KEITHLEY

PIO-24 Parallel Digital Interface Board
User's Guide

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User's Guide

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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Part Number 64230) ..... July 1991
Revision B (Part Number 64230) ..... July 1999
Revision C (Part Number 64230) ..... April 2001

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Installation Category I and Installation Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Installation Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Installation Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If  or  is present, connect it to safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

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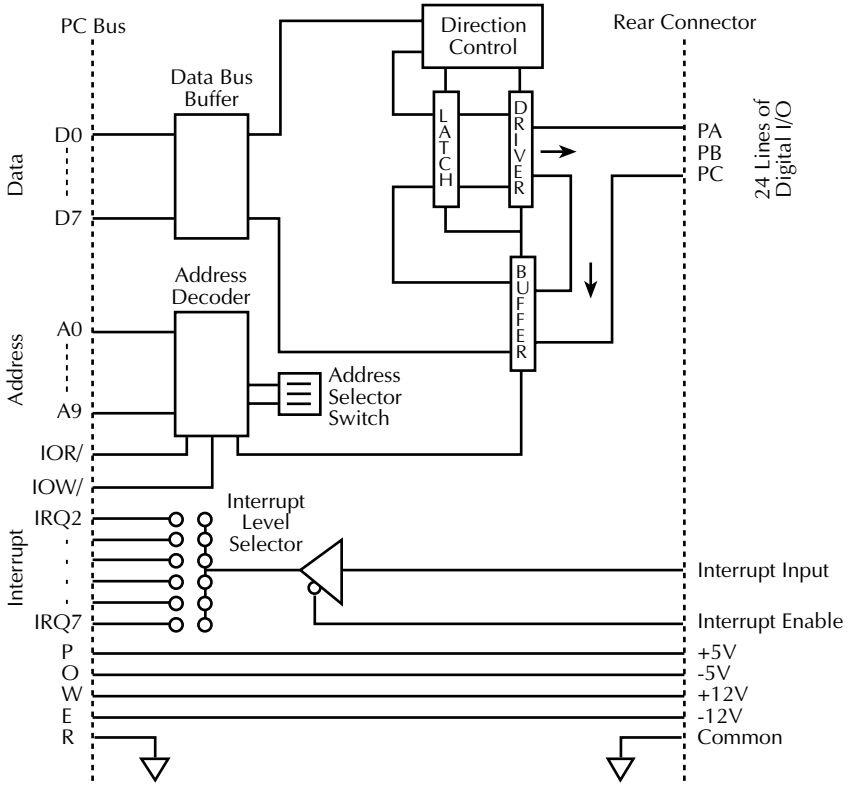
Introduction

General description

Figure 1-1
PIO-24 block diagram



Referring to the block diagram, the PIO-24 is a high-current, 24-line, parallel, digital I/O interface board for the IBM PC or PC-compatible. The board emulates an 8255 Programmable Peripheral Interface Control Word MODE 0. (While the Keithley PIO-12 also uses an 8255 Programmable Peripheral Interface chip, it drives much less current than the PIO-24.)

The PIO-24 and computer with DriverLINX software requires:

- an IBM PC or compatible AT (386, or Pentium CPU) with minimum of 2 MB of memory
- at least one floppy disk drive, and one fixed disk drive
- Microsoft Windows 95/98, or Windows NT 4.0 or higher
- a compiler supporting Microsoft Windows development
- a mouse is highly recommended.

The following software is available for operating PIO-24 boards:

- **PIO-24 standard software package** — Shipped with PIO-24 boards. Includes DriverLINX for Microsoft Windows 95/98 or Windows NT and function libraries for writing application programs under Windows in a high-level language such as Microsoft Visual C++, Microsoft Visual Basic; Borland Delphi support files; utility programs; and language-specific example programs.
- **DriverLINX** — the high-performance real-time data-acquisition device drivers for Windows application development including:
  - *DriverLINX API DLLs and drivers supporting the PIO-24 hardware*
  - *AIO Panel* — A DriverLINX program that verifies the installation and configuration of DriverLINX to your PIO-24 board and demonstrates several virtual bench-top instruments
  - *Learn DriverLINX* — an interactive learning and demonstration program for DriverLINX that includes a Digital Storage Oscilloscope
  - *Source Code* — for the sample programs
  - *DriverLINX Application Programming Interface files* — for the PIO-24 compiler
  - *DriverLINX On-line Help System* — provides immediate help as you operate DriverLINX
  - *Supplemental Documentation* — on DriverLINX installation and configuration; analog and digital I/O programming; counter/timer programming; technical reference; and information specific to the PIO-24 hardware.

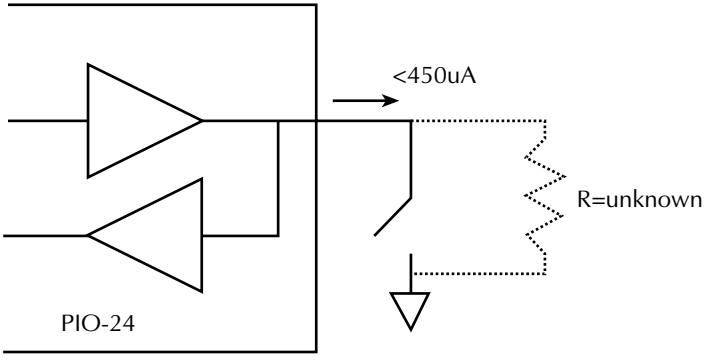
The major features of PIO-24 board are as follows:

- Three TTL/CMOS-compatible, digital I/O ports: PA, PB, and PC. PA and PB are both byte wide (8-bit) and are usable as inputs or outputs. PC is also byte wide but is adaptable for use as two separate 4-bit ports: PC Lower and PC Upper, each of which is usable as an input or output.
- An interrupt input channel with a corresponding interrupt-enable line. Interrupts can be directed to any of six interrupt levels available on the PC Bus. PIO-24 interrupts are unlatched and edge-sensitive.
- The PIO-24 performs a 10-bit I/O address decode and communicates with the PC Bus as an 8-bit peripheral. The address map uses four consecutive I/O addresses. Multiple PIO-24s may be installed in a computer at different Base Addresses.
- +5V, +12V, and -12V power levels from the PC supplies are provided on the rear connector. The 37-pin D connector of the PIO-24 is pin-compatible with the PIO-12 and is usable with all the accessories of the PIO-12.

Product change notice

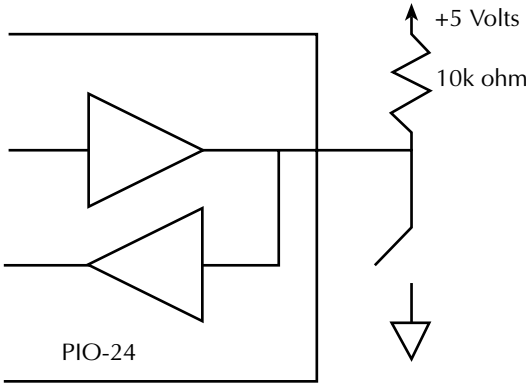
A component change was implemented in March 1999, reducing the input load current of the PIO-24 digital I/O card for improved consistency. The input load current on the newly designed board is now ≤-2µA, which continues to meet the product specification of ≤-450µA. This change was made because some devices having low drive current, such as the ERB-24, were accidentally being turned on when power was first applied to the PIO-24. The specific change involved changing parts U3, U6, and U9, the digital input latches. The older design used 74LS373 octal tri-state latches, which had a higher input load current than the 74HCT373 parts that are now being used. In existing designs using the PIO-24, this reduction in input load current will generally cause no problems. However, if the existing design depends on this input load current being near the -450µA limit, this change is important. The reduction in input load current reduces the possibility of the input state being driven high if the input is floating. Figure 1-2 shows an application monitoring a contact switch that would be a problem as a result of the new design, and Figure 1-3 shows the correct implementation of this application that would work with either design.

Figure 1-2
Poor implementation of monitoring a digital input



In Figure 1-2, the digital input would probably float high with an older design board because of the higher input load current. When the switch is closed, the input will be pulled low. While this would work on an older design of the PIO-24, this is a poor implementation because the input load current can vary from one board to the next. In the case of a new design board, this would not work because of the lower load current.

Figure 1-3
Better implementation of monitoring a digital input



In Figure 1-3, the digital input is guaranteed to be pulled high because of the 10k ohm resistor. This implementation would work on both the old and new design of the PIO-24 and is the preferred implementation to avoid dependence on a specific level of input load current.

Applications

Applications for the PIO-24 include all parallel digital I/O activities such as communicating with peripherals, operating relays, reading switch inputs, etc. Keithley Instruments applications engineers welcome inquiries into installation, operation, and applications of the PIO-24. To inquire, dial (440) 248-0400 and ask for technical support.

Accessories

Accessory products available for the PIO-24 include the SFC-37 Mating Connector, the C-1800 Flat Cable, the STA-U Screw Connector Panel, and the mechanical and solid-state relay board Models ERB-24, ERA-01, SRA-01, and SSIO-24.

Specifications

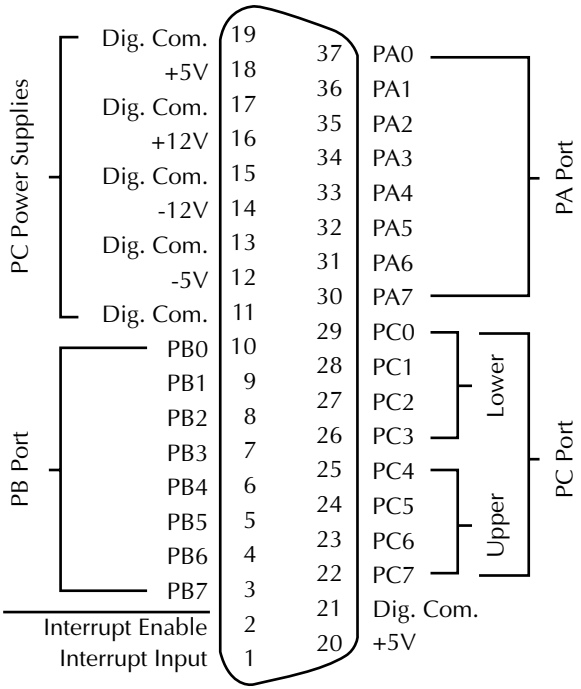
Table 1-1
Specifications

Parameters	Minimum	Maximum
LOGIC INPUTS & OUTPUTS		
Input low voltage	-0.5	+0.8V
Input high voltage	2.0	5.0V
Input low load current PA, PB & PC	-	-0.4mA
INTERRUPT ENABLE/	-	-0.9mA
(10Kohm Pull-up Resistor included)		
INTERRUPT	-	0.4mA
Input Load High Current PA, PB, PC	-	70µa
INTERRUPT ENABLE/	-	20µa
INTERRUPT	-	20µa
Output low voltage PA, PB, PC	-	0.55V
(Isink = 64mA)		
Output high voltage PA, PB, PC:		
Isource = 15mA	2.0V	
Isource = 3mA	2.7V	
Bus Loading Power Consumption	400mA typ. @ +5V	
ENVIRONMENTAL		
Operating Temperature Range:	0˚ to 70˚C	
Storage Temperature Range:	-40˚ to 100˚C	
Humidity:	0 to 90% Noncondensing	
Size:	Half Slot	

Connections

Figure 1-4 shows a rear view of the 37-pin D male I/O connector. The mating connector is a 37-pin D female (Part No. SFC-37).

Figure 1-4
I/O connector, rear view



2
Installation

General

This chapter contains instructions for installing the PIO-24. The chapter begins with procedures for unpacking and inspection and follows with descriptions of the options and methods for setting all configurable parameters. Hardware installation is the final topic.

Unpacking and inspecting

After removing the wrapped board from its outer shipping carton, proceed as follows:

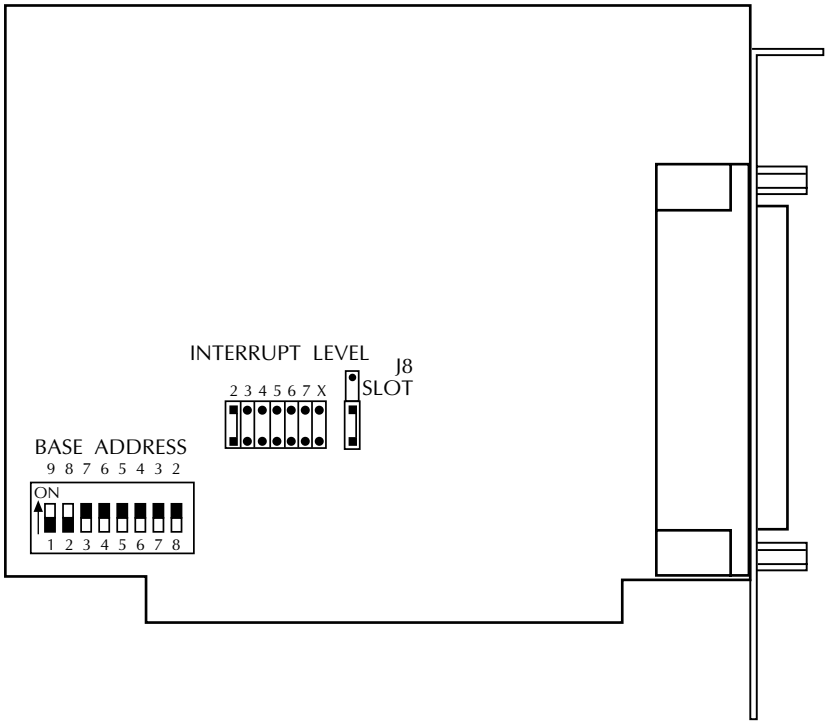
1. Place one hand firmly on a metal portion of the computer chassis (the computer must be turned OFF and grounded) to discharge static electricity from the package and your body, thereby preventing damage to board components.
2. Carefully unwrap the board from its antistatic wrapping material.
3. Inspect the board for signs of damage. If any damage is apparent, return the board to the factory.
4. Check the contents of your package against its packing list to be sure the order is complete. Report any missing items immediately.

You may find it advisable to retain the packing material in case the board must be returned to the factory.

Switch and jumper settings

The PIO-24 contains a switch for setting Base Address and jumper pads for selecting Interrupt Level and board location. Each is shown in Figure 2-1 and described in the following subsections.

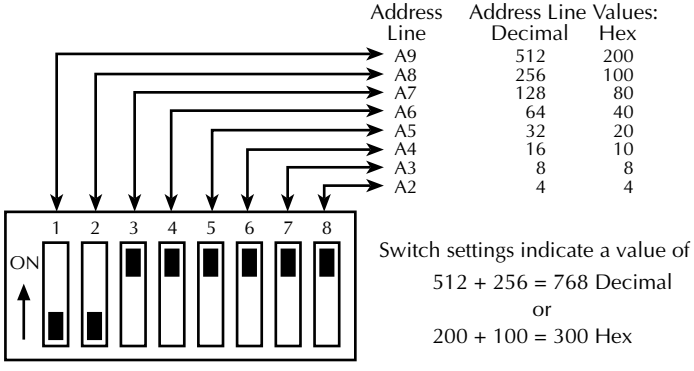
Figure 2-1
Switch and jumper layout



Base address switch

The Base Address switch is preset at the factory for 300 Hex, as shown in Figure 2-2.

Figure 2-2
Diagram of the base address switch (S2)



The factory-preset Base Address of 300 Hex is within the address range shown in the following table as *Reserved*. This default value will function in most computers without conflict, thereby eliminating any need for address selection and configuration. However, if you have a need to change the Base Address from its preset value, you must select an address within a range of 200 to 3FC Hex (512 to 1020 Decimal). In addition, the address must be on a 4-byte boundary and must not conflict with addresses already in use for other devices. As an aid to selecting a usable 3-digit Hex number, Table 2-1 is an industry-standard I/O address map for the full 000 to 3FF range.

Table 2-1
I/O address map

Hex Range	Usage	Hex Range	Usage
000 to 1FF	Internal system	380 to 38C	SDLC comm.
200 to 20F	Game	380 to 389	Binary comm. 2
210 to 217	Expansion unit	3A0 to 3A9	Binary comm. 1
220 to 24F	Reserved	3B0 to 3BF	Mono dsp/LPT1:
278 to 27F	Reserved	3C0 to 3CF	Reserved
2F0 to 2F7	LPT2:	3D0 to 3DF	Color graphics
2F8 to 2FF	COM2:	3E0 to 3E7	Reserved
300 to 31F	Prototype card	3F0 to 3F7	Floppy disk
320 to 32F	Hard disk	3F8 to 3FF	COM1:
387 to 37F	LPT1:		

J8 slot jumper

This jumper pad offers two selections: J8 Slot or Off, as shown in Figure 2-1. Placing a jumper on the upper pins enables the board to occupy the J8 slot of an IBM PC-XT (the J8 slot is rightmost on the PC-XT motherboard). Placing the jumper on the lower two pins simply turns this option off.

Interrupt level selection

You may select one of six Interrupt Levels (IRQ2 to IRQ7) from the PC Bus, or you may disable the Interrupt Levels. Each choice is jumper-selectable on a pad located as shown in Figure 2-1. Postions 2 to 7 on the pad correspond to IRQ2 to IRQ7, respectively. Position X disables the Interrupt Levels.

Installing and configuring DriverLINX for PIO-24 boards

IMPORTANT **As a precaution against a system crash the first time you install and test any new hardware, you should exit all other programs and, if you use a disk cache, disable write caching. If the system does crash and you're using disk compression software or a disk cache utility, and as a precaution after any crash, run the utility that checks the directory structures.**

IMPORTANT **Before you begin installing any hardware or software for the PIO-24, read the *DriverLINX Installation and Configuration Guide* and the *Using DriverLINX with your Hardware—Keithley PIO Series* manuals that are packaged with the DriverLINX software. They are accessed from the DriverLINX CD-ROM after you have installed Adobe Acrobat.**

Before installing DriverLINX

1. Inventory your PIO-24 board's configuration settings.
2. Determine the resources your PIO-24 board requires.
3. Inventory your computer's resources already allocated to other installed devices.
4. Determine whether your computer has sufficient resources for your PIO-24 board.
5. Determine whether your PIO-24 board can use your computer's free resources.
6. Set any jumpers/switches to configure your PIO-24 board to use your computer's free resources.
7. Set any other jumpers/switches to configure your PIO-24 board the way you want the board to operate.
8. Install your PIO-24 board into an appropriate free slot in your computer.

Selecting the DriverLINX components to install

For your convenience in installing and un-installing just the DriverLINX components you need, the DriverLINX CD Browser will assist you in selecting the components to install:

- **Install Drivers** — This required component installs only the files you need for configuring your hardware and running third-party data-acquisition applications that require DriverLINX.
- **Install Interfaces** — This optional component installs the files and example programs that you will need to develop custom applications for DriverLINX using C/C++, Visual Basic, Delphi, and LabVIEW.
- **Install Documentation** — This optional component installs electronic documentation for DriverLINX that you can read, search, and print using the Adobe Acrobat Reader.
- **Install Acrobat** — This optional component installs the Adobe Acrobat Reader for the DriverLINX electronic documentation.

Installing DriverLINX

1. Insert the DriverLINX CD-ROM into your computer's CD-ROM Drive.
2. Start the DriverLINX setup program. On most systems, wait a few seconds for automatic start-up. Otherwise, run the setup.exe program from the CD-ROM.
3. The DriverLINX CD-ROM Browser Map window appears on the screen. Click 'Install Drivers,' and follow the series of on-screen instructions.

NOTE *To display an explanation of a menu option on the DriverLINX CD browser map that appears next and on subsequent setup screens, place the mouse pointer over the menu item. A star next to a menu item means that the item was selected previously.*

4. Select 'Read Me First,' and follow the instructions.
5. Select 'Install Documentation.' If you do not have Adobe Acrobat installed on your computer, install it by selecting 'Install Adobe Acrobat.'
6. Open the manuals appropriate to the PIO-24 installation and read them before installing your PIO-24 board or configuring DriverLINX:
   - *Installation and Configuration*
   - *Using DriverLINX with Your Hardware—Keithley PIO Series*
   - *DriverLINX Technical Reference Manual*
   - *DriverLINX Digital I/O Programming Guide*
   - *DriverLINX Analog I/O Programming Guide*
   - *DriverLINX Counter/Timer Programming Guide*
   - *Appendix, I/O Port, Interrupt, and DMA Channel Usage*
   - Other manuals appropriate to your installation.

Configuration with DriverLINX

Follow the DriverLINX on-screen instructions for installation of drivers and interfaces. Refer to the *DriverLINX Installation and Configuration Guide and Using DriverLINX with Your Hardware—Keithley PIO Series manuals*.

NOTE *Be sure to note and follow all programming differences between installations for Windows NT and Windows 95/98.*

Before you configure DriverLINX for operation with the PIO-24 board, you must specify the base address and interrupt level by setting switches on the board.

Hardware installation

WARNING **Any attempt to insert or remove a board with the computer power on could damage your computer.**

1. Turn off power to the PC and all attached equipment.
2. Remove the cover of the PC as follows: First remove the cover-mounting screws from the rear panel of the computer. Then, slide the cover of the computer about 3/4 of the way forward. Finally, tilt the cover upwards and remove.
3. Choose an available option slot. Loosen and remove the screw at the top of the blank adapter plate. Then slide the plate up and out to remove.
4. Hold the PIO-24 board in one hand placing your other hand on any metallic part of the PC/AT chassis (but not on any components). This will safely discharge any static electricity from your body.
5. Make sure the board switches have been properly set (refer to the preceding section).
6. Align the board connector with the desired accessory slot and with the corresponding rear-panel slot. Gently press the board downward into the socket. Secure the board in place by inserting the rear-panel adapter-plate screw.
7. Replace the computer's cover. Tilt the cover up and slide it onto the system's base, making sure the front of the cover is under the rail along the front of the frame. Replace the mounting screws.
8. Plug in all cords and cables. Turn the power to the computer back on.

You are now ready to make any necessary system connections.

Using power from the PIO-24

Power from the PC's internal supply is available on the PIO-24 rear connector. In the applications this board is likely to see, the availability of PC internal power is a convenience. However, you are advised **not** to use PC's power unless you can safely avoid the following conditions:

1. Short circuits, overloads, or the application of other external voltages. All of these conditions may damage the PC system board and result in costly repairs. The PC power supply is designed to shutdown on a short circuit, but you should not rely on this characteristic.
2. A power draw in excess of the capacity of the PC power supply and its internal loads (see *IBM PC Technical Reference Manual*). Because of PC board connector and trace width limitations, Keithley recommends that you limit power draw to 1A from the +5V and +12V supplies (if available). The -12V and -5V supplies are capable of much lower loads.

In situations where the PIO-24 is used with a dedicated peripheral (for example, a switch pad) and the cabling and design loads are fixed, you may find it more feasible to use the PIO-24 power outputs. In most other cases, however, you are advised to power external devices from their own supplies.

NOTE *Typically, base addresses between 300h and 370h are available for use. However, keep in mind that a network board, a sound board, a CD-ROM, or other data acquisition board may use a base address within this space.*

DriverLINX allows you to set base addresses between 200h and 3FCh. If you are using your PIO-24 board, you must make sure that the four adjacent I/O addresses, needed for the PIO-24, are not used by other devices in the computer.

NOTE *If switches on the board are changed after the software has been installed, the software will need to be reconfigured.*

Before installing a PIO-24 board in your computer, make sure that the switches are set appropriately and that you have noted the switch settings so that you can match these settings when you program the configuration using DriverLINX. Refer to the *DriverLINX Installation and Configuration Guide* and *Using DriverLINX with Your Hardware—Keithley PIO Series* manuals.

Refer to the documentation provided with your computer for more information on installing boards.

3
I/O Address Map

General

The PIO-24 uses four locations in I/O address space as shown in Table 3-1. Note that the PIO-24 requires a full block of four I/O addresses.

Table 3-1
PIO-24 locations

Location	Function	Type
Base Address +0	PA Port	Read/Write
Base Address +1	PB Port	Read/Write
Base Address +2	PC Port	Read/Write
Base Address +3	Control	Write only

4
Configuring DriverLINX

General

After you have successfully installed the PIO-24 board in your computer, start Windows to run DriverLINX. For detailed instructions on installing DriverLINX, see the documentation provided on the DriverLINX CD-ROM; especially the *DriverLINX Installation and Configuration Guide* and *Using DriverLINX with Your Hardware—Keithley PIO Series manuals*.

NOTE *Be sure to note and follow differences in programming between Windows NT and Windows 95/98 as appropriate for your system.*

Run "Learn DriverLINX" (LearnDL.exe) from the DriverLINX program group to tell DriverLINX how you configured your PIO-24 board and to verify that everything is properly installed and configured.

1. Start Windows as you normally would and select the Program Manager window. Install DriverLINX if you have not previously done so.
2. Either select the "Learn DriverLINX" icon created when you installed DriverLINX or enter "<drive>:/DRVLNX/LEARNDL" in the Command Line edit box. The command line edit box is activated by selecting the Run... option. <drive> is the letter of the hard disk drive where DriverLINX is installed.
3. Immediately after loading Learn DL, the Open DriverLINX DLL dialog box appears. Select the name of the hardware-specific DLL from the list for your PIO-24 board. The name is an abbreviation of the board's model number.
4. From the main menu bar of **Learn DL**, select the Device menu and choose Select....
5. Select the Logical Device you wish to configure and then click on the OK button (return).
6. Again select the Device menu and then choose the Configure... option to display the Device Configuration Dialog Box.
7. From the Model list, select the model name for the PIO-24 board you are configuring.
8. If the value displayed in the Address edit box is not correct, type the correct value into the box. You may enter the address in decimal or hexadecimal using the c-notation for hex, (that is, 768 decimal = 0x300 hexadecimal).

9. Choose the correct options for the Analog, Digital, and Counter/Timer Sections by first clicking on the appropriate radio button in the middle of the dialog box and then completing the group of dialog fields in the lower third of the dialog box. Be sure to click on both the Input and Output radio buttons for the Analog and Digital groups to see all the dialog fields.
10. After you have made your selections, save the configuration parameters by clicking on the OK button. This will create or update the configuration for DriverLINX.
11. Repeat the preceding steps, starting at step 5, for each Logical Device you wish to configure.

You can use DriverLINX to verify board operation:

1. To physically initialize the PIO-24, select Device/Initialize from the main menu in Learn DriverLINX.
2. The first time the PIO-24 is initialized, or after a configuration change, DriverLINX runs a diagnostic program to verify the operation and accuracy of the configuration settings.

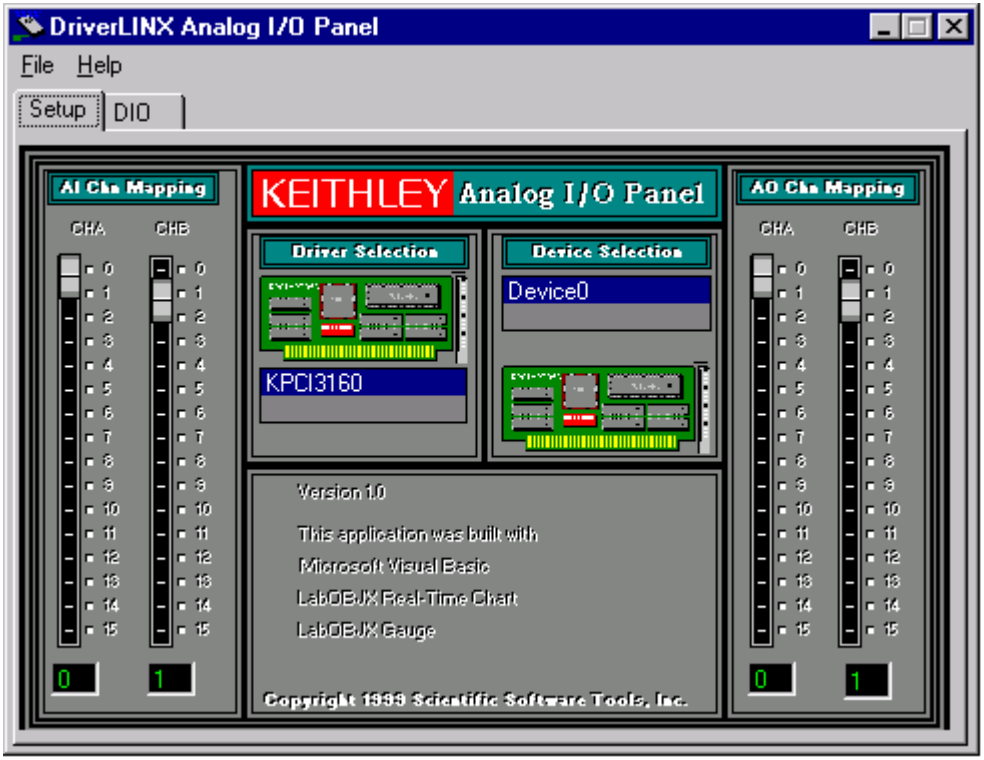
After you install the PIO-24 board and configure DriverLINX for the desired PIO-24 configuration, you can attach an accessory board and wire the appropriate signals to the board. Before writing your application program, you can test the functions of the PIO-24 board using the DriverLINX AIO Panel.

I/O bit tests

General information

1. Start the AIO Panel as follows:
   a. In the **Start** menu, click **Programs**.
   b. Find the **DriverLINX ▸ Test Panels** folder, under which you should find the **AIO Panel** entry.
   c. Click on the **AIO Panel** entry. The **Analog I/O Panel** should appear, similar to the example in Figure 4-1. (If you have other DriverLINX devices installed in addition to the digital input/output card you are testing, they will also be listed. In that case, select the desired digital I/O card and the proper device number before proceeding.)

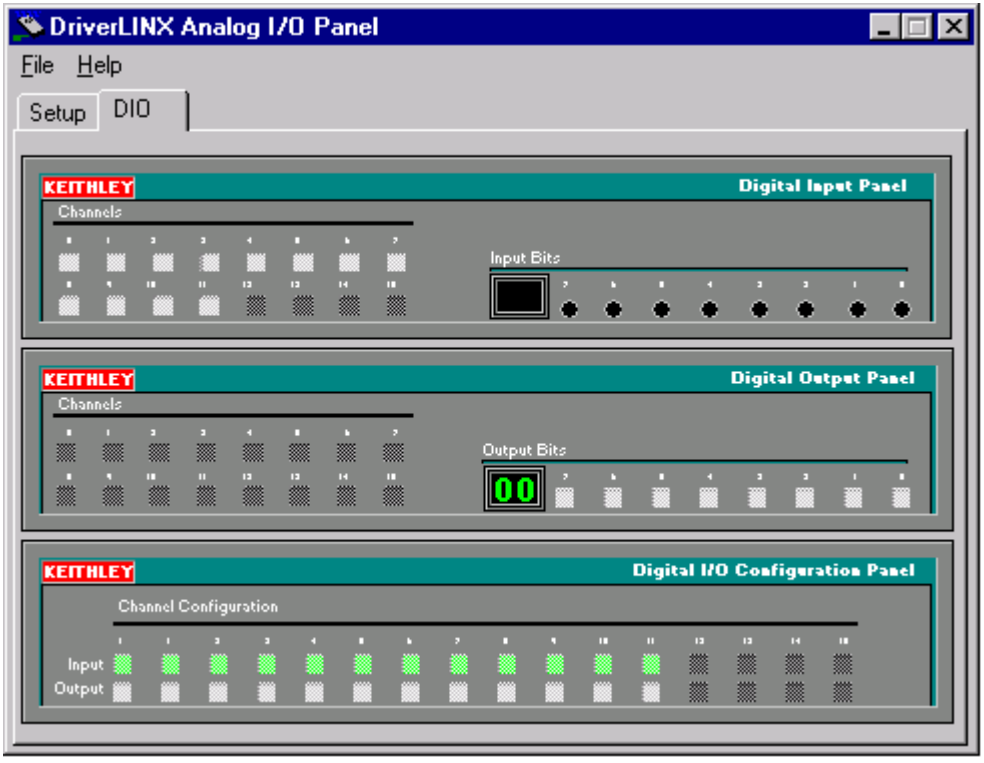
Figure 4-1
An AIO Panel example



NOTE *The "Driver Selection" column will show the actual DriverLINX driver(s) you have installed.*

2. On the **AIO Control Panel**, click the **DIO** tab.

Figure 4-2
DIO channel tab example



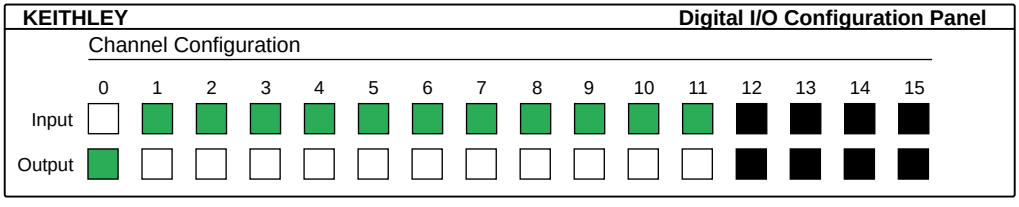
NOTE *The on-screen digital I/O controller works as follows:*

- *Channels 0 to 15 refer to the 8-bit general-purpose registers of your digital input-output card. (Depending on which card is used, the number of valid 8-bit registers will vary.) Bits displayed on the* ***Digital Input Panel*** *and the* ***Digital Output Panel*** *are numbered 0-7 for every channel. Refer elsewhere in this manual for a description of the available ports and their direction.*
- *Invalid channels and settings appear as dark gray squares. For example:*
  - *Non-existent channels always appear as dark gray squares.*
  - *Channels configured as inputs will appear as dark gray squares on the output panel.*

- *Valid channels and settings appear as white squares when OFF and green squares when ON. (When the manual is printed in black and white, valid channels and settings appear as white squares when OFF and as light gray squares when ON.)*
- *The two-digit numeric displays under **Input Bits** and **Output Bits** show the hexadecimal values of the adjacent bit patterns.*
- *To configure a valid channel either for input or output, use the **Digital Channel Configuration Panel**. Click on either the **Input** or **Output** square below the channel number. Note: this selection will be disabled for channels which are fixed as input or output by hardware design.*
- *To turn ON output-channel bits, use the **Digital Output Panel**. First select the channel number of the bits to be turned on by clicking on the appropriate square under **Channels**. Then, turn ON a bit by clicking the appropriate square under **Output Bits**. Turn OFF a bit in the same way.*
- *To read an input-channel bit, use the **Digital Input Panel**. First select the channel number to be checked by clicking the appropriate square under **Channels**. Then, read the numbered bit under **Input Bits**. OFF input bits appear as black dots and ON input bits appear as green dots. (When the manual is printed in black and white, OFF input bits appear as black dots and ON input bits appear as light gray dots.)*

3. Under **Digital I/O Configuration Panel**, configure channels as shown in Figure 4-3. (Actual channels available will vary according to your hardware.)

Figure 4-3
Configuring the digital I/O channels as inputs and outputs

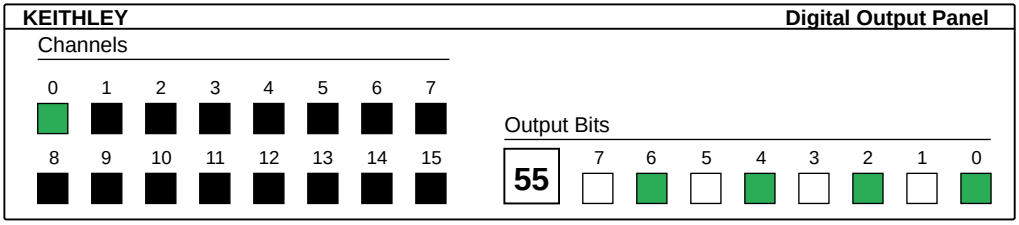


NOTE *For clarity when the manual is printed in black and white, the control colors in Figure 4-3 and subsequent drawings will be shown as follows:*

Illustration	Color on Actual Panel	Function
BLACK	DARK GRAY	Invalid
WHITE	LIGHT GRAY	OFF
GRAY	GREEN	ON

4. In the **Digital Output Panel** under **Channels**, click on a channel (here, channel **0**) as shown in Figure 4-4.

Figure 4-4
Configuring channel 0 for output bit pattern A



5. In the **Digital Output Panel** under **Output Bits**, set the bits of the channel as desired as shown in Figure 4-4. (Click on each bit position to turn it ON or OFF.)
6. In the **Digital Input Panel** under **Channels**, click on a channel to select it and display the logical state of its input lines.

Output set test

The output set test checks whether logic levels measured at all output pins agree with output bit patterns set by software, using a DriverLINX graphical interface (AIO Panel).

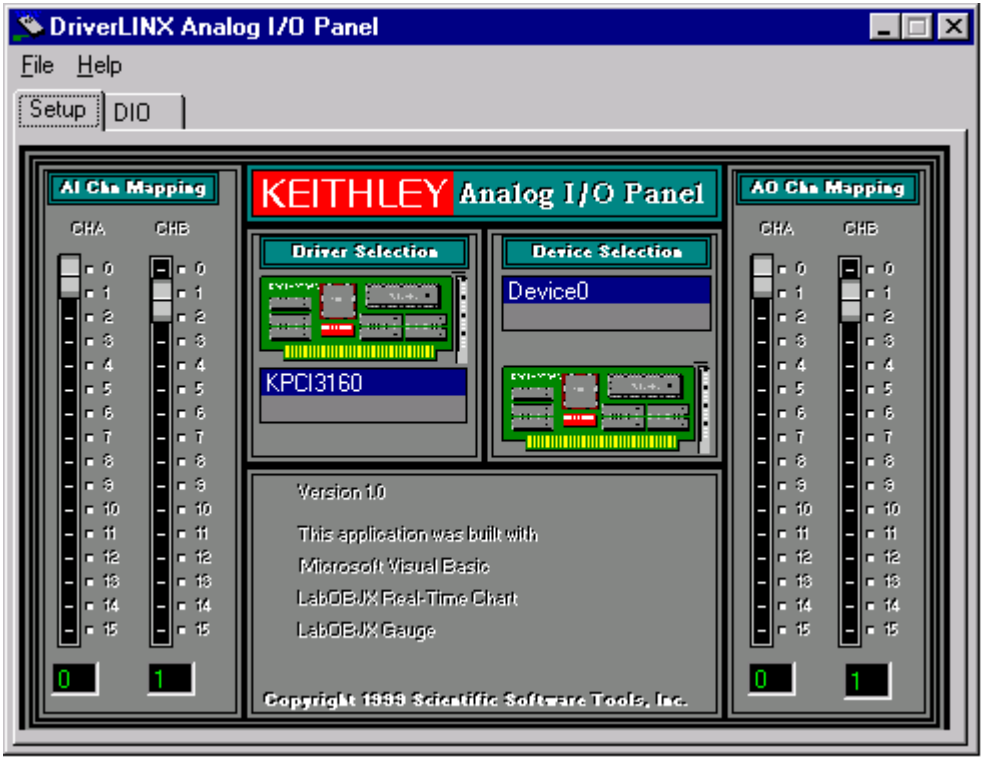
NOTE *This test is performed without user circuits being connected to the outputs.*

Perform the output set test as follows:

1. Ready the following equipment:
   - A digital voltmeter (DVM) or a digital multimeter (DMM) set to measure voltages, or a logic probe capable of reading TTL logic levels.
   - A suitable accessory and cable for the board being tested.
2. Turn OFF the host computer.
3. Connect the cable and accessory to your board.
4. Turn ON the host computer and boot Windows 95/98/NT.
5. Click the Windows 95/98/NT **Start** tab.

6. Start the AIO Panel as follows:
   a. In the **Start** menu, click **Programs**.
   b. Find the **DriverLINX ▸ Test Panels** folder, under which you should find the **AIO Panel** entry.
   c. Click on the **AIO Panel** entry. The **Analog I/O Panel** should appear, similar to the example in Figure 4-5. (If you have other DriverLINX devices installed in addition to the digital input/output card you are testing, they will also be listed. In that case, select the desired digital I/O card and the proper device number before proceeding.)

Figure 4-5
An AIO Panel example

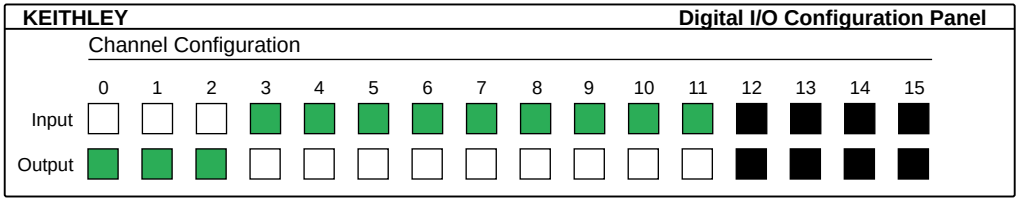


7. On the **AIO Panel**, click the **DIO** tab.

NOTE *To read an input-channel bit, use the **Digital Input Panel**. First, select the channel number to be checked by clicking the appropriate square under **Channels**. Then, read the numbered bit under **Input Bits**. OFF input bits appear as black dots and ON input bits appear as green dots. (When the manual is printed in black and white, OFF input bits appear as black dots and ON input bits appear as light gray dots.) Further information about this panel, how to make changes, and how to interpret displays, is given in "I/O Bit Tests" of this section.*

8. Under **Digital I/O Configuration Panel**, configure the output channels to be tested as shown in Figure 4-6. (Actual output channels available will vary according to your hardware.)

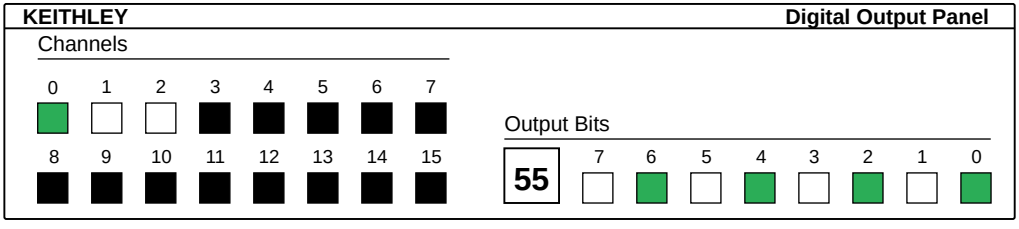
Figure 4-6
Configuring the digital I/O channels as inputs and outputs



NOTE *In Figure 4-6 and subsequent drawings of digital I/O controller panels, the squares below invalid channels are colored black instead of dark gray—for clarity when the manual is printed in black and white.*

9. In the **Digital Output Panel** under **Channels**, click on an output channel (channel **0** in this example) as shown in Figure 4-7.

Figure 4-7
Configuring channel 0 for output bit pattern A



10. In the **Digital Output Panel** under **Output Bits**, set the bits of channel **0** for bit pattern A as shown in Figure 4-7.

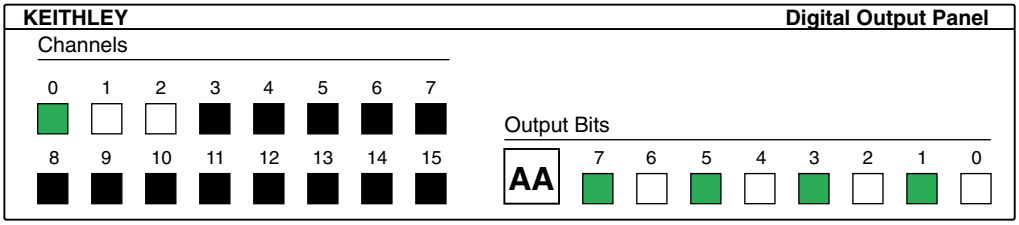
11. Measure the voltage between signal ground and each bit of the output port with a DMM or DVM. Make measurements at the cabled mating connector of your accessory.
12. Each bit set to ON in the **AIO Panel** should output a logic-high signal at the corresponding I/O terminal, reading typically about 4 volts (minimum of 2.2 volts) at a DMM/DVM. Each bit set to OFF in the **AIO Panel** should output a logic-low signal at the corresponding I/O terminal, reading typically about 0 volts (maximum of 0.8 volts) at a DMM/DVM. Do one of the following:

NOTE *The typical values shown are valid for boards with TTL compatible outputs. For boards with relay outputs (REL-16, PDISO-8, and PIO-32) the output will be a relay contact closure. For boards with open collector outputs (PIO-HV) use a pull up resistor to an appropriate voltage to detect output state. Refer to the hardware description in this user's guide for more details on the output's electrical specification.*

- If the bit patterns set on the **AIO Panel** do not agree with the logic levels measured at the I/O terminals, the board is not functioning properly. Stop here, and determine why.
- If the bit patterns set on the **AIO Panel** agree with the logic levels measured at the I/O terminals, then repeat steps 9, 10, and 11 for remaining output channels.

13. In the **Digital Output Panel** under **Channels**, click on the output channel to test (channel **0** in this example) as shown in Figure 4-8.

Figure 4-8
Configuring channel 0 for output bit pattern B



14. In the **Digital Output Panel** under **Output Bits**, set the bits of channel **0** for bit pattern B as shown in Figure 4-8.
15. Measure the voltage between signal ground and each bit of the output port with a DMM or DVM. Make measurements at the STA-50 terminals or the cabled mating connector that is connected to the selected CONN-3160-D1 50-pin connector.

16. Again, each bit set to ON in the **AIO Panel** should output a logic-high signal at the corresponding I/O terminal, reading typically about 4 volts (minimum of 2.2 volts) at a DMM/DVM. Each bit set to OFF in the **AIO Panel** should output a logic-low signal at the corresponding I/O terminal, reading typically about 0 volts (maximum of 0.8 volts) at a DMM/DVM.

NOTE *The typical values shown are valid for boards with TTL compatible outputs. For boards with relay outputs (REL-16, PDISO-8, and PIO-32) the output will be a relay contact closure. For boards with open collector outputs (PIO-HV) use a pull up resistor to an appropriate voltage to detect output state. Refer to the hardware description in this user's guide for more details on the output's electrical specification.*

- If the bit patterns set on the **AIO Panel** do not agree with the logic levels measured at the I/O terminals, the board is not functioning properly. Stop here, and determine why.
- If the bit patterns set on the **AIO Panel** do agree with the logic levels measured at the I/O terminals, and you have performed an output set test for all ports, the board is functioning properly.

17. Repeat steps 13, 14, and 15 for additional output channels.

Input read test

A similar test of input circuitry can be performed by applying an input signal of suitable type to each input line and verifying that the appropriate input indicator changes state. Refer to the hardware description in this user's guide for more details on the input's electrical specifications.

5
Programming

General

The PIO-24 emulates the Intel 8255 PPI Control Word Mode 0. On power up or whenever the PC Bus RESET line is asserted, all ports are initially set up in the Input Mode.

The PA and PB Ports are byte-wide, and the direction of all lines within a port is set by the Control Register. The PC Port can also be used as a byte-wide port, or it can be split into two ports of four bits (nibble wide). The PC0-3 Lines are known as *PC-Lower*, and the PC4-7 Lines as *PC-Upper*. Directions of the PC Upper and Lower ports are independently programmable. Detailed port descriptions are as follows:

- Port A — Consists of one 8-bit data output latch/buffer and one 8-bit data input latch.
- Port B — Consists of one 8-bit data output latch/buffer and one 8-bit data input buffer.
- Port C — Consists of one 8-bit data output latch/buffer and one 8-bit data input buffer. This port can be divided into two 4-bit ports under the Mode Control.

Control Byte

At power-up or after a system reset, all PIO-24 lines are configured as inputs. The Control Byte is an 8-bit (byte) hexadecimal number used to configure the direction of the PIO-24 ports: PA, PB, PC (lines 0-3) and PC (4-7). The controlling PIO-24 software program must output the Control Byte to the PIO-24 to change the directions (input or output) of the ports. It is important to note that there is one byte to control four ports and that when a port is initialized as an output port its lines are in a reset state. The Control Byte is output to the PIO-24 address location at base address+3.

To simplify your selection of a Control Byte to match your choice of port directions, use Table 5-1. This chart summarizes information from the Intel *Peripheral Data* book on control words and their port directions for Mode 0.

Table 5-1
Mode 0 control words and port directions

Control Byte	Port A	Port B	Port C (0 - 3)	Port C (4 - 7)
80h	Out	Out	Out	Out
81h	Out	Out	In	Out
82h	Out	In	Out	Out
83h	Out	In	In	Out
88h	Out	Out	Out	In
89h	Out	Out	In	In
8Ah	Out	In	Out	In
8Bh	Out	In	In	In
90h	In	Out	Out	Out
91h	In	Out	In	Out
92h	In	In	Out	Out
93h	In	In	In	Out
98h	In	Out	Out	In
99h	In	Out	In	In
9Ah	In	In	Out	In
9Bh	In	In	In	In

When a port is programmed as an output, you can return the data that is present on the output lines by reading the same location. Note that this reflects the actual state of the output lines: if one or more is shorted, you are actually reading back the state of the output lines.

Selecting an application programming interface

The PIO Series supports two different device driver interfaces to best match your programming needs. The supported driver interfaces are:

- **DriverLINX** — An interface that is hardware and operating system independent and supports multi-tasking, multi-threading applications.
- **Direct I/O** — An interface that is operating system independent and supports single-tasking, single-threaded access to an Intel 8255-like function call interface.

DriverLINX interface

For maximum portability and versatility, it is recommended that the DriverLINX interface be used. The DriverLINX interface has the following advantages:

- **Hardware independence** — DriverLINX supports ISA, PCMCIA, and PCI digital I/O boards with a common interface as well as digital ports on analog I/O and counter/timer boards.
- **Operating system independence** — DriverLINX supports Windows 95/98 and Windows NT with a common interface.
- **Shared hardware access** — DriverLINX allows multiple processes or threads to cooperatively share hardware resources.
- **Multi-tasking, multi-threading support** — DriverLINX provides the synchronization and coordination for multi-tasking, multi-threading applications to safely access shared hardware resources.
- **Portability** — DriverLINX supports older and newer hardware with a common interface for 16- and 32-bit applications on Windows 95/98 and Windows NT.
- **Versatility** — DriverLINX supports a wide variety of programming styles and languages including C/C++, Visual Basic, Delphi, and LabVIEW.
- **Background I/O** — DriverLINX supports background I/O using interrupts or other techniques so your application can overlap processing and data acquisition.
- **Full hardware support** — DriverLINX supports all the hardware's features.

The DriverLINX interface has a few disadvantages compared to the alternative interfaces:

- **Software modifications** — Existing applications will require rewriting to use DriverLINX.
- **No direct hardware access** — Before Windows NT, Microsoft discouraged, but nevertheless allowed, direct application program access to hardware.
- **Speed of single-value I/O** — Applications, especially those ported from DOS, that depend on rapid software polling of I/O ports will notice that the operating system time cost for multi-tasking, multithreading synchronization is higher than direct hardware access.

While writing your application to use a multi-product (portable application programming interface is the best long-term solution) you should consider the alternative API only for special purpose or short-term needs.

Direct I/O application programming interface

The Direct I/O interface uses the methods of an ActiveX Automation object to access the PIO hardware. This interface has the following advantages:

- **Operating system independence** — Both Windows 95/98 and Windows NT support this interface.
- **Intel 8255 emulation** — This interface uses the I/O address map and programming protocols of Intel's 8255 chip.
- **Fast hardware access** — This interface provides the fastest access to the hardware registers of the two interfaces.
- **Versatility** — Most Windows compilers and scripting languages support ActiveX Automation objects.
- **Native hardware register access** — For special-purpose applications, this interface also supports product-specific access to the hardware registers.
- **Speed of single-value I/O** — The I/O performance of this interface is the fastest of the two interfaces when using early binding to the interface.

The Direct I/O interface also has disadvantages:

- **Incompatible with DriverLINX** — Applications cannot use this interface with DriverLINX for the PIO Series either in the same or another application.
- **32-bit only interface** — 16-bit applications cannot use this interface.
- **Non-exclusive hardware access** — This interface does not synchronize or coordinate hardware access among threads or processes.
- **8-bit I/O only** — The Intel 8255-based methods only support 8-bit hardware access.
- **Supports subset of hardware features** — This interface does not support using interrupts.
- **ActiveX Interface** — Using Automation objects in some C++ compilers is more difficult than in Visual Basic.

Installing the Direct I/O Driver

The normal DriverLINX installation automatically installs the Direct I/O Driver. This driver is a registered ActiveX object that resides in KISAPIO.DLL.

This driver requires that you install the DriverLINX kernel drivers as it uses their services. On Windows NT, the kernel driver is KMBPIO.SYS. On Windows 95/98, it is KMBPIO.VXD. Follow the normal DriverLINX installation and configuration procedures to install these kernel drivers.

Configuring the Direct I/O Driver

The Direct I/O Driver requires that you configure a DriverLINX Logical Device using the DriverLINX Configuration Panel utility. The Direct I/O driver does not require any separate configuration.

Programming the Direct I/O Interface

The Direct I/O Interface is an ActiveX Automation object hosting one interface. This control is compatible with Microsoft Visual C++ and Visual Basic as well as other ActiveX-hosting languages.

The methods of the control's interface, ISAPIO, access the 8-bit ports of an Intel 8255 chip. Consult an Intel hardware manual or DriverLINX manual for information on programming the 8255 chip.

IISAPIO Intel 8255 interface

The following syntax descriptions are shown in C/C++. For Visual Basic, use the Object Browser to see the VB syntax (see the next subsection, *Using the Direct I/O Driver in Visual Basic*).

- **`HRESULT Open Device(long Device);`**
  Opens a PIO device
  Device is the DriverLINX Logical Device number of the PIO board to open.
- **`HRESULT CloseDevice();`**
  Closes a previously opened PIO device.
  The number of CloseDevice calls must match the number of OpenDevice calls.
- **`HRESULT Read(short Offset, unsigned char * Result);`**
  Reads an 8-bit value from the PIO board.
  Offset is the value of the register to read relative to the base I/O address.
  Result is the value read from the register.
- **`HRESULT Write(short Offset, unsigned char Value);`**
  Writes an 8-bit value to the PIO board.
  Offset is the value of the register to write relative to the base I/O address.
  Value is the output to write to the register.
- **`HRESULT OpenCount(long *Count);`**
  Returns the number of times a client has called OpenDevice for this Logical Device. Count is the address of the value for the result.
- **`HRESULT Device(long *LogicalDevice);`**
  Returns the Logical Device number if the device is open. Otherwise it returns -1. LogicalDevice is the address of the value for the result.

Using the Direct I/O Driver in Visual Basic

The following instructions are for Version 5 of Microsoft Visual Basic. If you have a different version, consult the Visual Basic documentation.

1. From VB's Project menu, select References....
2. Scroll through the Available References, looking for Keithley ISA PIO Direct I/O Library.
3. Check Keithley ISA PIO Direct I/O Library and then click OK.
4. From VB's View menu, select Object Browser to display a list of libraries.
5. Search for KISAPIOLib.
6. The Object Browser shows the VB syntax for the KISAPIO class.

Creating a simple Visual Basic application

1. Create a Visual Basic form.
2. Add the following source code to declare, open, close, read, and write a PIO device:

```
Option Explicit
Dim PIO As New KISAPIO
Private Sub Close_Click()
  PIO.CloseDevice
End Sub
Private Sub btOpen_Click()
  PIO.OpenDevice (Val(tbDevice))
End Sub
Private Sub btRead_Click()
  tbValue=Hex(PIO.Read(Val(tbAddr)))
End Sub
Private Sub btWrite_Click_()
  Dim v As Byte
  v=Val(tbValue)
  PIO.Write Val(tbAddr), v
End Sub
```

6
Troubleshooting

General

If your PIO-24 board is not operating properly, use the information in this chapter to isolate the problem. If the problem appears serious enough to warrant technical support, refer to *Technical support* on page 6-6 for information on how to contact an applications engineer.

Using the DriverLINX Event Viewer

The DriverLINX Event Viewer displays the Windows system event log. Applications and hardware drivers make entries in the system event log to assist in predicting and troubleshooting hardware and software problems.

DriverLINX uses the event log to report problems during driver loading or unexpected system errors. The event log can assist in troubleshooting resource conflicts and DriverLINX configuration errors. If you are having trouble configuring or initializing a Logical Device, check the event log for information from the DriverLINX driver.

Using the DriverLINX Event Viewer, you can view, save and e-mail DriverLINX event log entries under Windows 95/98 or Windows NT. DriverLINX event log entries can help you or technical support troubleshoot data-acquisition hardware and software problems.

Device initialization error messages

During device initialization, DriverLINX performs a thorough test of all possible subsystems on PIO-24 boards as well as the computer interface. If DriverLINX detects any problems or unexpected responses, it reports an error message to help isolate the problem. The device initialization error messages fall into three basic categories:

- **"Device not found"** — Board address does not match hardware setting or conflicts with another board. Verify the board's address settings. Also, do not confuse hexadecimal with decimal addresses in the DriverLINX Device Configure dialog box.
- **"Invalid IRQ level"** or **"Invalid DMA level"** — Selected level does not match hardware setting, conflicts with another board's IRQ/DMA levels, or is dedicated to the computer's internal functions (COM port, disk drive controller, network adapter, etc.)
- **"Hardware does not match configuration"** — Operating mode/range switch or jumper setting does not match selection(s) made in the DriverLINX Device Configuration dialog box.

Problem isolation

If you encounter a problem with a PIO-24 board, use the instructions in this section to isolate the cause of the problem before calling Keithley for technical support.

If your board is not operating properly after using the information in Table 6-1, continue with the next two sections to further isolate the problem.

Table 6-1
Troubleshooting information

Symptom	Possible Cause	Possible Solution
Board does not respond	Base address is incorrect or not consistent with what the program is addressing.	Check the base-address switch setting on the board against the setting shown in the DriverLINX configuration. If the base address is set correctly, make sure no other computer device is using any of the I/O locations beginning at the specified base address. If necessary, reconfigure the base address.
	The interrupt level is incorrect or not consistent with what the program is addressing.	Make sure no other computer device is using the interrupt level specified in your program. If necessary, reset the interrupt level.
	The board configuration is incorrect.	Check the remaining settings in the DriverLINX configuration.
	The board is incorrectly aligned in the accessory slot.	Check the board for proper seating.
	The board is damaged.	Contact the Keithley Applications Engineering Department.
Intermittent operation	The most common cause of this problem is that the I/O bus speed is in excess of 8 MHz.	Reduce the I/O bus speed to a maximum of 8 MHz (to change the I/O bus speed, run BIOS setup). See your computer documentation for instructions on running BIOS setup.
	Vibrations or loose connections exist.	Cushion source of vibration and tighten connections.
	The board is overheating.	Check environmental and ambient temperature. See the documentation for your computer.
	Electrical noise exists.	Provide better shielding or reroute unshielded wiring.

Table 6-1 (cont.)
Troubleshooting information

Symptom	Possible Cause	Possible Solution
Data appears to be invalid	The most common cause of this problem is that the I/O bus speed is in excess of 8 MHz.	Reduce the I/O bus speed to a maximum of 8 MHz (to change the I/O bus speed, run BIOS setup). See your computer documentation for instructions on running BIOS setup.
	An open connection exists.	Check wiring to screw terminal.
	Another system resource is using the specified base address.	Reconfigure the base address of the PIO-24 board. Check the I/O assignments of other system resources and reconfigure, if necessary.
Computer does not boot.	Board not seated properly.	Check the installation of the board.
	The base address setting of the PIO-24 board conflicts with that of another system resource.	Check the base address settings of your system resources; each address must be unique.
	The power supply of the host computer is too small to handle all the system resources.	Check the needs of all system resources and obtain a larger power supply.
System lockup	A timing error occurred.	Restart your computer.

Testing the board and host computer

To isolate the problem to the PIO-24 board or to the host computer, use the following steps:

CAUTION **Removing a board with the power ON can cause damage to your board and/or computer.**

1. Turn the power to the host computer OFF, and remove power connections to the computer.
2. While keeping connections to accessories intact, unplug the cable to the main I/O connector of the PIO-24 board.
3. Remove the board from the computer and visually check for damage. If a board is obviously damaged, refer to *Technical support* on page 6-6 for information on returning the board.
4. With the PIO-24 board out of the computer, check the computer for proper operation. Power up the computer and perform any necessary diagnostics.

At this point, if you have another PIO-24 board that you know is functional, you can test the slot and I/O connections using the instructions in the next section. If you do not have another board, refer to the instructions on page 6 before calling Keithley Instruments for technical support.

Testing the accessory slot and I/O connections

When you are sure that the computer is operating properly, test the computer accessory slot and I/O connections using another PIO-24 board that you know is functional. To test the computer accessory slot and the I/O connections, follow these steps:

1. Remove computer power again, and install a PIO-24 board that you know is functional. Do not make any I/O connections.
2. Turn computer power ON and check operation with the functional board in place. This test checks the computer accessory slot. If you were using more than one board when the problem occurred, use the functional board to test the other slot, as well.
3. If the accessory slots are functional, use the functional board to check the I/O connections. Reconnect and check the operation of the I/O connections, one at a time.
4. If operation fails for an I/O connection, check the individual inputs one at a time for shorts and opens.
5. If operation remains normal to this point, the problem is in the PIO-24 board(s) originally in the computer. If you were using more than one board, try each board one at a time in the computer to determine which is faulty.
6. If you cannot isolate the problem, refer to the next section for instructions on obtaining assistance.

Technical support

Before returning any equipment for repair, call Keithley for technical support at:

1-888-KEITHLEY
Monday - Friday, 8:00 a.m. - 5:00 p.m., Eastern Time

An applications engineer will help you diagnose and resolve your problem over the telephone. Please make sure that you have the following information available before you call:

PIO-24 board configuration	Model	
	Serial number	
	Revision code	
	Base address setting	
	Interrupt level setting	
	Number of channels	
	Output signal (V or I)	
	Mode (uni. or bip.)	
	Output span	
	Number SSH-8 boards	
	Number EXP boards	
Computer	Manufacturer	
	CPU type	
	Clock speed (MHz)	
	KB of RAM	
	Video system	
	BIOS type	
Operating system	Windows version	
	Windows mode	
Software package	Name	
	Serial number	
	Version	
	Invoice/Order number	
Compiler (if applicable)	Language	
	Manufacturer	
	Version	

Accessories	Type	
	Type	
	Type	
	Type	
	Type	
	Type	
	Type	
	Type	
	Type	

If a telephone resolution is not possible, the applications engineer will issue you a Return Material Authorization (RMA) number and ask you to return the equipment. Include the RMA number with any documentation regarding the equipment.

When returning equipment for repair, include the following information:

- Your name, address, and telephone number.
- The invoice or order number and date of equipment purchase.
- A description of the problem or its symptoms.
- The RMA number on the **outside of the package.**

Repackage the equipment, using the original anti-static wrapping, if possible, and handle it with ground protection. Ship the equipment to:

ATTN.: RMA# _____
Repair Department
Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139

Telephone 1-888-KEITHLEY
FAX (440) 248-6168

NOTE *If you are submitting your equipment for repair under warranty, you must include the invoice number and date of purchase.*

To enable Keithley to respond as quickly as possible, you must include the RMA number on the outside of the package.

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Specifications are subject to change without notice.

KEITHLEY

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