unison publishers

Research Journal of Modern Physics

Review article

A Low-Cost Ultrasonic Rain Gauge

Zvinodashe TT Feresu*

Department of Space Science and Applied Physics, University of Zimbabwe

*Corresponding author: Zvinodashe TT Feresu, Department of Space Science and Applied Physics, University of P.O. Box MP167, Mt Pleasant, Harare, Zimbabwe.

Received: 28-09-2022
Accepted: 10-10-2022
Published: 25-10-2022

Abstract:

Accurate measurements of precipitation are necessary for the analysis of weather by meteorologists and hydrologists. Successful design and implementation of electronic rain gauges is important because it will reduce human error such as that of trying to read the values accurately. The use of an electronic sensor such as the HC-SR04 connected to a microcontroller such as that in the Arduino is vital. The Arduino then transmits the results through a GSM modem to the internet. This helps in updating the weather station into that of this electronic era. The aim of the project was to design and build up an up-to-date low-cost rain gauge with the following principal characteristics: accuracy, ease of connection, immunity to noise, remote programmable and operation, interior temperature regulation, cosine error minimization, and to be portable. The designed HC-SR04-based rain gauge was calibrated in a standard laboratory. The calibration and test results of the low-cost rain gauge have characteristics such as accuracy and are error-free. Most of the characteristics of the designed rain gauge are similar to those of a tilting bucket rain gauge and, therefore, can be used in any application area where reliable measurement of precipitation is necessary.

Keywords: Rain gauge, Sensor, Precipitation, Ultrasonic, Calibration.

Introduction/Background:

A **rain gauge** (also known as an **udometer**, **pluviometer**, or an **ombrometer**) is an instrument used by meteorologists and hydrologists to gather and measure the amount of liquid precipitation over an area in a predefined period [1]. However, there are a couple of uses it serves and forms it may take, which are quite interesting. Generally, as the name itself suggests, a rain gauge (or "pluviometer") is an instrument that is used as a form of measurement item [2]. Hence, the basic design of this tool does just, measuring for the purpose of collecting data about falling precipitation. This is the most common use for a rain gauge and several different types have been developed for this purpose. A special weighing rain gauge features a rotating drum, a pen, and a storage bin [3]. The storage drum collects any form of precipitation while the pen positioned below the drum records its weight. A rain gauge is a crucial instrument utilized in the study of the weather phenomenon as well. Meteorologists and hydrologists use these instruments so that they will be able to examine and then gauge the exact level of precipitation or rainfall following a particular time frame. Long term data can help scientists predict weather patterns and learn from any trends exhibited in their data [4].

These are the most common uses of several types of rain gauges. Overly, whatever kind of rain gauge you prefer to use, what you should keep in mind is the purpose you're using it for. This will determine the best kind of gauge for the topic you're using it to study [5].

Materials And Methods:

The HC-SR04 is made up of two ultrasonic transducers mounted on a card, 15 degrees from each other.

Figure 1: The HC-SR04 ultrasound distance sensor

Ultrasonic transducers such as the HC-SR04 are transducers that convert ultrasonic sound waves into electrical signals or vice versa. When a sound wave is incident on an interface between two media, part of it is reflected in the original medium. The amount of energy reflected depends on the impedance of the media. The greater the difference in impedance between the media forming the interface, the greater the amount of energy that is reflected in the low impedance medium [6].

The HC-SR04 transmits ultrasound, high-pitched sound waves with frequencies higher than the audible limit of human hearing.

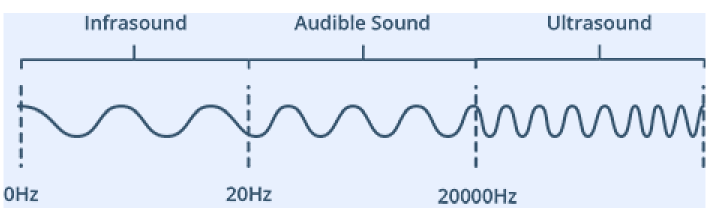


Figure 2: Sound level

Human ears can hear sound waves that vibrate in the range from about 20 times a second (a deep rumbling noise) to about 20,000 times a second (a high-pitched whistling) [7]. However, ultrasound has a frequency of over 20,000 Hz and is therefore inaudible to humans. One of the transducers will be transmitting the ultrasonic signal while the other will be receiving the echo signal [8].

The first medium is air and the second medium is water in the rain gauge. The ultrasound signal will be reflected when it reaches the air to water boundary. The time that it takes from the instant that a signal is sent to the time that the echo is received, is taken as twice the time that the signal travels to the boundary. The distance can be calculated since the speed of sound waves in the air is known to be 344 m/s. Ultrasonic sensor analogue outputs produce a linear current or voltage signal. The signal level is proportional to the distance between a detected object and the sensor [9].

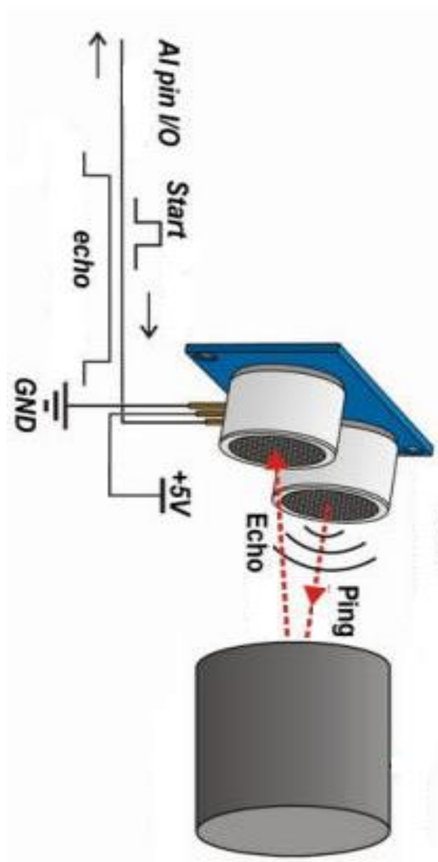


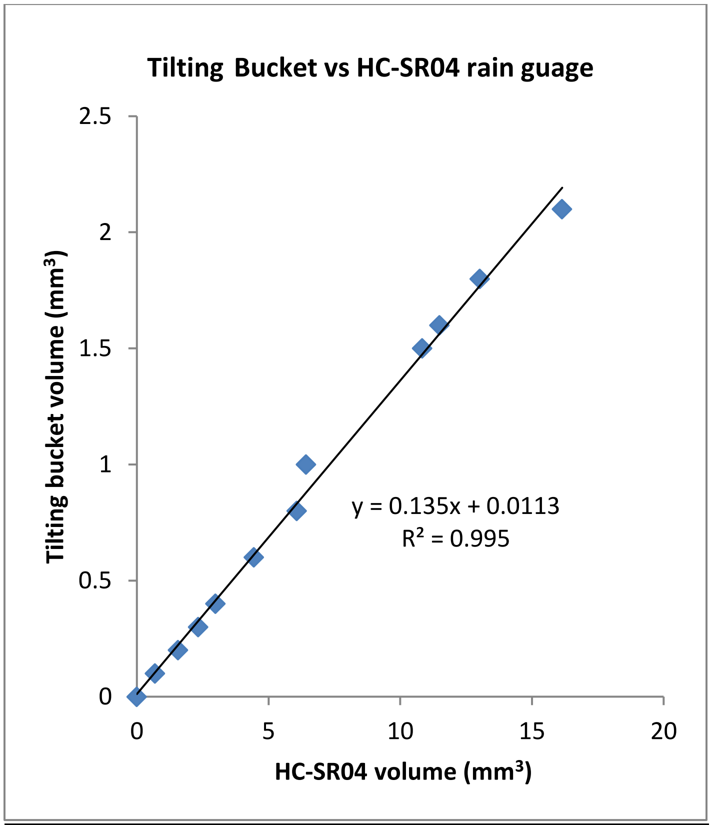
Figure: 3 Block diagram of an HC-SR04 rain gauge.

The output current is between 0 and 20 mA or 4 and 20 mA depending on the model. For analogue voltage versions, the range is between 0 and 10 V [10]. Analogue signals from the sensors are converted into digital form by the microcontroller in the Arduino circuit [11].

Results and Discussion:

The test rain gauge whose funnel is of standard dimensions was used to receive the rain. The volume is measured by the HC-SR04 mechanism and compared to the rainfall collected by a tipping bucket rain gauge. The volume of water in the receiving cylinder of the test mechanism was found by multiplying the area of the cylinder by the height of the cylinder covered by water. This was calculated through the software programmed in the Arduino microprocessor [12].

The amount of water collected by the HC-SR4 rain gauge was calibrated against that of a tipping bucket rain gauge.



Graph 1: Calibration of the HC-SR4 rain gauge.

Conclusion:

This system measures one vital climatic variable, liquid precipitation. The calibrated equation for the variable is given by the multiplying factor **m** and the addition of the constant **c**, in the equation y = mx + c which is to be used to get the real values. This equation is used to be programmed in the Arduino software to get the calculated value of the variable. The values of rainfall produced by the equation are to be saved on the SD memory card connected to the Arduino band periodically broadcast through a GSM modem to users through the internet for processing. The formulae are y = 0.135x + 0.0113 and R^2 = 0.995 which are excellent since R^2 is very close to unity. Graph.1 indicates how the values of the experimental rain gauge compare with those of the standard rain gauge [13].

References:

1. Rad AM, Ghahraman B, Khalili D, Ghahremani Z, Ardakani SA (2017) Integrated meteorological and hydrological drought model: a management tool for proactive water resources planning of semi-arid regions. Adv. Water Resour 107: 336-353.
2. Fabian NO (1966) Pluviometer.
3. Strangeways I (2010) A history of rain gauges. Weather 65: 133-138. https://doi.org/10.1002/wea.548
4. Harrison DL, Driscoll SJ, Kitchen M (2000) Improving precipitation estimates from weather radar using quality control and correction techniques. Meteorol. Appl 7: 135-144.
5. Schilling W (1991) Rainfall data for urban hydrology: what do we need? Atmospheric Res 27: 5-21.
6. Morgan EJ (2014) HC-SR04 ultrasonic sensor.
7. Risojević V, Rozman R, Pilipović R, Češnovar R, Bulić P (2018) Accurate indoor sound level measurement on a low-power and low-cost wireless sensor node. Sensors 18: 2351.
8. Zhmud VA, Kondratiev NO, Kuznetsov KA, Trubin VG, Dimitrov LV (2018) Application of ultrasonic sensor for measuring distances in robotics, in: Journal of Physics: Conference Series 032189.

9. Kulkarni AU, Potdar AM, Hegde S, Baligar VP (2019) RADAR based Object Detector using Ultrasonic Sensor, in: 2019 1st International Conference on Advances in Information Technology (ICAIT). IEEE 204-209.
10. Nasution TH, Siagian EC, Tanjung K (2018) Design of river height and speed monitoring system by using Arduino, in: IOP Conference Series: Materials Science and Engineering. IOP Publishing 012031.
11. Sinclair S, Pegram G (2005) Combining radar and rain gauge rainfall estimates using conditional merging. Atmospheric Sci. Lett 6: 19-22.
12. Rain gauge (2020) Wikipedia.
13. Nystuen JA, Proni JR, Black PG, Wilkerson JC (1996) A comparison of automatic rain gauges. J. Atmospheric Ocean. Technol 13: 62-73.