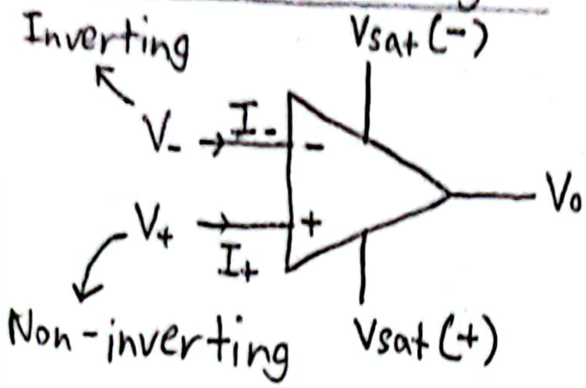
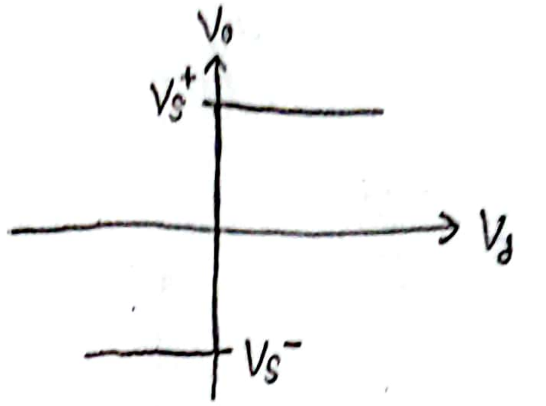
L-20 (Op-Amp)

Open loop config:





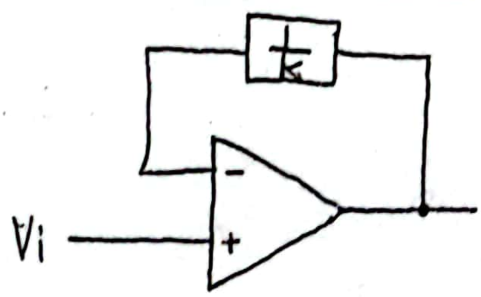
For ideal Op-Amp,
$R_{in} = \infty$, $R_{out} = 0$
$I_- = I_+ = 0$, $A = \infty$

$\boxed{V_d = V_+ - V_-}$

$$V_o = AV_d = \begin{cases} V_s^+ & \text{if } V_d > 0 \\ V_s^- & \text{"} \ V_d < 0 \end{cases}$$

Some Applications of Op-Amp:
1. Comparator
2. AC ON/OFF
3. Smoke Detector

Negative Feed Back (Closed loop config):



$$V_o = \frac{A}{\frac{A}{k}+1} V_i$$

$\boxed{\text{When } A = \infty, V_o = k V_i}$

* In feedback circuits the output slowly stabilizes.

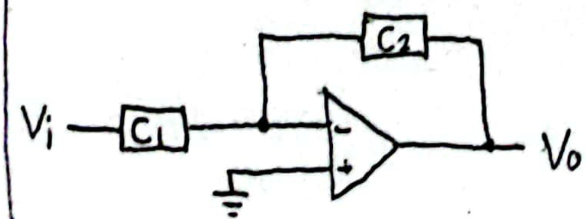
Since V_o = stable $\Rightarrow V_o = AV_d \Rightarrow V_d = \frac{V_o}{A} = \frac{\text{integer}}{\infty} = 0$

$\therefore$ In negative feedback,

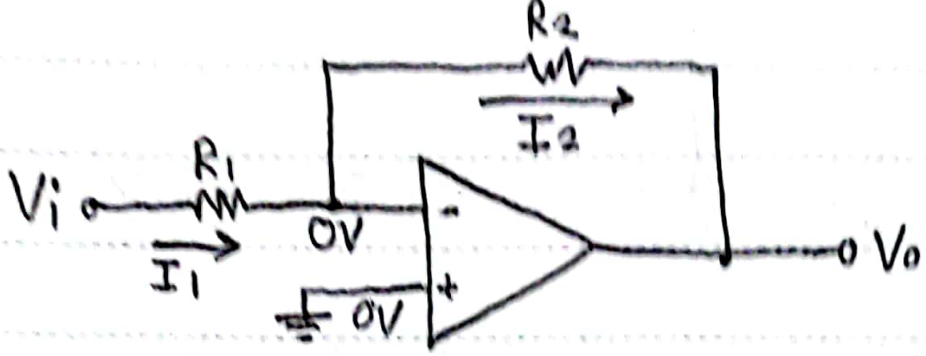
$V_d = 0$
$\Rightarrow V_+ - V_- = 0$
$\Rightarrow \boxed{V_+ = V_-}$

$\boxed{I_+ = 0, \ I_- = 0}$

* Basic Structure:



① Inverting Amplifier:



$$I_1 = \frac{V_i - 0}{R_1} = \frac{V_i}{R_1}$$

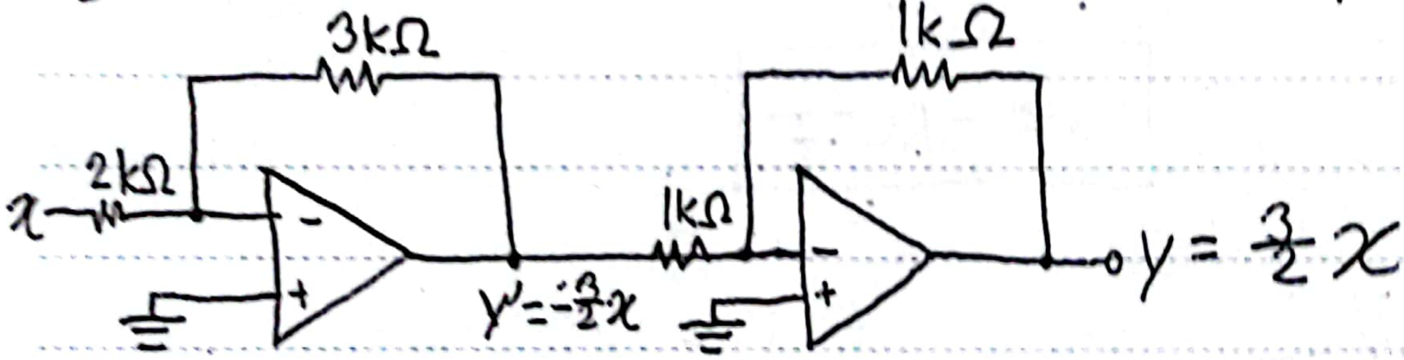
$$I_2 = I_1 = \frac{V_i}{R_1}$$

$$I_2 = \frac{0 - V_0}{R_2} \Rightarrow V_0 = -I_2 R_2$$

$$\Rightarrow V_0 = -\left(\frac{V_i}{R_1}\right) R_2$$

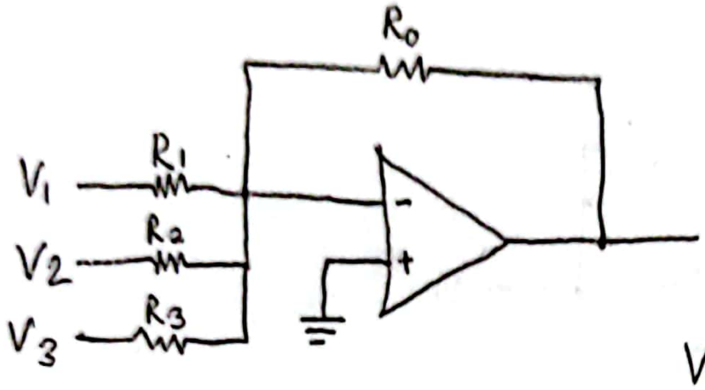
$$\Rightarrow V_0 = \underbrace{\left(-\frac{R_2}{R_1}\right)}_{\text{Gain}} V_i$$

Eg: $y = 1.5x$



Cascading Amplifier

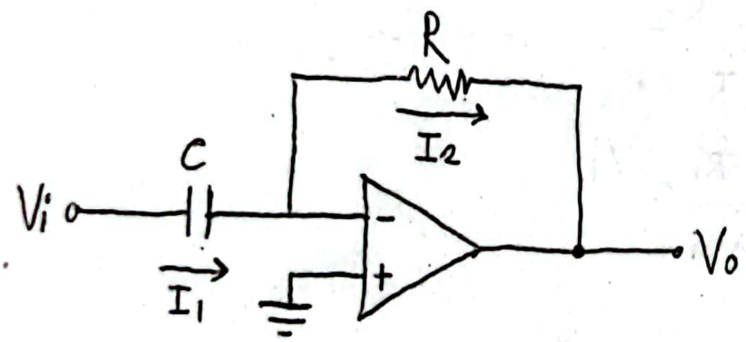
② Inverting Adder:



$$V_0 = -\frac{R_0}{R_1}V_1 - \frac{R_0}{R_2}V_2 - \frac{R_0}{R_3}V_3$$

$$V_0 = -R_0\left(\frac{1}{R_1}V_1 + \frac{1}{R_2}V_2 + \frac{1}{R_3}V_3\right)$$

③ Differentiator:



$$V_c = V_i - 0 = V_i$$

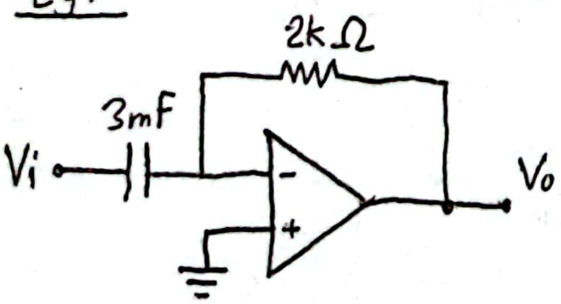
$$I_c = C\frac{dV_c}{dt} = C\frac{dV_i}{dt} = I_1$$

$$I_1 = I_2 = I_c$$

$$\Rightarrow I_2 = \frac{0 - V_0}{R} \Rightarrow V_0 = -I_2R$$

$$\therefore \boxed{V_0 = -RC\frac{dV_i}{dt}}$$

Eg:



if $V_i = 10\cos(2t)$

$$V_0 = -RC\frac{dV_i}{dt}$$

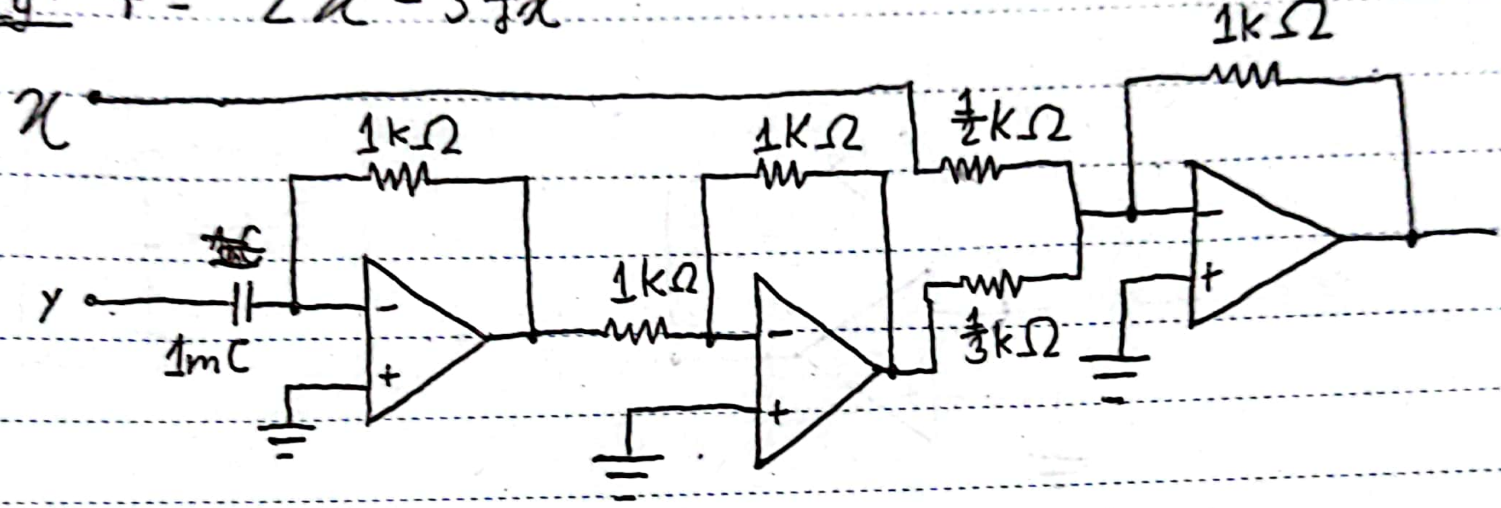
$$= -(2000)\left(\frac{3}{1000}\right)\left(\frac{d}{dt}(10\cos 2t)\right)$$

$$= -6(-20\sin 2t)$$

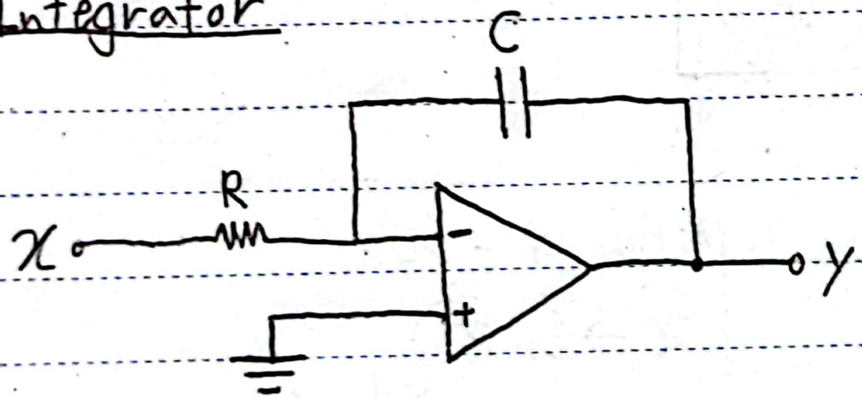
$$= \boxed{120\sin 2t}$$

10^3 $\quad$ 1

Eg: $f = -2x - 3\frac{dy}{dx}$

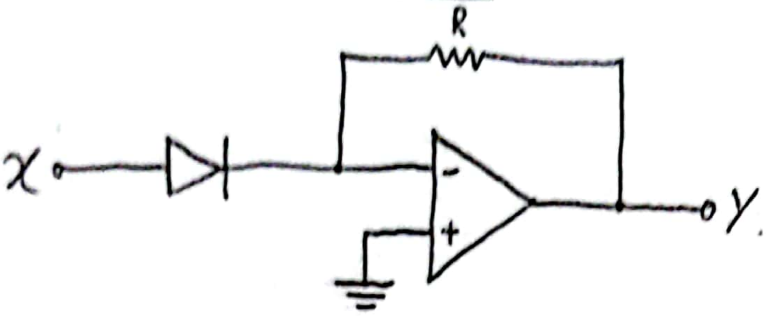


④ Integrator



$$\boxed{y = -\frac{1}{RC}\int x\, dt}$$

5 ~~Logari~~ Exponential

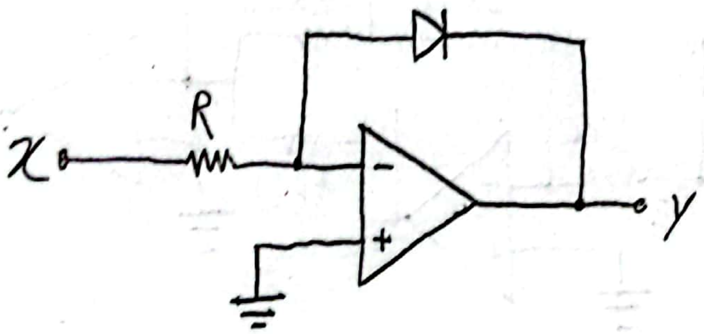


Conditions:
$I_s R = 1$
$V_T = 1$

$* \; I_D = I_S \exp\left(\frac{V_D}{V_T}\right)$

$$\boxed{y = -e^{x}}$$

6 Logarithm



Conditions
$I_s R = 1$
$V_T = 1$

$$\boxed{y = -\ln(x)}$$

Formulas:

1. $\ln(e^{x}) = x$
2. $e^{\ln(x)} = x$
3. $\ln(ab) = \ln(a) + \ln(b)$

$*$ For $f = xy$

$$\left.\begin{array}{l} x \rightarrow \ln x \\ y \rightarrow \ln y \end{array}\right\} \ln x + \ln y \rightarrow \ln xy$$

$$\downarrow$$

$$\exp(\ln xy)$$

$$\downarrow$$

$$xy$$