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Original Paper

Near-Infrared Alcohol Detection Circuit Based On Multisim

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Abstract

Because the number of private cars has expanded, drunk driving has become more and more frequent. The detection of a driver's alcohol concentration has become the focus of attention. Therefore, infrared alcohol detection was studied. The principle of infrared blood glucose noninvasive detection was investigated, and it was compared with infrared spectrum detection.

Finally, using transmission technology and an infrared emitter and receiver, an infrared alcohol identification circuit was designed by NBohr's Law and the Correcting Beer-Lambert Law. It was composed of an infrared acquisition circuit, an infrared electronic filter circuit, and an infrared amplifier circuit. And the infrared alcohol identification circuit was composed of multiple circuits in series and parallel. At various pins on the first AD844AN, the infrared electronic filter circuit receives an alternating current source voltage of 1000V with a basic signal frequency of 60 Hz. At the input end, the infrared amplifier circuit receives a current signal with a frequency of 1 Hz and an amplitude of 5 uA and performs the reproduction experiment using Multisim. As a result of the signal being upgraded to fulfill the objective of recognition, distinct information reappears and exhibits different waveforms.

Keywords

Multisim near-infrared alcohol by volume automobile drunk driving

1. Introduction

According to data, drunk driving is carefully investigated at home and abroad as the number of drunk driving accidents gradually grows to the greatest crime rate, culminating in one of the most dangerous traffic mishaps. At the moment, the only method for identifying drunk drivers in the United States and overseas are breathalyzers and blood tests, which waste police resources and are susceptible to resistance.

As a result, we propose using infrared detection of alcohol levels. Even though there have been few studies on infrared detection of alcohol content in China, the present infrared detection has the advantages of high efficiency, real-time detection, and non-invasiveness.

The mature field of infrared spectroscopy for human detection recently is mainly the detection of human blood sugar, tissue blood sugar, etc., such as non-invasive blood glucose detection by near-infrared spectroscopy. However, spectral analysis is difficult to take into account in terms of both cost and accuracy and is not suitable for the use of vehicle or portable alcohol detection. So the infrared detection method is redesigned and the transmission method is adopted. And because the blood sugar, tissue blood sugar, and other signals are higher than the human blood alcohol signal, the signal of the receiver will be too complicated to get the required data.

Based on this, this paper develops a low-cost, small infrared alcohol detection circuit that includes a collecting circuit, a filter circuit, and an amplifier circuit.

2. Design Principle of the Near-infrared Alcohol Detection Circuit

2.1 Design Principles

The frequency of near-infrared light is between visible light and middle infrared light, and the wavelength range is 780–2526 nm. It primarily stores information about the multiple-frequency vibration and frequency combination of the hydrogen-containing group X-H (X = C, N, O). The infrared wavelength is absorbed by the energy level transition after absorbing infrared. Different molecules in different environmental conditions have significant differences in the absorption wavelength of near-infrared light. The essence of infrared spectroscopy is this.

2.2 Basic Detection Theory

2.2.1 NBohr’s Law

When a molecule transitions between two different stationary states, it changes into two quantum states, and the difference in energy emitted or absorbed determines its frequency.

$$\triangle E= h\nu$$

In the above equation, v is the photon frequency, h is the Planck constant, and E is the energy level difference, the difference between the terminating energy level and the initial energy level.

2.2.2 Beer-Lambert Law

Also known as the “basic law of light absorption,” when the incident light is parallel monochromatic light and the absorption system is a continuous system with uniform and continuous distribution, the intensity of light absorbed by the solution is inversely related to its concentration and thickness:

$$A=lg(1/T)=KLc$$

In the above equation, A is absorbance, T is transmission ratio, the intensity of the outgoing light (I) versus the intensity of the incoming light (I0), K is the molar absorption coefficient, c is the concentration of the light-absorbing substance, and L is the thickness of the absorbing layer.

2.2.3 Correcting Beer-Lambert Law

Since the photon does not travel a straight-line distance but along a random path of a distance greater than L, the differential path length G is introduced:

A= KLcG

2.3 Method of Detecting Near-infrared

Near-infrared detection methods can be roughly divided into two categories: transmission methods and reflection methods.

The principle of the transmission method conforms to Beer-Lambert law, and monochromatic light vertically crosses the electrode or solution to detect the light absorption spectrum. At the same time, the detection is simple and the spectrum is less disturbed. The reflection method is to put the light source and the detector on the same side of the test object. And it is necessary to use a reflection accessory so that the detector will receive the reflected light source, which contains irregular diffuse reflection. The refractive index is abnormally dispersed, which is not conducive to direct calculation and needs additional analysis. Therefore, the transmission method is used for detection here.

2.4 Selection of an Infrared Emitter

According to the principle of infrared detection frequency change, the vibrational energy level of the ethanol O-H chemical bond transitions to a higher excited state under the infrared irradiation of 960 mm wavelength, which is a triple frequency absorption band, and its stretching vibration period is 3750–3000 cm-1. This project plans to use a 940mm infrared transmitting and receiving tube as an infrared sensor emitter.

Figure 1 shows the test circuit of the infrared sensor. The circuit is tested by monitoring resistance and sensor with series-parallel circuits, and then grounding with a series connection. According to the change in voltage in the circuit, the change in infrared intensity and residual intensity can be known, and the existence of ethanol and its concentration can be determined. Because the reverse current of the infrared receiving tube is small, all below 5 mA, the series resistance value should be greater to ensure normal operation. The circuit design and simulation diagram are shown in Figures 1 and 2.

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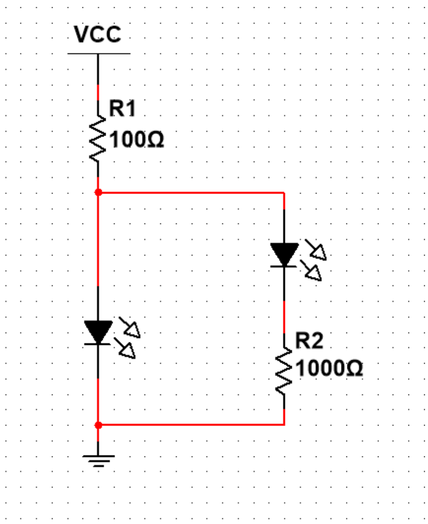

Figure 1. Infrared Sensor Test Circuit

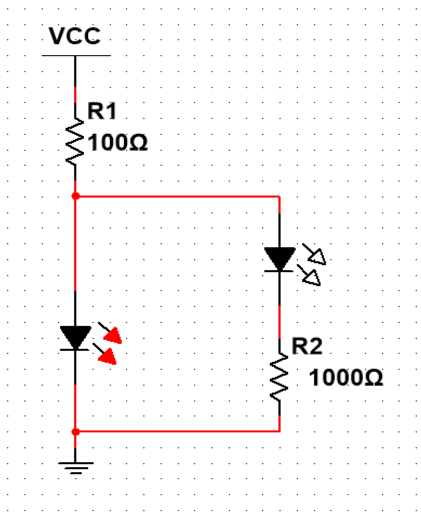

Figure 2. Infrared Sensor Simulation Circuit

3. Main Circuit Design of Infrared Alcohol Detection

3.1 Infrared Acquisition Circuit

Infrared acquisition circuits are divided into infrared transmitting circuits and infrared receiving circuits. The power of the infrared transmitting tube has a linear relationship with the current, so in order to increase the transmitting power of the transmitting tube, the circuit is designed in the form of an impulse excitation technique.

In the infrared emission circuit, a fixed-frequency clock pulse signal is used to carry out continuous pulse wave impact on the sample, so that the frequency of the continuous pulse wave is consistent with the natural frequency of the specimen and the maximum amplitude and delay time are obtained. Through the conduction cut-off of the bipolar junction transistor, the infrared emission tube is controlled to emit near-infrared rays. In the simulation experiment, the signal acquisition can be realized by using resistors with higher precision in parallel. The design circuit diagram is shown in Figure 3.

In the infrared receiving circuit, reverse bias is carried out on the receiving tube. When the transmitting circuit does not emit near-infrared light, it is in a cut-off state and only sends out a weak current. When the receiving tube receives the near-infrared light from the transmitting tube, it sends out a strong photocurrent, and its signal voltage is the voltage taken out from the upper end of the grounding resistance. The design circuit is shown in Figure 4. A resistor is connected in series to protect the circuit in the simulation experiment.

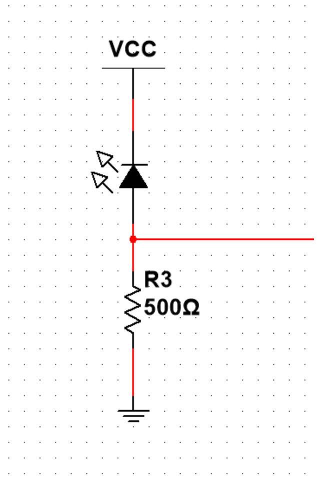

Figure 3. Infrared Transmitting Circuit

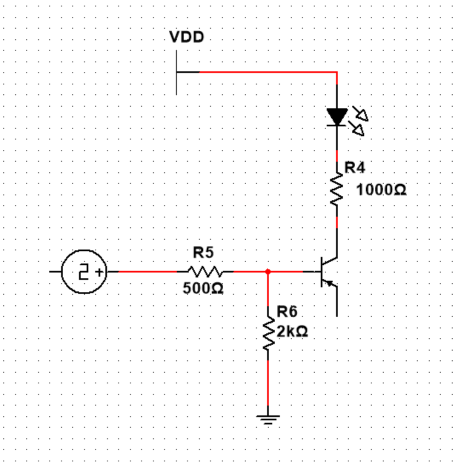

Figure 4. Infrared Receiving Circuit

3.2 Infrared Electronic Filters Circuit

Considering that the infrared collection signal is weak, and human blood is more complex. Individuals have differences that may cause interference with the monitoring of the -OH group in alcohol, the infrared signal filtering circuit is added for improvement. The filter circuit is often used to filter and rectify the ripples in the output voltage. In the design, the signal frequency band of a specific frequency is selected through the filter to reduce the influence of the useless signal frequency band on the experiment.

Under normal circumstances, the human pulse and heart rate are very similar. So the design of the filter circuit mainly considers the human pulse. When the human body is calm, the normal pulse output range is 60–100 times per minute. Gender and age will affect the pulse output. The pulse rate also changes when the body consumes energy drinks or exercises. The pulse wave energy is relatively concentrated and low, between about 0.5 and 10 Hz, and the normal pulse energy for adults is concentrated between 1 and 5 Hz, so the filter is designed with a frequency band between 0.3 and 15 Hz.

Combined with the characteristics of the filter, it is proposed to use high resistance, low capacitance, second-order filter, oscilloscope, etc. to form a filter circuit. Then, the same AC current source is connected through different points to form a current-mode filtering current and voltage-mode filtering circuit, which produces different simulation effects.

3.2.1 Schematic Diagram of Current Mode Infrared Electronic Filters Circuit

The second-order filter circuit is shown in Figure 5 and is designed as a current-mode filter. This circuit model is designed with three AD844AN modules, two capacitors, and five resistors from left to right. The current and voltage two-mode filtering circuit conversion is realized by changing the first AD844AN input AC current source and ground position. The positive pole of the AC current source is connected to the 3-pin of the first AD844 through the feedback resistor R10, and the negative pole is grounded. The 2-pin of the first AD844AN is grounded. The 3-pin parallel resistor R11 is connected with the 6-pin of the third AD844AN. The 5-pin is connected with the 6-pin of the second AD844AN through a feedback resistor R9. The output signal is transmitted to the second AD844AN through pin 6, and the oscilloscope XSC1 is connected in parallel during this process. The 3-pin of the second AD844AN receives the input signal through resistor R8. The 2-pin grounded. The 5-pin is connected to the capacitor and then grounded. The 6-pin output signal is connected to the 3-pin of the third AD844AN through resistor R7, and the oscilloscope XSC2 is connected in parallel. The 2-pin of the third AD844AN is grounded. The 5-pin is connected to the capacitor and then grounded. The 6-pin access oscilloscope XSC3.

The size of the resistance and capacitance in the circuit can be calculated through the KVL and KCL equations for each node of the current, combined with the expression of the resonant frequency of the filter.

R = R7 = R8 = R9 = R10 = R11 = 31.7 K

To make RC a constant, use the capacitor C = C1=C2=12nF, where the resistors have equal resistance values.

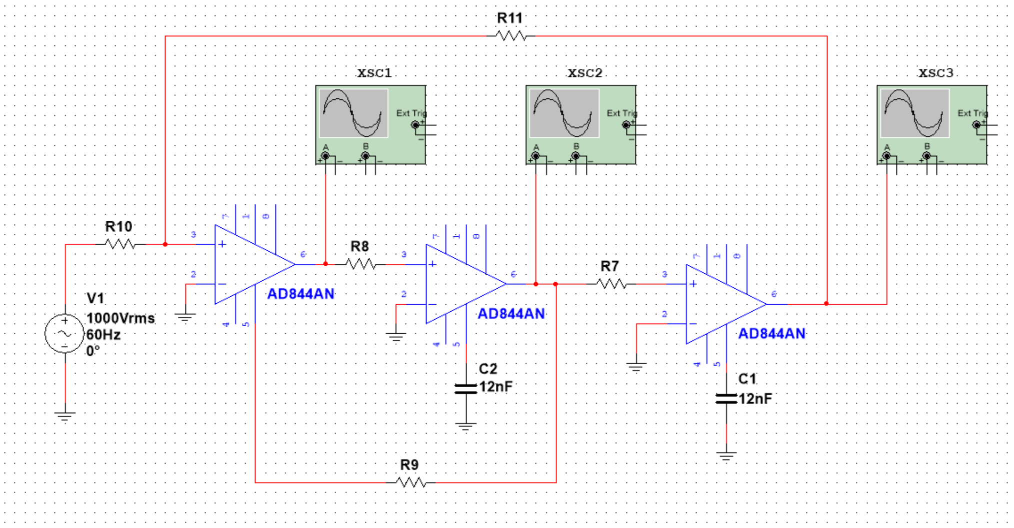

Figure 5. Schematic Diagram of Current Mode Infrared Electronic Filters Circuit

3.2.2 Infrared Voltage Mode Infrared Electronic Filters Circuit

The second-order voltage mode infrared electronic filter circuit is shown in Figure 6. In this module design, the positive pole of the AC current source is connected to the 2-pin of the first AD844AN via the feedback resistor R10. The negative pole is grounded. The 3-pin of the first AD844AN is grounded. The current-mode infrared electronic filter circuit is used in all other designs.

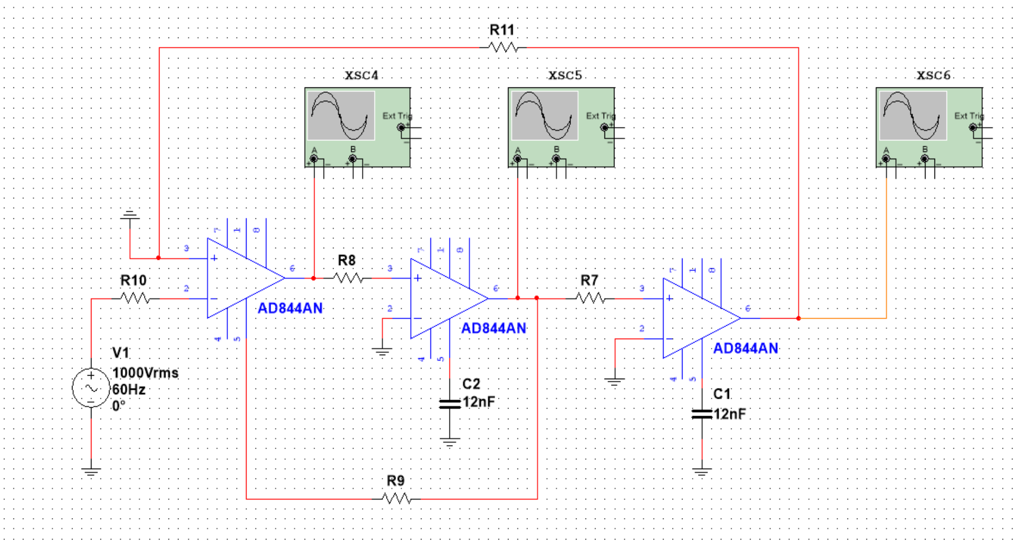

Figure 6. Schematic Diagram of Voltage Mode Infrared Electronic Filters Circuit

3.3 Infrared Amplifier Circuit

Blood alcohol detection refers to the modified Lambert-Beer law, which effectively reduces external interference and improves signal strength. According to beer-lambert law, when light with a specific wavelength is incident on arterial blood vessels, the volume fraction C of the substance remains unchanged and G remains unchanged for a short time. The intensity of emergent light is positively correlated with the electric signal generated by the photoelectric sensor. When the wavelength of incident light is constant, the volume fraction of alcohol can be obtained by extracting the maximum and minimum values of the corresponding electric signal. In order to collect and process electrical signals efficiently, it is necessary to convert weak current signals and then amplify them. The signal is weak, and the amplifier itself is noisy, and it will be amplified again after passing through the subsequent amplifier together with the signal. Considering these, the AD620 with low noise, high input impedance, and high CMRR is selected for differential amplification. In this experiment, a current source with a frequency of 1Hz and a vibration amplitude of 5uA is used as an analog signal source.

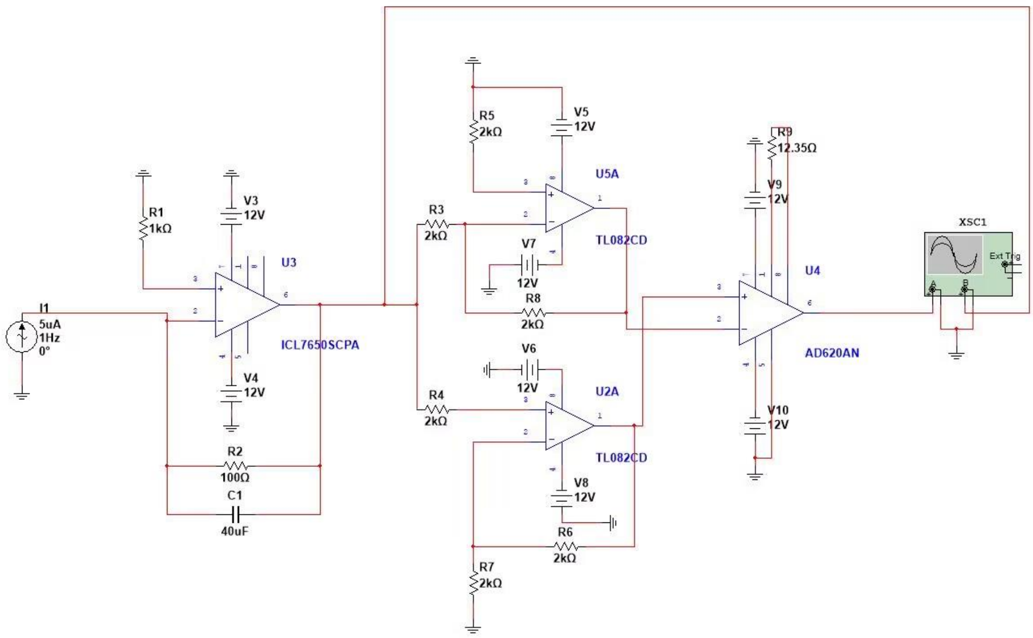

Figure 7. Infrared Amplifier Circuit

4. Simulation

This paper uses Multisim14 for simulation.

4.1 Current Mode Filtering Current Simulation Analysis

Under the simulation conditions, the 3-pin input AC current source voltage of the first AD844AN is 1000 volts, and the basic signal frequency is 60 Hz. Under this condition, the three oscilloscopes are simulated, as shown in the figure below.

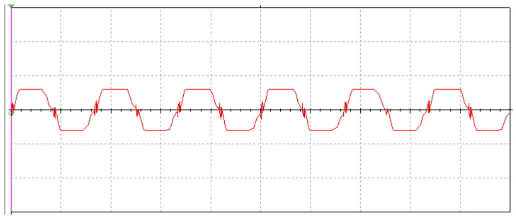

Figure 8. Simulation Diagram of XSC1 Oscilloscope

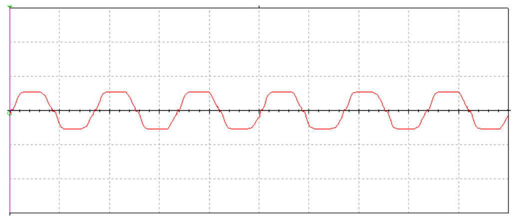

Figure 9. Simulation Diagram of Oscilloscope XSC2

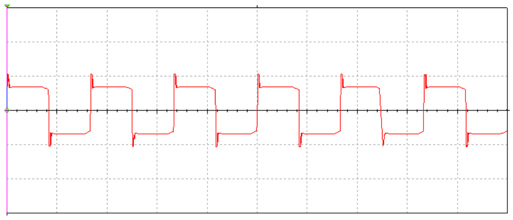

Figure 10. XSC3 Simulation Diagram of an Oscilloscope

According to the simulation results, the displayed waveform of the filter is different, which meets the requirements of performance indicators.

4.2 Voltage Mode Filtering Current Simulation Analysis

Under the simulation conditions, the 2-pin input AC current source voltage of the first AD844AN is 1000 volts, and the basic signal frequency is 60 Hz. Under this condition, the three oscilloscopes are simulated, as shown in the figure below.

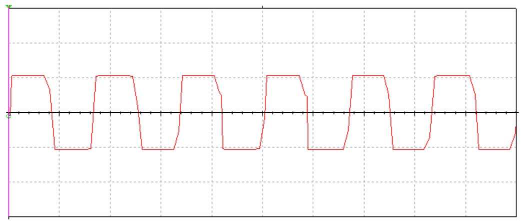

Figure 11. Simulation Diagram of XSC4 Oscilloscope

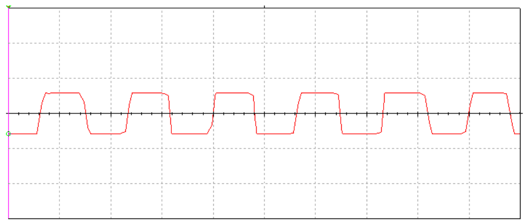

Figure 12. XSC5 Simulation Diagram of an Oscilloscope

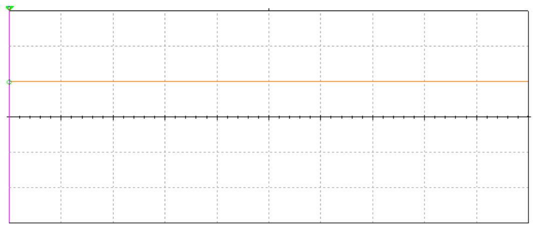

Figure 13. XSC6 Simulation Diagram of an Oscilloscope

From the simulation results, the filter simulation shows different waveforms under different input interfaces. In the current mode, the filter circuit is more sensitive and more reasonable for the experiment. Therefore, the current mode filtering current is more conducive to the detection of human blood alcohol concentration, which can better meet the performance requirements.

4.3 Simulation Analysis of Infrared Amplification Circuit

The infrared amplifier circuit simulation test is shown in Figure 14. Because the pulse wave's energy is primarily concentrated in the heart's frequency fluctuation point near 1 Hz, a current signal with a frequency of 1 Hz and an amplitude of 5 uA is input at the input end. Among them, the oscilloscope XSC1 shows the preamplifier circuit's input waveform and output waveform. As can be seen from Figure 14, compared with the input signal, the output signal is disproportionately amplified. This design achieves the goal of converting the weak current signal into a voltage signal and then amplifying it.

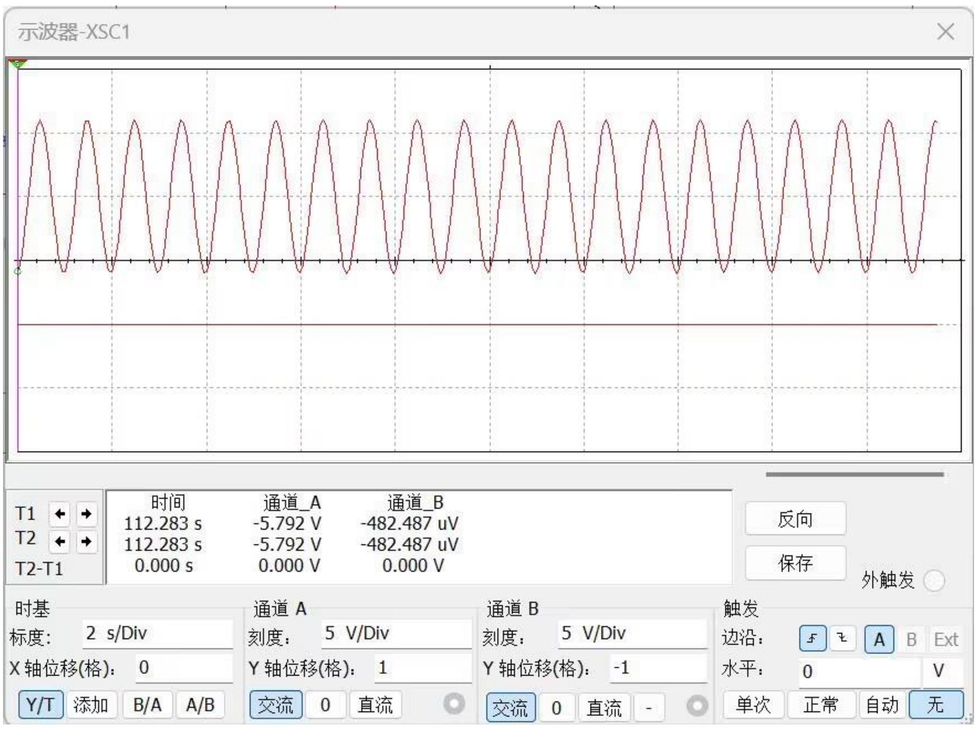

Figure 14. Simulation Diagram of Oscilloscope XSC1

5. Epilogue

The correcting Beer-Lambert law is used to detect alcohol by its volume in the body and reduce the interference of other signals. After investigating the infrared alcohol detection circuit, the infrared acquisition circuit, infrared electronic filters circuit, and infrared amplifier circuit are built.

The infrared transmitting circuit uses an impulse excitation technique, and the infrared receiving circuit sets the receiving reverse bias. The infrared electronic filters intend to use a high resistance, low capacitance, second-order high-pass low-pass filter, which is composed of a voltage filter circuit and a current filter circuit. The infrared amplifier circuit employs a symmetrical compensation circuit. The simulation results meet the performance requirements.

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