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Digital Pressure Meter Design to Calibrate a Sphygmomanometer Unit Equipped with Data Calibration Recording to External Memory

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ABSTRACT A sphygmomanometer is a medical device used to non-invasively measure arterial blood pressure. To ensure the accuracy of this device, it must be calibrated. The equipment used to calibrate this tool is a Digital Pressure Meter (DPM). This study aims to build a DPM device equipped with SD card storage. The device runs on the MPX5050GP sensor, the measurement results are displayed on a 16x4 Liquid Crystal Display Character (LCD) This device is also equipped with a leakage test timer, and data storage on the SD Card will be displayed in Notepad (txt) form. The variables measured in data collection were positive pressure and leakage test. The DPM feature of the Rigel Medical UNI-SiM Calibrator is used as the gold standard tool for comparing device accuracy. From the comparison with the gold standard, the smallest error is 0.00% and the largest error is 0.11% on the positive pressure variable and the error is 0.26. % on the leak test variable. The GEA Medical MI-2001 Mercury Sphygmomanometer was used as an under test standard with the smallest measurement error of 0.00% and the largest error of 0.81% and the value of the leak test error compared to the DPM Module which was 0.9%. Data storage is still manual. Automating data retrieval and transfer to computers or other digital gadgets will make it easier for officers who use this DPM tool. The next research will be good using web applications like data storage and processing.

INDEX TERMS Sphygmomanometer, Calibration, Positive Pressure, Leakage Test

I. INTRODUCTION

Medical equipment in hospitals makes diagnosis and treatment more accurate [1]. Currently, blood pressure measurement is still conventional using a sphygmomanometer and a stethoscope. This method requires a high-precision eye to see mercury on a sphygmomanometer and an ear to hear Korotkoff sounds (sound produced by blood pressure) on a stethoscope [2]. Errors in measuring blood pressure will greatly affect the diagnosis of the patient's condition. Systematic errors in blood pressure measurement are generally caused by inadequate maintenance and calibration of the sphygmomanometer. The way to reduce systematic errors is to use correct measurement techniques and ensure the instruments are properly maintained and calibrated [5]. Calibration is an observation activity to determine the correct value for measuring instruments and or measuring materials [3]. Direct calibration compares the

UUC reading (ie, sphygmomanometer) with the RSU reading. The RSU is a full-scale digital pressure indicator [4] The sphygmomanometer device should be checked regularly to ensure it is calibrated to the European Standard $\pm 3\text{mmHg}$ [6]. Digital Pressure Meter (DPM) is a tool used to calibrate sphygmomanometers and medical devices that have pressure parameters. This tool works by changing the pressure sensor value to be changed and displayed on the display [7].

The design of this DPM has been carried out by several previous researchers, In 2010 A de Greeff conducted a study on Non-invasive Blood Pressure Measurement Calibration Accuracy at London Hospitals, the study stated that only 4 of the 12 models identified in this study. studies have published valid evidence[6]. In 2019 Mukhamad Ryan Nur Rokhman in his research on the Digital Pressure Meter (DPM) design for

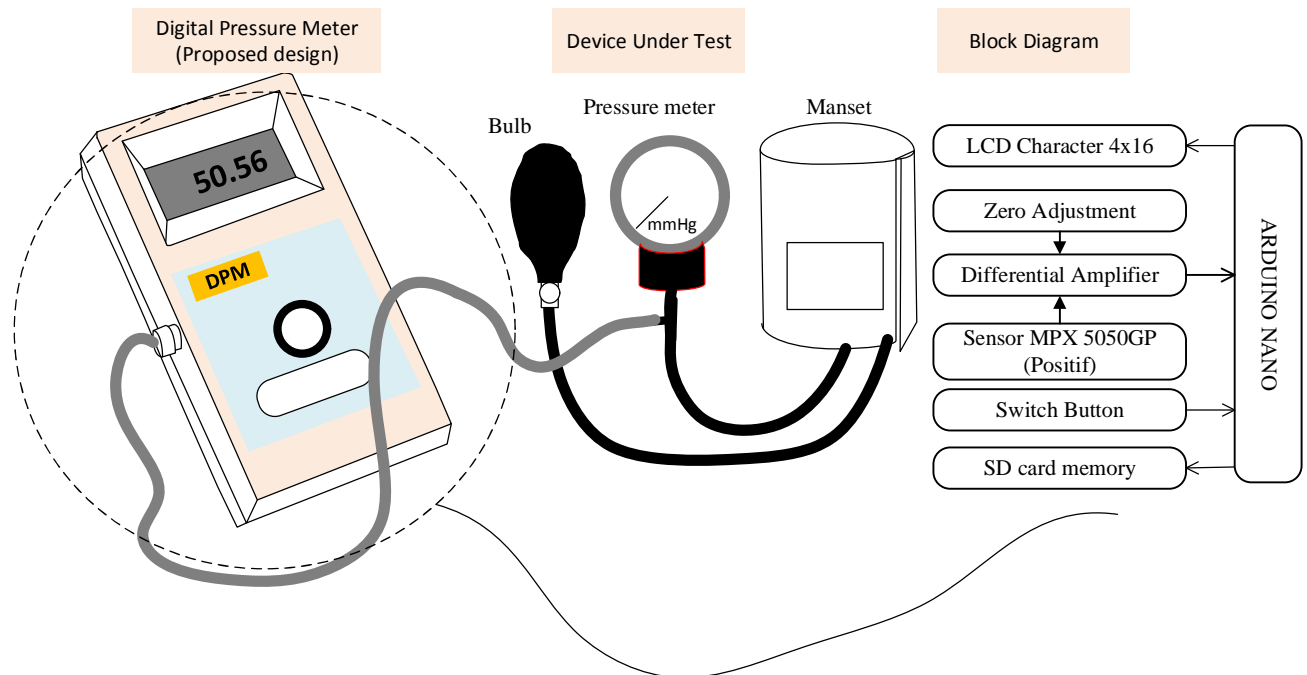


FIGURE 1. the block diagram of the proposed system

sphygmomanometer and Suction Pump, but the uncertainty value is still relatively high [8]. Then in 2020 Fita Florensa Rooswita designed this DPM but it does not have data storage [9].

Based on the reference search results above, the problem found is the level of accuracy of the DPM tool and its data storage features. The accuracy of the tool will greatly affect the calibration activities. This data storage feature is very necessary because of the large amount of data that is taken in one calibration activity. So the authors conducted this study aims to build a DPM device equipped with SD card storage. This tool will be compared with standard calibration tools and standard calibrated tools.

II. MATERIAL AND METHODS

A. EXPERIMENTAL SETUP

This research makes a Digital Pressure Meter (DPM) module using the mpx5050gp sensor as a pressure sensor. 16x4 character LCD as display and Arduino nano as the processor. After the module was finished, the study tested the module's ability by taking data 6 times with measurement points at 0, 50, 100, 150, 200,250 mmHg. Measurement results are saved on an SD card.

1) MATERIALS AND TOOLS

This study uses the MPX5050GP sensor which functions as a positive pressure detector. This sensor has a supply specification: 5 VDC, tip 7mA. Ported elements, gauges. Pressure range: 0-50 kPa. Sensitivity : 90 mV/kPa. Response time: 1 ms. Error: max 2.5%. The sensor output goes to the

differential circuit which then goes to the Arduino ADC pin. Arduino nano as the processor. Arduino output is a 16x4 character LCD as a display. And provide data to save on sd card. To test the capability and accuracy of the designed DPM module, a standard calibrator from the Rigel Medical UNI-SiM was used. Also used is the GEA MI-2001 medical sphygmomanometer as the unit under test.

2) EXPERIMENT

After the design is complete, the capability of the designed DPM module is tested. Two parameters were tested. The first is the pressure at the measuring points 0, 50, 100, 150, 200,250 mmHg. The second is the pressure loss due to leakage at a pressure setting of 200 mmHg for 1 minute. The tests were carried out in parallel with the Rigel Medical UNI-SiM calibrator and the GEA MI-2001 sphygmomanometer as the test unit. The test results were taken as data to be compared between the DPM module, Riegel calibrator, and the GEA MI-2001 sphygmomanometer. The comparison results were used to validate the results of this study.

B. THE DIAGRAM BLOCK

The Mpx5050gp pressure sensor functions as a positive pressure reader to calibrate the sphygmomanometer. As shown in FIGURE 1. Arduinobox functions as a sensor data processor and the results are displayed on the LCD.

C. THE FLOWCHART

The Arduino program is built based on a flowchart as shown in FIGURE 2. At the start, Arduino will initialize the

program. After selecting the positive pressure mode (calibration) or leak test, the Arduino will then read the ADC according to the selected mode. In calibration mode, data will be saved on an SD Card. The leak test is equipped with a timer for 60 seconds. Arduino will change the pressure value from kPa to mmHg. The results of data processing will be displayed on the LCD.

D. THE CIRCUIT

1) Circuit of minimum system

Analog data from the sensor is converted into digital data by Arduino via PIN A6. 16x4 LCD is used to display the pressure data that has been taken. This button is used to select the positive pressure or leak test mode. This button is also used to save data and start the timer. When the logic is high, the program will detect the input on the digital pin then the program will run the input reading mechanism. The input data is processed by equations so that a positive pressure reading occurs (Figure 3).

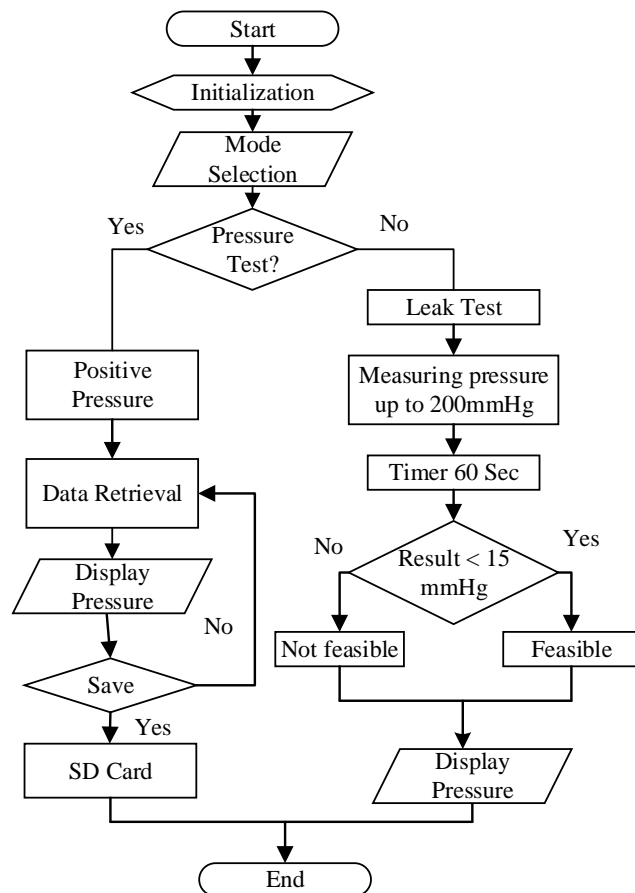


FIGURE 2.The Flowchart of the Digital Pressure Meter

2) *CIRCUIT OF MPX5050GP*

To use this pressure sensor, the MPX5050GP sensor must be assembled with several other suitable components [8]. The

input to the sensor circuit is pressure, the pressure captured by the sensor will be converted into voltage. In this sensor, the pressure value is directly proportional to the output voltage, so the higher the pressure, the higher the output voltage value.

3) *CIRCUIT OF ZERO ADJUSTMENT*

The zero adjustment circuit functions to adjust the pressure value so that it gets a value of 0 at the beginning of the reading (The zero adjustment circuit consists of a series of difference amplifiers using the LM358 IC and a variable resistor).

III. RESULTS

In this study, the Digital Pressure Meter has been tested using Rigel Medical UNI-SiM and GEA medical MI-2001 Mercury Sphygmomanometer. The proposed design is shown in FIGURE 3. Module was shown as front, side and back view.

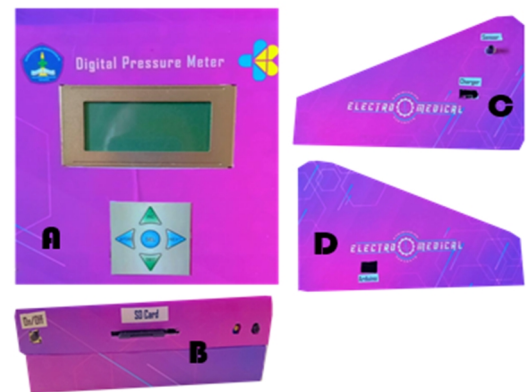


FIGURE 3.The Digital Pressure Design

A. THE DESIGN

The steps for measuring and testing this module can be explained as follows. First, must prepare the necessary equipment (sphygmomanometer). Connect hoses to standard tools and modules. Prepare a table to record the measurement results. Testing by measuring the pressure on the sphygmomanometer directly and simultaneously. e) Record the results of the sphygmomanometer measurement and leak test in the table that has been made.

B. MEASUREMENT RESULTS

The measurement results on the module are compared with Rigel Medical UNI-SiM and GEA medical MI-2001 Mercury Sphygmomanometer. The module measurement using DPM RigelMedical UNI-SiM was performed in a Poltekkes Kemenkes Surabaya laboratory. These measurements were made to know the accuracy of the DPM module. The measurement result was shown in TABLE 1. TABLE 1 shows the results of data collection using Rigel Medical UNI-SiM 6 times (3 times the data goes down and 3 times the data goes up). Setting point Measurements at pressure values of 0, 50, 100, 150, 200, and 250 mmHg. TABLE 2 shows the results of the module measurements

using the GEA Medical MI-2001 Mercury Sphygmomanometer.

TABLE 1
Measurements on rigel (calibrator)

Pressure (mmHg)	Mean (mmHg)	S.Dev (mmHg)
0	0	0,00
50	49,10	0,01
100	99,17	0,02
150	149,96	0,01
200	199,53	0,03
250	249,65	0,20

TABLE 2
Measurements on sphygmomanometer mercury

Pressure (mmHg)	Mean (mmHg)	S.Dev (mmHg)
0	0	0,00
50	49,9	0,17
100	100,0	0,41
150	150,1	0,40
200	199,8	0,41
250	250,5	0,24

The TABLE 2. Data retrieval was carried out 6 times (3 times the data went down and 3 times the data went up). Setting point Measurements at pressure values of 0, 50, 100, 150, 200, and 250 mmHg using the GEA Medical MI-2001 Mercury Sphygmomanometer.

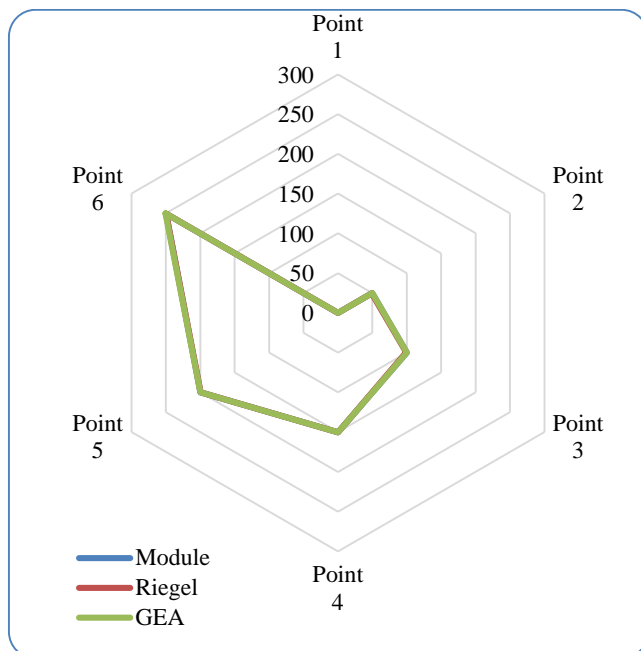


FIGURE 3.The Diagram of Comparison between Module, Riegel and GeA Med, it can be seen that the measurement values on the compared tools are not much different, it can even be said to be almost the same. This proves the accuracy of the module

TABLE 3
Results leakage test

Comparing device	Mean (mmHg)	Error %
Sphygmomanometer	195	0,9 %
Proposed design	193,12	
Rigel Medical UNI-SiM	203,52	0,26%
Proposed design	202,99	

TABLE 3 shows the results of the leak test. Leakage testing was carried out 6 times using the Sphygmomanometer compared to the DPM Module, resulting in an error value of 0.9%. When using Rigel Medical UNI-SiM compared to the DPM Module, the error is 0.26%.

In TABLE 4 the output voltage generated by the mpx5050gp sensor with a 5 volt supply is between 0.14 volts at 0 mmHg pressure to 2.97 volts at 250 mmHg pressure.

TABLE 4
Output sensor measurement mpx5050gp

Pressure (mmHg)	V. Out Sensor (volt)	
	Upward	Downward
0	0.14	0.16
50	0.70	0.68
100	1.28	1.29
150	1.84	1.83
200	2.40	2.39
250	2.94	2.97

IV. DISCUSSION

Based on the results of data collection 6 times at the measurement point settings at 0, 50, 100, 150, 200, and 250 mmHg, the DPM sensor circuit produces output according to sensor specifications. The output of the pressure sensor produces a linear voltage that increases and decreases between 0.14-2.97 V. The results of data collection using a DPM device were compared with the Rigel Medical UNI-SiM and the medical GEA MI-2001 Mercury Sphygmomanometer. Comparison of error values between DPM and Riegel UNI-SiM tools ranging from 0.00% (0), 0.03% (50), 0.05% (100), 0.01% (150), 0.02% (200), 0.11% (250). The difference in pressure on the 50 mmHg setting is 0.91 mmHg, on the 100 mmHg setting it's 0.88 mmHg, on the 150 mmHg setting it's 0.06 mmHg, on the 200 mmHg setting it's 0.89 mmHg, and on the 250 mmHg setting it's 0, 55 mm Hg. Error-values resulting from the comparison between the DPM Tool and the medical GEA MI-2001 Mercury Sphygmomanometer ranging from 0.00% (0), 0.52% (50), 0.81% (100), 0.51% (150), 0, 32% (200), 0.17% (250). The difference in pressure for the 50 mmHg setting is 0.25 mmHg, 0.46 mmHg for the 100 mmHg setting, 0.68 mmHg for the 150 mmHg setting, 0.82 mmHg for the 200 mmHg setting, and 0.24 mmHg for the 250 mmHg setting. The results of the leak test on the Mercury Sphygmomanometer using the module resulted in a data difference of 6.66 mmHg. When using the Riegel Medical UNI-SiM there is a difference of

10.9 mmHg. The results of the comparison of leakage test errors using Rigel Medical UNI-SiM yielded a value of 0.26% and using the GEA medical MI-2001 Mercury Sphygmomanometer resulted in an error value of 0.9%. Based on the results obtained, it is concluded that the DPM tool made can be applied to calibration activities

The implication of this research is that the designed DPM module can be used as a prototype of a domestically made DPM tool that can be used for sphygmomanometer calibration activities. In this study there are limitations in the form of storing data manually, you have to press the save button every time you save data. Automation of data retrieval and transfer to computers or other digital gadgets will make it easier for officers who use this DPM tool. Future research would be better to use web applications such as data storage and processing.

V. CONCLUSION

This study aims to build a DPM device equipped with SD card storage. Overall, this study concludes that the designed Digital Pressure Meter can be used to monitor the performance of the sphygmomanometer. This research is built based on Arduino Nano, MPX5050GP sensor, differential circuit, 16x4 character LCD. The results of data storage on the SD Card will be displayed in the form of a Notepad (txt) file. From the comparison with Rigel Medical UNI-SiM, the smallest error is 0.00% and the largest error is 0.11% and the error from the leak test is 0.26%. While the results of the comparison with the GEA medical MI-2001 Mercury Sphygmomanometer, the smallest error is 0.00% and the largest error is 0.81%, and the leak test error value is 0.9%.

REFERENCES

- [1] P. Cristina Silva, R. Souza de Faria, A. Gonçalves Sallum, L. Vinicius de Alcantara Sousa, V. E. Valenti, and P. José Oliveira Cortez, "Analysis of Mercury Sphygmomanometers in A Hospital School-Analysis of Mercury Sphygmomanometers," *J. Cardiol. Ther.*, vol. 5, no. 1, pp. 697–700, 2018, doi: 10.17554/j.issn.2309-6861.2018.05.138.
- [2] A. J. Puspitasari, E. Endarko, and I. Fatimah, "Blood Pressure Monitor Design Using MPX5050GP Pressure Sensor and Visual C# 2010 Express," *J. Fis. dan Apl.*, vol. 15, no. 3, p. 99, 2019, DOI: 10.12962/j24604682.v15i3.4929.
- [3] A. Cholid, H. G. Ariswati, and S. Syaifudin, "Digital Pressure Meter Equipped with Temperature and Humidity," *Indones. J. Electron. Electromed. Eng. Med. Informatics*, vol. 2, no. 1, pp. 1–5, 2020, doi: 10.35882/jeeemi.v2i1.1.
- [4] S. Ghareeb et al., "Results of a project to calibrate mercury sphygmomanometer blood pressure-measuring devices in Egypt," *J. Hum. Hypertens.*, 2020, DOI: 10.1038/s41371-020-00424-0.
- [5] M. J. Turner, C. Speechly, and N. Bignell, "Sphygmomanometer calibration Why, how and how often?" *Aust. Fam. Physician*, vol. 36, no. 10, pp. 834–837, 2007.
- [6] A. de Greeff, I. Lorde, A. Wilton, P. Seed, A. J. Coleman, and A. H. Shennan, "Calibration Accuracy of hospital-based non-invasive blood pressure measuring devices," *J. Hum. Hypertens.*, vol. 24, no. 1, pp. 58–63, 2010, DOI: 10.1038/jhh.2009.29.
- [7] B. Utomo, I. D. G. Hariwisana, and S. Misra, "Design a Low-Cost Digital Pressure Meter Equipped with Temperature and Humidity Parameters," *Indones. J. Electron. Electromed. Eng. Med. Informatics*, vol. 3, no. 2, pp. 59–64, 2021, doi: 10.35882/jeeemi.v3i2.4.
- [8] M. R. N. Rokhman, B. G. Irianto, and H. G. Ariswati, "Digital Pressure Meter Sphygmomanometer and Suction Pump," *J. Teknokes*, vol. 12, no. 1, pp. 1–4, 2019, DOI: 10.35882/teknokes.v12i1.1.
- [9] F. F. Rooswita, T. Rahmawati, and S. Syaifudin, "A Two-Mode Digital Pressure Meter Equipped With An Automatic Leak Test Using MPX5050gp And MPXv4115vc6u Sensors," *J. Electron. Electromed. Eng. Med. Informatics*, vol. 2, no. 2, pp. 80–85, 2020, DOI: 10.35882/jeeemi.v2i2.7.
- [10] A. J. Puspitasari, "Design and Build a Blood Pressure Monitor Using Oscillometric Method With MPX5050GP Pressure Sensor," *Jurnal Fisika dan Aplikasinya* volume 15, nomor 3, 2019, <http://dx.doi.org/10.12962/j24604682.v15i3.4611>
- [11] M. S. Stepanov, O. Y. Sorochkina, K. V. Kirimova, and I. G. Koshliakova, "Influence function as a metrological characteristic of the digital pressure meter," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1029, no. 1, 2021, DOI: 10.1088/1757-899X/1029/1/012126.
- [12] A. Pudji and M. R. Makruf, "Design of the Digital Pressure Meter with Thermohyrometer," *Journal of Information Engineering and Applications* vol. 7, no. 9, pp. 35–39, 2017.
- [13] Abd.Cholid R, Her G A, Syaifudin "DPM Two Modes Equipped With Temperature And Humidity" *IJEEMI*, Vol. 2, No. 1, February 2020, pp:1-5DOI:10.35882/jeeemi.v2i1.1
- [14] T. G. Ali, K. M. Amin, and D. A. Jalil, "A study on verification of sphygmomanometers," *Biomed. Res.*, vol. 29, no. 13, pp. 2797–2799, 2018, DOI: 10.4066/biomedicalresearch.29-17-3262.
- [15] R. Wadhvani, N. I. Siddiqui, and B. Sharma, "Assessment of the accuracy of mercury sphygmomanometer and automated oscillometric device of blood pressure measurement in the population of normal individuals," *Asian J. Med. Sci.*, vol. 9, no. 5, pp. 17–24, 2018, DOI: 10.3126/ajms.v9i5.20469.
- [16] G. Parati, A. Faini, and P. Castiglioni, "Accuracy of blood pressure measurement: Sphygmomanometer calibration and beyond," *J. Hypertens.*, vol. 24, no. 10, pp. 1915–1918, 2006, DOI: 10.1097/01.hjh.0000244935.19299.f5.
- [17] A. Mujadin and P. W. Kusuma, "Design a noninvasive digital blood pressure meter using high sensitivity pressure gauge MPX5050GP," *2017 Int. Symp. Electron. Smart Devices, ISESD 2017*, vol. 2018-Janua, pp. 236–241, 2017, DOI: 10.1109/ISESD.2017.8253339.
- [18] P. Muntner et al., Measurement of blood pressure in humans: A scientific statement from the American heart association, *AHA Journal* vol. 73, no. 5. 2019.
- [19] D. Parker, K. Liu, A. R. Dyer, D. Giumetti, Y. Liao, and J. Stamler, "A comparison of the random-zero and standard mercury sphygmomanometers," *Hypertension*, vol. 11, no. 3, pp. 269–272, 1988, DOI: 10.1161/01.HYP.11.3.269.