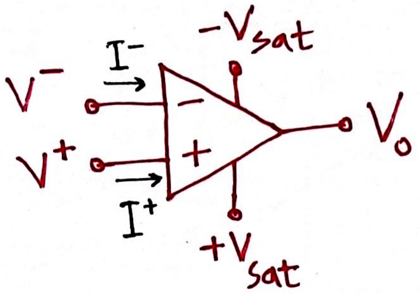
Op-Amp

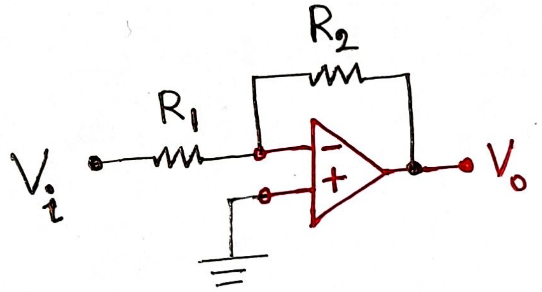
here, $v^- \rightarrow$ inverting input
$v^+ \rightarrow$ non-inverting input
$V_o \longrightarrow$ output



$$V_o = \begin{cases} +V_{sat} & \text{if } V^+ > V^- \\ -V_{sat} & \text{if } V^- > V^+ \end{cases}$$

$$I^+ = I^- = 0$$

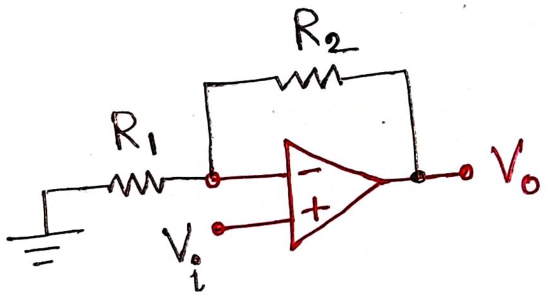
Inverting Amplifier



$$V_o = -\frac{R_2}{R_1} V_i$$

here, Gain $= \frac{V_o}{V_i} = \frac{-R_2}{R_1}$

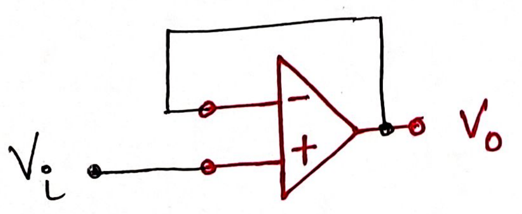
Non-Inverting Amplifier



$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_i$$

here, Gain, $\frac{V_o}{V_i} = \left(1 + \frac{R_2}{R_1}\right)$

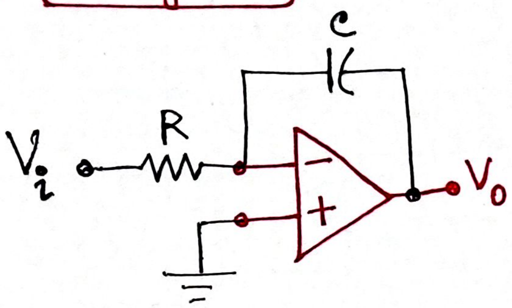
Buffer/Voltage Follower



$$V_o = V_i$$

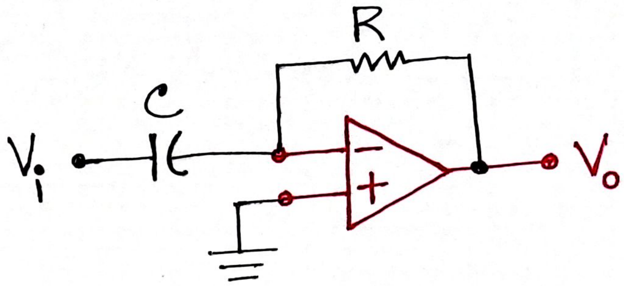
here, Gain $= \frac{V_o}{V_i} = 1.$

Integrator



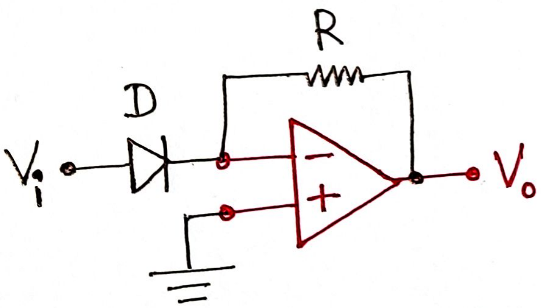
$$V_o = \frac{-1}{RC}\int V_i \, dt$$

Differentiator



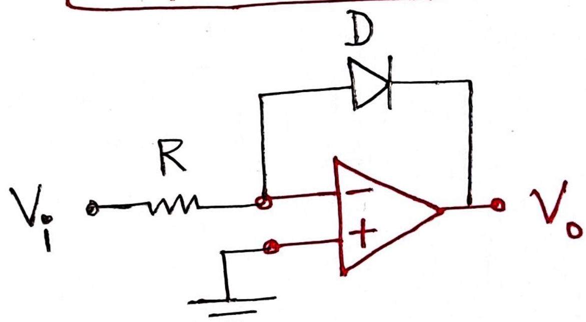
$$V_o = -RC\frac{d}{dt}(V_i)$$

Exponential Amplifier



$$V_o = -I_s R \exp\left(\frac{V_i}{V_T}\right)$$

Logarithmic Amplifier

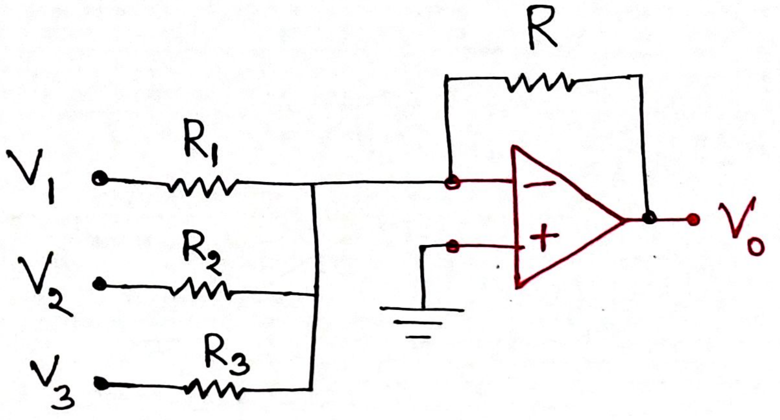


$$V_o = -V_T \ln\left(\frac{V_i}{I_s R}\right)$$

here, $V_T = 25\,mV$ (at room temperature)

$I_s = 10^{-9} A$

Inverting Adder



$$V_o = -\left(\frac{R}{R_1}V_1 + \frac{R}{R_2}V_2 + \frac{R}{R_3}V_3\right)$$

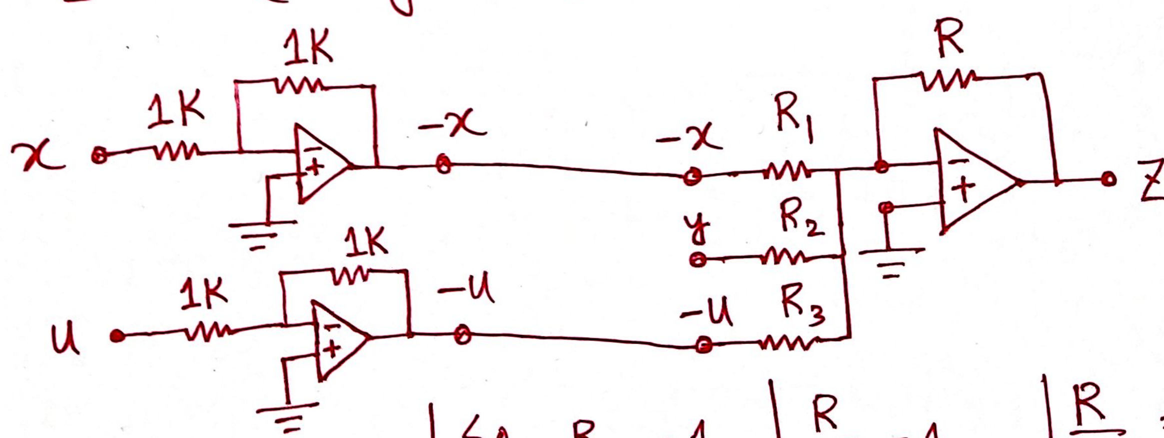
Examples

Implement the following mathematical operations using Op-Amp.

① $z = x - y + 5u$

Sol^n

$$z = -(-x + y - 5u) = -((1)(-x) + (1)(y) + (5)(-u))$$



let, $R = 10K$.

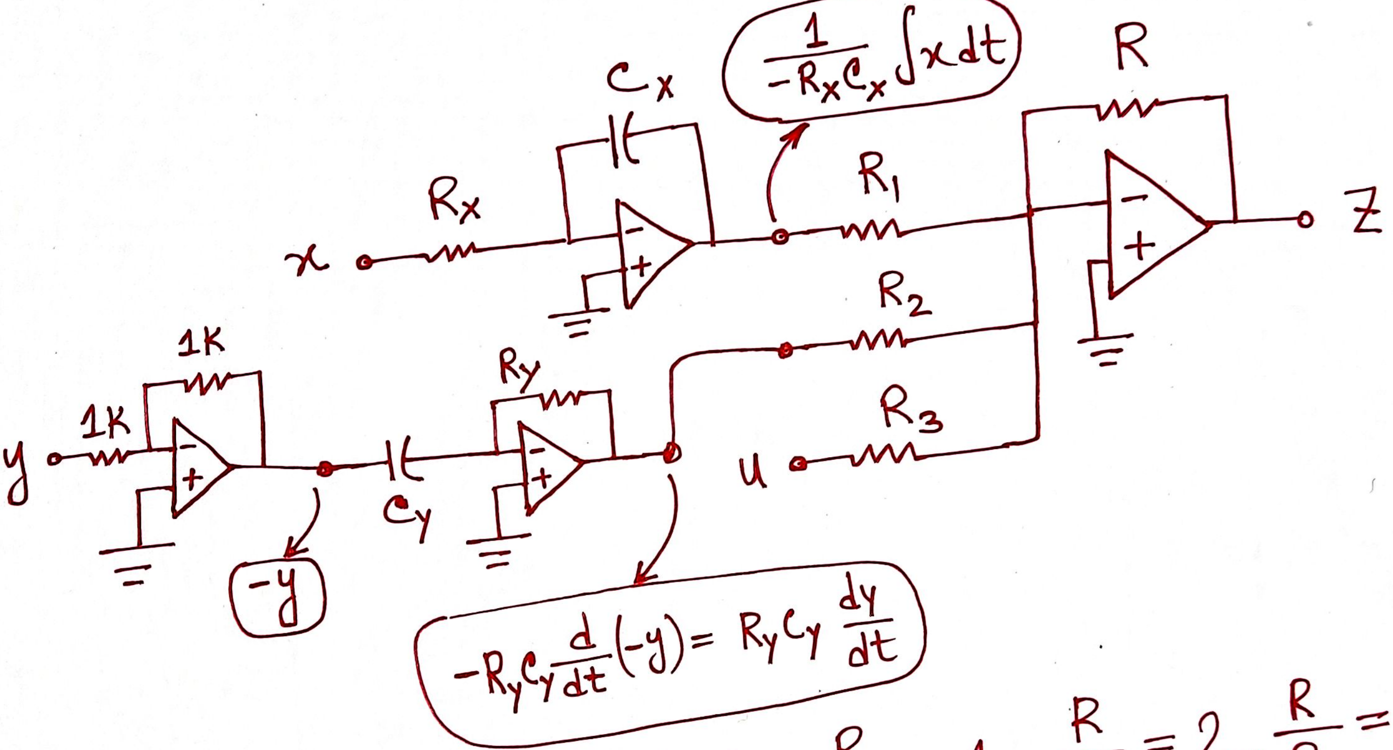
So, $\frac{R}{R_1} = 1$ ↪ $R_1 = 10K$ | $\frac{R}{R_2} = 1$ ↪ $R_2 = 10K$ | $\frac{R}{R_3} = 5$ ↪ $R_3 = 2K$.

② $z = \int x\,dt - 2\frac{dy}{dt} - u$

Sol^n

$$z = -\left(-\int x\,dt + 2\frac{dy}{dt} + u\right)$$

$$= -\left((1)\left(-\int x\,dt\right) + 2\left(-\frac{dy}{dt}\right)(-1) + (1)(u)\right).$$



here,

$$\frac{-1}{R_xC_x} = -1$$

let, $C_x = 47\,\mu F$

$\therefore R_x = 21.2766\ K\Omega$

Again, $-R_yC_y = -1$

let, $C_y = 47\,\mu F$

$\therefore R_y = 21.2766\ K\Omega$

Again, $\frac{R}{R_1} = 1$, $\frac{R}{R_2} = 2$, $\frac{R}{R_3} = 1$

let, $R = 10\ K\Omega$.

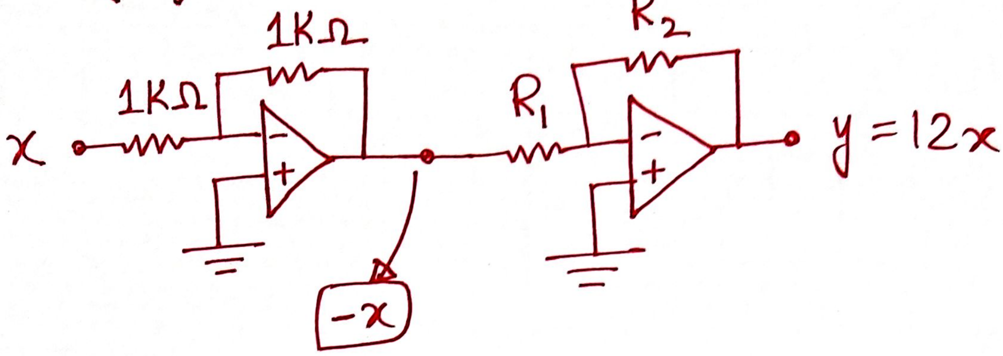
$\therefore R_1 = 10\ K\Omega$

$R_2 = 5\ K\Omega$

$R_3 = 10\ K\Omega$.

③ $y = 12x$

$= (-12)(-x)$



here, $\frac{-R_2}{R_1} = -12$

let, $R_1 = 1K\Omega$

$\therefore R_2 = 12K\Omega$

④ $y = x^2$

Solⁿ $y = x^2$

$\hookrightarrow \ln y = \ln x^2$

$\hookrightarrow \ln y = \ln x + \ln x$

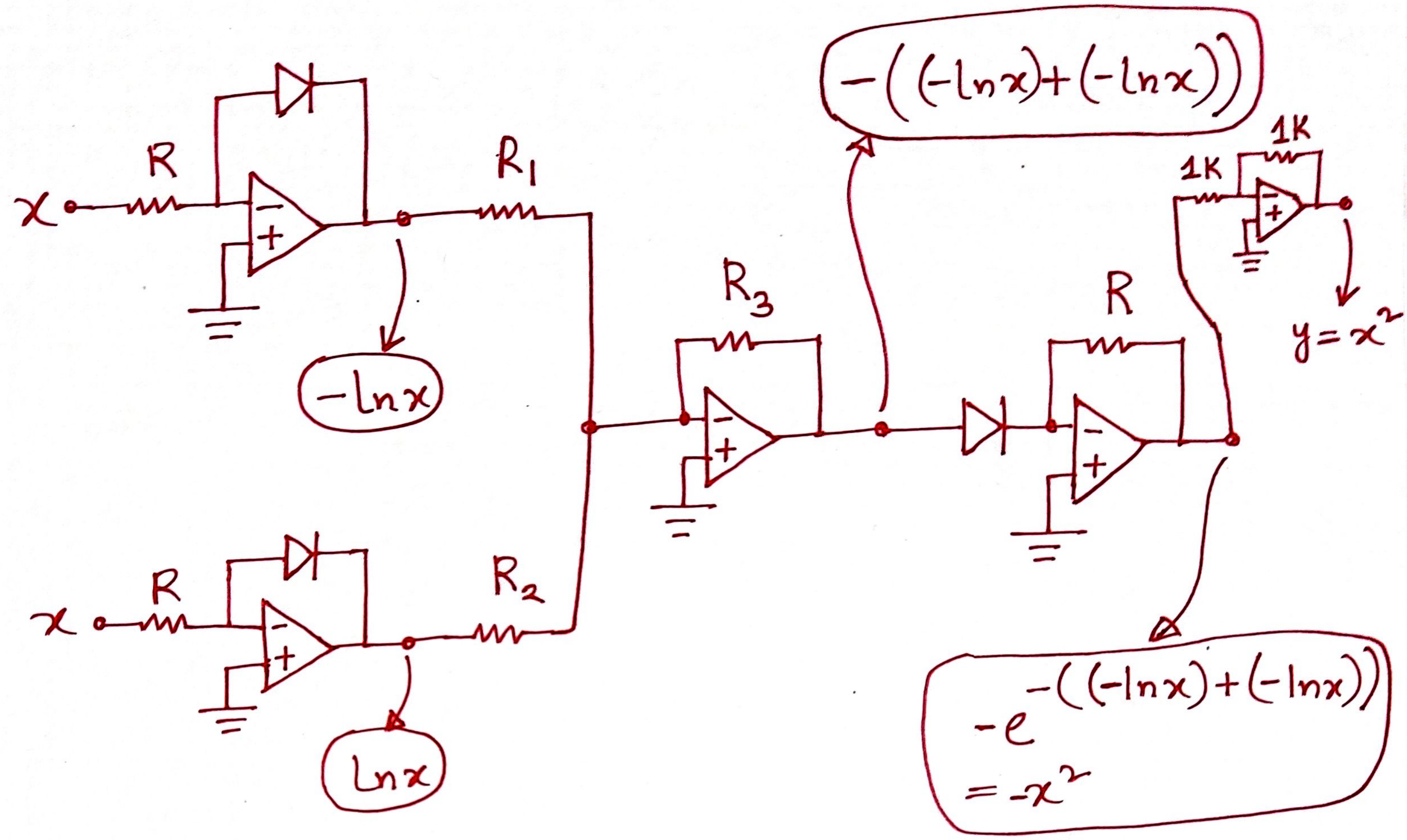
$\hookrightarrow y = e^{\ln x + \ln x}$

$\hookrightarrow y = e^{-((-\ln x) + (-\ln x))}$

we need to implement this function using exponential & Logarithmic amplifier.

let, $I_s R = 1$

$V_T = 1$.



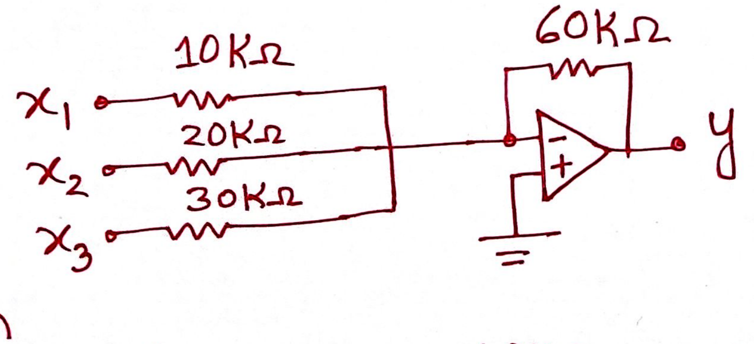
here, $\frac{R_3}{R_1} = 1$, $\frac{R_3}{R_2} = 1$

Let, $R_3 = 10\,K\Omega$

$\therefore R_1 = 10\,K\Omega$ and $R_2 = 10\,K\Omega$

Find the output of the following circuits.

①

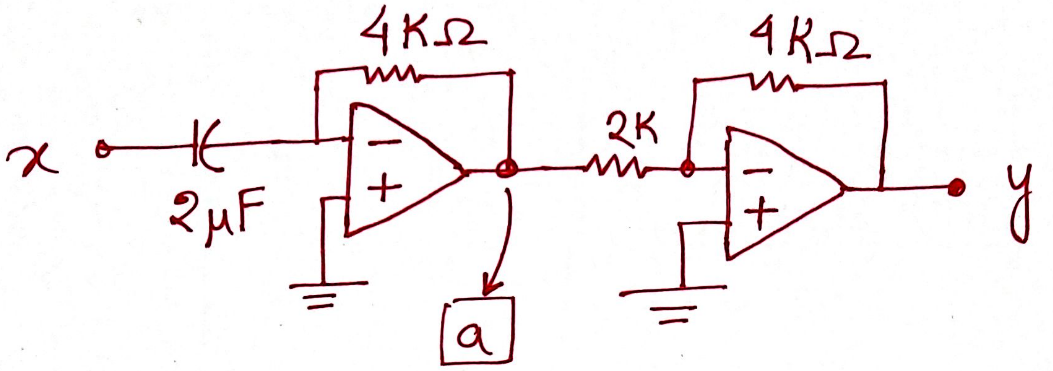


Solⁿ

$$y = -\left(\frac{60K\Omega}{10K\Omega} x_1 + \frac{60K\Omega}{20K\Omega} x_2 + \frac{60K\Omega}{30K\Omega} x_3\right)$$

$\hookrightarrow y = -(6x_1 + 3x_2 + 2x_3)$.

2



$$a = -RC\frac{d}{dt}(x) = -2\times10^{-6}\times 4\times10^{3}\times\frac{d}{dt}(x)$$

$$\hookrightarrow a = -8\times10^{-3}\times\frac{dx}{dt}.$$

$$\therefore\ y = -\left(\frac{4K\Omega}{2K\Omega}\right)(a) = -2\left(-8\times10^{-3}\times\frac{dx}{dt}\right)$$

$$\hookrightarrow y = 16\times10^{-3}\times\frac{dx}{dt}.$$