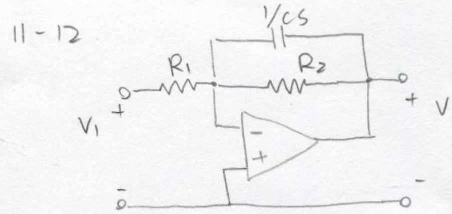
MAE 140 Linear Circuits Homework 8 Solution

11-12



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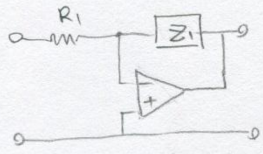


Inverting OpAmp

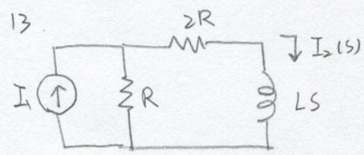
where $Z_1 = \frac{1}{CS} \,//\, R_2 = \frac{R_2}{R_2CS+1}$

use

$$V_2 = V_1 \cdot \frac{-Z_1}{R_1} \Rightarrow T_V(S) = \frac{V_2(S)}{V_1(S)} = \frac{-R_2/R_1}{R_2CS+1} = \frac{-1/R_1C}{S+\frac{1}{R_2C}}$$

pole @ $S = -\frac{1}{R_2C} = -250$, $\frac{R_2}{R_1} = 100$. choose $R_1 = 10\Omega$, $R_2 = 10^3\Omega$, $C = 4\times10^{-6}F$

11-13

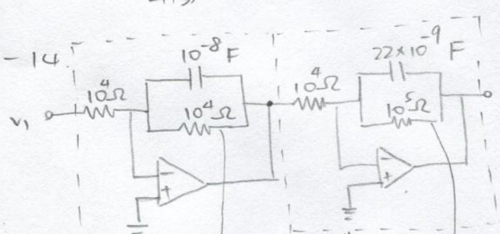


use the equation of current divider: $I_2 = I_1 \frac{1/_{2R+LS}}{1/_R + 1/_{2R+LS}} = I_1 \cdot \frac{R}{LS+3R}$

$T_I(S) = \frac{I_2(S)}{I_1(S)} = \frac{R}{LS+3R}$ pole @ $S = -\frac{3R}{L} = -377$

Choose: $L = 10^{-3}$ H, $R = 0.1257\Omega$

11-14



$Z_1 = \frac{10^4}{10^{-4}S+1}$ $Z_2 = \frac{10^5}{22\times10^{-4}S+1}$

The impedance of a capacitor in parallel with a resistor is:

$$\frac{1}{CS} \,//\, R = \frac{1}{CS+\frac{1}{R}} = \frac{R}{RCS+1}$$

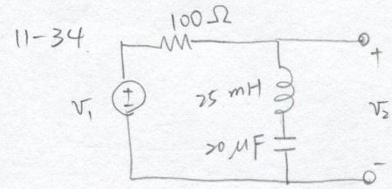
Transfer function for 1st stage inverting Op Amp: $T_1 = -\frac{Z_1}{10^4}$

" " " 2nd " " " : $T_2 = -\frac{Z_2}{10^4}$

$$T_V(S) = T_1 \times T_2 = \frac{10}{(10^{-4}S+1)(22\times10^{-4}S+1)}$$

poles @ $S = -10^4, -455$

11-34



$R = 100$
$L = 25 \times 10^{-3}$
$C = 20 \times 10^{-6}$

$$V_2(s) = V_1(s) \cdot \frac{sL + \frac{1}{Cs}}{R + sL + \frac{1}{Cs}} = V_1(s) * \frac{s^2 + \frac{1}{CL}}{s^2 + \frac{R}{L}s + \frac{1}{CL}}$$

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

poles @ -3414, -585.8

zeros @ $\pm 1414.2j$

For $v_1(t) = 5 \cdot \cos 1414.2t$,

$w = 1414.2$ is one of a zero of $T(s)$ $\Rightarrow V_{2ss}(t) = 0$

For $v_1(t) = 5 \cdot \cos 1000t$, $w = 1000$

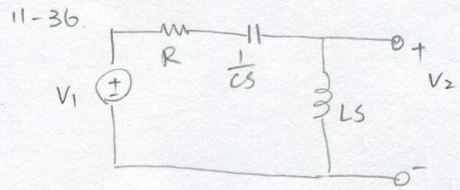
$|T(jw)| = 0.2425$, $\angle T(jw) = -1.3258$.

$V_{2ss}(t) = 5 \cdot |T(jw)| \cos(wt + \angle T(jw)) \approx \underline{1.2 \cdot \cos(1000t - 1.33)}$ (V)

For $v_1(t) = 5$ V. $V_1(s) = \frac{5}{s}$, $V_2(s) = T(s) \cdot V_1(s)$

$$V_{2ss}(t) = \lim_{s\to0} s \cdot V_2(s) = \lim_{s\to0} s \cdot \frac{s^2 + 2\times10^6}{s^2 + 4\times10^3 s + 2\times10^6} \cdot \frac{5}{s} = \underline{5} \text{ (V)}$$

11-36



$R = 10$
$C = 50 \times 10^{-6}$
$L = 5 \times 10^{-3}$

$$T(s) = \frac{V_2(s)}{V_1(s)} = \frac{Ls}{R + \frac{1}{Cs} + Ls} = \frac{s^2}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s^2}{s^2 + 2\times10^3 s + 4\times10^6}$$

$\underline{\text{poles @ } -1000 \pm 1732j, \text{ zeros @ } 0, 0}$

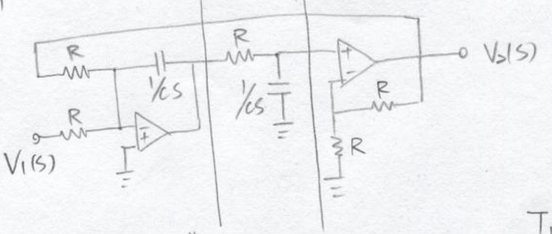
For $v_1(t) = 25 \cdot \cos(2000t)$, $w = 2000$ $T(jw) = j$

$|T(jw)| = 1$, $\angle T(jw) = 1.57$ $V_{2ss}(t) = 25 \cdot \cos(2000t + 1.57)$ (V)

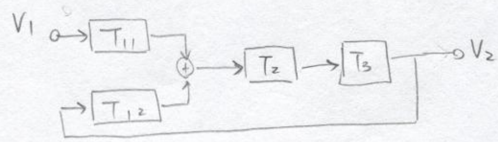
For $v_1(t) = 25 \cdot \cos(10^4 t)$, $w = 10^4$

$|T(jw)| = 1.02$ $\angle T(jw) = 0.205$. $V_{2ss}(t) = 25.5 \cdot \cos(10^4 t + 0.205)$ (V)

11-81



⇓



$T_{11} = -\frac{1/CS}{R} = -\frac{1}{RCS}$

$T_{12} = -\frac{1/CS}{R} = -\frac{1}{RCS}$

$T_2 = \frac{1/CS}{R + 1/CS} = \frac{1}{RCS+1}$

$T_3 = \frac{2R}{R} = 2$

$(V_1 \cdot T_{11} + V_2 \cdot T_{12}) \cdot T_2 \cdot T_3 = V_2$,

$V_1 \cdot T_{11} \cdot T_2 \cdot T_3 = V_2 (1 - T_{12} \cdot T_2 \cdot T_3)$

$T(S) = \frac{V_2(S)}{V_1(S)} = \frac{T_{11} T_2 T_3}{1 - T_{12} T_2 T_3} = \frac{-2}{R^2 C^2 S^2 + RCS + 2}$

There's no loading involved, stage 2 is connected to OpAmp output of stage 1, Stage 2 connected with stage 3 through OpAmp and no current is drawn.

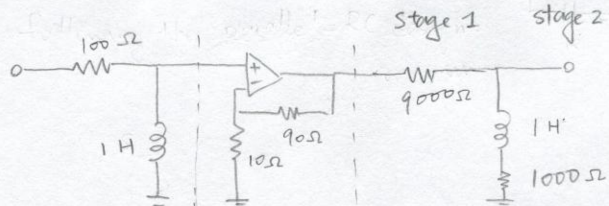
poles of T : $S = \frac{1}{RC} \cdot (-0.5 \pm 1.323 j)$

∵ Real (S) < 0 , the circuit is stable

11-83

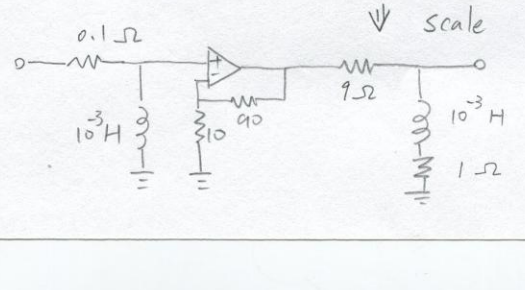
$T(S) = \frac{10 S (S+10^3)}{(S+10^2)(S+10^4)} = \frac{S}{S+10^2} \times 10 \times \frac{S+10^3}{S+10^4}$

stage 1 stage 2 stage 3



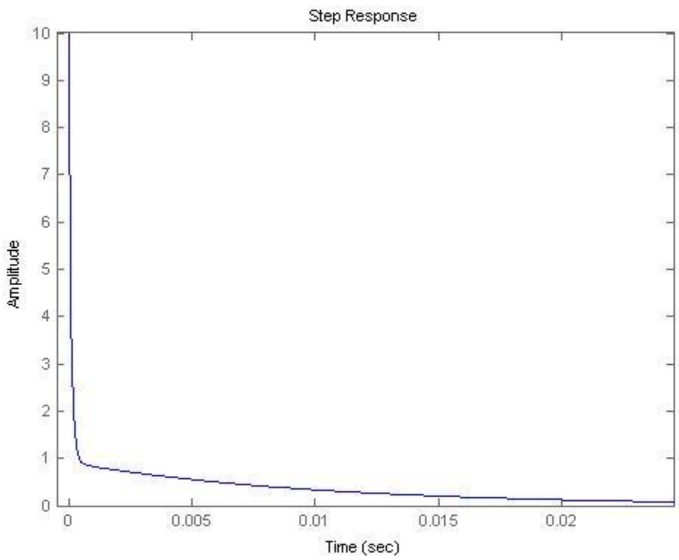
$T_1 = \frac{S}{S+100}$ $T_2 = 10$ $T_3 = \frac{S+1000}{S+10000}$

⇓ Scale

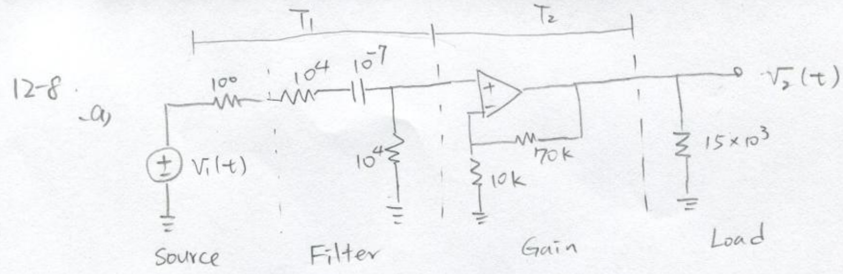


MATLAB:

```
Z  = tf([10 10^4 0],[1 10100 10^6]);
step(Z)
```



12-8. a)



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

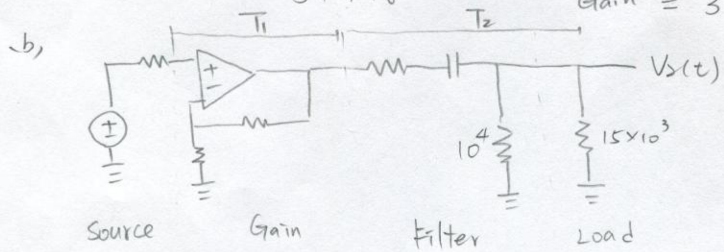
$$T_2 = \frac{80k}{10k} = 8$$

cutoff frequency

$$T = T_1 \cdot T_2 = \frac{3.98\,s}{s+498} \Rightarrow \text{pole @ } s = -498 \approx -500$$

$\text{Gain} = 3.98 \approx 4$

b)



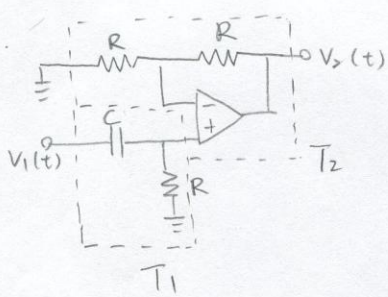
$$T_1 = \frac{80k}{10k} = 8$$

$$T_2 = \frac{10^4 \,//\, 15\times10^3}{10^4 \,//\, 15\times10^3 + 10^4 + \frac{1}{10^{-7}s}} = \frac{0.375\,s}{s+625}$$

$$T = T_1 \cdot T_2 = \frac{3\,s}{s+625} \Rightarrow \text{pole @ } s = -625.$$

cutoff frequency

12-15.



T_1: voltage divider:

$$T_1 = \frac{R}{R + \frac{1}{Cs}} = \frac{s}{s + \frac{1}{RC}}$$

T_2: Non-inverting OpAmp

$$T_2 = \frac{2R}{R} = 2$$

$$T_V(s) = T_1 \times T_2 = \frac{2s}{s + \frac{1}{RC}}$$ zero @ 0, pole @ $\frac{-1}{RC}$

choose $C = 10^{-6}$ F

cutoff frequency @ $\frac{1}{RC} = 300\times10^3$

$R = 3.3\times10^3\,\Omega$

This is a High pass filter with passband gain 2

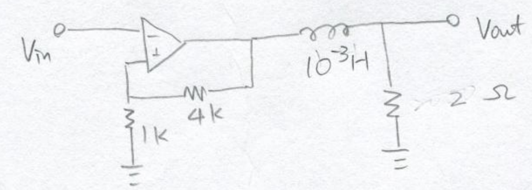
12-18

$T(S) = \frac{10{,}000}{s+2000}$

(a) pole @ $s = -2000$, This is a low-pass filter with cutoff frequency 2000 Hz and passband gain = 5.

$s \to 0$, $T(S) = 5$,

(c) $T(S) = 5 \cdot \frac{2000}{s+2000}$



MATLAB:

```
Z = tf(10^4,[1 2000]);
bode(Z)
```