

Experimental Verification of Hall Effect Sensor Properties

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Abstract The Hall element is constructed from a thin sheet of conductive material with output connections perpendicular to the direction of current flow. Hall Effect devices are included in many products, ranging from computers to sewing machines, automobiles to aircraft, and machine tools to medical equipment. The paper deals with identification of the static characteristic of this sensor for i.e. dependence of the output voltage on permanent magnet distance from sensor. The result of measurement is application recommendation.

Keywords: calibration, hall effect, sensor

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1. Introduction

The Hall effect has been known for over one hundred years, but has only been put to noticeable use in the last three decades. The first practical application (outside of laboratory experiments) was in the 1950s as a microwave power sensor. With the mass production of semiconductors, it became feasible to use the Hall effect in high volume products. For the first time, a Hall effect sensing element and its associated electronics were combined in a single integrated circuit. Today, Hall effect devices are included in many products, ranging from computers to sewing machines, automobiles to aircraft, and machine tools to medical equipment [1,2,3].

2. Basic Principle of the Hall Sensor

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.

The Hall effect is an ideal sensing technology. The Hall element is constructed from a thin sheet of conductive material with output connections perpendicular to the direction of current flow. When subjected to a magnetic field, it responds with an output voltage proportional to the magnetic field strength. The voltage output is very small (μV) and requires additional electronics to achieve useful voltage levels. When the Hall element is combined with the associated electronics, it forms a Hall effect sensor.

Although the Hall effect sensor is a magnetic field sensor, it can be used as the principle component in many other types of sensing devices (current, temperature, pressure, position, etc.). Hall effect sensors can be applied in many types of sensing devices. If the quantity (parameter) to be sensed incorporates or can incorporate a magnetic field, a Hall sensor will perform the task [1-7].

In this generalized sensing device, the Hall sensor senses the field produced by the magnetic system. The magnetic system responds to the physical quantity to be sensed (temperature, pressure, position, etc.) through the input interface. The output interface converts the electrical signal from the Hall sensor to a signal that meets the requirements of the application.

General features of Hall effect based sensing devices are: True solid state, long life (30 billion operations in a continuing keyboard module test program), high speed operation - over 100 kHz possible, operates with stationary input (zero speed), no moving parts, logic compatible input and output, broad temperature range (-40 to +150°C), highly repeatable operation [1-7].

Hall Effect Sensors are available with either

- linear output or
- digital output.

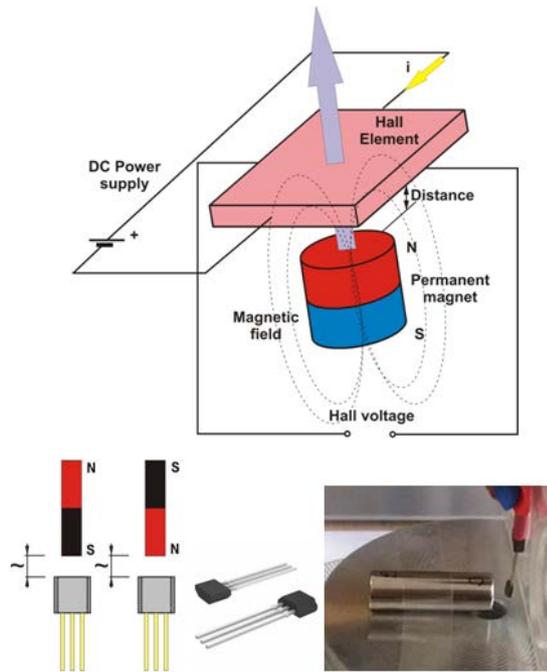


Figure 1. Principle of Hall sensor operation for distance measurement

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. This output Hall voltage is given as:

$$V_H = \frac{k_h}{d} \cdot I \cdot B \quad (1)$$

Where:

V_H is the Hall Voltage in volts,

k_h is the Hall Effect co-efficient,

I is the current flow through the sensor in amps,

d is the thickness of the sensor in mm,

B is the Magnetic Flux density in Teslas.

Linear Hall sensor (Analog ratiometric linear sensors) returns analogue Hall voltage proportional to the applied magnetic flux density. Change of the magnetic density flux can be caused via change of distance between the Hall sensor and permanent magnet connected with measured object. This type is used mainly in application, where linear distance is necessary to be measured.

Digital Hall sensor works as magnetic sensitive switch with output in form of logical levels zero “0” or logical level one “1”. They just know only two states ON/OFF. These types is frequently used in application as limit switch, keyboard switch, velocity rotation sensor, brushless DC motor sensor etc.

Output current of the sensor is small only several miliampers and cannot be used direct to control of any plants. The transistor switch is necessary to use for connecting to other devices [1-7].

3. Linear Hall Sensor

When interfacing with analog output sensors, it is important to consider the effect of the load. The load must

- provide a path to ground

- limit the current through the output transistor to the rated output current for all operating conditions.

This sensor has been selected for experimental testing for position measurement with NdFeB permanent disc magnet with anisotropic magnetization (diameter 4 mm and length 10 mm). Experimental apparatus have been designed and realised for this reason (Figure 2). The position is measured with resistive sensor and parallel length gauges have been used for calibration of this sensor.

Calibration process was executed for every 10th millimetres of overall range of resistive sensor. Result is static transformation characteristic, which can be described with math model obtained from regression (Figure 4).

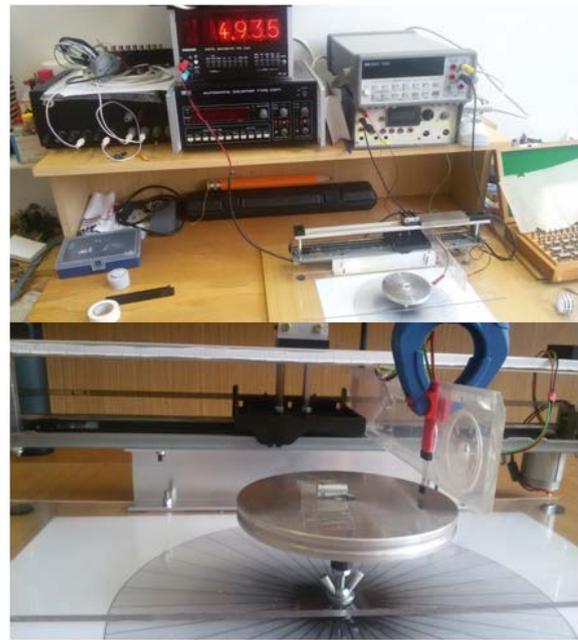


Figure 2. Principle of Hall sensor operation for distance measurement

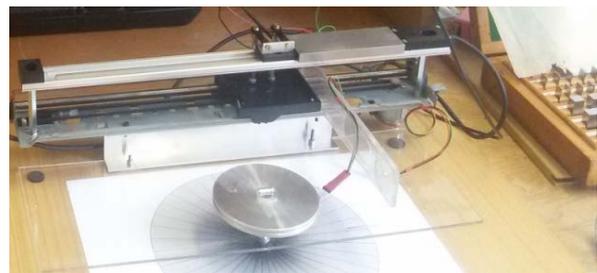


Figure 3. Calibration of resistive position sensor with length gauges

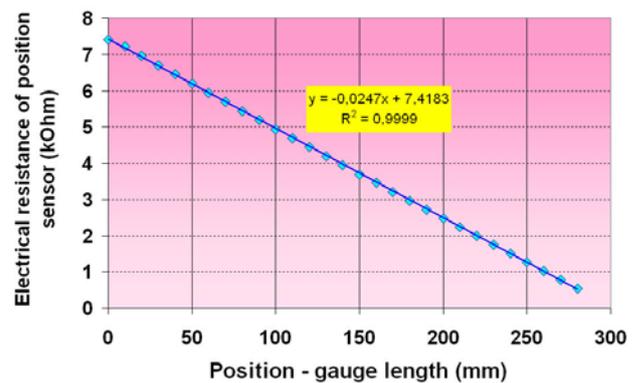


Figure 4. Static transformation characteristic of resistive position sensor

Results of calibration can be processed into calibration characteristic, which can be used for recalculation of position sensor resistance to information about actual position in millimetres (Figure 5).

Calibration model enables to measure position of Hall sensor from permanent magnet.

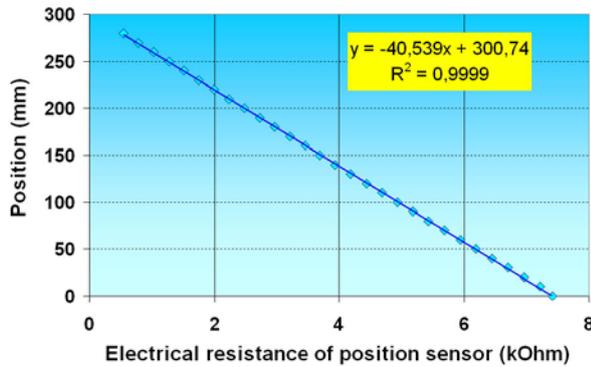


Figure 5. Calibration characteristic of resistive position sensor

4. Experimental Test of Hall Sensor

Aim of testing is to identify suitable orientation of permanent magnet and sensor. Very important is to recognize of working interval, where sensor has good sensitivity to position sensing. Magnetic sensor could be a sensitive also to direction of moving to or from permanent magnet which can occurs as hysteresis on static characteristic.

It is possible to arrange four states for position measurement:

- South pole of permanent magnet is toward to smaller surface of sensor (Figure 6).
- South pole of permanent magnet is toward to larger surface of sensor (Figure 7).
- North pole of permanent magnet is toward to smaller surface of sensor (Figure 8).
- North pole of permanent magnet is toward to larger surface of sensor (Figure 9).

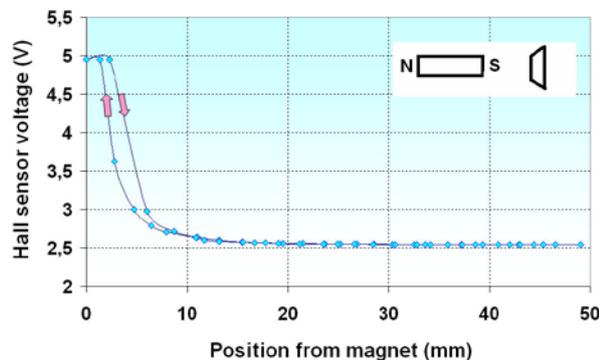


Figure 6. Calibration characteristic of resistive position sensor

Situation on Figure 6 shows the strong hysteresis and there is only small working area for position measurement 8 mm – 15 mm. There is a no change of voltage after this range.

Figure 7 also shows hysteresis, but there is also useful interval for position measurement in range 4 mm to 16 mm.

Figure 8 also has hysteresis and useful working area is too small 17mm – 22mm.

Best situation is on Figure 9, where hysteresis is negligible. Useful working interval is 3mm – 20 mm. Working range of measurement is 17 mm, which can be used for position measurement.

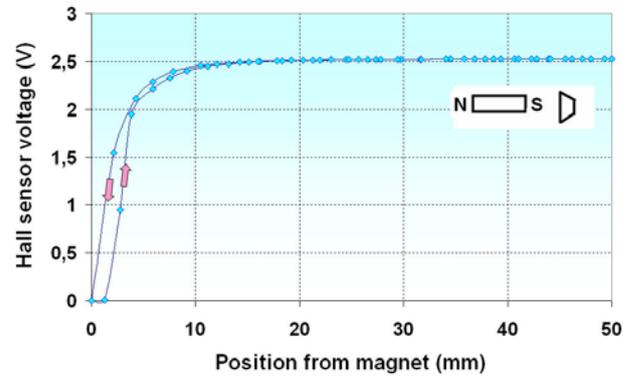


Figure 7. Calibration characteristic of resistive position sensor

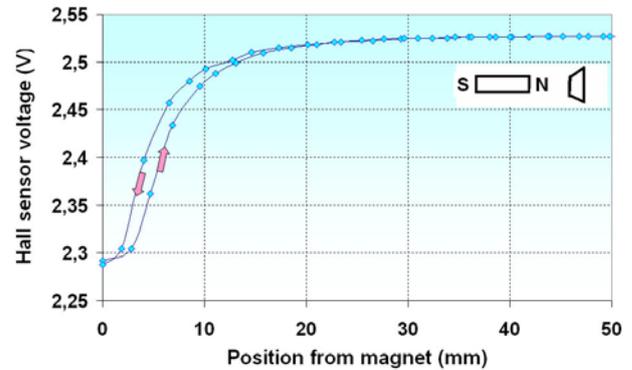


Figure 8. Calibration characteristic of resistive position sensor

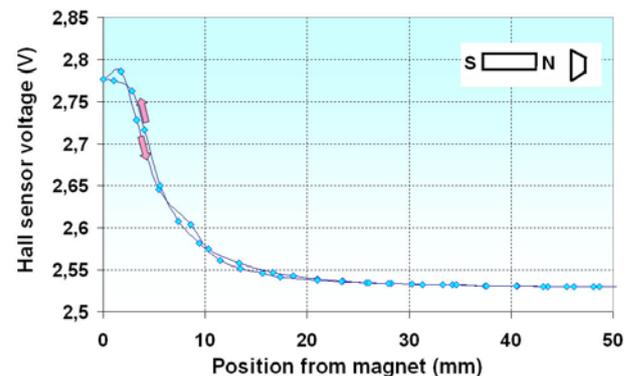


Figure 9. Calibration characteristic of resistive position sensor

This type of Hall sensor has optimal configuration when North pole of permanent magnet is toward to larger surface of sensor. This is recommendation for using of this sensor in practical application.

Our designed actuator tester includes also Hall sensor for position measurement (Figure 10).

Results from Hall sensor testing have been used for design of sensor configuration with aim to obtain maximum working range without or with minimum hysteresis effect.

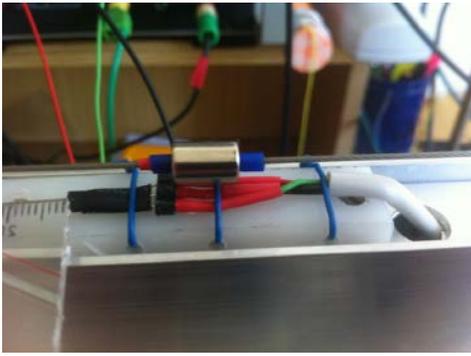


Figure 10. Hall sensor for position measurement

5. Conclusion

Currently, the Hall effect sensor application includes current sensor, gear tooth sensor, Hall effect based temperature sensor, Hall effect pressure sensor, speed sensor (tachometers and RPM sensor), position sensor (automotive sensor - valve, piston, shaft, crankshaft, ignition sensor, throttle angle sensor, anti-skid sensor, transmission sensor), door sensor (security sensor), brushless DC motor sensor, flow meter, relays, proximity sensor, encoder sensor, metal detector, vibration sensor, level and tilt sensor, etc. [8-24]

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