Final Control Elements

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FINAL CONTROL ELEMENTS

Lesson One

Final Control Elements in Process Loops

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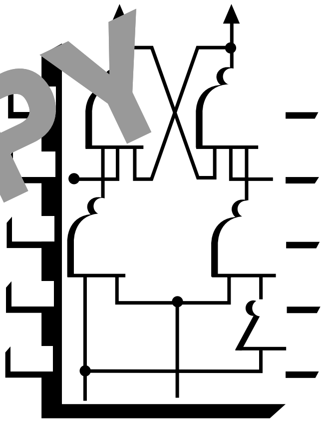

TPC Training Systems

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Lesson

1 Final Control Elements in Process Loops

TOPICS

What is a Final Control Element?
Compensation
Feedback Loops
A Typical System with Feedback
Effects of Disturbances on Performance
Parts of a Final Control Subsystem
Electrical Control Signals
Amplifiers
Digital Signals
Fluidic Control Signals

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OBJECTIVES

After studying this Lesson, you should be able to…

- Discuss the function of final control elements in process loops.
- Explain how an actuator is used with the final control element.
- Discuss the effect of a disturbance on the performance of a process loop.
- Describe the three parts of a final control element subsystem.
- Discuss the differences between electric and fluidic control signals in the operation of final control elements.

KEY TECHNICAL TERMS

Variable 1.01 a physical property that can be measured and controlled

Actuator 1.03 a device that receives information from a controller and causes action at the final control element

Disturbance 1.10 an uncontrolled variable that affects the output of the process; a system upset

Response time 1.13 the amount of time that a control system, loop, or device takes to react to a change

Process gain 1.13 the amount the measured variable changes in response to a change in the final control element

Analog 1.29 a kind of signal that is proportional to the variable

Digital 1.29 a kind of signal that controls by pulses related to logic low and high values

Transducer 1.36 a device that senses the value of a variable and converts that value to an output signal

Current gain (ß) 1.41 the ratio of output current to input current

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A process control system usually includes many subsystems. Each subsystem performs a specific task. One subsystem contains the controls that directly change the process for control of its output. This subsystem—the one containing the final control element—is the focus of this Unit.

This Lesson shows you how the subsystems fit together and how final control elements relate to the process control system. It introduces you to common final control elements you will study in detail in other Lessons in this Unit.

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What Is a Final Control Element?

1.01 The condition to be changed by a process—pressure, temperature, or flow rate, for example—is a variable. That is, a *variable* is a changeable process condition you can measure and control. Some variables are directly controlled by the process, others are by-products of the process, and still others are external forces that affect the process.

1.02 A variable can be described in one or more of three ways:

- A *directly controlled* variable originates a feedback signal.
- An *indirectly controlled* variable is affected by the directly controlled variable but does not enter the feedback loop.
- A *manipulated* variable is the quantity or condition that is varied to affect the value of the directly controlled variable.

The device or element that changes the value of the manipulated variable is the *final control element*. Valves and heaters are examples of common final control elements.

1.03 Suppose a valve is the final control element that regulates the flow of water. Someone or something must open and close the valve. You could position the valve yourself or you could use an *actuator* to position it. Many kinds of actuators operate devices in industrial processes—for example, motors, relays, and burners. Some are electric or electronic, some are pneumatic, and others are hydraulic. Because actuators and control valves are sometimes supplied as one assembly, the term *final control element* may mean just the device or it may refer to the device and its actuator.

Compensation

1.04 The block diagram in Fig. 1-1 on the following page shows how the subsystems in a typical process control system work together. Some control systems have fewer parts than the system shown. For example, an open-loop system has no feedback. Open-loop systems are adequate only in processes where the relationship between input and output need not be very precise. In this system, you regulate the system by manually adjusting the final control element or the setpoint. This kind of adjustment is sometimes called *compensation*.

1.05 *Load compensation* is the manual adjustment of final elements that is done to compensate for changes in the output variable. You must calculate the amount of adjustment needed to offset load changes and manually reset the output. In some systems, a computer in the load-compensation subsystem calculates the compensation needed for control under varying load conditions. However, the adjustment is still manual.

1.06 *Setpoint compensation* is manual adjustment of the setpoint to make the relationship between the input and the output more linear. In some systems, the relationship between setpoint and output is nonlinear. That is, a small change in the setpoint may affect the process output greatly at one setting and very little at another setting. Setpoint compensation is often desirable in these cases.

Feedback Loops

1.07 Figure 1-2 on the following page shows how a final control element—in this case, a valve—is affected by a control system without feedback in an open loop and with feedback in a closed loop. In both cases, the fluid's flow rate is the output of the process

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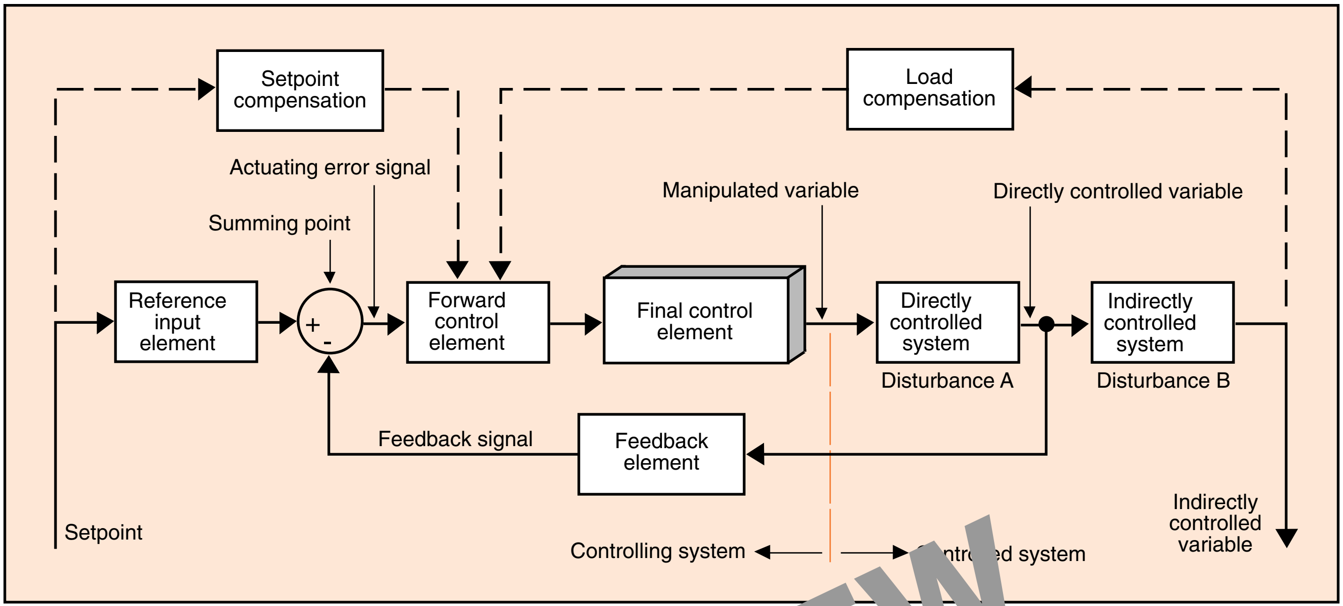
Fig. 1-1. General process control block diagram



and is the directly controlled variable. The important difference is that a properly adjusted feedback control system needs no manual adjustments.

1.08 If the pressure and viscosity of the fluid are constant, the flow rate depends on the valve setting alone. You can calculate the flow rate for valve settings at certain pressures and viscosities or you can develop the data experimentally. The next step is to set up a control system that operates the valve so that the flow rate matches the setpoint.

1.09 Without feedback, you control the fluid flow rate by adjusting the setpoint of the valve controller. This system works if the pressure and viscosity remain constant. However, if the pressure or viscosity changes, the flow rate at the output also changes. If a signal reflecting the change in flow rate is *not* fed back to the control system, the controller's output signal remains the same and the valve position does not change. Now the flow rate may not match the setpoint.

1.10 A change in pressure or viscosity in this example is called a *disturbance*—an uncontrolled variable that affects the process. By adding a sensing element (for example, a flowmeter) and feedback to the open loop in Fig. 1-2, you close the loop and provide a correction for disturbances.

1.11 As pressure increases (or viscosity decreases), the flowmeter senses the resulting increase in the flow rate. The output of the flowmeter is fed back to the controller. The signal from the controller causes the valve to close, reducing the flow until it matches

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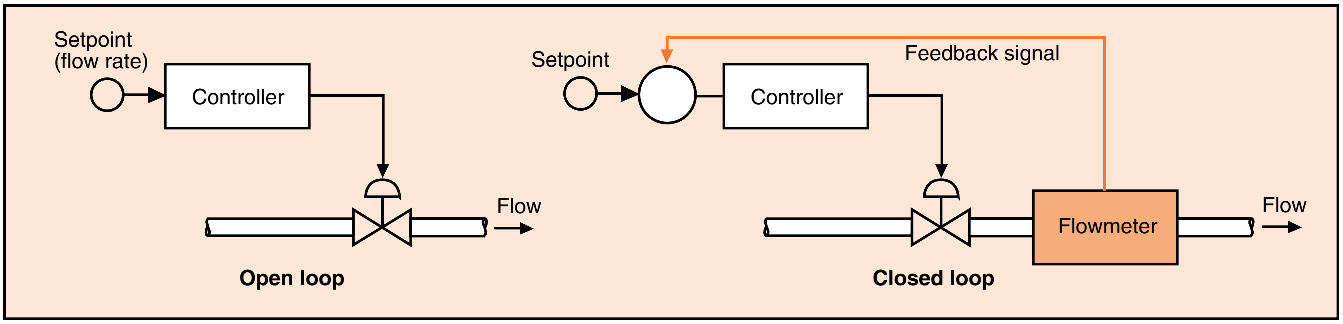
Fig. 1-2. Simple valve-controlled flow system



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the setpoint. That is, the final control element—the valve—is automatically adjusted by the controller to compensate for the disturbances in the system.

1.12 Note that the feedback signal does not affect the final control element directly. The valve responds to the output signal from the controller just as before. However, feedback causes the output of the controller to change, in turn correcting the valve setting.

1.13 In general, you can control or measure the variables in a process at any of several locations in the control loop. The choice of location usually depends on the following:

- control system response
- control system accuracy requirements
- probable system disturbances
- safety considerations
- accessibility and cost of components.

The most important consideration is the response of the control system to changes in the manipulated variable. The time the control system takes to react to changes, referred to as *response time*, is critical in maintaining process consistency. The amount of change in the measured variable in response to a change in the final control element, referred to as *process gain*, is crucial in maintaining accurate control. The control system must be designed to detect and compensate for those disturbances that may affect the manipulated variable.

1.14 Safety features include sensors and control devices that override normal system controls if a system malfunction is detected—for example, excessive pressure. These controls may adjust primary controls through a feedback loop or may shut down a process to prevent injury to personnel or damage to equipment. Safety controls are designed to alert operating personnel to system malfunctions and should *never* be defeated or compromised.

1.15 System components should be selected to provide the most economical method of control consistent with the accuracy needs of the process. Installation should allow for access for servicing and should protect the equipment from damage.

A Typical System with Feedback

1.16 The function of the system in Fig. 1-3 on the following page is the same as that in Fig. 1-2—to control flow rate. However, the way the fluid is controlled is different. In the system shown in Fig. 1-2, the flow rate depends on the position of the valve. The flow rate is the manipulated variable—it is directly changed by the final control element. It is also the directly controlled variable because it provides the feedback signal.

1.17 In the system shown in Fig. 1-3, the output pressure of the pump determines the flow rate. An error signal from the controller positions the final control element, a valve. The variable directly controlled by the valve is pneumatic pressure to the pump-stroke control rather than flow as in Fig. 1-2. In Fig. 1-3, flow is an indirectly controlled variable dependent on the output pressure of the pump.

1.18 In Fig. 1-3, the error signal from the controller is proportional to the difference between the feedback signal and the setpoint. The only variable directly controlled by this signal is the pneumatic pressure from the valve (P3) to the linear actuator. This pressure has no effect on the process except as feedback. Pneumatic pressure is the manipulated variable because it varies directly as a function of the error signal. The pneumatic valve is the final control element.

1.19 The feedback signal to the controller comes from a pressure transducer that measures the output pressure of the pump (P1). This pressure is the directly controlled variable and changes as the setpoint changes. The actuator and pump in Fig. 1-3 form a directly controlled subsystem that responds to the final control element (the valve) and adjusts the pneumatic pressure to the desired valvue. As the valve increases its pneumatic output pressure (P3), the actuator extends, which pushes the stroke-control lever of the pump. This, in turn, increases the pump stroke, resulting in an increase in the output pressure of the pump.

1.20 A control system would also include one or more safety devices—for example, a pressure switch or relief valve—to shut the process down if the pneumatic pressure (P3) increased or decreased too much. The system might also include a zero-speed switch to stop the process if the pump drive unit failed. Critical systems use more sophisticated equipment and methods to verify proper system performance.

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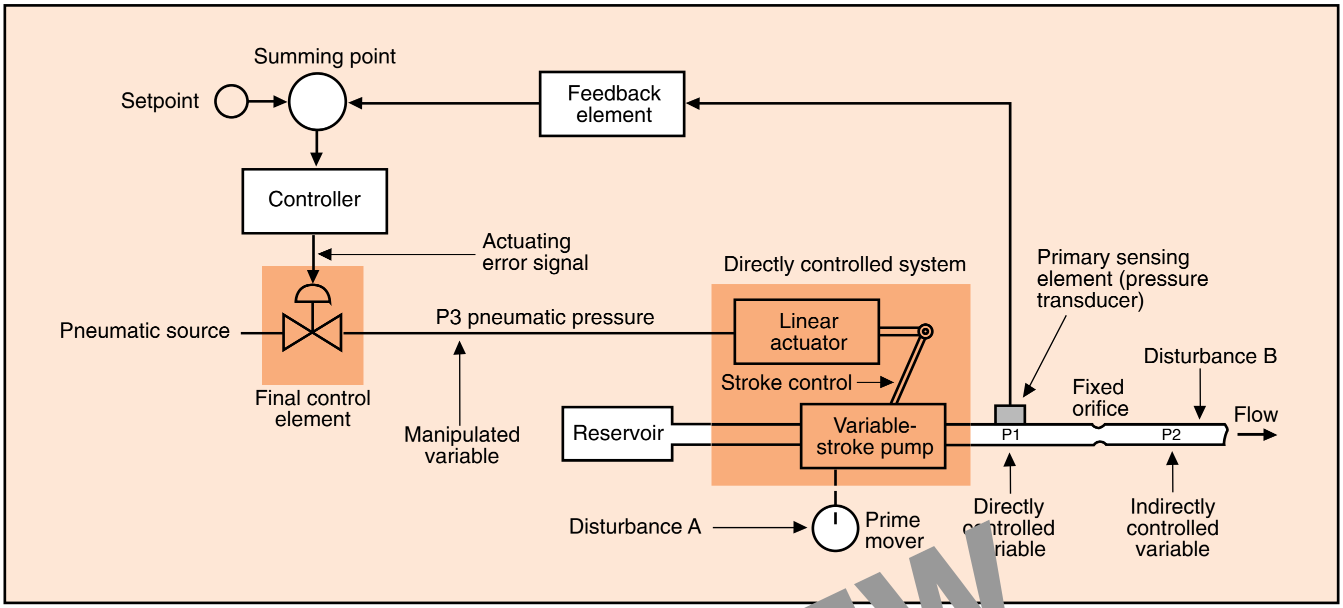
Fig. 1-3. Pump-controlled flow system



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For example, a pressure transducer could monitor the position of the stroke control actuator and a rotary transducer could measure the pump drive unit speed.

1.21 Processing the outputs of these transducers in a programmable logic controller (PLC) or through a supervisory computer allows you to detect and act upon failures of system components and also to note slight variations in system performance. For example, if the transducer monitoring pneumatic pressure (P3) detected that a higher-than-normal pressure was needed to move the stroke control to a certain position as measured by the linear transducer, this would indicate a fault in the control system. The fault could be a leak in the pneumatic control lines or wear in the pump's linear actuator. By detecting minor changes in system performance, you can schedule repairs or adjustments to prevent component failure and system shutdown during operation.

Effects of Disturbances on Performance

1.22 If a disturbance is *within* a process control loop, the feedback device senses the disturbance and corrects for it. However, a disturbance occurring *outside* the control loop may not be sensed by the feedback device, because the disturbance may not significantly affect the performance of the system. In Fig. 1-3, disturbance A is within the control loop but disturbance B is not.

Application 1-1

A manufacturing company uses a hydraulic press to compress a certain amount of material to a specific thickness. The speed at which the press moves and the distance it travels are critical to the quality of the finished product. A programmable logic controller (PLC) sends a current signal to an electronic servo valve, which causes the pump actuator to move, in turn sending hydraulic oil pressure to the press. A rotary transducer verifies that the pump actuator has moved the proper amount based on the control signal applied. A linear transducer measures the position of the press ram and the PLC calculates the speed at which the ram is traveling. The PLC then adjusts the signal to the servo valve on the pump control to obtain the proper ram speed.

When the linear transducer reaches the desired position, the controller reverses the pump signal to return the ram to the starting position. Hydraulic pressure in the press is measured by a pressure transducer. If the controller senses that the pressure is not within a certain range, it warns the operator of a potential fault and returns the press ram to the start position. This control system allows the speed of the press ram to be controlled within ±0.05 inches per second and the final ram position to be maintained within ±0.01 in.

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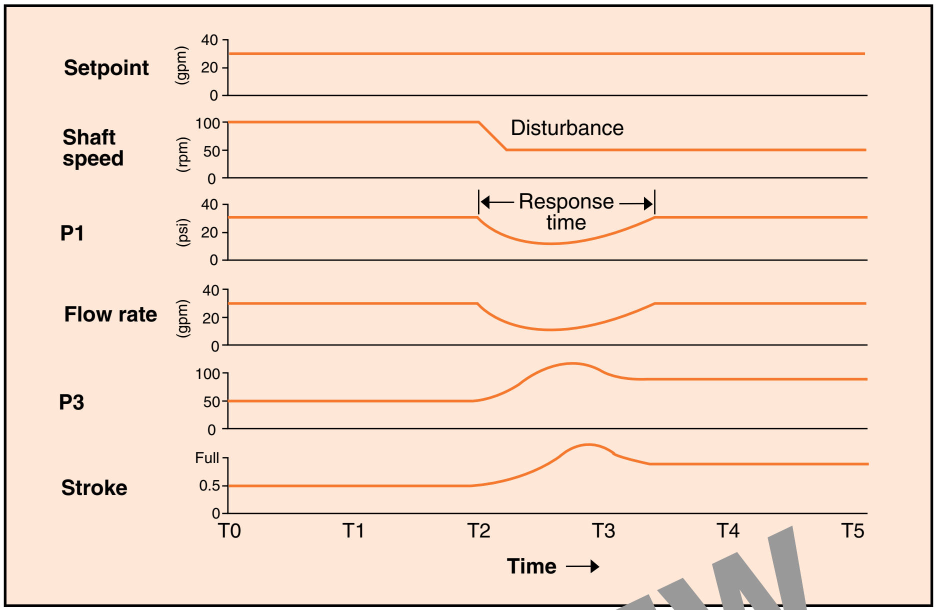
Fig. 1-4. Effect of feedback on disturbance



1.23 The prime mover providing the pumping energy in Fig. 1-3 could be any kind of engine or motor or other source of power. Most prime movers have an inconvenient feature—their shaft speeds can vary, causing a disturbance. For example, the speed will change if drive belts connecting the motor to the pump begin to slip. A change in speed causes a change in pump output pressure. Because the system output depends on pump output pressure, any change in the prime mover that affects pump pressure also affects system output flow.

1.24 Any disturbance that occurs between the controller and the pressure transducer is inside the loop and is compensated for by feedback. For example, assume the control system in Fig. 1-3 is operating under the following conditions:

- setpoint = 30 gal/min
- stroke control position set at 0.5 full
- shaft speed = 100 rpm
- P1 = 30 psi
- P2 = 15 psi
- P3 = 50 psi.

1.25 Figure 1-4 shows that at time T2, the prime mover's shaft speed decreases from 100 rpm to 50 rpm. This causes a decrease in the pressure output of the pump (P1) and results in a decreased flow rate, as shown on the graph. The reduced pressure is sensed by the pressure transducer, which changes the feedback signal.

1.26 A comparison of the new feedback signal to the setpoint results in a larger error signal from the controller, which increases the pneumatic pressure from the valve (P3). This, in turn, causes the pump-stroke control to compensate for reduced shaft speed. The increased pump stroke at the lower shaft speed returns pressure P1 to 30 psi and restores the flow rate to its setpoint value. The lag between the time the shaft speed changes and the time the stroke control position changes to compensate is an example of response time.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

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1-1. In a process control loop, the _______ variable originates a feedback signal.	1-1. DIRECTLY CONTROLLED Ref: 1.02
1-2. The device that positions a final control element is called a(n) ________.	1-2. ACTUATOR Ref: 1.03
1-3. An adjustment that makes the relationship between input and output more linear is referred to as ________ compensation.	1-3. SETPOINT Ref: 1.06
1-4. A control loop with feedback is referred to as a(n) ________ loop.	1-4. CLOSED Ref: 1.07
1-5. A(n) ________ is an uncontrolled variable that can affect the output of a process.	1-5. DISTURBANCE Ref: 1.10
1-6. The time the control system takes to react to changes is referred to as ________.	1-6. RESPONSE TIME Ref: 1.13
1-7. Process ________ is the amount of change in the measured variable in response to a change in the final control element.	1-7. GAIN Ref: 1.13
1-8. The ________ device corrects for disturbances that occur within a control loop.	1-8. FEEDBACK Ref: 1.22

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Parts of a Final Control Subsystem

1.27 The final control subsystem has three parts. As you can see in Fig. 1-5, they are a signal conditioner, an actuator, and a final control element. Table 1-1 below lists some of the devices used in final control subsystems.

1.28 First the control signal is *conditioned*. That is, it is amplified and (if necessary) converted for compatibility with the actuator. The *actuator* receives the conditioned signal and changes it to some form of mechanical energy or motion. The actuator output controls the *final control element*, which controls the process output.

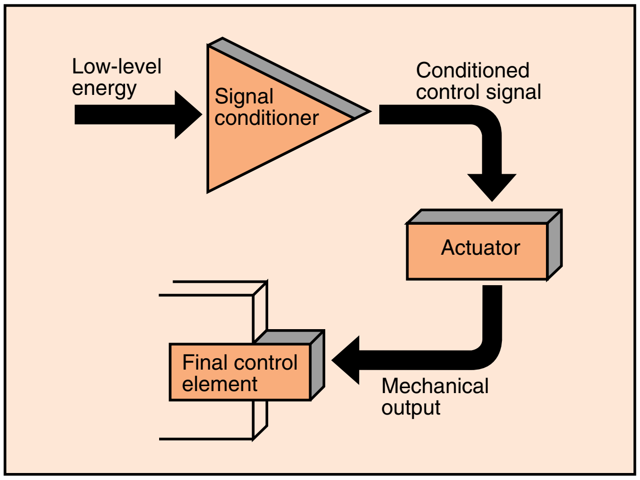
1.29 Signals may be converted from analog form to digital form. As you know, an *analog* signal is proportional to the variable. A *digital* signal controls by pulses related to logic low (0) and high (1) values. Analog-to-digital conversion is also called A/D or ADC. Signals also can be converted from digital to analog (abbreviated D/A or DAC). These conversions allow PLCs and computers to operate most actuators in use today.

1.30 The signal sent from a controller to the final control element can be in any one of several forms. The two most common kinds of control signals are electrical and fluidic. Other kinds of control signals—for example, light or microwaves—are used in special applications.

Table 1-1. Devices used in final control subsystems

Signal conditioners	Electric amplifiers Electronic amplifiers Pneumatic amplifiers Relays Current-to-voltage converters (I/V) Current-to-pneumatic converters (I/P) Digital-to-analog converters (DAC) Analog-to-digital converters (ADC)
Actuators	ac and dc motors Stepper motors Solenoids Pneumatic pistons Hydraulic pistons Hydraulic motors
Final control elements	Control valves Servo valves Heaters Conveyors Auger feeds Hopper gates

Fig. 1-5. Components of final control subsystem



Electrical Control Signals

1.31 The signals used most often in today's process control systems are low-power voltages or currents. Low-power signals are preferred to high-power signals, especially for long-distance transmission, for two main reasons:

- High-power signals require larger, more expensive wires or pipes. In turn, energy losses are higher.
- The high voltages and fluidic pressures that operate final control elements would be hazardous in the control room.

1.32 You can send an electrical equivalent of an actuator's position to the final control element as either a voltage signal or a current signal. Common signal levels for process control are 1 to 5 volts (V) or 4 to 20 milliamps (mA).

1.33 Voltage signals are preferred in certain applications—for example, instrument-to-instrument communications in panel boards—because they are easier to generate, measure, and amplify than current signals. However, voltage signals lose accuracy over long distances, mainly due to the resistance in the transmission path. Electrical interference (*noise*) causes variations in voltage signals, resulting in a loop disturbance.

1.34 In the top part of Fig. 1-6 on the following page, the controller transmits a voltage signal.

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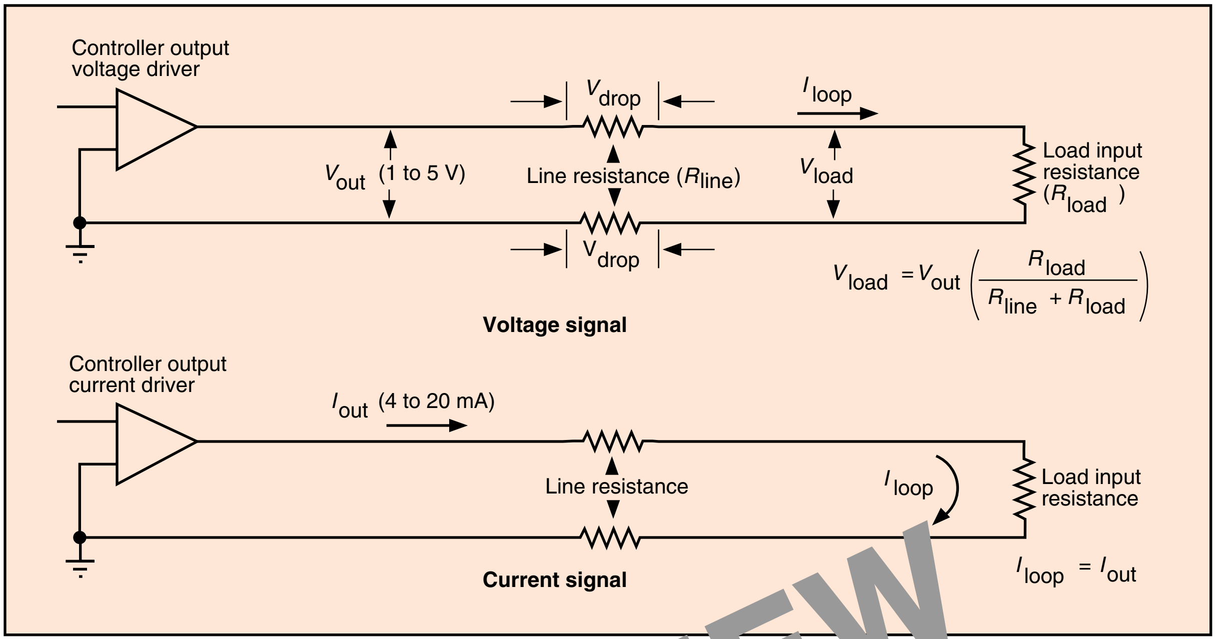
Fig. 1-6. Voltage and current signal transmission



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The resistance of the transmission line depends on several conditions:

- length and size of the wire
- temperature
- number and kind of interconnections.

1.35 Transmission of a current signal, shown in the bottom part of Fig. 1-6, is not affected by line resistance. In this loop, all the current from the controller flows around the circuit and returns to the source. The current signal through the load equals the output of the current driver regardless of transmission line resistance.

1.36 A device called a *transducer* senses a process variable—pressure, temperature, position, or flow, for example—and converts it to a current signal, usually in the range of 4 to 20 mA. For example, a transducer may sense a pressure and change it into a proportional output signal of some value between 4 and 20 mA.

Amplifiers

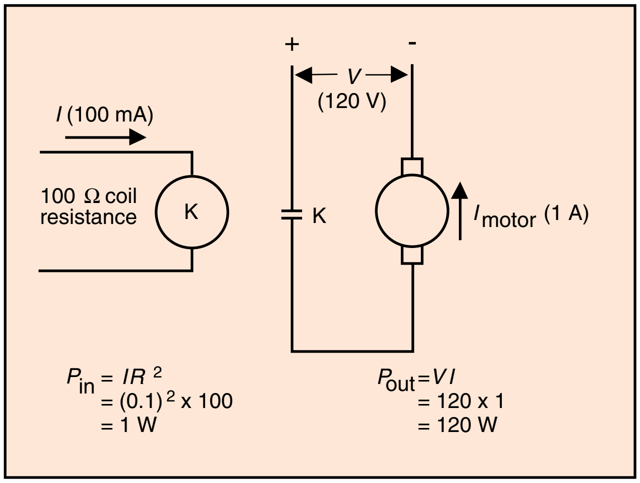
1.37 **Electromechanical relay amplifiers.** A low-level control signal must be amplified to operate a large actuator. A *power amplifier* is a device with a low-level input and a large output signal. In the relay shown in Fig. 1-7, for example, a control signal of 100 mA (0.1 A) through the relay coil causes the relay contacts to close. This action puts 120 V across the motor. In this circuit, the input to the relay coil is:

$$P_{in} = (0.1)^2 \text{ x } 100 = 1 \text{ watt (W)}.$$

The power output to the motor is:

$$P_{out} = 120 \text{ x } 1 = 120 \text{ W}.$$

Fig. 1-7. Relay power amplifier



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The ratio of the power output (120 W) to the power input (1 W) is referred to as the *power amplification factor*. In equation form:

$$\frac{\text{Output}}{\text{Input}} = \frac{120\text{ W}}{1\text{ W}} = 120$$

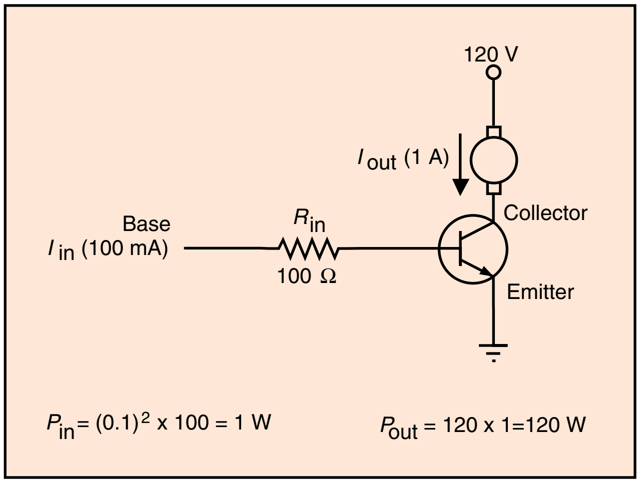
1.38 The electromechanical relay has been the main device in electrical control circuits for many years. When compared with modern devices—for example, the PLC or computer—a relay system has several significant disadvantages:

- Contacts wear out with normal use.
- It takes up a relatively large amount of space.
- Physical wiring changes are needed to modify the control circuit.
- It works only for on/off controls. That is, the signal is either on or off, and the motor either runs or stops.

1.39 The electromechanical relay's main advantage is that it can control devices that require high voltages and currents—for example, electric motors. Most modern control systems use electronic switching devices, including transistors, integrated circuits (ICs), silicon-controlled rectifiers (SCRs), and/or triacs.

1.40 **Electronic amplifiers.** An electronic power amplifier controls a power source by means of an electronic valve—for example, a transistor. In the circuit shown in Fig. 1-8, a large current through the transistor collector and emitter is controlled by a low-level signal at the transistor base.

Fig. 1-8. Transistor as linear power amplifier



1.41 The load current (I_{out}) flows from the power source to ground by traveling through the load, the collector, and the emitter. The load current is proportional to the input current to the transistor's base. The *current gain* (indicated by the Greek letter beta, ß) is the ratio of output current to input current. For example, if the input resistance is 100 Ω, the power output is 120 W for the transistor circuit (the same as for the relay circuit). However, unlike the relay circuit, you can adjust the output power (and thus the motor speed) to any value from completely off to completely on by varying the current to the transistor base (I_{in}).

1.42 Electronic variable-frequency drive systems provide speed control of AC motors. These systems can replace DC motors, lowering both initial and maintenance costs and eliminating the problem of brush and commutator wear and "sparking" normally associated with DC motors. The variable-frequency drive system changes the voltage and frequency levels of the line power supply. Lowering the frequency below 60 Hz decreases motor speed. Raising the frequency above 60 Hz increases motor speed.

Digital Signals

1.43 Some controllers, particularly those incorporating computer circuitry, have digital outputs. That is, the control signal is a series of distinct voltage levels or pulses rather than a continuous linear signal as in analog controls. Digital signals have several advantages. They are usually more accurate than analog signals and can be transmitted over long paths with no loss of information. Figure 1-9 on the following page shows three stages in digital signal transmission. Even though the digital pulses are degraded by the transmission line, they can be completely reconstructed at the receiver.

1.44 Some digital transmission systems use fiber optics instead of electrical wires. In these systems, the electrical signal is converted to a pulsed light signal that is carried on optical fibers instead of copper wires. Fiber optic systems allow very high data transmission speeds and are not affected by line resistance or electrical interference.

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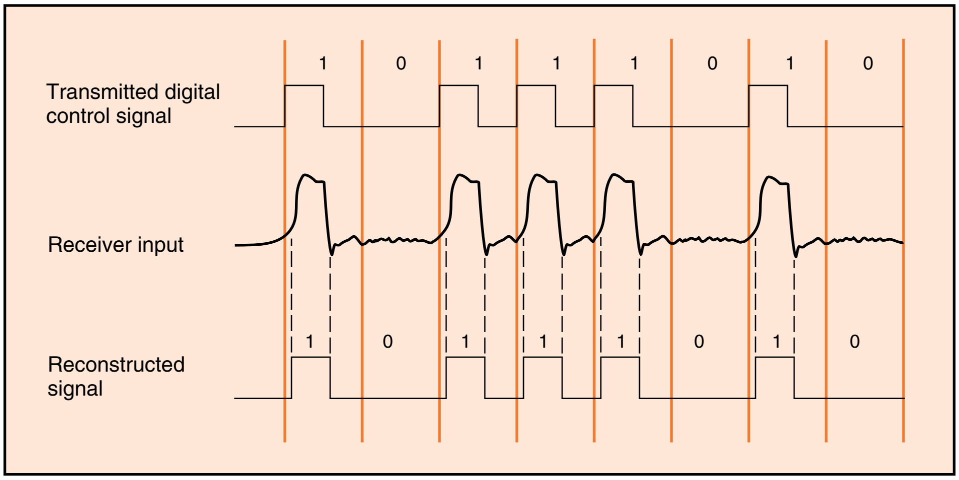
Fig. 1-9. Digital signal transmission



1.45 The relatively low cost and high reliability of PLCs, microprocessors, and microcomputer systems have greatly changed process control methods. Microprocessor-based control valves, electric drives, signal conditioners, and transmitters are common today. Figure 1-10 shows a microprocessor-controlled process management station. Here a technician can adjust the process, if necessary, after reviewing information stored in the computer memory and displayed on the screen.

1.46 All computer-based devices can receive input data and transmit output data. Input is usually digital, but can be analog. Output is to printers, cathode ray tubes (CRTs), and control devices. Control devices include:

- input and output modules to receive and send control signals
- a *central processing unit* (*CPU*) to perform the control steps (program) in the proper sequence
- memory sections including *read-only memory* (*ROM*), which contains the operating instructions for the device, and *random-access memory* (*RAM*), which contains the control system data.

To allow the devices to store or access larger amounts of data, they may be equipped with floppy or hard disk storage units or may be directly connected to a larger host computer.

Application 1-2

A modern iron foundry uses a programmable logic controller (PLC), supervised by a computer, to control the preparation of sand for its automated molding lines. The PLC collects data—for example, sand weight and temperature—through load cells and RTD thermocouples. This information is transmitted over digital communication lines to the supervisory computer, which determines the amount of clay and water that needs to be added to the sand. These calculated additions are based not only on the weight and temperature data collected by the PLC, but also on the properties of the previous batches of sand and the requirements of the molding lines.

These data then are transmitted to the PLC, which controls and monitors the additions and supervises the operation of the mixing equipment. The PLC measures final sand properties using RTD thermocouples and a linear transducer-based compaction device. The PLC then returns these data to the supervisory computer for use in calculating addition requirements for subsequent batches. The computer displays and stores the batch data for evaluation by operating personnel. This system, which is comprised of numerous directly controlled process loops, provides significantly more consistent molding sand than could possibly be obtained by making periodic manual adjustments to the addition and mixing systems.

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Fig. 1-10. Process management station

Fluidic Control Signals

1.47 Fluidic control signals may be hydraulic or pneumatic. In *hydraulic* systems, the fluid is a liquid. In *pneumatic* systems, the fluid is a gas (usually clean, dry air).

1.48 Today, the standard pressure range of most pneumatic control signals is 3 to 15 psi. However, because more than 15 psi is required to operate a large final control element, a pneumatic amplifier sometimes is needed to provide higher pressure. Figure 1-11 shows a typical pneumatic amplifier. The low-level pressure signal controls the position of the pilot valve. The pilot valve, in turn, directs the high-pressure pneumatic signal to the actuator cylinder. In process control loops, this device is often referred to as a *relay*.

1.49 Low-pressure fluidic signals have disadvantages similar to those of low-level voltage signals. Pressure drops through pipes and across fittings affect a fluidic signal the way voltage drops along an electrical transmission line affect a voltage signal. You can overcome this problem by using a controller that sends a 4- to 20-mA control signal. A current-to-pneumatic (I/P) converter can convert the current signal to a 3- to 15-psi signal. The 3- to 15-psi signal can serve as an input to a pneumatic amplifier like the one shown in Fig. 1-11.

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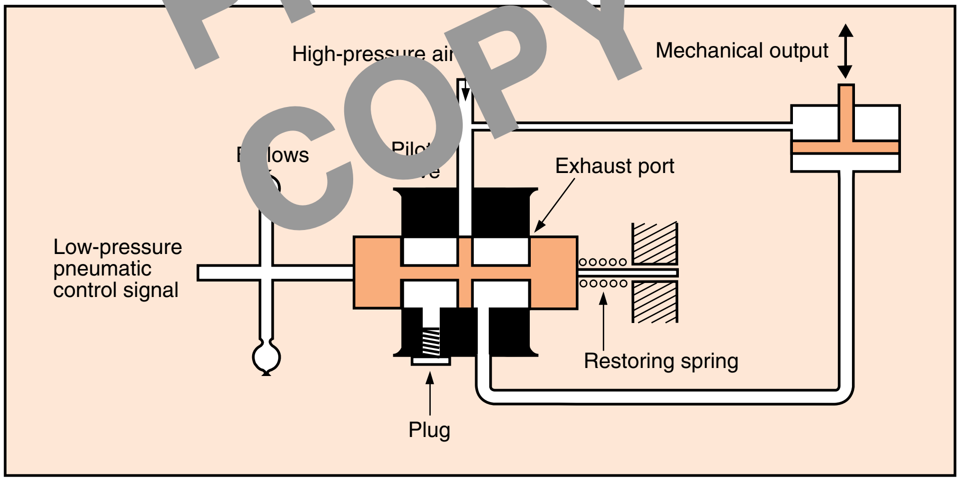
Fig. 1-11. Pneumatic amplifier



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1-9. The process of amplifying and converting a signal so that it can drive an actuator is referred to as signal ________.	1-9. CONDITIONING Ref: 1.28
1-10. A(n) ________ signal controls by pulses related to logic low and high values.	1-10. DIGITAL Ref: 1.29
1-11. Over long distances, it is more efficient to transmit ________-power control signals.	1-11. LOW Ref: 1.31
1-12. Resistance in the transmission line affects ________ signals sent over long distances.	1-12. VOLTAGE Ref: 1.33
1-13. A(n) ________ converts a sensed variable to a current signal, usually in the range of ________.	1-13. TRANSDUCER; 4 TO 20 mA Ref: 1.36
1-14. A low-level control signal must be ________ to operate a large actuator.	1-14. AMPLIFIED Ref: 1.37
1-15. Controllers that incorporate computer circuits usually have outputs in the form of ________ signals.	1-15. DIGITAL Ref: 1.43
1-16. To reduce transmission problems, signals in fluidic systems are often converted and transmitted as ________ signals.	1-16. CURRENT Ref: 1.49

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Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Which of the following originates a feedback signal?

☐ a. Directly controlled variable
☐ b. Disturbance
☐ c. Indirectly controlled variable
☐ d. Manipulated variable

1-2. Which of the following is an example of a final control element?

☐ a. Bellows
☐ b. Clock
☐ c. Thermometer
☐ d. Valve

1-3. Setpoint compensation

☐ a. has little effect on output
☐ b. increases system linearity
☐ c. is used only in closed loops
☐ d. requires a feedback signal

1-4. The important difference between open- and closed-loop systems is that the closed-loop system

☐ a. controls through digital signals
☐ b. provides automatic control through feedback
☐ c. requires manual operation
☐ d. uses smaller actuators

1-5. The most important consideration in loop control locations is

☐ a. accessibility
☐ b. accuracy
☐ c. cost
☐ d. response

1-6. A disturbance inside a control loop

☐ a. does not affect output
☐ b. is a manipulated variable
☐ c. is corrected for by feedback
☐ d. results in a process error

1-7. Which of the following may condition a signal in a final control subsystem?

☐ a. Electric motor
☐ b. Hydraulic piston
☐ c. Solenoid
☐ d. Transistor amplifier

1-8. The device in a final control subsystem that receives a conditioned signal and converts it to some form of mechanical energy is a(n)

☐ a. actuator
☐ b. amplifier
☐ c. P/I converter
☐ d. transducer

1-9. Which of the following statements is true?

☐ a. Current signals are easier to amplify than voltage signals
☐ b. Current signals are easier to measure than voltage signals
☐ c. Voltage signals are affected by transmission line resistance
☐ d. Voltage signals are harder to generate than current signals

1-10. The pressure range of most pneumatic control signals is usually

☐ a. 0 to 50 mV
☐ b. 1 to 5 V
☐ c. 3 to 15 psi
☐ d. 4 to 20 mA

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SUMMARY

Final control elements control the process by adjusting variables. Adjustments to manual systems are made by load and setpoint compensation. Signals from a process loop control the final elements. The main difference between open-loop and closed-loop systems is feedback. Any disturbance that occurs inside a closed loop is compensated for by feedback.

A control signal must first be conditioned. It is amplified and, if necessary, converted for compatibility with the actuator. The signal may be analog or digital. Amplifiers may be electromechanical or electronic. The actuator receives the conditioned signal and changes it to some form of mechanical energy. The final control element then uses the actuator output to control the process. Most signals are electrical (voltage or current) or fluidic (hydraulic or pneumatic).

Answers to Self-Check Quiz

1-1. a. Directly controlled variable. Ref: 1.02

1-2. d. Valve. Ref: 1.02

1-3. b. Increases system linearity. Ref: 1.06

1-4. b. Provides automatic control through feedback. Ref: 1.07

1-5. d. Response. Ref: 1.13

1-6. c. Is corrected for by feedback. Ref: 1.22

1-7. d. Transistor amplifier. Ref: 1.28, Table 1-1

1-8. a. Actuator. Ref: 1.28

1-9. c. Voltage signals are affected by transmission line resistance. Ref: 1.33

1-10. c. 3 to 15 psi. Ref: 1.48

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Contributions from the following sources are appreciated:

Figure 1-10 Leeds & Northrup
A Unit of General Signal

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