The Flexiforce Sensor as a Measurement of Rainfall Using an Analog Principle

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***Abstract*—The A201 flexiforce sensor has been characterized for rainfall measuring instrument. The flexiforce has been used as a sensor to measure the variation of the water mass in the form of water volume. The sensor response in resistance variation to the water volume is very sensitive with a gradient of 7.3 mOhm/ml. Voltage response of the sensor due to the effect of changes in pressure caused by variation in the volume of rainfall is processed into precipitation data using ATMEGA32 microcontroller. Rainfall data is displayed on a Liquid Crystal Display (LCD) and stored in a Micro Secure Digital (Micro SD) with delay for 6 seconds. The resolution of instrument is up to 5 ml volume variation, that is equivalent to the value of the precipitation of 0.28 mm.**

***Keywords*— flexiforce sensor, microcontrollers, rainfall.**

I. Introduction

The electronic measuring instrument of rainfall that are already on the market generally in the tipping bucket type, especially using optocoupler or laser sensor [1-5]. Precipitation that falls through the funnel will lead weights or arm seesaw. Water entering into the scales will be shed if the weight of the water exceeds the weight of the screw, the tube volume of 6.28 cm3 used to be equal to 6.28 ml. When the water as much as 6.28 ml is poured into a graduated tube must show the numbers 1 mm. The studying of rainfall measurement instrument has been conducted by using tipping bucket, the required volume of 24.53 ml bucket with a measurement resolution of 0.5 mm [1, 6]. Rainfall measurement is calculated from the volume of rainwater shared a graduated wide mouth (rain collector).

M. Oscar Kisaka, et al [7] have examined the extent of seasonal rainfall variability, drought occurrence, and the efficacy of interpolation techniques in eastern Kenya. Analyses of rainfall variability utilized rainfall anomaly index, coefficients of variance, and probability analyses. The inverse distance weighting interpolation techniques were assessed using daily rainfall data and digital elevation model using ArcGIS. Validation of these interpolation methods was evaluated by comparing the modeled or generated rainfall values and the observed daily rainfall data using root mean square errors and mean absolute errors statistics.

The path-integrated rainfall intensity is estimated from the received signal level. This method can reveal fine-scale evolution of rainfall in space and time and allows observation of near-surface rainfall at a spatial resolution of up to 1×1 km^2 and a temporal resolution of upto1 min, with no additional installation and maintenance costs. Two different methodologies for calculating instantaneous rainfall from microwave links have been evaluated. The study region covers a 1,600 km^2 area in central Israel which includes up to 70 commercial microwave links, and 7 rain gauges installed in the vicinity of the links. The 19 rainstorm events over a two year period covering about a 676 h overall period, are evaluated [8].

In this study designed rainfall measuring instrument with scales and methods of using sensors flexiforce A201 type 1 lbs, that we have developed and linearized by using our recently method [9]. The flexiforce sensor is a force or load sensor, the sensor is shaped printed circuit which is very thin and flexible. Flexiforce very easy to implement sensor for measuring the compressive force between two surfaces in a variety of applications. The greater the load received flexiforce sensor then its output resistance value will decrease.

To determine the response of the sensor flexiforce to the amount of rainfall, the sensor is placed under the scales with the mass use of rain water volume. The obtained data of rainfall is displayed on the LCD and stored on a Micro SD memory.

II. Methods

A. System Design

In this study there is a system control and data acquisition. Figure 1 is a schematic of hardware on the control system. This control system is used to control a solenoid valve as rain water discharge valve. Physical property which becomes the reference is the volume of rainwater which will then be read by the sensor flexiforce. When the volume of rain measured in accordance with reference value (60-310 ml), the microcontroller will control relay for opening and closing the valve.

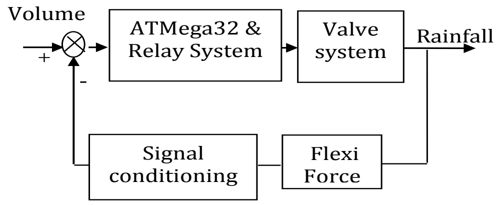


Fig 1. System design of realized instrument

B. *Realized Circuit*

This study uses a sensor that has 3 flexiforce pin connectors, the first pin is the output pin of the sensor, the second pin is a ground pin, while the third pin connected to the source voltage of 5 V. In the first pin of the sensor will be connected to the voltage divider circuit serves as a signal conditioner. The resistance used on voltage divider circuit of 1 MOhm. Figure 2 is a designed and realized circuit of system. In the entire circuit, port A is connected to the sensor, the RTC and the relay is connected to the port C, port B is used by the circuit and the LCD using a Micro SD port D.

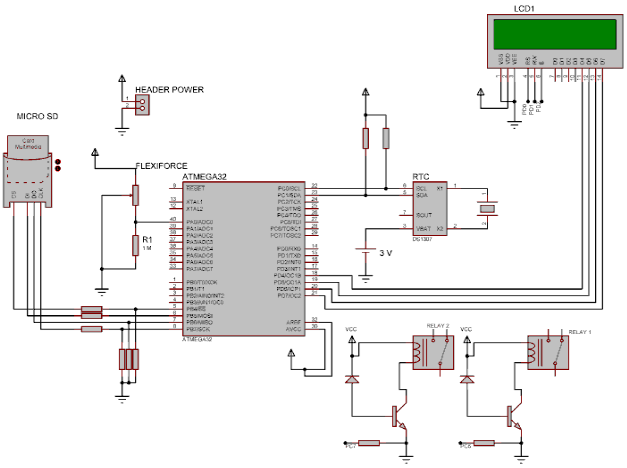


Fig 2. Realized Circuit

III. Results and Discussion

A. *Characteristics and Resolution of Sensor System*

Sensor testing done to determine how much total volume of rainwater that can be measured by the flexiforce sensor. The set-up of system characterization is done by placing the sensor under the scales in order to obtain the voltage value of the change in pressure due to the addition of the masses, in this study the mass used in the form of rain water volume.

Figure 3 shows the graph characteristics flexiforce sensor by using a variation of the masses, in this case the mass in the form of water volume. Value masses as large as the volume value for rainwater belongs to the category of fresh water so that the value of density as great with plain water, therefore the density of the rain water is 1 g/cm³ and the conversion of physical quantities of 1 g is 1 ml. The purpose of this variation to evaluate the response and how the maximum volume that can be read by the sensor flexiforce. The next step is to test and measurement data acquisition on samples (water). For obtaining the characteristic of system, we have used actually the maximum volume of water testing is 600 ml. The design tool used in this study using the maximum water volume of 450 ml. Based on the graph shows the greater the volume of water supplied to the sensor, the resistance generated will be smaller. In Figure 5 can be seen to the best measurement range between 50 ml- 350 ml.

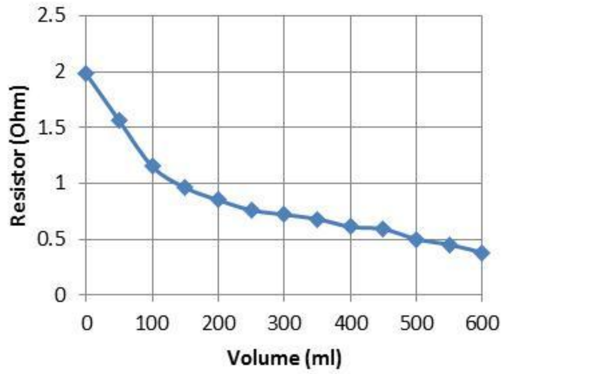


Fig 3. Flexiforce characterization response as a variation of water volume

Further testing on the nature of electrical sensor characteristics by connecting sensors to the input voltage of 5 volts and a voltage divider resistance of 1 Mohm has been done. This characterization using water volume 0-600 ml. Based on Table 1 can be formed a hysteresis graph. Making the graph of hysteresis is done to see the difference in sensor characterization data or deviation of measurement results. The Figure 4 shows that the deviation occurs in the water volume of 50-150 ml, by increasing and decreasing of water volume. The deviation value occurs at 100 ml, so the value of maximum hysteresis is about 0.25 V.

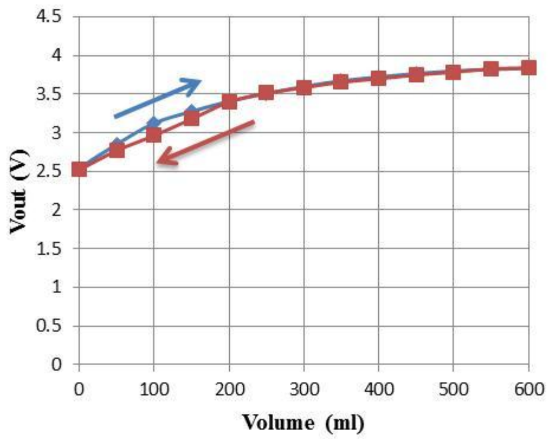


Fig. 4. Hysteresis response of realized system

Further testing the resolution of the measuring instrument. Resolution measurement was conducted to see the smallest value of the measurements performed. On this measure the resolution seen in changes in the value of 5 ml. Therefore, it can be known by measuring the value of the resolution of the tool with the following calculation:

$$Res = \frac{Vm}{A}$$

Where the value of the minimum volume derived from the value of 5 ml, when converted into units of mm obtained a value of 5,000 mm^3. While the value of 17,662.5 mm^2 surface area was obtained from the rain collector surface area which has a diameter of 15 cm, we get the resolution of realized system 0.28 mm.

B. Calibration System

Calibration test performed to compare the measuring instruments used in accordance with standardized measuring devices, calibration is done by using weights and a graduated measuring cup as water volume, calibration data is used to determine the real converter equation that will be recorded in microcontroller programming. Calibration test result has been shown in Figure 5, that we have some offset value of response about 0.81 V. This offset value is just easily suppressed in calibration equation.

After the calibration process is done, to do the processing and measurement of rainfall data. Values obtained by distributing rainfall volume amount of rain measured cross-sectional area rain collector.

The rainfall unit is shown on the form of mm. The obtained rainfall data (Crhj) is displayed on the LCD are shown in Figure 6 and stored on a Micro SD shown in Figure 7. The timing system is contained on the Micro SD display using the Real Time Clock (RTC). Values are displayed and stored on a Micro SD such as the date, time and amount of rainfall.

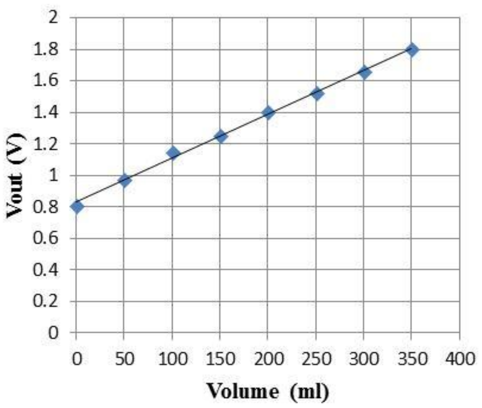


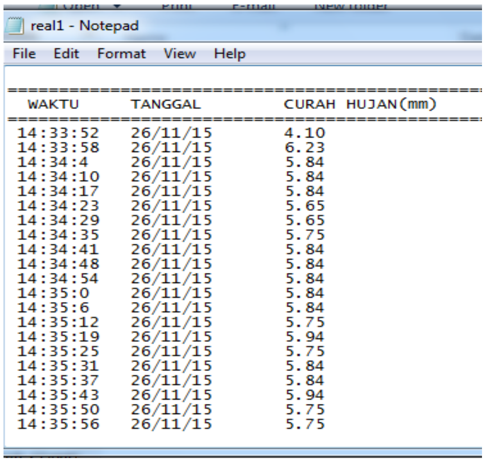
Fig 5. Calibration Response of Realized System

Process control is connected with the storage process. Values measured volume of a reference in the process of controlling the solenoid valve, solenoid valve which is used by 2 pieces first valve is an inlet valve that is used as a filling tap water and the second valve is an outlet valve that is used as tap water discharge. When the value reached 60 ml, the inlet valve opens and data storage will be done, when the volume reaches 310 ml, the outlet valve opens and closes the inlet valve so that the discharge of water in the tube will do.

C. Field Testing

Data were collected on November 26th 2015 are shown in Figure 7. Data storage on a Micro SD performed every 6 seconds, so the graph is able to read the time range is partitioned in a scale of 5 minutes. On November 26, 2015 at 14:33 o'clock, the value of rainfall is 4.10 mm. To determine the amount of rainfall in the range of 14:33 to 18:5 pm, it is necessary to average rainfall recorded at all the range time. The average value is 8.12 mm, and the minimum value of rainfall is 4.10 mm at 14:33 and the maximum value is 18.5 mm at 16:02.

Fig. 6. Rainfall data shown on LCD layer



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WAKTU	TANGGAL	CURAH HUJAN(mm)
14:33:52	26/11/15	4.10
14:33:58	26/11/15	6.23
14:34:4	26/11/15	5.84
14:34:10	26/11/15	5.84
14:34:17	26/11/15	5.84
14:34:23	26/11/15	5.65
14:34:29	26/11/15	5.65
14:34:35	26/11/15	5.75
14:34:41	26/11/15	5.84
14:34:48	26/11/15	5.84
14:34:54	26/11/15	5.84
14:35:0	26/11/15	5.84
14:35:6	26/11/15	5.84
14:35:12	26/11/15	5.75
14:35:19	26/11/15	5.94
14:35:25	26/11/15	5.75
14:35:31	26/11/15	5.84
14:35:37	26/11/15	5.84
14:35:43	26/11/15	5.94
14:35:50	26/11/15	5.75
14:35:56	26/11/15	5.75

Fig. 7. The recorded data on Micro SD

IV. CONCLUSION

An instrument for measuring the rainfall with weighing system has been designed using flexiforce sensor. This tool is able to measure tiny changes in the volume of rain water up to 5 ml. Test value resolution using sensors measuring tool of 0.28 mm.

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