Design of Heart Sound Analyzer

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Abstract. There is important physiological and pathological information in heart sound, so the patients' information can be obtained by detection of their heart sounds. In the hardware of the system, the heart sound sensor HKY06B is used to acquire the heart sound signal, and the DSP chip TMS320VC5416 is used to process the heart sound. De-noising based on wavelet and HHT and other technical are used in the process of heart sound. There are five steps in the system: acquisition, de-noising, segmentation, feature extraction, and finally, heart sounds are classified

Introduction

With pollution of environment and increasing of work pressure, cardiovascular disease has become one of the serious harm to human health diseases. There is important physiological and pathological information in heart sound, so the detection of heart sound is an important method to detect cardiovascular disease [1]. Now heart sounds are generally detected through the stethoscope, and is judged with the experience of health workers. There is a high degree of subjectivity in this method. So to design an equipment to acquire and analyze heart sound signal is very necessary. In this system, a heart sound analyzer based on DSP is designed, and many signal processing methods are used to analyze the heart sound signal. The heart sound signals can be quickly and efficiently analyzed in the system.

Hardware of the Analyzer

Block Diagram of the Analyzer. The analyzer's main function is the heart sound acquisition and analysis of heart sounds. According to the function of the analyzer, there are the following modules in the system: heart sound acquisition, Keyboard & LCD , power, memory expansion ,JTAG Etc. The block diagram of the system is shown in Fig. 1.
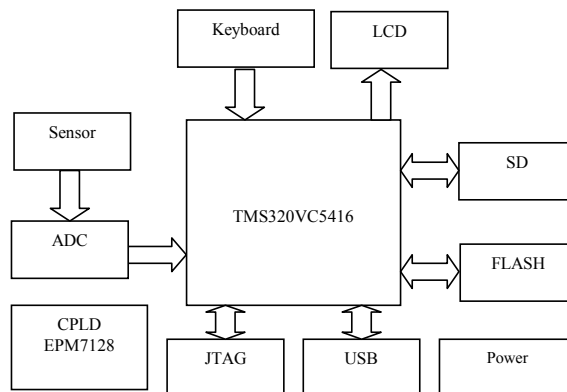

Fig.1 The flowchart of the analyzer

Select of the Mcu. The main function of the system is the analysis of the heart sound signal, in which processing of a lot of data and signal processing algorithms are required. So the DSP chip TMS320VC5416 is selected in this analyzer. TMS320VC5416 is low-power chip with16-bit fixed - point. Its highest processing speeds can be up to 160MIPS. Digital signal processing algorithms can be quickly implemented by it.

Heart Sound Acquisition. The circuit of heart sound acquisition module is shown Fig.2. The heart sound sensor HKY06B is used. Its main component is new polymer materials microphonic sensing element. The chest wall mechanical vibration is acquired by it, and low impedance audio signal output. The input frequency range of the sensor is 1 Hz to 1500 Hz. Its output voltage is up to 1.5V, so the output signal is no need to enlarge .In order to increase the load capacity of HKY06B, emitter follower is connected to the HKY06B output .

The 16-bit AD converter AD7705 produced by AD is selected in analyzer. Multiplexer tiny signal can directly be measured by the sensor ADC. It has many advantages such as high-resolution, wide dynamic range, self-calibration, excellent noise immunity and low voltage and low power consumption. It is ideal selection for instrumentation and measurement, industrial control and other fields of application. The operating voltage of AD7705 is 5V. It is connected to MS320VC5416 by the serial interface. The AD7705 serial data interface has five interfaces. The chip select input is CS; serial clock input is SCLK; data input is DIN; conversion data output is DOUT. Status signal output DRDY' is used to indicate when the output data register data ready. When DRDY' is low, the conversion data is available. When DRDY' is high, the output register is updated data and the data can not be read. In this system, the AD7705 DRDY' is connected with the TMS320C5416 Bio', the state of the AD7705 is obtained by reading the state of BIO'[2].

CPLD. The main function of CPLD module is to control the logic of the analyzer. EPM7128 produced by ALTERA is selected. It has the characteristics of high impedance, electrically erasable and so on. Its usable gate is 2500, and the operating voltage is +5V.

Other Circuit. There are also some conventional module in the heart sound analyzer, such as JTAG debug LCD module, USB module, power supply module . But these modules are not important part for the analyzer, so they are not need to be explained.
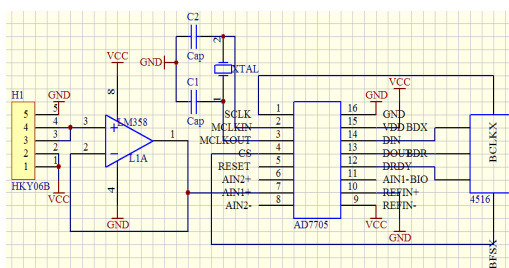

Fig.2 The heart sound acquisition

Algorithm of the Analyzer. Wavelet singular entropy is used to be the method of heart sound feature extraction of the analyzer.It is the product of the combination of information entropy principle and wavelet transform,which has not only statistical properties of information entropy processing the complexity of the signal, but also the advantage of wavelet analysis processing abnormal signal[3].

According to the definition of entropy, singular entropy is calculated as:

$$H = -\sum_{i=1}^{r} E_i \ln E_i$$

(1)

In the above equation 1, $E = \sigma_1 + \sigma_2 + \cdots + \sigma_r$, so $\sum_{i=1}^{r} E_i = 1$.

There are several steps in the heart sound feature extraction of this analyzer: segmentation of heart sound, wavelet transform, singular value decomposition, calculating the singular entropy, characteristic value extracting[4].

Software of the Analyzer. In the analyzer, the main program development work is heart sound signal feature extraction . There are five steps in the system: acquisition, de-noising, segmentation, feature extraction, and finally, heart sounds are classified.

Because of the acquisition environment, collecting equipment and other factors, there is certainly noise in the heart sound signal acquisition process. So de-noising became an essential process before analysis of the heart sound signa[5]l. The first work to be done after the acquisition of the heart sounds is the heart sound de-noising, and improved wavelet thresholding method is selected in this process.

Heart sound signals acquired by heart sound sensor are too long, so it is need for heart sound envelope extraction. Through this process, thereby a complete heart sound signal with not only s1&s2, but also s3&s4 is obtained. The method of Hilbert - Huang Transform (HHT) is used to extract heart sound envelope, then the heart sound extracted is segmented.

The last work of software development is the heart sound feature extraction and matching. Heart sound feature extraction based on wavelet singular entropy is used, and finally to match the feature library, to draw the type of lesion[6].
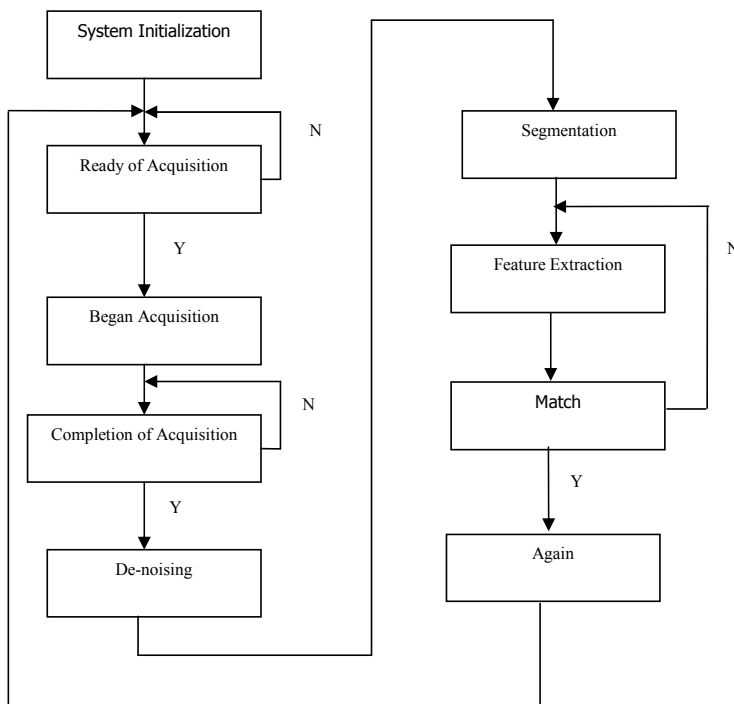
Fig.3 Program flow chart

Performance Analysis

In the Fig.4 there are heart sound signal waveforms collected through the analyzer. As is shown, in the Fig.4a there is a original heart sound collected with 4 KHz sampling frequency.Fig.4b shows a complete heart sound signal with not only s1&s 2 ,but also s3&s4.And the Fig.4c shows the contour signal of 6th order wavelet decomposition, that is to say, it shows the waveform between 0HZ to

125HZ.While the Fig.4d shows he their detail signal of 6th order wavelet decomposition, that is to say, it shows the waveform between 126HZ to 250 HZ.

More than 50 normal heart sounds are collected by this analyzer. And through the analysis of this analyzer, the singular entropy of 6th order of decomposition contour signal ca6 of the normal heart sound is 4.3451,while the singular entropy of 6th order of decomposition detail signal cd6 of the normal heart sound is 3.2617.And at the same time more than 50 wide splitting of the second sound are collected. The singular entropy of 6th order of decomposition contour signal ca6 of the wide splitting of the second sound is 9.8094,while the singular entropy of 6th order of decomposition detail signal cd6 of wide splitting of the second sound is 10.242.The result shows there is big difference not only the singular entropy of 6th order of decomposition contour signal ca6 but also the singular entropy of 6th order of decomposition detail signal cd6 of the two heart sounds .
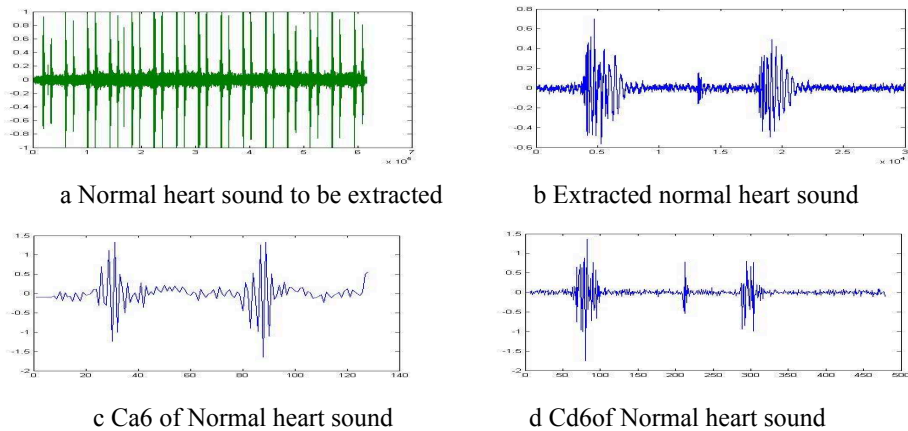

a Normal heart sound to be extracted   b Extracted normal heart sound

c Ca6 of Normal heart sound   d Cd6of Normal heart sound
Fig.4 Contrast of the system wave

Summary

The DSP chip TMS320C5416 is used to the Core processor of the analyzer. And there are also some function in the heart sound analyzer such as heart sound sensor, ADC, LCD, keyboard. Heart sounds segmentation based on HHT, heart sounds de-noising based on wavelet thres holding and heart sound feature extraction based on wavelet entropy are used in the analyzer to acquire and analyze heart sounds. The patient's heart sound signals are quickly and accurately detected by this analyzer.

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