Methodology for Static Parameters Testing of Magnetic Field Sensors

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Abstract – **A methodology for testing of basic static parameters of magnetic field sensors for position detection is presented in this paper. The methodology consists from appropriate hardware and software selection and suggestion for test procedure sequence. The primary application of presented approach is in industry during manufacturing however, it can also be used for scientific and educational purposes.**

Keywords – **Magnetic field sensors, position detection.**

I. INTRODUCTION

When the accurate and reproducible detection of piston positions in pneumatic cylinders is necessary, the magnetic sensors offer the right solution. The target markets of magnetic cylinder sensors include the pneumatics industry, material handling systems, the electronics industry, the packaging industry, as well as machine constructors. Initially, the particular automation task is of decisive importance in selecting the most suitable sensor solution.

Magnetic field sensors react to magnetic fields and are especially suited for position detection of pistons in pneumatic cylinders. Based on the fact that magnetic fields can permeate non-magnetisable metals, this sensor type is designed to sense through the aluminium wall of a cylinder by means of a permanent magnet fixed on the piston as can be seen in fig. 1.

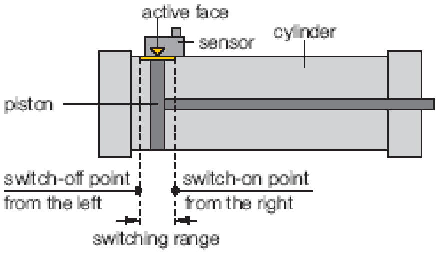


Figure 1. Position detection of pistons in pneumatic cylinders

The magnetic field sensors are used for registration and comparison of objects, for distance measurement, for measurements of fluids and raw materials, for measuring of temperature and pressure, for measuring movements, for measuring of flaw fluids, etc.

Using these sensors for solving particular industrial tasks besides the main parameters related to the reliability, accuracy and speed also a great number of other static parameters should be monitored. This allows for a detail classification and eases the selection of appropriate sensors for the particular case [2].

II. TEST SCENARIO AND MAIN PARAMETERS

By the magnetic field sensors the following basic function principles may be applied:

1. Fully electronic and contactless detection
2. Mechanical reed contacts

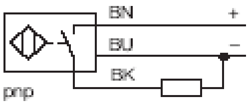
The purpose of investigation of this work are sensors with transistor output, 3-wire DC, NO (normally open), which are more complex for manufacturing, more sensitive, more reliable and with a wider areas of usability.

The main advantages of these sensors are: very low leakage current, easy connection to relays and PLCs, easy serial and parallel connection.

Contactless sensors of magnetic fields could be divided in two main groups depending on the way of connecting:

Sensors with switching output

a) PS (plus switching)



b) NS (negative switching)

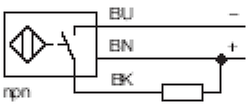


Figure 2. Types of sensors
BN-plus supply; BU-minus supply; BK-sensor output

The main task here is to present a methodology for testing of base static parameters of 3-wire, PS type sensors for magnetic fields.

In order to have equal results, when testing sensors from different vendors, the development methodology is based

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on the well accepted documents and standards (EN60947-5-2; EN60068-2-6; EN60529, etc), where the main technical requirements for these type of products are described. In order to trace the behavior of the parameters of the sensors placed in different climate conditions, the electrical tests are made in a climate chamber where real time conditions of operating of the sensors are simulated.

The values of the electrical characteristics of the sensors are highly influenced by the operating temperature in which they work and that's why tests made in different points of the temperature range are a key factor for their research. [2].

When developing the methodology a special attention is paid to the measurement of the parameters for typical classification of the sensors, parameters for verification of confidence of the product in the process of production for prove of quality.

Further in this paper, 4 basic measurements from the developed methodology are described in details:

- Measurement of minimal operational current Im,
- Measurement of Of-state current Ir,
- Measurement of supply current without load Io,
- Measurement of voltage drop Ud.

III. HARDWARE AND SOFTWARE SELECTION FOR THE EXPERIMENTAL SETUP

A. Helmholtz coils

In order to get the electrical parameters of the sensor it is needed its magnetic activation, which may be achieved by *Helmholtz coil.* With the realization of the parallel setup in one couple of the coils is guaranteed that the magnetic field in the center of the shown on fig. 5 coils could be considered for homogenous.

In this way the strength of the magnetic field H e proportional to submitted curnnet I. As a proportinal factor could be used the coeficient K, which can be determined through a probe for a magnetic field and a gauss meter and contains the magnetic characteristics of the material from which the coiled is produced. The mathematical equation between the two parameters is:

$$\mathrm{H[kA/m]} = \mathrm{B[Vs/m^2]^*}/(1000.\mu)\mathrm{[Vs/(A.m)]}, \quad (1)$$

where

$$^*1\mathrm{Vs/m^2} = 1\mathrm{T}. \quad (2)$$

Because the core of the Helmholtz coil is filled with air $(\mu_r = 1)$ and using

$$\mu = \mu_r . \mu_0, \quad (3)$$

then:

$$\mu = \mu_0 . \quad (4)$$

Relative magnetic permeability is:

$$\mu_0 = 4.\pi.10^{-7}[Vs/(A.m)] \quad (5)$$

Then for the calibration coefficient comes:

$$K[1/m] = (1000.H)[kA/m]/I[A], \quad (6)$$

where I is the current through the coil.

B. Power supplies

In order to have a normal operation of the coil there is a need for a power supply, which in our case, where there is an automated process of test, there should be a possibility for control by a computer. A regulated power source provides electrical energy which is precisely controlled. In this case current source 6625A from Agilent can be used, which can be controlled from a personal computer. The sensor can be powered with the device 6812B [3].

6812B AC Power Source/Power Analyzer, 750VA, 300V, 6.5A [3]:
Measurement Accuracy
DC Voltage: 0.05%+150mV
6625A Precision System Power Supply, 25W, 2 outputs
Programming Accuracy
Voltage 25W: 1.5mV+0.016% (low),
10mV+0.016% (high)
Readback Accuracy
Voltage 25W: 0.16%+2mV (low), 0.016%+10mV (high)

C. Digital multi meters

In order to measure the corresponding electrical parameters there is a need of two digital multi meters. For automation of the process, PC-based digital multi meters can be used like 34401A, which is with the following parameters [3]:
Measuring Characteristics:
<u>DC Voltage</u>
A/DLinearity: 0.0002% of reading +0.0001% of range
Input resistance:
0.1V, 1V,10V ranges Selectable 10MΩ or >10GΩ
100V, 1000V ranges 10MΩ±1%
<u>DC Current</u>
Shunt Resistor:0,1Ω for 1A, 3A. 5Ω for 10mA, 100mA
Input Protection: Externally accessible 3A, 250V fuse Internal 7A, 250V fuse
<u>Accuracy Specifications ±(%of reading+% of range)</u>
DC Voltage at 23°C±1°C
range 10.00000V – 0.0015+0.0004
DC Current at 23°C±1°C
Range 10.00000mA – 0.005+0.010

D. Electronic load

In order to have to ability to check the main electrical characteristics of a given sensor there is a need of an electronic load for the sensor witch which the current can be set up in the given ranges.

The "electronic load" is an instrument that functions as a programmable electrical energy absorption device. It typically has high output impedance that allows the output voltage and current to change rapidly. Usually, electronic load ratings vary from tens of watts to kilowatts, with current ratings from amperes to hundreds of amperes and voltage ratings from several volts to nearly 1 kV. The electronic load has three modes of operation: constant current, constant voltage, and constant resistance [3].

In order to test magnetic field sensors an electronic load with following capabilities is needed:

Upper limit:100mA/30V - 300Ω
Nominal mode: 10mA/24V – 2,4kΩ
Lower limit:1mA/10V – 10kΩ

Most appropriate electronic load is 6063B from Agilent with the following parameters [3]:

Amperes: 0 to 10A
Volts: 3 to 240V
Maximum power (at 40°C): 250W
Constant current mode
Ranges: 0 to 1A, 0 to 10A
Accuracy: 0,15%±10mA
Regulation point: 8mA
Constant resistance mode
Ranges: 0,20 to 24.0Ω
24.to 10.000Ω
240 to 50.000Ω
Readback measurement
Current accuracy: ±(0.12%±10mA),
Voltage accuracy: ±(0.1%+150mV).

E. Software selection

Software is the most important part of any testing system. Software controls how the various instrument components are combined and provides the test sequence. In large test systems, software investments often are much greater than the instrumentation hardware costs. But software does have the benefits of being very easy to customize. This allows engineers to have tremendous flexibility, and existing applications can often be adapted to suit a particular purpose.

There are two base kinds of software – graphical and textual. Graphical programming is a visually oriented approach to programming. This software is easier and more intuitive to use than traditional textual programming [6]. For presented methodology most appropriate is LabVIEW software environment but can be used also TestStand or Agilent VEE.

F. Architecture of the measurement system

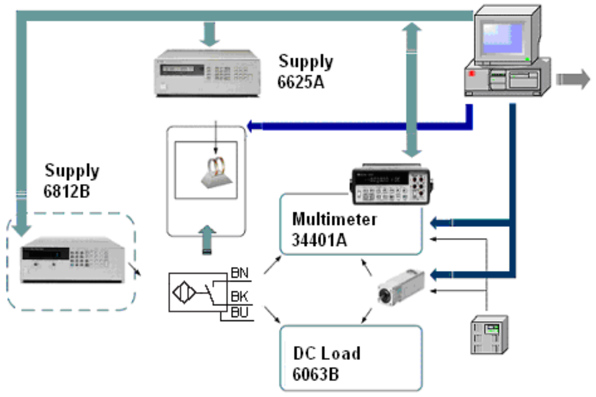

Figure 3. Hardware architecture of test system.

IV. EXPERIMENTAL SETUP FOR THE BASIC STATIC PARAMETER MEASUREMENT

In presented methodology the test procedures are implemented in following sequence:

- Test of minimum operational current Im;
- Of-state current (Ir) testing;
- Test of supply current without load Io;
- Test of voltage drop Ud.

A. Minimum operational current (Im)

Minimum current in a switched state to maintain the function. Minimal load current is the lowest current, which can flow through the output of the sensor, when magnetically activated, and thus making the product to function normally. Based on EN60947-5-2 this parameter should not exceed 1mA.

In order to measure the minimal load current, an electronic load is connected to the sensor, which after an appropriate tuning delivers the flow of minimum current Ie through the product. Through an additional tuning of the load, a gradual decrease of the current is achieved from Ie till reaching Im, which is the lowest possible current, which can flow through the product while keeping the sensor functionality. While decreasing the current, a constant monitoring of Ud is present and if it changes for Im we record the value when a change of Ud was not registered.

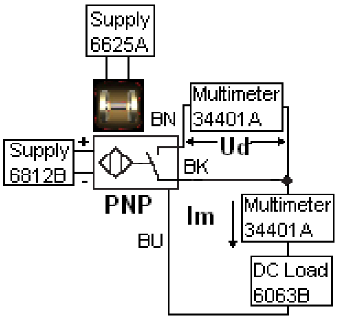

Figure 4

B. Off-state current (Ir)

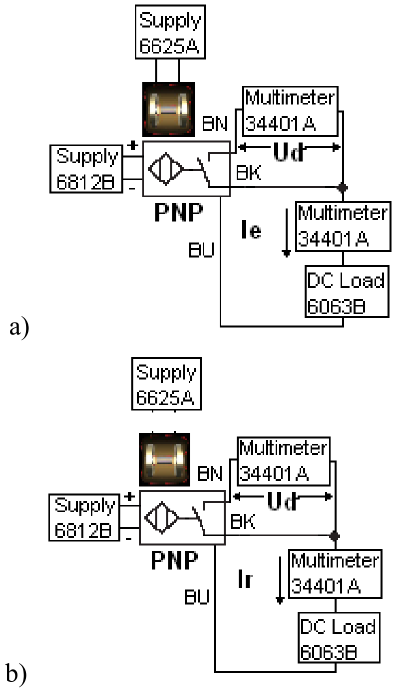

Figure 5

This is the current which flows in a non-active condition between the output and 0V (pnp-output), resp. the output and supply voltage (npn-output).

a) The sensor is powered with Ue, so through it flows Ie;

- via Helmholtz coil a magnetic field is generated with a value of 3,7 kA/m, which is enough to activate the sensor element;

b) The power to the coil is turned off and thus the magnetic activation of the sensor is ceased;

-with the digital multi meter the current flowing through the output of the product is measured, which is the Of-state current and should be in accordance to the technical specification of the product;

Of-state current is the maximum current, which in the most extreme working conditions can flow through the sensor. According to DIN EN60947-5-2 this current for 3-wire sensors, type PS should be less of 0,5 mA/DC.

C. No-load supply current (Io)

This is the current flowing between supply voltage and 0 V and is indicated for 3- and 4-wire sensors only.

This current is measured according to figure 6 without a load on the output, and includes the needed consumption for the LED indication of the sensor. This current can be of 2 types depending on where the sensor is magnetically activated Ios (magnetic switched) a) or not Ion (magnetic not switched) b). This parameter is defined by each manufacturer of magnetic field sensors but in most cases is in the following ranges:

Ios=(10 – 13)mA

Ion=(3 – 5)mA

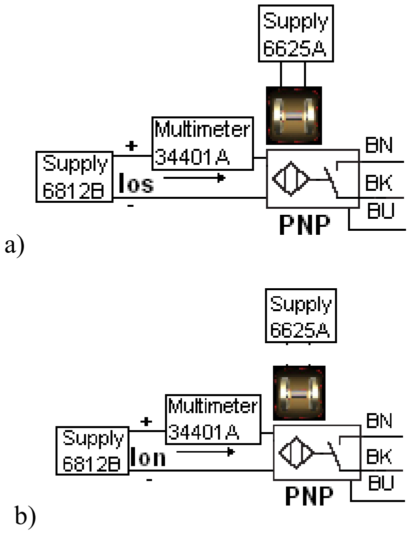

Figure 6

D. Voltage drop (Ud)

This parameter is the voltage of a switched output. This is the voltage drop which is measured on the active output of the sensor during in the process of its exploitation when is powered with Ue and current Ie is flowing. It is defined by the natural and non ideal characteristics of the sensor element and is measured with the help of a digital multi meter between the output of the sensor and the positive power supply. Range of the parameter: 3,5V ± 1V.

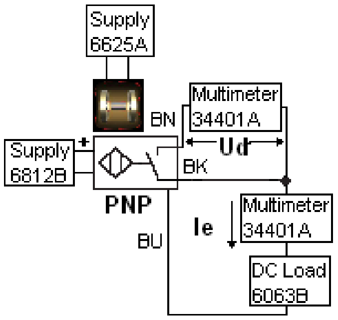

Figure 7

V. CONCLUSION

The presented methodology and the measuring system for testing of magnetic field sensors allow the measurement of a large number of sensor parameters. This allows quick and precise detail classification and selection of appropriate sensors for the particular case. Using a graphical programming environment for the implementation of the software allows easy upgrade of the system and expansion with additional testing procedures.

Acknowledgements

This investigation has been carried out in the framework of the research project № 092 NI 044-03.

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