

DAQPad[™]-MIO-16XE-50

User Manual

16-Bit Data Acquisition and Control for the Parallel Port

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Contents

About This Manual	ix
Organization of This Manual	ix
Conventions Used in This Manual	x
National Instruments Documentation	x
Related Documentation	xi
Customer Communication	xi
Chapter 1	
Introduction	1-1
About the DAQPad-MIO-16XE-50	1-1
What You Need to Get Started	1-2
Software Programming Choices	1-2
LabVIEW and LabWindows/CVI Application Software	1-2
NI-DAQ Driver Software.....	1-3
Register-Level Programming	1-4
Optional Equipment	1-4
BP-1 Battery Pack	1-4
Adding an Enhanced Parallel Port	1-4
Parallel Port Cables	1-4
Chapter 2	
Installation and Configuration	2-1
Hardware Installation	2-1
Software Configuration	2-2
Parallel Port	2-3
Power-Up Default Mode	2-3
Analog Input	2-3
Input Mode	2-3
Input Polarity and Input Range	2-4
Considerations for Selecting Input Ranges	2-5
Dither	2-5
Multiple-Channel Scanning Considerations	2-6
Analog Output.....	2-7
Cold-Junction Sensing	2-7
Digital I/O	2-8
Programmable Function Inputs	2-9
Chapter 3	
Signal Connections	3-1
Transparent Parallel Port Connector	3-1
DAQPad-TB-52 Terminal Block	3-2
DAQPad-TB-52 Signal Descriptions	3-3
DAQPad-TB-52 Signal Connections	3-6
Analog Input Signal Connections	3-7
Types of Signal Sources.....	3-8
Floating Signal Sources	3-8
Ground-Referenced Signal Sources	3-8

Input Configurations	3-9
Differential Connection Considerations	3-10
Differential Connections for Ground-Referenced Signal Sources	3-11
Differential Connections for Nonreferenced or Floating Signal Sources	3-12
Single-Ended Connection Considerations	3-13
Single-Ended Connections for Floating Signal Sources (RSE Configuration)	3-14
Single-Ended Connections for Grounded Signal Sources (NRSE Configuration)	3-14
Common-Mode Signal Rejection Considerations	3-15
External Current Excitation	3-16
Analog Output Signal Connections	3-17
Digital I/O Signal Connections	3-18
Power Connections	3-19
Timing Considerations	3-19
Programmable Function Input Connections	3-20
Data Acquisition Timing Connections	3-21
SCANCLK Signal	3-22
EXTSTROBE* Signal	3-22
TRIG1 Signal	3-23
TRIG2 Signal	3-24
STARTSCAN Signal	3-24
CONVERT* Signal	3-26
AIGATE Signal	3-27
SISOURCE Signal	3-27
Waveform Generation Timing Connections	3-28
WFTRIG Signal	3-28
UPDATE* Signal	3-29
UISOURCE Signal	3-30
General-Purpose Timing Signal Connections	3-31
GPCTR0_SOURCE Signal	3-31
GPCTR0_GATE Signal	3-32
GPCTR0_OUT Signal	3-32
GPCTR0_UP_DOWN Signal	3-33
GPCTR1_SOURCE Signal	3-33
GPCTR1_GATE Signal	3-34
GPCTR1_OUT Signal	3-34
GPCTR1_UP_DOWN Signal	3-35
FREQ_OUT Signal	3-36
Field Wiring Considerations	3-36

Chapter 4

Calibration	4-1
Loading Calibration Constants	4-1
Self-Calibration	4-2
External Calibration	4-2

Appendix A
SpecificationsA-1

Appendix B
Parallel Port Configuration Troubleshooting.....B-1

Appendix C
Customer Communication.....C-1

GlossaryGlossary-1

IndexIndex-1

Figures

Figure 1-1.	The Relationship between the Programming Environment, NI-DAQ, and Your Hardware	1-3
Figure 2-1.	Front and Rear View of the DAQPad-MIO-16XE-50	2-1
Figure 2-2.	Dither	2-6
Figure 2-3.	CONVERT* Signal Routing	2-9
Figure 3-1.	DAQPad-TB-52 Screw Terminal Layout	3-2
Figure 3-2.	DAQPad-MIO-16XE-50 PGIA	3-7
Figure 3-3.	Summary of Analog Input Connections	3-9
Figure 3-4.	Differential Input Connections for Ground-Referenced Signals	3-11
Figure 3-5.	Differential Input Connections for Nonreferenced Signals	3-12
Figure 3-6.	Single-Ended Input Connections for Nonreferenced or Floating Signals	3-14
Figure 3-7.	Single-Ended Input Connections for Ground-Referenced Sources	3-15
Figure 3-8.	RTD Connection Using External Current Excitation	3-16
Figure 3-9.	Analog Output Connections	3-17
Figure 3-10.	Digital I/O Connections	3-18
Figure 3-11.	Timing I/O Connections	3-20
Figure 3-12.	Typical Posttriggered Acquisition	3-21
Figure 3-13.	Typical Pretriggered Acquisition	3-21
Figure 3-14.	SCANCLK Signal Timing	3-22
Figure 3-15.	EXTSTROBE* Signal Timing	3-22
Figure 3-16.	TRIG1 and TRIG2 Input Signal Timing	3-23
Figure 3-17.	TRIG1 and TRIG2 Output Signal Timing	3-23
Figure 3-18.	STARTSCAN Input Signal Timing	3-25
Figure 3-19.	STARTSCAN Output Signal Timing	3-25
Figure 3-20.	CONVERT* Input Signal Timing	3-26
Figure 3-21.	CONVERT* Output Signal Timing	3-26
Figure 3-22.	SISOURCE Signal Timing	3-28
Figure 3-23.	WFTRIG Input Signal Timing	3-28
Figure 3-24.	WFTRIG Output Signal Timing	3-29
Figure 3-25.	UPDATE* Input Signal Timing	3-29
Figure 3-26.	UPDATE* Output Signal Timing	3-30
Figure 3-27.	UISOURCE Signal Timing	3-30
Figure 3-28.	GPCTR0_SOURCE Signal Timing	3-31
Figure 3-29.	GPCTR0_GATE Signal Timing	3-32
Figure 3-30.	GPCTR0_OUT Signal Timing	3-32
Figure 3-31.	GPCTR1_SOURCE Signal Timing	3-33
Figure 3-32.	GPCTR1_GATE Signal Timing	3-34
Figure 3-33.	GPCTR1_OUT Signal Timing	3-34
Figure 3-34.	GPCTR Timing Summary	3-35

Tables

Table 2-1.	Available Input Configurations for the DAQPad-MIO-16XE-50	2-4
Table 2-2.	Actual Range and Measurement Precision for the DAQPad-MIO-16XE-50	2-5
Table 3-1.	I/O Signal Summary, DAQPad-TB-52	3-5

About This Manual

This manual describes the electrical and mechanical aspects of the DAQPad-MIO-16XE-50 and contains information concerning its operation and programming. The DAQPad-MIO-16XE-50 is a high-resolution, multifunction, portable data acquisition (DAQ) system that communicates with IBM PC/XT/AT and compatibles through the parallel port. The DAQPad-MIO-16XE-50 includes the DAQPad-TB-52, a detachable terminal block with screw terminals for convenient, compact signal connections.

Organization of This Manual

The *DAQPad-MIO-16XE-50 User Manual* is organized as follows:

- Chapter 1, *Introduction*, describes the DAQPad-MIO-16XE-50; lists what you need to get started with your DAQPad-MIO-16XE-50; and describes the software programming choices and optional equipment.
- Chapter 2, *Installation and Configuration*, describes how to install and software configure the DAQPad-MIO-16XE-50.
- Chapter 3, *Signal Connections*, describes the connection of a standard parallel port device to the rear panel transparent parallel port connector and describes how to make signal connections to your DAQPad-MIO-16XE-50 via the DAQPad-TB-52.
- Chapter 4, *Calibration*, discusses the calibration procedures for the analog I/O circuitry on your DAQPad-MIO-16XE-50.
- Appendix A, *Specifications*, lists the DAQPad-MIO-16XE-50 specifications.
- Appendix B, *Parallel Port Configuration Troubleshooting*, contains parallel port configuration troubleshooting information.
- Appendix C, *Customer Communication*, contains forms you can use to request help from National Instruments or to comment on our products.
- The *Glossary* contains an alphabetical list and description of terms used in this manual, including abbreviations, acronyms, metric prefixes, mnemonics, and symbols.
- The *Index* contains an alphabetical list of key terms and topics in this manual, including the page where you can find each one.

Conventions Used in This Manual

The following conventions are used in this manual:

<i>bold italic</i>	Bold italic text denotes a note, caution, or warning.
<i>italic</i>	Italic text denotes emphasis, a cross reference, or an introduction to a key concept.
< >	Angle brackets containing numbers separated by an ellipsis represent a range of values associated with a port, bit, or signal name (for example, ACH<0..7> stands for the signals ACH0 through ACH7).
monospace	Text in this font denotes text or characters that are to be literally input from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, variables, filenames, and extensions, and for statements and comments taken from program code.
NB	NB refers to the NuBus series computers.
NI-DAQ	NI-DAQ is used throughout this manual to refer to the NI-DAQ software for PC compatibles, unless otherwise noted.
PC	PC refers to the IBM PC/XT, the IBM PC AT, and compatible computers.

Abbreviations, acronyms, metric prefixes, mnemonics, symbols, and terms are listed in the *Glossary*.

National Instruments Documentation

The *DAQPad-MIO-16XE-50 User Manual* is one piece of the documentation set for your system. You could have any of several types of manuals, depending on the hardware and software in your system. Use the different types of manuals you have as follows:

- Your DAQ hardware user manuals—These manuals have detailed information about the DAQ hardware that plugs into or is connected to your computer. Use these manuals for hardware installation and configuration instructions, specification information about your DAQ hardware, and application hints.
- Software manuals—Examples of software manuals you may have are the LabVIEW and LabWindows®/CVI manual sets and the NI-DAQ manuals. After you set up your hardware system, use either the application software (LabVIEW or LabWindows/CVI) manuals or the NI-DAQ manuals to help you write your application. If you have a large and complicated system, it is worthwhile to look through the software manuals before you configure your hardware.
- Accessory installation guides or manuals—If you are using accessory products, read the terminal block and cable assembly installation guides or accessory board user manuals. They explain how to physically connect the relevant pieces of the system. Consult these guides when you are making your connections.

Related Documentation

The following National Instruments document contains information that you may find helpful as you read this manual:

- Application Note 043, *Measuring Temperature with Thermocouples*

Customer Communication

National Instruments wants to receive your comments on our products and manuals. We are interested in the applications you develop with our products, and we want to help if you have problems with them. To make it easy for you to contact us, this manual contains comment and configuration forms for you to complete. These forms are in Appendix C, *Customer Communication*, at the end of this manual.

Chapter 1

Introduction

This chapter describes the DAQPad-MIO-16XE-50; lists what you need to get started with your DAQPad-MIO-16XE-50; and describes the software programming choices and optional equipment.

About the DAQPad-MIO-16XE-50

The DAQPad-MIO-16XE-50 is a high-resolution, multifunction, portable DAQ system that communicates through the parallel port on IBM PC/XT/AT and compatible computers. The DAQPad-MIO-16XE-50 features 16 analog input channels that you can configure as 16 single-ended or eight differential inputs; a 16-bit successive-approximation ADC; two 12-bit DACs with voltage outputs; one constant current source for powering RTDs or thermistors; eight lines of TTL-compatible digital I/O; and two 24-bit counter/timers for timing I/O. The DAQPad-MIO-16XE-50 analog I/O circuitry is completely software-configurable and self-calibrated.

The DAQPad-MIO-16XE-50 uses the National Instruments DAQ-STC system timing controller for time-related functions. The DAQ-STC consists of three timing groups that control analog input, analog output, and general-purpose counter/timer functions. These groups include a total of seven 24-bit and three 16-bit counters and a maximum timing resolution of 50 ns.

The DAQPad-MIO-16XE-50 includes the DAQPad-TB-52, a detachable terminal block with screw terminals for convenient, compact signal connections. Because the DAQPad-TB-52 is built into the enclosure of the DAQPad-MIO-16XE-50, you do not need additional cables or external termination accessories. The terminal block includes screw terminals for all I/O signals, strain-relief for reliable wiring, and a temperature sensor for cold-junction compensation with thermocouples.

The DAQPad-MIO-16XE-50 is Enhanced Parallel Port (EPP) compatible with IEEE 1284, a standard for high-performance PC parallel ports. The DAQPad-MIO-16XE-50 has two parallel port connectors. The first parallel port connector communicates with two different computer parallel port types—the original Centronics or unidirectional port for printers and the EPP. The DAQPad-MIO-16XE-50 has a second parallel port connector for transparent pass-through connection to a standard parallel port device.

You can power the DAQPad-MIO-16XE-50 from the included AC adapter, the optional BP-1 rechargeable DAQPad battery pack, or any 9 to 42 VDC source such as a standard 12 V car battery.

By combining multifunction analog, digital, and timing I/O capabilities in a compact, lightweight unit, the DAQPad-MIO-16XE-50 is ideal for portable applications using notebook computers or any PC with a parallel printer port. Because the DAQPad-MIO-16XE-50 can take advantage of the high throughput capabilities of the PC parallel port, the unit delivers high-performance data acquisition and control for any application.

Detailed specifications of the DAQPad-MIO-16XE-50 are in Appendix A, *Specifications*.

What You Need to Get Started

To set up and use your DAQPad-MIO-16XE-50, you will need the following:

- DAQPad-MIO-16XE-50 unit
- DAQPad-MIO-16XE-50 User Manual*
- One of the following software packages and documentation:
 - LabVIEW for Windows
 - LabWindows/CVI for Windows
 - NI-DAQ software for PC compatibles
- A parallel port cable
- 120 or 230 VAC wall-mount power supply adapter, the BP-1 battery power supply, or any 9–42 VDC power supply
- An IBM PC/XT/AT or compatible computer

Software Programming Choices

There are several options to choose from when programming your National Instruments DAQ and SCXI hardware. You can use LabVIEW, LabWindows/CVI, or NI-DAQ.

LabVIEW and LabWindows/CVI Application Software

LabVIEW and LabWindows/CVI are innovative program development software packages for data acquisition and control applications. LabVIEW uses graphical programming, whereas LabWindows/CVI enhances traditional programming languages. Both packages include extensive libraries for data acquisition, instrument control, data analysis, and graphical data presentation.

LabVIEW features interactive graphics, a state-of-the-art user interface, and a powerful graphical programming language. The LabVIEW Data Acquisition VI Library, a series of VIs for using LabVIEW with National Instruments DAQ hardware, is included with LabVIEW. The LabVIEW Data Acquisition VI Libraries are functionally equivalent to the NI-DAQ software.

LabWindows/CVI features interactive graphics, a state-of-the-art user interface, and uses the ANSI standard C programming language. The LabWindows/CVI Data Acquisition Library, a series of functions for using LabWindows/CVI with National Instruments DAQ hardware, is included with LabWindows/CVI. The LabWindows/CVI Data Acquisition libraries are functionally equivalent to the NI-DAQ software.

Using LabVIEW or LabWindows/CVI software will greatly reduce the development time for your data acquisition and control application.

NI-DAQ Driver Software

The NI-DAQ driver software is included at no charge with all National Instruments DAQ hardware. NI-DAQ is not packaged with SCXI or accessory products, except for the SCXI-1200. NI-DAQ has an extensive library of functions that you can call from your application programming environment. These functions include routines for analog input (A/D conversion), buffered data acquisition (high-speed A/D conversion), analog output (D/A conversion), waveform generation, digital I/O, counter/timer operations, SCXI, RTSI, self calibration, messaging, and acquiring data to extended memory.

NI-DAQ has both high-level DAQ I/O functions for maximum ease of use and low-level DAQ I/O functions for maximum flexibility and performance. Examples of high-level functions are streaming data to disk or acquiring a certain number of data points. An example of a low-level function is writing directly to registers on the DAQ device. NI-DAQ does not sacrifice the performance of National Instruments DAQ devices because it lets multiple devices operate at their peak performance—up to 500 kS/s on ISA computers and up to 1 MS/s on EISA computers.

NI-DAQ also internally addresses many of the complex issues between the computer and the DAQ hardware such as programming the PC interrupt and DMA controllers. NI-DAQ maintains a consistent software interface among its different versions so that you can change platforms with minimal modifications to your code. Figure 1-1 illustrates the relationship between NI-DAQ and LabVIEW and LabWindows/CVI. You can see that the DAQ parts of LabVIEW and LabWindows/CVI are functionally equivalent to the NI-DAQ software.

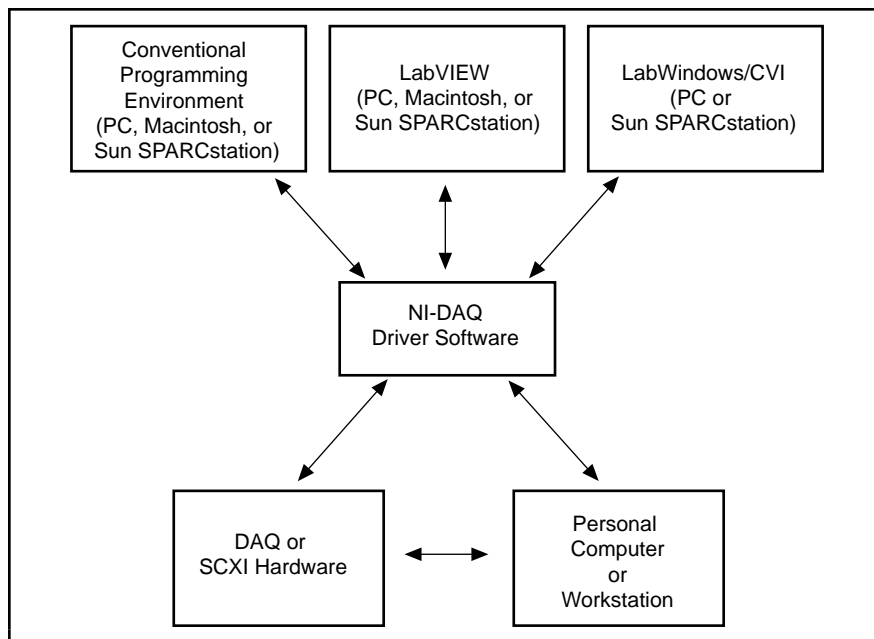


Figure 1-1. The Relationship between the Programming Environment, NI-DAQ, and Your Hardware

Register-Level Programming

The final option for programming any National Instruments DAQ hardware is to write register-level software. Writing register-level programming software can be very time-consuming and inefficient and is not recommended for most users.

Even if you are an experienced register-level programmer, consider using NI-DAQ, LabVIEW, or LabWindows/CVI to program your National Instruments DAQ hardware. Using the NI-DAQ, LabVIEW, or LabWindows/CVI software is easier than and as flexible as register-level programming and can save you weeks of development time.

Optional Equipment

You can use the following National Instruments products with your DAQPad-MIO-16XE-50:

- BP-1 battery pack with a 110 or 230 VAC charger
- 6 ft. parallel port cable
- 6 in. adapter parallel port cable

For more information about optional equipment available from National Instruments, refer to your National Instruments catalog or call the office nearest you.

BP-1 Battery Pack

For total portability, you can power the DAQPad-MIO-16XE-50 with the optional BP-1 battery pack. The BP-1 includes a 12 V, 3.2 Ahr battery packaged in an enclosure with the same dimensions as the DAQPad-MIO-16XE-50. A fully charged BP-1 typically powers the DAQPad-MIO-16XE-50 for 9 hours. A charger unit is included with the BP-1.

Adding an Enhanced Parallel Port

If you have a slot available in your PC, you can add an EPP card to achieve higher DAQ rates. You can order one such card, the F/Port Enhanced Parallel Port Card, from Far Point Communications. You can use the card in a PC/AT 386, 486, or compatible computer.

If you have a PCMCIA type II slot available in your PC, you can add a PCMCIA to an EPP card to achieve higher DAQ rates. Two options are the SPP-100 from Quatech and the ExpressPort from Far Point. Both cards comply with the PCMCIA PC Standard Specification 2.1.

Parallel Port Cables

The DAQPad-MIO-16XE-50 two rear connectors (the parallel and transparent parallel port connectors) are 36 pin MDR 1284-C female connectors.

You can use 36 pin MDR 1284-C male connectors as mating connectors for the DAQPad-MIO-16XE-50 rear connector, or you can use the National Instruments adapter parallel port cable, which allows you to use a standard DB-25-style male connector as a mating connector.

Chapter 2

Installation and Configuration

This chapter describes how to install and software configure the DAQPad-MIO-16XE-50.

Hardware Installation

There are five basic steps to installing the DAQPad-MIO-16XE-50. Figure 2-1 shows the front and rear view of a DAQPad-MIO-16XE-50.

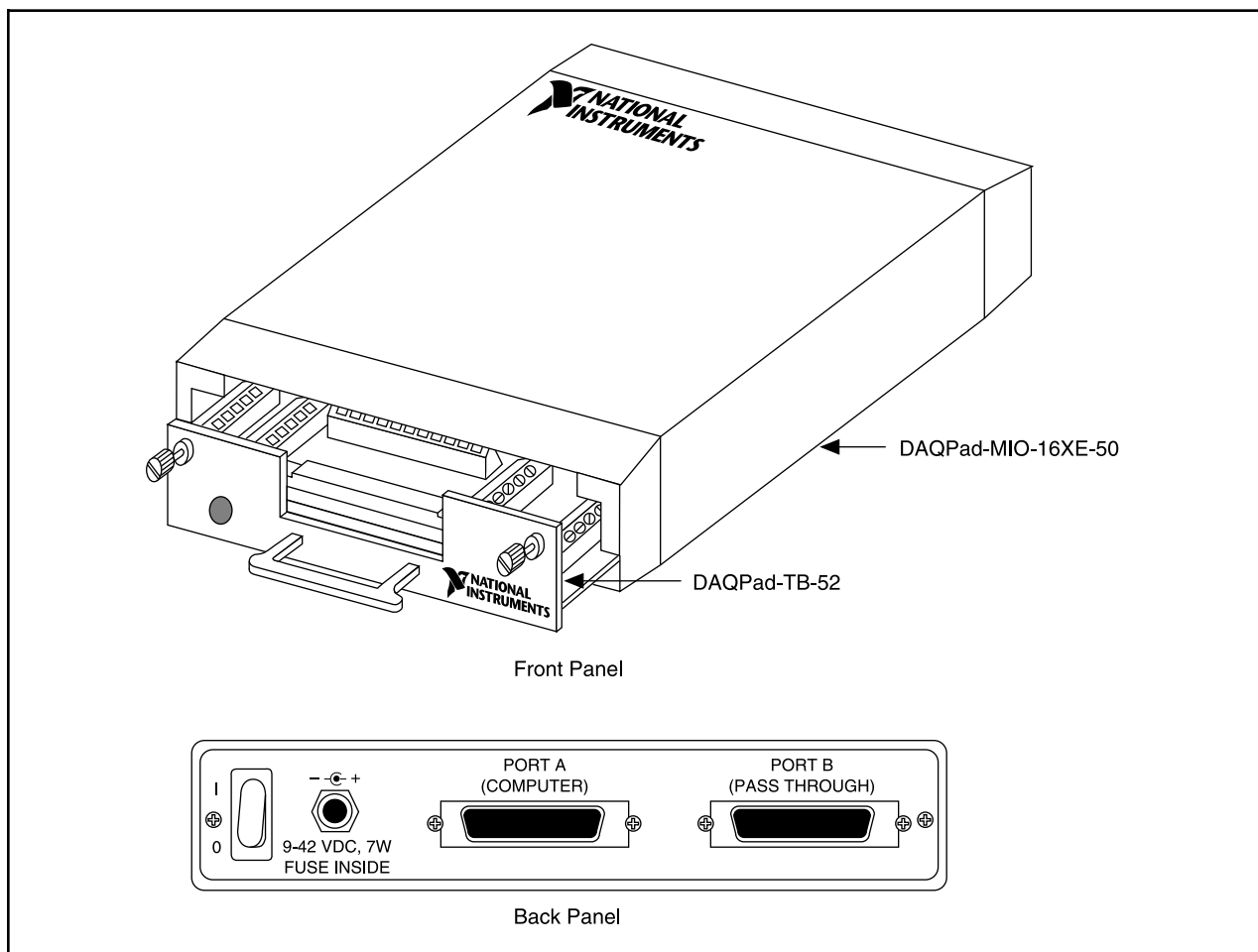


Figure 2-1. Front and Rear View of a DAQPad-MIO-16XE-50

Refer to Figure 2-1 as you perform the following steps.

Note: *If you are using the BP-1 battery pack, follow the installation instructions in your BP-1 installation guide instead of steps 1 and 2. The maximum recommended discharge time for a fully charged battery pack is 9 hours for an unloaded DAQPad-MIO-16XE-50.*

1. Verify that the voltage on the wall-mount power supply matches the voltage supplied in your area.
2. Connect one end of the wall-mount power supply to an electrical outlet. Connect the other end to the rear panel jack and screw in the plug to lock the power supply in place.
3. Connect the DB-25 connector (on one end of the parallel port cable) to the PC parallel port and screw in the mounting screws on the connectors to establish a firm connection. Connect the other end of the parallel port cable to port A on the DAQPad-MIO-16XE-50.
4. If you are using the transparent parallel port, connect another parallel port cable to port B on the DAQPad-MIO-16XE-50. Connect the other end of the second parallel port cable to any standard parallel port device.
5. Push the rear panel rocker switch to power up the DAQPad-MIO-16XE-50. The power LED on the DAQPad-TB-52 should light up immediately. If the power LED does not light up immediately, check the polarity of your power connections. The power input of the DAQPad-MIO-16XE-50 is protected by a positive temperature coefficient (PTC) resistor. It takes approximately 20 s for the PTC resistor to reset after being tripped. Contact National Instruments if the power LED does not light up after correcting any faulty power connections.

Note: *The LED on the DAQPad-TB-52 lights up only when the DAQPad-TB-52 is firmly connected to the DAQPad-MIO-16XE-50.*

The DAQPad-MIO-16XE-50 unit is installed. You are now ready to install and configure your software.

Software Configuration

Refer to your software manuals to install and configure the software.

If you are using NI-DAQ, refer to the *NI-DAQ User Manual for PC Compatibles*. The software installation and configuration instructions are in Chapter 1, *Introduction to NI-DAQ*. Find the installation and system configuration section for your operating system and follow the instructions given there.

If you are using LabVIEW, you do not need the NI-DAQ manuals; the software installation instructions are in your LabVIEW release notes. After you have installed LabVIEW, refer to the *Installation and Configuration* section of Chapter 1 of your LabVIEW user manual for software configuration instructions.

If you are using LabWindows/CVI, the software installation instructions are in Part 1, *Introduction to LabWindows/CVI*, of the *Getting Started with LabWindows/CVI* manual. After

you have installed LabWindows/CVI, refer to Chapter 1, *Configuring LabWindows/CVI*, of the *LabWindows/CVI User Manual* for software configuration instructions. Then follow DAQ configuration instructions in your NI-DAQ user manual.

Parallel Port

During configuration, you must know the parallel port I/O address and interrupt channel. Common parallel port I/O addresses are 0x378, 0x278, 0x3BC, 0x280 and 0x290. The DAQPad-MIO-16XE-50 can use the parallel port hardware interrupts for interrupt-driven data acquisition. Interrupt levels 7 and 5 are commonly used for parallel ports. Refer to your computer reference manual for details about interrupt selection and address assignment. For configuration problems, refer to Appendix B, *Parallel Port Configuration Troubleshooting*.

Power-Up Default Mode

When you cycle the power on the DAQPad-MIO-16XE-50, the device powers up in transparent mode. In this mode, all the parallel port lines are passed through to the transparent parallel port connector. To communicate with the DAQPad-MIO-16XE-50 after cycling the power, you must enable active mode by using one of the following methods.

If you are using LabVIEW, you can save your configuration in WDAQCONF or you can use either the Device Reset VI or the Set DAQ Device Info VI to enable active mode.

If you are in DOS or using NI-DAQ for Windows in an application other than LabVIEW, you can use `Init_DA_Brds` or `Set_DAQ_Device_Info` to enable active mode.

Analog Input

The analog input section of the DAQPad-MIO-16XE-50 is software configurable. You can select different analog input configurations through application software designed to control the DAQPad-MIO-16XE-50. The following sections describe in detail each of the analog input categories.

Input Mode

The DAQPad-MIO-16XE-50 has three different input modes—nonreferenced single-ended (NRSE) input, referenced single-ended (RSE) input, and differential (DIFF) input. The single-ended input configurations use up to 16 channels. The differential input configuration uses up to eight channels. Input modes are programmed on a per channel basis for multimode scanning. For example, you can configure the circuitry to scan 12 channels—four differentially configured channels and eight single-ended channels. Table 2-1 describes the three input configurations.

Table 2-1. Available Input Configurations for the DAQPad-MIO-16XE-50

Configuration	Description
DIFF	A channel configured in DIFF mode uses two analog channel input lines. One line connects to the positive input of the board programmable gain instrumentation amplifier (PGIA), and the other connects to the negative input of the PGIA.
RSE	A channel configured in RSE mode uses one analog channel input line, which connects to the positive input of the PGIA. The negative input of the PGIA is internally tied to analog input ground (AIGND).
NRSE	A channel configured in NRSE mode uses one analog channel input line, which connects to the positive input of the PGIA. The negative input of the PGIA connects to the analog input sense (AISENSE) input.

For more information about the three types of input configuration, refer to the *Input Configurations* section in Chapter 3, *Signal Connections*, which contains diagrams showing the signal paths for the three configurations.

Input Polarity and Input Range

The DAQPad-MIO-16XE-50 has two input polarities—unipolar and bipolar. Unipolar input means that the input voltage range is between 0 and V_{ref} , where V_{ref} is a positive reference voltage. Bipolar input means that the input voltage range is between $-V_{\text{ref}}$ and $+V_{\text{ref}}$. The DAQPad-MIO-16XE-50 has a unipolar input range of 10 V (0 to 10V) and a bipolar input range of 20 V (± 10 V).

The software-programmable gain on this board increases its overall flexibility by matching the input signal ranges to those that the ADC can accommodate. The DAQPad-MIO-16XE-50 has gains of 1, 2, 10, and 100 and is suited for a wide variety of signal levels. With the proper gain setting, you can use the full resolution of the ADC to measure the input signal. Table 2-2 shows the overall input range and precision according to the input range configuration and gain used. You can program polarity and range settings on a per channel basis so that you can configure each input channel uniquely.

Note: *You can calibrate your analog input circuitry for either a unipolar or bipolar polarity. If you mix unipolar and bipolar channels in your scan list and you are using NI-DAQ, NI-DAQ will load the calibration constants appropriate to the polarity for which analog input channel 0 is configured.*

Table 2-2. Actual Range and Measurement Precision for the DAQPad-MIO-16XE-50

Range Configuration	Gain	Actual Input Range	Precision ¹
0 to +10 V	1.0	0 to +10 V	152.59 μ V
	2.0	0 to +5 V	76.29 μ V
	10.0	0 to +1 V	15.26 μ V
	100.0	0 to 100 mV	1.53 μ V
-10 to +10 V	1.0	-10 to +10 V	305.18 μ V
	2.0	-5 to +5 V	152.59 μ V
	10.0	-1 to +1 V	30.52 μ V
	100.0	-100 to +100 mV	3.05 μ V
¹ The value of 1 LSB of the 16-bit ADC; that is, the voltage increment corresponding to a change of 1 count in the ADC 16-bit count. Note: See Appendix A, Specifications, for absolute maximum ratings.			

Considerations for Selecting Input Ranges

Which input polarity and range you select depends on the expected range of the incoming signal. A large input range can accommodate a large signal variation but reduces the voltage resolution. Choosing a smaller input range improves the voltage resolution but may result in the input signal going out of range. For best results, you should match the input range as closely as possible to the expected range of the input signal. For example, if you are certain the input signal will not be negative (below 0 V), unipolar input polarity is best. However, if the signal is negative or equal to zero, inaccurate readings will occur if you use unipolar input polarity.

Dither

The addition of dither adds approximately 0.5 LSB rms of white Gaussian noise to the signal to be converted by the ADC. This addition is useful for applications involving averaging to increase the resolution of your DAQPad-MIO-16XE-50, as in calibration or spectral analysis. In such applications, noise modulation is decreased and differential linearity is improved by the addition of the dither. When taking DC measurements, such as when checking the board calibration, average about 1,000 points to take a single reading. This process removes the effects of quantization and reduces measurement noise, resulting in improved resolution. Dither, or additive white noise, has the effect of forcing quantization noise to become a zero-mean random variable rather than a deterministic function of the input signal.

Figure 2-2 illustrates the effect of dither on signal acquisition. Figure 2-2a shows a small (± 4 LSB) sine wave acquired with dither off. The quantization of the ADC is clearly visible. Figure 2-2b shows what happens when 50 such acquisitions are averaged together; quantization is still plainly visible. In Figure 2-2c, the sine wave is acquired with dither on. There is a considerable amount of noise quantization. Dither has the effect of forcing quantization noise to become a zero-mean random variable rather than a deterministic function of the input signal.

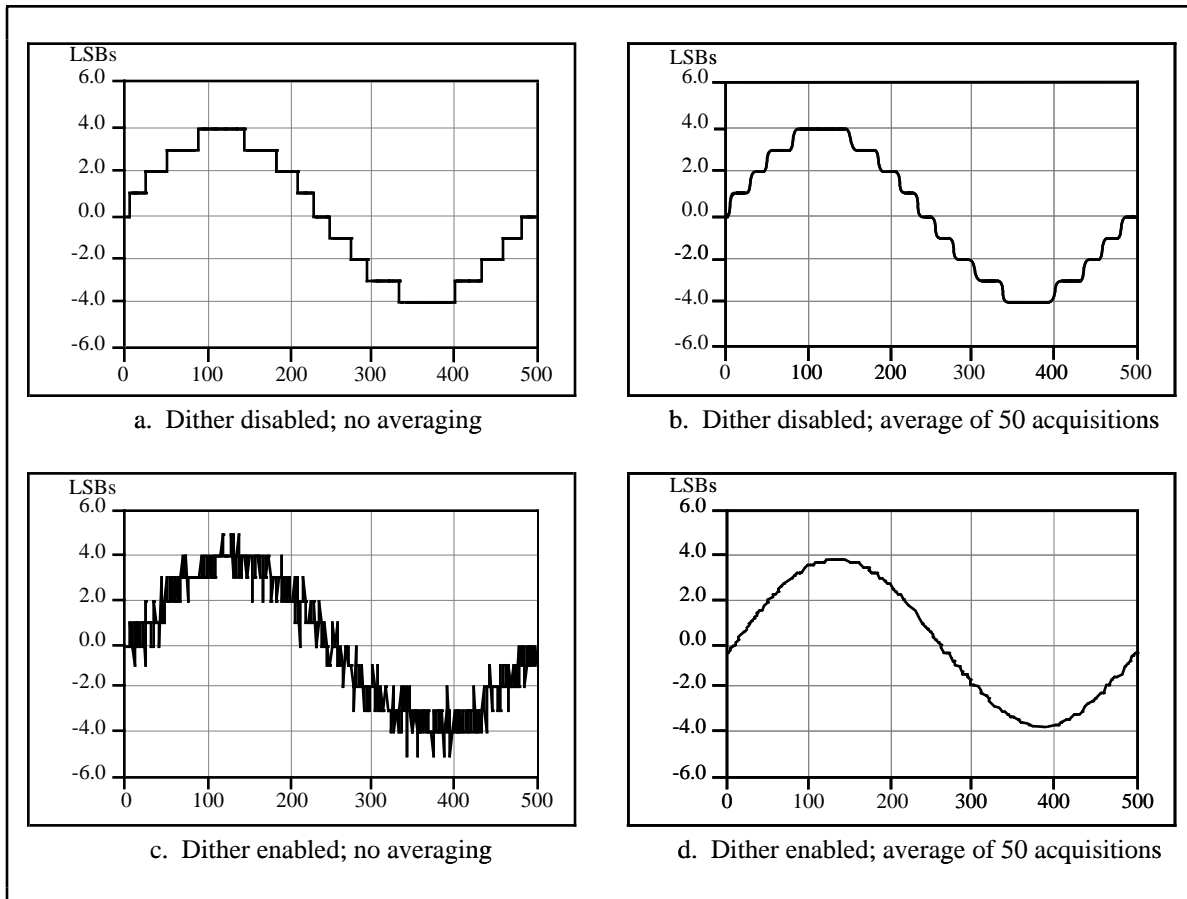


Figure 2-2. Dither

You cannot disable dither on the DAQPad-MIO-16XE-50 because the resolution of the ADC is so fine that the ADC and the PGIA inherently produce almost 0.5 LSB rms of noise. This is equivalent to having a dither circuit that is always enabled.

Multiple-Channel Scanning Considerations

The maximum multiple-channel scanning acquisition rate is identical to the single-channel acquisition rate for all gains. No extra settling time is necessary between channels as long as the gain is constant and source impedances are low.

When scanning among channels at various gains, the settling times may increase. When the PGIA switches to a higher gain, the signal on the previous channel may be well outside the new, smaller range. For instance, suppose a 4 V signal is connected to channel 0 and a 1 mV signal is connected to channel 1, and suppose the PGIA is programmed to apply a gain of 1 to channel 0 and a gain of 100 to channel 1. When the multiplexer switches to channel 1 and the PGIA switches to a gain of 100, the new full-scale range is 100 mV (if the ADC is in unipolar mode). The approximately 4 V step from 4 V to 1 mV is 4,000% of the new full-scale range. For a 16-bit board to settle within 0.0015% (15 ppm or 1 LSB) of the 100 mV full-scale range on channel 1, the input circuitry has to settle within 0.00004% (0.4 ppm or 1/400 LSB) of the

4 V step. It may take as long as 200 μ s for the circuitry to settle this much. In general, this extra settling time is not needed when the PGIA is switching to a lower gain.

Settling times can also increase when scanning high-impedance signals due to a phenomenon called charge injection, where the analog input multiplexer injects a small amount of charge into each signal source when that source is selected. If the impedance of the source is not low enough, the effect of the charge—a voltage error—will not have decayed by the time the ADC samples the signal. For this reason, you should keep source impedances under 10 k Ω to perform high-speed scanning.

Due to problems with settling times, multiple-channel scanning is not recommended unless sampling rates are low enough or it is necessary to sample several signals as nearly simultaneously as possible. The data is much more accurate and channel-to-channel independent if you acquire data from each channel independently (for example, 100 points from channel 0, then 100 points from channel 1, then 100 points from channel 2, and so on).

Analog Output

The DAQPad-MIO-16XE-50 supplies two channels of analog output voltage on the DAQPad-TB-52. The range is fixed at bipolar ± 10 V.

Cold-Junction Sensing

The DAQPad-MIO-16XE-50 includes a high accuracy thermistor temperature sensor for cold-junction compensation when you measure with thermocouples. The temperature sensor is read on a separate dedicated analog input channel. In other words, you do not use any of your 16 analog input channels to read the temperature sensor. However, you will need to realize both dither and multiple-channel scanning considerations as discussed in the analog input section.

To read the temperature sensor in LabVIEW, specify channel string `cjttemp`. When using any other programming language with NI-DAQ, use the pre-defined constant `ND_CJ_TEMP` to read the temperature sensor channel.

The temperature sensor channel will automatically be configured in differential input mode. You can configure this channel for either unipolar or bipolar input polarity. You should configure your temperature sensor channel gain such that the input range of this channel matches as closely as possible the expected range of the temperature sensor reading. From 0° to 55° C, the temperature sensor reading will vary from approximately 1.7 to 0.1 V.

Use the following steps to convert a temperature sensor reading to thermistor temperature.

1. Compute R_T using the following equation:

$$R_T = \frac{V_{temp\ sensor}}{100\ \mu A}$$

where R_T = the resistance of the thermistor in ohms,
 $V_{temp\ sensor}$ = the temperature sensor reading in volts.

2. Compute T_K using the following equation:

$$T_K = \frac{1}{\left[a + b(\ln R_T) + c(\ln R_T)^3 \right]}$$

where T_K = the thermistor temperature in Kelvin,

$$\begin{aligned} a &= 1.295361 \times 10^{-3} \\ b &= 2.343159 \times 10^{-4} \\ c &= 1.018703 \times 10^{-7} \end{aligned}$$

3. Compute T_C or T_F using one of the following equations:

$$T_C = T_K - 273.15$$

$$T_F = \left(\frac{9}{5} \right) T_C + 32$$

where T_C = thermistor temperature in Celsius,
 T_F = thermistor temperature in Fahrenheit.

Note: For further information on using thermocouples, refer to Application Note 043, *Measuring Temperature with Thermocouples*.

Digital I/O

The DAQPad-MIO-16XE-50 contains eight lines of digital I/O for general-purpose use. You can individually configure each line through software for either input or output. At system start up and reset, the digital I/O signals are all high impedance.

The hardware up/down control for general-purpose counters 0 and 1 are connected onboard to DIO6 and DIO7, respectively. Thus, you can use DIO6 and DIO7 to control the general-purpose counters. The up/down control signals are input only and do not affect the operation of the DIO lines.

Programmable Function Inputs

The DAQ-STC provides a very flexible interface for connecting timing signals to external circuitry. Your DAQPad-MIO-16XE-50 uses the Programmable Function Input (PFI) signals on the DAQPad-TB-52 for connecting to external circuitry. These connections are designed to enable the DAQPad-MIO-16XE-50 to both control and be controlled by other circuits.

There are a total of 13 timing signals internal to the DAQ-STC that can be controlled by an external source. These timing signals can also be controlled by signals generated internally to the DAQ-STC, and these selections are fully software configurable. For example, the signal routing multiplexer for controlling the CONVERT* signal is shown in Figure 2-3.

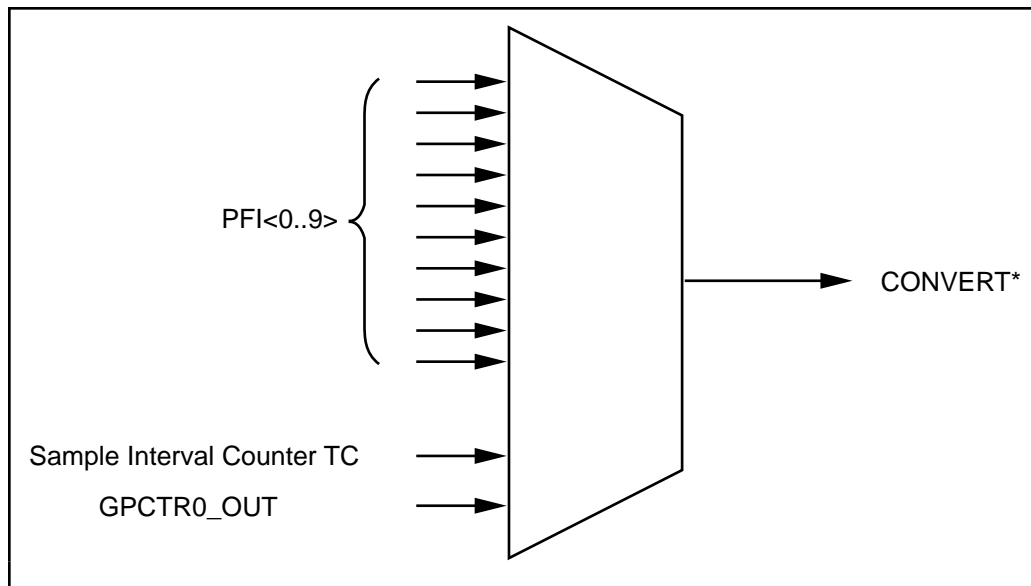


Figure 2-3. CONVERT* Signal Routing

This figure shows that CONVERT* can be generated from a number of sources, including the external signals PFI<0..9> and the internal signals Sample Interval Counter TC and GPCTR0_OUT.

Notice that any of the PFIs can be used as an input by any of the timing signals and that multiple timing signals can use the same PFI simultaneously. This flexible routing scheme reduces the need to change physical connections to the DAQPad-TB-52 for different applications.

You can also individually enable each of the PFI signals to output a specific internal timing signal. For example, if you need the UPDATE* signal as an output on the DAQPad-TB-52, software can turn on the output driver for the PFI5/UPDATE* pin.

Chapter 3

Signal Connections

This chapter describes the connection of a standard parallel port device to the rear panel transparent parallel port connector and describes how to make signal connections to your DAQPad-MIO-16XE-50 via the DAQPad-TB-52.

Transparent Parallel Port Connector

Note: *You must power on the DAQPad-MIO-16XE-50 to operate the standard parallel port device which is connected to the transparent parallel port connector.*

The DAQPad-MIO-16XE-50 supports transparent parallel port connection to any standard parallel port device. The DAQPad-MIO-16XE-50 does not support transparent parallel port connection to any device which supports the 1284 daisy-chain specification as defined by DISTEC, Inc.

When you power up the DAQPad-MIO-16XE-50, the unit is in transparent mode. In this mode, the DAQPad-MIO-16XE-50 will transparently pass through all of the parallel port lines with minimal propagation delay. In normal applications, you operate either the DAQPad-MIO-16XE-50 or the standard parallel port device connected to the transparent parallel port connector at any one time. For example, you cannot use a printer connected to the transparent parallel port connector and perform a data acquisition operation at the same time. You can use the printer only after the data acquisition operation has finished.

If you are using LabVIEW and you want to use the transparent parallel port, you must use the Set DAQ Device Info VI to disable active mode and place the DAQPad-MIO-16XE-50 in transparent mode. If you want to resume communication with the DAQPad-MIO-16XE-50, you can use either the Device Reset VI or Set DAQ Device Info VI to enable active mode.

If you are in DOS or are using NI-DAQ for Windows in an application other than LabVIEW, you can use `Set_DAQ_Device_Info` to disable active mode and place the DAQPad-MIO-16XE-50 in transparent mode. If you want to resume communication with the DAQPad-MIO-16XE-50, you can use either `Init_DA_Brds` or `Set_DAQ_Device_Info` to enable active mode.

DAQPad-TB-52 Terminal Block

The DAQPad-TB-52 is a detachable terminal block with 52 screw terminals designed to interface with the DAQPad-MIO-16XE-50. Figure 3-1 illustrates the 52 screw terminals and their corresponding signal assignments. The fuse labeled *F1* or *+5 V FUSED* limits the +5 V power output current. The fuse labeled *F2* or *SPARE* is placed on the terminal block for your convenience in case of accidental fusing of fuse *F1*. The slide switch labeled *IEX* turns external current excitation on and off. A signal description follows the terminal block layout.

Note: *If you do not need external current excitation but want to perform cold-junction sensor measurements, you must keep the slide switch in the OFF position.*

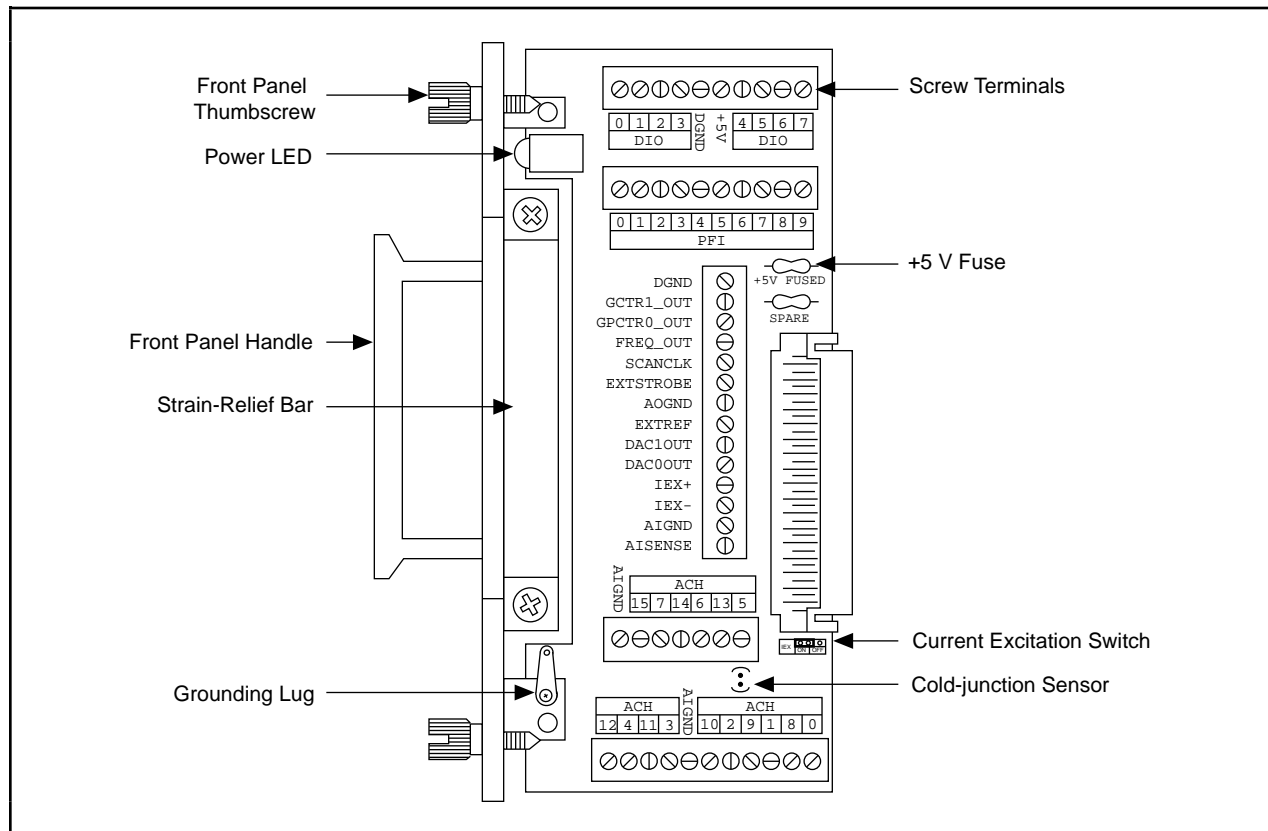


Figure 3-1. DAQPad-TB-52 Screw Terminal Layout

Warning: *Connections that exceed any of the maximum ratings of input or output signals on the DAQPad-MIO-16XE-50 can damage the DAQPad-MIO-16XE-50 and the PC. Maximum input ratings for each signal are given in this chapter under the discussion of that signal. National Instruments is NOT liable for any damages resulting from such signal connections.*

DAQPad-TB-52 Signal Descriptions

Signal Name	Reference	Direction	Description
AIGND	—	—	Analog Input Ground—These signals are the reference point for single-ended measurements and the bias current return point for differential measurements. All three ground references—AIGND, AOGND, and DGND—are connected together on your DAQPad-MIO-16XE-50.
ACH<0..15>	AIGND	Input	Analog Input Channels 0 through 15—Each channel pair, ACH< <i>i</i> , <i>i</i> +8> (<i>i</i> = 0..7), can be configured as either one differential input or two single-ended inputs.
AISENSE	AIGND	Input	Analog Input Sense—This signal serves as the reference node for any of channels ACH <0..15> in NRSE configuration.
DAC0OUT	AOGND	Output	Analog Channel 0 Output—This signal supplies the voltage output of analog output channel 0.
DAC1OUT	AOGND	Output	Analog Channel 1 Output—This signal supplies the voltage output of analog output channel 1.
EXTREF	AOGND	Input	External Reference—This is the external reference input for the analog output circuitry. This functionality is <i>not</i> available on the DAQPad-MIO-16XE-50.
AOGND	—	—	Analog Output Ground—The analog output voltages are referenced to this node. All three ground references—AIGND, AOGND, and DGND—are connected together on your DAQPad-MIO-16XE-50.
IEX+	IEX-	Output	Current excitation—This signal provides 100 μ A of external current excitation.
IEX-	—	—	Current excitation return—This signal provides the current return point for the external current excitation.
DGND	—	—	Digital Ground—These signals supply the reference for the digital signals at the DAQPad-TB-52 as well as the +5 VDC supply. All three ground references—AIGND, AOGND, and DGND—are connected together on your DAQPad-MIO-16XE-50.
DIO<0..7>	DGND	Input or Output	Digital I/O signals—DIO6 and 7 can control the up/down signal of general-purpose counters 0 and 1, respectively.
+5 V	DGND	Output	+5 VDC Source—This signal is fused for up to 250 mA of +5 V supply.
SCANCLK	DGND	Output	Scan Clock—This signal pulses once for each A/D conversion in the scanning modes when enabled. The low-to-high edge indicates when the input signal can be removed from the input or switched to another signal.
EXTSTROBE*	DGND	Output	External Strobe—This output can be toggled under software control to latch signals or trigger events on external devices.
PFI0/TRIG1	DGND	Input	PFI0/Trigger1—As an input, this is one of the Programmable Function Inputs (PFIs). PFI signals are explained in the <i>Timing Connections</i> section later in this chapter.
		Output	As an output, this is the TRIG1 signal. In posttrigger data acquisition sequences, a low-to-high transition indicates the initiation of the acquisition sequence. In pretrigger applications, a low-to-high transition indicates the initiation of the pretrigger conversions.

(continues)

Signal Name	Reference	Direction	Description (Continued)
PFI1/TRIG2	DGND	Input	PFI1/Trigger2—As an input, this is one of the PFIs.
		Output	As an output, this is the TRIG2 signal. In pretrigger applications, a low-to-high transition indicates the initiation of the posttrigger conversions. TRIG2 is not used in posttrigger applications.
PFI2/CONVERT*	DGND	Input	PFI2/Convert—As an input, this is one of the PFIs.
		Output	As an output, this is the CONVERT* signal. A high-to-low edge on CONVERT* indicates that an A/D conversion is occurring.
PFI3/GPCTR1_SOURCE	DGND	Input	PFI3/Counter 1 Source—As an input, this is one of the PFIs.
		Output	As an output, this is the GPCTR1_SOURCE signal. This signal reflects the actual source connected to the general-purpose counter 1.
PFI4/GPCTR1_GATE	DGND	Input	PFI4/Counter 1 Gate—As an input, this is one of the PFIs.
		Output	As an output, this is the GPCTR1_GATE signal. This signal reflects the actual gate signal connected to the general-purpose counter 1.
GPCTR1_OUT	DGND	Output	Counter 1 Output—This output is from the general-purpose counter 1 output.
PFI5/UPDATE*	DGND	Input	PFI5/Update—As an input, this is one of the PFIs.
		Output	As an output, this is the UPDATE* signal. A high-to-low edge on UPDATE* indicates that the analog output primary group is being updated.
PFI6/WFTRIG	DGND	Input	PFI6/Waveform Trigger—As an input, this is one of the PFIs.
		Output	As an output, this is the WFTRIG signal. In timed analog output sequences, a low-to-high transition indicates the initiation of the waveform generation.
PFI7/STARTSCAN	DGND	Input	PFI7/Start of Scan—As an input, this is one of the PFIs.
		Output	As an output, this is the STARTSCAN signal. This signal pulses once at the start of each analog input scan in the interval scan. A low-to-high transition indicates the start of the scan.
PFI8/GPCTR0_SOURCE	DGND	Input	PFI8/Counter 0 Source—As an input, this is one of the PFIs.
		Output	As an output, this is the GPCTR0_SOURCE signal. This signal reflects the actual source connected to the general-purpose counter 0.
PFI9/GPCTR0_GATE	DGND	Input	PFI9/Counter 0 Gate—As an input, this is one of the PFIs.
		Output	As an output, this is the GPCTR0_GATE signal. This signal reflects the actual gate signal connected to the general-purpose counter 0.
GPCTR0_OUT	DGND	Output	Counter 0 Output—This output is from the general-purpose counter 0 output.
FREQ_OUT	DGND	Output	Frequency Output—This output is from the frequency generator output.

(continues)

Table 3-1 shows the I/O signal summary for the DAQPad-TB-52.

Table 3-1. I/O Signal Summary, DAQPad-TB-52

Signal Name	Drive	Impedance Input/Output	Protection (Volts) On/Off	Source (mA at V)	Sink (mA at V)	Rise Time (ns)	Bias
ACH<0..15>	AI	20 G Ω in parallel with 100 pF	25/15	—	—	—	± 3 nA
AISENSE	AI	20 G Ω in parallel with 100 pF	25/15	—	—	—	± 3 nA
AIGND	AO	—	—	—	—	—	—
DAC0OUT	AO	0.1 Ω	Short-circuit to ground	5 at 10	5 at 10	2 V/ μ s	—
DAC1OUT	AO	0.1 Ω	Short-circuit to ground	5 at 10	5 at 10	2 V/ μ s	—
AOGND	AO	—	—	—	—	—	—
IEX+	AO	—	+14 to -40 V	100 μ A	—	—	—
IEX-	AI	1.5–16.3 k Ω	± 12 V	—	—	—	—
DGND	DO	—	—	—	—	—	—
VCC	DO	0.1 Ω	Short-circuit to ground	Fused at 250 mA	—	—	—
DIO<0..7>	DIO	—	V _{CC} +0.5	13 at (V _{CC} -0.4)	24 at 0.4	1.1	50 k Ω pu ¹
SCANCLK	DO	—	—	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
EXTSTROBE*	DO	—	—	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI0/TRIG1	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI1/TRIG2	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI2/CONVERT*	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI3/GPCTR1_SOURCE	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI4/GPCTR1_GATE	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
GPCTR1_OUT	DO	—	—	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI5/UPDATE*	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI6/WFTRIG	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI7/STARTSCAN	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI8/GPCTR0_SOURCE	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
PFI9/GPCTR0_GATE	DIO	—	V _{CC} +0.5	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
GPCTR0_OUT	DO	—	—	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu
FREQ_OUT	DO	—	—	3.5 at (V _{CC} -0.4)	5 at 0.4	1.5	50 k Ω pu

¹DIO <6..7> are also pulled down with a 50 k Ω resistor.
 AI = Analog Input DIO = Digital Input/Output pu = pullup
 AO = Analog Output DO = Digital Output

DAQPad-TB-52 Signal Connections

Note: *You do not have to turn off the DAQPad-MIO-16XE-50 before removing the DAQPad-TB-52.*

To connect signals to the DAQPad-TB-52, perform the following steps:

1. Disconnect and remove the DAQPad-TB-52 from the DAQPad-MIO-16XE-50 by unscrewing the front panel thumbscrews and then gently pulling on the front panel handle.
2. Remove the strain-relief bar by unscrewing and removing the strain-relief screws with a flathead screwdriver (3/16 in. maximum).
3. Connect your signals to the screw terminals by inserting the wires into the appropriate terminals and tightening the screws with a flathead screwdriver (1/10 in. maximum).
4. Flatten the wires to lay across the strain-relief opening. Replace the strain-relief bar over the wires and tighten the strain-relief screws.
5. Slide the DAQPad-TB-52 back into the DAQPad-MIO-16XE-50 until the terminal block is firmly connected. Retighten the front panel thumbscrews.

If your system (the DAQPad-MIO-16XE-50 and PC) is floating with respect to earth ground, for both safety and shielding reasons you should ground your system to earth ground using the grounding lug provided on the inside of the DAQ-TB-52 front panel, shown in Figure 3-1.

Analog Input Signal Connections

The analog input signals are ACH<0..15>, AISENSE, and AIGND. The ACH<0..15> signals are tied to the 16 analog input channels of your DAQPad-MIO-16XE-50. In single-ended mode, signals connected to ACH<0..15> are routed to the positive input of the board PGIA. In differential mode, signals connected to ACH<0..7> are routed to the positive input of the PGIA, and signals connected to ACH<8..15> are routed to the negative input of the PGIA.

Warning: *Exceeding the differential and common-mode input ranges distorts input signals. Exceeding the maximum input voltage rating can damage the DAQPad-MIO-16XE-50 and the PC. National Instruments is NOT liable for any damages resulting from such signal connections.*

In NRSE mode, the AISENSE signal is connected internally to the negative input of the DAQPad-MIO-16XE-50 PGIA. In DIFF and RSE modes, this signal is left unconnected.

AIGND is an analog input common signal that is routed directly to the ground tie point on the DAQPad-MIO-16XE-50. You can use this signal for a general analog ground tie point to your DAQPad-MIO-16XE-50 if necessary.

Connection of analog input signals to your DAQPad-MIO-16XE-50 depends on the configuration of the analog input channels you are using and the type of input signal source. With the different configurations, you can use the PGIA in different ways. Figure 3-2 shows a diagram of your DAQPad-MIO-16XE-50 PGIA.

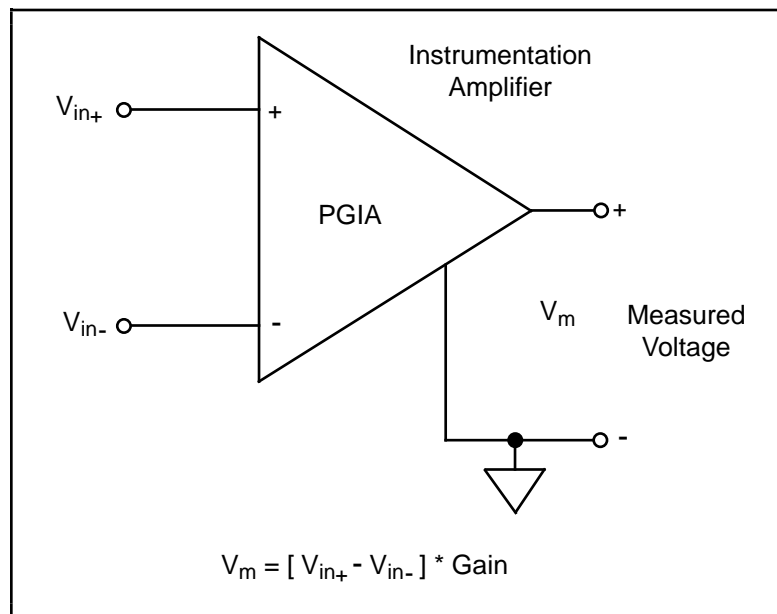


Figure 3-2. DAQPad-MIO-16XE-50 PGIA

The PGIA applies gain and common-mode voltage rejection and presents high-input impedance to the analog input signals connected to your DAQPad-MIO-16XE-50. Signals are routed to the positive and negative inputs of the PGIA through input multiplexers on the board. The PGIA converts two input signals to a signal that is the difference between the two input signals

multiplied by the gain setting of the amplifier. The amplifier output voltage is referenced to the ground for the board. Your DAQPad-MIO-16XE-50 A/D converter (ADC) measures this output voltage when it performs A/D conversions.

You must reference all signals to ground either at the source device or at the board. If you have a floating source, you should reference the signal to ground by using the RSE input mode or the DIFF input configuration with bias resistors (see the *Differential Connections for Nonreferenced or Floating Signal Sources* section later in this chapter). If you have a grounded source, you should not reference the signal to AIGND. You can avoid this reference by using DIFF or NRSE input configurations.

Types of Signal Sources

When configuring the input channels and making signal connections, you must first determine whether the signal sources are floating or ground-referenced. The following sections describe these two types of signals.

Floating Signal Sources

A floating signal source is one that is not connected in any way to the building ground system but, rather, has an isolated ground-reference point. Some examples of floating signal sources are outputs of transformers, thermocouples, battery-powered devices, optical isolator outputs, and isolation amplifiers. An instrument or device that has an isolated output is a floating signal source. You must tie the ground reference of a floating signal to your DAQPad-MIO-16XE-50 analog input ground to establish a local or onboard reference for the signal. Otherwise, the measured input signal varies as the source floats out of the common-mode input range.

Ground-Referenced Signal Sources

A ground-referenced signal source is one that is connected in some way to the building system ground and is, therefore, already connected to a common ground point with respect to the DAQPad-MIO-16XE-50, assuming that the PC is plugged into the same power system. Nonisolated outputs of instruments and devices that plug into the building power system fall into this category.

The difference in ground potential between two instruments connected to the same building power system is typically between 1 and 100 mV but can be much higher if power distribution circuits are not properly connected. If a grounded signal source is improperly measured, this difference may appear as an error in the measurement. The connection instructions for grounded signal sources are designed to eliminate this ground potential difference from the measured signal.

Note: *If you power both the DAQPad-MIO-16XE-50 and your PC with a floating power source (such as a battery) and you are not tying the DAQPad-TB-52 grounding lug to earth ground, your system will be floating with respect to earth ground. In this case, treat all of your signal sources as floating sources.*

Input Configurations

You can configure your DAQPad-MIO-16XE-50 for one of three input modes—NRSE, RSE, or DIFF. The following sections discuss the use of single-ended and differential measurements and considerations for measuring both floating and ground-referenced signal sources. Figure 3-3 summarizes the recommended input configuration for both types of signal sources.

Input	Signal Source Type	
	Floating Signal Source (Not Connected to Building Ground)	Grounded Signal Source
	<p>Examples</p> <ul style="list-style-type: none"> • Ungrounded Thermocouples • Signal conditioning with isolated outputs • Battery devices 	<p>Examples</p> <ul style="list-style-type: none"> • Plug-in instruments with nonisolated outputs
Differential (DIFF)	<p>See text for information on bias resistors.</p>	
Single-Ended — Ground Referenced (RSE)		<p>NOT RECOMMENDED</p> <p>Ground-loop losses, V_g, are added to measured signal</p>
Single-Ended — Nonreferenced (NRSE)	<p>See text for information on bias resistors.</p>	

Figure 3-3. Summary of Analog Input Connections

Differential Connection Considerations

A differential connection is one in which the DAQPad-MIO-16XE-50 analog input signal has its own reference signal or signal return path. These connections are available when the selected channel is configured in DIFF input mode. The input signal is tied to the positive input of the PGIA, and its reference signal, or return, is tied to the negative input of the PGIA.

When you configure a channel for differential input, each signal uses two multiplexer inputs—one for the signal and one for its reference signal. Therefore, with a differential configuration for every channel, up to eight analog input channels are available.

You should use differential input connections for any channel which meets any of the following conditions:

- The input signal is low level (less than 1 V).
- The leads connecting the signal to the DAQPad-MIO-16XE-50 are greater than 10 ft (3 meters).
- The input signal requires a separate ground-reference point or return signal.
- The signal leads travel through noisy environments.

Differential signal connections reduce picked-up noise and increase common-mode noise rejection. Differential signal connections also allow input signals to float within the common-mode limits of the PGIA.

Differential Connections for Ground-Referenced Signal Sources

Figure 3-4 shows how to connect a ground-referenced signal source to a DAQPad-MIO-16XE-50 channel configured in DIFF input mode.

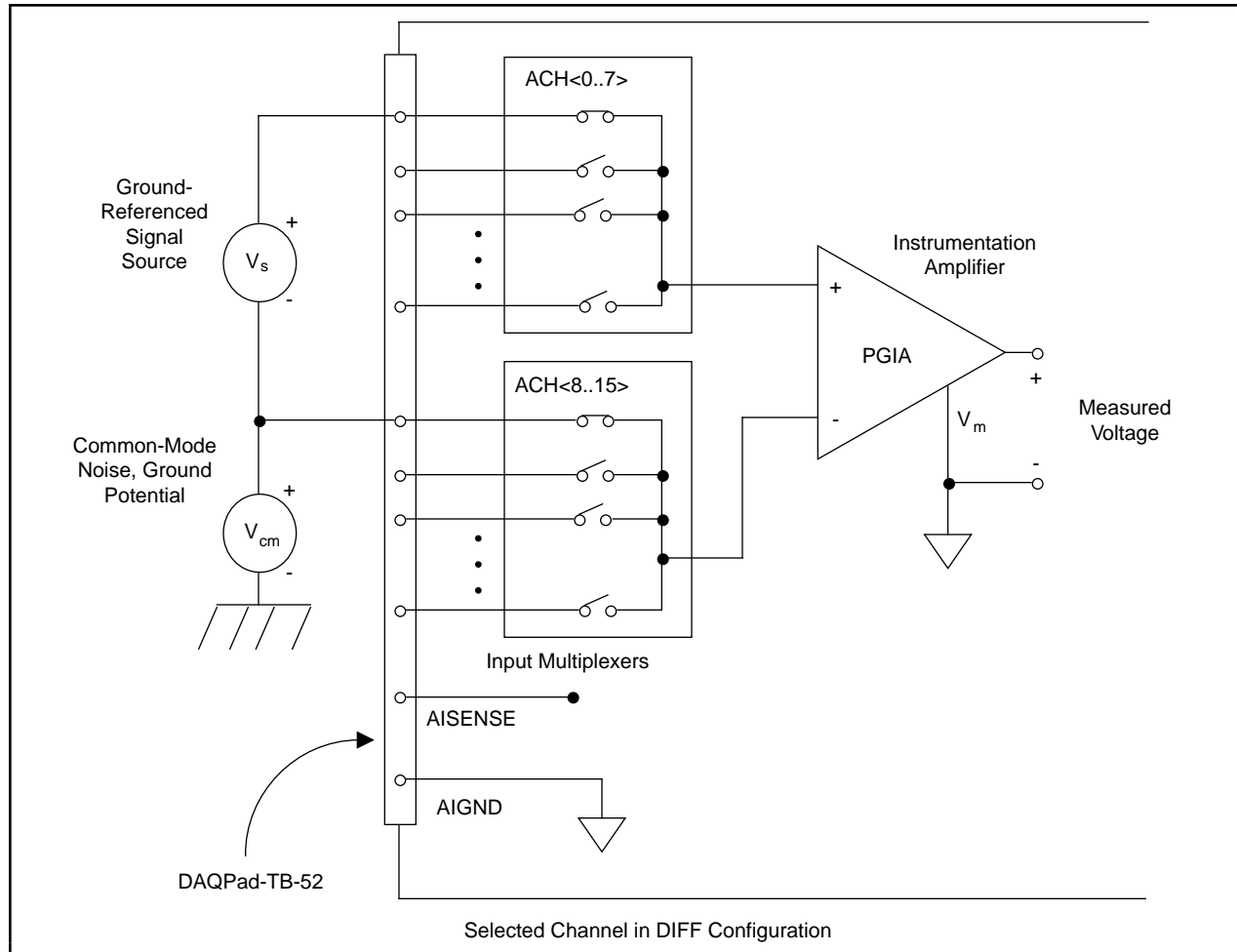


Figure 3-4. Differential Input Connections for Ground-Referenced Signals

With this type of connection, the PGIA rejects both the common-mode noise in the signal and the ground-potential difference between the signal source and the DAQPad-MIO-16XE-50 ground, shown as V_{cm} in Figure 3-4.

Differential Connections for Nonreferenced or Floating Signal Sources

Figure 3-5 shows how to connect a floating signal source to a DAQPad-MIO-16XE-50 channel configured in DIFF input mode.

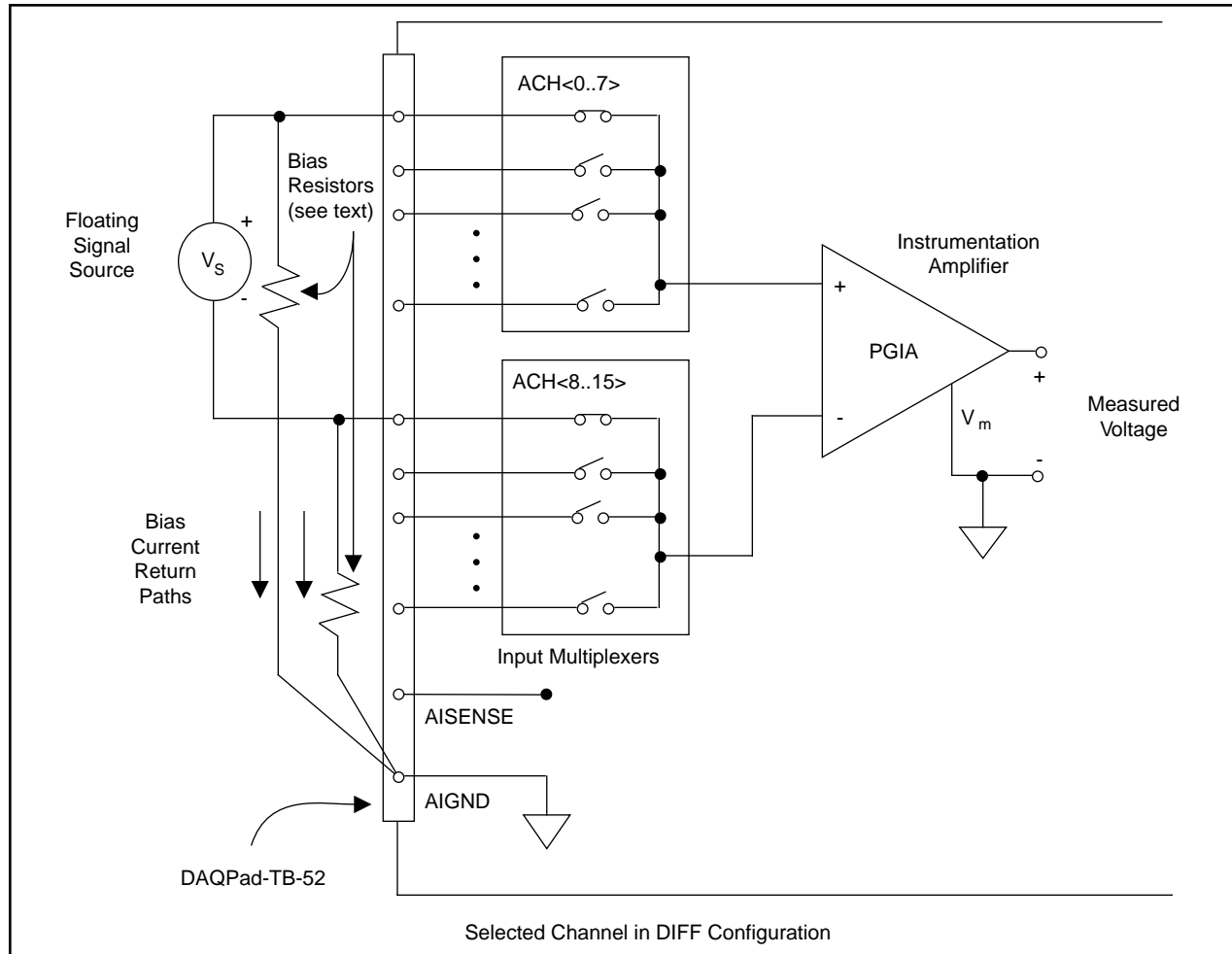


Figure 3-5. Differential Input Connections for Nonreferenced Signals

Figure 3-5 shows two bias resistors connected in parallel with the signal leads of a floating signal source. If you do not use the resistors and the source is truly floating, the source is not likely to remain within the common-mode signal range of the PGIA, and the PGIA will saturate, causing erroneous readings. You must reference the source to AIGND. The easiest way is simply to connect the positive side of the signal to the positive input of the PGIA and connect the negative side of the signal to AIGND as well as to the negative input of the PGIA without any resistors at all. This connection works well for DC-coupled sources with low source impedance (less than $100\ \Omega$).

However, for larger source impedances, this connection leaves the differential signal path significantly out of balance. Noise that couples electrostatically onto the positive line does not couple onto the negative line because it is connected to ground. Hence, this noise appears as a differential-mode signal instead of a common-mode signal, and so the PGIA does not reject it. In

this case, instead of directly connecting the negative line to AIGND, connect it to AIGND through a resistor that is about 100 times the equivalent source impedance. The resistor puts the signal path nearly in balance, so that about the same amount of noise couples onto both connections, yielding better rejection of electrostatically coupled noise. Also, this configuration does not load down the source (other than the very high input impedance of the PGIA).

You can fully balance the signal path by connecting another resistor of the same value between the positive input and AIGND, as shown in Figure 3-5. This fully balanced configuration offers slightly better noise rejection but has the disadvantage of loading the source down with the series combination (sum) of the two resistors. If, for example, the source impedance is 2 k Ω and each of the two resistors is 100 k Ω , the resistors load down the source with 200 k Ω and produce a -1% gain error.

Both inputs of the PGIA require a DC path to ground in order for the PGIA to work. If the source is AC coupled (capacitively coupled), the PGIA needs a resistor between the positive input and AIGND. If the source has low impedance, choose a resistor that is large enough not to significantly load the source but small enough not to produce significant input offset voltage as a result of input bias current (typically 100 k Ω to 1 M Ω). In this case, you can tie the negative input directly to AIGND. If the source has high output impedance, you should balance the signal path as previously described using the same value resistor on both the positive and negative inputs; you should be aware that there is some gain error from loading down the source.

Note: *These same issues regarding bias resistors also apply to a single-ended connection (NRSE configuration) for floating signal sources.*

Single-Ended Connection Considerations

A single-ended connection is one in which the DAQPad-MIO-16XE-50 analog input signal is referenced to a ground that can be shared with other input signals. The input signal is tied to the positive input of the PGIA, and the ground is tied to the negative input of the PGIA.

When every channel is configured for single-ended input, up to 16 analog input channels are available.

You can use single-ended input connections for any input signal that meets the following conditions:

- The input signal is high level (greater than 1 V).
- The leads connecting the signal to the DAQPad-MIO-16XE-50 are less than 10 ft (3 meters).
- The input signal can share a common reference point with other signals.

DIFF input connections are recommended for greater signal integrity for any input signal that does not meet the preceding conditions.

You can software configure the DAQPad-MIO-16XE-50 channels for two different types of single-ended connections—RSE configuration and NRSE configuration. Use the RSE configuration for floating signal sources; in this case, the DAQPad-MIO-16XE-50 provides the reference ground point for the external signal. Use the NRSE input configuration for ground-referenced signal sources; in this case, the external signal supplies its own reference ground point and the DAQPad-MIO-16XE-50 should not supply one.

In single-ended configurations, more electrostatic and magnetic noise couples into the signal connections than in differential configurations. The coupling is the result of differences in the signal path. Magnetic coupling is proportional to the area between the two signal conductors. Electrical coupling is a function of how much the electric field differs between the two conductors.

Single-Ended Connections for Floating Signal Sources (RSE Configuration)

Figure 3-6 shows how to connect a floating signal source to a DAQPad-MIO-16XE-50 channel configured for RSE mode.

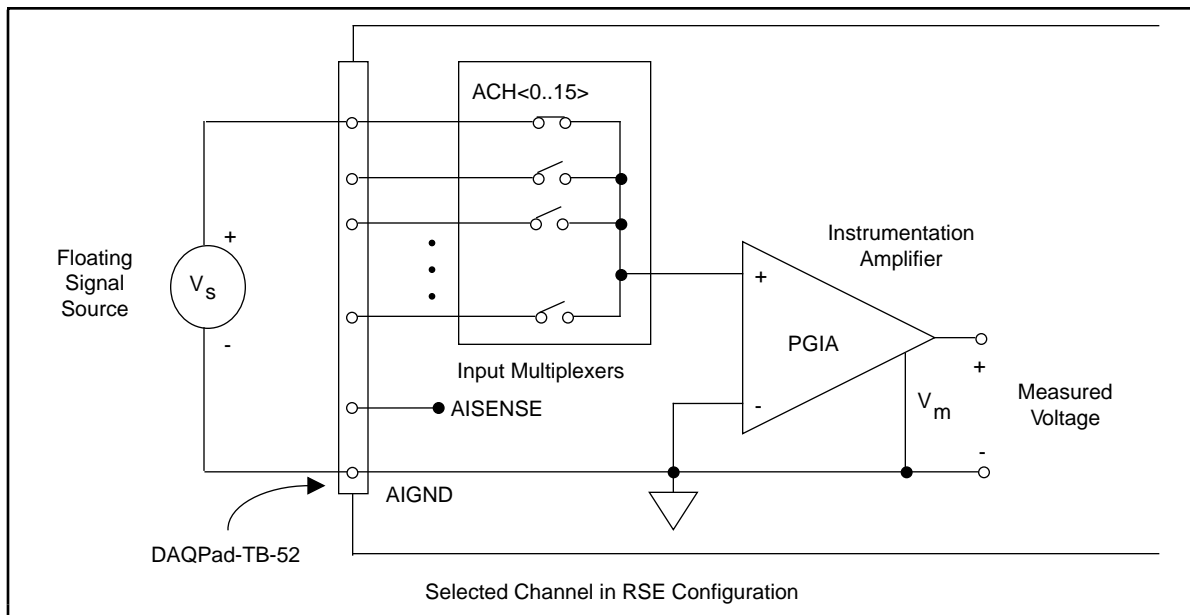


Figure 3-6. Single-Ended Input Connections for Nonreferenced or Floating Signals

Single-Ended Connections for Grounded Signal Sources (NRSE Configuration)

To measure a grounded signal source with a single-ended configuration, you must configure the DAQPad-MIO-16XE-50 for NRSE input. Connect the grounded signal to the positive input of the DAQPad-MIO-16XE-50 PGIA, and connect the signal local ground reference to the negative input of the DAQPad-MIO-16XE-50 PGIA. The ground point of the signal should, therefore, be connected to the AISENSE pin. Any potential difference between the DAQPad-MIO-16XE-50 ground and the signal ground appears as a common-mode signal at both the positive and negative inputs of the PGIA, and the amplifier rejects this difference. If the input circuitry of the DAQPad-MIO-16XE-50 were referenced to ground, in this situation as in the RSE input configuration, this difference in ground potential would appear as an error in the measured voltage.

Figure 3-7 shows how to connect a grounded signal source to a DAQPad-MIO-16XE-50 channel configured for NRSE mode.

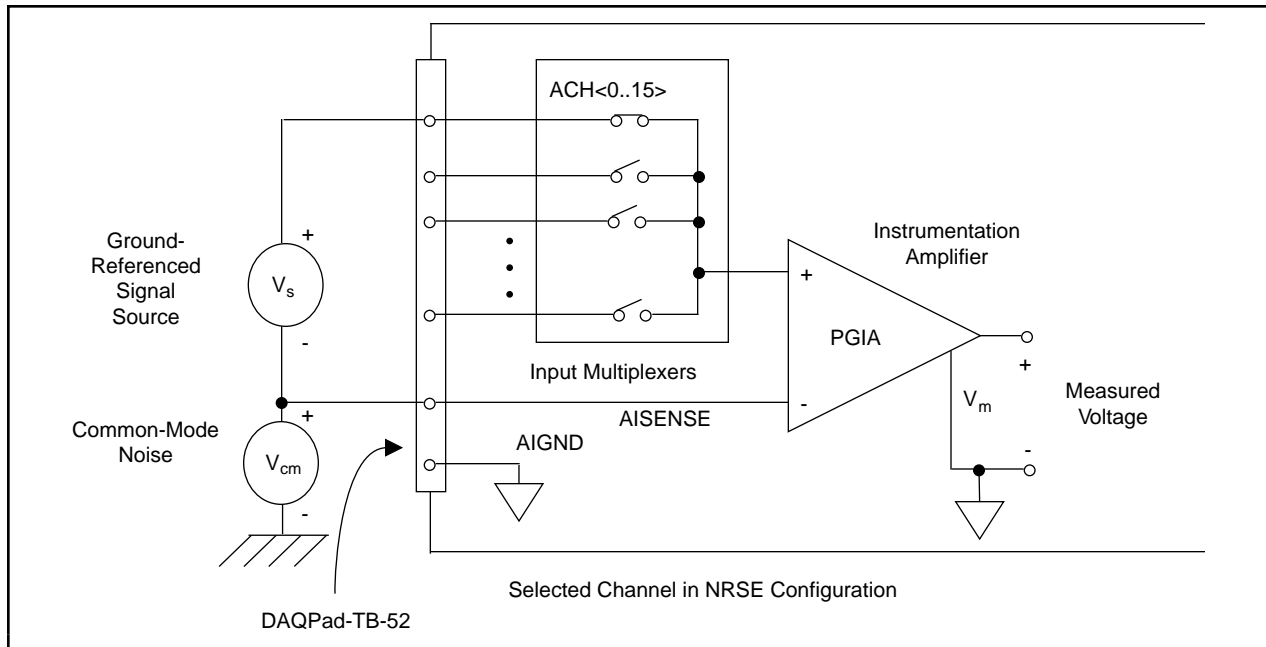


Figure 3-7. Single-Ended Input Connections for Ground-Referenced Signals

Common-Mode Signal Rejection Considerations

Figures 3-4 and 3-7 show connections for signal sources that are already referenced to some ground point with respect to the DAQPad-MIO-16XE-50. In these cases, the PGIA can reject any voltage caused by ground potential differences between the signal source and the DAQPad-MIO-16XE-50. In addition, with differential input connections, the PGIA can reject common-mode noise pickup in the leads connecting the signal sources to the DAQPad-MIO-16XE-50. The PGIA can reject common-mode signals as long as V_{in}^+ and V_{in}^- are both within ± 11 V of AIGND. The DAQPad-MIO-16XE-50 has the additional restriction that $V_{in}^+ + V_{in}^-$ added to the gain times $(V_{in}^+ - V_{in}^-)$ is within ± 26 V of AIGND. At gains of 1 and 2, this restriction is of little or no consequence, but at gains of 10 and 100, this is roughly equivalent to restricting the two input voltages to within ± 8 V of AIGND.

External Current Excitation

The screw terminals labeled IEX+ and IEX- provide external current excitation for temperature measurements using RTDs or thermistors. IEX+ is the current output and IEX- is the current return. The constant current source provides 100 μA of external excitation.

Figure 3-8 suggests how you can connect several RTDs in series to the DAQPad-MIO-16XE-50 using four-wire measurement techniques. For external current excitation, push the slide switch labeled IEX to the ON position.

Note: *If you do not externally connect IEX+ to IEX- and you want to perform cold-junction sensor measurements, you must push the slide switch to the OFF position.*

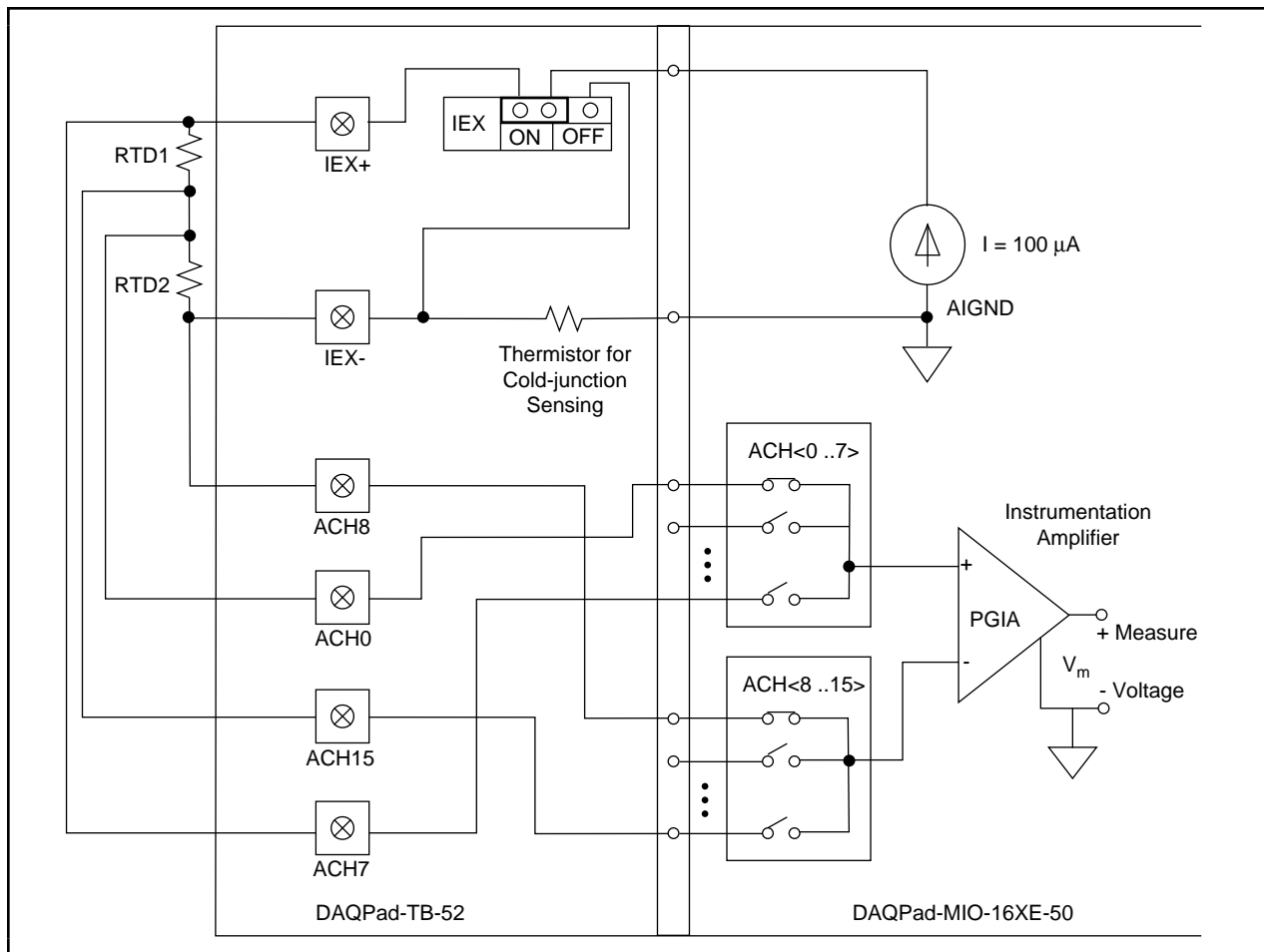


Figure 3-8. RTD Connection Using External Current Excitation

Configure the analog input channels for differential input mode. You can configure the analog input for either a unipolar or bipolar polarity. Your signal sources are not floating; therefore, do not connect bias resistors between your signal sources and AIGND. The voltage potential at IEX- will vary between 1.7 and 0.1 V from 0° to 55° C. You must take this voltage into account when realizing the common-mode signal rejection considerations discussed in the *Common-Mode Signal Rejection* section.

Analog Output Signal Connections

The analog output signals are DAC0OUT, DAC1OUT, and AOGND.

DAC0OUT is the voltage output signal for analog output channel 0. DAC1OUT is the voltage output signal for analog output channel 1.

AOGND is the ground-reference signal for both analog output channels and for the external reference signal.

Figure 3-9 shows how to make analog output connections and the external reference input connection to your DAQPad-MIO-16XE-50.

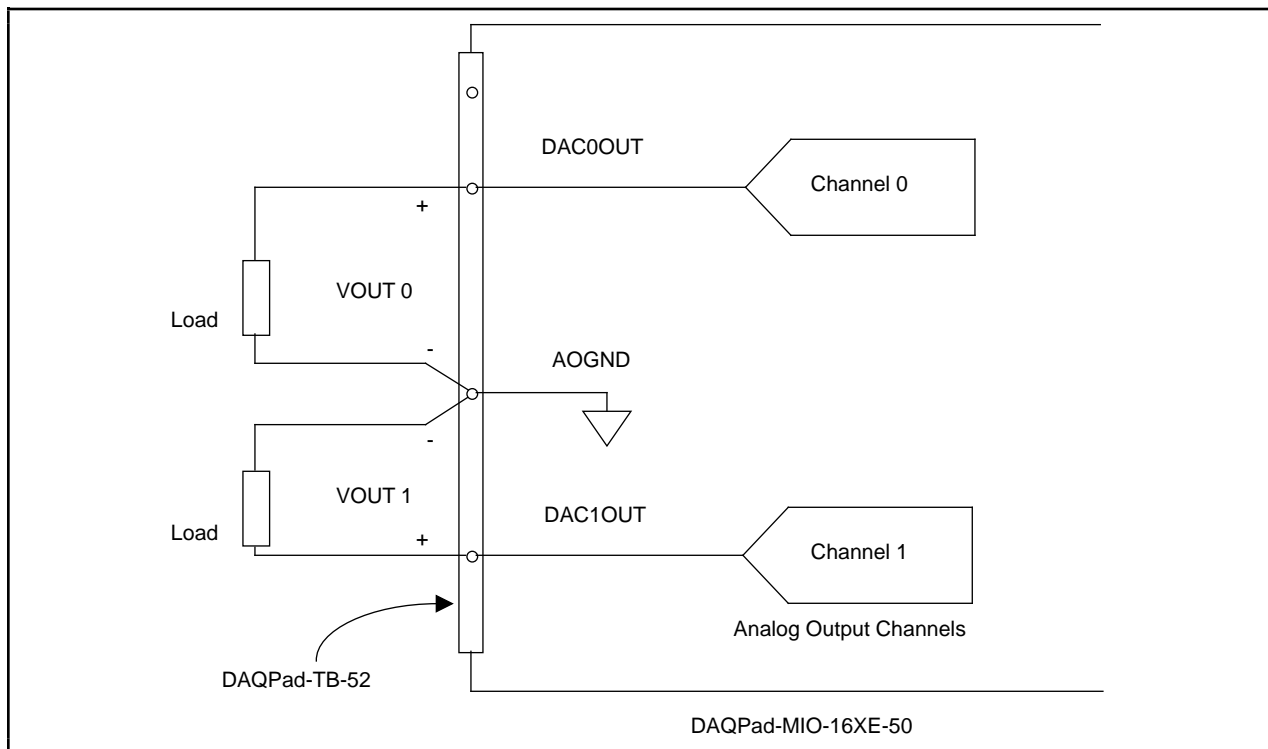


Figure 3-9. Analog Output Connections

Digital I/O Signal Connections

The digital I/O signals are DIO<0..7> and DGND. DIO<0..7> signals make up the DIO port, and DGND is the ground reference signal for the DIO port. You can program all lines individually to be inputs or outputs.

Figure 3-10 shows signal connections for three typical digital I/O applications.

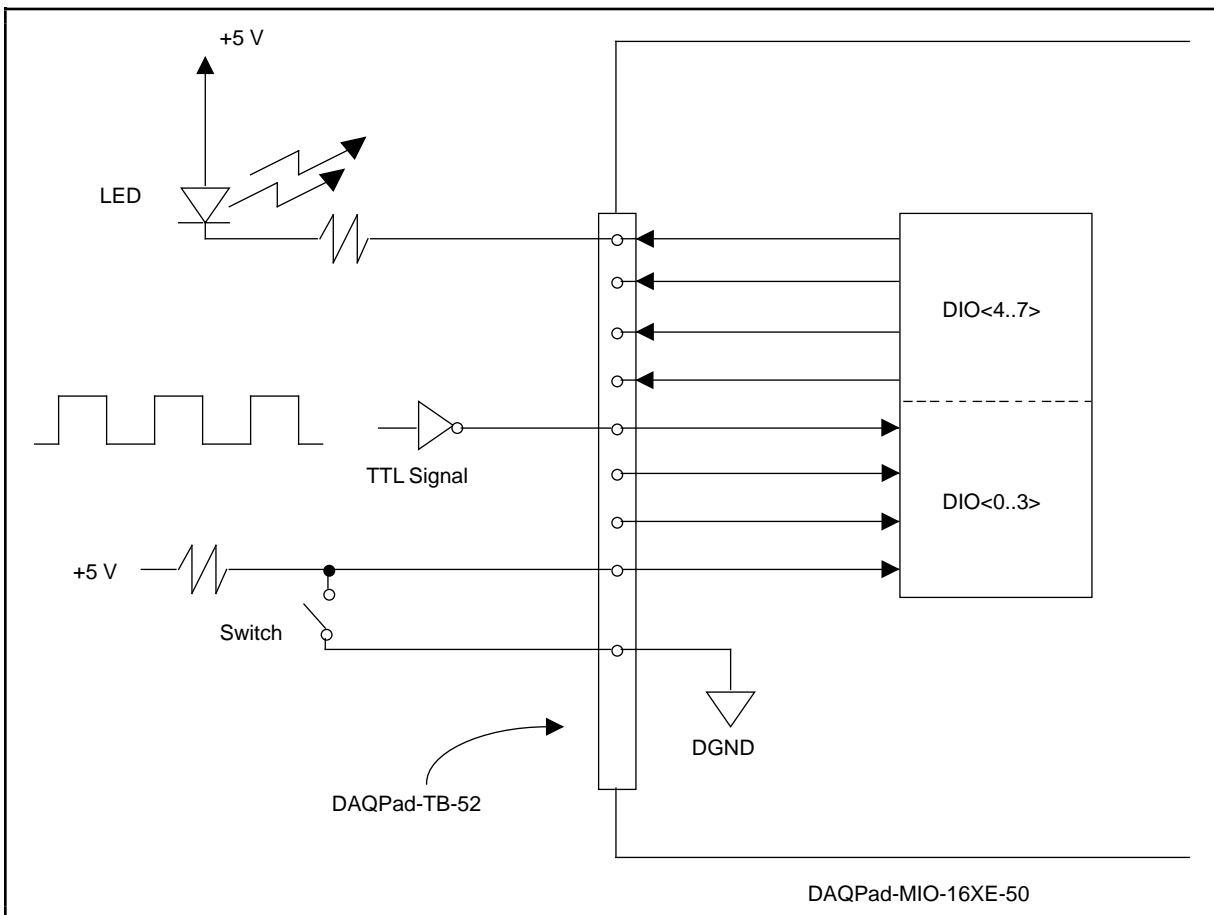


Figure 3-10. Digital I/O Connections

Figure 3-10 shows DIO<0..3> configured for digital input and DIO<4..7> configured for digital output. Digital input applications include receiving TTL signals and sensing external device states such as the state of the switch in Figure 3-10. Digital output applications include sending TTL signals and driving external devices such as the LED shown in Figure 3-10.

Power Connections

The power signal +5 V supplies +5 V from the DAQPad-MIO-16XE-50 power supply. This pin is referenced to DGND and you can use the +5 V to power external digital circuitry.

- Power rating 250 mA at +5 V maximum

The +5 V signal is fused for up to 250 mA. Blowing this fuse by shorting +5 V to ground will not damage the DAQPad-MIO-16XE-50. If you do not receive +5 V from this screw terminal, make sure that the rear panel rocker switch is turned on and that the DAQPad-TB-52 is firmly connected to the DAQPad-MIO-16XE-50 and check for any shorts between the +5 V power pin and ground. You can replace a blown fuse with the spare fuse located on the DAQPad-TB-52 or you can use a 250 mA, fast-acting Pico II fuse from Littlefuse.

Warning: *UNDER NO CIRCUMSTANCES should you connect this +5 V power signal directly to any other voltage source on the DAQPad-MIO-16XE-50 or any other device. Doing so can damage the DAQPad-MIO-16XE-50 and the PC. National Instruments is NOT liable for damages resulting from such a connection.*

Timing Connections

All external control over the timing of the DAQPad-MIO-16XE-50 is routed through the 10 programmable function inputs labeled PFI0 through PFI9. These signals are explained in detail in the section, *Programmable Function Input Connections*. These PFIs are bidirectional—as outputs they are not programmable and reflect the state of many data acquisition, waveform generation, and general-purpose timing signals. There are five other dedicated outputs for the remainder of the timing signals. As inputs, the PFI signals are programmable and can control any data acquisition, waveform generation, and general-purpose timing signals.

The data acquisition signals are explained in the *Data Acquisition Timing Connections* section later in this chapter. The waveform generation signals are explained in the *Waveform Generation Timing Connections* section later in this chapter. The general-purpose timing signals are explained in the *General-Purpose Timing Signal Connections* section later in this chapter.

All digital timing connections are referenced to DGND. This connection is demonstrated in Figure 3-11, which shows how to connect an external TRIG1 source and an external CONVERT* source to two of the DAQPad-MIO-16XE-50 PFI signals.

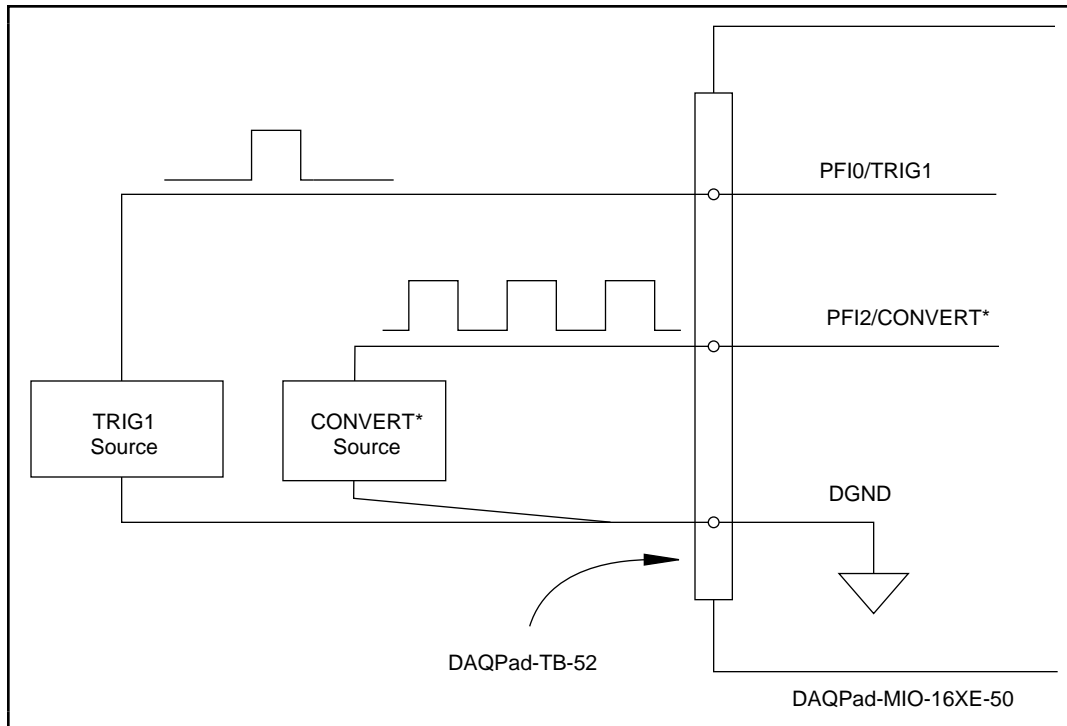


Figure 3-11. Timing I/O Connections

Programmable Function Input Connections

There are a total of 13 internal timing signals that you can externally control from the 10 PFI signals on the DAQPad-TB-52. The source for each of these signals is software selectable from any of the PFIs when you want external control. This flexible routing scheme reduces the need to change the physical wiring to the DAQPad-TB-52 for different applications.

You can individually enable each of the PFI signals to output a specific internal timing signal. For example, if you need the CONVERT* signal as an output on the DAQPad-TB-52, software can turn on the output driver for the PFI2/CONVERT* signal. You must be careful not to drive a PFI signal externally when it is configured as an output.

As an input, you can individually configure each PFI for edge or level detection and for polarity selection as well. You can use the polarity selection for any of the 13 timing signals, but using the edge or level detection will depend upon the particular timing signal being controlled. The detection requirements for each timing signal are listed within the section that discusses that individual signal.

In edge-detection mode, the minimum pulse width required is 10 ns. This applies for both rising-edge and falling-edge polarity settings. There is no maximum pulsewidth requirement in edge-detection mode.

In level-detection mode, there are no minimum or maximum pulsewidth requirements imposed by the PFIs themselves, but there may be limits imposed by the particular timing signal being controlled. These requirements are listed later in this chapter.

Data Acquisition Timing Connections

The data acquisition timing signals are SCANCLK, EXTSTROBE*, TRIG1, TRIG2, STARTSCAN, CONVERT*, AIGATE, and SISOURCE.

Posttriggered data acquisition allows you to view only data that is acquired after a trigger event is received. A typical posttriggered data acquisition sequence is shown in Figure 3-12.

Pretriggered data acquisition allows you to view data that is acquired before the trigger of interest in addition to a fixed number of data points acquired after the trigger. Figure 3-13 shows a typical pretriggered data acquisition sequence. The description for each signal shown in these figures is included later in this chapter.

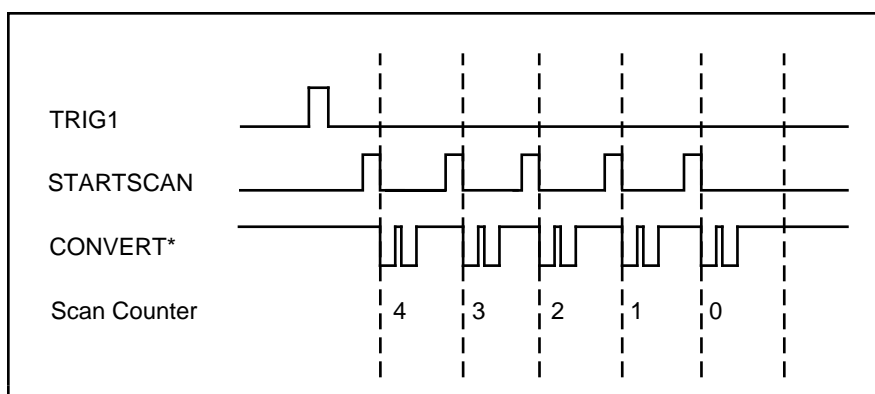


Figure 3-12. Typical Posttriggered Acquisition

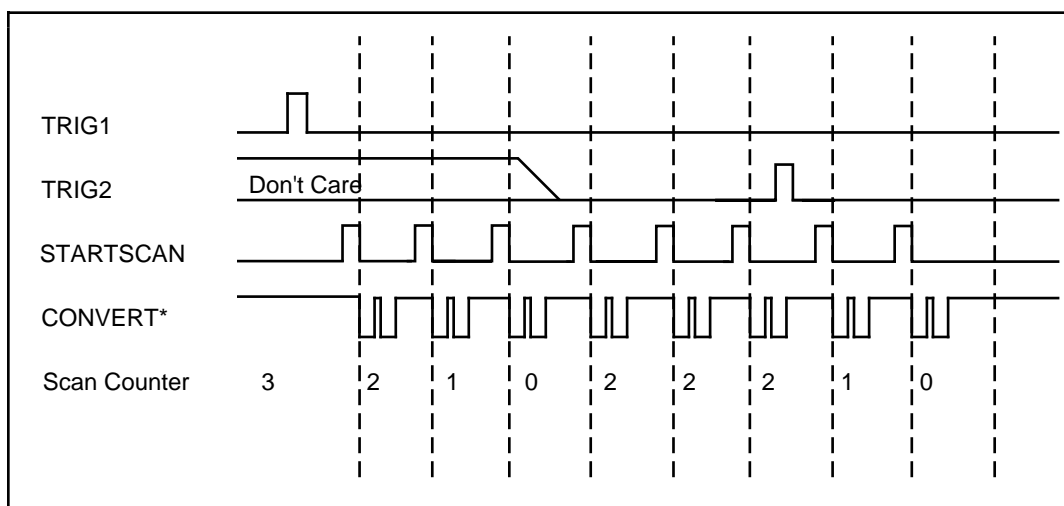


Figure 3-13. Typical Pretriggered Acquisition

SCANCLK Signal

SCANCLK is an output-only signal that generates a pulse with the leading edge occurring approximately 50 to 100 ns after an A/D conversion begins. The polarity of this output is software selectable but is typically configured so that a low-to-high leading edge can clock external analog input multiplexers indicating when the input signal has been sampled and can be removed. This signal has a 400 to 500 ns pulse width and is software enabled. Figure 3-14 shows the timing for the SCANCLK signal. In this figure, the falling edge of CONVERT* indicates the initiation of an A/D conversion.

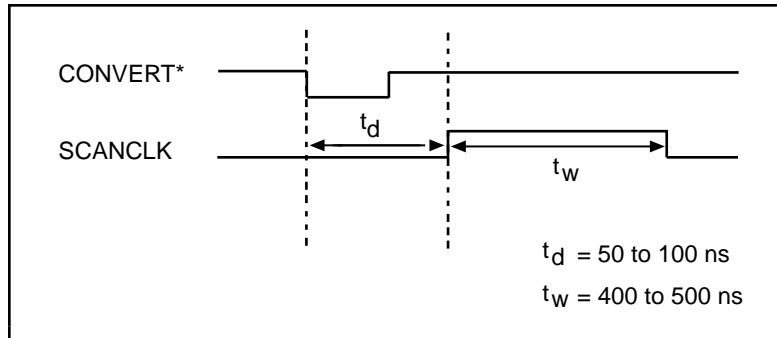


Figure 3-14. SCANCLK Signal Timing

EXTSTROBE* Signal

EXTSTROBE* is an output-only signal that generates either a single pulse in the single-pulse mode or a sequence of eight pulses in the hardware-strobe mode. These two modes are software selectable. An external device can use this signal to latch signals or to trigger events. In the single-pulse mode, software sets the level of the EXTSTROBE* signal high or low. Both a 10 μ s and a 1.2 μ s clock are available for generating a sequence of eight pulses in the hardware-strobe mode. Figure 3-15 shows the timing for the hardware-strobe mode EXTSTROBE* signal.

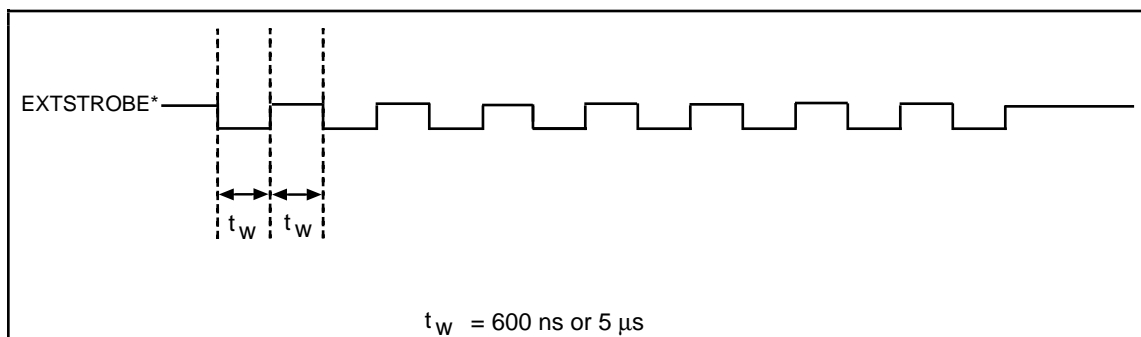


Figure 3-15. EXTSTROBE* Signal Timing

TRIG1 Signal

Any PFI signal can externally input TRIG1, which is available as an output on the PFI0/TRIG1 screw terminal.

Refer to Figures 3-12 and 3-13 for the relationship of TRIG1 to the data acquisition sequence.

As an input, the TRIG1 signal is configured in the edge-detection mode. You can select any PFI pin as the source for TRIG1 and configure the polarity selection for either rising or falling edge. The selected edge of the TRIG1 signal starts the data acquisition sequence for both posttriggered and pretriggered acquisitions.

As an output, the TRIG1 signal reflects the action that initiates a data acquisition sequence. This is true even if the acquisition is being externally triggered by another PFI. The output is an active high pulse with a pulse width of 50 to 100 ns. This output is set to tri-state at start up.

Figures 3-16 and 3-17 show the input and output timing requirements for the TRIG1 signal.

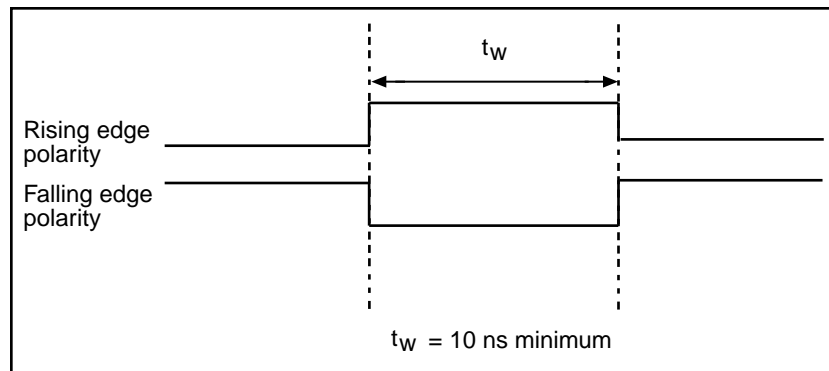


Figure 3-16. TRIG1 and TRIG2 Input Signal Timing

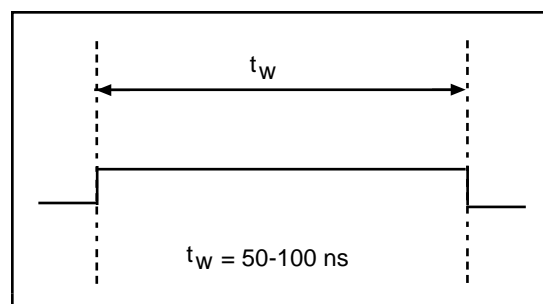


Figure 3-17. TRIG1 and TRIG2 Output Signal Timing

TRIG2 Signal

Any PFI signal can externally input TRIG2, which is available as an output on the PFI1/TRIG2 screw terminal.

Refer to Figure 3-13 for the relationship of TRIG2 to the data acquisition sequence.

As an input, the TRIG2 signal is configured in the edge-detection mode. You can select any PFI signal as the source for TRIG2 and configure the polarity selection for either rising or falling edge. The selected edge of the TRIG2 signal initiates the posttriggered phase of a pretriggered acquisition sequence.

In pretriggered mode, the TRIG1 signal initiates the data acquisition. The scan counter indicates the minimum number of scans before TRIG2 can be recognized. After the scan counter decrements to zero, it is loaded with the number of posttrigger scans to acquire while the acquisition continues. The board ignores the TRIG2 signal if it is asserted prior to the scan counter decrementing to zero. After the selected edge of TRIG2 is received, the board will acquire a fixed number of scans and the acquisition will stop. This mode acquires data both before and after TRIG2 is received.

As an output, the TRIG2 signal reflects the posttrigger in a pretriggered acquisition sequence. This is true even if the acquisition is being externally triggered by another PFI. The TRIG2 signal is not used in posttriggered data acquisition. The output is an active high pulse with a pulse width of 50 to 100 ns. This output is set to tri-state at startup.

Figures 3-16 and 3-17 show the input and output timing requirement for the TRIG2 signal.

STARTSCAN Signal

Any PFI signal can externally input STARTSCAN, which is available as an output on the PFI7/STARTSCAN screw terminal.

Refer to Figures 3-12 and 3-13 for the relationship of STARTSCAN to the data acquisition sequence.

As an input, the STARTSCAN signal is configured in the edge-detection mode. You can select any PFI signal as the source for STARTSCAN and configure the polarity selection for either rising or falling edge. The selected edge of the STARTSCAN signal initiates a scan. The sample interval counter is started if you select internally triggered CONVERT*.

As an output, the STARTSCAN signal reflects the actual start pulse that initiates a scan. This is true even if the starts are being externally triggered by another PFI. You have two output options. The first is an active high pulse with a pulse width of 50 to 100 ns, which indicates the start of the scan. The second option is an active high pulse that terminates at the start of the last conversion in the scan, which indicates a scan in progress. STARTSCAN will be deasserted t_{off} after the last conversion in the scan is initiated. This output is set to tri-state at start up.

Figures 3-18 and 3-19 show the input and output timing requirements for the STARTSCAN signal.

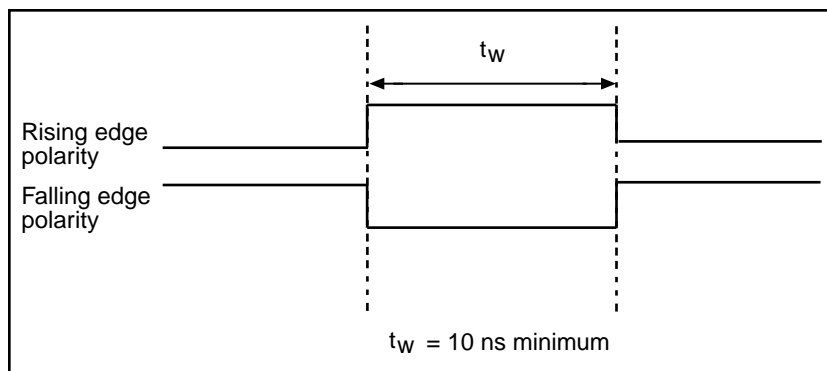


Figure 3-18. STARTSCAN Input Signal Timing

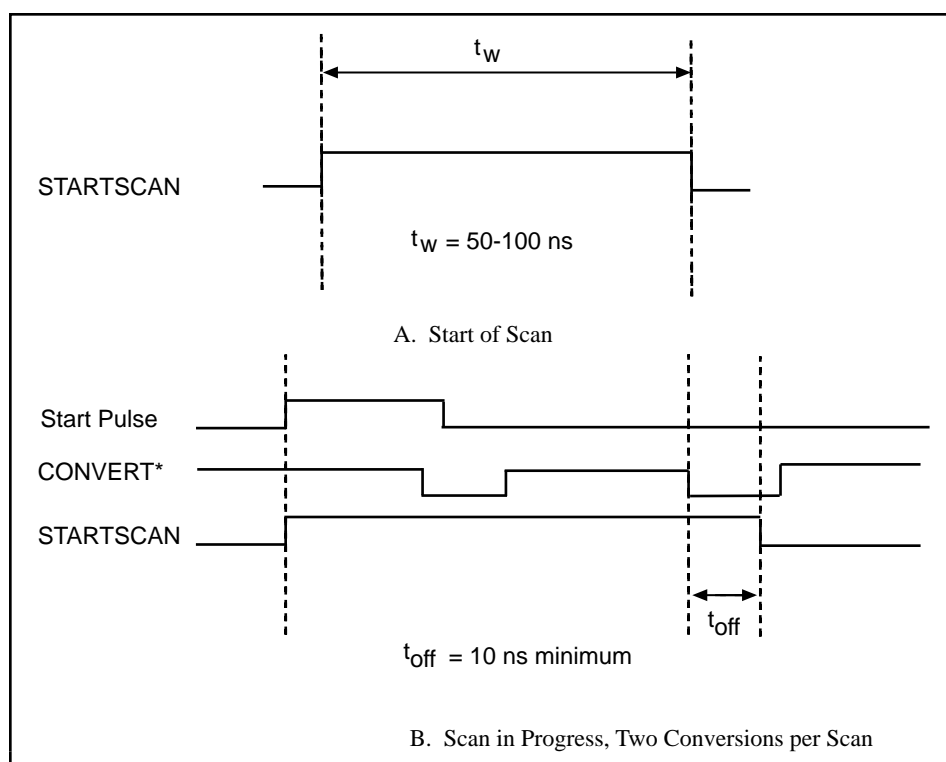


Figure 3-19. STARTSCAN Output Signal Timing

The CONVERT* pulses are masked off until the board generates the STARTSCAN signal. If you are using internally generated conversions, the first CONVERT* will appear when the onboard sample interval counter reaches zero. If you select an external CONVERT*, the first external pulse after STARTSCAN will generate a conversion. The STARTSCAN pulses should be separated by at least one scan period.

A counter on your DAQPad-MIO-16XE-50 internally generates the STARTSCAN signal unless you select some external source. This counter is started by the TRIG1 signal and is stopped either by software or the sample counter.

Scans generated by either an internal or external STARTSCAN signal are inhibited unless they occur within a data acquisition sequence. Scans occurring within a data acquisition sequence may be gated by either the hardware (AIGATE) signal or software gate.

CONVERT* Signal

Any PFI signal can externally input CONVERT*, which is available as an output on the PFI2/CONVERT* screw terminal.

Refer to Figures 3-12 and 3-13 for the relationship of CONVERT* to the data acquisition sequence.

As an input, the CONVERT* signal is configured in the edge-detection mode. You can select any PFI signal as the source for CONVERT* and configure the polarity selection for either rising or falling edge. The selected edge of the CONVERT* signal initiates an A/D conversion.

As an output, the CONVERT* signal reflects the convert pulse that is connected to the ADC. This is true even if the conversions are being externally generated by another PFI. The output is an active low pulse with a pulse width of 50 to 100 ns. This output is set to tri-state at start up.

Figures 3-20 and 3-21 show the input and output timing requirements for the CONVERT* signal.

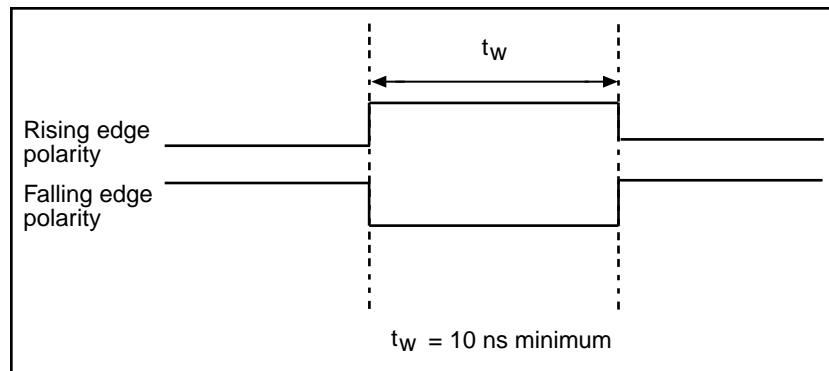


Figure 3-20. CONVERT* Input Signal Timing

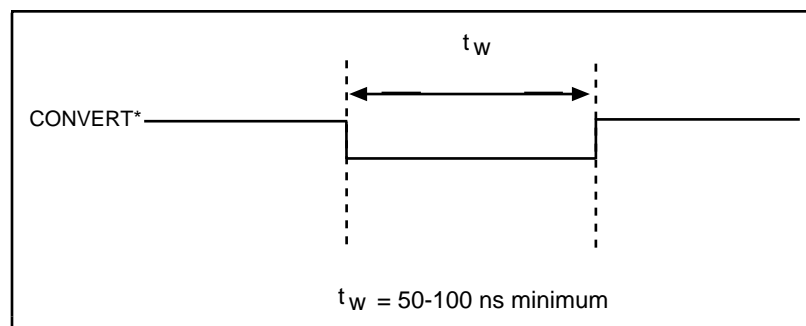


Figure 3-21. CONVERT* Output Signal Timing

The ADC switches to hold mode within 60 ns of the selected edge. This hold-mode delay time is a function of temperature and does not vary from one conversion to the next. Separate the CONVERT* pulses by at least one conversion period.

The DAQPad-MIO-16XE-50 sample interval counter normally generates the CONVERT* signal unless you select some external source. The counter is started by the STARTSCAN signal and continues to count down and reload itself until the scan is finished. It then reloads itself in readiness for the next STARTSCAN pulse.

A/D conversions generated by either an internal or external CONVERT* signal are inhibited unless they occur within a data acquisition sequence. Scans occurring within a data acquisition sequence may be gated by either the hardware (AIGATE) signal or software gate.

AIGATE Signal

Any PFI signal can externally input AIGATE, which is not available as an output on the DAQPad-TB-52. The AIGATE signal can mask off scans in a data acquisition sequence. You can configure the PFI signal you select as the source for the AIGATE signal in either the level-detection or edge-detection mode. You can configure the polarity selection for the PFI signal for either active high or active low.

In the level-detection mode, if AIGATE is active the STARTSCAN signal is masked off and no scans can occur. In the edge-detection mode, the first active edge disables the STARTSCAN signal, and the second active edge enables STARTSCAN.

The AIGATE signal can neither stop a scan in progress nor continue a previously gated-off scan; in other words, once a scan has started, AIGATE does not gate off conversions until the beginning of the next scan and, conversely, if conversions are being gated off, AIGATE does not gate them back on until the beginning of the next scan.

SISOURCE Signal

Any PFI signal can externally input SISOURCE, which is not available as an output on the DAQPad-TB-52. The onboard scan interval counter uses the SISOURCE signal as a clock to time the generation of the STARTSCAN signal. You must configure the PFI signal you select as the source for the SISOURCE signal in the level-detection mode. You can configure the polarity selection for the PFI signal for either active high or active low.

The maximum allowed frequency is 20 MHz, with a minimum pulse width of 23 ns high or low. There is no minimum frequency limitation.

Either the 20 MHz or 100 kHz internal timebase generates the SISOURCE signal unless you select some external source. Figure 3-22 shows the timing requirements for the SISOURCE signal.

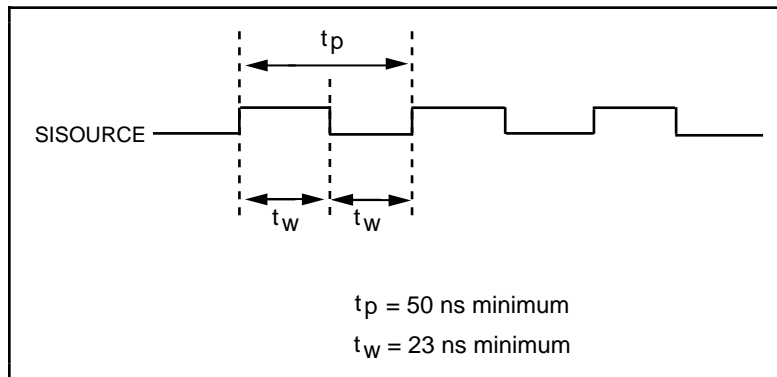


Figure 3-22. SISOURCE Signal Timing

Waveform Generation Timing Connections

The analog group defined for your DAQPad-MIO-16XE-50 is controlled by WFTRIG, UPDATE*, and UISOURCE.

WFTRIG Signal

Any PFI signal can externally input WFTRIG, which is available as an output on the PFI6/WFTRIG screw terminal.

As an input, the WFTRIG signal is configured in the edge-detection mode. You can select any PFI signal as the source for WFTRIG and configure the polarity selection for either rising or falling edge. The selected edge of the WFTRIG signal starts the waveform generation for the DACs. The update interval (UI) counter is started if you select internally generated UPDATE*.

As an output, the WFTRIG signal reflects the trigger that initiates waveform generation. This is true even if the waveform generation is being externally triggered by another PFI. The output is an active high pulse with a pulse width of 50 to 100 ns. This output is set to tri-state at start up.

Figures 3-23 and 3-24 show the input and output timing requirements for the WFTRIG signal.

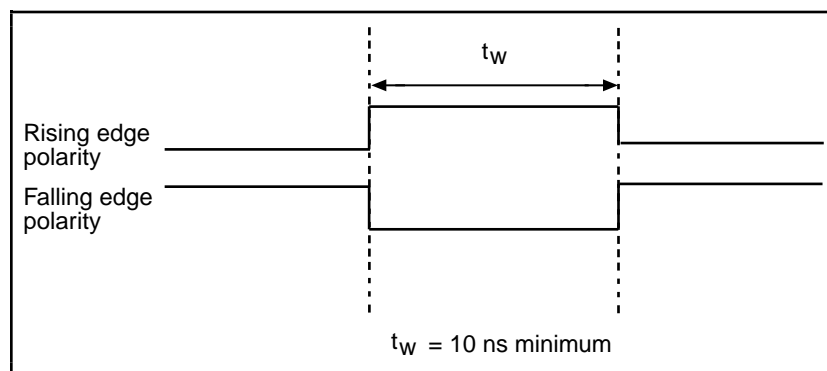


Figure 3-23. WFTRIG Input Signal Timing

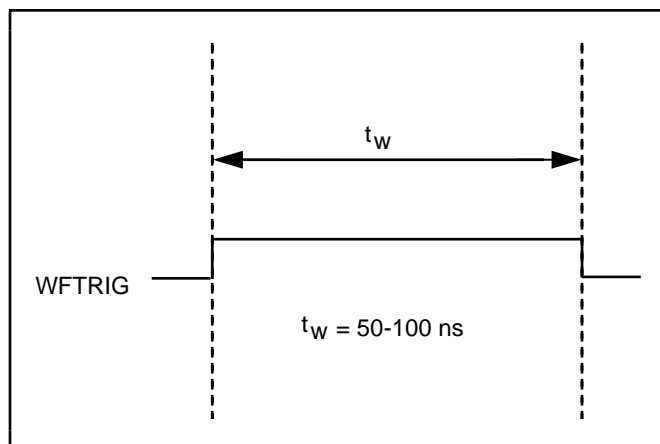


Figure 3-24. WFTRIG Output Signal Timing

UPDATE* Signal

Any PFI signal can externally input UPDATE*, which is available as an output on the PFI5/UPDATE* screw terminal.

As an input, the UPDATE* signal is configured in the edge-detection mode. You can select any PFI signal as the source for UPDATE* and configure the polarity selection for either rising or falling edge. The selected edge of the UPDATE* signal updates the outputs of the DACs. In order to use UPDATE*, you must set the DACs to posted-update mode.

As an output, the UPDATE* signal reflects the actual update pulse that is connected to the DACs. This is true even if the updates are being externally generated by another PFI. The output is an active low pulse with a pulse width of 300 to 350 ns. This output is set to tri-state at start up.

Figures 3-25 and 3-26 show the input and output timing requirements for the UPDATE* signal.

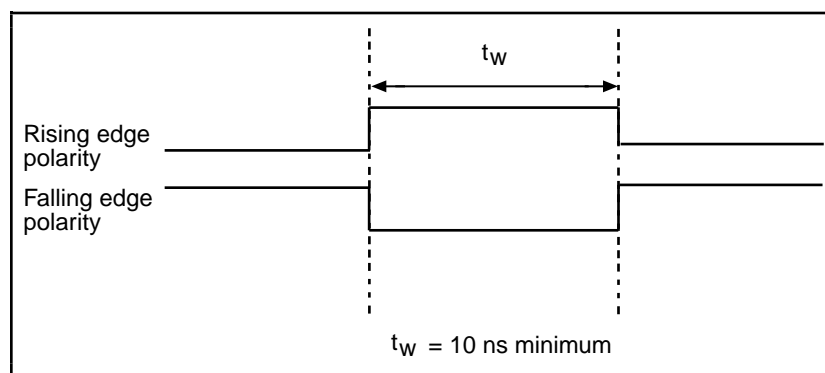


Figure 3-25. UPDATE* Input Signal Timing

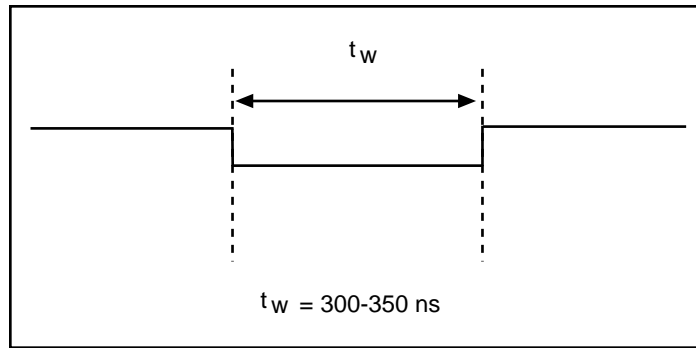


Figure 3-26. UPDATE* Output Signal Timing

The DACs are updated within 100 ns of the leading edge. Separate the UPDATE* pulses with enough time so that new data can be written to the DAC latches.

The DAQPad-MIO-16XE-50 UI counter normally generates the UPDATE* signal unless you select some external source. The UI counter is started by the WFTRIG signal and can be stopped by software or the internal Buffer Counter.

D/A conversions generated by either an internal or external UPDATE* signal do not occur when gated by the software command register gate.

UISOURCE Signal

Any PFI signal can externally input UISOURCE, which is not available as an output on the DAQPad-TB-52. The UI counter uses the UISOURCE signal as a clock to time the generation of the UPDATE* signal. You must configure the PFI signal you select as the source for the UISOURCE signal in the level-detection mode. You can configure the polarity selection for the PFI signal for either active high or active low. Figure 3-27 shows the timing requirements for the UISOURCE signal.

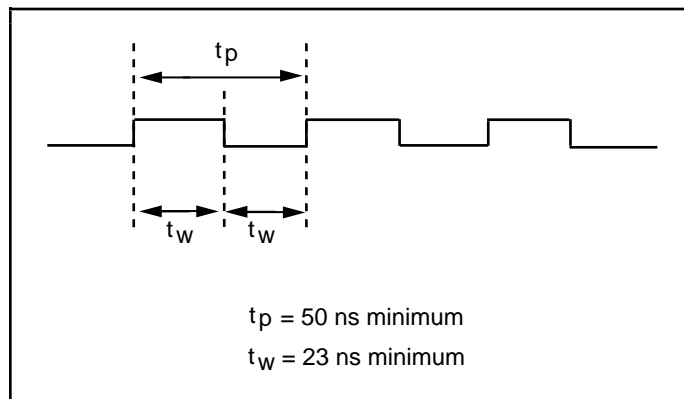


Figure 3-27. UISOURCE Signal Timing

The maximum allowed frequency is 20 MHz, with a minimum pulse width of 23 ns high or low. There is no minimum frequency limitation.

Either the 20 MHz or 100 kHz internal timebase normally generates the UISOURCE signal unless you select some external source.

General-Purpose Timing Signal Connections

The general-purpose timing signals are GPCTR0_SOURCE, GPCTR0_GATE, GPCTR0_OUT, GPCTR0_UP_DOWN, GPCTR1_SOURCE, GPCTR1_GATE, GPCTR1_OUT, GPCTR1_UP_DOWN, and FREQ_OUT.

GPCTR0_SOURCE Signal

Any PFI signal can externally input GPCTR0_SOURCE, which is available as an output on the PFI8/GPCTR0_SOURCE screw terminal.

As an input, the GPCTR0_SOURCE signal is configured in the edge-detection mode. You can select any PFI signal as the source for GPCTR0_SOURCE and configure the polarity selection for either rising or falling edge.

As an output, the GPCTR0_SOURCE signal reflects the actual clock connected to general-purpose counter 0. This is true even if another PFI is externally inputting the source clock. This output is set to tri-state at start up.

Figure 3-28 shows the timing requirements for the GPCTR0_SOURCE signal.

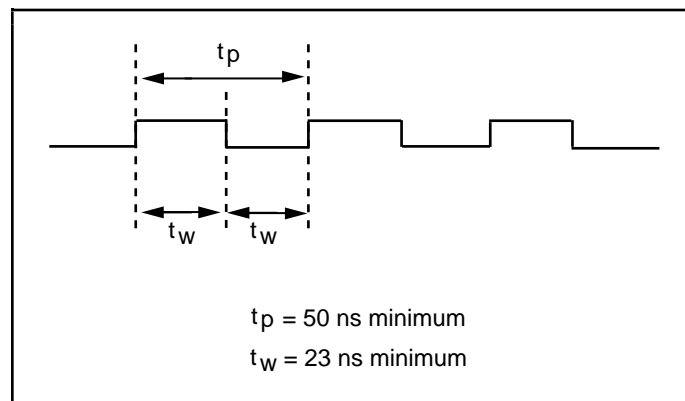


Figure 3-28. GPCTR0_SOURCE Signal Timing

The maximum allowed frequency is 20 MHz, with a minimum pulse width of 23 ns high or low. There is no minimum frequency limitation.

The 20 MHz or 100 kHz timebase normally generates the GPCTR0_SOURCE signal unless you select some external source.

GPCTR0_GATE Signal

Any PFI signal can externally input GPCTR0_GATE, which is available as an output on the PFI9/GPCTR0_GATE screw terminal.

As an input, the GPCTR0_GATE signal is configured in the edge-detection mode. You can select any PFI signal as the source for GPCTR0_GATE and configure the polarity selection for either rising or falling edge. You can use the gate signal in a variety of different applications to perform actions such as starting and stopping the counter, generating interrupts, saving the counter contents, and so on.

As an output, the GPCTR0_GATE signal reflects the actual gate signal connected to general-purpose counter 0. This is true even if the gate is being externally generated by another PFI. This output is set to tri-state at start up.

Figure 3-29 shows the timing requirements for the GPCTR0_GATE signal.

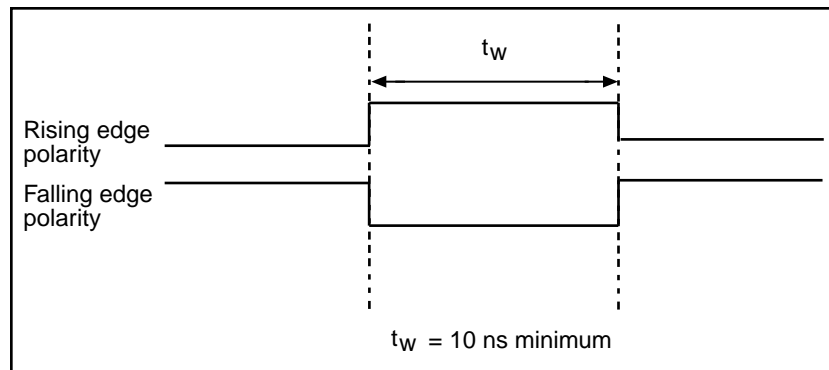


Figure 3-29. GPCTR0_GATE Signal Timing

GPCTR0_OUT Signal

This signal is available only as an output on the GPCTR0_OUT screw terminal. The GPCTR0_OUT signal reflects the terminal count (TC) of general-purpose counter 0. You have two software-selectable output options—pulse on TC and toggle output polarity on TC. The output polarity is software selectable for both options. This output is set to tri-state at start up. Figure 3-30 shows the timing of the GPCTR0_OUT signal.

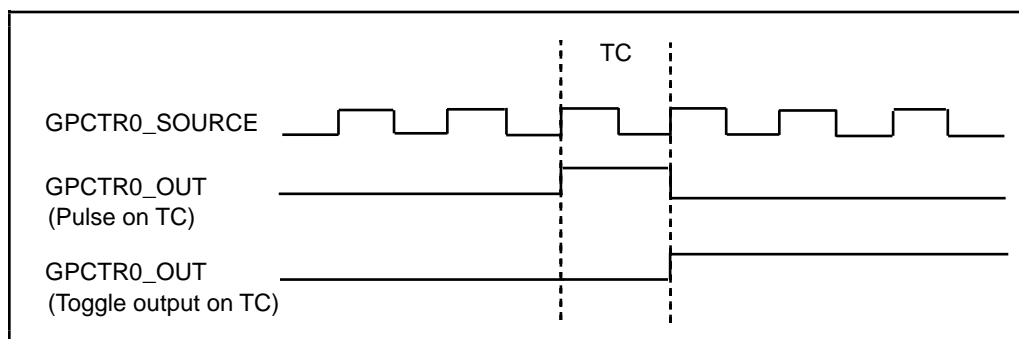


Figure 3-30. GPCTR0_OUT Signal Timing

GPCTR0_UP_DOWN Signal

This signal can be externally input on the DIO6 signal and is not available as an output on the DAQPad-TB-52. The general-purpose counter 0 will count down when this pin is at a logic low and count up when at a logic high. You can disable this input so that software can control the up-down functionality and leave the DIO6 signal free for general use.

GPCTR1_SOURCE Signal

Any PFI signal can externally input GPCTR1_SOURCE, which is available as an output on the PFI3/GPCTR1_SOURCE screw terminal.

As an input, the GPCTR1_SOURCE signal is configured in the edge-detection mode. You can select any PFI signal as the source for GPCTR1_SOURCE and configure the polarity selection for either rising or falling edge.

As an output, the GPCTR1_SOURCE monitors the actual clock connected to general-purpose counter 1. This is true even if the source clock is being externally generated by another PFI. This output is set to tri-state at start up.

Figure 3-31 shows the timing requirements for the GPCTR1_SOURCE signal.

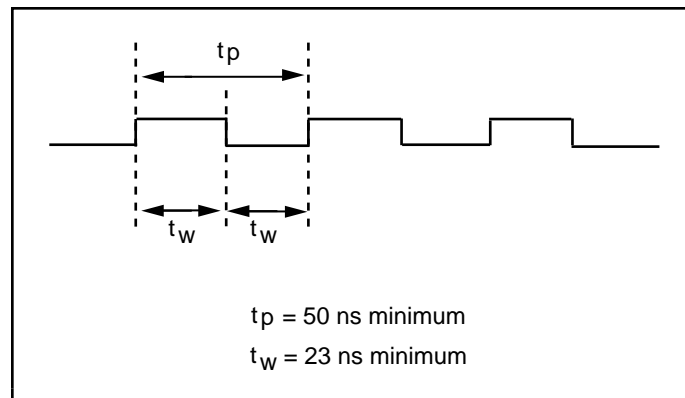


Figure 3-31. GPCTR1_SOURCE Signal Timing

The maximum allowed frequency is 20 MHz, with a minimum pulse width of 23 ns high or low. There is no minimum frequency limitation.

The 20 MHz or 100 kHz timebase normally generates the GPCTR1_SOURCE unless you select some external source.

GPCTR1_GATE Signal

Any PFI signal can externally input GPCTR1_GATE, which is available as an output on the PFI4/GPCTR1_GATE screw terminal.

As an input, the GPCTR1_GATE signal is configured in edge-detection mode. You can select any PFI screw terminal as the source for GPCTR1_GATE and configure the polarity selection for either rising or falling edge. You can use the gate signal in a variety of different applications to perform such actions as starting and stopping the counter, generating interrupts, saving the counter contents, and so on.

As an output, the GPCTR1_GATE signal monitors the actual gate signal connected to general-purpose counter 1. This is true even if the gate is being externally generated by another PFI. This output is set to tri-state at start up.

Figure 3-32 shows the timing requirements for the GPCTR1_GATE signal.

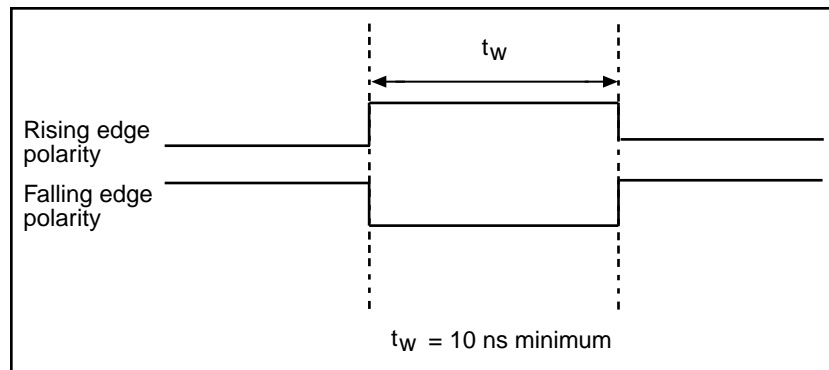


Figure 3-32. GPCTR1_GATE Signal Timing

GPCTR1_OUT Signal

This signal is available only as an output on GPCTR1_OUT. The GPCTR1_OUT signal monitors the TC board general-purpose counter 1. You have two software-selectable output options—pulse on TC and toggle output polarity on TC. The output polarity is software selectable for both options. This output is set to tri-state at start up. Figure 3-33 shows the timing requirements for the GPCTR1_OUT signal.

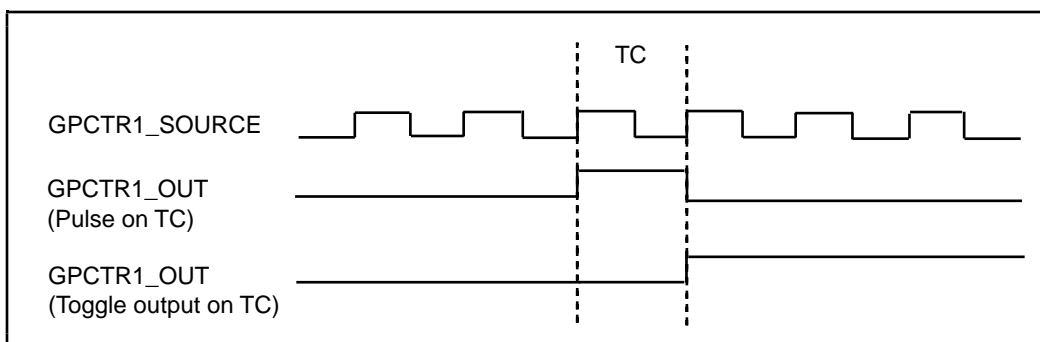


Figure 3-33. GPCTR1_OUT Signal Timing

GPCTR1_UP_DOWN Signal

This signal can be externally input on the DIO7 signal and is not available as an output on the DAQPad-TB-52. General-purpose counter 1 counts down when this signal is at a logic low and counts up at a logic high. This input can be disabled so that software can control the up-down functionality and leave the DIO7 signal free for general use.

Figure 3-34 shows the timing requirements for the GATE and SOURCE input signals and the timing specifications for the OUT output signals of your DAQPad-MIO-16XE-50.

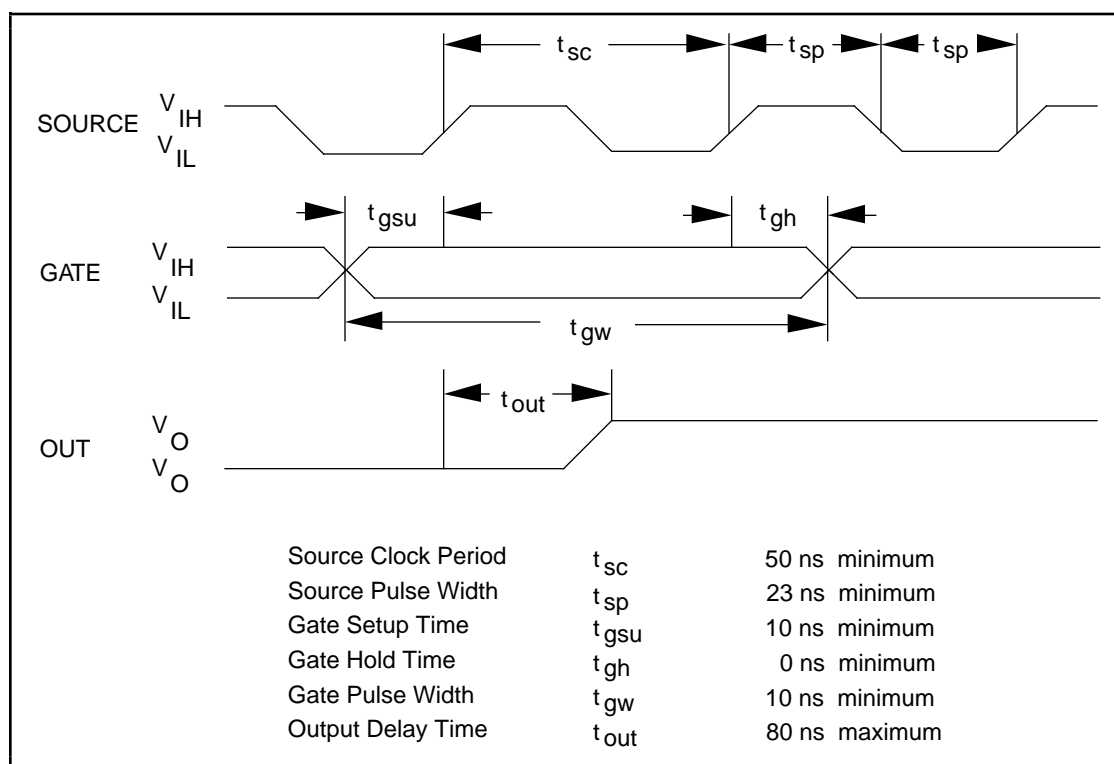


Figure 3-34. GPCTR Timing Summary

The GATE and OUT signal transitions shown in Figure 3-34 are referenced to the rising edge of the SOURCE signal. This timing diagram assumes that the counters are programmed to count rising edges. The same timing diagram, but with the source signal inverted and referenced to the falling edge of the source signal, would apply when the counter is programmed to count falling edges.

The GATE input timing parameters are referenced to the signal at the SOURCE input or to one of the internally generated signals on the DAQPad-MIO-16XE-50. Figure 3-34 shows the GATE signal referenced to the rising edge of a source signal. The gate must be valid (either high or low) at least 10 ns before the rising or falling edge of a source signal for the gate to take effect at that source edge as shown by t_{gsu} and t_{gh} in Figure 3-34. The gate signal is not required to be held after the active edge of the source signal.

If an internal timebase clock is used, the gate signal cannot be synchronized with the clock. In this case, gates applied close to a source edge take effect either on that source edge or on the next

one. This arrangement results in an uncertainty of one source clock period with respect to unsynchronized gating sources.

The OUT output timing parameters are referenced to the signal at the SOURCE input or to one of the internally generated clock signals on the DAQPad-MIO-16XE-50. Figure 3-34 shows the OUT signal referenced to the rising edge of a source signal. Any OUT signal state changes occur within 80 ns after the source signal rising or falling edge.

FREQ_OUT Signal

This signal is available only as an output on FREQ_OUT. The FREQ_OUT signal is the output of the DAQPad-MIO-16XE-50 frequency generator. The frequency generator is a 4-bit counter that can divide its input clock by 1 through 16. The input clock of the frequency generator is software selectable from the internal 10 MHz and 100 kHz timebases. The output polarity is software selectable. This output is set to tri-state at start up.

Field Wiring Considerations

Environmental noise can seriously affect the accuracy of measurements made with your DAQPad-MIO-16XE-50 if you do not take proper care when running signal wires between signal sources and the board. The following recommendations apply mainly to analog input signal routing to the board, although they also apply to signal routing in general.

You can minimize noise pickup and maximize measurement accuracy by taking the following precautions:

- Use differential analog input connections to reject common-mode noise.
- Use individually shielded, twisted-pair wires to connect analog input signals to the DAQPad-TB-52. With this type of wire, the signals attached to the ACH+ and ACH- inputs are twisted together and then covered with a shield. You then connect this shield only at one point to the signal source ground. This kind of connection is required for signals traveling through areas with large magnetic fields or high electromagnetic interference.
- Route signals to the board carefully. Keep cabling away from noise sources. The most common noise source in a PC data acquisition system is the video monitor. Separate the monitor from the analog signals as much as possible.

The following recommendations apply for all signal connections to your DAQPad-MIO-16XE-50:

- Separate DAQPad-MIO-16XE-50 signal lines from high-current or high-voltage lines. These lines are capable of inducing currents in or voltages on the DAQPad-MIO-16XE-50 signal lines if they run in parallel paths at a close distance. To reduce the magnetic coupling between lines, separate them by a reasonable distance if they run in parallel, or run the lines at right angles to each other.
- Do not run signal lines through conduits that also contain power lines.
- Protect signal lines from magnetic fields caused by electric motors, welding equipment, breakers, or transformers by running them through special metal conduits.

Chapter 4

Calibration

This chapter discusses the calibration procedures for the analog I/O circuitry on your DAQPad-MIO-16XE-50. If you are using the NI-DAQ device driver, that software includes calibration functions for performing all of the steps in the calibration process for the analog I/O circuitry.

You cannot calibrate the constant current source used for cold-junction sensing and external current excitation. The constant current source is factory calibrated, and National Instruments can recalibrate your unit if needed. To maintain the cold-junction sensor accuracy, National Instruments recommends recalibrating the current source every year.

Calibration refers to the process of minimizing measurement and output voltage errors by making small circuit adjustments. On the DAQPad-MIO-16XE-50, these adjustments take the form of writing values to onboard calibration DACs (CalDACs).

Some form of board calibration is required for all but the most forgiving applications. If no board calibration were performed, your signals and measurements could have very large offset, gain, and linearity errors.

This chapter describes three levels of calibration: loading calibration constants, self-calibration and external calibration. The first level is the fastest, easiest, and least accurate, whereas the last level is the slowest, most difficult, and most accurate.

Loading Calibration Constants

Your DAQPad-MIO-16XE-50 is factory calibrated before shipment to the levels indicated in Appendix A, *Specifications*. The associated calibration constants—the values that were written to the CalDACs to achieve calibration in the factory—are stored in the onboard nonvolatile memory (EEPROM). Because the CalDACs have no memory capability, they do not retain calibration information when the board is unpowered. Loading calibration constants refers to the process of loading the CalDACs with the values stored in the EEPROM. NI-DAQ software determines when this is necessary and does it automatically. If you are not using NI-DAQ, you must load these values yourself.

This method of calibration is not very accurate because it does not take into account the fact that the board measurement and output voltage errors can vary with time and temperature. It is better to self-calibrate when the board is installed in the environment in which it will be used.

Self-Calibration

There is room in the EEPROM for several modifiable user calibration areas in addition to the permanent factory calibration area. This means that you can load the CalDACs with values either from the original factory calibration or from a calibration that you subsequently performed.

Your DAQPad-MIO-16XE-50 can measure and correct for almost all of its calibration-related errors without any external signal connections. Your National Instruments software provides a self-calibration method you can use. This self-calibration process, which takes only a few seconds, is the preferred method of assuring accuracy in your application. You should initiate self-calibration to ensure that the effects of any offset, gain, and linearity drifts, particularly those due to warmup, are minimized.

Immediately after self-calibration, the only significant residual calibration error could be gain error due to time or temperature drift of the onboard voltage reference. This error is addressed by external calibration, which is discussed in the following section. If you are interested primarily in relative measurements, you can ignore a small amount of gain error, and self-calibration should be sufficient.

External Calibration

Your DAQPad-MIO-16XE-50 has an onboard calibration reference to ensure the accuracy of self-calibration. Its specifications are listed in Appendix A, *Specifications*. The reference voltage is measured at the factory and stored in the EEPROM for subsequent self-calibrations. This voltage is stable enough for most applications, but if you are using your board at an extreme temperature or if the onboard reference has not been measured for a year or more, you may wish to externally calibrate your board.

An external calibration refers to calibrating your board with a known external reference rather than relying on the onboard reference. Redetermining the value of the onboard reference is part of this process, and the results can be saved in the EEPROM, so you should not have to perform an external calibration very often. You can externally calibrate your board by calling the NI-DAQ `Calibrate_E_Series` function.

To externally calibrate your board, be sure to use a very accurate external reference. The reference should be several times more accurate than the board itself. For example, to calibrate a 16-bit board, the external reference should be at least $\pm 0.001\%$ (± 10 ppm) accurate.

Appendix A

Specifications

This appendix lists the DAQPad-MIO-16XE-50 specifications. These specifications are typical at 25° C unless otherwise noted.

Analog Input

Input Characteristics

Number of channels 16 single-ended or 8 differential (software-selectable)
 Type of ADC Successive approximation
 Resolution 16 bits, 1 in 65,536
 Maximum sampling rate 20 kS/s guaranteed
 Input signal ranges

Board Gain (Software Selectable)	Board Range (Software Selectable)	
	Bipolar	Unipolar
1	±10 V	0 to 10 V
2	±5 V	0 to 5 V
10	±1 V	0 to 1 V
100	±0.1 V	0 to 0.1 V

Input coupling DC
 Maximum working voltage Each input should remain within ±11 V of ground and the average of V_{+in} and V_{-in} should remain within ±8 V of ground
 Overvoltage protection ±25 V powered on, ±15 V powered off
 Inputs protected ACH<0..15>, AISENSE
 FIFO buffer size 512 samples
 Data transfers Interrupts, programmed I/O
 Configuration memory size 512 words

Transfer Characteristics

Relative accuracy ±0.5 LSB typ, ±1 LSB max
 DNL ±0.5 LSB typ, ±1 LSB max
 No missing codes 16 bits, guaranteed
 Offset error
 Pregain error after calibration ±3 µV max
 Pregain error before calibration ±1 mV max
 Postgain error after calibration ±76 µV max
 Postgain error before calibration ±4 mV max
 Gain error (relative to calibration reference)
 After calibration (gain = 1) ±30.5 ppm of reading max
 Before calibration ±2250 ppm of reading max
 With gain error adjusted to 0 at gain = 1
 Gain = 2, 10 ±100 ppm of reading
 Gain = 100 ±250 ppm of reading

Amplifier Characteristics

Input impedance	
Normal, powered on.....	20 G Ω in parallel with 100 pF
Powered off	820 Ω min
Overload.....	820 Ω min
Input bias current	
for ACH<0> and ACH<8>	± 3.5 nA
for ACH<1..7> and ACH<9..15>	± 3 nA
Input offset current	± 4 nA
CMRR, DC to 60 Hz	
Gain = 1	80 dB
Gain = 2.....	86 dB
Gain = 10.....	100 dB
Gain = 100.....	120 dB

Dynamic Characteristics

Bandwidth	
Gain = 1, 2.....	63 kHz
Gain = 10.....	60 kHz
Gain = 100.....	42 kHz
Settling time for full-scale step	50 μ s max to ± 1 LSB, all gains and ranges
System noise (including quantization noise)	
Gain = 1, 2, 10.....	0.5 LSB rms
Gain = 100.....	0.8 LSB rms bipolar, 1.4 LSB rms unipolar
Crosstalk.....	-85 dB max, DC to 20 kHz

Stability

Recommended warm-up time	15 minutes
Offset temperature coefficient	
Pregain	± 1 μ V/ $^{\circ}$ C
Postgain	± 12 μ V/ $^{\circ}$ C
Gain temperature coefficient.....	± 5 ppm/ $^{\circ}$ C
Onboard calibration reference	
Level	5.000 V (± 2.0 mV) (actual value stored in EEPROM)
Temperature coefficient	± 2 ppm/ $^{\circ}$ C max
Long-term stability.....	± 15 ppm/ $\sqrt{1,000}$ h

Analog Output

Output Characteristics

Number of channels	2
Resolution.....	12 bits, 1 in 4,096
Update rate ¹	500 S/s EPP
	400 S/s Centronics
Type of DAC	Double-buffered, multiplying
FIFO buffer size	None
Data transfers	Interrupts, programmed I/O

¹ Typical timing data observed in LabVIEW on a 486 DX2/66 MHZ PC using a Trunknet plug-in Centronics parallel port card and a FarPoint F/Port plug-in enhanced parallel port card.

Transfer Characteristics

Relative accuracy (INL)	± 0.5 LSB max
DNL	± 1 LSB max
Monotonicity	12 bits, guaranteed
Offset error	
After calibration	± 0.5 mV max
Before calibration	± 85 mV max
Gain error (relative to calibration reference)	
After calibration	$\pm 0.01\%$ of output max
Before calibration	$\pm 1\%$ of output max

Voltage Output

Range	± 10 V
Output coupling	DC
Output impedance	0.1Ω max
Current drive	± 5 mA
Protection	Short-circuit to ground
Power-on state	0 V (± 85 mV)

Dynamic Characteristics

Settling time for full-scale step	$50 \mu\text{s}$ to ± 0.5 LSB accuracy
Slew rate	2 V/ μs
Noise	$40 \mu\text{V}_{\text{rms}}$, DC to 1 MHz
Glitch energy (at major carry)	
Magnitude	± 30 mV
Duration	$10 \mu\text{s}$

Stability

Offset temperature coefficient	$\pm 25 \mu\text{V}/^\circ\text{C}$
Gain temperature coefficient	± 15 ppm/ $^\circ\text{C}$
Onboard calibration reference	
Level	5.000 V (± 2 mV) (actual value stored in EEPROM)
Temperature coefficient	± 2 ppm/ $^\circ\text{C}$ max
Long-term stability	± 15 ppm/ $\sqrt{1,000}$ h

Excitation

Current Output Characteristics

Channels	1
Level	$100 \mu\text{A} \pm 50$ nA
Max load resistance	80 k Ω
Temperature coefficient	± 20 ppm/ $^\circ\text{C}$
Long-term stability	$\pm 2,530$ ppm/ $\sqrt{1,000}$ h

Power Requirement

Voltage	9 to 42 VDC max
Reverse voltage protection	-42 VDC max
Power	325 mA at 12 VDC
Discharge time with BP-1 battery pack	9 h

Physical

Dimensions	3.8 by 14.6 by 21.3 cm (1.5 by 5.8 by 8.4 in)
Connector	Two 36-pin female MDR 1284-C rear connectors
Weight	0.8 kg (1.9 lb)

Environment

Operating temperature	0 to 55° C
Storage temperature	-55 to 70° C
Relative humidity	5% to 90% noncondensing

DAQPad-TB-52 Screw Terminal Block

I/O connections	52 labeled screw terminals, with strain relief
Field wire gauge	26–16 AWG
Fuse on +5 V screw terminal	250 mA, 125 V, Pico II, fast-acting from Littlefuse

DAQPad-TB-52 Cold-Junction Temperature Sensor

Absolute accuracy	2.0°C ³
Relative accuracy	0.5°C ³
Output	0.15 V (at 55°C) to 1.63 V (at 0°C)
Connection	Independent analog input channel (does not reserve any ACH inputs)

³ Includes errors from analog input, excitation current source with one-year calibration, cold-junction sensor thermistor and thermal gradient over screw terminals.

Appendix B

Parallel Port Configuration Troubleshooting

This appendix contains parallel port configuration troubleshooting information.

1. The configuration utility (WDAQCONF for Windows and DAQCONF for DOS) reports an error when I try to save the settings.

If you receive a base address or communication error, check items a through e:

- a. Make sure your chassis is switched on and the screws of the cable are tightly fastened.
- b. Make sure you have connected the parallel port cable from the computer to port A of the DAQPad-MIO-16XE-50.
- c. Check that your base address is correct. This can be done either by checking your computer technical manual or, in some cases, by checking the base address jumper. In Windows applications, you may have a Hardware Control panel that will allow you to enable and disable the parallel port. Common parallel port addresses are 0x378, 0x278, 0x3BC, 0x280, and 0x290 hex.

Note: *If your parallel port address does not appear under the Base Address window in WDAQCONF, you must turn off the Auto Test option under the Options menu in the main window to access the other parallel port addresses.*

- d. Check that you are using the included 1 m parallel port cable. If you suspect that you have a bad parallel port cable, replace it with a new cable or one that you know works with another peripheral. If you are using another parallel port cable, check to make sure it meets the required specifications. Refer to the *Parallel Port Cable Specifications* section for these specifications.
- e. If you are still having problems, please report the computer make and model number to National Instruments. If you have a noncompatible parallel port, try adding an enhanced parallel port as described in the *Optional Equipment* section of Chapter 1, *Introduction*.

If you receive an interrupt conflict error, check items f through i:

- f. IRQ levels 7 and 5 are the most common interrupt levels reserved for the parallel port. Try saving your configuration for both IRQ7 and IRQ5.

Note: *If either IRQ level 7 or level 5 is unselectable under the IRQ menu in WDAQCONF, another National Instruments board is using this interrupt. You will have to free the appropriate IRQ level to allocate it for your parallel port.*

- g. You may have an interrupt conflict with a non-National Instruments device. If you have installed a PCMCIA card or a plug-in board, you will have to ensure that neither IRQ5 nor IRQ7 has been allocated for these devices.

Note: *For some PCMCIA cards installed with Cardware, it may be possible to exclude your parallel port interrupt level by including the line XIRQ=7, E for IRQ 7 or XIRQ=5, E for IRQ 5 in the cardware.ini file.*

- h. You may have an interrupt conflict with a Windows-based application. You will have to ensure that neither IRQ5 nor IRQ7 has been allocated for this application. One place to search is your `system.ini` file under Windows.
- i. If you are still having problems, please report the computer make and model number to National Instruments.

2. The configuration utility works fine when I use a 3 ft. parallel port cable but reports an error when I try to use a longer parallel port cable.

- a. Ensure that your parallel port cable meets the required specifications. Refer to the *Parallel Port Cable Specifications* section for these specifications.
- b. You may have to use a unidirectional parallel port extender in order to achieve long distance solutions (one such extender is made by BRAVO Communications). Your parallel port will be recognized as a Centronics port with this extender.

Note: *National Instruments does not guarantee functionality with parallel port cables longer than 6 ft.*

3. I have an EPP port, but the configuration utility reports that I have a Centronics port when I try to save the configuration settings.

- a. You may have to enable your parallel port as an EPP port. Check for configuration utilities and ensure that your port is configured for EPP.
- b. It is possible that the DAQPad-MIO-16XE-50 and NI-DAQ software are not compatible with your EPP port. In this case, your parallel port will be treated as a Centronics port.

Parallel Port Cable Specifications

- Unbalanced impedance of each signal and ground pair of $62 \Omega \pm 6 \Omega$, 4 to 16 MHz
- Unbalanced capacitance of each cable pair less than 107 pF/m at 1 MHz
- DC resistance of each cable wire less than 0.22 Ω /m
- Total propagation delay less than 150 ns

Appendix C

Customer Communication

For your convenience, this appendix contains forms to help you gather the information necessary to help us solve technical problems you might have as well as a form you can use to comment on the product documentation. Filling out a copy of the *Technical Support Form* before contacting National Instruments helps us help you better and faster.

National Instruments provides comprehensive technical assistance around the world. In the U.S. and Canada, applications engineers are available Monday through Friday from 8:00 a.m. to 6:00 p.m. (central time). In other countries, contact the nearest branch office. You may fax questions to us at any time.

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Technical support fax: (800) 328-2203
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Technical Support Form

Photocopy this form and update it each time you make changes to your software or hardware, and use the completed copy of this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

If you are using any National Instruments hardware or software products related to this problem, include the configuration forms from their user manuals. Include additional pages if necessary.

Name _____

Company _____

Address _____

Fax (____) _____ Phone (____) _____

Computer brand _____ Model _____ Processor _____

Operating system _____

Speed _____ MHz RAM _____ MB Display adapter _____

Mouse _____ yes _____ no Other adapters installed _____

Hard disk capacity _____ MB Brand _____

Instruments used _____

National Instruments hardware product model _____ Revision _____

Configuration _____

National Instruments software product _____ Version _____

Configuration _____

The problem is _____

List any error messages _____

The following steps will reproduce the problem _____

DAQPad-MIO-16XE-50 Hardware and Software Configuration Form

Record the settings and revisions of your hardware and software on the line to the right of each item. Complete a new copy of this form each time you revise your software or hardware configuration, and use this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

National Instruments Products

- DAQPad Product _____
- Interrupt Level of Parallel Port _____
- Base Address of Parallel Port _____
- NI-DAQ or LabWindows/CVI Version _____
- Software Version _____

Other Products

- Computer Model _____
- Microprocessor _____
- Clock Frequency _____
- Type of Video Board Installed _____
- Operating System (DOS or Windows) _____
- Operating System Version _____
- Operating System Mode _____
- Programming Language _____
- Programming Language Version _____
- Other Boards in System _____
- Interrupt Level of Other Boards _____

Documentation Comment Form

National Instruments encourages you to comment on the documentation supplied with our products. This information helps us provide quality products to meet your needs.

Title: **DAQPad-MIO-16XE-50 User Manual**

Edition Date: **June 1995**

Part Number: **320935A-01**

Please comment on the completeness, clarity, and organization of the manual.

If you find errors in the manual, please record the page numbers and describe the errors.

Thank you for your help.

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Glossary

Prefix	Meaning	Value
p-	pico-	10 ⁻¹²
n-	nano-	10 ⁻⁹
μ-	micro-	10 ⁻⁶
m-	milli-	10 ⁻³
k-	kilo-	10 ³
M-	mega-	10 ⁶

°	degrees
>	greater than
≥	greater than or equal to
<	less than
-	negative of, or minus
Ω	ohms
%	percent
±	plus or minus
+	positive of, or plus
+5 V	+5 volts signal
A	amperes
AC	alternating current
ACH <0..7>	Analog Channel 0 through 7 signals
A/D	analog-to-digital
ADC	analog-to-digital converter
AIGATE	analog input gate signal
AIGND	analog input ground signal
AISENSE	analog input sense signal
ANSI	American National Standards Institute
AOGND	analog output ground signal
AWG	American Wire Gauge
C	Celsius
CJTEMP	temperature sensor channel
CONVERT*	convert signal
D/A	digital-to-analog
DAC	digital-to-analog converter
DAQ	data acquisition
DAC0OUT, DAC1OUT	voltage output signals for channels 0 and 1
dB	decibels
DC	direct current
DIFF	differential
DIN	Deutsche Industrie Norme
DIO<0..7>	digital I/O signals
DMA	direct memory access
EEPROM	electrically erased programmable read-only memory
EPP	Enhanced Parallel Port
EXTREF	external reference signal
EXTSTROBE*	external strobe signal

FREQ_OUT	frequency output signal
ft	feet
GPCTR0_GATE	counter 0 gate signal
GPCTR0_OUT	counter 0 output signal
GPCTR0_SOURCE	counter 0 source signal
GPCTR0_UP_DOWN	counter 1 up/down signal
GPCTR1_GATE	counter 1 gate signal
GPCTR1_OUT	counter 1 output signal
GPCTR1_SOURCE	counter 1 source signal
GPCTR1_UP_DOWN	counter 1 up/down signal
hex	hexadecimal
IEX+	current excitation signal
IEX-	current excitation return signal
in.	inches
I/O	input/output
LED	light-emitting diode
LSB	least significant bit
m	meters
max	maximum
MB	megabytes of memory
min	minimum
MIO	multifunction I/O
MSB	most significant bit
NRSE	nonreferenced single-ended
PA, PB, PC <0..7>	Port A, B, or C 0 through 7 signals
PFI<0..9>	programmable function input signals
PGIA	programmable gain instrumentation amplifier
PTC	positive temperature coefficient
rms	root mean square
R_T	thermistor resistance in ohms
RSE	referenced single-ended
RTD	resistance temperature device
RTSI	Real-Time System Integration
s	seconds
SCANCLK	scan clock signal
SCXI	Signal Conditioning eXtensions for Instrumentation (bus)
STARTSCAN	start of scan signal
T_C	thermistor temperature in Celsius
T_F	thermistor temperature in Fahrenheit
T_K	thermistor temperature in Kelvin
TRIG1, TRIG2	trigger 1,2 signals
TTL	transistor-transistor logic
typ	typical
U1SOURCE	counter 1 update interval source signal
UPDATE*	update signal
V	volts
V_{in}^{\pm}	positive/negative input voltage
V_{cm}	common-mode noise
V_{diff}	differential input voltage
V_{EXT}	external voltage
VI	virtual instrument
V_m	measured voltage
V_{rms}	volts, root-mean-square
V_s	signal source

V _{temp sensor}	temperature sensor in volts
W	watts
WFTRIG	waveform trigger signal

Index

Numbers/Symbols

32-bit registers, accessing, I-3

A

ACH<0..15> signal
 analog input connections, 3-7
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3
AIGATE signal, 3-27
AIGND signal
 analog input connections, 3-7 to 3-8
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3
 differential connections for floating signal sources, 3-12 to 3-13
AISENSE signal
 analog input connections, 3-7
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3
analog input
 configuration, 2-3 to 2-7
 dither, 2-5 to 2-6
 input mode, 2-3 to 2-4
 input polarity and range, 2-4 to 2-5
 multiple-channel scanning considerations, 2-6 to 2-7
 signal connections, 3-7 to 3-15
 differential connection considerations, 3-10 to 3-13
 exceeding input ranges (warning), 3-7
 floating signal sources, 3-8
 ground-referenced signal sources, 3-8
 input configuration (figure), 3-9
 single-ended connection considerations, 3-13 to 3-15
 types of signal sources, 3-8

 specifications
 amplifier characteristics, A-2
 dynamic characteristics, A-2
 input characteristics, A-1
 stability, A-2
 transfer characteristics, A-1

analog output
 configuration, 2-7
 signal connections, 3-17
 specifications
 dynamic characteristics, A-3
 output characteristics, A-2
 stability, A-3
 transfer characteristics, A-3
 voltage output, A-3
AOGND signal
 analog output connections, 3-17
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3

B

battery pack (BP-1), 1-4
bipolar input
 definition, 2-4
 mixing bipolar and unipolar channels (note), 2-4
board configuration. *See* configuration.
BP-1 battery pack, 1-4

C

cables
 field wiring considerations, 3-36
 parallel port cables, 1-4
 specifications, B-2
calibration, 4-1 to 4-2
 external calibration, 4-2
 loading calibration constants, 4-2
 self-calibration, 4-2

cold-junction temperature sensor
 converting sensor reading to thermistor temperature, 2-8
 description, 2-7
 specifications, A-5
 common-mode signal rejection, 3-15
 configuration. *See also* input configurations.
 analog input, 2-3 to 2-7
 dither, 2-5 to 2-6
 input mode, 2-3 to 2-4
 input polarity and range, 2-4 to 2-5
 multiple-channel scanning considerations, 2-6 to 2-7
 analog output, 2-7
 cold-junction sensing, 2-7 to 2-8
 digital I/O, 2-8
 parallel port, 2-3
 programmable function inputs (PFIs), 2-9
 troubleshooting parallel port configuration, B-1 to B-2
 CONVERT* signal
 signal routing multiplexer for controlling (figure), 2-9
 timing connections, 3-26 to 3-27
 input timing (figure), 3-26
 output timing (figure), 3-26
 customer communication, *xi*, C-1

D

DAC0OUT signal
 analog output connections, 3-17
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3
 DAC1OUT signal
 analog output connections, 3-17
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3
 DAQPad-MIO-16XE-50
 features, 1-1
 getting started, 1-2
 optional equipment, 1-4
 software programming choices
 LabVIEW and
 LabWindows/CVI, 1-2

NI-DAQ driver software, 1-3
 register-level programming, 1-4
 DAQPad-TB-52 terminal block
 description, 3-2
 I/O signal summary (table), 3-5
 screw terminal layout (figure), 3-2
 signal connections, 3-6
 signal descriptions (table), 3-3 to 3-4
 specifications, A-5
 data acquisition timing connections, 3-21 to 3-28
 AIGATE signal, 3-27
 CONVERT* signal, 3-26 to 3-27
 EXTSTROBE* signal, 3-22
 SCANCLK signal, 3-22
 SISOURCE signal, 3-27 to 3-28
 STARTSCAN signal, 3-24 to 3-26
 TRIG1 signal, 3-23
 TRIG2 signal, 3-24
 typical posttriggered acquisition (figure), 3-21
 typical pretriggered acquisition (figure), 3-21
 DGND signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3
 digital I/O connections, 3-18
 DIFF (differential) input mode
 description (table), 2-4
 ground-referenced signal sources, 3-11
 illustration, 3-11
 nonreferenced or floating signal sources, 3-12 to 3-13
 illustration, 3-12
 recommended configuration (figure), 3-9
 signal connection considerations, 3-10
 single-ended connections, 3-13 to 3-15
 floating signal sources (RSE), 3-14
 grounded signal sources (NRSE), 3-14 to 3-15
 when to use, 3-10
 digital I/O
 configuring, 2-8
 signal connections, 3-18
 specifications, A-4
 digital trigger specifications, A-4

DIO<0..7> signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3
 digital I/O connections, 3-18

dither
 enabling, 2-5 to 2-6
 signal acquisition effects (figure), 2-6

documentation
 conventions used in manual, *x*
 National Instruments documentation, *x*
 organization of manual, *ix*
 related documentation, *xi*

E

EEPROM storage of calibration constants, 4-1
 environment specifications, A-5
 equipment, optional, 1-4
 external current excitation
 connecting RTDs, 3-16
 illustration, 3-16
 specifications, A-3

EXTREF signal (table), 3-3

EXTSTROBE* signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3
 timing connections, 3-22
 illustration, 3-22

F

fax technical support, C-1
 field wiring considerations, 3-36
 floating signal sources
 description, 3-8
 differential connections, 3-12 to 3-13
 recommended configuration (figure), 3-9
 single-ended connections (RSE configuration), 3-14

FREQ_OUT signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-4

waveform generation timing connections, 3-36
 fuse, 3-2, 3-5

G

general-purpose timing signal connections, 3-31 to 3-36
 FREQ_OUT signal, 3-36
 GPCTR0_GATE signal, 3-32
 GPCTR0_OUT signal, 3-32
 GPCTR0_SOURCE signal, 3-31
 GPCTR0_UP_DOWN signal, 3-33
 GPCTR1_GATE signal, 3-34
 GPCTR1_OUT signal, 3-34
 GPCTR1_SOURCE signal, 3-33
 GPCTR1_UP_DOWN signal, 3-35 to 3-36

GPCTR0_GATE signal, 3-32
 GPCTR0_OUT signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-4
 waveform generation timing connections, 3-32

GPCTR0_SOURCE signal, 3-31
 GPCTR0_UP_DOWN signal, 3-33
 GPCTR1_GATE signal, 3-34
 GPCTR1_OUT signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-4
 waveform generation timing connections, 3-34

GPCTR1_SOURCE signal, 3-33
 GPCTR1_UP_DOWN signal, 3-35 to 3-36

ground-referenced signal sources
 description, 3-8
 differential connections, 3-11
 recommended configuration (figure), 3-9
 single-ended connections (NRSE configuration), 3-14 to 3-15

H

hardware installation
 front and rear view of
 DAQPad-MIO-16XE-50 (figure), 2-1
 steps for installation, 2-2

I

IEX- and IEX+ signals
 DAQPad-TB-52 I/O signal summary
 (table), 3-5
 description (table), 3-3
 external current excitation, 3-16
 input configurations, 3-9 to 3-15
 common-mode signal rejection, 3-15
 differential connections
 floating signal sources, 3-12 to 3-13
 ground-referenced signal
 sources, 3-11
 nonreferenced signal sources, 3-12
 to 3-13
 when to use, 3-10
 input modes, 2-3 to 2-4
 DIFF (table), 2-4
 NRSE (table), 2-4
 RSE (table), 2-4
 recommended configuration (figure), 3-9
 input polarity and range, 2-4 to 2-5
 actual range and measurement precision
 (table), 2-5
 mixing bipolar and unipolar channels
 (note), 2-4
 selection considerations, 2-5
 installation. *See* configuration;
 hardware installation.

L

LabVIEW and LabWindows/CVI
 software, 1-2

M

manual. *See* documentation.
 multiple-channel scanning, 2-6 to 2-7

N

NI-DAQ driver software, 1-3
 NRSE (nonreferenced single-ended input)
 description (table), 2-4
 differential connections, 3-12 to 3-13
 recommended configuration (figure), 3-9
 single-ended connections (NRSE
 configuration), 3-14 to 3-15

O

optional equipment, 1-4

P

parallel port
 adding enhanced parallel port, 1-4
 cable specifications, B-2
 configuration, 2-3
 troubleshooting, B-1 to B-2
 optional cables, 1-4
 specifications, A-4
 transparent parallel port connector, 3-1
 PFI0/TRIG1 signal
 DAQPad-TB-52 I/O signal summary
 (table), 3-5
 description (table), 3-3
 PFI1/TRIG2 signal
 DAQPad-TB-52 I/O signal summary
 (table), 3-5
 description (table), 3-4
 PFI2/CONVERT* signal
 DAQPad-TB-52 I/O signal summary
 (table), 3-5
 description (table), 3-4
 PFI3/GPCTR1_SOURCE signal
 DAQPad-TB-52 I/O signal summary
 (table), 3-5
 description (table), 3-4
 PFI4/GPCTR1_GATE signal
 DAQPad-TB-52 I/O signal summary
 (table), 3-5
 description (table), 3-4

PFI5/UPDATE* signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-4

PFI6/WFTRIG signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-4

PFI7/STARTSCAN signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-4

PFI8/GPCTR0_SOURCE signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-4

PFI9/GPCTR0_GATE signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-4

PFI (programmable function inputs)
 configuring, 2-9
 CONVERT* signal routing (figure), 2-9
 signal connections, 3-20

PGIA (programmable gain instrumentation amplifier)
 analog input connections, 3-7 to 3-8
 illustration, 3-7
 common-mode signal rejection, 3-15
 differential connections
 floating signal sources, 3-12 to 3-13
 ground-referenced signal sources, 3-11
 single-ended connections
 floating signal sources (figure), 3-14
 grounded signal sources, 3-14 to 3-15

physical specifications, A-5

polarity
 actual range and measurement precision (table), 2-5
 considerations for selecting input ranges, 2-5
 input polarity and range, 2-4 to 2-5

posttriggered data acquisition, 3-21
 illustration, 3-21

power connections, 3-19

power requirement specifications, A-5

pretriggered data acquisition, 3-21
 illustration, 3-21

programmable function inputs (PFIs).
See PFIs (programmable function inputs).

programmable gain instrumentation amplifier. *See* PGIA (programmable gain instrumentation amplifier).

R

referenced single-ended input (RSE).
See RSE (referenced single-ended input).

register-level programming, 1-4

RSE (referenced single-ended input)
 description (table), 2-4
 recommended configuration (figure), 3-9
 single-ended connections for floating signal sources, 3-14

RTD connections, 3-16
 using external current excitation (figure), 3-16

S

SCANCLK signal
 DAQPad-TB-52 I/O signal summary (table), 3-5
 description (table), 3-3
 timing connections, 3-22
 illustration, 3-22

settling time, multiple-channel scanning, 2-6 to 2-7

signal connections
 analog input, 3-7 to 3-15
 differential connection
 considerations, 3-10 to 3-13
 floating signal sources, 3-8
 ground-referenced signal sources, 3-8
 input configuration (figure), 3-9
 single-ended connection
 considerations, 3-13 to 3-15
 types of signal sources, 3-8

analog output, 3-17

common-mode signal rejection
 considerations, 3-15

- DAQPad-TB-52 terminal block
 - description, 3-2
 - I/O signal summary (table), 3-5
 - screw terminal layout (figure), 3-2
 - signal connections, 3-6
 - signal descriptions (table), 3-3 to 3-4
- digital I/O, 3-18
- external current excitation, 3-16
- field wiring considerations, 3-36
- power connections, 3-19
- timing connections, 3-19 to 3-36
 - data acquisition timing connections, 3-21 to 3-28
 - AIGATE signal, 3-27
 - CONVERT* signal, 3-26 to 3-27
 - EXTSTROBE* signal, 3-22
 - SCANCLK signal, 3-22
 - SISOURCE signal, 3-27 to 3-28
 - STARTSCAN signal, 3-24 to 3-26
 - TRIG1 signal, 3-23
 - TRIG2 signal, 3-24
 - typical posttriggered acquisition (figure), 3-21
 - typical pretriggered acquisition (figure), 3-21
 - general-purpose timing signal connections, 3-31 to 3-36
 - FREQ_OUT signal, 3-36
 - GPCTR0_GATE signal, 3-32
 - GPCTR0_OUT signal, 3-32
 - GPCTR0_SOURCE signal, 3-31
 - GPCTR0_UP_DOWN signal, 3-33
 - GPCTR1_GATE signal, 3-34
 - GPCTR1_OUT signal, 3-34
 - GPCTR1_SOURCE signal, 3-33
 - GPCTR1_UP_DOWN signal, 3-35 to 3-36
 - programmable function input connections, 3-20
 - waveform generation timing connections, 3-28 to 3-31
 - UISOURCE signal, 3-30 to 3-31
 - UPDATE* signal, 3-29 to 3-30
 - WFTRIG signal, 3-28 to 3-29
- transparent parallel port connector, 3-1
- single-ended connections
 - floating signal sources (RSE), 3-14
 - grounded signal sources (NRSE), 3-14 to 3-15
 - recommended configurations (figure), 3-9
 - signal connection considerations, 3-13
 - when to use, 3-13
- SISOURCE signal, 3-27 to 3-28
- software
 - configuration. *See* configuration.
 - programming choices
 - LabVIEW and LabWindows/CVI, 1-2
 - NI-DAQ driver software, 1-3
 - register-level programming, 1-4
- specifications
 - analog input
 - amplifier characteristics, A-2
 - dynamic characteristics, A-2
 - input characteristics, A-1
 - stability, A-2
 - transfer characteristics, A-1
 - analog output
 - dynamic characteristics, A-3
 - output characteristics, A-2
 - stability, A-3
 - transfer characteristics, A-3
 - voltage output, A-3
 - cold-junction temperature sensor, A-5
 - DAQPad-TB-52 terminal block, A-5
 - digital I/O, A-4
 - environment, A-5
 - excitation, A-3
 - parallel port, A-4
 - physical, A-5
 - power requirements, A-5
 - timing I/O, A-4
 - triggers, A-4
- STARTSCAN signal timing connections, 3-24 to 3-26
 - input timing (figure), 3-25
 - output timing (figure), 3-25

T

technical support, C-1

timing connections

- data acquisition timing connections, 3-21 to 3-28
 - AIGATE signal, 3-27
 - CONVERT* signal, 3-26 to 3-27
 - EXTSTROBE* signal, 3-22
 - SCANCLK signal, 3-22
 - SISOURCE signal, 3-27 to 3-28
 - STARTSCAN signal, 3-24 to 3-26
 - TRIG1 signal, 3-23
 - TRIG2 signal, 3-24
- typical posttriggered acquisition (figure), 3-21
- typical pretriggered acquisition (figure), 3-21

general-purpose timing signal connections, 3-31 to 3-36

- FREQ_OUT signal, 3-36
- GPCTR0_GATE signal, 3-32
- GPCTR0_OUT signal, 3-32
- GPCTR0_SOURCE signal, 3-31
- GPCTR0_UP_DOWN signal, 3-33
- GPCTR1_GATE signal, 3-34
- GPCTR1_OUT signal, 3-34
- GPCTR1_SOURCE signal, 3-33
- GPCTR1_UP_DOWN signal, 3-35 to 3-36

programmable function input connections, 3-20

waveform generation timing connections, 3-28 to 3-31

- UISOURCE signal, 3-30 to 3-31
- UPDATE* signal, 3-29 to 3-30
- WFTRIG signal, 3-28 to 3-29

timing I/O specifications, A-4

transparent parallel port connector, 3-1

TRIG1 signal timing connections, 3-23

- input timing (figure), 3-23
- output timing (figure), 3-23

TRIG2 signal timing connections, 3-24

- input timing (figure), 3-23
- output timing (figure), 3-23

trigger specifications, A-4

U

UISOURCE signal, 3-30 to 3-31

- illustration, 3-30

unipolar input

- definition, 2-4
- mixing bipolar and unipolar channels (note), 2-4

UPDATE* signal timing connections, 3-29 to 3-30

- input timing (figure), 3-29
- output timing (figure), 3-30

V

VCC signal (table), 3-5

W

waveform generation timing connections, 3-28 to 3-31

- UISOURCE signal, 3-30 to 3-31
- UPDATE* signal, 3-29 to 3-30
- WFTRIG signal, 3-28 to 3-29

WDAQCONF configuration utility, B-1 to B-2

WFTRIG signal timing connections, 3-28 to 3-29

- input timing (figure), 3-28
- output timing (figure), 3-29, 3-30