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, \(G_d = \frac{V_o}{V_B - V_A}\)?

\[
V_o = \frac{R_1 + R_2}{R_3 + R_4} \left(\frac{R_3}{R_2}\right) V_B - \left(\frac{R_1}{R_2}\right) V_B
\]
\[
V_o = \left(\frac{28 + 1.901}{28 + 1.9}\right) \left(\frac{28}{1.901}\right) V_B - \left(\frac{28}{1.901}\right) V_B = 14.7373 V_B - 14.7291 V_A
\]

Set \(V_B = -V_A = 1 V, V_d = V_B - V_A = 2 V\).
\(G_d = \frac{V_o}{V_d} = \frac{14.7373(1) - 14.7291(-1)}{2} = 14.7332\)

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

Set \(V_B = V_A = 1 V, V_{cm} = \frac{1}{2}(V_B + V_A) = 1 V\).
\(G_{cm} = \frac{V_o}{V_d} = \frac{14.7373(1) - 14.7291(1)}{1} = 0.0082\)

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

\(CMRR = 20 \log_{10} \frac{14.7332}{0.0082} = 65.09\)
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:

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

$$V_o = \left(1 + \frac{2 \times 46}{2.2}\right) \left(\frac{47}{3.8}\right) (V_B - V_A) = 529.6 (V_B - V_A)$$

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

$$V_x - V_y = 42.82 (V_B - V_A) = 42.82 (4.2 \text{ mV} - 2.2 \text{ mV}) = 0.086 \text{ V}$$
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: $G = 1 + \frac{R_1}{R_2} = 1 + \frac{57}{2.9} = 20.66$

Ideally, output would swing from $-41.32$ V (at $t = 0$ ms) to $41.32$ V (at $t = 20$ ms).

However, output is limited to ±10 V.

Slope is $2 \times \frac{41.32}{20} = 4.132$ V/ms.

So starting at $V=0$, the limit of 10 V is reached in

$\Delta t = 10 \frac{V}{4.132 \frac{V}{ms}} = 2.420$ ms

Thus:

\[
\begin{array}{ccc}
\text{t (ms)} & \text{t (ms)} & \text{V_o (V)} \\
10 - 2.420 & 7.58 & -10 \\
10 + 2.420 & 12.42 & +10 \\
30 - 2.420 & 27.58 & +10 \\
30 + 2.420 & 32.42 & -10 \\
\end{array}
\]