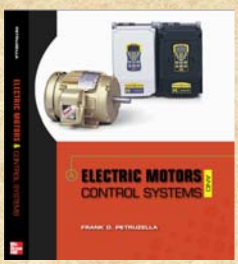
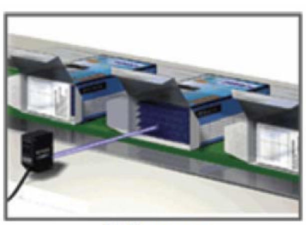


Chapter 4

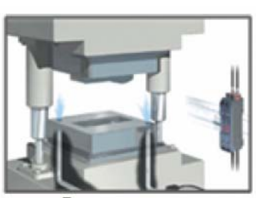
Motor Control Devices

PART 3 Sensors

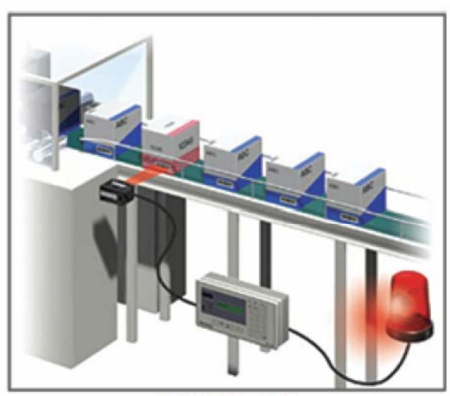
Sensors **are are used to detect, and often to measure, the magnitude of something. They basically operate by converting mechanical, magnetic, thermal, optical, and chemical variations into electric voltages and currents.**



Light sensor



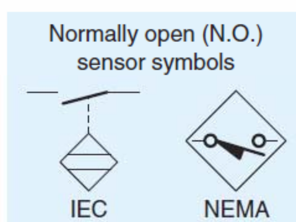
Pressure sensor



Bar code sensor

PROXIMITY SENSORS

Proximity sensors **detect the presence of an object (usually called the target) without physical contact.**

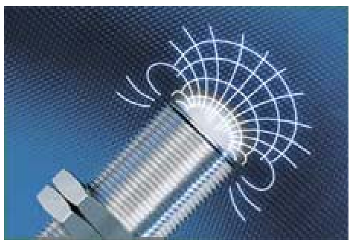


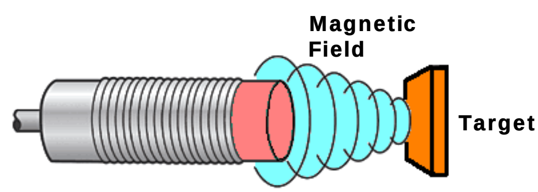
Proximity sensors are available in various sizes and configurations to meet different application requirements.

These electronic sensors that are completely encapsulated to protect against excessive vibration, liquids, chemicals, and corrosive agents found in the industrial environment.

Proximity sensors operate on different principles depending on the type of matter being detected. When an application calls for non-contact *metallic target* sensing an *inductive type* proximity sensor is used.

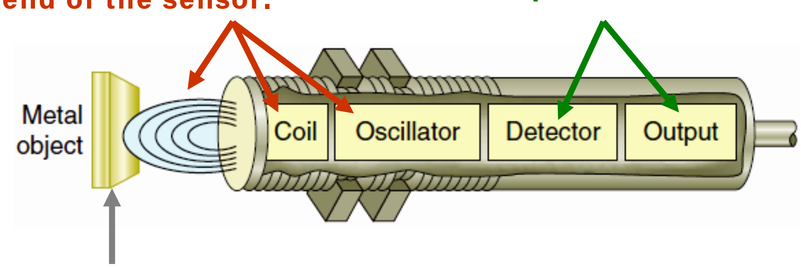
Inductive proximity sensors **operate under the electrical principle of inductance where a fluctuating current induces an electromotive force (emf) in a target object.**





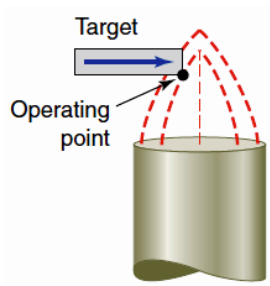
The oscillator circuit generates a high-frequency electromagnetic field that radiates from the end of the sensor.

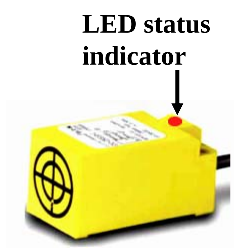
The sensor's detection circuit monitors the oscillator's strength and triggers a solid state output at a specific level.

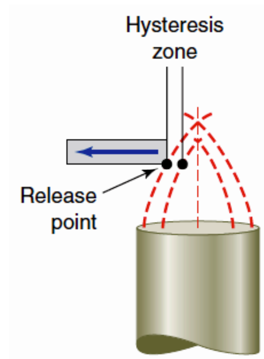


When a metal object enters the field eddy currents on the object absorb some of radiated energy from the sensor, resulting in a loss of energy and change of strength of the oscillator.

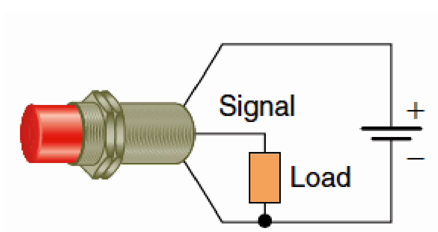
The type of metal and size of the target are important factors that determine the effective sensing range of the sensor. ***Ferrous metals*** may be detected up to ***2 inches*** away while most ***non-ferrous*** metals require a shorter distance usually ***within an inch*** of the of the device.

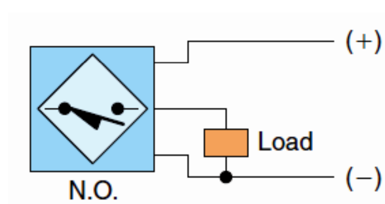




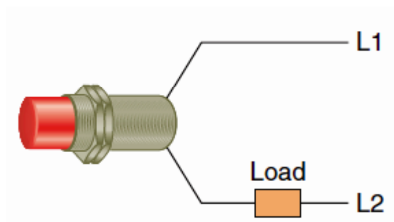


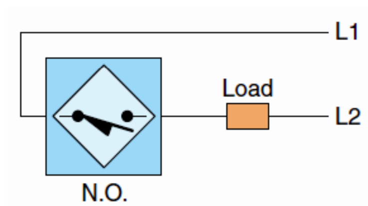
The ***three-wire DC*** proximity sensor has the positive and negative line leads connected directly to it. When the sensor is actuated the circuit will connect the signal wire to the positive side of the line if operating normally-open. If operating normally-closed the circuit will disconnect the signal wire from the positive side of the line.



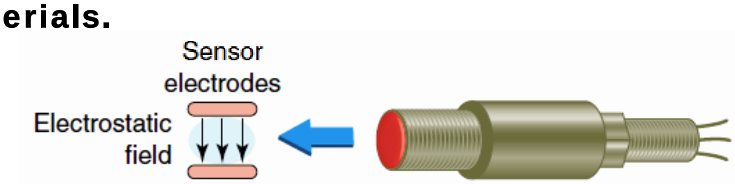


The ***2-wire*** **proximity sensor is manufactured for either AC or DC supply voltages. In the *off* state enough current must flow through the circuit to keep the sensor active. This off state current is called leakage current and typically may range from 1 to 2 milliamps. When the switch is actuated it will conduct the normal load circuit current.**

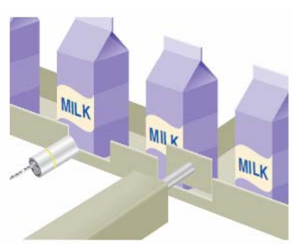




Unlike inductive proximity sensors *capacitive proximity sensors* produce an electrostatic field instead of an electromagnetic field and are actuated by both *conductive and non-conductive* materials.

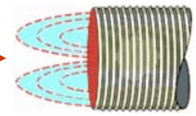


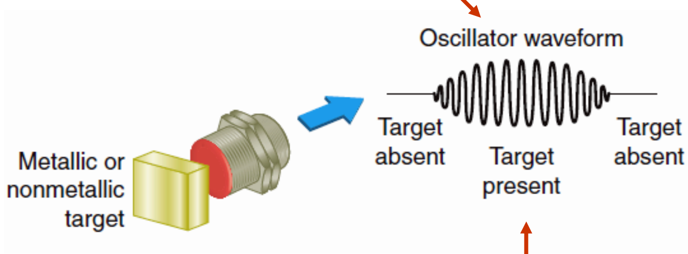
Capacitive proximity sensors resemble inductive types in appearance



Liquid detection

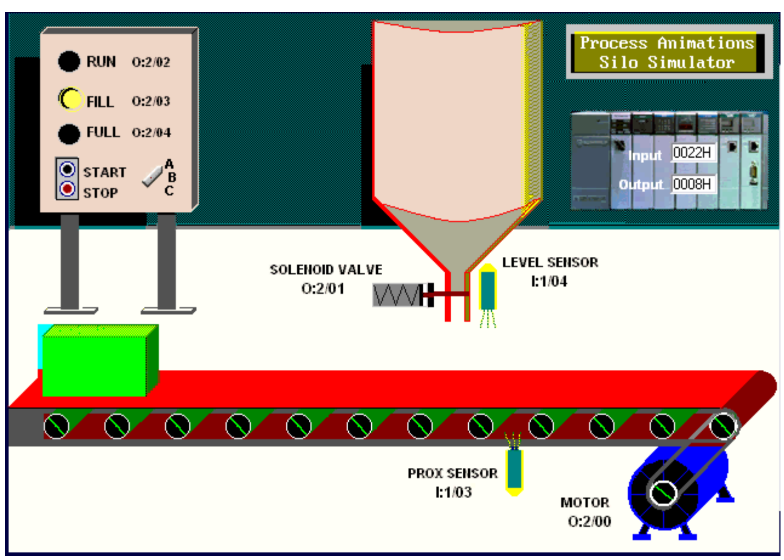
Capacitive sensors contain a *high frequency oscillator* along with a sensing surface formed by two metal electrodes





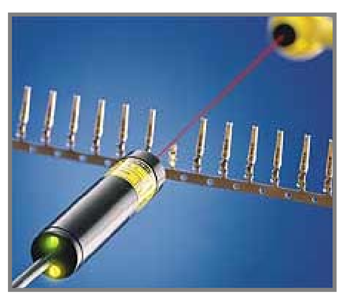
When the target is present it changes the capacitance of the oscillator. As a result, the oscillator circuit begins oscillating and changes the output state of the sensor

Proximity Position And Level Sensors



PHOTOELECTRIC SENSORS

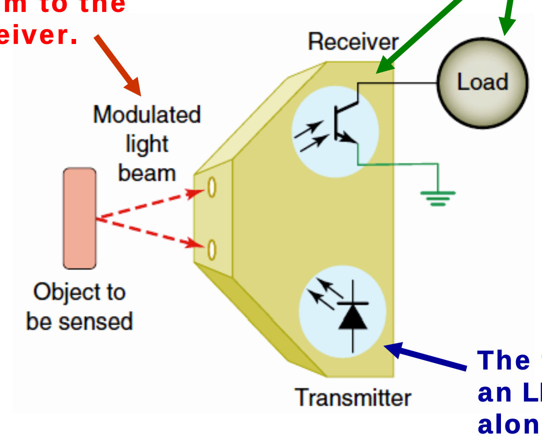
A *photoelectric sensor* is an optical control that detects a visible or invisible beam of light, and responds to a change in the received light intensity.



Photoelectric sensors are composed of two basic components: a transmitter (light source) and a receiver (sensor). These two components may or may not be housed in separate units.

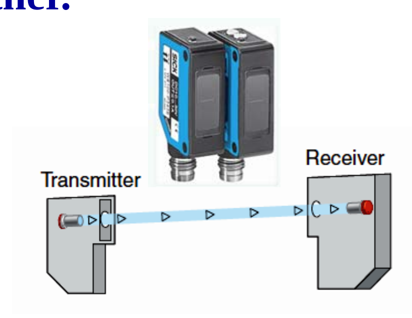
The transmitter sends the modulated light beam to the receiver.

The receiver decodes the light beam and switches the output device which interfaces with the load.

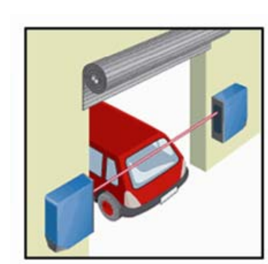


The transmitter contains an LED light source along with an oscillator that modulates the LED on and off at a high rate of speed.

The *through-beam* scan technique place the transmitter and receiver in direct line with each other.

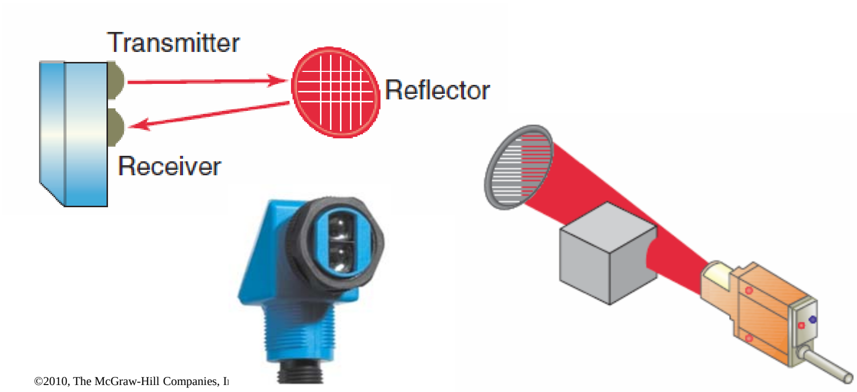


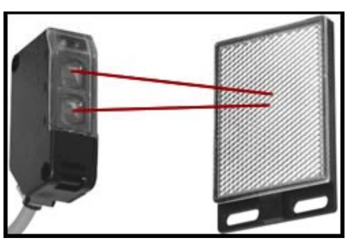
The object to be detected placed in the path of the light beam blocks the light to the receiver and causes the receiver's output to change state.



Because the light beam travels in only one direction, through-beam scan provides long-range sensing. The maximum sensing range is about 300 feet.

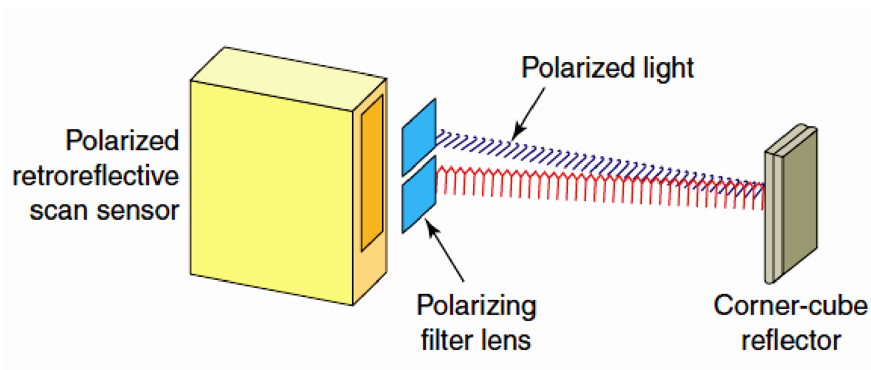
In a *retroreflective* scan the transmitter and receiver are housed in the same enclosure. This arrangement requires the use of a separate *reflector or reflective tape* mounted across from the sensor to return light back to the receiver.



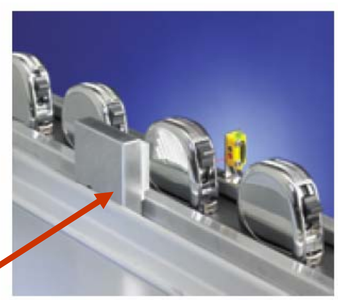


The retroreflective scan technique is designed to respond to objects which interrupt the beam normally maintained between the transmitter and receiver

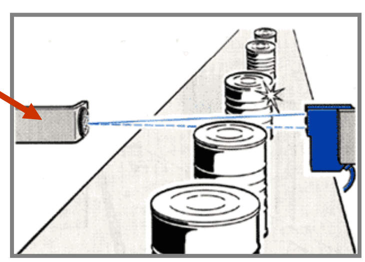
Retroreflective scan sensors may not be able to detect shiny targets because they tend to reflect light back to the sensor. A variation of retroreflective scan, the is *polarized retroreflective scan sensor* is designed to overcome this problem.



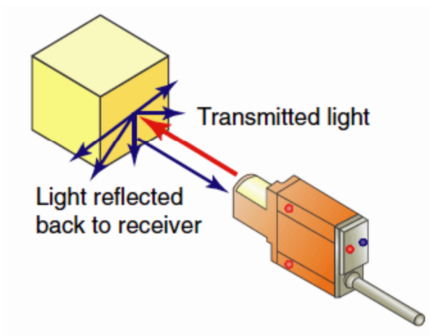
In a polarized retroreflective sensor *polarizing filters* are placed in front of the emitter and receiver lenses. The polarizing filter projects the emitter's beam in one plane only. As a result, this light is considered to be polarized.



A corner-cube reflector must be used to rotate the light reflected back to the receiver.



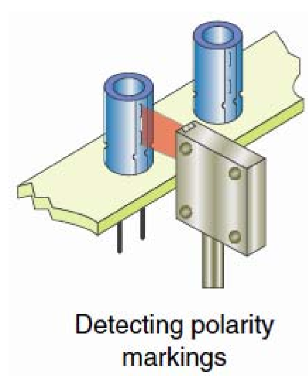
In a *diffuse scan* sensor the transmitter and receiver are housed in the same enclosure, but unlike similar retroreflective devices, they do not *rely on any type of reflector* to return the light signal to the receiver.



The light from the transmitter strikes the target and the receiver picks up some of the diffused (scattered) light. When the receiver receives enough reflected light the output will switch states.

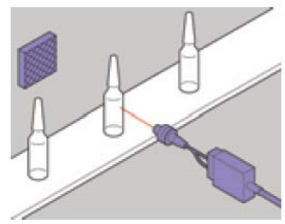
Diffuse Scanning

The sensitivity of the sensor may be set to simply detect an object or to detect a certain point on an object that may be more reflective. Often this is accomplished using various colors with different reflective properties.



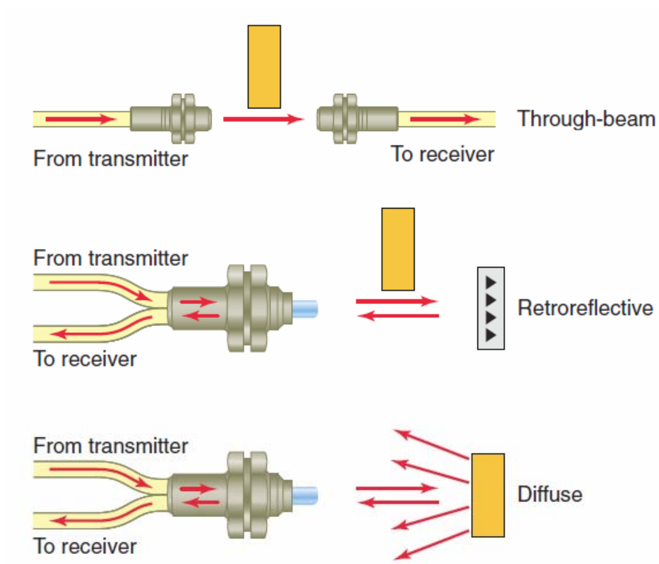
Fiber optics **is not a scan technique, but another method for transmitting light. Fiber optic sensors use a flexible cable containing tiny fibers that channel light from emitter to receiver.**

- **Fiber optic sensors systems are completely immune to all forms of electrical interference.**
- **Optical fiber only carries light means that there is no possibility of an electrical spark.**
- **They can be routed through extremely tight areas to the sensing location.**



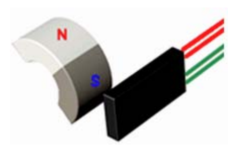
- **Certain fiber optics, particularly the glass fibers, has very high operating temperatures (450°F and higher).**

Fiber optics can be used with thru-beam, retroreflective scan, or diffuse scan sensors

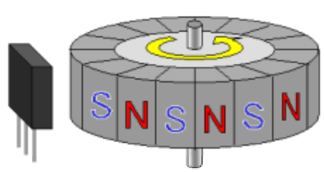


HALL EFFECT SENSORS

Hall effect sensors **are used to detect the proximity and strength of a *magnetic field*. They are constructed from a small, thin, flat slab of semiconductor material.**



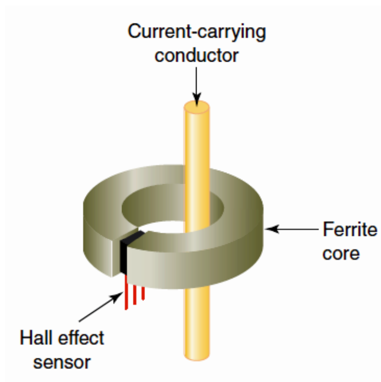
Hall Effect IC



A permanent magnet or electromagnet is used to trigger the sensor *on* and *off*. The sensor is *off* with no magnetic field and triggered *on* in the presence of a magnetic field.

Analog type Hall effect **sensors put out a continuous signal proportional to the sensed magnetic field.**

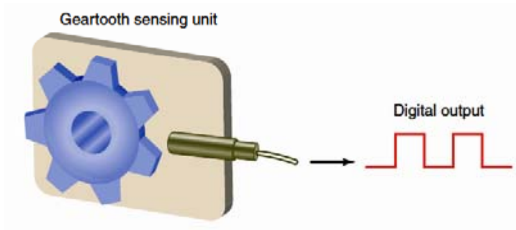
An analog linear Hall effect sensor may be used in conjunction with a split ferrite core. The magnetic field across the gap sawed in the ferrite core is proportional to the current through the wire, and therefore, the voltage reported by the Hall effect sensor will be proportional to the current.



Clamp-on ammeters that can measure *both AC and DC current* use a Hall effect sensor to detect the DC magnetic field induced into the clamp. The signal from the Hall effect device is then amplified and displayed.

AC/DC clamp-on ammeter

Digital type Hall effect devices are used in magnetically operated proximity sensors.

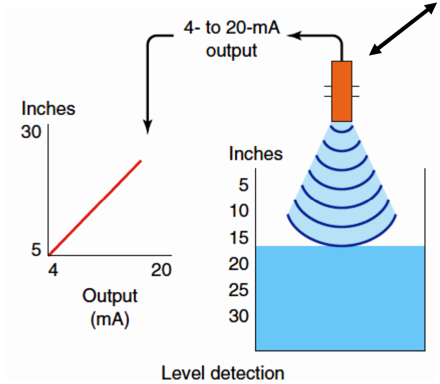


- When the sensor is aligned with the rotating ferrous gear tooth, the magnetic field will be at its maximum strength.
- When the sensor is aligned with the gap between the teeth the strength of the magnetic field is weakened.
- Each time the tooth of the target passes the sensor, the digital Hall switch activates, and a digital pulse is generated.
- By measuring the frequency of the pulses, the shaft speed can be determined.

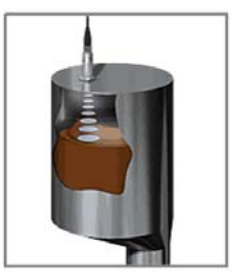
ULTRASONIC SENSORS

An *ultrasonic sensor* operates by sending high frequency sound waves toward the target and measuring the time it takes for the pulses to bounce back.

- The returning echo signal is electronically converted to a 4- to 20-mA output that represents the sensor's measurement span.
- The 4 mA set point is placed near the bottom of the tank and the 20 mA near the top.



An ultrasonic sensor can detect solids, fluids, granular objects, and textiles. In addition they enable the detection of different objects irrespective of color and transparency and therefore are ideal for monitoring ***transparent objects***.



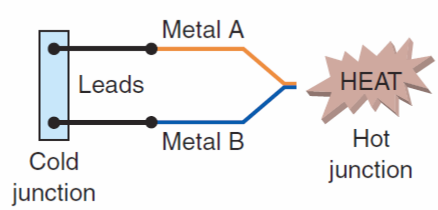
Detecting the level of chocolate

Detecting transparent bottles

TEMPERATURE SENSORS

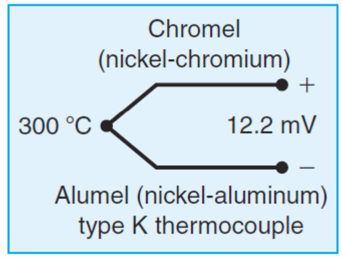
The *thermocouple (TC)* is the most widely used temperature sensor for industrial control.

Thermocouples operate on the principle that when two dissimilar metals are joined a predictable DC voltage will be generated that relates to the difference in temperature between the hot junction and the cold junction.



- A K type thermocouple when heated to a temperature of 300 °C at the hot junction will produce 12.2 millivolts at the cold junction.

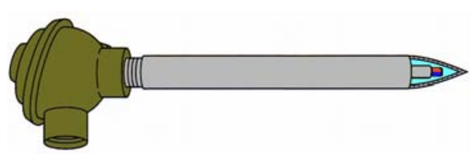
- It is important that the cold (or reference) junction be maintained at a constant known temperature to produce accurate temperature measurements.



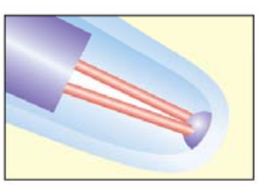
- The types of thermocouple metals used in their construction are based on intended operating conditions and different thermocouple types have very different voltage output curves.

- When a replacement thermocouple is required the thermocouple type used must match that of the original. As well, the extension wire, of the proper type, is required from the sensing element to the measuring element.

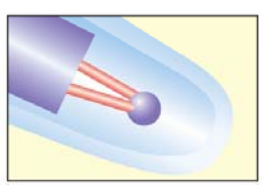
A thermocouple probe consists of thermocouple wire housed inside a metallic tube. The wall of the tube is referred to as the ***sheath*** of the probe.



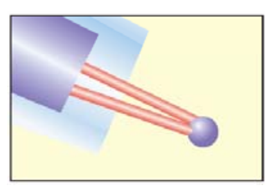
The tip of the thermocouple probe is available in three different styles; grounded, ungrounded and exposed



Grounded

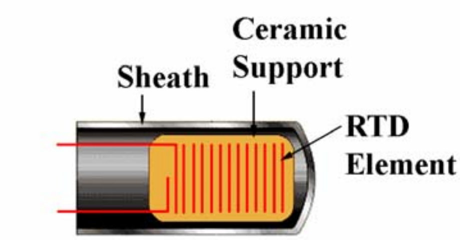


Ungrounded

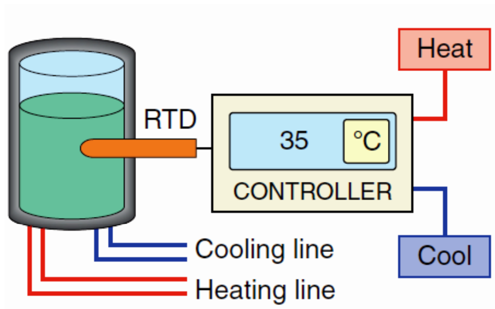


Exposed

Resistance Temperature Detectors (RTDs) **are wire wound temperature-sensing devices that operate on the principle of Positive Temperature Coefficient (PTC) of metals. The hotter they become, the larger or higher the value of their electrical resistance.**



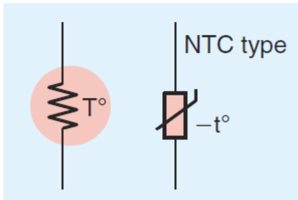
Encapsulated Type RTD
Wound With Platinum Wire



Temperature control system

- **The controller uses the signal from the RTD sensor to monitor the temperature of the liquid in the tank and control heating and cooling lines.**
- **RTDs are among the most precise temperature sensors available**
- **Platinum is the material most often used in RTDs because of its superiority regarding temperature limit, linearity, and stability.**

Thermistor circuit symbols



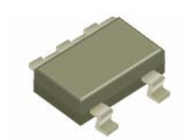
Thermistors **are thermally sensitive resistors that exhibit changes in resistance with changes in temperature.**

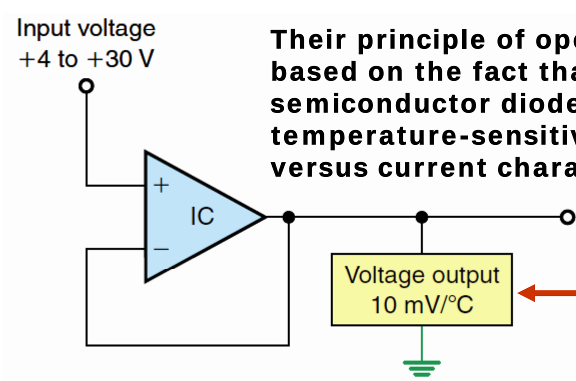
This change of resistance with temperature can result in a negative coefficient of resistance; where the resistance decreases with an increase in temperature (NTC thermistor). When the resistance increases with an increase in temperature, the result is a positive temperature coefficient or a PTC thermistor.

Thermistors allow the maximum motor winding temperature to be sensed.

Thermistor motor protection Relay.

Integrated circuit (IC) **temperature sensors use a silicon chip for the sensing element.**





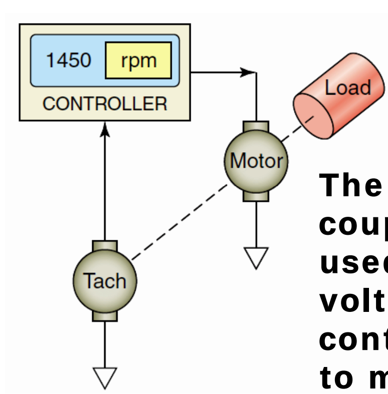
Analog voltage output type

Their principle of operation is based on the fact that semiconductor diodes have temperature-sensitive voltage versus current characteristics.

Analog IC sensors produce a voltage or current proportional to temperature.

VELOCITY AND POSITION SENSORS

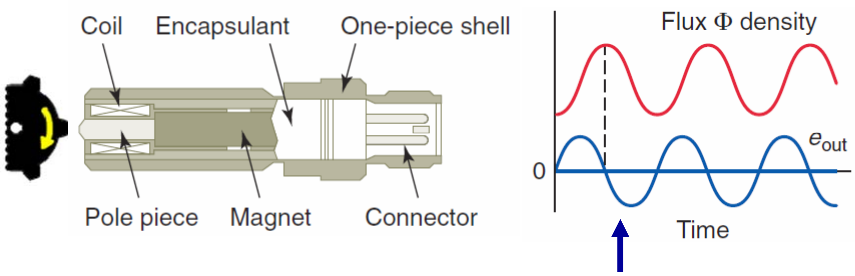
Tachometer generators provide a convenient means of converting rotational speed into an analog voltage signal that can be used for motor speed indication and control applications.



The rotor of the tachometer is coupled to the load and is used to provide a feedback voltage to the motor controller that is proportional to motor speed.

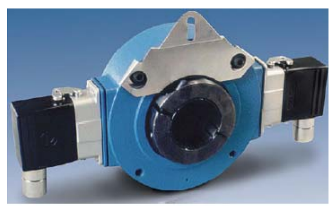
A *magnetic pickup* is essentially a coil wound around a permanently magnetized probe.

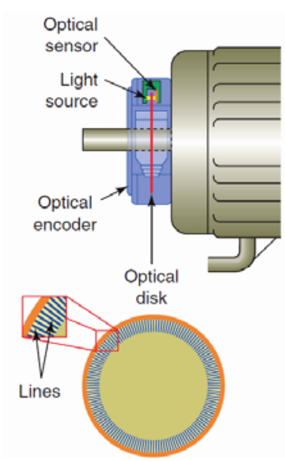
When a ferromagnetic object, such as gear teeth, area ferromagnetic object, such as gear teeth, is passed through the probe's magnetic field, the flux density is modulated. This induces AC voltages in the coil.



By measuring the frequency of these signal voltage pulses, the shaft speed can be determined.

An *encoder* is used to convert linear or rotary motion into a binary digital signal.

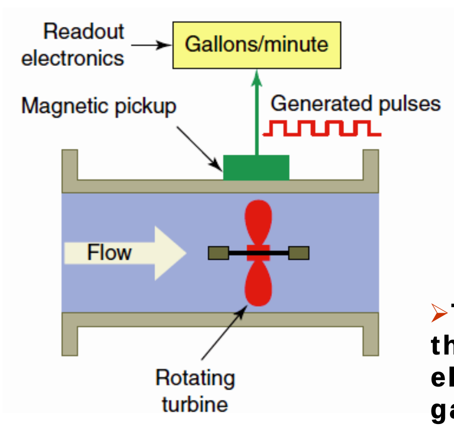




- **They are used in applications such as robotic control where positions have to be precisely determined.**
- **An optical encoder uses a light source shinning an optical disk with lines or slots that interrupt the beam of light to an optical sensor.**
- **An electronic circuit counts the interruptions of the beam and generates the encoder's digital output pulses.**

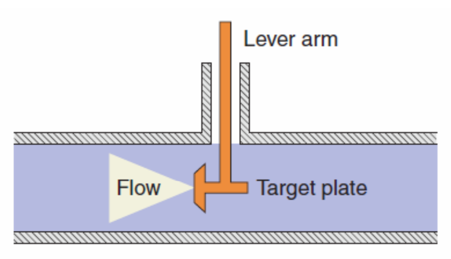
FLOW MEASUREMENT

Turbine flowmeters, like windmills, utilize their angular velocity (rotation speed) to indicate the flow velocity.



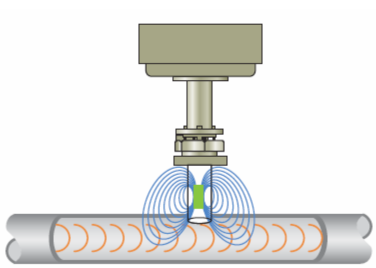
- The bladed rotor rotates on its axis in proportion to the rate of the liquid flow through the tube.
- Fluid passing through the flow tube causes the rotor to rotate, which generates pulses in the pickup coil.
- The frequency of the pulses is then transmitted to readout electronics and displayed as gallons per minute.

Target flowmeters **insert a target, usually a flat disk with an extension rod, oriented perpendicularly to the direction of the flow.**



- Fluid flow causes the target plate and lever arm to deflect against a spring.
- A permanent magnet attached to the lever arm and Hall effect sensor mounted inside the display unit translate the angular motion of the target to an electrical signal that operates a flow rate display.

Magnetic flowmeters **obtain the flow velocity by measuring the changes of induced voltage of the *conductive fluid* passing across a controlled magnetic field.**



- The magnetic flowmeter offers no restriction to flow.
- A coil in the unit sets up a magnetic field.
- If a conductive liquid flows through this magnetic field a voltage is induced which is proportional to the average flow velocity.

Flowmeter Tank Fill And Empty Operation