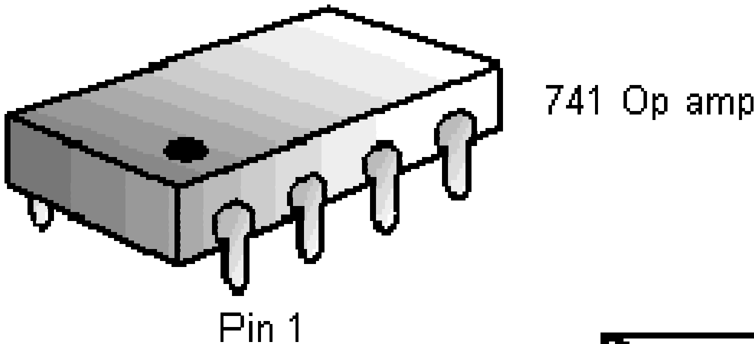
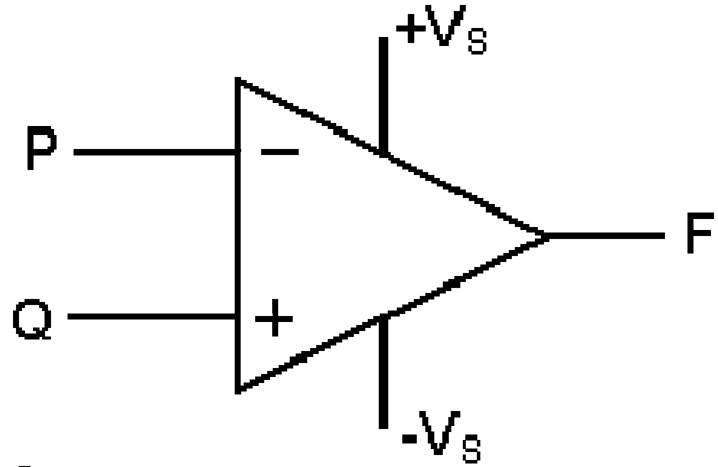
ECE 201, Section 3
Lecture 26

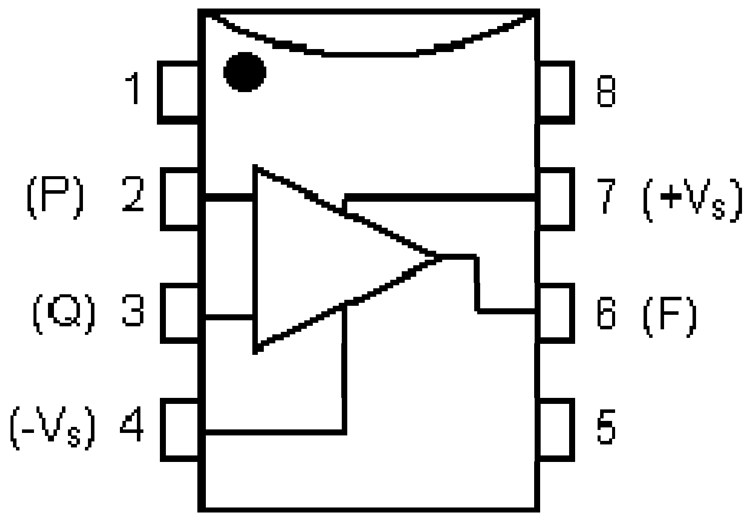
Prof. Peter Bermel

October 26, 2012

3 Views of Op-Amps







Op-Amp Applications

- Differential and summing amplifiers
- Filters
- Rectifiers
- Differentiators + Integrators
- Audio, video, and charge amplifiers
- Gyrators
- Ordinary, relaxation, and Wien bridge oscillators
- Comparators
- Waveform generators
- Active filters
- Capacitance multipliers
- Zero-level detectors
- Logarithmic and exponential outputs
- Negative impedance converter

Op-Amp Application Examples

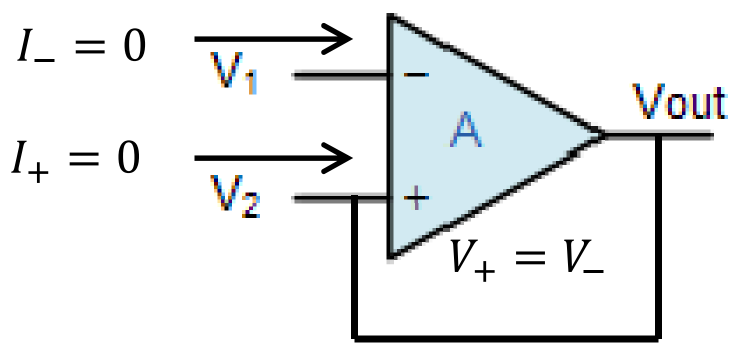
Mechanical motor controller

LED audio detector

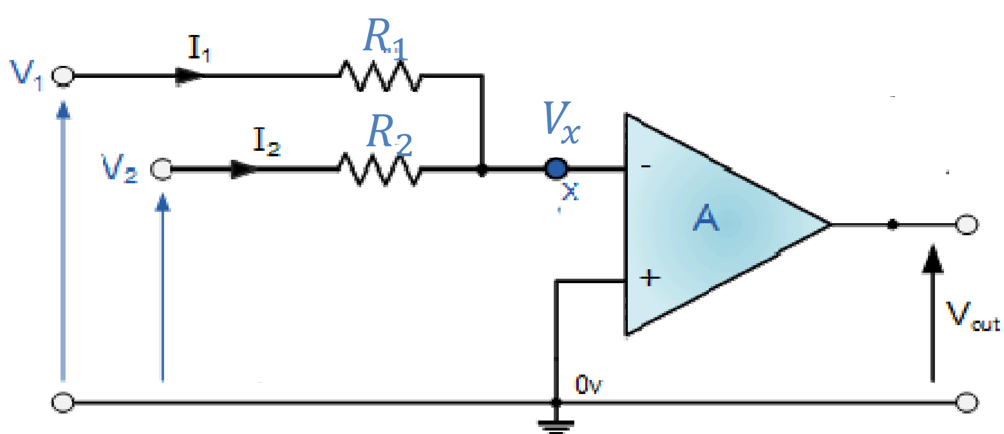
Cell phone detector

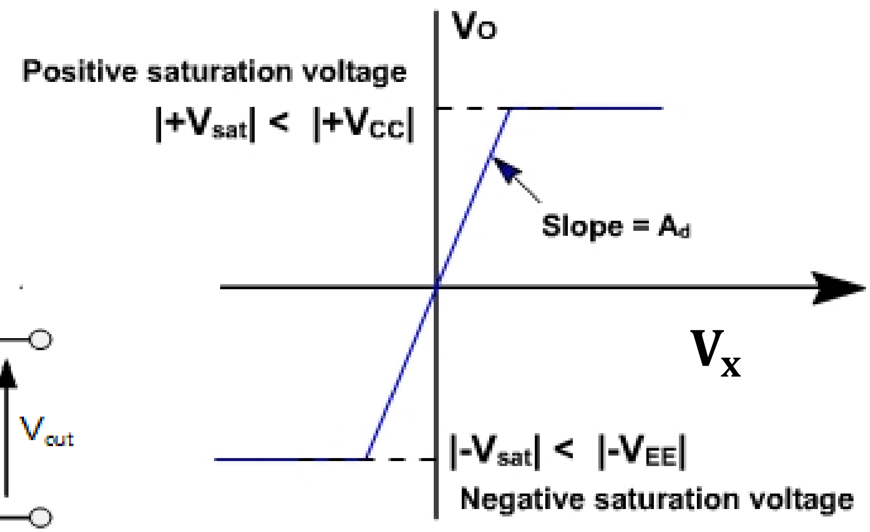
Ideal Op-Amps

- Golden rules:
  - Both input currents are zero
  - For closed loops: both input voltages are equal



Saturable Op-Amps

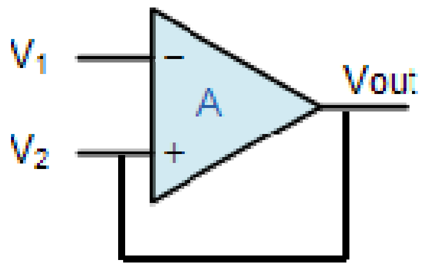




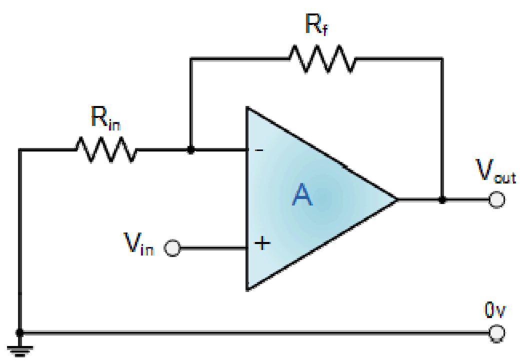
- Given that $V_x = \frac{R_2 V_1 + R_1 V_2}{R_1 + R_2}$, 3 solution regimes

Region Name	Input Values	Output Values
Positive saturation	$AV_x > V_{\text{sat}}$	V_{sat}
Active	$-V_{\text{sat}} < AV_x < V_{\text{sat}}$	AV_x
Negative saturation	$AV_x < -V_{\text{sat}}$	$-V_{\text{sat}}$

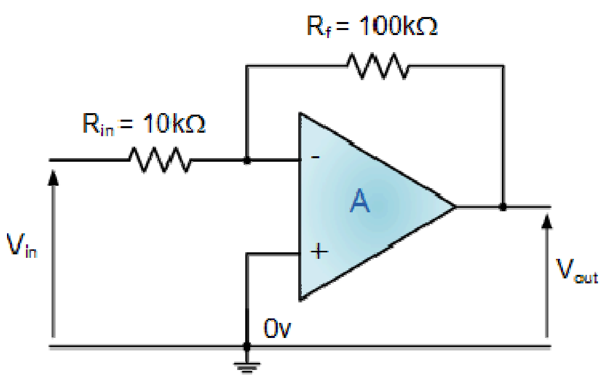
Op-Amps with Feedback



Voltage follower: $A = 1$



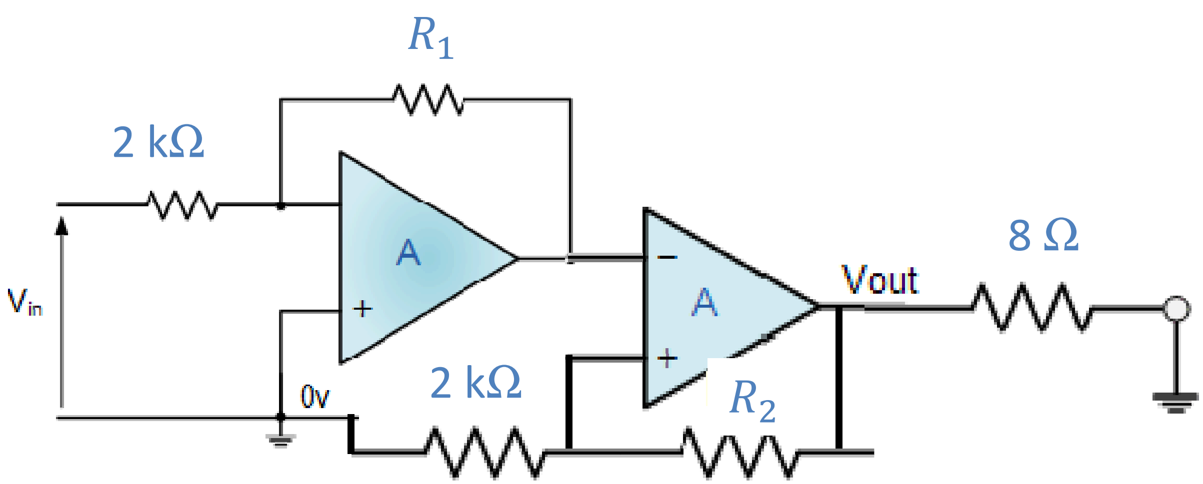
Non-inverting amp: $A = 1 + \frac{R_f}{R_i}$



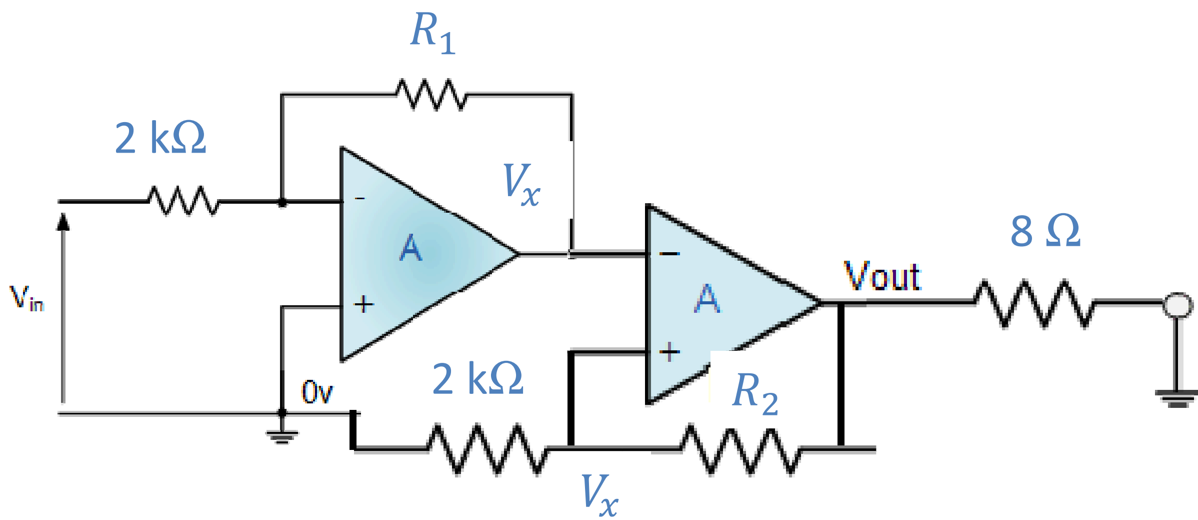
Inverting amp: $A = -\frac{R_f}{R_i}$

Example

- If $R_1=R_2$, what value is necessary to amplify the input amplitude by 20x? How can you achieve the same with $R_1=5\ k\Omega$, or $R_2=18\ k\Omega$?

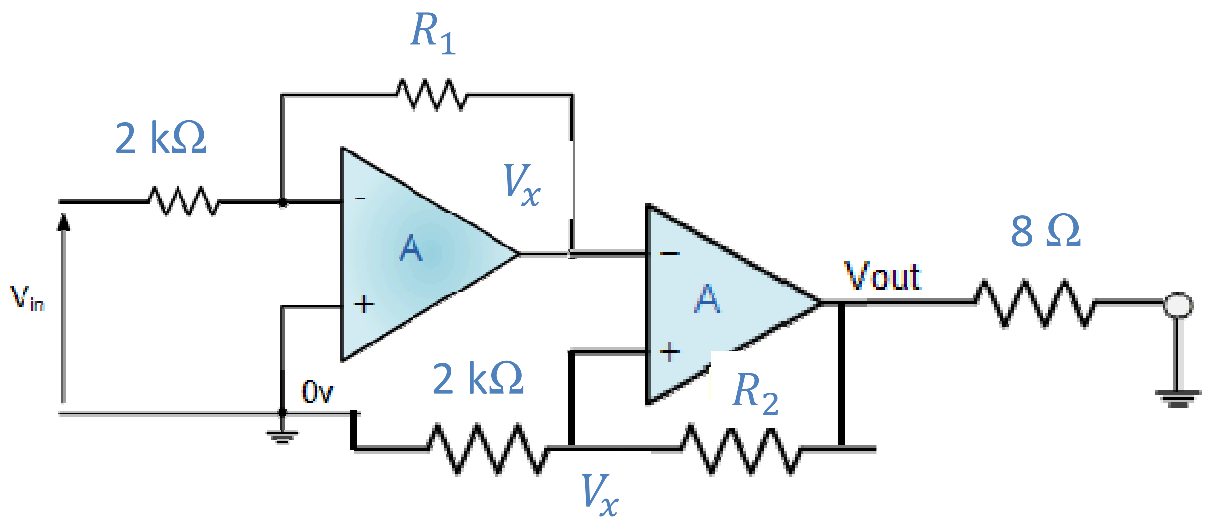


Solution



- Applying both golden rules, we know: $V_x = -\frac{R_1}{2\ k\Omega} V_{\text{in}}$
- Thus, current on bottom $I = V_x / 2k\Omega$
- So: $V_{\text{out}} = V_x + IR_2 = (1 + R_2/2k\Omega)V_x$
- Thus, $V_{\text{out}} = (1 + R_2/2k\Omega)(-R_1 V_{\text{in}}\ /2k\Omega)$

Solution



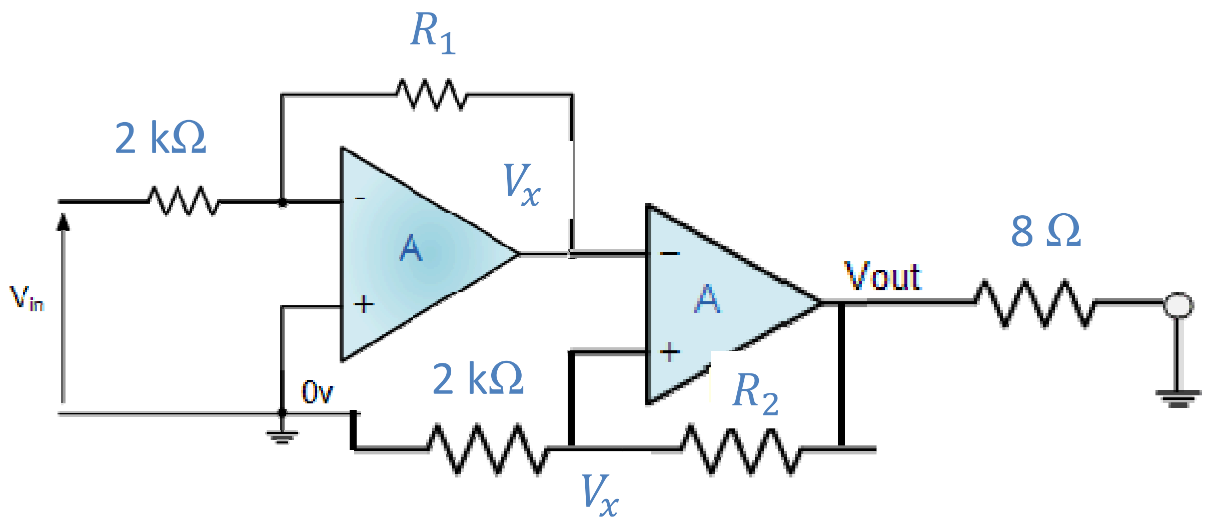
- Thus, A $= V_{\text{out}} / V_{\text{in}} = (1 + R_2/2k\Omega)(-R_1/2k\Omega)$
- If $R_1 = R_2$ and A $= -20 = \left(1 + \frac{R_1}{2}\right)\left(-\frac{R_1}{2}\right)$

$$5 \cdot (-4) = \left(1 + \frac{R_1}{2}\right)\left(-\frac{R_1}{2}\right)$$

$$5 = 1 + \frac{R_1}{2}$$

$$R_1 = 8\ \text{k}\Omega$$

Solution



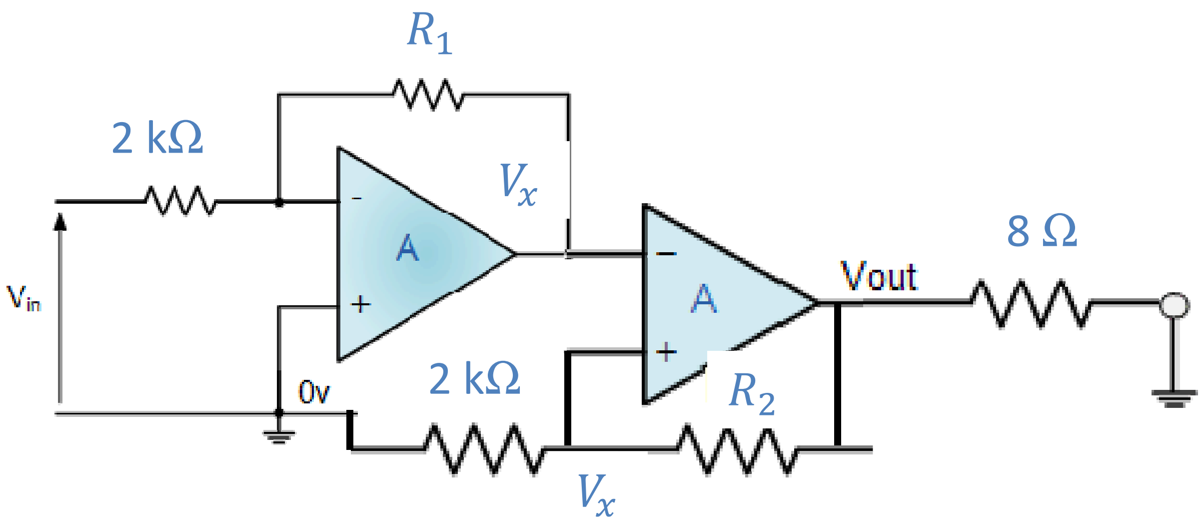
- Thus, $\mathrm{A} = V_{\text{out}} / V_{\text{in}} = (1 + R_2/2k\Omega)(-R_1/2k\Omega)$
- If $R_1 = 5$ kΩ and $\mathrm{A} = -20 = \left(1 + \frac{R_2}{2}\right)\left(-\frac{5}{2}\right)$

$$\left(-\frac{2}{5}\right) \cdot (-20) = \left(1 + \frac{R_2}{2}\right)$$

$$8 = 1 + \frac{R_2}{2}$$

$$R_2 = 14\ \mathrm{k\Omega}$$

Solution

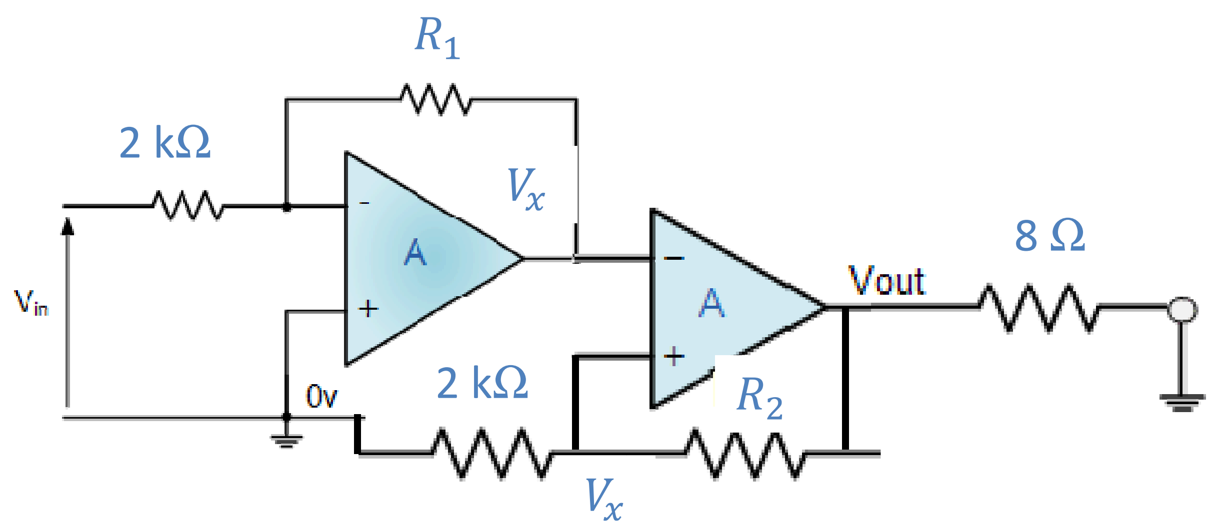


- Thus, A $= V_{\text{out}} / V_{\text{in}} = (1 + R_2/2k\Omega)(-R_1/2k\Omega)$
- If $R_2 = 18$ kΩ and A $= -20 = \left(1 + \frac{18}{2}\right)\left(-\frac{R_1}{2}\right)$

$$\frac{1}{10} \cdot (-20) = -\frac{R_1}{2}$$

$$R_1 = 4 \text{ k}\Omega$$

Solution

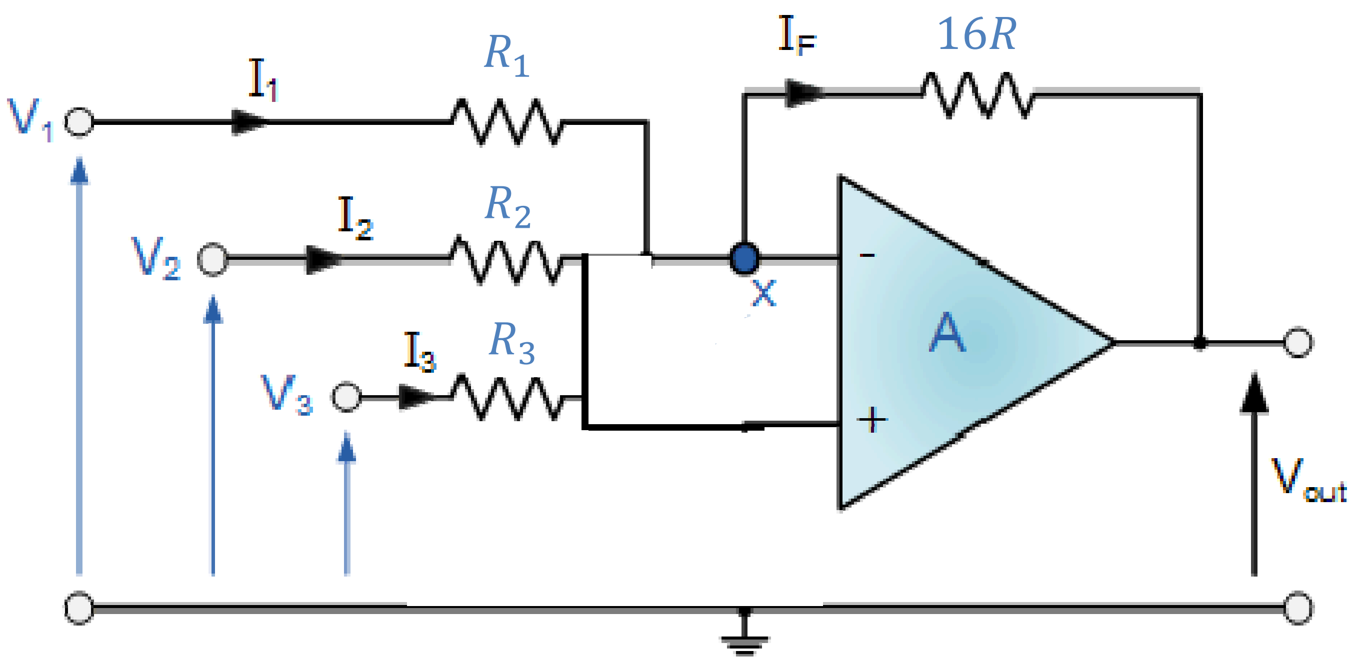


- If $V_{\text{in}} = 2$ V and $\text{A} = -20$, how much power is dissipated in the load on the right?

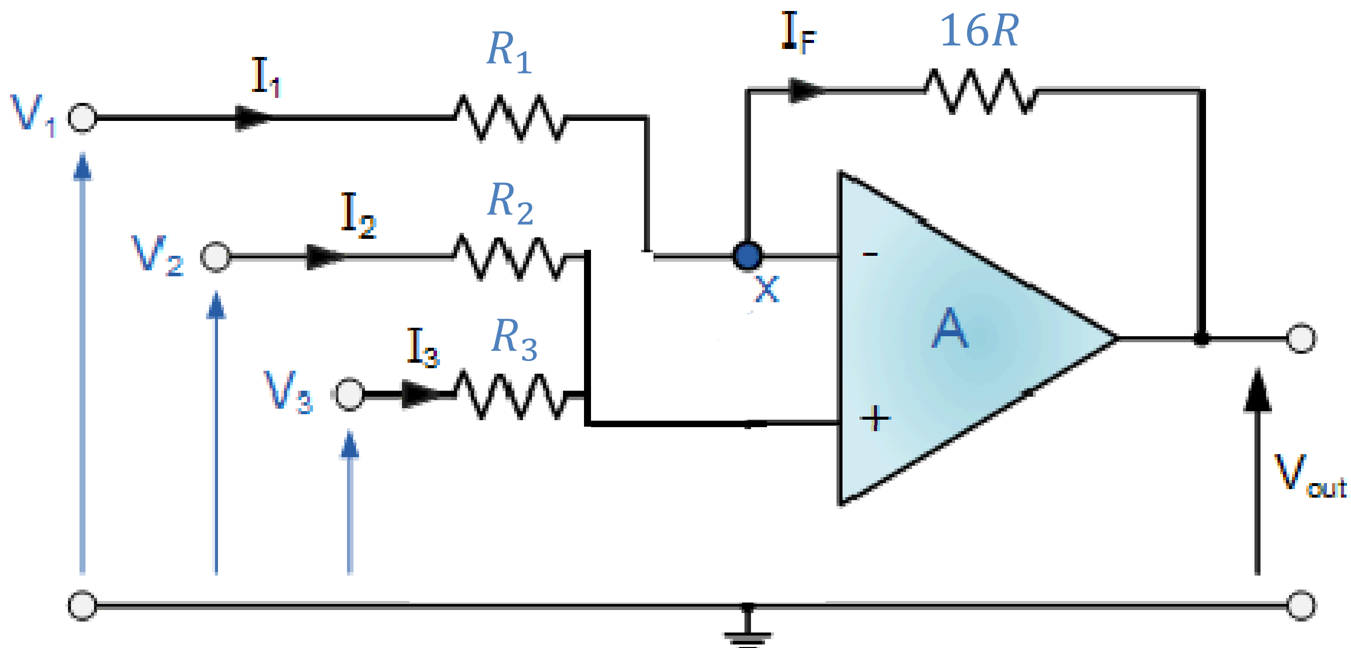
$$P = V^2/R = (-20 \cdot 2)^2/8 = 200 \text{ W}$$

Example #2

- What is the total output voltage for this circuit in general? What if $R_2 = R_3, V_1 = 0$, $V_2 - V_3 = 4$ V, and $R_1 = 8R$?

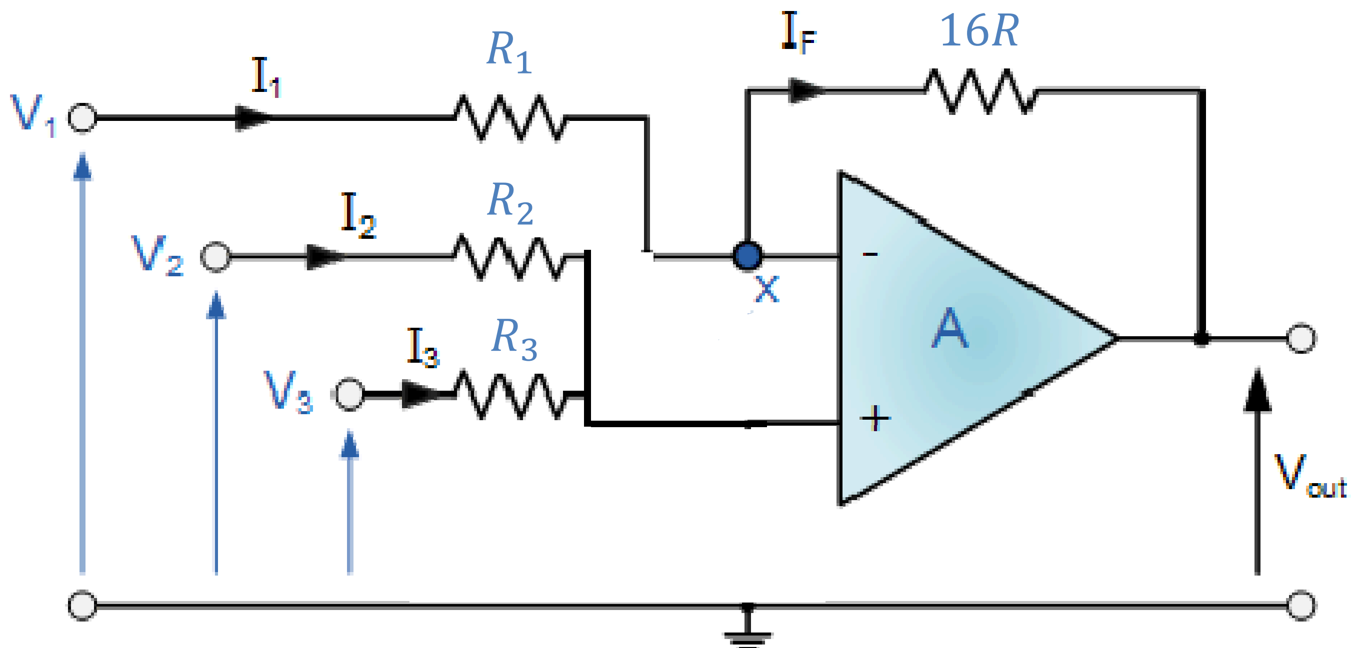


Solution



- By golden rule #1, $V_x = V_1 - I_1 R_1 = V_2 - I_2 R_2$
- By golden rule #2, $I_2 = -I_3$, and $I_1 = I_F$
- By Ohm's law, $V_x - V_{\text{out}} = I_1 \cdot 16R$

Solution

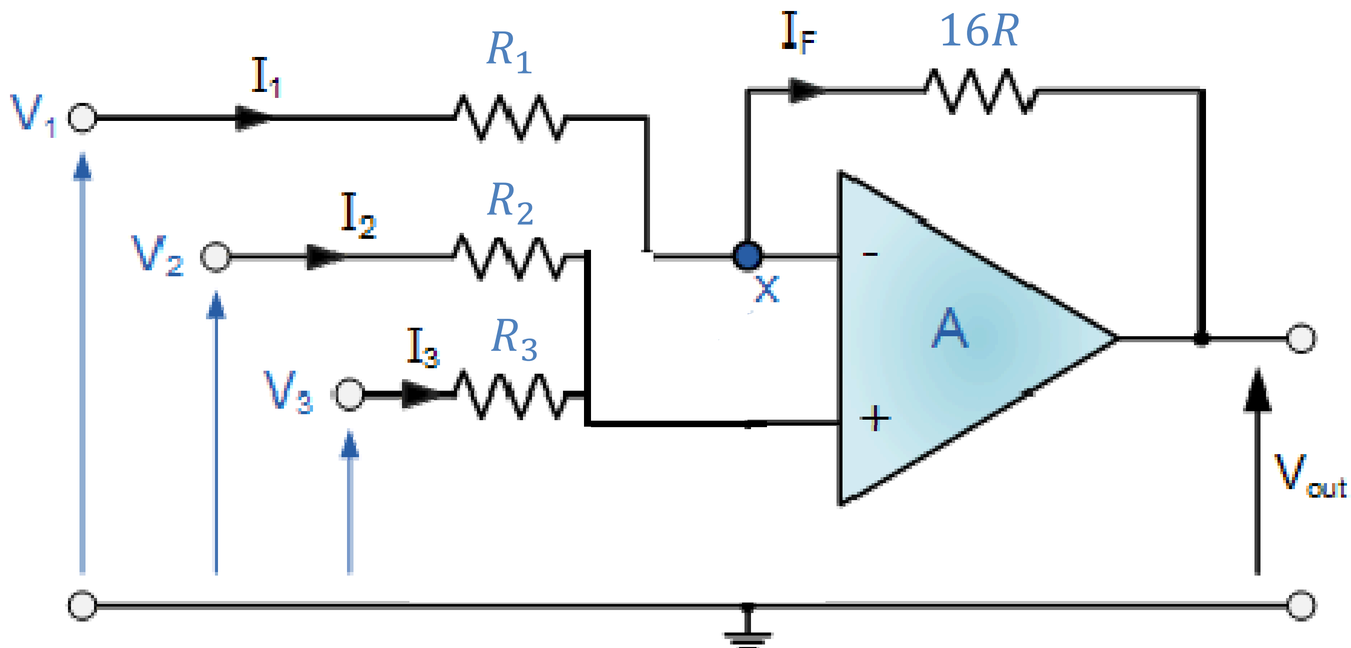


- Since $V_{\text{out}} = V_x - I_1 \cdot 16R$ and $V_1 - V_x = I_1 R_1$, we can write:

$$V_{\text{out}} = V_x - (16R/R_1)(V_1 - V_x)$$

- Need an expression for V_x!

Solution



- We now obtain:

$$V_{out} = (1 + 16R/R_1)(V_2 - V_3)R_3/(R_2 + R_3) - (16R/R_1)V_1$$

- If $R_2 = R_3$, $V_1 = 0$, $V_2 - V_3 = 4$ V, and $R_1 = 8R$:

$$V_{out} = (1 + 16R/8R) \cdot 4R_2/(R_2 + R_2) - (16R/8R) \cdot 0$$

$$V_{out} = (1 + 2) \cdot 4/2 = 6 \text{ V}$$

Homework

- HW #25 due today by 4:30 pm in EE 325B
- HW #26 due Mon.: DeCarlo & Lin, Chapter 4:
  - Problem 6
  - Problem 7