HW #5 for Quiz 5 on Oct 31

1) Prob 4.13
2) Prob 4.14
3) Prob 4.16
4) Prob 4.19
5) Prob 4.24
6) Prob 4.30
7) Prob 4.38
8) Prob 4.40
9) Prob 4.5x

Quiz 3

\[
\begin{align*}
\text{Ans} & = 5.99 \\
\alpha & = 3.86 \\
-4I_1 + 8(9-3I_1) + 40 & = 0 \\
-4I_1 + 72 - 12I_1 + 40 & = 0 \\
28I_1 & = 112 \\
I_1 & = 4A \\
\end{align*}
\]

Power supplied by 40V source = 40V x 3 = 120W

Figure 4-3: Op-amp transfer characteristics. The linear range extends between \( V_{th} = -V_c \) and \( V_c \). The slope of the line is the op-amp gain \( A \).

Figure 4-6: Equivalent circuit model for an op amp operating in the linear range \( (V_{in} \leq |V_{sat}|) \). Voltages \( V_{in}, V_{out} \), and \( V_{th} \) are referenced to ground.
Table 4.1: Characteristics and typical ranges of op-amp parameters. The rightmost column represents the values assumed by the ideal op-amp model.

<table>
<thead>
<tr>
<th>Op-Amp Characteristics</th>
<th>Parameter</th>
<th>Typical Range</th>
<th>Ideal Op-Amp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low input impedance</td>
<td>Input impedance $R_i$</td>
<td>$&lt; 100$ kΩ</td>
<td>$R_i = 0$</td>
</tr>
<tr>
<td>High output impedance</td>
<td>Output impedance $R_o$</td>
<td>$10^5$ to $10^6$ Ω</td>
<td>$R_o = 0$</td>
</tr>
<tr>
<td>Low offset voltage</td>
<td>Offset voltage $V_o$</td>
<td>$&lt; 1$ mV</td>
<td>$V_o = 0$</td>
</tr>
<tr>
<td>Low input current</td>
<td>Input current $I_i$</td>
<td>&lt; 1 nA</td>
<td>$I_i = 0$</td>
</tr>
<tr>
<td>Large bandwidth</td>
<td>Bandwidth $BW$</td>
<td>&gt; 1 GHz</td>
<td>$BW = ∞$</td>
</tr>
</tbody>
</table>

\[ V_o = A \cdot V_i \]

**Noninverting Amplifier**

\[ V_o = \frac{V_i}{R_1} \left( R_2 + \frac{R_1 R_2}{R_2 + R_o} \right) \]

\[ V_o = A \cdot V_i \]

When $A \to ∞$ (very large)

\[ V_o = \frac{1}{R_2 + R_o} \left( R_2 \frac{V_o}{R_2} \right) \]

\[ V_o = \left( \frac{R_1 + R_2}{R_2} \right) V_i \]

**Inverting Amplifier**

\[ V_o = -A \cdot V_i \]

\[ V_o = -G \cdot \left( \frac{R_2}{R_1} \right) V_i \]

Figure 4.10: Noninverting amplifier circuit: (a) using ideal op-amp model and (b) equivalent block-diagram representation.

Figure 4.11: Inverting amplifier circuit and its block-diagram equivalent.
4.5 For the op-amp circuit shown in Fig. P4.5:
(a) Use the model given in Fig. 4-6 to develop an expression for the current gain $G_i = i_2 / i_1$.
(b) Simplify the expression by applying the ideal op-amp model (taking $A \to \infty$, $R_1 \to \infty$, and $R_o \to 0$).

4.7 For the circuit in Fig. P4.7:
(a) Use the op-amp equivalent-circuit model to develop an expression for $G = v_o / v_i$.
(b) Simplify the expression by applying the ideal op-amp model parameters, namely $A \to \infty$, $R_i \to \infty$, and $R_o \to 0$. 

---

For the circuit shown in Fig. P4.5, we have:

\[ KCL \text{ at node } 2: i_1 + i_2 = 0 \]
\[ \frac{v_2}{V_o} = -\frac{R_1}{R_S} \]
\[ \frac{v_2}{V_o} = -\frac{R_1}{R_S} \]

The circuit is a virtual ground.

The circuit for Problem 4.5 is shown in the image.

For the circuit in Fig. P4.7, we have:

\[ R_S i_S = R_L i_L \]
\[ \frac{\Delta L}{L} = \frac{R_S}{R_L} = G_I \]

The circuit for Problem 4.7 is shown in the image.

For the circuit shown in Fig. P4.5, we have:

\[ V_S = 1 \]
\[ P_{RL} = \frac{(V_S)^2}{R_L} \]
Exercise 4.7: Express \( v_o \) in terms of \( v_1, v_2, \) and \( v_3 \) for the circuit in Fig. E4.7.

Answer: \( v_o = 12v_1 + 6v_2 + 3v_3. \) (See (a))

\[ v_o = \begin{bmatrix} \frac{20}{3} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} \]

\[ v_o = -2v_2 + \frac{1}{3}v_1 + \frac{1}{2}v_3 \]

\[ v_i = \frac{1}{3}v_1 + \frac{1}{2}v_2 + \frac{1}{3}v_3 \]

\[ v_i = \frac{1}{3}v_1 + \frac{1}{2}v_2 + \frac{1}{3}v_3 \]

Figure 4.47: The voltage follower provides no voltage gain (\( v_o = v_i \)), but it isolates the input circuit from the load.

Figure 4.10: Block diagram representation (Example 4.6).