How Proximity Switches Work

The uses of inductive and capacitive proximity switches

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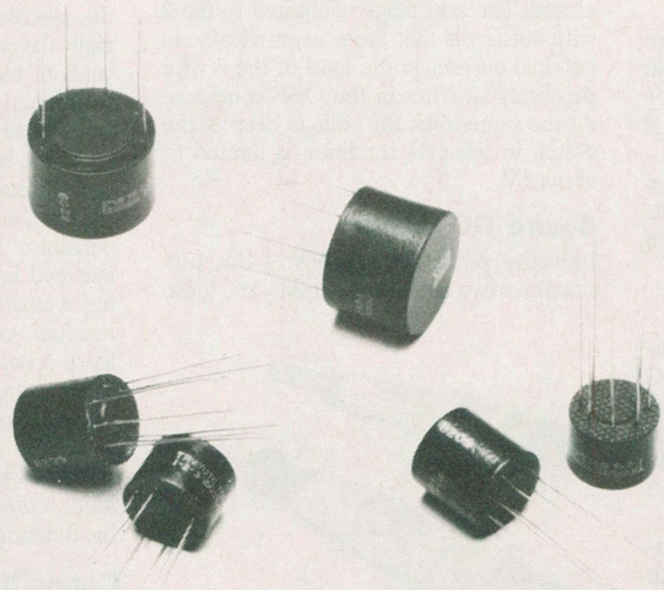


Automation of working processes means using machines for monitoring and control, tasks which have previously been carried out by people. These machines and installation systems need equipment which is at least partially able to replace the human eye in realizing certain processes, to replace the fingers in order to touch and to feel any changes, and to replace the abilities of the human brain and the human senses as their source of information.

When a machine takes over one of the functions of a human brain, the switch, sensor and key have to substitute for the functions of the senses. The higher the degree of automation, the greater the number of different working processes may be carried out by a machine or by a system without a human action and the more information is needed to control it.

Switches are one of the most important source of information whatever the function may be – switches that may be operated by hand, by the machine, or by the product to be manufactured.

The first function of switches was the monitoring at areas where environmental conditions meant an extraordinary stress for the operators. Therefore, especially at locations with extreme environmental factors, e.g., operation at humid locations, zones with temperatures below zero, zones with high temperatures, dirty or dusty zones etc., switches meet the special requirements.

Switch Requirements

However, mechanical switches, which had been successful for many years were no longer able to meet these requirements fully. The further development of the machines and the improved controls called for improved switches. The requirements for these new improved switches are roughly the following:

1. Unlimited quantity of switchings so that the switches have at least the same duration of life as the machine.
2. Waterproof and dust proof so that they may be used under all environmental conditions which may exist within machines and systems.
3. High switching speed so that the switches are still able to control the movements of machines and systems succeeding one another very quickly.
4. Reliable and clear execution of the switching process. Lack of contact bouncing, as the quick electric controls would take that for multiple switching, and would make a logical but false decision.
5. Low contact corrosion and low contact resistance, as the electric controls work only with very low current and control voltage.

Filling the bill

Inductive proximity switches have the following characteristics that make them particularly attractive for industrial use:

1. They're all-electronic; no parts are moved mechanically.
2. There is no wear and tear, and therefore they have the same durability as the machine itself.
3. They can be made absolutely waterproof and dustproof because there are no parts which move mechanically, so they are able to work with great reliability, even under the worst environmental factors.
4. They have, due to their solid state structure, determined constant electrical thresholds and therefore are able to actuate any electronic control without problems.

Inductive proximity switches, as a real supplement or alternative to mechanical switches, have become an indispensable switching unit of the automation industry. They are used as limit switches for the instrumentation, for automatic weighing devices, for the general mechanical engineering, and especially for conveyance plants.

In principle, an inductive proximity switch consists of a transistor oscillator and a switching amplifier. Generally, the oscillator is a series resonant circuit. When energy is supplied, the oscillator operates to generate a high-frequency field. At this moment, there must not be any conductive material in the high-frequency field.

If then a conductive material is placed in the electromagnetic field, energy is taken from the oscillator in the form of eddy current losses in conductive material. When the resonant circuit is disturbed, the oscillator is stopped. The power absorption of the whole thing will decrease. This varied energy intake is utilized by the control circuitry as a switching process. However, the consumption of energy is so small (about 16 milliwatts) that there will not be any important restoring force to the actuating element. The restoring force is less than 1 milligram and therefore is left out of account for nearly all measuring instruments.

Mechanical Versions

There are three different mechanical versions:

Slot sensors: The electromagnetic field is concentrated between two coils on a common axis. The sensor switches on when metal is placed into the airspace between the coils and actuates the oscillator.

Cylindrical and rectangular form: Here the field is arranged to be at the front end of the sensors. The sensor is influenced by the approach of metal in a radial or axial direction.

Ring type sensors: In these, the electromagnetic field is concentrated inside the ring. The sensor switches off when metal is placed inside the ring.

Electrical Versions

In principle, we have to distinguish between inductive proximity switches for DC and inductive proximity switches for AC. DC switches are divided into switches for applications in hazardous locations and switches for general applications in the general mechanical engineering.

In general this electrical version consists only of the transistor oscillator with the following functions: when there is no metal within the range of the active face the circuit oscillates. In this condition, the circuit appears as a very low resistance. With regard to a definite power source, the proximity switch has a current of more than 3mA. When the metal is placed in the electromagnetic field, the circuit appears as a relatively high resistance. The current decreases to a value of 1mA or less.

The difference in current through the circuit between oscillating and non-oscillating conditions is monitored by a trigger amplifier to give a definite switch point.

2-wire DC design

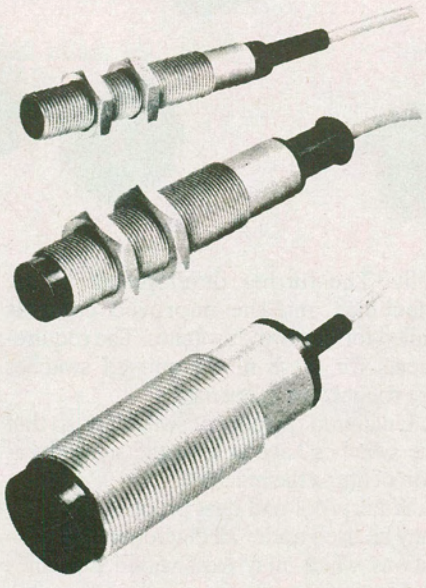
DC proximity switches in the two wire version for actuating electromagnetic relays or electronic control units are also delivered with oscillators and output amplifiers. The different versions may be compared to mechanical limit switches. For the installation, only two cores are necessary. In general, it is of no importance whether the load is connected in the positive or in the negative line. The disadvantage of this version is that these switches may only be used together with definite relays or electronic units, as the working energy for the proximity switch comes through the load and therefore, even in the ON condition, a residual voltage drop will occur.

3-wire DC design

This proximity switch consists of the oscillator as well as the output amplifier with triggering. It's then possible to operate electromagnetic relays or any electronic units without inserting between other coupling elements. Usually these switches are delivered normally-open or normally-closed. The advantage compared to the 2 wire version is that there is practically no residual current in the load of the 3 wire proximity switches in the OFF condition. At the same time, the voltage drop at the switch in the ON condition is limited to about 1V.

4-wire DC design

Inductive proximity switches of this version have two antivalent outputs, i.e., these outputs operate on the push-pull principle; when output 1 of a non-actuated proximity switch is in the ON condition, output 2 is in the OFF condition. If the proximity switch is actuated output 1 will be in the OFF condition and output 2 will be in the ON condition.



Inductive proximity detection sensors from Micro Switch.

By the function of the two outputs the changeover contact of a mechanical switching unit has been retained. Antivalent outputs are used mainly for monitoring systems.

2-wire AC design

These proximity switches are used for actuating AC consumers like contactors, solenoid valves etc., up to a voltage of 250V. They consist of the oscillator and, in general, also of a thyristor or triac switched output voltage, permitting the direct connection to an AC mains without inserting between a coupling element. The external dimensions of these switches are almost similar to those of the habitual housings of mechanical switches.

Besides the general known advantages of the electronics compared with the mechanics, we wish to mention especially the easy monitoring due to the 2 wire version. However, apart from the above mentioned advantages, there are also disadvantages: the 2 wire version needs no separate connection for the supply voltage, the sensor is connected in series with the load, and in the OFF condition a small current of about 5mA still flows in the circuit and in the ON condition (the sensor has a small potential drop) there is still a residual voltage of 5-10V. In low voltage loads (contactors or solenoid valves with a rated voltage of 24V, 36V or 42V) there may be problems. None of these problems will occur with proximity switches for the rated voltage of 110-220V. Then the residual voltage of 5-10V has no influence on the function reliability of the contactors.

Capacitive Proximity Switches

These differ from inductive proximity switches by the kind of operation. In order to actuate inductive proximity switches, we need a conductive material. Capacitive proximity switches may be actuated by any material — wood, plastics, liquids, sugar, flour, wheat, etc. However, this advantage of the capacitive proximity switches compared with the inductive proximity switches brings some disadvantages with it. Whereas inductive proximity switches may be actuated only by a metal and are insensitive to humidity, dust, dirt, etc., the capacitive proximity switches are also actuated by any dirt in their environment.

For general applications, the capacitive proximity switches are not really an alternative, but a supplement to the inductive proximity switches. They are a supplement where there is no metal available for the actuation, e.g. for woodworking machines, for determination of silo-levels.

The mode of operation of capacitive proximity switches is also based on the principle of a transistor-oscillator. However, instead of a coil, an anode is used. The earth is cathode. When a material approaches the anode and therefore changes the capacitance of this capacitor, the originally de-tuned resonant circuit is tuned, and the oscillator starts. Again the changes in the energy intake are utilized as a switching signal.

The effect of a material on capacitive proximity switch is essentially a characteristic of its composition. There are three different ways that the effect can be used in practice.

1. The effect of nonconducting material: the introduction of a nonconducting material into the field (e.g. glass, plastic, etc.) causes a change in the dielectric. Because, in general, this change is small, the practicable sensing distance is also small. Size thickness and dielectric characteristic all influence the sensing distances.

2. The effect of a material in front of conductor: the introduction of a conducting material behind a nonconductor causes a change in the dielectric and, in addition, the field is disturbed by the conductor, through the nonconductor. The influence of the conductor on the damping is larger and because of this a greater distance is obtained.

3. The effect of a material in front of a conductor with the materials grounded: this effect is similar to those described in 1 and 2 with the addition of an absorption factor. This actual effect gives the greatest possible sensing distance. In practice, it is found that the useable effect is a mixture of the three effects described above. Therefore, it is possible to give a fixed sensing distance for capacitive sensors without detailed information on the operating conditions. The sensing distance achieved is dependent both on the operating conditions, and the setting of the sensitivity control. When there is external interference (for example, changes in ambient temperature, relative humidity, dust, etc.) the sensor cannot be used at maximum sensitivity because the effects of the external interference automatically increase with increasing sensitivity. In principle, it is possible to produce the same electrical versions of the capacitive proximity switches. Due to the application, however, they are generally produced as cylindrical or rectangular switches. The capacitive proximity switches made by Pepperl and Fuchs are available in many electrical versions:

1. Proximity sensors in 2 wire design for DC circuits for actuating relays or electronic controls.
2. Proximity sensors in 3 wire design for DC circuit containing also a trigger.
3. Proximity sensors in 4 wire design for DC circuits with 2 antivalent push-pull outputs.
4. Proximity sensors in 2 wire design for DC circuits for actuating directly contactors or solenoid valves, etc.,.

During the last 30 years, the inductive and capacitive proximity switches have been improved continuously.

Pepperl and Fuchs switches are short circuit proof and have an overload protection. They are absolutely reverse polarity protected, i.e., each line may be exchanged against one another without destroying the switch. They operate within a large voltage range, for example DC = 10-30 V, AC = 20 – 250V. They have triple protection against penetrating humidity. ■