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 \( \bar{V}_o \)

\[
V_+ = \frac{30 \text{ k}\Omega}{30 + 2.3 \text{ k}\Omega} V_i = (9.290 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{30 \text{ k}\Omega}{2.3 \text{ k}\Omega}\right) V_+ = 14.043 V_+ = 130.459 \text{ mV}
\]

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

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

\[
V_o' = \left(1 + \frac{30 \text{ k}\Omega}{2.3 \text{ k}\Omega}\right) V_{OS} = 14.043 \times V_{OS} = 0.140 \text{ mV}
\]

\[
V_o = \bar{V}_o + V_o' = 130.599 \text{ mV}
\]

- 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.

\[
V_o' = -\left(1 + \frac{30 \text{ k}\Omega}{2.3 \text{ k}\Omega}\right) (R_1\parallel R_2) I_B = -14.043 \times 2.136 \text{ k}\Omega \times I_B = -0.300 \text{ mV}
\]

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 \( I_B \).

\[
V_o'' = (30 \text{ k}\Omega) I_B = 0.300 \text{ mV}
\]

\[
V_o = \bar{V}_o + V_o' + V_o'' = 130.459 \text{ mV}
\]
The op amp is ideal, except $f_T$ (= Gain-Bandwidth) is $120 \text{ kHz}$.

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, $\bar{V}_o$

\[
V_+ = \frac{25 \text{ k}\Omega}{25 + 2.4 \text{ k}\Omega} V_i = 0.912 V_i \quad \bar{V}_o = \left(1 + \frac{25 \text{ k}\Omega}{2.4 \text{ k}\Omega}\right) V_+ = 11.417 V_+ = 10.412 V_i
\]

- 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 10.412 which is less than 40, so we get the specified gain.
  $V_o = 10.412 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$.
  Answer: 416.5 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 10.412 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 ($\zeta$)?

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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 ($\zeta$)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.8 \text{ mH} \cdot 12.1 \mu F}} = 3064.545 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 19254.701 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{252 \text{ k}\Omega}{2} \sqrt{\frac{12.1 \mu F}{8.8 \text{ mH}}} = 4.672
\]

- 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.