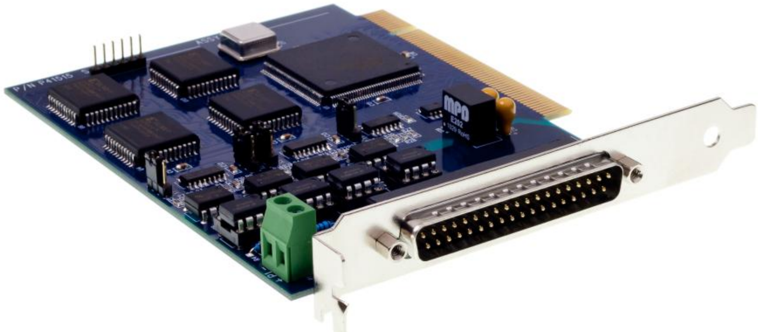
PCI4 User Manual



The PCI4 is a PCI 2.1 compatible PC expansion card that provides four channels of magnetostrictive linear transducer interface. When commanded by the host PC, the module interrogates the sensors and returns position data to the host PC. When operating with Start/Stop and PWM output sensors, the received pulse timing data is converted to position data and returned to the host PC. When operating with SSI output sensors, the received data word is made available to the host PC.

The PCI4 is designed for operation with magnetostrictive sensors, but can be used with other types of sensors. 24- and 25-bit binary SSI output sensors such as laser inferometers, absolute encoders and glass scales have been used with the PCI4.

The module can be configured to operate with Start/Stop, Trailing Edge Start/Stop, PWM (Pulse Width Modulated) or SSI output sensors. Each of the four channels can be configured independently. Each Start/Stop channel can support one to thirty one recirculations or from one to thirty one magnets in multi-magnet mode. PWM and Start/Stop output sensors are measured with a 56-MHz oscillator to provide 0.002-inch resolution without recirculations.

The sensors are galvanically isolated from the PCI4 logic and PCI bus. Sensor connections are made via a 37-pin DSUB connector. A DIN-rail mountable cable and screw-terminal breakout assembly is available to simplify sensor connection (order model CAB-TERM-37).

Sensor power can be distributed to sensors through 37-pin DSUB connector if it is applied to a 2-pin screw terminal on the PCI4, or the sensors can be powered externally.

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RAPID CONTROLS

Features and Specifications

- Supports Plug and Play, PCI 2.1 compatible
- Supports from 1 to 4 sensors
- Can be configured with any combination of Start/Stop, Pulse Width Modulated or SSI sensors
- 56 MHz timing provides 0.001 inch resolution with 2 recirculations
- All sensor channels are independent and can be used with different settings and timebases
- Sensor interface lines are differential RS-422; input lines have 120-ohm termination
- PWM sensors must support external interrogation, internal interrogation (free running) not supported
- SSI clock is 218kHz
- Occupies 16 bytes of IO space
- Power Requirements: 5 VDC @ < 500 mA
- Half-length PCI board, 5.2 x 4.2 inch (132 x 107 mm).

Ordering Information

Specify Model: **PCI-4-A B C D**

A - Channel A type
B - Channel B type
C - Channel C type
D - Channel D type

Substitute one of the following for the channel type:

R - Leading Edge Start/Stop or PWM*
S - SSI
T - Trailing Edge Start/Stop or PWM*

For example, a board with two start/stop interfaces on channels A and B and two SSI interfaces on channels C and D would be model PCI-4**-RRSS**.

*PWM operation requires an externally interrogated PWM sensor.

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1 Installation

1.1 Overview

The installation consists of two portions, the driver install and the SDK install. The driver install installs a driver that allows Windows applications to access the PCI4 hardware. The SDK install installs the DLLs and header files that provide an API allowing programs to use the PCI4 easily. See the PCI4 SDK Programmer's Reference for more information. The Windows NT installation combines these steps.

Note that the PCI4 is a Plug and Play device and has no jumpers to be set. The Plug and Play Bios will automatically assign the PCI4 an address space.

1.2 Installing the board

Install the PCI4 in an unused PCI slot. If you are using Windows 98, proceed to section 1.2.1. If you are using Windows NT, proceed to section 1.2.2. If you are using Windows 2000, proceed to section 1.2.3. Currently the PCI4 is not supported in Windows 95 or Windows ME. No special installation is required for DOS applications.

1.2.1 Windows 98 Driver Installation

After booting for the first time with the PCI4 installed, Windows will detect the PCI4 as an unknown PCI device. If this does not happen, use the Add New Hardware applet from the control panel.

1. After detection, the search for drivers dialog will open. Select "Next".
2. Select "Search for a suitable driver" and press "Next".
3. Uncheck all choices except "Specify a location". Enter the location of the PCI-4 SDK CD (e.g. D:\) and press "Next".
4. Windows should find the correct driver at this point. Press "Next". If Windows cannot locate the driver, check that the location entered in step 4 is correct.
5. Press finish after Windows installs the driver.

Continue with section 1.2.4.

1.2.2 Windows NT 4.0 Driver Installation

Skip to section 1.2.4. Setup.exe will install the drivers necessary for Windows NT.

1.2.3 Windows 2000 Driver Installation

After booting for the first time with the PCI4 installed, Windows will detect the PCI4 as an unknown PCI device. If this does not happen, use the Add/Remove Hardware applet from the control panel.

1. After detection, the search for drivers wizard will open. Select "Next".
2. Select "Search for a suitable driver" and press "Next".
3. Uncheck all choices except "Specify a location". Select "Next".
4. Enter the location of the PCI-4 SDK CD (e.g. D:\) and select "OK".
5. Windows should find the correct driver at this point. Press "Next". If Windows cannot locate the driver, check the location entered in step 4 is correct.

6. Press finish after Windows installs the driver.

Continue with section 1.2.4.

1.2.4 SDK Installation

Run setup.exe from the installation CD. This will install the PCI4 SDK and DLLs. The SDK files are installed to C:\pci4 (or x:\pci4 where x is the boot drive letter, if the boot drive is not C.) Reboot the computer before attempting to use the PCI4 SDK.

1.2.5 DOS Installation

There is no special procedure for DOS installation. The files in the SDKFiles directory of the PCI4 CD can be copied to the hard drive for use.

2 Theory of Operation

2.1 Board functions and addressing

The board is comprised of five logical sections: a PCI bridge and a programmable logic IC for each channel. The PCI bridge connects the programmable logic ICs to the PCI bus. The programmable logic ICs are responsible for interrogation of the sensor and timing of the sensor output.

2.1.1 Address decoding

The setup from the EEPROM defines the local bus space as 16 bytes of I/O. Address decoding is provided by the PCL9052 PCI interface chip. When the board is installed the operating system or plug and play BIOS assigns an address to the board. All access to the four sensor interfaces must be through the address space provided by the PCI BIOS.

3 Register Map

The PCI-4 board occupies 16 bytes of IO space, the base address of which is assigned dynamically by the Plug and Play BIOS or operating system. The IO map is divided into four 4-byte sections. Each section corresponds to a sensor channel: Channel A is mapped to bytes 0-3, B is mapped to bytes 4-7, C is mapped to bytes 8-11, and D is mapped to bytes 12-15. The contents of the status and command registers will vary depending on the type of sensor. See section 3.1.2 for detailed information on the registers when using a Start/Stop or PWM sensor. See section 3.1.3 for detailed information on the registers when using an SSI sensor.

Table 1 - PCI4 IO Map

Channel	Address (Base + *n*)	Register Name	Read Function	Write Function
A	0	DAT_{A0}	Sensor data (Low Byte)	-
	1	DAT_{A1}	Sensor data (Mid Byte)	-
	2	DAT_{A2}	Sensor data (High Byte)	-
	3	$CMND_{A}$	Channel Status	Command
B	4	DAT_{B0}	Sensor data (Low Byte)	-
	5	DAT_{B1}	Sensor data (Mid Byte)	-
	6	DAT_{B2}	Sensor data (High Byte)	-
	7	$CMND_{B}$	Channel Status	Command
C	8	DAT_{C0}	Sensor data (Low Byte)	-
	9	DAT_{C1}	Sensor data (Mid Byte)	-
	10	DAT_{C2}	Sensor data (High Byte)	-
	11	$CMND_{C}$	Channel Status	Command
D	12	DAT_{D0}	Sensor data (Low Byte)	-
	13	DAT_{D1}	Sensor data (Mid Byte)	-
	14	DAT_{D2}	Sensor data (High Byte)	-
	15	$CMND_{D}$	Channel Status	Command

3.1 Per-channel Registers

Each channel of the PCI4 operates independently and is accessed via a set of four registers. The Data Registers are read to retrieve the results of the latest sensor interrogation. The Command Register is read to determine the status of the latest interrogation. A write to the Command Register will configure the channel and begin a new sensor interrogation.

The contents of the Command Register varies depending on the type of sensor that the channel is configured to use. (-S channels support SSI sensors and -R and -T channels support Start/Stop and PWM sensors).

3.1.1 The Data Registers

Each channel has three data registers ($DAT_{n0..3}$). These registers contain an unsigned 24 bit integer representing the result of the previous sensor interrogation. While the DR (Data Ready) flag is 0, these registers will contain unpredictable values and should not be read. After the DR flag is 1 and until a new sensor interrogation is started by writing to the Command Register, these registers will hold the result data and will remain consistent.

Table 2 - The DATA Registers

Register	Result Bits	Description
DAT_{x0}	7..0	The least significant byte of result data.
DAT_{x1}	15..8	The mid byte of result data.
DAT_{x2}	23..16	The most significant byte of result data.

3.1.2 The Command Register with a Start/Stop or PWM Sensor

Writing to the Command Register will begin a sensor interrogation. The interrogation is controlled by the contents of the Command Register. The contents of the command register must be rewritten for each interrogation of the sensor. After an interrogation is started, the Command Register can be read to determine the status of the interrogation. The DR Flag should be checked to determine if the interrogation has completed successfully.

Table 3 – PWM & Start/Stop Command Register (Writes)

Bit	Name	Description
4..0	RC_x	Writing to the Command Register sets the number of recirculations or the magnet of interest for the channel. The value may range from 0 (1 recirculation or the 1st magnet) to 15 (16 recirculations or the 16th magnet)
5	PWM	If the PWM Flag is set, the sensor is treated as a PWM output sensor. If the PWM flag is not set, the sensor is treated as a Start/Stop output sensor.
6	MM	The MM Flag is only valid if the PWM Flag is not set, indicating that the sensor will be treated as a Start/Stop output sensor. If the PWM Flag is set, the MM flag is ignored. If the MM Flag is cleared, the sensor will be recirculated RC_x times. If the MM Flag is set, the position of the RC_xth magnet is retrieved.
7	IE	If the IE (Interrupt Enable) Flag is set, the completion of the next sensor interrogation will trigger an interrupt. If the IE Flag is cleared, no interrupt will be activated upon completion.

Table 4 - PWM & Start/Stop Command Register (Reads)

Bit	Name	Description
4..0	RC_x	During the sensor interrogation, RC_x will count towards zero as each recirculation or magnet is processed. When an interrogation is complete, RC_x should be zero.
5	PWM	If the PWM Flag was set in the previous Command Register write, it will be set in subsequent Command Register reads.
6	MM	If the MM Flag was set in the previous Command Register write, it will be set in subsequent Command Register reads.
7	DR	The DR (Data Ready) Flag will be set when the sensor interrogation has completed. If the interrogation doesn't complete due to a missing magnet or missing/malfunctioning sensor, the DR Flag will never be set. The host software is expected to detect a timeout in this case and restart the channel by writing to the Command Register.

3.1.3 The Command Register with an SSI Sensor

Writing to the Command Register will begin a sensor interrogation. The interrogation is controlled by the contents of the Command Register. The contents of the command register must be rewritten for each interrogation of the sensor. After an interrogation is started, the Command Register can be read to determine the status of the interrogation. The DR Flag should be checked to determine if the interrogation has completed successfully.

Table 5 - SSI Command Register (Writes)

Bit	Name	Description
4..0		Reserved
5	TF	If the TF Flag is cleared, the sensor is treated as a 24-bit binary SSI output sensor. If the TF Flag is set, the sensor is treated as a 25-bit binary SSI output sensor.
6		Reserved
7	IE	If the IE (Interrupt Enable) Flag is set, the completion of the next sensor interrogation will trigger an interrupt. If the IE Flag is cleared, no interrupt will be activated upon completion.

Table 6 - SSI Command Register (Reads)

Bit	Name	Description
0	Bit25	If the sensor is treated as a 25-bit sensor (the TF Flag is set) then Bit25 will contain the 25th bit of the result from the sensor. Otherwise the value of this bit is invalid.
4..1		Reserved
5	TF	If the TF Flag was set in the previous Command Register write, it will be set in subsequent Command Register reads.
6		Reserved
7	DR	The DR (Data Ready) Flag will be set when the sensor interrogation has completed. If the interrogation doesn't complete due to a missing/malfunctioning sensor, the DR Flag will never be set. The host software is expected to detect a timeout in this case and restart the channel by writing to the Command Register.

4 Using the PCI4 with Start/Stop and PWM output sensors

Start/Stop and PWM output sensors produce a pulse (or pulses) when interrogated by the PCI4. The pulse width is measured by the PCI4 and converted to an integer position value. The resolution of each count of the position value is based on the gradient of the sensor, the speed of the clock used for timing, and the number of recirculations performed.

Recirculation is accomplished by interrogating the sensor multiple times in succession. The effective resolution doubles each time the number of recirculations doubles. The time required to read the sensor also doubles. Recirculation can be performed by the sensor (internal recirculation) or can be performed by the PCI4 (external recirculation). If recirculations are performed both internally (by the sensor) and externally (by the PCI4), the effects are multiplied.

To determine the resolution, the following formula can be used:

$$Resolution = \frac{1}{Gradient \cdot Clock \cdot Recirculations}$$

where Resolution is the resolution of the integer position value in inches,
Gradient is the sensor gradient in micro-seconds per inch,
Clock is the timing clockspeed in MHz (56MHz for the PCI4),
and Recirculations is the total number of recirculations occurring.

Examples:

A PWM sensor with a gradient of 8.893μS with one internal recirculation (also called "no recirculations") will have a base resolution of $\frac{1}{8.893} \cdot 56 \cdot 1 = 0.002008$ inches per count. If the PCI4 is configured to perform two external recirculations, the same sensor will produce readings with a resolution of $\frac{1}{8.893} \cdot 56 \cdot 2 = 0.001004$ inches per count.

A PWM sensor with a gradient of 9.014μS and four internal recirculations will have a base resolution of $\frac{1}{9.014} \cdot 56 \cdot 4 = 0.0004953$ inches per count. If the PCI4 is configured to perform three external recirculations, an equivalent of 12 total recirculations will be performed and the same sensor will produce readings with a resolution of $\frac{1}{9.014} \cdot 56 \cdot 12 = 0.0001651$ inches per count.

A Start/Stop sensor with a gradient of 8.9905μS (Start/Stop sensors are not available with internal recirculations) will have a base resolution of $\frac{1}{8.9905} \cdot 56 \cdot 1 = 0.001986$ inches per count. If the sensor is used in multi-magnet mode, the resolution cannot be increased by recirculating the sensor. If the sensor is used with a single magnet, recirculations can be used. If the PCI4 is configured to perform fifteen external recirculations, the same sensor will produce readings with a resolution of $\frac{1}{8.9905} \cdot 56 \cdot 15 = 0.0001324$ inches per count.

Reading position from the sensor requires three steps. First, the sensor must be interrogated by sending an interrogate or start pulse to the sensor. Second, the sensor must end the PWM pulse or send a stop pulse after the magnetostrictive strain pulse has travelled the length of the sensor. Finally, the calculated position data must be read by the host PC.

1. To begin the reading, interrogate the sensor and reset the PCI4 counter and status registers, data is written to the Command register of the appropriate channel. The data written to the Command register controls how the PCI4 will interrogate the sensor. No other setup is required.

2. After the sensor has been interrogated, the PCI4 begins timing the output of the sensor. While waiting for a response, reads of the Status register will return a 0 in the Data Ready bit. If there is no magnet or sensor present, the Data Ready bit may never be set. The host PC is expected to detect this condition and retry the reading after an appropriate timeout delay.

3. When the Data Ready bit is set to a 1, the sensor read has been completed. At this point, the host PC can read the Sensor Data registers to retrieve the position data. The read sequence can be restarted

5 Using the PCI4 with SSI Sensors

SSI sensors produce a binary output in serial form in response to a clock signal from the host device. When an interrogation is started by writing to the Command Register, the PCI4 will produce the required clock signal and record the resulting output. The resolution of the data is controlled by the sensor, and must be configured when the sensor is purchased.

Reading position from the sensor requires three steps:

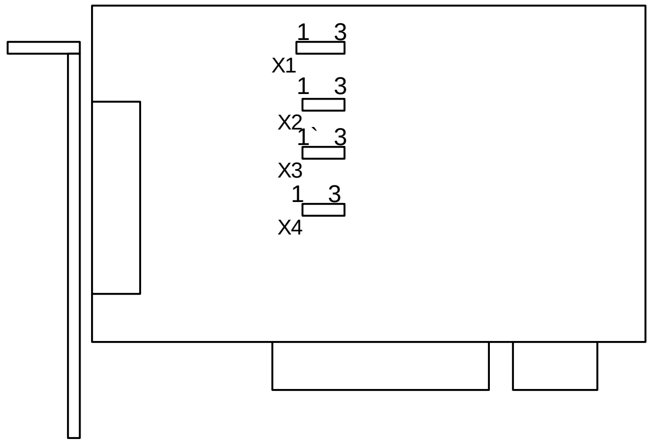
1. A write is made to the Command Register to begin sensor interrogation and reset the PCI4 counter and status registers. The data written to the Command Register controls how the PCI4 will interrogate the sensor. No other setup is required.

2. The PCI4 will immediately begin clocking data from the sensor. While the response is completing, the DR Flag will be 0.

3. When the DR Flag is set to a 1, the sensor read has been completed. At this point, the host PC can read the $DAT_{x2..0}$ registers to retrieve the position data.

6 Jumpers X1 through X4

Jumpers X1 through X4 must be set according to the sensor type the channel is configured for. These jumpers are factory set and should not need to be changed by the end user. Select 1-2 for Start/Stop and PWM sensors (channel types –R and –T). Select 2-3 for SSI sensors (channel type –S).



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Connections

6.1 Sensor Power Connector P1 (2-pin screw terminal)

Pin	Function	Description
1	Sensor Power Input	This pin is connected to all sensor power pins on connector P2.
2	Sensor Ground	This pin is connected to all sensor ground pins on connector P2.

6.2 Sensor Connector P2 (37-pin D-Sub)

Channel	Pin	Function	Description
A	1	Gate/Stop/Data -	Channel A input from sensor (inverted)
	2	Interrogate/Start/Clock +	Channel A output to sensor (non-inverted)
	3	Ground	Channel A sensor ground when distributing power through P1
	20	Gate/Stop/Data +	Channel A input from sensor (non-inverted)
	21	Interrogate/Start/Clock -	Channel A output to sensor (inverted)
	22	Power	Channel A sensor power when distributing power through P1
B	4	Gate/Stop/Data -	Channel B input from sensor (inverted)
	5	Interrogate/Start/Clock +	Channel B output to sensor (non-inverted)
	6	Ground	Channel B sensor ground when distributing power through P1
	23	Gate/Stop/Data +	Channel B input from sensor (non-inverted)
	24	Interrogate/Start/Clock -	Channel B output to sensor (inverted)
	25	Power	Channel B sensor power when distributing power through P1
C	7	Gate/Stop/Data -	Channel C input from sensor (inverted)
	8	Interrogate/Start/Clock +	Channel C output to sensor (non-inverted)
	9	Ground	Channel C sensor ground when distributing power through P1
	26	Gate/Stop/Data +	Channel C input from sensor (non-inverted)
	27	Interrogate/Start/Clock -	Channel C output to sensor (inverted)
	28	Power	Channel C sensor power when distributing power through P1
D	10	Gate/Stop/Data -	Channel D input from sensor (inverted)
	11	Interrogate/Start/Clock +	Channel D output to sensor (non-inverted)
	12	Ground	Channel D sensor ground when distributing power through P1
	29	Gate/Stop/Data +	Channel D input from sensor (non-inverted)
	30	Interrogate/Start/Clock -	Channel D output to sensor (inverted)
	31	Power	Channel D sensor power when distributing power through P1
Pins 13-19 and 32-37 are reserved and should not be used.			

Sensor grounds (P2 pins 3, 6, 9 and 12) must be connected to the PCI4, sensor, and sensor power supply. These pins are connected together on the PCI4 and are connected to P1-2.

Sensor power (P2 pins 22, 25, 28 and 31) are connected together on the PCI4 and connect to P1-1. Sensor power can be connected to P1 to distribute power to the sensors. Alternately, power can be provided to the sensors externally.

7 Optional Screw Terminal

The CAB-TERM-37 is a cable and DIN-rail mount screw terminal block. The cable is built with twisted pairs for all sensor signals and is available in lengths from 3 to 50 feet.

Using the CAB-TERM-37 removes the need to build a custom cable and provides convenient screw terminal connections. Screw terminal numbering matches the pin numbering of the P2 connector.