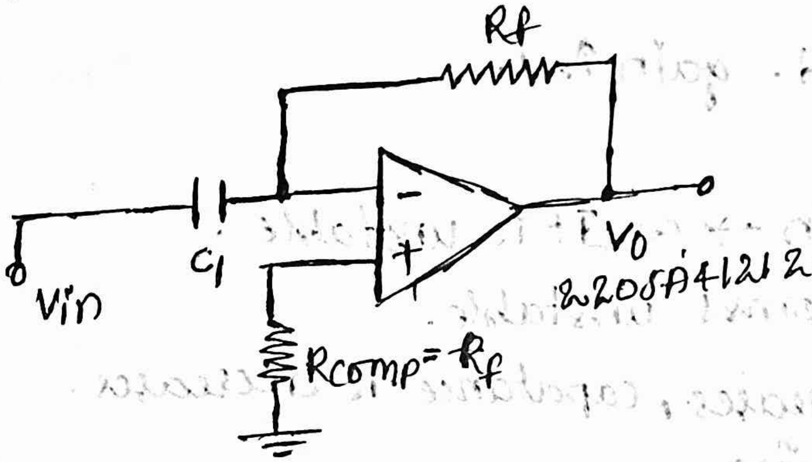
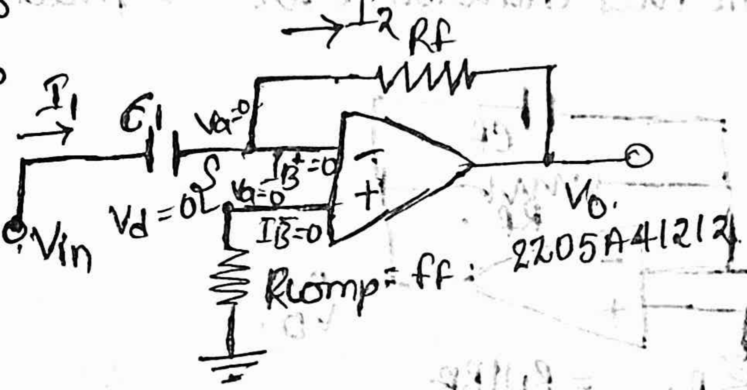
Differentiator:



$R_i = \infty$

$A = \infty$



$$I_1 = I_2 + I_B^-$$

$$C_1 \frac{d(V_{in} - V_a)}{dt} = \frac{V_a - V_o}{R_f} + 0$$

$$V_o = -R_f C_1 \frac{dv_{in}}{dt}$$

$$V_o(s) = -R_f C_1 \cdot s V_{in}(s)$$

$$\frac{V_o(s)}{V_{in}(s)} = -sR_f C_1$$

$$\left|\frac{V_o(s)}{V_{in}(s)}\right| = -j\omega R_f C_1$$

$$\left|\frac{V_o(s)}{V_{in}(s)}\right| = A = |-j\omega R_f C_1|$$

$|A| = \omega R_f C_1$

$|A| = 2\pi f R_f C_1$

$|A| = \frac{f}{f_a}$,

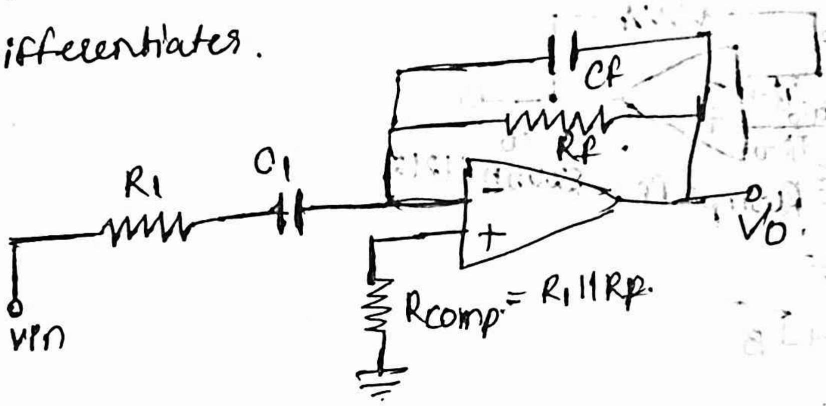
where $f_a = \frac{1}{2\pi R_f C_1}$ cutoff frequency.

(i) If f is ↑creased. gain ↑ed.

Drawback.

- as f is ↑ed. gain → ∞, It is unstable the system becomes unstable.
- as frequency increases, capacitance is decreases. $R_i = \infty$ is decreasing.

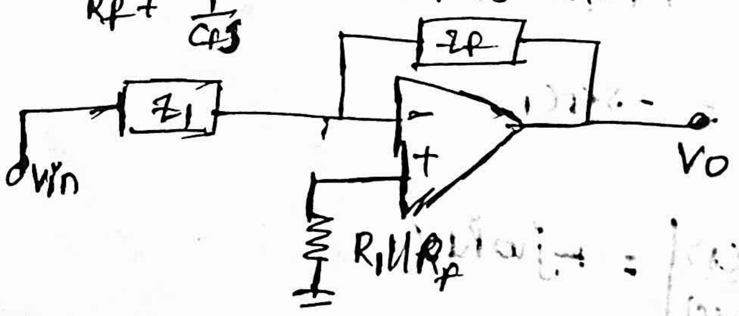
In order to over come this drawback we use practical Differentiator.



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

$R_1 + \frac{1}{Cs} = Z_1$

$R_f \| C_f = \frac{R_f \times \frac{1}{Cs}}{R_f + \frac{1}{C_f s}} = \frac{R_f}{1 + R_f C_f s} = Z_2$.



$V_o = -\frac{Z_F}{Z_1} V_{in}$ - I

$$\frac{V_o(s)}{V_{in}(s)} = \frac{\dfrac{-R_f}{1+R_f C_f s}}{R_1 + \dfrac{1}{C_1 s}}$$

$$= \frac{-R_f \cdot C_1 s}{(1+R_1 C_1 s)(1+R_f C_f s)}$$

Let, $R_1 C_1 = R_f C_f$.

$$\frac{V_o(s)}{V_{in}(s)} = \frac{-R_f C_1 s}{(1+R_1 C_1 s)^2} = \frac{-R_f C_1 s}{(1+ s f/f_b)^2}$$

where $f_b = \frac{1}{2\pi R_1 C_1}$

• problems:

Design op-amp differentiator that will differentiate the input signal with max frequency of 100Hz.

(i) the input signal with max frequency of 100 Hz.

(ii) Draw the output wave form for a sine wave of 1 volt peak to peak at 100 Hz is applied to differentiator.

(iii) Repeat the above 2 for a square wave input

Condition for design procedure.

(i) a good differentiator may be designed as follows following step

(i) choose f_a = highest value of given input signal and assume the practical value of C_1 is less than 1 micro farad. 1μf

(ii) choose $f_b = 10 f_a$ & assume $R_1 C_1 = R_f C_f$