SECTION TWO
Design the prototype
(Week 2 – 3)

SECTION OVERVIEW

In this section, you will design the schematic for your prototype USB powered audio amplifier. You will simulate and breadboard your design to check for functionality and consistency.

PRE-LAB (PART 1)

1. Review the three types of BJT amplifier configurations and complete the following table.
2. Comment on the advantage and disadvantages of each type of amplifier.
3. Design a single transistor amplifier with adjustable gain of 1 – 10 on paper.
4. Print out your simulation result showing outputs with gain of 1 – 10, with gain increment of 1.

Type	Gain equation	Input impedance	Output impedance	Advantage	Disadvantage
	A_v =	R_{in} =	R_{out} =		
	A_v =	R_{in} =	R_{out} =		
	A_v =	R_{in} =	R_{out} =		

PROCEDURE (PART 1)

Design specification

The project requirements are listed below. Your prototype must meet ALL of the "Absolute Minimum Requirements" now, and at least one requirement in the "Desired Features" after the 'Project Improvement' section.

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Absolute Minimum Requirements:

- ☐ USB powered
- ☐ Outputs at least 92dB
- ☐ Use only discrete components (resistor, capacitor, diode, transistor)
- ☐ Stereo output
- ☐ Adjustable gain
- ☐ System draws at least 90mA
- ☐ Total harmonic distortion less than 30%
- ☐ Receives audio signal from a computer
- ☐ Soldered

Desired Features

- Printed circuit board finish
- Louder output (more than 0.75 W)
- FM transmission
- Audio transmitted via USB
- Other student authored innovative improvements

Design Considerations

1. Are the components used in simulation reasonable?
    a. Can they be purchased?
    b. Will they handle the power dissipation needed?
2. How much current does your amplifier need? Can your amplifier supply enough current?
    a. Is your Beta affected?
3. What is the desired R_{in} and R_{out} for your amplifier(s)?
    a. Is a range allowable?

Design Process

1. First determine the audio signal you will need to amplify by measuring the signal output from your computer using the audio cable (provided in the lab kit) and oscilloscope.

A signal generator computer application will be helpful on determining the output signal amplitude. You may find an online audio frequency generator.

2. Determine the gain you will need to amplify the audio signal to the maximum
3. Design your gain amplifier
4. Simulate your design to verify functionality

PRE-LAB (PART 2)

1. Research the following basic output stage designs. The internet and Chapter 14 in Sedra/Smith should be helpful.
   a. Class A amplifier. What are the advantages and disadvantages to a Class A design?
   b. Class B amplifier. What are the advantages and disadvantages to a Class B design?
   c. Class AB amplifier. What are the advantages and disadvantages to a Class AB design?
   d. Class C amplifier. What are the advantages and disadvantages to a Class C design?

   (Hint: Two transistors, 2N4401 and 2N4403, as well as the audio transformer were included with your selection of parts for this section. A common design for this type of application is a Class-AB push-pull amplifier.)

2. Choose a topology from the list above or from your research (there are many more designs than those above and many of them could provide better characteristics than the simpler designs). Calculate the component values for your chosen topology based on the requirements of your system. You may want to check your textbook, look on-line, or ask professors for topology ideas. Also, there are a large number of schematic "cookbooks" with example circuits.

PROCEDURE (PART 2)

Design Process

Now you have your gain stage amplifier(s) simulated, does it supply enough current so that the audio output is audible? If not, find a solution to this problem using your knowledge from Pre-lab (part 2). Simulate your design result and fill out the table below.

Frequency	Vin (Peak-to-Peak)	Vout (Peak-to-Peak)	Phase Shift (Degrees)	THD
100Hz				
1kHz				
10kHz				
20KHz				

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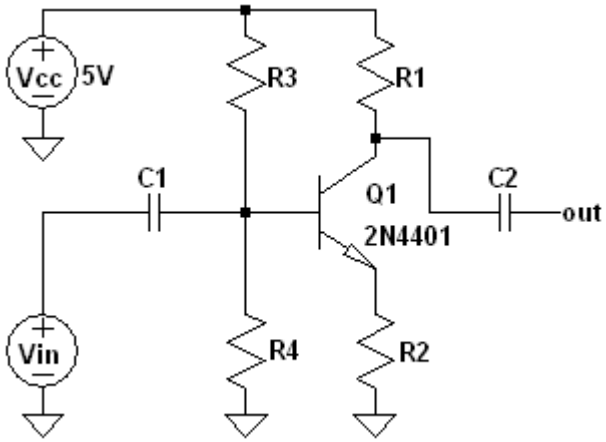
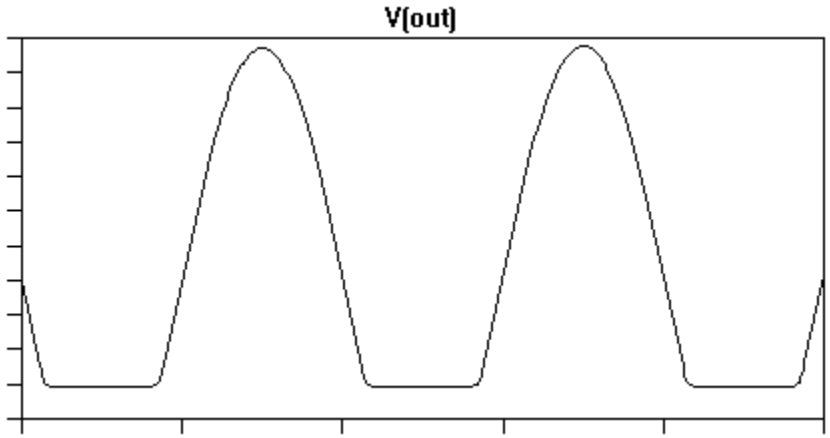
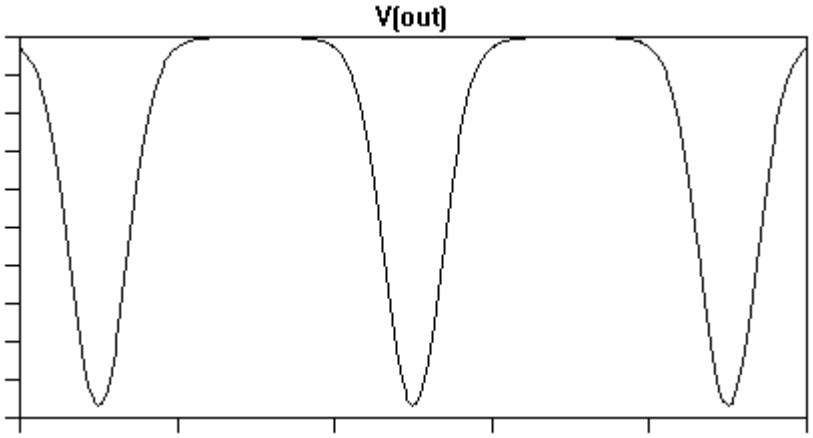
STUDY QUESTIONS

1. The following circuit has an input signal of 0.1Vp-p at 500 Hz. The output waveform is shown below. What could be the cause of the signal clipping? What can you do to make the circuit output a full waveform with a gain of at least 10? You may not adjust the supply and signal voltage. Please give calculation, equation, and reasoning.





2. Referring to the circuit in question #1, your output waveform is shown below. What could be the cause of this waveform? What can you do to make the circuit output a full waveform with a gain of at least 10? You may not adjust the supply and signal voltage. Please give calculation, equation, and reasoning.



TURN-IN

- ☐ A copy of your design process, include equation used and calculation results with units.
  a. Equations used to initially calculate all resistors in your design.
  b. Calculations showing that the circuit still functions for maximum and minimum values of Beta from the datasheet.
- ☐ A copy of your simulation result including:
  a. Input and Output Waveforms (on one graph)
  b. Magnitude and Phase Plots (on one graph)
  c. Input and Output Impedance
  d. The table of values based on frequency
- ☐ Answers to study questions (typed, with SPICE schematic, equation editor for equations).

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