2.1 Introduction

Sensors allow a PLC to detect the state of a process. Logical sensors can only detect a state that is either true or false.

2.1.2 Types of sensors

a) Contact switches

Contact switches are available as normally open and normally closed. Their housings are reinforced so that they can take repeated mechanical forces. These often have rollers and wear pads for the point of contact. Examples of applications include motion limit switches and part present detectors.

b) Photo Optic (photoelectric)

Optical sensors require both a light source (emitter) and detector. Emitters will produce light beams in the visible and invisible spectrums using LEDs and laser diodes. Detectors are typically built with photodiodes or phototransistors. The emitter and detector are positioned so that an object will block or reflect a beam when present. A basic optical sensor is shown in Figure 2.0 below.

![Figure 2.0 A Basic Optical Sensor](image-url)
c) Capacitive Sensor

Capacitive sensors are able to detect most materials at distances up to a few centimeters. Recall the basic relationship for capacitance.

\[ C = \frac{ka}{d} \]

where,
- \( C \) = capacitance (Farads)
- \( k \) = dielectric constant
- \( A \) = area of plates
- \( d \) = distance between plates (electrodes)

In the sensor the area of the plates and distance between them is fixed. But, the dielectric constant of the space around them will vary as different materials are brought near the sensor. An illustration of a capacitive sensor is shown in Figure 2.1. An oscillating field is used to determine the capacitance of the plates. When this changes beyond a selected sensitivity the sensor output is activated.

These sensors work well for insulators (such as plastics) that tend to have high dielectric coefficients, thus increasing the capacitance. But, they also work well for metals because the conductive materials in the target appear as larger electrodes, thus increasing the capacitance as shown in Figure 2.2. In total the capacitance changes are normally in the order of pF.
d) **Inductive Sensors**

- Inductive sensors use currents induced by magnetic fields to detect nearby metal objects. The inductive sensor uses a coil (an inductor) to generate a high frequency magnetic field as shown in Figure 2.3.
- These sensors will detect any metals, when detecting multiple types of metal multiple sensors are often used.

![Inductive Sensor Diagram](image)

- The sensors can detect objects a few centimeters away from the end. But, the direction to the object can be arbitrary as shown in Figure 2.4. The magnetic field of the unshielded sensor covers a larger volume around the head of the coil. By adding a shield (a metal jacket around the sides of the coil) the magnetic field becomes smaller, but also more directed. Shields will often be available for inductive sensors to improve their directionality and accuracy.

![Shielded and Unshielded Comparison](image)
e) Ultrasonic Sensors

An ultrasonic sensor emits a sound above the normal hearing threshold of 16KHz. The time that is required for the sound to travel to the target and reflect back is proportional to the distance to the target. The two common types of sensors are; electrostatic - uses capacitive effects. It has longer ranges and wider bandwidth, but is more sensitive to factors such as humidity. piezoelectric - based on charge displacement during strain in crystal lattices. These are rugged and inexpensive. These sensors can be very effective for applications such as fluid levels in tanks and crude distance measurement.

2.1.3 Switches Wiring

In general, **Sinking (NPN)** and **Sourcing (PNP)** are terms that define the control of direct current flow in a load. They are only pertinent with DC components and should not be associated with AC control structures. Devices like relay outputs, reed switches, etc, are typically not affected since they are not current direction dependent (unless they have an internal polarity sensitive device like LEDs or unidirectional spike suppressors).

The following is a detailed explanation of these concepts that, in short,

<table>
<thead>
<tr>
<th>Sinking (NPN) provides a path to 0 VDC (-DC)</th>
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<tbody>
<tr>
<td>Sourcing (PNP) provides a path to 24 VDC (+DC)</td>
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</table>

a) **Sinking (NPN) Outputs** – Are outputs that “Sink” or “pull” current through the load. In this case the common connection to the load is the 24 VDC (+DC) line. Sinking output modules require the load to be energized by a current, which flows from +24 VDC (+DC), through the load, through the NPN Output Switch Device to the 0 VDC (-DC) line. Below is a representation of the circuit connection.

Another way to describe this concept is:

“Positive side {+24 VDC (+DC)} common and Negative side {0 VDC (-DC)} switched.”
b) **Sourcing (PNP) Outputs** - Are outputs that “Source” or “push” current through the load. This means that the common connection to the load is the 0 VDC (-DC) line. Sourcing output modules require the load to be energized by a current that flows from +24 VDC (+DC), through the PNP Output Switch device, through the load, to the 0 VDC (-DC) line. Below is a representation of the circuit connection.

Another way to describe this concept is:

“Negative side {0 VDC (-DC)} common and Positive side {+24 VDC (+DC)} switched.”
c) **Sinking (NPN) Inputs** – Are inputs that require an external sensor device to “Sink” or “pull” current from the Input circuitry to 0 VDC (-DC). This means that the external sensor device provides a current path to the 0 VDC (-DC) common point. Below is a representation of the circuit connection.

![NPN Input Circuit Diagram](image1)

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d) **Sourcing (PNP) Inputs** – Are inputs that require an external sensor device to “Source” or “push” current from the 24 VDC (+DC) line to the Input Circuitry. This means that the external sensor device provides a current path from the 24 VDC (+DC) common point to the Input circuitry. Below is a representation of the circuit connection.

![PNP Input Circuit Diagram](image2)
2.2 Logical Actuators

2.2.1 Solenoid, Valves, Cylinders and Motors

a) Solenoid

Solenoids act as electric to mechanical energy converters, taking an electrical signal and converting it to work. The operation is based upon the reaction of a moving element, the armature or plunger, in response to a magnetic field developed by an electrical conductor, usually a winding. Solenoids can be configured to operate in either Direct Current (DC), or Alternating Current (AC). Solenoids are electromechanical actuating devices found in many types of applications.

![Figure 2.2.1 Internal Solenoid Operation](image1)

![Figure 2.2.2: Solenoid External and Internal Parts](image2)

b) Valves

Valves are a mechanical device that controls the flow of fluid and pressure within a system or process. There are many valve designs and types that satisfy one or more of the functions identified above. A multitude of valve types and designs safely accommodate a wide variety of industrial applications. A valve controls system or process fluid flow and pressure by performing any of the following functions:

- Stopping and starting fluid flow
- Varying (throttling) the amount of fluid flow
- Controlling the direction of fluid flow
- Regulating downstream system or process pressure
- Relieving component or piping over pressure
Basic Parts of Valve

![Diagram of Valve Parts](image)

**Figure 2.2.3: Parts of Valve**

**Valve Body**
- The *body*, sometimes called the shell, is the primary pressure boundary of a valve.
- It serves as the principal element of a valve assembly because it is the framework that holds everything together.

**Valve Bonnet**
- The cover for the opening in the valve body is the *bonnet*.
- The bonnet is the second principal pressure boundary of a valve.

**Valve trim**
- The internal elements of a valve are collectively referred to as a valve’s *trim*.
- The trim typically includes a *disk*, *seat*, *stem*, and *sleeves* needed to guide the stem.

**Disk and Seat**
- The disk is the third primary principal pressure boundary.
- The disk provides the capability for permitting and prohibiting fluid flow.
- The seat or seal rings provide the seating surface for the disk.
Stem

- The stem, which connects the actuator and disk, is responsible for positioning the disk.
- Stems are typically forged and connected to the disk by threaded or welded joints.
- Two types of valve stems are rising stems and non-rising stems.

Figure 2.2.4: Rising Stem

Figure 2.2.4: Non-Rising Stem
**Valve Actuator**

- The *actuator* operates the stem and disk assembly.
- An actuator may be a manually operated handwheel, manual lever, motor operator, solenoid operator, pneumatic operator, or hydraulic ram.

**Valve Packing**

- *Packing* is commonly a fibrous material (such as flax) or another compound (such as teflon) that forms a seal between the internal parts of a valve and the outside where the stem extends through the body.

**Introduction to the Types of Valves**

Examples of the common types are:

- globe valve
- gate valve
- ball valve
- plug valve
- butterfly valve
- diaphragm valve
- check valve
- pinch valve
- safety valve.