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 $\bar{V}_o$

  \[
  V_+ = \frac{21 \text{ kΩ}}{21 + 2.1 \text{ kΩ}} V_i = (9.090 \text{ mV}), \quad \bar{V}_o = \left(1 + \frac{21 \text{ kΩ}}{2.1 \text{ kΩ}}\right)V_+ = 11.000 V_+ = 99.990 \text{ mV}
  \]

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

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

  \[
  V_o' = \left(1 + \frac{21 \text{ kΩ}}{2.1 \text{ kΩ}}\right)V_{OS} = 11.000 \times V_{OS} = 0.110 \text{ mV}
  \]

  \[
  \bar{V}_o + V_o' = 100.100 \text{ mV}
  \]

- 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.

  \[
  V_o' = -\left(1 + \frac{21 \text{ kΩ}}{2.1 \text{ kΩ}}\right)(R_1\parallel R_2)I_B = -11.000 \times 1.909 \text{ kΩ} \times I_B = -0.210 \text{ mV}
  \]

  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 $I_B$.

  \[
  V_o'' = (21 \text{ kΩ})I_B = 0.210 \text{ mV}
  \]

  \[
  V_o = \bar{V}_o + V_o' + V_o'' = 99.990 \text{ mV}
  \]
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, \( V_o \)

\[
V_+ = \frac{29 \text{ k}\Omega}{29 + 2.8 \text{ k}\Omega} V_i = 0.912 V_i \quad V_o = \left(1 + \frac{29 \text{ k}\Omega}{2.8 \text{ k}\Omega}\right) V_+ = 11.357 V_+ = 10.358 V_i
\]

- 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 10.358 which is less than 40, so we get the specified gain.
  \( V_o = 10.358 \times (20 \text{ mV}) \cos(2\pi ft) \), and peak-peak voltage is \( 2 \times \max(V_o) \).
  Answer: 414.3 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 10.358 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 \( \zeta \)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4.4 \, \text{mH} \cdot 14.1 \, \mu\text{F}}} = 4014.802 \, \text{rad/s}, \quad f_c = 2\pi \omega_c = 25225.217 \, \text{Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{287 \, \text{k}\Omega}{2} \sqrt{\frac{14.1 \, \mu\text{F}}{4.4 \, \text{mH}}} = 8.123
\]

- 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.