Contact Distance Sensor

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***Abstract*— This project is designed to develop the sensor to evaluate the contact distance in a stick from the center of rotation. When the stick hits an object, the piezoelectric sensor produces an output voltage as a result of the impact/ vibration generated due to the collision. Then it measures the output voltage using the microcontroller unit and provides output on the display. The range is around 0.04 – 0.52m**

Keywords—contact distance, piezoelectric sensor, impact

I. Introduction

This project is conducted to develop a sensor that provides us with the contact distance from a particular point. Initially, an investigation was carried out regarding the principles of contact distance measurement sensors in the industry. There were several methods such as using an accelerometer [1], a piezoelectric sensor [2], using an acoustic sensor [3], and using an IR sensor [4]. From the above methods, the accelerometer method and the method using piezoelectric sensors are the more suitable methods. However, we were unable to use an accelerometer because of its signal processing complexity, and material dependency and it was difficult to calibrate for the application we are going to use. Due to that Piezoelectric sensor is used. The sensor is attached to an antenna, recording the output electrical signal during contact events.

We planned to generate voltage, which varies with the different points of contact from the antenna during contact events. For implementation, we secured one end of an antenna to a servo motor MG995s, enabling it to rotate within a 90-degree range. At the opposite end of the antenna, we affixed a piezoelectric sensor and a transmitter module SEN1626. We used a microcontroller to provide power to the sensor system and to record the output voltage generated by the transmitter module. The accuracy of this fundamental system is ±0.04m, this can be further improved through the incorporation of multiple piezoelectric sensors strategically placed and calibrated at different locations.

The intended application of this sensor is similar to a blind stick design, sensing the contact distance of an object in front by tapping on it. To enhance the system further, we have the potential to improve accuracy, response time, and introduce material classification to the application.

II. Initial specifications

A. Measurement Quality

This sensor is applicable to any objects that contact the antenna. But it does depend on the material in which it gets hit. Whenever the material changes the calibration curve also will change due to the frequency generated by the material

B. Range

This circuit design has a range of 0.5m which is 0.04m to 0.52m

C. Resolution

The sensor is designed to indicate a contact distance measurement. The basic design of the instrument is like an antenna with a piezoelectric sensor and a transmitter module. In this case, 1cm can be the resolution.

D. Other specifications

- Operating Voltage: 3.3 V – 5 V
- Operating Temperature: -20° - 60°
- Error: ± 4 cm
- Diameter of Receiver: 20 mm

III. Methods

A. Principle of Operation

Initially, the antenna rotates at a constant speed into a particular angle with the help of the MG995 Servo Motor. Then, when the antenna encounters an object. At that time, the Force will be detected due to the impact. It will be received using the piezoelectric sensor and converted into analog voltage. Afterward, that analog voltage will be converted into DC voltage using the transmitting module. The voltage generated by the piezoelectric sensor may vary due to the impact force. Therefore, using the transmitting module and servo motor the output voltage range is controlled from 10 mV to 220 mV.

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B. Circuit Diagrams

This sensor has two main parts.

- Sensor Module
- Transmitting Module
- Operation Module

These circuits contain a Piezoelectric sensor, Antenna, MG995 Servo Motor, and a transmitting module, which mainly contains a bridge rectifier.

C. Transmitter Circuit

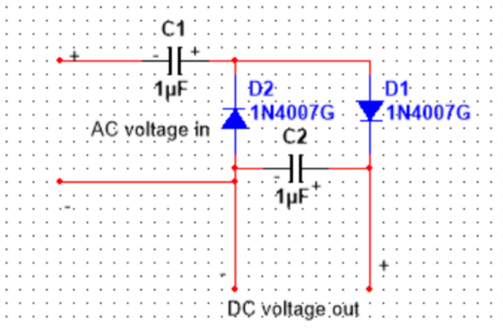

Fig 1. Transmitter Circuit Diagram

This transmitter circuit is used to convert the analog signal from the sensing module to DC output voltage.

D. The Sensor Module

Fig 2. Sensor Module

IV. Results

A. Observations

Distance (cm)	Voltage Variation(mV)				
	Set 1	***Set 2***	***Set 3***	***Set 4***	***Set 5***
4	198	203	197	204	196
8	184	186	180	188	189
12	180	184	190	190	182
16	176	178	175	175	178
20	124	136	134	134	129
24	110	107	120	120	118
28	81	103	108	108	87
32	74	96	101	101	88
36	68	83	98	98	75
40	48	72	74	74	54
44	32	58	62	62	48
48	23	40	40	40	37
52	12	28	24	24	19

TABLE I : VARIATION OF THE OUTPUT VOLTAGE WITH WATER LEVEL

B. Input-output characteristic graph

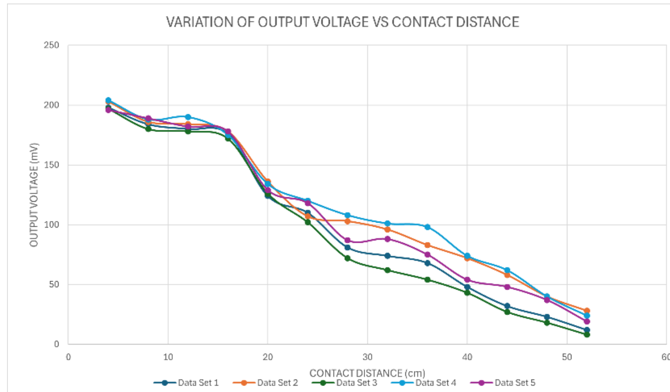

Fig 3. Variation of output voltage Vs water level

V. Discussion

A. Difficulties

1) Method selection: In the previous report, we have proposed 4 different methods for contact distance measurement In two out of 4 methods accuracy will be a huge drawback for us. Therefore we had to try both methods using the accelerometer and using the piezoelectric sensor. First, we tried using the accelerometer, but we were unable to obtain the expected accuracy as it was difficult to calibrate. The accelerometer started to give different readings depending on the different elevations It was differing too much where if we use that error will be very high. Therefore we had to choose a piezoelectric sensor, as this was the most suitable method depending on our application.

2) Identifying a method for generating and transmitting custom voltage data: We had to figure out a way to generate voltage as per our needs. With the help of websites, we found out the module SEN1626 [5] for transmitting generated voltage data to the microcontroller as per our need.

3) Designing the sensing circuit and noise and interference: To reduce the complexity of the system we decided to keep the circuit simple. As our output voltage generated is in a very small range about 10 mV to 220 mV, there could have been a significant loss in the wires which could have tampered the readings severely. For this, we considered using npn transistor to amplify the signal output from the sensor module[6].

4) Dynamic Environments: The working temperature of the piezoelectric sensor is -20C to 60C, therefore changes in temperature might influence the output readings. Also as we have fixed the antenna to the servo motor, contacting an object which is not perpendicular to the antenna’s movement might cause different voltage generation due to unpredictable vibration changes.[7]

5) Troubleshooting: This was the biggest difficulty we faced. we used a multimeter to check the continuity of the current flow. At the last time, the sensor stopped generating voltages for any kind of vibration. To figure out we tried changing the piezoelectric sensor plates but it was not the error.

B. Strengths

1) Cost-effectiveness: The project offers a cost-effective solution compared to alternative distance measurement technologies like the accelerometer method, making it accessible for a wide range of applications, also all the components used here are easily available so that setting up the system won’t be a hassle.

2) Direct mechanical to Electrical conversion: No transducers were needed to convert the physical parameter to an electrical signal. The sensor's ability to directly convert mechanical changes into electrical signals simplifies the overall signal acquisition process, reducing complexity in the system.

3) Compact design and mountability: The sensor's lightweight and compact design makes it easily mountable in various applications, enhancing its adaptability to different scenarios. Also handling the system is very easy and no need for any prior knowledge.

4) Installation: Installation of the system does not demand extensive knowledge about electronics or the sensor itself, contributing to user-friendly deployment.

C. Weaknesses

Nonetheless, the project encounters several noteworthy weaknesses. A primary challenge resides in the calibration process, where establishing a reliable relationship between observed electrical signal patterns and actual contact distances proves intricate. The calibration curve was non-linear, and output points were unevenly spaced. Environmental sensitivity further complicates matters, introducing variations in accuracy across different conditions. The application-specific accuracy of the piezoelectric sensor poses a potential limitation, such as temperature constraints and design complexities. Tailored solutions, such as integrating multiple sensors for improved output, are necessary to ensure optimal performance.

D. Comparison

The sensor has an adequate amount of range, easy installation setup, and a simple output-generating model compared with other sensor models in the field for the same application. By integrating multiple sensors accuracy can be improved more than other sensors. However, Dynamic environmental factors affect this system for a considerable amount.

VI. CONCLUSION

A Contact Distance Sensor is an electronic device that can be used to measure the distance from a particular point when it encounters an object. This method can be used for robotic arms to measure the distance of objects that can interfere in front of them. According to the output voltage, the distance can be obtained from the calibration curve.

This sensor is very cheap compared to the other sensors available in marketplaces, small, and compatible with many devices. It is also power efficient 10 V is more than enough to operate the whole sensor module.

However, we are planning to develop it furthermore using an accelerometer by resolving all the issues we have faced to get the most accurate results and also integrating material classification into this sensor with the help of Machine Learning models.

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REFERENCES

[1] Group, A. (2023) *Can an accelerometer measure distance?*, *Ascendtech*. Available at: https://www.ascend-tech.com/blog/can-an-accelerometer-measure-distance#:~:text=Estimating%20Distance%20with%20Accelerometers,essentially%20the%20change%20in%20position.

[2] Apc (2023) *How piezoelectric sensors work -*, *APC International Ltd.* Available at: https://www.americanpiezo.com/blog/how-piezo-sensors-work/

[3] Matan (2023) *Ultrasonic proximity sensor: How it works, application & advantages*, *Electricity*. Available at: https://www.electricity-magnetism.org/ultrasonic-proximity-sensor/

[4] Author links open overlay panelMustafa Özcan a *et al.* (2020) *Accurate and precise distance estimation for noisy IR sensor readings contaminated by outliers*, *Measurement*. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0263224120301706

[5] JunezRiyaz and Instructables (2017) *Electricity generation from piezoelectric element*, *Instructables*. Available at: https://www.instructables.com/Electricity-Generation-From-Piezoelectric-Element/

[6] Faizan, A. (2018) *Transistor as an amplifier: Working & Circuit: NPN transistor amplifier*, *Electrical Academia*. Available at: https://electricalacademia.com/electronics/transistor-amplifier-working-circuit-npn-transistor-amplifier/

[7] Jiang, X. *et al.* (2013) *High-temperature piezoelectric sensing*, *MDPI*. Available at: https://www.mdpi.com/1424-8220/14/1/144