



Introduction

Each student must make one oral presentation in lab during the semester. Contents for oral presentations are listed below for Lab 1. Talks start the second or third week of Lab 1.

Presentations will last **five minutes** and will be given at the beginning of the lab session. The presentations will typically describe work performed the previous week in lab by way of review. Practice your talk and be succinct. Stick to the five-minute time frame.

Presentation 1.1: Equivalent circuit for power supply

- a) Explain that your presentation will discuss the schematic diagram representation for the Agilent power supply used in Lab 1a.
- b) Draw a pictorial representation of the leads for the power supply, (i.e., sketch Fig. 4 from Lab 1a).
- c) Draw the schematic diagram shown below and explain that it is equivalent to the power supply. Be sure to show the reference (triangle).
- d) Explain that the power supply is like two batteries in series and that the reference is arbitrarily assigned as a point in the circuit that we think of as being at zero volts.
- e) Explain that the green banana plug connector on the power supply, (which we did not use), is actually connected to the ground pin on the power plug where the power supply is plugged into an outlet. That ground pin in the outlet eventually is connected to a metal rod buried in the ground.
- f) Explain that the reference and the ground are two distinct things, although people often refer to the reference as ground in a circuit. The reference may or may not actually be connected to ground. The distinction becomes important when two different circuits are connected together. In that case, whether or not the reference is actually grounded will determine whether there may be a "ground conflict" between two circuits, meaning the circuits effectively try to create different voltages for the grounds.
- c) Conclude your presentation by reminding the audience that care should be taken to refer to references and grounds correctly in order to avoid design mistakes.

Presentation 1.2: LED circuit model

- a) Explain that your presentation will describe a simple circuit model for an LED.
- b) Explain that the simple circuit model for an LED is voltage source with a value around 2.0 V.
- c) Say that you will draw a model of the power indicator circuit from Lab 1a, and draw a resistor in series with the 2.0 V source representing LED.
- d) Observe that as the power supply is adjusted from 2 V to 25 V, the LED would always have 2 V across it in our simplified model. Comment that this is why the graphs made in Lab 1a of LED current versus voltage tended to look like vertical lines at about 2 V.
- e) Explain that the model fails to make sense when the power supply is less than 2 V. The voltage source representing the LED only makes sense if the power supply is higher than 2 V. Otherwise, the LED would be able to generate power when the power supply is turned off!
- f) Conclude your talk by noting that modeling the LED as a voltage source (or voltage drop) works fairly well when the power supply is 12 V, as it normally is for Lab 1a.

Presentation 1.3: Exponential equation for LED

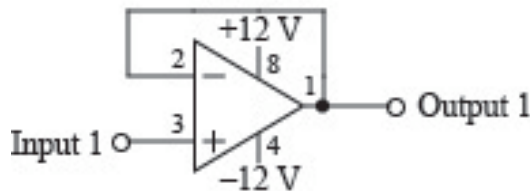
- Explain that your presentation will discuss a realistic model of an LED as having an exponential current versus voltage response.
- Sketch the data you obtained in Lab 1a for the LED current versus voltage. Make sure you have some data points for power supply voltages less than 2 V.
- Write the equation below that describes the current versus voltage for a diode:

$$i_{LED} = I_0 \left(e^{v_{LED}/v_T} - 1 \right)$$

- Explain that this equation is derived from solid state physics, (that EE students will cover in ECE 2280 and ECE 3200).
- Make the observation that I_0 is a constant that depends on how the diode is made, and v_T is the "thermal voltage" that has a value of about 26 mV.
- Sketch i_{LED} versus v_{LED} curve given by the above equation. (Use Matlab[®] or Excel to make a plot of the function beforehand.)
- Comment that the i_{LED} versus v_{LED} curve measured in lab looks similar to the calculated curve.
- Conclude by observing that the exponential curve may be crudely approximated by a vertical line, which is equivalent to the voltage drop model described in Talk 1.2.

Presentation 1.4: Derivation of *Output 1* versus *Input 1* for pre-amp

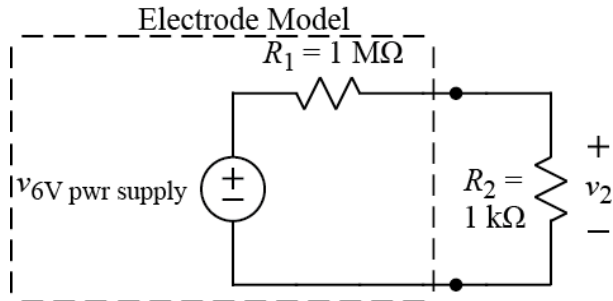
- Explain that your presentation will discuss the equations for voltage loops and current sums at nodes used to derive the equation for *Output 1* for the pre-amp circuit in Fig. 6 of Lab 1a.
- On the board, draw the circuit from Fig. 6 of Lab 1a, reproduced below.



- Add a wire across the bottom of the circuit and attach a triangle symbol for reference to it. The *Input 1* and *Output 1* voltages will be measured with the minus sign on this wire.
- Erase the op-amp and show a voltage-source between *Output 1* and the wire on the bottom.
- Add a voltage source labeled *Input 1* from the + input to the wire on the bottom.
- Comment that the voltage at the + input of the op-amp is *Input 1*.
- Comment that the op-amp has negative feedback from the output to the - input, which causes the voltage measured from the - input to the reference wire on the bottom to be the same as the voltage measured from the + input to the reference wire on the bottom.
- Observe that this means the voltage at the - input is also *Input 1*.
- Observe that since there is no voltage drop on a wire, this means the voltage at the op-amp output is also *Input 1*.
- Conclude your talk by noting that the pre-amp output voltage is the same as the input voltage, but the op-amp can supply up to 10 mA of current, whereas the input signal may be able to supply far less.

Presentation 1.5: Voltage-divider models of electrode and pre-amp output

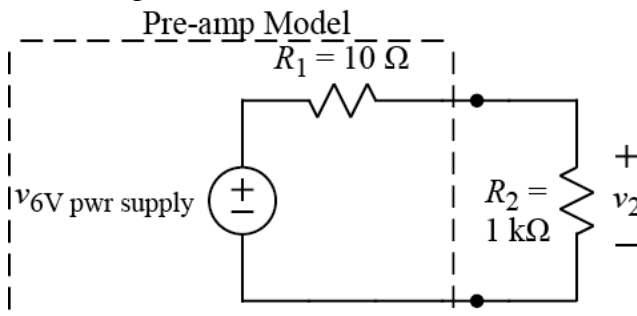
- a) Explain that your presentation will discuss the voltage-divider equations for the electrode model in Fig. 2 of Lab 1b and for the pre-amp model in Fig. 3 of Lab 1b. voltage loops and current sums at nodes used to derive the equation for Output 1 for the pre-amp circuit in Fig. 6 of Lab 1a.
- b) On the board, draw the voltage-divider model of an electrode from Fig. 2 of Lab 1b, reproduced below.



- c) Write the following voltage divider equation for v_2 versus $v_{6V \text{ pwr supply}}$ on the board:

$$v_2 = v_{6V \text{ pwr supply}} \cdot \frac{R_2}{R_1 + R_2} \approx v_{6V \text{ pwr supply}} \cdot \frac{1k}{1M} = \frac{v_{6V \text{ pwr supply}}}{1k}$$

- d) Comment that an electrode will produce an input voltage on the order of millivolts and the output voltage will be on the order of microvolts for this circuit.
- e) Comment that noise levels in a circuit may on the order of millivolts. Thus, microvolts would be lost in the noise.
- f) On the board, draw the voltage-divider model of the pre-amp output from Fig. 3 of Lab 1b, reproduced below.



- f) Write the following voltage divider equation for v_2 versus $v_{6V \text{ pwr supply}}$ on the board:

$$v_2 = v_{6V \text{ pwr supply}} \cdot \frac{R_2}{R_1 + R_2} \approx v_{6V \text{ pwr supply}} \cdot \frac{1k}{1k} = v_{6V \text{ pwr supply}}$$

- g) Comment that an electrode will produce an input voltage on the order of millivolts and the output voltage will be on the order of millivolts for this circuit.
- h) Conclude by commenting that noise levels in a circuit may on the order of millivolts. Thus, the output of the pre-amp may be somewhat noisy—but it is one thousand times

Presentation 1.6: Deriving expression for output voltage from differential amplifier

- a) Explain that your presentation will be a derivation of the output voltage for the differential amplifier, following the steps listed in part VI.A of Lab 1b.
- b) Use the steps from part VI.A of Lab 1b, reproduced her, to derive the following formula for output voltage, v_3 , of the differential amplifier. (Rather than doing algebra, just state in words how to obtain the results for each step of the derivation as listed here.)
 - 1) Use the circuit model in Fig. 5(a) and the voltage-divider formula to find voltage drop v_+ across R_4 .

$$\text{Result: } v_+ = v_2 \frac{R_4}{R_3 + R_4}$$

- 2) Use the circuit model in Fig. 5(b) and Kirchhoff's and Ohm's law to find voltage drop v_- across R_2 and v_3 . In other words, v_- is the sum of the voltage drops across R_2 and v_3 .

$$\text{Result: } v_- = v_1 \frac{R_2}{R_1 + R_2} + v_3 \frac{R_1}{R_1 + R_2}$$

- 3) State that the voltage drop across the + and - inputs equals 0 V, so $v_+ = v_-$.
- 4) Set $v_+ = v_-$ and solve for v_3 in terms of v_1 and v_2 .

$$\text{Result: } v_3 = \left(v_2 \frac{R_4}{R_3 + R_4} - v_1 \frac{R_2}{R_1 + R_2} \right) \frac{R_1 + R_2}{R_1}$$

- c) Conclude your talk by noting how ratios of resistor values, rather than individual resistor values, determine the value of v_3 .

Presentation 1.7: Differential and common mode signals

- a) Explain that your presentation will explain the idea of differential and common mode signals.
- b) Ask the listeners to consider two voltages, v_1 and v_2 , that arise from electrodes on the biceps.
- c) Describe the following scenario for what creates the signals on v_1 and v_2 :
 - 1) Small voltages from neuromuscular signals create a voltage difference between v_1 and v_2 that may be written as a negative and positive voltage:

$$v_{11} = -v_m, \quad v_{21} = +v_m$$

- 2) Small voltages from noise sources create voltages that change v_1 and v_2 by the same amount:

$$v_{12} = +v_n, \quad v_{22} = +v_n$$

- 3) The total voltages, v_1 and v_2 , are the sum and difference of the v_n and v_m :

$$v_1 = -v_m + v_n, \quad v_2 = +v_m + v_n$$

- d) Point out that when we measure an EMG, we want to eliminate v_n and amplify v_m .
- e) Conclude by pointing out that any pair of signals may be written as a differential mode signal like v_m and a common-mode signal like v_n .

$$v_1 = v_{cm} - \frac{v_{dm}}{2} \quad \text{and} \quad v_2 = v_{cm} + \frac{v_{dm}}{2}$$

where

$$v_{dm} \equiv v_2 - v_1 = 2v_m \quad \text{and} \quad v_{cm} \equiv \frac{(v_2 + v_1)}{2} = v_n$$

Presentation 1.8: Differential amplifier output when $R_1/R_2 = R_3/R_4$.

- a) Explain that your presentation will explain how choosing to make $R_1/R_2 = R_3/R_4$ in the differential amplifier causes the common mode signal to be removed and the differential mode signal to be amplified by the inverse of R_1/R_2 .
- b) Write down the formula for the output of the differential amplifier, v_3 :

$$v_3 = \left(v_2 \frac{R_4}{R_3 + R_4} - v_1 \frac{R_2}{R_1 + R_2} \right) \frac{R_1 + R_2}{R_1}$$

- c) Define the ratio \mathfrak{R} to be the ratio of R_1 to R_2 and R_3 to R_4 : $\mathfrak{R} = \frac{R_1}{R_2} = \frac{R_3}{R_4}$.

- d) Write down the formula for the output of the differential amplifier in terms of \mathfrak{R} :

$$v_3 = \left(v_2 \frac{1}{\mathfrak{R} + 1} - v_1 \frac{1}{\mathfrak{R} + 1} \right) \left(\frac{\mathfrak{R} + 1}{\mathfrak{R}} \right)$$

- e) Write down the simplified formula for the output of the differential amplifier in terms of \mathfrak{R} :

$$v_3 = (v_2 - v_1) \frac{1}{\mathfrak{R}}$$

- f) Conclude by pointing out that the differential amplifier will output only difference signal and that high gain is achieved by making R_2 and R_4 much larger than R_1 and R_3 .

Presentation 1.9: Using superposition to find v_3

- a) Explain that your presentation will demonstrate how to use the concept of superposition to derive the gain of the differential amplifier.
- b) Draw the differential amplifier circuit on the board.
- c) Explain that you are going to turn on the inputs, v_1 and v_2 , to the amplifier one at a time and treat the other input as 0 V, meaning that voltage source acts like a wire.
- d) Write down the formula for v_3 when v_1 alone is turned on:

$$v_+ = 0 \text{ V} \quad v_- = v_1 \frac{R_2}{R_1 + R_2} + v_3 \frac{R_1}{R_1 + R_2} \quad v_+ = v_- \Rightarrow v_3 = -v_1 \frac{R_2}{R_1 + R_2} \frac{R_1 + R_2}{R_1}$$

- e) Write down the formula for v_3 when v_2 alone is turned on:

$$v_+ = v_2 \frac{R_4}{R_3 + R_4} \quad v_- = v_3 \frac{R_1}{R_1 + R_2} \quad v_+ = v_- \Rightarrow v_3 = v_2 \frac{R_4}{R_3 + R_4} \frac{R_1 + R_2}{R_1}$$

- f) Comment that the sum of the two answers is the formula for v_3 .
- g) Conclude your talk by noting that superposition means summing results for power supplies, whether current or voltage sources, turned on one at a time. It gives the correct answer for any current or voltage in the circuit.