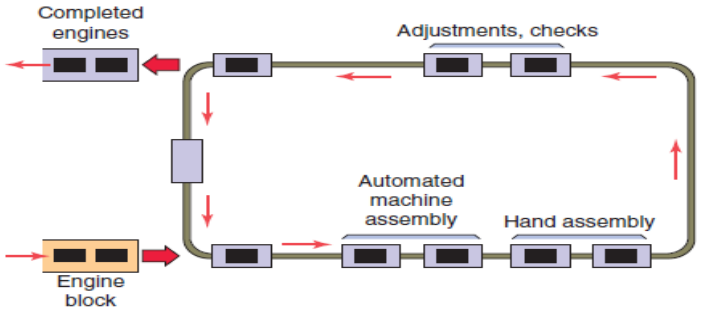
➢Chapter 14
Process Control, Network Systems, and SCADA

❑Types of Processes

✓Typical applications of process control systems include automobile assembly, petrochemical production, oil refining, power generation, and food processing

✓A *continuous process is one in which raw materials* enter one end of the system and the finished product comes out the other end of the system; the process itself runs continuously.

✓Figure shows a continuous process used in an automotive engine assembly line.



✓Parts are mounted sequentially, in an assembly-line fashion, through a Series of stations.

✓Assembly and adjustments are carried out by both automated machine and manual operations.

❑Types of Processes

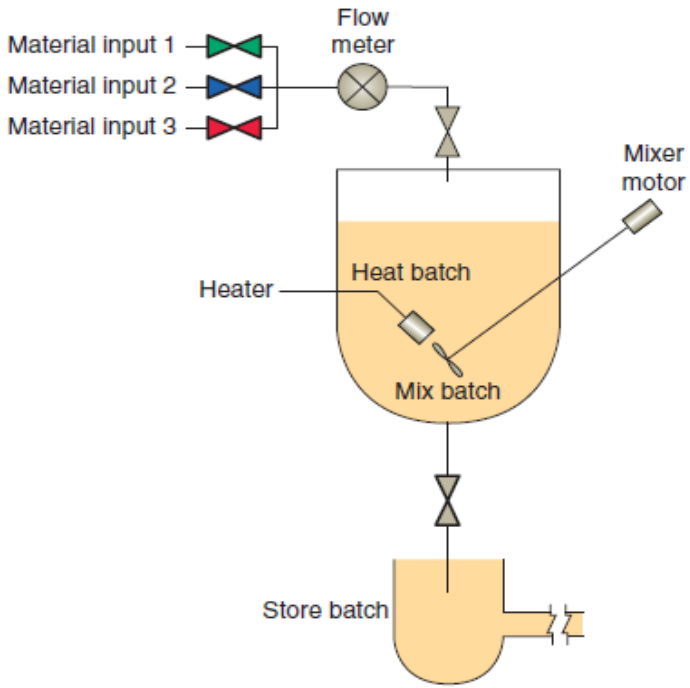
✓In *batch processing, there is no flow of product material* from one section of the process to another. Instead, a set amount of each of the inputs to the process is received in a batch, and then some operation is performed on the batch to produce a product.

✓Products produced using the batch process include food, beverages, pharmaceutical products, paint, and fertilizer.

✓Figure shows an example of a batch process

✓Three ingredients are mixed together, heated, and then stored.

✓Recipes are the key to producing batches as each batch may have different characterist by design..



❑Types of Processes

✓*Discrete manufacturing is characterized by individual* or separate unit production.

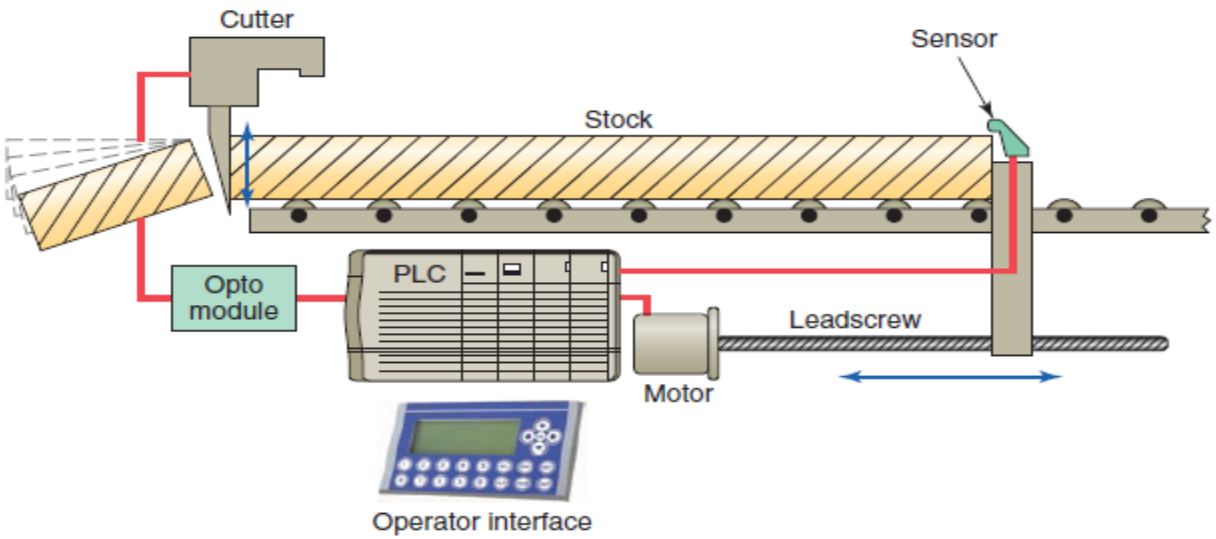
✓With this manufacturing process, a series of operations produces a useful output product.

✓Discrete manufacturing systems typically deal with digital inputs to PLCs that cause motors and robotic devices to be activated.

✓The work piece is normally a discrete part that must be handled on an individual basis. Making car interiors, as illustrated in Figure , is one example of discrete manufacturing.

❑Types of Processes

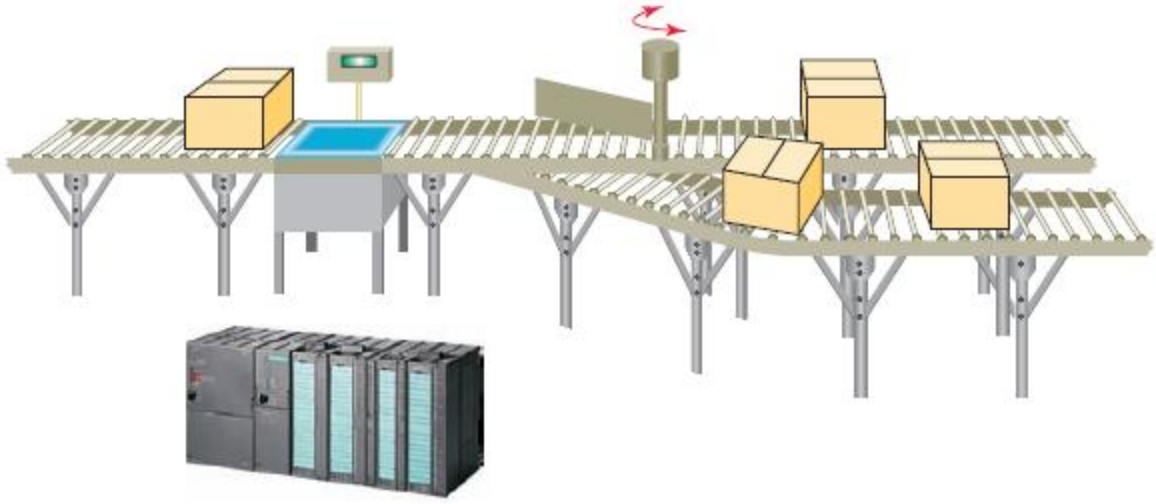
- Possible control configurations include individual, centralized, and distributed.
- *Individual control is used to* control a single machine.
- This type of control does not normally require communication with other controllers.
- The operator enters the feed length and batch count via the interface control panel and then presses the start button to initiate the process.
- Stock lengths vary so the operator needs to select the length and the number of pieces to be cut



❑Types of Processes

➢*Centralized control is used when several machines* or processes are controlled by one central controller.

➢The control layout uses a single, large control system to control many diverse manufacturing processes and operations, as illustrated in Figure

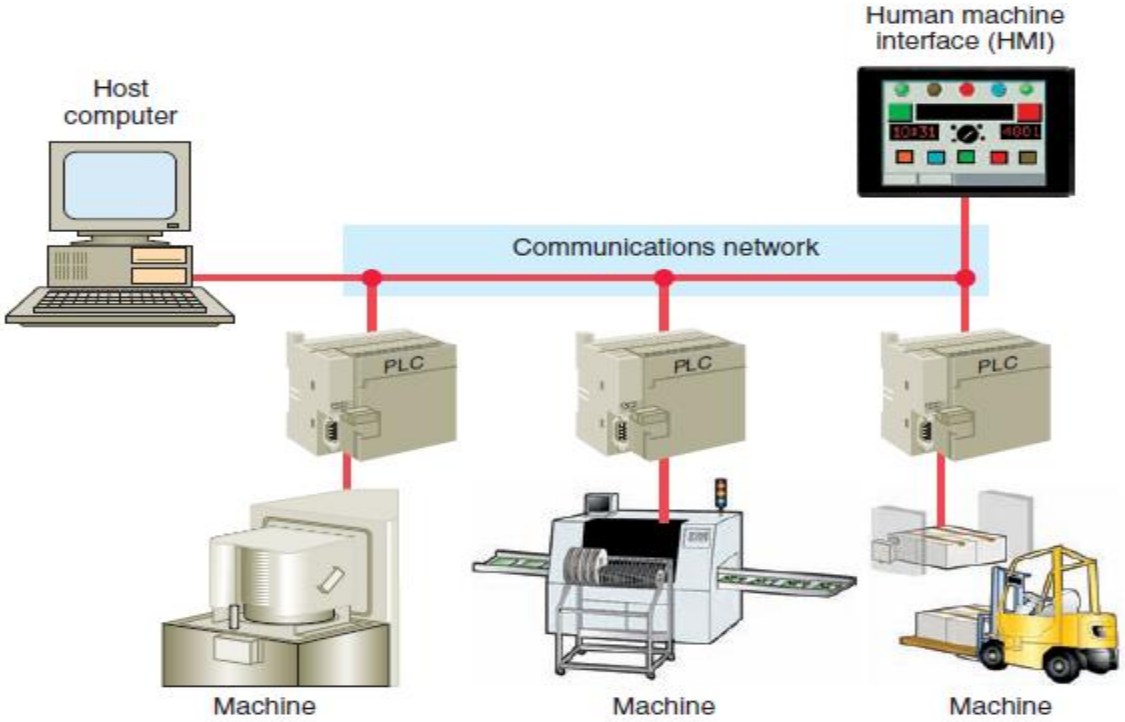


❑Types of Processes

➢*distributive control system (DCS) is a network-based* system.

➢Distributive control involves two or more PLCs communicating with each other to accomplish the complete control task, as illustrated in Figure .

➢Each PLC controls different processes locally and the PLCs are constantly exchanging information through the communications link and reporting on the status of the process.



❑Types of Processes

The main features of a distributive control system can be summarized as follows:

- Distributive control permits the distribution of the processing tasks among several controllers.
- Each PLC controls its associated machine or process.
- High-speed communication among the computers is done through CAT-5 or CAT-6 twisted pair wires, single coaxial cables, fiber optics, or the Ethernet.
- Distributive control drastically reduces field wiring and heightens performance because it places the controller and I/O close to the machine process being controlled.
- Depending on the process, one PLC failure would not necessarily halt the complete process.
- DCS is supervised by a host computer that may perform monitoring/supervising functions such as report generation and storage of data.

❑Structure of Control Systems

The major components of a process control system include the following:

➢**Sensors**

• Provide inputs from the process and from the external environment

• Convert physical information such as pressure, temperature, flow rate, and position into electrical signals

➢**Human Machine Interface (HMI)**

• Allows human inputs through various types of programmed switches, controls, and keypads to set up the starting conditions or alter the control of a process

❑Structure of Control Systems

The major components of a process control system include the following:

➢**Signal Conditioning**

• Involves converting input and output signals to a usable form

• May include signal-conditioning techniques such as amplification, attenuation, filtering, scaling, A/D and D/A converters

➢**Actuators**

• Convert system output electrical signals into physical action

• Process actuators that include flow control valves, pumps, positioning drives, variable speed drives, clutches, brakes, solenoids, stepping motors, and power relays

❑Structure of Control Systems

The major components of a process control system include the following:

➢**Controller**

- Makes the system's decisions based on the input signals
- Generates output signals that operate actuators to carry out the decisions

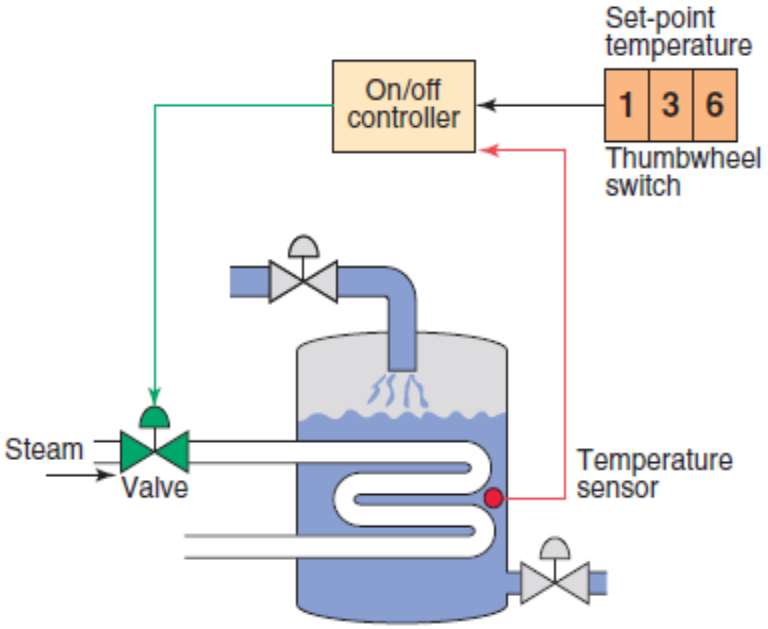
❑On/Off Control

✓With *on/off controllers the final control element is either* on or off—one for the occasion when the value of the measured variable is above the set-point and the other for the occasion when the value is below the set-point.

✓The controller will never keep the final control element in an intermediate position.

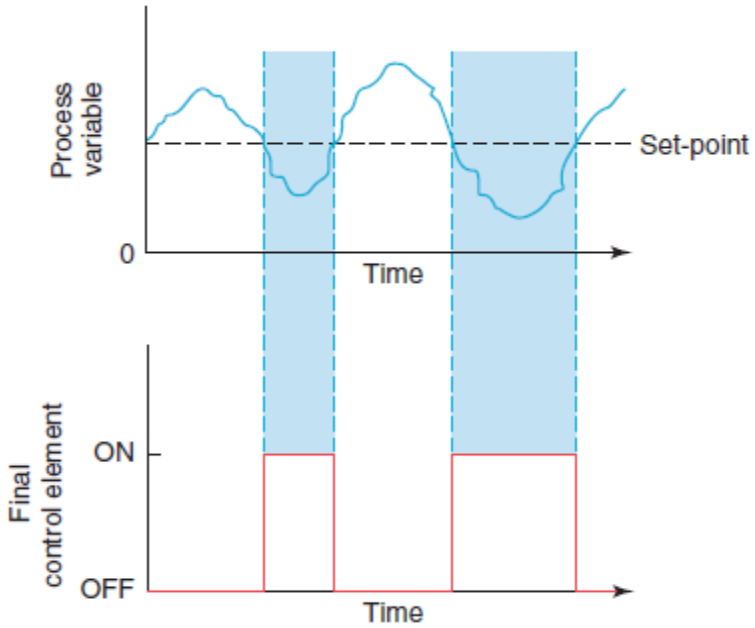
✓Controlling activity is achieved by the period of on-off cycling action

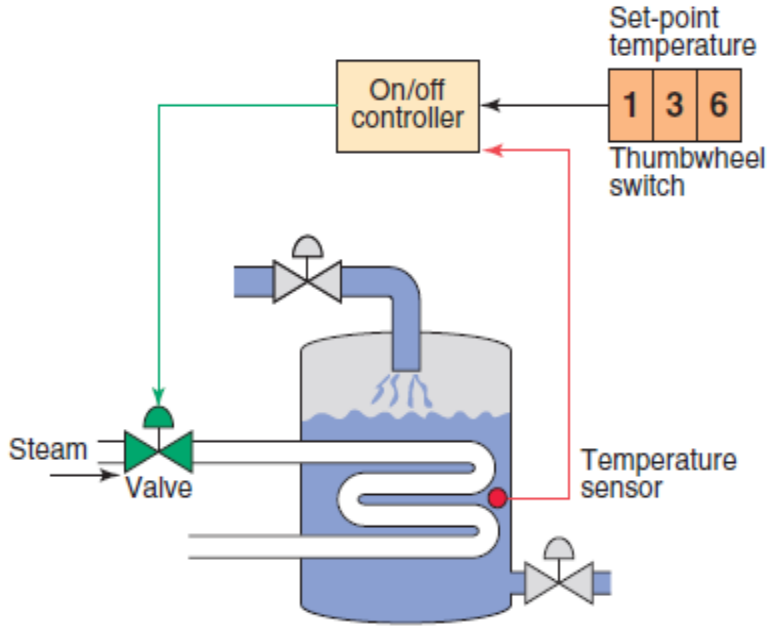
✓Figure shows a system using on/off control in which a liquid is heated by steam



❑On/Off Control

- If the liquid temperature goes below the set-point, the steam valve opens and the steam is turned on.
- When the liquid temperature goes above the set-point, the steam valve closes and the steam is shut off.
- The on/off cycle will continue as long as the system is operating.





❑PID Control

✓*Proportional controllers are designed to eliminate the* hunting or cycling associated with on/off control.

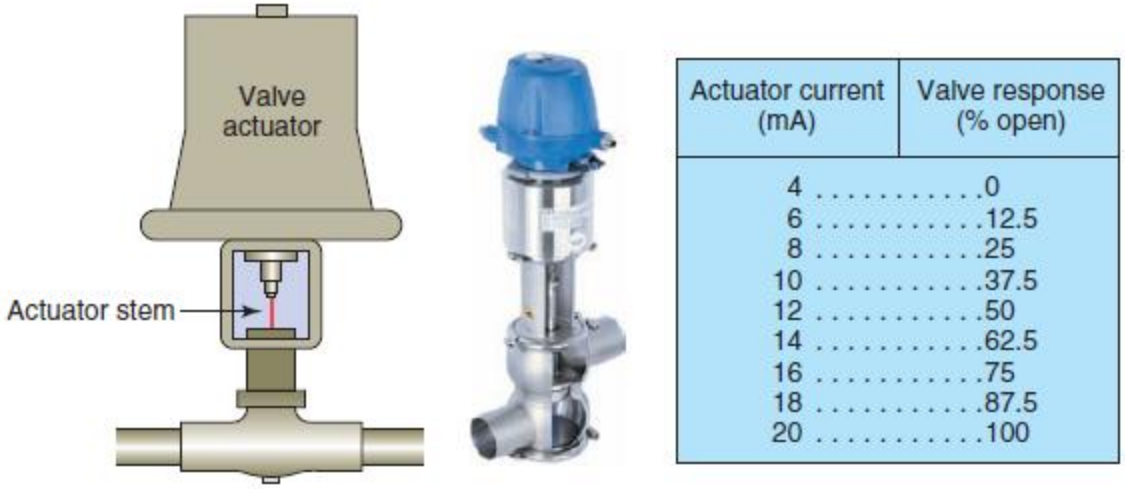
✓They allow the final control element to take intermediate positions between on and off.

✓Proportioning action permits *analoge control of the final control element to vary the* amount of energy to the process, depending on how much the value of the measured variable has shifted from the desired value.

✓A proportional controller allows tighter control of the process variable because its output can take on any value between fully on and fully off, depending on the magnitude of the error signal.

❑PID Control

✓Figure shows an example of a motor-driven analog proportional control valve used as a final control element



Actuator current (mA)	Valve response (% open)
4	0
6	12.5
8	25
10	37.5
12	50
14	62.5
16	75
18	87.5
20	100

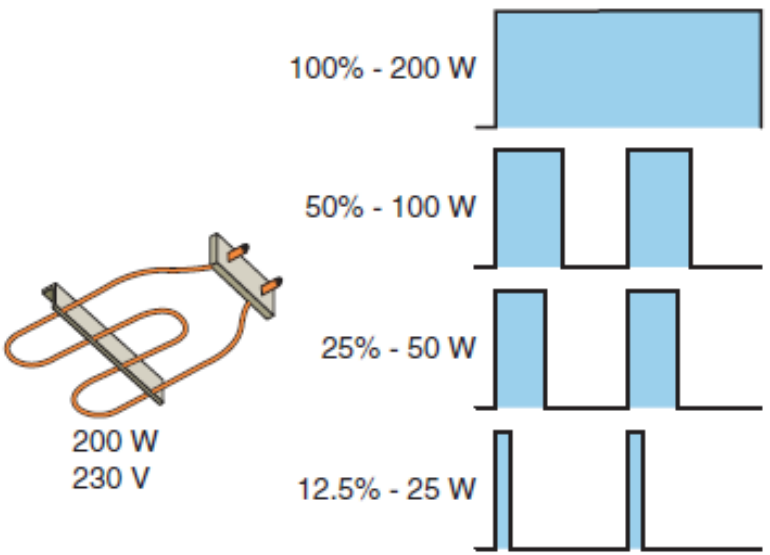
❑PID Control

✓Proportioning action can also be accomplished by turning the final control element on and off for short intervals.

✓This *time proportioning (also known as pulse width modulation*) varies the ratio of on time to off.

✓Figure shows an example of time proportioning used to produce varying wattage from a 200 watt heater element as follows:

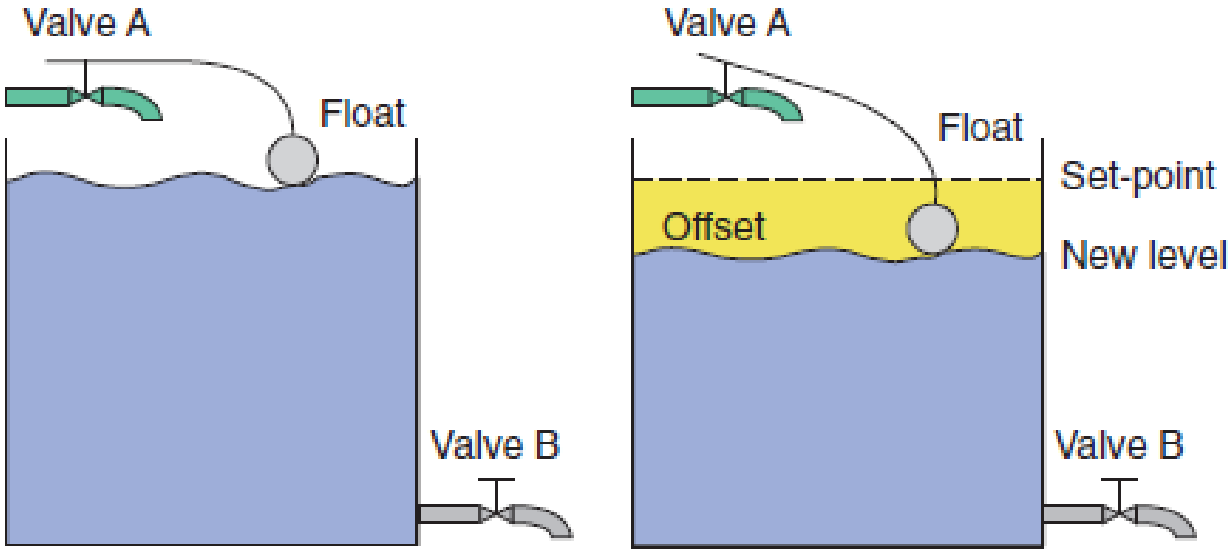
- To produce 100 watts the heater must be on 50% of the time.
- To produce 50 watts the heater must be on 25% of the time.
- To produce 25 watts the heater must be on 12.5% of the time.



❑PID Control

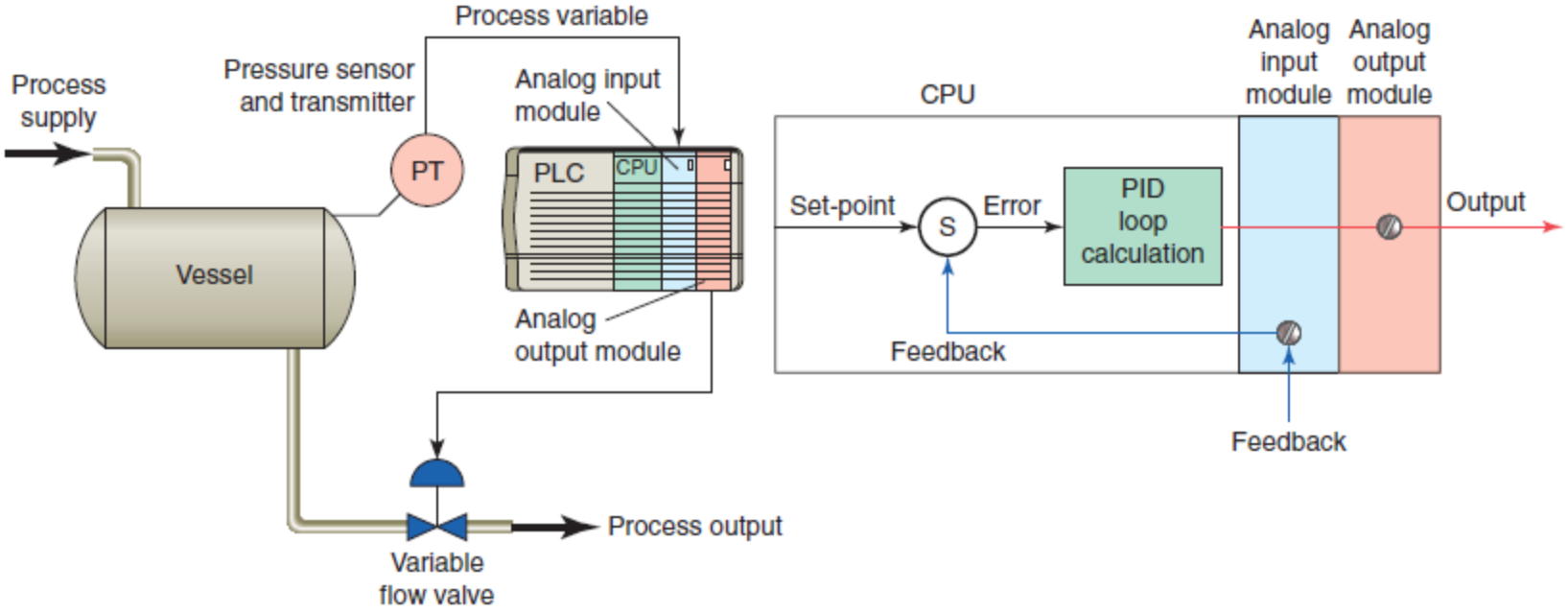
✓The process of Figure illustrates what effect a proportional control steady-state error might have on a tank-filling operation.

✓It may require an operator to make a small adjustment (manual reset) to bring the controlled variable to the set-point on initial start-up, or whenever.



❑PID Control

✓Figure illustrates how a programmable logic controller can be used in the control of a PID loop



❑Motion Control

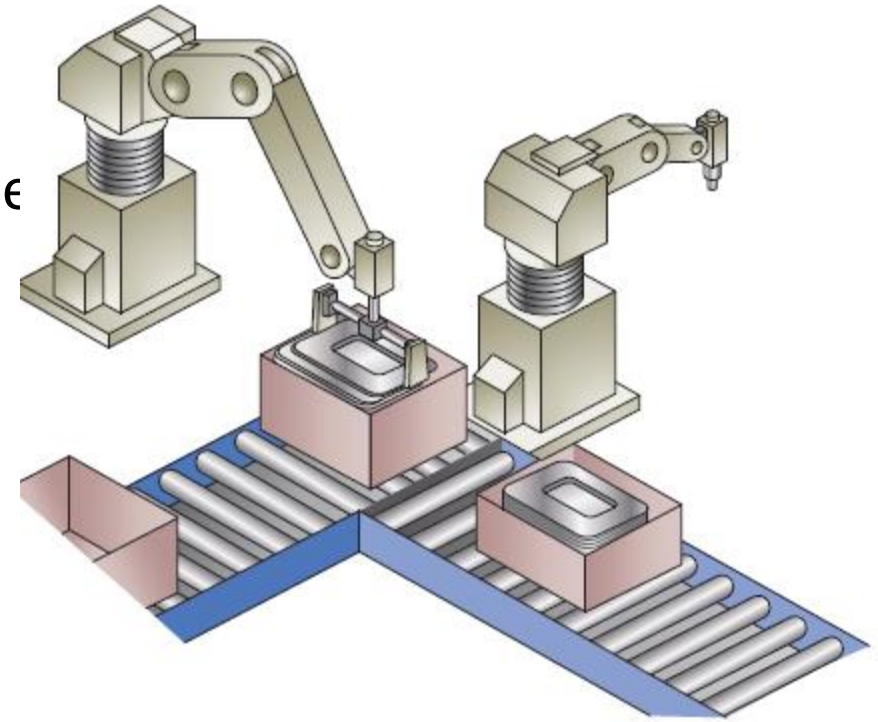
✓A motion control system provides precise positioning, velocity, and torque control for a wide range of motion applications

✓PLCs are ideally suited for both linear and rotary motion control applications.

✓*Pick and Place machines* are used in the consumer products industry for awide variety of product transfer applications.

✓The machine takes a product from one point to another.

✓One example is the transfer of a product to a moving conveyor belt as illustrated in Figure .

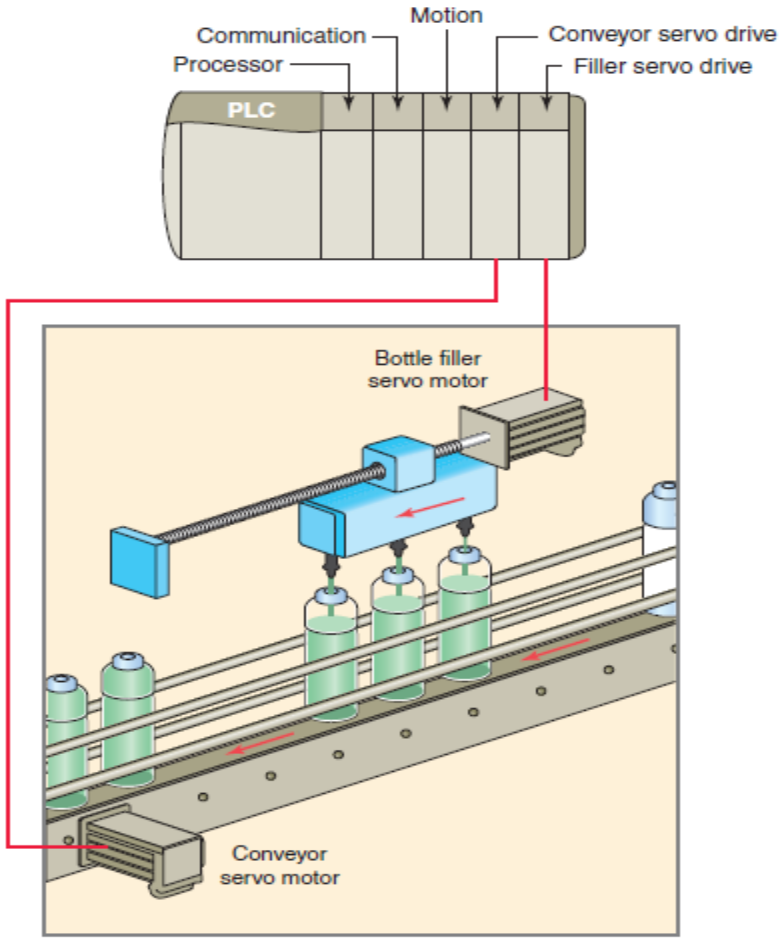


❑Motion Control

✓A basic PLC motion control system consists of a controller, a motion module, a servo drive, one or more motors with encoders, and the machinery being controlled.

✓Each motor controlled in the system is referred to as an axis of motion.

✓Figure illustrates a bottle-filling motion control process.



❑Motion Control

Programmable Logic Controller

- The controller stores and executes the user program that controls the process.
- This program includes motion instructions that control axis movements.
- When the controller encounters a motion instruction it calculates the motion commands for the axis.
- A motion command represents the desired position, velocity, or torque of the servo motor at the particular time the calculations take place.

❑Motion Control

Motion Module

- The motion module receives motion commands from the controller and transforms them into a compatible form the servo drive can understand.
- In addition it updates the controller with motor and drive information used to monitor drive and motor performance.

❑Motion Control

Servo Drive

• The servo drive receives the signal provided by the motion module and translates this signal into motor drive commands.

• These commands can include motor position, velocity, and/or torque.

• The servo drive provides power to the servo motors in response to the motion commands.

• Motor power is supplied and controlled by the servo drive.

• The servo drive monitors the motor's position and velocity by use of an encoder mounted on the motor shaft. This feedback information is used within the servo drive to ensure accurate motor motion.

❑Motion Control

Servo Motor

• The servo motors represent the axis being controlled.

• The servo motors receive electrical power from their servo drive which determines the motor shaft velocity and position.

• The fi ller motor must accelerate the filler mechanism in the direction the bottles are moving, match their speed, and track the bottles.

• After the bottles have been filled, the filler motor has to stop and reverse direction to return the filler mechanism to the starting position to begin the process again.

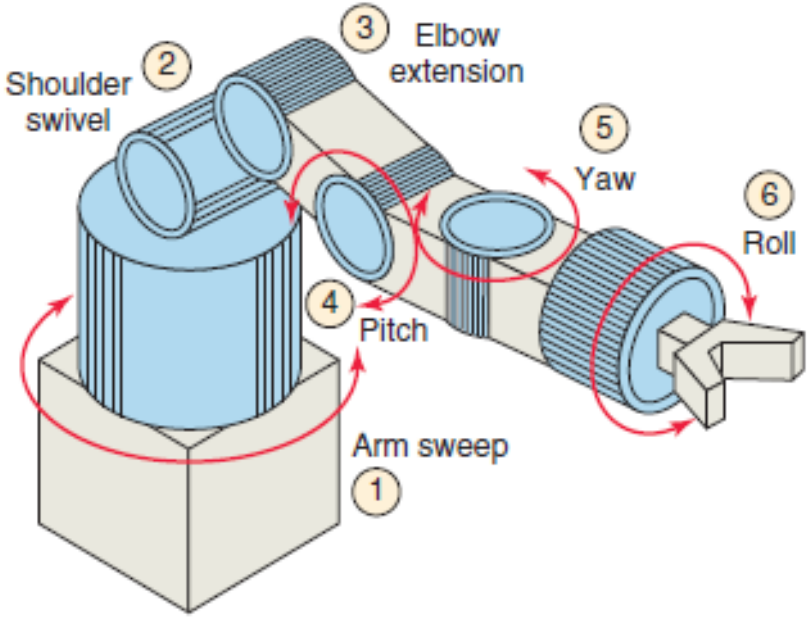
❑Motion Control

✓A robot is simply a series of mechanical links driven by servo motors.

✓The basic industrial robot widely used today is an *arm or manipulator that moves to perform industrial* operations.

✓Figure illustrates the motion of a six-axis robot arm.

✓Each axis of the robot arm is fundamentally a closed-loop servo control system

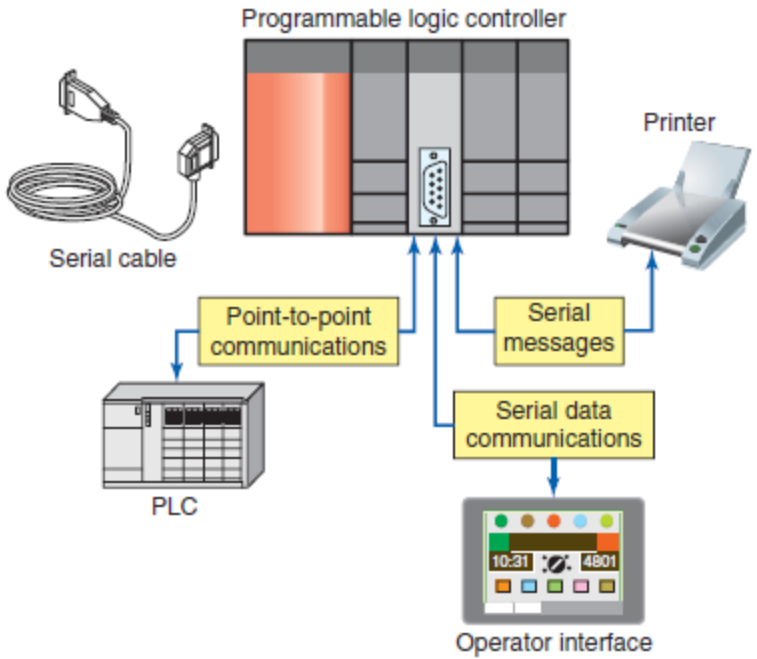


❑Data Communications

➢*Data communications refers to the different ways that* PLC microprocessor-based systems talk to each other and to other devices.

➢The two general types of communications links that can be established between the PLC and other devices are point-to-point links and network links.

➢Figure illustrates a *point-to-point serial communications* link.



❑Data Communications

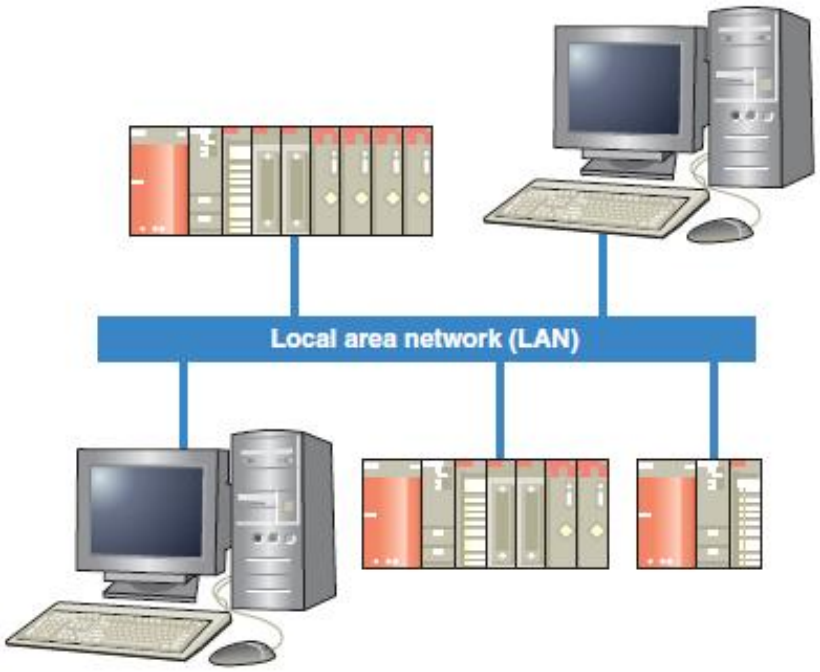
- Serial communications interfaces are either built into the processor module or come as separate modules.
- A serial module installed in each controller is normally all that is required for two PLCs of the same manufacturer to establish a point-to-point link.

❑Data Communications

✓As control systems become more complex, they require more effective communications schemes between the system components.

A *local area network or LAN is* a system that interconnects data communications components within a limited geographical area, typically no more than one or two miles.

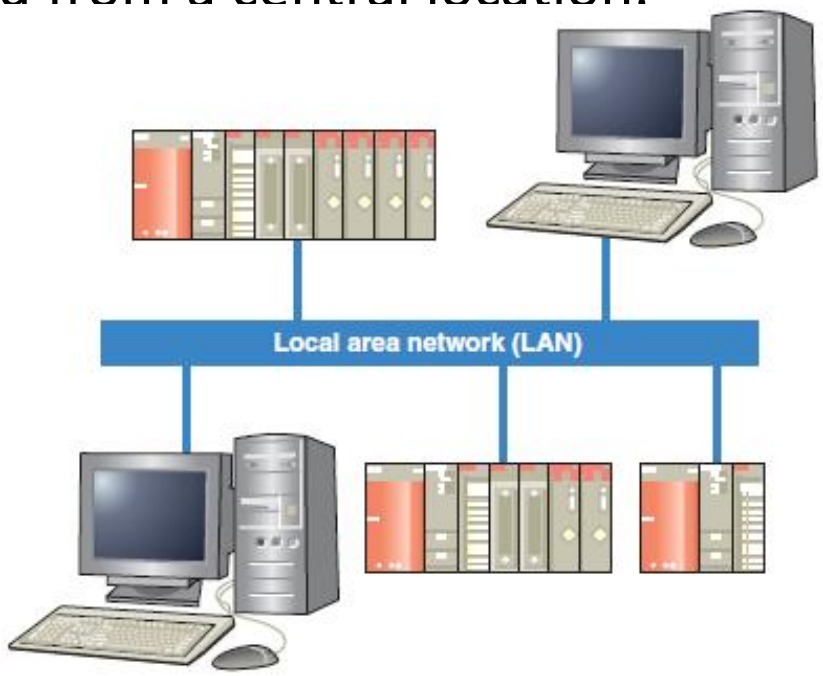
➢Figure illustrates a LAN communication



❑Data Communications

Network communications supports communication among multiple PLCs and other devices. PLC networks allow:

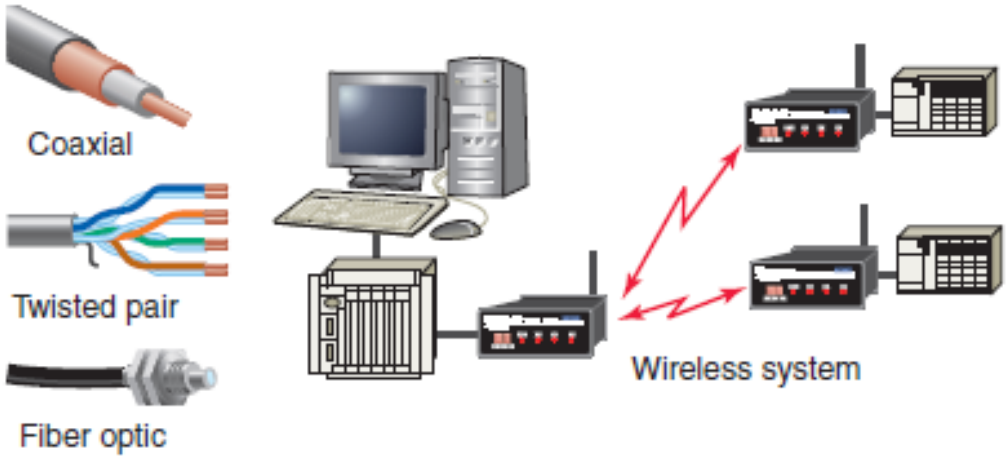
- Sharing of information such as the current state of status bits among PLCs that may determine the action of one another.
- Monitoring of information from a central location.
- Programs to be uploaded or downloaded from a central location.
- Several PLCs to operate in unison to accomplish a common goal.



❑Data Communications

✓*Transmission media are the cable through which data* and control signals flow on a network.

✓The transmission media used in data communications systems include coaxial cable, twisted pair, or fiber optics.

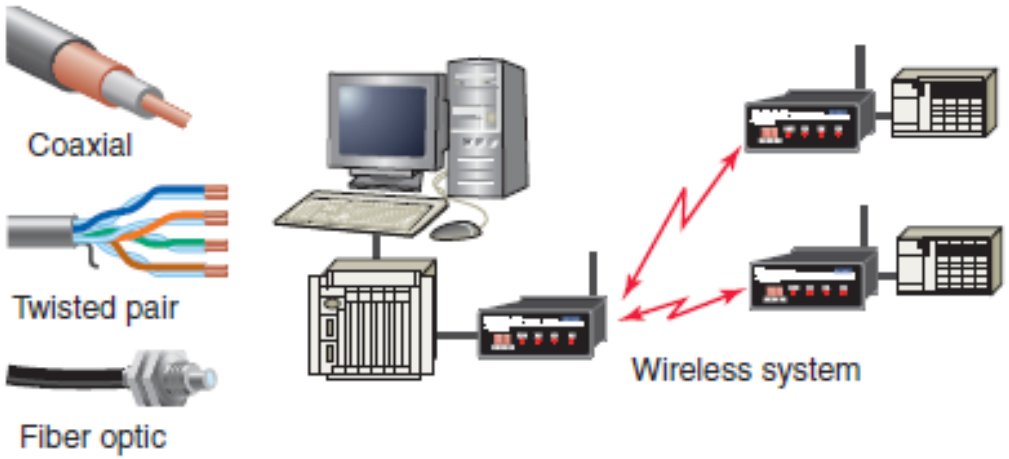


❑Data Communications

✓Each cable has different electrical capabilities and may be more or less suitable to a specific environment or network type.

✓Not all networks transmit information through cable.

✓ Wireless Wi-Fi Ethernet networks, such as the DF1 Radio Modem, communicate through radio waves, which are transmitted through the air.



❑Data Communications

✓In industrial applications, LANs have most often been used as the communication system for distributed control systems (DCS).

✓ Recall that a DCS system uses individual controllers to control the subsystems of a machine or process.

✓This approach contrasts with centralized control in which a single controller governs the entire operation.

✓A second major use of local area networks is that of supervisory control and data acquisition (SCADA).

✓A LAN allows data collection and processing for a group of controllers to be accomplished using one host computer as the central point for collecting data.

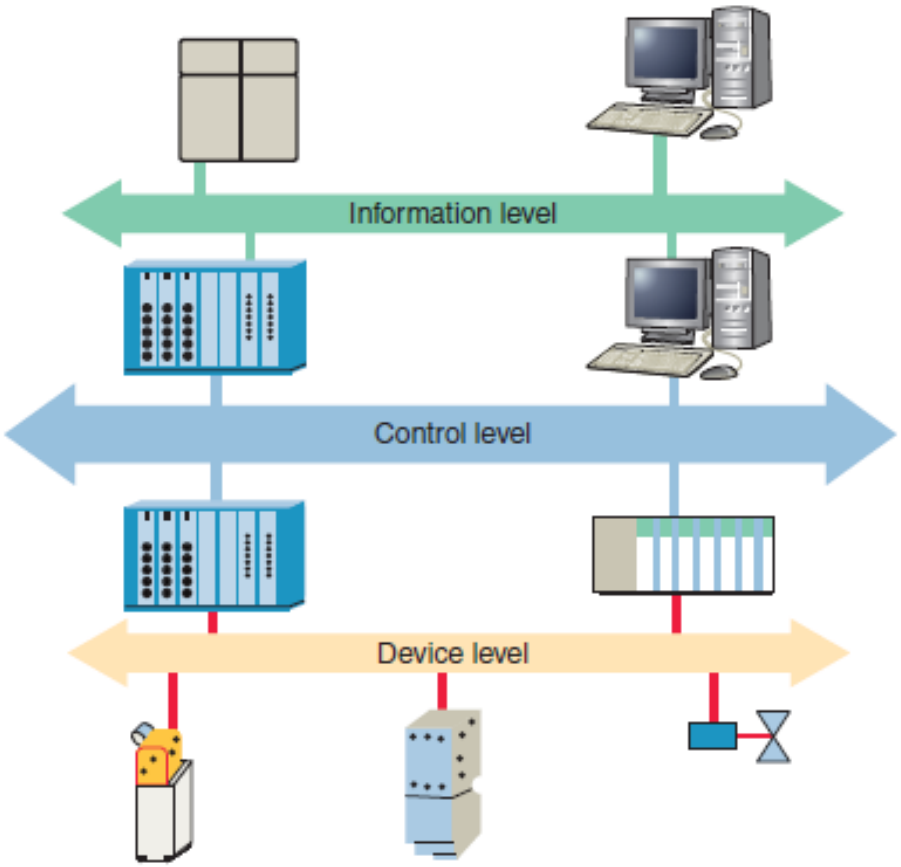
❑Data Communications

There are three general levels of functionality of industrial networks. Figure shows an illustration of the three levels, which can be summarized as follows:

Device Level.

Control Level

The information level



❑Data Communications

There are three general levels of functionality of industrial networks. Figure shows an illustration of the three levels, which can be summarized as follows:

Device Level —The device level involves various sensor and actuator devices of machines and processes. These may include devices such as sensors, switches, drives, motors, and valves.

Control Level —The control level would be the networks industrial controllers are on. This level may include controllers such as PLCs and robot controllers. Communications on the control level includes sharing I/O and program data between controllers.

Information Level —The information level is a plantwide network typically composed of the company's business networks and computers. This level may include scheduling, sales, management, and corporatewide information.

❑Data Communications

✓Each device connected on a network is known as a *node or station.*

✓*As signals travel along a network cable,* they degrade and become distorted in a process that is called attenuation.

✓If a cable is long enough, the attenuation will finally make a signal unrecognizable.

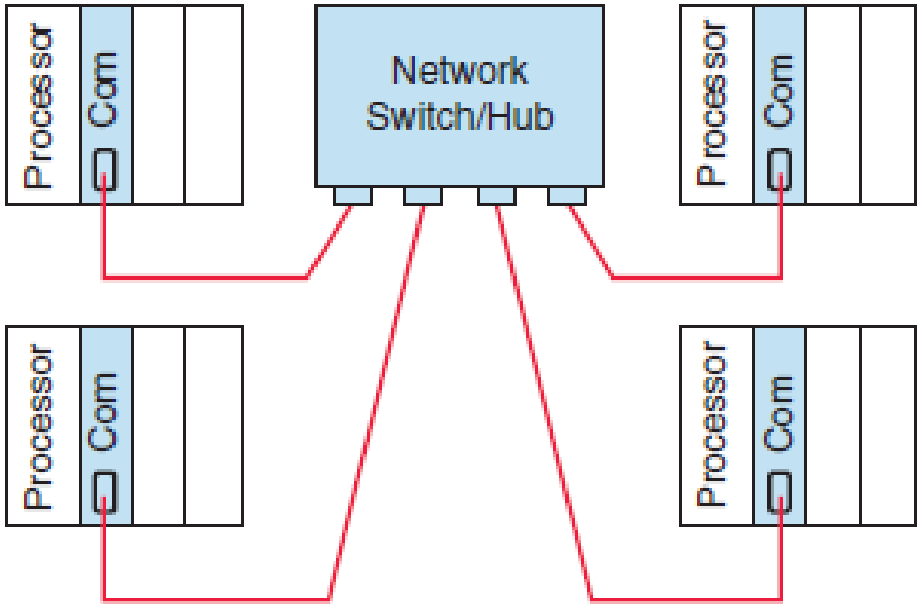
✓A *repeater* is a device that amplifies a signal to its original strength in order to enable its signals to travel further.

✓Different network types will have different specifications for cable length and type without a repeater

❑Data Communications

✓Network topology is the physical layout of devices on a network formed by the network cables when nodes are attached.

✓The *star topology illustrated in Figure*



❑Data Communications

its operation can be summarized as follows:

• A network controller switch or hub is connected to several PLC network nodes.

• Currently, most Ethernet networks use switches rather than hubs. A switch performs the same basic function as a hub but effectively increases the speed, size, and data handling capacity of the network.

• The configuration allows for bidirectional communication between switch/hub and each PLC.

• All transmission must be between the switch/hub and the PLCs because the network controller hub controls all communication.

• All transmissions must be sent to the switch/hub, which then sends them to the correct PLC.

❑Data Communications

its operation can be summarized as follows:

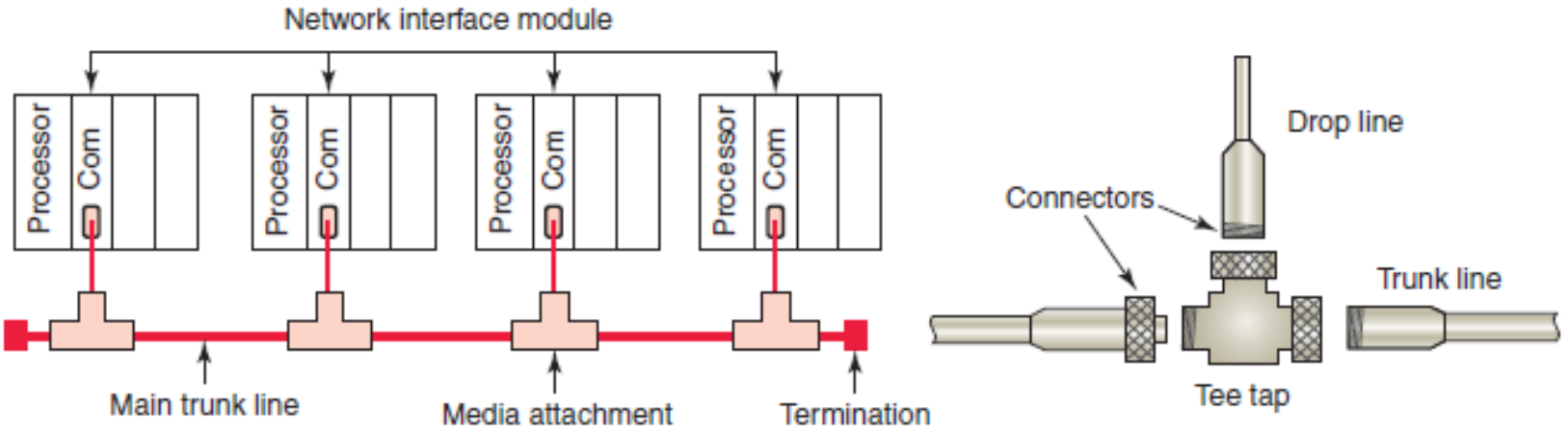
• One problem with the star topology is that if the switch/hub goes down, the entire LAN is down.

• This type of system works best when information is transmitted primarily between the main controller and remote PLCs. However, if most communication is to occur between PLCs, the operation speed is affected.

• Also, the star system can use substantial amounts of communication conductors to connect all remote PLCs to one central location.

❑Data Communications

Bus topology, illustrated in Figure , is a network configuration in which all stations are connected in parallel with the communication medium and all stations receive information from every other station on the network.



❑Data Communications

The operation of a bus topology network can be summarized as follows:

• Uses a single bus trunk cable to which individual PLC nodes are attached by a cable drop that taps off the main cable.

• Each PLC is interfaced to the bus using a network interface module that is attached using a drop cable or connector.

• Due to the nature of the bus technology, and the way the data are transmitted on the network, each end of the bus must be terminated with a terminating resistor.

• As the data move along the total bus, each PLC node is listening for its own node identification address and accepts only information sent to that address.

many nodes.

❑Data Communications

The operation of a bus topology network can be summarized as follows:

• Because of the simple linear layout, bus networks require less cable than all other topologies.

• No single station controls the network and stations can communicate freely to one another.

• Bus networks are very useful in distributive control systems, because each station or node has equal independent control capability and can exchange information at any given time.

• Another advantage of the bus network is that you can add or remove stations from the network with a minimum amount of system reconfiguration.

• This network's main disadvantage is that all the nodes rely on a common bus trunk line, and a break in that common line can affect many nodes.

❑Data Communications

✓I/O bus networks can be divided into two categories: device bus networks and process bus networks.

✓*Device bus networks interface with low-level information devices* such as pushbuttons and limit switches that primarily transmit data relating to the on/off state of the device and its operational status

✓Device bus networks can be further classified as bit-wide or byte-wide buses.

✓Device bus networks that include discrete devices as well as small analog devices are called *byte-wide bus networks.*

✓*These* networks can transfer 50 or more bytes of data at a time.

✓Device bus networks that interface only with discrete devices are called *bit-wide bus networks.*

✓*Bit-wide networks* transfer less than 8 bits of information to and from simple discrete devices.

❑Data Communications

✓*Process bus networks are capable of communicating* several hundred bytes of data per transmission.

✓The majority of devices used in process bus networks are analog, whereas most devices used in device bus networks are discrete.

✓Process bus networks connect with high-level information devices such as smart process valves and flowmeters, which are typically used in process control applications.

✓Process buses are slower because of their large data packet size.

✓ Most analog control devices are used in controlling such process variables as flow and temperature, which are typically slow to respond

❑Data Communications

✓A *protocol is a set of rules that two or more devices* must follow if they are to communicate with each other.

✓Protocols are to computers what language is to humans.

✓This book is in English, and to understand it, you must be able to read English.

✓ Similarly, for two devices on a network to successfully communicate, they must both understand the same protocols.

❑Data Communications

✓A network protocol defines how data is arranged and coded for transmission on a network.

✓In the past, communications networks were often proprietary systems designed to a specific vendor's standards; users were forced to buy all their control components from a single supplier.

✓This is because of the different communications protocols, command sequences, error-checking schemes, and communications media used by each manufacturer.

✓Today, the trend is toward open network systems based on international standards developed through industry associations

❑Data Communications

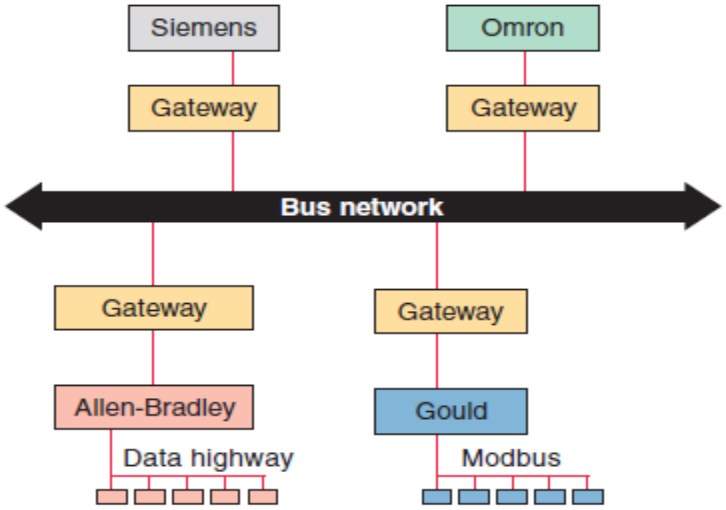
✓*Gateways make communication possible* between different architectures and protocols.

✓They repackage and convert data going from one network to another network so that the one can understand the other's application data.

✓Gateways can change the format of a message so that it will conform to the application program at the receiving end of the transfer.

✓If network access translation is their only function, the interfaces are known as *bridges.*

✓*If the interface also adjusts data* formats or performs data transmission control, then it is called a *gateway.*



❑Data Communications

✓Although many access methods exist, the most common are token passing, collision detection, and polling

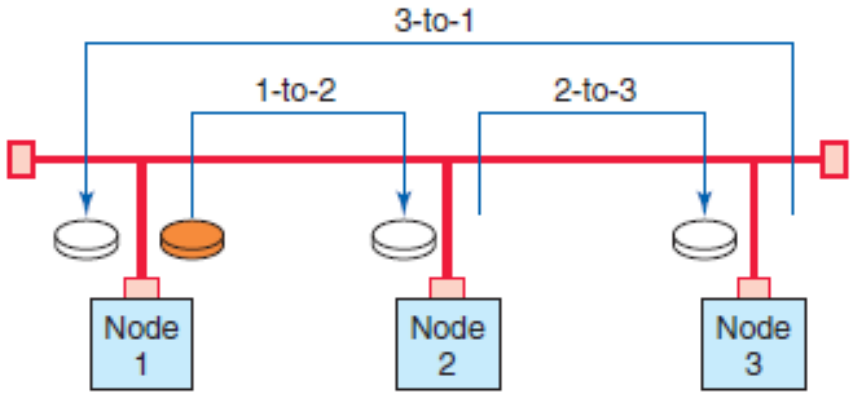
✓In a *token passing network, a node can transmit data* on the network only when it has possession of a token.

✓A token is simply a small packet that is passed from node to node as illustrated in Figure .

✓When a node finishes transmitting messages, it sends a special message to the next node in the sequence, granting it the token.

✓The token passes sequentially from node to node, allowing each an opportunity to transmit without interference.

✓Tokens usually have a time limit to prevent a single node from tying up the token for a long period of time



❑Data Communications

✓Ethernet networks use a *collision detection access* control scheme.

✓With this access method, nodes listen for activity on the network and transmit only if there are no other messages on the network.

✓On Ethernet networks there is the possibility that nodes will transmit data at the same time.

✓When this happens a collision is detected.

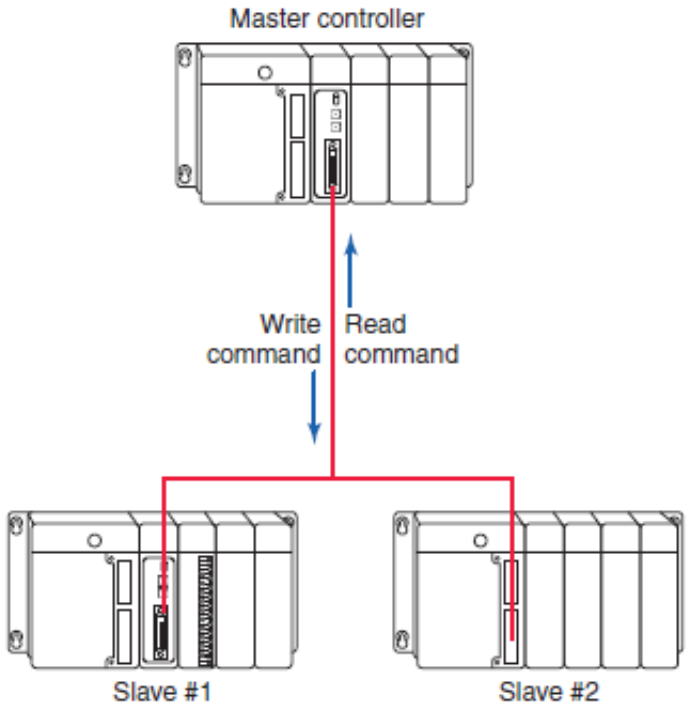
✓Each node that had sent out a message will wait a random amount of time and will resend its data if it does not detect any network activity.

❑Data Communications

✓The access method most often used in master/slave protocols is *polling.*

✓*The master/slave network is one in* which a master controller controls all communications originating from other controllers.

✓This configuration is illustrated in Figure and consists of several slave controllers and one master controller.



❑Data Communications

✓Its operation can be summarized as follows:

• The master controller sends data to the slave controllers.

• When the master needs data from a slave, it will *poll (address) the slave and wait for a response.*

• No communication takes place without the master initiating it.

• Direct communication among slave devices is not possible.

• Information to be transferred between slaves must be sent first to the network master unit, which will, in turn, retransmit the message to the designated slave device.

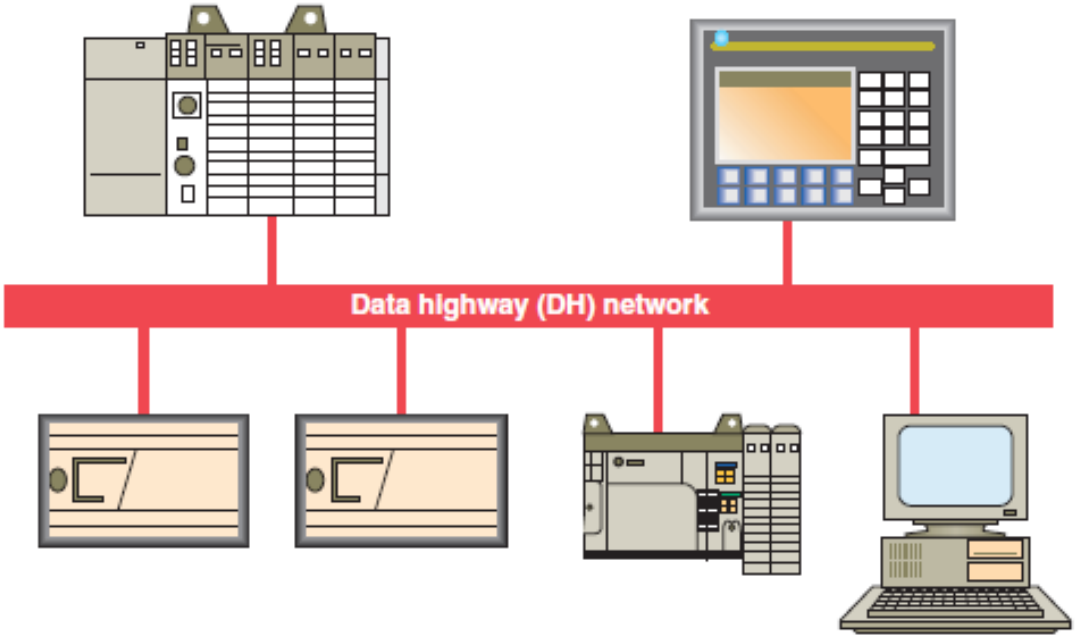
• Master/slave networks use two pairs of conductors.

• One pair of wires is used for the master to transmit data and the slave to receive them. On the other pair, the slaves transmit and the master receives

❑Data Communications

✓A peer-to-peer network has a distributive means of control, as opposed to a master/slave network in which one node controls all communications originating from other nodes.

✓The Allen-Bradley Data Highway, shown in Figure , is an example of a peer-to-peer network of programmable controllers and computers linked together to form a data communication system.



❑Data Communications

The operation of the network can be summarized as follows:

- Peer-to-peer networks use the token passing media access method.
- Each device has the ability to request use of, and then take control of, the network for the purpose of transmitting information to or requesting information from other network devices.
- Each device is identified by an address.
- When the network is operating, the token passes from one device to the next sequentially.
- The device that is transmitting the token also knows the address of the next station that will receive the token.
- Each device receives the packet information and uses it, if needed.
- Any additional information that the node has will be sent in a new packet

❑Data Communications

✓There are two methods of transmitting PLC digital data: parallel and serial transmission.

✓In *parallel data* transmission, all bits of the binary data are transmitted simultaneously, as illustrated in Figure .

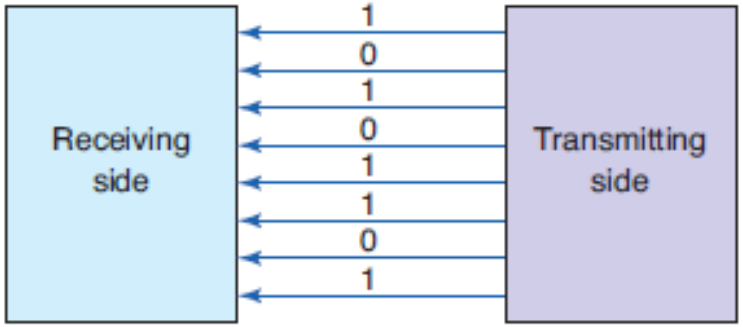
✓Parallel transmission of data can be summarized as follows:

• Eight transmission lines are required to transmit the 8-bit binary number.

• Each bit requires its own separate data path and all bits of a word are transmitted at the same time.

• Parallel data transmission is less common but faster than serial transmission.

• A common example of parallel data transmission is the connection between a computer and a printer



❑Data Communications

✓In *serial transmission one bit of the binary data is* transferred at a time, as illustrated in Figure .

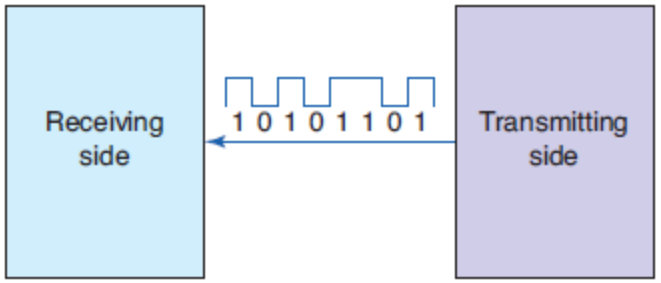
✓Serial transmission of data can be summarized as follows:

• In serial transmission, bits are sent sequentially on the same channel (wire) which reduces costs for wire but also slows the speed of transmission.

• Serial data can be transmitted effectively over much greater distances than can parallel data.

• Each data word in the serial transmission must be denoted with a known start bit sequence followed by the data bits that contain the intelligence of the data transmission and a stop bit.

• An extra bit, termed a *parity bit, may be used to* provide some error-detecting ability.



❑Data Communications

✓Following is an overview of some of the industrial communication technologies that play a critical role in today's control systems.

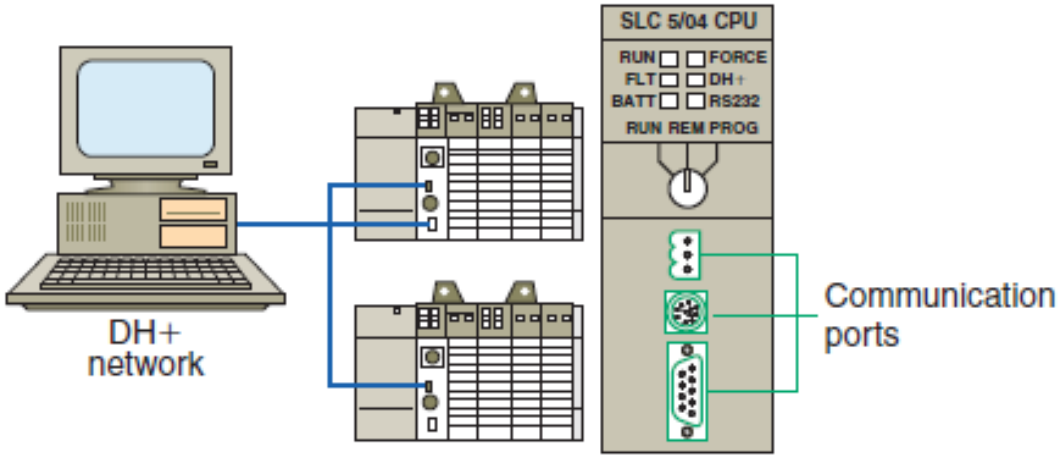
❖Data Highway

✓The Allen-Bradley Data Highway networks, Data Highway Plus (DH+) and DH-485, are proprietary communications networks.

✓ They use peer-to-peer communication implementing token passing.

✓The medium is shielded twisted pair cable.

✓Figure shows the DH+ network



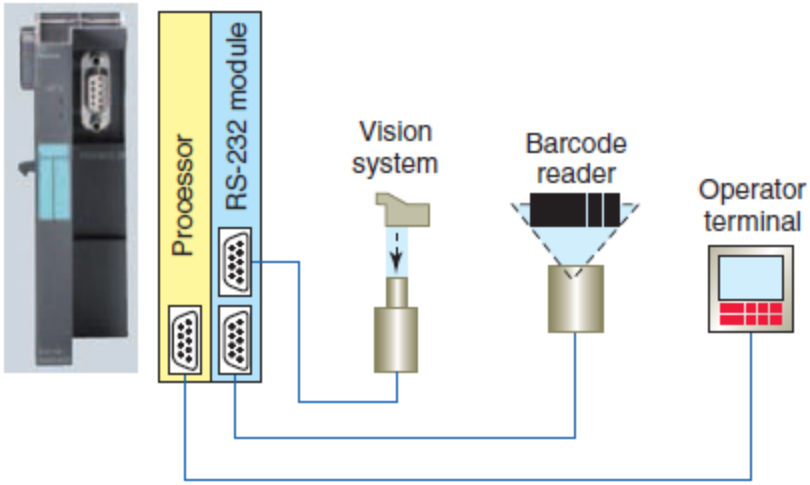
❑Data Communications

❖Serial Communication

✓Serial data communication is implemented using standards such as RS-232, RS-422, and RS-485.

✓The RS in the standard's name means *recommended standard that* specifies the electrical, mechanical, and functional characteristics for serial communications.

✓Serial communication interfaces are either built into the processor module or come as a separate communications interface module, as illustrated in Figure



❑Data Communications

❖Serial Communication

✓The simplest type of connection is the RS-232 serial port.

✓The RS interfaces are used to connect to devices such as vision systems, barcode readers, and operator terminals that must transfer quantities of data at a reasonably high rate between the remote device and the PLC.

✓The RS-232 type of serial transmission is designed to communicate between one computer and one controller and is usually limited to lengths up to 50 feet.

✓RS-422 and RS-485 serial transmission types are designed to communicate between one computer and multiple controllers, have a high level of noise immunity, and are usually limited to lengths of 650 feet (for RS-485) or 1650 feet (for RS-422).

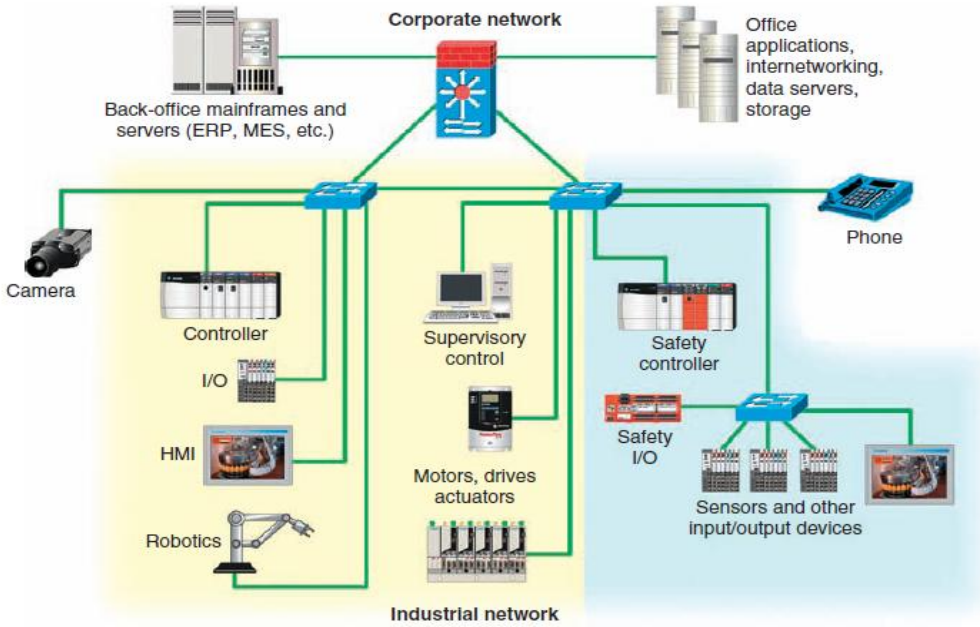
❑Data Communications

❖Serial Communication

❖EtherNet/IP

✓EtherNet/IP (Ethernet Industrial Protocol) is an open communications protocol based on the Common Industrial Protocol (CIP) layer

✓ It allows users to link information seamlessly between devices running the EtherNet/IP protocol without custom hardware, as illustrated in Figure .



❑Data Communications

❖Modbus

✓Modbus is a serial communication protocol originally developed by Modicon for use with its PLCs.

✓Basically, it is a method used for transmitting information over serial lines between electronic devices.

✓The device requesting the information is called the Modbus Master and the devices supplying information are Modbus Slaves.

✓ Modbus is an open protocol, meaning that it's free for manufacturers to build into their equipment without having to pay royalties.

✓It has become a standard communications protocol in industry, and is one of the most commonly available means of connecting industrial electronic devices

❑Data Communications

❖Modbus

Figure 14-44 shows an Omron PLC with Modbus-RTU network communication capabilities via RS-232C and RS-422/485 serial ports.

❑Data Communications

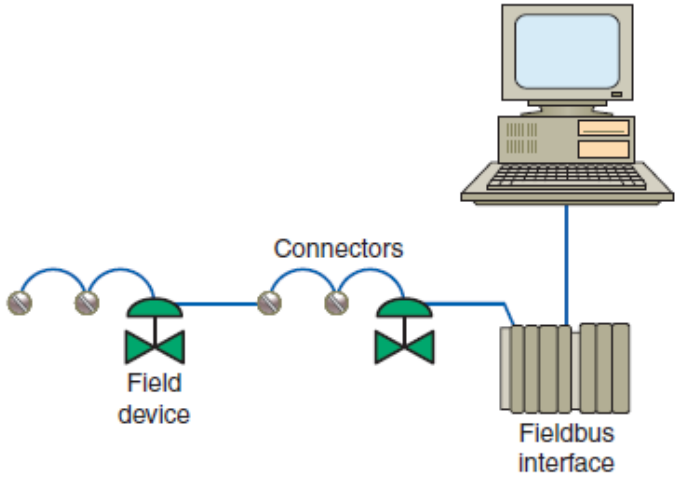
❖Fieldbus

✓Fieldbus is an open, serial, two-way communications system that interconnects measurement and control equipment such as sensors, actuators, and controllers.

✓ At the base level in the hierarchy of plant networks, it serves as a network for field devices used in process control applications.

✓There are several possible topologies for fieldbus networks.

✓Figure illustrates the *daisy-chain topology.*



❑Data Communications

❖Fieldbus

✓With this topology, the fieldbus cable is routed from device to device.

✓Installations using this topology require connectors or wiring practices such that disconnection of a single device is possible without disrupting the continuity of the whole segment.

❑Data Communications

❖PROFIBUS-DP

✓PROFIBUS-DP (where DP stands for Decentralized Periphery) is an open, international fieldbus communication standard that supports both analog and discrete signals.

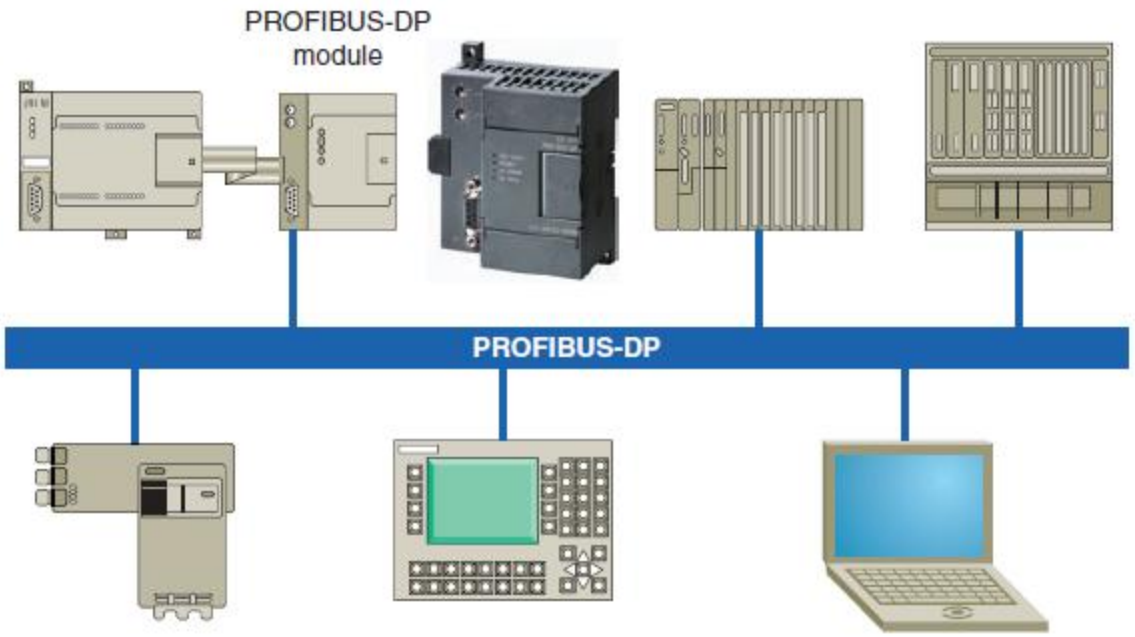
✓The physical media are defined via the RS-485 or fiber optic transmission technologies.

✓ PROFIBUS-DP communicates at speeds up to 12 Mbps over distances up to 1200 meters.

❑Data Communications

❖PROFIBUS-DP

✓Figure 14-46 illustrates a Siemens S7-200 Micro PLC system connection to a PROFIBUS-DP network.



❑Supervisory Control and Data Acquisition (SCADA)

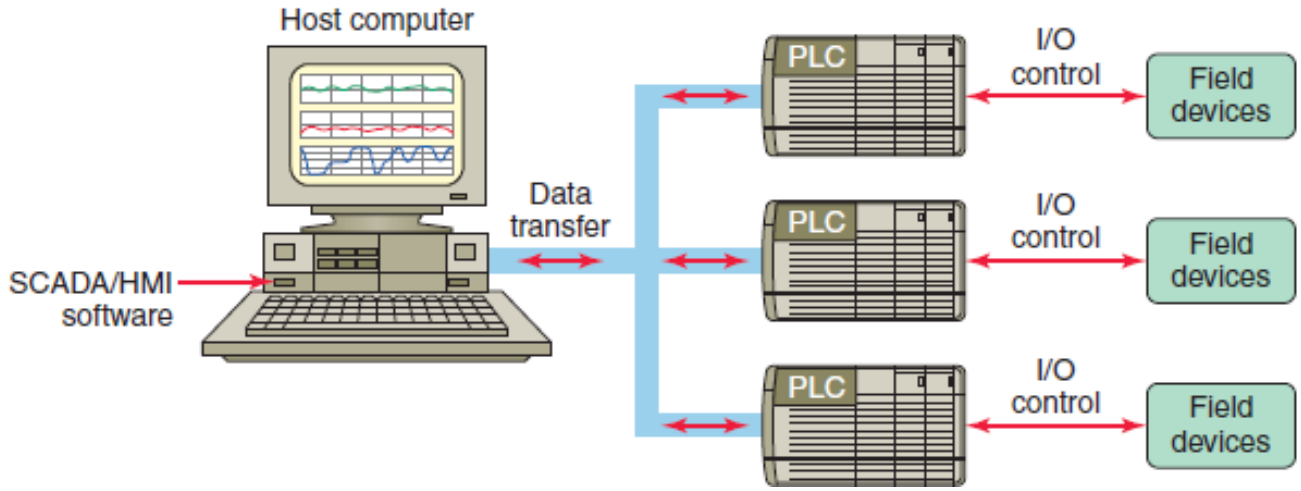
✓ Exchanging data from the plant floor to a supervisory computer allows data logging, data display, trending, downloading of recipes, setting of selected parameters, and availability of general production data.

✓The additional supervisory control output capabilities allow you to tweak your processes accurately for maximum efficiency.

✓In general, unlike distributive control systems, a SCADA system usually refers to a system that coordinates but does not control processes in real time .

❑Supervisory Control and Data Acquisition (SCADA)

✓ In a typical SCADA system, independent PLCs perform I/O control functions on field devices while being supervised by a SCADA/HMI software package running on a host computer, as illustrated in Figure



❑Supervisory Control and Data Acquisition (SCADA)

✓ Process control operators monitor PLC operation on the host computer and send control commands to the PLCs if required.

✓The great advantage of a SCADA system is that data are stored automatically in a form that can be retrieved for later analysis without error or additional work.

✓ Measurements are made under processor control and then displayed onscreen and stored to a hardcopy.

✓Accurate measurements are easy to obtain, and there are no mechanical limitations to measurement speed.