Chapter 1
Introduction To
Programmable Control

In this chapter you will be introduced to the basic terms and concepts common to the programmable control industry.

Numbering Systems

When working with programmable controllers, four numbering systems are commonly used: decimal, binary, binary coded decimal (BCD), and hexadecimal (hex). Each number system weights the value of a number by its position. For example, in the decimal number 1209, the 9 has the least value because it occupies the lowest position (right most) in the number. The 1 has the greatest value based on its position (left most) in the number.

Notice three things about all number systems.

The column weights are always powers of the base. In decimal, for example, the weight of the second column is 10 times the weight of the first column because its base is 10. The weight of the third column is 10 times larger than the second; etc.

The value of a position is the number multiplied by the column weight.

Once you have calculated the value of each position all you have to do is add them up to get the total value of the number.

Decimal

Decimal is a base 10 numbering system. There are 10 numbers, 0 through 9, that can occupy each position. Table 1-1 shows some examples of decimal numbers and their column weights.

Table 1-1 Decimal Numbers (Base 10)

Column Weights						
Powers of 10	10^4	10^3	10^2	10^1	10^0	
Decimal	10,000	1,000	100	10	1	
		1	0	3	4	= 1,000 + 0 + 30 + 4 = 1,034
			8	1	0	= 800 + 10 + 0 = 810
	1	1	0	0	0	= 10,000 + 1,000 + 0 + 0 + 0 = 11,000

Binary

Binary is a base 2 numbering system. There are two numbers, 0 and 1, that can occupy each position. Table 1-2 shows some examples of binary numbers and their column weights.

Table 1-2 A Sampling of Binary Numbers (Base 2)

Column Weights						
Powers of 2	2^4	2^3	2^2	2^1	2^0	
Decimal	16	8	4	2	1	
			1	0	1	= 4 + 0 + 1 = 5
		1	0	0	1	= 8 + 0 + 0 + 1 = 9
	1	0	1	1	1	= 16 + 0 + 4 + 2 + 1 = 23

Binary Coded Decimal (BCD)

BCD is also a base 2 number system. The numbers 0 and 1 are set in a coded format where every four columns of binary equals the column weight of one decimal column. There are two rules that apply to BCD numbers:

BCD numbers are divided into four-column groups

A single BCD group can represent decimal numbers between zero and nine inclusively

Table 1-3 shows some examples of BCD numbers and their column weights.

Table 1-3 A Sampling of BCD Numbers

Column Weights	2nd Group				1st Group				
Powers of 10	10^1				10^0				
Powers of 2	2^3	2^2	2^1	2^0	2^3	2^2	2^1	2^0	
					0	1	0	1	= 0 + 4 + 0 + 1 = 5
					1	0	0	1	= 8 + 0 + 0 + 1 = 9
	0	1	1	0	0	1	1	1	= 0 + 4 + 2 + 0 = 60
									0 + 4 + 2 + 1 = 7
									Or Decimal 67

Hexadecimal (Hex)

Hex is a base 16 number system. There are 16 numbers, 0 through F, that can occupy each position. This is a common computer numbering system and is used as shorthand notation for binary numbers. The numbers are: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F (where A=10, B=11, C=12, D=13, E=14, and F=15). Table 1-4 shows examples of hex numbers.

Table 1-4 A Sampling of Hexadecimal Numbers (Base 16)

Column Weights					
Powers of 16	16^3	16^2	16^1	16^0	
Decimal	4096	256	16	1	
			2	7	= 32 + 7 = 39
	1	0	A	1	= 4096 + 0 + 160 + 1 = 4257
	2	A	9	F	= 8192 + 2560 + 144 + 15 = 10911

Number System Examples

Table 1-5 shows examples of numbers written in the numbering systems described in this chapter.

Table 1-5 Number System Conversions

Decimal	BCD	Binary	Hexadecimal
1	0000 0001	00000001	0001
2	0000 0010	00000010	0002
3	0000 0011	00000011	0003
4	0000 0100	00000100	0004
5	0000 0101	00000101	0005
6	0000 0110	00000110	0006
7	0000 0111	00000111	0007
8	0000 1000	00001000	0008
9	0000 1001	00001001	0009
10	0001 0000	00001010	000A
11	0001 0001	00001011	000B
12	0001 0010	00001100	000C
13	0001 0011	00001101	000D
14	0001 0100	00001110	000E
15	0001 0101	00001111	000F
16	0001 0110	00010000	0010
17	0001 0111	00010001	0011

Controller Basics

Figure 1-1 shows a sample control application with:

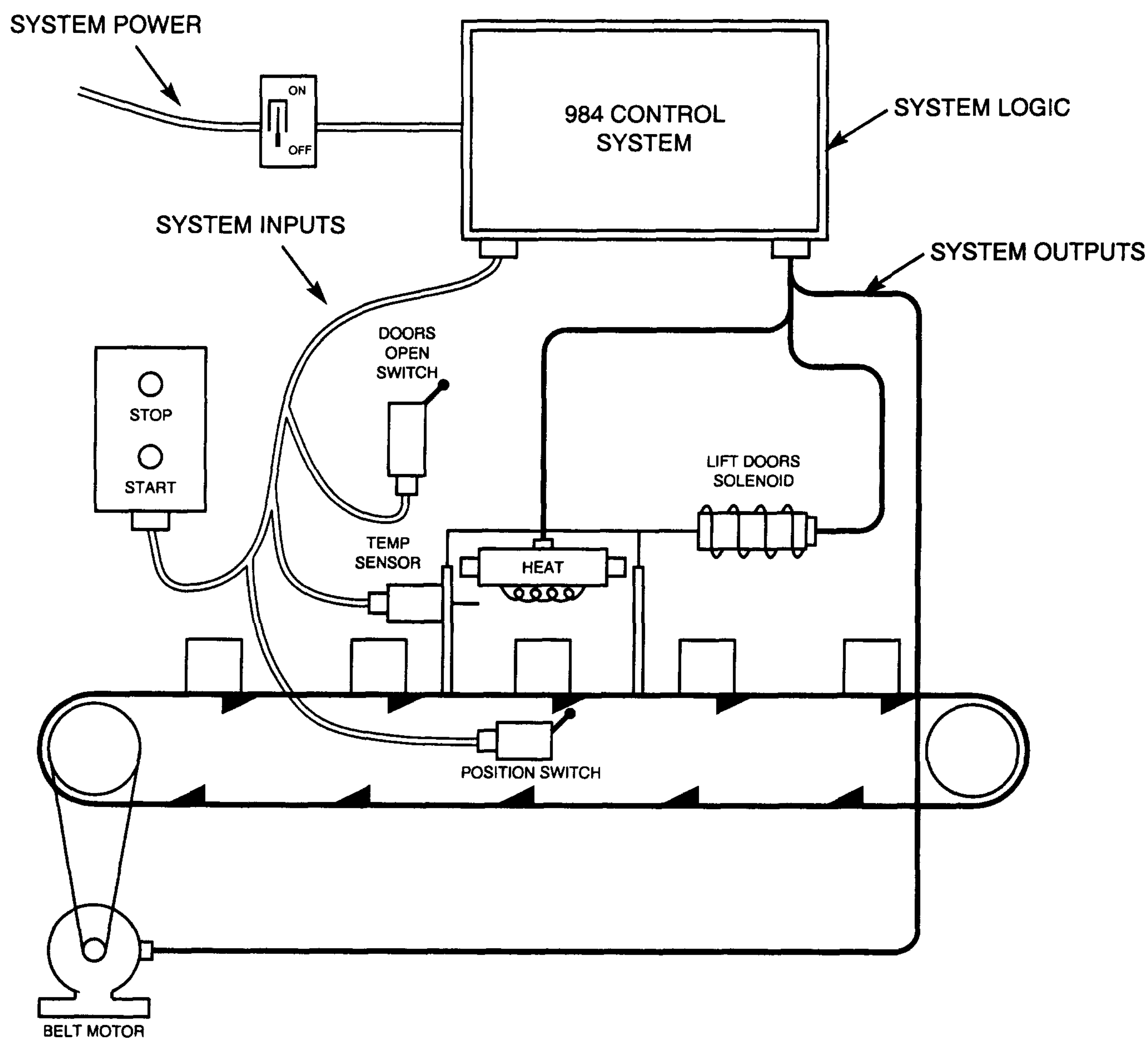
System inputs to identify process status

System logic to solve the user's control program

System outputs to turn process elements ON and OFF

Process under control

Figure 1-1 Representation of A Control Application Showing Simplified Field Wiring



There are seven parts to a system under programmable control:

Process Under Control - your application or process

Input Devices - switches, thumbwheels, light sensors

Input Module - protective interface and signal converter between input devices and controller

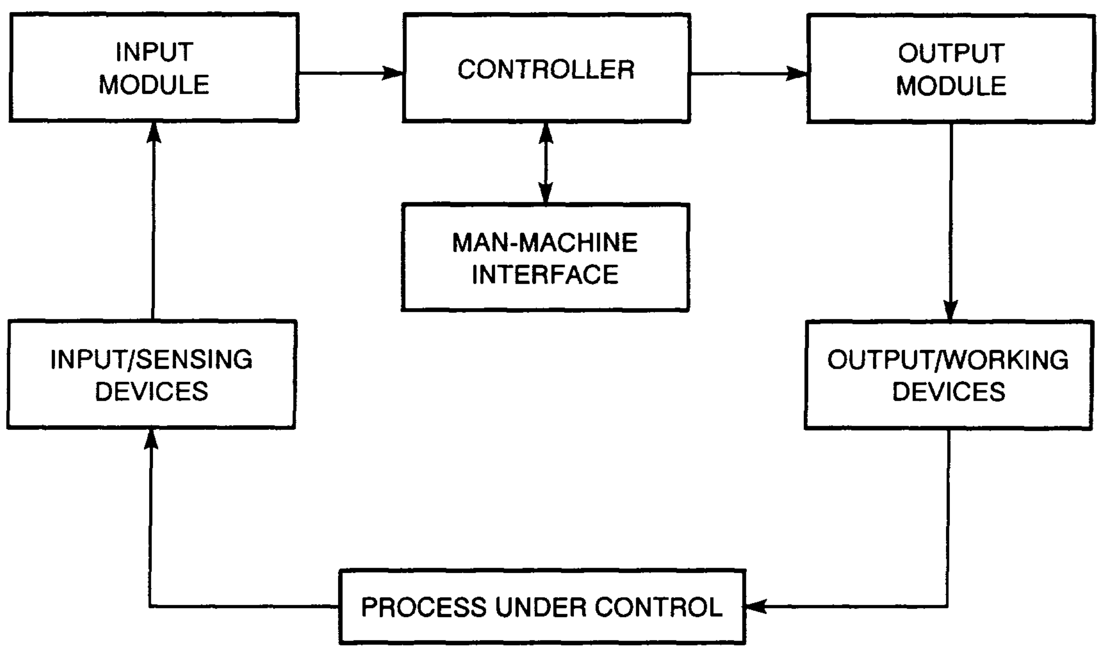
Controller - includes the communication, CPU, memory, and power supply modules

Output Module - protective interface and signal converter between controller and output devices

Output Devices - lights, solenoids, motors

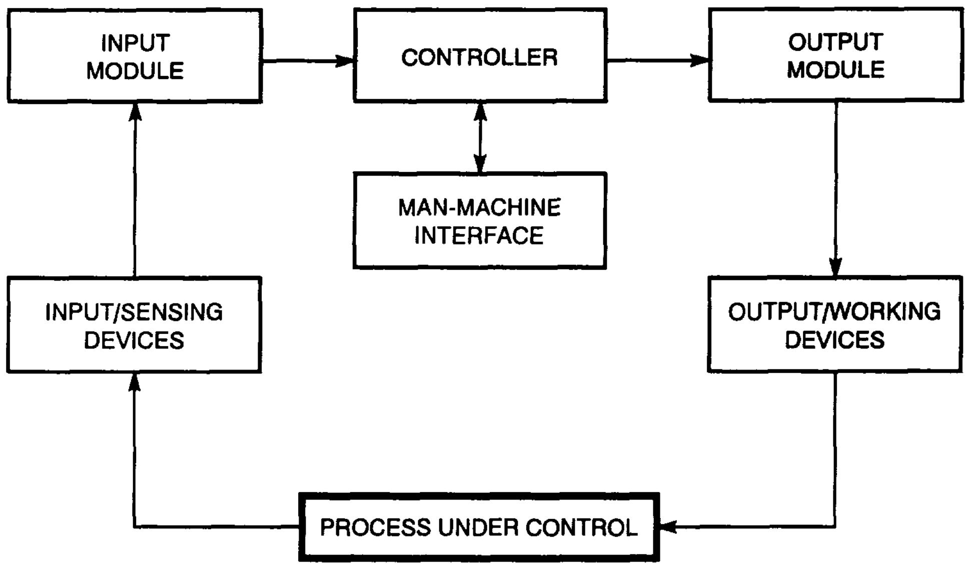
Man-Machine Interface (MMI) - programs and monitors the controller and process

Figure 1-2 Block Diagram of a System Under Control



Processes Under Control

Figure 1-3 Common Processes Managed by Control Systems



BEVERAGE
CHEMICAL
FILM
FOOD
GLASS
LUMBER
MACHINING
MANUFACTURING
METALS
MINING
PAPER
PETROCHEMICAL
POWER
PULP

Input/Sensing Devices

Figure 1-4 ON/OFF Type Input/Sensing Devices

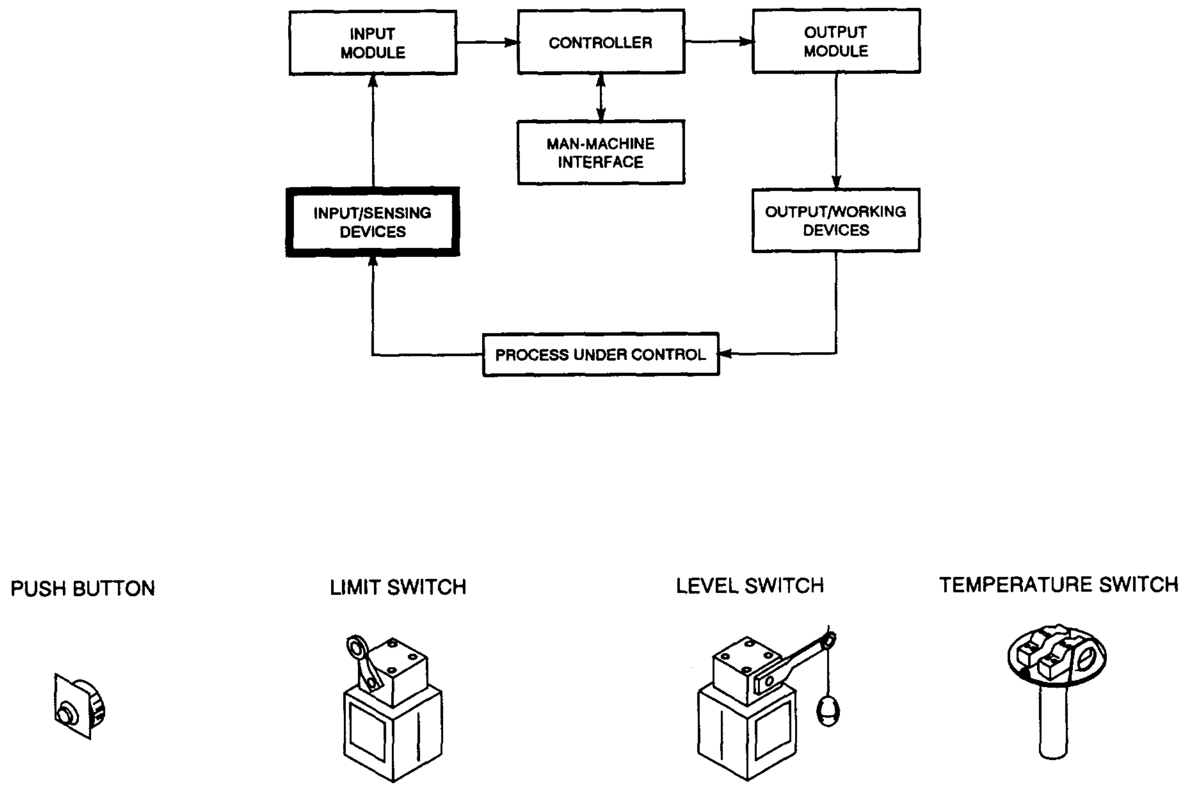
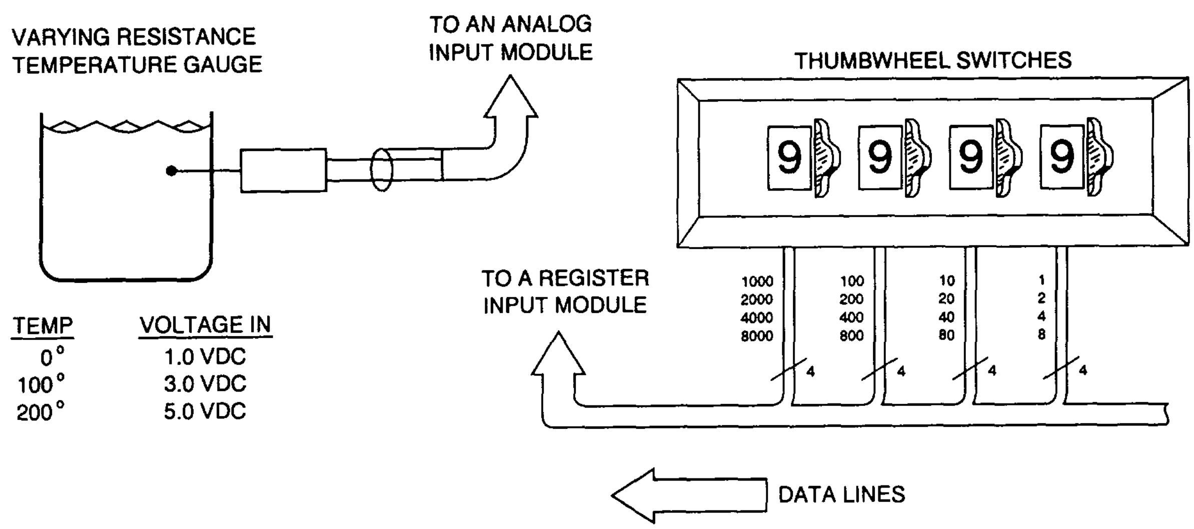


Figure 1-5 Register and Analog Input/Sensing Devices



Input Modules

Figure 1-6 Input Module with Wiring

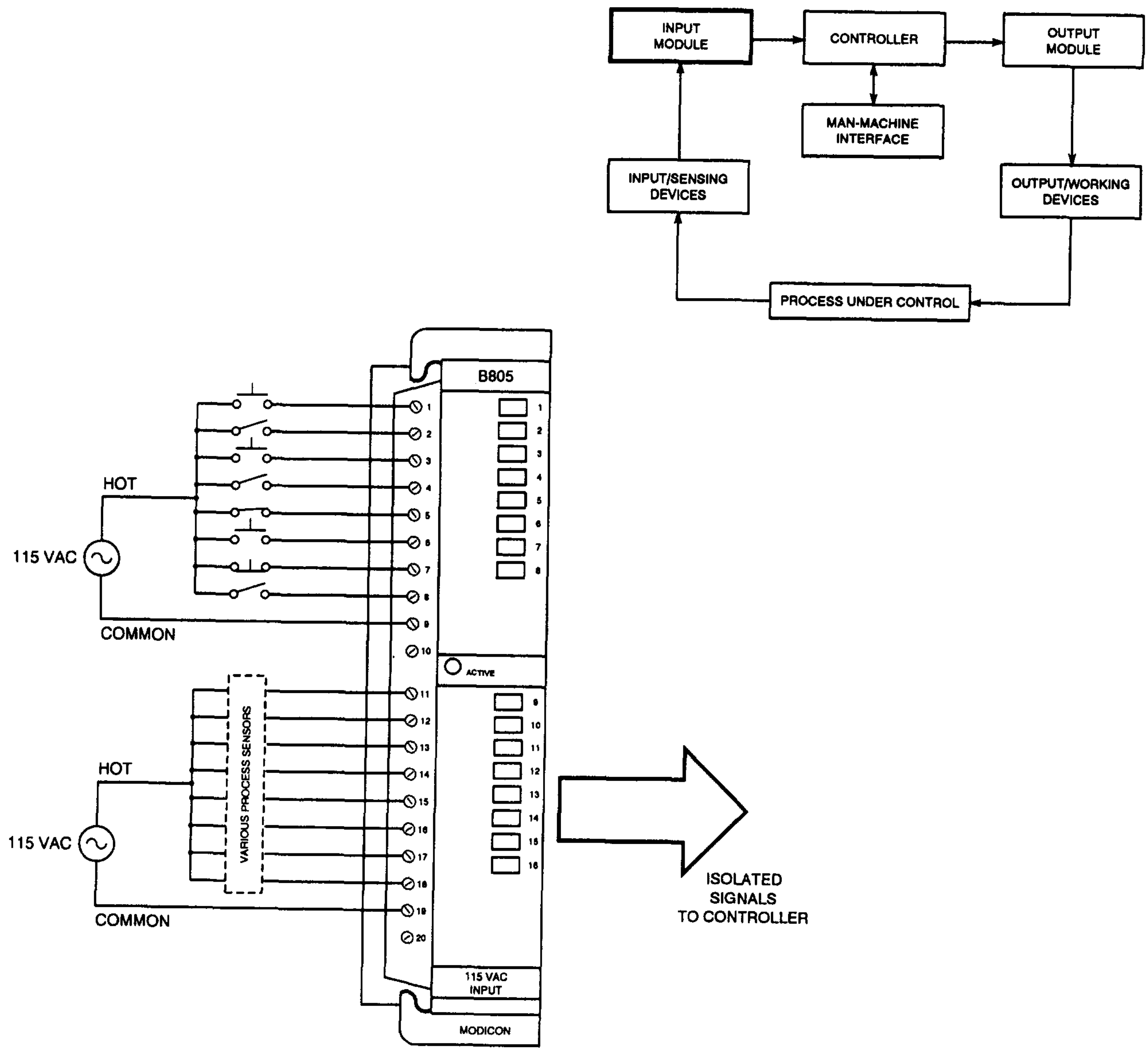


Figure 1-7   Register Input Module with Wiring

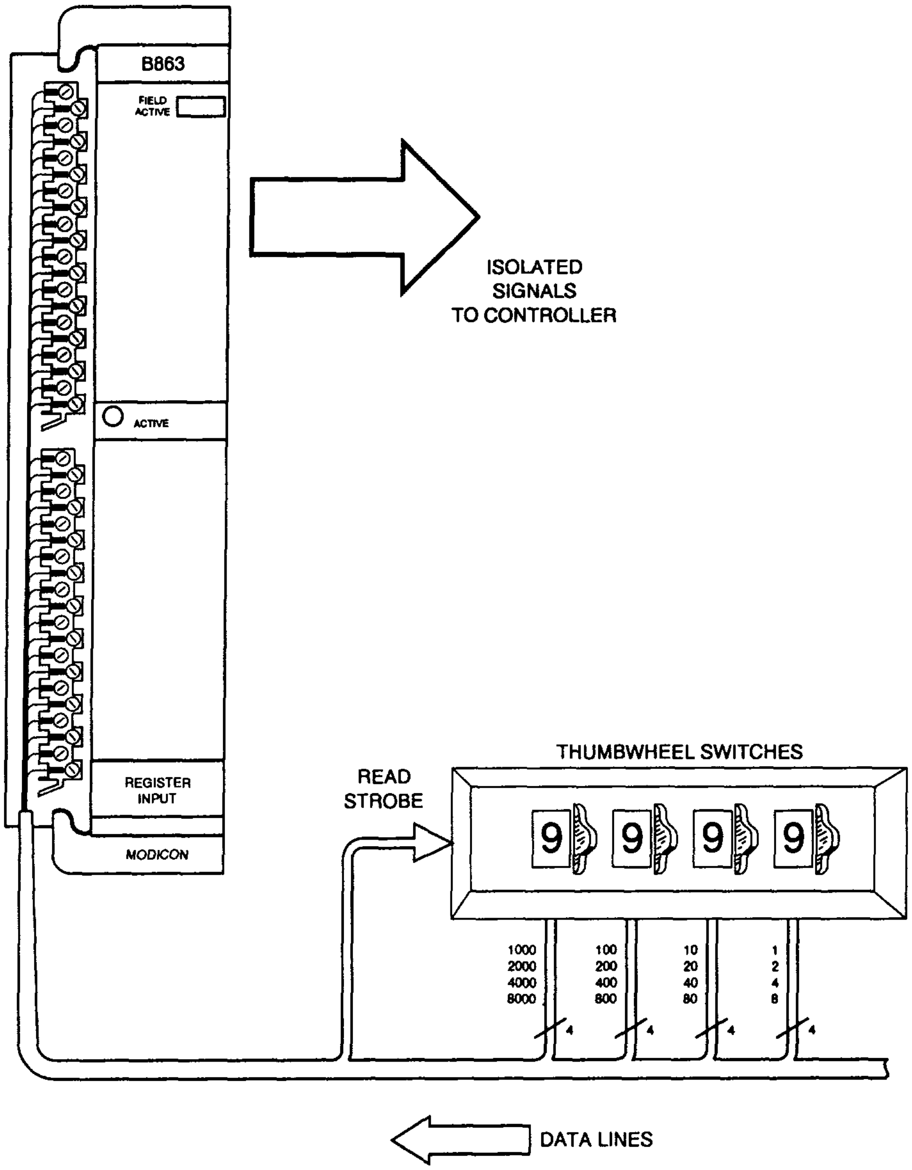
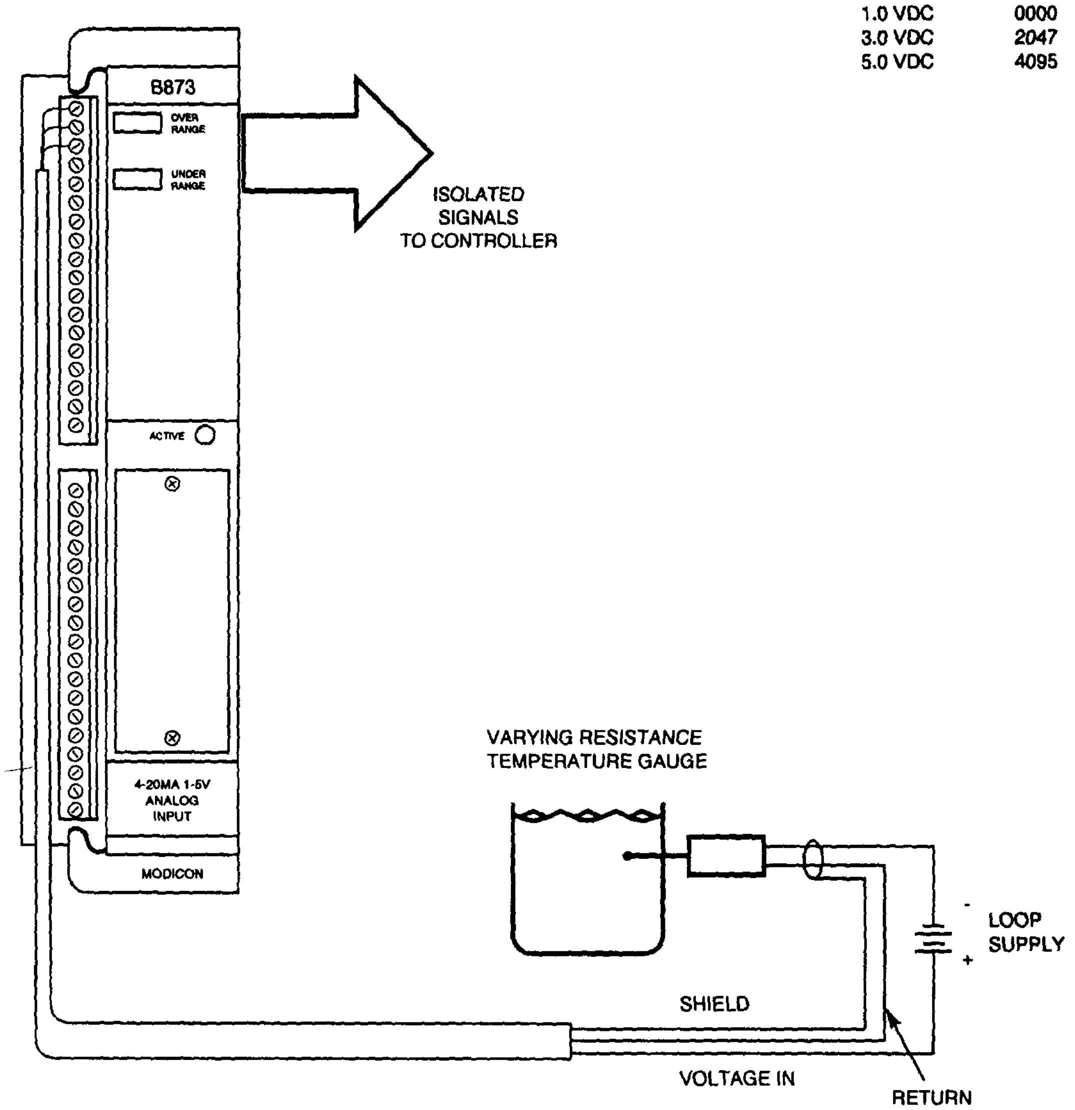


Figure 1-8 Analog Input Module with Wiring

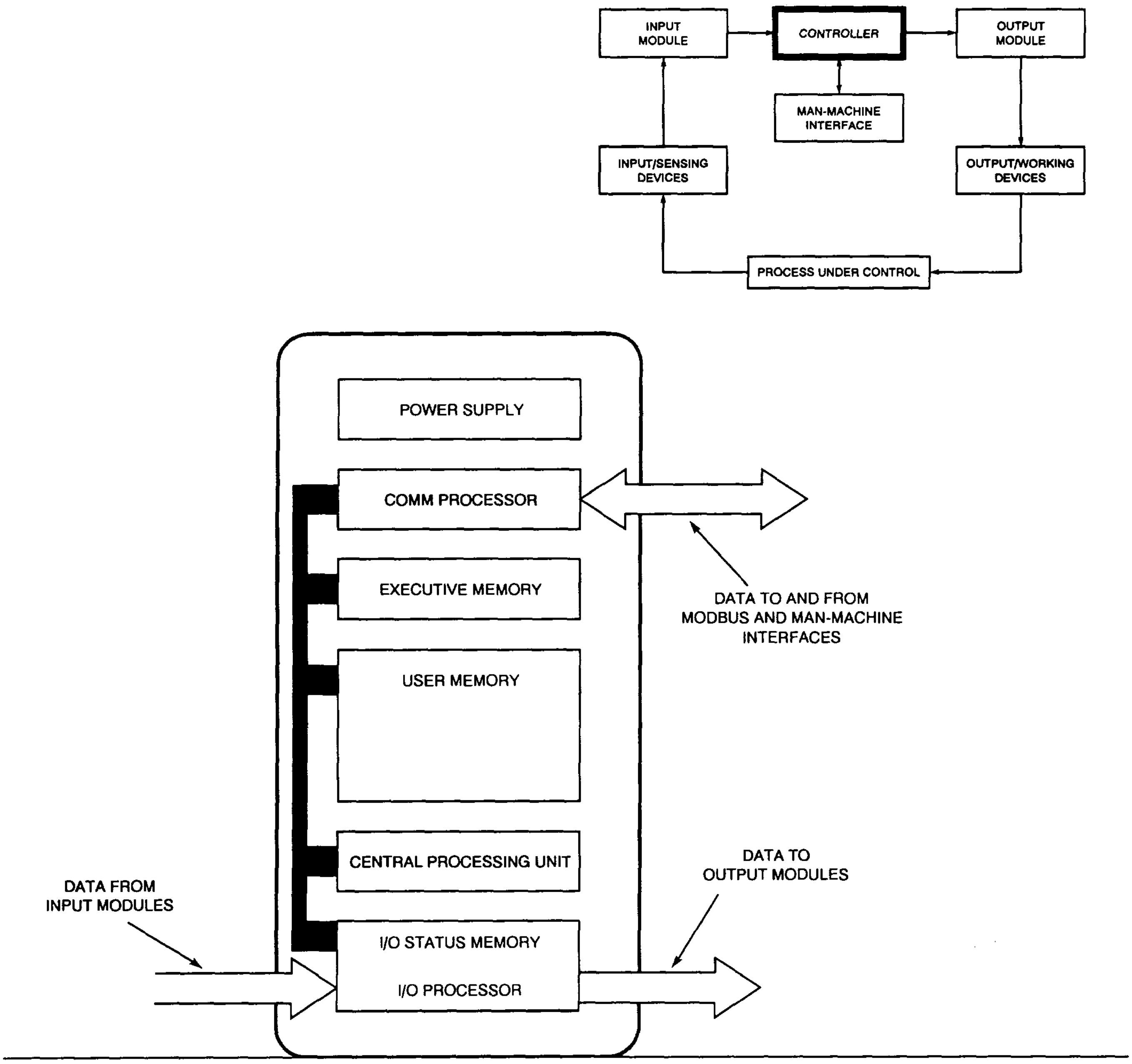
ANALOG/DIGITAL CONVERSION

VOLTAGE IN	VALUE
1.0 VDC	0000
3.0 VDC	2047
5.0 VDC	4095



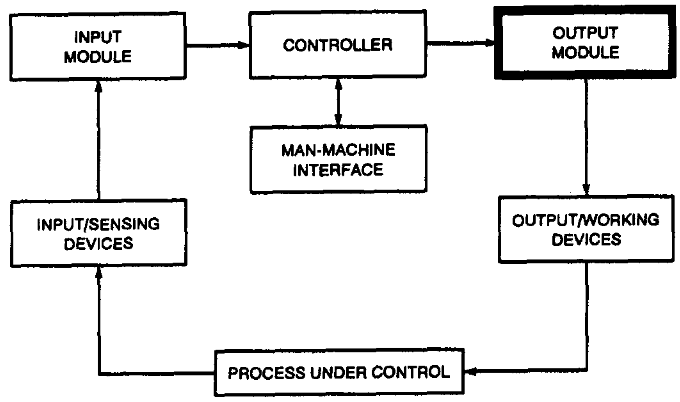
Controller

Figure 1-9 984 Controller Diagram



Output Modules

Figure 1-10 Discrete Output Module Wired to Supply



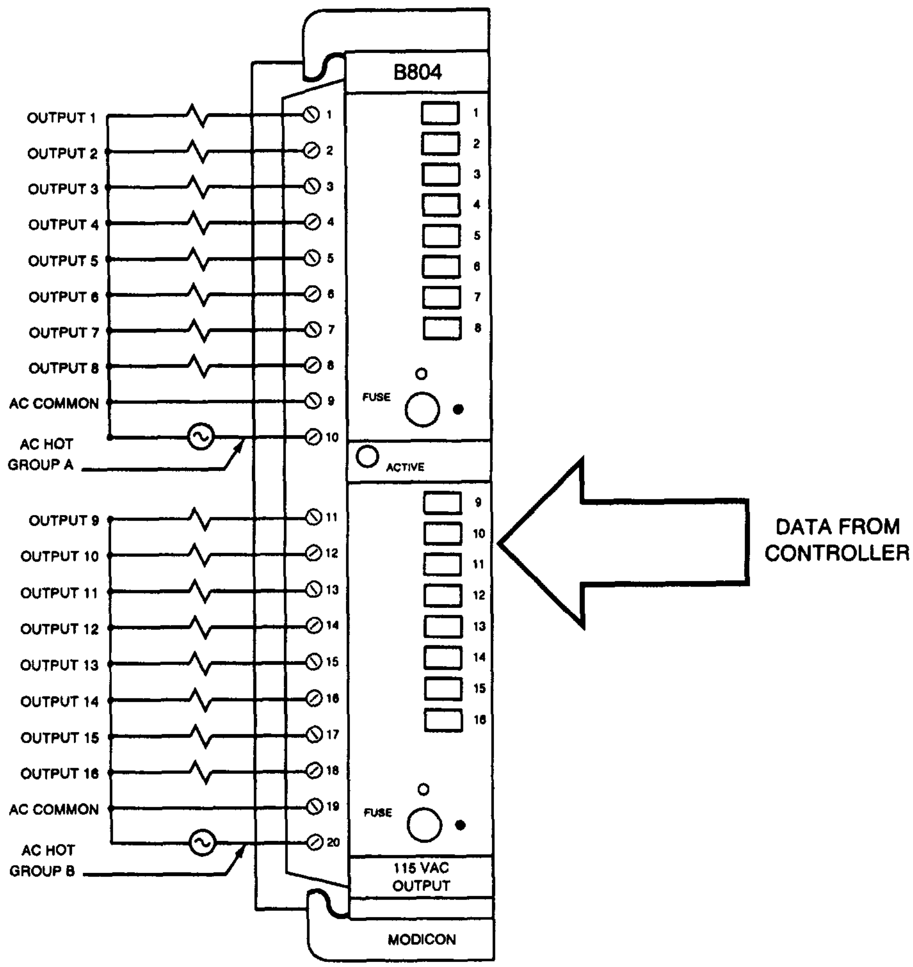


Figure 1-11 Register Output Module Wired to LED Display

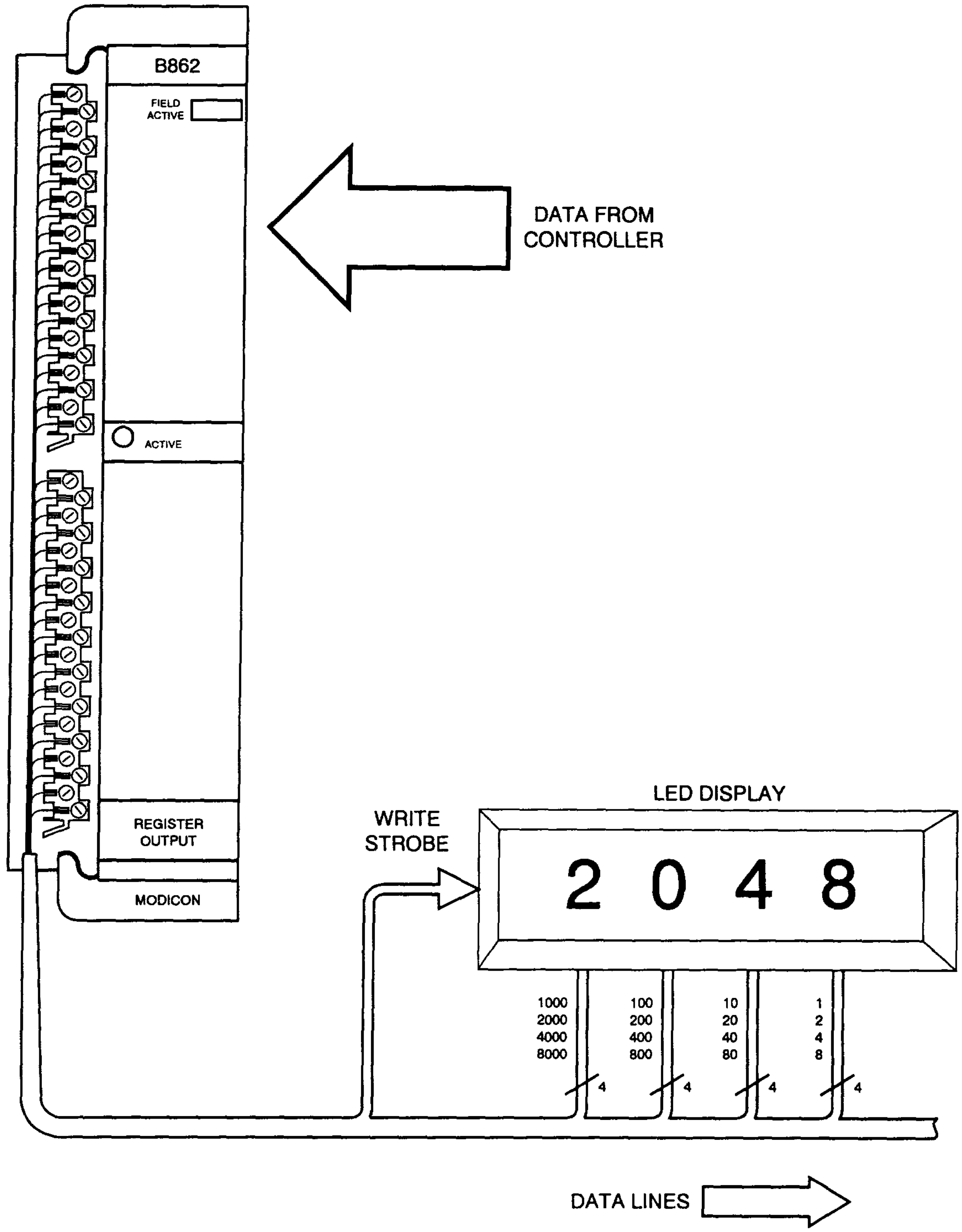
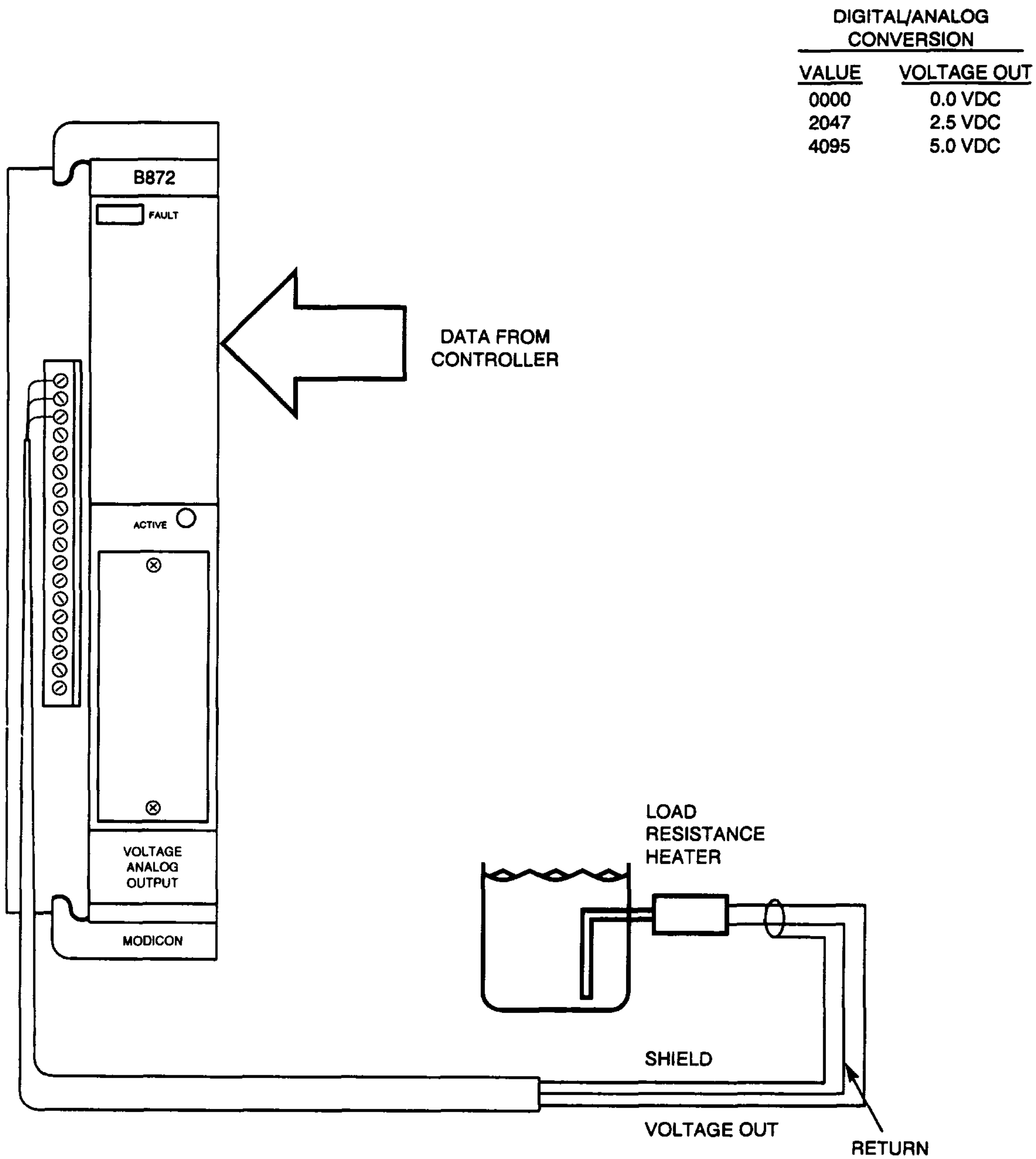
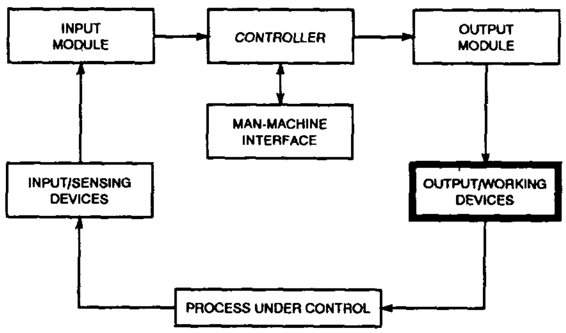


Figure 1-12 Analog Output Module Wired to a Load Resistance Heater



Output/Working Devices

Figure 1-13 ON/OFF Type Output Working Devices



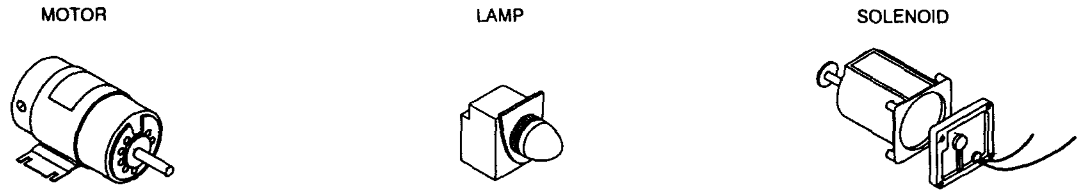
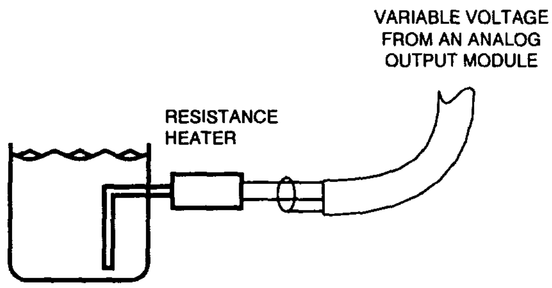
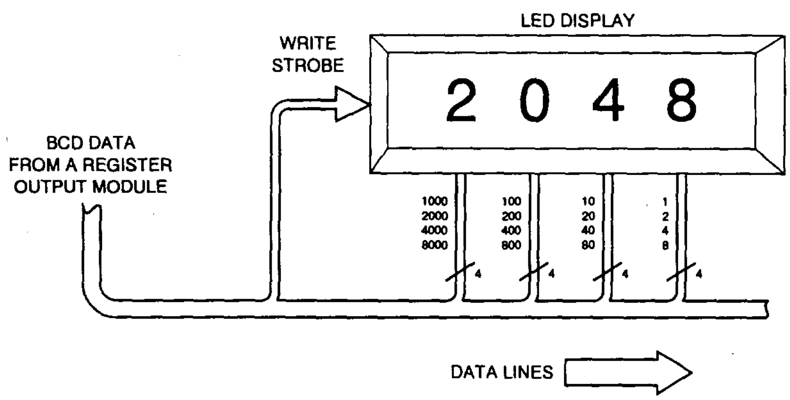


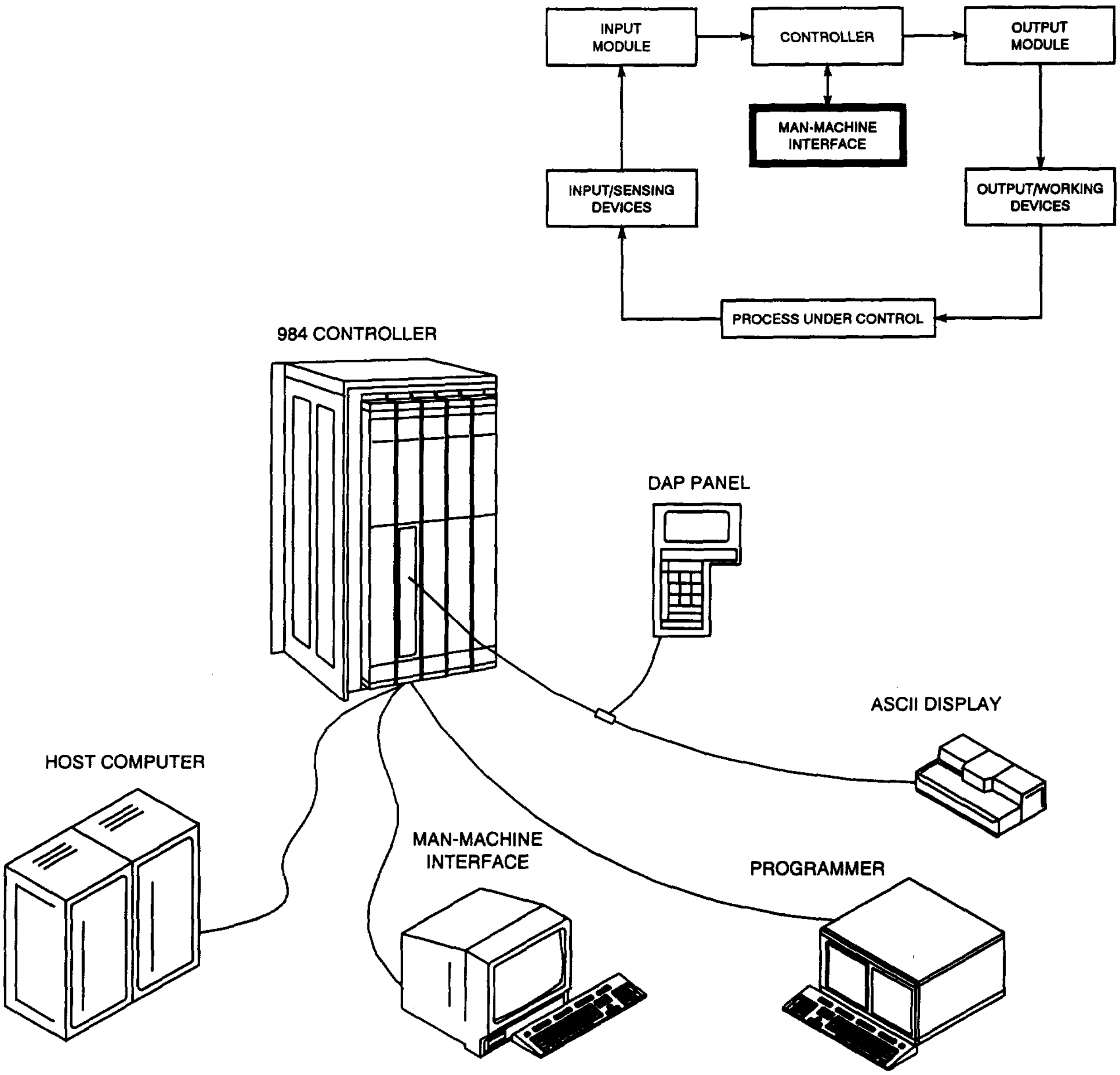
Figure 1-14 Register and Analog Output/Working Devices





Man-Machine Interface

Figure 1-15 Sample of Programming Interfaces



Information Structure

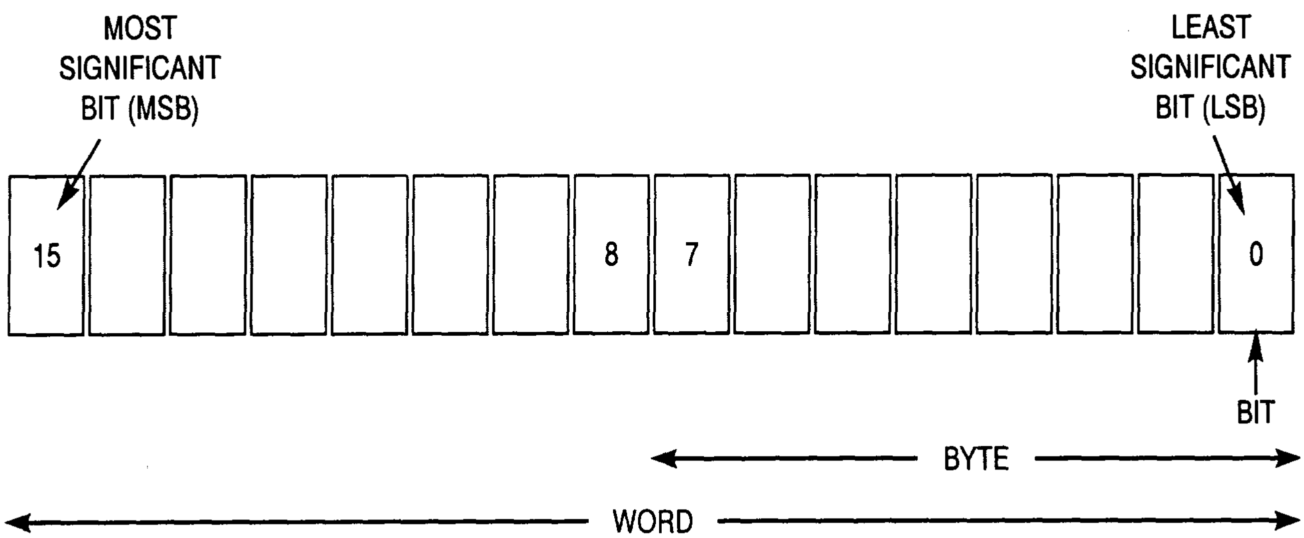
Bit is an acronym for **B**inary dig**IT**. It is the smallest unit of information in the binary number system. A bit can either be a 1 or a 0.

Byte is a sequence of bits that are grouped and operated on by the controller, as a unit. A byte of information is typically 8 bits long. For example: the bit pattern 00001111 is a byte of information, the bit pattern 10101010 is also a byte of information.

Word is a sequence of bits that are grouped and operated on as a unit and are stored in one memory location. Some 984 Programmable Controllers use 16 bits to equal one word of information.

Figure 1-16 shows the relationship of bits, bytes, and words.

Figure 1-16 Bits, Bytes, and Words



The information transferred may be:

A numerical value in binary format

A letter or other character in binary code

Serial Communications

To send information between devices, a serial communication format may be used. When using serial communications:

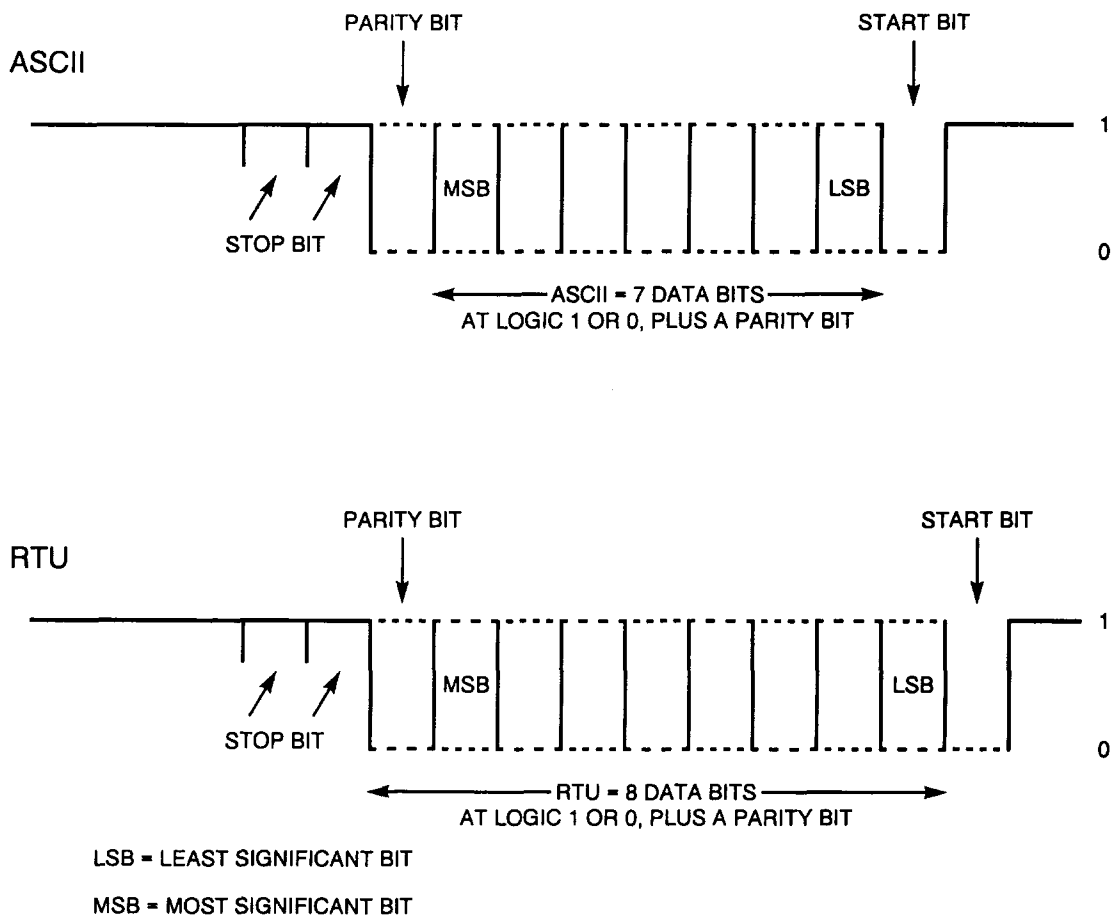
The coding may be either American Standard Code for Information Interchange (ASCII) or Remote Terminal Unit (RTU)

There may be one or two stop bits in each word

There may be a parity check bit

The line is held at logic ONE state when a message is not being transmitted

Figure 1-17 ASCII and RTU Serial Coding



Modulated Serial Communication

This type of communication uses two different frequencies, instead of voltage levels, to represent binary 1's and 0's. Modulated signals:

Can be sent long distances

Use common twisted pair telephone wire

Use modems or transmitters to modulate from voltage to frequency format and receivers to demodulate from frequency back to voltage format

Figure 1-18 Modulated Transmission Hardwareuency Modulated Formats

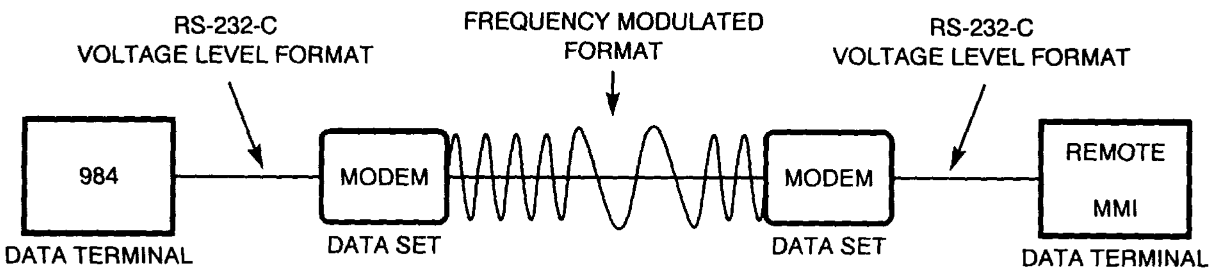
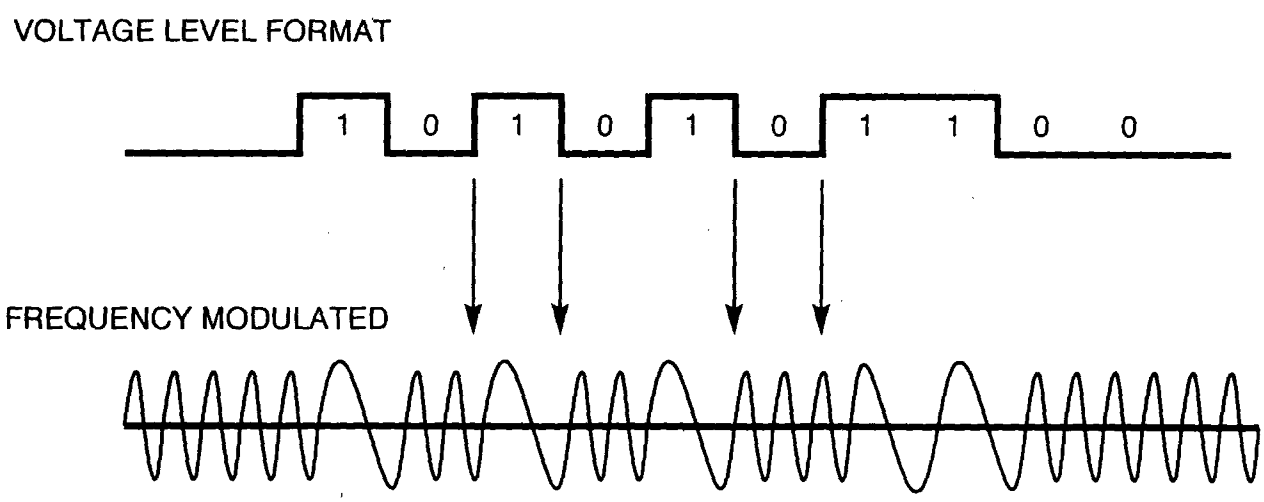


Figure 1-19 Relationship Between Voltage Level and Freq



RS-232-C

Electronics Industries of America (EIA) established the RS-232-C standard to provide the computer industry with a common method of bi- directional, serial communication between devices.

RS-232-C specifies:

Plus 3 to 24 volts equals a logic zero

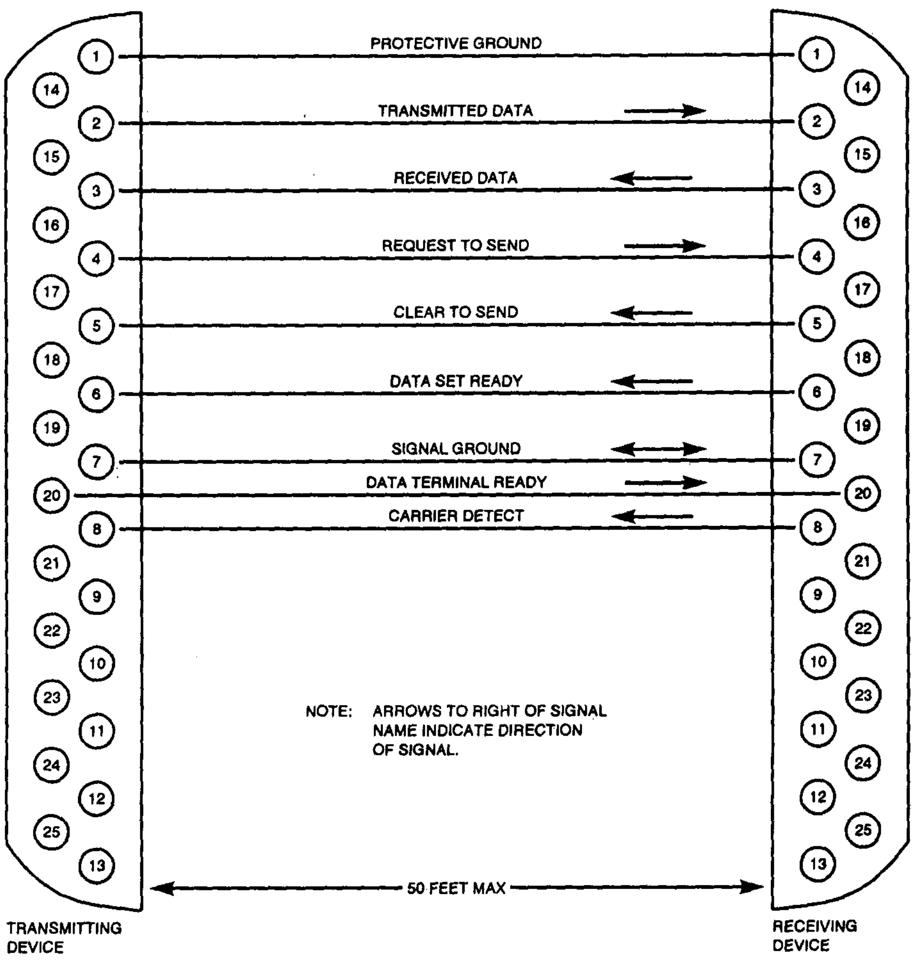
Minus 3 to 24 volts equals a logic one

A 25 pin "D type" connector (Amphenol #DB-25-P for male and #DB- 25-S for female) be used at each end

Various electronic parameters

Pin-out Definition (see Figure 1-20)

Figure 1-20 RS-232-C Pin-out Subset



Parallel Communications

Parallel communication is the fastest method of transferring data. Words are clocked through the system using an internal clock. The information is sent along a multi-wire bus. Each wire carries one bit of information with all of the bits in a byte, or word, transmitted and received during a single clock pulse.

The 984 Programmable Controllers communicate within the controller on 16 or 24 bit internal busses. This means that entire words of information are transferred with each clock pulse.

Figure 1-21 shows an 8 bit word being transferred along the internal bus, which has multiple wires or circuit board runs.

Figure 1-21 Parallel Bus Circuit