ECE210 Laboratory
PRE-LAB#2

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Net ID: varenya3 ,
Student Name:

Varenya Jain

Lab section:

ABH

# *Lab 2: Op-amps*

Labs 2 and 3 study operational amplifiers, or "op-amps." Op-amps were originally developed to implement mathematical operations in analog computers, hence their name. Today, op-amps are commonly used to build amplifiers, active filters, and buffers. You will work with many of these circuits in lab. The following table contrasts ideal versus practical characteristics of typical op-amps.

| Op-Amp Property | Ideal | in practice |
|---|---|---|
| Gain $A$ | $\infty$ | very large, $\sim 10^6$ and constrained by supply voltage |
| $R_i$ | $\infty$ | very large, $\sim 10^6\,\Omega$ |
| $R_o$ | 0 | very small, $\sim 15\,\Omega$ |
| Frequency response | flat | gain depends on frequency |

The objective of this experiment is to gain experience in the design and construction of operational amplifier circuits. You also will examine some non ideal op-amp behavior.

By the end of Lab 2, you will have designed and built two amplifiers for your radio circuit. Once you have verified that they work, you will connect them to your envelope detector from Lab 1 and listen to synthetic AM signals.

## 1 Prelab

In the prelab exercises, you will review the analysis of op-amp circuits and design amplifiers for your radio circuit.

1. Assuming an ideal op-amp, derive an expression for the output voltage $v_o$ in the circuit of Figure 1 in terms of $v_1$, $v_2$, and $v_3$. Hint: Notice that $v_+$ is equal to $v_-$ , then write the KCL eq. for the node $v_-$ and solve for $v_o$.

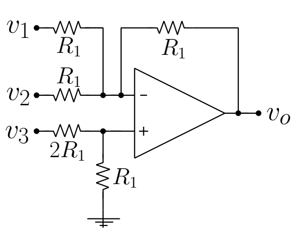



Figure 1: Op-amp circuit.

Show your work:

(v1 - v)/R1 + (v2 - v)/R1 = (v - v0)/R1,

(v3)/3 = v

v1 + v2 - (2*v3)/3 = (v3)/3 - v0

v0 = v3 - v1 - v2

$v_o =$ v3 - v2 - v1 (____/5)

2. Assuming an ideal op-amp, write two KCL equations in terms of $v_x$ that relates the output voltage to the input voltage for the circuit in Figure 2 (you do not need to solve the KCL equations). Simplify your expressions as much as possible.

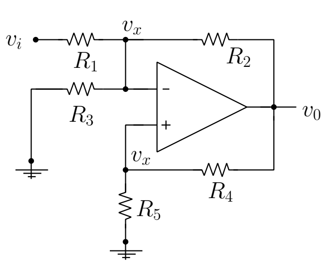



Figure 2: Op-amp circuit.

KCL1 : (vi - vx)/R1 = (vx)/R3 + (vx - v0)/R2 (____/2)

KCL2 : (vx)/R5 = (v0 - vx)/R4 (____/2)

3. Again assuming an ideal op-amp, derive an expression for the output voltage $v_o$ in the circuit in Figure 3.

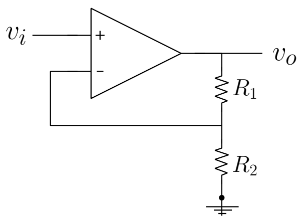



Figure 3: Op-amp circuit.

Show your work:

(v0 - vi)/R1 = (vi)/R2, v0 = (R1)*( ((vi)/R2) + ((vi)/R1) )

v0 = vi + (R1/R2) * vi = vi/2 * (R1 + R2);

(R1 + R2)/R2 = 21 = 1 + R1/R2,
R1/R2 = 20, R1 = 20 * R2

$v_o =$ vi(R1 + R2)/2 (____/5)

(a) For a gain $\frac{v_o}{v_i}$ of 2, how must $R_1$ and $R_2$ be related? R1 = R2 (____/2)

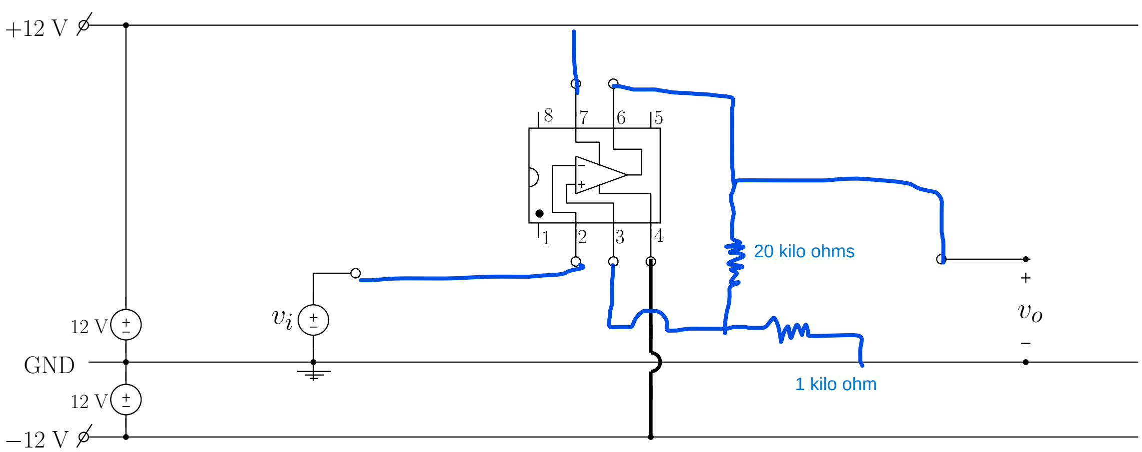
(b) For a gain $\frac{v_o}{v_i}$ of 21, how must $R_1$ and $R_2$ be related? R1 = 20 * R2 (____/2)

(c) How do you build two amplifiers, one with a gain of two and one with a gain of 21, given the following four resistors: one 1 k$\Omega$, two 10 k$\Omega$, and one 20 k$\Omega$?

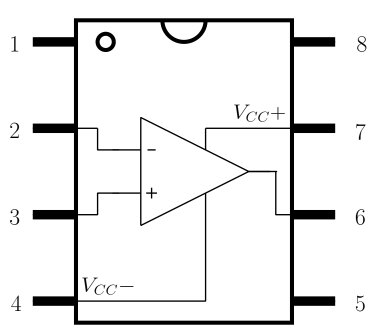
| | |
|---|---|
| Gain of 2 : $R_1 =$ 10 kilo Ohms and $R_2 =$ 10 kilo Ohms | Gain of 21: $R_1 =$ 20 kilo Ohms and $R_2 =$ 1 kilo Ohm |

(____/2)

(d) Using the pin-out diagram in Figure 4 as a reference, draw how you will wire the amplifier with a gain of 21. Draw in resistors and wires as needed. Include wires for input $v_i$, output $v_0$ and the bias voltages $V_{CC}+$ and $V_{CC}-$. As an example "$V_{CC}-$" is already connected.




(____/5)




| Pins 1,5 | offset null correction — not used |
|---|---|
| 2 | inverting input (-) |
| 3 | non-inverting input (+) |
| 4 | $V_{CC}-$ supply set to -5 V (DC) |
| 7 | $V_{CC}+$ supply set to 5 V (DC) |
| 6 | output voltage $v_o$ |
| 8 | not connected |

Figure 4: Pin-out diagram for the 741 op-amp.