

Electrocardiogram Detection System of Autistic Children Based on AD8232 for Healthcare

Cut Nanda Nurbadriani
Graduate program of
Electrical Engineering,
Faculty of Engineering
Universitas Syiah Kuala
Banda Aceh, Indonesia
nanda.n@mhs.unsyiah.ac.id

Melinda Melinda
dept. Electrical Engineering
Universitas Syiah Kuala
Banda Aceh, Indonesia
melinda@usk.ac.id

Yunidar Yunidar
dept. Electrical Engineering
Universitas Syiah Kuala
Banda Aceh, Indonesia
yunidar@usk.ac.id

Fitri Arnia
dept. Electrical Engineering
Universitas Syiah Kuala
Banda Aceh, Indonesia
f.arnia@usk.ac.id

Abstract— This study is to design and test an early detection tool based on the AD8232 sensor as an ECG detection system. This system is applied to autistic children. Potentially hyperactive autistic children may increase their heart rate suddenly compared to normal children. Through a system that can detect heart conditions can help experts who deal with ECG problems in autistic children. This system is applied to autistic children by using components that are arranged in such a way as to be easy to use for autistic children. With the help of three electrodes attached to the child's body, namely on the hands and chest, in a test period of 2500 ms. Utilization of the AD8232 sensor and other components can produce heartbeat waves of autistic children. Based on testing by filtering and segmenting, the signal recording results when the electrodes are attached to the hand there is interference from excessive movement. Whereas when the electrode is attached to the chest, it produces a stable signal because the movements made do not affect the electrode during the test. Thus, the use of electrodes on the chest is more appropriate because the sensor can record signals properly.

Keywords—autistic children, ECG, AD8232, data ECG

I. INTRODUCTION

Children with Autism spectrum disorders (ASD) or in this study mentioned “autistic children” is neurodevelopmental disorders related to the autonomic system characterized by faster-than-normal heart rate at rest, anxiety, atypical pupillary reflexes, and sleep disturbances [1]. The value of changes that occur in children with autism differs from those in normal children because the heart rate of children with autism tends to be higher. Heart rate variability (HRV) in individuals with ASD has been investigated in several studies, but the procedures and results vary. Based on data from the Ministry of Women's Empowerment and Child Protection, there are an estimated 2.4 million people with autism [2]-[4]. The high number of autism in Indonesia today is increasing significantly.

For this reason, it is the important for autistic children to know their heart condition through Electrocardiogram (ECG) examination. The importance of a system is to classify and detect the potential for autism in children from birth so that it can provide certain behavior early on and increase the possibility of reducing heart disease in children with autism starting from a young age.

Several studies have been conducted to solve this problem. Prototypes have been done in the form of ECG measuring devices used on the arm using MAX30100 sensors to measure heart rate as stress detection information [5], [6]. However, the

output of the sensor is only the result of measuring the heart rate of the heart in the form of the R wave value. Therefore, to complete the ECG examination, which has a signal output consisting of the PQRST wave. As research has been done in building prototypes using three electrodes into a thoracic belt [7]. A sensor capable of detecting ECG signals from a person's body is the AD8232 sensor with the help of electrodes attached to the body, as has been done by previous studies who designed a prototype using the AD8232 sensor as an ECG signal [7]-[10]. This device can display a real-time heart rhythm display according to the detected electrical activity of the heart. Detecting ECG conditions using these devices can be done by utilizing Android based on the Internet of Things (IoT) [9], [11]. This is done to easily monitor heart attacks and routine checks based on Bluetooth technology with a transmission radius of 15-120 meters [7].

Therefore, this study comparison by implementing an early detection system for autistic children's heart conditions using the AD8232 sensor with the help of three electrodes, which are the Right Arm (RA), Left Arm (LA), and Right Leg (RL), which can detect accurate ECG signals of autistic children. This tool reduces the number of electrodes attached to the child's body. An ECG examination in a public hospital requires twelve electrodes to be attached to the body. This can make autistic children feeling uncomfortable and complicate the examination process.

The contributions of the proposed study are:

- Designing an ECG detection system for children with ASD based on the AD8232 sensor.
- Testing the prototype in detecting ECG in children with ASD and comparing the test results of ECG detection on the hand and chest.

Several sections are contained in this study are explaining the proposed method in section II. Section III has results and discussions from testing the system on ASD children. Conclusions and some future work from this study are in section IV.

II. METHOD PROPOSED

A. Autism Spectrum Disorder (ASD)

Children with Autism Spectrum Disorder (ASD) difficulties in social interaction, communication skills, repetition of behavior or limited interests, and low emotional regulation skills [12][13]. Emotional regulation is a person's ability to monitor, evaluate, and change the form of emotions by what should be [14][15]. Sometimes children with autism

experience tantrums because their wishes are not conveyed properly and endanger themselves and those around them.

The effects of this behavior can result in drastic increases in blood flow and blood pressure to heart attacks, especially if they have a history of congenital heart disease [16]. Thus, it is important to know the heart condition of children with autism to get treatment early so they can continue their lives like normal children. To find out the condition of the heart, a heart examination can be done using an ECG, which produces the child's heart rate.

B. Electrocardiogram (ECG)

An electrocardiogram (ECG) is a device that can detect the heartbeat in the form of a graph of recorded electrical activity in the heart. The signal waves produced by the ECG of a normal patient are the P wave, QRS complex, and T wave, as shown in Fig. 1 [17]. This ECG recording becomes a reference in diagnosing diseases or abnormalities in the heart, making it easier for experts to provide further treatment to patients.

Based on the results of tests that have been carried out on autistic children state that the heart rate range for children aged 3-5 years is 95-140 bpm, and they experience stress when doing activities [7]. This supports research in designing and building early detection systems in children, especially children with ASD, as has been done in detecting anomalies in the heart rate of children with autism and classifying each activity based on the value of low frequency, high frequency, and low frequency/high-frequency ratio [19].

C. Design System

The experiments in this study used the AD8232 sensor with the help of electrodes to detect ECG signals in the human body [20]. The ECG signal data obtained from the sensor is processed to remove the noise generated during data collection [21]. This module is capable of removing 60 Hz noise [22]. The AD8232 has 9 pins LO+, LO-, Output, 3.3V, RA (+), LA (-), and RL (GND), then the data obtained is processed using Arduino to produce ECG signals [23].

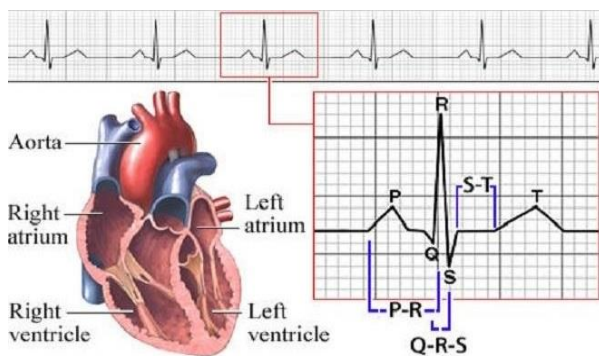


Fig. 1. Electrocardiogram Signals [9]

TABLE I. EQUIPMENTS

No	Equipment	Unit	Specification	Justification
1	Module SD card	1 pc	SPI Communication VCC: 5V	Read and save data to SD card
2	Power bank	1 pc	Power supply 10000mAh	Power supply to enable sensor performance.

3	Module LCD	1 pc	16x2 Dimension	Display heart rate data capture information
4	Arduino Uno R3	1 pc	Microcontroller ATmega328	Main controller ECG signal detection system
5	USB cable	1 pc	USB A 2.0 Male to USB B Male – 1 meter	The connecting cable between the Arduino and the computer and also for the power supply to the system
6	AD8232 ECG Sensor	1 pc	Common-Mode Rejection Ratio, DC to 60 Hz	The main sensor used for the measurement of cardiac activity.
7	Electrode	3 pcs	Soft cloth, snap, and diameter 50 mm	Intermediaries to record electrical activity in the heart.
8	Box type X4	1 pc	Thick plastic	Protects the circuit to avoid unwanted things.

This module has an analog-type output by connecting the pin to a microcontroller such as Arduino based on the ATmega328P chip. Arduino Uno also has 14 digital I/O pins that are used as outputs (pins 0 - 13), 6 analog input pins, 16 MHz crystal (pins A0 - A5), a USB connector, a power jack, ICSP header, and reset button [24]. All of these components are used to support the microcontroller circuit. Specifications and justifications of some of the components that are used in the design of this system can be seen in Table I.

All the components as shown in Table 1 used are put into a single unit in a box, as shown in Fig. 2. The system that has been put together, as shown in Fig. 2 (a), contains components designed in such a way. Fig. 2 (b) shows the components arranged in a box with a length of 17 cm, a width of 8.6 cm, and a height of 5.2 cm. Each component's working system is interconnected and has been programmed using Arduino IDE and the system can work properly.

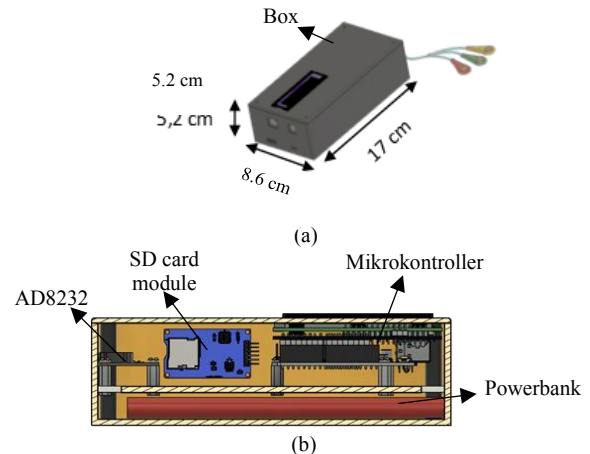


Fig. 2 System design (a) Overall view of the tool (b) View of component in the system

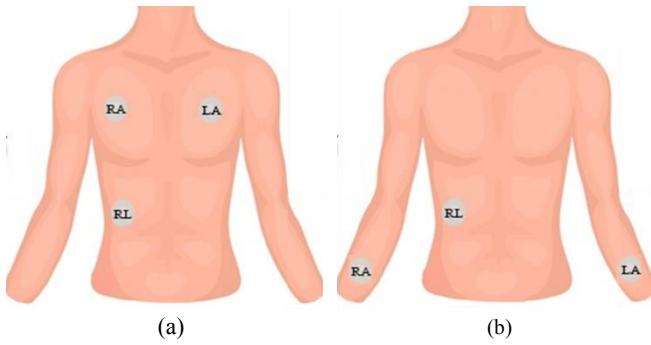


Fig. 3 Electrode position (a) Chest (b) Hand

D. Test Method

The system that has been designed is shown in Fig. 2. There are three electrodes attached to three points (as in Fig. 3) they were attached electrodes to the hand and chest. RA is attached to the right-hand pulse when testing on the hand, LA is attached to the left-hand pulse, and RL is attached to the left abdomen [25]. While the testing position on the chest attaches the RA electrode to the right chest, LA to the left chest, and RL to the left abdomen. The system is then activated to start recording ECG data by the AD8232 sensor and stored on the memory card. The system detected the signal repetitively until the testing and data collection was completed.

E. Data Acquisition

Several stages were considered in testing the ECG detection system for children with ASD.

1) Subject: the dataset was obtained from My Hope Needs Center School, Banda Aceh, Indonesia. Data were collected from 4 children aged 6-10 with two different testing system positions, 3 on the chest and 4 on the hands, for 2500 ms.

2) Stimulus: the children were informed that they would be tested by attaching 3 electrodes to the body during the test. Under parental supervision, the children were expected to be calm by taking their eyes off the system so that the system could record the child's ECG signal properly.

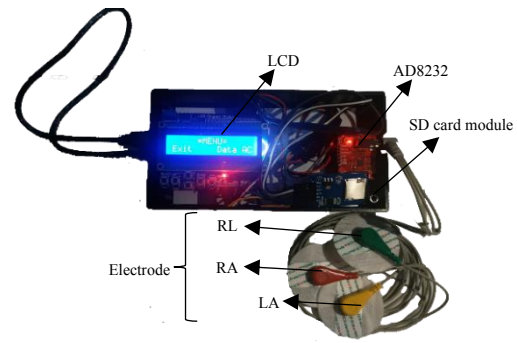


Fig. 4 The result of the system circuit

III. RESULT AND DISCUSSION

A. Tool Design Result

This section displays the results of a series of tools that have been made, which measure 9 x 5 cm and consist of an Arduino Uno R3, AD8232 sensor and 3 electrodes, a power bank, an SD card module, and a 16x2 LCD. Based on Fig. 4 is the result of the designed prototype; it can be seen that the tool is assembled in such a way on the Arduino uno R3 by connecting components as a microcontroller that controls the tool's performance. This tool will be active when given a power supply, such as in this test, using a power bank to make it easy to move. Then the three electrodes in the AD8232 sensor are attached to the child's hand to record the child's heart rate. The recorded data will be stored in the memory contained in the SD card module. Finally, the heart signal recording process is displayed on the 16x2 LCD.

B. System Testing

If the components are well designed, the system is tested by providing an algorithm to activate all the components. The test is conducted on autistic children accompanied by a therapist as shown in Fig. 5. When the three electrodes are attached to the child's body, the AD8232 sensor will record the resulting ECG signal. Then the data is stored in the Sd card that has been provided. To view the recorded signal results, the data will be visualized using matplotlib with python language. As a result, the system is able to produce ECG signals as expected.

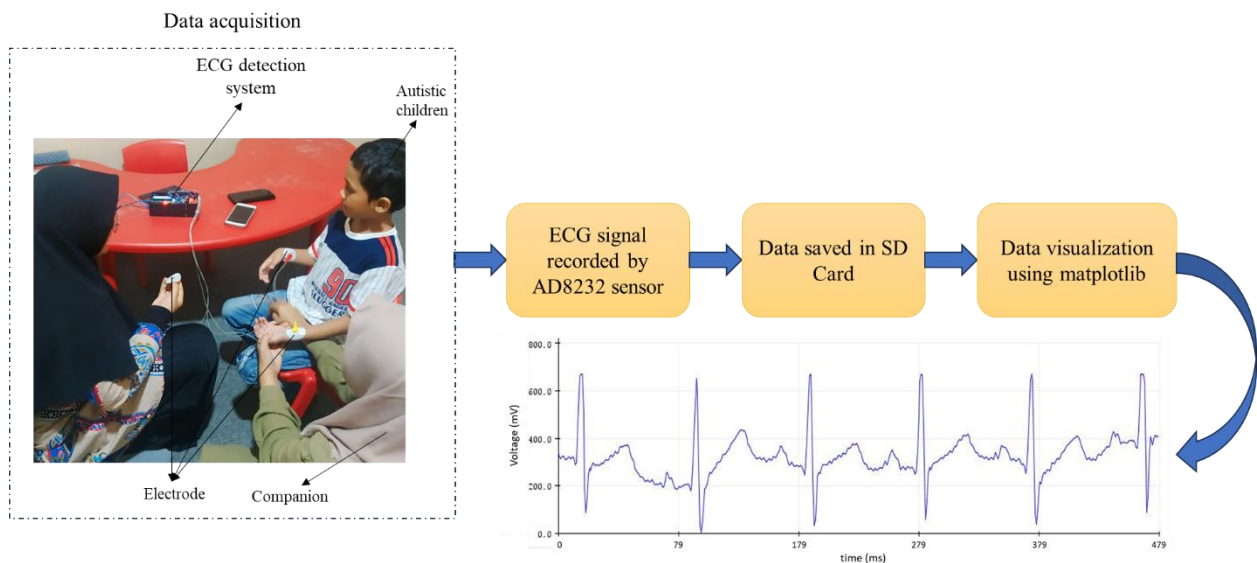


Fig. 5 Data acquisition process

C. Analysis of Testing Result

Algorithm 1 ECG signal outlier filter

Input: Array ECG signal (x_i), filter window size (s)
Output: Filtered ECG signal (C)

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1  for  $i \in (0, \dots, \text{len}(x_i))$  do
2     $l \leftarrow \max(0, i - s \text{ div } 2 + 1)$ 
3     $r \leftarrow \text{resize}(\min(\text{len}(x_i), i + s \text{ div } 2 + 1))$ 
4     $x_f[i] \leftarrow \text{apply mean to } x_i[l:r]$ 
7  end for
8  return  $x_f$ 

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This section we analyzed the results we got when we tested our ECG tool on ASD children. we took a sample of data for 2500 ms of 5 minutes total record per person that we have took for visualization to simplify the analysis process. the data we get still has some outliers that bother us in the analysis process. we use a filter on algorithm 1 to eliminate outliers in the data. we use visualization techniques per segment or we divide the data into several segments as explained in algorithm 2, which makes it easier for us to choose which part of the data we will see the visualization results. in this research we use python and the matplotlib library to help the visualization process. The results of data visualization, as shown in Fig. 7. This test obtained ECG data with a comparison of testing on the hands and the chest of a child with ASD for 2500 ms under calm conditions. Based on Fig. 7, the comparison between the different electrode attachment positions affects the ECG signal results obtained Fig. 7(a) shows the test of electrodes attached to the hand. The ECG results with this test obtained an unstable signal amplitude. This is due to the vulnerability of the electrodes to movements that occur during data collection. Meanwhile, the test conducted by attaching the electrodes to the chest showed a stable ECG signal, as shown in Fig. 7(b). As in time 0-3000 ms, the amplitude was stable at 0-650 mV. To clarify the comparison of the two tests, signal

segmentation was performed at 800-2000 ms using algorithm 2.

Algorithm 2 ECG signal visualization by segment

Input: ECG played signal path, ECG chill signal path, number segment (num), index segment (i), Filter ($f(.)$), $len = 3000$
Output: ECG Signal visualization figure

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1.  $x_p \leftarrow$  Open ECG signal played file
2.  $x_c \leftarrow$  Open ECG signal chill file
3.  $x_{pp} \leftarrow [0, \dots, len]$ 
4.  $x_{pc} \leftarrow [0, \dots, len]$ 
5.  $t \leftarrow [1, \dots, len]$ 
6.  $n\_idx \leftarrow []$ 
7.  $n = 0$ 
8. for  $i \in (0, \dots, \text{len}(x_p))$  do # cut signal same with len
9.   if  $i < \text{length data}$  do
10.     $x_{pp}[i] = x_p[i]$ 
11.   end if
12. end for
13. for  $i \in (0, \dots, \text{len}(x_c))$  do # cut signal same with len
14.   if  $i < \text{length data}$  do
15.     $x_{pc}[i] = x_c[i]$ 
16.   end if
17. end for
18.  $i_1 = \text{len}/num$ 
19. for  $i \in (0, \dots, num)$  do # find segmen index
20.    $n = n + i_1$ 
21.   if  $i == 0$  do
22.     $n\_idx[i] = 0$ 
23.   end if
24.    $n\_idx[i] = \text{int}(n)$ 
25. end for
26.  $x_{pf} \leftarrow \text{apply EKG signal outlier filter with window size 3 to } x_{pp}$ 
27.  $x_{cf} \leftarrow \text{apply EKG signal outlier filter with window size 3 to } x_{pc}$ 
28. Set figure size with row=2, col=1, figure size (15, 10) using matplotlib
29. Apply plot function matplotlib to ( $t, x_{pf}$ )
30. Apply plot function matplotlib to ( $t, x_{cf}$ )

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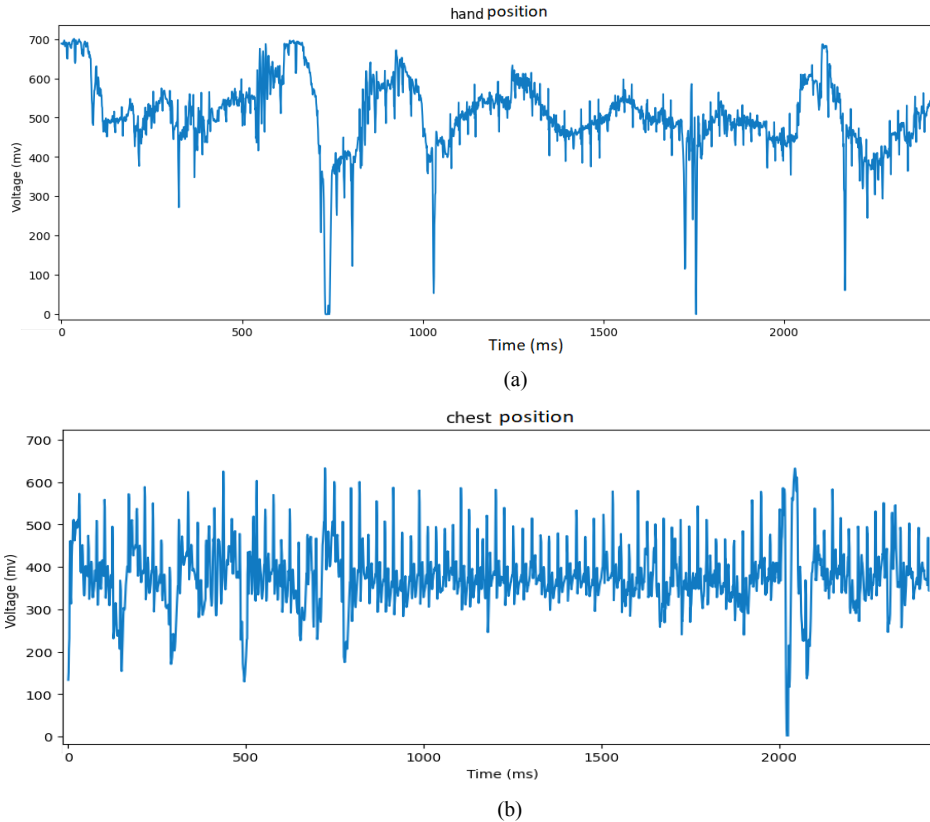


Fig. 7 ECG signal (a) Electrode position on hand (b) Electrode position on chest

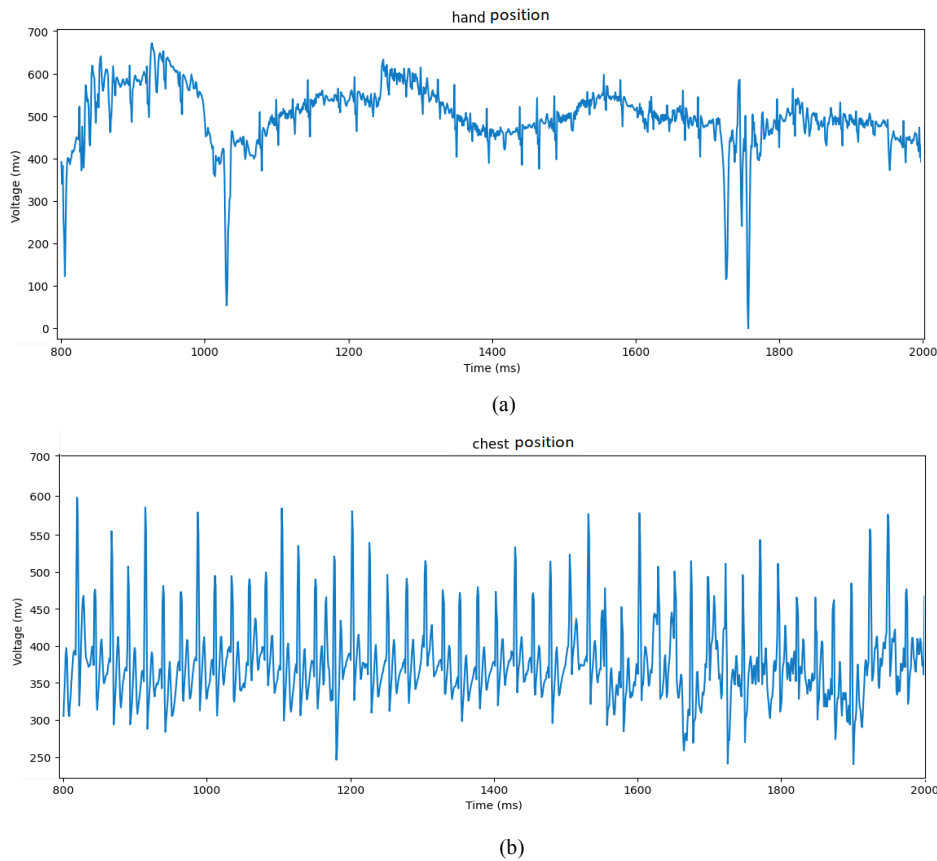


Fig. 8 ECG signal segmentation (a) Electrode position on hand (b) Electrode position on chest

After segmentation, the signal results were obtained as shown in Fig. 8. Comparison of signals obtained from different electrode attachment positions shows that the signal from the electrode attached to the chest is more stable than the signal from the electrode attached to the hand. As shown in Fig. 8(a), signals with a time range of 800-2000 ms obtained signal amplitudes of 0-650 mV due to excessive movement. The ECG signal with the electrodes attached to the chest, as shown in Fig. 8(b), remains stable at 800-2000 ms with an amplitude of 250-600 mV. This is due to the lack of movement that can interfere with the system during the test.

According previous study [9], which conducted tests using the AD8232 capable of detecting ECG signals. This study states that AD8232 can be used for ECG detection in autistic children and generate a stable signal. In a comparative analysis with previous study [7] has tested ECG detection using 3 electrodes to detect ECG signals. The result of this study is testing of AD8232 sensor electrodes to the hand can also produce a stable ECG signal, but it takes time and a stimulus that can calm the child. The signal obtained is repetitive and requires further signal processing to determine the child's heart condition. with the data obtained using the AD8232 sensor can be classified based on machine learning to determine the heart condition of autistic children in real-time. So that medical experts can find out the condition of the child's heart and be able to provide follow-up for the child's survival.

IV. CONCLUSION

Based on the study that has been conducted, it can be concluded that the device has functioned properly. The tool developed using the AD8232 ECG sensor can produce ECG

signals. The process of taking ECG data from ASD children runs smoothly. The test results of attaching the electrodes to the chest are more stable than on the hand, so attaching the electrodes to the chest is recommended to get a stable signal. From the signals obtained, the data can be processed to find samples to classify normal and abnormal conditions using Machine Learning to get a more realistic value with good accuracy.

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