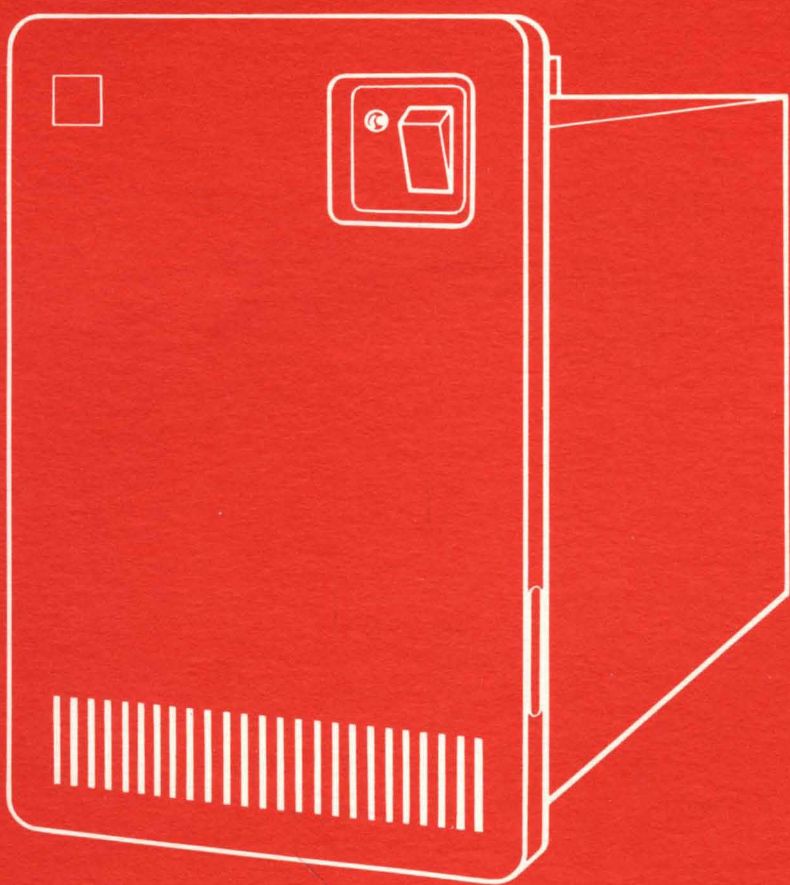
IBM

GA34-0027-0

Series/1

4982 Sensor Input/Output Unit Description



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First Edition (November 1976)

Changes are periodically made to the information herein; any such changes will be reported in subsequent revisions or Technical Newsletters.

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Contents

Preface

This publication contains the IBM Series/1 4982 Sensor Input/Output Unit Feature descriptions and the 4982 feature performance specifications necessary for the user to design a sensor I/O system application. It also contains information for programming the applications of the 4982 unit in Series/1 machine language.

Introductory material necessary to understand this book is presented in the prerequisite publications listed below. In addition, a general knowledge of sensor input/output such as contained in the IBM data processing application manual, *Principles of Data Acquisition Systems,* GE20-0090, is assumed.

ORGANIZATION OF THIS BOOK

This publication contains three chapters and three appendixes.

Chapter 1 introduces the IBM Series/1 4982 Sensor Input/Output Unit, its associated sensor I/O feature cards, and the Sensor Input/Output Unit Attachment Feature card. Specific topics covered are:

- Sensor Input/Output Unit Attachment Feature
- Digital Input/Process Interrupt (DI/PI)–Isolated Feature
- Digital Input/Process Interrupt (DI/PI)–Nonisolated Feature
- Digital Output (DO)–Nonisolated Feature
- Analog Input (AI) Control Feature
- Amplifier–Multirange Feature (AI)
- Multiplexer–Solid State Feature (AI)
- Multiplexer–Reed Relay Feature (AI)
- Analog Output (AO) Feature

Chapter 2 describes in detail the sensor I/O unit performance specifications useful in the design of a sensor I/O subsystem application.

Chapter 3 describes the use of the sensor I/O feature machine language commands and functions.

Appendix A provides IBM definition of analog performance terminology.

Appendix B is a detailed description of the solid state multiplexer low pass filter selection.

PREQUISITE AND RELATED PUBLICATIONS

Prerequisite Series/1 publications are the *IBM Series/1 Model 3 4953 Processor and Processor Features Description* Manual, GA34-0022, or the *IBM Series/1 Model 5 4955 Processor and Processor Features Description* Manual, GA34-0021.

Related Series/1 publications are the *IBM Series/1 System Summary,* GA34-0035 and the *IBM Series/1 Physical Planning Manual*, GA34-0029.

Chapter 1. 4982 Sensor Input/Output Unit and Attachment Feature

INTRODUCTION

The IBM Series/1 4982 Sensor Input/Output Unit is a flexible, modular approach to attaching sensor user processes to the IBM Series/1 (Figure 1-1). The 4982 sensor I/O unit attaches to the Series/1 by means of the IBM 4982 Sensor Input/Output Unit Attachment Feature, a prerequisite for the sensor I/O unit. Location of the attachment feature, which controls the transfer of information between the processor and the 4982, may be in any of the following system units:

- IBM Series/1 Model 5 4955 Processor
- IBM Series/1 Model 3 4953 Processor
- IBM Series/1 4959 Input/Output Expansion Unit

Together, the sensor I/O unit and the attachment feature provide the Series/1 user with a broad base for general digital and analog I/O feature applications. Optimum use of sensor I/O feature space is attained by the flexibility of feature locations. Planned modularity allows for easy expansion of a small initial installation to a larger configuration as needs change.

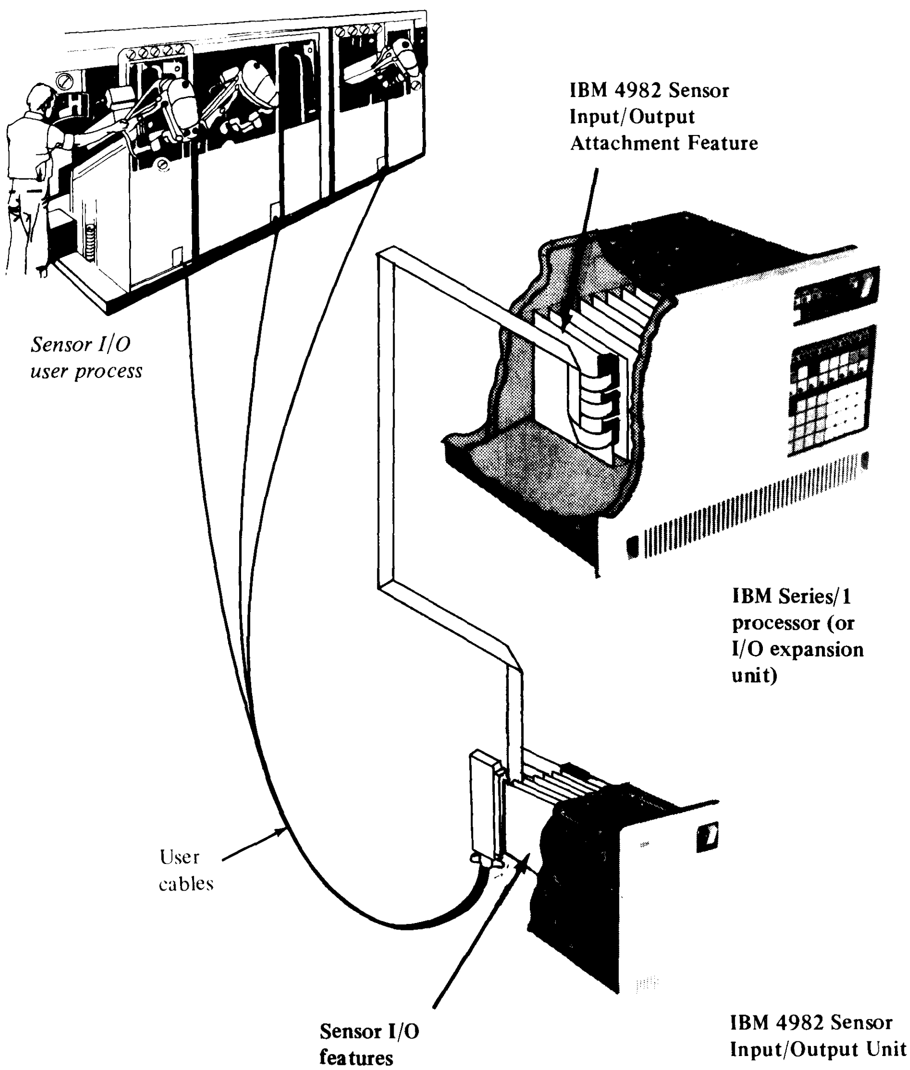


Figure 1-1. Series/1 sensor I/O application

Located near the processor in a rack enclosure, the 4982 sensor I/O unit is a subsystem of the Series/1—providing an extensive subset of the processor I/O channel for control, data transfer extensive error analysis and recovery for the sensor I/O processes.

The 4982 sensor I/O unit offers the following features:

- Analog Input
  - —Analog Input Control
  - —Amplifier—Multirange
  - —Multiplexer—Solid State
  - —Multiplexer—Reed Relay
- Analog Output
- Digital Input/Process Interrupt—Isolated
- Digital Input/Process Interrupt—Nonisolated
- Digital Output—Nonisolated

UNIT DESCRIPTION

The 4982 Sensor Input/Output Unit (Figure 1-2) is a half-rack unit, equipped with the following:

- A nine card socket circuit board (eight sensor I/O feature sockets and one termination socket)
- A 3.1 m (10 ft) attachment feature cable
- Cable termination and control functions (termination card)
- A power supply

The eight feature sockets and the termination card are accessable from the rear of the unit. The termination card, which connects the 4982 to the attachment feature cable, contains termination and control logic for the unit. Located in the front section of the unit, the 4982 power supply receives input power from the individual primary power distribution panel in the 4997 Rack Enclosure.

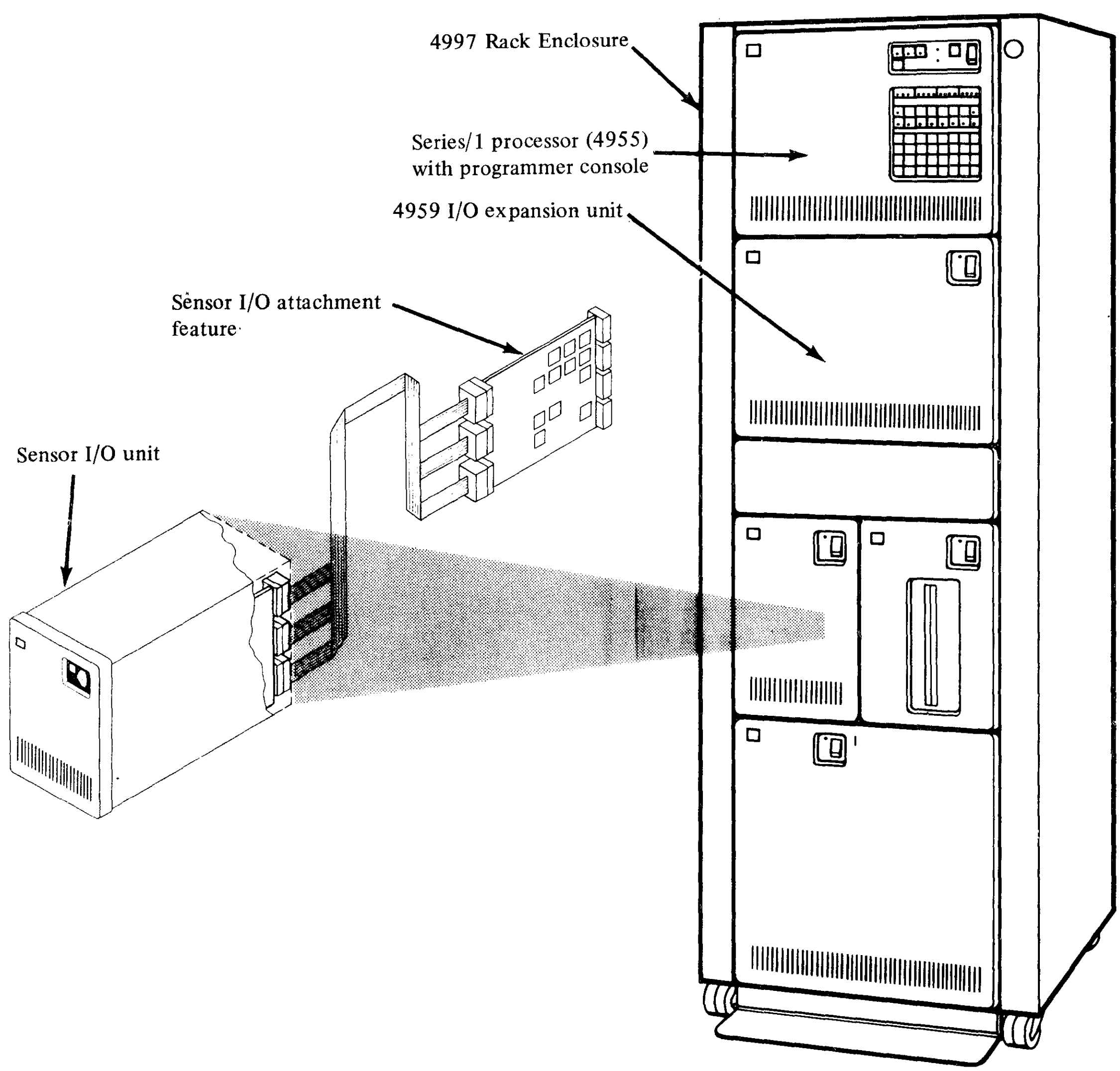


Figure 1-2. 4982 Sensor Input/Output Unit

Card locations (slots) for the 4982 termination card and sensor I/O features are shown in Figure 1-3. Sensor I/O features are installed in any location and in any order, with the exception of analog input. The analog input control feature (if used) occupies card location 0, and the multirange amplifier feature (if used) occupies card location 1. A multiplexer feature occupies the location adjacent to the analog input control feature or to the multirange amplifier feature. Additional multiplexer features occupy successively adjacent locations.

The attachment feature may be installed in either a 4953 or 4955 Series/1 processor or a 4959 I/O expansion unit, see Figure 1-1. The user provides the cables to connect an application to the various 4982 sensor I/O features.

The suggested user cable connector is a commercially available 56 pin connector with a protective hood. This connector requires no special tools and provides an orderly method of terminating the large number of connections required for attaching a typical user process.

Direct program control commands are used for data transfer between the processor I/O channel and the sensor I/O features. The features are individually addressed from the processor using assigned feature addresses. The sensor I/O and attachment features are extremely flexible, employing parameters variable either by programming or feature card plugging. Chapter 3 explains direct program control, feature addressing, variable parameters, and the commands used with each feature.

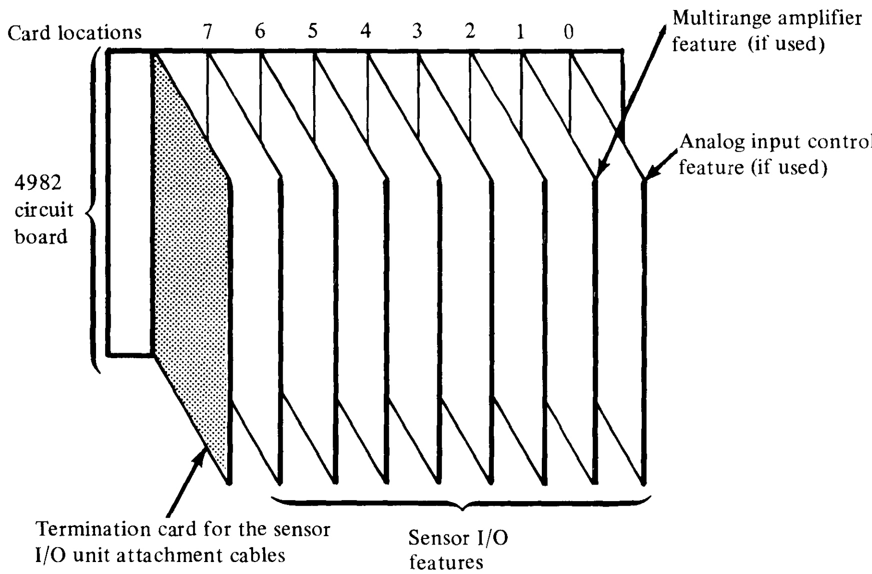


Figure 1-3. Sensor I/O unit card locations (rear view)

ATTACHMENT FEATURE

The sensor I/O unit attachment feature logically adapts the processor I/O channel to the 4982 unit termination card. In turn, the termination card contains the logic to adapt the attachment feature to the sensor I/O features. Together, 4982 sensor I/O unit and the attachment feature furnish the IBM Series/1 user with a versatile sensor I/O subsystem (Figure 1-4.)

The attachment feature performs the following functions:

- Interprets and executes commands from the channel
- Changes the I/O device address to a unique feature address
- Provides the path for data between the processor I/O channel and the 4982
- Furnishes status information to the processor I/O channel
- Performs diagnostic functions for itself and for the 4982 termination card

ANALOG INPUT FEATURES

Analog input (AI) features (Figure 1-5) furnish AI control, analog-to-digital conversion (ADC), and AI signal multiplexing for the Series/1. AI features are grouped together because at least two features are required to perform any AI application–the AI control feature and a multiplexer feature. Basically the AI control feature consists of control and voltage conversion logic. The multiplexer feature (solid state or reed relay) selects the desired AI signal for conversion to a binary value. The multirange amplifier feature (a programmable, seven range amplifier) is optional. For definition of analog terms refer to Appendix A.

Analog Input Control Feature

The AI control feature contains the following circuit logic for the AI features:

- Twelve bit (including sign bit) successive approximation ADC with an input voltage range of ±5 volts.
- Logical zero correction (reduces offset drift errors due to temperature and aging)
- Error checking and status
- Control

Only one AI control feature is used in a 4982 unit.

Amplifier–Multirange Feature

The multirange amplifier feature improves measurement resolution for low amplitude AI signals (full-scale ranges of ±10 m V through −500 m V to +5V). If the multirange amplifier feature is used, the AI features can read voltages in seven programmable ranges (see "Analog Input Commands" in Chapter 3). Only one multirange amplifier feature is used in a 4982 unit.

Multiplexer–Solid State Feature

The solid state multiplexer feature provides the user with sixteen 2-wire analog input channels each having an input range of up to ±5V. Fast scanning and sampling rates are obtainable with this feature. This feature furnishes a program controlled means of selecting a single user input to the ADC (through the multirange amplifier if used). Solder terminals are included on the feature for user addition of low-pass filters (see Appendix B). Adding low-pass filters reduces the feature's susceptibility to high frequency electrical noise.

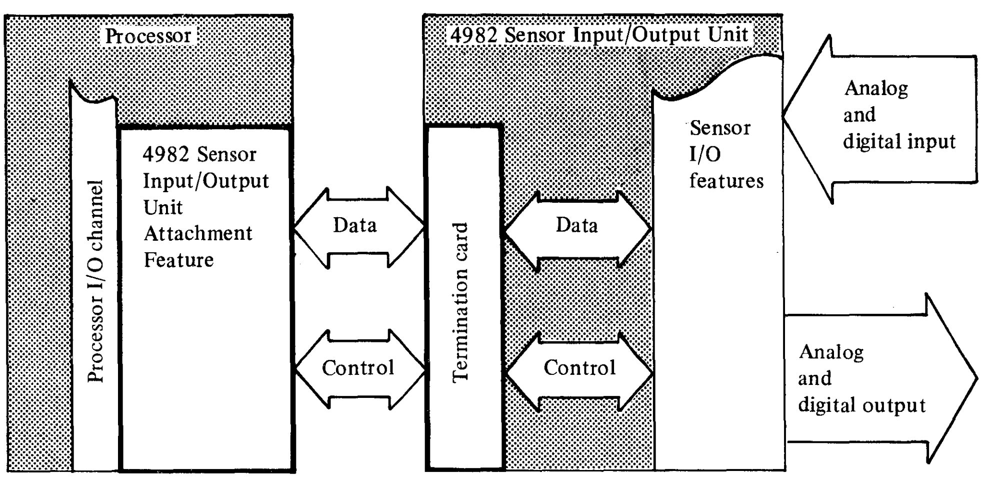


Figure 1-4. Sensor I/O subsystem simplified data flow

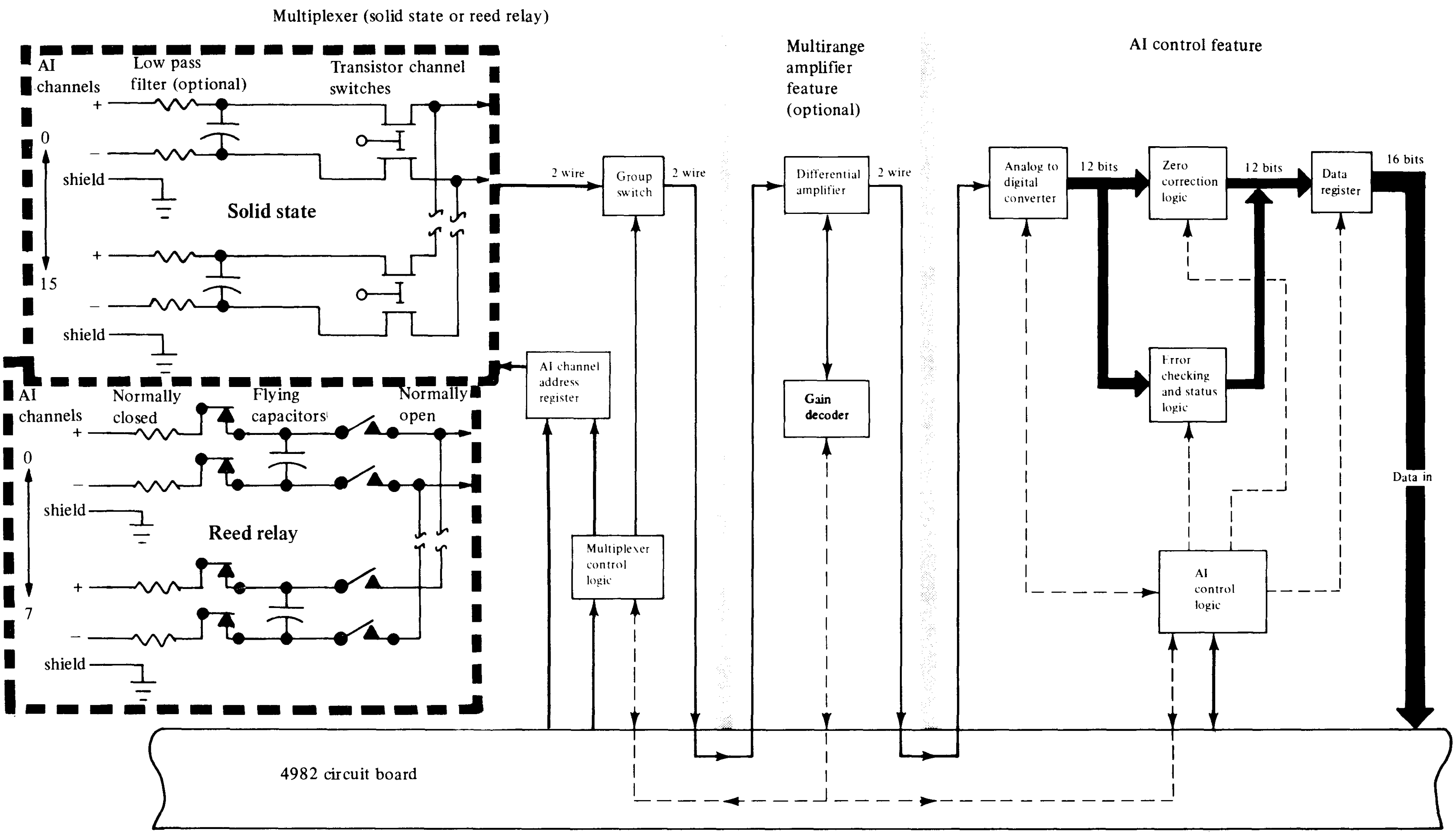


Figure 1-5. AI features

Multiplexer–Reed Relay Feature

Using the reed relay multiplexer feature provides the user with eight 2-wire analog input channels each having an input range of +5V to −500mV. This feature employs the *flying capacitor* principle to isolate the common-mode voltage (up to 200 volts) from the internal circuitry and to provide high common-mode rejection. The multiplexer feature furnishes a program-controlled means of selecting a single user input to the ADC (through the multirange amplifier feature, if used).

ANALOG OUTPUT FEATURE

The analog output (AO) feature (Figure 1-6) uses a digital-to-analog converter to convert a binary digital value to an analog output voltage of the corresponding value. This feature provides two points of nonisolated analog output. Each point has three selectable output voltage ranges. The ranges are selected by jumper plugs on the feature card. The range is selected when the feature is ordered, and may be changed by the user. User connections to each point are made to screw terminals.

DIGITAL INPUT FEATURES

There are two versions of the digital input (DI) feature–isolated digital input/process interrupt (DI/PI) and nonisolated DI/PI (Figure 1-7). With the exception of the input characteristics these two features are identical. The differences in input characteristics is discussed later in this chapter.

The DI/PI features are versatile, programmable features of the sensor I/O unit. These features, under program control, may be used in three separate modes:

- Processor initiated (not in response to an interrupt)
- External sync interrupt initiated
- Process interrupt initiated

With processor initiated mode, the processor reads the DI register without an interrupt.

External sync interrupt initiated mode requires the feature to be armed (or enabled) for external sync. The user external sync input interrupts the processor to indicate a DI external sync operation; the DI register is latched and available for reading. The external sync mode relieves the Series/1 processor of DI polling and allows up to 16 DI register bits to be set asynchronously and read as a single group.

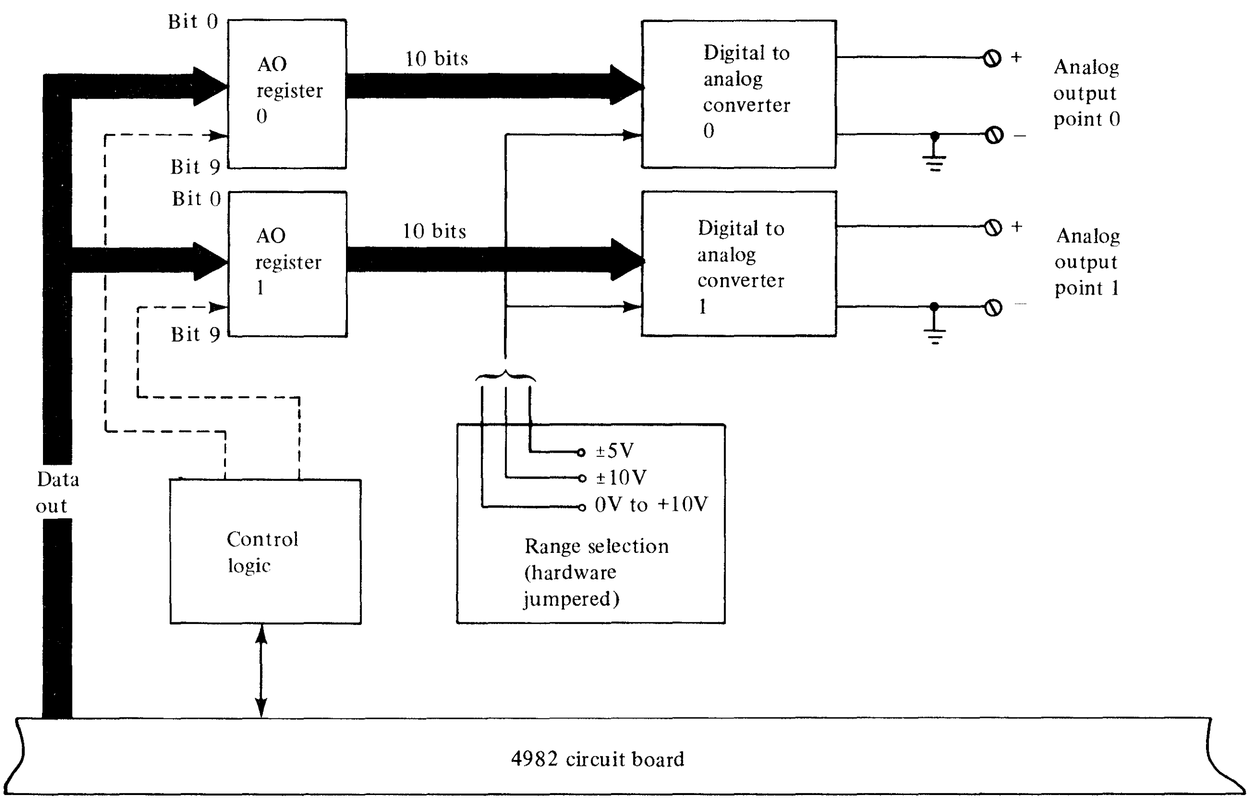


Figure 1-6. AO feature

Process interrupt (PI) initiated mode requires the feature to be armed for PI. Activating any PI register latch presents a PI interrupt to the Series/1 processor and indicates the PI register is available for reading. Activation of additional PI register latches will not create additional interrupts until the PI register is reset. DI diagnostic operations are also performed with the DI/PI feature.

The three program modes can be combined to provide the user with an extremely flexible DI/PI process control. Also, due to the versatile design of the DI/PI features, certain modes may be program overlapped (see Chapter 3, "Digital Input/Process Interrupt Feature Commands").

Digital Input/Process Interrupt–Isolated Feature

DI/PI isolation, achieved by photo couplers, allows the user signal source ground reference to be different from the sensor I/O unit ground reference. Improved common-mode rejection is provided with the isolated DI/PI feature. This feature accepts only voltage level inputs (no contact sense). Each of the 16 points has both high and low level inputs.

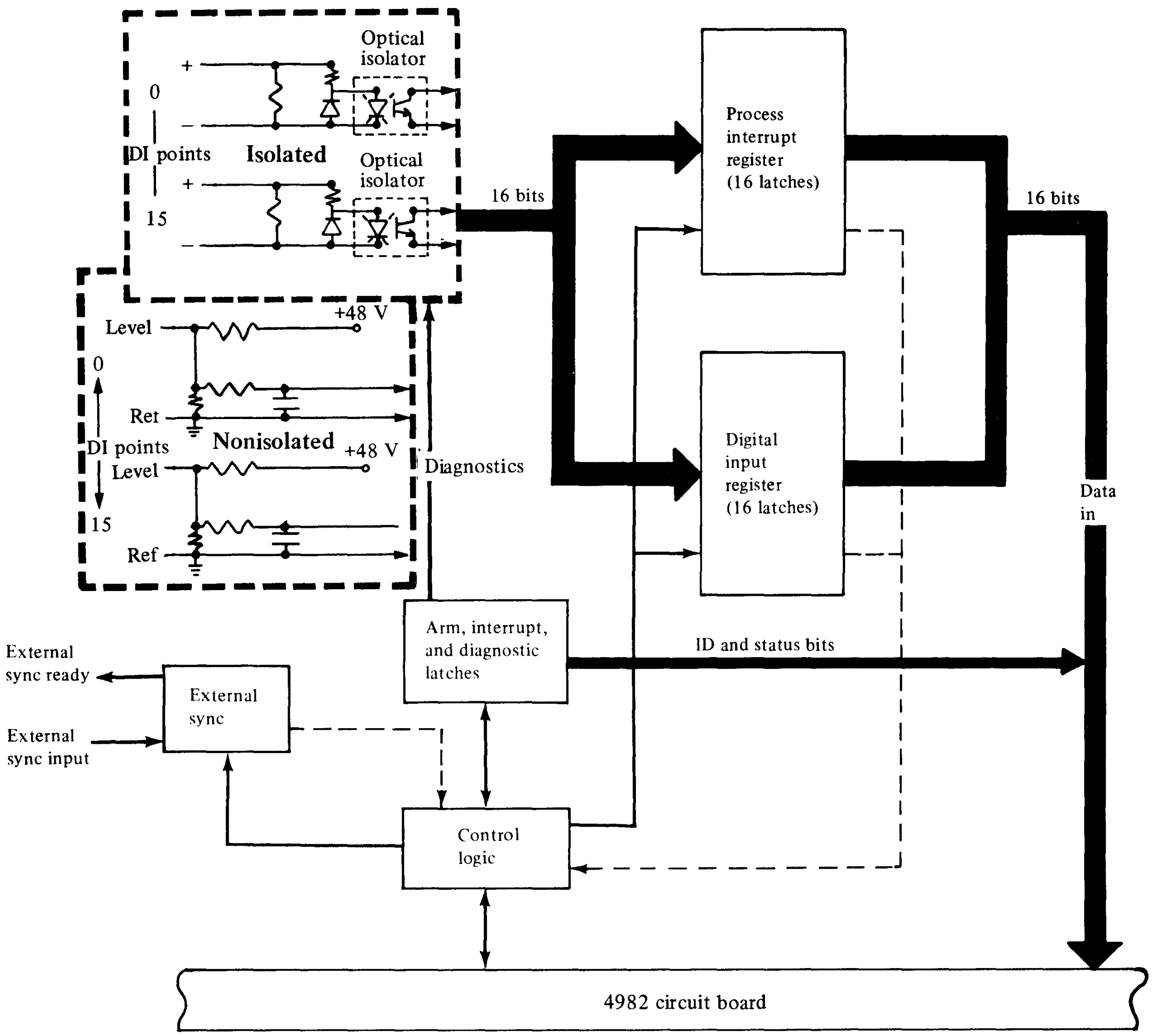


Figure 1-7. DI/PI features (isolated or nonisolated)

Digital Input/Process Interrupt–Nonisolated Feature

The nonisolated DI/PI feature is similar to the isolated DI/PI feature with exception of the following:

- Ground reference for all user input points is the sensor I/O unit chassis
- A process interrupt input is sensed as a negative transition
- No common-mode voltage is allowed
- Each of the 16 input points, with high or low level capabilities, can detect either user contact closure (contact sense) or user voltage levels (voltage sense)

A +48 volts dc is supplied by the 4982 to sense the opening and closing of the user contacts in the contact sense application. The user contacts are connected directly to the input terminals.

The absence or presence of a user voltage is sensed in the voltage sense application. The user voltage is connected to the input terminals and is referenced to ground.

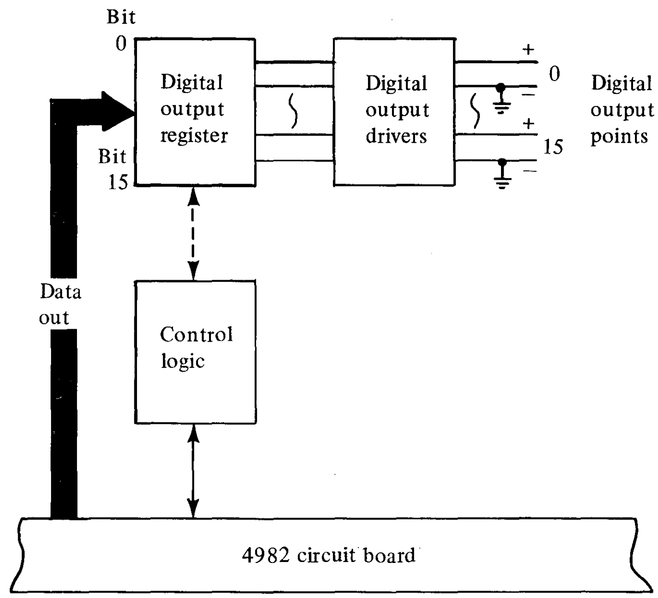


Figure 1-8. DO feature

DIGITAL OUTPUT-NONISOLATED FEATURE

The nonisolated digital output (DO) feature (Figure 1-8) provides 16 points of solid state nonisolated digital output. The DO feature contains one group of 16 grounded emitter output transistors. A binary one turns the transistor on, causing a negative transition. A binary zero turns the transistor off, causing the output to go to +5.5 V dc maximum or to the user supply voltage level (whichever is larger). All 16 bits are written to the output in parallel and latched until a new word is loaded into the DO register.

The DO feature switches user loads, with a user supplied voltage, or drives TTL loads directly. User supplied voltage (a maximum of +52.8 volts dc) is referenced to processor ground. Each point is capable of shunting or switching up to 250 milliamps of current.

CONFIGURATIONS

Figure 1-9 summarizes sensor I/O feature configurations.

The following are samples of different 4982 configurations, showing the flexibility of the 4982 features:

- 64 DI/PI points and 64 DO points
- 32 DI/PI points, 32 DO points, 2 AO points, and 32 solid state multiplexer channels with AI control only (single range)
- 16 DI/PI points, 16 DO points, 2 AO points, and 24 reed relay multiplexer channels with AI control and multirange amplifier

SENSOR INPUT/OUTPUT APPLICATIONS

The 4982 Sensor Input/Output Unit is used with Series/1 to monitor and control the user processes. Sensors installed at equipment being monitored send digital or analog input signals to the computer. The input signals represent the status of the activity being monitored, and the computer translates the signals into meaningful data. The computer can be programmed to accept the input signals on a priority basis, measure and/or record the data, check the data against predetermined standards, and return output signals to the attached equipment.

Sensor I/O can be used in many ways; for example, it can be used to monitor large numbers of manufacturing machines, to control one or more continuous or batch processes, or to monitor one or more sensor-based inputs from a test instrument. Input signals to the computer can come from analog transducers and from digital sources, such as contact closures. Computer output (both analog and digital) can control many kinds of displays, recorders and control mechanisms.

Designed for flexibility, Series/1 with sensor I/O can serve a wide variety of applications in:

- Data acquisition
- Process control
- Plant automation
- Laboratory automation
- Other

These applications:

- Collect data from instruments or sensors associated with a physical operation
- Generate signals, operator messages, or reports which in turn control some aspect of the associated physical operation

So that control can be efficient and timely, applications often require that data be acquired on a real time basis. Applications differ in the balance sought between data acquisition, control, and the required response times.

When designing a data acquisition system for either a data-logging or a real time operating environment, certain aspects of the equipment specifications must be considered, such as:

- Output signal levels
- Signal conditioning requirements
- Required sampling rates
- Resolution and accuracy
- System interrupts
- Operating environment

Knowledge of these specifications guides you in selecting the right components for a configuration.

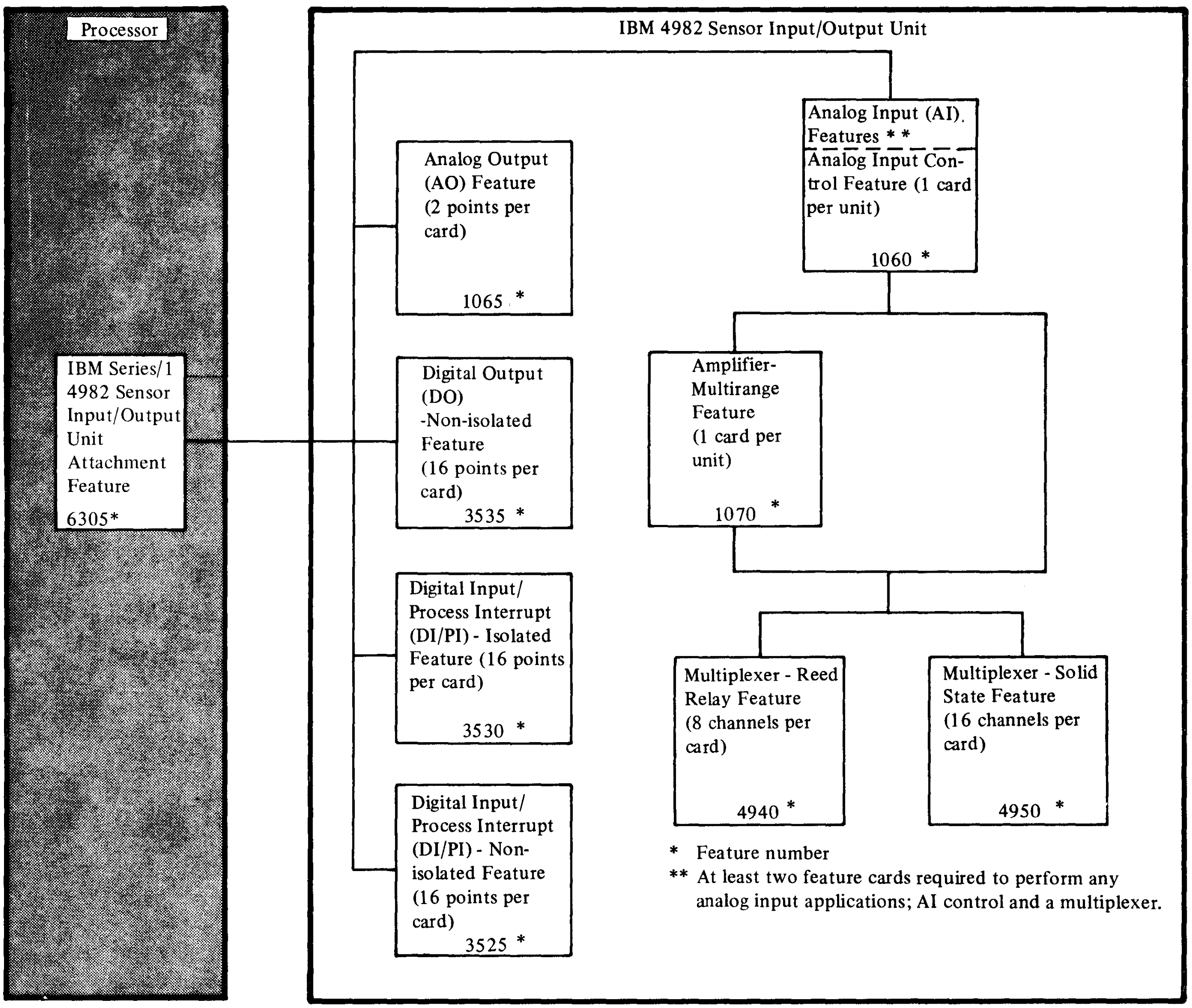


Figure 1-9. IBM Series/1 4982 Sensor Input/Output Unit configurator

Chapter 2. Feature Performance Specifications

Successful Series/1 sensor I/O installation requires a thorough knowledge of the 4982 sensor I/O unit performance specifications. This chapter contains detailed specifications for all 4982 features. These specifications are designed to aid the user in feature selection and usage for a sensor I/O application. The feature specifications are presented in the following sequence:

1 Analog input–Solid State Multiplexer Feature

2 Analog Input–Reed Relay Multiplexer Feature

3 Analog Output Feature

4 Digital Input/Process Interrupt–Isolated Feature

5 Digital Input/Process Interrupt–Nonisolated Feature

6 Digital Output–Nonisolated Feature

Analog input (AI) features performance specifications, using a solid state or reed relay multiplexer, apply when the following conditions are met:

- User environment is at reference conditions
- AI features have been calibrated at reference conditions
- Operating limits are not exceeded
- The 4982 is at thermal equilibrium (power on for ten minutes with all covers installed/closed)

AI and AO features specifications include the effect of all errors intrinsic to the features, exclusive of the effect of external electromagnetic interference or errors caused by user-provided cables.

The DI/PI and DO features operate within the reference conditions stated in the *IBM Series/1 Physical Planning Manual*, GA34-0029. For definitions of analog terms, refer to Appendix A.

Also included in this chapter are the following illustrations and tables:

7 Features User Connections

8 Feature Cycle Time Samples

1 PERFORMANCE SPECIFICATIONS–AI FEATURES, SOLID STATE MULTIPLEXER (PART 1 OF 2)

Reference conditions: temperature–25° C ±2.8° C (77° F ±5° F); relative humidity–40% to 60%

All specifications apply to user connections.

Feature capacity
The solid state multiplexer card contains 16 single ended two-wire channels with a maximum of 112 channels (96 channels with multirange amplifier) per 4982.

Operating voltage limits
Normal-mode–±5V dc or ±5V peak ac
Common-mode–±10V dc or ±10V peak ac
Normal-mode plus common-mode–±10V dc or ±10V peak ac

Overvoltage limits
Maximum ±15V dc or ±15V peak ac

Overload
Positive overloads occur when the input signal causes the ADC output binary value to equal or exceed 2047. Negative overload occurs when the input signal causes the ADC output binary value to be equal to or more negative than minus 2048.

Common-mode rejection ratio
With multirange amplifier feature–minimum 70 dB from 0–60 Hz.
Without multirange amplifier feature–not applicable. When the multirange amplifier feature is not used, the AI feature group with solid state multiplexer feature is single-ended. The negative input is connected to the unit ground in this case.

Differential input resistance
10 Megohms minimum (with multirange amplifier

Source resistance
1 kilohm maximum

Source unbalance
250 ohms maximum

Crosstalk
100 db minimum

Input voltage ranges A
Without multirange amplifier feature–±5V.
With multirange amplifier feature–±10 mV, ±20mV, ±50 mV, ±100 mV, ±200 mV, ±500 mV, and ±5V.

Resolution B
The analog-to-digital converter converts the voltage to an eleven bit plus sign bit binary number. Eleven bits provide a total ADC output binary value of 2048.

Accuracy C **and Repeatability** D
The total accuracy specified for each range includes the repeatability specification of that range and the effects of short-term drift (less than 24 hours). These specifications are valid if no capacitors are soldered to the solder terminals, or if 10 microfarad polycarbonate capacitors are soldered to the terminals. Without zero correction, accuracy and repeatability are expressed in % of full scale ±1/2 of the least significant bit value (%FS±1/2LSB). With zero correction, the values are expressed as %FS±1LSB.

Temperature coefficient E
The AI features are generally calibrated at referenced conditions. The zero correction logic provides temperature coefficient characteristics that make recalibration unnecessary when the ambient temperature changes. The user should recalibrate the AI features if the area where the Series/1 is installed has a significantly higher or lower ambient temperature. Such recalibration minimizes the input voltage range shift that accompanies a change. When the zero correction feature is not used, it is recommended that a program routine be used to subtract offset errors. Temperature coefficient is expressed in % of full scale per degree Celsius (%FS/° C).

A *Input voltage range (millivolts)*	B *Resolution (microvolts)*	C *Accuracy (%FS±½LSB)*	D *Repeatability (%FS±½LSB)*	E *Temperature coefficient* with zero correction (%FS/ °C)	*without zero correction (%FS/ °C)*
5000	2,441.4	± .05	± .045	± .005	± .02
500	244.14	± .08	± .065	± .01	± .025
200	97.656	± .12	± .085	± .01	± .03
100	48.828	± .15	± .09	± .01	± .04
50	24.414	± .21	± .13	± .01	± .06
20	9.766	± .35	± .22	± .01	± .12
10	4.883	± .55	± .36	± .01	± .20

PERFORMANCE SPECIFICATIONS–AI FEATURES, SOLID STATE MULTIPLEXER (PART 2 OF 2)

Sampling rate

100 samples per second maximum using a 10 microfarad capacitor low-pass filter (15 Hertz bandwidth). By using smaller capacitors, faster sampling rates may be achieved with some degradation of accuracy and repeatability.

Long-term drift F

The long-term drift error is eliminated by recalibration. The drift is greatest soon after manufacture and gradually declines as components age. Long-term drift is expressed in % of full scale per 6 months (%FS/6mos).

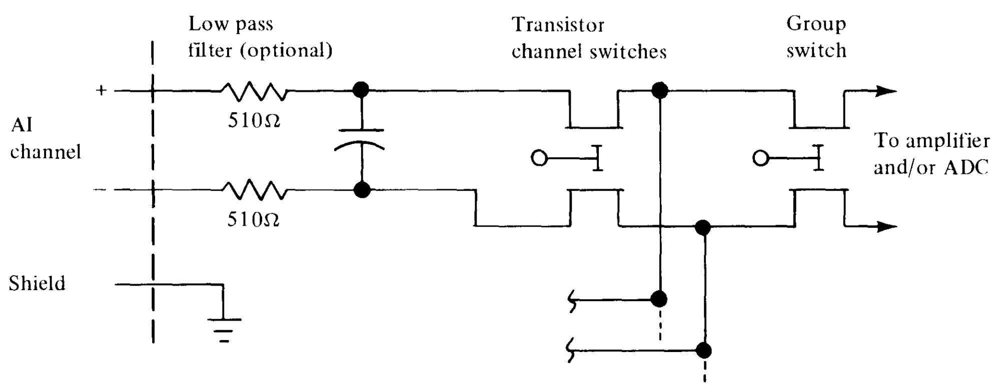
Total read time G

Total read time is derived from best and worst case conversion cycles.

Conversion time H

Conversion times do not include command and interrupt cycle times.

Input voltage range (millivolts) A	*Long-term drift* F		*Total read time* G		*Conversion time* H	
	with zero correction (%FS/mos)	*without zero correction (%FS/mos)*	*with zero correction*	*without zero correction*	*with zero correction*	*without zero correction*
5000	.030	.090	165 μs	105 μs	132 μs	72 μs
500	.031	.094	205 μs	125 μs	172 μs	92 μs
200	.033	.102	205 μs	125 μs	172 μs	92 μs
100	.036	.114	205 μs	125 μs	172 μs	92 μs
50	.043	.138	205 μs	125 μs	172 μs	92 μs
20	.063	.210	205 μs	125 μs	172 μs	92 μs
10	.103	.330	205 μs	125 μs	172 μs	92 μs



Solid state multiplexer equivalent circuit

2 PERFORMANCE SPECIFICATIONS–AI FEATURES, REED RELAY MULTIPLEXER (PART 1 OF 2)

Reference conditions: temperature–25°C ±2.8°C (77°F ±5°F); relative humidity–40% to 60%

All specifications apply to user connections.

Feature capacity
The reed relay multiplexer card contains 8 double ended two-wire channels with a maximum of 56 channels (48 channels with multirange amplifier) per 4982.

Operating voltage limits
Normal-mode—−500 mV to +5V dc or −500 mV to +5V peak ac
Common-mode–Maximum ±200V dc or ±200V peak ac; 10VA maximum

Overvoltage limits
Normal-mode—−1V dc to +6V dc, or −1V to +6V peak ac
Common-mode– ±200V dc or ±200V peak ac; 10VA maximum

Overload
Positive overload occurs when the binary input signal causes the ADC output binary value to equal or exceed 2047. Negative overload occurs when the input signal causes the ADC output binary value to be equal to or more negative than minus 2048.

Common-mode rejection ratio
120 dB minimum from 0 to 60 Hz for all conditions 1 kilohm source unbalance

Differential input resistance
10 Megohms minimum

Source resistance
1 kilohm maximum

Source unbalance
1 kilohm maximum

Input filter
One pole, low-pass, balance RC filter, .64 Hz bandwidth

Crosstalk
120 dB minimum (common-mode and normal-mode)

Sampling rate
One sample per second per channel maximum. Faster sampling rate may be achieved with some degradation of accuracy and repeatability, and decreased life time for the reed relays.

Input voltage ranges A
With multirange amplifier– ±10 mV, ±20mV, ±50 mV, ±100 mV, ±200 mV, ±500 mV, and −500 mV to +5V. Without multirange amplifier—−500 mV to +5V.

Resolution B
The analog-to-digital converter converts the voltage to an eleven-bit plus a sign bit binary number. Eleven bits provide a total ADC output binary value of 2048.

Accuracy C **and Repeatability** D
The total accuracy specified for each range includes the repeatability specification for that range and the effects of short-term drift (less than 24 hours). Accuracy and repeatability are expressed in % of full scale ±1 of the least significant bit value (%FS±1 LSB). With the reed relay multiplexer, zero correction is always used.

Temperature coefficient E
The AI features are generally calibrated at reference conditions. The zero correction logic provides a temperature coefficient characteristic that makes recalibration unnecessary when the ambient temperature changes. However, the user should recalibrate the AI features if the Series/1 is installed in an area with a significantly higher or lower ambient temperature. Zero correction is always performed since no speed advantage can be gained by eliminating it. Temperature coefficient is expressed in % of full scale per degree Celsius (%FS/°C).

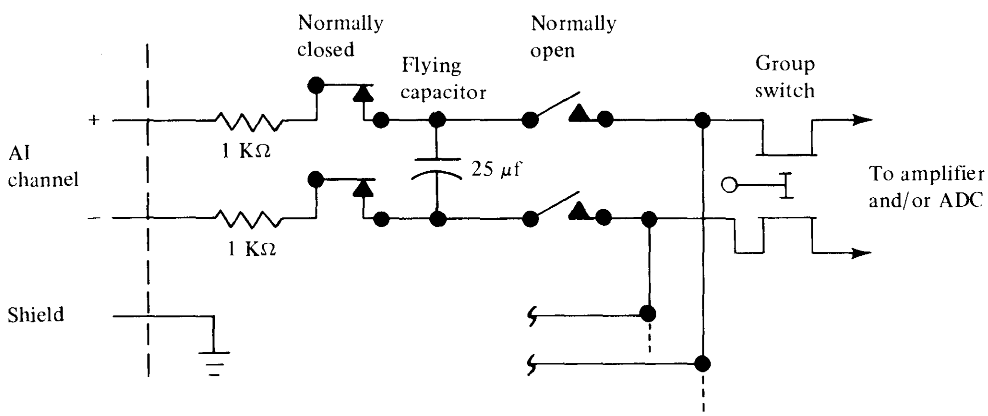
Input voltage range (millivolts) A	B *Resolution (microvolts)*	C *Accuracy (%FS±1LSB)*	D *Repeatability (%FS±1LSB)*	E *Temperature coefficient* *with zero correction (%FS/°C)*	*Temperature coefficient* *without zero correction (%FS/°C)*
5000	2,441.4	± .05	± .045	± .005	(zero correction is always used)
500	244.14	± .08	± .065	± .01	
200	97.656	± .12	± .085	± .01	
100	48.82	± .15	± .09	± .01	
50	24.414	± .21	± .13	± .01	
20	9.766	± .35	± .22	± .01	
10	4.883	± .55	± .36	± .01	

Long-term drift F
The long-term drift error is eliminated by recalibration. The drift is greatest soon after manufacture and gradually declines as components age. Long-term drift is expressed in % of full scale per six months (%FS/6mos).

Total read time G
Total read time is derived from best and worst case conversion cycles.

Conversion time H
The conversion time for the 500 mV range is 4.9 milliseconds. The conversion time for the other voltage ranges is 8.2 milliseconds. Both timing sequences include zero correction, since no speed advantage can be obtained by eliminating the zero correction feature.

Input voltage range (millivolts) A	*Long-term drift* F		*Total read time* G		*Conversion time* H	
	with zero correction (%FS/6 mos)	*without zero correction (%FS/6 mos)*	*with zero correction*	*without zero correction*	*with zero correction*	*without zero correction*
5000	.030	(zero correction is always used)	5 ms	(zero correction is always used)	4.9 ms	(zero correction is always used)
500	.031		8.25 ms		8.2 ms	
200	.033		8.25 ms		8.2 ms	
100	.036		8.25 ms		8.2 ms	
50	.043		8.25 ms		8.2 ms	
20	.063		8.25 ms		8.2 ms	
10	.103		8.25 ms		8.2 ms	



Reed relay multiplexer equivalent circuit

3 PERFORMANCE SPECIFICATIONS–AO FEATURE

All specifications apply to user connections.

Feature capacity
The AO feature card contains two points with a maximum of 16 points per 4982.

Output voltage ranges
±10V dc
±5V dc
0V to +10V dc

Output current
+5 mA maximum at ±10V

Output impedance
1 ohm maximum

Output capacitance
2000 pf maximum

Maximum settling time
Thirty microseconds are required to stabilize after a full-scale voltage step on the ±10.0V range into a 2000 ohm or greater resistive load. Settling time is measured from the fall of the data strobe until the value of the output value is within 10% of the desired voltage. Longer settling times occur if the output drives stored-energy components (inductance and capacitance).

Long-term stability
±1/2 least significant bit/10,000 hours

Total accuracy
The cumulative sum of the error introduced by offset, gain, linearity, potentiometer stability errors, and power supply rejection ratio. It does not include long-term stability errors and output noise errors. Offset and gain are adjusted at 25°C. At 25°C, total accuracy is ±1 least significant bit. In the range between 0°C and 70°C, total accuracy is ±7 least significant bits.

Output noise
2.5 mV peak-to-peak at 10 Hz to 300 KHz

Resolution
10 bits

4 PERFORMANCE SPECIFICATIONS–DI/PI FEATURE, ISOLATED (PART 1 OF 2)

All specifications apply to user connections.

Feature capacity
The isolated DI/PI feature card contains 16 points with a maximum of 128 points per 4982.

Common-mode voltage A
Common-mode voltage is measured between the isolated digital input points and Series/1 ground.

Minimum detectable pulse width B
This specification includes the nonquiescent condition of a 6 microsecond DI/PI feature addressing period for read PI operations, to ensure DI or PI register latching.

Response time C
The time between 50% points of a data input transition and the DI or PI register latching while the feature is in a quiescent state. A data input transition of duration equal to or greater than the specified logic 1 response time will be detected and latched in the PI register. If the transition occurs while a read PI or read PI with reset is in operation, the transition must be greater than logic 1 response time plus the maximum duration of the processor read operation (6 usec). An input pulse of shorter duration would go undetected.

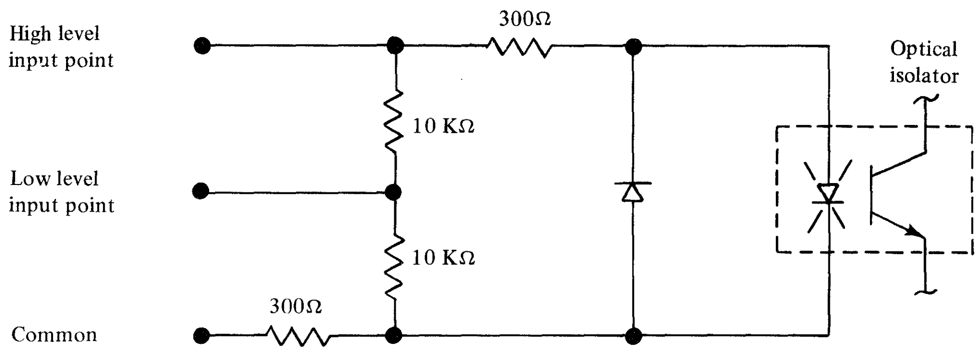
External sync input
External sync input point is a nonisolated connector with 390 ohm impedence pulled up to +5 volts.

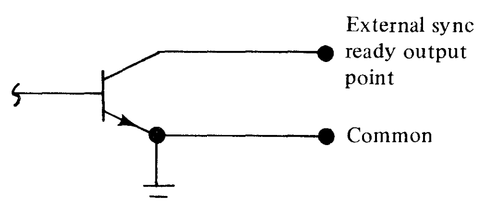
Input logic 0:	⩾ 2.5V
Input logic 1:	⩽ 1V
Input overload limits:	+10V, –2V
Minimum detectable pulse width:	
Logic 0	10 microsecs (0V to +4.5V)
Logic 1	4 microsecs (+5.5V to 0V)
Maximum open circuit voltage:	+5.5V
Maximum short circuit current:	15 mA

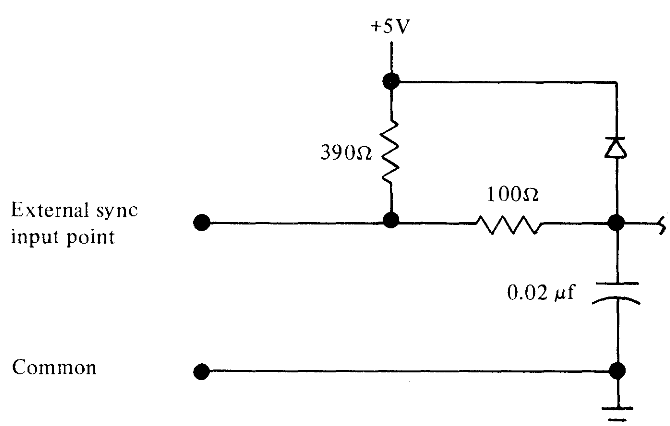
External sync ready output
External sync ready output point is a nonisolated connector with an open collector driver output.

Max. collector voltage:	+5.5V (user supplied through a pull-up resistor)
Max. sink current:	48 mA

		High level	*Low level*
		User supplied voltage sense	
Isolation		> 1000 Megohms	> 1000 Megohms
Input impedance (Z)		5K ohms ⩽ Z, Z ⩽ 12K ohms	570 ohms ⩽ Z, Z ⩽ 22K ohms
Input limits (voltage and current)	Logic 0	–52.8V to +2V –10 mA to +0.25 mA	–12V to +1V –20 mA to +0 mA
	Logic 1	+12V to +52.8V +2.1 mA to +10 mA	+2V to +12V +1.1 mA to +18 mA
Common-mode voltage (0–60 Hz) A		±250Vdc ±250V peak ac	±250Vdc ±250V peak ac
Input overload limits		±52.8V max ±10 mA	±12V max ±20 mA
Minimum detectable pulse width-logic 1 B		11 μs typical (0V to ⩾ 18V) 26 μs max (0V to +12V)	11 μs typical (0V to ⩾ +3V) 26 μs max (0V to +2V)
C Response time	Logic 0	⩽ 5 μs typical (+18V to 0V) 20 μs max (52.8V to 0V)	⩽ 5 μs typical (+3V to 0V) 20 μs max (+12V to 0V)
	Logic 1	5 μs typical (0V to ⩾ 18V) 20 μs max (0V to +12V)	5 μs typical (0V to ⩾ +3V) 20 μs max (0V to +2V)







Isolated DI/PI equivalent circuits

5 PERFORMANCE SPECIFICATIONS–DI/PI FEATURE, NONISOLATED (PART 1 OF 2)

All specifications apply to user connections.

Feature capacity
The nonisolated DI/PI feature card contains 16 points with a maximum of 128 points per 4982.

Input limits A
A low resistive metal contact (e.g., gold, silver) is required for low level current contact sense.

Minimum detectable pulse width B
This specification includes the nonquiescent condition of 6 microseconds DI/PI feature addressing period for read PI operations, to ensure DI or PI register latching.

Response time C
The time between 50% points of a data input transition and DI or PI register latching, while the feature is in a quiescent state. A data input transition of duration equal to or greater than the specified logic 1 response time will be detected and captured in the PI latches. If the transition occurs while a read PI or read PI with reset is in operation, the transition must be greater than logic 1 response time plus the maximum duration of the processor Read operation (6 usec). An input pulse of shorter duration could go undetected.

		High level		*Low level*	
		Contact sense	*Voltage sense*	*Contact sense*	*Voltage sense*
Input impedance		⩾ 22.5K ohms	⩾ 22.5K ohms	⩾ 8K ohms	⩾ 2K ohms
Input limits A	Logic 0	⩾ 150K ohms (contact open)	⩾ +25V (0V to +52.8V)	⩾ 56K ohms (contact open)	⩾ +2.5V
	Logic 1	⩽ 5K ohms (contact closed)	⩽ +8V (0V to +52.8V)	⩽ 2K ohms (contact closed)	⩽ +1V (±24V)
Maximum open circuit voltage out		+43.2V	+43.2V	+5.4V	+5.4V (±24V)
Maximum short circuit current out		2 mA	2 mA	0.56 mA	0.56 mA
Minimum detectable pulse width-logic 1 B		10 ms typical 16 ms max	10 ms typical 16 ms max	8 μs typical 10 μs max	8 μs typical 10 μs max
C Response time	Logic 0	8 ms typical 22 ms max (⩾ 10M ohms open) 28 ms max (150K ohms open)	8 ms typical 10 ms max (0V to +36V)	⩽ 10 μs typical (⩾ 10M ohms) open)	⩽ 2 μs typical (0V to +4V)
	Logic 1	10 ms typical 16 ms max (⩽ 100 ohms closed) 35 ms max (5K ohms closed)	10 ms typical 13 ms max (+36V to 0V)	⩽ 2 μs typical 4 μs max (⩽ 100 ohms closed)	⩽ 2 μs typical 4 μs max (+4V to 0V)

5 PERFORMANCE SPECIFICATIONS–DI/PI FEATURE, NONISOLATED (PART 2 OF 2)

External sync input

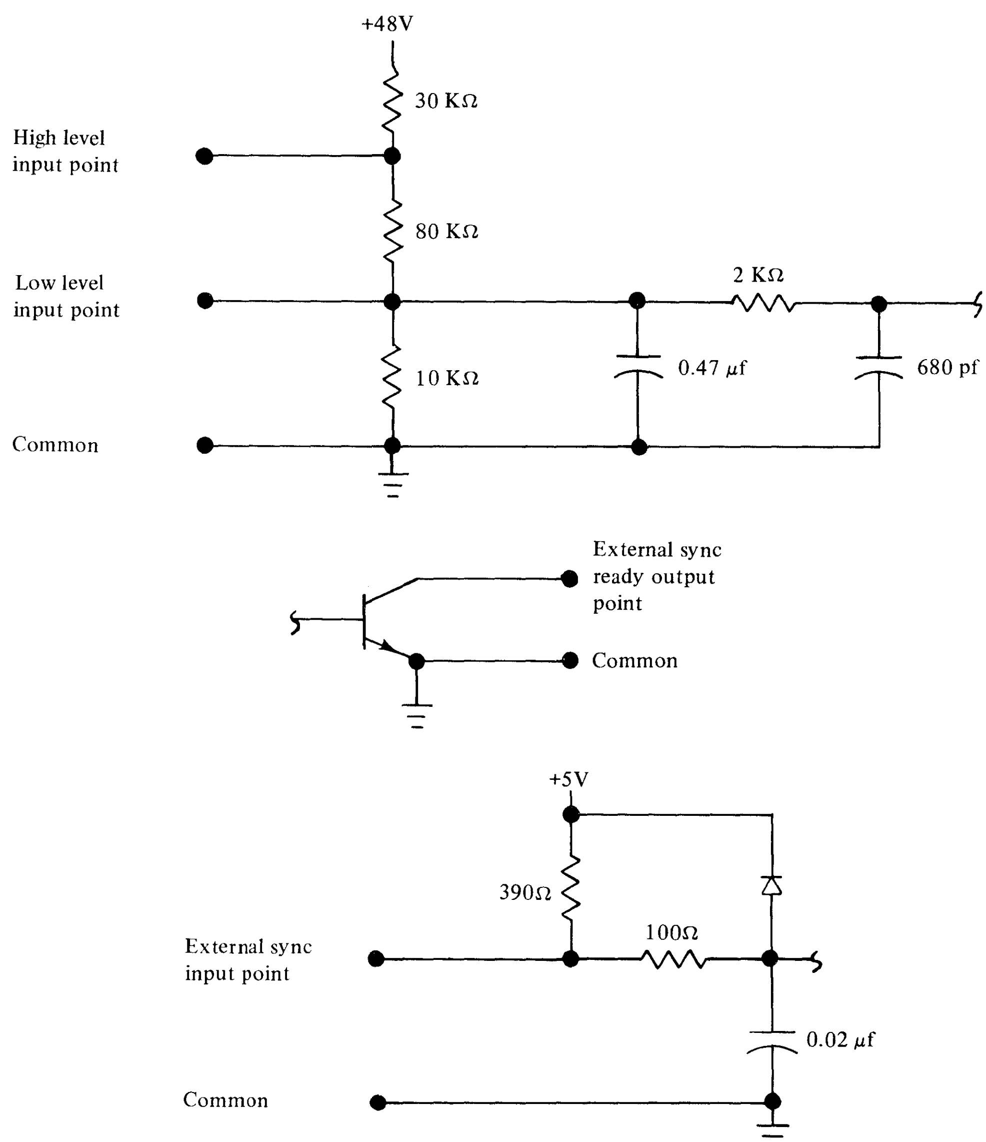
External sync input point is a nonisolated connector with 390 ohm impedence pulled up to +5 volts.

Input logic 0: ⩾ 2.5V
Input logic 1: ⩽ 1V
Input overload limits: +10V, –2V
Minimum detectable pulse width:
  Logic 0 10 microsecs (0V to 4.5V)
  Logic 1 4 microsecs (5.5V to 0V)
Maximum open circuit voltage: +5.5V
Maximum short circuit current: 15 mA

External sync ready output

External sync ready output point is a nonisolated connector with an open collector driver output.

Max. collector voltage: +5.5V (user supplied through a pull-up resistor)
Max. sink current: 48 mA



Nonisolated DI/PI equivalent circuits

6 PERFORMANCE SPECIFICATIONS–DO FEATURE

All specifications apply to user connections.

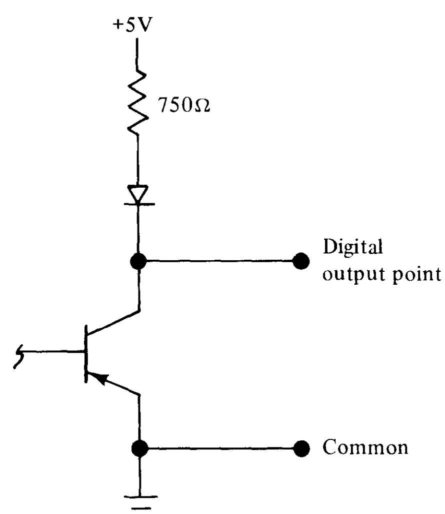
Feature capacity
The DO feature card contains 16 points with a maximum of 128 points per 4982.

Output voltage A
The output point has a feature supplied +5V dc (±10%) or is connected to a user supplied voltage (+52.8V max.) whichever is larger.

Output current B
Each output point is capable of shunting or switching up to 250 milliamps.

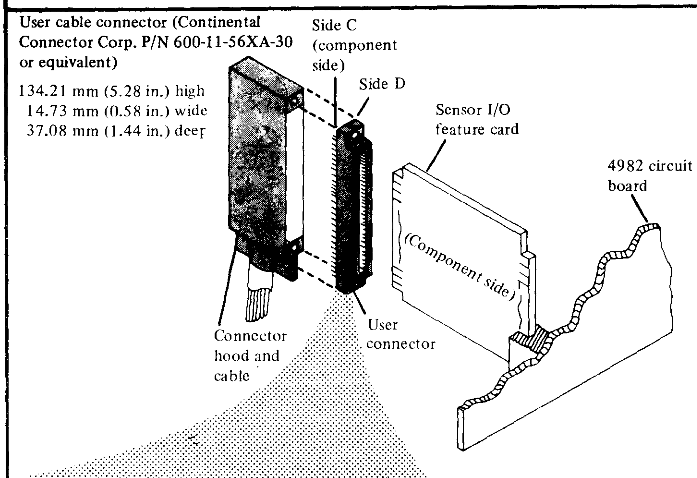
Response time C
The time required for the DO drivers to respond to write a DO command.

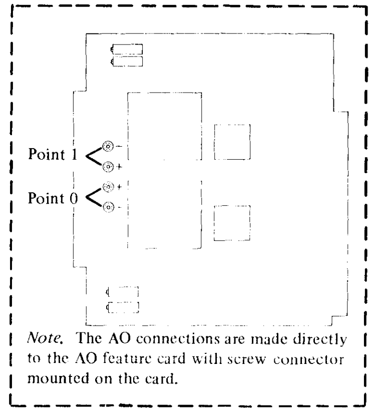
		With user source	*Without user source*
A Output voltage	Logic level 0	+52.8 V max	+5.5V max @ 0.0 amps +2.4V min @ 1 mA (drive)
	Logic level 1	+0.8V max @250 mA (sink)	0.8V max @ 250 mA (sink)
B Output current	Logic level 0	500 μA	500 μA
	Logic level 1	250 mA	250 mA
Response time C		8 μs typical	8 μs typical



Nonisolated DO equivalent circuit

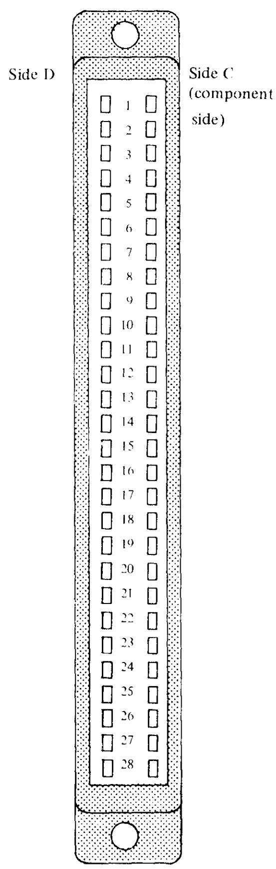
7 FEATURES USER CONNECTIONS





AO feature card

User connector (cable side view)



Pins	*Solid state multiplexer feature card*	*Reed relay multiplexer feature card*	*Isolated DI/PI feature card*	*Nonisolated DI/PI feature card*	*Nonisolated DO feature card*
C1	Channel 0 (–)	Channel 0 (–)	Point 1 high level	Point 1 high level	Point 0
C2	Shield	No connection	Point 1 reference	Point 3 high level	Point 1
C3	Channel 1 (–)	No connection	Point 1 low level	Point 5 high level	Point 2
C4	Channel 2 (–)	Channel 1 (–)	Point 3 high level	Point 7 high level	Point 3
C5	Shield	No connection	Point 3 reference	Point 9 high level	No connection
C6	Channel 3 (–)	No connection	Point 3 low level	Point 11 high level	No connection
C7	No connection	No connection	Point 5 high level	Point 13 high level	No connection
C8	Channel 4 (–)	Channel 2 (–)	Point 5 reference	Point 15 high level	No connection
C9	Shield	No connection	Point 5 low level	Ground	No connection
C10	Channel 5 (–)	No connection	Point 7 high level	Ground	Point 4
C11	Channel 6 (–)	Channel 3 (–)	Point 7 reference	Ground	Point 5
C12	Shield	No connection	Point 7 low level	Point 1 low level	Point 6
C13	Channel 7 (–)	No connection	Point 9 high level	Ground	Point 7
C14	No connection	No connection	Point 9 reference	Point 3 low level	No connection
C15	Channel 8 (–)	Channel 4 (–)	Point 9 low level	Ground	No connection
C16	Shield	No connection	Point 11 high level	Point 5 low level	No connection
C17	Channel 9 (–)	No connection	Point 11 reference	Ground	Point 8
C18	Channel 10 (–)	Channel 5 (–)	Point 11 low level	Point 7 low level	Point 9
C19	Shield	No connection	Point 13 high level	Ground	Point 10
C20	Channel 11 (–)	No connection	Point 13 reference	Point 9 low level	Point 11
C21	No connection	No connection	Point 13 low level	Ground	No connection
C22	Channel 12 (–)	Channel 6 (–)	Point 15 high level	Point 11 low level	No connection
C23	Shield	No connection	Point 15 reference	Ground	No connection
C24	Channel 13 (–)	No connection	Point 15 low level	Point 13 low level	No connection
C25	Channel 14 (–)	Channel 7 (–)	Ground	Ground	Point 12
C26	Shield	No connection	Ground	Point 15 low level	Point 13
C27	Channel 15 (–)	No connection	Ground	Ground	Point 14
C28	No connection	No connection	Ground	Ext. sync ready	Point 15
D1	Channel 0 (+)	Channel 0 (+)	Point 0 high level	Point 0 high level	Ground
D2	Shield	Shield	Point 0 reference	Point 2 high level	Ground
D3	Channel 1 (+)	No connection	Point 0 low level	Point 4 high level	Ground
D4	Channel 2 (+)	Channel 1 (+)	Point 2 high level	Point 6 high level	Ground
D5	Shield	Shield	Point 2 reference	Point 8 high level	Ground
D6	Channel 3 (+)	No connection	Point 2 low level	Point 10 high level	Ground
D7	No connection	No connection	Point 4 high level	Point 12 high level	Ground
D8	Channel 4 (+)	Channel 2 (+)	Point 4 reference	Point 14 high level	Ground
D9	Shield	Shield	Point 4 low level	Ground	Ground
D10	Channel 5 (+)	No connection	Point 6 high level	Ground	Ground
D11	Channel 6 (+)	Channel 3 (+)	Point 6 reference	Point 0 low level	Ground
D12	Shield	Shield	Point 6 low level	Ground	Ground
D13	Channel 7 (+)	No connection	Point 8 high level	Point 2 low level	Ground
D14	No connection	No connection	Point 8 reference	Ground	Ground
D15	Channel 8 (+)	Channel 4 (+)	Point 8 low level	Point 4 low level	Ground
D16	Shield	Shield	Point 10 high level	Ground	Ground
D17	Channel 9 (+)	No connection	Point 10 reference	Point 6 low level	Ground
D18	Channel 10 (+)	Channel 5 (+)	Point 10 low level	Ground	Ground
D19	Shield	Shield	Point 12 high level	Point 8 low level	Ground
D20	Channel 11 (+)	No connection	Point 12 reference	Ground	Ground
D21	No connection	No connection	Point 12 low level	Point 10 low level	Ground
D22	Channel 12 (+)	Channel 6 (+)	Point 14 high level	Ground	Ground
D23	Shield	Shield	Point 14 reference	Point 12 low level	Ground
D24	Channel 13 (+)	No connection	Point 14 low level	Ground	Ground
D25	Channel 14 (+)	Channel 7 (+)	Ground	Point 14 low level	Ground
D26	Shield	Shield	Ext. sync input	Ground	Ground
D27	Channel 15 (+)	No connection	Ground	Ext. sync input	Ground
D28	No connection	No connection	Ext. sync ready	Ground	Ground

8 FEATURE CYCLE TIME SAMPLES

Specification data for the feature cycle time samples are based on the following considerations:

- An IBM 4955 processor is used
- The 4982 attachment feature is installed in the processor
- No other programs are running in the processor
- All power supplies are within specifications.

Analog input

The scanning rate from the initiation of an AI conversion cycle on the first channel until the program is ready to initiate a conversion on the next channel is:

- Solid state multiplexer

	Best case Without zero correction	Best case With zero correction
Unity gain	102 us	162 us
Other gains	122 us	202 us

	Worst case Without zero correction	Worst case With zero correction
Unity gains	110 us	170 us
Other gains	130 us	210 us

- Reed relay multiplexer

	Best case With zero correction
Unity gains	5 ms
Other gains	8.2 ms

	Worst case With zero correction
Unity gain	5.05 ms
Other gains	8.25 ms

The following program, used to depict cycle times, is in the supervisor state with a vector to B after the first interrupt:

```
A        IO     CONV1
         LEX
B        IO     CONV2
         LEX
CONV1    DC     /40XX
         DC     /CTL1
CONV2    DC     /40XX
```

Analog output

The time from the completion of the first write AO command to the completion of the second write AO is:

Best case	11 us (AO settling time not included)
Worst case	13.5 us (AO settling time not included)
Throughput best case	90,900 outputs/sec
Throughput worst case	74,074 outputs/sec

The following program, used to depict cycle times, is in the supervisor state with vector to B after the first interrupt:

```
A        IO     WT1        write AO
         IO     WT2        write AO
         BL
WT1      DC     /40XX
         DC     Data1
WT2      DC     /40XX
         DC     Data2
```

Digital input/process interrupt

The time from completion of the first read DI command to the completion of the second read DI command is:

- For isolated DI/PI

Best case	11 us*
Worst case	13.5 us*
Throughput worst case	74,074 readings/sec

- For nonisolated DI/PI

Best case	11 us*
Worst case	13.5 us*
Throughput best case	90,900 readings/sec
Throughput worst case	74,074 readings/sec

*Does not include user input circuit response time.

The following program, used to depict DI cycle times, is in the supervisor state:

```
A        IO     RD1        read DI
         IO     RD2        read DI
         BL     A
RD1      DC     /00XX
         DC     /Data1
RD2      DC     /00XX
         DC     /Data2
```

The time from the user's input switching from inactive state to active state, followed by a PI, then by a read PI command is:

- For isolated DI/PI

	Best case	Worst case
Low level	35 us	58 us
High level	35 us	58 us

- For nonisolated DI/PI

	Low level Best case	Low level Worst case
Contact sense	32 us	48 us
Voltage sense	32 us	48 us

	High level Best case	High level Worst case
Contact sense	10.03 us	35 us
Voltage sense	10.03 us	38 us

Digital output

The time for the completion of the first write DO command to the completion of the second write DO command is:

Best case	11 us (DO driver response time not included)
Worst case	13.5 us (DO driver response time not included)
Throughput best case	90,900 outputs/sec
Throughput worst case	74,074 outputs/sec

The following program, used to depict DO cycle times is in the supervisor state:

```
A        IO     WT1        write DO
         IO     WT2        write DO
         BL
WT1      DC     /40XX
         DC     Data1
WT2      DC     /40XX
                Data 2
```

Chapter 3. Sensor Input/Output Commands

This chapter, intended primarily for the user programmer, describes Series/1 I/O data transfer and sensor I/O commands for the following 4982 Sensor Input/Output Unit features:

- Sensor I/O attachment feature
- AI features
- AO feature
- DI/PI features
- DO feature

INPUT/OUTPUT DATA TRANSFER OPERATIONS

I/O data transfer between the 4982 unit and the Series/1 processor is accomplished via the the processor I/O channel (Figure 3-1).

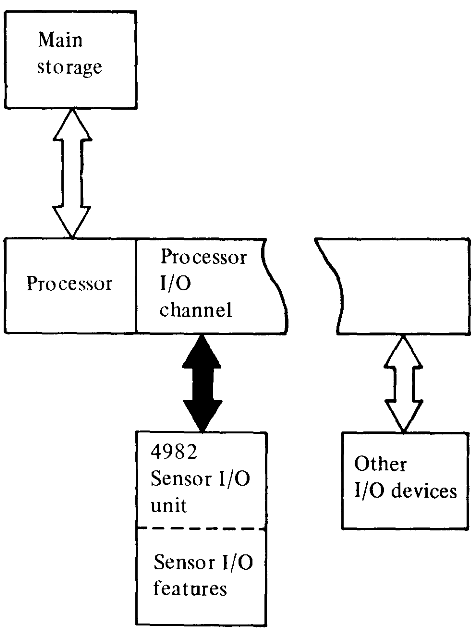


Figure 3-1. Series/1 I/O data transfer simplified data flow

Data transfer between the processor I/O channel and the 4982 features is by direct program control (DPC) operations (see "Direct Program Control Operations"). The Series/1 has four priority interrupt levels to facilitate data transfer. These levels, listed in priority sequence, are numbered 0, 1, 2, and 3 with level 0 having highest priority. The processor switches from one level to another in two ways:

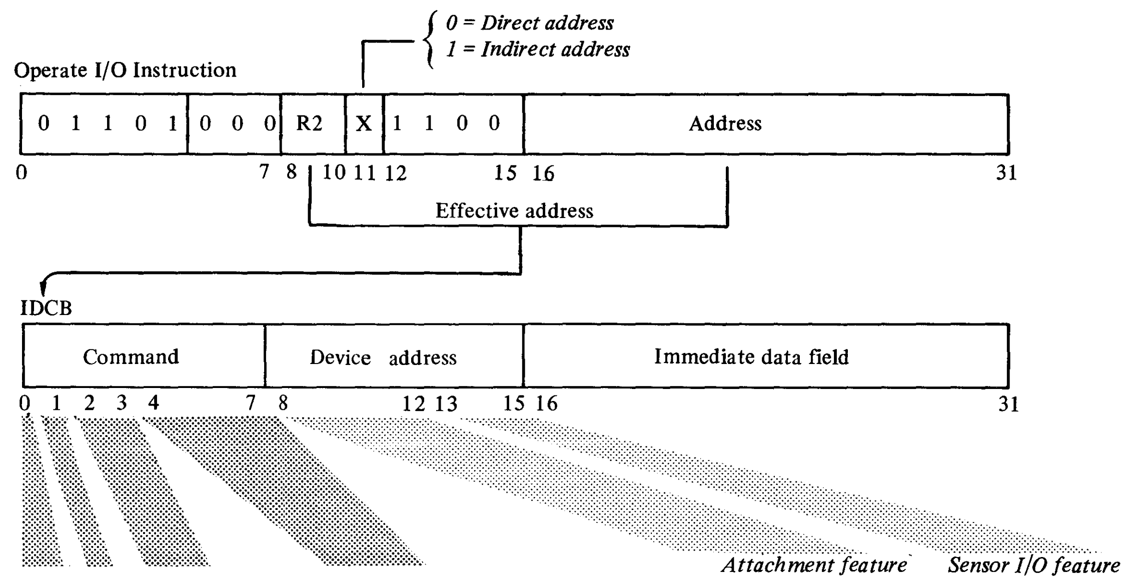
- Automatically, when an interrupt request is accepted from an I/O device operating on a higher priority level than the current level.
- Under program control, by using the set level block instruction

Both types of level switching are discussed in detail in the Series/1 Processor and Processor Features Description manuals. Only one priority level at a time can be assigned to a 4982 for all the features within that unit.

The processor receives status information from the processor I/O channel via condition codes, interrupt information bytes, and device dependent status words. (See "I/O Condition Codes and Status Information").

Operate Input/Output Instruction

The operate I/O instruction (mnemonic of "IO") initiates all I/O operations from the processor. Operate I/O is a privileged instruction and is independent of specific I/O parameters. The generated effective address points to an immediate device control block (IDCB) consisting of two words in main storage. For details of the IO instruction see the Series/1 Processor and Processor Features Description manuals. Figure 3-2 shows the relationship of the IDCB to the IO instruction, a composite chart of the various sensor I/O commands, and a chart of sensor I/O feature addressing.



Chan	R/W	Function	Modifier	Hex	Specific command	Attachment feature address	Sensor I/O feature address
0	0	00 Read	xxxx	0X	Read	0000 0	000
0	0	10 Read status	0000	20	Read ID	0000 1	001
0	0	10 Read status	xxxx	2X	Read status		
0	1	00 Write	xxxx	4X	Write		
0	1	10 Control	0000	60	Prepare		
0	1	10 Control	xxxx	6X	Control	1111 0	110
0	1	10 Control	1111	6F	Device reset	1111 1	111

Note. Modifier xxxx is feature dependent.

Figure 3-2. Sensor I/O subsystem IDCB

Immediate Device Control Block

The storage location specified by the IO instruction contains the IDCB. The IDCB, always located on a word address boundary, contains a command that describes the sensor I/O operation. The processor I/O channel uses the command for execution of the operation. Also contained in the IDCB is a 4982 feature device address and an immediate data field for use by the processor I/O channel.

The format of the IDCB (see Figure 3-2) is as follows:

Command field (bits 0–7)

Bit 0 — *Channel directed.* This bit is zero for sensor I/O commands.

Bit 1 — *Read/Write.* If this bit is one, the data contained in the immediate data field is transferred to the addressed sensor I/O feature during the I/O operation. If this bit is zero, data received from the feature at the conclusion of the I/O operation is placed in the immediate data field.

Bits 2–3 — *Function.* This field specifies the general type of I/O operation to be performed.

Bits 4–7 — *Modifier.* This field, an extension of the function field, is used for further definition of the I/O operation. The contents of this field are feature dependent and are defined in the sections of this chapter describing each feature command.

Device address field (bits 8–15)

This field contains the sensor I/O *device address* with a range of 00 through FF (hex).

Bits 8–12 — *Attachment feature address.* This field addresses a specific sensor I/O attachment feature on the processor I/O channel.

Bits 13–15 — *Sensor I/O feature address.* This field addresses a specific feature within a 4982 that is connected to the addressed attachment feature (bits 8–12). The 4982 feature location determines the value used in this field.

Attachment feature address and sensor I/O feature address are combined to make the device address. Although a number of user connections may be coupled to a single sensor I/O feature, the entire feature is addressed by a single device address.

Immediate data field (bits 16–31)

This field contains a data word for the following DPC commands:

Command (bits 0–7)	*Immediate data field (bits 16-31)*
Read	Data
Read ID	Feature ID word
Read status	Feature status word
Write	Data
Prepare	Interruption parameters
Control	Data
Device reset	Zero

Direct Program Control Operation

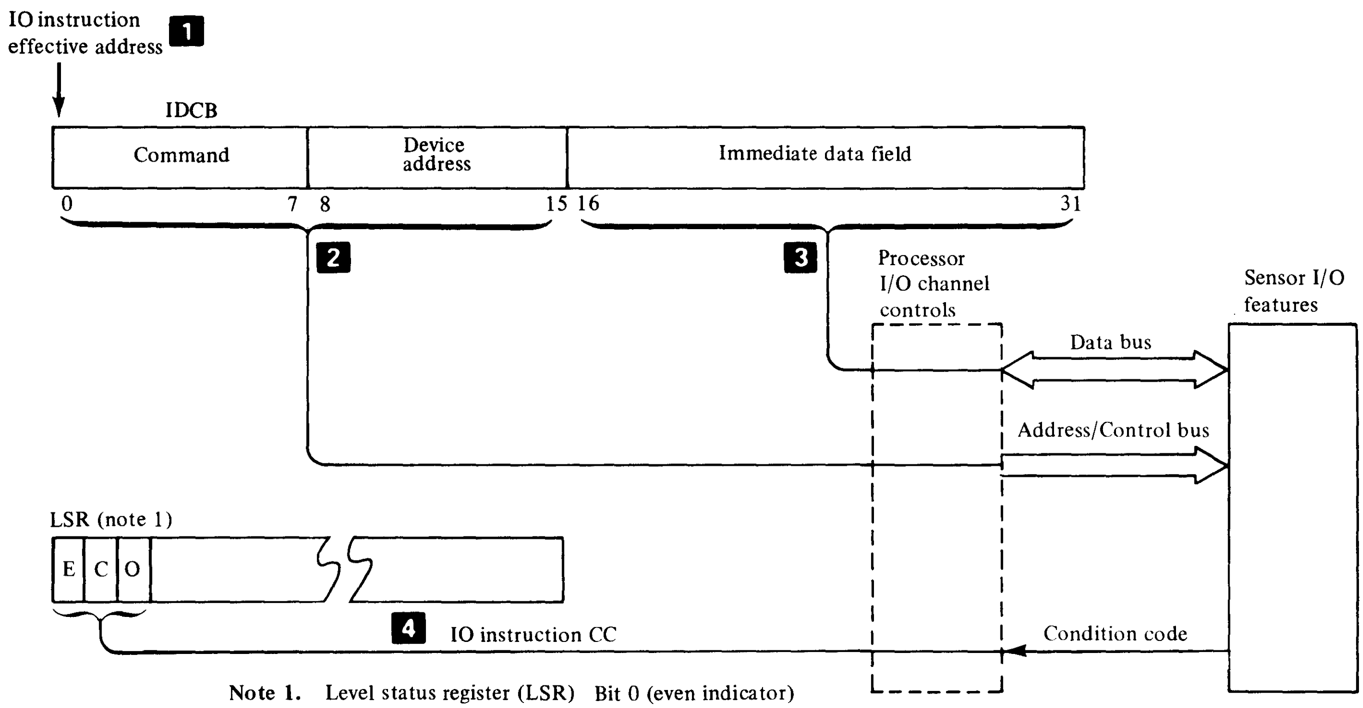
A DPC operation causes an immediate transfer of one 16-bit word of data or control information to or from a sensor I/O feature. An IO instruction, executed for each data transfer, causes the following events to occur (Figure 3-3):

1 IO instruction points to an IDCB in main storage

2 The processor I/O channel uses the IDCB to select the addressed feature and to determine the operation to perform.

3 The processor I/O channel sends data to the feature from the immediate data field, or from the feature to the immediate data field.

4 A condition code is presented to the processor from the feature.



Note 1. Level status register (LSR) Bit 0 (even indicator)
Bit 1 (carry indicator)
Bit 2 (overflow indicator)

Figure 3-3. Direct program control I/O operation

The DPC operation may be terminated by a priority interrupt. When the processor accepts the interrupt request, the feature sends an interrupt condition code and an interrupt identification (ID) word. For details of I/O interruption acceptance and processing, refer to the Series/1 Processor and Processor Features Description manuals.

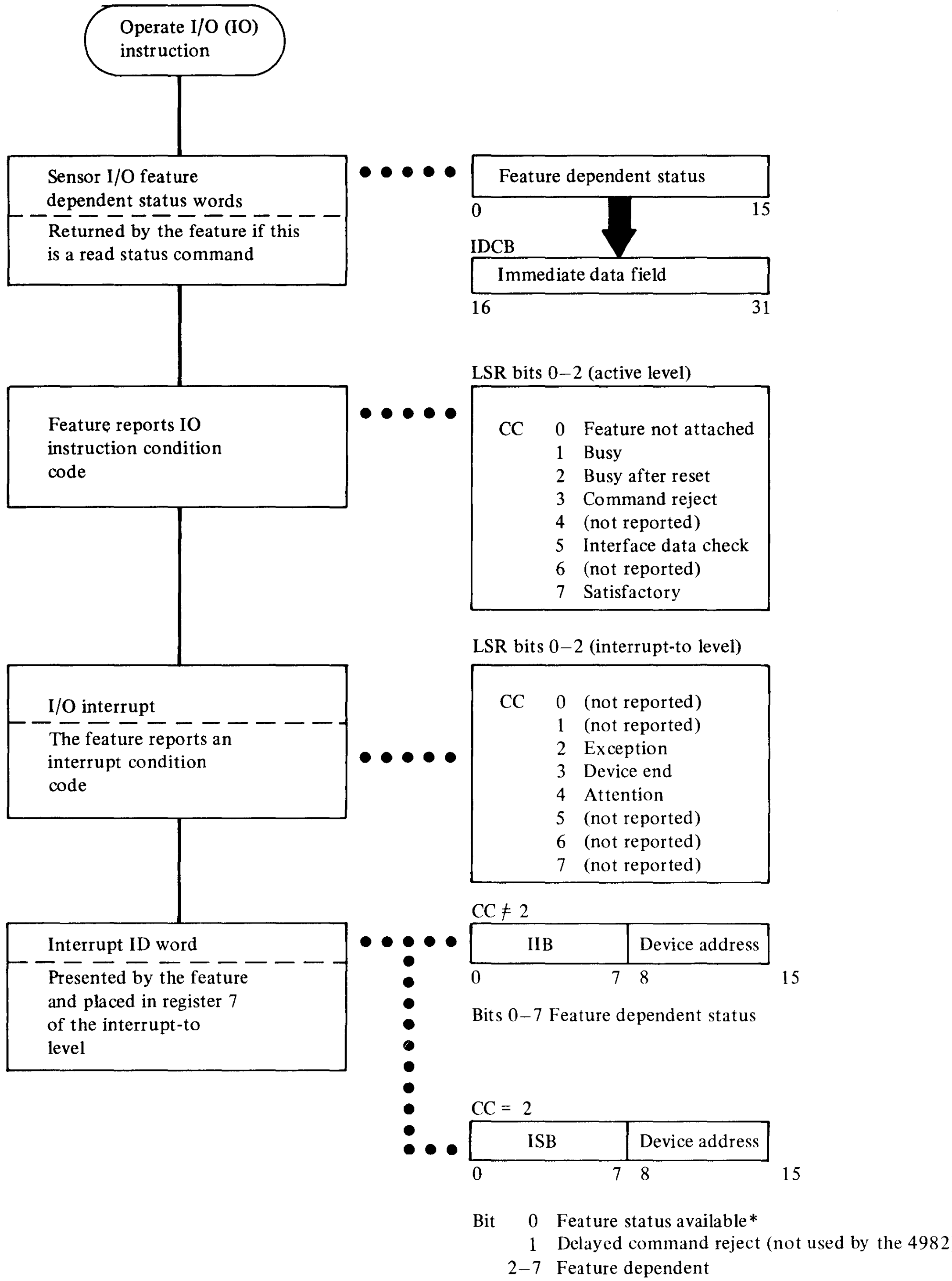
INPUT/OUTPUT CONDITION CODES AND STATUS INFORMATION

Each time an IO instruction is issued to the processor a condition code pertaining to execution of the I/O command is reported. Depending on the condition that occurs, the sensor I/O feature, the attachment feature, or the processor I/O channel may report a condition code. Three bits are used to encode a condition code value (range 0 through 7). The bits (see Figure 3-3) are recorded in positions 0, 1 and 2 (also known as the even, carry, and overflow indicators) of the level status register (LSR) and may be interrogated by specific instructions such as branch on condition code and branch on not condition code. (See the Series/1 Processor and Processor Features Description manuals.)

Feature dependent status information is obtained by issuing a read status command (See "Read Status") or by reading the interrupt ID word that accompanies a priority interrupt.

During a priority interrupt, interrupt condition codes are reported. These condition codes pertain to an operation that continues beyond execution of the IO instruction. Along with the interrupt condition code, the feature also transfers an interrupt identification (ID) word to the processor (see "Interrupt Identification Word"). Bits 0 through 7 of the interrupt ID word contain feature dependent status related to interrupt processing. These bits are called the interrupt information byte (IIB). If an interrupt condition code 2, exception, is reported by the feature, the IIB becomes an interrupt status byte (ISB). (See "Interrupt Status Byte".)

Details of condition codes and status information are discussed in the following sections. Figure 3-4 presents an overall view of condition code reporting along with status information.



*The available status is returned by the feature when the read status command is used.

Figure 3-4. Condition codes and status information

Operate Input/Output Instruction Condition Code

These codes are reported during execution of an IO instruction.

Condition code (CC) value	*LSR bit positions* 0 *(even)*	1 *(carry)*	2 *(overflow)*	*Meaning*
0	0	0	0	Feature not attached
1	0	0	1	Busy
2	0	1	0	Busy after reset
3	0	1	1	Command reject
4	1	0	0	(Not reported)
5	1	0	1	Interface data check
6	1	1	0	(Not reported)
7	1	1	1	Satisfactory

CC=0 *Feature not attached.* Reported by the processor I/O channel when the addressed feature is not attached to the system.

CC=1 *Busy.* Reported by a feature when it is unable to execute a command because it is in the busy state. The DI/PI feature enters the busy state upon acceptance of a command that requires an interruption for termination and an interrupt is pending. Following an AI command, that initiates a conversion cycle, the AI control feature enters the busy state and remains busy until the completion of the cycle and the interrupt service. A feature exits the busy state when the processor takes action on the interrupt.

CC=2 *Busy after reset.* Reported by the AI control feature when it is unable to execute a command because the feature has not yet returned to the quiescent state following a device reset command. This condition will occur if a device reset command is issued to the control feature and a conversion cycle (initiated by a previous command) is still process.

No interruption occurs to indicate termination of this condition.

CC=3 *Command Reject.* Reported by the feature when:

- A command is issued that is outside the feature command set.
- The IDCB contains an incorrect parameter. For example: an incorrect function/modifier combination.

CC=5 *Interface data check.* Reported by the sensor I/O attachment feature or the processor I/O channel when a parity error is detected on the I/O data bus during a data transfer.

CC=7 *Satisfactory.* Reported by the feature when it accepts the command.

These condition codes are mutually exclusive and have a priority sequence. That is, beginning with CC=7 (lowest priority), each successive condition code through CC=0 (highest priority) takes precedence over the previous code. For example, if a feature cannot accept a command because it is busy, it reports CC=1, regardless of error conditions encountered.

Interrupt Condition Codes

These condition codes are reported by the feature during priority interrupt acceptance.

Condition code (CC) value	*LSR bit positions* 0 *(even)*	1 *(carry)*	2 *(overflow)*	*Meaning*
0	0	0	0	(Not reported)
1	0	0	1	(Not reported)
2	0	1	0	Exception
3	0	1	1	Device end
4	1	0	0	Attention
5	1	0	1	(Not reported)
6	1	1	0	(Not reported)
7	1	1	1	(Not reported)

CC=2 *Exception.* Reported when an error or exception condition is associated with the interruption. The condition is described in the interrupt status byte (ISB) or in feature dependent status words.

CC=3 *Device end.* Reported when no error, exception, or attention condition has occurred during the I/O operation.

CC=4 *Attention.* Reported when the interruption was caused by an external event rather than execution of an IO instruction. Additional status information is not provided unless the event requires further definition.

The interrupt condition codes are mutually exclusive and have no priority sequence. That is, if one condition occurs before another, only the first is reported. And no one condition code has priority over another.

Input/Output Status Information

Feature dependent status information is transferred from the feature to the processor as a result of a read status command (see "Read Status" in this chapter) or a priority interrupt.

The interrupt status information is detailed in the sections "Interrupt Identification Word" and "Interrupt Status Byte".

Interrupt Identification Word

Acceptance of an I/O interruption, by the processor, causes the feature to present an interrupt ID word to the processor. The ID word is stored in interrupt-to level register 7 in the processor. This word has the following format:

Interrupt ID word

IIB	*Device address field*
0 — 7	*8 — 15*

Bits 0–7 *Interrupt information byte (IIB).* For interrupt condition code 2, the IIB has a fixed format. This is a special format of the IIB and is called an interrupt status byte (ISB). For other interrupt condition codes, implementation of the IIB is feature dependent. Refer to *Read Status* commands for each sensor I/O feature.

Bits 8–15 *Device address.* This byte contains the address of the interrupting feature.

Details on how the processor uses the interrupt ID word are explained in the IBM Series/1 Processor and Processor Features Description manuals.

Interrupt Status Byte

The ISB is a special format of the IIB and contains detailed information on the nature of the interruption. These bits are normally set as a result of status errors that occur during a DPC operation that cannot be indicated via a condition code.

After the processor has accepted the interruption request, the feature resets the ISB. The ISB is presented with interrupt condition code 2. Bits 0–7 of the ISB are explained below.

Bit 0 *Feature dependent status available.* This bit set to one signifies that additional status information is available from the feature. The information content and method of reading is described in the individual sensor I/O feature command description.

Bit 1 *Delayed Command reject.* Not used by the 4982.

Bits 2–7 *Feature dependent.* These bits are described in the individual sensor I/O feature command description.

COMMAND SUMMARY

Figure 3-5 shows the I/O commands for the 4982 unit and the possible IO instruction condition codes reported for each command.

	Command	*IDCB bits 0–7*	*Hex*	*IO instruction condition codes*
Attachment feature	Prepare	01100000	60	0, 5, 7
	Set diagnostic mode	01100001	61	0, 5, 7
	Reset diagnostic mode	01100010	62	0, 5, 7
	Read status	00101110	2E	0, 5, 7
	Read diagnostic data	00101111	2F	0, 5, 7
AI features	Read ADC	00000000	00	0, 1, 2, 5, 7
	Read ID	00100000	20	0, 1, 2, 5, 7
	Read status	00101000	28	0, 1, 2, 5, 7
	Convert AI	01001000	48	0, 1, 2, 5, 7
	Convert diagnostic zero	01101000	68	0, 1, 2, 5, 7
	Convert diagnostic voltage	01101010	6A	0, 1, 2, 5, 7
	Device reset	01101111	6F	0, 7
AO feature	Read ID	00100000	20	0, 5, 7
	Read status	00101000	28	0, 5, 7
	Write AO point 0	01001000	48	0, 5, 7
	Write AO point 1	01001001	49	0, 5, 7
	Device reset	01101111	6F	0, 7
DI/PI features	Read DI	00000000	00	0, 1, 5, 7
	Read PI	00000001	01	0, 5, 7
	Read PI with reset	00000010	02	0, 1, 5, 7
	Read ID	00100000	20	0, 5, 7
	Read status	00101000	28	0, 5, 7
	Arm PI	01101000	68	0, 1, 5, 7
	Arm DI external sync	01101001	69	0, 1, 5, 7
	Set test 0	01101010	6A	0, 1, 5, 7
	Set test 1	01101011	6B	0, 1, 5, 7
	Device reset	01101111	6F	0, 7
DO features	Read ID	00100000	20	0, 5, 7
	Read status	00101000	28	0, 5, 7
	Write DO	01001000	48	0, 5, 7
	Device reset	01101111	6F	0, 7

Figure 3-5. Sensor I/O commands

SENSOR INPUT/OUTPUT UNIT ATTACHMENT FEATURE COMMANDS

In addition to adapting the sensor I/O unit logically to the processor I/O channel, the sensor I/O unit attachment feature (Figure 3-6):

- Prepares the attachment feature and the 4982 features for interrupting the processor.
- Performs diagnostics issued to the attachment feature.
- Performs diagnostics issued to the sensor I/O unit termination card.

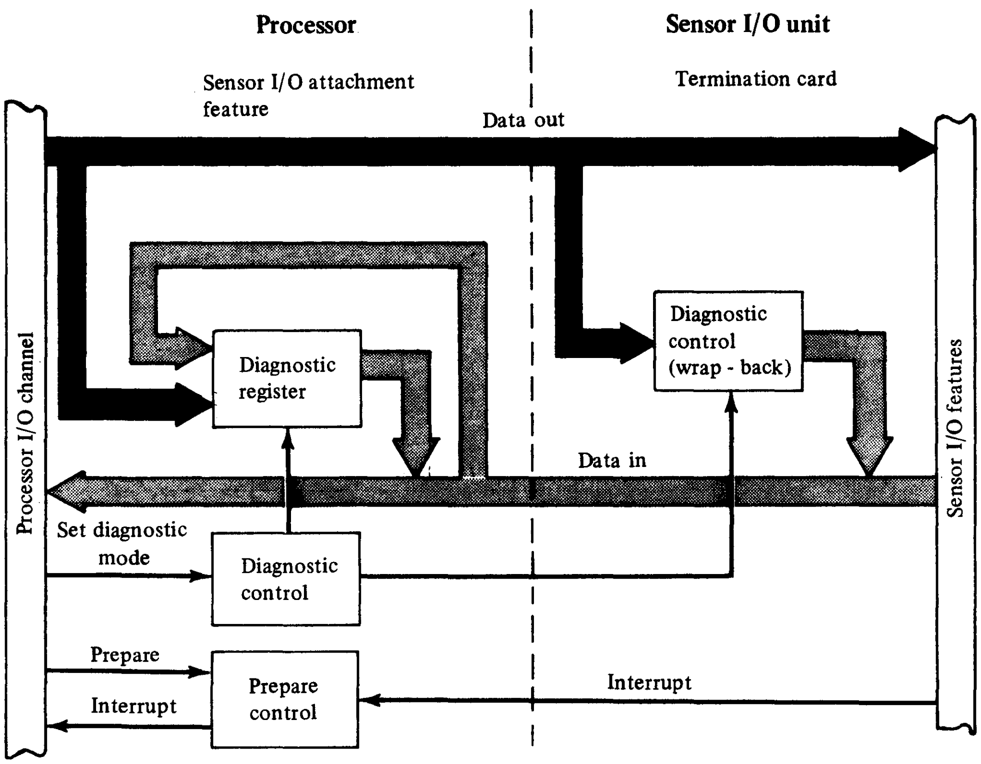


Figure 3-6. Attachment feature diagnostic and prepare simplified data flow

Common Commands

Two commands, prepare and read status, that are directed to the attachment feature, are common to the 4982 features.

Prepare

IDCB (immediate device control block)

Command field	*Device address field*
0 1 1 0 0 0 0 0	
0 … 7	*8 … 15*
60	*00–FF*

Immediate data field		
Zeros	Level	X
16 … 26	*27 … 30*	*31*

Interrupt control (bit 31)
0 = No interrupt
1 = Interrupt

Note. Series/1 Processor and Processor Features Description manuals contain information about interrupt levels.

The prepare command enables the attachment feature and the 4982 features to allow interrupts to the processor. A prepare command must be executed before any interrupt request from a sensor I/O feature can be accepted. If a parity error is detected during a prepare command, IO instruction condition code 5 (interface data check) is returned to the processor and the command is not executed.

Only one prepare command is required to enable interrupts from all of the sensor I/O features attached to the attachment feature. If an interrupt is not required, the prepare command is not necessary for the successful execution of any subsequent commands.

The prepare command also determines at what level the interrupts are accepted. The prepare command stores the level bits and the device mask (I-bit) conditions of the IDCB in latches in the attachment feature. Device mask is explained in the Series/1 Processor and Processor Features Description manuals.

Read Status

IDCB (immediate device control block)

Command field	*Device address field*
0 0 1 0 1 1 1 0	
0 … 7	*8 … 15*
2E	*00–FF*

Immediate data field	
X X X X X X X X	Zeros
16 … 23	*24 … 31*

Sensor I/O unit attachment feature: (this bit is one on a read status from the attachment feature.)

Four device address: (attachment feature is configured for four sensor I/O device addresses.)

Eight device address: (attachment feature is configured for eight sensor I/O device addresses.)

Parity option selected: (this bit is always one.)

Input parity error: (parity error was detected during a command that reads from an I/O feature.)

Output parity error: (parity error was detected during a command that writes to a feature.

External diagnostic mode: (attachment feature is in external diagnostic mode.

Local diagnostic mode: (attachment feature is in the local diagnostic mode.)

The read status command transfers the status word from the attachment feature to the immediate data field of the IDCB. Executing this or any other I/O command successfully resets the status field. If a parity error is detected during a read status command, the IO instruction condition code 5 (interface data check) is returned to the processor and the status word in the immediate data field of the IDCB is invalid.

Diagnostic Commands

Attachment feature diagnostic commands test data and control logic for the attachment feature and for the 4982 termination card. Diagnostic commands for the 4982 feature are discussed in the individual feature command sections.

These diagnostic commands are intended primarily for field maintenance testing. The user programmer may use these commands for testing the sensor I/O subsystem prior to running a production program.

By using the set diagnostic mode command followed by other sensor I/O commands, the program can force an interrupt from the attachment feature, force data and control information to read into the diagnostic register, or force a reset to all sensor I/O features attached (see Figure 3-6). Information in the diagnostic register is obtained by issuing the read diagnostic data command. The reset diagnostic mode command is required to end diagnostic mode and begin normal operation.

Set Diagnostic Mode

IDCB (immediate device control block)

Command field	*Device address field*
0 1 1 0 0 0 0 1	
0 — 7	*8 — 15*
61	*00–FF*

Immediate data field		
X	Zeros	X X
16		*30 31*

16: *Diagnostic mode control*
0 = Local diagnostic mode
1 = External diagnostic mode

30–31: *Operation control bits*

The set diagnostic mode command, depending on the condition of *diagnostic mode control* bit 16 of the immediate data field, sets the attachment feature into either *local diagnostic mode* or *external diagnostic mode.* If bit 16 is zero, diagnostic actions performed by this command or by subsequent commands are directed to the attachment feature. If bit 16 is a one, diagnostic actions are directed to the 4982 termination card. The meaning of the *operation control* bits 30 and 31 varies with the diagnostic mode control bit as follows:

Bits

16	*30*	*31*
0	*0*	*0*

The attachment is in local diagnostic mode and disables all interrupts and data transfers to and from the 4982 features. The attachment feature generates an attention interrupt to the processor. The interrupt is generated at the priority level of the prepared attachment feature; and an interrupt condition code 4, attention, is reported.

The IIB presented with the interrupt is all zeros.

Bits

16	*30*	*31*
0	*0*	*1*

The attachment feature is in local diagnostic mode and disables all interrupts and data transfers to and from the 4982 features. The attachment feature sets the diagnostic register with data from a subsequent command directed to the attached 4982 features.

If the subsequent command is a write (bit 1 of the IDCB = 1), the attachment feature loads the immediate data field of the IDCB into the diagnostic register. The diagnostic register is held for reading by a read diagnostic data command. A parity error detected on the write command causes the attachment feature to report IO instruction condition code 5 (interface data check) to the processor. The write command is not executed; and the data in the diagnostic register is not changed.

If the subsequent command is a read (bit 1 of the IDCB = 0), the attachment feature returns all zeros and sets all zeros in the diagnostic register. A parity error detected on the read command causes IO instruction condition code 5 (interface data check) to be returned to the processor. Data in the diagnostic register does not change.

Bits

16	*30*	*31*
0	*1*	*0*

The attachment feature is in local diagnostic mode and disables all interrupts and data transfers to and from the 4982 features. The attachment feature control information is loaded into the diagnostic register during any subsequent command not directed to the attachment feature.

The attachment feature control information is bits 1–7 of any subsequent 4982 feature directed command and bits 12–15 of the device address field to which the command is directed. The data in the diagnostic register will have the following format:

	Bits 1–7 subsequent command	*Bits 12–15 device addr field*
0 0 0 0 0		
0 — 4	*5 — 11*	*12 — 15*

If a parity error is detected on any subsequent 4982 feature command, IO instruction condition code 5 (interface data check) is returned to the processor and data in the diagnostic register is not changed.

Bits

16	*30*	*31*
0	*1*	*1*

The attachment feature is in local diagnostic mode and disables all interrupts and data transfers to and from the sensor I/O features. The diagnostic register is loaded with the result of an AND operation between the immediate data field and the attachment feature control information during the execution of the subsequent command. The control information is bits 1–7 of any subsequent 4982 feature directed command and bits 12–15 of the device address field to which the command is directed.

A parity error detected on any subsequent sensor I/O feature command causes IO instruction condition code 5 (interface data check) to be returned to the processor. Data in the diagnostic register is not changed.

Bits

16	*30*	*31*
1	*1*	*X*

The sensor I/O attachment feature is in external diagnostic mode and activates a halt I/O or machine-check line to the 4982 features. This line causes certain resets to occur as described under "Condition After Power On Transition and Resets" for each major group of commands (attachment, AI, AO, DI/PI, and DO).

Bits

16	*30*	*31*
1	*X*	*1*

The attachment feature is in external diagnostic mode. The attachment feature loads the diagnostic register with termination card wrap-back data (see Figure 3-6) from a subsequent command directed to a 4982 feature.

If the subsequent command is a write (bit 1 of the IDCB = 1), the attachment feature loads the immediate data field of the IDCB into the diagnostic register. A parity error detected on the write command causes IO instruction condition code 5 to be returned to the processor. The command is not executed and data in the diagnostic register is not changed. If the subsequent command is a read command (bit 1 of the IDCB = 0), the attachment feature returns all zeros and sets all zeros in the diagnostic register to be read back during a read diagnostic data. A parity error detected on the read command causes IO instruction condition code 5 (interface data check) to be returned to the processor. Data in the diagnostic register is not updated.

Bits

16	*30*	*31*
1	*X*	*0*

The attachment feature is in external diagnostic mode. The attachment feature loads the diagnostic register with termination card wrap-back control information from a subsequent command directed to a 4982 feature.

The attachment feature control information is bits 1–7 of any subsequent 4982 feature directed command, and bits 12–15 of the device address field to which the command is directed. Under this mode of operation, the data in the diagnostic register has the following format:

0 0 0 0 0	*Bits 1–7 subsequent command*	*Bits 12–15 device addr field*
0 – 4	*5 – 11*	*12 – 15*

If the subsequent command is a write (bit 1 of the IDCB = 1), the control information is loaded into the diagnostic register.

If the subsequent command is a read (bit 1 of the IDCB = 0), the control information is loaded into the immediate data field of the IDCB and the diagnostic register.

A parity error detected on a subsequent command causes IO instruction condition code 5 (interface data check) to be returned to the processor, and the diagnostic register is not updated. The data in the immediate data field of the IDCB is invalid.

Read Diagnostic Data

IDCB (immediate device control block)

Command field	*Device address field*
0 0 1 0 1 1 1 1	
0 – 7	*8 – 15*
2F	*00–FF*

Immediate data field
Data
16 – 31
From attachment feature diagnostic register

The read diagnostic command is directed to the attachment feature to transfer the data stored in the diagnostic register to the processor. The data in the diagnostic register is the data stored by operations specified in set diagnostic mode IDCB.

A parity error detected on this command causes IO instruction condition code (interface data check) to be returned to the processor and the diagnostic data in the immediate data field of the IDCB is invalid.

Reset Diagnostic Mode

IDCB (immediate device control block)

Command field (bits 0–7)	Device address field (bits 8–15)
0 1 1 0 0 0 1 0	
62	00–FF

Immediate data field (bits 16–31)
Zeros

The reset diagnostic mode command resets diagnostic mode in the attachment feature. The immediate data field in the IDCB is zero, and is checked for parity. If the attachment feature is not in diagnostic mode, execution of this command is accepted but the status and data of the attachment feature is unchanged. A parity error detected on this command causes IO instruction condition code 5 (interface data check) to be returned to the processor and this command is not executed.

IO Instruction Condition Codes

The following IO instruction condition codes may be returned on any of the attachment feature commands:

Condition codes	*Meaning*
0	Feature not attached
5	Interface data check
7	Satisfactory

Condition After Power On Transition and Resets

Halt I/O or Machine Check. A halt I/O command or a machine check condition causes the attachment feature to reset diagnostic mode, the diagnostic register, and the status field.

Reset Key. Pressing the reset key on the Series/1 processor console causes the attachment feature to reset diagnostic mode, the diagnostic register, the status field, and the prepare field.

Power On. Applying power to the Series/1 causes the attachment feature to reset diagnostic mode, the diagnostic register, the status field, and the prepare field.

COMMON SENSOR INPUT/OUTPUT COMMANDS

Three commands are common to all features in the 4982; read ID, read status, and device reset. For these three commands, the contents of the device address field determines which feature is to be used. Although these commands can be issued to any sensor I/O feature, the response of each feature is unique.

Read ID

IDCB (immediate device control block)

Command field (bits 0–7)	Device address field (bits 8–15)
0 0 1 0 0 0 0 0	
20	00–FF

Immediate data field (bits 16–23)	24	25–28	29–31
1 0 0 0 0 0 0 0	0	X X X X	0 0 0

The read ID command is used to determine the feature installed in the addressed position. The attachment feature ID is placed in the first byte of the immediate data field, while the contents of the second byte of the immediate data field (feature ID) identifies the feature as shown in Figure 3-7.

Feature / Data	*Description*
AI control	
00100000	Without multirange amplifier
00101000	With multirange amplifier
Multirange amplifier	This feature is not addressable
Multiplexer	
00110000	Reed relay multiplexer
00111000	Solid state multiplexer
AO	
01000000	Analog output
DI/PI	
00001000	Isolated DI/PI
00010000	Nonisolated DI/PI
DO	
00011000	Digital output

Figure 3-7. Feature ID bytes

Read Status

IDCB (immediate device control block)

Command field	*Device address field*
0 0 1 0 1 0 0 0	
0 – 7	*8 – 15*
28	*00–FF*

Immediate data field			
X X X X X X X X	0	X X X X	0 0 0
16 17 18 19 20 21 22 23	*24*	*25 26 27 28*	*29 30 31*

The read status command transfers a feature dependent status (bits 16–23) and a feature ID (bits 24–31) to the immediate data field. The feature IDs (second bytes) are shown in Figure 3-7. The status bytes are shown in Figure 3-8.

Feature / Data	*Description*
AI control	
00000000	Always all zeros
Multirange amplifier	This feature is not addressable
Multiplexer	
00000000	Always all zeros
AO	
0000XX00	Point 0 = ±5V
0001XX00	Point 0 = ±10V
0010XX00	Point 0 = 0 to 10V
00XX0000	Point 1 = ±5V
00XX0100	Point 1 = ±10V
00XX1000	Point 1 = 0 to 10V
DI/PI	
00XXXX00	No interrupt is pending
00XXXX01	An interrupt has been serviced. If PI is armed, a read PI with reset has not occurred. If external sync is armed, a read DI has not occurred.
00XXXX10	Not presented
00XXXX11	An interrupt is pending
00XX01XX	Diagnostic set test 0 mode
00XX10XX	Diagnostic set test 1 mode
0001XXXX	External sync armed
0010XXXX	PI armed

Figure 3-8. Feature dependent status bytes

Device Reset

IDCB (immediate device control block)

Command field	*Device address field*
0 1 1 0 1 1 1 1	
0 – 7	*8 – 15*
6F	*00–FF*

Immediate data field
Zeros
16 – 31

The device reset command is used to reset the addressed features as described below. The IDCB immediate data field is not used by this command and should be all zeros.

AI A device reset command addressed to the AI control feature resets all the AI features. The AI channel inputs for the multiplexer features are set to an open circuit condition. Interrupt pending conditions, the status word, and the ADC data register are all reset. If an AI conversion cycle is in process, the ADC cannot regain its quiescent state immediately on receiving a device reset command. Until the conversion cycle is completed, an IO instruction condition code 2 (busy after reset) is reported for any subsequent AI command following the device reset command.

AO A device reset command addressed to the AO feature is accepted by the feature but does not change the values in the AO feature registers.

DI/PI A device reset command addressed to the DI/PI feature resets arm conditions, interrupt pending, diagnostic test mode, the status field, and all data registers.

DO A device reset command addressed to the DO feature is accepted by the feature, but no reset operation occurs.

ANALOG INPUT COMMANDS

Analog input (AI) features (Figure 3-9) may be considered a program controlled voltmeter, with the capability to select one of up to 112 input signals under program control. Due to the complexity of the AI features, they require more program control than other 4982 features. The physical characteristics of the AI features are described in Chapter 1.

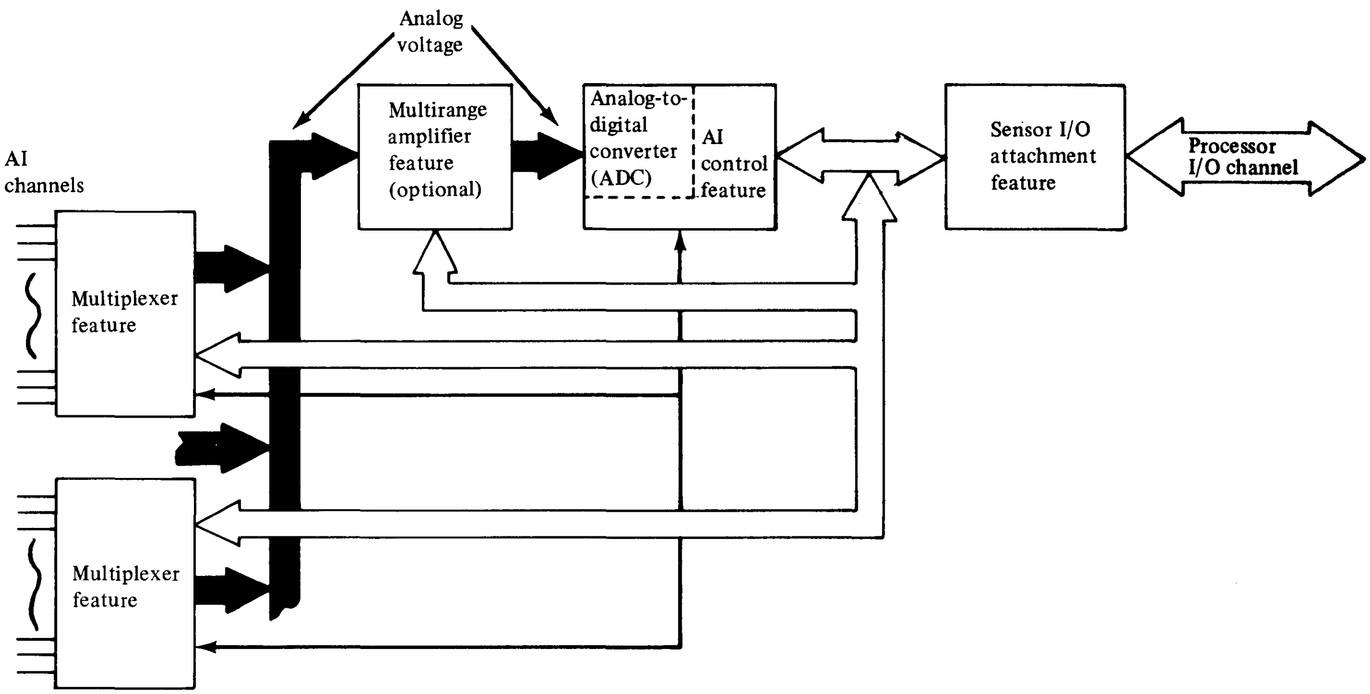


Figure 3-9. AI features data flow

AI features provide a choice of two multiplexer features. A reed relay multiplexer permits selection of one of eight channels per feature. A solid state multiplexer permits selection of one of sixteen channels per feature. Each channel carries one signal.

If the multirange amplifier feature is not used, the full-scale range is ±5 volts for a solid state multiplexer and +5 volts to −500 millivolts for a reed relay multiplexer. The addition of the multirange amplifier feature permits program controlled selection of seven full scale ranges (Figure 3-10) for increased accuracy in the measurement of low-level voltages.

Amplifier gain	*Full scale range*
1	*
10	± 500 millivolts
25	± 200 millivolts
50	± 100 millivolts
100	± 50 millivolts
250	± 20 millivolts
500	± 10 millivolts

*± 5 volts for solid state multiplexer +5 volts to −500 millivolts for reed relay multiplexer

Figure 3-10. Multirange amplifier full scale range

The analog-to-digital converter (ADC) in the AI control feature converts the selected AI voltage to a binary number. The binary results of the analog-to-digital conversion for a positive full scale reading is represented by a field with data bits of ones and a sign bit of zero. A negative full scale reading is a field with data bits of zero (two's complement of the positive full scale) and a sign bit of one. The conversion data field and the binary range code are expressed in the following word format:

X X X X	X X X X	X X X X	0	X X X
0			12	15

Data, binary representation of input voltage value

Sign: *0 = positive*
1 = negative

Range code	*Gain*	*Input range*
001	*1*	*
010	*10*	*±500 mV*
011	*25*	*±200 mV*
100	*50*	*±100 mV*
101	*100*	*±50 mV*
110	*250*	*±20 mV*
111	*500*	*±10 mV*

**±5V (solid state)*
+5V to −500 mV (reed relay)

The following sections describe the I/O commands that support the AI features. The features use these commands to convert input voltages to binary data, to transfer data from the AI features to the processor, and to test and diagnose the AI features. Convert AI command is addressed only to a multiplexer feature. Read ADC, convert diagnostic zero, and convert diagnostic voltage commands are addressed only to the AI control feature. No commands are addressed to the multirange amplifier feature.

Common Commands

Three commands can be issued to retrieve ID, retrieve status information, and reset the AI features. These commands; read ID, read status, and device reset are common to other 4982 features. Refer to "Common Sensor Input/Output Commands."

Analog Input Convert Commands

The following two commands are used to determine an AI channel voltage: convert AI and read ADC.

Convert AI

IDCB (immediate device control block)

Command field	*Device address field*
0 1 0 0 1 0 0 0	
0–7: 48	*8–15: 00–FF*

Immediate data field						
0 0 0 0 0	X X X	0	X	0 0	X X X X
16	*21 22 23*		*25*		*28*	*31*

Range code	*Gain*	*Input level*
000	*	*
001	*1*	*5V (solid state) +5V to −500 mV (reed relay)*
010	*10*	*500 mV*
011	*25*	*200 mV*
100	*50*	*100 mV*
101	*100*	*50 mV*
110	*250*	*20 mV*
111	*500*	*10 mV*

Bit 25: *0 = No zero correction*
1 = Zero correction

Channel Address
Reed relay multiplexer 0–7
Solid state multiplexer 0–15

**Invalid gain*

The convert AI command is addressed to a multiplexer feature. This command sets the multirange amplifier feature (if used) to a specified input voltage range, defines the AI multiplexer channel, and initiates an AI conversion cycle. The immediate data field of the IDCB specifies the input voltage range, the input channel address, and whether the conversion is to incorporate zero correction.

Zero correction is an automatic method of eliminating internal offset drift errors due to temperature and aging. Because zero correction involves two conversions, it takes longer than a conversion command without zero connection. (See Chapter 2, "Performance Specifications," for actual conversion times.)

If an IO instruction condition code 7 is returned, the AI convert command has been successfully initiated and an analog-to-digital conversion of the selected input channel occurs. When the conversion is completed, an interrupt is requested. When the interrupt is accepted, the program may respond by issuing a read ADC command. The read ADC command transfers the results of the conversion from the AI control feature to the immediate data field. The 4982 is now available for another AI convert command.

The AI control feature reports only two interrupt condition codes, condition code 2 and condition code 3. Condition code 2, exception, is reported and an interrupt status byte (ISB) is presented when the condition occurs. Condition code 3, device end, is reported at the end of a successful conversion cycle. The format of the ISB is:

0	0	X	X	X	0	0	0
0							*7*

Overvoltage—During the last conversion, the input voltage was out of range. (bit 4)

Invalid range—The last AI convert command specified an invalid input range (range value was 000) or a range other than 1 with no multirange amplifier installed. (bit 3)

Invalid channel—The last convert command specified an invalid multiplexer channel. (bit 2)

Read ADC

IDCB (immediate device control block)

Command field	*Device address field*
0 0 0 0 0 0 0 0	
0 7	*8 15*
00	*00*

Immediate data field
X X X X X X X X X X X X 0 X X X
16 27 28 29 31

Data, binary representation of input voltage value (bits 16–27)

Sign: 0 = Positive
1 = Negative

Range code	*Gain*	*Input level*
000	*	*
001	*1*	*±5V (solid state)* *+5V to −500 mV (reed relay)*
010	*10*	*±500 mV*
011	*25*	*±200 mV*
100	*50*	*±100 mV*
101	*100*	*±50 mV*
110	*250*	*±20 mV*
111	*500*	*±10 mV*

**Returned following a reset or following a convert diagnostic voltage command if the multirange amplifier feature is installed.*

The read ADC command is addressed to the AI control feature and transfers a data word to the immediate data field. The data word contains the range of the last conversion, the sign of the input voltage, and the 11 bit binary value of the input voltage. Reading the ADC does not reset the data register in the AI control feature.

Figure 3-11 shows AI binary value (IDCB bits 16–27) converted to an analog voltage. The voltage values of a selected range (IDCB bits 29–31) corresponding to the 1 bits of the binary value are added together.

The following examples demonstrate the use of Figure 3-11. Note that the negative voltage binary equivalent is a two's complement of the positive voltage binary equivalent of the same magnitude.

Read ADC command (IDCB immediate data field) example of positive voltage

Immediate data field

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	0	1	1	0	0	0	1	0	1	1	0	0	1	1

Positive sign

200 mV range

Value

25.000000
12.500000
.781250
.195313
.097656

+ 38.574219 mV total

Read ADC command (IDCB immediate data field) example of negative voltage (two's complement)

Immediate data field

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	1	0	1	1	0	0	1	0	1	1	0	0	1	0	1

Two's complement: 0 1 0 0 1 1 0 1 0 1 0 0

50 mV range

Negative sign

Value

12.500000
1.562500
.781250
.195313
.048828

– 15.087891 mV total

Figure 3-12 shows typical AI voltage conversions for the seven input ranges.

Diagnostic Commands

The diagnostic commands, convert diagnostic zero and convert diagnostic voltage, are intended primarily for field maintenance testing of the AI features. The user programmer may use these commands for testing the AI features prior to running a production program.

Convert Diagnostic Zero

IDCB (immediate device control block)

Command field (bits 0–7)	*Device address field* (bits 8–15)
0 1 1 0 1 0 0 0	
68	00–FF

Immediate data field

16–20	21 22 23	24–31
0 0 0 0 0	X X X	0 0 0 0 0 0 0 0

Range code	*Gain*	*Input level*
000	*	*
001	*1*	*±5V (solid state)* *+5V to –500 mV (reed relay)*
010	*10*	*±500 mV*
011	*25*	*±200 mV*
100	*50*	*±100 mV*
101	*100*	*±50 mV*
110	*250*	*±20 mV*
111	*500*	*±10 mV*

**Invalid gain*

The convert diagnostic zero command initiates an AI conversion (without zero correction) with the input to the AI control feature or the multirange amplifier feature (if used) shorted to ground. When the conversion is complete or if an error occurs, the AI control feature initiates an interrupt to the processor and becomes interrupt pending.

The AI control feature reports only two I/O interrupt conditions, code 2 and code 3. Condition code 2, exception, is reported and an ISB is presented when a condition occurs. Condition code 3, device end, is reported at the end of a successful conversion cycle. The format of the ISB is:

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

Bit 4: *Overvoltage–During the last conversion, the input voltage was out of range.*

Bit 3: *Invalid range–The last AI convert command specified an invalid input range (range value 000) or a range other than 1 with no amplifier installed*

IDCB bit	*Range code IDCB bits 29–31*						
	111 (±10 mV)	*110 (±20 mV)*	*101 (±50 mV)*	*100 (±100 mV)*	*011 (±200 mV)*	*010 (±500 mV)*	*001 (±5000 mV)*
16	*	*	*	*	*	*	*
17	5.000000	10.000000	25.000000	50.000000	100.000000	250.00000	2500.000
18	2.500000	5.000000	12.500000	25.000000	50.000000	125.00000	1250.000
19	1.250000	2.500000	6.250000	12.500000	25.000000	62.50000	625.000
20	.625000	1.250000	3.125000	6.250000	12.500000	31.25000	312.500
21	.312500	.625000	1.562500	3.125000	6.250000	15.62500	156.250
22	.156250	.312500	.781250	1.562500	3.125000	7.81250	78.125
23	.078125	.156250	.390625	.781250	1.562500	3.90625	39.063
24	.039063	.078125	.195313	.390625	.781250	1.95313	19.531
25	.019531	.039063	.097656	.195313	.390625	.97656	9.766
26	.009766	.019531	.048828	.097656	.195313	.48828	4.883
27	.004883	.009766	.024414	.048828	.097656	.24414	2.441

*Bit 16 is the sign bit–"0" for positive voltages and "1" for negative voltages.

Figure 3-11. Binary to analog voltage conversion

IDCB bits 16–27	*Range*						
	±10 mV	*±20 mV*	*±50 mV*	*±100 mV*	*±200 mV*	*±500 mV*	*±5000 mV*
0111 1111 1111	9.995	19.990	49.976	99.951	199.902	499.756	4997.6
0100 0000 0000	5.000	10.000	25.000	50.000	100.000	250.000	2500.0
0000 0000 0001	.005	.010	.024	.049	.098	.244	2.4
0000 0000 0000	.000	.000	.000	.000	.000	.000	.0
1111 1111 1111	– .005	– .010	– .024	– .049	– .098	– .244	– 2.4
1100 0000 0000	–5.000	–10.000	– 25.000	– 50.000	–100.000	–250.000	– 2500.0
1000 0000 0000	–10.000	–20.000	–50.000	–100.000	–200.000	–500.000	–5000.0

Figure 3-12. Typical AI voltage conversions

When the interrupt is accepted the program may respond by issuing a read ADC command. The data for a convert diagnostic zero is dependent on the offset drift.

Convert Diagnostic Voltage

IDCB (immediate device control block)

Command field	*Device address field*
0 1 1 0 1 0 1 0	
0 7	*8 15*
$\underbrace{\hspace{3em}}_{6A}$	$\underbrace{\hspace{3em}}_{00–FF}$

Immediate data field
Zeros
16 31

The convert diagnostic voltage command, addressed to the AI control feature, initiates a conversion with zero correction. A diagnostic voltage of 4.5 volts (±.5 V) is automatically applied to the input of the AI control feature or the multirange amplifier feature *if installed*. The conversion is performed at a gain of 1. The immediate data field of the IDCB is not used and should be zero. When the conversion is complete or if an error occurs, the AI control feature initiates an interrupt to the processor and becomes interrupt pending.

The AI control feature reports only two interrupt condition codes, code 2 and code 3. Condition code 2, exception, is reported and an ISB is presented when a condition occurs. Condition code 3, device end, is reported at the end of a successful conversion cycle. The format of the ISB is:

0 0 0 0	X	0 0 0
0 3	*4*	*7*

Overvoltage–During the last conversion, the input voltage was out of range.

IO Instruction Condition Codes

The following IO instruction condition codes may be returned on any AI feature command with the exception of device reset:

Condition codes	*Meaning*
0	Feature not attached
1	Busy
2	Busy after reset
5	Interface data check
7	Satisfactory

Device reset reports only condition codes 0 and 7

Condition After Power On Transition and Resets

Halt or Machine Check. A halt I/O command or a machine check condition resets interrupt pending conditions, diagnostic mode, the status word, and the multiplexer features.

RESET Key. Pressing the reset key on the Series/1 console resets interrupt pending conditions, diagnostic mode, the ADC register, the status word, and the multiplexer features.

Power On. Applying power to the Series/1 resets interrupt pending conditions, diagnostic mode, the ADC register, the status word, and the multiplexer cards.

ANALOG OUTPUT COMMANDS

The Analog output (AO) feature (Figure 3-13) has two analog output points, is noninterrupting, and occupies one device address. The two AO points produce analog voltages of three manually selected ranges developed by the AO digital-to-analog converter. The operating range of the points is selected using jumpers on the AO feature. The ranges are selected when the feature is ordered, and can be changed by the user.

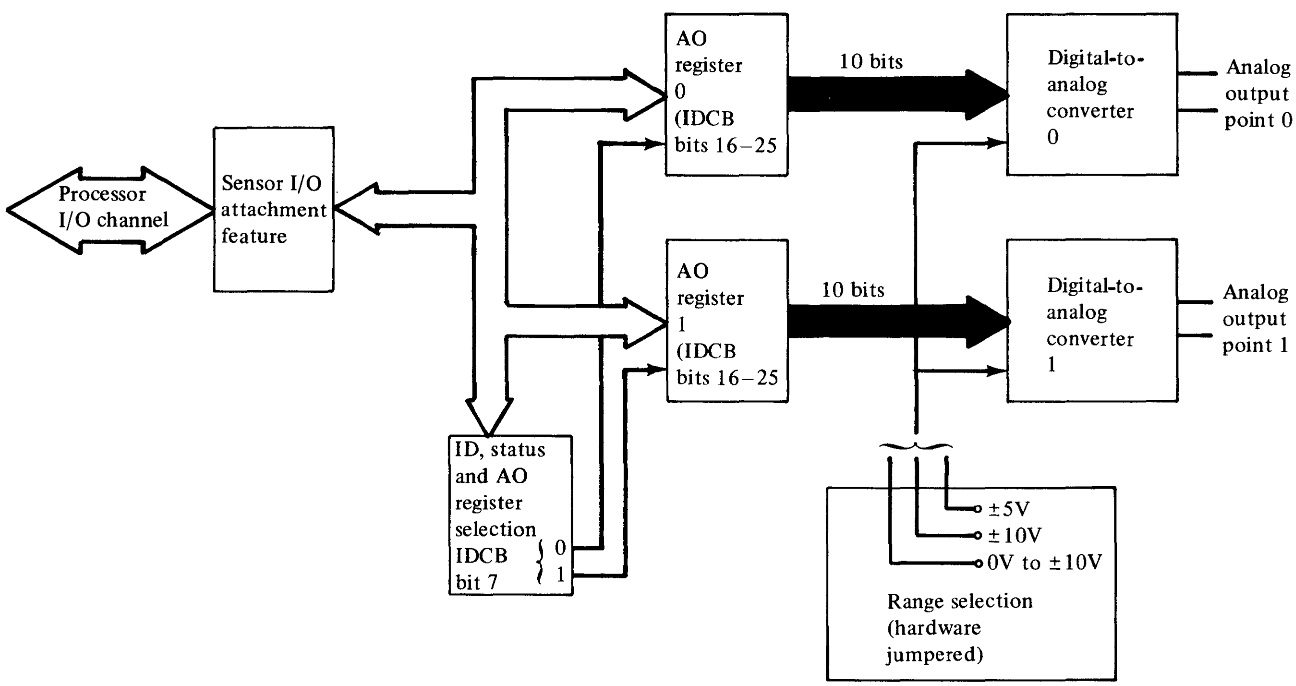


Figure 3-13. AO feature data flow

Common Commands

The read ID and the read status commands can be issued to retrieve AO ID and status information. A device reset can be issued to an AO feature but the AO registers do not change. These commands are common to other 4982 features. Refer to "Common Sensor Input/Output Commands".

Write Analog Output Commands

IDCB (immediate device control block)

Command field	*Device address field*
0 1 0 0 1 0 0 X	
0 ... *7*	*8* ... *15*
48–49	*00–FF*

Bit 7 = 0-AO write point 0
Bit 7 = 1-AO write point 1

Immediate data field	
Data	Zeros
16 ... *25*	*26* ... *31*

The write analog output (AO) commands transfer digital data from the immediate data field (bits 16–25) of the IDCB to the digital-to-analog converter via a selected AO register (see Figure 3-13). The digital-to-analog conversion is performed within the selected AO voltage range.

Figure 3-14 shows typical AO conversions for the three selectable voltage ranges. The voltage ranges vary in increments by the voltage value of the least significant bit (LSB), bit 25 of the IDCB. For example, for the ±5V range the LSB represents 9.7656 millivolts.

		IDCB bits									
Range	*Voltage*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*
±5V	+4.990 234 4V	0	1	1	1	1	1	1	1	1	1
(LSB =	+4.980 468 8V	0	1	1	1	1	1	1	1	1	0
9.7666 mV)	0V	0	0	0	0	0	0	0	0	0	0
	–4.990 234 4V	1	0	0	0	0	0	0	0	0	1
	–5V	1	0	0	0	0	0	0	0	0	0
±10V	+9.980 468 8V	0	1	1	1	1	1	1	1	1	1
(LSB =	+9.960 937 5V	0	1	1	1	1	1	1	1	1	0
9.5332 mV)	0V	0	0	0	0	0	0	0	0	0	0
	–9.980 468 8V	1	0	0	0	0	0	0	0	0	1
	–10V	1	0	0	0	0	0	0	0	0	0
+10V	+9.990 234 4V	1	1	1	1	1	1	1	1	1	1
(LSB =	+5V	1	0	0	0	0	0	0	0	0	0
9.7666 mV)	+0.009 765 6V	0	0	0	0	0	0	0	0	0	1
	0V	0	0	0	0	0	0	0	0	0	0

Figure 3-14. Typical AO conversions

IO Instruction Condition Codes

The following IO instruction condition codes may be returned on any AO feature command with the exception of device reset:

Condition codes	*Meaning*
0	Feature not attached
5	Interface data check
7	Satisfactory

Device reset reports only condition codes 0 and 7.

Condition After Power On Transition And Resets

Halt I/O or Machine Check. A halt I/O command or a machine check condition does not cause any reset action in the AO feature.

Reset Key. Pressing the reset key on the Series/1 console does not cause any reset action in the AO feature.

Power On. Applying power to the Series/1 causes the AO feature to reset the output points to a 0 V.

DIGITAL INPUT/PROCESS INTERRUPT FEATURE COMMANDS

There are two versions of the digital input (DI) feature–isolated digital input/process interrupt (DI/PI) and nonisolated DI/PI. There are 16 points of DI per feature, each point is represented by a bit in the IDCB immediate data field of a read command. With the exception of the input characteristics, these two features are identical; the exceptions are discussed in chapter 1 (Figure 3-13). Both DI/PI features use the same commands, and differ to the program by their ID and status information.

The DI/PI commands may be considered in four separate program modes. These program modes are the following:

- Processor initiated (not in response to an interrupt) using the read DI command.
- External sync interrupt initiated using the arm external sync and read DI commands.
- Process interrupt (PI) initiated using the arm PI, read PI, and read PI with reset commands.
- Diagnostic using the set test 0 and set test 1 commands.

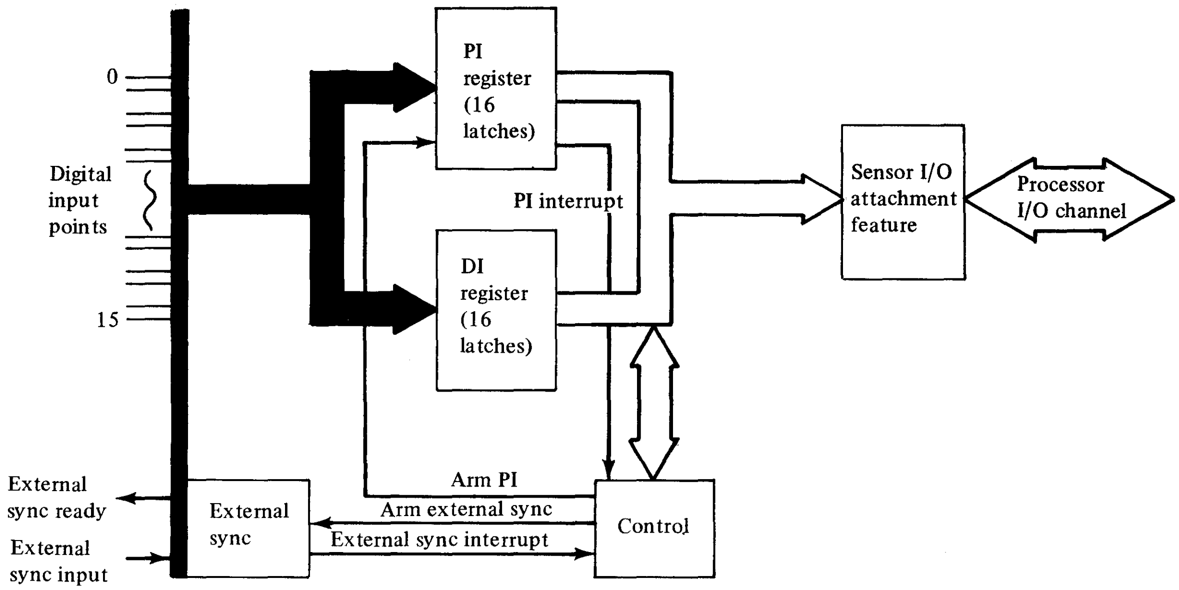


Figure 3-15. DI/PI features data flow

Utilizing the same DI/PI feature, certain programming modes may be overlapped with other modes. Processor initiated and external sync initiated modes may be overlapped; also processor initiated and PI initiated modes may be overlapped. For example, while the processor is reading the feature's DI register, a latch in the armed PI register can be set and a PI is requested. The processor can except the interrupt and read the PI register.

Because, the arm PI and the arm external sync conditions reset each other, they cannot be overlapped. The diagnostic mode cannot be program overlapped with other program modes. DI/PI feature program modes are explained under the applicable commands.

Common Commands

Three commands can be issued to retrieve ID and status information and reset the DI/PI features. These commands; read ID, read status, and device reset are common to other 4982 features. Refer to "Common Sensor Input/Output Commands".

Digital Input Commands

During a processor initiated program mode only the read DI command is used. Both the read DI and arm external sync commands are used during an external sync interrupt initiated program mode.

Read DI

IDCB (immediate device control block)

Command field	*Device address field*
0 0 0 0 0 0 0 0	
0 … *7*	*8* … *15*
00	*00–FF*

Immediate data field
Data
16 … *31*

The read DI command initiation differs depending on whether it is issued initially by the processor or in response to an external sync interrupt. If the processor initiates the command (not in responses to an interrupt), 16 points of user DI information is transferred from an unlatched DI register to the immediate data field. This is considered a processor initiated program mode.

For a read DI command issued in response to an external sync interrupt, see "Arm DI External Sync".

For the read DI command, the feature reports IO instruction condition code 1, busy, only if the feature is armed for external sync.

Arm DI External Sync

IDCB (immediate device control block)

Command field	*Device address field*
0 1 1 0 1 0 0 1	
0 … *7*	*8* … *15*
69	*00–FF*

Immediate data field
Zeros
16 … *31*

Issuing the arm DI external sync command activates the external sync ready output line (see Figure 3-13) and sets the IDCB bit 19 of the feature dependent status to a one. If the DI/PI feature is armed for external sync, activating the user external sync input line latches the DI register in a static condition (no additional digital inputs), deactivates the external sync ready line, and presents an interrupt to the processor. The DI register remains latched until a read DI command is issued; the external sync ready line is then reactivated. This is considered an external sync initiated program mode. This program mode allows the user to sample a DI process using an external signal as an interrupt source.

For an external sync interrupt, the feature reports an I/O interrupt condition code of 4, attention. The IIB has the same format as the feature dependent status (see "Read Status").

The armed external sync is reset by a device reset or by an arm PI command.

Process Interrupt Commands

During a PI initiated program mode the three commands that are used are: arm PI, read PI, and read PI with reset.

Arm PI

IDCB (immediate device control block)

Command field	*Device address field*
0 1 1 0 1 0 0 0	
0 … *7*	*8* … *15*
68	*00–FF*

Immediate data field
Zeros
16 … *31*

Issuing the arm PI command resets previously latched PI data in the PI register, enables the PI register to except user digital inputs, and sets IDCB bit 18 of the feature dependent status. Once this command is executed, any 1-bit transition (positive for isolated DI/PI feature, negative for nonisolated DI/PI feature) causes the presentation of a PI and latches the 1-bit condition in the PI register. The 1 condition remains latched in the PI register until a read PI with reset command is issued, another arm PI command is issued, or any device reset operation is performed. If a read PI command is issued, the PI register is not reset. Additional latches may be set, but no interrupts are presented.This is considered a PI initiated program mode.

For a PI, the feature reports an I/O interrupt condition code 4, attention. The IIB has the same format as the feature dependent status (see "Read Status").

The armed PI condition is reset by a device reset, or by an arm external sync command.

Read PI

IDCB (immediate device control block)

Command field	*Device address field*
0 0 0 0 0 0 0 1	
0 … *7*	*8* … *15*
01	*00–FF*

Immediate data field
Data
16 … *31*

The read PI command transfers 16 bits of user DI from the latched PI register to the immediate data field. The feature remains armed for PI, the data remains latched in the PI register, and no new interrupts can occur without resetting the PI register (see "Read PI with Reset").

Read PI with Reset

IDCB (immediate device control block)

Command field	*Device address field*
0 0 0 0 0 0 1 0	
0 … *7*	*8* … *15*
02	*00–FF*

Immediate data field
Data
16 … *31*

The read PI with reset command performs the same as the read PI command, with the exception that the PI register latches are reset. After issuing this command, the feature remains armed for PI.

Diagnostic Commands

The diagnostic commands, set test 0 and set test 1, are intended primarily for field maintenance testing of the DI/PI features. The user programmer may use these commands for testing the DI/PI features prior to running a production program. These commands do not reset an armed external sync condition.

Set Test 0

IDCB (immediate device control block)

Command field	*Device address field*
0 1 1 0 1 0 1 0	
0 – *7*	*8* – *15*
6A	*00–FF*

Immediate data field
Zeros
16 – *31*

The set text 0 command is a diagnostic mode command. It disables all user digital inputs and forces all the DI/PI feature registers to a logical zero state.

Set Test 1

IDCB (immediate device control block)

Command field	*Device address field*
0 1 1 0 1 0 1 1	
0 – *7*	*8* – *15*
6B	*00–FF*

Immediate data field
Zeros
16 – *31*

The set test 1 command is a diagnostic mode command. The command disables all user digital inputs and forces all the DI/PI feature register latches to a logical one state. To ensure the PI latched data is forced to all logical ones in diagnostic mode, a set test 0 command should be issued prior to issuing the set test 1 command.

IO Instruction Condition Codes

The following IO instruction condition codes may be returned on the DI/PI commands with exceptions of read ID, read status, read PI, and device reset:

Condition codes	*Meaning*
0	Feature not attached
1	Busy
5	Interface data check
7	Satisfactory

Read ID, read status, read PI only report condition codes 0, 5, and 7. Device reset reports just 0 and 7.

Condition After Power On Transition and Resets

Halt I/O or Machine Check. A halt I/O command or a machine check condition resets any arm condition, diagnostic mode, interrupt pending, and all data registers.

Reset Key. Pressing the reset key on the Series/1 console causes the DI/PI feature to reset any arm condition, diagnostic mode, interrupt pending, and all data registers.

Power On. Applying power to the Series/1 causes the DI/PI feature to reset any arm condition, diagnostic mode, interrupt pending, and all data registers.

DIGITAL OUTPUT COMMANDS

The digital output (DO) feature (Figure 3-16) has 16 DO points, is noninterrupting, and occupies one device address per feature.

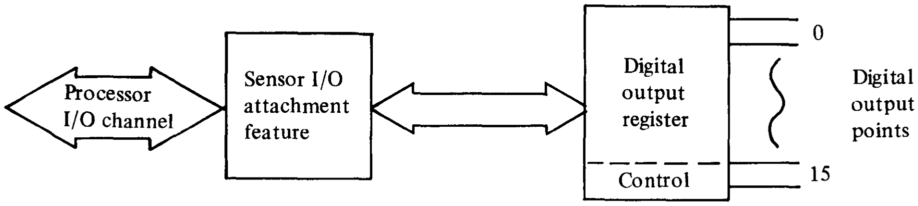


Figure 3-16. DO feature data flow

Common Commands

The read ID and read status commands can be issued to retrieve DO ID and status information. A device reset command can be issued to a DO feature but no reset operation is performed. Refer to "Common Sensor Input/Output Commands".

Write DO

IDCB (immediate device control block)

Command field	*Device address field*
0 1 0 0 1 0 0 0	
0 … 7	*8 … 15*
48	*00–FF*

Immediate data field
Data
16 … 31

The write DO command transfers 16 bits of DO data from the immediate data field to the DO register. When the data is latched into DO register, it provides a continuous output to the user process. The data remains latched in the DO register until another write DO command is issued to the DO feature or a power on reset occurs.

IO Instruction Condition Codes

The following IO instruction condition codes maybe returned on the DO commands with the exception of device reset:

Condition codes	*Meaning*
0	Feature not attached
5	Interface data check
7	Satisfactory

Device reset reports only condition codes 0 and 7.

Condition After Power On Transition and Resets

Halt I/O or Machine Check. A halt I/O command or a machine check condition does not reset the DO register.

Reset Key. Pressing the reset key on the Series/1 console does not reset the DO register.

Power ON. Applying power to the Series/1 causes the DO feature to reset the DO register to all zeros.

Appendix A. Analog Performance Terminology

accuracy. A value specifying the maximum deviation of a converted value from the true value. The deviation is attributed to linearity, offset, gain, short-term (within 24 hours of calibration), repeatability, and temperature variation within reference conditions.

channel. A path for the transmission of analog input signals.

common-mode voltage. The voltage between the input on the multiplexer card and the sensor I/O unit frame ground. The maximum common-mode voltage is limited by the breakdown voltage of components and by the breakdown voltage of the insulation resistance between the multiplexer input circuit and ground.

crosstalk. This describes the normal-mode error on one channel produced by application of a signal to another channel on the same multiplexer card, or to a channel on an adjacent multiplexer card.

differential input. A two-terminal input where neither input line is connected to ground. A common-mode signal may exist at the input of a channel with this input configuration. A 'flying-capacitor' multiplexer or differential amplifier may be used in subsequent circuitry to reject the common-mode voltage and reduce the normal-mode error that is produced.

drift. Represents the maximum change of the statistical mean of may readings within a specified time at a constant temperature. Short-term drift applies to a duration of 24 hours or less. Long-term drift applies to a duration of more than 24 hours.

full scale. Full scale is the maximum nominal value represented by the largest possible binary count of the converter data register plus one. For an n-bit binary converter, the full-scale value is that value which would correspond to a carry out of the data register, or 2– n counts. This full-scale value generally cannot be achieved, but only approached within

isolated input. The signal input terminals are electrically isolated from all other terminals. The 'flying capacitor' type of multiplexer is an example of an isolated input, because there is an open relay in each channel input to isolate the signal from all other channel inputs.

least significant bit. The size of the smallest step made by the analog-to-digital converter.

maximum. The maximum (max) value of a statistically significant sample of readings.

noise. Extraneous disturbances which may be either steady state or transient in nature and may contain frequency components from dc to high frequency.

normal-mode rejection ratio. The ratio of the normal-mode voltage that is measured to the normal-mode voltage on the channel input. In a data acquisition system, it is desirable to discriminate against high frequency normal-mode noise; therefore, low-pass filters are used. Normal-mode rejection ratio is frequently expressed for a given frequency or range of frequencies.

normal-mode voltage. The voltage between the – input and the + input on a multiplexer channel. The normal-mode voltage is limited by the breakdown voltage of the components in the multiplexer input circuit.

nyquist rate. The minimum sampling rate required to completely characterize a signal of a given frequency content.

overload. Overload is defined for analog input as the least input absolute voltage value above which the analog-to-digital converter cannot distinguish a change. The overload value can be different for plus and minus inputs. An overload occurs when the input voltage to the analog-to-digital converted exceeds its input voltage range. A higher input voltage range should be used if a conversion fails because of an overload condition on a lower range.

overvoltage. A voltage greater than the normal operating voltage limits. If the maximum overvoltage is exceeded, damage to components may result.

range. The region between the limits within which a voltage is measured, expressed by stating the lower and upper range limits.

reference Conditions. A temperature of 25°C ± 2.8C (77°F ± 5°F) and relative humidity of 40% to 60%.

repeatability. The closeness of agreement among repeated conversions of the input for the same value of analog input signal made under the same operating conditions. It is the maximum deviation of converted values from the mean value within a ten-minute interval. It may vary with sampling rate. A repeatability specification of ± .30% says that 99.7% of the readings in a statistically significant sample will lie within ± .30% of the mean value.

resolution. The maximum capability of a system to convert an analog signal to a proportional digital value (e.g., resolution is one part in 2048, or 11 binary bit. Voltage resolution is determined by dividing the maximum input signal by 2048.)

sampling rate. The speed in samples per second at which a multiplexer channel may be repetitively addressed. Sampling rate is limited by the effects of pump–out current on multiplexer input capacitances.

scanning rate. The speed in channels per second at which a multiplexer is addressed between different channels.

shielding. A metallic enclosure surrounding some portion of an electronic system. To be effective, shielding should be a grounded conductor of relatively low impedance at the frequency of the disturbance. It must be located between the noise source and the noise sensitive circuit to provide a path to ground for the capacitively coupled noise energy.

single-ended input. A one-terminal input to a nonisolated input circuit. When the -input of a multiplexer channel is connected to the sensor I/O unit frame ground, the channel is said to be single-ended. This eliminates any common-mode input signal. This term is to be contrasted with the terms differential input and floating input.

source resistance. The dc impedance of the input channel under reference conditions during the period when that input channel is selected as seen by the input signal source at the connector on the multiplexer card. The sum of the equivalent resistances in the two lines coming from the signal source when looking toward the signal source.

source unbalance. The difference between the equivalent resistances in the two lines coming from the signal source when looking toward the signal source from the connector on the multiplexer channel input.

temperature coefficient. A factor used to calculate the change in mean accuracy and repeatability attributed to variations in temperature beyond reference conditions (Figure A-1).

total performance. The actual total performance on any single analog reading is determined by the combined effects of mean accuracy, repeatability, temperature outside of reference conditions, long-term drift, common-mode voltage, crosstalk and normal-mode and common-mode external noise.

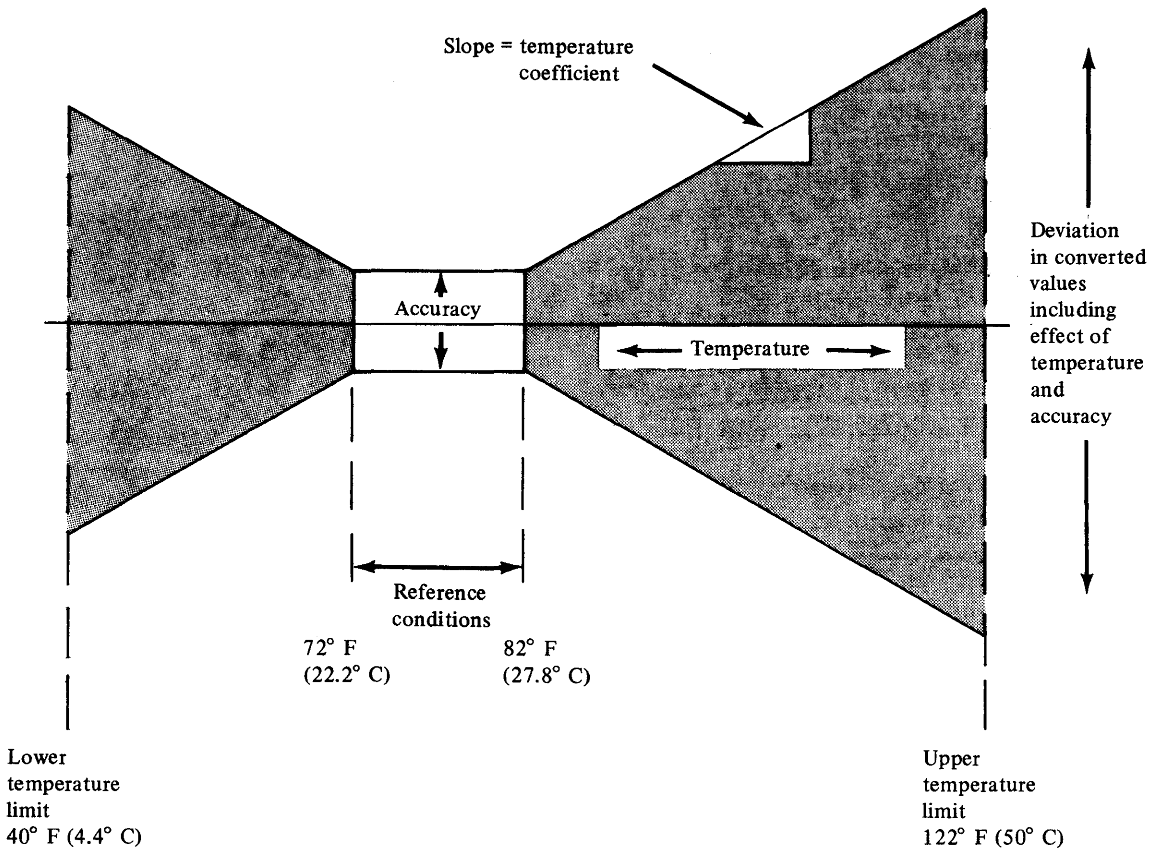


Figure A-1. Temperature coefficient definition

Appendix B. Solid State Multiplexer Low Pass Filter Selection

Solder terminals are included on the solid state multiplexer feature for a user addition of a low-pass filter capacitor to adjust the input filter to the bandwidth required. Adding the capacitors reduces the feature's susceptibility to electrical noise, therefore improving feature performance. If there is no external electrical noise, adding the capacitor will not improve performance. However, in the average industrial environment, electrical noise is severe and a low pass filter is desirable. For slowly changing signals, such as thermocouple outputs, this is not a disadvantage.

In electrically quiet environments or where signals with high frequency components are to be measured, the capacitor can be eliminated or its capacitance reduced to obtain a wider bandwidth.

The bandwidth of the low-pass filter is defined as the range from dc to the frequency at which the attenuation equals three decibels. The following table gives the capacitance required to obtain various filter bandwidths:

Filter bandwidth (Hertz)	*Capacitor (microfarads)*
150.0	1.0
75.0	2.0
30.0	5.0
15.0	10.0
7.5	20.0
3.0	50.0
1.5	100.0

For intermediate values not shown in the previous table, the bandwidth (BW) and capacitance (C) may be read from the log-linear graph in Figure B-1.

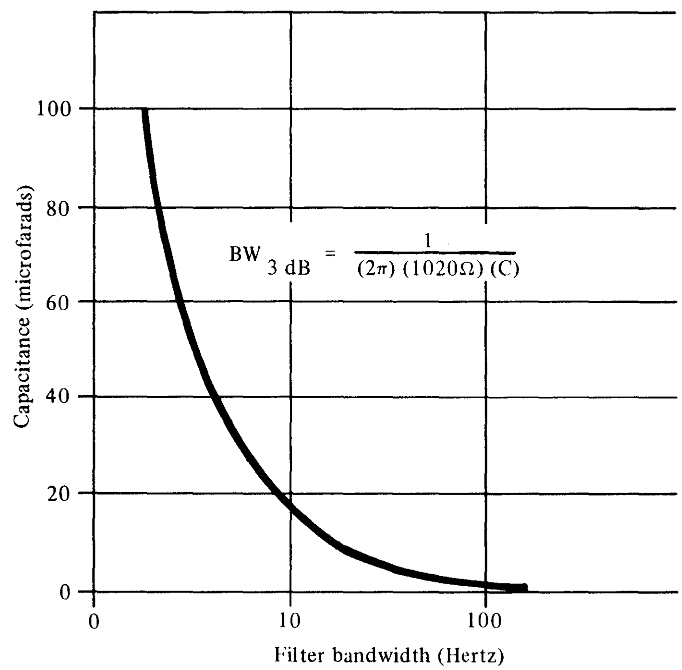


Figure B-1. Capacitance vs. bandwidth

The following restrictions must be observed when selecting a capacitor:

- The Dielectric should be polycarbonate, polystyrene, or teflon to eliminate dielectric absorption effects.
- The leakage rating should be .1 microamp maximum.
- The voltage rating must be 20 volts or higher to prevent breakdown when a multiplexer channel is overloaded.
- The tolerance may be 5–20%. This results in a filter bandwidth tolerance of 5–20%.
- The physical size is restricted to 1.3 inches in length and .4 inches in diameter.

When choosing the bandwidth of the filter, the following electronic principles should be considered:

- Noise occurs at all frequencies, but 60 Hertz line noise is of major concern. The following table shows how different filter bandwidths affect the attenuation of 60 Hertz normal-mode noise. Notice that the greatest attenuation of line noise is with the filter with the lowest bandwidth.

Filter bandwidth (Hertz)	*Attenuation (decibels)*
.6	43
6.0	23
60.0	3

For intermediate values not shown in the previous table, the bandwidth and alteration may be read from the log-liner graph in Figure B-2.

- The input filter also attenuates the high frequency components of the input normal-mode signal. To restrict the attenuation to .05% (1 least significant Bit), the bandwidth should be about 31 times greater than the signal bandwidth. The following table gives recommended low pass filter bandwidths for various signal frequencies:

Filter bandwidth (Hertz)	*Signal bandwidth (Hertz)*
3000.0	97.00
1500.0	49.00
300.0	9.70
150.0	4.90
75.0	2.40
30.0	1.00
15.0	.50
7.5	.24
3.0	.10
1.5	.05

- The sampling rate need not be greater than 2–10 times the Nyquist rate. The solid state multiplexer performance sampling rate is specified at 100 samples per second maximum for a DC input signal. This rate is adequate to meet the nyquist requirement.

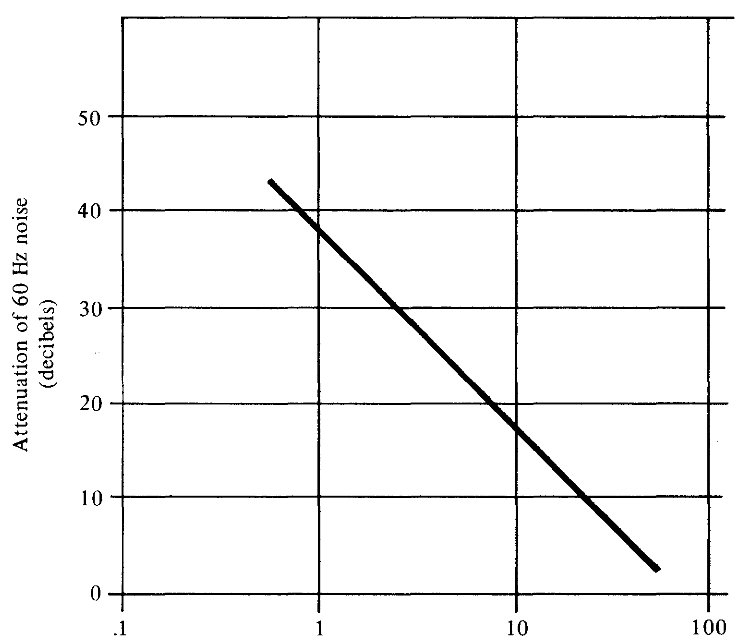


Figure B-2. Attenuation vs. bandwidth

- The maximum signal frequency that can be measured is restricted by the conversion speed of the analog-to-digital converter. The 48 microsecond conversion time can be thought of as uncertainty time. If the input signal changes by more than a quantizing error during the conversion the conversion value will have an uncertainty of 1 least significant bit or more.

  A study of a sinusoidal input signal shows that the rate of change is (1) greater as it crosses through zero, (2) greater for higher frequencies and (3) greater for larger amplitude signals. Therefore, it is evident that performance conversion time and input signal bandwidth are related. The input signal frequency and input signal amplitude can be raised to a certain point, beyond which accuracy begins to suffer.
- The accuracy is related to the capacitance in the input filter. Multiplexer switching transients put charge on the capacitor; A smaller capacitor will have its voltage raised more by the addition of the charge than a larger capacitor. This error increases as the sampling rate increases. These errors are not noticable on the highest input ranges. However, they are significant on the lowest ranges where the error in percent of full-scale is largest. It is desirable to use the biggest capacitor and the lowest bandwidth consistent with signal frequency, external noise and accuracy requirements.

Index

Series/1 4982 Sensor Input/Output Unit
Description

GA34-0027-0

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