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 $\bar{V}_o$

  $$V_+ = \frac{27 \text{k}\Omega}{27 + 1.2 \text{k}\Omega} V_i = (9.570 \text{ mV})$$
  $$\bar{V}_o = \left(1 + \frac{27 \text{k}\Omega}{1.2 \text{k}\Omega}\right) V_+ = 23.500 \text{ V}_+ = 224.895 \text{ mV}$$

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

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

  $$V_o' = \left(1 + \frac{27 \text{k}\Omega}{1.2 \text{k}\Omega}\right) V_{OS} = 23.500 \times V_{OS} = 0.235 \text{ mV}$$
  $$V_o = \bar{V}_o + V_o' = 225.130 \text{ mV}$$

- 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.

  $$V_o'' = -\left(1 + \frac{27 \text{k}\Omega}{1.2 \text{k}\Omega}\right) (R_1 \parallel R_2) I_B = -23.500 \times 1.149 \text{k}\Omega \times I_B = -0.270 \text{ mV}$$

  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 $I_B$.

  $$V_o'' = (27 \text{k}\Omega) I_B = 0.270 \text{ mV}$$

  $$V_o = \bar{V}_o + V_o' + V_o'' = 224.895 \text{ mV}$$
The op amp is ideal, except $f_T (= \text{Gain-Bandwidth})$ is 120 kHz.

For the circuit above, $V_i = (20 \text{ mV}) \cos(2 \pi f t)$:

- 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, $\bar{V}_o$

$$V_+ = \frac{21 \text{ k} \Omega}{21 + 2.8 \text{ k} \Omega} V_i = 0.882 V_i \quad \bar{V}_o = \left(1 + \frac{21 \text{ k} \Omega}{2.8 \text{ k} \Omega}\right) V_+ = 8.500 V_+ = 7.497 V_i$$

- 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 7.497 which is less than 40, so we get the specified gain.

$V_o = 7.497 \times (20 \text{ mV}) \cos(2 \pi f t)$, and peak-peak voltage is $2 \times max(V_o)$.

Answer: 299.9 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 7.497 which is greater than 4, so we only get a gain of 4.

$V_o = 4 \times (20 \text{ mV}) \cos(2 \pi f t)$, 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 ($\zeta$)?

\[
\omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{7.5 \, \text{mH} \cdot 14.1 \, \mu\text{F}}} = 3075.104 \, \text{rad/s}, \quad f_c = 2\pi\omega_c = 19321.044 \, \text{Hz}
\]

and,

\[
\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{215 \, \text{k}\Omega}{2} \sqrt{\frac{14.1 \, \mu\text{F}}{7.5 \, \text{mH}}} = 4.661
\]

- 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.