A RESEARCH AND DESIGN ON SURFACE EMG AMPLIFIER

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***Abstract*—As the characteristics of SEMG are weak and vulnerable to external noise, it must to establish the appropriate acquisition and amplification system. INA128 chip is used to be as the core IC of the SEMG amplifier. The IC UAF42 is used to be the notch filter to keep out of frequency of 50Hz. Multisim2001 is used to simulate and test the SEMG amplifier is feasible. The amplifier can be used to help amputation acquire EMG in effect.**

Key words- Surface EMG; signal amplifier; notch filter; Multisim Simulation.

Ⅰ. INTRODUCTION

Around the world, there are a large number of persons with amputation due to war, disease and accidents. There is about 1 million amputated patients need to assembly prosthetic in China[1]. There are many difficulties in their daily life, so it needs to design a prosthetic control device such as control nature, easy to use, the signal stability and painless to solve the problem.

Surface electromyography (SEMG) is a kind of bioelectric phenomena as muscle activity associated on the skin surface, which contains an abundance of muscle movement information. SEMG can record muscle biological signals on the surface skin by Electrode when the muscle movement[2]. Because of the control signal is derived from the prosthesis surface of the skin of the patient's own biological signals, the SEMG is a source of painless, steady and continuous prosthetic control. For example, it is used in the mechanical arm by EMG Application[3], and is used in upper-limb prosthetic by control of SEMG[4].

As research on SEMG develops rapidly, especially in recent years, technology study on SEMG has been mature, it has developed to all areas of intelligent systems. However, study on SEMG is now still at the stage of theoretical research, by the limitations of size and anti-noise, the equipment of collecting EMG is unable to meet the requirements on assembly and control artificial limbs. To solve this problem, this article researches and designs a new Novel SEMG amplifier. Acquire the generation mechanism and characteristics of the analysis of major noise about SEMG, the article analysis the major noise to design the parameters about SEMG amplifier and simulates the circle by use of virtual software Multisim2001. The article proves the design on SEMG amplifier is feasible by virtual software Multisim2001. And it can achieve the amply the SEMG signal.

□. SEMG Mechanism and Properties

EMG signal is from the motor neuron of the central nervous spinal cord. The motor neuron cell bodies in the spinal cord and its axons extend to the muscle fibers department, through the end-plate area and muscle fiber coupling. These sections together constitute a motor unit.

Under the control of the central nervous system, motor neurons produce electrical impulses along the axon conduction to the muscle fiber, and cause pulse sequence along the muscle fibers to the spread of the two parties in all of the muscle fibers. While the electrical impulses spread in human soft tissue cause current field, and make the difference between the test electrodes. The muscle fibers show potential waveform in the test points, its polarity and

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endplates is related with the position of the detection point, and the distance between the fiber and testing while the distance between points related to the more far away from the smaller amplitude (Figure 1).

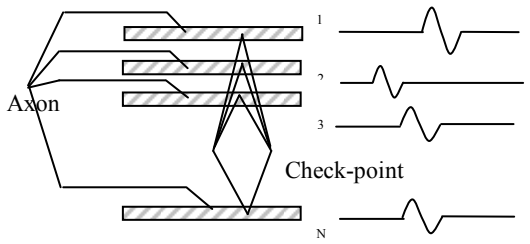

Fig.1 Unit action potential

SEMG is a kind of weak bio-signal, the range of normal person's SEMG is tens of microvolt to several millivolt, and the frequency is mainly in 5Hz-1000Hz, specially between the frequency of 10Hz-200Hz. Because of the length of time by the disability, tendon injury, muscle signals incomplete and other factors, they makes the Amputee EMG is usually weaker than normal, and individual differences obviously.

There is several noise between the SEMG signal amplification, such as frequency interference, the noise exposed by electrode, polarization noise, ECG interference, Circuit internal interference and so on[5]. For example in everyday life, assembly artificial limbs would be influenced by 50Hz frequency, the frequency on surface of the body is detected 50Hz frequency induction electromotive force relative to the instruments above ground up to 1V. We can accurately extract the zoom out of EMG only by correctly analyze and eliminate the impact of noise on the EMG amplifier.

Ⅲ. SEMG Amplifier Design

SEMG amplifier picks up and detects the EMG by the use of electrodes, and adds another electrode between the two electrodes in order to reduce the noise and improve the common-mode rejection ratio. Reduce the impact of EMG "common mode" component through the two pickup electrodes, and achieve the amplification of EMG acquisition through the amplification "differential Mode" section.

First of all, pick up muscle power with two electrodes and pre-zoom the EMG signal by use of low-noise differential pre-amplification of Burr-Brown's INA128, and put the reference level signal into INA128 all the same with two chip of INA137. While put the EMG which preamp from INA128 into the high-pass filter circuit to weed out low-frequency noise and DC component. Second, weed out the impact of 50Hz frequency noise in the system by use of the 50Hz frequency notch filter. Then, select the appropriate magnification of the EMG signal for further amplification by use of the variable gain amplifier and put the EMG signal into the low-pass filter circuit to remove the high-frequency noise. Fourth, put the EMG signal after filter amplification into the Analog-Devices' AD536 to true RMS-to-DC. The last, put the transformation of the EMG signal into the follow-up of the AD signal processing unit circuit (Figure 2).

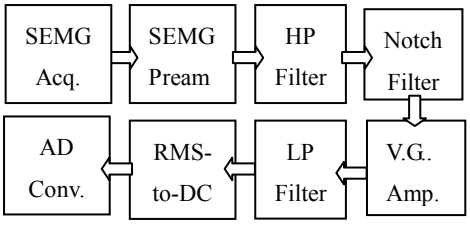

Fig.2 Conditioning Circuit of SEMG AMPLIFIER

A. Preamplifier and High-Pass Filter

The preamplifier circle makes use of the Burr-Brown's INA128, the chip has a lot of benefits, such as high input impedance, high common-mode rejection ratio, adjustable gain and other characteristics, it can effectively reduce the electrode contact with the skin produces noise.

The EMG signal acquired by low-noise preamplifier, can amplify firstly. The EMG signal acquisition is mingled with noise, and the noise is a large-signal for EMG signal. So pre-magnification can not be made too large. Set pre-magnification is 10, then:

$$G_A = 1 + \frac{50k\Omega}{2R} \qquad (1)$$

$$\mathrm{R} = \frac{50\mathrm{K}\Omega}{10 \times 2} = 2.4\mathrm{K}\Omega \qquad (2)$$

EMG signal must to be filtered EMG signal noise after preamplifier. Use the Sallen-Key low-pass filter and chose the cut-off frequency of 10Hz, it can weed out the DC component and low-frequency noise which impact on the EMG signal and device effects.

B. 50Hz Notch Filter

After preamplifier, we must use the 50Hz notch filter to cut off 50Hz noise. It is usually to use a low-pass filter and a high-pass filter to compose T notch circle, the notch frequency:

$$f_N = \frac{1}{2\pi}\frac{1}{RC} \quad (3)$$

$$Q = \frac{1}{2(2-A_{up})} \qquad \text{其中 } A_{up} = 1 + \frac{R_f}{R_1} \quad (4)$$

However, when the accuracy of this notch is bad, the notch will affect the notch frequency and quality factor. So use the burr-brown UAF42 chip to compose the T notch. Set parameters and make the Notch center frequency to be 49.8Hz and 50.2Hz by use of software CAD- FILTER42 from burr-brown. (Table.1)

TABLE.1 The notch frequency parameter selection with two-piece UAF42 notch frequency

f_N	BW	Q	RF1	RF2	RQ	Rz1	Rz2	Rz3
Hz	Hz		MΩ	MΩ	MΩ	MΩ	MΩ	MΩ
49.8	5	9.96	3.16	3.16	2.80	2	2	20
50.2	5	10.0	3.16	3.16	2.74	2	2	20

Both of two notches are used of PP4 model:

$$\omega_n^2 = \frac{R_2}{R_1 R_{F1} R_{F2} C_1 C_2} \quad (5)$$

Quality factor:

$$Q = \frac{1 + \frac{R_4(R_3 + R_Q)}{R_3 R_Q}}{1 + \frac{R_2}{R_1}} \left[\frac{R_2 R_{F1} C1}{R_1 R_{F2} C_2}\right]^{1/2} \quad (6)$$

C. Variable Gain Amplifier and Low-pass Filtering

After 50Hz notch filter, it will zoom further to make EMG signal amplitude has been further enhanced. And use low-pass filter to cut off high frequency noise affected. The further amplifier use potentiometer to compose the variable-gain amplifier. In order to adapt the different the disabled need and make the effective design, it can use 100K potentiometer resistance. And it will easily to choose magnification.

The maximum gain of variable gain adjustment as follows:

$$G_{2MAX} = 1 + \frac{100K}{470} = 213 \quad (7)$$

The final magnification as follows:

$$G_{MAX} = G_A \times G_{2MAX} = 10 \times 213 \approx 2K \quad (8)$$

It can choose Sallen-Key filter to be low-pass filter. Set the cut-off frequency to 200Hz. The filter has simple structure, quality factor adjusted easily and magnification adjusted fast.

D. RMS to DC

After low-pass filter, it can use the AD536 to achieve the transformation from RMS to DC. AD536 is the IC that turn RMS to DC from ANALOG DEVICES. It is excellent performance. It can calculate the input of any complex waveforms, including true RMS AC and DC waveforms. The chip contains the absolute value of the circuit, square device divider, as well as mirroring current circuit. It can use of being taken to the filtered EMG signal to RMS processing, in order to deal with the follow-up of the AD circuit to facilitate the future rules of the smart prosthesis control analysis study.

Ⅳ. SEMG Software Simulation

After the completion of the hardware design, we can use the software to simulate the hardware design. To use the Canadian Interactive Image's Multisim2001 simulation software, with the help of virtual reality technology, it can easily choose equipment and replace components. It is convenient and fast to simulate analysis design to test what about the performance of the circuit. Multisim2001 can

offer as low as the signal of a Microvolt, so that it can effectively carry out the virtual validation of surface EMG signals.

Suppose that input of surface EMG signal is a sine signal, sent to the predetermined circuit can be effectively inhibited 50Hz notch frequency of the circuit (Figure 3).

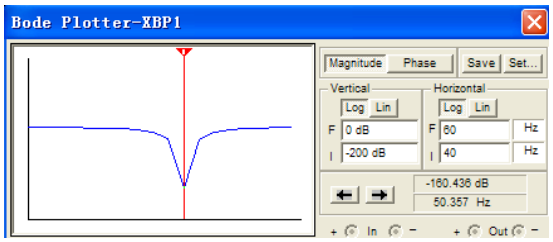

Fig.3 50Hz notch filter bode with UAF42

Through frequency 50Hz notch filter, the SEMG signals is about-160.436dB attenuation, which can effectively restrain the external frequency signal EMG impact. When adjust the resistance of potentiometer, it can effectively change the system magnification (Table 2). We can see from Table 2, it is different between the theoretical and practical magnification, but the theoretical and practical magnification ratio is basically constant value. It may be caused by software in the difference between chip set and actual parameters. However we can see that the SEMG amplifier can effectively Acquire and amplify.

TABLE.2 The relationship between Potentiometer and magnification

Potentiometer Resistance (KΩ)	Magnification of Theory	Original Signal (μV)	Output Signal (mV)	Final Magnification
5K	106.38	12.9	5.0	387.59
10K	212.76	12.2	9.1	745.90
20K	425.53	12.3	17.8	1447.15
40K	851.06	12.3	35.3	2869.91
80K	1702.12	12.3	69.9	5682.92

Ⅴ. CONCLUSION

SEMG signal is so weak that it is easily impacted by the surrounding noise. To design the SEMG signal acquisition device is not only to amplify the EMG signal, but more work is accurately extracted SEMG from a strong noise environments. It must weed out the 50Hz frequency out of the EMG signal and shield the surrounding noise. For acquiring the SEMG signal from noise approach, it is usually by the use of digital filter analysis and process SEMG signal. But this article is by use of the hardware design and software analysis composing, present one kind of acquisition of SEMG interference amplification device which can effectively remove the noise. In this paper, it can use burr-brown UAF42 chip to achieve frequency 50Hz notch filter design and make the circuit work by simulation software Multisim2001. It can achieve SEMG amplifier circuit design and conveniently assembly to amputation.

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