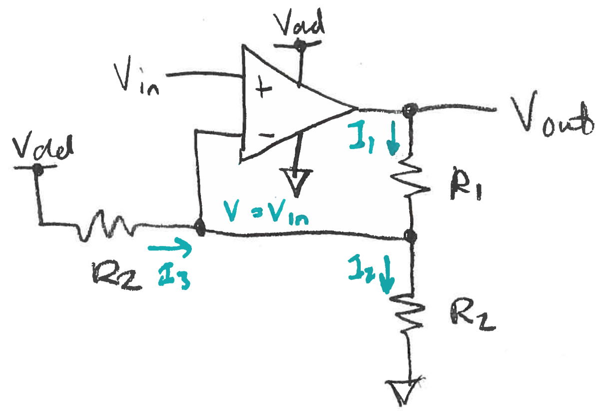
ISIM 10/19/2015

①



$0V < V_{out} < V_{dd} \Rightarrow V \approx V_{in}$

$KCL @ V \Rightarrow I_1 + I_3 = I_2$

$$\Rightarrow \underbrace{\frac{V_{out} - V_{in}}{R_1}}_{I_1} + \underbrace{\frac{V_{dd} - V_{in}}{R_2}}_{I_3} = \underbrace{\frac{V_{in} - 0V}{R_2}}_{I_2}$$

$$(=) \times R_1 \Rightarrow \boxed{V_{out} = \left(1 + 2\frac{R_1}{R_2}\right)V_{in} - \frac{R_1}{R_2}V_{dd}}$$

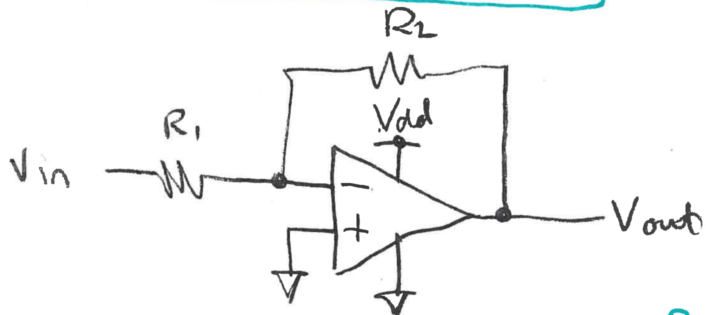
$$(=) - \frac{V_{dd}}{2} \Rightarrow$$

$$V_{out} - \frac{V_{dd}}{2} = \left(1 + 2\frac{R_1}{R_2}\right)V_{in} - \left(\frac{1}{2} + \frac{R_1}{R_2}\right)V_{dd}$$

$$\Rightarrow V_{out} - \frac{V_{dd}}{2} = \left(1 + 2\frac{R_1}{R_2}\right)V_{in} - \left(1 + 2\frac{R_1}{R_2}\right)\frac{V_{dd}}{2}$$

$$\Rightarrow \underbrace{V_{out} - \frac{V_{dd}}{2}}_{U_{out}} = \underbrace{\left(1 + 2\frac{R_1}{R_2}\right)}_{A}\underbrace{\left(V_{in} - \frac{V_{dd}}{2}\right)}_{U_{in}}$$

②

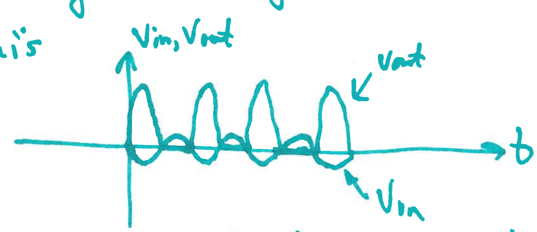


Inverting amplifier, Gain $= -\frac{R_2}{R_1}$, $V_{ref} = 0V$.

Expect $V_{out} = -\frac{R_2}{R_1}V_{in}$. However, V_{out} can't go below 0V!

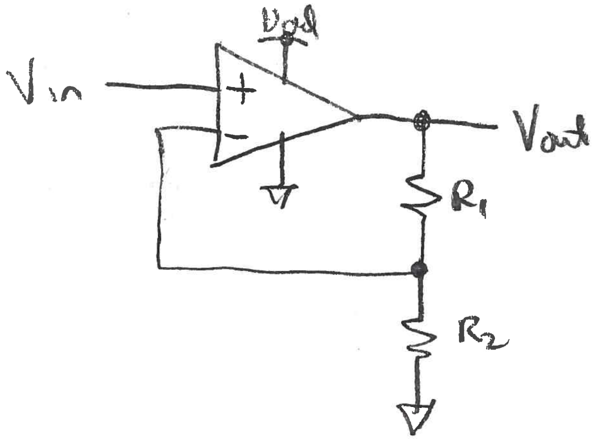
If $V_{in} > 0V$, V_{out} wants to go below 0V, but gets stuck at 0V.

So, if V_{in} can go below ground, the circuit's response will look like this



If the input range were limited to positive voltages, the output will always be stuck at 0V!

③

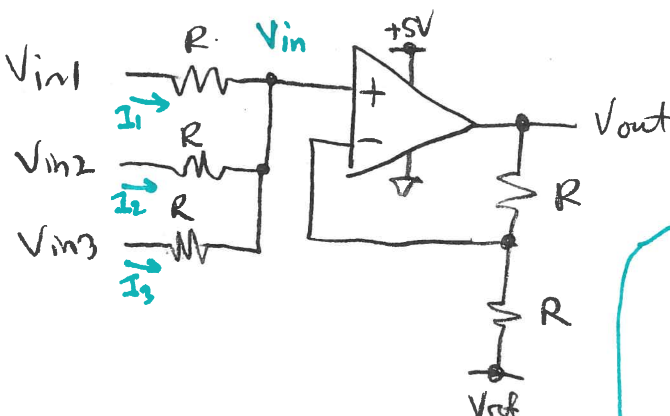


Noninverting amp with Vref = 0V.

$$V_{out} - 0V = \left(1 + \frac{R_1}{R_2}\right)(V_{in} - 0V)$$

$$\Rightarrow \boxed{V_{out} = \left(1 + \frac{R_1}{R_2}\right)V_{in} \text{ until } V_{out} \text{ saturates @ } V_{dd}}$$

④



Noninverting amp w/ $R_1 = R_2 = R$.

$\Rightarrow A = 2.$

$$\Rightarrow V_{out} - V_{ref} = 2(V_{in} - V_{ref})$$

$$\Rightarrow \boxed{V_{out} - V_{ref} = 2\left(\frac{V_{in1} + V_{in2} + V_{in3}}{3} - V_{ref}\right)}$$

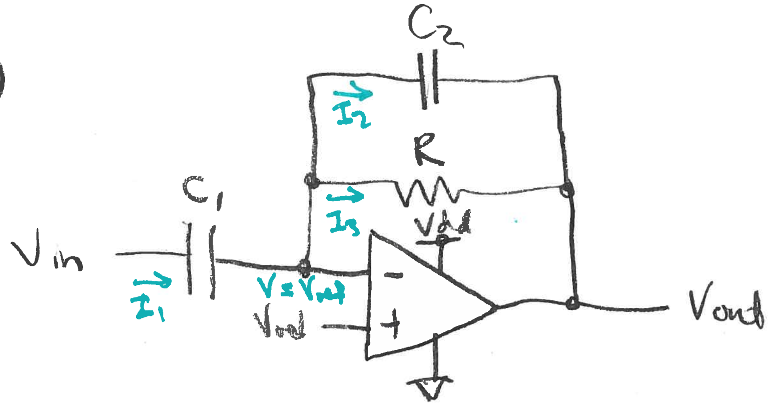
KCL @ V_{in} $\Rightarrow I_1 + I_2 + I_3 = 0A$

$$\Rightarrow \underbrace{\frac{V_{in1} - V_{in}}{R}}_{I_1} + \underbrace{\frac{V_{in2} - V_{in}}{R}}_{I_2} + \underbrace{\frac{V_{in3} - V_{in}}{R}}_{I_3} = 0A.$$

$(=) \times R \Rightarrow V_{in1} + V_{in2} + V_{in3} = 3V_{in}$

$$\Rightarrow \boxed{V_{in} = \frac{1}{3}(V_{in1} + V_{in2} + V_{in3})}$$

⑤



$0V < V_{out} < V_{dd} \Rightarrow V = V_{ref}$

$I_1 = C_1 \frac{d}{dt}(V_{in} - V_{ref})$,

$I_2 = C_2 \frac{d}{dt}(V_{ref} - V_{out})$,

and $I_3 = \frac{V_{ref} - V_{out}}{R}$

KCL @ $V \Rightarrow I_1 = I_2 + I_3$

$$\Rightarrow \underbrace{C_1 \frac{d}{dt}(V_{in} - V_{ref})}_{I_1} = \underbrace{C_2 \frac{d}{dt}(V_{ref} - V_{out})}_{I_2} + \underbrace{\frac{V_{ref} - V_{out}}{R}}_{I_3}$$

$$(=) \times -R \Rightarrow -RC_1 \frac{d}{dt}(V_{in} - V_{ref}) = RC_2 \frac{d}{dt}(V_{out} - V_{ref}) + (V_{out} - V_{ref})$$

$$\Rightarrow \underbrace{RC_2}_{\tau} \frac{d}{dt}\underbrace{(V_{out} - V_{ref})}_{U_{out}} + \underbrace{(V_{out} - V_{ref})}_{U_{out}} = \underbrace{-\frac{C_1}{C_2}}_{A} \cdot \underbrace{RC_2}_{\tau} \frac{d}{dt}\underbrace{(V_{in} - V_{ref})}_{U_{in}}$$

$$\boxed{\tau \frac{dU_{out}}{dt} + U_{out} = A\tau \frac{dU_{in}}{dt}}$$ First-order high-pass filter!

when $\tau = RC_2$

$A = -\frac{C_1}{C_2}$