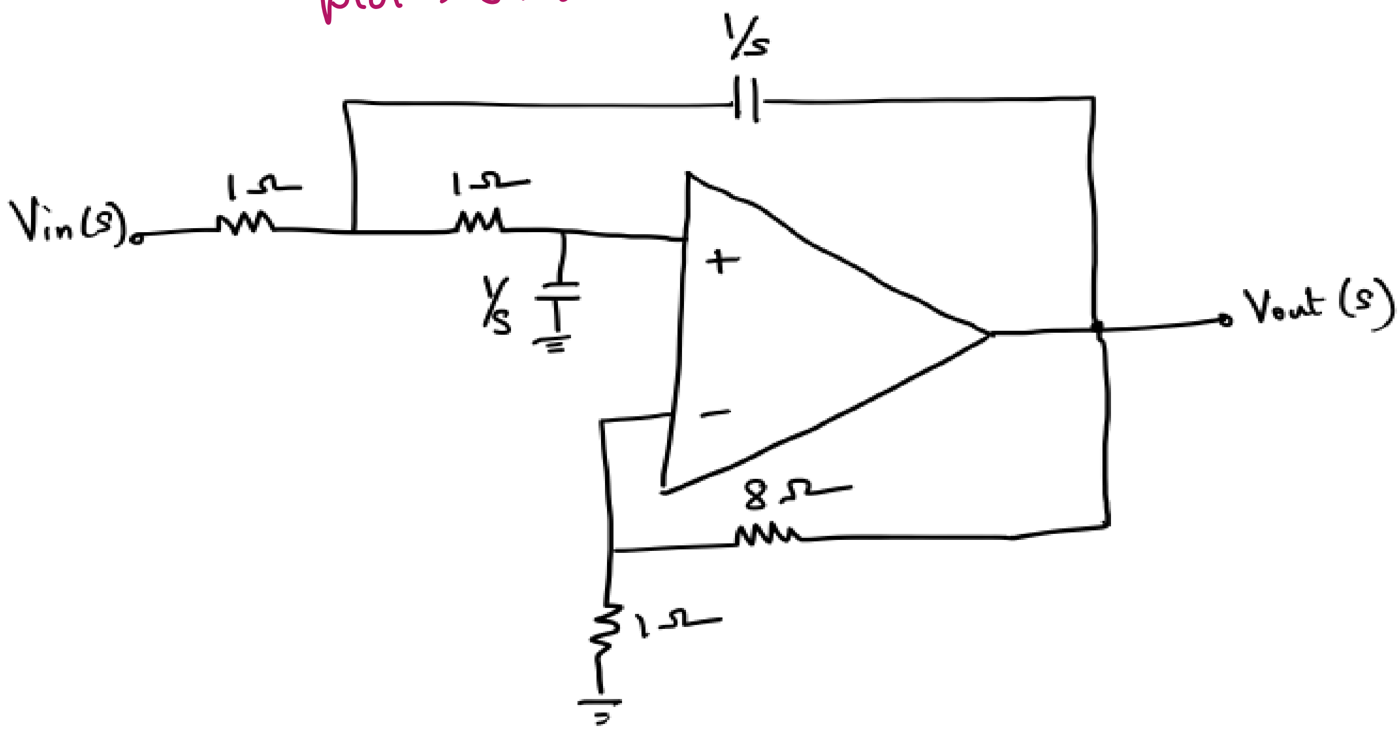
Set 1

Quiz 4 (20 marks)

Consider the circuit shown below with an ideal op-amp.

1. **(3 marks)** Describe the type of filter (order, whether its active or passive, lpf/hpf/bpf/bsf) 1 + 1 + 1 marks
2. **(10 marks)** Plot the magnitude response of the circuit $H(s) = \|\frac{V_{out}(s)}{V_{in}(s)}\|$ on the semi-log sheet attached to the answer sheet.
   5 marks
   mag. eq^n → 2 marks
   plot → 3 marks
3. **(7 marks)** Draw the phase response of the above circuit on the semi-log sheet.
   ↳ phase eq^n → 2 marks
   plot → 5 marks.

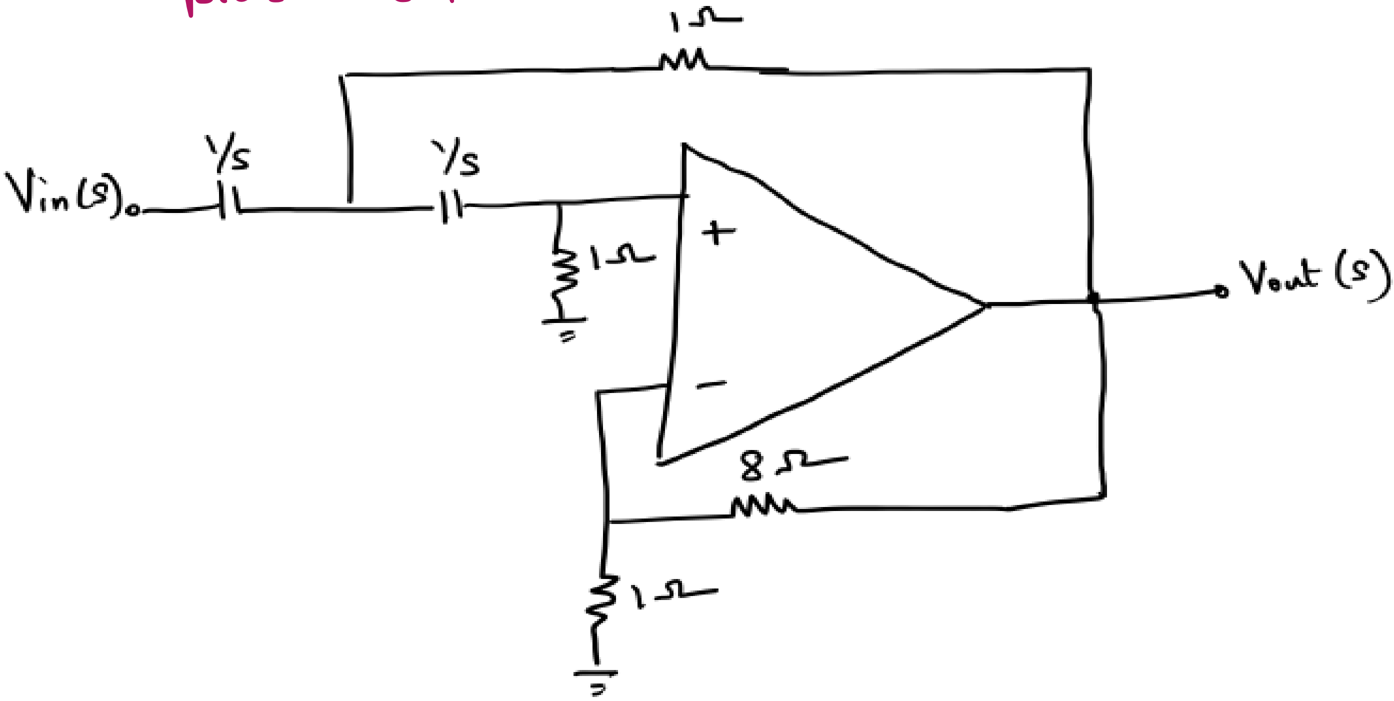


Set-2

Quiz 4 (20 marks)

Consider the circuit shown below with an ideal op-amp.

1. **(3 marks)** Describe the type of filter (order, whether its active or passive, lpf/hpf/bpf/bsf) 1 + 1+1
2. **(10 marks)** Plot the magnitude response of the circuit $H(s) = \|\frac{V_{out}(s)}{V_{in}(s)}\|$ on the semi-log sheet attached to the answer sheet.
   5 marks
   mag eq → 2 m
   plot → 3 m.
3. **(7 marks)** Draw the phase response of the above circuit on the semi-log sheet.
   phase eqn → 2 m
   plot → 5 m



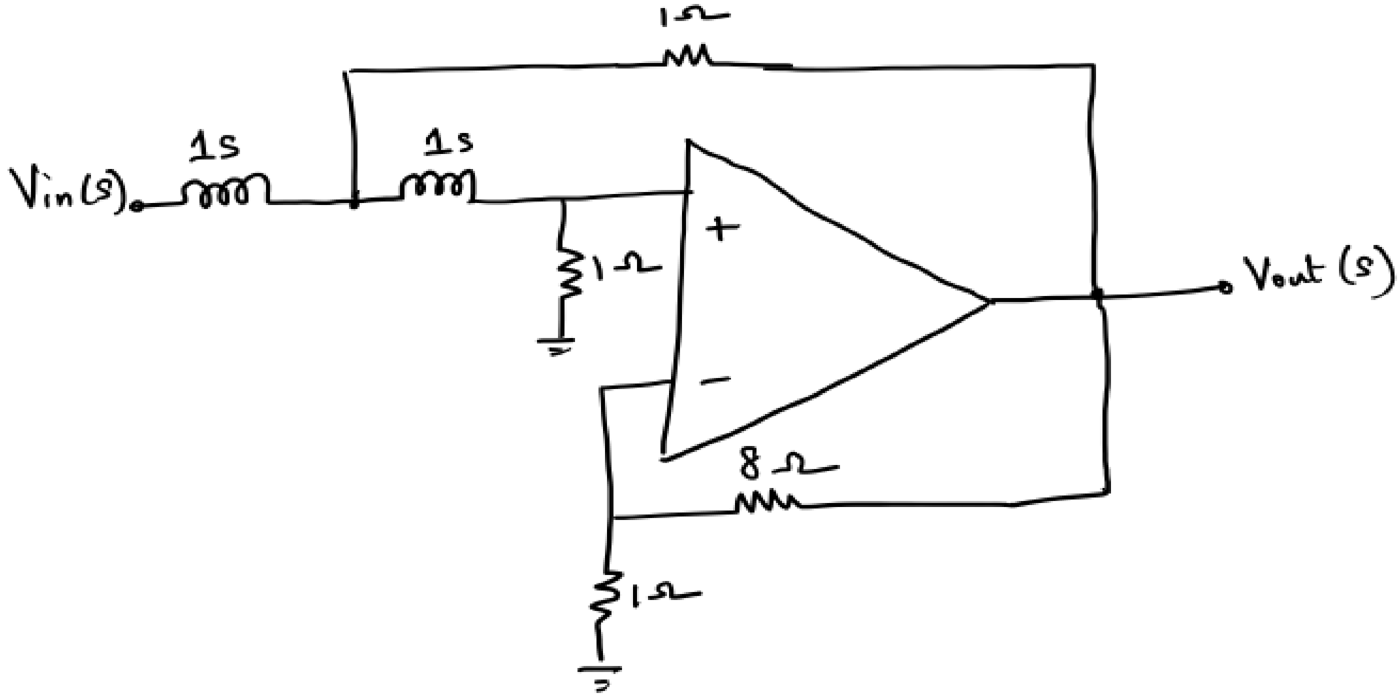
Quiz 4 (20 marks)

Set-3

Consider the circuit shown below with an ideal op-amp.

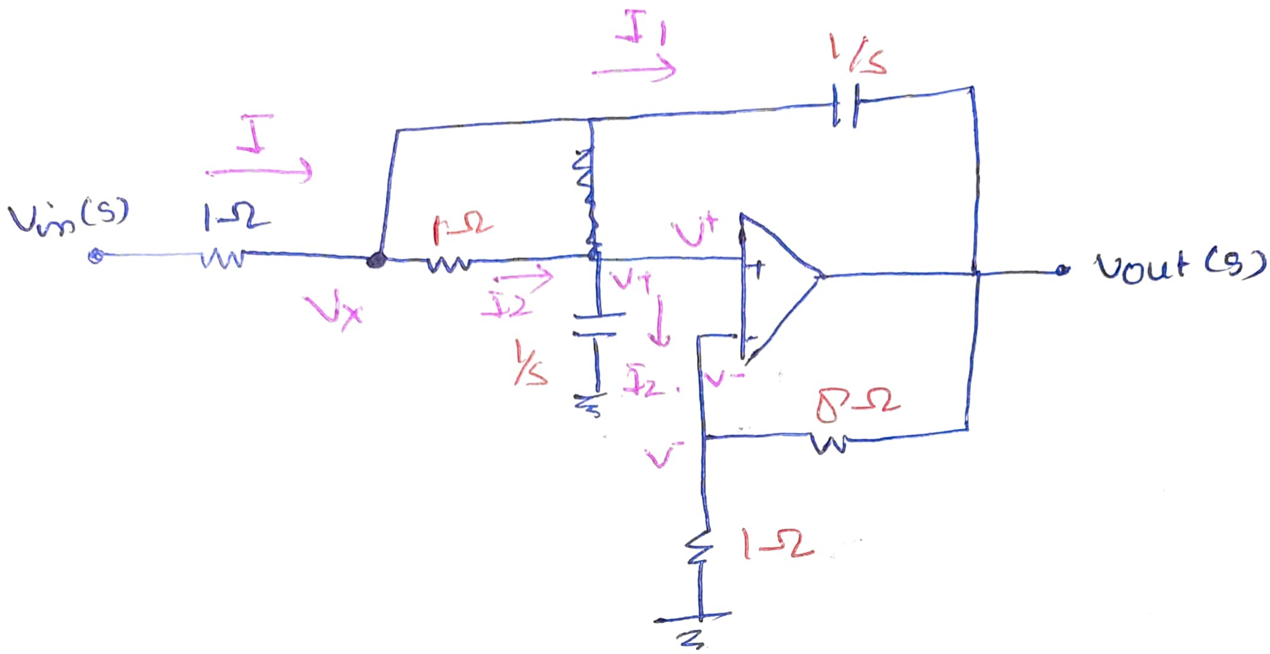
1. **(3 marks)** Describe the type of filter (order, whether its active or passive, lpf/hpf/bpf/bsf) 1 + 1 + 1
2. **(10 marks)** Plot the magnitude response of the circuit $\underbrace{H(s) = \|\frac{V_{out}(s)}{V_{in}(s)}\|}_{5m}$ on the semi-log sheet attached to the answer sheet.
   mag eq → 2m
   plot → 3m
3. **(7 marks)** Draw the phase response of the above circuit on the semi-log sheet.

phase eqn → 2m.
plot → 5m.



Set 1

Quiz 4 solution set 1



$\because$ it is an ideal op-amp

$\therefore$ we can write,

$$\boxed{V^- = V^+ = Vout\left(\frac{1}{9}\right) = \frac{Vout}{9}} \longrightarrow (1).$$

↳ voltage divider rule

Now, $I_2 = \frac{V_x - V^+}{1} = \frac{V^+ - 0}{1/s} = sV^+$

$\Rightarrow V_x = sV^+ + V^+$

$\Rightarrow \boxed{V_x = (1+s)V^+}$ —— (2)

Now applying KCL,

$$\frac{V_{in} - V_x}{1} = \frac{V_x - V_{out}}{1/s} + \frac{V_x}{1/s + 1}$$

$$\Rightarrow V_{in} - V_x = sV_x - sV_{out} + \frac{sV_x}{1+s}$$

$$\Rightarrow V_{in} - V_x = \left[s + \frac{s}{1+s}\right] V_x - sV_{out}.$$

$$\Rightarrow V_{in} - V_x = \left(\frac{s^2 + s + s}{s+1}\right) V_x - sV_{out}.$$

$$\Rightarrow V_{in} = \left[\frac{s^2 + 3s + 1}{s+1}\right] V_x - sV_{out}.$$

from (2)

$$V_{in} = \frac{s^2 + 3s + 1}{(\cancel{s+1})} \times (\cancel{s+1}) \times V^+ - sV_{out}.$$

from (1)

$$\Rightarrow V_{in} = \left(\frac{s^2 + 3s + 1}{9}\right) V_{out} - sV_{out}$$

$$\Rightarrow V_{in} = V_{out}\left[\frac{s^2 + 3s + 1 - 9s}{s}\right]$$

$$\Rightarrow \boxed{\frac{V_{out}}{V_{in}} = \frac{9}{s^2 - 6s + 1}} \Rightarrow \boxed{H(s) = \frac{9}{s^2 - 6s + 1}}$$

Now, we can write,

$$H(S) = \frac{9}{(S-5.82)(S-0.17)}$$

$$\Rightarrow H(j\omega) = \frac{9}{(j\omega-5.82)(j\omega-0.17)}$$

$\therefore$ Poles $\rightarrow$ $\omega_1 = 5.82$ rad/s

$\omega_2 = 0.17$ rad/s.

in dB $\rightarrow 20\log_{10}\left(\frac{9}{\sqrt{K}}\right.$

+:

dB

Now $$|H(\omega)| = \frac{9}{\sqrt{(1-\omega^2)^2 + 36\omega^2}}$$

$$\angle H(\omega) = -\tan^{-1}\left[\frac{6\omega}{1-\omega^2}\right]$$

ω	$\lvert H(\omega) \rvert$ dB	$\angle H(\omega)$
0.01	19.08	3.43°
0.1	17.87	31.22°
0.17	16.16	46.4°
5.82	−14.53	−46.73°
10	− ~~26.18~~ −16.35	−31.22°
100	−36.35	−3.43°

(a). we can observe and say that it is —

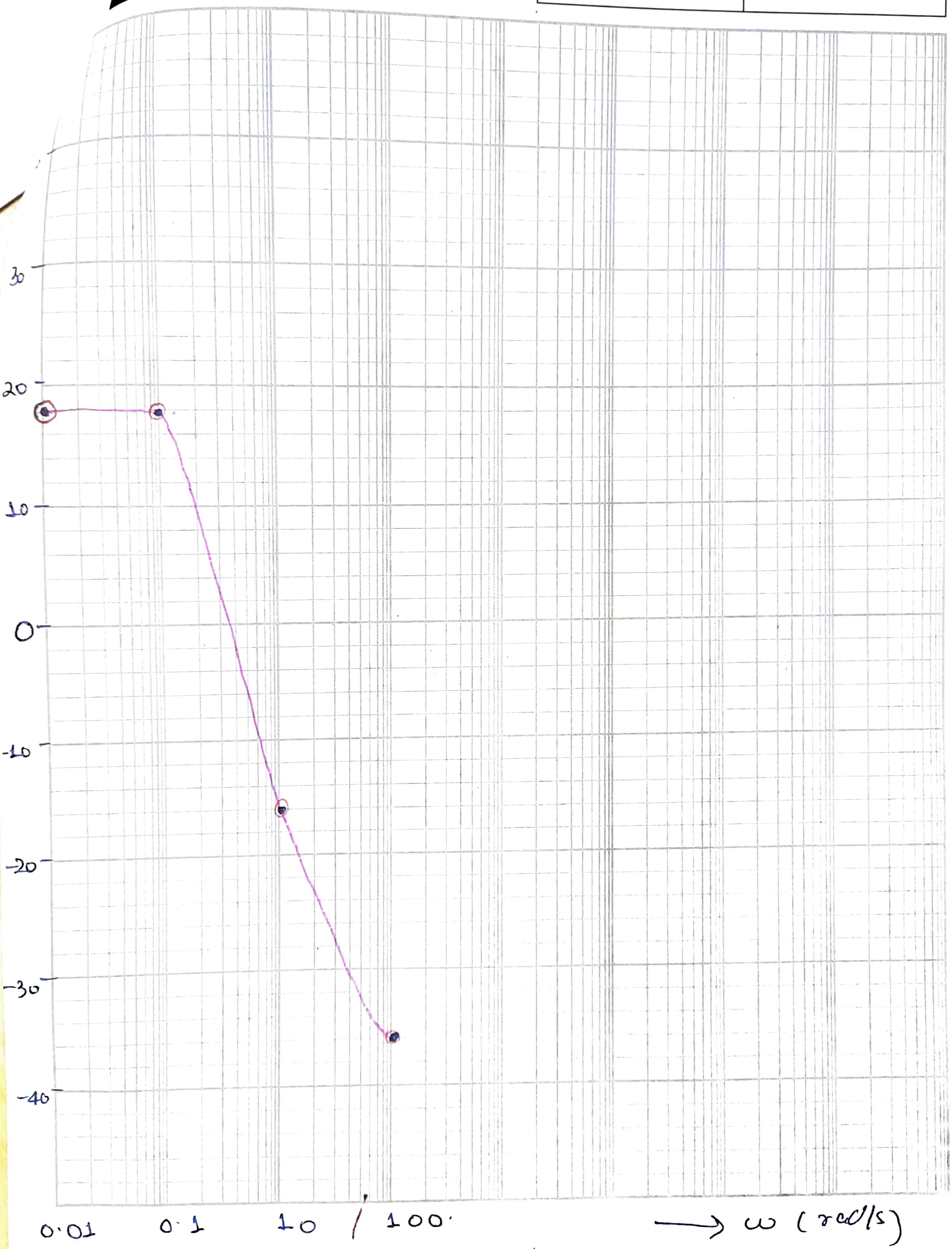
1. Active filter
2. Second order
3. low pass filter.

Magnitude plot.

$|H(\omega)|$

TITLE

NAME | DATE



$\angle H(\omega)$

Phase Plot

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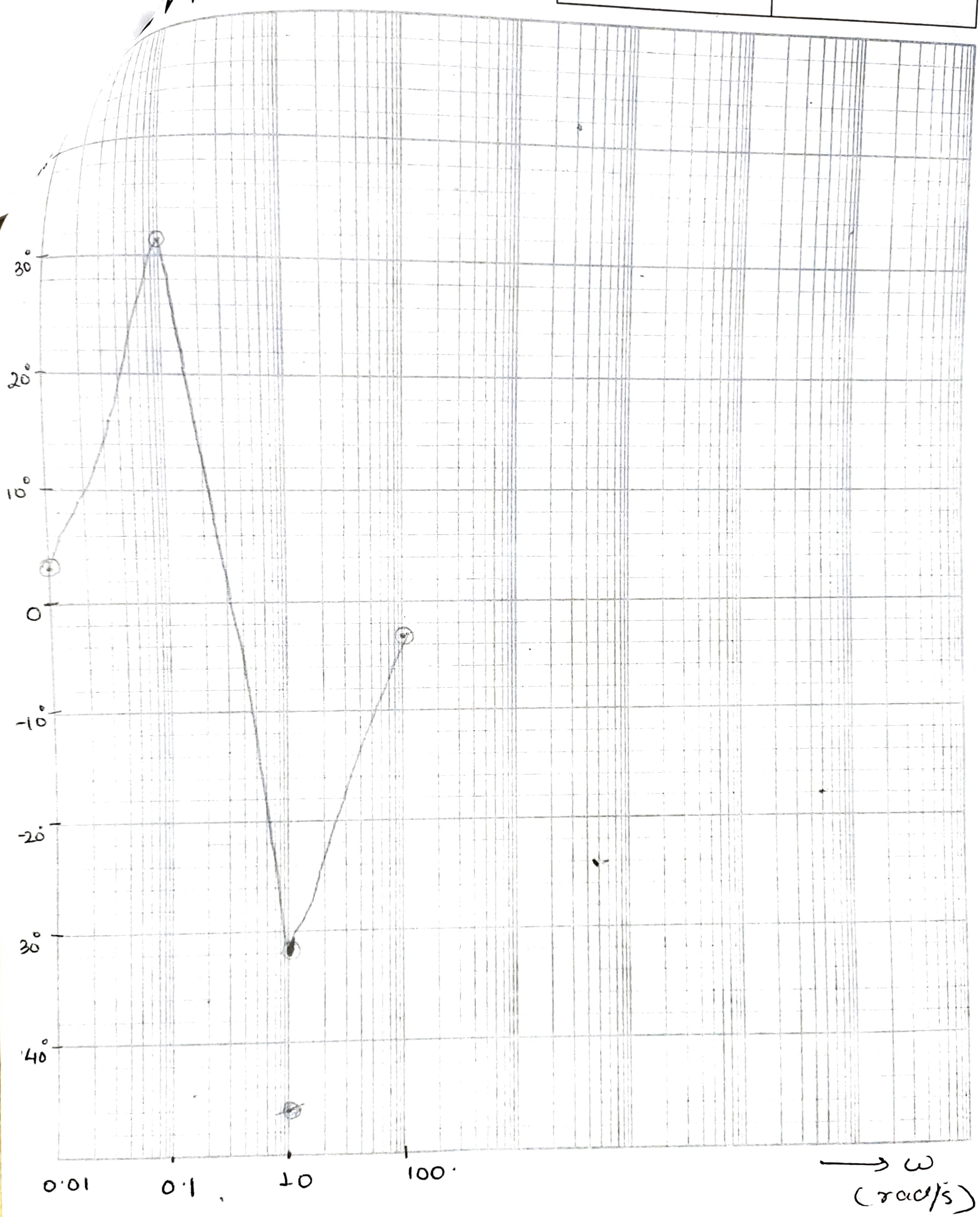
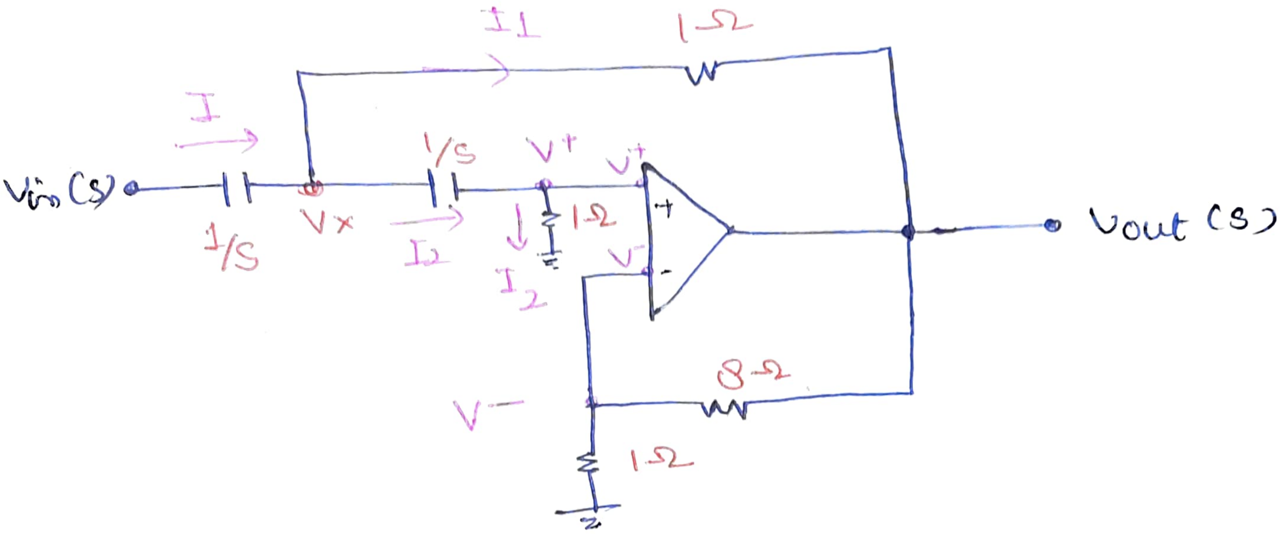


Quiz 4 — Set 2 Solutions

Set-2



∵ it is an ideal op-amp.

∴ we can write,

$$\boxed{V^- = V^+ = V_{out}\left(\frac{1}{9}\right) = \frac{V_{out}}{9}} \quad \text{— (i)}$$

Now, $I_2 = \dfrac{V_x - V^+}{1/s} = \dfrac{V^+ - 0}{1}$

$\Rightarrow sV_x = V^+ + sV^+$ — (ii)

$$\Rightarrow \boxed{V_x = \frac{V^+(1+s)}{s}}$$

Applying KCL at V_x.

$$\frac{V_{in}-V_x}{1/s} = \frac{V_x}{1/s+1} + \frac{V_x - V_{out}}{1}.$$

$$\Rightarrow s(V_{in}-V_x) = \frac{sV_x}{s+1} + V_x - V_{out}.$$

$$= V_x\left(\frac{s}{s+1}+1\right] - V_{out}.$$

$$\Rightarrow s(V_{in}-V_x) = V_x\left[\frac{2s+1}{s+1}\right] - V_{out}.$$

$$\Rightarrow sV_{in} = V_x\left[\frac{2s+1}{s+1}+s\right] - V_{out}.$$

$$\Rightarrow sV_{in} = V_x\left[\frac{2s+1+s(s+1)}{(s+1)}\right] - V_{out}.$$

$$\Rightarrow sV_{in} = V_x\left[\frac{s^2+3s+1}{s+1}\right] - V_{out}.$$

from (ii)

$$\Rightarrow sV_{in} = \left(\frac{\cancel{s+1}}{s}\right)V^+\left[\frac{s^2+3s+1}{\cancel{s+1}}\right] - V_{out}.$$

from (i)

$$\Rightarrow sV_{in} = \left[\frac{s^2+3s+1}{s}\right]\frac{V_{out}}{9} - V_{out}.$$

$$\Rightarrow V_{in} = \frac{V_{out}}{s}\left[\frac{s^2+3s+1-9s}{9s}\right]$$

$\Rightarrow \quad V_{in} = V_{out}\left[\frac{s^2-6s+1}{9s^2}\right]$

$\Rightarrow \quad \frac{V_{out}}{V_{in}} = \frac{9s^2}{s^2-6s+1}$

$\therefore \quad \boxed{H(s) = \frac{9s^2}{s^2-6s+1}}$

Replacing s by $j\omega$.

$$H(\omega) = \frac{-9\omega^2}{-\omega^2 - j6\omega + 1} = \frac{9\omega^2}{\omega^2 - 1 + j6\omega}.$$

Now, $$|H(\omega)| = \frac{9\omega^2}{\sqrt{(\omega^2-1)^2 + 36\omega^2}} \xrightarrow{\text{to dB}} 20\log_{10}\left(\frac{9\omega^2}{\sqrt{(\omega^2-1)^2+36\omega^2}}\right)$$

$$\angle H(j\omega) = -\tan^{-1}\left[\frac{6\omega}{\omega^2-1}\right]$$

Poles of ω = $\omega_1 = 5.82$ rad/s

$\omega_2 = 0.17$ rad/s.

ω	$\lvert H(\omega)\rvert$ dB.	$\angle H(\omega)$
0.01	-60.89	3.43°
0.17	-18.9	31.22°
0.1	-0.10	46.4°
5.82	18.70	-46.73°
10	23.40	-31.22°
100.	43.40.	-3.43°.

From the observations in the plot & transfer function obtained, we can say that the given filter is –

1) Active filter.
2) High pass filter.
3) Second order filter.

Magnitude Plot
|H(ω)|

TITLE

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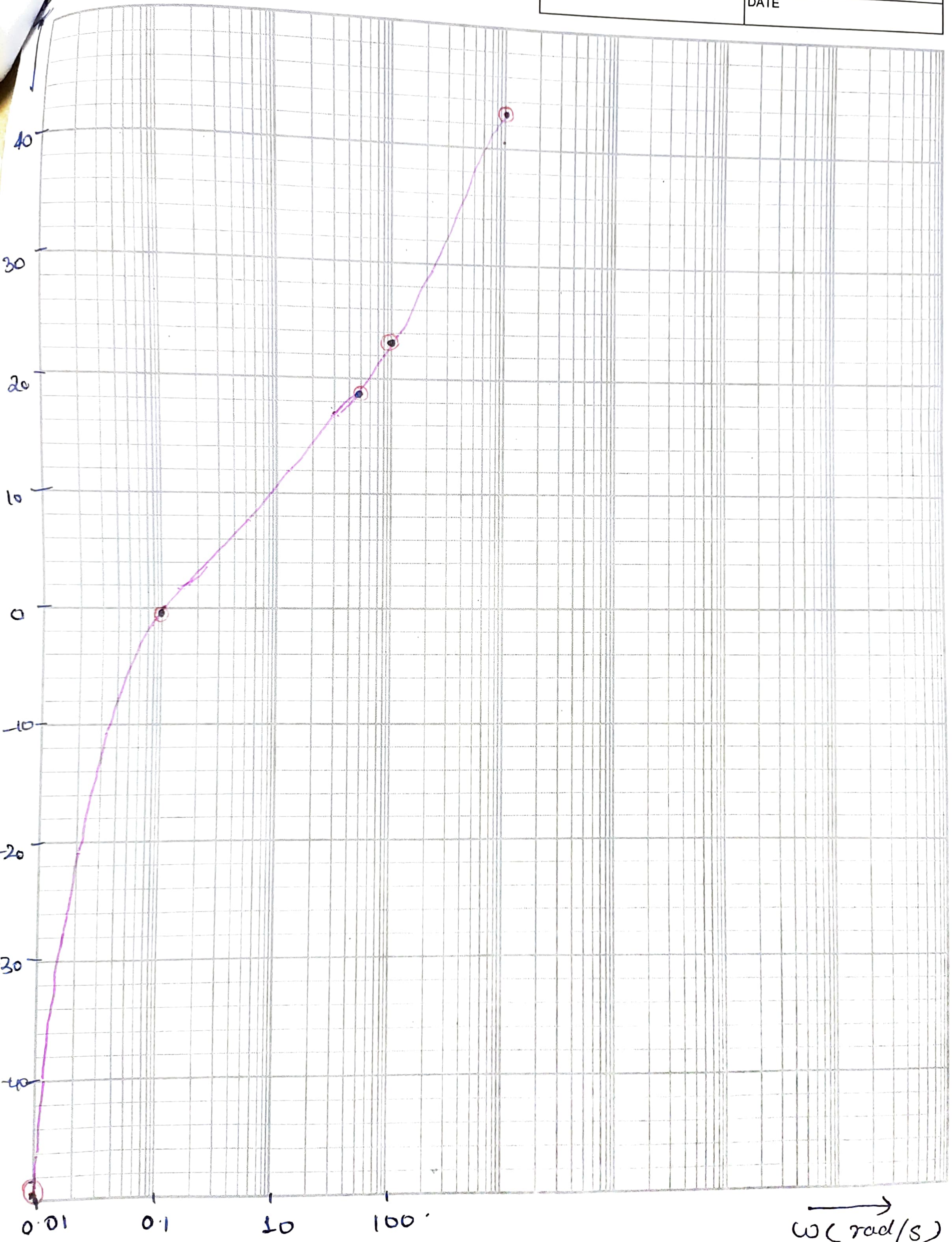
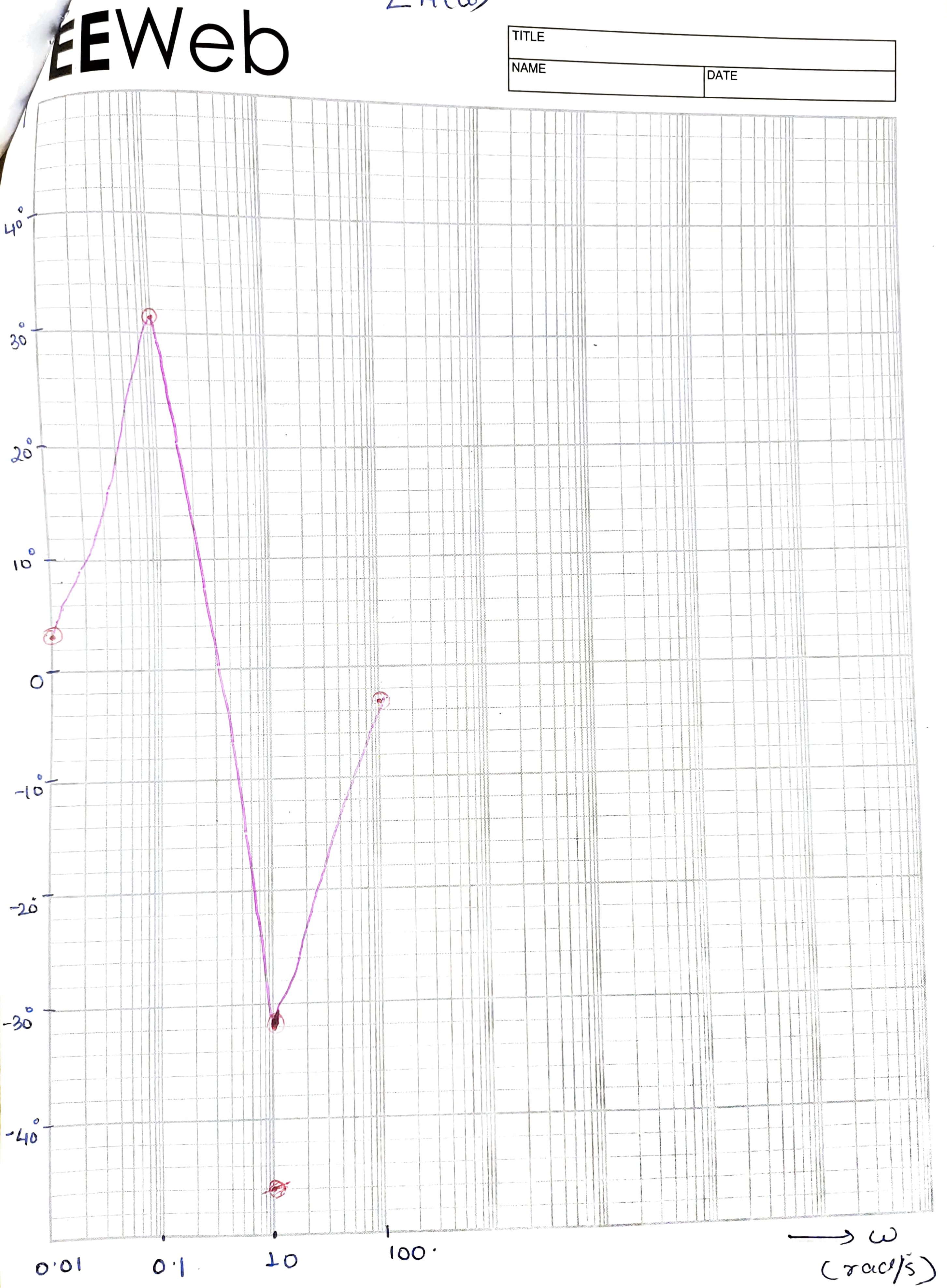


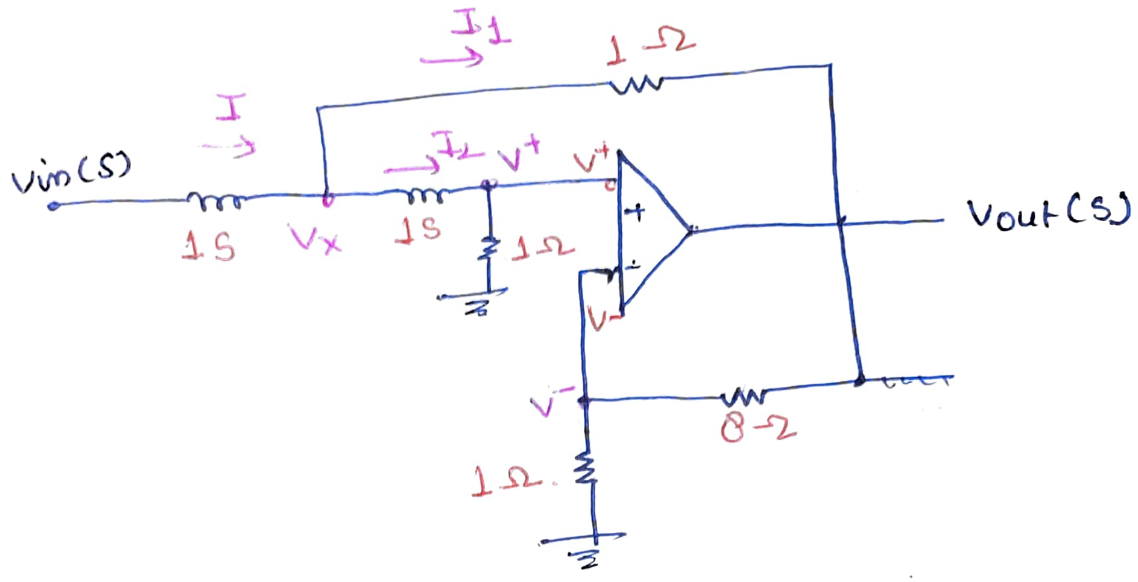
Phase plot.

$\angle H(\omega)$



Quiz 4 - Set 3 solutions

Set-3



$\because$ it is an ideal op-amp.

$\therefore$ we can write,

$$\boxed{V^- = V^+ = Vout\left(\frac{1}{9}\right) = \frac{Vout}{9}.} \quad -① $$

Now, $I_2 = \dfrac{V_x - V^+}{S} = \dfrac{V^+ - 0}{1}$

$\Rightarrow V_x - V^+ = SV^+$

$$\Rightarrow \boxed{V_x = (1+S)V^+} \quad -② $$

Now applying KCL,

$$I = I_1 + I_2.$$

$$\Rightarrow \frac{V_{in} - V_x}{S} = \frac{V_x - V_{out}}{1} + \frac{V_x}{(1+S)}$$

$$\Rightarrow \frac{V_{in}}{S} - \frac{V_x}{S} = V_x - V_{out} + \frac{V_x}{1+S}.$$

$$\Rightarrow \frac{V_{in}}{S} = V_x\left[\frac{1}{S} + 1 + \frac{1}{S+1}\right] - V_{out}.$$

$$\Rightarrow \frac{V_{in}}{S} = V_x\left(\frac{1+S}{S} + \frac{1}{S+1}\right] - V_{out}$$

$$\Rightarrow \frac{V_{in}}{S} = V_x\left[\frac{(S+1)^2 + S}{S(S+1)}\right] - V_{out}$$

from ②

$$\Rightarrow \frac{V_{in}}{S} = (1+S)V^+\left[\frac{(S+1)^2 + S}{S(S+1)}\right] - V_{out}.$$

from ①

$$\Rightarrow \frac{V_{in}}{S} = (1+S)\left[\frac{S+1)^2 + S}{S(S+1)}\right]\frac{V_{out}}{9} - V_{out}$$

$$\Rightarrow \frac{V_{in}}{S} = V_{out}\left[\frac{(S+1)^2 + S}{9S} - 1\right]$$

$$\Rightarrow \frac{V_{in}}{\cancel{S}} = V_{out}\left[\frac{(S+1)^2 + S - 9S}{9\cancel{S}}\right)$$

$$\Rightarrow \frac{V_{in}}{V_{out}} = \frac{(S+1)^2 - 8s}{9}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{9}{(S+1)^2 - 8s} = \frac{9}{s^2 - 6s + 1}$$

$$\therefore \boxed{H(s) = \frac{9}{s^2 - 6s + 1}}$$

Now, we can write,

$$H(s) = \frac{9}{(s-5.82)(s-0.17)}$$

$$\Rightarrow H(j\omega) = \frac{9}{(j\omega - 5.82)(j\omega - 0.17)}$$

$\therefore$ Poles $\rightarrow$ $\omega_1 = 5.82$ rad/s

$\omega_2 = 0.17$ rad/s.

$$\text{Now } |H(\omega)| = \frac{9}{\sqrt{(1-\omega^2)^2 + 36\omega^2}}$$

in dB: $\Rightarrow 20 \log_{10} \left(\frac{9}{\sqrt{(1-\omega^2)^2 + 36\omega^2}} \right)$ dB.

$$\angle H(\omega) = -\tan^{-1}\left[\frac{6\omega}{1-\omega^2}\right]$$

ω	|H(ω)| dB	∠H(ω)
0.01	19.08	3.43°
0.1	17.87	31.22°
0.17	16.16	46.4°
5.82	-14.53	-46.73°
10	- ~~26.18~~ -16.35	-31.22°
100	-36.35	-3.43°

a). we can observe and say that it is —

1. Active filter
2. Second order
3. Low pass filter.

Magnitude plot.

$|H(\omega)|$

TITLE

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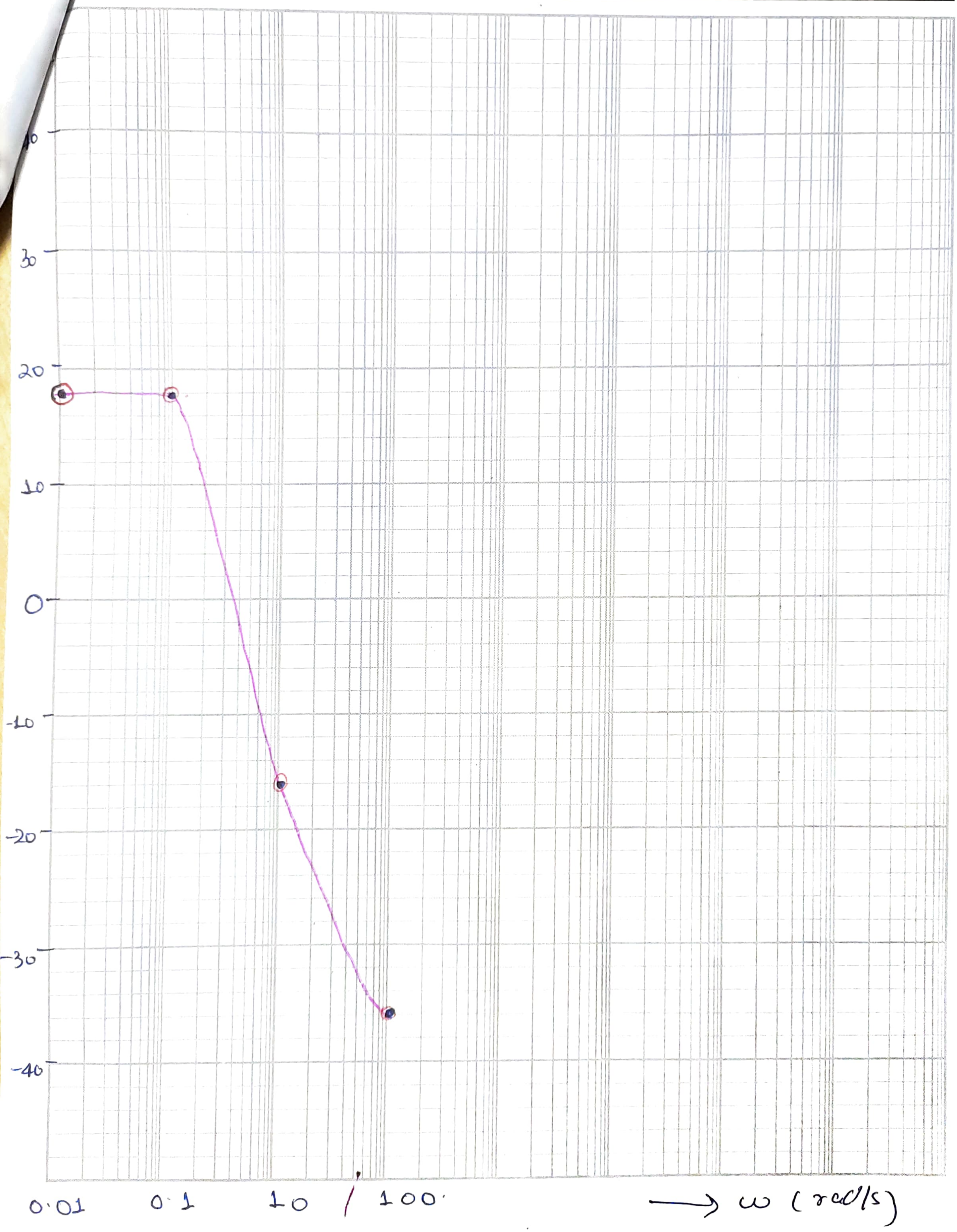

EEWeb Phase-Plot

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