3 Contactless sensing technologies

The commonly used contactless sensors are of four types: inductive, capacitive, ultrasonic and photoelectric.

3.1 Inductive sensors

They create a radio frequency field using an oscillator and a coil. The presence of a metal object changes the frequency of the oscillator and the sensor is able to detect this.

The applications of this kind of sensors are:

- Conveyor on/off switches
- Begin machine cycle
- Quality control (sense lids, proper alignment)
- Count, determine direction of motion and rotation positioning and anytime you want to sense metal

The advantages are that they can detect metal target even through non-metallic barriers, eliminate need for contact, operate in harsh condition, rapid response time and long life. For these reasons they are widely adopted in industrial control process applications.

The limitations are: they can only detect conductive metal, short range (less than 1" sensing distance) and may be affected by metal chips collecting on sensor face

3.2 Ultrasonic sensors

They send out sound waves above audible frequencies and listen for the return. Uses the time delay and the speed of sound in air to determine presence and distance to object. There are different types of ultrasonic sensors:

1. *Ultrasonic proximity sensor with analogue output stage*: Both current and voltage outputs from the sensor are proportional to the distance of the sensor from the target. This allows simple non-contact measurement.
2. *Ultrasonic retroreflective sensor: A fixed machine is used here as a reflector. The time between the emission and the reception of an ultrasonic signal (propagation time) is fixed and know. When an object comes within this sensing distance the output is activated.*
3. *Ultrasonic through beam sensor: These sensors are ideal for applications in which objects follow each other in succession. They are also recommended when high switching frequencies are required up to 200 Hz*

The advantages of this kind of sensors are that they can detect more types of objects than other type of sensors, they are very good for telling distance, have a longer operative range than inductive and capacitive sensors.

Their limitations are that they have a "dead zone" close to the face of the sensors so the cannot detect very close objects, the can't detect very small object (depending on the wavelength) and smooth surfaced objects must be aligned correctly or echo won't return to sensor. Also the very high cost is a major limitation for this sensor.

3.3 Photoelectic sensors

A photoelectric sensor is one in which the light source and light sensor are housed in the same unit. The sensor picks-up the pulse of the emitting Led which is usually in either the infrared or visible light range, as it reflects off the object being sensed

The various kinds are:

1. *Thru-Beam*: Source unit in one location sends a light beam to a detector unit in other location . An object is detected when it passes between the source unit and the detector unit interrupting light beam
2. *Reflex*: The source and detector are housed in one package and placed on the same side of the target object's path. When the object passes by, the source signal is reflected back to the detector by a retro-reflection
3. *Diffuse Reflective*: It Is analogue to the Reflex but the source signal is reflected back to the detector off the target objects itself.
4. *Background Rejection*: This is a special type of diffuse reflective sensor that includes two detectors. This arrangement allows the sensor to detect target reliably within a defined range., and to ignore objects just outside of this range. Unlike a standard diffuse reflective sensor, color or reflectivity has minimal effect on the sensing range.

The advantages are a very great sensing range, and very accurate response but its limitation is being too expensive and doesn't function in contaminated environment.

3.4 **Capacitive sensors**

The whole next section focuses on these kind of sensors, whose application has been specifically challenged by the user experiments carried out under the SIDCOM Action.

This technology works using two plates to form a linear capacitor. The amount of energy that can be stored between the plates depends on the material between them. When a material other than air is present the sensor can detect this variation.

The first reference to capacitive sensors is found in Nature, 1907, but the penetration today is only a few percent of all sensor types. This is surprising, with the technology low cost and stability and its simple conditioning circuits often, the offset and gain adjustments needed for most sensor types are not required, as the raw output span of the signal on the capacitive sense electrodes can be nearly to the supply rails.

An often-heard objection to capacitive sensor technology is that it is sensitive to humidity and needs unstable, high impedance circuits. In fact, as the dielectric constant of humid air is only a few ppm higher than dry air, humidity itself isn't a problem. Very high impedance circuits are needed, but with proper circuit design and proper printed circuit board layout, capacitive sensors are as rugged as any other sensor type.

In addition today, some techniques are available based on capacitive sensing, that permits a digital control of the sensing, enabling to manipulate system gain, response time, filtering, and amazing variety of options to increment stability and immunity of the sensors.

Capacitive sensors can sense a variety of things motion, chemical composition, electric field and, many other variables which can be converted into motion or dielectric constant, such as pressure, acceleration, fluid level, and fluid composition.

Capacitive sensors are contactless, the sensing element can be placed anywhere, close the sensing zone, and any object can become as sense element itself, because the interesting measure depend only on the capacitive coupling between the electrodes. All the substances have dielectric properties so we can sense through any material.

Case Study

BONFERRARO S.p.A., and Italian leader in the manufacture of white goods has improved its high-end dishwasher machines by realising an advanced water softener unit, using non-contact sensing to determine the degree of exhaustion of resins used to softener water hardness and to start automatically the adding of salts to the brine used for ionic regeneration of resins

3.5 **Capacitive sensing system**

Capacitive sensing system requires, in addition to sense plates, a means of interpreting the information acquired form the sense and an information management system. A system will also include the driving capabilities of the sense plates itself.

A basic capacitive system consist of two components:

- the *sensing electrodes*, which is located close the measuring zone.
- the EU or *elaboration unit*, which, depending upon design and the technology used, may be a simple microcontroller or a specific devices.

The function of each component may vary between systems, but basically perform in a similar manner.

Sensing electrodes are a critical part of any capacitive sensing solution. Most conducting objects can become an intrinsic electrode and even a non conductive objects can act as electrodes simply adhering a wire or a metal foil to the object. However to obtain good results is suggested usually follows these steps:

- Design electrode plates to measure the desired variable. Maximize capacitance with large-area, close-spaced plates
- Surround this sensor with appropriate guard or shield electrodes to handle stray capacitance and crosstalk from other circuits
- Calculate sensor capacitance, stray capacitance and output signal swing
- Choose an excitation frequency high enough for low noise. As excitation frequency increases, external and circuit-generated noise decreases
- Design circuit to meet accuracy specifications and provide immunity to environ-mental challenges

The *interpretation unit* can differ quite considerably in complexity, depending upon the functions to be fulfilled. However, the overall function is to provide the acquisition of the data from the sensing element its elaboration and optionally conversion in the output desirable format (i.e. digital serial communication, 4-20 mA line, voltage output).

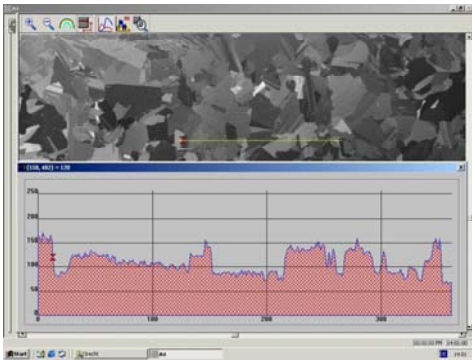
3.6 **Key attributes and limitations**

Main beneficial key attributes of non-contact capacitive sensors are in their features of being:

- Versatile: it can detect just about anything because all materials have a distinct dielectric constant. In addition can detect differences of objects not only presence
- Robust: it can operate in harsh condition, and has a long operation life
- Low cost: Its cost is lower than photoelectric and ultrasonic sensor

As limitations are that it can be affected by varying of temperature and humidity conditions.

Case Study:
SUNWAYS AG produces poly silicon solar cells SUNWAYS has gained very good experience in the field contactless optical identification of polycrystalline silicon cells within the production flow. The process control system lead to a growth of conversion efficiency and production yield.



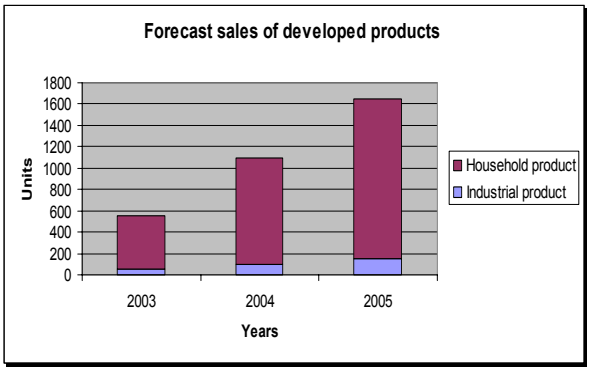
Non-contact sensor for fluid level measurement

Implementation of the function of level sensing in fuel tanks, driven by the market demand for higher accuracy and reliability of this kind of sensors, within the specific market sector of safety detectors - where the Company is already Italian leader - as well as by the demand for reduction in their cost.

SENSITRON S.r.l. is small Italian company based in Milan, hearth of northern Italy business area.
The company has been committed for years to the research and development of inflammable and toxic gas detectors, and has, in a very short time, attained the position of market leader in specific market sectors like that of gas detectors for specialised industrial applications. These detectors are used in many and different industrial sites where gas pollution have to be under control: soldering or welding sites, chemical processing sites, furnaces sites, leather tanning sites, beverages fermenting sites e.g. beer or wine manufactures.

SENSITRON S.r.l.	
Employees	7
Turnover	1.7 M€
Industrial	PRODCOM CODE 3320
Technology Introduced	Charge-transfer non-contact capacitive sensing

ECONOMIC BENEFITS



The company applied the new technology of Charge-transfer non-contact capacitive sensing to develop two new products: LPG level detectors both for home and for industrial application. The sided bar chart shows the expected sales increased thanks to the additional benefits that the new products will bring to the market.
The Return on Investment (ROI) is an essential element to assess the project value. Calculated as the ratio between the product total margin and the total investment, in the case of this new technology adoption case ROI per year widely exceeds the current discount rate (equal to 2.75%). Consequently, the project was a very profitable investment.
The break-even on the investment over 3 years - meant as the time period in which the investment on the project will be paid back - is equal to 32 months.

PRODUCT IMPROVEMENTS

The company has designed and manufactured two different products for LPG level sensing to overcome the main drawbacks of existing *mechanical floating sensors*:

- Poor measurement accuracy
- Complex installation
- High maintenance costs

and for *analogue capacitive sensors*:

- Complexity of the system, including complex electronics for calibration
- Uneasy maintenance required
- High selling price, (high–end of the market).

In both versions the system constitutes of the following parts:

- a suitable mechanical sensing probe, designed to guarantee the required accuracy
- an electronic board as core of the sensing unit, including microcontroller for interfacing and data

Household

Industrial

How to go about it

The major objective of the project was to generate best practice on using capacitive sensing passive technology to develop innovative sensors for fluid level measurement in industrial applications.
The problem of the control of the combustibles level is of outstanding importance for a smart and rationalised management of the tanks park that oil manufactures and distributors have all over the national territory. This is not only in order to get an optimised planning and management of supply, but also to integrate safety features, supervise and control the whole LPG supply and distribution process.
The technical objective was the development of a complete new sensing unit consisting of sensing probe for continuous LPG level sensing, electronic control unit of the sensor, and software for remote monitoring.
The business objectives were to establish new business product lines, to provide a performing fluid level measurement function as an added value to the company's customers, to enhance the competitiveness of the company, to utilise the experiences and best practice for the next generation of sensing products i.e. for detecting kind of stocked product, and measure pressure and density of fluids.

TECHNICAL IMPLEMENTATION

By utilising Charge-transfer capacitive sensing the company has developed a sensing unit for LPG level sensing, in two different versions:

- Sensing unit for LPG level measurement in tanks for home application (with volumes of 1, 1.75 and 3 cubic metres). This board uses a low cost sense IC, it is a battery supplied stand-alone one and mounts a commercial microcontroller for measure processing and control of display, LEDs and alarms.
- Sensing unit for LPG level and volume measurement in industrial tanks (with volumes of 15,30 and 50 cubic metres). The board provides the quantity of LPG present in the tanks in liquid phase and converts the measured level into volume (cubic metres), through a FW implemented algorithm. The board is supplied through main and at present provides a 4-20 mA output, the input required by many industrial control boards that could interface with it. This version needs in fact to be

Task	Planned Person Days	Actual Person Days
Management	20	33
Training	26	26
Design	64	64
Fabrication	31	31
Testing	33	37
Total	**174**	**191**

The development of two version of level sensing units was conducted over a period of 12 months. The company required a subcontractor to assist in design and in prototype manufacturing of complete new sensing units consisting of sensing probe for LPG level sensing, electronic control unit of the sensor, and software for remote monitoring.

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