Design of ECG Signal Generator Based on Motion Scene

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Abstract With the normalization of cardiovascular diseases (CVD) in many countries, portable ECG monitoring devices have gradually become popular. However, since the current portable ECG monitoring equipment lacks a unified testing standard specification, a suitable calibration device is required for restraint. This research simulates a multi-state ECG signal generation system built using Arduino uno board for calibration of portable ECG monitoring devices. The system can generate human ECG signals of different intensities under different heart rates based on the operation of the host computer. The equipment has the advantages of simple, easy-to-use and low cost, and can be used as an ECG signal source for a portable ECG monitoring device in a simple laboratory environment.

1. Introduction
Cardiovascular disease (CVD) has gradually become one of the primary factors threatening the health of people in many countries at present. According to NHANES 2015-2018 data, the prevalence of cardiovascular diseases (coronary heart disease, heart failure, stroke, hypertension) among American adults (≥ 20 years old) is as high as 49.2% (2018 statistics reached 126.9 million). The prevalence of CVD in men and women increases with age. After excluding hypertension, the prevalence of CVD was 9.3% (statistics reached 26.1 million in 2018) [1].

With the normalization of cardiovascular diseases in many countries, related portable ECG monitoring devices have gradually become popular. The use of portable devices for timely ECG monitoring can not only judge the health of the human body by recording the electrical activity of the normal human heart, but also detect and report in time when the human body has arrhythmia, myocardial infarction, and cardiac hypertrophy [2]. However, due to the lack of unified testing standards and specifications for current portable ECG monitoring equipment, product quality cannot be well guaranteed. Therefore, it is necessary to calibrate such equipment. In the current calibration process for this type of monitoring equipment, many manufacturers use real human body as the ECG signal source of the equipment. The calibration method using real human body has a lot to do with the physical fitness and current body condition of the subject, and it is difficult to be representative. Therefore, there is a need for a signal source that can accurately restore the standard ECG signal and the ECG waveform under different conditions of the human body, that is, an ECG signal generator.

There have been some researches on ECG signal generators. They are all based on various data acquisition methods and hardware devices. For example, study [3] used PIC16F877 to design a biomedical signal generator and compared the experimental measurement signal with the circuit generated signal. There are also studies based on ARM9 [4], NI-USB platform [5] and other hardware to measure and collect ECG signals, or use a host computer to control a programmable microcontroller to simulate ECG signals [6]. In addition, in some studies, Labview and Matlab [4,7] are also utilized to
simulate and analyze EEG signals.
In this study, the EEG signal generator under different heart rate conditions (motion scene) was implemented. The Arduino uno board was used for simulation. The experimental heart rate waveform was good. It can meet the calibration work requirements of portable ECG monitoring equipment at a lower cost without subjects.

2. Material and Method
The standard electrocardiogram waveform used in the experiment is shown in Figure 1 below. The electrocardiogram contains a complete P-R interval and Q-T interval, with obvious P wave, QRS complexes and T wave, which can represent a relatively standard single ECG cycle.

![Figure 1. ECG signal used in the experiment.](image)

This study used Proteus 8 software to simulate the ECG signal generation system. In the simulation, Arduino uno board component was used for digital signal processing, and MCP4921 chip was used to realize the digital-to-analog conversion function and output the ECG signal to be monitored.

First, the standard ECG waveform should be digitized. In order to cooperate with the 12-bit DAC chip, the waveform was normalized to a maximum of 4096, and linear interpolation is performed every 1ms, which can preserve the trend of the ECG waveform and smooth the waveform to the greatest extent. After the DAC chip was connected to the voltage follower and non-inverting amplifier composed of LM358N, the ECG signals of different strengths can be obtained by adjusting the ratio of R5 and R4. The experimental simulation circuit was shown as follows:
The waveform stored in the Arduino uno was transferred to the SDI port of the DAC through the digital port 11. In order to ensure the correct timing and protect the components, a state machine is used to delay the output of the digital waveform. The heart rate value of 30-120Bpm can be input from the host computer to specify the number of "waiting" states in the state machine to control the frequency of the ECG signal generated (that is, to control the heart rate in different motion scenes).

3. Result

The comparison chart of different heart rates displayed by the oscilloscope under the same time base in the simulation is shown in Figure 3 below.

The oscilloscope result also contains the ECG signal before and after the magnification of 5 times. It can be found that the system can generate ECG signals of different frequencies with the changes of
the Arduino host computer settings. In addition, the intensity of the generated ECG can be changed by changing the resistance in series in the non-inverting amplifier circuit.

4. Discussion
In this study, a ECG signal generator based on different motion scene for the calibration of portable ECG monitoring devices was built through the Arduino uno board. The frequency of the generated ECG signal can be changed by inputting different heart rate value via the host computer, thereby simulating ECG signal of the human body in different motion states at different heart rates. The system involved in this study is simple to build, has the characteristics of adjustable heart rate and intensity of the generated signal, and is low in cost. It can help manufacturers and testers of portable ECG monitoring devices to perform convenient and quick device calibration.

This device still has room for improvement. For example, it still relies on the host computer instructions when changing the heart rate. This function can be further integrated into the development board and operated by keys. Second, the device designed in this study only stores a standard ECG signal. In the future, more waveforms can be stored, and different modes can be switched by key operation, so as to respond to the ECG signal under different conditions (especially pathological conditions) and perform further simulations. In addition, this study did not carry out actual experimental measurement operations, and a lot of noise will be generated during the actual measurement of bioelectric signals such as ECG signals. The subsequent amplification operations will also amplify the noise, so the necessary filtering means need to be Included in consideration.

5. Conclusion
In this study, a motion-scene-based ECG signal generation system for portable ECG monitoring device calibration built using the Arduino uno board was simulated through Proteus software. The system can generate human ECG signals of different heart rates and different strengths based on the operation of the host computer. The equipment was simple, easy-to-use and low cost, and can be used as an ECG signal source for a portable ECG monitoring device in a simple laboratory environment.

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