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

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

- 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.
  
  $$V''_o = -\left(1 + \frac{28 \text{ k}\Omega}{2.1 \text{ k}\Omega}\right) (R_1||R_2)I_B = -14.333 \times 1.953 \text{ k}\Omega \times I_B = -0.280 \text{ mV}$$
  
  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 $I_B$.
  
  $$V''_o = (28 \text{ k}\Omega) I_B = 0.280 \text{ mV}$$
  
  $$V_o = \overline{V}_o + V'_o + V''_o = 133.297 \text{ mV}$$
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, $\bar{V}_o$

$$V_+ = \frac{30 \text{k}\Omega}{30 + 3.3 \text{k}\Omega} V_i = 0.901 V_i \quad \bar{V}_o = \left(1 + \frac{30 \text{k}\Omega}{3.3 \text{k}\Omega}\right) V_+ = 10.091 V_+ = 9.092 V_i$$

- 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 9.092 which is less than 40, so we get the specified gain.
  
  $V_o = 9.092 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  
  Answer: 363.7 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 9.092 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 \( (\zeta) \)?

\[
\begin{align*}
\omega_c &= \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.1 \, \text{mH} \cdot 16.4 \, \mu \text{F}}} = 2743.693 \, \text{rad/s}, \\
f_c &= 2\pi \omega_c = 17238.771 \, \text{Hz}
\end{align*}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{298 \, \text{k}\Omega}{2} \sqrt{\frac{16.4 \, \mu \text{F}}{8.1 \, \text{mH}}} = 6.704
\]

- **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 \( (\zeta) \)?

- 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.