Name- Manju Thakur
Reg no.- 21BLC1428

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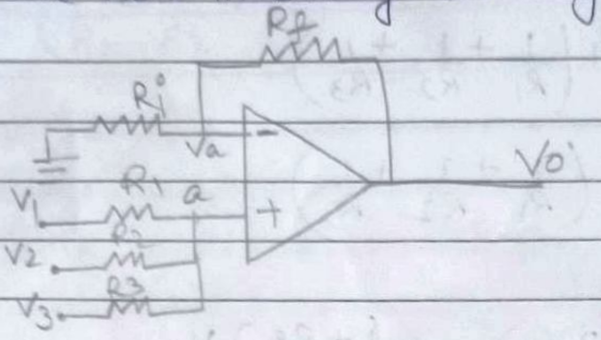
Mod-4 (part-2)

Q5 Consider the non-inverting summing amplifier



(a) Find the gain of the amplifier

Ans. Applying KCL at node 'a' :-

$$\frac{0-V_a}{R_i} = \frac{V_a - V_o}{R_f} \Rightarrow \frac{V_o}{R_f} = \frac{V_a}{R_f} + \frac{V_a}{R_i} \quad \text{—①}$$

$$\frac{V_1 - V_a}{R_1} + \frac{V_2 - V_a}{R_2} + \frac{V_3 - V_a}{R_3} = 0 \quad \text{—②}$$

from ①, $\frac{V_o}{R_f} = V_a\left(\frac{R_f + R_i}{R_f R_i}\right)$

$$\frac{V_o R_f R_i}{R_f (R_f + R_i)} = V_a \Rightarrow V_a = \frac{V_o R_i}{R_f + R_i}$$

$$\frac{V_1 - \frac{V_o R_i}{R_f + R_i}}{R_1} + \frac{V_2 - \frac{V_o R_i}{R_f + R_i}}{R_2} + \frac{V_3 - \frac{V_o R_i}{R_f + R_i}}{R_3} = 0.$$

$$V_a = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$$V_o = \left(1 + \frac{R_f}{R_i}\right) V_a$$

$$V_o = \left(1 + \frac{R_f}{R_i}\right) \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

if $V_1 = V_2 = V_3$

$$V_o = \left(1 + \frac{R_f}{R_i}\right) \frac{V_1\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)}{\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)}$$

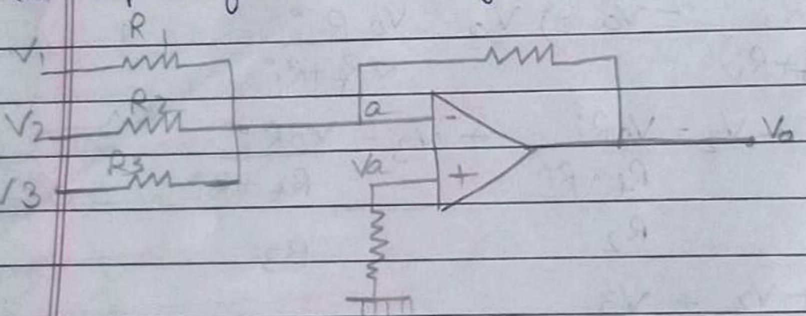
if $R_1 = R_2 = R_3$

$$V_o = 1 + \frac{R_f}{R_i} \frac{\left(\frac{3V_1}{R_1}\right)}{\left(\frac{3}{R_1}\right)} = \left(1 + \frac{R_f}{R_i}\right) V_1$$

Here, $V_{in} = V_1 = V_2 = V_3$.

So, gain of the amplier $= \frac{V_o}{V_{in}} = \frac{\left(1 + \frac{R_f}{R_i}\right) V_1}{V_1} = 1 + \frac{R_f}{R_i}$

(b) Repeat for inverting summing amplifier.



Applying KCL at node a,

$$\frac{V_1 - V_a}{R_1} + \frac{V_2 - V_a}{R_2} + \frac{V_3 - V_a}{R_3} + \frac{V_a - V_o}{R_f}$$

$V_a = 0$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = -\frac{V_o}{R_f}$$

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

If $V_1 = V_2 = V_3$

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

If $R_1 = R_2 = R_3$

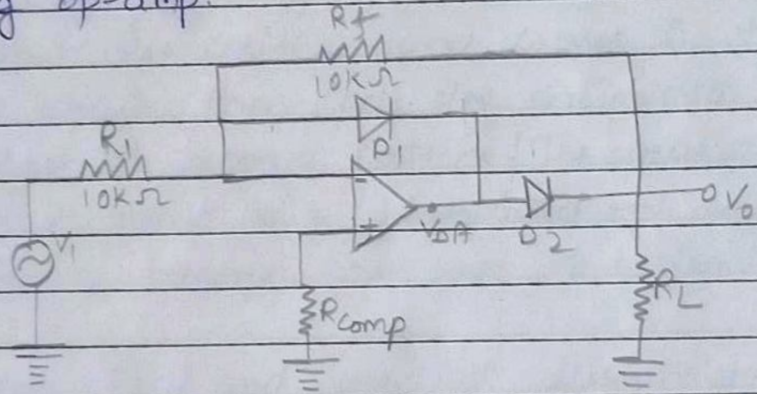
$$V_0 = \frac{-3R_f V_1}{R_1}.$$

Here, $V_{in} = V_1 = V_2 = V_3$.

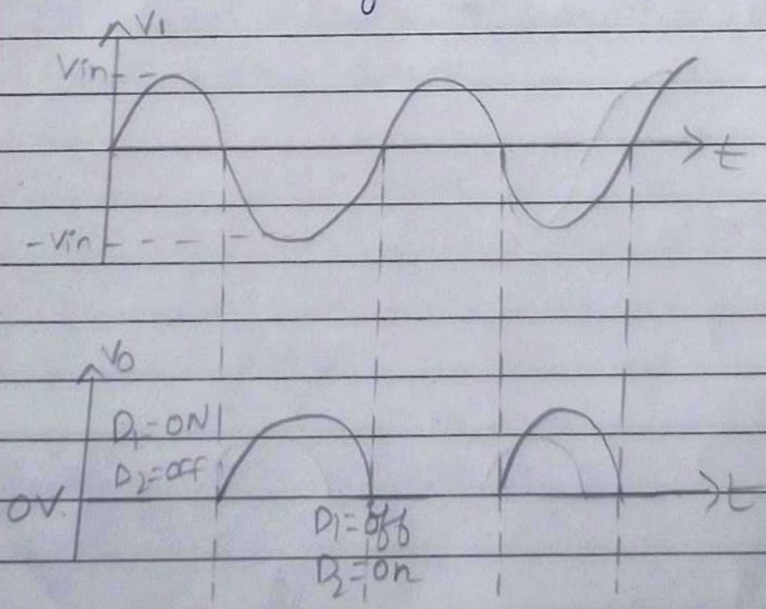
So, gain of the amplifier $= \frac{V_0}{V_{in}} = \frac{\frac{-3R_f V_1}{R_1}}{V_1} = \frac{-3R_f}{R_1}$.

26. Explain the working principal of half wave rectifier using op-amp.

Ans.



Ideal half wave rectifier

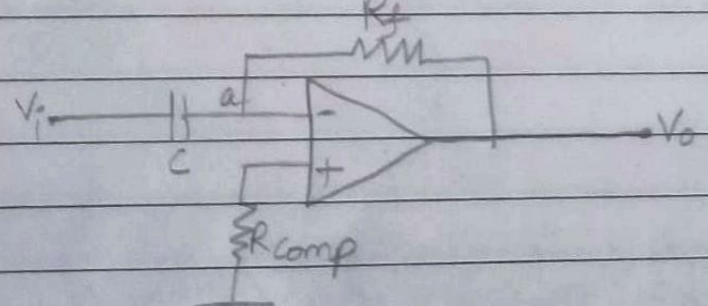


Input/output waveforms

An inverting amplifier can be converted into an ideal half-wave rectifier by adding two diodes as drawn in the diagram. when v_i is positive, diode D_1 conducts causing V_{OA} to go to ~~pos~~ negative by one diode drop. Hence Diode D_2 is reverse biased. The output voltage V_o is zero, because, for all practical purposes, no current flows through R_f and the input current flows through D_1.
For negative input, i.e., $V_i < 0$ diode D_2 conducts and D_1 is off. The negative input V_i forces the op-amp output V_{OA} positive and causes D_2 to conduct. The circuit then acts like an inverter for $R_f = R_1$ and output V_o becomes positive. The op-amp in the circuit must be a high speed op-amp since it alternates between open loop and closed loop operations.

Q7.) Design ideal and practical differentiator using op-amp and draw its frequency response.

Ans: For ideal differentiator, capacitor is in series with the input voltage source.



$V_a = 0V$

$$i_c = C\frac{dv}{dt}$$

$$= C\frac{dV_i}{dt}$$

Applying KCL at node a,

$$C\frac{dV_i}{dt} = \frac{V_a - V_o}{R_f}$$

$$= \frac{-V_o}{R_f} \quad (V_a = 0)$$

$\Rightarrow -R_f C \dfrac{dV_i}{dt} = V_0$

$V_i(t) = V_i(s)$

$V_0(t) = V_0(s).$

$\dfrac{dV_i(t)}{dt} = sV_i(s).$

Taking s domain :- $V_0(s) = R_f C(sV_i(s)).$

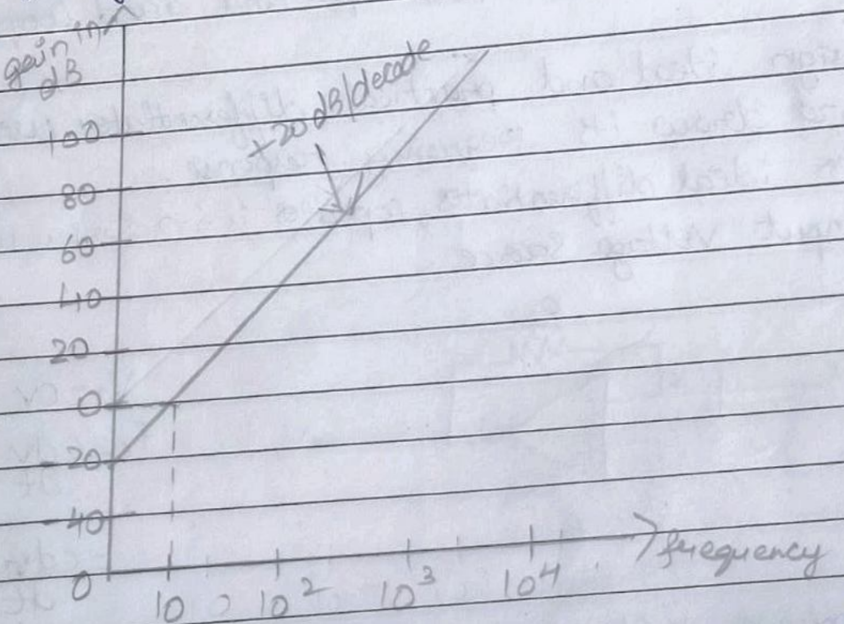
$\dfrac{V_0(s)}{V_i(s)} = -sR_f C$

$s = j\omega.$

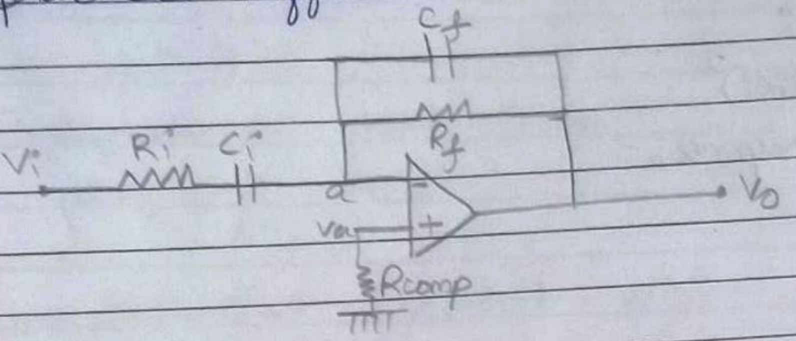
$\dfrac{V_0(j\omega)}{V_i(j\omega)} = -j\omega R_f C.$

$\therefore |A| = \omega R_f C.$

Frequency response :-



practical Differentiator:-



Applying KCL at node a,

$$i = \frac{V_i - V_a}{R_i + \frac{1}{j\omega C}}$$

$$\frac{V_i - V_a}{R_i + \frac{1}{j\omega C}} = -\frac{V_o}{Z_f}$$

$$Z_f = R_f \parallel C_f = \frac{R_f \times \frac{1}{j\omega C}}{R_f + \frac{1}{j\omega C}}$$

$$\frac{V_i}{R_i + \frac{1}{j\omega C_i}} = \frac{-V_o}{R_f} = \frac{V_o}{\frac{1}{j\omega C_f}}$$

$$\frac{V_i(s)}{R_i + \frac{1}{sC_i}} = \frac{-V_o(s)}{\frac{\frac{R_f}{sC_f}}{R_f + \frac{1}{sC_f}}}$$

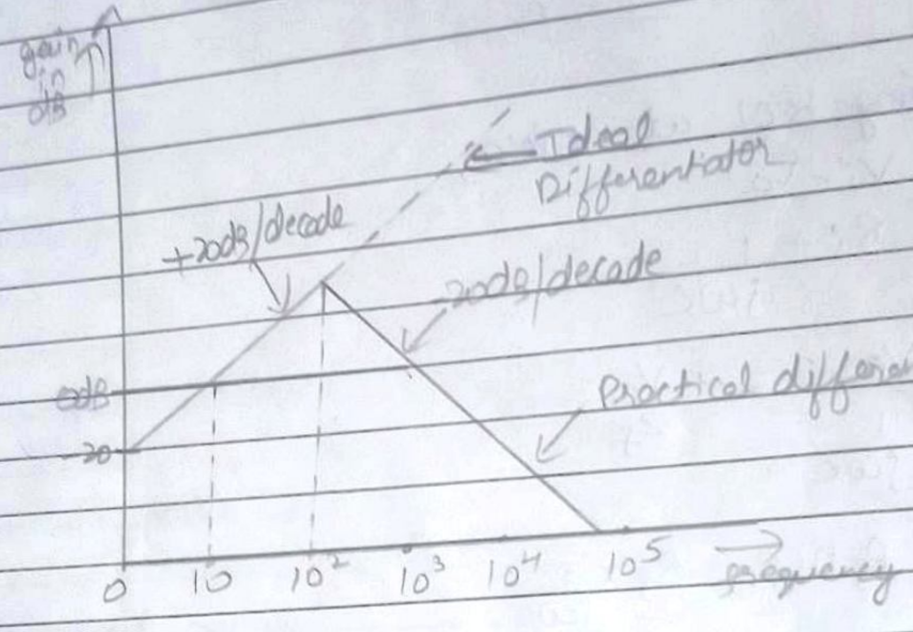
$$\frac{V_o(s)}{V_i(s)} = \frac{\frac{-R_f}{1 + sR_fC_f}}{\frac{1 + sR_iC_i}{sC_i}}$$

$$= \frac{-sR_fC_i}{(1 + sR_fC_f)(1 + sR_iC_i)}$$

If $R_f C_f = R_i C_i$

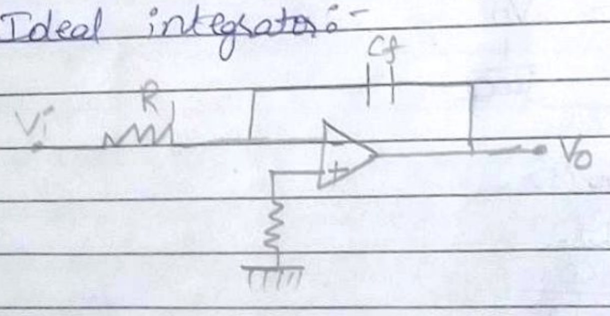
$$A = \frac{-SR_iC_i}{(1+SR_iC_i)^2}$$

- Frequency response:-



28.)(a) Design ideal and practical integrator using op-amp and draw its frequency response.

Ans: Ideal integrator:-



$V_a = 0V$

Applying KCL at node a,

$$\frac{V_i}{R_i} = V_o j\omega C_f \quad \text{or}$$

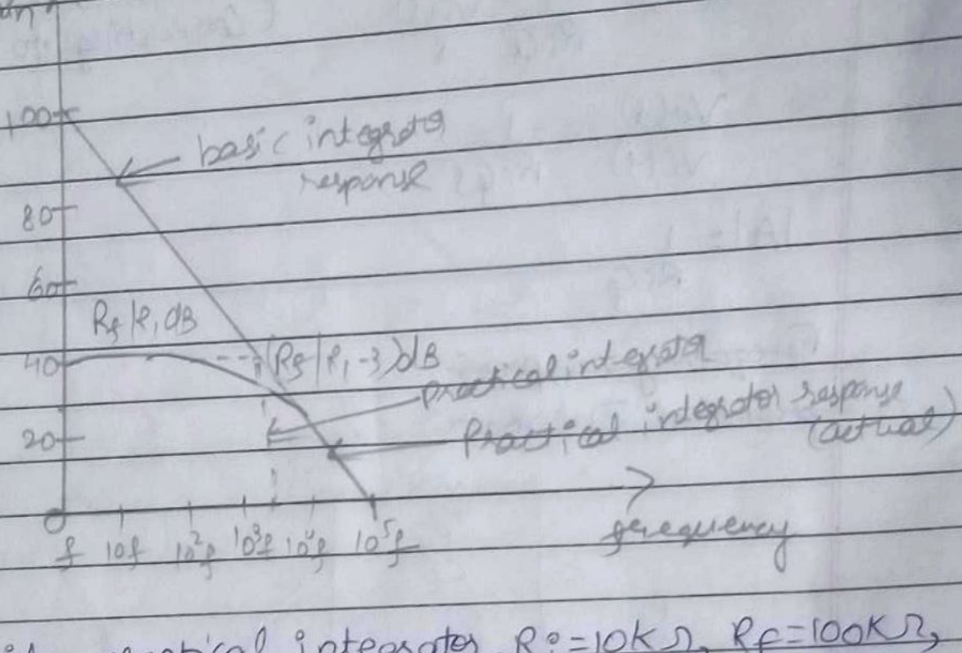
$$\frac{V_i}{R_i} = -C_f \frac{dV_o}{dt}$$

$$\frac{dV_o}{dt} = \frac{-1}{R_i C_f} V_i$$

$$= \frac{\frac{-R_f}{R_i}}{1 + SC_f R_f}$$

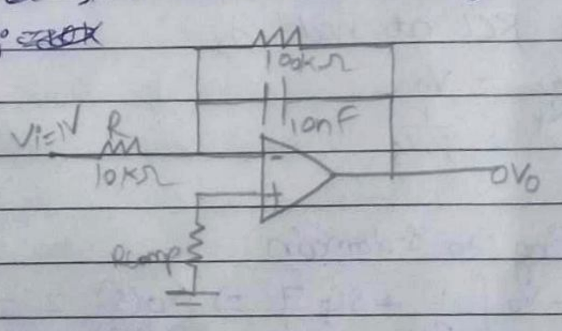
$$|A| = \left| \frac{V_o(s)}{V_i(s)} \right| = \frac{\frac{R_f}{R_i}}{1 + R_f C_f}$$

Frequency response:-



(b) Consider practical integrator, $R_i = 10K\Omega$, $R_f = 100K\Omega$, $C_f = 10nF$, determine the lower frequency level of integration and find the output if the input is 1V peak ~~at~~ sine wave at 5KHz.

Ans: Here, ~~R_f~~



We know that the lower frequency limit of integration,

$$f = \frac{1}{(2\pi R_f C_f)}$$

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$$f = \frac{1}{2\pi \times 100\times10^{3} \times 10\times10^{-9}} = 159.23\,Hz.$$

Also,

As $\omega = 5KHz \Rightarrow V_{in}(t) = 1\sin 2\pi 5000t$

we know that

$$V_{out}(t) = \frac{-1}{R_1C}\int V_{in}(t)\,dt$$

$$= \frac{-1}{10K \times 10nF}\int 1\sin 2\pi 5000t\,dt$$

$$V_{out}(t) = -10^4 \int 1\sin 2\pi 5000t\,dt$$

$$V_{out}(t) = -10^4 \frac{1}{2\pi 5000t}\int 2\pi 5000t\,dt \sin 2\pi 5000t\,dt$$

$$V_{out}(t) = -0.318(-\cos 2\pi 5000t)$$

$$V_{out}(t) = 0.318 \cos 2\pi 5000t.$$

29) Repeat problem 25, if $V_1 = V_2 = V_3 = 5V$, $R_1 = R_2 = R_3 = R = 1K$, $R_f = 10K$. Find V_o. Consider non-inverting amplifier.

Ans $V_o = \left(1 + \frac{R_f}{R_i}\right)V_1$

Here, $V_1 = 5V$, $R_1 = 1K$, $R_f = 10k$.

$$V_o = \left(1 + \frac{10k}{1k}\right)5$$

$$= 11 \times 5$$

$$= 55\ \text{volts}.$$