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 \( \bar{V}_o \)

\[
V_+ = \frac{29 \text{k} \Omega}{29 + 2.1 \text{k} \Omega} \quad V_i = (9.320 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{29 \text{k} \Omega}{2.1 \text{k} \Omega}\right) V_+ = 14.810 \quad V_+ = 138.029 \text{ mV}
\]

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

Use superposition to get \( (V_o') \) then add to ideal \( V_{OS} \):

\[
V_o' = \left(1 + \frac{29 \text{k} \Omega}{2.1 \text{k} \Omega}\right) V_{OS} = 14.810 \times V_{OS} = 0.148 \text{ mV}
\]

\[
V_o = \bar{V}_o + V_o' = 138.177 \text{ mV}
\]

- 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.

\[
V_o' = -\left(1 + \frac{29 \text{k} \Omega}{2.1 \text{k} \Omega}\right) (R_1 \parallel R_2) I_B = -14.810 \times 1.958 \text{k} \Omega \times I_B = -0.290 \text{ mV}
\]

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 \( I_B \).

\[
V_o'' = (29 \text{k} \Omega) I_B = 0.290 \text{ mV}
\]

\[
V_o = \bar{V}_o + V_o' + V_o'' = 138.029 \text{ mV}
\]
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, $\bar{V}_o$

$$V_+ = \frac{26 \text{ k}\Omega}{26 + 3.2 \text{ k}\Omega} V_i = 0.890 V_i \quad \bar{V}_o = \left(1 + \frac{26 \text{ k}\Omega}{3.2 \text{ k}\Omega}\right) V_+ = 9.125 V_+ = 8.121 V_i$$

- What is the peak-to-peak amplitude of $V_o$ if $f = 3 \text{ kHz}$?
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot BW)/f = 120/3 = 40$.
  We specify a gain of 8.121 which is less than 40, so we get the specified gain.
  $V_o = 8.121 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 324.8 mV.

- What is the peak-to-peak amplitude of $V_o$ if $f = 30 \text{ kHz}$?
  Given Gain-Bandwidth, maximum possible gain is $G = (G \cdot BW)/f = 120/30 = 4$.
  We specify a gain of 8.121 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)
  - This is a low pass filter

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

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.7 \text{ mH} \cdot 16.2 \mu\text{F}}} = 2663.685 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 16736.076 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2\sqrt{C/L}} = \frac{256 \text{ k}\Omega}{2 \sqrt{\frac{16.2 \mu\text{F}}{8.7 \text{ mH}}}} = 5.523
\]

- 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.