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# Position Measurement with Hall Effect Sensors

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**Abstract** Paper deals with hall effect sensors used for position measurement. Hall Effect sensor reacts to magnetic array with change of its output analogue voltage. Static characteristic is measured for both polarity of permanent magnet, which has been used as source of magnetic array. Hall Effect sensor can be used for contact less precise measurement of position.

***Keywords:*** *Hall Effect, sensor, measurement, position*

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## 1. Introduction

Magnetic sensors are solid state devices that are becoming more and more popular because they can be used in many different types of application such as sensing position, velocity or directional movement. They are also a popular choice of sensor for the electronics designer due to their non-contact wear free operation, their low maintenance, robust design and as sealed Hall Effect devices are immune to vibration, dust and water.

A Hall Effect sensor is a transducer that varies its output voltage in response to a magnetic field (Figure 1). Hall potential difference – Hall voltage depends on both magnitude and directions of magnetic field and electric current (power supply). The magnetic field is sensed by the Hall plate and a "Hall" voltage is developed across the biased Hall plate proportional to the induced magnetic flux. In its simplest form, the sensor operates as an analog transducer, directly returning a voltage. With a known magnetic field, its distance from the Hall plate can be determined. Using groups of sensors, the relative position of the magnet can be deduced. Hall Effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications.

The Hall Effect is named after Edwin Hall, who in 1879 discovered that a voltage potential develops across a current-carrying conductive plate when a magnetic field passes through the plate in a direction perpendicular to the plane of the plate. Hall-effect (magnetic field) sensing applications have become practical recently through advancements in supporting technologies. Hall Effect sensors may require analog circuitry to be interfaced to microprocessors. These interfaces may include input diagnostics, fault protection for transient conditions, and short/open circuit detection. It may also provide and monitor the current to the Hall Effect sensor itself. There are precision IC products available to handle these features.

Hall Effect Sensors are available with either linear or digital outputs. The output signal for linear (analogue) sensors is taken directly from the output of the operational amplifier with the output voltage being directly proportional to the magnetic field passing through the Hall sensor.

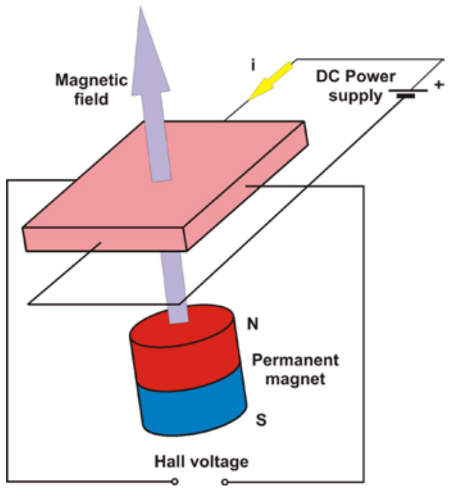



**Figure 1.** Hall-effect sensor principle [1]

Linear or analogue sensors give a continuous voltage output that increases with a strong magnetic field and decreases with a weak magnetic field. In linear output Hall Effect sensors, as the strength of the magnetic field increases the output signal from the amplifier will also increase until it begins to saturate by the limits imposed on it by the power supply. Any additional increase in the magnetic field will have no effect on the output but drive it more into saturation.

Digital output sensors on the other hand have a Schmitt-trigger with built in hysteresis connected to the op-amp. When the magnetic flux passing through the Hall sensor exceeds a preset value the output from the device switches quickly between its "OFF" condition to an "ON" condition without any type of contact bounce. This built-in hysteresis eliminates any oscillation of the output signal as the sensor moves in and out of the magnetic field. Then digital output sensors have just two states, "ON" and "OFF" [1,2,3,4,5,6].

Hall Effect ICs typically come under the following major types, primarily depending upon their modes of switching [7]:

Sensors with Bipolar Switching Mode: In this type the IC shows distinct switching behaviour for both the poles of the induced magnetic flux. With the South Pole directed towards the branded side of the IC, its output is switched low and with the North Pole applied to the branded side forces the IC's output to go high. On complete removal of the applied magnetic field may cause the IC either to lose the switched instantaneous output state or retain it, the result may not be defined with ICs coming under the above type.

Sensors with Unipolar Switching Mode: As the name suggests these sensors will respond particularly when a magnetic south pole is induced over its branded surface making its output immediately low, and, turning it high as soon as the induction is abandoned. The sensor won't respond to the flipped side that is to the North Pole of a magnet.

Sensor with Unipolar Switching and Output Inverted: Here the basic nature of the sensor remains quite similar to the above type, however the output behaviour exhibits exactly the opposite results with the respective inductions.

Sensors With Latching Feature: Again the name refers to the specific nature that these particular types may own, the branded side when subjected to a magnetic South Pole switches its output high and switches back to low in response to a North Pole, however the removal of the magnetic fields does not inhibit the output from changing state, rather keeps it latched to the particular instantaneous level [7].

## 2. Tested of the Hall Sensor

The Hall Effect sensor SS495A (Figure 2) has been tested. It belongs to SS490 series by Honeywell. SS490 Series MRL (Miniature Ratiometric Linear) sensors have a ratiometric output voltage, set by the supply voltage. It varies in proportion to the strength of the magnetic field.

A new Hall Effect integrated circuit chip provides increased temperature stability and sensitivity. Laser trimmed thin film resistors on the chip provide high accuracy and temperature compensation to reduce null and gain shift over temperature. The quad Hall sensing element minimizes the effects of mechanical or thermal stress on the output. The positive temperature coefficient of the sensitivity helps compensate for the negative temperature coefficients of low cost magnets, providing a robust design over a wide temperature range [5,6].

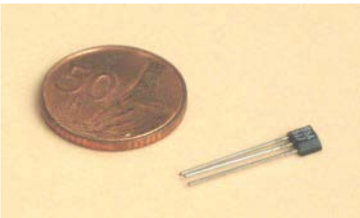


**Figure 2.** SS495A Hall Effect sensor by Honeywell [5,6]

This sensor has typically magnetic range -67 mT to 67 mT [-670 G to 670 G]. Response time is better than 3 µs.

The sensor is very interesting for application in mechatronic and robotic systems for measurement of position.

All measurements and experiments have been realized with same permanent magnet (Figure 3) made from SmCo (Samarium Cobalt) with magnetic induction 0,35mT with axial polarization.

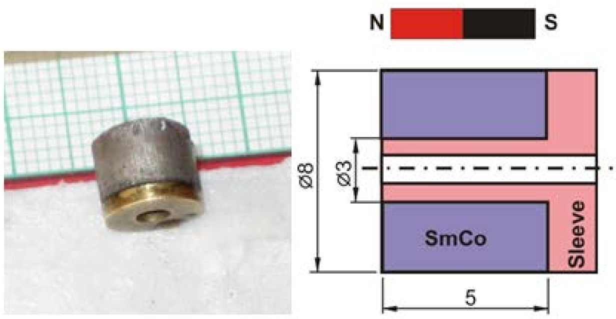



**Figure 3.** Used permanent magnet

## 3. Experiments with Hall Sensor

Aim of these experiments is to explore the static characteristic as dependence between the sensor output voltage and position of permanent magnet from sensor.

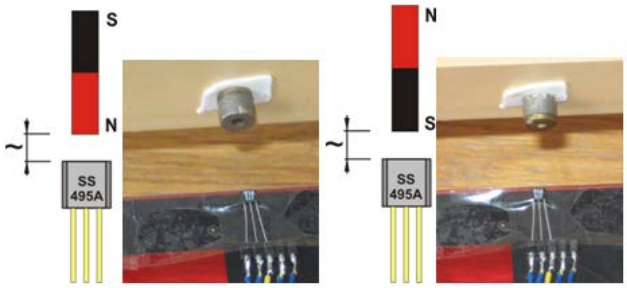



**Figure 4.** Position of permanent magnet from sensor

Measurements have been realized for both polarity of permanent magnet (Figure 4). Permanent magnet is fixed on plastic holder (Figure 5). The sensor was placed on XY table with micrometric screw adjusting mechanism. Position of permanent magnet was adjusted with parallel gage blocks.

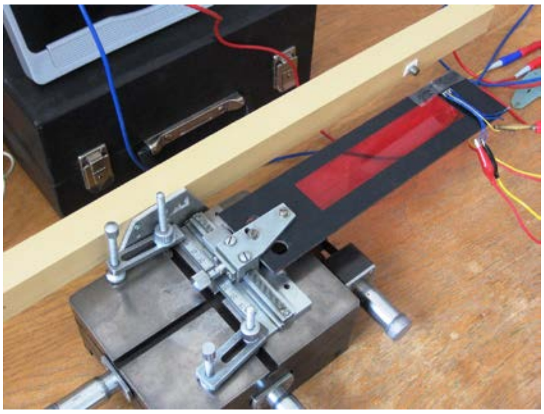


**Figure 5.** Experiments arrangement with SS495 Hall Effect sensor

## 4. Results of Experiments

Results of experiments are shown on Figure 6. Sensor has better sensitivity for small distances, when permanent magnet is placed with North Pole towards the sensor. North Pole orientation limits the range of measurement only for interval (1 mm to 4 mm). Sensor has larger measurement range if sensor is placed with South Pole towards the sensor, but sensitivity is worse, then for previous case. Useful measurement range is from 1 mm to 16 mm.

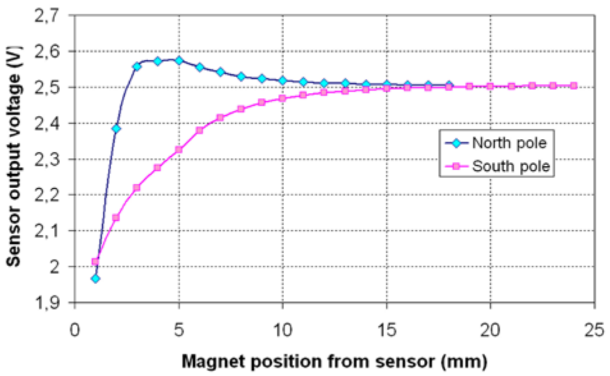



**Figure 6.** Static characteristic of SS495A Hall Effect sensor

These characteristic depends on used permanent magnet. For this reason, it is necessary to make calibration for every new combination of sensor and permanent magnet. Producer notes maximum inaccuracy in range ±1%.

## 5. Application of Hall Effect Sensor

This sensor can be used as position sensor for linearly moved or rotated objects. The main areas of applications of these devices mostly include speed measurements as in speedometers, frequency meters, tachometers etc. Magnetic levitation (Figure 7) is one of our applications, where Hall Effect sensor has been used for sensing of levitated object position.

Figure 8 shows the transducer which is formed of a current carrying conductor creating a magnetic field. The field is concentrated by a magnetic core, which is cut to create an air gap. Within the air gap, a Hall element is used to sense the magnetic flux density. The control current and differential amplification are applied electronically, with the components normally integrated within the transducer [8].

Open loop transducers measure DC, AC and complex current waveforms, while providing galvanic insulation. As mentioned earlier, the advantages include low cost, small size and low power consumption. They are also especially advantageous in applications where high currents (>300A) are being measured. The limitations of open loop transducers include poor bandwidth and response time – due to the magnetic losses in the magnetic circuit – and a relatively large gain drift with respect to temperature.

In comparison, closed loop transducers, also called Hall Effect compensated, or 'zero flux' transducers, use the Hall element voltage to generate a compensation current in a secondary coil, in order to create a total magnetic flux equal to zero [8].

Apparatus (Figure 9) consists of a frame with an arm and two pulley for guiding of nylon wire connected with SMA wire actuator. One end of the Flexinol wire is attached with the frame and second free end is connected via nylon wire with bias weight. Nylon wire is guided with two pulleys to the place for hook with bias weight. There is a reference point (Figure 100) from permanent magnet placed on the nylon wire. Deformation of the Flexinol wire is represented with the reference point (permanent magnet) and position of the magnet is measured via Hall position sensor SS495A. Consequently, output sensor voltage represents the deformation of the Flexinol wire [9].

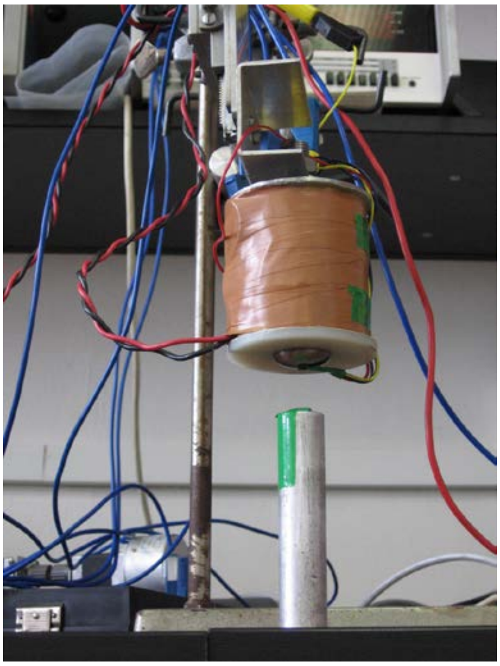


**Figure 7.** Application of Hall Effect sensor for didactic model of levitation

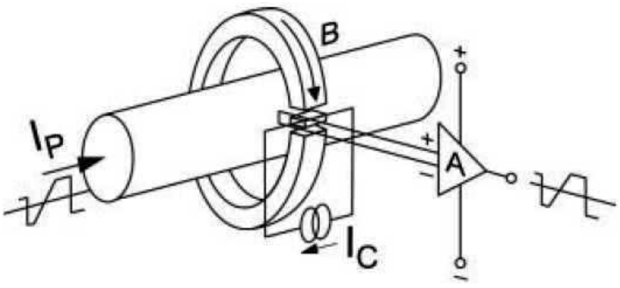



**Figure 8.** Measurement of electric current through the Open loop Hall Effect current transducers [8]

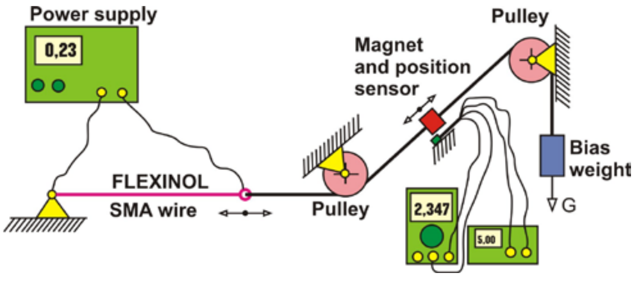



**Figure 9.** Measurement of SMA actuator activity [9]

Several years we have dealt with design of in-pipe machines (Figure 111), which locomote inside pipe for pipe inspection or cable drawing into pipes. Also wheeled machines have been developed for this purpose. Consequently, the main disadvantage of the wheeled construction is tending to slipping and self-blocking of the wheels caused with changed in-pipe geometry. Very small normal force of the wheels against the inner pipe wall causes the wheels slipping. But, very large normal force of the wheels against the inner pipe wall causes the wheels self-blocking. So, it is necessary to change normal force of wheels against the inner pipe wall in dependence of the actual status inside the pipe.

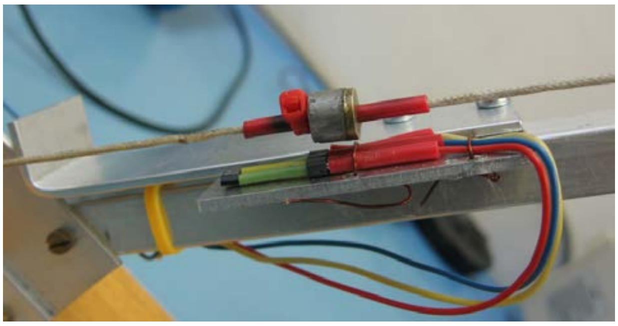
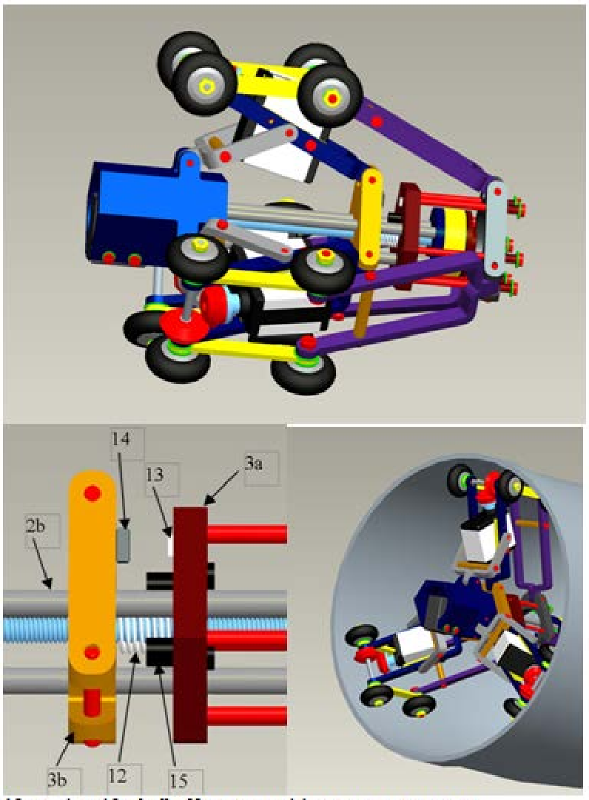


**Figure 10.** Reference point (magnet) for contact-less measuring of SMA deformation [9]

Spring deformation (Figure 111) is measured through the miniature hall sensor (13) (placed on part 3a) and permanent magnet (14) (placed on part 3b). The microcomputer will evaluate the change of distance between the part (3a) and (3b). After that, microcomputer can affect to actuator for opening and closing of the arms. This is a way how to control normal force between the driven wheels and inner pipe wall [10,11].




12 – spring, 13 – hall effect sensor, 14 – permanent magnet,

**Figure 11.** Model of the adaptable in-pipe machine inside the pipe with measurement of normal force through the SS495A Hall Effect sensor

Hall Effect sensors have been used frequently for rotation sensing in DC brush less motors (Figure 122). Rotor shaft holds also disk with magnets for position sensing with Hall Effect sensors. Information from Hall Effect sensors is used for feedback controlling of motor rotation. These motors are also called electronically commutated. Big advantage of this concept is much longer life and better reliability [12].

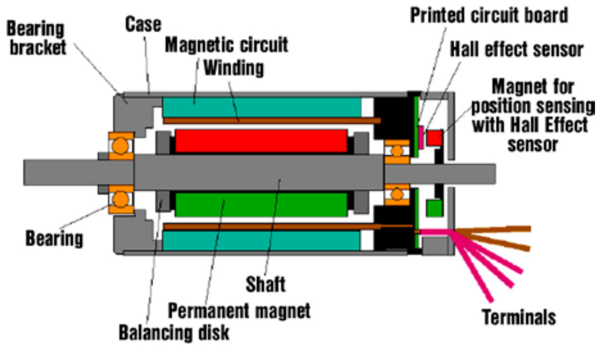



**Figure 12.** Hall Effect sensor for electronic commutation of DC brush less motor [12].

## Conclusion

Hall sensors are commonly used to time the speed of wheels and shafts, such as for internal combustion engine ignition timing, tachometers and anti-lock braking systems. They are used in brushless DC electric motors to detect the position of the permanent magnet.

Critical requirements, such as: cost, distance of travel (effective operating air gap), resolution, accuracy, and often times cost again, all need to be determined to effectively and efficiently select the proper sensing technology. Of course, constructing answers for each of these elements is not always a straightforward task. Here, though, the flexibility of Hall-effect sensing technology is most advantageous. High reliability, small size, production-viable cost, wide operating voltage ranges, variety of output options, and ease of implementation allow Hall-effect sensing technology to service applications in most every market. [13-40].

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