For the circuit above:

- What is the Differential Gain, \( G_d = V_o/(V_B - V_A) \)?

\[
V_o = \left( \frac{R_3 + R_4}{R_1 + R_2} \right) \left( \frac{R_3}{R_2} \right) V_B - \left( \frac{R_1}{R_2} \right) V_B
\]

\[
V_o = \left( \frac{25 + 1.9}{25 + 1.901} \right) \left( \frac{25}{1.901} \right) V_B - \left( \frac{25}{1.901} \right) V_B = 13.1574V_B - 13.1510V_A
\]

Set \( V_B = -V_A = 1 \text{ V} \), \( V_d = V_B - V_A = 2 \text{ V} \).

\[
G_d = V_o/V_d = (13.1574(1) - 13.1510(-1))/2 = 13.1542
\]

- What is the Common-mode Gain, \( G_{cm} = V_o/(\frac{1}{2}(V_B + V_A)) \)?

Set \( V_B = V_A = 1 \text{ V} \), \( V_{cm} = \frac{1}{2}(V_B + V_A) = 1 \text{ V} \).

\[
G_{cm} = V_o/V_d = |13.1574(1) - 13.1510(1)|/1 = 0.0064
\]

- What is the Common-mode Rejection Ratio (CMRR)?

\[
\text{CMRR} = 20 \log_{10} \frac{13.1542}{0.0064} = 66.26
\]
For the circuit above:

- Sketch $V_o$ as a function of time.
- What is $V_x - V_y$ at $t = 45$ ms?

All op amps are ideal with $V_{CC} = 15$ V and $V_{CC} = -15$ V.

- Sketch $V_o$ as a function of time.

\[
V_o = \left(1 + \frac{2R_A}{R_G}\right) \left(\frac{R_1}{R_2}\right) (V_B - V_A)
\]

\[
V_o = \left(1 + \frac{2 \times 46}{3.0}\right) \left(\frac{49}{2.6}\right) (V_B - V_A) = 596.8 \ (V_B - V_A)
\]

Thus:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$V_A$ (mV)</th>
<th>$V_B$ (mV)</th>
<th>$V_o$ (V) = 596.8($V_B - V_A$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.1</td>
<td>4.0</td>
<td>1.134</td>
</tr>
<tr>
<td>15</td>
<td>2.9</td>
<td>4.0</td>
<td>0.656</td>
</tr>
<tr>
<td>25</td>
<td>2.1</td>
<td>4.0</td>
<td>1.134</td>
</tr>
<tr>
<td>35</td>
<td>2.1</td>
<td>6.5</td>
<td>2.626</td>
</tr>
<tr>
<td>45</td>
<td>2.1</td>
<td>4.0</td>
<td>1.134</td>
</tr>
</tbody>
</table>

- What is $V_x - V_y$ at $t = 45$ ms?

\[
V_x - V_y = \left(1 + \frac{2R_A}{R_G}\right) (V_B - V_A)
\]

\[
V_x - V_y = 31.67 \ (V_B - V_A) = 31.67 \ (4.0 \text{ mV} - 2.1 \text{ mV}) = 0.060 \text{ V}
\]
For the input, $V_i$, below, sketch the output, $V_o$, on the same graph. Indicate voltage levels and the times of any transitions. (The op amp is ideal with the indicated $V_{CC}$ and $V_{EE}$ values).

Non-inverting amplifier:
Gain: $G = 1 + R_1/R_2 = 1 + 50/2.9 = 18.24$
Ideally, output would swing from $-36.48\, \text{V}$ (at $t = 0\, \text{ms}$) to $36.48\, \text{V}$ (at $t = 20\, \text{ms}$).
However, output is limited to $\pm 10\, \text{V}$.
Slope is $2 \times 36.48/20 = 1.824\, \text{V/\text{ms}}$.
So starting at $V=0$, the limit of $10\, \text{V}$ is reached in
$\Delta t = 10\, \text{V}/1.824\, \text{V/\text{ms}} = 5.482\, \text{ms}$

Thus:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$t$ (ms)</th>
<th>$V_o$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 - 5.482$</td>
<td>$4.52$</td>
<td>$-10$</td>
</tr>
<tr>
<td>$10 + 5.482$</td>
<td>$15.48$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 - 5.482$</td>
<td>$24.52$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 + 5.482$</td>
<td>$35.48$</td>
<td>$-10$</td>
</tr>
</tbody>
</table>