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Glucose level detection system in glucose solution using TCS3200 sensor with if-else method

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Abstract

Early and routine examination of glucose levels plays an important role in preventing and controlling diabetes mellitus and maintaining the quality of life. Checking blood sugar levels by hurting the body (invasive) can lead to infections caused by needles. As an alternative, the examination is carried out in a non-invasive way using excretory fluid in the form of urine, which is reacted with Benedict's solution that create a color change. Experts in the laboratory only carry out an examination using non-invasive methods because in determining glucose levels, it requires accuracy and eye health factors. Therefore, a glucose level detection system was created using a sample of glucose solution to determine the system's parameters using the if-else method. The glucose level detection system is conducted by mixing the glucose solution with Benedict's solution to produce a color change. Then the reaction results are read by the TCS3200 sensor and processed by Arduino to be classified, according to predetermined parameters. The decision results based on the classification of the glucose level parameters that have been determined are displayed on a 16x2 LCD. The results achieved in this study on 10 samples of glucose solution that were tested and processed by the if-else method were successfully read and classified based on predetermined parameters.

Keywords: Non-Invasive; Glucose Solution; TCS3200 Sensor; If-Else; Arduino

Introduction

Diabetes Mellitus (DM) is a metabolic disease with characteristics of hyperglycemia that occurs due to increased blood sugar (glucose) levels due to insulin deficiency or resistance in the body. It is still a serious threat to global health [1][2]. Early detection routinely plays an important role in controlling diabetes mellitus to avoid and maintain quality of life [3]. Examination by hurting the body (invasive) can lead to an infection caused by needles. As an alternative, non-invasive examination of blood sugar levels can use excretory fluid samples in the form of urine [4]. Experts in the laboratory only perform examinations using non-invasive methods because determining glucose levels requires accuracy and eye health factors [5][6].

By measuring glucose levels in urine samples using Benedict's solution as a reagent solution can produce the output of the reaction in the form of a color change [7]. The result of the chemical solution reaction produces a color change from clear blue to brick red depending on the glucose level in the urine sample [8], [9]. Measurement of glucose levels in 10 ml urine samples mixed with 5 ml of Benedict's solution then heated until the reaction produces a color change that can affect the light intensity of the TCS3200 sensor [10][11][12]. Based on research [9], the color parameters used to determine glucose levels are based on changes in the color of the Benedict's solution reaction as follows:

1. Negative: Clear blue or slightly greenish and slightly cloudy.
2. Positive 1: Green is slightly yellow and cloudy (glucose level = 0.5-1%).
3. Positive 2: Greenish yellow or cloudy yellow (glucose content = 1-1.5%).
4. Positive 3: Orange or cloudy brown (glucose level = 2-3.5%).
5. Positive 4: Brick red or cloudy red (glucose level > 3.5%).

Considering the significance of identifying color changes in the urine from the Benedict's solution reaction based on predetermined color parameters, this study will focus on making a glucose level detection system using a sample of glucose solution to achieve predetermined parameters using the TCS3200 sensor and processed by Arduino Uno with the if-else method. Then the processing results are displayed on a 16x2 LCD. The use of glucose solution samples in this study aims to identify the color changes of the reaction results according to the glucose level parameters using the TCS3200 sensor.

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Method

The object of this research is glucose solution of 0.2%, 0.5%, 0.7%, 1.0%, 1.1%, 1.5%, 2.0%, 2.5%, 3.5%, 5.0% which is used as a sample for testing glucose levels. The materials used in this study were glucose powder, distilled water, glucose solution, and Benedict's solution. Meanwhile, the tools used are the TCS3200 sensor as a color change reader [13][14][15], Arduino uno as a processor and sensor controller [16][17], a 16x2 LCD as a display of the results of data processing [18], a beaker glass as a container for Benedict's solution and glucose solution to be mixed. The system design is presented in a block diagram of a glucose level detection system in a glucose solution using a TCS3200 sensor with the if-else method shown in **Figure 1**.

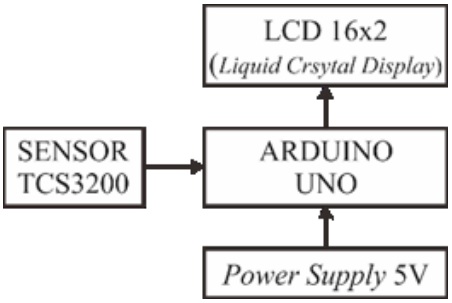


Figure 1. Block diagram of glucose level detection system

The measured variable is a 8-bit RGB value as a result of the conversion of the RGB frequency value from the TCS3200 sensor reading [19][20]. In this study, the RGB reading value of the change of color reaction is processed by Arduino Uno and compared with the parameters determined to classify glucose levels with the if-else method. This is carried out so that the output displayed can detect glucose levels in the glucose solution. While the flow chart or Flowchart in this study in controlling components and processing data using the if-else method is shown in **Figure 2**. There are several color conditions: clear blue, yellowish-green, greenish-yellow, orange-brown, and brick red. This color condition will decide the number of negative signs and the number of positive signs. The more negative or positive signs indicate the level of glucose in the solution

Based on the system block diagram, the components used in this study were assembled into a single system in order to detect glucose levels in glucose solutions. The design of the system wiring diagram for detecting glucose levels in glucose solutions is shown in **Figure 3**. The communication line between Arduino and LCD uses I2C communication lines. While the communication line between Arduino and the sensor uses an SPI communication line.

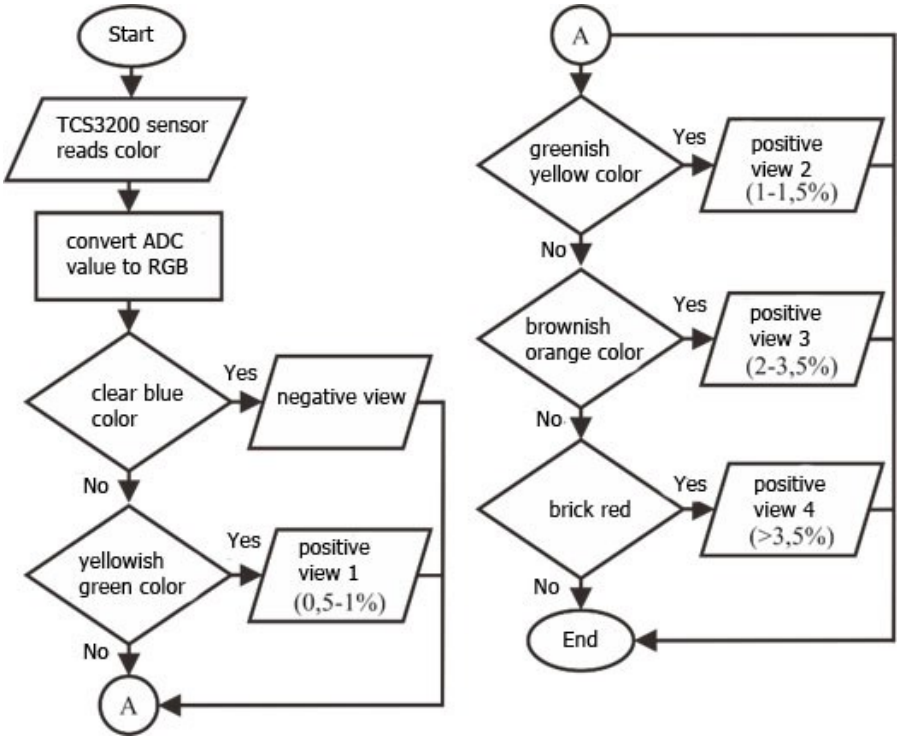


Figure 2. Flowchart of glucose level detection system

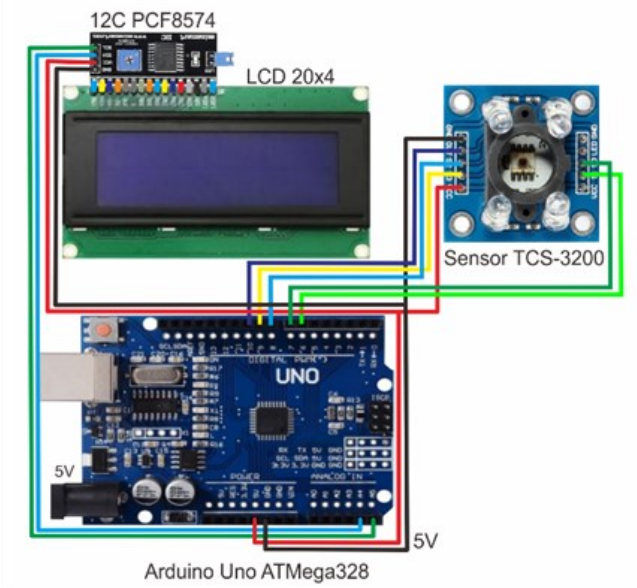


Figure 3. Wiring diagram of glucose level detection system

Results and Discussion

A. Censor Calibration Test TCS3200

In this study, the TCS3200 sensor calibration test serves to obtain an optimal 8-bit RGB value (0-255) resulting from the conversion of RGB frequency values from the reading of red, green, blue, black, and white media samples by the sensor. Therefore, in order to achieve the desired R, G, and B values, the RGB sensor frequency value is added to the mapping function in the program. The mapping function requires the smallest and largest values of the color media sample reading by the TCS3200 sensor with a 20% scaling setting to be converted to an 8-bit RGB value with a range of 0 to 255. The results of the color media reading by the sensor are listed in **Table 1**.

Table 1. Results of reading colored media samples

Color	Description	Scaling 20%		
		R	G	B
Red	Min	63	182	117
	Max	70	189	125
Green	Min	133	120	127
	Max	140	125	131
Blue	Min	196	90	47
	Max	200	97	54
White	Min	27	21	18
	Max	28	27	19
Black	Min	224	229	157
	Max	231	236	164
	Min	63	90	47
	Max	200	189	131

Based on the tests that have been conducted, the use of 20% scaling produces a medium RGB value range that is not too high or low, quite stable, and quite optimal in the color reading process by the TCS3200 sensor. In Table 1 the test results get the results of the minimum and maximum values of R (63, 200), B (90, 189), G (47, 131). The RGB frequency value that has been obtained was converted to RGB using the mapping function in the program as follows.

$$\text{redColor} = \text{map}(\text{redfrequency}, 63, 200, 0, 255) \quad (1)$$

$$\text{greenColor} = \text{map}(\text{greenfrequency}, 90, 189, 0, 255) \quad (2)$$

$$\text{blueColor} = \text{map}(\text{bluefrequency}, 47, 131, 0, 255) \quad (3)$$

After adding the mapping function command to the program, the TCS3200 sensor reads back the color media sample. In the red, green, and blue media samples, the converted RGB values are quite close to the primary color parameter values. Meanwhile, in black and white media samples, the converted RGB values are in line with the primary color parameter values. The results of the conversion of RGB sensor readings to the sample are in **Table 2**.

Table 2. TCS3200 censor calibration test

Primary Color Parameter Value					20% Scaling Mapping Results		
Color	**R**	**G**	**B**		**R**	**G**	**B**
Red	255	0	0		255	8	16
Green	0	255	0		109	226	9
Blue	0	0	255		22	110	214
White	255	255	255		255	255	255
Black	0	0	0		0	0	0

B. Glucose Solution Test

In testing the glucose solution, the materials used were glucose powder, distilled water, and Benedict's solution. This test aims to determine the RGB value of the color change of the appropriate solution reaction as a parameter for measuring glucose levels in urine. The glucose levels in the 20ml glucose solution sample to be tested were 0.2%, 0.5%, 0.7%, 1.0%, 1.1%, 1.5%, 2.0%, 2.5%, 3.5%, and 5.0%. The glucose solution test was carried out in two stages. The first stage was making a 20ml glucose solution sample with the glucose level to be tested. Then in the second stage, the glucose solution was tested. The glucose solution sample that had been made was flowed with 10 ml of Benedict's solution to be mixed by heating and stirring until it got a color change. After that the reaction results were cooled for 3 minutes and then read by the TCS3200 sensor.

The first stage of testing the glucose solution is to make a sample of glucose solution with glucose levels of 0.2%, 0.5%, 0.7%, 1.0%, 1.1%, 1.5%, 2.0%, 2 .5%, 3.5%, and 5.0% as much as 20ml per sample. In making a sample of glucose solution with a predetermined glucose level, it is necessary to calculate the percent concentration of glucose to get the mass of glucose powder to be dissolved in 20 ml of distilled water. Calculation of percent concentration to determine glucose levels in glucose solution samples using equation (1).

$$m\ solute = \frac{(\%W/V)\ solute}{100\%} \times V\ solution \quad (1)$$

Description m is the mass of glucose powder (gr), (%W/V) solute is the concentration of glucose (%) and V of $Solution$ is Aquadest or distilled water (ml)

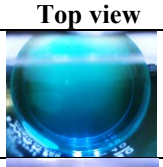
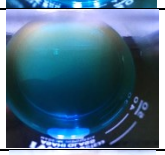
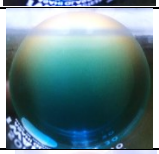
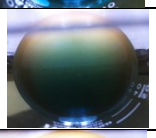
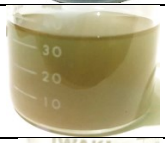
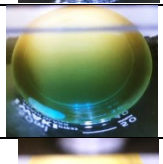
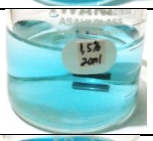
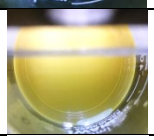
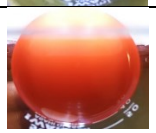
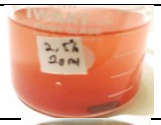
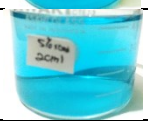
The results of calculating the percentage of glucose concentration in the glucose solution samples to find the mass value of glucose powder based on equation (1) are shown in Table 3. After calculating the mass requirement needed to make glucose levels in the glucose solution sample, then the glucose powder was weighed according to the calculation results from equation (1) in **Table 3**. The weighed glucose powder was then dissolved by distilled water with a volume of 20 ml. After making a glucose solution sample with a predetermined glucose level, the glucose solution sample was given 10 ml of Benedict's solution.

Table 3. The results of the calculation of glucose powder mass.

No.	Glucose level (%)	Aquades Volume (ml)	mass of glucose powder (gr)
1.	0.20	20	0.04
2.	0.50		0.10
3.	0.70		0.14
4.	1.00		0.20
5.	1.10		0.22
6.	1.50		0.30
7.	2.00		0.40
8.	2.50		0.50
9.	3.50		0.70
10.	5.00		1.00

In the second stage of testing the glucose solution, a sample of glucose solution that has been given Benedict's solution was heated and stirred until it produces a color change. Then it was cooled for 3 minutes and the beaker was put into the glucose level detector room for color readings by the TCS3200 sensor. Photos of the changes of the color reaction results in the glucose solution test are in **Table 4**.

Table 4. Sample photo of the change of color reaction result

No.	Glucose solution	Photo Before Processed	Photo After Processed	
			Front look	Top view
1.	0.2%			
2.	0.5%			
3.	0.7%			
4.	1.0%			
5.	1.1%			
6.	1.5%			
7.	2.0%			
8.	2.5%			
9.	3.5%			
10.	5.0%			

After reading by the TCS3200 sensor, the read RGB value data was classified by the if-else method based on predetermined parameters. Then the color change of the reaction results was re-read by the TCS3200 sensor and the results are displayed on the LCD. The results of testing glucose solutions with 10 different types of glucose levels are shown in **Table 5**.

Table 5. Test results of glucose solution

No.	Glucose solution	Temperature (˚C)	Reading Result				Decision
			R	G	B	Color	
1.	0.2%	43.9	67	200	150		-
2.	0.5%	42.3	80	224	86		+
3.	0.7%	45.2	60	133	0		+
4.	1.0%	44.2	118	140	0		+
5.	1.1%	44.7	167	194	2		++
6.	1.5%	43.7	208	208	2		++
7.	2.0%	43	225	138	9		+++
8.	2.5%	44.2	214	116	8		+++

No.	Glucose solution	Temperature (˚C)	Reading Result				Decision
			R	G	B	Color	
9.	3.5%	42.9	144	104	24		+++
10.	5.0%	43.5	151	52	7		++++

Based on Table V, the test results of glucose solution samples 0.2%, 0.5%, 0.7%, 1%, 1.1%, 1.5%, 2%, 2.5%, 3.5% , and 5% , the results of changes in the color of the glucose solution sample in this test which were read by the TCS3200 sensor have met the parameter criteria that have been set. Changes in the color of the reaction results that have been classified resulted in a decision that a 0.2% glucose solution indicates a negative glucose level. 0.5%, 0.7%, and 1.0% glucose solutions resulted in a positive decision of 1 (0.5-1.0% glucose level). Glucose solutions of 1.1%, and 1.5% yielded a positive result of 2 (1.0-1.5% glucose level). 2.0%, 2.5%, and 3.5% glucose solutions resulted in a positive result of 3 (2.0-3.5% glucose level). A 5.0% glucose solution resulted in a positive result of 4 (>3.5% glucose level). Heating process is carried out to mix the Benedict's solution to the glucose solution until it creates a color change at a temperature of 42.3-45.2˚C.

Conclusion

Based on the research and discussion results, it can be concluded that the glucose level detection system in glucose solution using the TCS3200 sensor with the if-else method can read the color changes of the reaction results. It also can make the decisions according to the parameters that have been set. To implement the glucose level detection system, it is necessary to develop detecting glucose levels in the urine for early detection of diabetes mellitus.

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