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 $\bar{V}_o$

$$V_+ = \frac{29 \text{k} \Omega}{29 + 1.0 \text{k} \Omega} V_i = (9.670 \text{ mV})$$

$$\bar{V}_o = \left(1 + \frac{29 \text{k} \Omega}{1.0 \text{k} \Omega}\right) V_+ = 30.000 \text{ V}_+ = 290.100 \text{ mV}$$

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

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

$$V'_o = \left(1 + \frac{29 \text{k} \Omega}{1.0 \text{k} \Omega}\right) V_{OS} = 30.000 \times V_{OS} = 0.300 \text{ mV}$$

$$V_o = \bar{V}_o + V'_o = 290.400 \text{ mV}$$

- 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.

$$V'_o = -\left(1 + \frac{29 \text{k} \Omega}{1.0 \text{k} \Omega}\right) (R_1 || R_2) I_B = -30.000 \times 0.967 \text{k} \Omega \times I_B = -0.290 \text{ mV}$$

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 $I_B$.

$$V''_o = (29 \text{k} \Omega) I_B = 0.290 \text{ mV}$$

$$V_o = \bar{V}_o + V'_o + V''_o = 290.100 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{22 \text{ k}\Omega}{22 + 3.9 \text{ k}\Omega} V_i = 0.849 V_i \quad \bar{V}_o = \left(1 + \frac{22 \text{ k}\Omega}{3.9 \text{ k}\Omega}\right) V_+ = 6.641 V_+ = 5.638 V_i$$

- 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 5.638 which is less than 40, so we get the specified gain.
  $V_o = 5.638 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 225.5 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 5.638 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 ($\zeta$)?

  \[
  \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.3 \text{ mH} \cdot 19.5 \mu\text{F}}} = 2485.671 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 15617.605 \text{ Hz}
  \]

  and,

  \[
  \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{220 \text{ kΩ}}{2} \sqrt{\frac{19.5 \mu\text{F}}{8.3 \text{ mH}}} = 5.332
  \]

- 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.