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# Development Arduino Data Logger using TDR H3CR for Tidal Simulator

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***Abstract*— Tides are the rise and fall of sea level repeatedly over a certain period of time. Tides have an important role in life, such as in the aspects of tourism, fisheries, economy, shipping, and student research. Learning media innovation develops until it looks real, which is called a simulation or simulator application. Simulator media as learning has many benefits, such as shortening research time and reducing research funds. Raja Ali Haji Maritime University has a tidal simulation model that has been equipped with a floodgate, and the weakness of the simulator is that it still uses a manual system. Researchers developed a new tidal simulation tool without a generator and only analyzed the up and down data that had been set using H3CR, DC Water Pump, and DC Selenoid Valve as a tool for automatic tidal circulation commands.**

***Keywords*—TDR H3CR, Tides Simulator, and Ultrasonic Sensor.**

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## I. Introduction

Tides are periodic rises and falls in sea level [1]. The seawater tides play an important role in many aspects of life, including tourism, fishing, the economy, and shipping [2]. Therefore, knowing the tidal tide time is essential.

Water tides can be predicted using animal behavior [1], wind speeds [3], and the development of ultrasonic sensors HC-SR04 [4]. Obtaining tidal information data on seawater takes a very long time and a lot of money. One option for reducing time and money is to design a seawater tide simulator to learn about the characteristics of seawater tides. The phenomenon of sea tides can be simulated using a simulator tool. The simulator will change the state of the water into a tide and then recede. Sensors will be used to observe the occurrence of tides and ebbs in the simulator. Raja Ali Haji Maritime University has a tidal simulation model [5]. The simulator's shortcomings include the use of a manual system and a lack of data on the tides it generates. The shortcomings of such research can be addressed by redesigning a new tidal simulator device that operates automatically without the use of a power plant and only performs data analysis when tides occur.

The research will create an automatic tide measuring simulator device using a timer (H3CR) and an ultrasonic sensor (HC-SR04). Tides are measured by the height of the water. This research has the advantage of using H3CR as a timer because setting the H3CR time is very practical.

## II. Literature Review

### A. Tidal Energy

The ebb and flow of seawater is caused by gravitational attraction and centrifugal forces. The centrifugal effect is a push toward the earth's outside center of rotation. Gravity is proportional to mass but not to distance. Although the moon is smaller in size than the sun, its gravitational attraction force is twice as strong in awakening the sea tides. This is because the moon is closer to the earth than the sun. The gravitational attraction pulls seawater towards the moon and sun, resulting in two gravitational tidal bulges (bulges) in the sea. Declination, the angle between the Earth's rotation axis and the orbital planes of the moon and the sun, determines the latitude of the tidal protrusion [2].

According to the equilibrium theory, the rotation of the earth on its axis, the revolution of the moon against the sun, and the revolution of the earth against the sun are the factors that cause the occurrence of tides. Meanwhile, according to dynamic theory, it is the depth and breadth of the water, the influence of the earth's rotation (coriolis force), and bottom friction. Furthermore, there are several local factors that can affect the tides in a specific area, such as seabed topography, strait width, bay shape, and so on, resulting in different tidal characteristics in different locations [6].

### B. Types of Tidal Energy

One or two tides may occur in a given area per day. There are four types of tides [7].

1. Double daily tides (semi-diurnal tides) are tides that occur twice in one day, with nearly the same height, and the tides occurring sequentially on a regular basis.
2. A single daily tide (diurnal tide) is a tidal that occurs when there is only one tide and one ebb on a single day.
3. The semi-diurnal mixed tide is an ebb that occurs twice a day, twice the tide, but with a different height and period.
4. A diurnal mixed tide is a one-day tidal tide that occurs once a high and once a low tide, but occasionally there are two tides and two low tides with very different heights and periods.

### C. Arduino Uno

Arduino UNO R3 (Arduino UNO revision 3) is an Atmega 328, an AVR-RISC-based 8-bit microcontroller chip made by Atmel with 32 KB of ISP flash memory with read/write capabilities, 1 KB of EEPROM, and 2 KB of SRAM [8]. Figure 1 shows the Arduino UNO R3, and Table 1 shows the

Arduino UNO R3 specification table. The Arduino UNO module's comprehensive set of features makes it simple to use.


Figure 1. Arduino Uno

Table 1. Specifications Arduino Uno.

| **No** | **Specifications Arduino Uno** | |
|---|---|---|
| 1 | Operating Voltage | 5V DC |
| 2 | Input Voltage | 7-12 V DC |
| 3 | Batas Input Voltage | 6-20 V DC |
| 4 | Digital I/O | 14 pin (of which 6 provide PWM output) |
| 5 | Analog Input | 6 |
| 6 | DC Current pin I/O | 20 Ma |
| 7 | DC Current for pin 3,3V | 50 Ma |
| 8 | Flash Memory | 32 KB of which 0.5 KB used by bootloader |
| 9 | SRAM | 2 KB |
| 10 | EEFROM | 1KB |
| 11 | Clock Speed | 16 MHz |

Source: (Handoko, 2017)

Arduino UNO module is an open-source physical computing platform. Arduino IDE is the platform (Integrated Development Environment). Arduino UNO module is used in conjunction with the Arduino IDE platform, which supports C programming. Arduino IDE also includes an upload feature that allows you to send the program in the sketch to the Arduino UNO [8]. Figure 2 shows the Arduino IDE.


Figure 2. Arduino IDE

*D. HC-SR04 Ultrasonic Sensor*

HC-SR04 ultrasonic sensor converts physical magnitudes (sounds) to electrical quantities and vice versa. Ultrasonic waves can travel through solid, liquid, and gaseous media. The reflectivity of ultrasonic sound waves on the surface of the substance is nearly identical to the reflectivity of ultrasonic sound waves in liquid paint. At a specific frequency, piezoelectricity produces ultrasonic waves. When an oscillator is applied to a piezoelectric object, it will emit ultrasonic waves with a frequency of 40kHz. In general, HC-SR04 ultrasonic sensor works by firing ultrasonic waves at a target. The reflected ultrasonic waves from the target will return to the sensor. The sensor will receive the reflected wave and then calculate the difference between the time the wave was sent and the time the reflected wave was received. HC-SR04 ultrasonic sensor can measure the distance between objects from 2 cm to 4 m with a 3 mm accuracy [9]. Figure 3 shows HC-SR04 ultrasonic sensor.


Figure 3. HC-SR04 Ultrasonic Sensor

*E. 16x2 LCD and I2C*

An electronic display is a type of electronic component that displays data in the form of characters, letters, or graphics. LCD (Liquid Crystal Display) is a type of electronic display that uses CMOS logic technology to work by reflecting light around it against the front-lit or transmitting light from the back-lit. LCD (Liquid Crystal Display) displays data in the form of characters, letters, numbers, or graphics [10]. Figure 4 shows the 16x2 LCD.

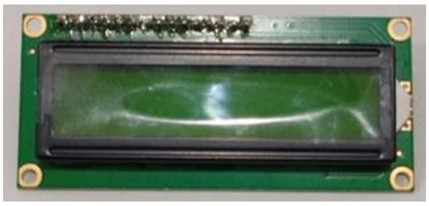


Figure 4. 16x2 LCD

The Inter Integrated Circuit or I2C, is a two-way serial communication standard that uses two channels to send and receive data. The I2C system is made up of SCL (Serial Clock) and SDA (Serial Data) channels that carry data between I2C and its controllers. I2C Bus-connected devices can function as both Master and Slave. The master is a device that initiates data transfer on the I2C bus by generating a start signal, terminates data transfer by generating a stop signal, and generates a clock signal [11]. Figure 5 shows the I2C module.

Figure 5. I2C Module

### *F. Valve Selenoid DC*

Valve Selenoid DC is a valve that is powered by electrical energy via solenoids and has a coil as a drive that functions to move the piston, which can be powered by either AC or DC currents. Pneumatic solenoid valves or solenoid valves have output, input, and exhaust holes. The input hole is a terminal where compressed air enters or supplies (service unit), while the output hole is a terminal or place for wind pressure to escape connected to the pneumatic, and the exhaust hole is a channel to expel compressed air that is trapped when the plunger moves or moves. when the pneumatic solenoid valve operates [12].

A solenoid valve is the most common type of fluid control element. The solenoid valve's function is to turn off, release, dose, distribute, or mix fluids. The solenoid valve can be divided into two parts based on the model, namely the solenoid valve single coil and the solenoid valve double coil. The solenoid valve operates as an electric valve with a coil as the drive. When the coil receives a voltage supply, it becomes a magnetic field and moves the piston on the inside when the piston is pressurized by the supply (service unit). In general, this pneumatic solenoid valve has a working voltage of 100/200 VAC, but there are some that have a DC working voltage [13]. Figure 6 shows the DC solenoid valve.

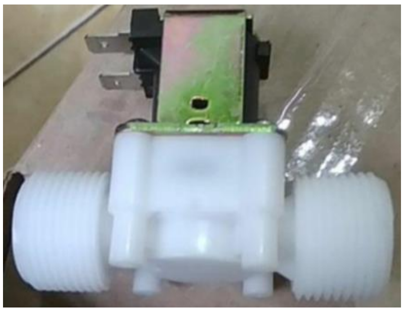


Figure 6. Valve Selenoid DC

### *G. Water Pump DC*

A water pump is a mechanical machine or piece of equipment used to raise liquid from the ground to a plateau or to drain liquid from a low-pressure area to a high-pressure area, as well as to act as a flow rate booster in a piping network system. The pump works by emphasizing and sucking fluid. The pump element will lower the pressure in the pump room on the suction side of the pump (suction), resulting in a pressure difference between the surface of the sucked fluid and the pump chamber [14]. Figure 7 shows the DC water pump.

Figure 7. Water Pump DC

### *H. H3CR Time Delay Relay (TDR)*

A Time Delay Relay (TDR) is a device that uses an electromagnet to operate a set of switch contacts. It is commonly used in motor installations, particularly those requiring automatic timing. This control equipment can be combined with other control equipment, such as an MC (Magnetic Contactor) and a Thermal Over Load Relay. The timer is installed as a timer for the equipment it controls. This timer is designed to set the contactor's on or off time with a time delay. When the timer (Time Delay Relay) is given a time setting, the NO and NC contacts on the timer will function. This time setting can be determined using the timer's potentiometer. For example, the H3CR timer is set to 10 seconds. After the timer is connected to an electric current source, the contacts NO and NC will activate for 10 seconds [15]. Figure 8 shows a Time Delay Relay (TDR).


Figure 8. H3CR Time Delay Relay

### *I. Micro SD Card Adapter Module*

A MicroSD Card is a data storage component. A microSD card requires an adapter, specifically the MicroSD Card Adapter Module. The MicroSD Card Adapter Module acts as a MicroSD Card reader and writes data to the MicroSD Card Card Module. There is a file system and an SPI driver interface on the MicroSD Card Adapter Module [16]. Figure 9 shows the MicroSD Card Adapter Module.

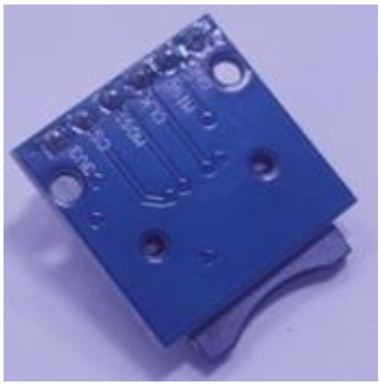


Figure 9. Micro SD Card Adapter Module

## III. RESEARCH METHOD

### *A. Tools and Materials*

The research tools and materials listed below are in accordance with the research objectives. These tools and materials are used to achieve the desired result. Table 2 shows the tools used, and Table 3 shows the materials used.

Table 2. Research Tools

| No | Tools | Amount | Unit |
|---|---|---|---|
| 1 | Laptop | 1 | Pcs |
| 2 | Solder | 1 | Pcs |
| 3 | Drill | 1 | Pcs |
| 4 | Multimeter | 1 | Pcs |
| 5 | Scissors | 1 | Pcs |

Table 3. Research Materials

| No | Materials | Amount | Unit |
|---|---|---|---|
| 1 | Arduino | 1 | Pcs |
| 2 | HC-SR04 Ultrasonic Sensor | 1 | Pcs |
| 3 | 16x2 LCD | 1 | Pcs |
| 4 | H3CR Timer Delay Relay | 1 | Pcs |
| 5 | Water pump DC | 2 | Pcs |
| 6 | Valve Selenoid DC | 2 | Pcs |
| 7 | Relay DC | 1 | Pcs |
| 8 | Pipe ¾ - ½ | 4 | Meter |
| 9 | Box ATS | 1 | Pcs |

*B. System Design*

This research was conducted at the Renewable Energy Laboratory of the Faculty of Engineering, Raja Ali Haji Maritime University. The system is made up of H3CR components, relays, water pumps, and an Arduino Uno. The relay is an input, the H3CR is a process, and the water pump is an output. The Arduino Uno is a device for measuring the height of low tides. If H3CR is set to repeat the time, for example, if H3CR is set to 6 minutes, H3CR will activate the water pump for 6 minutes and then turn it off for 6 minutes. The design of the tidal simulator system (Figure 10). The water level monitoring device on the tidal simulator is built with an Arduino, HC-SR04 sensors, and an LCD. The water level monitoring device can be seen in Figure 11.

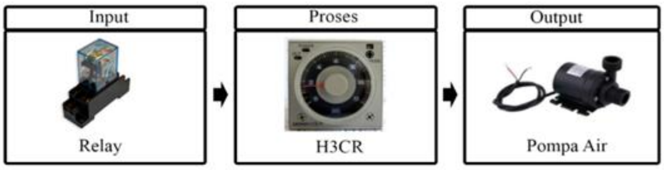



Figure 10. Tidal Simulator System

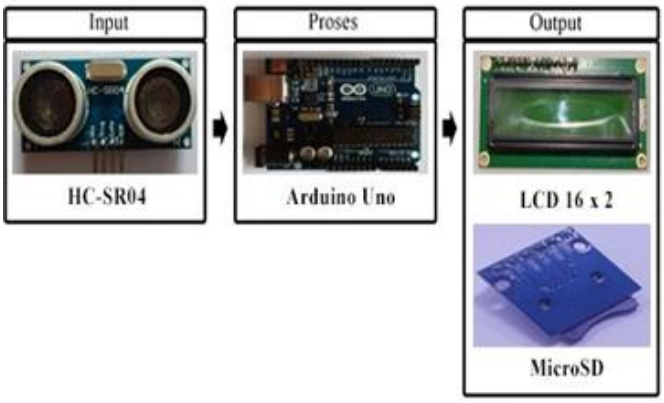



Figure 11. The Water Level Monitoring Device

*C. Data Processing and Analysis*

*Sensor Calibration*

The ultrasonic sensor HC-SR04 is calibrated first before use. The higher the level of sensor accuracy, the more effective a system. Calibration of an ultrasonic sensor HC-SR04 is performed to determine the accuracy level by reading the sensor distance and comparing it to the calibrator (ruler). The comparison of the ultrasonic sensor HC-SR04 value and the calibrator value yields a linear equation [17]. The linear equation is as follows:

$$y = ax + b \tag{1}$$

Description:
y and x = Variable of observation
a and b = Constanta

The next step is to calculate the difference between the reading value of the ultrasonic sensor HC-SR04 and the calibrator value. The sensor error value is defined as the difference between the sensor and the calibrator. The following equation is used to find sensor error values:

$$error = \left(\frac{NP-NS}{NP}\right) \tag{2}$$

Description:
*error* = Error sensor value
*NP* = Calibrator value
*NS* = Sensor value

Then, look for the error percentage of the obtained sensor error value. The following equation is used to calculate the percentage of sensor errors:

$$error = \left(\frac{NP-NS}{NP}\right) = x\ 100\% \tag{3}$$

Calculations with Root Mean Square Error (RMSE) and Standard Deviation were performed to improve the results of the sensor's accuracy level calculation. The higher the sensor accuracy, the lower the RMSE value and standard deviation [18]. The RMSE equation is as follows:

$$RMSE = \sqrt[2]{\frac{\sum(NP-NS)^2}{n}} \tag{4}$$

Description:
RMSE = Root Mean Square Error
n = Number of Readings
NP = Calibrator value
NS = Sensor value

The standard deviation equation is as follows:

$$std = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1} \tag{5}$$

Description:
std = Standard deviation
$\bar{x}$ = Mean
xi = First value of x
n = Number of readings

*Data Analysis*

The tidal measuring simulator will change the tides every 6 minutes. The tidal process happens twice, as does the receding process. The tidal and low-tide processes take 24 minutes in total. The dissimulator represents 24 hours. This is based on the tides, which happen every 6 hours. The H3CR regulates the tides and tides alternation.

When the Start button is pressed, the tidal process begins. The water pump will drain water from the reservoir into the tidal tub at this time. The water pump will be turned on for 6 minutes. H3CR has complete control over the uptime setting. H3CR will turn off the water pump from the reservoir to the tidal bath after 6 minutes, and then activate the water pump from the tidal tub to the reservoir. The receding process takes 6 minutes. This process will be repeated indefinitely.

Tides are caused by alternating active water pumps controlled by the H3CR. When given a voltage of 12 V, the water pump turns on and off. When water pump 1 and water pump 2 are both active, water pump 2 will turn off. The water pump will alternate between turning on and off. These alternately activated water pumps cause tidal and ebb processes.

When the tidal and low tide processes occur at the same time, the ultrasonic sensor measures the water level. A water level of 0 cm is measured using ultrasonic sensors. The water level at 0 cm indicates that the water in the trough is receding. A water level of 60 cm is measured by ultrasonic sensors. The water level in the trough at 60 cm indicates that it is high tide. It takes 6 minutes to return to the tide. The water level is measured in conjunction with the time. The water level data cuplic updates every 1 second. This water level data is then saved on a microSD card. This water level data will be used to prove that the tidal basin exists.

## IV. Result and Discussion

### A. Hardware Design

*Simulator Design*

Tidal simulators are made of acrylic. The simulator is outfitted with a 5 mm PVC pipe as the water channeling line and a DC water pump as the water pump. The simulator measures 200 cm long, 30 cm wide, and 42 cm tall. The simulator is divided into three sections: the reservoir, the limiting room, and the tidal tub. The simulator's base is not the same height as the top, but rather an inclined plane. The simulator's base is an inclined plane, similar to the shape of the beach's base, which is also tilted. The tidal simulator can be seen in Figure 12.

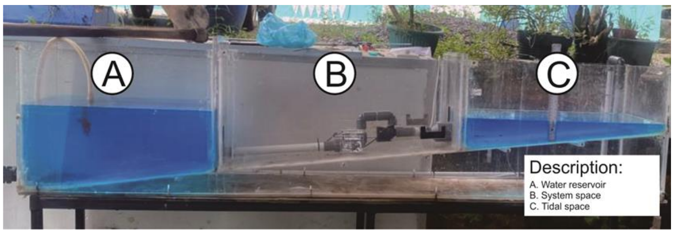
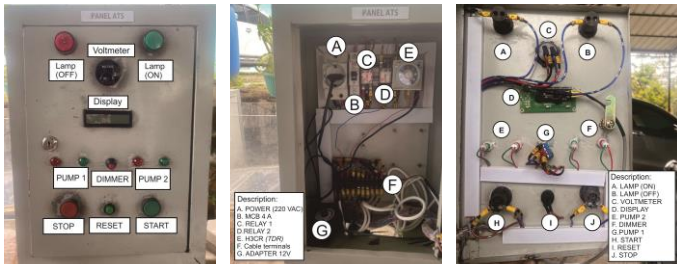



Figure 12. Tidal Simulator

*ATS Panel Design*

The ATS (Auto Transfer Switch) panel controls the tidal simulator. The ATS panel is made up of several parts, including an H3CR, a relay, and two dc water pumps. Water pump 1 directs water from the reservoir into the tidal basin. Water pump 2 directs water from the tidal tub into the reservoir. Every 6 minutes, the ATS panel controls water circulation. H3CR will activate water pump 1 for 6 minutes while turning off water pump 2. When 6 minutes have passed, H3CR will turn off water pump 1 and activate water pump 2 for 6 minutes. This process will be carried out automatically and indefinitely. The ATS Panel Box can be seen in Figure 13a. The path of the inner circuit can be seen in Figure 13b. Figure 13c shows the cable path of the ATS panel button. Figure 14 shows the ATS Panel's wiring diagram. Tidal simulator with ATS panel as a control system can be seen in Figure 15.




(a) (b) (c)

Figure 13. a) The ATS Panel Box, b) Path of inner circuit, and c) Cable pathe of the ATS panel button

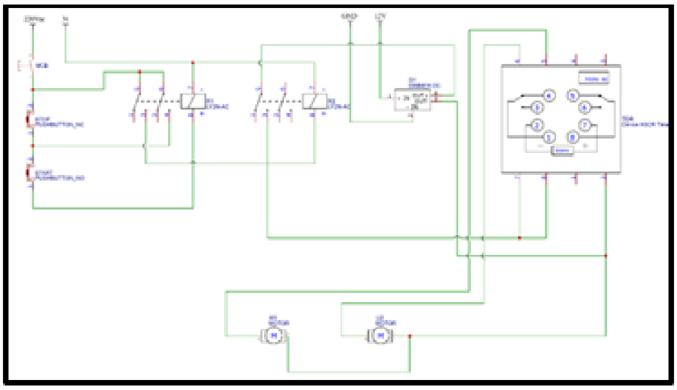


Figure 14. ATS Panel wiring diagram

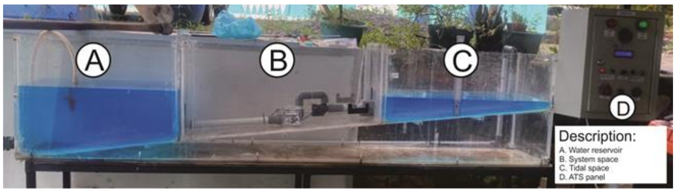



Figure 15. Tidal simulator with ATS panel as a control system

### B. Component Integration

The components that have been tested for functionality are then connected on a single PCB (Printed Circuit Board). Component integration is performed so that the Arduino UNO, MicroSD Card Module Adapter, ultrasonic sensor, and H3CR can be connected and work together. The design of schematics is the first step in component integration. The Schematic is used to guide the fabrication of PCBs. Easy EDA, an open source software, was used for schematic design. Figure 16 shows a schematic of the device's components.

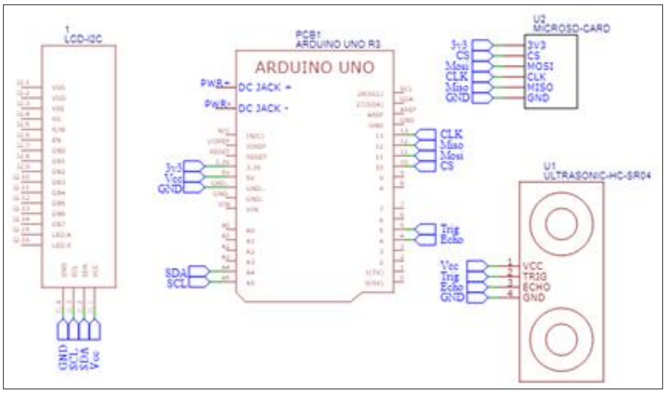



Figure 16. Component Schematic

The next step is to solder the components to the PCB. The components will be soldered to the PCB and connected to other components via small cables. Figure 17 shows the completed soldered device.

Figure 17. The device is connected to the control panel

## C. Laboratory Experiment

*H3CR Calibration*

H3CR is used to set the time. The H3CR's timing accuracy is determined by comparing it to a stopwatch. H3CR is compared to stopwatches three times, at 2 minutes, 4 minutes, and 6 minutes. Table 4 shows the results of the H3CR calibration.

Table. 4. H3CR Calibration

| No | H3CR | Stopwatch | Error |
|---|---|---|---|
| 1 | 2 Minutes | 2 Minutes 5 Second | 5 Detik |
| 2 | 4 Minutes | 4 Minutes 5 Second | 5 Detik |
| 3 | 6 Minutes | 6 Minutes 8 Second | 8 Detik |

The comparison results show that H3CR has an accuracy percentage rate of 98.14%. Figures 18a and 18b show a comparison of H3CR and the stopwatch.


(a) (b)

Figure 18. a) Start, b) Stop

*HC-SR04 Ultrasonic Sensor*

Calibration of ultrasonic sensors is accomplished by comparing sensor readings to a ruler. The ruler spacing in relation to the sensor is 5 cm, 10 cm, 15 cm, 20 cm, and 25 cm. Sensor calibration is performed by collecting data 30 times and then calculating up to 30 average values from that data. The calibration results show that the sensor has an R2 value of 0.9983. R2 is the coefficient of determination calculated from linear regression results for the comparison of ultrasonic sensors and rulers. The sensor accuracy value is 96.55% based on the calibration data, the standard deviation value is 0.077, and the RMSE value is 0.388. The sensor calibration value indicates that the sensor is accurate. Table 5 compares ultrasonic sensors and rulers. Figure 19 shows the graph of compare ultrasonic sensor and ruler.

Table 5. Compares Ultrasonic Sensor and ruler

| No | Ruler | Ultrasonic Sensor | Error |
|---|---|---|---|
| 1. | 5 cm | 5,35 cm | 0,35 cm |
| 2. | 10 cm | 10,58 cm | 0,58 cm |
| 3. | 15 cm | 14,87 cm | 0,13 cm |
| 4. | 20 cm | 20,65 cm | 0,65 cm |
| 5. | 25 cm | 25,08 cm | 0,8 cm |

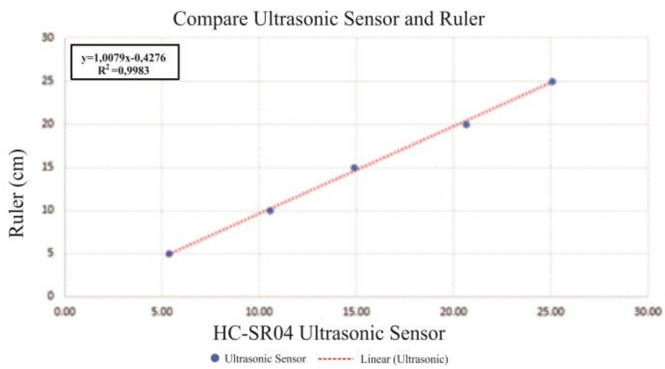



Figure 19. Compare Ultrasonic Sensor and Ruler

## D. Overall System Experiment

An overall system experiment is performed to determine whether the tidal simulator system is functional. The H3CR was tested to see if it could set the time, if the ultrasonic sensor could read the water level data, if the 16x2 LCD displayed the time and water level data, and if the ultrasonic sensor reading data and time were saved on the MicroSD Card. Figure 20 shows a overall system experiment.

Figure 20. overall system experiment

### E. *Experiment Result*

The experiment was carried out at Raja Ali Haji Maritime University's Faculty of Engineering's Renewable Energy Laboratory. The tidal simulator test lasted 24 minutes. The process time to the tide is 6 minutes, and the process time to receding is 6 minutes. The experiment was carried out over two tidal cycles. The tidal simulator graph can be seen in Figure 21.

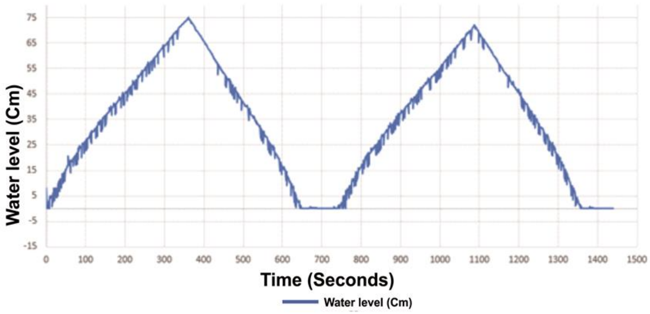



Figure 21. Tidal Simulator Graph

### F. *Data Analysis*

The tidal simulator's experiment data, which lasted for two tides, revealed that the highest water level was 75 cm and the lowest water level was 0 cm. When the water level is at zero centimeters, the tide process begins. The simulator's output tide pattern is not always stable; there is some noise in the water level. When the water pump introduces water into the tidal bath, small waves create this noise. The tidal cycle lasts 360 seconds. The receding process begins when it reaches 360 seconds. As a result, at the highest tide, the H3CR timer immediately activates to drive the pump that will sucking water. There is no long time interval between tides. However, at low tide, the opposite occurs. There is a long period of low tide. The total time for receding is 1000 seconds. This is due to a difference in working voltage between water pump 1 (the pump that drains water from the reservoir to the tidal tub) and pump 2. (the water pump that drains water from the tidal tub to the sump). Water pump 2 receives a boost in voltage. Water pump 1 receives 7.75 V, while water pump 2 receives 8.65 V. This is what causes the process to recede faster because water pump 2 drains water more quickly.

The simulator's tidal pattern isn't perfectly sinusoidal. The sinusoidal form has sloping tops and sheets. The simulator's tidal pattern is sinusoidal, but it has pointed peaks and valleys. This imperfect sinusoidal pattern occurs because there is no time interval between tidal to tidal processes and no time interval between ebb to tidal processes. H3CR is configured to change the state of one active water pump for 6 minutes, then change the states of the other two active water pumps without a pause. This is what causes the tidal peak and ebbing peak to become conical.

### G. *Discussion*

In this research, the simulator device was able to simulate tidal and ebb processes. The formed tides and ebbs already resemble the shape of sinusoidal waves. The waveform generated by the simulator has a pointed peak, which should be the shape of the sinusoidal peak. The sinusoidal waveform is the same as in the study conducted [19], which measured seawater tides. The results showed that seawater tidal waves had a sinusoidal shape.

The simulator device records the tides and noise at each water level. On the tidal pattern graph, this noise appears as a small serration. The noise is read because there are small waves and because ultrasonic sensors cannot reduce noise. This is similar to the research of Missa et al. (2018), who used ultrasonic sensors to measure tidal waves [4]. The research result revealed the presence of noise from ultrasonic sensors, which caused small serrations in the graph of tidal wave patterns.

The tidal simulator device's design can be used as a learning tool for sea tides. Students can use simulators to learn about sea tides. This is very useful because it can save time and money. The tidal data of the simulator results and the tidal data of seawater are not significantly different, so the tidal simulator can be used as an effective learning tool.

## V. Conclusion

In this research, tidal simulator tools and tidal surface measurements were successfully designed and measured. This tidal simulator makes use of H3CR, a DC water pump, and a DC solenoid valve. H3CR can be used on this simulator. Tidal surface measurements include the following: Arduino UNO R3, Ultrasonic sensor HC-SR04, LCD 16x2, and Micro SD Card.

## Ackknowledgement

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