

# Operation Speaker Circuit



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### Material List (For Testing on Breadboard)

- 9 Volt Battery
- Battery Snap
- 555 Timer
- 10  $\mu$ F Electrolytic Capacitor
- Breadboard
- 10  $\Omega$  Resistor [Brown, Black, Black, Gold] (2x)
- 220  $\Omega$  Resistor [Red, Red, Brown, Gold] (2x)
- 47  $\Omega$  Resistor [Yellow, Violet, Black, Gold]
- 270  $\Omega$  Resistor [Red, Violet, Brown, Gold]
- 100  $\Omega$  Resistor [Brown, Black, Brown, Gold]
- 200  $\Omega$  Resistor [Red, Black, Brown, Gold]
- 1K  $\Omega$  Resistor [Brown, Black, Red, Gold]
- 150  $\Omega$  Resistor [Brown, Green, Brown, Gold]
- Wires of varying lengths
- Speaker
- Buttons
- Multimeter
- Wire Stripers
- CircuitMaker software
- Super PCB software

### Material List (For final board and prototype)

- 9 Volt Battery
- Battery Snap
- 555 Timer
- Dip 8 Socket
- 10  $\mu$ F Electrolytic Capacitor
- 10  $\Omega$  Resistor [Brown, Black, Black, Gold] (2x)
- 220  $\Omega$  Resistor [Red, Red, Brown, Gold] (2x)
- 47  $\Omega$  Resistor [Yellow, Violet, Black, Gold]
- 270  $\Omega$  Resistor [Red, Violet, Brown, Gold]
- 100  $\Omega$  Resistor [Brown, Black, Brown, Gold]
- 200  $\Omega$  Resistor [Red, Black, Brown, Gold]
- 1K  $\Omega$  Resistor [Brown, Black, Red, Gold]
- 150  $\Omega$  Resistor [Brown, Green, Brown, Gold]
- Wires of varying lengths
- Speaker
- Positive pre-sensitized copper clad boards
- Ferrous Chloride, Tetrahydrate or also known as Iron (II) chloride ( $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$ )
  - Ferric Chloride, Hexahydrate can also be used ( $\text{Fe}_2\text{Cl}_3 \cdot 4\text{H}_2\text{O}$ )
- Ilfosol 3 film developer

- Any type of equipment that can safely cut through the positively pre-sensitized copper clad boards
- Acetate
- Printer
- Timer
- LV 204 UV exposure Unit
- Tongs
- RC Hagen A803 Elite 803 Air Pump - Single Outlet
- Soldering Iron (along with your preferred stands/holders, etc)
- Tip Tinner
- Solder
- Drill Press
- Exacto Knife
- Foamboard
- Paint
- Aluminum Foil
- Tape
- Steel wool
- Gloves
- Lab Coats
- Multimeter
- Wire Strippers

## Warnings

Some chemicals that are used in this project is dangerous, the end of this report will contain all the Safety Data Sheets (SDS) for all dangerous chemicals that are dealt with in this project. Please read all the information in the last few pages before starting this project

## Nodes list

- Node 1: - Battery to Pin 1
- Node 2: - Battery to – Capacitor
- Node 3: - Capacitor to Pin 1
- Node 4: + Capacitor to Pin 2
- Node 5: Pin 2 to Pin 6
- Node 6: Pin 3 to – Resistor 11
- Node 7: + Resistor 11 to – Speaker
- Node 8: + Speaker to Pin 4
- Node 9: + Speaker to + Resistor 10
- Node 10: + Speaker to Pin 8
- Node 11: + Speaker to + Battery
- Node 12: + Resistor 10 to Pin 4
- Node 13: + Resistor 10 to Pin 8
- Node 14: + Resistor to + Battery
- Node 15: Pin 4 to Pin 8
- Node 16: Pin 4 to + Battery
- Node 17: Pin 8 to + Battery
- Node 18: Pin 6 to – Resistor 1
- Node 19: Pin 6 to – Resistor 2
- Node 20: Pin 6 to – Resistor 3
- Node 21: Pin 6 to – Resistor 4
- Node 22: Pin 6 to – Resistor 5
- Node 23: Pin 6 to – Resistor 6
- Node 24: Pin 6 to – Resistor 7
- Node 25: Pin 6 to – Resistor 8
- Node 26: + Resistor 1 to - Switch 1

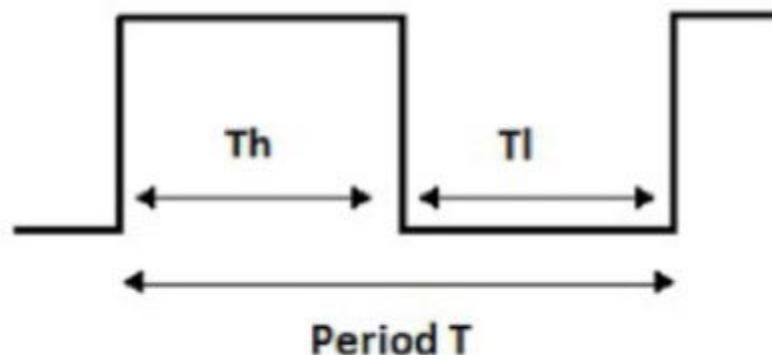
Node 27: + Resistor 2 to - Switch 2  
Node 28: + Resistor 3 to - Switch 3  
Node 29: + Resistor 4 to - Switch 4  
Node 30: + Resistor 5 to - Switch 5  
Node 31: + Resistor 6 to - Switch 6  
Node 32: + Resistor 7 to - Switch 7  
Node 33: + Resistor 8 to - Switch 8  
Node 34: + Switch 1 to – Resistor 9  
Node 35: + Switch 2 to – Resistor 9  
Node 36: + Switch 3 to – Resistor 9  
Node 37: + Switch 4 to – Resistor 9  
Node 38: + Switch 5 to – Resistor 9  
Node 39: + Switch 6 to – Resistor 9  
Node 40: + Switch 7 to – Resistor 9  
Node 41: + Switch 8 to – Resistor 9  
Node 42: + Resistor 9 to Pin 7  
Node 42: + Resistor 9 to - Resistor 10  
Node 43: - Resistor 10 to Pin 7

## The Goal of the Speaker Circuit Project

The goal of the Speaker Circuit is to teach me more about the process of planning, testing, evaluating an electrical circuit and the process of creating a circuit board. More specifically, this process includes utilizing Circuit Maker, Super PCB, testing the circuit on a breadboard and going through the steps of changing “Positive Presensitized Copper Clad Boards” into circuit boards. Unlike the “555 Timer Flasher Circuit”, this project will not just be theoretical, the SuperPCB design will actually put into use. I will use this complete circuit to create my version of the board game “Operation”.

## What is a 555 Timer?

The 555 Timer is a very versatile integrated circuit that can be used anywhere from a “Light Up Flashing New Year’s Hats” to “Automatic Aerosol Air Dispensers for Air Fresheners.” It can be used as a pulse generator or an oscillator by using its astable and monostable modes. These modes and the duration of the pulses/oscillations can be varied using combinations of different resistors and capacitors. Basically, it is a versatile timer that is used in electrical circuits.



## Problems with Researching the Applications of the 555 Timer Integrated Circuit

Honestly, it was quite hard to find specific products where 555 timers are found. Most websites just say something along the lines of, “The 555 Timer’s ease of use, simplicity, and low cost allows it to be used in thousands of applications”. If any examples were listed, it usually cites a DIY craft project. The reason for this is probably due to how prevalent and widely used the 555 timer is. It’s like searching up specific uses for a Logic Gate. Logic Gates and 555 Timer Circuits are used so much in the industry that people don’t bother to write about it. The only people that seem to write about 555 timers are the tutorial and DIY communities.

## The Uses of Each Pin in the 555 Timer

### Pin 1 (Ground)

- Connected to circuit ground

### Pin 2 (Trigger)

- A low voltage (less than  $\frac{1}{3}$  supply Voltage) applied to trigger momentarily will cause the output to go high. The output will remain high until high voltage applied to threshold pin

### Pin 3 (Output)

- Low state = close to 0 V
- High state = 1.7 V lower than the supply voltage

### Pin 4 (Reset)

- A low voltage of less than 0.7V will cause the output to become low

### Pin 5 (Control)

- The control threshold voltage (default it  $\frac{2}{3}$  supply voltage)
- You can vary threshold from 45% to 90% of supply Voltage
- Allows you to vary the length of the output pulse in monostable mode
- Allows you to vary the output frequency in astable mode

### Pin 6 (Threshold)

- the voltage across the timing capacitor is monitored through the Threshold input.
- When the voltage at this input rises above the threshold value the output will go from high to low.

### Pin 7 (Discharge)

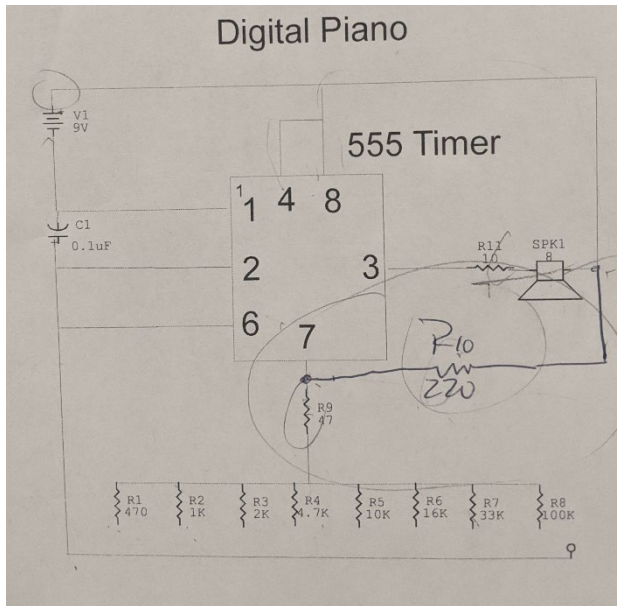
- The extra voltage will come out of here

### Pin 8 (Vcc)

- Power supply

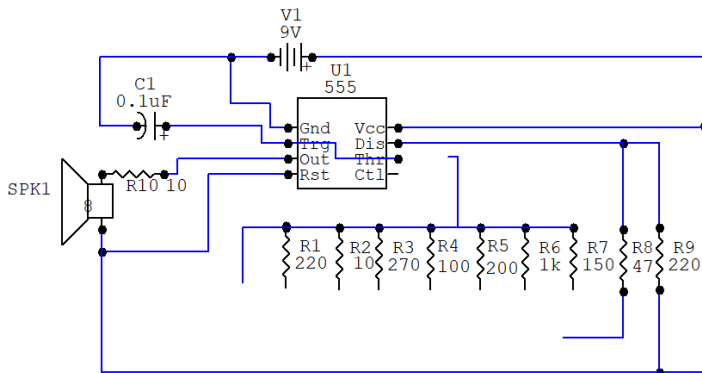
## The Use of Circuit Maker to Plan the Speaker Circuit

Circuit Maker is a great program that can be used to make circuit diagrams and plan the design of your circuit. The creation of the Circuit in Circuit Maker is honestly the hardest part of this entire process. The problem is that you need to recreate this Circuit without overlapping lines. If you copy this exact diagram in Circuit Maker, the pins won't line up. This means that I need to modify the positioning of some wires in order to get it to work.



The Reference I Used to Build my Circuit Design (left)

In order to recreate this Circuit in Circuit Maker, some modifications had to be made. For example, in order to connect Pin 6 to Pin 2, a trace must be added beneath the Timer. It's just figuring out these tiny things that are a little difficult. However, unlike last time (when I created my "555 Timer Flasher Circuit" in CircuitMaker), I had some experience with Circuit Maker. Due to the practice with Circuit Maker from last time, "the circuit maker process" this time was easy, I had no problem at all making up the circuit for the speaker.



My CircuitMaker Design (Left)

## Strategy for Circuit Maker

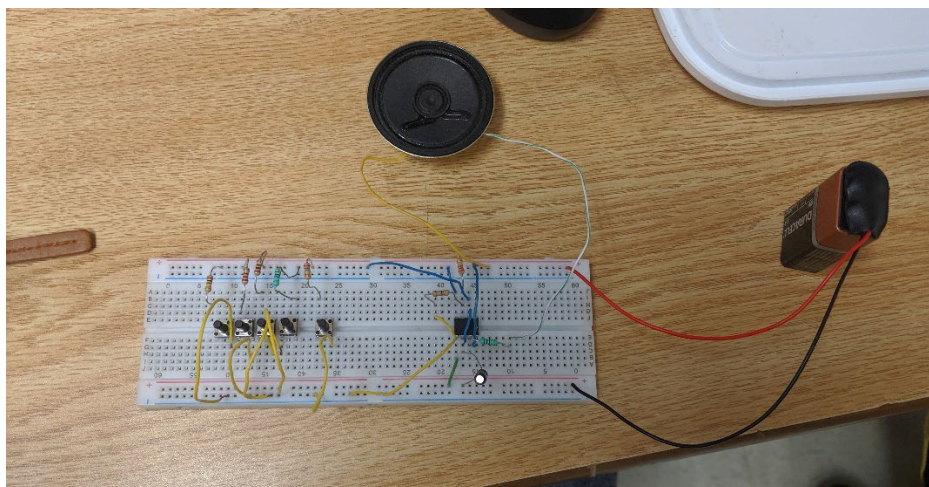
This time when using Circuit Maker, I developed a strategy to more easily create the speaker in circuit maker. Last time, I had a lot of problems finding alternate positions for my parts that allow for the circuit to work. My strategy for making sure my “modifications” to the circuit (that was given by Ms.McEwen) worked is by looking to the nodes list. I made sure that the nodes in the given circuit were the exact same as the one I made in Circuit maker. By doing this several times throughout the creation of the circuit maker design, I can fully confirm that my design is exactly the same as the diagram given to us.

## The Reducing of The Overall Size of the Speaker Circuit

Now that I have figured out how the circuit will look like; I can't simply leave it like that. The circuit is no compact at all! I needed to reduce the overall footprint of the circuitry. Why do I need to reduce the footprint? The reason for doing this is to save on material. In the real world, cost-saving is key. Why waste material and practically give out money when you can just have a more efficient design? It is good practice learning how to reduce the size of a circuit. Unlike last time with the “555 Timer Flasher Circuit”, I did not make my circuit maker too small. Last time, my circuit maker design was so small that there were many overlapping words making it very hard to read unless you are experienced.

## Creating the Circuit on a Breadboard

Before fully finalizing my design for the Speaker Circuit, I need to confirm that my design actually works! My design worked perfectly the first try, it was pretty simple. The only problem was that the speaker makes a horrible sound when connected with the resistor I had. It would make this super annoying high pitched sound. Now I just needed to test out different resistors to find a pleasant sound that I can use in my project.

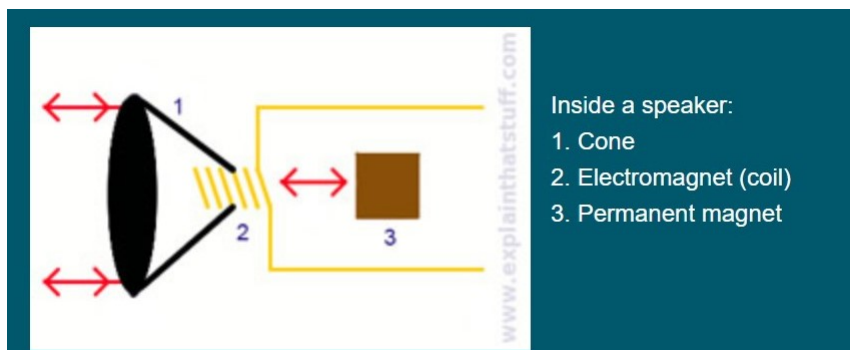


## The Science behind the speaker

First, let us talk about how speakers work in the first place. To be frank, my explanation will be very simplified. I just wanted a basic idea of how the speaker worked. Inside the speaker, there are 3 main parts: a cone, electromagnet (coil) and a permanent magnet. A speaker creates sound by vibrating a coil using electromagnets and creating a frequency that we perceive as sound. Actually, I think that physics.org's explanation puts it best:

“Inside a speaker, an electromagnet is placed in front of a permanent magnet. The permanent magnet is fixed firmly into position whereas the electromagnet is mobile. As pulses of electricity pass through the coil of the electromagnet, the direction of its magnetic field is rapidly changed. This means that it is, in turn, attracted to and repelled from the permanent magnet, vibrating back and forth.”

The timing of the pulses changes the frequency of the vibrations and we perceive these vibrations as different pitches.

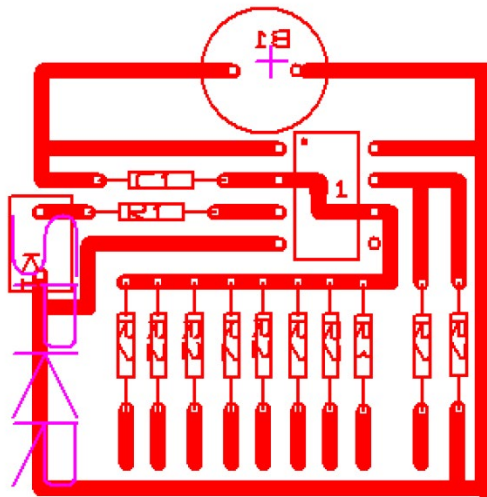


## The Relation Between Resistor Values and Pitches

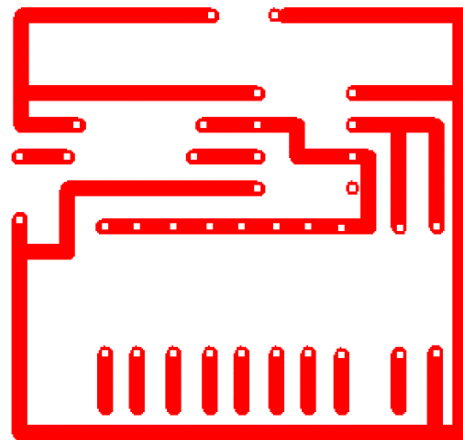
Now, what does the 555 timer and resistors take part in all of this? In the explanation above, it mentions how pulses of electricity are required to make this all work. The timing of the pulses changes the frequency of the vibrations and we perceive those different frequencies of vibrations as different pitches. The 555 timer provides these pulses using its astable mode and creating a 555 oscillator. The astable 555 oscillator charge and discharge times (or electrical pulses) are varied using resistor values and that's how we get different pitches when we change the resistor values in the 555 timer circuit.

## Super PCB

Now that I have tested my circuit design and have finished the Circuit Maker design, I have my work cut out for me. I just needed to copy my Circuit Maker design into Super PCB, and I would be ready to actually create my circuit board in real life. It was pretty simple. I already did all the heavy lifting in the previous steps. Below are my Super PCB designs.



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However, this time, I needed to think about the spacing of the parts in SuperPCB. In Theory, all the parts will fit on to the board, however, you need to think about engineering/dimensional tolerances. If I put the traces and parts too close to each other, will I actually be able to create it in real life? Will the holes created by the drill press be exact? Will I be able to solder in such close spaces? That's why my final SuperPCB design above isn't as compact as it could be. I needed to try and find a balance between how compact I want the circuit to be, and how much room for error I want to have.

## Starting the Process of Creating the PCB

To begin with, we need a way to get the SuperPCB design on to the board. We will do this using a printer, acetate, and an LV 204 UV exposure Unit. First of all, you need to cut the board to size. In this part, you can use any method you want. You just need to cut the positively pre-sensitized copper clad boards into a more manageable size. Remember to not cut it too small though, the edges of the board often become unusable because the pre-sensitized PCB accidentally reacts with UV light. Basically, you want to transfer your SuperPCB to the positive-resist PCB by reacting to specific parts of the board with UV light. You do this by printing out your SuperPCB design onto Acetate and taping it to the board. The ink on the acetate will cover the part of the board you want and expose the rest of the board to UV light. To speed up the process, you can put the board into a UV machine for 5 minutes to get the reaction to react faster. Then, you could wash off the reacted photoresist chemical using Ilfosol 3 film developer. You will be left with your circuit on the board in green and the rest will be exposed copper. Essentially, you are just masking the parts of the board you don't want Ferric/ferrous chloride tetrahydrate to react with in the next step.

### Correcting any mistakes

If the board goes through the developer and extra resist was washed off, you can just use a permanent marker to fix up the traces. The permanent marker will work as a resist against the ferrous chloride.

### Ferric/ ferrous chloride

Now that you have your masked off circuit with exposed copper, you can react to the copper in ferrous chloride. Basically, you put the circuit into a big tub of ferrous chloride to get a reaction that takes off any exposed copper. Due to your traces being covered by the resist, they won't react with the ferrous chloride, and in the end, you will get a board with copper traces of your design. Your circuit will react in the tub for about 45 minutes with you needing to flip the board halfway, preferable using tongs. There is a pump in the tub to create bubbles that will allow the reaction to happen faster. Remember to wear gloves, goggles, and lab coats during this process to protect yourself from the corrosive Ferric/ferrous chloride.

### Drilling holes and cleaning up the board.

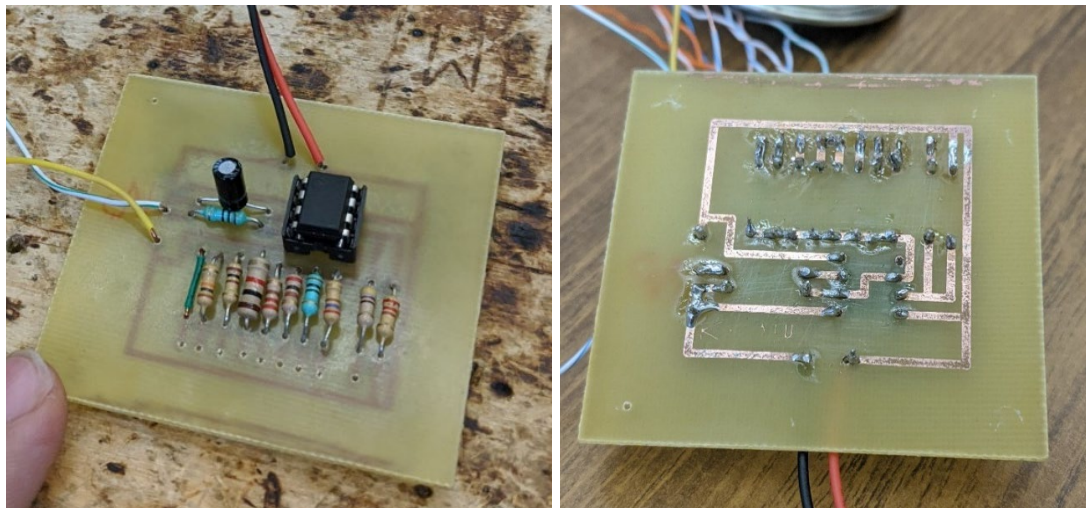
After washing off any excess ferrous chloride from the board, you can scratch off the green resist on the board with a ball of steel wool, revealing your perfect traces (if you did everything perfectly). Now you can just drill holes into the board for the resistors, capacitors, wires, etc. A drill press works perfectly for this.

## Soldering the components onto the board.

Now that you have the board ready, just do one more quick check of your circuit on the breadboard and take note of any components where positioning matters, (like the battery snap, the polar cap, etc) Now you can start soldering.

## Problems with soldering

Though I am pretty well-rehearsed with soldering from previous experiences. I had some problems soldering at school. Usually, I can solder nicely and get “Hershey’s kisses”. However, I couldn’t achieve that type of excellence at school. The soldering iron tips at school are horrible, most of them never get hot enough to melt the solder or only get hot in only specific places on the soldering iron. Using tip tinner can only help to a certain point. That’s why my soldering didn’t come out as well as I would have thought. The wires that we were working with also very thin, making them break easily. I had many instances where wires would break right where the wire meets the PCB, forcing me to go desolder the wire. I think that a thicker wire would have helped in this case or a bigger/ less crowded container where I can put the board without any pressure being put on the wires. I think that if I had some better equipment (stronger wires and better soldering irons) my circuit would look nicer. However, in the end, my circuit still worked.



My Circuit before soldering wires (Left)

My Circuit after soldering everything (Right)

## Creating the Housing

Now that my actual circuit is finished, I just need to create the housing for the circuit. In my case, I am creating the board game "Operation". I am going to get each hole to play a different note. Basically, if you fail at grabbing the piece out of the board, you will get a beep from the speaker. Each piece will have a different note that will be played if you fail. To get the holes to be conductive and to play a sound, I added aluminum foil and connected each piece of aluminum foil to a different resistor. When the tweezers touch the aluminum foil, they would complete the speaker circuit and make a sound.



The inner workings of my board game (left)

## Conclusion

In this project, not only did I learn about how the 555 Timer IC works, I learned more about the process of creating an electrical circuit. From first starting out and creating a schematic diagram in Circuit Maker to actually creating it on a breadboard. This project helped me develop crucial skills that will help me build more circuits in the future: Skills like manipulating parts and wires in Circuit Maker to get no overlapping lines, diagnosing malfunctioning circuits, creating node lists, the ability to use and understand 555 Timer ICs, using Ferric Chloride to create a PCB; the list goes on and on. All these tools will definitely help me in the future, where I may need to create electrical circuits. I think that going through all these processes (from the design process to using chemicals to creating PCB) helped me better understand and appreciate all the work that goes into creating a circuit. I will be sure to remember all the work I have done the next time I see a circuit board. This culminating project helped me advance my electrical circuitry skills and is key for my success in this Computer Engineering course, for I will need to refer back to the skills developed in this project regularly in the future.

## References

- 555 Oscillator Tutorial—The Astable Multivibrator. (2013, September 6). Retrieved November 18, 2019, from Basic Electronics Tutorials website: [https://www.electronicstutorials.ws/waveforms/555\\_oscillator.html](https://www.electronicstutorials.ws/waveforms/555_oscillator.html)
- 555 Timer and Its Applications | Relay | Electronic Circuits. (n.d.-a). Retrieved October 12, 2019, from <https://www.scribd.com/doc/110814953/555-Timer-and-Its-Applications>
- 555 Timer and Its Applications | Relay | Electronic Circuits. (n.d.-b). Retrieved October 12, 2019, from <https://www.scribd.com/doc/110814953/555-Timer-and-Its-Applications>
- 555 Timer Circuits and Applications—EasyEDA. (n.d.). Retrieved October 12, 2019, from [https://easyeda.com/Selina/555\\_Timer\\_Circuits\\_and\\_Applications-9a49f1b727cf471a8eed0d26d1ac946b](https://easyeda.com/Selina/555_Timer_Circuits_and_Applications-9a49f1b727cf471a8eed0d26d1ac946b)
- 555 Timer tutorial. (n.d.). Retrieved October 12, 2019, from <https://www.jameco.com/Jameco/workshop/TechTip/555-timer-tutorial.html>
- admin. (2017, September 15). Audio Tone generator circuit using 555, 741 IC. Retrieved November 18, 2019, from Mechatroffice website: <https://mechatroffice.com/circuits/audio-tone-generator>
- Best of 555 Timer Application Circuits Explained. (n.d.). Retrieved October 12, 2019, from <https://www.brighthubengineering.com/diy-electronics-devices/121945-simple-astable-and-monostable-multivibrator-circuits-using-ic-555-explained/>
- How do speakers work?| Explore | physics.org. (n.d.). Retrieved November 18, 2019, from <http://www.physics.org/article-questions.asp?id=54>
- T<sup>3</sup>: Etching your own circuit boards—News—SparkFun Electronics. (n.d.). Retrieved November 27, 2019, from <https://www.sparkfun.com/news/2116>

Working with Dimensional Tolerances. (2012, May 11). Retrieved November 21, 2019, from  
Machine Design website: <https://www.machinedesign.com/materials/working-dimensional-tolerances>