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 $\bar{V}_o$

  \[
  V_+ = \frac{23 \text{k}\Omega}{23 + 1.0 \text{k}\Omega} V_i = (9.580 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{23 \text{k}\Omega}{1.0 \text{k}\Omega}\right) V_+ = 24.000 \text{ V}_+ = 229.920 \text{ mV}
  \]

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

  \[
  V'_o = \left(1 + \frac{23 \text{k}\Omega}{1.0 \text{k}\Omega}\right) V_{OS} = 24.000 \times V_{OS} = 0.240 \text{ mV}
  \]

  \[
  V_o = \bar{V}_o + V'_o = 230.160 \text{ mV}
  \]

- 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.

  \[
  V'_o = -\left(1 + \frac{23 \text{k}\Omega}{1.0 \text{k}\Omega}\right) (R_1 \parallel R_2) I_B = -24.000 \times 0.958 \text{k}\Omega \times I_B = -0.230 \text{ mV}
  \]

  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 $I_B$.

  \[
  V''_o = (23 \text{k}\Omega) I_B = 0.230 \text{ mV}
  \]

  \[
  V_o = \bar{V}_o + V'_o + V''_o = 229.920 \text{ mV}
  \]
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, $\bar{V_o}$

$$V_+ = \frac{27 \text{ k}\Omega}{27 + 3.6 \text{ k}\Omega} V_i = 0.882 V_i \quad \bar{V_o} = \left(1 + \frac{27 \text{ k}\Omega}{3.6 \text{ k}\Omega}\right) V_+ = 8.500 V_+ = 7.497 V_i$$

- 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 7.497 which is less than 40, so we get the specified gain.
  
  $V_o = 7.497 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$.
  
  Answer: 299.9 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 7.497 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 $V_o/V_i$ 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 ($\zeta$)?

  $$\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5.6 \text{ mH} \cdot 17.9 \text{ } \mu F}} = 3158.490 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 19844.963 \text{ Hz}$$

  and,

  $$\zeta = \frac{R}{2 \sqrt{C/L}} = \frac{269 \text{ k}\Omega}{2 \sqrt{\frac{17.9 \text{ } \mu F}{5.6 \text{ mH}}}} = 7.604$$

- Sketch the amplitude of $V_o/V_i$ as a function of frequency. Label the passband, stopband and roll-off rate.

  $V_o/V_i$ starts near 1.0. After $f_c$, graph decreases at 40 dB/decade.