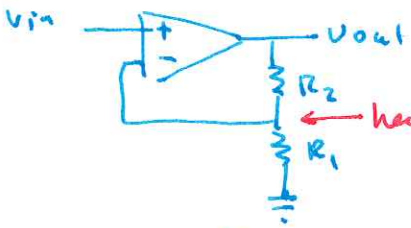
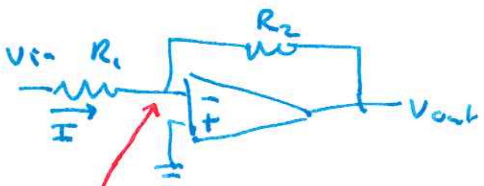
Op-Amps: $R_{in} \to \infty$, $R_{out} \to 0$, $A \to \infty$

OR: Golden Rules: ① zero current thru inputs ($R_{in} \to \infty$)

② $V_+ = V_-$ ($A \to \infty$)



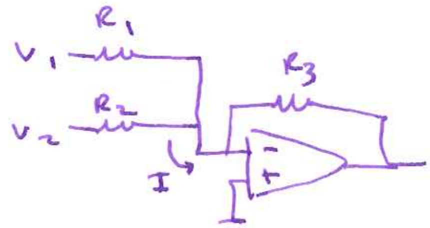
here $V = \frac{R_1}{R_1+R_2} V_{out} = V_{in} \Rightarrow V_{out} = \left(1 + \frac{R_2}{R_1}\right) V_{in}$



$I = \frac{V_{in}}{R_1}$ & $V_{out} = 0 - R_2 I$

$= -\frac{R_2}{R_1} V_{in}$

Summing:

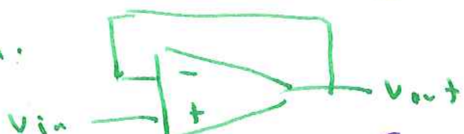


$I = \frac{V_1}{R_1} + \frac{V_2}{R_2}$

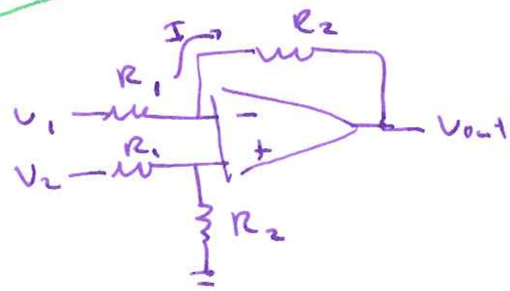
$V_{out} = 0 - R_3 I$

$= -\left(\frac{R_3}{R_1} V_1 + \frac{R_3}{R_2} V_2\right)$

Follower:



Differential:



$V_+ = \frac{R_2}{R_1+R_2} V_2$

$I = \frac{1}{R_1}(V_1 - V_+)$

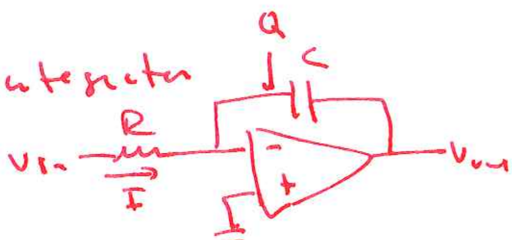
$V_{out} = -I R_2 + V_+$

$= -\frac{1}{R_1}\left(V_1 - V_+\right) R_2 + V_+$

$= -\frac{R_2}{R_1} V_1 + \left(\frac{R_2}{R_1} + 1\right) V_+$

$= -\frac{R_2}{R_1}(V_1 - V_2)$

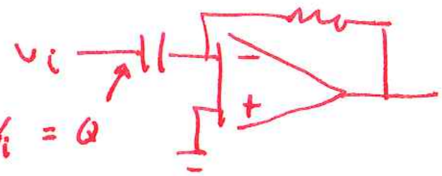
Integrator



$Q = \int I\,dt = \int \frac{V_1}{R}\,dt$

$V_{out} = -\frac{Q}{C} = -\frac{1}{RC}\int V_1\,dt$

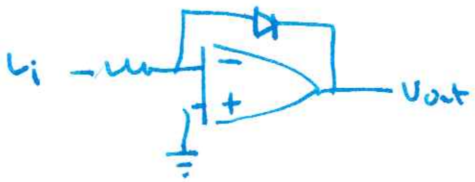
differentiator (problems!)



$cV_i = Q$

$I = \dot{Q} = c\dot{V}_i \quad \therefore \quad V_{out} = -RI = -RC\dot{V}_i$

Log Amp: $V_o \propto \log(V_i)$ [note $V_i > 0$!]

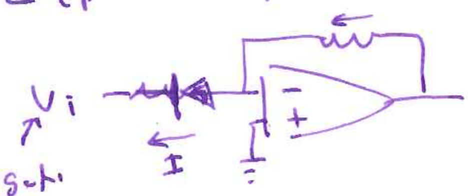


$I = \frac{V_i}{R} = I_o\left(e^{\frac{-V_o}{V_T}} - 1\right) \approx I_o e^{\frac{-V_o}{V_T}}$

$V_T = \frac{kT}{e} \approx \frac{1}{40}\,eV$

$-V_T \ln\left(\frac{V_i}{I_o R}\right) = V_o$

Expo Amp



negati

$I = I_o\left(e^{\frac{-V_i}{V_T}} - 1\right)$

$V_o = +IR \approx I_o R e^{-V_i/V_T}$