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Comparative SNR Analysis Between Instrument ADAS1000 and AD620

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Abstract

The semiconductor technology for a certain function, such as instrumentation amplifier ICs is currently developing very fast, commercially available and can be obtained easily on the market. An instrumentation amplifier is a very important part in the process of data acquisition, especially for biopotential signals from the human body because its amplitude is very small and susceptible to noise interference. The selection of the proper amplifier instrumentation will produce an accurate biopotential signal reading. This paper explains the use of 2 types of instrumentation amplifiers, namely AD620 and ADAS1000, which are used in the design and realization of 12-channel ECG (Electrocardiograph). The performance and noise resistance of the two instrumentation amplifiers are compared and analyzed so that an appropriate instrumentation amplifier can be determined especially in the case of 12-channel ECG applications. 12-channel ECG was chosen because of the complexity of the design and can provide more detailed information as well as to detect the abnormalities heart's functions. The results shows that 12-channel ECG using AD620 instrumentation amplifier has an SNR value below 12.04 dB, while using the ADAS1000 instrumentation amplifier has an SNR value below 35.5 dB and it is more resistant to noise interference.

Keywords: Comparative, AD620, ADAS1000, ECG 12 Channel, Noise.

1. Introduction

ECG is a medical instrument used to record electrical activity in the heart. This instrument is used to help diagnose heart disorders such as arrhythmias, inflammation of the heart, enlarged heart and coronary heart [1-3]. ECG signal has a specific form that can be used as a reference for heart health conditions [4]. Currently, there is an ECG that uses 12 channels that provide more detailed and accurate information regarding heart health conditions [5]. The 12-channel ECG is widely developed with various types of instrumentation amplifiers. The instrumentation amplifier is the main component that affects the quality of the ECG signal output. This study aims to design and implement a 12-channel ECG using two types of instrumentation amplifiers, namely the AD620 and ADAS1000. Then the quality of the signal will be compared in producing an ECG signal. The results of this comparison can then be used as a reference for researchers, especially those related to the acquisition of biopotential signals from the human body.

2. Literature Review

2.1. ECG 12 Channel

The ECG signal is the result of the leads of two or more electrodes attached to the surface of the body. By using a 12-channel ECG (also called Lead), all electrical activity in the heart muscle can be observed so that it can be used for diagnosing heart disorders. Figure 1 shows the waveform of the ECG signal.

The leads on a 12-channel ECG generally consist of:

a. Frontal Lead (Limb Lead)

These leads use the Einthoven triangle method which will generate 3 Channel ECG signals, namely Lead I, Lead II, and Lead III. Heart signals tapped into the right hand (RA), left hand (LA), and left foot (LL).

Unipolar limb lead (augmented limb lead)

This lead compares the stress at one point of the body to the average tension of two other body points. These leads produce 3 Channel ECG signals namely aVR, aVL, and aVF. Resistors are used to get the leads aVR, aVL, and aVF.

b. Precordial Lead

The precordial leads are used to record the electrical activity of the heart from the horizontal plane. The precordial lead is derived from the comparison between the electrodes placed on the chest and the Wilson Central Terminal (WCT) sequence. The electrode is used as a positive voltage while the WCT circuit is used as a negative voltage. The result of these precordial leads is the 6 Channel ECG signal, namely V1, V2, V3, V4, V5, and V6.

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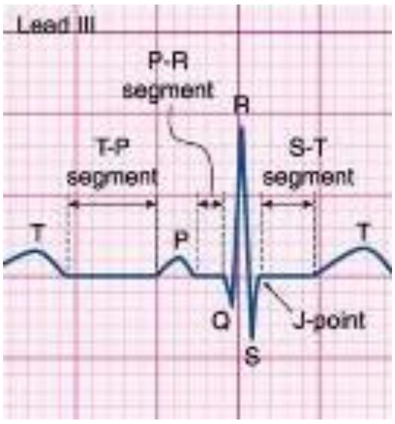

Figure 1. ECG signal waveform [9]

2.2. AD620 Instrumentation Amplifier

The AD620 instrumentation amplifier is an instrumentation amplifier component that has 2 inputs and 1 output where to determine the required gain, it can be calculated using equation 1. With RG is external resistance. This amplifier has a high enough CMRR (Common Mode Rejection Ratio) and a gain of up to 1000 times the gain [11]. Figure 2 shows the use of the AD620 to obtain an ECG signal, using three electrodes for both the right arm and leg (as in a standard limb lead connection) [12]. The ECG signal has an amplitude of 0.1 mV to 3 mV so it requires a high gain instrumentation amplifier to Equation 1.

$$G = 1 + \frac{(49.4k\Omega)}{R_G} \tag{1}$$

2.3. ADAS1000 Instrumentation Amplifier

ADAS1000 is a Front End Analog system that has a function to measure 12-channel ECG signals and respiration systems, with the ability to transmit data of 128 ksps per ECG channel.

This device has an SPI- / QSPI ™ - / DSP-compatible Serial interface. The board of the ECG ADAS1000 is shown in Figure 3.

2.4. Signal to noise ratio(SNR)

Signal to noise ratio (SNR) is a representation of signal strength to noise. The ECG signal and noise are formulated using the mean of the absolute squares of the signal according to Equation 2.

$$P = \frac{1}{N}\sum_{i=1}^{N} |x_i|^2 \tag{2}$$

Feature reliability is checked by adding artificial white Gaussian noise (AWGN) to the original ECG signal. The AWGN is randomly generated and standard deviations adjusted. The standard deviation of the AWGN is set such that the SNR can range from 60 to 0 dB as in equation 3 [14].

$$SNR(dB) = 10\log_{10}\left(\frac{P_s}{P_n}\right) \tag{3}$$

Where x_i represents the ECG signal, N represents the length of the ECG signal, P_s is the ECG signal strength, and P_n is the noise strength.

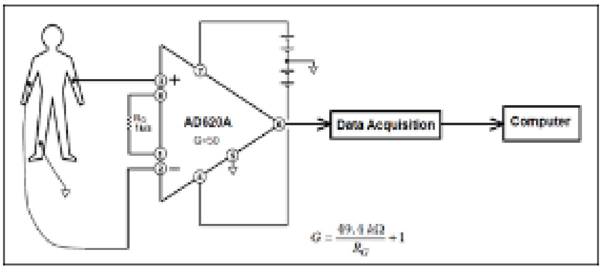

Figure 2. Schematic diagram of the AD620 [11]

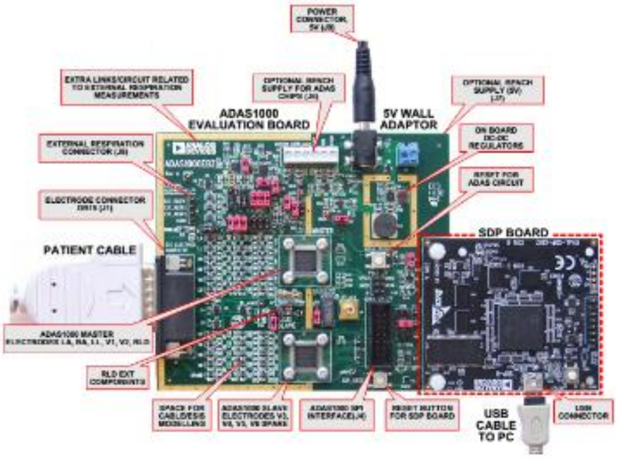

Figure 3. Board ADAS1000 Evaluation Board [14]

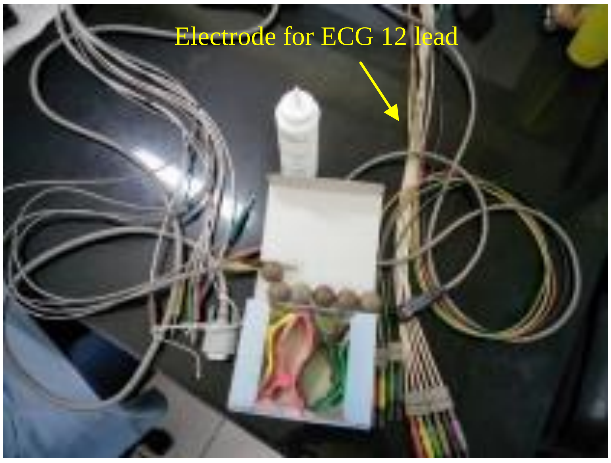

Figure 4. 12-channel ECG electrodes

3. Research Method

The research begins with the design and realization of 2 12-channel ECG devices using different instrument amplifiers, namely the AD620 and ADAS1000. The results obtained from each ECG will then be compared with the medical standard 12-channel ECG. Testing is also carried out using an ECG signal generator /

simulator and taking ECG data directly from volunteers.

3.1. ECG with AD620 Instrument

In the 12-channel ECG design paper, it is composed of filters, protection, buffers, AD620 instrument amplifiers and band pass filters. The 20dB LPF filter is designed with passive filters R, C to pass frequencies below 150 Hz. Protection is designed to protect the instrument from excess voltage that is not required by the system. The buffer circuit in this design is built from an op-amp which functions as a current amplifier without voltage amplification, where Vout ≈ Vin with gain is equal to one. The AD620 instrument amplifier is the main component of the ECG signal bioelectric (biopotential) amplifier. The 12-channel ECG design is shown in Figure 5. The output signal from the bioelectric amplifier below 150 Hz is filtered with a 40 dB band pass filter. Band pass filters are used to ensure the ECG signal is within 0.05Hz to 150Hz range. To calculate the component value using equation (5), (6). The band pass filter design is shown in Figure 6.

To determine the component value in the 20dB LPF design using Equation 4.

$$f = \frac{1}{2\pi RC} \tag{4}$$

The output signal from the bioelectric amplifier from the AD620 is filtered with a band pass filter using Equation (5) and Equation (6).

$$f_H = \frac{1}{2\pi R C_{LPF}} \tag{5}$$

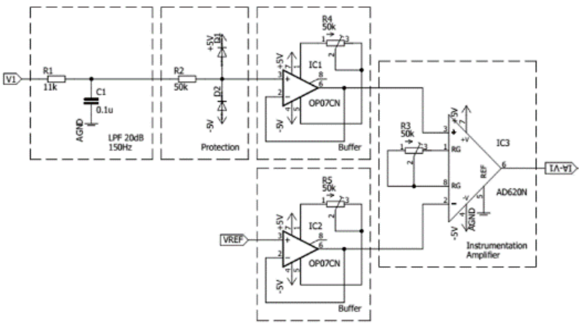

Figure 5. Schematic Of AD620 Instrumentation Gain

$$f_L = \frac{1}{2\pi R C_{HPF}} \tag{6}$$

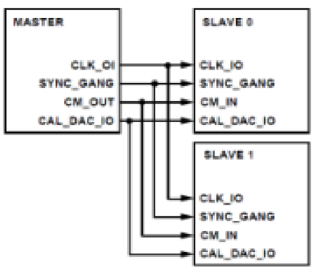

Figure 7. Synchronization of The Master Slave of The ADAS1000 [13]

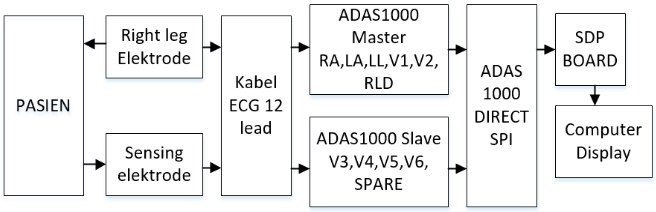

Figure 8. Block Diagram of the ADAS1000 System

3.2. *ECG WITH ADAS1000 instrument*

In the 12-channel ECG design paper using the ADAS1000 instrument. This 12-channel ECG requires 2 ADAS1000 ICs where, in 1 IC it only supports 5 electrodes with 1 RLD. The ADAS1000 IC is connected digitally which is set to be master and slave. All devices must share the signal by synchronizing CLK_Io master with an external Crystal with a generator frequency of 9,192 MHz. Synchronization of the two ADAS1000 instrument ICs is shown in Figure 7. The system block diagram of the ADAS1000 is shown in Figure 8.

4. Result and Discussion

Research has carried out the design and realization of 2 12-channel ECG devices using different instrument amplifiers, namely the AD620 and ADAS1000. For a comparison of the two instruments, testing was carried out. Tests include looking at the signal results from the two 12-channel ECG instruments. Where the ECG simulator generator is done 5 times data retrieval. Data was also collected from patients using the two 12-channel ECG instruments.

4.1. Testing Instrument AD620

The 12-channel ECG with the AD620 is equipped with filters, protection, buffers, AD620 instrument amplifiers and band pass filters. The design results are shown in Figure 9. The ECG signal issued by the AD620 instrument is mixed with noise reaching 720 mVpp in theory, having an amplitude of 0.1 mV to 3 mV. From the reading result, the oscilloscope instrument measurement dial shows that the pure ECG signal has a combined noise of SNRdB = 18.06 dB. The result of the pure ECG signal is shown in Figure 10. Seeing the output of the 12-channel ECG signal with the AD620 instrument is still accompanied by noise. The 12-channel ECG with the AD620 was tested by taking data to volunteers. The volunteer data sample is taken from the best data that has been confirmed by standard 12-channel ECG testing. Installation to the volunteer test is shown in Figure 11.From the results of the diagnosis of cardiac activity the volunteer sample is shown in Figure 12.

Figure 9. The result of 12-channel ECG design with AD620

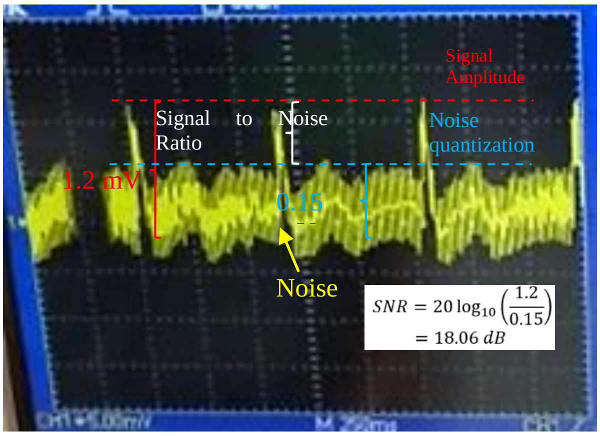

Figure 10. Measurement results from the ECG instrument AD620

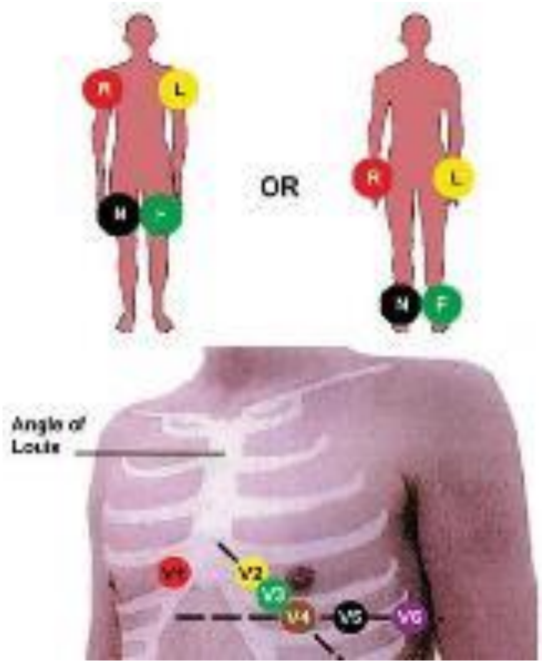

Figure 11. 12-channel ECG electrode installation [12]

4.2. Comparison Analysis of AD620 and ADAS1000

The two 12-channel ECG instruments were compared to determine system reliability. One way is to compare the signal results. For the signal results from the test using the ECG instrument AD620 simulator generator which was carried out 5 times. In this study, the reference for the medical standard 12-channel ECG signal is shown in Figure 13. The signal leads containing noise occur 4 times. Figure 14 shows that the SNR value of lead 1 signal is 12.04 dB.

For signal tapping results from testing the ADAS1000 instrument which was carried out 5 times. 1 lead contains noise. Figure 15 shows that the SNR value of lead 1 signal leads is 35.5 dB. Of all the tests carried out, the SNR value of 1 was below 35.5 dB. Based on the results obtained, the SNR value of the two 12-channel ECG instruments is good. When compared to the two, the best leads are on the ADAS1000 instrument.

Judging from the features offered by the ECG made from the AD620, it can be monitored using a PC with the basic C program, other features can be installed with 12 ECG channels. For the ECG features that are made from the ADAS1000 display using USB attached to the computer. The features offered can detect with 3 channels, 6 channels, or 12 channels. Another feature of the ADAS1000 can be used to detect respiration with the lead 1 lead electrode. Judging by the price of making the ECG for the AD620 the price is IDR 1,700,000. The ECG design for the ADAS1000 the priced is IDR 4,172,000.

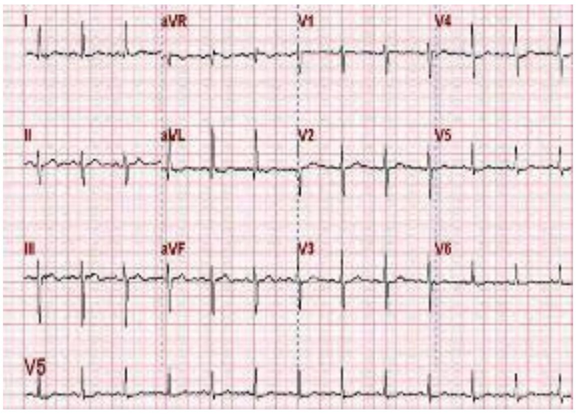

Figure 12. Results of heart diagnosis of volunteer samples with 12-channel AD620 ECG

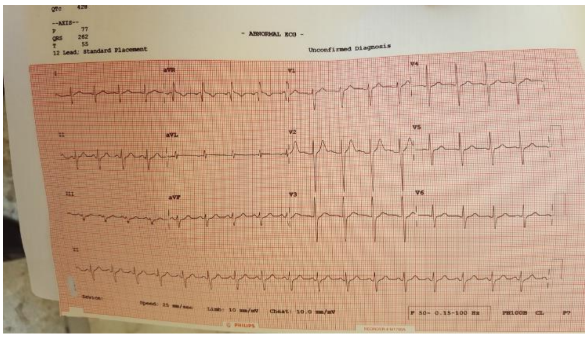

Figure 13. Results of volunteer diagnosis with medical standard 12-channel ECG

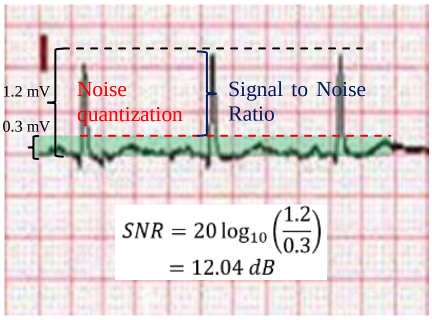

Figure 14. Results of the AD620 instrument channel 1 signal

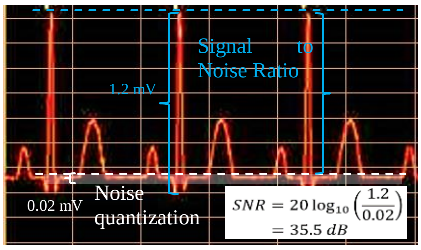

Figure 15. Results of the ADAS1000 instrument Lead 1 signal

5. Conclusion

This paper has realized the 12-channel ECG from the AD620 and ADAS1000 instruments. Both instruments had results close to the medical Standard 12-channel ECG. From the tests carried out using the ECG simulator generator 5 times for the AD620 4 signal amplifier containing noise with an SNR below 12.04 dB and the ADAS1000 1 signal amplifier containing noise with an SNR below 35.5 dB. The test results with the same volunteers for the signal from the AD620 system escaped noise interference while the ADAS1000 system was not followed by noise interference. This paper concludes that the signal tapping results from the ADAS1000 instrument are better than the AD620. When viewed from the features offered by the ECG with the ADAS1000, it has the advantage of respiration detection. When viewed from the price, the AD620 is much cheaper in its manufacture.

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