MODELING AND SIMULATION OF PROXIMITY SENSORS

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Abstract: In the context of the pandemic caused by the COVID-19 virus, the transition to online education was forced. Also, the laboratory works from the engineering disciplines must be adapted to the online environment. This paper presents the study of infrared proximity sensors, raising the operating characteristic and comparing it with that provided by the sensor manufacturer. The transfer function of the sensor will be determined annalistically and will be compared with the one obtained from the simulation. At the end, the conclusions we can draw will be presented.

Keywords: Arduino, Proteus, infrared sensors, simulation, transfer function

1. INTRODUCTION

In this paper were analysed the operation of Sharp digital distance sensors from the GP2 series.

GP2Y0A21YK0F is a sensory distance measuring unit, composed of an integrated combination of PSD (position sensitive detector), IRED (infrared emitting diode) and signal processing circuit.

The variety of object reflectivity, ambient temperature and operating time do not easily influence the detection of distance due to the adoption of the triangulation method.

This device transmits the voltage corresponding to the detection distance. So, this sensor can also be used as a proximity sensor.

We also have several Sharp analogue distance sensors: Sharp GP2Y0A51SK0F 2 - 15 cm, Sharp GP2Y0A41SK0F 4 - 30 cm, Sharp GP2Y0A21YK0F 10 - 80 cm and Sharp GP2Y0A02YK0F 20 - 150 cm.

These analog distance sensors have longer minimum detection distances and much slower response times than GP2Y0D805, GP2Y0D810 and GP2Y0D815, but they can see further and report the distance to the detected object, rather than simply if an object is detected [1].

Among the applications in which these sensors can be used, we mention:
- Touch-free switch (sanitary equipment, lighting control, etc.);
- Cleaning robot (vacuum cleaner robot);
- Energy saving sensor (ATM, copier, vending machine);
- Fun Equipment (Robot, Arcade Game Machine).

The Table 1 shows, for comparison, the functional characteristics for three types of sensors.

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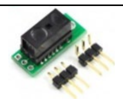
Table 1. Functional characteristics of Sharp GP2 series proximity sensor types.

	GP2Y0A21YK0F	GP2D120	GP2Y0D805Z0F
			
Distance	10-80 cm	4-30cm	0,5-5cm
Output	Analog	Analog	Digital
Current consumed	30mA	33mA	5mA
Supply voltage	4,5-5,5 Vcc	4,5-5,5 Vcc	2,7-6,2Vcc
Time until the first measurement	38.3ms±9.6ms	44 ms	
Response to state change	Max 5.0ms	Max 5.0ms	Max 3,77ms

2. EXPERIMENTAL SETUP

2.1. Analytical determination of the sensor transfer function

Figure 1 shows the block diagram, taken from [2], and Figure 2 shows the synchronization chart [2] between the moment of application of the supply voltage and the moment when the output voltage correctly indicates the measured distance.

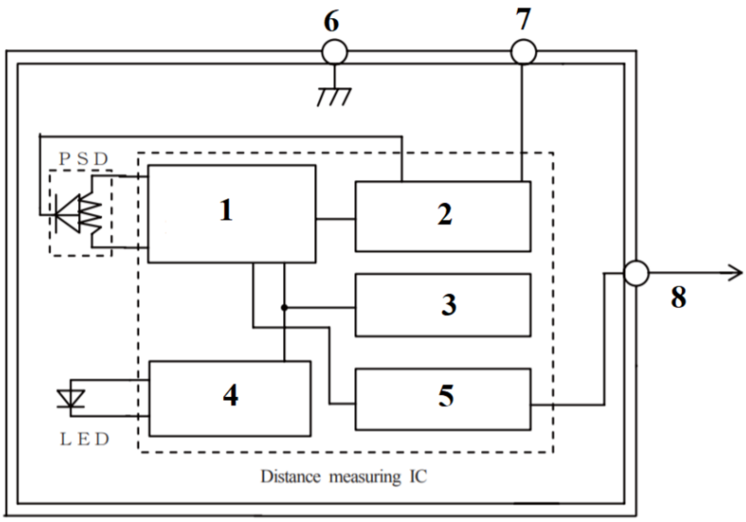


Fig. 1. Proximity sensor block diagram:
1 – Signal processing circuit; 2 – Voltage regulator; 3 – Oscillation circuit; 4 – LED drive circuit; 5 – Output circuit; 6 – GND; 7 – Vcc (4.5 V – 5.5 V); 8 – Vo; Output voltage; PSD – position sensitive detector; LED – Infrared emitting diode.

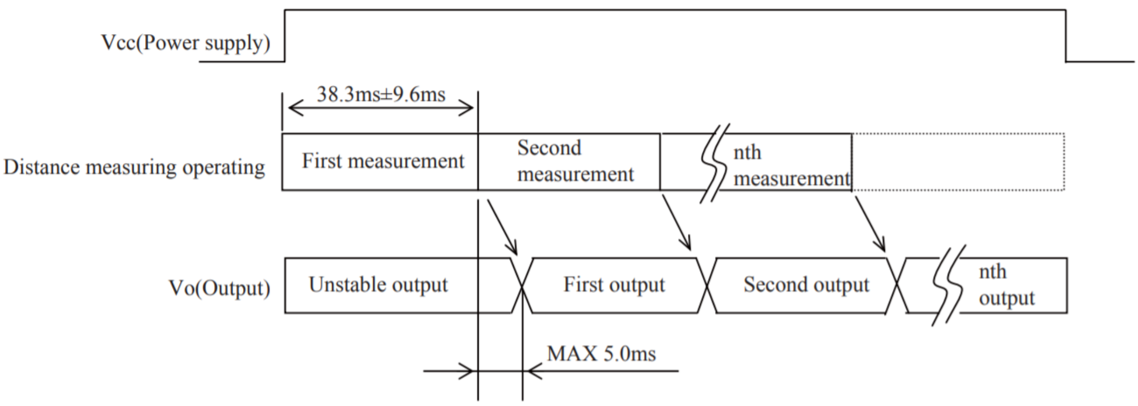


Fig. 2. Timing chart.

From the above graph, Figure 3, we can extract the function after which we will calculate the measured distance as a function of the output voltage from the integrated d = f (U), which is of the form:

$$d = a \cdot U^{-b} \tag{1}$$

To determine the parameters a and b, we will consider 2 points far enough from the measuring range of the sensor (in this case for 10cm and 80cm) and we will form the system of 2 equations with two unknowns:

$$\begin{cases} d_1 = a \cdot U_1^{-b} \\ d_2 = a \cdot U_2^{-b} \end{cases} \tag{2}$$

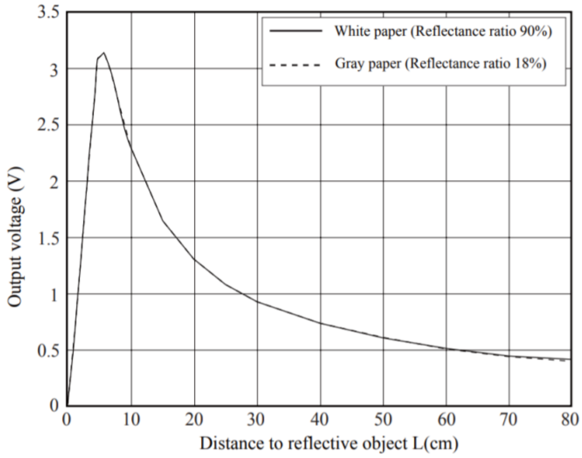


Fig. 3. Example of distance measuring characteristics (output).

The following is the solution of equation no. (2).

$$\ln(d_1) - b \cdot \ln(U_2) = \ln(d_2) - b \cdot \ln(U_1) \tag{3}$$

The solution of equation (3) is presented in formula (4).

$$b = \frac{\ln(d_2)}{\ln(d_2)} \tag{4}$$

The coefficient "a" will be calculated as the average of the 2 values obtained from the system of equations, as presented in equation (5) and (6).

$$a_1 = \frac{d_1}{U_1^{-b}} \quad a_2 = \frac{d_2}{U_2^{-b}} \tag{5}$$

$$a = \frac{a_1 + a_2}{2} \tag{6}$$

From the graph in Figure 3 we obtain the data presented in Table 2:

Table 2. Data used to determine the transfer function.

d [cm]	10	80
U [V]	2.25	0.41

Replacing the values in Table 2 in equations (4), (5) and (6) we obtain for a and b the following values (equations (7) and (8)):

$$b = 1.2214 \tag{7}$$

$$a = 26.92 \tag{8}$$

Equation (8) shows the transfer function obtained for the sensor used in this paper.

$$d = 26.92 \cdot U^{1.22} \tag{9}$$

2.2. Simulation circuit

To simulate the operation of the proximity sensor (distance) we used the professional Proteus 8.0 application. The Proteus program also allows the simulation of microcontroller operation, and has a built-in module for Arduino UNO, equipped with an ATMega 232 microcontroller.

As can be seen in [3], Proteus is frequently used in modelling the operation of microcontrollers, and, as shown in [4] and [5], Proteus is used for learning and research in various fields of science. Proteus can also be used to model and simulate complex systems, such as the operation of photovoltaic panels [6].

In Proteus Professional 8.0, the electrical diagram shown in Figure 4 is made, with the connection of pin AD0 to Analog pin A0 from Arduino UNO (which is no longer represented in the figure).

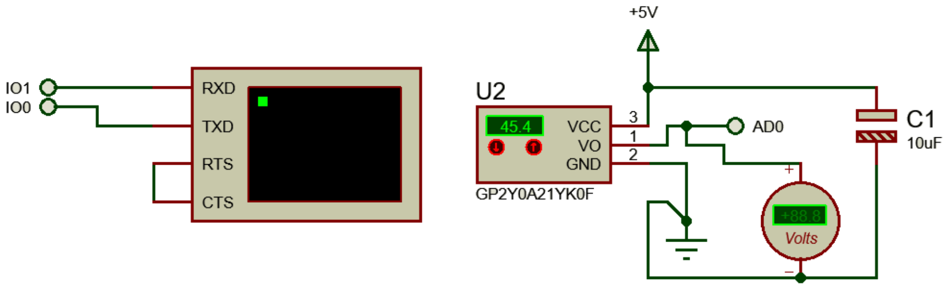


Fig. 4. Wiring diagram made in Proteus Professional 8.0 for simulating the GP2Y0A21YK0F proximity sensor.

Arduino is a development board widely used in applied research projects, which controls various sensors [7] or automation systems [8].

The program for Arduino UNO [9-10], shown in Figure 5, reads the voltage value on port A0, calculates the average for 10 consecutive measurements, calculates the distance with equation (9), and displays the results in the virtual terminal.

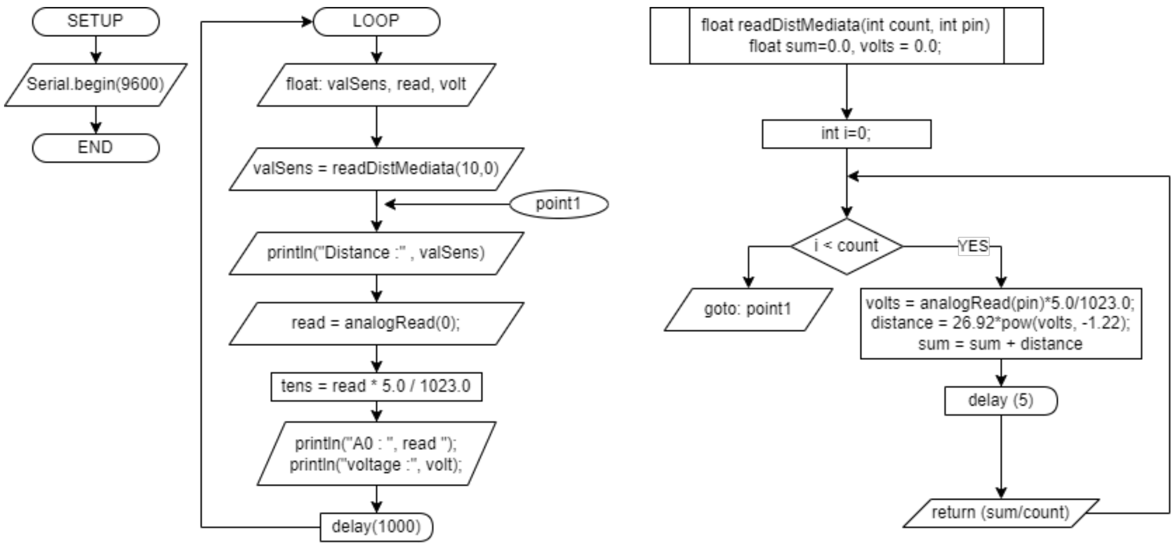


Fig. 5. Logic diagram of the program written in Arduino.

3. RESULTS AND DISCUSSION

The experimental data are presented centrally in Table 3, and in Figures 6, 7 and 8 are represented the variation of the output voltage from the sensor depending on the set distance, the variation of the absolute error, respectively the variation of the relative error.

Table 3.Values measured with the GP2Y0A21YK0F proximity sensor simulation circuit.

Distance sensor model IR: GP2Y0A21YK0F									
Dr [cm]	10	20	30	40	50	60	70	80	
U [V]	2.25	1.27	0.91	0.72	0.6	0.51	045	0.41	
Dm [cm]	9.99	20.1	30.2	40.2	50.239	61.27	71.39	79.98	Average
ε_a=Dr-Dm [cm]	0.56	0.71	0.74	0.79	0.76	-0.32	-0.54	0.75	0.433
ε_r=(Dr-Dm)/Dr	0.056	0.035	0.024	0.019	0.015	0.005	0.007	0.009	0.021

Where: Dr - regulated distance, U - voltage, Dm - measured distance, ε_a - absolute error,ε_r- relative error.

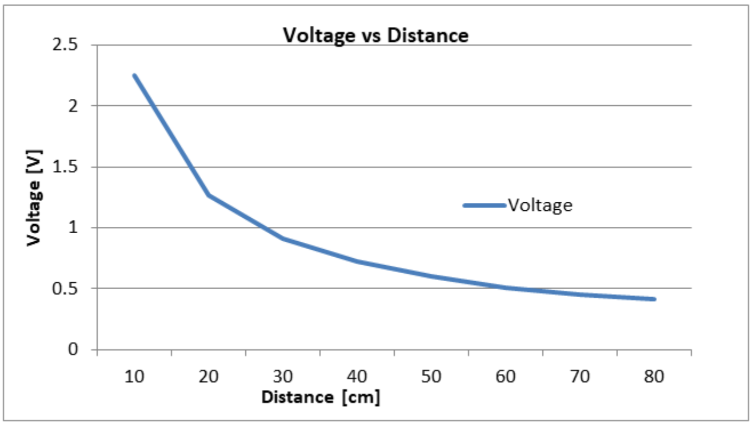


Fig. 6. The variation of the output voltage of the sensor depending on the set distance.

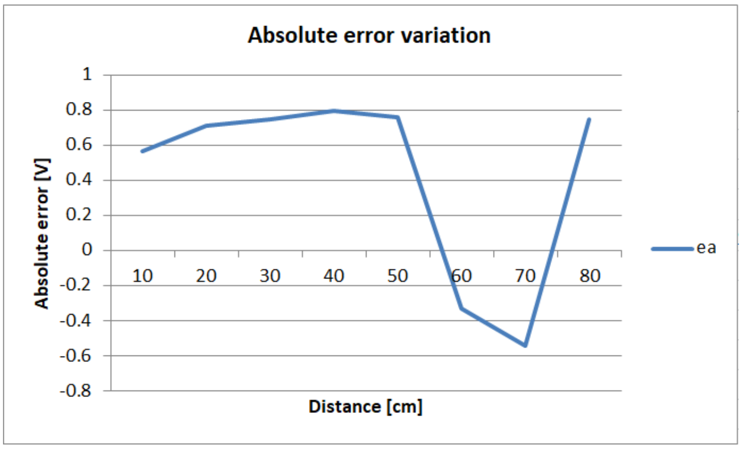


Fig. 7. The variation of the absolute error of the sensor depending on the set distance.

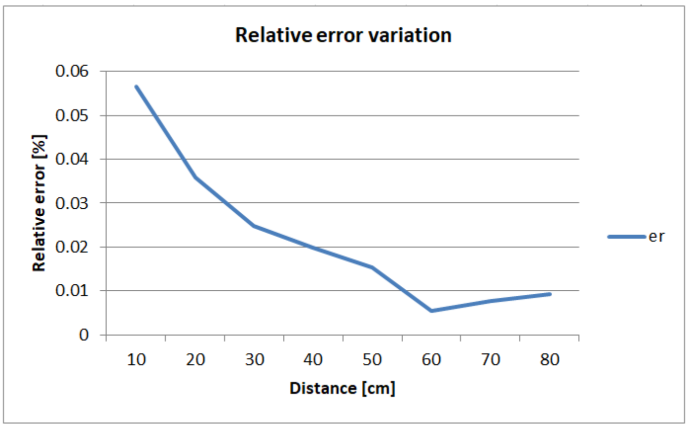


Fig. 8. The variation of the relative error of the sensor depending on the set distance.

4. CONCLUSIONS

From the graph in Figure 6, it is observed that the output voltage of the simulated sensor corresponds to the voltage variation given by the sensor manufacturer and shown in Figure 3. That is, the voltage-distance characteristic of the manufacturer is identical to that of the simulator.

Regarding the simulated measurement error, the following can be concluded from Table 2 and the graphs in Figures 7 and 8:
- The absolute error has an average value of 0.433 cm, with a maximum of 0.79 cm for the distance of 40 cm (ie in the middle of the measuring range);
- The minimum value of the absolute error is -0.32 cm and is obtained at a distance of 6 cm, ie at 75% of the maximum distance;
- The relative error has an average value of 2,1%, a minimum of 0,9% for the maximum distance (80 cm) and a maximum of 5,6% for the minimum distance (10 cm);
- Therefore, the closer the measurement distance is to the lower limit, the higher the relative error.

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