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A Wearable Wireless General Purpose Bio-signal Acquisition Prototype System for Home Healthcare

Junwei Duan, Changhao Chen, Sio Hang Pun,
Feng Wan, Peng Un Mak, Pui In Mak, Mang I Vai
Department of Electrical and Computer Engineering
University of Macau
Macau, China

Yong Hu
Department of Orthopaedics and Traumatology
University of Hong Kong, Pokfulam
Hong Kong, China

***Abstract*—A wearable wireless general purpose bio-signal acquisition prototype system is presented in this paper. Three types of bio-signals could be acquired by the system then wirelessly transmitted to the computer for real-time processing. The prototype experimental results show that the system could acquire electrocardiogram (ECG), surface-electromyography (s-EMG) and electroencephalogram (EEG) for home healthcare and telemedicine.**

Keywords-data acquisition; bio-signal; EMG; ECG; EEG

I. INTRODUCTION

Personalized, predictive, preventive, and participatory home healthcare have drawn much attention in recent years. Systems owning wearable and wireless characteristics are also playing an important enabling role in this gradual but certain revolution of healthcare system [1].

For ubiquitous monitoring, real-time diagnostics and patient-centric therapies, bio-signals, such as the s-EMG， ECG, EEG signals, have become three of the most significant non-invasive diagnostic references. s-EMG is used as a diagnostic tool for identifying neuromuscular diseases, assessing low-back pain, kinesiology and a control signal for prosthetic devices such as prosthetic hands, arms, and lower limbs or for some interactive video games and electronic devices such as mobile phone or PDA[2]. And, ECG is the standard method to diagnose cardiac dysrhythmia, particularly abnormal rhythms caused by damage to the conductive tissue that carries electrical signals, or by electrolyte imbalances [3] [4]. Additionally, the EEG signals have a close relationship with cerebral diseases, such as cerebrovascular diseases, migraine and epilepsy. As a consequence, it is very useful to analyze and process EEG signals and then extract their underlying features so as to diagnose and cure the diseases.

Although measured results vary primarily due to different environmental conditions, there are commonalities among our chosen targeting bio-signals. As shown in Figure1, recorded s-EMG potentials range from about 100μV to 100 mV, depending on the muscle under observation. Typical measured frequency range spans from 14Hz to 8 kHz, depending on the muscular activity under consideration. For ECG & EEG, their frequency ranges about 0.01Hz to 100Hz and about 0.01Hz to 150Hz [5], respectively; while their amplitude spans from 50μV to 10 mV and from 1μV to 1 mV, correspondingly.

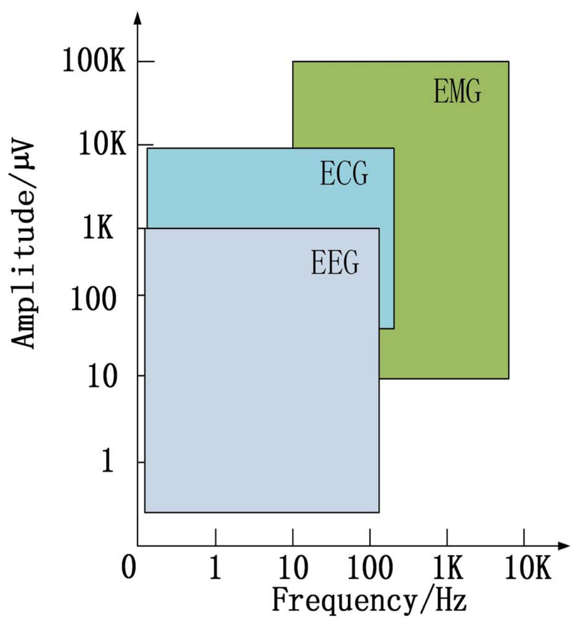

Figure1. Amplitude and bandwidth characteristic of bio-signals

Accurate bio-signals acquisition directly affects the truthfulness of the patient's illness diagnosis and the subsequent treatment effects. For home health care usage, the trend has driven the development of performance-intensive, small in volume, low power and portable bio-signal acquisition systems. Hence, biomedical electronics call for not only technical merits (such as accurate bio-signal acquisition, recording and display) but also in user-friendliness (such as size in volume and easy to wear). Yet traditional acquisition systems [6] involve the issues of inconvenience and complexity of design.

In this paper, we attempt to address these issues by presenting the system design including the analog front-end, wireless communication, DSP part, which is described in the Section Ⅱ. In addition, Section Ⅲ explains the experiments on how to acquire & transmit the ECG, EEG, EMG bio-signals. Section IV gives the conclusion of this article.

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II. SYSTEM DESIGN

A. System Architecture

The block diagram of the proposed system is depicted in Figure 2. The system is primarily composed of four parts: electrodes, bio-signal acquisition part, wireless communication part and bio-signal processing part. We will focus on the system level design in this paper.

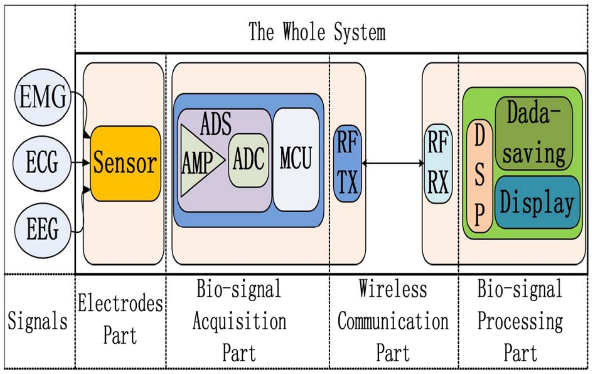


Figure 2. Block diagram of the data acquisition system

B. Bio-signal acquisition part

Bio-signal acquisition part is integrated on the PCB board, which is shown in Figure 3. The analog front-end, battery, microcontroller are shown in Figure 3a.

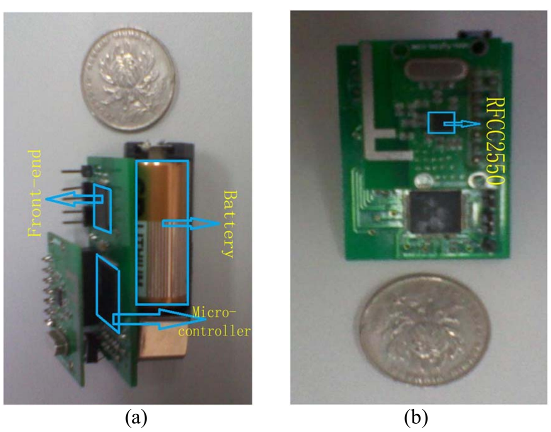


Figure 3. The bio-signal acqusition device in (a) lateral view (b) front view

Considering to simplify the system framework with significantly reduced size, power and overall cost, the highly integrated chip ADS1298 [7] was used to acquire, amplify and digitize the input bio-signal. ADS1298 is a multichannel, simultaneous sampling, 24-bit, delta-sigma analog-to-digital converters (ADC) with a built-in programmable gain amplifier (PGA), internal reference, and an onboard oscillator. It incorporates all of the features that are commonly required in medical ECG, EMG and EEG applications, and satisfies typical requirements as stated in [8] [9]. By the advantages of the IC we adopted in this design, the size of the overall system is small even with a battery. The projected size (shown in Figure 3b) of this device is two times larger than the one RMB Yuan coin. Since the acquisition device is very small in volume, and battery powered without other galvanic connection, the system is user-friendly and safe.

The multi-channel digitalized data obtained by ADS1298 is collected and packaged with the Microprocessor, which is C8051F121 in our proposed scheme.

To acquire the data, the C8051F121 MCU was used to control the ADS1298. These two chips were implemented on a PCB board. The entire acquisition device is powered by a 1400mAh Lithium Battery that can last approximately 11 hours of continuously recording. Besides, the transmitter module is embedded above the basic PCB board, which is also presented in Figure 3.

C. Wireless communication part

In the system design, we adopt the radio frequency (RF) transceiver RFCC2550 modules. This module supports the serial peripheral interface (SPI) bus, which is compatible to the C8051F121 and ADS1298 for data exchange. C8051F121 controls the ADS1298 to send the digitized signal to the RFCC2550 modules, and then the transmitter RFCC2550 module transmits the signal to the receiver though SPI bus, which is a synchronous serial data link standard that operates in full duplex mode. However, the modules only operated at simplex mode here. The modules can communicate with each other within a room size of $10m^2$.

D. Bio-signal processing part

We connected the RF receiver to C8051FX20 SCM and then sent the data to the serial port of computer to enable the system to receive and store data collected by the front-end. Although the data rate of serial port is not too high but it is enough for collecting low frequency biomedical signals such as EMG, ECG, EEG signals. All the processing part is implemented in MATLAB software kit by UART communication technology.

We built the serial port object to do the operation on the serial port and set the propriety of object and communication mode. We set up the baud rate as 115200 and the bit of data as 8. The data can be restored and the signal also can be processed and displayed easily in the MATLAB either real-time processing or off-line processing. The signal display part and data restoring part are implemented in MATLAB Simulink. In order to ensure the data transmission is correct, we also design a receiver based MATLAB program for checking. We also add the FFT algorithm that can apply to the bio-signal, which is useful to obtain the frequency information of the signal. For the sake of removing the power-line signal, we have added a 50Hz notch filter for better signal quality.

III. EXPERIMENT METHODS AND RESULTS

Before actual experiments, we have done the calibration to the display amplitude of the signal. Firstly, we set the input sine wave signal with 1Hz frequency and amplitude of 254 μV. And according to the output of the system, we got

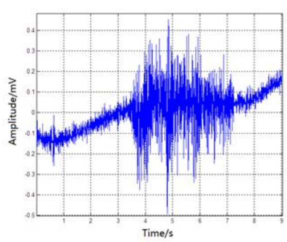
87 digitized values equal to 1μV. For the front end bio-signal acquirements in all 3 types of experiments, the standard Ag/AgCl adhesive electrodes were connected to the acquisition part of the system. And the acquisition part was put into a small package, which could be worn to the arm of our subjects, who are healthy adult males and their ages are in late 20s. Detail experimental set-up of these experiments can be found in [5][10].

In our experiments, four channels of ADS1298 were used and all these data were stored. The sampling rate was configured to 500 Sample Per Second (SPS) while the resolution was 24 bits. Since the sampling rate was 500 SPS, according to Nyquist–Shannon sampling theorem, signal with maximum frequency lower than 250Hz could be correctly sampled by the system. The signals with the frequency lower than 250Hz could be correctly sampled by the system here.

A. EMG Signal Acquisition

After wearing the system, the subject did the muscle contraction of arm, which is presented in Figure 4a, we have obtained the corresponding bicep EMG signal in Figure 4b when the arm was bent 90 degrees. When his arm was relaxed, the signals die away.

(a)



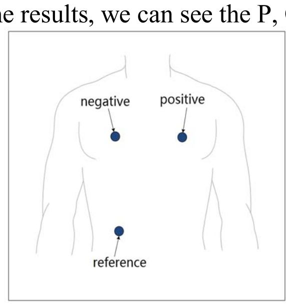
(b)

Figure 4. (a) the EMG experiment set-up (b) the obtain EMG signal

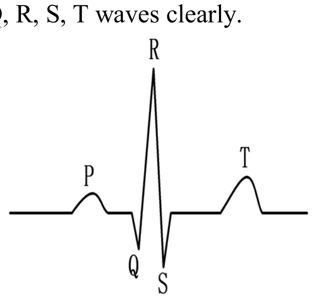
B. ECG Signal Acquisition

The standard three-lead system was used to measure ECG signal. Figure 5a shows a typical segment of ECG signal measured by placing the positive electrode on left side and negative electrode on right side. The reference electrode is also shown in the picture.

Figure 5c shows that the setup of the ECG signal acquisition experiment while the subject was standing quietly. All relevant ECG features are clearly visible. From the results, we can see the P, Q, R, S, T waves clearly.



(a)



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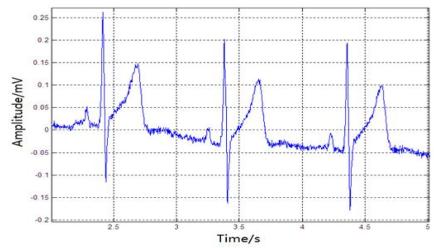


(c)

Figure 5. (a) the locations of ECG experiment electrodes

(b) typical ECG signal (c) the captured ECG signal

C. EEG Signal Acquisition

The skin surface of the body and the cortical surface of the brain were selected to record the signals. There has been growing interests in using steady-state visual evoked potential (SSVEP) in brain-computer interface systems (BCIs).To capture the EEG signal from human brain, the steady-state visual evoke potential (SSVEP) experiment of human brain commonly used in BCI application was done [11]. The visual stimulator used here consisted of a LED array and the clock generator, and the LEDs were driven by the clock generator. The stimulator is shown in Figure 6. And the frequency of flicking LED arrays in the experiment was 14.7Hz. One electrode was placed on the back of the left ear (A1), likewise, another was placed on the back of the right ear (A2). We used the back of the head (Oz) as the SSVEP signal channel. Figure 7 points out the location of electrodes on the scalp. In the left picture, the green color in the international 10/20 system means the channel we placed the electrodes.

In the processing part, the FFT algorithm was applied in the real-time processing part in order to show the frequency information of SSVEP signals.

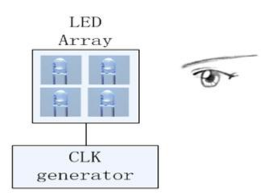
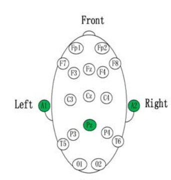
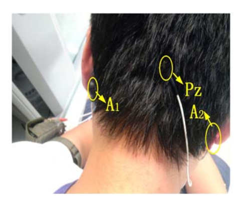


Figure 6. The stimulator of SSVEP experiment of human



(a)



(b)

Figure 7. The place of elcetrodes

(a)international 10/20 system (b) subject

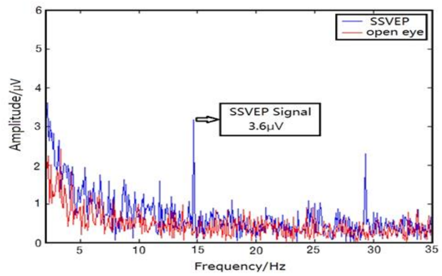


Figure 8. FFT of SSVEP signal and signal of open eye.

We also collected the signal when the eyes of subjects were open and did the comparison with SSVEP signal we captured. Figure 8 shows FFT of SSVEP signal and the signal when the eyes of subject were open. We can see that the 14.7Hz SSVEP signal appeared in Figure 8 with second harmonic at 29.4 Hz.

From these experiments, the power consumption of the bio-signal acquisition part and wireless communication part were 22mW. Most of the power is consumed by the RF transceiver. The system is rather configurable in terms of channel number, sampling rate and resolution. There are totally 8 channels available on the chip ADS1298. The sampling frequency can be set from 250 Hz to 32 kHz and the resolution of the on chip A/D can be configure either 16 bits or 24 bits. We also show the adopted chip ADS1298 and Transmitter specifications in TABLE I.

TABLE I. THE ADOPTED CHIP AND TRANSMITTER SPECIFICATIONS

Parameter	Value
Total Tx. Power Consumption	22mW
channel power	0.75mW
Input-Referred Noise	4μVPP (150Hz BW, G = 6)
Data Rate	250SPS to 32kSPS
CMRR	–115dB
Programmable Gain	1, 2, 3, 4, 6, 8, or 12
Input Impedance	10M ohm

IV. CONCLUSION

Experimental results show that this system could be used for various bio-signal (ECG, EMG and EEG) acquisition and wireless transmission. This system could be beneficial to home health care system. Based on this system, we could develop a wireless Brain Computer Interface for human beings. Our wearable system based on wireless communication integrates novel, powerful chip ADS1298, which greatly shrinks the circuit and reduces the power cost, as well as implements the wireless transmission with another module.

The present work is a first step towards this wearable, low-cost general purpose data acquisition system for home health care. And the next step is to migrate this system into a single IC chip design & fabrication.

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