Capacitive Proximity Switches for Level Sensing

Introduction

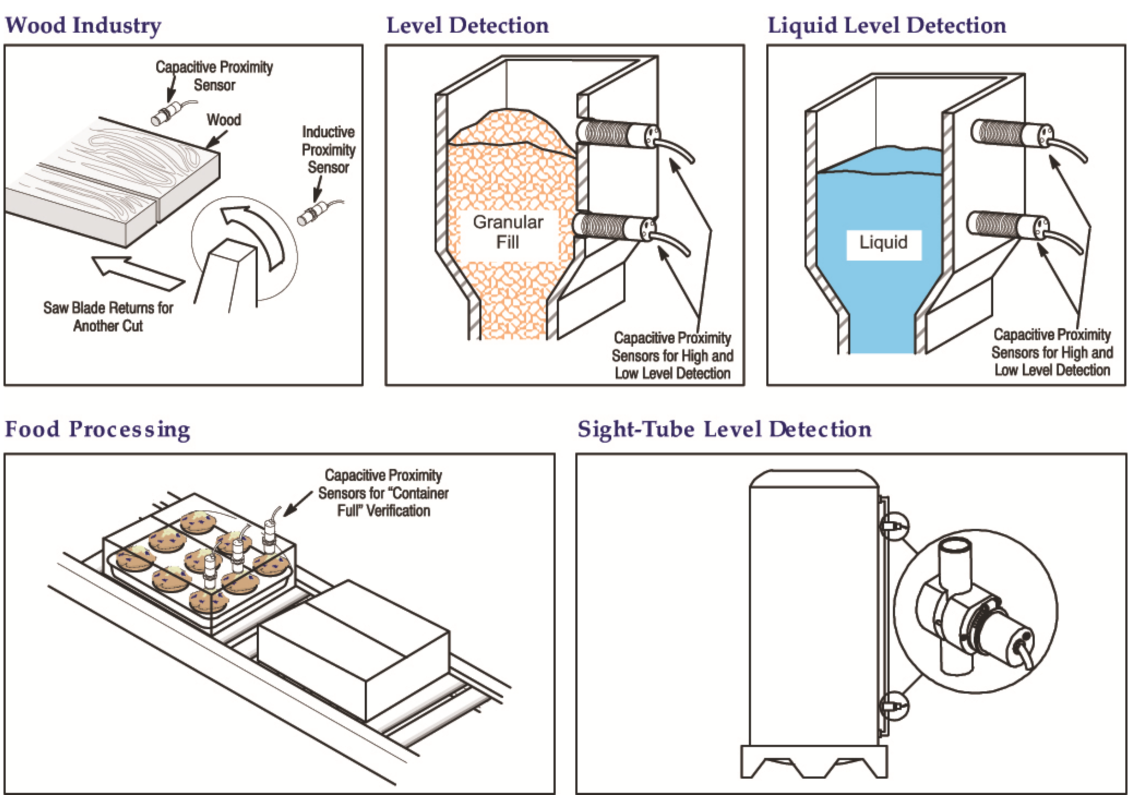
The use of instruments to detect the presence and absence of materials at predetermined points within various types of vessels has been a need for centuries. Since the industrial revolution began in the 1800's an increasing number of methods to detect a wide range of materials has evolved. Capacitive proximity switches are one such method or technology that currently has a relatively high level (pun intended) of popularity.

However, capacitive proximity switches are classified as "proximity sensors" rather than level detectors and they evolved along a different branch of the instrumentation chain. Use as a level detector requires sensing the material "proximity". In level sensing we are not typically concerned about sensing the presence of an item as it approaches or gets close to the sensor, rather only when it is in contact with the sensor.

Capacitive proximity switches used for level detection are not always considered industrial process applications. However, they are great for providing digital discrete inputs to PLC's and other type of control systems, are economical and have a good application fit in powders, granular and liquid materials.

Some examples of typical applications for capacitive proximity switches are shown in the illustration below.

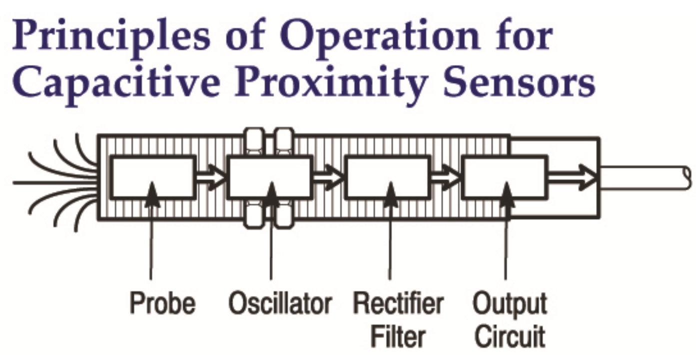
Figure 1: Various examples of capacitive proximity use



How Capacitive Proximity Switches Work

Capacitive proximity sensors generate an electrostatic field and sense changes caused by the proximity of a target. In a level detection application the target is the presence of the material. As the material comes close to the sensor the capacitance of the sensor electronics increases. The sensor oscillator becomes active as the capacitance exceeds the threshold and this triggers the sensor output. The threshold at which the output is activated is based on the setting of the sensor. The capacitance generated by the sensor electronics is based on the proximity or closeness of the target, the size of the target and the dielectric constant of the target. The closer the target, the greater the size of the target, and the higher the dielectric constant, the larger the capacitance. An adjustment potentiometer is placed on the backside of the sensor allowing for regulation of the operating distance or threshold. This regulation adjusts the sensitivity of the sensor and is useful in most applications, such as with the detection of full or empty conditions in hoppers, tanks and bins. The sensitivity can be adjusted so that the material is sensed at whatever distance you desire, or upon contact. These sensors will have a maximum sensing distance, usually 16, 20 or 25mm but it does vary from brand-to-brand.

Figure 2: Block diagram of capacitive proximity switch operation



There are two styles of capacitive proximity switches and they are based on the voltage of the load to be switched. AC and DC capacitive proximity switches are commonly available, that will switch either an AC load or a DC load.

AC capacitive proximity switches will generally operate with load voltages from 20-250VAC and are provided with 2-wire output switching loads from 10mA up to 500mA of current.

DC capacitive switches are a little different than AC switches in that they can use one of two types of transistors as the switching output. These two types of transistors are NPN and PNP. NPN is a transistor output that switches the common or negative voltage to the load; the load is connected between the sensor output and the positive voltage supply. PNP is a transistor output that switches the positive voltage to the load; the load connected between the sensor output and the voltage supply common or negative. Wire configurations for DC switches can be 3-wire NPN, 3-wire PNP, 4-wire NPN, and 4-wire PNP. Switch types can be normally open (NO) or normally closed (NC). The 4-wire DC switches allow you to wire either NO or NC.

Choosing a Capacitive Proximity Switch

The type of load you are switching will dictate whether you need to choose an AC or DC switch.

Most AC switches use a 2-wire configuration and allow for switch selection of normally open (NO) or normally closed (NC) output. However, some remain 2-wire or 3-wire and which are dedicated for NO or NC operation.

In the DC switch lineup you have to choose the wiring configuration and transistor type, i.e. 3-wire or 4-wire, PNP or NPN. The transistor type can depend on a few things but a general rule of thumb is that if the device monitoring the capacitive proximity switch output, usually a PLC, uses an NPN transistor on its input you should select a PNP transistor output in the capacitive proximity switch. Conversely, if the input device uses a PNP you should use an NPN proximity switch.

The wire selection for the DC switches, 3-wire or 4-wire, is generally based on whether you only need one switch (make or break; NO or NC) with 3-wire units or you want the flexibility of having both with the 4-wire switch.

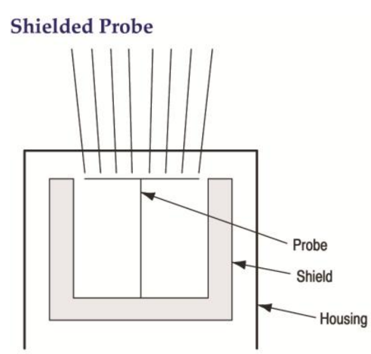
Applications Using Capacitive Proximity Switches

Capacitive proximity switches are generally used in applications with the following characteristics:

1. Tight space constraint: The amount of space surrounding the point of mounting on the vessel is very small. Low profile devices are needed that do not require a great deal of room outside the vessel. Capacitive proximity switches fit this need. They are 30mm in diameter (a little more than an inch) and only protrude outside the vessel a few inches. They can be equipped with a wire “pigtail” or with a connector including built-in terminals. These sensors are ideal for small hoppers such as those above molding machines in plastic processing or small tanks and other types of small vessels.

2. Low profile in vessel: Shielded capacitive proximity switches allow for mounting such that the sensing portion of the switch is flush with the inside wall of the vessel. This means the capacitive proximity switch can work in applications where a flush mounting inside the vessel is needed. These situations can occur because of a variety of reasons including internal obstructions, mixers etc. However, be sure to

Figure 3: Shielded capacitive proximity switch probe area



get a shielded style, not unshielded. This refers to the sensing area. Unshielded proximity sensors will sense material along their sides not just from the front face. If you need to mount the sensor with the face flush to the inside wall of the vessel or if the vessel wall is quite thick, a shielded capacitive proximity switch should be used. Refer to Appendix 2 for more information regarding the use of Shielded vs. Unshielded capacitive proximity switches.

3. Low cost: At a list price typically under $165, capacitive proximity switches are one of the lowest cost alternatives.

4. Clean dry free-flowing material: Applications using capacitive proximity switches generally must be for clean non-sticky liquids and dry free-flowing powders and granular materials. These sensors do not have the ability to ignore any build-up or coating of material in the application. It is possible to recalibrate them to null the effect of non-conductive coatings and build-up that are permanent in nature, to a certain extent depending on the dielectric constant of the material. Unshielded capacitive proximity switches will be less susceptible to false triggers due to accumulation of dust or moisture on the sensor face. Unshielded sensors are also more widely used for liquid level applications because of the use of a mounting well. The well is mounted through a hole in the tank wall and the sensor is slipped into the well's receptacle. The sensor detects the liquid in the tank through the wall of the sensor well. The well serves as a plug for the hole in the tank wall and a mounting receptacle for the sensor.

   Removal of the sensor from the vessel, when using a mounting well, can be done without leaving a hole in the tank wall or requiring the emptying or lowering of the level of the material in the vessel.

5. Ambient conditions: Capacitive proximity switches are generally used for indoor ambient operating conditions. However, they can be used outdoors and temperature swings of from -25°C to +70°C (-13°F to +158°F) for operation are acceptable.

Illustration of typical applications using capacitive proximity switches can be found in Figure 1 on a previous page.

Advantages / Disadvantages

The following table indicates the primary advantages and disadvantages of capacitive proximity switches versus other point level sensing technologies. Refer to the White Paper titled “Application Considerations for Point Level Monitoring of Powders and Bulk Solids” for additional information about the other technologies.

Table 1: Advantages and Disadvantages of Capacitive Proximity Switches

ADVANTAGES	DISADVANTAGES
✓ Low profile mounting – minimal invasiveness in tank	✓ Use with dry and free-flowing material and clean non-sticky liquids only
✓ Small size - can be installed where tight space constraints exist around vessel	✓ No high current load handling capability - geared for PLC and control system input
✓ Low cost - For simple applications this is a good low cost alternative to Rotary, RF and Vibrating units	✓ Not as sensitive as many RF Admittance or Vibrating Element sensors for lightweight bulk powders
✓ Easy to install and setup	✓ Relatively low process temperatures
✓ Hazardous location designs available	
✓ Good life when installed correctly	

Conclusion

Point level monitoring is a critical application in many instances. High level detection is used to prevent overfilling and fill shutoff. Low level monitoring ensures timely re-ordering of material to avoid material outages and production shutdown. Several viable technology choices exist, and capacitive proximity switches are one of them.

APPENDIX 1
Dielectric Constants of Common Industrial Materials

MATERIAL	DIELECTRIC CONSTANT (ε_r)
Acetone	19.5
Acrylic Resin	2.7-4.5
Air	1.0
Alcohol	25.8
Ammonia	15-25
Aniline	6.9
Aqueous Solutions	50-80
Bakelite	3.6
Benzene	2.3
Carbon Dioxide	1.0
Carbon Tetrachloride	2.2
Celluloid	3.0
Cement Powder	4.0
Cereal	3-5
Chlorine Liquid	2.0
Ebonite	2.7-2.9
Epoxy Resin	2.5-6
Ethanol	24
Ethylene Glycol	38.7
Fired Ash (fly ash)	1.5-1.7
Flour	1.5-1.7
Freon R22 & 502 (liquid)	6.11
Gasoline	2.2
Glass	3.7-10
Glycerin	47
Marble	8.0-8.5
Melamine Resin	4.7-10.2
Mica	5.7-6.7
Nitrobenzene	36

Material	Dielectric Constant
Nylon	4-5
Oil Saturated Paper	4.0
Paraffin	1.9-2.5
Paper	1.6-2.6
Perspex	3.2-3.5
Petroleum	2.0-2.2
Phenol Resin	4-12
Polyacetal	3.6-3.7
Polyamide	5.0
Polyester Resin	2.8-8.1
Polyethylene	2.3
Polypropylene	2.0-2.3
Polystyrene	3.0
Polyvinyl Chloride Resin	2.8-3.1
Porcelain	4.4-7.0
Powdered Milk	3.5-4.0
Press Board	2-5
Quartz Glass	3.7
Rubber	2.5-35
Salt	6.0
Sand	3-5
Shellac	2.5-4.7
Shell Lime	1.2
Silicon Varnish	2.8-3.3
Soybean Oil	2.9-3.5
Styrene Resin	2.3-3.4
Sugar	3.0
Sulphur	3.4
Teflon	2.0
Toluene	2.3
Transformer Oil	2.2

Material	Dielectric Constant
Turpentine Oil	2.2
Urea Resin	5-8
Vaseline	2.2-2.9
Water	80
Wood, Dry	2-7
Wood, Wet	10-30

APPENDIX 2
Shielded Vs. Unshielded

Every capacitive proximity switch can be either shielded or unshielded. This refers to the sensor construction.

Shielded

Shielded sensors are constructed with a metal band around the sensing probe portion of the proximity switch. Refer to Figure 4. This helps direct the sensing field to the front of the proximity switch rather than the sides. It results in a more intense field and slightly greater sensitivity than the unshielded sensor.

Figure 4: Shielded probe section of capacitive proximity switch

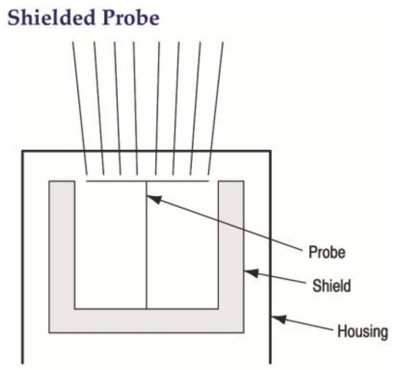
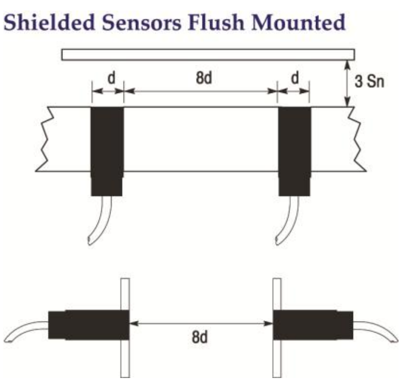


Figure 5: Mounting distance between flush mounted shielded sensors

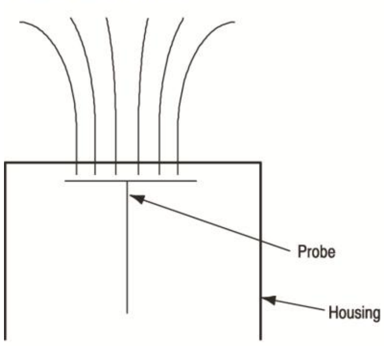


Shielded sensors, because of the shielding, can be mounted flush to the inside of the vessel without causing a false indication from the surrounding tank wall material. Refer to Figure 5. There is a minimum distance that the capacitive proximity switches can be mounted in respect to each other. This is because of interference that can occur between the sensors electrostatic fields. Shielded capacitive proximity switches are best suited for sensing low dielectric materials. Because of the concentrated field of energy they are more "sensitive" than the unshielded versions. Low dielectric materials tend to be more difficult to sense because they introduce lower capacitance impact to the oscillator circuit.

Unshielded

Unshielded capacitive proximity switches do NOT have a metal shield or band surrounding the sensing probe area within the unit. Therefore, their electrostatic filed is less concentrated. Some unshielded sensors may be equipped with "compensation probes" in addition to the main sensor probe. These are said to increase the stability of unshielded probes but are not always needed. Refer to Figure 6.

Figure 6: Unshielded capacitive proximity switch probe section



Unshielded capacitive proximity switches are more suitable for use in liquid level detection where sensor mounting wells are to be used. The mounting well is mounted to the vessel wall and the capacitive proximity sensor mounted inside the well. The sensor senses material presence within the vessel through the wall of the mounting well. This allows the sensor to be removed without leaving an open hole in the vessel.