For the circuit above, $V_i = 10 \text{ mV}$:

- What is $V_o$ if the amplifier is ideal?

- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu\text{V}$?

- What is $V_o$ if the bias current, $I_B = 10\text{ nA}$?

• What is $V_o$ if the amplifier is ideal?

Represent ideal as $\bar{V}_o$

$$V_+ = \frac{28 \text{ k}\Omega}{28 + 2.0 \text{ k}\Omega} V_i = (9.330 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{28 \text{ k}\Omega}{2.0 \text{ k}\Omega}\right) V_+ = 15.000 \text{ V}_+ = 139.950 \text{ mV}$$

- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu\text{V}$?

Use superposition to get ($V'_o$) then add to ideal $V_{OS}$:

$$V'_o = \left(1 + \frac{28 \text{ k}\Omega}{2.0 \text{ k}\Omega}\right) V_{OS} = 15.000 \times V_{OS} = 0.150 \text{ mV} \quad V_o = \bar{V}_o + V'_o = 140.100 \text{ mV}$$

- What is $V_o$ if the bias current, $I_B = 10\text{ nA}$?

First, use superposition to get ($V''_o$) for $I_B$ into $V_+$. Current travels through parallel resistors.

$$V''_o = -\left(1 + \frac{28 \text{ k}\Omega}{2.0 \text{ k}\Omega}\right) (R_1||R_2)I_B = -15.000 \times 1.867 \text{ k}\Omega \times I_B = -0.280 \text{ mV}$$

Next, use superposition to get ($V'''_o$) for $I_B$ into $V_-$. Current through $R_1$, since FB keeps $V_-$ at ground. Note that this resistor configuration cancels $I_B$.

$$V'''_o = (28 \text{ k}\Omega) I_B = 0.280 \text{ mV}$$

$$V_o = \bar{V}_o + V'_o + V'''_o = 139.950 \text{ mV}$$
The op amp is ideal, except $f_T (= \text{Gain-Bandwidth})$ is 120 kHz.

For the circuit above, $V_i = (20 \text{ mV}) \cos(2\pi ft)$:

- What is the peak-to-peak amplitude of $V_o$ if $f = 3 \text{ kHz}$?
- What is the peak-to-peak amplitude of $V_o$ if $f = 30 \text{ kHz}$?

First, analyse ideal gain, $\bar{V}_o$

\[
V_+ = \frac{20 \text{k}\Omega}{20 + 2.5 \text{k}\Omega} V_i = 0.889 V_i \quad \bar{V}_o = \left(1 + \frac{20 \text{k}\Omega}{2.5 \text{k}\Omega}\right) V_+ = 9.000 V_+ = 8.001 V_i
\]

- What is the peak-to-peak amplitude of $V_o$ if $f = 3 \text{ kHz}$?
  Given Gain-Bandwidth, maximum possible gain is $G = \frac{G \cdot BW}{f} = \frac{120}{3} = 40$.
  We specify a gain of 8.001 which is less than 40, so we get the specified gain.
  $V_o = 8.001 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 320.0 mV.

- What is the peak-to-peak amplitude of $V_o$ if $f = 30 \text{ kHz}$?
  Given Gain-Bandwidth, maximum possible gain is $G = \frac{G \cdot BW}{f} = \frac{120}{30} = 4$.
  We specify a gain of 8.001 which is greater than 4, so we only get a gain of 4.
  $V_o = 4 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 160.0 mV.
For the circuit above:

- **What type of filter is this?** (high pass, low pass, band pass, band stop)
- Sketch the amplitude of \( \frac{V_o}{V_i} \) as a function of frequency. Label the passband, stopband and roll-off rate.
- What is the cut-off frequency \( (f_c) \) and damping constant \( (\zeta) \)?

**What type of filter is this?** (high pass, low pass, band pass, band stop)

This is a low pass filter

What is the cut-off frequency \( (f_c) \) and damping constant \( (\zeta) \)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{7.8 \text{ mH} \cdot 12.4 \mu\text{F}}} = 3215.451 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 20202.852 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{1}{L}} = \frac{205 \text{ k}\Omega}{2} \sqrt{\frac{12.4 \mu\text{F}}{7.8 \text{ mH}}} = 4.087
\]

Sketch the amplitude of \( \frac{V_o}{V_i} \) as a function of frequency. Label the passband, stopband and roll-off rate.

\( \frac{V_o}{V_i} \) starts near 1.0. After \( f_c \), graph decreases at 40 dB/decade.