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Original scientific paper

Distance Measurement Sensors – A Comparative Case Study with Example from Education*

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Abstract: A modern approach to active learning is a technique called "learning by doing". It is usually the most wanted approach. As an example of this technique, this paper presents a student learning process about sensors and their properties by performing experiments and learning from sensors' manuals. In order to compare distance sensors in industry applications, an experiment was conducted. Experimental results leads to conclusion which of the available sensors showed the most accurate results in relation to the results given by the manufacturer. Finally, conclusions have been made about reasons for the deviation of individual sensors from the predicted values.

Keywords: Distance measuring sensors, Photoelectric sensor, Capacitive sensor, Inductive sensor, Marine engineering education.

1. Introduction

It could be expected that distance sensors will play important role in future autonomous traffic in ports, and in land traffic as well. Furthermore, it is important in robots, which could operate both indoor and outdoor. Hence, it is important that students get in touch with such sensors to be better prepared for future needs.

Inductive proximity switches were already considered for Industry 4.0 [1]. Implementation [2] and a structure [3] of the inductive proximity switches were considered as an introduction to energy efficiency research. Except for proximity sensing [4], capacitance proximity sensors were used even for identification of the materials [5], which also has interesting implications in maritime industry. Reed switches design was considered in [6]. The design and implementation of photoelectric sensor for color fault detection is an interesting additional use of distance sensors [7]. Mentioned examples shows that sensors of interest in this paper can be widely used in many applications. Hence, it is important to students to learn of them.

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The paper is organized as follows. The second section provides details about equipment and experimental setup. The third section presents results. Finally, conclusions are given.

2. Experimental Data

2.1. Experimental equipment

The IA 120 Principles of industrial sensor technology unit allows experimental investigation of the functioning of various industrial sensors, including both non-contact (capacitive proximity switch, inductive proximity switch, reed contacts, reflex photoelectric proximity switch, reflex photoelectric barriers, and one-way photoelectric barriers) and contact sensors (limit switches).

Technical data for reflex photoelectric barrier are:

– Range limit S_n = 4.0 m,

– Operating range S_b = 3.2 m,

– Light source / wavelength - pulsed red light diode / 660 nm,

– Operating voltage: 10-30 VDC,

– Average current consumption: 22 mA,

– Current consumption max: 35 mA,

– Max. switching current: 200 mA,

– Voltage drop: 1.8 VDC, and

– Working temperature: -25...+55 °C.

Light guide (one-way photoelectric barrier) has characteristics:

– Operating range S_b = 800 mm,

– Scanning range T_w = 150 mm,

– Light source / wavelength - Pulsed IR diode / 880 nm,

– Operating voltage: 10-30 VDC,

– Average current consumption: 40 mA,

– Max. current consumption: 55 mA,

– Max. switching current: 200 mA,

– Voltage drop: 1.8 VDC,

– Working temperature: -25...+55 °C.

Reflex photoelectric proximity switch (red light) has characteristics:

– Scanning range T_w = 5...200 mm,

– Light source / wavelength - Pulsed red light diode / 660 nm,

– Operating voltage: 10-30 VDC,

– Average current consumption: 20 mA,
– Max. current consumption: 30 mA,
– Max. switching current: 100 mA,
– Voltage drop: 1.8 VDC,
– Working temperature: -25...+65 °C.

Reflex photoelectric proximity switch (infrared) have technical characteristics:

– Scanning range T_w = 20...150 mm,
– Light source / wavelength - Pulsed IR diode / 880 nm,
– Operating voltage: 10-30 VDC,
– Average current consumption: 30 mA,
– Current consumption max: 45 mA,
– Max. switching current: 200 mA,
– Voltage drop: 1.8 VDC,
– Working temperature: -25...+55 °C.

Technical data for capacitive proximity switch are:

– Nominal switching distance S_n = 5 mm,
– Min. switching distance S_{min} = 0.5 mm,
– Max. switching distance S_{max} = 10 mm,
– Operating voltage: 10-35 VDC,
– Idle current: 15 mA,
– Max. switching current: 400 mA,
– Voltage drop: 2.0 VDC,
– Working temperature: -25...+70 °C.

Inductive proximity switch has characteristics:

– Nominal switching distance S_n = 5 mm,
– Operating voltage: 10-35 VDC,
– Idle current: 15 mA,
– Max. switching current: 250 mA,
– Voltage drop: 2.5 VDC,
– Working temperature: -25...+70 °C.

Reed contact has maximum switching voltage: 24 V, maximum switching current: 0.1 A, breaking capacity of maximum 1 W, and operates at ambient temperatures between -30 and +85 °C.

2.2. Experimental setup

Experimental setup consists of a reflector, which represents sensor's platform, e.g. car, and a barrier, which represents e.g. wall, IA 120 unit, and plate with meter. It is shown in Fig. 1.

The reflector part is moving away from the stationary part. At marked distances (150, 250, 360 mm), the moving part (reflector) is stopped. If the signal is detected, the operator (e.g. student) writes "yes", and otherwise "no" (see tables in the Results section).

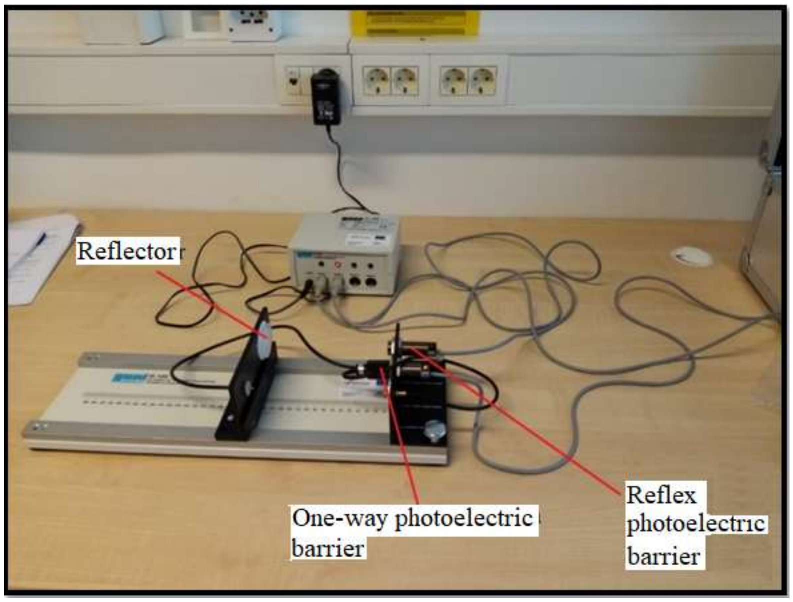

Fig. 1 – *Experimental setup.*

By changing types of plates, students can learn about reflexive properties of various materials by actually performing the experiment. Hence, they learn by doing.

3. Results

Experimental results are shown in Table 1 for one-way photoelectric barrier and reflex photoelectric barrier. To correctly compare results, the same distances were marked and used in experiment with both one-way and reflex photoelectric barrier. If there is a switch at some distance, "Yes" is circled. Experiment is repeated for three distances and five plates.

Table 1 – *Switching distances for one-way and reflex photoelectric barrier - results.*

Sensor	Experimental plate					
	Sensor distance (mm)	Aluminum sheet	Steel sheet, textured, matt black	Steel sheet, smooth, silver	Plexiglass, Transparent	Plastic, smooth, white
One-way photoelectric barrier: switches	360	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
	250	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
	150	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Reflex photoelectric barrier: switches	360	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
	250	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
	150	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No

As it can be seen from the results, the white sheet provides the best detection by photoelectric sensors. It is obvious, because white surface reflects all light.

Another observation from the results is that transparent sheets are less detectable by reflex methods. Silver and aluminum are similar colors. Hence, the results are the same.

Table 2 shows measured switching distances for inductive, capacitive, reflex photoelectric IR, and red light proximity switches. Three measurement were carried out for every plate and switch. N/A means that this case is not possible for the declared setup. Since, setup is such that there is no setup for distances greater than 360 mm, "360+" means that the switch detects marked plate at higher distance than 360 mm.

Table 2 – *Measured switching distances.*

Sensor	Experimental plate				
	Aluminum sheet	Steel sheet, textured, matt black	Steel sheet, smooth, silver	Plexiglass, transparent	Plastic, smooth, white
Inductive proximity switch [mm]	4.8	5.2	5.7	N/A	N/A
	4.75	4.95	5.45	N/A	N/A
	4.35	5.1	5.47	N/A	N/A
Capacitive proximity switch [mm]	7.5	6.6	7.55	4.47	5.49
	7.49	6.95	7.65	4.89	4.9
	7.48	6.9	7.49	4.1	4.8
Reflex photoelectric proximity switch (IR) [mm]	157	64	248	105	101
	156	65	250	106	104
	157	65	249	106	105
Reflex photoelectric proximity switch (red light) [mm]	124	128	360+	211	230
	123	129	360+	211	228
	123	128	360+	213	231

4. Conclusions

The equipment obtained by the EU project (see Acknowledgment) can be used for education of marine engineers. It can be useful to get in touch with sensors which are widely used. This papers presents experimental data, which is obtained by "learning by doing" technique by student of marine engineering.

Experimentally used sensors can be applied in many usages in maritime industry, but also in advanced applications, such as robotics, Internet of Things, etc.

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