Design and development of water condition measurement in soil using a capacitive based sensor

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Abstract *AUKAK is a soil moisture detector using a capacitive-based sensor on a parallel plate. The dielectric material used was soil with three different water content estimates. The main components contained in the device consist of an adapter as an electric current converter, Arduino nano as a signal reader, a moisture module as a voltage reader and a capacitive plate sensor parallel to the signal catcher. Before AUKAK was designed, the sensor capacitance value was tested using an LCR meter. Dielectric materials used in sensor testing are water, air, and salt solution. This is done because the three substances have known dielectric constants. As for the accuracy and accuracy of AUKAK, when compared to moisturemeter the value reaches 90%.* [DESIGN AND DEVELOPMENT OF WATER CONDITION MEASUREMENT IN SOIL USING A CAPACITIVE BASED SENSOR] ***(J. Math. Nat. Sci., 1(1): 1 - 4, 2021)***

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Moisture, Dielectric, Accuracy

Introduction

The A sensor is a device for detecting / measuring something, which is used to convert mechanical, magnetic, heat, light and chemical variations into voltage and electric current. In the environment of control systems and robotics, sensors provide similarities that resemble eyes, hearing, nose, tongue which will then be processed by the controller as the brain (Frank, 2001; Rajagukguk and Sari, 2018; Sinaga and Rajagukguk, 2019).

Water content is the percentage of water content in a material which can be expressed based on wet weight or based on dry weight (Taib et al., 1988). The moisture content of the wet weight has a theoretical maximum limit of 100 percent, while the water content based on dry weight can be less than 100 percent. The water content of the material shows the amount of water content per unit weight of the material. In this case, there are two things that must be known to determine the moisture content (KA) of the material, namely based on dry weight (wb) and based on wet weight (wa). In this calculation the following formula applies:

$$KA = \left(\frac{Wa}{Wb}\right).100\%$$

Capacitor is an electronic device capable of storing electric charge (capacitance). Generally, the capacitance value of a capacitor is determined by the dielectric material used. Capacitors come in all shapes and sizes, but in principle they are the same as being made up of two conductors separated by a dielectric. The two conductors in the capacitor are charged the same but are of opposite sex. One chip is given a positive charge and the other chip is given a negative charge (Asfiati et al., 2020).

In dielectric materials there are no conduction electrons that are free to move throughout the material by the influence of the electric field. The electric field will not produce a movement of charge in the dielectric material (Cahyono et al., 2017). Dielectric material is very important in making capacitors, namely to increase the capacitance value, increase the operating voltage, provide mechanical support between the two pieces so that it can reduce the distance between the plates without making the plates touch (Susanti and Nurul, 2016). Soil moisture content sensors were developed based on indirect measurements of the dielectric constant of the soil (Segundo et al., 2011). Material located between three parallel stainless steel bars, coated with insulating material 9.

Using the capacitive concept can develop a sensor to measure moisture content. This sensor works based on changes in the charge of electrical energy that can be stored by the sensor due to changes in plate distance, changes in cross-sectional area and changes in the dielectric volume of the capacitive sensor. Capacitive sensors have several advantages of not having the potential health risks extension of radiation-based methods and making and operating low-frequency capacitive sensors is relatively simple (Mander and Arora, 2014). In this study, the dielectric material used was acrylic. This sensor can be used in various ways in an effective and relatively affordable way.

Materials and Methods

Theoretical studies of components and preparation of tools and materials that have been tested, then design each component and combine them into one more complex system. Then make a circuit layout on the assembly of a moisture meter and then test the circuit and enter the programming on the Arduino-nano. After completion, the tool was tested with different sample variations and conducted an analysis of the experiment.

Results

Table 1 above presents the measurement results using a digital multi-meter to find out the voltage on each parallel plate when a voltage of 5 volts is given. Figure 1 shows the complete components of AUKAK, consisting of 3 types of sensors with various variations in the distance between the plates (d), namely 0.5 cm. 0.8 cm, and 1.5 cm as well as the moisture-meter module, LCD, and adapter. Table 2 shows the results of measurements made three times for each dielectric material with three spacing between plates (0.5 cm, 0.8 cm, and 1.5 cm). The results of the test showed that the closer the distance between the plates (0.5 cm) the more accurateor the smaller the differencethe.

After the test is carried out three times, an average is obtained and these results can be used to calculate the value of precision. The precision value of soil sample 1 with d = 0.5 can be measured using the following formula.

$$\Delta x = |x_n - x^-|$$

$$x^- = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

$$\bar{x} = \frac{18 + 19 + 18}{3}$$

$$\bar{x} = 18.33$$

$$\Delta x = |(18 - 18.33) + (19 - 18.33) + (18 - 18.33)| = 1.33$$

$$Precision\ Value = \frac{100 - \Delta x}{100}$$

Table 3 shows from the calculations obtained in theory and practice, the data shows that the capacitance value has a range of values that is close to that so that the sensor is ready to be assembled into a measuring instrument for moisture in the soil. In Figure 2 which is a graph of the comparison between the design tool (AUKAK) and the KS-05 moisture meter. The range of data displayed on the AUKAK LCD screen ranges from 0% - 100%. This is an advantage of this AUKAK tool compared to a comparison tool, namely the KS-05 moisture meter, which results from measurements using a scale of 1-8, this shows that the design tool can be more precise in determining the value of water content in the soil.

Table 1. Results of voltage and capacitance measurement.

No.	Dielectric Material	Plate Distance (cm)	Voltage (V)	Capacitance (c) x 10-12F				Average
				Theory	LCR Meter			
					C1	C2	C3	
1.	Air	0.5	4.24	22.15	25.40	25.50	24.40	25.10
		0.8	4.26	13.82	19.30	19.10	19.10	19.16
		1.5	4.28	7.35	12.50	14.30	12.50	13.10
2.	Water	0.5	4.23	1774.20	1657.40	1666	1663.50	1662.30
		0.8	4.25	1107.11	1212.40	1310.5	1245.40	1256.11
		1.5	4.27	589.03	620.00	632.0	623.00	625.00
3.	Saline solution	0.5	4.30	135.11	140.60	145.3	144.7	143.50
		0.8	4.32	84.31	88.00	89.31	88.55	88.62

	1.5	4.34	44.80	49.00	45.43	47.78	47.40

Figure 1. Measuring Water Content in Soil-Based Capacitive (AUKAK)

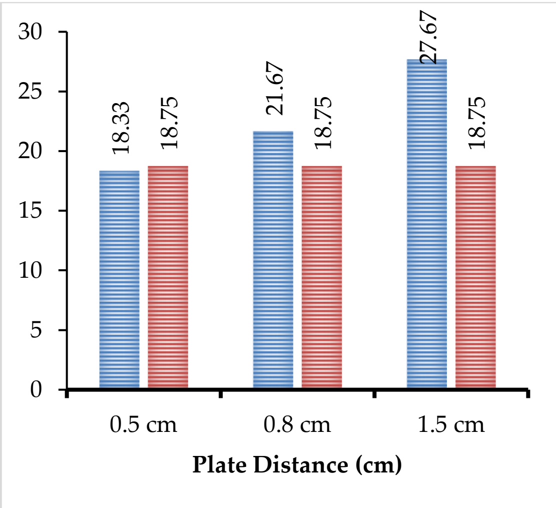

Figure 2. Comparison graph of AUKAK results with moisture-meter, Where blue color is design tool and red color is standard tools

From Figure 2 above, it appears that the biggest difference with standard tools is the distance on the large plate which is 1.5 cm and the smallest difference is the closest plate distance, which is 0.5 cm. This means that the closer the distance between the plates, the closer to the true value of water content in the soil.

Discussion

This stress test (V) is conducted to determine the stress value on each plate with variations in distance and dielectric material. The reason for choosing the three dielectric materials is because the dielectric constant of these materials is known. Tests are carried out to compare the three materials using the distance between the plates (d) which is the same as the theoretical input voltage of 5V but in practice it ranges from 4.2V. In testing all dielectric materials, it is found that the greater the distance the lower the capacitance value.

The moisturer module functions as a voltage reader and a microcontroller as a data processor for display on the LCD. The results show the measurement value of water content in the soil in the form of a percentage. For testing the flow of electricity, it is connected to a source of electric current through a power supply of 5 volts. The LCD display lights up when an electric current is applied indicating the appliance is ready to work properly.

From the results of the sample 1 soil trial, the difference between repeated measurements is 1.33, so the precision value is 98.67%. This high value indicates that in repeated measurements the measuring instrument can be used properly. This value indicates that the measuring instrument using this capacitive-based sensor has high precision.

Table 2. Water content (%) of soil samples measured by AUKAK.

Samples	Measurement to	Plate Distance of Sensor	Water Content (%)
Sample 1	1	0.5	18.00
	2		19.00
	3		18.00
	1	0.8	22.00
	2		22.00
	3		21.00
	1	1.5	27.00
	2		28.00
	3		28.00
Sample 2	1	0.5	34.00
	2		34.00
	3		34.00
	1	0.8	38.00
	2		39.00
	3		38.00
	1	1.5	44.00
	2		44.00
	3		45.00
Sample 3	1	0.5	74.00
	2		74.00
	3		75.00
	1	0.8	80.00
	2		80.00
	3		81.00
	1	1.5	85.00
	2		85.00
	3		86.00

Table 3. Results of Measurement of Moisture Content for Several Dielectric Medium Using AUKAK

No.	Dielectric material	Measurement to	Water content (%)				
			Moisture-meter	$\bar{x}$ Moisture meter ($\bar{x}_1$)	Plate Distance (cm)	AUKAK	Difference $\bar{x}_1$ and $\bar{x}_2$
1	Air	1	0	0	0.5	0.00	0
		2	0		0.8	0.00	0
		3	0		1.5	0.00	0
2	Water	1	100	100	0.5	100.00	0
		2	100		0.8	100.00	0
		3	100		1.5	100.00	0
3	Soil Samples 1	1	12.5	12.5	0.5	18.33	5.83
		2	12.5		0.8	21.67	9.17
		3	12.5		1.5	27.67	15.67
4	Soil Samples 2	1	32.5	32.5	0.5	34.00	1.50
		2	32.5		0.8	38.33	5.83
		3	32.5		1.5	44.33	11.83
5	Soil Samples 3	1	75	75	0.5	74.33	0.67
		2	75		0.8	80.33	5.33
		3	75		1.5	85.33	10.33

Conclusion

Measuring tool work serves to detect changes in the composition of the dielectric material by determining the capacitance value and dielectric constant. In this study, changes in the composition of the dielectric material in the form of water content in the soil will provide a voltage which will then be read by a series of sensors. Capacitive-based sensor testing with indicates that a high precision value of 99.57% with repeated measurements and the sensor is working properly. PFrom the calculations obtained in theory and practice, the data show that the capacitance value has a range of values close to it, so this indicates that the sensor gives almost the same results as the formula calculation.

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