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Water Data Communication for Scuba Divers Health Monitoring and Risk Management System

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ABSTRACT: In high-risk or remote environments where immediate medical assistance may not be available is a need for health monitoring with real-time risk management to ensure the safety and well-being of individuals. Therefore, this paper presents a water data communication for SCUBA divers health monitoring and risk management system that aims to enhance diver safety by providing real-time monitoring of critical physiological and environmental parameters, with the added advantage of Electromagnetic (EM) wave communication for data transmission. In this system, various sensors such as a pulse sensor for heart rate, a MAX30102 sensor for oxygen saturation, a MS5803 depth sensor for measuring dive depth, and a DS18B20 temperature sensor for water temperature are connected to the microcontroller. The use of EM wave communication enhances the system's reliability, ensuring that important health data is transmitted efficiently even in underwater conditions. The system is capable of monitoring critical health metrics in real-time, and if any parameters such as oxygen levels, heart rate, or dive depth go beyond safe thresholds, it triggers alerts to surface personnel or emergency response teams. Overall, this system improves diver safety, providing both real-time health tracking and risk management features while utilizing a more robust and efficient communication method than traditional acoustic systems.

Keywords: Water Data Communication, SCUBA Divers, Arduino Uno, Pulse Sensor, Depth Sensor, Temperature Sensor.

1. Introduction

In the industry world, in high-risk scenarios such as scuba diving, remote work sites, hazardous industrial areas, or medical emergencies, changes in vital signs like heart rate or oxygen saturation indicate life-threatening conditions such as cardiac arrest, hypoxia, or heatstroke [1]. Hence, analysis of the health monitoring process is essential for enhancing safety, preventing emergencies, and supporting timely interventions in environments where human health is quickly compromised. Health monitoring with real-time risk management is an innovative approach that combines continuous physiological data tracking with immediate assessment and response mechanisms to ensure individual safety and well-being, especially in high-risk environments [2-4]. It enables the continuous tracking of vital signs such as heart rate, Oxygen Saturation (SpO2), body temperature, and more allowing early detection of physiological abnormalities that may indicate serious health conditions like hypoxia, cardiac arrest, or dehydration [5-6]. When combined with real-time risk management, this data becomes actionable, and systems immediately alert individuals or emergency teams when critical thresholds are crossed, allowing for rapid response and potentially life-saving interventions. In high-risk environments like scuba diving, where delayed response is fatal, such integration is essential [7-9]. Water data communication for scuba divers' health monitoring and risk management systems involves the use of advanced sensors and wireless technologies to continuously track vital signs and environmental conditions underwater. By integrating biometric sensors such as pulse rate and SpO2 with water-related sensors like depth and temperature, the system collects crucial real-time data about the diver's physiological status and surrounding environment [10]. This information is then transmitted wirelessly to surface support teams or monitoring stations using specialized underwater communication methods or radio frequencies when surfaced. Such a system enhances diver safety by enabling early detection of health risks like hypoxia, decompression sickness, or extreme environmental conditions, allowing for timely interventions and informed decision-making [11-13]. The combination of reliable water data communication and health monitoring represents a significant advancement in scuba diving safety, providing both divers and rescue teams with critical information to manage risks effectively in challenging underwater environments. The scuba diver's health monitoring and risk management system is a safety-focused technological solution designed to monitor the vital signs and environmental conditions affecting scuba divers during underwater activities [14-15]. By continuously tracking health data and instantly analyzing it for risks, such systems detect abnormalities early, trigger alerts, and guide immediate responses, potentially saving lives. Therefore, this paper proposes water data communication for SCUBA divers' health monitoring and a risk management system to enhance diver safety by providing real-time monitoring. Overall, this system enhances diver safety and situational awareness, and a water data communication system integrated with health monitoring and risk management functionalities offers a cutting-edge solution.

2. Proposed Methodology

The proposed water data communication for SCUBA diver health monitoring using Arduino UNO and an EM wave communication system aims to enhance diver safety by integrating real-time monitoring of health parameters, such as heart rate, oxygen saturation, depth, and water temperature, with a reliable communication system. The proposed block diagram is presented in Figure 1.

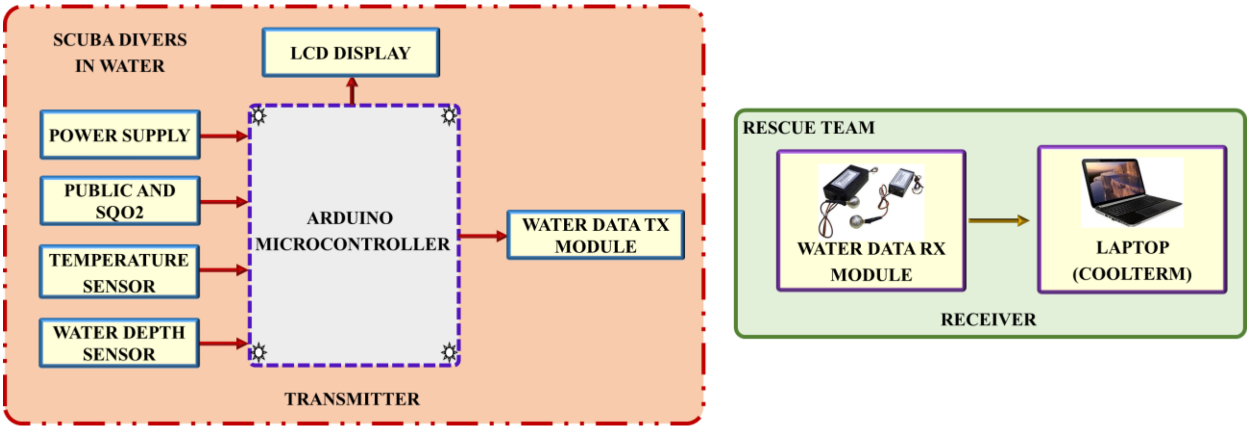

Figure 1: *Proposed block diagram*

At the heart of the system is the Arduino Uno, which serves as the central microcontroller. Using an Arduino Uno as the central controller, the system connects to sensors like a pulse sensor, MAX30102 oxygen sensor, MS5803 depth sensor, and DS18B20 temperature sensor to collect data about the diver's health and environmental conditions. These sensors continuously collect important health and environmental data. The processed data is then transmitted wirelessly to a surface station to monitor the diver's health in real-time. The system is powered by a rechargeable Li-ion or Li-polymer battery, which Rescue Team Laptop (Coolterm) Water Data Rx module 22 ensures long-lasting performance throughout the dive. In case of abnormal readings, such as dangerously low oxygen or unsafe depth, the system triggers an emergency alert system, using Light Emitting Diode (LED) lights or a buzzer to notify the diver and surface personnel. All the components are housed in a waterproof enclosure, ensuring the electronics are protected from water damage. The addition of the Liquid Crystal Display (LCD) display enhances the user experience by providing instant feedback and improving the diver's situational awareness, making this system a comprehensive and effective solution for SCUBA diver health monitoring and safety.

2.1 Power Supply

A power supply is an essential electrical device that provides power to an electrical load, converting energy from a source into the correct voltage, current, and frequency needed by the connected device. It draws energy from various sources, such as the electrical grid, batteries, or solar panels, and delivers it in a controlled manner. It provides the necessary electrical energy to operate sensors, microcontrollers, communication modules, and displays. In underwater applications, the power supply is compact, reliable, and capable of long-duration operation, often relying on rechargeable lithium-ion or lithium-polymer batteries due to their high energy density and lightweight properties. The power system is waterproof and pressure-resistant to function safely and effectively in underwater conditions. The power supply is shown in Figure 2.

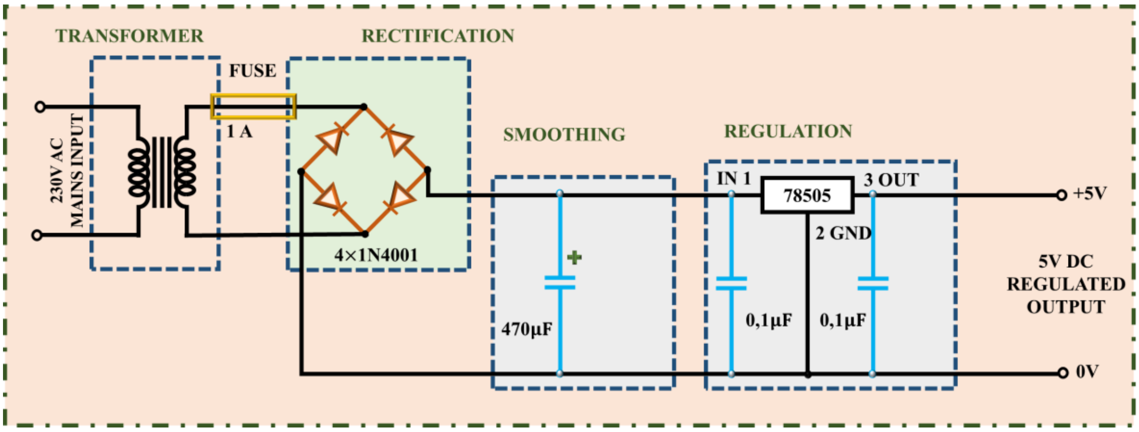

Figure 2: *Power supply*

Additionally, it should deliver stable voltage and current to ensure accurate sensor readings and uninterrupted data transmission. Efficient power management is also crucial to maximize battery life, especially during extended dives, by minimizing energy consumption through low-power components and optimized programming. It enables the continuous and reliable operation of the entire system, making it a key element in ensuring diver safety and the effectiveness of real-time health monitoring and risk management.

2.2 Arduino UNO

In this system, Arduino Uno is employed. The Arduino UNO is a widely used microcontroller board based on the ATmega328P chip, popular among beginners, educators, and hobbyists for its simplicity and versatility. Operating at 5 volts with a 16 MHz clock speed, it features 14 digital input/output pins, six analog inputs, and interfaces for USB connection, external power supply, and in-system programming. The board is programmed using the Arduino IDE, which supports a simplified version of C++, making it accessible to those with little or no programming experience. It is integrated with various sensors to measure parameters such as pH, turbidity, temperature, water level, and flow rate. Arduino Uno is appeared in Figure 3.

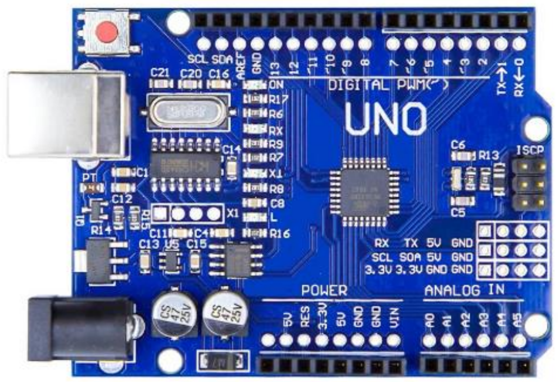

Figure 3: *Arduino uno*

Its open-source nature, wide range of compatible sensors, and wireless communication modules make it ideal for building systems that monitor, transmit, and analyze water-related data. With the help of IoT platforms, Arduino makes it easy to visualize trends and automate responses, such as triggering pumps or sending notifications. Its ease of use, wide community support, and compatibility with a variety of modules make Arduino an ideal choice for building reliable and scalable water data communication systems.

2.3 Temperature Sensor

A temperature sensor is an essential electronic component used to measure the heat or thermal energy of an environment or object, converting the physical temperature into a readable electronic signal. These sensors are commonly used in various applications, including environmental monitoring, industrial processes, home automation, medical devices, and weather stations. Accurate water temperature data is essential for assessing water quality, as it influences the levels of dissolved oxygen, the metabolic rate of aquatic life, and chemical reaction rates. Sensors like the DS18B20 are commonly used in Arduino-based systems due to their durability and digital output, which allows for reliable communication even in wet conditions. Temperature Sensor is represented in Figure 4.

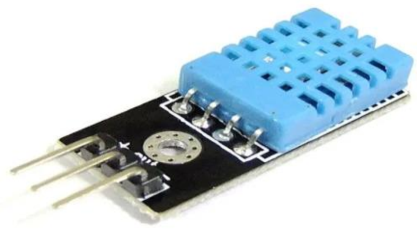

Figure 4: *Temperature sensor*

These sensors are integrated with microcontrollers to collect temperature readings and transmit the data wirelessly using communication modules. This information is then sent to remote servers or cloud platforms for analysis, visualization, and automated decision-making. It used to control heating and cooling systems, trigger alarms when temperatures exceed thresholds, or collect data for analysis and reporting. It enables real-time monitoring and automation, making them vital components in both every day and advanced technological applications. Further, it helps ensure safe and efficient water resource management by enabling continuous and remote observation through data communication networks.

2.4 Pulse Sensor

A pulse sensor is a compact electronic device used to measure the heart rate by detecting the changes in blood volume through the skin, typically using Photoplethysmography (PPG) technology. It consists of an LED and a photodetector that work together to sense the pulsing of blood with each heartbeat, usually from a fingertip or earlobe. In microcontroller-based projects, especially those involving Arduino, pulse sensors are popular for building health monitoring systems, fitness trackers, and biomedical applications. The sensor outputs an analog signal corresponding to the heartbeat, which is read and processed by the Arduino to calculate the pulse rate in Beats Per Minute (BPM). In this work, it is used to measure human heart rate, and it has a unique role in water data communication when integrated into health and safety systems related to water environments. Figure 5 displays the pulse sensors.

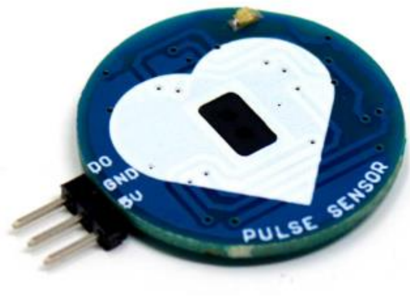

Figure 5: *Pulse sensor*

The underwater monitoring devices for divers and a pulse sensor are track the wearer's heart rate in real time. This data, when combined with environmental sensors are transmitted via wireless communication systems like Bluetooth, LoRa, or GSM to a monitoring station or mobile device. Moreover, the pulse sensor contributes to health-focused water data communication, helping ensure the safety of individuals by detecting abnormal heart rate patterns that might indicate stress, fatigue, or drowning risk. Though not used to monitor water itself, the pulse sensor adds a biometric layer to water-related data systems, enhancing the ability to respond quickly in emergency situations in aquatic environments.

2.5 Depth Sensor

A depth sensor is an essential device used to measure the depth or level of a liquid, typically water, by detecting the distance from the sensor to the surface or bottom of the water body. In water data communication systems, depth sensors play a vital role in applications such as reservoir monitoring, groundwater management, flood prediction, and tank level measurement. These sensors operate using various principles, including pressure, ultrasonic waves, or optical methods. It measures the force exerted by the water column above the sensor, providing accurate readings of water depth. When connected to a microcontroller like an Arduino, the depth sensor collects real-time data and transmits it wirelessly using communication technologies like LoRa, GSM, or Wi-Fi to remote servers or IoT dashboards. The depth sensor is presented in Figure 6.

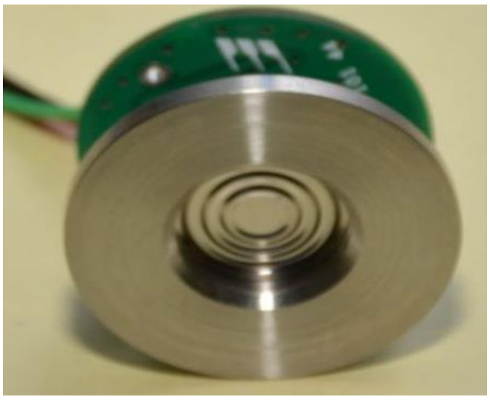

Figure 6: *Depth sensor*

These sensors often use pressure, ultrasonic, or sonar technologies to detect the distance to the water surface or bottom. It enables continuous monitoring of water levels, which is critical for early warning systems, automated irrigation, and efficient water resource management. The integration of depth sensors into smart water monitoring systems enhances the ability to collect, analyze, and act upon accurate hydrological data in both urban and rural settings.

2.6 SPO2 Sensor

An SpO2 sensor is a specialized device that measures the oxygen saturation level in the blood, indicating how effectively oxygen is being transported throughout the body. It works by emitting light waves through a part of the body, typically a fingertip or earlobe, and detecting the amount of light absorbed by oxygenated and deoxygenated hemoglobin. This non-invasive measurement is crucial in medical monitoring, fitness tracking, and health diagnostics to assess respiratory function and detect conditions like hypoxia. Its ability to monitor SpO2 continuously and communicate this data via IoT platforms makes these sensors valuable tools in telemedicine, emergency response, and wearable health technologies, enhancing both personal health awareness and clinical care. The SPO2 sensor is presented in Figure 7.

Figure 7: *The SPO2 Sensor*

This vital health data, combined with environmental water parameters such as temperature and depth, is transmitted wirelessly via communication modules like Bluetooth, GSM, or LoRa to remote monitoring stations. Integrating SpO2 sensors into water-related data communication systems adds an important biometric dimension, allowing real-time health monitoring of users in potentially hazardous water conditions and enabling faster response in emergencies. Although SpO2 sensors do not measure water properties directly, their inclusion enhances the overall safety and effectiveness of water data communication systems focused on human health in aquatic environments.

2.7 Water Data Communication Module

Water data communication module or IOUT(Internet of Underwater things) is a communication module in which Water is used as the communication medium, Currently this device is capable of Transmitting data through water with the ball antenna for a distance of approximately 7 - 10 Feet, This Module comes with the full setup as Water Data Communication Module 2 Set of Transformers with Power Supply Board and 3 Pin Power Chord all the items will be integrated and supplied. Figure 8 displayed the water data communication module.

Figure 8: *Water data communication module*

The water data communication module is a specialized underwater wireless communication system designed for real-time data transmission in submerged environments. Utilizing acoustic, optical, or electromagnetic waves, it enables IoUT applications by connecting underwater devices to the internet for monitoring, navigation, and exploration.

2.8 LCD Display

An LCD display is a common output device used in electronic projects to visually present data, making it easier for users to read information such as sensor readings, system status, or menu options. In water data communication systems, an LCD display is often integrated with microcontrollers like Arduino to show real-time measurements from sensors monitoring water parameters such as temperature, pH, turbidity, or water level. This immediate visual feedback allows users to quickly assess the condition of water without needing to access a computer or remote device.

Figure 9: *The LCD*

The LCD appears in Figure 9. Combined with wireless communication modules, the LCD complements remote monitoring by providing on-site data display, enhancing user interaction, troubleshooting, and system control in applications ranging from environmental monitoring to smart irrigation and industrial water management.

3. Results and Discussions

In this work, water data communication using Arduino Uno is implemented for scuba divers' health monitoring and risk management system. The hardware image of the water data communication system is given in Figure 10.

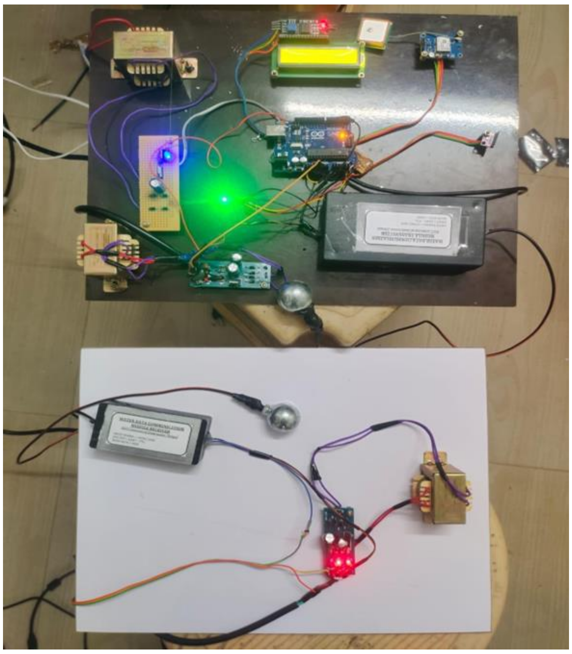

Figure 10: *Hardware image of scuba divers health monitoring system*

This hardware board has amount of equipment. The charger and cables are connected to the Arduino Uno microcontroller's control device, which is finished with an IoT device for real-time application monitoring.

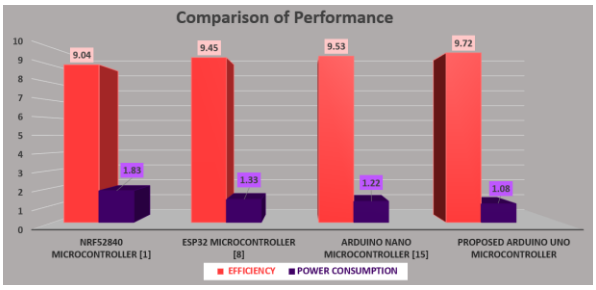

Figure 11: *Comparison of performance*

Figure 11 compares the efficiency and power consumption of a number of microcontrollers. The graph illustrates the proposed Arduino Uno microcontroller's power consumption of 1.08 W. The ESP32 [8] and Arduino Nano [15] accomplish 1.33 W and 1.22 W in power consumption, respectively, whereas the older NRF52840 microcontroller [1] has a maximum power consumption figure of 1.83 W. It shows that 9.72% efficiency is attained with the proposed Arduino Uno microcontroller. The proposed microcontroller outperforms microcontrollers like the Arduino Nano (9.53%), ESP32 (94.5%), and NRF52840 (9.04%) in terms of efficiency.

4. Conclusion

This paper develops the design of a water data communication for scuba divers' health monitoring and risk management system. The integration of water data communication with real-time physiological and environmental monitoring creates a powerful and reliable health and risk management system for SCUBA divers. By combining sensors for SpO_2, heart rate, temperature, and water depth with an Arduino-based controller and a water data transceiver, the system provides continuous feedback to both the diver and surface teams. This enables timely detection of health risks such as hypoxia, overheating, or decompression sickness, and facilitates rapid response through real-time alerts and communication. The use of a waterproof LCD display ensures the diver remains informed throughout the dive, while the data transceiver allows remote monitoring and logging for post-dive analysis. Overall, this system enhances diver safety, supports proactive risk management, and represents a significant step forward in underwater health monitoring technology.

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