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 $\bar{V}_o$

  \[
  V_+ = \frac{24 \text{ k}\Omega}{24 + 2.4 \text{ k}\Omega} V_i = (9.090 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{24 \text{ k}\Omega}{2.4 \text{ k}\Omega}\right) V_+ = 11.000 \text{ V}_+ = 99.990 \text{ mV}
  \]

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

  \[
  V_o' = \left(1 + \frac{24 \text{ k}\Omega}{2.4 \text{ k}\Omega}\right) V_{OS} = 11.000 \times V_{OS} = 0.110 \text{ mV}
  \]

  \[
  V_o = \bar{V}_o + V_o' = 100.100 \text{ mV}
  \]

- 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.

  \[
  V_o' = -\left(1 + \frac{24 \text{ k}\Omega}{2.4 \text{ k}\Omega}\right) (R_1\|R_2) I_B = -11.000 \times 2.182 \text{ k}\Omega \times I_B = -0.240 \text{ mV}
  \]

  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 $I_B$.

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

  \[
  V_o = \bar{V}_o + V_o' + V_o''' = 99.990 \text{ mV}
  \]
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, \( \tilde{V}_o \)

\[
V_+ = \frac{22 \text{k}\Omega}{22 + 3.0 \text{k}\Omega} V_i = 0.880 V_i \quad \tilde{V}_o = \left( 1 + \frac{22 \text{k}\Omega}{3.0 \text{k}\Omega} \right) V_+ = 8.333 V_+ = 7.333 V_i
\]

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

Given Gain-Bandwidth, maximum possible gain is \( G = (G \cdot \text{BW})/f = 120/3 = 40 \).
We specify a gain of 7.333 which is less than 40, so we get the specified gain.
\( V_o = 7.333 \times (20 \text{ mV}) \cos(2\pi ft) \), and peak-peak voltage is \( 2 \times max(V_o) \).
Answer: 293.3 mV.

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

Given Gain-Bandwidth, maximum possible gain is \( G = (G \cdot \text{BW})/f = 120/30 = 4 \).
We specify a gain of 7.333 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 ($\zeta$)?

### Answer

- **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 ($\zeta$)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{6.0 \text{ mH} \cdot 14.9 \mu \text{F}}} = 3344.500 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 21013.673 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{221 \text{ k}\Omega}{2} \sqrt{\frac{14.9 \mu \text{F}}{6.0 \text{ mH}}} = 5.507
  \]

- 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.