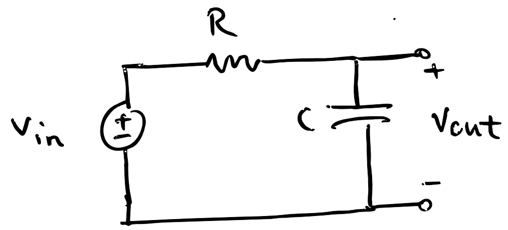
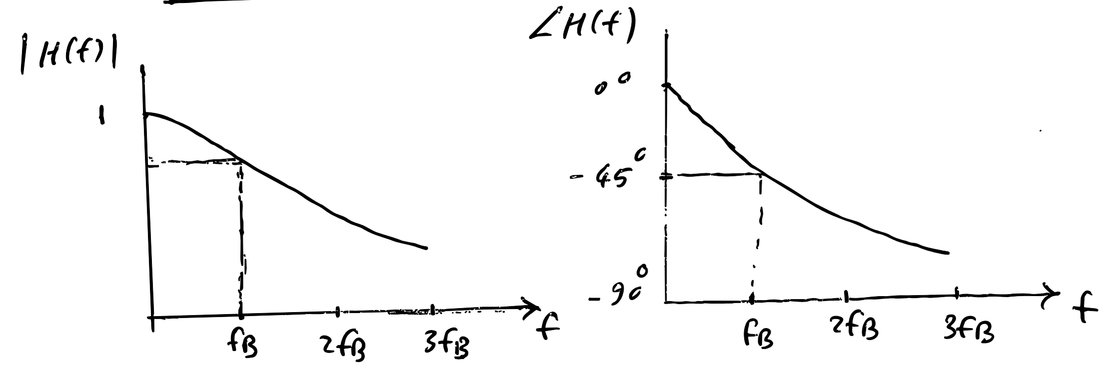
EE 40
HW4 Solution / Summer 05

① P 6.17



$$f_B = \frac{1}{2\pi RC}$$



② P 6.19

The half power frequency of the filter is $f_B = \frac{1}{2\pi RC} = 500\ HZ$

The transfer function is given by $H(f) = \frac{1}{1 + j(f/f_B)}$

The given input signal is $V_{in}(t) = 5\cos(500\pi t) + 5\cos(1000\pi t) + 5\cos(2000\pi t)$

which has components with frequencies of 250, 500 and 1000 HZ.

We evaluate the transfer function for each one of these frequencies.

$$H(250) = \frac{1}{1 + j(250/500)} = 0.8944\angle -26.57^\circ$$

$$H(500) = 0.7071\angle -45^\circ$$

$$H(1000) = 0.4472\angle -63.43^\circ$$

$$V_{out}(t) = H(250)\cdot 5\cos(500\pi t) + H(500)\cdot 5\cos(1000\pi t) + H(1000)\cdot 5\cos(2000\pi t)$$

note that we applied the appropriate value of the transfer function to each component of the input signal.

Thus, $$\boxed{V_{out}(t) = 4.472\cos(500\pi t - 26.57^\circ) + 3.535\cos(1000\pi t - 45^\circ) + 2.236\cos(2000\pi t - 63.43^\circ)}$$

3 P6.25

$$\angle H(f) = -\tan^{-1}(f/f_B)$$

$$\Rightarrow f = -f_B \tan[\angle H(f)]$$

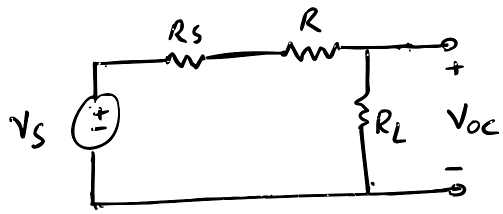
For $\angle H(f) = -1^\circ$, $f = 0.0175 f_B$

For $\angle H(f) = -10^\circ$, $f = 0.176 f_B$

For $\angle H(f) = -89^\circ$, $f = 57.29 f_B$

(4) P6.26 part a

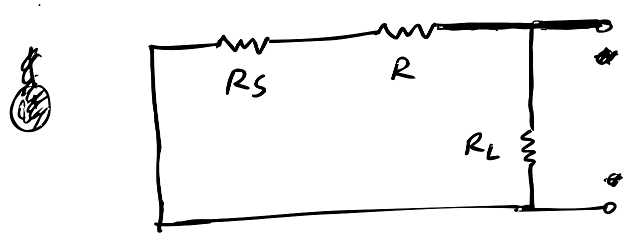
First, we find the Thevenin equivalent for the source and resistances



The open circuit voltage is given by:

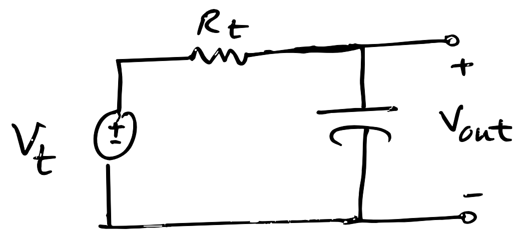
$$V_t = V_{oc} = V_S \frac{R_L}{R_S + R + R_L} \qquad (1)$$

Zeroing the source, we can find the Thevenin resistance



$$R_t = \frac{1}{1/R_L + 1/(R+R_S)}$$

Thus, the original circuit has the equivalent



$$V_t = V_{oc} = \frac{R_L}{R_S + R + R_L} V_S$$

$$R_t = \frac{1}{1/R_L + 1/(R+R_S)}$$

The transfer function for this circuit is

$$\frac{V_{out}}{V_{t}} = \frac{1}{1 + j\left(\frac{f}{f_B}\right)}, \quad f_B = \frac{1}{2\pi R_t C}$$

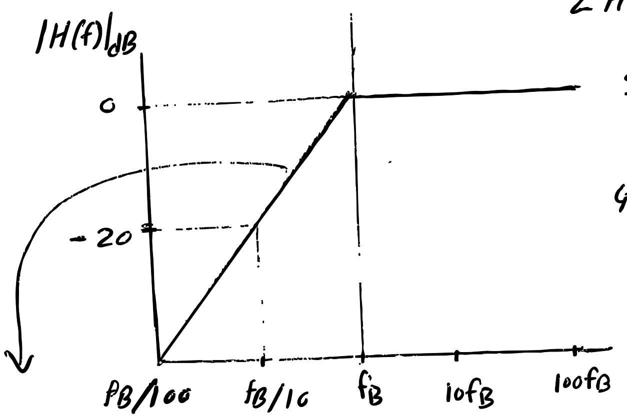
using equation (1) to substitute for V_t we get

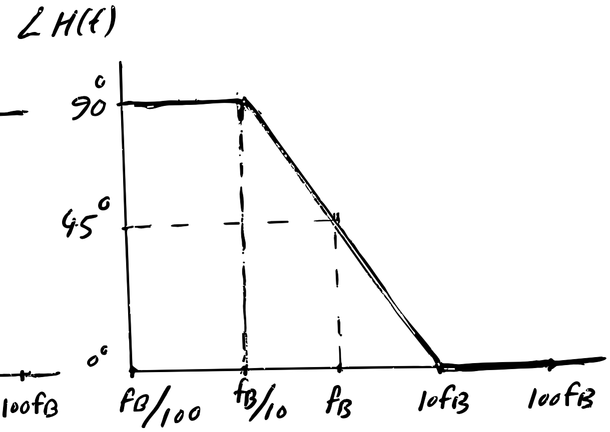
$$\boxed{H(f) = \frac{V_{out}}{V_s} = \frac{R_L}{R_S + R + R_L} \times \frac{1}{1 + j(f/f_B)}}$$

(5) P 6.55

This is a first-order high pass filter.

$$H(f) = \frac{j(f/f_B)}{1 + j(f/f_B)}, \quad f_B = \frac{1}{2\pi RC} = 3.183 \text{ KHZ}$$





note:
The slope is
20 $\frac{dB}{decade}$

⑥ P 6.58

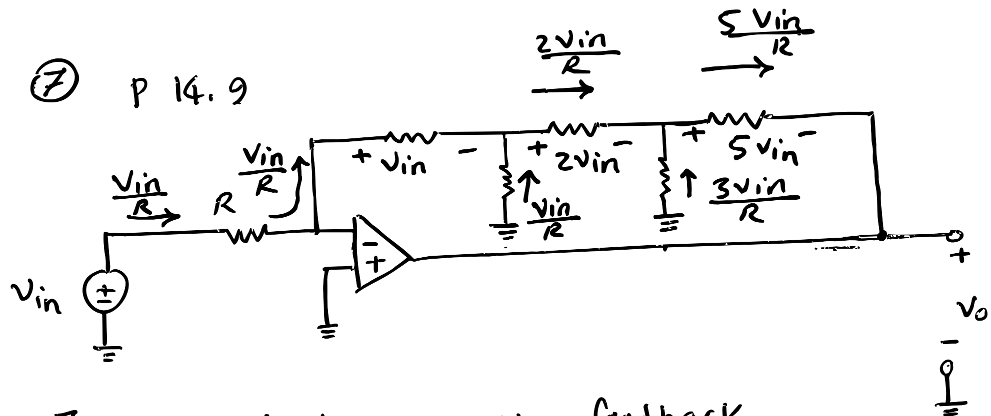
- To attenuate the 60-HZ component by 40 dB, the break frequency must be two decades higher than 60 HZ because the roll-off slope is 20 $\frac{dB}{decade}$.

Thus, the break frequency must be $f_B = 6\,KHZ$

- The 600-HZ component is attenuated by 20 dB.
- Since $f_B = \frac{1}{2\pi RC}$, we have

$$C = \frac{1}{2\pi R f_B} = \frac{1}{2\pi(1000)6000} = 0.0265\ \mu F$$

⑦ P 14.9

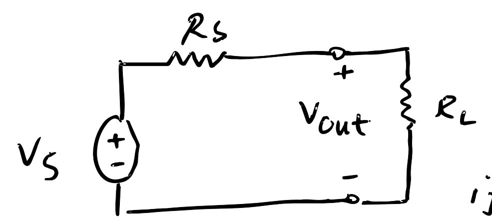


The circuit has negative feedback so we can employ the summing-point constraint. Then successive application of Ohm's and Kirchhoff's laws starting from the left-hand side of the circuit produces the result shown above.

Thus: $V_o = -8\,V_{in} \Rightarrow \boxed{A_v = -8\ V}$

(8) P14.16

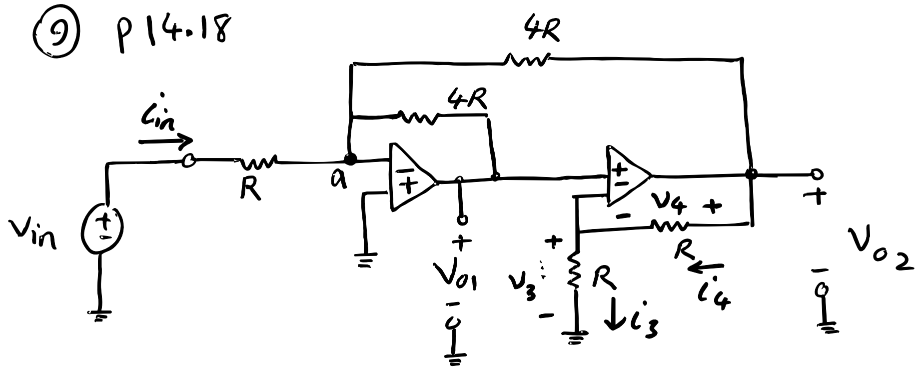
If the source has a non zero series impedance, loading (reduction in voltage) will occur when the load is connected directly to the source. On the other hand, the input impedence of the voltage follower is very high (ideally infinite) and loading does not occur. If the source impedence is very high compared to the load impedance, the voltage follower will deliver a much larger voltage to the load than direct connection.



$$V_{out} = \frac{R_L}{R_L + R_S} V_S$$

if $R_S \gg R_L$, $V_{out} \to 0$

⑨ P14.18



From the circuit, we can write:

$V_{o1} = V_3$

$i_4 = i_3 = \frac{V_{o1}}{R}$

Thus we have

$V_4 = V_3 = V_{o1}$

$V_{o2} = V_3 + V_4 = 2V_{o1}$ (1)

$i_{in} + \frac{V_{o1}}{4R} + \frac{V_{o2}}{4R} = 0$ (KCL at a)

$i_{in} = \frac{V_{in}}{R}$

$\frac{V_{in}}{R} + \frac{V_{o1}}{4R} + \frac{V_{o2}}{4R} = 0$ (2)

Using (1) and (2):

$$\boxed{A_1 = \frac{V_{o1}}{V_{in}} = -4/3}$$

$$\boxed{A_2 = \frac{V_{o2}}{V_{in}} = \frac{2V_{o1}}{V_{in}} = 2A_1 = -8/3}$$

(10) P 14.20

Analysis of the circuit using the summing-point constraint yields:

$$V_o = -\frac{R_2}{10^4} V_{in} + \left(1 + \frac{R_2}{10^4}\right)$$

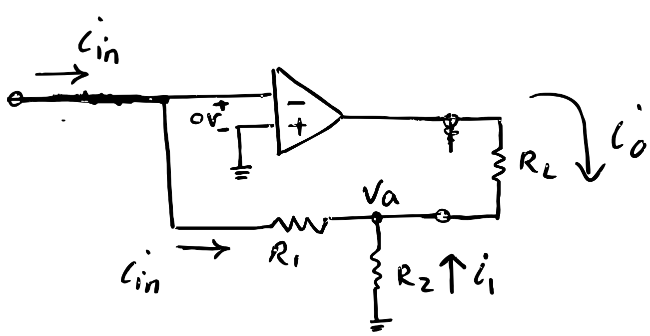
Substituting the expression given for Vin yields

$$V_o = -2\frac{R_2}{10^4} - 3\frac{R_2}{10^4}\cos(2000\pi t) + \left(1 + \frac{R_2}{10^4}\right)$$

now, we set the dc component to zero.

$$0 = -2\frac{R_2}{10^4} + \left(1 + \frac{R_2}{10^4}\right) \Rightarrow \boxed{R_2 = 10\,k\Omega}$$

(11) P 14.26



$$V_a = -R_1 i_{in}$$

$$i_1 = \frac{R_1 i_{in}}{R_2}$$

$$i_o = -(i_{in} + i_1) = -\left(\frac{R_1}{R_2} i_{in} + i_{in}\right) \Rightarrow \boxed{i_o = -\left(1 + \frac{R_1}{R_2}\right) i_{in}}$$

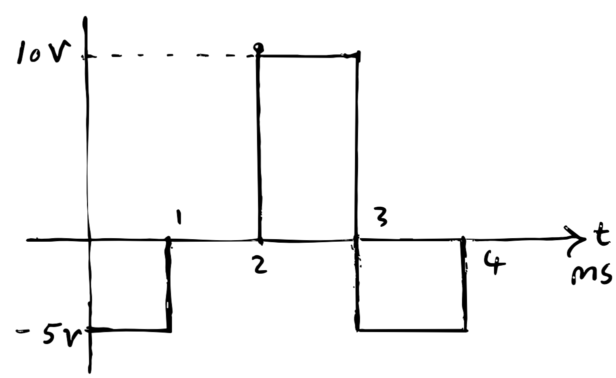
Because of the summing-point constraint, we have $V_{in} = 0$. Thus $R_{in} = 0$. Because the output current is independent of R_L, the output impedence is infinite. In other words looking back from the load terminals, the circuit behaves like an ideal current source.

(12) P14.64

This is a differentiator circuit, and the out put is given by:

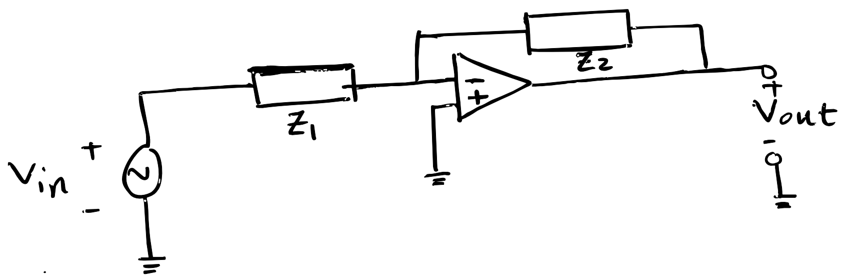
$$V_o(t) = -RC \frac{dV_{in}(t)}{dt} = -10^{-3} \frac{dV_{in}(t)}{dt}$$

A sketch of $V_o(t)$ versus t is:



(13) P 14. 66

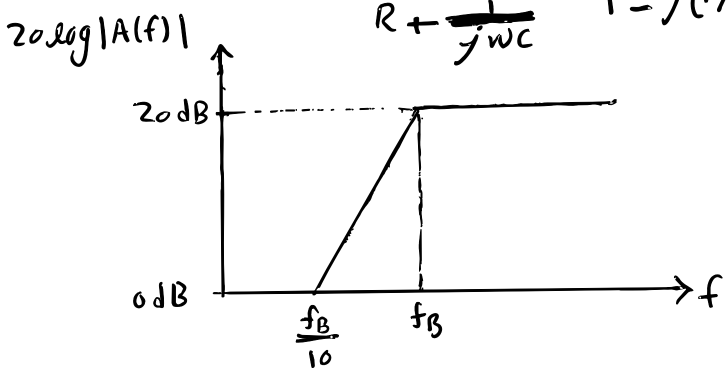
All of the circuits are of the form :



This is the inverting amplifier configuration and the gain is

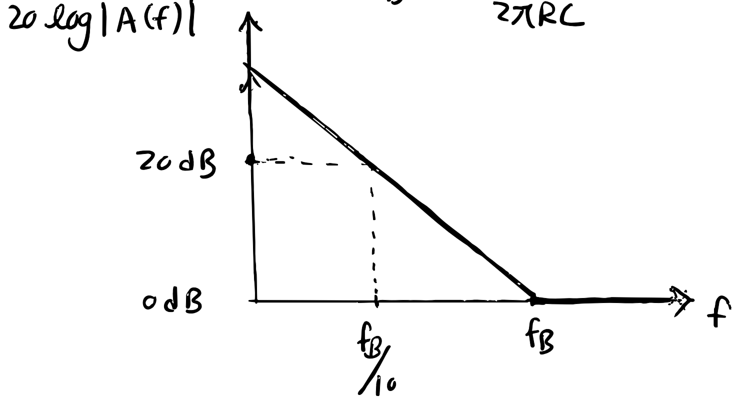
$$A(f) = \frac{V_o}{V_{in}} = -\frac{Z_2}{Z_1}$$

(a) $A(f) = -\dfrac{10R}{R + \dfrac{1}{j\omega C}} = \dfrac{-10}{1 - j(f/f_B)}$ where $f_B = \dfrac{1}{2\pi RC}$



(b) $A(f) = -\dfrac{R + 1/jwC}{R} = -\left(1 - j\dfrac{f_B}{f}\right)$

where $f_B = \dfrac{1}{2\pi RC}$



(C) $A(f) = -\dfrac{\dfrac{1}{1/R + jwC}}{R} = -\dfrac{1}{1 + jf/f_B}$

where $f_B = \dfrac{1}{2\pi RC}$