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PowerDAQ User Manual

PD2/PDXI-MF Series Multifunction DAQ Boards
PD2/PDXI-MFS Series Simultaneous Sampling DAQ Boards
PDL-MF "Lab" Series Multifunction DAQ Boards

April 2006 Edition
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1. Introduction

This manual describes the features and functions of hardware in the PowerDAQ series of PCI and PXI multifunction data-acquisition boards. These high-performance systems support functions including analog input (AI), analog output (AO), digital I/O (DIO), and user counter/timer I/O (UCT) for either PCI-bus or PXI/CompactPCI-based systems.

Note All PDXI cards support the PXI Trigger Bus, Star Trigger lines and Local Bus on the P2 connector. Nonetheless, they run without modification in any C-sized CompactPCI backplane except they lose support for PXI-specific functions.

These boards all fall into one of the following broad classifications:

- PD2/PDXI-MF Series—Multifunction (analog I/O, digital I/O, counter/timer)
- PD2/PDXI MFS Series—Simultaneous Sampling Multifunction
- PDL-MF—"Lab" Series Entry-level Multifunction

This manual uses the word "PowerDAQ" to collectively reference all the models listed above.

Other boards in the PowerDAQ Series (see separate manuals) include the

- PD2/PDXI-AO Series—Analog Output (with digital I/O, counter/timers)
- PD2/PDXI-DIO Series—Digital I/O (with counter/timers)
- PDL-DIO Series—"Lab" Series Entry-level Digital I/O (with counter/timers)

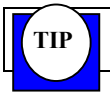
Who should read this manual?

This manual has been written to make the installation, configuration and operation of our PowerDAQ multifunction boards as straightforward as possible. However, it assumes that the user has basic PC skills and is familiar with the Microsoft Windows XP/2000/NT/9x, QNX or Linux/RTLinux/RTAI Linux operating environments.

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Conventions

To help you get the most out of this manual and our products, please note that we use the following conventions:



Tips are designed to highlight quick ways to get the job done, or reveal good ideas you might not discover on your own.

Note Notes alert you to important information.

CAUTION! *Caution advises you of precautions to take to avoid injury, data loss, or system crash.*

Text formatted in **bold** typeface generally represents type that should be entered verbatim. For instance, it can represent a command, as in the following example: "You can instruct users how to run setup using a command such as **setup.exe**."

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Organization of this manual

Chapter 1: Introduction
The section you are reading now. It explains which products are covered and gives you tips on how to best use this manual.

Chapter 2: PowerDAQ MF/MFS Series Features Overview
This chapter provides an overview of the key features of the PowerDAQ series and detailed information on the various PowerDAQ models currently available. It also lists what you need to get started.

Chapter 3: Installation and Configuration
This chapter explains how to install and configure your PowerDAQ board. Among other things, it shows where various I/O connectors are located on various boards and also shows their pinout definitions.

Chapter 4: PowerDAQ Architecture
This chapter discusses the subsystems of your PowerDAQ board, and it gives an overview of the programming model, showing how various cards and software modules intercommunicate.

Chapter 5: Analog-Input Subsystem
This and the following three chapters are each devoted to one of the PowerDAQ MF/MFS Series subsystems. Each chapter is divided into two major sections. The first gives a description of the hardware and gives tips for making best use of these features in a test system. The second section introduces you to the best way to program this subsystem and reviews the most frequently used commands and operating methods.

Chapter 6: Analog-Output Subsystem
This chapter contains two major sections: the first describes the hardware and its features; the second introduces you into techniques for programming this subsystem.

Chapter 7: Digital I/O Subsystem
This chapter contains two major sections: the first describes the hardware and its features; the second introduces you into techniques for programming this subsystem.

Chapter 8: User Counter/Timer Subsystem
This chapter contains two major sections: the first describes the hardware and its features; the second introduces you into techniques for programming this subsystem.

Chapter 9: Support Software

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This chapter outlines the various example programs supplied with the PowerDAQ Software Suite CD-ROM. It also describes the third-party software we support with PowerDAQ hardware.

Appendix A: Specifications
This appendix lists the hardware specifications of the PowerDAQ product series.

Appendix B: PowerDAQ A/D Timing
This appendix gives tables that help you determine the fastest acquisition times when using various options such as Slow Bits.

Appendix C: Accessories
This appendix provides a list of available PowerDAQ accessories.

Appendix D: PowerDAQ SDK Structure
This appendix shows the directories and files that are created when you install the PowerDAQ Software Developers Kit.

Appendix E: Application Notes
This appendix provides application notes to enhance your understanding of PowerDAQ products.

Appendix F: Warranty
This appendix contains a detailed explanation of PowerDAQ warranty.

Appendix G: Glossary
This is an alphabetical listing of the terms used in this manual along with their definitions.

Index
This is an alphabetical listing of the topics covered in this manual.

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Other PowerDAQ Documentation

The PowerDAQ PD2 / PDXI / PDL-MF Manual is one part of the documentation available for the PowerDAQ system. There are several other manuals you might want to read before programming your application. They are available either on the PowerDAQ Software Suite CD or can be downloaded from the UEI web site.

Software:

PowerDAQ Programmer Manual
PowerDAQ for LabVIEW User Manual

Hardware:

PowerDAQ ASTP User Manual
PowerDAQ Thermocouple Rack User Manual.

Feedback

We are interested in any feedback you might have concerning our products and manuals. A Reader Evaluation form is available on the last page of the manual.

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2. PowerDAQ MF/MFS Series Features Overview

This chapter provides an overview of the key features of the PowerDAQ Series and detailed information on the various PowerDAQ models currently available. It also lists what you need to get started.

Overview

Thank you for purchasing a PowerDAQ board. These advanced multifunction boards all feature an onboard DSP that allows simultaneous operation of all I/O subsystems without host intervention. In addition, the DSP runs a firmware-based command interpreter that makes it easy and convenient to program these cards from virtually any programming language using the same API.

Features

Key features of PowerDAQ boards include:

- 24-bit Motorola 56301 digital signal processor
- PCI-bus host interface (PCI 2.1 compliant)
- Custom-designed programmable gain amplifier
- Analog inputs—from 16 to 64 channels, 12-, 14- or 16-bit resolution, A/D FIFO buffer size varies with board and options.
- Analog outputs—2 channels, 12-bit resolution, 2k-sample DSP-based FIFO
- Digital inputs—16 or 24 points
- Digital outputs—16 or 24 points
- Three user counter/timers (8254 based), each with its own Clock In/Gate controls (the PDL-MF uses the three 24-bit counters on the DSP)
- Auto calibration
- Extensive triggering and clocking of analog inputs
- Extensive triggering and clocking of analog outputs
- Simultaneous operation of all subsystems (Analog In, Analog Out, Digital In, Digital Out and Counter/Timer).

Note For the full list of specifications, see *Appendix A: Specifications.*

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PowerDAQ Models

PowerDAQ model numbers are based on the following conventions:

[Family] - [Type of Board] - [Channels] - [Speed] / [Resolution][Gain]

Family:

- PD2 PowerDAQ PCI-bus boards
- PDXI PowerDAQ PXI/CompactPCI boards

The types of boards currently available include the following:

- MF Multifunction
- MFS Multifunction with simultaneous sampling
- AO Analog Output (details supplied in separate PD2-AO manual)
- DIO Digital Input/Output (details supplied in separate PD2-DIO manual)

In the gain position, you sometimes find one of these two types:

- "L"—intended for low-level signals that might need considerable amplification, so gains are typically 1, 10, 100 and 1000
- "H"—intended for higher-level signals that need less amplification, so gains are typically 1, 2, 4 and 8 or 1, 2, 5 and 10 depending on the model.

PowerDAQ PD2-MF Series

Model	Analog features
PD2-MF-16-2M/14H	2.2M samples/sec, 14-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As
PD2-MF-64-2M/14H	2.2M samples/sec, 14-bit A/D, 64 SE / 32 DI inputs, Gains: 1 2, 4, 8; two 12-bit D/As
PD2-MF-16-500/16L	500k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PD2-MF-16-500/16H	500k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2 4, 8; two 12-bit D/A
PD2-MF-64-500/16L	500k samples/sec, 16-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PD2-MF-64-500/16H	500k samples/sec, 16-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/A
PD2-MF-16-400/14L	400k samples/sec, 14-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PD2-MF-16-400/14H	400k samples/sec, 14-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2 4, 8; two 12-bit D/As

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PD2-MF-64-400/14L	400k samples/sec, 14-bit A/D, 64 SE / 32 DI inputs, Gains: 1,10,100,1000; two 12-bit D/As
PD2-MF-64-400/14H	400k samples/sec, 14-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/A
PD2-MF-16-333/16L	333k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PD2-MF-16-333/16H	333k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2 4, 8; two 12-bit D/A
PD2-MF-64-333/16L	333k samples/sec, 16-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PD2-MF-64-333/16H	333k samples/sec, 16-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/A
PD2-MF-16-150/16L	150k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PD2-MF-16-150/16H	150k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2 4, 8; two 12-bit D/A

Table 2.1—PowerDAQ PD2-MF Series models

Note All PD2-MF Series models also include three counter/timers and 32 digital I/O lines.

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PowerDAQ PD2-MFS Series:

Model	Analog features
PD2-MFS-4-2M/14	2M samples/sec, 14-bit A/D, 4 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-8-2M/14	2M samples/sec, 14-bit A/D, 8 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-4-1M/12	1M samples/sec, 12-bit A/D, 4 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-8-1M/12	1M samples/sec, 12-bit A/D, 8 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-4-800/14	800k samples/sec, 14-bit A/D, 4 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-8-800/14	800k samples/sec, 14-bit A/D, 8 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-4-500/16	500k samples/sec, 16-bit A/D, 4 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-8-500/16	500k samples/sec, 16-bit A/D, 8 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-4-500/14	500k samples/sec, 14-bit A/D, 4 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-8-500/14	500k samples/sec, 14-bit A/D, 8 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-4-300/16	300k samples/sec, 16-bit A/D, 4 SE simultaneous inputs; two 12-bit D/As
PD2-MFS-8-300/16	300k samples/sec, 16-bit, 8 SE simultaneous inputs; two 12-bit D/As

Table 2.2—PowerDAQ PD2-MFS Models

Note All PD2-MFS Series models also include three counter/timers and 32 digital I/O lines.

Note PD2-MFS Series boards provide a dedicated sample/hold amplifier (S/H) for each analog-input channel. These S/Hs are integrated into the board's hardware design and do not require any user software programming to enable their operation.

Note All PD2-MFS Series models come standard only with G = 1; for other gains, you can purchase the DG option outlined in Table 2.5

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PowerDAQ PDXI-MF Series

Model	Analog features
PDXI-MF-16-2M/14H	2.2M samples/sec, 14-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As
PDXI-MF-64-2M/14H	2.2M samples/sec, 14-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As
PDXI-MF-16-1M/12L	1.25M samples/sec, 12-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PDXI-MF-16-1M/12H	1.25M samples/sec, 12-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/A
PDXI-MF-64-1M/12L	1.25M samples/sec, 12-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 10 100, 1000; two 12-bit D/As
PDXI-MF-64-1M/12H	1.25M samples/sec, 12-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As
PDXI-MF-16-500/16L	500k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PDXI-MF-16-500/16H	500k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As
PDXI-MF-64-500/16L	500k samples/sec, 16-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PDXI-MF-64-500/16H	500k samples/sec, 16-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As
PDXI-MF-16-400/14L	400k samples/sec, 14-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PDXI-MF-16-400/14H	400k samples/sec, 14-bit A/D, 16 SE / 8DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As
PDXI-MF-64-400/14L	400k samples/sec, 14-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PDXI-MF-64-400/14H	400k samples/sec, 14-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As
PDXI-MF-16-333/16L	333k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PDXI-MF-16-333/16H	333k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As
PDXI-MF-64-333/16L	333k samples/sec, 16-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PDXI-MF-64-333/16H	333k samples/sec, 16-bit A/D, 64 SE / 32 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/A
PDXI-MF-16-150/16L	150k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 10, 100, 1000; two 12-bit D/As
PDXI-MF-16-150/16H	150k samples/sec, 16-bit A/D, 16 SE / 8 DI inputs, Gains: 1, 2, 4, 8; two 12-bit D/As

Table 2.3—PowerDAQ PDXI-MF Series Models

Note All PDXI-MF Series models also include three counter/timers and 32 digital I/O lines.

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PowerDAQ PDXI-MFS Series

Model	Analog features
PDXI-MFS-4-2M/14	2M samples/sec, 14-bit A/D, 4 SE simultaneous inputs, G = 1; two 12-bit D/As
PDXI-MFS-8-2M/14	2M samples/sec, 14-bit A/D, 8 SE simultaneous inputs, G = 1; two 12-bit D/As, G = 1
PDXI-MFS-4-1M/12	1M samples/sec, 12-bit A/D, 4 SE simultaneous inputs, G = 1; two 12-bit D/As
PDXI-MFS-8-1M/12	1M samples/sec, 12-bit A/D, 8 SE simultaneous inputs, G = 1; two 12-bit D/As
PDXI-MFS-4-800/14	800k samples/sec, 14-bit A/D, 4 SE simultaneous inputs, G = 1; two 12-bit D/As, G = 1
PDXI-MFS-8-800/14	800k samples/sec, 14-bit A/D, 8 SE simultaneous inputs, G = 1; two 12-bit D/As,
PDXI-MFS-4-500/16	500k samples/sec, 16-bit A/D, 4 SE simultaneous inputs, G = 1; two 12-bit D/As
PDXI-MFS-8-500/16	500k samples/sec, 16-bit A/D, 8 SE simultaneous inputs, G = 1; two 12-bit D/As
PDXI-MFS-4-500/14	500k samples/sec, 14-bit A/D, 4 SE simultaneous inputs, G = 1; two 12-bit D/As
PDXI-MFS-8-500/14	500k samples/sec, 14-bit A/D, 8 SE simultaneous inputs, G = 1; two 12-bit D/As
PDXI-MFS-4-300/16	300k samples/sec, 16-bit A/D, 4 SE simultaneous inputs, G = 1; two 12-bit D/As
PDXI-MFS-8-300/16	300k samples/sec, 16-bit A/D, 8 SE simultaneous inputs, G = 1; two 12-bit D/As

Table 2.4—PowerDAQ PDXI-MFS Models

Note All PDXI-MFS Series models also include three counter/timers and 32 digital I/O lines.

Note PDXI-MFS Series boards provide a dedicated sample/hold amplifier (S/H) for each analog-input channel. These S/Hs are integrated into the board's hardware design and do not require any user software programming to enable their operation.

Note All PDXI-MFS Series models come standard only with G = 1; for other gains, you can purchase the DG option outlined in Table 2.5

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PowerDAQ PD2/PDXI MFS Series differential upgrade with gains (DG option)

The PD2/PDXI-MFS (simultaneous-sampling) Series can be upgraded from single-ended to differential inputs with gains for each channel. One programmable-gain amplifier (PGA) per channel is installed on the board.

Upgrade Part Number	Additional features added
PD2-MFS-4-DG4	Upgrade any PD2-MFS board from 4 SE to 4 DI and add Gains = 1, 2, 5, 10
PD2-MFS-8-DG8	Upgrade any PD2-MFS board from 8 SE to 8 DI and add Gains = 1, 2, 5, 10
PDXI-MFS-4-DG4	Upgrade any PDXI-MFS board from 4 SE to 4 DI and add Gains = 1, 2, 5, 10
PDXI-MFS-8-DG8	Upgrade any PDXI-MFS board from 8 SE to 8 DI and add Gain = 1, 2, 5, 10

Table 2.5—MFS Differential Upgrade Options

Note PowerDAQ MFS boards with the -DGx option installed have the same number of single-ended or differential channels.

PowerDAQ MF/MFS FIFO upgrade options:

You can upgrade the analog-input FIFOs on PD2/PDXI PowerDAQ multifunction boards. Below is a list of currently available upgrade options:

Upgrade part number	Additional features added
PD-16KFIFO	Upgrade onboard analog-input FIFO buffer to 16k samples
PD-32KFIFO	Upgrade onboard analog-input FIFO buffer to 32k samples
PD-64KFIFO	Upgrade onboard analog-input FIFO buffer to 64k samples

Table 2.6—PD2-/PDXI FIFO upgrade option

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PowerDAQ PDL-MF Lab Board:

This budget-priced “Lab” Series board features the following:

PDL-MF/PDL-MF-50	50k samples/sec, 16-bit A/D, 16 SE / 16 PDI / 8 DI inputs.
PDL-MF-333	333k samples/sec, 16-bit A/D, 16 SE / 16 PDI / 8 DI inputs.

Table 2.7—PDL-MF board specifications

The PDL-MF board has the following additional features:

- Analog Outputs Two 12-bit 100-kHz D/As
- Digital Inputs 24 lines
- Digital Outputs 24 lines
- Counter Timers Three 24-bit counters (run at 16.5-MHz from external clock or 33-MHz from internal clock)

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3. Installation and Configuration

Before you begin

Before installing your PowerDAQ board, be sure to read and understand the following information.

System requirements

To install and run a PowerDAQ board, you need the following:

- A PCI-bus system, a PXI-bus system or a CompactPCI-bus system with a free slot, a Pentium-class processor, and a BIOS compliant with *PCI Local Bus Specification Rev 2.1* or greater
- Windows 95, 98, NT 4.0, 2000/XP, Linux, Realtime Linux or QNX

Packing list

In your PowerDAQ package, you should have received the following:

- a PowerDAQ board
- a calibration certificate
- this User Manual
- a CD containing the PowerDAQ Software Suite, including the full Software Development Kit (SDK) and documentation

Note The CD label shows the version number of the SDK.

Precautions

PowerDAQ boards contain sensitive electronic components. When handling your PowerDAQ board, you should:

- ensure that you are properly grounded.
- discharge any static electricity by touching the metal part of your PC while holding the board in its antistatic bag.

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Installing the software

Note All third-party software must be installed prior to installing the PowerDAQ SDK.

Note The PowerDAQ SDK must be installed before you plug in a PowerDAQ board to ensure that the driver properly detects the board.

To install the PowerDAQ SDK:

1. Start your PC and, if running Windows NT, 2000 or XP, log in as an administrator.
2. Insert the PowerDAQ Software Suite CD into your CD-ROM drive. Windows should automatically start the PowerDAQ Setup program. If you see the UEI logo and then the PowerDAQ Welcome screen, go to Step 6.
3. If the Setup program does not start automatically, select Run from the Start menu.
4. Enter **D:\Setup.exe** in the Open: textbox (substitute the correct letter if D is not the drive letter for your CD-ROM drive.)
5. Click OK.



Figure 3.1—PowerDAQ Software Installation Startup Screen

6. As the Setup program runs, you will be asked to enter information about your PowerDAQ configuration. Unless you are an expert user and have specific

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requirements, you should select a Typical installation and accept the default configuration.

7. If the Setup program asks for information about third-party software packages that you do not have installed on your PC, leave the text box blank and click the Next button.
8. When the installation is complete, restart your PC when prompted.

Installing PowerDAQ hardware

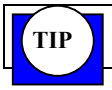
To install your PowerDAQ board:

1. Turn off your PC and remove its cover.
2. Locate an empty PCI slot and remove the slot cover on the back panel of the chassis. Save the screw.
3. Insert the board into the PCI slot.

Note If you plan to work only with analog I/O, the connector on the board's mounting bracket that shows through the chassis slot carries all necessary signals. However, if you plan to use digital I/O or the counter/timer features, in most cases (depending on model) you must attach a second cable to a header on the board; that cable requires a second empty chassis slot as detailed in the following section. It is also recommended that you use this second cable for external clocking and triggering signals. It is advisable to plug in all headers and closely examine the board in relationship to free PCI slots before actually inserting the board and going any further.

1. Inspect the board and ensure that you have inserted it properly into the slot.
2. Fasten the board's mounting bracket to your PC's back panel with the screw that held the slot cover.
3. Replace the PC's cover and turn on the power.

Note The PowerDAQ PCI interface must be set to 32-bit, 5V power and signaling (the default setting for most PCs).



To limit noise interference, install the board as far as possible from other devices and hardware.

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Confirming the installation

Once you have installed the PowerDAQ board and software on your PC, you should confirm the installation:

- Select **Programs → PowerDAQ → Control Panel**: from the **Start** menu (see Fig 3.2). If the Control Panel applet is displayed and correctly identifies your PowerDAQ board, the installation is correct.

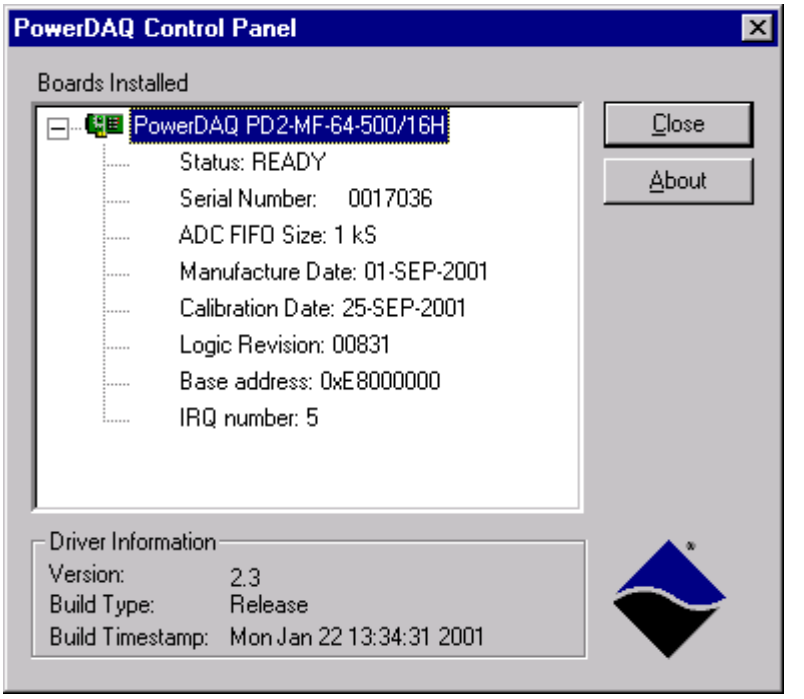


Figure 3.2—Control Panel Application

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Configuring a PowerDAQ board

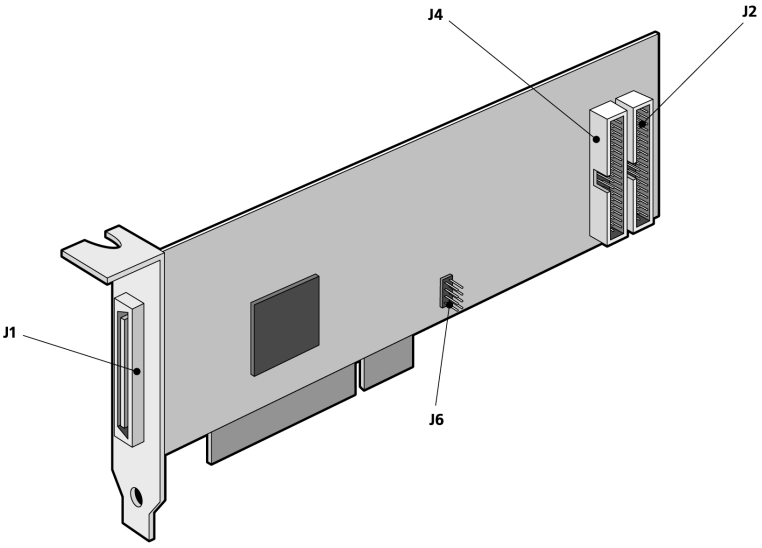


Figure 3.3a—Connector layout for long-slot PD2 Family boards

The layout in Fig 3.3a is used for old "legacy" PD2-MF boards and legacy PD2-MFS boards, which have since been converted to a "sandwich" design (Fig 3.3b). This diagram points out any on-board connectors or headers of interest to end-users; all others are reserved for factory use.

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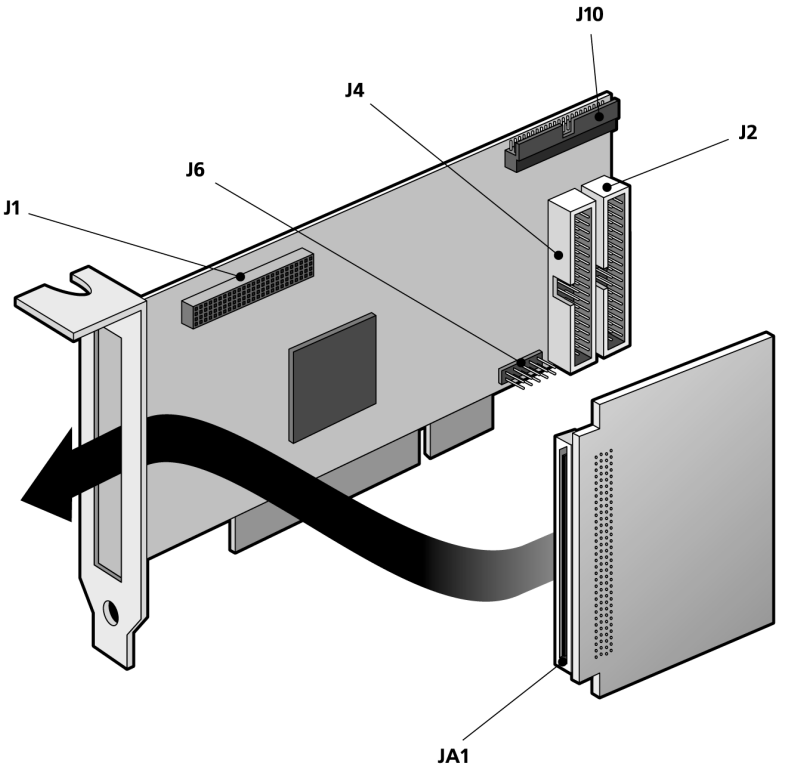


Figure 3.3b—Connector layout for "sandwich" format PD2 family boards

The Sandwich format (Fig 3.3b) is used for all MFS Series boards and MF Series boards. Note that you make external connections to the analog I/O section with the JA1 Connector; the J1 Connector serves to make electrical connections between the motherboard and the daughtercard. This diagram points out all available on-board connectors or headers of interest to end-users; all others are reserved for factory use.

Note PowerDAQ MF(S) cards using the "sandwich" form factor add support for the RTSI intercard communications bus on J10.

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Note Some PD2 Family boards now ship in the alternate short-slot "sandwich" form factor in Fig 3-3b. At the time of this writing, they include all PD2-MFS Series boards as well as the PD2-MF-xx-2M Series boards. We anticipate that other boards will use this form factor in the future. The location of the headers might change from the previous long-card format, but the connector pinouts remain the same.

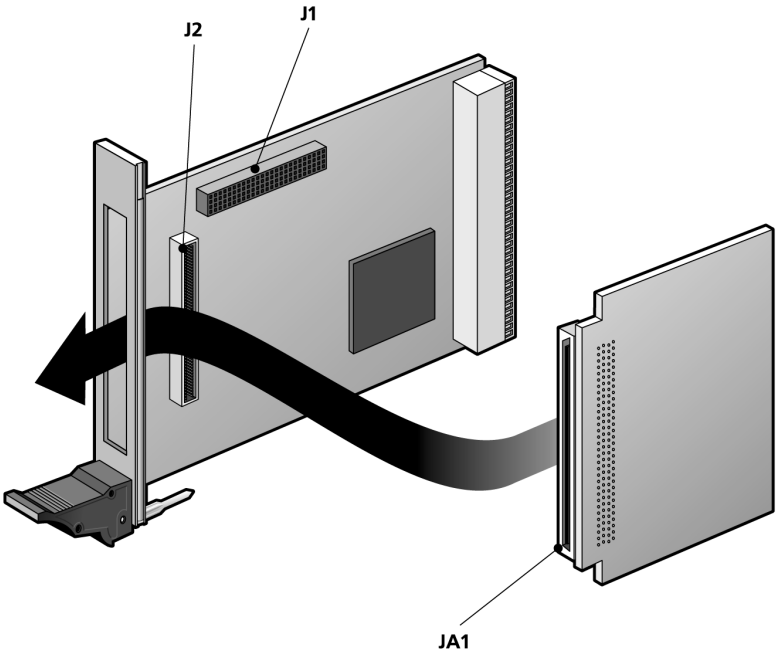


Figure 3.4—Connector layout for PDXI-MF(S) Series boards.

When working with PDXI-MF(S) boards, note that you make external connections to the analog I/O section with the JA1 Connector; the J1 Connector serves to make electrical connections between the motherboard and the daughtercard. This diagram points out any on-board connectors or headers of interest to end-users; all others are reserved for factory use.

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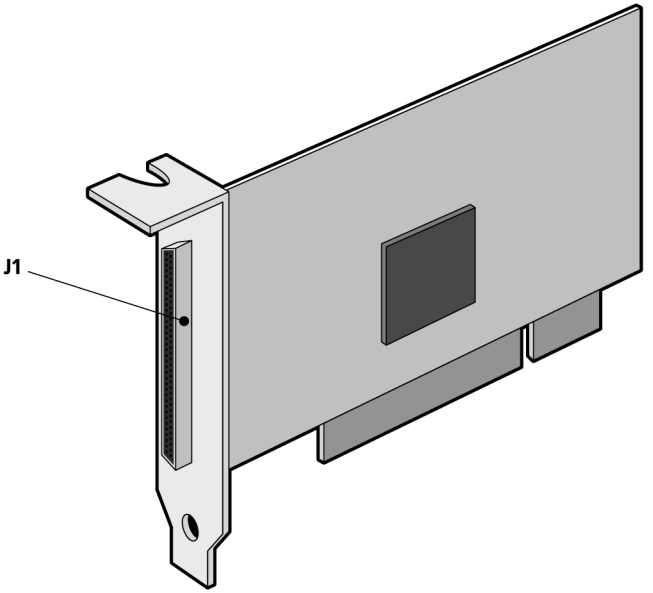


Figure 3.5—Connector layout for PDL-MF board.

The PDL-MF layout diagram in Fig 3.5 points out any on-board connectors or headers of interest to end users; all others are reserved for factory use.

Installing, synchronizing multiple boards

Some systems require more channels than are available on a single board. Even so, it's possible to configure a system in which you coordinate the actions of channels from multiple boards. To synchronize a multiboard acquisition run, program the master board's Burst clock (the CL clock) or its Pacer clock (the CV clock) to use the internal timebase, an external clock or software clocking. Then set the slave boards to use an external CL or CV clock. The best way to set up multiboard operation is to launch separate execution threads for each board. Start the slave boards threads first, and then execute the master board's thread.

To route these clock signals among multiple boards you need a special synchronization cable (the PD-CBL-SYNC4, see Appendix C). This cable has one connector for a master board and three connectors for slaves. (Synchronization cables for more than four boards are available from your distributor or the factory.)

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Note You synchronize a PDL-MF board to a system that also uses MF/MFS Series boards through clock connections you make on an external screw-terminal panel. If the PDL-MF is the master, connect CL Out or CV Out to CL In or CV In of the slave boards. If the PDL-MF is a slave, connect the CL Out or CV Out of the master to EXTCLK.

Note To use more than four PCI slots (the configuration in a standard PC) under control of one Master requires a PCI bridge chip. While these chips support additional PCI slots, they also reduce PCI-bus throughput and thus reduce the boards' maximum sampling rate. The reduction depends on the PC configuration, but a typical value is near 10% per board.

For PDXI boards, you must make all synchronization settings over the PXI backplane with the PDXI Configurator software (see Fig 3.6). By clicking on the lines you wish to connect, you instruct the software to write the new configuration to an EEPROM that stores these connections.

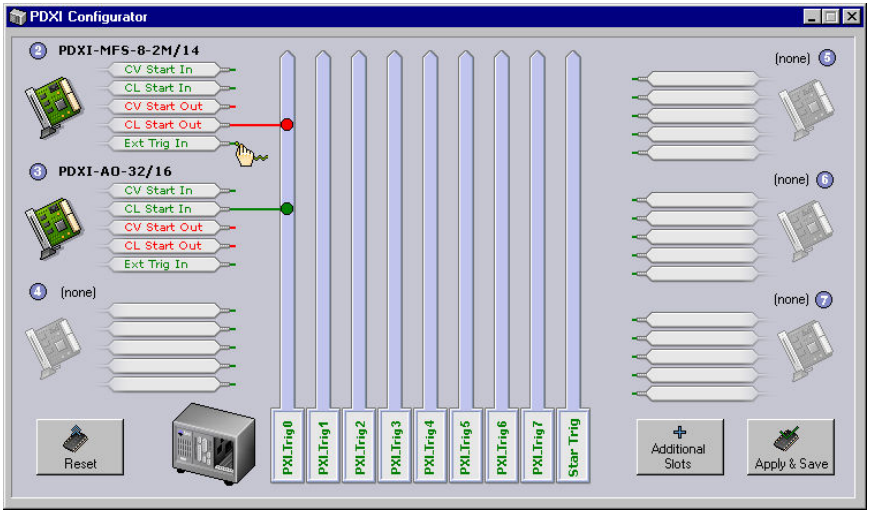


Figure 3.6—PDXI Configurator

Base address, DMA and interrupt settings

When you power up your PC, the PCI bus automatically configures any PowerDAQ boards that are installed. You don't have to set any base address, DMA channels or interrupt levels. Be aware, though, that performance problems can arise when the system has insufficient interrupts and can't assign a unique one to each peripheral so that a PowerDAQ board must share an interrupt with some other device. One solution is to decide which system resources you do not need—candidates being serial ports, the parallel port, USB ports or network interfaces—and disable their interrupts, thereby freeing those lines up for assignment to other devices. This can lead to the optimal case where a PowerDAQ board is assigned a dedicated IRQ line.

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Note A data-acq card's interrupt is generally assigned by the PC BIOS, and some PC systems even let you reassign it during the boot process. If your motherboard has an Advanced Interrupt Controller, simply enable it in the BIOS. This allows you to use more than 16 generic interrupt lines. If you don't have this facility, use manual settings to assign the interrupt to the PCI slot where PowerDAQ board is installed

Note Modern motherboards can easily contain four, five or even more PCI slots plus integrated PCI devices such as networking modules and a video driver. Usually only three of these slots are independent and don't share interrupts with these host system peripherals. Please refer to your motherboard manual to find out which slots share interrupts and cannot be used for fast data acquisition.

Note PowerDAQ boards are designed to share interrupts, but we do not recommend that they share interrupts with devices such as video drivers, network cards or hard disks. These devices tie up interrupt lines extensively and can significantly delay responding to an interrupt from a data-acquisition board. Although Windows 9x/NT/2000 are not realtime operating systems, your PowerDAQ board is a real-time system within the PC thanks to its own DSP and realtime kernel. Many motherboard manufacturers allow you to set an IRQ level to a particular PCI slot. If you do not use your PC's serial or parallel ports, you can disable them and use IRQ 3, 4, 5 or 7 for your data-acquisition boards.

Connectors for PD2 MF/MFS Series boards

PowerDAQ PD2 Series multifunction boards have four connectors:

- A main bracket connector for analog I/O signals (J1)—A 96-contact pinless male board-edge connector manufactured by Fujitsu (PN# FCN-245P096-G/U, see details for this connector on the datasheet for the corresponding PowerDAQ boards on the UEI website). The pin assignments on this connector differ depending on whether you configure the analog inputs as single-ended or differential, and whether you are dealing with MF or MFS Series boards.
- On-card connector for digital I/O and counter/timer signals as well as external clocks and triggering lines (J2)—A 36-pin flat cable to pc-board connector, male IDC header, manufactured by Thomas and Betts (PN# 609-3627, see details for this connector on the datasheet for the corresponding PowerDAQ boards on the UEI website).
- On-card connector for additional digital I/O signals (J4)—A 36-pin flat cable to pc-board connector, male IDC header, manufactured by Thomas and Betts (PN# 609-3627, see details for this connector on the datasheet for the corresponding PowerDAQ boards on the UEI website).
- On-card connector for intraboard synchronization clock signals (J6)—An 8-pin flat cable to pc-board connector, male IDC header, manufactured by Methode / Adam Tech (PN# PH2-08-TA-SMT, see details for this connector on the datasheet for the corresponding PowerDAQ boards on the UEI website).

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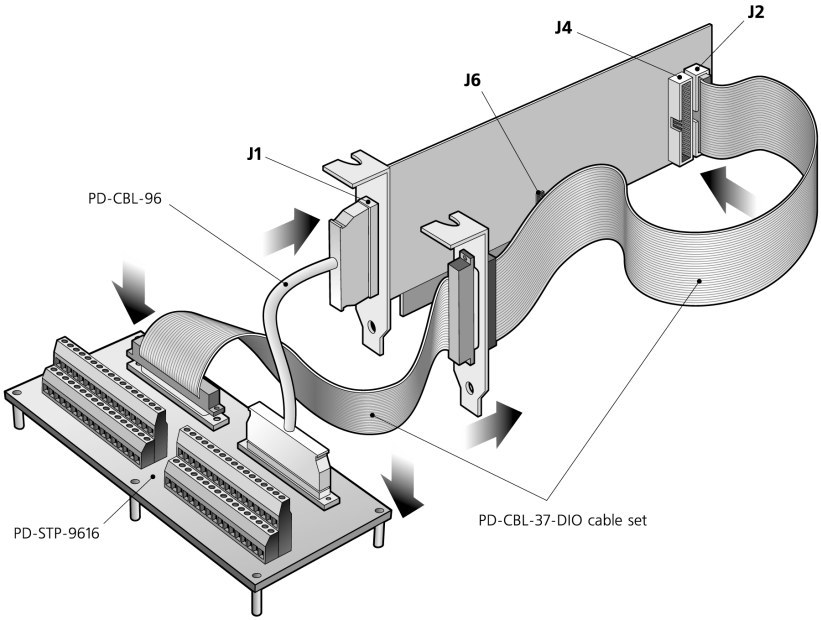


Figure 3.7—Cable connection diagram for PowerDAQ MF (S) boards

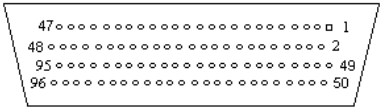


Figure 3.8a—Physical layout of J1 / JA1 Connector on PD2 MF(S) Series boards

Fig 3.8a gives a view looking at the connector as mounted on the board.

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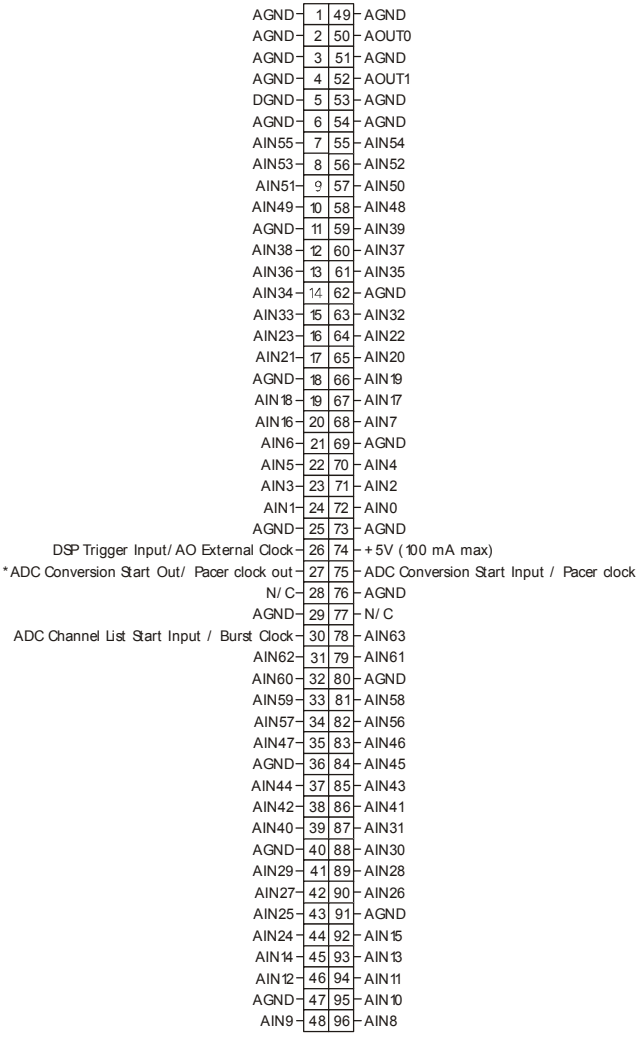


Figure 3.8b—Pin assignments on J1 / JA1 Connector on PD2-MF boards, in single-ended mode

In Fig 3.8b, the * symbol means that the line is disconnected by default, consult factory if you need this clock on the J1 connector.

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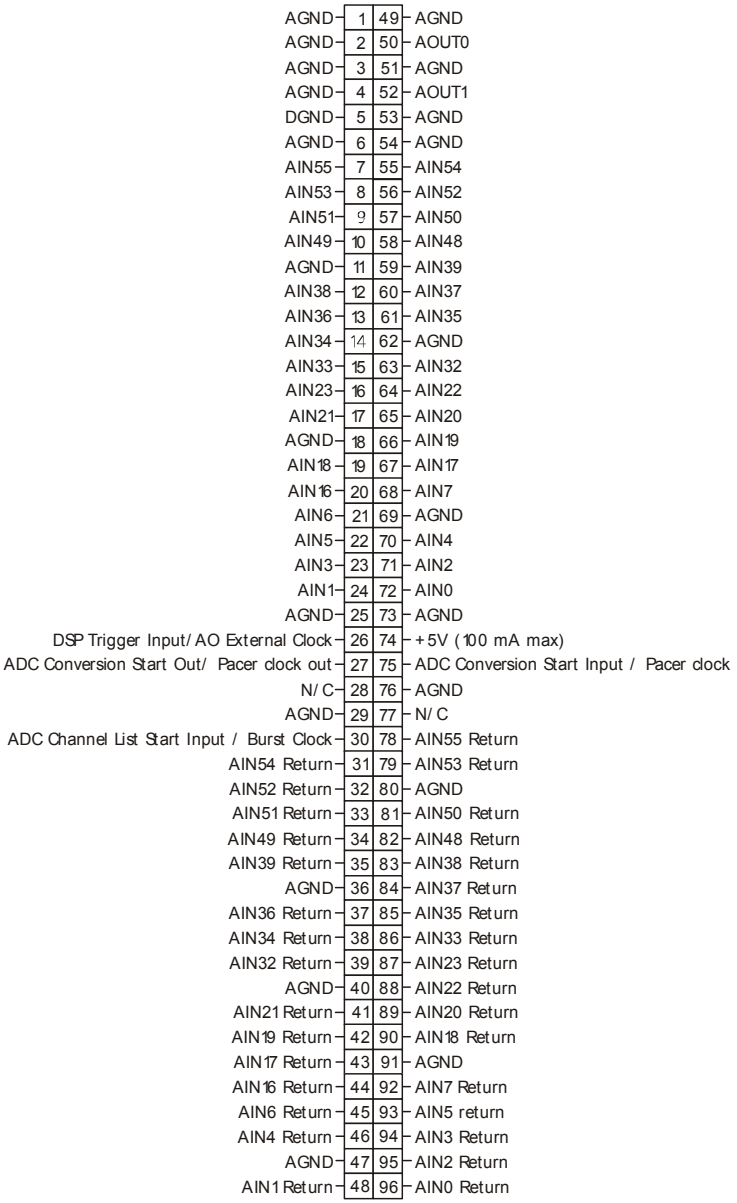


Figure 3.8c—Pin assignments on J1 / JA1 Connector on PD2-MF boards, in differential mode

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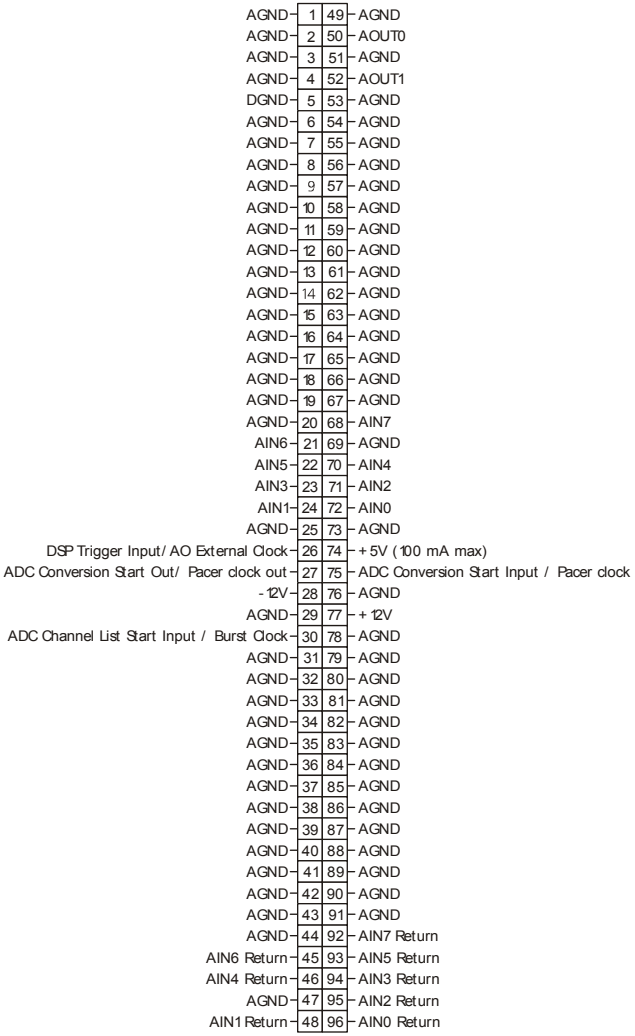


Figure 3.8d—J1 / JA1 Connector on PD2-MFS boards, single-ended or differential modes

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Connector pin assignments for J2

The J2 digital internal connector handles eight digital input and eight digital output lines, the counter/timers, and an external A/D pacer clock.

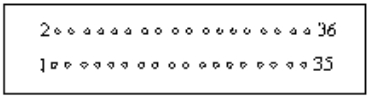


Figure 3.9a—Physical layout of J2 on PD2 MF/MFS Series boards

Fig 3.9a gives a view looking into the connector socket mounted on the board.

CTR0-IN	1	2	CTR2-IN
CTR0-OUT	3	4	CTR2-OUT
CTR0-GATE	5	6	CTR2-GATE
CTR1-IN	7	8	CTR1-GATE
CTR1-OUT	9	10	+5V (100 mA max)
DIN0	11	12	DGND
DIN1	13	14	DOUT0
DIN2	15	16	DOUT1
DIN3	17	18	DOUT2
DIN4	19	20	DOUT3
DIN5	21	22	DOUT4
DIN6	23	24	DOUT5
DIN7	25	26	DOUT6
Burst Clock / ADC Channel List Start Input	27	28	DOUT7
DSP Trigger Input /AO External Clock	29	30	DGND
Pacer Clock / ADC Conversion Start Input	31	32	ADC Conversion Start Output / Pacer Clock Output
DGND	33	34	DGND
Burst Clock / ADC Channel List Start Output	35	36	NC

Figure 3.9b—Pin assignments for J2 Connector on PD2-MF/MFS boards

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Connector pin assignments for J4

The J4 Connector handles an additional eight digital-input and eight digital-output lines on boards with these extra DIO features.

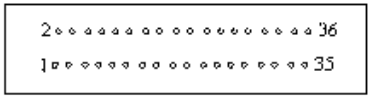


Figure 3.10a—Physical layout of J4 on PD2 MF/MFS Series boards

Fig 3.10a gives a view looking into the connector socket mounted on the board.

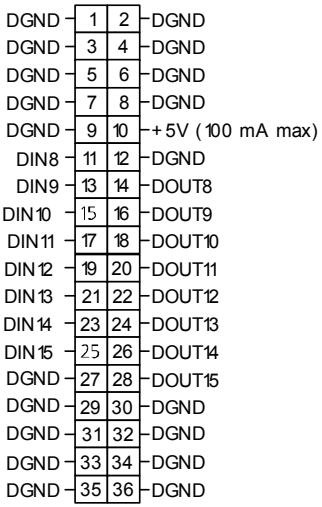


Figure 3.10b—Pin assignments for J4 Connector on PD2-MF/MFS boards

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Connector pin assignments for J6

The J6 intraboard-synchronization connector contains two pairs of clock signal lines:

- The CV Clock (the conversion clock, also known as the Pacer clock)
- The CL Clock (the Channel List clock, also known as the Scan clock or Burst clock).

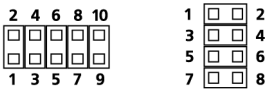


Figure 3.11a—Physical layout of J6 on PD2-MF(S) Series boards

Fig 3.11a gives a view looking into the connector socket mounted on the board.

Note The J6 connector on full-slot MF(S) boards uses an 8-pin connector for J6, whereas the newer "sandwich boards" generally use a 10-pin connector. Furthermore, the PD-CBL-SYNC synchronization cable is equipped with 10-position connectors. When using this 10-pin cable on an 8-pin connector, leave the two lowest holes (pins 9 and 10) free.

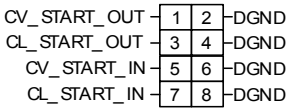


Figure 3.11b—Pin assignments for J6 Connector on PD2-MF/MFS boards

Connector for PDL-MF-X

PowerDAQ PDL Series multifunction boards have one connector: a main bracket connector (J1)—100-pin male pinless connector manufactured by Fujitsu (PN# TYCO-787169-9, see details for this connector on the datasheet for the corresponding PowerDAQ boards on the UEI website).



Figure 3.12a—Physical layout of J1 on PDL-MF-X board

Fig 3.12a shows the view looking into the connector socket mounted on the board.

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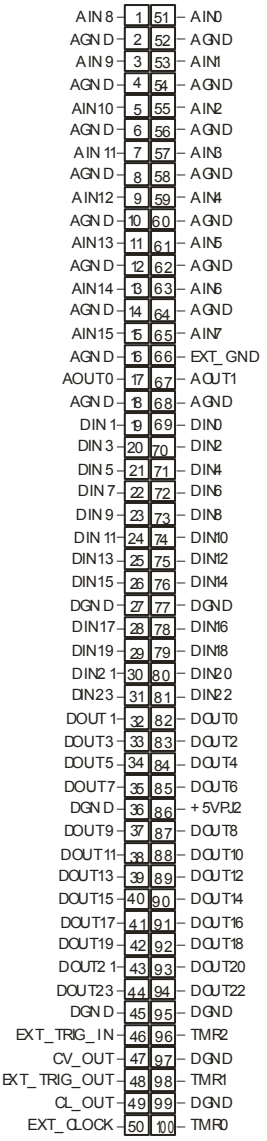


Figure 3.12b—Pin assignments for J1 Connector on PDL-MF-X Series board

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Connectors for PDXI MF(S) Series boards

PowerDAQ PDXI-MF(S) Series multifunction boards have two connectors:

- A main bracket connector for analog I/O signals (J1)—A 96-contact pinless male connector manufactured by Fujitsu (PN# FCN-245P096-G/U, see details for this connector on the datasheet for the corresponding PowerDAQ boards on the UEI website).

Note The connector pinout for J1 on the PDXI MF/MFS Series is identical to the pinouts on the PD2-MF/MFS Series. See Figures 3.8a-d

- On-card connector for digital I/O and counter/timer signals (J2)—An 80-pin flat cable to pc-board connector, male IDC header, manufactured by Methode/Adam Tech (PN# HBMR-A-80-VSG, see details for this connector on the datasheet for the corresponding PowerDAQ boards on the UEI website).

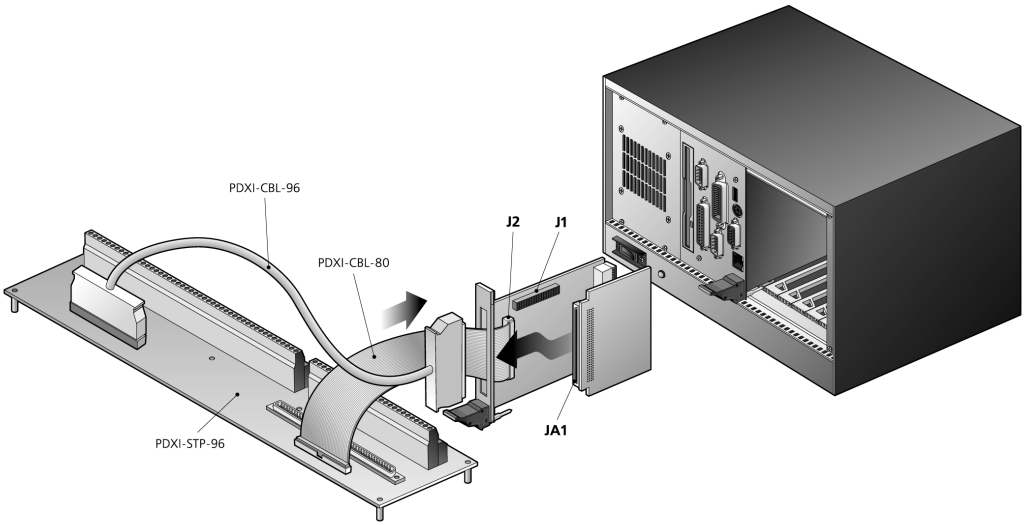


Figure 3.13—Cable connection diagram for PDXI-MF(S) boards

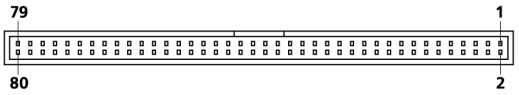


Figure 3.14a—Physical layout of J2 on PDXI-MF/MFS Series boards

Fig 3.14a gives a view looking into the connector socket mounted on the board.

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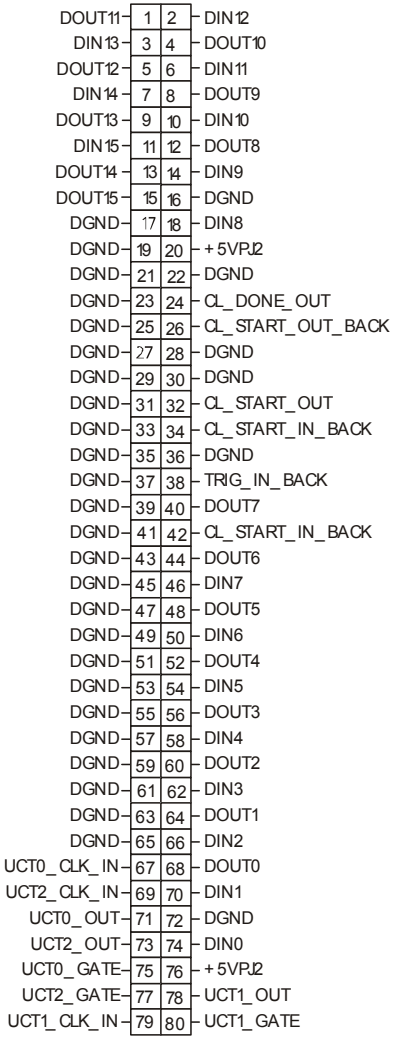


Figure 3.14b—Pin assignments of J2 Connector on PDXI MF/MFS Series boards

The PXI_TRIG 0…7 and PXI_STAR lines on the PXI system backplane (located on Connector P2, above Connector P1) can be used for interboard synchronization.

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"Simple Test" program

After wiring external signals to your PowerDAQ board, run the PowerDAQ Simple Test program to verify that all subsystems are operating properly.

From the **Start** menu, select **Programs ➞ PowerDAQ ➞ Simple Test**, and the utility's dialog box appears.

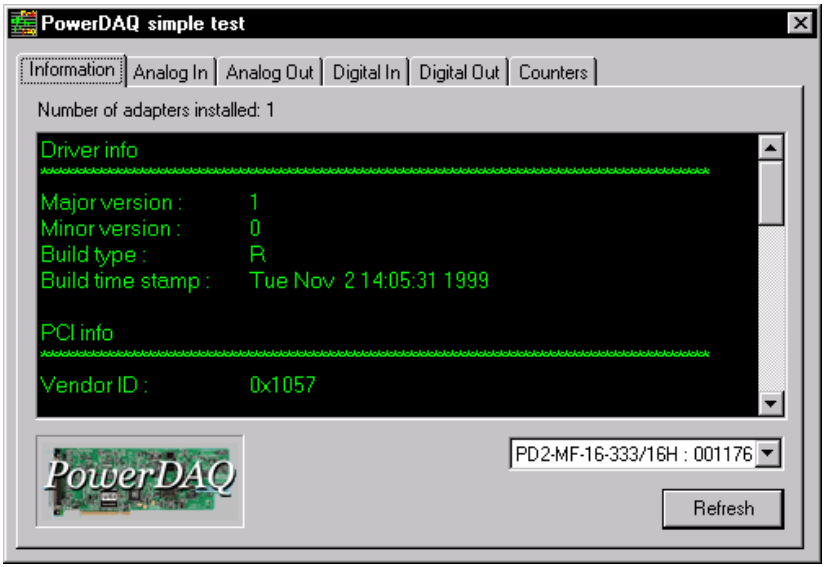


Figure 3.15—Simple Test application

Use the **Analog In**, **Analog Out**, **Digital In**, **Digital Out** and **Counters** tabs to observe your application running on the board. From these pages you can control the mode (single-ended or differential), range, gain, number of channels activated and the channel whose value appears on the screen.

It's often helpful to run an analog I/O loopback test with the help of this utility. First wire AOut0 to all even-numbered AIn channels and then wire AOut1 to all odd-numbered AIn lines. Be sure to increase the number of active channels in the AnalogIn tab to the maximum, and click Start. Now go to the AnalogOut tab, select two different waveforms for the two active channels and click Start. Return to the AnalogIn tab and scroll through various channels to verify the operation of each.

You can similarly run a digital I/O loopback test. Wire Dout channels to corresponding Din channels. Click Start on the DigitalOut tab, then return to the DigitalIn tab and verify the operation of each line.

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Calibration

All PowerDAQ hardware ships fully calibrated and do not require additional calibration on the part of the user. The boards store calibration values for each range and each gain in EEPROM. When you initially load the PowerDAQ board driver and configure the analog-input subsystem, that process loads the calibration values from EEPROM.

However, to ensure peak performance from your PowerDAQ hardware, we suggest that a PowerDAQ board be recalibrated every 12 months.

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4. PowerDAQ Architecture

Functional Overview

The PowerDAQ MF/MFS Series features extensive input modes, clocking and triggering capabilities. It also provides simultaneous subsystem operation.

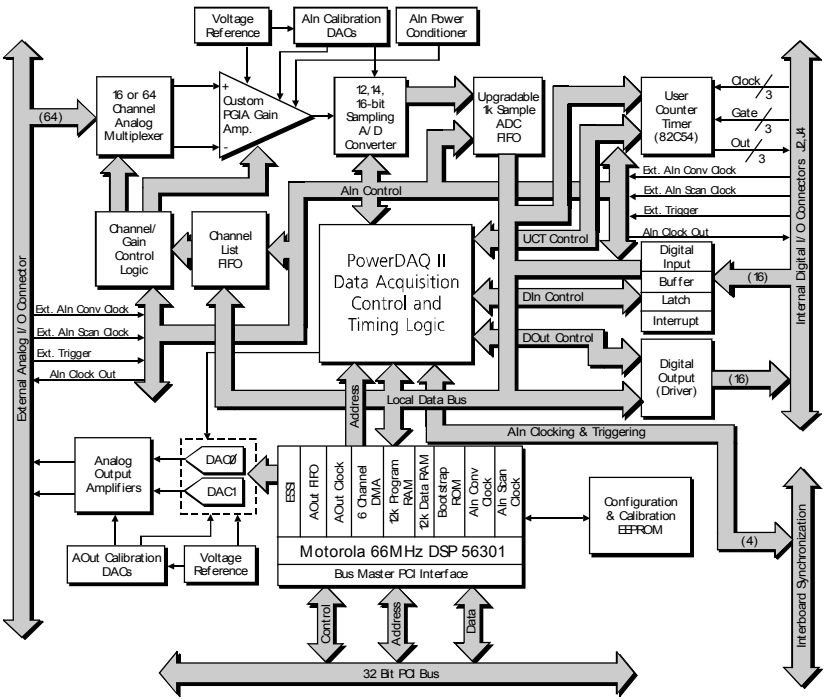


Figure 4.1—PowerDAQ PD2-MF/MFS Series block diagram

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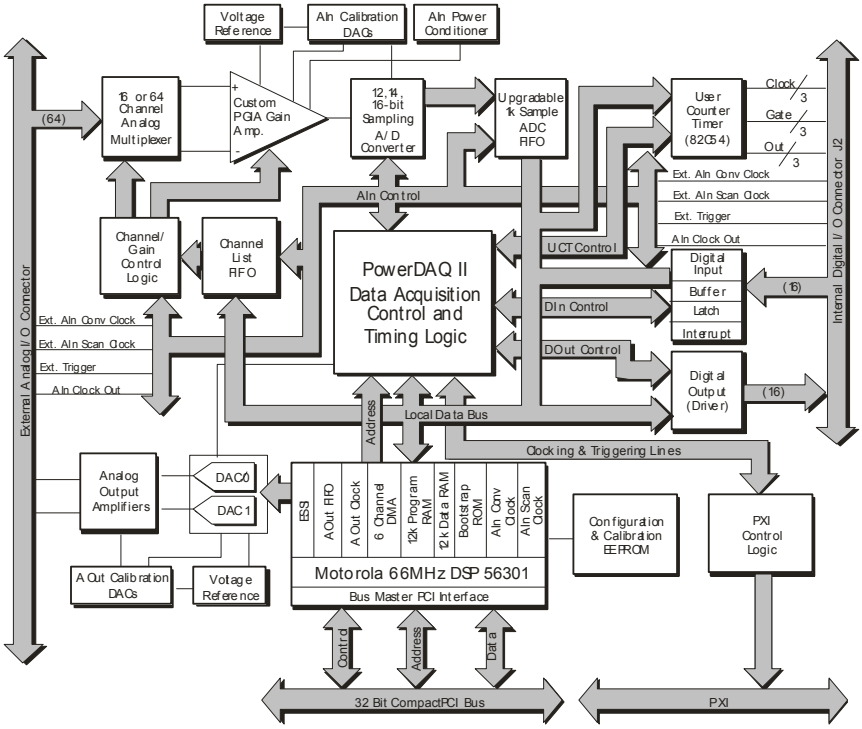


Figure 4.2—PowerDAQ PDXI-MF/MFS Series block diagram

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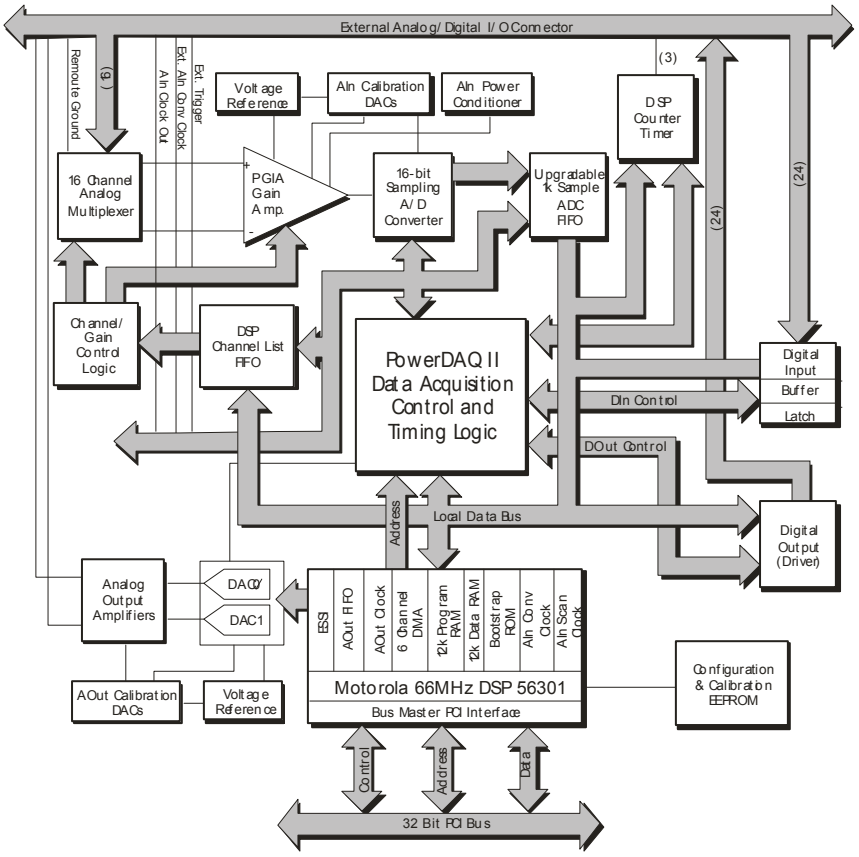


Figure 4.3—PowerDAQ PDL-MF block diagram

The heart of each board in the MF/MFS Series is a Motorola 56301, a 66-MHz DSP. That device ensures a highly efficient interface with the PCI/PXI bus, and it also provides control over all board subsystems.

The Analog Input subsystem includes:

- An input multiplexer (Mux) selects which channels to acquire. The Channel List FIFO contains a list of each channel to be acquired along with its gain; the subsystem reads this data and sets up the input mux accordingly. PD2-MFS boards have per-channel sample/ hold amplifiers (S/Hs) preceding the mux. The S/Hs acquire a signal from all input channels simultaneously and then hold the acquired voltages while the A/D digitizes them channel-by-channel.
- A Programmable Gain Amplifier (PGA) increases the level of an input signal in order to provide an adequate voltage to the A/D. The PGA's level of amplification depends on the board model and can be software selected on a per-channel basis. Models in the MF

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Series come with one of two sets of amplification levels. For low-level signals that need considerable boosting, select the /L option (G = 1, 10, 100 or 1000); for high-level signals that don't require as much amplification, select the /H option (G = 1, 2, 4 or 8). The PDL-MF board ships two versions, both with G = 1, 2, 5 or 10. MFS Series boards ship standard only with unity gain; for other gains (G = 1, 2, 5 or 10 you must purchase the –DG option).

- An A/D FIFO holds digitized samples until the DSP transfers them into host memory over the PCI/PXI bus. The default A/D FIFO size starts at 1k samples and depending on the board model can be as large as 4k samples. You can upgrade the FIFO to 16k, 32k or 64k samples depending on application requirements. Note that while larger FIFOs achieve smoother operation, especially at high acquisition rates, there is a tradeoff in terms of response time. Specifically, the driver normally transfers data from the buffer only when the FIFO is half full, so a larger buffer means you wait longer for a transfer. This extra time can degrade system response in closed-loop control applications.
- A calibration D/A generates voltages to adjust the offset and gain settings on the analog-input section to ensure accurate performance. As noted in the previous section, all boards are factory calibrated for each input range and mode.
- The timing, triggering and clocking controls allow you to select the timebase, clock and triggering sources, a "slow bit" and other options.
- An interrupt mechanism notifies the DSP of special conditions on this subsystem so the user application can take appropriate action.

The Analog Output subsystem includes:

- A DSP-based FIFO that holds as many as 2k samples of digitized waveform values to feed to the output D/A.
- A 12-bit D/A that converts digitized waveform values into analog output voltages.
- A calibration D/A that provides voltages to adjust offset and gain on the analog output to ensure accurate performance.
- Timing, triggering and clocking controls that allow you to select the analog-output rate and clock source.
- An interrupt mechanism that notifies the DSP of special conditions on this subsystem so the user application can take appropriate action.

The Digital Input/Output subsystem includes:

- A 16-bit register to read logic levels on digital input lines (24-bit register on PDL-MF).
- An 8-bit Schmidt trigger to catch logic-level changes on digital input lines (not present on PDL-MF).

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- A 16-bit register to hold logic levels on digital output lines once the program has written data to the outputs (24-bit register on PDL-MF).
- An interrupt mechanism notifies the DSP of special conditions on this subsystem so the user application can take appropriate action.

The User Counter/Timer subsystem includes:

- Three 16-bit Intel 82C54 counter timers, fully accessible by the user (the counter/timers on the PDL-MF are shared with the 24-bit DSP 56301).
- Clock-source selection and control logic.
- Gate-source selection and control logic.
- An interrupt mechanism notifies the DSP of special conditions on this subsystem so the user application can take appropriate action.

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Programming Model

No matter which subsystem you choose to work with, the way you initialize and set up the board is very much the same, so before digging into details of individual subsystems it makes sense to review these general procedures.

An onboard DSP controls all subsystems. User applications communicate with the board via the PowerDAQ API, which is integrated into the PowerDAQ dynamic-link library (DLL). To inform an application about hardware events, the driver creates kernel events. Data is transferred from the board through the PCI bus and stored in the user-level buffer. The PowerDAQ API includes a set of information functions that allow user applications to get board-specific information, such as model, serial number and IRQ line.

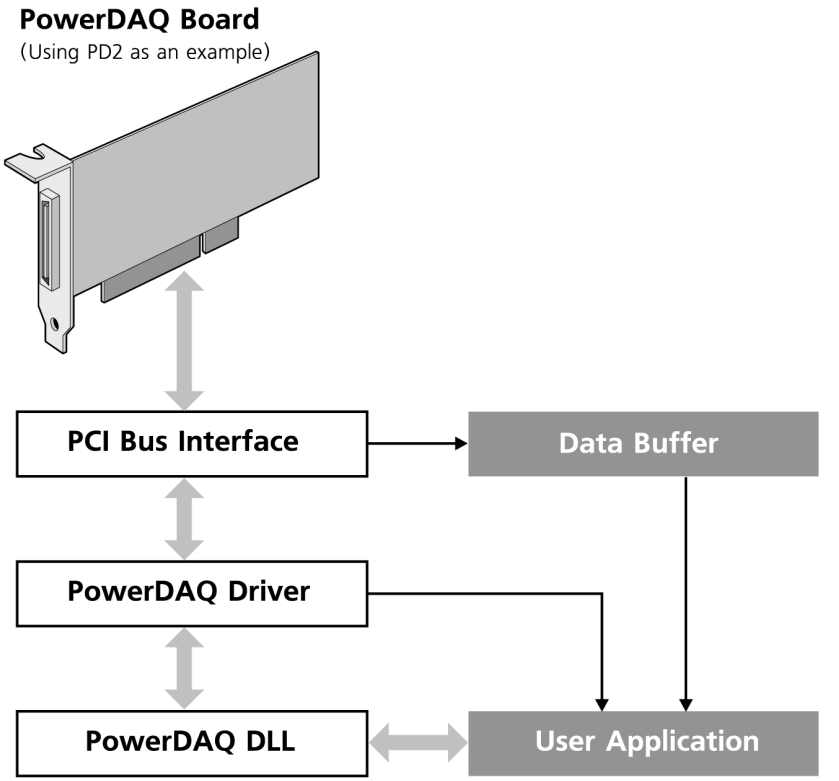


Figure 4.4—Communication between a user application and a PowerDAQ multifunction board

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Programming subsystems

All PowerDAQ subsystems have two modes of operation:

- Polled
- Event-based

In Polled mode, the user application queries the board about the status of various subsystems as needed. This method is preferred when the application does not need to be notified about hardware events. In Event-based mode, the board notifies the user application of certain predefined subsystem events using Win32 calls. With this mode you can write truly asynchronous applications.

Opening a subsystem

Before starting any board operations whatsoever, you must first open the driver, open the adapter (another term that refers to a specific board), and acquire the subsystem. After completion of a specific task the user application can release the subsystem, and when the application has completed its work make sure it closes the adapter and driver.

This manual explains the general procedures for creating a program and important API calls. The following calls outline the sequence you must make when programming under Win32; in particular, the calls to open/close the driver and open/close the adapter are specific to Windows. The remaining calls are valid for any OS.

For details on various functions and their calling parameters, see the *PowerDAQ Programmer Manual*. The specific calls and their names might vary with other operating systems, so once again you might want to refer to that manual.

API calls required for opening/closing a subsystem

- *_PdDriverOpen(...)*
  Open the driver
- *_PdAdapterOpen(...)*
  Open the adapter; only one process can open a given adapter at a time. This function returns *phAdapter*, a handle for the adapter, and you will need this variable in many later functions.
- *_PdAcquireSubsystem(...)*
  Acquire the named subsystem for use (if you set *dwAcquire* = 1), and the parameter *dwSubsystem* can be one of the following (as defined in *typedef enum*

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_PD_SUBSYSTEM): AnalogIn, AnalogOut, DigitalIn, DigitalOut, CounterTimer.

… let the user app work with the subsystem, then …

- *_PdAcquireSubsystem(...)*
  Release the subsystem from use (if you set *dwAcquire* = 0)
- *_PdAdapterClose(...)*
  Close the adapter
- *_PdDriverClose(...)*
  Close the drive

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5. Analog-Input Subsystem

Architecture

The analog-input subsystem consists of an A/D converter, signal-conditioning circuitry and control of other front-end devices such as a multiplexer or multiple sample/hold amplifiers. The subsystem's first stage multiplexes raw signals from the input channels into a successive-approximation A/D with a resolution of 12, 14 or 16 bits. The A/D subsystem also includes selection of input mode (single-ended or differential), polarity, gain settings, range settings, set up of the Channel List, trigger and clocking control.

The multiplexer on MF boards is located at the signal inputs and can be switched to function either in single ended (SE) or differential (DI) mode (Fig 5.1). The selected mode is applied to all input channels. The output of the mux feeds an instrumentation amplifier and then the signal goes into a custom programmable gain amplifier (PGA). Channel numbers, along with their gains, are stored in a Channel List. With this mechanism you can select the order in which the channels are read as well as set different gains on a per-channel basis.

Input Ranges

The majority of PowerDAQ boards feature four possible input ranges, which are applied globally across all input channels and are applied to all signals. You select the input mode (SE/DI) and range from Table 5.1 with the *_PdAInSetCfg()* command.

Unipolar	Bipolar
0-10V	±10V
0-5V	±5V

Table 5.1—PowerDAQ analog-input ranges

Note The only exception to this table is the PDL-MF, which does not offer the 0-5V range.

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Gain Settings

You can set a gain for each channel on an MF/MFS Series board prior to acquisition, and you do so by setting up a Channel List as described in the next section. There are three gain ranges. In Table 5-2 below, the "L" or "H" appears at the end of the model number as appropriate (such as PD2-MF-64-2M/14L) and applies to the MF Series boards only. An "L" indicates that a board is appropriate for working with low-level signals that need a large gain. An "H" indicates that a board is appropriate for high-level signals that need less gain. The PDL-MF boards and the standard MFS Series are available only with one set of gains.

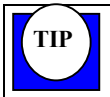
MF Series "L" Suffix	MF Series "H" Suffix	Preselected gains on PDL-MF or options for MFS Series cards
G = 1, 10, 100, 1000	G = 1, 2, 4, 8	G = 1, 2, 5, 10

Table 5.2—Programmable Gains

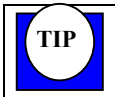
Channel List

Often you want to sample only over a certain subset of channels, sample them in various orders or apply different gains to each channel. These options are all possible with an A/D Channel List, which you create with the *_PdAInSetChList()* command. It is mandatory that you create a channel list, otherwise the board will not collect the correct data.

The Channel List is resident in the on-card memory known as the Channel List FIFO and thus must be programmed every time you power up the card. It contains from one to 256 entries (64 entries maximum on the PDL-MF). Each reading of the full list is called a scan. Configuration data for each entry includes the channel number, gain, and Slow Bit setting. A Channel List remains active until you overwrite it with a new set of entries. Writing a Channel List with 0 entries clears the list



To effectively change the sampling rate of just one channel, make multiple entries for it in the Channel List instead of reading it just once per scan.



You can use averaging over several scans to increase the effective resolution and reduce noise. For applications where the dc value is crucial, consider using a software filter that consists of an averaging window over an array of averages. Each time you calculate the average value of a channel you put it into an array, and if that array is already full you replace the oldest one. Then your program calculates the average value of the array of averages and uses it as a final value.

Giving you added flexibility in setting up a Channel List is the Slow Bit feature. It is a special marker you can activate in every channel, and it instructs the analog front end to insert a delay in the acquisition sequence, thus allowing the input amplifier to settle before it clocks the A/D to make a conversion. This feature is useful if you are applying a high gain (100 or 1000) to a signal.

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With a Slow Bit you can give that channel extra time without slowing down all the others. Be aware, though, that turning on the Slow Bits can result in a reduction in a board's maximum throughput rate.

The amount of delay due to a Slow Bit varies with each PowerDAQ model. A table giving the minimum time between conversions you can expect with any particular model with the Slow Bit active appears in Appendix B.

The Channel List has the following format:

Bit 8	Bits 7, 6	Bits 5-0
Slow bit (0 = Off 1 = On)	Gain (see Table 5.3b)	Channel to acquire (000000 = Ch 0 111111 = Ch 63)

Table 5.3a—Channel List format

Gain coding (Bits 7, 6)	"L" Gains (MF Series)	"H" Gains (MF Series)	Gains for MFS and PDL-MF boards
00	1	1	1
01	10	2	2
10	100	4	5
11	1000	8	10

Table 5.3b—Programmable-gain codes

Input modes

The analog-input section on all PowerDAQ boards multiplexes the active input channels into a single 12-, 14- or 16-bit successive approximation A/D. The boards can be configured to work with either single-ended (16 to 64) or differential (8 to 32) inputs, and the selected mode must be the same for all channels.
This selection of input mode can lead to some confusion. No matter what the underlying test-system configuration, all voltage measurements are made between two points and thus are inherently differential. One node is at a potential as compared to the level on the other input terminal, and that level can be at a ground reference or at an elevated voltage level. On a PC-based data-acq card, one line of the input amplifier is always connected to the signal of interest. To what level the second (referenced) line on the input amp is connected determines in which of three possible input modes the amp is operating.

- ***Single-ended*** channels refer all their inputs to a common ground that is also connected to the computer ground.
- ***Pseudodifferential*** channels refer all their inputs to a common ground—but this ground is not connected to the computer ground.

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- ***Differential*** inputs use an independent reference for each channel, and these references are not connected to the computer ground (and instead are generally a return path directly to the source of the signal being digitized).

Each mode has its strengths and weaknesses, so you should pay close attention to the connection on the input's reference terminal.

Note No matter whether you choose single-ended, pseudodifferential or differential mode, be sure to short unused channels to ground using a 1 kΩ to 10-kΩ resistor.

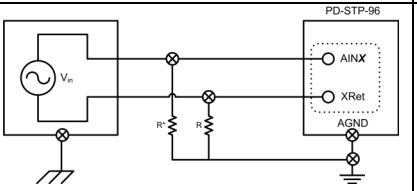
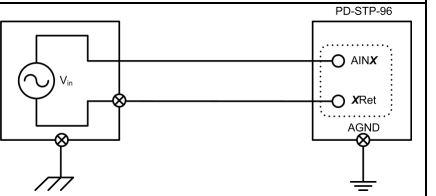
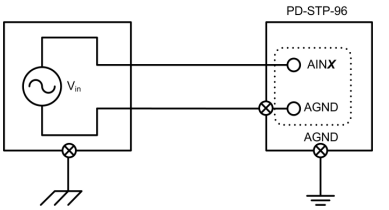
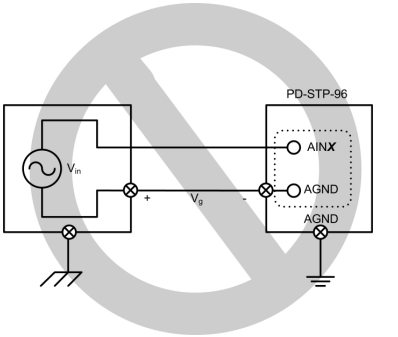
Input configuration	**Signal Source Type**	
	Floating Signal Source (Not connected to ground)	Grounded Signal Source
	Examples • Thermocouples • Signal Conditioning with Isolated Outputs • Battery Devices	Examples • Plug-in instruments with Non-isolated Inputs
Differential	 Two resistors (10kΩ < R < 100kΩ) provide return paths to ground for bias currents; In most cases R* is optional	
Single-Ended Ground Referenced		

Table 5.3c—Analog Input Configurations

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Single-ended

A PowerDAQ card operating in single-ended mode (Fig 5.1) digitizes across as many as 64 channels. For single-ended inputs you connect one wire from each signal source to the High input of the data-acq system's input amplifier, and all signals share a common return path connected to analog ground (AGND). You should connect this common return path to both a ground near the signal source and also to the ground on the PC, which in this way gets set at the same level as the signal ground.

Pseudodifferential

The PDL-MF card allows operation in pseudodifferential mode (Fig 5.1). For pseudodifferential inputs you connect one wire from each signal source to the High input of the data-acq system's input amplifier, and all signals again share a common return path to AGND. However, this ground signal is typically referenced to a remote source and it is separated from the PC ground; thus it can float at a different level. The maximum difference between common ground and PC ground should never exceed 10V. You can remove the effect of this voltage offset from measurement results by subtracting the difference between AGND and COM from the measured result. Because the AGND line in a pseudodifferential setup is not connected to the computer ground, it is not subject to the associated digital noise within the PC.

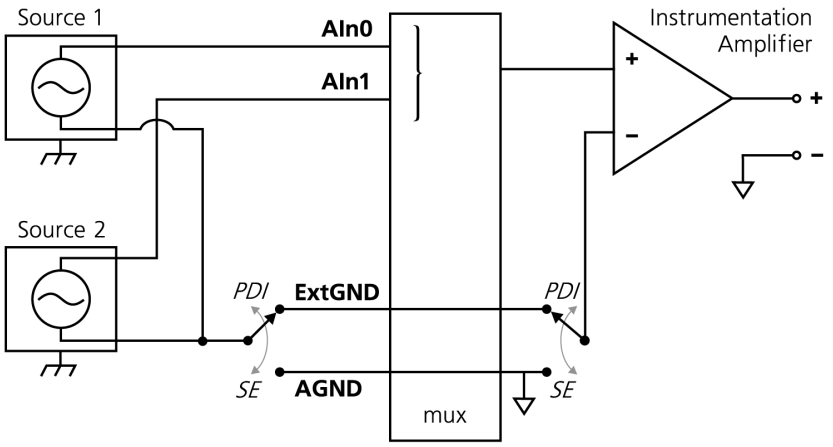


Figure 5.1—Wiring for single-ended and pseudodifferential inputs

Differential

A PowerDAQ card operating in differential mode digitizes across as many as 32 channels. Each channel uses two lines on the data-acquisition system's input amplifier (Fig 5.2)—you connect one lead from the signal source to the channel's High input (the positive input of the amp) and

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connect the other signal lead to the channel's Low input (the amp's negative input). Each signal floats at its own level without any reference to ground or other inputs.

For example, when working with a 16-channel PowerDAQ board in differential mode, Ch 0 and 8 form the High and Low inputs of differential-input Ch 0; next, for differential-input Ch 1 you use Ch 1 and 9; follow this pattern for all eight differential-input pairs. Follow this procedure when wiring the PDL-MF board according to the pin assignments in Fig 3.12b. However, we have prepared separate differential-input pin-assignment diagrams for the PD2/PDXI-MF(S) boards, and they appear in Figs 3.8c and 3.8d.

The voltage between the inputs and the PC ground is monitored by two high-impedance amplifiers. A third amplifier measures the difference between the Positive and Negative inputs, eliminating any voltage common to both wires. This method eliminates problems that can arise with a single-ended system because this configuration attenuates noise common to both channel inputs (common-mode noise). Thus it's wise to use twisted-pair cable to bring signals to the data-acq card because that setup ensures that any noise generated along the wiring path is the same for each line, and this noise gets subtracted by the amplifier.

Although using differential inputs on MF Series and PDL-MF boards cuts in half the number of channels you can read with a given data-acq card compared to single-ended or pseudodifferential setups, there are several cases where you are well advised to use differential inputs:

- when signal leads are over a few meters in length, because the instrumentation amp can eliminate the effect of noise pickup from signal leads and also eliminate the possibility of ground differentials.
- when measuring signals less than approximately 100 mV, because such low-level signals can otherwise be easily overwhelmed by noise and ground differentials that only the differential mode can remove.
- when measuring the output from high-impedance sensors such as strain gauges, because their high impedances can lead to higher common-mode voltages, which the differential inputs are able to remove thus leading to higher resolution.

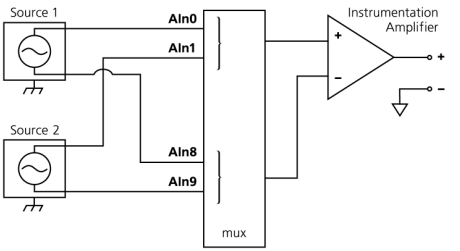


Figure 5.2—Wiring for differential inputs

In the pin-assignment of Fig 3.8c, AIn8 has the name AIn0Return, while AIn9 has the designation AIn1Return)

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Note Do not drive positive and negative differential inputs with voltages that exceed a value of AGND ± 14V; otherwise, the input multiplexers could lock up and even be damaged. Always connect equipment grounds together in a star configuration with low resistance.

Overall Recommendations

In summary, when wiring applications the analog-input subsystem, keep the following factors in mind:

- Pseudodifferential inputs cannot eliminate the effects of noise.
- Use differential inputs when working in an environment with electrical noise or when using gains to amplify the raw signal.
- Use individually shielded twisted-pair wires between the sensor and the terminal panel and also connect the shield to analog ground when working in an environment with electrical noise.
- Run signal lines near devices that create high levels of electrical noise through a metal cable tray above or below the work area.
- Keep wiring paths or conduits carrying power lines and signal lines physically separate.
- Never put signal cables in the same wiring harness as high-current or high-voltage cables.
- Avoid routing signal and power cables together in parallel paths unless a reasonable distance separates the paths, *reasonable* being determined by the strength of the power signals and the amount of shielding.
- Be aware that many external factors—among them power lines, poorly designed video monitors or switching power supplies, solenoids, electric arcs from circuit breakers or welders, and unshielded signal cables—can have a negative impact on the accuracy of your measurements.
- Single-ended inputs are appropriate when you need to measure a large number of signals but you also need to keep system costs to a minimum—and you are confident that the above noise-inducing situations can be avoided.

Note Input multiplexers have a high input impedance. It is highly recommended that you ground all unused channels using a 1-kΩto 10-kΩ resistor. Further, try to use signal sources with a low output impedance (<100Ω) to avoid crosstalk. To limit signal bandwidth, you can also place a capacitor on the screw-terminal panel between the signal and ground (single-ended mode) or for differential mode between signal and return lines. The suggested capacitor values are between 1000 pF and 0.047 μF depending on the input frequency and the impedance of the signal source according to $F = 1 / (2\pi RC)$.

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Sequential vs simultaneous sampling

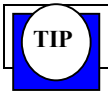
Users have several choices in determining the relationship of one sample to the next: You can sample a series of signals sequentially, and you can simulate simultaneous sampling by sampling adjacent signals at the highest possible rate to minimize the time skew among them (pseudosimultaneous); both of those methods are possible with MF Series boards. For true simultaneous sampling where you must eliminate time skew among multiple channels, the best solution is to work with MFS Series boards. The fact that all MFx boards use one A/D converter determines their front-end architecture ahead of the converter.

Sequential sampling

For sequential sampling, a multiplexer feeds signals to a common input amplifier, which then feeds the A/D converter (Fig 5-3). Clearly, the front end needs some time to switch from one input to the next and allow the amplifier time to settle. In the MF Series cards there is very little difference between the time the multiplexer switches to a new signal—when the front end sees a new signal—and when that new signal is digitized.

On MF and PDL-MF Series boards the minimum delay between each channel readings is limited by the rated speed of the board, which you can calculate as 1/rate. For instance, for a board rated at 2.2M samples/sec, the interchannel digitization delay is $1 / 2.2 \times 10^{6} = (1 \times 10^{-6}) / 2.2 = 450$ nsec.

By selecting a card with a fast front end (such as UEI cards that operate at megahertz speeds) and collecting samples as quickly as possible, the delay between samples (ie, the time between t_0, t_1, t_2 and so on) can be extremely short. If the input signal's frequency is relatively low (5-10 times lower than the acquisition rate), the difference in the acquired signal level from one sample to the next is minimal. For many applications, especially where the signals you are measuring change slowly, this interchannel delay is so small that you can consider the samples to be *virtually simultaneous*. This is also referred to as pseudosimultaneous operation.



If you are interested in phase differences between channels, an MFS board is more suitable for such an application.

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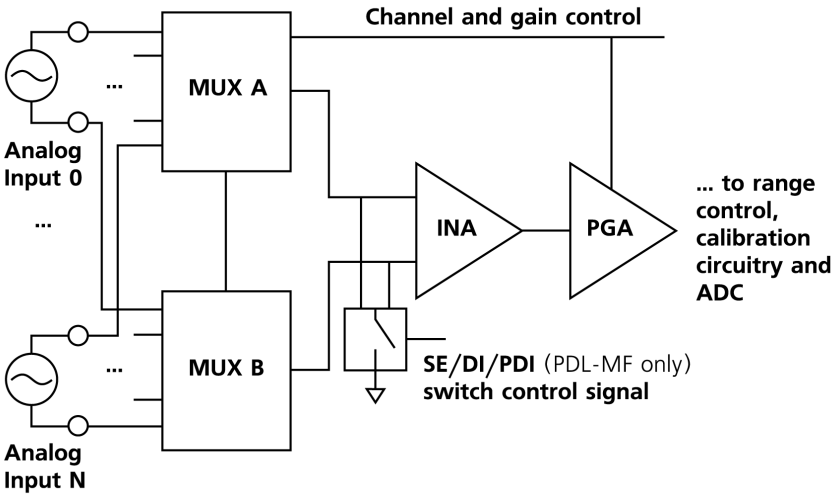


Figure 5.3a—Analog front end of a PowerDAQ MF Series board

In Fig 5.3b, CL refers to the CL Clock, also known as the Channel List clock or the Scan Clock. CV refers to the CV Clock, also known as the Conversion Clock.

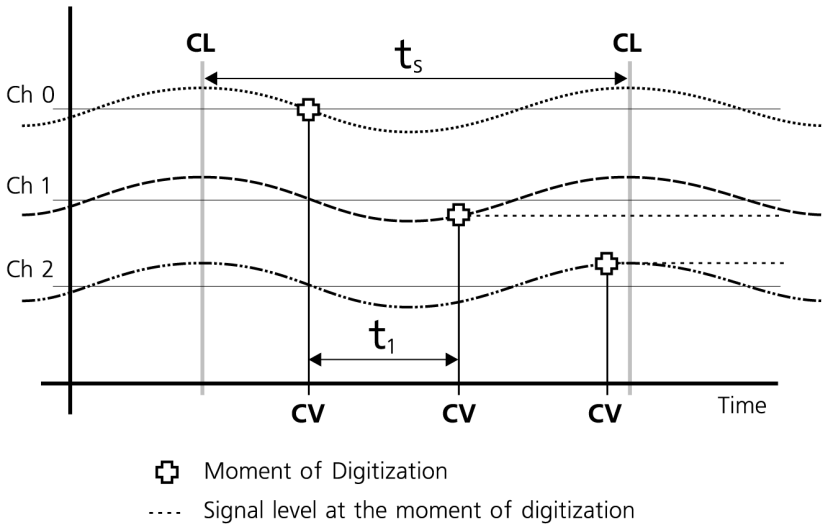


Figure 5.3b—Acquisition sequence for multiplexed inputs on MF Series and PDL boards

Note that t_1 shows the time between individual samples on the A/D; the time between CV clocks is limited by the board's maximum digitization rate. If you need to increase the settling time between samples, slow down the board by decreasing its digitization rate.

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Next, t_s is the minimal time between scans of the Channel List; it depends on t1 and the number of entries in the Channel List. The value of 1 / ts is the maximum scan rate (in Hz). If the board is set up such that the CL Clock comes before the board is ready to accept a new scan, the board ignores the clock and sets an Error bit.

Note When driven with the internal clock, the preferred configuration for MF Series boards is CL = continuous and CV = internal. For MFS Series boards, the preferred configuration is the reverse, specifically, CL = internal and CV = continuous (see following section on clocking).

The effective per-channel sampling rate also depends on the number of channels in the Channel List. In this case, a PowerDAQ board acquires data across all channels sequentially at the selected speed, which need not be the peak speed, and this rate is referred to as the aggregate rate. When the Channel List contains two channels, the per-channel rate is one half of the aggregate rate. For multiple channels, you can thus calculate the maximum per-channel rate as:

Per-channel rate = Aggregate rate / Number of channels

Simultaneous sampling

In contrast, our MFS Series cards (Fig 5-4) achieve true simultaneous sampling. To do so, they supply a sample/hold amplifier (S/H) at each signal input. When waiting for a conversion command, all the S/H amplifiers track their respective input signals and change their outputs to reflect the value of the continually varying input. However, when the analog front end sees a conversion command, all the S/Hs immediately stop tracking their input values and instead freeze and hold the last values until they are once again freed up to track the inputs. While the S/Hs are holding the inputs, the A/D converter can service them in turn through the multiplexer. Thus, even though the A/D cannot digitize more than one signal simultaneously, the use of the S/Hs allows the card to achieve true simultaneous sampling regardless of the input signal's frequency.

Note Always use MFS Series boards if you require the exact difference between input levels at a specific time or if you are working with signals close to their Nyquist frequencies.

The MFS Series boards have a unique exact-timing feature. An MFS board's control logic needs 15 nsec to process an external Hold signal. To compensate for this small delay, the S/H amps have a negative delay. In other words, the signal level that such an amp captures when the board logic switches it into Hold mode is the level that appeared at the input 15 nsec earlier. This guarantees that the board acquires a signal level at the exact time you apply an external pulse.

The standard configuration on MFS Series boards is for single-ended inputs with unity gain, however the PD2-MFS-DG differential-input option adds one device on the back side of the board that combines an instrumentation amp and a programmable-gain amplifier. As with MF Series

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boards, you store channel numbers along with their respective gains in the Channel List memory. This mechanism allows you to select different gains on a per-channel basis.

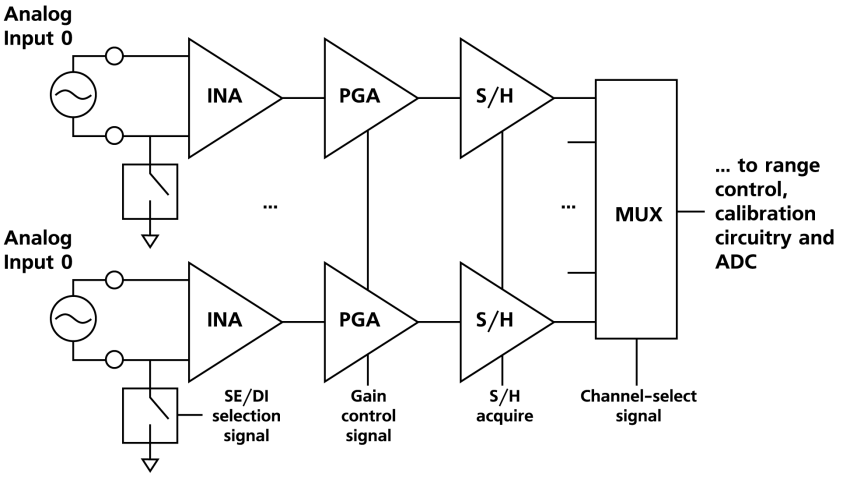


Figure 5.4a—Analog front end on PowerDAQ MFS simultaneous-sampling boards (with both SE and DI modes available)

Here, again, t_1 is the board's conversion time, which is limited by the A/D's maximum speed and the ability of the board's input amplifiers to settle. Compared to a multiplexed MF Series board, though, t_2 represents the hold time after the board has switched the sample/hold amp into the Hold state; t_3 is the time the sample/hold amp requires to once again start tracking the input signal after the board has switched it back into Sample mode.

Given these parameters, you can determine t_{ssh} -- the minimum time between scans – as the sum of $t_2 + t_3 + (t_1 *$ number of channels). The maximum scan rate now equals $1 / t_{ssh}$. PowerDAQ boards use analog pipelines to cut down both the settling time and the sample/hold times.

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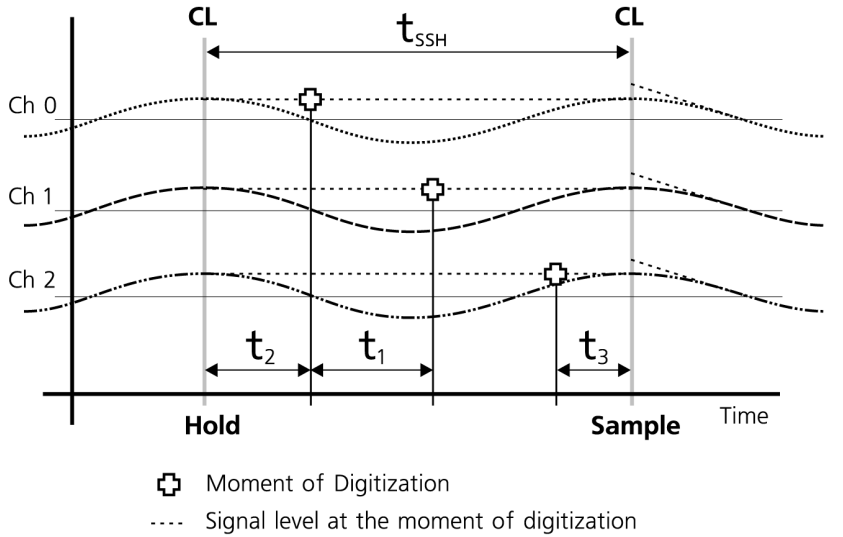


Figure 5.4b—Acquisition sequence for simultaneous inputs using S/H amplifiers on MFS Series boards

Simultaneous sample/hold settling-time issues

The analog-input timing on MFS Series boards (in which dedicated sample/hold amplifiers on each channel feed a common multiplexer) is slightly different than the timing on MF Series boards (where the analog-input channels feed directly into a multiplexer). Specifically, on MF Series boards, the front end can start an A/D conversion on the first channel in the current run through the Channel List immediately after it has digitized the last channel in the previous Channel List.

On MFS boards, in contrast, an additional delay is required when the sequencer starts to work from the first entry of a Channel List because before a new Channel List can be read, the board must instruct the bank of S/H amps to hold at a new set of values. Thus, the sample/hold amps need a certain amount of time to settle to sufficient accuracy prior to the digitization stage. Note that acquiring a lower number of channels leads to a lower maximum aggregate speed for the board. This drop in speed arises due to S/H amp settling-time delay, which must allow for every time the Channel List is processed

Clrate = 1 / [(S/H settling time) + (A/D conversion time * Number of channels)]

Clocking and Triggering

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PowerDAQ cards offer considerable flexibility in how fast they digitize and collect real-world samples. To set up any analog-input operation, you must configure both of two clocks; to activate this operation, the subsystem must also receive a trigger pulse.

Clocking

Let's first examine the two clocks:

- the CL clock or Channel List clock—also known as the Burst clock, it tells the control logic when to start processing a full scan through the Channel List.
- the CV clock or Conversion clock—also known as the Pacer clock, it triggers individual acquisitions or entries in the Channel List and thus tells the A/D how fast to digitize successive samples.

Note When the CL clock has read the last entry in the Channel List, it automatically fetches a new set of entries for the Channel List from the CL FIFO and sets up the mux and amplifiers to be ready to take the next sample when a new CL clock pulse arrives.

For both of these clocks, you have the choice of four sources:

- Software clock—a software command in the application program issues a clock pulse.
- Internal clock—derived from a timebase on the board. Each PowerDAQ board offers two software-selectable base frequencies (11 and 33 MHz). You obtain lower frequencies by dividing the base frequency with a 24-bit divisor that has a value from 1 to 2^{24} (= 16,777,216). To calculate the new frequency, use the formula: Timebase = Base Frequency / (divisor + 1). To implement this new timebase, pass the required value in the divisor variable in the configuration function.
- External clock—the user connects this signal to a terminal panel. For instance, you might want to export a clock from one card and have another card read that clock so both work in a synchronized fashion. All the signals of interest on MFx Series boards are located on the J2 digital I/O connector:

  Pin 27—read external CL clock
  Pin 35—export CL clock
  Pin 31—read external CV clock
  Pin 32—export CV clock.

  Note that most of these signals are also available on J1, the main connector on the mounting bracket that carries the analog I/O signals. However, we recommend you working with clock signals from J2 where there is no chance that they could potentially degrade the quality of the analog signals on which the board is operating. However, if you are not planning to use digital I/O, using the J2 clock lines means you must purchase an additional cable. Note further that on its external clock inputs, the board provides 4.7 kΩ pull-up resistors.
- Continuous clocking—essentially gates the clock always On, sending the next pulse at the earliest possible opportunity.

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CAUTION! If you define a clock whose speed is too high for the subsystem to handle, the board simply ignores any pulses that arrive before it is ready to respond to them, but it does not issue an error message.

Note Both the CL and CV clocks are required. Even if your application takes just one sample from one channel, you must create a minimal Channel List. Failure to create this list and activate it with the CL clock before activating the CV clock will result in false data. Put another way, a PowerDAQ card ignores the CV clock until it senses a CL clock pulse; until you activate the Channel List, the A/D doesn't do any digitizing.

You define the source of each of the two clocks during the card's configuration and initialization stages, specifically with the command *_PdAInSetCfg()*. One of the parameters you pass to that command, *dwAInCfg*, is a configuration word whose bits set the values of various analog-input parameters.

More specifically, you set two configuration bits in *dwAInCfg* to establish the source of each clock signal. For the Channel List clock you work with AIB_CLSTART0 and AIB_CLSTART1, and for the Conversion clock you work with AIB_CVSTART0 and AIB_CVSTART1.

To specify a clock source, set the bits as follows (Bit 1, Bit 0)

0, 0	software clock
0, 1	internal clock
1, 0	external clock
1, 1	continuous

The default value for each of these four bits is Zero, so not setting any of the bits leaves the default value of the two setup pairs 0,0 = software clock. To change a value there is no need to insert a line of code that toggles the bit value; rather, merely placing its variable name in the configuration word will change it to a One. In many situations you will want to change the values of multiple bits to a One; you do so by ORing them. For instance, to change the CL clock to internal and the CV clock to continuous, use AIB_CLSTART0+AIB_CVSTART0+AIB_CVSTART1, which sets CL to 0,1 and CV to 1,1.

Note On the PDL-MF board, you can specify only one clock at a time. If you configure the CV clock as internal or external, you must then set the CL clock to continuous. If you set the CL clock to internal or external, the board ignores the CV clock and runs the A/D at its maximum speed.

Note The PDL-MF board provides a Gated mode when you work with the external trigger line to activate the clock you have selected as active. If you set the bit AIB_EXTGATE by including it in the *dwAInCfg* configuration word, then the board uses the ExtTrig terminal as a gate for the selected A/D clock regardless of the clock source selected. A High on the ExtTrig terminal enables conversions, and a Low disables them. This mode is incompatible with other trigger modes, and you should clear all AIB_xxTRIGxx bits when working with this mode. Note also that you can implement Gated mode on any MF/MFS boards using the 8254 counter/timers.

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It's important to realize that you can scan channels in two basic ways: either very fast by using the CL clock to control the speed at which you start a new scan of the Channel List, or you can allow for a specific amount of time between adjacent samples, such as to ensure that the front-end amplifiers settle, by using the CV clock. In either case, when you set a speed on one clock, it's generally advisable to set the other clock to continuous mode so it has no effect on the speed of the overall operation.

Clearly these two clocks often run at different speeds. Unless the board is sampling just one channel, the maximum CL clock has a value of (CV clock / number of channels). As just mentioned, setting one clock to continuous is an easy way to avoid any timing conflicts between the two clocks. In fact, there are few cases where you might want to set both clocks exactly.

In addition, anytime you apply a clock signal before the subsystem is ready to process it, the board generates an error condition. For example, if you input a clock at a frequency higher than the rated aggregate rate, the board sets a bit in one of the status registers whenever a CL or CV clock pulse occurs before it's ready to process the pulse.

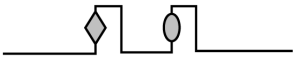
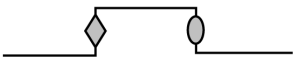
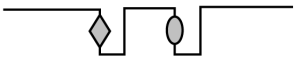
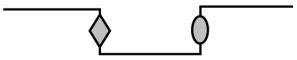
Triggering

Once you set up the Channel List clock and the Conversion clock with the commands just described, the board doesn't yet start collecting data. You must also supply a start trigger to activates both clocks. The clocks are like runners at the starting line, sitting still, waiting for the starting gun. Once the trigger signal arrives, the clocks start running. Thus, the maximum possible delay from the time the trigger arrives to when the board digitizes its first sample is the period of the CV clock. Similarly, you later need a stop trigger to halt both clocks. In this way, the application has control over the exact time during which it digitizes signals. The trigger signal can be either a software command or an external pulse, with the software trigger being the default; you must either put a trigger command in the application or enable an external trigger.

Note If the CV clock is set to continuous or internal, the trigger is guaranteed to start and stop acquisition at the beginning of a Channel List scan. If the CV clock is external, the external equipment is responsible for providing enough clock pulses to complete a pass through the Channel List.

Don't forget that if you set up the board to start on an external trigger, the analog input subsystem ignores both the CL and CV clocks until the pulse arrives. Acquisition continues until the stop trigger occurs. Within an application program, you generate a software trigger with the command *_PdAInSwStartTrig()*. Using this command, a program can request immediate acquisition or it can trigger an acquisition based on a review of incoming data to see if they meet some user-specified requirement such as a certain level (see Table 5.4).

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Start trigger edge	Stop trigger edge	External TTL signal	Constants to use in *dwAInCfg* configuration word
Rising	Rising		AIB_STARTTRIG0+ AIB_STOPTRIG0
Rising	Falling		AIB_STARTTRIG0+ AIB_STOPTRIG0+ AIB_STOPTRIG1
Falling	Falling		AIB_STARTTRIG0+ AIB_STARTTRIG1+ AIB_STOPTRIG0+ AIB_STOPTRIG1
Falling	Rising		AIB_STARTTRIG0+ AIB_STARTTRIG1+ AIB_STOPTRIG0

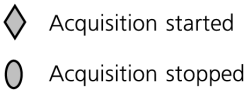


Table 5.4—External trigger modes

If you prefer to use an external clock, you apply it to Pin 29 on the J2 connector (also Pin 26 on the J1 connector). This line, as are all logic inputs on the board, is supplied with a 4.7 kΩ pull-up resistor. Note, though, that this pin also serves as the input for the Analog Output subsystem's external clock input, and obviously you can't use that line for both purposes at the same time. The external trigger input on a PowerDAQ board is edge-sensitive, that is, you can trigger the acquisition to begin on either a rising or falling edge by setting the appropriate configuration bits in the *dwAInCfg* word in the *_PdAInSetCfg()* function.

Generally, data acquisition begins immediately upon a trigger signal. In some cases, however, it's desirable to have analog pretriggering (examining input levels to trigger an acquisition run and then retrieving data that led up to an external event) or analog posttriggering (starting data collection after one of the inputs reaches a certain level). In the analog-input subsystem such functionality must be implemented in the user application with the Advanced Circular Buffer (see Appendix E). Note also that digital pretriggering is not possible.

Software can examine the value of incoming samples and compare them to a setpoint. Many third-party applications include built-in functions for this task, among them are LabVIEW, DASYLab, DIADem, TestPoint and Agilent VEE. UEI has implemented analog-trigger support in our drivers for these packages. For example, in our LabVIEW VI named *PD AIRead*, that VI supplies a node where you can activate analog triggering as well as specify parameters such as the threshold.

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Clocking/Triggering Examples

A few brief examples should help you get a better idea of how to work with the clocks and triggers.

1. Single sample

Suppose you want to take just one sample and no more. First make sure that you have defined a Channel List, where the first entry defines the channel number and its gain setting. Next set the CL clock to continuous, and then activate the Start trigger. Now any call to the function *_PdAInSwCvStart()* generates a single pulse on the CV clock, and so it reads the next value in the Channel List and then pauses. Because the CL clock is continuous, it effectively pulses again as quickly as possible, once again setting the pointer to the top of that list. Thus, calling *_PdAInSwCvStart()*again at any desired time digitizes just that one desired channel as before. Recall once more that the function call will have no effect unless you have already activated the Start trigger.

Note that you could exchange the order of the clocks; that is, you could set the CV clock to continuous (so a reading is made immediately whenever the board activates the Channel List), and you could use the function *_PdAInSwClStart()*to issue one pulse in the CL clock from an application program. This has the same effect of reading one channel because this setup allows one pass through the Channel List, but for this application the list contains only one entry.

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2. Single scan through Channel List

As you might surmise, only a slight variation in the procedure could allow the board to make one reading from multiple channels: simply expand the number of entries in the Channel List. In addition, you now work with clocks a bit differently. First set the CV clock to continuous for the fastest stepping through the list. For the CL clock, use a software source and have the application program make a call to the *_PdAInSwClStart()* function to start one run though the Channel List—assuming that you have also set the Start trigger active. Note that you need one CV clock pulse for each entry in the Channel List, but you first need a CL clock pulse to activate the list and set the pointer to the first entry. For instance, you can set the CV clock running free, but nothing happens until you pulse the CL clock.

3. Multiple scans through Channel List

If you want multiple runs through the Channel List, you must pulse the CL clock each time you want to enable another run, although the CV clock steps through the list. You might think it would be convenient to set both clocks to continuous, but that setup is not advised because you don't have a reliable timebase; there might be some slight delay in starting another run and that delay could vary from run to run.

In addition, you might think that a good option would be to set both clocks to software, but that setup actually isn't terribly productive. In this setup, you would theoretically call one function to start the CL clock and then call another function to read each entry in the list; this operation would essentially single-step through the list. If you wish to single step in this fashion, it's far easier to set the CL clock to continuous at the start of the program and then just use the CV clock when you want another sample; because the CL clock is continuous, it will set the list pointer to the top of the Channel List at the first available opportunity.

For an application that requires repeated runs through the Channel List, the recommended setup is CL clock = internal and CV clock = continuous. The CV clock thus will step through the Channel List as quickly as possible, and the CL clock activates the list according to the internal timebase (either 11 or 33 MHz, modified by a user-applied divisor). Be careful when setting the timebase because the subsystem ignores any interim clock pulses that arrive before it is able to handle them. That situation will set an error bit but it won't halt activity. Alternately, you could reverse the configuration and set the CL clock = continuous and the CV clock = internal.

Table 5.5 examines all the possible clock combinations and gives you some comments on where they are best applied. The last column tells you which bits to mention (and thereby set to One) in the configuration word; not including the bits in this word uses the default value of Zero.

Clock combination		Typical use	Bits to set in the dwAInCfg configuration word
CL Clock source	CV Clock source		
Software	Continuous	To acquire one set of data points (one scan). A	AIB_CVSTART0+

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		software clock initiates one pass through the Channel List and then the board waits for another CL clock before restarting. This method is useful in voltmeter type programs as well as in realtime control and hardware-in-the-loop systems	AIB_CVSTART1
Internal	Continuous	For continuous acquisition with an accurate timebase. After each CL Clock pulse, the Channel List is executed at the maximum acquisition rate. This is the primary mode for use with MFS cards, and use it with MF cards when it's critical to minimize channel skew.	AIB_CLSTART0+ AIB_CVSTART0+ AIB_CVSTART1
External	Continuous	For continuous acquisition when each run of the Channel List is triggered by an external signal. Use this mode to synchronize scans with external events.	AIB_CLSTART1+ AIB_CVSTART0+ AIB_CVSTART1
Continuous	Continuous	To perform acquisition at the maximum speed possible. Less accurate than using the timebase.	AIB_CLSTART0+ AIB_CLSTART1+ AIB_CVSTART0+ AIB_CVSTART1
Continuous or Software	Internal	Primary mode for use with MF boards; do not use with MFS boards. The internal CV clock sets the time between conversions. Use this type of clocking when you want to increase the settling time between acquisitions, especially when the signal source has a high output impedance.	AIB_CLSTART0+ AIB_CLSTART1+ AIB_CVSTART0+ or AIB_CVSTART0
Continuous	External	Used with MF boards only. This mode is useful when acquiring data from just one channel, or if you want to start a channel conversion exactly at an external pulse edge.	AIB_CLSTART0+ AIB_CLSTART1+ AIB_CVSTART1
External or Software	Internal	Use internal CV clock on MF board to set the time between conversions	AIB_CLSTART+ AIB_CVSTART0 or AIB_CVSTART0
External	External	This mode provides full control of the board's timing from an external device. It is rarely used because it requires the external device it sophisticated enough to assume all timing functions.	AIB_CLSTART1+ AIB_CVSTART1
Software	Software	Although this mode gives full control of the board's timing to the user application, it is rarely used because you can't achieve high precision compared to that possible with a hardware clock source.	0+0 (default)

Table 5.5—Possible clocking combinations (the shaded rows at the bottom indicate rarely used combinations).

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The A/D Sample FIFO

When you collect analog samples with a PowerDAQ board, they do not go directly into host memory. Instead, all digitized values first go into an onboard A/D FIFO memory. The standard size of this FIFO starts at 1k samples (4k samples for high-speed 2-MHz boards), but you can purchase options that upgrade the FIFO size to as many as 64k samples.

Note Keep in mind that a DAQ-card driver differs from one for a printer, CD-ROM or other peripheral in one fundamental way: realtime operation. A printer can wait before it gets the next data to print; and a CD-ROM can pause for a short while to let other activity go on. A data-acq board, however, typically collects data continuously and can pause only as long as its onboard FIFO has sufficient room to store intermediate results. If this buffer overflows, incoming data is lost.

This combination of an onboard DSP and a data FIFO has several advantages. First, a PowerDAQ board can collect data at its full rated speed no matter what the host PC is doing. The DSP controls the acquisition process and stores the data locally. So even if you're running a graphics-intensive application, it has no negative impact on the data-collection process. Further, virtually all of the host CPU's horsepower is available for post-acquisition analysis such as running a control loop.

Before moving on to other issues related to acquiring digitized data, it's important to understand the distinction between a *scan* and *frame*. A scan is one run through of the presently configured Channel List. In contrast, a frame consists of a user-defined number of scans, and these datapoints reside in a predefined portion of a buffer in host-memory. This host-memory buffer is also known as the Advanced Circular Buffer (ACB). We elected to define these two objects to give you the utmost in flexibility when deciding how to collect data. Keeping both scans and frames in mind, we will now examine the various methods of moving data from the data-acq card into the host PC where the application can use it.

Moving data into the host PC

Once you have acquired samples into the A/D FIFO buffer, you can choose from four modes that transfer data into host memory for use by the user application.

- Normal Mode
- Fast Mode
- Bus Mastering
- Bus Mastering/Short Burst

It's unusual that a program will use more than one of these methods. Thus, the normal procedure is to select the desired transfer mode by going to the PowerDAQ Control Panel application, clicking on the Driver Settings tab and selecting the mode. In the unusual event that you do want to change transfer modes from within a user application, use the software command

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_pdDiagSetPrm(). However, use this function with great caution. If not set up exactly right, the host system could easily lock up.

1. Normal mode

In some cases, all the datapoints from an acquisition run fit easily into the A/D FIFO. In that case you can use software commands to empty the FIFO into host memory at your convenience—but at the latest before another acquisition run. Starting another acquisition run adds more samples to the existing values in the FIFO. For this type of operation, you work with the first two modes, Normal and Fast. If the FIFO is full, the board ignores any additional samples.

When you set Normal mode active, the driver transfers one-half the A/D FIFO buffer (512 samples for a 1k-sample buffer) per interrupt, but for larger buffers this transfer is never any larger than 4k samples. While it empties one half of the FIFO, the board places newly acquired values in the other half. The driver runs in a loop, moving a sample at a time into host memory. Further, the driver verifies the availability of each individual sample in the before it retrieves it. Thus this is the safest transfer mode, but it's also the slowest. This mode works with any PCI-bus implementation.

Note The PDL-MF board does not include an onboard A/D FIFO memory. Thus, Normal mode, which transfers data samples individually, is the only data-transfer method available for that card.

2. Fast mode

This is the default transfer mode for most MF(S) cards. Here the driver transfers samples from the A/D FIFO into host memory using programmed I/O but without checking whether a given sample is actually available. Thus it consumes fewer processor resources than Normal mode. As is the case in Normal mode, the transfer size in Fast mode is the lesser of one-half the A/D FIFO or 4k samples.

We have found that 99% of all PCI motherboards handle this mode well. However a few systems with PCI bridges can ignore the situation that data is not yet available and nonetheless complete the PCI Read cycle normally but with zero data. In those systems you should revert to Normal mode.

3. Bus Mastering

In many cases, programmed I/O (Method 2) can empty the A/D FIFO in sufficient time so there is always room in the FIFO for data coming from the next scan. However, if you collect data at a

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very high rate (1 MHz or greater), the potential exists for a buffer overrun where incoming data wants to overwrite the half of the FIFO that hasn't yet been transferred to host memory. Such conditions will result in an error message.

If a PowerDAQ board is configured such that the amount of incoming data could eventually exceed the size of the FIFO buffer, you should set this mode active, whereby the DSP uses bus mastering to handle buffer maintenance automatically. Specifically, the DSP detects when the FIFO becomes half full and at that point initiates a data transfer from the FIFO into host memory. This mode thus unloads the host processor from the task of transferring samples into host memory. But because the PowerDAQ board takes control of the system bus, it might interrupt other host processes that require bus access. Thus, you should set up the system so it doesn't request a DMA transfer for small amounts of data. We recommend that the minimum size of a frame for bus mastering should be 4096 samples.

Two modes of bus-master transmissions are available, and you switch between them using the PowerDAQ Control Panel application or the *_pdDiagSetPrm()* command mentioned earlier.

3a. Bus Master (standard)

Bus Master mode is employs a standard method of data transmission over the PCI bus. The board transfers samples into locked pages of host memory that are preallocated by the VMM (virtual memory manager). It moves data over the bus in bursts of 32 transfers, each with 32 bits of data. Bus Master mode transfers at least 4k samples at a time regardless of the FIFO size.

Note that the PowerDAQ driver includes a special function call, *_pdDiagSetPrm(),* to adjust bus-master operating parameters. However, the initial page-allocation size equals two sets of four pages (4096 samples) and that allocation cannot be changed on the fly. Boards with larger FIFOs can allocate more memory, as much as 16,384 samples in a single contiguous block. When the data transfer is complete, the board fires an interrupt to the driver.

A/D FIFO Size (k bytes)	Bus Master Transfers when FIFO Half Full (samples)	Bus Master Transfers per Interrupt (samples)	Transfer Size in Normal and Fast modes (k bytes)
1	512	4096	512
2	1024	4096	1024
4	2048	4096	2048
8	4096	4096	4096

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16	8192	8192	4096
32	8192	8192	4096
64	8192	8192	4096

Table 5.6—Default Bus Mastering parameters for various FIFO sizes

Our tests show that with the maximum number of boards tested simultaneously (four boards) this mode achieves rates of 3M samples/sec per board. With a 1-GHz CPU, the load per board at this rate is less than 5%.

3b. Bus Master/Short Burst

We developed this mode to accommodate industrial PCs with secondary bridges on the PCI bus and that don't properly handle PCI Abort errors and where a bus lockup can occur. In this mode, the firmware shortens the number of 32-bit transfers per master cycle from 32 to 8, and if the firmware encounters PCI Abort termination, it retransmits the burst completely. In this mode our tests show transfer rates of 1.3M samples/sec per board, again with four boards running simultaneously. The CPU load per board using this mode is <3%.

Note Some legacy PowerDAQ PD2 MF/MFS boards cannot guarantee sustained bus-mastering operation, especially on some PCs with a secondary PCI bridge such as large industrial PCs or on machines with a PCI-bus extender. You can identify these boards by going to the PowerDAQ Control Panel applet (Ver 3.13 or higher) and checking which version of the Motorola DSP is on the board; a version 2 DSP indicates a board in this legacy category.

You can examine a PowerDAQ board's data-transfer mode settings by going to the PowerDAQ Control Panel applet. In the screen shot in Fig 5.5, the last line shows some typical settings for a board that has a 1k-sample A/D FIFO.

xMd:1	Transfer mode—Fast mode (1)
xFh:1	Transfer size—move one 512-sample block upon FIFO half full event
xPg:8	Page size—interrupt the driver after it makes eight transfers (or 4k samples). This value depends on the size of the FIFO installed on the board, and these transfer parameters default to the values in Table 5.6.

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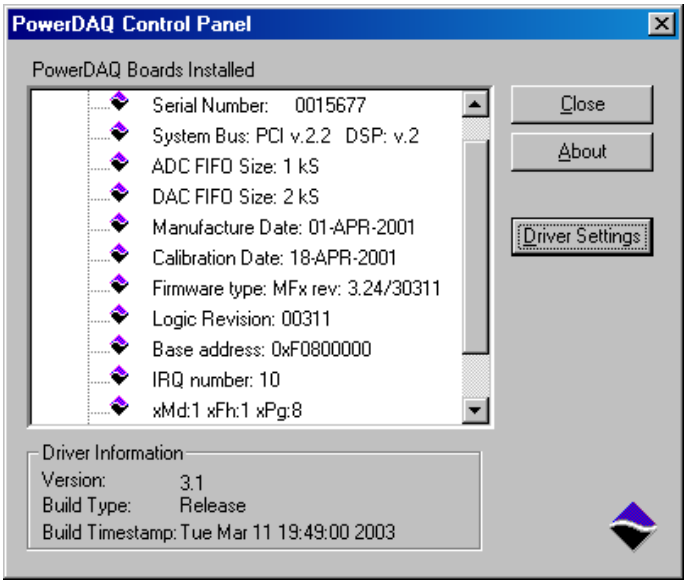


Figure 5.5—Control Panel applet with typical PowerDAQ board settings

Data-transfer method tradeoffs

Depending on the speed of your board and how often you want to read new data from the board, you must choose between programmed I/O and bus mastering. In general, if you need a short response time, use Normal mode or Fast mode.

Consider an example of a 100-kHz board with a 1k-sample A/D FIFO. The FIFO gets emptied when it is half full, or 512 samples / 100k samples/sec, so you have access to data every 5 msec. In Bus Mastering you have no access to new data until incoming data can fill a full bus-master page, which is at least 4096 samples. Thus, you would have to wait 41 msec to have access to that data.

Another factor to consider is that under Normal and Fast modes (but not Bus Master modes) you can take advantage of the *_PdImmediateUpdate* command. Among other things, it immediately fetches all acquired samples from the board.

This command is particularly useful in these cases:

1. Acquisition rates < 10k samples/sec. If a board running at 100 Hz has the default A/D FIFO of 1k samples, and if you select a frame size of 50 samples, you'll get 11

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frames per event, a frame every 5.5 sec. To achieve better response time, include *_PdImmediateUpdate* call in a timer loop.

2. When you want to clock an acquisition externally and the clock frequency can vary, we recommend you call *_PdImmediateUpdate* periodically to see if any scans are available.

3. Be aware that *_PdImmediateUpdate* consumes some processor time. Thus for boards running at high acquisition rates (>100k samples/sec) we do not recommend that you call this function more then 10 times/sec.

Host-based buffer usage

What you do with the data once they arrive in host memory can also have a major impact on system performance. The PowerDAQ drivers set up an Advanced Circular Buffer (ACB). When combined with applications tuned to take advantage of this flexible buffering mechanism, the system as a whole runs much more efficiently.

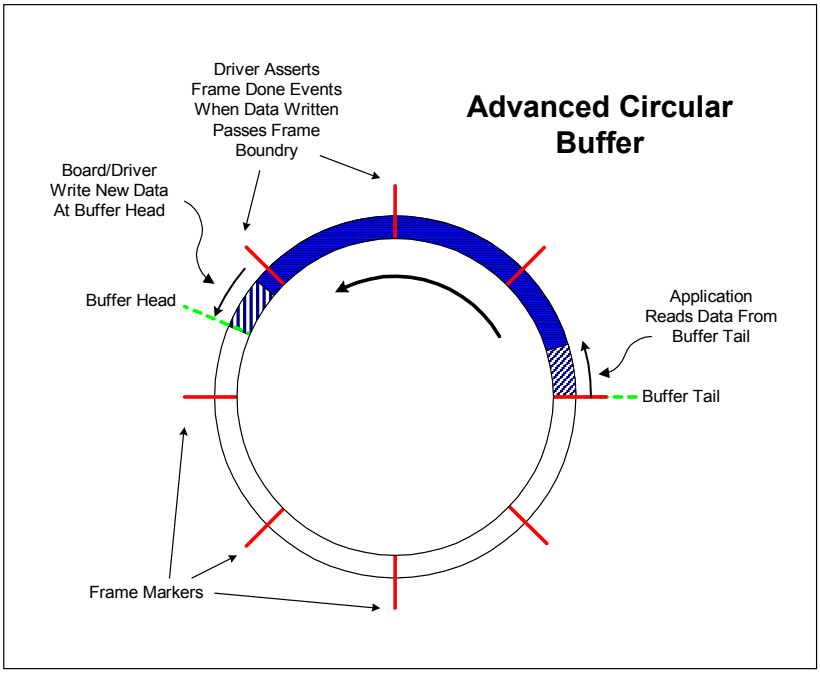


Figure 5.6—Advanced Circular Buffer

Once an acquisition is started, the board/driver stores data into the buffer at a known point (called the head), while the application generally reads data at another position (known as the tail). Both operations occur asynchronously and can run at different rates. However, you can synchronize

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them by either timer notification or by a driver event. To be able to issue a notification to the user application upon receipt of a specific sample or when incoming data reach a scan-count boundary, the driver segments the buffer into frames. Whenever incoming data crosses a frame boundary, the driver sends an event to the application. If multichannel acquisition is performed, the frame size should be a multiple of the scan size to keeps pointer arithmetic from becoming unnecessarily complex.

With the ACB, three modes of operation are possible depending on the action taken when the end of the buffer is reached or if the buffer head catches up with the tail.

- In *Single Buffer* mode, acquisition stops when the driver reaches the buffer's end. The user app can access the buffer and process data during acquisition or wait until the buffer is full. This approach is appropriate when you're not acquiring data in a continuous stream, and it resembles the way a digital scope operates.
- In *Circular Buffer* mode the head and tail each wrap to the buffer start when they reach the end. If the head catches up to the tail pointer, the buffer is considered full and acquisition stops. This mode is useful in applications that must acquire data with no sample loss. Data acquisition continues until either a predefined trigger condition or the application stops the driver. If the app can't keep up with the acquisition process and the buffer overflows, the driver halts the acquisition and reports an error condition.
- *Recycled* mode resembles Circular Buffer mode except that when the head catches up with the tail pointer, it doesn't stop but instead overwrites the oldest scans with the new incoming scans. As the buffer fills up, the driver is free to recycle frames, automatically incrementing the buffer tail. This buffer-space recycling occurs irrespective of whether or not the application reads the data. In this mode a buffer overflow never occurs. It's best for applications that monitor acquired signals at periodic intervals. The task might require that the system digitize signals at a high rate but not need to process every sample. Also, an application might need only the latest block of samples.

While the ACB might seem a departure from single and double-buffer schemes you'll see on most other DAQ cards, it's actually a superset of them. In Single Buffer mode, the ACB behaves like a single buffer. Configured as Circular Buffer with two frames, it behaves as a double buffer. With multiple frames, the ACB can function in algorithms designed for buffer queues. The only limitation, which results in more efficient performance, is that the logical buffers in the queues can't be dynamically allocated or freed and their order is fixed.

Data format

When working with data in the host memory space, you must be aware of the format in the datastream. Every two consecutive bytes in the stream make up one sample from the A/D converter. These datapoints appear in a file in the order they come from the A/D converter following the order defined in the Channel List. The format for each data word differs according to the A/D's resolution (PowerDAQ boards automatically place Zeros in any unused bit locations), as shown in Fig 5.7, where bit0 is the LSB.

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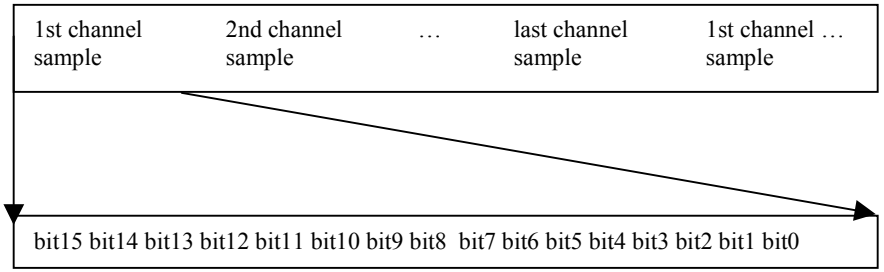


Figure 5.7a—PowerDAQ 16-bit data format

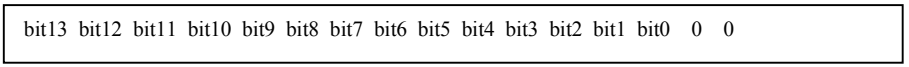


Figure 5.7b—PowerDAQ 14-bit data format

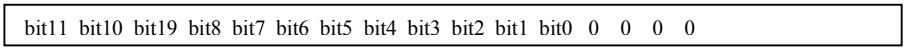


Figure 5.7c—PowerDAQ 12-bit data format

In an application, you'll generally want to convert these raw values (in hexadecimal) into a scaled value, typically a voltage. To do so, use the following formula:
Output (V) = ((HexData XOR 0x8000) * BitWeight + Displacement) / Gain

You needn't place this equation in a user application because the PowerDAQ API includes two useful functions for this purpose: *_PdAInRawToVolts()* and *_PdAInScanToVolts()*. However, should you want to include a conversion function in the user code, perform the following calculations to convert raw hex data to scaled (voltage) data:

1. Determine the value of a single bit ("bit weight") in volts. This value depends on the input range.

Input Range	Bit Weight (Span / 65535)
0-5V unipolar (5V span)	0.000076295 V/bit
0-10V unipolar (10V span)	0.000152590 V/bit
±5V bipolar (10V span)	0.000152590 V/bit
±10V bipolar (20V span)	0.000305180 V/bit

Table 5.8—Bit weight by input range

2. Determine the zero offset (or displacement), which again depends on the input range.

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Input Range	Displacement
5V or 10V unipolar	0
±5V bipolar	-5V
±10V bipolar	-10V

Table 5.9—Displacement by input range

3. Perform an arithmetical XOR on the raw data value with 0h8000

4. Multiply this intermediate result by the Bit Weight from Step 1

5. Add the Zero Offset from Step 2

6. If the board applied a gain other than 1 to a selected channel (as defined in the Channel List), divide the value from Step 5 by this gain factor (this step guarantees maximal data accuracy).

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Programming Techniques

With this knowledge of the analog-input hardware, you are better prepared to understand how to program the board to perform various digitizing functions. This subsystem is very flexible, and it offers a variety of operating methods. Before selecting one, it's wise to read through this manual to understand what each does and then compare it to the application requirements.

With any of these methods, you must first specify how you are using the analog inputs, whether in single-ended or differential mode, and indicate the range of the raw inputs prior to applying any gain. To tell a user program which you have selected, you must OR the analog-input configuration word *dwAInCfg* with one of the Mode constants in Table 5.10

Input Mode	Constant for use in *dwAInCfg*
Single-Ended, 0-5V*	0
Single-Ended, 0-10V	AIB_INPRANGE
Single-Ended, ±5V	AIB_INPTYPE
Single-Ended, ±10V	AIB_INPTYPE + AIB_INPRANGE
Differential, 0-5V*	AIB_INPMODE
Differential, 0-10V	AIB_INPMODE + AIB_INPRANGE
Differential, ±5V	AIB_INPMODE + AIB_INPTYPE
Differential, ±10V	AIB_INPMODE + AIB_INPTYPE + AIB_INPRANGE

** Not available in PDL-MF.*

Table 5.10—Mode constants for use in analog-input configuration word

Almost every digitization task falls into one of the following categories.

- Method A—Single scan
- Method B—Burst buffered acquisition (1-shot)
- Method C—Continuous acquisition using Advanced Circular Buffer (ACB)
- Method D—Recycled-buffer mode

Method A—Single scan

A single scan, where you take one reading across the Channel List, is useful when you need to get one set of datapoints, where a scan might even consist of just one entry in the Channel List. Applications such as a multichannel voltmeter or sensor/thermocouple monitor are well suited for this method. Depending on the Channel List size (maximum number of entries equals 256) and maximum board speed, you can acquire as many as 100 scans/sec in non-realtime applications and roughly 10 scans/sec in a realtime application.

You can initiate an acquisition with a software command or by monitoring the external CL Clock. The maximum number of samples acquired is less then the minimal size of the A/D FIFO, so all data stay in that FIFO and there's no need to work with an ACB in host memory.

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Note The PowerDAQ Software Suite CD-ROM contains a large number of functioning sample programs written for various languages. They might come close to approximating what you would like an application to do, so you might want to take a closer look at them. The examples in the SDK that fall into the category of Method A are:

- simpleAin.c
- simplescan.pas
- simplescan.bas
- vm64.pas
- voltmeter.vbp
- Vl16.cpp
- PDGABoards.cpp

Programming Model

Now let's take a detailed look at what's involved when working with a program that follows the model of Method A.

Note We urge you to read through this and all other programming models because they will give you valuable tips on how best to work with the PowerDAQ API.

Initialization

Reset the board

PdAInReset(...)

Set up configuration

_PdAInSetCfg(...)

where *dwAInCfg* is the analog-input configuration word whose bits define the operating parameters for the subsystem including the mode (SE or DI), input range, clock and trigger sources. Analog-input configuration bits are defined in the file *pdfw_def.h*. Note that if you want to change any parameter, you must make a function call that includes all the parameters, not just the one you wish to modify. The recommended configurations for Method A are

for software clocking:

dwAInCfg = (AIB_CVSTART0 | AIB_CVSTART1)

or for an external clock

dwAInCfg = (AIB_CVSTART0 | AIB_CVSTART1 | AIB_CLSTART1)

For details on clocking options, refer back to Table 5.5.

Set up the Channel List

_PdAInSetChList(...)

where one parameter indicates the number of channels in the list, and another parameter represents the Channel List data array.

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Enable conversions

_PdAInEnableConv(...) with *dwEnable = 1*

_PdAInSwStartTrig(...) to issue the software-based Start trigger

Now, if you have selected the software clock, clock the first scan into the A/D FIFO.

_PdAInSwClStart(...)

Acquisition

Now the user application can instruct the board to collect analog samples as required using the onboard timer or a program loop. In either case, you must allow sufficient time for the A/D to acquire all points in a scan and digitize the entire Channel List. You normally allow (1 / maximum board rate) seconds for each channel.

Note As described earlier, PowerDAQ boards have a special Slow Bit you can insert in the Channel List. You might want to increase settling time for a particular channel when you've selected a high gain setting, or for a channel connected to a signal with a high output impedance. See Appendix B for each specific board to determine how much a Slow Bit affects the time needed to acquire a channel.

Get the samples already acquired out of the A/D FIFO and move them into the array declared in the user application

_PdAInGetSamples(...)

If you have selected the software clock, clock in the next scan

_PdAInSwClStart(...)

Note If you are using external pulses to start clocking of the Channel List, make sure to address the situation whereby the next scan clock comes during the *_PdAInGetSamples(...)* call. This function returns the number of points stored in the buffer. If the number of scans equals the A/D FIFO size, the subsystem could lose scan synchronization because you might not be aware of an overrun condition. It's possible to enable/disable conversions on the fly with *_PdAInEnableConv(...)*, and you can clear the A/D FIFO with *_PdAInClearData(...)*.

Method B—Burst buffered acquisition (1-shot)

This method is useful when you need a series of 1-shot acquisitions with a significant delay between runs. An example of such an application might be when simulating an oscilloscope or signal analyzer, where you run an acquisition one time, stop the process, analyze the data, and run it again as required. However, the size of the acquired data likely require buffered A/D FIFO reads. Consequently, this method requires initializing and use of the PowerDAQ buffering mechanism (see Appendix E).

Method B uses an asynchronous notification from the driver through Win32 events. Thus you should program the board for asynchronous operation and use Win32 function such as *WaitForSingleObject(...)* to initiate a wait until the driver notifies that the data has been successfully acquired.

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Note Examples in the SDK that fall into the category of Method B are:

- Stream2.c
- SimpleExample.vbp

Programming Model

Initialization

Reset the board

_PdAInReset(...)

Allocate and register a buffer for the board. The buffer should be accessible in both the user and kernel spaces, and it should be locked to the physical pages. Use as big a buffer as you need; its size is limited by the amount of memory installed on your PC. The buffer should contain at least two frames so you can empty one while the A/D fills the other. The PowerDAQ API allocates buffers for you.

_PdAcquireBuffer(...)

Register the buffer with the AnalogIn subsystem. Use *dwMode* with BUF_BUFFERWRAPPED and BUF_BUFFERRECYCLED. for single-run operation whereby acquisition stops when the buffer is filled.

_PdAcquireBuffer(...)

Set up the analog-input configuration and events about which you want to be notified. The analog-input configuration bits are defined in the file *pdfw_def.h*. Here are the recommended configurations for Method B:

- For the internal software clock,
  dwAInCfg = (AIB_CVSTART0 | AIB_CVSTART1 | AIB_CLSTART0)
- for an external clock,
  dwCfg = (AIB_CVSTART0 | AIB_CVSTART1 | AIB_CLSTART1)

Add the *AIB_INTCLSBASE* constant to select the 33-MHz base frequency instead of the default of 11 MHz

The application needs to know what's going on in the buffer, so set up the board to fire events on certain conditions. To do so, use the function

_PdSetUserEvents(…)

Analog-input event bits are defined in the file pwrdaq.h. The recommended event notification method is

dwEvents = eFrameDone | eBufferDone | eBufferError | eStopped

Your application is notified when at least one frame is complete. Upon notification, the buffer in

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host memory is filled with data or you will receive a buffer error. The most common reason for buffer errors is heavy loading from other applications running on the PC during acquisition, so that the system cannot service the interrupt in time. Consider using an A/D FIFO upgrades to improve system performance (PD-16KFIFO or PD-32KFIFO) or try Method 3, bus mastering.

Initiate asynchronous operation

_PdAInAsyncInit(...)

This command sets up the data-acquisition hardware with all its basic parameters such as input mode, type, range and clock sources. Again, you define these settings in the bits of *dwAInCfg*. Provide a value for *dwAInClClkDiv* to set the desired scan rate. Fill and pass the Channel List as explained in Method A. Make sure that that the aggregate rate you have set up (scan rate * number of channels) is lower or equal to the maximum board rate.

Set up event notification

_PdAInSetPrivateEvent(...)

The API creates Win32 events and returns a valid event handle.

Acquisition

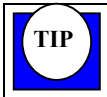
Start asynchronous operation

_PdAInAsyncStart(...)

and either have the user app issue a software trigger or wait for a hardware trigger, and then wait for event notification that the card has digitized some data.

The following function puts your program into Sleep mode and gives the system CPU time for other processes. The function returns control when the board signals an event or the timeout period has expired. The timeout period should be long enough to fill your buffer with samples. When this function returns an event from the board, you must check to see what caused it.

WaitForSingleObject(hEventObject, Timeout)



If the board is clocked from the low-frequency internal timebase or a slow external clock, you likely won't get an immediate event notification upon the acquisition of the first datapoints. This is because the board transfers data from the on-board A/D FIFO into host memory only when the FIFO reaches 50% capacity. For example, if your board's FIFO size is 1k samples, the acquisition rate is 100 Hz and you put only one channel into the Channel List, the board notifies the driver (and thus the application) only after 500 samples = 5 sec of acquisition, no matter how small your frame is. If you clock the board externally, no response comes from the board until it gets enough pulses to fill its FIFO half full with samples. However, you can use *_PdImmediateUpdate(...)* on a timer loop to force data from the A/D FIFO into the host buffer. Don't call this function too often because it can degrade system performance. Note also that this function does not work in Bus Mastering mode.

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Check events with the function

_PdGetUserEvents(...)

This function returns events for the specified subsystem (here be sure to specify *AnalogIn*). The user application should analyze the events and take appropriate action. An event word can contain following flags:

- *eFrameDone*—a frame of data is ready for retrieval.
- *eBufferDone*+ *eStopped*—Acquisition is complete. All data is stored in the buffer and is available for analysis.
- *eBufferError*—Data integrity was compromised because of a lack of performance or system latency while serving interrupts. In such cases the on-board A/D FIFO overflows. If this error persists, check the interrupt settings, purchase a larger A/D FIFO option or consider using Method D with bus mastering.

Reset events. Call this function to notify the driver that events are processed.

_PdSetUserEvents(...)

Restart

The following calls stop asynchronous operation. You need to call them before you again call *_PdAInAsyncInit(...)* and *_PdAInAsyncStart(...)*. You can start and restart acquisition as many times as the application requires. Each time you restart an acquisition, the board overwrites data in the buffer with a new values.

_PdAInAsyncStop(...)
_PdAInAsyncTerm(...)

De-Initialization

Stop asynchronous operation

_PdAInAsyncStop(...)
_PdAInAsyncTerm(...)

Release event object handle

_PdAInClearPrivateEvent(...)

Unregister and deallocate buffer

_PdReleaseBuffer(...)

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Method C—Continuous acquisition using the Advanced Circular Buffer (ACB)

Method C employs the PowerDAQ Advanced Circular Buffer mechanism (see Appendix E). Here you work with one part of a buffer you set up in host memory while the A/D FIFO fills the other half. In this way, an acquisition can run continuously, and each time an event occurs (such as frame filled), the application receives program control again. The data-acq thread waits on the function call and won't do anything until that call comes.

You can create separate threads for each board in your application to run the acquisition process.

Note Examples in the SDK that fall into the category of Method C are:

- Stream2.c

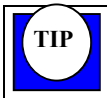
Set up the buffers

The analog-input configuration is very similar to Method B except you set up the buffer in a different way. First, allocate the buffer and register it with the board. Make the buffer as large as necessary. Here you define a frame, which is a user-defined number of scans, and you define how many frames (and thus number of scans) must be in the buffer before the driver issues an *eFrameDone* event to notify the application that data is ready for retrieval. Each user application processes events in different ways, but each time an application detects an *eFrameDone* event, it knows that one or more frames are filled with data. For Method C, the minimum buffer size is two frames, which implements the classic double-buffering mechanism. The largest possible size is limited by the amount of free memory in the host. A larger number of frames makes the operation more flexible and decreases probability of buffer overflow because the host CPU isn't involved as frequently.

_PdAcquireBuffer(…)

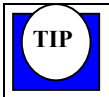
When registering the buffer and if you want to use the ACB, be sure to set

Set dwWrapAround = AIB_BUFFERWRAPPED.
_PdAcquireBuffer(…)



How can you determine the optimal buffer size and number of frames? Normally four frames in a buffer are enough to achieve smooth operation. They provide enough time to avoid a buffer overflow if the OS encounters a delay in responding. The buffer should be big enough to accommodate from 0.33 to 1 sec of incoming data.

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How can you determine the optimal frame size for an acquisition run? When selecting the frame size, take the following items into account. Events consume host CPU and on-board DSP time, so a small frame needs servicing more often and thus decreases overall system performance. On the other hand, larger frames decrease the event rate, which isn't desirable in situations where you need faster response, especially in control-loop applications. We recommend setting a frame size so the application receives from 4 to 10 events per second. For example, if the Channel List has four entries and the acquisition rate is 100k scans/sec, the recommended frame size is from 10,000 scans (calculated as 100k scans/10) to 25,000 scans. (calculated as 100k scans/4).

Acquisition

Wait for event notification with

WaitForSingleObject(hEventObject, Timeout)

This function puts the user application into Sleep mode and gives the host CPU time for other processes. The user app gets activated when the board signals an event or the timeout period has expired. The timeout period should be long enough to fill the host buffer with samples. When this function returns an event from the board, the application must check to see what caused it.

Check events with

_PdGetUserEvents(...)

This function returns events for the specified subsystem. The user application should analyze the events and take appropriate action. An event word can contain following flags:

- *eFrameDone*—a frame of data is ready for retrieval.
- *eBufferDone* + *eStopped*—The acquisition is complete. All data is stored in the buffer and is available for analysis.
- *eBufferDone* + *eBufferWrapped*—Incoming data has reached the end of the buffer. The next frame that will be filled is at the start of the buffer.
- *eStopped*—The acquisition has stopped. The reason could be a trigger pulse on the external trigger line, a software command or a buffer error. It's possible that the user application is not retrieving data from the buffer fast enough and there's no room for new incoming data. Check other events to find out what caused the acquisition to stop.
- *eBufferError*—Data integrity was compromised because of a lack of performance or system latency while serving interrupts (see note about interrupts).
- *eStopTrig*—The acquisition stopped because it received the Stop trigger pulse or a software command.

Retrieve data with

_PdAInGetBufState(...)

This function retrieves information about the position of unread frames in the buffer *n scans* (*ScanIndex*) and the number of scans available for the application (*NumValidScans*). In other words, it tells you how much new data there is and where it is located. If incoming data has passed the buffer boundary and starts filling it from the beginning, the *eFrameDone* event occurs twice:

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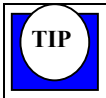
once to let the user application retrieve data at the end of the buffer (that is, from the point of the last retrieval to the end of the buffer), and a second time to let the application retrieve data from the beginning of the buffer to the latest complete frame. During any *_PdAInGetBufState(...)* call the application gets the data in one piece. This eliminates the need for the user application to deal with wraparound situations. Finally, note that *_PdAInGetBufState(...)* has a side effect: When called, it marks frames it returns as "read" and thus these frames can be reused for new data.

Reset events with

_PdSetUserEvents(...)

Call this function to tell the driver that events have been processed.

Now perform application-specific tasks on the data. Make sure that each procedure is short enough to process everything required before the next *eFrameDone* event arrives. Otherwise the buffer can overflow and the driver can stop acquisition.



Tips for reading thermocouples and other slow-speed processes. There are two ways of reading slow-speed processes. Method A is better when the application doesn't require a precise timebase and needs 10 or fewer datapoints per sec. Method C is better for rates exceeding 10 datapoints per sec. For faster update rates, either use a *_PdImmediateUpdate(...)* call on a timer loop or let the driver do the same thing by calling _PdAInEnableTimer(…). Both functions force the board to move all samples from the A/D FIFO to the buffer; the difference is that *_PdAInEnableTimer(...)* also starts and stops the built-in timer in the driver. By making the frame sizes smaller, you get events more quickly. Note that *_PdImmediateUpdate()* doesn't work in Bus Mastering mode.

Method D—Recycled-buffer mode

If you want to make certain that the entire buffer contains only the latest data, use the recycled-buffer method of working with the ACB (explained in detail in Appendix E). It overwrites the oldest frames with new data without the requirement that the data first be read. For example, you can run an acquisition continuously as in Method C. However, if at some time the application needs much more time to process data than the time needed to fill the frame, the acquisition doesn't halt and you don't get an error message. Instead, the driver continues the acquisition and all frames that the application hasn't yet retrieved get overwritten with new data. When the application receives the next event, that event sets the *eFrameRecycled* event flag.

One obvious situation in which to use this mode is when you cannot predict the exact time needed to process the data. Consider the case when a control application monitors input datastreams and at some point it needs to perform exhaustive calculations and change equipment settings. Instead of stopping and restarting the process, Recycling buffer mode allows the data acquisition to keep running. After processing is completed, the control application catches up with the latest data. This mode is also suited for pretriggering applications.

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Note Examples in the SDK that fall into the category of Method D are:

- Stream2.c

To switch your buffer into this mode, first call

_PdAcquireBuffer(...)

and be sure to set *dwWrapAround = BUF_BUFFERRECYCLED* to use the ACB's Recycled mode.

Combining Analog and Digital subsystems

It's often desirable to coordinate analog inputs with digital inputs. When doing so, the part that requires special attention is event handling. The PowerDAQ API has two sets of functions to address this issue.

1. Set up all subsystem operations in one thread and create an event using *_PdSetPrivateEvent(...)*.This function creates a single event that is set when either subsystem needs attention. Be sure to retrieve and process each active subsystem event in the order they arrive. To release a event object, use *_PdClearPrivateEvent(...)*.

2. Set up each subsystem operation in a separate thread. You can create a separate event object for each subsystem using

_PdAInSetPrivateEvent(...)
_PdAOutSetPrivateEvent(...)
_PdDInSetPrivateEvent(...)
_PdUctSetPrivateEvent(...)

When one of these subsystem needs attention, it sets the appropriate event. Subsystem threads wake up on *WaitForSingleObject(...)*, Win32 API calls and process events as described above. To release event objects, use the appropriate *_PdxxxClearPrivateEvent(...)* call.

Note Examples in the SDK that fall into the category of Method G are:

- SimpleTest.dpr

Synchronous stimulus/response

Some applications require that a test setup apply an analog stimulus to an experimental system and then read the response read. To address this task, use a subset of Method A. Set the analog output to generate its next datapoint on a pulse connected to that output's external trigger line. Apply that same pulse to one of the UCTs (user counter/timers) and have it start counting down from a predetermined value. Upon reaching the terminal value, it generates a pulse, which you connect to the external clock (CL Clock line) on the analog-input subsystem to start a scan. This setup provides a user-defined delay from the analog output to the time you read the response with an analog-input scan.

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6. Analog-Output Subsystem

Architecture

The analog-output subsystem on every PowerDAQ multifunction board (PD2, PDL or PXI) is the same: it consists of two 12-bit D/A converters and supports several operating methods: one single-value update method and several waveform-generation (or streaming) methods.

The following methods are available:

Single-value update

- Method A—Single update

Buffered Waveform Generation

- Method B—Single-shot waveform generation
- Method C—Continuous waveform generation
- Method D—Repetitive waveform generation

Non-buffered Waveform Generation (backward compatibility)

- Method E—Auto-regeneration
- Method F—Events in non-buffered mode

Single-value update method

Single update (Method A)

The single update method uses an API command from the user program to write the digital representation of the desired analog output value directly into the output register of a D/A converter. This digital word remains in the output register indefinitely until you overwrite it with a new value. The maximum rate at which you can update the actual analog output generated from the D/A depends on the configuration of the host PC system, but it is at least 1 kHz.

Buffered waveform generation methods

When you are working with waveforms whose shape you know in advance, it is possible to calculate the corresponding values for the D/A's output register and send multiple datapoints to the analog-output subsystem all at once. There are several ways to transfer these points:

Single-shot waveform generation (Method B)

This method outputs the waveform only once and then the subsystem stops.

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Continuous waveform generation (Method C)

This method allows the continuous generation of waveforms, and there is no limit to the total amount of data the system can output. When a frame of the buffer has been output, the driver issues an event to allow you to write more data to the buffer.

Repetitive waveform generation (Method D)

This method can create fixed-length waveforms greater than 2048 samples. The size of the buffer is limited by the amount of physical memory in the PC. An application writes data to the PowerDAQ driver buffer, and each time the end of the buffer is reached, the PowerDAQ driver resends the same buffer until instructed to stop.

Non-buffered waveform generation methods

Autoregeneration (Method E)

This method can create fixed length waveforms (maximum size limited by the D/A FIFO) without any host PC intervention. An application writes data to the FIFO buffer, and each time the end of buffer is reached, the DSP resends the same buffer until instructed to stop.

Note Rev 3.x of the PowerDAQ SDK allows you to create waveforms up to the size of the memory available on your PC. (See Method D)

Events in non-buffered mode (Method F)

The events in this method allow the continuous generation of waveforms, and there is no limited to the total amount of data the system can output. When the FIFO on the DSP drops to less than half full, the board issues an interrupt requesting more data. Thus, with a 2k-sample FIFO, you can load a maximum of 1024 samples at a time.

Note If the FIFO is empty and the card has sent out the last value, it continues outputting that last value until the program instructs it to do otherwise.

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Channel List

Just as the analog-input subsystem offers a Channel List, so does the analog-output subsystem in buffered mode. There is a fixed Channel List for the analog output on the PD2-MF(S) boards, and it always contains values for both analog outputs (Ch 0 and Ch 1), and they are updated simultaneously.

Note Because both output channels are updated at the same time, you must configure both D/As for the same mode of operation.

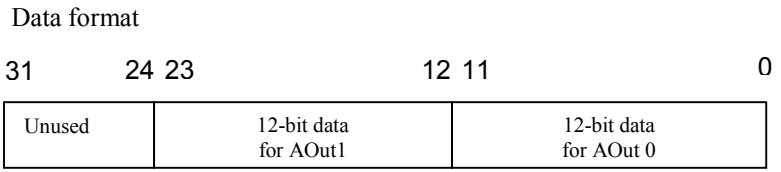


Figure 6-1—Analog-output data format

The analog outputs have a fixed output range of ±10V. The data representation is straight binary. To convert a voltage into binary codes, use the following formula:

HexValue = ((Voltage + 10V) / 20) * 0xFFF

You can combine the two Hex values that Aout Ch 0 and Ch 1 should write as follows:

Value_To_Write = (HexValue1 << 12) OR (HexValue0)

TIP To convert floating-point values to raw voltages use the function _PdAOutVoltsToRaw(…)

Clocking

You must clock the analog-output subsystem for each new voltage level being generated. Specifically, every time a clock pulse occurs, the board reads the next value from the D/A FIFO, converts it into a voltage representation, and generates the analog voltage on the selected channel. You can clock the subsystem using a software command, the internal 11 or 33 MHz base frequency, or from with a signal on an external trigger input line.

To calculate the output frequency, use the following formula:

Acquisition Rate = Base Frequency / (divisor + 1)

To calculate the divisor use:

Divisor = (Base Frequency/Acquisition Rate)-1

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Triggering

The external trigger line can serve as a Start/Stop trigger for free-running analog outputs. You can select the internal clock as the analog-output timebase and then use the trigger line to start and stop the output.

Additionally, the external trigger line can synchronize the analog-input and the analog-output subsystems.

Programming Techniques

Let's now take a look at how to program a PowerDAQ MF/MFS card's analog-output subsystem for each of the operating methods described above.

Method A—Single update

This simple method allows you to update the analog-output value on either or both D/As immediately.

Note Examples in the SDK that fall into the category of Method A are:

- SimpleAOut.cpp
- SimpleTest.vbp

Initialization

Reset the board (if required)
_PdAOutReset(...)

Generate output

Output the analog output value.
_PdAOutPutValue(...)

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Method B—Single-shot waveform generation

This method is useful when you need a series of single-shot waveforms with a significant delay between runs where you output the waveform one time, stop the process, and run it again as required. However, the size of the waveform data likely requires buffered D/A FIFO writes. Consequently, this method requires initialization and use of the PowerDAQ buffering mechanism (see Appendix E).

Method B uses an asynchronous notification from the driver through Win32 events. Thus you should program the board for asynchronous operation and use Win32 function such as *WaitForSingleObject(...)* to initiate a wait until the driver notifies that the data has been successfully output.

Initialization

Reset analog output from previous operation
_PdAOutReset(…)

Acquire buffer for analog output
_PdAcquireBuffer(…) without setting the BUF_BUFFERWRAPPED flag
and fill the buffer with data

Initialize asynchronous operation
_PdAOutAsyncInit(...)
and set *dwConfig = AOB_CVSTART0* to use internal clock
and calculate the divisor as described above

Set up event notification
_PdAOutSetPrivateEvent(...)

Start waveform generation

Start asynchronous operation
_PdAOutAsyncStart(...)
Wait for an eBufferDone event from the board or a timeout
WaitForSingleObject(hEventObject, Timeout)

Event handler

Check why the event object was set with
_PdGetUserEvents(...)

Re-enable events with
_PdSetUserEvents(...)

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Restart

Stop asynchronous operation
_PdAOutAsyncStop(...)
_PdAOutAsyncTerm(...)
before starting again
_PdAOutAsyncInit(...)
_PdAOutAsyncStart(...)

only include
_PdAOutAsyncTerm(...)
and
_PdAOutAsyncInit(...)
if you need to change parameters

Deinitialize the subsystem

Stop asynchronous operation
_PdAOutAsyncStop(...)
_PdAOutAsyncTerm(...)

Release event object handle (optional)
_PdAOutClearPrivateEvent(...)

Release the buffer
_PdReleaseBuffer(...)

Clear the subsystem and set both outputs to 0V (optional)
_PdAOutReset(...)

Method C—Continuous waveform generation

Method C uses the PowerDAQ Advanced Circular Buffer mechanism (see Appendix E). Here you work with one frame of a buffer you set up in host memory while the driver empties the other frames. In this way, the output can run continuously, and each time an event occurs, the application takes control. You can create separate threads in your application to run the acquisition process.

Initialization

Reset analog output (if required)
_PdAOutReset(…)

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Acquire buffer for analog output
_PdAcquireBuffer(…) set the BUF_BUFFERWRAPPED flag and fill the buffer with data

Initialize asynchronous operation
_PdAOutAsyncInit(…)
and set *dwConfig = AOB_CVSTART0* to use internal clock
and calculate the divisor as described above

Set up event notification
_PdAOutSetPrivateEvent(...)

Start waveform generation

Start asynchronous operation
_PdAOutAsyncStart(...)

Wait for an event from the board or a timeout
WaitForSingleObject(hEventObject, Timeout)

Event handler

Check why the event object was set with
_PdGetUserEvents(...)

Check where to put new data in the buffer
_PdAOutGetBufState(...)
and write the new data

Re-enable events with
_PdSetUserEvents(...)

Stop waveform generation

Stop asynchronous operation
_PdAOutAsyncStop(...)
_PdAOutAsyncTerm(...)

Deinitialize the subsystem

Release event object handle (optional)
_PdAOutClearPrivateEvent(...)

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Release the buffer
_PdReleaseBuffer(...)

Clear the subsystem and set both outputs to 0V (optional)
_PdAOutReset(...)

Method D—Repetitive waveform generation

Use this method to create fixed-length waveforms. The PowerDAQ buffering mechanism handles all data transfers to the D/A FIFO. After an application writes data to the buffer, the board starts to output the waveform and restarts automatically when the pointer reaches the end of the buffer. This method is suitable when you need a continuous repetitive waveform.

Initialization

Reset analog output (if required)
_PdAOutReset(…)

Acquire buffer for analog output
_PdAcquireBuffer(…) set BUF_BUFFERWRAPPED | BUF_BUFFERRECYCLED flags and fill the buffer with data

Initialize asynchronous operation
_PdAOutAsyncInit(…)
and set *dwConfig = AOB_CVSTART0* to use internal clock and calculate the divisor as described above

Set up event notification
_PdAOutSetPrivateEvent(...)

Start waveform generation

Start asynchronous operation
_PdAOutAsyncStart(...)

Wait for an event from the board or a timeout
WaitForSingleObject(hEventObject, Timeout)

Event handler

Check why the event object was set with
_PdGetUserEvents(...)

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Re-enable events with
_PdSetUserEvents(...)

Stop waveform generation

Stop asynchronous operation
_PdAOutAsyncStop(...)
_PdAOutAsyncTerm(...)

Deinitialize the subsystem

Release event object handle (optional)
_PdAOutClearPrivateEvent(...)

Release the buffer
_PdReleaseBuffer(...)

Clear the subsystem and set both outputs to 0V (optional)
_PdAOutReset(...)

Method E—Autoregeneration

Use this method to create fixed-length waveforms (2048 samples maximum, or 65536 with external memory) without using any host CPU cycles; the onboard DSP handles all subsystem operations. It's easier than using Method D, but the size is limited to the D/A FIFO size. After an application writes data to the D/A FIFO, the board starts to output the waveform and the subsystem restarts automatically when the pointer reaches the end of the buffer. This method is suitable when you need a continuous repetitive waveform less than or equal to the D/A FIFO size.

Note Examples in the SDK that fall into the category of Method E are:

- SimpleTest.dpr

Initialization

Reset the analog output (optional)
_PdAOutReset(...)

Set the analog-output configuration
_PdAOutSetCfg(...)

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setting *dwConfig = AOB_CVSTART0 | AOB_DACBLK0 | AOB_DACBLK1 | AOB_REGENERATE* to use the 11-MHz internal clock for autoretriggerable waveform generation.

Set the timebase
_PdAOutSetCvClk(...)
using the same calculations to set up the timebase as described in the analog-input subsystem

Write data to the D/A FIFO with
_PdAOutPutBlock(...)

Start waveform generation

_PdAOutEnableConv(...) using 1 as the value for dwEnable
_PdAOutSwStartTrig(...)

Stop waveform generation

Reset the analog-output subsystem (optional)
_PDAOutReset(...)

Note The board also stops waveform generation when it reaches the end of the buffer.

Method F—Event-based waveforms using PCI interrupts

There are several ways to generate long continuously changing waveforms. The event-based waveform technique empties the board's onboard FIFO memory into the analog-output subsystem. When the FIFO is less than half full, the board sends an interrupt to the host to request additional data. You can process analog-output events in a separate event handler or in the common event handler for all subsystems. Please note that Method C has replaced Method F, which we include for backward compatibility.

Note Examples in the SDK that fall into the category of Method F are:

- AOEvents.c
- AEOutBlk.vbp

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Initialization

Reset the analog output

_PdAOutReset(…)

This function resets both analog outputs to 0V, and you must reset all operating parameters before running an analog output.

Set the analog-output configuration with

_PdAOutSetCfg(…)

and set *dwConfig = AOB_CVSTART0* to use the 11-MHz internal base clock.

Set the timebase with

_PdAOutSetCvClk(...)

and use the same calculations to set up the timebase as described in the analog-input subsystem.

Set up an event object

_PdAOutSetPrivateEvent(...)

Enable the interrupt

_PdAdapterEnableInterrupt(...)

Set the events about which you wish to be notified

_PdSetUserEvents(...)

and set *dwEventsNotify = eFrameDone | eBufferDone | eBufferError | eStopped*. You need these all for event-based waveform mode. Don't forget to set the subsystem parameter to *AnalogOut*

Write the first block of data

_PdAOutPutBlock(...)

Enable and start analog-waveform generation

_PdAOutEnableConv(...) using 1 for *dwEnable*

_PdAOutSwStartTrig(...)

Note To start waveform generation with a software command, use *_PdAOutSwStartTrig()*. If you wish to synchronize an analog output with an external trigger, set the appropriate flags in *_PdAOutSetCfg()*. Note that the flags *AOB_STARTTRIG0*, *AOB_STARTTRIG1*, *AOB_STOPTRIG0* and *AOB_STOPTRIG1* have the same functionality as for the analog-input subsystem.

Wait for events and process them using the Win32 API call

WaitForSingleObject(...).

Event handler

Check why the event object was set with

_PdGetUserEvents(...)

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Examine the return from this function for these events: *eFrameDone* means that the D/A has output a voltage for half the values in the D/A FIFO; *eBufferDone* + *eBufferError* means that the D/A has emptied the entire buffer and that no more datapoints are available.

Re-enable events with
_PdSetUserEvents(...)

Write additional data to the D/A FIFO with
_PdAOutPutBlock(...)

Continue waveform generation
_PdAOutEnableConv(...) and use 1 for *dwEnable*
_PdAOutSwStartTrig(...)

Stop waveform generation

Issue a stop trigger if you haven't configured the external trigger
_PdAOutSwStopTrig()

and then disable D/A conversions
_PdAOutEnableConv(…) and use 0 (FALSE) for *dwEnable*

De-initialize the subsystem

Disable the board interrupt (if no other subsystem are using the interrupt at the time)
_PdAdapterEnableInterrupt(...) and use *dwEnable* = 0

Release the event object
_PdAOutClearPrivateEvent(…)

Clear the subsystem and set both outputs to 0V.
_PdAOutReset(…)

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7. Digital I/O Subsystem

Architecture

The digital I/O subsystem in almost all PD2/PDXI MF/MFS Series boards contains one 16-bit input register and one 16-bit output register. The only exception is the PDL-MF, which uses two 24-bit registers. In all cases, the digital I/O registers do not support clocked operation, so this subsystem can be used only in software-polled mode.

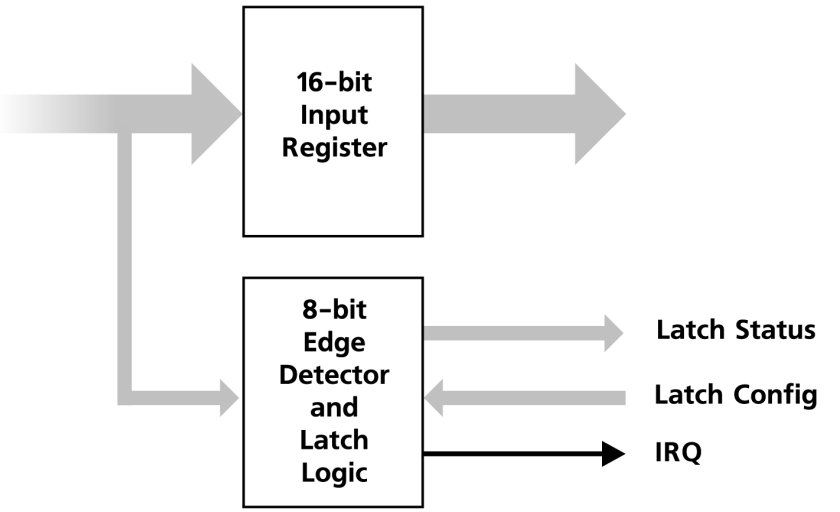


Figure 7.1—Digital-input subsystem hardware block diagram

On all dedicated digital input lines the board comes with 4.7kΩ pull-up resistors. (We supply these pull-up resistors on all digital inputs including all external trigger lines, all external clock inputs and counter/timer inputs.)

In the standard configuration (excluding the PDL-MF), the eight lower lines of the digital input connect to a latch register. You can then program this register to detect rising or falling edges on these lines.

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To configure the latch you send a 16-bit word, two bits being assigned to each of the eight sense inputs. Setting the F bit for a given input to a One makes that input sensitive to a falling edge; setting the R bit to a One makes that input sensitive to a rising edge.

Bit 7		Bit 6		Bit 5		Bit 4		Bit 3		Bit 2		Bit 1		Bit 0	
F	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R

Figure 7.2—Digital-input configuration word

The latch register in the digital-input subsystem provides one status bit for each line. When it detects the configured edge (falling or rising), the detection/latch logic does two things. First, it sets this status bit to a One; second, it fires an interrupt to inform the DSP that the configured conditions have been met.

If you set up a latch to watch for edges on several lines, the interrupt fires as soon as any of the selected conditions happens. However, the interrupt will not refire until the user application clears the status bit for that first line. Then, when the logic detects another change on any line, the interrupt fires again. To determine which line has caused an interrupt, the user program must read the digital-input status bits in the latch register.

Programming Techniques

The digital input/output subsystem can be used in two ways, and recall that this subsystem has no clocked operations available.

Method A—Polled I/O

This method works by using software to poll 16 digital inputs and 16 digital outputs.

Note Examples in the SDK that fall into the category of Method A are:

- SimpleTest.dpr

Initialization

Reset the digital subsystem

_PdDOutReset(...) sets the output lines to Zero
*_PdDInReset(...)*clears the latch and the configuration register

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Set up the digital input configuration

Set up edge-sensitivity configuration with

_PdDInSetCfg(...)

Specify an input line and an edge to be detected using a configuration word as described earlier in this section.

Read the status of the digital input latch with

_PdDInGetStatus(...)

This function returns the current state of the digital-input lines in one byte and the status of the digital-input latch register in a second byte. If the specified edge was detected, the latch contains a One in the appropriate bit.

Clear the status of the digital input latch with

_PdDInClearData(...)

This function clears the latch register and re-enables edge detection on the line that previously caused an event

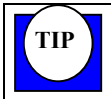
Input/output

Read digital inputs

_PdDInRead(...)

Write digital outputs

_PdDOutWrite(...)



It's possible to acquiring a digital signal using analog techniques. as analog. In an application where you need to acquire some digital signals along with an analog input, you can build a simple D/A converter using a resistor ladder. It allows you to convert up to eight digital input lines into one analog signal, which you then digitize and from its value you can determine the values of the original digital bits. for reliable detection using a 12-bit PowerDAQ board.

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Method B—Generate an event upon edge detection

In this scheme you set up an input configuration, and the subsystem fires an event when it detects a specified edge on the corresponding input line. The eight lower lines of the 16-bit digital input subsystem are edge-sensitive.

The setup parameters for this method are very similar to those used in Method A. The difference is that you should additionally enable and set up event notification. As does the analog-output subsystem, digital inputs can share an event handler with other subsystems or have a dedicated event handler.

Note Examples in the SDK that fall into the category of Method B are:

- DIEvents.c

Initialization

Reset the digital-input subsystem with
_PdDInReset(...)
to clear the latch and configuration register

Set up the digital-input configuration

Set up the edge-sensitivity configuration
_PdDInSetCfg(...)
Specify an input line and an edge to be detected using a configuration word as described earlier in this section.

_PdAdapterEnableInterrupt(...) with *dwEnable* set to 1
_PdDInSetPrivateEvent(...) sets up event object
_PdSetUserEvent(...)
and use *DigitalIn* as a subsystem name. The driver defines only one digital-input event, *eDInEvent*, which means that one or more edges were detected

Event handler

Check event
_PdGetUserEvent(...)
should return the *eDInEvent* flag in the status word.

Read the status of the digital-input latch
_PdDInGetStatus(...)

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This function returns the current state of the digital-input lines in one byte and the status of the digital-input latch register in a second byte. If the specified edge was detected, the latch contains a One in the appropriate bit.

Clear the status of the digital input latch with
_PdDInClearData(...)
It clears the latch register and re-enables edge detection on the line that previously caused an event

Re-enable events with
_PdSetUserEvent(...)
and use *DigitalIn* as a subsystem name. The driver defines only one digital-input event, *eDInEvent*, which means that one or more edges were detected

De-Initialization

Disable interrupts if there is no other subsystem running
_PdAdapterEnableInterrupt(...) with *dwEnable* set to 0

Release the event object and clear user-level events
_PdDInClearPrivateEvent(...)
_PdClearUserEvent(...) and use *DigitalIn* as the subsystem name

Reset the digital inputs to clear the configuration and latch registers
_PdDInReset(...)

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8. User Counter/Timer Subsystem

Architecture

Unlike the counter/timers on many other data-acq boards, those on the MF/MFS Series boards are fully dedicated to user tasks. You can set up the three on-board counter-timers to any mode compatible with the Intel 82C54 chip. Using a counter/timer output to control the analog-input and -output subsystems can result in setups that perform sophisticated data-acquisition tasks. Certain applications, though, might require you to build external digital circuitry.

Additionally, when they reach Zero counts these counter-timers can generate events, which can clock other subsystems and perform various operations.

The user counter/timer (UCT) subsystem on MF/MFS Series boards is based on Intel's 16-bit 82C54 counter-timer chip (again, the PDL-MF has a different configuration as described below). That device contains three counter/timers that are not required by any PowerDAQ subsystems and thus are fully dedicated to user applications. Further, the three counter/timers are fully independent so that each can function in a different mode, if desirable.

Note: You can combine UCT0 with UCT1 to implement a 32-bit counter or use UCT0 as a common prescaler for UCT1 and UCT2.

The 82C54 solves a common problem that arises in setting up test systems, the generation of accurate time delays under software control. Instead of setting up timing loops in software, the programmer configures the chip to meet system requirements and programs one of the counters for the desired delay. After the desired delay, the 82C54 interrupts the CPU. Software overhead is minimal and variable-length delays can easily be accommodated.

Some other counter/timer functions you can easily implement with the 82C54 are:

- Event counter
- Digital one-shot
- Programmable rate generator
- Squarewave generator
- Binary rate multiplier
- Complex waveform generator
- Complex motor controller

The UCT is extremely useful in combination with the external clock and trigger lines. Using the UCT you can create very sophisticated acquisition setups.

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At a high level, the programmer need only be concerned with selecting the input clock source and then selecting the gate signal (setting the Gate to Logic 1 enables counting; setting it to Logic 0 disables counting; it has no effect on the counter/timer output lines). The UCT generates an output signal depending on its operating mode and the input conditions. In addition, a counter/timer's outputs can also generate an interrupt to the host PC when a change in state occurs.

You can feed a clock input from one of the following sources:

- Software command
- 1-MHz internal timebase
- External clock input line (10 MHz max)
- Output from UCT0 (available as input for UCT1 and 2)

It is possible to control the gate from the following sources:

- Software command
- External gate input line

You can operate each UCT in several modes (for details, see the 82C54 datasheet available on the Intel web site):

- ***Single pulse*** **(82C54 Mode 1)—**The output line is initially High, and it goes Low on the clock pulse following a trigger on the gate line to begin a 1-shot pulse. It remains Low until the counter reaches zero. At that point the output again goes High and remains in that state until the clock pulse after the next trigger.
- ***Pulse train*** **(82C54 Mode 2)—**This mode functions like a divide-by-N counter so the pulse length equals 1 / clock frequency. The output line is initially High. When the initial count decrements to 1, the output goes Low for one clock pulse, and then it goes High again at which time the counter reloads the initial count and the process repeats. This mode is periodic, and the same sequence repeats indefinitely until it is instructed to stop.
- ***Rate*** **(82C54 Mode 3)—**This mode is similar to Pulse train mode except for the output line's duty cycle. That line is initially High, and when half the initial count has expired it goes Low for the remainder of the count. The sequence repeats indefinitely. An initial count of N results in a square wave with a period of N clock cycles.
- ***Delay*** **(82C54 Mode 5)—**This mode generates a single pulse after waiting a programmed amount of time. The output line is initially High. The rising edge of the gate line triggers counting. When the initial count has expired, the output line goes Low for one clock pulse and then returns to a High state.

A special frequency measurement mode is implemented on PD2/PDXI boards. Using this mode you can measure an external frequency; you connect the signal to the counter's input terminal and measure the number of counts (up to 65,535) that arrive in a 1-sec interval (see the UCTMeasFrequency example program).

Note It's not necessary to implement an event handler and enable interrupts for most UCT applications. Set one up only if the application must be informed on specific countdown conditions.

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Note You can use UCT to stop an analog acquisition run after acquiring N scans. To do so, program the device to count the N scans, and also connect its output to the analog input's external trigger. Then set up the A/D to stop on the external trigger's falling edge of the external trigger.

PDL-MF-X

The PDL-MF also supplies three user counter/timers, but they are implemented with 24-bit registers on the 56301 DSP. They are independent of each other and can generate interrupts. The maximum clock frequency is 16.5 MHz for an external clock and 33 MHz for an internal clock. Please refer to Motorola DSP56301 user manual for details.

This UCT functions in the following modes:

- timer
- external event counting
- pulse output
- squarewave output
- PWM (pulse-width modulation) output
- width/period/capture measurement

Note On the MF-PDL card, TMR0 is shared with the AIn clock; TMR2 is shared with the AOut clock.

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Programming Techniques

Programming the Intel 82C54 can be difficult because of its various modes and settings. To ease this job, the PowerDAQ SDK provided the definitions you need along with a set of example functions in the file *uct_progr.c*, which is located in the same folder with the UCTEvents Visual C++ example. Please refer to that file and to the Intel 82C54 datasheet to assist you in learning how to program the UCT subsystem.

Please be aware that the PowerDAQ API provides separate event flags for each counter/timer.

Note To write to the counter/timer, you must apply an input clock to the selected UCT. You can control its Gate line using the *_PdUctSwSetGate(...)* function.

Note Examples in the SDK that fall into the UCT category are:

- DIEvents.c
- uct_progr.c
- SimpleTest.dpr
- SimpleTest.vbp

Using UCT events

Initialization

Reset the UCT subsystem with

_PdUctReset(...) to clear the latch and configuration register

Set up UCT configuration

Set up the edge-sensitivity configuration

_PdUctSetCfg(...)

and refer to *uct_progr.c* in the SDK files for bit definitions

_PdAdapterEnableInterrupt(...) using *dwEnable* = 1
_PdUctSetPrivateEvent(...) sets up event object
_PdSetUserEvent(...)

and use *CounterTimer* as the subsystem name. The driver defines three events, one for each counter/timer: *eUct0Event*, *eUct1Event* and *eUct2Event*

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Event handler

Check for an event
_PdGetUserEvent(...)
can return either the *eUct0Event*, *eUct1Event* or *eUct2Event* flag in the status word.

Read the status of the UCT output
_PdUctGetStatus(...)

Re-enable events
_PdSetUserEvent(...)

Deinitialization

Disable interrupts if no other subsystem is running
_PdAdapterEnableInterrupt(...) while setting *dwEnable* = 0

Release the event object and clear user-level events
_PdUctClearPrivateEvent(...)
_PdClearUserEvent(...) using *CounterTimer* as the subsystem name

Reset the UCT to clear its configuration and stop ongoing operations
_PdUctReset(...)

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9. Support Software

PowerDAQ Example Programs

A complete range of sample programs with source code is included with each PowerDAQ board as part of the PowerDAQ Software Suite CD-ROM. For complete details on programming the PowerDAQ board, refer to the PowerDAQ Software Manual

Note Listed below are summaries of just a few of the examples we supply. Please review the installation directories for new examples or visit us online at www.PowerDAQ.com

Visual C++ examples

Versions supported: VC 1.5 (16 bit), VC 5 and 6 (32 bit)

Examples supplied:

- VM16.exe–simple voltmeter application displaying as many as 64 channels.
- Stream4.exe–continuous acquisition and stream-to-disk application.

Visual BASIC examples

Versions supported: VB 3 (16 bit), VB 5 and 6 (32 bit)

Examples supplied:

- The SimpleTest utility (SimpleTest.vbp), which allows the simultaneous operation, if desired, of all subsystems: Analog Input, Analog Output, Digital Input, Digital Output and Counter/Timer operation.
- Additional examples are located on the PowerDAQ Software Suite CD-ROM in the VBExecutables directory. After running the installation, look in the PowerDAQ\SDK\Examples\VisualBasic\VB5 (OR VB6)\[Example Name] directory.

Delphi examples

Versions supported: Delphi 3 and 4 (32-bit)

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Examples supplied include the following:

- The SimpleTest utility (SimpleTest.dpr), which allows the simultaneous operation, if desired, of all subsystems: Analog Input, Analog Output, Digital Input, Digital Output and Counter/Timer operation.

Borland C++ Builder examples

Versions supported: Inprise/Borland 3.5

Examples supplied:

- Stream4.exe – continuous acquisition and stream-to-disk application.

Note The files included for the above programming languages may have the same file name. This means they can be used with either language.

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Third-Party Software Support

The PowerDAQ CD contains drivers for most popular third-party software packages. The installation procedure automatically detects if you have installed any of the third-party packages, and will install the drivers and examples automatically. If you install a third-party software package after installing the PowerDAQ software, you must reinstall our software to include support for this new third-party package.

As of the writing of this manual, we support the following third-party software:

Software Package	Version	Supports multiple PowerDAQ boards	What's included
LabVIEW	5.x or greater	Yes	Extensive VIs including click-and-replace low-level VIs
LabVIEW for Linux	6.x or greater	Yes	VIs that mirror standard LabVIEW support but run under Linux
LabVIEW Real-Time	6.x or greater	Yes	VIs that mirror standard LabVIEW support but run under this environment.
Agilent VEE	5.x or greater	Yes	Examples
DASYLab	4.x or greater	No	Examples
TestPoint	3.3 or greater	Yes	Examples
LabWindows/CVI	5.x or greater	Yes	Callable from our VC++ support
DIADEM	6.x or greater	Yes	Examples
MATLAB Data-Acquisition Toolbox	6.x or greater	Yes	Examples
xPC Target	2.x or greater	Yes	Examples

Table 9.1—Third-party software support

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Appendix A: Specifications

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PD2-MF Multifunction Boards

Model: PD2-MF-xx-	3M/12x	2M/14H	1M/12x	500/16x
Resolution	12 bits	14 bits	12 bits	16 bits
Number of Channels Single-Ended Differential	16 or 64 8 or 32			
Maximum Sampling Rate	3M S/sec	2.2M S/sec	1.25M S/sec	500k S/sec
Onboard FIFO Size (upgradeable to 16k, 32k, 64k)	16k samples	4k samples		2k samples
Channel-Gain List	256 entries			
Input Ranges	0–5V, 0–10V, ±5V, ±10V (software selectable)			
Programmable Gains by channel	L=1,10,100,1000 H=1, 2, 4, 8	H=1, 2, 4, 8	L=1,10,100,1000 H=1, 2, 4, 8	
Drift Zero Gain	±30 µV/°C ±30 ppm/°C			
Input Impedance	10 MΩ			
Input Bias Current	±20 nA			
Input Overvoltage	±20V,2000V ESD 10 mA max		±35V continuous	
A/D Conversion Time	283 ns	0.45 µsec	0.8 µsec	2 µsec
A/D Settling Time	250 ns	0.37 µsec	0.6 µsec	1.2 µsec
DC Accuracy				
Nonlinearity	±1 LSB	±2 LSB	±0.5 LSB	±1 LSB
System Noise	0.8 LSB	1.2 LSB	0.3 LSB	1.3 LSB
AC Accuracy				
Effective Number of Bits	11.2	12.2	11.63	14.5
Total Harmonic Distortion+ Nonlinearity+Noise	72 dB	76 dB	71.8 dB	88 dB
Channel Crosstalk	-80 dB @ 1k S/sec			
Clocking and Trigger Input				
Maximum A/D Pacer Clock Aggregate Throughput @ 0.01% Accuracy	3000k S/sec	2200k S/sec @ 1 ch 1800k S/sec @ all	1250k S/sec	500k S/sec
External A/D Sample Clock Maximum Frequency	3000k S/sec	2200k S/sec @ 1 ch 1800k S/sec @ all	1250k S/sec	500k S/sec
Minimum Pulse Width	20 nsec			
External Digital (TTL)Trigger High-level Input Voltage Low-level Input Voltage Minimum Pulse Width	2.0V min 0.8V min 20 nsec			

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Model: PD2-MF-xx-	**400/14x**	**333/16x**	**150/16x**
Resolution	14 bits	16 bits	16 bits
Number of Channels Single-Ended Differential	16 or 64 8 or 32		16 8
Maximum Sampling Rate	400k S/sec	333k S/sec	150k S/sec
Onboard FIFO Size (upgradeable to 16k, 32k, 64k)	1k samples		
Channel-Gain List	256 entries		
Input Ranges	0–5V, 0–10V, ±5V, ±10V (software selectable)		
Programmable Gains by channel	L = 1,10,100,1000 H = 1, 2, 4, 8		
Drift Zero Gain	±30 µV/°C ±30 ppm/°C		
Input Impedance	10 MΩ		
Input Bias Current	±20 nA		
Input Overvoltage	±35V continuous		
A/D Conversion Time	2.5 µsec	2.0 µsec	6 µsec
A/D Settling Time	2.0 µsec	1.2 µsec	5 µsec
DC Accuracy			
Nonlinearity	±0.5 LSB	±1 LSB	±1 LSB
System Noise	0.8 LSB	1.3 LSB	1.2 LSB
AC Accuracy			
Effective Number of Bits	13.1	14.5	14.8
Total Harmonic Distortion+ Nonlinearity+Noise	81 dB	89 dB	91 dB
Channel Crosstalk	-80 dB @ 1k S/sec		
Clocking and Trigger Input			
Maximum A/D Pacer Clock Aggregate Throughput @ 0.01% Accuracy	400k S/sec	333k S/sec	150k S/sec
External A/D Sample Clock Maximum Frequency	400k S/sec	333k S/sec	150k S/sec
Minimum Pulse Width	20 ns		
External Digital (TTL)Trigger High-level Input Voltage Low-level Input Voltage Minimum Pulse Width	 2.0V min 0.8V min 20 nsec		

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Analog Outputs - all PD2-MF models

Number of Channels	2
Resolution	12 bits
Update Rate	200k S/sec each
Onboard FIFO Size	2k samples (on DSP)
Analog Output Range	±10V
Error	
Gain	±1 LSB
Zero	Calibrated to 0
Current Output	±20 mA max
Output Impedance	0.3Ω typ
Capacitive Drive Capability	1000 pF
Nonlinearity	±1 LSB
Protection	Short circuit to analog ground
Power-on Voltage	0V ±10 mV
Setting Time to 0.01% of FSR	10 µsec, 20V step 1 µsec, 100-mV step
Slew Rate	30 V/µsec

Counter/Timer - all PD2-MF models

Number of Counters	3 available to user (Intel 82C54)
Resolution	16 bits on each counter
Clock Inputs: Software configurable High-level Input voltage Low-level Input voltage High-level Input current Low-level Input current	 Internal 1M S/sec External < 10M S/sec 2.0V min 0.8V max 20 µA -20 µA
Gate Inputs: Maximum Pulse Width	 100 nsec (High) 100 nsec (Low)
Counter Outputs: Output Driver High Voltage Output Driver Low Voltage	Inverted 2.5V min (IOH = 24 mA) 0.55V max (IOH = 48 mA)

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Digital I/O—all PD2-MF models

Input Bits (8 can generate IRQ)	16
Output Bits	16
Inputs: High-level Input Voltage Low-level Input Voltage High-level Input Current Low-level Input Current	 2.0V min 0.8V max 20 µA -20 µA
Outputs: Output Driver High Voltage Output Driver Low Voltage	 2.5V min, 3.0V typ (IOH = -32 mA) 0.55V max (IOL = 64 mA)
Current Sink	-32/64 mA max, 250 mA per port
Pulse Width	20 ns min, interrupt bit latched on rising, falling or either edge
Power-on Voltage	Logic Zero

General Specifications and Connectors - all PD2-MF models

Power Requirements	5V
Physical Dimensions	10.5 x 3.8” (262 x 98 mm)
Environmental: Operating Temperature Range Storage Temperature Range Relative Humidity	 0 to 70°C -25 to 85°C to 95%, noncondensing
Connector J1	96-pin high-density Fujitsu connector (male) (Fujitsu PN#FCN-245P096-G/U)
Connector J2	36-pin header connector (male) (Thomas and Betts PN#609-3627)
Connector J4	36-pin header connector (male) (Thomas and Betts PN#609-3627)
Connector J6	8-pin male connector (Adam-Tech PN#PH2-SMT-8-SGA)

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PD2-MFS Simultaneous Sampling Boards

Model: PD2-MFS-xx-	2M/14	1M/12	800/14
Resolution	14 bits	12 bits	14 bits
Number of Channels Single-Ended Differential	4 (8 optional) 4 (8 optional)		
Maximum Sampling Rate (multiple channels)	2M S/sec	1M S/sec	800k S/sec
Onboard FIFO Size (upgradeable to 16k, 32k, 64k)	4k samples	1k samples	
Input Ranges	0–5V, ±5V, 0–8V, ±8V @ 10V ranges	0–5V, 0–10V, ±5V, ±10V (software selectable)	
Channel-Gain List	256 entries		
Programmable Gains by channel	256 entries		
Drift Zero Gain	±30 µV/°C ±30 ppm/°C		
Input Impedance	1 MΩ		
Input Bias Current	±100 pA		
Input Overvoltage			
A/D Conversion Time	0.45 µsec	0.8 µsec	1.25 µsec
SSH Amp Settling Time	0.7 µsec	0.9 µsec	1.0 µsec
A/D Settling Time	0.4 µsec	0.6 µsec	1.25 µsec
DC Accuracy			
Nonlinearity (no missing codes)	±2 LSB	±0.5 LSB	±0.5 LSB
AC Accuracy			
Effective Number of Bits	12.1	11.3	12.7
Channel Crosstalk	-80 dB @ 1k S/sec		
Clocking and Trigger Input			
Maximum A/D Pacer Clock	1500k S/sec, 4 ch, 1700k S/sec, 8 ch	975k S/sec, 4 ch, 1095k S/sec, 8 ch	800k S/sec
External A/D Sample Clock Maximum Frequency	1500k S/sec, 4 ch 1700k S/sec, 8 ch	975k S/sec, 4 ch, 1095k S/sec, 8 ch	800k S/sec
Minimum Pulse Width	20 nsec		
External Digital (TTL)Trigger High-level Input Voltage Low-level Input Voltage Minimum Pulse Width	2.0V min 0.8V min 20 nsec		

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Model: PD2-MFS-xx-	**500/16**	**500/14**	**300/16**
Resolution	16 bits	14 bits	16 bits
Number of Channels Single-Ended Differential	4 (8 optional) 4 (8 optional)		
Maximum Sampling Rate (multiple channels)	500k S/sec	500k S/sec	300k S/sec
Onboard FIFO Size (upgradeable to 16k, 32k, 64k)	1k samples		
Input Ranges	0–5V, 0–10V, ±5V, ±10V (software selectable)		
Channel-Gain List	256 entries		
Programmable Gains by channel	1, 2, 5, 10		
Drift Zero Gain	±30 µV/°C ±30 ppm/°C		
Input Impedance	1 MΩ		
Input Bias Current	±100 pA		
Input Overvoltage	±18V SE, ±40V DI		
A/D Conversion Time	2 µsec	2.0 µsec	3 µsec
SSH Amp Settling Time	1.2 µsec	1.2 µsec	1.2 µsec
A/D Settling Time	1.5 µsec	1.2 µsec	2.7 µsec
DC Accuracy			
Nonlinearity (no missing codes)	±1 LSB	±1 LSB	±1 LSB
AC Accuracy			
Effective Number of Bits	13.8	12.7	13.8
Channel Crosstalk	-80 dB @ 1k S/sec		
Clocking and Trigger Input			
Maximum A/D Pacer Clock	500k S/sec		300k S/sec
External A/D Sample Clock Maximum Frequency	500k S/sec		300k S/sec
Minimum Pulse Width	20 nsec		
External Digital (TTL)Trigger High-level Input Voltage Low-level Input Voltage Minimum Pulse Width	2.0V min 0.8V min 20 nsec		

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Analog Outputs - all PD2-MFS models

Number of Channels	2
Resolution	12 bits
Update Rate	200k S/sec each
Onboard FIFO Size	2k samples (on DSP)
Analog Output Range	±10V
Error	
Gain	±1 LSB
Zero	Calibrated to 0
Current Output	±20 mA max
Output Impedance	0.3Ω typ
Capacitive Drive Capability	1000 pF
Nonlinearity	±1 LSB
Protection	Short circuit to analog ground
Power-on Voltage	0V ±10 mV
Setting Time to 0.01% of FSR	10 µsec, 20V step, 1 µsec, 100-mV step
Slew Rate	30 V/µsec

Counter/Timers - all PD2-MFS models

Number of Counters	3 available to user (Intel 82C54)
Resolution	16 bits on each counter
Clock Inputs: Software configurable High-level Input voltage Low-level Input voltage High-level Input current Low-level Input current	 Internal 1M S/sec External 10M S/sec 2.0V min 0.8V max 20 µA -20 µA
Gate Inputs: Maximum Pulse Width	 100 nsec (High) 100 nsec (Low)
Counter Outputs: Output Driver High Voltage Output Driver Low Voltage	Inverted 2.5V min (IOH = 24 mA) 0.55V max (IOH = 48 mA)

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Digital I/O - all PD2-MFS models

Input Bits (8 can generate IRQ)	16
Output Bits	16
Inputs: High-level Input Voltage Low-level Input Voltage High-level Input Current Low-level Input Current	 2.0V min 0.8V max 20 µA -20 µA
Outputs: Output Driver High Voltage Output Driver Low Voltage	 2.5V min, 3.0V typ (IOH = -32 mA) 0.55V max (IOL = 64 mA)
Current Sink	-32/64 mA max, 250 mA per port
Pulse Width	20 nsec min, interrupt bit latched on rising, falling or either edge
Power-on Voltage	Logic Zero

General Specifications and Connectors – all PD2-MFS models

Power Requirements	5V
Physical Dimensions	10.5 x 3.8” (262 x 98 mm)
Environmental: Operating Temperature Range Storage Temperature Range Relative Humidity	 0 to 70°C -25 to 85°C to 95%, noncondensing
Connector J1	96-pin high-density Fujitsu connector (male) (Fujitsu PN#FCN-245P096-G/U)
Connector J2	36-pin header connector (male) (Thomas and Betts PN#609-3627)
Connector J4	36-pin header connector (male) (Thomas and Betts PN#609-3627)
Connector J6	8-pin male connector (Adam-Tech PN#PH2-SMT-8-SGA)

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PDL-MF "Lab" Multifunction Boards

Model: PDL-MF-x	**50**	**333**
Resolution	16 bits	
Number of Channels Single-Ended Pseudo-Differential Differential	 16 16 8	
Maximum Sampling Rate (single or multiple channel)	50k S/sec	333k S/sec
Onboard FIFO Size (upgradeable to 32k)	1k samples 64k samples with SRAM option	
Channel-Gain List	64 entries	
Input Ranges	0–10V, ±5V, ±10V (software selectable)	
Programmable Gains	1, 2, 5, 10	
Drift Zero Gain	 ±30 µV/°C ±30 ppm/°C	
Input Impedance	10 MΩ	
Input Bias Current	±20 nA	
Input Overvoltage	±35V cont. 10 mA max	
A/D Conversion Time	2.7 µsec	1.8 µsec
A/D Settling Time (@gain=1)	20 µsec	3 µsec
DC Accuracy		
Nonlinearity	±1 LSB	
System Noise	1.2 LSB	
AC Accuracy		
Effective Number of Bits	14.8	
Total Harmonic Distortion+ Nonlinearity+Noise	91 dB	
Channel Crosstalk	-80 dB @ 1k S/sec	
Clocking and Trigger Input		
Maximum A/D Pacer Clock Aggregate Throughput @ 0.01% Accuracy	50k S/sec	333k S/sec
External A/D Sample Clock Maximum Frequency Minimum Pulse Width	 50 kHz 20 nsec	 333 kHz 20 nsec
External Digital (TTL)Trigger High-level Input Voltage Low-level Input Voltage Minimum Pulse Width	 2.0V min 0.8V min 20 nsec	
Analog Trigger	2 channels-level and edge	

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Analog Outputs—PDL-MF

Number of Channels	2
Resolution	12 bits
Update Rate	100k S/sec each
Onboard FIFO Size	2k samples
Analog Output Range	±10V
Current Output	±20 mA max
Output Impedance	0.3Ω typ
Capacitive Drive Capability	1000 pF
Nonlinearity	±1 LSB
Protection	short circuit to analog ground
Power-on Voltage	0V ±10 mV
Setting Time to 0.01% of FSR	10 µsec, 20V step 1 µsec, 100 mV step
Slew Rate	30 V/µsec

Digital I/O—PDL-MF

Input Bits	24
Output Bits	24
High-level Input Voltage	2.0V min
Low-level Input Voltage	0.8V max
High-level Input Current	20 µA
Low-level Input Current	-20 µA
Output Driver High Voltage	2.5V min, 3.0V typ (IOH=-32 mA)
Output Driver Low Voltage	0.55V max (IOL = 64 mA)
Current Sink	-32/64 mA max, lines 8-16 -24/24 mA max, lines 0-7 250 mA per port

Counter/Timer—PDL-MF

Number of Channels	3
Resolution	24 bits
Maximum Frequency	16.5M S/sec for external clock and 33M S/sec for internal DSP clock
Minimum Frequency	0.00002 Hz for internal clock, no low limits for external clock
Minimum Pulse Width	20 nsec
Output High Level	2.0V min @ -4 mA
Output Low Level	0.5V max @ 4 mA
Protection	7 kV ESD, ±30V overshoot/undershoot
Input Low Voltage	0.0–0.8V
Input High Voltage	2.0–5.0V

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PDXI-MF Multifunction Boards

Model: PDXI-MF-xx-	2M/14H	1M/12x	500/16x
Resolution	14 bits	12 bits	16 bits
Number of Channels: Single-Ended Differential	16 or 64 8 or 32		
Maximum Sampling Rate	2.2M S/sec	1.25M S/sec	500k S/sec
Onboard FIFO Size (upgradeable to 16k, 32k, 64k)	4k samples		2k samples
Channel-Gain List	256 entries		
Input Ranges	0–5V, ±5V, 0–8V, ±8V @ 10V ranges	0–5V, 0–10V, ±5V, ±10V (software selectable)	
Programmable Gains by channel	H=1, 2, 4, 8	L=1,10,100,1000 H=1, 2, 4, 8	
Drift: Zero Gain	±30 µV/°C ±30 ppm/°C		
Input Impedance	10 MΩ		
Input Bias Current	±20 nA		
Input Overvoltage	±20V,2000V ESD 10 mA max	±35V continuous	
A/D Conversion Time	0.45 µsec	0.8 µsec	2 µsec
A/D Settling Time	0.37 µsec	0.6 µsec	1.2 µsec
DC Accuracy			
Nonlinearity	±2 LSB	±0.5 LSB	±1 LSB
System Noise	1.2 LSB	0.3 LSB	1.3 LSB
AC Accuracy			
Effective Number of Bits	12.2	11.63	14.5
Total Harmonic Distortion+ Nonlinearity+Noise	76 dB	71.8 dB	88 dB
Channel Crosstalk	-80 dB @ 1k S/sec		
Clocking and Trigger Input			
Maximum A/D Pacer Clock Aggregate Throughput @ 0.01% accuracy	2200k S/sec @ 1 ch 1800k S/sec @ all	1250k S/sec	500k S/sec
External A/D Sample Clock Maximum Frequency	2200k S/sec @ 1 ch 1800k S/sec @ all	1250k S/sec	500k S/sec
Minimum Pulse Width	20 nsec		
External Digital (TTL)Trigger High-level Input Voltage Low-level Input Voltage Minimum Pulse Width	2.0V min 0.8V min 20 nsec		

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Model: PDXI-MF-xx-	**400/14x**	**333/16x**	**150/16x**
Resolution	14 bits	16 bits	16 bits
Number of Channels: Single-Ended Differential	16 or 64 8 or 32		16 8
Maximum Sampling Rate	400k S/sec	333k S/sec	150k S/sec
Onboard FIFO Size (upgradeable to 16k, 32k, 64k)	1k samples		
Channel-Gain List	256 entries		
Input Ranges	0–5V, 0–10V, ±5V, ±10V (software selectable)		
Programmable Gains by channel	L=1,10,100,1000 H=1, 2, 4, 8		
Drift: Zero Gain	 ±30 µV/°C ±30 ppm/°C		
Input Impedance	10 MΩ		
Input Bias Current	±20 nA		
Input Overvoltage	±35V continuous		
A/D Conversion Time	2.5 µsec	2.0 µsec	6 µsec
A/D Settling Time	2.0 µsec	1.2 µsec	5 µsec
DC Accuracy			
Nonlinearity	±0.5 LSB	±1 LSB	±1 LSB
System Noise	0.8 LSB	1.3 LSB	1.2 LSB
AC Accuracy			
Effective Number of Bits	13.1	14.5	14.8
Total Harmonic Distortion+ Nonlinearity+Noise	81 dB	89 dB	91 dB
Channel Crosstalk	-80 dB @ 1k S/sec		
Clocking and Trigger Input			
Maximum A/D Pacer Clock Aggregate Throughput @ 0.01% accuracy	400k S/sec	333k S/sec	150k S/sec
External A/D Sample Clock Maximum Frequency	400k S/sec	333k S/sec	150k S/sec
Minimum Pulse Width	20 nsec		
External Digital (TTL)Trigger High-level Input Voltage Low-level Input Voltage Minimum Pulse Width	 2.0V min 0.8V min 20 nsec		

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Analog Outputs - all PDXI-MF models

Number of Channels	2
Resolution	12 bits
Update Rate	200k S/sec each
Onboard FIFO Size	2k samples (on DSP)
Analog Output Range	±10V
Error	
Gain	±1 LSB
Zero	Calibrated to 0
Current Output	±20 mA max
Output Impedance	0.3W typ
Capacitive Drive Capability	1000 pF
Nonlinearity	±1 LSB
Protection	Short circuit to analog ground
Power-on Voltage	0V ±10 mV
Setting Time to 0.01% of FSR	10 µsec, 20V step 1 µsec, 100-mV step
Slew Rate	30 V/µsec

Digital I/O - all PDXI-MF models

Input Bits (8 can generate IRQ)	16
Output Bits	16
Inputs: High-level Input Voltage Low-level Input Voltage High-level Input Current Low-level Input Current	 2.0V min 0.8V max 20 µA -20 µA
Outputs: Output Driver High Voltage Output Driver Low Voltage	 2.5V min, 3.0V typ (IOH = -32 mA) 0.55V max (IOL = 64 mA)
Current Sink	-32/64 mA max, 250 mA per port
Pulse Width	20 nsec min, interrupt bit latched on rising, falling or either edge
Power-on Voltage	Logic Zero

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Counter/Timer - all PDXI-MF models

Number of Counters	3 available to user (Intel 82C54)
Resolution	16 bits on each counter
Clock Inputs: Software configurable High-level Input voltage Low-level Input voltage High-level Input current Low-level Input current	 Internal, 1M S/sec, External, 10M S/sec 2.0V min 0.8V max 20 µA -20 µA
Gate Inputs: Maximum Pulse Width	 100 nsec (High), 100 nsec (Low)
Counter Outputs: Output Driver High Voltage Output Driver Low Voltage	Inverted 2.5V min (IOH = 24 mA) 0.55V max (IOH = 48 mA)

General Specifications and Connectors – all PDXI-MF models

Power Requirements	5V
Physical Dimensions	7 x 4" (177 x 101 mm)
Environmental: Operating Temperature Range Storage Temperature Range Relative Humidity	 0 to 70°C -25 to 85°C to 95%, noncondensing
Connector J1	96-pin high-density Fujitsu connector (male) (Fujitsu PN# FCN-245P096-G/U)
Connector J2	80-pin header connector (male) (Adam Tech PN# HBMR-A-80-VSG)

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PDXI-MFS Simultaneous Sampling Boards

Model: PDXI-MFS-xx-	**2M/14**	**1M/12**	**800/14**
Resolution	14 bits	12 bits	14 bits
Number of Channels Single-Ended Differential (optional)	4 or 8 4 or 8		
Maximum Sampling Rate (multiple channels)	2M S/sec	1M S/sec	800k S/sec
Onboard FIFO Size (upgradeable to 16k, 32k, 64k)	4k samples	1k samples	
Input Ranges	0–5V, ±5V, 0–8V, ±8V @ 10V ranges	0–5V, 0–10V, ±5V, ±10V (software selectable)	
Channel-Gain List	256 entries		
Programmable Gains by channel	1, 2, 5, 10		
Drift Zero Gain	±30 µV/°C ±30 ppm/°C		
Input Impedance	1 MΩ		
Input Bias Current	±100 pA		
Input Overvoltage	±18V SE ±40V DI		
A/D Conversion Time	0.45 µsec	0.8 µsec	1.25 µsec
SSH Amp Settling Time	0.7 µsec	0.9 µsec	1.0 µsec
A/D Settling Time	0.4 µsec	0.6 µsec	1.25 µsec
DC Accuracy			
Nonlinearity (no missing codes)	±2 LSB	±0.5 LSB	
AC Accuracy			
Effective Number of Bits	12.1	11.3	12.7
Channel Crosstalk	-80 dB @ 1k S/sec		
Clocking and Trigger Input			
Maximum A/D Pacer Clock	1500k S/sec @ 4 ch, 1700k S/sec @ 8 ch	975k S/sec @ 4 ch, 1095k S/sec @ 8 ch	800k S/sec
External A/D Sample Clock Maximum Frequency	1500k S/sec @ 4 ch 1700k S/sec @ 8 ch	975k S/sec @ 4 ch, 1095k S/sec @ 8 ch	800k S/sec
Minimum Pulse Width	20 ns		
External Digital (TTL)Trigger High-level Input Voltage Low-level Input Voltage Minimum Pulse Width	2.0V min 0.8V min 20 nsec		

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Model: PDXI-MFS-xx-	**500/16**	**500/14**	**300/16**
Resolution	16 bits	14 bits	16 bits
Number of Channels Single-Ended Differential (optional)		4 or 8 4 or 8	
Maximum Sampling Rate (multiple channels)		500k S/sec	300k S/sec
Onboard FIFO Size (upgradeable to 16k, 32k, 64k)		1k samples	
Input Ranges		0–5V, 0–10V, ±5V, ±10V (software selectable)	
Channel-Gain List		256 entries	
Programmable Gains by channel		1, 2, 5, 10	
Drift Zero Gain		±30 µV/°C ±30 ppm/°C	
Input Impedance		1 MΩ	
Input Bias Current		±100 pA	
Input Overvoltage		±18V SE ±40V DI	
A/D Conversion Time	2 µsec	2.0 µsec	3 µsec
SSH Amp Settling Time	1.2 µsec	1.2 µsec	1.2 µsec
A/D Settling Time	1.5 µsec	1.2 µsec	2.7 µsec
DC Accuracy			
Nonlinearity (no missing codes)		±1 LSB	
AC Accuracy			
Effective Number of Bits	13.8	12.7	13.8
Channel Crosstalk		-80 dB @ 1k S/sec	
Clocking and Trigger Input			
Maximum A/D Pacer Clock		500k S/sec	300k S/sec
External A/D Sample Clock Maximum Frequency		500k S/sec	300k S/sec
Minimum Pulse Width		20 nsec	
External Digital (TTL)Trigger High-level Input Voltage Low-level Input Voltage Minimum Pulse Width		2.0V min 0.8V min 20 nsec	

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Analog Outputs—all PDXI-MFS models

Number of Channels	2
Resolution	12 bits
Update Rate	200k S/sec each
Onboard FIFO Size	2k samples (on DSP)
Analog Output Range	±10V
Error	
Gain	±1 LSB
Zero	Calibrated to 0
Current Output	±20 mA max
Output Impedance	0.3W typ
Capacitive Drive Capability	1000 pF
Nonlinearity	±1 LSB
Protection	Short circuit to analog ground
Power-on Voltage	0V ±10 mV
Setting Time to 0.01% of FSR	10 µsec, 20V step 1 µsec, 100-mV step
Slew Rate	30 V/µsec

Counter/Timer—all PDXI-MFS models

Number of Counters	3 available to user (Intel 82C54)
Resolution	16 bits on each counter
Clock Inputs Software configurable High-level Input voltage Low-level Input voltage High-level Input current Low-level Input current	 Internal, 1M S/sec External, 10M S/sec 2.0V min 0.8V max 20 µA -20 µA
Gate Inputs Maximum Pulse Width	 100 nsec (High), 100 nsec (Low)
Counter Outputs Output Driver High Voltage Output Driver Low Voltage	Inverted 2.5V min (IOH = 24 mA) 0.55V max (IOH = 48 mA)

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Digital I/O—all PDXI-MFS models

Input Bits (8 can generate IRQ)	16
Output Bits	16
Inputs High-level Input Voltage Low-level Input Voltage High-level Input Current Low-level Input Current	 2.0V min 0.8V max 20 µA -20 µA
Outputs: Output Driver High Voltage Output Driver Low Voltage	 2.5V min, 3.0V typ (IOH = -32 mA) 0.55V max (IOL = 64 mA)
Current Sink	-32/64 mA max, 250 mA per port
Pulse Width	20 ns min, interrupt bit latched on rising, falling or either edge
Power-on Voltage	logic Zero

General Specifications and Connectors - all PDXI-MFS models

Power Requirements	5V
Physical Dimensions	7 x 4” (177 x 101 mm)
Environmental: Operating Temperature Range Storage Temperature Range	 0 to 70°C -25 to 85°C
Relative Humidity	to 95%, noncondensing
Connector J1	96-pin high-density Fujitsu connector (male) (Fujitsu PN#FCN-245P096-G/U)
Connector J2	80-pin header connector (male) (Adam Tech PN# HBMR-A-80-VSG)

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Appendix B: PowerDAQ A/D Timing

The following tables are intended to help you determine the fastest acquisition rates for various models when working with various gains.

In the Board Model column, note that an "x" is a placeholder for various models and represents the number of channels on the board.

In the Resolution / Speed / Gain column, "Low" refers to a board with modest gain capabilities (either 1, 2, 4, 8 or 1, 2, 5, 10) and are intended to work with high-level signals—and hence the "H" suffix on the board model number. Conversely, "High" in the second column refers to a board with high gain capabilities (1, 10, 100, 1000) and are intended to work with low-level signals—and hence the "L" suffix on the board model number.

The column "Fast Acq Delay" gives the minimum time between conversions when the board is digitizing at its maximum rate.

The column "Slow Acq Delay (using Slow Bit)" gives the minimum time between conversions when you activate the Slow Bit for a channel. Recall that a Slow Bit setting instructs the board to wait an extra amount of time before taking the next sample, thereby giving the amplifier and other front-end elements time to settle to the next value before actually digitizing the signal. This column tells you exactly how much time you can expect to wait until the next channel is digitized.

Note We are working constantly to improve these specifications, and so they are subject to change. Please check with the factory for the latest values.

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PD2-MF Series Timing

Board Model	Resolution / Speed / Gain	Fast Acq Delay	Slow Acq Delay (using Slow Bit)
PD2-MF-xx-3M/12L	12 / 3 MHz / High	283 nsec	800 µsec
PD2-MF-xx-3M/12H	12 / 3 MHz / Low	283 nsec	800 µsec
PD2-MF-xx-2M/14H	14 / 2.2 MHz / Low	450 nsec	3.0 µsec
PD2-MF-xx-500/16L	16 / 500 kHz / High	2.0 µsec	20 µsec
PD2-MF-xx-500/16H	16 / 500 kHz / Low	2.0 µsec	10 µsec
PD2-MF-xx-400/14L	14 / 400 kHz / High	2.5 µsec	25.0 µsec
PD2-MF-xx-400/14H	14 / 400 kHz / Low	2.5 µsec	10.0 µsec
PD2-MF-xx-333/16L	16 / 333 kHz / High	3.0 µsec	20.0 µsec
PD2-MF-xx-333/16H	16 / 333 kHz / Low	3.0 µsec	10.0 µsec
PD2-MF-16-150/16L	16 / 150 kHz / High	6 µsec	20 µsec
PD2-MF-16-150/16H	16 / 150 kHz / Low	6 µsec	10 µsec

PD2-MFS Series Timing

Board Model	Resolution / Speed	Fast Acq Delay	Slow Acq Delay (using Slow Bits)	SSH Acq Delay	SSH Hold Delay
PD2-MFS-x-2M/14	14 / 2.2 MHz	450 nsec	2.0 µsec	700 nsec	500 nsec
PD2-MFS-x-800/14	14 / 800 kHz	1.25 µsec	3.0 µsec	900 nsec	700 nsec
PD2-MFS-x-500/14	14 / 500 kHz	2.0 µsec	3.0 µsec	900 nsec	700 nsec
PD2-MFS-x-333/16	16 / 333 kHz	3.0 µsec	10.0 µsec	900 nsec	700 nsec

PDL-MF Series Timing

Board Model	Resolution / Speed / Gain	Fast Acq Delay	Slow Acq Delay (no Slow Bits)
PDL-MF/PDL-MF-50	16 / 50 kHz / 1,2,5,10	20 µsec	N/A
PDL-MF-333	16 / 333 kHz / 1,2,5,10	3 µsec	N/A

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PDXI-MF Series Timing

Board Model	Resolution / Speed / Gain	Fast Acq Delay	Slow Acq Delay (using Slow Bits)
PDXI-MF-xx-2M/14H	14 / 1.65 MHz / Low	450 nsec	3.0 µsec
PDXI-MF-xx-1M/12L	12 / 1.25 MHz / High	800 nsec	20.0 µsec
PDXI-MF-xx-1M/12H	12 / 1.25 MHz / Low	800 nsec	5.0 µsec
PDXI-MF-xx-800/14L	14 / 800 kHz / High	1.25 µsec	20.0 µsec
PDXI-MF-xx-800/14H	14 / 800 kHz / Low	1.25 µsec	10.0 µsec
PDXI-MF-xx-500/16L	16 / 500 kHz / High	2.0 µsec	20.0 µsec
PDXI-MF-xx-500/16H	16 / 500 kHz / Low	2.0 µsec	10.0 µsec
PDXI-MF-xx-400/14L	14 / 400 kHz / High	2.5 µsec	25.0 µsec
PDXI-MF-xx-400/14H	14 / 400 kHz / Low	2.5 µsec	10.0 µsec
PDXI-MF-xx-333/16L	16 / 333 kHz / High	3.0 µsec	20.0 µsec
PDXI-MF-xx-333/16H	16 / 333 kHz / Low	3.0 µsec	10.0 µsec
PDXI-MF-xx-150/16L	16 / 150 kHz / High	6.0 µsec	20.0 µsec
PDXI-MF-xx-150/16H	16 / 150 kHz / Low	6.0 µsec	10.0 µsec
PDXI-MF-xx-100/16L	16 / 100 kHz / Low	10.0 µsec	50.0 µsec
PDXI-MF-xx-100/16H	16 / 100 kHz / High	10.0 µsec	50.0 µsec

PDXI-MFS Series Timing

Board Model	Resolution / Speed	Fast Acq Delay	Slow Acq Delay (using Slow Bits)	SSH Acq Delay	SSH Hold Delay
PDXI-MFS-x-2M/14	14 / 2.2 MHz	450 nsec	2.0 µsec	700 nsec	500 nsec
PDXI-MFS-x-1M/12	12 / 1.25 MHz	800 nsec	2.0 µsec	700 nsec	500 nsec
PDXI-MFS-x-800/14	14 / 800 kHz	1.25 µsec	3.0 µsec	900 nsec	700 nsec
PDXI-MFS-x-500/14	14 / 500 kHz	2.0 µsec	3.0 µsec	900 nsec	700 nsec
PDXI-MFS-x-333/16	16/ 333 kHz	3.0 µsec	10.0 µsec	900 nsec	700 nsec

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Appendix C: Accessories

UEI supplies a wide range of accessories for the PowerDAQ PD2/PDXI boards. They greatly expand the core functionality of standard MF(S) hardware and allow you to employ these cards in very demanding applications. These accessories also provide the means for implementing custom interconnection schemes for OEM applications.

Screw-Terminal Panels (PD2/PDXI)

PD/PDXI-STP-96	Screw-terminal panel with 96- and 37-pin connector, suited for boards with as many as 64 analog channels
PD/PDXI-STP-96-KIT	Complete kit: Includes PD-STP-96, PD-CBL-96 and PD-CBL-37 for 64-channel boards
PD/PDXI-STP-9616	Screw-terminal panel with 96-pin and 37-pin connector for 4/8/16-channel boards
PD/PDXI-STP-9616-KIT	Complete kit: Includes PD-STP-9616, PD-CBL-96 and PD-CBL-37 for 4/8/16-channel boards
PD-STP-3716	Low-cost screw-terminal panel with 37-pin connector for 16-channel boards
PD-STP-3716-KIT	Complete kit: Includes PD-STP-3716 and PD-CBL-9637 for 16-channel boards
PD-STP-DIO	Screw-terminal panel with 37-pin connector, handles digital I/O and counter/timer signals only.

Screw Terminal Panels (PDL-MF only)

PDL-STP	100-way screw terminal with dual 50-pin IDC connectors
PDL-CBL-100	18” cable, connects 100-way connector on PDL-MF board and is terminate with dual 50-way IDC connectors for the PDL-STP
PDL-MF-CONN	Connector for direct attachment of signal leads to PDL-MF board, no cable required

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BNC & Distribution Panels (PD2/PDXI)

PD-BNC-16	BNC panel for 16-channel boards
PD-BNC-16-KIT	Complete kit: Includes PD-BNC-16, PD-CBL-96, PD-CBL-37 (for 16-channel boards)
PD/PDXI-BNC-64	BNC panel for 64-channel boards
PD/PDXI-BNC-64-KIT	Complete kit: Includes PD-BNC-64, PD-CBL-96, PD-CBL-37 (for 64-channel boards)

Note See Appendix E for PD-BNC wiring tips.

Cables (PD2/PDXI)

PD/PDXI-CBL-96	96-way pinless, round, 1m shielded cable with metal cover plates
PD/PDXI-CBL-96-6FT	96-way pinless, round, 6-ft shielded cable with metal cover plates
PD/PDXI-CBL-96-9FT	96-way pinless, round 9-ft shielded cable with metal cover plates
PD/PDXI-CBL-37	DIO cable set: 37-way, 1m D-sub cable, internal cable with mounting bracket
PD-CBL-37-6FT	DIO cable set: 37-way, 6-ft D-sub cable, internal cable with mounting bracket
PD-CBL-37-9FT	DIO cable set: 37-way, 9-ft D-sub cable, internal cable with mounting bracket
PD-CBL-37BRKT	DIO cable: 37-way, 1m internal cable with mounting bracket
PD-CBL-37TP	DIO twisted-pair cable set: 37-way, 1m D-sub cable, internal cable with mounting bracket
PD-CBL-3650-8/8	DIO cable set: 36/50-way 1m ribbon cable, internal cable with mounting bracket (for 8 DI and 8 DO)
PD-CBL-3650-16I	DIO cable set: 36/50-way 1m ribbon cable, internal cable with mounting bracket (for 16 DI)
PD-CBL-3650-16O	DIO cable set: 36/50-way 1m ribbon cable, internal cable with mounting bracket (for 16 DO)
PD-CBL-5B	18” ribbon cables that connect from the PD-5BCONN to 5B-xx racks
PD-CBL-7B	18”. ribbon cables that connect from the PD-7BCONN to 7B-xx racks
PD-CBL-SYNC4	Internal cable to synchronize up to four PowerDAQ MF(S) boards
PD-CBL-SYNC5	Internal cable to synchronize up to five PowerDAQ MF(S) boards
PD-CBL-SYNC10	Internal cable to synchronize up to ten PowerDAQ MF(S) boards

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Mating cables, connectors, rack mounts (PD2/PDXI)

PD-CONN	Mating connector with metal cover (includes Fujitsu PN# FCN-230C096-C/E and FCN-247J096-G/E). Allows users to create custom connector pinouts from PowerDAQ board.
PD-CONN-CBL	96-way pinless, 0.5m, round shielded cable with metal cover plate (bare wires at one end)
PD-CONN-PCB	PowerDAQ mating connector with pc-board attached
PD-CONN-9696	PowerDAQ connector for interfacing to custom/OEM boxes or equipment.
PD-CONN-NI	Converts 100-way NI multipurpose analog-digital connector to the PowerDAQ 96-way analog and 37-way digital connectors
PD-CONN-STR	Individual Fujitsu connector (PN FCN-244P096-G/E), with a vertical pc-board mount
PD-CONN-RTA	Individual Fujitsu connector (PN FCN-245P096) with a right-angle pc-board mount (version used on PowerDAQ boards)
PD-19RACK	19” rack, holds 3.5” deep terminal panels such as the PD-STP-96, PD-STP-9616, and PD-BNC-16
PD-19RACKW	19” rack, wide version holds 7” deep terminal panels such as the PD-TCR-16-x or PD-BNC-64
PD-5BCONN	Connects 16- or 64-channel PowerDAQ board to one to four 5B-xx racks
PD-7BCONN	Connects 16- or 64-channel PowerDAQ board to one to four 7B-xx racks
PD-100HDR	Connects 16- or 64-channel PowerDAQ board to two 50-way IDC headers

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Signal Conditioning (all boards)

PD-PSU-5/15	Power supply (110/200V ac in; 5V, ±5V dc out) for use with PD-TCR-16-x racks or with PD-ASTPs
PD-SCXU-AOMUX	8-channel analog-output multiplexer
PD-ASTP-16	16-channel AIn active screw-terminal panel (G = 1, 6-dB cutoff @ 100 Hz)
PD-ASTP-16X	16-channel ASTP panel that adds 2 analog excitation-voltage channels
PD-ASTP-16SG	Precision version of ASTP-16X with G = 100, cutoff of 10 Hz, for use with strain gages and thermocouples
PD-5B-CONN	Connects 64-channel PowerDAQ board to four ASTPs
PD2-DIO-BPLANE16	16-channel backplane for solid-state relay modules
PD2-DIO-CONN64-4	Distribution board (converts 100-way connector to four 50-way IDC headers)
PD2-DIO-CBL-100	100-way 1m cable
PD2-DIO-CBL-50	18” 50/50-way IDC ribbon cable, connects PD2-DIO-CONN64-4 to PD2-DIO-BPLANE16
PD-5B-04	2-channel backplane, mounts 5B analog I/O modules to MF(S) boards
PD-5B-08	8-channel backplane, mounts 5B analog I/O modules to MF(S) boards
PD-5B-01	16-channel backplane, mounts 5B analog I/O modules to MF(S) boards

Note UEI supplies a wide range of analog and digital signal-conditioning modules for use on these racks. The list is far too extensive to publish in this manual. For the latest list, contact the factory or your local distributor, or review the list on our web site at www.ueidaq.com.

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Appendix D: PowerDAQ SDK Structure

The installation will create the following directory structure in Program Files. This assumes you selected the SDK installation (default). This software ships on the PowerDAQ Software Suite CD-ROM that accompanies each board.

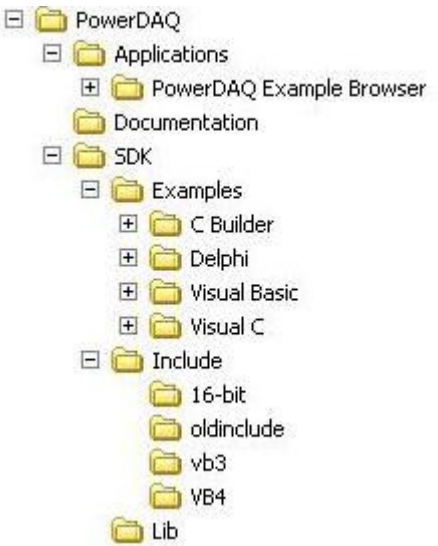


Figure D.1—PowerDAQ Software Structure

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PowerDAQ Windows device drivers

Windows 9x
\windows\system pwrdaq95.vxd
Windows NT
\winnt\system32\drivers pwrdaq.sys
Windows 2000
\winnt\system32\drivers PwrDAQ2K.sys
\winnt\inf PwrDAQ2K.inf
Windows XP
\windows\system32\drivers PwrDAQ2K.sys
\windows\inf PwrDAQ2K.inf

Note The PDL-MF works on all operating systems except Windows 9x, and it also runs under Linux and QNX. The PowerDAQ Software Suite Version 3 or above is required.

PowerDAQ Windows DLLs

The PowerDAQ Software Suite includes various DLLs (dynamic linked libraries) for different versions of the Windows operating system. The location of these DLLs is as follows:

Windows 9x
\windows\system PwrDAQ32.dll (32-bit)
PwrDAQ16.dll (16-bit)
Windows NT/2000
\winnt\system32 PwrDAQ32.dll
PwrDAQ16.dll
Windows XP
\windows\system32 PwrDAQ32.dll
PwrDAQ16.dll

The DLLs have identical names for Windows 9x and NT/2000/XP, but note that they are implemented differently. Both support the same API, so PowerDAQ applications that don't use functions specific to Win9x or WinNT/2000/XP should run on any version of Windows.

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PowerDAQ Language Libraries

PowerDAQ SDK contains libraries for all major software development tools.

/lib

pwrdaq32.lib	MSVC/MSVS v.5.x, 6.x
pd32bb.lib	Borland C Builder v.3.0, 4.0
pd16bb.lib	16-bit Borland compilers
pwrdaq16.lib	16-bit MSVC 1.5x

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PowerDAQ Include Files

/include

aliases.bas	auxiliary functions to access PowerDAQ structures from within VB
DAQDefs.bas	DAQ constant and variable definitions file for Visual Basic
DAQDefs.pas	DAQ constant and variable definitions file for Delphi
pdApi.bas	module used in SimpleTest VB example
pd_dsp_ct.h	DSP counter-timer register definitions file for C/C++
pd_dsp_ct.pas	DSP counter-timer register definitions file for Delphi
pd_dsp_es.h	ESSI port register definitions file for C/C++
pd_dsp_es.pas	ESSI port register definitions file for Delphi
pd32hdr.h	PowerDAQ DLL driver interface function definitions file for C\C++
pd32hdr.pas	PowerDAQ DLL driver interface function definitions file for Delphi
pdfw_bitsdef.bas	PowerDAQ Firmware Command definitions file for Visual Basic
pdfw_bitsdef.pas	PowerDAQ Firmware Command definitions file for Delphi
pdfw_def.h	firmware constant definition file for C/C++
pdfw_def.pas	firmware constant definition file for Borland Delphi
pdfw_def.bas	firmware constant definition file for Visual Basic
pd_hcaps.h	boards capabilities definition file for C/C++
pd_hcaps.pas	PowerDAQ Firmware PCI interface definitions file for Visual Basic
pdpcidef.h	PowerDAQ Firmware PCI interface definitions file for C\C++
pdpcidef.pas	PowerDAQ Firmware PCI interface definitions file for Delphi
pwrdaq.h	driver constants and definitions file for C/C++
pwrdaq.pas	driver constants and definitions file for Delphi
pwrdaq.bas	driver constants and definitions file for Visual Basic
pwrdaq32.h	API function prototypes and structures file for C
pwrdaq32.hpp	API function prototypes and structures file for C++
pwrdaq32.pas	API function prototypes and structures file for Delphi
pwrdaq32.bas	API function prototypes and structures file for Visual Basic
pxi.bas	PXI related function definitions file for Visual Basic
pxi.h	PXI related function definitions file for C\C++
sigproc.h	PowerDAQ FFT and windows routines definition file for C
sigproc.hpp	PowerDAQ FFT and windows routines definition file for C++

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vbdll.bas	auxiliary functions to access PowerDAQ buffer from within VB
/include/vb3	
pwrdaq16.bas	API function prototypes and structures file for Visual Basic v.3.0
pdfw_def.bas	firmware constant definition file for Visual Basic v.3.0
pd_hcaps.bas	boards capabilities definition file for Visual Basic v.3.0
daqdefs.bas	event word definition for Visual Basic v.3.0
/include/16-bit	
pwrdaq16.h	API function prototypes and structures file for 16-bit C/C++
pwrdaq.h	driver constants and definitions file for 16-bit C/C++
pdd_vb3.h	auxiliary functions to access PowerDAQ structures from within VB v.3.0
pd_hcaps.h	boards capabilities definition file for 16-bit C

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PowerDAQ Linux support

The PowerDAQ API for Linux, which also supports two variations of realtime Linux (the kernels from RTAI and FSMLabs) is very similar to the Windows API.

Kernel driver:
/lib/modules/<kernel_version>/misc/pwrdaq.o

Shared library:
/usr/local/lib/libpowerdaq32.so.1.0

Header files:

win_sdk_types.h	datatype definitions needed by the files above.
pdfw_def.h	firmware constant definition file for C/C++
powerdaq.h	driver constants and definitions file for C/C++
powerdaq32.h	API function prototypes and structures file for C/C++

PowerDAQ QNX Support

QNX driver:
/usr/bin/dev-pwrdaq

Shared library:
/usr/lib/libpwrdaq.so
/usr/lib/libpowerdaq32.so

Header files:

pdl_headers.h	header files specific to QNX6 and QNX4
powerdaq.h	driver constants and definitions file for C/C++
powerdaq32.h	API function prototypes and structures file for C/C++
pdfw_def.h	firmware constant definition file for C/C++
win2qnx.h	DDK types conversion into QNX types.

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Appendix E: Application Notes

1. PowerDAQ Advanced Circular Buffer (ACB)

The Advanced Circular Buffer (ACB) solves many of the problems associated with high-throughput data acquisition on a multithreaded /multitasking operating system. For simplicity, data acquisition as an input process is discussed here. However, the same concepts can be applied to output-signal generation.

- Asynchronous operation
- Nondeterministic processor time slots per thread
- Dynamic processor loading
- Nondeterministic user operation

The ACB requires that the DAQ interface library allocate a large circular buffer in the application's memory space. The buffer size must be no larger than the available physical memory with sufficient physical memory left over for most of the executable portion of the OS and active applications to reside in memory. This prevents code or data from frequently being swapped to disk. Consequently, if continuous gap-free acquisition is to be performed, the buffer should be large enough to hold all the acquired data for the maximum time period expected between application execution latency and the time required for the application to process all data in a full buffer. This also implies that the application must be able to process the data at a rate faster than the rate of acquisition.

Once acquisition is started, the DAQ board/driver transfer and store data into the buffer at one rate, and the application generally reads the data from the buffer at another rate. Both operations occur asynchronously of each other.

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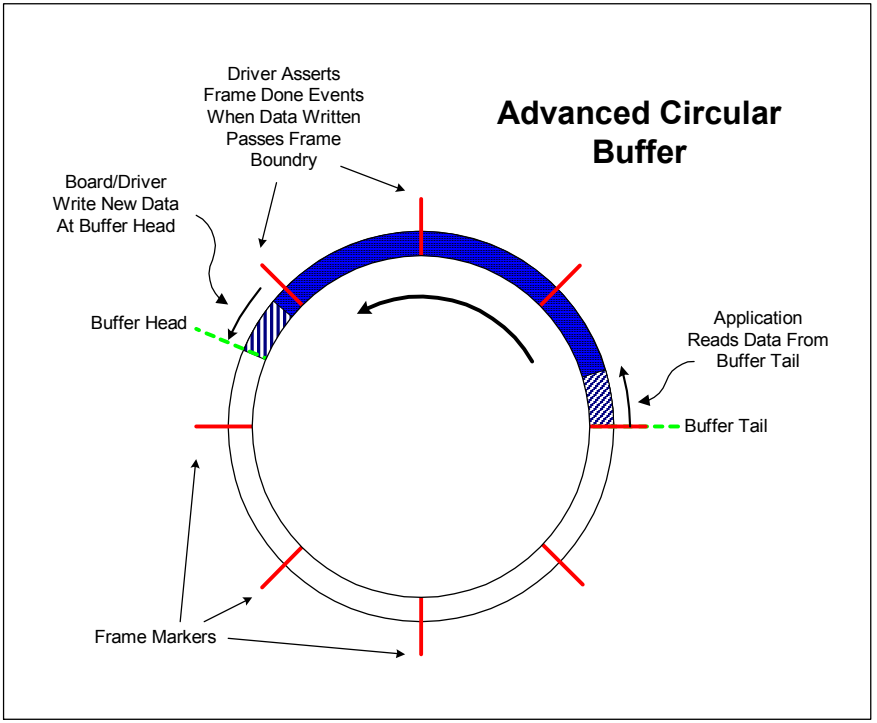


Figure E.1—Advanced Circular Buffer

The application can be synchronized to the acquisition process by either timer notification or by an event from the driver notifying that a certain sample count boundary has been passed.

In order to receive notification on a sample or scan count boundary, the buffer is segmented into frames. Whenever the data transferred to the buffer crosses a frame boundary, the driver sends an event to the application. This event wakes up the application thread that is responsible for processing data in the buffer. To keep the frame boundaries at fixed buffer locations, the buffer size should be a multiple of the frame size. If multichannel acquisition is performed, then the frame size should also be a multiple of the scan size. Doing so keeps the pointer arithmetic from becoming unnecessarily complex.

With the ACB, three modes of operation are possible:

- Single Buffer
- Circular Buffer
- Recycled Circular Buffer

In all three modes, data is written to the beginning of the buffer at the start of acquisition. The three modes differ in what is done when the end of the buffer is reached and if the buffer head catches up with the buffer tail.

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Single Buffer
In the Single Buffer mode, acquisition stops when the buffer end is reached. In this mode, the application can access the buffer and process the data any time during acquisition or wait until the buffer is full, and acquisition stops. The Single Buffer mode is the simplest to program, and it's also the most common. It is useful in applications where acquiring data in a continuous stream is not required. This is similar to the way digital multimeters and storage scopes acquire signals, whereby a single buffer is filled and then the waveform is displayed. This process can also be repeated any number of times.

Circular Buffer
In the Circular Buffer mode, the buffer head and tail wrap to the beginning of the buffer when the end is reached. Data is written at the location pointed to by head and the head pointer is incremented, and likewise data is read from the location pointed to by the tail and the tail pointer is incremented. When the head pointer wraps around and reaches the tail pointer, then the buffer is considered full and acquisition stops with a buffer overflow condition. To prevent unintentional incrementing of the tail pointer, the pointer should be incremented after the application has finished reading the data in the buffer and has indicated that the buffer space is relinquished for the write operation.

The Circular Buffer mode is useful in applications that must acquire data with no sample loss. Each acquired sample must be stored by the hardware/driver and read by the application. The data-acquisition operation continues until the application issues a stop command to the driver. If the application cannot keep up with the acquisition process and the buffer overflows, then the acquisition is stopped and the error condition is reported.

Recycled Circular Buffer
The Recycled Circular Buffer mode is similar to the Circular Buffer mode except that when the head pointer catches up with the tail pointer, the tail pointer is automatically incremented to the next frame boundary. This buffer-space recycling occurs irrespective of whether the application read the data or not. In this mode, a buffer overflow condition never occurs.

The Recycled Circular Buffer is best suited for applications that monitor acquired signals at periodic intervals. The application may require the signals to be acquired at a high rate, but not all acquired samples need to be processed. Also, an application may only need the latest block of samples acquired. As the buffer fills up, the driver is free to recycle frames, automatically incrementing the buffer tail, and using the space to store new samples.

While the Advanced Circular Buffer may appear a much different buffering mechanism when compared to the much simpler single and double buffer mechanisms, it is actually a superset of the simpler buffers. The ACB configured in the single buffer mode will behave just as the simple ordinary single buffer. If the ACB is configured as Circular Buffer with two frames, it will behave as a double buffer. With multiple frames, the ACB can be used in algorithms that were designed for buffer queues. The only limitation, which consequently results in more efficient performance, is that the logical buffers in the buffer queues cannot be dynamically allocated and freed. In addition, their order is fixed.

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2. PD-BNC-xx wiring options:

Voltage dividers

To build a voltage divider, install resistors in the R0A, R8A and R0C positions for the Ch0 and Ch8 pair, and similarly for other pairs. Note that when supplied by the factory, the RxA resistors have 0Ω (wire) jumpers installed

Lowpass filtering

To build a lowpass filter, install resistors in the R0A and R8A positions. Also install a capacitor in the C0B position for the Ch 0 and Ch 8 pair, and for other pairs as well. Note that when supplied by the factory, the RxA resistors have 0Ω (wire) jumpers installed.

Highpass filtering

In order to build a highpass filter, install capacitors in the R0A and R8A positions. Also install a resistor into the C0B position for the Ch 0 and Ch 8 pair and for other pairs as well. Note that when supplied by the factory, the RxA resistors have 0Ω (wire)jumpers installed.

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Appendix F: Warranty

All PowerDAQ boards have received CE Mark certification according to the following:

EN55011	*Radiated Emissions Standard*
EN50082-1	*Generic Immunity Standard*

UEI **Terms and Conditions** for all products are available as copies on demand, and online at http://ueidaq.com/company/terms.aspx

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Appendix G: Glossary

A

ACB	see Advanced Circular Buffer
A/D (see ADC)	Analog/digital, often used in connection with an A/D converter.
adapter	Alternate designation for a function card that plugs into a backplane, often a PC.
ADC (also see A/D)	Analog-to-Digital Converter. An integrated circuit that converts an analog voltage to a digital number.
ADC conversion	The process of converting an analog input to its digital equivalent.
ADC conversion Start	Signal used to start the process of converting an analog input to a digital value. The source of this signal can be an internal clock or an external asynchronous signal.
ADC Channel List Start	Signal used to start the acquisition of digitized values as defined in the Channel List. The triggering edge of this signal (falling edge) enables the ADC conversion Start signals.
Advanced Circular Buffer	A special user-defined buffer in host memory that stores frames of collected data. The PowerDAQ driver allows the user application to fetch data from this buffer in several modes.
alias	A false lower-frequency component that appears in sampled data that has been acquired at an insufficiently high sampling rate.
analog trigger	A trigger that occurs when an analog signal reaches a user-selected level. Users can configure triggering to occur at a specific level on either an increasing or a decreasing signal (positive or negative slope).
API	Application Programming Interface, a collection of high-level language function calls that provide access the functions in a driver or other utility.
asynchronous	(1) Hardware—A property of an event that occurs at an arbitrary time, without synchronization to a reference clock.

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(2) Software—A property of a function that begins an operation and returns prior to the completion or termination of the operation.

B

background acquisition Data is acquired by a DAQ system while another program or processing routine is running without apparent interruption.

base address A memory address that serves as the starting address for programmable registers. All other addresses are located by adding to the base address.

bipolar A signal range that includes both positive and negative values (for example, -5V to +5V, also represented as ±5V).

bit One binary digit, either 0 or 1.

Block mode A high-speed data transfer in which the address of the data is sent followed by a specified number of back-to-back data words.

Burst mode A high-speed data transfer in which the address of the data is sent followed by back-to-back data words while a physical signal is asserted.

bus The group of conductors that interconnect individual circuitry in a computer. Typically, a bus is the expansion vehicle to which I/O or other devices are connected. Examples of PC buses are the PCI bus and the PXI bus.

bus master A type of plug-in board or controller that can read and write to devices on the computer bus without the assistance of the host CPU.

byte Eight related bits of data, an 8-bit binary number. Also used to denote the amount of memory required to store one byte of data.

C

cache High-speed processor memory that buffers commonly used instructions or data to increase processing throughput.

calibration The setting or correcting of a measuring device or base level, usually by adjusting it to match or conform to a dependably known and unvarying measure.

channel list A variable length list of from 1 to 256 entries, each of which defines a channel, its gain any Slow Bits. In continuous A/D acquisition mode, the list wraps around to the first channel after it reaches the end. The channels need not be in any particular order and may appear multiple times in the list.

Channel List FIFO The on-board memory that holds the Channel List.

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CL clock	The Channel List clock, also known as the Burst clock, tells the control logic how quickly to move to the next entry in the Channel List and set up the front-end operating parameters such as gain.
control register	Register containing control bits that set up and configure various onboard subsystems.
CMRR	Common-Mode Rejection Ratio, a measure of an instrument's ability to reject interference from a common-mode signal, usually expressed in decibels (dB).
code generator	A software program, controlled from an intuitive user interface, that creates syntactically correct high-level source code in languages such as C or Basic.
cold-junction compensation	The means to compensate for the ambient temperature in a thermocouple measurement circuit.
common-mode range	The input range over which a circuit can handle a common-mode signal.
common-mode signal	The mathematical average voltage, relative to the computer's ground, of the signals going into a differential input.
component software	An application that contains one or more component objects that can freely interact with other component software. Examples include OLE-enabled applications such as Microsoft Visual Basic and OLE Controls.
conversion time	The time, in an analog input or output system, from the moment a channel is interrogated (such as with a Read instruction) to the moment that accurate data is available.
counter/timer	A circuit that counts external pulses or clock pulses (timing), such as the Intel 8254 device.
coupling	The manner in which a signal is connected from one location to another.
crosstalk	An unwanted signal on one channel due to an input on a different channel.
current drive capability	The amount of current a digital or analog output channel can source or sink while still operating within voltage range specifications.
current sinking	The ability of a DAQ board to dissipate power from an output signal, either analog or digital. Some sensors apply a voltage to a loop, and the DAQ card must be able to accept the resulting current flow.
current sourcing	The ability of a DAQ board to supply current for analog or digital output signals.

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CV clock — The Conversion Clock, also known as the Pacer clock, it triggers individual acquisitions and thus tells the A/D how fast to digitize successive samples.

D

D/A — Digital-to-analog, digital/analog

DAC — Digital-to-Analog Converter, an integrated circuit that converts a digital value into a corresponding analog voltage or current.

DAC conversion Start — Signal used to start the process of converting a digital value to an analog output. The source of this signal can be either an internal synchronous clock or an external asynchronous signal.

DAQ — Data Acquisition

(1) Collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures, and moving them to a computer for processing;

(2) Collecting and measuring the same kinds of electrical signals with A/D or DIO boards plugged into a PC, and possibly generating control signals with D/A or DIO boards in the same PC.

dB — Decibel, the unit for expressing a logarithmic measure of the ratio of two signal levels: $dB = 20\log_{10}(V1/V2)$ for signals in volts.

differential input — An analog-input configuration that measures the difference between signals on two terminals, both of which are isolated from computer ground.

DIO — Digital input/output.

DLL — Dynamic Link Library, a software module in Microsoft Windows containing executable code and data that can be called or used by Windows applications or other DLLs. Functions and data in a DLL are loaded and linked at run time when they are referenced by a Windows application or other DLLs.

DNL — Differential nonlinearity, a measure in LSBs of the worst-case deviation of code widths from their ideal value of 1 LSB.

DMA — Direct Memory Access, a method of transferring data to/from computer memory from/to a device or memory on the bus, taking place while the host processor does something else. DMA is the fastest method of transferring data to/from computer memory.

drivers — Software that controls a specific hardware device such as a DAQ board.

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DSP Digital signal processing.

dual-access memory Memory that can be sequentially accessed by more than one controller or processor but not simultaneously. Also known as shared memory.

dual-port memory Memory that can be simultaneously accessed by more than one controller or processor.

dynamic range The ratio, normally expressed in dB, of the largest signal level in a circuit to the smallest signal level. In DAQ boards it typically refers to the range of signals a board can handle or the amount of noise it suppresses.

E

EEPROM Electrically Erasable Programmable Read-Only Memory, a nonvolatile memory device you can repeatedly program for storage, erase and reprogram.

encoder A device that converts linear or rotary displacement into digital or pulse signals. The most popular type of encoder is the optical encoder.

EPROM Erasable Programmable Read-Only Memory: A nonvolatile memory device that can be erased (usually by ultraviolet light exposure) and reprogrammed.

event A signal or interrupt generated by a device to notify another device of an asynchronous event. The contents of events are device-dependent.

event-based mode A board operating mode whereby it notifies the user application of certain predefined subsystem events using Win32 calls. It allows you to write asynchronous applications.

external trigger A voltage pulse from an external source that triggers an event such as an A/D conversion.

F

FIFO First-In First-Out, usually used in reference to a memory buffer where the first data stored is the first sent out.

fixed point A format for processing or storing numbers as digital integers. In fixed-point arithmetic all numbers are represented by integers, fractions (usually restricted between ±1.0) or a combination of both integers and fractions. Thus integer mathematics can be implemented on all general-purpose processors.

floating point Representing data as a combination of a mantissa and an exponent. The mantissa is usually described by a signed fractional value that has a magnitude >= 1.0 and restricted to< 2.0. The exponent, instead, is an integer and represents the

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number of places any binary number must be shifted, left or right, in order to yield the desired value.

frame — A user-defined number of scans, and these datapoints reside in a predefined portion of a buffer in host-memory. This host-memory buffer is also known as the Advanced Circular Buffer (ACB).

function — A set of software instructions executed by a single line of code that may have input and/or output parameters and returns a value when executed.

G

gain — The factor by which a signal is amplified, sometimes expressed in dB.

gain accuracy — A measure of the deviation of an amplifier's gain from the ideal gain.

GUI — Graphical User Interface, an intuitive means of communicating information to and from a computer program by means of graphical screen displays. GUIs can resemble the front panels of instruments or other objects associated with a computer program.

H

handler — A device driver installed as part of the computer's OS.

hardware — The physical components of a computer system, such as the circuit boards, plug-in boards, chassis, enclosures, peripherals, cables, and so on.

I

IMD — Intermodulation Distortion, the ratio, in dB, of the total RMS signal level of harmonic sum and difference distortion products, to the overall RMS signal level. The test signal consists of two sinewaves added together.

INL — Integral Nonlinearity, a measure in LSB of the worst-case deviation from the ideal A/D or D/A transfer characteristic of the analog I/O circuitry.

input bias current — The current that flows into the inputs of a circuit.

input impedance — The measured resistance and impedance between the input terminals of a circuit.

input offset current — The difference in the input bias currents of the two inputs of an instrumentation amplifier.

instrumentation amplifier — A circuit whose output voltage with respect to ground is proportional to the difference between the voltages at its two inputs.

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integral control — A control action that eliminates the offset inherent in proportional control.

integrating A/D — An A/D whose output code represents the average value of the input voltage over a given time interval.

interrupt — A computer signal indicating that the CPU should suspend its current task to service a designated activity.

I/O — Input/Output, the transfer of data to/from a computer system involving communications channels, operator interface devices, and/or data-acquisition and control interfaces.

IPC — Interprocess Communication, protocol by which processes can pass messages. Messages can be either blocks of data and information packets, or instructions and requests for process(es) to perform actions. A process can send messages to itself, other processes on the same machine, or processes located anywhere on the network.

isolation voltage — The voltage that an isolated circuit can normally withstand, usually specified from input to input and/or from any input to the amplifier output, or to the computer bus.

K

k — kilo, the standard metric prefix for 1000 or 10^3, used with units of measure such as volts, Hertz, and meters.

L

linearity — The adherence of device response to the equation R = KS, where R = response, S = stimulus, and K is a constant.

LSB — Least-significant bit.

M

M — mega, the standard metric prefix for 1 million or 10^6, when used with units of measure such as volts and Hertz; the prefix for 1,048,576, or 2^{20}, when used to quantify data or computer memory.

Mbytes/s — A unit for data transfer that means 1 million or 10^6 bytes/sec.

MMI — Man-machine interface, the means by which an operator interacts with an industrial automation system; often called a GUI.

multiplexer — A switching device with multiple inputs that sequentially connects each of its inputs to its output, typically at high speeds, in order to measure several signals with a single analog input channel.

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multitasking A property of an operating system in which several processes can run simultaneously.

mux see multiplexer

N

noise An undesirable electrical signal. Noise comes from external sources such as the AC power line, motors, generators, transformers, fluorescent lights, soldering irons, CRT displays, computers, electrical storms, welders, radio transmitters as well as internal sources such as semiconductors, resistors and capacitors.

O

OLE Object Linking and Embedding, a set of system services that provides a means for applications to interact and interoperate. Based on the underlying Component Object Model, OLE is object-enabling system software. Through OLE Automation, an application can dynamically identify and use the services of other applications. OLE also makes it possible to create compound documents consisting of multiple sources of information from different applications.

OLE controls see ActiveX controls.

operating system Base-level software that controls a computer, runs programs, interacts with users, and communicates with installed hardware or peripheral devices.

optical isolation The technique of using an optoelectric transmitter and receiver to transfer data without electrical continuity to eliminate high potential differences and transients.

OS see operating system

output settling time The amount of time required for the analog output voltage of an amplifier to reach its final value within specified limits.

output slew rate The rate of change of an analog output voltage from one level to another.

overhead The amount of computer processing resources, such as time or memory, required to accomplish a task.

P

paging A technique used for extending the address range of a device to point into a larger address space

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PCI	Peripheral Component Interconnect, an expansion bus architecture originally developed by Intel to replace ISA and EISA. It offers a theoretical maximum transfer rate of 132M bytes/sec.
PDXI	PowerDAQ eXtensions for Instrumentation, UEI's implementation of the PXI bus standard.
PGA	see Programmable-gain amplifier
PID control	A 3-term control algorithm combining proportional, integral and derivative control actions.
pipeline	A high-performance processor structure in which the completion of an instruction is broken into its elements so that several elements can be processed simultaneously from different instructions.
PLC	Programmable logic controller, a special-purpose computer used in industrial monitoring and control applications. PLCs typically have proprietary programming and networking protocols and special-purpose digital and analog I/O ports.
Polled mode	DAQ board operating mode whereby the user application queries the board about the status of various subsystems as needed.
port	A communications connection on a computer or a remote controller.
postriggering	The technique used on a DAQ board to acquire a programmed number of samples after trigger conditions are met.
potentiometer	An electrical device whose resistance you can manually adjusted; known among engineers as a "pot."
pretriggering	The technique used on a DAQ board to keep a continuous buffer filled with data, so that when the trigger conditions are met, the sample includes the data leading up to the trigger condition.
programmable-gain amplifier	also see PGA, an amplifier where you can change the amount of gain applied to the inputs. Gain settings today are usually made with software instead of setting jumpers as was necessary with first-generation DAQ boards.
programmed I/O	The standard method a CPU uses to access an I/O device—each byte of data is read or written by the CPU.
propagation delay	The amount of time required for a signal to pass through a circuit.
proportional control	A control action whose output is proportional to the deviation of the controlled variable from a desired setpoint.
protocol	The exact sequence of bits, characters and control codes used to transfer data between computers and peripherals through a communications channel.

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pseudodifferential An analog-input configuration where all channels refer their inputs to a common ground—but this ground is not connected to the computer ground.

PXI PCI eXtensions for Instrumentation, a bus standard that combines the mechanical form factor of the CompactPCI specification and the electrical aspects of the PCI bus. It also adds integrated timing and triggering designed specifically for measurement and automation applications.

Q

quantization error The inherent uncertainty in digitizing an analog value due to the finite resolution of the conversion process.

R

real time A system in which the desired action takes place immediately when all input conditions are fulfilled; it never has to wait for other processes to complete before it can start. In DAQ terms, it generally refers to the processing of data as it is acquired instead of being accumulated and getting processed at a later time.

relative accuracy A measure in LSB of the accuracy of an A/D. It includes all nonlinearity and quantization errors. It does not include offset and gain errors of the circuitry feeding the ADC.

resolution The smallest signal increment that a measurement system can detect. Resolution can be expressed in bits, in proportions, or in percent of full scale. For example, a system has a resolution equal to 12 bits = one part in 4,096 = 0.0244% of full scale.

resource locking A technique whereby a device is signaled not to use one of its resources, often local memory, while that resource is being used by another device, generally the system bus.

ribbon cable A flat cable in which conductors are placed side by side.

RMS Root-mean square, computed by squaring the instantaneous voltage, integrating over the desired time and taking the square root.

RTD Resistance temperature detectors operate based on the principle that electrical resistance varies with temperature. They generally use pure metal elements, platinum being the most widely specified RTD element type although nickel, copper, and Balco (nickel-iron) alloys are also used. Platinum is popular due to its wide temperature range, accuracy, stability as well as the degree of standardization among manufacturers. RTDs are characterized by a linear positive change in resistance with respect to temperature. They exhibit

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	the most linear signal over temperature of any electronic sensing device
RTSI	Real Time Systems Integration bus, developed by National Instruments, this intercard bus allows you to transfer data and control signals without using the backplane bus.

S

samples/sec	expresses the rate at which a DAQ board digitizes an analog signal.
scan	one run through the presently configured Channel List
SDK	Software developer's kit, a collection of drivers and utilities that allow engineers to write their own application programs.
SE	see single-ended.
self-calibrating	reference to a DAQ board that calibrates its own A/D and D/A circuits with a reference source, sometimes provided internally with a precision D/A converter.
sensor	A device that generates an electrical signal in response to a physical stimulus (such as heat, light, sound, pressure, motion or flow).
S/H	Sample/Hold, a circuit that acquires and stores an analog voltage on a capacitor for a short period of time.
simultaneous sampling	the act of digitizing multiple channels simultaneously, with interchannel skew often being measured in psec.
single-ended	a term used to describe an analog-input configuration where you measure each channel with respect to a common analog ground.
Slow Bit	a control bit in the analog-input configuration word that instructs the A/D to wait a short while before actually digitizing the input voltage; it gives the input amplifier time to settle, and is very useful when working with very high gains.
SNR	also S/N ratio or Signal/Noise ratio, the ratio of the peak power level to the remaining noise power, expressed in dB.
software trigger	A programmed event that triggers an event such as a data acquisition.
SPDT	Single-pole double-throw, a switch in which one terminal can be connected to one of two other terminals.
SSH	Simultaneous Sample/Hold, see simultaneous sampling
S/s, S/sec	see samples/sec
strain gage	A sensor that converts mechanical motion into an electronic signal. A change in capacitance, inductance or resistance is proportional to the strain experienced by the sensor, but

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	resistance is the most widely used characteristic that varies in proportion to strain.
subroutine	A set of software instructions executed by a single line of code that may have input and/or output parameters.
subsystem	On PowerDAQ cards, a group of circuits that perform either analog input, analog output, digital input, digital output or counter/timer functions.
successive-approximation A/D	An A/D that sequentially compares a series of binary-weighted values with an analog input to produce an output digital word in n steps, where n is the A/D's resolution in bits.
synchronous	A property of a function that begins an operation and returns only when the operation is complete.
system noise	A measure of the amount of noise seen by an analog circuit or an A/D when the analog inputs are grounded.

T

TCP/IP	Transmission Control Protocol/Internet Protocol, the basic 2-layer communication protocol of the Internet but that is also used in a private network (either an intranet or an extranet). The higher layer, TCP, manages the assembling of a message or file into smaller packets that are transmitted and received by a TCP layer that reassembles the packets into the original message. IP handles the address portion of each packet so it gets to the right destination.
THD	Total harmonic distortion, the ratio of the total RMS signal due to harmonic distortion to the overall RMS signal, expressed in dB or percent.
THD+N	The percentage of Total Harmonic Distortion + Noise (THD+N) of a sine wave equals 100 times the ratio of the RMS voltage measured with the fundamental component of a sine wave removed by a notch filter, to the RMS voltage of the fundamental component.
thermistor	A temperature-sensing element that exhibits a large change in resistance proportional to a small change in temperature. Thermistors usually have negative temperature coefficients. They tend to be more accurate than thermocouples or RTDs, but they have a much more limited temperature range.
thermocouple	A temperature sensor created by joining two dissimilar metals. The junction produces a small voltage as a function of temperature.
throughput rate	The flow of data, measured in bytes/sec, for a given continuous operation.

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transducer — A device that converts energy from one form to another. Generally applied to devices that convert a physical phenomenon (such as pressure, temperature, humidity or flow) to an electrical signal.

transfer rate — The rate, measured in bytes/sec, at which data is moved from a source to a destination after software initialization and setup operations; the maximum rate at which the hardware can operate.

Trigger — A signal, in either hardware or software, that initiates or halts a process. In DAQ boards, it generally refers to a signal that starts or stops an A/D, D/A or DIO operation.

U

UCT — User counter/timer

unipolar — A signal range that is always positive (for example, 0 to 10 V).

Z

zero offset — The difference between true zero and an indication given by a measuring instrument.

zero-overhead looping — The ability of a high-performance processor to repeat instructions without requiring time to branch to the beginning of the instructions.

zero-Wait-State memory — Memory fast enough that the processor does not have to wait during any reads and writes to the memory.

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