Sensors, Actuators, and other control system components

L-22

Contents

Categories of Computer Input/Output Interface for the different types of Process Parameters and variables

TABLE 5.1 Categories of Computer Input/Output Interface for the Different Types of Process Parameters and Variables

	Type of Data from/to Process	*Input Interface to Computer*	*Output Interface from Computer*
1	Continuous analog signal	Analog-to-digital converter	Digital-to-analog converter
2(a)	Discrete data—binary (on/off)	Contact input	Contact output
2(b)	Discrete data other than binary	Contact input array	Contact output array
2(c)	Discrete pulse data	Pulse counters	Pulse generators

1) Sensors

- A wide variety of measuring devices is available for collecting data from the manufacturing process for use in feedback control
- In general, a measuring device is composed of two components: sensor and a transducer.
- The sensor detects the physical variable of interest (such as temperature, force, or pressure). The transducer converts the physical variable into an alternative form (commonly electrical voltage), quantifying the variable in the conversion.

Desirable features for selecting Measuring Devices used in Automated Systems

TABLE 5.2 Desirable Features for Selecting Measuring Devices Used in Automated Systems

Desirable Feature	*Definition and Comments*
High accuracy	The measurement contains small systematic errors about the true value.
High precision	The random variability or noise in the measured value is low.
Wide operating range	The measuring device possesses high accuracy and precision over a wide range of values of the physical variable being measured.
High speed of response	The ability of the device to respond quickly to changes in the physical variable being measured. Ideally, the time lag would be zero.
Ease of calibration	Calibration of the measuring device should be quick and easy.
Minimum drift	Drift refers to the gradual loss in accuracy over time. High drift requires frequent recalibration of the measuring device.
High reliability	The device should not be subject to frequent malfunctions or failures during service. It must be capable of operating in the potentially harsh environment of the manufacturing process where it will be applied.
Low cost	The cost to purchase (or fabricate) and install the measuring device should be low relative to the value of the data provided by the sensor.

Common Measuring Devices used in Automation

Measuring Device	*Description*
Accelerometer	Analog device used to measure vibration and shock. Can be based on various physical phenomena.
Ammeter	Analog device that measures the strength of an electrical current.
Bimetallic switch	Binary switch that uses bimetallic coil to open and close electrical contact as a result of temperature change. *Bimetallic coil* consists of two metal strips of different thermal expansion coefficients bonded together.
Bimetallic thermometer	Analog temperature measuring device consisting of bimetallic coil (see definition above) that changes shape in response to temperature change. Shape change of coil can be calibrated to indicate temperature.
DC tachometer	Analog device consisting of dc generator that produces electrical voltage proportional to rotational speed.
Dynamometer	Analog device used to measure force, power, or torque. Can be based on various physical phenomena (e.g., strain gage, piezoelectric effect).
Float transducer	Float attached to lever arm. Pivoting movement of lever arm can be used to measure liquid level in vessel (analog device) or to activate contact switch (binary device).
Fluid flow sensor	Analog measurement of liquid flow, usually based on pressure difference between flow in two pipes of different diameter.
Fluid flow switch	Binary switch similar to limit switch but activated by increase in fluid pressure rather than by contacting object.
Linear variable differential transformer	Analog position sensor consisting of primary coil opposite two secondary coils separated by a magnetic core. When primary coil is energized, induced voltage in secondary coil is function of core position. Can also be adapted to measure force or pressure.

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TABLE 5.3 *(continued)*

Measuring Device	Description
Limit switch (mechanical)	Binary contact sensor in which lever arm or pushbutton closes (or opens) an electrical contact.
Manometer	Analog device used to measure pressure of gas or liquid. Based on comparison of known and unknown pressure forces. A *barometer* is a specific type of manometer used to measure atmospheric pressure.
Ohmmeter	Analog device that measures electrical resistance.
Optical encoder	Digital device used to measure position and/or speed, consisting of a slotted disk separating a light source from a photocell. As disk rotates, photocell senses light through slots as a series of pulses. Number and frequency of pulses are proportional (respectively) to position and speed of shaft connected to disk. Can be adapted for linear as well as rotational measurements.
Photoelectric sensor	Binary noncontact sensor (switch) consisting of emitter (light source) and receiver (photocell) triggered by interruption of light beam. Two common types: (1) *transmitted type,* in which object blocks light beam between emitter and receiver; and (2) *retroreflective type,* in which emitter and receiver are located in one device and beam is reflected off remote reflector except when object breaks the reflected light beam.
Photoelectric sensor array	Digital sensor consisting of linear series of photoelectric sensors. Array is designed to indicate height or size of object interrupting some but not all of the light beams.
Photometer	Analog sensor that measures illumination and light intensity.
Piezoelectric transducer	Analog device based on piezoelectric effect of certain materials (e.g., quartz) in which an electrical charge is produced when the material is deformed. Charge can be measured and is proportional to deformation. Can be used to measure force, pressure, and acceleration.
Potentiometer	Analog position sensor consisting of resistor and contact slider. Position of slider on resistor determines measured resistance. Available for both linear and rotational (angular) measurements.
Proximity switch	Binary noncontact sensor is triggered when nearby object induces changes in electromagnetic field. Two types: (1) inductive and (2) capacitive.
Radiation pyrometer	Analog temperature-measuring device that senses electromagnetic radiation in the visible and infrared range of spectrum.
Resistance-temperature detector	Analog temperature-measuring device based on increase in electrical resistance of a metallic material as temperature is increased.
Strain gage	Widely used analog sensor to measure force, torque, or pressure. Based on change in electrical resistance resulting from strain of a conducting material.
Thermistor	Analog temperature-measuring device based on decrease in electrical resistance of a semiconductor material as temperature is increased.
Thermocouple	Analog temperature-measuring device based on thermoelectric effect, in which the junction of two dissimilar metal wires emits a small voltage that is a function of the temperature of the junction. Common standard thermocouples include: chromel-alumel, iron-constantan, and chromel-constantan.
Ultrasonic range sensor	Time lapse between emission and reflection (from object) of high-frequency sound pulses is measured. Can be used to measure distance or simply to indicate presence of object.

2) Actuators

- In industrial control systems, an actuator is a hardware device that converts a controller command signal into a change in a physical parameter
- The change in physical parameter is usually mechanical, such as position or velocity change
- An actuator is a transducer, because it changes one type of physical quantity, say electric current, into another type of physical quantity, say rotational speed of electric motor
- The controller command signal is usually low level, and so an actuator may also include an amplifier to strength the signal sufficiently to drive the actuator. Depending on the type of amplifier used, most actuators can be classified into one of three categories

(i) Electrical   (ii) hydraulic   (iii) pneumatic

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- Electrical actuators are most common, they include ac and dc motors of various kinds, stepper motors and solenoids. Electrical actuators include both linear devices (output is linear displacement) and rotational devices (output is rotational displacement or velocity)
- Hydraulic actuators use hydraulic fluid to amplify the controller command signal. The available devices provide both linear abd rotational motion. Hydraulic actuators are often specified when large forces are required.
- Pneumatic actuators use compressed air (typically shop air in the factory environment) as the driving power. Both linear and rotational pneumatic actuators are available
- Because of the relatively low air pressures involved, these actuators are usually limited to relatively low force application compared with hydraulic actuators.

Common Actuators Used in Automated Systems

TABLE 3.4 Common Actuators Used in Automated Systems

Actuator	Description
DC motor	Rotational electromagnetic motor. Input is direct current (dc). Very common servomotor in control systems. Rotary motion can be converted to linear motion using rack-and-pinion or ball screw.
Hydraulic piston	Piston inside cylinder exerts force and provides linear motion in response to hydraulic pressure. High force capability.
Induction motor (rotary)	Rotational electromagnetic motor. Input is alternating current (ac). Advantages compared with dc motor: lower cost, simpler construction, and more-convenient power supply. Rotary motion can be converted to linear motion using rack-and-pinion or ball screw.
Linear induction motor	Straight-line motion electromagnetic motor. Input is alternating current (ac). Advantages: high speed, high positioning accuracy, and long stroke capacity.
Pneumatic cylinder	Piston inside cylinder exerts force and provides linear motion in response to air pressure.
Relay switch	On-off switch opens or closes circuit in response to an electromagnetic force.
Solenoid	Two-position electromechanical assembly consists of core inside coil of wire. Core is usually held in one position by spring, but when coil is energized, core is forced to other position. Linear solenoid most common, but rotary solenoid available.
Stepping motor	Rotational electromagnetic motor. Output shaft rotates in direct proportion to pulses received. Advantages: high accuracy, easy implementation, compatible with digital signals, and can be used with open-loop control. Disadvantages: lower torque than dc motors, limited speed, and risk of missed pulse under load. Rotary motion can be converted to linear motion using rack-and-pinion or ball screw.

3) Analog-to-digital conversion

- Continous analog signals from the process must be converted into digital values to be used by the computer, and digital data generated by the computer must be converted to analog signals to be used by analog actuators.
- The procedure for converting an analog signal from the process into digital form typically consists of the following steps and hardware devices

(i) Sensor and transducer

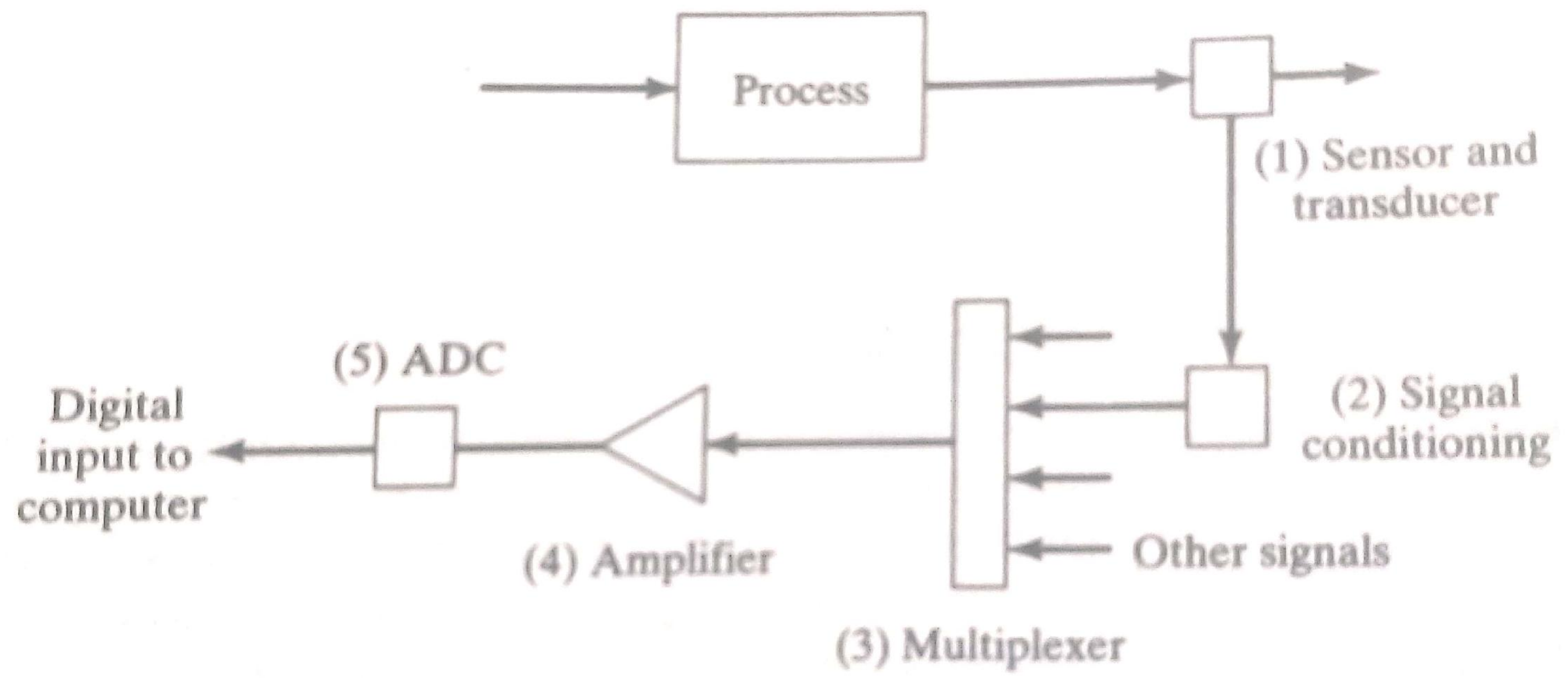
(ii) Signal conditioning

(iii) Multiplexer

(iv) Amplifier

(v) Analog to digital converter

Steps in analog-to-digital conversion of continuous analog signals from process



4) Digital to Analog Conversion

- The process performed by a digital-to-analog converter (DAC) is the reverse of ADC process.
- The DAC transforms the digital output of the computer into a continuous signal to drive an analog actuator or other analog device
- Digital to analog conversion consists of two steps

(i) decoding, in which the digital output of the computer is converted into a series of analog values at discrete moments in time

(ii) Data holding, in which each successive value is changed into a continuous signal(usually electrical voltage) used to drive the analog actuator during the sampling interval.

5) Input/Output devices for discrete data

The discrete data divide into three categories

(i) Binary data (ii) discrete data other than binary (iii) pulse data

a) Contact Input/Output Interfaces

- A contact input interface is a device by which binary data are read into computer from some external source (e.g, the process).
- It consists of a series of simple contacts that can be either closed or open (on or off) to indicate the status of binary devices connected to the process such as limit switches (contact or no contact), valves (open or closed), or motor pushbuttons (on or off).

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- The contact output interface is the device that communicates on/off signals from the computer to the process. The contact positions are set in either of two states: ON or OFF.
- These positions are maintained until changed by the computer, perhaps in response to events in the process
- In computer process control applications, hardware controlled by the contact output interface include alarms, indicator lights (on control panels), solenoids, and constant speed motors.

b) Pulse Counters and Generators

- A pulse counter is a device used to convert a series of pulses called pulse train into digital value. The value is then entered into the computer through its input channel
- The most common type of pulse counter is one that counts electrical pulses. It is constructed using sequential logic gates, called flip-flops, which are electronic devices that possess memory capability and hence can be used to store the results of the counting procedure.

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- A pulse generator is a device that produces a series of electrical pulses whose total number and frequency are specified by the control computer. The total number of pulses might be used to drive the axis of a positioning system.
- The frequency of pulse train or pulse rate, could be used to control the rotational speed of a stepper motor.
- A pulse generator operates by repeatedly closing and opening an electrical contact, thus producing a sequence of discrete electrical pulses. The amplitude(voltage level) and frequency are designed to be compatible with the device being controlled.