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 $V_{CC} = 15$ V and $V_{CC} = -15$ V.

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

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

\[
V_o = \left(\frac{29 + 1.2}{29 + 1.201}\right) \left(\frac{29}{1.201}\right) V_B - \left(\frac{29}{1.201}\right) V_B = 24.1659 V_B - 24.1465 V_A
\]

Set $V_B = -V_A = 1$ V, $V_d = V_B - V_A = 2$ V.

\[
G_d = \frac{V_o}{V_d} = \frac{24.1659(1) - 24.1465(-1)}{2} = 24.1562
\]

- 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.

\[
G_{cm} = \frac{V_o}{V_d} = \frac{|24.1659(1) - 24.1465(1)|}{1} = 0.0194
\]

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

\[
CMRR = 20 \log_{10} \frac{24.1562}{0.0194} = 61.90
\]
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.

\[ V_x - V_y = \left( 1 + \frac{2R_A}{R_G} \right) (V_B - V_A) \]
\[ V_x - V_y = 40.17 (V_B - V_A) = 40.17 (4.0 \text{ mV} - 2.2 \text{ mV}) = 0.072 \text{ V} \]
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: $G = 1 + R_1/R_2 = 1 + 59/2.2 = 27.82$

Ideally, output would swing from $-55.64\,\text{V}$ (at $t = 0\,\text{ms}$) to $55.64\,\text{V}$ (at $t = 20\,\text{ms}$).

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

Slope is $2 \times 55.64/20 = 2.782\,\text{V/ms}$.

So starting at $V=0$, the limit of $10\,\text{V}$ is reached in $\Delta t = 10\,\text{V}/2.782\,\text{V/ms} = 3.595\,\text{ms}$

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>3.595</td>
<td>6.41</td>
</tr>
<tr>
<td>10 + 3.595</td>
<td>13.60</td>
<td>+10</td>
</tr>
<tr>
<td>30 - 3.595</td>
<td>26.41</td>
<td>+10</td>
</tr>
<tr>
<td>30 + 3.595</td>
<td>33.59</td>
<td>$-10$</td>
</tr>
</tbody>
</table>