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 $\bar{V}_o$

  $$V_+ = \frac{21 \text{k} \Omega}{21 + 1.9 \text{k} \Omega} V_i = (9.170 \text{ mV}, \quad \bar{V}_o = \left( 1 + \frac{21 \text{k} \Omega}{1.9 \text{k} \Omega} \right) V_+ = 12.053 V_+ = 110.526 \text{ mV}$$

- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu \text{V}$?
  Use superposition to get $(V_o')$ then add to ideal $V_{OS}$:

  $$V_o' = \left( 1 + \frac{21 \text{k} \Omega}{1.9 \text{k} \Omega} \right) V_{OS} = 12.053 \times V_{OS} = 0.121 \text{ mV}$$

  $$V_o = \bar{V}_o + V_o' = 110.647 \text{ mV}$$

- 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.

  $$V_o' = - \left( 1 + \frac{21 \text{k} \Omega}{1.9 \text{k} \Omega} \right) (R_1 \parallel R_2) I_B = -12.053 \times 1.742 \text{k} \Omega \times I_B = -0.210 \text{ mV}$$

  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 $I_B$.

  $$V_o'' = (21 \text{k} \Omega) I_B = 0.210 \text{ mV}$$

  $$V_o = \bar{V}_o + V_o' + V_o'' = 110.526 \text{ mV}$$
The op amp is ideal, except \( f_T (= \text{Gain-Bandwidth}) \) is 120 kHz.

\[
\begin{align*}
&3.8 \, \text{k}\Omega \\
&\triangleleft \\
&\triangle > \end{align*}
\]

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, \( \bar{V}_o \)

\[
V_+ = \frac{25 \, \text{k}\Omega}{25 + 3.8 \, \text{k}\Omega} V_i = 0.868 V_i \quad \bar{V}_o = \left(1 + \frac{25 \, \text{k}\Omega}{3.8 \, \text{k}\Omega}\right) V_+ = 7.579 V_+ = 6.579 V_i
\]

- 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 6.579 which is less than 40, so we get the specified gain.
  \( V_o = 6.579 \times (20 \, \text{mV}) \cos(2\pi ft) \), and peak-peak voltage is \( 2 \times max(V_o) \).
  Answer: 263.2 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 6.579 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 ($\zeta$)?
  
  \[ \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4.6 \text{ mH} \cdot 18.9 \mu \text{F}}} = 3391.487 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 21308.895 \text{ Hz} \]
  
  and,
  
  \[ \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{248 \text{ k}\Omega}{2} \sqrt{\frac{18.9 \mu \text{F}}{4.6 \text{ mH}}} = 7.948 \]

- 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.