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LIFI BASED PARAMETERS MONITORING SYSTEM UNDERWATER COMMUNICATION

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ABSTRACT - In this research paper, we present the development of an underwater wireless optical communication (UWOC) system, designed to overcome the unique challenges of communication in underwater environments, specifically within underwater sensor networks (UWSNs). UWOC is becoming a key enabler for faster data transmission rates, which are critical for enhancing the performance of UWSNs, particularly in applications such as underwater monitoring, environmental sensing, and communication between underwater vehicles. The proposed system utilizes a blue-colored light-emitting diode (LED), controlled by a microcontroller, to transmit data via optical pulses through the water. These pulses are received by a photodiode at the receiving end, where they are converted back into data signals. To further optimize the system's performance, Optical Code Division Multiple Access (OCDMA) codes are employed to emulate a multi-user communication environment at the transmitter. This method allows multiple users to communicate simultaneously over the same optical medium by encoding their data using unique optical codes, which helps in mitigating issues related to interference and signal collision that typically arise in shared communication channels. The simulation of the system was carried out using Vivado, a leading platform for hardware description and simulation. The experimental setup for a single-user communication system was successfully implemented on a Nexsys 4 DDR field-programmable gate array (FPGA) board, which served as the platform for both data transmission and reception. This FPGA board was chosen due to its flexibility, processing power, and suitability for high-speed data handling, making it ideal for testing and deploying real-time communication systems. The research demonstrates the feasibility of UWOC for underwater communication applications, with a particular focus on using optical signals for reliable and efficient data transmission in challenging underwater environments. One of the key advantages of UWOC is its ability to support high data rates, which are essential for modern underwater communication needs, where large volumes of data, such as sensor readings or imaging information, need to be transmitted in real time. The system's implementation also opens up opportunities for future work in multi-user underwater communication systems. The next step in the development process involves implementing the multi-user communication system using OCDMA on the Nexsys 4 DDR FPGA board. This enhancement will enable simultaneous communication between multiple users, significantly improving the system's capacity and efficiency. The research also outlines the communication challenges encountered in underwater environments, such as the limited range of optical signals, water turbidity, and signal attenuation, which are all critical factors that impact the performance of UWOC systems. By addressing these challenges through system optimization and simulation, the paper

contributes to the advancement of underwater communication technologies. The results of this research pave the way for the deployment of more robust and scalable underwater communication systems in the future, particularly for applications that require reliable, high-speed data transfer in harsh and unpredictable underwater environments. Overall, the proposed UWOC system offers a promising solution to the communication challenges in underwater sensor networks, with potential applications in environmental monitoring, marine biology, and underwater robotics.

I. INTRODUCTION As the Earth's surface is composed of one-third land and two-thirds water, the increasing global human population has exacerbated the depletion of land resources. Industrial activities, road traffic, and thermal power plants have all contributed to significant environmental changes, leading to climate disruption and natural disasters like floods, landslides, and earthquakes. These challenges have prompted researchers to explore ocean resources as a sustainable alternative for meeting the growing demand for resources. One of the key areas of exploration is underwater communication, which has become increasingly important for monitoring the vast and often inaccessible underwater environment. The need for efficient communication systems in such environments has led to the development of underwater wireless communication (UWC), which employs various techniques including radio frequencies (RF), acoustic waves, and optical frequencies. However, RF and acoustic wave communications face several limitations, particularly in terms of bandwidth, range, and data rates, making them less ideal for high-performance underwater systems. In contrast, optical frequencies, particularly those in the blue and green spectrum (450-550 nm), have shown considerable promise in overcoming these limitations. The use of blue light in underwater optical communication is advantageous because of its low attenuation in water, allowing for better transmission over longer distances compared to other frequencies. Underwater wireless optical communication (UWOC) has emerged as a pivotal technology for enabling high data rates in underwater wireless sensor networks (UWSNs), which consist of seabed sensors, relay buoys, autonomous underwater vehicles (AUVs), and remotely operated underwater vehicles (ROVs). These networks create a distributed system for monitoring and collecting data from the underwater environment, supporting applications such as environmental monitoring, marine biology, and underwater exploration. Different UWOC configurations, such as point-to-point line of sight (LOS), diffused LOS, retro-reflector-based LOS, and non-line of sight (NLOS), each have their own advantages and challenges when it comes to providing effective communication among UWSN nodes. Acoustic communication, although widely used in underwater systems, has several disadvantages including low data rates, large delays, bulky equipment, and potential harm to aquatic life. This has led researchers to investigate alternative solutions, such as RF communication, which offers the potential to cross boundaries more easily and is less affected by water turbulence and turbidity. However, RF signals suffer from significant attenuation, limiting their range and effectiveness. In this context, UWOC presents a superior alternative, offering higher data rates, secure communication, lower transmission delays, and more cost-

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effective installation compared to both acoustic and RF systems. Despite its many advantages, UWOC also faces challenges such as signal absorption, scattering, transceiver misalignment, and the lack of reliable underwater devices, which hinder its widespread adoption. This research aims to investigate these challenges in greater depth and explore the potential of UWOC as a viable solution for achieving high data rates in underwater environments. By addressing the limitations of existing communication methods and advancing the understanding of underwater optical communication systems, this study seeks to contribute valuable insights that could enhance the future of underwater communication technologies.

II.IMPLEMENTATION

BLOCK DAIGRAM

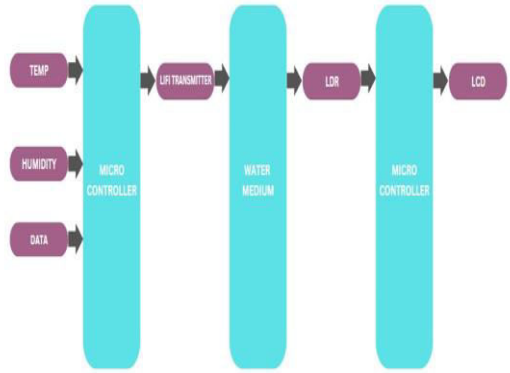

Fig: Block Diagram

DESCRIPTION

POWER SUPPLY

A **regulated power supply** transforms unregulated AC (Alternating Current) into a stable DC (Direct Current). It guarantees consistent output despite variations in input. A regulated DC power supply is also known as a linear power supply, it is an embedded circuit and consists of various blocks

- **Regulated Power Supply Definition**: A regulated power supply ensures a consistent DC output by converting fluctuating AC input.
- **Component Overview**: The primary components of a regulated power supply include a transformer, rectifier, filter, and regulator, each crucial for maintaining steady DC output.
- **Rectification Explained**: The process involves diodes converting AC to DC, typically using full wave rectification to enhance efficiency.
- **Filter Function**: Filters, such as capacitor and LC types, smooth the DC output to reduce ripple and provide a stable voltage.
- **Regulation Mechanism**: Regulators adjust and stabilize output voltage to protect against input changes or load variations, essential for reliable power supply

SENSORS

Sensors are used for sensing things and devices etc. A device that provides a usable output in response to a specified measurement. The sensor attains a physical parameter and converts it into a signal suitable for processing (e.g. electrical, mechanical, optical) the characteristics of any device or material to detect the presence of a particular physical quantity. The output of the sensor is a signal which is converted to a human-readable form like changes in characteristics, changes in resistance, capacitance, impedance, etc.

DHT11 SENSOR

Humidity is the measure of water vapour present in the air. The level of humidity in

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air affects various physical, chemical and biological processes. In industrial applications, humidity can affect the business cost of the products, health and safety of the employees. So, in semiconductor industries and control system industries measurement of humidity is very important. Humidity measurement determines the amount of moisture present in the gas that can be a mixture of water vapour, nitrogen, argon or pure gas etc… Humidity sensors are of two types based on their measurement units. They are a relative humidity sensor and Absolute humidity sensor. DHT11 is a digital temperature and humidity sensor.

What is a DHT11 Sensor?

DHT11 is a low-cost digital sensor for sensing temperature and humidity. This sensor can be easily interfaced with any micro-controller such as Arduino, Raspberry Pi etc… to measure humidity and temperature instantaneously.

DHT11 humidity and temperature sensor is available as a sensor and as a module. The difference between this sensor and module is the pull-up resistor and a power-on LED. DHT11 is a relative humidity sensor. To measure the surrounding air this sensor uses a thermistor and a capacitive humidity sensor.

Working Principle of DHT11 Sensor

DHT11 sensor consists of a capacitive humidity sensing element and a thermistor for sensing temperature. The humidity sensing capacitor has two electrodes with a moisture holding substrate as a dielectric between them. Change in the capacitance value occurs with the change in humidity levels. The IC measure, process this changed resistance values and change them into digital form.

For measuring temperature this sensor uses a Negative Temperature coefficient thermistor, which causes a decrease in its resistance value with increase in temperature. To get larger resistance value even for the smallest change in temperature, this sensor is usually made up of semiconductor ceramics or polymers.

The temperature range of DHT11 is from 0 to 50 degree Celsius with a 2-degree accuracy. Humidity range of this sensor is from 20 to 80% with 5% accuracy. The sampling rate of this sensor is 1Hz .i.e. it gives one reading for every second. DHT11 is small in size with operating voltage from 3 to 5 volts. The maximum current used while measuring is 2.5mA.

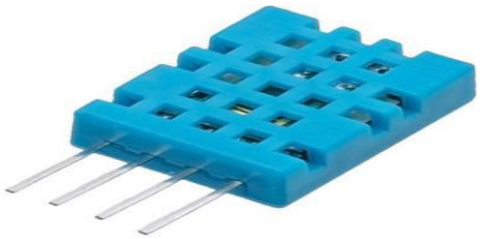

Fig: DHT11 SENSOR

DHT11 sensor has four pins- VCC, GND, Data Pin and a not connected pin. A pull-up resistor of 5k to 10k ohms is provided for communication between sensor and micro-controller.

LIFI MODULE

PAM8403 AMPLIFIER

The main power amplifier IC is the PAM8403, as you can see from the figure below, other than the IC, the module consists of a few components, such as capacitors and resistors.

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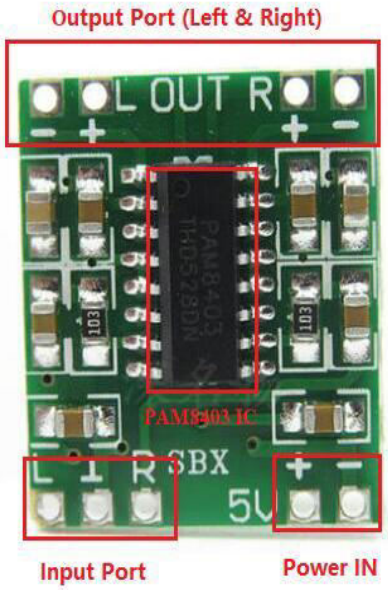

Fig :PAM8403 Amplifier Board Overview

The PAM8403 amplifier board is a dual-channel (stereo) amplifier that produces 6W (3W+3W) output. As any major amplifier system needs short circuit protection, PAM8403 has built-in short circuit protection that is essential for trouble-free operation.

PAM8403 Amplifier IC itself does not require any kind of heat sink, so this will be the perfect choice for custom speaker projects. It can drive 4 or 8 speakers directly. It is mandatory to use a proper speaker with no more than a 3W output rating.

Since this is a stereo amplifier board, the input section has two inputs L (Left) and R (Right) with a common ground between them. Use any type of audio input that needs to be amplified and produce 3W + 3W audio output.

This amplifier board provides a maximum gain of 24 dB with 10 percent THD at 5V DC input and 4 Ohm load output. It does not require heatsink, which means that it also saves additional board space. Irrespective of the heatsink, it could also provide thermal protection, which is another essential feature of such a small wattage amplifier module

NODEMCU:

NodeMCU is an open source LUA based firmware developed for ESP8266 wifi chip. By exploring functionality with ESP8266 chip, NodeMCU firmware comes with ESP8266 Development board/kit i.e. NodeMCU Development board. Since NodeMCU is open source platform, their hardware design is open for edit/modify/build. NodeMCU Dev Kit/board consist of ESP8266 wifi enabled chip. The ESP8266 is a low-cost Wi-Fi chip developed by Espressif Systems with TCP/IP protocol. For more information about ESP8266, you can refer ESP8266 WiFi Module. There is Version2 (V2) available for NodeMCU Dev Kit i.e. NodeMCU Development Board v1.0 (Version2), which usually comes in black colored PCB.

NodeMCU Development Kit/Board consist of ESP8266 wifi chip. ESP8266 chip has GPIO pins, serial communication protocol, etc. features on it.

ESP8266 is a low-cost Wi-Fi chip developed by Espressif Systems with TCP/IP protocol. For more information about ESP8266, you can refer ESP8266 WiFi Module.

The features of ESP8266 are extracted on NodeMCU Development board. NodeMCU (LUA based firmware) with Development board/kit that consist of ESP8266 (wifi enabled chip) chip combines NodeMCU Development board

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which make it stand-alone device in IoT applications.

Let's see 1st version of NodeMCU Dev Kit and its pinout as shown in below images.

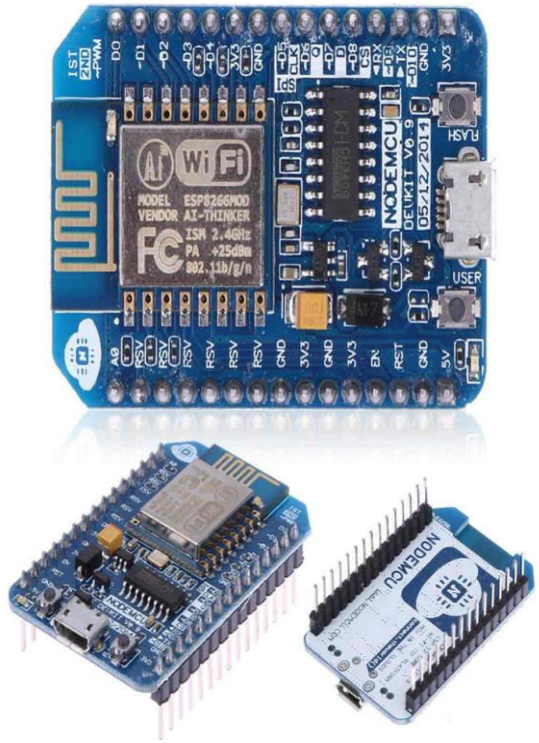

Fig: Node Mcu

III. LITERATURE SURVEY

A. Z. Zeng, H. Zhang, Y. Dong, J. Cheng, "A survey of underwater wireless optical communication," IEEE Commun. Surveys & Tutorials, vol. 19, pp. 204-238, Oct. 2016.

The paper by Zeng et al. (2016) provides a comprehensive survey on underwater wireless optical communication (UWOC), a technology that has garnered significant attention as a promising solution to the limitations of traditional underwater communication systems. The authors delve into the fundamental principles of UWOC, explaining how optical frequencies, particularly in the blue and green light spectrum (450-550 nm), offer advantages over other communication methods, such as radio frequencies (RF) and acoustic waves. UWOC benefits from low signal attenuation in water, which enables longer transmission distances and higher data rates. However, the paper also highlights several challenges faced by UWOC, such as signal absorption and scattering, limited range in turbid waters, and the need for precise alignment of the transceivers. The study categorizes the different UWOC systems, including point-to-point communication and multi-user communication schemes, and provides insights into the various modulation techniques employed to optimize performance in underwater environments. Moreover, the paper reviews several key applications of UWOC, particularly in underwater sensor networks (UWSNs), which are crucial for environmental monitoring, marine exploration, and autonomous underwater vehicle communication. The authors also address the technological advancements that have been made to overcome some of the challenges associated with UWOC, including innovations in transceiver designs, advanced coding schemes, and the use of multiple-input multiple-output (MIMO) techniques to enhance data transmission. The survey emphasizes the importance of improving the reliability, scalability, and energy efficiency of UWOC systems to support large-scale deployments in real-world underwater environments. Lastly, the paper discusses future research directions, such as the integration of UWOC with other communication methods like acoustic and RF systems to form hybrid systems, which could potentially mitigate the inherent limitations of each individual technology.

This comprehensive survey serves as a valuable resource for researchers and engineers seeking to advance the field of UWOC and its applications in underwater communications.

B. Z. Zhou, H. Zhang, C. Lin, A. Sharma, "Performance Analysis of Duobinary and CSRZ Modulation Based Polarization Interleaving for High-Speed WDM-FSO Transmission System" Journal of Optical Communications, vol. 43, no. 1, 2022, pp. 147-152.

In the paper by Zhou et al. (2022), the authors conduct a detailed performance analysis of duobinary and carrier-suppressed return-to-zero (CSRZ) modulation schemes in the context of polarization interleaving for high-speed wavelength division multiplexing free-space optical (WDM-FSO) communication systems. The authors explore how modulation techniques, such as duobinary and CSRZ, can be effectively combined with polarization interleaving to enhance the efficiency and capacity of WDM-FSO systems. By analyzing various key parameters, such as bit error rate (BER) and system power penalty, the paper demonstrates how these modulation schemes improve signal quality and system performance under different transmission conditions. The study also highlights the trade-offs between the complexity of modulation schemes and the resulting improvements in transmission quality, making it a valuable contribution to the optimization of WDM-FSO systems for future high-speed optical communications. The paper also discusses the influence of polarization interleaving on the system's performance. Polarization interleaving is a technique used to maximize the utilization of available optical resources by separating different data channels in the polarization domain, which improves the overall bandwidth efficiency of the system. The results show that combining duobinary or CSRZ modulation with polarization interleaving significantly enhances the performance of WDM-FSO systems, providing better tolerance to atmospheric impairments and reducing the impact of signal distortions. The authors compare the performance of these modulation techniques in terms of spectral efficiency and signal integrity, providing insights into the advantages of using polarization interleaving with advanced modulation formats. This work concludes that polarization interleaving, when combined with duobinary or CSRZ modulation, can achieve superior performance for high-speed WDM-FSO systems, offering a promising solution for next-generation optical communication networks.

C. A. Sharma, V. Mishra, K. Singh, and J. Malhotra, "Hybrid RoF-RoFSO system for broadband services by incorporating polarization division multiplexing scheme," Journal of Optical Communications, 2023.
In the paper by Sharma et al. (2023), the authors propose a hybrid Radio-over-Fiber (RoF) and Radio-over-Free-Space-Optics (RoFSO) system designed to enhance broadband services. RoF and RoFSO systems have been identified as promising solutions for future communication networks, as they can support high-speed data transmission over both wired and wireless channels. The hybrid approach combines the advantages of both RoF, which uses fiber optics for efficient long-distance transmission, and RoFSO, which leverages free-space optical technology for

high-capacity, line-of-sight communication over short to medium distances. By incorporating PDM, the system further increases its capacity by utilizing both orthogonal polarization states to carry separate data streams, effectively doubling the data rate without requiring additional bandwidth. The paper explores how this hybrid architecture can provide reliable, high-speed broadband access, particularly in urban environments where traditional wired infrastructure may be limited or difficult to deploy. The authors also evaluate the performance of the proposed system through simulations, focusing on key parameters such as signal quality, data throughput, and system resilience to environmental factors such as turbulence and weather conditions. The use of PDM in the RoFSO part of the system plays a critical role in improving the robustness and capacity, particularly in challenging free-space environments where atmospheric disturbances can degrade the signal quality. The study demonstrates that the hybrid RoF-RoFSO system with PDM can offer high bandwidth efficiency, reduced power consumption, and lower latency compared to traditional broadband systems. Furthermore, the integration of RoFSO in the system allows for seamless communication over the air, bridging the gap between fiber-based and wireless networks. The paper concludes that the hybrid RoF-RoFSO system incorporating PDM is a viable solution for meeting the growing demand for broadband services, offering a flexible and scalable architecture that can be adapted to a wide range of applications in modern optical communication networks.

IV.DESCRIPTION

The paper on the development of a wireless optical communication link for secure underwater communication explores the advancements in underwater communication technologies, with a specific focus on using optical communication for secure and high-speed data transmission in underwater environments. The growing importance of secure underwater communication systems is driven by the increasing need for real-time data transmission in applications such as underwater sensor networks, environmental monitoring, marine exploration, and defense-related operations. Traditional methods, such as acoustic and radio frequency (RF) communications, face significant limitations in underwater environments, including low data rates, high power consumption, and limited range. These challenges, coupled with the potential for interference and security vulnerabilities, have prompted researchers to explore alternative solutions. The paper introduces underwater wireless optical communication (UWOC) as a promising alternative, highlighting its potential for high-speed data transmission with minimal latency and lower power requirements compared to conventional communication methods. The use of optical frequencies, particularly in the blue and green light spectrum, allows for better signal propagation through water due to the lower attenuation characteristics of these wavelengths. By employing a secure optical link for communication, the paper aims to address the challenges of secure and reliable data transmission in underwater systems, which are increasingly being deployed in sensitive and high-stakes environments, such as military operations

or scientific research in protected marine areas.The study emphasizes the development of a robust optical communication link capable of providing secure, interference-resistant communication in underwater settings. One of the key aspects of this research is the integration of advanced encryption and security protocols into the optical communication system to ensure that sensitive data transmitted underwater is protected from unauthorized access or interception. Additionally, the paper discusses the importance of using advanced modulation techniques and error-correction algorithms to overcome the challenges posed by the underwater medium, such as signal scattering, absorption, and turbulence. The authors also explore the impact of various environmental factors, such as water turbidity, temperature, and salinity, on the performance of the optical communication link, providing insights into how these factors can be mitigated for more reliable operation. Furthermore, the research evaluates the system's potential for integration with other communication technologies, such as acoustic or RF systems, to form hybrid communication solutions that can ensure continuous and stable data transmission over longer distances or in challenging environmental conditions. Through a series of experiments and simulations, the paper demonstrates the feasibility of the proposed wireless optical communication system for secure underwater communication, showing its potential for various applications that require high data rates and secure transmission in environments where traditional communication methods fall short. The study concludes by highlighting the advantages of UWOC in terms of security, speed, and power efficiency, positioning it as a viable solution for next-generation underwater communication systems.

CONCLUSION

In conclusion, the performance of the underwater communication system has been thoroughly investigated, utilizing two experimental setups to evaluate various aspects of the transmission and reception process. In the first setup, microcontrollers were employed at both the transmitter and receiver ends to facilitate basic communication, while in the second setup, a more advanced configuration incorporating both FPGA and microcontroller was used to enhance the data processing capabilities and achieve more complex transmission functions. The study highlighted the significant impact of varying the distance between the transmitter and receiver, revealing how the signal strength and communication quality degrade as the distance increases, which is a common challenge in underwater communication systems. Additionally, the effect of data rate variation was analyzed, with results indicating that higher data rates may lead to increased signal loss or distortion, making it necessary to optimize the transmission parameters to maintain effective communication. These findings confirm the suitability of the experimental setups in achieving secure and reliable underwater communication, demonstrating their capability to deliver successful data transmission under various environmental conditions. The study also established that while secure communication can be achieved using microcontrollers and FPGA-based systems, there are still challenges related to signal degradation over longer distances and the impact of environmental factors such as water turbidity and temperature, which can affect the system’s overall performance.Looking toward future improvements, the next phase of the research involves the implementation of Optical Code Division Multiple Access

(OCDMA) on FPGA boards to support multi-user communication. This would allow for simultaneous communication between multiple underwater units, thereby addressing scalability issues and expanding the system's potential applications. The ability to handle multiple users without interference is essential for large-scale underwater sensor networks or communications in marine environments, where many devices need to transmit data concurrently. Furthermore, the current study has focused primarily on the transmission and reception of basic data bits, but the future direction includes the transmission of more complex data types such as audio and video. By integrating FPGA boards into the multi-user underwater communication system, these more advanced data types can be transmitted efficiently, enabling real-time underwater video surveillance or audio communications for remote underwater operations, which are particularly valuable in applications such as deep-sea exploration, marine monitoring, and defense. The integration of optical technologies, particularly with OCDMA, offers the potential to overcome bandwidth limitations and enhance the data throughput, making it an ideal solution for high-demand underwater communication applications. In summary, the research demonstrates the viability of using FPGA and microcontroller-based systems for secure underwater communication and lays the groundwork for more advanced, multi-user systems capable of handling more complex data types in the future, advancing the field of underwater communication.

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