C-Tel Corporation

CAPACITIVE SENSING SOLUTIONS

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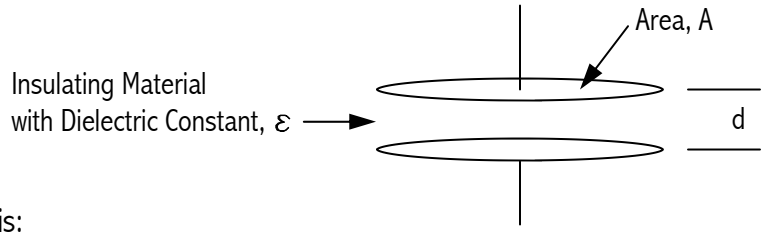
C-Tel Sensors, Theory and Application Notes

- Introduction to Capacitive Sensors

Capacitive sensors detect the presence, position or physical properties of an object by monitoring the electrical capacitance between the sensor and the object being sensed.

- Operating Principles

Electrical capacitance exists between any two conductors that are insulated from each other. Capacitance increases if the area of the conductors increases or if the distance between the conductors decreases. The capacitance also depends on the dielectric constant of the insulating material.



A simplified formula for capacitance is:

$$\text{Capacitance, } C = \frac{A \times \varepsilon}{d}$$

A capacitive sensor can have one half of the capacitor, i.e. one of the conductive surfaces, included in the sensor. In the case of sensors using remote sense heads this surface is located in the sense head. The targeted object is then the other conducting surface; and, hence, its presence can be sensed. However, one of the major advantages of capacitive sensing is that the target need not be conductive. In this case, the target becomes the dielectric, and the rest of the world plays the role of the second conductive surface. It happens like this – the non-conductive target, when interposed near the sensing face, increases the capacitance between the conductive surface in the sensor and the rest of the world because the target material has a dielectric constant greater than that of air. Thus, non-conductive targets such as plastic can be detected, although the sensing distance depends on the dielectric constant and is always somewhat less than for conductive targets.

- Remote Capacitive Sensors

C-Tel remote sensors have an input jack for connecting the coaxial cable from a remotely located sense head which contains the sensing surface. Because the sense heads are passive, containing no electronic parts, they can be made to operate in hostile environments such as high temperature, and they can be made very small and in different shapes to accommodate special applications.

- Choosing Sense Heads

The application determines the sense head. Whether for liquid level monitoring, piece-part detection, robotic control, high-temperature applications, tool location devices – whatever the application; the sense heads take

on any of a variety of sizes, shapes, and materials. The possibilities are infinite, and we stand ready to assist in determining what is best for your application. In some instances we supply custom sense heads, and in other situations customers construct their own sense heads. In addition, we are in the process of developing a line of sense heads that may be ordered from stock. Data sheets will be posted on the web site as these become available.

- Sensing Range

While the sensing distance is adjustable from near zero to some maximum value, the sensing distance is greater when the target is large, conductive, and grounded; or, in the case of non-conductive targets, when the dielectric constant of the target material is much greater than that of air. The maximum sensing distance also depends on how the sense head is mounted – if it is mounted so that the sensing surface is flush with a grounded metal plane in the host machine you can expect a maximum reliable sensing distance of about one third the diameter of the sensing electrode, whereas, if the sense head is mounted above the ground plane, the maximum sensing distance increases to typically much more than the diameter of the sense electrode.

- Guidelines For Using Remote Sensors

Mounting the Sense Head:
The sense head is to be securely mounted so that the target is within the maximum sensing range of the sense head.

Mounting the Sensor Unit:
The sensor electronic unit is to be mounted to the frame of the host machine. This insures that the sensor is referenced to machine ground and is necessary for reliable sensing. C-Tel sensors are designed with through-holes for convenient mounting against any flat metal surface in the host machine.

Routing the wires:
When routing the wiring, it is best that neither the dc power wires for the sensor nor the coaxial cable to the sense head be bundled together with ac wiring or other noisy wiring due to the possibility of interference. Also, it should be noted that the braided shield of the coaxial cable is a driven shield and must not be connected to ground or to the shield from another sensor.

Adjusting Sensitivity:
After mounting the sensor and the sense head, make the proper electrical connections and apply power. Without a target being present, increase the sensitivity by turning the adjustment screw clockwise until the sensor is "on". Back off the adjustment screw (counter-clockwise) until the sensor is just off. Now place the target in the desired sensing position; the sensor turns on. Next, continue turning the screw counter-clockwise, while counting the turns, until the sensor just turns off. This should be at least a half turn of the adjustment screw. Now, turn the screw clockwise for one half the counted number of turns. This setting should insure consistent detection of the target.

Examples of Sense Heads:

The absolute simplest sense head is really no sense head at all. If so happens that if the coaxial braid is stripped back at the remote end of the coaxial lead that the inner conductor becomes sensitive where the shield braid has been removed. Although this is not a very practical sense head, we do mention it just to demonstrate the simplicity of the concept — a sense head needs no electronic components; it is simply a means of supporting an electrode which is connected to the inner conductor of the coaxial cable.

Another simple but useful sense head can be made with simple tools from circuit board laminate material that has a conductive copper layer on both sides. The top layer is connected to the inner conductor of the coaxial cable so that it becomes the sensing surface. This layer will have the copper removed in the area near any mounting screws. The bottom layer is connected to the shield of the coaxial cable. This layer serves to guard the sensing surface from capacitance to objects near the back side of the board. This back layer must not be electrically connected to ground.

An improved laminate sense head has a simple pattern etched or cut on the top of the board such that the sensitive area is surrounded by a guard ring. This guard ring is electrically connected to the bottom layer and to the coaxial shield. The improved laminate sense head also has a thin layer of insulation on top and bottom to protect from electrical contact with other objects. The guard ring serves to minimize stray capacitance from the sensitive area to peripheral objects while also minimizing the effects of surface contamination on the sense head. Laminate sense heads have the potential for being made very thin, and they can be made in various shapes to accommodate different applications.

Many other sense head designs are possible depending on the application, from tubular sense heads, which are useful for projecting the sensing surface through a plate or wall, to special sense heads where an object in the host machine is made sensitive for a special application.