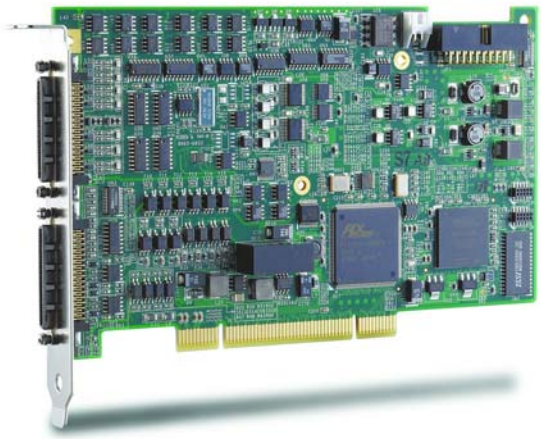
PCI-9524

24-Bit Precision Load Cell Input Card

User's Manual



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2.02	2008/08/26	Correct typo

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Preface

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Using this Manual

Audience and Scope

The PCI-9524 User's Manual is intended for hardware technicians and systems operators with knowledge of installing, configuring and operating industrial grade PCI cards.

Manual Organization

This manual is organized as follows:

Preface: Presents important copyright notifications, disclaimers, trademarks, and associated information on the proper understanding and usage of this document and its associated product(s).

Chapter 1, Introduction: Introduces the PCI-9524, its features, applications, specifications and operating software environment.

Chapter 2, Installation: Describes how to install the PCI-9524 into your chassis and basic PCI configuration settings.

Chapter 3, Signal Connections: Describes signal connections between PCI-9524 and external devices.

Chapter 4, Operation Theory: Describes A/D and D/A conversions, pulse-commands, encoder inputs and isolated digital I/O signals to assist users in understanding how to configure and program the cPCI-9524.

Chapter 5, Calibration: Presents the calibration process to minimize measurement and output errors.

Important Safety Instructions: Presents safety instructions all users must follow for the proper setup, installation and usage of equipment and/or software.

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Take note of the following conventions used throughout this manual to make sure that users perform certain tasks and instructions properly.



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Information to prevent ***minor*** physical injury, component damage, data loss, and/or program corruption when trying to complete a task.



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1 Introduction

The ADLINK PCI-9524 is a 24-bit high-resolution multifunction DAQ card capable of up to 30 kS/s sampling rate, providing 4-CH load-cell transducer input channels, and 4-CH general purpose analog input. In addition, the PCI-9524 comes with a 2-CH 16-bit analog output, isolated motion I/O and digital I/O. The highly integrated function makes the PCI-9524 the ideal solution for combined data acquisition and motion control functionalities. Ideal for manufacturing, laboratory research, and factory automation, the PCI-9524 comes with all the features and performance you need at an affordable price.



Figure 1-1: PCI-9524 Product Image

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1.1 Features

PCI-9524 24-bit multifunction DAQ card provides the following advanced features:

- Supports 32-bit 3.3 V or 5V PCI bus
- Load-cell transducer input channels
  - 4-CH differential analog input with remote-sense
  - 4-CH transducer excitation, 10 V or 2.5 V selectable
  - Auto-zero capability
  - Up to 30 kS/s sampling rate without auto-zero
  - IIR digital filter for post-processing
- General purpose analog input channels
  - 4-CH differential analog input
  - Programmable gains: x1, x2, x4, x8
  - Up to 30 kS/s sampling rate
- 2-CH 16-bit analog output
- 3-CH opto-isolated pulse-command output, supporting AB phase, CW/CCW, CLK/DIR modes
- 3-CH opto-isolated encoder input, supports AB phase inputs in quadrature mode
- 8-CH opto-isolated digital inputs
- 8-CH opto-isolated digital outputs with N-MOS sink drivers
- Auto-calibration

1.2 Applications

- Materials Testing Systems
- Precision Weighting Systems
- Automotive Testing
- Process Control
- Laboratory Automation
- Biotech Measurements

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1.3 Specifications

Analog Input (AI) for Transducers

- Number of channels: (programmable)
  - 4 differential inputs (DI)
- A/D converter:
  - ADS1255
- Maximum sampling rate:

  Without Auto-zero
  - 30,000 samples/s (single channel)
  - 1,638 samples/s (multiplexed/scanning)

  With Auto-zero
  - 819 samples/s (single channel or multiplexed/scanning)
- Resolution:
  - 24-bit
- Input coupling: DC
- Input range and gain:
  - ±200 mV relative to a common-mode input voltage
  - A fixed gain of 25x
- Operational common-mode input range:
  - -2 V to +6 V
- Transducer Excitation Voltage Sources:
  - 4-CH differential output
  - 10 V or 2.5 V selectable (all 4-CH share same settings)
  - Driving up to four 120-ohm load-cells
  - Short-circuit protection
- Remote-sense input:
  - 4-CH differential input
  - 0 V to 10 V operating input range
- Overvoltage protection:

  Transducer inputs
  - Power on: +28.7 V to -35.7 V (continuous)
  - Power off: ±15 V (continuous)

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Remote-sense inputs:

- ▷ Power on: -40 V to +55 V (continuous)
- ▷ Power off: -40 V to +55 V (continuous)

- ▶ FIFO buffer size: 1024 samples (1024 x 32 bits)
- ▶ Data transfers:
  - ▷ Programmed I/O
  - ▷ Bus-mastering DMA with scatter/gather

Table 1-1: -3dB small signal bandwidth: (Typical, 25°C)

Input Range	Bandwidth (-3dB)
±200 mV	2,730 Hz

Table 1-2: System Noise (including Quantization, Typical, 25°C)

Input Range	Data Rate in SPS	System Noise in LSB_{rms}	RMS Res. in Bits (ENOB)	Peak Res. in Bits	RMS Res in µV	Peak Res. in µV
±200 mV	1.25	0.5	23.0	21.0	0.013	0.053
	2.5	0.6	22.8	20.4	0.014	-0.079
	5.0	0.6	22.7	20.4	0.016	0.079
	7.5	0.7	22.6	20.0	0.017	0.079
	12	0.9	22.2	19.7	0.023	0.159
	15	0.8	22.3	19.7	0.020	0.132
	24	1.2	21.8	19.2	0.031	0.212
	29	1.1	21.9	19.0	0.030	0.185
	47	1.9	21.1	18.6	0.037	0.291
	194	2.9	20.5	17.7	0.078	0.583

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Input Range	Data Rate in SPS	System Noise in LSB_{rms}	RMS Res. in Bits (ENOB)	Peak Res. in Bits	RMS Res in µV	Peak Res. in µV
±200 mV	316	3.7	20.1	17.1	0.101	0.742
	463	5.5	19.6	16.4	0.146	1.113
	595	6.9	19.2	16.4	0.185	1.351
	704	8.9	18.9	15.9	0.243	1.748
	768	10.9	18.6	15.5	0.306	2.305
	819	12.6	18.4	15.4	0.328	2.331

Test conditions: Rice Lake Load-cell Simulator IV set at 0mV/V output, 10V excitation and six-wire remote-sense connection, auto-zero enabled. The RMS resolution and peak resolution are calculated relative to full-scale input range of ±200mV.

Table 1-3: Transducer Input Impedance

Normal Power On	Power Off	Overload
1 GΩ || 3 pF	1 KΩ	1 KΩ

Table 1-4: Transducer CMRR (DC to 60 Hz, Typical 25°C)

Input Range	CMRR
±200 mV	90 dB (Auto-zero Disabled)
	102 dB (Auto-zero Enabled)

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Table 1-5: Settling Error: (Typical, 25°C)

Input Range	Condition	Settling Error
±200 mV	Scanning 200 mV step	max 0.01%

- Time-base source: Internal 40 MHz
- Trigger mode: post-trigger
- Offset error:
  - Before calibration: ±0.5 mV typical
  - After calibration: ±0.001 mV typical (auto-zero disabled), < ±0.001 mV typical (auto-zero enabled)
- Transfer Linearity:
  - Better than: ±0.0035% over full-scale input range
- Gain error:
  - Before calibration: ±1% typical
  - After calibration: ±0.5% typical

Analog Input (AI) for General Purpose

- Number of channels: (programmable)
  - 4 differential input (DI)
- A/D converter:
  - ADS1255
- Maximum sampling rate:
  - 30,000 samples/s (single channel)
  - 1.638 samples/s (multiplexed/scanning)
- Resolution:
  - 24-bit
- Input coupling: DC

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Table 1-6: Programmable input range and gain

Bipolar Input Range	Gain
±10 V	1
±5 V	2
±2.5 V	4
±1.25 V	8

- Operational common-mode input range: ±13V
- Overvoltage protection:
  - Power on: ±30 V (continuous)
  - Power off: ±15 V (continuous)
- FIFO buffer size: 1024 samples (1024 x 32 bits)
- Data transfers:
  - Programmed I/O
  - Bus-mastering DMA with scatter/gather
- -3dB small signal bandwidth (Typical, 25ºC)

Table 1-7: -3dB small signal bandwidth vs. input range

Input Range	Bandwidth (-3dB)
±10 V	5,800 Hz
±5 V	5,900 Hz
±2.5 V	5,900 Hz
±1.25 V	5,900 Hz

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Table 1-8: -3dB small signal bandwidth vs. sampling rates, in ±10V range

Sampling Rate In Samples-per-second (SPS)	Bandwidth (-3 dB)
2.5	1.1 Hz
5	2.2 Hz
10	4.4 Hz
15	6.6 Hz
25	11 Hz
30	13 Hz
50	22 Hz
60	26 Hz
100	44 Hz
500	220 Hz
1,000	440 Hz
2,000	880 Hz
3,750	1,600 Hz
7,500	3,000 Hz
15,000	4,800 Hz
30,000	5,800 Hz

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System Noise (LSBrms, including Quantization, Typical, 25ºC)

Figure 1-2: Effective-number-of-bits vs. Gain

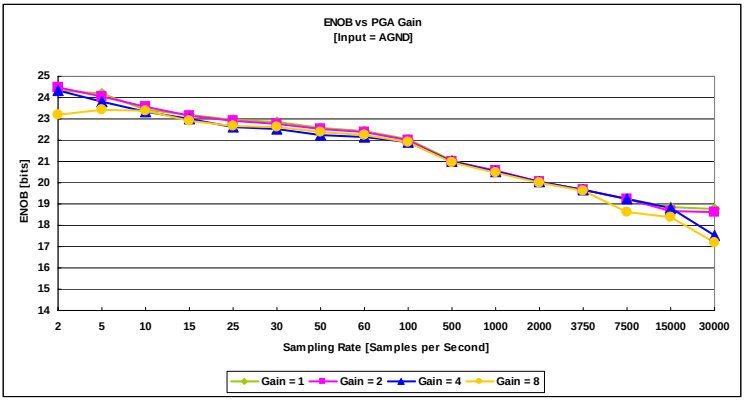
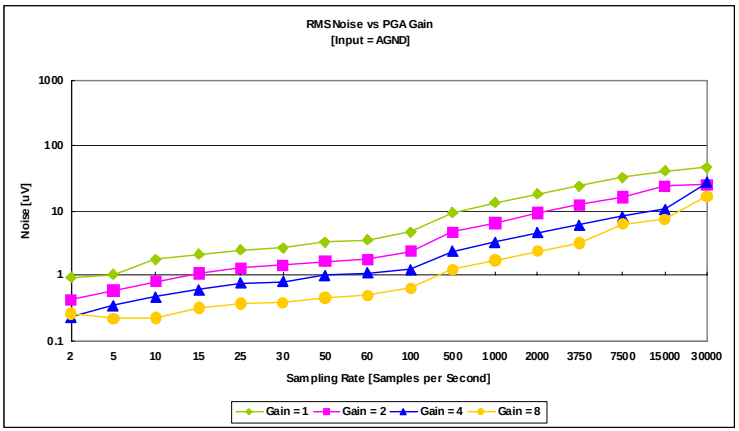


Figure 1-3: RMS Noise in µV vs. Gain



Test conditions: RMS resolution and peak resolution are calculated relative to the full-scale range of their gain settings, using internal calibration voltage references.

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Spectral Response (At 30,000-SPS, Typical, 25ºC)

Figure 1-4: Spectral Response ±10 V range, 0.996094 Hz sine wave, -1 dB FS

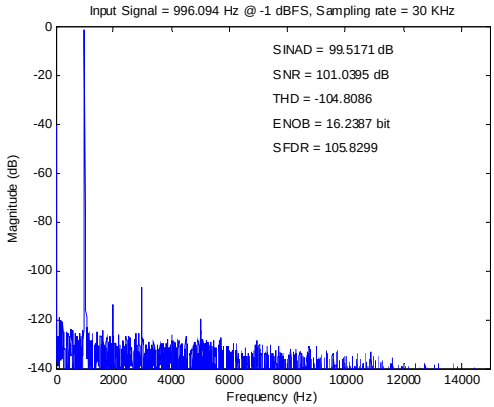
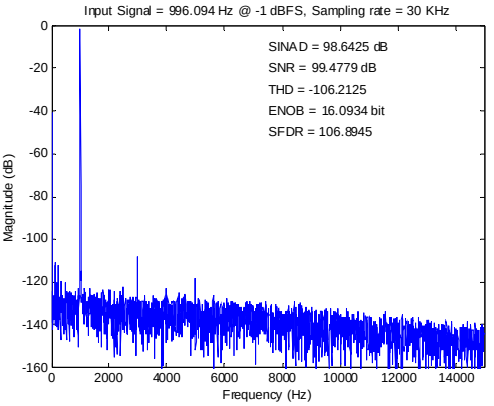


Figure 1-5: Spectral Response ±5 V range, 0.996094 Hz sine wave, -1 dB FS



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Figure 1-6: Spectral Response ±2.5 V range, 0.996094 Hz sine wave, -1 dB FS

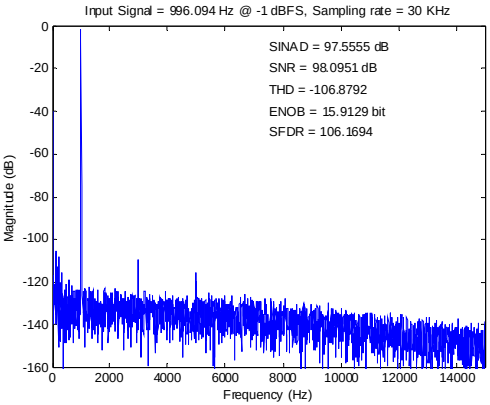
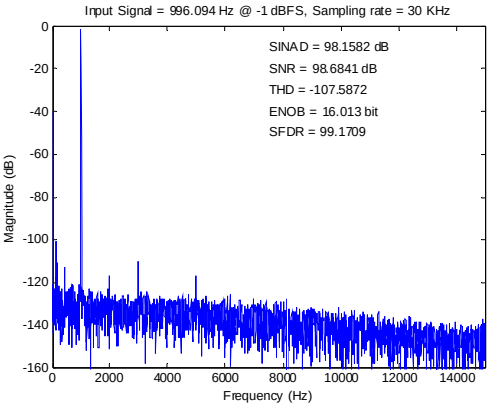


Figure 1-7: Spectral Response ±1.25 V range, 0.996094 Hz sine wave, -1 dB FS



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Frequency Response (vs. normalized sampling frequencies):

Figure 1-8: Frequency Response Sampling at 30,000 SPS

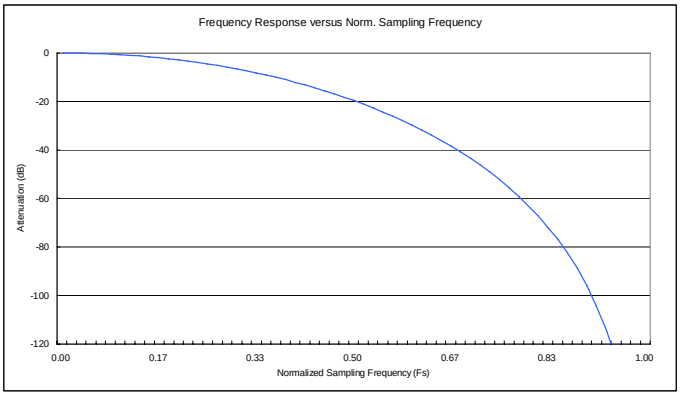
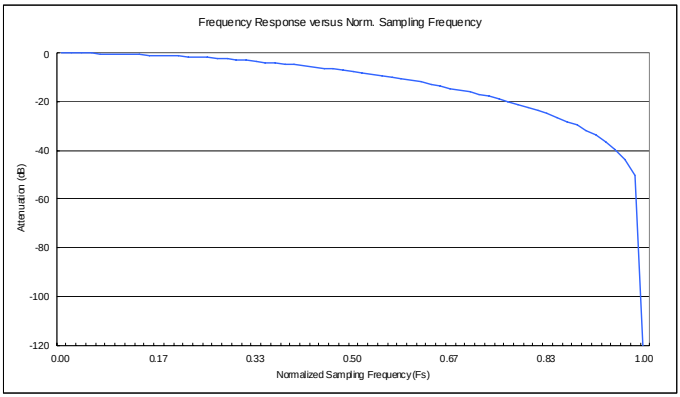


Figure 1-9: Frequency Response Sampling at 15,000 SPS



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Figure 1-10: Frequency Response Sampling below 15,000 SPS

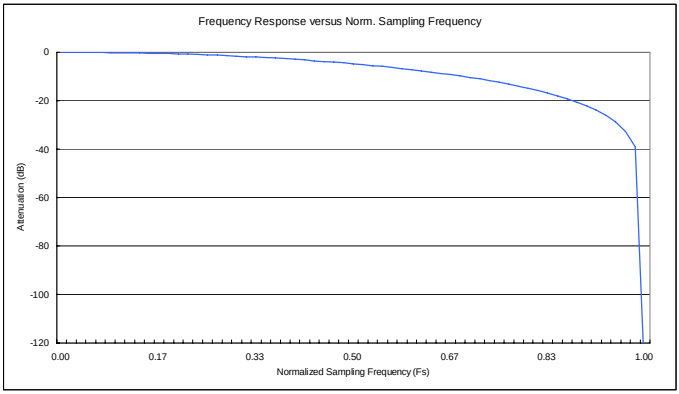


Table 1-9: General Purpose Input Impedance

Normal Power On	Power Off	Overload
1 GΩ || 3 pF	1 KΩ	1 KΩ

Table 1-10: General Purpose CMRR (DC to 60 Hz, Typical, 25°C)

Input Range	CMRR
±10 V	80 dB
±5 V	86 dB
±2.5 V	94 dB
±1.25 V	98 dB

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Table 1-11: **Settling Error: (Typical, 25ºC)**

Input Range	Condition	Settling Error
±10 V	Scanning 20 Vpp	<0.0005%
±5 V	Scanning 10 Vpp	<0.0005%
±2.5 V	Scanning 5 Vpp	<0.0005%
±1.25 V	Scanning 2.5 Vpp	<0.0005%

- Time-base source: Internal 40 MHz
- Trigger mode: post-trigger
- Offset error:
  - Before calibration: ±2 mV typical 25ºC
  - After calibration: ±0.1 mV typical 25ºC
- Gain error:
  - Before calibration: ±0.5% typical 25ºC
  - After calibration: ±0.01% typical 25ºC

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Analog Output (AO)

- Number of channels: 2 analog voltage outputs
- D/A converter: DAC8812
- Maximum update rate: 10 K sample/s
- Resolution: 16-bit
- Data transfers: Programmed I/O
- Output range: ±10 V
- Settling time (0.1% of full scale): 2 µs
- Slew rate: 15 V/µS
- Output coupling: DC
- Protection: Short-circuit to ground, indefinitely
- Output impedance: 0.1 Ω max
- Output driving: ±5 mA max.
- Stability: Any passive load, up to 1500 pF
- Power-on state: Around 0 V steady-state
- Offset error:
  - Before calibration: ±4 mV typical 25ºC
  - After calibration: ±1 mV typical 25ºC
- Gain error:
  - Before calibration: ±0.8% of output max.
  - After calibration: ±0.015% of output max.

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Isolated Pulse Command Outputs

- Number **of channels: *3***
- Output type: AM26LS31 differential line-driver
- Compliant to ANSI TIA/EIA-422-B and ITU Recommendation V.11 standards
- Logic Compatibility: 5V TTL with complementary output
- Output voltage:
  - Logic low: VOL = 0.5 V max.; IOL = 20 mA max.
  - Logic high: VOH = 2.4 V min.; IIH = -20 mA max.
- Programmable duty cycle: 1% to 99%
- Maximum pulse frequency: 1 MHz
- Direction control modes: CLK/DIR & CW/CCW
- Pulse counter: 1 to 16777215
- Pulse Comparator Trigger to initiate AI acquisition once condition is met
- Data transfers: Programmed I/O

Isolated Quadrature Encoder Inputs

- Number of channels: 3
- Input type: AB-Phase differential inputs
- **Input impedance: 249 Ω || 220 pF**
- Input voltage:
  - Logic low: VIL = 0.8 V max.
  - Logic high: VIH = 3.8 V min.
  - Logic high: VIH = 9 V max.
- Maximum Encoder frequency: 1 MHz
- Decoder type: Quadrature, 4X resolution
- Decoder counts: -8388608 to +8388607
- Positional Comparator Trigger to initiate AI acquisition once condition is met
- Data transfers: Programmed I/O

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Isolated Digital Inputs

- Number of channels: 8
- Input type: Bipolar, resistive differential
- Input impedance: 2.7 KΩ || 250 pF
- Input voltage:
  - Logic low: VIL = 0.7 V max.
  - Logic high: VIH = 4.8 V min.
  - Logic high: VIH = 24 V max.
- Maximum input frequency: 5 KHz
- Data transfers: Programmed I/O
- Digital Trigger to initiate AD conversion on DI channel 0, with programmable detection polarity

Isolated Digital Outputs

- Number of channels: 8
- Output type: N-Type MOSFET current sinker with a command ground
- Maximum external power-supply voltage: 60 V DC
- Drain-off leakage current: 10 μA
- Drain-on resistance: 75 mΩ
- Maximum drain current: 5 A DC
- Maximum toggling frequency: 5 KHz
- Data transfers: Programmed I/O

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Isolated Power Supplies

- Number of channels: 2
- Nominal output voltage
  - ISO5VDD: 5 V ±0.05V
  - ISOPWR: 5 V ±0.15V
- Output current (Pulse Command channels are unused)
  - ISO5VDD: 160 mA max.
  - ISOPWR: 16 mA max.
- Maximum output current (n^{th} channel of Pulse Command channel is used)
  - ISO5VDD: 160 - (20 x n) mA max.
  - ISOPWR:1 6mA max.

Physical

- Dimensions: 156 mm x 116 mm
- I/O connectors: two 68-pin SCSI-VHDCI connectors

Power Requirement (typical, 25ºC)

- +5 V DC: 2A

Operating Environment

- Ambient temperature: 0ºC to 45ºC
- Relative humidity: 10% to 90% non-condensing

Storage Environment

- Ambient temperature: -20ºC to 80ºC
- Relative humidity: 5% to 95% non-condensing

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1.4 Software Support

Software Support

ADLINK provides versatile software drivers and packages to suit various user approach to building a system. Aside from programming libraries, such as DLLs, for most Windows-based systems, ADLINK also provides drivers for other application environment such as LabVIEW®.

All software options are included in the ADLINK All-in-One CD. Commercial software drivers are protected with licensing codes. Without the code, you may install and run the demo version for trial/demonstration purposes only up to two hours. Contact your ADLINK dealers if you want to purchase the software license.

Programming Library

For customers who want to write their own programs, ADLINK provides the PCIS-DASK function library that is compatible with various operating systems.

PCIS-DASK

The PCIS-DASK includes device drivers and DLL for Windows 98/NT/2000/XP/Vista. DLL is binary compatible across Windows 98/NT/2000/XP/Vista. This means all applications developed with PCIS-DASK are compatible with these Windows operating systems. The developing environment may be VB, VC++, Delphi, BC5, or any Windows programming language that allows calls to a DLL. The PCIS-DASK user's and function reference manuals are in the ADLINK All-in-One CD. (\\Manual\Software Package\PCIS-DASK).

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2 Getting Started

This chapter further describes the PCI-9524; a proper installation environment, its package contents and basic information users should be aware of.

2.1 Installation Environment

Whenever unpacking and preparing to install any equipment described in this manual, please refer to the ***Important Safety Instructions*** chapter of this manual.

Only install equipment in well lit areas on flat, sturdy surfaces with access to basic tools such as flat and cross head screwdrivers, preferably with magnetic heads as screws and standoffs are small and easily misplaced.

Recommended Installation Tools

- Phillips (cross-head) screwdriver
- Flat-head screwdriver
- Anti-static Wrist Strap
- Anti-static mat

ADLINK PCI-9524 DAQ cards are electro-static sensitive equipment that can be easily damaged by static electricity. The equipment must be handled on a grounded anti-static mat. The operator must wear an anti-static wristband, grounded at the same point as the anti-static mat.

Inspect the carton and packaging for damage. Shipping and handling could cause damage to the equipment inside. Make sure that

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the equipment and its associated components have no damage before installing.



The equipment must be protected from static discharge and physical shock. Never remove any of the socketed parts except at a static-free workstation. Use the anti-static bag shipped with the product to handle the equipment and wear a grounded wrist strap when servicing.

2.2 Package Contents

Before continuing, check the package contents for any damage and check if the following items are included in the packaging:

- PCI-9524 Multi-function Data Acquisition Card
- ADLINK All-in-one Compact Disc
- Software Installation Guide
- PCI-9524 User's Manual

If any of these items are missing or damaged, contact the dealer from whom you purchased the product. Save the shipping materials and carton in case you want to ship or store the product in the future.

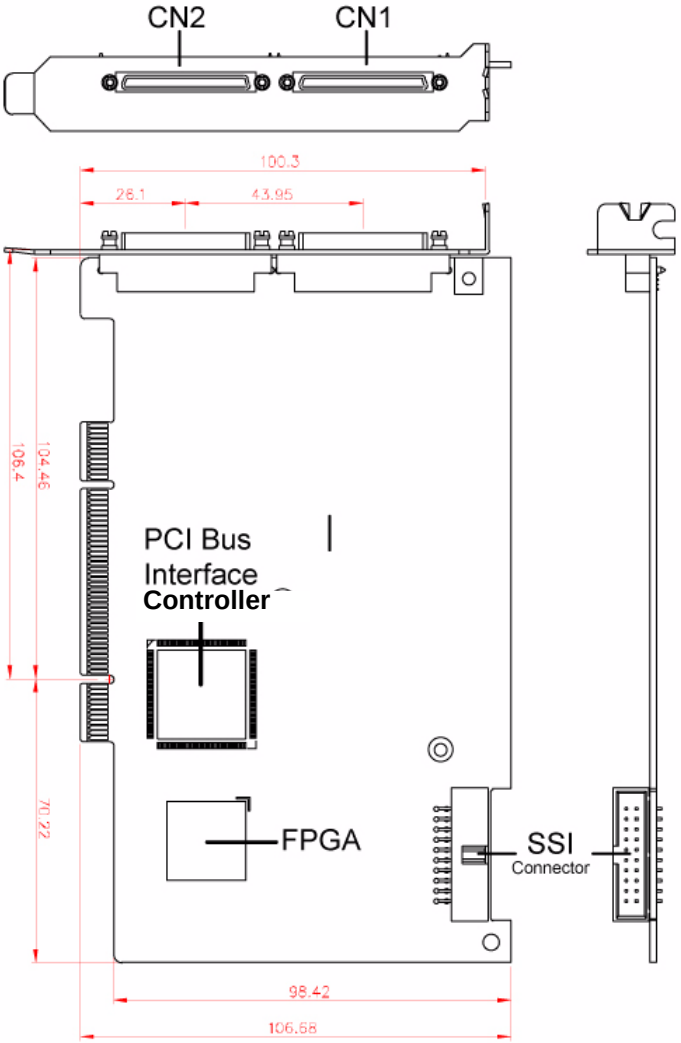


DO NOT install or apply power to equipment that is damaged or if there is missing/incomplete equipment. Retain the shipping carton and packing materials for inspection. Please contact your ADLINK dealer/vendor immediately for assistance. Obtain authorization from your dealer before returning any product to ADLINK.

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2.3 PCI-9524 Layout

Figure 2-1: PCI-9524 PCB Layout and Mechanical Drawing



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2.4 Installing the Card

To install the card:

1. Turn off the system/chassis and disconnect the power plug from the power source.
2. Remove the system/chassis cover.
3. Select the PCI slot that you intend to use, then remove the bracket opposite the slot, if any.
4. Align the card connectors (golden fingers) with the slot, then press the card firmly until the card is completely seated on the slot.
5. Secure the card to the chassis with a screw.
6. Replace the system/chassis cover.
7. Connect the power plug to a power source, then turn on the system/chassis.

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2.5 PCI Configuration

1. Plug and Play:

As a plug and play component, the card requests an interrupt number via its PCI controller. The system BIOS responds with an interrupt assignment based on the card information and on known system parameters. These system parameters are determined by the installed drivers and the hardware load recognized by the system. Users can use the PCI_SCAN software utility on the ADLINK All-in-One CD to read/check the system configuration.

2. Configuration:

The board configuration is done on a board-by-board basis for all PCI boards on your system. Because configuration is controlled by the system and software, there is no jumper setting required for base-address, DMA, and interrupt IRQ.

The configuration is subject to change with every boot of the system as new boards are added or removed.

3. Trouble shooting:

If your system doesn't boot or if you experience erratic operation with your PCI board in place, it's likely caused by an interrupt conflict (perhaps the BIOS Setup is incorrectly configured). In general, the solution, once you determine it is not a simple oversight, is to consult the BIOS documentation that comes with your system.

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3 Signal Connections

This chapter describes the connectors of PCI-9524, and the signal connections between PCI-9524 and external devices. Please see Figure 3-1, Figure 3-2 and Figure 3-3 for details.

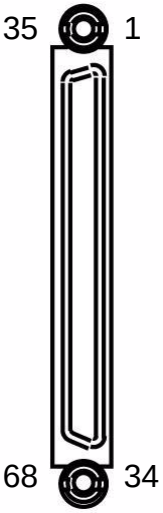
- CN1/CN2 - 68-pin VHDCI Connector
- SSI - SSI Connector

3.1 Connectors & Pin Assignments

PCI-9524 is equipped with two 68-pin VHDCI connectors. They are used for digital input/output, analog input/output, etc. The SSI connector is used for system synchronization.

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Figure 3-1: CN1 Connector & Pin Assignments



	Pin #	Pin #	
AI0+	34	68	AI0-
VEX0+	33	67	VEX0-
VEX_SEN0+	32	66	VEX_SEN0-
NC	31	65	NC
AI1+	30	64	AI1-
VEX1+	29	63	VEX1-
VEX_SEN1+	28	62	VEX_SEN1-
NC	27	61	NC
AI2+	26	60	AI2-
VEX2+	25	59	VEX2-
VEX_SEN2+	24	58	VEX_SEN2-
NC	23	57	NC
AI3+	22	56	AI3-
VEX3+	21	55	VEX3-
VEX_SEN3+	20	54	VEX_SEN3-
NC	19	53	NC
AGND	18	52	AGND
AIH4	17	51	AIL4
AIH5	16	50	AIL5
AIH6	15	49	AIL6
AIH7	14	48	AIL7
AGND	13	47	AGND
AGND	12	46	AGND
AGND	11	45	AGND
AGND	10	44	AGND
AGND	9	43	AGND
AGND	8	42	AGND
AGND	7	41	AGND
AGND	6	40	AGND
AGND	5	39	AGND
AO0	4	38	AGND
AGND	3	37	AGND
AO1	2	36	AGND
AGND	1	35	AGND

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Figure 3-2: CN2 Connector & Pin Assignments

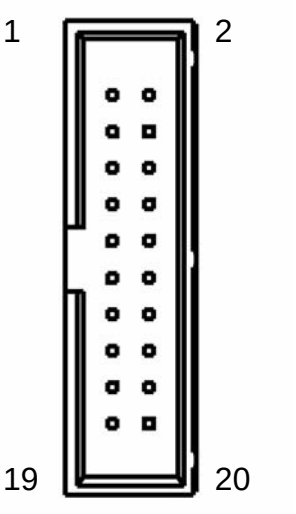


	Pin #	Pin #	
PULSE0_A+	34	68	PULSE0_A-
PULSE0_B+	33	67	PULSE0_B-
ISO5VDD	32	66	ISOGND
PULSE1_A+	31	65	PULSE1_A-
PULSE1_B+	30	64	PULSE1_B-
ISO5VDD	29	63	ISOGND
PULSE2_A+	28	62	PULSE2_A-
PULSE2_B+	27	61	PULSE2_B-
ISO5VDD	26	60	ISOGND
ENC0_A+	25	59	ENC0_A-
ENC0_B+	24	58	ENC0_B-
ISOPWR	23	57	ISOGND
ENC1_A+	22	56	ENC1_A-
ENC1_B+	21	55	ENC1_B-
ISOPWR	20	54	ISOGND
ENC2_A+	19	53	ENC2_A-
ENC2_B+	18	52	ENC2_B-
ISOPWR	17	51	ISOGND
IDI0+	16	50	IDI0-
IDI1+	15	49	IDI1-
IDI2+	14	48	IDI2-
IDI3+	13	47	IDI3-
ISOPWR	12	46	ISOGND
IDI4+	11	45	IDI4-
IDI5+	10	44	IDI5-
IDI6+	9	43	IDI6-
IDI7+	8	42	IDI7-
ISOPWR	7	41	ISOGND
IDO0	6	40	IDO1
IDO2	5	39	IDO3
EXT_ISOPWR	4	38	ISOGND
ISOPWR	3	37	ISOGND
IDO4	2	36	IDO5
IDO6	1	35	IDO7

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Figure 3-3: SSI Connector & Pin Assignments

PIN	Signal Name
11	SSI_AD_TRIG_IN
1, 3, 5, 7, 9, 13, 15	RSV
17	NC
19	NC
2, 4, 6,..., 20	DGND



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Table 3-1: I/O Signal Descriptions

Signal Name	Reference	Direction	Description
AI*n*+	AI*n*-	Input	Differential analog input channels. Channels 0 to 3 are for load-cell transducer inputs [1] [2], and channels 4 to 7 are for general purpose analog inputs.
VEX*n*+	VEX*n*-	Output	Analog outputs for transducer voltage excitation, in selectable ranges of 2.5V or 10V. Connect one excitation source to only one load-cell transducer; sharing a common wiring between transducers will degrade gain accuracy. Up to four 120-ohm load-cells can be connected to one PCI-9524. Load-cells with larger impedance can also be used.
VEX_SEN*n*+	VEX_SEN*n*+	Input	Remote-sense analog inputs for transducer excitation sensing. Always connect VEX_SENn+ to VEXn+, VEX_SENn- to VEXn-, and as close as possible to transducers excitation terminals.
AGND	--	--	Analog ground.
AO*n*	AGND	Output	Single-ended analog output channel.
PULSE*n*_A+	PULSE*n*_A-	Output	Pulse-command differential voltage outputs. As Clock signal in single phase mode. As Clock signal in CLK/DIR mode. As CW signal in CW/CCW mode.
PULSE*n*_B+	PULSE*n*_B-	Output	Pulse-command differential voltage outputs. Unused in single phase mode. As DIR signal in CLK/DIR mode. As CWW signal in CW/CCW mode.
ENC*n*_A+	ENC*n*_A-	Input	Encoder phase A inputs.
ENC*n*_B+	ENC*n*_B-	Input	Encoder phase B inputs.
IDI*n*+	IDI*n*-	Input	Isolated digital inputs. Accepts bipolar input signal.
IDO*n*+	IDO*n*-	Output	Isolated digital outputs. Using N-MOS as current sinker.

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ISO5VDD	ISOGND	Output	Isolated 5V output from internal regulator. Insignificant driving capacity, used for resistor pull-ups only.
ISOPWR	ISOGND	Output	Isolated 5V output from internal regulator. Insignificant driving capacity, used for resistor pull-ups only. May be modified to have 12 V output capability.
EXT_ISOPWR	ISOGND	Input	Use in conjunction with IDOn and external power supply, to provide current return path for fly-wheel diodes.
ISOGND	--	--	Isolated digital ground.
NC	--------	--------	Shall be left unconnected.


NOTE:

1) Short AIn+ and AIn- to AGND for unused transducer input channels
2) Exceeding the maximum input voltage range may permanently degrade performance, or damage the input amplifier.

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3.2 Analog Input Signal Connections

PCI-9524 provides eight differential analog input channels. To avoid ground loops and to achieve accurate low-level-signal measurements the PCI-9524 provides only differential input mode.

3.2.1 Signal Sources

Ground-Referenced Signal Sources

A ground-referenced signal is connected in some way to the buildings power system. That is, the signal source is already connected to a common ground point with respect to PCI-9524, assuming that the computer is plugged into the same power system. Non-isolated outputs of instruments and devices that plug into the buildings power system are ground-referenced signal sources.

Floating Signal Sources

A floating signal source is not connected in any way to the buildings ground system. A device with an isolated output is a floating signal source, such as optical isolator outputs, batteries, transformer outputs, load-cells and thermocouples.

3.2.2 Input Configurations

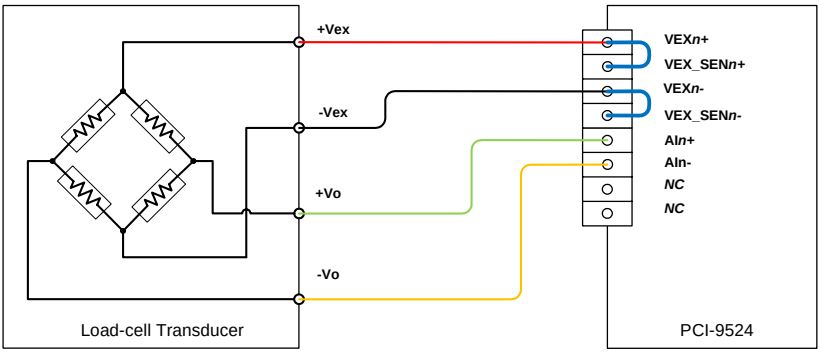
Differential input mode for transducer input channels

AI channels 0 to 3 are dedicated to connecting to load-cell transducers in differential mode.

A load-cell is comprised of four resistive strain-gauges connected in Wheatstone bridge form, and is inherently a floating differential output device. Since a load-cell transducer is a passive device, it requires voltage excitation in order to transform the resistive change into electrical signals. A typical four-wire connection is shown on Figure 3-4.

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Figure 3-4: Connecting to a four-terminal load-cell transducer using a four-wire connection

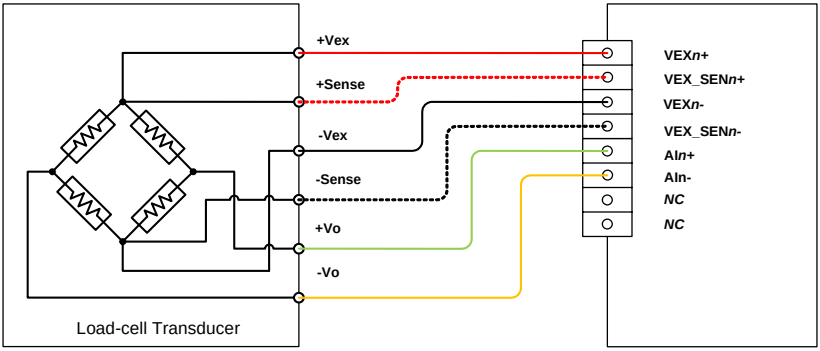


It is recommended to enable the remote-sense function, and loop-back the VEXn+/- to VEX_SENn+/- on the terminal board you're using when connecting to the transducer. A lengthy extension cable between PCI-9524 and the terminal board inevitably has some lead resistance that results in voltage drop; looping-back the excitation on the terminal board creates a six-wire connection and compensates for voltage drop.

A better approach is to use specially designed load-cell transducers having two additional SENSE terminals. The voltage difference across the bridge excitation junctions is fed back to the voltage excitation circuitry by two separate 'sense-wires', to further correct the voltage drops due to the resistance in the excitation wiring. Be sure to enable the remote-sense function to take full advantage of a six-wire connection. A typical six-wire connection is shown in Figure 3-5.

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Figure 3-5: Connecting to a six-terminal load-cell transducer using a six-wire connection

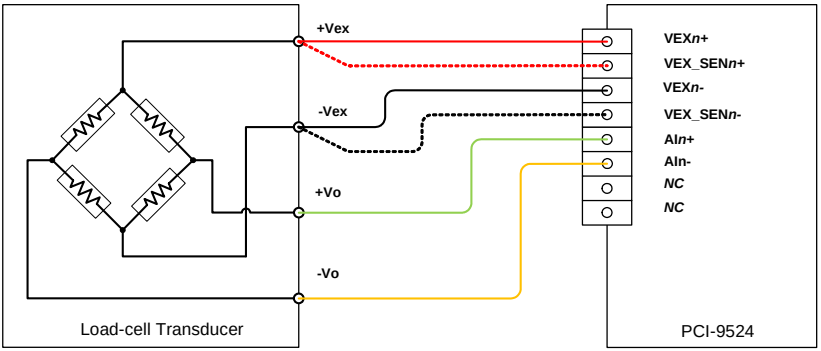


Whether to use a six-wire connection is dependent on the impedance of the load-cell transducers you are using, length of the wiring cable, wire-gauge inside the cable, and the required measurement accuracy. We recommend you to use a six-wire connection as the default connection method for high-accuracy load-cell transducers.

To add remote-sense capability to a four-terminal load-cell transducer, simply run two separate sense-wires, and join them together with the excitation wires at the transducer's excitation terminals.

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Figure 3-6: Connecting to a four-terminal load-cell transducer using a six-wire connection

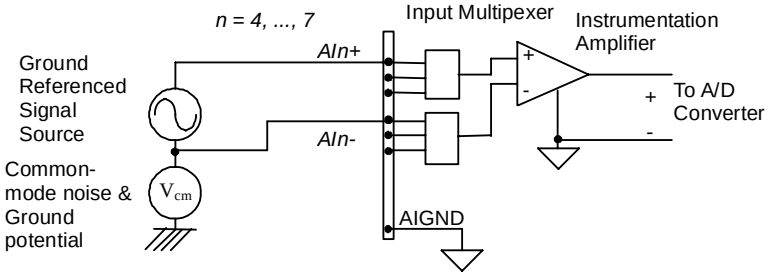


Differential input mode for general purpose input channels

AI channels 4 to 7 are designed for connecting to ground-referenced or floating sources in differential mode.

The differential input mode provides two inputs that respond to signal voltage difference between them. If the signal source is ground-referenced, the differential mode can be used for the common-mode noise rejection. Figure 3-7 presents an example of ground-referenced signal source connections under differential input mode.

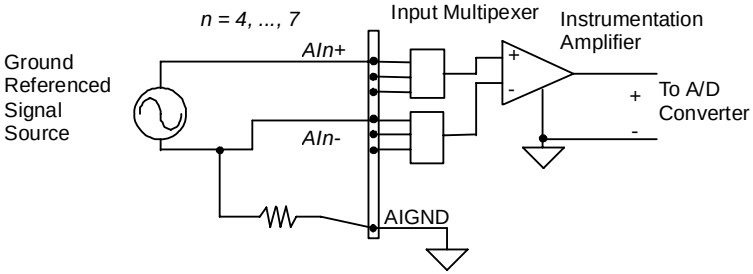
Figure 3-7: Ground-referenced source and differential input



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Figure 3-8 shows how to connect a floating signal source to PCI-9524 in differential input mode. For floating signal sources, you need to add a resistor at each channel to provide a bias return path. The resistor value should be about 100 times the equivalent source impedance. If the source impedance is less than 100Ω, you can simply connect the negative side of the signal to AIGND as well as the negative input of the Instrumentation Amplifier without any resistors. In differential input mode, less noise couples into the signal connections than in single-ended mode.

Figure 3-8: Floating source and differential input



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3.3 Isolated Digital Signal Connection

PCI-9524 provides three opto-isolated encoder input channels, three opto-isolated pulse-command outputs, eight channel opto-isolated digital inputs as well as eight channel isolated digital outputs. Also, a built-in isolated power supply can be used as a resistors pull-up source.

3.3.1 Signal Sources and Terminal Devices

Open-collector and open-drain outputs

Open-collector or open-drain output stages are commonly used in industrial I/O. Open-collector/open-drain output stages made of NPN or N-MOS type transistors are for sink-type drivers, while those made of PNP or P-MOS type are for source-type drivers. A sink-driver sinks current from the external pull-up resistor when it is activated, and floats when it is inactivated; conversely, a source-driver sources current to the external pull-down resistor when it is activated, and floats when it is inactivated. High-side voltage can usually go as high as the output transistor can tolerate, and hence offers a wider, more versatile output voltage selection. The drawback is that when the output stage is inactivated, either the signal fall-time of a source-driver or the rise-time of a sink-driver, is determined by the RC time-constant formed by the pull-up/pull-down resistor and the stray capacitance. The asymmetrical rise/fall-time somehow limits the frequency response of the output stage.

Push-pull outputs

Push-pull output stages are comprised of a complementary transistor pair, say, a PNP plus a PNP, or a P-MOS plus an N-MOS. Unlike open-collector output stages, they can sink or source current and hence a symmetrical rise/fall-time that is independent of the external load resistance. Push-pull output stages can generally toggle at a much faster speed than open-collector output stages.

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Line-driver outputs

A Line-driver output stage is of differential output type, providing a normal output and a complementary output for each signal port. A Line-driver usually works at a much lower supply voltage and can toggle quickly. By utilizing differential transmission topology, the transmission distance can be extended considerably and with relatively low EMI.

The line-driver used on PCI-9524 is of voltage-driving type AM26LS31, compliant with ANSI TIA/EIA-422-B requirements. Either one of the two complementary outputs can be regarded as a single-ended push-pull output, and can be connected to an opto-isolated input or a TTL input.

Opto-coupler Inputs

Opto-coupler inputs are of current input type devices, made of a light-emitting-diode (LED) and an integrated light-sensitive transistor. They accept wide input voltage ranges, provided that the input current is limited by a series external resistor in order to protect the integrated LED device.

Line-receiver inputs

The line-receiver, as its name implies, is used to accept signals from line-drivers. It's of differential input type, providing a normal input and a complementary input for each signal port.


NOTE:

1) The isolated ground (ISOGND) is shared between all isolated functions in PCI-9524. Make sure the ISOGND is connected to a known ground potential, only at one point in the system.
2) Do not let the ISOGND float, nor connect it directly to a chassis, as it may cause EMI and/or accumulate a charge that lead to safety hazards.
3) Shield the exposed ISOGND pins, connectors, and wiring, if possible to run a ground potential that is greater then 30-VDC.
4) Do not connect the ISOGND to analog ground (AGND), the noise on ISOGND will ruin analog performance.

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3.3.2 Connecting to/from External Encoders

Figure 3-9: Connecting to an external encoder with NPN sink drivers

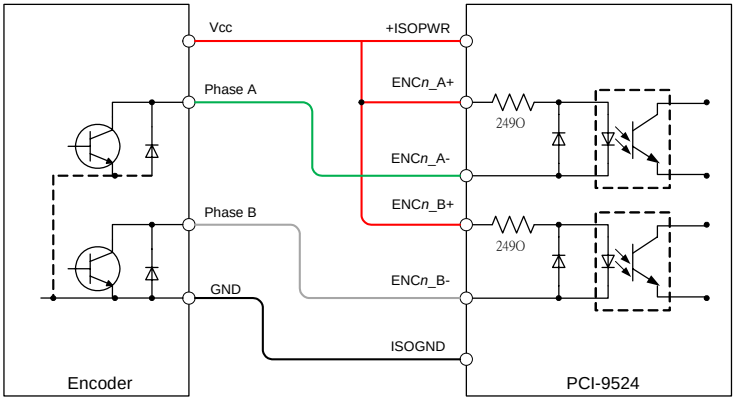
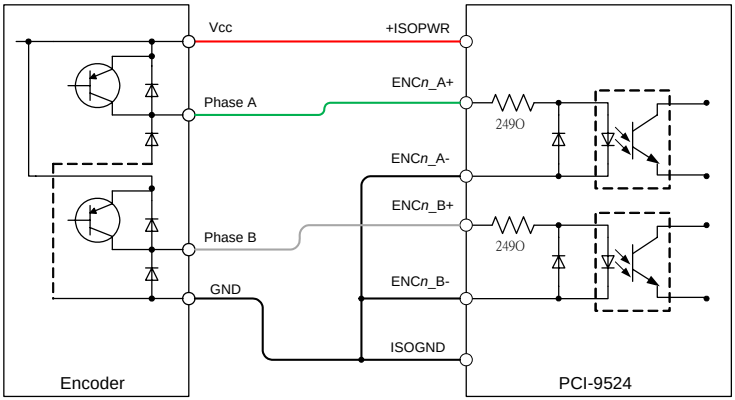


Figure 3-10: Connecting to an external encoder with PNP source drivers



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Figure 3-11: Connecting to an external encoder with push-pull source drivers

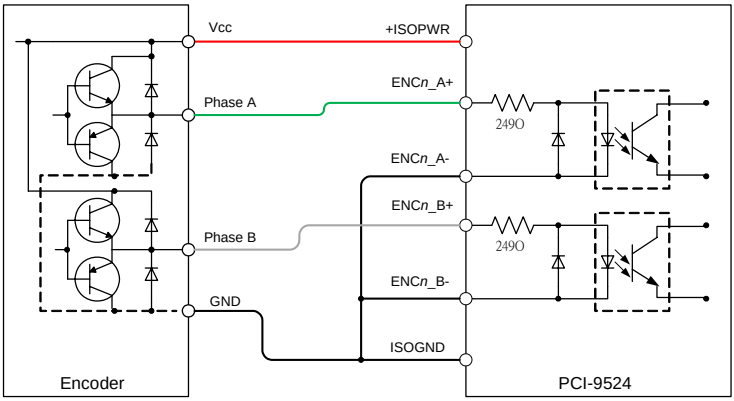
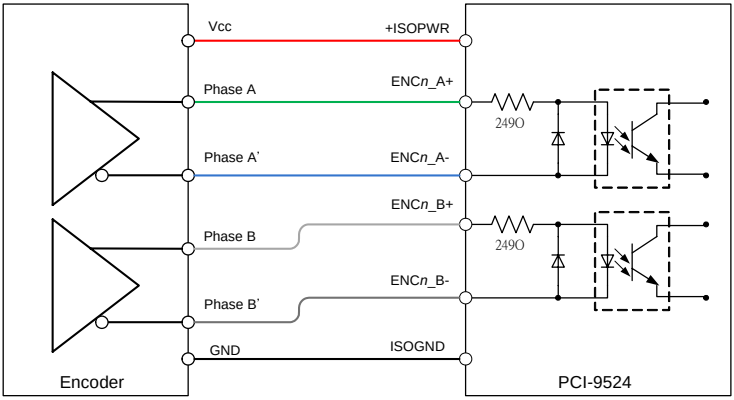


Figure 3-12: Connecting to an external encoder with differential line-drivers



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3.3.3 Connecting to External Servo Amplifiers

Figure 3-13: Connecting to an external servo-amplifier with opto-coupler inputs

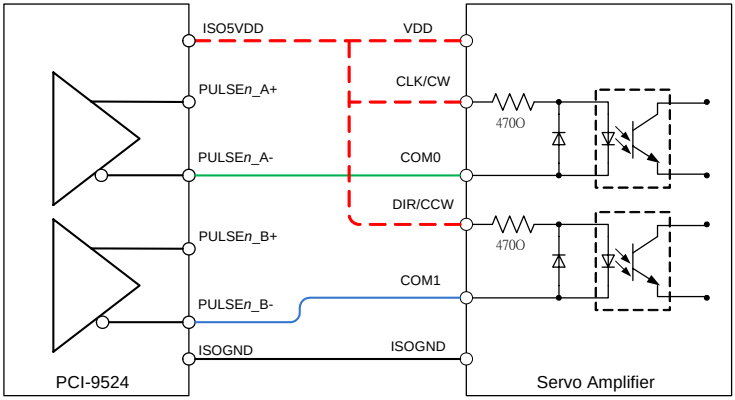
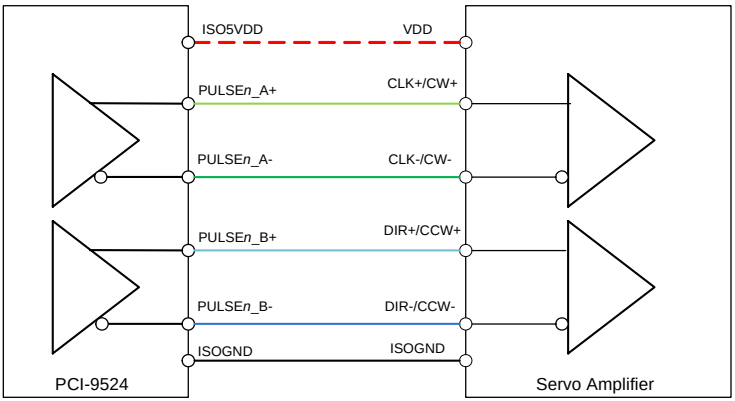


Figure 3-14: Connecting to an external servo-amplifier with differential line-receivers



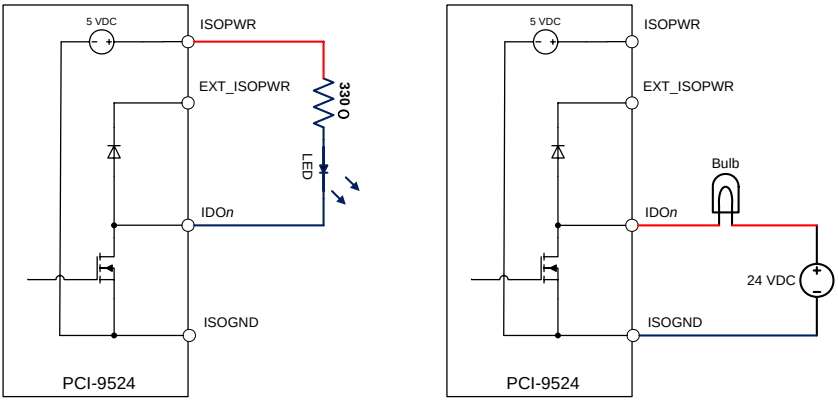
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3.3.4 Interfacing Isolated DO with External Loads

Connecting to external resistive loads

Figure 3-15 presents connecting to external resistive loads. The left side illustrates driving an external LED using the internal ISOPWR source; the right side illustrates driving an external 5W, 24-VDC Bulb using an external power supply.

Figure 3-15: Connecting to an external resistive load from the isolated DO sink driver

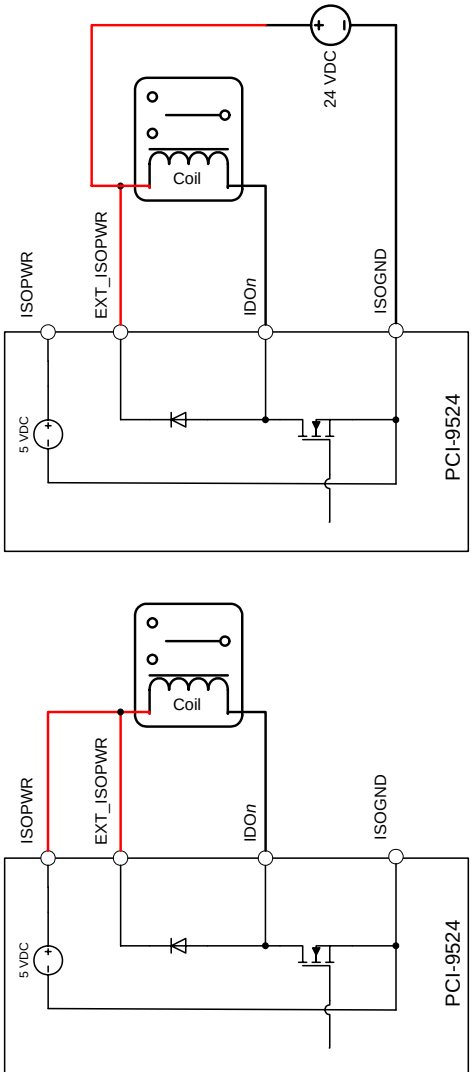


Connecting to external inductive loads

Figure 3-16 presents connecting to external resistive loads. The left side illustrates driving a 5-VDC relay coil using the internal ISOPWR source; the right side illustrates driving an external 12-VDC relay coil using an external power supply.

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Figure 3-16: Connecting to an external inductive load from an isolated DO sink driver



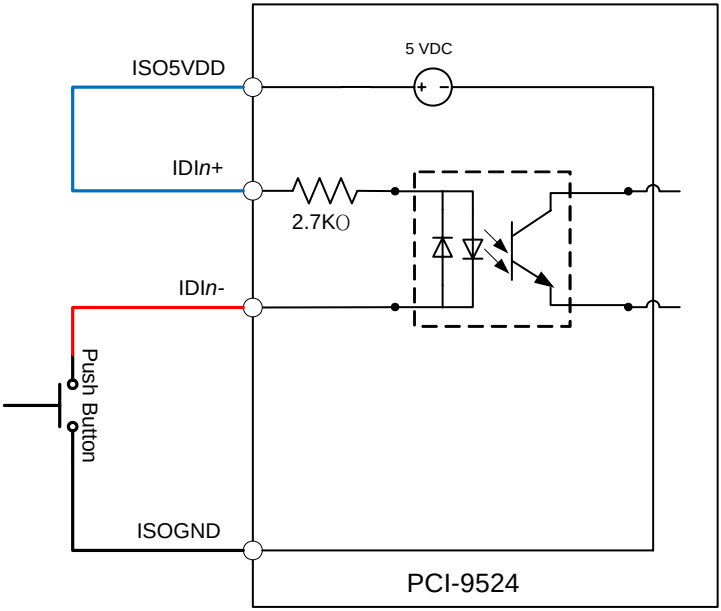
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3.3.5 Interfacing Isolated DI with External Devices

Connecting to a low-side push button

Alternatively, the push button can be connected at the high-side, i.e. between the ISOVDD and IDn+ pins. Also, the IDIn+ and IDIn- can be interchanged, since the opto-coupler accepts bipolar input signals.

Figure 3-17: Connecting to a low-side push button

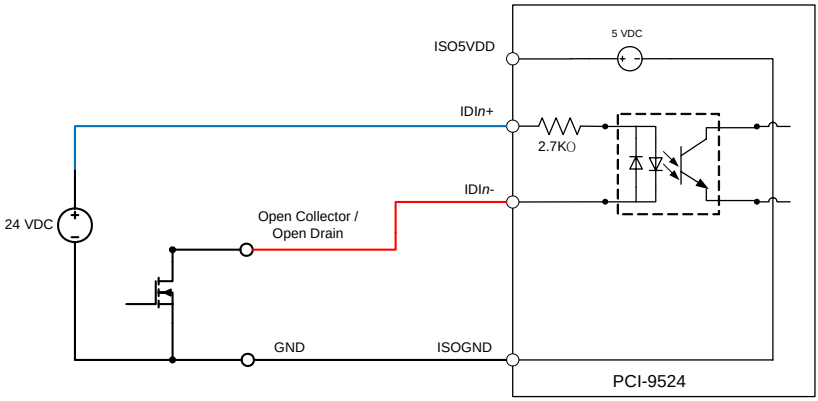


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Connecting to an external sink driver

The sink driver can also be replaced by a mechanical switch, a proximity-sensor, etc. An external power-supply can be used instead of the internal isolated power source.

Figure 3-18: Connecting to an external sink driver



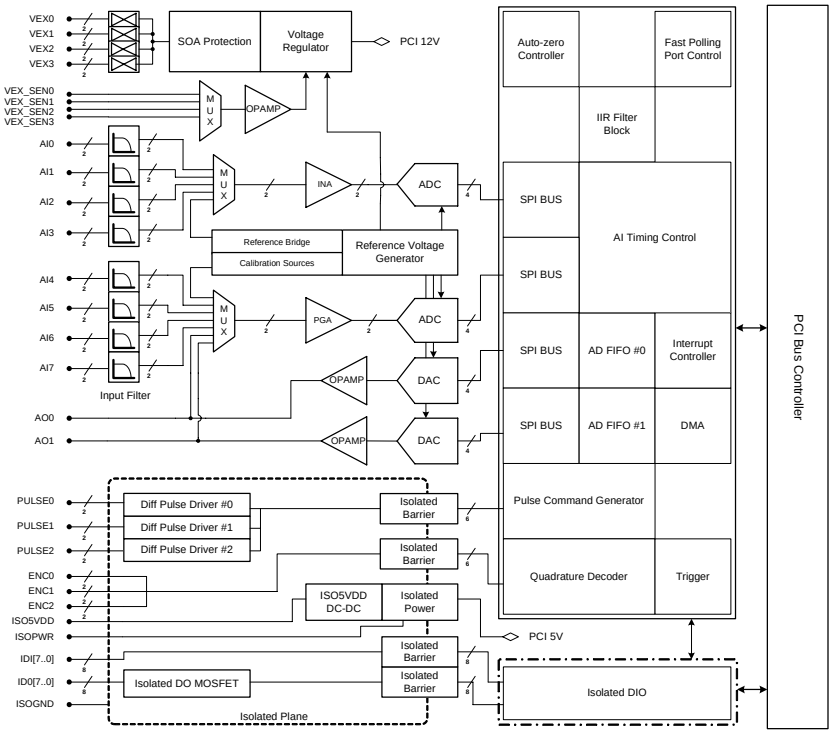
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4 Operation Theory

The operation theory of the functions of PCI-9524 are described in this chapter. The functions include A/D conversion, D/A conversion, pulse-commands, encoder inputs, and isolated digital I/O. Operation theory helps users understand how to configure and program PCI-9524.

4.1 PCI-9524 Function Diagram

Figure 4-1: PCI-9524 Function Diagram



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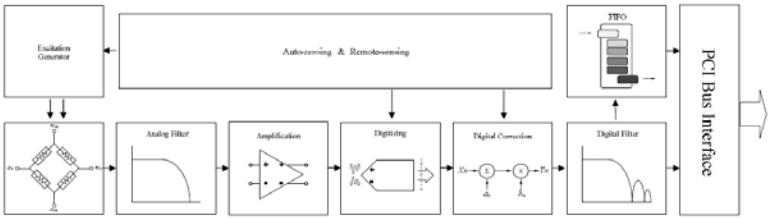
4.2 Analog Input Channels

The following sub-sections depict the internal operations of signal amplification, conversion, post-processing, and calibration.

4.2.1 Signal Acquisition and Processing Flow

PCI-9524 was designed to detect weak signals through proper signal conditioning, amplification and digital post filtering, as depicted.

Figure 4-2: Signal acquisition and data processing flow for transducer input channels



At the first stage, the voltage excitation applied to the load-cell transducer transforms the resistive change into an electric signal, in the range of tens of milli-volts. Before entering amplification stage, the signal passes through a passive filter stage to filter out unwanted interference. A custom-made, low temperature coefficient instrumentation amplifier provides a fixed gain of 25, and the necessary level-shift (1). The amplified signal is fed into a sigma-delta modulator running at 1.92 MHz, pushing the in-band quantization noise to a higher frequency, and filtering most of which out using a 5-order SINC filter. The filtered digital data passes through an averager to tune down the data rate to a specific sampling rate. A built-in correction algorithm automatically calibrates the output data, which can then be pushed into the on-board FIFO for data transfer to PC memory, or sent to the next DSP stage described below.

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There are four programmable post-processing IIR digital filter banks (2), one for each load-cell transducer input channel. Each bank is a fixed-coefficient, variable-length IIR digital filter, and can be instructed to flush itself once a large input-step is observed. The processed data are pushed into the on-board FIFO for DMA data transfer to PC memory; otherwise, they are read by user applications directly, without buffering, through fast-polling data transfers.

The software driver utilizes a look-up-table to correct the null offset and gain error of the analog front-end, using a built-in 1.25kΩ bridge, to provide adequate absolute accuracy for applications that do not calibrate load-cell transducers in the field. For applications that always perform null and gain calibrations in the field, users can manipulate the 2's complementary binary code directly.

Throughout the acquisition and processing flow, remote-sensing (3) and auto-zeroing (4) are working simultaneously to compensate voltage drops over excitation wires, and to remove thermal drift and 1/f noise in signal paths. The dynamic error compensation is essential to achieve high-stability measurements; otherwise the output will drift at a very low frequency that is difficult to be reconstructed using any other post-filtering method.


NOTE:

1) For general purpose analog input channels, i.e. channels 4 to 7, the available gain ranges are 1, 2, 4, and 8.
2), 3), 4) The general purpose analog input channels, i.e. channel 4 to 7, do not support the remote-sensing and auto-zeroing functions.

4.2.2 How to Define a 1 in 200,000 Count Resolution

It is common in the weight-scaling or material-testing industries to specify the resolution capability of a measurement device such as PCI-9524, in Counts or Digits, rather than in bits.

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For example, a measurement device that is capable of resolving 1 in 1000 counts, can successfully register a 1-gram change on a 1-kg capacity load-cell transducer. Consequently, a measurement device that is capable of resolving 1 in 200,000 counts, can successfully register a 1-gram change on a 200-kg capacity load-cell transducer.

In practical applications, the sensitivity of load-cell transducers vary from model to model (typically form 1 to 4mV/V), and the full-scale output range of a transducer is usually only a fraction of the full-scale input range of a measurement device. The convenience of using Counts rather than Bits, is that the specified Count achievable by a measurement device, is relative to the transducers full-scale output, rather than the full-scale input range of the analog input amplifier. Thus, theoretically, no matter what the sensitivity of the 200-kg capacity load-cell transducer you are using, a 200,000 count measurement device can always resolve a 1-gram measurement.

Please also note, as a weight/force indicator, the displayed Counts or Digits shall be flicker-free while the applied force is in steady state. Therefore, a measurement device specified to have a 200,000 count resolution, must guarantee peak-to-peak system noise and short-term drift to below 1 / 200,000, or 5-ppm of the full-scale output range of the transducer.

The specified 200,000 count resolution capacity of PCI-9524 is verified by a precision load-cell simulator utilizing 3mV/V sensitivity, under 10-V excitation and using a six-wire remote-sense connection. The auto-zero function is enabled throughout acquisition, while the ADC sampling rate is set to 60 samples-per-second (the equivalent data rate is 29 samples-per-second, see Section 4.2.3 for details), and using an IIR post digital filter of 32-taps (see Section 4.2.9 for details). Under these conditions, the peak-to-peak system noise and drift are well below 150-nano-Volts, the limit of 1 in 200,000 count resolution. The recording duration is 30

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minutes, and the ambient temperature fluctuation is within ± 1ºC throughout.

4.2.3 Data Rate versus Sampling Rate

Due to the internal delay time and manipulations required for auto-zeroing and remote-sensing functions, the 'Sampling Rate' that the ADC is actually running at can be different from the actual 'Data Rate'.

In the following sections, the term 'Sampling Rate' and 'Data Rate' are of different meaning. The 'Sampling Rate' stands for the ADC's internal conversion speed set by users, whereas the 'Data Rate' stands for the output rate of the processed data.

See Table 4-1 for equivalent data rates versus ADC actual sampling rates, under different operating modes. When programming through a software API, users must set the desired ADC sampling rate, and the actual 'Data Rate' will be looked-up and returned by the software API for your reference.

4.2.4 Auto-scan, Multiplexing and Settling Time

PCI-9524 uses multiplexing for transducer input channels, and up to four transducers can be attached. When the Auto-scan feature is enabled, the hardware multiplexes and scans the four transducers in sequence; AI0, AI1, AI2, AI3, and AI0…etc.

Multiplexing increases the number of transducers that a single amplifier can deal with, it does however require additional time for the signal to rise/fall and propagate through the circuit stages. The time delay therefore required is called 'Settling Time'. Besides the propagation delay within PCI-9524, the parasitic in the cabling, the impedance of the transducers, and the amplitude difference between channels, affect final settling time figures.

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PCI-9524 is programmed to have 400-µs default settling time, and this works best with low impedance transducers, such as 120 or 350-ohm load-cells. Insufficient settling time may causes inter-channel crosstalk; the new signal will not be able to fully settle to its final value, and some 'residual' signals in the previous measurement will be present in the current measurement. Users may increase the hardware settling time, to check if a lesser inter-channel crosstalk is perceived. See Table 4-1 for the equivalent Data Rates versus ADC actual Sampling Rates, under different operating modes.

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Table 4-1: Data Rates vs. Multiplexing, Auto-zero & ADC Sampling Rates, in Samples-per-second (SPS)

ADC Sampling Rate	Non-multiplexed		Multiplexed	
	Auto-zero Disabled	Auto-zero Enabled	Auto-zero Disabled	Auto-zero Enabled
30,000	30,000	818.73	1637.47	818.73
15,000	15,000	768.40	1536.81	768.40
7,500	7,500	703.53	1407.06	703.53
3,750	3,750	594.74	1189.48	594.74
2,000	2,000	462.66	925.33	462.66
1,000	1,000	316.32	632.63	316.32
500	500	193.75	387.49	193.75
100	100	47.26**	94.51	47.26**
60*	60	29.00	58.00	29.00
50**	50	24.29	48.59	24.29
30*	30	14.74	29.49	14.74
25**	25	12.32	24.64	12.32
15*	15	7.44	14.87	7.44
10***	10	4.97	9.94	4.97
5***	5	2.49	4.99	2.49
2.5***	2.5	1.25	2.5	1.25


NOTE:

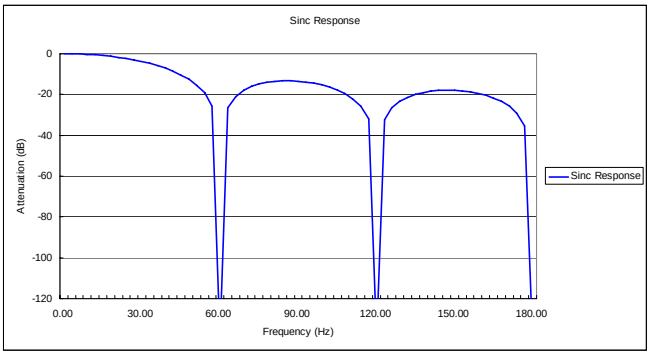
1) For the equivalent data rate per channel, divide the multi-plexed data rate figures by four.
2) *60 Hz Rejection, **50 Hz Rejection, ***Simultaneous 50 and 60 Hz Rejection.
3) Auto-zero function is always disabled for general purpose input channels, i.e. channels 4 to 7.

4.2.5 Power Line Noise Rejection

The SINC filter built into the PCI-9524 works best for suppressing power line noise, if the ADC sampling rate is set to match power line frequency. The harmonics of the power line noise can also be suppressed as well, see Table 4-3 for illustration. For applications demanding high-stability, low-drifting measurements, selecting a sampling rate that provides inherent power line noise rejection is recommended.

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Figure 4-3: SINC Filter Power Line Noise Rejection at 60 Hz Multiples



The power line frequency is either 50 or 60-HZ in most countries. For sampling rates supporting power line noise rejection, please refer to the notes after Table 4-1 for your reference.

The SINC filter cannot suppress power line noise for a sampling rate above 60 SPS (or 100 SPS with auto-zero). Under such conditions, power line noise rejection relies on the inherent common-mode rejection ability of the input amplifier. Under this circumstance, using the post-processing IIR digital filter can attenuate power line noise somewhat, at the cost of increased signal settling time. See Section 4.2.9 for details.

4.2.6 Excitation and Remote-sensing

Users can select excitation voltages from either 2.5V or 10V sources. For most load-cell transducers, 10V is recommended. The higher the excitation, the higher the resolution will generally be; since the signal is larger at the beginning of the signal chain and hence a better overall 'signal-to-noise ratio' (SNR).

The remote-sensing function requires users to connect all the excitation voltage driving pins to the corresponding remote-sens-

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ing pins. For channels that are not connected to a transducer, feedback the excitation voltage to the corresponding remote-sensing pins directly on the terminal board. Please refer to section 3.2 for details.

PCI-9524 applies simulated AC excitation to the load-cell transducers and must respond quickly toward the excitation voltage change, otherwise amplitude attenuation will occur. In general, calibrating your system and working at a fixed sampling rate not exceeding 100-SPS is preferred for most high accuracy applications. Also, using a lower impedance transducer, shortening the connecting cable, and increasing the wiring gauge will help to improve the response time.

Load-cell transducers with inductive properties are not recommended to be used with PCI-9524.

4.2.7 Thermal EMF, 1/f Noise and Auto-zero

Thermal electromotive force (Thermal EMF) is the most common error in a low-level signal measurement system. A junction made of dissimilar metals develops some voltage difference across it. Working like a tiny thermal-couple, this phenomenon is also known as the Seebeck effect. Common lead-tin solder junctions can have 1 to 3μV/ºC temperature coefficients, and even tight connected cooper-cooper junctions without oxidation will have as much as 0.3μV/ºC temperature coefficients. For high-resolution load-cell applications calling for a voltage resolution higher than 100 nano-Volts, obviously, a 1ºC fluctuation in temperature will bury the signal of interest.

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Table 4-2: Temperature Coefficient of different metal junctions

Junction Type	Temperature Coefficient (μV/ºC)
Copper–Copper	< 0.3
Copper–Gold	0.5
Copper–Silver	0.5
Copper–Lead-Tin Solder	1 to 3
Copper–Brass	3
Copper–Aluminum	5
Copper–Nickel	10
Copper–Copper Oxide	> 500

Wiring made to connect the load-cell and PCI-9524, inevitably creates multiple metal junctions. When there are temperature differences between these junctions, the thermal EMF will not be able to cancel out each other, and generates an offset error that fluctuates with ambient temperature change. The worst problem of thermal EMF is that it creeps slowly in a very low frequency range, typically below 1Hz, rendering any post digital filtering impractical due to the extremely long settling time therefore required.

Besides thermal EMF, they are other noise sources that reside in semiconductor devices, exhibiting 1/f noise properties; i.e. noise density increases as frequency of interest decreases.

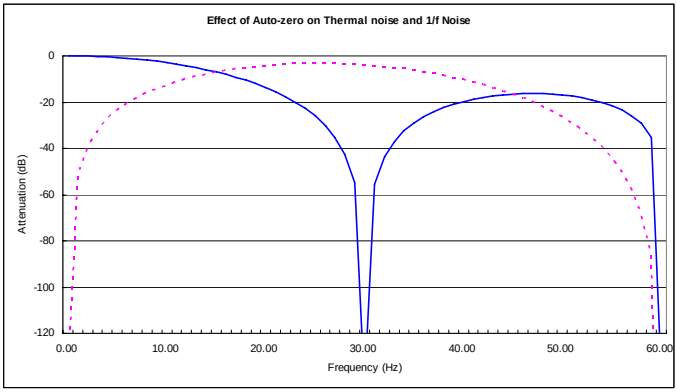
The auto-zeroing technique used on PCI-9524 helps to remove systematic offset errors in the signal chain, including thermal EMF drift and 1/f noise from the transducers, cabling, wiring, signal conditioning and amplifiers.

For noise rejection response when auto-zero is enabled, please refer to Figure 4-4. The solid line denotes SINC responses of ADC signal gain running at 60 SPS; the dotted line denotes the simultaneous noise attenuation at both near-DC (0Hz) and near ADC's

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sampling rate. Also note that the output data rate is 29.5 SPS rather than 60 SPS, due to auto-zeroing. As the sampling rate changes, the notches' frequency change accordingly.

Figure 4-4: The Effect of Auto-zero on Thermal Noise and 1/f Noise, ADC running at 60 SPS



As many bipolar-input low-noise amplifiers, those used in PCI-9524 start to assert their 1/f noise below 10 Hz, the gradually increasing noise attenuation from below 20 Hz is a nice feature. This also implies that a too-low sampling rate will not improve the stability performance significantly, since noise attenuation may start at a frequency much lower than where the amplifier's 1/f noise emerges.

To successfully resolve low-level signals, always enable the auto-zero and remote-sense function, keeping transducers and installation of PCI-9524 away from heat radiating sources, EMI radiating sources, and free of mechanical vibration. Also, shield transducers from airflow, and make sure all the connecting junctions are fastened tight and free of oxidation.

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4.2.8 Warm-up Requirement

PCI-9524 requires sufficient warm-up time before operation to achieve its specified accuracy. Typically a 25-minute warm-up time is required. Specifications are tested after 2-hour warm-up.

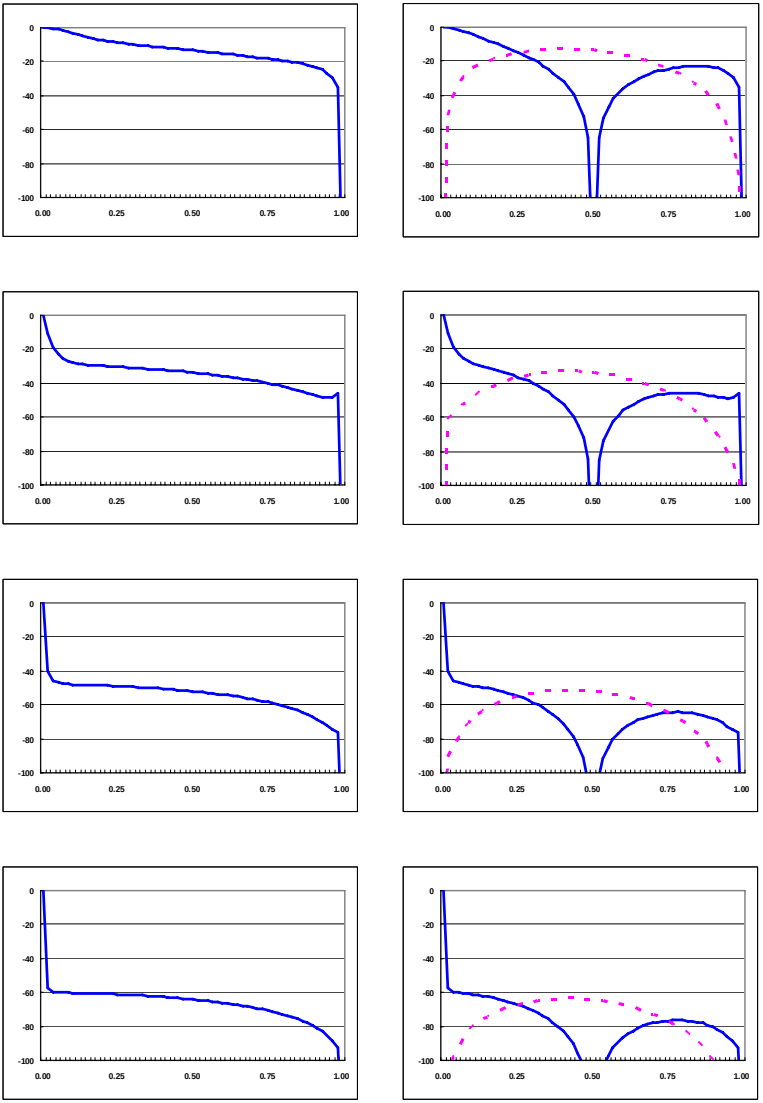
4.2.9 Post-processing IIR Digital Filter

Digital filter banks are provided to improve visual stability of displayed numbers in digital weighting or metering systems, without the need for software-based averaging algorithms in user applications. The tap length can be programmed in ranges of 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, and 1024.

Figure 4-5 illustrates several frequency response curves versus different filter tap lengths and normalized sampling rate. Rows from top to bottom are of tap length of 2, 16, 128 and 512. The figures in the left column have their auto-zeros disabled; those in right column have their auto-zeros enabled, with the noise attenuation response shown in dotted lines. Note the figures with auto-zero disabled have Nyquist rates of 0.5 * fs, while those with auto-zero enabled have Nyquist rates of 0.25 * fs. As sampling theorem implies, keeping a source bandwidth only as large as it is necessary, is a good practice to optimize noise performance.

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Figure 4-5: Digital Filter Tap Length Effects on Signal Frequency Responses



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In order to improve filter settling time, a threshold detection block was added in front of each digital filter bank. The threshold detection block continuously compares the previous output from the digital filter, to the current conversion results from the ADC. Once the difference exceeds a predefined threshold, the filter is commanded to flush its internal data with the new data. Please note that the threshold counts mentioned hereafter are in terms of ADC binary counts, not voltage level.

To select an appropriate threshold value, however, is a complex process. First, a too-low settling will falsely flush the digital filter due to system noise; whereas a too-high settling will not improve the filter's settling time. Second, system noise grows proportionally to ADC sampling rates.

PCI-9524 is shipped with a set of predefined threshold values as listed in Table 4-3, one for each given sampling rate, as listed in Table 4-1. The listed figures are a good starting point to top up threshold counts if your transducer or environment is too noisy. The predefined thresholds are actually two times the peak-to-peak noise code deviation of the given sampling rate, as compared to a 350Ω, 3mV/V bridge simulator in our lab experiments.

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Table 4-3: Default Threshold Values (ADC counts) vs. ADC Sampling Rates

ADC Sampling Rate	Threshold Counts
30,000	268
15,000	176
7,500	188
3,750	104
2,000	90
1,000	56
500	46
100	22
60	16
50	14
30	12
25	10
15	8
10	8
5	8
2.5	8

4.2.10 RAW Data Format

To maximize data processing flexibility, it is possible for users to deal with raw data directly, rather than scaled data. The data format of the acquired 32-bit raw AI is shown in Table 4-4.

Table 4-4: RAW Data Format

BIT[31..8]	BIT[7..4]	BIT[3..2]	BIT[1]	BIT[0]
AD Data	Channel No.	RSV	DSP Flushed	Data Refreshed

The 'AD Data' field contains a 2's complement coded AD data, to manually scale them to physical units; please refer to Section 4.2.11. To convert the AD data to a decimal count, first convert it to a signed decimal integer, and divide it by 256; bit 7 to 0 are automatically eliminated during the conversion process.

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Bypassing the API's internal software calibrating mechanism may, however, invalidate the specified absolute accuracy.

The 'Channel No.' ranges from 0 to 3, indicating which of the input channels of that analog input group is converted during auto-scan mode. This represents channels 0 to 3 for transducer input channels, and channels 4 to 7 for general purpose input channels. If auto-scan is disabled, the Channel No. will remain at zero.

The 'RSV' field is reversed.

The 'DSP Flushed' field denotes whether the current AD Data is a large input step that has been recognized, and validated to flush the post-processing IIR digital filter contents.

The 'Data Refreshed' bit is valid only in Fast-polling Data Transfer mode (see Section 4.2.12 for Data Transfer Modes), a '1' indicates that the AD data for that specific channel has been updated, and it is the first time it is being read.

4.2.11 AD Data Format

The data format of the acquired 24-bit AD data is in 2's Complement coding. Table 4-5 illustrates valid input ranges and the ideal transfer characteristics for transducer input channels, i.e. analog input channels 0 to 3.

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Table 4-5: Bipolar analog input ranges and output digital codes for transducer input channels

Description	Analog Input Range	AD Code (Hex)	Count (Decimal)
Full-scale Range	±200,000 µV		
Least significant bit (LSB)	0.0238 µV		
FSR-1LSB	199,999 µV	7FFFFF	8388607
Midscale +1LSB	0.0238 µV	000001	1
Midscale	0 µV	000000	0
Midscale -1LSB	-0.0238 µV	FFFFFF	-1
-FSR	-200,000 µV	800000	-8388608

Table 4-6 presents valid input ranges and ideal transfer characteristics for general purpose input channels, i.e. analog input channels 4 to 7.

Table 4-6: Bipolar analog input ranges and AD codes for general purpose input channels

Description	Bipolar Analog Input Range				AD Code (Hex)	Count (Decimal)
Full-scale Range	±10V	±5V	±2.5V	±1.25V		
Least significant bit	1.325µV	0.662µV	0.331µV	0.1656µV		
FSR-1LSB	9.9999V	4.9999V	2.49999V	1.249999V	733332	7549746
Midscale +1LSB	1.32µV	0.662µV	0.331µV	0.116µV	000001	1
Midscale	0V	0V	0V	0V	0	0
Midscale -1LSB	-1.32µV	-0.662µV	-0.331µV	-0.116µV	FFFFFF	-1
-FSR	-10V	-5V	-2.5V	-1.25V	8CCCCD	-7549747

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4.2.12 Data Transfer Modes

Fast-polling data transfer (non-buffering programmed I/O)

The fast-polling mode in PCI-9524 benefits timing sensitive applications such as servo-control-loops that require retrieving the latest data without FIFO buffering latency.

PCI-9524 continuously updates the latest acquired data onto a data port for that specific channel. In other words, there are eight separate data ports holding the latest converted data for analog input channels 0 to 7. When auto-scan is enabled, users can poll the data ports in any sequence and guarantee that only the latest data is retrieved. Data not retrieved in time by users are overwritten by new data without notice.

As the polling rate of a PC may go much faster than the data rate, it is possible that users get multiple identical data before a new conversion has completed. A 'Data Refreshed' bit in the raw data (see Section 4.2.10) indicates whether AI data has been updated or not since its last fast-polling data transfer. This bit helps to save computation power which allows the close-loop control algorithm update to control outputs only when new data arrives.

Bus-mastering DMA data transfer

PCI bus-mastering DMA is essential for continuous data streaming, as it helps to achieve full potential PCI bus bandwidth, and also to improve bus efficiency. The bus-mastering controller controls the PCI bus when it becomes the master of which, and the host CPU is free of burden since data are directly transferred to the host memory without intervention. Once analog input operation begins, the DMA returns control of the program. During DMA transfer, the hardware temporarily stores acquired data in the onboard AD Data FIFO, and then transfers the data to a user-defined DMA buffer in the computer.

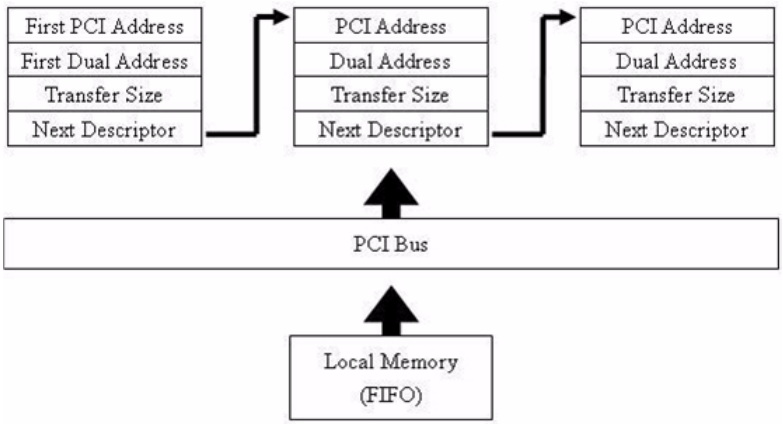
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By using a high-level programming library for high speed DMA data acquisition, users simply need to assign the sampling period and the number of conversions into their specified counters. After the AD trigger condition is met, the data will be transferred to the system memory by the bus-mastering DMA.

In a multi-user or multi-tasking OS, such as Microsoft Windows, Linux, and so on, it is difficult to allocate a large continuous memory block. Therefore, the PCI controller provides DMA transfer with scatter-gather function to link non-continuous memory blocks into a linked list so users can transfer large amounts of data without being limited by memory limitations. In non-scatter-gather mode, the maximum DMA data transfer size is 2 MB double words (8 MB bytes); in scatter-gather mode, there is no limitation on DMA data transfer size except the physical storage capacity of your system. Users can also link descriptor nodes circularly to achieve a multi-buffered DMA.

Figure 4-6 illustrates a linked list that is comprised of three DMA descriptors. Each descriptor contains a PCI address, PCI dual address, a transfer size, and the pointer to the next descriptor. PCI address and PCI dual address support 64-bit addresses which can be mapped into more than 4 GB of address space.

Figure 4-6: Linked List of PCI address DMA descriptors



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Most software drivers provide easy access for users to handle scatter-gather DMA functions, and sample programs are also provided in the ADLINK All-in-One CD.

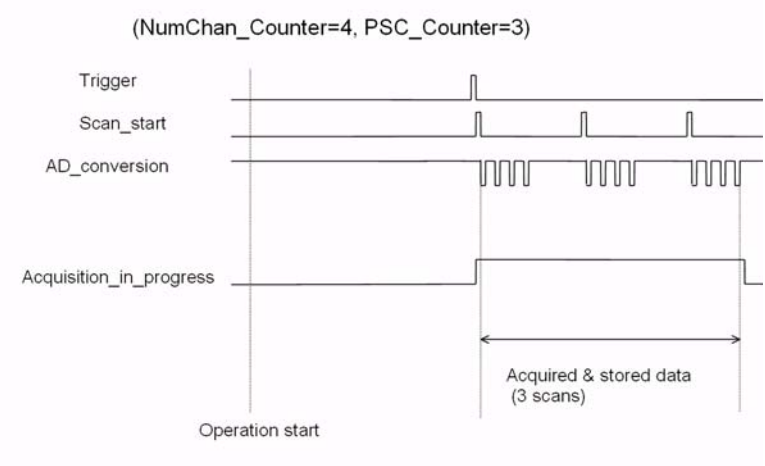
4.2.13 Trigger Modes

PCI-9524 supports a post-trigger mode, which initiates data acquisition timing right after a trigger event occurs. A trigger event occurs when the specified condition is detected on the selected trigger source. There are five trigger sources in PCI-9524, including software, SSI AD Trigger, Isolated Digital Input, Pulse Comparator, and Position Comparator. You must select one of them as the source of the trigger event.

Post-Trigger Acquisition

Use post-trigger acquisition in applications where you want to collect data after a trigger event. The number of scans after the trigger is specified is PSC_counter, as illustrated in Figure 4-7. The total acquired data length = 4 * PSC_counter. Note that PCI-9524 supports auto-scan mode, so the value of NumChan_Counter is always set to four.

Figure 4-7: Post trigger



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4.3 D/A Conversion

There are two single-ended channels of 16-bit analog outputs available on PCI-9524. They support software polling to update the output status. Therefore, the update rate is fully controlled by software timing.

PCI-9524 supports a maximum ±10V voltage output. Table 4-7 illustrates the relationship between 2's Complement coded binary and output voltage.

Table 4-7: Bipolar output code table

Binary Code (Hex)	Analog Output
0x7FFF	10V * (65535/65536)
0x0001	10V * (1/65536)
0x0000	0V
0xFFFF	-10V * (1/65536)
0x8000	-10V

The D/A is designed to have 0.5% over-range used for internal digital calibration. Therefore, there are approximately 327 codes being traded at the extreme ends of the D/A transfer function. While the transfer function remains linear after calibration, code mapping is required to have calibrated output voltages. Using the supplied API and software routines will do the required mapping for you; the valid input binary code range remains unchanged, from 0x0000 to 0xFFFF.

4.4 Isolated Encoder Input Channels

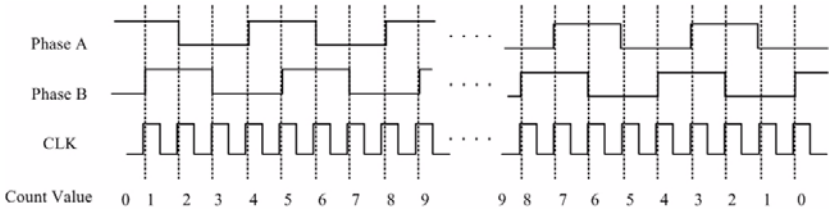
There are three opto-isolated differential encoder input channels in PCI-924 accepting both single-end and differential encoder signals, including NPN sink drivers, PNP source drivers, push-pull drivers, and differential line drivers.

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Encoders using open-drain/open-collector output stages can generally go as high as 500-kHz pulses per second. For higher speed applications, use encoders with differential line-driver output stages. To ensure low EMI leakage, use twisted pair cabling for high-speed differential signal transmissions.

PCI-9524 uses quadrature decoding logic, or X4 encoder mode, that increments/decrements the counter value on every edge of either Phase A or Phase B waveform. This provides four times the resolution of angular/linear displacement, as shown in Figure 4-8.

Figure 4-8: X4 Encoder mode



The decoder has a built-in position comparator that generates an AD trigger signal whenever the count value matches the user specified one.

The PCI-9524 has an internal power supply for powering the external encoders and their output stages. The default output voltage is 5V. For applications requiring 12V output, please consult ADLINK technical support or Field Application Engineers (FAE).

For encoders that require currents exceeding the capacity of the internal power supply, an external power supply is required. If needed, connect its power ground to isolated ground (ISOGND) on PCI-9524.

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4.5 Isolated Pulse-Command Generator

There are three opto-isolated differential pulse output channels in PCI-9524, supporting typical servo amplifiers equipped with opto-isolated inputs and/or differential line-receivers. Each pulse-command channel can be programmed to support single phase or dual phase operations, including DIR/CLK and CW/CCW direction control.

The pulse-command generator has two operating modes, Burst mode and Infinite Mode. The former generates user specified pulses, while the later generates pulses continuously until a stop command is issued by user's application.

The pulse frequency, and duty-cycle can be programmed through a windows API, although most servo amplifiers accept a 50% duty cycle as default.

Servo amplifiers using opto-coupler input stages generally accept as high as 500-kHz pulses per second. For higher speed pulse-command applications, use servo amplifiers with differential line-receivers. Use twisted pair wiring for high-speed differential signal transmissions to ensure low EMI leakage.

The pulse-command generator has a built-in pulse comparator that generates an AD trigger signal when the number of pulses generated has reached a user specified threshold.

4.6 Isolated Digital I/O

PCI-9524 supports eight channels of opto-coupler isolated digital inputs, and eight channels of N-MOS sink drivers. Users can use these I/O functions to control relays, actuators, bulbs, etc...

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4.6.1 Isolated Digital Inputs

PCI-9524 has isolated digital inputs based on non-polarity opto-coupler devices, and accepts input signals in either direction. Each isolated digital input can be connected to external devices with different common-mode voltages, without interfering with each other.

4.6.2 Isolated Digital Outputs

PCI-9524 offers isolated digital outputs based on N-MOS sink drivers; they handle larger power and are sturdier than conventional Darlington output stages. However, when connecting to inductive loads, be sure to utilize the built-in fly-wheel diodes to prevent sink drivers from being destroyed by kick-back voltage. Follow the signal connection illustrated in Figure 3-15 when connecting to inductive loads.

4.7 Trigger Sources

PCI-9524 supports four trigger sources, including software trigger, external digital trigger, pulse comparator trigger, and position comparator trigger.

4.7.1 Software-Trigger

The trigger asserts immediately after users execute the specified API function calls to begin data acquisition.

4.7.2 External Digital Trigger

An external digital trigger occurs when a rising edge or a falling edge is detected on the digital signal connected to PCI-9524's isolated digital input channel #0.

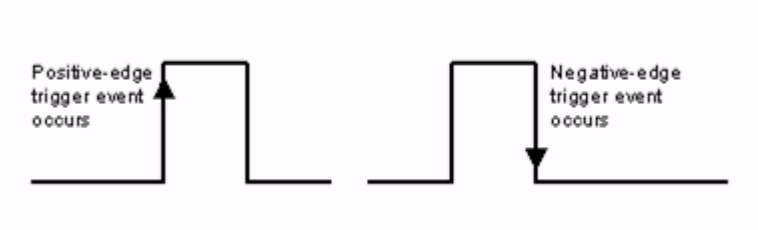
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This trigger source can work together with an external optical-approximation-sensor and starts AI acquisition when the target test device is placed in an appropriate position.

Users can program the trigger polarity through ADLINK's software drivers easily. Note that the level of the external digital trigger signal shall be compliant with the transition thresholds of the isolated digital input, with a minimum pulse width of 1ms.

If re-trigger is enabled, the AI acquisition accepts a new trigger after the specified number of samples has been readily acquired; else the trigger signal is ignored.

Figure 4-9: External digital trigger



4.7.3 Pulse Comparator Trigger

The pulse-command generator has a built-in pulse comparator that generates an AD trigger signal when the number of pulses generated has reached a user specified threshold.

This trigger can be used whenever user applications require that AI acquisition begins after the external servo motor/stepper is actuated and positioned accordingly. For example, a destructive material-testing-system, that finding the maximum tension/stress a specimen-under-test can tolerate, will shut down before the specimen is broken down. It is common for such a system to pre-press

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the specimen-under-test to a certain level before the AI acquisition starts.

For applications that do not need pulse-command channel #0, this trigger source can be used to turn post-trigger mode to delay-trigger mode; by specifying the pulse frequency and pulse count, and starting the pulse-command generator, the AI acquisition starts immediately after the duration pulse_counts x (1 / pulse_frequency) has expired.

If re-trigger is enabled, users may re-start the pulse-command generator and generate a new trigger, without first stopping the AI acquisition. The AI acquisition accepts a new trigger and re-starts, after the specified number of samples has been readily acquired; else the trigger signal is ignored.

4.7.4 Position Comparator Trigger

The quadrate decoder has a built-in position comparator that generates an AD trigger signal whenever the counter value matches the user specified one; that is, when the movement/displacement crosses a physical point set by user. This trigger can be useful if it is desired to start AI acquisition after the expected displacement is reached.

Due to the nature of reversed rotation the decoder accepts, it is possible to generate multiple AD triggers if the movement/displacement is moving forth and back near the specified physical point. If re-trigger is enabled, the AI acquisition re-starts after the specified number of samples has been acquired; else the trigger signal is ignored.

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5 Calibration

This chapter introduces the calibration process to minimize AD measurement errors and DA output errors.

5.1 Loading Calibration Constants

The PCI-9524 is factory calibrated before shipment by writing the associated calibration constants of TrimDACs firmware to the on-board EEPROM. TrimDACs firmware is the algorithm in the FPGA. Loading calibration constants is the process of loading the values of TrimDACs firmware stored in the on-board EEPROM. ADKLINK provides a software utility for reading the calibration constants automatically if necessary.

There is a dedicated space for storing calibration constants in the EEPROM. In addition to the default bank of factory calibration constants, there are three more user-utilization banks. That means users can load TrimDAC firmware values either from the original factory calibration or from a calibration that is subsequently performed.

Because errors in measurements and outputs will vary with time and temperature, it is recommended to re-calibrate when the card is installed in the user's environment. The auto-calibration function used to minimize errors will be introduced in the next sub-section.

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5.2 Auto-calibration

By using the auto-calibration feature of PCI-9524, the calibration software can measure and minimize measurement errors without external signal connections, reference voltages, or measurement devices.

PCI-9524 has an on-board calibration reference to ensure the accuracy of auto-calibration. The reference voltage is measured on the production line through a digital potentiometer and compensated in the software. The calibration constant is memorized after this measurement.

5.3 Saving Calibration Constants

Factory calibrated constants are permanently stored in a onboard EEPROM data bank and cannot be modified. When you re-calibrate the device, software stores new constants in a user-modifiable section of the EEPROM. To return a device to its initial factory calibration settings, software copies the factory calibrated constants to the user-modifiable section of the EEPROM. After an auto-calibration is completed, users can save the new calibration constants into the user-modifiable banks in the EEPROM. The date, temperature and calibration constants of the auto-calibration will be saved. Therefore users can store three sets of calibration constants according to three different environments and re-load the calibration constants later.


NOTE:

1) Before auto-calibration starts, it is recommended to warm up the card for at least 25 minutes.
2) Please remove cables before an auto-calibration procedure is initiated because the DA outputs will change in the calibration process.

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Important Safety Instructions

For user safety, please read and follow all **instructions**, **WARNINGS**, **CAUTIONS,** and **NOTES** marked in this manual and on the associated equipment before handling/operating the equipment.

- Read these safety instructions carefully.
- Keep this user's manual for future reference.
- Read the specifications section of this manual for detailed information on the operating environment of this equipment.
- When installing/mounting or uninstalling/removing equipment:
  - Turn off power and unplug any power cords/cables.
- To avoid electrical shock and/or damage to equipment:
  - Keep equipment away from water or liquid sources;
  - Keep equipment away from high heat or high humidity;
  - Keep equipment properly ventilated (do not block or cover ventilation openings);
  - Make sure to use recommended voltage and power source settings;
  - Always install and operate equipment near an easily accessible electrical socket-outlet;
  - Secure the power cord (do not place any object on/over the power cord);
  - Only install/attach and operate equipment on stable surfaces and/or recommended mountings; and,
  - If the equipment will not be used for long periods of time, turn off and unplug the equipment from its power source.

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- Never attempt to fix the equipment. Equipment should only be serviced by qualified personnel.
- A Lithium-type battery may be provided for uninterrupted, backup or emergency power.



RISK OF EXPLOSION IF BATTERY IS REPLACED BY AN INCORECT TYPE. DISPOSE OF USED BATTERIES ACCORDING TO THEIR INSTRUCTIONS.

- Equipment must be serviced by authorized technicians when:
  - The power cord or plug is damaged;
  - Liquid has penetrated the equipment;
  - It has been exposed to high humidity/moisture;
  - It is not functioning or does not function according to the user's manual;
  - It has been dropped and/or damaged; and/or,
  - It has an obvious sign of breakage.

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