ESP32-Based Real-Time Blood Typing Detection For Emergency And Rural Use

Alphin Stephanus[1], Elisabeth Tansiana Mbitu[2*], Syukri Gazali Suatkab[3], Thenny Daus Salamoni[4]

[1,2,3,4] Department of Electrical Engineering, Politeknik Negeri Ambon, Maluku 97234, Indonesia.
[*]Corresponding Author:
Email: elisabethtansianambitu@gmail.com

Abstract.

Accurate blood group identification is essential in emergency medical care, especially in rural or remote areas with limited access to laboratory facilities. This paper presents the design and development of a low-cost, real-time blood typing detection device focused on the ABO blood group system. The device utilizes an ESP32 microcontroller to process optical input signals based on agglutination reactions between blood samples and antisera. Measurement results are displayed directly on an LCD screen, providing immediate and easy-to-read feedback without the need for internet connectivity or external devices. The system is compact, portable, and user-friendly, making it ideal for use in field operations, mobile clinics, or basic healthcare units. Initial testing shows the device is capable of accurately determining blood types A, B, AB, and O in real-time, supporting rapid decision-making in critical situations.

Keywords: *ESP32; blood typing; ABO group; portable and photodiode sensor.*

I. INTRODUCTION

Blood type is vital medical information, especially in emergency situations or in remote areas with limited laboratory facilities. Rapid identification of a patient's blood type can accelerate the transfusion process and ensure appropriate medical treatment. Information about blood type and the Rhesus factor is crucial in the medical field, particularly in blood transfusion procedures, childbirth, and organ transplantation. Accuracy and speed in determining blood type and Rhesus status are essential for the success of these medical procedures. Blood type and Rhesus identification is carried out by testing red blood cells using antisera (specialized serum) [1]. Blood grouping is based on the presence of two types of molecules: antigens and antibodies. The two main blood grouping systems are the ABO system and the Rhesus (Rh factor) system. The ABO system classifies blood into four types: A, B, AB, and O. Meanwhile, the Rhesus system categorizes blood based on the presence of the Rh factor, resulting in Rh-positive and Rh-negative classifications [2].The most commonly used system for blood type classification is the ABO system. In this system, the presence or absence of A and B antigens on the surface of red blood cells determines a person's blood type. Identification is carried out by reacting a blood sample with anti-A and anti-B serums.

This technique is a standard procedure for determining blood type. The test results are observed based on the occurrence of agglutination—whether or not the blood clumps—which then serves as the basis for determining the blood type [3, 4].There are three manual methods commonly used for blood type testing: the slide test, the tube test, and the microwell plate method. The principle behind these tests is that blood containing antigens corresponding to the added reagents will undergo agglutination. The reagents used in the test are anti-A, anti-B, and anti-D [5, 6].The conventional method of blood type determination requires laboratory equipment and skilled personnel, making it less accessible in remote areas [7]. Based on observations conducted by the researcher at the research site, Ch. Tiahahu Community Health Center in Ambon City, Maluku, blood type testing is performed by relying solely on direct visual observation. It is known that visual ability can be affected by fatigue or eye strain. Additionally, the time required to test a single blood sample is approximately 30 minutes. Therefore, this method is less suitable for rapid and large-scale blood sample testing.

The lack of accuracy in this manual testing process can lead to fatal errors, particularly in blood transfusion procedures or genetic identification [8,9]. To address this issue, this study developed a device based on the ESP32 microcontroller capable of detecting ABO blood types in real-time using a simple, low-power system that operates without an internet connection. The main focus of this device is to detect agglutination between the blood sample and Anti-A and Anti-B reagents. This electronic device is designed to read blood types digitally and allows for simultaneous testing of multiple blood samples. The device features two light sensors (LDR) for detection, an Arduino UNO R3 as the processing unit, and an LCD to display the test results.

II. METHODS

The system development process used in this study follows the Prototype Model, which is a method based on the concept of a working model [10]. The goal is to evolve the prototype into the final system. This approach allows for faster system development compared to traditional methods and is more cost-effective. The stages of the prototype model are illustrated in Figure 1.

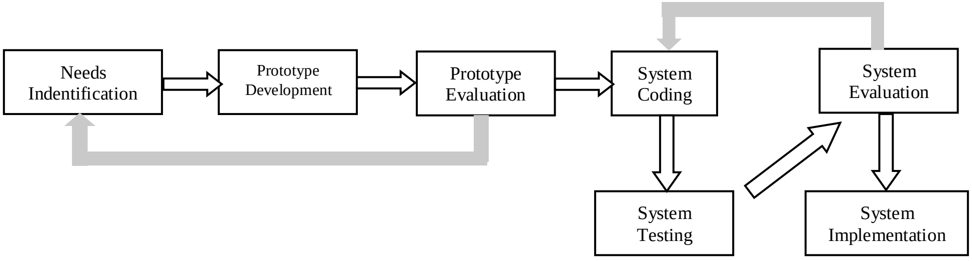

Fig 1. Prototyping Model

System Design

This device utilizes a photodiode sensor and an LED to automatically and rapidly detect human blood types using the ABO method. The sensor data is processed by an Arduino Uno, which is programmed to display the blood type test results on an LCD and print the outcome.

Supporting Device Design

The design of supporting components for the blood type detection device involves the development and integration of both hardware and software elements that enable the device's operation and functionality. These supporting components are engineered to ensure that the device operates effectively, delivers accurate results, and is user-friendly. The objectives of the supporting device design include accuracy and precision, ease of use, operational efficiency, portability, effective system integration, and ease of maintenance.

Device Design Diagram

The device design diagram is shown in Figure 2

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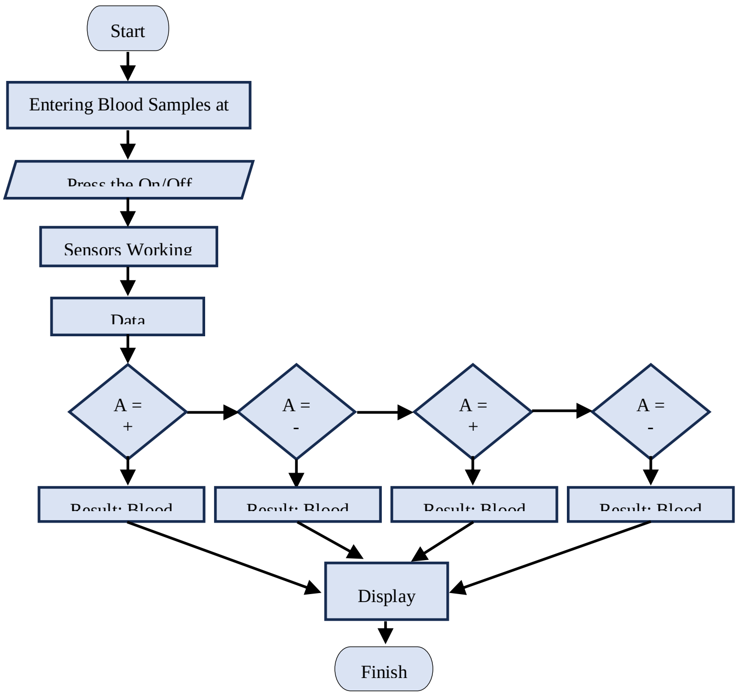

Fig 2. Program Design Diagram

Mechanical Diagram

Figure 3 presents a three-dimensional view of the blood type measuring device. The device is operated by pressing the power switch and inserting the blood sample data obtained from the health center laboratory. The sensor in the device processes the data, and the results can then be viewed on the display screen.

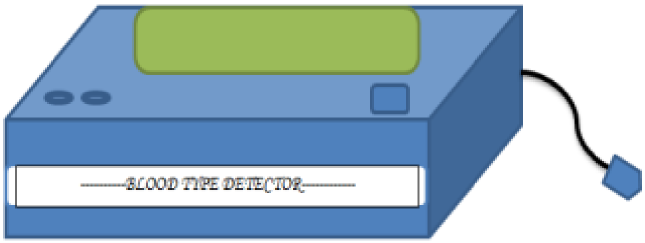

Fig 3. Three-dimensional view of the device

III. RESULT AND DISCUSSION

The Blood Type Detection Device

The physical appearance of the developed device is shown in Figure 4. The operation of the device can be explained as follows: first, press the switch to power on the device. Next, insert the prepared blood sample into the device. The system will then detect the blood type based on the inserted sample. It will identify whether the blood type is A, B, AB, or O, and display the result on the Liquid Crystal Display (LCD).

Fig 4. The view of Blood Typing Detector

Testing of the Blood Type Detection Device

System testing was carried out to determine whether the blood type detection device operates correctly. The testing process began with individual component testing and concluded with full system testing. Component testing allowed the researchers to verify the performance of each part used in constructing the Blood Type Detection System. This step helped ensure that all components function properly and meet the expected specifications.Figure 5 shows the testing of the photodiode sensor component. The test results indicate that the sensor has been successfully tested under light exposure. The greater the amount of light received by the photodiode, the higher the current generated.

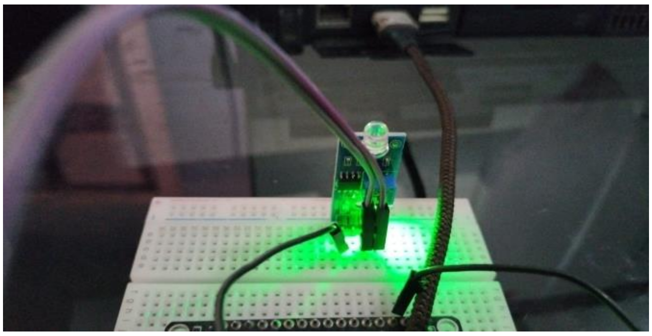

Fig 5. Photodiode Test Results

During the LED testing, the researcher activated all four LEDs to verify whether each one was functioning properly. The results of the LED test can be seen in Figure 6.

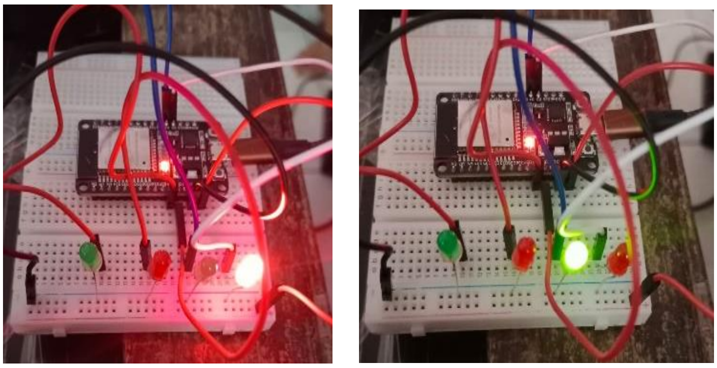

Fig 6. LED Test Results

Figure 7 shows the results of the overall testing of the blood type detection device. As seen in the figure, the output on the serial monitor indicates that the device perfoms very well in reading blood type samples accurately.

Fig 7. Hasil Pengujian Alat Pendeteksi Golongan Darah

Table of Blood Type Test Results

The testing was conducted on 45 blood samples. Each sensor was tested ten times to ensure consistency and accuracy. The data from the blood type sample testing is presented in Table 1.

Tabel 1. *Blood Type Test Results*

Blood Type	Number of Samples
A	12
B	9
AB	2
O	19

IV. CONCLUSION

Based on the design and testing results, it can be concluded that the blood type detection device is capable of performing identification quickly and efficiently without requiring high operational costs. Initial testing showed that the device can accurately and in real-time determine blood types A, B, AB, and O, supporting rapid decision-making in critical situations. This device can be used to detect human blood types in large quantities by utilizing a photodiode light sensor, without any capacity limitations. The measurement results are displayed directly on an LCD screen, providing immediate and easy-to-read feedback without the need for internet connectivity or external devices. The system is compact, portable, and user-friendly, making it highly suitable for use in field operations, mobile clinics, or basic healthcare units.

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