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Study of a weak signal conditioning circuit design method

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Abstract. The basic of the measurement and control technology is the technology of signal conditioning amplifier. In order to solve the problem of weak signal processing, this paper design a new amplifying and conditioning circuit through a combination of switched capacitor filter and programmable gain amplifier. The filter parameter of the switched capacitor and the magnification of the program control amplifier will be adaptive adjusted by ATMEGA128. The test shows, the sensitivity is 1 uV, the response time is less than 1ms, and voltage dynamic range is large.

Introduction

Precise signal conditioning is the key technology in weak signal detection [1, 2]. It makes it possible to detect weak amount (such as weak light, small displacement, micro vibration, weak voice and micro current), which greatly improves accuracy of the weak signal detection. Signal conditioning is to convert the signal to be measured by amplifying, filtering it into the standard signal which can be identified by the collection device. This technology has wide prospect of application in the industrial, instrumentation and portable consuming electronic devices.

In this paper, a new signal conditioning circuit is designed based on the switched capacitor and program control amplifier. The filter parameters and the amplification of the circuit are adaptively adjusted by using ATMEGA128 microcontroller. Finally, microphone (a few microvolts ~ tens of millivolts) experimental results of signal processing is made.

Systematic Framework

The basic process of sensor signal conditioning is: after Physical quantity sensor signal is converted into electric signal, it goes through the filter, amplifier module, and finally it is sent into the A / D converter to be process as digital signal. Figure 1 shows the structural framework of the signal conditioning circuit, including 3 parts: the preprocessing part; programmable control part; microcontroller control part.

Hardware circuit design and noise Analysis

The design of the preprocessing part and noise Analysis. This part consists of a preamplifier, a primary filter and two stage amplifier circuit to accomplish the primary filtering and amplification. The voltage of Microphone output signal ranges from a few tens of micro volts to MV. So we must choose appropriate Pre amplifier type to reduce the noise made by amplifier itself. The three main sources of the Pre amplifier circuit are: Voltage noise, current noise of operating amplifiers and Johnson noise. The general distribution characteristic of the current noise of operating amplifiers

is that the white noise appears in medium frequency, 1/f noise appears in the low frequency (The spectral density is inversely proportional to square root of frequency.) The 1/f noise is the main noise source of DC coupling measurement [3, 4]. The auto-zero operation can greatly decrease the 1/f noise, and it also has extremely small input Offset voltage (a few micro volts), which is most suitable for the measurement of low frequency or DC weak signals. There are many types of the operating amplifiers. The system uses the MAXIM's ICL7650 preamplifier, which amplify the useful signal as well as the noise signal. In order to eliminate the noise, it needs to set the filter, and select the suitable filter and parameters Sensor signal filtering is the most commonly used RC active analog filter, which has simple structure, low cost and can preliminarily filter background noise. The amplification of preamplifier circuit is generally small due to the limits of operational amplifier bandwidth. At the same time as the load capacity is low, so it needs the two stage amplification. The two stage amplifying parts need low noise, high bandwidth amplifier; the system adopts the AD company's AD620.

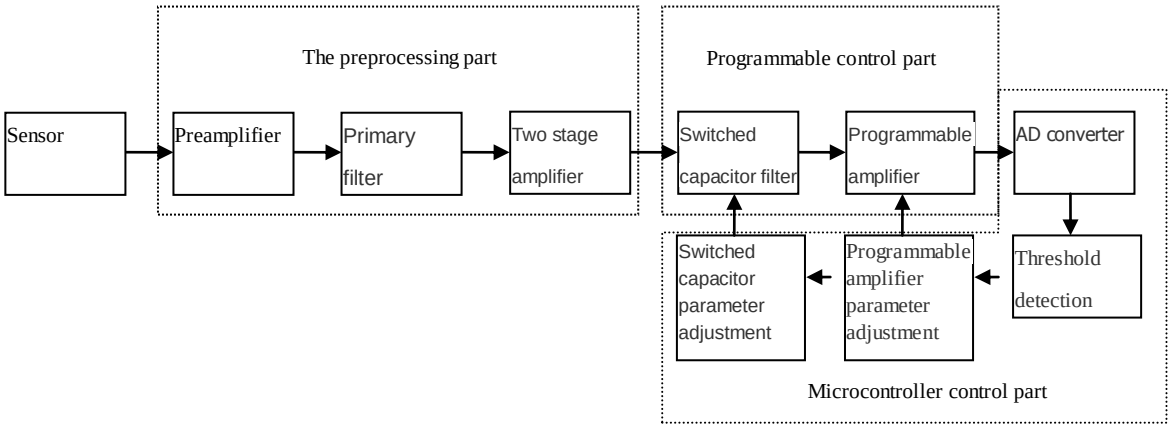

Fig. 1 The block diagram of weak signal conditioning circuit

Programmable control part. The part consists of a switched capacitor filter and programmable gain amplifier, which is the key of the signal conditioning circuit.

Switched capacitor is an automatic tracking filter. The frequency signal gain and phase in the filter is constant when the signal being tracked goes through the filter. At the same time, other frequencies are weakened and thus the ratio of Signal to noise is improved.

This design uses the MAX260 automatic tracking filter set. Each MAX260 consists of two two order switched capacitor active filters. Each of the two order filter assembly has 4 working modes, the clock input and independent F_0 and Q control. Each center frequency of two order group is determined by the input clock frequency and 6 programming code. Q value is controlled by a 7 bit code. The design connect two order band pass filters to make up a four stage active filter.

The input signal requiring filtering is divided into two: one goes through MAX260 and the other goes through the trigger CD4093 to be converted into a square wave signal. It then enters the CD4046 phase locked loop circuit. The phase-locked circuit generates N times frequency clock signal required by filter required by MAX260 automatic Tracking filter, in which the value of N equals 100. The Square wave is input into CD4046 and outputs through pin 3, then enter the 100 times frequency divider and return to the pin 4 of CD4046. Therefore, the 100 frequency of the square wave signal from the pin 4 of the CD4046 can be used as the clock signal MAX260.

Through 100 times frequency, the wave frequency $f_{CLK} = 100 \times f_0$, and then it enters into

pin11,12 of MAX260. As for MAX260, because $f_{CLK} / f_0 = 100$, the central frequency of the signal filtered equals to the original input signal, which makes the central frequency f_0 of band pass filter keep tracking the variation of the input signal frequency.

Programmable amplifier change the gains automatically controlled by software, to adapt to the input analogue signal voltage. The design adopts the combination of PGA204 and PGA205. There are 16 steps to adjust including multiple 1、2、4、8、10、20、40、80、100、 200、400、800、1000、2000、4000、8000. The output signal is sampled by AD and then the magnification can be adaptively switched by software judgment of threshold.

Software design

The main function of microcontroller control part: Through the analysis of the A/D sampled amplitude magnification filter, we can adaptively adjust parameter of switch capacitor and program control amplifier. Modular program design adopts the principles of software design. The system consists of main program and subroutine modules. The main programs set the related parameter MAX260 and PGA204/5, and then gain the sampled amplitude L of the original signal on the basis of A/D analysis. Then the threshold is judged. When L is not in the range between L_{min} and L_{max}, the main program adjusts the related parameter MAX260 and PGA204/5, until L satisfy the demand of the threshold. When $L_{min} < L < L_{max}$, we set L as L_0 and $L_0 = L/c$. c is the multiple of gains of Programmable device MAX260 and PGA204/5. The L_0 is only related with the size of original signal and the fixed magnification of the preprocessing circuits. L_0 can reflect the amplitude of the original signal accurately. Finally L_0 is sent to LCD and the data is sent to the PC machine backup through the serial port.

Subroutine includes MAX260 programming module, PGA204/205 programming module, A /D sampling and digital filtering module, LCD display module and serial data transmission module etc. MAX260 programming module is used for setting F0 and Q in each of the two order group by adopting the logic input circuit. The MAX comes with the MAX260 filter design software for MAX260 datasheet or query:

When MAX260 works, N=100, and Q=8, the design software of MAX260 filter of MAX company is used or MAX260 datasheet can be checked. The programming coefficient is acquired to satisfy four order Chebyshev bandpass filter as is shown in table 1. When we program, we only need to satisfy the MAX260 read and write timing, at the same time, increase or decrease the corresponding pin voltage.

Table 1 The programming coefficient and code of MAX 260

Parameter	MA/MB	FA/FB	QA/QB
Programming coefficient	120	0	120
Programming code	1111000	000000	1111000

PGA 204/205 programming module is finished. PGA204 and PGA205 gear switch; A /D sampling and digital filtering module completes acquisition and digital filtering of the original data. The module gets the useful signals at the same time, provides the original basis for threshold analysis; LCD display module is used for displaying the original signal size; serial data transmission module sent the tested data and intermediate variables (mainly the value of Q for MAX260 and the amplification of PGA204/5) to the PC machine regularly. The detection of circuit performance can be achieved by instant and long-term data collection through the serial

port of PC.

Microphone signal conditioning results

Microphone uses Konwles company's FG-23629, through which the M shape faint two-peak acoustic signal is obtained (peak value is at about 100 uV). It is then sent to the signal processing circuit. Experimental results show: the original sound signal microphone output (blue wave) has been completely submerged in the background noise, while the M shape two-peak acoustic signal can be clearly observed as it has been filtered in conditioning circuit (yellow wave), whose background noise is basically filtered.

Conclusion

Based on the noise analysis, this paper discusses signal conditioning circuit design in details, and it points out the circuit structure and each part's components selection. The experimental results of the microphone signal detection are given. Experiments show that: the signal conditioning circuit has the advantages of stable performance, high reliability, strong flexibility and programmability. It can fundamentally solve the problem such as the signal conditioning performance is not stable and greatly influenced by the environment as well as the small dynamic range etc. The technical indicators of this circuit include: (1) dynamic range: from a few micro volts to tens of mill volt (2) sensitivity: 1 uV; (3) response time: shorter than 1ms.

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