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Ways to improve the quality of the ECG amplifier

Tiancheng Tang

Department of Physics, Shanghai University, Shanghai, 200000, China

tang20011120@shu.edu

Abstract. Cardiovascular disease is becoming increasingly common, so ECG is becoming increasingly important in our daily life. ECG amplifier, which amplifies the body's weak signals, are getting more and more attention. It becomes necessary to improve the ECG amplifier's performance. This paper discusses four key ways to enhance the performance of the ECG amplifier: lowering the cost of the ECG amplifier; lowering the power consumption and noise of the ECG; and creating a circuit for specific use. The article lists other researchers' works. By comparing with each other, the author gives his own opinion on improving the quality of the ECG amplifier. It shows that the improvement of the ECG is strictly connected to the new scientific results like new materials or circuit methods, and the conflicts between the quality and the cost of building an ECG should be balanced. In the end, the author also gives the prospection of the ECG amplifier research field.

Keywords: ECG amplifier, circuit, health.

1. Introduction

Electrocardiogram, mainly known as ECG, is becoming increasingly important in our daily life. An electrocardiogram examination is an essential means of examination in clinical practice. It can determine the frequency and rhythm of the heart and can also see whether there is myocardial ischemia and other conditions. According to the 2020 China Cardiovascular Health and Disease Report, the Patients with cardiovascular disease in China have increased to 330 million, which gives a heavy burden to the social environment 0. Electrocardiogram is one of the primary basis for determining heart disease. However, the commonly used electrocardiogram detection machine can detect ECG signals and diagnose disease types. Meanwhile, the signal in the human body is quite faint and hard to be detected, which could be easily interrupted by the noise in the human body. That's why the ECG amplifier was developed. An electronic component called an electrocardiogram (ECG) amplifier transforms the heart's relatively weak electrical signals into signals that may be sent to a monitoring system. Typically, alarms are first detected by body electrodes. ECG machines often feature a differential preamplifier, which can further improve the electrical signal by more than 100 times, and a buffer amplifier that analyses the signal and amplifies it by a factor of 10 after that. A heart monitor normally comprises several parts, including diodes, capacitors, and other elements on the circuit board, in addition to the ECG amplifier. Electronic filters, a gain stage, and an ECG amplifier can all be incorporated into a circuit[2]. The gain stage normally enhances the excellent direct current. In addition to isolated organs, some versions can record human or animal data and are set to measure different electrical signals. However, the high price of the equipment and the characteristics of not easy to carry bring a lot of limits to electrocardiogram detection.

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So in recent years, various research institutes have been developing more portable and accurate ECG amplifiers.

2. Ways to improve the quality of the ECG amplifier

2.1. Reducing power consumption

The first and most essential way to improve the quality of the ECG amplifier is to lower the power consumption of the amplifier. Current trends in ECG monitoring and diagnosis are increasing the use of portable and even wearable devices. Displays tend to be smaller and easier to carry around, often in the form of electronic devices such as watches and wristbands. Smaller batteries are required as medical gadgets become more portable and even wearable. Nevertheless, it is highly undesirable to replace batteries frequently. Therefore, lowering electricity usage can help with both of these issues. The primary way to fulfill it is to change the structure of the devices. Smaller batteries are required as medical gadgets become more portable and even wearable. Nevertheless, it is highly undesirable to replace batteries frequently. Therefore, lowering electricity usage can help with both of these issues. 0. The low pass filter's power consumption can be managed in 13.43nw using the low power, low transconductance OTA. The technology can be introduced to biomedical applications, such as ECG. Another group decides to use a single-supply ECG system. Using a switching voltage inverter, the Indira Gandhi Centre for Atomic Research group successfully developed the single-supply ECG circuitry to drop the voltage from 18v to 9v. Scientists used base dual power supplies to record signals. However, biological potential amplifiers that operate using bipolar signals require a dual power supply to function properly, which is demanding for battery-powered applications. The use of switching voltage inverters can significantly reduce power consumption. It can be utilized concurrently with the MCG configuration without significantly increasing the noise level in the MCG measuring system. Comparing the two ways shows that power consumption has become an important criterion when scientists develop a new ECG system. There are many ways to achieve it, mainly by changing the traditional structure or combining new technology. It seems that power consumption has become a promising research field.

2.2. Reducing noise

The noise is also a necessary standard when designing an ECG amplifier. Different factors, such as line interference, contact noise between the skin and the electrodes, motion artifacts, muscle contractions, and electromagnetic interference from other electronic devices, might interfere with the ECG signal. Baseline drift (BW), muscle pseudo-noise (MA) or electromyogram (EMG) noise, channel noise (additive white Gaussian noise, AWGN), power line interference (PLI), complex noise (CN), random noise, electrode motion pseudo-noise (EM), and instrument noise are just a few examples of the various sources of noise. This makes it challenging to identify disease-specific morphological abnormalities in ECG signals. For the doctor, it is crucial that the ECG signal be clear and that any electrical noise be as minimal as possible to prevent interfering with the ECG diagnosis. Nowadays, there are mainly six ways to reduce noise. The first is the locally adaptive frequency-time electrocardiogram (EMD). Deep learn-based autoencoder models (DAEs), which are used to regenerate clean ECG signals from imperfect ECG signals, are under the second category. Wavelet-based techniques are within the third group. The signal was broken down, the threshold type was determined, the signal was rebuilt, and the ECG signal was denoised using wavelet transforms (WT). The fourth is sparse denoising of the ECG signal caused by its rarity. The Kalman filter's traditional dynamic ECG model, which is used in the fifth category, is modified using Bayesian filters to denoise ECG signals. The final classification is hybrid, which integrates many approaches described in the literature. Removing the noise of ECG is an essential part, and there are six methods to fulfill it. Meanwhile, changing the structure of the ECG devices to remove noise is also a practical method. By adding different digital filters, diverse sources of noise source can be eliminated. The ZPBPF, which comprises a low-pass and a high-pass filter, is an enhancement in the digital processing of ECG signals. The ECG signal is first forward-filtered, and then the filtered sequence is reversed and passed back through the filter. The resulting sequence is referred to as a zero-

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phase filter since it exhibits accurate zero-phase distortion and has two filter orders. The signal-to-noise ratio of ECG signals is enhanced by this filter block.

2.3. Specializing the use

Specializing the use of ECG amplifiers is also a practical method. In the past, the ECG is mainly used to monitor patients' health conditions for clinical use. But nowadays, people also try to add ECG to the electronics, such as smartwatches or bracelets. This reduces the requirement for the accuracy of the device. But the size should be smaller. At the same time, the ECG can be specialized for different use. Not only the patients may need the ECG, but the athletes or the aged may also need the monitor of ECG. Based on the requirement of different people, the standard should be changed. A home electrocardiogram should be easy to carry, have low power consumption, be real-time, intelligent, and so on. An MSP430 single-chip microcomputer used by a research team from Shenzhen Vocational and Technical College has successfully created a portable wireless ECG monitor that can amplify and filter patients' ECG signals before sending them to a central controller. It uses real-time ECG data capture and short-distance transmission. It can be used for sports training, community healthcare, and at-home healthcare. The athletes, need to wear ECG devices for a long time to monitor their body condition. This tests ECG's ability to fulfill long-term monitoring during daily activities. At the same time, athletes, like swimmers, may require the ECG to work nicely when they are submerged in fresh water. Creating an ECG recording system with an extremely high input impedance that permits the use of dry electrodes is one option to address the issue. The system is raised by a group at Sydney University whose leader is Gaetano Gargiulo. The group uses dry electrodes instead of the traditional electrically conductive gel, which will quickly become dry and reduce the signal quality. The device has a low power consumption due to the development of a dry electrode biopotential amplifier with an ultra-high input impedance; the overall power consumption is lower than 5 mA at 4.8 V. Laboratory and clinical trials have shown that the system can collect a subject's electrocardiogram and reliably monitor it for at least 24 hours. Experiments also showed that the device worked even when subjects were completely immersed in fresh water. In conclusion, the biopotential amplifier can be successfully used for a wide range of novel and unusual clinical monitoring applications, including dynamic patient tracking, sports medicine, underwater monitoring, and heart rate monitoring of patients who are lying, sitting, or standing. By developing a dry electrode biopotential amplifier with ultra-high input impedance, the device has low power consumption, and the system power consumption is less than 5 mA at 4.8 V. Laboratory and clinical trials have shown that the system can collect a subject's electrocardiogram and reliably monitor it for at least 24 hours. Experiments also showed that the device worked even when subjects were completely immersed in fresh water. In conclusion, the biopotential amplifier can be successfully used for a wide range of novel and unusual clinical monitoring applications, including dynamic patient tracking, sports medicine, underwater monitoring, and heart rate monitoring of patients who are lying, sitting, or standing.

2.4. Reducing the cost

As the ECG's role becomes more and more intricate. The ECG's cost and complexity are being reduced by the researchers. By 2010, cardiovascular disease will overtake cancer as the top cause of death globally. To aid medical professionals in developing nations in providing reliable diagnoses, a low-cost ECG should be developed. A portion of the device was created by Indian researchers employing three waste metal electrodes coupled to a high-gain low-power amplifier. Since nearly all cell phones include USB and Bluetooth connectors, it is possible to employ a low-cost interface to transform an analog ECG signal into a digital stream that can be shown on the phone. Due to its widespread availability in underdeveloped nations, the cell phone can be used to display ECG signals, giving local clinicians a way of diagnosing before the need for any medical evacuation. The amplifier component costs less than five Australian dollars, and the processor costs only a couple of dollars more, so it can be concluded that the project is feasible for deployment in developing countries. The usage of micropower amplifiers in a wireless ECG monitoring system that is powered by rectifying RF energy or other energy sources, such

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as body vibration and body heat, is another issue. The daily body movement and the heat generated by the movement could be collected by energy harvesters, which will significantly lower the power supply standard. In addition to changing the energy supply, downsizing the ECG is also a method. The University of Dublin researchers created a very low-power preamplifier for use in pasteless electrocardiogram (ECG) recording. The amplifier uses 30 /spl mu/W of power when powered by a 3.3 V battery. It is utilized for compact, lightweight, portable heart rate monitors and ECG devices. It is also feasible to modify the ECG's structure by removing the ground electrode. By removing the ground electrode from the two-electrode method, patient safety can be increased. Patient attachment is facilitated and electrode expenses are reduced with fewer electrodes. However, not every eventuality may be covered by the design. The technique is useful for portable arrhythmia monitoring, portable Holter monitors, and biotelemetry. In terms of outcomes, the price drop signals the growth of daily ECG monitoring. According to projections from market research firm GlobalData, the global electrocardiography (ECG) market will increase at a 3.7 percent annual pace to reach $157.9 million in 2015 from a market of $122.2 million in 2008. It is shown that the expense reduction is at the cost of accuracy or sustainability, which shows the problem of balancing the performance and the price. But relatively poor performance is acceptable since the low-cost ECG is mainly designed for daily use or the people in developing countries.

Table 1. Ways to improve the quality of ECG amplifiers and their advantages.

	Ways to fulfill it	Advantages
Reducing power consumption	Change the structure of the ECG amplifier	Highly related to the development of science and technology, having broad prospects
Reducing noise	Adding different digital filters	Improves the signal-to-noise ratio of ECG signals
Reducing the cost	1. Utilizing a single-chip MSP430 microcontroller to control a portable wireless ECG monitor 2. Using dry electrodes instead of the traditional electrically conductive gel	Extremely low cost, easy to fulfill
Specializing the use	1. Constructing a wireless portable MSP430 computer-controlled ECG monitor 2. Creating a recording system for ECGs with a very high input impedance	The standards of ECG amplifiers can change flexibly by different users.

3. Conclusion

The paper mainly listed four ways to improve the quality of the ECG amplifier. By listing other researchers' works, it has been shown that improvement of the ECG amplifier is strictly connected to the technology renewal. When discoveries are made, the ECG amplifier can be improved. From the noise to the power consumption aspect, the researchers add new circuits or change the materials and power to improve the quality of the amplifier. At the same time, the specialization of functionality can save a lot of cost or effort, even at the price of some accuracy. By sacrificing the circuit's quality to

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make the system more portable and cheaper. To meet the need of a certain group, new technology needs to be added to fulfill them. Of course, the new theory needs more clinical practice to improve. In the future, adding newly discovered materials or circuit elements and removing some unnecessary functions to meet certain needs and reduce cost may be a popular research field. It seems that there is still a massive scope for the improvement of ECG performance.

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