MATERIAL DETECTING GLOVE FOR BLIND PEOPLE

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Abstract

Blind people identify materials by touching them and decide by the previous experience they have had. However, this is not an accurate method when some coatings were applied. The aim of this research was to design a material-detecting glove for blind people which will help them to understand and feel better about the surroundings.

While investigating the existing literature and technologies which support blind people, it was found that many were available to avoid obstacles but not to detect materials. Further, there were some to detect the distance and the location.

The principal theory behind the design is based on capacitive proximity sensing. First, it investigated the effects of dielectric constants of different single- and two-layer target materials for the variations of sensor head capacitance (ΔC). Then a mathematical function for ΔC was derived using the method of image theory in electrostatics for two layers of the material case. Then, the derived results were verified by simulations in MATLAB®. Finally, the plots were obtained and observations and data required for the design were collected.

A variable was derived which is used for the calibration of the sensor with respect to the different materials and was investigated through experiments carried out. By selecting the appropriate electronic components and utilizing the research data with several testing, the material-detecting glove with a wireless communication facility was designed and implemented successfully.

Keywords: material detection, capacitive proximity sensing, dielectric constant

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INTRODUCTION

Blind people identify materials by touching them and decide by the previous experience they have had. However, this is not an accurate method when some coatings are applied. The aim of this research was to design a material-detecting glove for blind people which will help them to understand and feel better about their surroundings.

During the literature review, it was found that the recent development of the numbers of devices such as hand gloves, band type wearable devices, prototype caps, stick shape devices and many more such have been developed to support blind people. Most of them were to identify the obstacles surrounding them (Adi & Agustin, 2020, Alkandari et al., 2016, Goel et al 2020) and few of them to track their location. However, there was no device developed to detect the types of materials they touch.

Therefore, this project aimed at designing a glove equipped with electronic components capable of sensing and detecting various materials. The glove would provide voice signals wirelessly through a Bluetooth module. The design will be helpful for blind people to experience real world surroundings. The research activity was most useful in data analysis and supported to find out suitable system development strategies to achieve the final design.

METHODOLOGY

The theory behind the design is based on capacitive proximity sensing (Deng et al., 2020, George, Tan & Nihtianov 2017, Pavliuk et al., 2019, Texas Instruments Incorporated 2015). In their approach for the case of mutual mode (Figure 1), a study has been carried out to investigate the effects of dielectric constants, thickness of different single and two-layer target materials and the sensing distance for the variations of sensor head capacitance (ΔC).

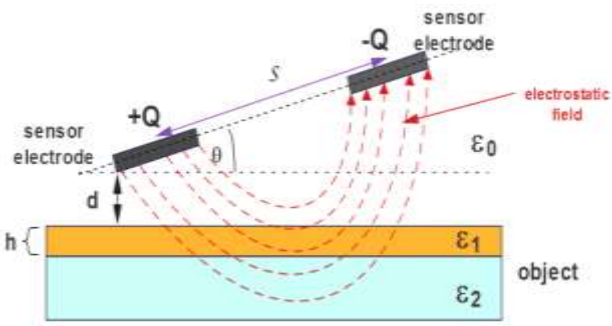

Figure 1 Capacitive proximity sensing for the case of mutual mode

Here, a mathematical model for the two layers of material configuration (Figure 2) was developed by using the method of image theory in electrostatics. The Gauss's Law, Maxwell's famous equations for the static electric fields and equation for the electric potential due to point charges were used to investigate a function for the ΔC.

By considering the layered structure of the developed model, boundary conditions were applied for the set of equations which governs the system ($\nabla \times E = 0$, $\nabla \cdot E = \rho$ and $\nabla \cdot E = 0$) and transformation equations (a and b) for the image charges Q' and $Q"$ were obtained.

$$Q' = \frac{(\varepsilon_0 - \varepsilon_1)}{(\varepsilon_0 + \varepsilon_1)} Q_0 \text{----- (a)}$$

$$Q'' = \frac{2\varepsilon_1}{(\varepsilon_0+\varepsilon_1)}\frac{(\varepsilon_1-\varepsilon_2)}{(\varepsilon_1+\varepsilon_2)}Q_0 \text{----- (b)}$$

Then, further applying the potential equation for the image charge system and with the help of suitable approximations, the required final mathematical function for the variations of capacitance (ΔC) was derived. The theoretically derived function was simulated using MATLAB® software and relevant plots were obtained to get the useful observations and data required for the design.
An experiment was carried out to find out a suitable variable which can be used for the calibration of the sensor by considering the RC oscillation stage of the capacitive proximity sensor. Due to variations of the sensor head capacitance values when the materials are sensing, the oscillation frequency of the RC oscillator circuit which is connected to the sensor head capacitor (Figure 3) will change. To get the desired oscillations for the material detection, it is required to adjust the resistance value (R) of the RC oscillator until it gives a transistor output. By observing that the value of R required to get the desired oscillations were different for each material. The sensor was calibrated using R values with respect to the different material samples.

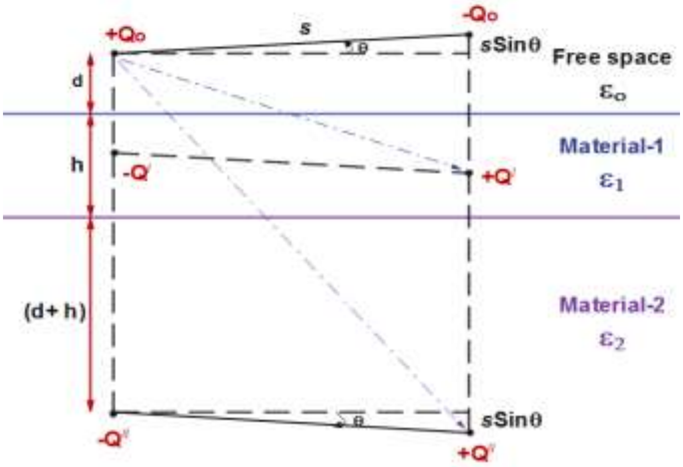

Figure 2 Mirror charges when the conducting object is far larger than the electrodes
LJC18A3-H-Z/BY type capacitive proximity sensor was used for this experiment. The resistance and the voltage across the potentiometer (of the sensor RC circuit) which were required to adjust desired oscillations for detecting materials were measured for deferent scenarios (a, b and c) using the setup shown in Figure 4 instead of measuring variations of capacitance.

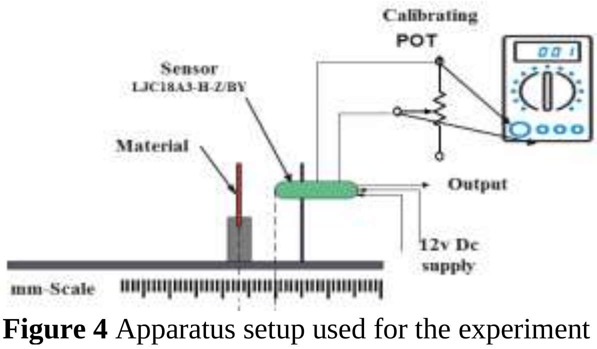

Figure 4 Apparatus setup used for the experiment

a. By varying the thickness of different types of single layer materials for 1mm sensing distance
b. By varying the thickness of different types of single layer materials for 15mm sensing distance
c. By varying the thickness of different types of second layer materials by keeping the first layer material constant for two layers of materials for 1mm sensing distance

For the implementation, ATmega328p microcontroller was used as the main controller and a capacitive proximity sensor, an Ultrasonic sensor, a Bluetooth module, a digital potentiometer, voltage regulators, a buzzer, LEDs, resistors and two $3.7\ V$ Lithium Polymer power sources were selected and fabricated according to the Figure 5.

Table 1 Resistance and voltage readings across the POT for the scenario-a

Materials at 1mm sensing distance	Potentiometer readings (Ω) for thickness				Voltage across POT (mV) for thickness			
	2 mm	5 mm	10 mm	20 mm	2 mm	5 mm	10 mm	20 mm
Aluminums	412.0	431.0	496.0	502.0	107.5	111.9	128.1	133.6
Wood	254.0	270.0	314.0	320.4	66.6	70.2	90.8	94.4
Glass	227.0	276.0	276.0	278.0	60.3	72.7	84.7	90.3
Cardboard	192.8	245.0	275.0	282.0	49.0	64.8	72.6	78.5
Rubber	139.1	155.3	156.3	158.2	36.8	41.2	41.8	42.4
Plastic	161.5	199.0	214.0	217.1	42.6	52.8	59.3	62.0

Table 2 Resistance and voltage readings across the POT for the scenario-b

Materials at 15mm sensing distance	Potentiometer readings (Ω) for thickness				Voltage across POT (mV) for thickness			
	2 mm	5 mm	10 mm	20 mm	2 mm	5 mm	10 mm	20 mm
Aluminums	150.0	150.6	153.0	154.0	40.0	40.3	40.7	40.9
Wood	132.4	139.3	142.6	144.2	34.3	37.2	37.6	37.6
Glass	135.5	152.5	153.3	154.3	36.1	40.5	41.0	41.8
Cardboard	144.7	147.8	151.1	152.0	38.3	39.5	40.6	40.8
Rubber	132.2	134.8	142.6	148.5	35.2	36.1	37.8	38.0
Plastic	132.2	135.0	142.6	148.2	35.2	36.1	38.0	38.6

Table 3 Resistance and voltage readings across the POT for the scenario-c

Materials at 1mm sensing distance	Potentiometer readings (Ω) for thickness				Voltage across POT (mV) for thickness			
	2 mm	5 mm	10 mm	20 mm	2 mm	5 mm	10 mm	20 mm
Plastic - Aluminums	283.0	313.0	320.0	322.0	74.6	82.5	84.6	85.2
Plastic - Wood	237.0	238.0	252.0	252.0	62.4	63.2	68.0	69.4
Plastic - Glass	182.1	227.0	237.0	238.0	48.1	59.0	62.9	63.5
Plastic - Cardboard	208.0	234.0	237.0	237.0	55.2	62.0	62.9	63.6
Plastic - Rubber	164.1	173.1	182.3	18.5	44.2	45.6	53.0	56.2

By utilizing the research data and through several testing with software programmes, the material detecting glove with wireless communication facility with Bluetooth technology was designed and implemented successfully.

RESULTS

The derived mathematical function for the ΔC for two layers of material case was,

$$\Delta C = \frac{-C^2 s^2}{32\pi\varepsilon_0}\left(\frac{1}{\varepsilon_0+\varepsilon_1}\right)\left\{\frac{\varepsilon_0-\varepsilon_1}{d^3}+\frac{2\varepsilon_1(\varepsilon_1-\varepsilon_2)}{(d+h)^3(\varepsilon_1+\varepsilon_2)}\right\}\left(\sin^2\theta+1\right) \text{------}(1)$$

Simulations were carried out and results obtained by using MATLAB® for the above equation 1 and Figures 6 and 7 were potted. The variations of sensor capacitance affected the dielectric constant of different types of materials, thickness of each material and the sensing distance to the object according to the observations.

According to the plots (Figure 8) obtained by using the experimental data, it was concluded that,

1. $\Delta C \propto$ variations of resistance of the potentiometer to obtained desired oscillations for sensing the object.
2. $\Delta C \propto$ variations of voltage of the potentiometer to obtain desired oscillations for sensing the object.

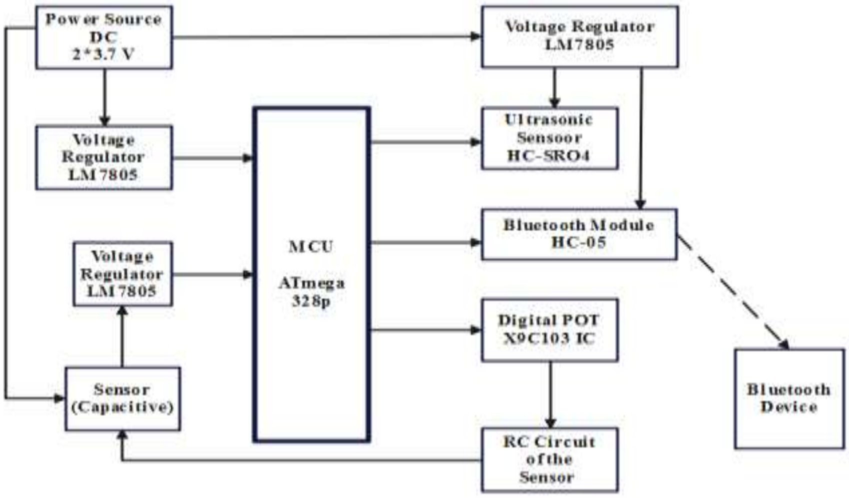

Figure 5 Block diagram for the design

That is, resistance or voltage across the potentiometer can be used for the calibration of the sensor by considering the RC oscillation stage of the capacitive proximity sensor.

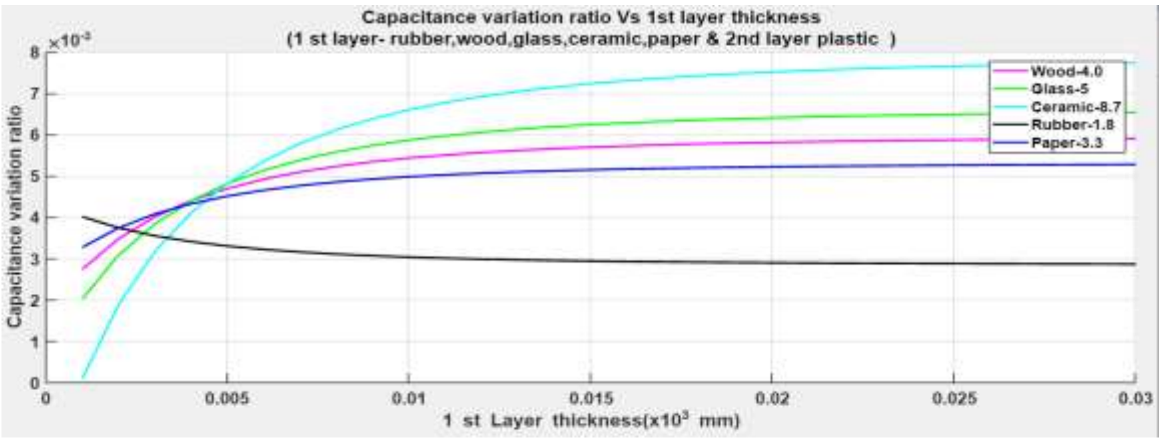

Figure 6 Variation of capacitance with 1st layer material thickness for different 1st layer non metallic materials

Comparisons of simulated results and experimental results

Simulation results were obtained for the derived mathematical equation of ΔC, i.e., graphs were plotted for the variations of capacitance. Yet, the experimental results obtained for the variations of resistance and voltage across the POT of the RC circuit could be measured more practically than measuring ΔC.

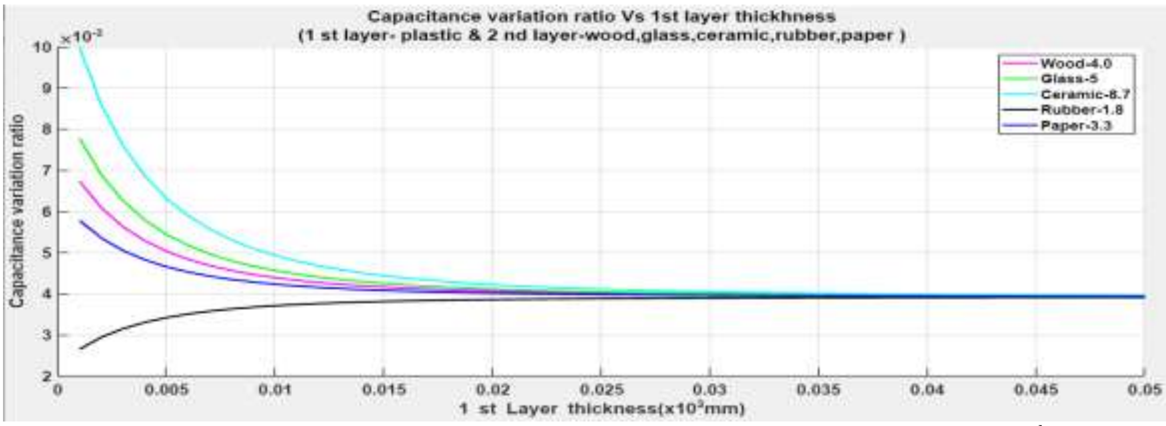

Figure 7 Variation of capacitance with 1st layer material thickness for different 2nd layer non metallic materials

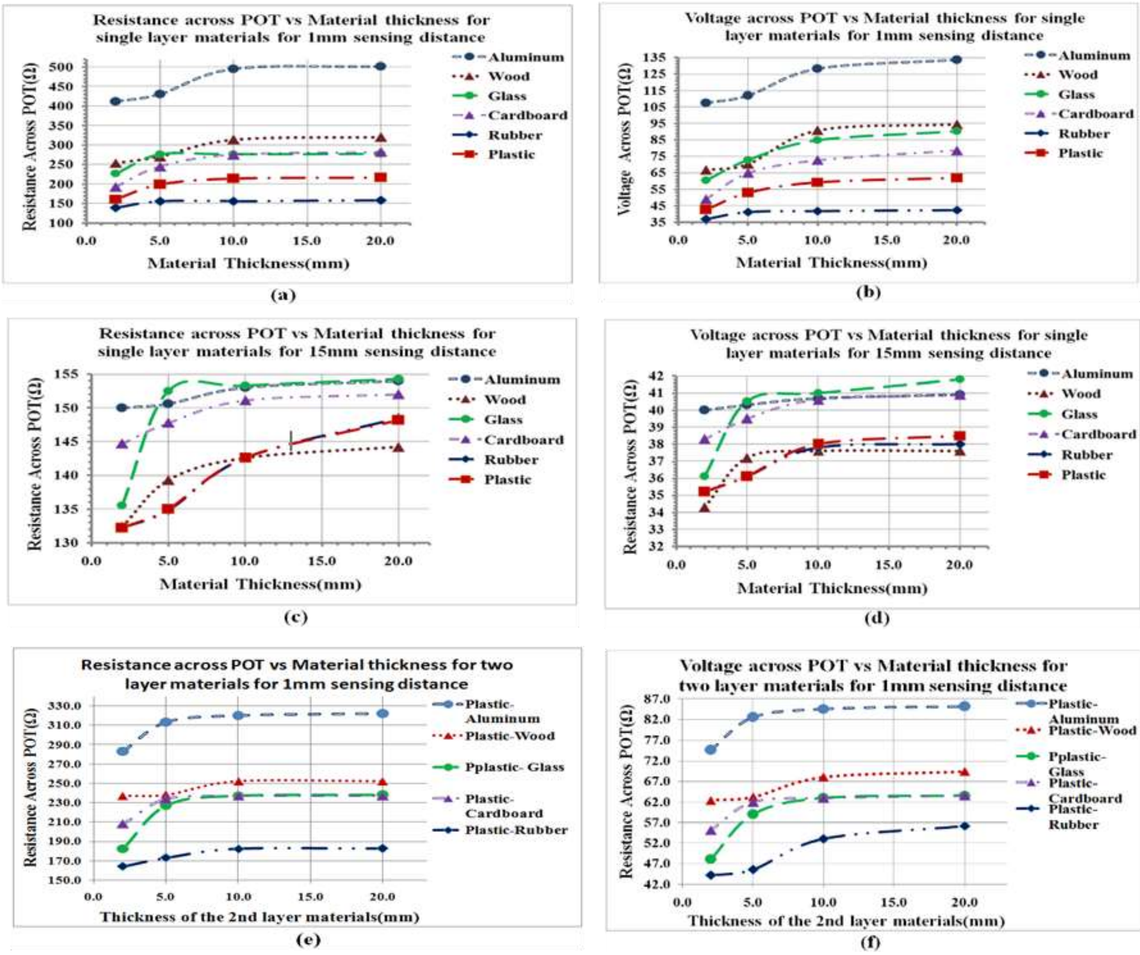

Figure 8 a,b,c,d - Potentiometer values for single layer materials: e,f - Potentiometer values for two layer materials.

According to the simulation results for the case of two layers of non-metallic, plots for the ΔC for the deferent first layer materials have considerable deviations with each other, when the 1st layer materials have considerably different dielectric constant values (ε_1). When $\varepsilon_1 > \varepsilon_2,$ ΔC values are increasing and reaches to a constant value. When $\varepsilon_1 < \varepsilon_2,$ ΔC values are decreasing and goes to a constant value. For both layers are non-metallic plots for the ΔC for the deferent second layer materials have considerable deviations with each other, when the 2nd layer materials have considerably different dielectric constant values (ε_2) and 1st layer materials thickness smaller than 1.5 mm.

According to the experimental results for the case of single layer materials, it was observed that plots for aluminium, glass, plastics, wood and rubber which have considerably different dielectric constant values (ε_1) were deviated to each other. However, the plots for glass and cardboard do not have a considerable deviation with each other i.e., they coincide.

For the case of two-layer materials with fixed type of first layer material, it was observed that the plots for the plastic-aluminium, plastic-glass, plastics-wood and plastic-rubber were deviated to each other that means pots were deviated when 2nd layer dielectric constant values (ε_2) are considerably different.

DISCUSSION

The designed glove can be successfully used to identify materials such as glass, metals and wood. As the device consists of Bluetooth technology, a voice signal can be taken out from a separate Bluetooth device at a distance or a head set without disturbing others.

There was no deviation between simulation results and experimental results which will verify the accuracy of the conclusions and confirmation of the derived equation for ΔC.

The numbers of materials which can be detected are defendants on the sensitivity of the sensor and the step size of the digital potentiometer. Sensing distance is set to constance for better accuracy of the material detection and so, if any manufacture could develop a capacitive proximity sensor with auto focusing, it will be a major advantage for accuracy and higher range of detections.

CONCLUSIONS

Detection of variations of dielectric constant values can be used for the material detection successfully as it has concluded that the variation of capacitance of the capacitive proximity sensor is considerably affected due to the different dielectric constant values and thickness of the different types of materials for single and two layers of materials in the research.

A variable such as resistance or voltage across potentiometer of RC oscillator circuit of the capacitive sensor can be used successfully instead of measuring variations of capacitance for the material detection. According to the observations for Figures 8(a) and 8(b), it can be concluded that the single layer materials such as metal, wood, glass, rubber and plastics can identify separately for any thickness value. However, it is hard to detect glass and cardboard separately using this sensor.

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REFERENCES

Adi, N. P., & Agustin, R. (2020). Development of distance glove for blind people as an alternative tool. *Gravity*, 6(2), 138-143. https://jurnal.untirta.ac.id/index.php/Gravity/article/download/8558/5998

Alkandari, A., Alajmi, A., Muhammad, S., & Alshammari, A. (2016). Ultrasonic sensors gloves for blind people using Lilypad Arduino. *International Journal of New Computer Architectures and their Applications*, 6(1), 16-22. https://www.researchgate.net/publication/300344608_ULTRASONIC_SENSORS_GLOVES_FOR_BLIND_PEOPLE_USING_LILYPAD_ARDUINO

Arcos, H., & Valencia, F. (2020). Method of Images for a Charge inside a Three-Layer Medium and Implementation of a Dirichlet Border Condition. *Revista Politécnica* , 44(2), 7-14.

https://www.researchgate.net/publication/339870346_Method_of_Images_for_a_Charge_inside_a_Three-Layer_Medium_and_Implementation_of_a_Dirichlet_Border_Condition

Deng, J., Huang, J., He, C., Wang, X., Ye, Y., & Zhang, C. (2020). A Review on Applications of Capacitive Displacement Sensing for Capacitive Proximity Sensor. *IEEEAccess,* 8(10), 45325-45338. https://ieeexplore.ieee.org/iel7/6287639/8948470/09020070.pdf

George, B., Tan, Z., & Nihtianov, S. (2017). Advances in Capacitive, Eddy Current, and Magnetic Displacement Sensors and Corresponding Interfaces. *IEEE Transactions on Industrial Electronics*, 64(12), 9595-9607. https://www.researchgate.net/publication/318693610_Advances_in_Capacitive_Eddy_Current_and_Magnetic_Displacement_Sensors_and_Corresponding_Interfaces

Goel, A., Mishra, P., Sahu, S., & Jaiswal, S. (2020). Smart hand gloves for blind and dump people. *International Research Journal of Engineering* and *Technology*, 7(6), 5090-5093. https://www.irjet.net/archives/V7/i6/IRJET-V7I6957.pdf

Mazadi, M.N., Naimi, S., & Naimi, S. (2011). *The avr microcontroller and embedded systems.* Prentice Hall.

Pavliuk, N., Cherskikh, E., Pshchelko, N., & Shabanova, A. (2019). *Circuit Schematics of a Capacitive Proximity Sensor*: *Control Systems, Mathematical Modelling, Automation and Energy Efficiency 2019 Conference* (pp. 486-490). Lipetsk: Russia.