For the circuit above:

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

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

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

All op amps are ideal with \( V_{CC} = 15 \text{ V} \) and \( V_{CC} = -15 \text{ V} \).

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

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

\[
V_o = \left( \frac{25 + 1.201}{25 + 1.2} \right) \left( \frac{25}{1.201} \right) V_B - \left( \frac{25}{1.201} \right) V_B = 20.8341 V_B - 20.8160 V_A
\]

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

\( G_d = V_o/V_d = (20.8341(1) - 20.8160(-1))/2 = 20.8251 \)

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

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

\( G_{cm} = V_o/V_d = |20.8341(1) - 20.8160(1)|/1 = 0.0181 \)

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

\( \text{CMRR} = 20 \log_{10} \frac{20.8251}{0.0181} = 61.22 \)
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.

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

Thus:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$V_A$ (mV)</th>
<th>$V_B$ (mV)</th>
<th>$V_o(V)$ = $1131.1(V_B - V_A)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.1</td>
<td>4.2</td>
<td>2.375</td>
</tr>
<tr>
<td>15</td>
<td>2.4</td>
<td>4.2</td>
<td>2.036</td>
</tr>
<tr>
<td>25</td>
<td>2.1</td>
<td>4.2</td>
<td>2.375</td>
</tr>
<tr>
<td>35</td>
<td>2.1</td>
<td>6.6</td>
<td>5.090</td>
</tr>
<tr>
<td>45</td>
<td>2.1</td>
<td>4.2</td>
<td>2.375</td>
</tr>
</tbody>
</table>

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

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

$$V_x - V_y = 46.45 \ (V_B - V_A) = 46.45 \ (4.2 \text{ mV} - 2.1 \text{ mV}) = 0.098 \text{ V}$$
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 idea with the indicated \( V_{CC} \) and \( V_{EE} \) values).

Non-inverting amplifier:
Gain: \( G = 1 + R_1 / R_2 = 1 + 50 / 2.2 = 23.73 \)

Ideally, output would swing from \(-47.46 \text{ V} \) (at \( t = 0 \text{ ms} \)) to \(47.46 \text{ V} \) (at \( t = 20 \text{ ms} \)).

However, output is limited to \( \pm 10 \text{ V} \).

Slope is \( 2 \times 47.46 / 20 = 4.746 \text{ V/ms} \).

So starting at \( V=0 \), the limit of \( 10 \text{ V} \) is reached in 
\[ \Delta t = 10 \text{ V} / 4.746 \text{ V/ms} = 2.107 \text{ ms} \]

Thus:

<table>
<thead>
<tr>
<th>( t ) (ms)</th>
<th>( t ) (ms)</th>
<th>( V_o ) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 2.107</td>
<td>7.89</td>
<td>-10</td>
</tr>
<tr>
<td>10 + 2.107</td>
<td>12.11</td>
<td>+10</td>
</tr>
<tr>
<td>30 - 2.107</td>
<td>27.89</td>
<td>+10</td>
</tr>
<tr>
<td>30 + 2.107</td>
<td>32.11</td>
<td>-10</td>
</tr>
</tbody>
</table>