1.67 The LP factor \( \frac{1}{1 + \frac{1}{f_0}} \) results in a Bode plot like that in Fig. 1.23(a) with the 3 dB frequency \( f_0 = 10^4 \) Hz. The high-pass factor \( \frac{1}{1 + \frac{1}{f}} \) results in a Bode plot like that in Fig. 1.24(a) with the 3 dB frequency \( f_0 = 10^4 \) Hz.

The Bode plot for the overall transfer function can be obtained by summing the dB values of the two individual plots and then raising the resulting plot vertically by 40 dB (corresponding to the factor 100 in the numerator). The result is as follows:

\[
\frac{V_o}{V_i} = \frac{Z_i}{Z_i + R_i} = \frac{1}{1 + \frac{R_i}{Z_i}} = \frac{1}{1 + \frac{R_i}{R_i} \left( \frac{1}{Z_i} + sC_i \right)} = \frac{1}{1 + \frac{R_i}{R_i} \left( \frac{1}{R_i} + sC_i \frac{R_i + R_i}{R_i} \right)} = \frac{R_i}{R_i + R_i \left( sC_i \right)}
\]

This transfer function is of the STC low-pass type with a dc gain \( K = R_i / (R_i + R_i) \) and a 3-dB frequency \( \omega_0 = 1 / (R_i / \left( R_i \right)) \).

For \( R_i = 20 \text{k}\Omega, R_i = 80 \text{k}\Omega, \) and \( C_i = 5 \text{pF} \).

\[
\omega_0 = \frac{1}{5 \times 10^{-12} \times 20 \times 80 \times 10^4} = 1.25 \times 10^7 \text{rad/s}
\]

\[
f_0 = \frac{\omega_0}{2\pi} = \frac{1.25 \times 10^7}{2\pi} = 2 \text{ MHz}
\]
For $T_c(s)$, the following equivalent circuit can be used:

\[ T_c(s) = \frac{R_3}{R_2 + R_3 + 1/sC_2} \]

3 dB frequency \( = \frac{1}{2\pi C_2(R_2 + R_3)} = \frac{1}{2\pi \times 10^{-11} \times 10^6} = 15.9 \text{ Hz} \)

2.53

a) Source is connected directly:

\[ V_s = 10 \times \frac{1}{100} = 0.099 \text{ V} \]

\[ i = \frac{V_s}{R_1} = \frac{0.099}{10^3} = 0.099 \text{ mA} \]

b) Inserting a buffer

\[ i = \frac{10 \text{mA}}{1000} = 0.01 \text{ mA} \]

The load current $i_L$ comes from the power supply of the op-amp.
2.76

A of the second stage is \( R_2 = 0.5 \)
\( R_2 = 1 \) MΩ + 200 kΩ
we use a series configuration of \( R_1 \) and \( R_2 \)
\( R_1 \) (tot): \( R_1 = \text{100 kΩ} \)
Minimum gain = 0.5 \( \left( 1 + \frac{R_2}{R_1} \right) \) \( \frac{1}{2} \)
\( \frac{1}{2} R_2 (100) = 1 \)
\( \left( 1 + \frac{2 \times 100}{50} \right) \)
\( \frac{1}{2} R_2 (100) = 2 R_2 \) ①
Max. gain = 100 = 0.5 \( \left( 1 + \frac{R_2}{R_1} \right) \)
2 \( R_2 = 1 \) MΩ ②

\( R_1 + 100 = 2 R_2 \) ①
\( R_2 = 50.25 \) kΩ ②

2.83

\[ G_{\text{com}} = \frac{-R_2}{R_1} = -20 \]

\[ A_c = 10^4 \frac{V_0}{V_i} \]

\[ f_c = 10^6 \text{ Hz} \]

Eq. 2.35: \( \omega_{3dB} = \frac{2 \pi \times 10^6}{1 + R_2/R_1} = 2 \pi \times 47.6 \text{ kHz} \)

\( f_{3dB} = 47.6 \text{ kHz} \)

Eq. 2.34: \( \frac{V_o}{V_i} = \frac{-R_2/R_1}{1 + \frac{R_2}{R_c}} \)

\[ -\frac{20}{1 + \frac{1000}{100}} = -19.9 \frac{V_o}{V_i} \]

\[ f = 0.1 \frac{f_{3dB}}{10^4} = 1.99 \frac{V_o}{V_i} \]

\[ f = 10 \frac{f_{3dB}}{10^4} = 1.99 \frac{V_o}{V_i} \]

2.93

D2.89

a) Assume two identical stages, each with a gain function:

\[ G_r = \frac{G_0}{1 + \frac{120}{R_2}} \]

\[ G_r = \frac{G_0}{1 + \frac{120}{R_2}} \]

Overall gain of the cascade is \( \frac{2 G_0}{1 + (\frac{G_0}{R_2})^2} \)

The gain will drop by 3 dB when:

\[ 1 + (\frac{G_0}{R_2})^2 = \frac{1}{2} \]

\[ G_0 = 20 \log \sqrt{2} \]

\[ f_{3dB} = \frac{f_c}{\sqrt{2} - 1} \]

b) \( 40 \text{ dB} = 20 \log \frac{C_s}{G_0} \Rightarrow C_s = 100 \times (1 + \frac{R_2}{R_1}) \)

\[ f_{3dB} = \frac{f_c}{1 + \frac{R_2}{R_1}} = \frac{10^6}{100} = 10^4 \text{ Hz} \]

c) Each stage should have 20 dB gain or \( 1 + \frac{R_2}{R_1} = 10 \) and therefore a 3 dB frequency of:

\[ f_c = 10^4 \times 10^5 \text{ Hz} \]

The overall \( f_{3dB} = 10^5 \sqrt{10^4 - 1} = 64.3 \text{ kHz} \)

which is 6 times greater than the bandwidth achieved using single op-amp.

(c) Case b above)

2.93

The peak value of the largest possible sine wave that can be applied at the input without
output clipping is:\[ \frac{\pm 12V}{100} = 0.12V = 120 \mu V \]

rms value: \[ \frac{120}{\sqrt{2}} = 85 \mu V \]
D2.99

a) \( V_i = 0.5 \) → \( V_o = 10 \times 0.5 = 5 \text{V} \)
Output distortion will be due to slew rate limitation and will occur at the frequency for which \( \frac{dV_o}{dt} \) \( \text{max} \) = \( SR \)

\[
\omega_{\text{max}} \times 5 = \frac{1}{100} = 2 \times 10^5 \text{ rad/s} = \frac{3188}{\text{kHz}}
\]

b) The output will distort at the value of \( V_i \) that results in \( \frac{dV_o}{dt} \) \( \text{max} \).

\[
V_i = 10 \pi 20 \times 10^3
\]

\[
\frac{dV_o}{dt} = 10 \pi 2 \times 20 \times 10^3
\]

Thus \( \frac{dV_o}{dt} = \frac{1}{18^6}{10 \times 2 \times 20 \times 10^3} = 0.795 \text{V} \)

C. \( V_i = 50 \text{mV} \)  \( V_o = 500 \text{mV} = 0.5 \text{V} \)
Slew rate begins at the frequency for which \( \omega = 0.5 \text{ rad/s} \)

which gives \( \omega = \frac{V_i}{0.5} = 2 \times 10^5 \text{ rad/s} \) or \( f = 318.3 \text{kHz} \)

However the small signal 3dB frequency is

\[
\frac{f_{\text{3dB}}}{f = \frac{f_8}{1 + \frac{R_i}{R_8}}} = \frac{2 \times 10^6}{50} = 200 \text{kHz}
\]

Thus the useful frequency range is limited at 200kHz.

b) \( f = 51 \text{kHz} \), the slew rate limitation occurs at the value of \( V_i \) given by

\( \omega \times 10^5 \times 10 \Rightarrow V = \frac{1}{20 \times 10^3} = 318 \text{V} \)

Such an input voltage, however, would ideally result in an output of 31.8V which exceeds \( V_{\text{max}} \). Thus \( V_{\text{max}} = \frac{V_{\text{output}}}{10} = 1 \text{V peak} \).