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ADAPTIVE METHOD ON SIGNAL PROCESSING FOR HEART RATE MEASUREMENT

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ABSTRACT

An adaptive method on signal processing for heart rate measuring SoC (System on a chip) was designed in this paper. The digital filter is the basic measure to process the physiological signal. This paper adopts adaptive algorithm and wavelet transform theory to design kinds of digital adaptive filters- adaptive noise cancellation filter and wavelet transform filter to process the corresponding noises. At last, a good result was obtained.

Index Terms—Heart rate measurement, signal processing digital filter, adaptive method, wavelet transform.

1. INTRODUCTION

SoC technology is an important electronic application technology and suitable for biomedical engineering area. To satisfy the requirement of low power consumption, low voltage, and low cast, the SoC technology could be selected in biomedical signal process system.

Heart rate (HR) is an important live signal not only in clinic diagnosis but also in daily live. To measure the HR, there are some technologies can be used, such as blood measurement, heart voice measurement, ECG measurement, and so on.

In this paper, part 2 gives a design of system architecture, part 3 discusses the HR signal processing problem, part 4 is the design of the software filter for HR signal process, part 5 tests its functions and targets to verify the accuracy of the design, and part 6 is the conclusion.

2. SOC ARCHITECTURE FOR HR MEASUREMENT

The mixed-signal SoC is designed for HR signal process in this paper. The design requirements include low power consumption and low power supply. The power supply is 3.3 V.

The system architecture is shown as in Figure 1 designed in this paper.

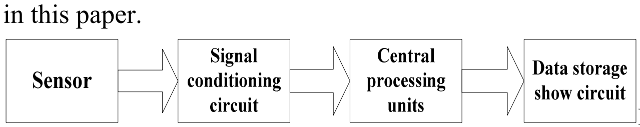

Figure 1 Architecture of SoC system

In Figure 1, The Sensor is an infrared photoelectric used for converting the HR signal into voltage signal.

The signal conditioning circuit is a processing circuit constructed with amplifier, filter, and comparator. The input signal of the signal conditioning circuit is analog signal of HR from the Sensor, and the output signal of the signal conditioning circuit is a pulse signal cluster with digital voltage level.

3. HR SIGNAL ACQUISITION

Cardiac systolic and diastolic is the pulse will cause elastic deformation of the blood vessel. This artery is elastic deformation of the surface that shows the number of beats per minute. A healthy adult HR is steady in 50~100 beats per minute. When the pulse of less than 50 times per minute, it called bradycardia; higher than 160, it is known as tachycardia. Bradycardia and tachycardia may lead to life-threatening. [1] Especially for people who have heart problems, if it can monitor their HR by times, and take relief measures in patients with rapid onset. We think it is the best way to help them save lives.

Blood is a highly opaque liquid, which contains large amounts of red blood cells. This cell has a strong infrared absorption capacity. Therefore, the infrared penetrability in the general organization is higher than in the blood several times. When the body's arteries with cyclical systolic and diastolic heart, artery blood volume will change, and the artery lies in the infrared part of the human tissue for transmission will change, it will lead to human tissues reflected infrared corresponding light changes in light intensity. This phenomenon is obvious in the hands of human tissue thin fingertip, earlobe and other parts. The human finger has radial artery and ulnar artery, and the finger is full with vasa. Along with the heart beat, blood microcirculation in a row for exchange inflows fingertip. Meanwhile, the vascular fingertip accept sympathetic nerve control, vasoconstriction is very sensitive. Therefore, take part in finger as signal acquisition. [2]

As shown in Fig.2 (a). There is a pair of infrared transmitter and receiver to probe arterial side. When the blood flow in the finger tip changes by the heart beats, the infrared receiving probe will receive a cyclical contraction and relaxation of the heart artery pulse signal, then the heart

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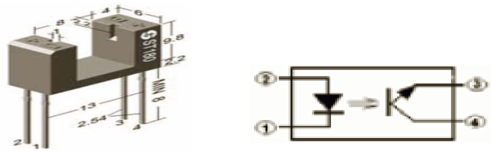
beat signal can be collected. [3]



(a) Appearance (b) internal structure

Figure 2 the infrared photoelectric sensor

Figure2 is a single-beam direct admission forms photoelectric sensor. This kind of groove coupler is formed infrared photodiode which has high-power and the phototransistor which has strength lens' sensitivity, wide extension in collector current. Due to the hemoglobin in blood to the near-infrared has absorption with biological effects, thus such kind of sensor has high sensitivity, output signal stability.

The technology indicators are shown in Table 1.

Table 1 Photoelectric sensor technology indicators

Testing conditions	Symbol	Mini mum	Typ ical	Maxi mum	Units
I_F=20mA	V_F	–	1.25	1.5	V
V_R=3V	I_R	–	–	10	μA
V_{ce}=20V	I_{ceo}	–	–	1	μA
V_{ce}=5V I_F=8mA	I_L	0.25	–	–	mA
I_F=8mA I_c=0.15mA	V_{CE}	–	–	0.4	V
I_F=20mA V_{ce}=5V R_c=100Ω	T_r	–	5	–	μs

The original HR signal collecting by infrared sensor is shown in figure 3.

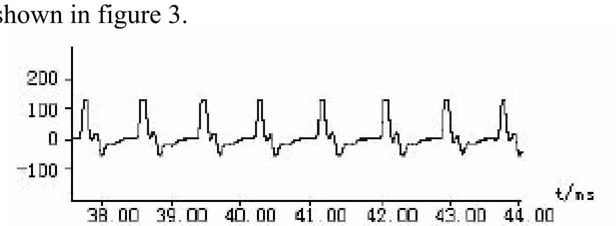


Figure 3 the original HR signal waveform

4. HR SIGNAL FILTERING

4.1. HR types of signal interference

HR voltage is weak signal (mV), its main frequencies are between 0.05HZ and 100HZ. When HR signals are in the testing process, it can easily be affected by outside interference and noise, and these disturbances are diverse. Several major disturbances are following: [4]

(1). Because of the indoor lighting and power equipment affected by the distributed capacitance, it engenders the industrial frequency interference (50Hz) and its harmonic frequency inter- ference.

(2). Due to the Human movement, breathing and Electrodes blight, the HR signal occur drift from the original baseline levels.(<0.03Hz)

And than, there are many kinds of human electrical phenomenon mixed up together, a certain physiological character is signal sometimes, but on another occasion it might be noise. That is beyond human capacity measured physiological phenomena caused by noise. It is generally between DC and 1000Hz .Now, let's introduce the filter design.

4.2. Frequency Interference and adaptive band-pass filter

In order to filter out the frequency interference of the main interference (1), we propose an adaptive band-pass filter.

Adaptive filter for noise elimination is the typical application of adaptive filter. Noise Cancellation is used in very weak signals, or signals which can not detect, from one or more sensors the auxiliary input or the input reference to filtration, includes signal from the noise and the original input subtracted. The results, the original noise was attenuated, or because of their elimination was removed.

The diagram of adaptive filter for noise elimination is shown in figure 4. It has two inputs, which are original input and reference input. The original input is the disturbed signal $d_j (d_j = s + v_0)$ .The reference input is the signal v_1, it associate with disturbed signal v_0, but not related to S. In the figure, the adaptive filter accepts the error signal e_j control, adjusts the weight vector W_j, than makes the output Y_j tend to v_0, so e_j which is the dispersion of d_j and Y_j is very close to or equal to the signal detection S.

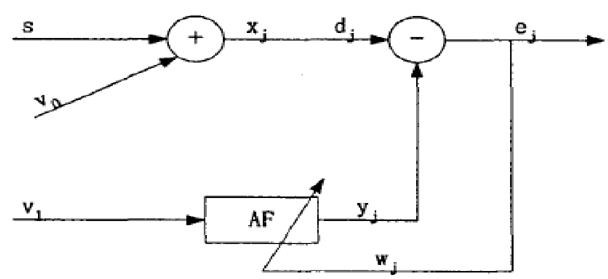


Figure 4.Adaptive filter for noise elimination

Corresponding with this, adaptive band-pass filter is the typical application of adaptive filter for noise elimination. If the signal has the monochromatic noise interference (The sine wave interference whose frequency is ω_0), the method of eliminating the interference is the application of band-pass filter. Adaptive Filter consisting of Notch compares with the general fixed network Notch, it has the following advantages:

(1) It can track the frequency interference signals adaptively and accurately;

(2) It is easier to control the bandwidth.

It can be seen from figure 5, the band-pass filter is composed of 2 weights single-frequency interference cancellation

$$d_j = s_j + A\cos(\omega_{0j}T + a)$$

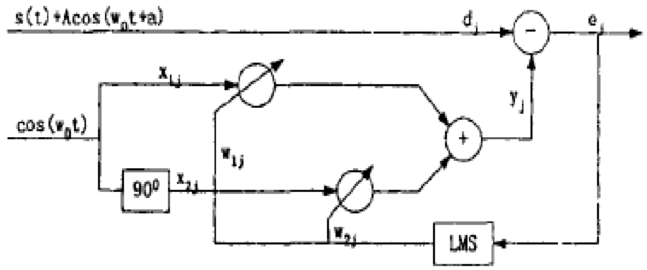


Figure 5. Adaptive band—pass filter

A reference input is a standard sine wave $\cos(\omega_0 t)$, after the sampling, it is given to x_{1j} and x_{2j}, The latter is after 90 Phase shift, resulting $x_{1j=}\cos(\omega_{0j}T)$ and $x_{2j=}\sin(\omega_{0j}T)$. The com bination of the weights w_{1j} and w_{2j} makes the sine wave am- plitude and phase can be adjusted. The weights have two de- grees of the freedom adjustment. After a combined sum to be y_j ,its amplitude and phase can be same as the original input the same weight interference, make the single-frequency interferen- ce in output e_j offsetting, achieve notching. As the fixed fre- quency interference of 50 Hz sine wave signal of the heart rate signal, so it can use the adaptive band-pass filter.

4.3. Baseline drift and the filter based on wavelet transform

In order to filter out the baseline drift of the main interference (2), we propose an adaptive filter design based on wavelet transform, which is only relevant to the original signal.

According to wavelet transform, it could signal a 2j multiplied, divided into different frequency, and according to different frequencies, make appropriate treatment. We know most of physiological signals are at low frequency, high frequency signals are almost the interference and noise, so it can make the high frequency signals based on wavelet transform are 0. It just like a lowpass filter [6]

$$W_f(a,b) = \int_{-\infty}^{+\infty} f(t)\Psi_{a.b}(t)dt = \int_{-\infty}^{+\infty} f(t)\frac{1}{\sqrt{a}}\Psi(\frac{t-b}{a})dt$$

$$a > 0,\ f \in L^2(R)$$

Assume the bandwidth of original signal is F, the cutoff frequency of filter is f, then $f = F / 2^j$

In the formula, j is the stage of Wavelet Transform, it can be seen the cutoff frequency is only relevant to the bandwidth of the original signal and the stage of the wavelet transform. Because of different signal, the filter can automatically adjust the cutoff frequency, so the algorithm carries out the adaptive low-pass filter function. As shown in figure 6

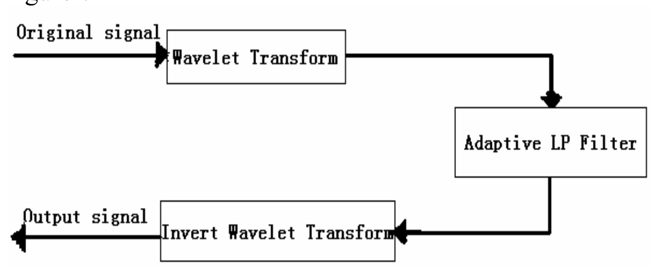


Figure 6 Architecture of adaptive filter design

The frequency of heart rate distributes 0~20Hz, the highest frequency not exceed 40Hz, the heart rate of the finger show in figure 3

The signal above pass through three stages Wavelet Transform, its picture is shown in figure 7. Assume T is the whole sampling time, the T/2-T means the frequency F/2-F whose signal distributable instance. The T/4-T/2 means the frequency F/4-F/2 whose signal distributable instance. And 0-T/2 means the frequency 0-F/8. From the figure we can see, the heart rate of the finger mainly focus on the low frequency.

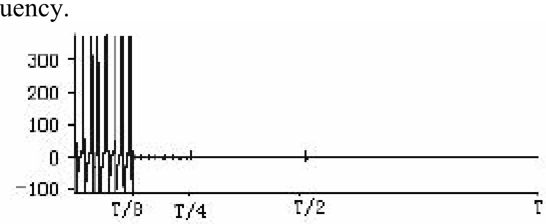


Figure 7 the signal after Wavelet Transform

Figure 8 shows the finger signal after adaptive filter, compares with figure 3, it feels more smooth, and less interfere.

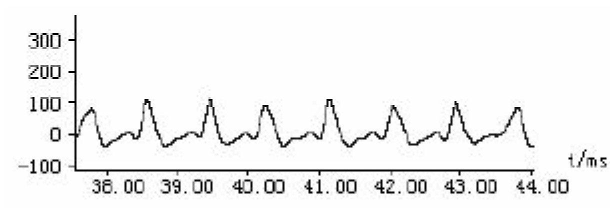


Figure 8 the signal after digital filter

The original acquisition by infrared photoelectric sensor, then let it go into the conditioning circuit, after amplification, shaping and filtering, the last waveform shown in figure 9.

Figure 9 output waveform of signal conditioning circuit

We can see from Figure9, HR signal after amplification, shaping and filtering, its pulse waveform is stability. Basically, it has removed all kinds of interference, so it is a true reflection of beating heart. This can directly import this pulse signal to the central processing unit for treatment.

5. THE FUNCTION TEST OF THE SYSTEM

In order to verify the accuracy of the design, we test its functions and targets. Let measure it in three times before and after sport. Experiment data are recorded in table 2.

Table 2 experiment data

Units: times/minute		Manually Measure	LED Display
Before Sport	1	66	68
	2	84	85
	3	67	67
After Sport	4	116	120
	5	105	105
	6	83	85

From table 1, we can see:

(1) The change between before sport and after sport.

Sport will consume some energy and make the heart speed transporting blood, which will cause the increment of heart rate. Moreover, the value of heart rate will turn to natural gradually after sport.

(2) The difference between manually measure value and LED display value.

Manually measure means press in wrist by finger to measure. LED display means the result displayed by SoC system. The main reasons of difference between two sets of data are the limit of sensor's sensitivity and the 50HZ industry frequency interference which is hard to filter clean.

6. CONCLUSION

The design of microelectronic technology and biomedical engineering will work closely together to achieve the design requirements. It has greater innovation and practical value, and also there is a good market value.

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