Design and Development of Esp32-Based Non-Invasive Blood Sugar Level Measurement Equipment

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Abstract: This research was conducted to produce a non-invasive blood sugar measuring device, which is a device that can measure blood sugar levels without having to test and examine the blood directly but using a finger attached to the sensor as a specimen, the Photoplethysmography (PPG) method is used in the design of the device system in this work is to measure blood sugar levels. The architecture of this system uses an easy-to-use and low-cost optical measurement technique. The ILI9488 LCD module also functions to display, in this study the results of the calculation of the average percentage error of the tool are 3.52% with a calculation that has an accuracy value of 95.48% from the actual tool. Judging from the calculation results, the percentage experienced a measurement error of 0% - 3.52% in 16 trials. Thus, this GlucoTest tool can only be used as a comparison of the sugar content of a glucometer in general. And it takes a lag time of 1 to 3 minutes for the same patient or respondent to take measurements again.

1 INTRODUCTION

Diabetes mellitus (DM) is a disease in which the amount of sugar in the blood is too high (hyperglycemia) due to the inability of the pancreas to produce insulin. When the pancreas cannot produce insulin, the body has difficulty maintaining blood sugar levels, resulting in high blood sugar levels or hyperglycemia. Diabetes is divided into type I diabetes and type II diabetes. Type I diabetes occurs when the body is unable to produce insulin, while type II diabetes occurs when the body is unable to receive and process insulin efficiently. This second can lead to obesity and lack of physical activity (F. Z. Kamilah et al.,2021).

In blood or serum there is a concentration of glucose called blood glucose, a normal limit for a person who has not eaten for 3 or 4 hours and then close to 90 milligrams or dl. Even though the consumption of foods that contain lots of carbohydrates, this focus does not often increase above 140 milligrams or dl, but the person has Diabetes Mellitus. Glucose that flows through the blood is an important base of energy for the body's cells. Blood glucose is sugar in the blood that is created from carbohydrate metabolism. Checking blood glucose is one of the checks in clinical trials (N. F. Fahmi et al., 2021)

Currently, the most commonly used tool to measure blood sugar levels is a blood glucose meter. Measurement of blood glucose levels was carried out using a glucometer which works enzymatically based on the glucose oxidase reaction. The glucose meter works on the principle of a biosensor. A biosensor is a combination of a biological receptor and a transducer. Bioreceptors are devices used to sense the concentration of biological elements, such as enzymes, antibodies, living cells, and other tissues. The function of the sensor is to convert biochemical signals into electrical signals, which then appear on the blood glucose meter screen (J Fine et al., 2021).

However, in taking blood samples, it is necessary to use a tool in the form of a syringe, although the process is carried out quickly but there are still many patients who are afraid of needles for taking blood samples. Therefore, an accurate blood glucose meter is needed without injuring the body first (non-invasive).

In this study, a tool was made to measure blood sugar levels without injuring the body. The device does not require urine as a test material to measure the patient's blood sugar level. This tool works on the principle that the photodiode sensor will capture light

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from a light source. used are LEDs. When the tool is turned on, the light from the LED will radiate and pass through the finger before reaching the photodiode. The intensity of light received by the photodiode changes from a factor of changes in the number of blood sugar molecules. The photodiode output signal will be processed on the ESP32. After the signal is processed by esp32, the patient's blood sugar value can be known. This blood sugar value is shown on the TFT LCD screen attached to Glucotest. The output of the tool includes the value of blood glucose levels and a description (low/normal/high) in units (mg/dl).

2 RESEARCH METHODS

This research was conducted in several locations, the place is in the electrical laboratory at the University of 17 August 1945, Jakarta to design a non-invasive blood sugar level measuring device based on esp32. And for sampling, the trial was carried out in the author's home area.

2.1 System Block Diagram Design Tool

The overall planning of the hardware block diagram made in this research is as follows:

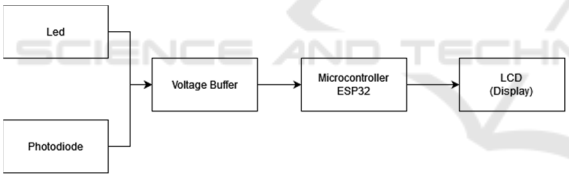

Figure 1. System Block Diagram.

In the block diagram, the output system of the photodiode will enter the microcontroller for processing and display

2.2 Sensor System Design

The design of this sensor system circuit uses a red LED as a light source and a Photodiode sensor as a receiver. With a schematic of the circuit as shown in Figure 2.

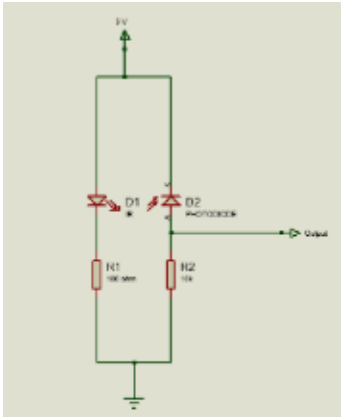

Figure 2: Sensor Circuit.

The resistance value of the resistor can be calculated using the formula:

$$R = \frac{V_S - V_L}{I} \quad (1)$$

$$R = \frac{V_S - V_L}{I}$$

$$R = \frac{5-1}{50\ mA} = 100\Omega$$

So the value of the resistor is considered to be 100Ω

where

R = current limiting resistor

v_S = 5v (tegangan Input)

v_L = 2v (Input voltage)

I = 50 mA = 0,05 A

2.3 Voltage Buffer Design

The voltage buffer circuit design stage is needed to stabilize the sensor reading value. In this circuit the components used are 538 op-amp and 10kΩ trimmer

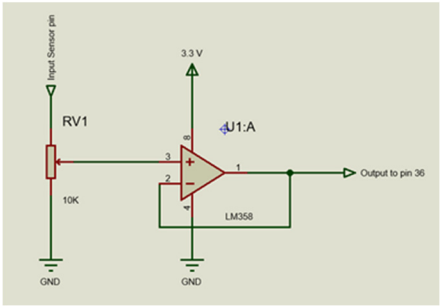

Figure 3. Voltage buffer Circuit.

This arrangement is very profitable because we can get an amplifier with very large input resistance (input impedance) and with very small output resistance (output impedance), which is close to

perfect conditions. As a result, an operational amplifier with a shape like the one in the picture above acts as a buffer with a gain = 1. The application of a good buffer arrangement made of a transistor amplifier or operational amplifier (Op-Amp) is usually used as a signal stabilizer.

2.4 Program Design

The software design stage begins with making a flowchart followed by making a lasting program using Arduino Uno. The software design flowchart is as follows:

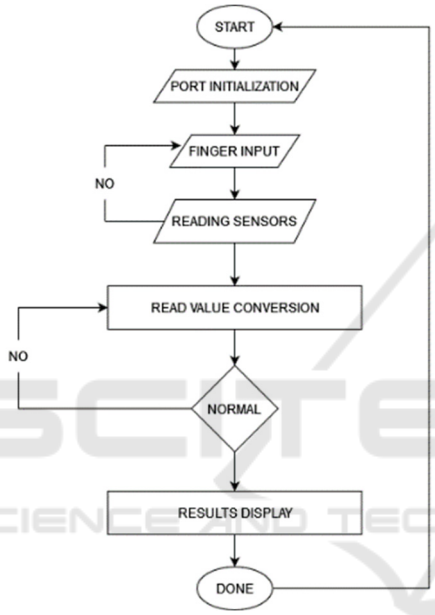

Figure 4: Flowchart Program.

When the start button is pressed, the program will start port initialization, if the sensor detects a finger, the program will read the sensor value, if the sensor does not detect a finger, the program will again ask for finger input, then if the value is obtained, the value will be converted and determined whether the blood sugar level is low, normal or height is then displayed on the LCD.

3 RESULTS AND ANALYSIS

This chapter discusses the results and systems that have been designed and built. It is designed to determine if the system meets the standards the author wants. Each block is tested with the aim of Knowing the work of each circuit block, making it possible to know whether each circuit module performs its function properly. Proceed with the overall test. The test of this tool consists of 7 main parts, namely:

1. Sensor Testing
2. Measurement Condition Testing
3. LCD Testing
4. Overall Tool Testing
5. Reading Value
6. Research Results.
7. Error Percentage.

3.1 Sensor Testing

In sensor testing, it is done by measuring the output voltage of the sensor when it is not blocked by a finger and when the sensor is blocked by a finger. The sensor measurement results can be seen in table 1.

Table 1: Sensor Measurement Results.

No	Condition	ADC	Output Voltage
1	Not blocked by fingers	470	1,51 V
2	Blocked by finger	878	2,83 V

In this test, the adc value is 470 when the sensor is not blocked by a finger and will produce an adc value of more than 470 when the sensor is blocked by a finger. This shows the sensor is functioning properly. According to the way the photodiode sensor works, the brighter the light, the smaller the sensor reading value. Conversely, the darker the light, the greater the sensor reading value.

3.2 Measurement Condition Testing

In this test, it is carried out by simulating two measurement conditions, namely when measuring in the dark (the instrument is in a closed condition) and when the instrument is in a light condition (the instrument is in an open condition). The results of this test can be seen from table 2.

Table 2. Testing Measurement Conditions

Condition	ADC	LUX	Tool Results	Glukometer Results
Dark conditions	788	281	94 mg/dL	98 mg/dl
Light Condition	920	680	165 mg/dL	

The results of these tests show that the darker the measurement conditions, the more accurate the measurement results, on the contrary, the brighter the measurement conditions, the more error the reading value will be.

3.3 LCD Testing

The ILI9488 TFT LCD test aims to find out whether the lcd can function properly. The use of pins on the ILI9488 TFT LCD, there are several pins that are used as data sender and data receiver pins, namely CS, RESET, DC/RS, SDI(MOSI), SCK pins. For the touchscreen pins, namely T_CLK, T_CS, T_DIN, TDO. and for power use the VCC, GND, and LED pins as the backlight power which is connected directly to the esp32 pin.

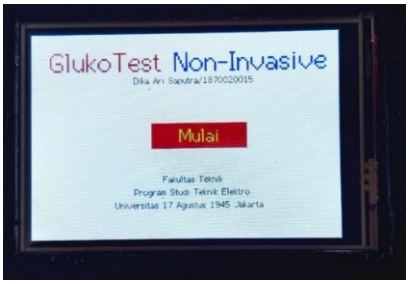

Figure 5: Tool Preview.

3.4 Overall Tool Testing

Overall system testing is carried out after testing in each part of the tool. The purpose of this test is to understand how the esp32-based non-invasive blood glucose meter works as shown in Figure 5. The whole system of the whole system

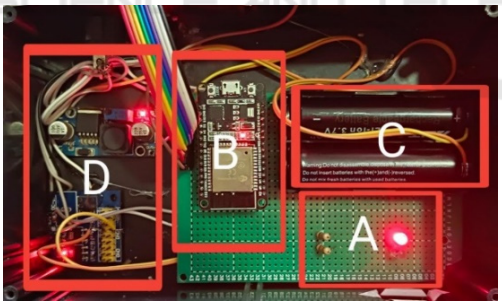

Figure 6: Overall System Circuit.

Block diagram A shows the sensor network, the output from the photodiode sensor is passed to pin A0 on the esp32,. Block B shows the overall picture of the esp32 network and input from the tft lcd module, .In block C there is a battery as a voltage source, and in block D is the power supply network.suplay.

Figure 7: Overall View of the Tool.

Figure 6 shows the overall shape of the finished tool, where all the components needed have been assembled into a single unit and the tool is ready to be used.

3.5 Reading Value Converter

The test between the 3 in 1 autocheck medical device and the tool made has a different display of measurement results so that conversion must be done in order to get good results, the adc value is obtained when taking measurements and then converted so that the measurement results displayed show the mg/dl value. this conversion is done withdengan

$$\text{Nilai Gula Darah} = \frac{ADC}{2} - 295 \quad (2)$$

The test results after conversion are obtained that are close to the 3 in 1 autocheck comparison tool. As shown in Figure 8.

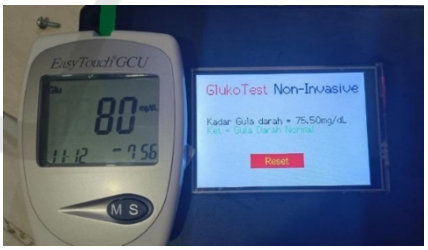

Figure 8: Measurement results.

3.6 Research Result

In this study, it was carried out by measuring ten respondents who would be measured using a tool that was made and simultaneously it would also be measured with a 3-in autocheck tool, the measurement data would be written into a table to find out the measurement error between the tool made and the tool used as a comparison. shown in table 3.

Table 3: Blood Sugar Level Measurement Results

No	ADC	Conversion Value (mg/dL)	Standard Value (mg/dL)
1	776	93	96
2	740	75	78
3	765	87,5	91
4	779	94,5	97
5	810	110	113
6	706	58	62
7	768	89	91
8	804	107	110
9	713	61,5	65
10	780	95	99
11	878	144	148
12	868	139	147
13	847	128,5	135
14	770	90	93
15	720	65	69
16	790	100	103

3.7 Persentasi Error

Table 4: Presentation Error.

No	ADC	Nilai Konversi (mg/ dL)	Nilai Standart (mg/dL)	Keakurasian
1	776	93	96	3,13%
2	740	75	78	3,13%
3	765	87,5	91	3,65%
4	779	94,5	97	2,60%
5	810	110	113	3,13%
6	706	58	62	4,17%
7	768	89	91	2,08%
8	804	107	110	3,13%
9	713	61,5	65	3,65%
10	780	95	99	4,17%
11	878	144	148	4,17%
12	868	139	147	4,17%
13	847	128,5	135	4,69%
14	770	90	93	3,13%
15	720	65	69	4,17%
16	790	100	103	3,13%

The results obtained from the overall instrument testing will be compared with the results obtained from the invasive blood sugar measuring instrument namely the glucometer so that the percentage error is obtained using the equation.

4 CONCLUSIONS

After carrying out the design and manufacture of the tool, which is then followed by the testing and analysis phase, the following conclusions can be drawn: Measurable blood sugar levels of 25-300mg/dLd, The resistance sensor used is sensitive to the state of the blood when it is fresh and accurate. reading persists 30 seconds after sensor reading, Judging from the results of the calculation of the percentage experienced a measurement error of 0% - 4.62% in 16 trials. Thus the tool cannot be used as a reference for measuring blood sugar values in the body. Judging from the results of the research, the tools made show that the 11th to 16th measurements show a decreasing accuracy. It takes a lag time of 1 to 3 minutes for the same patient or respondent to take measurements again.

REFERENCES

F. Z. Kamilah *et al.*, “Analysis of the Determinants of Diabetes Mellitus in Indonesia: A Case Study of the 2014 Indonesian Family Life Survey,” *Disease Prevention and Public Health Journal*, vol. 15, no. 2, 2021, doi: 10.12928/dpphj.v15i2.3079.

N. F. Fahmi, N. Firdaus, and N. Putri, “Article PENGARUH WAKTU PENUNDAAN TERHADAP KADAR GLUKOSA DARAH SEWAKTU DENGAN METODE POCT PADA MAHASISWA.”

J. Fine *et al.*, “Sources of inaccuracy in photoplethysmography for continuous cardiovascular monitoring,” *Biosensors*, vol. 11, no. 4. 2021. doi: 10.3390/bios11040126.