

Signal conditioning

by Xuyuan Liu

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Transducers and signal conditioning
– Signal conditioning

Experimental report

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Transducers & signal conditioning – Signal conditioning

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ABSTRACT

This experimental report is about signal conditioning circuits. In order to convert a temperature voltage generated sensor to produce a 0V signal at -20°C , a 5 V signal is generated at 100°C . And eliminate the clutter pollution. In order to achieve these two purposes, design a circuit consisting of a voltage divider circuit, overvoltage protection, filtering, level shifting and gain circuits. Simulate in the simulation software, debug and verify the usability of the circuit. Discuss and analyze the results.

Introduction

Voltage divider resistor

The voltage divider resistor refers to the resistance of the conductor in series with a certain circuit. When the total voltage is constant, a voltage divider resistor is connected in series with a certain circuit, which will function as a partial voltage, and a part of the voltage will drop to the voltage divider resistor. Above, the voltage across the portion of the circuit is reduced. The larger the resistance of the voltage dividing resistor, the more obvious the partial pressure effect.

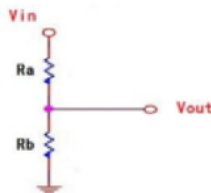


Figure 1. Voltage divider circuit

Zener diode

The Zener diode uses the reverse characteristic. After a certain reverse voltage is applied to both ends, the diode is reverse-conducted, thereby achieving the function of "regulation". When a certain value of the voltage regulator is at both ends of the load, when the voltage is less than this value, the Zener diode does not work. When it is greater than this value, the Zener tube breaks down and

the voltage drops, making the voltage regulator (load) The voltage at both ends remains at this value.

From the safety of the Zener diode, as long as the current flowing through it does not exceed the maximum reverse withstand current of the Zener diode, there is no danger of damage to the circuit components. The normal working area of the Zener diode refers to the value of the terminal voltage change in a large current change region under a certain current flowing condition under the condition of a reverse current, which is relatively small or even negligible.

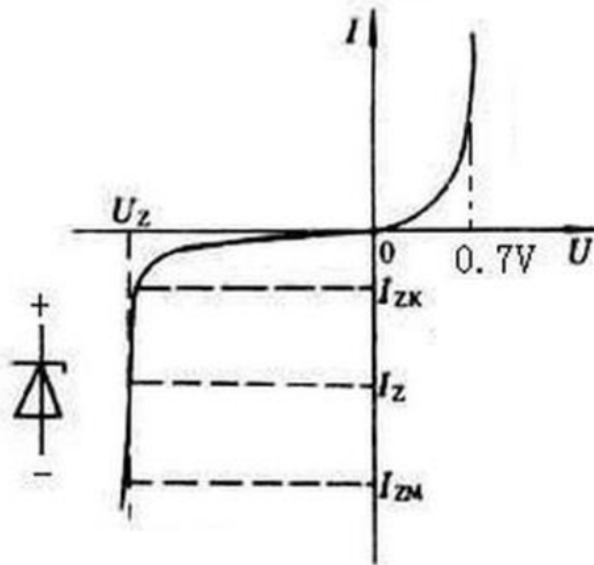


Figure 2. Zener diode characteristic curve

Filter

Filters, as the name suggests, are devices that filter waves. "Wave" is a very general physical concept. In the field of electronic technology, "wave" is narrowly limited to the process of describing the fluctuations of various physical quantities over time. This process is converted into a time function of voltage or current by the action of various types of sensors, which is called a time waveform of various physical quantities, or a signal. Because the independent variable time 'is continuous value, it is called continuous time signal, and is used to call it analog signal. With the rapid development of digital electronic computer (commonly referred to as computer) technology, in order to facilitate the computer to process the signal, a complete theory and method for transforming continuous time signals into discrete time signals under the guidance of sampling theorem is generated. That is to say, the original signal can be expressed only by the sample values of the original analog signal at a series of discrete time coordinate points without losing any information. The concepts of waves,

waveforms, and signals express the changes of various physical quantities in the objective world. Nature is the carrier of all kinds of information that modern society depends on. Information needs to be transmitted, relying on the transmission of waveform signals. Every part of the signal generation, conversion, and transmission may be distorted due to the existence of environment and interference. Even in a considerable number of cases, the distortion is so serious that the signal and the information it carries are deep. Deep buried in the noise. The role of the filter is to extract the information from it.

Second-order active low-pass filter

The second-order active filter circuit is composed of two RC filter circuits and the same analog circuit, and a negative feedback is introduced between the integrated operational amplifier output and the integrated operational amplifier non-inverting input. The polarity of the feedback is different in different frequency bands. When the signal frequency is $f \gg f_0$ (f_0 is the cutoff frequency), the phase shift of each stage of the RC circuit of the circuit tends to -90° , and the phase shift of the two-stage RC circuit to -180° , the output voltage of the circuit is opposite to the phase of the input voltage. Therefore, the feedback that is led to the non-inverting terminal of the integrated operational amplifier through the capacitor C is negative feedback, and the feedback signal will act to weaken the input signal, so that the voltage amplification factor is reduced, so the feedback will make the second-order active low-pass filter. The high-frequency end of the amplitude-frequency characteristic is rapidly attenuated, allowing only the low-frequency end signal to pass.

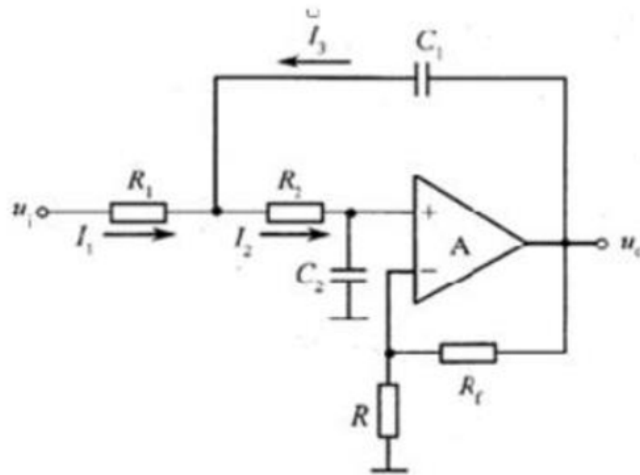
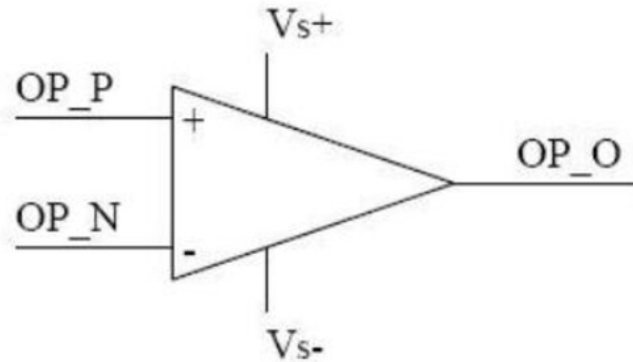


Figure 3. Second-order active low-pass filter circuit

Operational Amplifier

An operational amplifier is a circuit unit with a very high amplification factor. In an actual circuit, a feedback function is usually combined with a feedback network to form a certain functional module. It is an amplifier with a special

coupling circuit and feedback. The output signal can be the result of mathematical operations such as addition, subtraction or differentiation of the



input signal, integration, etc.

Figure 4. Operational Amplifier

Connecting the inverting input of the op amp to the output, the amplifier circuit is in a negative feedback configuration, and the circuit can often be referred to simply as a closed-loop amplifier. The closed-loop amplifier enters the end of the amplifier according to the input signal, and can be divided into an inverting amplifier and a non-inverting amplifier.

The inverted closed-loop amplifier is shown below. Assuming that the closed-loop amplifier uses an ideal op amp, the open-loop gain of the op amp is infinitely large, so the two inputs of the op amp are virtual ground, and the relationship between the output and the input voltage is as follows:

$$V_{out} = -(R_f / R_{in}) \times V_{in}$$

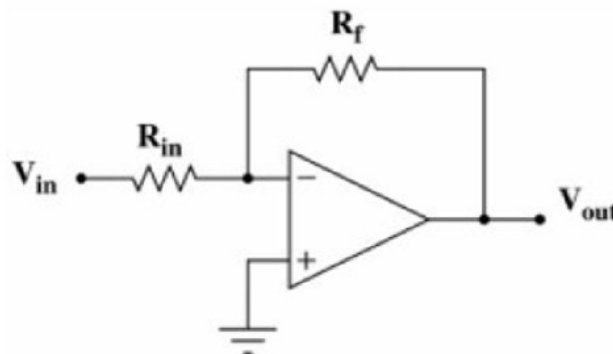


Figure 5. Inverted closed-loop amplifier

Non-inverted closed-loop amplifier is shown in the figure Assuming that the closed-loop amplifier uses an ideal op amp, the open-loop gain of the op amp is infinite, so the voltage difference between the two inputs of the op amp is

almost zero. The relationship between the output and the input voltage is as follows:

$$V_{out} = ((R_2 / R_1) + 1) \times V_{in}$$

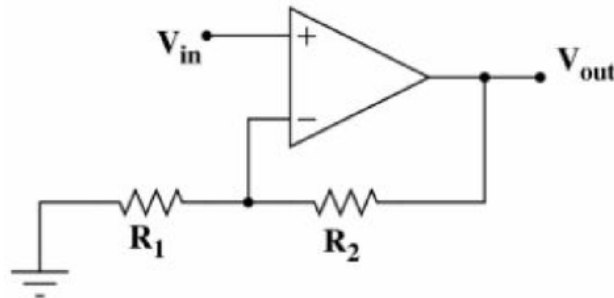


Figure 6. Non-inverted closed-loop amplifier

Method

Draw a circuit block diagram according to design requirements. The filter circuit is used to filter out sine wave noise. The range of signals needs to be moved by level shifting the signals so that the lowest input signal gives 0V. Amplifying from this point will ensure that the signals remain within the capabilities of the amplifier. The purpose of the op amp is to amplify the otherwise small input voltage to the final desired output voltage.

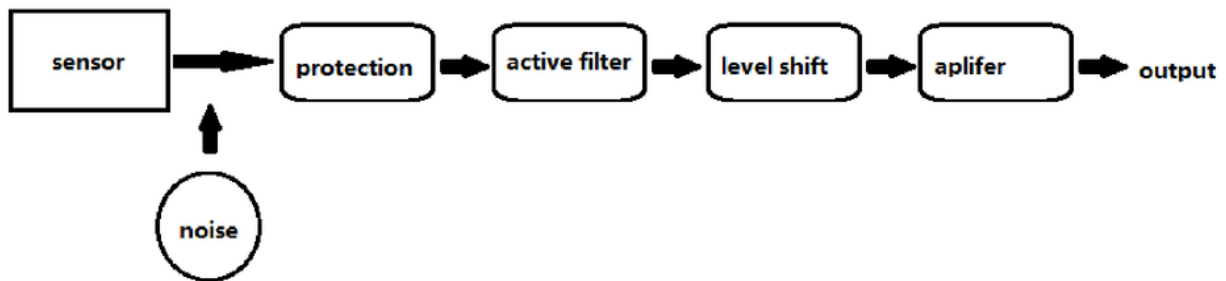


Figure 7. block diagram

The circuit is designed on the simulation software according to each circuit module. And connect the various circuit modules together on the simulation software. Among them, a voltage divider circuit is used to simulate the temperature sensor. A protection circuit is formed by a resistor and a Zener diode. The noise is filtered using an active second-order low-pass filter. To prevent the range of the expected signal from moving beyond the function of the operational amplifier, the signal range is shifted by the level shifting signal. Finally, the op amp amplifies the voltage to the expected value.

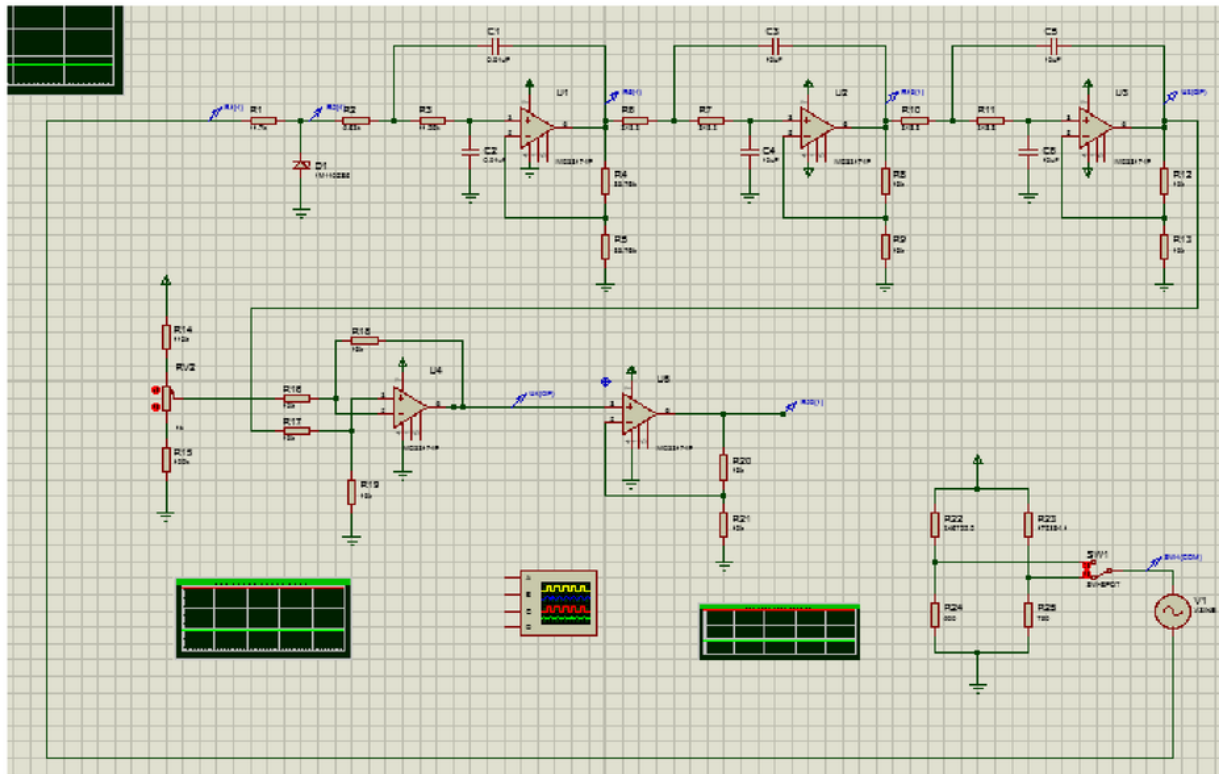


Figure 8. Simulation circuit diagram on proteus

Design

Voltage divider circuit

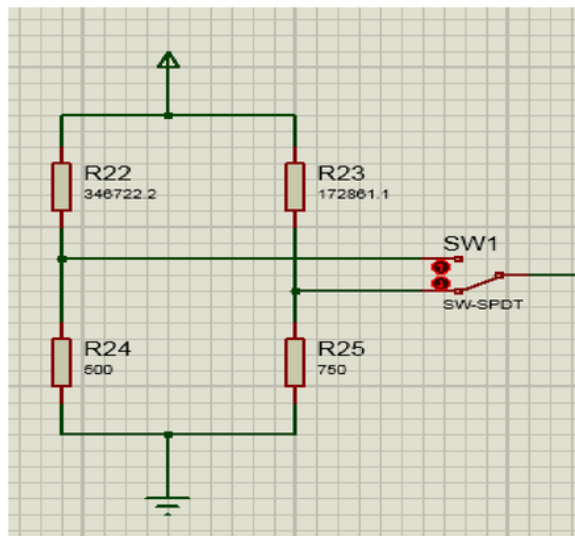


Figure 9. Voltage divider circuit

Use this circuit instead of the temperature sensor. Because the temperature sensor produces $120\mu\text{V}/^\circ\text{C}$ with $0\text{V} = -80^\circ\text{C}$. circuit that will produce a signal of 0V for a temperature of -20°C and 5V for 100°C .

Then have $[-20^\circ\text{C} - (-80^\circ\text{C})] \times 120 \times 10^{-6} = 7.2\text{mV}$

$[100^\circ\text{C} - (-80^\circ\text{C})] \times 120 \times 10^{-6} = 21.6\text{mV}$

According to:

$$V_{\text{out}} = (R_b / R_a + R_b) \times V_{\text{in}}$$

Can calculate the value of resistors. And output the voltage of 7.2mV and 21.6mV .

Overvoltage protection

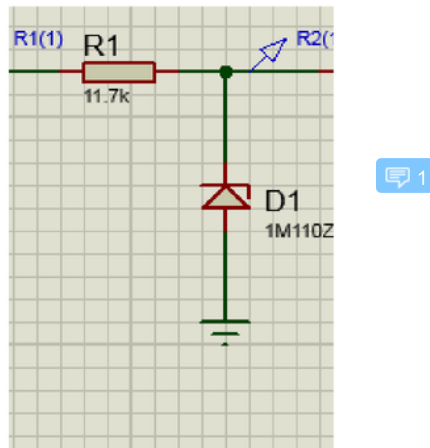


Figure 10. Protection circuit

This is the simplest regulator circuits made with Zener diodes. There are two regulations for the Zener circuit.

1. The input voltage of the Zener diode shunt regulator must be greater than the output voltage.
2. When the maximum input voltage is used, the maximum power consumption of the Zener diode must be less than the rated power consumption of the Zener diode.

Filter circuit

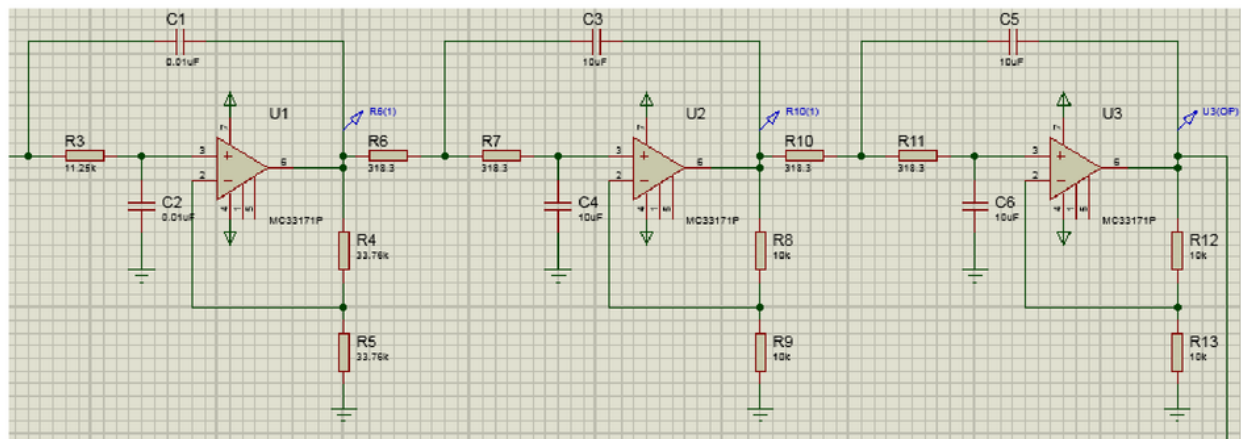


Figure 11. Filter circuit

This is a filter circuit consisting of three active low-pass second-order filters. The cut-off frequency is given by

$$f_c = 1 / (2 \cdot \pi \cdot R \cdot C)$$

Known frequency is 50Hz, and then determine the value of a capacitor to find the value of the filter resistor.

The next step is to determine the resistor values for the gain. For the circuit shown the gain K is given by $(1 + R_2/R_1)$. Determine the K to find the value of gain resistor.

Level shifting circuit

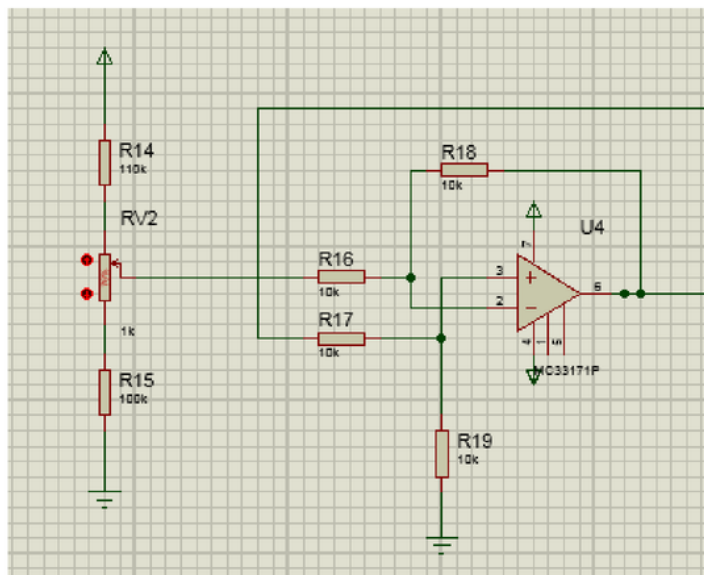


Figure 12. Level shifting circuit

The level shift circuit is composed of an operational amplifier, a sliding varistor and a plurality of resistors. The signal range is changed by adjusting the sliding rheostat. Multiple adjustments are made in the simulation software to determine the resistance parameters.

Operational Amplifier circuit

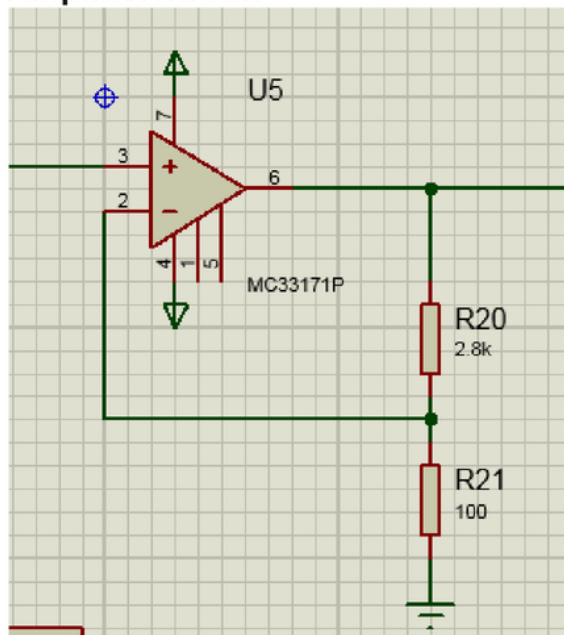


Figure 13. Operational Amplifier circuit

This is a simple non-inverting closed-loop amplifier whose output is related to the input voltage as follows:

$$V_{out} = ((R2 / R1) + 1) \times V_{in}$$

Simulation results

After mixing 1.2V,50Hz noise at 21.6mV.

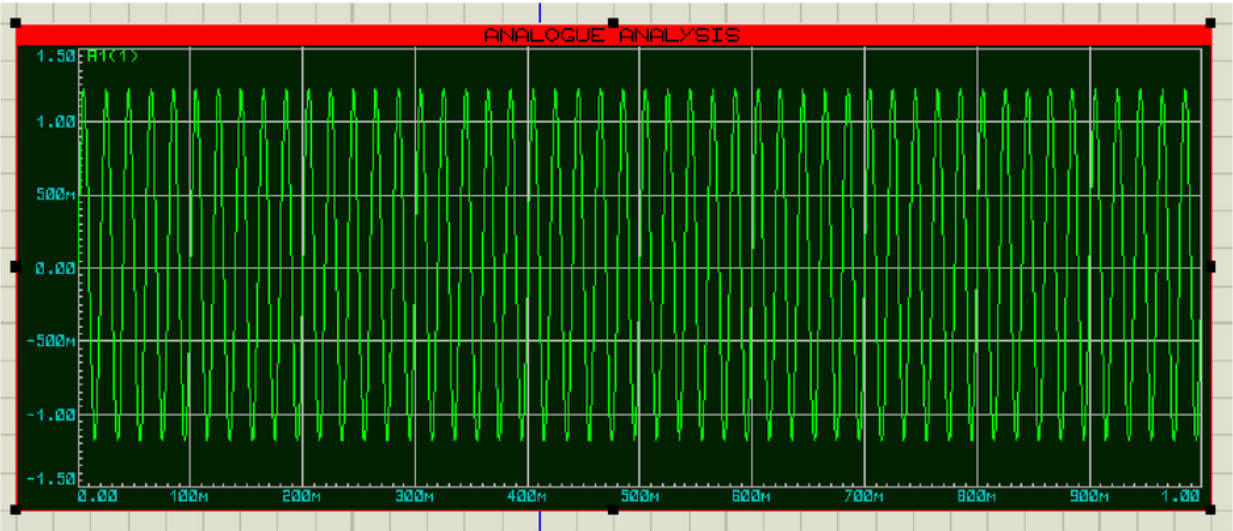


Figure 14. Simulation results one

The voltage image obtained after three times of filtering.

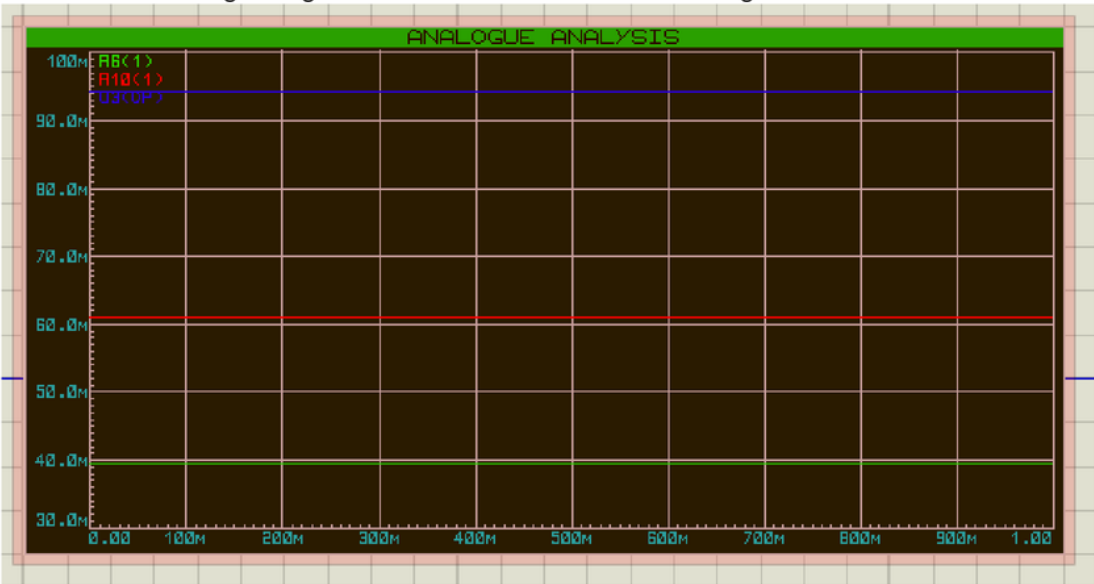


Figure 15. Simulation results two

The final image obtained by the operational amplifier.

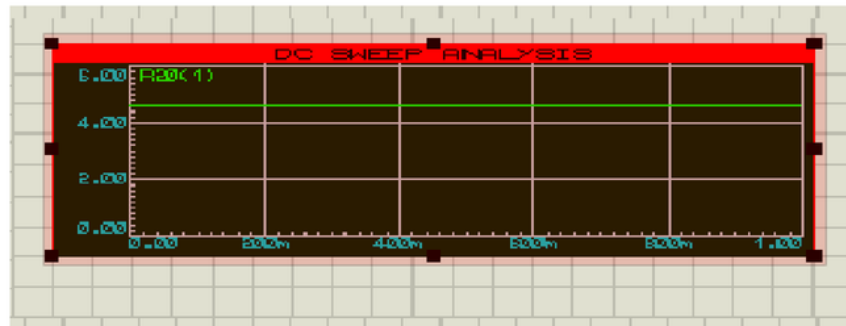


Figure 16. Simulation results three

Available from the image, the final output is 4.8V. It is slightly less than the 5V requirement. It may be caused by errors in the operation.

Response time

To calculate the response time. Connect a pulse in the circuit. And the wave of the power have changed.

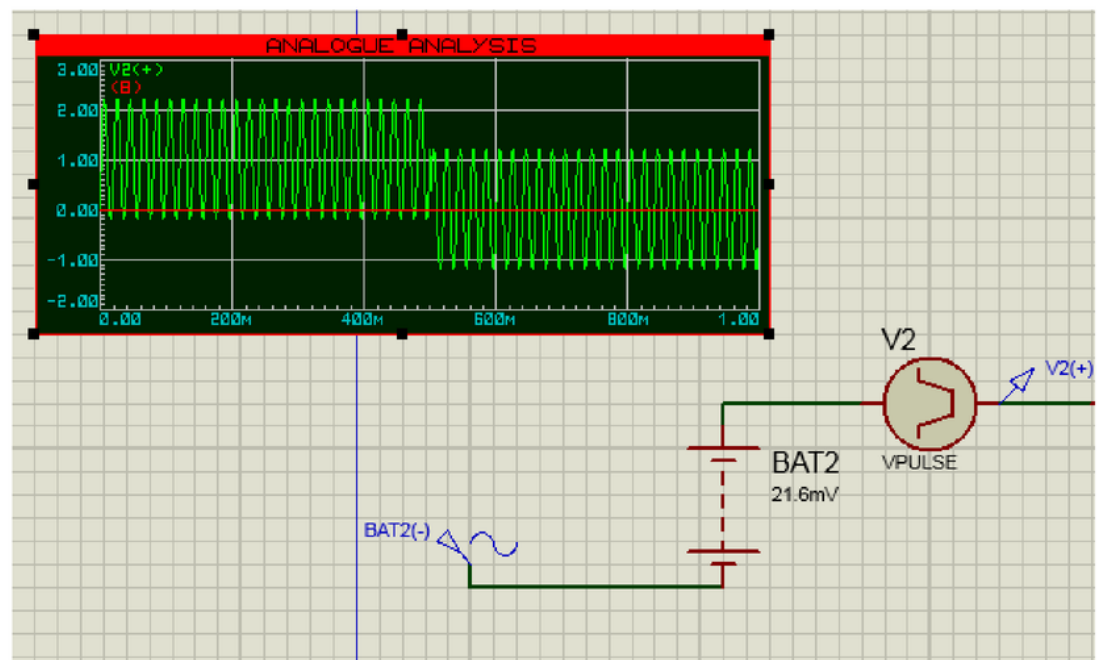


Figure 17. Response time

Discussion

Design of Active Low-Pass Second Order Filter

The active second-order source filter circuit is shown in the figure, and a negative feedback is introduced between the integrated operational amplifier output and the integrated operational amplifier non-inverting input. In different frequency bands, the feedback polarity is different, when the signal frequency is $f \gg f_c$ (f_c is the cutoff frequency), the phase shift of each stage of the RC circuit of the circuit tends to -90° , the phase shift of the two-stage RC circuit to -180° , the output voltage of the circuit is opposite to the phase of the input voltage, so the integration is introduced through the capacitor C . The feedback of the non-inverting terminal of the operational amplifier is negative feedback, and the feedback signal will act to weaken the input signal, so that the voltage amplification factor is reduced, so the feedback will rapidly attenuate the high-frequency end of the amplitude-frequency characteristic of the second-order active low-pass filter. Only the low frequency end signal is allowed to pass, and the transfer function is::

$$A(s) = \frac{A_v \frac{1}{R_1 R_2 C_1 C}}{s^2 + \left[\frac{1}{R_1 C} + \frac{1}{R_2 C} + (1 - A_v) \frac{1}{R_2 C_1} \right] s + \frac{1}{R_1 R_2 C C_1}}$$

Compared with the general expression of the low-pass filter transmission function.

$$A(s) = A_v \omega_c^2 / (s^2 + \frac{\omega_c}{Q} s + \omega_c^2)$$

The performance parameter expression of the active second-order low-pass filter is obtained as follows:

$$\omega_c^2 = 1/(R_1 R_2 C C_1)$$

$$\frac{\omega_c}{Q} = \frac{1}{R_1 C} + \frac{1}{R_2 C} + (1 - A_v) \frac{1}{R_2 C_1}$$

$$A_v = 1 + \frac{R_4}{R_3}$$

In order to balance the op amp input to ground resistance, an equation $R_1 + R_2 = R_3 \parallel R_4$ is added to solve the circuit parameters. If the cutoff frequency of the active second-order low-pass filter is $f_c = 2\text{kHz}$, the voltage gain is $A_v = 2$, and the quality factor is $Q = 0.707$, select the model of the integrated op amp as $\mu A741$ and take the capacitor. $C = 0.01\mu\text{F}$, then $C = 0.01\mu\text{F}$, $Q = 0.707$, $A_v = 2$, $f_c = 2\text{kHz}$. The known condition is substituted into the performance parameter equation obtained above and $R_1 + R_2 = R_3 \parallel R_4$ expression. Then, the quaternion cubic equation is formed. To solve the equation, the circuit

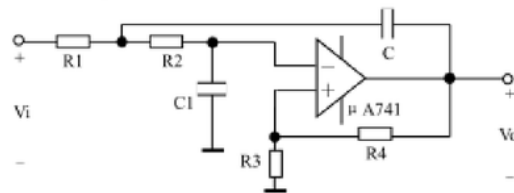


Figure 18. Active Low-Pass Second Order Filter

parameters are: $R_1 = 5.63\text{K}\Omega$ (take the nominal value of $5.6\text{K}\Omega + 30\Omega$), $R_2 = 11.25\text{K}\Omega$ (take the nominal value of $11\text{K}\Omega + 240\Omega$), $R_3 = R_4 = 33.76\text{K}\Omega$ (take nominal value $33\text{K}\Omega + 750\Omega$), $C_1 = C = 0.01\mu\text{F}$.

Virtual short and virtual break

When analyzing an op amp application circuit, in most cases, the integrated op amp can be thought of as an ideal op amp. Ideally, the ideal operational amplifier is ideal for the technical indicators of the integrated operational amplifier. Since the technical specifications of the actual operational amplifier are closer to the ideal operational amplifier, the error caused by idealization is very small and can be ignored in general engineering calculations.

The actual op amp's parameters can be treated as ideal with the following levels:

The voltage amplification factor is $10^4 \sim 10^5$ times; the input resistance reaches $10^5\Omega$; the output resistance is less than several hundred ohms; the current in the external circuit is much larger than the bias current; the offset voltage, the offset current and its temperature drift are small, causing the circuit drift to allow. Within the scope, the stability of the circuit can meet the requirements; when inputting the minimum signal, there is a certain signal-to-noise ratio, and the common mode rejection ratio is greater than or equal to 60 dB; the bandwidth can meet the circuit bandwidth requirement.

The short and false meanings in the op amp:

Because the voltage amplification factor of the ideal op amp is very large, and the op amp works in the linear region, it is a linear amplifying circuit, and the output voltage does not exceed the linear range (ie, finite value). Therefore, the potential of the non-inverting input terminal and the inverting input terminal of the operational amplifier are very close to equal. When the op amp supply voltage is $\pm 15\text{V}$, the maximum output is generally $10 \sim 13\text{V}$. Therefore, the voltage difference between the two input terminals of the op amp is below 1 mV, and the two input terminals are short-circuited. This feature is called a virtual short. Obviously, this is not a true short circuit, but a reasonable approximation within the allowable error range when analyzing the circuit.

Since the input resistance of the op amp is generally several hundred kilo ohms or more, the current flowing into the non-inverting input and the inverting input of the operational amplifier is very small, several orders of magnitude smaller than the current in the external circuit, and the current flowing into the operational amplifier can often be ignored, this is quite an open circuit at the input of the op amp. This feature is called virtual break. Obviously, the input of the op amp can't really open the way.

Using the two concepts of "virtual short" and "virtual break", the analysis process of the application circuit can be simplified when analyzing the linear application circuit of the operational amplifier. The operational circuits formed by the operational amplifiers all require a certain functional relationship between the input and the output, so both conclusions can be applied. If the op amp does not work in the linear region, there is no "virtual short" or "virtual break" feature. If the potential of the two inputs of the op amp is measured and reaches a few

millivolts or more, the op amp often does not work in the linear region or is damaged.

Conclusions

Through a series of circuits, the intended function is finally completed. Make a temperature sensor which produces $120\mu\text{V}/^\circ\text{C}$ with $0\text{V} = -80^\circ\text{C}$ to produce a signal of 0V for a temperature of -20°C and 5V for 100°C . Successfully eliminated a 1.2Vpk-pk 50Hz mains hum noise.

A voltage divider circuit is used to simulate the temperature sensor. And a sine wave connected with it to produce the noise. The filter circuit is used to filter out sine wave noise. After the signal pass the filters, there is a chance that the signal will move the range of expected signals outside the capabilities of the op-amps. So when the input signal increases, the output would effectively move to the supply rail and not exceed it for further increases in input voltage. To get around this, the range of signals needs to be moved by level shifting the signals so that the lowest input signal gives 0V . Amplifying from this point will ensure that the signals remain within the capabilities of the amplifier. The purpose of the op amp is to amplify the otherwise small input voltage to the final desired output voltage.

Through this assignment, I got a deeper understanding of the functions of the op amp and the principles of the op amp. The operational amplifier is a DC-coupled, differential-mode (differential mode) input, usually a high-gain voltage amplifier with a single-ended output, which is named for its initial use in arithmetic circuits such as addition and multiplication. An ideal op amp must have the following characteristics: an infinite input impedance, an output impedance equal to zero, an infinite open loop gain, an infinite part of the common mode rejection ratio, and an infinite bandwidth. A method of using a simple protection circuit has been learned in the design circuit. Eliminating the AC wave in the DC power supply is a very complex part of this test. The filter is filtered multiple times to remove the AC wave. Moreover, the filter not only acts to block the alternating current, but also functions as a direct current and can function as a gain. When an op amp is typically used, its output is connected to its inverting input to form a negative feedback configuration. The reason is that the op amp's voltage gain is very large, ranging from hundreds to tens of thousands of times, using negative feedback to ensure stable operation of the circuit. But this does not mean that the op amp cannot be connected to positive feedback. Conversely, in many systems that require an oscillating signal, an operational amplifier with a positive feedback configuration is a very common component.

The use of proteus simulation software is also very important. The designed circuit is run in the simulation software, and a probe is inserted into the simulation software to observe the result. Presenting data on a chart is also an important skill in using simulation software.

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Signal conditioning

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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Comment 1

Using a zener diode as protection provides a simple means of over voltage protection although a single diode will only protect against positive voltages and not negative voltages.

To protect against negative voltages a second diode should be connected in reverse parallel to the diode you have.

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GRADING FORM: SMU GENERIC_SMOSEY

XUYUAN LIU

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ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



You have included a range of research-informed literature, including sources retrieved independently. Although you have not indicated which parts of your text have used which sources. The locations in your text where you have used a reference source should be indicated by a number in square brackets corresponding to the source [1]. More information on this can be found on the university library website.

2.5

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Although judging your understanding of the subject is difficult given that you have not indicated which information comes from which source, I will give you the benefit of the doubt. Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.

19.5

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Evidence of some logical, analytical thinking and synthesis. You only seem to have analysed the time response of your circuit and not included any frequency domain analysis. Valid conclusions

15.9

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A good and appropriate application of standard methods. Good appreciation of the context of the application, with some use of examples, where relevant.

17.4

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate effectively in a suitable format, but may have minor errors. Mostly coherent work and is in a suitable structure.

2.7