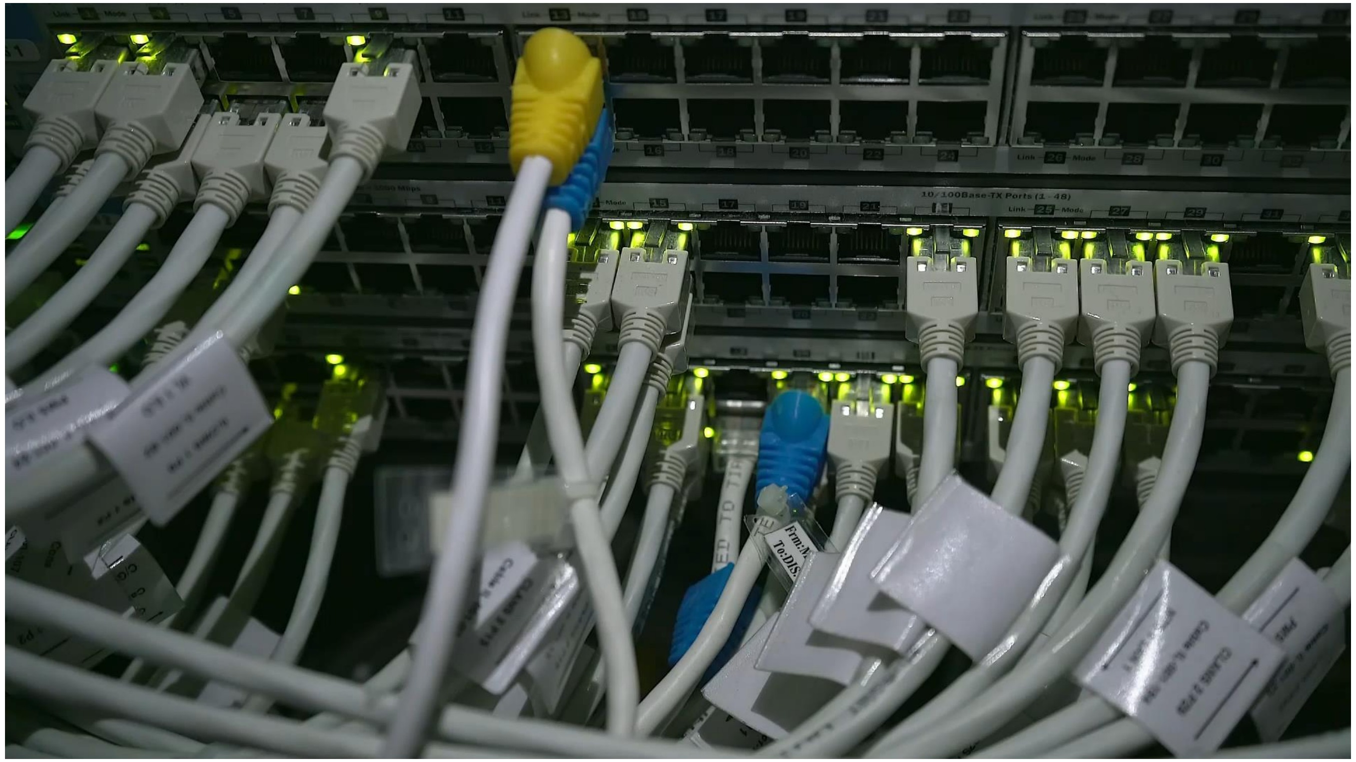
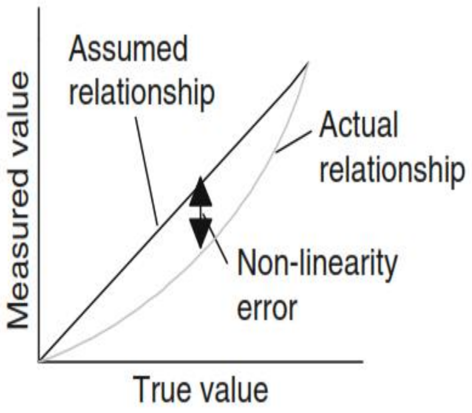
PLC Lesson 2

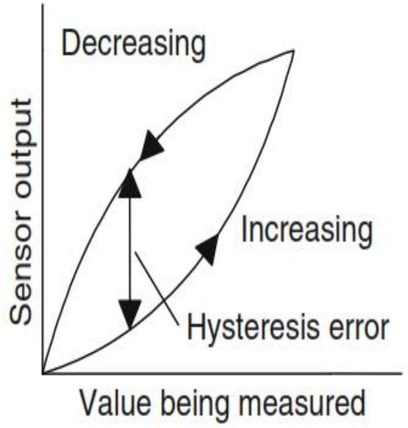
Input / Output



Inputs

- The term sensor is used for an input device that provides a usable output in response to a specified physical input. For example, a thermocouple is a sensor that converts a temperature difference into an electrical output.
- The term transducer is generally used to refer to a device that converts a signal from one form to a different physical form.
- Sensors that give digital or discrete, that is, on/off, outputs can be easily connected to the input ports of PLCs.
- An analog sensor gives an output proportional to the measured variable. Such analog signals have to be converted to digital signals before they can be input to PLC ports.
- The following are some of the more common terms used to define the performance of sensors:





Inputs

- Accuracy is the extent to which the value indicated by a measurement system or element might be wrong. For example, a temperature sensor might have an accuracy of 0.1 C.

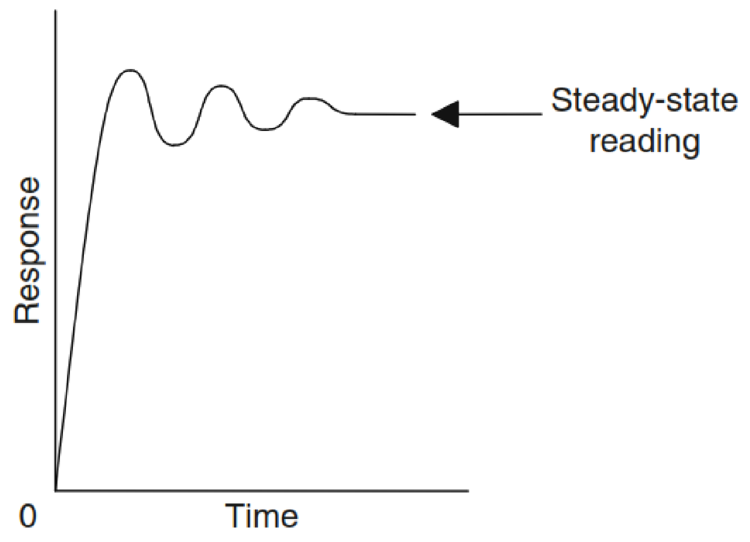
- The error of a measurement is the difference between the result of the measurement and the true value of the quantity being measured.

- Errors can arise in a number of ways; the term nonlinearity error is used to describe the error that occurs as a result of assuming a linear relationship between the input and output over the working range, that is, a graph of output plotted against input is assumed to give a straight line.

- Few systems or elements, however, have a truly linear relationship and thus errors occur as a result of the assumption of linearity.

- The term hysteresis error is used for the difference in outputs given from the same value of quantity being measured according to whether that value has been reached by a continuously increasing change or a continuously decreasing change.

Inputs



- The range of variable of a system is the limits between which the inputs can vary. For example, a resistance temperature sensor might be quoted as having a range of 200 to 800 C.

- When the input value to a sensor changes, it will take some time to reach and settle down to the steady-state value.

- The response time is the time that elapses after the input to a system or element is abruptly increased from zero to a constant value for ex. 95%, of the value of the input.

- The rise time is the time taken for the output to rise to some specified percentage of the steady-state output. Often the rise time refers to the time taken for the output to rise from 10% of the steady-state.

- The settling time is the time taken for the output to settle to within some percentage, such as 2%, of the steady-state value.

Inputs

- The sensitivity indicates how much the output of an instrument system or system element changes when the quantity being measured changes by a given amount, that is, the ratio ouput/input. For example, a thermocouple might have a sensitivity of 20 mV/ C and so give an output of 20 mV for each 1 C change in temperature.

- The stability of a system is its ability to give the same output when used to measure a constant input over a period of time. The term drift is often used to describe the change in output that occurs over time. The drift may be expressed as a percentage of the full range output. The term zero drift refers to the changes that occur in output when there is zero input.

- The term repeatability refers to the ability of a measurement system to give the same value for repeated measurements of the same value of a variable. Common causes of lack of repeatability are random fluctuations in the environment, such as changes in temperature and humidity. The error arising from repeatability is usually expressed as a percentage of the full range output. For example, a pressure sensor might be quoted as having a repeatability of 0.1% of full range. With a range of 20 kPa this would be an error of 20 Pa.

- The reliability of a measurement system, or the element in such a system, is defined as being the probability that it will operate to an agreed level of performance for a specified period, subject to specified environmental conditions. The agreed level of performance might be that the measurement system gives a particular accuracy.

Inputs

- As an illustration of the use of these terms in specification, the following were included in the specification of a MX100AP pressure sensor:

- Supply voltage: 3 V (6 V max)

- Supply current: 6 mA

- Full-scale span: 60 mV Range:

- 0 to 100 kPa Sensitivity: 0.6 mV/kPa

- Nonlinearity error: 0.05% of full range

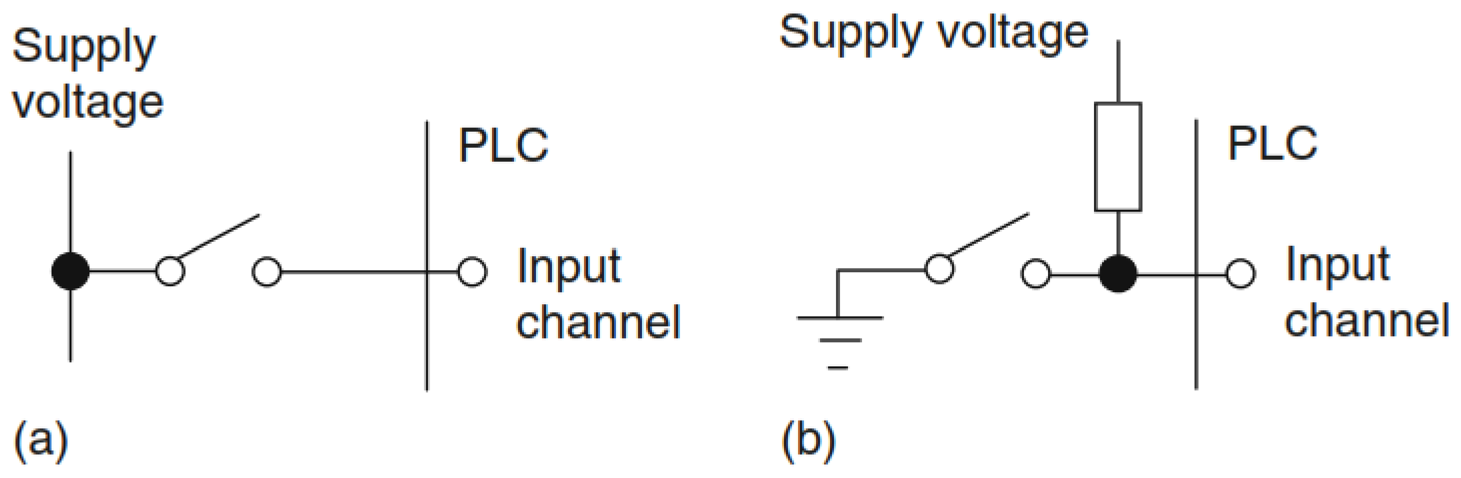
- Temperature hysteresis: 0.5% of full scale

- Input resistance: 400 to 550 O

- Response time: 1 ms (10% to 90%)

Sensors

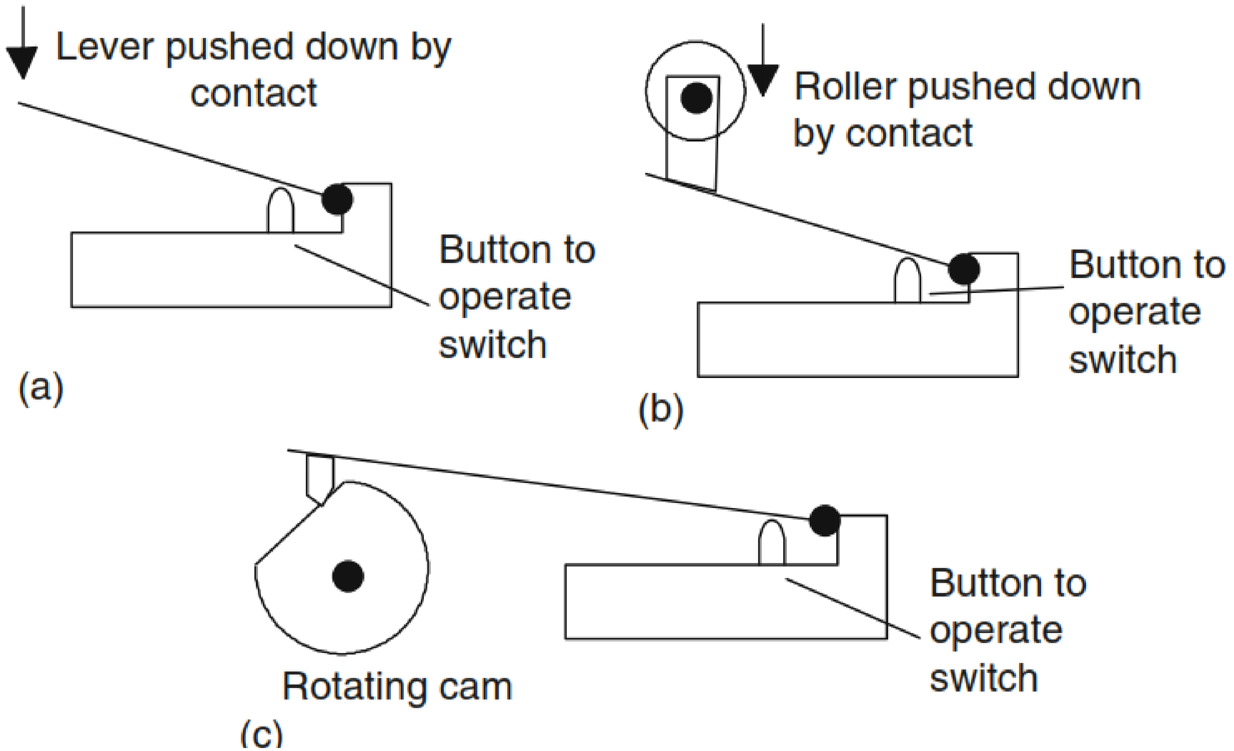
- A **mechanical switch** generates an on/off signal or signals as a result of some mechanical input causing the switch to open or close. Such a switch might be used to indicate the presence of a workpiece.
- Case a. the input signals to a single input channel of the PLC are thus the logic levels:
  - Workpiece not present: 0
  - Workpiece present: 1
- Case b. when the switch is closed the input voltage drops to a low value. The logic levels are thus:
  - Workpiece not present: 1
  - Workpiece present: 0



Sensors

- A **mechanical switch**

The term limit switch applies to a switch that is used to detect the presence or passage of a moving part. It can be actuated by a cam, roller, or lever. Figure shows some examples. The cam (Figure c) can be rotated at a constant rate and so can turn the switch on and off for particular time intervals.



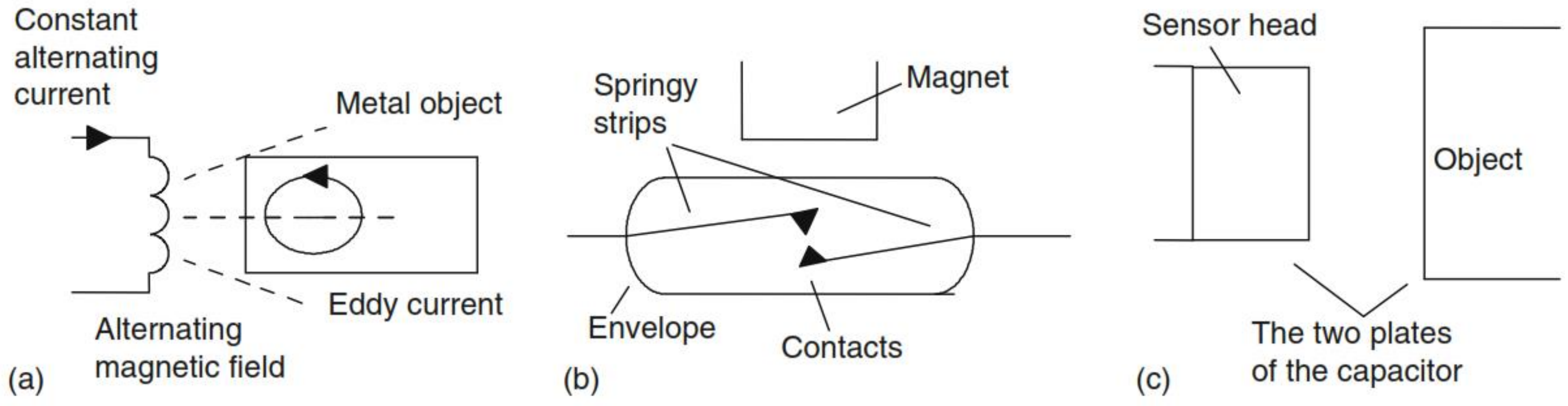
Sensors

- **Proximity switches** are used to detect the presence of an item without making contact with it. There are a number of forms of such switches, some being suitable only for metallic objects.

- The eddy current type of proximity switch has a coil that is energized by a constant alternating current and produces a constant alternating magnetic field. When a metallic object is close to it, eddy currents are induced in it (Figure a). The range over which such objects can be detected is typically about 0.5 to 20 mm.

- Another switch type is the reed switch. This consists of two overlapping, but not touching, strips of a springy ferromagnetic material sealed in a glass or plastic envelope (Figure b). When a magnet or current-carrying coil is brought close to the switch, the strips become magnetized and attract each other. The magnet closes the contacts when it is typically about 1 mm from the switch.

- A proximity switch that can be used with metallic and nonmetallic objects is the capacitive proximity switch. The sensor of the capacitive proximity switch is just one of the plates of the capacitor, the other plate being the metal object for which the proximity is to be detected (Figure c). Thus the proximity of the object is detected by a change in capacitance. Capacitive proximity switches can be used to detect objects when they are typically between 4 mm and 60 mm from the sensor head.

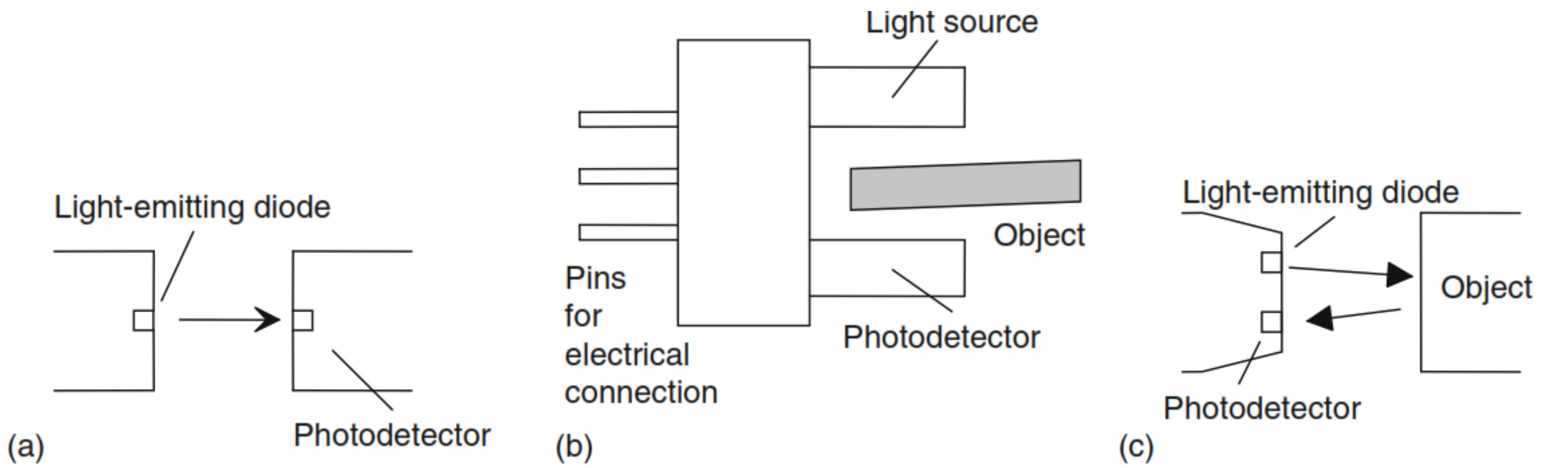


Sensors

- **Photoelectric** switch devices can either operate as transmissive types, in which the object being detected breaks a beam of light, usually infrared radiation, and stops it reaching the detector (Figure a), as in Figure b, which shows a U-shaped form in which the object breaks the light beam; or reflective types, in which the object being detected reflects a beam of light onto the detector (Figure c).

- The transmissive form of sensor is typically used in applications involving the counting of parts moving along conveyor belts and breaking the light beam; the reflective form is used to detect whether transparent containers contain liquids to the required level.

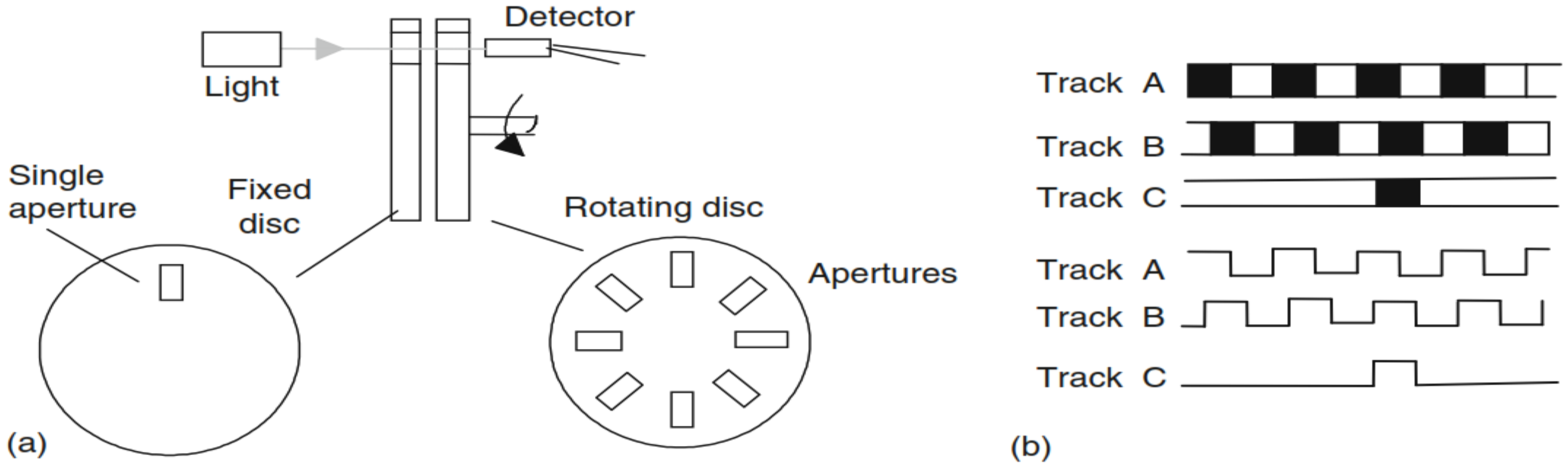
- The radiation emitter is generally a light-emitting diode (LED). The radiation detector might be a phototransistor, often a pair of transistors, known as a Darlington pair, to increase the sensitivity.



Sensors

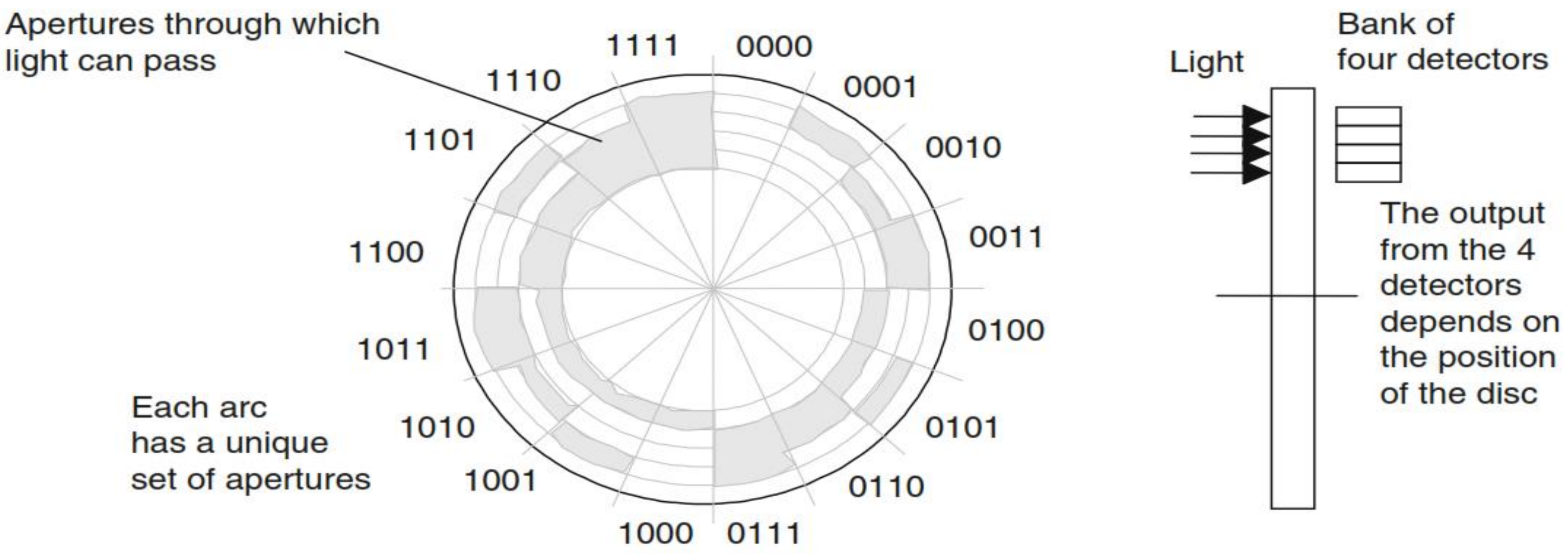
- The term **encoder** is used for a device that provides a digital output as a result of angular or linear displacement. An incremental encoder detects changes in angular or linear displacement from some datum position; an absolute encoder gives the actual angular or linear position.

- Figure shows the basic form of an incremental encoder for the measurement of angular displacement. A beam of light, perhaps from an LED, passes through slots in a disc and is detected by a light sensor, such as a photodiode or phototransistor. When the disc rotates, the light beam is alternately transmitted and stopped, and so a pulsed output is produced from the light sensor. The number of pulses is proportional to the angle through which the disc has rotated, the resolution being proportional to the number of slots on a disc. With 60 slots, then, since one revolution is a rotation of 360 , a movement from one slot to the next is a rotation of 6.



Sensors

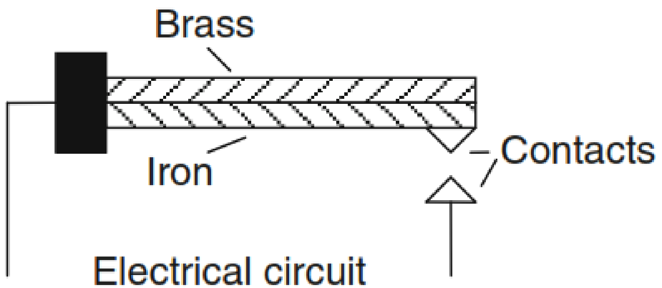
- The absolute encoder differs from the incremental encoder in having a pattern of slots that uniquely defines each angular position. With the form shown in Figure, the rotating disc has four concentric circles of slots and four sensors to detect the light pulses. The slots are arranged in such a way that the sequential output from the sensors is a number in the binary code, each number corresponding to a particular angular position. With four tracks there will be 4 bits, and so the number of positions that can be detected is 24 ¼ 16, that is, a resolution of 360/16 ¼ 22.5 . Typical encoders have up to 10 or 12 tracks. Thus with 10 tracks there will be 10 bits, and so the number of positions that can be detected is 210, that is, 1024, a resolution of 360/1024 ¼ 0.35 .

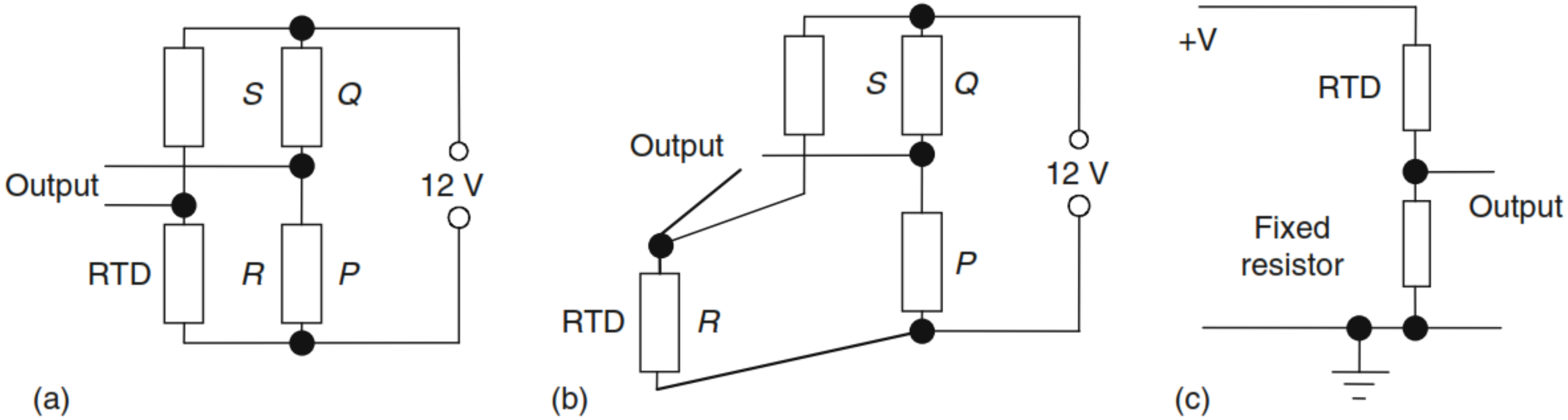


Sensors

- **Temperature Sensors** A simple form of temperature sensor that can be used to provide an on/off signal when a particular temperature is reached is the bimetal element. This consists of two strips of different metals, such as brass and iron, bonded together. The two metals have different coefficients of expansion. Thus, when the temperature of the bimetal strip increases, the strip curves in order that one of the metals can expand more than the other. The higher expansion metal is on the outside of the curve. As the strip cools, the bending effect is reversed.

- Another form of temperature sensor is the resistive temperature detector (RTD). The electrical resistance of metals or semiconductors changes with temperature. In the case of a metal, the ones most commonly used are platinum, nickel, or nickel alloys. Such detectors can be used as one arm of a Wheatstone bridge and the output of the bridge taken as a measure of the temperature.

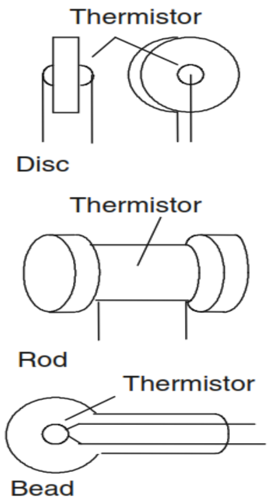


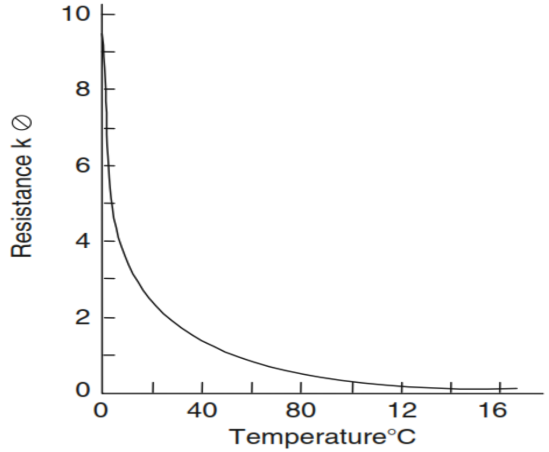


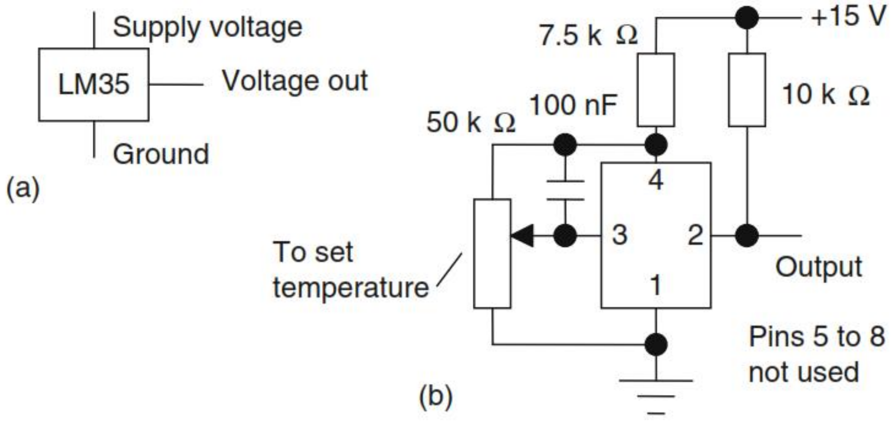
Sensors

- Semiconductors, such as thermistors, show very large changes in resistance with temperature. The change, however, is nonlinear. Those specified as NTC have negative temperature coefficients, that is, the resistance decreases with increasing temperature, and those specified as PTC have positive temperature coefficients, that is, the resistance increases with increasing temperature. Thermistors have the advantages of being cheap and small, giving large changes in resistance, and having fast reaction to temperature changes.

- Thermodiodes and thermotransistors are used as temperature sensors since the rate at which electrons and holes diffuse across semiconductor junctions is affected by the temperature. Integrated circuits can combine such a temperature-sensitive element with the relevant circuitry to give an output voltage related to temperature. A widely used integrated package is the LM35, which gives an output of 10 mV/ C when the supply voltage is 5 V.



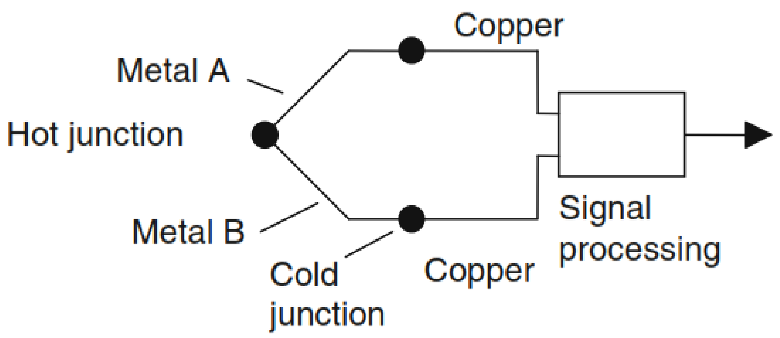




Sensors

- Another commonly used temperature sensor is the thermocouple. The thermocouple consists essentially of two dissimilar wires, A and B, forming a junction. When the junction is heated so that it is at a higher temperature than the other junctions in the circuit, which remain at a constant cold temperature, an EMF is produced that is related to the hot junction temperature. The EMF values for a thermocouple are given in Table, assuming that the cold junction is at 0 C. The thermocouple voltage is small and needs amplification before it can be fed to the analog channel input of a PLC.

- Thermocouples have the advantages of being able to sense the temperature at almost any point, ruggedness, and being able to operate over a large temperature range. They have the disadvantages of giving a nonlinear response.



Ref.	Materials	Range (°C)	μV/°C
B	Platinum, 30% rhodium/platinum, 6% rhodium	0 to 1800	3
E	Chromel/constantan	−200 to 1000	63
J	Iron/constantan	−200 to 900	53
K	Chromel/alumel	−200 to 1300	41
N	Nirosil/nisil	−200 to 1300	28
R	Platinum/platinum, 13% rhodium	0 to 1400	6
S	Platinum/platinum, 10% rhodium	0 to 1400	6
T	Copper/constantan	−200 to 400	43

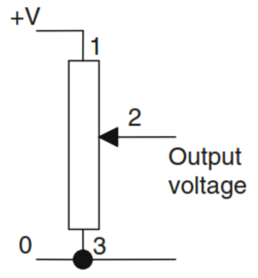
Sensors

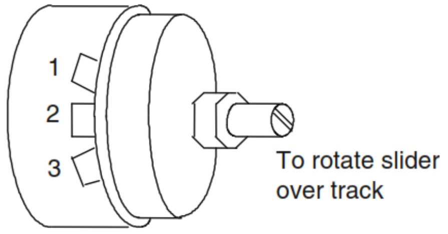
- **Position/Displacement Sensors:** The term position sensor is used for a sensor that gives a measure of the distance between a reference point and the current location of the target, while a displacement sensor gives a measure of the distance between the present position of the target and the previously recorded position.

- Resistive linear and angular position sensors are widely used and relatively inexpensive. These are also called linear and rotary potentiometers.

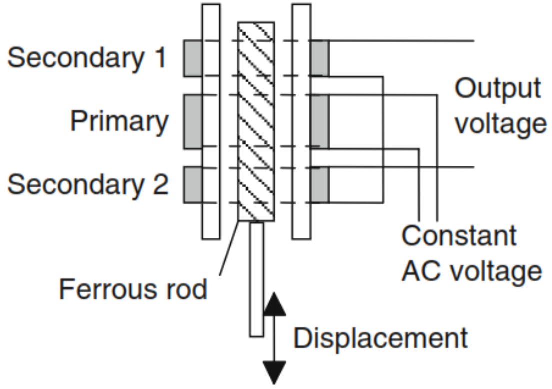
- Another form of displacement sensor is the linear variable differential transformer (LVDT), which gives a voltage output related to the position of a ferrous rod.

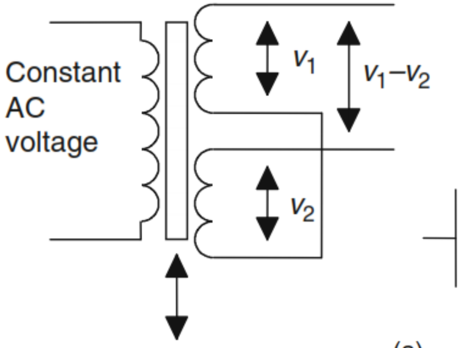
- Capacitive displacement sensors are essentially just parallel plate capacitors. The capacitance will change if the plate separation changes, the area of overlap of the plates changes, or a slab of dielectric is moved into or out of the plates.

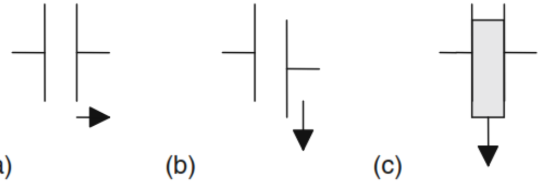




A rotary potentiometer





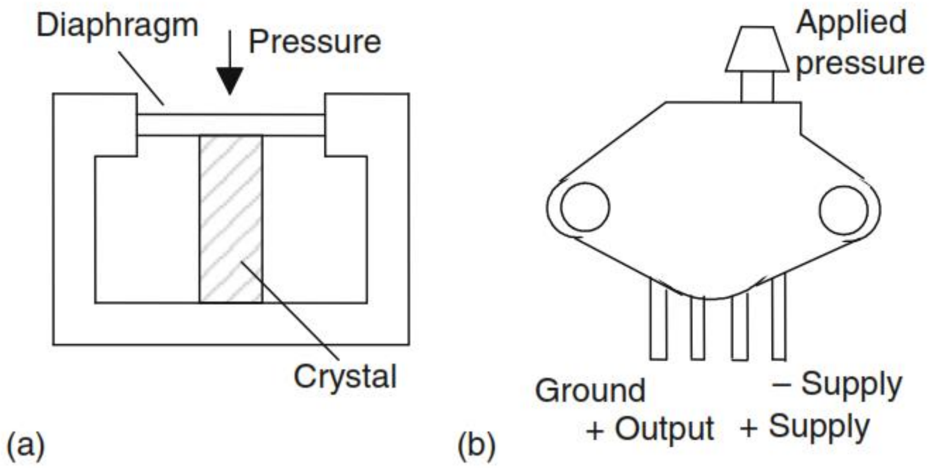


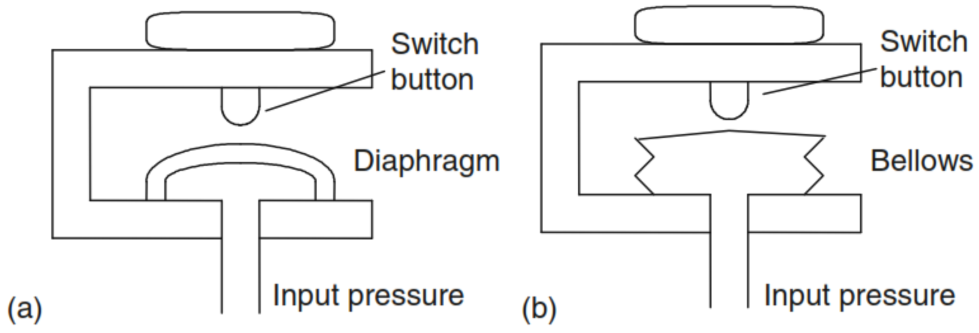
Sensors

- **Pressure sensors** can be designed to give outputs that are proportional to the difference in pressure between two input ports. If one of the ports is left open to the atmosphere, the gauge measures pressure changes with respect to the atmosphere and the pressure measured is known as gauge pressure. The pressure is termed the absolute pressure if it is measured with respect to a vacuum. Commonly used pressure sensors that give responses related to the pressure are diaphragm and bellows types.

- An example of such a sensor is the Motorola MPX100AP sensor (Figure b). This has a built-in vacuum on one side of the diaphragm and so the deflection of the diaphragm gives a measure of the absolute pressure applied to the other side of the diaphragm. The output is a voltage that is proportional to the applied pressure, with a sensitivity of 0.6 mV/kPa.

- Pressure switches are designed to switch on or off at a particular pressure.

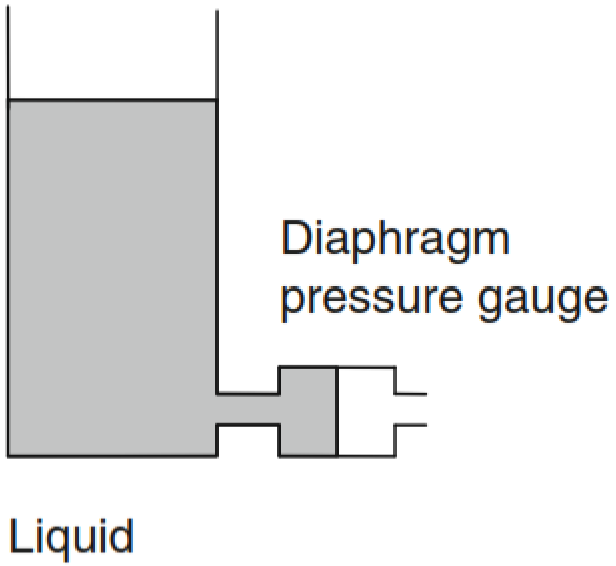


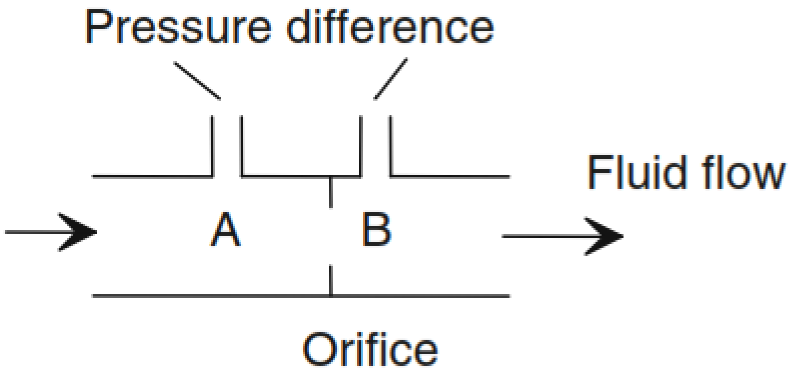


Sensors

- **Liquid-Level Detectors:** Pressure sensors may be used to monitor the depth of a liquid in a tank. Often a sensor is just required to give a signal when the level in some container reaches a particular level. A float switch that is used for this purpose consists of a float containing a magnet that moves in a housing with a reed switch.

- Fluid Flow Measurement A common form of fluid flow meter is one based on measuring the difference in pressure that results when a fluid flows through a constriction. Figure shows a commonly used form, the orifice flow meter. As a result of the fluid flowing through the orifice, the pressure at A is higher than that at B, the difference in pressure being a measure of the rate of flow.

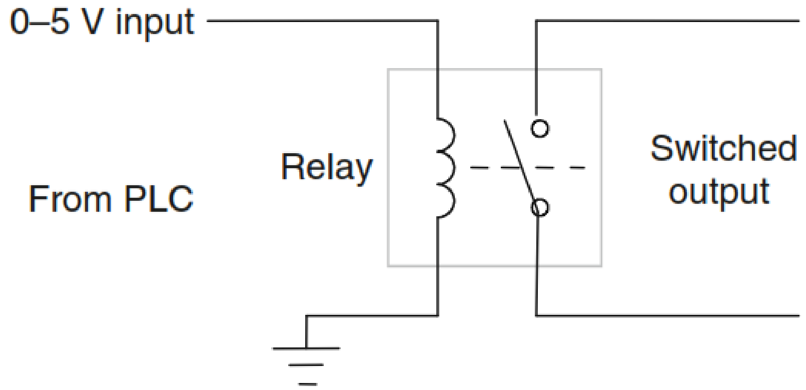




Output Devices

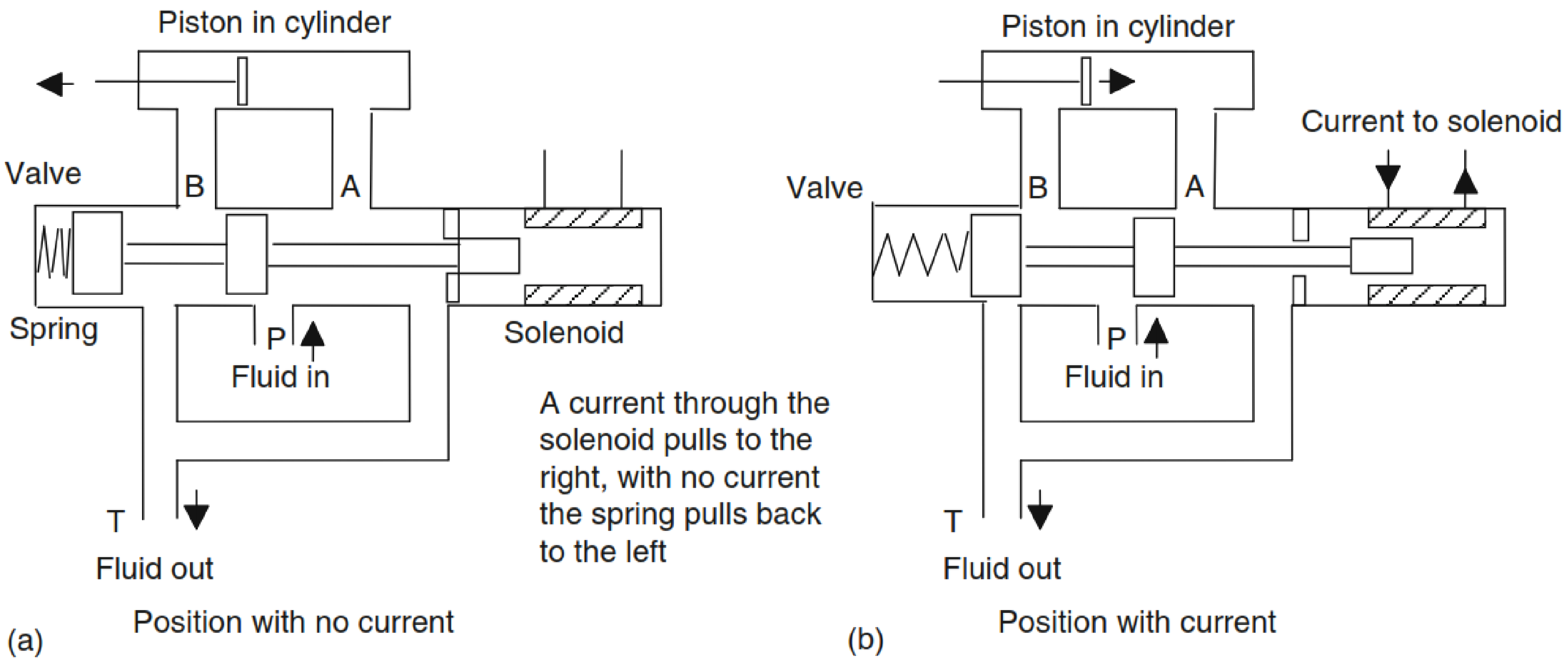
- The output ports of a PLC are relay or optoisolator with transistor or triac, depending on the devices that are to be switched on or off. Generally, the digital signal from an output channel of a PLC is used to control an actuator, which in turn controls some process. The term actuator is used for the device that transforms the electrical signal into some more powerful action, which then results in control of the process.

- **Relay:** When a current passes through a solenoid, a magnetic field is produced; this can then attract ferrous metal components in its vicinity. With the relay, this attraction is used to operate a switch. Relays can thus be used to control a larger current or voltage and, additionally, to isolate the power used to initiate the switching action from that of the controlled power. For a relay connected to the output of a PLC, when the output switches on, the solenoid magnetic field is produced, and this pulls on the contacts and so closes a switch or switches



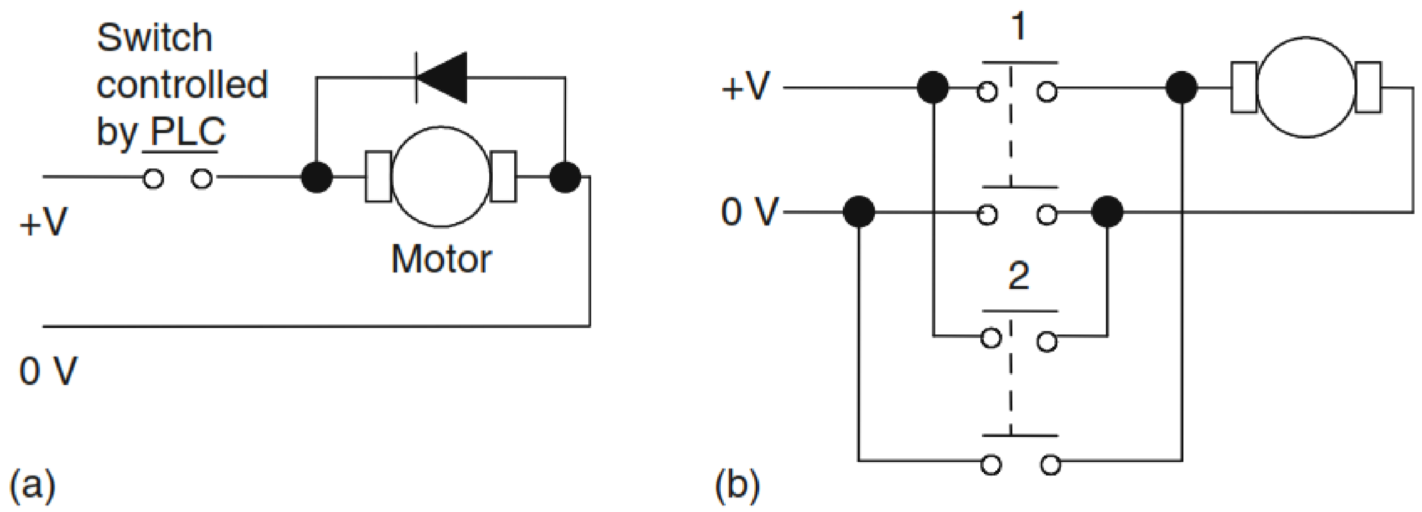
Output Devices

- **Directional Control Valves:** Another example of the use of a solenoid as an actuator is a solenoid operated valve. The valve may be used to control the directions of flow of pressurized air or oil and so used to operate other devices, such as a piston moving in a cylinder. Figure shows one such form, a spool valve, used to control the movement of a piston in a cylinder. Pressurized air or hydraulic fluid is input from port P, which is connected to the pressure supply from a pump or compressor, and port T is connected to allow hydraulic fluid to return to the supply tank or, in the case of a pneumatic system, to vent the air to the atmosphere.



Output Devices

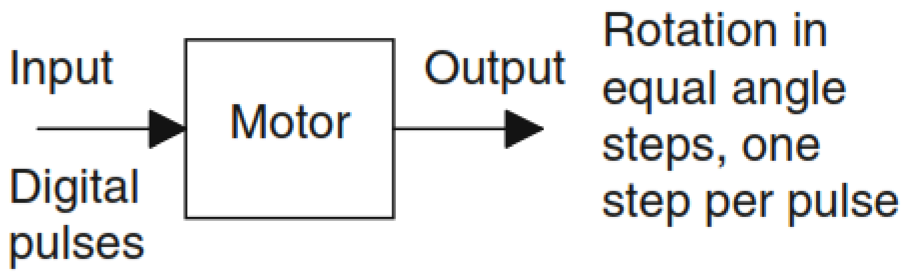
- **Motors:** A DC motor has coils of wire mounted in slots on a cylinder of ferromagnetic material, which is termed the armature. The armature is mounted on bearings and is free to rotate. It is mounted in the magnetic field produced by permanent magnets or current passing through coils of wire, which are called the field coils. When a current passes through the armature coil, forces act on the coil and result in rotation. Brushes and a commutator are used to reverse the current through the coil every half rotation and so keep the coil rotating. The speed of rotation can be changed by changing the size of the current to the armature coil. Many industrial processes only require the PLC to switch a DC motor on or off. This might be done using a relay. Sometimes a PLC is required to reverse the direction of rotation of the motor.

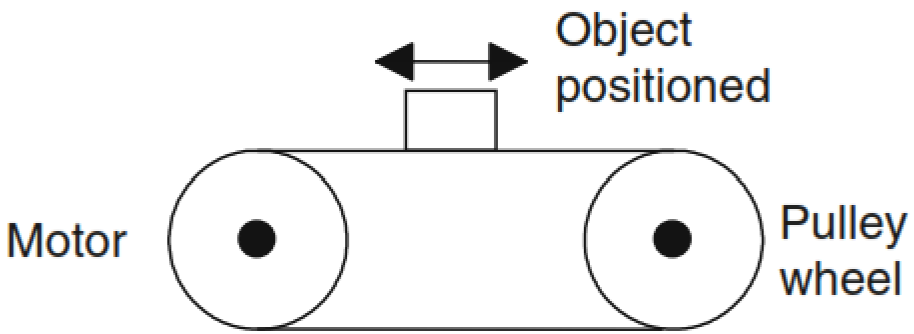


Output Devices

- **The stepper or stepping motor** is a motor that produces rotation through equal angles, the so-called steps, for each digital pulse supplied to its input. Thus, if one input pulse produces a rotation of 1.8 , then 20 such pulses would give a rotation of 36.0 .To obtain one complete revolution through 360 , 200 digital pulses would be required. The motor can thus be used for accurate angular posi ioning.

- If a stepping motor is used to drive a continuous belt, it can be used to give accurate linear positioning. Such a motor is used with computer printers, robots, machine tools, and a wide range of instruments for which accurate positioning is required.





I/O Processing

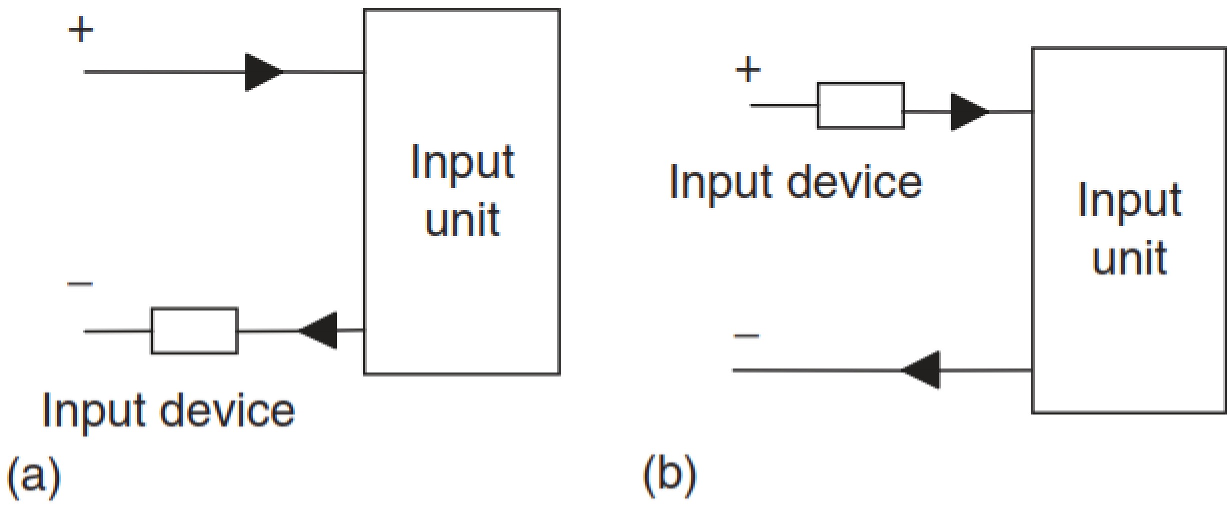
- Input signals from sensors and outputs required for actuating devices can be:
  - Analog. A signal for which the size is related to the size of the quantity being sensed.
  - Discrete. Essentially just an on/off signal.
  - Digital. A sequence of pulses.

- The CPU, however, must have an input of digital signals of a particular size, normally 0 to 5 V.
- The output from the CPU is digital, normally 0 to 5 V.
- Thus there is generally a need to manipulate input and output signals so that they are in the required form.

The input/output (I/O) units of PLCs are designed so that a range of input signals can be changed into 5 V digital signals and so that a range of outputs are available to drive external devices. It is this built-in facility to enable a range of inputs and outputs to be handled that makes PLCs so easy to use.

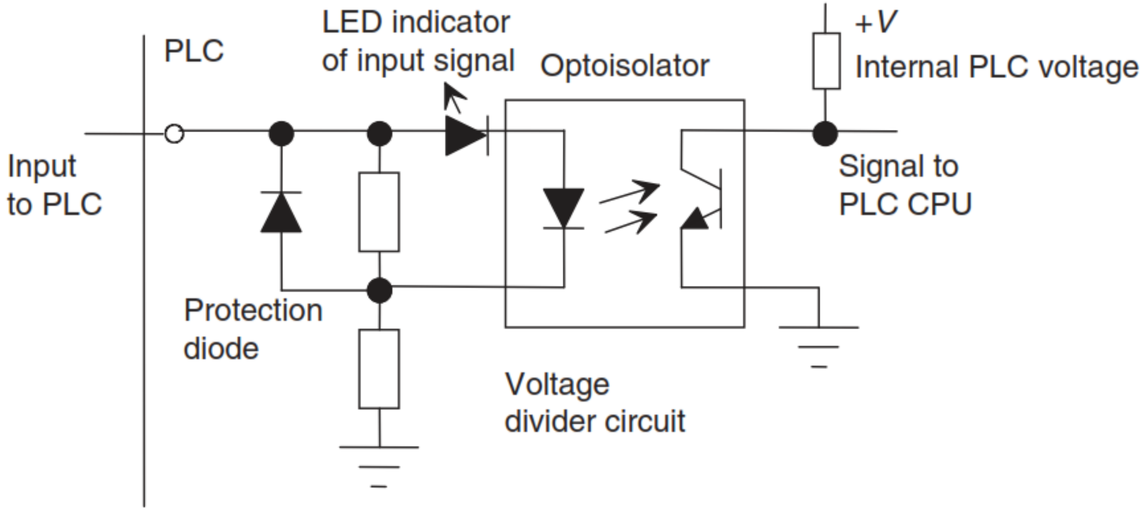
I/O Processing

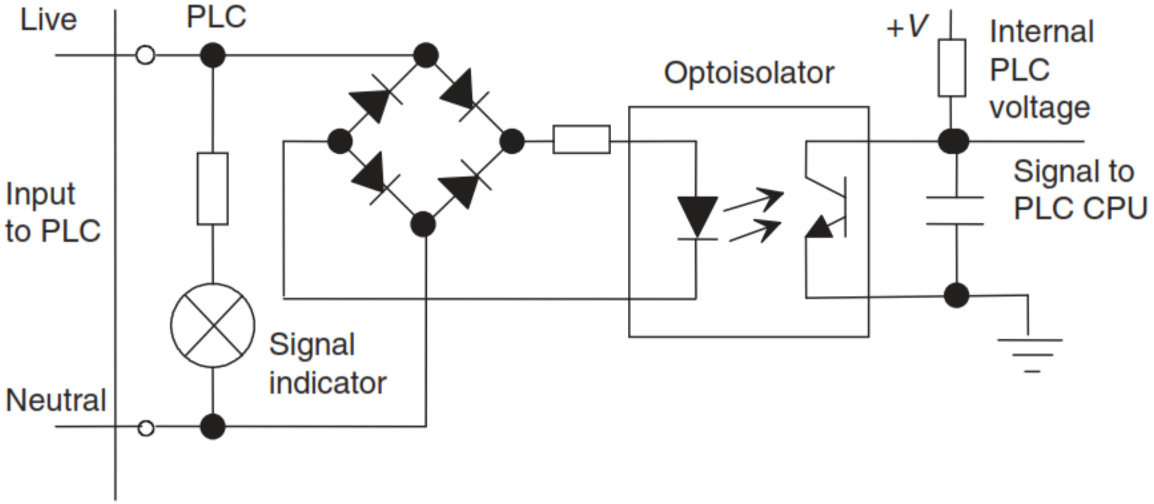
- Input Units: The terms sourcing and sinking refer to the manner in which DC devices are interfaced with the PLC. For a PLC input unit with sourcing, it is the source of the current supply for the input device connected to it (Figure a). With sinking, the input device provides the current to the input unit (Figure b)



I/O Processing

- Figures show the basic input unit circuits for DC and AC inputs. Optoisolators are used to provide protection. With the AC input unit, a rectifier bridge network is used to rectify the AC so that the resulting DC signal can provide the signal for use by the optoisolator to give the input signals to the CPU of the PLC. Individual status lights are provided for each input to indicate when the input device is providing a signal.



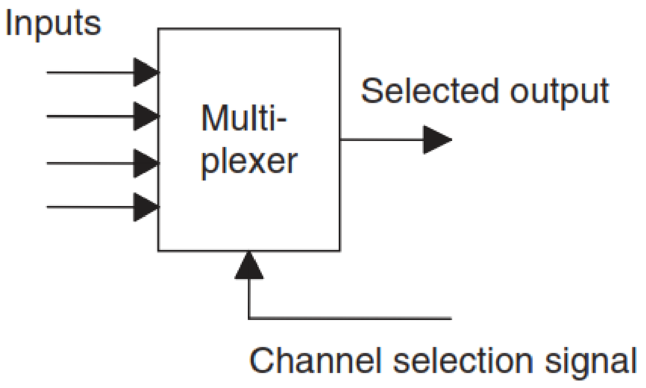


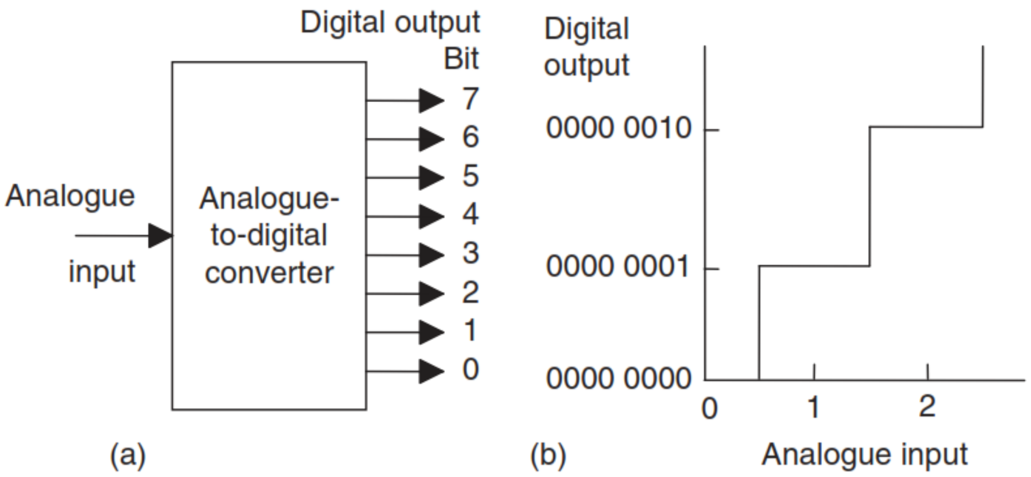
I/O Processing

- When analog signals are inputted to a PLC, the input channel needs to convert the signal to a digital signal using an analog-to-digital converter. With a rack-mounted system this may be achieved by mounting a suitable analog input card in the rack. So that one analog card is not required for each analog input, multiplexing is generally used.

- Figure a illustrates the function of an analog-to-digital converter (ADC). A single analog input signal gives rise to on/off output signals along perhaps eight separate wires. The eight signals then constitute the so-termed digital word corresponding to the analog input signal level. The digital output goes up in steps (Figure 4.5b) and the analog voltages required to produce each digital output are termed quantization levels.

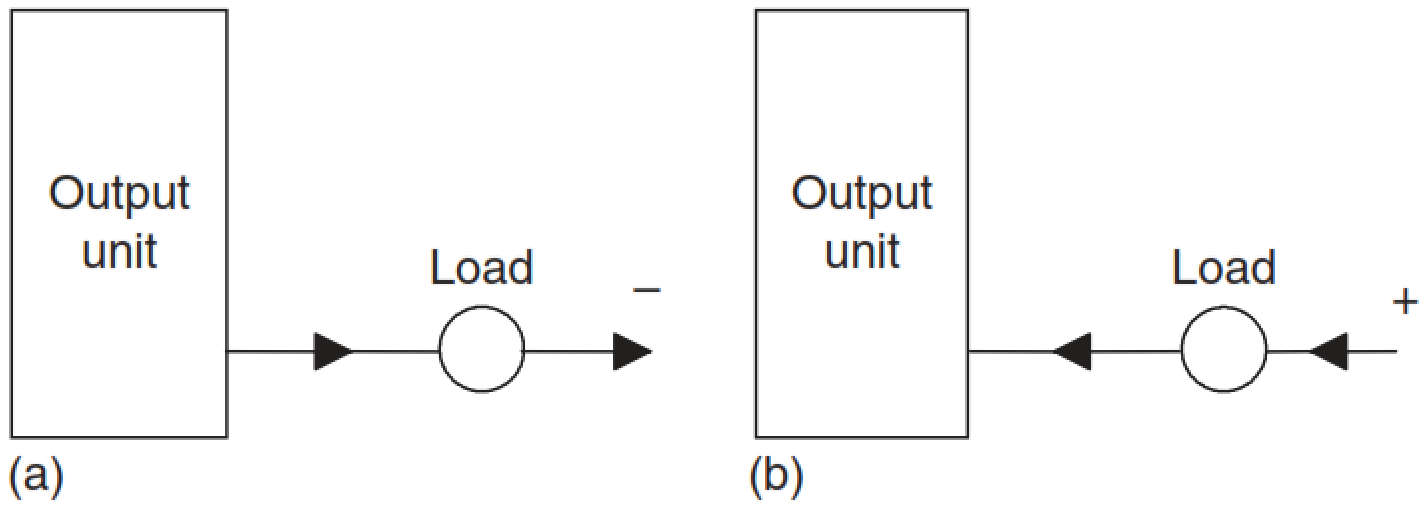
- If the binary output is to change, the analog voltage has to change by the difference in analog voltage between successive levels. The term resolution is used for the smallest change in analog voltage that will give rise to a change in 1 bit in the digital output. With an 8-bit ADC, if, say, the full-scale analog input signal varies between 0 and 10 V, a step of one digital bit involves an analog input change of 10/255 V or about 0.04 V.





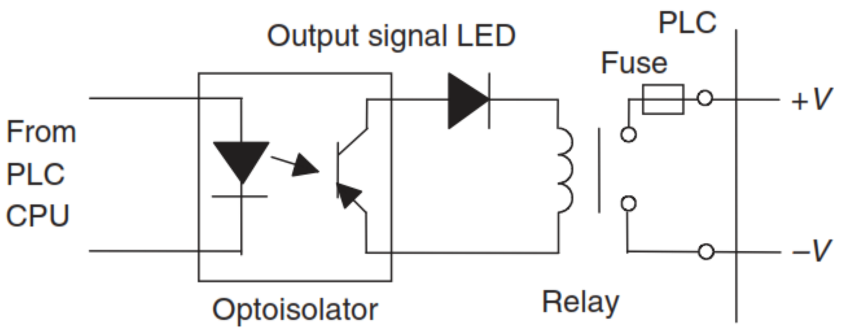
I/O Processing

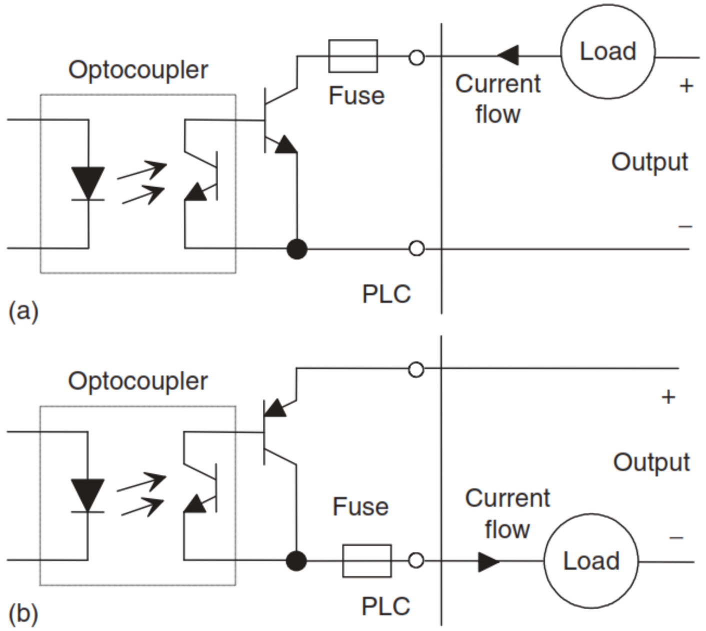
- Output Units: With a PLC output unit, when it provides the current for the output device (Figure a) it is said to be sourcing, and when the output device provides the current to the output unit, it is said to be sinking (Figure b). Quite often, sinking input units are used for interfacing with electronic equipment and sourcing output units for interfacing with solenoids

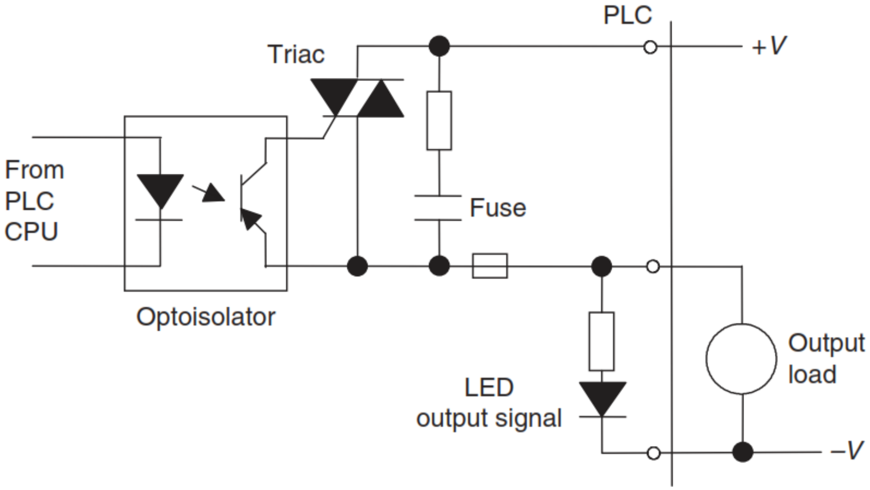


I/O Processing

- Output units can be relay, transistor, or triac. Figures shows the basic form of a relay output unit, a transistor output unit, and a triac output unit.







I/O Processing

- Analog outputs are frequently required and can be provided by digital-to-analog converters (DACs) at the output channel. The input to the converter is a sequence of bits with each bit along a parallel line. Figure shows the basic function of the converter.

- When the digital input changes, the analog output changes in a stepped manner, the voltage changing by the voltage changes associated with each bit. For example, if we have an 8-bit converter, the output is made up of voltage values of 28 ¼ 256 analog steps. Suppose the output range is set to 10 V DC. One bit then gives a change of 10/255 V or about 0.04 V.