

Programmable Logic Controllers

*Hardware and
Programming*

Second Edition

by

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Flow switch:

Switch that opens or closes for a preset flow rate of liquid or gas through a pipe.

Float switch:

Switch used to open and close contacts in response to changes in liquid level.

Foot switch:

Foot-operated switch placed in factory environments in which workers are using both hands.

Limit switch:

Switch that opens or closes when an object contacts the handle of the switch.

Proximity switch:

Switch that consists of a light-emitting diode (LED) and a phototransistor. It opens or closes a circuit when the presence of an object is detected. The object breaks the path of the beam of light between the LED and the phototransistor.

Light-emitting diode (LED):

A diode device that emits light when forward biased. When the LED is forward biased (current flows through it), some of the electric energy is converted to light energy.

Phototransistor:

Device that allows current to flow from its collector to the emitter when a beam of light strikes its base.

Flow switches are set to detect specific flow rates. For flow rates above the set point, the normally open flow switch closes and the normally closed flow switch opens. Flow switches are generally placed in pipes and in the heating, ventilation, and air conditioning (HVAC) air ducts.

Float switches are used to open and close contacts in response to changes in liquid level. Float switches are used in water treatment plants, wastewater treatment plants, and storage tanks.

Foot switches can be used as emergency or contact switches. They are placed in factory environments in which workers are using both hands.

Limit switches and proximity switches are used to detect parts in a process or manufacturing system. The **limit switches** are physically touched by the part. They open or close when objects, such as moving parts on a conveyor, physically hit their actuator, which is projected outward. A limit switch consists of an actuator that is mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection. Limit switches are used in a variety of applications for detecting the presence of parts.

Proximity switches use a light-emitting diode (LED) and a phototransistor. The **light-emitting diode** is the transmitter that generates an infrared light beam. The **phototransistor** is the receiver that detects the presence of the light beam. The switch is triggered when the light beam is interrupted by the objects placed in the light beam's path. **Figure 4-5** shows a photo-based proximity switch.

Light transmitters and receivers for a proximity switch can be placed in two separate housings or be packaged in a single housing unit. When they have a separate housing, they are placed on the opposite sides of a conveyor. When they are in a single housing unit, a reflector is placed on the opposite side of the conveyor. **Figure 4-6** displays two types of proximity sensors and their application for detecting parts in a process control system. In both cases, the light beam is interrupted by the moving parts.



4.3 Sensors

Electronic sensors are used in PLC control systems to detect changes in the environment and industrial settings. There are sensors in the market that can emulate the five human senses and convert the changes to electronic signals. **Table 4-1** shows a partial list of comparison of human senses and electronic sensors. Signals from these sensors are modified by electronic signal conditioning circuits prior to input to the PLC devices. Electronic conditioning circuits consist of integrated circuits (ICs) and operational amplifiers (op amps). **Figure 4-7** illustrates one example of how a sensor is used in a PLC control system.

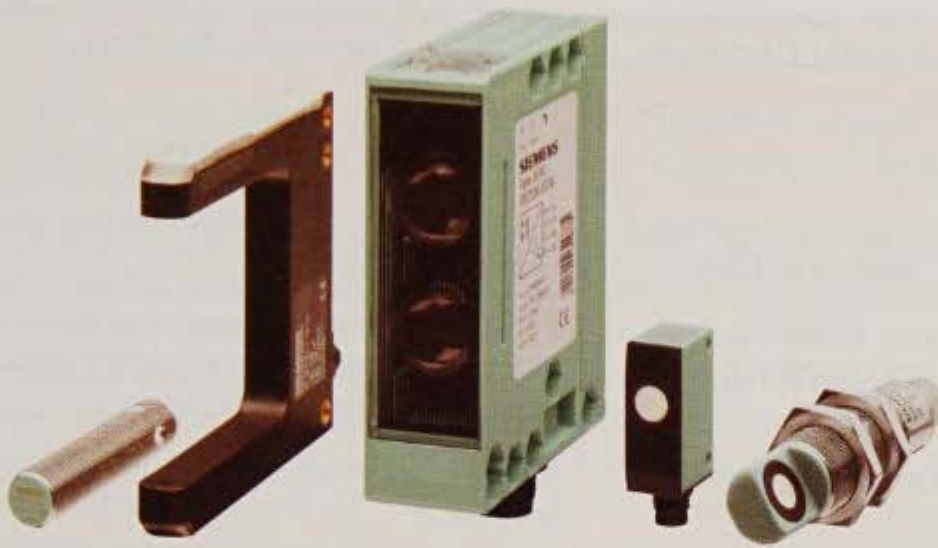


Figure 4-5. A photo-based proximity switch. (Siemens)

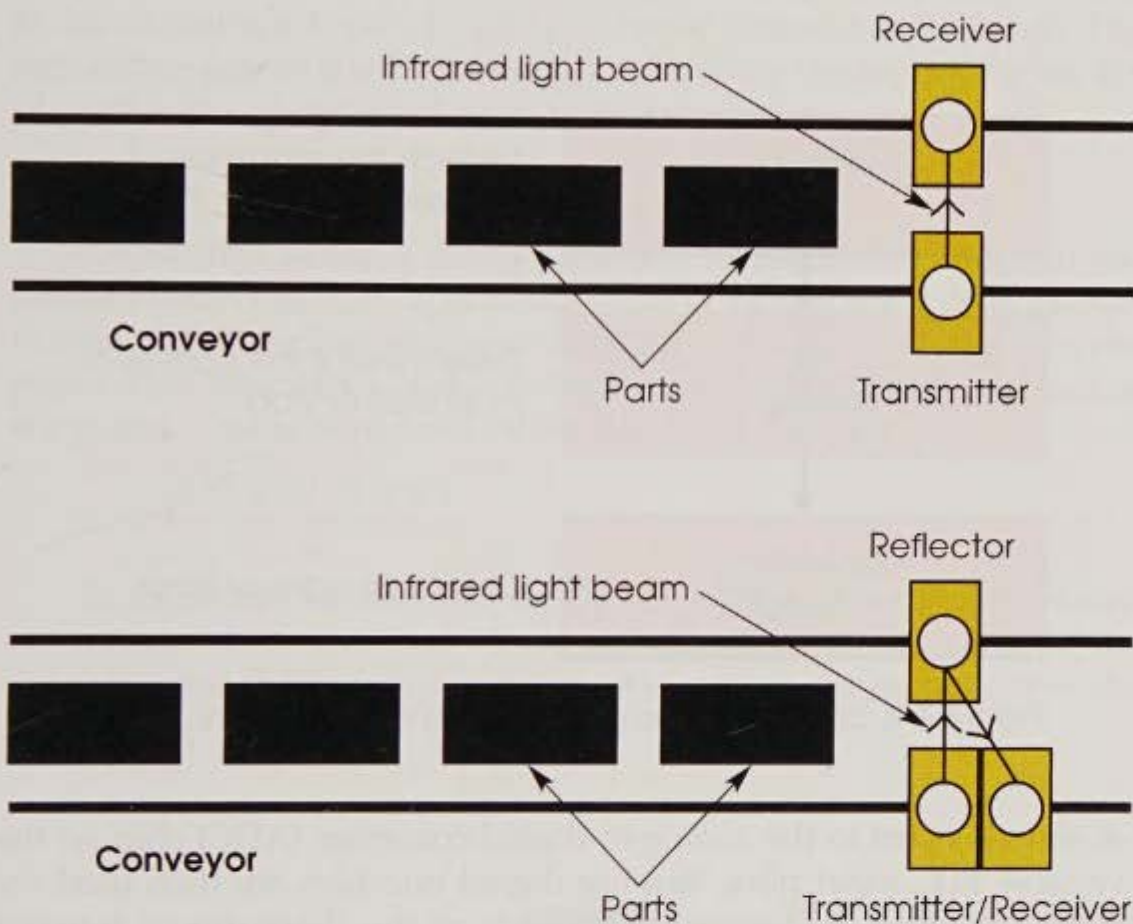


Figure 4-6. Use of proximity sensors to detect a part on a conveyor.

Electronic sensor output in its simplest form provides logic high or low output. This two-state sensor signal can then be sent to the discrete PLC input ports to signal the existence of an object or normal operating environment for the system. The signal from electronic sensors can also provide a range of current or voltage levels. This type

Human Senses	Environmental Changes	Electronic Sensors
Sight	Light, size, shape, detection, being near or far, and color	Photoelectric sensor, laser sensor, infrared light sensor, and TV camera
Hearing	Loudness of sound, high and low tones, and vibrations	Microphone, sonic level sensor, and wave level sensors
Touch	Temperature, pressure humidity, and contact	Proximity sensor, thermometer vibration sensor, electrostatic sensor, and electromagnetic sensor
Taste	Sweet, sour, bitter, hot or cold, and salty	Sugar level measurer and temperature sensors
Smell	Chemical gas presence	Gas detector and alcohol detector

Table 4-1. Comparison of human senses and electronic sensors.

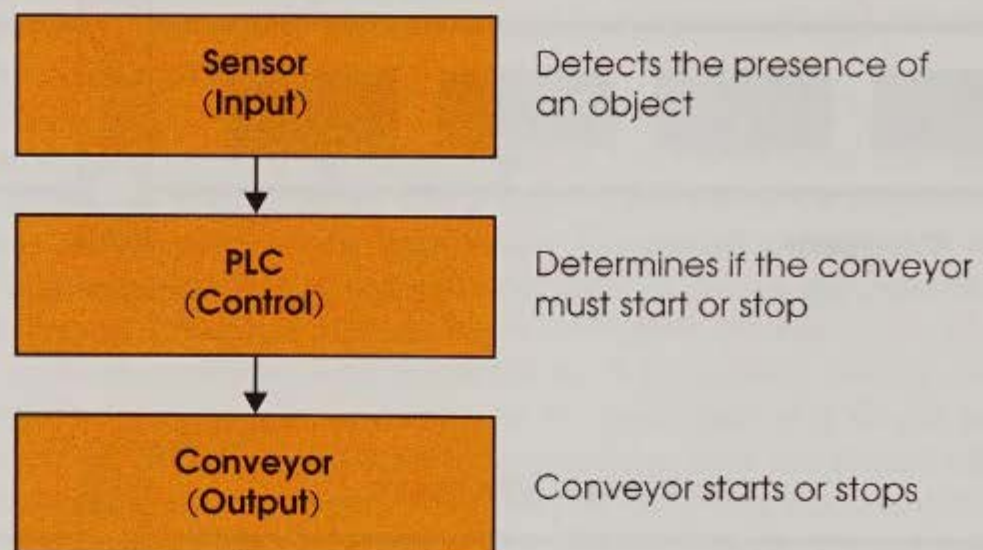


Figure 4-7. Basic operation of a sensor in a PLC system.

of signal is sent to the analog-to-digital converter (ADC) chip on the variable PLC input port. Varying digital numbers are then used for more advanced PLC instructions such as the Proportional Integral Derivative (PID) instruction. There are several textbooks available in the market on instrumentation and sensor topics. In this chapter, we will briefly describe a few of the more commonly used sensors in a PLC control system.

Proximity Sensors

Proximity sensor:
Sensor that can detect the existence of an object.

Proximity sensors, similar to limit switches, can detect the existence of an object. The difference is that an electronic signal is used with the proximity sensor to detect an object. Therefore, the object

does not have to be touched. Proximity sensors can only have a state that is either true or false. They can either be inductive-, capacitive-, or optical-type sensors.

Inductive Sensors

Inductive sensors detect the presence of currents induced by magnetic fields to detect nearby metallic objects. This phenomenon was proved by Faraday in the 1800s. An inductive sensor uses a coil to generate a magnetic field. If there is a moving metal object near the magnetic field, current will flow into the object. This current flow in the object will in turn generate another magnetic field that opposes the original magnetic field, **Figure 4-8**. This results in a change of inductance value of the coil in the sensor. The change of a coil's inductance can be interpreted to see if the object is within close proximity of the sensor. Note that the induced current in the object depends on the type of metal within that object. Therefore, these sensors can be used to detect multiple types of metals and send different signal levels. The signals are sent to the PLC through its variable input port. Figure 4-8 illustrates the operation of an inductive sensor.

Inductive sensor:

Sensor that detects the presence of currents induced by magnetic fields to detect nearby metallic objects.

Capacitive Sensors

Capacitive sensors detect an object through the change in the sensor's dielectric. The capacitance value of a capacitor is directly proportional to the plate area and dielectric constant used between the plates. The capacitance is also inversely proportional to the distance of the plates. This is illustrated by the following formula:

$$C = \frac{(8.85 \times 10^{-12}) A \times k}{d}$$

In capacitive sensors, the area of the plates (A) and the distance (d) between them are fixed. However, the dielectric constant (k) of the space around them varies as different materials are brought near the

Capacitive sensor:

Sensor that detects an object through the change in the sensor's dielectric.

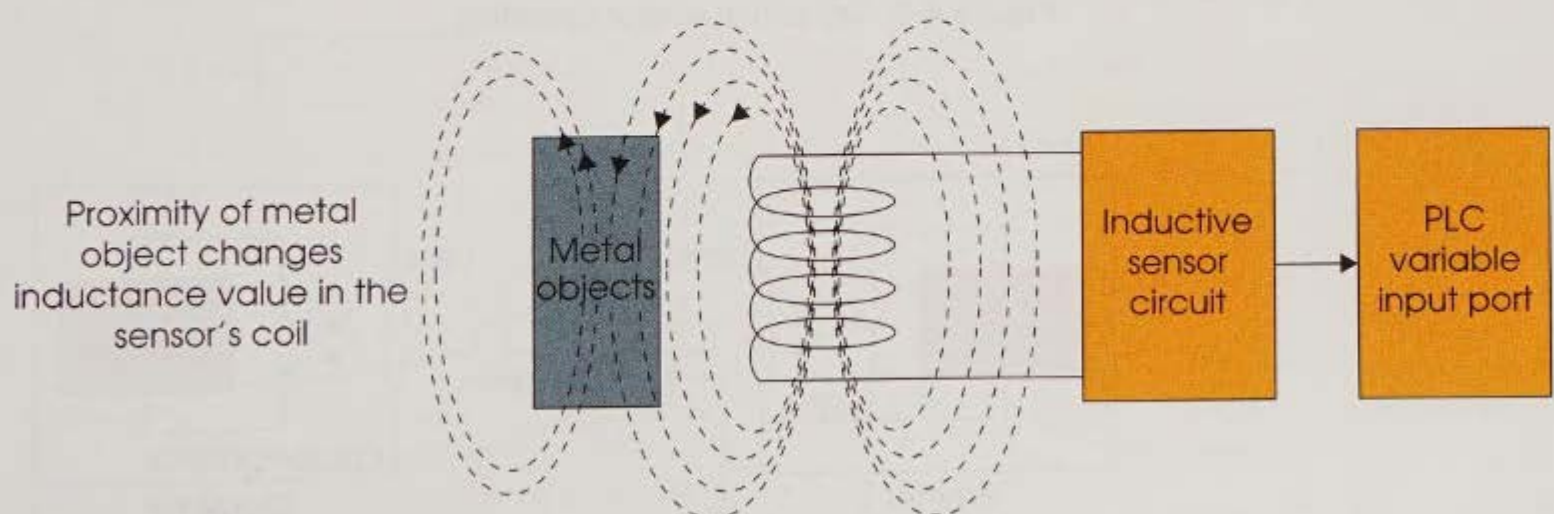


Figure 4-8. Inductive sensor operation.

sensor. The dielectric k is a constant value that depends on the material used to isolate the capacitor plates. An oscillator is used to generate the electric field to determine the capacitance of the plates. Notice that unlike the inductive sensor, the moving object does not have to be metallic to be detected by the capacitive sensor. **Figure 4-9** illustrates the operation of a capacitive sensor.

Optical Sensors

Optical sensors can use visible, ultraviolet, infrared, or laser lights. Modern optical sensors are very sophisticated and can even detect the type of object according to the intensity of the reflected light from the object's surface. Optical sensors require both an emitter to generate the light beam and a detector. **Figure 4-10** illustrates the operation of a basic optical sensor.

Emitters are used to generate light beams in the visible and invisible spectrums using light-emitting diodes (LEDs) and laser diodes. Detectors are typically built with photodiodes or phototransistors. Notice that the emitter and detector in Figure 4-10 are positioned to

Capacitive sensor measures the distance between the object and the sensor

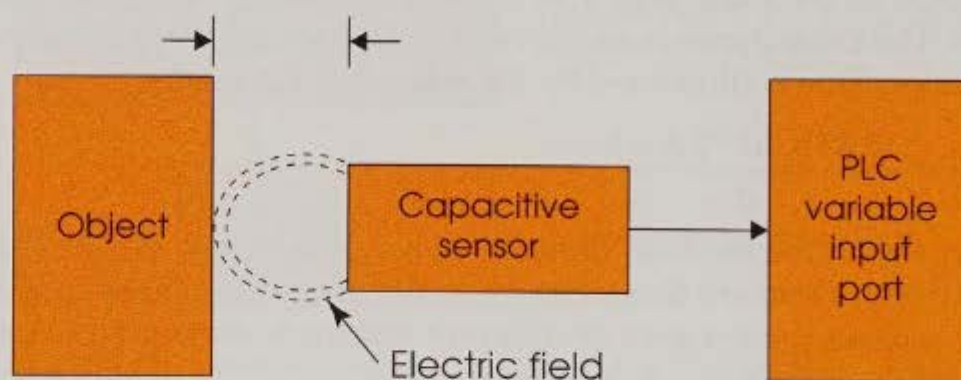


Figure 4-9. Capacitive sensor operation.

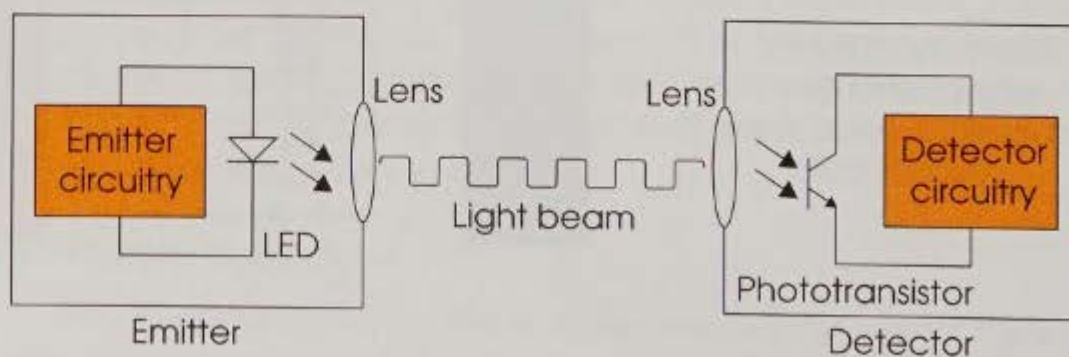


Figure 4-10. Optical sensor operation.

detect an object when it blocks the light beam. You can mount the emitter and detector on opposite sides of a conveyor or on the same side of a conveyor if a reflector is used on the opposite side.

Hall Effect Sensors

Hall effect sensors are basically semiconductor devices (transistors) that can be switched by magnetic fields. Their applications are very similar to those of reed switches and relays, but because they are solid state, they tend to be more rugged and resist vibration. Automated machines often use these to complete the initial calibration and then detect end stops.

In reed switches and relays, contacts are closed or open due to magnetic pull. A relay's magnetic push or pull is produced by a wired coil that is energized. The reed switch's operation is similar to a relay's operation, except a permanent magnet instead of a wire coil is used to produce the magnetic push or pull. When the magnet is far away, the switch is open, but when the magnet is brought near, the switch is closed. **Figure 4-11** illustrates how an open switch is closed when a permanent magnet is brought near the switch.

Hall effect sensor:

Semiconductor device (transistor) that can be switched by magnetic fields.

Ultrasonic Sensors

Ultrasonic sensors produce sound above the normal human hearing threshold of 16 kHz and use this sound to detect the distance to an object. The time that is required for the sound to travel to the target and reflect back is proportional to the distance to the target. Ultrasonic sensors are relatively accurate for short distances and are economical.

Ultrasonic sensor:

Sensor that produces sound above the normal human hearing threshold of 16 kHz and uses this sound to detect the distance to an object.

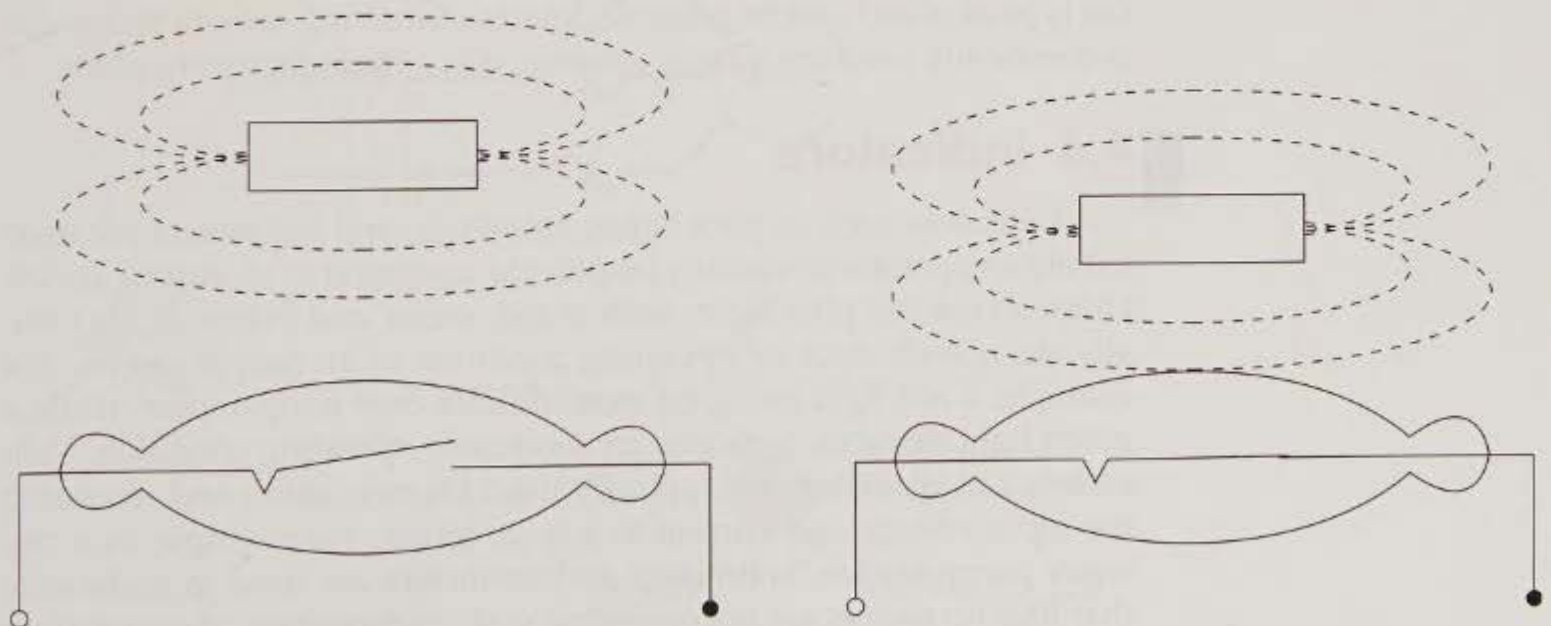


Figure 4-11. Reed switch.

Electrostatic ultrasonic sensor:

A sensor that uses capacitive effects where a short sound wave is transmitted to hit an object.

Piezoelectric ultrasonic sensor:

A sensor that works using charge displacement strain on crystal lattices where a reflected sound wave hits a crystal and the crystal produces a small AC voltage signal.

Radio Detection and Ranging (RADAR) sensor:

Sensor used to detect metallic objects where there are several cycles of high-frequency waves transmitted into the environment and the reflection is picked up via a receiver.

Two commonly used ultrasonic sensors are electrostatic and piezoelectric types. *Electrostatic ultrasonic sensors* use capacitive effects. A short sound wave is transmitted to hit an object. The frequency of the sound wave is typically limited to around 50 kHz. The reflected wave from the object then hits the back of the movable plate of a capacitor. The movement of this capacitor plate changes the capacitance, and this change is measured. Electrostatic ultrasonic sensors have longer ranges and wider bandwidths than piezoelectric ultrasonic sensors, but are more sensitive to factors such as humidity.

Piezoelectric ultrasonic sensors work by charge displacement strain on crystal lattices. When the reflected sound wave hits a crystal, the crystal produces a small AC voltage signal. This signal is then measured. The frequency of the sound wave can be up to 1 MHz. These sensors are rugged and inexpensive and can be very effective for applications such as fluid levels in tanks and crude distance measurement.

RADAR Sensors

Radio Detection and Ranging (RADAR) sensors are used to detect metallic objects. Several cycles of high-frequency waves are transmitted into the environment and the reflection is picked up via a receiver. The speed of traveling waves is too fast to use RADAR in factory for object detection.

Cameras and Object Recognition Software

A moving camera can be used to record the image of an object at different locations and to save the images in a computer. First, the camera records the image of an object, and then the camera is moved to the other sides of an object to record the image points. These images are then used by a computer's object recognition software to identify the type of object and its possible defects. A moving camera technique is commonly used for quality assurance in a manufacturing plant.



4.4 Indicators

Indicators such as pilot lights, ammeters, and voltmeters are used to help an operator to visually inspect the operation of an output device. Different colored pilot lights such as red, green, and yellow lights visually show each stage or operating condition of an output device. For example, a red light being on may indicate over-temperature, while a green light being on indicates an acceptable operating condition. Voltmeters and ammeters are typically used for measuring and recording the input voltage and current to a large motor. For example, in a city water pump station, voltmeters and ammeters are used to make sure that 1000 hp motors are not operating with undervoltage or overcurrent condition. These abnormal operating conditions will eventually damage the motors.