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Design of a Blood Pressure Measurement System Equipped with Voice Information and Measurement Memory

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ABSTRACT Blood pressure is a vital indicator for assessing a person's cardiovascular health. Conventional digital blood pressure monitors still have limitations, particularly for lay users, the elderly, and people with visual impairments, as measurement results are only displayed numerically. This study presents the design of a digital blood pressure measurement system equipped with voice input and memory for storing measurement data. The system utilizes an MPX5050GP pressure sensor, an Arduino Mega 2560 microcontroller, an oscillometric method, a DF Player Mini audio module, and a graphical LCD display. Testing was conducted using the NIBP Simulator at five blood pressure levels: 80/50 mmHg, 100/65 mmHg, 120/80 mmHg, 150/100 mmHg, and 200/150 mmHg, with 30 repetitions. The research results show that the device is capable of measuring blood pressure with an accuracy of 92.63% systolic and 92.66% diastolic, displaying blood pressure classifications (hypotension, normal, and hypertension), providing voice information, and storing up to 100 measurement data. Thus, the designed system can improve user convenience, accessibility, and understanding in self-monitoring blood pressure.

INDEX TERMS blood pressure, digital sphygmomanometer, voice information, oscillometric method, measurement memory.

I. INTRODUCTION

Blood pressure is one of the body's indicators that is often measured in health checks[1]. Blood pressure measurement will provide important information about the patient's cardiovascular status and response to activity. Age is one factor that influences blood pressure. As we age, normal blood pressure increases. This is because the walls of the left ventricle and *corpus callosum* thicken and the elasticity of blood vessels decreases with age, which makes the heart work harder[2]. There are two types of blood pressure measurements: systolic and diastolic. Systolic blood pressure occurs when the heart contracts and pumps blood into the arteries, when the pressure in the arteries reaches its highest point. Diastolic blood pressure, on the other hand, is the blood pressure when the heart is at rest, when the pressure in the arteries reaches its lowest point[3], [4].

According to the National Guidelines for Medical Services for the Management of Adult Hypertension, an increase or decrease in blood pressure outside the normal range can indicate pathological conditions such as hypotension or hypertension[5], [6]. Hypertension is an increase in systolic blood pressure of more than or equal to 140 mmHg and diastolic blood pressure of more than or equal to 90 mmHg[7]. Low blood pressure or hypotension occurs when blood pressure is less than 90/60 mmHg[8].

A sphygmomanometer is a device used for early detection of a patient's blood pressure health[9], [10]. Blood pressure measurement can be done using two approaches: invasive and non-invasive[5]. Invasive methods involve measuring blood pressure directly through methods that penetrate the skin, while non-invasive methods refer to measuring blood pressure without skin penetration or physical injury. The oscillometric method is a non-invasive method that uses a pressure sensor connected to a cuff and can measure cuff pressure to detect blood vessel pulses[11][12]. The latest technological developments have given birth to digital tensiometers based on pressure sensors that can measure blood pressure automatically and display it on an LCD screen[13], [14], Pressure sensors such as the MPX5050GP convert cuff pressure into an analog electrical signal suitable for digital processing [15]. Although digital devices are more practical where systolic and diastolic pressures are displayed on the LCD screen, the examiner himself cannot yet know whether he is hypotensive (low blood pressure), normal or hypertensive (high blood pressure) due to a lack of understanding of the conversion of the systolic and diastolic values obtained and also the public still experiences obstacles, such as difficulty reading the results for the elderly or people with visual disabilities, as well as a lack of intuitive feedback for lay users.

Based on previous research conducted by Brilian Aulia in 2022 entitled Arduino Uno-Based Digital Blood Pressure Monitoring System Simulation with MPX5050GP Pressure Sensor where the researcher tested the sensor using TinkerCaD with the main component MPX 5050 GP. In the above study, it was not equipped with a sound sensor that provides information about systolic and diastolic blood pressure. Likewise, research conducted by Puji Supriyanto in 2024 entitled Design of a Digital Tensimeter Based on the Oscillometric Method Equipped with Sound Output where the researcher used an MPX 5050 GP sensor whose measurement results were displayed on the screen and sound on the speaker. In the above study, it was not equipped with measurement information whether the measured blood pressure was classified as hypotension, normal or hypertension and could not save measurement data.

II. METHOD

This study used an applied experimental research design with a quantitative approach, focusing on the development and performance evaluation of a digital blood pressure measurement system. The researchers designed, built, and tested a digital blood pressure measurement system. Testing was conducted by comparing the device's measurement results with a standard NIBP simulator.

A. RESEARCH DESIGN

The research stages in designing a blood pressure measurement system equipped with voice information and measurement memory are illustrated in the flowchart in Figure 1.

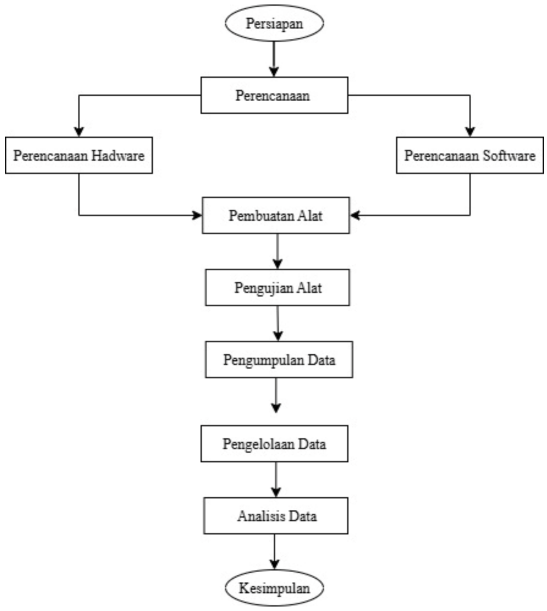

Figure 1. Research flowchart illustrating the sequential steps performed in the research

As shown in Fig 1, the process begins with preparation, including problem identification, a literature review, and goal formulation. Then, hardware and software planning is carried out. The next step is to build the instrument by assembling and programming it according to the mechanical, physical, and electronic circuit designs. Testing is then conducted to ensure the instrument's performance and accuracy. Once the system is functioning properly, the next step is to collect and process data, perform analysis, and draw conclusions.

B. BLOK DIAGRAM

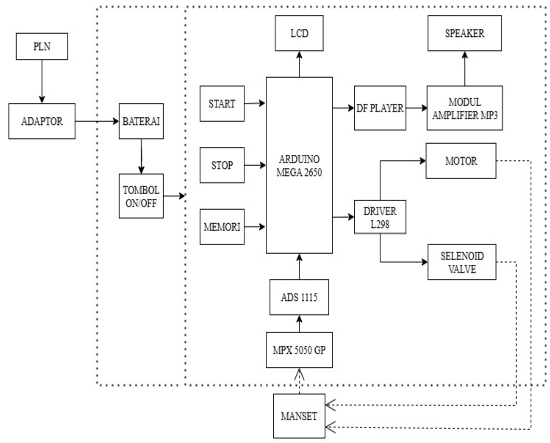

Figure 2. Block diagram of the design of a blood pressure measurement monitoring system equipped with audio information and measurement memory.

Fig. 2 shows a block diagram of the circuit where the adapter is connected to the electrical network as a voltage source. The adapter acts as a voltage reducer and regulator, and also serves to charge the battery. The battery is used as a backup power source to ensure the device remains operational when disconnected from the electrical network.

System operation is controlled via the ON/OFF button, as well as the START, STOP, and MEMORY buttons for user input. The entire system is controlled by an Arduino Mega 2560 microcontroller, which serves as the data processing center and controller for the input and output components.

When the ON/OFF button is pressed, the device turns on. Pressing the START button begins the measurement. During the measurement process, the motor pumps air into the cuff while the solenoid is off. The air pressure in the cuff is detected by the MPX5050GP pressure sensor, which generates an analog signal. This signal is then converted to digital data using the ADS1115 module before being processed by the Arduino Mega 2560. Based on the received pressure data, the microcontroller controls the L298 driver to regulate the operation of the air pump motor and solenoid valve. The pump motor fills the cuff with air, while the solenoid valve regulates the release of air during the measurement process. When the STOP button is pressed, the Arduino Mega commands the motor/solenoid valve to stop working via the L298 driver.

The processed pressure data is displayed on the LCD screen as visual information for the user. Additionally, the system is equipped with an MP3 module and an MP3 amplifier module controlled by the Arduino to output audio information through the speaker. When the start button is pressed, the Arduino stores the measurement data, and when the stop button is pressed, the device returns to perform the next measurement. When the memory button is pressed, the Arduino Mega displays the stored measurement data on the LCD screen.

C. FLOWCHART PROGRAM

In Fig.3, The LCD will light up when the device is turned on and begins initialization. When this happens, the device will command to press start. The device will begin the working process when the start button is pressed. The solenoid will close the exhaust port while the device is in use, and the motor will pump air pressure. As a result, the sensor will measure the pressure pumped by the motor.

When the sensor detects a pressure of 200 mmHg, the motor will turn off, the solenoid will partially open to gradually release the pressure, and the pressure sensor will measure the amount of pressure released. The pressure sensor measures slowly during the air release process. When the first vibration surge is detected, it determines the systolic pressure; when it detects the weakest or second vibration pulse, it determines the diastolic pressure. Once the systolic and diastolic pressures are reached, the solenoid will turn off and fully open the exhaust port, releasing the remaining air pressure. Then the systolic and diastolic data are processed, after which the LCD displays the systolic and diastolic values and measurement classifications, and the speaker will emit a recorded sound from the results of the blood pressure classification into hypertension, normal, and hypotension. Next, the measurement data is saved or not? If saved, the memory will store the measurement data, completing the measurement process. If not saved, the instrument will immediately complete the measurement

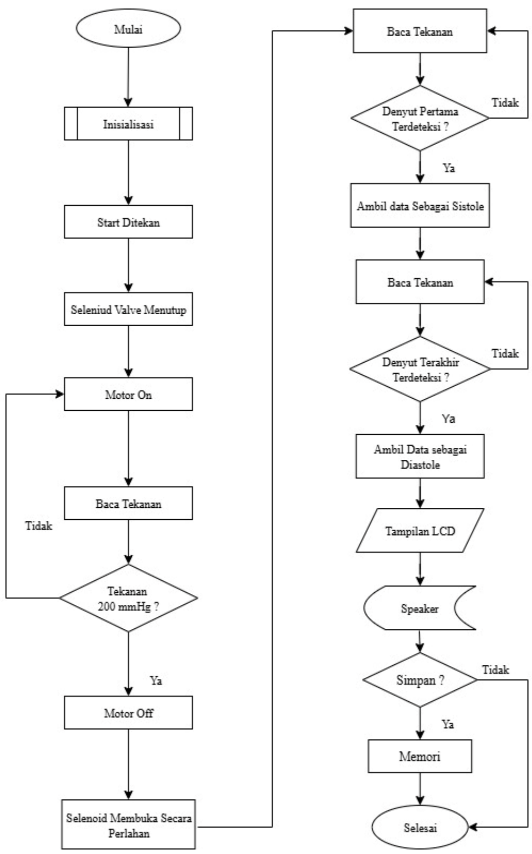

Figure 3 Flowchart for the design of a blood pressure measuring device equipped with audio information and measurement memory.

D. DATA COLLECTION TECHNIQUES

Once the device is designed according to plan, the next step is to collect or capture data. The data collection process involves measuring blood pressure directly on the module and comparing the results with those from the NIBP Stimulator, which indicates the module is functioning properly. There are five measurement points in the accuracy data: 80/50 mmHg, 100/65 mmHg, 120/80 mmHg, 150/100 mmHg, and 200/100 mmHg. Each measurement point will be tested 30 times.
The analysis technique used is the following formula:

Average value (mean)

$$\bar{x} = \frac{\sum xl}{n} \quad (1)$$

Error Value

$$Error = \bar{x} - p \quad (2)$$

Percentage Error Value

$$Error = \frac{Error}{p} \text{X } 100\% \quad (3)$$

Accuracy Percentage Value

$$\%Akurasi = 100\% - \%\ error \quad (4)$$

III. RESULTS

A. PHYSICAL APPEARANCE OF THE TOOL

Figure 4 Front view of the finished device, already equipped with a monitor or LCD screen.

Fig. 4 shows the design of a blood measurement system equipped with audio information and measurement memory. The device is encased in a white casing to protect its internal components. Equipped with an adapter that functions to change AC voltage to DC voltage, the ON/OFF button functions to turn the device on and off, the LCD display functions to display all measurement data results, the cuff functions to hold pressure on the arm, the speaker functions to output audio, the start button functions to start measurements and view previous measurement history, the stop button to stop measurements and return to measurements after viewing measurement history and the memory button to view saved measurement results and view the latest measurements.

Figure 5 Initial Display of LCD Screen on blood pressure measurement system design equipped with audio information and measurement memory

Fig. 5 shows the lcd screen displaying system status information, including the text "READY TO MEASURE," indicating that the device has completed the initialization process and is ready for use. The screen also displays the [start] and [memory] history function options, which are used to initiate the measurement process and access the measurement data stored in the device's memory.
At the bottom of the panel are three push buttons labeled start, stop, and memory. The start button is used to start the blood pressure measurement process, the stop button is used to manually stop the measurement process if necessary, and the memory button is used to recall previously saved measurement results.

C.TEST RESULT DATA

After completing the training and validation process, system performance was evaluated using a calibration tool, the NIBP Simulator. Testing was performed 30 times to ensure device reliability. Five blood pressure conditions were used as reference parameters with the NIBP Simulator: hypotension (80/50 mmHg), normal (100/65 mmHg and 120/80 mmHg), and hypertension (150/100 mmHg and 200/150).

Table 1 presents the results of testing the performance of the blood pressure measurement module using the BP Simulator at various systolic and diastolic pressure settings. The parameters analyzed included the mean, absolute error, percentage error, and accuracy levels for systolic and diastolic pressures.

At the 80/50 mmHg setting, the module produced an average systolic value of 78.1 mmHg with an error of 1.9 mmHg (2.38%) and an accuracy of 97.63%. For diastolic pressure, the average value was 49.73 mmHg with an error of 0.27 mmHg (0.53%) and an accuracy of 99.47%.

These results demonstrate excellent accuracy at low pressures.

TABEL I
ANALYSIS VALUES AT 80/50 MMHG, 100/65 MMHG, 120/80 MMHG, 150/100 MMHG AND 200/150 MMHG WERE TAKEN IN 30 MEASUREMENTS.

Setting BP Simulator (mmHg)		Hasil Pada Modul							
Sistolik	Diastolik	Sistolik				Diastolik			
		Mean	Error	Error %	Akurasi %	Mean	Error	Error (%)	Akurasi (%)
80	50	78,1	1,9	2,38	97,63	49,73	0,27	0,53	99,47
100	65	96,33	3,67	3,67	96,33	65,87	0,87	1,33	98,67
120	80	118,8	1,2	1	99	82,8	2,8	3,5	96,5
150	100	144,7	5,3	3,53	96,47	101,07	1,07	1,07	98,93
200	150	147,4	52,6	26,3	73,7	104,57	45,43	30,29	69,71

At the 100/65 mmHg setting, the average systolic reading was 96.33 mmHg with an error of 3.67 mmHg (3.67%) and an accuracy of 96.33%. The diastolic reading was 65.87 mmHg with an error of 0.87 mmHg (1.33%) and an accuracy of 98.67%. The module still demonstrated stable performance with an accuracy above 95%.

Tests at 120/80 mmHg yielded an average systolic reading of 118.8 mmHg with an error of 1.2 mmHg (1%) and a maximum accuracy of 99%. However, the diastolic reading yielded a larger error of 2.8 mmHg (3.5%) with an accuracy of 96.5%, although this is still within acceptable accuracy limits.

At the 150/100 mmHg setting, the average systolic reading was recorded at 144.7 mmHg with an error of 5.3 mmHg (3.53%) and an accuracy of 96.47%. Meanwhile, the diastolic reading showed an average reading of 101.07 mmHg with an error of 1.07 mmHg (1.07%) and an accuracy of 98.93%. These results indicate that the module still performs well at high pressures.

Conversely, at the extreme 200/150 mmHg setting, the module's performance decreased significantly. The average systolic reading reached only 147.4 mmHg with an error of 52.6 mmHg (26.3%) and an accuracy of 73.7%. The diastolic reading resulted in an error of 45.43 mmHg (30.29%) and an accuracy of 69.71%. This indicates that the module is less than optimal for use in very high blood pressure ranges. The cause is the manual valve installed on the device which causes the motor to be unable to pump up to 200 mmHg.

Overall, the test results show that the module has a good level of accuracy in the normal to moderate hypertension blood pressure range, but experiences a significant decrease in accuracy at very high blood pressure.

For audio information on each measurement result, the device can provide audio information regarding blood pressure classification results according to guidelines. Hypertension is an increase in systolic blood pressure of more than or equal to 140 mmHg and diastolic blood pressure of more than or equal to 90 mmHg[7]. Low blood pressure or hypotension occurs when blood pressure is less than 90/60 mmHg[8].

For storage memory, this blood pressure measuring device is capable of storing data up to 100 times.

Figure 6 **Memory storage display image no.1**

Fig. 6 shows the device's memory display. At the top of the screen, "MEMORY - 1/100" is written, indicating that the currently displayed measurement is the first measurement out of a total storage capacity of 100. This feature indicates that the device is equipped with an internal storage system to record blood pressure measurements sequentially.

The value of 73/47 mmHg displayed in the center of the screen represents the blood pressure measurement, with 73 mmHg representing the systolic pressure and 47 mmHg representing the diastolic pressure.

At the bottom of the screen, the date and time of the measurement are displayed: January 12 at 11:27 AM, which serves as a time stamp for each stored measurement.

Fig. 7 displays "MEMORY – 100/100," indicating that the data currently displayed is the 100th measurement data out of a total storage capacity of 100 data. Because the data is full for subsequent storage, it will automatically delete the first storage of the stored measurement.

Figure 7. **Image shows memory storage no.100**

IV. CONCLUSION.

Based on the testing conducted, the following conclusions can be drawn: This study successfully designed a blood pressure monitoring system that provides audible information on whether the measured blood pressure is low (hypotension), normal, or high (hypertension) based on the systolic and diastolic readings. This device can also store up to 100 measurement results.

In module testing using the NIBP Simulator, the systolic pressure test results achieved an average accuracy of 92.63%. The average diastolic accuracy percentage was 92.66%. This indicates that the device is reliable enough to detect blood pressure conditions, although the measurement accuracy at 200/150 mmHg still needs to be improved in further development.

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