A wireless EEG device using Bluetooth for brain activity measurement

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ABSTRACT

The electroencephalogram (EEG) is vital for analyzing brain electrical activity in medical diagnosis and research. Aiming at the limitations of large size, high price, and inability to monitor EEG activity daily, a wireless wearable EEG measuring device was designed for patients with epilepsy. The designed system, with its low-power Bluetooth module, EEG acquisition module, and motion module, is not only efficient but also user-friendly. The system works at a sampling rate of 250 Hz for 8 channels and transmits data to a host computer or cell phone via Bluetooth. In addition, head movements are also recorded for behavior analysis. The results showed that the designed system has low noise and high-resolution performance, meeting the requirements for daily EEG measurement. The key benefit of this new device is its convenience and efficiency, providing a more user-friendly and effective tool for EEG monitoring, which could benefit seizure recording for patients with epilepsy in a home environment.

Keywords: Epilepsy, EEG, Motion, Bluetooth

1. INTRODUCTION

Epilepsy is a common neurological disorder that affects an estimated 65 million people worldwide, according to the World Health Organization. Epilepsy is characterized by recurrent abnormal electrical discharges in the brain [1]. However, the onset of epilepsy is often unpredictable, which makes people with epilepsy need long-term monitoring and treatment. Scalp EEG is a non-invasive method of monitoring brain activity and is commonly used to diagnose epilepsy and evaluate the effects of treatment. However, traditional EEG collection requires the patient to visit a hospital or clinic, requires wired sensors and devices, and is inconvenient and uncomfortable to operate. The abnormal EEG activity of the epileptic brain is important for diagnosing and treating, such as recording habitual seizures, which makes it important to record brain activity in daily life.

Medical services are more inclusive and convenient, promoting the development of medical informatization [2]. With the rapid development of wireless technology, Bluetooth, Wi-Fi, and Zigbee are commonly used in homes and workplaces. Bluetooth technology has shown the advantages of good compatibility, accurate data transmission, low power consumption, and low cost. Wi-Fi technology is a local area network wireless communication technology that can achieve high-speed data transmission and a large coverage area. However, it also has a high power consumption; Wi-Fi cannot provide support if the subject is out of the building. Zigbee technology is a low-speed, short-range wireless communication technology suitable for large-scale sensor networks; it fits situations such as smart homes and industrial automation; it is difficult to provide support outdoors. Cell phones and personal computers with Bluetooth are very common now, which makes them suitable for use in electrophysiological data acquisition and analysis without additional cost.

The amplitude of EEG is in microvolts, and it is easy to be contaminated by artifacts and noises. To lower the noise level of the EEG acquisition system is always challenging, especially in a home environment. Based on Bluetooth communication technology, this paper will develop a device more suitable for daily EEG monitoring of epilepsy patients, with an EEG acquisition module and motion module. The motion module tracts head movement and is then used for artifact reduction. In addition, that movement can be used to analyze the subject's behavior, which is also important for seizure analysis. This system can also provide more comprehensive and accurate data for the study of epilepsy and promote the treatment and scientific research process of epilepsy [3].

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2. METHODS

2.1 Overall system design

EEG results from a tiny electrical signal generated by mass neurons when active, which is recorded on the scalp. The spatial features of EEG describe the relative position relationships between different brain regions. Therefore, the spatial features between different brain regions can be described by analyzing the distribution of EEG on the scalp [4]. The electrical signal interference (motion artifact interference) caused by the subject's or patient's head or facial muscle movement during EEG measurement can affect the accuracy and reliability of the measurement results. In this design, EEG module ADS1299 collects EEG signals, motion module MPU6000 removes motion artifacts, and the data is transmitted to the host computer through the Bluetooth module CC2652 for subsequent processing. The overall block diagram of the system is shown in Figure 1.

2.2 System hardware design

2.2.1 EEG acquisition module

The EEG acquisition module of the EEG measuring device is designed with high precision, portable, and low power consumption, and the EEG acquisition module is the core basis of the whole design. ADS1299, produced by TI Company, is selected as the core device, and its hardware circuit is designed and implemented. ADS1299 is a kind of analog-to-digital conversion chip specially used for EEG acquisition. It has outstanding features and is suitable for high precision, portable, low-power consumption EEG acquisition system design. Figure 2 shows the circuit design diagram of ADS1299. The chip has eight differential input channels, the voltage input range is ± 5 mV ~± 2.5V, and each input end is integrated with an electromagnetic interference filter, which is used to separate useful signal and useless noise in the circuit, improve the signal-to-noise ratio of the circuit signal and anti-interference performance so that the EEG acquisition accuracy is higher [5][6][7].

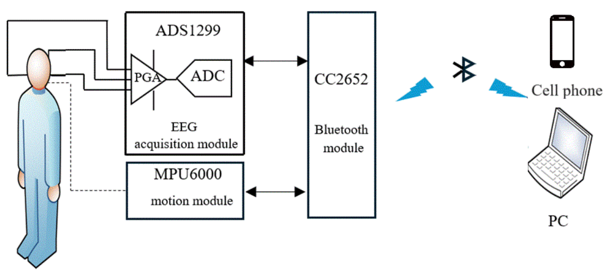

Figure 1. Overall block diagram of the system

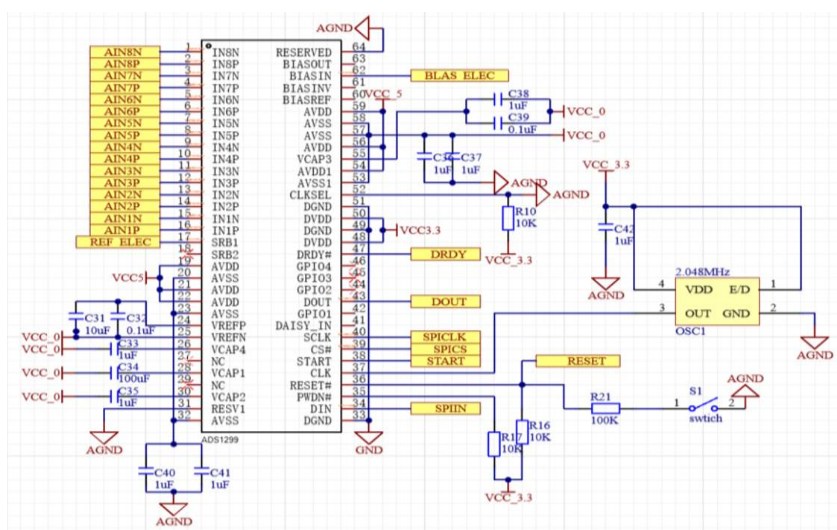

Figure 2. ADS1299 circuit design

2.2.2 Bluetooth low power module

Bluetooth is a short-range wireless communication technology. Introducing a Bluetooth module in the design aims to realize wireless transmission of EEG data. The design of the Bluetooth module was selected by TI company CC2652 Bluetooth chip. CC2652 Bluetooth chip, a high-performance wireless MCU chip that integrates Bluetooth low energy consumption and multi-protocol, has powerful processing power, rich peripheral interfaces, low power design, and high security[8]. It is suitable for a wide range of Internet of Things and wireless communication application scenarios, and the specific Bluetooth module circuit is shown in Figure 3.

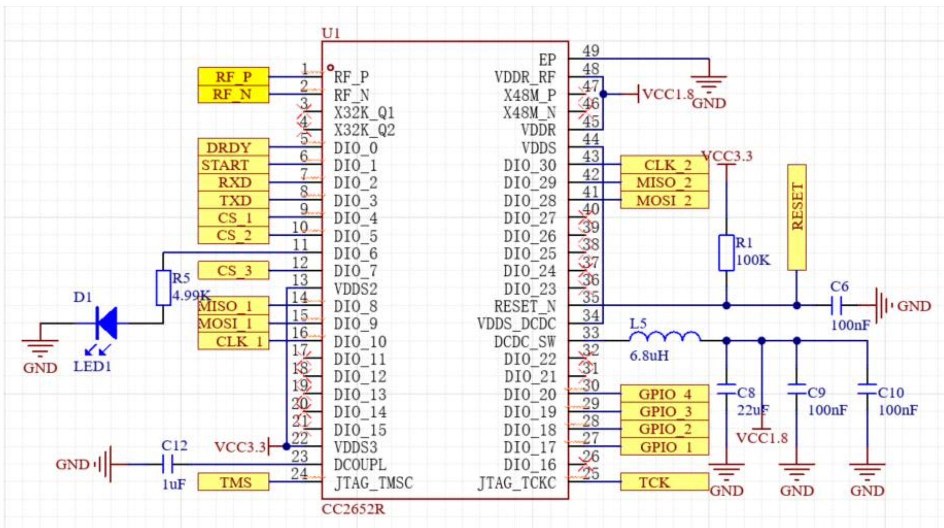

Figure 3. Circuit of CC2652 Bluetooth chip

2.2.3 Motion module

In the process of EEG acquisition, there is interference from other signals, so the EEG acquisition equipment needs to be able to remove interference. The main function of the motion module is to remove motion artifacts and improve the quality of EEG. The MPU6000 chip in the motion module is a high-performance inertial measurement unit (IMU), the most widely used in the Internet of Things due to its low price, high accuracy, and small size advantages. In the internal structure of the MPU6000, the accelerometer and gyroscope are composed of piezoelectric sensing elements and amplification filtering elements. The peripheral circuit is built around the MPU6000 to meet the chip design requirements. The connection structure between the motion chip and the peripheral circuit is shown in Figure 4.

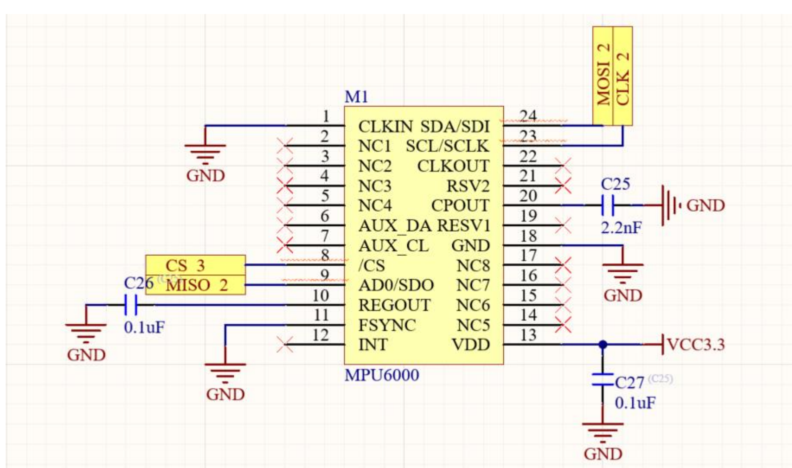

Figure 4. MPU6000 circuit diagram

2.3 System software design

The software program controls data acquisition and processes the collected EEG data. The device's software design is written in C language, and SPI realizes the communication between modules. The program design comprises a Bluetooth low-power module, an EEG acquisition module, and an acceleration sensor module. Finally, the data is received through the mobile phone's Bluetooth app to verify whether the circuit design's function can be used normally.

2.4 System function test

Physical design using PCB board technology. The circuit boards for EEG collection, motion and Bluetooth integration, and power supply are made. After debugging and assembly, the EEG can be used normally and measured. The designed EEG acquisition device is shown in Figure 5.

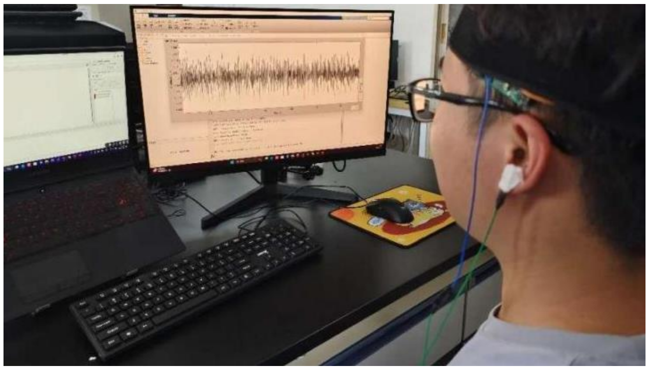

Figure 5. Device physical picture

3. RESULTS

3.1 Internal noise test

To verify whether the performance of the wireless EEG collection system designed for epileptic patients has reached the expected goal and the quality of scalp EEG signal collection, the system's internal noise was first tested: Power on the system and use the external clock signal and internal reference signal. The input signal of each channel is set to enter the short-circuit mode through the software control command, the programmable gain amplification is set to 24, the sampling rate is set to 250 Hz, and the sampling time is set to 10 s. Multiple samples are collected, and the collected signal data is saved. Finally, the system noise level is evaluated by averaging the results of multiple measurements. The results of internal noise are shown in Figure 6. Through analysis, the internal noise peak-peak value of the system is 0.7 μV.

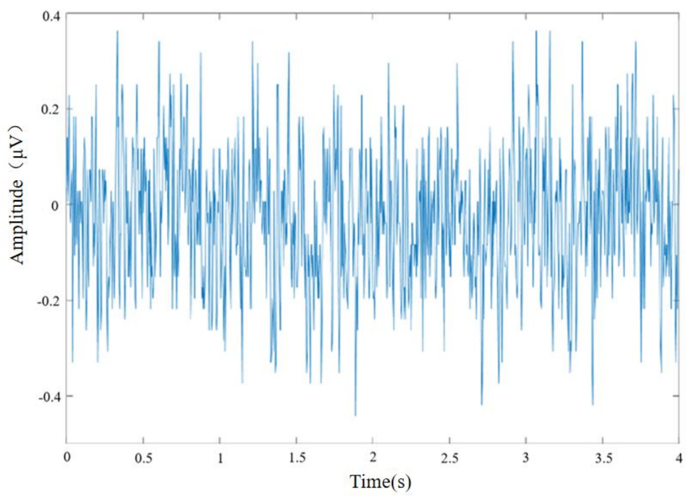

Figure 6. Internal noise measurement results

3.2 Experimental measurement

The tester wore the device, and the subjects were asked to clean their hair and remove fine dust before the experiment. The scalp of the corresponding electrode should be cleaned with a scrub. During the experiment, the subjects were in a quiet environment with three electrodes: positive, negative, and biased. First, the positive electrode was placed at the Oz of the 10-20 lead cap, that is, the position of the back of the head; second, the negative electrode was placed at the A1 position of the left ear mastoid; and finally, the biased electrode was placed at the A2 position of the right ear mastoid. The EEG of the subjects with closed eyes was collected in the experiment, and the measurement time was 20 s each time, and the interval was 3 min each time. In data acquisition, the sampling rate of 8 channels for data collection is 250 Hz, and the sampling time is 20 s. b, the data is saved in text format, the data is put into MATLAB for processing, the data of each channel is distinguished, and each channel is processed separately. Then, the distinguished data is imported into Brainstorm, the EEG is bandpass filtering, and the low-pass filter filters signals higher than a specific frequency to retain lower frequency signals. After parameter calculation and frequency domain analysis, the waveform diagram that needs to be analyzed can be obtained.

To ensure the reliability of the measurement results, the scalp EEG of the subjects was analyzed and processed to avoid the influence of chance. The measured results of the subjects all showed alpha waveforms and the brain wave shape of one of the subjects, and the corresponding analysis results are presented in this paper. The experimental measurement results recorded the rhythm information of the Alpha waveform of the subjects. Figure 7 shows scalp EEG acquisition with eyes closed.

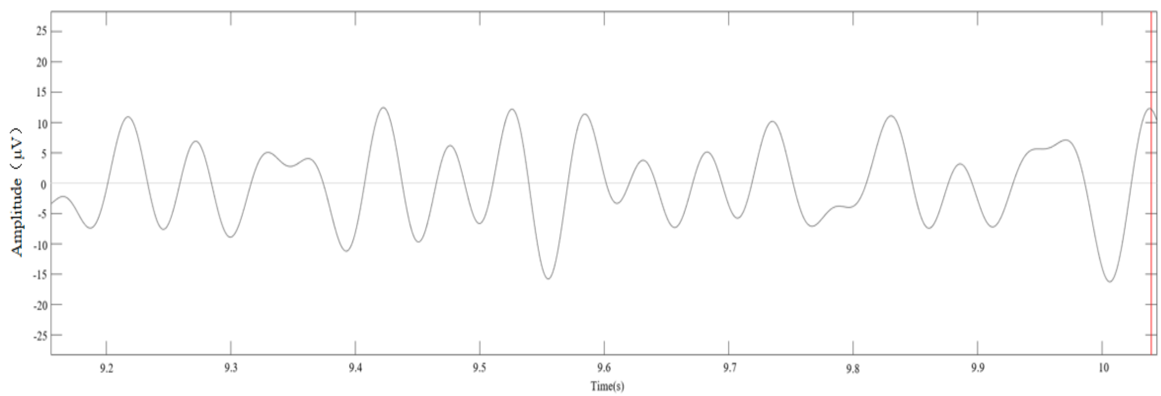

Figure 7. Alpha wave measurement waveform with eyes closed

4. CONCLUSION

In this study, we implemented a wearable wireless EEG acquisition device that meets the needs of epilepsy monitoring in the home environment. Bluetooth connection with a cell phone makes the system suitable for indoor and outdoor recording. The preliminary measurement results showed that the designed system can achieve low-noise and high-precision electrophysiological data acquisition with a common sampling rate. The motion track unit empowered the system with behavior analysis and artifact reduction. To make it useful for daily epilepsy monitoring, some improvements are still needed in our future work, such as designing a user-friendly user interface for cell phones, lowering power consumption, and real-time analysis of EEG and motion data to provide alarms for critical cases.

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