I-CUBEX • Sensors & Interfaces • Software • Support

ELECTRODE DESIGN
for
CHARGE TRANSFER SENSING

Hal Philipp, Quantum Research Group Ltd.

Sense electrodes are a critical part of any capacitive sensing solution. The QProx charge transfer sensor affords a huge operating signal range, and so for the first time users can contemplate making enormous electrodes, or make objects themselves intrinsically sensitive. One user reports using QProx to turn a section of a chain link fence into a sensor! The fence ***becomes*** the electrode. A door, a car, a window frame, or a probe the size of a pinhead - all can become electrodes, so long as they can be isolated from the local ground (the fence's mesh was apparently plastic coated).

There are three basic issues related to electrode size, shape, and placement:

1. What can be made into a proximity sensing electrode.
2. How sensitive will the sensor be. A corollary question is, "How far can it sense?"
3. What will the sense field shape be.

An excellent book which covers many of these topics is by Larry Baxter, ***"Capacitive Sensors, Design and Applications",*** IEEE Press (available from Quantum), which covers electrode design in depth.

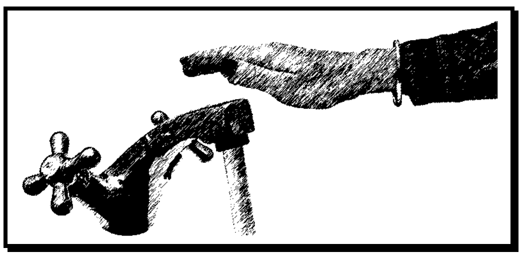

Figure 1: A faucet as Intrinsic Electrode

Intrinsic Electrodes

Most conducting objects can become an intrinsic electrode. While the object must not be directly grounded, QProx technology is particularly immune to partial conductance to ground when set to a short pulsewidth transfer time. Example conductances are from water films, or from the conductivity of electrode substrate materials such as wood.

Example Intrinsic Electrodes: Lamps, the human body, vehicles, parked aircraft, mats, door knobs, faucets, filing cabinets, metal plates, common wire, transducer elements, odd shapes of metal sheet, and aqueous fluids.

Virtual Electrodes

Non-conductive objects or conductive objects having an insulating layer can act as electrodes, so long as part of the surface is metallized or has a piece of metal attached, touching, or close by. A nonconductor that is made to act as a capacitive electrode can be thought of as a 'virtual' electrode. Almost anything can be made into a virtual electrode; the effect works because objects and fluids have a much higher dielectric constant than air, and propagate the electric field quite well. The resulting fields are weaker than had the object been made of metal, so the sense distance is less as well. However in many cases, such as with touch detection, this is not an issue.

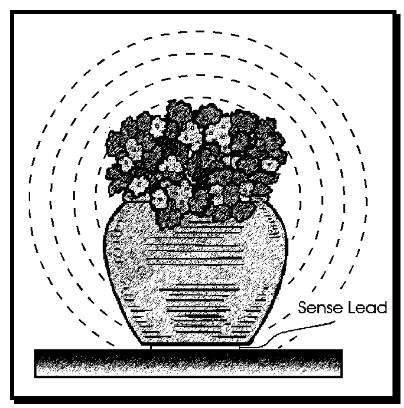

Figure 2: A Plant as Virtual Electrode

A plant can become a virtual electrode. Place a foil under the pot, and the effect will propagate through the pot, the soil and the plant. Coming close to the plant or touching a leaf can create a detectable increase in capacitance. This also works by driving a metal stake into the soil and attaching it to the sensor. Pulsewidth dependency of the measured capacitance is a function of soil and plant moisture content, since these affect electrical conductivity; longer pulses will therefore create an increasingly more intense field. This effect can be used to create a "water me" meter that, as shown, is simply a metallized plate under the pot.

Example Virtual Electrodes: Table surfaces, walls, stone statues, ceramic table lamps, nonmetallic transducers, wood or tile floors, a chair, control surfaces made of shaped plastic.

Virtual Electrode Surfaces

A surface to which a metal electrode is attached can appear to exhibit a much larger 'virtual' electrode surface. As shown, the field will propagate laterally through the surface, effectively enlarging the sensitive surface area. This effect will result in higher sensitivity than can be achieved with the metal electrode in free space alone, since capacitance is directly proportional to surface area.

The degree of lateral spreading depends on the substrate thickness, composition, and nearness to grounded surfaces. Thick materials will tend to conduct the field through to the other side and spread the field thinly over a larger area, diluting the effect. Very thin materials will not be able to propagate the field laterally very far. Between these extremes are thicknesses which spread the field quite effectively. A grounded perimeter will help kill the field off beyond the confines of the grounding.

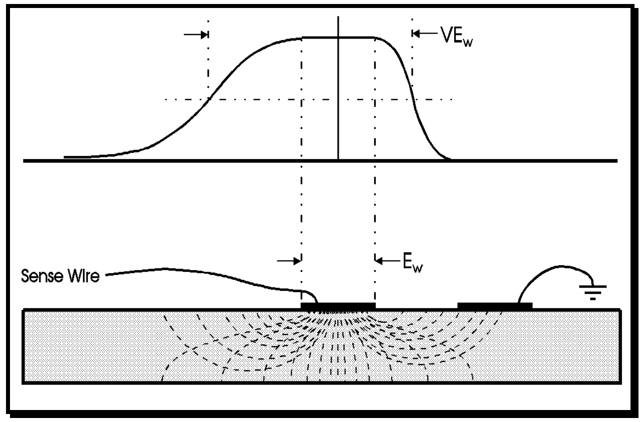

Figure 3: A virtual electrode surface is larger than the metal electrode which stimulates it. The virtual field can extend from both front and back of the substrate; the intensity of the field will exhibit a Gaussian rolloff beyond the metal electrode. Grounded strips will 'kill' most of the field beyond where they are placed; such strips can be used to shape the field, for example to create an asymetric field as shown.

Electrodes for Material Handling and Fluid Flow

The QProx sensor can turn any piece of metal into a prox sensor provided it is not grounded. A piece of copper foil can be adhered to almost anything, and so long as it is insulated from ground it will function fine. In material handling applications, shaped metal can be used to detect moving objects, obstructions, or flow or height of liquids, powders, or granules within vats, pipes, or along conveyors. Robotic arms can have shaped metal attached to them to detect impending collisions. Almost 'anything goes' when designing with the charge transfer sensor.

Although capacitive fields are normally omnidirectional, the shape of the metal electrode and the use of nearby grounded metal can be used to tailor the sense field preferrentially in certain directions (Figure 4).

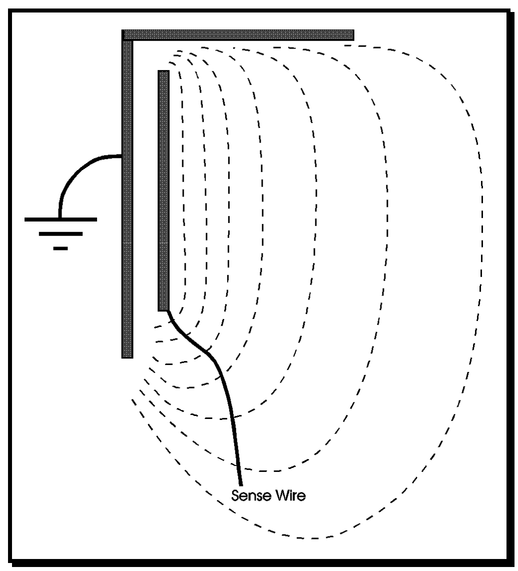

Figure 4: Grounded metal can be used to shape the sense field to avoid certain areas.

For detecting the flow of materials in pipes, the pipe can have placed inside an isolated wire probe, or it can be partially lined with a thin layer of isolated metal. If the pipe is plastic or ceramic, or in the case of a plastic hose, the exterior of the pipe can have attached two metal foil electrodes (Figure 5). The liquid's high dielectric constant generates a strong signal. Conversely bubbles in the fluid are low dielectric regions that will create drops in the signal level; the QT sensor can thus be used to detect voids or bubbles.

For conduits, where there is normally a large open air space, the signal level can be used to indicate the fluid level.

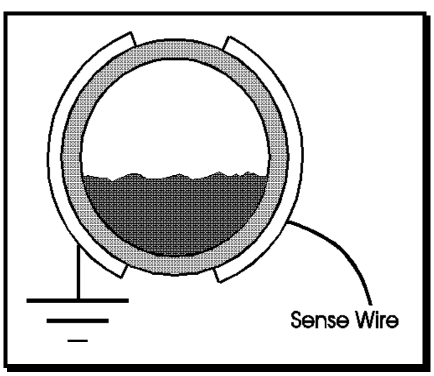

Figure 5: A plastic tube with an electrode pair for monitoring flow.

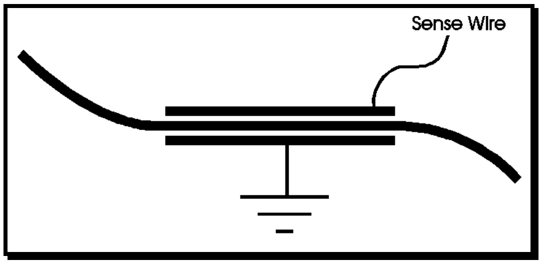

Figure 6: A web can be sensed between two parallel plates.

Thin Material Sensing

In films or webs, the material being sensed has little bulk and acts as a very weak target. Unless the web is partly conducting (for example a damp web of paper), the signal to be detected is challengingly small. One method of sensing the web is to use two parallel plates with the material running between them, thus amplifying the capacitive effect. The plates must be mechanically very stable for this to work. Air gaps reduce the percentage change caused by the web material, so the spacing should be as close as possible.

If the material is conductive or wet, the sense electrode should have an insulating coating so that the material cannot short the electrodes together.

Another method of sensing a web is to use electrodes from only one side (Figure 7). The web should be taut over the electrode set to ensure consistent contact. The sense electrode should have an insulating cover layer (see reason above), and the gap between the electrodes should be comparable to or less than the material thickness. The length of the electrodes across the width of the web will control the sensitivity. This type of configuration can also be used to determine the moisture content of a moving web, at the same time as it checks for a web break.

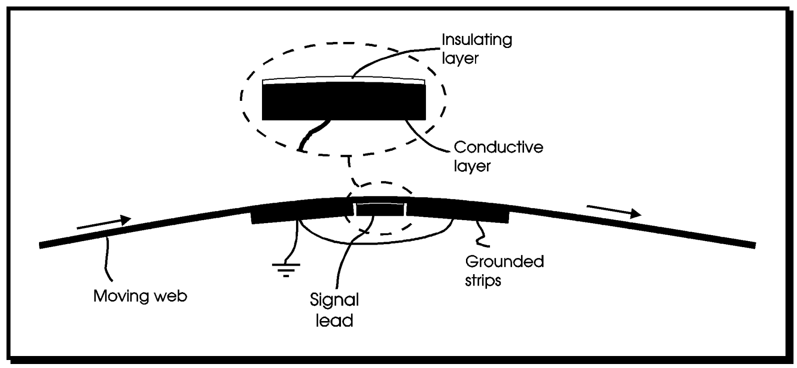

Figure 7: A web can be sensed from one side, provided the gaps between the sense strip and ground strips are comparable to the material thickness, or less.

Fill Level

Tank fill level can be monitored by simply inserting a plastic coated metal rod into the tank (figure 8) or attaching a strip to the side of the tank. There are probably dozens of alternative ways of doing this.

If the tank is metal, it should be grounded with respect to the sensor. If plastic, the base of the tank should have a consistent contact to an earth referenced surface beneath it. The sense strip should be shielded if there is walk-by traffic which may disturb the sense field.

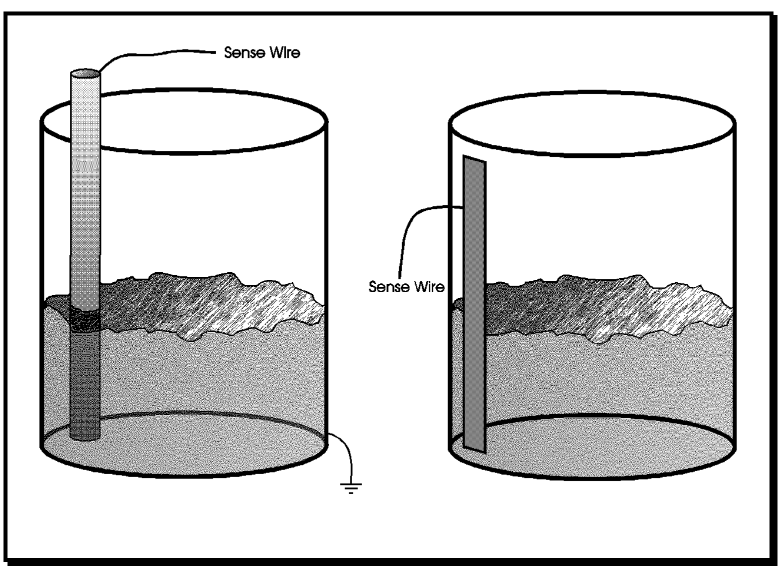

Figure 8: Fill level monitoring using an insulated rod in a metal tank, or an external strip on a plastic tank.

Another way to sense fill level is to use the configuration of Figure 5, inserted as a rigid tube vertically into the tank as in Figure 8. There is nothing sacred about a tubular shape; the electrodes could be flat, parallel facing strips.

The method of Figure 5 would also work in a "sight glass" configuration to the side of the tank; if the sense tube were oriented vertically its signal output would indicate fill level.

To guard against walk-by signals, the tube can be inserted into a larger metal pipe which in turn is grounded; an air gap should exist between the sense tube and the outer metal pipe.