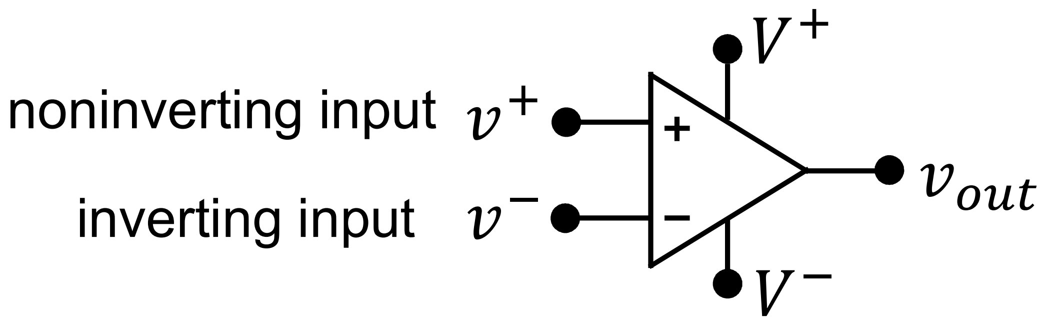
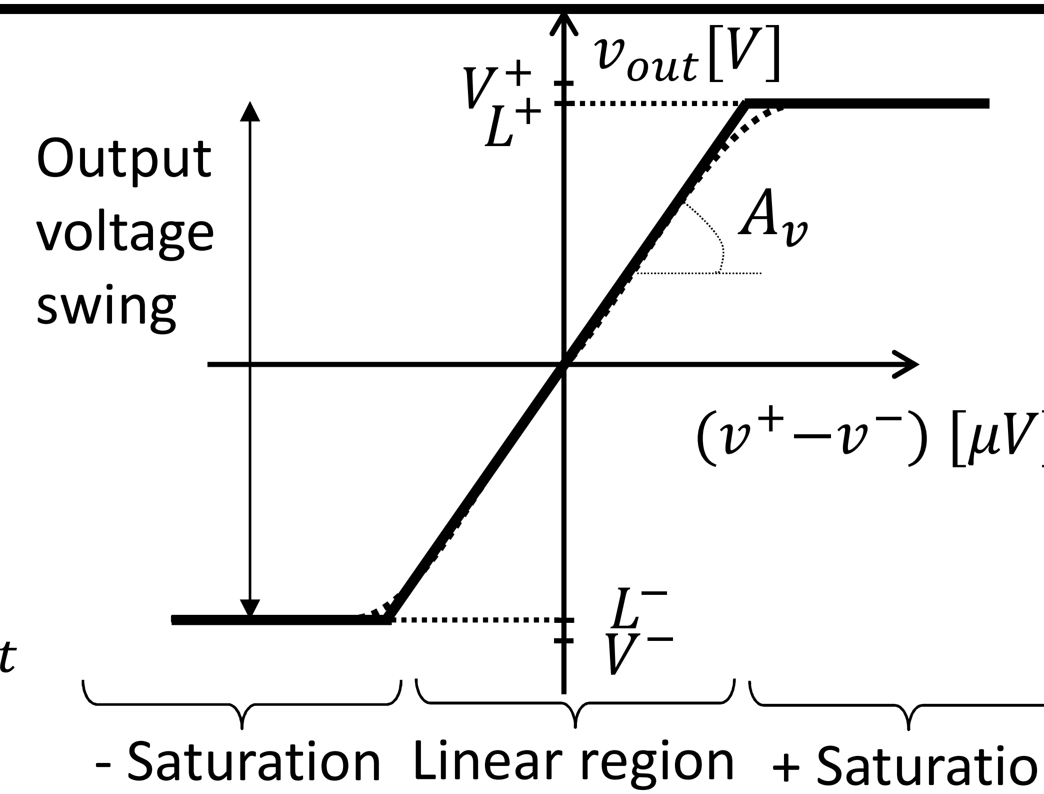
Session5 Electronics1

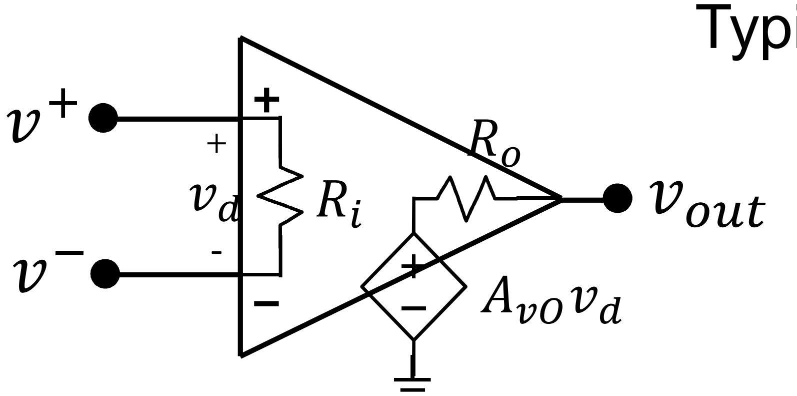
Review OpAmp

Review Operational Amplifier

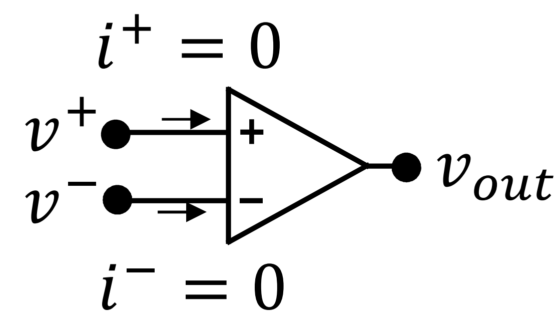
OP AMP is a differential amplifier





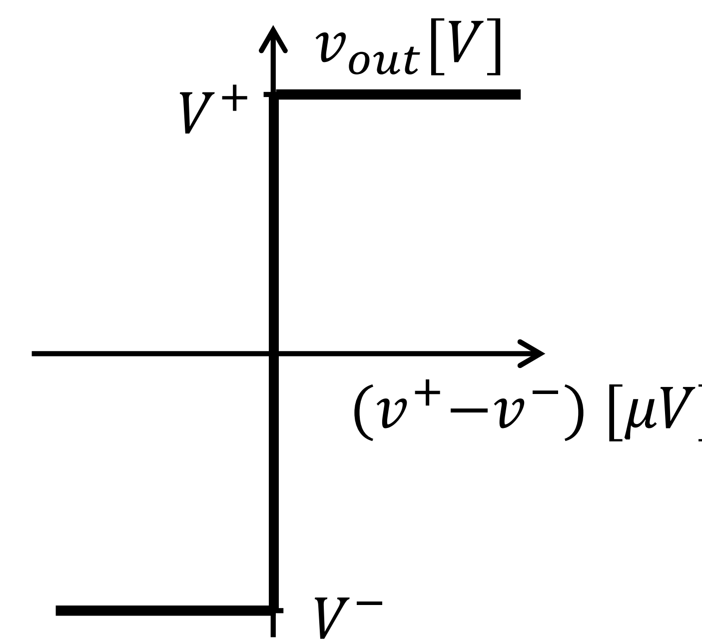


Typical values:	ideal
$R_i \sim 100^{M\Omega}$	$\rightarrow \infty$
$R_o \sim 10^{\Omega}$	$\rightarrow 0$
$A_{vO} \sim 10^6$	$\rightarrow \infty$



Regions:

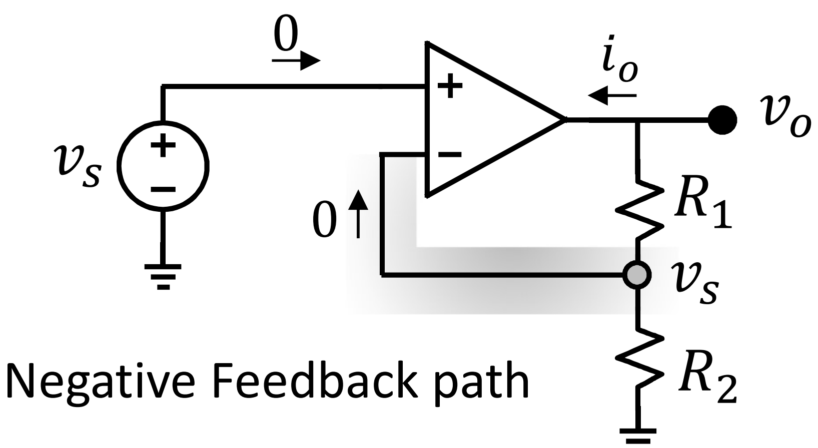
- Linear: $v^- = v^+$, $v_0 = ?$, when: $V^- < v_0 < V^+$
- + Saturation : $v_0 = V^+$, $v^+, v^- = ?$, when: $v^+ > v^-$
- − Saturation : $v_0 = V^-$, $v^+, v^- = ?$, when: $v^+ < v^-$



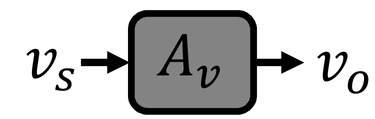
Rules @ Linear: 1. $i^+ = i^- = 0$, 2. $v^- = v^+$

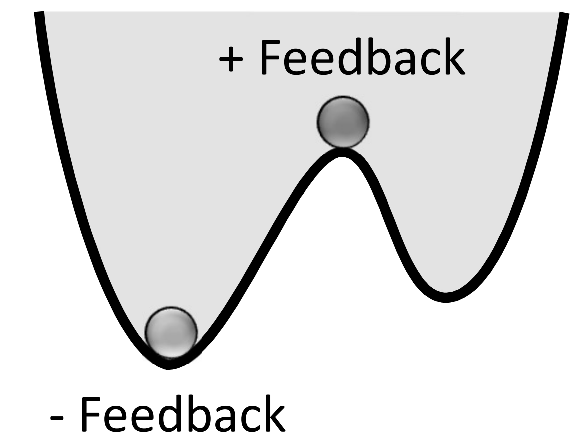
Noninverting OpAmp

1. $i^+ = i^- = 0$, @ Linear: 2. $v^- = v^+$



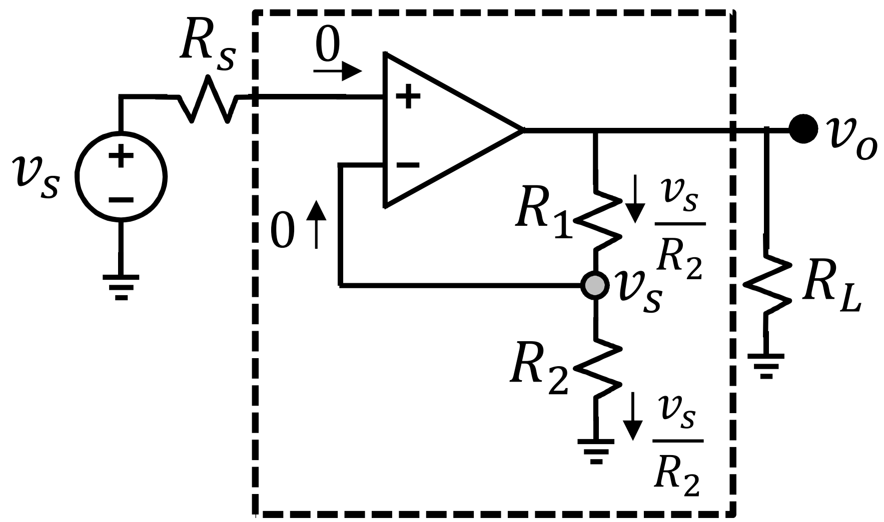
KCL: $\dfrac{v_o - v_s}{R_1} + \dfrac{0 - v_s}{R_2} = 0$





$$\frac{v_o}{v_s} = A_v = 1 + \frac{R_1}{R_2}$$

$$i_0 = -v_s/R_2$$

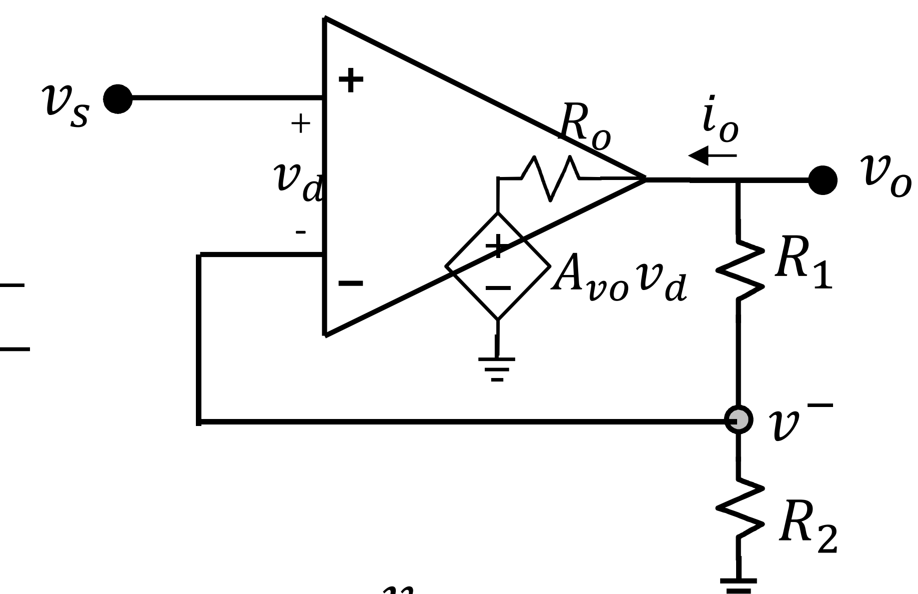


$$v_0 = v_s + \frac{R_1 v_s}{R_2}$$

$$i_0 = -\frac{v_s}{R_2} - \frac{v_o}{R_L}$$

$$\frac{v_o - v^-}{R_1} + \frac{0 - v^-}{R_2} = 0$$

$$\frac{A_{vo}(v_s - v^-) - v_o}{R_0} = \frac{v_o - v^-}{R_1}$$



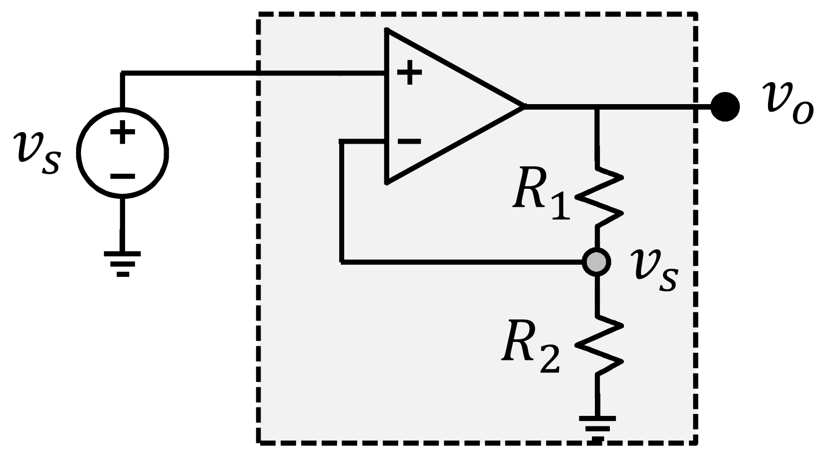
$$K = 1 + \frac{R_1}{R_2}$$

$$\frac{v_o}{v_s} = \frac{K}{\frac{K}{A_{vo}}\left[1 + \frac{R_o}{R_1 + R_2}\right] + 1}$$

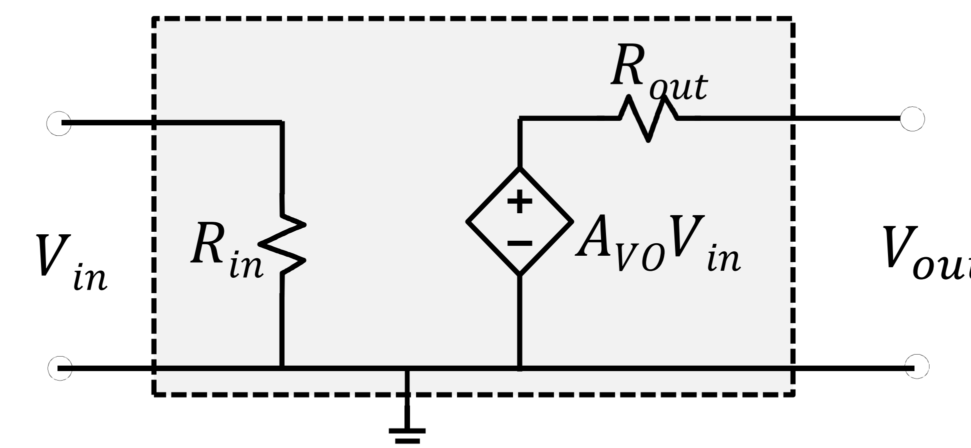
$$R_o \ll R_1 + R_2 \rightarrow R_o \sim 0 \quad \rightarrow \frac{v_o}{v_s} = \frac{K}{\frac{K}{A_{vo}} + 1}$$

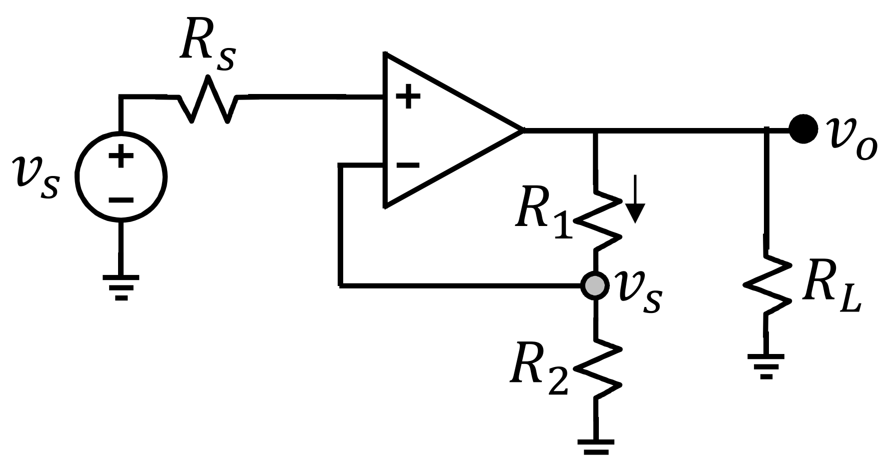
$$A_{v0} \gg K \rightarrow \frac{v_o}{v_s} = K$$

Noninverting OpAmp / Buffer



$$\frac{v_o}{v_s} = A_v = 1 + \frac{R_1}{R_2}$$

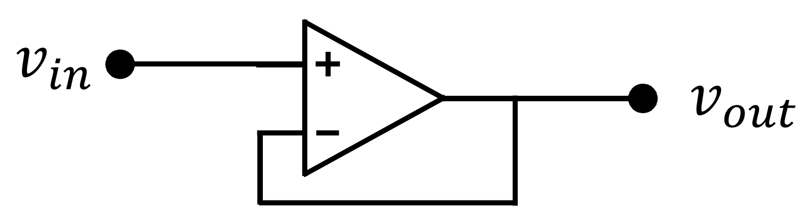


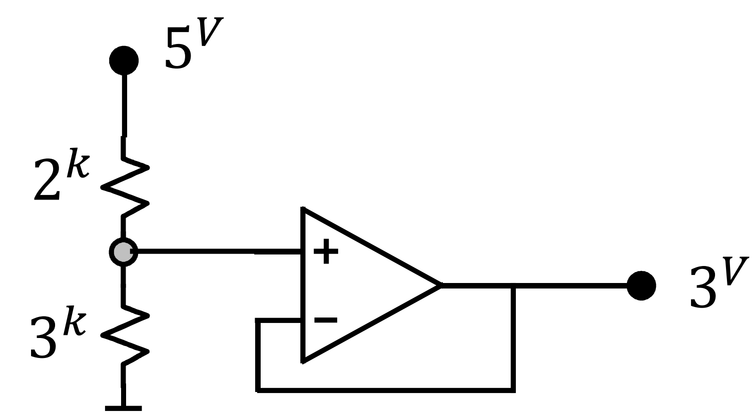


$$A_v = 1 + \frac{R_1}{R_2}$$

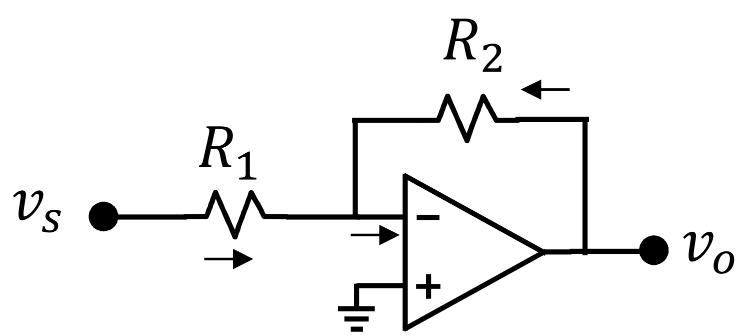
(Voltage) Buffer

Voltage follower





Inverting OpAmp

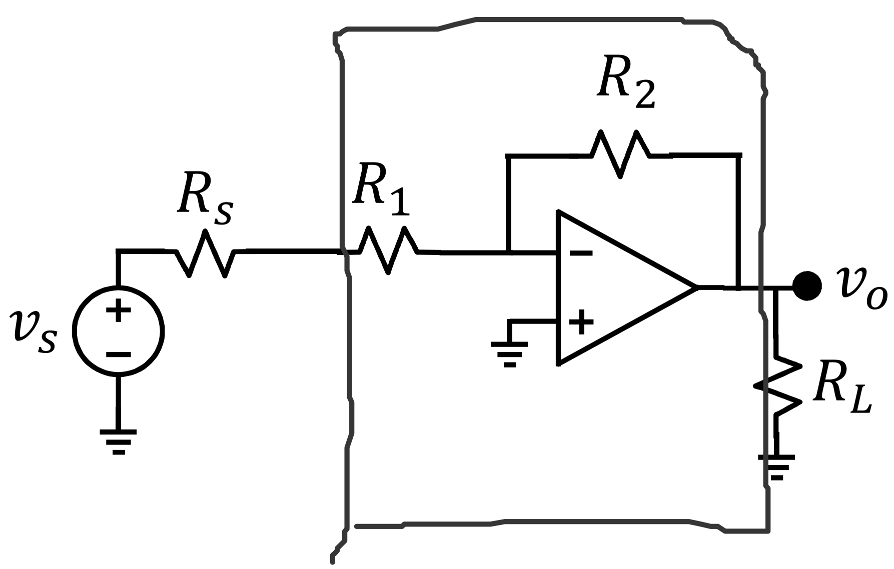


KCL: $$\frac{v_s - v^-}{R_1} + \frac{v_o - v^-}{R_2} = i^-$$

Virtual ground $v^- = 0$

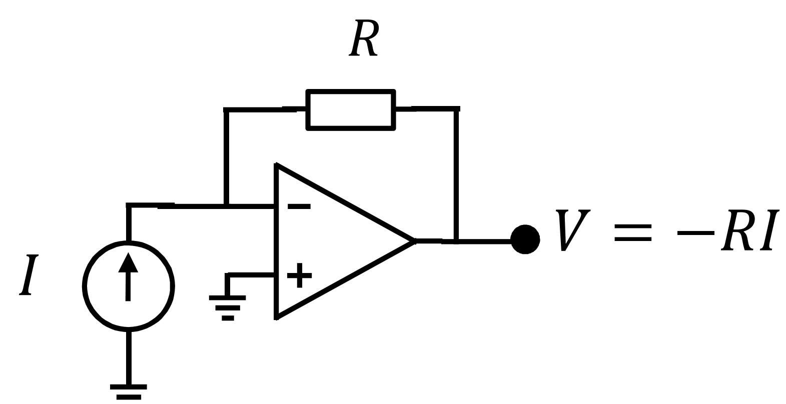
$i^- = 0$

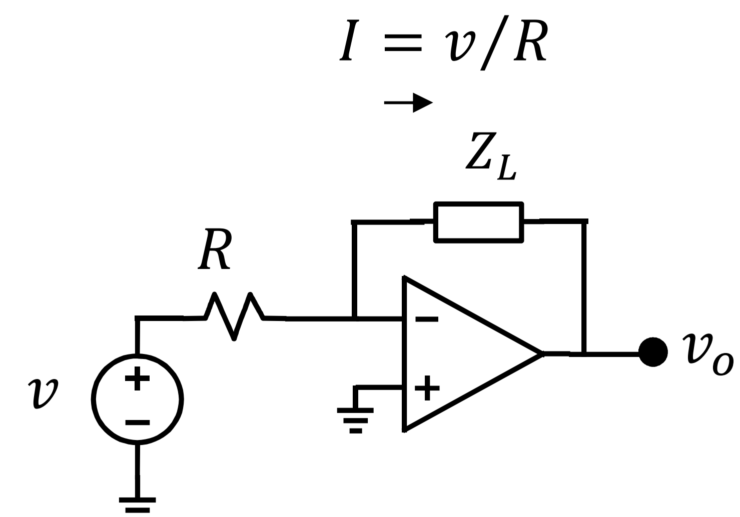
$$\frac{v_o}{v_s} = A_V = -\frac{R_2}{R_1}$$



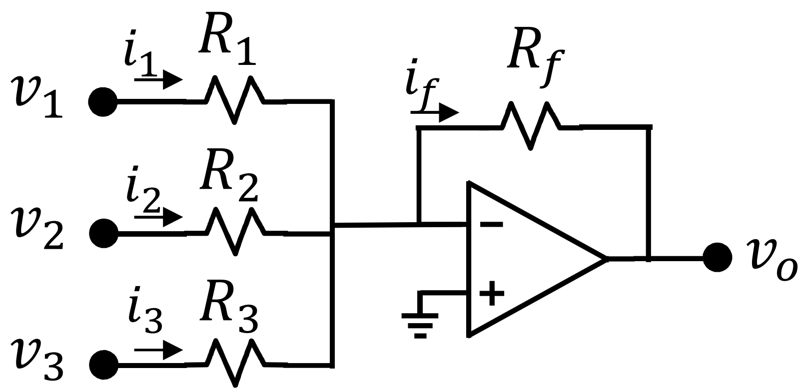
$$\frac{v_o}{v_s} = -\frac{R_2}{R_1 + R_s}$$

I/V V/I





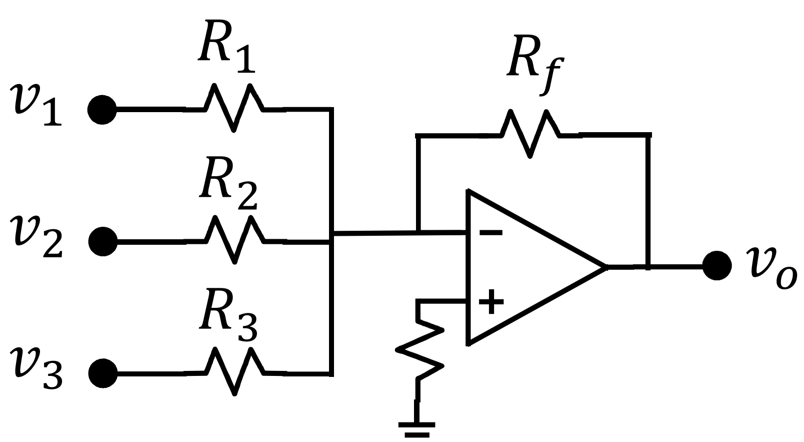
summing amplifier (adder)

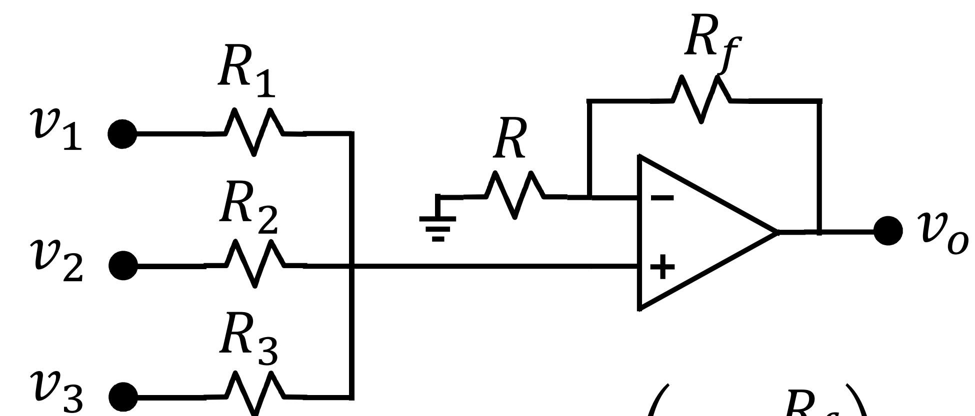


KCL: $i_1 + i_2 + i_3 = i_f$

$$\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3} = \frac{-v_o}{R_f}$$

$$v_o = -R_f\left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3}\right)$$



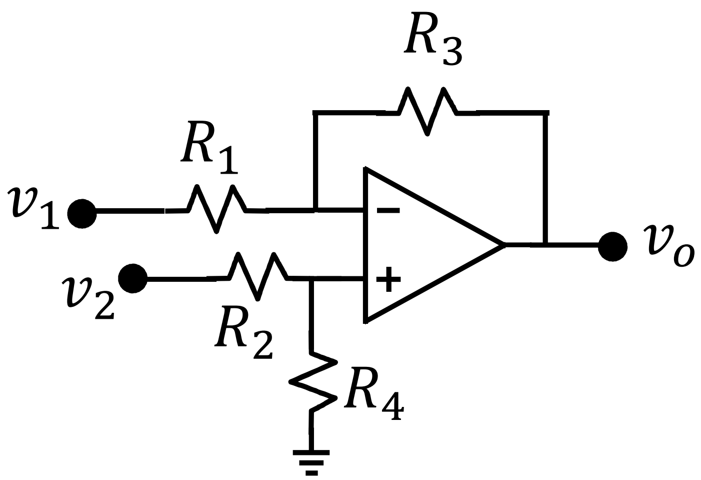


$$v_o = v^+\left(1 + \frac{R_f}{R}\right)$$

$$\frac{v_1 - v^+}{R_1} + \frac{v_2 - v^+}{R_2} + \frac{v_3 - v^+}{R_3} = 0$$

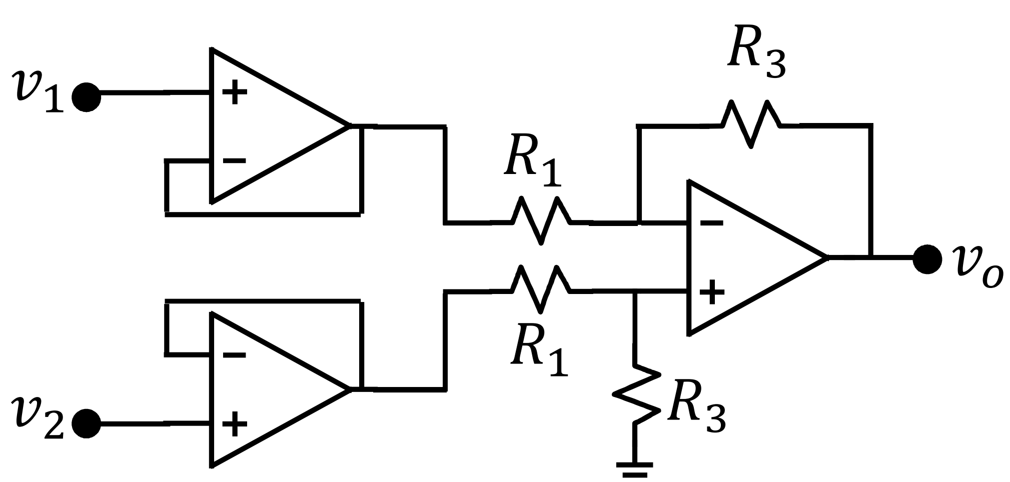
$$v_o = (R_1 \parallel R_2 \parallel R_3)\left(1 + \frac{R_f}{R}\right)\left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3}\right)$$

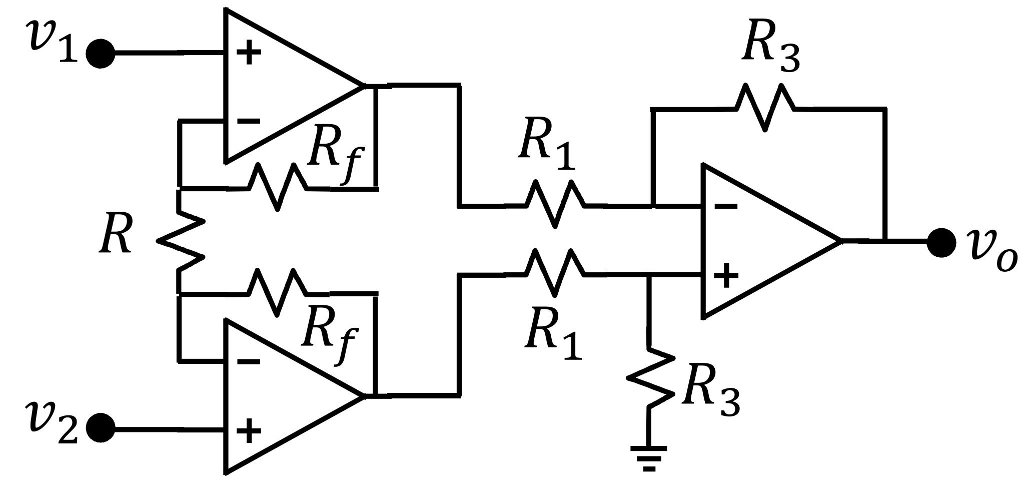
Differential Amplifier



$$v_o = -\left(\frac{R_3}{R_1}\right)v_1 + \left(\frac{R_4}{R_2 + R_4}\right)\left(1 + \frac{R_3}{R_1}\right)v_2$$

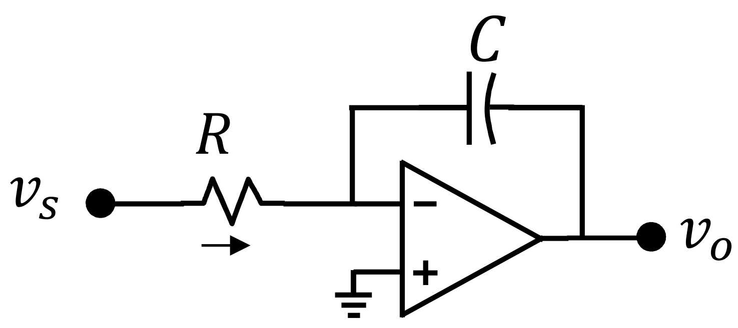
$$R_1 = R_2\,, R_3 = R_4 \quad \rightarrow v_o = \left(\frac{R_3}{R_1}\right)(v_2 - v_1)$$





$$v_o = \left(\frac{R_3}{R_1}\right)\left(1 + \frac{2R_f}{R}\right)(v_2 - v_1)$$

Integrator / Differentiator Amplifier

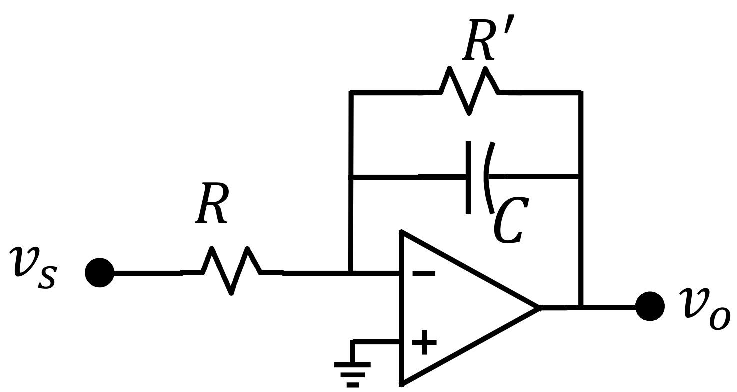


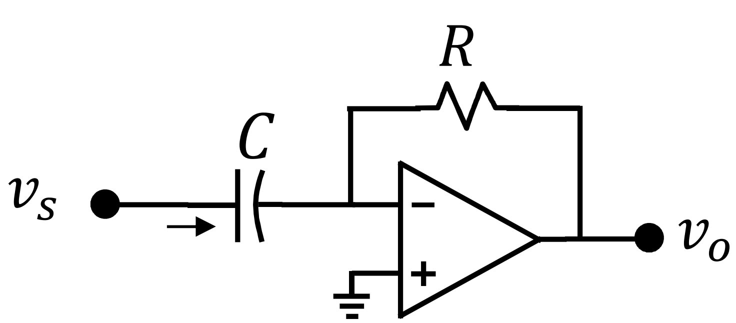
$$i = \frac{v_s}{R}$$

$$v_o = -v_c$$

$$v_c = v(0) + \frac{1}{C}\int_0^t i(\tau)d\tau$$

$$v_o = -v(0) - \frac{1}{RC}\int_0^t v_s(\tau)d\tau$$

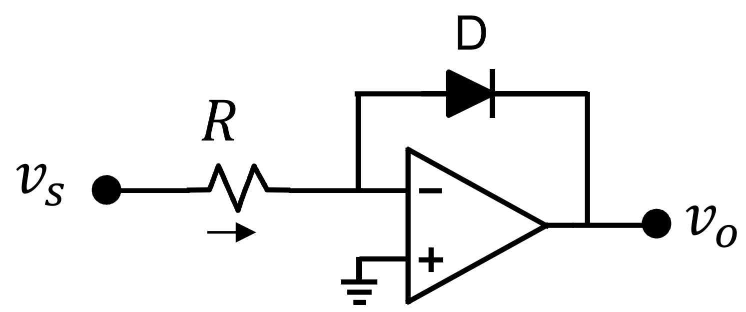




$$i = C\frac{dv_s}{dt}$$

$$v_o = -RC\frac{dv_s}{dt}$$

Logarithmic / Exponential Amplifier

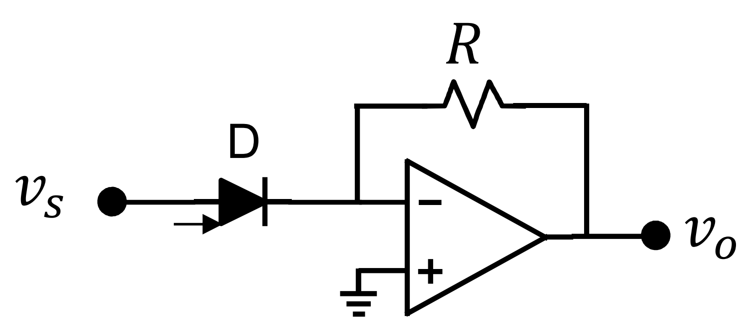


$$i = \frac{v_s}{R}$$

$$i_D = I_S\left(e^{v_D/VT} - 1\right) \cong I_S\, e^{v_D/VTh}$$

$$v_D = V_{Th} \ln\left(\frac{i_D}{I_S}\right) = V_{Th} \ln\left(\frac{v_s}{RI_S}\right)$$

So what?



$$i_D = I_S\left(e^{v_D/VTh} - 1\right) \cong I_S\, e^{v_s/VTh}$$

$$v_o = -Ri_D = -RI_S\, e^{v_s/VTh}$$

end