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Development of a Monitoring System for Daily Fuel Tank Levels on Ships

Anggara Trisna Nugraha[1], Moh Ghafirul Pratama Aprilian Sugianto [2]
[1,2] Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya
[1] anggaranugraha@ppns.ac.id

Abstract

The advancement of technology in maritime engineering has reached remarkable levels, particularly in fuel management systems on ships. However, the majority of fuel tanks still rely on manual monitoring methods, with fuel levels typically displayed using traditional sight glasses. This conventional approach lacks real-time monitoring capabilities and fails to provide data visualization on modern interfaces such as LCD screens, which is a growing demand among operators. Addressing these limitations, this research explores the use of light sensors in conjunction with laser modules to develop an automated monitoring system for daily fuel tanks. Unlike conventional float switches that require direct contact with the fuel, the proposed system utilizes a non-intrusive method. The laser module emits a beam towards the tank, and when the fuel level intersects with the laser, the light sensor detects the reflected ray. This innovative approach enables real-time monitoring of fuel levels, which can be displayed on an LCD screen, enhancing operational efficiency and reducing manual intervention.

Keywords: maritime, fuel management, monitoring

1. Introduction

Indonesia, as a maritime nation, relies heavily on ship transportation for economic and logistical needs, although other forms of transportation are also widely utilized. The rapid advancement of technology across various sectors has significantly transformed human activities, including the maritime industry (Alwan, 2020). These technological developments aim to create more efficient and safe working conditions, particularly in the operation and management of ships.

One critical aspect of technological innovation in maritime engineering is the improvement of daily fuel tank monitoring systems on ships (Amrul, 2014). Conventional methods, which rely on manual observation or basic mechanical systems, are becoming obsolete in the face of modern requirements for precision, automation, and data visualization (Nugraha et al., 2023). The integration of advanced technology, such as light sensors and laser modules, into daily fuel tank monitoring systems provides a significant step forward.

The proposed system operates by leveraging light sensors in combination with laser modules to provide accurate and real-time fuel level monitoring (Nugraha, 2022). In this design, the laser module emits a beam towards the tank, which interacts with the fuel level. When the fuel level is below the designated point, the laser beam reaches the light sensor, allowing it to detect the presence of light and thus indicate a low fuel level (Anugraini, 2018). Conversely, when the fuel level is above the laser's position, the beam is blocked by the fuel, and the light sensor does not receive any light, signaling a sufficient or high fuel level.

A notable advantage of this system is its non-intrusive nature, as the light sensors and laser modules are placed outside the tank, reducing risks associated with direct contact with fuel (Pambudi et al., 2021). This design not only enhances safety but also simplifies maintenance and extends the durability of the monitoring components. Additionally, the system is designed to display fuel level information on an LCD screen, providing operators with a user-friendly interface and facilitating real-time decision-making.

2. Material and methods

2.1. Material

A. Light Sensor

The light sensor module offers a practical solution for integrating an LDR (Light Dependent Resistor) sensor to measure light intensity with high precision and ease of use (Faj'riyah, Setiyoko, & Nugraha, 2021). This module is equipped with both analog output pins (A0) and digital output pins

(D0), as clearly labeled on the PCB, ensuring versatile application across various engineering systems (Ariawan et al., 2016).

In its operation, the resistance value of the LDR sensor at the analog output varies inversely with light intensity: as the light intensity increases, the LDR's resistance decreases, and vice versa. This characteristic allows for a highly accurate measurement of varying light conditions. For digital outputs, the signal toggles between high and low states based on a predefined threshold (Baharuddin, 2016). This threshold can be adjusted using the built-in potentiometer, enabling users to customize the sensitivity of the module for specific applications.

Figure 1. light sensor

B. Laser

The term "laser" is an acronym for "Light Amplification by Stimulated Emission of Radiation." A laser is a device that emits electromagnetic radiation, typically in the form of a highly focused and coherent light beam. This light can range from visible wavelengths to infrared and ultraviolet, often falling outside the range detectable by the human eye (Chesa, 2020). The laser operates through the process of stimulated emission, where photons interact with excited electrons in a medium, causing the emission of additional photons with identical phase, direction, and frequency (Hakim, 2020).

Unlike traditional light sources, lasers produce a beam that is monochromatic, directional, and coherent, which means that all the light waves move in unison and in the same direction. This characteristic makes lasers highly suitable for precision applications, including in engineering fields such as maritime technology.

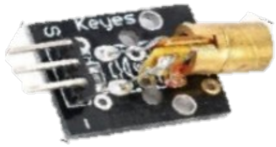

Figure 2. laser

C. Arduino Uno

The Arduino Uno R3 is an advanced electronic platform built around the ATmega328P microcontroller, originally developed in Italy (Nugraha & Agustinah, 2018). As an open-source hardware development board, the Arduino Uno R3 offers unparalleled flexibility, allowing users to modify and adapt its functionality to meet specific project requirements. This adaptability has made the Arduino Uno R3 a preferred choice for engineers, researchers, and hobbyists in the fields of electronics and embedded systems (Tiwana, Adianto, & Nugraha, 2021).

Often referred to as a "development board," the Arduino Uno R3 simplifies the integration of microcontrollers into electronic projects (Sitanggang, 2020). It eliminates the need for creating circuits from scratch, enabling users to focus on innovation and functionality. The board is particularly well-suited for prototyping and research applications, especially in the field of engineering, where precision, adaptability, and reliability are crucial.

Figure 3. Arduino Uno R3

D. LCD I2C

A Liquid Crystal Display (LCD) is a widely used display technology that employs liquid crystals to generate visible images (Tsauqi, 2016). This technology has become an integral part of many electronic devices, including laptops, smartphones, calculators, digital clocks, multimeters, computer monitors, televisions, portable gaming consoles, digital thermometers, and numerous other electronic products. The use of LCDs has revolutionized the design of electronic devices by allowing for thinner, more compact displays compared to older technologies like Cathode Ray Tubes (CRT) (Febrianto, 2015).

One of the key advantages of LCD technology over CRT displays is its superior energy efficiency (Nugraha, Anshory, & Rahim, 2018). LCDs operate based on the principle of blocking light rather than guiding it, as is the case with CRTs. This results in lower power consumption and, consequently, longer battery life for portable devices. However, a fundamental characteristic of LCDs is that they do not emit light on their own. Instead, they rely on external light sources for visibility. To achieve this, LCDs require backlighting, typically provided by either Cold Cathode Fluorescent Lamps (CCFL) or Light Emitting Diodes (LEDs) (Jalil, 2017).

A basic LCD consists of two primary components: the backlight and the liquid crystal panel. The backlight is responsible for providing the light that passes through the liquid crystals, which then manipulate the light to create the desired image. The liquid crystals themselves are electrically controlled to either block or allow light to pass through, depending on the display requirements. This technology enables the high-definition images and energy-efficient displays that have become commonplace in modern electronics.

Figure 4. LCD 20x4

E. Siren

The siren is an essential signaling device designed to produce loud, attention-grabbing noises to alert individuals to imminent dangers, particularly in emergency situations (Alawiah & Al Tahtawi, 2017). Historically, sirens were utilized for natural disaster warnings and are still widely used by emergency services such as ambulances, police, and fire departments. The concept of the siren is deeply rooted in both practical use and mythology, with connections to the sirens of ancient Greek mythology, who were known for their sound-producing abilities. Over time, the functionality of sirens has expanded beyond emergency warnings to include their role as community alert systems, particularly in the context of air-raid warnings during times of conflict (Miftachulhuda, 2014).

Today, sirens come in two main types: pneumatic and electronic. Pneumatic sirens operate by utilizing compressed air to create sound, whereas electronic sirens employ electrical components to produce and amplify sound. These sirens are commonly installed at elevated locations, such as the tops of buildings, water towers, and government facilities. Their strategic positioning ensures that the warning sounds can be heard over large areas, providing coverage for the surrounding community.

Figure 5. Sirens

F. Warning Light

A warning light is a flashing or flickering light used to signal a potential hazard or to alert individuals to a specific condition. These lights are commonly utilized as visual signals for safety purposes in areas that are prone to danger. For example, they are frequently installed in industrial settings such as factories, on machines in operation, at automated gates, and on power turbines. Warning lights serve as essential indicators to prevent accidents and ensure that safety protocols are followed.

In addition to industrial applications, warning lights are also employed in residential and office environments to signal important notifications or to indicate the completion of specific processes. Their usage in such settings highlights their versatility in providing clear, visible cues for both operational and safety purposes.

2.2. Methods

A. Flowchart

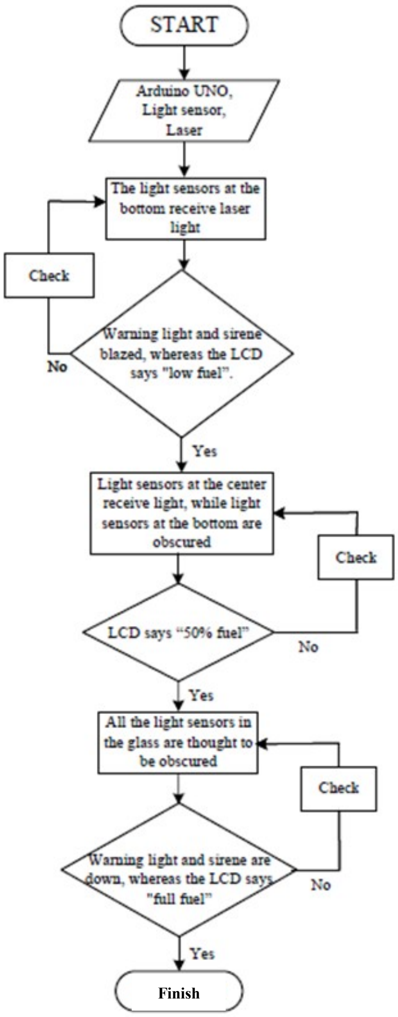

Figure 6. Performance

The proposed monitoring system utilizes a combination of three light sensors and three laser modules to accurately measure and detect fuel levels. These laser modules act as light emitters, shooting a laser beam towards the fuel tank, while the light sensors receive the reflected beam to assess the fuel level. The system's actuators include a warning light and sirens, which serve as alerts for the operator in case of fuel level abnormalities.

The central control unit of the system is an Arduino Uno, which processes input from the light sensors. The sensor data is then processed by the Arduino and relayed to a relay system, which triggers the LCD display to show real-time fuel level information. The warning light and sirens are activated based on programmed conditions and automatic relay switches, ensuring that any abnormal fuel level is immediately signaled. Power for the warning system is supplied by a 12V power source, ensuring reliable operation of the actuators.

B. Testing light sensors with laser light

In the evaluation of light sensors, two experimental conditions are tested: the first test is conducted in the absence of light, and the second test is conducted in the presence of light. To perform these experiments, the sensor's output voltage is calibrated and compared to a digital multimeter reading.

The calibration process involves converting the sensor's ADC (Analog-to-Digital Converter) value into the corresponding voltage, which is then compared against the digital multimeter's measurements. This conversion is crucial for accurate sensor readings. The formula used for converting the ADC value to voltage is as follows:

Voltage = ((Value of ADC X Input Voltage)/ 1023)

Using this formula, the light sensor's ADC value is first obtained, then converted into voltage. The calibration results of the light sensors are presented in Table 1 and Table 2.

Table 1. light sensors test at bottom point results with laser light

Test	Voltage from ADC	Voltage from Multimeter	Error
1	1.31V	1.33V	1.5%
2	1.30V	1.33V	2,26%
3	1.31V	1.33V	1.5%
4	1.31V	1.33V	1.5%
5	1.30V	1.33V	2,26%
6	1.31V	1.32V	0,75%
7	1.30V	1.32V	1,5%
8	1.31V	1.32V	0,75%
9	1.31V	1.33V	1.5%
10	1.30V	1.33V	2,26%

The chart shows that the error occurred no more than 50% of the ones where light sensors were tested efficiently and accurately.

Table 2. light sensors at center point test results with laser light

Test	Voltage from ADC	Voltage from Multimeter	Error
1	1.10V	1.10V	0%
2	1.12V	1.10V	1,8%
3	1.11V	1.10V	0,6%
4	1.10V	1.11V	0,6%
5	1.10V	1.10V	0%
6	1.10V	1.10V	0%
7	1.10V	1.10V	0%
8	1.12V	1.11V	0,6%
9	1.11V	1.10V	0,6%
10	1.10V	1.10V	0,6%

Table 2 For the light sensor that's in the center of the glass is expected, the calibration results are not large and an average error below 0%

Table 3. light sensor at high point test results with laser light

Test	Voltage from ADC	Voltage from Multimeter	Error
1	1.20V	1.20V	0%
2	1.22V	1.20V	2,4%
3	1.20V	1.20V	0%
4	1.20V	1.20V	0%
5	1.22V	1.20V	2,4%
6	1.22V	1.20V	2,4%
7	1.22V	1.20V	2,4%
8	1.22V	1.20V	2,4%
9	1.22V	1.20V	2,4%
10	1.22V	1.20V	2,4%

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Table 3, The light sensors at the top of the glass are fairly accurate, with no error exceeding 5%, all under 5%

C. Testing light sensors with laser no light

The testing of light sensors, both with and without the laser light source, does not exhibit significant differences in their basic operation. The primary variation is seen in the response of the sensor to the presence of the laser beam, which is either exposed or blocked during testing. In both conditions, the sensor's behavior is evaluated by observing its ability to detect light under varying circumstances.

The calibration process for the light sensors is carried out using a digital multimeter. To begin, the ADC (Analog-to-Digital Converter) sensor value is first converted into the corresponding voltage reading. This process is crucial for obtaining accurate sensor readings. The relationship between the ADC value and the voltage is given by the following formula:

Voltage = ((Value of ADC X Input Voltage)/ 1023)

In this formula, the ADC value is first obtained and subsequently converted into a voltage. The results from the calibration process, as observed through the different light conditions, are displayed in Table 1 and Table 2.

Table 4. light sensors test at bottom point results with laser no light

Test	Voltage from ADC	Voltage from Multimeter	Error
1	2.31V	2.30V	0,43%
2	2.31V	2.30V	0,43%
3	2.31V	2.30V	0,43%
4	2,30V	2.30V	0%
5	2.31V	2.30V	0,43%
6	2.31V	2.30V	0,43%
7	2.31V	2.30V	0,43%
8	2.31V	2.30V	0,43%
9	2.31V	2.30V	0,43%
10	2.31V	2.30V	0,43%

Table 4 has an error just under 5% or even still at 0% error, so it's arguably calibrated

Table 5. light sensors at center point test results with laser no light

Test	Voltage from ADC	Voltage from Multimeter	Error
1	2.30V	2.30V	0%
2	2.30V	2.30V	0%
3	2.30V	2.30V	0%
4	2.30V	2.30V	0%
5	2.30V	2.30V	0%
6	2.30V	2.30V	0%
7	2.30V	2.30V	0%
8	2.30V	2.30V	0%
9	2.30V	2.30V	0%
10	2.30V	2.30V	0%

Table 5, For the light sensor that's in the center of the glass is expected, the calibration results are not large and an average error below 0%

Table 6. light sensor at high point test results with laser no light

Test	Voltage from ADC	Voltage from Multimeter	Error
1	2.20V	2.20V	0%
2	2.22V	2.20V	0,9%
3	2.22V	2.20V	0,9%
4	2.22V	2.20V	0,9%
5	2.22V	2.20V	0,9%
6	2.22V	2.20V	0,9%
7	2.20V	2.20V	0%

DOI xxxxxx

8	2.20V	2.20V	0%
9	2.22V	2.20V	0,9%
10	2.22V	2.20V	0,9%

Table 6, The light sensors at the top of the glass are fairly accurate, with no error exceeding 5%, all under 5%

3. Results and discussion

3.1. Testing as the daily fuel tank runs out

When the fuel level in the daily tanks reaches the bottom, and the fuel is situated beneath the light sensors and laser modules, the Arduino will receive a signal from the light sensors. In response, the system activates the warning light and siren through an automatic relay switch, powered by a 12V power supply unit (PSU). This process is clearly depicted in Table 7, which provides a visual representation of the system's response at this particular fuel level.

Table 7. test results when the tank runs out

Test	Voltage light sensor 1	Warning light And sirene	LCD
1	1.30V	ON	Low fuel
2	1.30V	ON	Low fuel
3	1.30V	ON	Low fuel
4	1.31V	ON	Low fuel
5	1.30V	ON	Low fuel
6	1.31V	ON	Low fuel
7	1.30V	ON	Low fuel
8	1.31V	ON	Low fuel
9	1.31V	ON	Low fuel
10	1.30V	ON	Low fuel

3.2. Testing daily fuel tanks at 50%

The next stage of control testing occurs when the fuel reaches the center of the tank, which corresponds to the midpoint of the fuel level indicator. At this point, the system should display "50% fuel" on the LCD screen. Additionally, the two actuators—comprising the warning light and sirens—will be deactivated. This process and its results are clearly illustrated in Table 8, which provides a comprehensive view of the system’s performance during this phase of testing.

Table 8. test results when tank at 50%

Test	Voltage light sensor 1	Voltage light sensor 2	Warning light And sirene	LCD
1	2.20V	2.29V	OFF	50% fuel
2	2.22V	2.29V	OFF	50% fuel
3	2.22V	2.29V	OFF	50% fuel
4	2.22V	2.30V	OFF	50% fuel
5	2.22V	2.30V	OFF	50% fuel
6	2.22V	2.30V	OFF	50% fuel
7	2.20V	2.29V	OFF	50% fuel
8	2.20V	2.30V	OFF	50% fuel
9	2.22V	2.30V	OFF	50% fuel
10	2.22V	2.30V	OFF	50% fuel

3.3. Testing daily fuel tanks at full

At table 9 is a test result when the daily tank is full

Table 9. test results when tank at full

Test	Voltage light sensor 1	Voltage light sensor 2	Voltage light sensor 3	Warning light And sirene	LCD
1	2.20V	2.29V	2.20V	OFF	full fuel
2	2.22V	2.29V	2.20V	OFF	full fuel

3	2.22V	2.29V	2.20V	OFF	full fuel
4	2.22V	2.30V	2.20V	OFF	full fuel
5	2.22V	2.30V	2.20V	OFF	full fuel
6	2.22V	2.30V	2.20V	OFF	full fuel
7	2.20V	2.29V	2.20V	OFF	full fuel
1	2.20V	2.29V	2.20V	OFF	full fuel
2	2.22V	2.29V	2.19V	OFF	full fuel
3	2.22V	2.29V	2.19V	OFF	full fuel

When the fuel touches the point above the light sensor and the laser then the light from the laser can't shoot light into the light sensor. When it's full, LCD says "full fuel"

4. Conclusion

1. The light sensor is designed to operate effectively in monitoring applications, especially when installed in a transparent or glass housing, referred to as the "guessing glass." To ensure accurate functionality and response, the integration of a laser light source is essential. The laser acts as a crucial supplementary component, providing a defined light beam that interacts with the sensor. This interaction enables precise measurements of the fuel tank levels, which is critical for continuous monitoring in marine applications.
2. During testing, it was observed that external ambient light does not significantly affect the performance of the light sensor. When tested without the laser light, the sensor's voltage reading remained stable at around 2.1 to 3.0 volts. However, when the laser light was activated, the voltage decreased to a range between 1.1 and 1.3 volts. This variation of approximately 1.0 volts is indicative of the sensor's response to the presence of the laser light, highlighting its sensitivity to light changes. The ability to decouple this light change from other environmental factors is essential for ensuring the sensor's reliability in various operating conditions on the ship.
3. The calibration process, conducted under controlled conditions with the full instrumentation setup, consistently demonstrated that the LDR (Light Dependent Resistor) sensor voltage remained within the 1.1 to 1.3 volts range when the laser light was active. Conversely, when the laser light was obstructed, preventing the light from reaching the sensor, the voltage readings increased to between 2.1 and 2.3 volts. These voltage fluctuations, based on the presence or absence of laser light, were consistent across multiple calibration and testing sessions, confirming the sensor's reliability and responsiveness. Such consistent behavior is crucial for integrating the light sensor into the broader monitoring system for fuel tank levels on ships.

Credit authorship contribution statement

Author Name: Conceptualization, Writing – review & editing. **Author Name**: Supervision, Writing – review & editing. **Author Name**: Conceptualization, Supervision, Writing – review & editing.

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