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, \( G_d = V_o/(V_B - V_A) \)?

\[
V_o = \left( \frac{R_1 + R_2}{R_3 + R_4} \right) \left( \frac{R_3}{R_2} \right) V_B - \left( \frac{R_1}{R_2} \right) V_B \\
V_o = \left( \frac{27 + 1.701}{27 + 1.7} \right) \left( \frac{27}{1.701} \right) V_B - \left( \frac{27}{1.701} \right) V_B = 15.8829 V_B - 15.8730 V_A
\]

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

\[
G_d = \frac{V_o}{V_d} = \frac{(15.8829(1) - 15.8730(-1))}{2} = 15.8780
\]

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

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

\[
G_{cm} = \frac{V_o}{V_d} = \left| \frac{15.8829(1) - 15.8730(1)}{1} \right| = 0.0099
\]

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

\[
\text{CMRR} = 20 \log_{10} \frac{15.8780}{0.0099} = 64.10
\]
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:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$V_A$ (mV)</th>
<th>$V_B$ (mV)</th>
<th>$V_o$ (V) = 357.0 ($V_B - V_A$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.1</td>
<td>4.0</td>
<td>0.678</td>
</tr>
<tr>
<td>15</td>
<td>2.7</td>
<td>4.0</td>
<td>0.464</td>
</tr>
<tr>
<td>25</td>
<td>2.1</td>
<td>4.0</td>
<td>0.678</td>
</tr>
<tr>
<td>35</td>
<td>2.1</td>
<td>6.1</td>
<td>1.428</td>
</tr>
<tr>
<td>45</td>
<td>2.1</td>
<td>4.0</td>
<td>0.678</td>
</tr>
</tbody>
</table>

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

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

$$V_x - V_y = 30.14 \ (V_B - V_A) = 30.14 \ (4.0 \text{ mV} - 2.1 \text{ mV}) = 0.057 \text{ V}$$
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: $G = 1 + R_1/R_2 = 1 + 54/2.7 = 21.00$

Ideally, output would swing from $-42.00\text{ V}$ (at $t = 0\text{ ms}$) to $42.00\text{ V}$ (at $t = 20\text{ ms}$).

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

Slope is $2 \times 42.00/20 = 4.200\text{ V/ms}$.

So starting at $V=0$, the limit of $10\text{ V}$ is reached in $\Delta t = 10\text{ V}/4.200\text{ V/ms} = 2.381\text{ ms}$

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>7.62</td>
<td>$-10$</td>
</tr>
<tr>
<td>10 + 2.381</td>
<td>12.38</td>
<td>$+10$</td>
</tr>
<tr>
<td>30 - 2.381</td>
<td>27.62</td>
<td>$+10$</td>
</tr>
<tr>
<td>30 + 2.381</td>
<td>32.38</td>
<td>$-10$</td>
</tr>
</tbody>
</table>