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 $\bar{V}_o$

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

- 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.

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

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.

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

- 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, $\bar{V}_o$

\[
V_+ = \frac{26 \text{k}\Omega}{26 + 3.0 \text{k}\Omega} V_i = 0.897 V_i \quad \bar{V}_o = \left(1 + \frac{26 \text{k}\Omega}{3.0 \text{k}\Omega}\right) V_+ = 9.667 V_+ = 8.671 V_i
\]

- 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 8.671 which is less than 40, so we get the specified gain.
  $V_o = 8.671 \times (20 \text{ mV}) \cos(2\pi f t)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 346.8 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 8.671 which is greater than 4, so we only get a gain of 4.
  $V_o = 4 \times (20 \text{ mV}) \cos(2\pi f t)$, 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 \( (\zeta) \)?

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- **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 \( (\zeta) \)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4.3 \text{ mH} \cdot 15.1 \mu\text{F}}} = 3924.436 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 24657.443 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{261 \text{ k\Omega}}{2} \sqrt{\frac{15.1 \mu\text{F}}{4.3 \text{ mH}}} = 7.733
  \]

- 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.