Electronic Devices

Homework # 1 Solution

March 2020

Question 1. (20 pts)

- a. The amplifier can be used as a linear amplifier for input swing: $L_-/A_v \leq v_I \leq L_+/A_v$. The input must be used is $3\sin(\omega t)$ [mV]. *(10 pts)*
- *b.*
  We have:
  $v_o = A_{vo} v_i \frac{R_L}{R_L + R_o}$ (1)
  Substitute $v_o = 200\ mV$ and $R_L = 1\ k\Omega$ to (1):
  $A_{vo} v_i \frac{1000}{1000 + R_o} = 0.2$ (2) (5pts)

  If $R_L = \infty$, based on (1) and (2), we have:

  $v_o = A_{vo} v_i = \frac{0.2 \times (1000 + R_o)}{1000} = \frac{0.2 \times (1000 + 50)}{1000} \Leftrightarrow v_o = 0.21\ V$ (5pts)

Question 2: (30pts)

- a.

$$A_v = 100 \times \frac{1}{\left(1 + \frac{jf}{10^5}\right)} \times \frac{1}{\left(1 + \frac{10^2}{jf}\right)}$$

The transfer function is a result of STC low pass and high pass circuit with a gain of 100

- The high pass circuit transfer function is:

$$\frac{1}{\left(1 + \frac{10^2}{jf}\right)}$$

The first cutoff frequency is $f_0 = 10^2$ Hz

- The low pass circuit transfer function is:

$$\frac{1}{\left(1 + \frac{jf}{10^5}\right)}$$

The second cutoff frequency is $f_1 = 10^5$ Hz (5 pts)

- The magnitude of A_v

$$|A_v| = 100 \times \frac{1}{\sqrt{1+\frac{f^2}{10^{10}}}} \times \frac{1}{\sqrt{1+\frac{10^4}{f^2}}}$$

Then
$f = 10^2 \rightarrow |A_v| = 70.71$
$f = 10^5 \rightarrow |A_v| = 70.39.$ (5 pts)

- (b) Bode Plot of bandpass response has correct axis-names, units, 3dB frequency and slopes (10pts)
- (c) Bandwidth of this bandpass amplifier is the frequency range between the two cutoff frequencies
  $BW = f_1 - f_0 = 10^5 - 10^2 = 99900\ (Hz) = 99.9 (kHz)$ (10pts)

Question 3: Band Pass Filter (20 pts)

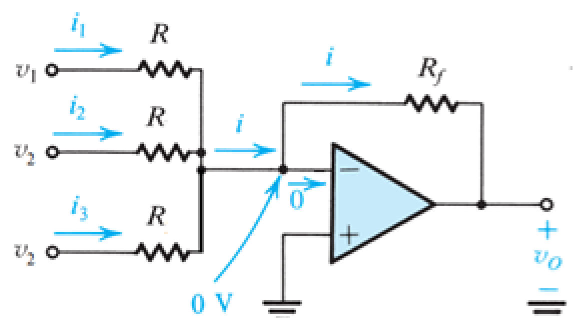
- a.
- The input resistance is 100 Ω

$$R_i = \frac{v_i}{i} = R_1 = 100\ \Omega$$

- The inverting amplifier has a close-loop gain of $-100\, V/V$

$$G = -\frac{R_2}{R_1} = -100 \Leftrightarrow R_2 = 100R_1 = 10\ k\Omega \qquad \text{(5pts)}$$

- Draw correct inverting amplifier circuit (5pts)
- b.



(5pts)

- $R = 1\ k\Omega$ and $R_f = 5\ k\Omega$ are given

$$v_0 = -\left(\frac{R_f}{R}v_1 + \frac{R_f}{R}v_2 + \frac{R_f}{R}v_2\right) = -\left(2 \times \frac{5}{1}v_2 + \frac{5}{1}v_1\right)$$

$\Leftrightarrow v_0 = -10v_2 - 5v_1$ (1)

- Substitute $v_1 = 1\ V$ and $v_2 = -1\ V$ to (1)

$v_0 = 5\ V$ (5pts)

Problem 4: (10 pts)

- Differential input $R_i = 10\ k\Omega = 2R_1 \rightarrow R_1 = 5k\Omega = \mathrm{R}_3$ (5pts)
- Differential voltage gain: $A_d = \frac{R_2}{R_1} = 50 \rightarrow R_2 = 50R_1 = 250\ k\Omega = R_4$ (5pts)

Problem 5: (20 pts)

- a.
- Inverting amplifier: $\frac{v_o}{v_i} = -\frac{R}{R_f + \frac{1}{j\omega C}} = \frac{-\frac{R}{R_f}}{1 - \frac{j}{\omega C R_f}}$ (5pts)
- High pass network: $\omega_{3dB} = 2\pi f_{3dB} = \frac{1}{CR_f} \rightarrow\ f_{3dB} = \frac{1}{2\pi C R_f}$ (5pts)
- b.
- $R_{in} = R_f = 1k\Omega$.
- $f_{3dB} = 2k\mathrm{Hz} \rightarrow C = \frac{1}{2\pi * 2000 * R_f} = 79.5\ nF.$
- Gain of 20 dB
- $\frac{R}{R_f} = 10^{20/20} = 10 \rightarrow R = 10R_f = 10\ k\Omega$ (5pts)
- Bode Plot has correct axis-names, units, 3dB frequency (5pts)