1. Explain in your own words how to minimize the following imperfections:
   a. Input offset voltage, $V_{os}$.
   b. Input bias current

2. You are given the following characteristics for a real amplifier along with the circuit on the right.

   **Op amp Characteristics:**
   - Input offset voltage: $V_{os} = 4.0 \text{mV}$
   - Input offset current: $I_{os} = 200 \text{nA}$
   - Input bias current: $I_{ib} = 600 \text{nA}$
   - Input resistance: $R_i = 1 \text{M} \Omega$
   - Output resistance: $R_o = 50 \Omega$
   - Open-loop gain: $A_{ol} = 100 \text{dB}$
   - Unity-gain bandwidth: $f_u = 2 \text{MHz}$
   - Output swing limits (within 2V or supply) $\pm 15 \text{V}$
   - Slew rate: $4 \text{V/\mu s}$

   \[ R_2 = 50 \text{ k} \Omega \]

   \[ R_1 = 1 \text{ k} \Omega \]

   \[ V_{in} \]

   \[ V_{out} \]

   \[ -17 \text{V} \]

   \[ +17 \text{V} \]

   \[ \]

   (a) What is the voltage gain of the circuit? (make sure the sign is right)
   (b) For small input signals, what is the bandwidth of the circuit?
   (c) For an output signal of 10Vpp, what is the bandwidth of the circuit?
   (d) What is the maximum peak-to-peak output you can get without clipping?
   (e) Find the effect of the input offset voltage ($V_{in}=0 \text{V}$). (i.e. find output value when input =0)
   (f) How should the circuit be modified to minimize the effect of the input bias current? Show the
   modification on the schematic above and find the value of any added parts.

3. Drill Exercises 2.24, 2.26
4. Book Problems: 2.101, 2.110, 3.2
5. Assume the diodes are both ideal. State whether D1 and D2 are forward biased or reverse biased and
   verify your results. Determine $I$ and $V_o$

6. Assume the diodes are both ideal. State whether D1 and D2 are forward biased or reverse biased and verify your results. Determine $I$ through D1 and D2, and $V_o$

7. Assume the diode is ideal.
   Let $R_s = 10 \text{k}\Omega$, $R_L = 10 \text{k}\Omega$.
   Sketch and clearly label the voltage transfer characteristic $V_o$ vs. $V_s$. 

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The image contains a diagram of a circuit with labeled components and text that describes the characteristics and problems related to the circuit. The text also contains several questions and tasks related to the circuit analysis and design.
1. a. Input offset voltage \( (V_{os}) \): connect dc power supply between the positive and negative inputs. Several opamps provide an offset-nulling terminals that can accept a potentiometer that can be varied to remove the input offset.

b. Input bias current

In an inverting configuration:

\[
\begin{align*}
&V_{in} R_1 \quad \Rightarrow \quad \frac{V_{in}}{R_1} \quad \Rightarrow \quad \frac{V_{in}}{R_3}
\end{align*}
\]

where \( R_3 = R_1 \| R_2 \)

\( \rightarrow \) (Note: the value of \( R_3 \) depends on the resistors connected to the negative input. It is \( R \text{th seen from that node (the + input) to ground.} \)

2. a. \( A_v = -\frac{R_2}{R_1} \) \( \left\lvert -50 \frac{V}{V} \right\rvert \)

b. Bandwidth determined by \( \omega_{3dB} \) for \( \text{inverting amplifier:} \)

\[
\omega_{3dB} = \frac{\omega_c}{(1+R_2R_1)} \quad \text{(eq. 2.35)}
\]

\[
\omega_{3dB} = 24.65 \text{kHz/s} \quad f_{3dB} = \frac{\omega_{3dB}}{2\pi} = 39.32 \text{kHz}
\]

C. 5. \( V_p \Rightarrow \text{SR} \Rightarrow V_{in} \Rightarrow 450 \text{V/s, } 2 \text{msec} \rightarrow 800 \text{kHz, 127 kHz}

\[
\omega_t = \frac{4}{\mu \text{sec}} = 800 \text{kHz}
\]

d. \( a(\pm 15V) = 30 \text{Vpp} \)

\[
\omega_{max} = \frac{\omega_t}{\pi} = 800 \text{kHz}
\]

\( f_c = \frac{1}{2\pi} \) 

\[
R_3 = 980 \Omega
\]

\( f_c \) 

\[
V_o = \frac{V_{in}}{1 + R_2}
\]

\[
V_o = 0.204 \text{V}
\]
3. 2.24  \( V_{os} = 3 \text{mV} \), output limits \( \pm 10 \text{V} \), inverting amp

a) \( \frac{\pm 10 \text{V}}{(1,000 + 1)} = 10 \text{mV} \) : peak value at \( 10 \text{m} - 3 \text{m} = (+7 \text{mV}) \)

b) i) from (a): \( +10 \text{mV} \)

ii) \( (75^\circ - 25^\circ) \times 10 \mu\text{V}/\theta_C = 0.5 \text{mV} \) \( (\text{max}) \)

\( (25^\circ - 0^\circ) \times 10 \mu\text{V}/\theta_C = 0.25 \text{mV} \)

\( (10 \text{m} - 0.5 \text{m}) \times (1,000 + 1) \approx 9.5 \text{mV} \)

Drill

2.26  \( I_B = 100 \text{nA} \), \( I_{os} = 10 \text{nA} \) : inverting amp \( R_2 = 1 \text{M}, R_1 = 10 \text{k} \)

\( V_o = I_B \left[ R_2 \right] = 100 \text{nA} \left( 1 \text{M} \right) = 0.1 \text{V} \)

\( R_3 = \frac{1 \times 10^6 \left( 10^3 \times 9 \right)}{1 \times 10^6 + 1 \times 10^3} = 9.9 \text{K} \)

\( V_o = I_{os} R_2 = 10 \text{nA} \left( 1 \text{M} \right) = 0.01 \text{V} \)
2.10  
**gain = 200**

\[ V_{in} = \pm 2 \text{mV} \]

\[ \text{input} = 0.01 \sin \omega t \]

**noninverting amp**

\[ V_o = \frac{(0.01 \sin \omega t \cdot \pm 2 \text{mV}) \times 200}{(0.01 \sin \omega t \cdot \pm 0.4 \text{V})} \]

\[ V_o = (0.01 \sin \omega t \cdot \pm 0.1 \text{V}) \]

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2.110  
**feedback \( R = 1 \text{M} \Omega \), gain = 100**

a. \( V_i = I \beta \cdot R = 100 \times 10^{-6} \cdot 1 \text{M} \Omega = \boxed{0.1 \text{V}} \)

b. \( V_{in} = \pm 1 \text{mV} \)

\[ V_o = \pm 1 \text{mV} \cdot 100 = \pm 100 \text{mV} \]
\[ V_{o \max} = 100 \text{mV} + 100 \text{mV} = \boxed{200 \text{mV}} \]

c. \( R_3 = R_1 || R_2 \rightarrow \text{(need } R_1) \)

\[ \text{gain} = 100 = 1 + \frac{R_3}{R_1} \Rightarrow R_1 = 10 \text{K} \]

\[ R_3 = 10 \text{K} || 1 \text{M} \Omega = \boxed{10 \text{K}} \]

\[ I_{os} = \frac{10 \text{mA}}{10} = 1 \text{mA} \Rightarrow V_o = 10 \text{mA} \cdot 1 \text{M} \Omega = \boxed{10 \text{V}} \]

d. \( V_o = +10 \text{V} + 10 \text{mV} - \boxed{110 \text{mV}} \)

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3.2

(a) \[ +3 \text{V} \rightarrow \text{Assume "on"} \]

\[ V = -3 \text{V} \]

\[ I = \frac{V}{10 \text{K}} = \frac{-3 \text{V}}{10 \text{K}} = -0.3 \text{mA} \]

\[ I < 0 \Rightarrow \text{diode on} \]

(b) \[ +3 \text{V} \rightarrow \text{"off"} \]

\[ V_o = +3 \text{V} \]

\[ I = 0 \]

\[ V_o = -3 \text{V} \]

\[ V_o < 0 \Rightarrow \text{off} \]

(c) \[ +3 \text{V} \rightarrow \text{"on"} \]

\[ I = \frac{V_o}{10 \text{K}} = \frac{-3 \text{V}}{10 \text{K}} = -0.3 \text{mA} \]

\[ I < 0, \text{on} \]

(d) \[ +3 \text{V} \rightarrow \text{"off"} \]

\[ V_o = -3 \text{V} \]

\[ I = \frac{V_o}{10 \text{K}} = \frac{-3 \text{V}}{10 \text{K}} = -0.3 \text{mA} \]

\[ V_o < 0 \Rightarrow \text{off} \]
2.f. Answer is more accurate by using the following:
I_{os} = |I_B1-I_B2|; \ I_B = (I_B1+I_B2)/2
I_B1 = 700\text{nA}; \ I_B2 = 500\text{nA}
V_o = -I_B2R_3+R_2(I_B1-I_B2R_3/R_1)
V_o = 0 =>
R_3 = 1373