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 \( \bar{V}_o \)

  \[
  V_+ = \frac{29 \text{k} \Omega}{29 + 1.7 \text{k} \Omega} \cdot V_i = (9.450 \text{ mV}) \quad \bar{V}_o = \left(1 + \frac{29 \text{k} \Omega}{1.7 \text{k} \Omega}\right) V_+ = 18.059 \text{ mV} = 170.658 \text{ mV}
  \]

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

  \[
  V_o' = \left(1 + \frac{29 \text{k} \Omega}{1.7 \text{k} \Omega}\right) V_{OS} = 18.059 \times V_{OS} = 0.181 \text{ mV}
  \]

  \[V_o = \bar{V}_o + V_o' = 170.839 \text{ mV}\]

- 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.

  \[
  V_o'' = -\left(1 + \frac{29 \text{k} \Omega}{1.7 \text{k} \Omega}\right) (R_1 \parallel R_2) I_B = -18.059 \times 1.606 \text{k} \Omega \times I_B = -0.290 \text{ mV}
  \]

  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 \( I_B \).

  \[
  V_o''' = (29 \text{k} \Omega) I_B = 0.290 \text{ mV}
  \]

  \[V_o = \bar{V}_o + V_o' + V_o''' = 170.658 \text{ mV}\]
The op amp is ideal, except $f_T$ (= 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, $\bar{V}_o$

$$V_+ = \frac{24 \text{ k}\Omega}{24 + 4 \text{ k}\Omega} V_i = 0.857 V_i \quad \bar{V}_o = \left(1 + \frac{24 \text{ k}\Omega}{4 \text{ k}\Omega}\right) V_+ = 7.000 V_+ = 5.999 V_i$$

- 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 5.999 which is less than 40, so we get the specified gain.
  $V_o = 5.999 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times max(V_o)$.
  Answer: 240.0 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 5.999 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 (\( \zeta \))?

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

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8.6 \text{ mH} \cdot 20.0 \text{ } \mu\text{F}}} = 2411.214 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 15149.787 \text{ Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{244 \text{ k}\Omega}{2} \sqrt{\frac{20.0 \mu\text{F}}{8.6 \text{ mH}}} = 5.883
\]

- 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.