Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 09, September - 2025

STM-32 Based Underwater Submarine Engine

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Abstract: **Underwater exploration has gained growing importance in marine monitoring. However, conventional submarines and advanced autonomous underwater vehicles (AUVs) are often costly and technologically complex, restricting their use in small-scale research and educational applications. This paper presents the design and working of a low-cost Radio-Controlled (RC) underwater submarine engine that integrates propulsion, buoyancy management, and electronic control. The system employs gear motors, pumps, and an STM32 microcontroller interfaced with motor drivers and wireless modules to achieve real-time maneuverability and depth regulation. Buoyancy is controlled through water pumps operating ballast tanks, while propulsion relies on compact DC motors. Wireless communication, using Bluetooth or RF modules, enables remote operation of the submarine in a user-friendly manner. Key challenges such as waterproofing, structural stability, and energy efficiency are also addressed. The study demonstrates that RC submarines serve as a practical testbed for understanding underwater propulsion and control, with potential applications in research, defense training, and student- level innovation.**

Keywords: **RC Submarine, Underwater Propulsion, Buoyancy Control, STM32 Microcontroller, Motor Driver, Wireless Communication, Ballast Tanks**

1. INTRODUCTION

Underwater exploration has become increasingly important for marine research, environmental monitoring, and defense applications. Conventional submarines and autonomous underwater vehicles (AUVs) provide advanced capabilities but are often expensive and technically complex, limiting their use in small-scale research and educational projects. To address this gap,

Radio-Controlled (RC) submarines offer a cost-effective alternative for studying propulsion, buoyancy, and control mechanisms in aquatic environments.

This paper presents the design and working of an RC underwater submarine engine that integrates gear motors, pumps, and electronic control through an STM32 microcontroller. The system enables propulsion, maneuverability, and depth regulation while maintaining low cost and adaptability. By focusing on practical challenges such as waterproofing, structural stability, and energy management, the study demonstrates how miniature RC submarines can serve as experimental platforms for both academic learning and preliminary research in underwater robotics.

1.1 Motivation and Objective

The demand for low-cost and adaptable underwater exploration systems has increased due to their applications in marine biology, oceanographic research, defense surveillance, and environmental monitoring. While conventional submarines and advanced hauigthonomous underwater vehicles (AUVs) deliver particularly in academic and experimental setups. This creates the need for simplified platforms that can demonstrate key underwater concepts such as propulsion, buoyancy control, and wireless operation without requiring large financial or technological investments. RC submarines fulfill this role by offering an affordable and scalable solution that can be developed with commercially available components. The primary objective of this work is to design and analyze the working of an RC underwater submarine engine that integrates propulsion, buoyancy regulation, and electronic control using an STM32 microcontroller. Specific goals include the development of a reliable propulsion system using gear motors, implementation of a pump-based ballast mechanism for depth control, and integration of wireless modules for remote operation. Additionally, the study aims to address practical challenges such as waterproofing, structural stability, and energy efficiency. By achieving these objectives, the project provides a strong foundation for future research and innovations in small-scale underwater robotic platforms.

1.2 Overview of STM32 & HC-05 Interface The system uses an STM32 microcontroller as the main control unit, paired with an HC-05 Bluetooth module for wireless communication.

2. SYSTEM COMPONENTS AND CONNECTIONS The design of the hardware for the proposed RC submarine system is based around the STM32 microcontroller, which acts as the central processing and control unit. This controller interfaces with the propulsion motors, water pumps for buoyancy control, and the HC- 05 Bluetooth module for wireless communication. The L298N motor driver is used to control both the gear motors and pumps, providing bidirectional drive capability and current handling.

STM32 Microcontroller The STM32 is a high-performance microcontroller widely used in embedded systems. It provides multiple GPIOs, UART, and PWM support, which makes it suitable for motor control and wireless communication tasks. Its low power consumption and real-time processing capability make it ideal for compact robotic systems like RC submarines.

Fig-1:STM32 - Bluepill

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L298N Motor Driver

The L298N is a dual H-bridge motor driver that allows the STM32 to control the speed and direction of DC motors and pumps. It acts as an interface between the low-power control signals from the STM32 and the higher-power motors required for propulsion and ballast control.

Fig -2: L298N Motor Driver

Water Pumps Small water pumps are employed to regulate buoyancy by filling and releasing water in the ballast tanks. This enables the submarine to dive and surface as required.

Fig -3: 12V DC Water Pump

HC-05 Bluetooth Module The HC-05 module provides wireless communication between the STM32 and a mobile device or controller. Using UART communication (TX/RX pins), it enables real-time control of propulsion and buoyancy functions.

Fig -4: HC-05 Bluetooth Module

Battery Pack The system uses rechargeable Li-ion batteries as the primary power source. Separate lines are allocated for motors and the control circuitry to ensure stable operation.

Fig -5: 3.7v Li-Po Battery

TP4056 Charging Module The TP4056 adjustable 1A Li-ion charging module is used to recharge the onboard batteries safely. It provides overcharge, over-discharge, and short-circuit protection, reliability of the submarine'sthereby enhancing the power system.

Fig -6: TP4056 Charging Module

DC Gear Motors DC gear motors are used for forward, reverse, and turning operations of the submarine. Their compact size and torque output make them effective for propulsion in water while maintaining efficiency.

Fig -7: N20 Geared Motor

Hardware Connections

- Motors/Pumps: Connected to STM32 via L298N inputs and outputs.
- HC-05 Bluetooth: Connected to STM32 via UART pins (TX → RX).
- Battery Pack: Powers the motors through L298N and provides regulated supply for STM32 and HC-05.
- TP4056 Module: Linked to the battery pack for safe charging and protection.

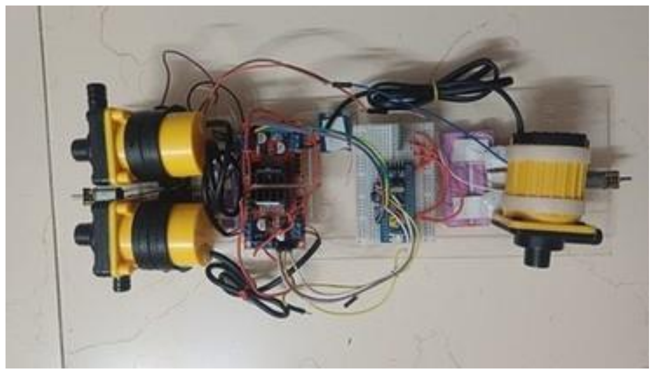

Fig -8: Connection Diagram

International Journal of Engineering Research & Technology (IJERT)
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3. SOFTWARE IMPLEMENTATION

The control program for the
RC submarine was developed using the Arduino IDE, which supports STM32 microcontrollers
tishrough additional board configurations. The software structured to handle propulsion, buoyancy management, and wireless communication in real time.

The code initializes the STM32 peripherals, sets up UART communication with the HC-05 Bluetooth module, and configures PWM signals for driving motors and pumps through the L298N driver. Commands sent from a mobile device via Bluetooth are decoded by the STM32, which then activates the corresponding propulsion motors or ballast pumps.

For buoyancy control, the software executes pump operations based on user inputs, allowing the submarine to dive or surface. Propulsion is managed by varying PWM duty cycles to control motor speed and direction. Error handling routines ensure that invalid or conflicting commands are ignored to maintain stability.

The program is modular, with separate functions for:

- Bluetooth Command Processing (via HC-05 using UART).
- Motor Control (PWM-based speed and direction).
- Pump Control (ballast tank fill and release).
- Power Monitoring (basic checks to avoid over-discharge).

This structured software design ensures reliable underwater operation, easy debugging, and flexibility for future upgrades such as sensor integration and autonomous navigation.

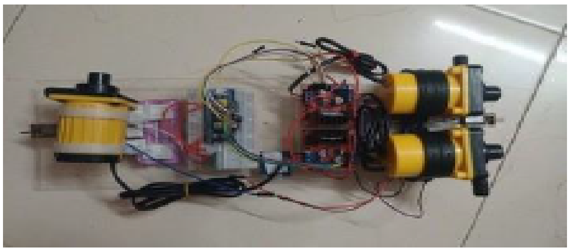
IMPLEMENTATION

The implementation of the RC underwater submarine involves integration of hardware components with firmware to enable wireless control and maneuverability. 3.1 Hardware Setup

- Controller: STM32 Bluepill acts as the central processor, interfacing with motors, pumps, and sensors. Actuators: Two
- geared DC motors provide lateral motion; three water pumps enable vertical movement (diving and surfacing). Motor Drivers: L298N modules drive motors and pumps, receiving
- PWM and direction signals from the STM32. Wireless Communication: HC-05 Bluetooth module enables command
- reception from an Android-based controller application. Power Supply: A combination of 12V and 3.7V Li-ion batteries powers motors, pumps, and the STM32. The TP4056 Adjustable 1A Li-
- ion Battery Charging Module manages safe charging of the 3.7V battery. Connections: Motors and pumps are connected through L298N motor drivers. STM32 GPIO pins control motor directions, while PWM regulates speed. UART interface
- handles Bluetooth commands.

3.2 Software Implementation

- Firmware Development: Implemented using STM32 HAL library in C. Initialization: Configures GPIOs, UART,
- and PWM outputs. Command Handling: Bluetooth
- commands are parsed to control direction (forward, backward, left, right) and vertical movement (dive/surface). Motor & Pump Control: L298N drivers receive signals according to parsed commands, ensuring
- synchronized operation for smooth navigation. Safety Measures: Battery voltage monitoring prevents undervoltage damage; emergency stop commands halt all actuators. Execution Flow:
- The microcontroller continuously listens for commands, updates actuators, and maintains safety checks.



4. RESULTS AND ANALYSIS

The developed RC submarine system was tested in a controlled water environment to evaluate propulsion, buoyancy regulation, and wireless control. The STM32 microcontroller successfully processed Bluetooth commands from the HC-05 module, and the L298N driver reliably operated both motors and pumps. The submarine demonstrated smooth forward, reverse, and turning motions, while the ballast system allowed stable diving and resurfacing. Response time between command input and motor/pump activation was observed to be minimal, ensuring near real-time control. The Bluetooth range was adequate for short-range testing, with consistent connectivity and no noticeable delays. Power consumption tests confirmed that separate supply lines for motors and control circuits improved stability. The system performed reliably for shallow-water experiments, validating the effectiveness of gear motors for propulsion and pumps for buoyancy management. However, challenges such as long-term waterproofing, limited battery life, and pressure handling at greater depths were identified as areas requiring further improvement.

Fig -11: Future Product (Hardware Implementation)

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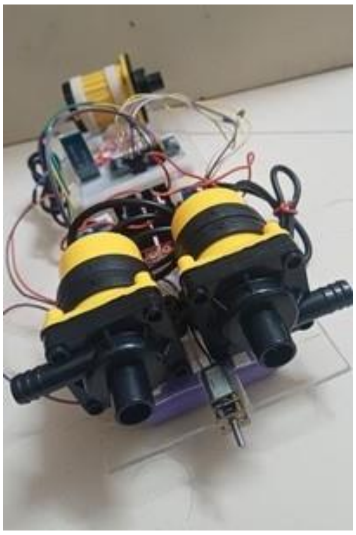

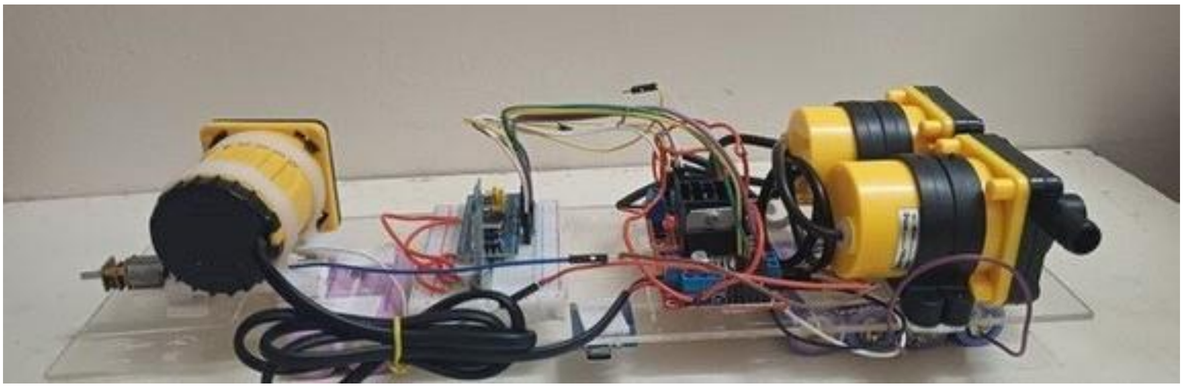

Fig -10: Implemented (Under Production)

BLOCK AND FLOW DIAGRAM

The system architecture of the RC underwater submarine is illustrated using a block diagram and a flow diagram. The block diagram provides a high-level overview of the main components— STM32 microcontroller, L298N motor drivers, motors, pumps, ballast tanks, Bluetooth module, and power supply—and their interconnections. The flow diagram depicts the operational logic, showing how the microcontroller receives Bluetooth commands, processes them, controls actuators for movement and diving/surfacing, and monitors battery status for safe operation. Together, these diagrams offer a clear visual representation of both the structural layout and the functional workflow of the submarine system.

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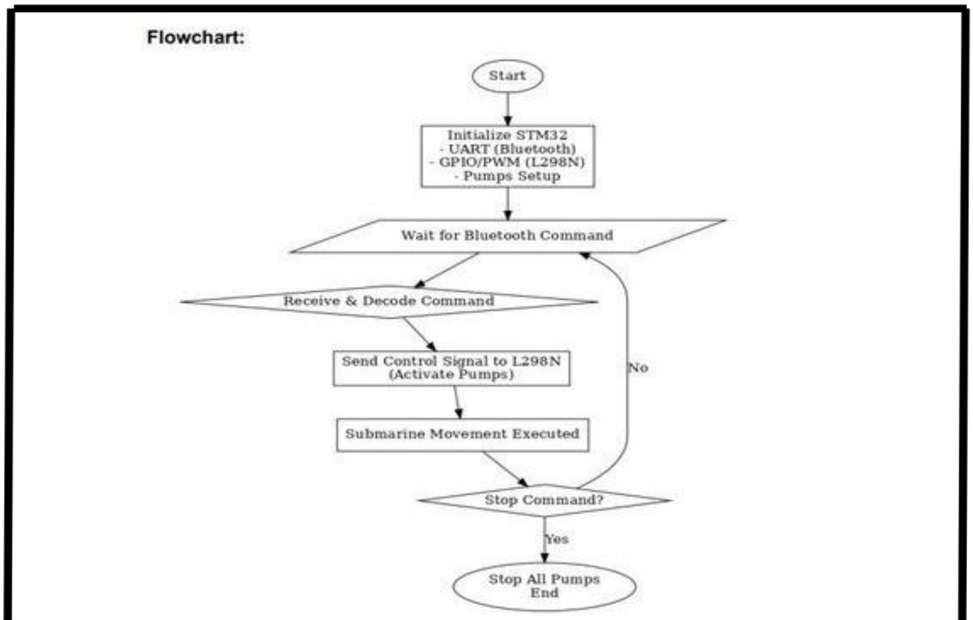

Fig -12: Flowdiagram

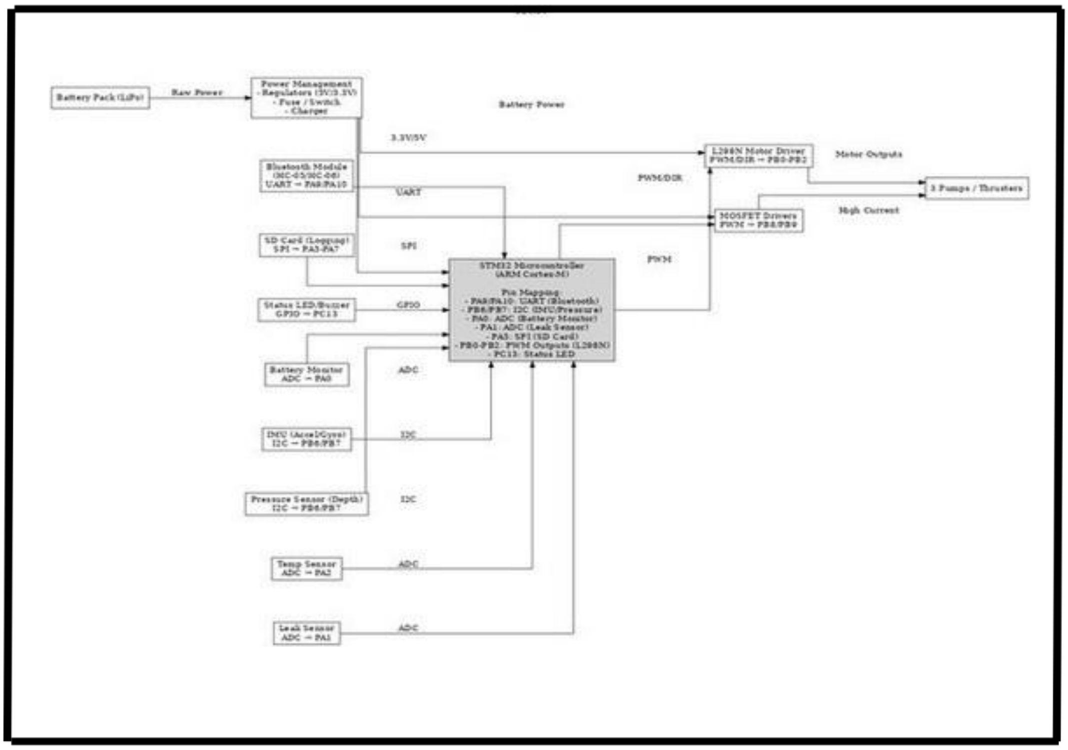

Fig -12:Block diagram

International Journal of Engineering Research & Technology (IJERT)
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