Microcontrollers Performance in Portable Electronic Stethoscope Design with a Disease Symptoms Detection Feature

Torib Hamzah¹, Endang Dian Setioningsih¹, and Sumber¹

¹Department of Electromedical Engineering Poltekkes Kemenkes, Surabaya
Corresponding author: Torib Hamzah (e-mail: thorib@poltekkesdepkes-sby.ac.id).
This paper is supported and funded by Pusat Penelitian dan Pengabdian Kepada Masyarakat Poltekkes Kemenkes Surabaya, Indonesia

ABSTRACT One of the early examinations that is often done is to detect heart disease using a stethoscope. The electronic stethoscope consists of a membrane and tube from a conventional stethoscope coupled with a condenser microphone which is then connected to a computer. The purpose of this study is to analyze the comparison of two types of microcontrollers in the design of a portable electronic stethoscope equipped with a symptom detector. The research method used is instrumentation with 2 types of microcontrollers to design a heart sound detector. In processing the data to be displayed on the 16x2 Character LCD. Sending heart signal data for 60 seconds to produce BPM data which is processed using 2 different types of microcontrollers. The results of data collection on battery consumption of power usage on the AT mega 2560 resulted in an average saving of 0.11W. Therefore, it can be concluded that the two stethoscopes have a significant difference when compared, where the Arduino Mega 2560 is able to process data from heart signals faster than the AT mega 328P. The results of the research that have been carried out can be implemented using a system that strongly supports the needs when checking heart sound signals.

INDEX TERMS Stethoscope, Electronics, Heart, Disease

I. INTRODUCTION

Technological progress is something that we cannot avoid in this life, because technological progress will go according to the progress of science. Every innovation is created to provide positive benefits for human life [1]. Provides many conveniences, as well as a new way of doing human activities. Especially in the field of technology, people have enjoyed many of the benefits brought by the innovations that have been produced. The technological revolution in the health sector that has been achieved to date is a significant feature of modern life. However, the power of technology must be used carefully and responsibly, to ensure that we apply it efficiently and humanely [2]. Appropriate use of health technology involves not only mastery of science, engineering or machine tools and concepts but also to know economic, ethical and moral issues[3]. The human body is at rest, the heart beats 70 times/minute, when the body moves a lot, the heart rate can reach 150 times/minute with a pumping power of 20-50 liters/minute, cardiac output is the volume of blood pumped by each person, each ventricle per minute. The normal speed of heart rate per minute is in newborns 140 per minute, age one year 120 per minute, age two years 110 per minute, age five years 96-100 per minute, age ten years 80-90 per minute, in adults adult 60-80 per minute[4]. A stethoscope is basically an acoustic medical device that is used to examine sounds in the body. One of them is to hear the sound of the heartbeat and detect the abnormality. The stethoscope was invented in france in 1816 by a man named Rene Theophile Hyacinthe. Earpieces, tubing or tube, diaphragm and bell[5]. Auscultation is a technique or method most often used by medical personnel in the initial examination of patients. One way is to use a tool called a stethoscope. A stethoscope is a simple acoustic medical instrument that is used to diagnose sounds in the human body. One sound that can be detected is the sound associated with the pumping activity of the heart. Voices claim indication of heart rate and heart rhythm. These sounds are also useful for providing information about the effectiveness of the pumping activity of the heart and heart valves. Until
now, the clinically used instrument for detecting heart sounds is the acoustic stethoscope [6]. Problems that arise in auscultation of the lungs or heart using a stethoscope are environmental noise, low sensitivity, low amplitude and frequency, and relatively the same sound pattern [7]. Medical auscultation ability depends on hearing ability and clinical experience of sound to analyze internal organs. This often causes several problems in analyzing acoustic signals, including the difficulty of detecting the presence of several types of noise and noise from outside which makes sound auscultation difficult to detect [8]. Since 1991, many researchers have demonstrated that continuous wavelet analysis can provide an adequate representation of the primary heart sound. The calculation of the approach is based on digital one-dimensional signal processing using DWT [9]. The heart sound heard by the doctor using a stethoscope actually occurs when the valve is closing. This event may lead to the erroneous assumption that the sound is caused by the closing of the valve leaflets, but is actually due to the effect of eddy currents in the blood due to the closing of the valve [10].

The heart as the center of blood circulation in the human body has a very vital role. Without a heart, humans will not be able to live, because the organs in the body will lack oxygen and die. Jantung yang sehat bagus diperlukan seseorang. Without a healthy heart, one will lose the quality of life. Knowing the rhythm of the heartbeat is one way to maintain a healthy heart[11]. A heart that works too fast will disrupt the balance of the body and will also have the same result if the heart works too slowly. One way to find out the patient's condition is to listen to sounds from inside the human body, namely through an instrument called a stethoscope [12]. The process of examining the sound of respiration or heartbeat is called auscultation. Problems that occur in cardiac auscultation using a conventional stethoscope are environmental noise, ear sensitivity, low frequency and amplitude, and relatively the same sound pattern. The results of hearing sound are also very subjective, so everyone can interpret the results differently[2]. Heart sounds are classified into two classes: normal and abnormal[13][14]. The activity of each cardiac cycle produces a sound that is identified as a heart sound or sometimes called a heart sound. These activities, such as contraction of the heart muscle, blood flow and pressure as well as the opening and closing of heart valves, produce vibrations that propagate through the tissues to the surface of the thorax, and are measured as sound[15]. These heart sounds can be divided into four types, which are denoted as the first heart sound (S1), second heart sound (S2), third heart sound (S3), and fourth heart sound (S4)[16]. The PCG signal is accompanied by noise components generated by various sources such as ambient noise, respiratory and chest muscle noise, sub-optimal recording locations, and weak sound however, providing accurate subject recognition requires a considerable reduction in noise contribution [17].

Based on this, the purpose of this study is to analyze the comparison between the two types of microcontrollers in the design of a portable electronic stethoscope equipped with symptom detection.

II. MATERIALS AND METHODS

A. Experimental Setup

This study used five normal subjects with criteria for age between 19 and 21 years and weight between 45 and 50 kg. Subjects were randomly sampled and data collection was repeated 6 times.

1) MATERIAL AND TOOL

This study uses the bell on the stethoscope (Brand Onemed). The bell containing the condenser mic is attached to the heart. Instrumentation amplifier and adder built on TL072P. The filter circuit uses IC TL084D. ATMEGA2560 and ATMEGA328P microcontrollers were used for BPM data acquisition. Results are displayed on a 16x2 Crystal LCD.

2) EXPERIMENTAL

In this study, after the design was completed, the frequency response of this device was tested using the human body. Measurements were made by attaching a chestpiece to the left side of the respondent's chest and then displaying it on a 16x2 character LCD. This measurement was carried out using the same subject by comparing Arduino ATmega 328p and ATMEGA2560 with 6 measurements for each respondent.

B. BLOCK DIAGRAM

The instrumentation used in data collection is to design a heart sound detection device. Heart sound signal with a comparison of two types of Microcontrollers displayed through a 16x2 Character LCD as shown in the concept framework (FIGURE 1).
From FIGURE 2 can explain the heart sound condenser mic will convert the sound into an electrical signal, this signal will enter the conditioning circuit. This circuit consists of a pre-amp, filter, and main gain, the pre-amp circuit serves to amplify the electrical signal that is tapped by the condenser mic because the electrical signal from the condenser mic output is still small. After going through the pre-amp, the heart signal is still not clearly visible because there is still other signal interference, so it requires a filter circuit so that it produces a good heart signal and no other signals interfere. After being filtered, it still requires the main gain or the last amplification, here in addition to linking the signal, this signal is also increased in reference so that it can be processed using a microcontroller.

C. FLOW DIAGRAM

When the tool is turned on the condenser mic will convert the signal and enter the PSA circuit. After processing by ADC, the data will enter ATMEGA2560 and ATMEGA 328P to be processed digitally to determine normal, tachycardia or bradycardia, the signal will be forwarded to earphones and displayed on LCD Character 16x2.

Pseudocode: 1. Program process low data

```
void loop() {
  if (millis() - tsLastReport1 > waktusensor) {
    ref = analogRead(A0);
    tegangan = (sinyal / 1023) * 5;
    ref = tegangan;
  } else {
    ref = ref;
  }
  if (tegangan < hold) {
    waktureset = millis() - wakturesetnow;
    if (waktureset > 2000) {
      ref = 0;
      hold = 1.9;
    } else {
      ref = ref;
      hold = 1.9;
    }
    if (tegangan < hold) {
      waktureset = millis() - wakturesetnow;
      if (waktureset > 2000) {
        ref = 0;
        hold = 0;
      } else {
        ref = ref;
      }
      if (tegangan < hold) {
        bpmtanda = 1;
        wakturesetnow = millis();
        if (waktureset > 2000) {
          ref = 0;
          hold = 0;
        } else {
          ref = ref;
        }
        if (tegangan < hold) {
          if (bpmtanda == 1) {
            waktuawal = millis() - waktuBPM;
            BPMpalsu++;}
          if (BPMpalsu == 3) {
            BPMasli = 180000 / waktuawal;
            BPMpalsu = 0;
            waktuBPM = millis();
          }
        }
      }
    }
  }
}
```

C. THE LISTING PROGRAM OF ARDUINO

In this research, the program listing can be divided into 2 sections, among which, the program displays the results and the program to process the raw data. Pseudocode: 1. the program processes raw data, analog data that enters pin A0 for ATmega 2560 and ATmega 328P

Pseudocode: 1. Program process low data
III. RESULT

The circuit in the FIGURE 2 is an overall circuit consisting of a pre amp circuit, a filter circuit in the form of LPF and HPF, and an adder circuit. The heart signal captured by the condenser mic will then be amplified by a non-inverting amplifier. However, there is still interference or noise. Then the output of the gain is inputted to the filter circuit to remove the noise. The heart sound signal after passing through the LPF filter is seen more clearly. This is because the noise that previously still interfered with the heart sound signal had been muted. The output of the filter circuit will go through multiturn to adjust the reference value of the signal. The signal which was originally referenced at 0V or below 0V has now been increased and the reference is no longer at 0V. This is so that the signal can be processed in the microcontroller.

A. PRE AMP OUTPUT

In the pre-amp circuit there is a process of amplifying the signal from the condenser mic but there is still interference or noise. It can be seen in FIGURE 4 that the signal from the heart sound can be seen.

B. FILTER OUTPUT

It can be seen in FIGURE 5 that the heart sound signal after passing through the BPF filter is seen more clearly. This is because the noise that previously still interfered with the heart sound signal has been muted.

C. BPM COMPARISON

TABLE 1 is the data obtained from respondents 1 to 5 by taking 6 measurements, the data above is the average of 6 measurements taken from various ages. BPM data is obtained after 60 seconds of doing calculations on the microcontroller through the obtained heart rate (FIGURE 6).

| Responden | Average (BPM) | Difference |
|-----------|---------------|------------|
| 1         | 72            | 0          |
| 2         | 96.6          | 1.8        |
| 3         | 95.8          | 0.2        |
| 4         | 94            | 0          |
| 5         | 72            | 0          |

D. BATTERY CONSUMPTION COMPARISON

The power consumption value is measured to determine the power required by the two microcontrollers (TABLE 2 and FIGURE 7).

| Time   | ATmega 2560 (W) | ATmega 328P (W) |
|--------|-----------------|-----------------|
| 0:00   | 0.3704          | 0.508           |
| 0:30   | 0.3759          | 0.4811          |
| 1:00   | 0.3752          | 0.478           |
| 1:30   | 0.3683          | 0.4782          |
| 2:00   | 0.3725          | 0.4825          |
| 2:30   | 0.3722          | 0.483           |
| 3:00   | 0.3684          | 0.4799          |
| 3:30   | 0.3727          | 0.4748          |
E. MIC CONDENSER READING TIME TEST
In testing the reading time of the condenser mic in reading BPM every 60 seconds, it will be compared with the difference in using ATMega 2560 and ATMega 328P. The following is a comparison of usage between ATMega 2560 and ATMega 328P. The test is carried out in 5 minutes or 5 times the BPM reading (TABLE 3).

| Number of Data | ATMega 2560 (Sec) | ATMega 328P (Sec) |
|---------------|------------------|------------------|
| 1             | 63               | 63               |
| 2             | 62               | 62               |
| 3             | 62               | 62               |
| 4             | 63               | 63               |
| 5             | 62               | 62               |
| Rata-rata     | 62.4             | 62.4             |
| Error         | 0                | 0                |
| STDEV         | 0.548            |                  |
| UA            | 0.224            |                  |
| UB 1          | 0.136            |                  |
| UB 2          | 0.003            |                  |
| UC            | 0.262            |                  |
| u             | 0.523            |                  |

F. MICROCONTROLLER TESTING WITH TEMPERATURE
In this test, the test is carried out with a stable BPM number, which is 80. The following is a test carried out to determine the stability of the BPM value at a certain temperature by using a comparison of ATmega 2560 and ATmega 328P (TABLE 4 and FIGURE 8).

| Temperature (°C) | ATMega 2560 (BPM) | ATMega 328P (BPM) |
|------------------|-------------------|-------------------|
| 30               | 80                | 80                |
| 35               | 80                | 80                |
| 40               | 80                | 80                |
| 45               | 80                | 88                |
| 50               | 89                | 93                |

FIGURE 8. BPM Test Result With Different Temperature

III. DISCUSSION
Pre-amp circuit serves to amplify the electrical signal generated by the condenser mic when tapping the heart sound signal. This signal amplification is very important because the electrical signal output from the condenser mic is very small, so it requires initial amplification first. This circuit has a maximum gain of 102 times where the value of this gain can be adjusted via the multiturn contained in this circuit.

The measurement of the Adder circuit above uses a frequency of 1.130 Hz and an amplitude of 4.12V. The filter circuit serves to reduce noise or signal interference that is not a heart sound signal. This filter uses a BPF filter with a cut-off frequency of 30 – 1000 Hz. After testing the filter, it can be seen that the amplitude suppression occurs when the input frequency is outside the cut-off frequency.

Figures 6 above are data obtained from respondents 1 to 5 by taking 6 measurements, BPM data is obtained after 60 seconds of doing calculations on the microcontroller through the heart rate obtained. Figure 8 is a graph of the measurement results for respondent 1 with an average BPM of 72 on ATmega 2560 and BPM 72 on ATmega 328P after 6 measurements were made with a difference of 0. In Figure 4.8 is a graph of the results of measurements on respondent 2 with an average The average BPM is 96.66667 at ATmega 2560 and BPM is 94.83333 at ATmega 328P after 6 measurements were made with a difference of 0.
are made with a difference of 1.83333. In Figure 10 is a graph of the measurement results for respondent 3 with an average BPM of 95.83333 at ATMega 2560 and BPM 95.66667 at ATMega 328P after 6 measurements with a difference of 0.16667. Figure 11 is a graph of the measurement results for respondent 4 with an average BPM of 94 on ATMega 2560 and BPM 94 on ATMega 328P after 6 measurements were made with a difference of 0. In Figure 12 is a graph of the results of measurements on respondent 5 with an average BPM 71.5 on ATMega 2560 and BPM 72 on ATMega 328P after 6 measurements with a difference of 0.5.

In Figure 7 there is a difference in the use of power consumption between ATMega 2560 and ATMega 328P. The power usage on the ATMega 2560 saves an average of 0.11W. With this power saving, the use of battery life automatically increases. These results indicate that the use of ATMega 2560 has a significant effect on battery usage. From table 3 it is known that there is no difference in BPM readings between ATMega 2560 and ATMega 328P. The table explains that the average BPM reading is 62.4 seconds. Figure 8 takes data from BPM 80 with different temperatures with an increase of 5°C, from these measurements it can be seen that at ATMega 2560 the temperatures are 30°C, 35°C, 40°C, 45°C BPM is still stable at 80. Meanwhile for ATMega 328P the temperature of 45°C is not stable. So it can be concluded that ATMega 2560 is more heat resistant than ATMega 328P.

IV. CONCLUSION

Through research conducted, it is known that, first, ATMega 2560 is able to process data from the received heart signal and produces BPM faster than ATMega 328P. Second, there are differences between the five respondents' results for the six measurements. Thus, it can be concluded that the two stethoscopes have a significant difference when compared. Another test is that the battery consumption of the ATMega 2560 is more efficient when compared to the ATMega 328P. Then there is no time difference in BPM readings between ATMega 2560 and ATMega 328P with an average reading of 62.4 seconds. When the microcontroller was tested with a certain temperature, it was found that ATMega 2560 was more heat resistant than ATMega 328P. So it can be concluded that the use of ATMega 2560 is more than ATMega 328P.

REFERENCES

[1] K. Pariaszewska, M. Młyńczak, W. Niewiadomski, and G. Cybulski, “Digital stethoscope system: the feasibility of cardiac auscultation,” Photonics Appl. Astron. Commun. Ind. High-Energy Phys. Exp. 2013, vol. 8903, p. 890315, 2013, doi: 10.1117/12.2032161.

[2] S. Swarup and A. N. Maka, “System for heart diseases monitoring,” IEEE Energy Conversion Congress and Exposition, ECCE 2014, pp. 2121–2126, 2014, doi: 10.1109/ECCE.2014.6953683.

[3] R. C. Pratama, E. S. Pramukantoro, and A. Basuki, “Electronic stethoscope: a didactic and low cost acquisition system for auscultation,” Int. J. Biosens. Bioelectron., vol. 5, no. 5, pp. 160–164, 2019, doi: 10.2147/IJDBER.S135882.

[4] C. Aguilera, J. L. Garcia, and M. Chavez, “Real-time smart-digital stethoscope system for heart diseases monitoring,” Sensors (Switzerland), vol. 19, no. 12, 2019, doi: 10.3390/s19122781.

[5] R. N. Ritonga, T. Hamzah, and D. Titisari, “Stetoskop Elektronik Sederhana untuk Auskultasi Jantung dan Paru,” 2017, 10.56346/jeemiv.21l.7.

[6] R. C. Pratama, E. S. Pramukantoro, and A. Basuki, “VII Latin American Congress on Biomedical Engineering CLAIB 2016, Bucaramanga, Santander, Colombia, October 26th -28th, 2016,” IFMBE Proc., vol. 60, pp. 520–523, 2017, doi: 10.1007/978-981-10-4086-3.

[7] S. Leng, R. S. Tan, K. T. C. Chai, C. Wang, D. Ghista, and L. Zhong, “The electronic stethoscope,” Biomed. Eng. Online, vol. 14, no. 1, 2015, doi: 10.1186/s12938-015-0056-y.

[8] S. Biswas, “Design and Implementation of a PC based Electronic Stethoscope,” vol. 9, no. 10, pp. 207–213, 2013, doi: 10.5614/jits.2013.9.3.7.

[9] C. Ahlström, Processing of the Phonocardiographic Signal — Methods for the Intelligent Stethoscope, no. 1253, 2006.

[10] H. U. az et al., “ce pte D m us pt,” J. Phys. Energy, vol. 2, no. 1, pp. 0–31, 2020, doi: 10.35882/iee.v2i1.7.

[11] A. Jain, R. Sahu, A. Jain, T. Gaumnitz, P. Sethi, and R. Lodha, “Development and validation of a low-cost electronic stethoscope: Dý digital stethoscope,” BMJ Innov., no. 8, 2021, doi: 10.1136/bmjinnov-2021-000715.

[12] A. J. Diwi, R. R. Mangkuudaja, and I. Wahidah, “Analysis Kualitas Layanan Video Live Streaming pada Jaringan Lokal Universitas Telkom,” Bul. Pos dan Telekomun., vol. 12, no. 3, p. 207, 2015, doi: 10.17933/bpostel.2014.120304.

[13] A. J. Diwi, R. R. Mangkuudaja, and I. Wahidah, “Analysis Kualitas Layanan Video Live Streaming pada Jaringan Lokal Universitas Telkom,” Bul. Pos dan Telekomun., vol. 12, no. 3, p. 207, 2015, doi: 10.17933/bpostel.2014.120304.

[14] A. J. Diwi, R. R. Mangkuudaja, and I. Wahidah, “Analysis Kualitas Layanan Video Live Streaming pada Jaringan Lokal Universitas Telkom,” Bul. Pos dan Telekomun., vol. 12, no. 3, p. 207, 2015, doi: 10.17933/bpostel.2014.120304.
[24] G. H. Prabowo, M. R. Mak’ruf, S. Sumber, L. Soetjiatie, and B. Utomo, “Perancangan Stetoskop Elektronik Portable”, Teknokes, vol. 12, no. 1, pp. 39-44, Sep. 2019.

[25] S. Sumber and E. Dian S., “Rancang Bangun Stetoscope Elektronik Berbasis Mikrokontroller Atmega328”, Teknokes, vol. 12, no. 2, pp. 64-68, Feb. 2021.