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 \( \bar{V}_o \)

  \[
  V_+ = \frac{21 \text{ k}\Omega}{21 + 1.1 \text{ k}\Omega} V_i = (9.500 \text{ mV}, \quad \bar{V}_o = \left(1 + \frac{21 \text{ k}\Omega}{1.1 \text{ k}\Omega}\right) V_+ = 20.091 \text{ mV}_+ = 190.864 \text{ mV}
  \]

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

  \[
  V'_o = \left(1 + \frac{21 \text{ k}\Omega}{1.1 \text{ k}\Omega}\right) V_{OS} = 20.091 \times V_{OS} = 0.201 \text{ mV}
  \]

  \[
  V_o = \bar{V}_o + V'_o = 191.065 \text{ mV}
  \]

- 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.

  \[
  V'_o = -\left(1 + \frac{21 \text{ k}\Omega}{1.1 \text{ k}\Omega}\right) (R_1 \parallel R_2) I_B = -20.091 \times 1.045 \text{ k}\Omega \times I_B = -0.210 \text{ mV}
  \]

  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 \( I_B \).

  \[
  V''_o = (21 \text{ k}\Omega) I_B = 0.210 \text{ mV}
  \]

  \[
  V_o = \bar{V}_o + V'_o + V''_o = 190.864 \text{ mV}
  \]
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, $\vec{V}_o$

$$V_+ = \frac{30 \text{ kΩ}}{30 + 3.9 \text{ kΩ}} V_i = 0.885 V_i \quad \vec{V}_o = \left(1 + \frac{30 \text{ kΩ}}{3.9 \text{ kΩ}}\right) V_+ = 8.692 V_+ = 7.692 V_i$$

- 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 7.692 which is less than 40, so we get the specified gain.
  
  $V_o = 7.692 \times (20 \text{ mV}) \cos(2\pi ft)$, and peak-peak voltage is $2 \times \max(V_o)$.
  
  Answer: 307.7 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 7.692 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 ($\zeta$)?

**Answer:**

- **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 ($\zeta$)?

  $$\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4.5 \text{ mH} \cdot 19.6 \mu\text{F}}} = 3367.175 \text{ rad/s}, \quad f_c = 2\pi\omega_c = 21156.142 \text{ Hz}$$

  and,

  $$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{296 \text{ k}\Omega}{2} \sqrt{\frac{19.6 \mu\text{F}}{4.5 \text{ mH}}} = 9.768$$

- 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.