High Frequency Amplifier

[EN2091] Analog Lab Project

Group O1 : Intake 20

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Outline

Introduction

- The objective of this project is to create a distortion free output for an input signal with a single tone sine wave of $0.1\ V$ peak to peak voltage.
- The amplifier should be compatible with $8\ \Omega$ speaker and $12\ V$ power source.

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Functionality

- The low amplitude of the input signal is insufficient for speaker action. The signal power and signal-to-noise ratio must then be increased. When amplitudes are tiny, the noise effect will be very strong.
- The input sine wave's amplitude should be increased first, with *a voltage amplifier used as a pre-Amplifying stage.*
- When driving the output signal to a headset, a high power gain is preferred. The pre-amplifier can only provide 50 mA of current, which is not enough to operate the speaker.
- In order to produce a *power amplification*, we have therefore chosen to use a *class AB amplifier* after the voltage amplifier.

Functionality - *Stage A : Pre-Amplifier*

The BJT transistor can be used in three different configurations as a Voltage Amplifier.

- Common Collector
- Common Emitter
- Common Base

The **Common Emitter configuration** has been selected.

when compared to the other two configuration techniques, maximum power gain can get through this configuration.

Functionality - *Stage B : Power-Amplifier*

There are several classes of transistor-based power amplifiers[Tob07].

- Class A
- Class B
- Class AB
- Class C

The Class AB Power Amplifier has been selected.

This configuration eliminates crossover distortion as the input signal won't be used to bias junctions, and the Q point operates at the edge of the cutoff and active regions, making this type more power efficient.

Common collector transistors have been used for AB amplifier biasing.

Common collector transistors provide an initial forward bias and buffer for impedance matching when cascading two stages.

Functionality - *Block Diagram*

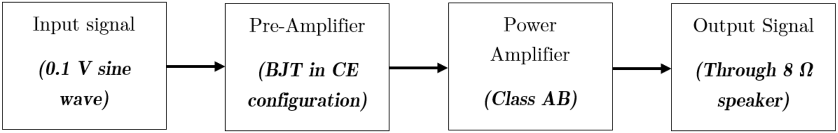

Figure: Block Diagram

Outline

System Model : *Stage 01 : Pre- Amplifier*

Transition frequency and **current gain** of the most used transistors for the pre-amplifying stage

Characteristic	**BC107** [SEM97b]	**BC547**	**2N2222** [SEM97a]
Trans. Freq.	150	300	250
Gain	110-450	110-800	30-300

BC547 transistor has been used as the voltage Amplifier.

The BC547 transistor is the **highest transition frequency** and has **high current gain** for the voltage amplifying stage. It also has **fast switching and fast responding time**, making it an ideal choice for the Common Emitter amplifier.

System Model : *Stage 01 : Pre- Amplifier : Initial Calculations*

For **BC547**;

We have chosen 20 mA as the quiescent current and maintain $V_{CE} = 6\ V$ near the mid point[a].

[a]From the Data sheet, considering the highest gain bandwidth product

For **BC547**; *From* ***KCL***:

$V_{CC} = I_C R_C + V_{CE} + V_E$
As a rule of thumb, we need to maintain V_E less than 10% of V_{CC}.
$R_C = 240\ \Omega$

Since I_B is a very small current, Let assume that $I_C = I_E$; *From* ***KCL***:

Using Ohm's law for R_E:
$R_E = 60\ \Omega$

System Model : *Stage 02 : Power - Amplifier*

For AB class operation, a **Complementary Symmetry pair** is also required.
We have chosen the complementary symmetry pair of **TIP31** and **TIP32**, which has a maximum collector current of 5 A, due to the requirement for **through-hole transistors**.

Thermal Stability

To guarantee the thermal stability of an AB push-pull amplifier, resistors are required. As a result, we use resistors with 2.2 Ω resistance to decrease power dissipation as well.

Thermal Management

For Common Collector and class AB amplifiers, respectively, **2 W** and **5 W** resistors are used

Outline

Schematic

We modified our computations to use component values in a practical manner.

$$R_C = 220\ \Omega, R_E = 68\ \Omega,\ R_{B2} = 2\ k\Omega$$

$$For\ input\ coupling\ capacitor : 4.7\ \mu F$$

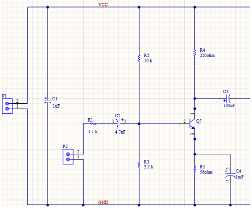

Figure: Voltage Amplifier

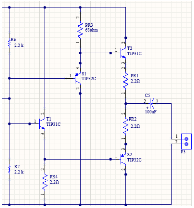

Figure: Power Amplifier

The Breadboard implementation requires changing values to account for wire resistance.

Therefore to maintain the Q point in the linear region in the output characteristic, $R_E = 56\ \Omega$ and $R_{B2} = 2.2\ k\Omega$.

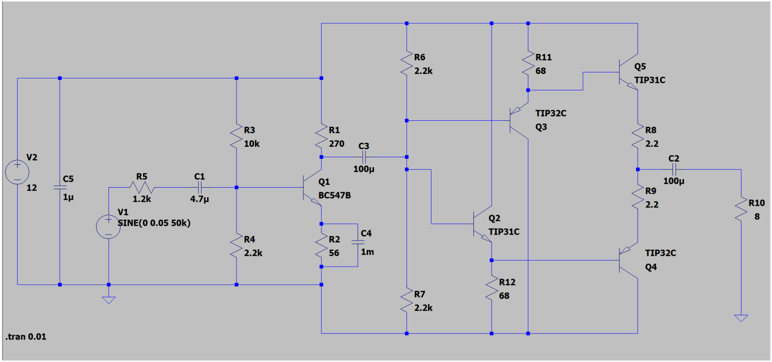

Figure: LTspiceXVII

Outline

Simulation Results

With Load(8 Ω)

- Input Current (pk to pk) : 64.39 μA
- Bandwidth : 212 kHz
- Output Voltage (pk to pk) : 1.556 V

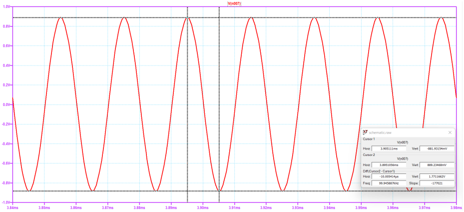

Figure: Output Signal

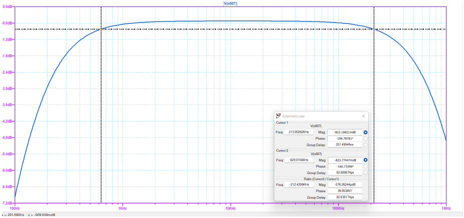

Figure: Bandwidth

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PCB Design

The PCB layout is designed to accommodate high-frequency applications while minimizing temperature increase.

1. The angle between two adjacent current passing lines is taken at an obtuse angle to minimize interference.
2. Two layers in the PCB are used to reduce high-frequency noise and ground the signal as rapidly as possible.
3. The two transistors of $TIP31C$ and $TIP32C$ are power related, so they are placed in the four corners of the PCB board.

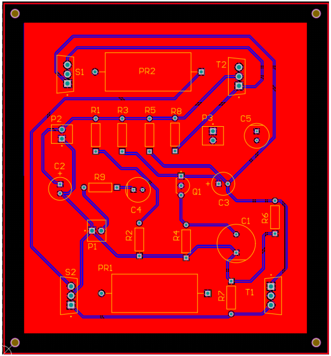

Figure: PCB - *Top*

Outline

Enclosure Design

1. The enclosure is $110 \times 62 \times 107\ mm^3$ and consists of an upper half and a lower half joined by eight tiny nails.
2. The thickness of the walls is $2\ mm$ to achieve strength and lightness, and vents are positioned to allow heated air to flow out.
3. The SPST switch and red LED are placed on the backside, and three ports are connected to the lower part of the enclosure for easy maintenance.

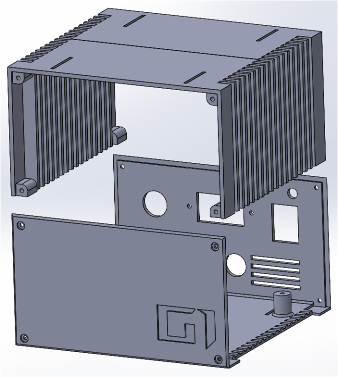

Figure: Enclosure

Final Enclosure Design

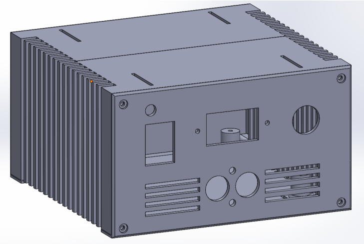

Figure: Enclosure - Assembled

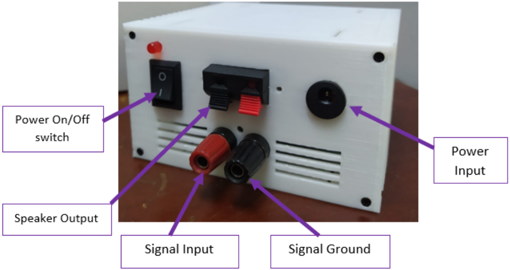

Figure: Enclosure - Printed

Outline

Final Results

SYM.	PARA.	COND.	MIN.	TYP.	MAX.	UNI.
BW	Bandwidth	$R_L = 8\ \Omega$	20		360	kHz
A_{vo}	Voltage Gain	$R_L = \infty$		27.5		dB
A_v	Voltage Gain	$R_L = 8\ \Omega$		26.1		dB
R_{in}	Input Impedance	$R_L = \infty$		1.55		$k\Omega$
R_{out}	Output Impedance	$R_S = 0$		12		Ω
P_{out}	Output Power	$R_L = 8\ \Omega$	0.225	0.25	0.33	W
T_o	Operation Temperature	$R_L = 8\ \Omega$	25		32	$^\circ C$

Outline

Future Works

Differential Amplifier

To further reduce the potential for noise, we could use constant current differential amplifier that utilizes transistors in place of a voltage amplifie

Complementary Symmetry Darling ton Pairs

Transistors with Darling-ton pairs can improve the power gain of a high frequency amplifier, but cost concerns prevent implementation.

Outline

Acknowledgement

The success of this project was dependent on various factors, one of which was the guidance and assistance of numerous individuals. We express our utmost gratitude to our project guides, Mr. Tharindu, Ms. Yomali, and Ms. Amashi, whose unwavering dedication and keen interest in our work helped in the successful completion of our project. Furthermore,we would like to thank everyone who contributed even in small ways to the success of this endeavor.

References

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- ———, *Bc107; bc108; bc109.*
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