Design of ECG signal acquisition and processing system

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Abstract: *In this paper, the electrocardiogram (ECG) signal detecting, amplifying, anti-aliasing filtering circuits were designed and made to get the analog ECG signal, and then make it necessarily conditioned to meet the requirement of data acquisition card USB-6008(signal frequency: 0.05Hz ~ 159Hz, signal amplification: + 1000 times). Using the data acquisition card USB-6008 developed by NI Company for A/D conversion, digital form of ECG signal may be gotten, and it can be transmitted to a personal computer for further processing by LabVIEW2009 (evaluation version). We carried out multi-resolution analysis of the digital ECG signal and got ECG signal components in different sub bands. For the purpose of wavelet filtering, the ECG signal was reconstructed with the signal components in sub bands which reflect the characteristics of ECG and ideal effect of ECG was obtained.*

Keywords: ECG signal acquisition; ECG signal processing; USB-6008; LabVIEW2009

I. INTRODUCTION

The electrocardiogram (ECG) signal is weak signal with low-frequency and high impedance, so it is necessary to conduct the signal processing before it can be properly displayed. The wavelet transform is a new mathematical theory and method developed in recent years, and it is an ideal tool for signal analysis and processing. Application of wavelet analysis in the ECG signal processing is the frontier of modern ECG signal processing. The study design and produce the ECG detecting, anti-aliasing filtering and amplifying circuits to obtain analog ECG signal. With the data acquisition card NI USB-6008, the analog ECG signal is converted to digital signal and transmitted to a personal computer (PC). Using LabVIEW2009 as development environment, the wavelet analysis and processing for ECG signal is carried out, and ideal effect electrocardiogram on PC is obtained.

II. STRUCTURE AND HARDWARE DESIGN OF ECG SIGNAL ACQUISITION AND PROCESSING SYSTEM

A. Structure of ECG signal acquisition and processing system

The ECG signal acquisition and processing system consists of a detecting circuit, a filtering circuit (0.05Hz ~ 159Hz band pass) [1], an amplifying circuit, a data acquisition card (NI USB-6008) and a PC, as shown in figure 1. The ECG signal is detected by the electrodes and amplified by the general instrument amplifier and filtered by the filter, and then the ECG analog signal is obtained. Through NI USB-6008, the analog signal is converted into digital signal and then sent to PC. In the PC, the ECG signal processing is conducted by LabVIEW2009 and the ECG is displayed.

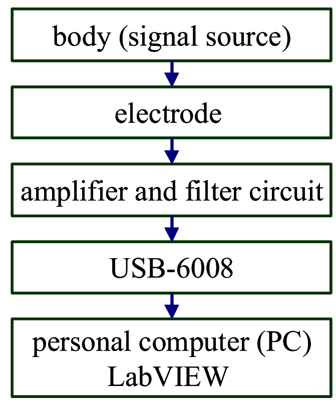

Figure 1. The ECG signal acquisition and processing system.

B. Signal detecting, filtering and amplifying circuit design

As shown in Figure 2, the ECG signal detecting, amplifying and filtering circuits consist of A101 ~ A302 and some related components. A101 is amplifier LF353P. It is high input impedance, low bias current operational amplifier. With the surrounding resistance, it made up the right foot drive circuit, and the output end RL is connected with the patient's right foot to reduce the input common-mode voltage of A201 to increase amplifying accuracy. LA and RA are lead electrodes. The output of A102 is connected to the shielding line to increase the system input impedance and reduce the leakage current [2]. A201 is precision instrumentation amplifier INA118P, the magnification of which is designed for + 3.5 times. C301, C302, R301 - R304, A301 make up a 0.053Hz high-pass filter, the magnification of which is designed for + 2 times. R305 ~ R308, C303, C304 and A302 make up a 159Hz low-pass filter (anti-aliasing filter), and the magnification of which is designed for + 2 times. A401 is the instrument amplifier AD620. Controlled by R401, it provides a magnification of + 71.43. So the total magnification is:

$$3.5 \times 2 \times 2 \times 71.43 = 1000$$

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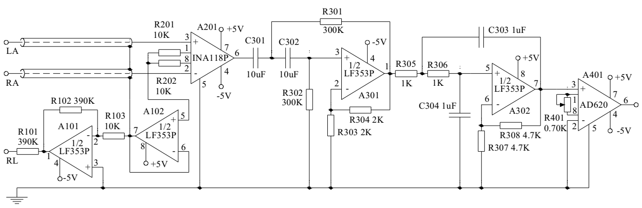

Figure 2. The diagram of ECG signal detecting, amplification, and filtering circuit.

C. *NI-USB6008 data acquisition card*

The NI-USB6008 data acquisition card is a 12 bit resolution, maximum sampling rate of 10KS / s plug-and-play USB data acquisition card [3]. According to the sampling theorem, the NI-USB6008 data acquisition card can work for signal up to 5KHz without distortion, so it can satisfy the sampling requirements of ECG signal (0.053Hz~159Hz).

D. *The production of hardware and system construction*

According to Figure 2, the ECG signal sampling, amplifying and filtering circuit was made on a breadboard. According to Figure1, connect the circuit, USB-6008 and PC to make up ECG signal acquisition and processing hardware system. Based on LABVIEW 2009, the ECG signal acquisition and processing system was made up. The system is shown in Figure 3.

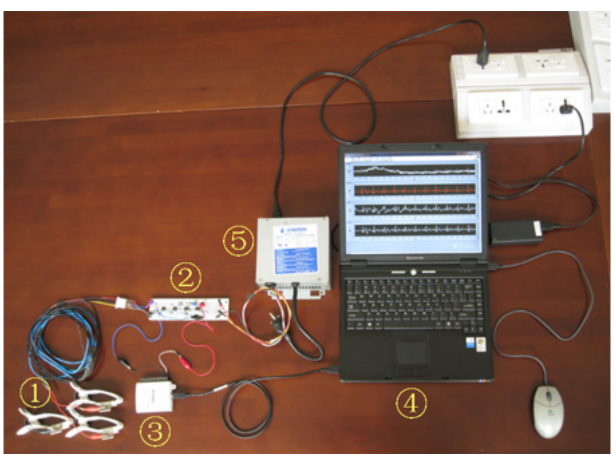

Figure 3. The Physical map of ECG signal acquisition and processing system. (①electrodes ②amplifier and filter circuit ③USB-6008 ④PC ⑤±5V power supply)

III. LABVIEW BASED MULTI-RESOLUTION ANALYSIS AND FILTERING FOR ECG SIGNAL

The signal which frequency varies with time is called time-varying signal. For the time-varying signal, Fourier transform analysis and filtering can not achieve very good results. In order to remove the "accidental" disturbances effectively, multi-resolution analysis [4] and filtering are used for signal processing, and better filtering effect may be obtained.

Figure 4 shows the diagram program of ECG signal processing based on LabVIEW2009. The ECG signal data that obtained by USB-6008 are stored as constants in the array of" ECG201004190959.VI" [5]. The sampling rate is 10K (Samples / second), and the amount of data is 100K (Samples); "原信号.VI" is used to display the untreated ECG signal; "Multiresolution Analysis.VI" is used for ECG signal multi resolution analysis and filtering [4]; "Mul-An.VI" is used to display the results of multi resolution analysis.

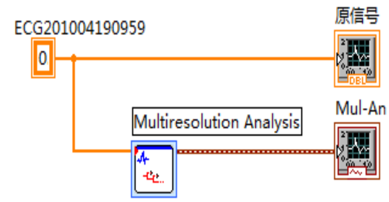

Figure 4. The diagram program of wavelet filtering based on LabVIEW2009.

Double click on the "Multiresolution Analysis.VI", and then the configuration dialog of the Multi-resolution analysis can be displayed as shown in Figure 5. "Original and Reconstructed Signal" displays pending signal (white curve) and reconstructed signal (red curve); Wavelet Transform and Subband Selection" shows the sub bands in which signal is decomposed, and the mouse can be used to choice particular sub band(s) for signal reconstruction; " Wavelet" offers a variety of available wavelets, and the desired wavelet can be selected from the drop-down menu; "Levels" provides a selection of decomposition level. The decomposition level is an integer less than or equal to $Int[Log_2 N]$ [6].

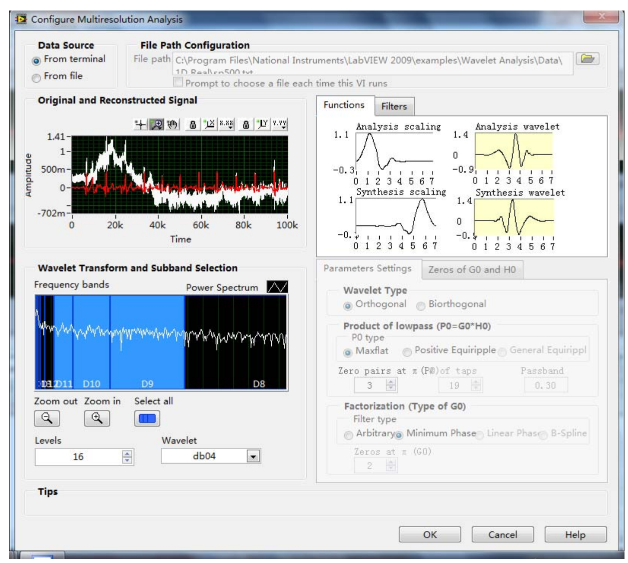

Figure 5. The configuration dialog of the Multi-resolution analysis.

Because the ECG signal sample number is 100K, the maximum wavelet decomposition level is:

$$(Levels)_{\max} = Int[\log_2 10^5] = Int[16.6] = 16$$

In "Wavelet Transform and Subband Selection", D1, D2, D3, ... , D16 and A16 are used to represent wavelet decomposition sub bands of the ECG signal.

In the multi resolution analysis of the ECG signal, db04 wavelet is selected. Figure6 shows the signals reconstructed with D1, D2, D3, ... , D16 and A16, respectively.

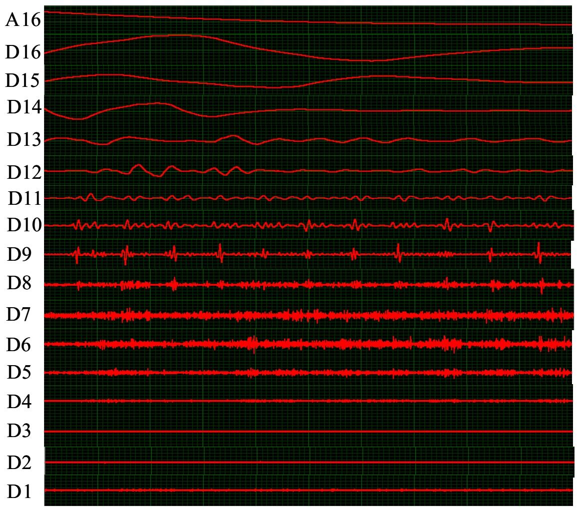

Figure 6. The signals reconstructed with different subbands of the ECG signal.

Figure6 shows that the signal components in sub-bands D9, D10 and D11 are more regular and coincide with the ECG waveform. In these three sub-bands nearly all effective components of ECG signal are concentrated. The signal components in D12 ~ D16 and A16 are mainly low-frequency disturbances, while the signal components in D4 ~ D8 are mainly some high-frequency interferences. These sub-bands can be ignored in signal reconstruction.

The signal components in D1 ~ D3 are 0, which tell us that the selected sampling rate (10k Samples/second) is redundant. Lower sampling rate can be used to reduce the amount of sample data, thereby saving system resources without reducing the sampling quality.

Figure 7 shows the signal reconstructed from the signal components in three sub bands: D9, D10 and D11. The white curve represents untreated signal while the red curve represents the signal reconstructed.

Figure 7. The reconstructed ECG signal after multi-resolution analysis and filtering

IV. Conclusions

Figure 7 shows that ideal results can be achieved by using multi-resolution analysis and filtering. It works better in removing the higher and lower frequency interferences. Especially, the problem of the ECG baseline drift can be solved effectively.

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