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, $V_{OS} = 10 \mu V$?
- 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 $\bar{V}_o$
  
  $$V_+ = \frac{29 \text{ k} \Omega}{29 + 1.3 \text{ k} \Omega} V_i = (9.570 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{29 \text{ k} \Omega}{1.3 \text{ k} \Omega}\right) V_+ = 23.308 \text{ V}_+ = 223.058 \text{ mV}$$

- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu V$?
  
  Use superposition to get $(V_o')$ then add to ideal $V_{OS}$:
  
  $$V_o' = \left(1 + \frac{29 \text{ k} \Omega}{1.3 \text{ k} \Omega}\right) V_{OS} = 23.308 \times V_{OS} = 0.233 \text{ mV}$$
  
  $$V_o = \bar{V}_o + V_o' = 223.291 \text{ mV}$$

- 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.
  
  $$V_o' = -\left(1 + \frac{29 \text{ k} \Omega}{1.3 \text{ k} \Omega}\right) (R_1 \parallel R_2) I_B = -23.308 \times 1.244 \text{ k} \Omega \times I_B = -0.290 \text{ mV}$$

  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 $I_B$.
  
  $$V_o'' = (29 \text{ k} \Omega) I_B = 0.290 \text{ mV}$$

  $$V_o = \bar{V}_o + V_o' + V_o'' = 223.058 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{29 \text{ k}\Omega}{29 + 2.5 \text{ k}\Omega} V_i = 0.921 V_i \quad \bar{V}_o = \left(1 + \frac{29 \text{ k}\Omega}{2.5 \text{ k}\Omega}\right) V_+ = 12.600 V_+ = 11.605 V_i$$

- 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 11.605 which is less than 40, so we get the specified gain.
  $V_o = 11.605 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \text{max}(V_o)$.
  Answer: 464.2 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 11.605 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 $2 \times \text{max}(V_o)$.
  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 ($\zeta$)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.3 \text{ mH} \cdot 12.5 \text{ } \mu\text{F}}} = 3104.602 \text{ rad/s}, \quad f_c = 2\pi \omega_c = 19506.381 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2 \sqrt{\frac{C}{L}}} = \frac{289 \text{ k}\Omega}{2} \sqrt{\frac{12.5 \text{ } \mu\text{F}}{8.3 \text{ mH}}} = 5.608
\]

- 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.