Exercise 1.10

\[ A_{vo} = \frac{v_o}{v_i} = \frac{200i_i R_o}{i_i R_i} = 4 \quad R_i = 1000 \, \Omega \quad R_o = 20 \, \Omega \]

Exercise 1.11

\[ G_{msc} = \frac{i_{osc}}{v_i} = \frac{100i_i}{500i_i} = 0.2 \, \text{S} \]

\[ R_i = 500 \, \Omega \]
\[ R_o = 50 \, \Omega \]
Exercise 1.12

\[ R_{\text{noC}} = \frac{v_{\text{oc}}}{i_1} = \frac{G_{\text{msc}} v_i R_o}{v_i / R_i} = G_{\text{msc}} R_o R_i = 500 \, \text{k}\Omega \]
**Problem 1.19**

With the switch open we have:

\[ V_o = 50 \text{ mV} = V_s \frac{R_i}{R_i + 10^6} A_{vo} \frac{R_L}{R_L + R_o} \]  

(1)

With the switch closed we have:

\[ V_o = 100 \text{ mV} = V_s A_{vo} \frac{R_L}{R_L + R_o} \]  

(2)

Dividing the respective sides of Equation (1) by those of Equation (2), we have:

\[ \frac{50 \text{ mV}}{100 \text{ mV}} = \frac{R_i}{R_i + 10^6} \]

Solving we obtain \( R_i = 1 \text{ M}\Omega \).

**Problem 1.20**

If we cascade two amplifiers A and B the equivalent circuit is:

![Cascaded Amplifier](image)

The open-circuit voltage gain of the cascaded amplifier is:

\[ A_{vo} = A_{voA} A_{voB} \frac{R_{iB}}{R_{oA} + R_{iB}} \]

**Problem 1.21**

See the figure shown in the solution for Problem 1.20. When the amplifiers are cascaded in the order A-B, we have:
\[ R_i = R_{iA} = 3 \text{ k}\Omega \]
\[ R_o = R_{OB} = 20 \text{ } \Omega \]

\[ A_{vo} = A_{voA}A_{voB} \frac{R_{iB}}{R_{OA} + R_{iB}} = 4.998 \times 10^4 \]

On the other hand for the B-A cascade we have:

\[ R_i = R_{iB} = 1 \text{ M}\Omega \]
\[ R_o = R_{OA} = 400 \text{ } \Omega \]

\[ A_{vo} = A_{voA}A_{voB} \frac{R_{iA}}{R_{OB} + R_{iA}} = 4.967 \times 10^4 \]
Problem 2.40

Op amp imperfections in the linear range of operation include:

- finite input impedance
- nonzero output impedance
- finite open-loop gain
- finite bandwidth
- nonzero common-mode gain

Problem 2.41

For the noninverting amplifier with a given op amp, the product of dc gain and closed-loop bandwidth is constant as the dc gain is changed.

Problem 2.42

(a) Refer to Figure P2.42 in the text.

\[ v_s = R_{\text{in}} i_s + R_o i_s + A_{\text{OL}} (R_{\text{in}} i_s) \]

\[ v_o = R_o i_s + A_{\text{OL}} (R_{\text{in}} i_s) \]

\[ A_{\text{VS}} = \frac{v_o}{v_s} = \frac{R_o + A_{\text{OL}} R_{\text{in}}}{R_{\text{in}} + R_o + A_{\text{OL}} R_{\text{in}}} \]

\[ A_{\text{VS}} = \frac{25 + 10^5 \times 10^6}{10^6 + 25 + 10^5 \times 10^6} = 0.99999 \]

The gain would be 1.00000 for an ideal op amp.

(b) \[ Z_{\text{in}} = \frac{v_s}{i_s} = R_{\text{in}} + R_o + A_{\text{OL}} R_{\text{in}} = 10^{11} \Omega \]

In comparison, we would have \( Z_{\text{in}} = \infty \) for an ideal op amp.
\[ v_i = -v_x \quad i_x = \frac{v_x}{R_{in}} + \frac{v_x - A_{OL}v_i}{R_o} \quad z_o = \frac{v_x}{i_x} = \frac{1}{\frac{1}{R_{in}} + \frac{1}{1 + A_{OL}R_o}} \]

Evaluating we find \( z_o = 2.5 \times 10^{-4} \, \Omega \) compared to \( z_o = 0 \) for an ideal op amp.

**Problem 2.43**

(a) Refer to Figure P2.43 in the text. Writing current equations at the input terminal of the op amp and at the output terminal we have:

\[ \frac{v_s + v_i}{R_1} + \frac{v_o + v_i}{R_2} + \frac{v_i}{R_{in}} = 0 \quad (1) \]

\[ \frac{v_o + v_i}{R_2} + \frac{v_o - A_{OL}v_i}{R_o} = 0 \quad (2) \]

Now we solve Equation (1) for \( v_i \), substitute into Equation (2), and use algebra to obtain:

\[ A_{VS} = \frac{v_o}{v_s} = \frac{-R_2}{R_1 \left[ 1 + \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_{in}} \right) \frac{R_oR_2 + R_2^2}{A_{OL}R_2 - R_o} \right]} \]

Evaluating we find \( A_{VS} = -9.9989 \) compared to \( A_{VS} = -10 \) for an ideal op amp.