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Design and Manufacture of Rainfall Measuring Instruments Based on Android Smartphone and ATmega328P Microcontroller Using Hall Effect Sensor

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To produce low-cost measuring instruments with high accuracy, which are expected to be used as a reference in developing rainfall observation instruments to reduce observation costs.
Study Design: Design of Rainfall measuring instruments based on Android Smartphone and ATmega328P microcontroller using hall effect sensor.
Place and Duration of Study: Department of Physics, Udayana University, and Indonesian Agency of Meteorology, Climatology, and Geophysics (BMKG), Region-III Badung, from June 2022 to August 2022.
Methodology: Calibration is done by comparing the output value of the rainfall measuring instruments using hall effect sensor and the BMKG calibration standard tool. The calibrated

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parameter is rainfall. The relationship between the measurement values of the design tool and the standard tool is determined using linear regression method to obtain a correction equation.

Results: Rainfall measuring instruments based on Android Smartphone and ATmega328P microcontroller using hall effect sensor have been produced. The measurement accuracy obtained for the rainfall parameter is 97.97% with uncertainty (U95) of 0.06 mm/min. The accuracy value indicates that the resulting tool has a good level of accuracy to the standard tool.

Conclusion: In this research, has been produced a rainfall measuring instrument at a low-cost with high accuracy and precision, which has been calibrated with BMKG standard tool.

Keywords: Rainfall; ATmega328P; hall effect sensor; telemetry.

1. INTRODUCTION

Rain is an important factor in all aspects of life, uncertainty the arrival of rain currently is very influential on industrial activities, especially in the agricultural sector [1]. Technological developments demand that all aspects contribute to its use, except for the determination of rainfall [2]. Various applications of climatology and hydrology in agriculture, plantations and agricultural industry very depend on rain. The rainfall data is the main input to the bulk simulation model surface flow (rainfall-runoff) for urban hydrology applications. The design and analysis of urban drainage systems are greatly influenced by rainfall intensity and duration data recorded [3,4]. Although the sensing method is widely used in rainfall estimation, measurements from the rain gauge are still used for operational and calibration purposes. The observation of rain gauge is also necessary for the radar rainfall estimation algorithm [5]. The instrument for measuring rainfall that falls to the ground surface per unit area is called a rain gauge. Several types of rain measuring instruments that have been developed include weighing, capacitance, tipping bucket, optics, and others [6]. Rainfall intensity measuring devices have a very important role in monitoring the productivity of an area. Based on the description above, researchers are interested in conducting research to produce rainfall measuring instruments based on Android Smartphone and ATmega328P microcontroller using hall effect sensor at a low-cost with high accuracy, which is expected to facilitate the measurements of rainfall intensity and can be used as a reference in developing rainfall observation instruments.

1.1 Arduino Uno R3 ATmega328P

Arduino Uno R3 ATmega328P is one of the microcontrollers that are widely used today because of the ease of use of Arduino and its program language compared to the minimum microcontroller system [7]. Arduino Uno is one version of the existing Arduino. The Arduino Uno is equipped with ATmega328P as a microcontroller, 14 digital pins and 6 analog input pins but the use of programming languages is still the same as another Arduino [8]. The Arduino Uno R3 ATmega328P can be powered by a 7–12 V power supply. The memory on The Arduino Uno R3 ATmega328P has 32 KB (0.5 KB used as bootloader), 2 KB and SRAM, and 1 KB EEPROM [9].

1.2 Hall Effect Sensor

Hall effect sensor is a device that can be activated by an external magnetic field. The input of this sensor is the magnetic density around the sensor, if the magnetic density exceeds a predetermined threshold, then the sensor will detect and produce output [10]. The basic principle of the hall effect sensor is to convert the current flowing through the conductor around the magnetic field into a voltage proportional to the amount of current passing through the conductor. If there is no magnetic field on the sensor, the distribution of current flowing on the sensor does not cause voltage [11].

1.3 Organic Light Emitting Diode (OLED)

Organic light emitting diode is one of the technologies for flat light emitting media. OLED is formed from a series of placement processes of organic thin film between two conductors. The device has 4 I2C interfaces pins to be connected to the microcontroller pins [12]. OLED is more economical in power consumption compared to Liquid Crystal Display (LCD). The device requires 3.3 – 5 V and OLED can be programmed with an I2C microcontroller [13].

1.4 HC-05 Bluetooth Module

HC-05 Bluetooth module is a Bluetooth serial port protocol (SPP) module. The device can be connected to wireless systems and designed for wireless serial connection setup [14]. Connectivity modes on the HC-05 Bluetooth module include slave/receiver (RX) mode and master/transceiver (TX) mode. The device can operate without using a special driver. When the devices communicate with other devices or Bluetooth, there are two requirements, namely communication between the master and slave, and the password must be correct when pairing the device. The device has an effective range of 10 meters [15].

2. METHODOLOGY

2.1 Design of System

The design used is shown in Fig. 1. This design tool uses a hall effect sensor as input. The Arduino Uno R3 ATmega328P microcontroller is the center of processing input and output sensor reading data. HC-05 Bluetooth module as data sender via Bluetooth connection. There are two outputs of design tool, namely display media on OLED and application on Android Smartphone.

2.2 Calibration Methods

Calibration is the application of observation equipment by comparing the designation of the measuring instrument with known and traceable standard values [16]. Data collection for calibration is carried out by observing the output data of rainfall measuring instruments and BMKG standard tool. The calibrated parameter is the rainfall parameter.

3. RESULTS AND DISCUSSION

3.1 Results

Research on the design and manufacture of rainfall measuring instruments based on Android Smartphone and ATmega328P microcontroller using hall effect sensor, was carried out at the Electronics and Instrumentation Laboratory of the Physics Study Program, Udayana University and the Meteorology, Climatology and Geophysics Calibration Laboratory, Region-III Badung, from June 2022 to August 2022. The design results of the rainfall measuring instruments based on Android Smartphone and ATMega328P microcontroller using a hall effect sensor are shown in Fig. 2 and the schematic design is shown in Fig. 3.

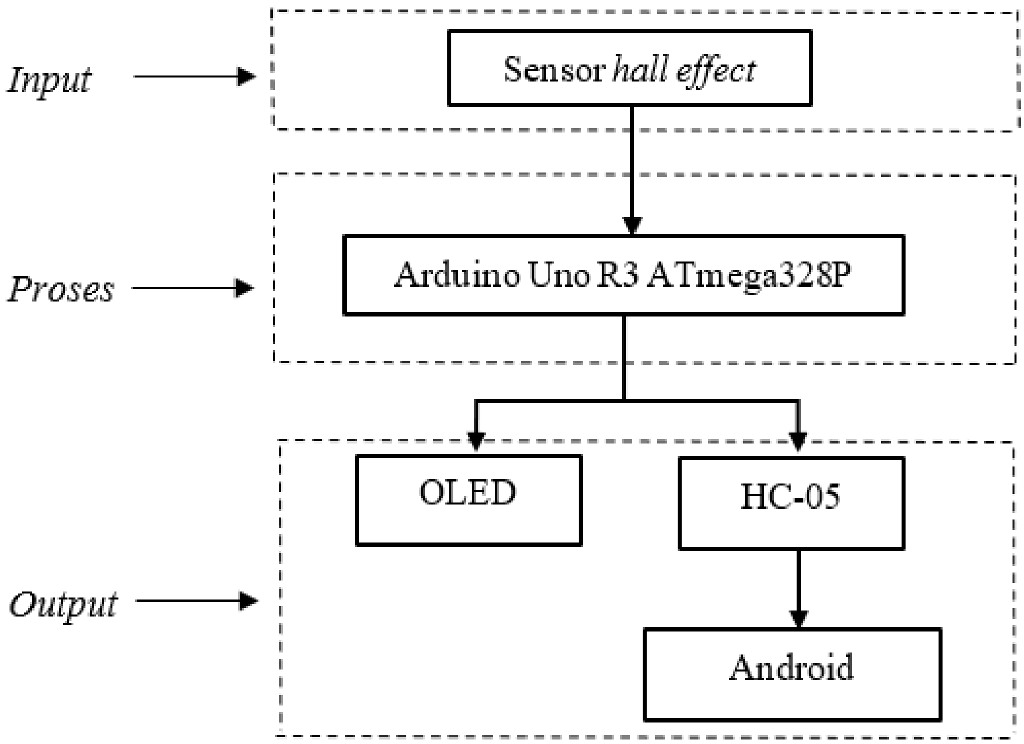

Fig. 1. Block diagram of design tool

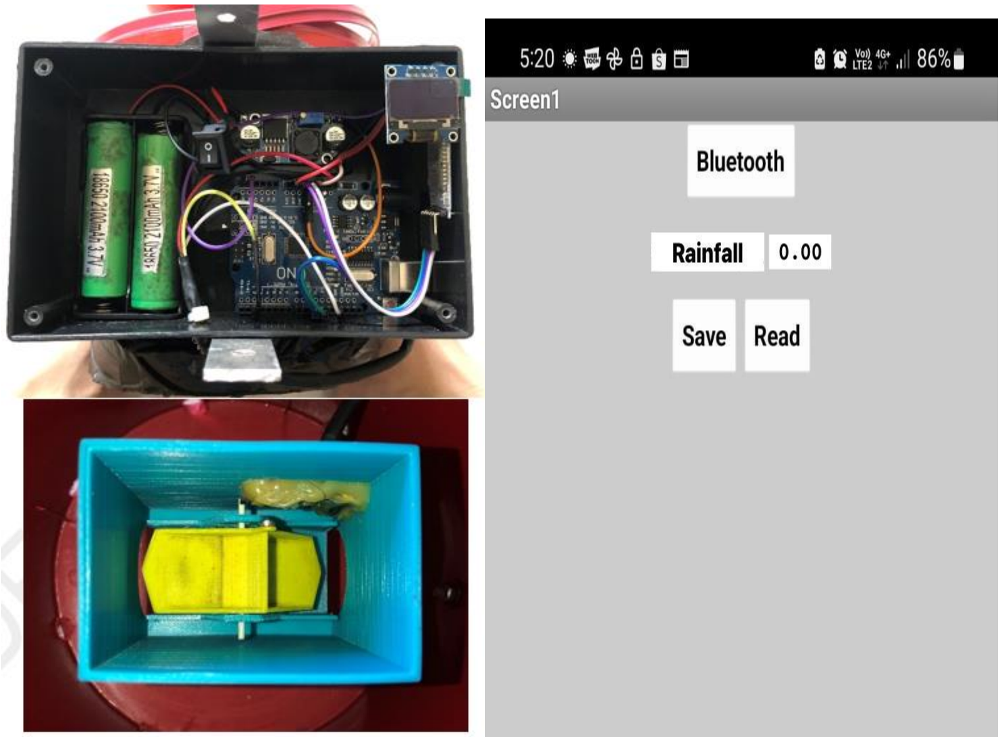

Fig. 2. Result of design tool

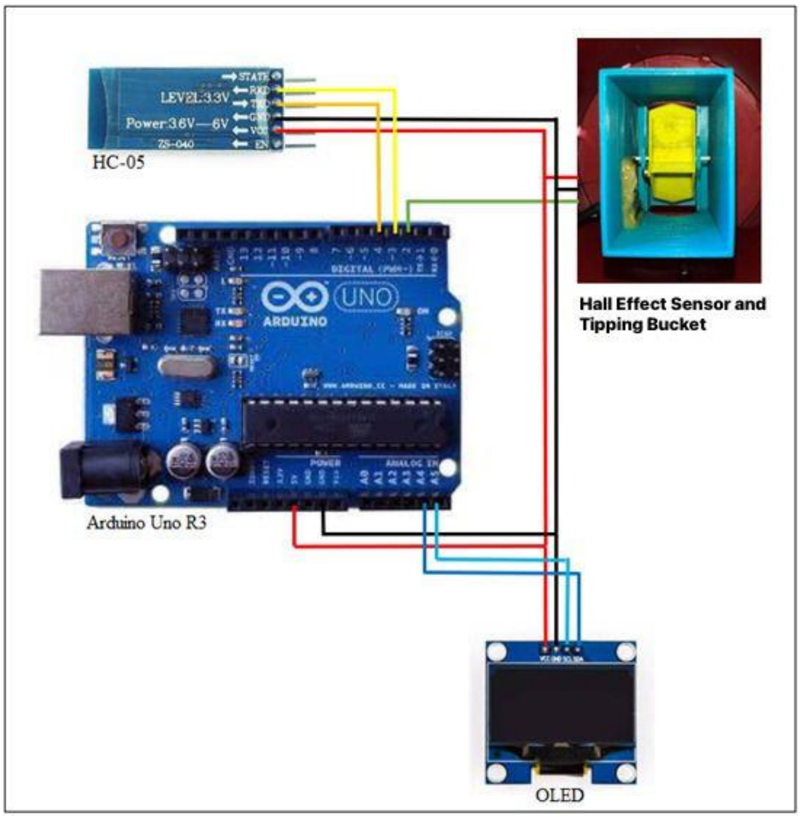

Fig. 3. Schematic design

3.2 Discussion

3.2.1 Calibration of RAINFALL PARAMETER

Calibration of rainfall parameters is carried out to test the rainfall measurement value of the design tool with Tipping Bucker Rain Gauge Calibrator. The set point range used in the calibration process is between the nozzle rate 25-300 mm/hour. The rainfall parameter calibration result data is shown in Table 1.

The data in Table 1 shows that the error value of the rainfall measurement obtained is less than 5%. This value still meets the tolerance for the classification of rainfall measurement error values set by WMO, which is a maximum of 5% [16]. The standard deviation value obtained shows a small value, this shows that the design tool has a good level of precision for rainfall parameters. The calibration data in Table 1 are plotted into a linear test graph as shown in Fig. 4.

Based on the plotted data, a linear equation was obtained with a regression coefficient (gradient) of 1.6624 and a regression constant of -14.116 so that an equation close to y = x could be obtained. This shows that the measurement results between design tool and standard tool are close to the same. In addition, the value of the coefficient of determination (R^2) of 0.9627 was obtained. This value can be interpreted as the accuracy of the measurement results of design tool against standard tool is 96.27%.

3.2.2 Application of rainfall parameter

Applications of rainfall parameter were carried out at the Tool Park of BMKG Region-III Badung in August 2022 and compared with a reference tool, The Automatic Rain Gauge. The application data can be seen in Table 2.

Table 1. Calibration data of rainfall parameter

Set Point (mm/hour)	Reference Tool (mm)	Design Tool (mm)	Correction (mm)	Error* (%)	Deviation Standard
25	21.67	21.93	0.27	1.23	0.23
50	21.47	21.67	0.20	0.93	0.20
100	21.27	21.20	-0.07	0.31	0.12
200	20.67	20.07	-0.60	2.90	0.35
300	19.87	19.00	-0.87	4.36	0.23

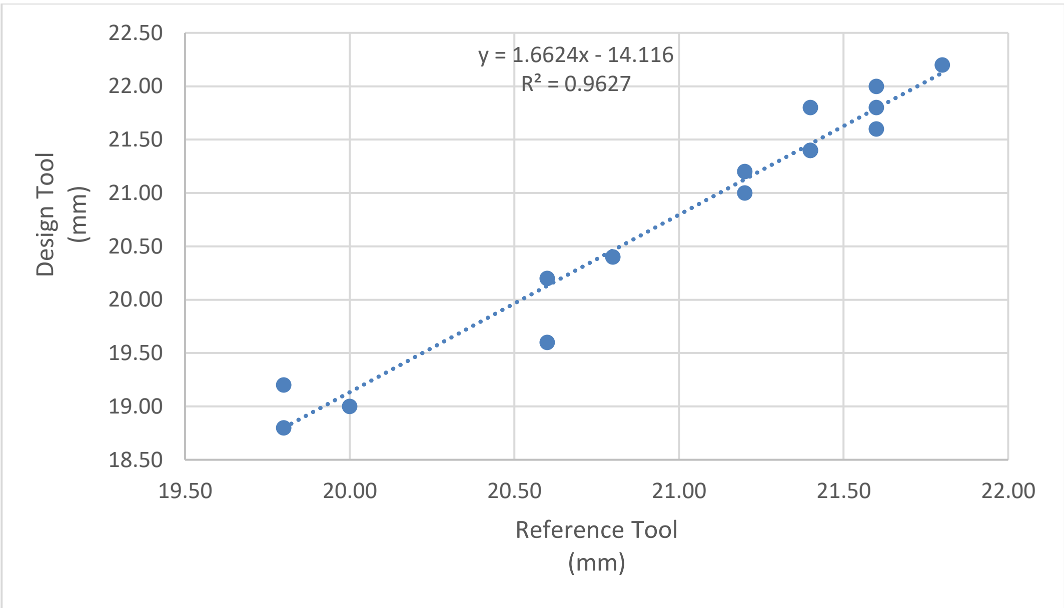

Fig. 3. Graph of rainfall parameter calibration

Table 2. Application data of rainfall parameter

Date (August 2022)	Reference Tool (mm)	Design Tool (mm)
11	0.8	0.6
12	1	0.6
13	0.2	0
14	0	0
15	3.8	3.2
16	0	0
17	0	0
18	2.6	2.2
19	0.6	0.4
20	0	0
21	0	0
22	1.8	1.4
23	6	5.2
24	0.8	0.6
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0
31	3.4	2.8

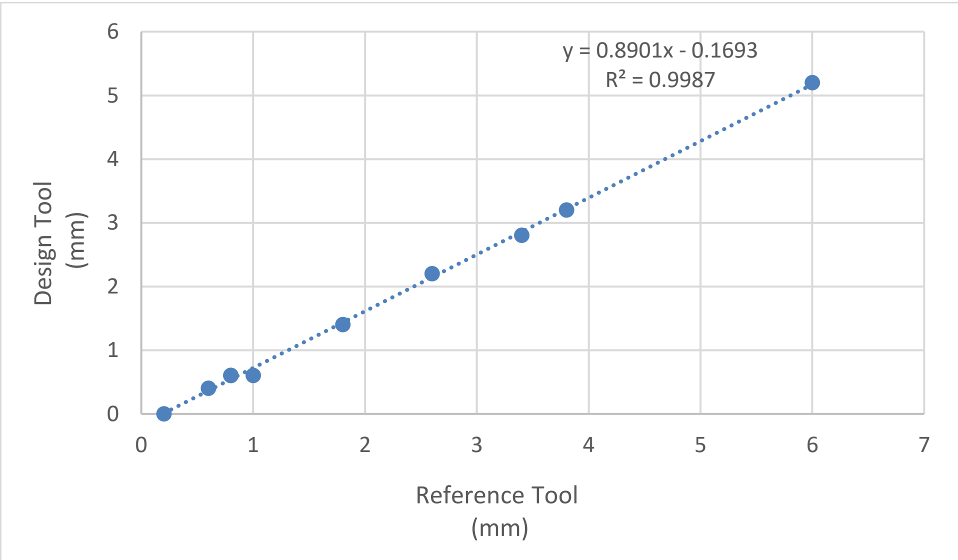

Fig. 5. Graph of rainfall parameter application

Based on the overall data in Table 2, it can be plotted in the graph can be seen in Fig. 5.

Based on the plotted data, a linear equation was obtained with regression coefficient (gradient) of 0.8901 and a regression constant of -0.1693 so that equation close to y = x could be obtained. This shows that application results between design tool and reference tool are close to the same. In addition, the value of the coefficient of determination (R^2) of 0.9987 was obtained. This value can be interpreted as the accuracy of the measurement results of design tool against reference tool is 99.87%.

4. CONCLUSION

The conclusions obtained are:

1. The design of Rainfall measuring instruments based on Android Smartphone

and ATmega328P microcontroller using a hall effect sensor has been produced.
2. The resulting tool design has been calibrated with BMKG standard tools. Calibration is carried out by comparing the measurement results of the design tool with the BMKG tool so that the accuracy of the tool is obtained through the calculation of the coefficient of determination. The resulting tool has a good level of accuracy and precision for the measurement of rainfall parameters.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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