

**BEE 332 Devices and Circuits II**  
**Spring 2017**  
**Design project: 0.5 W audio amplifier**

## **1 Objectives**

You are to design, verify in simulation and then build and demonstrate an audio amplifier capable of 1/2 W undistorted output at 1 KHz into an 8  $\Omega$  load with  $V_{in} = 0.5 V_{rms}$ .

## **2 Requirements**

### **2.1 Demonstration**

Your amplifier must deliver 1/2 W into 8  $\Omega$  with no clipping and I need to see it on the oscilloscope. It must also play music and I need to hear it. I'll try to be available additional hours to hear it when it happens. I'll have speakers and cables available so you can plug your amps into your iPods and cellphones for your demonstrations.

### **2.2 Report**

To document your design, you will need to provide the following. (This will be the shortest report you'll submit to me all quarter.)

1. A schematic of the entire design copied from your simulation.
2. A short explanation of how it works.
3. Screenshots with suitable on-screen measurements of  $V_{in}$  and  $V_{out}$  for  $V_{in} = 0.5 V_{rms}$  at 1 KHz and  $V_{out}$  into an 8  $\Omega$  load from both simulation and actual measurement.
4. Calculation of your amplifier's simulated and measured power output.
5. Bode plots of the gain in dB versus frequency from simulation and from measurements taken in a 1-2-5-10 sequence (i.e., 1 Hz, 2 Hz, 5 Hz, 10 Hz, 20 Hz, etc.) from 1 Hz to just past your 3 dB point.

Deadline is Friday, June 3, last day of instruction. No late submissions, please.

## **3 Discussion**

I think you'll find the design project is not as hard as you may have expected. You already know pretty much everything you need to know from Lab 4. If you kept your breadboards from that lab, half the job is done.

### 3.1 Circuit

To achieve 0.5 W output into 8 Ω with  $V_{in} = 0.5 V_{rms} = 1.414 V_{pp}$ , requires  $V_{out} = 2 V_{rms} = 5.656 V_{pp}$ . To achieve that with requires an  $A_v = 4$ .

$$P = I * E$$

$$P = \frac{E^2}{R}$$

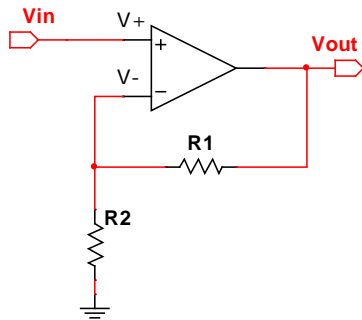
$$E = \text{sqrt}(P * R) = \text{sqrt}(0.5 * 8) = 2 V_{rms}$$

$$I = \frac{E}{R} = \frac{2}{8} = 250 mA_{rms}$$

$$A_v = \frac{V_{out}}{V_{in}} = \frac{2}{0.5} = 4$$

This can be achieved using simple variations of the multi-stage amplifier you built in Lab 4. But you will need to increase  $A_v$ , the supply voltages and the short circuit cutoff limits.

Your multi-stage amplifier used feedback to achieve unity gain. But you can adjust the gain with a voltage divider. For this op amp circuit,  $A_v = (R1 + R2)/R2$ .



$$V_+ = V_- = V_{in}$$

$$V_- = \left( \frac{R2}{R1 + R2} \right) * V_{out}$$

$$V_{in} = \left( \frac{R2}{R1 + R2} \right) * V_{out}$$

$$V_{out} = \left( \frac{R1 + R2}{R2} \right) * V_{in}$$

$$A_v = \frac{V_{out}}{V_{in}} = \frac{R1 + R2}{R2}$$

You'll probably also have to trim the bias points more carefully so you don't begin clipping on just one peak before you hit full power.

### 3.2 Bode plots

The gain of an amplifier or filter circuit will vary with frequency, either by design or because of the component limits. At any given frequency and with a sine wave input, we measure gain as either voltage gain,  $G = \text{Gain}(A_v) = |A_v| = |V_{\text{out}}/V_{\text{in}}|$ , or in dB (decibels), where  $\text{Gain}(\text{dB}) = 20 \log_{10}(G)$ . We can then plot this against frequency to show the bandwidth.

For example, here are the expected results for a low-pass filter, plotting gain versus frequency on a linear scale.

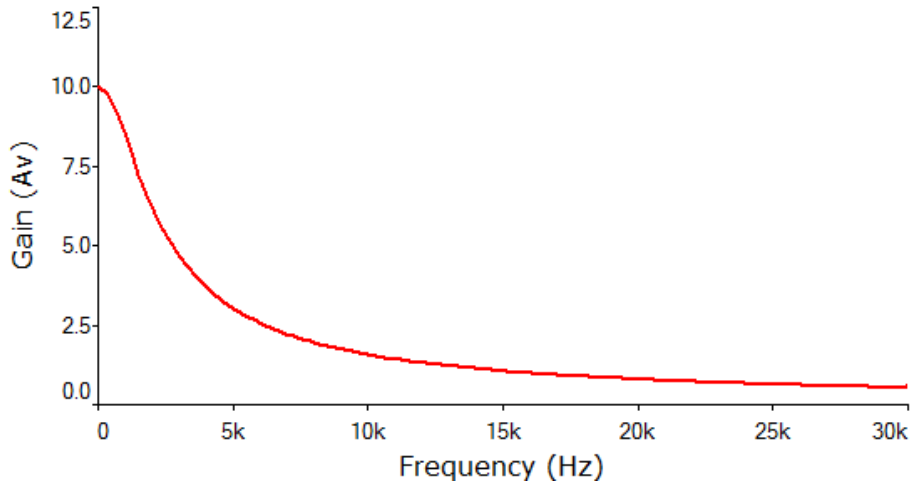


Figure 1. Linear plot of gain versus frequency.

A more useful and more common way to plot frequency response, however, is to plot gain in dB versus frequency on a log scale. This is called a Bode plot.

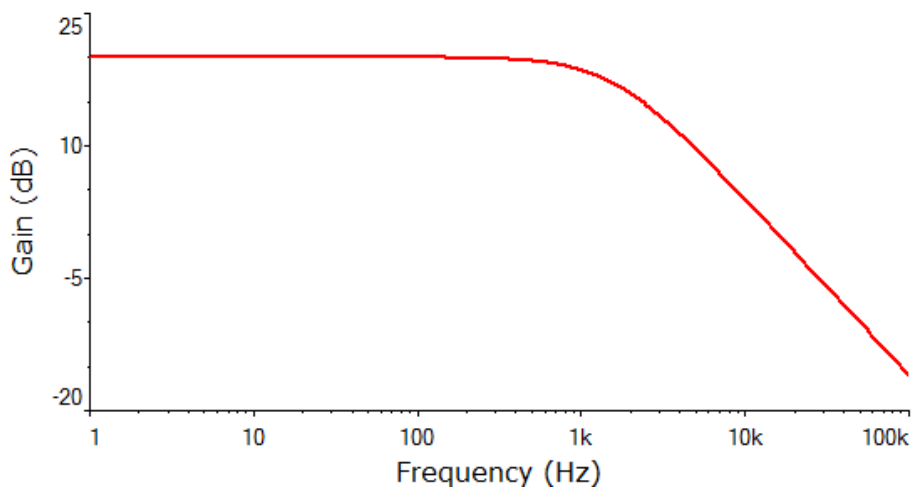


Figure 2. Bode plot of gain in dB versus frequency on a log scale.

The point at which the gain has fallen by 3 dB is referred to as the cutoff frequency.

### 3.3 Bode plots in Multisim

The easy way to generate a Bode plot in Multisim is with the Bode plotter, chosen from the same instrument toolbar where the oscilloscope is found.

The input is connected to  $V_{in}$  and the output to  $V_{out}$ . You must excite your circuit with  $V_{in}$  set to be a sine wave, but it doesn't matter much what amplitude and frequency you choose. Notice how the cursor can be used to find the 3 dB point. The "I" and "F" settings refer to the initial and final values on the horizontal and vertical axes; you will have to adjust these to get a usable display.

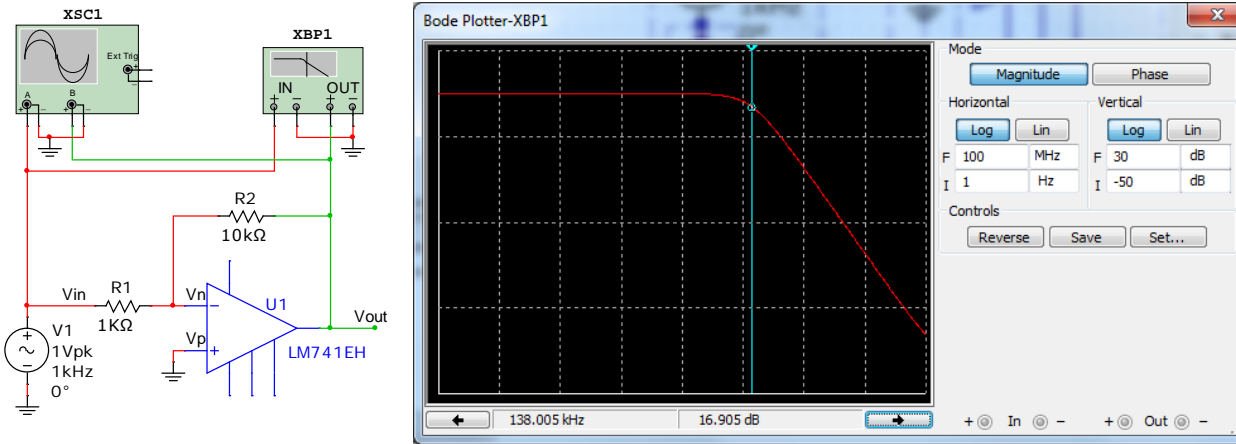


Figure 3. Using the Bode plotter.