UNIVERSIDAD ANA G. MÉNDEZ

UAGM

Recinto de Gurabo

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Audio Amplifier: Class A

BY

Miranda Pomales, Hiram Y.	**S01424803**	
Pedraza Mendoza, Gabriel A.	**S01355613**	
Ednel J. Sepulveda Rodriguez	**S01317260**	

ELEN 330 DESIGN PROJECT

AUG – DEC / 2022

DR. DIEGO A. APONTE ROA

DEC 08, 2022

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1. LITERATURE REVIEW

In order to showcase our low-cost "Class A Audio Power Amplifier," we will be using the principles and techniques of circuits and electronics learned in our separate classes, ELEN 301 and ELEN 330. Due to their high voltage gain, this style of amplifier is the most common. The power amplifier's primary job is to deliver power, which is the result of the load's voltage and current. A power amplifier is essentially the same as a voltage amplifier with the exception that the load resistance linked to the output is much lower. The Class A amplifier, which employs a single switching transistor in the conventional common emitter circuit design, is the most basic type of power amplifier. The transistor is always biased ON so that it conducts for one complete cycle of the input signal waveform, producing the least distortion and the maximum amplitude of the output signal. With this in mind, our Class A amplifier will amplify the sound coming from the electronics connected to the aux cable.

2. INTRODUCTION

2.1 Problem Statement

For this final project we are going to be presenting an audio power amplifier. In this project we are trying to make a speaker using a simple and low cost power amplifier (class A amplifier). This type of amplifiers are the most commonly used type, as they can have very large voltage gain. These amplifiers are designed to produce a large output voltage swing from a relatively small input signal voltage of only a few millivolts and are primarily used as small signal amplifiers as we've already seen in other entries. The main function of the power amplifier is to supply power, which is the product of the voltage and current of the load. Basically, a power amplifier is also a voltage amplifier, with the difference that the load resistance connected to the output is relatively low. The most commonly used type of power amplifier configuration is the Class A amplifier. The Class A amplifier is the simplest form of power amplifier that uses a single switching transistor in the standard common emitter circuit configuration. The transistor is always biased ON so that it conducts for one complete cycle of the input signal waveform, producing the least distortion and the maximum amplitude of the output signal. This means that the Class A amplifier configuration is the ideal mode of operation, as there can be no crossover distortion or dropout to the output waveform even during the negative half of the cycle. Class A power amplifier output stages can use a single power transistor or pairs of transistors connected together to share the high load current.

2.2 Objectives

2.2.1 General Objective

Our general objective will be applying the concepts and methods of circuits and electronics learned in our respective classes, ELEN 301 and ELEN 330. We will divide this work in four parts: Design Details, Cost analysis, Design verification, and conclusions/ future work.

2.2.2 Specific Objectives

- The first objective would be to gather information to find the best possible way to make a low cost speaker.
- Our second objective is to design the speaker or class A amplifier circuit using the gathered information.
- The third objective would be to use the gathered information and design for our low cost class A amplifier, to build or cost analysis for our project.
- The fourth and final step would be to build and analyze our class A amplifier, and see what things could be better to make it more efficient for future work.

2.3 Constraints

Building this Class A audio Amplifier we found two constraints:

- Our first constraint was caused by the time to wait for the materials, because if we wanted to change something in the process, we would have to wait for those new materials to arrive, stopping the experimentation process.
- Our second constraint was the search for a simulator that can add an audio in, since we couldn't find one, we didn't got the chance to simul

3. DESIGN DETAILS

3.1 Amplifier Design

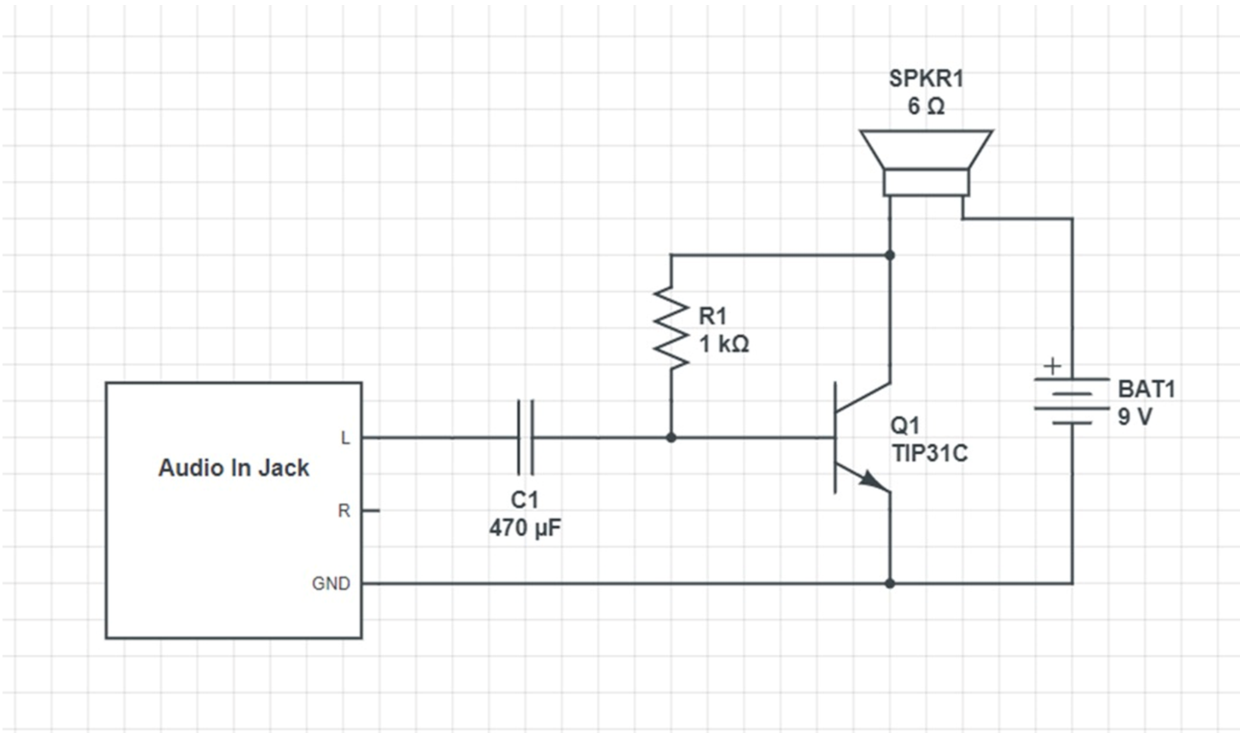

Figure 1: Circuit Design

3.1.1 Transistor

For this class A amplifier circuit, we utilized a TIP31C power transistor. The TIP31C is a NPN bipolar junction transistor, which can be used to produce a switching circuitry or an amplifier circuitry, in our case we used it for amplifying properties. This BJT transistor has three terminals, this one being the emitter, base and collector. In figure 2 we can see the schematics for the TIP31C transistor. Our amplifier needs to drive a large resistive load since we are using a loudspeaker; For this reason we need a power transistor. Now, the main function of a power amplifier, also known as a “Large signal amplifier” is to deliver the power, and we need this to properly make this audio amplifier work. For this circuit, the transistor will always be biased ON, doing so it conducts during the complete cycle of the input signal waveform, minimizing distortion and maximizing the amplitude of the

output signal. In the next tables we have the datasheet for the TIP31C Transistor. In Table 1 we can see the "Absolute maximum ratings" while in Table 2 we have the " Electrical characteristics".

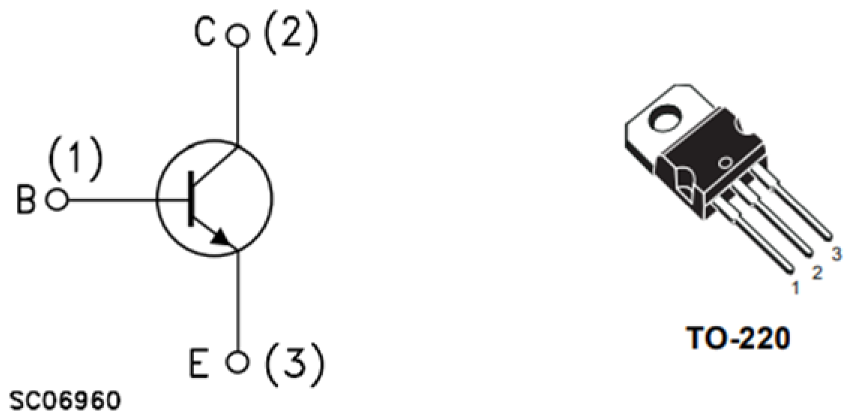

Figure 2: TIP31C Schematics. Taken from [1].

Symbol	Parameter	Value	Unit
V_{CBO}	Collector-base voltage ($I_E = 0$)	100	V
V_{CEO}	Collector-emitter voltage ($I_B = 0$)	100	V
V_{EBO}	Emitter-base voltage ($I_C = 0$)	5	V
I_C	Collector current	3	A
I_{CM}	Collector peak current	5	A
I_B	Base current	1	A
P_{TOT}	Total dissipation at $T_{case} = 25°C$ Total dissipation at $T_{amb} = 25°C$	40 2	W W
T_{stg}	Storage temperature	-65 to 150	°C
T_J	Max. operating junction temperature	150	°C

Table 1: Absolute maximum ratings. *Taken from [1].*

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I_{CEO}	Collector cut-off current ($I_B = 0$)	$V_{CE} = 60V$			0.3	mA
I_{EBO}	Emitter cut-off current ($I_C = 0$)	$V_{EB} = 5V$			1	mA
I_{CES}	Collector cut-off current ($V_{BE} = 0$)	$V_{CE} = 100V$			0.2	mA
$V_{CEO(sus)}{}^{(1)}$	Collector-emitter sustaining voltage ($I_B = 0$)	$I_C = 30mA$	100			V
$V_{CE(sat)}{}^{(1)}$	Collector-emitter saturation voltage	$I_C = 3A$ $I_B = 375mA$			1.2	V
$V_{BE(on)}{}^{(1)}$	Base-emitter voltage	$I_C = 3A$ $V_{CE} = 4V$			1.8	V
$h_{FE}{}^{(1)}$	DC current gain	$I_C = 1A$ $V_{CE} = 4V$ $I_C = 3A$ $V_{CE} = 4V$ Group R Group O Group Y	25 10 20 40		 24 44 50	

1. Pulsed duration = 300 ms, duty cycle ≥ 1.5%

Table 2: Electrical characteristics. *Taken from [1].*

3.1.2 Capacitor

The 470uf capacitor of 16 volts prevents any interference of the transistors Bias voltage, or the current on the source audio. Its other purpose is to act as a "DC Blocker", meaning that it does not let DC frequencies pass, and only AC frequencies can pass.

3.1.3 Resistor

In this circuit the 1k ohm resistor serves as the transistors base resistor, and with the help of this the transistor is driven to saturation.

3.1.4 Audio Jack

For our audio jack, we bought some cheap earphones and used some cable strippers to separate the audio jack. Using our soldering iron we connected a

connector to each end of the cable, separating L and R, while also connecting the two grounds together.

3.2 Power Supply

The power in our class A audio amplifier circuit comes from a nine Volt battery. This nine volt battery is the main and only source of energy for this circuit, and which is connected to the circuit via a battery clip connected at its head.

4. Design Verification

4.1 Testing

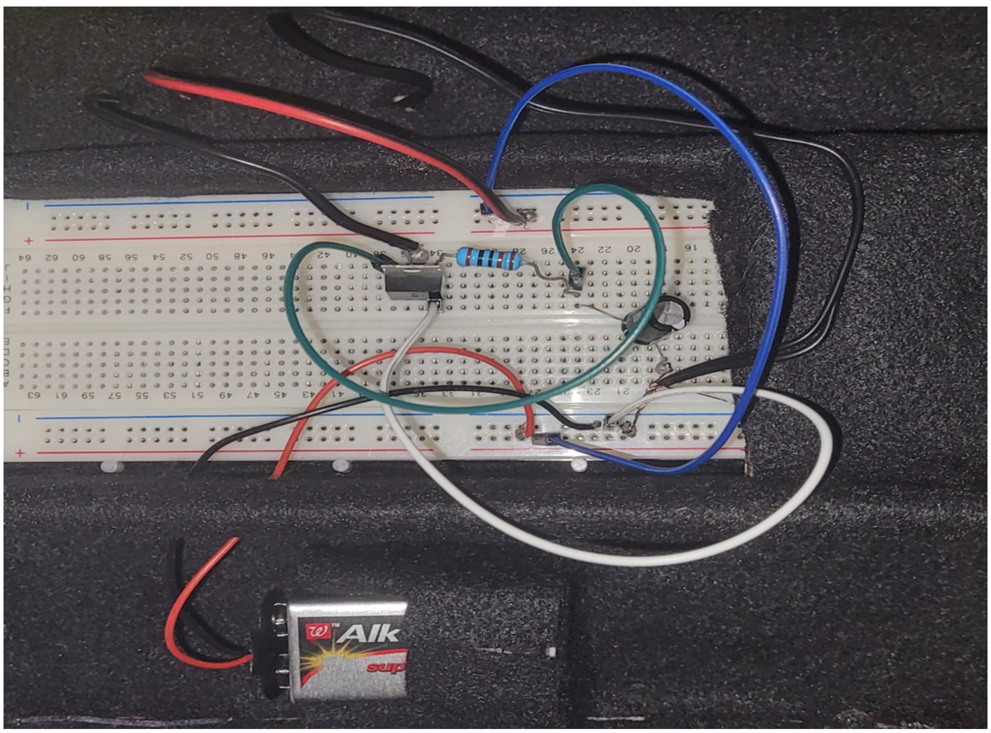

Figure 3: Circuit Breadboard

After designing our circuit, since we couldn't find any simulator that had an audio in, we decided to jump that step and built our circuit with the materials we bought. Using our breadboard we connected our TIP31C transistor. then connecting the emitter of the transistor via a jumper wire, to ground. After this, we connected our audio jack, connecting left or right to the 470uf capacitor, and the ground cable to ground. We then connected one end of the 1k ohm resistor to the capacitor. Using a jumper wire we connected the capacitor and resistor to the base of the transistor, then connected the other end of the 1k ohm resistor to the collector of the transistor. Finally we connected our 6 ohm 5W speaker, and our power supply, connecting both corresponding positive cables together, then connecting the negative of the speaker to the collector of the transistor, and the negative of the battery to ground. After our circuit was finally built we decided to test it, and it didn't work. While analyzing the circuit we decided to use a multimeter to check the battery, and it supplied a voltage of 9.24 volts. The problem was the voltage wasn't being delivered to the breadboard, and that's how we got the idea to solder on the same connectors we used for the audio jack, to the battery clip. And it finally got on.

4.2 Evaluation of Results

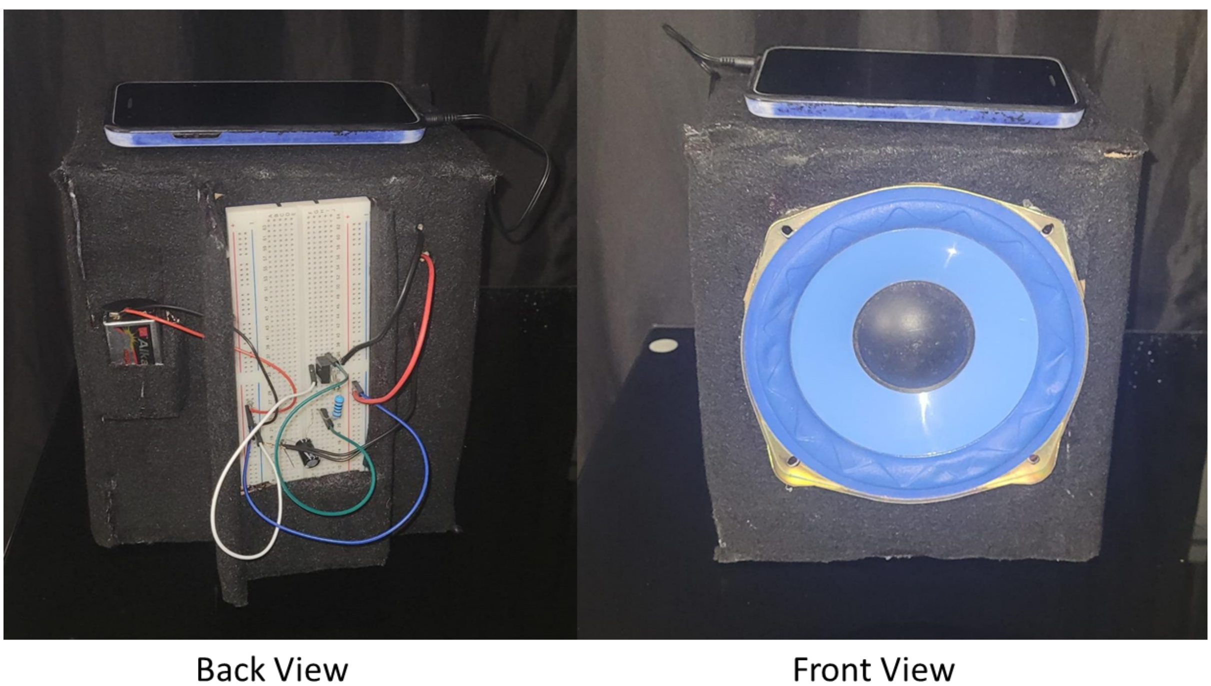

Figure 4: Circuit Front and Back view

After our first failed attempt at this circuit, and then soldering the connector to the battery clip, the circuit finally worked. In truth the circuit worked, but depending on the type of music and volume the speaker will receive a bit of noise. Secondly when we first tried it, it was inside of a box, receiving little to none of ventilation; we fixed this problem by adding a holder for both the battery and breadboard outside the box. Playing music for about 15 minutes we noticed that since it was receiving a more proper ventilation the transistor stopped overheating, while the battery was less hotter.

After building this circuit, we compared this one with the circuit shown in Figure 5, which instead of a transistor utilizes an audio amplifier called LM-386. Comparing these two we noticed that the other audio circuit had a louder sound, it wasn't received as clearly as our Class A audio amplifier circuit.

After testing our audio amplifier a couple of times, we noticed there was a difference in the audio quality, everytime it became less and less constant. While finding our problem we decided to test our battery yet again, and the battery had a voltage of 7.24 Volts. With this we saw how our amplifier circuit had a high battery drain, we then proved if this was actually the problem with the sound, by changing the battery to a new one. Improving the sound and finally completing our project.

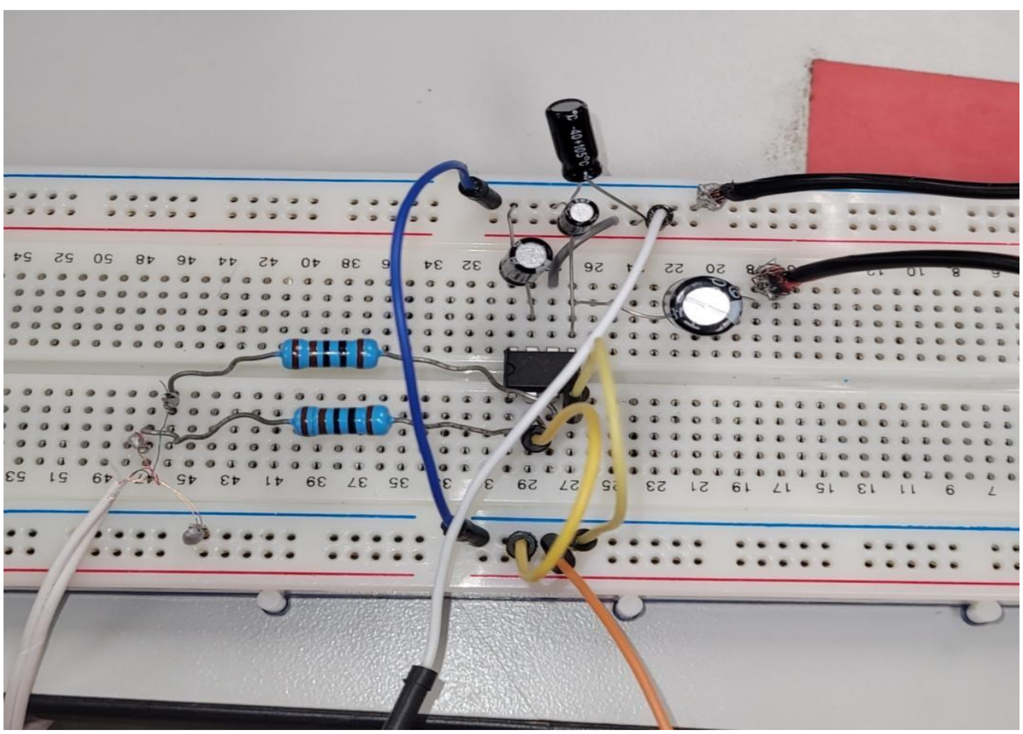

Figure 5: LM-386 Circuit

5. COST ANALYSIS

5.1 Parts

Most of the materials used to build our class A amplifier circuit were easy to find. In table 3 you can see the cost of each one of the materials utilized for our circuit. All of them can be easily found on ebay or even Amazon. There is still a problem with this one, you need to have a little patience since it could take a couple of weeks for them to arrive. Because of this, we had a time constraint, and there were some materials that we had to buy in local stores. Our 9 volt battery was bought at a nearby Walgreens, while our 9 volt battery clip was a little harder to find. After going to a couple of stores we finally found one that had a couple of them left, buying an extra one in case of an emergency.

Materials:	**Prices:**	**Quantity**
1. *TIP31C Power Transistor*	≈ $0.22	1
2. *6ohm Speaker*	$9.75	1
3. *Jumper wires*	≈ $0.18	3
4. *9V Battery clip*	$1.00	1
5. *9V Battery*	$6.12	1
6. Earphone with aux	$4.99	1
7. *470uf Capacitor (16V)*	≈ $0.07	1
8. *Breadboard*	$6.50	1
9. *Red & Black Low Voltage Cables (18AWG, 40FT)*	$11.99	1
10. *Soldering Kit*	N/A	1
11. *Felt Paper*	$0.76	5
12. *Glue Gun*	N/A	1
13. *Cardboard Box*	N/A	2
	Total Cost: ≈$41.58	

Table 3: Materials and Cost

5.2 Total cost

Our whole circuit had a combined cost of more or less $41.58. In reality it could have been even less, since we didn't use the whole roll of our "*Red & Black Low Voltage Cables*". With this in mind, if we wanted to make a new one, including materials we already have, the total cost of this class A audio amplifier would be more or less $29.59.

Buying an already built Power amplifier can have a total cost ranging from $6 for a low-end amplifier, and up to $2,200,000, for a high-end power amplifier like the Pivetta Opera Only.

6. CONCLUSIONS AND FUTURE WORK

8.1 Conclusions

Now to conclude with the electrical networks project. In a summary the given voltage of the battery (9V) has been found to be insufficient to drive the speaker load of 6 ohm. Thus, a class A amplifier using a BJT TIP31C has been designed as shown in this work. The desired collector current in our design is to enter the collector current. As this current also flows through the BJT and is also quite high, the BJT dissipates a lot of heat reducing the efficiency of the system. It is also found that the circuit has minimum distortion of the output for the complete input signal as in a Class A amplifier, the BJT is always in the saturation region or always on.

The major disadvantage of the circuit is the overall efficiency of the power amplifier. Since the circuit is a basic construction of class A amplifiers, almost a large amount of current is lost as heat dissipation across the power transistor TIP31C. It is mandatory to connect a large heatsink to accommodate heat dissipation. The conversion efficiency of the circuit is low. Since we are interested in delivering maximum a.c. to the load, while consuming as little DC power as possible from the supply, we are primarily concerned with the conversion efficiency of the amplifier. However, one of the main disadvantages of power amplifiers and especially the Class A amplifier is that their overall conversion efficiency is very low, as the large currents mean that a considerable amount of energy is lost as heat. Of course it is not as good as the traditional Power Amplifier available on the market in actual time. But for further improvement it can be done and the overall performance can be increased.

8.2 Future Work

The circuit that we built had a couple of errors, yet it has potential. There are a couple of errors we made while building this circuit. The first one was the power supply. We used a 9 volt alkaline battery as our power source, the problem with this was that while the amplifier is continuously used, it keeps draining the battery, and its voltage keeps dropping. A better way to fix this is using a 9 volt lithium battery, where the voltage is constant until the battery drops to zero.

Another problem we had is the heat the circuit gathers. The last thing we need is for the amplifier to overheat, because of this in our original model we had to leave it outside of the box. This can be fixed by adding a heat sink, this way we can dissipate the heat, while keeping the circuit inside the box.

Another error of ours is that the circuit was always on, draining the battery as long as it is connected. Adding a switch connected to the batteries and the speakers, can fix this error. Only delivering voltage as long as the switch was ON.

Finally we also decided to add another speaker, connecting the same circuit to the Right side of the aux. In the figure 6, we can see our new circuit design, incorporating these new features to our circuit.

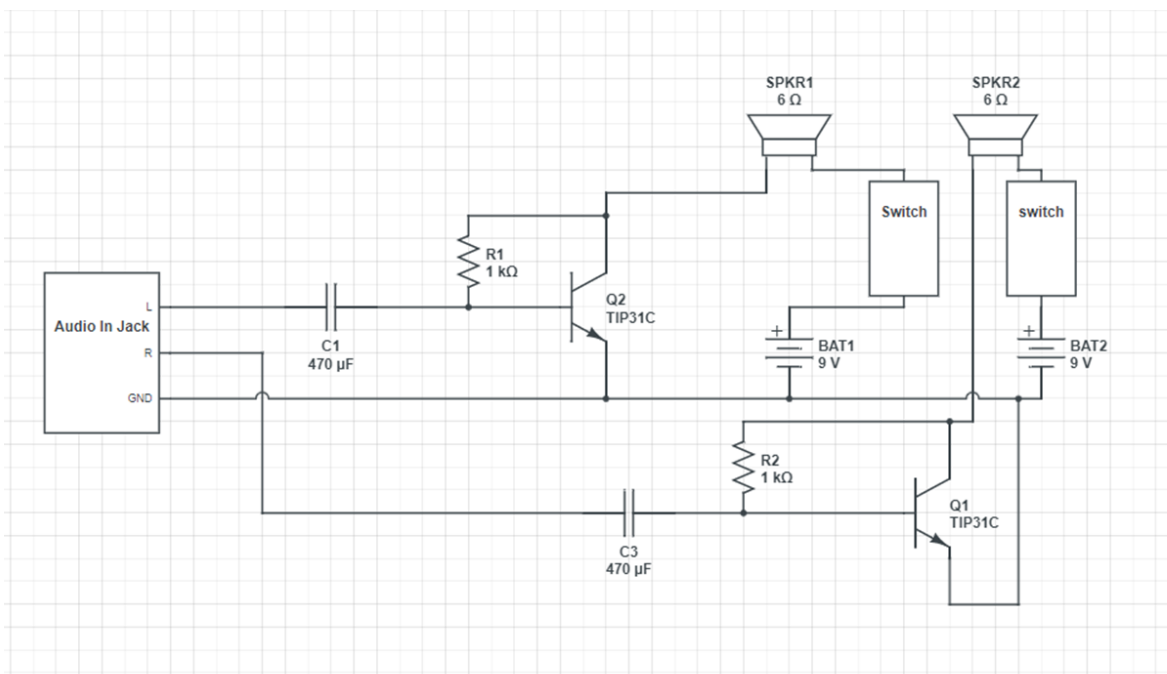

Figure 6: New circuit design

While in figure 7 we have a rendering of how the outside of the amplifier will look like, with the battery pack being the dark part in the back, and the circuit being the white one inside. In figure 8 we have the design for the back of the electronic.

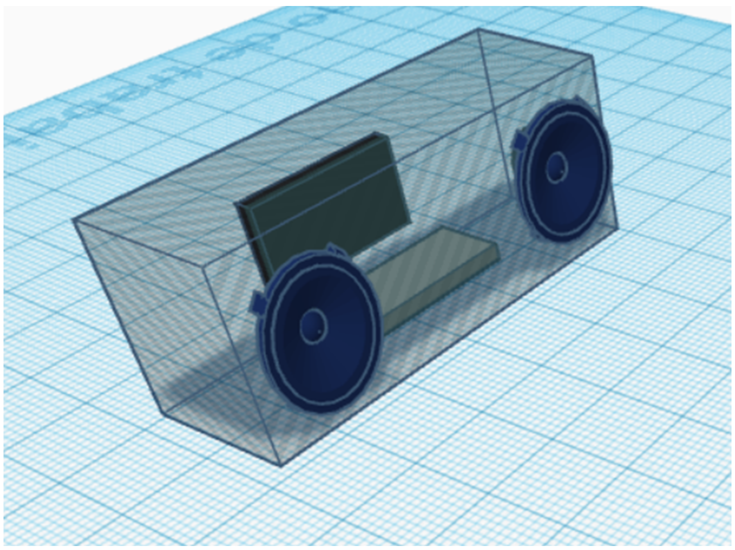

Figure 7: Amplifier 3D model

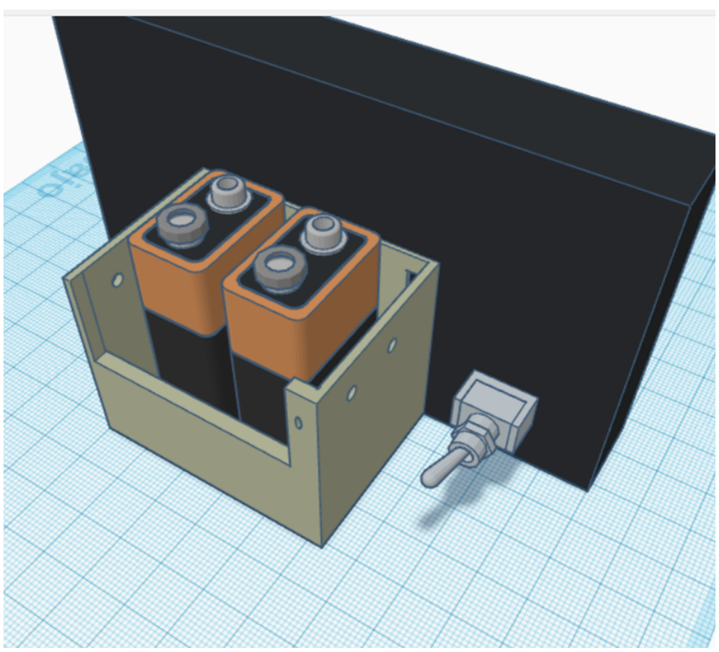

Figure 8: Battery pack 3D model

7. REFERENCES

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APPENDIX A- Diagrams

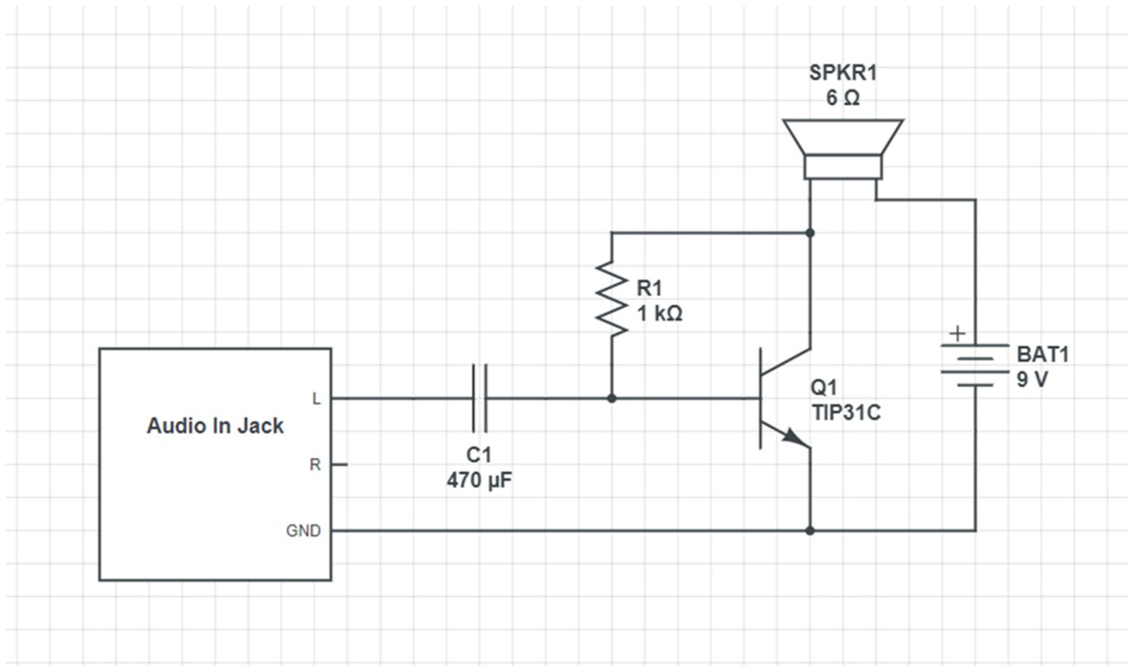
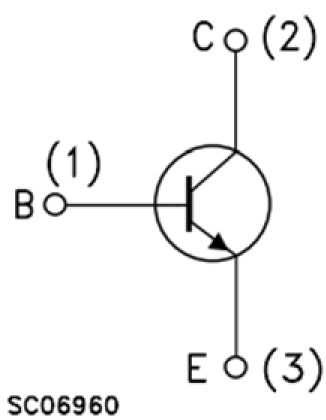


Figure 1: Circuit Design



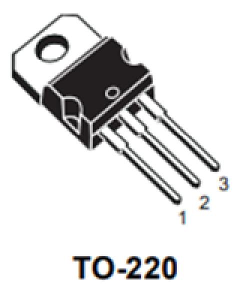


Figure 2: TIP31C Schematics. Taken from [1].

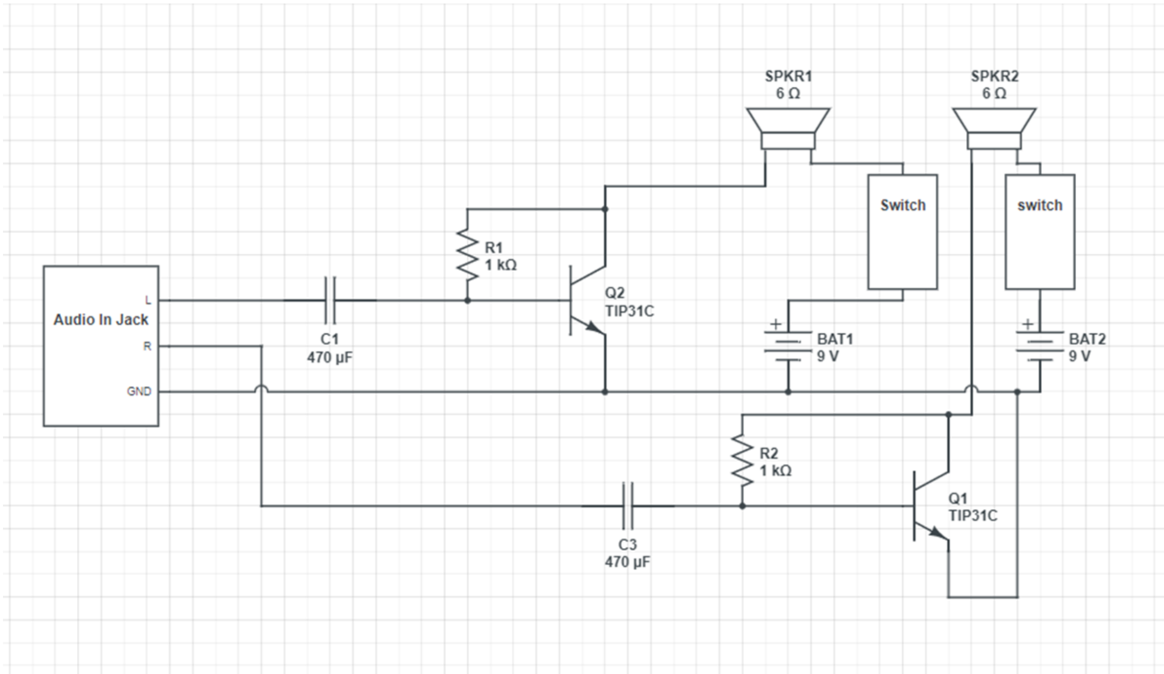


Figure 6: New circuit design

Symbol	Parameter	Value	Unit
V_{CBO}	Collector-base voltage ($I_E = 0$)	100	V
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P_{TOT}	Total dissipation at T_{case} = 25°C Total dissipation at T_{amb} = 25°C	40 2	W W
T_{stg}	Storage temperature	-65 to 150	°C
T_J	Max. operating junction temperature	150	°C

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I_{CES}	Collector cut-off current ($V_{BE} = 0$)	$V_{CE} = 100V$			0.2	mA
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$h_{FE}^{(1)}$	DC current gain	$I_C = 1A$ $V_{CE} = 4V$ $I_C = 3A$ $V_{CE} = 4V$ Group R Group O Group Y	25 10 20 40		 24 44 50	

1. Pulsed duration = 300 ms, duty cycle ≥ 1.5%

Table 2: Electrical characteristics. *Taken from [1].*

APPENDIX B- Figures, Pictures

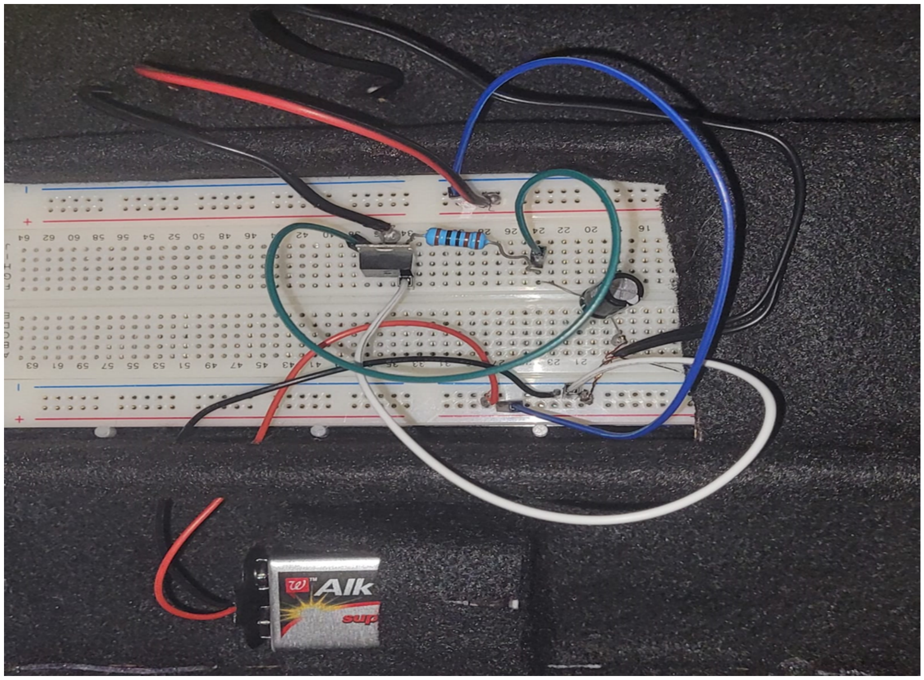
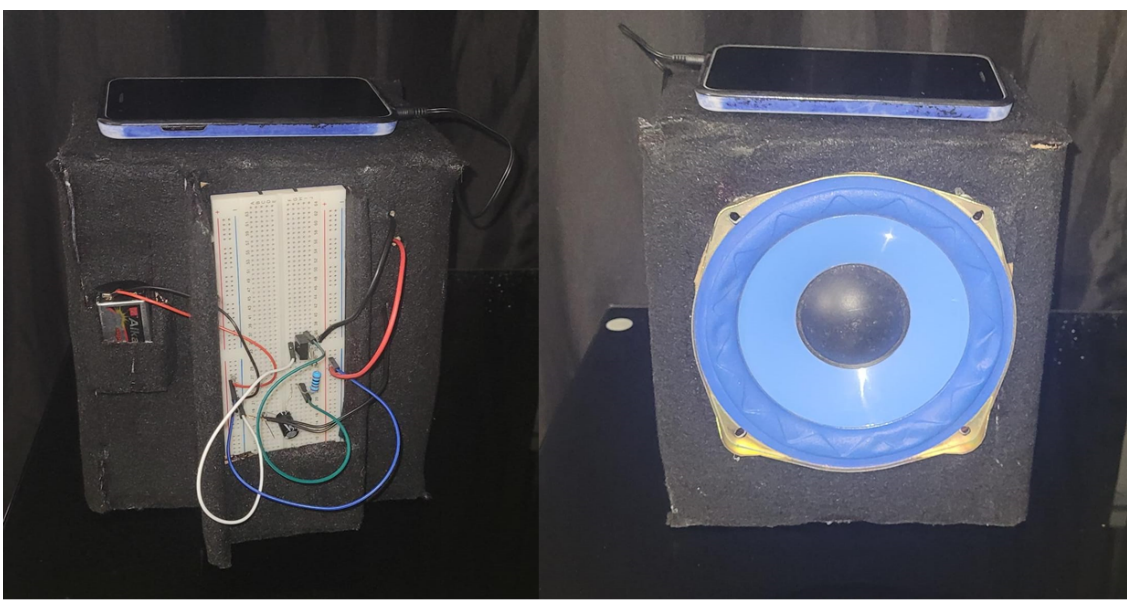


Figure 3: Circuit Breadboard



Back View

Front View

Figure 4: Circuit Front and Back view

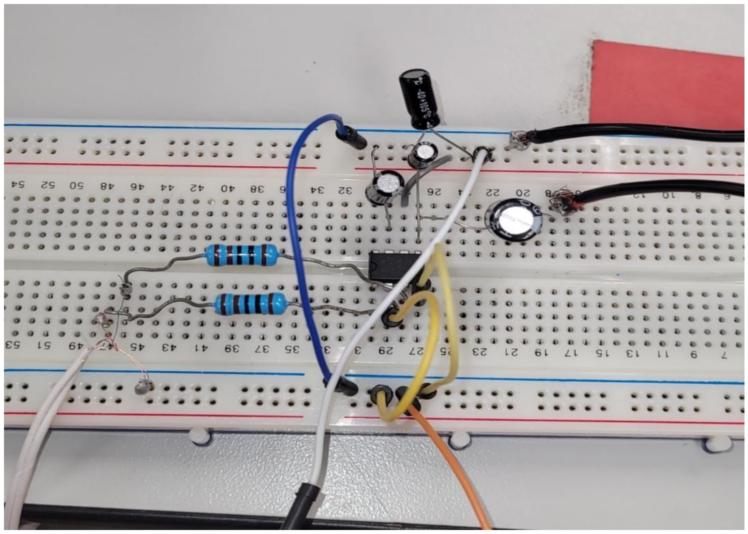


Figure 5: LM-386 Circuit

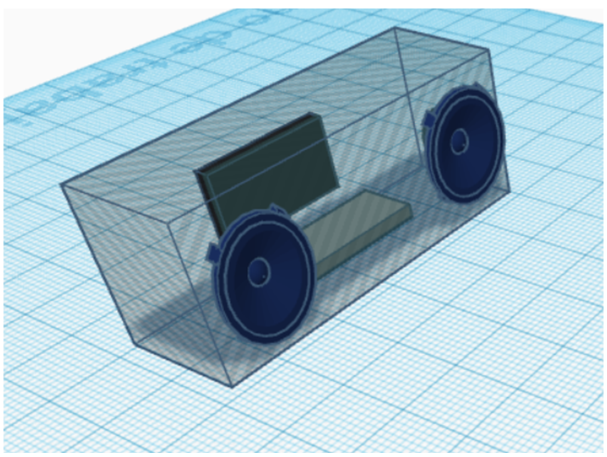


Figure 7: Amplifier 3D model

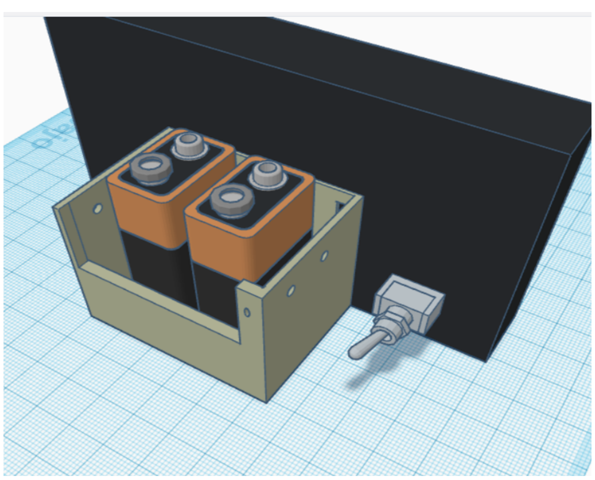


Figure 8: Battery pack 3D model

APPENDIX C- Cost

Materials:	**Prices:**	**Quantity**
1. *TIP31C Power Transistor*	≈ $0.22	1
2. *6ohm Speaker*	$9.75	1
3. *Jumper wires*	≈ $0.18	3
4. *9V Battery clip*	$1.00	1
5. *9V Battery*	$6.12	1
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10. *Soldering Kit*	N/A	1
11. *Felt Paper*	$0.76	5
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Table 3: Materials and Cost