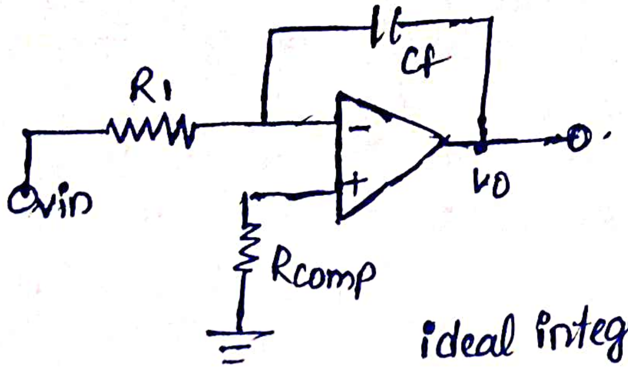
Integrator:

Ideal Integrated circuit.

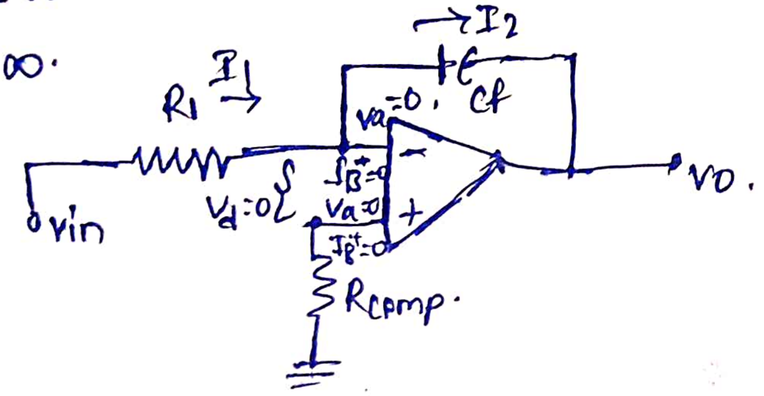


ideal integrated circuit.

from ideal characteristics of OP-Amp

$R_i = \infty$

$A = \infty$.



Apply KCL at inverting terminal.

$$I_1 = I_2 + I_B^-$$

$$\frac{V_{in} - 0}{R_1} = C_f \frac{d(0 - v_o)}{dt} + 0$$

$$\frac{dv_o}{dt} = -\frac{1}{R_1 C_f} v_{in}$$

integrating on both sides.

$$\int \frac{d}{dt} v_o = \int -\frac{1}{R_1 C_f} v_{in}(t)$$

$$v_o = -\frac{1}{R_1 C_f} \int v_{in}(t) + v_{in}(0)$$

$v_{in}(0)$ = initial condition.

For practical op-amp

$$V_o(s) = \frac{-1}{R_1 C_f} \cdot \frac{V_{in}(s)}{s}$$

$$\frac{V_o(s)}{V_{in}(s)} = \frac{-1}{s R_1 C_f} \; ; \; \left| \frac{V_o(s)}{V_{in}(s)} \right| = H(s) = \frac{-1}{j2\pi f R_1 C_f}$$

$$|H(s)| = |A| = \frac{1}{2\pi f R_1 C_f} = \frac{1}{f/f_b} = \frac{f_b}{f} , \; f_b = \frac{1}{2\pi R_1 C_f}$$

At $f=0 \Rightarrow |A| = \infty$ (drawback)

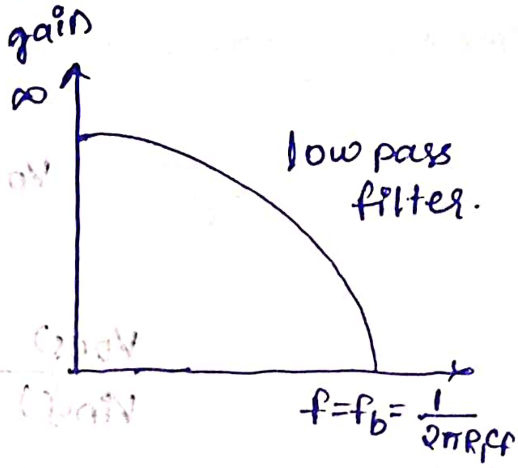
At $f = f_b \Rightarrow |A| = 1$

when normal gain = 1

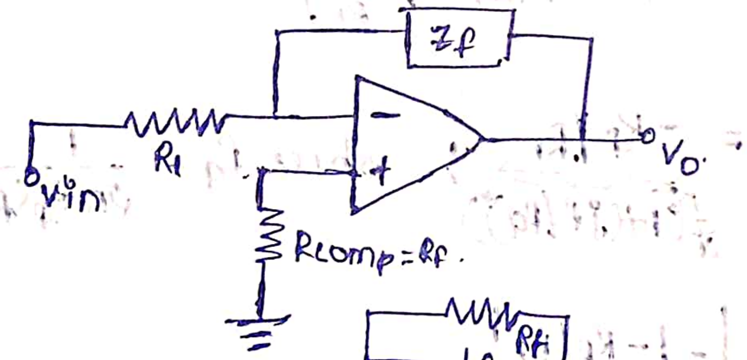
gain in dB $|A|_{dB} = 0$

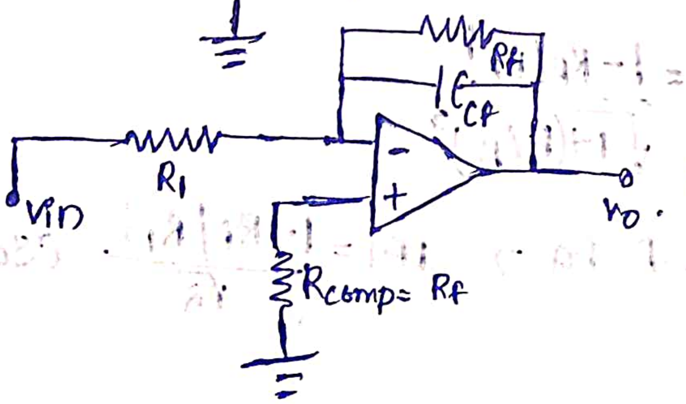
$$|A|_{dB} = 20 \log A$$
$$= 20 \log 1$$
$$= 0$$

• gain is ∞ at low frequency.



To overcome the drawback at $f=0$ gain is ∞, we use a resistor (to get finite gain value) is connected parallel to feed back capacitor.





$R_i = \infty$; $A = \infty$

$$Z_f = R_f \| C_f = \frac{R_f \times \frac{1}{C_f s}}{R_f + \frac{1}{C_f s}} = \frac{R_f}{1 + R_f C_f s}$$

from the circuit.

$$V_o = \frac{-Z_f}{R_1} V_{in}$$

$$V_o = \frac{\frac{-R_f}{1 + R_f C_f s}}{R_1} \cdot V_{in}$$

$$V_o(s) = \frac{-R_f / R_1}{1 + R_f C_f s} V_{in}(s)$$

$$\frac{V_o(s)}{V_{in}(s)} = \frac{-R_f / R_1}{1 + R_f C_f s}$$

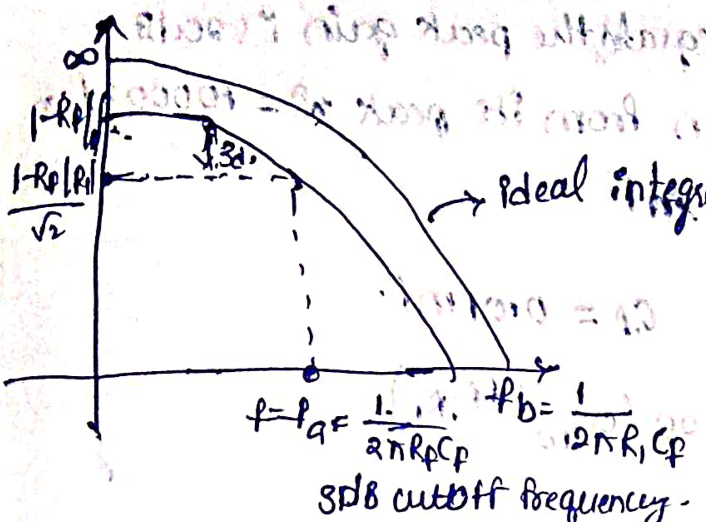
$$|A| = \frac{-R_f / R_1}{\sqrt{1 + (2\pi f R_f C_f)^2}}$$

when $f = 0$; $|A| = \left| \frac{-R_f}{R_1} \right|$

$$\frac{V_o(s)}{V_{in}(s)} = \frac{-R_f / R_1}{(1 + (jf / f_a))} \text{ ; where, } f_a = \frac{1}{2\pi R_f C_f}$$

$$\left| \frac{V_o(s)}{V_{in}(s)} \right| = \frac{|-R_f / R_1|}{\sqrt{1 + (f / f_a)^2}}$$

At, $f = f_a \Rightarrow |A| = \frac{|-R_f / R_1|}{\sqrt{2}}$ (3dB frequency)



· because of R_f & C_f ∥ combination Integrated the overall power dissipation will be increased ∴ that is the reason.
~~(Design)~~ practical integrated is also called as lossy Integrator.

Consider a lossy integrator as shown in fig.

$R_1 = 10K\Omega$.

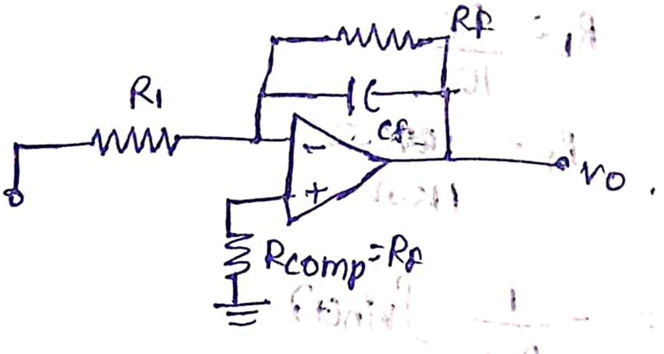
$R_f = 100K\Omega$.

$C_f = 10\,nF$.

Determine the lower frequency of integration and study the responds for inputs

(i) sin wave with 1V peak to peak at 5KHz

(ii) Square wave with 1V peak to peak at 5KHz.



for proper integration $f_a = 10f_b$.

$$\boxed{f_a = \frac{1}{2\pi R_f C_f}}$$

• Find R_1, R_f in lossy integrator, the peak gain is 20dB and the gain is 3dB down from its peak $\omega = 10000$ rad/sec use a capacitance of 0.01 μF

Given peak 20dB ; $C_f = 0.01\,mF$

$$\Rightarrow 20 \log_{10} 10 = 20 \log_{10} (R_f / R_1)$$

$$R_f / R_1 = 10$$

$$R_f = 10 R_1$$

$$f_a = \frac{1}{2\pi R_f C_f}$$

$$2\pi f_a = \frac{1}{R_f C_f}$$

$$10000 = \frac{1}{R_f \times 0.01 \times 10^{-6}} \qquad R_f = \frac{1}{10000 \times 0.01 \times 10^{-6}}$$

$$= \frac{1 \times 10^{6}}{10^{4} \times 10^{-2}} = 10^{4} = \cancel{100}\,K = 1K$$

$$R_f = \cancel{100}\,K\Omega \quad 10K\Omega$$

$$R_1 = \frac{R_f}{10}$$

$$R_1 = \cancel{100}\,\Omega \quad 1K\Omega$$

$$V_o = -\frac{1}{R_1 C_f} \int v_{in}(t)$$

$$V_o = -\frac{1}{1000 \times 0.01 \times 10^{-6}} \int \sin(2\pi 5000 \times 1)$$

$$= -\frac{10^{3}}{1 \times 10^{-2}} \int \sin((2\pi)(5000)(1)t)$$

$$= + 10^{5} \left(-\frac{\cos(2\pi(5000)(1))}{2\pi 5000}\right)$$

$$= \frac{100}{\pi}$$

$-\cos 10$