Chapter 1

Introduction to Microcontrollers

ABSTACT

This chapter highlights the family members of Intel 8051 Microcontrollers and features of 8051 Microcontroller in detail.

1.1 Introduction to Microcontrollers

Today we see many industrial and domestic products like remote controllers, telephone bill printing machines, automatic power regulators, automatic or semiautomatic washing machines, microwave ovens, automobiles, engines, indicating and measuring instruments and similar products. Automation is needed to facilitate the process or mechanism for its operation and control. Data storage and processing is an integral part of any automatic control system. The need is to have a device so called 'microcontroller' which allows controlling and timing and sequencing of these machines and processes. Further with the help of microcontroller, it is possible to carry out simple arithmetic and logical operations. Almost any system that has a remote controller contains a microcontroller.

Microcontrollers are single chip microcomputers, more suited for control and automation of machines and processes.

Microcontrollers have central processing unit, memory, input/output ports (I/O), timers and counters, analog-to-digital converter (ADC), digital-to-analog (DAC) serial ports, interrupt logic, oscillator circuitry and many more functional blocks on chip. Figure 11 shows the general block diagram of a microcontroller.

All the functional blocks on a single Integrated Circuit (IC) results in a reduced size of control board, low power consumption, more reliability and ease of integration within an application design. The usage of microcontrollers not only reduces the cost of automation but also provides more flexibility. The designer is little bit relieved from the complex interfacing of external peripherals like ADC/DACS etc. and can concentrate on applications and development aspects.

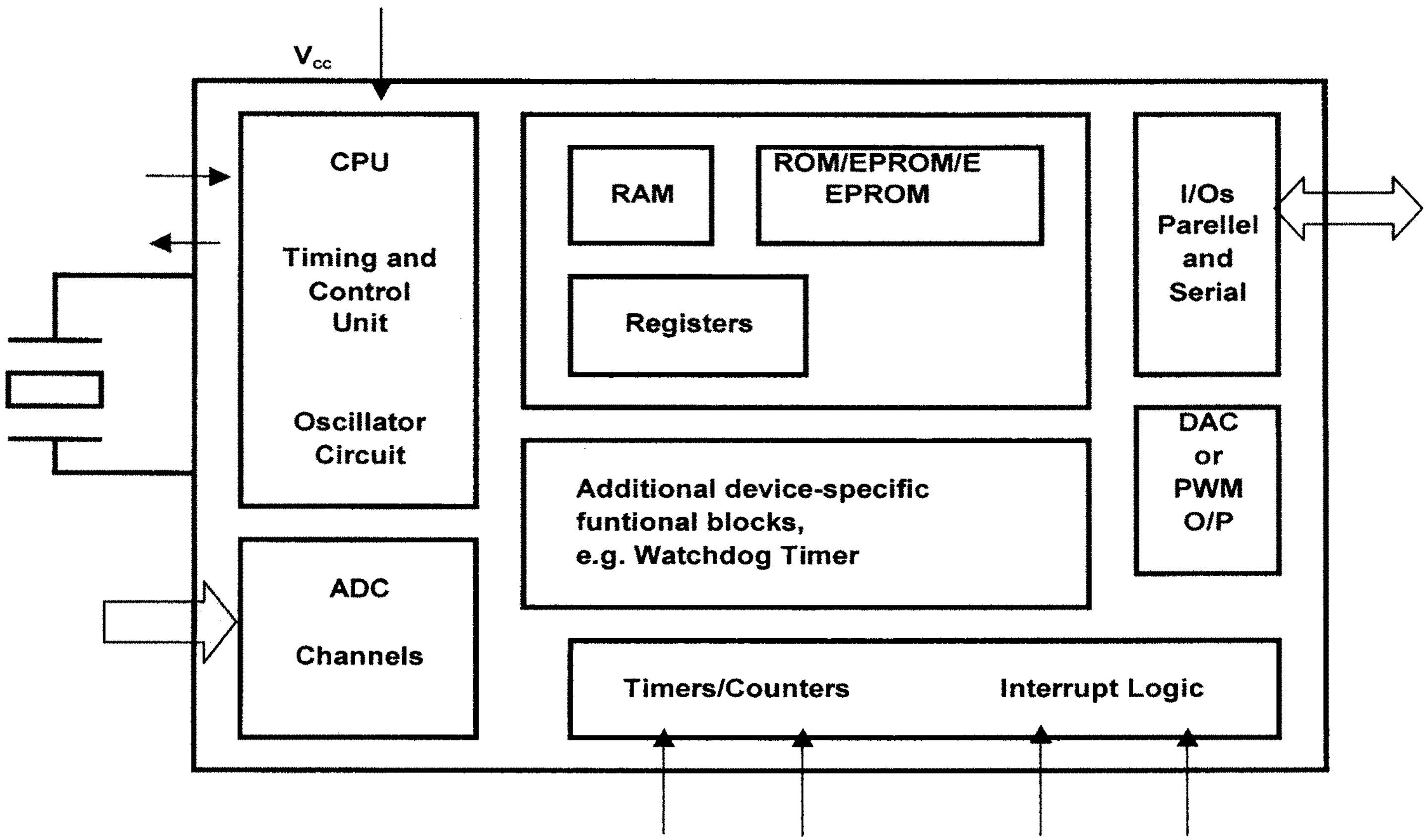


Figure 1.1 Generalized Functional Block Diagram of a Micro controller

The device can be programmed to make the system intelligent. This is possible because of the data processing and memory capability of microcontrollers.

Some of the commonly used microcontrollers are Intel MCS-51, MCS-96, Motorola 68 HC/2 family, Microchip's peripheral interface controller (PIC) family of microcontrollers 16CXX, 17CXX etc.

Microcontrollers have all the functional blocks which can fulfil the general needs of automation.

If we see the design requirements of automation, we need a device which has all the functional blocks inside a single IC. Therefore the concept of "single chip" microcomputers came into reality. Single chip microcomputers are "microcontrollers". The examples are Intel MCS-51, (or 8051), PIC family by Microchip, Atmel89CXX, 89CXX51. These are the microcontrollers used for general purpose applications in the sense that they are user-programmable and have functional blocks suitable to meet a more general design requirement.

1.2 Commercial Microcontroller Devices:

For a given application it is necessary to find out the functional needs and select a suitable microcontroller. One should be aware of some of the commercially available microcontrollers. A brief overview of some commercial microcontrollers is given below. We discuss here 8051 or Intel MCS-51 and Atmel 89C51 and 89C2051.

1.2a INTEL 8051 and ATMEL 89C51, 89C2051 Microcontrollers:

Intel 8051 and Atmel 89C51, 89C2051 microcontrollers are 8-bit microcontrollers. Atmel 89C51 and 89C2051 are compatible with Intel 8051 family. Therefore while learning Intel 8051, one can learn these Atmel microcontrollers too.

1.2b The INTEL 8051 Family:

Intel 8051 or MCS-51 is the family of 8-bit microcontrollers, operating at the frequency of 12MHz and it was introduced to replace the earlier MCS-48 microcontrollers. Table 1.1 lists the various devices of this family.

1.2c ATMEL Microcontrollers:

Few devices from Atmel family are listed in Table 1.2. Mainly we discuss here the programmable flash devices. Atmel 89C1051/2051 are 20-pin devices which support low-voltage operation.

Atmel 89C2051 and 89C51 are CMOs 8-bit microcontrollers. These devices are compatible with the 8051 microcontrollers. Atmel 89C51 and 89C2051 have flash programmable and erasable read only memory (PEROM). Flash memory is a non-volatile memory which can be electrically erased for lines and blocks. The mechanism for erasing the memory is easier and faster than that is needed for EEPROM. There is no waiting time for the erasing the program memory.

Development tools like assemblers and simulators for 8051 may also be used for 89C51 and 89C2051. Further the user who is already familiar with

Table1.1 MCS-51 Family Members

Device	On -chip data memory(bytes)	On-chip program memory	No of 16-bit timers/counters	No of interrupts	Full duplex serial I/o
8031	128	None	2	5	1
8032	256	None	3	6	1
8051	128	4K ROM	2	5	1
8052	256	8K ROM	3	6	1
8751	128	4K EPROM	2	5	1
8752	256	8K EPROM	3	6	1

TABLE1.2 Atmel Microcontrollers

Device	On-chip data memory(bytes)	On-chip program memory	No of 16-bit timers/counters	DigitalI/Os	Full duplex serial I/Os	No of pins in (PDIP)	Precision on-chip analog comparators
AT89C51	128	4K	2	32	1	40	None
AT89C52	256	8K	3	32	1	40	None
AT89C55WD	256	20K	3	32	1	40	None
AT89C1051	64	1K	2	15	1	20	1
AT89C2051	128	2K	2	15	1	20	1
AT89C4051	128	4K	2	15	1	20	1
AT89LV52	256	8K	3	32	1	40	None

MCS-51 instruction set need not put any additional efforts for learning the instruction set of Atmel 89CXX and 89C20XX microcontrollers. These devices have the same instruction set as that of 8051.

Another common feature of 89CXX, and 89C20XX, which is also available in 8051 microcontrollers, is that they support fully static operation. The operating frequency of 89C51 and 89C2051 could be from 0 Hz to 24 MHz. For applications where pin count is important, 20-pin devices 89C2051 and 89C1051 are suitable. 89C1051 has only one timer and 1K PEROM whereas 89C2051 has two timers and 2K flash PEROM.

1.3 Architectural overview of an ATMEL 89C51 and ATMEL 89C2051:

Atmel 89C51 block diagram is shown in Figure1.2(a). The architecture has almost all the blocks which are present in MCS-51. Only the difference is that there is a 4K on-chip flash programme memory in 89C51. Registers and organization are the same as that of the MCS-51 products. There are two 16-bit timer/counters, one full duplex serial port, 128 bytes of on-chip RAM, 32 I/o lines, on-chip oscillator and clock circuitry. It supports six interrupt sources. Figure 1.2(b) shows the block diagram of Atmel 89C2051. Apart from some common building blocks of the 89C51 microcontroller, there is a precision analog comparator. It must be noted that pin p3.6 is not available externally. However, it can be read in software. P3.6 is the output of the precision analog comparator. There are only 15 I/o lines. Only ports P1 and P3 are available. Thus the programs which are written for 89C51 may not always work on 89C2051 because of the absence of Ports P0 and P2 in 89C2051.

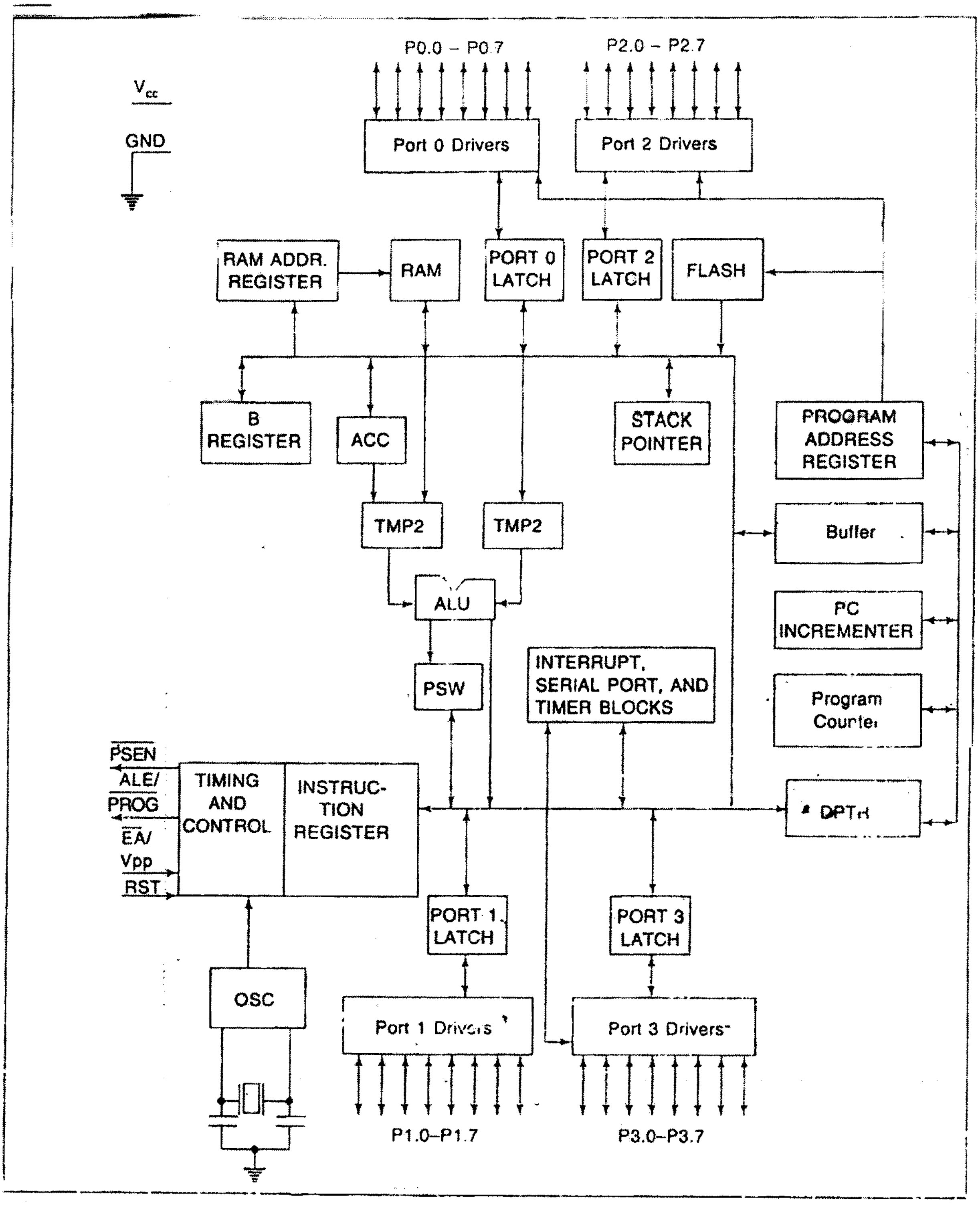


Figure 1.2(a) Block diagram of Atmel 89C51 Microcontroller

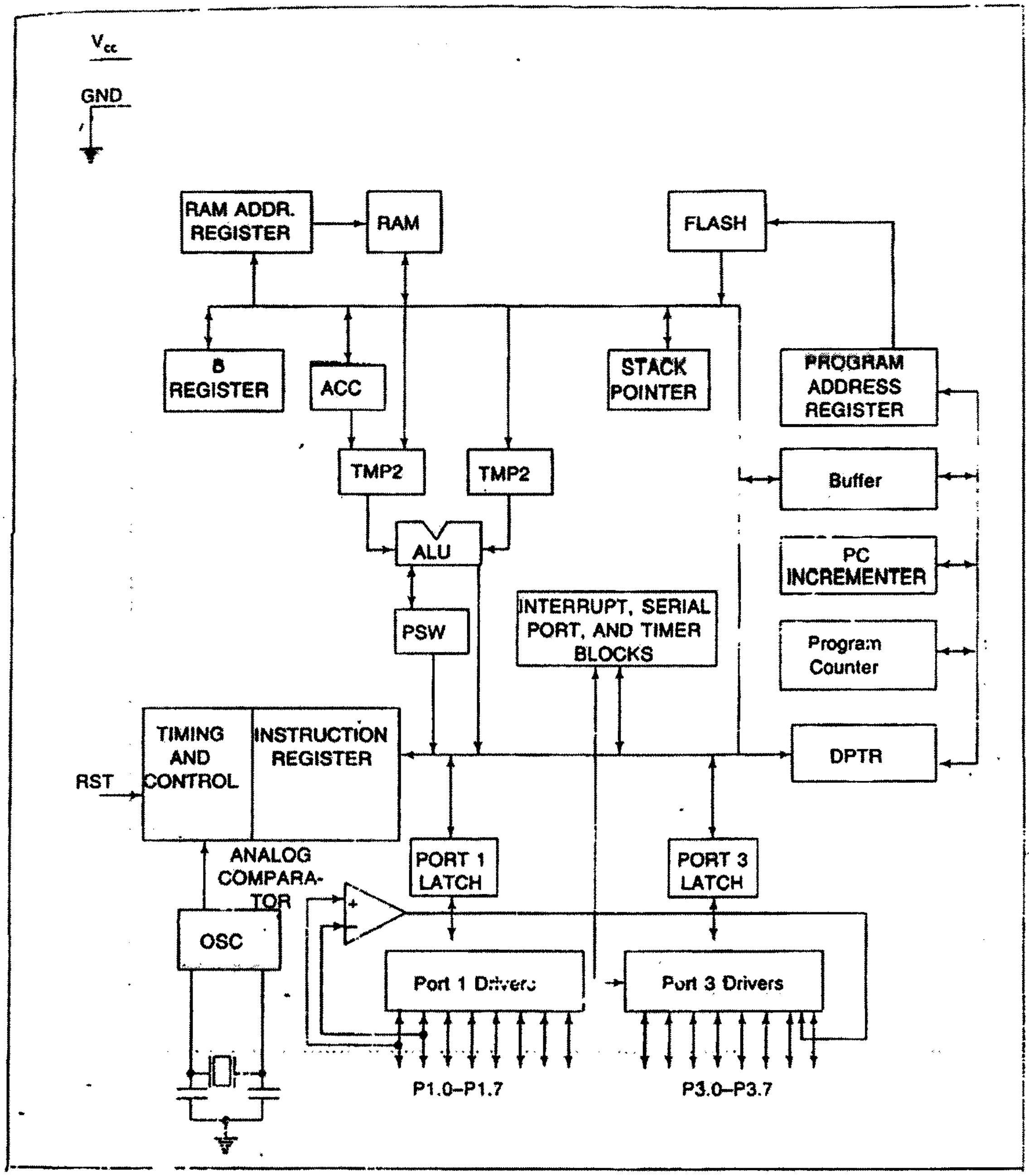


Figure 1.2(b) Block Diagram of Atmel 89C2051 Microcontroller

Similarly any program related to 89C2051 precision comparator will not work in 89C51. Register structure, memory organisation is almost same as that of 89C51. The architecture does not support any external address/data bus and therefore RD, WR signals are absent in 89C2051. Similarly ALE, PSEN, EA signals are not there in 89C2051. 89C2051 also supports the full duplex serial communication and six interrupt sources. Fully static operation is possible for operating frequency down to zero frequency. 0 to 24 MHz is the range of operating frequency for both 89C51 and 89C2051. Similar to 89C51, two power saving modes, i.e., "Idle mode" and "Power-down mode," are possible in 89C2051. Both 89C51 and 89C2051 provide cost effective, compact and flexible solutions to many industrial applications.

1.4 Pin Description of 89C51 and 89C2051:

Figure 1.3(a) shows the pin diagram of Atmel 89C51 microcontroller. Pin functions of 89C51 are same as those of MCS-51 microcontrollers. Atmel 89C2051 is a 20-pin device. It has 15 digital I/o lines. Note that in 89C2051 P3.6 is not seen externally. It is the output of a precision analog comparator and accessible through software. It must be noted that there is no external address/data bus on 89C2051. Therefore, no external memory connections are possible. In fact only Port 1 and Port 3 (except P3.6) functions are available in 89C2051 as seen above. The connections of external crystal and reset circuit for 89C51 and 89C2051 are same as that of Intel 8051.

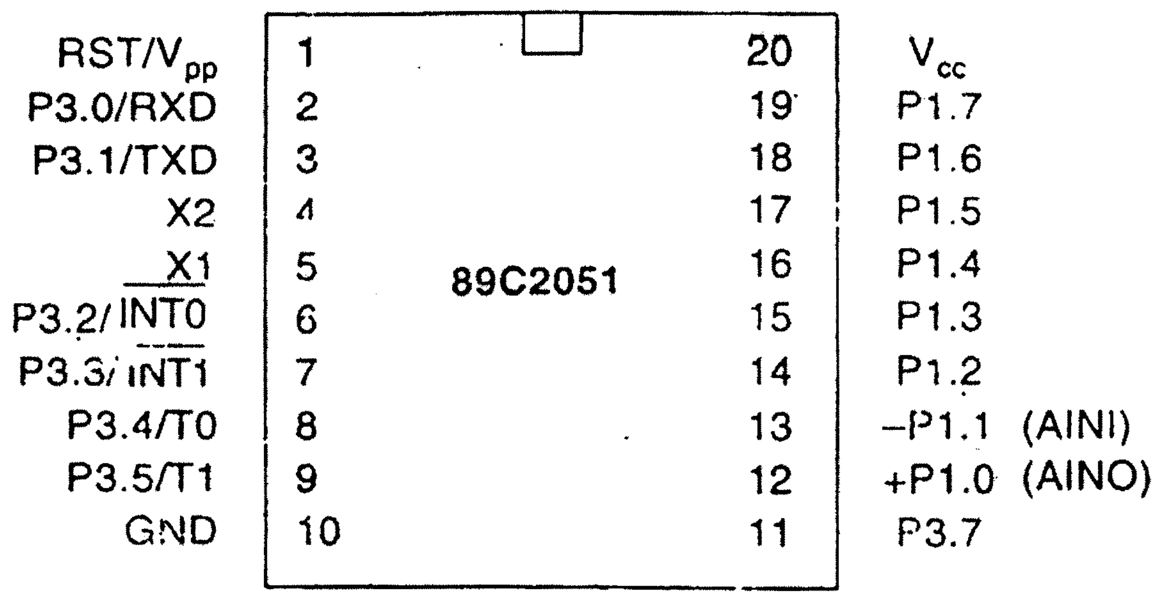


Figure 1.3(b) Pin Configuration of 89C2051

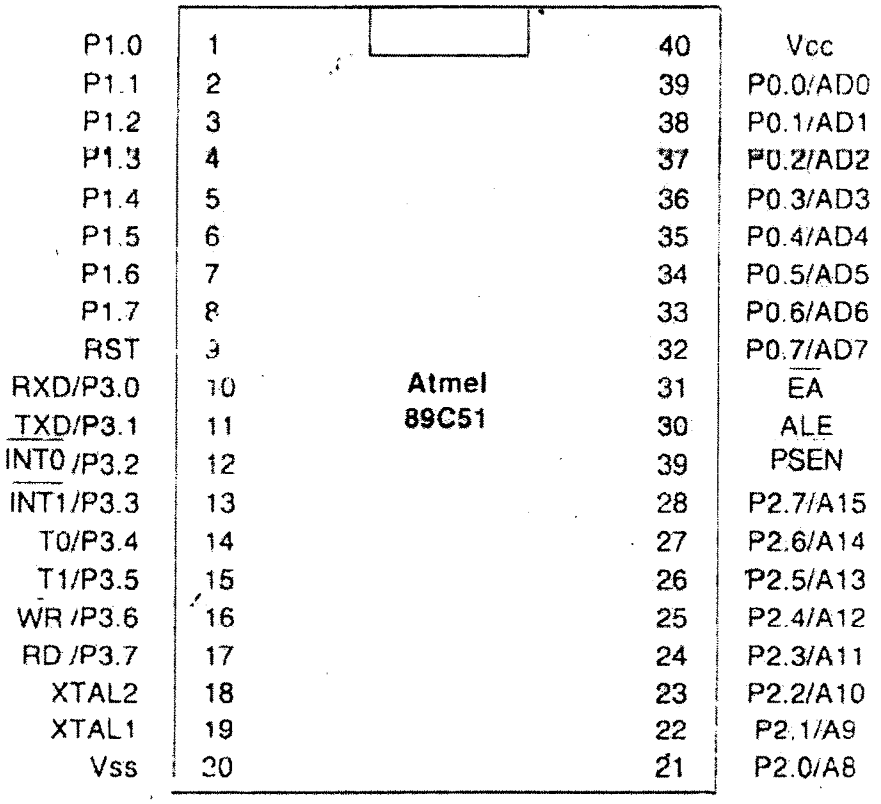


Figure 1.3(a) Pin Configuration of 89C51 Microcontroller

1.5 Overview of the 8051 Family:

In this section we discuss various members of the 8051 family of microcontrollers and their internal features.

1.5a A Brief History of the 8051 Microcontroller:

In 1981, Intel Corporation had introduced an 8-bit microcontroller called the 8051. This microcontroller had 128 bytes of RAM, 4K bytes of on-chip ROM, two timers, one serial port and four ports (each 8-bits wide) all on a single chip. At the time it was also referred to as a "system on chip". The 8051 is an 8-bit processor, meaning that the CPU can work on only 8 bits of data at a time. Data larger than 8-bits has to be broken into 8-bit pieces to be processed by the CPU. The 8051 has a total of four I/o ports, each 8 bits wide. Although the 8051 can have a maximum of 64 bytes of on-chip ROM, many manufacturers put only 4K bytes on the chip.

8051 became widely popular after Intel allowed other manufacturers to make and market any flavour of the 8051. This has led to many versions of the 8051 with different speeds and amounts of on-chip ROM marketed by more than half a dozen manufacturers. It is important to note that although these are different flavours of the 8051 in terms of speed and amount of on-clip ROM, they are all compatible with the original 8051 as far as instructions are concerned.

1.6 8051 Microcontroller:

The 8051 is the original member of the 8051 family. Intel refers to it as MCS-51. Table 1.3 shows the main features of the 8051.

FEATURES OF THE 8051	
Feature:	Quantity:
ROM	4K bytes
RAM	128 bytes
Timer	2
I/o pins	32
Serial port	1
Interrupt sources	6

1.6a Pin Description of the 8051:

Figure 1.4 shows the Pin assignments of 8051 Microcontroller. The block diagram of the 8051 shows all of the features unique to microcontrollers:

Internal ROM and RAM, I/O ports with programmable pins, Timers and Counters, serial data communication and also the CPU components: program counter, ALU, working registers and clock circuits.

Table1.3 Comparison of 8051 Family Members

Feature	8051	8052	8031
ROM (on-chip program space in bytes)	4K	8K	0K
RAM (bytes)	128	256	128
Timers	2	3	2
I/O pins	32	32	32
Serial port	1	1	1
Interrupt sources	6	8	6

Figure 1.4. 8051 DIP Pin Assignments

Port 1 Bit 0	1 P1.0	Vcc 40	+5V
Port 1 Bit 1	2 P1.1	(AD0)P0.0 39	Port 0 Bit 0 (Address/Data 0)
Port 1 Bit 2	3 P1.2	(AD1)P0.1 38	Port 0 Bit 1 (Address/Data 1)
Port 1 Bit 3	4 P1.3	(AD2)P0.2 37	Port 0 Bit 2 (Address/Data 2)
Port 1 Bit 4	5 P1.4	(AD3)P0.3 36	Port 0 Bit 3 (Address/Data 3)
Port 1 Bit 5	6 P1.5	(AD4)P0.4 35	Port 0 Bit 4 (Address/Data 4)
Port 1 Bit 6	7 P1.6	(AD5)P0.5 34	Port 0 Bit 5 (Address/Data 5)
Port 1 Bit 7	8 P1.7	(AD6)P0.6 33	Port 0 Bit 6 (Address/Data 6)
Reset Input	9 RST	(AD7)P0.7 32	Port 0 Bit 7 (Address/Data 7)
Port 3 Bit 0 (Receive Data)	10 P3.0(RXD)	(Vpp)/$\overline{EA}$ 31	External Enable (EPROM Programming Voltage)
Port 3 Bit 1 (XMIT Data)	11 P3.1(TXD)	(PROG)ALE 30	Address Latch Enable (EPROM Program Pulse)
Port 3 Bit 2 (Interrupt 0)	12 P3.2($\overline{INT0}$)	$\overline{PSEN}$ 29	Program Store Enable
Port 3 Bit 3 (Interrupt 1)	13 P3.3($\overline{INT1}$)	(A15)P2.7 28	Port 2 Bit 7 (Address 15)
Port 3 Bit 4 (Timer 0 Input)	14 P3.4(T0)	(A14)P2.6 27	Port 2 Bit 6 (Address 14)
Port 3 Bit 5 (Timer 1 Input)	15 P3.5(T1)	(A13)P2.5 26	Port 2 Bit 5 (Address 13)
Port 3 Bit 6 (Write Strobe)	16 P3.6($\overline{WR}$)	(A12)P2.4 25	Port 2 Bit 4 (Address 12)
Port 3 Bit 7 (Read Strobe)	17 P3.7($\overline{RD}$)	(A11)P2.3 24	Port 2 Bit 3 (Address 11)
Crystal Input 2	18 XTAL2	(A10)P2.2 23	Port 2 Bit 2 (Address 10)
Crystal Input 1	19 XTAL1	(A9)P2.1 22	Port 2 Bit 1 (Address 9)
Ground	20 Vss	(A8)P2.0 21	Port 2 Bit 0 (Address 8)

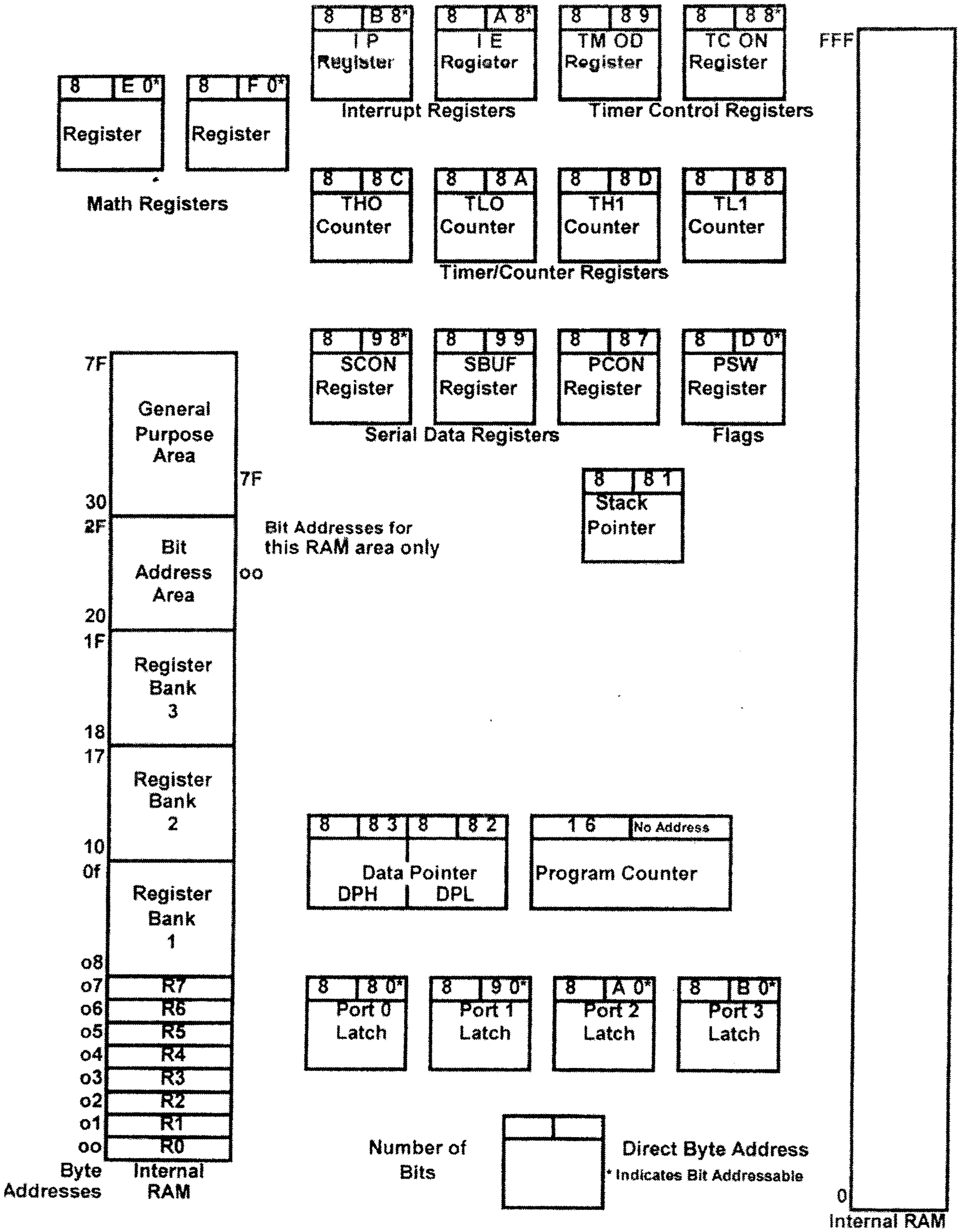
Note: Alternate functions are shown below the port name (in parentheses). Pin numbers and pin names are shown inside the DIP package.

The 8051 architecture consists of the following specific features:

- Eight-bit CPU with registers A(the accumulator) and B
- Sixteen-bit program counter (PC) and data pointer (DPTR)
- Eight-bit program status word (PSW)
- Eight-bit stack pointer (SP)
- Internal ROM or EPROM
- Internal RAM of 128 bytes:
    - Four register banks, each containing eight registers
    - Sixteen bytes which may be addressed at the bit level
    - Eighty bytes of general purpose data memory
- Thirty two Input/Output pins arranged as four 8-bit ports P0-P3
- Two 16-bit timer/counters: T0 and T1
- Full duplex serial data receiver/transmitter: SBUF
- Control register: TCON, TMOD, SCON, PCON, IP and IE
- Two external and three interrupt sources
- Oscillator and clock circuits

The programming model of the 8051 in the Figure 1.4 shows the 8051 as a collection of 8-bit and 16-bit registers and 8-bit memory locations. These registers and memory locations can be made to operate using the software instructions that are incorporated as part of the design. The program instructions have to do with the control of the registers and digital data paths that are physically contained inside the 8051, as well as memory locations that are physically located outside the 8051.

Figure 1.4(a) 8051 Programming Model



The model is complicated by the number of special purpose registers that must be present to make a microcomputer a microcontroller.

Most of the registers have a specific function, those that do occupy an individual block with a symbolic name, such as A or THO or PC. Others which are generally indistinguishable from each other are grouped in a larger block such as internal ROM or RAM memory.

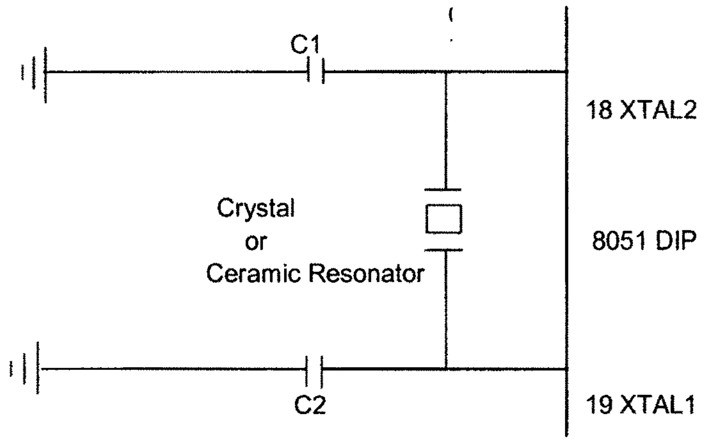
Each register, with the exception of the program counter has an internal 1-byte address assigned to it. Some registers are both 1-byte and bit addressable. That is the entire byte of data at such register addresses may be read or altered, or individual bits may be read or altered. Software instructions are generally able to specify a register by its address, its symbolic name, or both.

A pinout of the 8051 packaged in a 40-pin DIP is shown in the Figure 1.4 with the full abbreviated names of the signals for each pin. It is important to note that many of the pins are used for more than one function.

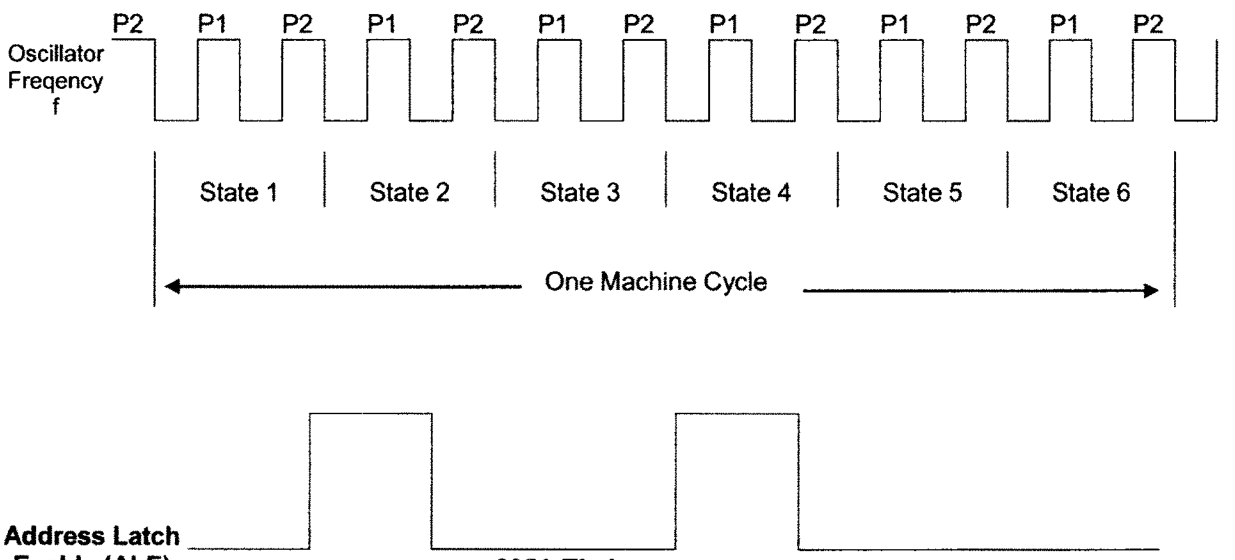
1.6b The 8051 Oscillator and Clock:

The heart of the 8051 is the circuitry that generates the clock pulses by which all internal operations are synchronised. Pins XTAL1 and XTAL2 are provided for connecting a resonant network to form an oscillator typically, a quartz crystal and capacitors are employed as shown in the Figure 1.5. The crystal frequency is the basic internal clock frequency of the microcontroller.

Figure 1.5 Oscillator Circuit and Timing



Crystal or Ceramic Resonator Oscillator Circuit



8051 Timing

1.6c PROGRAM COUNTER AND DATA POINTER:

The 8051 contains two 16-bit registers namely the program counter (PC) and the data pointer (DPTR). Each is used to hold the address of a byte in memory.

Program instruction bytes are fetched from locations in memory that are addressed by the PC. The program counter (PC) is automatically incremented after every instruction byte is fetched and may also be altered by certain instructions. The PC is the only register that does not have an internal address.

The Data Pointer Register (DPTR) is made up of two 8-bit registers named DPH and DPL which are used to furnish memory addresses for internal and external code access and external data access. The DPTR is under the control of program instructions and can be specified by its 16-bit name, DPTR, or by each individual by name. DPH and DPL do not have a single internal address, DPH and DPL are each assigned an address.

1.6d A and B CPU Registers:

The 8051 contains 34 general purpose or working registers. Two of these registers are A and B, hold results of many instructions particularly match and logical operations of the 8051 central processing unit (CPU). The other 32 are arranged as part of internal RAM in four banks B0 to B3, of eight registers and comprise the mathematical core.

Figure 1.6 8051 CPU Registers

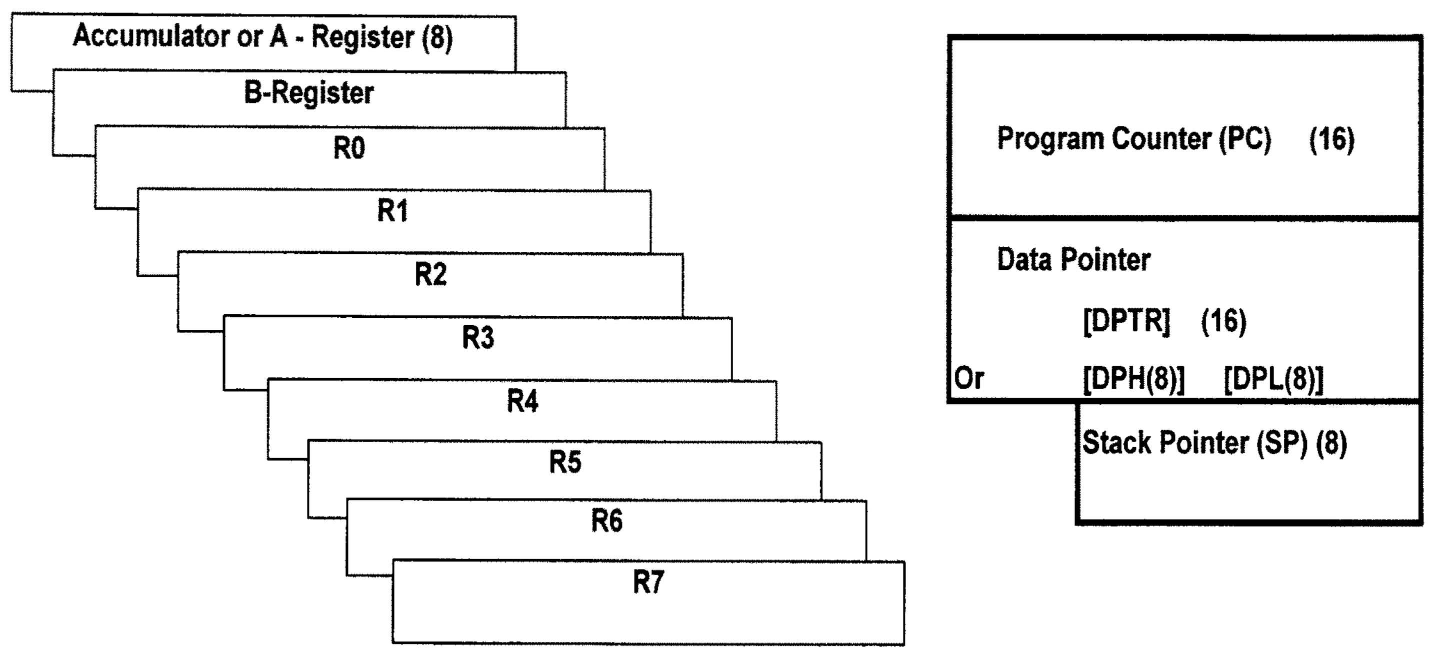


Figure 1.7 Internal RAM Organisation

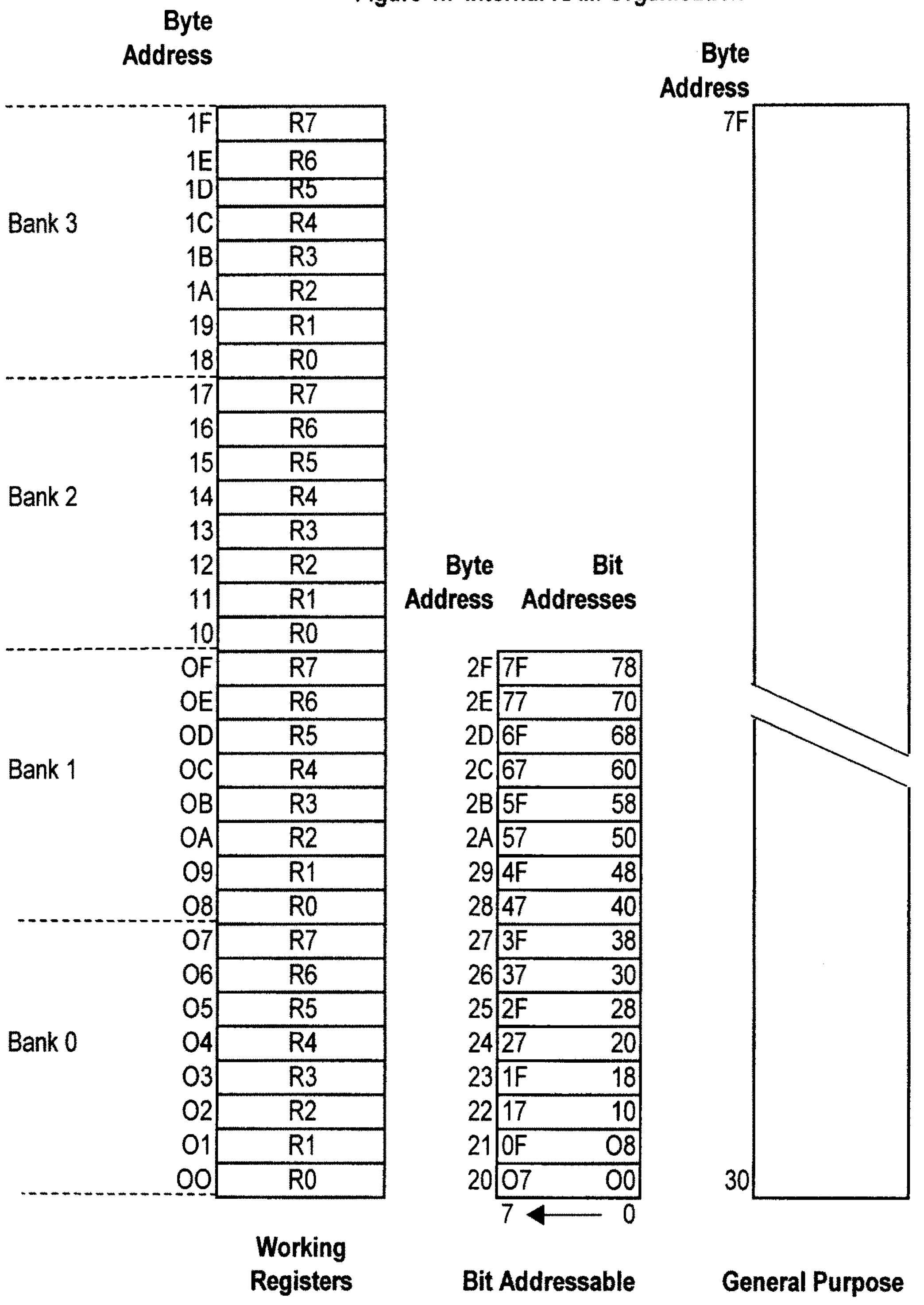


Table 1.4

Name	Function	Internal RAM Address (HEX)
A	Accumulator	0EO
B	Arithmetic	0FO
DPH	Addressing external memory	83
DPL	Addressing external memory	82
IE	Interrupt enable control	0A8
IP	Interrupt priority	0B8
P0	Input/output port latch	80
P1	Input/output port latch	90
P2	Input/output port latch	CA0
P3	Input/output port latch	0B0
PCON	Power control	87
PSW	Program status word	0D0
SCON	Serial port control	98
SBUF	Serial port data buffer	99
SP	Stack pointer	81
TMOD	Timer/counter mode control	89
TCON	Timer/counter control	88
TLO	Timer 0 low byte	8A
THO	Timer 0 high byte	8C
TL1	Timer 1 low byte	8B
TH1	Timer 1 high byte	8D

The A (accumulator) register is the most versatile of the two CPU registers and is used for many operations, including addition, subtraction, integer multiplication and division and Boolean bit manipulations. The A register is also used for all data transfers between the 8051 and any external memory. The B register is used with the A register for multiplication and division operations and has no other functions other than as a location where data may be stored.

1.7 Flags and Program Status Word(PSW):

Flags are 1-bit registers provided to store the results of certain program instructions. Other instructions can test the condition of the flags and make decisions based on the flag states. In order that the flags may be conveniently addressed or grouped inside the program status word (PSW) and the power control (PCON) registers.

The program status word (PSW) is an 8-bit register. It is also referred to as the flag register. Although the PSW register is 8-bits wide, only 6 bits of it are used by the 8051. The two unused bits are user-definable flags. Four of the flags are called conditional flags. Meaning that they indicate some conditions that resulted after an instruction was executed. These four are CY (carry), AC (auxiliary carry), P (parity), and OV (over flow).

As seen from the Table 1.5, the bits PSW3 and PSW4 are designated as RS0 and RS1, and are used to change the bank registers. The PSW.5 and PSW.1 are

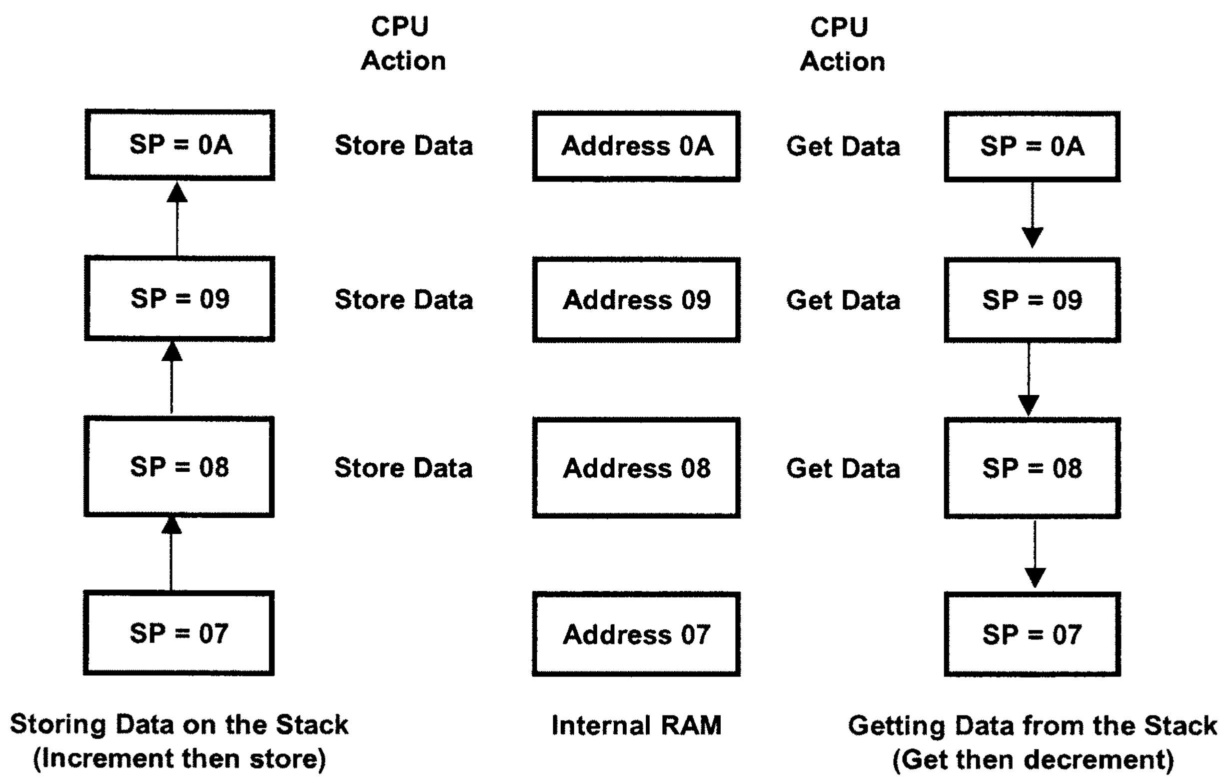
Table 1.5 Bits of the PSW Register

CY	AC	F0	RS1	RS0	OV	--	P

CY	**PSW.7**	**Carry flag.**
AC	**PSW.6**	**Auxiliary carry flag.**
--	**PSW.5**	**Available to the user for general**
	purpose.	
RS1	**PSW.4**	**Register Bank selector bit 1.**
RS0	**PSW.3**	**Register Bank selector bit 0.**
OV	**PSW.2**	**Overflow flag.**
--	**PSW.1**	**User definable bit.**
P	**PSW.0**	**Parity flag. Set/cleared by hardware each instruction cycle to indicate an odd/even number of 1 bits in the accumulator.**

RS1	RS0	Register Bank	Address
0	0	0	00H - 07H
0	1	1	08H - 0FH
1	0	2	10H - 17H
1	1	3	18H - 1FJ

Figure 1.8 Stack Operation



general purpose status flag bits and can be used by the programmer for any purpose. In other words they are user-definable.

Introduction to Programmable Logic Controllers (PLC's)

Industrial Control Systems

Fall 2006

The Need for PLCs

- Hardwired panels were very time consuming to wire, debug and change.
- GM identified the following requirements for computer controllers to replace hardwired panels.
  - Solid-state not mechanical
  - Easy to modify input and output devices
  - Easily programmed and maintained by plant electricians
  - Be able to function in an industrial environment

The First Programmable Logic Controllers (PLCs)

- Introduced in the late 1960's
- Developed to offer the same functionality as the existing relay logic systems
- Programmable, reusable and reliable
  - Could withstand a harsh industrial environment
  - They had no hard drive, they had battery backup
  - Could start in seconds
  - Used Ladder Logic for programming

Programmable Logic Controller

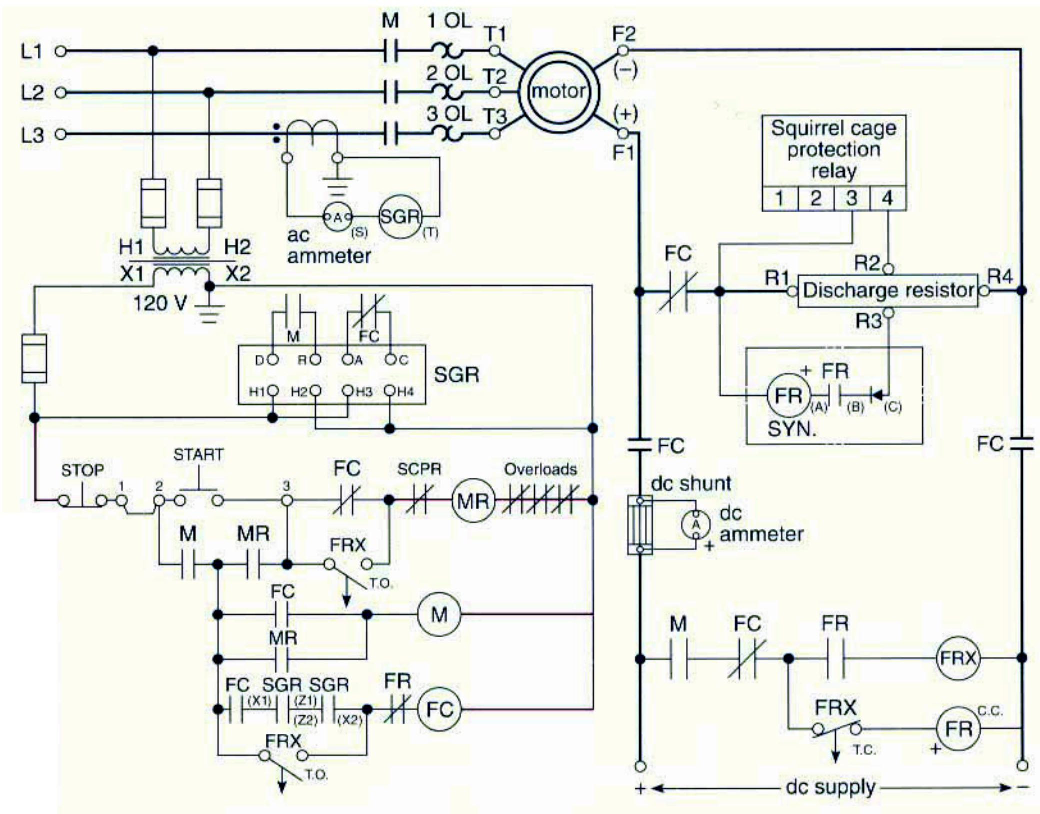
- A programmable logic controller (PLC) is a specialized computer used to control machines and process.
- It uses a programmable memory to store instructions and specific functions that include On/Off control, timing, counting, sequencing, arithmetic, and data handling

Advantages of PLC Control Systems

- Flexible
- Faster response time
- Less and simpler wiring
- Solid-state - no moving parts
- Modular design - easy to repair and expand
- Handles much more complicated systems
- Sophisticated instruction sets available
- Allows for diagnostics “easy to troubleshoot”
- Less expensive

Advantages of a PLC Control System

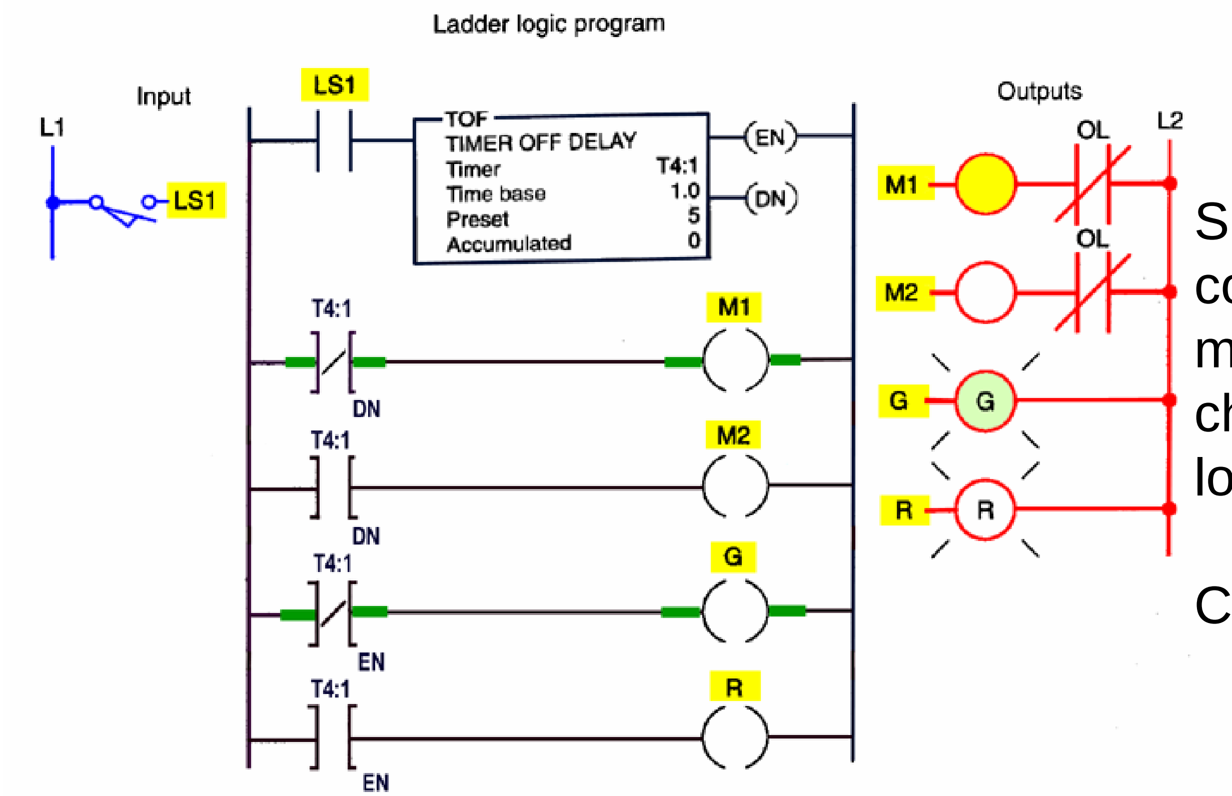
Eliminates much of the hard wiring that was associated with conventional relay control circuits.



The program takes the place of much of the external wiring that would be required for control of a process.

Advantages of a PLC Control System

Increased Reliability:
Once a program has been written and tested it can be downloaded to other PLCs.

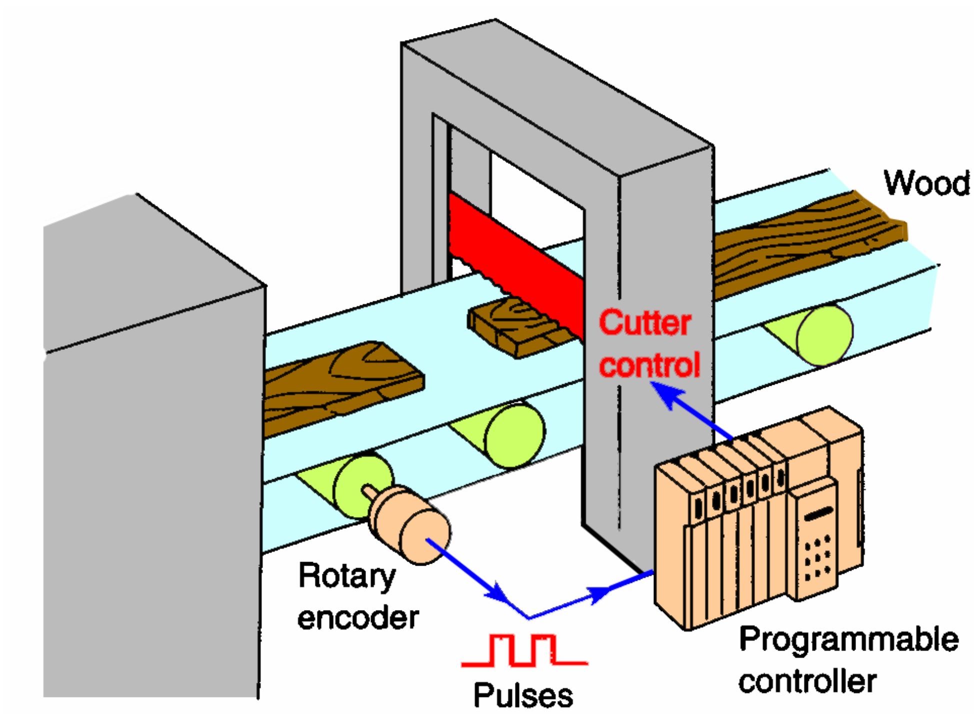


Since all the logic is contained in the PLC's memory, there is no chance of making a logic wiring error.

Conversely ......

Advantages of a PLC Control System

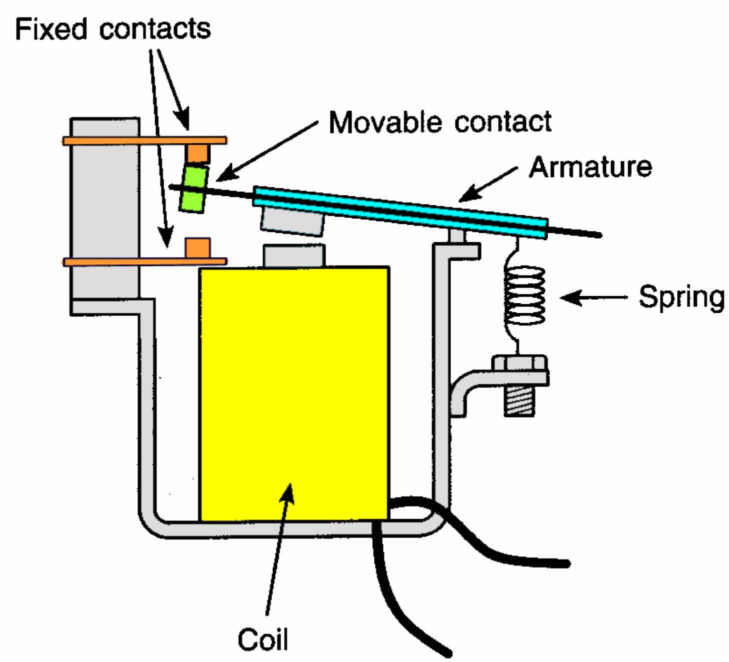
More Flexibility:
Original equipment manufacturers (OEMs) can provide system updates for a process by simply sending out a new program.



It is easier to create and change a program in a PLC than to wire and rewire a circuit. End-users can modify the program in the field.

Advantages of a PLC Control System

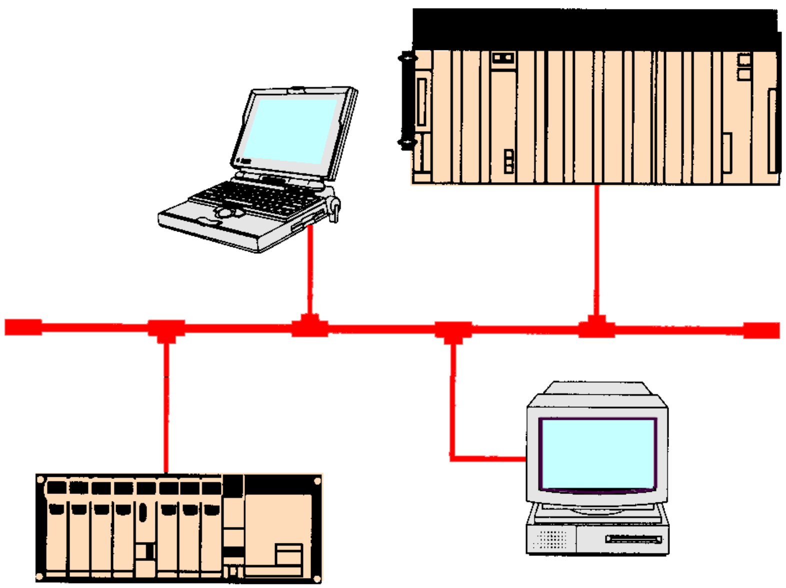
Lower Costs:
Originally PLCs were designed to replace relay control logic. The cost savings using PLCs have been so significant that relay control is becoming obsolete, except for power applications.



Generally, if an application requires more than about 6 control relays, it will usually be less expensive to install a PLC.

Advantages of a PLC Control System

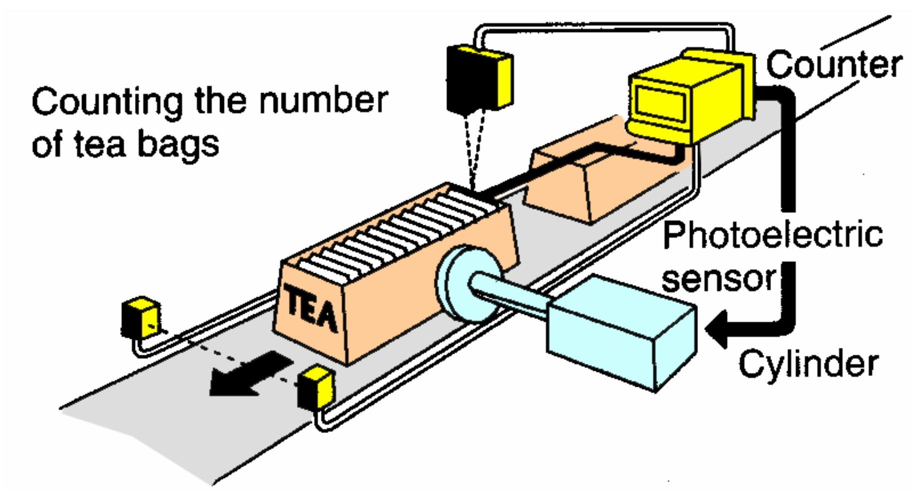
Communications Capability:
A PLC can communicate with other controllers or computer equipment.



They can be networked to perform such functions as: supervisory control, data gathering, monitoring devices and process parameters, and downloading and uploading of programs.

Advantages of a PLC Control System

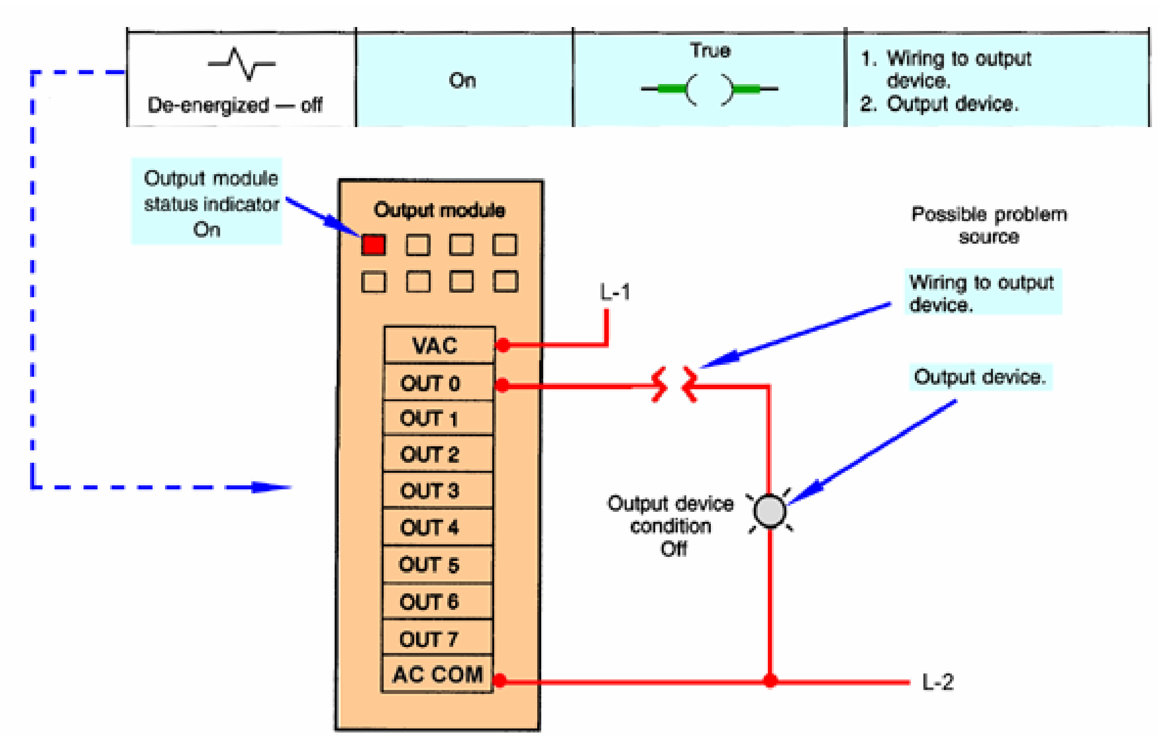
Faster Response Time:
PLCs operate in real-time which means that an event taking place in the field will result in an operation or output taking place.



Machines that process thousands of items per second and objects that spend only a fraction of a second in front of a sensor require the PLC's quick response capability.

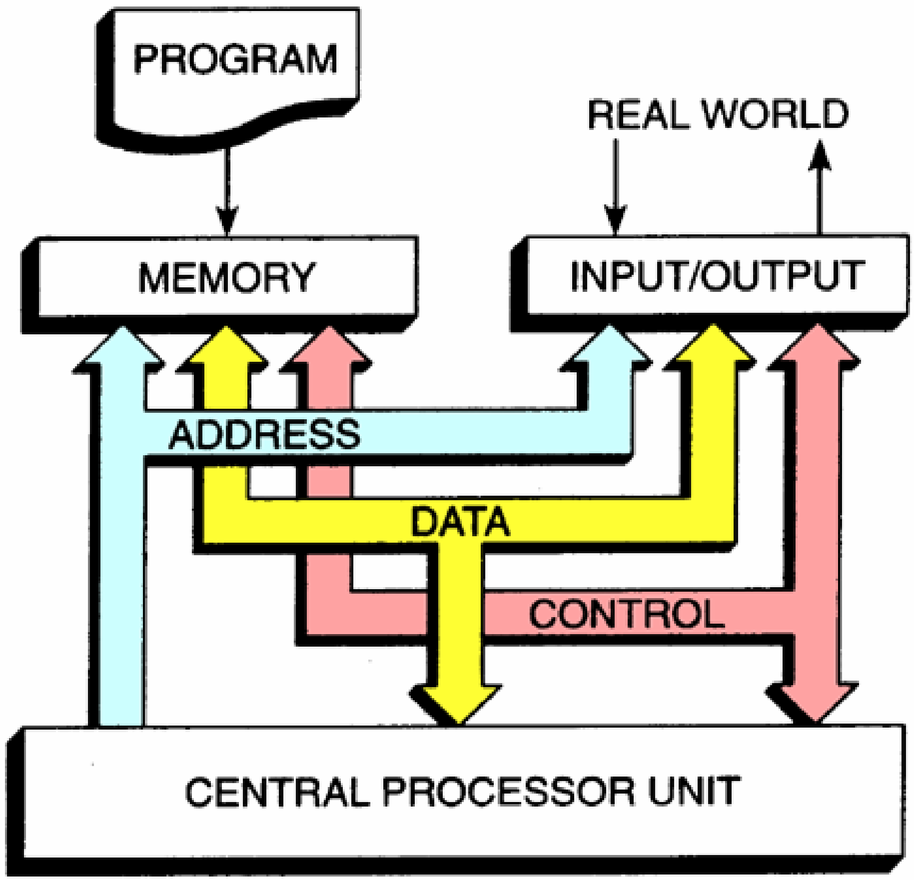
Advantages of a PLC Control System

Easier To Troubleshoot:
PLCs have resident diagnostic and override functions allowing users to easily trace and correct software and hardware problems.



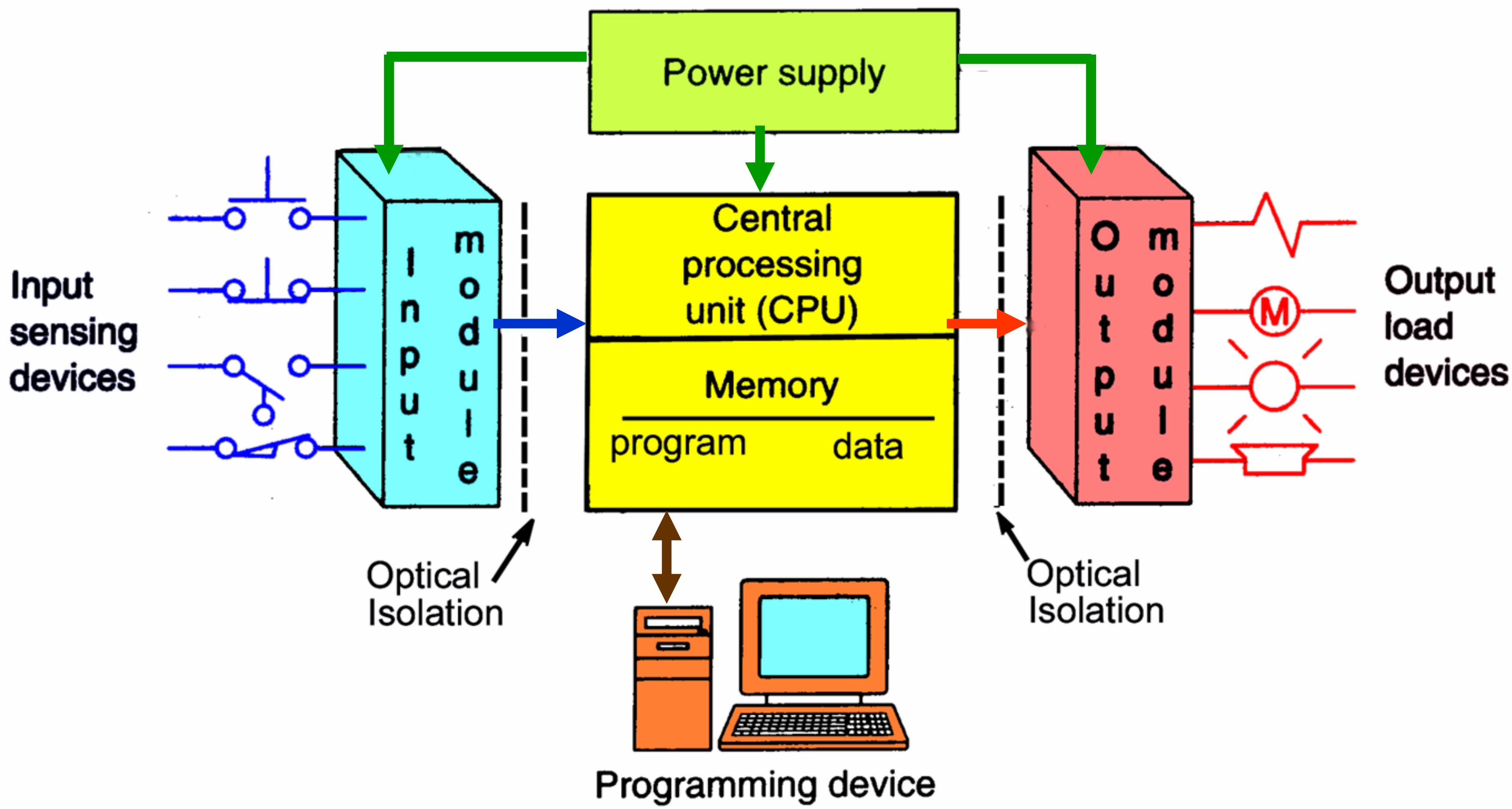
The control program can be watched in real-time as it executes to find and fix problems

PLC Architecture



The structure of a PLC is based on the same principles as those employed in computer architecture.

PLC System


Power supply
Input sensing devices
Input module
Central processing unit (CPU)
Memory
program
data
Output module
Output load devices
M
Optical Isolation
Optical Isolation
Programming device

PLC Architecture

- An *open architecture* design allows the system to be connected easily to devices and programs made by other manufacturers.

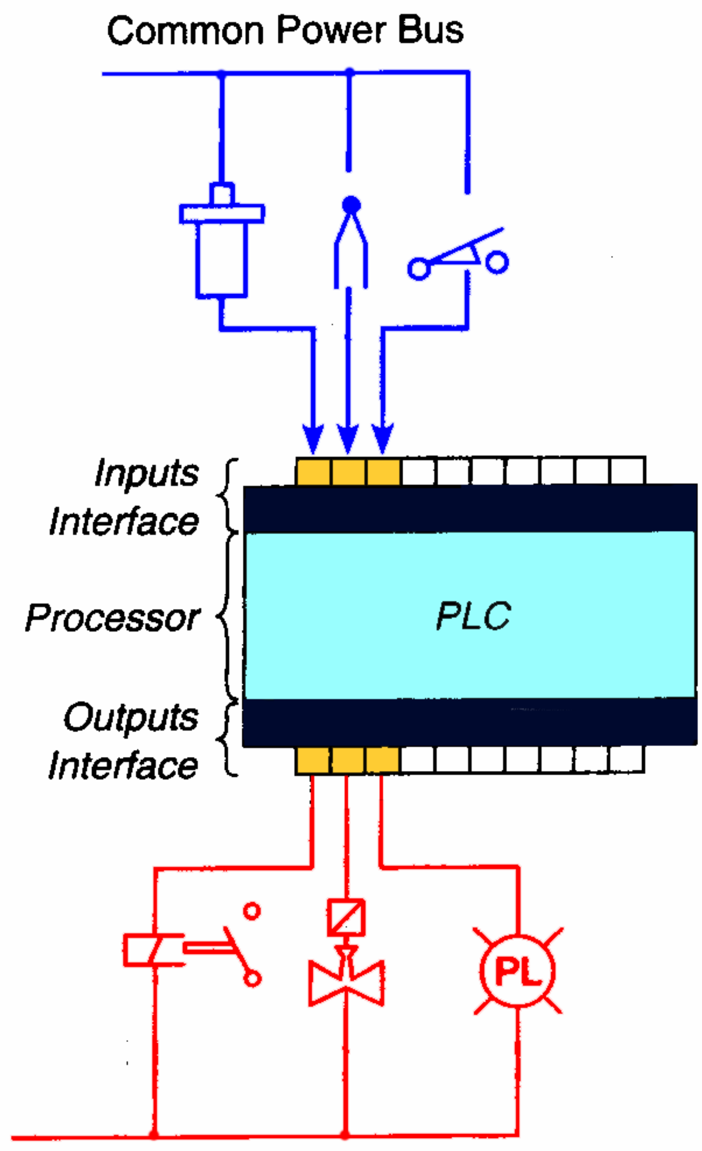
- A *closed architecture* or *proprietary* system, is one whose design makes it more difficult to connect devices and programs made by other manufacturers.

NOTE: When working with PLC systems that are proprietary in nature you must be sure that any generic hardware or software you use is compatible with your particular PLC.

I/O Configurations

Fixed I/O

- Is typical of small PLCs
- Comes in one package, with no separate removable units.
- The processor and I/O are packaged together.
- Lower in cost – but lacks flexibility.

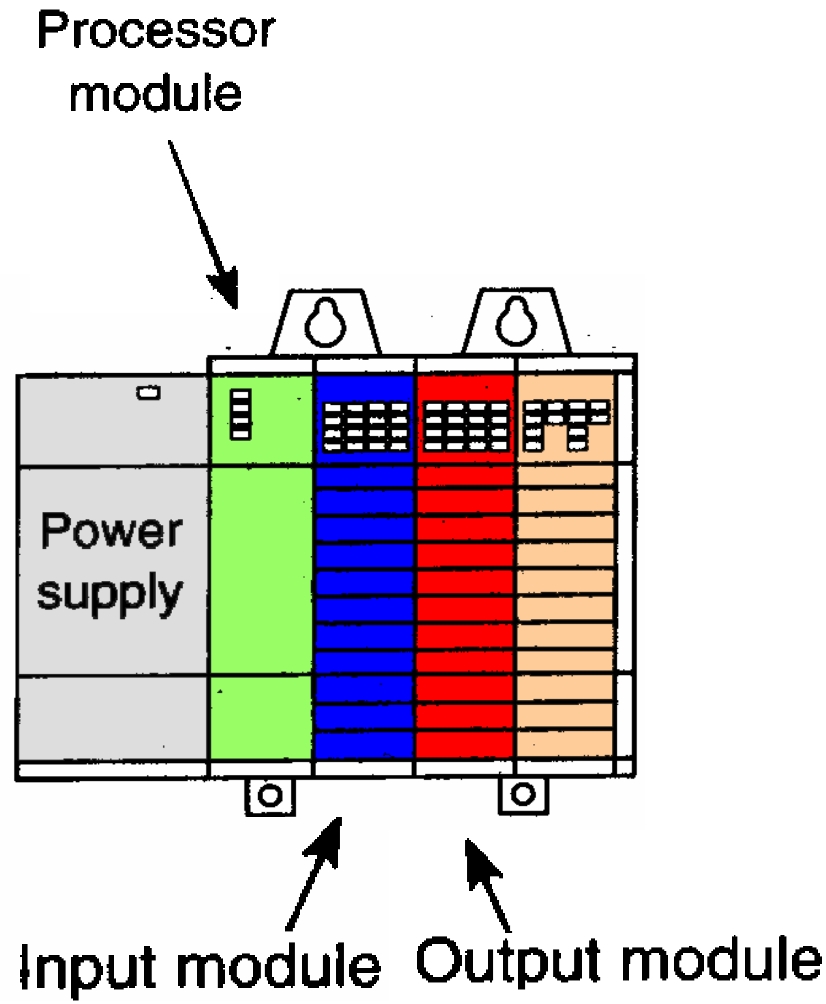


I/O Configurations

Modular I/O

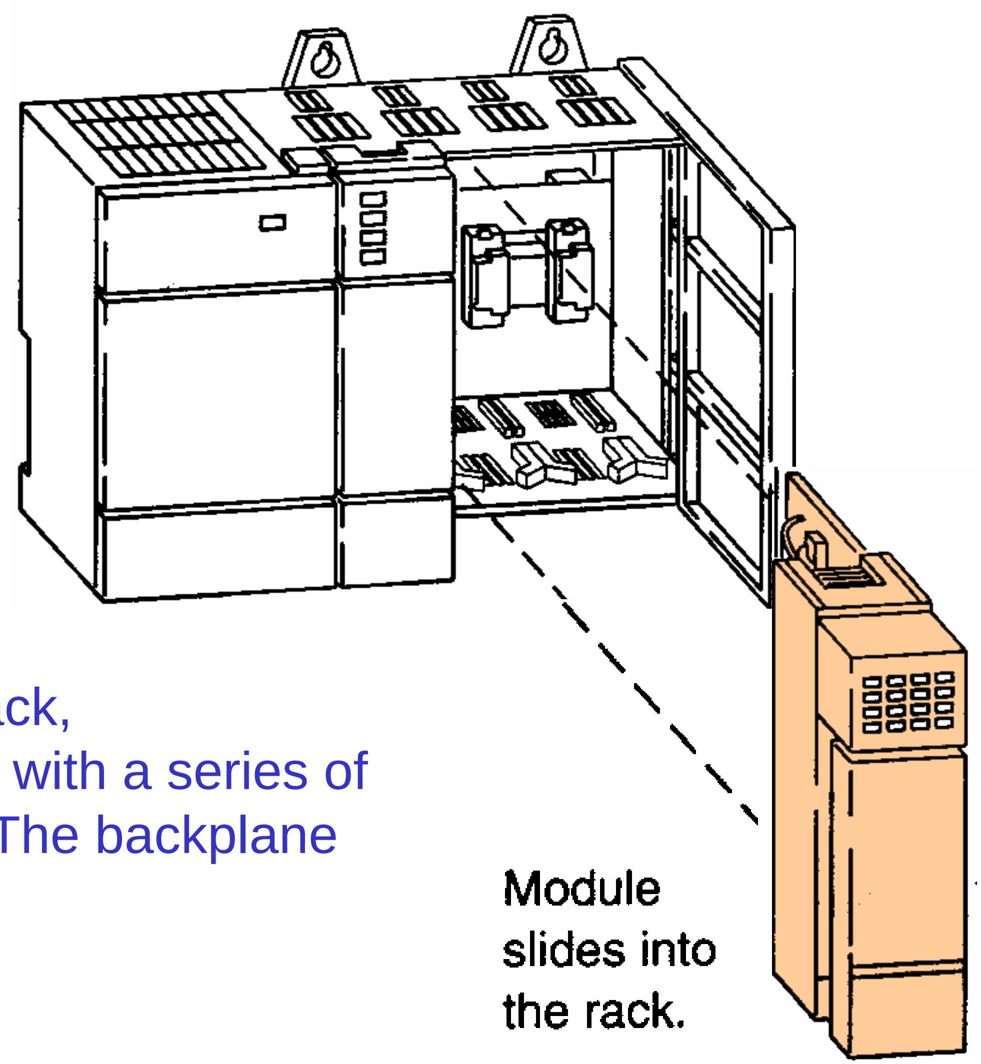
Is divided by compartments into which separate modules can be plugged.

This feature greatly increases your options and the unit's flexibility. You can choose from all the modules available and mix them in any way you desire.



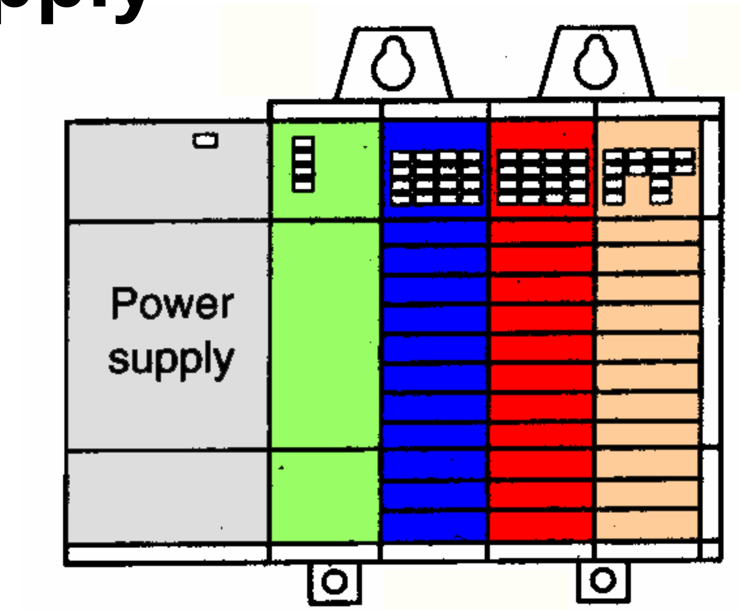
I/O Configurations

Modular I/O



When a module slides into the rack,
it makes an electrical connection with a series of contacts - called the *backplane.* The backplane is located at the rear of the rack.

Power Supply



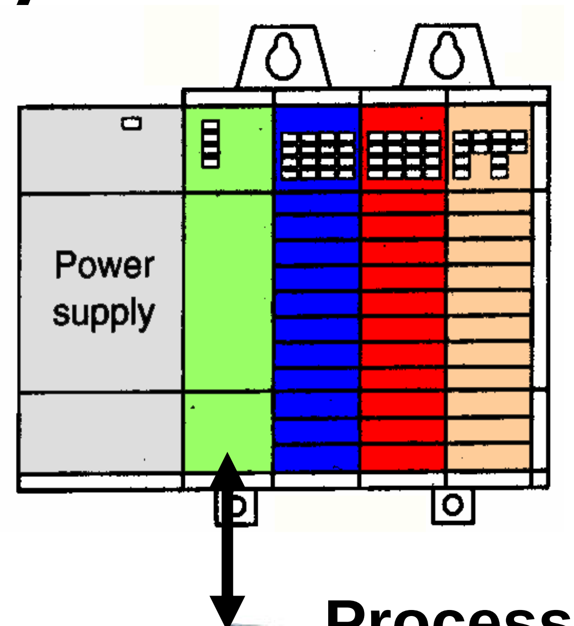
- Supplies DC power to other modules that plug into the rack.

- In large PLC systems, this power supply does not normally supply power to the field devices.

- In small and micro PLC systems, the power supply is also used to power field devices.

Processor (CPU)

- Is the "brain" of the PLC.
- Consists of a microprocessor for implementing the logic, and controlling the communications among the modules.
- Designed so the desired circuit can be entered in relay ladder logic form.
- The processor accepts input data from various sensing devices, executes the stored user program, and sends appropriate output commands to control devices.

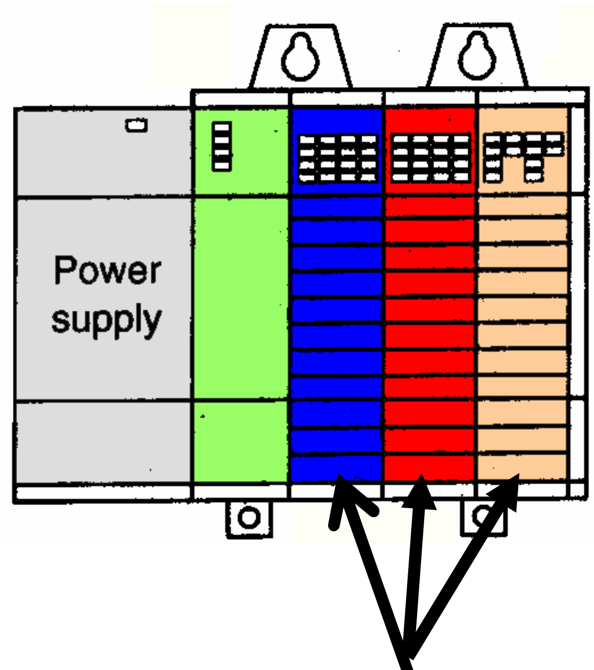


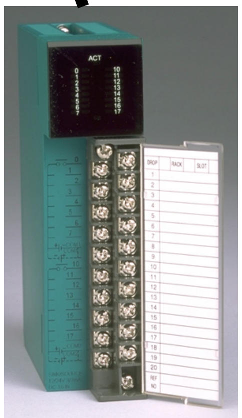
Processor
Module

I/O Section

Consists of:

- Input modules
- Output modules.



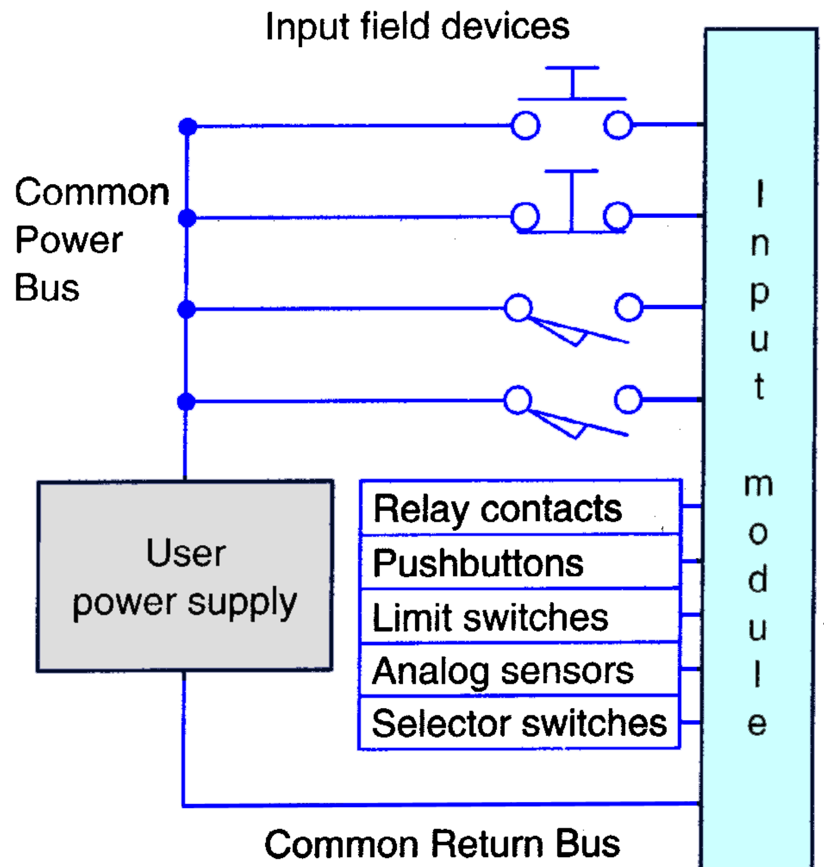


I/O Section

Input Module

- Forms the interface by which input field devices are connected to the controller.

- The terms “field” and “real world”are used to distinguish actual external devices that exist and must be physically wired into the system.

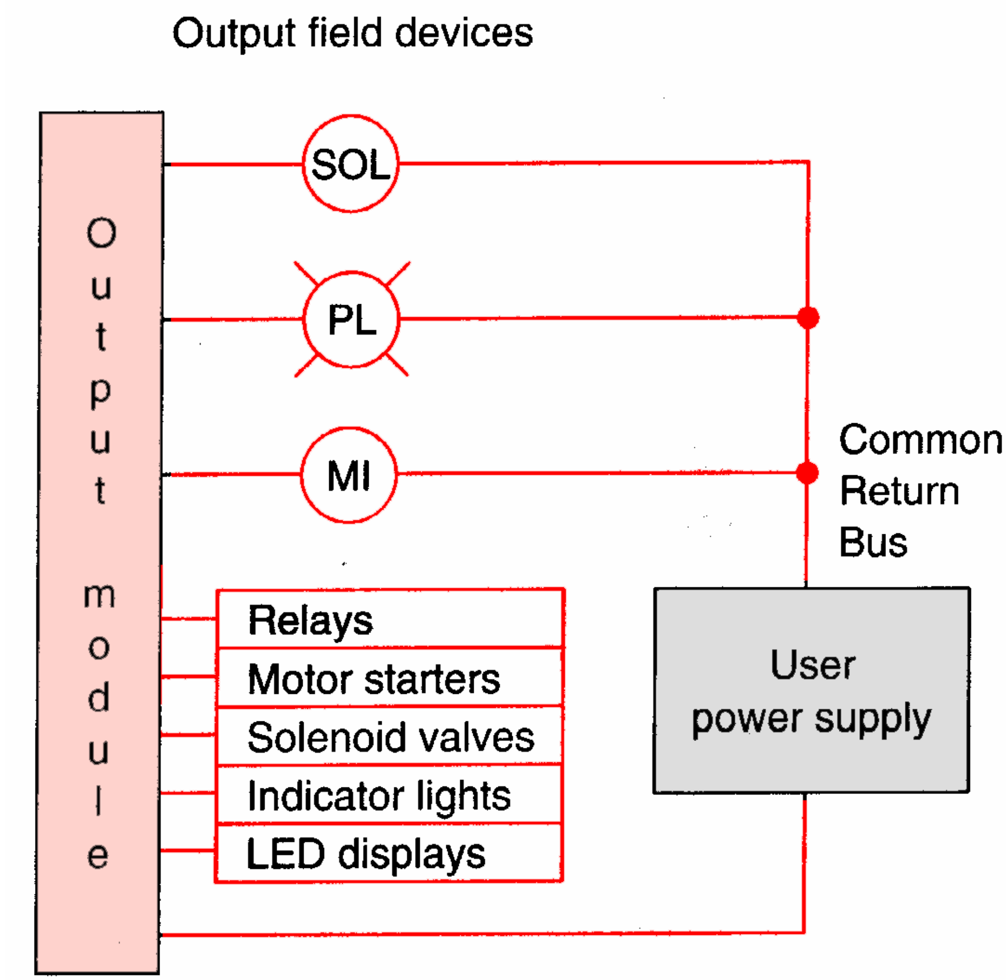


I/O Section

Output Module

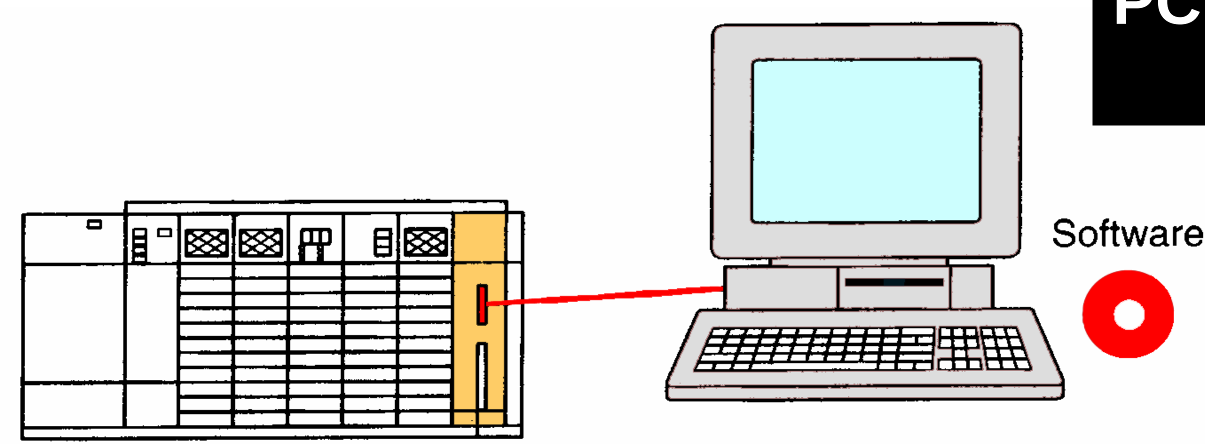
- Forms the interface by which output field devices are connected to the controller.

- PLCs employ an optical isolator which uses light to electrically isolate the internal components from the input and output terminals.



Programming Device

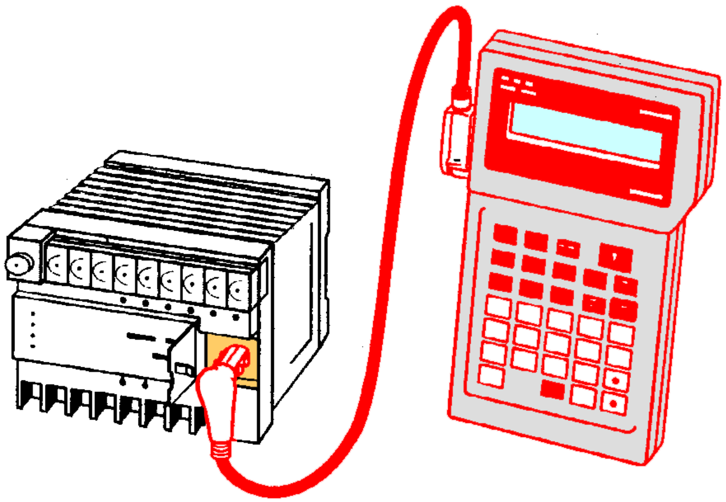
PC with appropriate software



- A personal computer (PC) is the most commonly used programming device
- The software allows users to create, edit, document, store and troubleshoot programs
- The personal computer communicates with the PLC processor via a serial or parallel data communications link

Programming Device

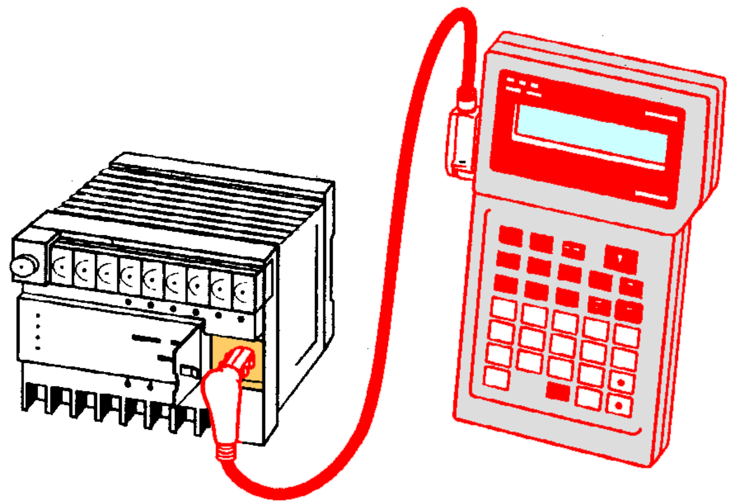
Hand-held unit with display



- Hand-held programming devices are sometimes used to program small PLCs
- They are compact, inexpensive, and easy to use, but are not able to display as much logic on screen as a computer monitor

Programming Device

Hand-held unit with display

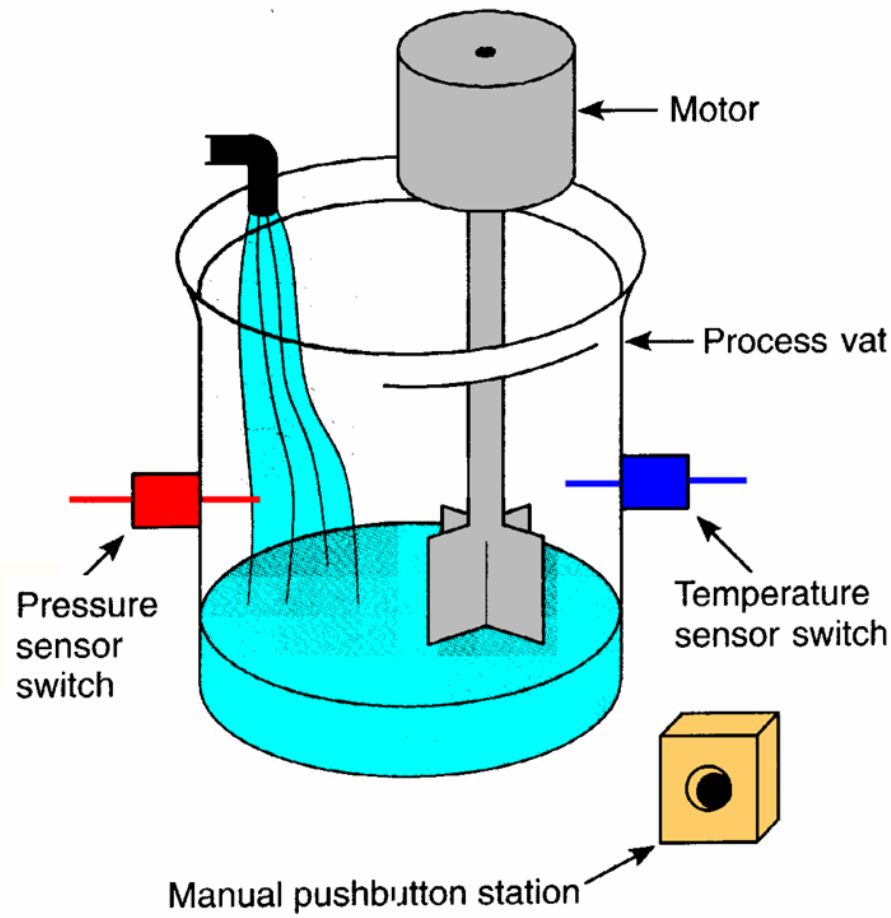


- Hand-held units are often used on the factory floor for troubleshooting, modifying programs, and transferring programs to multiple machines.

PLC Mixer Process Control Problem

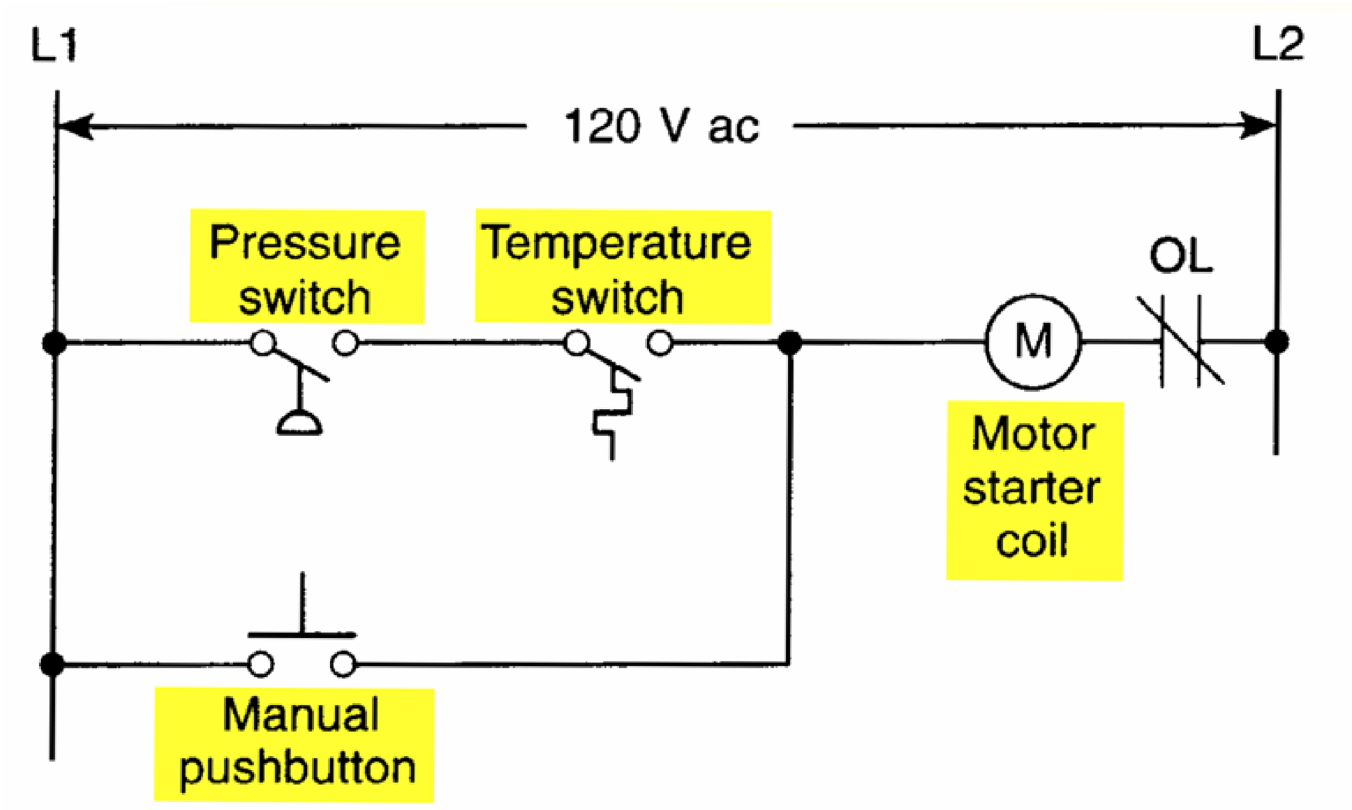
Mixer motor to automatically
stir the liquid in the vat
when the temperature and
pressure reach preset values

Alternate manual
pushbutton control
of the motor to be
provided



The temperature and
pressure sensor switches
close their respective contacts when conditions reach
their preset values

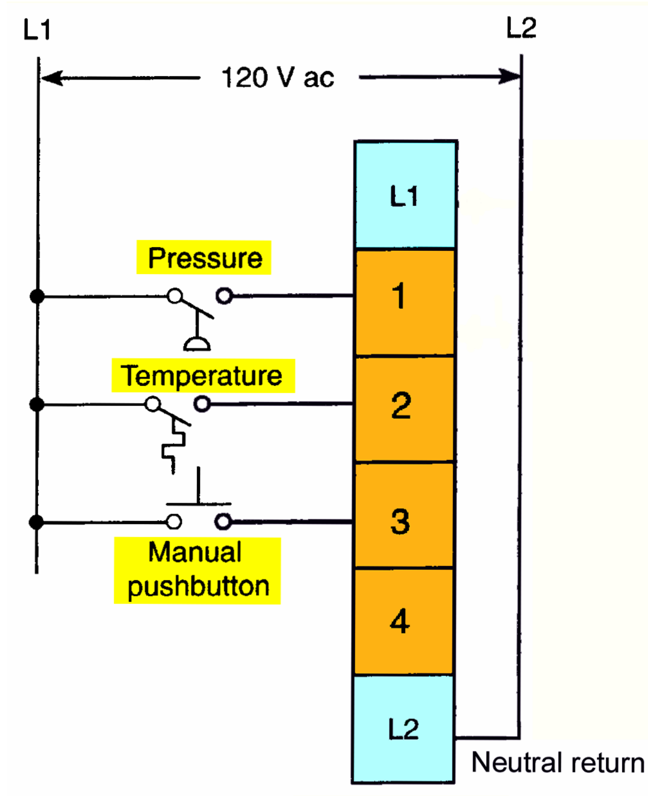
Process Control Relay Ladder Diagram



Motor starter coil is energized when both the pressure and temperature switches are closed or when the manual pushbutton is pressed

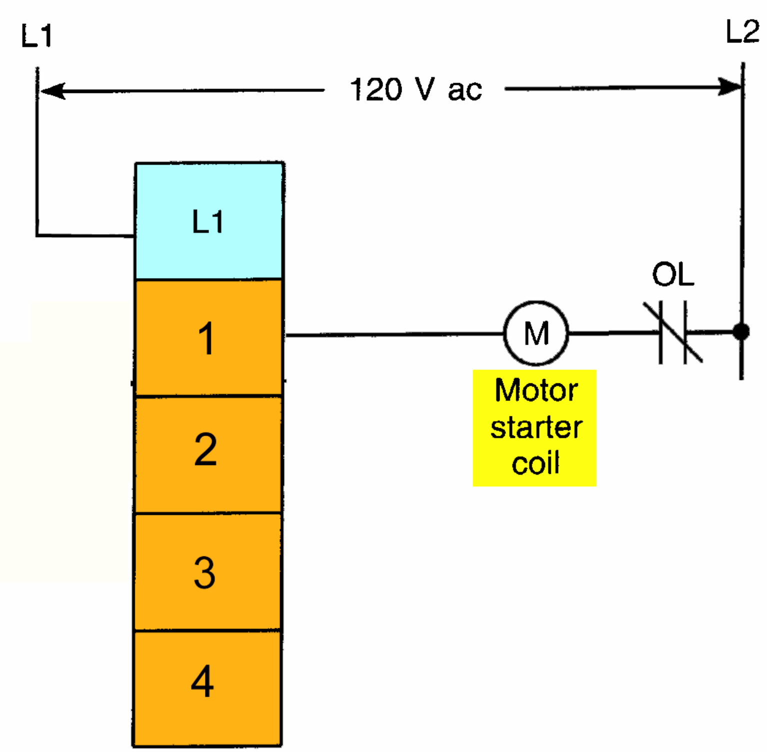
PLC Input Module Connections

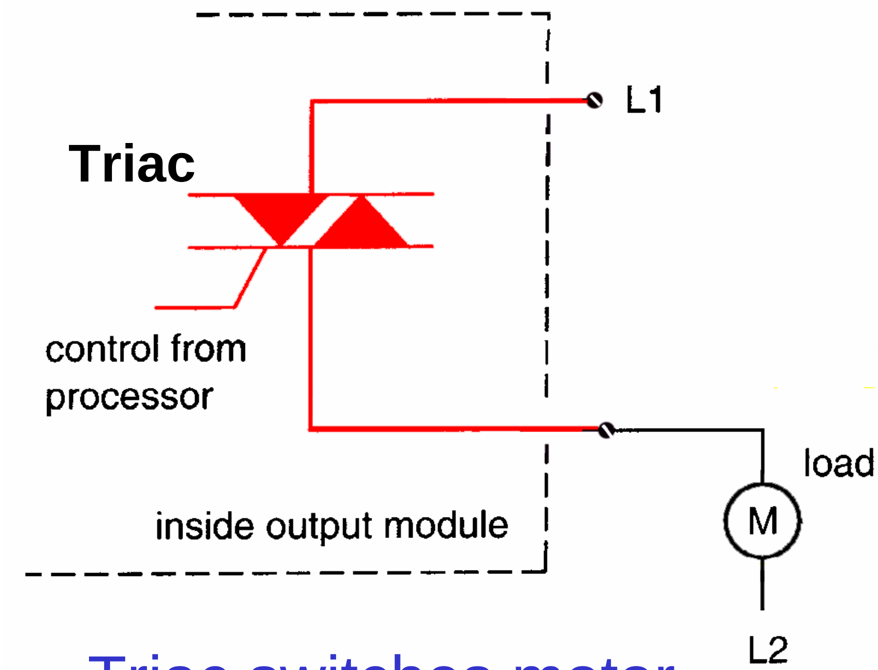
- The same input field devices are used
- These devices are wired to the input module according to the manufacturer's labeling scheme



PLC Output Module Connections

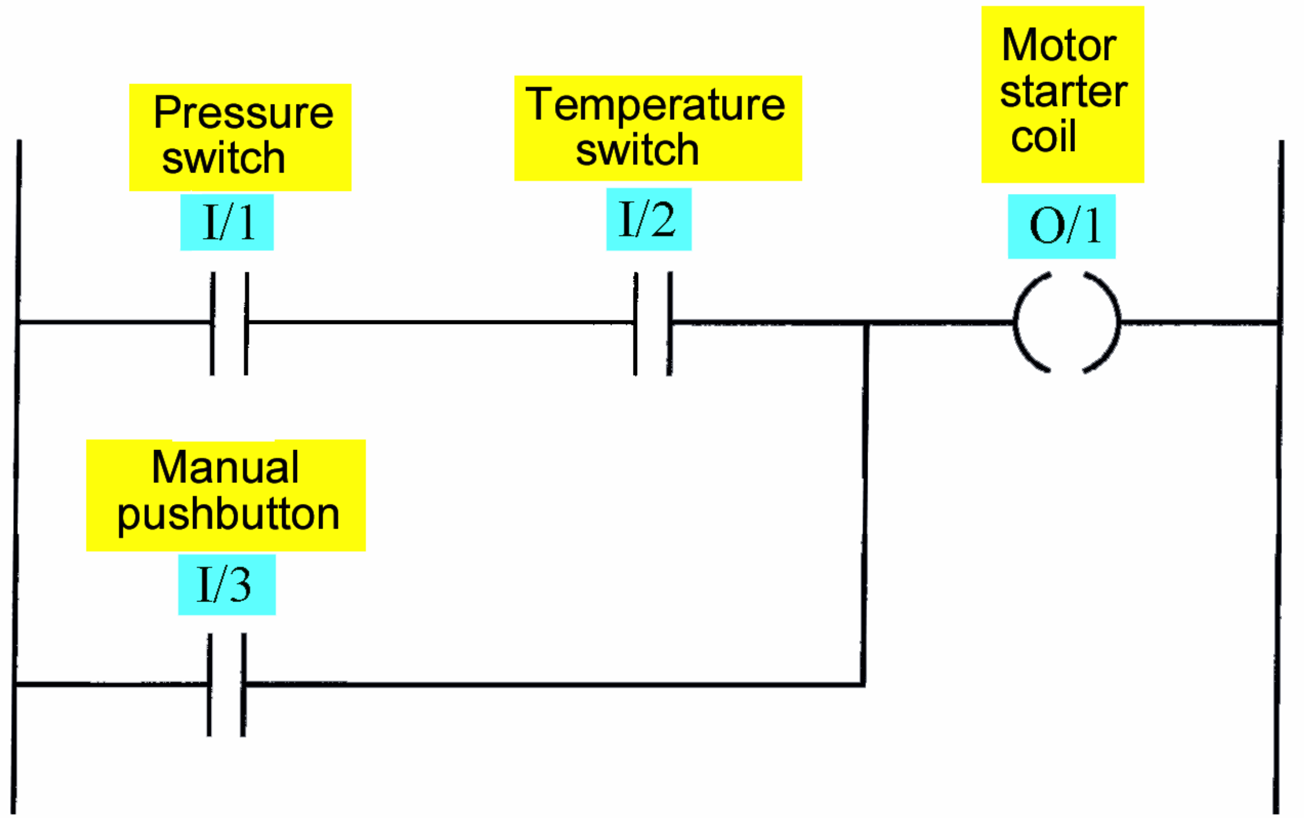
Same output field device is used and wired to the output module





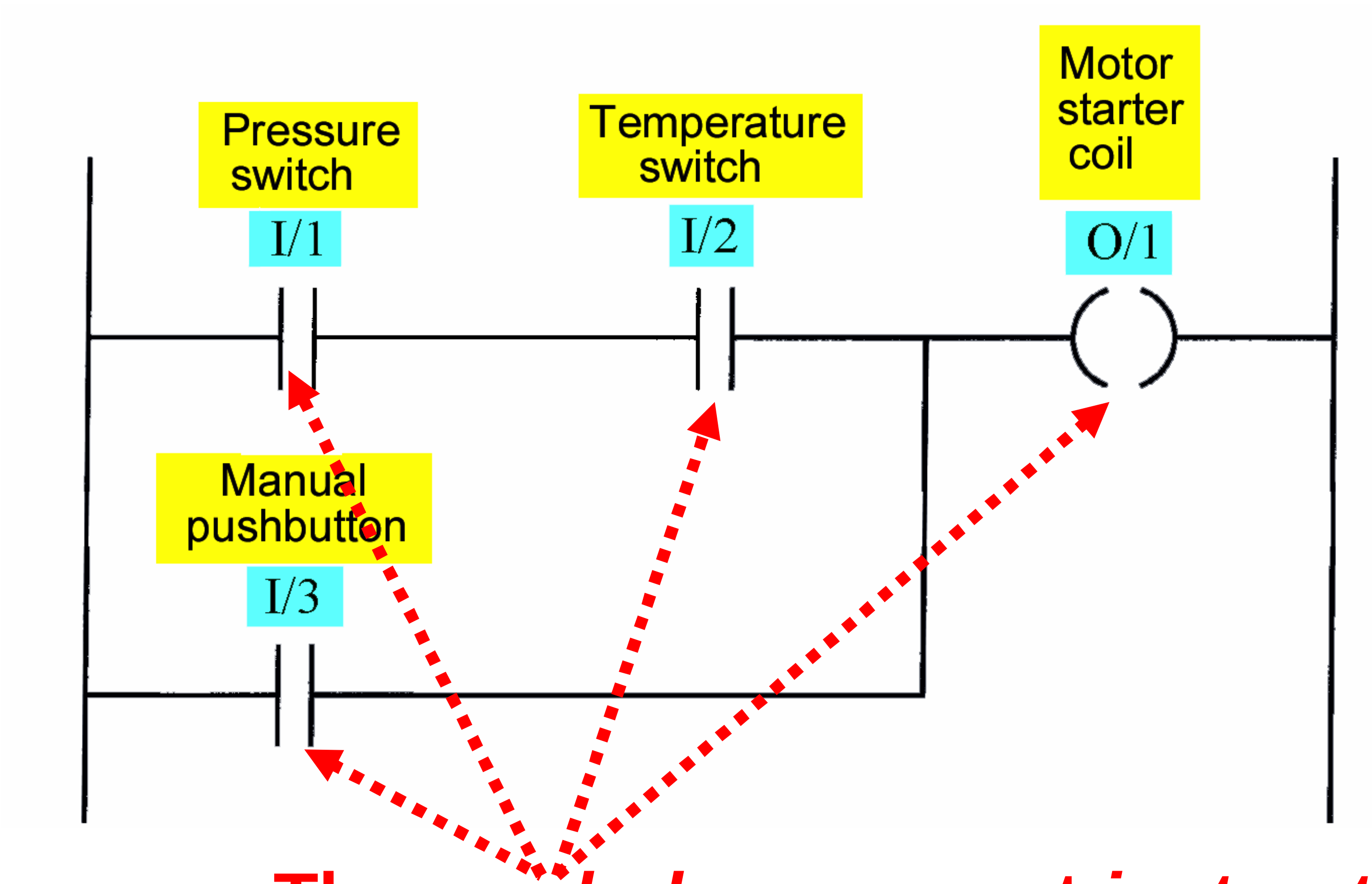
Triac switches motor ON and OFF in accordance with the control signal from the processor

PLC Ladder Logic Program



- The format used is similar to that of the hard-wired relay circuit

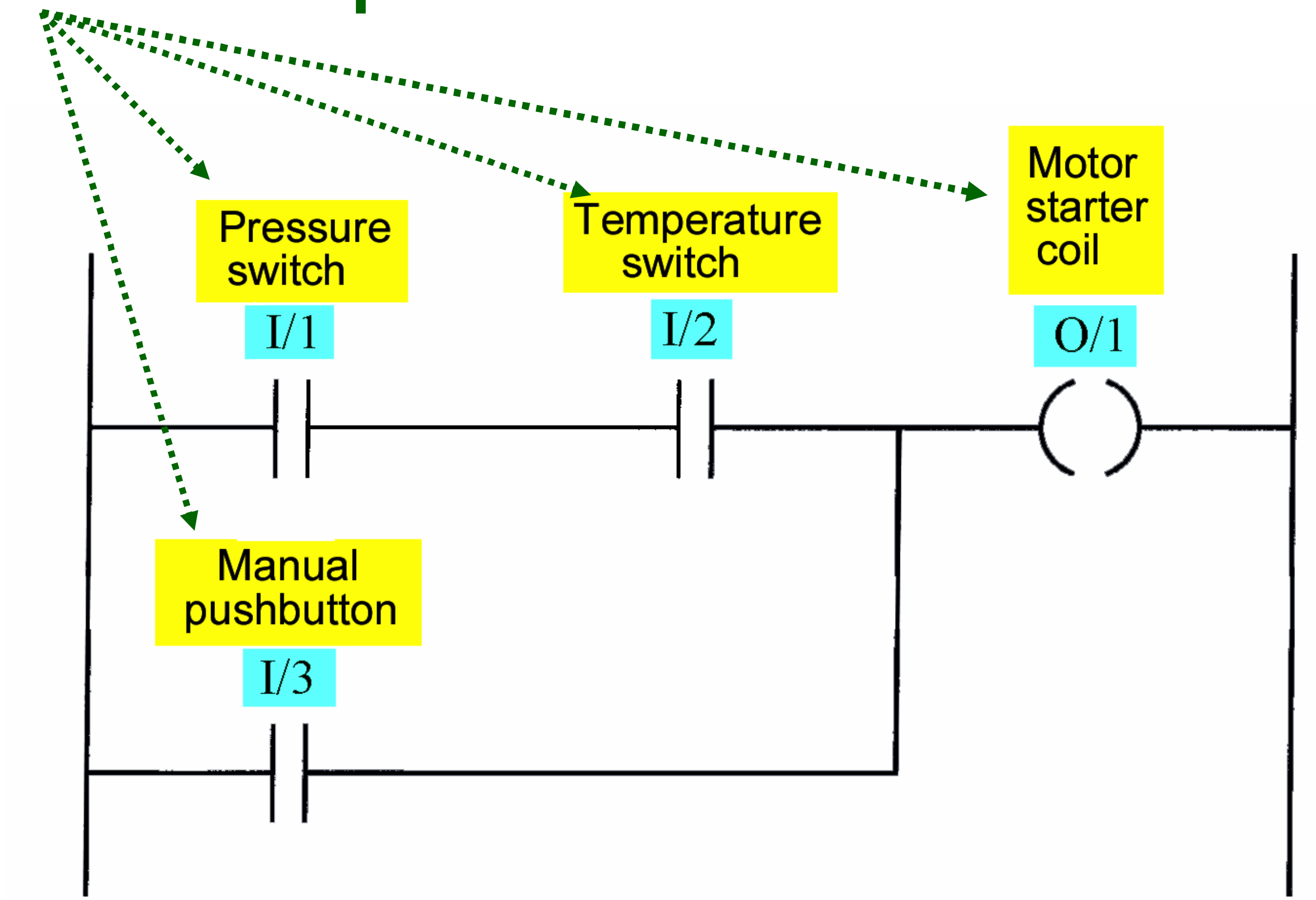
PLC Ladder Logic Program



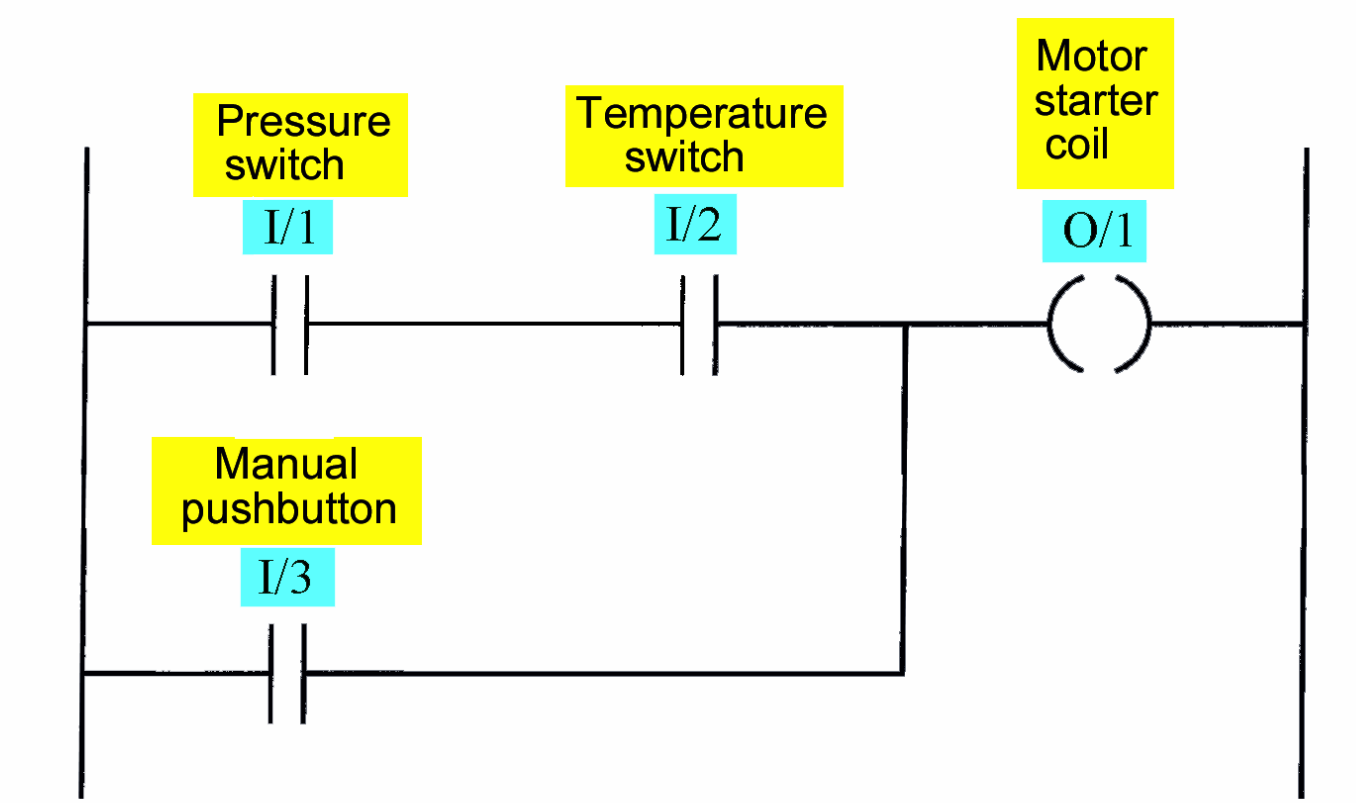
The *symbols* represent *instructions*

PLC Ladder Logic Program

The *numbers* represent *addresses*

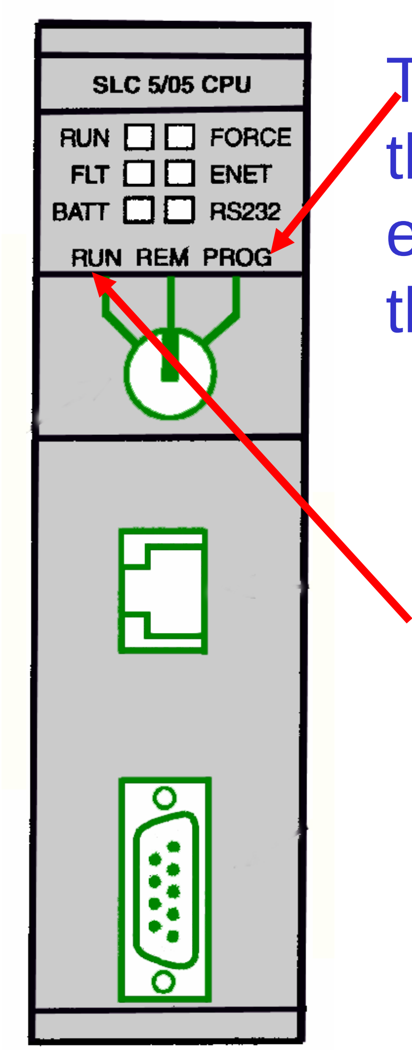


PLC Ladder Logic Program



- I/O address format will differ, depending on the PLC manufacturer. You give each input and output device an address. This lets the PLC know where they are physically connected

Entering And Running The PLC Program

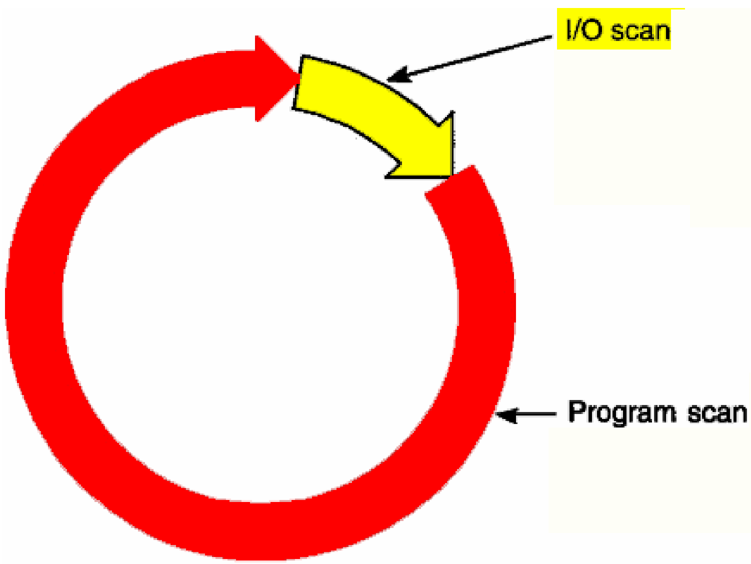


To enter the program into the PLC, place the processor in the PROGRAM mode and enter the instructions one-by-one using the programming device

To operate the program, the controller is placed in the RUN mode, or operating cycle

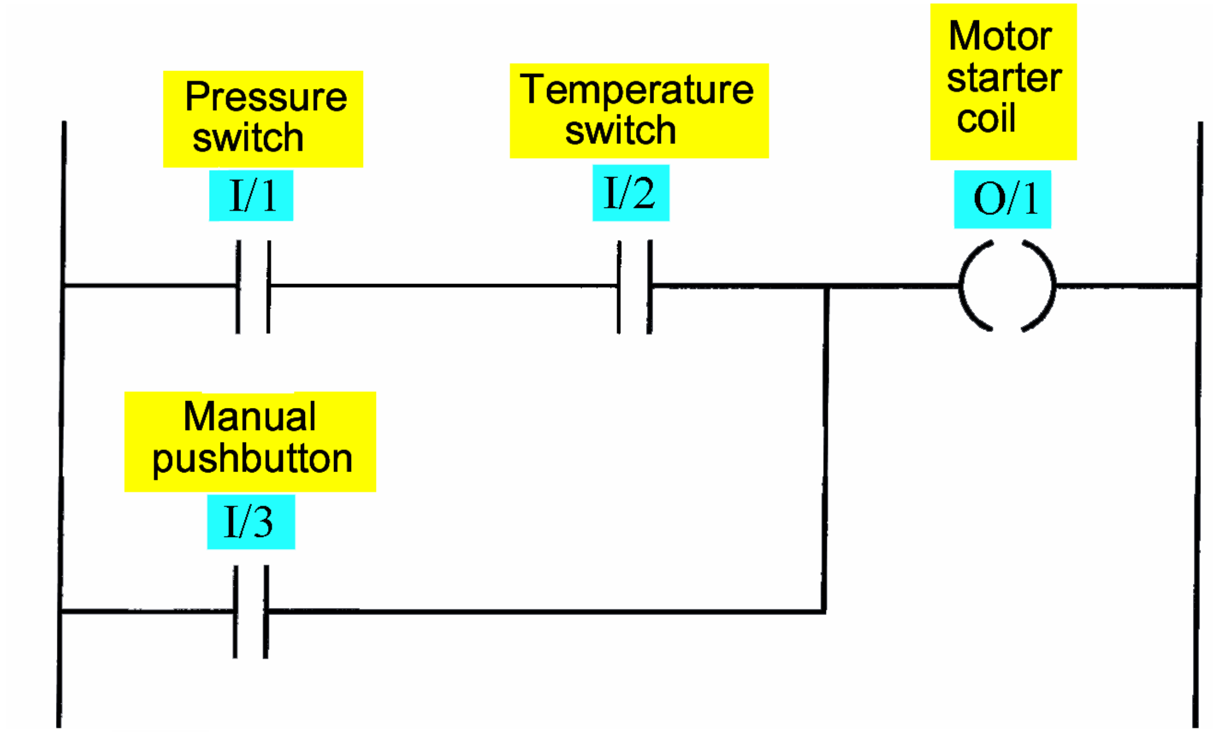
PLC Operating Cycle

During each operating cycle, the controller examines the status of input devices, executes the user program, and changes outputs accordingly



The completion of one cycle of this sequence is called a *scan*. The scan time, the time required for one full cycle, provides a measure of the speed of response of the PLC

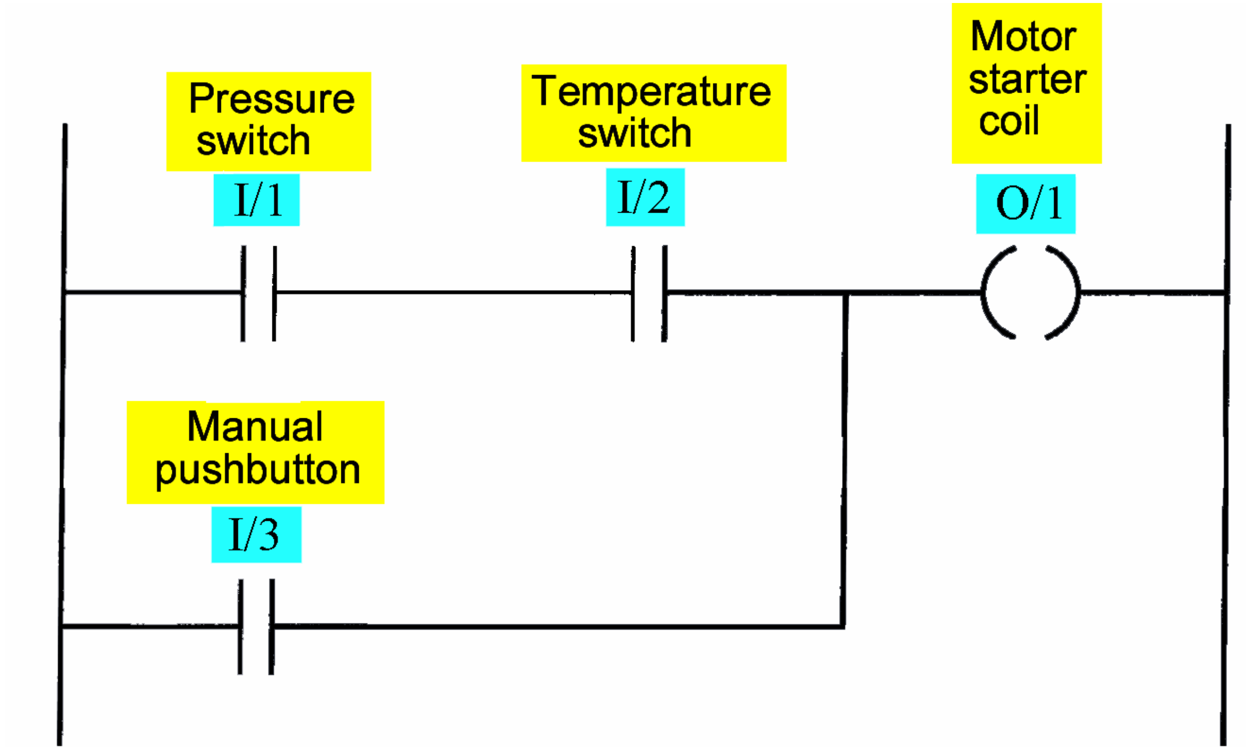
PLC Operating Cycle



Each  can be though of as a set of normally open contacts

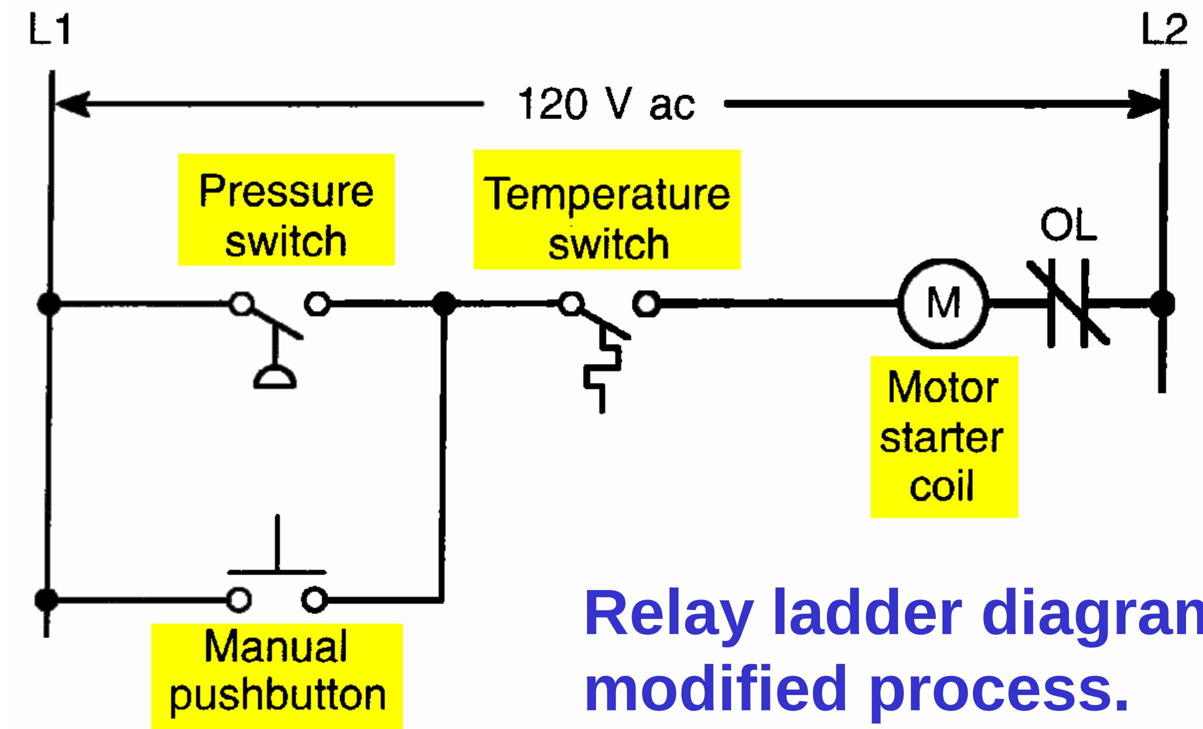
The  can be considered to represent a coil that, when energized, will close a set of contacts.

PLC Operating Cycle



Coil O/1 is energized when contacts I/1 and I/2 are closed or when contact I/3 is closed. Either of these conditions provides a continuous path from left to right across the rung that includes the coil.

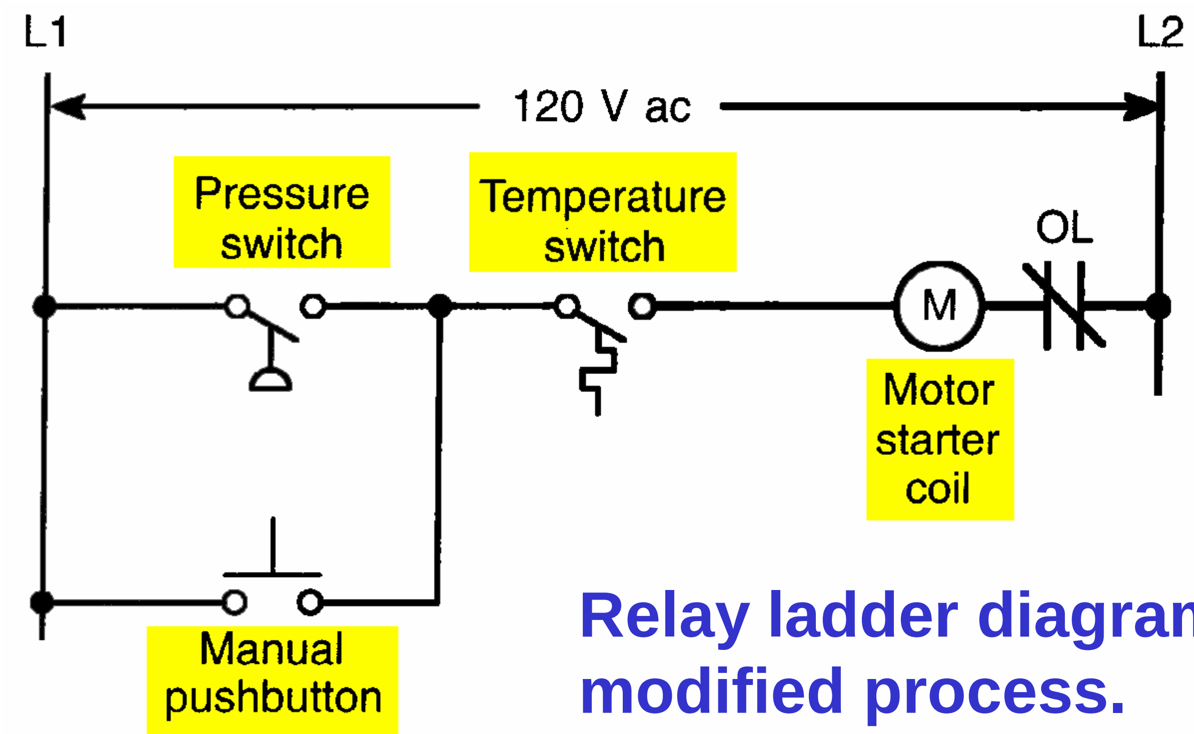
Modifying A PLC Program



Relay ladder diagram for modified process.

The change requires that the manual pushbutton control should be permitted to operate at any pressure but not unless the specified temperature setting has been reached.

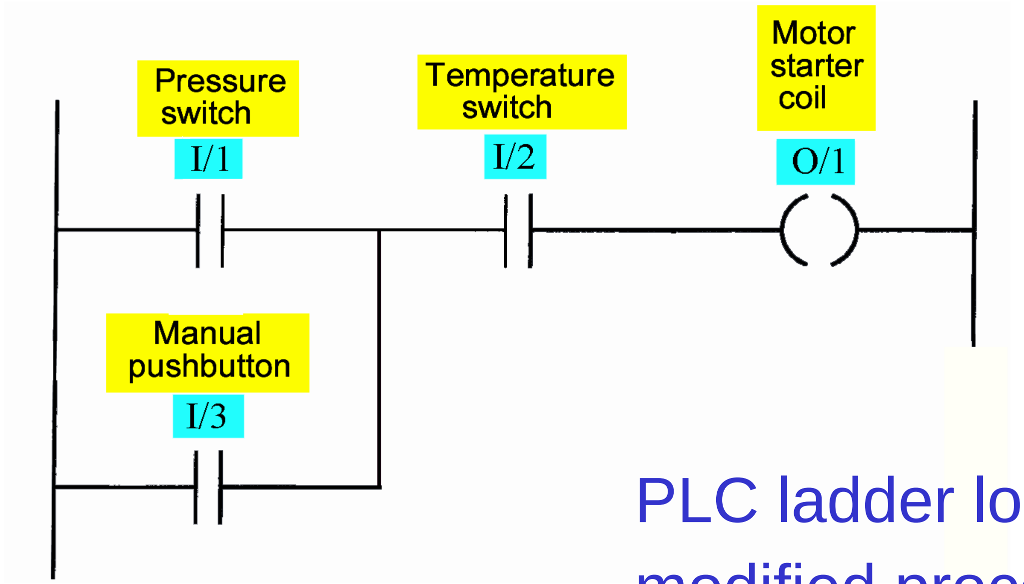
Modifying A PLC Program



Relay ladder diagram for modified process.

If a relay system were used, it would require some rewiring of the system, as shown, to achieve the desired change.

Modifying A PLC Program



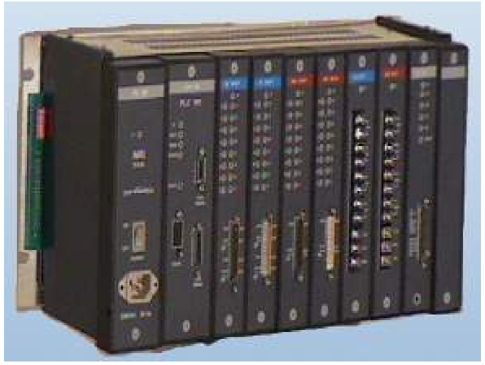
PLC ladder logic diagram for modified process.

If a PLC is used, no rewiring is necessary!

The inputs and outputs are still the same.

All that is required is to change the PLC program

PLCs Versus Personal Computers



Same basic architecture

PLC

- Operates in the industrial environment
- Is programmed in relay ladder logic
- Has no keyboard, CD drive, monitor, or disk drive
- Has communications ports, and terminals for input and output devices

PC

- Capable of executing several programs simultaneously, in any order
- Some manufacturers have software and interface cards available so that a PC can do the work of a PLC

PC Based Control Systems

Advantages

- Lower initial cost
- Less proprietary hardware and software required
- Straightforward data exchange with other systems
- Speedy information processing
- Easy customization

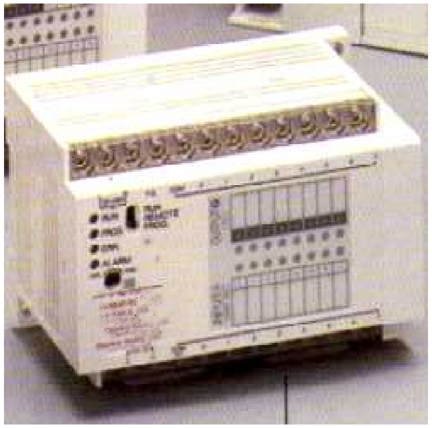
PLC Size Classification

Criteria

- Number of inputs and outputs (I/O count)
- Cost
- Physical size

Nano PLC

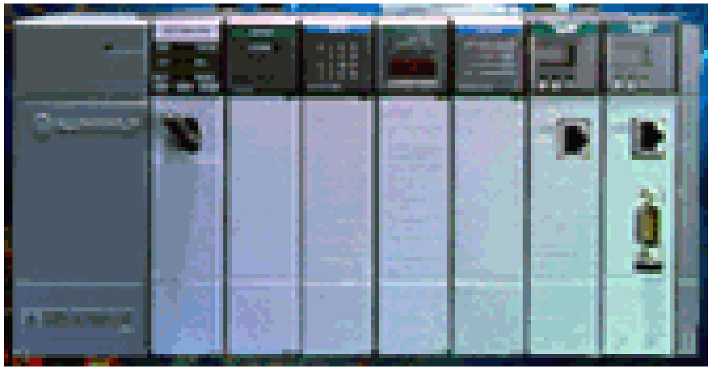
- Smallest sized PLC
- Handles up to 16 I/O points



Micro PLC

- Handles up to 32 I/O points

PLC Size Classification

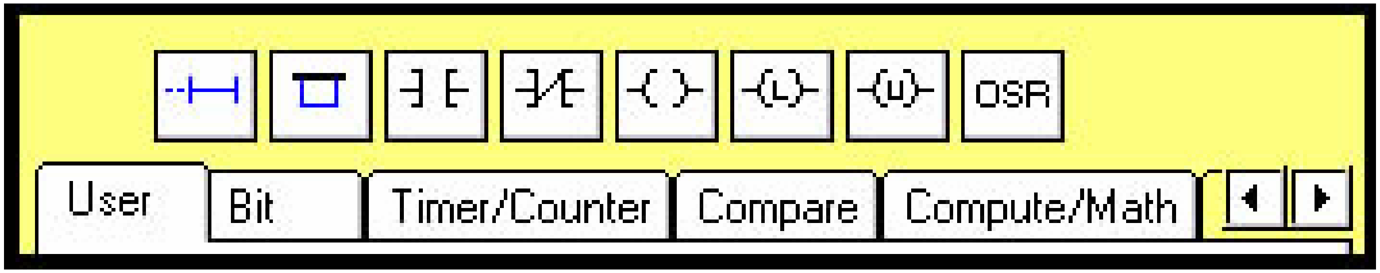


Allen-Bradley SLC-500 Family
- Handles up to 960 I/O points

Allen-Bradley PLC-5 Family
- Handles several thousand I/O points

PLC Instruction Set

The instruction set for a particular PLC type lists the different types of instructions supported.



An instruction is a command that will cause a PLC to perform a certain predetermined operation.

Typical PLC Instructions

XIC (Examine ON) . . . . Examine a bit for an ON condition
XIO (Examine OFF) . . . . Examine a bit for an OFF condition
OTE (Output Energize) . . . . Turn ON a bit (non retentive)
OTL (Output Latch) . . . . Latch a bit (retentive)
OTU (Output Unlatch) . . . . Unlatch a bit (retentive)
TOF (Timer Off-Delay) . . . . . Turn an output ON or OFF after its rung has been OFF a preset time interval
TON (Timer On-Delay) . . . . Turn an output ON or OFF after its rung has been ON for a preset time interval
CTD (Count Down) . . . . Use a software counter to count down from a specified value
CTU (Count Up) . . . . Use a software counter to count up to a specified value