For the circuit above:

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

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

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

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

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

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

\[
V_o = \left(\frac{25 + 1.901}{25 + 1.9}\right) \left(\frac{25}{1.901}\right) V_B - \left(\frac{25}{1.901}\right) V_B = 13.1584 V_B - 13.1510 V_A
\]

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

\( G_d = \frac{V_o}{V_d} = \left(13.1584(1) - 13.1510(-1)\right)/2 = 13.1547 \)

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

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

\( G_{cm} = \frac{V_o}{V_d} = \left|13.1584(1) - 13.1510(1)\right|/1 = 0.0074 \)

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

\( CMRR = 20 \log_{10} \frac{13.1547}{0.0074} = 65.00 \)
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.

Thus:

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

$$V_o = \left(1 + \frac{2 \times 42}{2.9}\right) \left(\frac{56}{2.1}\right) (V_B - V_A) = 799.1 (V_B - V_A)$$

Thus:

$$
\begin{array}{c|c|c|c|c}
 t \text{ (ms)} & V_A \text{ (mV)} & V_B \text{ (mV)} & V_o(V) = 799.1(V_B - V_A) \\
\hline
  5 & 2.1 & 4.0 & 1.518 \\
 15 & 2.8 & 4.0 & 0.959 \\
 25 & 2.1 & 4.0 & 1.518 \\
 35 & 2.1 & 6.3 & 3.356 \\
 45 & 2.1 & 4.0 & 1.518 \\
\end{array}
$$

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

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

$$V_x - V_y = 29.97 (V_B - V_A) = 29.97 (4.0 \text{ mV} - 2.1 \text{ mV}) = 0.057 \text{ V}$$
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 $2 \times 36.48/20 = 3.648 \, \text{V/ms}$.

So starting at $V=0$, the limit of $10 \, \text{V}$ is reached in

$$\Delta t = 10 \, \text{V} / 3.648 \, \text{V/ms} = 2.741 \, \text{ms}$$

Thus:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$t$ (ms)</th>
<th>$V_o$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>7.26</td>
<td>-10</td>
</tr>
<tr>
<td>10</td>
<td>12.74</td>
<td>+10</td>
</tr>
<tr>
<td>30</td>
<td>27.26</td>
<td>+10</td>
</tr>
<tr>
<td>30</td>
<td>32.74</td>
<td>-10</td>
</tr>
</tbody>
</table>