AT-MIO-16
User Manual

Multifunction I/O Board for the PC/AT

February 1995 Edition

Part Number 320476-01

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About This Manual

This manual describes the electrical and mechanical aspects of the AT-MIO-16 and contains information concerning its operation and programming. The AT-MIO-16 is a high-performance multifunction analog, digital, and timing I/O board, and is a member of the National Instruments AT Series of expansion boards for the IBM PC AT and compatible computers. The AT-MIO-16 contains a 12-bit ADC with up to 16 analog inputs, two 12-bit DACs with voltage outputs, eight lines of TTL-compatible digital I/O, and three 16-bit counter/timer channels for timing I/O. If you need additional analog inputs, you can use the AMUX-64T multiplexer board, which is a four-to-one multiplexer that can process 64 single-ended inputs. You can cascade up to four AMUX-64Ts to obtain 256 single-ended inputs.

Organization of This Manual

The *AT-MIO-16 User Manual* is organized as follows:

- Chapter 1, *Introduction*, describes the AT-MIO-16; lists the contents of your AT-MIO-16 kit, the optional software, and optional equipment; and explains how to unpack the AT-MIO-16.
- Chapter 2, *Configuration and Installation*, describes how to configure the AT-MIO-16 jumpers and how to install the AT-MIO-16 board into the PC.
- Chapter 3, *Signal Connections*, describes the signal connections to the AT-MIO-16 board, and cable wiring.
- Chapter 4, *Calibration Procedures*, discusses the calibration procedures for the AT-MIO-16 analog input and analog output circuitry.
- Appendix A, *Specifications*, lists the specifications for the AT-MIO-16.
- Appendix B, *Revisions A through C Parts Locator Diagram*, contains the parts locator diagram for revisions A through C of the AT-MIO-16 board.
- 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 acronyms, abbreviations, metric prefixes, mnemonics, and symbols.
- The *Index* alphabetically lists topics covered in this manual, including the page where you can find the topic.

Conventions Used in This Manual

The following conventions are used in this manual.

bold italic	Bold italic text denotes a note, caution, or warning.
italic	Italic text denotes emphasis, a cross reference, or an introduction to a key concept.
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 AT and compatible computers.

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

Related Documentation

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

- *IBM Personal Computer AT Technical Reference* manual

You may also want to consult the following Advanced Micro Devices manual if you plan to program the Am9513A counter/timer used on the AT-MIO-16:

- *Am9513A/Am9513 System Timing Controller* technical manual

National Instruments offers a register-level programmer manual at no charge to customers who are not using National Instruments software:

- *AT-MIO-16 Register-Level Programmer Manual*

If you are using NI-DAQ, LabVIEW, or LabWindows®, you should not need the register-level programmer manual. Using NI-DAQ, LabVIEW, or LabWindows is quicker and easier than and as flexible as using the low-level programming described in the register-level programmer manual. Refer to *Software Programming Choices* in Chapter 1, *Introduction*, of this manual if you need more information about your programming options.

If you are not using National Instruments software, you can request the register-level programmer manual by mailing or faxing the *Register-Level Programmer Manual Request Form* at the back of this manual to National Instruments.

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 AT-MIO-16; lists the contents of your AT-MIO-16 kit; describes the optional software and optional equipment; and explains how to unpack the AT-MIO-16.

About the AT-MIO-16

Congratulations on your purchase of the National Instruments AT-MIO-16. The AT-MIO-16 is a high-performance, software-configurable 12-bit DAQ board for laboratory, test and measurement, and data acquisition and control applications. The board performs *high-accuracy* measurements with high-speed settling to 12 bits, noise as low as 0.1 LSBrms, and a typical DNL of ±0.5 LSB. Because of its FIFOs and dual-channel DMA, the AT-MIO-16 can achieve *high performance*, even when used in environments that may have long interrupt latencies such as Windows.

A common problem with DAQ boards is that you cannot easily synchronize several measurement functions to a common trigger or timing event. The AT-MIO-16 has the Real-Time System Integration (RTSI) bus to solve this problem. The *RTSIbus* consists of our custom RTSI bus interface chip and a ribbon cable to route timing and trigger signals between several functions on one or DAQ boards in your PC.

The AT-MIO-16 can interface to the Signal Conditioning eXtensions for Instrumentation (SCXI) system so that you can acquire over 3,000 analog signals from thermocouples, RTDs, strain gauges, voltage sources, and current sources. You can also acquire or generate digital signals for communication and control. SCXI is the instrumentation front-end for plug-in DAQ boards.

What You Need to Get Started

Two versions of the AT-MIO-16 are available–one version for each of two gain ranges. The AT-MIO-16L (L stands for low-level signals) has software-programmable gain settings of 1, 10, 100, and 500 for low-level analog input signals. The AT-MIO-16H (H stands for high-level signals) has software-programmable gain settings of 1, 2, 4, and 8 for high-level analog input signals. The AT-MIO-16(L/H)-9 contains an ADC with a 9 µs conversion time. The AT-MIO-16(L/H)-9 is capable of data acquisition rates of up to 100 kHz.

To set up and use your AT-MIO-16 board, you will need the following:

- ❑ An AT-MIO-16 board
- ❑ *AT-MIO-16 User Manual*

❑ Either of the following software:

NI-DAQ software for PC compatibles, with manuals
LabVIEW for Windows, LabWindows for DOS, or LabWindows/CVI for Windows, with manuals

❑ Your computer

Detailed specifications of the AT-MIO-16 are listed in Appendix A, *Specifications*.

Software Programming Choices

There are four options to choose from when programming your National Instruments plug-in DAQ and SCXI hardware. You can use LabVIEW, LabWindows, NI-DAQ, or register-level programming software.

The AT-MIO-16 works with LabVIEW for Windows, LabWindows for DOS, LabWindows/CVI for Windows, and NI-DAQ for PC compatibles.

LabVIEW and LabWindows Application Software

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

LabVIEW currently runs on four different platforms—AT/MC/EISA computers running Microsoft Windows, NEC 9800 computers running Microsoft Windows, the Macintosh platform, and the Sun SPARCstation platform. 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 boards, is included with LabVIEW. The LabVIEW Data Acquisition VI Libraries are functionally equivalent to the NI-DAQ software.

LabWindows has two versions—LabWindows for DOS is for use on PCs running DOS, and LabWindows/CVI is for use on PCs running Windows and Sun SPARCstations. LabWindows/CVI features interactive graphics, a state-of-the-art user interface, and uses the ANSI standard C programming language. The LabWindows Data Acquisition Library, a series of functions for using LabWindows with National Instruments boards, is included with LabWindows for DOS and LabWindows/CVI. The LabWindows Data Acquisition libraries are functionally equivalent to the NI-DAQ software.

Using LabVIEW or LabWindows software will greatly diminish 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 data acquisition 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 data acquisition device. NI-DAQ does not sacrifice the performance of National Instruments data acquisition 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 includes a *Buffer and Data Manager* that uses sophisticated techniques for handling and managing data acquisition buffers so that you can simultaneously acquire and process data. NI-DAQ functions for the AT-MIO-16 can transfer data using interrupts or software polling.

With the NI-DAQ *Resource Manager*, you can simultaneously use several functions and several DAQ devices. The Resource Manager prevents multiple-device contention over DMA channels, interrupt levels, and RTSI channels.

NI-DAQ can send *event-driven messages* to DOS, Windows, or Windows NT applications whenever a user-specified event occurs. Thus, polling is eliminated and you can develop event-driven data acquisition applications. An example of a NI-DAQ user event is when a specified digital I/O pattern is matched.

NI-DAQ also internally addresses many of the complex issues between the computer and the DAQ hardware such as programming interrupts 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. You can see that the data acquisition parts of LabVIEW and LabWindows are functionally equivalent to the NI-DAQ software.

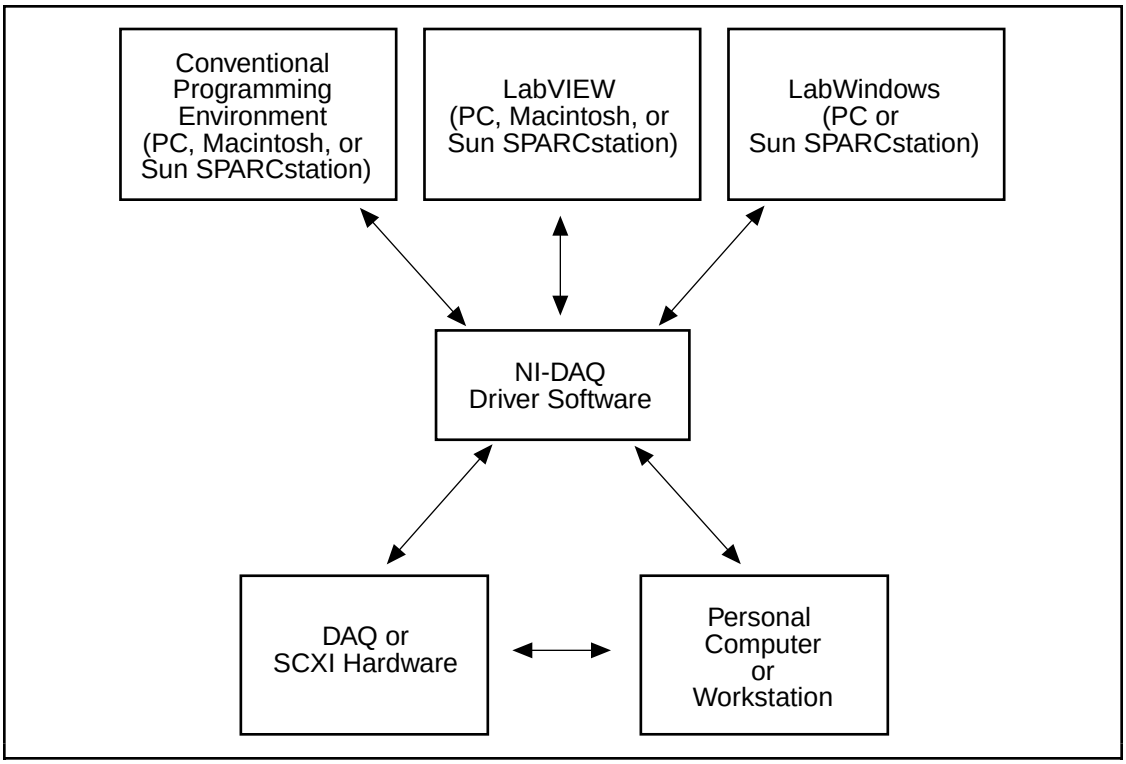


Figure 1-1. The Relationship between the Programming Environment, NI-DAQ, and Your Hardware

The National Instruments PC, AT, MC, EISA, DAQCard, and DAQPad Series DAQ hardware and the SCXI-1200 are packaged with NI-DAQ software for PC compatibles. NI-DAQ software for PC compatibles comes with language interfaces for Professional BASIC, QuickBASIC, Visual Basic, Borland Turbo Pascal, Turbo C++, Borland C++, Microsoft Visual C++, and Microsoft C for DOS; and Visual Basic, Turbo Pascal, Microsoft C with SDK, Microsoft Visual C++, and Borland C++ for Windows; and Microsoft Visual C++ for Windows NT. You can use your AT-MIO-16, together with other PC, AT, MC, EISA, DAQCard, and DAQPad Series DAQ and SCXI hardware, with NI-DAQ software for PC compatibles.

The National Instruments NB Series DAQ boards are packaged with NI-DAQ software for Macintosh. NI-DAQ software for Macintosh comes with language interfaces for MPW C, THINK C, Pascal, and Microsoft QuickBASIC. Any language that uses Device Manager Toolbox calls can access NI-DAQ software for Macintosh. You can use NB Series DAQ boards and SCXI hardware with NI-DAQ software for Macintosh.

The National Instruments SB Series DAQ boards are packaged with NI-DAQ software for Sun, which comes with a language interface for ANSI C.

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. The *only* users who should consider writing register-level software should meet at least one of the following criteria:

- National Instruments does not support your operating system or programming language.
- You are an experienced register-level programmer who is more comfortable writing your own register-level software.

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

The *AT-MIO-16 User Manual* and your software manuals contains complete instructions for programming your AT-MIO-16 board with NI-DAQ, LabVIEW, or LabWindows. If you are using NI-DAQ, LabVIEW, or LabWindows to control your board, you should not need the register-level programmer manual.

The *AT-MIO-16 Register-Level Programmer Manual* contains low-level programming details, such as register maps, bit descriptions, and register programming hints, that you will need only for register-level programming. If you want to obtain the register-level programmer manual, please fill out the *Register-Level Programmer Manual Request Form* at the end of this manual and send it to National Instruments.

Unpacking

Your AT-MIO-16 board is shipped in an antistatic package to prevent electrostatic damage to the board. Electrostatic discharge can damage several components on the board. To avoid such damage in handling the board, take the following precautions:

- Ground yourself via a grounding strap or by holding a grounded object.
- Touch the antistatic package to a metal part of your computer chassis before removing the board from the package.
- Remove the board from the package and inspect the board for loose components or any other sign of damage. Notify National Instruments if the board appears damaged in any way. *Do not* install a damaged board into your computer.
- *Never* touch the exposed pin of connectors.

Chapter 2
Configuration and Installation

This chapter describes how to configure the AT-MIO-16 jumpers and how to install the AT-MIO-16 board into the PC.

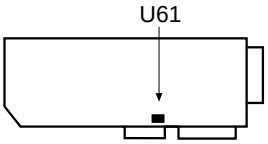
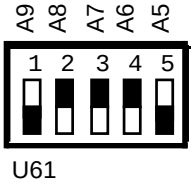
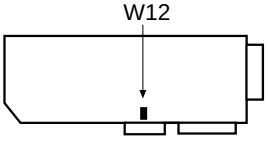
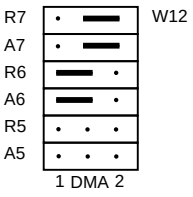
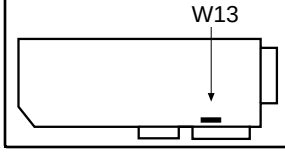
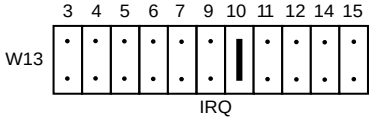
Board Configuration

The AT-MIO-16 contains 13 jumpers and one DIP switch to configure the AT bus interface and analog I/O settings. The DIP switch is for setting the base I/O address. Two jumpers are interrupt channel and DMA selectors. The remaining 11 jumpers change the analog input and analog output circuitry. The parts locator diagram in Figure 2-1 shows the user-configurable jumpers. Jumpers W1, W4, W6, and W9 configure the analog input circuitry. Jumpers W2, W3, W7, W8, W10, and W11 configure the analog output circuitry. Jumper W5 selects the clock signal the Am9513A counter/timer uses and selects the clock pin on the RTSI bus. Jumpers W12 and W13 select the DMA channel and the interrupt level, respectively.

AT Bus Interface

The AT-MIO-16 is configured at the factory to a base I/O address of hex 220, to use DMA channels 6 and 7, and to use interrupt level 10. These settings, as shown in Table 2-1, are suitable for most systems. If your system, however, has other hardware at this base I/O address, DMA channel, or interrupt level, you will need to change these settings on the other hardware or on the AT-MIO-16 as described in the following pages.

Table 2-1. AT Bus Interface Factory-Default Settings

AT-MIO-16 Board	Default Setting	Hardware Implementation
Base I/O address 	Hex 220 Range: hex 220 to hex 23F	
Address space	32 bytes (hex 20)	
DMA channel 	DMA 1 = DMA channel 6 DMA 2 = DMA channel 7	
Interrupt level 	Interrupt level 10 selected	

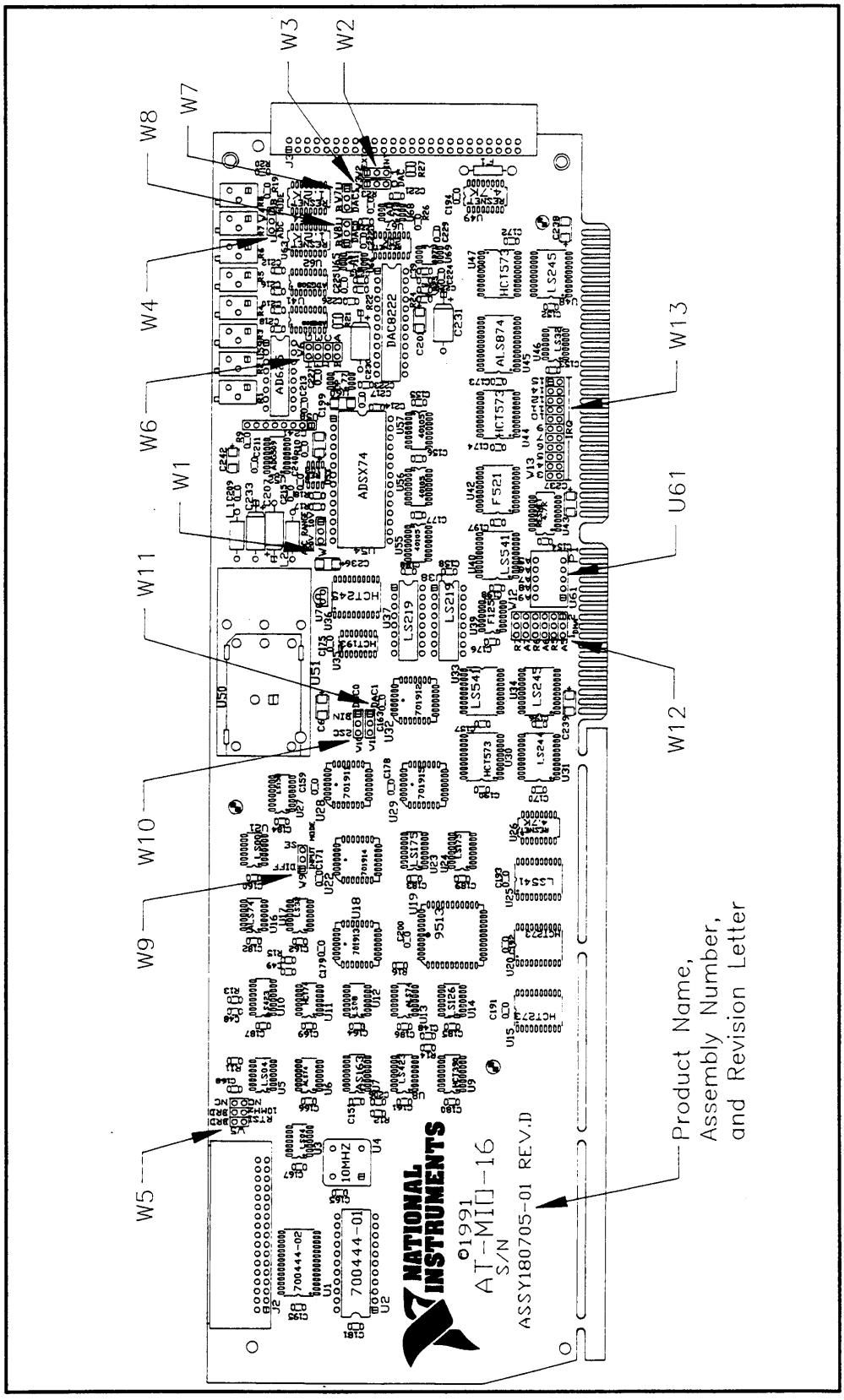


Figure 2-1. AT-MIO-16 Parts Locator Diagram

Note: ***The parts locator diagram shown in Figure 2-1 is for revision D and subsequent revisions of the AT-MIO-16 board. See Appendix B,*** *Revisions A through C Parts Locator Diagram****, for earlier revisions of the AT-MIO-16 board. The remainder of this chapter applies to all revisions of the AT-MIO-16 board.***

In the configuration illustrations throughout this chapter, the black bars on the jumper diagrams indicate where to place jumpers. On the switch diagrams, the shaded portion indicates the side of the switch that is pressed down.

Base I/O Address Selection

The switches at position U61 determine the base I/O address for the AT-MIO-16, as shown in Figure 2-1. Each switch in U61 corresponds to one of the address lines A9 through A5. Press the side marked OFF to select a binary value of 1 for the corresponding address bit. Press the other side of the switch to select a binary value of 0 for the corresponding address bit. Figure 2-2 shows two possible switch settings.

Note: ***Verify that other equipment installed in your computer does not already occupy the AT-MIO-16 address space. If any equipment in your computer uses this base I/O address space, you must change the base I/O address of either the AT-MIO-16 or that of the other device. If you change the AT-MIO-16 base I/O address, you must make a corresponding change to any software you use with the AT-MIO-16. For more information about the I/O address of your PC AT, refer to the technical reference manual for your computer.***

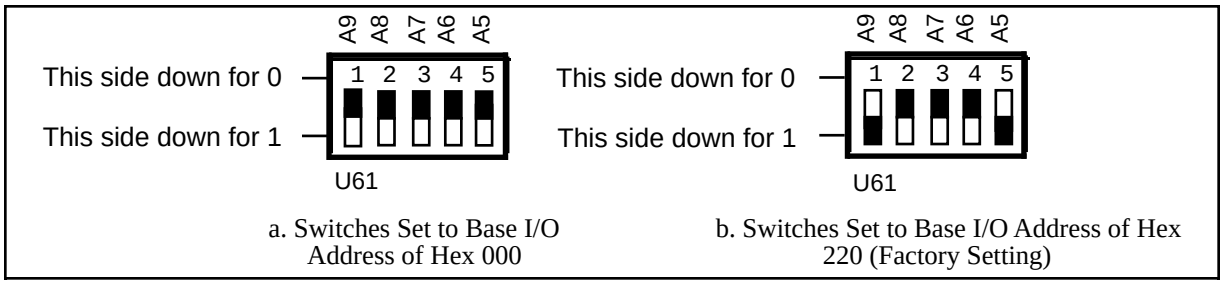


Figure 2-2. Example Base I/O Address Switch Settings

To change the base I/O address, remove the plastic cover on U61; press each switch to the desired position; check each switch to make sure the switch is pressed down all the way; and replace the plastic cover. Make a note of the new AT-MIO-16 base I/O address on the configuration form in Appendix C, *Customer Communication*, to use when configuring the software you are using with the AT-MIO-16. Table 2-2 lists the possible switch settings, the corresponding base I/O address, and the base I/O address space for each setting.

Table 2-2. Switch Settings with Corresponding Base I/O Address and Base I/O Address Space

Switch Setting					Base I/O Address	Base I/O Address
A9	**A8**	**A7**	**A6**	**A5**	**(hex)**	**Space Used (hex)**
0	1	1	0	0	180	180-19F
0	1	1	0	1	1A0	1A0-1BF
0	1	1	1	0	1C0	1C0-1DF
0	1	1	1	1	1E0	1E0-1FF
1	0	0	0	0	200	200-21F
1	0	0	0	1	220	220-23F
1	0	0	1	0	240	240-25F
1	0	0	1	1	260	260-27F
1	0	1	0	0	280	280-29F
1	0	1	0	1	2A0	2A0-2BF
1	0	1	1	0	2C0	2C0-2DF
1	0	1	1	1	2E0	2E0-2FF
1	1	0	0	0	300	300-31F
1	1	0	0	1	320	320-33F
1	1	0	1	0	340	340-35F
1	1	0	1	1	360	360-37F
1	1	1	0	0	380	380-39F
1	1	1	0	1	3A0	3A0-3BF
1	1	1	1	0	3C0	3C0-3DF
1	1	1	1	1	3E0	3E0-3FF

Note: ***Base I/O address values hex 000 through 0FF are reserved for system use. Base I/O address values hex 100 through 3FF are available on the I/O channel.***

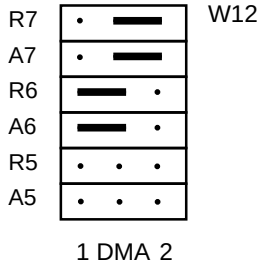
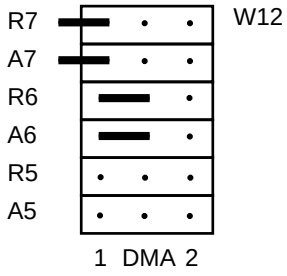
DMA Channel Selection

The AT-MIO-16 uses the DMA channel you select with the jumpers on W12 as shown in Figure 2-1. The AT-MIO-16 is set at the factory to use DMA channels 6 and 7. Verify that equipment already installed in your computer does not also use these DMA channels. If any device uses DMA channel 6 or 7, change or disable the DMA channel or channels of either the AT-MIO-16 or the other device. The AT-MIO-16 hardware supports DMA channels 5, 6, and 7. Notice that these are the three 16-bit channels on the PC AT I/O channel. The AT-MIO-16 *does not use* and *cannot be configured to use* the 8-bit DMA channels on the PC AT I/O channel.

You must install two jumpers on W12 to select a DMA channel. The DMA Acknowledge lines (*A*- prefix is printed on the board) and the DMA Request lines (*R*- prefix is printed on the board) that you select must have the same number suffix (*5*, *6*, or *7*) for proper operation. When you enable two DMA channels, the driver software has the option of using dual DMA mode, which may improve performance in high-rate data acquisition. However, data acquisition can operate properly with one or both DMA channels disabled. Disabling DMA 2 or disabling both DMA channels may be necessary if no more DMA channels are available on your system. If two AT-MIO-16s are installed in the same computer, for instance, you must disable DMA 2 on one of the boards. The left two columns of W12 are for DMA 1, which is referred to as DMA A in National Instruments software. The right two columns of W12 are for DMA 2, which is referred

to as DMA B in National Instruments software. Table 2-3 shows the jumper positions for selecting two, one, or no DMA channels.

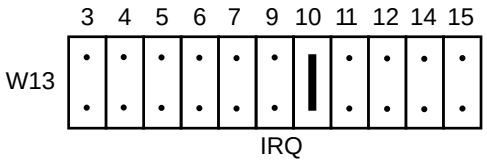
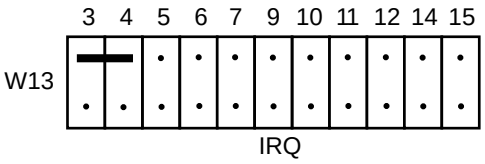
Table 2-3. DMA Jumper Settings

Selecting Two DMA Channels	**Selecting One DMA Channel**	**Disabling DMA Channels**
DMA jumper settings for DMA channels 6 and 7 (factory setting)	DMA jumper settings for DMA channel 6 only	DMA jumper settings for disabling DMA transfers
		

Interrupt Selection

The AT-MIO-16 board can connect to any one of the 11 interrupt lines of the PC AT I/O channel. You select the interrupt line with a jumper on one of the double rows of pins located above the I/O slot edge connector on the AT-MIO-16 (refer to Figure 2-1). To use the AT-MIO-16 interrupt capability, you must select an interrupt line and place the jumper in the appropriate position to enable that particular interrupt line, as shown in Table 2-4.

Table 2-4. Interrupt Jumper Settings

Interrupt Jumper Setting IRQ10 (Factory Setting)	**Interrupt Jumper Setting for Disabling Interrupts**
	

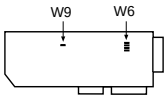
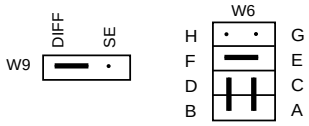
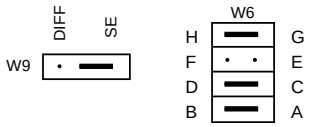
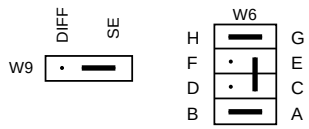
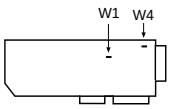
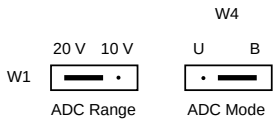
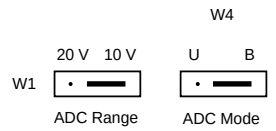
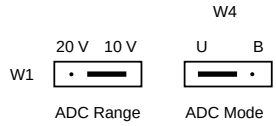
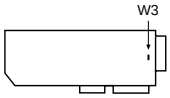
The AT-MIO-16 can share interrupt lines with other devices by using a tristate driver to drive its selected interrupt line. The AT-MIO-16 interrupt lines are IRQ3, IRQ4, IRQ5, IRQ6, IRQ7, IRQ9, IRQ10, IRQ11, IRQ12, IRQ14, and IRQ15.

Note: ***DO NOT use interrupt line 6 or interrupt line 14. The diskette drive controller uses interrupt line 6. The hard disk controller on most IBM PC ATs and compatible computers uses interrupt line 14.***

Analog I/O Configuration

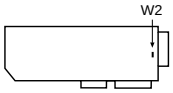
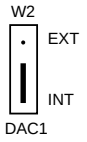
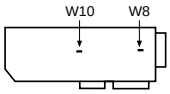
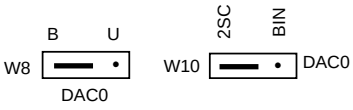
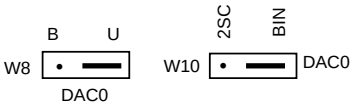
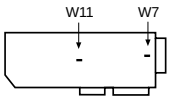
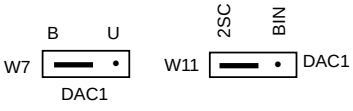
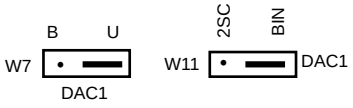
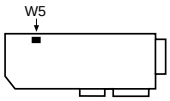
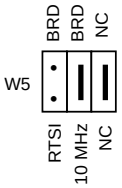
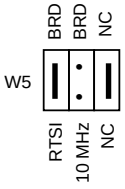
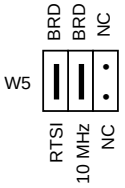
Table 2-5 is a quick reference guide that lists all of the analog I/O jumper configurations for the AT-MIO-16 with the factory settings noted. If you can configure your board for your application by using this table, you can skip the in-depth configuration descriptions in the remainder of this chapter and proceed to Chapter 3, *Signal Connections*.

Table 2-5. Analog I/O Jumper Settings Quick Reference

Circuitry	Configuration	Jumper Settings
ADC input mode 	Differential (DIFF) (factory setting)	
	Referenced single-ended (RSE)	
	Nonreferenced single-ended (NRSE)	
ADC input polarity and range 	Bipolar ±10 V (factory setting)	
	Bipolar ±5 V	
	Unipolar 0 to +10 V	
DAC0 reference 	Internal (factory setting)	
	External	

(continues)

Table 2-5. Analog I/O Jumper Settings Quick Reference (Continued)

Circuitry	Configuration	Jumper Settings
DAC1 reference 	Internal (factory setting)	
	External	
DAC0 output polarity–digital format 	Bipolar—Two's complement mode (factory setting)	
	Unipolar—Straight binary mode	
DAC1 output polarity–digital format 	Bipolar—Two's complement mode (factory setting)	
	Unipolar—Straight binary mode	
Am9513A and RTSI bus clock selection 	AT-MIO-16 clock signal = 10 MHz (factory setting)	
	AT-MIO-16 clock signal = RTSI clock signal	
	AT-MIO-16 and RTSI clock signals both = 10 MHz	

Analog Input Configuration

The AT-MIO-16 handles 16 channels of analog input with software-programmable gain and 12-bit A/D conversion. You change the position of jumpers to change the input mode, range, and polarity. Figure 2-3 shows a block diagram of the analog input and data acquisition circuitry.

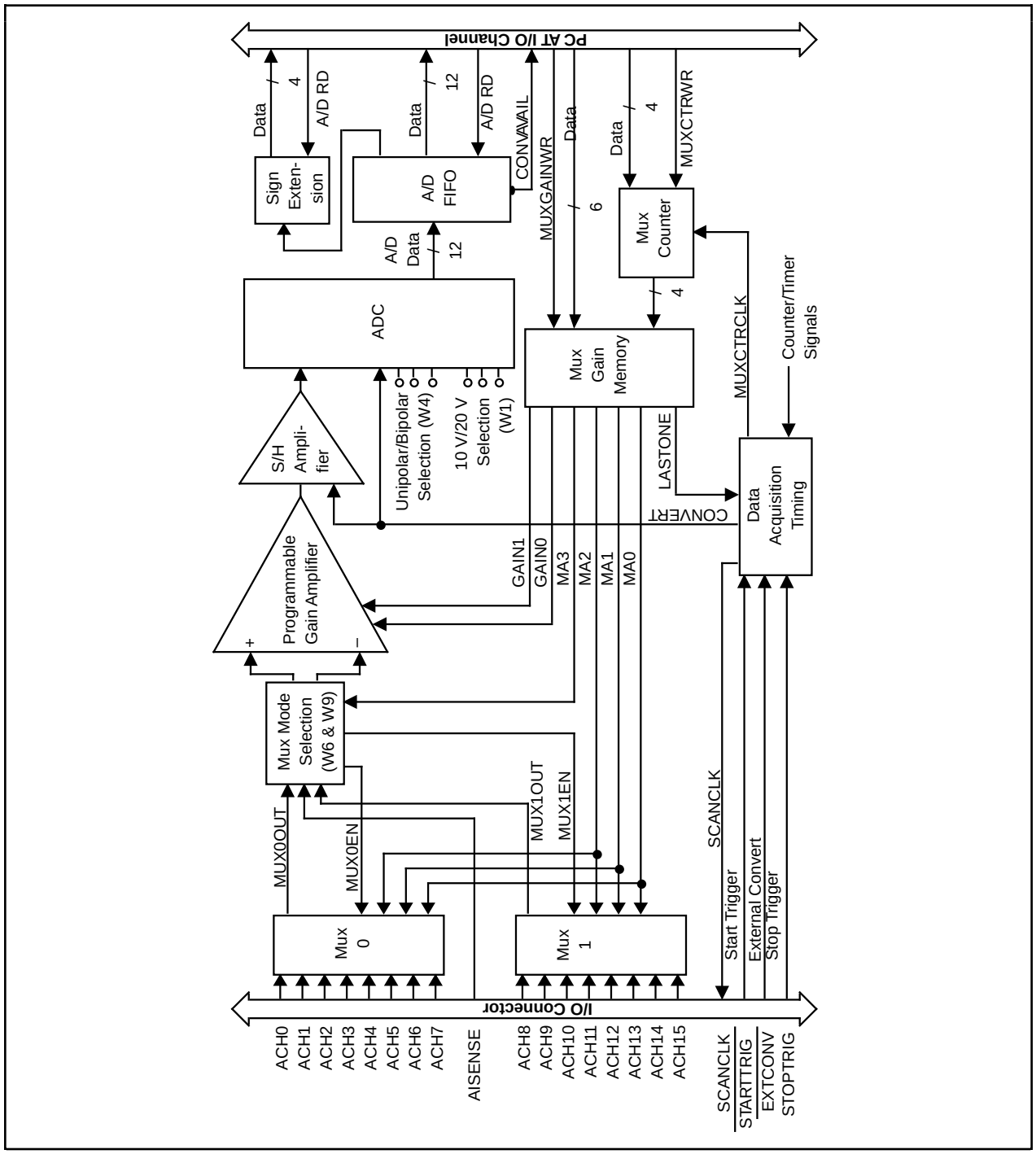


Figure 2-3. Analog Input and Data Acquisition Circuitry Block Diagram

Input Mode

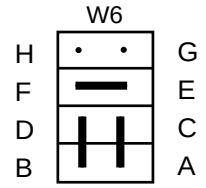
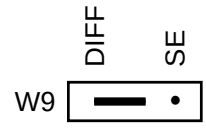
The AT-MIO-16 has three different input modes—differential (DIFF) input, referenced single-ended (RSE) input, and nonreferenced single-ended (NRSE) input. The single-ended input configurations use 16 channels. The DIFF input configuration uses eight channels. You may find it helpful to refer to the *Analog Input Signal Connections* section in Chapter 3, *Signal Connections*, which contains diagrams showing the signal paths for the three configurations.

The multiplexer-mode selection jumpers configure the analog input channels as 16 single-ended inputs or 8 differential inputs. When single-ended mode is selected, the outputs of the two multiplexers are tied together and routed to the positive (+) input of the instrumentation amplifier. The negative (-) input of the instrumentation amplifier is tied to the AT-MIO-16 ground for RSE input or to the analog return of the input signals via the AI SENSE input on the I/O connector for NRSE input. When DIFF mode is selected, the output of MUX0 is routed to the positive (+) input of the instrumentation amplifier, and the output of MUX1 is routed to the negative (-) input of the instrumentation amplifier.

DIFF Input (Eight Channels, Factory Setting).

DIFF input means that each input signal has its own reference, and the difference between each signal and its reference is measured. The signal and its reference are each assigned an input channel. With this input configuration, the AT-MIO-16 can monitor eight different analog input signals. You select the DIFF input configuration by setting jumpers W6 and W9 shown in Table 2-6.

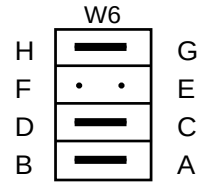
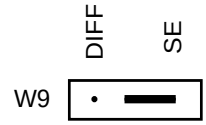
Table 2-6. DIFF Input Configuration (Factory Setting)

Jumper Settings	Description
	Jumper is placed in standby position or can be discarded. AISENSE is tied to the instrumentation amplifier output ground point. Channels 0 through 7 are tied to the positive input of the instrumentation amplifier. Channels 8 through 15 are tied to the negative input of the instrumentation amplifier.
	The multiplexer is configured to control eight input channels.

RSE Input (16 Channels).

RSE input means that all input signals are referenced to a common ground point that is also tied to the analog input ground of the AT-MIO-16 board. The negative input of the differential input amplifier is tied to the analog ground. This configuration is useful when measuring floating signal sources. See the *Types of Signal Sources* section in Chapter 3, *Signal Connections*, for more information. With this input configuration, the AT-MIO-16 can monitor 16 different analog input signals. You select the RSE input configuration by setting jumpers W6 and W9 as shown in Table 2-7.

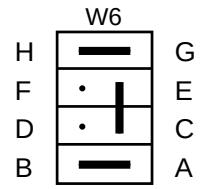
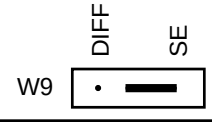
Table 2-7. RSE Input Configuration

Jumper Settings	Description
	AISENSE is tied to the instrumentation amplifier signal ground. The instrumentation amplifier negative input is tied to the instrumentation amplifier signal ground. The multiplexer outputs are tied together into the positive input of the instrumentation amplifier.
	The multiplexer is configured to control 16 input channels.

NRSE Input (16 Channels).

NRSE input means that all input signals are referenced to the same common mode voltage, but that this common mode voltage is allowed to float with respect to the analog ground of the AT-MIO-16 board. This common mode voltage is subsequently subtracted out by the input instrumentation amplifier. This configuration is useful when measuring ground-referenced signal sources. See the *Types of Signal Sources* section in Chapter 3, *Signal Connections*, for more information. With this input configuration, the AT-MIO-16 can measure 16 different analog input signals. You select the NRSE input configuration by setting jumpers W6 and W9 as shown in Table 2-8.

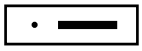
Table 2-8. NRSE Input Configuration

Jumper Settings	Description
	AISENSE is tied to the negative input of the instrumentation amplifier. The jumper is placed in standby position or can be discarded. The multiplexer outputs are tied together into the positive input of the instrumentation amplifier.
	The multiplexer control is configured to control 16 input channels.

Analog Input Polarity and Range

The AT-MIO-16 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 some positive reference voltage. Bipolar input means that the input voltage range is between $-V_{ref}$ and $+V_{ref}$. The AT-MIO-16 also has two input ranges—a 10 V input range and a 20 V input range. You can select one of three possible input polarity and range configurations as shown in Table 2-9.

Table 2-9. Configurations for Input Range and Input Polarity

Input Polarity Jumper Settings	**Input Range Jumper Settings**
Bipolar (factory setting) W4 U B  ADC Mode	-10 to +10 V (20 V range) (factory setting) 20 V 10 V W1  ADC Range
	-5 to +5 V (10 V range) 20 V 10 V W1  ADC Range
Unipolar W4 U B  ADC Mode	0 to +10 V (10 V range) 20 V 10 V W1  ADC Range

Sign-extension circuitry at the ADC FIFO output adds four most significant bits (MSBs), bits 15 through 12, to the 12-bit FIFO output (bits 11 through 0) to produce a 16-bit result. The sign-extension circuitry is software programmable to generate either straight binary numbers or two's complement numbers. In straight binary mode, bits 15 through 12 are always zero and provide a range of 0 to 4,095. In two's complement mode, the MSB of the 12-bit ADC result, bit 11, is inverted and extended to bits 15 through 12, providing a range of -2,048 to +2,047.

Considerations for Selecting Input Ranges.

Input polarity/range selection depends on the expected input range of the incoming signal. A large input range can accommodate a large signal variation but sacrifices voltage resolution. Choosing a smaller input range increases voltage resolution but may cause the input signal to go out of range. For best results, match the input range as closely as possible to the expected range of the input signal. For example, if the input signal will never become negative (below 0 V), a unipolar input is best. However, if the signal does become negative, inaccurate readings will occur.

The AT-MIO-16 software-programmable gain increases its overall flexibility by matching input signal ranges to those the AT-MIO-16 ADC accommodates. The AT-MIO-16H board has gains of 1, 2, 4, and 8 and is suited for high-level signals near the range of the ADC. The AT-MIO-16L board is designed to measure low-level signals and has gains of 1, 10, 100, and 500. With the proper gain setting, you can use the full resolution of the ADC to measure the input signal. Table 2-10 shows the overall input range and precision according to the input range

configuration and gain used. In single-channel data acquisition applications, the maximum allowable rate is 100 kHz, or the maximum specified rate of the AT-MIO-16 board.

Multichannel applications may need to slow the acquisition rate due to gain. These numbers are listed in Table 2-10 as well.

Table 2-10. Actual Range and Measurement Precision Versus Input Range Selection and Gain

Range Configuration	Board Model	Gain	Actual Input Range	Precision	Maximum Multichannel Acquisition Rate
0 to +10 V	-H	1	0 to +10 V	2.44 mV	100 kHz
		2	0 to +5 V	1.22 mV	100 kHz
		4	0 to +2.5 V	610 µV	100 kHz
		8	0 to +1.25 V	305 µV	100 kHz
	-L	1	0 to +10 V	2.44 mV	100 kHz
		10	0 to +1 V	244 µV	100 kHz
		100	0 to +0.1 V	24.4 µV	70 kHz
		500	0 mV to +20 mV	4.88 µV	20 kHz
-5 to +5 V	-H	1	-5 to +5 V	2.44 mV	100 kHz
		2	-2.5 to +2.5 V	1.22 mV	100 kHz
		4	-1.25 to +1.25 V	610 µV	100 kHz
		8	-0.625 to +0.625 V	305 µV	100 kHz
	-L	1	-5 to +5 V	2.44 mV	100 kHz
		10	-0.5 to +0.5 V	244 µV	100 kHz
		100	-50 mV to +50 mV	24.4 µV	70 kHz
		500	-10 mV to +10 mV	4.88 µV	20 kHz
-10 to +10 V	-H	1	-10 to +10 V	4.88 mV	100 kHz
		2	-5 to +5 V	2.44 mV	100 kHz
		4	-2.5 to +2.5 V	1.22 mV	100 kHz
		8	-1.25 to +1.25 V	610 µV	100 kHz
	-L	1	-10 to +10 V	4.88 mV	100 kHz
		10	-1 to +1 V	488 µV	100 kHz
		100	-0.1 to +0.1 V	48.8 µV	70 kHz
		500	-20 mV to +20 mV	9.76 µV	20 kHz

* The value of 1 LSB of the 12-bit ADC, that is, the voltage increment corresponding to a change of 1 count in the ADC 12-bit count.

Analog Output Configuration

The AT-MIO-16 provides two channels of 12-bit digital-to-analog (D/A) output. Each analog output channel provides options such as unipolar or bipolar output and internal or external reference voltage selection. Figure 2-4 shows a block diagram of the analog output circuitry.

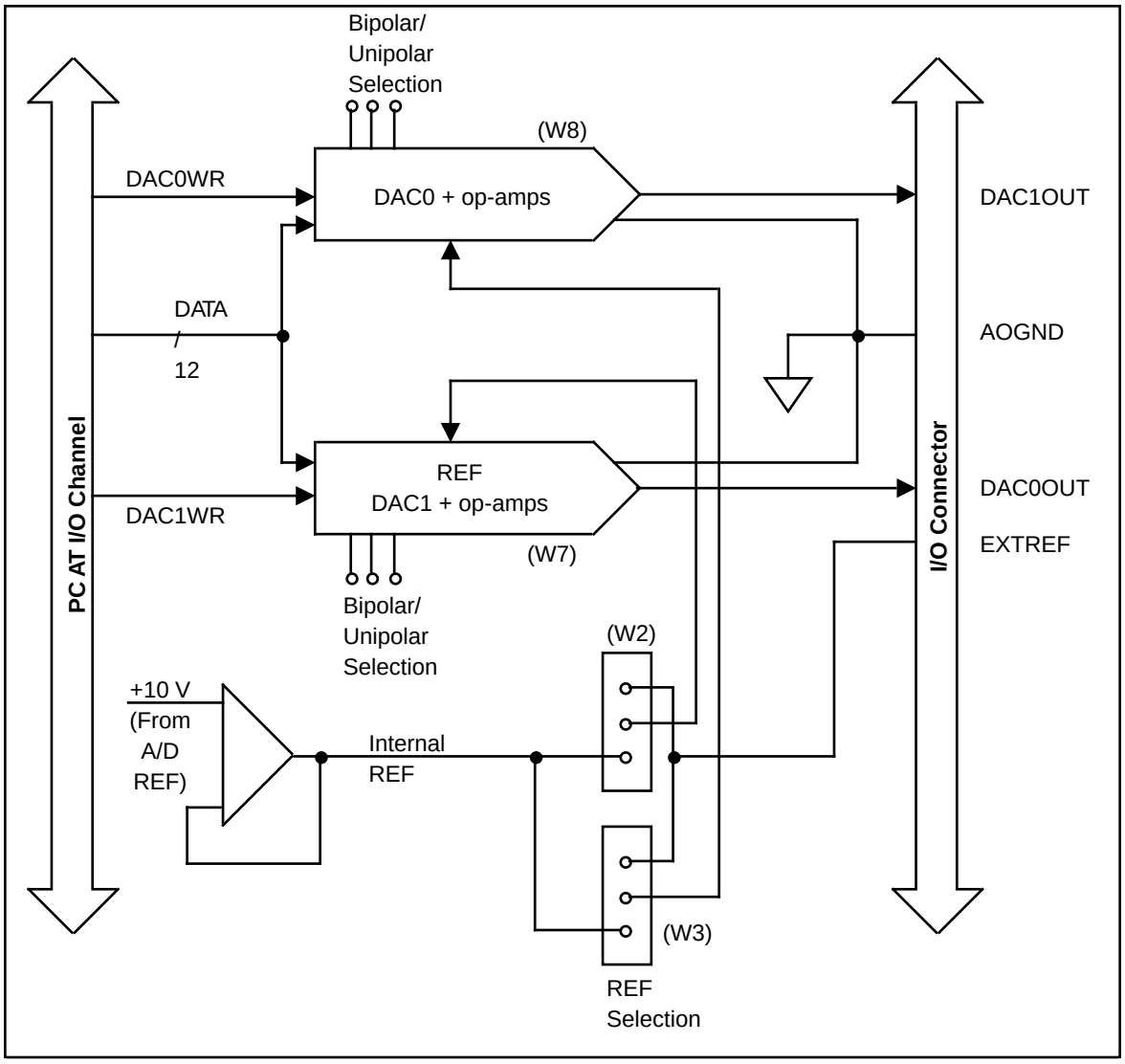


Figure 2-4. Analog Output Circuitry Block Diagram

Analog Output Reference

You can connect each DAC to the AT-MIO-16 internal reference of 10 V or to the external reference signal connected to the EXTREF pin on the I/O connector. This signal applied to EXTREF must be between -10 V and +10 V. Both channels need not be configured the same way. When you select the external reference jumper setting, the voltage at EXTREF on the I/O connector is connected to the DAC reference input. When you select the internal reference jumper setting, the onboard 10 V reference signal is connected to the DAC reference input.

You select the external or internal reference signal for each analog output channel by setting jumpers W2 and W3 as shown in Table 2-11.

Table 2-11. Internal and External Reference Selection

Analog Output Channel	Jumper Settings	
	Internal (Factory Setting)	**External**
0	W3 EXT INT DAC0	W2 EXT INT DAC0
1	W3 EXT INT DAC1	W2 EXT INT DAC1

Analog Output Polarity Selection

You can configure each analog output channel for either unipolar or bipolar output. A unipolar configuration has a range of 0 to V_{ref} at the analog output. A bipolar configuration has a range of $-V_{ref}$ to $+V_{ref}$ at the analog output. V_{ref} is the voltage reference the DACs use in the analog output circuitry and can either be the 10 V onboard reference or an externally supplied reference between -10 V and +10 V. Both channels need not be configured the same way; however, at the factory both channels are configured for bipolar output.

Analog Output Data Coding.

You must select whether to write to the DAC in straight binary format or two's complement format. In two's complement mode, data values written to the analog output channel range from -2,048 to +2,047 decimal (F800 to 07FF hex). In straight binary mode, data values written to the analog output channel range from 0 to 4,095 decimal (0 to 0FFF hex). Two’s complement coding is best suited to the bipolar analog output mode, which is the AT-MIO-16 factory setting. Straight binary coding is usually used for the unipolar analog output configuration.

The analog output polarity and data mode configurations are shown in Table 2-12. Table 2-13 shows the relationship of the output range to the polarity.

Table 2-12. Analog Output Polarity and Data Mode Configuration

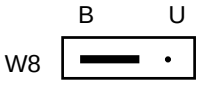
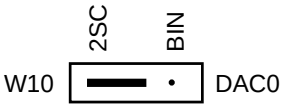
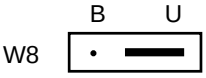
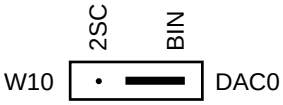
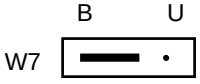
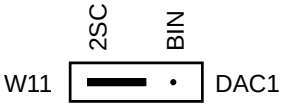
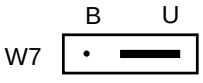
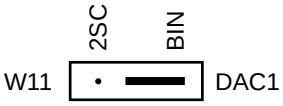
Analog Output Channel	Polarity	Jumper Settings	Data Mode	Jumper Settings
0	Bipolar (factory setting)		Two's complement (factory setting)	
	Unipolar		Straight binary	
1	Bipolar (factory setting)		Two's complement (factory setting)	
	Unipolar		Straight binary	

Table 2-13. Output Range Selection and Precision

Polarity	Output Range	Precision
Unipolar	0 - 10 V	2.44 mV
Bipolar	-10 - +10 V	4.88 mV

Note: ***If you are using software such as LabVIEW, LabWindows, or NI-DAQ, you may need to reconfigure your software to reflect any changes in jumper or switch settings.***

Digital I/O Configuration

The AT-MIO-16 provides eight digital I/O lines. These lines are divided into two ports of four lines each and are located at pins ADIO<3..0> and BDIO<3..0> on the I/O connector. You can configure each port for input or output through software programming of a register on the AT-MIO-16 board. Figure 2-5 shows a block diagram of the digital I/O circuitry.

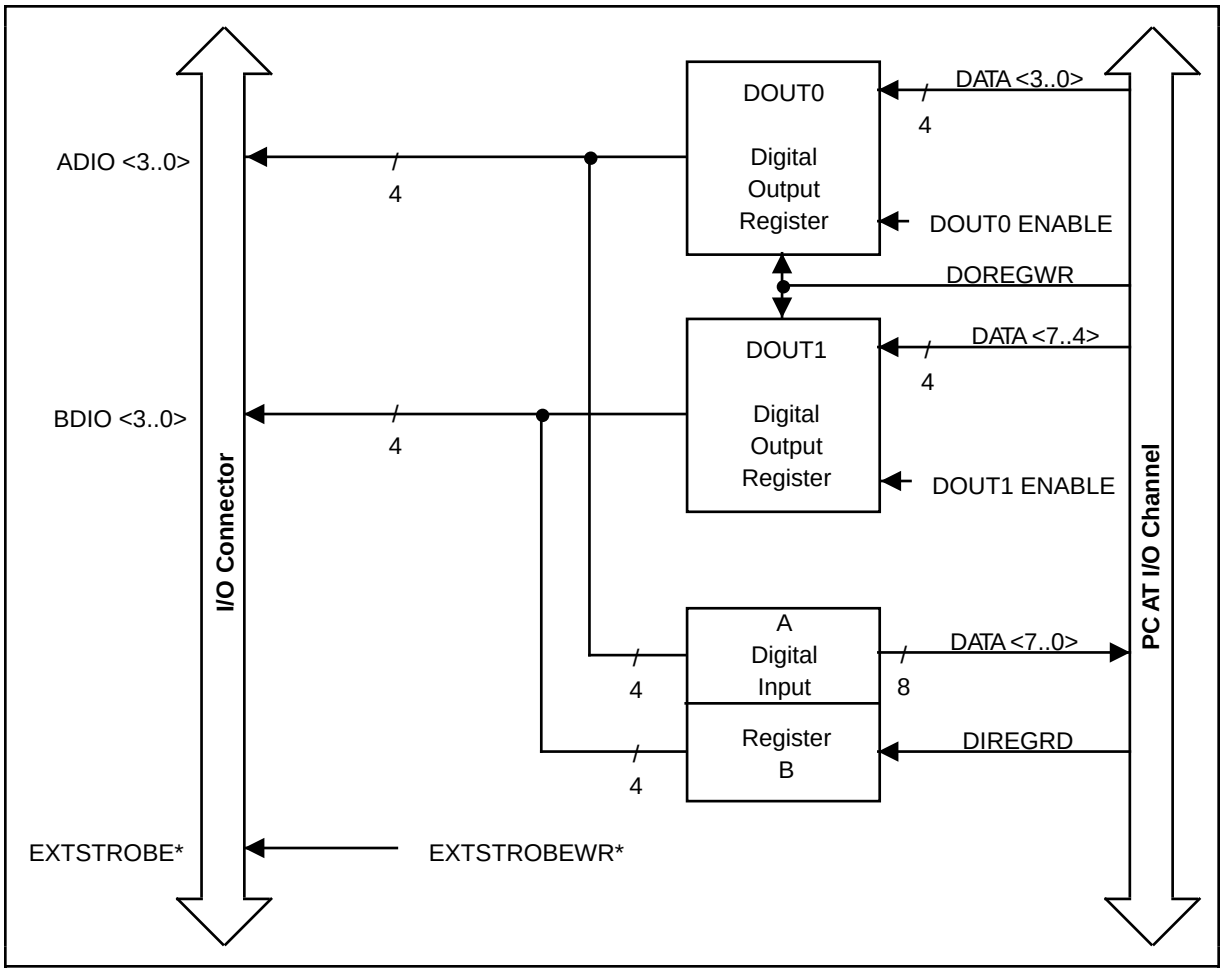


Figure 2-5. Digital I/O Circuitry Block Diagram

The Digital Output Register controls the digital I/O lines and the Digital Input Register monitors them. The Digital Output Register is an 8-bit register that contains the digital output values for both ports 0 and 1. When port 0 is enabled, bits <3..0> in the Digital Output Register are driven onto digital output lines ADIO<3..0>. When port 1 is enabled, bits <7..4> in the Digital Output Register are driven onto digital output lines BDIO<3..0>.

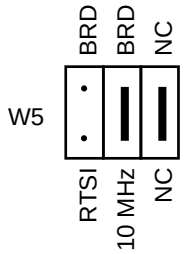
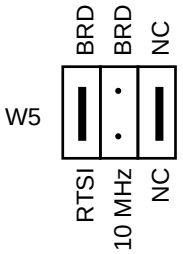
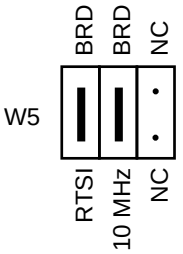
Reading the Digital Input Register returns the state of the digital I/O lines. Digital I/O lines ADIO<3..0> are connected to bits <3..0> of the Digital Input Register. Digital I/O lines BDIO<3..0> are connected to bits <7..4> of the Digital Input Register. When a port is enabled, the Digital Input Register serves as a read-back register, returning the digital output value of the port. When a port is not enabled, reading the Digital Input Register returns the state of the digital I/O lines as driven by an external device.

RTSI Bus Clock Selection

When multiple AT Series boards are connected via the RTSI bus, you may want all the boards to use the same 10 MHz clock. This arrangement is useful for applications that require counter/timer synchronization between boards. Each AT Series board with a RTSI bus interface has an onboard 10 MHz oscillator. Thus, one board can drive the RTSI bus clock signal, and the other boards can receive this signal or disconnect from it.

The configuration for jumper W5 specifies whether a board is to drive the onboard 10 MHz oscillator onto the RTSI bus, receive the RTSI bus clock, or disconnect from the RTSI bus clock. This clock source, whether local or RTSI signal, is then divided by 10 and used as the Am9513A frequency source. The jumper selections are shown in Table 2-14.

Table 2-14. Configurations for RTSI Bus Clock Selection

Local Clock	Slave Clock	Master Clock
Use the local oscillator as the board clock (factory setting)	Receive the RTSI bus clock signal	Drive the RTSI bus clock and the board clock signal with the local oscillator
		

Hardware Installation

You can install the AT-MIO-16 in any available 16-bit expansion slot (AT style) in your computer. The AT-MIO-16 *does not* work if installed in an eight-bit expansion slot (PC style). After you have changed (if needed), verified, and recorded the switches and jumper settings, you are ready to install the AT-MIO-16. The following are general installation instructions, but consult your PC AT user manual or technical reference manual for specific instructions and warnings.

1. Turn off your computer.

2. Remove the top cover or access port to the I/O channel.

3. Remove the expansion slot cover on the back panel of the computer.

4. Write down your hardware configuration settings in the *AT-MIO-16 Hardware and Software Configuration Form* in Appendix C at the back of this manual. You will need these settings when you install and configure your software.

5. Insert the AT-MIO-16 into a 16-bit slot. It may be a tight fit, but do not *force* the board into place.

6. Screw the mounting bracket of the AT-MIO-16 to the back panel rail of the computer.

7. Check the installation.

8. Replace the cover.

The AT-MIO-16 board is installed. You are now ready to install and configure your software.

If you are using NI-DAQ, refer to the *NI-DAQ Software Reference 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, the software installation instructions are in your LabVIEW release notes. After you have installed LabVIEW, refer to the *Configuring LabVIEW* section of Chapter 1 in your LabVIEW user manual for software configuration instructions.

If you are using LabWindows, the software installation instructions are in Part 1, *Introduction to LabWindows*, of the *Getting Started with LabWindows* manual. After you have installed LabWindows, refer to Chapter 1, *Configuring LabWindows*, of the *LabWindows User Manual* for software configuration instructions.

Chapter 3
Signal Connections

This chapter describes the signal connections to the AT-MIO-16 board, and cable wiring.

I/O Connector

Figure 3-1 shows the pin assignments for the AT-MIO-16 I/O connector. This connector is located on the back panel of the AT-MIO-16 board and is accessible at the rear of the computer after the board has been properly installed.

Warning: ***Connections that exceed any of the maximum ratings of input or output signals on the AT-MIO-16 can damage the AT-MIO-16 board and the PC AT. The description of each signal in this section includes information about maximum input ratings. National Instruments is not liable for any damages resulting from incorrect signal connections.***

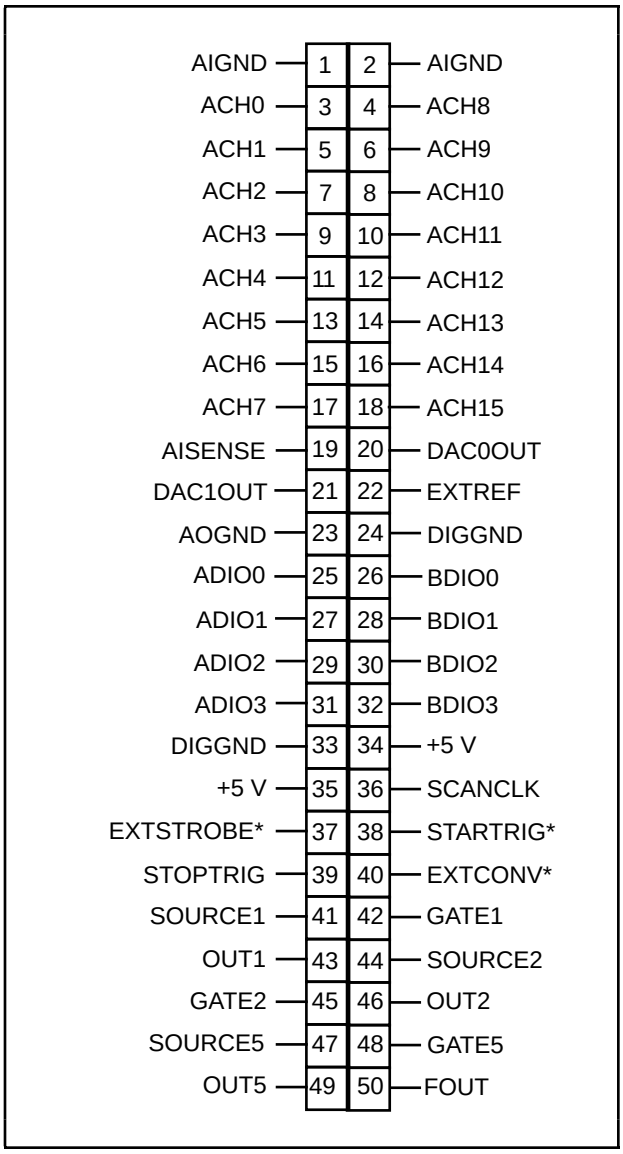


Figure 3-1. AT-MIO-16 I/O Connector Pin Assignments

Signal Descriptions

Pin	Signal Name	Reference	Description
1, 2	AIGND	N/A	Analog Input Ground—These pins are the reference point for single-ended measurements and the bias current return point for differential measurements.
3–18	ACH<0..15>	AIGND	Analog Input Channels 0 through 15—In the DIFF mode, the input is configured for up to 8 channels. In single-ended mode, the input is configured for up to 16 channels.
19	AISENSE	AIGND	Analog Input Sense—This pin serves as the reference node when the board is in NRSE configuration. If desired, this signal can be programmed to be driven by the board analog input ground.
20	DAC0OUT	AOGND	Analog Channel 0 Output—This pin supplies the voltage output of analog output channel 0.
21	DAC1OUT	AOGND	Analog Channel 1 Output—This pin supplies the voltage output of analog output channel 1.
22	EXTREF	AOGND	External Reference—This is the external reference input for the analog output circuitry.
23	AOGND	N/A	Analog Output Ground—The analog output voltages are referenced to this node.
24, 33	DIGGND	N/A	Digital Ground—This pin supplies the reference for the digital signals at the I/O connector as well as the +5 VDC supply.
25, 27, 29, 31	ADIO<0..3>	DIGGND	Digital I/O port A signals.
26, 28, 30, 32	BDIO<0..3>	DIGGND	Digital I/O port B signals.
34, 35	+5 V	DIGGND	+5 VDC Source—This pin is fused for up to 1 A of +5 V supply.
36	SCANCLK	DIGGND	Scan Clock—This pin pulses once for each A/D conversion in the scanning modes. The low-to-high edge indicates when the input signal can be removed from the input or switched to another signal.
37	EXTSTROBE*	DIGGND	External Strobe—Writing to the EXTSTROBE* Register results in a minimum 200 ns low pulse on this pin.
38	STARTTRIG*	DIGGND	External Trigger—In posttrigger data acquisition sequences, a high-to-low edge on STARTTRIG* initiates the sequence. In pretrigger applications, the high-to-low edge of STARTTRIG* initiates pretrigger conversions while the STOPTRIG signal initiates the posttrigger sequence.
39	STOPTRIG	DIGGND	Stop Trigger—In pretrigger data acquisition, the low-to-high edge of STOPTRIG initiates the posttrigger sequence.
40	EXTCONV*	DIGGND	External Convert—A high-to-low edge on EXTCONV* causes an A/D conversion to occur. If EXTGATE* or EXTCONV* is low, conversions are inhibited.
41	SOURCE1	DIGGND	SOURCE1—This pin is from the Am9513A Counter 1 signal.
42	GATE1	DIGGND	GATE1—This pin is from the Am9513A Counter 1 signal.

(continues)

Pin	Signal Name	Reference	Description (Continued)
43	OUT1	DIGGND	OUTPUT1—This pin is from the Am9513A Counter 1 signal.
44	SOURCE2	DIGGND	SOURCE2—This pin is from the Am9513A Counter 2 signal.
45	GATE2	DIGGND	GATE2—This pin is from the Am9513A Counter 2 signal.
46	OUT2	DIGGND	OUT2—This pin is from the Am9513A Counter 2 signal.
47	SOURCE5	DIGGND	SOURCE5—This pin is from the Am9513A Counter 5 signal.
48	GATE5	DIGGND	GATE5—This pin is from the Am9513A Counter 5 signal.
49	OUT5	DIGGND	OUT5—This pin is from the Am9513A Counter 5 signal.
50	FOUT	DIGGND	FOUT—This pin is from the Am9513A FOUT signal.

The signals on the connector can be grouped into analog input signals, analog output signals, digital I/O signals, digital power connections, or timing I/O signals. Signal connection guidelines for each of these groups are described in the following sections.

Analog Input Signal Connections

Pins 1 through 19 of the I/O connector are analog input signal pins. Pins 1 and 2 are AIGND signal pins. AIGND is an analog input common signal that is routed directly to the ground tie point on the AT-MIO-16. You can use these pins for a general analog power ground tie point to the AT-MIO-16 if necessary. Pin 19 is the AISENSE pin. In single-ended mode, this pin is connected internally to the negative input of the AT-MIO-16 instrumentation amplifier. In DIFF mode, this signal is connected to the reference ground at the output of the instrumentation amplifier.

Pins 3 through 18 are the ACH<15..0> signal pins. These pins are tied to the 16 analog input channels of the AT-MIO-16. In single-ended mode, signals connected to ACH<15..0> are routed to the positive input of the AT-MIO-16 instrumentation amplifier. In DIFF mode, signals connected to ACH<7..0> are routed to the positive input of the AT-MIO-16 instrumentation amplifier, and signals connected to ACH<15..8> are routed to the negative input of the AT-MIO-16 instrumentation amplifier.

The following input ranges and maximum ratings apply to inputs ACH<15..0>:

- Differential input range ±10 V
- Common-mode input range ±7 V with respect to AT-MIO-16 AIGND
- Input range ±12 V with respect to AT-MIO-16 AIGND
- Maximum input voltage rating ±20 V for the AT-MIO-16 board powered off
±35 V for the AT-MIO-16 board powered on

Warning: ***Exceeding the differential and common-mode input ranges results in distorted input signals. Exceeding the maximum input voltage rating may damage the AT-MIO-16 board and the PC AT. National Instruments is not liable for any damages resulting from incorrect signal connections.***

Connection of analog input signals to the AT-MIO-16 depends on the configuration of the AT-MIO-16 analog input circuitry and the type of input signal source. The different AT-MIO-16 configurations use the AT-MIO-16 instrumentation amplifier in different ways. Figure 3-2 shows a diagram of the AT-MIO-16 instrumentation amplifier.

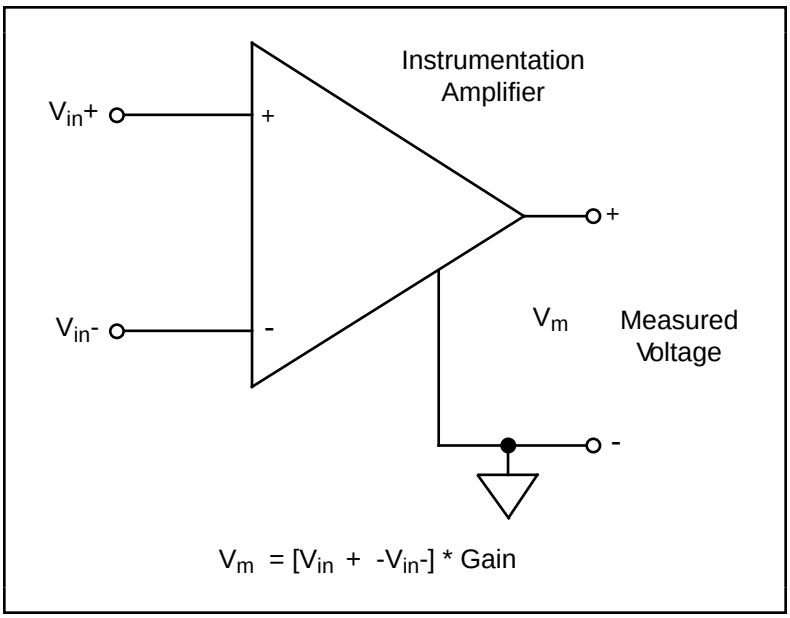


Figure 3-2. AT-MIO-16 Instrumentation Amplifier

The AT-MIO-16 instrumentation amplifier applies gain, common-mode voltage rejection, and high-input impedance to the analog input signals connected to the AT-MIO-16 board. Signals are routed to the positive and negative inputs of the instrumentation amplifier through input multiplexers on the AT-MIO-16. The instrumentation amplifier 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 AT-MIO-16 ground. The AT-MIO-16 ADC measures this output voltage when it performs A/D conversions.

All signals must be referenced to ground somewhere, either at the source device or at the AT-MIO-16. If you have a floating source, you must use a ground-referenced input connection at the AT-MIO-16. If you have a grounded source, you must use a nonreferenced input connection at the AT-MIO-16.

Types of Signal Sources

When configuring the input mode of the AT-MIO-16 and making signal connections, you must first determine whether the signal source is floating or ground referenced. These two types of signals are described in the following sections.

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. The ground reference of a floating signal must be tied to the AT-MIO-16 analog input ground to establish a local or onboard reference for the signal. Otherwise, the measured input signal varies or appears to float. An instrument or device that provides an isolated output falls into the floating signal source category.

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 AT-MIO-16 board, assuming that the PC AT 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 mV and 100 mV, but can be much higher if power distribution circuits are not properly connected. If grounded signal source is measured improperly, this difference may show up as an error in the measurement. The following connection instructions for grounded signal sources should eliminate this ground potential difference from the measured signal.

Input Configurations

You can configure the AT-MIO-16 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. Table 3-1 summarizes the recommended input configuration for both types of signal sources.

Table 3-1. Recommended Input Configurations for Ground-Referenced and Floating Signal Sources

Type of Signal	Recommended Input Configuration
Ground-Referenced (nonisolated outputs, plug-in instruments)	DIFF NRSE
Floating (batteries, thermocouples, isolated outputs)	DIFF with bias resistors RSE

Differential Connection Considerations (DIFF Configuration)

Differential connections are those in which each AT-MIO-16 analog input signal has its own reference signal or signal return path. These connections are available when the AT-MIO-16 is configured in the DIFF mode. Each input signal is tied to the positive input of the instrumentation amplifier. The reference signal, or return, is tied to the negative input of the instrumentation amplifier.

When the AT-MIO-16 is configured for DIFF input, each signal uses two of the multiplexer inputs–one for the signal and one for its reference signal. Therefore, only eight analog input channels are available when using the DIFF configuration. Use the DIFF input configuration when any of the following conditions are present:

- Input signals are low level (less than 1 V).
- Leads connecting the signals to the AT-MIO-16 are greater than 15 ft.
- Any of the input signals requires a separate ground-reference point or return signal.
- The signal leads travel through noisy environments.

Differential signal connections reduce picked-up noise, increase common-mode signal and noise rejection, and cause input signals to float within the common-mode limits of the input instrumentation amplifier.

Differential Connections for Grounded Signal Sources

Figure 3-3 shows how to connect a ground-referenced signal source to an AT-MIO-16 board configured for DIFF input. Configuration instructions are included in the *Analog Input Configuration* section of Chapter 2, *Configuration and Installation*.

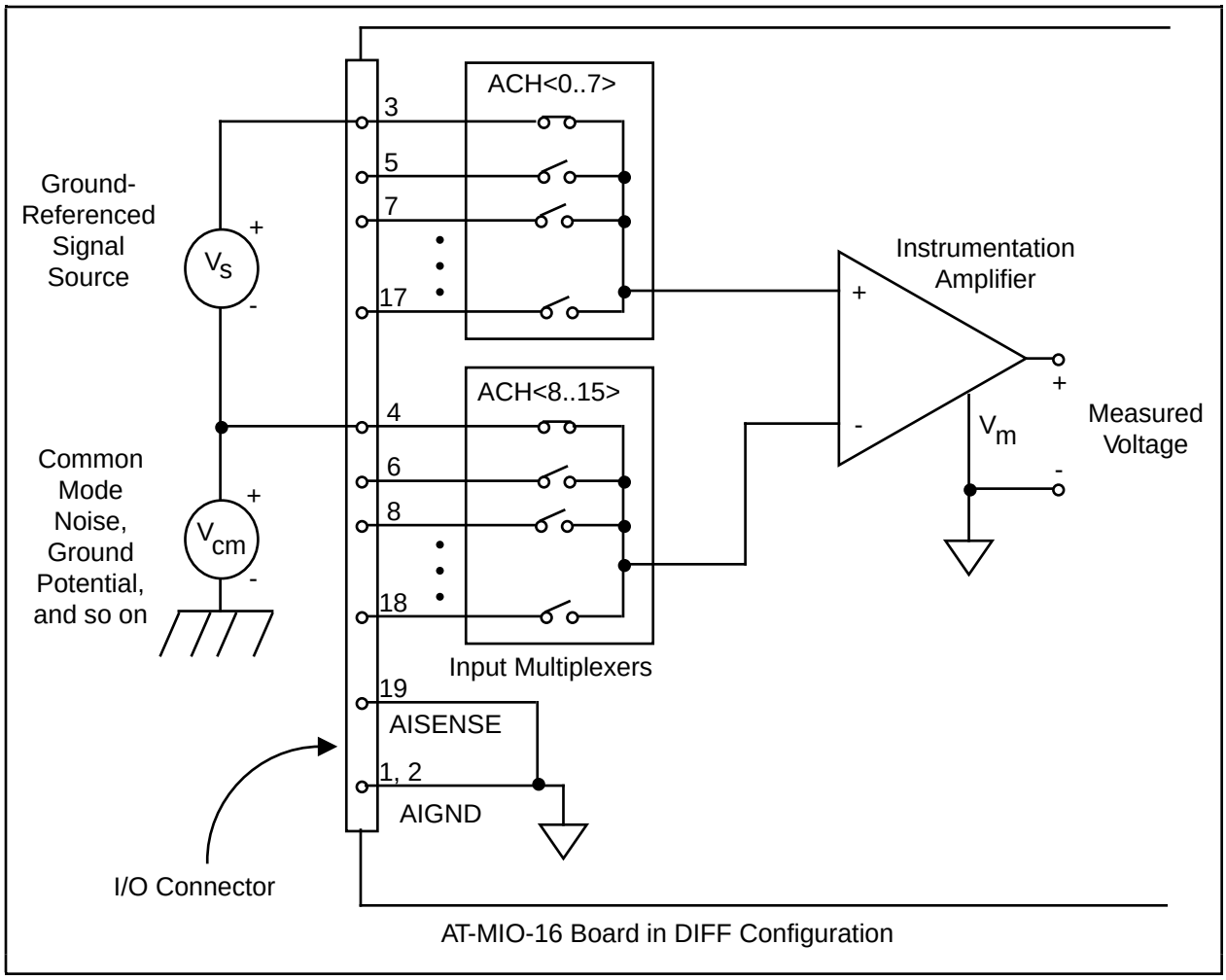


Figure 3-3. Differential Input Connections for Grounded Signal Sources

With this type of connection, the instrumentation amplifier rejects both the common-mode noise in the signal and the ground-potential difference between the signal source and the AT-MIO-16 ground (shown as V_{cm} in Figure 3-3).

Differential Connections for Floating Signal Sources

Figure 3-4 shows how to connect a floating signal source to an AT-MIO-16 board configured for DIFF input. Configuration instructions are included in the *Analog Input Configuration* section of Chapter 2, *Configuration and Installation*.

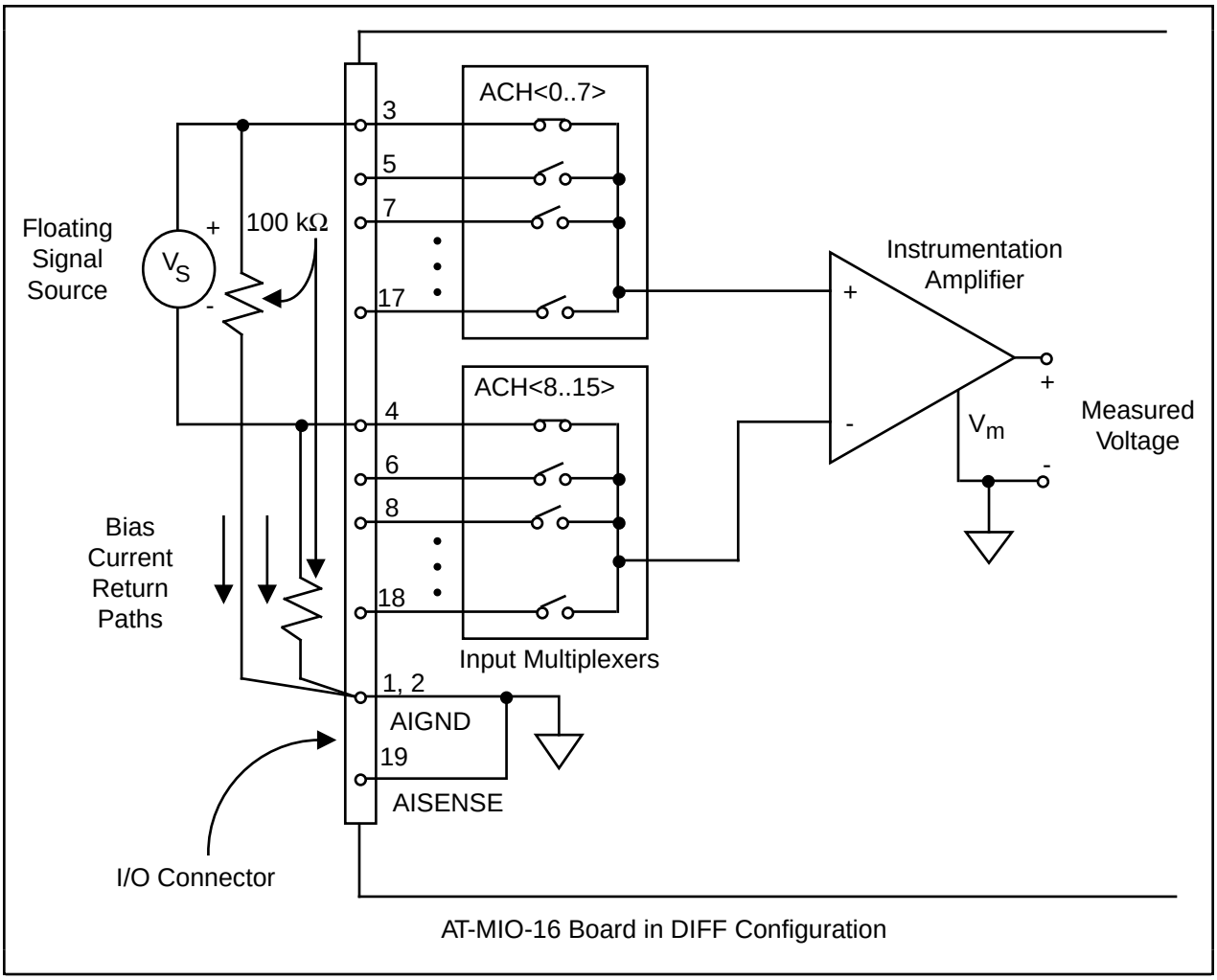


Figure 3-4. Differential Input Connections for Floating Signal Sources

The 100 kΩ resistors shown in Figure 3-4 create a return path to ground for the bias currents of the instrumentation amplifier. If there is no return path, the instrumentation amplifier bias currents charge up stray capacitances, resulting in uncontrollable drift and possible saturation in the amplifier. Typically, resistors from 10 kΩ to 100 kΩ are used.

A resistor from each input to ground, as shown in Figure 3-4, produces bias current return paths for an AC-coupled input signal. This solution, although necessary for AC-coupled signals, lowers the input impedance of the analog input channel. In addition, the input offset current of the instrumentation amplifier contributes a DC offset voltage at the input. The amplifier has a maximum input offset current of ±15 nA and a typical offset current drift of ±20 pA/°C. Multiplied by the 100 kΩ resistor, this current contributes a maximum offset voltage of 1.5 mV and a typical offset voltage drift of 2 µV/°C at the input. Keep this in mind when you observe DC offsets with AC-coupled inputs.

If the input signal is DC-coupled, you need only the resistor that connects the negative signal input to ground. This connection does not lower the input impedance of the analog input channel.

Single-Ended Connection Considerations

Single-ended connections are those in which all AT-MIO-16 analog input signals are referenced to one common ground. The input signals are tied to the positive input of the instrumentation amplifier, and their common ground point is tied to the negative input of the instrumentation amplifier.

When the AT-MIO-16 is configured for single-ended input (NRSE or RSE), 16 analog input channels are available. You can use single-ended input connections when the following criteria are met by all input signals:

- Input signals are high level (greater than 1 V).
- Leads connecting the signals to the AT-MIO-16 are less than 15 ft.
- All input signals share a common reference signal (at the source).

If any of the preceding criteria are not met, using DIFF input configuration is recommended.

You can jumper configure the AT-MIO-16 for two different types of single-ended connections—RSE configuration and NRSE configuration. The RSE configuration is for floating signal sources; in this case, the AT-MIO-16 produces the reference ground point for the external signal. The NRSE configuration is for ground-referenced signal sources; in this case, the external signal supplies its own reference ground point and the AT-MIO-16 should not supply one.

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

Figure 3-5 shows how to connect a floating signal source to an AT-MIO-16 board configured for single-ended input. You must configure the AT-MIO-16 analog input circuitry for RSE input to make these types of connections. Configuration instructions are included in the *Analog Input Configuration* section of Chapter 2, *Configuration and Installation*.

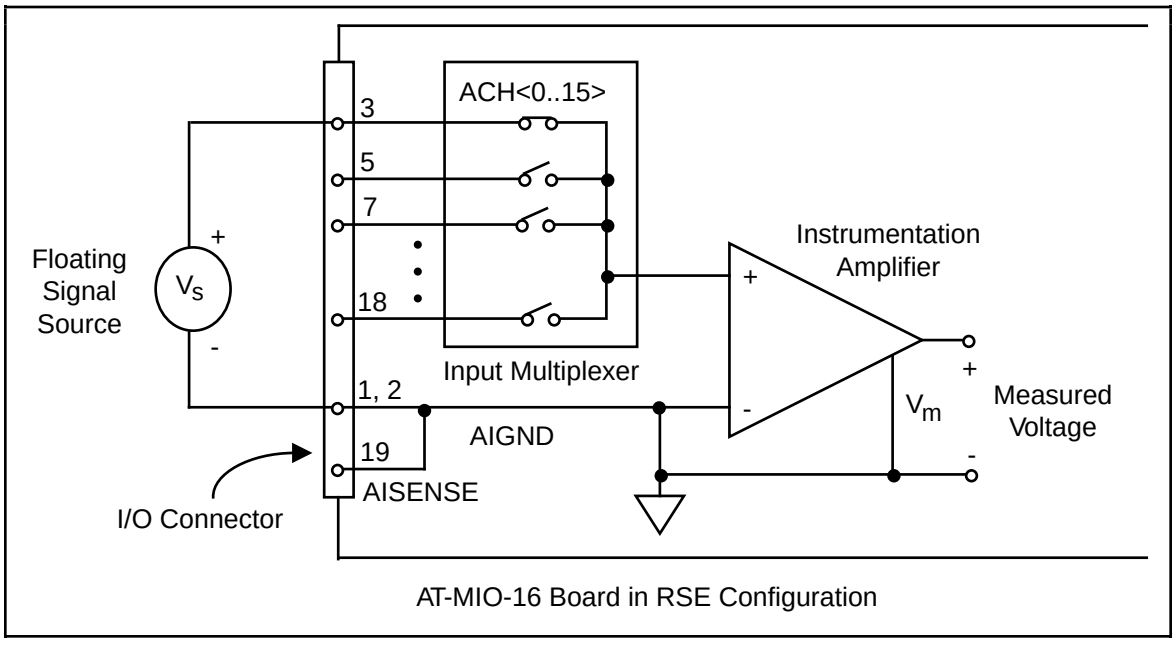


Figure 3-5. Single-Ended Input Connections for Floating Signal Sources

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

If you are measuring a grounded signal source with a single-ended configuration, you must configure the AT-MIO-16 in the NRSE input configuration. Connect the signal to the positive input of the AT-MIO-16 instrumentation amplifier and connect the signal local ground reference to the negative input of the AT-MIO-16 instrumentation amplifier. Therefore, you must connect the ground point of the signal to the AISENSE pin. Any potential difference between the AT-MIO-16 ground and the signal ground appears as a common-mode signal at both the positive and negative inputs of the instrumentation amplifier; the amplifier rejects this difference. On the other hand, if the input circuitry of the AT-MIO-16 is referenced to ground, such as in the RSE configuration, this difference in ground potentials appears as an error in the measured voltage.

Figure 3-6 shows how to connect a grounded signal source to an AT-MIO-16 board in the NRSE configuration. Configuration instructions are included in the *Analog Input Configuration* section of Chapter 2, *Configuration and Installation*.

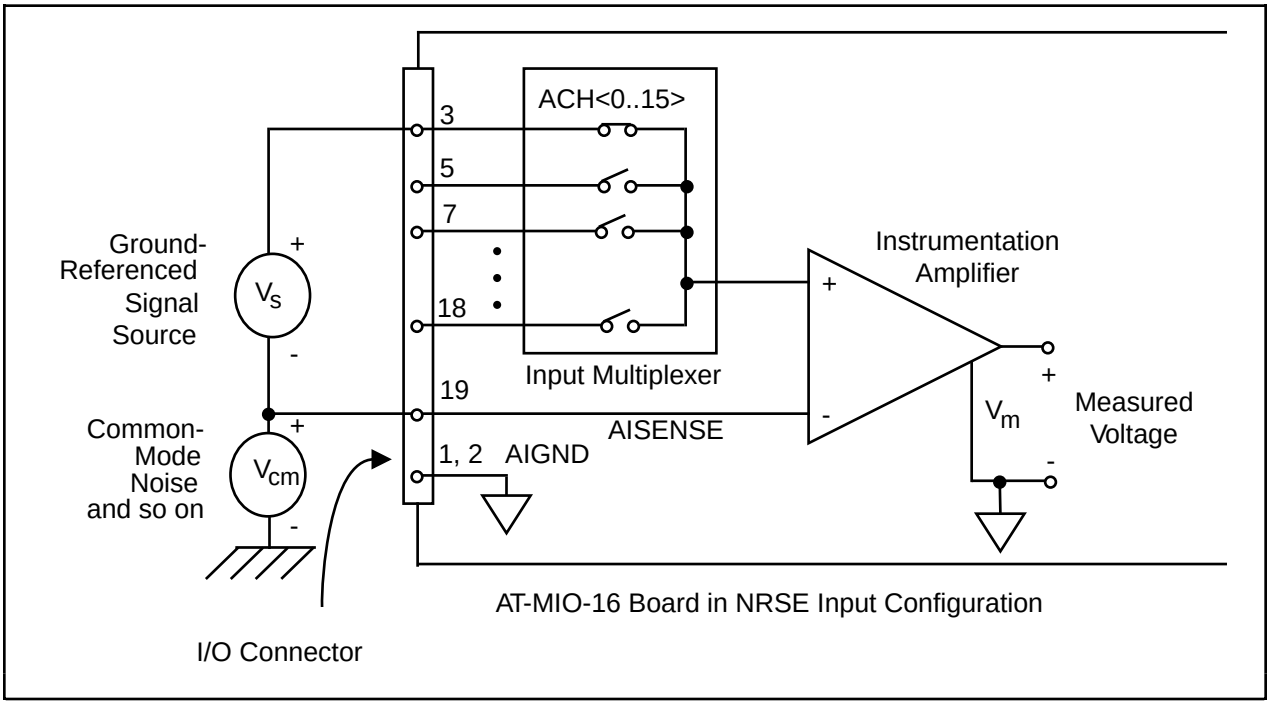


Figure 3-6. Single-Ended Input Connections for Grounded Signal Sources

Common-Mode Signal Rejection Considerations

Figures 3-3 and 3-6 show connections for signal sources that are already referenced to some ground point with respect to the AT-MIO-16. In these cases, the instrumentation amplifier can reject any voltage caused by ground-potential differences between the signal source and the AT-MIO-16. In addition, with differential input connections, the instrumentation amplifier can reject common-mode noise pickup in the leads connecting the signal sources to the AT-MIO-16.

The common-mode input range of the AT-MIO-16 instrumentation amplifier is defined as the magnitude of the greatest common-mode signal that can be rejected.

The common-mode input range for the AT-MIO-16 depends on the size of the differential input signal ($V_{diff} = V^+_{in} - V^-_{in}$) and the gain setting of the instrumentation amplifier. The exact formula for the allowed common-mode input range is as follows:

$$V_{cm\text{-}max} = \pm \left(12\ V - \frac{V_{diff} * Gain}{2}\right)$$

where the maximum value for V_{diff} is as follows:

±10 V range	$V_{diff\text{-}max} = \pm 10$ V
0 to +10 V range	$V_{diff\text{-}max} = 10$ V
±5 V range	$V_{diff\text{-}max} = \pm 5$ V

For example, for a differential voltage as large as 20 mV and a gain of 500, the largest common-mode voltage that can be rejected is ±7 V. However, if the differential signal is 10 mV with a gain of 500, a ±9.5 V common-mode voltage can be rejected.

The common-mode voltage is measured with respect to the AT-MIO-16 ground and can be calculated by the following formula:

$$V_{cm\text{-}actual} = \frac{V^+_{in} + V^-_{in}}{2}$$

where V^+_{in} is the signal at the positive input of the instrumentation amplifier and V^-_{in} is the signal at the negative input of the instrumentation amplifier.

If the input signal common-mode range exceeds ±7 V with respect to the AT-MIO-16 ground, you must limit the amount of floating that occurs between the signal ground and the AT-MIO-16 ground.

Analog Output Signal Connections

Pins 20 through 23 of the I/O connector are analog output signal pins.

Pins 20 and 21 are the DAC0OUT and DAC1OUT signal pins. DAC0OUT is the voltage output signal for analog output channel 0. DAC1OUT is the voltage output signal for analog output channel 1.

Pin 22, EXTREF, is the external reference input for both analog output channels. You must individually configure each analog output channel for external reference selection in order for the signal applied at the external reference input to be used by that channel. Analog output configuration instructions are included in the *Analog Output Configuration* section of Chapter 2, *Configuration and Installation*.

The following ranges and ratings apply to the EXTREF input:

- Useful input voltage range ±10 V peak with respect to AOGND
- Absolute maximum ratings ±25 V peak with respect to AOGND

Pin 23, AOGND, is the ground-reference point for both analog output channels and for the external reference signal.

Figure 3-7 shows how to make analog output connections and the external reference input connection to the AT-MIO-16 board. If neither channel is configured to use an external reference signal, do not connect anything to the EXTREF pin.

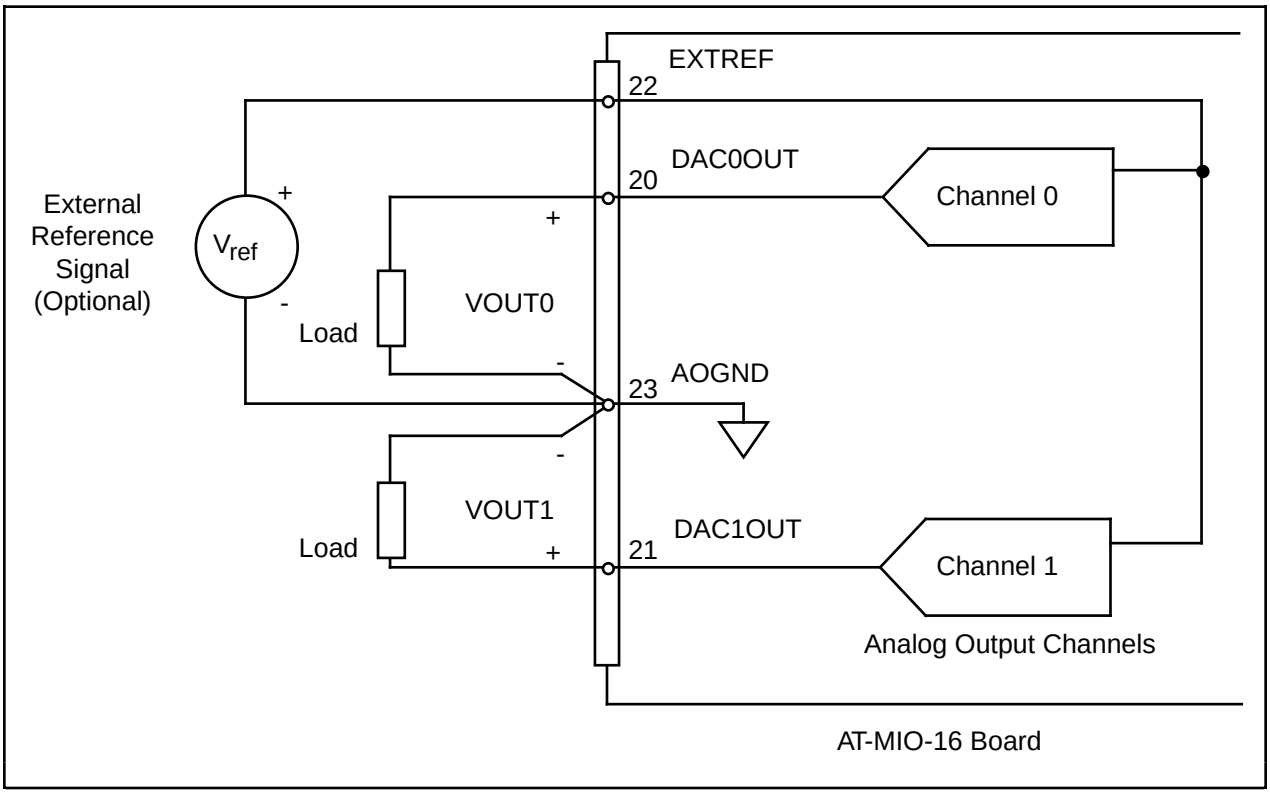


Figure 3-7. Analog Output Connections

The external reference signal can be either a DC or an AC signal. This reference signal is multiplied by the DAC code to generate the output voltage. The DACs in the analog output channels are rated for -82 dB THD with a 1 kHz, 6 Vrms sine wave reference signal and with the DACs set at their maximum (full-scale) digital value.

Digital I/O Signal Connections

Pins 24 through 32 of the I/O connector are digital I/O signal pins.

Pins 25, 27, 29, and 31 are connected to the digital lines ADIO<3..0> for digital I/O port A. Pins 26, 28, 30, and 32 are connected to the digital lines BDIO<3..0> for digital I/O port B. Pin 24, DIGGND, is the digital ground pin for both digital I/O ports. You can individually program ports A and B to be inputs or outputs.

The following specifications and ratings apply to the digital I/O lines.

- Absolute maximum voltage input rating 6.0 V with respect to DIGGND
- Digital input specifications (referenced to DIGGND):
  - V_{IH} input logic high voltage 2 V min
  - V_{IL} input logic low voltage 0.8 V max
  - I_{IH} input current load, logic high input voltage 20 µA max
  - I_{IL} input current load, logic low input voltage -20 µA max
- Digital output specifications (referenced to DIGGND):
  - V_{OH} output logic high voltage 2.4 V min
  - V_{OL} output logic low voltage 0.5 V max
  - I_{OH} output source current, logic high 2.6 mA max
  - I_{OH} output sink current, logic low 24 mA max

With these specifications, each digital output line can drive 11 standard TTL loads and over 50 LS TTL loads.

Figure 3-8 depicts signal connections for three typical digital I/O applications.

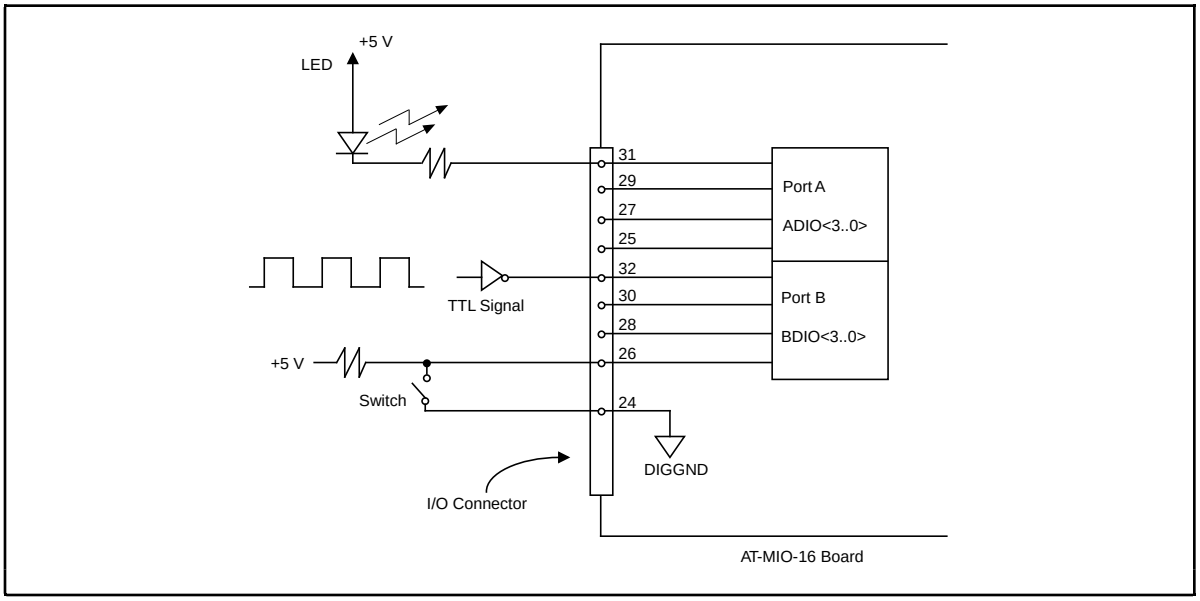


Figure 3-8. Digital I/O Connections

In Figure 3-8, port A is configured for digital output, and port B is configured for digital input. Digital input applications include receiving TTL signals and sensing external device states such as the state of the switch in Figure 3-8. Digital output applications include sending TTL signals and driving external devices such as the LED shown in Figure 3-8.

Timing I/O Signals

The AT-MIO-16 uses an Am9513A counter/timer for data acquisition timing and for general-purpose timing I/O functions. An onboard oscillator generates the 10-MHz clock.

RTSI Bus Signal Connections

The AT-MIO-16 is interfaced to the National Instrument RTSI bus. The RTSI bus has seven trigger lines and a system clock line. You can wire any National Instruments AT Series boards that have a RTSI bus connector together inside the PC AT and share these signals. Figure 3-9 is a block diagram of the RTSI bus interface circuitry.

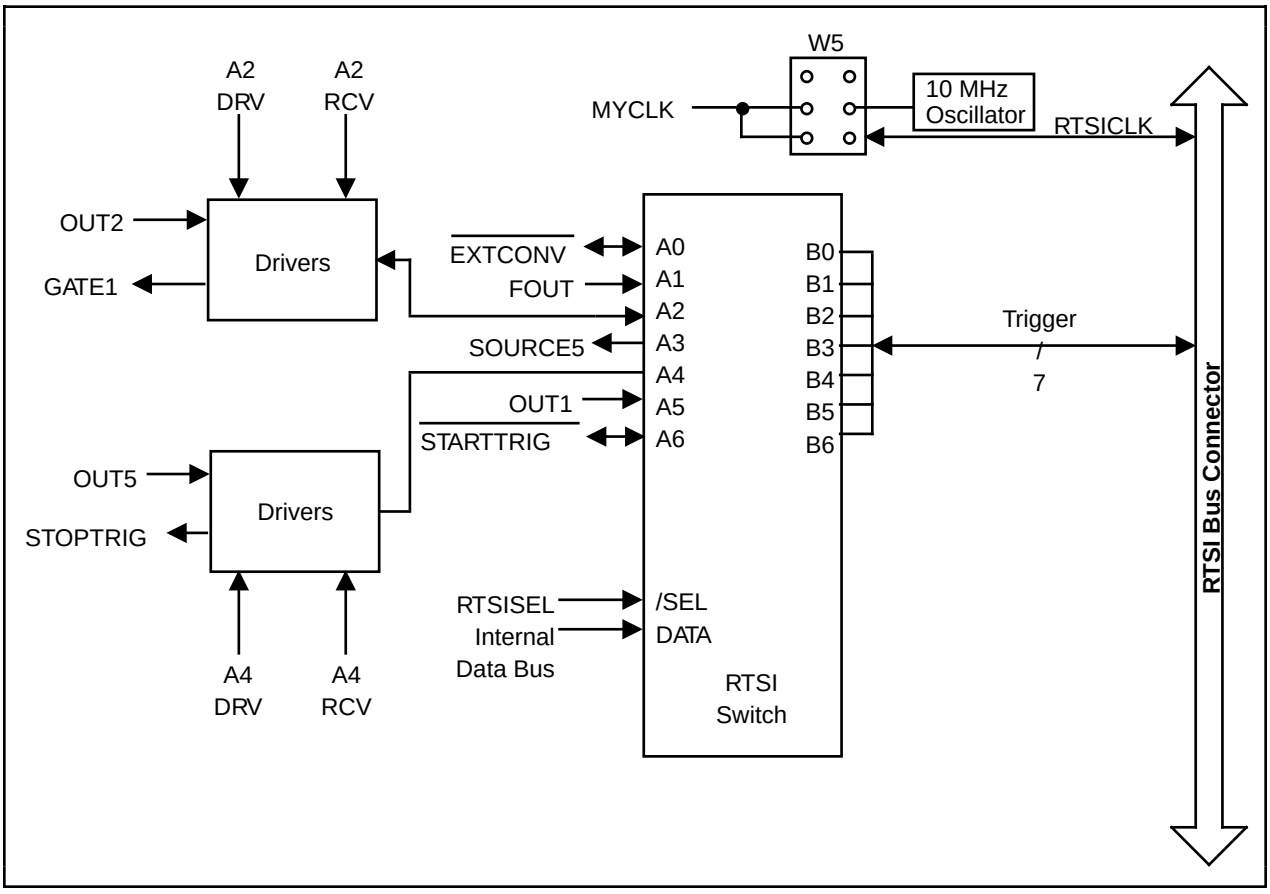


Figure 3-9. RTSI Bus Interface Circuitry Block Diagram

The RTSI switch is a National Instruments custom integrated circuit that acts as a 7x7 crossbar switch. Pins B<6..0> are connected to the seven RTSI bus trigger lines. Pins A<6..0> are connected to seven signals on the board. The RTSI switch can drive any of the signals at pins A<6..0> onto any one or more of the seven RTSI bus trigger lines and can drive any of the seven trigger line signals onto any one or more of the pins A<6..0>. This signal trigger produces a completely flexible signal interconnection scheme for any AT Series board sharing the RTSI bus. You program the RTSI switch via its select and data inputs.

On the AT-MIO-16 board, nine signals are connected to pins A<6..0> of the RTSI switch with the aid of additional drivers. The signals GATE1, OUT1, OUT2, OUT5, FOUT, and STOPTRIG are shared with the AT-MIO-16 I/O connector and Am9513A counter/timer. The signal SOURCE5 is connected to the Am9513A SOURCE5 pin. The I/O connector and the data acquisition timing circuitry share the EXTCONV* and STARTTRIG* signals. Through these onboard interconnections, you can control the AT-MIO-16 general-purpose and data acquisition timing over the RTSI bus as well as externally, and use the AT-MIO-16 and the I/O connector to supply timing signals to other AT boards connected to the RTSI bus.

Power Connections

Pins 34 and 35 of the I/O connector supply +5 V from the PC AT power supply. These pins are referenced to DIGGND and you can use them to power the external digital circuitry.

- Power rating: 0.5 A at +5 V ± 10%

Warning: ***These +5 V power pins should NOT be directly connected to analog or digital ground or to any other voltage source on the AT-MIO-16 or any other device. Doing so can damage the AT-MIO-16 and the PC AT. National Instruments is NOT liable for damages resulting from such a connection.***

Timing Connections

Pins 36 through 50 of the I/O connector are connections for timing I/O signals. Pins 36 through 40 carry signals used for data acquisition timing. These signals are explained in the next section, *Data Acquisition Timing Connections*. Pins 41 through 50 carry general-purpose timing signals produced by the onboard Am9513A counter/timer. These signals are explained in the *General-Purpose Timing Signal Connections* section later in this chapter.

Data Acquisition Timing Connections

The data acquisition timing signals are SCANCLK, EXTSTROBE*, STARTTRIG*, STOPTRIG, and EXTCONV*.

SCANCLK is an output signal that generates a high-to-low edge whenever an A/D conversion begins. SCANCLK pulses only when scanning is enabled on the AT-MIO-16. SCANCLK is normally high and pulses low for approximately 1 µs after the A/D conversion begins. The low-to-high edge signals that the input signal has been acquired. You can use this signal to clock external analog input multiplexers. One LS TTL gate drives the SCANCLK signal.

A low pulse is generated on the EXTSTROBE* pin when the External Strobe Register is accessed (see the `REG_Level_Write` function in the *NI-DAQ Function Reference Manual for PC Compatibles* or the *External Strobe Register* description in Chapter 2, *Register Maps and Descriptions,* of the *AT-MIO-16 Register-Level Programmer Manual*). Figure 3-10 shows the timing for the EXTSTROBE* signal.

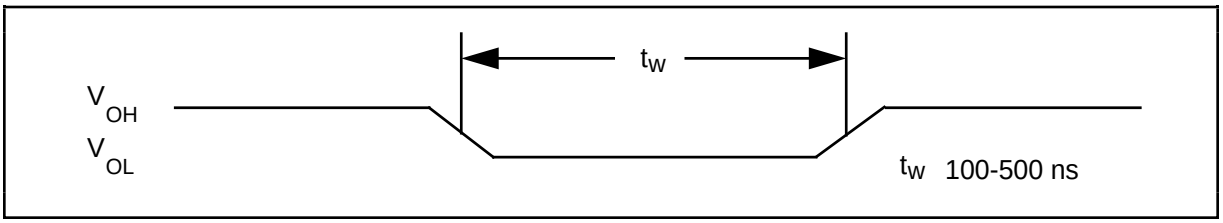


Figure 3-10. EXTSTROBE* Signal Timing

The pulse is typically between 100 ns and 500 ns in width. An external device can use the EXTSTROBE* signal to latch signals or trigger events. The EXTSTROBE* signal is an LS TTL signal.

The EXTCONV* pin can externally trigger A/D conversions. Applying an active low pulse to the EXTCONV* signal initiates an A/D conversion. The low-to-high edge of the applied pulse initiates the A/D conversion. Figure 3-11 shows the timing requirements for the EXTCONV* signal.

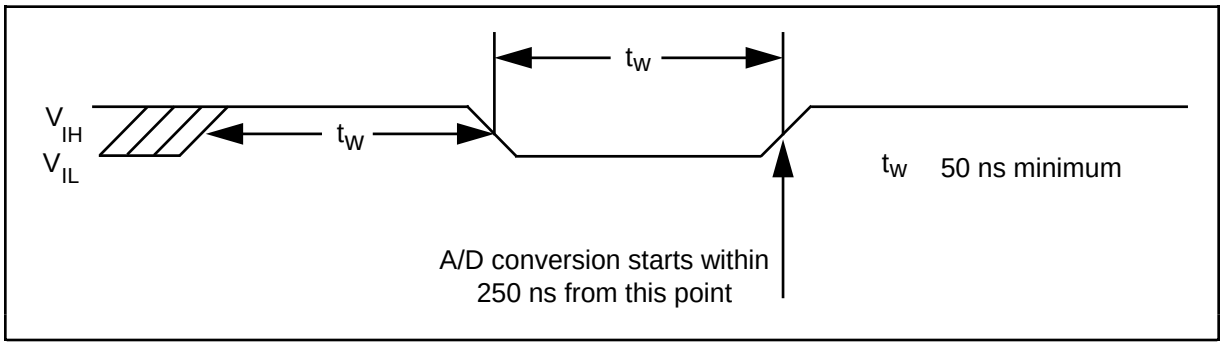


Figure 3-11. EXTCONV* Signal Timing

The minimum allowed pulse width is 50 ns. An A/D conversion starts within 250 ns of the low-to-high edge. There is no maximum pulse-width limitation. EXTCONV* should be high for at least 50 ns before going low. The EXTCONV* signal is one LS TTL load and is pulled up to +5 V through a 4.7 kΩ resistor.

Note: ***The output of the Am9513A counter/timer counter 3 also drives EXTCONV*. This counter is also referred to as the sample-interval counter. You must disable the output of counter 3 to a high-impedance state if pulses applied to the EXTCONV* pin are to control A/D conversions. If you use counter 3 to control A/D conversions, you can monitor its output signal at the EXTCONV* pin.***

An external trigger applied to the STARTTRIG* pin can initiate any data acquisition sequence that the onboard sample-interval and sample counters control. If the EXTCONV* signal generates conversions, STARTTRIG* does not affect the acquisition timing. After the two counters are initialized and armed, applying a falling edge to the STARTTRIG* pin starts the counters, thereby initiating a data acquisition sequence.

The high-to-low edge of the applied pulse initiates the data acquisition operation. Figure 3-12 shows the timing requirements for the STARTTRIG* signal.

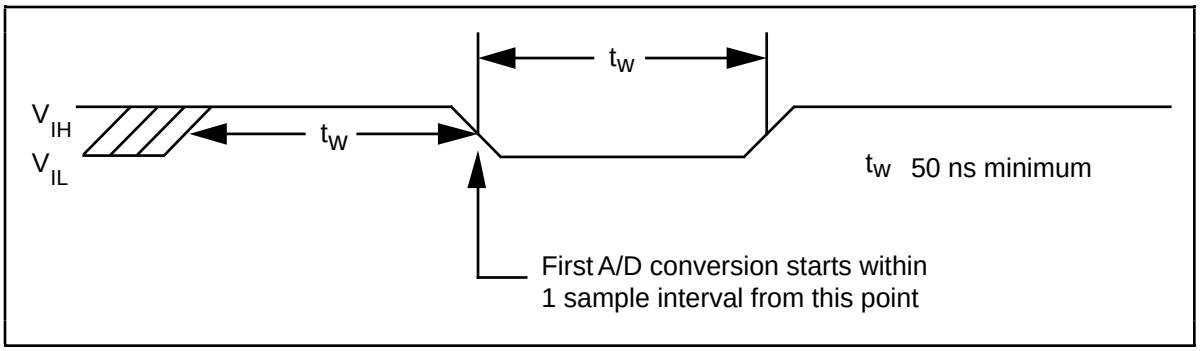


Figure 3-12. STARTTRIG* Signal Timing

The minimum allowed pulse width is 50 ns. The first A/D conversion starts within one sample interval from the high-to-low edge. Counter 3 controls the sample interval.

There is no maximum pulse-width limitation; however, STARTTRIG* should be high for at least 50 ns before going low. The STARTTRIG* signal is one LS TTL load and is pulled up to +5 V through a 4.7 kΩ resistor.

The STOPTRIG pin is used during AT-MIO-16 pretriggered data acquisition operations. In pretriggered mode, data is acquired but no sample counting occurs until a rising edge is applied to the STOPTRIG pin. This causes the sample counter to start counting conversions. The acquisition completes when the sample counter decrements to zero. This mode acquires data both before and after a hardware trigger is received. Figure 3-13 shows the timing requirements for the STOPTRIG signal. The STOPTRIG signal is one LS TTL load and is pulled up to +5 V through a 4.7 kΩ resistor.

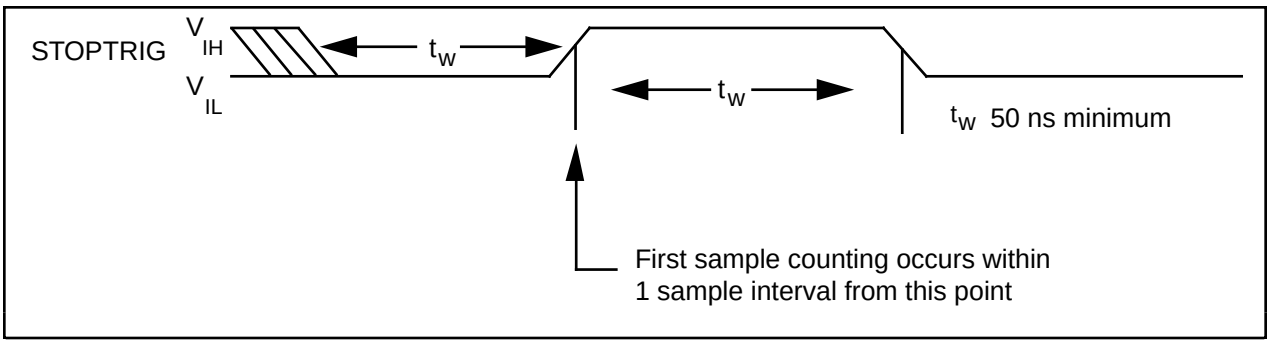


Figure 3-13. STOPTRIG Signal Timing

General-Purpose Timing Signal Connections

The general-purpose timing signals include the GATE, SOURCE, and OUT signals for the Am9513A counters 1, 2, and 5, and the FOUT signal that the Am9513A generates. You can use the Am9513A counter/timer counters 1, 2, and 5 for general-purpose applications such as pulse and square wave generation, event counting, and pulse-width, time-lapse, and frequency measurements. For these applications, you can directly apply SOURCE and GATE signals to the counters from the I/O connector and program the counters for various operations. Figure 3-14 shows a block diagram of the timing I/O circuitry.

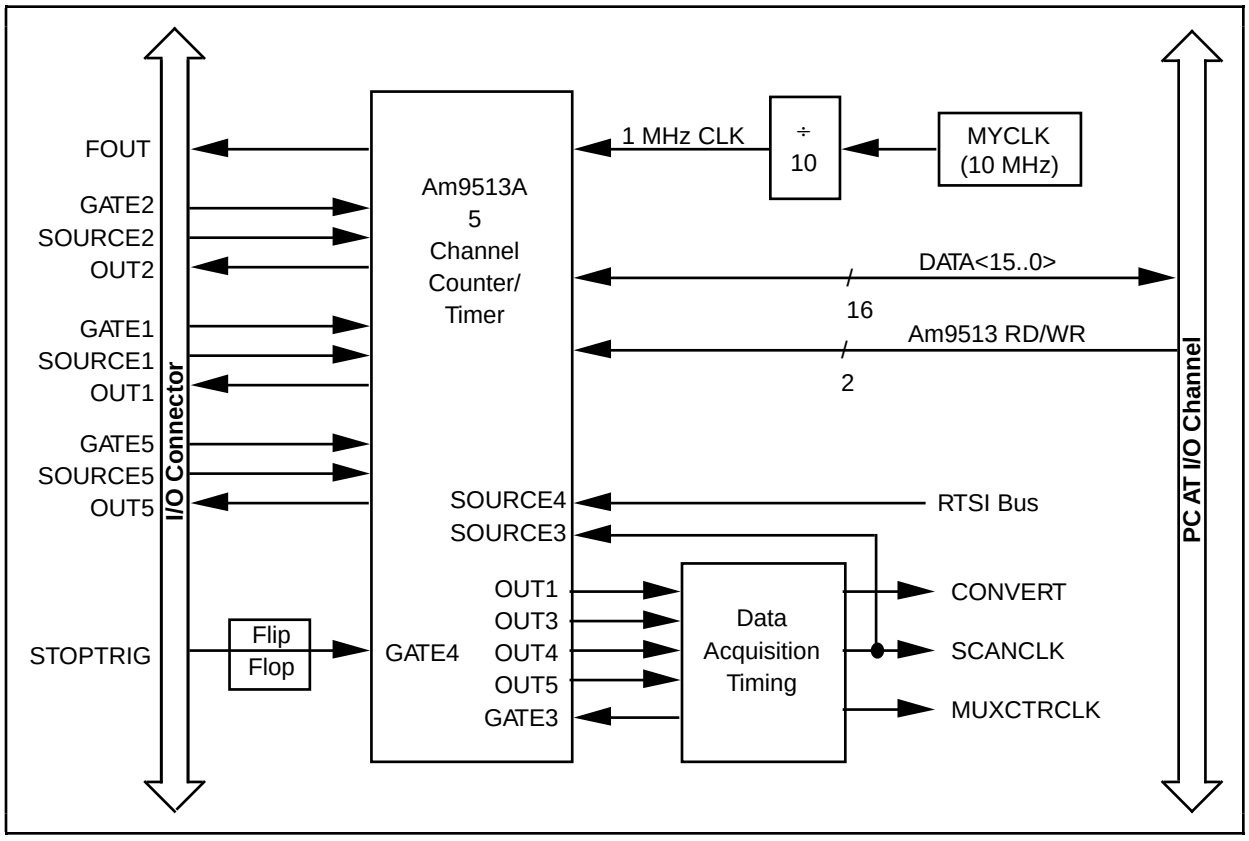


Figure 3-14. Timing I/O Circuitry Block Diagram

The Am9513A contains five independent 16-bit counter/timers, a 4-bit frequency output channel, and five internally generated timebases. You can program the five counter/timers to operate in several useful timing modes.

The Am9513A clock input is one-tenth the MYCLK frequency selected by the W5 jumpers. The factory-default setting for MYCLK is 10 MHz, which generates a 1-MHz clock input to the Am9513A. The Am9513A uses this clock input to generate five internal timebases. The counter/timers and the frequency output channel can use these timebases as clocks. When MYCLK is 10 MHz, the five internal timebases normally used for AT-MIO-16 timing functions are 1 MHz, 100 kHz, 10 kHz, 1 kHz, and 100 Hz.

Note: ***For detailed programming information, consult the AMD Am9513A Data Sheet in the*** *AT-MIO-16 Register-Level Programmer Manual.* ***For detailed application information, consult the*** *Am9513A/Am9513A System Timing Controller* ***technical manual published by Advanced Micro Devices, Inc.***

Figure 3-15 is a diagram of the 16-bit counters in the Am9513A.

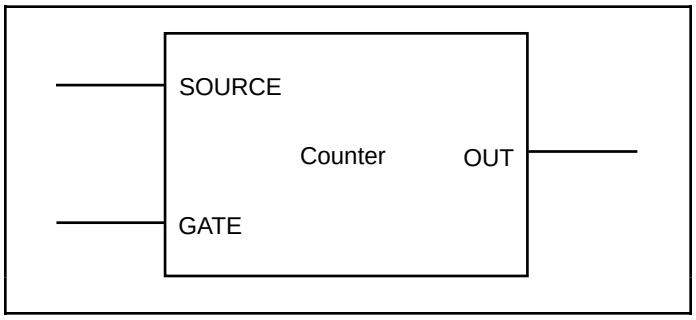


Figure 3-15. Counter Block Diagram

Each counter has a SOURCE input pin, a GATE input pin, and an output pin labeled OUT. The Am9513A counters are numbered 1 through 5, and their GATE, SOURCE, and OUT pins are labeled GATE *N*, SOURCE *N*, and OUT *N*, where *N* is the counter number.

For counting operations, you can program the counters to use any of the five internal timebases, any of the five GATE and five SOURCE inputs to the Am9513A, and the output of the previous counter (counter 4 uses counter 3 output, and so on). You can configure a counter to count either falling or rising edges of the selected input.

With the counter GATE input, you can gate counter operation. When you have configured a counter for an operation through software, a signal at the GATE input can start and stop counter operation. The Am9513A has five gating modes—no gating, level gating active high, level gating active low, low-to-high edge gating, and high-to-low edge gating. A counter can also be active high level gated by a signal at GATE *N*+1 and GATE *N*-1, where *N* is the counter number.

The counter generates timing signals at its OUT output pin. You can also set the OUT output pin to a high-impedance state or a grounded-output state. The counters generate two types of output signals during counter operation—terminal-count pulse output and terminal-count toggle output. Terminal count is often referred to as *TC*. A counter reaches TC when it counts up or down and rolls over. In many counter applications, the counter reloads from an internal register when it reaches TC. In TC pulse output mode, the counter generates a pulse during the cycle that it reaches TC and reloads. In TC toggle output mode, the counter output changes state after it reaches TC and reloads. In addition, you can configure the counters for positive logic output or negative (inverted) logic output for a total of four possible output signals generated for one timing mode.

The SOURCE, GATE, and OUT pins for counters 1, 2, and 5 of the onboard Am9513A are located on the AT-MIO-16 I/O connector. A rising-edge signal on the STOPTRIG pin of the I/O connector sets the flip-flop output signal connected to the GATE4 input of the Am9513A and can be used as an additional gate input. The flip-flop output connected to GATE4 is cleared when the sample counter reaches TC, when an overflow or overrun occurs, or when the A/D Clear Register is written to.

The Am9513A SOURCE5 pin is connected to the AT-MIO-16 RTSI switch, which means that you can use a signal from the RTSI trigger bus as a counting source for the Am9513A counters.

You can use the Am9513A OUT2 pin in several different ways. If you configure the board for the later update mode, an active low pulse on OUT2 updates the analog output on the two DACs. You can also use OUT2 to trigger interrupt requests. If counter interrupts are enabled, an interrupt occurs when a rising-edge signal is detected on OUT2. You can use this interrupt to update the DACs or to interrupt on an external signal connected to OUT2 through the I/O connector.

Counters 3 and 4 of the Am9513A are dedicated to data acquisition timing and therefore are not made available for general-purpose timing applications. Signals generated at OUT3 and OUT4 are passed to the data acquisition timing circuitry. The data acquisition timing circuitry controls GATE3.

Counter 5 is sometimes used by the data acquisition timing circuitry and concatenated with counter 4 to form a 32-bit sample counter. The SCANCLK signal is connected to the SOURCE3 input of the Am9513A, and OUT1 is sent to the data acquisition timing circuitry. Thus, counter 1 divides the SCANCLK signal for sequencing the channel-gain memory.

The data acquisition timing circuitry sometimes uses counter 2 to assign a time interval to each cycle through the scan sequence programmed in the mux-gain memory. This mode is called interval channel scanning.

The Am9513A 4-bit programmable frequency output channel is provided at the I/O connector FOUT pin. You can select any of the five internal timebases and any of the counter SOURCE or GATE inputs as the frequency output source. The frequency output channel divides the selected source by its 4-bit programmed value and sends the divided down signal at the FOUT pin.

You can produce pulses and square waves at the I/O connector by programming counter 1, 2, or 5 to generate a pulse signal at its OUT output pin or to toggle the OUT signal each time the counter reaches the terminal count.

For event counting, program one of the counters to count rising or falling edges applied to any of the Am9513A SOURCE inputs. You can then read the counter value to determine the number of edges that have occurred. Counter operation can be gated on and off during event counting.

Figure 3-16 shows connections for a typical event-counting operation in which a switch gates the counter on and off.

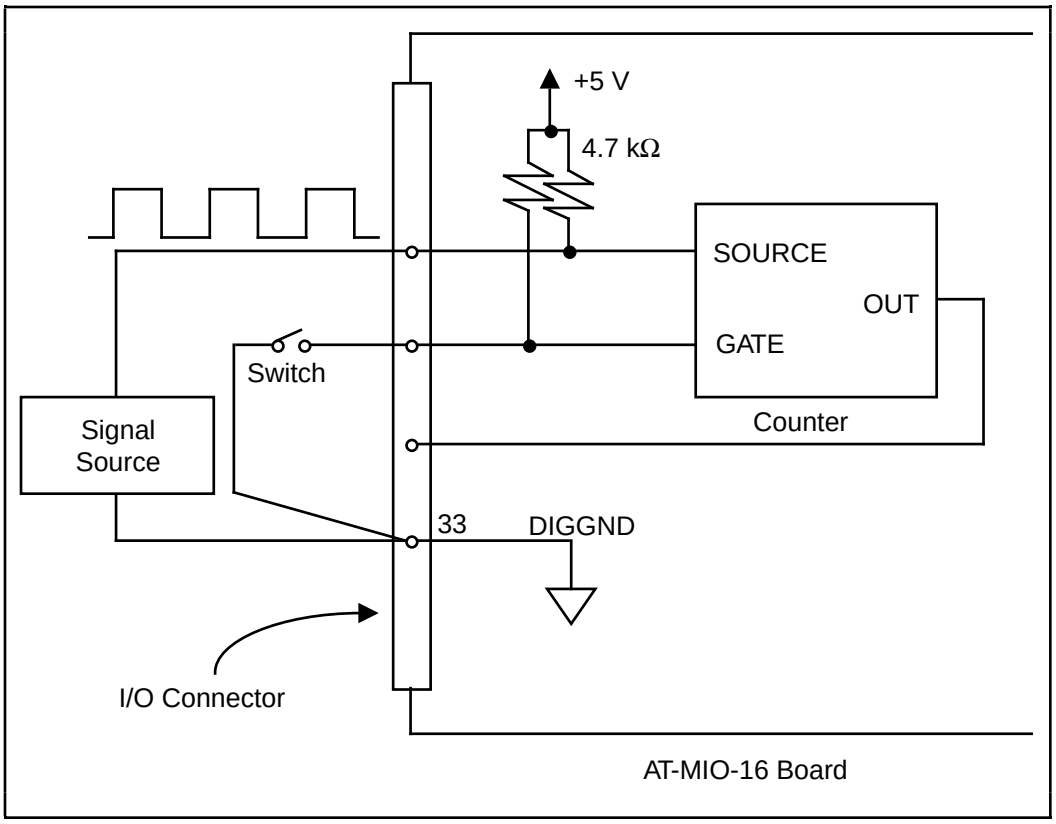


Figure 3-16. Event-Counting Application with External Switch Gating

To perform pulse-width measurement, program a counter to be level gated. Apply the pulse to be measured to the counter GATE input. Program the counter to count while the signal at the GATE input is either high or low. If the counter is programmed to count an internal timebase, the pulse width is equal to the counter value multiplied by the timebase period.

For time-lapse measurement, program a counter to be edge gated. Apply an edge to the counter GATE input to start the counter. You can program the counter to start counting after receiving either a high-to-low edge or a low-to-high edge. If the counter is programmed to count an internal timebase, the time lapse since receiving the edge is equal to the counter value multiplied by the timebase period.

To measure frequency, program a counter to be level gated and to count the rising or falling edges of a signal applied to a SOURCE input. The gate signal applied to the counter GATE input is of some known duration. In this case, program the counter to count either rising or falling edges at the SOURCE input while the gate is applied. The frequency of the input signal is equal to the count value divided by the known gate period. Figure 3-17 shows the connections for a frequency measurement application. You could also use a second counter to generate the gate signal in this application.

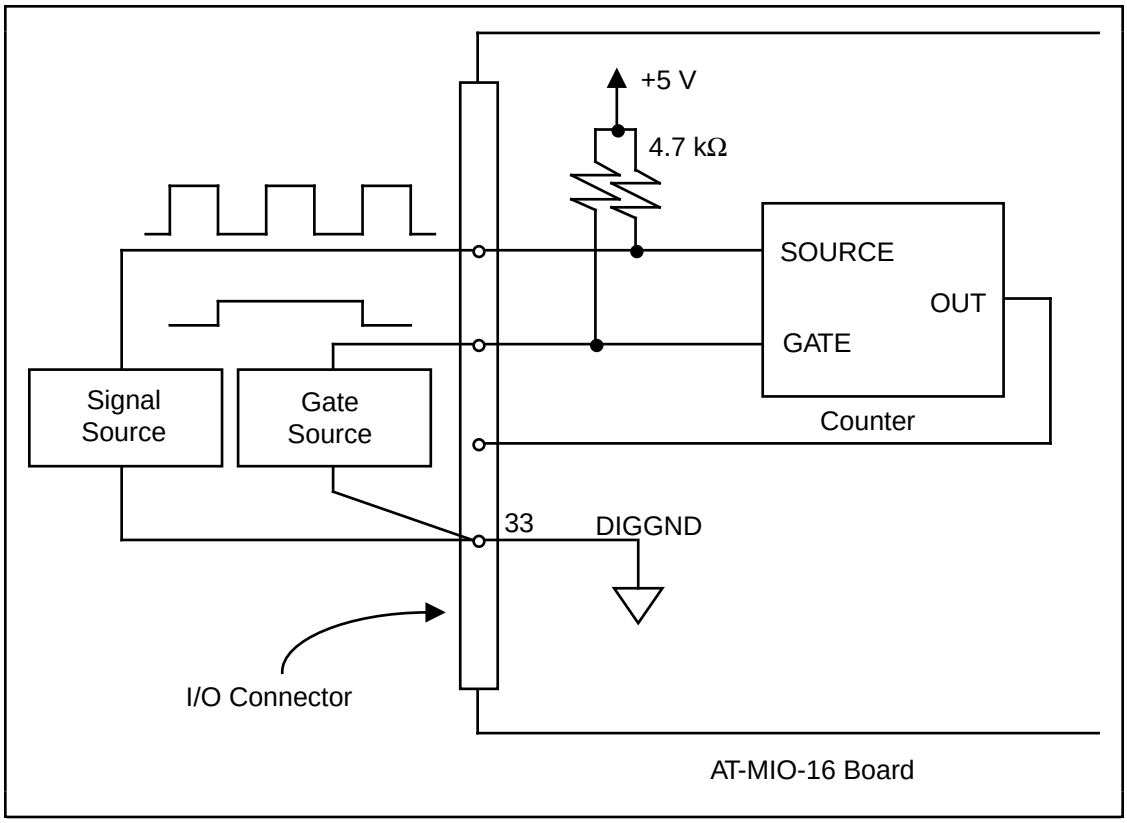


Figure 3-17. Frequency Measurement Application

You can concatenate two or more counters by tying the OUT signal from one counter to the SOURCE signal of another counter. You can then treat the counters as one 32-bit or 48-bit counter for most counting applications.

The GATE, SOURCE, and OUT signals for counters 1, 2, and 5, and the FOUT output signal are tied directly from the Am9513A input and output pins to the I/O connector. In addition, the GATE, SOURCE, and OUT1 pins are pulled up to +5 V through a 4.7 kΩ resistor.

The following input and output ratings and timing specifications apply to the Am9513A signals:

- Absolute maximum voltage input rating -0.5 V to +7.0 V with respect to DIGGND
- Am9513A digital input specifications (referenced to DIGGND):
  - V_{IH} input logic high voltage 2.2 V min
  - V_{IL} input logic low voltage 0.8 V max
  - Input load current ±10 µA max

- Am9513A digital output specifications (referenced to DIGGND):
  - V_{OH} output logic high voltage 2.4 V min
  - V_{OL} output logic low voltage 0.4 V max
  - I_{OH} output source current, at V_{OH} 200 µA max
  - I_{OL} output sink current, at V_{OL} 3.2 mA max
  - Output current, high-impedance state ±25 µA max

Figure 3-18 shows the timing requirements for the GATE and SOURCE input signals and the timing specifications for the OUT output signals of the Am9513A.

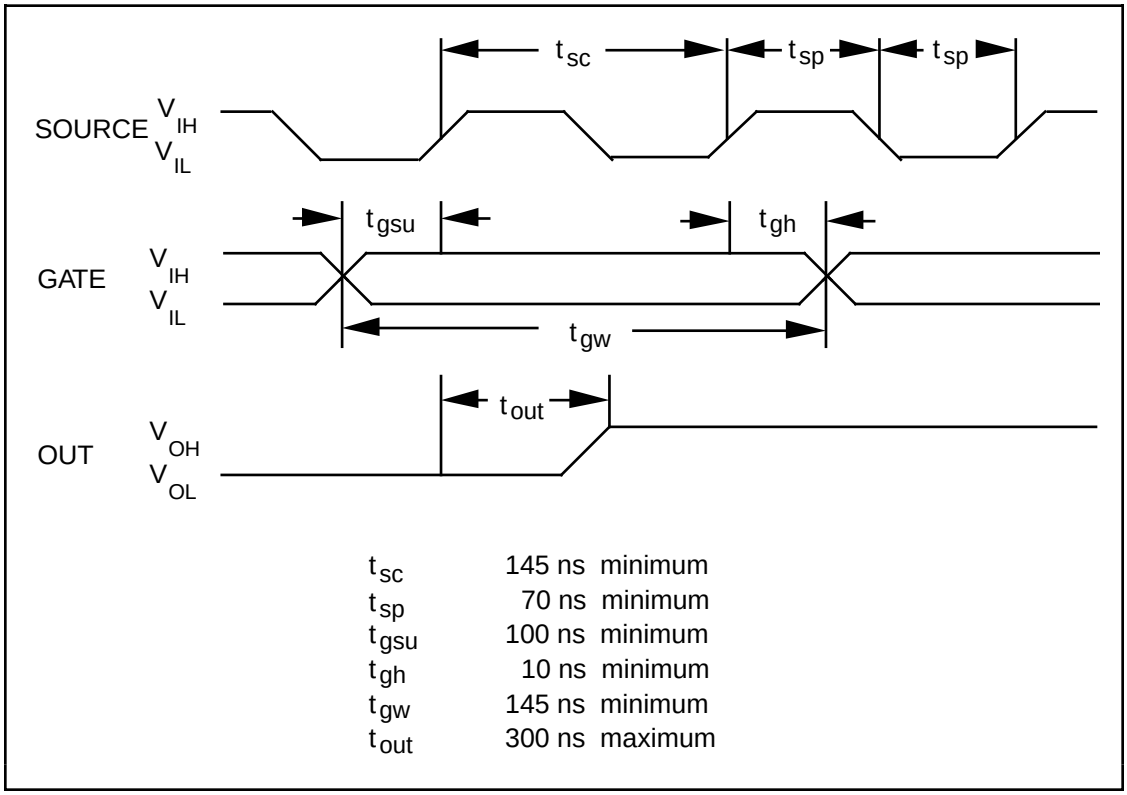


Figure 3-18. General-Purpose Timing Signals

The GATE and OUT signal transitions in Figure 3-18 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, with the source signal inverted and referenced to the falling edge of the source signal, applies to the case in which the counter is programmed to count falling edges.

Any of the Am9513A counter/timers and the Am9513A frequency division output FOUT can use the signal applied at a SOURCE input as a clock source. The signal applied to a SOURCE input must not exceed a frequency of 6 MHz for proper operation of the Am9513A. You can individually program the Am9513A counters to count rising or falling edges of signals applied at any of the Am9513A SOURCE or GATE input pins.

In addition to the signals applied to the SOURCE and GATE inputs, the Am9513A generates five internal timebase clocks from the clock signal supplied by the AT-MIO-16. This clock signal is selected by the W5 jumper and then divided by 10. The factory default value is 1 MHz into the Am9513A (10 MHz clock signal on the AT-MIO-16). You can use the five internal timebase clocks as counting sources, and these clocks have a maximum skew of 75 ns between them. The SOURCE signal shown in Figure 3-18 represents any of the signals applied at the SOURCE inputs, GATE inputs, or internal timebase clocks.

Specifications for signals at the GATE input are referenced to the signal at the SOURCE input or one of the Am9513A internally generated signals. Figure 3-18 shows the GATE signal referenced to the rising edge of a source signal. The gate must be valid (either high or low) at least 100 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 3-18. Similarly, the gate signal must be held for at least 10 ns after the rising or falling edge of a source signal for the gate to take effect at that source edge. The gate high or low period must be at least 145 ns in duration. If you use an internal timebase clock, 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 creates an uncertainty of one source clock period with respect to unsynchronized gating sources.

Signals generated at the OUT output are referenced to the signal at the SOURCE input or to one of the Am9513A internally generated clock signals. Figure 3-18 shows the OUT signal referenced to the rising edge of a source signal. Any OUT signal state changes occur within 300 ns after the source signal rising or falling edge.

Cabling and Field Wiring

This section describes cabling and field wiring guidelines for the AT-MIO-16 board.

Field Wiring Considerations

Environmental noise can seriously affect the accuracy of measurements made with the AT-MIO-16 if you do not make proper considerations when running signal wires between signal sources and the AT-MIO-16 board. The following recommendations mainly apply to analog input signal routing to the AT-MIO-16 board, although they are applicable for signal routing in general.

You can minimize noise pickup and maximize measurement accuracy by doing the following things:

- Use individually shielded, twisted-pair wires to connect analog input signals to the AT-MIO-16. With this type of wire, the signals attached to the CH+ and CH- inputs are twisted together and then covered with a shield. This shield is then connected at only 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.

- Use differential analog input connections to reject common-mode noise.

The following recommendations apply for all signal connections to the AT-MIO-16:

- Physically separate the AT-MIO-16 signal lines from high-current or high-voltage lines. These lines can induce currents in or voltages on the AT-MIO-16 signal lines if they run in parallel paths at a close distance. To reduce the magnetic coupling between lines, separate the lines by a reasonable distance if they run in parallel, or run the lines at right angles to each other.

- Do not run the AT-MIO-16 signal lines through conduits that also contain power lines.

- To protect the AT-MIO-16 signal lines from magnetic fields caused by electric motors, welding equipment, breakers, or transformers, run the AT-MIO-16 signal lines through special metal conduits.

Cabling Considerations

National Instruments has a cable termination accessory, the CB-50, for use with the AT-MIO-16 board. This kit includes a terminated, 50-conductor flat ribbon cable and a connector block. You can attach signal input and output wires to screw terminals on the connector block and thereby connect to the AT-MIO-16 I/O connector.

The CB-50 is useful for prototyping an application or in situations where AT-MIO-16 interconnections are frequently changed. When you develop a final field wiring scheme, however, you may want to develop your own cable. This section contains information and guidelines for designing custom cables.

The AT-MIO-16 I/O connector is a 50-pin male ribbon-cable header. The manufacturer part numbers for this header that National Instruments uses are as follows:

- Electronic Products Division/3M (part number 3596-5002)

- T&B/Ansley Corporation (part number 609-5007)

The mating connector for the AT-MIO-16 is a 50-position polarized, ribbon-socket connector with strain relief. National Instruments uses a polarized, keyed connector to prevent inadvertent upside-down connection to the AT-MIO-16. Recommended manufacturer part numbers for this mating connector are as follows:

- Electronic Products Division/3M (part number 3425-7650)
- T&B/Ansley Corporation (part number 609-5041CE)

The following are standard 50-conductor, 28 AWG, stranded ribbon cables that work with these connectors:

- Electronic Products Division/3M (part number 3365/50)
- T&B/Ansley Corporation (part number 171-50)

In making your own cabling, you may decide to shield your cables. The following guidelines may help:

- For the analog input signals, shielded twisted-pair wires for each analog input pair yield the best results, assuming that you use differential inputs. Tie the shield for each signal pair to the ground reference at the source.
- Route the analog lines, pins 1 through 23, separately from the digital lines, pins 24 through 50.
- When using a cable shield, use separate shields for the analog and digital halves of the cable. Failure to do so will result in noise from switching digital signals coupling into the analog signals.

Chapter 4
Calibration Procedures

This chapter discusses the calibration procedures for the AT-MIO-16 analog input and analog output circuitry.

The AT-MIO-16 is calibrated at the factory before shipment. To maintain the 12-bit accuracy of the AT-MIO-16 analog input and analog output circuitry, check your board's analog input with a precise voltage source. If the board is out of calibration, then calibrate it. Otherwise, the board does not need to be calibrated.

The AT-MIO-16 is factory calibrated in its factory-default configuration:

- DIFF analog input mode
- -10 to +10 V analog input range (bipolar)
- -10 to +10 V analog output range (bipolar with internal reference selected)

Whenever you change your board configuration, recalibrate your AT-MIO-16 board.

Calibration Equipment Requirements

For best measurement results, the AT-MIO-16 needs to be calibrated so that its measurement accuracy is within ±0.012% of its input range (±1/2 LSB). According to standard practice, the equipment you use to calibrate the AT-MIO-16 should be 10 times as accurate, that is, have ±0.001% rated accuracy. Practically speaking, calibration equipment with four times the accuracy of the item under calibration is generally considered acceptable. Four times the accuracy of the AT-MIO-16 is 0.003%. You need the following equipment to calibrate the AT-MIO-16 board:

- For analog input calibration, you need a precision variable DC voltage source (usually a calibrator) with these features:
  - Accuracy — ±0.001% standard
±0.003% sufficient
  - Range — Greater than ±10 V
  - Resolution — 100 µV in ±10 V range (5 1/2 digits)
- For analog output calibration, you need a voltmeter with these features:
  - Accuracy — ±0.001% standard
±0.003% sufficient
  - Range — Greater than ±10 V
  - Resolution — 100 µV in ±10 V range (5 1/2 digits)

Calibration Trimpots

The AT-MIO-16 has eight trimpots for calibration. The location of these trimpots on the AT-MIO-16 board is shown in the partial diagram of the board in Figure 4-1.

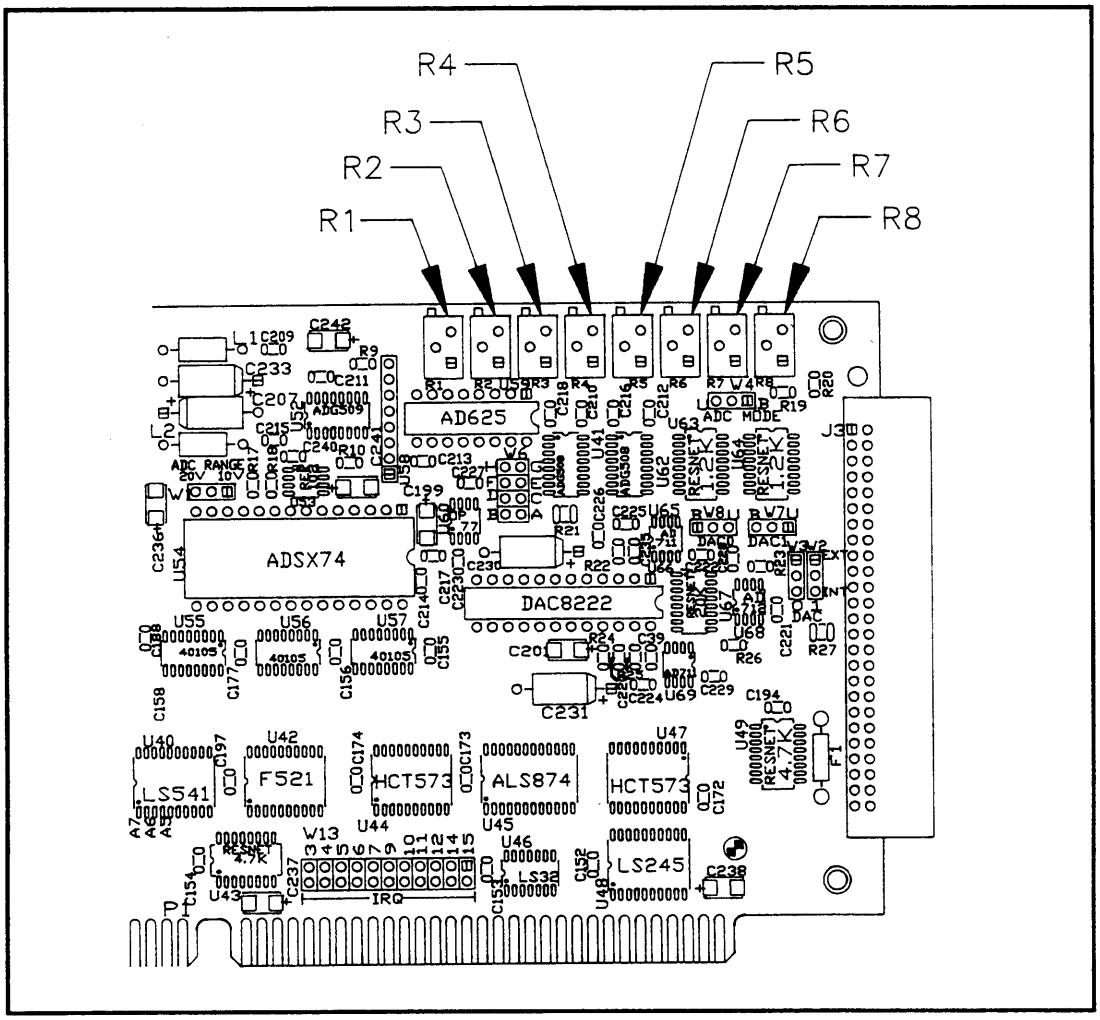


Figure 4-1. Calibration Trimpot Location Diagram

Use the following trimpots to calibrate the analog input circuitry:

- R1—Gain trim, analog input
- R6—Bipolar offset trim, analog input
- R8—Unipolar offset trim, analog input
- R2—Instrumentation amplifier input offset trims

Use the following trimpots to calibrate the analog output circuitry:

- R5—Gain trim, analog output channel 0
- R4—Gain trim, analog output channel 1

- R7—Offset trim, analog output channel 0
- R3—Offset trim, analog output channel 1

Analog Input Calibration

To null error sources that compromise the quality of measurements, you must calibrate the analog input circuitry by adjusting the following potential sources of error:

- Offset error at the input of the instrumentation amplifier
- Offset error at the input of the ADC
- Gain error of analog input circuitry

Offsets at the input to the instrumentation amplifier contribute gain-dependent offset error to the analog input circuitry. This offset is multiplied by the gain of the instrumentation amplifier. To calibrate this offset, you must ground the analog input, read it at two different gain settings, and adjust a trimpot until the readings match at the two different gain settings.

Offset error at the input of the ADC is the total of the voltage offsets contributed by the circuitry from the output of the instrumentation amplifier to the ADC input, including the offsets of the ADC itself. Offset errors appear as a voltage added to the input voltage being measured. To calibrate this offset, you must apply V_{-fs} + 1/2 LSB to the analog input circuitry and adjust a trimpot until the ADC returns readings that flicker between its most negative count and the most negative count plus one. The voltages corresponding to V_{-fs} and 1 LSB are given in Table 4-1.

All the stages up to and including the input of the ADC contribute to the gain error of the analog input circuitry. With the instrumentation amplifier set to a gain of 1, the gain of analog input circuitry is ideally 1. The gain error is the deviation of the gain from 1 and appears as a multiplication of the input voltage being measured. To calibrate this offset, you must apply V_{+fs} - 3/2 LSB to the analog input circuitry and adjust a potentiometer until the ADC returns readings that flicker between its most positive count and the most positive count minus 1. The voltages corresponding to V_{+fs} and 1 LSB are given in Table 4-1.

The voltages corresponding to V_{-fs}, which is the most negative voltage that the ADC can read, V_{+fs} - 1, which is the most positive voltage the ADC can read, and 1 LSB, which is the voltage corresponding to one count of the ADC, depend on the input range selected. The value of these voltages for each input range is given in Table 4-1.

Table 4-1. Voltage Values for Calculating Offset Error

Input Range	V_{-fs}	V_{+fs} - 1	1 LSB	1/2 LSB
-10 to +10 V	-10 V	+9.99512 V	4.88 mV	2.44 mV
-5 to +5 V	-5 V	+4.99756 V	2.44 mV	1.22 mV
0 to 10 V	0 V	+9.99756 V	2.44 mV	1.22 mV

Board Configuration

The calibration procedure differs depending on the input ranges and input configuration modes you select. Two analog input calibration procedures are described in the following sections–one for the two bipolar input configurations (-10 to +10 V and -5 to +5 V), and one for the unipolar input configuration (0 to +10 V). These calibration procedures assume that your AT-MIO-16 is configured for DIFF input. If necessary, reconfigure your board for DIFF input before using the following calibration procedures.

To calibrate your board with a nondifferential input setting, the procedure is similar to the procedures in this manual with one exception–the following procedures apply the input calibration voltages across the positive and negative inputs for DIFF channel 0. For single-ended input, apply your calibration voltages between the channel 0 positive input and the ground system you are using (refer to Chapter 2, *Configuration and Installation*, for instructions on using single-ended input connections).

Bipolar Input Calibration Procedure

If your board is configured for bipolar input, which provides the ranges -5 to +5 V or -10 to +10 V, then complete the following procedure in the order given. This procedure assumes that ADC readings are in the range -2,048 to +2,047.

1. Adjust the Amplifier Input Offset

To adjust the amplifier input offset, follow these steps:

a. Connect both ACH0 (pin 3 on the I/O connector) and ACH8 (pin 4) to AISENSE (pin 19).

b. Take analog input readings from channel 0 at the following gains:

- Both 1 and 500 for the AT-MIO-16L
- Both 1 and 8 for the AT-MIO-16H

c. Adjust trimpot R2 until the readings match to within one count at both gain settings.

2. Adjust the ADC Input Offset

To adjust the ADC input offset, apply an input voltage across ACH0 and ACH8. This input voltage is V_{-fs} + 1/2 LSB and depends on the input range you selected:

Input Range	Calibration Voltage
-10 to +10 V	-9.99756 V
-5 to +5 V	-4.99878 V

a. Connect the calibration voltage across ACH0 (pin 3 on the I/O connector) and ACH8 (pin 4). Connect the ground point on the calibration voltage source to AISENSE (pin 19).

b. Take analog input readings from channel 0 at a gain of 1 and adjust trimpot R6 until the ADC readings flicker evenly between -2,048 and -2,047.

3. Adjust the Analog Input Gain

To adjust the analog input gain, apply an input voltage across ACH0 and ACH8. This input voltage is V_{+fs} - $^3/_2$ LSB and depends on the input range you selected:

Input Range	Calibration Voltage
-10 to +10 V	-9.99268 V
-5 to +5 V	-4.99634 V

a. Connect the calibration voltage across ACH0 (pin 3 on the I/O connector) and ACH8 (pin 4). Connect the ground point on the calibration voltage source to AISENSE (pin 19).

b. Take analog input readings from channel 0 at a gain of 1 and adjust trimpot R1 until the ADC readings flicker evenly between 2,046 and 2,047.

Unipolar Input Calibration Procedure

If your board is configured for unipolar input, which provides an input range of 0 to +10 V, then complete the following procedure in the order given. This procedure assumes that ADC readings are in the range 0 to +4,095.

1. Adjust the Amplifier Input Offset

To adjust the amplifier input offset, follow these steps:

a. Connect both ACH0 (pin 3 on the I/O connector) and ACH8 (pin 4) to AISENSE (pin 19).

b. Take analog input readings from channel 0 at a gain of 1 and adjust trimpot R8 until a reading of roughly two counts is returned.

c. Take analog input readings from channel 0 at the following gains:

- Both 1 and 500 for the AT-MIO-16L
- Both 1 and 8 for the AT-MIO-16H

d. Adjust trimpot R2 until the readings at each gain setting match to within one count of each other.

2. Adjust the ADC Input Offset

To adjust the ADC input offset, apply an input voltage across ACH0 and ACH8. This input voltage is 1.22 mV, or 0 V + 1/2 LSB.

a. Connect the calibration voltage (1.22 mV) across ACH0 (pin 3 on the I/O connector) and ACH8 (pin 4). Connect the ground point on the calibration voltage source to AISENSE (pin 19).

b. Take analog input readings from channel 0 at a gain of 1 and adjust trimpot R8 until the ADC readings flicker evenly between zero and one.

3. Adjust the Analog Input Gain

To adjust the analog input gain, apply an input voltage across ACH0 and ACH8. This input voltage is +9.99634 V, or V_{+fs} - 3/2 LSB.

a. Connect the calibration voltage (+9.99634 V) across ACH0 (pin 3 on the I/O connector) and ACH8 (pin 4). Connect the ground point on the calibration voltage source to AISENSE (pin 19).

b. Take analog input readings from channel 0 at a gain of 1 and adjust trimpot R1 until the ADC readings flicker evenly between 4,094 and 4,095.

Analog Output Calibration

To null error sources that affect the accuracy of the output voltages generated, you must calibrate the analog output circuitry by adjusting the following potential sources of error:

- Analog output offset error
- Analog output gain error

Offset error in the analog output circuitry is the total of the voltage offsets that each component in the circuitry contributes. This error appears as a voltage difference between the desired voltage and the actual output voltage generated and is independent of the DAC setting. To correct this offset gain error, set the DAC to negative full scale and adjust a trimpot until the output voltage is the negative full-scale value ±1/2 LSB.

Gain error in the analog output circuitry is the product of the gains that each component in the circuitry contributes. This error appears as a voltage difference between the desired voltage and the actual output voltage generated, which depends on the DAC setting. To correct this gain error, set the DAC to positive full scale and adjust a trimpot until the output voltage corresponds to the positive full-scale value ±1/2 LSB.

Board Configuration

The calibration procedure differs depending on whether you select the bipolar or the unipolar output configuration. A procedure for each configuration is described in the following sections. These calibration procedures assume that you have selected the internal voltage reference (+10 V) for the analog output channel to be calibrated.

To calibrate your board to an external reference input (DC only), you must recalculate the desired output voltages to which you want the board to be calibrated.

- For bipolar output:
  - 1 LSB = V_{extref} /2,048 (therefore, 1/2 LSB = V_{extref} /4,096)
  - $V_{-fs} = -V_{extref}$
  - $V_{+fs} = V_{extref}$ - 1 LSB
- For unipolar output:
  - 1 LSB = V_{extref} /4,096 (therefore, 1/2 LSB = V_{extref} /8,192)
  - V_{-fs} = 0 V
  - $V_{+fs} = V_{extref}$ - 1 LSB

To calibrate to your own external reference, you should write your own procedures using the following procedures as a guide. Substitute your calculated voltages for those given.

Bipolar Output Calibration Procedure

If your board is configured for bipolar output and two's complement mode, which provides an output range of -10 to +10 V, complete the following procedure in the order given.

1. Adjust the Analog Output Offset

To adjust the analog output offset, measure the output voltage generated with the DAC set at negative full scale (0). This output voltage should be V_{-fs} ±1/2 LSB. For bipolar output, V_{-fs} = -10 V, and 1/2 LSB = 2.44 mV.

- For analog output channel 0:
  a. Connect the voltmeter between DAC0OUT (pin 20 on the I/O connector) and AOGND (pin 23).
  b. Set the analog output channel to -10 V by writing -2,048 to the DAC.
  c. Adjust trimpot R7 until the output voltage read is -10 V ±2.44 mV, that is, between -10.00244 V and -9.99756 V.

- For analog output channel 1:

  a. Connect the voltmeter between DAC1OUT (pin 21 on the I/O connector) and AOGND (pin 23).

  b. Set the analog output channel to -10 V by writing -2,048 to the DAC.

  c. Adjust trimpot R3 until the output voltage read is -10 V ± 2.44 mV, that is, between -10.00244 V and -9.99756 V.

2. Adjust the Analog Output Gain

To adjust the analog output gain, measure the output voltage generated with the DAC set at positive full scale (2,047). This output voltage should be V_{+fs} ±1/2 LSB. For bipolar output, V_{+fs} = +9.99512 V, and 1/2 LSB = 2.44 mV.

- For analog output channel 0:

  a. Connect the voltmeter between DAC0OUT (pin 20 on the I/O connector) and AOGND (pin 23).

  b. Set the analog output channel to +9.99512 V by writing 2,047 to the DAC.

  c. Adjust trimpot R5 until the output voltage read is +9.99512 V ±2.44 mV, that is, between 9.99268 V and 9.99756 V.

- For analog output channel 1:

  a. Connect the voltmeter between DAC1OUT (pin 21 on the I/O connector) and AOGND (pin 23).

  b. Set the analog output channel to +9.99512 V by writing 2,047 to the DAC.

  c. Adjust trimpot R4 until the output voltage read is +9.99512 V ±2.44 mV, that is, between 9.99756 V and 9.99268 V.

Unipolar Output Calibration Procedure

If your analog output channel is configured for unipolar output, which provides an output range of 0 to +10 V, calibrate your board by performing the following procedure.

1. Adjust the Analog Output Offset

To adjust the analog output offset, measure the output voltage generated with the DAC set at zero. This output voltage should be V_{-fs} ±1/2 LSB. For unipolar output, V_{-fs} = 0 V, and 1/2 LSB = 1.22 mV.

- For analog output channel 0:

  a. Connect the voltmeter between DAC0OUT (pin 20 on the I/O connector) and AOGND (pin 23).

  b. Set the analog output channel to 0 V by writing 0 to the DAC.

  c. Adjust trimpot R7 until the output voltage read is 0 V ±1.22 mV.

- For analog output channel 1:

  a. Connect the voltmeter between DAC1OUT (pin 21 on the I/O connector) and AOGND (pin 23).

  b. Set the analog output channel to 0 V by writing 0 to the DAC.

  c. Adjust trimpot R3 until the output voltage read is 0 V ±1.22 mV.

2. Adjust the Analog Output Gain

To adjust the analog output gain, measure the output voltage generated with the DAC set at positive full scale (4,095). This output voltage should be V_{+fs} ±1/2 LSB. For unipolar output, V_{+fs} = +9.99756 V, and 1/2 LSB = 1.22 mV.

- For analog output channel 0:

  a. Connect the voltmeter between DAC0OUT (pin 20 on the I/O connector) and AOGND (pin 23).

  b. Set the analog output channel to +9.99756 V by writing 4,095 to the DAC.

  c. Adjust trimpot R5 until the output voltage read is +9.99756 V ±1.22 mV, that is, between 9.99634 V and 9.99878 V.

- For analog output channel 1:

  a. Connect the voltmeter between DAC1OUT (pin 21 on the I/O connector) and AOGND (pin 23).

  b. Set the analog output channel to +9.99756 V by writing 4,095 to the DAC.

  c. Adjust trimpot R4 until the output voltage read is +9.99756 V ±1.22 mV, that is, between 9.99634 V and 9.99878 V.

Appendix A
Specifications

This appendix lists the specifications for the AT-MIO-16. These specifications are typical at 25° C unless otherwise noted.

Analog Input

Input Characteristics

Number of channels: 16 single-ended or 8 differential, jumper-selectable

Type of ADC: Sampling, successive approximation

Resolution: 12 bits, 1 in 4,096

Max sampling rate: 100 kS/s

Input signal ranges

AT-MIO-16H and AT-MIO-16DH

Board Gain (Software Selectable)	Board Range (Jumper Selectable)		
	±10 V	±5 V	0 to 10 V
1	±10 V	±5	0 to 10 V
2	±5 V	±2.5	0 to 5 V
4	±2.5 V	±1.25 V	0 to 2.5 V
8	±1.25 V	±0.63 V	0 to 1.25 V

AT-MIO-16L and AT-MIO-16DL

Board Gain (Software Selectable)	Board Range (Jumper Selectable)		
	±10 V	±5 V	0 to 10 V
1	±10 V	±5	0 to 10 V
10	±1 V	±0.5	0 to 1 V
100	±0.1 V	±0.05 V	0 to 0.1 V
500	±0.02 V	±0.01 V	0 to 0.02 V

Input coupling: DC

Max working voltage (signal + common mode): Each input should remain within 12 V of AIGND

Overvoltage protection: ±35 V powered on, ±20 V powered off

Inputs protected: ACH <0..15>

FIFO buffer size: 16 samples

Data transfers: DMA, interrupts, programmed I/O

DMA modes: Demand

Transfer Characteristics

Relative accuracy: ±0.9 LSB typical, ±1.5 LSB max

DNL: ±0.50 LSB typical, ±0.95 LSB max

No missing codes — 12 bits, guaranteed

Offset error

Pregain error after calibration	±2.44 µV (-L board)
Pregain error before calibration	±153 µV (-H board)
Postgain error after calibration	±1.22 mV max
Postgain error before calibration	±85 V max

Gain error (relative to calibration reference)

After calibration	0.0244% of reading (244 ppm) max
Before calibration	0.85% of reading (8,500 ppm) max
Gain ≠ 1 with gain error adjusted to 0 at gain = 1	0.02% of reading (200 ppm) max

Amplifier Characteristics

Input impedance	1 GΩ in parallel with 50 pF
Input bias current	±25 nA
Input offset current	±15 nA

CMRR

Gain	CMRR DC to 100 Hz
1	75 dB
10	95 dB
100	105 dB

Dynamic Characteristics

Bandwidth

Small signal (-3 dB) — 650 kHz @ gain = 1

Settling time to full-scale step

Gain	Accuracy	
	±0.024% (±1 LSB)	±0.012% (±0.5 LSB)
≤10	10 µs	10 µs
100	14 µs	14 µs
500	47 µs	50 µs

System noise *(including quantization error)*

Gain	20 V Range	10 V Range
≤10	0.10 LSBrms	0.20 LSBrms
100	0.15 LSBrms	0.20 LSBrms
500	0.30 LSBrms	0.40 LSBrms

Slew rate — 5.0 V/µs

Stability

Recommended warm-up time	15 min
Offset temperature coefficient	
Pregain	6 µV/°C
Postgain	160 µV/°C
Onboard calibration reference	
Level	2.5 V ±10 mV
Temperature coefficient	10 ppm/°C max
Long-term stability	$20\ \text{ppm}/\sqrt{1,000\ \text{hr}}$

Analog Output

Output Characteristics

Number of channels	2 voltage
Resolution	12 bits, 1 in 4,096
Max update rate	250 kS/s
Type of DAC	Double-buffered, multiplying
Data transfers	Interrupts, programmed I/O

Transfer Characteristics

Relative accuracy (INL)	
Bipolar range	±0.25 LSB typical, ±0.5 LSB max
Unipolar range	±0.50 LSB typical, ±1.0 LSB max
DNL	±0.2 LSB typical, ±1 LSB max
Monotonicity	12 bits, guaranteed
Offset error	
After calibration	488 µV max
Before calibration	±64 mV max
Gain error (relative to internal reference)	
After calibration	±0.017% of reading (170 ppm) max
Before calibration	±0.77% of reading (7,700 ppm) max

Voltage Output

Ranges	±10 V, 0–10 V, jumper selectable
Output coupling	DC
Output impedance	≤ 0.2 Ω
Current drive	±2 mA max
Protection	Short-circuit protection
Power-on state	Undetermined
External reference input	
Range	±10 V
Overvoltage protection	±25 V powered on
Input impedance	11 kΩ

Dynamic Characteristics

Settling time to 0.024% FSR	4 µs for a 20 V step
Slew rate	30 V/µs
Noise	1 mVrms, DC to 1 MHz

Digital I/O

Number of channels: 8 I/O
Compatibility: TTL
Digital logic levels:

Level	Min	Max
Input low voltage	0 V	0.8 V
Input high voltage	2 V	6 V
Input low current (V_{in} = 0.4 V)		-20 µA
Input high current (V_{in} = 2.7 V)		20 µA
Output low voltage (I_{out} = 24 A)		0.5 V
Output high voltage (I_{out} = -2.6 A)	2.4 V	

Power on state: Configured as input
Data transfers: Programmed I/O

Timing I/O

Number of channels: 3 counter/timers, 1 frequency scalers
Resolution
- Counter/timers: 16 bits
- Frequency scalers: 4 bits

Compatibility: TTL, pulled high with 4.7 kΩ resistors
Base clocks available: 1 MHz, 100 kHz, 10 kHz, 1 kHz, 100 Hz
Base clock accuracy: ± 0.01 %
Max source frequency: 6.897 MHz
Min source pulse duration: 70 ns
Min gate pulse duration: 145 s
Data transfers: Programmed I/O

Triggers

Digital Trigger

Compatibility: TTL
Response: Falling edge
Pulse width: 50 ns min

RTSI

Trigger lines: 7

Bus Interface

Slave

Power Requirement

+5 VDC (±5 %)	1.6 A

Physical

Dimensions	13.3 by 3.9 in. (33.782 by 9.906 cm)
I/O connector	50-pin male ribbon connector
Form factor	AT

Environment

Operating temperature	0° to 70° C
Storage temperature	-55° to 150° C
Relative humidity	5% to 90% noncondensing

Appendix B
Revisions A through C
Parts Locator Diagram

This appendix contains the parts locator diagram for revisions A through C of the AT-MIO-16 board.

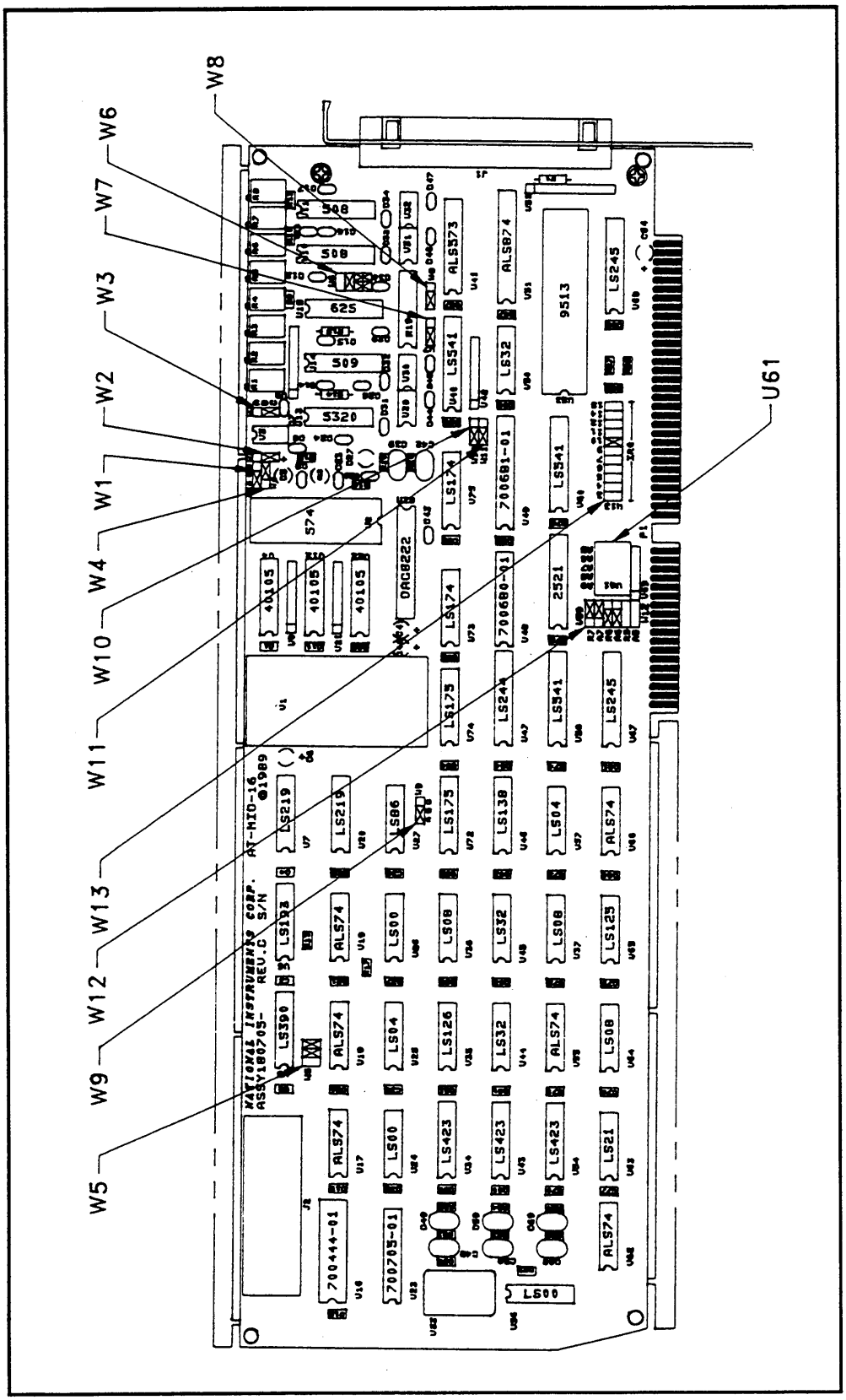


Figure B-1. Revisions A through C Parts Locator Diagram

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
(512) 794-5678

Branch Offices	Phone Number	Fax Number
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Austria	(0662) 435986	(0662) 437010-19
Belgium	02/757.00.20	02/757.03.11
Denmark	45 76 26 00	45 76 71 11
Finland	(90) 527 2321	(90) 502 2930
France	(1) 48 14 24 00	(1) 48 14 24 14
Germany	089/741 31 30	089/714 60 35
Italy	02/48301892	02/48301915
Japan	(03) 3788-1921	(03) 3788-1923
Mexico	95 800 010 0793	95 800 010 0793
Netherlands	03480-33466	03480-30673
Norway	32-848400	32-848600
Singapore	2265886	2265887
Spain	(91) 640 0085	(91) 640 0533
Sweden	08-730 49 70	08-730 43 70
Switzerland	056/20 51 51	056/20 51 55
Taiwan	02 377 1200	02 737 4644
U.K.	0635 523545	0635 523154

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 _____

_____

_____

AT-MIO-16 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

- AT-MIO-16 Model Number (For example, AT-MIO-16L-9) _____
- AT-MIO-16 Revision _____
- Interrupt Level of AT-MIO-16 (Factory Setting: 10) _____
- DMA Channels of AT-MIO-16 (Factory Setting: 6 and 7) _____
- Base I/O Address of AT-MIO-16 (Factory Setting: hex 0220) _____
- Programming Choice (NI-DAQ, LabVIEW, LabWindows or other) _____
- Software Version _____

Other Products

- Computer Make and Model _____
- Microprocessor _____
- Clock Frequency _____
- Type of Video Board Installed _____
- Operating System (DOS or Windows) _____
- Operating System Version _____
- Programming Language _____
- Programming Language Version _____
- Other Boards in System _____
- Base I/O Address of Other Boards _____
- DMA Channels of Other Boards _____
- 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: **AT-MIO-16 User Manual**

Edition Date: **February 1995**

Part Number: **320476-01**

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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National Instruments Corporation
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(512) 794-5678

Register-Level Programmer Manual Request Form

National Instruments offers a register-level programmer manual at no charge to customers who are not using National Instruments software.

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Part Number: **340695-01**

Please indicate your reasons for obtaining the register-level programmer manual. Check all that apply.

☐ National Instruments does not support your operating system or programming language.

☐ You are an experienced register-level programmer who is more comfortable writing your own register-level software.

☐ Other. Please explain.

_____

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Thank you for your help.

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Title _____

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National Instruments Corporation
6504 Bridge Point Parkway
Austin, TX 78730-5039

Fax to: Data Entry Department
National Instruments Corporation
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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}
G-	giga-	10^{9}

%	percent
±	plus or minus
°	degrees
/	per
+	positive of, or plus
–	negative of, or minus
≠	not equal to
√	square root of
+5V	+5 VDC source signal
A	amperes
AC	alternating current
ACH	analog input channel signal
A/D	analog-to-digital
ADC	A/D converter
ADIO	digital input/output port A 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
BDIO	digital input/output port B signal
C	Celsius
CMRR	common-mode rejection ratio
CVI	C Virtual Instrument
D/A	digital-to-analog
DAC	D/A converter
DAC0WR	analog channel 0 output
DAC1WR	analog channel 1 output
dB	decibels
DC	direct current
DIFF	differential mode

DIGGND	digital ground signal
DIP	dual inline package
DMA	direct memory access
EISA	Extended Industry Standard Architecture
EXTCONV	external Convert Signal
EXTREF	external reference signal
EXTSTROBE	external strobe signal
FIFO	first-in-first-out
FSR	full-scale ratio
ft	feet
hex	hexadecimal
Hz	hertz
in.	inches
INL	integral nonlinearity
I/O	input/output
IRQ	interrupt lines
I_{IH}	current, input high
I_{IL}	current, input low
I_{OH}	current, output high
I_{OL}	current, output low
LED	light-emitting diode
LS	low-power Schottky
LSB	least significant bit
max	maximum
min	minimum
MSB	most significant bit
mux	multiplexer
NRSE	nonreferenced single-ended mode
Ω	ohms
OUT	output
PC	personal computer
ppm	parts per million
rms	root mean square
RSE	referenced single-ended mode
RTSI	Real-Time System Integration
RTSICLK	Real-Time System Integration clock
s	seconds
S	samples
SCANCLK	scan clock signal
SCXI	Signal Conditioning eXtensions for Instrumentation
SDK	Software Developer's Toolkit
SE	single-ended inputs
S/H	sample and hold
STARTTRIG	external trigger signal
STOPTRIG	stop trigger signal
TC	terminal count
THD	total harmonic distortion
TTL	transistor-transistor logic
V	volts

VDC	volts direct current
V_{fs}	output offset voltage
V_{IH}	volts, input high
V_{IL}	volts, input low
V_{in}	volts in
V_{OH}	volts, output high
V_{OL}	volts, output low
V_{ref}	reference voltage
Vrms	volts, root mean square

Index

Numbers/Symbols

A

H

I

J

L

N

O

P

R

S

T

U