Term Project - Audio Amplifier

Objectives

- To understand the principles of a Darlington push-pull power amplifier and its application.
- To construct an audio power amplifier on a vero board and heatsink, and troubleshoot the circuit.
- To test performances of the amplifier under the laboratory conditions.

Project Description

Audio power amplifiers are designed to drive loudspeakers. They have DC power supplies, input stage, and output stage, as shown in Fig.1. The input stage of a power amplifier (sometimes called the "front end") is to receive and prepare the input signals for "amplification" by the output stage. It is a stage of pre-amplification or voltage amplification. The output stage converts the signal into a much more powerful "replica" that is capable of driving high power to a speaker. It amplifies current. As Power = current × voltage (for resistive loads), this is where the “power” amplification comes from.

Audio power amplifiers get the energy from a DC power supply to amplify an audio input signal. Power ratings and efficiency are two of important specifications for audio amplifiers (also noise and THD for commercial amplifiers). The rated power output of an amplifier is referred to its maximum output and may be stated for various load impedances. The efficiency is determined by the class of an amplifier (i.e. class A, B and AB) and its circuit configuration. Class AB is probably the most common one currently used in home stereo.
For this term project, a simple audio power amplifier shown in Fig. 2 will be designed and built [1]. In the front stage, an audio signal is pre-amplified by a non-inverting op-amp with a voltage gain of about 10 (determined by R2 and R1). In the output stage, a Darlington push-pull configuration is used to amplify the current. The audio amplifier uses dual DC supply of ±15V so that coupling capacitors at outputs of two stages can be omitted. Four diodes D1 to D4 are used to reduce the cross over distortion to form a class AB amplifier.

![Circuit diagram of an audio amplifier](image)

**Design Specifications**

- Power Supply voltage: Vcc= +15 Volts and Vee= -15 Volts.
- The output power $P_{out}$ should be at least more than 2Watt with a load of 8Ω.
- The frequency response of your amplifier must be “flat” within 3 dB from about 30Hz to 30kHz.
- Quiescent DC power (when no signal is being amplified) should be as low as possible while eliminating cross-over distortion in the push-pull output stage. In other words,
the efficiency of the amplifier should be maximized, as close as possible to the efficiency of a class AB amplifier.

**Project Tasks**

1. **Design**: Choose values for the resistor RE1, RE2, RB1, and RB2 in the circuit of Fig.2, to set up proper DC bias to achieve maximum swing of output voltage Vo.

2. **Spice simulation** – to optimise your design and theoretically predict the performance of the amplifier.
   - DC bias analysis for all nodes. Create a table to record the values, and compare them with experimental ones later on.
   - Transient analysis to show maximum output voltage and current to 8Ω load. It might be necessary to adjust the resistances of RB1 and RB2 to obtain higher swing of the output voltage. Calculate the maximum output power and power efficiency.
   - AC analysis to show the frequency response of the amplifier, mark out lower and higher 3dB cut-off frequencies.

3. **Construct** the power amplifier circuit on a bread board first and measure DC bias, voltage gain, output power, and efficiency for the amplifier using a dummy load (8Ω resistor, power rating needs to suit to the output power) and the function generator.

4. **If** the measurements for the amplifier on the breadboard meet the required design specifications, solder the circuit on a vero board (Check [4] [5] for basic soldering information and working with vero board). Note: take a photo of the breadboard setup before soldering the circuit on the vero board to keep a record in your logbook. Again use the dummy load and function generator to measure the maximum output power and power efficiency.

5. **For** the circuit on the vero board, measure the voltage gain for sinusoidal inputs at several frequencies. Plot the frequency response and indicate the 3dB break points. Compare these results to the Spice simulation plots.

6. **Finally** connect an audio signal source and a speaker (to replace the FG and dummy load) with the amplifier and listen to the output. How much is the voice from the audio source amplified? Note: the power rating of the speaker should match the output power of the amplifier.
Design and Construct Guidelines

The following steps help you proceed the design and construction of your audio amplifier.

**Design:**

- To calculate the DC biasing conditions and resistor values, start from the output stage and work backward to the input stage. For example, according to the maximum output current, the collector current of Q1 can be estimated by the load current. Then the base current of Q3 can be worked out by the total current gain of the Darlington transistor (Q1 and Q3). This current is the majority of the current flowing through RB1 (say about 90%) as the current flowing through the diodes is very small.
- RE1 and RE2 in the circuit are to keep thermal stability of the push-pull amplifier because the V_{BE} of the transistors drop when transistors getting hot [2]. Typically the two resistors are a few ohms or less to provide a “buffer” for the critical quiescent current biasing.
- Use Spice to verify and optimize your design.
- The total voltage gain of the audio amplifier is provided by the non-inverting op-amp circuit. The voltage gain is determined by R1 and R2 (Av=1+R2/R1).
- Calculate the DC bias according to the transistor specifications which can be found from the datasheet [3] or test by the curve tracer of BJT transistors (available in the Lab 440).
- Determine the maximum power for all components in order to choose their power ratings. Standard resistors are 1/4^th watt. Check the transistors’ specification for the power and peak voltage.

**Construction:**

- Start to build and test the output stage of the amplifier first. Without AC input and the load, apply the DC voltage to the output stage only and test it. Ensure the DC supply current stable. Measure the biasing voltage at every node in the circuit of the output stage and compare with the values in the Spice.
- If the measured biasing voltages agree with those obtained from the Spice, apply an AC signal (1 kHz sine wave from the function generator) to the anode of D3 (in Fig.2) and test the output voltage with no load. What is the maximum voltage you can obtain without distortion?
Now you may add the 8Ω load to the output to test the output stage. Start with a small input, and slowly increase it to get a maximum undistorted output. With the max. output voltage you can calculate the output power. If the output voltage clips at a lower power, you may need to reduce the resistance of your base resistors (RB1 and RB2) to maximize the output swing.

The power transistors (TIP31 and TIP32 in Fig.2) may get hot when testing with a load. Make sure they are mounted on a heat sink properly.

Now wire up the front stage on the breadboard and connect it with the output stage tested above.

Apply 1kHz sinusoidal signal from the function generator to the front stage, as shown in Fig.2, and test the whole circuit with the 8Ω load. Note: you may need to reduce the signal from the function generator as it will be amplified about ten times by the op-amp circuit when the two stages are connected.

Support and Resources

- The scheduled lecture, tutorial and laboratory sessions will offer adequate support for your basic understanding of the amplifier.
- The laboratory is available during the university working hours for you to build and test the project.
- A packed kit including resistors, capacitors, transistors, op-amp, and diodes is provided.
- DC power supply, oscilloscope, function generator, heatsink, soldering station, breadboard, veroboard, wires are available in the laboratory. Contact with Ms. Kavitha in R441 for the help regarding the hardware in the laboratory.
- Laboratory supervisor and tutors will provide assistance on project development during the allocated sessions. For further help about the term project please contact with Dr. Chu by ruihong@ee.usyd.edu.au.

Assessment

The project takes 15% mark of this UoS and is assessed by an **individual logbook** and **group demonstration** (group of 2 students). The assessment of the project will take place
during the week of 12 of the semester. The detailed timetable for the group demonstration will be issued on the unit lab web site later on.

In the group demonstration, the understanding and design of the audio power amplifier should be presented. The measurement of the maximum output power and the power efficiency of the amplifier need to be demonstrated. Questions related to the theoretical understanding, testing skills, and calculations could be asked randomly. In the logbooks, students are required to record details of each stage of the project development, including analysis, calculations, diagrams, waveforms, observations, comparisons, troubleshooting, as well as problems and solutions. Evidence of all work undertaken must be included and documented clearly in your logbook. Ensure that waveforms are represented in the same time domain, where the period, amplitude, and DC values must be clearly indicated on your sketches. Note: The logbooks are to record the development of the project and are not lab reports. The logbooks must be handed in to a lab staff immediately after your group demonstration.

Reference