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

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

\[
V_o = \left( \frac{21 + 1.4}{21 + 1.401} \right) \left( \frac{21}{1.401} \right) V_B - \left( \frac{21}{1.401} \right) V_B = 14.9993 V_B - 14.9893 V_A
\]

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

\[
G_d = V_o/V_d = (14.9993(1) - 14.9893(-1))/2 = 14.9943
\]

- 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.

\[
G_{cm} = V_o/V_d = |14.9993(1) - 14.9893(1)|/1 = 0.0100
\]

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

\[
CMRR = 20 \log_{10} \frac{14.9943}{0.0100} = 63.52
\]
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.

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

Thus:

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

\[
V_x - V_y = 28.50 (V_B - V_A) = 28.50 (4.1 \text{ mV} - 2.0 \text{ mV}) = 0.060 \text{ V}
\]
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: $G = 1 + R_1/R_2 = 1 + 42/2.4 = 18.50$

Ideally, output would swing from $-37.00$ V (at $t = 0$ ms) to $37.00$ V (at $t = 20$ ms).
However, output is limited to $\pm 10$ V.
Slope is $2 \times 37.00/20 = 1.850$ V/ms.
So starting at $V=0$, the limit of 10 V is reached in $\Delta t = 10$ V/1.850 V/ms = 5.405 ms

Thus:

<table>
<thead>
<tr>
<th>$t$ (ms)</th>
<th>$V_o$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10 - 5.405$</td>
<td>$-10$</td>
</tr>
<tr>
<td>$10 + 5.405$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 - 5.405$</td>
<td>$+10$</td>
</tr>
<tr>
<td>$30 + 5.405$</td>
<td>$-10$</td>
</tr>
</tbody>
</table>