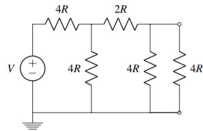


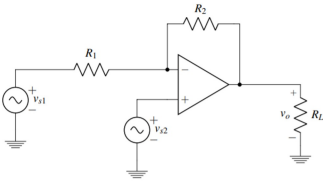
1. OPTIONAL: Power to Resist (from Spring 2018 midterm 2)

Find the power dissipated by the voltage source in the circuit below. Be sure to use passive sign convention



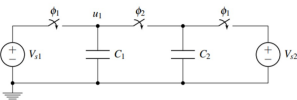
2. OPTIONAL: Amplifier with Multiple Inputs

In this problem we will use superposition and the Golden Rules to find the output of the following op amp circuit with multiple inputs:



4. OPTIONAL: Capacitive Charge Sharing (from Spring 2020 Midterm 2)

Consider the circuit below with $C_1 = C_2 = 1 \mu\text{F}$ and two switches ϕ_1, ϕ_2 . Suppose that initially the switch ϕ_1 is closed and ϕ_2 is open such that C_1 and C_2 are charged through the corresponding voltage sources $V_1 = 1\text{V}$ and $V_2 = 2\text{V}$.



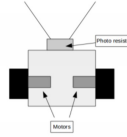
- (a) How much charge is on C_1 and C_2 ? How much energy is stored in each of the capacitors? What is the total stored energy?
- (b) Now suppose that some time later, switch ϕ_1 opens and switch ϕ_2 closes. What is the value of voltage v_1 at steady state?

3. OPTIONAL: PetBot Design (from Fall 2016 Final exam)

In this problem you will design circuits to control PetBot, a simple robot designed to follow light. PetBot measures light using a photoresistor, which is a light-sensitive resistor. As it is exposed to more light, its resistance decreases. The diagram below shows the circuit symbol for a photoresistor.



The basic layout of PetBot can be seen below. It is driven by one motor that will be modeled as a resistor. PetBot drives forward (towards the said light source) when a positive voltage is applied across the motor, and conversely a negative applied voltage drives PetBot backward (away from the light source). In this system the light sensor is mounted to the front of the robot, and the speed of PetBot is proportional to the applied voltage to the motor.



(a) **Speed control**

In our first circuit design, we will begin by making PetBot decrease speed as it drives towards light. Design a motor-driving circuit that outputs a decreasing positive motor voltage as PetBot drives toward the light source. The motor voltage should be at least 5V when far away from the light. At this far away from the light source, the photoresistor value will be 10kΩ, and then drop towards 100Ω as it approaches the light.

In your design, you may use any number of resistors and op-amps. You also have access to voltage sources of 10V and -10V. Based on your circuit, derive an expression for the motor voltage as a function of the circuit components that you used.

NOTE! Since the motor is a resistor, the circuit design MUST have a buffer so that the applied voltage to the motor does not depend on its resistance.

(b) **Distance control**

When the PetBot stops at a distance of 1m away from the light, the photo-resistor has a value 1kΩ. We would like to have the PetBot drive away when closer than 1m from the light (so for lower R_p), and drive towards the light when exceeding 1m (so for greater R_p).

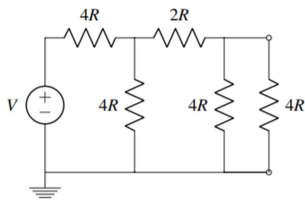
Design a comparator circuit that outputs a positive motor voltage when the PetBot exceeds 1 m in distance from the flashlight (making the PetBot move toward it), and a negative voltage when PetBot is within 1 m of flashlight (making the PetBot back away from the flashlight).

In your design, you may use any number of resistors along with the comparator. You also have access to voltage sources of 10V and -10V.

We probably won't get to every problem so use the poll to choose which are your top 2 problems that you would like to go over.

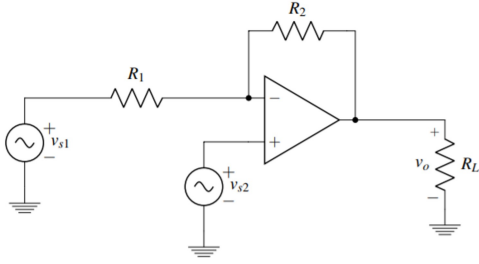
1. OPTIONAL: Power to Resist (from Spring 2018 midterm 2)

Find the power dissipated by the voltage source in the circuit below. Be sure to use passive sign convention.

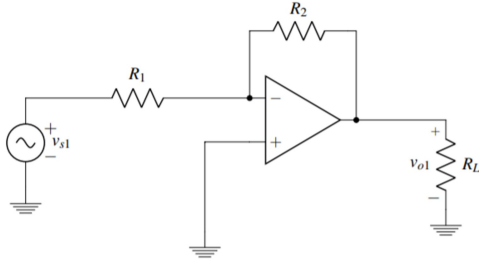


2. OPTIONAL: Amplifier with Multiple Inputs

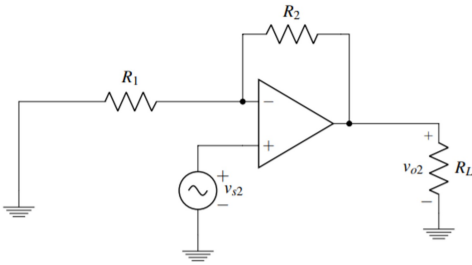
In this problem we will use superposition and the Golden Rules to find the output of the following op amp circuit with multiple inputs:



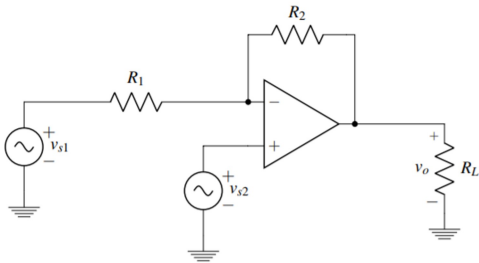
(a) First, let's turn off v_{s2} . Use the **Golden Rules** to find v_{o1} for the circuit below.



(b) Now let's turn off v_{s1} . Use the **Golden Rules** to find v_{o2} for the circuit below.



(c) Use **superposition** to find the output voltage v_o for the circuit shown below.

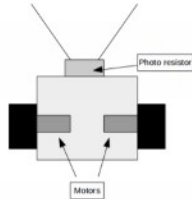


3. OPTIONAL: PetBot Design (from Fall 2016 Final exam)

In this problem you will design circuits to control PetBot, a simple robot designed to follow light. PetBot measures light using a photoresistor, which is a light-sensitive resistor. **As it is exposed to more light, its resistance decreases.** The diagram below shows the circuit symbol for a photoresistor.



The basic layout of PetBot can be seen below. It is driven by one motor that will be modeled as a resistor. PetBot drives **forward** (towards the said light source) when a **positive voltage** is applied across the motor, and conversely a **negative applied voltage** drives PetBot **backward** (away from the light source). In this system the light sensor is mounted to the front of the robot, and the speed of PetBot is proportional to the applied voltage to the motor.



V_m motor voltage

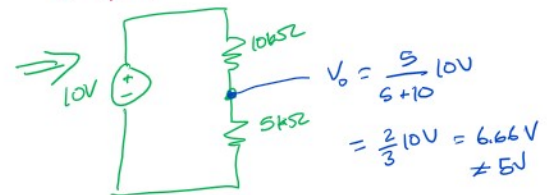
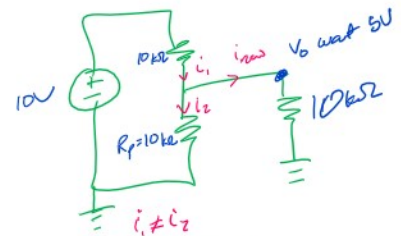
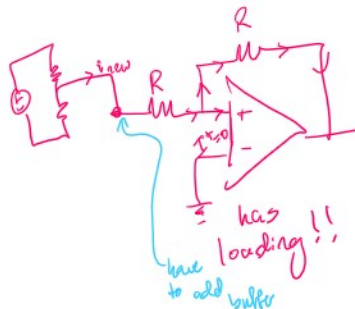
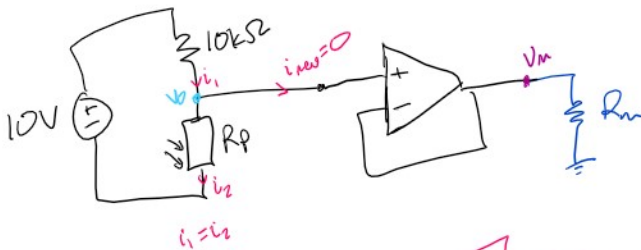
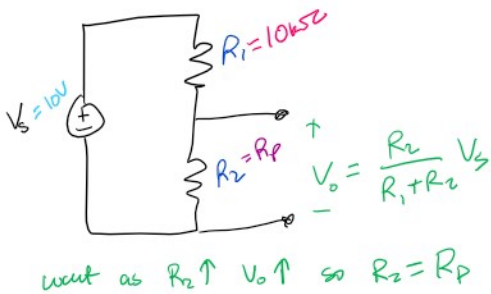
(a) Speed control

In our first circuit design, we will begin by making PetBot decrease speed as it drives towards light. **Design a motor-driving circuit that outputs a decreasing positive motor voltage as PetBot drives toward the light source.** The motor voltage should be at least 5V when far away from the light. At this far away from the light source, the photoresistor value will be 10kΩ, and then drop towards 100Ω as it approaches the light.

In your design, you may use any number of resistors and op-amps. You also have access to voltage sources of 10V and -10V. Based on your circuit, derive an expression for the motor voltage as a function of the circuit components that you used.

NOTE! Since the motor is a resistor, the circuit design **MUST** have a buffer so that the applied voltage to the motor does not depend on its resistance.

have 10V, -10V, unlimited resistors, unlimited op-amps
voltage divider



| Reference Circuits | | |
|---|---|---|
| <p>Voltage Divider</p> <p>$V_{out} = V_{in} \left(\frac{R_2}{R_1 + R_2} \right)$</p> | <p>Inverting Amplifier</p> <p>$V_{out} = V_{in} \left(-\frac{R_f}{R_i} \right)$</p> | <p>Noninverting Amplifier</p> <p>$V_{out} = V_{in} \left(1 + \frac{R_{f2}}{R_{f1}} \right)$</p> |
| <p>Current Divider</p> <p>$I_1 = I_2 \left(\frac{R_2}{R_1 + R_2} \right)$</p> | <p>Inverting Amplifier with Reference</p> <p>$V_{out} = V_{in} \left(-\frac{R_f}{R_i} \right) + V_{REF} \left(\frac{R_f}{R_i} + 1 \right)$</p> | <p>Noninverting Amplifier with Reference</p> <p>$V_{out} = V_{in} \left(1 + \frac{R_{f2}}{R_{f1}} \right) - V_{REF} \left(\frac{R_{f2}}{R_{f1}} \right)$</p> |
| <p>Voltage Summer</p> <p>$V_{out} = V_1 \left(\frac{R_2}{R_1 + R_2} \right) + V_2 \left(\frac{R_1}{R_1 + R_2} \right)$</p> | <p>Unity Gain Buffer</p> <p>$V_{out} = V_{in}$</p> | <p>$R_p \uparrow V_m \uparrow$</p> |

* could
 $V_{out} \approx 5V$
want
 $R_p = 10k\Omega$
given
 $V_{in} = 10V$
 \rightarrow no
 $V_{out} > 10V$

far from light

$V_m \geq 5V$
 $R_p = 10k\Omega$

close to light

$V_m < 5V$
 $R_p \approx 100\Omega$

as $R_p \uparrow V_m \uparrow$

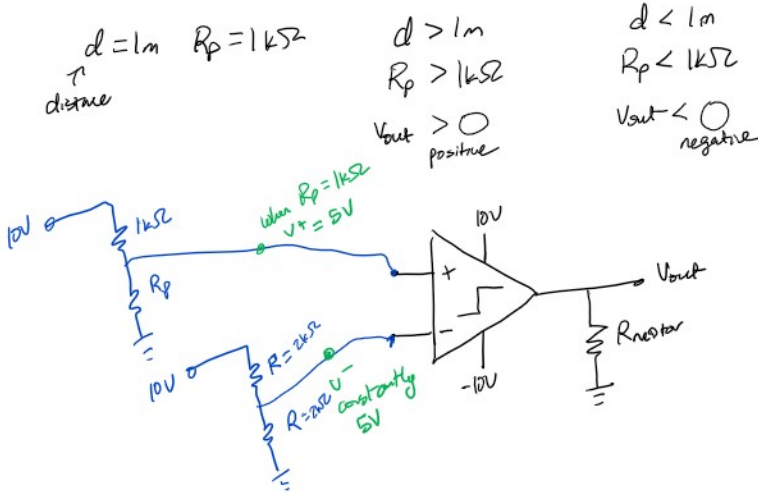
* how do we choose R_1
when $R_p = 10k\Omega$ want $V_0 = 5V$
 $V_0 = 5V = \frac{10k\Omega}{R_1 + 10k\Omega} (10V)$
 $\rightarrow R_1 = 10k\Omega$

(b) Distance control

When the PetBot stops at a distance of 1m away from the light, the photo-resistor has a value 1kΩ. We would like to have the PetBot drive away when closer than 1m from the light (so for lower R_p), and drive towards the light when exceeding 1m (so for greater R_p).

Design a comparator circuit that outputs a positive motor voltage when the PetBot exceeds 1m in distance from the flashlight (making the PetBot move toward it), and a negative voltage when PetBot is within 1m of flashlight (making the PetBot back away from the flashlight).

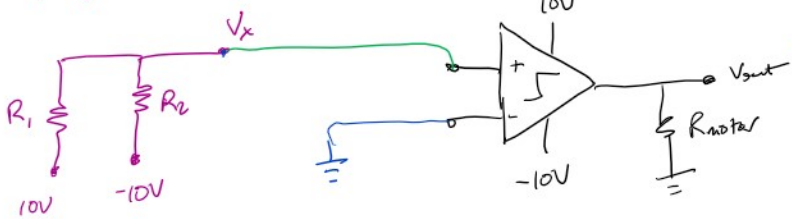
In your design, you may use any number of resistors along with the comparators. You also have access to voltage sources of 10V and -10V.



flip points when $d=1m$, $R_p=1k\Omega$, $v^+ = v^-$
 want if $R_p > 1k\Omega$ $v_{out} = 10V$ $v^+ > v^-$ ✓
 $R_p < 1k\Omega$ $v_{out} = -10V$ $v^+ < v^-$
 * because no op-amps only have the options of voltage divider & voltage summer

← completely valid soln
check when $R_p > 1k\Omega$ $v^+ > 5V$ $v_{out} = 10V$ ✓

other possible soln: voltage summer
 when $R_p = 1k\Omega$ $v_x = \left(\frac{R_p - 1k\Omega}{R_p + 1k\Omega}\right) 10V = 0V$



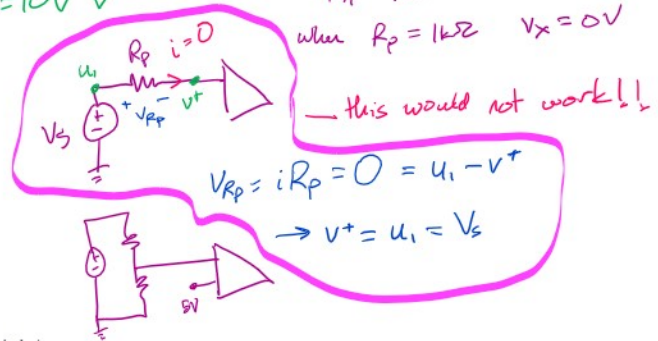
$$v_x = \left(\frac{R_2}{R_1 + R_2}\right) (10V) + \left(\frac{R_1}{R_1 + R_2}\right) (-10V)$$

$$= \left(\frac{R_2 - R_1}{R_1 + R_2}\right) 10V$$

which resistor should be R_p
 $R_2 = R_p$ let's choose
 $R_1 = 1k\Omega$
 when $R_p = 1k\Omega$ $v_x = 0V$

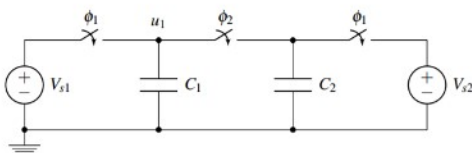
check if $R_p > 1k\Omega$ $v_x > 0$ $v^+ > v^-$ $v_{out} = 10V$ ✓

if I had chosen $R_1 = R_p$ $R_2 = 1k\Omega$
 then v_x should be connected to v^-
 and ground to v^+



4. OPTIONAL: Capacitive Charge Sharing (from Spring 2020 Midterm 2)

Consider the circuit below with $C_1 = C_2 = 1 \mu F$ and two switches ϕ_1, ϕ_2 . Suppose that initially the switch ϕ_1 is closed and ϕ_2 is open such that C_1 and C_2 are charged through the corresponding voltage sources $V_{s1} = 1V$ and $V_{s2} = 2V$.



- How much charge is on C_1 and C_2 ? How much energy is stored in each of the capacitors? What is the total stored energy?
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