

# SENSOR TECHNOLOGIES TO DETECT PNEUMATIC CYLINDER POSITION

**White Paper**

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In the field of automation, a very popular choice for prime mover duties is the pneumatic cylinder. Pneumatic cylinders carry many advantages in terms of relatively low first cost, application simplicity, and durability. To integrate a pneumatic cylinder into an automated system, it is necessary to supply electrical signals to the controller indicating the position status of the cylinders. Toward that end, pneumatic cylinder manufacturers, machine builders, and end users have developed a number of ways to detect extension or retraction of a pneumatic cylinder and provide an electrical signal to the control system.

## Position Sensing Techniques

One position sensing technique is to install external electro-mechanical limit switches or inductive proximity switches that detect metal flags on the moving parts of the machine.

The disadvantages of this approach include the cost and complexity of the brackets and associated hardware, the difficulty of making adjustments, and the increased physical size of the overall assembly. Another problem is that the external hardware is prone to damage and misalignment due to everyday incidental contact or impact.

A more popular and widely used method is to attach magnetically actuated switches or sensors to the sides of the cylinder, or into a slot extruded into the body of the cylinder. Through the aluminum wall of the pneumatic cylinder, magnetic field sensors detect an internal magnet that is mounted on the moving piston. In most applications, magnetic sensors provide end-of-stroke detection in either direction; however, installation of multiple sensors along the length of a cylinder allows detection of several discrete positions.

There are commonly two different types of cylinder magnets used with magnetic field sensors. The first and probably the most widespread is the axially magnetized magnet, which is ideal for actuating most reed switches.

Then viewed from the side, this magnet has the north and south poles next to each other in the axial plane as shown.

The second commonly encountered cylinder magnet is the radially magnetized magnet, which works well with the Hall Effect sensor. Instead of the north and south poles next to each other, one is the inner diameter and the other is the outer diameter, as shown. The Hall Effect sensor only looks for a magnetic pole; it does not matter if it is north or south.



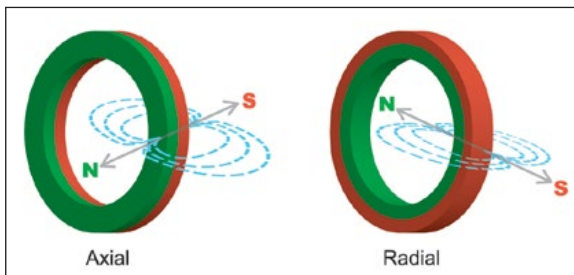
Cut-away view of a pneumatic cylinder with magnetic ring



Traditionally, two proximity switches detect flags for end of stroke of a pneumatic carriage



A better solution is to use cylinder mounted magnetic field sensors that can replace two proximity switches, targets, or additional mounting hardware



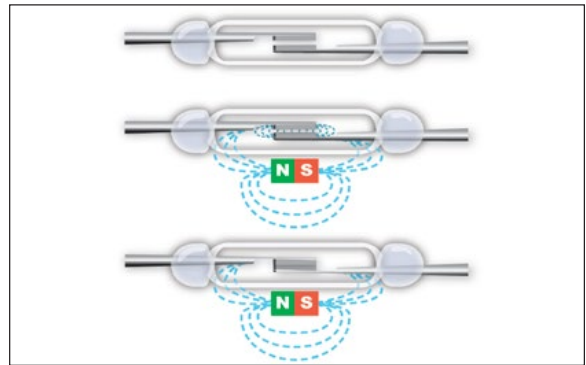
Axial and radial magnetic field orientations

## Magnetic Sensor Types

The simplest magnetic field sensor is the reed switch. This device consists of two flattened ferromagnetic nickel and iron reed elements, enclosed in a hermetically sealed glass tube. The glass tube is evacuated to a high vacuum to minimize contact arcing. As an axially aligned magnet approaches, the reed elements attract the magnetic flux lines and draw together by magnetic force, thus completing an electrical circuit. The magnet must have a strong enough Gauss rating, usually in excess of 50 Gauss, to overcome the return force, i.e. spring memory, of the reed elements.

## Reed Switches

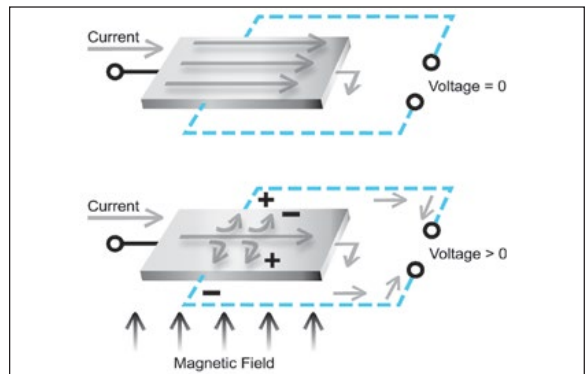
The benefits of reed switches are that they are low cost, they require no standby power, and they can function with both AC and DC electrical loads. However, reed switches are relatively slow to operate, therefore they may not respond fast enough for some high-speed applications. Since they are mechanical devices with moving parts, they have a finite number of operating cycles before they eventually fail. Switching high current electrical loads can further cut into their life expectancy. In addition, low cost reed switches can sometimes deliver multiple switching points as the twin lobes of certain magnets pass by. Lastly, reed switches installed in high shock and vibration applications may exhibit contact bounce or even become physically damaged. In many automated factories, reed switches are a major source of unplanned downtime. In plants with hundreds of reed switches, failures can occur almost hourly and represent a continuous maintenance headache, not to mention lost productivity.



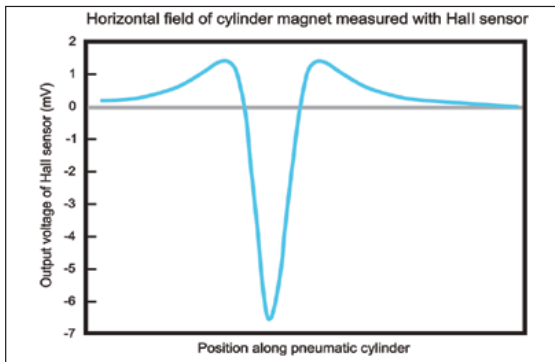
Reed switch

## Hall Effect Sensors

Hall Effect sensors are solid-state electronic devices. They consist of a voltage amplifier and a comparator circuit that drives a switching output. In a Hall Effect sensor, a steady DC current passes through the thin Hall Effect chip. The distribution of electrons across the element is uniform and the current moves in a straight line, with no potential difference generated at the outputs (located on the sides of the chip). As a radially oriented magnet approaches, the magnetic field is perpendicular to the current flow through the Hall element. The presence of the perpendicular magnet pushes the electrons out of their straight-line path and towards one side of the chip. The imbalance of electron charge thus creates a potential voltage across the Hall Effect element. The small micro-voltage that is created is proportional to the strength of the magnetic field. Once the voltage amplitude generated across the chip has satisfied the threshold level of a comparator circuit, the sensor output switches on.



Hall Effect Sensor



Magnetic field measured with a Hall-Effect sensor

Since Hall Effect sensors are electronic devices, they have no moving parts. Unlike a reed switch, their response time is not dependent on magnetic force overcoming mechanical inertia. They operate faster and are more resistant to shock and vibration.

It might seem like an easy solution to simply replace reed switches with Hall Effect sensors. The problem is that the magnetic field orientation of a cylinder designed for reed switches may be axial, whereas the orientation for a Hall Effect sensor is radial. The result? There is a chance that a Hall Effect sensor will not operate properly when activated by an axially oriented magnet. Another concern is that Hall Effect sensors typically have rather low sensitivity, such that the magnetic field strength must be in the 30 – 60 Gauss range. Finally, some inexpensive Hall Effect sensors are susceptible to double switching, which occurs because the sensor will detect both poles of the magnet, not simply one or the other.

## AMR Magneto-resistive Sensors

Another type of solid-state magnetic field sensor is called an AMR magneto-resistive. The operating principle of AMR magneto-resistive sensors is simple: the sensor element undergoes a change in resistance when a magnetic field is present, changing the flow of a bias current running through the sensing element. A comparator circuit detects the change in current and switches the output of the sensor. Compared to Hall Effect sensing technology, which generates a tiny microvolt-level signal, the magneto-resistive element responds with a more robust 3-4% change in bias current. This results in more noise immunity and less susceptibility to false tripping.

Magneto-resistive sensors are about 200 times more responsive than a typical Hall Effect sensor to a given magnetic field strength. The practical magnetic field strength required to operate a magneto-resistive sensor can be as low as 15 Gauss. Improvements in magneto-resistive technology now allow these sensors to detect both axially and radially magnetized magnets.

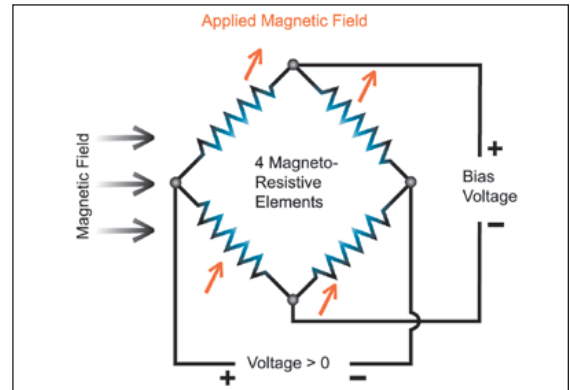
In addition to the ruggedness benefits of solid-state construction, the magnetoresistive sensor offers better noise immunity, smaller physical size, and lower mechanical hysteresis (the difference in switch point when approaching the sensor from opposite directions). Quality manufacturers of magnetoresistive sensors incorporate additional output protection circuits to improve overall electrical robustness, such as overload protection, short-circuit protection, and reverse-connection protection. Unlike Hall Effect sensors, there are no double switching points, because the higher sensitivity of the magnetoresistive sensor allows it to remain in the “on” state as the low-strength portion of the magnetic field passes under the sensor. Hall Effect sensors, being less sensitive, will often “drop out” when they see a weaker portion of a magnetic field located between two stronger areas, then switch on again when the field strength increases.

Leading manufacturers of magnetoresistive sensors have developed weld field immune versions that can operate reliably in AC welding fields as strong as 200kA/m with no false signals or electrical damage. Many of these welding sensors are available with metallic housings to further guard against hot weld spatter that would melt into a plastic-bodied sensor.

## Summary

Over the years, many users have abandoned the use of reed switches due to their failure rate and have utilized mechanical or inductive sensors to detect pneumatic cylinder position. AMR sensors are smaller, faster, and easy to integrate and are much more reliable, however, they must overcome the stigma left by their predecessors. With the vast improvements in sensor technology, AMR sensors should now be considered the primary solution for detecting cylinder position.

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**AMR Magnetoresistive Sensor Wheatstone Bridge**

## Comparison of Sensor Technologies

	Reed	Hall	AMR
Sensing Element Size	Large	Small	Medium
Construction	Mechanical	Solid State	Solid State
Magnet Strength Required	Medium	High	Low
Sensitivity	Medium	Low	High
Temperature Stability	Medium	Low	Medium
Power Consumption	Zero	Low	High
Noise Immunity	High	Low	High
Mechanical Robustness	Low	Medium	High
Electrical Robustness	Low	Low	High
Double Switch Points	Yes	Possible	No

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