

IoT-Based Ship Tank Leak Detection System Prototype to Enhance Security

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Abstract

This research discusses the design and development of a Prototype Ship Tank Leak Detection System Based on the Internet of Things (IoT) to enhance safety and operational efficiency of ships. This system utilizes the ESP32 microcontroller connected to an ultrasonic sensor to detect changes in liquid volume within the tank. The detection results are displayed via an LCD and sent in real-time to the Blynk application on smartphones, accompanied by an alarm in the form of a buzzer as an early warning. The implementation results show that the system is capable of detecting leaks effectively and provides notifications quickly when there is a significant decrease in liquid volume.

Keywords: Blynk, ESP32, Internet of Things, Tank Ship, Ultrasonic Sensor

1. Introduction

Ballast tanks are a concern during the loading and mitigation process, as severe pressure and operations can increase the risk of leaks. According to the International Maritime Organization (IMO), ballast leaks are one of the main causes of ship damage at sea and accidents. The IMO reports that about 25 ship accidents are related to structural damage associated with ballast systems[1]. Ships have various types of tanks with different cargoes. A cofferdam is a tank used as a separator to prevent fluid mixing in the event of a leak. Conventional inspection methods through manholes or sounding pipes are less accurate, necessitating a system that can replace them.

The occurrence of a leak in the fuel tank does not rule out the possibility that the leak could occur in the fuel filling pipe. A leak in the filling pipe can lead to various serious issues such as environmental damage, operational disruptions, or even dangers to human health. Therefore, leak detection needs to be conducted regularly and accurately. The term robot comes from the Czech word "robota" which means a worker or laborer who does not know fatigue or boredom. Robots are typically used for heavy, dangerous, repetitive, and dirty tasks. Other uses of robots include cleaning toxic waste, underwater and space exploration, mining, search and rescue operations, and for mine searching. Recently, robots have started to enter the consumer market in the field of entertainment and household assistance, such as vacuum cleaners and robotic lawn mowers, which can be interpreted as machines[2].

2. Theoretical Fondation

2.1. Ship Tank

A tank is a container or storage place used to store water, kerosene, and other liquids; this tank is made of metal. In an oil tanker, the tank is one of the main structures of the ship because it serves as the storage space for all liquid cargo. Not only in oil tankers, but every ship must have a storage tank for storing fuel or water (freshwater) for drinking and other activities that require water[3].

Ships are an important and vital means, especially as a transportation tool and as part of the economic development infrastructure of community society between regions, and they can also function as a main tool in the national defense system. The existence of a ship, whether during its construction (new building vessel) or during the repair process (repairing/docking process), is always related to shipyards as a main part of the maritime industry[4].

2.2. ESP32

NodeMCU ESP32 is a low-power system on a chip (SoC) series with Wi-Fi and dual-mode Bluetooth capabilities. The ESP32 uses a dual-core or single-core Tensilica Xtensa LX6 microprocessor with a clock rate of up to 240 MHz. The ESP32 comes integrated with built-in antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power management modules. The ESP32 is a successor to the popular ESP8266 for Internet of Things applications. The ESP32 has a faster CPU core, more GPIOs, and supports Bluetooth Low Energy[5].

2.3. Internet of Things

The Internet of Things, often referred to as the Internet of Things, is an embedded system aimed at expanding the utilization of continuously connected internet connectivity. Capabilities such as data sharing, remote control, and so on, also include real-world objects such as food, electronics, and equipment connected with sensors and linked to networks[6].

2.4. Ultrasonic Sensor

An ultrasonic sensor is a type of sensor that can read distances of approximately 2 cm to 4 meters. An ultrasonic sensor is a device that can measure distances starting from 2 cm to 4 cm, with an accuracy of up to 3 mm. The ultrasonic sensor functions to convert sound measurements into electrical measurements and vice versa. This ping sensor can detect the distance from an object by emitting ultrasonic waves at a frequency of 40 KHz and then detecting the echo. This sensor can measure distances between 3 cm and 300 cm. The output from this sensor is in the form of pulses whose width represents the distance. The pulse width varies from 115 microseconds to 18.5 milliseconds. Essentially, the PING sensor consists of a 40 KHz signal generator chip, an ultrasonic speaker, and an ultrasonic microphone. The ultrasonic speaker functions to convert the 40 KHz signal into sound, and the ultrasonic microphone detects the echo of the sound[7].

2.5. Stepdown

DC-DC Stepdown is an electronic circuit that functions as a DC to DC voltage reducer (DC-to-DC converter) using switching methods. There are several types of DC-DC Stepdown, one of which is the LM2596 DC-DC Stepdown Specifications and features of the LM2596[8].

2.6. LCD

LCD is a type of electronic display made with CMOS logic technology that works by not generating light, but reflecting the ambient light towards a front-lit or transmitting light from a back-lit. LCD functions as a data display, whether in the form of characters, letters, numbers, or graphics. An LCD is a layer of a mixture of organic materials between a clear glass layer with transparent indium oxide electrodes in the form of a seven-segment display and an electrode layer on the back glass. When the electrodes are activated by an electric field (voltage), the long cylindrical organic molecules align with the electrodes of the segments. The sandwich layer has a front vertical light polarizer and a back horizontal light polarizer followed by a reflector layer. The reflected light cannot pass through the aligned molecules, and the activated segments appear dark, forming the desired data characters[9].

2.7. Jumper Cable

Jumper cables are electrical cables used to connect components on a breadboard without the need for soldering. Jumper cables typically have connectors or pins at each end. The connector that is inserted is called a male connector, and the connector that is inserted into is called a female connector[10].

3. Design and Analysis

3.1. Research Methodology

The method used in this research is the design method (prototyping). This method includes several main stages, namely:

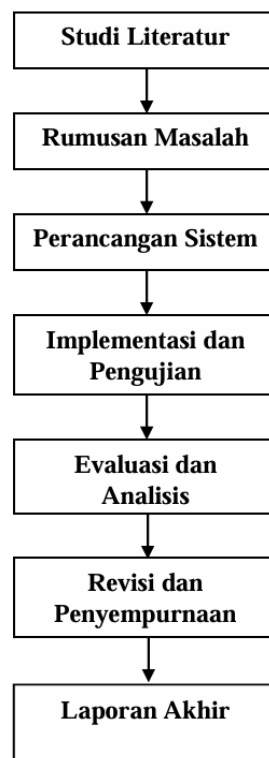


Fig. 1: Research Methodology

3.2. Control System Flowchart

The design of this tool begins with the creation of a flowchart to facilitate the planning and development of the program on the microcontroller. The creation of a flowchart is useful for simplifying the understanding of the working process of the tool. The program flowchart from this research includes the control system of the tool's operation, which can be seen below:

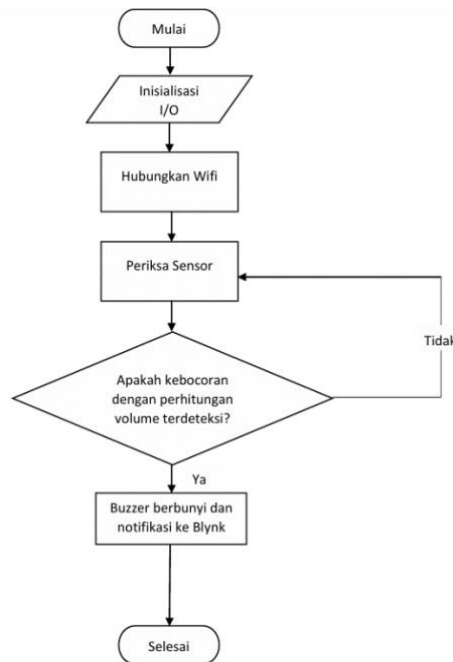


Fig. 2. Control System Flowchart

The following is an explanation of the Flowchart for the Ship Tank Leak Detection Control System as follows:

1. Start.
2. Initialize Input/Output.
3. Connect the device to the local internet.
4. Check if the sensors are active and can detect.
5. Then, is a leak detected in the tank? If yes, the Buzzer sounds and a notification is sent to Blynk.
6. If not, check the sensors.
7. Finish.

3.3. Block Diagram Series

The design of the block diagram circuit is the design of electronic components in such a way that it has the desired function. Generally, the planning of the tool design is as follows:

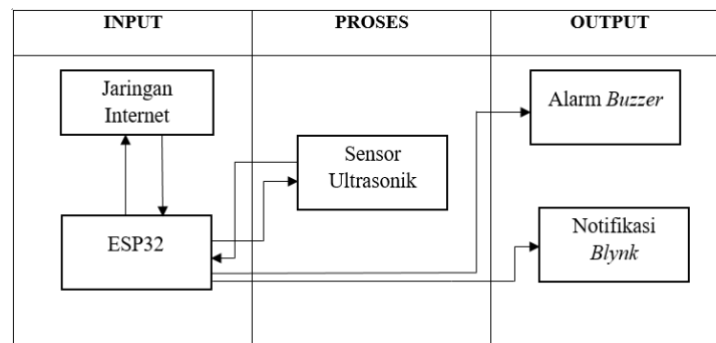


Fig. 3: Block Diagram Series

The block diagram in Figure III.2 shows that the first process is to connect the hardware used, such as a smartphone or computer, to Wi-Fi. In the next process, the sensor detects leaks. Then, the data from the Ultrasonic sensor is sent to the ESP32, which will later notify Blynk and activate the alarm on the Buzzer.

3.4. Electronic Circuit Scheme

Schematic of an electronic circuit using ESP32 as a microcontroller that receives data from an Ultrasonic sensor. The ESP32 design serves as a connection between the hardware and the internet. The output of the ESP32 will be connected to a Buzzer and Blynk for notifications.

4. Result and Discussion

In this chapter, the author outlines and explains the research results by conducting tests. The tests to be conducted are software and hardware tests. Here is the explanation:

4.1. Software Testing

To conduct the program test, the initial steps in this experiment are as follows:

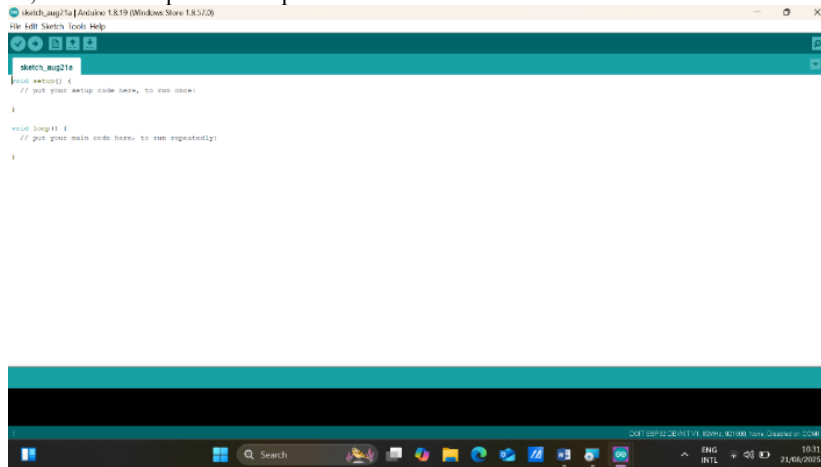


Fig. 4: Initial Display of Arduino IDE

4.2. Hardware Testing

After all the programs are typed, design the hardware as shown below:



Fig. 5: ESP32 Circuit With Ultrasonic Sensor & LCD

Next, the test for the device's activity, based on the indicators in the active/on circuit:

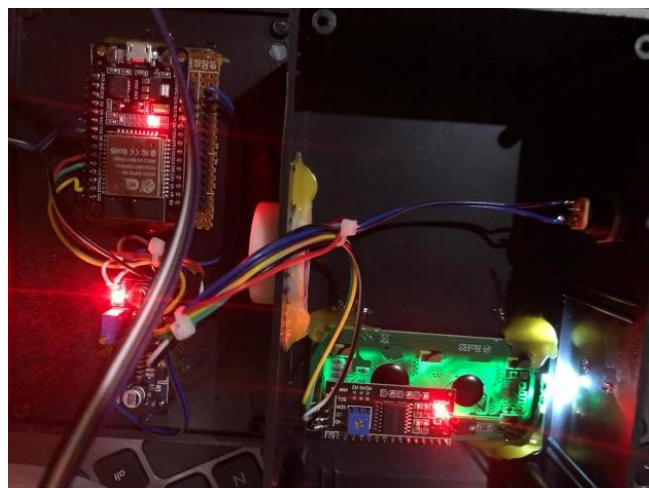


Fig. 6: Position Of The Tool When Active

4.3. Blynk Testing

In this Blynk testing, we create a new template with widgets as shown in the image below:

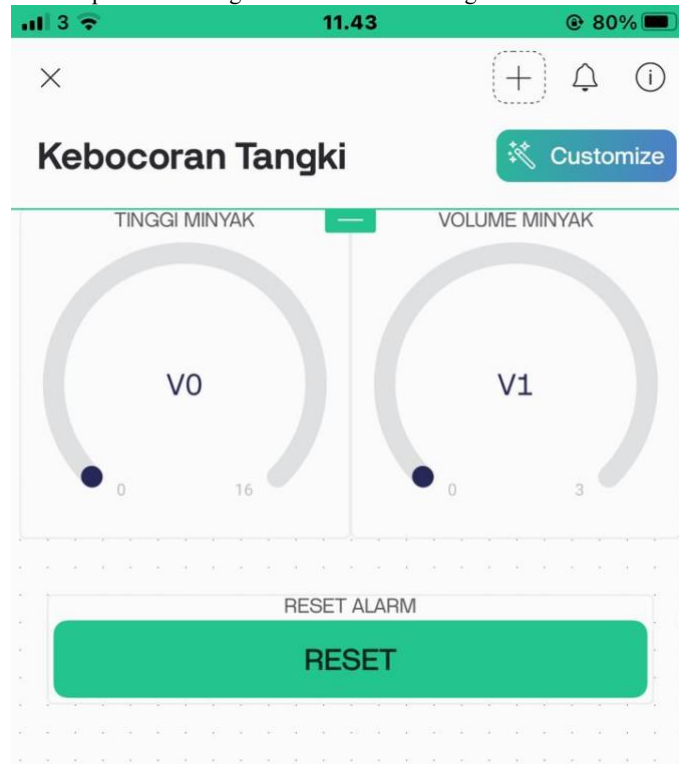


Fig. 7: Blynk Display

After the program has been fully typed, the next step is to input the program code into the circuit by clicking the Bar menu on the Arduino IDE and then clicking upload, with the note that the Board and Port in the Arduino IDE Bar menu are already set. Next, wait a moment until the upload process is complete, then the program that has been uploaded will automatically be saved to the microcontroller.

4.4. Blynk Testing

This experiment was conducted by placing a sensor at the top of the tank filled with 0.5 liters of oil, as a test for leaks and for testing notifications and LCD display when a leak occurs. The next step was to open the valve at the bottom of the tank. Additionally, the notification experiment on Blynk was carried out in real-time. After all the circuits were successfully designed for the 'IoT-Based Tank Leak Detection System Prototype to Enhance Safety,' below is the image of the successful leak detection testing on the tank using IoT shown below:



Fig. 8: Overall Circuit Results

5. Conclusion

Based on the results of the design, implementation, and testing of the Internet of Things (IoT)-based ship tank leak detection system prototype, it can be concluded that the prototype was successfully developed using an ESP32, ultrasonic sensors, a buzzer, an LCD, and the Blynk application as the monitoring medium. The system reliably detects decreases in liquid volume in real time, with the LCD presenting live level readings and local status indicators while Blynk provides a remote dashboard, push notifications, and basic data logging for later review. Calibration and simple filtering help convert distance to volume and reduce sensor noise, enabling the device to recognize gradual drops as well as sudden changes. Integration between sensors and IoT modules proved robust: threshold-based logic triggers the buzzer as an early warning alarm and simultaneously sends leak alerts through Blynk, and Wi-Fi connectivity remained stable during bench and simulated on-board conditions. Overall, the prototype demonstrates practical feasibility for early leak warning and remote supervision on small vessels, with potential future enhancements including waterproof enclosure improvements, redundant sensors for cross-validation, automatic valve control, and GPS tagging of alert events.

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