Microelectronics Project:
Multi-Function Clapper Circuit

ECE 314: Microelectronic Circuits
Justin Ross
Shawn Woleslagle

Abstract:

The Clapper is an analog circuit with the function of a sound activated switch. The intention of this project was to redesign this product and implement an improvement or extra function to the circuit. We feel that we successfully adapted the circuit in parts with new implementation and improved upon some of it's design.

Introduction and Goals:

The goal of this project was to improve upon the clapper circuit by having a second switch activate off of a snap sound and to also implement a distance factor to have the device only activate within a specific radius. For this the circuit would be split into two parts, one for the clap and one for a snap. Our thought was to design this entirely as an analog circuit as it fit more with this class's study and that perhaps an improvement in the future would be to implement the circuit with a microcontroller.

Experimental Design Principles and Calculations:

Circuit Diagram:

The design of this project was based off of Patrick Mitchell's circuit that was found on Instructables.com. He built an analog clapper circuit that checks the amplitude of the input soundwave and turns on an LED if the amplitude passes a certain threshold. Using that principle, it was decided that another function can be added by checking for a different amplitude. Since the amplitude of sound decreases exponentially over the radius in which it travels, the second functionality can be activated at a different distance. But, a single microphone can receive inputs from a single direction, so the part of the circuit before the OR gates was replicated two more times so the effective area was at least 180 degrees.

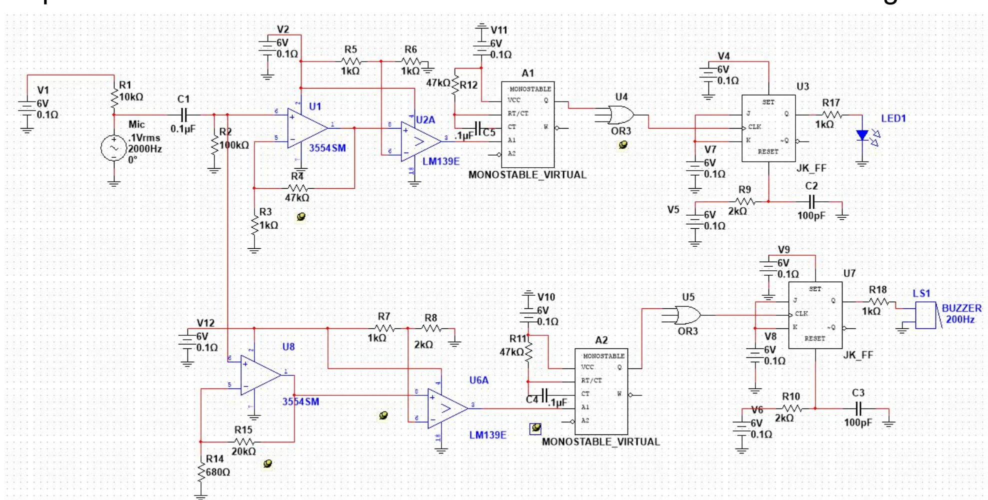

Figure 1: The Circuit diagram that was built

Microphone:

The first and most obvious component that was used was the AUM-5047L-3-LW100-R Unidirectional Condenser Microphone. This microphone was chosen because of the fact that it's unidirectional in nature. So, we could change the effective region of the final circuit by changing the orientation of the three microphones. The microphone circuit that was built has a the output hooked to a capacitor. The capacitor acts as an AC coupling, which allows the signal through.

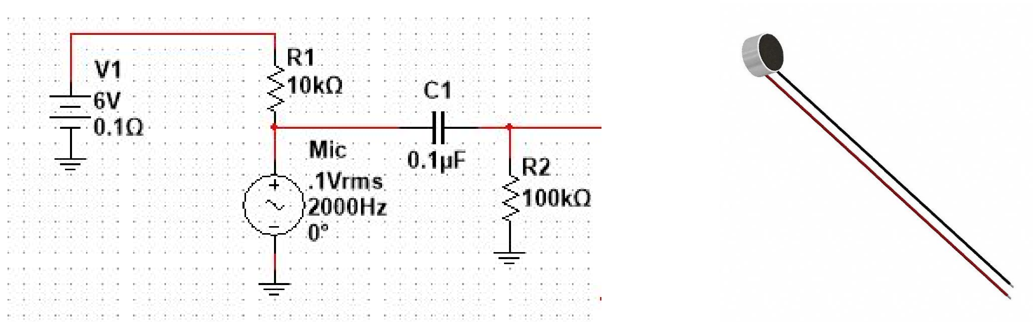

Figure 2: (left) The Circuit diagram the allows the microphone to function.
(right) an image of the microphone that was used.

<u>Amplifiers and Comparators:</u>

Since the microphone only produces a few millivolts, an amplifier is crucial to being able to process the signal. To achieve this, the LM324N Quad input Op-Amp was used. The first op amp that is used in the circuit is set in the non-inverting configuration. The actual amplification is entirely dependent on the resistor that's attached to the output. The amplification can be calculated using *Equation 1* where R_f is the resistor connected to the output of the amplifier, and R_A is the resistor connected to ground. Each distance has a slightly different amplification. The part of the circuit dedicated to further distance a 47 times amplification whereas the part dedicated to a closer distance has a 29.41 times amplification.

Equation 1:

$$A = 1 + \frac{R_f}{R_A}$$

After the signal was amplified, it's passed through another Op-Amp in a comparator configuration. The negative pin of the comparator is connected to a voltage divider that determines the threshold voltage that the amplified signal from the microphone has to exceed. The closer distance has to exceed a value of 4 Volts, and the further distance has to exceed a value of 3 Volts. This means that both outputs will activate when the logic for the closer distance is activated.

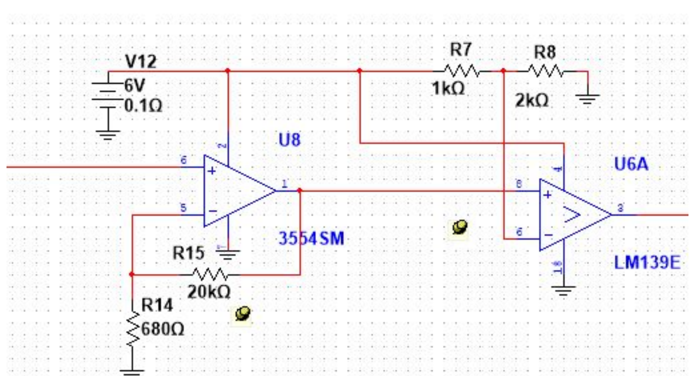

Figure 3: The amplifier and comparator used in the initial signal processing steps.

Monostable Multivibrator:

Due to the amount of pressure waves caused by a clap, the output of the comparator will oscillate seemingly randomly. To control the output, the 74LS123 Monostable Multivibrator was implemented. A Monostable Multivibrator allows a multitude of square waves as input, and produces one single square wave as an output. The time between waves can be adjusted by using *Equation 2*. The time is entirely dependent on the resistor and capacitor values that are attached to the integrated circuit. The maximum time between waves that was used in the circuit was 1.55 milliseconds.

Equation 2:

$$delay \;=\; 0.33 * R * C$$

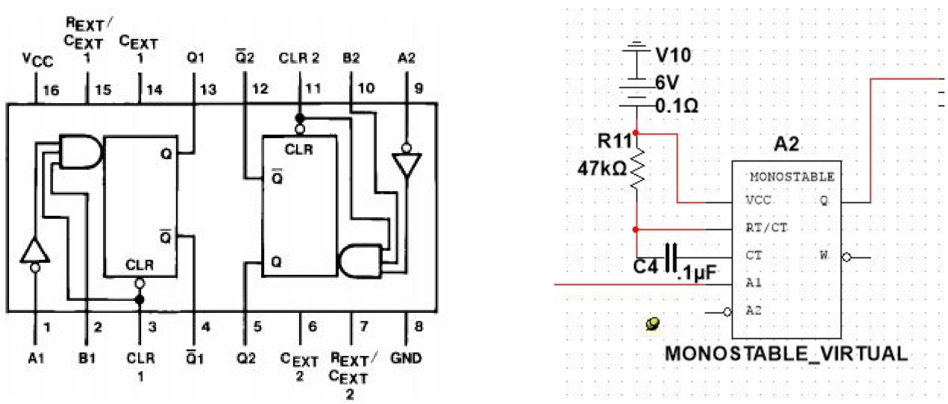

Figure 4: (left) The internal logic of the Monostable Multivibrator.
(right) The multivibrator as seen in the clapper circuit diagram.

Three Input OR Gate:

The CD4075 Three Input OR Gate was the key in tying all three of circuits together. The outputs from the three monostable multivibrators will become inputs for the OR gate. The thinking is that if one microphone picks up a clap, the other two do not. Each distance gets it's own OR gate.

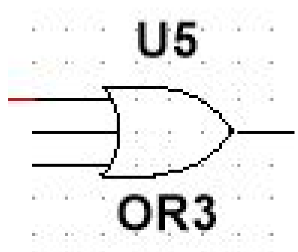

Figure 5: The three input OR gate from the circuit diagram.

JK Flip-Flop:

The final component before the output is the 74LS109 JK Flip-Flop. This JK flip-flop is set up in the toggle orientation. It was implemented in order to more easily see if the clapper is working. If a clap is received, the output will go high and stay high until another clap is detected. There is a resistor and a capacitor tied to the RESET pin of the JK Flip-Flop. This was done to ensure that the output starts out low. The capacitor takes some time to charge up, so the RESET pin stays low.

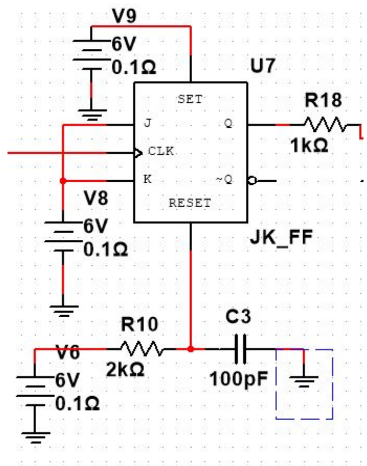

Figure 6: The JK Flip-flop from the circuit diagram.

Output Devices:

To determine if the circuit was functioning properly, two output devices were used. The output for the closer circuit was the buzzer, which was in series with a 1 kΩ resistor. The output for the further circuit was the red LED, which was also in series with a 1 kΩ resistor. The resistors serve as a basic protection for the output devices. The red LED was selected because it had the smallest threshold voltage to surpass to become active.

As stated earlier, when the close circuit was activated, both outputs would become active. And when the further circuit was activated only the red LED toggled. But, since there's no logic that checks amplitude in ranges, whenever the closer distance circuit is activated, both outputs will be toggled.

Discussion:

Changes from the Proposal:

Due to some unforeseen challenges, the project needed to be modified from the original project proposal. The original proposal was largely the same, but instead of the second function being toggled by a clap from further away, it would have been toggled by a snap. We changed the functionality for one main reason, the circuit did not reliably detect snaps. Snaps are generally much quieter that claps and they more singular in their waveform. So, with a snap, if the circuit misses the one change that snapping creates, then that test failed. This would happen about half of the time. So, we changed the functionality to clapping at different distances because the waveforms that claps create are much more forgiving in the circuit.

Challenges:

When the circuit was initially prototyped, voltage source was set to 5 Volts. But, in that configuration, the LED would not turn on at all. This has to do with the voltage drop across the three input OR gate, which the design that we were referencing did not use. The output of the OR gate was reading around 1 Volt, which is too small to allow an LED to turn on. To alleviate this issue, the voltage source was set to 6 Volts.

The next big challenge that was faced was fine tuning the resistances on the amplifiers. As previously discussed, the resistance values really determine how sensitive the microphone is to sounds. If the resistance is is higher, the sensitivity is higher. So, determining what values to use was a process of trial and error. This was the most time consuming part of the entire project.

The last set of problems that were faced have to with the nature of sound. Sound travels very fast and can bounce off of surfaces, which means that two or all three mics can receive the same signal at very similar times. So the output would flicker seemingly randomly. This wasn't something that was fixed, but we found how to avoid the issues that came with it. It was important that the three microphones were facing in distinct directions. If there was any overlap, the output would not be reliable. For the best results, the claps also need to be clear and distinct.

<u>Conclusions:</u>

The circuit we implemented in the end didn't fully achieve our initial goal of a second function from a snap. We ultimately determined the source of errors and adapted the circuit to be multifunctional with distance of the clap, one for close and one for far. This project was an excellent way to work on analog circuits and apply the knowledge from this class and the others we have taken prior. We gained a lot of information from this project in how the parts used work and ways to improve upon our design.

References:

Mitchell, Patrick, and EngineeringShock. “How to Make a CLAP ON - CLAP OFF Circuit From Scratch - No Software Required.” *Instructables.com*, Instructables, 30 Oct. 2017, www.instructables.com/id/How-to-make-a-CLAP-ON-CLAP-OFF-circuit-from-scra/.

Fairchild Semiconductors. “DM74LS123 Dual Retriggerable One-Shot with Clear and Complementary Outputs.” DM74LS123 Dual Retriggerable One-Shot with Clear and Complementary Outputs, Jameco, Apr. 2000, www.jameco.com/Jameco/Products/ProdDS/46480.pdf.

Texas Instruments. “ TEXAS INSTRUMENTS (LM324NE4) QUAD GENERAL PURPOSE OP-AMP.” *Quadruple Operational Amplifiers* , Jameco, Jan. 2005, www.jameco.com/Jameco/Products/ProdDS/826671.pdf.

Fairchild Semiconductors. “DM74LS109A Dual Positive-Edge-Triggered J-K Flip-Flop with Preset, Clear, and Complementary Outputs.” *DM74LS109A Dual Positive-Edge-Triggered J-K Flip-Flop with Preset, Clear, and Complementary Outputs*, Jameco, Mar. 2000, www.jameco.com/Jameco/Products/ProdDS/46421.pdf.

National Semiconductors. “Triple 3-Input OR gate.”*MAJOR BRANDS (CD4075) IC,CD4075,DIP-14*, Jameco, www.jameco.com/Jameco/Products/ProdDS/676094-DS01.pdf.

DB Products Unlimited. “Piezo Buzzer.”*32S4120LFPN*, Jameco, Dec. 2004, www.jameco.com/Jameco/Products/ProdDS/138713.pdf.

PUI Audio. “ AUM-5047L-3-LW100-R Drawing.” *AUM-5047L-3-LW100-R*, PUI Audio, July 2015, www.puiaudio.com/pdf/AUM-5047L-3-LW100-R.pdf.