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DIGITAL WRIST SPHYGMOMANOMETER WITH AUDIO ALERTS FOR ABNORMAL BLOOD PRESSURE DETECTION

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ABSTRACT Monitoring blood pressure regularly is essential for the early detection of abnormalities such as hypertension and hypotension. This study presents the design and development of a wrist-based digital sphygmomanometer equipped with an audio alert system to indicate abnormal blood pressure conditions. The device uses an MPS20N0040D-S pressure sensor to measure cuff pressure, controlled by an Arduino Nano microcontroller, and displays the measurement results on a Nextion LCD. A buzzer is integrated as an audio indicator when systolic or diastolic values exceed predefined thresholds. Performance evaluation was conducted by comparing the device readings with a calibrated NIBP simulator under three conditions: low, standard, and high blood pressure. The results show an average accuracy of 93.66% for systolic pressure, 83.29% for diastolic pressure, and 99.47% for heart rate (BPM). These findings demonstrate that the proposed wrist-based sphygmomanometer can serve as a practical and accessible tool for preliminary blood pressure monitoring.

INDEX TERMS Blood, Blood Pressure, Digital Sphygmomanometer, MPS20N0040D-S, Arduino Nano, Buzzer.

I. INTRODUCTION

Blood is a high-level fluid that delivers substances and oxygen needed by body tissues, transports chemicals from metabolism, and serves as the body's defense against viruses and bacteria. Human blood is a tissue fluid of the body. Its primary function is to transport oxygen to cells throughout the body. Blood also supplies the body with nutrients, transports metabolic waste products, and contains components of the immune system that defend the body against various diseases, including *hypertension [1].*

High blood pressure is one of the risk factors for heart attack, heart failure, stroke, and *arterial aneurysm*, and is a leading cause of chronic heart failure. Meanwhile, hypotension is a condition in which a person's blood pressure is below normal limits. This condition is the opposite of hypertension or high blood pressure. This low blood pressure can occur as a health disorder on its own or as a symptom of certain diseases, such as dengue fever. If blood pressure is very low, blood flow throughout the body can be blocked, which can lead to complications from certain diseases, such as heart problems and strokes. However, the possibility of high or low blood

Pressure can be avoided as early as possible by conducting periodic blood pressure checks with a sphygmomanometer [2]. Even though each part of the body has the same blood pressure, measurements are taken in sensitive areas to facilitate the procedure. Sensitive areas often used for measurement include the chest, wrists, and upper arms. Based on the method used, sphygmomanometers can be divided into two categories: Korotkoff and oscillometry.

The Korotkoff method uses a stethoscope to listen for the heartbeat sound at the cuff during a measurement. The oscillometry method uses sensors to determine systolic and diastolic values more practically [3]. Blood pressure is usually described as the ratio of systolic pressure to diastolic pressure. Human blood pressure is measured by two main parameters, namely systolic and diastolic pressure. Systolic blood pressure is the blood pressure that occurs when the heart muscle contracts. Diastolic blood pressure is the blood pressure that occurs when the heart does not contract[4].

BPM or *Heart Rate* is a representation of the pulse rate per unit of time of an object. *Heart rate* is a health parameter related to the cardiovascular system. The number of heartbeats per minute can reflect a person's physiological condition, such as activity level, stress, and sleepiness. Pulse is the number of times an artery (a clean blood vessel) expands and contracts in a minute in response to a heartbeat. The number of pulses is equal to the heart rate. This is because heart contractions increase blood pressure and pulse in the arteries. Measuring pulse is the same as measuring heart rate [4]. The number of pulses a person has can differ from that of others. A low pulse rate usually occurs at rest and increases with exercise [6]. Pulse measurements can be performed using a variety of methods, such as manual palpation, pulse oximetry, mobile apps, and wearable devices.

Hendrayana et al (2016) stated that there are two types of sphygmomanometers: invasive and non*invasive* [5]. When the cuff presses against the arm, the blood vessels will be partially closed. When the heart pumps, blood pressure rises slightly in the closed area, and then vibrations will appear in the air inside the cuff. Oscillations are small air-pressure fluctuations in the cuff that occur as the heartbeat resumes when cuff pressure is released [4]. The systolic point is determined from the moment the vibration amplitude (oscillation) begins to appear and reaches about 50% of the maximum amplitude before the MAP (*Mean Arterial Pressure*) point.

Meanwhile, the diastolic point is determined from the moment the amplitude decreases to about 70–80% of the maximum amplitude after passing the MAP. Differences in diastolic values with calibration settings often occur because the amplitude waveform is not always perfect, e.g., it decreases too quickly or too slowly, so the diastolic detection point shifts. This can be caused by cuff tightness, hand position, movement during measurement, or blood vessel characteristics, leading to measured results that may differ from formal calibration values [4].

Based on the previous explanation, a study was conducted to design an automatic, noninvasive blood pressure-measuring device using the oscillometry method to assist doctors in diagnosing patients. This design measures the patient's systolic and diastolic blood pressures and heart rate in a noninvasive, simple, fast, and easy way. The device uses a cuff with a diameter of 13.5 to 19.5 cm, which is placed on the wrist to capture the pulse, connected to a motor pump and a valve [6]. The hardware is the physical form in the design of this final project, consisting of a sensor circuit, an Arduino Nano microcontroller [7], [8], MPS20N0040D-S Sensor [13], an Nextion LCD [14], a power supply from ION 18650 Lithium Battery [4], a DC-DC *Step down* module LM2596 [15], and a buzzer [16].

In a study on Self Wrist Digital titled "Design of an Automatic Blood Pressure Measuring Device on the Wrist using Oscillometry Method Based on Arduino Mega 2560" (Aditya, Munawar Agus Riyadi, and Drajat, 2016), the research still uses a 20x4 LCD to display systole and diastole values, where the LCD is not yet a touchscreen. In the study, an Arduino Mega 2560 was used as the microcontroller, and an instrument amplifier, INA125P, was used to amplify the voltage output from the pressure sensor [8].

II. RESEARCH METHODS

A. RESEARCH DESIGN

The research stages in developing the wrist sphygmomanometer prototype are illustrated in the flowchart in Fig. 1. The process begins with a literature study and problem formulation, followed by system design, hardware and software development, and prototype assembly. The device is then tested to determine whether the output matches the expected results. If the output is not as expected, improvements are made, and the tool is retested. Once the system functions as intended, data collection, analysis, and conclusion drawing are carried out until the research is completed.

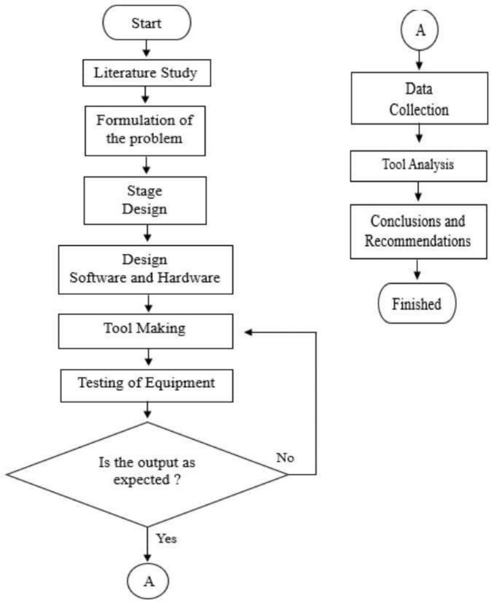

Figure 1. Research flowchart illustrating the sequential steps performed in the research. If any step does not meet expectations, the process is repeated until the desired results are achieved.

B. DESIGN PLANNING OF THE DEVICE

Fig. 2 shows a 3-dimensional design of the tool. The following is an explanation of the letters in the figure:

A. The 2.4-inch Nextion LCD serves as the main screen for the touch panel and displays the measurement result.
B. A cuff to measure blood pressure by applying pressure to the blood vessels in the wrist.
C. On/Off button to turn the appliance on and off.

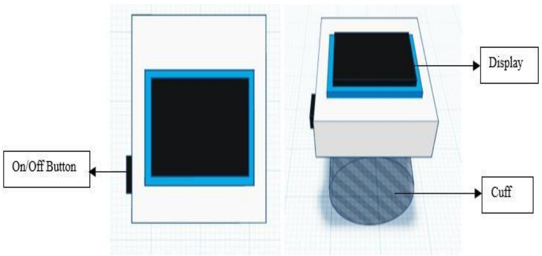

Figure 2. Design planning of the device, showing main components: (A) Display screen, (B) Cuff, and (C) On/Off Button.

C. DEVICE SPECIFICATIONS

The wrist sphygmomanometer, equipped *with a Buzzer* as an Indicator *of Hypertension* and *Hypotension,* has the following specifications: 1) Display: 2.4-inch nextion LCD
2) Microcontroller: Arduino Nano
3) Cuff: Diameter 13.5-19.5 cm
4) Supply Voltage: Battery
5) Blood pressure measurement range: Systolic 84-198 mmHg, Diastol 53-164 mmHg
6) Device dimensions: 9.3cm x 8cm x 3.6cm

D. LCD Screen Display

Figure 3. The initial display shows the tool's title.

Fig. 3 shows that the LCD appears as the initial screen when the tool is first turned on, providing the user with an initial indication of the tool's functionality.

Figure 4. The screen will show a green "START" button.

Fig. 4 shows that the button starts the blood pressure measurement process.

Figure 5. While the measurement process is ongoing, the screen will display the message "Loading.. Please wait!" and a red "STOP" button.

Fig. 5 shows that the device is taking blood pressure and heart rate data, and the user is expected to remain motionless until the process is complete.

Figure 6. If the measurement results indicate a blood pressure value below the standard limit, the "HYPOTENSION" indicator will be displayed on a blue background.

Fig. 6 and Fig. 7 showed the Systolic, diastolic, and pulse rate data in full for user analysis. This display also comes with a buzzer that will sound as an early warning of low blood pressure.

Figure 7. If the measurement results are within the normal blood pressure range, the screen will display a "NORMAL" status with a green background. Systole, diastole, and pulse values were also displayed, indicating no signs of hypertension or hypotension.

Figure 8. If the measurement results show "PREHYPERTENSION", the systolic pressure value is between 120–139 mmHg, or the diastolic pressure is between 80–89 mmHg.

Fig. 8 is shown on a yellow background to signal early warnings of the potential risk of future high blood pressure.

Figure 9. If the measurement shows a blood pressure value above the standard limit, the "HYPERTENSION" indicator will be displayed on a red background. This display is also equipped with a buzzer that will sound as an early warning of high blood pressure.

E. BLOCK DIAGRAM

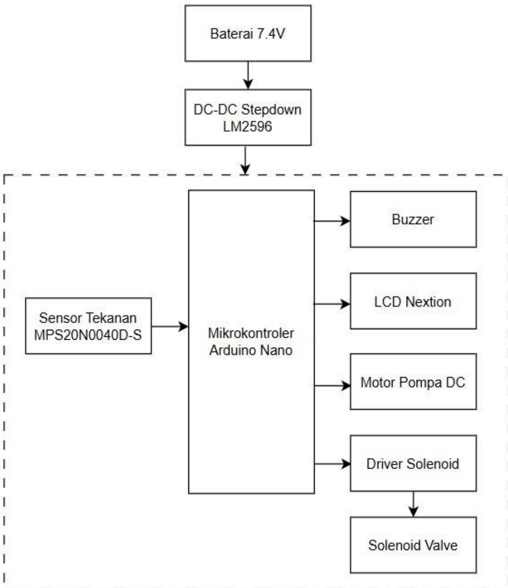

Figure 10. Block diagram of the wrist-based digital sphygmomanometer system. The device is powered by a 7.4V battery regulated through a DC-DC step-down converter (LM2596) to supply the Arduino Nano microcontroller. The system integrates an MPS20N0040D-S pressure sensor for cuff pressure measurement, an LCD Nextion display for user interface, a buzzer for alert indication, a DC motor pump for inflation, and a solenoid valve with its driver for controlled deflation.

Fig. 10 illustrates the following functions of each component:

1) Battery: This circuit requires a DC supply voltage to operate the appliance.
2) DC-DC Step down LM2596: Lowers the input voltage from 7.4V to 3.6V.
3) Microcontroller: plays a role in controlling the entire system.
4) MPS20N0040D-S sensor: Functions to detect how much pressure is inside the cuff.
5) Pump driver: Serves to provide air pressure into the cuff.
6) Pulse BPM: To measure the number of pulses per minute during the blood pressure measurement process.
7) Solenoid driver: Functions as a solenoid controller or controller run by Arduino Nano.

8) Solenoid valve: Works to slowly release air pressure inside the cuff.
9) Cuff: Serves to measure blood pressure by applying pressure to the blood vessels in the wrist.

F. FLOWCHART PROGRAM

In Fig. 12, the process begins with an initialization step, then the motor pumps air until the pressure reaches 200 mmHg. After that, the motor stops, and the valve slowly lowers the pressure while the pressure sensor starts reading blood pressure data. When the pressure drops to 50 mmHg, the *valve* stops, and the system begins calculating systole, diastole, and pulse values (beats per minute), then displays them on the screen. Based on the measurement results, the system determines whether the condition includes hypertension, hypotension, or normal. If the result shows hypertension or hypotension, *the buzzer* will light up as a warning, and can be turned off by pressing a button on the screen. Finally, the tool will display complete results, including systole, diastole, diagnostic classification, and Pulse values, before the process is complete.

Fig. 13 shows the entire circuit of the sphygmomanometer with a buzzer for hypertension and hypotension. The system consists of several main blocks. A 7.4 V battery serves as the power source, which is regulated by the LM2596 DC-DC converter to supply a stable voltage to the circuit. The Arduino Nano functions as the central controller, processing input and controlling the system's operation. The nextion LCD provides a user interface for displaying measurement results. The pump and DC solenoid valve, driven by the controller, regulate cuff inflation and deflation. A buzzer is used as an indicator for hypertension and hypotension conditions. Overall, the integration of these components enables the wrist sphygmomanometer to automatically measure blood pressure and provide both visual and audio indications.

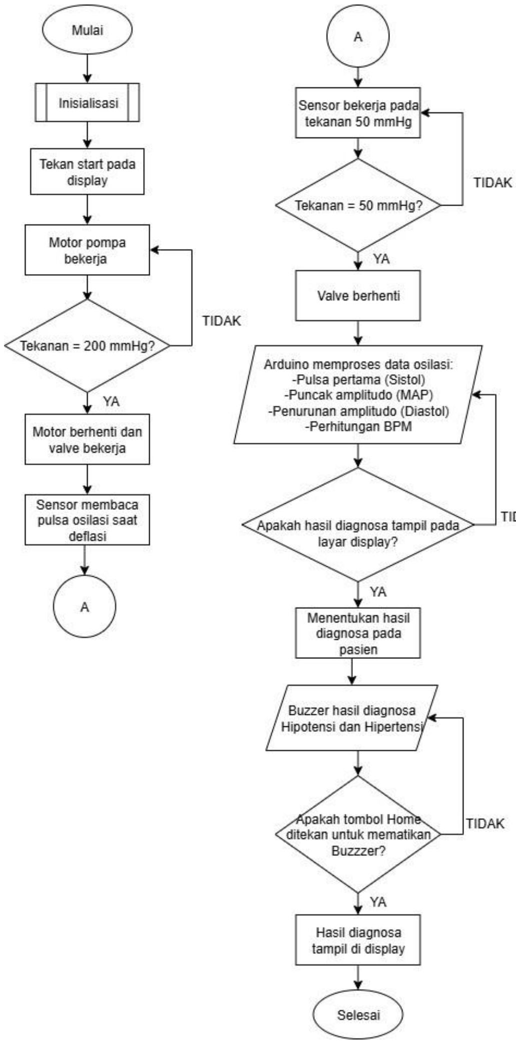

Figure 12. Flowchart for the design of a wrist sphygmomanometer with a buzzer for hypertension and hypotension.

G. ELECTRONIC CIRCUIT DESIGN

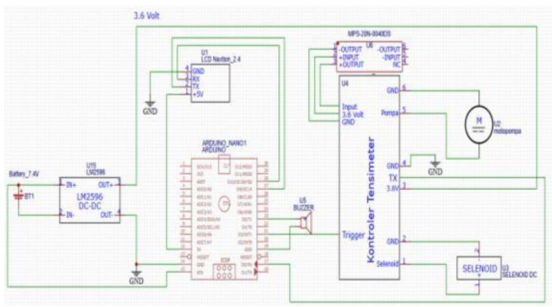

Figure 13. Circuit diagram of the wrist sphygmomanometer system based on an Arduino Nano, equipped with a pump, solenoid, buzzer, and a Nextion LCD as the display interface. The system is powered by a 7.4 V battery, regulated by an LM2596 DC-DC module to supply the main components.

H. DATA COLLECTION TECHNIQUES

Once the tool is designed according to the plan, the next step is to collect or retrieve the data. The data collection process involves measuring blood pressure directly on the module and comparing the results with those of the calibration device, which indicates that the module is functioning correctly. Blood pressure measurements were carried out 30 times which were grouped into three conditions, namely low blood pressure with a systolic range of 80–89 mmHg and diastole 40–59 mmHg displayed on an LCD with a blue background, normal blood pressure with a systole range of 90–120 mmHg and diastole 60–80 mmHg displayed on an LCD with a green background. and high blood pressure with a systolic range of 181–200 mmHg and diastolic 111–140 mmHg displayed on an LCD with a red background.

III. RESULT AND DISCUSSION

A. PHYSICAL APPEARANCE OF THE TOOL

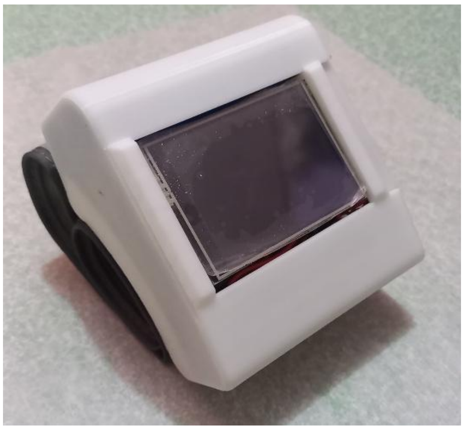

Figure 14. Front view of the finished device, already equipped with a monitor or LCD screen.

Figure 14 shows a prototype wrist sphygmomanometer based on an Arduino Nano, equipped with a Nextion LCD. The device is enclosed in a white casing to protect its internal components, with a black cuff wrapped around the wrist during blood pressure measurement.

B. STANDARD OPERATING PROCEDURE (SOP)

- Attach the cuff to the patient's wrist with the cuff positioned 1-2 cm above the wrist crease.
- Make sure the air hose is on the inside of the wrist, parallel to the pulse.
- Turn the appliance on by pressing the ON/OFF button.
- If it is on, wait for the screen to finish displaying initialization.
- Press the start button on the LCD screen to start the measurement.
- When the measurement is complete, the patient's results will be displayed, including systole, diastole, BPM, and diagnostic classification values.
- To turn off the appliance, press the ON/OFF button.
- Finish.

C. TEST RESULT DATA

After completing the training and validation process, the system's performance was evaluated using 10 tests on testing modules created with calibration tools. The testing was performed 10 times to ensure the device's reliability. Three blood pressure conditions were used as reference parameters with the NIBP Simulator: hypotension (80/40 mmHg), normal (120/80 mmHg), and hypertension (180/140 mmHg). In addition, pulse rate accuracy testing was performed at 50, 80, and 120 BPM.

TABLE I
TEST DATA WITH PARAMETER OF 80/40 MMHGG

NIBP Simulator Settings		Measurement Results		Error		Average		Percentage Error	
Systole	Diastole	Systole	Diastole	Systole	Diastole	Systole	Diastole	Systole	Diastole
80	40	84	54	4	14	84,8	53,9	6%	34,75%
		85	53	5	13				
		85	54	5	14				
		84	55	4	15				
		85	54	5	14				
		85	54	5	14				
		85	54	5	14				
		85	54	5	14				
		85	54	5	14				
		85	53	5	13				

The results in Table 1 showed that the average systolic value was 84.8 mmHg with a 6% error, while the average diastolic value was 53.9 mmHg with a 34.75% error. The systolic values were consistently slightly higher than the reference, while the diastolic values showed a greater deviation. The cuff placement on the wrist is likely to influence this discrepancy.

Table 2 showed that the average systolic result was 124.4 mmHg (error 3.67%) and the diastolic result was 93.1 mmHg (error 16.4%). The device tended to read higher than the reference values; however, the measurements were stable across all 10 trials.

TABLE 2
TEST DATA WITH PARAMETER OF 120/80 MMHGG

NIBP Simulator Settings		Measurement Results		Error		Average		Percentage Error	
Systole	Diastole	Systole	Diastole	Systole	Diastole	Systole	Diastole	Systole	Diastole
120	80	115	87	5	7	115,1	87,5	4,08%	9,38%
		115	87	5	7				
		114	87	6	7				
		114	86	6	6				
		116	87	4	7				
		115	88	5	8				
		117	89	3	9				
		116	88	4	8				
		113	88	7	8				
		116	88	4	8				

TABLE 3
TEST DATA WITH PARAMETER OF 120/80 MMHG

NIBP Simulator Settings		Measurement Results		Error		Average		Percentage Error	
Systole	Diastole	Systole	Diastole	Systole	Diastole	Systole	Diastole	Systole	Diastole
180	140	166	132	14	8	163,9	131,6	8,94%	6%
		163	132	17	8				
		163	132	17	8				
		164	132	16	8				
		163	132	17	8				
		163	133	17	7				
		165	131	15	9				
		166	130	14	10				
		163	130	17	10				
		163	132	17	8				

Table 3 showed that the systolic readings ranged from 163–166 mmHg (average error ±9%), while the diastolic values ranged from 130–133 mmHg (average error ±7%). Although deviations were observed, the device still classified the condition as hypertension, with the buzzer functioning as an alert.

TABLE 4
TEST DATA WITH A PULSE VALUE OF 50 BPM

Calibration Tool Setting (BPM)	Tool Module Measurement Results (BPM)	Error	Average	Percentage Error	Accuracy Percentage
50	50	0	50	0%	100%
	50	0			
	50	0			
	50	0			
	50	0			

Table 4 shows the results of the pulse measurement accuracy (BPM) test for the wrist sphygmomanometer module compared with NIBP. Simulator standard calibration device setting set at 50 BPM. Measurements were taken 5 times to ensure data consistency and reliability. In each measurement, the artificial tool module successfully reads exactly 50 BPM, as set in the NIBP Simulator.

TABLE 5
TEST DATA WITH A PULSE VALUE OF 80 BPM

Calibration Tool Setting (BPM)	Tool Module Measurement Results (BPM)	Error	Average	Percentage Error	Accuracy Percentage
80	80	0	80,6	0,75%	99,25%
	80	0			
	81	1			
	81	1			
	81	1			

Table 5 shows the results of the pulse measurement
(BPM) accuracy test of the wrist sphygmomanometer module against the NIBP
Simulator standard calibration device setting set at 80 BPM. Measurements were taken 5 times to ensure data consistency and reliability. The instrument's readings range from 80 to 81 BPM. Although there is a slight variation, the value is still within acceptable tolerance limits.

TABLE 6
TEST DATA WITH A PULSE VALUE OF 120 BPM

Calibration Tool Setting (BPM)	Tool Module Measurement Results (BPM)	Error	Average	Percentage Error	Accuracy Percentage
120	121	1	121	0,83%	99,17%
	121	1			
	121	1			
	121	1			
	121	1			

Table 6 shows the results of the pulse measurement
(BPM) accuracy test of the wrist sphygmomanometer module against the NIBP
Simulator standard calibration device setting set at 120 BPM. Measurements were taken 5 times to ensure data consistency and reliability. The instrument's readings range from 120 to 121 BPM. Although there is a slight variation, the value remains one. One plausible explanation is that cuff placement on the wrist is susceptible to arm posture, distance from the heart, arterial depth, and improper alignment with the brachial artery, all of which can disproportionately affect diastolic accuracy [9]. Overall, the systolic readings tended to be slightly higher than the reference values. In contrast, the diastolic readings demonstrated substantially greater deviation. This performance pattern is consistent with recent studies indicating that wrist-based sphygmomanometers generally show higher variability in diastolic measurements due to anatomical and positioning factors[10]

Several comparative evaluations of wrist versus upper-arm devices have reported that wrist devices often underestimate or overestimate diastolic pressure by 20–30%, especially when the wrist is not positioned at heart level, which aligns with the deviation observed in this study [11] [12] [13][14].

In contrast, the relatively low error in systolic measurement (6%) falls within the acceptable performance range reported in recent literature for low-cost wrist-based digital sphygmomanometers [15] [16] [17] [18]. This suggests that the sensing mechanism and signal processing method used in the device were sufficiently reliable for detecting peak arterial pressure but still less stable in capturing diastolic oscillations, which are typically smaller in amplitude and more susceptible to noise. Future improvements in sensor calibration, cuff design, and posture-guidance mechanisms may help reduce this discrepancy[17] [19] [20]

IV. CONCLUSION

Based on the tests conducted, the following conclusion can be drawn: This study successfully designed and developed a wrist-based sphygmomanometer equipped with a buzzer to indicate hypertension and hypotension, using the MPS20N0040D-S pressure sensor and an Arduino Nano microcontroller. The results showed that the device displayed systolic, diastolic, and pulse rate (BPM) parameters on the Nextion LCD and emitted an audio alert via the buzzer when the measurement results were outside the normal range. The accuracy of systolic measurements was 93.66%, diastolic 83.29%, and BPM 99.47%, indicating that the device is sufficiently reliable for detecting blood pressure conditions. Therefore, this wrist sphygmomanometer can serve as a practical alternative for early detection of hypertension and hypotension, although the accuracy of diastolic measurements still requires improvement in future developments.

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