The voltage amplifier shown uses an ideal op amp.

a.) Find the voltage gain, \( \frac{v_{out}}{v_{in}} \) in terms of the resistors \( R_1, R_2, R_3 \) and \( R_4 \).

b.) Find the input resistance, \( R_{in} \), in terms of resistors \( R_1, R_2, R_3 \) and \( R_4 \).

c.) If \( R_1 = R_4 = 90k\Omega \) and \( R_2 = R_3 = 100k\Omega \) numerically evaluate \( \frac{v_{out}}{v_{in}} \) and \( R_{in} \).

Solution

a.) This problem cannot be worked using the inverting and voltage amplifier configurations so we must use that fact that the input voltage to the op amp is zero.

\[
\therefore \quad v_{id} = v^+ - v^- = \frac{v_{out} R_3}{R_3 + R_4} - \left[ \frac{v_{in} R_2}{R_1 + R_2} + \frac{v_{out} R_1}{R_1 + R_2} \right] = 0
\]

\[
v_{out} \left[ \frac{R_3}{R_3 + R_4} - \frac{R_1}{R_1 + R_2} \right] = \left( \frac{R_2}{R_1 + R_2} \right) v_{in} \quad \rightarrow \quad \frac{v_{out}}{v_{in}} = \frac{R_2}{R_3 - R_1 + R_2}
\]

Thus,

\[
\frac{v_{out}}{v_{in}} = \frac{R_2}{R_3 - R_1 + R_2} = \frac{R_2(R_3 + R_4)}{R_3 R_2 - R_1 R_4}
\]

b.) \( v_{in} = i_1 R_1 - i_2 R_3 \) but \( i_1 R_2 = i_2 R_4 \) so we get,

\[
v_{in} = i_1 R_1 - R_3 \left( \frac{R_2}{R_4} \right) i_1 = i_1 \left( R_1 - \frac{R_2 R_3}{R_4} \right)
\]

\[
\therefore \quad R_{in} = R_1 - \frac{R_2 R_3}{R_4} = \frac{R_1 R_4 - R_2 R_3}{R_4}
\]

c.) The numerical values become,

\[
\frac{v_{out}}{v_{in}} = \frac{100k\Omega}{100k\Omega(1) - 90k\Omega} = \frac{10V}{V} \quad \text{and} \quad R_{in} = 90k\Omega - \frac{100k\Omega \cdot 100k\Omega}{90k\Omega} = -21.11k\Omega
\]

\[
\frac{v_{out}}{v_{in}} = 10 \text{V/V} \quad \text{and} \quad R_{in} = -21.11k\Omega
\]

Obviously, the voltage source driving this voltage amplifier must have a source resistance greater than 21.11k\Omega for the circuit to remain stable.