A novel digital sphygmomanometer using Cortex-M3 microcontroller

Hu pan
School of Information Engineering
Wuhan University of Technology
Wuhan, China
hupan@whut.edu.cn

Hu junping
School of Information Engineering
Wuhan University of Technology
Wuhan, China
hu_junping@126.com

***Abstract*—This issue introduced a new design of sphygmomanometer which do not need complicated signal conditioning circuit. Based on digital signal processing technology, it achieved a sphygmomanometer with the least spare parts needed. All signal processing procedures are accomplished by digital filters using ARM Cortex-M3 microcontroller, which were both stable and cost-saving.**

Keywords-sphygmomanometer; digital signal processing; cortex

I. INTRODUCTION

As hypertension become more and more widespread, people tend to pay more attention to their health. We need to measure our blood pressure often, especially who were diagnosed with hypertension. Traditional mercury sphygmomanometer needs special training to get the right systolic and diastolic pressure. Therefore, digital sphygmomanometer becomes more and more necessary in our daily life. Usually, a digital sphygmomanometer needs signal conditioning circuit to separate alternation signal from direct signal. This thesis introduced a new way of using Finite impulse response filter to replace that. It does not need any active component such as operational amplifier. Meanwhile it does not affected by environment variables such as temperature and humidity.

There are many methods to measure blood pressure[1] such as korotkoff sound、ultrasonic wave and oscillometric. Most sphygmomanometers use oscillometric method because it has excellent anti-jamming capability. The principle of oscillometric method is shown in figure 1.

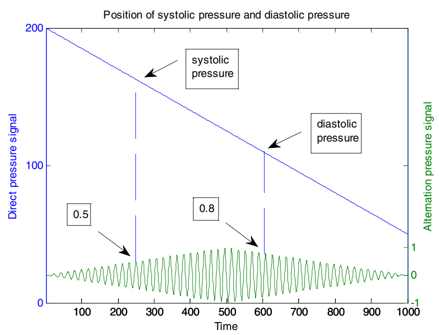

Fig.1 Position of systolic pressure and diastolic pressure

Firstly, the user presses the "start" button and the air pump blow air into the inflatable sleeve to block blood flow. Then the sleeve begins to deflate. The air pressure sensor will measure the oscillation of blood flow. When the pressure of sleeve is high above the systolic pressure, the oscillation of blood will disappear. Along with the pressure of sleeve keep going down, the oscillation of blood will begin to appear. When the pressure of sleeve going down from higher than systolic pressure to equal the systolic pressure, the oscillation of blood will increase suddenly. When the pressure of sleeve is equal to the mean pressure, the oscillation reaches its highest amplitude. With the process of deflate keep going, the oscillation of blood becomes smaller and smaller. We could use the relationship between the amplitude of oscillation and the pressure of sleeve. The pressure of sleeve correspond to mean pressure when the amplitude of oscillation reaches its peak; when the oscillation is half of the peak amplitude, the pressure of sleeve is just as systolic pressure, four fifth of the peak amplitude, the pressure of sleeve is as same as diastolic pressure[2][3].

So, the key problem to measure blood pressure is to measure the pressure and separate alternative component from direct component. Next I will put forward a new solution of this issue.

II. HARDWARE INTRODUCTION

This system consist of five parts: a digital pressure sensor, a microcontroller, a keypad, an air pump and a graphic user interface. The microcontroller receives commands from keypad and start the test procedure. Air pump Signal acquired from pressure sensor is directly feed into the microcontroller. The system block diagram is shown in figure 2.

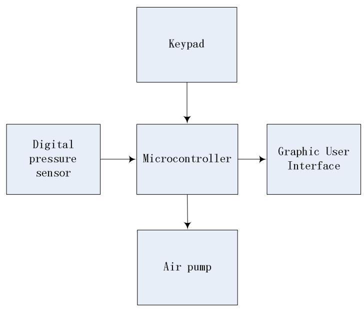

Fig.2 System block diagram

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The schematic diagram is shown in figure 3.

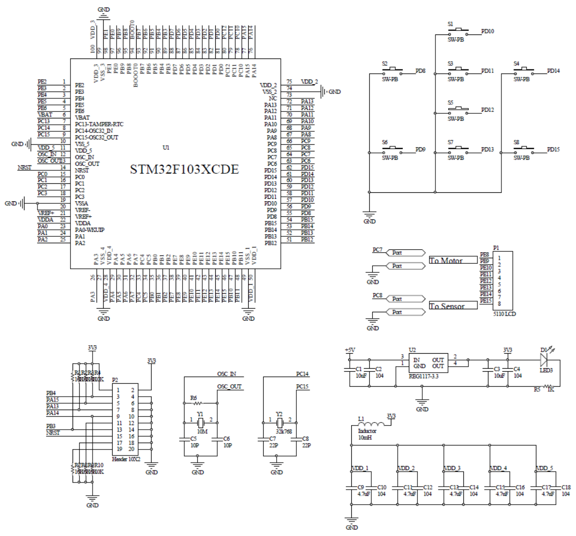

Fig.3 Hardware schematic diagram

The microcontroller is STM32F103VET6 from ST Microelectronics. It is a high-density performance line ARM-based 32-bit microprogrammed control unit. It features a ARM 32-bit Cortex-M3 core which could working at 72MHz with single-cycle multiplication and hardware division, 512Kbytes of Flash memory and 64Kbytes of SRAM. The typical current consumption in run mode with peripherals disabled is less than 35 milliamps. All of this makes it perfect for digital signal processing in portable devices.

What's more, STMicroelectronics also provides a DSP library for STM32F103 series, making it easier and faster for developers to achieve a FIR filter.

The air pressure is a frequency-output one. The air pressure change the distance between the plates of capacitor thus causing the change in capacitance. The sensor convert capacitance into frequency signal varies with capacitance.

We use TFT LCD with IL9325 controller to display a graphic user interface. The size of LCD is 2.4 inches while the resolution is 240 multiply by 320.I use it in 16-bit mode which can display 65536 kinds of colors.

III. SOFTWARE SCHEME INTRODUCTION

The way to get air pressure information from senor is to use time-constant gate frequency measuring. The MCU count the input signal every 64 millisecond and the equivalent sample rate is 15.625Hz which is enough for blood pressure signals range from 0.8Hz to 3Hz.

According to oscillometric method, one of the keys to achieve blood pressure is to separate alternative component from direct component. Here, we realize it by digital filter. In compare with traditional analog filters using operational amplifier, it need less component and immune to environment changes.

Mainly there are two kinds of digital filter: Finite impulse response and Infinite impulse response. The expression of a FIR filter is:

$$y(k)=\sum_{n=0}^{L-1}h(n)x(k-n) \qquad (1)$$

Figure 4 is the flow block of a FIR filter.

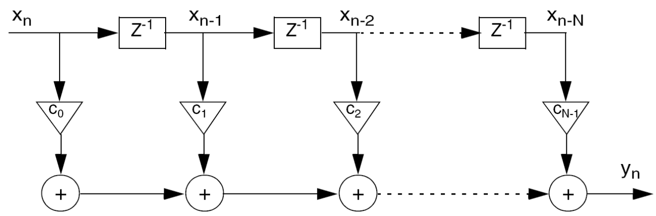

Fig.4 Flow block of FIR filter

The expression of an IIR filter is:

$$y(k)=\sum_{n=0}^{L-1}\alpha(n)x(k-n)-\sum_{n=1}^{L-1}\beta(n)y(k-n) \qquad (2)$$

Figure 5 is the flow block of a five-order IIR filter is.

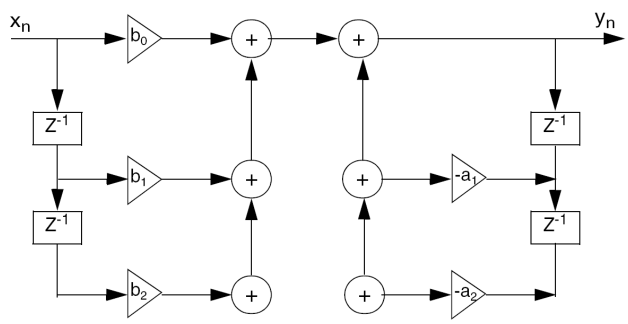

Fig.5 Flow block of IIR filter.

Figure 6 is the amplitude-frequency and phrase-frequency characteristic of a typical low-pass FIR filter.

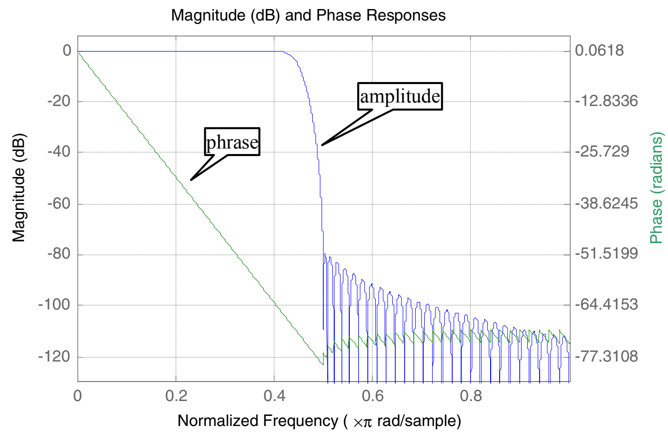

Fig.6 Typical frequency response of FIR filter

Figure 7 is the amplitude-frequency and phrase-frequency characteristic of a typical low-pass IIR filter is.

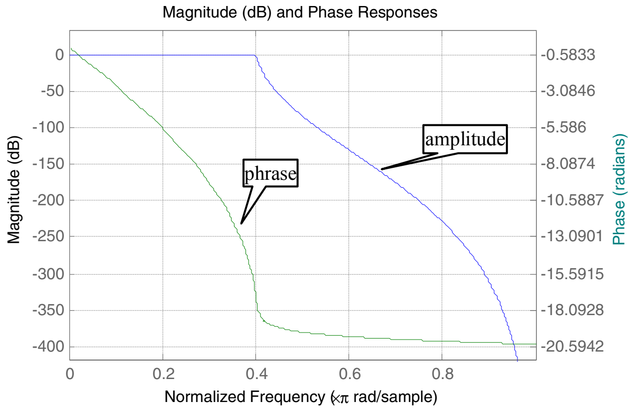

Fig.7 Typical frequency response of IIR filter

From the flow block we could see thar IIR filters have a feedback making it possess better cut off characterstic than FIR filters which do not have a feedback.Generally speaking,to achieve the same cut off characterstic FIR filters need ten times the order of IIR filters,but IIR filters have worse phrase-frequency charcterstic.FIR filters can achive a linear phrase structure,which is important in this design,so we choose to use FIR filters to seperate alternative componet with frequency ranging from 0.8Hz to 3Hz.

We use filter design and analysis tool (FDAtool) in Matlab to design a FIR filter.

According to our experiment, a 20 order FIR filter with Kaiser Window will do. A greater order will have better frequency response but will cause longer delay from input to output of the filter. Figure 8 is the frequency response of a 20 order FIR filter.

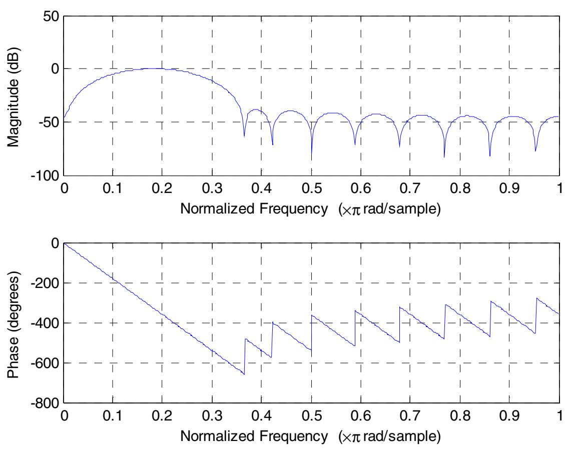

Fig.8 The frequency response of a 20 order FIR filter

IV. Processing procedure and results

The software flow pattern is shown in figure 9.

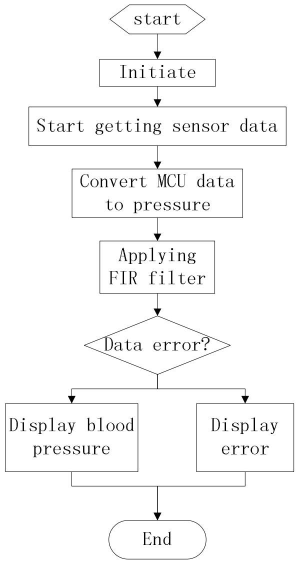

Fig.9 Software flow pattern

The signal processing procedure of sphygmomanometer is as follows:

First we convert raw data of frequency to pressure, as from figure 10 to figure 11.

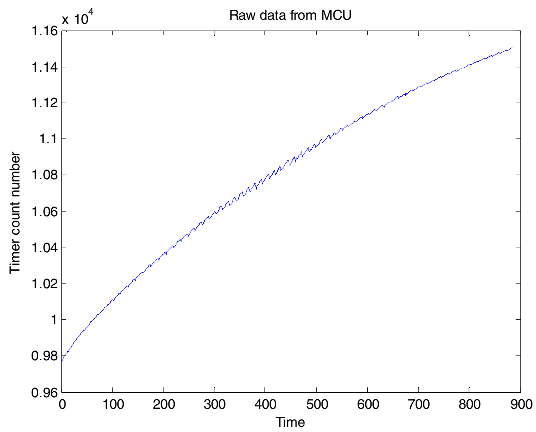

Fig.10 Raw data from MCU

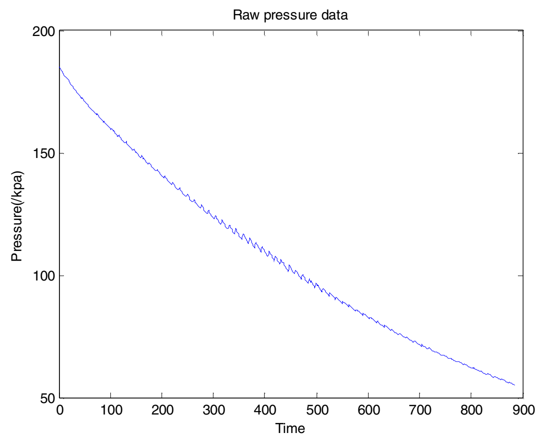

Fig.11 Converted data of pressure

Then we use FIR filter to separate alternative component, as figure 12.

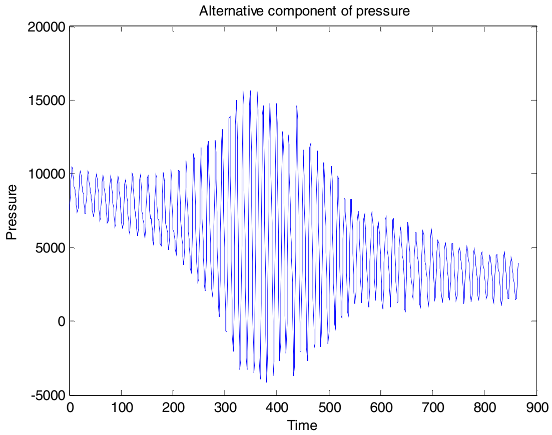

Fig.12 Alternative component of pressure

Next we need to get the envelope of the alternative, just search the minium and maxium pressure and minus each other. The result is shown in figure 13 and figure 14.

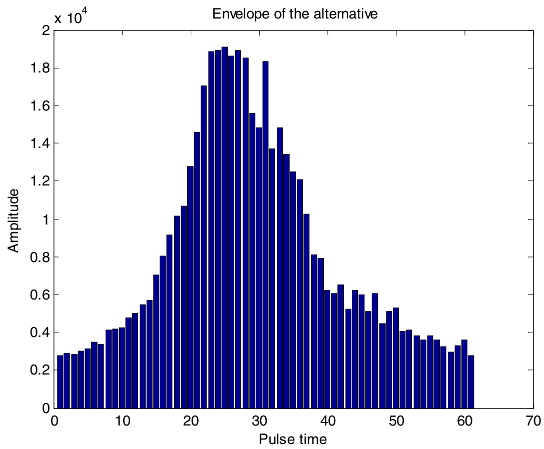

Fig.13 Envelope of the alternative (versus pulse)

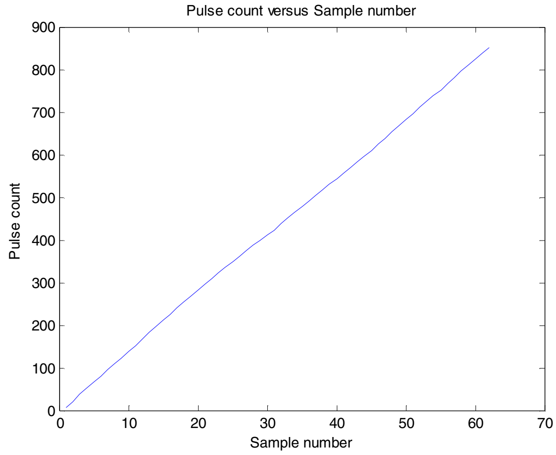

Fig.14 Pulse time

At last from the characteristic point [4] we could get the systolic pressure is 132kPa, and diastolic pressure is 87kPa, which is relatively accurate.

V. CONCLUSION

This design using Cortex-M3 with its FIR function achieved a sphygmomanometer with fewer components and good stability, what's more, the graphic user interface makes it easy to use.

ACKNOWLEDGMENT

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