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, \( I_B = 10 \, \text{nA} \)?

\[ V_{+} = \frac{24 \, \text{k}\Omega}{24 + 1.7 \, \text{k}\Omega} \, V_i = (9.340 \, \text{mV}, \quad \bar{V}_o = \left( 1 + \frac{24 \, \text{k}\Omega}{1.7 \, \text{k}\Omega} \right) V_{+} = 15.118 \, V_{+} = 141.202 \, \text{mV} \]

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

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

\[ V'_o = \left( 1 + \frac{24 \, \text{k}\Omega}{1.7 \, \text{k}\Omega} \right) V_{OS} = 15.118 \times V_{OS} = 0.151 \, \text{mV} \]

\[ V_o = \bar{V}_o + V'_o = 141.353 \, \text{mV} \]

- 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.

\[ V''_o = -\left( 1 + \frac{24 \, \text{k}\Omega}{1.7 \, \text{k}\Omega} \right) \left( R_1 \parallel R_2 \right) I_B = -15.118 \times 1.588 \, \text{k}\Omega \times I_B = -0.240 \, \text{mV} \]

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 \( I_B \).

\[ V''_o = (24 \, \text{k}\Omega) I_B = 0.240 \, \text{mV} \]

\[ V_o = \bar{V}_o + V'_o + V''_o = 141.202 \, \text{mV} \]
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, \( \bar{V_o} \)

\[
V_+ = \frac{21 \text{k}\Omega}{21 + 2.7 \text{k}\Omega} V_i = 0.886 V_i \quad \bar{V_o} = \left(1 + \frac{21 \text{k}\Omega}{2.7 \text{k}\Omega}\right) V_+ = 8.778 V_+ = 7.777 V_i
\]

- 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 7.777 which is less than 40, so we get the specified gain.
  \( V_o = 7.777 \times (20 \text{ mV}) \cos(2\pi ft) \), and peak-peak voltage is \( 2 \times max(V_o) \).
  Answer: 311.1 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 7.777 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 ($\zeta$)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5.9 \text{ mH} \cdot 13.7 \text{ } \mu\text{F}}} = 3517.335 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 22099.605 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{211 \text{ k} \Omega}{2} \sqrt{\frac{13.7 \text{ } \mu\text{F}}{5.9 \text{ mH}}} = 5.084
  \]

- 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.