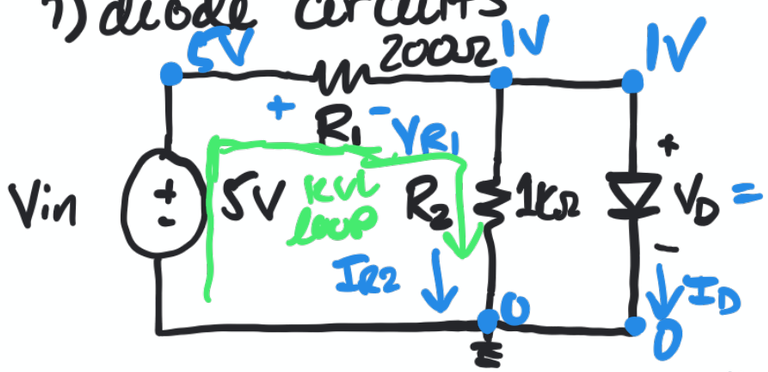
Intro to ECSE Lecture Notes 3/24/23

1) Quiz 2 topics:
   - Linear & Non-linear devices (IV Characteristics)
   - Diodes
   - Differential Resistance
   - Nodal Analysis
   - Op-amp basics/properties
   - Op-amp circuits/applications
   - Properties of Linear Devices & Systems
   - Superposition (property)
   - Superposition (circuit analysis method)
   - Transfer functions
   - Cascading op-amp circuits
   - Setting the reference level for a decision-making circuit

2) Some Example Problems

i) diode circuits

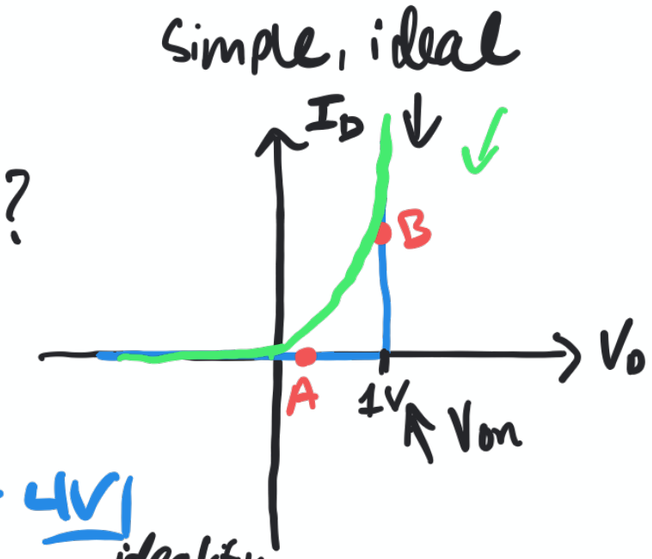


a) If $V_D = 1V$, what is I_{R2}?

$$\frac{V_{R2}}{R_2} = I_{R2} = \frac{1V}{1k\Omega} = 1mA$$

b) What is V_{R1}?

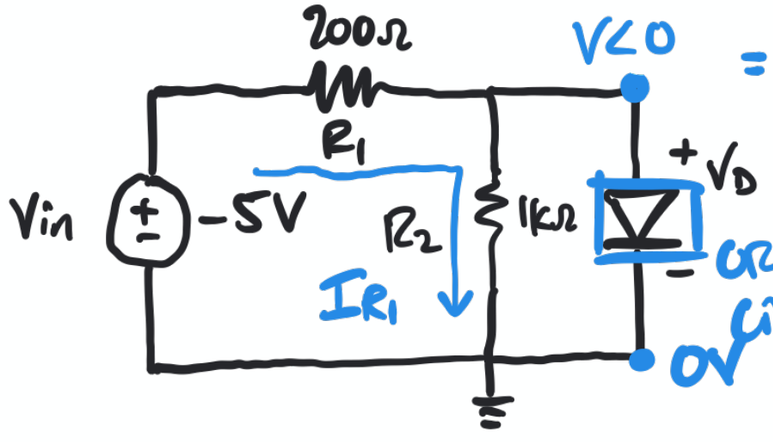
KVL: $V_{R1} = V_{in} - V_{R2} = 5V - 1V = 4V$



datasheet → $n = 1$ ← ideality factor

c) What is I_D if $I_S = 1 \times 10^{-15} A$ ← datasheet (saturation current), $T = 300K$, $k_B = 1.38 \times 10^{-23} J/K$, $q < 1.602 \times 10^{-19} C$?

$$I_D = I_S\left(e^{\frac{qV_D}{nk_BT}} - 1\right) = 0.0039\,A$$

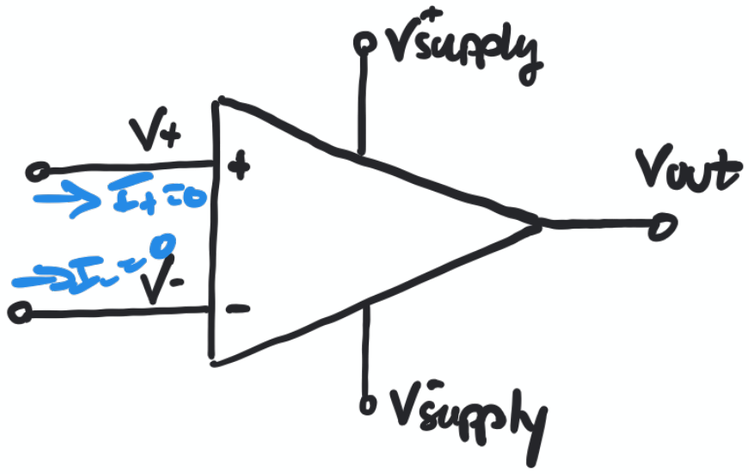


d) If $V_{in} = -5V$, what is the current through R_1? Assume the IV characteristic above

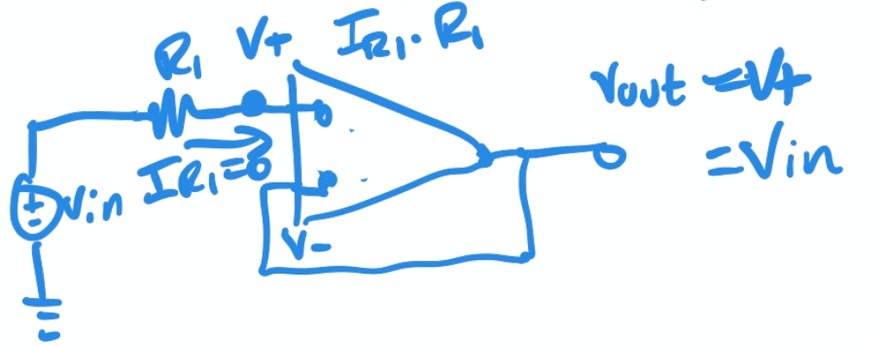
$$I_{R1} = \frac{V_{in}}{R_1 + R_2} = \frac{-5V}{1.2k\Omega} = -4.17mA$$

e) What is the differential resistance of the diode at A and B? $R = \frac{\Delta V}{\Delta I}$ → A: slope: 0, $R_A = \infty$ | B: slope ∞, R_B: 0

ii) op-amp basics/properties



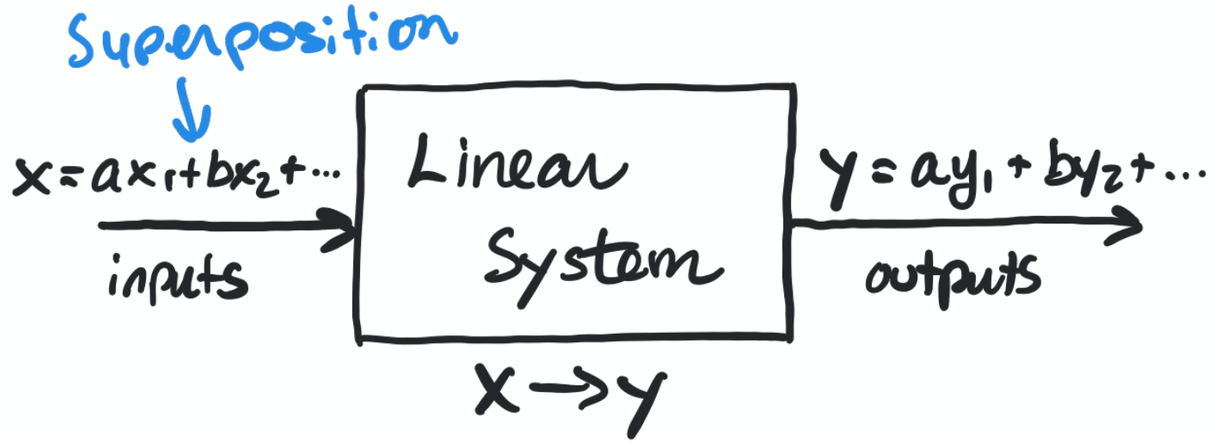
$V_+ = V_{in} - V_{R1} = V_{in} - I_{R1} \cdot R_1$ ($I_{R1} \approx 0$)



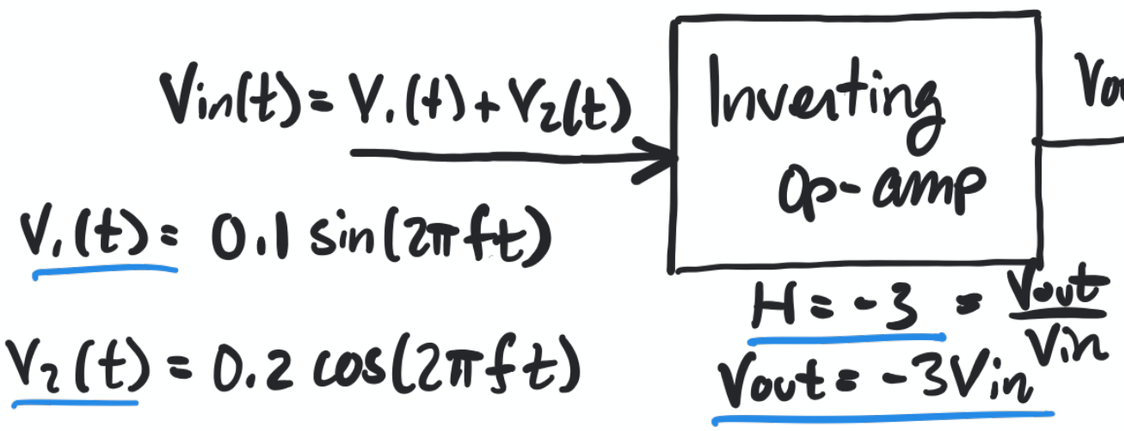
ideal op-amps

- an op-amp is a voltage amplifier, so { input = voltage; output = voltage }
- **Golden Rule #1**: no current will flows into the V_+ or V_- terminals (due to $R_{in} = \infty$)
  - more important for ECSE 1010
- **Golden Rule #2**: when configured in negative feedback, $V_+ = V_-$ (due to assumption that $A_0 = \infty$)
  - ECSE 2010

iii) properties of linear devices and systems



Ex.



V_{out} for $V_1(t)$

- What is $V_{out}(t)$?

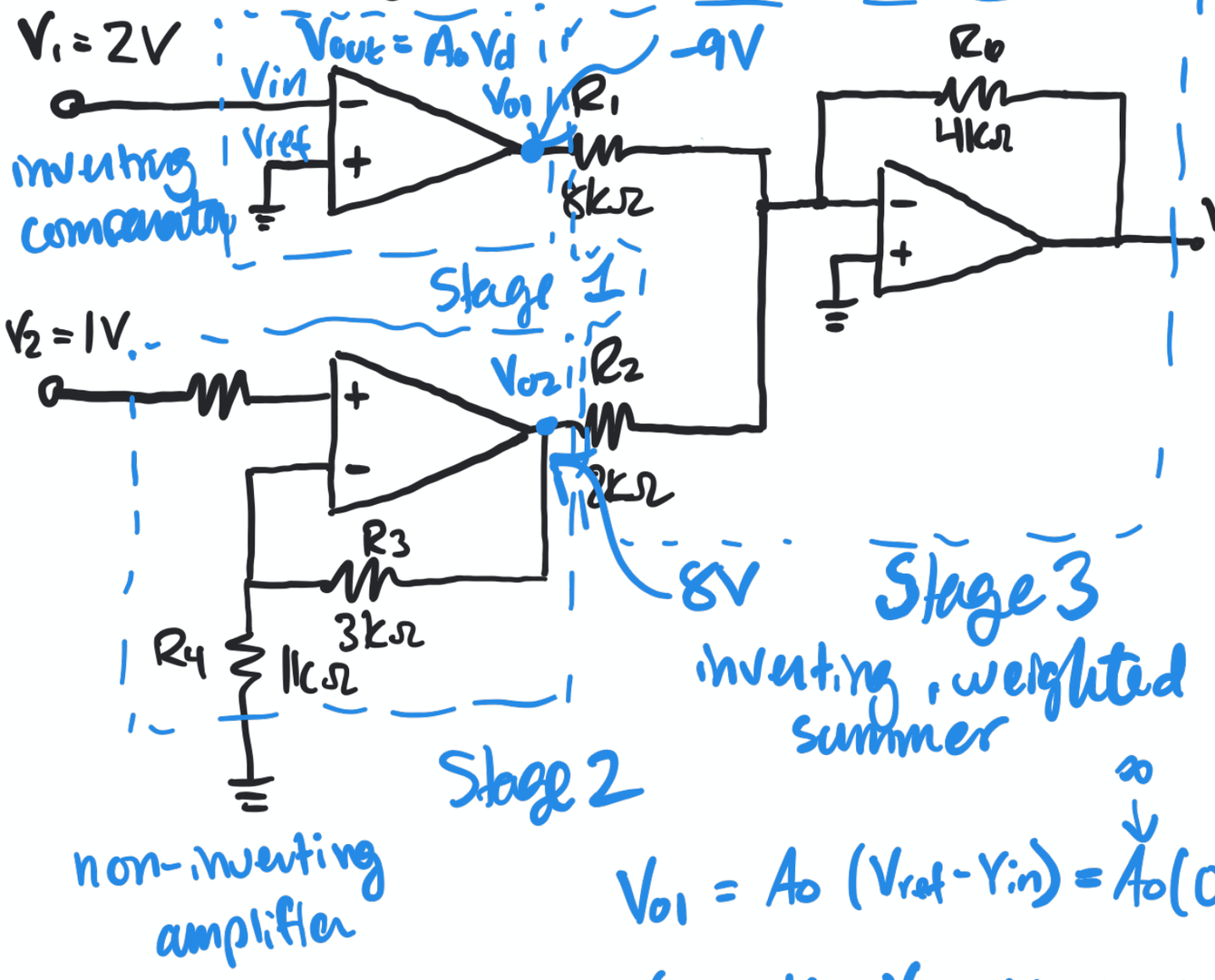
$V_{out}(t) = V_{out,1}(t) + V_{out,2}(t)$

$V_{out,1} = -3V_i(t) = -0.3 \sin(2\pi f t)$

$V_{out,2} = -3V_2(t) = -0.6 \cos(2\pi f t)$

- $V_{out}(t) = -0.3 \sin(2\pi f t) - 0.6 \cos(2\pi f t)$

iv) Cascading op-amp circuits



- Supply voltages are +/-9V, but are not shown
- Find Vout: $V_{out} = A_0(V_+ - V_-)$ (V_+: Vref, V_-: Vin)

a) identify stages

b) function of stages

- Stage 1: $V_{out} = \begin{cases} +9 & V_{in} < V_{ref} \\ -9 & V_{in} > V_{ref} \end{cases}$
- Stage 2: $H_2 = \left(1 + \frac{R_3}{R_4}\right) = 4$
- Stage 3: $V_{out} = \left(-\frac{R_0}{R_1}V_{o1} - \frac{R_0}{R_2}V_{o2}\right)$

$V_{o1} = A_0(V_{ref} - V_{in}) = A_0(0 - 2V) = -9V$ ($A_0 \to \infty$, $-V_{supply}$)

$= \left(-\frac{1}{2}V_{o1} - 2V_{o2}\right)$

$V_{o2} = H_2 \cdot V_2 = 4 \cdot 1V = 4V$

$V_{out} = \left(-\frac{1}{2}(-9V) - 2(4V)\right) = 4.5V - 8V = -3.5V$