Final Project: Optical Theremin

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Abstract

a) A title page with your name, your partners name, the date, and a short abstract (less than 100 words) summarizing your circuit and the results of any measurements.

We build a optical theremin Applying our knowledge about op-amps, transistors, diodes and knowledge from the previous labs, we designed and built an optical theroemin consisting of bandpass filter, full wave rectifier, voltage controlled oscillator, and relaxation oscillator module. many changes and —- as we built

1. Abstract

Applying our knowledge about op-amps, transistors, diodes and knowledge from the previous labs, we designed and built an optical theremin that changes the frequency and amplitude of the sound output based on the amount of light incident on the device. The circuit consists of bandpass filter, full wave rectifier, voltage-controlled oscillator, and relaxation oscillator module that are connected in series to perform the modulation. In this report, we describe the reasoning behind the various circuit modifications that we implemented and demonstrate how they improved the performance of the modulation control and the audio quality of the theremin.

2. Introduction

b) A one-page introduction.

3. Circuit Description

c) A description of your circuit:

3.1. Functional Description

i) Start with a functional description: a block diagram listing all the major operations in your circuit. ii) A readable circuit diagram.

3.2. Component Description

3.2.1. Bandpass filters

Initially, the filters was designed to pass through signals of frequencies between 900 and 1100 Hz. Using a 1μF capacitor, we computed the resistance values as:

$$f = \frac{1}{2\pi RC}$$
$$R = \frac{1}{2\pi(1.0 \times 10^{-6}F)f}$$

Since we found that the signal that passes through was too low, we redesigned a the filters to increase the range to 500~2000 Hz.

3.2.2. Inverting Amplifer

We also build two inverting amplifier We built an inverting amplifier as shown in Fig.**??**. First tried using R1= 47kΩ resistor as we did in the circuit in Lab 6, but we found that since to the variable resistance shown in Table **??** , the V_{out} only rails as we cover up the photoresistor. In order to map out a more detectable change, we increase the gain by decreasing the value of R1 to 1kΩ, since

$$V_{out} = -R_2 I = \frac{-R_2 V_{in}}{R_1} \tag{1}$$

where the gain is -R2/R1. When testing, we use two 1μF capacitor to decouple the power supply and minimize the parasitic oscillation.

3.2.3. Full Wave Rectifier

We build a Graetz bridge full wave rectifier using four 1N4007 diodes. Since the diode only passes through current in one direction, the arrangements of diodes shown in Fig.1, passes through the positive current and flips the negative signal up.

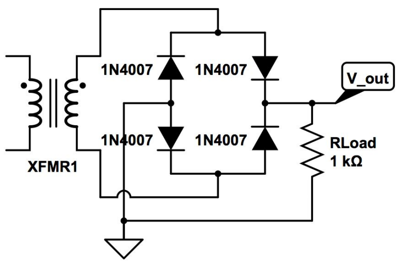

Figure 1: Full Wave Rectifier Circuit.

The performance of the full wave rectifier is liekley the source of sound quality degradtion in our circuit because —–. Therefore, we used an active full wave rectifier to —-.

3.2.4. Voltage Controlled Oscillator

The Voltage Controller

3.2.5. JFET Modulator

Multiplier

3.2.6. Relaxation Oscillator

We use a relaxation oscillator to generate the “On-Off signal” for the LED flashing at 1kHz. The output frequency of the circuit

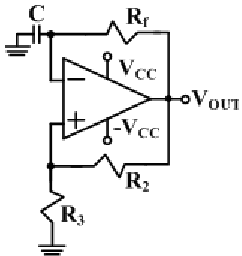

Figure 2: Relaxation Oscillator Schematic.

is described by :

$$f = \frac{1}{2R_f C ln\frac{1+\beta}{1-\beta}} \tag{2}$$

where β is the ratio of the resistances $\frac{R_3}{R_3+R_2}$.

Initially, we built the circuit using the combination of $R_f = 100\Omega$ and $R_3 = 100\Omega$, C=1000μF and $R_2 = 3M\Omega$. However, we found that the output frequency deviate largely from our computed frequency of 10Hz (initially designed for the photoresistor circuit). We suspect that this is due to our use of a the large 1000μF electrolytic capacitor. After trying different combinations of resistances and capacitance, we found that the circuit yields optimal performance when R_2 and R_3 are approximately equal.

This new approach simplifies the calculation so that no matter what R_2 and R_3 is chosen to be the β is still 0.5. In our final design, we chose R_2 and R_3 to be 1kΩ, with C=10μF. The computed R_f served as a convenient baseline for us to then fine-tuned the resistance so that we achieve the 1kHz signal as measured by the oscilloscope shown in 3.

Although the output voltage is suppose to switch from positive to negative $V_c c$, we

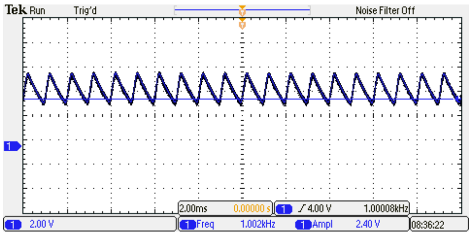

Figure 3: 1kHz signal generated by the relaxation oscillator.

found that the output voltage was only around 1.6V, which was below the turn on voltage of the LED. We tried using the signal as a switch with an additional 5V with a resistor to "boost up" the signal to the LED, but had trouble figuring out how to arrange the activation signal with respect to the output LED and the rest of the circuit the for this purpose. By building an amplifier connecting to the output of the relaxation oscillator, we were able to attain a output voltage of around 3V while retaining the 1kHz signal.

When soldered together, this circuit served as a convenient module that can be easily moved to change the light incident on the detector, without the bulkiness of the waveform generator.

3.3. Simulation

d) Multisim circuits, if any.

e) If appropriate, a description of the theory behind your experiment.

4. Experiment and Results

f) A description of the experiments you performed with your circuit and the measurements you made, including your experimental methods, your raw data (in tabular or graphical form), and data and error analysis. Since some of our component did not come with spec sheets We conducted initial measurements to get a sense of what the

4.1. Calibrating Phototransistors

Initially, we used a photoresistor to detect our optical signal. Even though the photoresistor gave a sufficiently large range (267Ω to 4.353kΩ) of continuous signal change, there was significant lag between the circuit signal response shown on the oscilloscope relative to when we actuated the change.

We improved the performance of the detection module by using the OP802SL NPN phototransistor, as this resolves the lagging issue seen with the phototransistors. We had a lot of difficulty in testing whether the phototransistor gave a response, so we began by first building a test circuit where we attached a 12V power supply to the collector and the — giving a response. We chose to use a red LED because its wavelength is closer to the peak on the spectral response graph as detailed in the OP802SL spec sheet.Since the light incident on the detector is what changes the signal through the base, the base should be connected to nothing, as denoted in most schematics on phototransistor spec sheets[1]

continuous instantaneous circuit response, Approx linear response as expected since inside operating region, use for calibrating theremin.

5. Conclusion

g) Conclusions.

Acknowledgments

The author would like to acknowledge support from the GSI and Professor Holzapfel in this lab in addressing our questions about our circuits and ways to improve the performance. I would also like to thank my partner, Leah Tom, for helpful discussion and

[1] In fact most manufacturer sells two-pronged, phototransistors without the base.

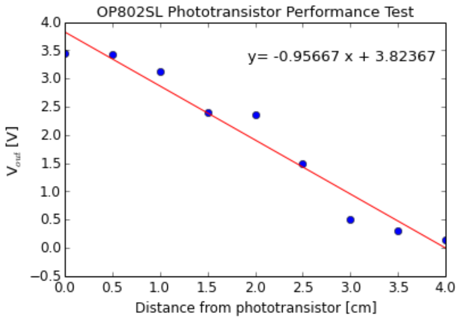

Figure 4: Quantify the performance of the phototransistor by varying its separation distance from a red (660nm), 1kHz, 4V$_{Vpp}$ LED source.

collaboration that helped this work. We also appreciate debugging assistance from ——

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