The City University of New York

New York City College Of Technology

Electrical and Telecommunications Engineering Technology Department

Audio Power Amplifier with IC TDA2030

EET2171 - Projects Laboratory

Final Report

Due Date: May 13, 2020
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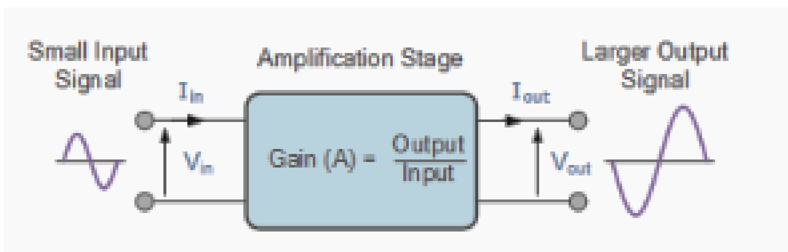
Section I: Opening Remarks

Objective: Apply the knowledge obtained in EET2171 to research, design and build an audio amplifier using the IC TDA2030.

Section II: Amplifiers

Definition of an Amplifier

An Amplifier is a device that is used to enhance a voltage input signal and its power output. Unlike transformers, amplifiers have a power gain. In BJT amplifiers, the base of the transistor acts as a valve and manipulates a small AC voltage signal to control the flow of heavy current through a device with the assistance of a higher DC voltage supply. The gain produced by an amplifier is calculated by the ratio of the output voltage to the input voltage.



Voltage Amplifier Gain

$$Voltage\,Gain\,(A_v) = \frac{Output\ Voltage}{Input\ Voltage} = \frac{Vout}{Vin}$$

Current Amplifier Gain

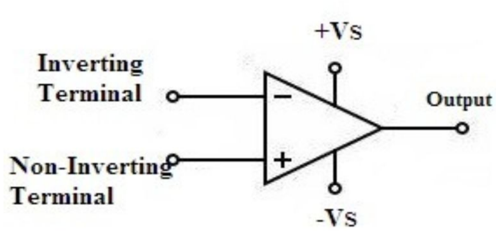
$$Current\,Gain\,(A_i) = \frac{Output\ Current}{Input\ Current} = \frac{Iout}{Iin}$$

Power Amplifier Gain

$$Power\,Gain\,(A_p) = A_v \ x \ A_i$$

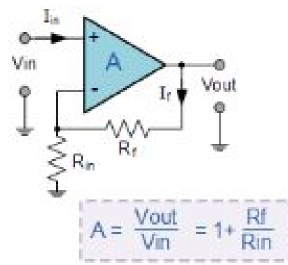
Definition of an Operational Amplifier

An Operational Amplifier, or Op-Amp, is an amplifier that enhances the difference of two input signals. Because of this, the presence of noise is eliminated. Op-Amps have 3 terminals: a non-inverting (+) input terminal; an inverting (-) input terminal; and a single output terminal. The output for an Op-Amp is Vout = (V+ - V-)*Aol. The symbols of a typical Operational Amplifier are shown below. +Vs and -Vs represent the DC supply power input.



The Op-Amp has different configurations. Some of them are: Inverting Op-Amp, Non-Inverting Op-Amp, Voltage Follower Op-Amp, etc. For this project, we will focus on the Non-Inverting Operational Amplifier. Its circuit and formulas for the open-loop gain (Aol), input impedance (Zin) and output impedance (Zout) are shown below.

Aol = 1 + (Rf/Ri)
Zin = (1 + Aol B) Zin(ol)
Zout = Zout(ol) / (1+ Aol B)



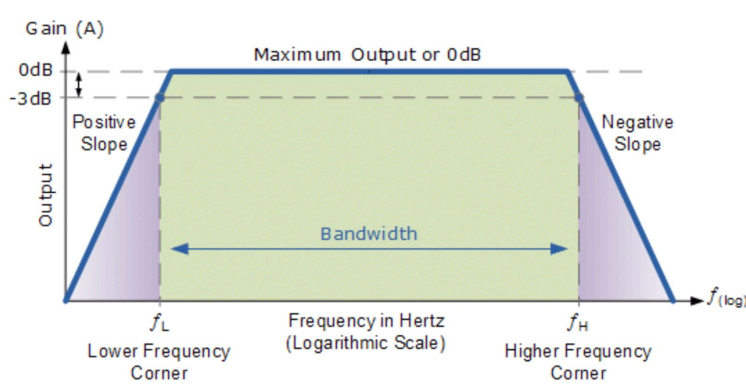
Amplifiers in context of level and frequency

Amplifiers can be classified into different applications such as: 1. A small signal amplifier, or a **Voltage Amplifier**; 2. **BJT amplifiers**; 3. A large signal amplifier, or a **Power Amplifier**.

Voltage amplifiers are class A amplifiers. They are mostly configured as common-emitter amplifiers and operate with a DC power supply. Power amplifiers are either class B, class AB or class C amplifiers. They can be configured as common-base or common-collector amplifiers. Common-base amplifiers have no current gain and have the highest input impedance. Common-collector amplifiers, also known as “emitter-followers”, have no voltage gain and are also the most immune to distortion. They also have the lowest input impedance. Common-emitter amplifiers have both current and voltage gain. Among these three configurations, common-emitter amplifiers exhibit the most power gain.

The graph below shows the frequency response curve of an amplifier.

Frequency Response Curve:



The ideal gain is referred to as the midband gain. This gain value exists in a region called the midband region, or the bandwidth, and is defined as the maximum output an amplifier can produce. The bandwidth is enclosed by two points: the lower cutoff frequency and the higher cutoff frequency. The graph above shows that for a certain frequency range, the gain behaves in a constant value.

Bandwidth = $f_{upper\ cutoff} - f_{lower\ cutoff}$

We can attribute the rise in gain from 0 Hz to the lower cutoff frequency to the effects produced by the coupling and bypass capacitors within the amplifier. They produce a high pass filter response and only allow low frequencies to pass. We can attribute the drop in gain after the higher cutoff frequency to the effects produced by the internal, transistor and stray capacitances within the amplifier. They produce a low pass filter response.

Audio Amplifier and Audio Power Amplifier

An audio power amplifier (or power amp) is an electronic amplifier that amplifies low-power electronic audio signals such as the signal from radio receiver or electric guitar pickup to a level that is high enough for driving loudspeakers or headphones. Power amplifiers are those amplifiers that have the objective of delivering power to a load. This means that components must be considered in terms of their ability to dissipate heat.

Audio power amplifiers are found in all manner of sound systems including sound reinforcement, public address and home audio systems and musical instrument amplifiers like guitar amplifiers. It is the final electronic stage in a typical audio playback chain before the signal is sent to the loudspeakers.

Classes of Amplifiers

The Class A Power Amplifier

A class A amplifier is a type of amplifier that operates in the linear region. In this case, the output signal is an amplified version of the input signal.

The Class B and Class AB Push-Pull Amplifiers

A class B amplifier is a type of amplifier that is in cutoff for 180º and operates in the linear region for 180º of the input cycle.

Class AB amplifiers are types of amplifiers that are biased to conduct for slightly more than 180º. Class B and Class AB amplifiers produce more output power for a given amount of input power. However, it is more difficult to implement the circuit in order to get a linear reproduction of the input waveform. The term push-pull refers to a common type of class B or class AB amplifier circuit in which two transistors are used on alternating half-cycles to reproduce the input waveform at the output.

The Class C Amplifier

A Class C amplifier is a type of amplifier that is biased so that conduction occurs for much less than 180º. Class C produces the most output power and is considered to be the most efficient amplifier. Because its output amplitude is a nonlinear function of the input, class C amplifiers are not used for linear amplification. They are generally used in radio frequency (RF) applications, including circuits, such as oscillators, that have a constant output amplitude, and modulators, where a high-frequency signal is controlled by a low-frequency signal.

Section III: Theory of Operation

Definition of IC TDA2030

The TDA2030 is a monolithic integrated circuit in the Pentawatt® package, intended for use as a low frequency class-AB amplifier. Typically it provides 14 W output power (d = 0.5%) at 14 V/4 Ω. At ±14 V or 28 V, the guaranteed output power is 12 W on a 4 Ω load and 8 W on an 8 Ω (DIN45500). The TDA2030 provides high output current and has very low harmonic and crossover distortion. Furthermore, the device incorporates an original (and patented) short-circuit protection system comprising an arrangement for automatically limiting the dissipated power so as to keep the operating point of the output transistors within their safe operating range. A conventional thermal shutdown system is also included. The pin connection is shown below.

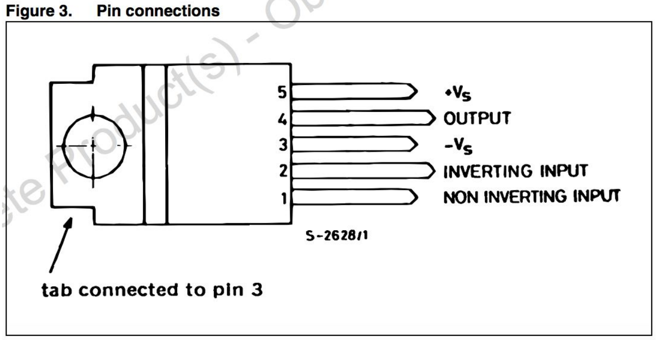


Figure 3. **Pin connections**

Pin 1 *(Non Inverting Input, Vin) - The input signal is fed into this pin. Because of this, the output of the amplifier is positive and is in phase with the input signal.*

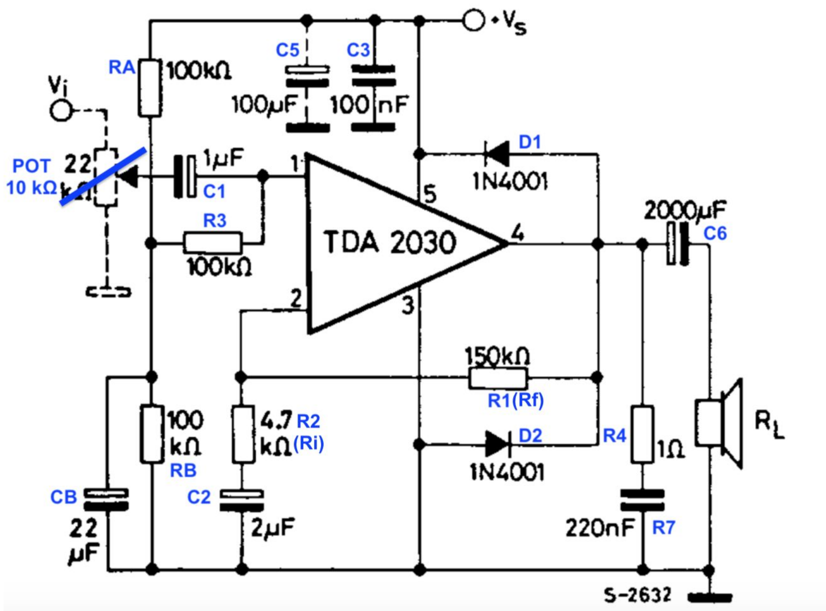
Pin 2 *(Inverting Input, Feedback) - The output of the amplifier is spread across two resistors, Rf and Ri; and is fed back into this inverting input pin. A feedback control is achieved and a negative feedback is produced. Because of this, the amplification is more stable with a very high input impedance.*

Pin 3 *(-Vs, Ground) - The common ground pin is the 0 volt pin and connects to the negative terminal of the power supply. It enables the heavy current to flow through the load and return to its source.*

Pin 4 *(Output) - The output pin is where the amplified signal is produced. It is connected back to the inverting input for feedback control and is connected to the load.*

Pin 5 *(+Vs, Power Supply) - The pin for the DC power supply. This particular amplifier uses a DC power supply to drive the load. It is manipulated by the transistor inside the amplifier so that it can provide the heavy current that is necessary to power the load. It is also the source of the power gain in the amplifier.*

The objective of this project is to build an audio power amplifier using the integrated circuit, TDA2030. It is a single application of the IC chip. Just like with the general audio amplifiers, this project utilizes the concept of differential and feedback voltage. The circuit of this project is shown below.



Amplifier Components and Their Functions

Resistors:

R1(Rf):150kΩ - connected to the output and the inverting input. This resistor, with Ri, defines the closed loop gain. A larger resistance value increases the gain and a smaller resistance value decreases the gain.

R2(Ri): 4.7kΩ - connected to the inverting DC decoupling capacitor and the inverting input. This resistor, with Rf, defined the closed loop gain. A larger resistance value decreases the gain and a smaller resistance value increases the gain.

R3: 100kΩ - connected to the non-inverting input and biases the input voltage. A larger resistance value increases the input impedance and a smaller resistance value decreases the input impedance.

R4: 1Ω 1W - connected to the output and in series with the frequency stabilizing capacitor.

RA & RB: 100kΩ - both are connected to the non-inverting input and biases the input voltage. RA is connected to the DC voltage source. A larger resistance value results in poor high-frequency attenuation and a smaller resistance value might result in instability/oscillation.

Capacitors:

C1: 1µF 25V Electrolytic - connected to the non-inverting input and acts as the DC decoupling capacitor. A value smaller than what's recommended increases the lower cutoff frequency.

C2:2.2µF 25V Electrolytic - connected to the inverting input and is in series with R2. It

acts as the inverting DC decoupling capacitor. A value smaller than what's recommended increases the lower cutoff frequency.
C3:100nF polyester or ceramic - connected to the DC power supply and supplies voltage bypass. A value smaller than what's recommended could result in instability/oscillation.
C4:22µF/25 V ELECTROLYTIC - connected in parallel with RB and aids RB in properly biasing the non-inverting input.
C5: 100µF - connected to the DC power supply and supplies voltage bypass. A value smaller than what's recommended could result in instability/oscillation.
C6: 2200µF / 35V - connected to the output and is in series with the load. It acts as a frequency stabilizer for the load.
C7: 220nF polyester or ceramic - connected in series with R4 and acts as a frequency stabilizer. A larger value than what's recommended results in a smaller bandwidth and a smaller value than what's recommended results in a larger bandwidth.

Semiconductors

D1/D2: 1N4001 - protects the device against output voltage spikes.

Theoretical Gain Calculation and Maximum Power Availability of TDA2030

The Various Amplifier Gains:

$$A_V = \frac{\text{Output Voltage}}{\text{Input Voltage}} = \frac{1}{0.01} = 100$$

$$A_i = \frac{\text{Output Current}}{\text{Input Current}} = \frac{10}{1} = 10$$

$$A_p = A_V \times A_i = 100 \times 10 = 1{,}000$$

Amplifier Gains given in Decibels (dB):

$$a_v = 20\log A_v = 20\log 100 = 40\,\text{dB}$$

$$a_i = 20\log A_i = 20\log 10 = 20\,\text{dB}$$

$$a_p = 10\log A_p = 10\log 1000 = 30\,\text{dB}$$

Calculations

Given theoretical maximum output voltage = 12Vpp
Given theoretical maximum output voltage for calculations = 11.2Vpp (4 Vrms)
Theoretical Gain = Acl = 1 + (Rf/Ri) = 1 + (150 kΩ/4.7 kΩ) = 32.91
Theoretical Gain in dB = 20 log (32.91) = 30.34 dB
Maximum Power = Vrms^2/R = (4Vrms)^2/8 = 2 W

Theoretical Gain and Maximum Power Availability According to the Schematic Diagram

Absolute Maximum Ratings:

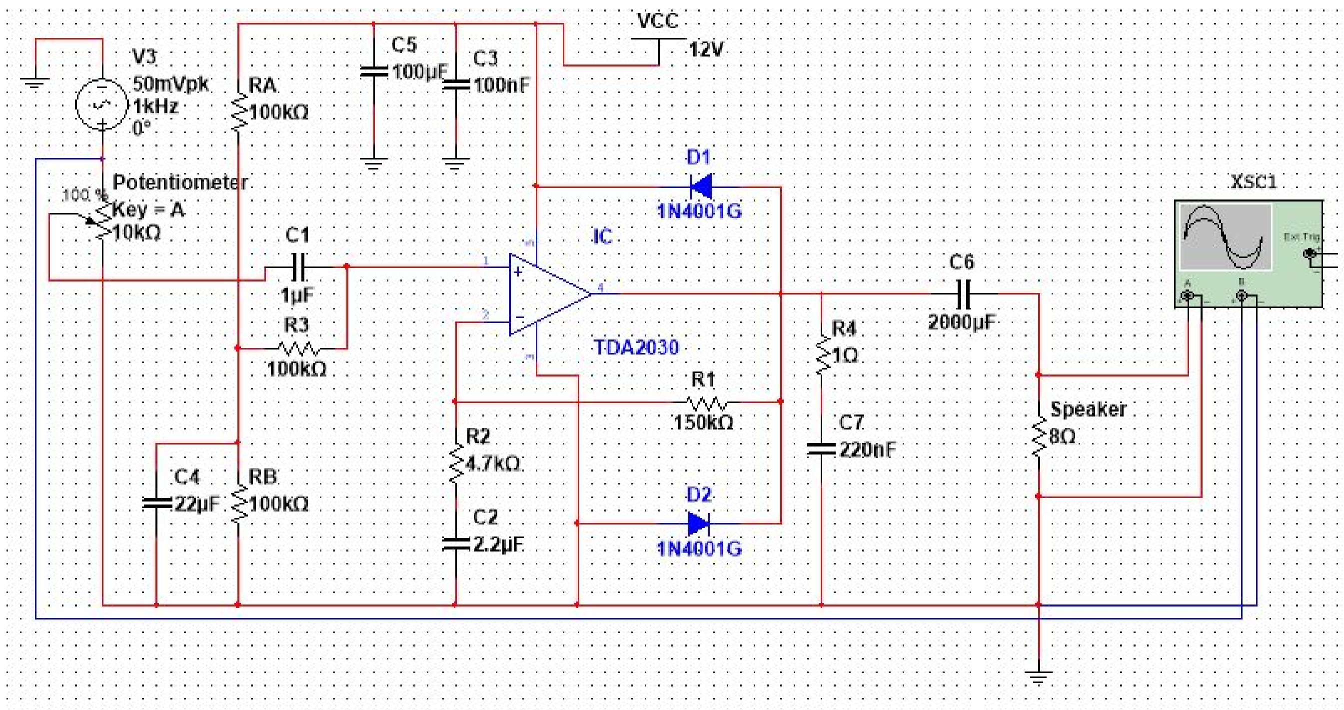
Symbol	Parameter	Value	Unit
V_s	Supply voltage	±18 (36)	V
V_i	Input voltage	Vs	
V_i	Differential input voltage	±15	V
I_o	Output peak current internally limited)	3.5	A
P_{tot}	Power dissipation at T_{case} = 90 °C	20	W
T_{stg}, T_j	Storage and junction temperature	-40 to 150	°C

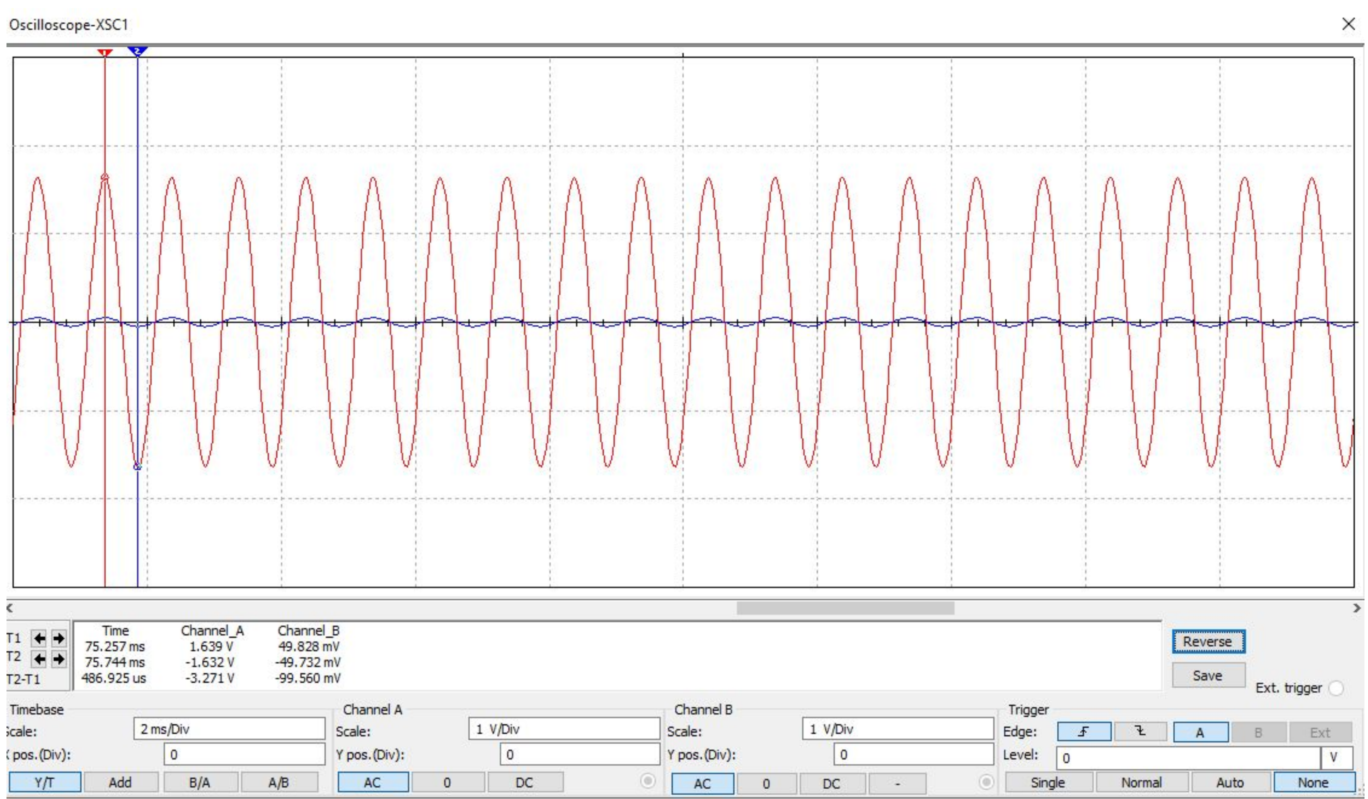
Electrical Characteristics:

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
d	Distortion	P_o = 0.1 to 12 W, R_L = 4 Ω, G_V = 30 dB f = 40 to 15.000 Hz		0.2	0.5	%
		P_o = 0.1 to 8 W, R_L = 8 Ω, G_V = 30 dB f = 40 to 15.000 Hz		0.1	0.5	%
B	Frequency response (–3 dB)	P_o = 12 W, R_L = 4 Ω; G_V = 30 dB	10 Hz to 140			Hz
R_i	Input resistance (pin 1)		0.5	5		MΩ
G_V	Voltage gain (open loop)			90		dB
G_V	Voltage gain (closed loop)	f = 1 kHz	29.5	30	30.5	dB
e_N	Input noise voltage	B = 22 Hz to 22 kHz		3	10	µV
i_N	Input noise current			80	200	pA
SVR	Supply voltage rejection	G_V = 30 dB; R_L = 4 Ω, R_g = 22 kΩ, f_{ripple} = 100 Hz; V_{ripple} = 0.5 Veff	40	50		dB
I_d	Drain current	P_o = 14 W, R_L = 4 Ω P_o = 9 W, R_L = 8 Ω		900 500		mA
T_j	Thermal shutdown junction temperature				145	°C

Test Procedure and Results

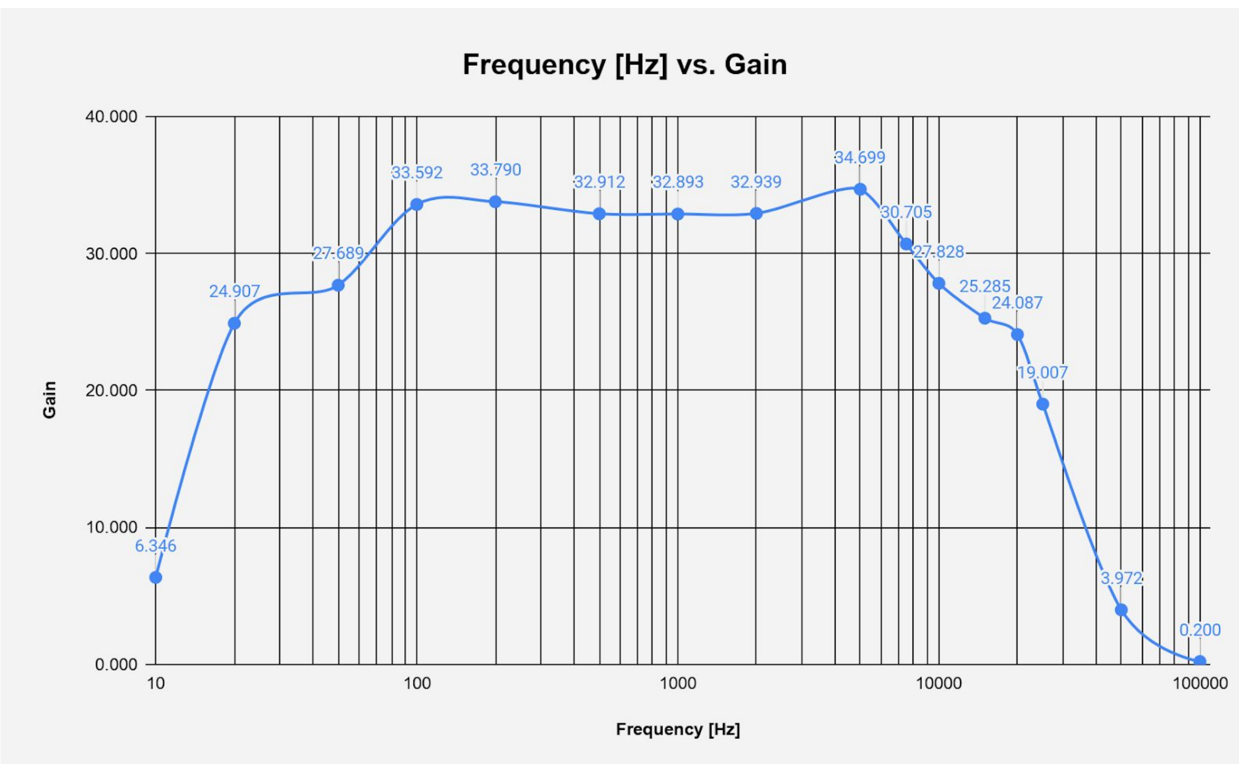
Multisim Simulation of the Circuit:





Multisim Simulation for the Frequency Response Curve:

Frequency [Hz]	Input Level [V]	Output Level [V]	Gain
10	0.03795	0.240823	6.346
20	0.040088	0.998457	24.907
50	0.049694	1.376	27.689
100	0.047987	1.612	33.592
200	0.049956	1.688	33.790
500	0.04986	1.641	32.912
1000	0.049828	1.639	32.893
2000	0.049486	1.63	32.939
5000	0.045073	1.564	34.699
7500	0.048429	1.487	30.705
10000	0.048585	1.352	27.828
15000	0.045798	1.158	25.285
20000	0.032028	0.771446	24.087
25000	0.042229	0.802631	19.007
50000	0.044469	0.176643	3.972
100000	0.154264	0.030834	0.200

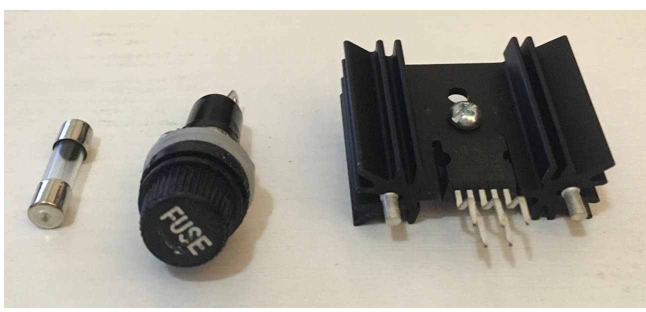


Calculations:
Theoretical Data
Gain = Acl = 1 + (Rf/Ri) = 1 + (150 kΩ/4.7 kΩ) = 32.91
Gain in dB = 20 log (32.91) = 30.34 dB

Experimental Results *(f = 1 kHz, Vi = 100mVpp)*
Input voltage = 49.828mVpk
Output voltage = 1.639Vpk
Output Vrms = 1.639Vp*0.707 = 1.159Vrms
Mid-band voltage gain = Amb = (1.639/0.049828) = 32.893
Mid-band voltage gain in dB = 20 log (32.893) = 30.34 dB
Mid-range voltage rms gain = 0.7*Amb = 0.7*32.893 = 23.025
Input power = Vrms^2/R = 49.828mVpk^2/8 = 310 μW
Output power = Vrms^2/R = 1.159Vrms^2/8 = 1.34/8 = 0.168 W
Power gain = 0.168 W/310 μW = 541.94
Lower cutoff frequency = 16 Hz
Upper cutoff frequencies = 21 kHz
Given theoretical maximum output voltage for calculations = 11.2Vpp (4 Vrms)
Maximum power available across load = Vrms^2/R = (4Vrms)^2/8 = 2 W

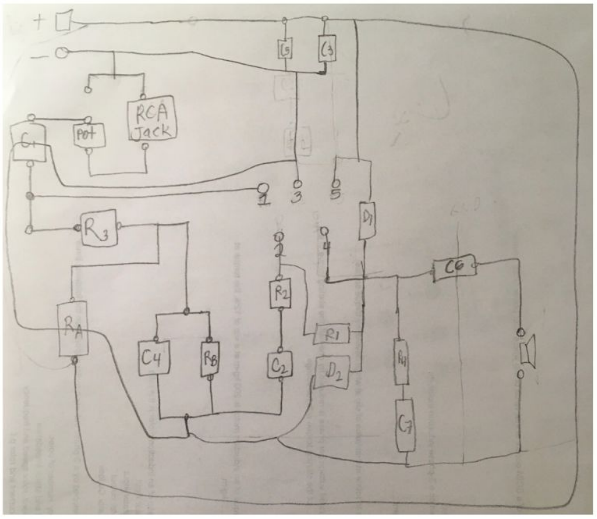
Manufacturing and Assembly Process

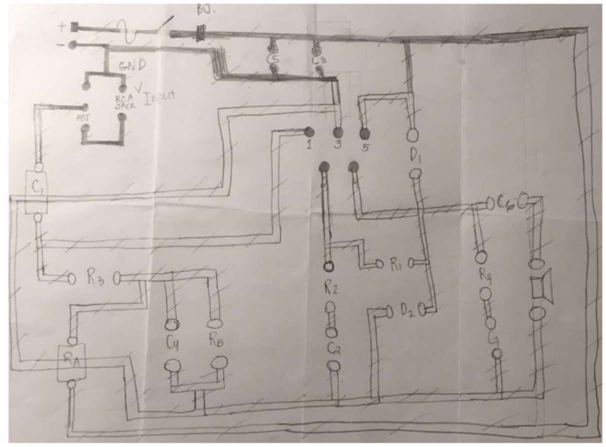
- To protect the circuit, a 2 amperage fuse and a heatsink for the IC TDA2030 are used.



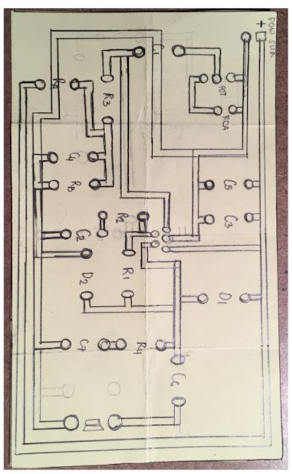
Procedure:
1. Identify the type and size of the components
2. Design the circuit layout
    a. Remember that pads must be off the conductive lines
3. Clean the PC board
4. Transfer layout to the PC board
5. Etch the PC board
    a. Remember to submerge the pc board with the resist on top
6. Drill holes
7. Solder the components in
    a. Remember to not apply too much heat on the components
8. Assemble the enclosure

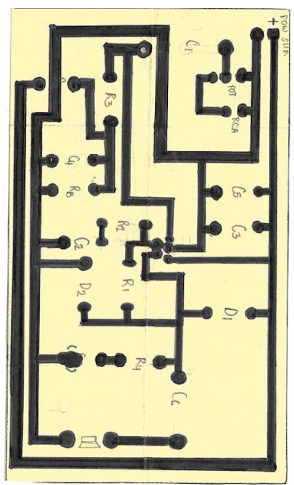
Design the circuit layout pictures:

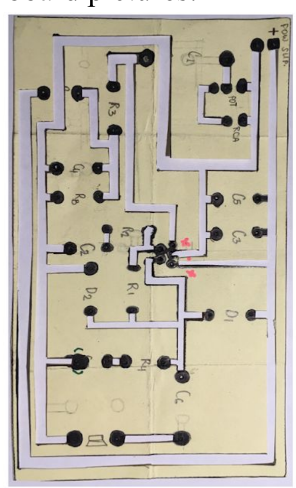


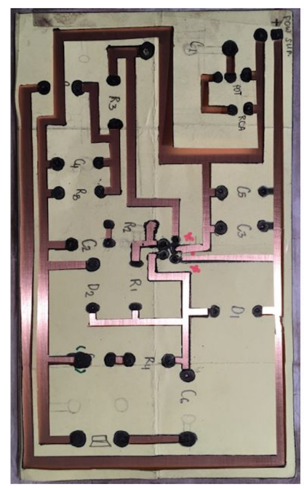


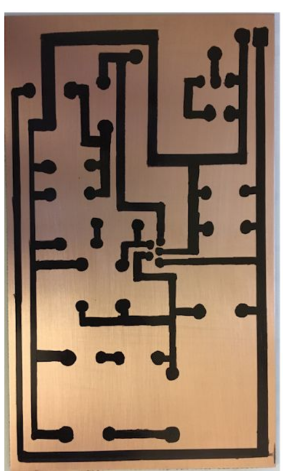
Transfer layout to the PC board and Etch the PC board pictures:

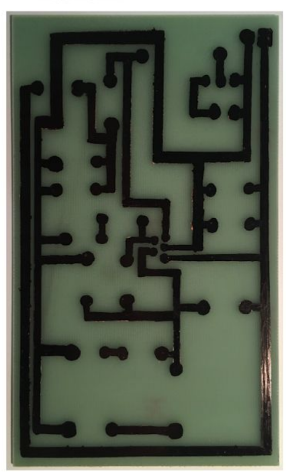




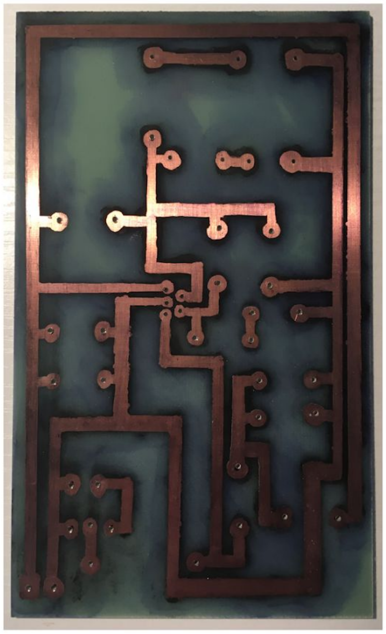


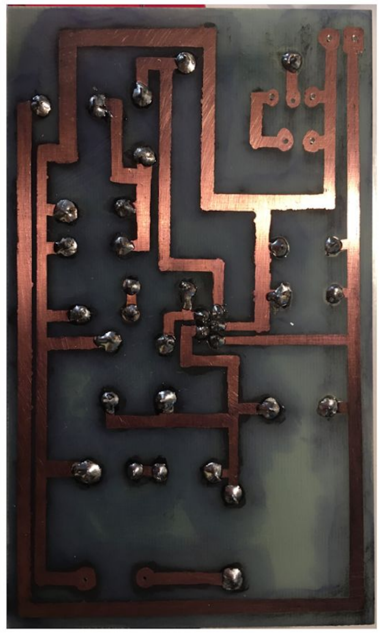


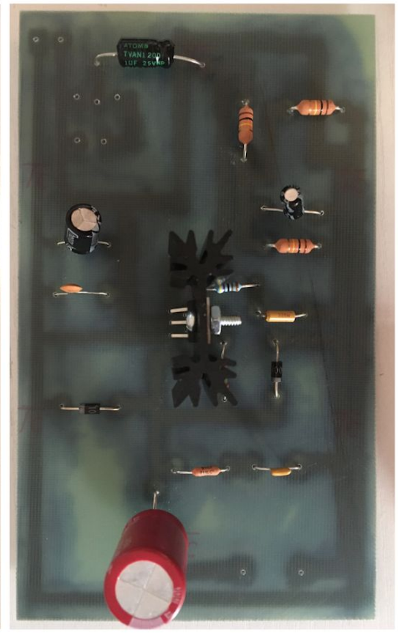




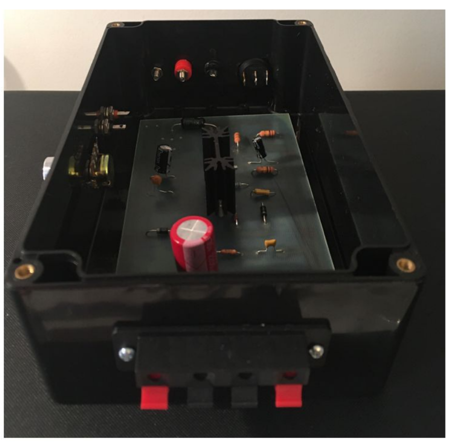
Drill holes and Solder the components in pictures:







Assemble the enclosure pictures:

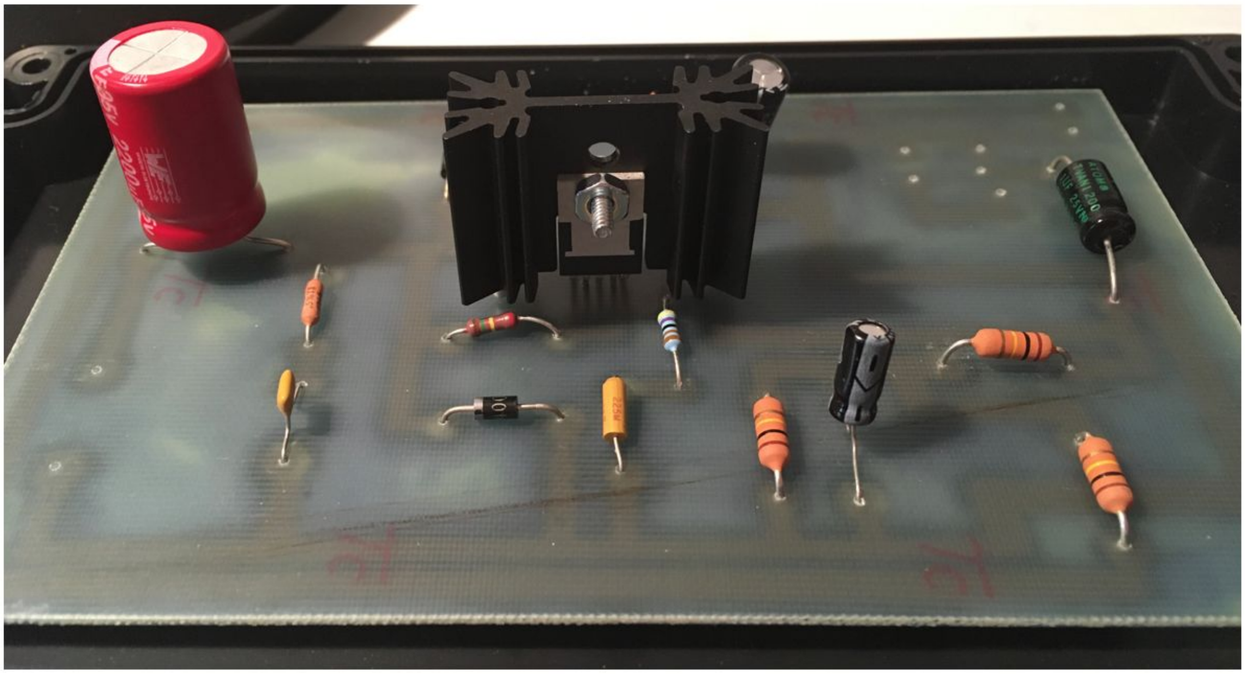


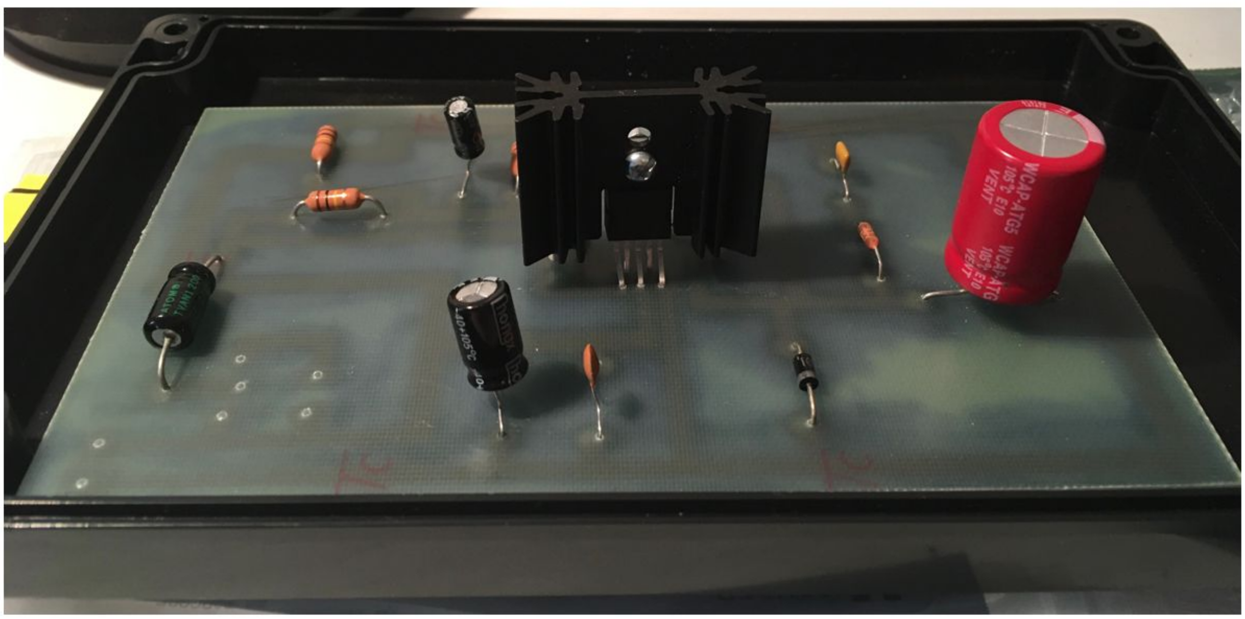
Output Jack

Power Supply Jack

Input Jack

PC board with components side pictures:





Functionality Testing and Troubleshooting

I am currently working with wiring and then testing. I will submit a pdf of pictures and will prepare a video for professor's reference.

Section IV: Closing Remarks

Conclusion

Amplifiers are devices that amplify a voltage signal. Operational Amplifiers are active devices that amplify a voltage between two inputs. A non-inverting operational amplifier has a voltage output that is positive and is in phase with the input signal. Unlike transformers, amplifiers produce a power gain. This is accomplished by using a DC supply voltage that is manipulated by transistors (in BJT amplifiers) to power a particular load. The output voltage of an amplifier can never be greater than the DC supply voltage. When the output voltage reaches the value of the DC supply voltage or when the input impedance reaches zero, the Op-Amp saturates. Amplifiers operate in a region called the mid-band region where the gain is optimal. This gain is called the mid-range gain and is calculated by output voltage divided by the input voltage. The mid-band region, also referred to as the bandwidth of an amplifier, is defined by the lower cutoff frequency and the upper cutoff frequency. The lower and upper cutoff frequencies are frequencies where the gain is the rms value of the mid-range gain. Audio amplifiers are a great application for amplifiers because of the significant gain produced. With a fair knowledge about electronics and research, anyone is able to build a good amplifier at home.

Professor Nasser Barkhordar's Projects Laboratory class taught me a number of valuable skills. These skills range from knowing how to apply the knowledge that I learned from my electrical engineering classes to understanding the concepts and theories more in-depth. This project helped me understand what an amplifier is, its functions and its value; and how to build one from a simple schematic diagram. I learned how to design a layout, etch a PC board and solder components better. This course sharpened my research and problem solving skills because I had to think like an engineer - I had to be organized, I had to plan my timeline, I had to make sure that I have enough resources and that all of my electrical components are well taken care of. The most challenging part of this project is the research part because in order for me to write this report, I needed to really understand what I am doing and what my project is about. Thankfully, the internet is full of helpful resources like videos and articles. Professor Barkhordar's instructiveness, clarity, knowledge and patience contributed significantly to my progress. I am in the final steps of this project. I am in the wiring part and I look forward to testing. I would like to express my gratitude to Professor Barkhordar and to the ETET Department for this pivotal and fulfilling course.

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