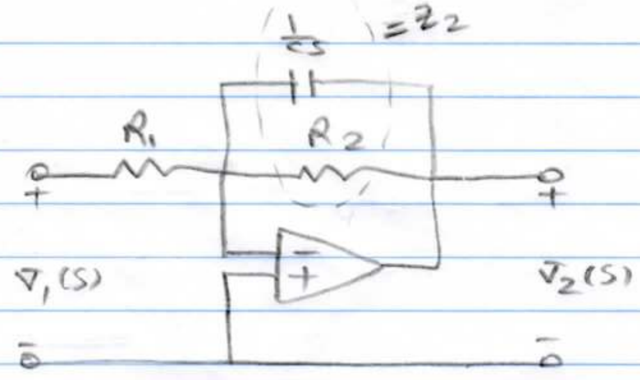
11-12



$$Z_2 = \frac{1}{CS} \parallel R_2 = \frac{R_2}{R_2CS+1}$$

The circuit is an inverting op-amp:

$$\Rightarrow T_V(S) = \frac{V_2(S)}{V_1(S)} = \frac{-Z_2}{R_1} = \frac{-\frac{R_2}{R_2CS+1}}{R_1}$$

$$\Rightarrow T_V(S) = \frac{-\frac{1}{R_1C}}{S+\frac{1}{R_2C}}$$

pole: $S = \frac{-1}{R_2C}$

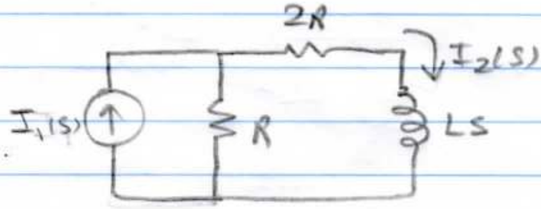
pole $= -250$ krad/s

$\frac{R_2}{R_1} = 100 \rightarrow$ choose $R_1 = 1\,k\Omega \Rightarrow R_2 = 100\,k\Omega$

$$\frac{-1}{R_2C} = -250\times10^3$$

$$\Rightarrow C = \frac{1}{100\times10^3 \times 250\times10^3} = 0.04\ nF$$

$\boxed{11-13}$



use current division:

$$I_2 = I_1 \frac{R}{R+2R+Ls} = \frac{RI_1}{3R+Ls}$$

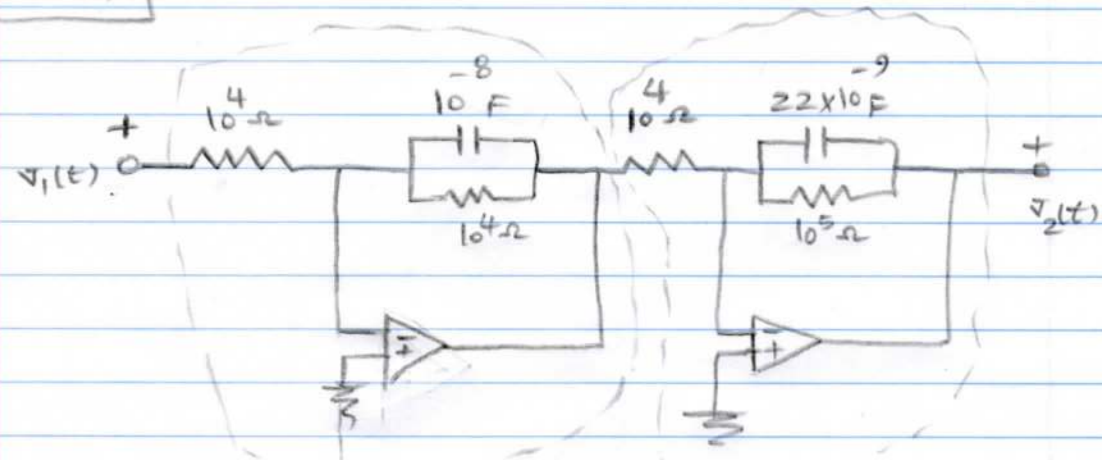
$$\Rightarrow T_I(s) = \frac{I_2(s)}{I_1(s)} = \frac{R}{3R+Ls}$$

pole: $s = \frac{-3R}{L}$

$s = -377 \text{ rad/s} \Rightarrow \frac{3R}{L} = 377$

choose $R = 100\,\Omega \Rightarrow L = 796 \text{ mH}$

$\boxed{11-14}$



first Stage T_1

Second Stage T_2

Both stages are inverting op-amp $\Rightarrow$

$$T_1 = -\frac{\left(10^4 \,//\, \frac{1}{10^{-8}s}\right)}{10^4}$$

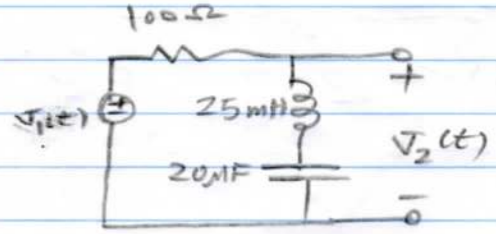
$$T_2 = -\frac{\left(10^5 \,//\, \frac{1}{22\times10^{-9}s}\right)}{10^4}$$

$T_v(s)$ of both Stages together $= T_1 \cdot T_2$

$$\Rightarrow T_v(s) = \frac{10}{(10^{-4}s+1)(22\times10^{-4}s+1)}$$

poles: $s = -10^4, -454.55$

$\boxed{11-34}$



From Voltage division:

$$V_2(S) = V_1(S)\,\frac{SL + \frac{1}{CS}}{R + SL + \frac{1}{CS}} = V_1(S)\,\frac{S^2 + \frac{1}{CL}}{S^2 + \frac{R}{L}S + \frac{1}{CL}}$$

$$\Rightarrow T(S) = \frac{V_2(S)}{V_1(S)} = \frac{S^2 + \frac{1}{CL}}{S^2 + \frac{R}{L}S + \frac{1}{CL}} = \frac{S^2 + 2\times10^6}{S^2 + 4\times10^3 S + 2\times10^6}$$

poles: $s = -3414, -585.8$ rad/s

zeros: $S = \pm 1414.2j$ rad/s

→ For $V_1(t) = 5\cos(1414.21t)$ (V)

$w = 1414.2$ is one of the zeros of $T(S)$

$\Rightarrow V_{2SS}(t) = 0$ (V)

→ For $V_1(t) = 5\cos(1000t)$ (V), $w = 1000$

$|T(jw)| = 0.2425$, $\measuredangle T(jw) = -1.3258 \simeq -1.33$ rad

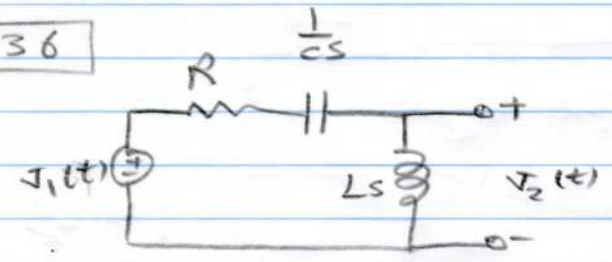
$$V_{2SS}(t) = 5\,|T(jw)|\cos(wt + \measuredangle T(jw))$$

$$\Rightarrow V_{2SS}(t) \simeq 1.2\cos(1000t - 1.33) \text{ (V)}$$

→ For $V_1(t) = 5V$, $V_1(S) = \frac{5}{S}$, $V_2(S) = T(S)V_1(S)$

$$V_{2SS}(t) = \lim_{S\to 0} S V_2(S) = \lim_{S\to 0} S\,\frac{S^2 + 2\times10^6}{S^2 + 4\times10^3 S + 2\times10^6}\cdot\frac{5}{S} = 5 \text{ (V)}$$

$\boxed{11-36}$



$R = 10\,\Omega$
$C = 50\times10^{-6}$ F
$L = 5\times10^{-3}$ H

$$T(s) = \frac{V_2(s)}{V_1(s)} = \frac{Ls}{R+\frac{1}{cs}+Ls} = \frac{s^2}{s^2+\frac{R}{L}s+\frac{1}{LC}}$$

$$\Rightarrow T(s) = \frac{s^2}{s^2+2\times10^3 s+4\times10^6}$$

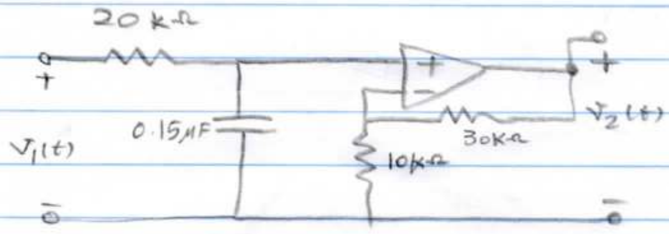
poles: $s = -1000 \pm 1732j$ rad/s
zeros: $s = 0, 0$ rad/s

For $v_1(t) = 25\cos(2000t)$, $\omega = 2000$
$|T(j\omega)| = 1$, $\measuredangle T(j\omega) = 1.57$ rad
$\Rightarrow V_{2ss}(t) = 25\cos(2000t + 1.57)$ (V)

For $v_1(t) = 25\cos(10^4 t)$, $\omega = 10^4$
$|T(j\omega)| = 1.02$, $\measuredangle T(j\omega) = 0.205$ rad

$\Rightarrow V_{2ss}(t) = 25.5\cos(10^4 t + 0.205)$ (V)

$\boxed{12-6}$



$$T_v(s) = \frac{V_2(s)}{V_1(s)} = \underbrace{\left(\frac{10\times10^3 + 30\times10^3}{10\times10^3}\right)}_{\text{Non-inverting op-amp}} \underbrace{\left(\frac{\frac{1}{0.15\times10^{-6}s}}{20\times10^3 + \frac{1}{0.15\times10^{-6}}}\right)}_{\text{voltage divider}}$$

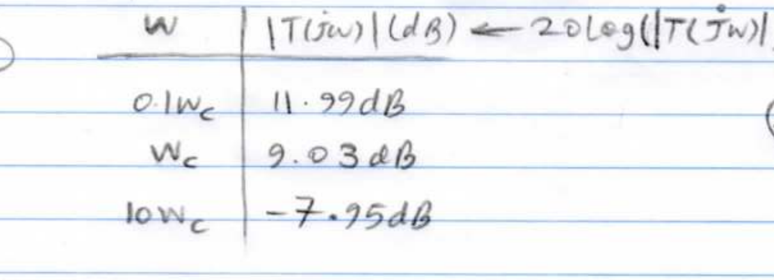
$$\Rightarrow T_v(s) = \frac{1333.3}{s+333.3}$$

(a) $T_v(s)$ is in the form of transfer function for a low-pass filter;

$\Rightarrow w_c = 333.3 \, \frac{rad}{s}$ cutoff frequency

$$s = jw \Rightarrow \begin{cases} |T(j0)| = 4 \Rightarrow |T(j0)| = 20\log(4) = 12.04\,dB \\ |T(j\infty)| = \infty \end{cases}$$

(b)



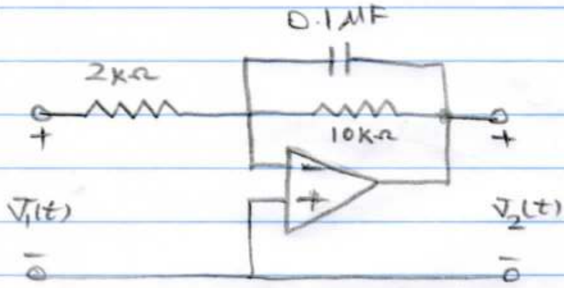
(c)

w	$\vert T(jw)\vert$ (dB) ← $20\log(\vert T(jw)\vert)$
$0.1w_c$	11.99 dB
w_c	9.03 dB
$10w_c$	−7.95 dB

(f) $-7.95 - 9.03 = -16.98\,dB$

(e) By changing feedback resistor from 30kΩ to 90 kΩ

$\boxed{12-7}$



$$T_v(s) = \frac{V_2(s)}{V_1(s)} = \frac{-\left(10\times10^3 \,\|\, \frac{1}{0.1\times10^{-6}s}\right)}{2\times10^3}$$

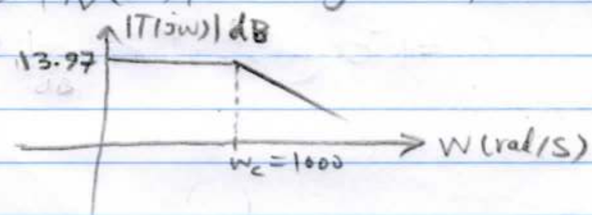
$$= \frac{-5000}{s+1000}$$

ⓐ $s = j\omega \Rightarrow \begin{cases} |T_v(j0)| = 5 \\ |T_v(j\infty)| = 0 \end{cases}$

$T_v(s)$ is in the form of a low-pas filter

$\Rightarrow \omega_c = 1000$ rad/s   cutoff frequency

ⓑ $|T_v(j0)| = 5 \Rightarrow |T_v(j0)| = 20\log(5) = 13.97\,dB$



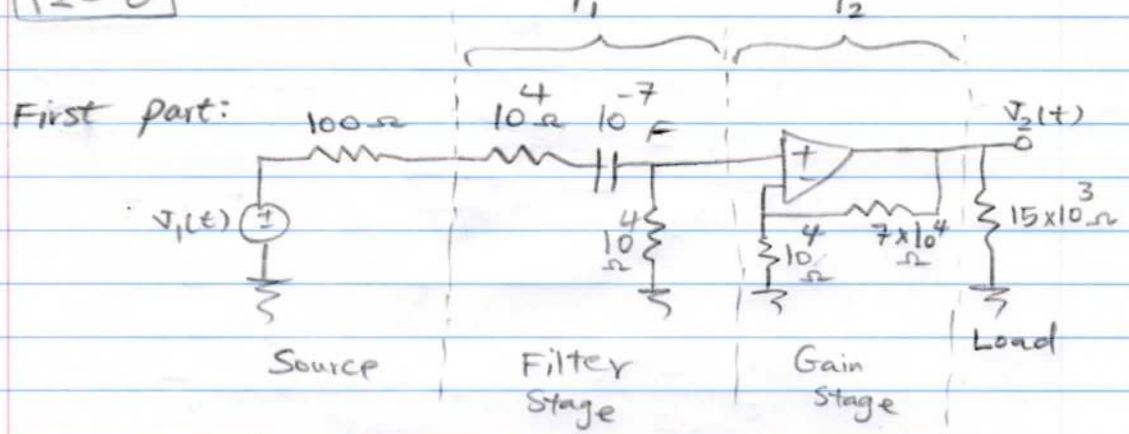
ⓒ

W	$\|T(j\omega)\|$ (dB)
$0.1\omega_c$	13.94 dB
ω_c	10.97 dB
$10\omega_c$	−6.06 dB

ⓔ By changing the 2-kΩ resistor with a 1-kΩ resistor

$\boxed{12-8}$

First part:

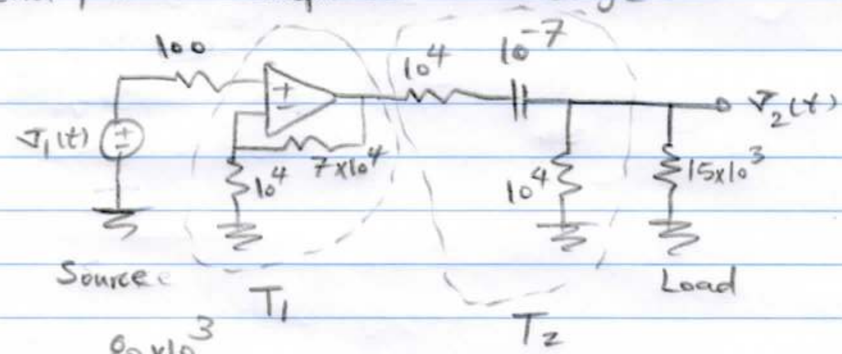


$$T_1 = \frac{10^4}{10100 + \frac{1}{10^{-7}s} + 10^4} = \frac{0.498\,s}{s + 498}$$

$$T_2 = \frac{80 \times 10^3}{10 \times 10^3} = 8$$

$$T = T_1 \times T_2 = \frac{3.98\,s}{s + 498} \Rightarrow \begin{cases} \text{pole: } s = -498 \Rightarrow w_c \simeq -500 \ \frac{rad}{s} \text{ cutoff frequency} \\ \text{Gain} = 3.98 \simeq 4 \end{cases}$$

Second part: Replace Gain Stage with Filter Stage as:



$$T_1 = \frac{80 \times 10^3}{10 \times 10^3} = 8$$

$$T_2 = \frac{(10^4 \,||\, 15 \times 10^3)}{(10^4 \,||\, 15 \times 10^3) + 10^4 + \frac{1}{10^{-7}s}} = \frac{0.375\,s}{s + 625}$$

$$T = T_1 \times T_2 = \frac{3\,s}{s + 625} \Rightarrow \text{pole: } s = -625 \ \frac{rad}{s} = w_c$$

cutoff frequency

12-46

(a) $$T(s) = \frac{700(s+10)}{(s+7)(s+100)}$$

$$T(s) = \frac{(700)(10)(\frac{s}{10}+1)}{7(\frac{s}{7}+1)(100)(\frac{s}{100}+1)}$$

$$T(s) = 10\,\frac{\frac{s}{10}+1}{(\frac{s}{7}+1)(\frac{s}{100}+1)}$$

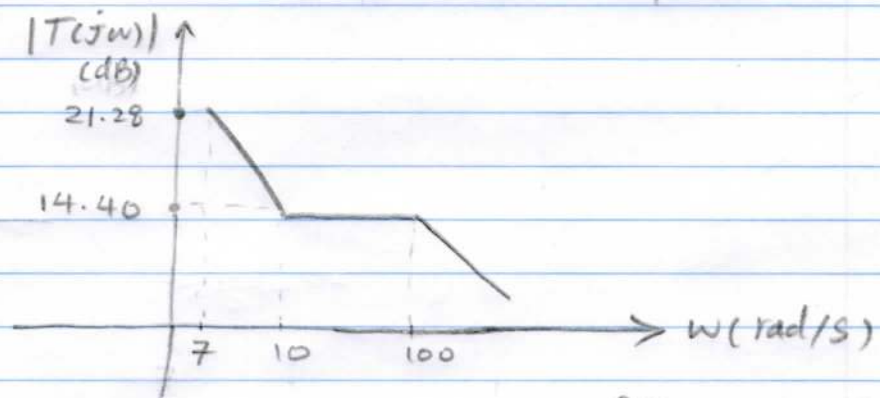
Scale factor → $K_0 = 10 \Rightarrow 20\log(10) = 20$ dB

$s = j\omega$

(*) we can form frequencies at based on zero & poles:

$\omega = 10\ \frac{rad}{s},\ 7\ \frac{rad}{s},\ 100\ \frac{rad}{s}$

w (rad/s)	zero/pole	slope (dB/decade)	|T(jw)| (dB)
7	pole	-20	21.28 dB
10	zero	20	Baseline
100	pole	-20	14.40 dB



This is a low-pass filter

passband gain is 20 dB

(c) There are different designs to satisfy the transfer function. there is one of possible designs:

$$T(S) = \frac{700(S+10)}{(S+7)(S+100)}$$

$$= 700 \frac{1}{S+7} \frac{S+10}{S+100}$$

$$= \underbrace{700}_{\substack{\downarrow \\ \text{gain coefficient}}} \underbrace{\frac{1/s}{1+7/s}}_{T_1(S)} \underbrace{\frac{1+\frac{10}{s}}{1+\frac{100}{s}}}_{T_2(S)}$$

$$T_1(S) = \frac{1/s}{1+\frac{7}{s}} = \frac{1/s}{1/s+(1+\frac{6}{s})}$$

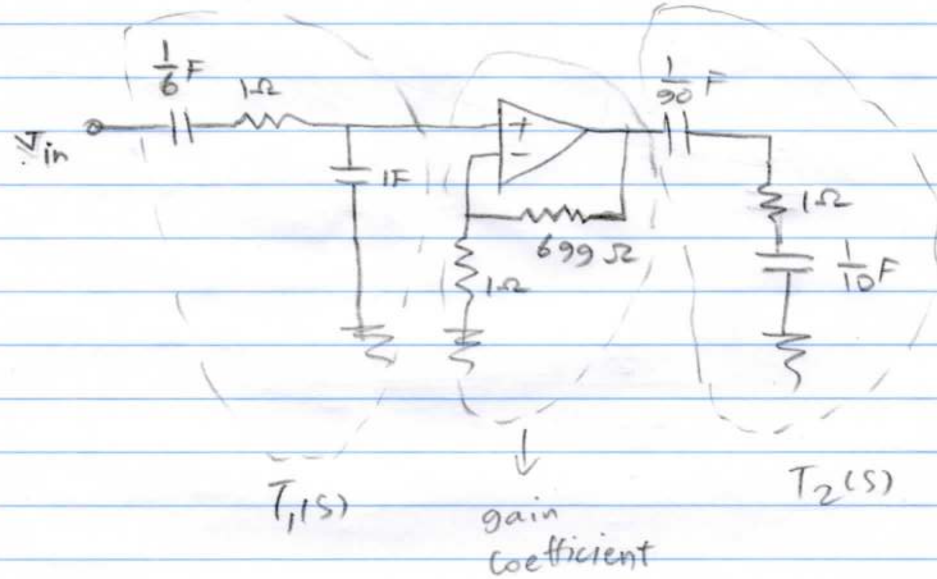
using a voltage divider with $\begin{cases} C_1 = 1F \\ R_1 = 1\Omega \\ C_2 = \frac{1}{6}F \end{cases}$

$$T_2(S) = \frac{1+\frac{10}{s}}{1+\frac{100}{s}} = \frac{1+\frac{10}{s}}{(1+\frac{10}{s})+\frac{90}{s}}$$

using another voltage divider with $\begin{cases} R_2 = 1\Omega \\ C_2 = \frac{1}{10}F \\ C_3 = \frac{1}{90}F \end{cases}$

Gain coefficient can be satisfied with a non-inverting op-amp using $\begin{cases} R_3 = 699\Omega \\ R_4 = 1\Omega \end{cases}$

The whole circuit design can then be like;



12-48

$$T(S)=\frac{100S(S+300)}{(S+30)(S+3000)}$$

ⓐ $S=j\omega$

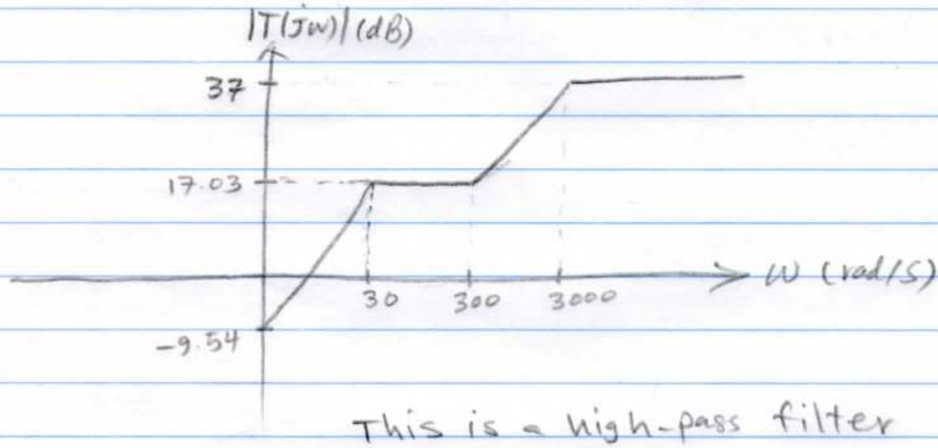
$$T(j\omega)=\frac{100(j\omega)(300)(\frac{j\omega}{300}+1)}{30(\frac{j\omega}{30}+1)(3000)(\frac{j\omega}{3000}+1)}$$

$$T(j\omega)=\frac{\frac{1}{3}(j\omega)(\frac{j\omega}{300}+1)}{(\frac{j\omega}{30}+1)(\frac{j\omega}{3000}+1)}$$

Scale factor: $K_0=\frac{1}{3} \Rightarrow 20\log(\frac{1}{3})=-9.54\ dB$

(*) we can form frequencies at (based on zero & poles):
$w=0\ \frac{rad}{s},\ 30\ \frac{rad}{s},\ 300\ \frac{rad}{s},\ 3000\ \frac{rad}{s}$

W(rad/s)	zero/pole	slope (dB/decade)	$\lvert T(j\omega)\rvert$ (dB)
0	zero	20	Baseline
30	pole	-20	17.03 dB
300	zero	20	Baseline
3000	pole	-20	37 dB



This is a high-pass filter
passband gain is 37 dB

(c) There are different designs to satisfy the transfer function. Here is one of possible designs:

$$T(s) = \frac{100s(s+300)}{(s+30)(s+3000)}$$

$$= \frac{100(s+300)}{(s+30)} \times \frac{s}{(s+3000)}$$

$$= \frac{100(300s)\left(\frac{1}{300}+\frac{1}{s}\right)}{30s\left(\frac{1}{30}+\frac{1}{s}\right)} \times \frac{1}{1+\frac{3000}{s}}$$

$$= \underset{\substack{\downarrow \\ \text{gain coefficient}}}{(1000)} \underbrace{\frac{\frac{1}{300}+\frac{1}{s}}{\frac{1}{30}+\frac{1}{s}}}_{T_1(s)} \times \underbrace{\frac{1}{1+\frac{3000}{s}}}_{T_2(s)}$$

$$T_2(s) = \frac{1}{1+\frac{3000}{s}}$$

using a voltage divider $\Rightarrow \begin{cases} R_2 = 1\,\Omega \\ C_2 = \frac{1}{3000}\,F \end{cases}$

$$T_1(s) = \frac{\frac{1}{300}+\frac{1}{s}}{\frac{1}{30}+\frac{1}{s}} = \frac{\left(\frac{1}{300}+\frac{1}{s}\right)}{\left(\frac{1}{300}+\frac{1}{s}\right)+\frac{9}{300}}$$

using another voltage divider $\Rightarrow \begin{cases} R_1 = \frac{1}{300}\,\Omega \\ C_1 = 1\,F \\ R_3 = \frac{9}{300}\,\Omega \end{cases}$

To have the gain coefficient of 1000, we can use a non-inverting op-amp with $R_4 = 999\,\Omega$ and $R_5 = 1\,\Omega$

The whole circuit design can then be like;