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 $\bar{V}_o$
  
  $$V_+ = \frac{28 \text{k}\Omega}{28 + 2.1 \text{k}\Omega} V_i = (9.300 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{28 \text{k}\Omega}{2.1 \text{k}\Omega}\right) V_+ = 14.333 \text{ V}_+ = 133.297 \text{ mV}$$

- What is $V_o$ if the offset voltage, $V_{OS} = 10 \mu \text{V}$?
  
  Use superposition to get ($V_o'$) then add to ideal $V_{OS}$:
  
  $$V_o' = \left(1 + \frac{28 \text{k}\Omega}{2.1 \text{k}\Omega}\right) V_{OS} = 14.333 \times V_{OS} = 0.143 \text{ mV}$$
  
  $$V_o = \bar{V}_o + V_o' = 133.440 \text{ mV}$$

- 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.
  
  $$V_o'' = -\left(1 + \frac{28 \text{k}\Omega}{2.1 \text{k}\Omega}\right) (R_1 \parallel R_2) I_B = -14.333 \times 1.953 \text{k}\Omega \times I_B = -0.280 \text{ mV}$$

  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 $I_B$.
  
  $$V_o''' = (28 \text{k}\Omega) I_B = 0.280 \text{ mV}$$
  
  $$V_o = \bar{V}_o + V_o' + V_o''' = 133.297 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{29 \text{ k}\Omega}{29 + 3.6 \text{ k}\Omega} V_i = 0.890 V_i \quad \bar{V}_o = \left(1 + \frac{29 \text{ k}\Omega}{3.6 \text{ k}\Omega}\right) V_+ = 9.056 V_+ = 8.060 V_i$$

- 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 8.060 which is less than 40, so we get the specified gain.
  $$V_o = 8.060 \times (20 \text{ mV}) \cos(2\pi ft), \text{ and peak-peak voltage is } 2 \times max(V_o).$$
  Answer: 322.4 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 8.060 which is greater than 4, so we only get a gain of 4.
  $$V_o = 4 \times (20 \text{ mV}) \cos(2\pi ft), \text{ and peak-peak voltage is } 2 \times max(V_o).$$
  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 \( (\zeta) \)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{7.8 \text{ mH} \cdot 17.8 \mu\text{F}}} = 2683.754 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 16862.171 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{285 \text{ k\Omega}}{2} \sqrt{\frac{17.8 \mu\text{F}}{7.8 \text{ mH}}} = 6.807
\]

• 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.