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 opamps are ideal with \(V_{CC} = 15\) V and \(V_{CC} = -15\) V.

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

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

\[
V_o = \left(\frac{26 + 1.9}{26 + 1.901}\right) \left(\frac{26}{1.901}\right) V_B - \left(\frac{26}{1.901}\right) V_B = 13.6837 V_B - 13.6770 V_A
\]

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

\(G_d = V_o/V_d = (13.6837(1) - 13.6770(-1))/2 = 13.6804\)

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

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

\(G_{cm} = V_o/V_d = |13.6837(1) - 13.6770(1)|/1 = 0.0067\)

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

\(CMRR = 20 \log_{10} \frac{13.6804}{0.0067} = 66.20\)
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) = 396.0$(V_B - V_A)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.1</td>
<td>4.1</td>
<td>0.792</td>
</tr>
<tr>
<td>15</td>
<td>2.9</td>
<td>4.1</td>
<td>0.475</td>
</tr>
<tr>
<td>25</td>
<td>2.1</td>
<td>4.1</td>
<td>0.792</td>
</tr>
<tr>
<td>35</td>
<td>2.1</td>
<td>6.6</td>
<td>1.782</td>
</tr>
<tr>
<td>45</td>
<td>2.1</td>
<td>4.1</td>
<td>0.792</td>
</tr>
</tbody>
</table>

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

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

$$V_x - V_y = 25.71 \times (V_B - V_A) = 25.71 \times (4.1 \text{ mV} - 2.1 \text{ mV}) = 0.051 \text{ V}$$
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: $G = 1 + R_1/R_2 = 1 + 51/2.9 = 18.59$

Ideally, output would swing from $-37.18\, \text{V}$ (at $t = 0\, \text{ms}$) to $37.18\, \text{V}$ (at $t = 20\, \text{ms}$).
However, output is limited to $\pm 10\, \text{V}$.
Slope is $2 \times 37.18/20 = 1.859\, \text{V/ms}$.
So starting at $V=0$, the limit of $10\, \text{V}$ is reached in $
\Delta t = 10\, \text{V}/1.859\, \text{V/\text{ms}} = 5.379\, \text{ms}$

Thus:

<table>
<thead>
<tr>
<th>$t (\text{ms})$</th>
<th>$t (\text{ms})$</th>
<th>$V_o (\text{V})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 5.379</td>
<td>4.62</td>
<td>-10</td>
</tr>
<tr>
<td>10 + 5.379</td>
<td>15.38</td>
<td>+10</td>
</tr>
<tr>
<td>30 - 5.379</td>
<td>24.62</td>
<td>+10</td>
</tr>
<tr>
<td>30 + 5.379</td>
<td>35.38</td>
<td>-10</td>
</tr>
</tbody>
</table>

![Graph showing the input and output voltages with transition times indicated.]