Tutorial 5 Questions

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Overview

* **Learning Objectives:**
  Analyze circuits with ideal operational amplifiers
* **Basics**
  - Symbols & Rules
  - Operational Amplifiers
    - The Ideal op-amp Model
    - Ideal op-amp in a negative feedback configuration
* **Questions & Summary**

- **Operational Amplifiers**

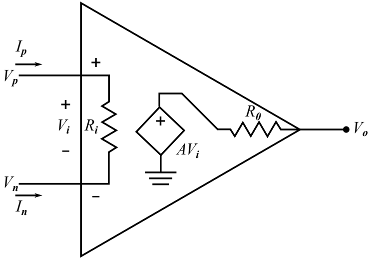


Figure : **Equivalent circuit model of op-amp device**

In the absence of any load at the output, the output voltage is

$$V_o = AV_i = A(V_p - V_n)$$

Operational Amplifiers(Recap)

- **Operational Amplifiers**

  In the absence of any load at the output, the output voltage is
  $$V_o = AV_i = A(V_p - V_n)$$

Which indicates that the output voltage V_o is a function of the difference between the input voltages V_p and V_n. For this reason op-amps are **difference amplifiers**.

Operational Amplifiers(Recap)

- **The Ideal Op-amp Model**

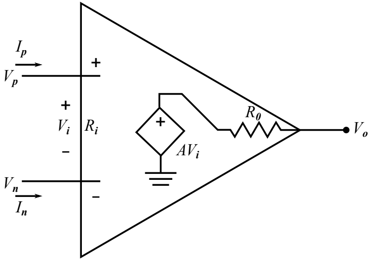


Figure : **Ideal op-amp model**

Operational Amplifiers(Recap)

An ideal op-amp is a device which acts as an ideal voltage controlled voltage source. Referring to Figure in the previous slide, this implies that the device will have the following characteristics:

* **No current flows into the input terminals** of the device. This is equivalent to having an infinite input resistance $R_i = \infty$. In practical terms this implies that the amplifier device will make no power demands on the input signal source.
* **Have a zero output resistance** $(R_o = 0)$. This implies that the output voltage is independent of the load connected to the output.

- **The Ideal Op-amp Model**

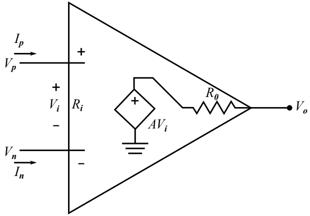


Figure : **Ideal op-amp model**

* In summary, the ideal op-amp conditions are:

- $I_p = I_n = 0$ **No current into the input terminals**
- $R_i \to \infty$ **Infinite input resistance**
- $R_o = 0$ **Zero output resistance**
- $A \to \infty$ **Infinite open loop gain**

Operational Amplifiers(Recap)

- When an op-amp is arranged with a **negative feedback** the ideal rules are:

∗ $I_p = I_n = 0$: input current constraint

∗ $V_n = V_p$: input voltage constraint

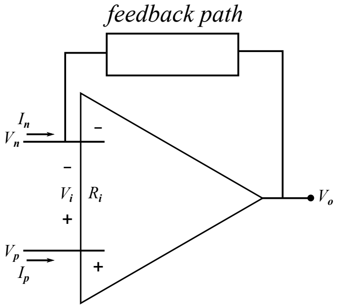
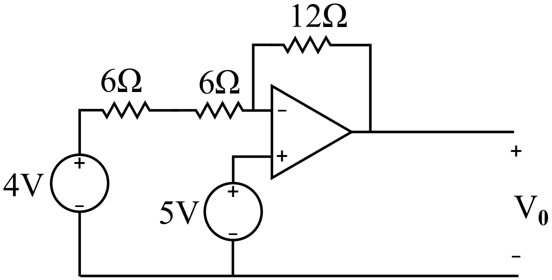


Figure : **Basic negative feedback configuration.**

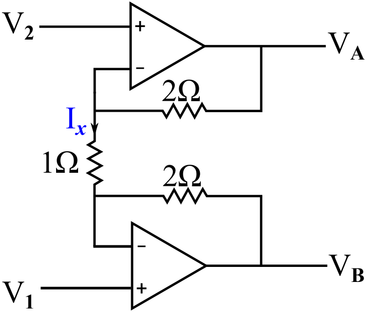
Question 1

* Determine V_0 in the following circuit. Assume that the op-amp is ideal.



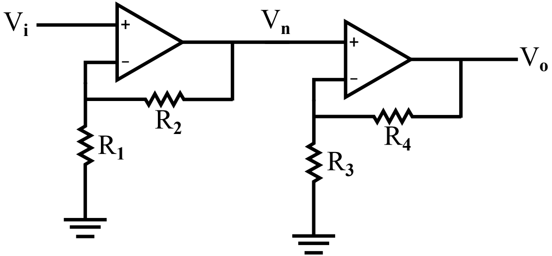
Question 2

- Determine the current I_x when $V_1 = 1V$ and $V_2 = 2V$.
- Determine the voltage V_A when $V_1 = 1V$ and $V_2 = 2V$.
- Determine a general expression for V_A in terms of V_1 and V_2.



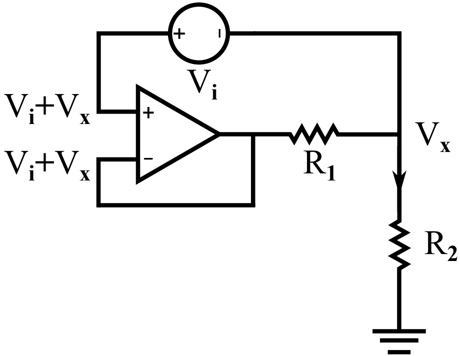
Question 3

* Use a single op-amp and resistors to make a circuit that is equivalent to the following circuit.



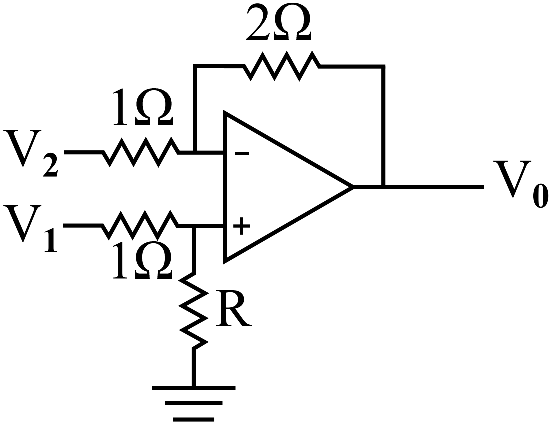
Question 4

* Use the ideal op-amp model($V_+ = V_-$)to determine an expression for the output current I_0 in terms of the input voltage V_i and resistors R_1 and R_2.



Question 5

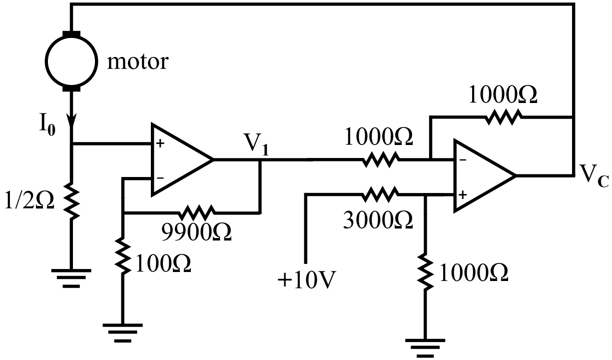
* Determine R so that $V_0 = 2(V_1 - V_2)$.



Question 6

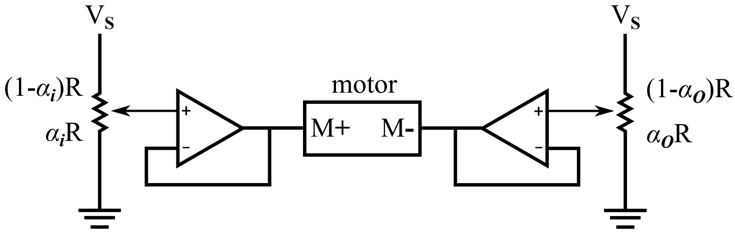
* A proportional controller that regulates the current through a motor by setting the motor voltage V_C to $V_C = K(I_d - I_0)$

* K is the gain(ohms)
* I_d is the desired motor current
* I_0 is the actual current through the motor.



Question 7

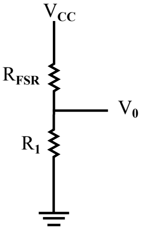
* The shaft angle of the output pot tracks that of the input pot
  * If the person turn the left potentiometer (the input pot), then the motor will turn the right potentiometer (the output pot)



Question 8

- You have to design a hammer machine(i.e. using a hammer to hit a platform to see how strong the participants are). The design goal is to generate an output voltage (V_o) which is proportional to the force(F) applied on the hammer, i.e. $V_o = m \times F + C$, with $m > 0$ and $C > 0$.
- (a) You found a force-sensitive resistor (FSR) from the catalog, which can be modeled by $R_{FSR} = 10k\Omega/F$

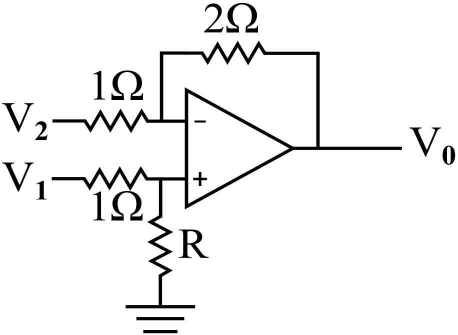
- You then design a circuit as a potential divider. Will this circuit correctly implement?
- No, because V_o is not linearly proportional to F.



Appendix(Question 9)

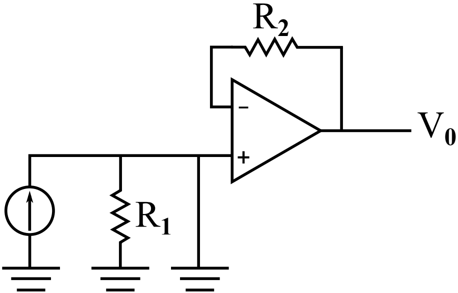
* Fill in the values of R_1 and R_2 required to satisfy the equations in the left column of the following table. The values must be non-negative (i.e., in the range $[0, \infty]$)

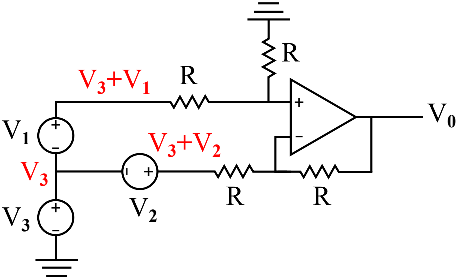
	R_1	R_2
$V_0 = 2V_2 - 2V_1$		
$V_0 = V_2 - V_1$		
$V_0 = 4V_2 - 2V_1$		



Appendix(Question 10)

* What is V_o?

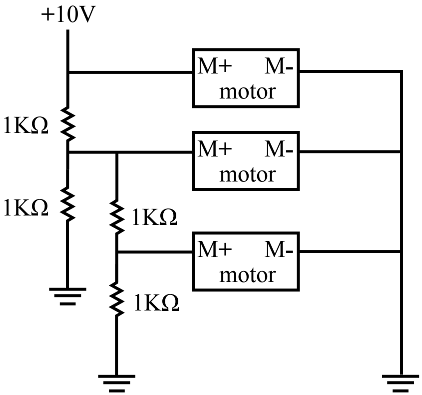




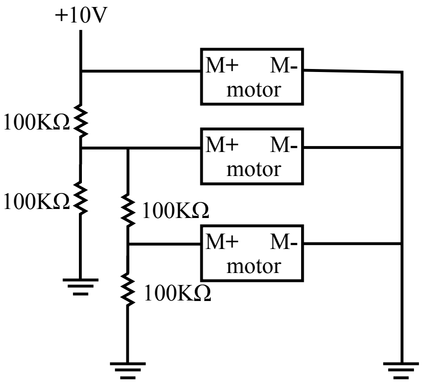
Appendix(Question 11)

- Students **Jody**, **Chris**, **Pat**, **Kim** and **Leon** are trying to design a controller for a display of three robotic mice in the Rube Goldberg Machine, using a $10V$ power supply and three motors.
  - The first is supposed to spin as fast as possible (in one direction only), the second at half of the speed of the first, and the third at half of the speed of the second.
  - Assume the motors have a resistance of approximately 5Ω and that rotational speed is proportional to voltage.
- For each design, indicate the voltage across each of the motors.

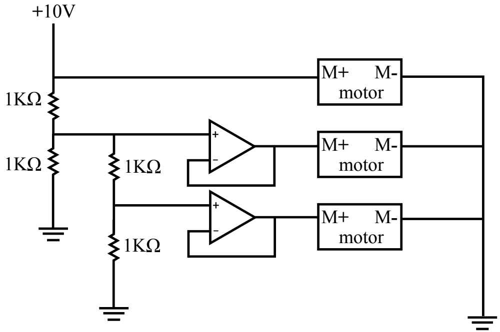
Appendix(Question 11 – Jody's Design)



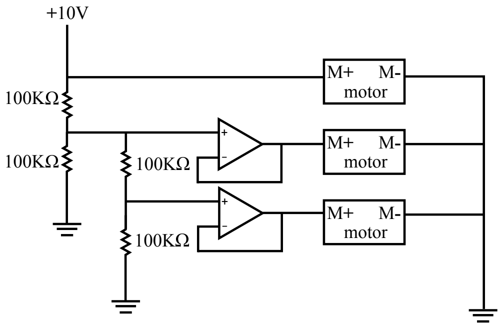
Appendix(Question 11 – Chris's Design)



Appendix(Question 11 – Pat's Design)



Appendix(Question 11 – Kim's Design)



Appendix(Question 11 – Leon's Design)