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# A simple calibration methods of relative humidity sensor DHT22 for tropical climates based on Arduino data acquisition system

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# A Simple Calibration Methods of Relative Humidity Sensor DHT22 for Tropical Climates Based on Arduino Data Acquisition System

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**Abstract.** Nowadays, there are many sensors that can be directly connected to the microcontroller to measure and calculate the value of relative humidity immediately. However, the existing sensors are made designed and tested to measure the conditions of the location where the sensor is made, which will cause deviation of the results at other locations. Therefore, it should be known more accurately the characteristics of DHT22 sensor in the tropical region. This calibration is done by comparing the relative humidity value on the sensor with the relative humidity value obtained from the manual measurement by the ASTM E337-84 method that taken at the same time. The advantages of DHT22 sensor are relatively cheap and easily obtained through online purchases. The Data collected would be engineered to the output of the sensor so that the detected value on DAQ will generate humidity value that is close to the humidity value with the ASTM E337-84 method. In conclusion, DHT22 sensor has different characteristics than the existing specifications in the data sheet, and this calibration method can improve the performance of this DHT22 sensor that this sensor after calibration, DHT22 will be used fregmently for testing the performance of portable incubator made by Universitas Indonesia.



## INTRODUCTION

Humidity is one of the important parameters in a baby incubator because humidity and air temperature in the incubator must be able to maintain the baby's condition [1]. In determining a humidity, it is necessary to dry bulb and wet bulb data [2]. In this experiment a data acquisition system based on Arduino will be created to read the results of the DHT22 sensor. The sensor used to measure humidity is DHT22 sensor. DHT22 contains a thermistor to measure dry bulb temperature and humidity sensor measured by utilizing changes in the conductivity of the substrate material that is sensitive to moisture [3]. The environmental conditions at the time these sensors are made are sometimes not the same as the conditions when these sensors are used, that caused deviations in results due to use in different locations which are also called environmental errors [4,5,6]. Though the DHT22 sensor has been widely used for several studies [7,9,10,11]. For this reason, calibration is needed for this sensor in local conditions by utilizing ASTM E337-84 as the basic principle used as a reference for calibration. Calibration is done by engineering the output of the sensor in the Arduino Uno microcontroller.

## METHODOLOGY

### Design of *Apparatus*

Apparatus manufacturing began by looking at ASTM E337-84 to adjust the data collection conditions regulated by ASTM E337-84. The settings made focus on the thermometer, wet air temperature, and air flow.

The thermometer used to collect moisture data using the ASTM E337-84 method is a thermometer that has a range specification not exceeding 0-80$^{o}$C with 0.2$^{o}$C uncertainty and the accuracy level reaches 0.1$^{o}$C [2]. So using

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the ASTM 91C thermometer [12]. For wet bulb temperature measurement, use a thermometer coated with cotton with a linear density of 1-1.2g/m by covering the bulb from the thermometer not too tightly. The thermometers are placed above the water surface at a distance of 5-25mm. Measurements are made with conditions of 3-10m/s air velocity[2]. For sensors that are calibrated, four DHT22 sensors are used to get a variety of sensors. Then Arduino uno is used as a microcontroller to read the humidity value from the sensor and engineer the output value of the sensor.

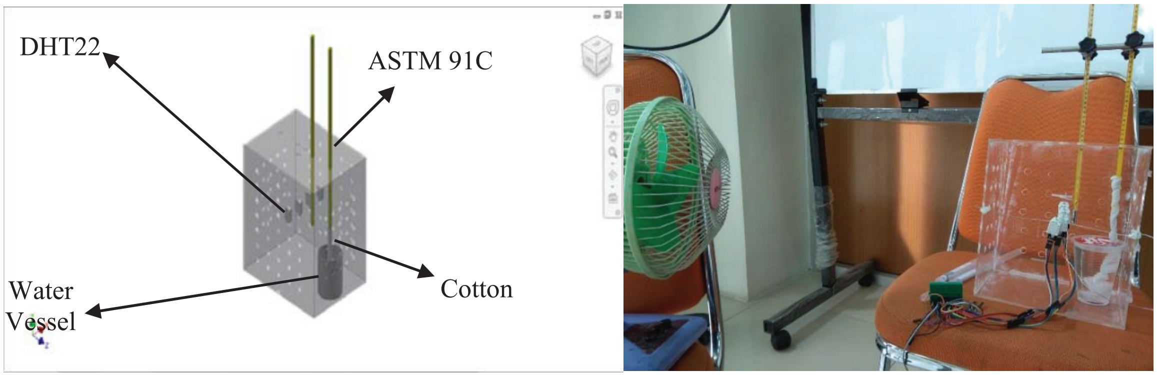


**FIGURE 1.** Setting of *Apparatus*

## Coding and Data Retrieval

After the apparatus is finished, made a coding that used to run the DHT22 sensor to read the humidity value. Then given a little change from the code obtained from the internet so that it can take the humidity value of four sensors at a time. Then the data retrieval is done with a pause each data retrieval is five minutes. Each data retrieval from the sensor also takes the data on the wet bulb temperature and the dry bulb temperature to see the humidity value.



## Determination of Equations and Calibration

After obtaining humidity data on DHT22 sensor and humidity from wet bulb temperature and dry ball temperature measurement, a comparison was made between the two by looking at the relationship between ASTM RH and RH DHT22. After that linear regression and get the equation of the two measuring instruments. From the equation of the relationship between the two measuring instruments, a calibration equation is sought to engineer the output value of the DHT22 sensor by inversing the equations obtained from the RH DHT22 sensor linear regression relationship with ASTM RH. With the aim of the output of the sensor approach to value of RH DHT22 = RH ASTM. However, the regression equation must be viewed with uncertainty to give confidence to the equation. so that the equation can be used in which this equation is entered into the microcontroller to engineer the output value

# RESULTS

## Results of Data Retrieval

RH data obtained from the DHT22 sensor is in the range of 40-94%, and the RH data obtained from the ASTM method is between 46-96%. The range represents the humidity value of Indonesian humidity and the incubator cabin [13,14,15,16,18]. It can be seen that the humidity value obtained from the DHT22 sensor is mostly below the humidity value of the ASTM method. And the humidity value obtained from the DHT22 sensor has an error value when compared between the sensors.

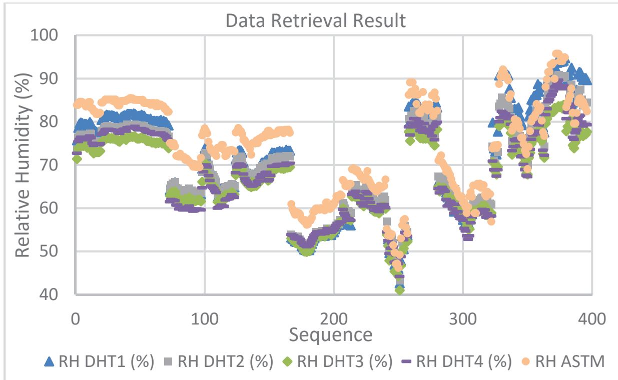


**FIGURE 2.** Graph of RH Data Retrieval Results

This shows that the characteristics of the DHT22 sensor are different when used in Indonesia because they have a different environmental conditions with the environmental conditions where the sensor is made which is also called environmental error [4,5,6]. Therefore, calibration is needed to reduce the error value of the sensor.

## Data Processing Results

The DHT22 RH vs. ASTM RH chart was created to see the relationship between the two measuring instruments so that they obtained the equation from the DHT22 sensor to the RH value of ASTM. The graph is plotted based on when data are collected together or in the same sequence. A comprehensive equation is sought that can be used by all DHT22 sensors and in environmental conditions in Indonesia. Then, look for the linear regression line equation from the data obtained.

The selection of linear regression lines because the relationship between the x and y axes does not have a physical relationship because it is only a comparison between two measuring instruments. Then, this linear regression line selection makes it easy to find the calibration equation that will be used. And the thermometer used is a thermometer that contains liquid mercury, which has linear characteristics[12].

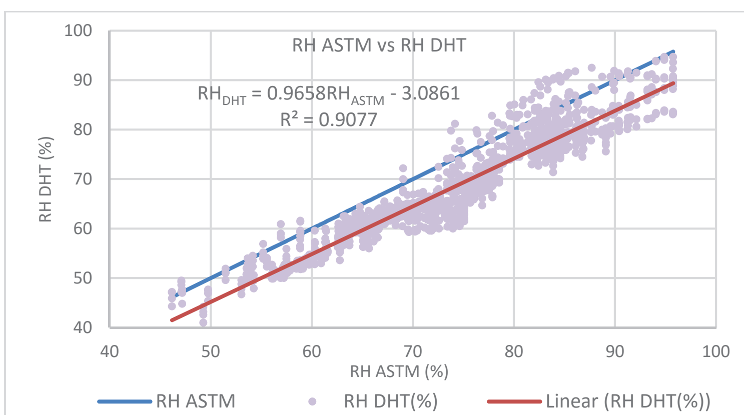


**FIGURE 3.** Regression Processing Chart

Judging from the linear regression line, it can be seen that the regression line representing the data retrieval points has the equation $RH_{DHT} = 0.97RH_{ASTM}-3.09$ which shows that the DHT22 sensor has such characteristics. This regression equation applies only to environmental conditions when the data is obtained in the humidity range of 46-95% at a temperature of 20-35$^o$C. The regression line has zero and sensitivity drift[19] to the moisture line ASTM or y = x. the regression line can be reviewed further with the results of further regression processing, namely:

**TABLE 1.** Table of Regression Calculation Results

| | |
|---|---|
| m | 0.97 |
| sm | 0.01 |
| B | -3.09 |
| sb | 0.58 |
| Standard Error | 3.27 |

There is a standard deviation for both the slope and intercept of the equation. These standard deviation values cause doubts in choosing the right regression equation because the linear regression equation will be in the range $RH_{DHT}$ = (0.97 ± 0.01) $RH_{ASTM}$- (3.09 ± 0.58). The standard deviation value of the coefficient of the equation is quite small because the error value that may occur is only 0.77 + 0.58 that is 1.35% RH when compared to the RH value range, which is from 0-100%

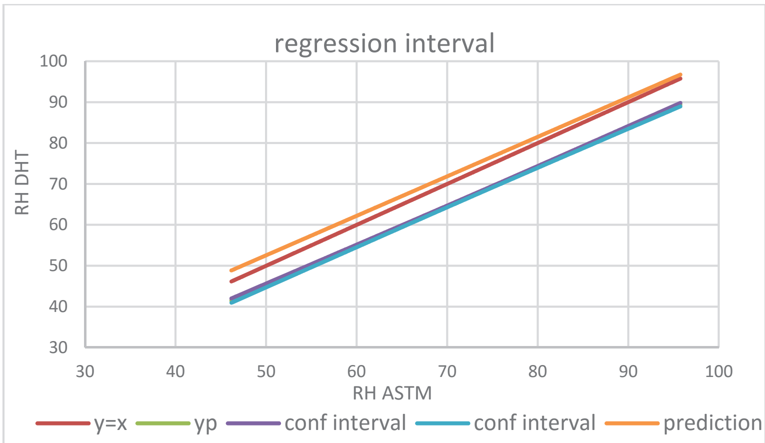


**FIGURE 4.** Regression Interval Graph

From the value of the doubt obtained from the regression equation, the confidence interval is obtained. To see if the confidence interval of the linear regression has a range that can still be trusted or not.
If viewed from the interval contained in linear regression, it can be seen that the range in the confidence interval has a very narrow range. This means that the linear regression line used is very reliable because of its confidence interval range ± 0.5% RH. Because the confidence interval is a range that indicates how sure the regression line is obtained from the uncertainty of the equation. Then the prediction interval obtained in the regression equation has a range of ± 7.3% RH. Which line of prediction interval is a line that predicts the range where a point taken later (before calibration) 95% will fall in that range. Which means the spread of DHT22 sensor points spread over a wide enough range [20].

After obtaining a regression line with the equations that can be trusted, then obtained the equation used to calibrate the DHT22 sensor by engineering the output on the microcontroller. The sensor calibration equation is obtained by invading the regression equation from the sensor so that the value will approach the y = x line or the RH ASTM value line that is the reference.

## Data Retrieval Results After Calibration

After doing the calibration using the calibration equation that is entered into the code on the Arduino, the data is taken to see the results of the calibration that has been done. If you look at the retrieval data at the time after calibration and compare the results of the capture on the DHT sensor with ASTM, it can be seen that this time the value of the DHT22 sensor has a higher value compared to the ASTM RH value. This means that there is still an error value that occurs after the calibration. This error value is called random error, because this error value is difficult to eliminate [4,6,19,21,22].

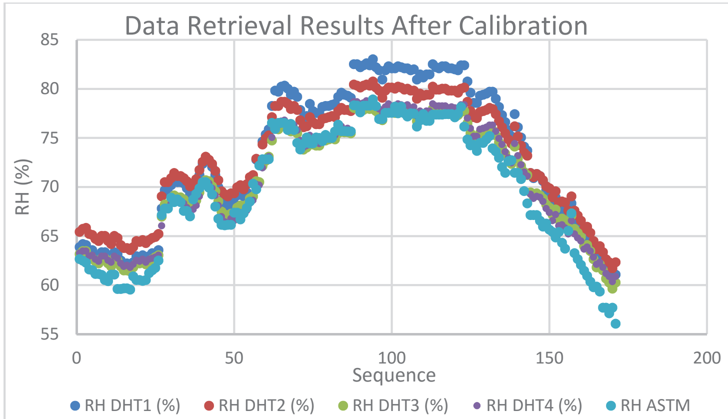


**FIGURE 5**. Data Retrieval Results after Calibration

This error value can occur because the calibration equation used is a universal equation that can be used for all conditions in Indonesia for various DHT22 sensors, namely the humidity range of 46-95% and temperature of 20-35$^{o}$C. So it is not specific to one environmental condition and one sensor only.

## Error Calculation Results

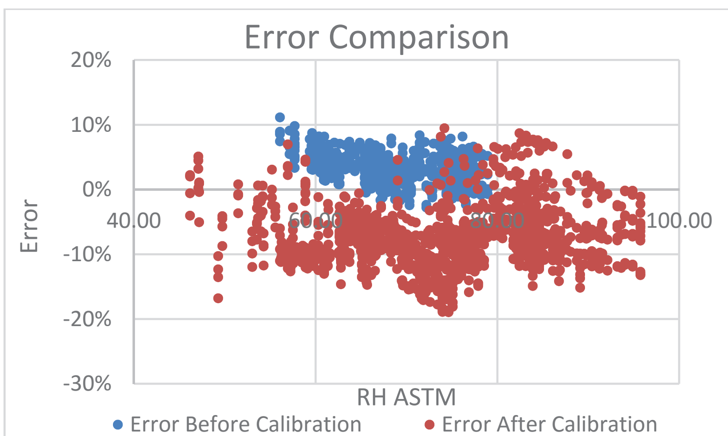


**FIGURE 6**. Graph of Error Value Comparison

If you see an error value from DHT22 sensor against ASTM RH. It can be seen that the DHT22 error value before calibration has a large error value that is the Root Mean Square Error (RMSE) value of 9% with a range of -19% to 10%. However, after calibration using the equation that has been obtained from the regression, the error value of the DHT22 sensor against the ASTM RH reference has decreased the error value to RMSE 4% with a range of error -3 to 11%, which means the accuracy of the sensor is increased because it has better value of RMSE[4,6,21,23].

**TABLE 2**.Table of Intervals Comparison Before and After Calibration

| | Before Calibration | After Calibration |
|---|---|---|
| Standard Error | 3.27 | 1.59 |
| range confidence interval | ±0.5%RH | ±0.3%RH |
| range prediction interval | ±7.3%RH | ±3.5%RH |

From processing regression data before and after the calibration, it is seen that the standard error value or the distribution of data from the DHT22 sensor after the calibration has decreased by almost 50% when compared to RH DHT22 data before calibration. Likewise, the prediction interval value from the DHT22 sensor after calibration has a half value before the calibration. This shows that the DHT22 sensor has a better level of precision after calibration when compared to before calibration because the variation of the value of this sensor has a smaller value [4,6,20,21,23,24,25,26].

## CONCLUSION

This study aims to determine the characteristics of the DHT22 sensor in the conditions of tropical climates such as Indonesia and look for simple methods that can be used to calibrate this sensor so that later this sensor will be used to measure the grashof incubator owned by mechanical engineering department Universitas Indonesia. It can be seen that the DHT22 sensor has different characteristics from the sensor datasheet which has an error value ranging from -19% to 10% which should have an error value of ± 5%. After doing the calibration with the output engineering method using the calibration equation of the linear regression data obtained, the accuracy and precision of these sensors increased which had a 9% RMSE with a standard error of 3.2%, to have a RMSE 4% with a standard error of 1.6% for range conditions 46-95% humidity at a temperature of 20-36$^{o}$C

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