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KEITHLEY

DAS-16 Series

User's Manual



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DAS-16 Series
User's Guide

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Preface

This guide describes how to set up, install, and operate the following Keithley products:

- The DAS-16, and DAS-16F boards, which are referred to collectively as DAS-16/16F Series boards.
- The DAS-16G1 and DAS-16G2 boards, which are referred to collectively as DAS-16G1/G2 Series boards.

Unless this manual refers specifically to a particular board, it refers to all models collectively as the DAS-16 Series boards.

To follow the information and instructions contained in this manual, you must be familiar with the operation of an IBM PC AT, or equivalent computer in the Windows (95/98, or NT) environment. You must also be familiar with data acquisition principles and the requirements of your applications.

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Manual Organization

The following table lists the topics this guide focuses on and indicates where you can find information about a topic.

To learn more about	See
The capabilities of DAS-16 Series boards	Section 1
What software is available for the boards	Section 1
What accessories are available for the boards	Section 1
Functionality of DAS-16 Series boards	Section 2
Installing the DAS-16 Series DriverLINX and associated software	Section 3
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Installing your boards	Section 3
Attaching accessories	Section 4
Precautions to observe when connecting signals	Section 4
Using the DriverLINX Analog I/O Panel software for test and data acquisition	Section 5
Calibrating the board	Section 6
Troubleshooting and obtaining technical support	Section 7
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I/O connector pin assignments	Appendix B
The register level I/O map	Appendix C
IBM DMA Structure	Appendix D

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Related Documents

You can find more information on DAS-16 Series software and accessories in the related documents listed in the following table.

Document
EXP-16 & EXP-16/A Expansion Multiplexer/Amplifier System User's Guide
EXP-GP Signal Conditioning Multiplexer User's Guide
MB Series User's Guide
ISO-4 User's Guide
DriverLINX User's Guides: *DriverLINX Installation and Configuration Guide* DriverLINX Appendix F: Configuration and Implementation Notes for Keithley DAS-16/1600 DriverLINX Analog I/O Programming Guide DriverLINX Digital I/O Programming Guide DriverLINX Counter/Timer Programming Guide

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1

Overview

The Model DAS-16, DAS-16F, and DAS-16G (hereinafter referred to as DAS-16) are multi-function, high-speed, programmable, A/D (and D/A) I/O expansion boards for the IBM Personal Computer. They are full length boards that install internally in an expansion slot of an IBM PC and compatibles to turn the computer into a fast, high-precision data acquisition and signal analysis instrument. DAS-16 boards are of multilayer construction with integral ground plane to minimize noise and crosstalk at high frequencies. The DAS-16G includes an additional register at an I/O address location for setting the gain.

Table 1-1. DAS-16 Series Models

Model	Description
DAS-16	Includes the DAS-16, a 16-channel, high speed A/D interface with DMA, (70,000 samples/sec. max.) as well as software and appropriate documentation.
DAS-16F	Includes the DAS-16F, a 16-channel, high speed A/D interface with DMA, (100,000 samples/sec. max.) as well as software and appropriate documentation.
DAS-16G1	Includes the DAS-16G1, a 16-channel, high speed A/D interface with software selectable input gains (1, 10, 100, and 500), software, and appropriate documentation.
DAS-16G2	Includes the DAS-16G2, a 16-channel, high speed A/D interface with software selectable input gains (1, 2, 4, and 8), software, and appropriate documentation.

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System requirements

The system capabilities required to run the DAS-16 Series board, and to use the DriverLINX software supplied with the board, are listed in Table 1-2.

Table 1-2. System requirements

CPU Type	Pentium or higher processor on motherboard with PCI bus version 2.1.
Operating system	Windows 95 or 98.
	Windows NT version 4.0 or higher.
Memory	16 MB or greater RAM when running Windows 95 or 98.
	32 MB or greater RAM when running Windows NT.
Hard disk space	4 MB for minimum installation.
	50 MB for maximum installation.
Other	A CD-ROM drive.*
	A free PCI-bus expansion slot capable of bus mastering.
	Enough reserve computer power supply capacity to power the KPCI-3101–4 Series board, which draws 0.9A at 5VDC and 48mA at +12VDC.
	A VGA, or compatible, display (640 x 480 or higher, 256 colors recommended).

*Any CD-ROM drive that came installed with the required computer should be satisfactory. However, if you have post-installed an older CD-ROM drive or arrived at your present system by updating the microprocessor or replacing the motherboard, some early CD-ROM drives may not support the long file names often used in 32 bit Windows files.

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Software

DriverLINX — the high-performance real-time data-acquisition device drivers for Windows application development including:

- *DriverLINX API DLLs* and drivers supporting the DAS-16 Series hardware.
- *Analog I/O Panel* — A DriverLINX program that verifies the installation and configuration of DriverLINX to your DAS-16 Series 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 DAS-16 Series 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 DAS-16 Series hardware.
- DAS-16 Series utilities — The following DriverLINX utilities are provided as part of the DAS-16 Series standard software package:
  - Calibration Utility
  - Test Panel Utility

The user can select a fully integrated data acquisition software package such as TestPoint or LabVIEW or write a custom program supported by DriverLINX.

DriverLINX is the basic Application Programming Interface (API) for the DAS-16 Series boards:

- It supports programmers who wish to create custom applications using Visual C/C++, Visual Basic, or Delphi.
- It accomplishes foreground and background tasks to perform data acquisition.

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- It is the needed interface between TestPoint and LabVIEW and a DAS-16 Series board.

DriverLINX software and user's documentation on a CD-ROM are included with your board.

TestPoint is an optional, fully featured, integrated application package with a graphical drag-and-drop interface which can be used to create data acquisition applications without programming.

LabVIEW is an optional, fully featured graphical programming language used to create virtual instrumentation.

Features

Features shared by the DAS-16 Series boards are as follows:

- Boards are switch-configurable for 16 single-ended or eight differential analog input channels.
- Analog inputs are switch-configurable for either unipolar (0 to 10V) or bipolar (±10V) signals.
- Analog input gain may be set for the DAS-16/G1 boards to 1, 10, 100, or 500. The DAS-16/G2 boards have gain selection of 1, 2, 4, or 8.
- Analog input sampling is a maximum of 70ksamples/s for DAS-16 and 100ksamples/s for DAS-16F; with 12-bit resolution.
- The base I/O address and Direct Memory Address (DMA) channel are switch-configurable; interrupt levels are software-configurable.
- The boards perform 8-bit data transfers on the ISA bus.
- Switch selectable Channel Input Configuration, High Impedance Ranges, Base I/O Address, and DMA Level.
- A/D conversions can be triggered by any of the following: software command, internal programmable-interval timer, or direct external trigger to the A/D. Once the A/D conversion has been completed, data transfers are accomplished via program transfer, interrupt, or DMA.

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- A 3-channel programmable interval timer (Intel 8254) provides trigger pulses for the A/D at any rate from 250KHz down to 8 pulses/hr. Two channels are operated in fixed divider configuration from an internal crystal clock. The third channel is uncommitted and provides a gated 16-bit binary counter that can be used for event or pulse counting, delayed triggering, and in conjunction with the other channels for frequency and period measurement.
- The boards have four unidirectional digital inputs and four unidirectional digital outputs.
- Digital I/O consists of four bits of TTL/DTL-compatible digital output and four bits of digital input. Apart from being addressed as individual I/O ports, some of the digital inputs do double duty in some modes as A/D trigger and counter gate control inputs.
- One feature of the DAS-16 is the availability of two channels of multiplying 12-bit D/A output. The DACs may use a fixed -5V reference available from on-board for a 0 to +5V output range. Alternatively, an external AC or DC reference may be used to give different output ranges or programmable attenuator action on an AC signal. D/A's are double-buffered to provide instantaneous single-step updates.
- A -5V (± 0.05V) precision reference voltage output is derived from the ADC reference. Typical applications are providing a DC reference input for the DACs and providing offsets and bridge excitation to user-supplied input circuits.

For more information on these features, refer to the functional description in Section 2.

Accessories

The following accessories are available for use with the DAS-16 Series boards.

- **STA-16** — Screw-terminal adapter accessory that connects to the main I/O connector of a DAS-160 Series board through a C-1800 cable.
- **STA-U** — Universal screw-terminal accessory that connects to the DAS-16 Series board through a C-1800 cable.

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- **STC-37** — Direct DAS-16 Series board to screw terminal interface.
- **STP-37** — Screw-terminal panel that connects to the main I/O connector of a DAS-16 Series board through a C-1800 cable.
- **MB Series modules and backplanes** — Plug-in, isolated, signal-conditioning modules and the backplanes that hold them. Supported backplanes include the MB01, MB02, and MB05.
- **STA-MB** — Screw terminal accessory for MB Series modules. The STA-MB connects to a DAS-16 Series board through a C-1800 cable and contains mounting holes for up to four MB Series modules. The STA-MB brings all signal lines from the DAS-16 Series board and all inputs and outputs from the MB Series modules out to external screw terminals.
- **STA-SCM16** — Screw terminal accessory that attaches to the main I/O of a DAS-16 Series board through a C-1800 cable and attaches up to four MB02 backplanes through C-2600 cables.
- **EXP-16 and EXP-16/A** — 16-channel expansion multiplexer and signal conditioning boards; requires the S-1600 cable and the PG-408A option.
- **C-1800** — Cable for attaching the main I/O connector of a DAS-16 Series board to an STA-16, STA-MB, STA-SCM-16, or STP-37 accessory. This cable can also be used to connect a DAS-16 Series board to an STA-U accessory; or to cascade additional EXP-GP or EXP-16 accessories.
- **S-1800** — Shielded version of the C-1800 cable.
- **S-1600** — Cable for attaching an STA-16 or STA-MB to an EXP-16, EXP-GP, or ISO-4 accessory.
- **C-16MB1** — Cable for attaching the main I/O connector of a DAS-16 Series board to an MB01/05 backplane.
- **C-2600** — Cable for attaching an STA-SCM16 to an MB02 backplane.

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2

Functional Description

This section describes the following features of DAS-16 Series boards:

- Analog input
- Analog output
- Digital I/O
- 82C54 counter/timer
- Wait state selection
- Power

These descriptions are offered to familiarize you with the operating options and to enable you to make the best use of your board. The block diagrams in Figure 2-1 and Figure 2-2 represent the DAS-16 Series boards.

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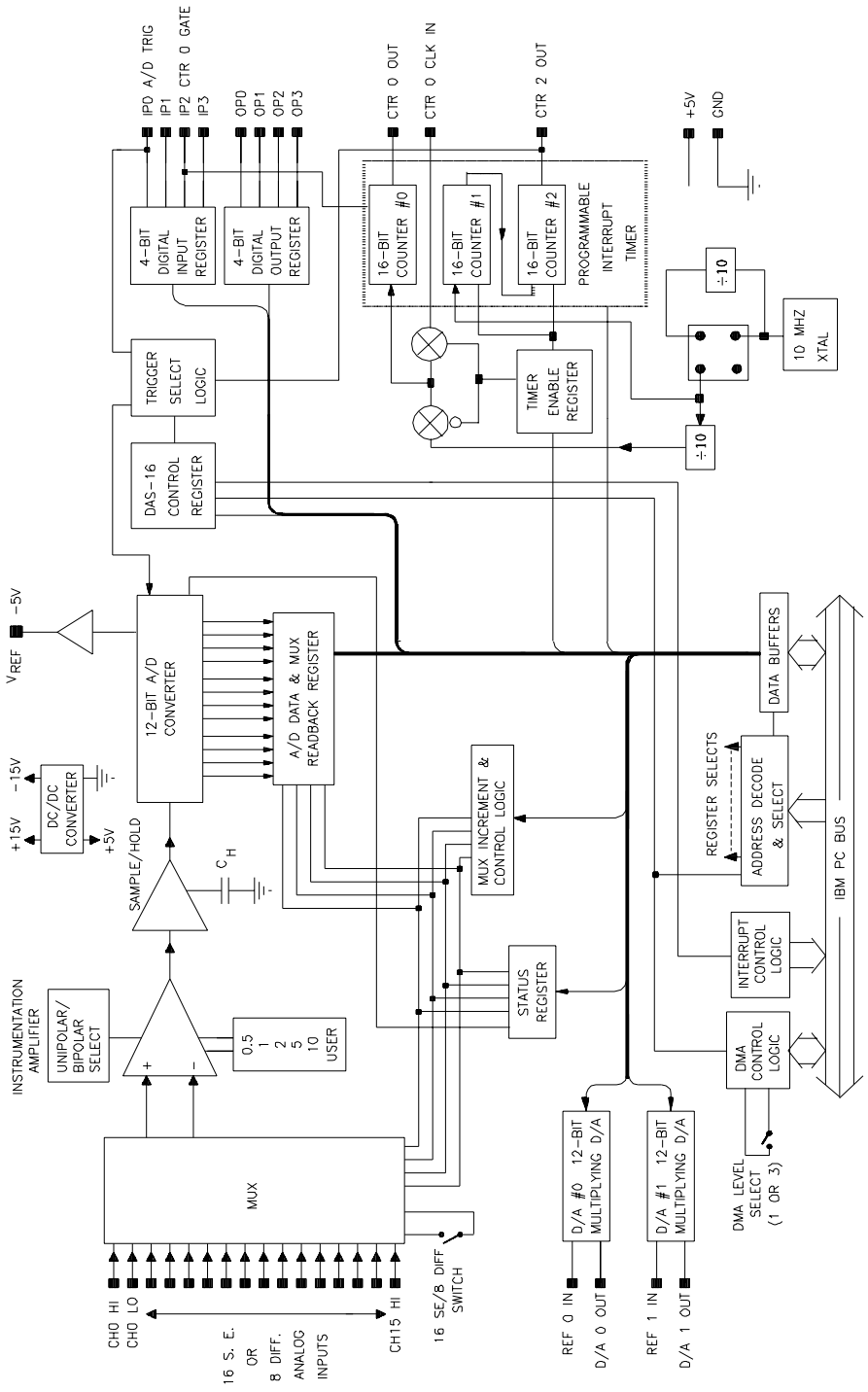


Figure 2-1. DAS-16/16F Functional Block Diagram

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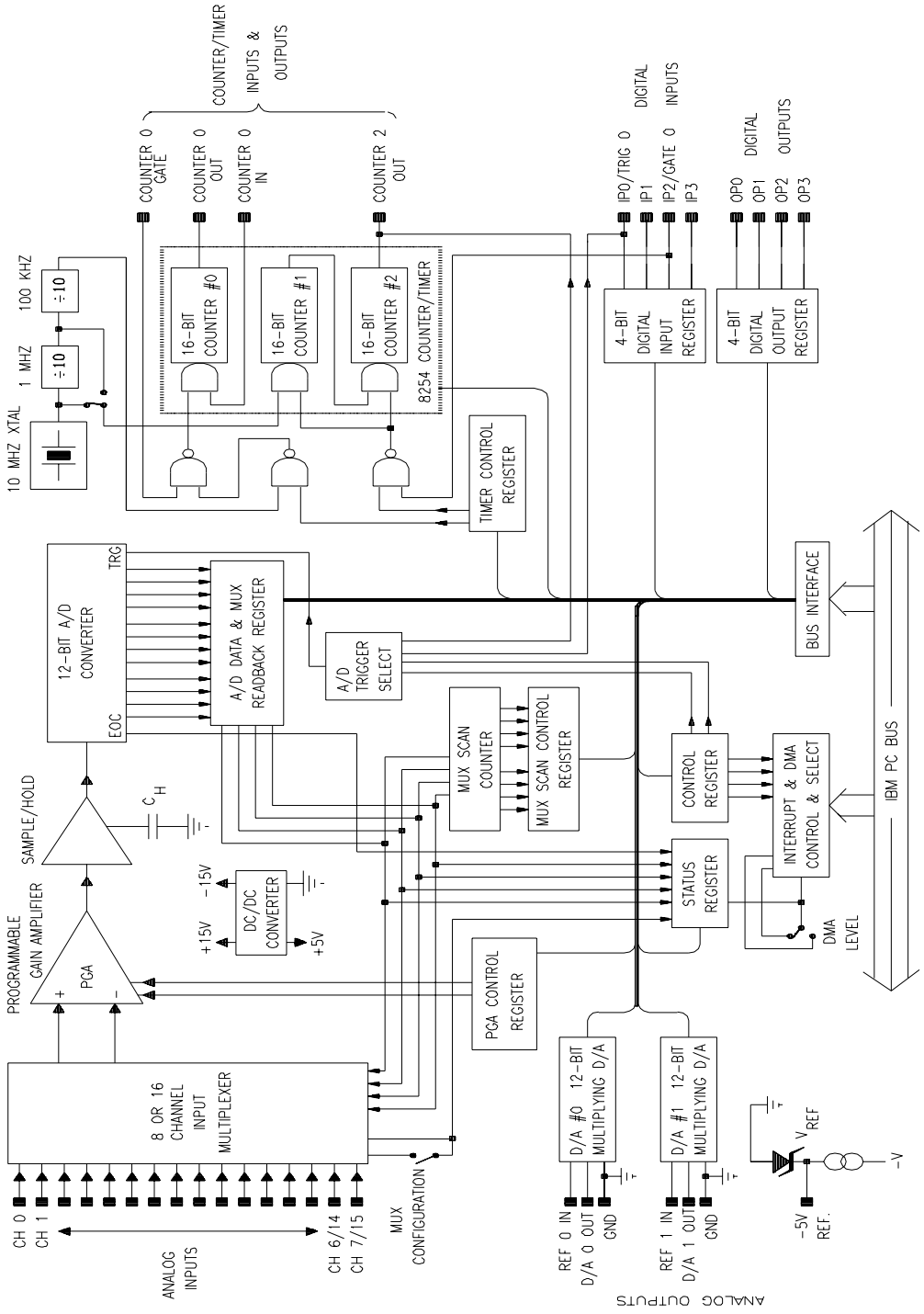


Figure 2-2. DAS-16G1/G2 Functional Block Diagram

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Analog Input Features

The analog input section of a DAS-16 Series board multiplexes all the active input channels (up to 16 single-ended or eight differential) into a single, 12-bit, sampling, analog-to-digital converter (ADC).

Other features of this section include input configurations, gain selection, conversion modes, triggers, clock sources, and data transfer modes. These features are described in the following subsections.

Differential/Single-Ended Selection

Using configuration switches, you can select either eight differential or 16 single-ended inputs. Differential inputs measure the difference between two signals. Single-ended inputs are referred to a common ground.

Generally, you want to use differential inputs for low-level signals whose noise component is a significant part of the signal or for signals that have nonground common mode. You want to use single-ended inputs for high-level signals whose noise component is not significant.

The specific level at which input configurations work best depends on the application. However, you generally use differential inputs for voltage ranges of 100mV and less.

Unipolar/Bipolar Selection

Using configuration switches, you can set the DAS-16 Series boards to operate in either unipolar or bipolar input mode. A unipolar signal is always positive (0 to 10V, for example), while a bipolar signal can swing up and down between negative and positive peak values (–10V to +10V, for example).

The DAS-16 Series boards use left-justified, offset binary to represent signals. In a given input range with the same peak-voltage capacity for both modes, unipolar mode doubles the converter’s resolution.

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Channel Selection

You can use DAS-16 Series boards to acquire data from a single analog input channel or from a range of contiguous, on-board analog input channels using automatic channel scanning. These two methods of channel selection are described as follows:

- **Single channel** — You use software to specify a single channel and initiate a conversion.
- **Automatic channel scanning** — You use software to specify the first and last channels in a range of contiguous, on-board channels (0 to 7). The channels are sampled in order from first to last; the hardware automatically increments the analog input multiplexer address shortly after the start of each conversion. When the last address is reached, the multiplexer returns to the start address and the channels are sampled again. For example, assume that the start channel is 4, the stop channel is 7, and you want to acquire five samples. Your program reads data first from channel 4, then from channels 5, 6, and 7, and finally from channel 4 again.

Note: An error results if the start channel number is higher than the stop channel number.

When using automatic channel scanning, all contiguous, on-board channels must have the same gain (analog input range).

DriverLINX allows you to acquire data from a range of multiple channels that includes channels on expansion boards or MB Series backplanes. DriverLINX provides for expansion board configuration in its Special selection of the Device Subsystem page, which allows you to record the settings of your analog input multiplexers and enable the expansion channels. Refer to *Appendix F: Configuration and Implementation Notes, Keithley DAS-16/1600 Series* manual that accompanies DriverLINX.

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Channel Selection in Expanded Configurations

The DAS-16 Series supports 16 single-ended or eight differential analog input channels. If you require additional analog input channels or signal conditioning for transducer inputs, you can attach EXP-16, EXP-16/A, or EXP-GP expansion accessories. Attaching any combination of up to eight 16-channel EXP-16 or EXP-16/A accessories, and/or eight 8-channel EXP-GP accessories can increase the number of available channels to 128. Attaching up to sixteen 16-channel EXP-16 accessories can increase the number of available channels to 256.

When you daisy-chain expansion boards from the analog inputs, you are advised to make the first expansion board multiplex onboard channel 0, the next expansion board multiplex channel 1, and so on. You select an onboard channel using jumper settings on the expansion board.

You can access any unused onboard channels by placing an STA-16 screw terminal accessory first in the daisy-chain configuration. Figure 2-3 illustrates how expansion boards and accessories interface with the analog channels of DAS-16 Series boards.

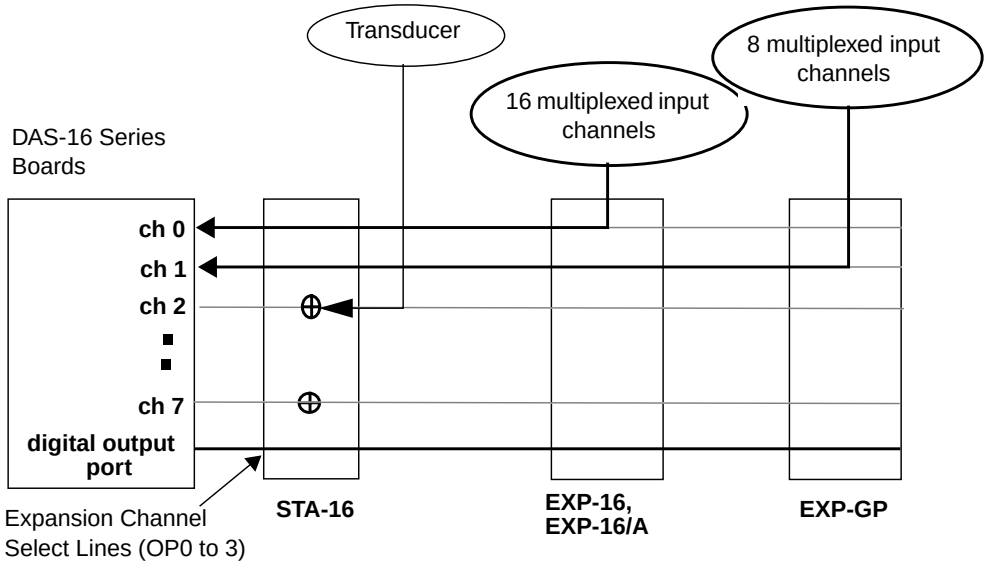


Figure 2-3. Expanding the Analog Inputs of DAS-16 Series Boards

You can also use up to four MB02 backplanes to increase the number of available channels to 64 isolated or 12 nonisolated. For more information about connecting channel expansion boards, refer to Section 4.

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Notes: You must specify a single-ended input configuration for all onboard channels associated with channels on MB02 backplanes.

If you are using EXP-16, EXP-16/A, or EXP-GP expansion accessories or MB Series backplanes, the digital output lines of the DAS-16 Series board select a particular channel on the expansion board or backplane to read.

Selecting Input Channel Range and Gain

The DIP switch labeled GAIN controls the full-scale range common to all the channels. The slide switch marked A/D has two positions: UNI (Unipolar) and BIP (Bipolar). These two switches determine the input scaling and whether the range is unipolar (zero to some positive full scale) or bipolar (from a negative to a positive full scale).

DriverLINX detects the position of the UNI/BIP switch through the DAS-16 status register, and it adjusts the data for unipolar and bipolar ranges accordingly. Unipolar scalings correspond to 0 to 4095 bits of output from the A/D, whereas bipolar scalings correspond to -2048 to +2047 bits. In this way 0 bits always corresponds to 0 volts, so the only operation usually required is a simple multiplication to scale the reading to real units; for example, on the ±5V or 0–10V range, multiply the integer data returned by DriverLINX by the actual bit weight (2.44 millivolts/bit) to obtain volts. Refer to *Appendix F: Configuration and Implementation Notes, Keithley DAS-16/1600 Series* manual that accompanies DriverLINX.

The DAS-16/16F has a 5-position DIP switch (marked A, B, C, D, USER) which is set according to the instructions given in Section 3. You can have a non-standard input scale by soldering a precision resistor into the USER location and selecting the USER position on the GAIN switch. Scale span (the difference between full-scale limits) is related to resistor value as follows:

Span (in volts) = 10 / (1 + 20,000/Ruser).

For example, Ruser = 1053 ohms gives 0.5V span.

Signals below 0.5 volt are subject to system noise and should therefore be pre-amplified using an EXP-16 (or equivalent) before applying them to DAS-16 inputs).

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The available gains, their corresponding input ranges, and throughput rates are listed in Table 2-1 for the DAS-16G1 and Table 2-2 for the DAS-16G2.

Table 2-1. DAS-16G1 Gains, Ranges, and Throughput Rates for Unipolar and Bipolar Selections

Gain	Unipolar Range	Bipolar Range	Maximum Throughput Rate
1	0.0 to +10.0V	–10.0 to +10.0V	70ksamples/s
10	0.0 to +1.0V	–1.0 to +1.0V	60ksamples/s
100	0.0 to +100mV	–100 to +100mV	50ksamples/s
500	0.0 to +20mV	–20 to +20mV	30ksamples/s

Table 2-2. DAS-16G2 Gains, Ranges, and Throughput Rates for Unipolar and Bipolar Selections

Gain	Unipolar Range	Bipolar Range	Maximum Throughput Rate
1	0.0 to +10.0V	–10 to +10V	70ksamples/s
2	0.0 to +5.0V	–5.0 to +5.0V	60ksamples/s
4	0.0 to 2.5V	–2.5 to + 2.5V	60ksamples/s
8	0.0 to 1.25V	–1.25 to +1.25V	60ksamples/s

Clock Sources

DAS-16 Series boards support the paced conversion mode. Paced mode is best-suited for continuous scanning of multiple channels at a constant rate. In paced mode, the conversion rate equals the pacer clock rate. The sample rate, which is the rate at which a single channel is sampled, is the pacer clock rate divided by the number of channels sampled.

The following clock sources are available for conversions on DAS-16 Series boards:

- **Software** — DAS-16 Series boards allow you to acquire single or multiple samples under program control.
- **Hardware (internal clock source)** — The internal pacer clock is derived from the onboard 82C54 counter/timer and a switch-configurable, crystal-controlled 1MHz or 10MHz timebase. The

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pacer clock uses two cascaded counters of the 82C54. The maximum allowable rate is 100ksamples/s, and the minimum conversions per hour is determined as follows:

$$\frac{10MHz}{2^{32}} = 2.328 \times 10^{-3} = 8.38 \qquad \frac{1MHz}{2^{32}} = 2.328 \times 10^{-4} = 0.838$$

When not used to pace the analog input, the internal clock source can pace other events, such as digital I/O and analog outputs (on the DAS-16 Series boards), through the use of interrupts.

- **Hardware (external clock source)** — The external pacer clock source must be an externally applied, TTL-compatible, rising-edge signal attached to the IP0/TRIG 0 pin (25) of the main I/O connector.

  An external clock source is useful if you want to pace at rates not available with the 82C54 counter/timer, if you want to pace at uneven intervals, or if you want to pace on the basis of an external event. An external clock also allows you to synchronize multiple boards with a common timing source.

Figure 2-4 illustrates how conversions are initiated when using an internal and an external clock source. (Note that Figure 2-4 assumes that you are not using a hardware trigger; refer to Figure 2-5 for an illustration of conversions when using a hardware trigger.)

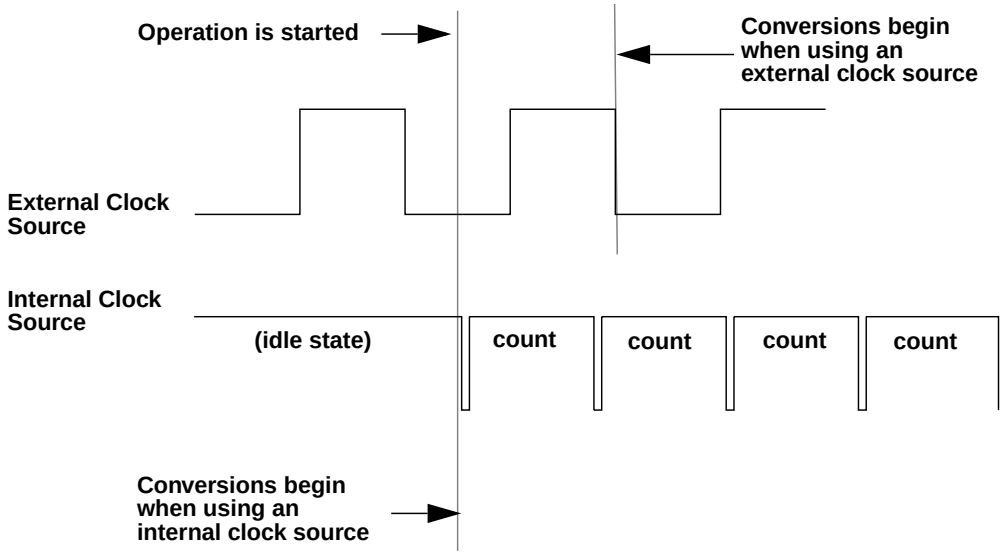


Figure 2-4. Initiating Conversions

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Note: The ADC acquires samples at a maximum of 100ksamples/s (one sample every 10.0µs). If you are using an external clock, make sure it does not initiate conversions at a faster rate than the ADC can handle.

If you are acquiring samples from multiple channels, the maximum sampling rate for each channel is equal to 100ksamples/s divided by the number of channels.

Triggers

A trigger starts an analog input operation. The polarity of external triggers in the DAS-16 Series boards is software-configurable. You can use one of the following trigger sources to start an analog input operation:

- **Internal** — When you enable the analog input operation, conversions begin immediately.
- **External Analog** — While an analog trigger is not a hardware feature of the DAS-16 Series boards, you can program an analog trigger using one of the analog input channels as the trigger channel. DriverLINX provides functions for an analog trigger; refer to the *DriverLINX Installation and Configuration Guide* and *Appendix F: Configuration and Implementation Notes—for Keithley DAS-16/1600* manuals for more information.
- **External Digital** — While a digital trigger is not a hardware feature of the DAS-16 Series boards, you can apply a digital trigger to the digital input IP1 pin (6) of the main I/O connector. Refer to the *DriverLINX Installation and Configuration Guide* and *Appendix F: Configuration and Implementation Notes—For Keithley DAS-16/1600* manuals.

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Trigger types are as follows:

– *Positive-edge trigger* — Conversions begin on the rising edge of the trigger signal.

– *Negative-edge trigger* — Conversions begin on the falling edge of the trigger signal.

– *Positive-level trigger* — Conversions begin when the signal is above a positive level. See Appendix A for logic levels.

– *Negative-level trigger* — Conversions begin when the signal is below a negative level. See Appendix A for logic levels.

Figure 2-5 illustrates how conversions are started when using a hardware trigger.

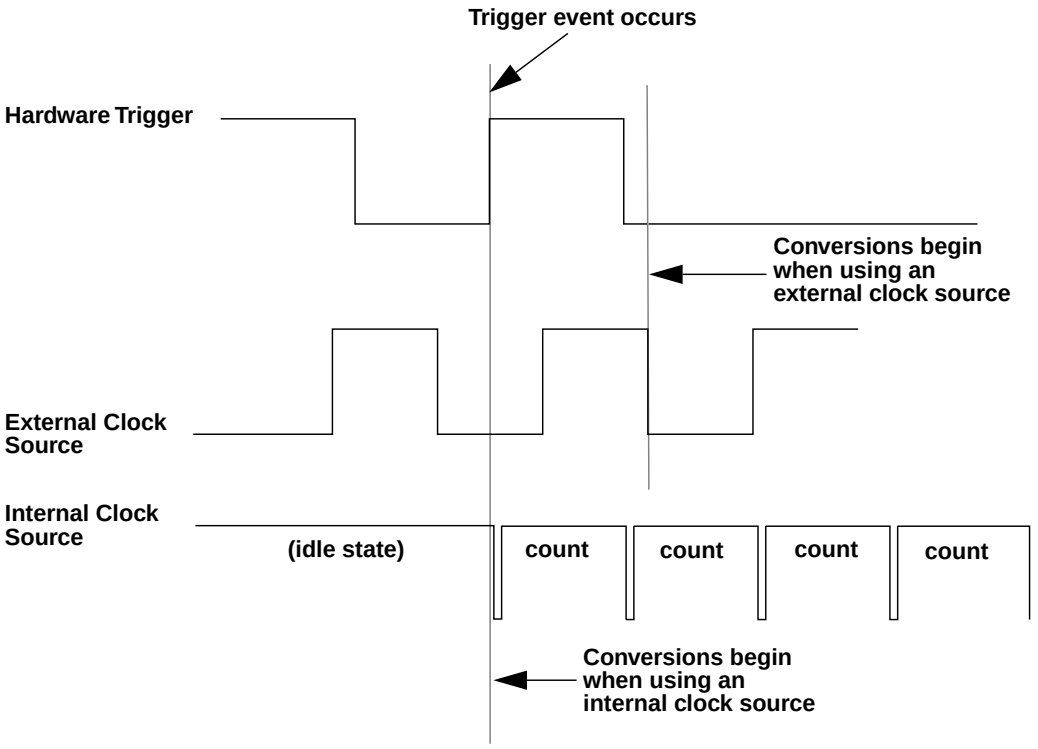


Figure 2-5. Initiating Conversions with a Hardware Trigger

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Hardware Gates

A hardware gate is an externally applied digital signal that determines whether conversions occur. You connect the gate signal to the IP0/TRIG 0 pin (pin 25) on the main I/O connector. DAS-16 Series boards support a positive gate only. Therefore, if the hardware gate is enabled and the signal to IP0/TRIG 0 is high, conversions occur; if the signal to IP0/TRIG 0 is low, conversions are inhibited.

Note: You cannot use the hardware gate with a hardware trigger. However, the gate signal itself can act as a trigger. If the gate signal is low when the software starts the analog input operation, the board waits until the gate signal goes high before conversions begin.

When using the hardware gate, the way conversions are synchronized depends on whether you are using a hardware external clock or a hardware internal clock, as follows:

- **External clock** — The signal from the external clock continues uninterrupted while the gate signal is low; therefore, conversions are synchronized to the external clock.
- **Internal clock** — The 82C54 does not count while the gate signal is low. Whenever the gate signal goes high, the 82C54 is loaded with its initial count value and starts counting; therefore, conversions are synchronized to the gate signal.

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Figure 2-6 illustrates how to use the hardware gate with both an external clock and an internal clock.

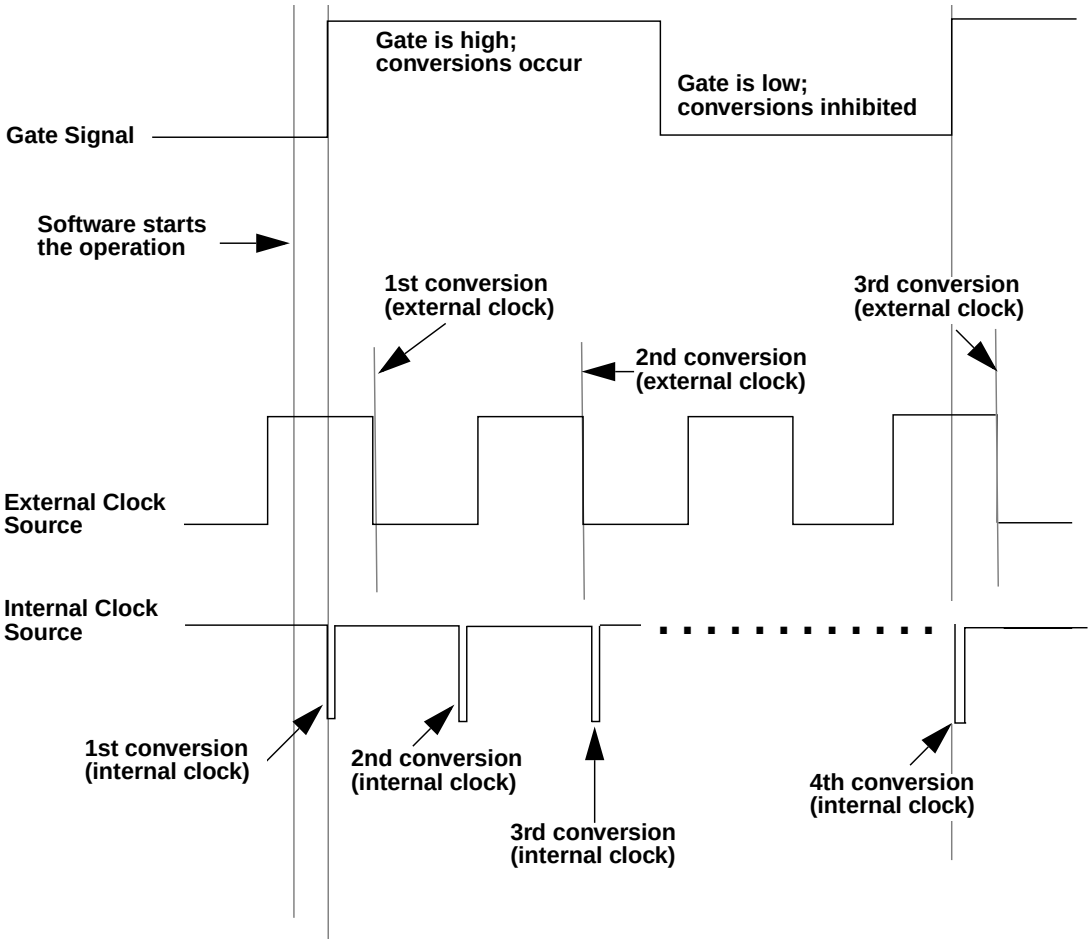


Figure 2-6. Hardware Gate

Note: Although DAS-16 Series boards do not provide a hardware-based analog trigger, you can program an analog trigger through software, using one of the analog input channels as the trigger channel. DriverLINX provides functions for both an analog trigger and a digital trigger. Refer to the DriverLINX *Appendix F: Configuration and Implementation Notes: Keithley DAS-16/1600* manual for more information.

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Data Transfer Modes

You can transfer data from the DAS-16 Series boards to the computer using the following data transfer modes:

- **Single mode** — In a single-mode operation, a data acquisition board acquires a single sample from a single channel; you cannot perform any other operation until the single-mode operation is complete.
- **Synchronous** — In a synchronous-mode operation, a data acquisition board acquires one or more samples from one or more channels; you cannot perform any other operation until the synchronous-mode operation is complete.
- **Interrupt** — You can program the board to acquire data, then generate an interrupt when data is available for transfer. When interrupt mode is used, data is transferred by an interrupt service routine; you can perform other operations while an interrupt mode operation is in progress. The interrupt level is software-configurable.

  Unpredictable interrupt latencies in the Windows environment tend to make maximum board speeds unachievable in the interrupt mode. When in the Windows environment, you are advised to use DMA mode instead of interrupt mode.
- **DMA** — DMA is a method of bypassing the CPU to transfer data directly between an I/O device and computer memory. In the IBM PC family, DMA is directed by the DMA controller and executes independently while the CPU is executing other instructions. Therefore, you can perform other operations while a DMA mode operation is in progress. The ability to run independently of the CPU and at high-transfer rates makes DMA an attractive method for transferring data in data acquisition systems.

  DAS-16 Series boards can use either DMA channel 1 or 3 to perform single-cycle DMA transfers of A/D data from the board to memory.

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Analog Output Features

The D/A channels consist of two separate double–buffered, 12–bit multiplying D/A converters. Each D/A may be used with the fixed -5V DC reference as a conventional 0 to +5V output D/A. Alternatively, the D/As may be operated with a variable, or AC, reference signal as multiplying D/As, the output is the product of reference and digital inputs. Accuracy remains at 12–bits up to 1KHz. The maximum output swing of the D/As is ±10V. A simplified diagram of each D/A channel is shown in the following diagram.

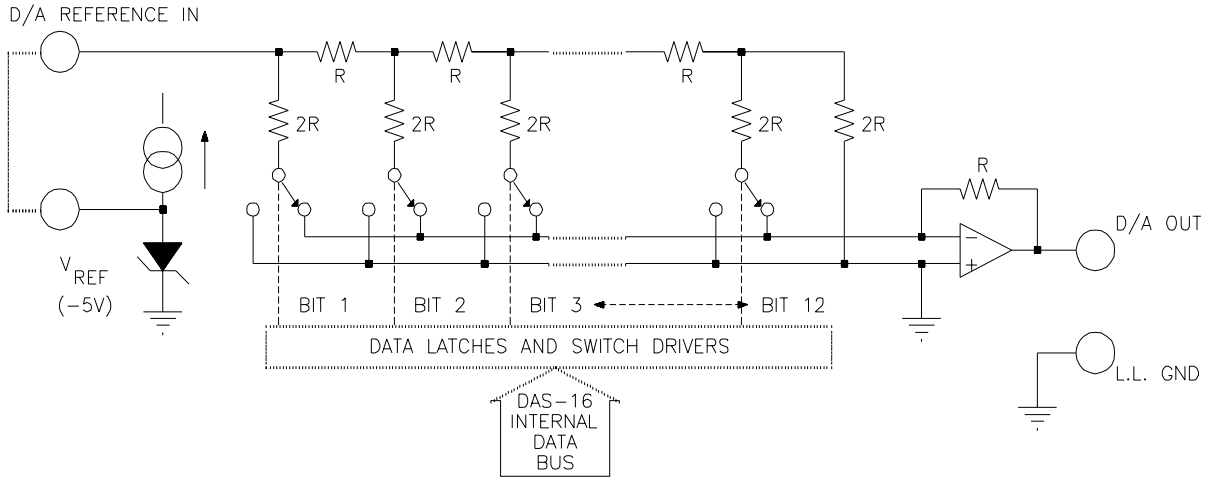


Figure 2-7. D/A Configuration and connections

Since data is 12 bits, it must be written to each D/A in two consecutive bytes. The first byte is the least significant and contains the four least significant bits of data. The second byte is the most significant and contains the most significant eight bits of data. The least significant byte should be written first and is stored in an intermediate register in the D/A, having no effect on the output. When the most significant byte is written, its data is added to the stored least significant data and presented “broadside” to the D/A converter thus assuring a single step update. This process is known as double buffering. See Appendix C.

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You can write single values to the DACs using synchronous mode or single mode. You can write multiple values to the DACs using synchronous mode.

The DAS-16 Series provides a –5V (±0.05V) precision reference voltage that is derived from the DAC reference voltage. Typical applications for precision voltages are providing a DC reference input for the DACs and providing offsets and bridge excitation to user-supplied input circuits.

Used with an AC Reference (Digital Attenuator)

Apart from its use as a standard DC output D/A, the D/As can be used with variable bipolar, AC, or DC reference signals. In this mode, they behave as a digitally programmed gain control or attenuator. The voltage output V_{out} is as follows:

$$V_{out} = -(\text{Digital input}) * V_{ref} / 4096$$

Two additional parameters are of interest in AC operation. The first is feedthrough, the amount of residual signal at digital zero. The second parameter is the accuracy/frequency characteristic—it is a limit at a lower frequency. Feedthrough which is mainly a function of stray capacitance, rises with frequency; at 10KHz, it is typically 5mV peak–peak with a ±5V reference. Due to distributed capacitance in the R–2R ladder network of the D/A, the full 12 bit performance falls off as the frequency rises. Above about 1KHz the dynamic performance of the D/A will have less than 12-bit accuracy.

The D/As will perform well in synchro-digital and resolver applications for sine/cosine generation with 400 Hz reference.

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Arbitrary Waveform Output

One common requirement is to output a waveform from a D/A converter. At slow speeds this can be done with a timing loop in your program, but it is usually difficult to control the timing with any degree of precision especially when operating at more than a few points per second.

The lower the frequency the more steps or points we can put in the waveform. Using a clock frequency of 10MHz, we can set Counters 1 and 2 to output a frequency of 3000.3Hz with a division C ratio of 3333. In turn with 50 points per cycle, this would give us an output of 60.006Hz, fairly close to the desired 60Hz.

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Digital I/O Features

DAS-16 Series boards contain four digital inputs (IP0 to IP3) and four digital outputs (OP0 to OP3) that are accessible through the main I/O connector.

Logic 1 on an I/O line indicates that the input/output is high; logic 0 on an I/O line indicates that the input/output is low (see Appendix A for logic levels). The digital inputs are compatible with TTL-level signals. These inputs are provided with 10kΩ pull-up resistors to +5V; therefore, the inputs appear high (logic 1) with no signal connected.

You can use the digital inputs and outputs for any general-purpose tasks except the following:

- If you are using an external digital trigger or gate, you must use digital input line IP0/TRIG 0 to attach the trigger and digital input line IP2/CTR 0 GATE to attach the counter 0 gate signal. In either of these cases, you cannot use the corresponding bit for general-purpose digital input.
- If you are using an external pacer clock, you must use digital input line IP0/TRIG 0 to attach the external pacer clock signal; in this case, you cannot use IP0/TRIG 0 for general-purpose digital input.

When the analog inputs are disabled, you can pace the digital I/O with interrupts generated by the onboard pacer clock.

You can read or write a single value from or to a DAS-16 Series board using synchronous mode or single mode. You can read or write multiple values from or to a DAS-16 Series board using synchronous mode or interrupt mode.

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Counter/Timer Features

The Intel 82C54 programmable interval timer is used in the DAS–16. This is a flexible but complex device consisting of three independent 16–bit pre-settable down counters. Each counter can be programmed to divide by any integer in the range 2 – 65,536. In the DAS-16, Counters 1 and 2 are cascaded with the input of Counter 1 connected to a precision 1 or 10MHz crystal oscillator. The output of Counter 1 is connected to the input of Counter 2, and Counter 2 output may be selected internally as well as being available to the user at the COUNTER 2 OUT (Pin 20). The other counter, Counter 0, is uncommitted and its input, output, and gate control are available to the user on COUNTER 0 IN (Pin 21), COUNTER 0 OUT (Pin 2), and IP2 (Pin 24). A block diagram of the DAS-16 counter arrangement is shown in Figure 2-8.

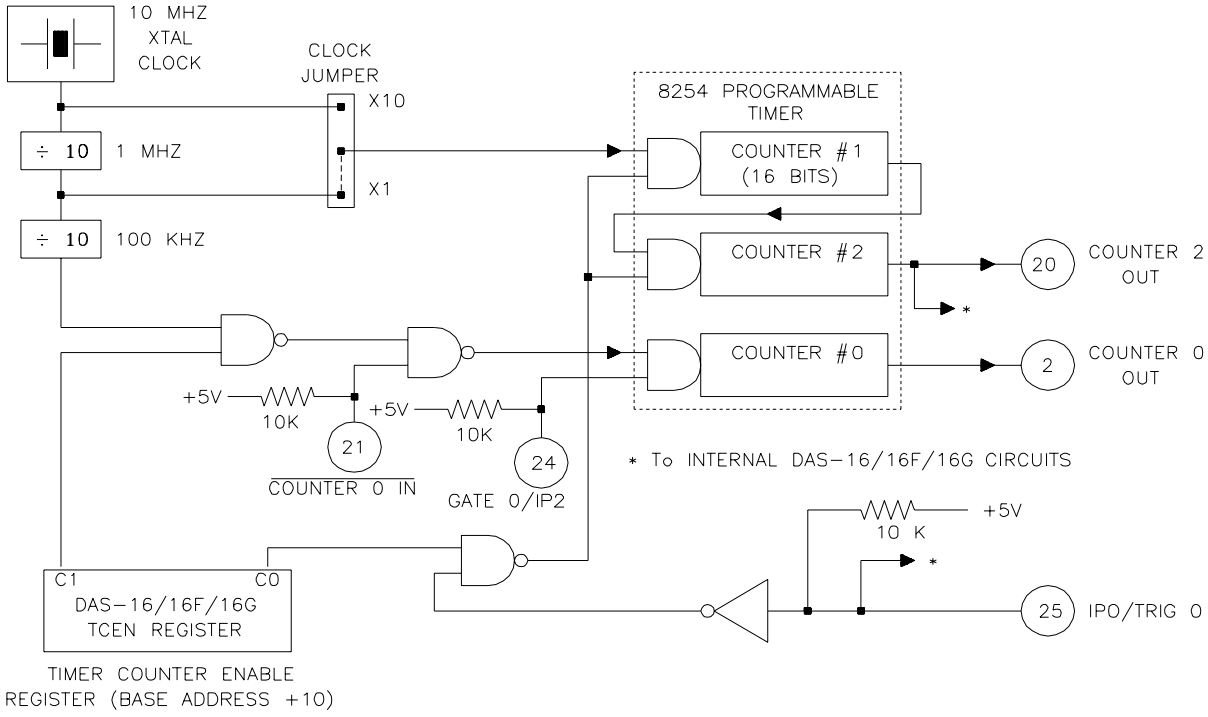


Figure 2-8. Programmable Timer Configuration

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Programmable timer configuration principal uses of the 82C54 are as follows:

1. A programmable timer for generating interrupts and triggering periodic A/D conversions.
2. A variable-frequency square wave generator for testing and for frequency synthesis.
3. An event counter for external pulse inputs.
4. A time–delay generator.

Each counter has a clock input, a gate input that controls counting and triggering, and an output. The maximum clock input frequency on any counter is 10MHz with minimum clock duty cycles of 30ns high and 50ns low (note that this specification applies only to the -2 version of the 82C54). On later models of the DAS-16, it is also possible to drive Counters 1 and 2 from a 10MHz clock. This selection is made via a jumper block on the board marked TIMER, the 1 position corresponding to a 1MHz clock and the 10 position to 10MHz. The usual function of these two counters is to provide programmable pulse rates to trigger the A/D. Counter 0 is uncommitted and can be used as a secondary pulse-rate generator, a square-wave generator, a programmable monostable delay or an event counter. Counters 1 and 2 are initialized by the DAS-16 driver to operate in the Rate Generator Configuration (#2) and output 1KHz (10KHz with 10MHz clock) after running initializing MODE 0; but there are actually six possible operating configurations for each counter, as described in the next section.

You can program the 82C54 counter/timer circuitry to operate in one of the following counter/timer modes:

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Pulse on terminal count (Mode 0) — This mode is useful for event counting or for programming a time delay. The software forces the output low. On the next clock pulse after the software writes the initial count value, the counter is loaded. When the counter reaches zero, the output goes high and remains high until the software writes a new count value. Note that the output does not go high until $n + 1$ clock pulses after the initial count is written, where n indicates the loaded count.

A high gate input enables counting; a low gate input disables counting. The gate input has no effect on the output. Note that an initial count value written while the gate input is low is still loaded on the next clock pulse.

Figure 2-9 illustrates pulse on terminal count mode.

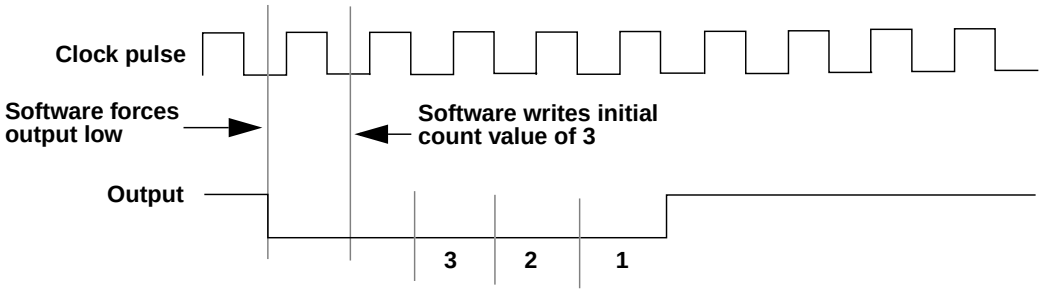


Figure 2-9. Pulse on Terminal Count Mode

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- **Programmable one-shot (Mode 1)** — This mode is useful for providing a hardware-triggered delay or one-shot pulse. The output is initially high. A trigger loads the initial count value into the counter. At the next clock pulse after the trigger, the output goes low and remains low until the counter reaches zero. (The one-shot pulse is *n* clock cycles in duration, where *n* indicates the loaded count.) After the counter reaches zero, the output goes high and remains high until the clock pulse after the next trigger; this makes the one-shot pulse retriggerable.

  You do not have to reload the count into the counter. The gate input has no effect on the output. Writing a new count to the counter during a one-shot pulse does not affect the current one-shot pulse.

  Figure 2-10 illustrates programmable one-shot mode.

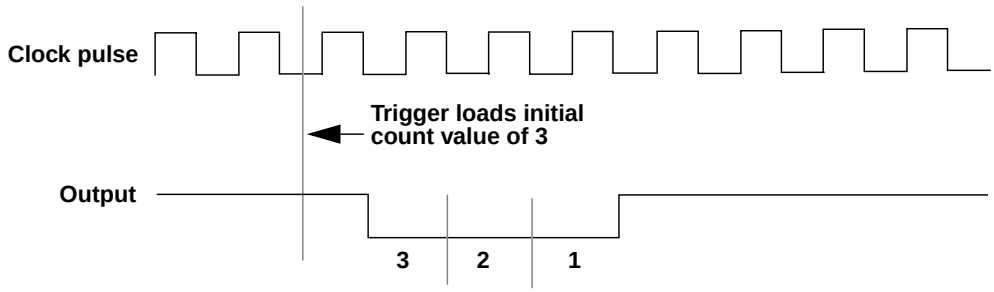


Figure 2-10. Programmable One-Shot Mode

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- **Rate generator (Mode 2)** — This mode is useful for generating a real-time clock interrupt. The output is initially high. A trigger loads the initial count value into the counter. At the next clock pulse after the trigger, the counter starts counting down. When the counter reaches one, the output goes low for one clock pulse and then goes high again. The counter is then reloaded with the initial count value and the process repeats.

  A high gate input enables counting; a low gate input disables counting. If the gate goes low during an output pulse, the output is set high immediately; this allows you to use the gate input to synchronize the counter.

  Writing a new count to the counter while counting does not affect the current counting sequence. In this mode, a count of 1 is illegal.

  Figure 2-11 illustrates rate generator mode.

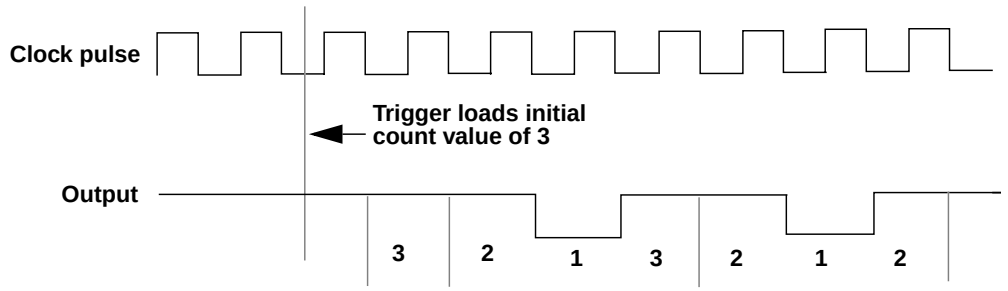


Figure 2-11. Rate Generator Mode

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- **Square-wave generator (Mode 3)** — This mode is useful for square-wave generation. The output is initially high. A trigger loads the initial count value into the counter. At the next clock pulse after the trigger, the counter starts counting down. When half the initial count has elapsed, the output goes low for the remainder of the count. When the total count elapses, the counter is reloaded with the initial count value, the output goes high again, and the process repeats. If the initial count is odd, the output is high for $(n + 1) / 2$ counts and low for $(n - 1) / 2$ counts, where n indicates the loaded count.

  A high gate input enables counting; a low gate input disables counting. If the gate goes low while the output is low, the output is set high immediately; this allows you to use the gate input to synchronize the counter.

  Figure 2-12 illustrates square-wave generator mode.

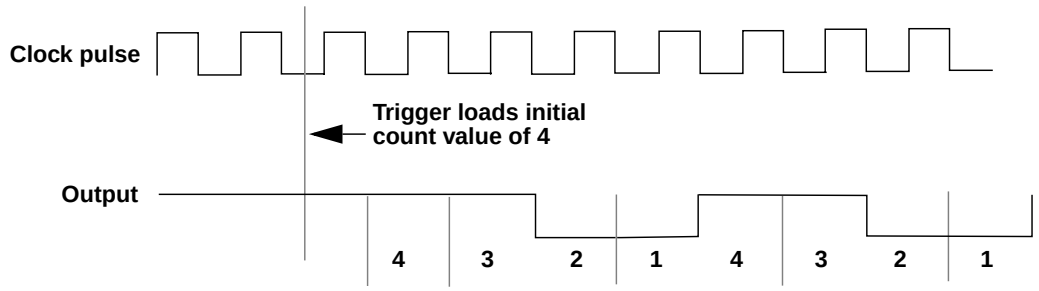


Figure 2-12. Square-Wave Generator Mode

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- **Software-triggered strobe (Mode 4)** — The output is initially high. Writing the initial count through software loads the initial count value into the counter at the next clock pulse, but the counter does not start counting. At the next clock pulse, the counter starts counting down. When the counter reaches zero, the output goes low for one clock pulse and then goes high again. Note that the output does not go low until $n + 1$ clock pulses after the initial count is written, where n indicates the loaded count.

  A high gate input enables counting; a low gate input disables counting. The gate input has no effect on the output.

  Figure 2-13 illustrates software-triggered strobe mode.

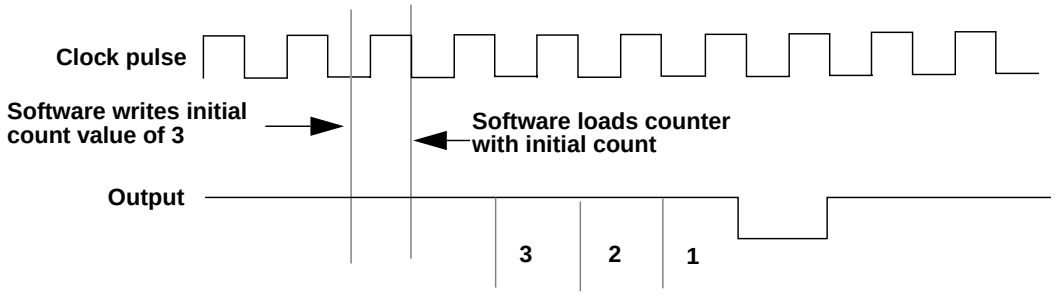


Figure 2-13. Software-Triggered Strobe Mode

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- **Hardware-triggered strobe (Mode 5)** — The output is initially high. A rising edge of the gate input acts as a trigger. The counter is loaded with the initial count value on the next clock pulse after the trigger, but the counter does not start counting. At the next clock pulse, the counter starts counting down. When the counter reaches zero, the output goes low for one clock pulse and then goes high again. Note that the output does not go low until $n + 1$ clock pulses after the trigger event occurs, where n indicates the loaded count.

  After the trigger event occurs, the gate input has no effect on the output. Writing a new value during counting does not affect the counting sequence.

  Figure 2-14 illustrates hardware-triggered strobe mode.

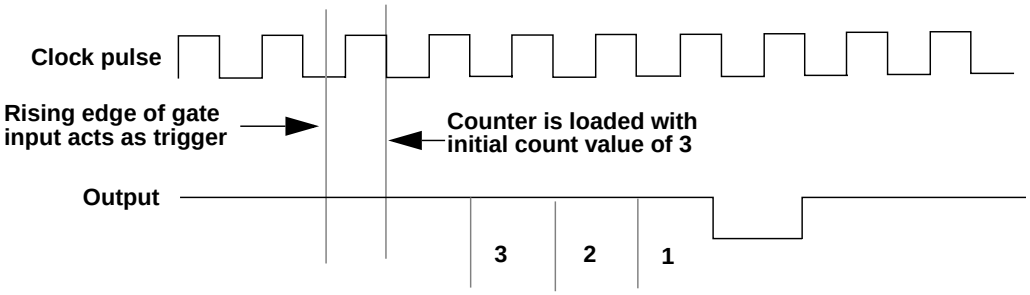


Figure 2-14. Hardware-Triggered Strobe Mode

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Using the Timer-Counter Enable with the Counter

The Timer Counter Enable register is a 2-bit Write Only register located at BASE ADDRESS +Fh. The register is described in more detail in Appendix C. If the least significant bit, C0, is high, it allows IP0/TRIG0 to control the gates of Counters 2 and 3. This provides a means of holding off trigger pulses to the A/D from the programmable timer until IP0 is taken high. If C0 is low, then IP0 has no control over the programmable interval timer.

The second bit, C1, controls the source of the clock input for Counter 0. If C1 = 0, then the external clock input, COUNTER 0 IN, is enabled. If C1 = 1 then Counter 0 is connected to a stable 100KHz internal crystal clock source. This is useful if Counter 0 is used for pulse width measurement, delay generation, frequency synthesis, or a secondary timer.

Generating Square Waves of Programmed Frequency

Both the Counter 1 and 2 combination and Counter 0 may be used to generate square waves of programmable frequency. With the C1 bit of the Timer Counter Enable register set high and Counter 0 clock input open or high, Counter 0 is internally connected to a 100KHz crystal signal source. Counter 0 can be operated in Mode 3 (square wave generator) with a maximum divisor of 65,536. The lowest output frequency obtainable from Counter 0 directly will be about 1.5Hz (100000 / 65535). The minimum divisor can be as low as 2 to obtain a maximum output frequency of 50KHz.

Use DriverLINX to select the square wave configuration. Counters 1 and 2 provide considerable flexibility in frequency range, a minimum division ratio of 4 (2 x 2) with a 10Mhz clock providing a 2.5MHz output at one extreme, and a division ratio of 232 (65,535 x 65,535) with a 1MHz clock providing an output of about 1 pulse/hour at the other extreme.

In practice, to obtain a symmetrical square wave, the divisor loaded into the counter should be an even number. If it is an odd number, one half of the square wave will be 1 input clock pulse period longer than the other half.

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Calculating the divisor is straightforward. Assume you desire an output frequency of 1KHz. The input frequency to the Counter 0 is 100Khz so you must divide this by 100 to obtain 1Khz.

Measuring Frequency and Period

It is possible to use the 82C54 to measure frequency by raising the gate input of Counter 0 for some known interval of time, say 10, 100, or 1000ms and counting the number of pulses clocked into the counter for that interval. The gating signal can be derived from Counters 1 and 2 operating in square–wave mode. Also, the computer has to be informed about the start and finish of the measurement cycle, so one of the DAS-16 digital inputs can be used to monitor the gate input to achieve this requirement.

Counter 0 can also be used to measure pulse width or half period of a periodic signal. The signal should be applied to the gate input of Counter 0 and a known frequency applied to Counter 0 clock input (100KHz) from the internal crystal. During the interval when the gate input is low, Counter 0 is loaded with a full count, 65,536. The gate input then goes high at the beginning of the measurement, and the counter decrements until the gate input goes low at the end of the pulse. The counter is then read and the change in the count is the duration of the gate input signal. If Counter 0 is fed with 10 microsecond duration clock pulses (100KHz), the maximum pulse duration that can be measured is 65,535*10 = 655 milliseconds. Longer pulse durations can be measured using Counters 1 and 2 as an input clock source for Counter 0. One of the digital inputs should also be connected to the gate of Counter 0 to synchronize the loading and reading operations.

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Frequency Measurement

Without external hardware, support of frequency measurement using the DAS-16 hardware configuration is limited. Frequency measurement requires an external connection between two counters.

Frequency measurement requires two counter/timers used as measurement and gating counters. The unknown frequency is input as the clock source to the measurement counter. The gate input of the measurement counter is then activated for a known interval as timed by the gating counter. The gating counter is clocked from a known internal crystal reference clock.

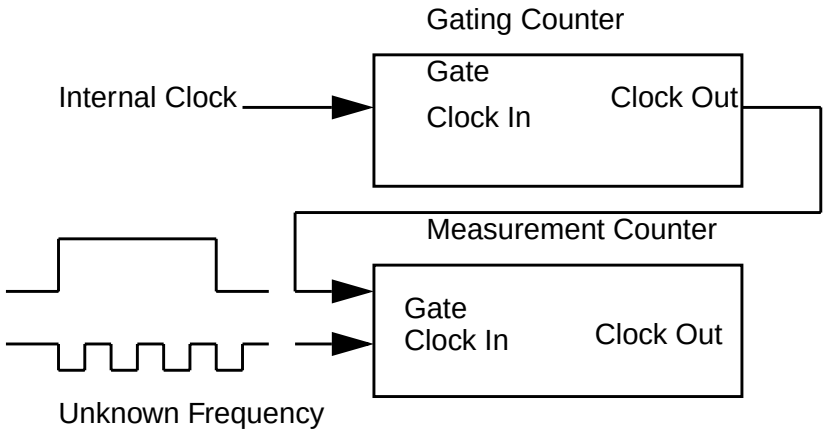


Figure 2-15. Counter Setup for Frequency Measurement

The unknown input frequency is then calculated as

$$\text{Frequency} = \frac{\text{Measured count}}{\text{Gate time}}$$

The accuracy of the measurement is a function of the unknown input frequency and the gate time. As the input frequency decreases, the gate time must increase to preserve accuracy. It is the responsibility of the application program to chose the gate time. To measure a 0.1Hz signal, the gate time should be approximately three minutes.

In DriverLINX for the DAS-16, logical counter 0 is the measurement counter and logical counter 1 is the gating counter. Therefore, the operation is only defined for logical counter 1 which uses the 1/10 MHz internal clock. The output of logical counter 1 (**Counter 2 Out** [pin 20]) must be externally connected to the gate input of logical counter 0 (**Gate**

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0/IP2 [pin 24]). The frequency to be measured is fed to the clock input of logical counter 0 (**Counter 0 In** [pin 21], active low). Remember the signal must be TTL (0 to 5 volts). Do not exceed this voltage range as damage to the counter could result.

Clock pulses are defined as a falling edge followed by a rising edge. This is a function of the Intel 82C54 hardware and cannot be changed without external hardware.

Refer to 82C54 documentation for information on programming the 82C54 counter/timer circuitry for general-purpose tasks. Table 2-1 lists several companies that provide documentation for the 82C54.

Table 2-1. Sources for 82C54 Documentation

Company	Address and Telephone Number
Intel Corporation	Literature Sales P.O. Box 7641 Mt. Prospect, IL 60056-7641 (800) 468-3548
Harris Semiconductor	Literature Department P.O. Box 883, MS CB1-28 Melbourne, FL 32901 (407) 724-3739
Newbridge Microsystems	603 March Road Kanata, Ontario Canada K2K 1X3 (613) 592-0714 (800) 267-7231

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Triggering the A/D Periodically

When you are using the A/D converter, one of the key uses for the 82C54 programmable interval timer is in providing trigger pulses for starting the A/D to perform periodic samples.

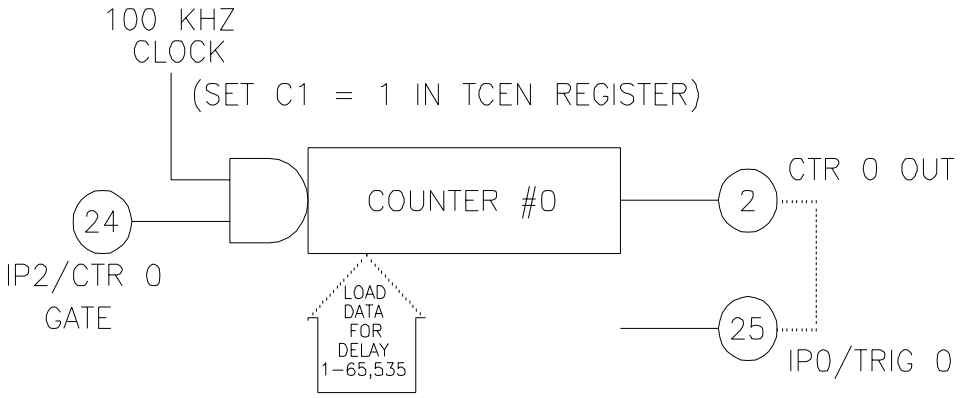


Figure 2-16. Using Counter 0 to Generate a Delayed Start

You can set up any given output frequency to load Counters 1 and 2 with the required divisors. As an example, let us set up a trigger rate of 8.3KHz. First, work out the overall division ratio from 1MHz or 10MHz (depending on setting of TIMER jumper block):

1,000,000 / 8300 = 120.48 (for 1MHz clock)

The closest frequency obtainable will be:

1,000,000 / 120 = 8.333 KHz

Next, apportion the divisor between the 2 counters:

If we had used the 10MHz clock source we could get closer to the desired frequency of 8.300KHz with the limitation of integer division ratios of the counters:

10,000,000 / 8300 = 1204.8 (for 10MHz clock)

The closest frequency obtainable will be:

10,000,000 / 1205 = 8.299KHz

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Note that a counter cannot divide by one; the minimum divisor is two, and the maximum 65,536. Initialize Counters 1 and 2 to the Rate Generator configuration with a division ratio of 1,000. You can change the frequency (division ration) while not altering the counter configuration.

Generating Interrupts with the Counter/Timer

DAS-16 architecture does not allow direct generation of an interrupt from the Counter/Timer. However, it is easy to set up the A/D to be triggered by the Counter/Timer and in turn have the A/D generate an interrupt at the end of its conversion cycle (a constant delay of 8-12 microseconds). This setup is performed through the DAS-16 control register. Indirectly, this accomplishes the desired result of generating a periodic interrupt from the timer, and you can then install any desired interrupt routine to service the interrupt.

Note also that it is possible to trigger the A/D any other way (externally or by a programmed write to an I/O port) and invoke an interrupt at the end of A/D conversion in the same way.

An interrupt request level in the range 2–7 must be selected in the DriverLINX software. Interrupt lines can be shared so long as two devices sharing an interrupt will not be used concurrently.

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Wait State Selection

Although most current-generation PCs and compatibles extend bus cycles during 8-bit data transfers, the DAS-16 Series provides a jumper-configurable option that allows you to enable or disable wait states that extend bus cycles during 8-bit data transfers.

Inclusion of this option maintains backward compatibility with boards that may be used in early generation machines.

Power

+5V power is available from the main I/O connector. The +5V supply is brought out from your host computer.

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3

Setup and Installation

Read this section and all related DriverLINX documentation before you attempt to install and use your DAS-16 Series board.

Unwrapping and Inspecting Your Board

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

1. Your board is packaged at the factory in an anti-static wrapper that must not be removed until you have discharged any static electricity by either of the following methods:
   - If you are equipped with a grounded wrist strap, you discharge static electricity as soon as you hold the wrapped board.
   - If you are not equipped with a grounded wrist strap, discharge static electricity by holding the wrapped board in one hand while placing your other hand firmly on a metal portion of the computer chassis (your computer must be turned off but grounded).
2. Carefully unwrap your board from its anti-static wrapping material. (You may store the wrapping material for future use.)
3. Inspect the board for signs of damage. If damage is apparent, arrange to return the board to the factory (see Section 7).
4. Check the remaining contents of your package against the packing list to be sure your order is complete. Immediately report any missing items.
5. When you are satisfied with the inspection, proceed with the software and hardware setup instructions.

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Note: DAS-16 Series boards are factory calibrated; they require no further adjustment prior to installation. If at a later time you decide to recalibrate the board, refer to Section 6 for instructions.

Standard Software for DAS-16 Series 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, as a precaution after any crash, run the utility that checks the directory structures.

This section describes how to install the DAS-16 Series standard software package. The contents of these software packages are described as follows:

- **DAS-16 Series standard software package** — Shipped with DAS-16 Series boards. Includes DriverLINX for Microsoft Windows and function libraries for writing application programs under Windows in a high-level language such as C/C++, Turbo Pascal, and Visual Basic; Delphi, Test Point, LabVIEW support files; utility programs; and language-specific example programs.
- **DriverLINX** — The high-performance real-time data-acquisition device drivers for Windows application development includes:
  - *DriverLINX API DLLs* and drivers supporting the DAS-16 Series hardware.
  - *Analog I/O Panel* — A DriverLINX program that verifies the installation and configuration of DriverLINX to your DAS-16 Series 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.

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  - *DriverLINX Application Programming Interface files* — for the DAS-16 Series 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 DAS-16 Series hardware.

- **DAS-16 Series utilities** — The following utilities are provided as part of both the DAS-16 Series standard software package:
  - DriverLINX Calibration Utility
  - DriverLINX Test Utility
- LV-16 — LabVIEW driver for the DAS-16 Series boards.

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Installing the Software

Note: Install the DriverLINX software before installing the DAS-16 Series board. Otherwise, the device drivers will be more difficult to install.

Software Options

Users of DAS-16 Series boards have the following two software options. In both cases, the software interfaces with your system via the DriverLINX software provided with your board.

- The user can run a fully integrated data-acquisition software package such as TestPoint or LabVIEW.
- The user can write and run a custom program in Visual C/C++, Visual Basic, or Delphi, using the programming support provided in the DriverLINX software.

The DAS-16 Series has fully functional driver support for use under Windows 95/98/NT.

DriverLINX driver software for Windows 95/98/NT

DriverLINX software, supplied by Keithley with the DAS-16 Series board, provides convenient interfaces to configure analog and digital I/O modes without register-level programming.

Most importantly, however, DriverLINX supports those programmers who wish to create custom applications using Visual C/C++, Visual Basic, or Delphi. DriverLINX accomplishes foreground and background tasks to perform data acquisition. The software includes memory and data buffer management, event triggering, extensive error checking, and context sensitive on-line help.

DriverLINX provides application developers a standardized interface to over 100 services for creating foreground and background tasks for the following:

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- Analog input and output
- Digital input and output
- Time and frequency measurement
- Event counting
- Pulse output
- Period measurement

In addition to basic I/O support, DriverLINX also provides:

- Built-in capabilities to handle memory and data buffer management.
- A selection of starting and stopping trigger events.
- Extensive error checking.
- Context-sensitive on-line help system.

DriverLINX is essentially hardware independent, because its portable APIs (Application Programming Interfaces) work across various operating systems. This capability eliminates unnecessary programming when changing operating system platforms.

TestPoint

TestPoint is a fully featured, integrated application package that incorporates many commonly used math, analysis, report generation, and graphics functions. The TestPoint graphical drag-and-drop interface can be used to create data acquisition applications, without programming, for IEEE-488 instruments, data acquisition boards, and RS232-485 instruments and devices.

TestPoint includes features for controlling external devices, responding to events, processing data, creating report files, and exchanging information with other Windows programs. It provides libraries for controlling most popular GPIB instruments. OCX controls plug directly into TestPoint, allowing additional features from third party suppliers.

TestPoint interfaces with your DAS-16 Series board through DriverLINX, using a driver that is provided by the manufacturer.

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LabVIEW

LabVIEW is a fully featured graphical programming language used to create virtual instrumentation. It consists of an interactive user interface, complete with knobs, slide switches, graphs, strip charts, and other instrument panel controls. Its data-driven environment uses function blocks that are virtually wired together and pass data to each other. The function blocks, which are selected from palette menus, range from arithmetic functions to advanced acquisition, control, and analysis routines. Also included are debugging tools, help windows, execution highlighting, single stepping, probes, and breakpoints to trace and monitor the data flow execution. LabVIEW can be used to create professional applications with minimal programming.

A Keithley VI palette provides standard virtual instruments (VIs) for LabVIEW that interface with your DAS-16 Series board through DriverLINX. The needed driver is provided on your DriverLINX CD-ROM.

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Installing DriverLINX

Refer to the instructions on the *Read this first* sheet and the manuals on the DriverLINX CD-ROM, both shipped with your board, for information on installing and using DriverLINX.

Installing Application Software and Drivers

Installing the TestPoint software and driver

The DriverLINX driver for TestPoint is provided as part of the TestPoint software. The driver therefore installs automatically when you install TestPoint.

You can install TestPoint application software at any time before or after installing DriverLINX and the DAS-16 Series board. For TestPoint installation instructions, consult the manual provided with TestPoint.

Note: Before using TestPoint with the DAS-16 version of DriverLINX, check with Keithley to ensure that your version of TestPoint is compatible with DriverLINX.

Installing the LabVIEW software and driver

A DriverLINX driver for LabVIEW is provided on your DriverLINX CD-ROM. The LabVIEW driver does not install automatically when you install DriverLINX and your board. You must first install the LabVIEW application program, then install the DriverLINX driver. Access the LabVIEW driver installation routine by starting setup.exe on the DriverLINX CD-ROM, then selecting LabVIEW Support from the Install These DriverLINX components screen.

Consult the manual provided by National Instruments for LabVIEW installation instructions.

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Setting Switch-Configurable Options

This section contains information and illustrations that you can use to verify default switch configurations and reconfigure switch-configurable options. Sections 1 and 2 contain information about product features that help you determine the board configuration that best suits the needs of your application.

Be sure to make note of the configuration of all switches and jumpers on the board. You will use this information to enter the correct configuration parameters using DriverLINX. Also locate any information or notes about the interrupt and DMA channels used by the other hardware devices in your computer system.

Figure 3-1 shows the switches for DAS-16/16F Series boards; Figure 3-2 shows the switches for the DAS-16G1/G2 Series boards. The remaining subsections describe the switches and how to configure them.

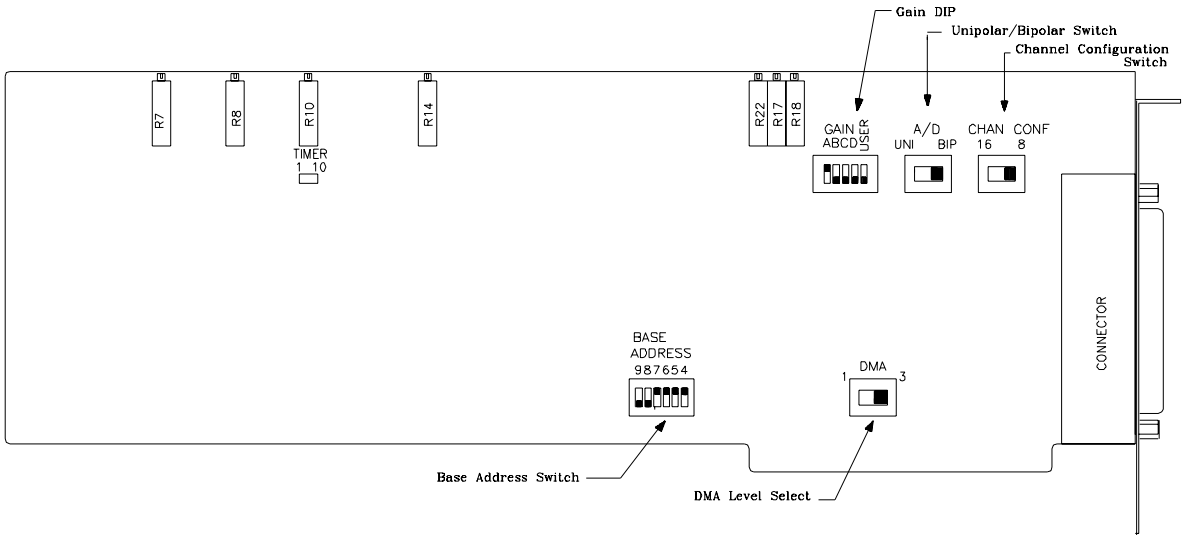


Figure 3-1. Default Switch Configuration for DAS-16/16F Series Boards

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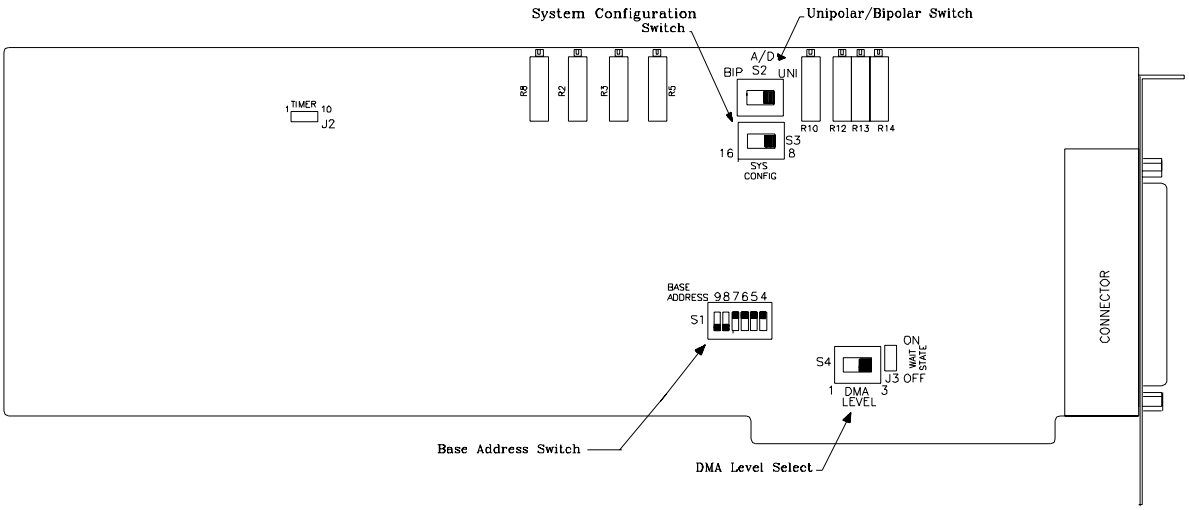


Figure 3-2. Default Switch Configuration for DAS-16G1/G2 Series Boards

Table 3-1. Default Switch Settings

Switch/Jumper	Default
Base Address	300H
DMA Channel	3
A/D Mode	16-Channel Single-Ended
A/D Input Range	±10V
A/D Coding	Straight Binary
Timer Source Clock	1MHz

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DAS-16 must be configured for operation via several on-board switches, as follows:

Wait State
Base Address
Channel/System Configuration
Unipolar/Bipolar Modes
DMA Level Select
Gain (DAS-16/16F only)

Except for Base Address, none of these functions requires immediate attention.

Base Address Switch

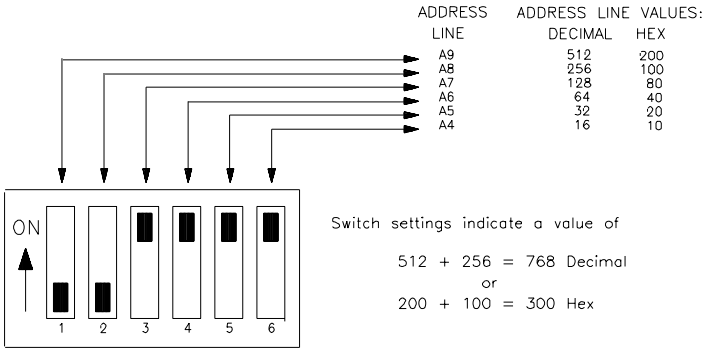


Figure 3-3. Base Address Switch

The DAS-16 is factory-configured for a Base Address of 300 Hex (768 decimal). If this Base Address is already occupied, you will need to change the Base Address switch setting. (Figure 3-3 shows the Base Address Switch.) It is essential that each peripheral device, such as a DAS-16, be assigned a unique Base Address within the range of 200 to 3F0 (512 to 1008 Decimal) and that the address is on a 16-byte boundary. Use Table 3-2 as an aid to selecting an unoccupied Base Address.

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Table 3-2 lists I/O addresses commonly used by IBM PC/XT, AT, and compatible computers. Determine an even boundary of eight I/O addresses within the range of 000H to 3F8H that are not being used by another resource in your system (including another DAS-16 Series board), and set the switches to the appropriate base address.

Table 3-2. I/O Address Map (000H to 3FFH)

Address Range	Use
000H to 00FH	8237 DMA #1
020H to 021H	8259 PIC #1
040H to 043H	8253 timer
060H to 063H	8255 PPI (XT)
060H to 064H	8742 controller (AT)
060H to 06FH	8042 Keyboard controller
070H to 071H	CMOS RAM and NMI mask register (AT)
080H to 08FH	DMA page registers
0A0H to 0A1H	8259 PIC #2 (AT)
0A0H to 0AFH	NMI mask register (XT)
0C0H to 0DFH	8237 DMA #2 (AT - word-mapped)
0F0H to 0FFH	80287 numeric processor (AT)
170H to 177H	Hard disk controller #1
1F0H to 1F8H	Hard disk controller #2
1F0H to 1FFH	Hard disk controller (AT)
200H to 2FFH	Game / control
210H to 21FH	Expansion unit (XT)
238H to 23BH	Bus mouse
23CH to 23FH	Alternate bus mouse
278H to 27FH	Parallel printer
2B0H to 2DFH	EGA
2E0H to 2EFH	GPIB (AT)
2E8H to 2EFH	Serial port

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Table 3-2. I/O Address Map (000H to 3FFH) (cont.)

Address Range	Use
2F8H to 2FFH	Serial port
300H to 31FH	Prototype card
320H to 32FH	Hard disk (XT)
370H to 377H	Floppy disk controller #2
378H to 37FH	Parallel printer
380H to 38FH	SDLC
3A0H to 3AFH	SDLC
3B0H to 3BBH	MDA
3BCH to 3BFH	Parallel printer
3C0H to 3CFH	VGA EGA
3D0H to 3DFH	CGA
3E8H to 3EFH	Serial port
3F0H to 3F7H	Floppy disk controller #1
3F8H to 3FFH	Serial port

Channel (System) Configuration Switch

This slide switch is used to select whether 8 differential or 16 single-ended analog input channels are to be used. On the DAS-16/16F, this switch is marked CHAN CONF. On the DAS-16G, it is marked SYS CONFIG. On either switch, to select eight differential input channels, move the switch to the right (towards the 8 designator). Likewise, to select 16 single-ended analog input channels, move the switch to the left (towards the 16 designator).

DMA Level Switch

This slide switch selects the DMA level. This two-position slide switch selects the DMA as 1 or 3. Some early PC's utilize Channel 3 for their hard drives. If this is the case, you cannot choose DMA Channel 3 for your DAS-16. More information regarding DMA is provided in Appendix D.

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A/D Switch

This slide switch controls the input range. When moved to the UNI (unipolar) position, inputs can be positive only (ranges are from zero to some positive full-scale voltage). When moved to the BIP (bipolar) position, inputs can range from equal negative to positive full scale limits.

GAIN Switch (DAS-16/16F Only)

This switch is a 5-position DIP switch and is found only on the DAS-16/16F boards. The five positions on the switch are marked A, B, C, D, and USER. These are used to set the range as shown in Table 3-3.

Table 3-3. DAS-16/16F Gain Switch Positions

A	B	C	D	USER	UNIPOLAR	BIPOLAR
OFF	OFF	OFF	OFF	OFF	N/A	± 10V
ON	OFF	OFF	OFF	OFF	0-10V	± 5V
ON	ON	OFF	OFF	OFF	0-5V	± 2.5V
ON	OFF	ON	OFF	OFF	0-2V	± 1V
ON	OFF	OFF	ON	OFF	0-1V	± 0.5V
ON	OFF	OFF	OFF	ON	User Set	User Set

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Jumpers

The DAS-16/16F has only one jumper block: the TIMER jumper block. The DAS-16G has two jumper blocks: the TIMER and WAIT STATE jumper blocks.

The TIMER Jumper

This jumper selects a timer input frequency of 10MHz or 1MHz. For most applications, 10MHz is more useful and will give a finer time interval resolution at higher conversion rates.

The WAIT STATE Jumper

This jumper, when set to ON, will cause the DAS-16G to generate a 450ns wait state on I/O accesses. This jumper will only need to be set to ON, if you have built your own computer and know that the I/O read and write pulses will be less than 210ns duration.

Generally, this jumper should be in the OFF position. Most computer manufacturers include internal wait states on all I/O accesses to maintain compatibility with other standard peripherals.

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Main I/O Connector

Analog and Digital I/O occurs through a 37-pin, D-type connector that projects through the computer case at the rear of the board. The mating connector for DAS-16 is a standard, 37-pin D-type female such as an ITT/Cannon #DC-37S for soldered connections. Insulation displacement (flat cable) types are readily available (for example, Amp #745242-1). Other manufacturers make equivalent parts. This connector and its signal conductor functions are described in Figure 3-4.

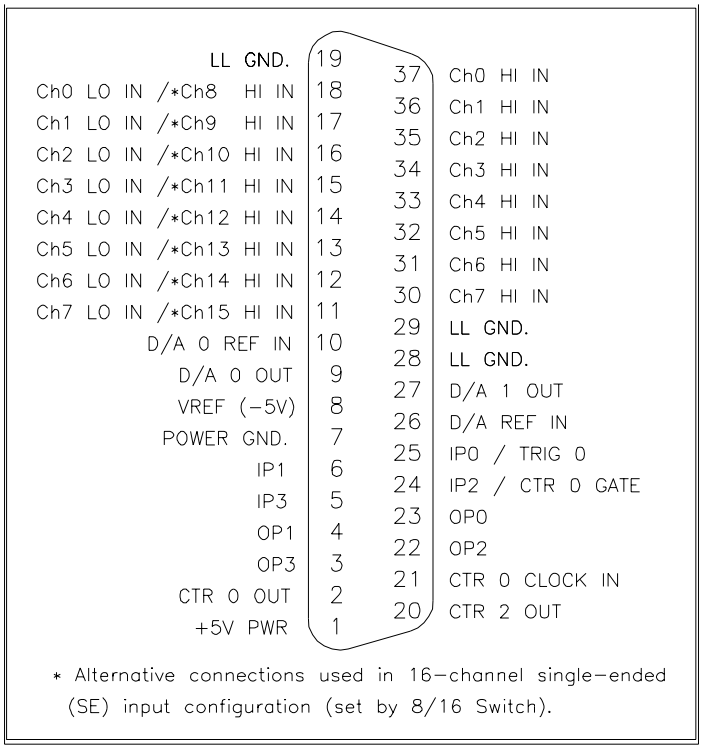


Figure 3-4. Main I/O Connector

Note: Pins 11 through 18 perform a double function depending on the setting of the channel configuration switch. In 8-channel differential configuration, these pins provide the low inputs of Channels 0 – 7 corresponding to the high inputs of these channels on Pins 30 – 37. In 16 channel single-ended configuration, they provide additional channel high inputs for Channels 8 – 15.

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Setting up the Computer

Caution: To prevent damage that can occur when handling electronic equipment, use a ground strap or similar device when performing this installation procedure.

Caution: Installing or removing a board while power is on can damage your computer.

1. Turn off the computer.
2. Turn off all peripherals (printer, modem, monitor, and so on) connected to the computer.
3. Unplug the computer and all peripherals.
4. Remove the cover from you computer. Refer to your computer's user manual for instructions.

Selecting an Expansion Slot

1. Select a 32-bit or 64-bit ISA expansion slot.

   ISA slots are longer than PCI slots. One of the ISA slots may be a shared ISA/PCI slot. If a PCI board exists in the shared slot, you cannot use the slot for an ISA board; if an ISA board exists in the shared slot, you cannot use the slot for a PCI board.

2. Remove the cover plate from the selected expansion slot. Retain the screw that held it in place; you will use it later to install the board.

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Installing the Board

Note: You must observe the current-capacity limits of the PC supply; allow for the power used by any other boards that may be in use. See Appendix A for DAS-16 Series power requirements.

1. Make sure the option switch settings match the settings shown in the configuration-utility switch diagram.
2. Carefully lower the board into the ISA expansion slot using the card guide to properly align the board in the slot. When the bottom of the board contacts the bus connector, gently press down on the board until it clicks into place.

Caution: Do not force the board into place. Moving the board from side to side during installation may damage the bus connector. If you encounter resistance when inserting the board, remove the board and try again.

3. Secure the board in place at the rear panel of the system unit using the screw removed from the slot cover.
4. Replace the computer cover.
5. Turn on power to the computer.

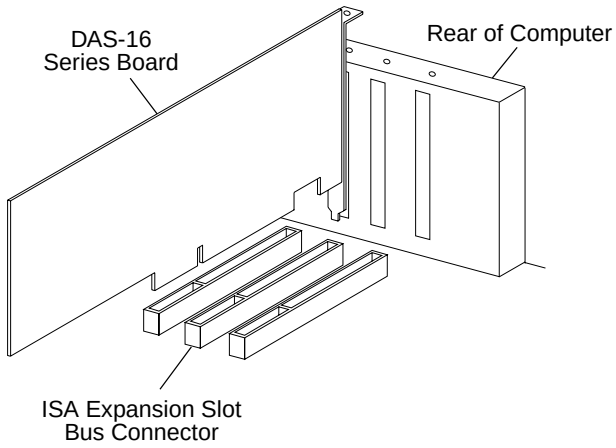


Figure 3-5. Installing the DAS-16 Series Board

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Configuring DriverLINX

After you have successfully installed the DAS-16 Series board in your computer, start Windows to install DriverLINX. For detailed instructions on installing DriverLINX, see the documentation provided on the DriverLINX CD-ROM; especially the *DriverLINX Installation and Configuration Guide* and *Appendix F: Configuration and Implementation Notes—for Keithley DAS-16/1600* manuals.

Run "Learn DriverLINX" **(LearnDL.exe)** from the DriverLINX program group to tell DriverLINX how you configured your DAS-16 Series 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. Select the "Learn DriverLINX" icon created when you installed DriverLINX. You may also use the Command Line edit box activated by selecting *Run...* option from the *File* menu. Enter "<drive>:/DRVLNX/LEARNDL" in the command line edit box (<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 DAS-16 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 your DAS-16 Series 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

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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 file in the Windows directory.
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 DAS-16, select *Device/Initialize* from the main menu in Learn DriverLINX.
2. The first time the DAS-16 is initialized, or after a configuration change, DriverLINX runs a diagnostic program to verify the operation and accuracy of the configuration settings.

You can use the control panel (see Section 5 to verify board operation).

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4

Cabling and Wiring

In most applications, you use accessories to connect external I/O devices to the DAS-16 Series boards. Keithley accessories extend signals from the main I/O connector to corresponding screw terminals of the accessory.

This section describes the cabling and accessories required for attaching field wiring to your DAS-16 Series boards.

Caution: To avoid electrical damage, turn off power to the computer and any attached accessories before making connections to DAS-16 Series boards.

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Attaching Screw Terminal Accessories

You can use the following screw terminal connectors and accessories to simplify connection of field wiring to DAS-16 Series boards:

- STC-37 screw terminal connector; when using a DAS-16 Series board, your application may require two connectors.
- STP-37 screw terminal panel; when using a DAS-16 Series board, your application may require two panels.
- STA-16 screw terminal accessory.
- STA-U universal screw terminal accessory.

The following sections describe how to attach these accessories to DAS-16 Series boards.

Attaching an STC-37

The screw terminals on the STC-37 screw-terminal connector allow you to connect field wiring to a DAS-16 Series board. The screw terminals accept wire sizes 12 – 22 AWG.

To connect an STC-37 to the main I/O connector of a DAS-16 Series board, attach the 37-pin connector on the STC-37 directly to the main I/O connector. Figure 4-1 illustrates the connection of an STC-37 to a DAS-16 Series board.

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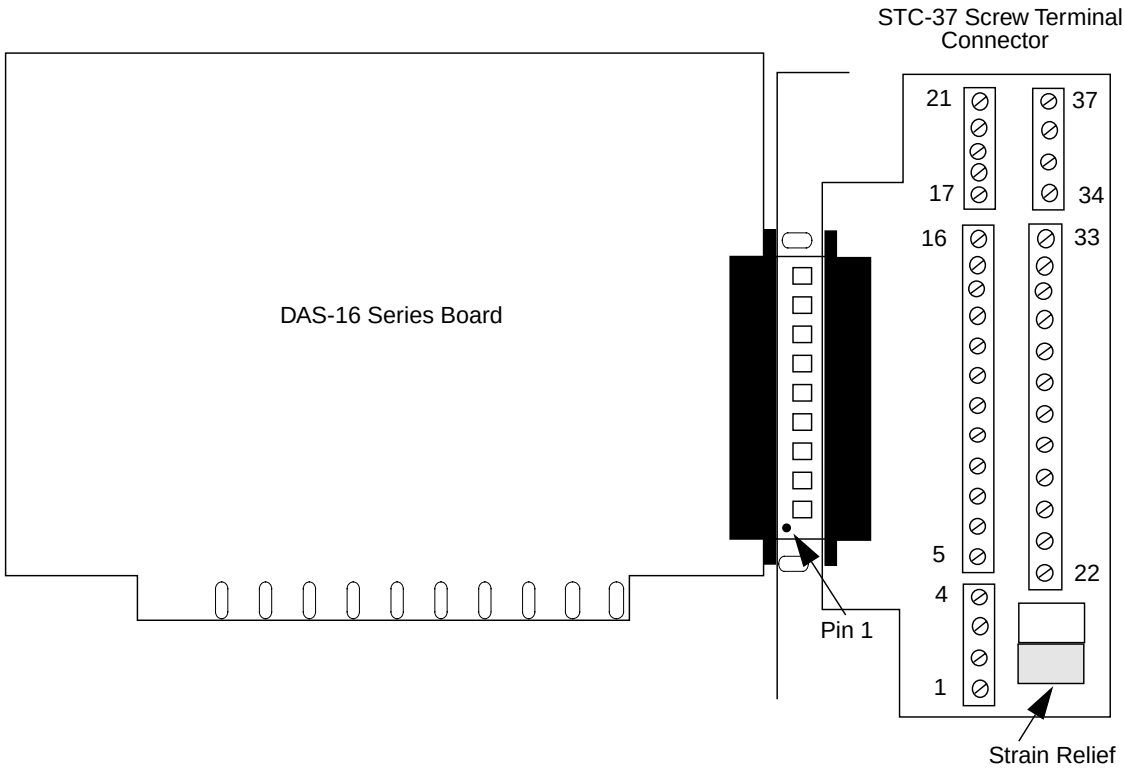


Figure 4-1. Attaching an STC-37 Screw Terminal Connector

The screw terminals are labeled from 1 to 37 and correspond directly to the functions of the pins on the main I/O connector (see Figure 4-2). For example, since pin 25 is assigned to IP0/TRIG 0, use screw terminal 25 to attach a digital signal to bit 0 of the standard digital input port.

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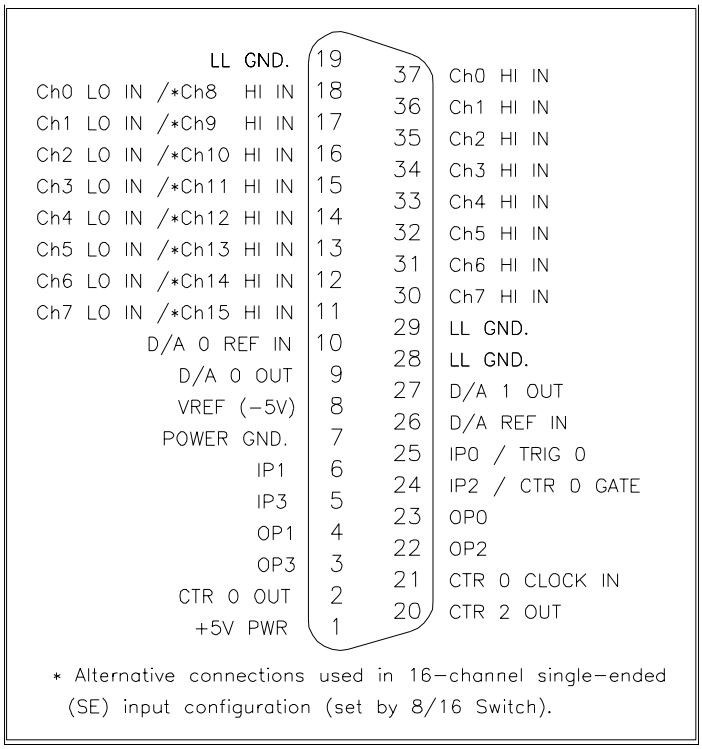


Figure 4-2. Pin Assignments of the Main I/O Connector.

Attaching an STP-37

The screw terminals on the STP-37 screw terminal panel allow you to connect field wiring to DAS-16 Series boards. The STP-37 contains the following components:

- A 37-pin male connector for cabling to the main I/O connector of a DAS-16 Series board.
- Labeled screw terminals for connecting sensor outputs and test equipment. These terminals accept wire sizes 12 through 22 AWG.

You attach an STP-37 screw terminal panel to the main I/O connector on the DAS-16 Series board with a C-1800 or S-1800 cable. The C-1800 is the unshielded version of the cable; the S-1800 is the shielded version of the cable. Figure 4-3 shows how to attach an STP-37 to a DAS-16 Series board.

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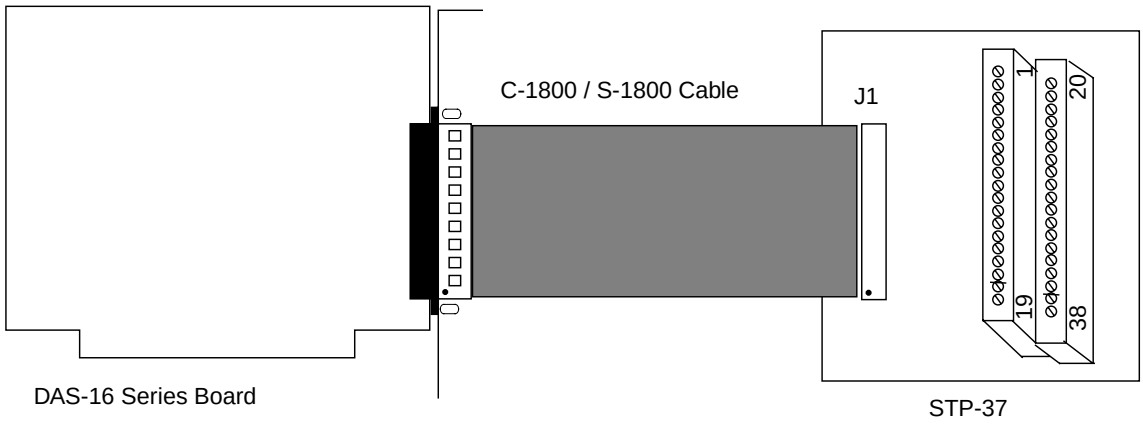


Figure 4-3. Attaching an STP-37 to the Main I/O Connector

The screw terminals are labeled 1 to 38 and correspond directly to the functions of the main I/O connector. See Figure 4-2 for the pin assignments of the main I/O connector.

Attaching an STA-16

The screw terminals on the STA-16 screw terminal accessory allow you to connect field wiring to DAS-16 Series boards. The STA-16 contains the following components:

- Two 37-pin male connectors. One for cabling to the main I/O connector of a DAS-16 Series board and a second for daisy-chaining additional accessories.
- Labeled screw terminals for connecting sensor outputs and test equipment. These terminals accept wire sizes 12 through 22 AWG.
- A breadboard area for user-installed circuitry.

Attach an STA-16 screw terminal accessory to the main I/O connector on the DAS-16 Series board with a C-1800 or S-1800 cable. The C-1800 is the unshielded version of the cable; the S-1800 is the shielded version of the cable. Figure 4-4 shows how to attach an STA-16 to a DAS-16 Series board.

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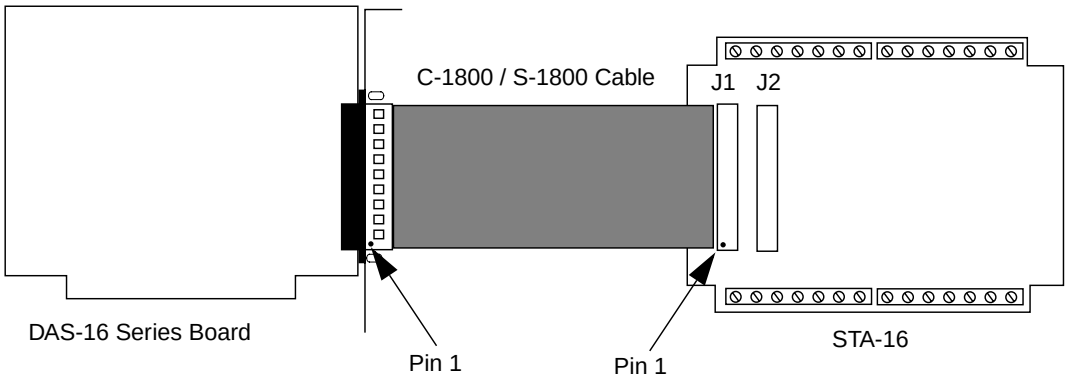


Figure 4-4. Attaching an STA-16

Figure 4-5 shows the screw terminal names on the STA-16.

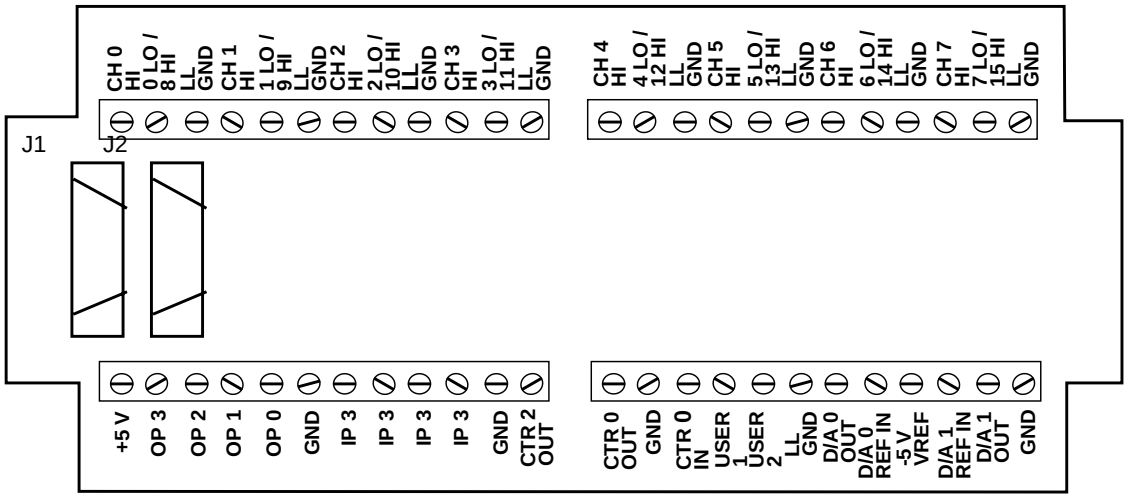


Figure 4-5. STA-16 Terminal Names

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Attaching Expansion Accessories

You can use the following expansion accessories to increase the number of channels available and add signal conditioning to your application:

- EXP-16
- EXP-16/A
- EXP-GP

The following section describes how to attach these expansion accessories to DAS-16 Series boards.

Attaching an EXP-16 or EXP-16/A Expansion Accessory

Each expansion multiplexer/amplifier accessory provides up to 16 analog input channels (labeled 0 to 15). Table 4-1 lists the terminal names used on EXP-16 and EXP-16/A expansion accessories.

Table 4-1. EXP-16 and EXP-16/A Terminal Names

Terminal Name	Signal
LL GND	low-level ground
CH*n* HI	positive input; where *n* indicates the channel number
CH*n* LO	negative input; where *n* indicates the channel number

To connect an EXP-16 or EXP-16/A to a DAS-16 Series board, you must first connect an STA-16 or STA-MB accessory, as shown in Figure 4-6.

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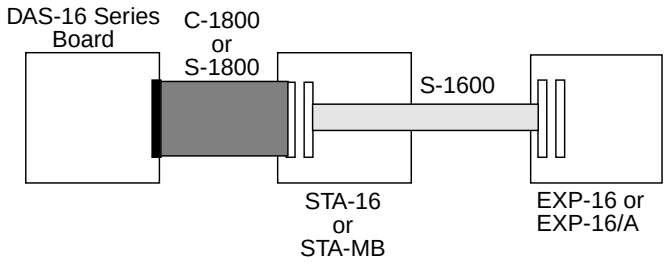


Figure 4-6. Attaching an EXP-16 or EXP-16/A Expansion Accessory

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Note: The S-1600 cable must be used to connect the first EXP to the DAS-16 Series board.

Refer to the EXP-16 and EXP-16/A expansion board documentation for more information about these accessories and instructions for installing the PG-408A option on the board.

Attaching an EXP-GP Expansion Accessory

Each EXP-GP expansion multiplexer/signal conditioner board provides up to eight analog input channels (labeled 0 to 7). Table 4-2 lists the terminal names used on each EXP-GP channel.

Table 4-2. EXP-GP Terminal Names

Terminal Name	Signal
+IEXC	positive current excitation
+SENSE	positive input
–P	negative voltage excitation
–IEXC	negative current excitation
–SENSE	negative input
+P	positive voltage excitation

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To connect an EXP-GP to a DAS-16 Series board, attach one end of an S-1600 cable to the DAS-16 Series main I/O connector and the other end of the cable to the J1 connector on the EXP-GP. Figure 4-7 illustrates the connection of an EXP-GP to a DAS-16 Series board.

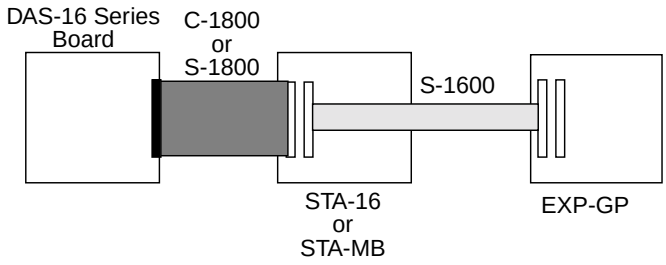


Figure 4-7. Attaching an EXP-GP Expansion Accessory

Refer to the EXP-GP expansion board documentation for more information about this expansion accessory.

Attaching Multiple Expansion Accessories

You can cascade up to eight EXP-16, EXP-16/A, and/or EXP-GP expansion accessories to provide up to 128 analog input channels.

Figure 4-8 shows how to attach multiple EXP-16, EXP-16/A, and EXP-GP accessories to a DAS-16 Series board.

Notes: In a mix of EXP-16, EXP-16/A, and EXP-GP accessories, the EXP-16 and EXP-16/A accessories must be placed ahead of the EXP-GP accessories.

All multiple EXP-16 and EXP-16/A accessories attached to a DAS-16 Series board, as shown in Figure 4-8, must contain a PG408A accessory.

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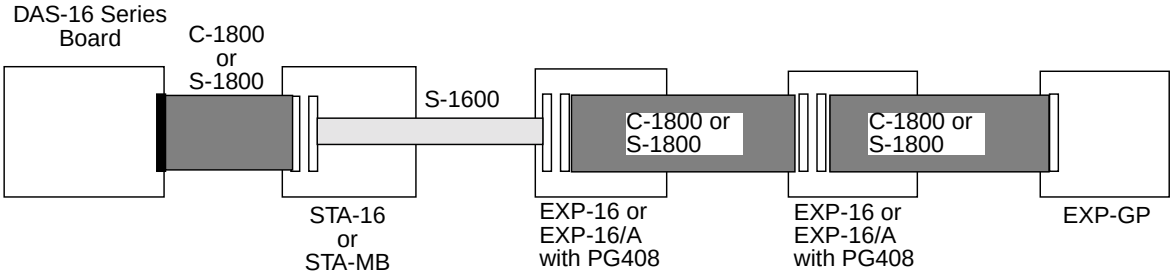


Figure 4-8. Attaching Multiple EXP-16, EXP-16/A, and /or EXP-GP Accessories

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Notes: Each EXP-16, EXP-16/A, or EXP-GP expansion accessory is associated with an analog input channel on a DAS-16 Series board. You specify the associated DAS-16 input channel by setting a jumper on each expansion accessory. Use a unique jumper setting for each expansion accessory you are using. Refer to your expansion board documentation for more information.

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Attaching an MB Series Backplane

MB Series modules are ideally suited to applications where monitoring and control of temperature, pressure, flow, and other analog signals are required. Figure 4-9 shows a block diagram of a typical MB Series measurement and control application.

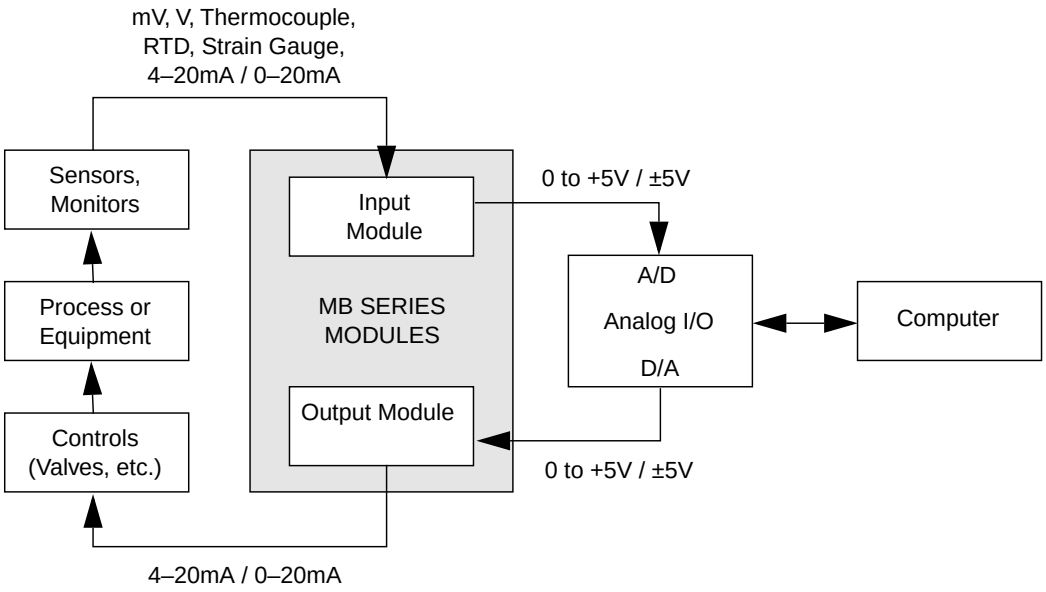


Figure 4-9. Typical Measurement and Control Application

Table 4-3 provides a brief summary of the backplanes available for use with MB Series modules.

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Table 4-3. MB Series Backplanes

Model	Description
MB01	Holds up to 16 modules and mounts in a 19-inch equipment rack. Provides direct channel-to-channel connection to a DAS-16 Series board.
MB02	Holds up to 16 modules and mounts in a 19-inch equipment rack. Up to four MB02s can be multiplexed together, providing a total of 64 channels. This makes it suitable for larger systems.
MB05	Functionally equivalent to half an MB01, the MB05 backplane accepts eight modules. Provides direct channel-to-channel connection to a DAS-16 Series board.
STA-MB	Holds up to four modules and provides general-purpose screw terminal connections for all other signals on the DAS16 Series board.

Attaching an MB01/05 Backplane

Use the C16-MB1 cable to connect a DAS-16 Series board to an MB01/05 backplane. This cable connects MB01/05 channels 0 through 15 to analog input channels 0 through 15 on the DAS-16 Series board. Refer to Figure 4-10 for a cabling diagram.

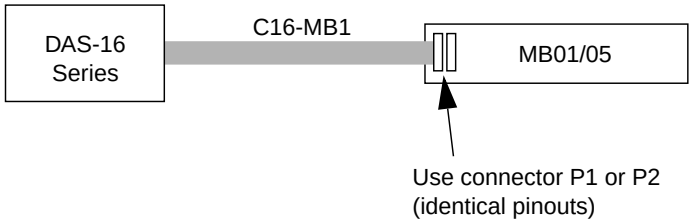


Figure 4-10. Attaching an MB01/05 Backplane

Note: The channel connections are single-ended. Make sure that the DAS-16 Series board is set for 16-channel, single-ended operation.

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Attaching an MB02 Backplane

Figure 4-11 shows how to connect a DAS-16 Series board to up to four MB02 backplanes. The STA-SCM16 interface connects one MB02 board to one analog input channel of the DAS-16 Series board. One C-2600 cable connects each MB02 to the STA-SCM16, and the C-1800 cable connects the STA-SCM16 to the DAS-16 Series board.

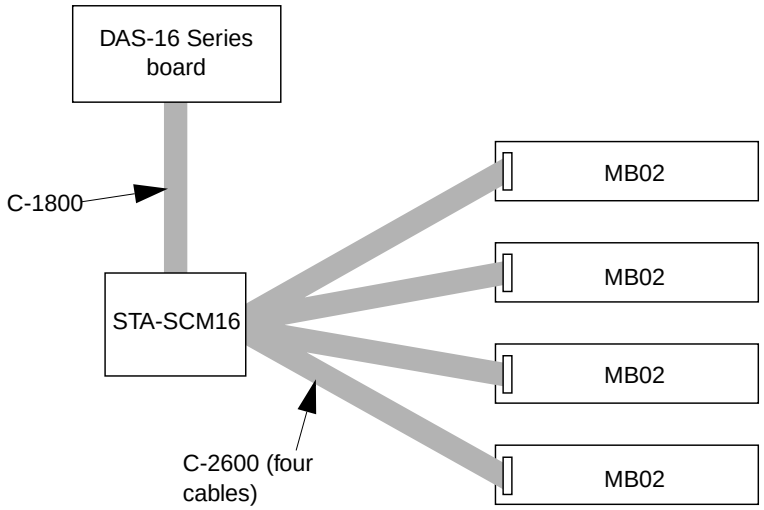


Figure 4-11. Attaching Multiple MB02 Backplanes

Figure 4-12 shows how the STA-SCM16 connects DAS-16 Series boards with MB02 backplanes.

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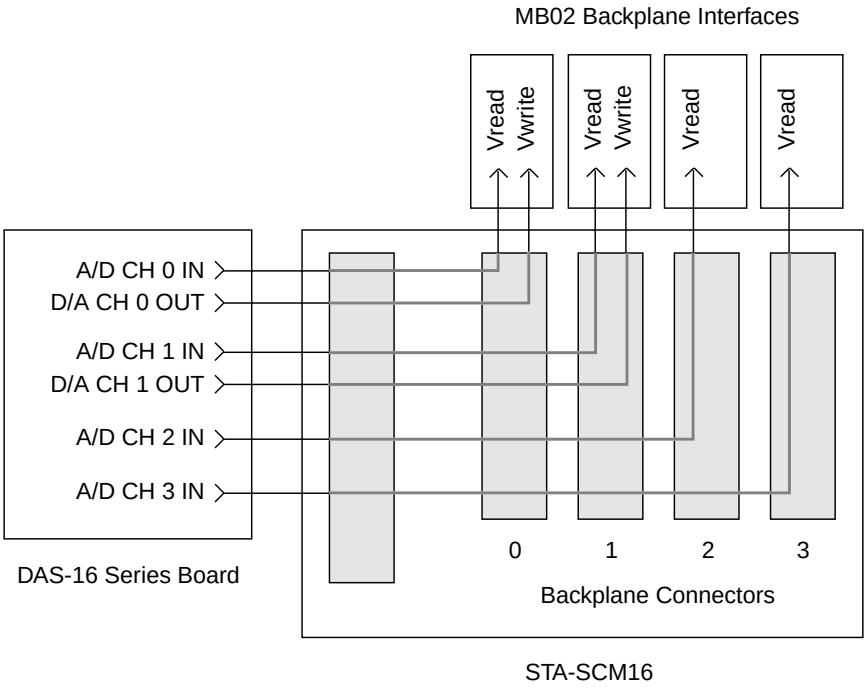


Figure 4-12. MB02 I/O Connections

The four digital output lines on the DAS-16 Series boards select one of the 16 MB02 channels. For example, if you set the digital output lines to 1000 (8 decimal), MB02 channel 8 is selected on all four backplanes. Analog input channels 0 to 3 on the DAS-16 Series board map directly to the connectors labeled 0 to 3 on the STA-SCM16. In this arrangement, the channel connections are single-ended. Make sure that the DAS-16 Series board is set for single-ended, 16-channel operation. Refer to the *MB Series User's Guide* for more information.

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Attaching an STA-MB

The screw terminals on the STA-MB screw-terminal accessory accept field wiring to up to four MB Series modules whose outputs are brought through an C-1800/S-1800 cable to the main I/O connector of a DAS-16 Series board.

The STA-MB contains the following components:

- Two 37-pin male connectors. One for cabling to the main I/O connector of a DAS-16 Series board and a second for cascading additional accessories.
- Labeled screw terminals for connecting sensor outputs and test equipment. These terminals accept wire sizes 12 through 22 AWG.
- Mounts for up to four MB Series modules.

Attach an STA-MB screw terminal accessory to the main I/O connector on the DAS-16 Series board with a C-1800 or S-1800 cable. The C-1800 is the unshielded version of the cable; the S-1800 is the shielded version of the cable. Figure 4-13 shows how to attach an STA-MB to a DAS-16 Series board.

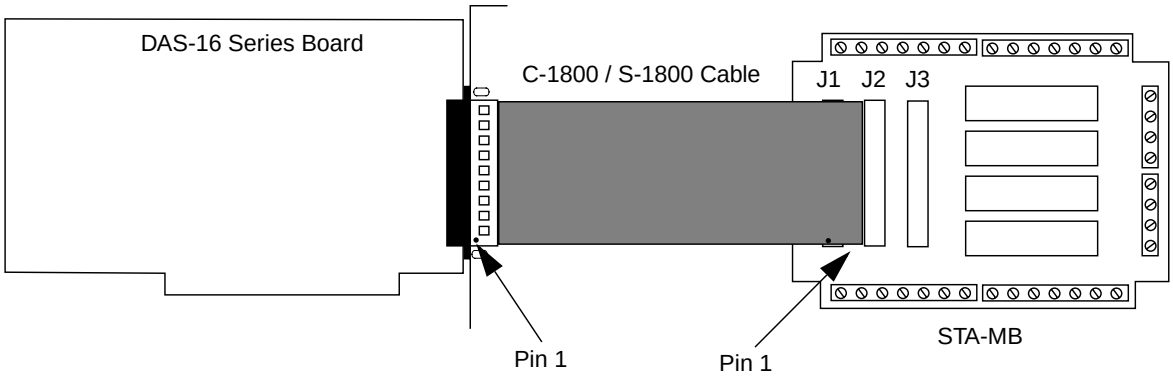


Figure 4-13. Cabling and Connections for Attaching an STA-MB

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Connecting Analog Input Signals

This section shows circuits for wiring signal sources to input channels of DAS-16 Series boards. While the circuit diagrams show direct connections to channel input pins of the main I/O connector, you must make actual connections through corresponding inputs of an accessory, such as a screw terminal panel.

The circuit diagrams represent a single signal source wired to a single channel (channel *n*). In reality, you can wire eight separate signal sources to eight differential inputs or 16 separate signal sources to 16 single-ended inputs.

If you expect to use a DAS-16G1 board at high gain, read the precautionary information in “Precautions for Operating at High Gains” on page 4-24. Other considerations for I/O connections are offered under “Additional Precautions” on page 4-25.

Connecting a Signal to a Single-Ended Analog Input

Figure 4-14 shows the connections between a signal source and a channel of a DAS-16 Series board configured for single-ended input mode.

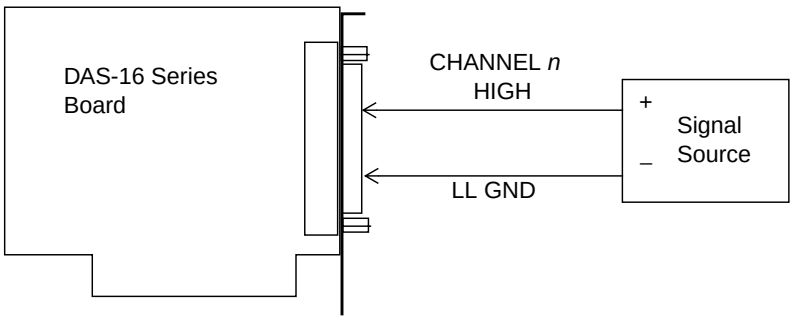


Figure 4-14. Connections for Wiring a Signal Source to a DAS-16 Series Board Configured for Single-Ended Inputs

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The main I/O connector contains the following two ground connections:

- POWER GND is the noisy or "*dirty*" ground that carries all digital signal and power supply currents.
- LL GND or low level ground is the ground reference for all analog input functions and it only carries signal currents that are less than a few mA.

Contact resistance and cable resistance can make a voltage difference of many millivolts between the two grounds although they are connected to each other.

Note: When you wire signals to the analog input channels, you are advised to wire all unused channels to LL GND. This action prevents the input amplifiers from saturating, and it ensures the accuracy of your data.

Connecting a Signal to a Differential Analog Input

Figure 4-15 shows three methods of wiring a signal source to a channel of a DAS-16 Series board configured for differential input mode.

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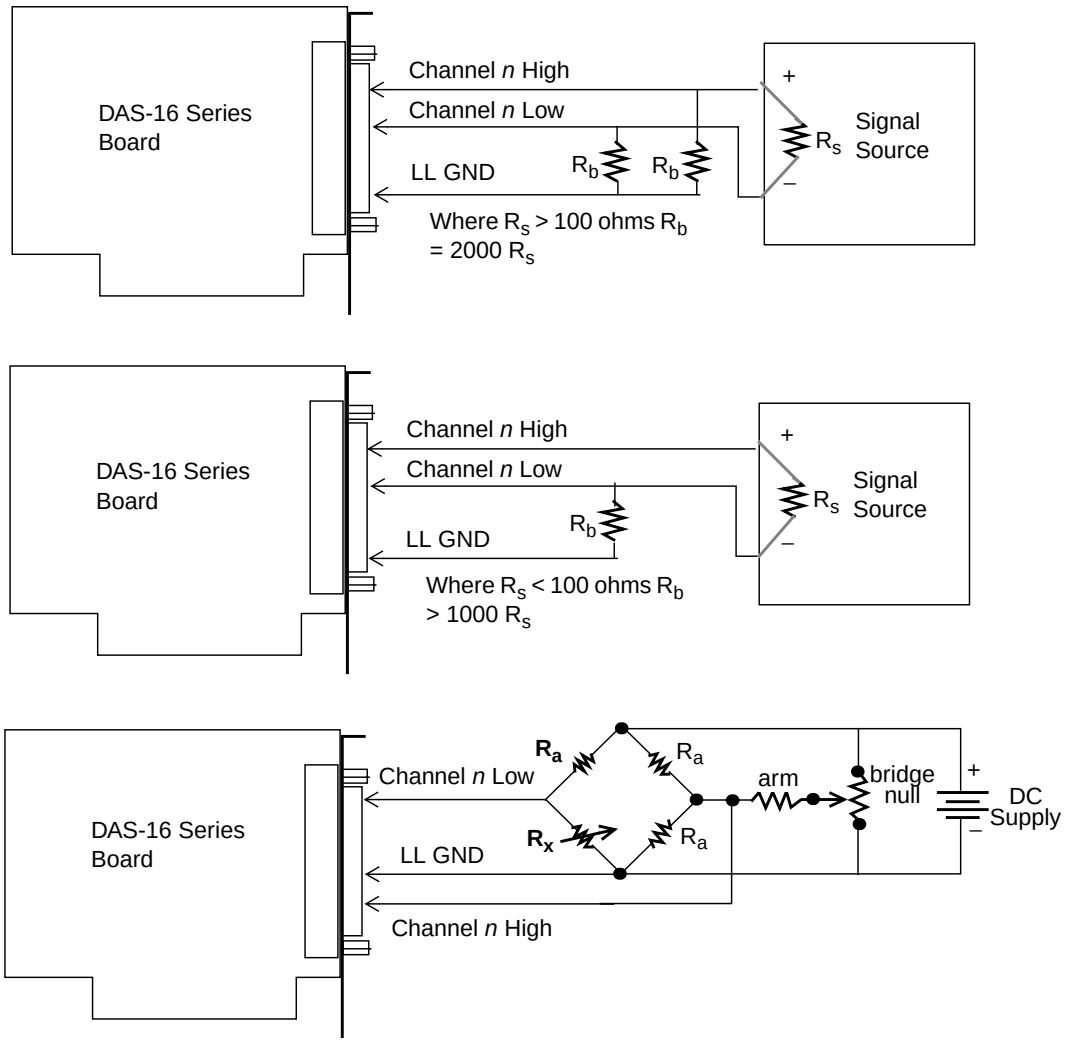


Figure 4-15. Three Methods of Wiring Differential Inputs

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The upper two circuits of the diagram require the addition of resistors to provide a bias-current return. You can determine the value of the bias return resistors (R_b) from the value of the source resistance (R_s), using the following relationships:

- When R_s is greater than 100Ω, use the connections in the upper circuit. The resistance of each of the two bias return resistors must equal 2000 R_s.
- When R_s is less than 100Ω, use the connections in the middle circuit. The resistance of the bias return resistor must be greater than 1000 R_s.

In the lower circuit, bias current return is inherently provided by the source. The circuit requires no bias resistors.

Avoiding a Ground Loop Problem

Very often, the signal-source ground and the DAS-16 Series board ground are not at the same voltage level because of the distances between equipment wiring and the building wiring. This difference is referred to as a *common-mode voltage* (Vcm) because it is normally common to both sides of a differential input (it appears between each side and ground).

Using a differential input lets you avoid a ground loop problem. Since a differential input responds only to the difference in the signals at its high and low inputs, its common-mode voltages cancel out and leave only the signal. However, if your input connections contain a ground loop, your input could see incorrect data readings resulting from the sum of the signal-source and common-mode voltages. Figure 4-16 shows the proper way to connect a differential input while Figure 4-17 illustrates the effect of a ground loop on a differential channel converted to a single-ended channel by the installation of a wire jumper between Channel n Low and LL GND on the DAS-16 board side of the cable. Figure 4-17 also illustrates the ground loop problem for a channel already configured in the configuration utility as single-ended.

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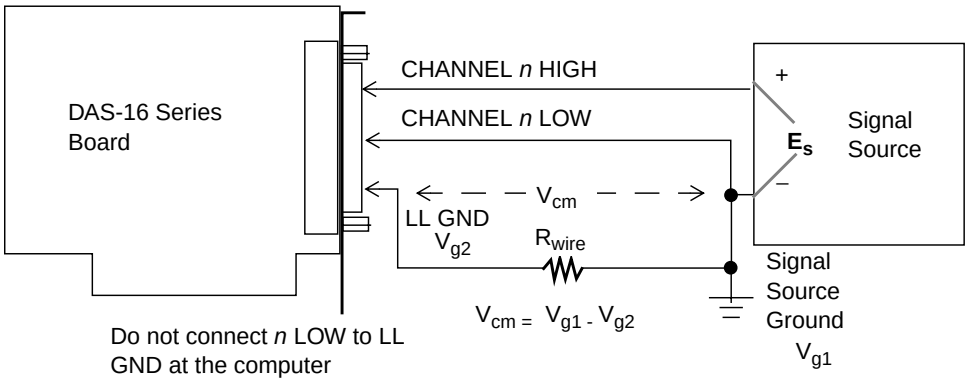


Figure 4-16. A Differential Input Connection that Avoids a Ground Loop Problem

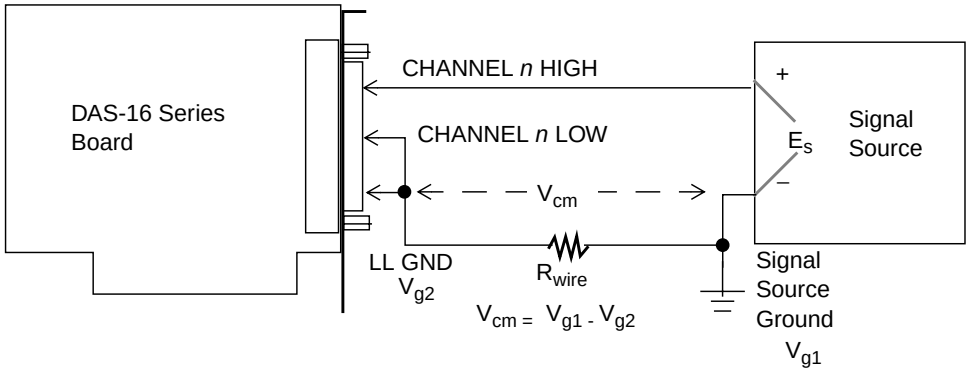


Figure 4-17. Differential or Single-Ended Input Connection that Introduces a Ground Loop Problem

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Connecting Analog Output Signals

Make the D/A output connections from the appropriate D/A output and LL GND, as shown in Figure 4-18.

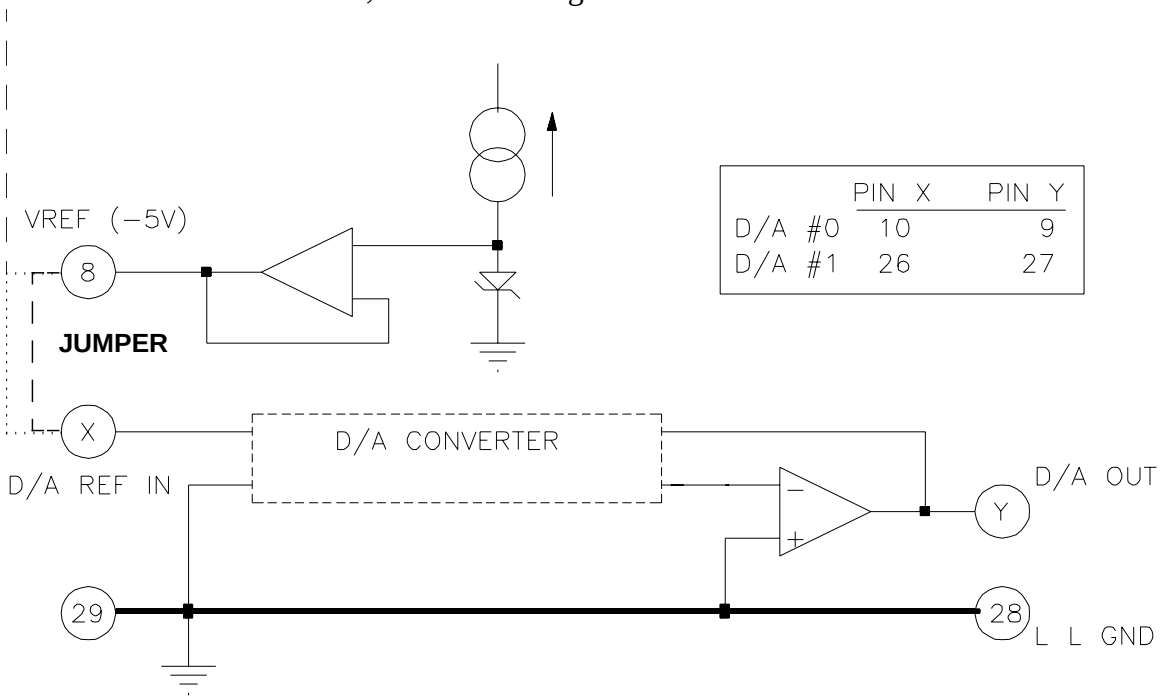


Figure 4-18. D/A Converter Connections

The D/A reference inputs can be connected to the –5V reference signal on the rear connector. In this case, the D/A output scaling will be 0 to +5V. It is also possible to connect the reference inputs to an external reference signal whether it be AC or DC.

DAS-16 Series boards include two DACs. Refer to the specifications in Appendix A for voltages, current limits, and other loading information. Make your connections to the DAC output terminals through

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corresponding screw terminals of your accessory. Table 4-4 lists the input and output connections of the DACs in the DAS-16 Series boards.

Table 4-4. DAC Input and Output Connections

Signal	Main I/O Connector
D/A 0 User Reference Voltage In	pin 10
D/A 1 User Reference Voltage In	pin 26
D/A 0 Out	pin 9
D/A 1 Out	pin 27

Measuring Current and 4–20mA Current Loops

Process control current loop transducers are easily interfaced to DAS-16 by adding a suitable shunt resistor across the input. Since the maximum current will be 20mA, the precision shunt resistor should have a resistance in ohms of 50 * Vfs. The resistor should be of low–temperature, coefficient–metal film or wirewound construction for stability with time and temperature. Using this interface, the 4–20mA working range of the current loop corresponds to 80% of the normal resolution; about 3,277 bits for unipolar ranges and 1,638 bits for bipolar ranges.

Non–ground referred currents outside the common–mode range can also be measured with a suitable shunt. Non–ground referred currents can be measured through an isolation amplifier, DC, or Hall Effect current transformer.

The D/A Voltage Reference

A –5V stable reference voltage (Vref) is brought out for users. This voltage is derived from the A/D converter reference. Apart from its use as a D/A reference, it can also be used for offsetting signals, powering bridge transducers, etc. The maximum available output source/sink current is 5mA.

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Interface to Transducers, Thermocouples, etc.

Low level transducers such as thermocouples and strain gauge bridges (load cells, pressure and force transducers) require amplification before applying to the high level DAS-16 inputs. The EXP-16 expansion multiplexer incorporates an instrumentation amplifier that can provide stable amplification and also includes circuitry that allows cold junction compensation of thermocouples. EXP-16 will handle most interfacing requirements to DC output transducers and also includes spaces for filters, shunts, and attenuators.

For inexpensive temperature measurement in the –50 to +125˚C temperature range, semiconductor temperature transducers are a good choice. The most popular types are the AD590/592 (Analog Devices) which behave like a constant current source with an output of 273µA at 0˚C and a scaling of 1µA/ ˚C and the LM335 (National Semiconductor) that has an output of 2.73 volts at 0˚C and a temperature coefficient of 10mV/ ˚C.

For measuring high temperatures, up to 1800˚C or more, thermocouples are the most satisfactory solution. The base metal thermocouples (types J, K, T, and E) have outputs around 40 microvolts/ ˚C while the platinum and tungsten types are used for the highest temperature measurement. Thermocouple types S, B, and R tend to have lower outputs—in the 6 to 12 microvolt/ ˚C range. A further complication encountered in the use of thermocouples is the “cold–junction” compensation. Where the thermocouple wire is terminated to the copper EXP–16 connections, an unwanted thermocouple junction is formed. As the connector temperature varies, this introduces an error. The error can be bucked out by sensing the connector temperature using a semiconductor sensor on another channel, and correcting the thermocouple readings in software. This is required only at the highest levels of accuracy, since in most cases connector temperature (usually room temperature) varies little. EXP–16 provides the sensing hardware needed to perform this correction.

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Precautions for Operating at High Gains

Operating DAS-16G1 boards at gains of 100 or 500 can lead to problems if your application is unable to cope with noise. At a gain of 500, with a bipolar input range of –10.0V to +10.0V, each bit of A/D output corresponds to 10µV of analog input. Thus, with the high speed and bandwidth of this board, analog noise and performance degradation come easily unless you take precautions to avoid them. The following collection of ideas and suggestions is aimed at avoiding these problems:

- Operate DAS-16G1 boards in 8-channel differential mode. Using the board in 16-channel, single-ended mode at high gains introduces enough ground-loop noise to produce large fluctuations in readings.
- Minimize noise from crosstalk and induced-voltage pickup in the flat cables and screw terminal accessories by using shielded cable. Connect the shield to LL GND and the inner conductors to Channel LO and HI. Channel LO and LL GND should have a DC return (or connection) at some point; this return should be as close to the signal source as possible. Induced noise from RF and magnetic fields can easily exceed tens of microvolts, even on one- or two-foot cables; shielded cable eliminates this problem.
- Avoid bi-metallic junctions in the input circuitry. For example, the kovar leads, used on reed relays, typically have a thermal emf to copper of 40µV/˚C. Thermals can introduce strange random variations caused by air currents and so on.
- Consider filtering. This approach can use hardware (resistors, capacitors, and so on) but is often accomplished more easily with software. Instead of reading the channel once, read it 10 or more times in quick succession and average the readings. If the noise is random and Gaussian, it will be reduced by the square-root of the number of readings.

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Additional Precautions

Do not mix your data acquisition inputs with the AC line, or you risk damaging the computer. Data acquisition systems provide access to inputs of the computer. An inadvertent short between data and power lines can cause extensive and costly damage to your computer. The manufacturer can accept no liability for this type of accident. To prevent this problem, use the following precautions:

- Avoid direct connections to the AC line.
- Make sure all connections are tight and sound so that signal wires are not likely to come loose and short to high voltages.
- Use isolation amplifiers and transformers where necessary.

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5

DriverLINX Analog I/O Panel

The DriverLINX Analog I/O Panel is an application that demonstrates analog input/output using DriverLINX. With the Analog I/O Panel you can:

- Analyze analog signals using the simulated two-channel Oscilloscope.
- Measure analog voltages using the simulated Digital Volt Meter.
- Generate Sine, Square and Triangle waves using the SST Signal Generator.
- Output DC Level voltages using the Level Control.

The Analog I/O Panel is useful for:

- Testing the DAS-16 DriverLINX installation and configuration.
- Verifying signal inputs to your DAS-16 board.
- Sending test signals to external devices.

To access this DriverLINX Analog I/O Panel:

1. Start the Analog I/O Panel with the “AIO Panel” item on the Windows™ start menu. Then perform the following steps:
2. Click the [...] button in the Driver Selection section.
3. Select the driver for your board using the *Open DriverLINX* dialog.
4. Click *OK*.
5. Select the Logical Device you want to operate by dragging the pointer in the Device Selection section. The Analog I/O Panel displays the Scope, Meter, SST, and Level control tabs, depending on the capabilities of your DAS-16 board.

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6. The Scope uses two analog input channels, referred to as ChA and ChB. Drag the channel selectors in the AI Channel Mapping section to map them to different channel numbers.
7. The SST Signal Generator uses two analog output channels, referred to as ChA and ChB. Drag the channel selectors in the AO Channel Mapping section to map them to different channel numbers.

You can now select the Scope, Meter, SST and Level Control tabs to operate your DAS-16 board.

Test Panel Application

Depending upon the DriverLINX drivers you have installed on your system, you will have one or more of the following example applications:

- *Single-Value AI* for analog input
- *Single-Value AO* for analog output
- *PIO Panel* for digital input and output
- *CTM Test Bench* for counter/timer applications

To access this DriverLINX Test Panel, select Test Panel with the “Test Panel” item on the Windows start menu.

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6

Calibration

Your DAS-16 Series board is initially calibrated at the factory. You are advised to check the calibration of a board every six months and to calibrate again when necessary. This section provides the information you need to calibrate a DAS-16 Series board.

Equipment Requirements

The equipment requirements for calibrating a DAS-16 Series board are as follows:

- A digital voltmeter accurate to a minimum of 41/2 digits
- An adjustable ±10V power source

Potentiometers and Test Points

Figure 6-1 and Figure 6-2 show the locations of the potentiometers and test points that are used during the calibration of a DAS-16/16F Series or DAS-16G1/16G2 Series board.

The calibration utility, described in the next section, directs you to components and explains what to do with them during the calibration process.

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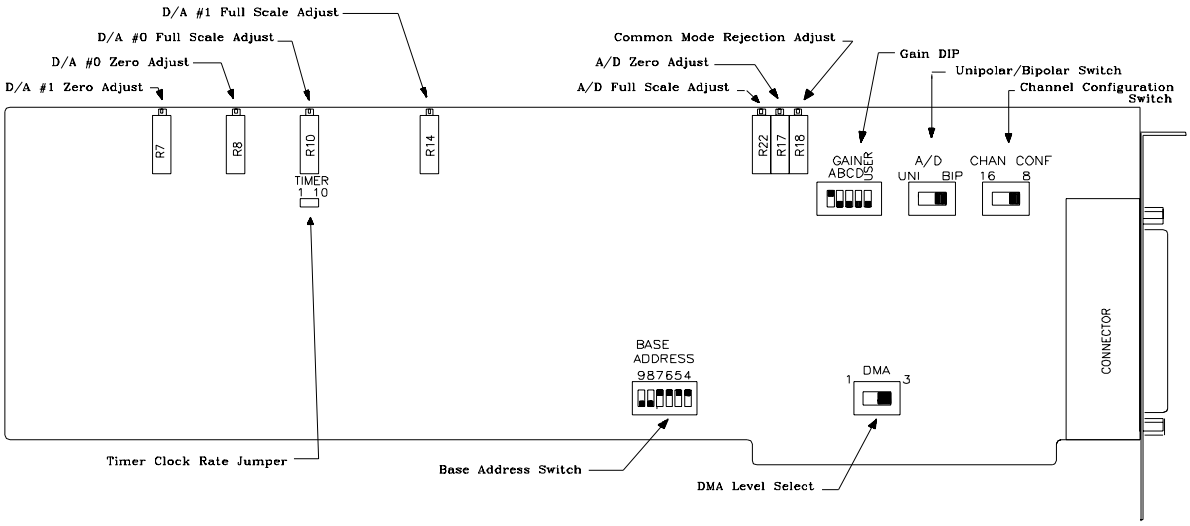


Figure 6-1. DAS-16/16F Switch and Control Locations

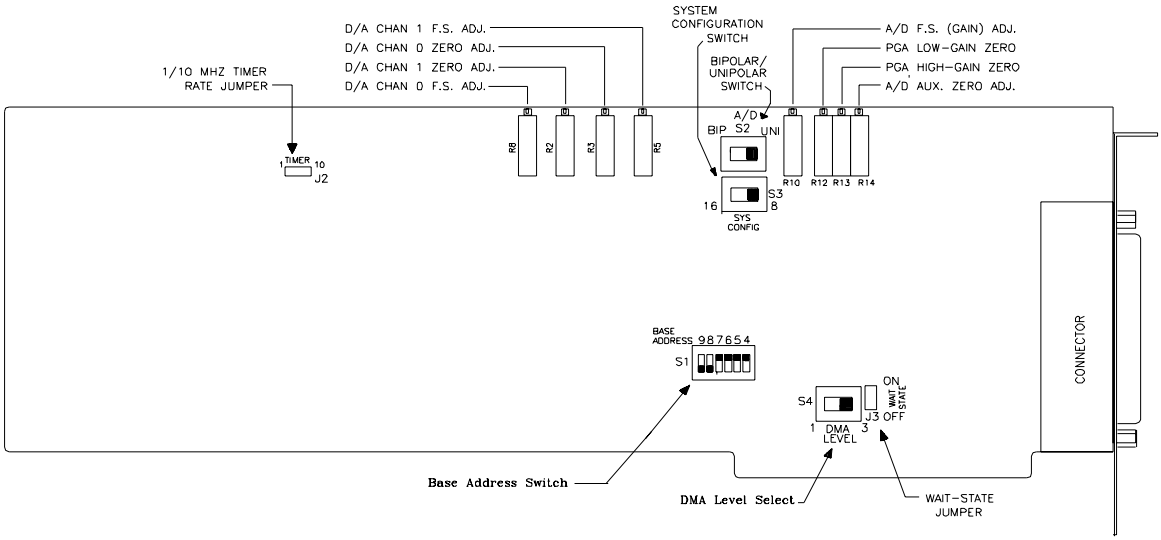


Figure 6-2. DAS-16/16G Switch and Control Locations

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Calibration Utility

DriverLINX Calibration Utility will guide you through the calibration procedure. Before calibration, specify the following parameters in the setup panel to get the correct instructions:

- **Logical Device** — Board's device number, model and address
- **Accessory** — Connection method used to connect the board to the calibration stimulus
- **Shorted channel** — Input channel to be "shorted" high to low
- **Voltage Channel** — Input channel to use to apply the various calibration voltage levels
- **Calibration range** — Input range to be calibrated

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Calibrating the A/D

The A/D output should be observed (the calibration programs do this) while applying a known calibration voltage to any or all analog input channels. The A/D should be calibrated on the range you are going to use since calibration on one range does not insure correct calibration on any other range. Briefly, the adjustment sequence is as follows:

1. Apply an analog input of 1/2 bit above –F.S. and adjust the A/D zero pot so that the output flickers between –2048 and –2047 (bipolar) or 0 and 1 (unipolar).
2. Apply an analog input of +0.0V (bipolar) or 1/2 of F.S. unipolar and adjust the A/D full-scale pot for a reading of 0 or 2048, respectively. Other inputs such as 1/4 and 3/4 full scale can be applied to check the linearity.

All DAS-16 models contain an adjustment to optimize the common–mode rejection of the input amplifier. Make this adjustment only in the 8–channel differential mode, and connect the “Hi” and “Lo” of a channel as shown in Figure 6-3. The voltage calibrator should be varied from zero to + or –10 volts and the pot adjusted for no change in the reading of the selected channel. Any channel may be used for this test; the calibration programs use Channel 0.

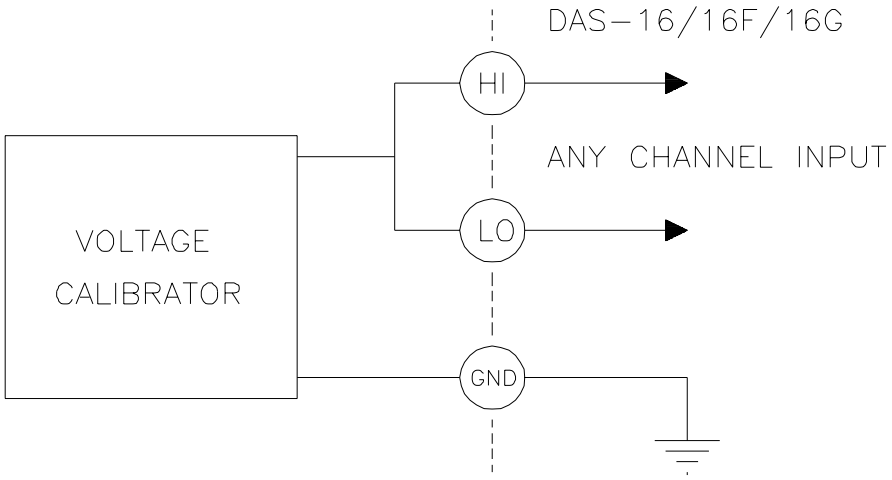


Figure 6-3. Common Mode Adjustment Test Configuration

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Calibrating the D/As

Connect the D/A reference inputs to the –5V reference voltage and then, using the calibration program, make the following adjustments to each D/A. Connecting the digital voltmeter to each D/A output in turn, set the voltages to within ±0.0005V (1/2 millivolt) of the recommended values, which are shown in Table 6-1.

Table 6-1. D/A Recommended Calibration Values

D/A	Digital Input	Digital Pot.	Adjust Output to
0	0	D/A 0 zero	0.0000V
0	4095	D/A 0 F.S.	+4.9988V
1	0	D/A 1 zero	0.0000V
1	4095	D/A 1 F.S.	+4.9988V

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Programmable Timer and Digital I/O

No special calibration for the counter/timer or digital I/O is required, but you can make a check of the functionality of Counters 1 and 2 and the internal crystal clock by performing an accumulated–count test against the system clock.

The calibration program also lets you read and write to the digital I/O. The functionality of each output can be checked by grounding inputs and using a voltmeter or a logic probe on outputs.

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7

Troubleshooting

If your DAS-16 Series board is not operating properly, use the information in this section to isolate the problem. If the problem appears serious enough to warrant technical support, refer to “Technical Support” on page 7-7 for further information.

Problem Isolation

If you encounter a problem with a DAS-16 Series board, use the instructions in this section to isolate the cause of the problem before calling Keithley for technical support.

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.

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Device Initialization Error Messages

During device initialization, DriverLINX performs a thorough test of all possible subsystems on DAS-16 Series 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, don't 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.

Identifying Symptoms and Possible Causes

Use the troubleshooting information in Table 7-1 to try to isolate the problem. Table 7-1 lists general symptoms and possible solutions for problems with DAS-16 Series boards.

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Table 7-1. Troubleshooting Information

Symptom	Possible Cause	Possible Solution
Board does not respond	Base address is incorrect.	Make sure the base address switch on the board is set correctly and that your program references the same base address. 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. Refer to page 3-10 for instructions on setting the base address.
	The interrupt level is incorrect.	Make sure no other computer device is using the interrupt level specified in your program. If necessary, reset the interrupt level.
	The board is incorrectly aligned in the accessory slot.	Check installation.
	The board is damaged.	Contact Keithley for technical support; see page 7-7.
Intermittent operation	The most common cause of this problem is that the I/O bus speed is in excess of 8MHz.	Reduce I/O bus speed to a maximum of 8MHz (to change the I/O bus speed, run BIOS setup). See the documentation for your computer 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 wiring.
	Bus cycles require wait state.	Enable wait states on the DAS-16 Series board.

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Table 7-1. Troubleshooting Information (cont.)

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 8MHz.	Reduce I/O bus speed to a maximum of 8MHz (to change the I/O bus speed, run BIOS setup). See the documentation for your computer for instructions on running BIOS setup.
	An open connection exists.	Check wiring to screw terminal.
	Another device is using the specified base address.	Reconfigure the base address of the DAS-16 Series board; refer to page 3-10 for more information. Check the I/O assignments of other system devices and reconfigure, if necessary.
Computer does not boot	Board not seated properly.	Check that the board is properly installed.
	The base address setting of the DAS-16 Series board conflicts with that of another device.	Verify that the base address setting of your DAS-16 Series board is unique. Refer to page 3-10 for instructions on setting the base address.
	The power supply of the host computer is too small to handle all the devices installed in your system.	Check the needs of all system devices and obtain a larger power supply if necessary.

If your board is not operating properly after using the information in Table 7-1, continue with the next two sections to further isolate the problem.

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Testing the Board and Host Computer

To isolate the problem to the DAS-16 Series board or to the host computer, use the following steps:

1. Turn the power to the host computer OFF, and remove power connections to the computer.

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

---

2. While keeping connections to accessories intact, unplug the accessory connector(s) or cable(s) from the DAS-16 Series board(s).
3. Remove the DAS-16 Series board(s) from the computer and visually check for damage. If a board is obviously damaged, refer to "Technical Support" on page 7-7 for information on returning the board.
4. With the DAS-16 Series board(s) 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 DAS-16 Series 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 page 7-7 for instructions on calling Keithley for technical support.

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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 DAS-16 Series 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 DAS-16 Series 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 DAS-16 Series board when the problem occurred, use the functional board to test the other slot(s) 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 DAS-16 Series 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.

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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:

DAS-16 Series board configuration	Model	_____
	Serial Number	_____
	Revision Code	_____
	Base address setting	_____
	Interrupt level setting	_____
	Number of channels	_____
	Input (S.E. or Diff.)	_____
	Mode (uni. or bip.)	_____
	DMA chan(s)	_____
	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	_____

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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.

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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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A

Specifications

DAS-16 Series Specifications

Power Consumption

+5V supply	800mA typ. / 1A max.
+12V supply	13.5mA typ. / 18mA max.
-12V supply	23.5mA typ. / 31mA max.

Analog Inputs

Number of Channels	8 differential (HI/LO/GND) or 16 single-ended (HI/GND) switch selectable
Resolution	12 bits
Accuracy	0.01% of reading ±bit
Input Range	**DAS-16/16F** ±10V, ±5V, ±2.5V, ±1V, and ±0.5V; or 0-10V, 0-5V, 0-2V, and 0-1V switch selectable

DAS-16G1

Gain	Unipolar	Bipolar	Throughput
1	0 to +10V	±10V	70KHz
10	0 to +1V	±1V	60KHZ
100	0 to +100mV	±100mV	50KHz
500	0 to +20mV	±20mV	30KHz

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DAS-16G2

Gain	Unipolar	Bipolar	Throughput
1	0 to +10V	±10V	70KHz
2	0 to +5V	±5V	60KHZ
4	0 to +2.5mV	±2.5mV	60KHz
8	0 to +1.25mV	±1.25mV	60KHz

Note that the GAIN ranges of both DAS-16G models have a 12-bit resolution (4096 steps), so that resolutions of the DAS-16G1 vary from 4.8mV/bit (±10V) to 4.8µV/bit (0 to +20mV), and reolutions of the DAS-16G2 vary from 4.8mV/bit (±10V) to 305µV/bit (0 to +1.25V). The programmable gain amplifier is a fixed-gain bandwidth product so that its settling time increases at higher gain. This causes the maximum throughput rate to decrease as the gain increases and is especially noticeable on the high-gain Model DAS-16G1.

Overvoltage — Continuous single channel to ±35V

Input current — DAS-16: 250nA max. (125nA typ.) at 25˚ C
DAS-16F: 250nA max. (125nA typ.) at 25˚ C
DAS-16G: ±50nA max. at 25˚ C

Temperature Coefficient — DAS-16/16F
Gain or Full Scale: ±25 ppm/˚C max.
Zero: ±12ppm/˚C max.

DAS-16G
Gain or Full Scale: ±15 ppm/˚C max.
Zero: ±3ppm/˚C max.

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A/D Specification

Type	Successive approximation
Resolution	12 bit
Coding:	Offset binary (bipolar ± inputs) True binary (unipolar ± inputs)
Conversion Time	DAS-16/16G: 15ms max. (12 typ.) DAS-16F: 8.5ms max.
Type:	DAS-16/16G: Harris HI-674A or equivalent DAS-16F: Harris HI-774
Monotonicity	Guaranteed over operating temperature range
Linearity	±1bit
Zero drift	±10ppm/˚C max.
Gain drift	±30ppm/˚C max.
Trigger Source	By external trigger, programmable timer source, or program command; software selectable.

Sample Hold Amplifier

Acquisition time	1ms to 0.01%, typ. for full-scale step input
Aperture Uncertainty	0.3ns typical
Type	Harris HI-5320 or Signetics NE5060

Reference Voltage Output

Ref. Voltage	-5.0V ±0.05V
Temp. Coeff.	±30 ppm/˚C max
Load current	±5 mA max.

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D/A Converters

Channels	2 independent
Type	12-bit, multiplying, double-buffered Analog Devices AD-7548
Linearity	±1/2 bit
Monotonicity	±1/2 bit
Output Range	0 to +V with fixed –5V reference. May also be used with other AC or DC reference input. Maximum output limit ±10V
Output Drive	5mA minimum
Output Resistance	<0.1 ohm
Ref. Input Range	10V
Gain	–1.000 adjustable 1%
Setting Time	30ms to 0.01% for full-scale step

Digital I/O

Output Port	4 bits
OP0–3 output low voltage	0.5V max. @ 8.0mA (current sink)
OP0–3 output high voltage	2.4V min. @ –0.4 mA (current source)
Input Port & Trig.	4 bits
IP0–3 input low voltage	0.8V max.
IP0–3 input low current	–0.4 max.

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IP0–3 input high voltage	2.0V min.
IP0–3 input high current	20mA max. @ 2.7V

Interrupt Inputs

Type	Positive (rising) edge triggered
Level	2–7 software selectable
Enable	Via INT of CONTROL Register

Interrupts are latched in an internal flip-flop on the DAS-16/16F/16G. The state of this flip-flop corresponds to the INT bit (STATUS Register). It is cleared by a write to the CONTROL Register. Service routines should acknowledge and re-enable interrupt flop.

Direct Memory Access Channel

Levels	1 or 3 switch-selected
Enable	Via DMA bit of CONTROL register
Termination	By interrupt on T/C (or auto-initialize)
Transfer	DAS-16: Hardware capable of up to 70,000 conversions/sec DAS-16F: Haardware capable of up to 100,000 conversions/sec DAS-16G: Hardware capable of up to 70,000 conversions/sec

Users are responsible for initialization of the 8237 DMA controller on the system board. With DMA bit set, double-byte requests are generated at the end of each A/D conversion. Data is latched and available for DMA transfer until the end of the following conversion. Transfer sequence is low byte/high byte.

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Programmable Timer

Type	8254-2 programmable interval timer
Counters	3 down-counters (16-bit). Two permanently connected to 1 or 10MHz clock as programmable timer. One counter free.
Driver capability	2.2mA @ 0.45Vdc (5 LSTTL loads)
Input, Gate, Clock load	TTL/DTL/CMOS compatible
Input Clock Frequency	DC to10MHz
Active count edge	Negative (falling)
Clock pulse width	30ns high/50ns low (min.)
Timer Range	2.5MHz to <1 pulse/hr.

For additional information on programming see DriverLINX manuals.

Power Outputs

IBM/PC Bus Supplies	+5V
Tolerance	+5V ±5%
Loading	Dependent upon peripherals and on computer type

General Environmental

Operating Temp.	0 to 50˚C
Storage Temp.	–20 to 7˚C
Humidity	0 to 90% (non-condensing)
Weight	9 oz. (255 g)

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B

Connector Pin Assignments

This appendix contains pin assignments for the I/O connectors of the DAS-16 Series boards.

Main I/O Connector

The pin assignments of the main I/O connector on the DAS-16 Series board are shown in Figure B-1.

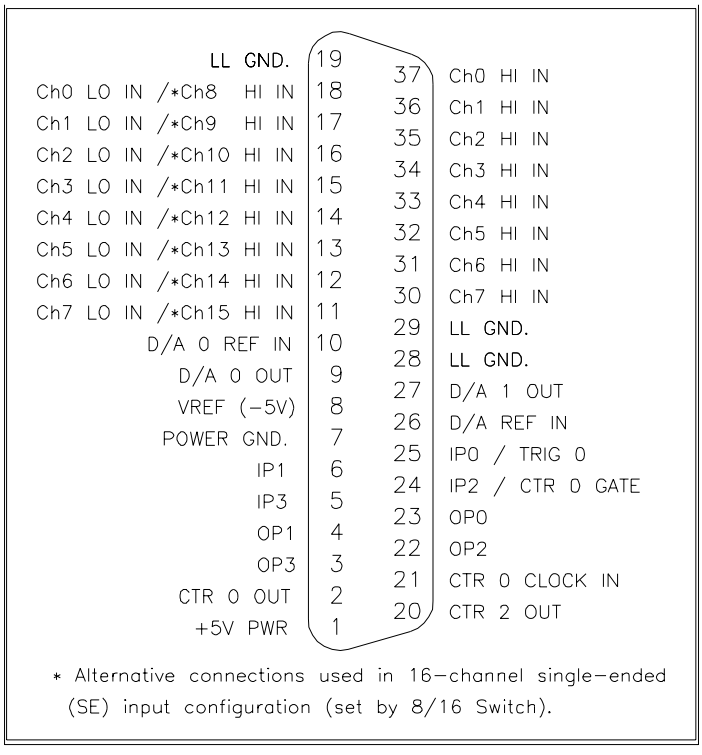


Figure B-1. Pin Assignments of Main I/O Connector on DAS-16 Series

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Table B-1. Main I/O Connector Pin Assignments for the DAS-16

Pin	Name	Function
1	+5V	+5V (±0.1 V) output (from computer)
2	CTR 0 OUT	82C54 C/T0 clock output
3	OP3	Digital output bit 2
4	OP1	Digital output bit 0
5	IP3	Digital input bit 2
6	IP1	Digital input bit 0 / Digital trigger input
7	PWR GND	Return for all logic signals and power supply currents. Connected to computer frame.
8	VREF(-5V)	-5V (±0.1V) reference output
9	D/A 0 OUT	D/A Channel 0 output
10	D/A 0 REF IN	D/A Channel 0 input reference (10V range)
11	CH7 LO IN/ *CH15 HI IN	Analog input channel 7, low; Single-ended Channel 15 high
12	CH6 LO IN/ *CH14 HI IN	Analog input channel 6, low; Single-ended Channel 14 high
13	CH5 LO IN/ *CH113 HI IN	Analog input channel 5, low; Single-ended Channel 113 high
14	CH4 LO IN/ *CH112 HI IN	Analog input channel 4, low; Single-ended Channel 12 high
15	CH3 LO IN/ *CH11 HI IN	Analog input channel 3, low; Single-ended Channel 11 high
16	CH2 LO IN/ *CH10 HI IN	Analog input channel 2, low; Single-ended Channel 10 high
17	CH1 LO IN/ *CH9 HI IN	Analog input channel, low; Single-ended Channel 9high
18	CH0 LO IN/ *CH8 HI IN	Analog input channel 0, low; Single-ended Channel 8 high

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Table B-1. Main I/O Connector Pin Assignments for the DAS-16 (cont.)

Pin	Name	Function
19	LL. GND	Low-level ground. Common return and shield for the analog input channels.
20	CTR 2 OUT	82C54 C/T2 clock output
21	CTR 0 CLOCK IN	82C54 C/T0 clock input
22	OP 2	Digital output bit
23	OP0	Digital output bit
24	IP2/ CTR 0 GATE	Digital input bit 1 82C54 C/T0 gate input
25	IP0/ TRIG 0	Digital input bit 0 / Digital trigger input
26	D/A 1 REF IN	D/A Channel 1 input reference (10V range)
27	D/A 1 OUT	D/A Channel 1 output
28	LL. GND	Low-level grounds. These are common returns and shields for the analog input channels.
29	LL. GND	
30	CH7 HI IN	Analog high input channel 7
31	CH6 HI IN	Analog high input channel 6
32	CH5 HI IN	Analog high input channel 5
33	CH4 HI IN	Analog high input channel 4
34	CH3 HI IN	Analog high input channel 3
35	CH2 HI IN	Analog high input channel 2
36	CH1 HI IN	Analog high input channel 1
37	CH0 HI IN	Analog high input channel 0

*Alternative connections apply in 16 Channel Single-Ended (S.E.) input configuration.

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C

Register-Level Address Map

DAS-16 Series boards are programmable at the register-level using I/O instructions. In BASIC, I/O instructions are **INP(X)** and **OUT X,Y**. In assembly and most other low-level languages, the I/O instructions are similar to BASIC's I/O instructions; for example, the assembly language equivalents are **IN AL,DX** and **OUT DX,AL**.

As an aid to register-level programming, this section describes each I/O register in terms of function, address, bit structure, and bit functions. The section does not describe how to program at the register-level.

Register Functions

DAS-16 Series register functions are categorized as follows:

- Analog-to-Digital converter (ADC) registers
- MUX scan register
- Digital input and output registers
- Digital-to-Analog converter (DAC) output registers
- Status registers
- Control register
- Programmable gain selection register
- Timer/Counter enable register
- 82C54 programmable interval counter/timer registers

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DAS-16 boards use 16 consecutive addresses starting at the base address in the computer's I/O space and extend as shown in the I/O map of Table C-1.

Table C-1. Register-Level Address Map

Location	Function	Type	Name
Base Address +0h	Low-byte of ADC register, A/D conversion	Read/Write	AD0
Base Address +1h	High-byte of ADC register	Read	AD1
Base Address +2h	ADC MUX scan register	Read/Write	MUX
Base Address +3h	Digital input byte (IP0-3), Board ID	Read	DIO
	Digital output byte (OP0-3)	Write	
DAC Output Registers Base Address +4h to +7h			
Base Address +4h	Low-byte of DAC0	Write	DAOLB
Base Address +5h	High-byte of DAC0	Write	DA0HB
Base Address +6h	Low-byte of DAC1	Write	DA1LB
Base Address +7h	High-byte of DAC1	Write	DA1HB
Base Address +8h	Status register	Read	STATUS A
Base Address +9h	Control register	Read/Write	CTRL
Base Address +Ah	Counter enable (2 bit*) register	Read/Write	CNTEN
Base Address +Bh	Gain selection register (DAS-16G only*)	Read/Write	GAIN
82C54 Programmable Interval Timer			
Base Address +Ch	Counter 0 register	Read/Write	TIMER0
Base Address +Dh	Counter 1 register	Read/Write	TIMER1
Base Address +Eh	Counter 2 register	Read/Write	TIMER2
Base Address +Fh	82C54 Counter Control	Write	TIMERCTL

*Users writing drivers for the DAS-16G who have already developed code for the fixed gain DAS-16/16F should note the following differences:

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1. *Base Address + Ah (Counter Enable) Read/Write:* On DAS-16/16F this is a 2-bit write-only register. On DAS-16G, it is an 8-bit read/write register, although the same two bits (D0 and D1) are used for counter control. The remaining six bits are unused on DAS-16G and non-existent on DAS-16/16F.
2. *Base Address + Bh (Programmable Gain) Read/Write:* This address was unused on DAS-16/16F. On DAS-16G it is an 8-bit read/write register, the upper six bits are unused, and the lower two bits select the gain range.
3. All software developed for the fixed gain DAS-16/16F operates with the DAS-16G, although it will need modification to use the programmable gain feature. If you want to set DAS-16G gain before running application software designed for the older fixed gain DAS-16/16F, use software programming to set the programmable gain register to BASE ADDRESS + Bh.

The following sections describe the I/O registers in more detail.

ADC Registers (Base Address +0h and +1h)

Base address +0h and base address +1h are used for the following:

- A/D conversion data
- MUX channel number from which data is converted
- Start a software controlled A/D conversion

The ADC registers are read in standard Intel 8088 Lo/Hi-byte sequence. A write to base +0 initiates an A/D conversion.

Data is left-justified true binary, and the MUX channel address is in the least-significant nibble; thus, data is tagged according to its channel of origin. ADC data is latched so that data from the previous conversion is available until the end of the following conversion. You can mask or discard channel information, as required.

A write to base address +0h initiates an A/D conversion. Any data written to these addresses is ignored.

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Bit assignments of base address +0h are as follows:

7	6	5	4	3	2	1	0
CD3	CD2	CD1	CD0	MA3	MA2	MA1	MA0

The bit names are defined and used as follows:

- **MA0 to MA3** = Number of MUX channel converted.
- **CD0 to CD3** = Four least significant bits of data converted from MUX channel specified by MA0 to MA3.

Bit assignments of base address +1h are as follows:

7	6	5	4	3	2	1	0
CD11	CD10	CD9	CD8	CD7	CD6	CD5	CD4

- **CD4 to CD11** = Eight most significant bits of data converted from MUX channel specified by MA0 to MA3.

MUX Scan Register (Base Address +2h)

The MUX scan register is a read and write register that controls the channel-scan limits of the ADC multiplexer. The high nibble provides the *end of scan address* and the low nibble provides the *start of scan address*.

The MUX scan register is set to 00h on power-up (reset).

About 400ns after the ADC multiplexer begins a conversion (and the sample-and-hold is holding the previous channel) the multiplexer address increments to be ready for the next conversion.

On finishing the conversion performed with the *end of scan address*, the cycle repeats starting with the *start of scan address*. On writing to the MUX scan register, the counter is automatically initialized to the start of scan address.

To perform conversions on a single channel, the *end of scan* and *start of scan addresses* should both be made equal to the target channel. If the

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DAS-16 Series board is to operate in 8-channel differential mode, insure that the AH3 and AL3 bits are zero. The operating mode can always be determined by reading bit 5 in status register A.

Bit assignments of base address +2h are as follows:

7	6	5	4	3	2	1	0
AH3	AH2	AH1	AH0	AL3	AL2	AL1	AL0

The bit names are defined and used as follows:

- **AL0 to AL3** = Start of scan address.
- **AH0 to AH3** = End of scan address.

Unidirectional Digital I/O Registers (Base Address +3h)

DAS-16 Series unidirectional digital input and output consists of two hardware-configured ports: a 4-bit latched output port (OP0 to 3) and a 4-bit input port (IP0 to 3).

These ports share the same I/O address but are independent; that is, data written to the output port is not readable by the input port unless the OP0 to OP3 lines are externally connected to the IP0 to IP3 lines. The output port is set to 0h on power-up (reset).

In addition, some input port lines perform secondary functions. IP0 is also XPCLK and TRIG 0. XPCLK provides an external pacer clock to initiate A/D conversions and TRIG 0 is used as a gate for the 82C54 counters one and two. IP2 is also CTR 0 GATE, which controls operation of counter 0 in the 82C54 counter/timer.

Depending on your application, you may or may not use these secondary functions. However, if you want to know the state of these inputs, read base address +3h.

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Bit assignments of base address +3h during a write are as follows:

7	6	5	4	3	2	1	0
X	X	X	X	OP3	OP2	OP1	OP0

The bit names are defined and used as follows:

- **OP0 to OP3** = Bits 0 to 3 of the digital output port.
- **X** = Data insensitive.

Bit assignments of base address +3h during a read are as follows:

7	6	5	4	3	2	1	0
0	0	0	0	IP3	IP2	IP1	IP0

The bit names are defined and used as follows:

- **IP0 to IP3** = Bits 0 to 3 of the digital input port.
- **Bits 7 to 4** = Board ID; these bits have a fixed value of 0000 for DAS-16 Series boards.

DAC Output Registers (Base Address +4h to +7h)

DAC output registers are write only and in standard Lo/Hi-byte sequence. DAC output registers are double-buffered so that the 12-bit DAC converters are not updated until the second (high) byte is written. This insures a single-step transition on the analog output of the DAC.

Note: DACs power up with 0V out regardless of selected range. The DAC output register data formats are true-binary and left-justified.

Base address +4h and +5h correspond to DAC 0; base address +6h and +7h correspond to DAC 1.

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DAC0

Bit assignments of base address +4h are as follows:

7	6	5	4	3	2	1	0
DD3	DD2	DD1	DD0	X	X	X	X

The bit names are defined and used as follows:

- **X** = Data insensitive.
- **DD0 to DD3** = Four least significant bits of DAC0 data.

Bit assignments of base address +5h are as follows:

7	6	5	4	3	2	1	0
DD11	DD10	DD9	DD8	DD7	DD6	DD5	DD4

The bit names are defined and used as follows:

- **DD4 to DD11** = Eight most significant bits of DAC0 data.

DAC1

Bit assignments of base address +6h are as follows:

7	6	5	4	3	2	1	0
DD3	DD2	DD1	DD0	X	X	X	X

The bit names are defined and used as follows:

- **X** = Data insensitive.
- **DD0 to DD3** = Four least significant bits of DAC1 data.

Bit assignments of base address +7h are as follows:

7	6	5	4	3	2	1	0
DD11	DD10	DD9	DD8	DD7	DD6	DD5	DD4

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The bit names are defined and used as follows:

- **DD4 to DD11** = Eight most significant bits of DAC1 data.

Status Register (Base Address +8h)

Status register A is read only and provides information on the operation and configuration of the DAS-16 Series board. Writing to the status register address clears the interrupt request.

Bit assignments of base address +8h are as follows:

7	6	5	4	3	2	1	0
EOC	U/B	MUX	INT	MA3	MA2	MA1	MA0

The bit names are defined and used as follows:

- **MA0 to MA3** = Current multiplexer address. This is the MUX address (channel number) of the next channel to be converted if EOC = 0. The channel address changes about 400 ns after EOC goes high. These status bits provide information on the setup for the next conversion.
- **INT** = Interrupt status. A 1 in this bit position indicates that an ADC conversion has taken place and an interrupt has been set. The state of this bit is not gated by the interrupt enable bit in the DAS-16 Series control register. A write of any value to the status register A location clears the interrupt bit.
- **MUX** = Single-ended or differential. The bit value is controlled by the position of the channel configuration (CHAN) switch.

  Table C-2 defines the logic states of the MUX bit.

Table C-2. Logic State of Status Register A; MUX (Bit 5)

Channel Selection	State
16-channel single-ended	logic 1
8-channel differential	logic 0

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- **U/B** = Unipolar/bipolar. This bit can be useful in scaling routines. The U/B bit indicates whether the ADC input is operating in unipolar or bipolar mode (as set by UNI/BIP switch). Table C-2 defines the logic states of the U/B bit.

Table C-3. Logic State of Status Register; UB (Bit 6)

Mode Selection	State
unipolar	logic 1
bipolar	logic 0

- **EOC** = End of conversion. If EOC = 1, the ADC is busy. EOC = 0 implies that the ADC is ready to perform the next conversion and the ADC data registers contain valid data from the previous conversion.

Control Register (Base Address +9h)

The control register is read/write and controls the DAS-16 Series operating modes. The control register is cleared on power-up (reset), thereby disabling DMA, interrupt, and external A/D start modes.

Bit assignments of base address +9h are as follows:

7	6	5	4	3	2	1	0
INTE	IL2	IL1	IL0	X	DMAE	S1	S0

The bit names are defined and used as follows:

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- **S0 to S1** = Pacer clock source. These bits control the pacer clock source for the ADC. Table C-4 lists pacer clock sources selected by the states of S0 and S1.

Table C-4. Control Register: Pacer Clock Source Selection

S1	S0	Pacer Clock Source
0	X[1]	software start only
1	0	start on rising TRIG 0
1	1	start on counter/timer output

[1] X = data insensitive.

Note: Regardless of the state of the S0 and S1 bits, an A/D conversion can always be initiated by a write to register AD0.

- **DMAE** = Enable/Disable DMA. Direct memory access transfers are enabled when DMAE = 1 and disabled when DMAE = 0.

Note: You must set up the computer's DMA controller and page registers before enabling DMA on a DAS-16 Series board.

- **X** = This bit has no assigned function but can be written to and read from.
- **IL0 to IL2** = Interrupt level select. Selects the interrupt level for processing interrupts. Avoid using a level already assigned to another I/O device (for example, Level 6 is used by the floppy disk drive(s)). Table C-5 lists the interrupt levels selected by the states of IL0 through IL2.

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Table C-5. Control Register: Interrupt Level Selection Bits 4, 5, and 6

IL2	IL1	IL0	Interrupt Level
0	0	0	none (disabled)
0	0	1	none (disabled)
0	1	0	level 2
0	1	1	level 3
1	0	0	level 4
1	0	1	level 5
1	1	0	level 6
1	1	1	level 7

- **INTE** = Interrupt enable. This bit enables and disables the generation of interrupts. Interrupts are enabled when INTE = 1 and disabled when INTE = 0.

  If INTE = 1 and DMAE = 0, an interrupt is generated at the end of each A/D conversion when valid data is available. If INTE = 1 and DMAE = 1, an interrupt is generated when a Terminal Count (T/C) is received from the computer's DMA controller to signify completion of the DMA transfer.

Counter Enable Register (Base Address +Ah)

This 8-bit read/write register controls the operation of the following:

- 82C54 counter/timer
- 100kHz pacer clock

The counter enable register is set to 00h upon power-up (reset).

DAS-16 Series boards use an Intel 82C54 programmable interval counter/timer for pacing the ADC. Counters 1 and 2 of the 82C54 are cascaded and are driven by a 1MHz or 10MHz switch-configurable clock

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so that periods ranging from 10 microseconds to 0.12 pulses per hour for 10MHz and 1.192 pulses per hour for 1MHz can be programmed.

When programming the board for A/D conversions using the internal timer, bit 0 (CEN0) of this register and the IP0/TRIG 0/XPCLK input signal can be used to enable counters 1 and 2 of the 82C54, thereby initiating A/D conversions. To accomplish this, bits CEN0 and IP0 are NANDed and the output is routed to counter gates 1 and 2 of the 82C54.

The function of CEN1 is somewhat different. When CEN1 and CTR 0 CLOCK IN are both high, counter 0 input of the 82C54 is internally connected to a 100kHz clock source.

The CTR 0 CLOCK IN, CTR 0 GATE, and CTR 0 OUT of counter 0 are all brought out to external connections, so that the counter can be used as a waveform generator, a secondary timer, or a period counter using the gate and internal clock.

By disabling the internal 100kHz clock (by setting CEN1 = 0), external clock pulses can be connected to the CTR 0 CLOCK IN pin (21). In this mode, counter 0 functions as an event counter, or if the CTR 0 GATE input is connected to a timebase (for example, CTR 2 OUT), counter 0 can be used to determine frequency.

Bit assignments of base address +Ah are as follows:

7	6	5	4	3	2	1	0
X	X	X	X	X	X	CEN1	CEN0

The bit names are defined and used as follows:

- **CEN0 =** Counter/timer enable. In conjunction with the state of IP0/TRIG 0/XPCLK, this bit enables and disables counters 1 and 2 to provide a means of holding off trigger pulses from the counter/timer to the ADC until IP0 goes high. If CEN0 is low, IP0 has no control over the programmable interval timer.

  When CEN0 is logic 0, the counter/timers are enabled.

  When CEN0 is a logic 1 and IP0/TRIG 0/XPCLK is logic 0, the counter/timers are enabled.

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When CEN0 is a logic 1 and IP0/TRIG 0/XPCLK is logic 1, the counter/timers are disabled.

- **CEN1** = Counter 0 clock input control. If CEN1 = 0, then the external clock input, CTR 0 CLOCK IN, is enabled. If CEN1 = 1 then counter 0 is connected to the 100kHz internal crystal clock.

  This is useful if counter 0 is used for pulse width measurement, delay generation, frequency synthesis, or a secondary timer.

- **X** = These bits have no assigned function but can be written to and read from.

Programmable Gain (Base Address +Bh)

The programmable gain register is an 8-bit read/write register that sets the gain of the programmable gain amplifier. Only the bottom two bits are used, the upper six bits have no effect on the hardware and can be used by the programmer for any other purpose. Note that the Programmable Gain register is not cleared by power on reset, it must be explicitly loaded and initialized by the user.

Bit assignments of base address +Bh are as follows:

7	6	5	4	3	2	1	0
X	X	X	X	X	X	GN1	GN0

The bit names are defined and used as follows:

- **GN0 to GN1 =** Gain code select bits. These are used to select the gain.

Table C-6. Programmable Gain Register: Gain Selection Bits 0 and 1

GN1	GN0	DAS-16G1 Gain	DAS-16G2 Gain
0	0	1	1
0	1	10	2
1	0	100	4
1	1	500	8

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Programmable Interval Counter/Timer (Base Addresses +Ch, +Dh, +Eh, +Fh)

The Intel 82C54 programmable interval counter/timer is a flexible device consisting of three, independent, 16-bit, presettable down counters and a control register. Table C-7 maps counter/timer registers to their addresses.

Table C-7. Counter/Timer Address Map

Address	Register	Type
Base Address +Ch	Counter 0	Read/Write
Base Address +Dh	Counter 1	Read/Write
Base Address +Eh	Counter 2	Read/Write
Base Address +Fh	Counter control	Write Only

You can program each counter to divide by any integer in the range 2 to 65,535. Counters 1 and 2 are cascade-connected to form a 32-bit counter. The counter/timer clock source is a 10MHz precision, crystal oscillator. Principal uses of the 82C54 are as follows:

- A programmable timer for generating interrupts and clocking for periodic A/D conversions.
- A variable-frequency square-wave generator for testing and frequency synthesis.
- An event counter of external input pulses.
- A time-delay generator.

Counter/Timer Control Register (Base Address +Fh)

Bit assignments of base address +Fh are as follows:

7	6	5	4	3	2	1	0
SC1	SC0	RL1	RL0	M2	M1	M0	BCD

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The bit names are defined and used as follows:

- **BCD =** The BCD bit (0) can be used to program the counter to count in binary (modulus 2) or binary coded decimal (modulus 10) modes.

  Binary mode, with a full count of 65,535, provides a greater count range than the BCD mode, which has a 9,999 full-scale range.

  16-bit binary is enabled when BCD = 0 and 4-decimal decades is enabled when BCD = 1.

- **M0 to M2** = These bits control the functionality of the counters as shown in Table C-8.

Table C-8. 82C54 Counter/Timer Control Register: Selecting Functionality

M2	M1	M0	Function
0	0	0	Pulse on terminal count
0	0	1	Programmable one-shot
X[1]	1	0	Rate generator
X	1	1	Square wave generator
1	0	0	Software triggered strobe
1	0	1	Hardware triggered strobe

[1] X = data insensitive

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- **RL0 to RL1** = Control the type of read/load operations performed on counters, as shown in Table C-9.

Table C-9. 82C54 Counter/Timer Control Register: Bits 4 and 5

RL1	RL0	Operation
0	0	Counter latch
0	1	Read/load least significant byte (LSB)
1	0	Read/load most significant byte (MSB)
1	1	Read/load least significant byte (LSB), followed by most significant byte (MSB)

To minimize I/O port usage, the 16-bit counters of the 82C54 can be loaded or read by successive 8-bit writes or reads to the same I/O address if the RL0 and RL1 bits of the 82C54 counter/timer control register are both set high.

In the IBM PC 80X86 architecture, setting RL0 and RL1 both high is usually the most convenient setting. Data is written in least significant/most significant order and the 82C54 uses an internal flip-flop to keep track of the byte order. It is important not to get this flip-flop out of step when programming in this way (make sure your read/load instructions are in pairs).

If you are programming an IBM PC AT in assembly language, make sure that you put delays (short jumps) between back-to-back I/O instructions for correct operation. This precaution is based on the design of the IBM PC AT (see the IBM PC AT Technical Reference Manual) and does not apply to the 8088-based PC and 8086-based PC XT.

If you attempt to read the counters “on the fly” at a high input frequency, you will probably obtain erroneous data. This error is due partly to the rippling of the counter during the read operation and partly to the fact that the low and high bytes are read sequentially rather than simultaneously, making it highly probable that carries are propagated from the low to high byte during the read cycle.

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To circumvent these problems, you can perform a *counter latch operation* in advance of the read cycle. You can latch the counter by loading the RL0 and RL1 bits of the control register with 0s, which instantaneously latches the count of the selected counter in a 16-bit hold register.

An alternative method of counter latching (which has an advantage of operating simultaneously on several counters) is to use the *Readback Command*.

A subsequent read operation on the selected counter returns the held value. Counter latching is the only way of correctly reading a counter "on the fly" without disturbing the counting process. If you do not specify a counter-latching operation, the counter itself is read. You can rely only on directly read counter data if the counting operation is suspended while reading (by removing the clock input or taking the counter gate low).

For each counter, you are required to specify in advance the type of read or load operation that you intend to perform. You have a choice of loading/reading the high or the low byte of the count, or the low byte followed by the high byte.

This last mode is most generally used and is selected for each counter by setting the RL1 and RL0 bits to 1s. Subsequent read/load operations must be performed in pairs in this sequence, otherwise the internal sequencing flip-flop of the 82C54 gets out of step.

- **SC0 and SC1** = These bits control counter selection, as shown in Table C-10.

Table C-10. 82C54 Counter/Timer Control Register: Readback Command

SC1	SC0	Counter
0	0	0
0	1	1
1	0	2
1	1	Readback Command

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If the SC0 and SC1 bits are both set to 1, you can perform two types of operations. When CNT = 0 (see below), counters selected by C0 through C2 are latched simultaneously. When STA = 0, the counter status byte is read on accessing the counter I/O location. The status byte provides information on the current output state of the counter and its operating configuration.

Readback Command Byte

The Readback Command Byte is returned when SC1 and SC0 are 1. The format of the readback command byte is as follows:

7	6	5	4	3	2	1	0
SC1	SC0	CNT	STA	C2	C1	C0	0

The bit names are defined and used as follows:

- **C0 to C2** = Select the counters that are affected by CNT and STA. Table C-11 lists the bit conditions that select each counter.

Table C-11. Counter Status Byte Selection: Bits 0, 1, and 2

C2	C1	C0[1]	Selects
X	X	1	Counter 0
X	1	X	Counter 1
1	X	X	Counter 2

[1] X = data insensitive.

- **STA** = When set to 0, STA returns the Status Byte of the counter selected by C0 to C2.
- **CNT** = When set to 0, CNT latches the counter selected by C0 to C2. See Table C-11 for counter selected by C0 to C2.
- **SC0 and SC1** = The readback command occurs when SC1 and SC0 are both set to 1.

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Status Byte Format (Returned if STA =0)

The format of the status byte is as follows:

7	6	5	4	3	2	1	0
OUT	NC	RL1	RL0	M2	M1	M0	BCD

With the exception of bits 6 and 7, the definitions are the same as those defined at the beginning of this section. Bits 6 and 7 are defined and used as follows:

- **NC** = Null count; indicates when the last count loaded into the counter register has actually been loaded into the counter itself. The exact time of load depends on the selected configuration. Until the count is loaded into the counter itself, it cannot be read from the counter.
- **OUT** = Current state of counter output.

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D

The IBM PC DMA Structure

This appendix describes the DMA feature available to DAS-16 Series boards.

A slide switch on the DAS-16 Series board selects between levels 1 or 3 for DMA operations. The factory configuration is for level 1. If you want to use DMA and you have more than one Keithley board, or another card which uses Channel 1, then you will need to slide the switch to select Channel 3. If you are using an XT, the hard disk may be using level 3. DMA operations are available for A/D conversions only.

To obtain a higher speed of data transfer, the IBM PC uses an Intel DMA controller. The DMA controller improves transfer speed by moving data directly between an I/O device and memory, bypassing the CPU.

The DMA controller provides four prioritized, direct-memory-access (DMA) channels. Each channel responds to two control signals: a DMA request (DRQ) and a DMA acknowledge (DACK).

The A/D on DAS-16/16F/16G is triggered by the programmable timer or an external start pulse; it performs a conversion and issues two sequential DRQs at the end of conversion. On receipt of each DACK, the two bytes of data corresponding to each conversion are transferred to the memory location put on the address bus by the DMA controller. This transfer usually takes place in 5 to 9 microseconds and is undisturbed by interrupts, etc. Since the A/D data is latched and held until the end of the next conversion, the maximum sample rate is a minimum of 10 microseconds (A/D conversion time) for the transfer to take place. This is more than enough time, even with activity on higher-priority DMA levels.

When the DMA controller receives a DRQ, it issues a hold request (HRQ) to the 8088 CPU asking it to release the address and data bus to the DMA controller chip. As soon as the CPU is able to do this (within one machine

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cycle), it responds by returning a hold acknowledge (HLDA) to the DMA controller to tell it that it has the bus. The DMA controller then supplies the memory address on the address bus, issues a DACK to the I/O device to tell it to place its data on the data bus, and also provides simultaneous I/O read (IOR) and memory write pulses (MEMW) to effect the data transfer. Control is then returned to the CPU for at least one machine cycle before another DMA cycle is possible (this prevents the DMA controller from hogging the bus).

The DMA controller handles a total of four DMA channels (three of which are available on the expansion bus), as follows:

Table D-1. DMA Channels

DMA Level	Function	Signals	Priority
0	Memory refresh	Not on bus	Highest
1	Not used	DRQ1/DACK1	
2	Floppy disk(s)	DRQ2/DACK2	
3	Hard disk (XT)	DRQ3/DACK3	Lowest

Note: DMA Channel 0 is used by the system to perform a dummy read of each memory location every 15 microseconds and thereby refresh the dynamic memory. It is important not to interfere with the setup or operation of Channel 0 as this may lead to loss of memory and a computer crash.

- DMA Level 2 is always used by the floppy disk(s) to read/write data; it cannot be shared with other devices.
- DMA Level 1 is not committed to any internal device and is generally available on all versions of PCs; although, if you have them installed, some local area network interfaces may use this level.
- On floppy-disk-only machines, DMA Level 3 is also free. If the PC has a hard disk, Level 3 may be used by the hard disk, but depending on the type of hard disk controller used it may be free. The hard-disk controller card contains the fixed disk BIOS. Some manufacturers

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make use of block moves (MOVS), others use hardware DMA to transfer data between the disk controller and DOS disk buffers in memory. This is transparent to the user as the BIOS calls are functionally identical. However, when you come to install another peripheral that uses DMA, it is useful to know whether your particular controller uses Level 3 or is free. Running LEV3.EXE performs a check. If you find it is unused, then the DAS-16/16F/16G can be safely set to this level.

The DAS-16/16F/16G may be operated on either of Levels 1 or 3. The DMA level is selected by the slide switch marked DMA above gold edge connector P1. Since the DAS-16/16F/16G is a relatively slow device in terms of DMA service, the higher priority Level 1 offers little real performance advantage over Level 3. Note also that until a DMA operation is enabled on the DAS-16/16F/16G, the DMA request (DREQ) line from the board is disabled (tri-state). You can therefore share it with other devices on the same level as long as they are not enabled at the same time.

Page Register and DMA Controller Functions

The DMA controller on the system board was designed in the days of 8-bit CPUs and 64K memories; it can handle only a 16-bit address (A0-A15). Since the 8088 uses a 20-bit address bus, the high-order bits (A16-A19) are provided by a set of supplemental registers for each DMA level. These are known as the DMA page registers, and although there are four DMA levels, there are only three page registers. DMA Level 0, used internally for memory refresh, does not really require a page register since it refreshes all pages regardless of the A16-A19 address bits. To economize, it shares the same page register as Level 1. The page register I/O locations are as follows:

Table D-2. DMA Page Register I/O Locations

DMA Level	Page Register	I/O Location
0 and 1	1	&H83
2	2	&H81
3	3	&H82

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The DMA controller contains four registers that must also be initialized before a DMA transfer. These are as follows:

1. Mode register: Controls type of operation.
2. Base & current address: Sets start memory address.
3. Word count: Sets number of transfers.
4. Mask: Enables/disables DMA levels.

In addition, a fifth register, the Command register, is set by the BIOS on boot up and should not be altered.

Before a DMA operation can be started, all these registers must be initialized. This is taken care of by DriverLINX; but, if you intend to write your own driver, call the Technical Support Department for guidance. In addition to setting up the DMA controller and page registers, the DAS-16/16F/16G control register must also be loaded to enable the DAS-16/16F/16G DMA hardware.

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