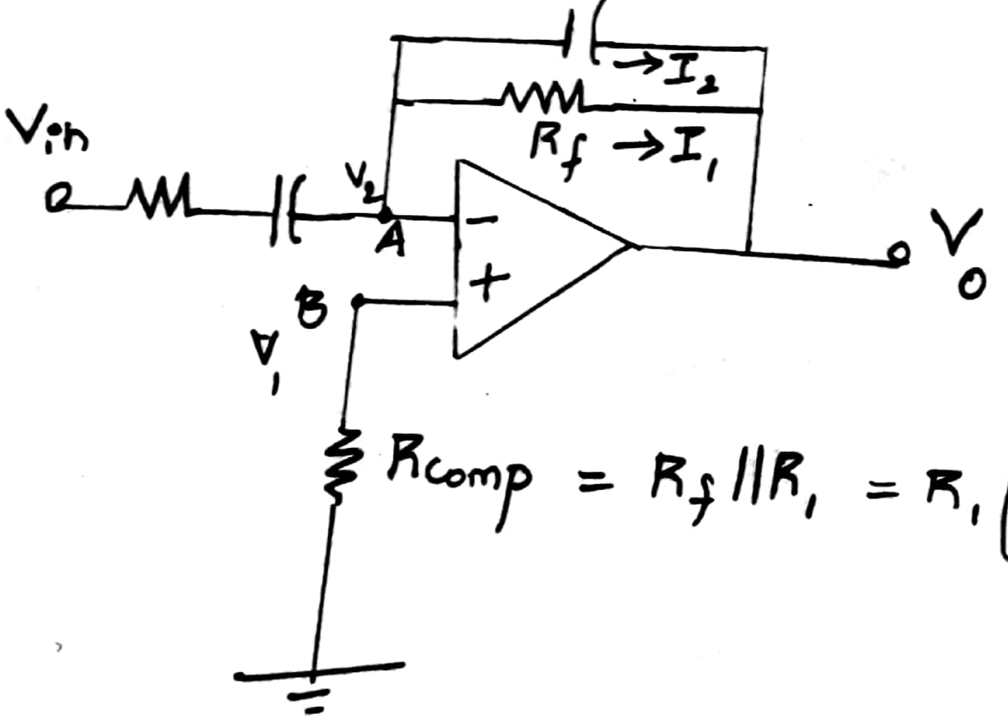
Practical Differentiator :→

→ The noise and stability at high frequency can be corrected. But in the Practical differentiator circuit by using resistance R_1 in series with C



$$R_{comp} = R_f \| R_1 = R_1 \quad (R_f \gg R_1)$$

Analysis of Practical Differentiator

→ Inside the op-amp current is "zero"

→ there is no current i/p at node B

→ $V_1 = V_2 = 0$

The current I is given by

$$I = \frac{V_{in} - V_2}{Z_1} = \frac{V_{in}}{Z_1} \longrightarrow (1)$$

Where $Z_1 = R_1$ in series with C_1

So in laplace domain we can write

$$Z_1 = R_1 + \frac{1}{SC_1} = \frac{1 + SR_1C_1}{SC_1}$$

substitute the Z_1 Value in Eq (1)

$$I = \frac{V_{in}(s)}{\frac{1 + SR_1C_1}{SC_1}} = \frac{SC_1 V_{in}(s)}{1 + SR_1C_1} \longrightarrow (2)$$

Now the current I_1 is given by

$$I_1 = \frac{V_2 - V_{out}}{R_f} = \frac{-V_{out}}{R_f} \longrightarrow (3)$$

In laplace form, we have

$$I_1 = \frac{-V_{out}(s)}{R_f}$$

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and $I_2 = c_f \frac{d(V_2 - V_{out})}{dt}$

$$= -c_f \frac{dV_{out}}{dt} \longrightarrow 4$$

Taking laplace transform, we obtain

$$I_2 = -sc_f V_{out}(s)$$

Applying KCL at node A,

$$I = I_1 + I_2 \text{ --- } 5$$

substitute Equ. in 2, 3 & 4

Equ in 5

$$\frac{sc_1 V_{in}(s)}{(1+sR_1c_1)} = \frac{-V_{out}(s)}{R_f} - sc_f V_{out}(s)$$

$$\frac{sc_1 V_{in}(s)}{(1+sR_1c_1)} = -V_{out}(s)\left[\frac{1}{R_f} + sc_f\right]$$

$$= -V_{out}(s)\left\{\frac{1+R_f sc_f}{R_f}\right\}$$

$$\frac{SR_f C_1 V_{in}(s)}{(1+R_f SC_f)(1+SR_{f1})} = -V_{out}(s)$$

~~(5)~~

If $R_1 C_1 = R_f C_f$ then

$$V_{out}(s) = \frac{-SR_f C_1 V_{in}(s)}{(1+SR_f C_f)^2} \rightarrow (6)$$

→ $R_f C_1$ is much greater than $R_1 C_1$ & $R_f C_f$ we can write above equ.

$$\boxed{V_{out}(s) = -SR_f C_1 V_{in}(s)}$$

on applying increase laplace transform we get

$$\boxed{V_{out} = -R_f C_1 \left[\frac{d}{dt} V_{in}(t)\right]}$$

final equ