of the data word is command dependent.

0x????	1st word sent	-	Command Packet ID Word
0x????	2nd word sent	-	Most Significant Word Of Long Word (32 bit) data value.
0x????	3rd word sent	-	Least Significant Word Of Long Word (32 bit) data value.
0x????	Last word sent	-	Command Packet Terminator Word.

Command packets sent to the pcControl board must follow one of the previous packet formats described. If an error occurs during packet sending or an incorrect packet format is sent, the command error bit will be set in the status register. This command error bit can be read and tested by a byte wide read of the Communications Status Register address location.

A Command Packet Terminator word may be sent to the Command & Data I/O Register address at any time. Sending a Command Packet Terminator word to this register will reset the receive command packet controller, clearing any command error conditions, and set up the board to receive new send command packets.

As mentioned above, all command and data word writes to the Command & Data I/O Register must be proceeded by a check of the Ready To Receive and Command Error status bits in the Communications Status Register. Command & data writes that occur when this bit is not valid will be ignored and in some instances may cause erroneous operation . Use the Command Packet Terminator word to reset a command error condition.

All command and data word transfers to the pcControl board via the Command & Data I/O register address must be word width (16 bits).

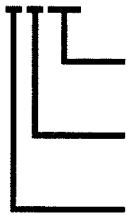
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3.4.2 Send Command Packet ID. Word.

The Command Packet ID. word is a 16 bit value (word wide) and has the following configuration.

0x???? Command Packet ID. Word



Command ID. (See Command Table listing, section #4.1)

Axis ID. # (Axis # 1,2,3,4 or Board Level Command =0)

Word count checksum.

The Command ID. value is explicit for each pcControl command.

Axis ID. # numbers are used to specify destination axis information or board level command identification. These values are checked by the pcControl board to determine valid command packet configurations.

Word count checksum values are used to control packet communication size and to cross check packet size validity with command type. The word count checksum is the total number of words contained in the packet including the Command Packet Terminator word.

3.4.3 Send Command Packet Data Words.

(See the Command Table listing in Section #4.1 for expected input data word size and format for individual commands.)

The command packet data size can be either zero words, one word (16 bit value) or two words in length (32 bit value). For one word (16 bit) data values, the single word value is sent as the data word or second word of a 3 word size packet. For two word (32 bit) data values, the two words are sent consecutively following the Command Packet ID. word as the second and third words of a 4 word size packet. The most significant word (upper 16 bits) of the two word value is sent first followed by the least significant word (lower 16 bits) of the two word (32 bit hex) value.

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3.4.4 Send Command Packet Terminator Word.

NOTE: All send command packet transfers must end with a terminator word.

The pcControl board communications format offers three possible terminator word values. All three terminator word options provide the same functionality for send command packet termination or to reset command error conditions. The three options for terminator words (16 bits) are sent as the last word of a Command Packet transfer to complete a pcControl command.

Terminator words may also be sent at any time to reset the pcControl receive command controller. If the terminator word is sent when the receive command controller circuit is expecting a data value based on the checksum provided, then the terminator word will be interpreted as a data value. Multiple terminator words sent in succession will guarantee that the receive command controller is reset after a command error condition or an incomplete send packet.

The following three word values (hexadecimal) are the Command Packet Terminator Word options. Any of these three may be used. Each provides the same functionality as the others.

Command Packet Terminator Word Options.

0x000A	Terminator Word Type	#1
0x000D	" " "	#2
0x0020	" " "	#3

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3.4.5 Send Command Packet Examples.

Example #1:

Send the Start Motion Command to Axis #2.

Complete Command Packet (2 Words Total).

0x2261 First Word Sent - Command Packet ID. Word.

0x000A Last Word Sent - Command Packet Terminator Word.

Detailed Overview.

First Word Sent - 0x2261 Command Packet ID. Word.



{61} Command ID. #

{2} Axis ID. # - (Axis #2)

{2} Word Count Checksum. - (2 Words Sent)

Second Word Sent - 0x000A Command Packet Terminator Word.

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Send Command Packet Format Examples. (cont...)

Example #2:

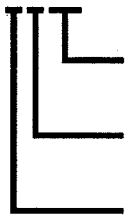
Send the Enable Limit Switch Inputs Command as a board level control command to the pcControl board.

Complete Command Packet (3 Words Total).

0x304B	First Word Sent	-	Command Packet ID. Word.
0x????	Data Word Sent (Limit Switch Enable Configuration Value.)		
0x000A	Last Word Sent-Command Packet Terminator Word.		

Detailed Overview.

First Word Sent - 0x304B Command Packet ID. Word.



{4B} Command ID. #

{4} Axis ID. # - (Board Level Command = 4)

{3} Word Count Checksum. - (3 Words Sent)

Second Word Sent - 0x???? Data Word Value.

Third Word Sent - 0x000A Command Packet Terminator Word.

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Send Command Packet Format Examples. (cont...)

Example #3:

Send the Load Target Position Command to Axis #1.

Complete Command Packet (4 Words Total).

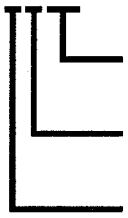
0x414E	First Word Sent	-	Command Packet ID. Word.
0x????	Second Word Sent	-	Data Word Sent (Most Significant Word (upper 16 bits) of Long Word (32 bit) value.
0x????	Third Word Sent	-	Data Word Sent (Least Significant Word (lower 16 bits) of Long Word (32 bit) value.
0x000A	Last Word Sent	-	Command Packet Terminator Word.

Detailed Overview.

Assuming that the desired position value in hexadecimal is:

0x004C F200 Long Word (32 bit) Position Value.

First Word Sent - 0x414E Command Packet ID. Word.



{4E} Command ID. #

{1} Axis ID. # - (Axis #1)

{4} Word Count Checksum. - (4 Words Sent)

Second Word Sent - 0x004C Data Word Value. - Most Significant Word of 32 bit value.

Third Word Sent - 0xF200 Data Word Value. - Least Significant Word of 32 bit value.

Forth Word Sent - 0x000A Command Packet Terminator Word.

NOTE: It is good practice to check the command error bit in addition to the required Ready To Receive Data status bit prior to sending out each word of the command packet. If a command error exists it can be cleared by sending Command Packet Terminator words.

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3.4.6 Send Command Packet Flowchart

The following command packet and flowchart shows an example of loading the Velocity for Axis #3, where the loaded value is a 32 bit data value equal to: 0x0002 7FFF.

A total of four (4) word values will be sent to the Command & Data I/O register to complete this command.

Command Packet To Be Sent:

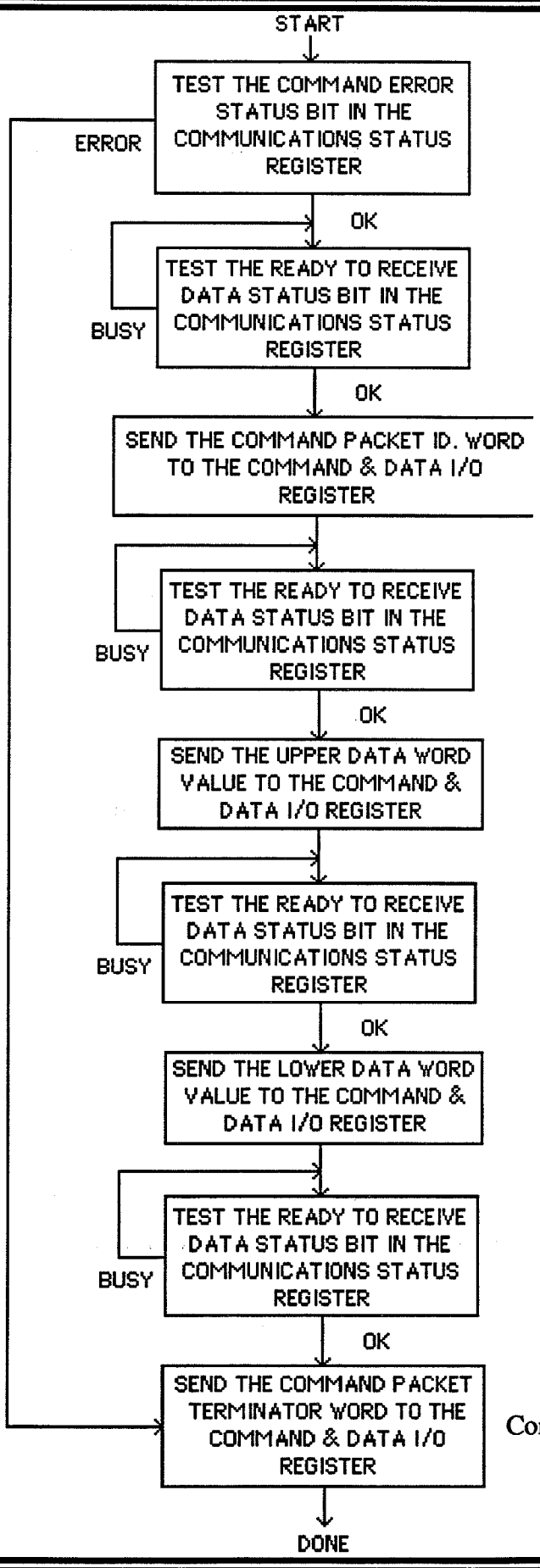
1st Word Sent	0x434F	Command Packet Id Word
		{4F} Command Id #
		{3} Axis Id # - (Axis #3)
		{4} Word Count Checksum - (4 words sent)
2nd Word Sent	0x0002	Most Significant Word Of Long Word Data (32 bit) Value.
3rd Word Sent	0x7FFF	Least Significant Word Of Long Word Data (32 bit) Value.
4th Word Sent	0x000A	Command Packet Terminator Word.

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SEND COMMAND PACKET EXAMPLE FLOWCHART

FIGURE #19



Command Packet ID. Word = 0x434F

Upper Data Word = 0x0002

Lower Data Word = 0x7FFF

Command Packet Terminator Word = 0x000A

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3.5 Return Data Packets.

Programming the pcControl board provides the opportunity to take advantage of commands requesting readback and status information on both a per axis basis and a board level basis. This data includes but is not limited to: position information, velocity values, limit switch status, per axis hardware status, and many more.

When a command is executed that causes readback data to be generated for the host to read, the return data generated is buffered in a return data buffer on the pcControl board and is held in the sequence that it was requested and generated. This data is held buffered until it is read out by the host. When there is valid data present in the readback data buffer, the RETURN DATA PENDING status bit is valid in the Communications Status Register.

This bit must be valid prior to reading each return data word from the read buffer. Read data buffered by the pcControl board for host read is saved in a format very similar to the send command packet format. This format is called the **Return Data Packet Format.**

3.5.1 Return Data Packet Format.

The Return Data Packet Format contains all of the information required by the host to determine how many words are to be read back for the present return data packet. The Return Data Packet ID. Word also contains the originating Command ID. #, the packet word count checksum and the originating Axis ID. # or board level function ID. #. (#1, 2, 3 or 4 for Per Axis ID. #'s & #0 for Board Level ID.)

0x????	1st Word Read Back	-	Command Packet ID Word
0x????	2nd Word Read Back	-	Least Significant Word of long word (32 bit) data value.
0x????	3rd Word Read Back	-	Most Significant Word of long word (32 bit) data value. [optional]

RETURN DATA PACKET FORMAT OVERVIEW

FIGURE #20

The main difference between the Return Data Packet Format and the Send Command Packet Format, is that the return data packet does **not** include a Packet Terminator word at the end of the packet.

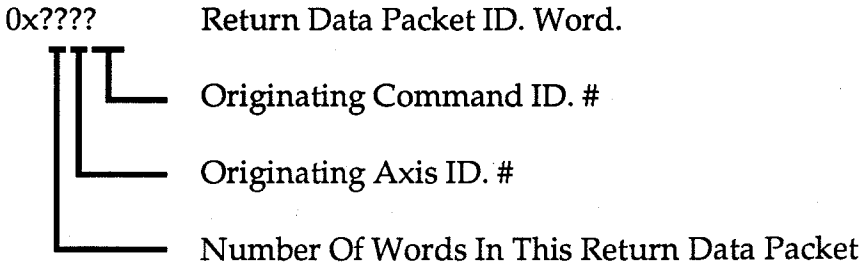
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3.5.2 Return Data Packet ID. Word.

The Return Data Packet ID. word is the first word read back in a return data packet and should be used to determine the number of data words to be read for the present pending return data packet.

The Return Data Packet ID. Word has the following format.



(See The Command Table Listing in Section #4.1 for Command ID. # and Axis ID. # values.)

The originating Command ID. # is explicit for individual commands listed in the command table. The originating Command ID. # is the ID. of the command that caused the readback data packet to be generated. The originating Axis ID. # is the Axis ID. # that corresponds to the return data values and the originating command.

3.5.3 Return Data Packet Data Words.

The return packet data value can be either one word or two words in length depending upon the originating command type requesting return data. For one Word (16 bit) data values, the single word value is returned as the data word value. For two word (32 bit) data values, the two words are returned consecutively following the Return Packet ID. word. The least significant (lower 16 bits) of the two word (32 bits) value is returned first followed by the most significant (upper 16 bits) word.

2 Word Length Return Data Packet.

A two word return data word packet consists of a Return Data Packet ID. Word and the word wide (16 bit) return data value.

0x????	-	1st Word Read Back	-	Return Data Packet ID. Word.
0x????	-	2nd Word Read Back	-	Return Data Value (16 bits).

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3 Word Length Return Data Packet.

A three word return data word packet consists of a Return Data Packet ID. Word and a Long Word width (32 bit) return data value. This 32 bit value is read back as two 16 bit word values. The first data word is the least significant word of the 32 bit long word value and the second data word is the most significant word of the 32 bit long word value.

0x????	-	1st Word Read Back	-	Return Data Packet Id Word.
0x????	-	2nd Word Read Back	-	Least significant word - lower 16 bits of 32 bit value.
0x????	-	3rd Word Read Back	-	Most significant word - upper 16 bits of 32 bit value.

All return data packets read from the pcControl board will follow one of the two above formats. The first word read back should always be checked to determine the return packet configuration including: the total number of words in the packet, the originating Axis ID. # and the originating Command ID. #.

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3.5.4 Return Data Packet Example and Flowchart.

Example #1:

The command executed that requested and generated this return data was a Read Position Command. Axis #2 was the originating Axis ID. #.

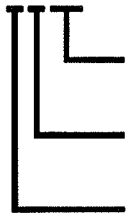
The return data packet would have the following format.

Complete Return Data Packet.

0x3253	First Word Returned	-	Return Packet ID. Word.
0x????	Data Word Returned	-	Least Significant Word (LSW) of the 32 bit Long Word Data Value.
0x????	Data Word Returned	-	Most Significant Word (MSW) of the 32 bit Long Word Data Value.

Detailed Overview.

First Word Returned - 0x3253 Return Packet Id Word.



{53} Originating Command Id. # 0x53

{2} Originating Axis Id. # - (Axis #2)

{3} Word Count Checksum. - (3 Words Returned)

Second Word Returned - 0x???? Data Word Value - (LSW)

Third Word Returned - 0x???? Data Word Value - (MSW)

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Assuming that the position value was 0x007C 63FE, then the;

Second Word Returned is: 0x63FE and the

Third Word Returned is: 0x007C

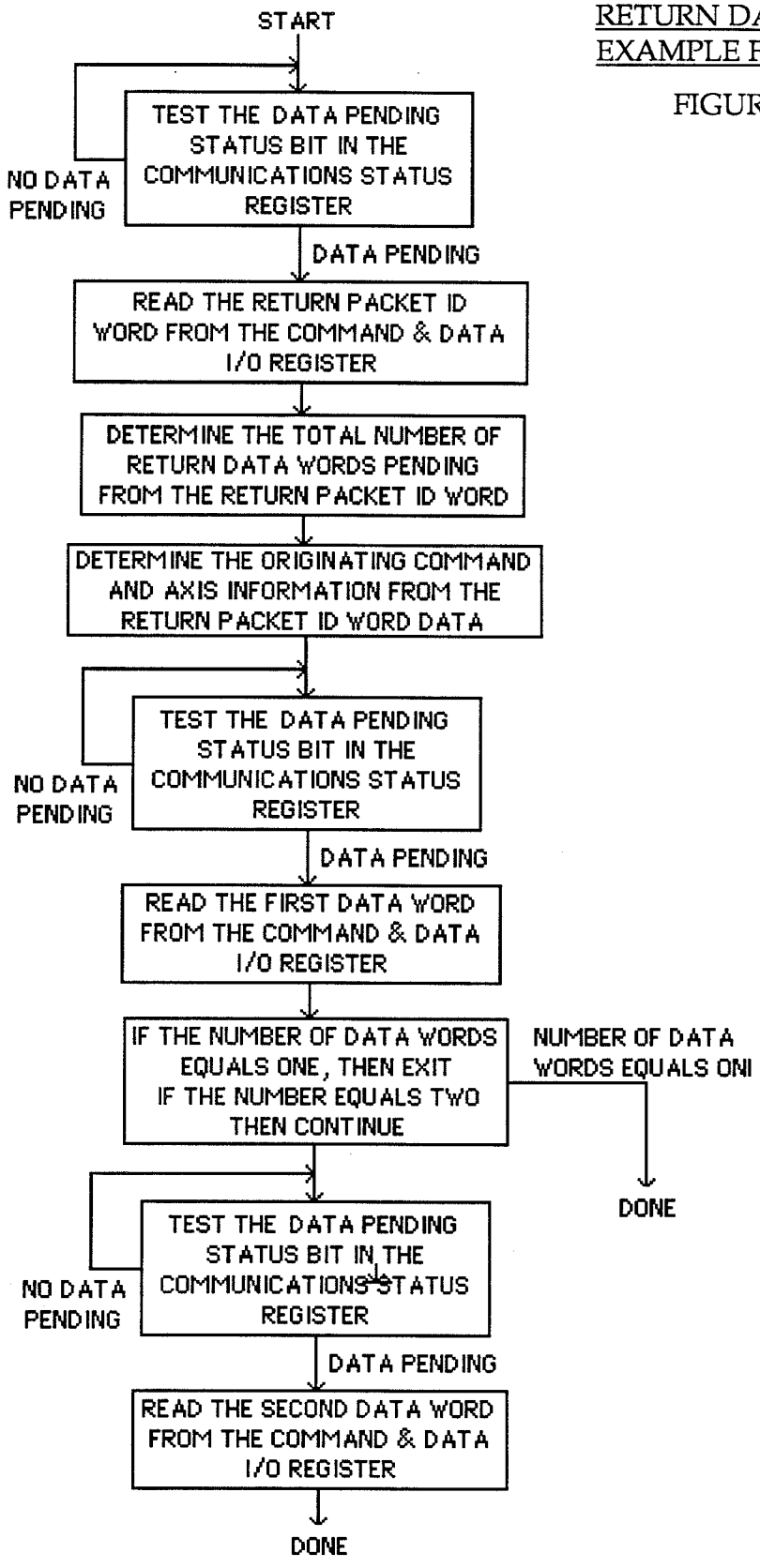
This return value is the present position value for the Axis Id. number indicated. This value is measured in quadrature counts.

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RETURN DATA PACKET
EXAMPLE FLOWCHART

FIGURE #21



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3.6 Communications Buffers

The pcControl board provides RAM (Random Access Memory) buffers for incoming command buffering and for return data buffering. Altogether, there are ten different buffers in the pcControl board communications section. These buffers can be described in individual function groups as follows.

Per Axis Buffers	4 Buffers	-	1 Each For Axis #1,2,3 & 4 Commands
Board Level Buffer	1 Buffer	-	For Board Level Control Commands.
Return Data Buffer	1 Buffer	-	For Return Data Storage
I/O Trigger Buffers	4 Buffers	-	1 Each For The Four I/O Port Triggers.

The buffers are all structured as FIFO (first in - first out) where incoming commands are buffered and executed in the order that they arrive. Return data packets available for host read are buffered in the order that they are generated.

Per Axis & Board Level Command Buffers.

The first five buffers are standard input command buffers for the four individual axis servo controllers and for the board level setup and control commands. Standard command buffers are 30 command packets deep for each of the four Axis control circuits and for system level command inputs. If commands are buffered, then they will be executed in the order that they are received.

Return Data Buffer.

The sixth buffer is the Return Data Packet Storage Buffer. This buffer is utilized by the pcControl board to hold return data packets until the host is ready to read them out. The Return Data Packet information contained in this buffer is generated by individual data requesting or generating commands. This buffer is 1800 Return Data Packets deep. The contents of this buffer is available for readback by the host at any time when the Return Data Pending status bit is valid in the Communications Status Register.

Note: For most applications, the Return Data Buffer only needs to be one packet deep. In general, it is recommended that data be read from the Return Data Buffer immediately after it is requested. However, the Acquire Samples command (Cmd. Id. 0x5E) needs a large Return Data Buffer.

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I/O Port Trigger Buffers.

The next four buffers are the I/O Port Trigger Buffers. These buffers can be used to store commands that will be automatically loaded and executed by the occurrence of a valid trigger input signal or by direct control via the manual Trigger I/O Port # command (Cmd. Id. 0x48.)

Command sequences are loaded into these buffers by using the Begin Trigger # Prestore and End Trigger Prestore commands. (Cmd. Id. 0x5F & 0x60) Single or multiple move sequences can be loaded. Multiple sequences are delimited by use of the Trigger Buffer Delimiter command (Cmd. Id. 0x5D.) Once loaded, these buffers are maintained regardless of the number of times the buffer is triggered. The only way that the buffer contents will change is by writing new commands over the old ones or by a pcControl hardware reset.

The size of the individual Trigger Buffers is as follows:

Trigger Buffer #	Size (in command packets)
1	1000
2	1000/2000 (See Below)
3	1000
4	2000

All Trigger Buffers have permanently allocated memory space except for Trigger Buffer #2. It can either hold up to 1000 commands (without impacting Trigger Buffer #3), or up to 2000 command packets by utilizing the space reserved for Trigger Buffer #3. If Trigger Buffer #3 is going to be used, Trigger Buffer #2 must be limited to 1000 commands to avoid overwriting the commands in Trigger Buffer #3.

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3.7 pcControl Command Overview.

3.7.1)	Operation Mode Selection.	*	-	Per Axis
3.7.2)	Motion Trajectory Parameters.	*	-	Per Axis
3.7.3)	Filter Parameters.	*	-	Per Axis
3.7.4)	Limit and Home Switch Configuration.	*	-	Board Level
3.7.5)	I/O Port Configuration.	*	-	Board Level
3.7.6)	Stop Mode Selection.	*	-	Per Axis
3.7.7)	Stop On Following Error.	*	-	Per Axis
3.7.8)	Trigger Buffer Functions.	*	-	Board Level
3.7.9)	Breakpoint Functions.	*	-	Per Axis

The following is a brief description of the functionality of each area. Details on the individual commands in each section may be found in the command description section. (See Command Description Section #4.3)

Please refer to the end of this section for a sample list of commands to be executed during per axis & board level initialization.

3.7.1 Operation Mode Selection. - Per Axis

The desired mode of operation must be programmed for each axis by use of the Set Operation Mode Command (Cmd. Id. 0x64). Mode selections include Velocity Mode or Position Mode and Position Mode may be configured for Absolute or Relative Mode operation. A complete discussion of the function of each of these modes and their application is covered in the Command Description Section #4.3.

3.7.2 Motion Trajectory Parameters. - Per Axis

The motion trajectory parameters must be properly setup prior to motion control on an individual axis basis. The motion trajectory parameter commands are:

Load Acceleration	(Cmd. Id. 0x62)
Load Velocity	(Cmd. Id. 0x4F)
Load Target Position	(Cmd. Id. 0x4E)

These values are loaded via their individual commands, and must be set to a known value prior to motion control. Their values are zero (0) at power up and if left unchanged, will create a "do nothing" trajectory when a Start Motion command is issued. Refer to the Command Description Section #4.3 for detailed information on programming considerations for each of these commands.

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3.7.3 Filter Parameters. - Per Axis

Filter parameter determination is entirely dependent upon the system dynamics for the motion control elements involved. Filter parameters include.

Filter Derivative Sample Period.	(Cmd. Id. 0x57)
Filter Proportion Gain.	(Cmd. Id. 0x58)
Filter Integral Gain.	(Cmd. Id. 0x59)
Filter Derivative Gain.	(Cmd. Id. 0x5A)
Filter Integration Limit.	(Cmd. Id. 0x5B)

These parameters must be setup on an individual axis basis prior to motion control. The value of each of these parameters is utilized by the digital filter in axis motion control servo loop. The parameter values will affect loop response and update time, impulse response, holding force and many other factors. Motor size, speed of operation, acceleration requirements, position tracking, motor loading and other variables will affect the proper determination of these parameters.

Recommended starting values for these parameters are shown in the command description section for each digital filter command. Actual parameter value determination is dependent upon specific system configurations and cannot be easily presented in a simple to use formula.

See the Command Description Section #4.3 for further information on programming these values.

The next six sections fall into the area of enhanced features and system specific functions for user customization. Some or all of these items may be utilized depending upon the requirements of individual motion system application.

3.7.4 Limit and Home Switch Configuration. - Board Level

The parameters for this function should be setup and initialized if operation of each axis motion will include limit switch & home switch inputs. The limit switch parameters may be setup by use of the following commands.

Set Limit Switch Input Polarity.	(Cmd Id. 0x4A)
Enable Limit Switch Inputs.	(Cmd id. 0x4B)

These commands are board level functions and may be used to setup the Limit Switch and Home Input switches for all four axis control circuits. The limit switch input signal polarity defaults to inverting input (active low) for all signal sources. If limit or home switch inputs are to be used, their polarity must be properly set prior to enabling. Improper configuration of limit switch polarity when the limit switch signals are enabled will cause faulty operation.

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3.7.5 I/O Port Configuration. - Board Level

The parameters in this area should be setup if operation of the pcControl board will include the programmable I/O Port bits. This port may be setup on an individual bit basis for input or output signals. Hardware jumpers must be set to correspond to the programmed I/O direction for each bit. (See Section #2.4.4, Jumper Configuration)

When setup as outputs, each port may be programmed for desired polarity and output level. A logic "true" can alternatively result in either an active high or active low output signal.

When setup as inputs, each bit may be configured as an inverting input or non-inverted input and may be enabled as Trigger Input. (See Section #3.7.8, Trigger Buffer Functions)

The following commands are used for I/O Port configuration and control:

Set I/O Port Polarity & Direction	(Cmd. Id. 0x44)
Set I/O Port Output	(Cmd. Id. 0x45)
Read I/O Port	(Cmd. Id. 0x47)

Refer to the Command Description Section #4.3 for detailed descriptions of each command covered in this area.

3.7.6 Stop Mode Selection. - Per Axis

The pcControl board provides the ability to preprogram the stop mode utilized when a Stop command is issued, on a per axis basis. The Stop Modes are:

Decelerated Stop

Halt Stop

Kill Stop

Decelerated Stop

In this mode, motion is stopped by decelerating at the preprogrammed acceleration value to a stop from the present trajectory in process.

Halt Stop

In this mode, motion is stopped immediately by setting the destination position value equal to the present position when the Stop Motion command is executed. This causes an instantaneous stop in an abrupt fashion at maximum deceleration. This is the stop type used by all limit and home input signal controlled stops.

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Kill Stop

When this stop mode is selected and the Stop Motion command is executed on a per axis basis, the motor drive signal is set to zero and a motor off condition occurs in the per axis servo circuit. This mode will turn off position tracking and allow the motor to move freely. Stop commands issued with this mode selected will behave just like the Kill Motion command.

The stop mode desired is set by use of the Set Stop Mode command (Cmd. Id. 0x55). This command must be used to setup the desired stop mode to be used by the Stop Motion command execution on a per axis basis. See the Command Description Section #4.3 for more information on this command.

3.7.7 Stop On Following Error. - Per Axis

A following error count may be programmed on a per axis basis. Exceeding the following error will cause an automatic internal Kill Motion command to execute. The Following Error Count is programmed in quadrature counts by the use of the Load Following Error Count command (Cmd. Id. 0x56).

This function affords protection against motor run-away and position tracking or position input signal loss. This function can also be used to protect against a stalled motor or bound motion hardware as well as other mechanical failures and conditions that may cause excessive position and tracking errors.

For more information on this command and its programming, please refer to the Command Description Section #4.3.

3.7.8 Trigger Buffer Functions. - Board Level

This section presents a brief description of the Trigger Buffer functions on the pcControl board. The details of setup and programming of these functions is covered in the command description section for each of the commands presented here.

Trigger Buffer functions provide the ability to preprogram a sequence of commands and store this sequence in a trigger buffer for execution by a single command packet transfer or by a previously enabled I/O Port input bit designated as a trigger input bit.

For example, once an axis control loop has been setup and initialized for motion by proper programming of its required initialization commands, it may be utilized in the prestore command and trigger mode. A sequence of commands including Load Velocity, Load Target Position and Start Motion could be prestored in a trigger buffer and executed by a single command packet transfer using the manual Trigger I/O Port # command or executed by an active signal on an enabled I/O Port input bit corresponding to the trigger buffer containing the prestored commands.

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Commands are prestored in the trigger buffers by use of the following commands:

Begin Trigger # Prestore.	(Cmd. Id. 0x5F)
End Trigger Prestore.	(Cmd. Id. 0x60)

Warning: Trigger buffer prestore should only be executed at a time when motion control interaction is not required. All normal command execution is disabled during trigger buffer command sequence prestore.

I/O Port bits to be used as trigger inputs must first be configured by use of their setup commands. I/O Port bits are enabled for use as trigger inputs by the following command:

Enable I/O Port Trigger Inputs.	(Cmd. Id. 0x46)

For trigger buffers, the trigger execution function can be manually initiated by use of the following command:

Trigger I/O Port #.	(Cmd. Id. 0x48)

The Trigger I/O Port # function will operate regardless of the I/O Port or Trigger Input Enable setup.

Single or multiple command sequences can be prestored. Multiple sequences are separated and delimited by the use of the following command:

Trigger Buffer Delimiter	(Cmd. Id. 0x5D)

Each time a trigger buffer is triggered, the contents of the buffer up to the next delimiter (or to the end of the buffer) are automatically transferred to the per axis command buffers as if the commands were sent from the host. The contents of the trigger buffer remains undisturbed in its original sequence. When the end of the buffer is reached, the next trigger will retrigger the first command sequence up to the first delimiter.

The trigger function is a very powerful high level set of command tools that allow preprogrammed motion and multi-axis coordinated motion initiation via a single command or input bit trigger.

Please refer to the Command Description Section #4.3 for detailed descriptions of each of the commands in this section.

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3.7.9 Breakpoint Functions. - Per Axis Level

Breakpoints may be programmed to generate an external signal transition on a dedicated I/O Port bit when a desired position or time is reached. The two types of available breakpoints are:

Position Breakpoint
Anticipation Time Breakpoint

When breakpoints are setup and the breakpoint location is reached a level transition will occur on a properly enabled I/O Port bit. I/O Port bits 1, 2 and 3 are dedicated for use with the corresponding Axis #'s 1, 2 and 3.

The two breakpoint types, position and anticipation time share the same low level hardware and are mutually exclusive. The most recent breakpoint type programmed is the one that will be used when the breakpoint function is enabled for the axis selected.

Position breakpoints may be specified as either an absolute position or a relative position when the breakpoint is enabled.

Anticipation breakpoints provide the ability to generate a breakpoint at a programmable time prior to the completion of a move in position mode. This time value is programmed as a multiple of base sample periods (341 microseconds).

The commands used to load and enable position and anticipation time breakpoints are:

Load Position Breakpoint	(Cmd. Id. 0x65)
Load Anticipation Time Breakpoint	(Cmd. Id. 0x67)
Enable Breakpoint Function	(Cmd. Id. 0x66)

Breakpoint data is not used until an enable breakpoint command is issued. The data is buffered internal to the pcControl board so if the same value is desired on a repetitive basis, it is not necessary to reload the position or time data value after each use. It is necessary to re-enable the breakpoint each time, however.

Please refer to the Command Description Section #4.3 for detailed descriptions of each of the commands in this section.

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3.8 Recommended Initialization Procedure.

The following section presents a recommended list of commands to be executed for system initialization. This recommended list covers the minimum areas of initialization for basic motion control. Additional commands must be added to this list for enhanced system configuration initialization requirements.

The following list of commands should be executed for each axis used in the motion control application. The per axis control circuits will not function properly if these initialization steps are not performed.

1) Set Operational Mode.
2) Set Stop Mode.
3) Load Filter Proportional Gain.
4) Load Filter Derivative Gain.
5) Load Filter Derivative Sample Period.
6) Load Acceleration.
7) Load Velocity.

This is the minimum initialization list. For applications using limit and home switches, the following system level commands might need to be executed:

1) Set Limit Switch Input Polarity
2) Enable Limit Switch Inputs

At power-up, all axes are "Killed" with the servo circuits disabled. An axis will automatically start to servo when a Start Motion command is executed. The following sequence of commands can be used to turn on the servo controller for an axis without moving anywhere:

1) Reset Position Counter to Zero
2) Load Target Position = 0
3) Start

Other commands typically used during initialization include: Find Home, Find Index, Load Following Error, Load Filter Integral Gain, etc. See the individual command Section #4.3 for information on these commands.

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3.9 Operational Modes

The pcControl board may be programmed to operate in any one of three operational modes. These modes may be independently programmed for each of the four axis servo controllers. The operational modes are Absolute and Relative parameter interpretation for Position Mode and absolute parameter interpretation for Velocity mode.

3.9.1 Position Control - Absolute Mode.

All motion control in this mode uses the trapezoidal profile generation for motion execution. This mode is used for absolute positioning applications, typically with reference to a home switch position.

When the pcControl board individual axis control circuits are setup for Position Control - Absolute Mode, loaded target position values are interpreted as the absolute position count value of the motion destination location (Position value). When a Start Motion command is issued following a Load Target Position command, motion will proceed to the loaded target position location. When motion is completed successfully, the Read Present Position command will return a position count equal to the loaded target position value. The velocity and acceleration values loaded in this mode configuration are used during move profile determination and actual motion control.

In this mode, when the destination position is reached, the servo circuitry will maintain the position until a new position valued is loaded and a Start Motion command is issued, or until a Kill Motion command is issued. The position tracking servo will turn off the motor position maintenance if the following error exceeds a programmed count value. (See: Load Following Error Count in the Command Description Section #4.3)

3.9.2 Position Control - Relative Mode.

This mode uses position, velocity and acceleration input parameter values to perform position servo motion control. All motion control in this mode will utilize the trapezoidal profile generation for motion control execution. This mode is used for relative positioning applications, with reference to the present position.

When the pcControl board individual axis control circuit is setup for Position Control - Relative Mode, loaded target position values are interpreted as relative position count values. The loaded value is summed with the present position (or previously loaded target position if the move is still in process) to determine the new destination position.

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For Example:

If the present position	=	0010 0000 (hex)
and the loaded target position Position Control - Relative Mode,	=	0020 0000 (hex) in
then the new destination position	=	0030 0000 (hex)

Destination Position = Present Position + Newly Loaded Target Position

In this mode, when the destination position is reached, the servo circuitry will maintain that position until a new position valued is loaded and a start command is issued, or until a Kill Motion Command is issued. The position tracking servo will turn off the motor position maintenance if the following error exceeds a programmed following error count value. (See Load Following Error Count in the Command Description Section #4.3)

3.9.3 Velocity Control Mode.

This mode uses velocity and acceleration input parameter values to perform closed loop velocity servo motion control. All motion control in this mode will use programmed velocity control profile generation for motion control. This mode is used for continuous stable velocity control applications and velocity profiling (regular updating of velocity parameters for velocity profile generation). Position feedback information is available for positional tracking and the full functionality of limit switch and home switch input signals is available in this mode.

When the pcControl board axis control circuits are setup for Velocity Control Mode, loaded velocity values are interpreted as the absolute velocity measured in counts/sample period (See Section #1.3, Velocity Value Loading). The loaded velocity is used directly to control the desired velocity. Programmed velocity will be maintained indefinitely until a command or limit switch input signal is used to stop motion.

In this mode, when the destination velocity is reached, the servo circuit will maintain the velocity until a new velocity valued is loaded and a Start Motion command is issued, or until a Kill Motion or Stop Motion command is issued. The velocity tracking servo will turn off the motor velocity maintenance if the following error exceeds a programmed following error count. (See Load Following Error Count in the Command Description Section #4.3.)

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3.10 Command and Hardware Interactions

This section covers Command Interactions with Limit Switch, Home Switch & Encoder Input signals.

Special attention must be paid to the operation of the pcControl board in conjunction with limit switches, home switches and the encoder signals. There are three commands, Start Motion, Multi-Axis Start and Go Home that operate in a unique fashion when used with valid limit and home switch input signals. The Go Home Command requires properly configured and enabled limit and home switches in order to function correctly. The Multi-Axis Start Command has the same interaction concerns as the Start Motion Command.

3.10.1 Start Motion Command Interaction.

The Start Motion Command will check the end-of-travel limit switch input signals to determine if any are active prior to starting motion. If a limit switch is active, and the desired direction of motion is further into the limit condition, as opposed to away from the limit condition, then the Start Motion Command will be ignored. In order for this safety and control feature to function properly, the limit switch inputs must be properly configured. This includes software configuration and enabling, as well as proper connection for forward and reverse limits at the appropriate end-of-travel limit positions.

Warning: Care must be taken to insure that the Forward and Reverse Limits are consistent with the desired direction of motion. The Limit Switches must be wired so that a move commanded in the forward or positive direction moves the motion system towards the Forward Limit Switch.

3.10.2 Find Home Command Interaction.

The Find Home Command requires valid and enabled limit switch and home switch signals in order to function properly. The Find Home Command utilizes limit switch data and home switch data to ensure proper location of the home position. (See Find Home command details in the command description section #4.3)

3.10.3 Find Index Command Interaction.

The Find Index Command requires a valid encoder generated index signal for the per axis control circuit programmed with this command. The Find Index command will look for an index transition within one revolution of the present position. If it encounters the index, it will make that pulse position location its target position and move to that position. The success or failure to find the index pulse is indicated by the Index Found status bit available through the Read Per Axis Hardware Status command. (See Section #4.3, Find Index Command description.)

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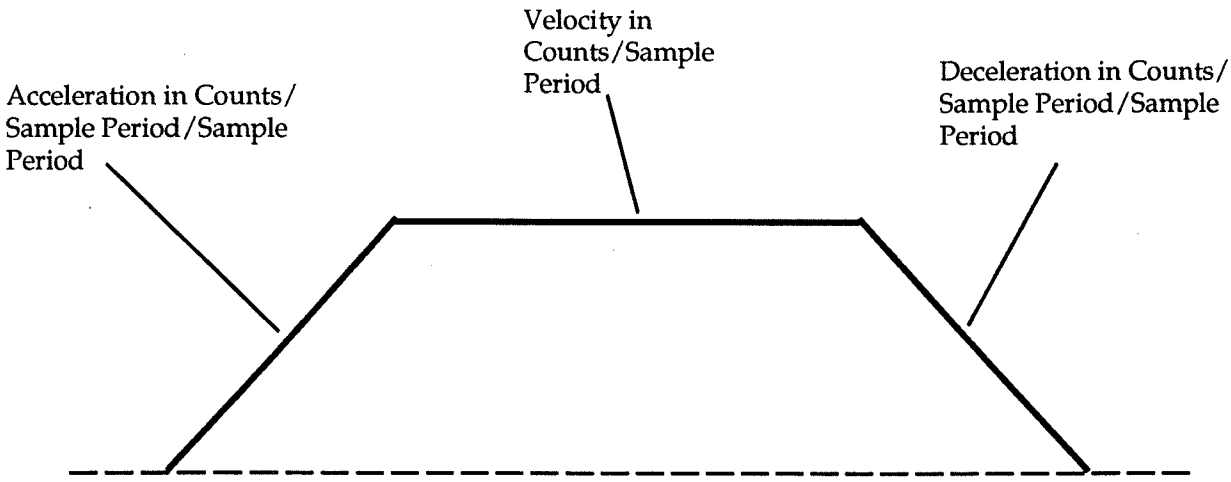
3.11 Motion Trajectory Programming.

Motion trajectory programming involves the process of motion control via trajectory parameter loading and Start/Stop Motion Command execution. The list of possible combinations for trajectory type based upon operational mode selections for velocity servo and position servo control loops are nearly endless.

Motion trajectory control technique is primarily the area of design and implementation covered by the system designer and implemented by the control software developer. In this section, we will cover some basic principals of motion trajectory programming and the affects upon parameter value storage and retention by the pcControl board hardware, based upon specific command executions.

As a general overview of basic motion control, trajectory parameter values including velocity, acceleration and target position information are loaded into the per axis servo control circuits on the pcControl board. Motion is then initiated by the Start Motion command and will either conclude when the programmed trajectory is completed or when a Stop or Kill Motion command packet is issued. Motion is also stopped by an enabled limit or home switch occurrence.

As shown in Figure #22, a typical motion trajectory is via trapezoidal profile where the motor accelerates up to the programmed velocity using the programmed acceleration, traverses at the programmed velocity and then decelerates at the programmed acceleration to the target position.



TRAPEZOIDAL TRAJECTORY PROFILE
FIGURE #22

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Trajectory parameter values are loaded and retained in the servo control circuits until new values are loaded or the hardware is reset. Trajectory values updated during a move take effect when the Start Motion command is executed. This "on-the-fly" capability means that motion profiles significantly more complex than the trapezoidal profile shown in Figure #21 are possible. For example, velocity profiling (regular updating of velocity parameters for velocity profile generation) can be used for circular interpolation and continuous path contouring applications. The type of control utilized may be as varied as the possible applications developed for use with the pcControl board. The pcControl board is provided as a generic servo motion control tool and allows full custom configuration depending upon the individual system designers needs.

To give a few additional examples:

A motion trajectory program using fixed velocity and acceleration values with constantly varying position destinations may be used to move around in a 2 dimensional plane (x,y motion) to random locations that are generated by external system components and calculations.

A motion trajectory program using fixed velocity and acceleration values with repetitive, identical destination position moves may be used to move a single axis or a number of axis back and forth to well defined locations for repetitive fixed tasks such as production assembly hardware control.

A motion trajectory program using constant fixed value velocity controlled motion with limit switch input or I/O Port input based stopping control may be used to control a conveyor type system designed to operate at a fixed velocity, but requiring external event control to stop motion or reverse direction.

A motion trajectory program using velocity profile motion with fixed value acceleration, in a multi-axis motion control environment, may be used to simulate the motion of a car on a rough road in order to evaluate the affect upon other systems under test.

These are only a few brief examples, the actual implementations are infinite and limited only by the system designers requirements.

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3.12 Error Conditions.

The pcControl board has been designed to minimize the occurrence of error conditions. There are two types of error conditions. The first type is Fatal Errors which require system power cycling or board level hardware reset signal generation in order to attempt recovery. These error types may indicate an internal problem on the pcControl board.

Fatal Errors include, but may not be limited to:

Hardware Fail Status Bit Set.
Watchdog Timer Terminal Count Reached.
NuBus Communications Loss.

Fatal Errors are extremely unlikely, but if they occur, try to clear them by power cycling or hardware reset. If this procedure does not clear the problem, contact nuLogic.

The second type of error conditions are soft errors:

Command Error Status Bit Set.
Command Not Executed Status Bit Set.

The Command Error status bit typically indicates an error in command packet transfer, and can easily be cleared by sending the Command Packet Terminator Word data to the Command & Data I/O Register address when the Ready To Receive Data Bit Is valid in the communications status register.

The Command Not Executed status bit indicates that the last command was received correctly but was determined to be illegal due to the operating condition of one or more axes. This status bit is set globally in the communications status register and set on a per axis basis in the Per Axis Hardware Status word. See Communications Status (Section #3.2) and the command descriptions for Read Per Axis Hardware Status (Cmd Id 0x49) and Read Communications Status (Cmd Id 0x41) command for further details.

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4.0 pcControl COMMANDS

4.1 Command List. - Figure #23

Command Id # (hex)		Command Name	Input Data Size	Word Count Checksum	Dest. Axis Id.	Return Data Size.
41		Read Communications Status	-	2	0	1 Word
42		Read Limit Switch Status	-	2	0	1 Word
43		System Reset	1 Word	3	0	None
44		Set I/O Port Polarity & Direction	1 Word	3	0	None
45		Set I/O Port Output	1 Word	3	0	None
46		Enable I/O Port Trigger Inputs	1 Word	3	0	None
47		Read I/O Port	-	2	0	1 Word
48		Trigger I/O Port #	1 Word	3	0	None
49		Read Per Axis H/W Status	-	2	1,2,3,4	1 Word
4A		Set Limit Switch Input Polarity	1 Word	3	0	None
4B		Enable Limit Switch Inputs	1 Word	3	0	None
4C		Stop Motion	-	2	1,2,3,4	None
4D		Kill Motion	-	2	1,2,3,4	None
4E		Load Target Position	2 Words	4	1,2,3,4	None
4F		Load Velocity	2 Words	4	1,2,3,4	None
50		Reset Position Counter To Zero	-	2	1,2,3,4	None
51		Find Home	1 Word	3	1,2,3,4	None
52	**	Find Index	2 Words	4	1,2,3,4	None
53		Read Present Position	-	2	1,2,3,4	2 Words
54		Read Present Velocity	-	2	1,2,3,4	1 Words
55		Set Stop Mode	1 Word	3	1,2,3,4	None
56		Load Following Error Count	1 Word	3	1,2,3,4	None
57		Load Filter Derivative Sample Period	1 Word	3	1,2,3,4	None
58		Load Filter Proportional Gain	1 Word	3	1,2,3,4	None

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4.1 Command List (cont...)

Command Id # (hex)		Command Name	Input Data Size	Word Count Checksum	Dest. Axis Id.	Return Data Size.
59		Load Filter Integral Gain	1 Word	3	1,2,3,4	None
5A		Load Filter Derivative Gain	1 Word	3	1,2,3,4	None
5B		Load Filter Integration Limit	1 Word	3	1,2,3,4	None
5C		Multi-Axis Start	1 Word	3	0	None
5D		Trigger Buffer Delimiter	-	2	0	None
5E		Acquire Samples	1 Word	3	0	Lots
5F		Begin Trigger # Prestore	1 Word	3	0	None
60		End Trigger Prestore	-	2	0	None
61		Start Motion	-	2	1,2,3,4	None
62		Load Acceleration	2 Words	4	1,2,3,4	None
63	***	Set Direction	1 Word	3	1,2,3,4	None
64		Set Operation Mode	1 Word	3	1,2,3,4	None
65		Load Position Breakpoint	2 Words	4	1,2,3,4	None
66		Enable Breakpoint Function	1 Word	3	1,2,3,4	None
67		Load Anticipation Time Breakpoint	1 Word	3	1,2,3,4	None
68		Load Position Reference Offset	2 Words	4	1,2,3,4	None
69		Load Position Scale Factor	2 Words	4	1,2,3,4	None
6A		Set Scale Factor Sequence	1 Word	3	1,2,3,4	None
6B		Set Run / Stop Status Pulse Width	1 Word	3	1,2,3,4	None
6C		Load Rotary Counts	2 Words	4	1,2,3,4	None

NOTES:

**	Requires Index Input signal feedback from encoder.
***	Valid only when Velocity mode is selected.
XX	**Bold** signifies new or changed command compared to 3 Axis board.

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4.2 Command Types.

The variety of commands available for programming the pcControl board may be divided into two basic types. They are: System Level commands and Per Axis commands.

System Level Commands.

System level commands are typically used for setting up, controlling and reading back data for multi-axis functions and board level functions. These functions are primarily system enhancement setup and control functions for external input and I/O Port configuration. A few examples of system level commands would be; Watchdog Timer Control, Set Limit Switch Input Polarity, Enable Limit Switch Inputs, and others. System level commands are entered into the system level command input buffer by sending them to Axis ID #0.

Per Axis Specific Commands.

Per axis specific commands are functions for setting up, controlling and reading back data on an individual axis basis. These commands have the identical functionality for all four axis servo control circuits. The Command Packet ID. word sent as the first word in the command packet for each command will include an Axis ID. # specifier value. This value determines the destination axis servo control circuit for the command packet being sent. Per axis specific commands are entered into individual per axis specific command input buffers depending on the Axis ID. #. in the Command Packet ID. word.

Priority Commands.

Priority commands will be executed immediately upon their arrival in the axis specific buffer, regardless of the contents of the destination buffer or any previously pending commands.

Buffered Commands.

Buffered commands will be placed at the end of the existing list of buffed and unexecuted pending commands (if any). Buffered commands will be executed in the order that they are received, when all internal status conditions have been met for their execution requirements.

4.3 pcControl Command Descriptions.

The following section provides a command description for each of the individual commands available for programming the pcControl board in all aspects of motion control for a complete 4 Axis motion system.

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COMMAND NAME: Read Communications Status

COMMAND ID: 41

Command: Read Communications Status

Command ID. Number: 0x41

Command Type: System Level

Command Packet Size: 2 Words

Command Packet Configuration:

	0x2041	-	Command Packet ID. Word
	0x000A	-	Command Packet Terminator Word
or,	0x000D	-	"
or,	0x0020	-	"

Return Data: 1 Word

The Read Communications Status command returns the same status information found by directly reading a word wide value from the Communications Status register. The returned data from this command has the following format.

Return Packet Configuration:

0x2041	1st word returned:	Packet ID. Word
0x00??	2nd word returned:	Communications Status Data Word

See next page for the Communications Status Data Word bit level values.

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The return data word has the same status information but is byte swapped as compared to a word wide read of the Communications Status register. The return data word has the following binary format:

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Where the value for "X" can be interpreted as follows:

D15 - 1 = Axis #4 Move Complete
0 = Axis #4 Move In Process

D14 - 1 = Axis #3 Move Complete
0 = Axis #3 Move In Process

D13 - 1 = Axis #2 Move Complete
0 = Axis #2 Move In Process

D12 - 1 = Axis #1 Move Complete
0 = Axis #1 Move In Process

D11 - 1 = Axis #4 Motor Running
0 = Axis #4 Motor Stopped

D10 - 1 = Axis #3 Motor Running
0 = Axis #3 Motor Stopped

D9 - 1 = Axis #2 Motor Running
0 = Axis #2 Motor Stopped

D8 - 1 = Axis #1 Motor Running
0 = Axis #1 Motor Stopped

Continued on the next page...

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D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Where the value for "X" can be interpreted as follows:

D7 - 1 = Last Command Not Executed
0 = Command Executed Successfully

D6 - 1 = System Hardware Failure
0 = System Hardware Ok

D5 - 1 = Power On Reset or Watchdog Occurred (Send Reset Position Counter Command to clear)
0 = OK

D4 - 1 = Command Error (Send Terminator Word To Clear)
0 = Command & Data Interface Ok

D3 - 1 = Command In Process
0 = Command Complete

D2 - Not Used

D1 - 1 = Return Data Pending
0 = No Data Pending

D0 - 1 = Ready To Receive Bus Command & Data Word
0 = Not Ready To Receive / Busy

The Move Complete status bits indicate that the axis has either reached its target position or has stopped trying to move due to an error. This information is similar but not identical to the Profile Complete status bits available through the Read Per Axis Hardware Status command.

The Last Command Not Executed status bit indicates that the command was received sucessfully but could not be executed because the board was performing some action that temporarily made the command invalid. For example, issuing a Multi-Axis Start while one axis cannot start due to a limit condition generates this Command Not Executed status. The Last Command Not Executed bit available through a Read Per Axis Hardware Status command can be used to further isolate the problem to a specific axis.

The Command-In-Process status bit indicates that the last command sent is in the process of being executed. Any Command Errors are guaranteed to be set by the time the command is complete.

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COMMAND NAME: Read Limit Switch Status

COMMAND ID: 42

Command: Read Limit Switch Status

Command ID. Number: 0x42

Command Type: System Level

Command Packet Size: 2 Words

Command Packet Configuration:

	0x2042	-	Command Packet ID. Word
	0x000A	-	Command Packet Terminator Word
or,	0x000D	-	"
or,	0x0020	-	"

Return Data: 1 Word

Return Packet Configuration:

0x2042	1st word returned:	Packet ID. Word
0x0???	2nd word returned:	Limit Switch Status Data Word

Note: The logical value (True or False) read back for limit switch status may not directly correspond to the input signal level (high or low). Actual input signals may be inverted for active low limit switch configurations. (See the Set Limit Switch Polarity Command.)

See next page for the Limit Switch Status Data Word bit level values.

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The Limit Switch Status data word has the following format.

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	X	X	X	X	X	X	X	X	X	X	X	X

Where the value for "X" can be interpreted as follows:

D15 thru D12 - Always = 0

D11 - 1 = Axis #1 Home Signal True
0 = Axis #1 Home Signal False

D10 - 1 = Axis #2 Home Signal True
0 = Axis #2 Home Signal False

D9 - 1 = Axis #3 Home Signal True
0 = Axis #3 Home Signal False

D8 - 1 = Axis #4 Home Signal True
0 = Axis #4 Home Signal False

D7 - 1 = Axis #1 Forward Limit Signal True
0 = Axis #1 Forward Limit Signal False

D6 - 1 = Axis #1 Reverse Limit Signal True
0 = Axis #1 Reverse Limit Signal False

D5 - 1 = Axis #2 Forward Limit Signal True
0 = Axis #2 Forward Limit Signal False

D4 - 1 = Axis #2 Reverse Limit Signal True
0 = Axis #2 Reverse Limit Signal False

D3 - 1 = Axis #3 Forward Limit Signal True
0 = Axis #3 Forward Limit Signal False

D2 - 1 = Axis #3 Reverse Limit Signal True
0 = Axis #3 Reverse Limit Signal False

D1 - 1 = Axis #4 Forward Limit Signal True
0 = Axis #4 Forward Limit Signal False

D0 - 1 = Axis #4 Reverse Limit Signal True
0 = Axis #4 Reverse Limit Signal False

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COMMAND NAME: System Reset

COMMAND ID: 43

Command: System Reset

Command ID. Number: 0x43

Command Type: System Level

Command Packet Size: 3 Words

Command Packet Configuration:

0x3043	-	Command Packet Id. Word
0x9876	-	Password Data Word
0x000A 0x000D 0x0020	-	Command Packet Terminator Word

Return Data: None

The System Reset command resets the pcControl board by forcing a Watchdog Time-out. This returns the pcControl to the same state it was in at initial power-up.

Warning:

Do not communicate with the pcControl board for at least 30 seconds after issuing a System Reset. Doing so will result in a fatal Bus Error.

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COMMAND NAME: Set I/O Port Polarity & Direction

COMMAND ID: 44

Command: Set I/O Port Polarity & Direction

Command ID. Number: 0x44

Command Type: System Level

Command Packet Size: 3 Words

Command Packet Configuration:

	0x3044	-	Command Packet ID. Word
	0x????	-	I/O Port Polarity & Direction Word
			See The Individual Bit Binary Values Table.
	0x000A	-	Command Packet Terminator Word
or,	0x000D	-	"
or,	0x0020	-	"

Return Data: None

The Set I/O Port Polarity & Direction command is used to set the polarity and direction of the programmable I/O port on an individual bit basis. This command provides the ability to custom tailor the I/O port bits for system hardware signal direction and polarity requirements. It is important to note that the proper function of the I/O port as a trigger input is dependent upon the correct setup of this command, the Enable I/O Port Trigger Inputs command and the proper positioning of the Input / Output signal Jumpers #JP1 - #JP8 & #JP9 - #JP16. (See I/O Hardware Jumper Setup, Section #2.4.4)

See next page for the Set I/O Port Polarity & Direction Data Word bit level values.

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The I/O Port Polarity & Direction Setup Word sent as part of this command packet has the following format. Use this command to setup the desired direction (Input / Output) and polarity (Inverting / Non-inverting) configuration for the progammable I/O ports on a individual bit basis. The default configuration on power up for all I/O Bits is: Inverting Inputs.

Polarity & Direction setup word = 0xPPDD

Where: Upper Byte (PP) - Polarity Control
Lower Byte (DD) - Direction Control

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

The value for "X" can be interpreted as follows:

D15 - I/O Bit #8 Polarity Control
1 = Inverting
0 = Non-inverting

D14 - I/O Bit #7 Polarity Control
1 = Inverting
0 = Non-inverting

D13 - I/O Bit #6 Polarity Control
1 = Inverting
0 = Non-inverting

D12 - I/O Bit #5 Polarity Control
1 = Inverting
0 = Non-inverting

D11 - I/O Bit #4 Polarity Control
1 = Inverting
0 = Non-inverting

D10 - I/O Bit #3 Polarity Control
1 = Inverting
0 = Non-inverting

D9 - I/O Bit #2 Polarity Control
1 = Inverting
0 = Non-inverting

D8 - I/O Bit #1 Polarity Control
1 = Inverting
0 = Non-inverting

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D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

The value for "X" can be interpreted as follows: (Cont...)

D7 - I/O Bit #8 Direction Control
1 = Input Signal Bit
0 = Output Signal Bit

D6 - I/O Bit #7 Direction Control
1 = Input Signal Bit
0 = Output Signal Bit

D5 - I/O Bit #6 Direction Control
1 = Input Signal Bit
0 = Output Signal Bit

D4 - I/O Bit #5 Direction Control
1 = Input Signal Bit
0 = Output Signal Bit

D3 - I/O Bit #4 Direction Control
1 = Input Signal Bit
0 = Output Signal Bit

D2 - I/O Bit #3 Direction Control
1 = Input Signal Bit
0 = Output Signal Bit

D1 - I/O Bit #2 Direction Control
1 = Input Signal Bit
0 = Output Signal Bit

D0 - I/O Bit #1 Direction Control
1 = Input Signal Bit
0 = Output Signal Bit

WARNING:
If an I/O bit is set as an input port, and is enabled as a trigger input, but its polarity is set incorrectly, it will cause degraded system performance. It may also erroneously load stored trigger commands. Be sure to check signal polarity setup prior to enabling the I/O Port bits as trigger inputs.

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COMMAND NAME: Set I/O Port Output

COMMAND ID: 45

Command: Set I/O Port Output

Command ID. Number: 0x45

Command Type: System Level

Command Packet Size: 3 Words

Command Packet Configuration:

	0x3045	-	Command Packet ID. Word
	0x00??	-	I/O Port Output Word
			See The Individual Bit BinaryValues Table.
	0x000A	-	Command Packet Terminator Word
or,	0x000D	-	"
or,	0x0020	-	"

Return Data: None

This command is used to set the logical (True or False) output value of the individual I/O port bits. The functionality of this command is dependent upon the proper configuration of the I/O Port by use of the Set I/O Port Polarity & Direction Command and the correct setting of the I/O Port hardware jumpers. The power up default configuration for the I/O Port has all bits set as inverting inputs.

Output values set using this command will be held until changed by this command.

See next page for the Set I/O Port Output Data Word bit values.

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The I/O Port Output Value Word sent as part of this command packet has the following format. Use this command to set the desired logic level for the programmable Output bits. The actual output signal level is dependent on the polarity selected.

Output Value Word = 0x00??

Where: Upper Byte (00) - Always = 0
Lower Byte (??) - Output Value

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0	X	X	X	X	X	X	X	X

The value for "X" can be interpreted as follows:

D7 - I/O Bit #8 Output Value
1 = True Output
0 = False Output

D6 - I/O Bit #7 Output Value
1 = True Output
0 = False Output

D5 - I/O Bit #6 Output Value
1 = True Output
0 = False Output

D4 - I/O Bit #5 Output Value
1 = True Output
0 = False Output

D3 - I/O Bit #4 Output Value
1 = True Output
0 = False Output

D2 - I/O Bit #3 Output Value
1 = True Output
0 = False Output

D1 - I/O Bit #2 Output Value
1 = True Output
0 = False Output

D0 - I/O Bit #1 Output Value
1 = True Output
0 = False Output

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COMMAND NAME: Enable I/O Port Trigger Inputs

COMMAND ID: 46

Command: Enable I/O Port Trigger Inputs

Command ID. Number: 0x46

Command Type: System Level

Command Packet Size: 3 Words

Command Packet Configuration:

	0x3046	-	Command Packet ID. Word
	0x00??	-	I/O Port Trigger Inputs Enable Word
			See The Individual Bit BinaryValues Table.
	0x000A	-	Command Packet Terminator Word
or,	0x000D	-	"
or,	0x0020	-	"

Return Data: None

This command is used to individually enable I/O Port bits #1 - #4 for use as trigger inputs. I/O Port bits enabled as trigger inputs are used to automatically execute a preprogrammed list of commands that have been stored in a trigger buffer. I/O Port bits that have their direction and hardware jumpers set as inputs, may be used as simple signal input bits, as trigger input bits or both.

When properly set for direction & polarity, and enabled by use of this command, an I/O port input trigger true will cause the stored commands relating to the I/O Port bit number to be executed as if they had been issued by the host via ISA Bus transfers. At power-up, all I/O Trigger inputs are disabled by default.

See next page for the I/O Port Trigger Inputs Enable Data Word bit values.

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The I/O Port Trigger Inputs Enable Word sent as part of this command packet has the following format. Use this command to enable the individual I/O Port bits as event triggers.

Output Value Word = 0x000?

Where: Upper Byte (00) - Always = 0
Lower Byte (0?) - Enable / Disable Value

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0	0	0	0	0	X	X	X	X

The value for "X" can be interpreted as follows:

D15 - D4 - Always = 0

D3 - I/O Bit #4 Trigger Enable
1 = Enable Trigger Input
0 = Disable Trigger Input (Default)

D2 - I/O Bit #3 Trigger Enable
1 = Enable Trigger Input
0 = Disable Trigger Input (Default)

D1 - I/O Bit #2 Trigger Enable
1 = Enable Trigger Input
0 = Disable Trigger Input (Default)

D0 - I/O Bit #1 Trigger Enable
1 = Enable Trigger Input
0 = Disable Trigger Input (Default)

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COMMAND NAME: Read I/O Port

COMMAND ID: 47

Command: Read I/O Port

Command ID. Number: 0x47

Command Type: System Level

Command Packet Size: 2 Words

Command Packet Configuration:

	0x2047	-	Command Packet ID. Word
	0x000A	-	Command Packet Terminator Word
or,	0x000D	-	"
or,	0x0020	-	"

Return Data: 1 Word

Return Packet Configuration:

0x2047	1st word returned:	Packet ID. Word
0x00??	2nd word returned:	I/O Port Value Word

The read I/O Port command will return the logical values for all input and output bits.

See next page for the I/O Port Data Word bit values.

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The upper byte of the return data is always zero. The lower byte contains the value of the individual I/O Port bits and has the following binary format.

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0	X	X	X	X	X	X	X	X

Where the value for "X" can be interpreted as follows:

D15 thru D8 - Always = 0

D7 - I/O Bit #8 Value
1 = True Value
0 = False Value

D6 - I/O Bit #7 Value
1 = True Value
0 = False Value

D5 - I/O Bit #6 Value
1 = True Value
0 = False Value

D4 - I/O Bit #5 Value
1 = True Value
0 = False Value

D3 - I/O Bit #4 Value
1 = True Value
0 = False Value

D2 - I/O Bit #3 Value
1 = True Value
0 = False Value

D1 - I/O Bit #2 Value
1 = True Value
0 = False Value

D0 - I/O Bit #1 Value
1 = True Value
0 = False Value

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COMMAND NAME: Trigger I/O Port

COMMAND ID: 48

Command: Trigger I/O Port #

Command ID. Number: 0x48

Command Type: System Level

Command Packet Size: 3 Words

Command Packet Configuration:

	0x3048	-	Command Packet ID. Word
	0x000?	-	I/O Port Trigger Number (? = 1 thru 6)
	0x000A	-	Command Packet Terminator Word
or,	0x000D	-	"
or,	0x0020	-	"

Return Data: None

The Trigger I/O Port # command provides the ability to implement the same trigger function caused by a properly configured and enabled I/O Port input trigger bit, without actually using the I/O Port input signal. The I/O Port event trigger system allows for the pre-storage of commands in a trigger buffer, for execution by a valid trigger event input. (See: Using The Event Trigger System, Section #3.7.8)

When using this Trigger I/O Port # command, only a single event trigger may be initiated by each command packet transfer.

See next page for the Trigger I/O Port # Data Word format.

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The I/O Port Trigger Number Data Word sent as part of this command packet has the following format. Use this command to manually trigger the execution of a prestored command or list of commands in a trigger buffer.

I/O Port Trigger Number Word = 0x000?

Where: Upper Byte (00) - Always = 0
Lower Byte (0?) - I/O Port Trigger Nunber

0x0000 - Illegal Value (Do Not Use!)

0x0001 - Trigger I/O #1 Stored Commands

0x0002 - Trigger I/O #2 Stored Commands

0x0003 - Trigger I/O #3 Stored Commands

0x0004 - Trigger I/O #4 Stored Commands

0x0005 thru 0x000F - Illegal Values (Do Not Use!)

Note: This command does not require that the I/O Port bits be set up as inputs or that they be enabled as trigger inputs. This command overrides all I/O Port settings and automatically executes previously buffered trigger commands.

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