ECE 1270 LABORATORY PROJECT NO. 2

LAB 2 Oral Presentation Contents

Introduction

Each student must make one oral presentation in lab during the semester. Contents for oral presentations are listed below for Lab 2. Talks start the second week of Lab 2.

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 or current week in lab by way of review. Practice your talk and be succinct. Stick to the five-minute time frame.

Presentation 2.1: Comparator circuit overview

a) Explain that your presentation will discuss the comparator circuit of Lab 2, Fig. 3.
b) Draw the circuit of Fig. 3 on the board. Show a dependent voltage source driving the output, v_o, of the op-amp. Label the dependent source with a value of $v_o = A(v_1 - v_2)$ where $A = 10^5$. (v_1 and v_2 are the voltages at the + and – inputs of the op-amp.)
c) Point out that the potentiometer forms a voltage divider that gives an adjustable value of v_2.
d) Comment that $v_1 \neq v_2$, since it is impossible to adjust the potentiometer to output exactly 0 V. Point out that, even with a voltage drop across the op-amp inputs of just 10 μV, the op-amp output will be 1 V. Consequently, for any $v_1 - v_2$ we can achieve in practice, v_o becomes a very large positive or negative value, limited only by the power supply voltage of the op-amp (which v_o cannot exceed). Thus, we may model the op-amp as a fixed positive or negative voltage source (until the output switches from positive to negative).
e) Replace the dependent voltage source in the op-amp with an independent source that has a value of $\mathrm{v}_\mathrm{o} = \pm\mathrm{V}_\mathrm{rail} = \pm$power supply voltage for the op-amp.
f) Conclude your presentation by commenting that treating the op-amp as a voltage source makes circuit analysis easier later on.

Presentation 2.2: Comparator circuit output with no load

a) Explain that your presentation will discuss the value of the comparator circuit output, (i.e., the op-amp output), with no load resistance, and that this voltage is the so-called "rail voltage".
b) Draw the circuit of Fig. 3 on the board, without the load resistor, R_L.
c) Draw Table II from Lab 2 on the board, and list the values you measured for comparator input, v_2, and comparator output, v_0.
d) Comment that the output voltage for the op-amp is slightly less than the power supply voltages because some voltage drops are required inside the op-amp to make the output driver circuits work.
e) Finish your talk by noting the values for v_0 in Table II that you would choose to approximate the actual rail voltage of the op-amp, meaning the highest (or lowest) voltage it outputs.

Presentation 2.3: Comparator circuit output with varying loads

a) Explain that your presentation will discuss the behavior of the comparator circuit output, (i.e., the op-amp output), as a function of the load resistance.

b) Draw the circuit of Fig. 3 on the board, including the load resistor, R_L.

c) Draw Table III from Lab 2 on the board, and list the values you measured for comparator input, v_2, and comparator output, v_0.

d) Comment that the output voltage for the op-amp is roughly constant, meaning the op-amp may be modeled as a voltage source, as claimed in Presentation 2.1.

e) Point out that the smallest resistor used is 1 kΩ because a lower resistance could draw more than the maximum 10 mA that the op-amp is able to source, and this might cause the op-amp output voltage to droop significantly.

f) Finish your talk by noting the values for v_0 in Table III that you would choose to approximate the actual rail voltages of the op-amp, meaning the highest and lowest voltages it outputs.

Presentation 2.4: Operation of Schmidt trigger

a) Explain that your presentation will discuss the operation of the Schmidt trigger circuit.

b) Draw the circuit of Fig. 5 on the board.

c) Point out that the circuit has only positive feedback and the input voltages are not equal, meaning the output, v_0, will be at the positive or negative rail voltage.

d) Comment that the output voltage for the op-amp, v_0, may be treated as a voltage source, and R_1 and R_2 my be treated as a voltage divider driven by v_0.

e) Tell the audience that, using the voltage-divider formula, the trigger voltage for the Schmidt trigger circuit, i.e., v_1, will be as follows:

$$v_1 = v_0 \frac{R_1}{R_1 + R_2} = \pm v_{\text{rail}} \frac{R_1}{R_1 + R_2}$$

f) Finish your talk by noting the output of the Schmidt trigger circuit switches from high to low or vice versa when $v_1 = v_2$, and the positive feedback of the op-amp causes the trigger voltage, v_1, to shift to the opposite polarity when switching occurs.

Presentation 2.5: LED circuit for Schmidt trigger

a) Explain that your presentation will discuss the LED on the output of the Schmidt trigger circuit.

b) Draw the circuit of Fig. 5 on the board.

c) Point out that the circuit has only positive feedback and the input voltages are not equal, meaning the output, v_0, will be at the positive or negative rail voltage.

d) Comment that the output voltage for the op-amp, v_0, may be treated as a voltage source driving two separate circuits: the voltage divider formed by R_1 and R_2, and the LED and R_4. Thus, the two circuits may be analyzed separately.

e) Tell the audience that the LED acts like a 2 V drop (approximately), as was shown in Lab 1a, and the current in R_4 and in the LED is given by the following formula:

$$i_{\text{LED}} = \frac{v_0 - 2\,\text{V}}{R_4} \approx \frac{7.4\,\text{V} - 2\,\text{V}}{1\,\text{k}\Omega} = 5.4\,\text{mA}$$

f) Finish your talk by noting the typical LED's have maximum currents of either 20 mA or 30 mA, and the LED current may be controlled by the choice of R_4.

Presentation 2.6: Superposition solution for v_2

a) Explain that your presentation will discuss the calculation of v_2 from the potentiometer using superposition.

b) Draw the circuit of Fig. 6 on the board, and point out that the part of the circuit generating v_2 may be drawn as two 9 V v-sources and two resistors that comprise R_3. (Note that the point between the 9 V v-sources is tied to reference.) Then draw that circuit, labeling the two parts of R_3 as $R_{3\text{top}}$ and $R_{3\text{bottom}}$.

c) Comment that v_2 may be found by turning on one 9 V source at a time, finding the v_2 with only that source on, and summing the results for the two sources. This is superposition.

d) Note that the equations for v_2's are voltage dividers, and write the resulting superposition equation for v_2: (Note that 100 kΩ = $R_{3\text{top}} + R_{3\text{bottom}}$)

$$v_2 = +9\,\mathrm{V}\frac{R_{\text{bottom}}}{100\,\mathrm{k\Omega}} + -9\,\mathrm{V}\frac{R_{\text{top}}}{100\,\mathrm{k\Omega}}$$

f) Finish your talk by noting that v_2 changes continuously from –9 V to +9 V as the potentiometer is adjusted, and this may be seen in the superposition solution where $R_{3\text{top}}$ and $R_{3\text{bottom}}$ vary between 0 Ω and 100 kΩ.

Presentation 2.7: Solution of *RC* charging circuit

a) Explain that your presentation will discuss the solution of a simple capacitor charging circuit like the one consisting of R_3 and C_1 in the circuit for Lab 2, Fig. 7.

b) Draw the capacitor charging circuit in Fig. 7, including labels, and add a label for v_C with + on the top side of the *C* and – on the bottom side of the *C*. ($v_C = v_2$)

c) Describe the capacitor as acting like a water tank that fills through a hose (the resistor) until it reaches the height of the reservoir (v_{s2}).

d) Write down the equation that defines the capacitor's behavior:

$$i(t) = C\frac{dv_C(t)}{dt}$$

e) Note that we can write a circuit equation by equating the current in the resistor with the current in the capacitor:

$$\frac{v_{s2} - v_C(t)}{R_3} = C\frac{dv_C(t)}{dt}$$

f) Finish your talk by noting that this differential equation always has the same form of solution defined in terms of the initial voltage on the capacitor, the final voltage on the capacitor, and the *RC* time constant, which is equal to the resistor times the capacitor:

$$v_C(t) = v_C(t \to \infty) + [v_C(t = 0^+) - v_C(t \to \infty)]e^{-t/R_3C}$$

Presentation 2.8: Graphical interpretation of v_2 (i.e., v_C) for final oscillator

a) Explain that your presentation will discuss the operation of the final oscillator.

b) Plot the op-amp output, v_o, as a function of time. That is, draw a square wave that varies between $\pm V_{\text{rail}}$. Assume the square wave rate is about 10 Hz.

c) Draw horizontal dashed lines across the plot at heights $v_1 = \pm V_{\text{rail}}\ R_1/(R_1+R_2)$. Comment that v_o switches from high to low, (and v_1 also switches from high to low) or vice versa when v_C reaches a value of $\pm v_1$.

d) Draw the exponential curves representing $v_C(t)$. The rising part of the curve resembles an ocean wave moving left to right that is just about to curl over and break. The falling part of the curve resembles a downhill slide that flattens out at the bottom. The rise starts when the op-amp output, v_o, switches from low to high, and the fall starts when v_o switches from high to low.

e) Comment that $v_C(t)$ heads toward a final asymptotic value of $\pm v_{rail}$ but hits the trip point at $\pm v_1$ before it gets there.

f) Conclude your presentation by noting that the flashing rate is directly proportional to R_3C. That is, doubling R_3 or C doubles the time, T, it takes for v_o to switch from high to low or vice versa.

Presentation 2.9: Finding the equation for v_2 (i.e., v_C) in final oscillator circuit

a) Explain that your presentation will focus on finding the equation describing the capacitor charging circuit consisting of R_3 and C_1 in the final oscillator circuit.

b) Draw the capacitor charging circuit consisting of an independent source (whose value is $v_o = \pm V_{rail}$), R_3, and C_1, and note that you will assume $v_o = +V_{rail}$ for the remainder of your talk so you can illustrate the charging of the capacitor, C_1.

c) Write down the general solution for the capacitor charging circuit and comment that the goal is to determine $v_C(t = 0^+)$ and $v_C(t \to \infty)$:

$$v_C(t) = v_C(t \to \infty) + [v_C(t = 0^+) - v_C(t \to \infty)]e^{-t/R_3C}$$

d) Comment that the oscillator circuit output voltage switched to $v_o = +V_{rail}$ when $v_2 = v_1$ = voltage divider value given by $v_o = -V_{rail}\, R_1/(R_1+R_2)$. Since the capacitor voltage cannot change instantly, it follows that the capacitor voltage (which was equal to v_2) equaled $-V_{rail}\, R_1/(R_1+R_2)$ immediately after switching. This is, therefore, the initial voltage on the capacitor.

$$v_C(t = 0^+) = -v_{rail}\frac{R_1}{R_1 + R_2}$$

e) Explain that, since $v_o = +V_{rail}$, the capacitor charges toward a final voltage of $v_o = +V_{rail}$. The output of the circuit will switch before the capacitor voltage reaches its final value, but this is the value it is heading towards. This is, therefore, the final voltage for the capacitor.

$$v_C(t \to \infty) = +v_{rail}$$

f) Conclude your presentation by noting that we know the initial and final voltage values for the capacitor charging equation, and we can use the general solution equation to design values for R_1, R_2, R_3 and C that will achieve a given flash rate.