Acta Mechatronica - International Scientific Journal about Mechatronics
Volume: 9 2024 Issue: 4 Pages: 27-31 ISSN 2453-7306



*https://doi.org/doi:10.22306/am.v9i4.123*

*Received: 27 Oct. 2024*
*Revised: 22 Nov. 2024*
*Accepted: 04 Dec. 2024*

# Universal tester of length sensors

**Katarina Palova**
Technical University of Kosice, Faculty of Mechanical Engineering, Letna 9, Kosice, Slovak Republic, EU, katarina.palova@tuke.sk
**Tatiana Kelemenova**
Technical University of Kosice, Faculty of Mechanical Engineering, Letna 9, Kosice, Slovak Republic, EU, tatiana.kelemenova@tuke.sk (corresponding author)

***Keywords:*** sensor, signal, uncertainty, gauge, length.
***Abstract:*** The article deals with the design of a universal tester of length and position sensors. It is composed of a rotary table and a sliding mechanism for generating displacement. Length parallel gauges are used as standards. The result of the testing is the static and calibration characteristics of the sensor and the verification of the maximum permissible errors of the sensor and measuring chain.

## 1 Introduction

Position sensors are a relatively widespread category of sensors applied in almost all areas of science and technology. Before the actual application of position sensors, it is necessary to verify the properties of the selected sensor and possibly identify the unknown properties of the tested sensors.

The properties of the sensors listed in the catalogue sheets are specified under certain measurement conditions. However, sensors are often used in other than laboratory conditions, so it is necessary to verify their properties in other conditions as well.

Existing test equipment is developed for each sensor type and application separately and does not allow testing other sensors and testing multiple sensor properties. Test devices are developed as single-purpose test devices for output control by sensor manufacturers.

In the case of sensors, it is necessary to test the static characteristic as the dependence of the sensor's output reference value on the input measured value. The dynamic properties of the sensors include the transient characteristic, which shows the response of the sensor to a step change in the measured input quantity. Among the dynamic properties of the sensor is also the impulse characteristic, which describes the response of the sensor to the impulse of the input measured value. Another dynamic property is the speed characteristic, which investigates the response of the sensor to the input quantity with increasing speed of change of the input quantity. A frequently monitored dynamic property is also the frequency characteristic, which describes the response of the sensor to the harmonically varying input quantity. With some types of sensors, it is also necessary to investigate the influence of the inaccuracy of the positioning of the sensor with respect to the detected object. This means that during testing it is necessary to deviate the axis of the sensor with respect to the perpendicular to the detected object. With sensors sensitive to magnetic fields, it is necessary to place a permanent magnet as the detected object, and the solution of the test equipment must be adapted to this. Another feature that is interesting for the application of sensors is their lifetime defined by the number of cycles that can be realized during the entire lifetime of the sensor [1-5].

Current solutions of test equipment do not allow comprehensive testing of sensors from the point of view of the mentioned properties.

Parallel gauge blocks (Figure 1) are precisely manufactured prisms with defined dimensions that can be used as length standards. These are materialized length measures, which are used for the verification of length sensors and length gauges. They are made of metal or ceramics with a low coefficient of thermal expansion. Parallel gauge blocks are available as a multi-piece set that allows for any size assembly. The accuracy of these etalons is defined by the ISO 3650 standard [2].

*Figure 1 Set of parallel gauge blocks*

Acta Mechatronica - International Scientific Journal about Mechatronics
Volume: 9 2024 Issue: 4 Pages: 27-31 ISSN 2453-7306



## 2 Length sensor tester concept

In the test device (Figure 2), the tested position sensor is placed on a plastic arm connected to a slide moving along a horizontal line. The detected object is placed on a rotary and height-adjustable table attached to the base plate. The slide is attached to the toothed belt with a slide carrier. The movement of the slide with the sensor is ensured by a toothed belt and toothed pulleys. This toothed pulley is attached to a DC motor with a gearbox, which ensures the movement of the toothed belt and thus the slide. The movement of the slide is also sensed by a separate sensor of the position of the slide to obtain information about its current position. The runner of this sensor is connected by means of a runner carrier with a slide. The horizontal guide of the slide, the sensor of the position of the slide and the gear with a DC motor are attached to the frame, which is placed on a rotating base, which allows the rotation of the whole system with respect to the detected object by a specified angle. A DC motor with a gearbox and a toothed gear enables automated testing of the static and dynamic properties of the tested position sensor, and it is also possible to carry out tests of the life of the tested sensor. In addition, the rotary table makes it possible to test the influence of the deviation of the sensor from the perpendicular with respect to the detected object, whose position the sensor detects (Figure 2).

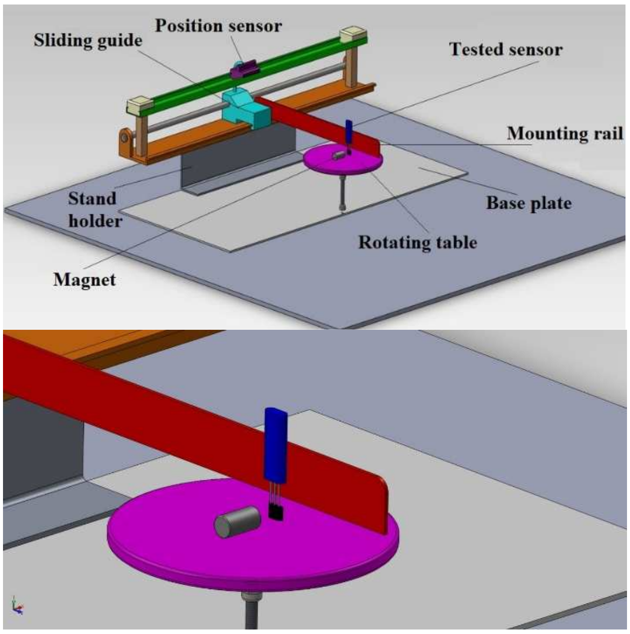
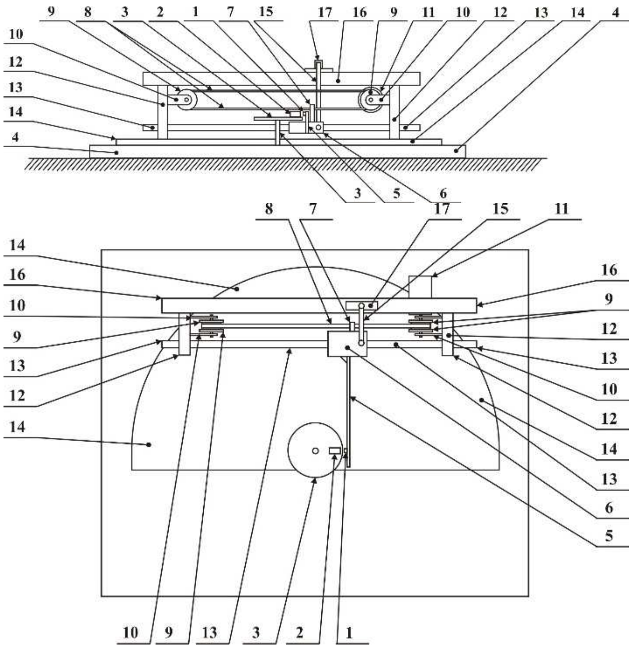



*Figure 2 Length sensor tester concept*

## 3 Technical solution of the tester

In the tester (Figure 3), the detected object 2 is mounted on a rotary and height-adjustable table 3, which is attached to the base plate 4. The tested sensor 1 is mounted on a plastic arm 5 firmly connected to a slide 6 moving along a horizontal guide 13.



1 – Tested sensor; 2 – Detected object; 3 – Rotating and height adjustable table; 4 – Base plate; 5 – Plastic arm; 6 – Slide; 7 – Slide driver; 8 – Timing belt; 9 – Toothed pulleys; 10 – Bearing the pulley; 11 – DC motor with gearbox; 12 – Frame; 13 – Horizontal line; 14 – Swivel base; 15 – Runner drifter; 16 – Slider position sensor; 17 – Slide position sensor runner.

*Figure 3 Tester arrangement*

The slide 6 is attached by means of the carrier 7 of the slide 6 to the toothed belt 8, which moves with the help of a DC motor 11 with a gearbox connected to one of the toothed pulleys 9 on which the toothed belt 8 is mounted. The toothed pulleys 9 are stored in the bearing 10 of the pulleys. The movement of the DC motor 11 with the gearbox creates the movement of the toothed belt 8 and thus also the slide 6 with the tested sensor 1. The slide 6 is connected to the runner 17 of the sensor 16 of the position of the slide 6, which is part of the sensor 16 of the position of the slide 6. Horizontal line 13, storing 10 pulleys, DC motor 11 s by the gearbox and the position sensor 16 of the slide 6 are attached to the frame 12, which is firmly connected to the rotating base 14. The entire horizontal positioning system is formed by the pay arm 5, the slide 6, the driver 7 of the slide 6, the toothed belt 8, the toothed pulleys 9, the bearings 10 of the pulley , DC motor 11 with gearbox, frame 12, the horizontal guide 13, the rotating base 14, the driver 15 of the runner, the sensor 16 of the position of the slide 6 and the runner 17 of the sensor 16 of the position of the slide 6, together with the tested sensor 1, it is thus possible to film with respect to the axis of the rotary and height adjustable table 2 with the detected object 2 and to investigate the influence of the deviation of the perpendicularity of the tested sensor 1 with respect to k to the detected object 2. The detected object 2 is selected according to the type of the tested sensor 1. For example, for the tested sensor 1 sensitive to the magnetic field, a permanent magnet is used as the detected object 2. If the

Volume: 9 2024 Issue: 4 Pages: 27-31 ISSN 2453-7306


tested sensor 1 is based on the inductive principle, a metal object and the like is selected as the detected object 2.

## 4 Experimental testing of the Hall-effect distance sensor

During the experimental testing of the distance sensor based on the Hall-effect principle (Figure 4), a permanent magnet was placed on the rotary table, which is made of non-ferromagnetic material so as not to affect the magnetic field of the placed permanent magnet. Hall-effect distance sensor vol mounted on a plastic beam that can be positioned relative to the permanent magnet. The relative position of the sensor relative to the permanent magnet can be adjusted using parallel gauge blocks.

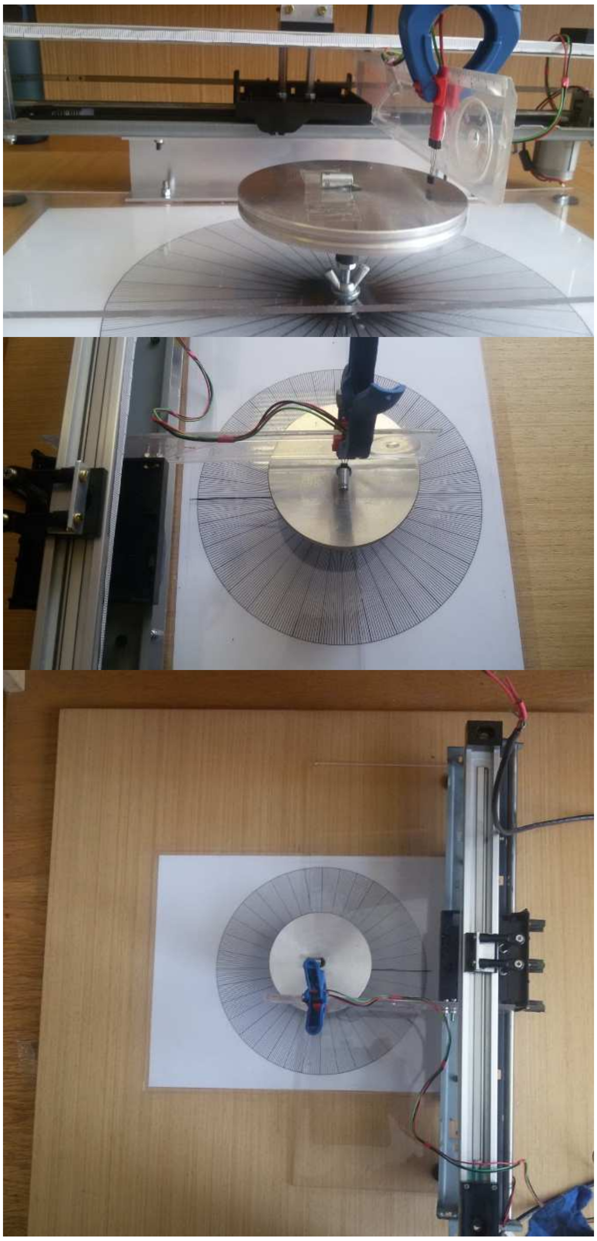



*Figure 4 Experimental testing of the Hall-effect distance sensor*

When testing the Hall-effect distance sensor, it is possible to realize four possible configurations of the arrangement of the sensor and the permanent magnet (Figure 5). From the obtained experimental data, the best solution is the U4 configuration, which has the largest useful distance measurement range and the minimum hysteresis.

The result of the experimental testing of the sensor (Figure 6) shows the course of the output electric voltage of the sensor when changing its position relative to the permanent magnet in the U4 configuration. The graph shows a slight hysteresis, which, however, can be neglected and the working area of the distance measurement range is suitable for dimensions from 4mm to 20mm (Figure 6).

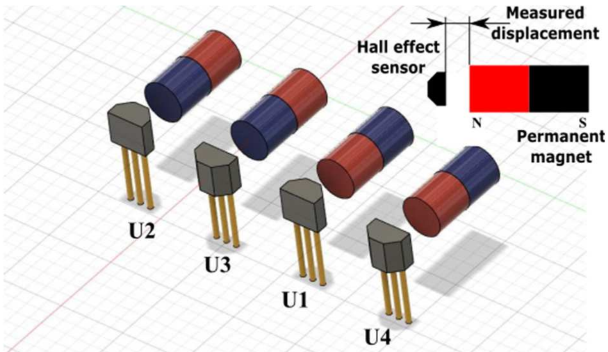



*Figure 5 Sensor and permanent magnet arrangement options configurations*

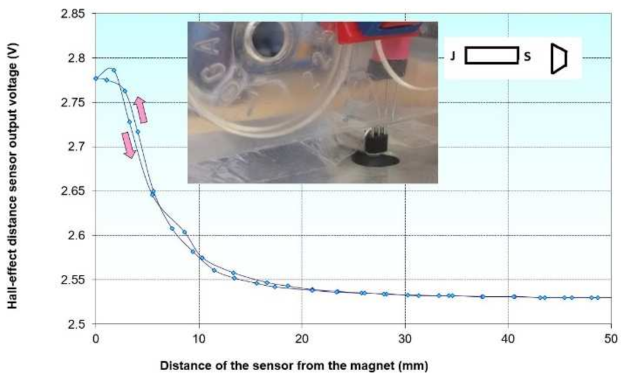



*Figure 6 Experimental testing of the Hall-effect distance sensor during uniaxial distance change*

The proposed test device also provides the possibility of changing the direction of the permanent magnet relative to the axis of the sensor (Figure 7). With this multi-axis approach and distance of the sensor with respect to the magnet, it is possible to observe the directional characteristics of the sensor based on the principle of the Hall effect. The 90° rotation angle is when the axis of the sensor is identical to the axis of the permanent magnet. It can be seen from the graph (Figure 7) that when the sensor is rotated with respect to the magnet, the sensitivity of the sensor improves and the usable range of distance measurement also increases slightly. At the same time, it is possible to find out from the graph (Figure 7) how sensitive the sensor is to the accuracy of the adjustment of the axis of the sensor to the axis of the permanent magnet.

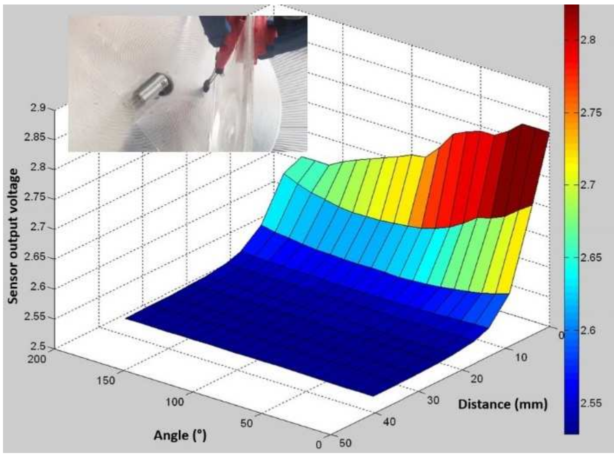



*Figure 7 Experimental testing of the Hall-effect distance sensor during multi-axis distance change*

## 5 Conclusion

The result of this study is the design of an experimental test device that allows testing the characteristics of the distance sensors and at the same time it is possible to identify the directional characteristics of the sensors using a rotary table.

The proposed tester for testing sensors can be used to simulate the application of the tested position sensor and verify its properties in this application. In addition to the static and dynamic characteristics of the sensor, it is also possible to test the lifetime of the sensor and non-standard motion cycles according to the application in which the sensor is planned to be used.

Similar to other applications, it is important to test and diagnose systems for identifying their properties and for their periodic diagnostic verification of their functionality [6-21].

**Acknowledgement**

The work has been accomplished under the research project VEGA 1/0191/24 and project KEGA 004TUKE-4/2024 financed by the Slovak Ministry of Education.

## References

[1] EA-4/02 M:2013 *Evaluation of the Uncertainty of Measurement in Calibration*, EA-4/02 is a mandatory document belongs to Category: Application documents and Technical Advisory documents for Conformity Assessment Bodies. National translation MSA-L/12 Expression of the Uncertainty of Measurement in Calibration (EA-4/02 M:2013), Publication Reference, European Accreditation Laboratory Committee, September 2013 rev 01, [Online], Available: https://european-accreditation.org/wp-content/uploads/2018/10/ea-4-02-m-rev01-september-2013.pdf. [15 Oct 2024], 2013.

[2] ISO 3650:1998(E) International Standard: *Length standards – Gauge Blocks*, International Organization for Standardization, Geneva, Switzerland, 1998.

[3] ISO 10360-7:2011 *Geometrical product specifications (GPS) -- Acceptance and reverification tests for coordinate measuring machines (CMM)* -- Part 7: CMMs equipped with imaging probing systems, 2011.

[4] CHUDÝ, V., PALENČÁR, R., KUREKOVÁ, E., HALAJ, M.: *Measurement of technical quantities*, Edition of STU, 1999. (Original in Slovak)

[5] JCGM 100 – *Evaluation of measurement data – Guide to the expression of uncertainty in measurement (ISO/IEC Guide 98-3)*, [Online], Available: http://www.iso.org/sites/JCGM/GUM-JCGM100.htm [15 Oct 2024], 2008.

[6] IVANOVA, T.N., BOŽEK, P., KORSHUNOV, A.I., KORETCKIY, V.P.: Control of the Technological Process of Drilling, *MM Science Journal*, Vol. 2020, No. October, pp. 4035-4039, 2020. https://doi.org/10.17973/MMSJ.2020_10_2020052

[7] KAYAL, M., PASTRE, M.: Automatic calibration of Hall sensor microsystems, *Microelectronics Journal*, Vol. 37, pp. 1569-1575, 2006. https://doi.org/10.1016/j.mejo.2006.04.013

[8] PAVLASEK, P., HARGAŠ, L., KONIAR, D., PRANDOVÁ, A., SIMONOVÁ, A., ŠPÁNIK, P., URICA, T.: *Flexible Education Environment: Learning Style Insights to Increase Engineering Students Key Competences*, EDULEARN18, 10th International Conference on Education and New Learning Technologies, Palma, Spain, Edited by: Chova, L.G., Martinez, A.L., Torres, I.C., Book Series, EDULEARN Proceedings, pp. 10156-10165, 2018.

[9] BOŽEK, P., PIVARČIOVÁ, E.: Registration of Holographic Images Based on Integral Transformation, *Computing and Informatics*, Vol. 31, No. 6, pp. 1369-1383, 2012.

[10] BRATAN, S., SÁGOVÁ, Z., SÁGA, M., YAKIMOVICH, B., KURIC, I.: New Calculation Methodology of the Operations Number of Cold Rolling Rolls Fine Grinding, *Applied Sciences*, Vol. 13, No. 6, pp. 1-16, 2023. https://doi.org/10.3390/app13063484

[11] KURIC, I., KLAČKOVÁ, I., Nikitin, Y.R., ZAJAČKO, I., CÍSAR, M., TUCKI, K.: Analysis of Diagnostic Methods and Energy of Production Systems Drives, *Processes*, Vol. 9, No. 5, 843, pp. 1-19, 2021. https://doi.org/10.3390/pr9050843

[12] ABRAMOV, I.V., NIKITIN, Y.R., ABRAMOV, A.I., SOSNOVICH, E.V., BOŽEK, P.: Control and Diagnostic Model of Brushless DC Motor, *Journal of Electrical Engineering*, Vol. 65, No. 5, pp. 277-282, 2014.

[13] KONIAR, D., HARGAŠ, L., ŠTOFAN, S.: Segmentation of Motion Regions for Biomechanical Systems, *Procedia Engineering*, Vol. 48, pp. 304-311, 2012.

[14] VIRGALA, I., MIKOVÁ, Ľ., KELEMEN, M., HRONCOVÁ, D.: Snake-like robots, *Acta Mechatronica*, Vol. 3, No. 4, pp. 7-10, 2018. https://doi.org/10.22306/am.v3i4.43

[15] MIKOVÁ, Ľ., VIRGALA, I., KELEMEN, M.: Embedded systems, *Acta Mechatronica*, Vol. 3, No. 2, pp. 1-5, 2018. https://doi.org/10.22306/am.v3i2.32

[16] KELEMENOVÁ, T., FRANKOVSKÝ, P., VIRGALA, I., MIKOVÁ, Ľ., KELEMEN, M., DOMINIK, L.: Educational models for mechatronic courses, *Acta Mechatronica*, Vol. 1, No. 4, pp. 1-6, 2016.

[17] LIPTÁK, T., KELEMEN, M., GMITERKO, A., VIRGALA, I., HRONCOVÁ, D.: The control of holonomic system, *Acta Mechatronica*, Vol. 1, No. 2, 2016, pp. 15-20.

[18] KURYŁO, P., PIVARČIOVÁ, E., CYGANIUK, J., FRANKOVSKÝ, P.: Machine vision system measuring the trajectory of upper limb motion applying the Matlab software, *Measurement Science Review*, Vol. 19, No. 1, pp. 1-8, 2019.

[19] OLEJAROVÁ, S., KRENICKÝ, T.: Monitoring the Condition of the Spindle of the Milling Machine Using Vibration, *MM Science Journal*, Vol. 2016, pp. 1227-1231, 2016. https://doi.org/10.17973/MMSJ.2016_11_201653

[20] TLACH, V., KURIC, I., SÁGOVÁ, Z., ZAJAČKO, I.: Collaborative assembly task realization using selected type of a human-robot interaction, *Transportation Research Procedia*, Vol. 40, pp. 541-547, 2019. https://doi.org/10.1016/j.trpro.2019.07.078

[21] ZIDEK, K., VASEK, V., PITEL, J., HOSOVSKY, A.: Auxiliary Device for Accurate Measurement by the Smartvision System, *MM Science Journal*, Vol. 2018, pp. 2136-2139, 2018. https://doi.org/10.17973/MMSJ.2018_03_201722

**Review process**
Single-blind peer review process.