Problem 9.37 For the op-amp circuit of Fig. P9.37:

(a) Obtain an expression for $\mathbf{H}(\omega) = \mathbf{V}_o/\mathbf{V}_s$ in standard form.

(b) Generate spectral plots for the magnitude and phase of $\mathbf{H}(\omega)$, given that $R_1 = 1$ kΩ, $R_2 = 4$ kΩ, and $C = 1\ \mu$F.

(c) What type of filter is it? What is its maximum gain?

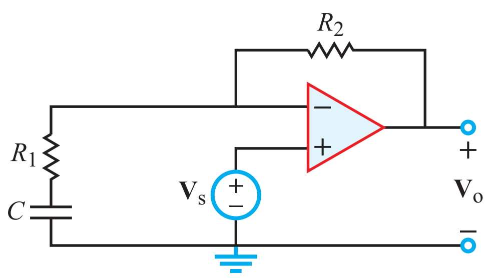
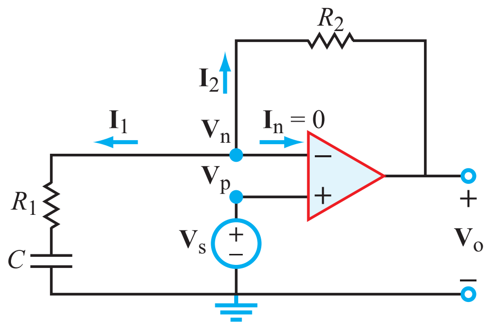


Figure P9.37: Circuit for Problem 9.37.

Solution:



(a)

$$\mathbf{V}_p = \mathbf{V}_n = \mathbf{V}_s$$

$$\mathbf{I}_1 + \mathbf{I}_2 = 0,$$

or equivalently,

$$\frac{\mathbf{V}_s}{R_1 + \frac{1}{j\omega C}} + \frac{\mathbf{V}_s - \mathbf{V}_o}{R_2} = 0,$$

which leads to

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_s} = \frac{1 + j\omega(R_1 + R_2)C}{1 + j\omega R_1 C}$$

$$= \frac{1 + j\omega/\omega_{c_1}}{1 + j\omega/\omega_{c_2}},$$

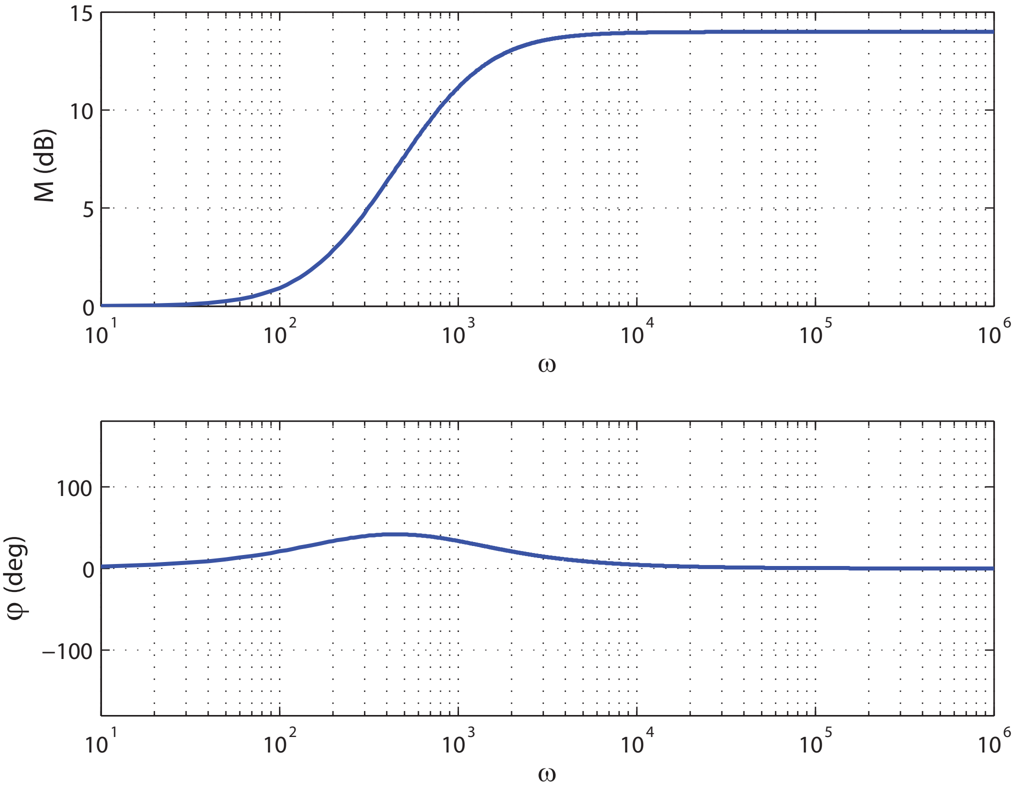
with

$$\omega_{c_1} = \frac{1}{(R_1 + R_2)C}, \qquad \omega_{c_2} = \frac{1}{R_1 C}.$$

(b) For $R_1 = 1$ kΩ, $R_2 = 4$ kΩ, and $C = 1\ \mu$F,

$$\omega_{c_1} = 200 \text{ rad/s}, \qquad \omega_{c_2} = 1000 \text{ rad/s}.$$

Spectral plots are shown in Figs. 9.37(b) and (c).



Figures P9.37(b) and (c)

(c) It is a high-pass filter. For $\omega \gg \omega_{c_2}$,

$$\mathbf{H}(\omega) \simeq \frac{\omega_{c_2}}{\omega_{c_1}} = 5.$$

Hence, maximum gain $= 20\log 5 \simeq 14$ dB.