

A Low-Power Audio Amplifier

The object of this experiment is to assemble and test a low-power audio amplifier that might be used to drive headphones. Because an op amp is current limited to less than 25 mA, it cannot be used to directly drive a low impedance load. A solution to this problem is to add current boosters between the op-amp output and the load as shown in Figure 1. BJT's Q_1 and Q_2 are connected as a complementary common-collector amplifier to supply load current. Q_1 supplies positive load current and Q_2 supplies negative load current. The op amp is connected as a unity-gain voltage follower. A two-resistor feedback network can be added to the op amp to increase the gain of the circuit for any specific application.

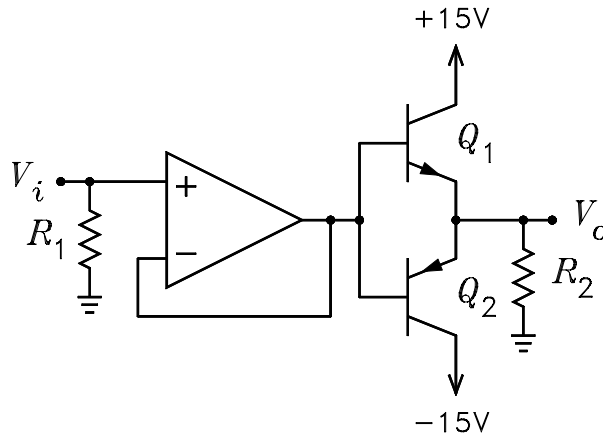


Figure 1: Op amp with complementary common-collector stage.

Assemble the circuit with $R_1 = 10\text{ k}\Omega$. You may use any op amp that is available in the laboratory. A TL071, TL081, or LF351 is recommended. The transistors should be a complement pair such as the 2N4401/2N4403 or the 2N3904/2N3906. Because the laboratory only has 0.25 W resistors, the value of R_2 must be calculated so that it does not become a smoking resistor at the maximum power output. Calculate the value of R_2 so that it dissipates 0.25 W when the output voltage is a sine wave with a peak value of 10 V.

1. Assemble the circuit.
2. Drive the circuit with a sine wave to produce a peak output voltage of 1 V at a frequency of 100 Hz.
3. Observe and record the waveforms at the output of the op amp and across the load resistor R_2 .
4. Increase the input voltage to produce a peak output voltage of 8 V and repeat the measurements.
5. In your report, explain the cause of any observed distortion.

A method of reducing the distortion at the output is to take the feedback from the output of the common-collector stage rather than from the output of the op amp as shown in Figure 2. Assemble this circuit and repeat the above measurements. Note that the distortion in the waveform has been moved from the output to the input of the common-collector stage. You should explain this in your report.

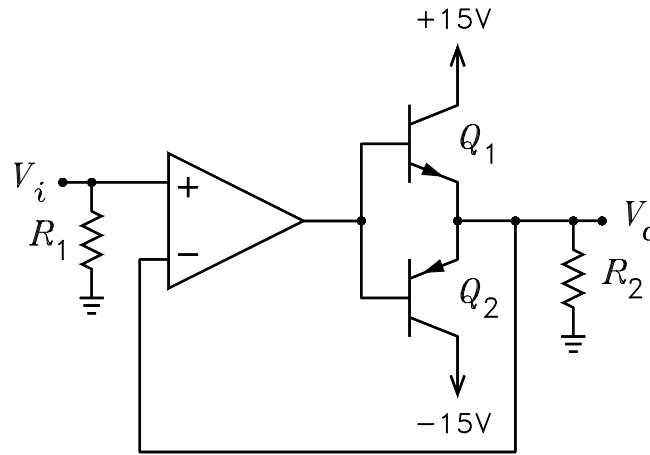


Figure 2: Circuit with feedback taken at the load.

Although the circuit in Figure 2 is an improvement over the circuit in Figure 1, distortion measurements would reveal some residual distortion caused by the two BJT's turning on and off as the output signal swings positive and negative. An improvement is to add bias voltages that will bias the BJT's at or near the threshold of conduction in order to decrease the distortion seen at the base inputs of the transistors. A possible circuit is shown in Figure 3. Diodes D_1 and D_2 are biased on by resistors R_3 and R_4 . With $R_3 = R_4$, calculate the value of the resistors which will bias the two diodes at 1 mA. Assume a typical diode voltage of 0.65 V. Assemble the circuit using 1N4148 diodes.

Power should be applied to the circuit in Figure 3 with caution. If the diode voltages are larger than the threshold voltages for Q_1 and Q_2 , the bias current in the BJT's can become excessive and you will have smoking transistors. You should monitor the current output of the power supply as the dc voltages are increased. If you see a rapid increase in current, it will be necessary to connect a resistor between the bases of the BJT's to decrease the bias voltage across the bases. The value of this resistor must be tweaked to obtain an acceptable compromise. The threshold voltage of the 1N4148 diode should be slightly less than that of the BJT's so that this should not be a problem. When you have an operating circuit, repeat the measurements made for the circuit in Figure 1. The distortion observed at the output of the op amp should be decreased compared to that observed for the circuit in Figure 2. You should explain this in your report.

In real world applications of circuits such as these, the class of operation specifies how the two transistors are biased. If both transistors are cut off quiescently, the circuit is said to be biased class-C. Such is the case for the circuit in Figure 2. If a bias is added between the BJT bases such that the transistors are biased just at the threshold of conduction, the circuit is said to be biased class-B. If neither transistor cuts off when power is delivered to

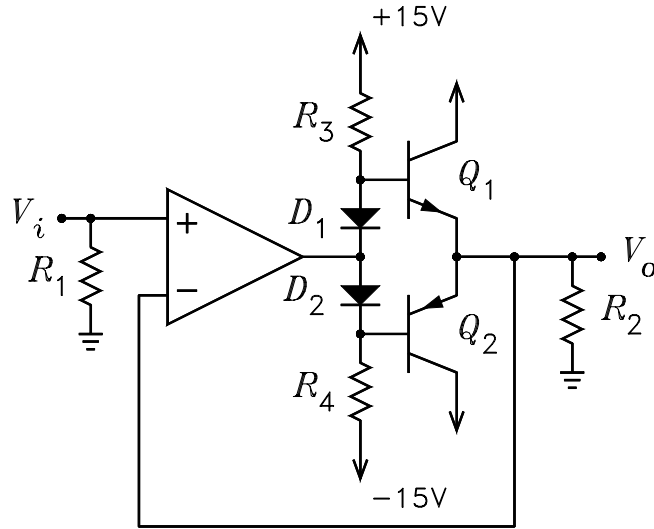


Figure 3: Circuit with bias diodes.

the load, the circuit is said to be biased class-A. It can be shown that a class-A amplifier must have a quiescent bias current in the output transistors that is equal to one-half the peak load current. For high-power amplifiers, this current can be quite large, causing high quiescent power dissipation in the transistors. A compromise is to bias both transistors just above the threshold of conduction. The amplifier is then said to be biased class-AB. This is the most commonly used method used in audio power amplifiers. The bias voltage is usually adjustable via a potentiometer. Thermal runaway can be a problem with these circuits unless the bias voltage is varied with the temperature of the transistors so as to keep the quiescent bias current constant. There are standard circuits used to achieve this that use a diode or a BJT attached to the heat sinks to sense the temperature and adjust the bias voltage accordingly. It is anticipated that the circuit as shown in Figure 3 will be biased class-B just below class-AB so that thermal runaway will not be a problem with the circuit.