ECE 3355: Electronics

Section 15217/14031
Spring 2023

Exam 1

Version A

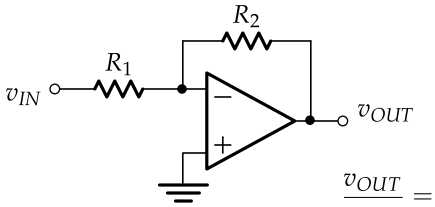
March 4, 2023

Do *not* open the exam until instructed to do so. Complete the exam on your own, without the help of your notes, prior examples or solutions, your book, or any communication/interaction with others. You must write a complete solution that shows the steps you took to solve the problem to receive full credit. You may use a calculator and a crib sheet is provided as part of this exam. Answer the questions in the spaces provided on the question sheets. If you run out of room for an answer, continue on the back of the page. **You will have 1 hour 15 minutes to finish the exam.**

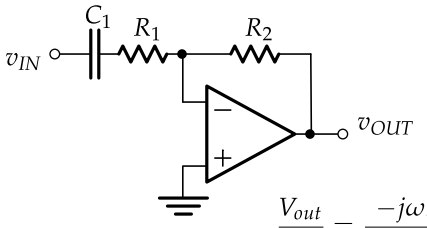
Student's Name: _____

Question	Points	Score
1	15	
2	10	
3	15	
4	15	
5	15	
6	15	
7	15	
Total:	100	

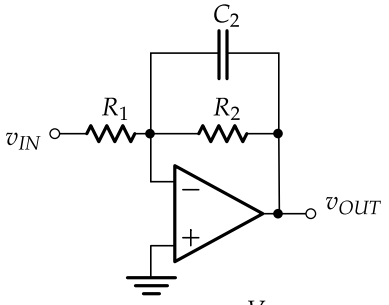
Inverting Amplifier



$$\frac{v_{OUT}}{v_{IN}} = -\frac{R_2}{R_1}$$

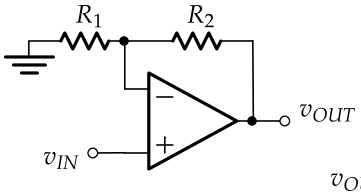


$$\frac{V_{out}}{V_{in}} = \frac{-j\omega R_2 C_1}{1 + j\omega R_1 C_1}$$

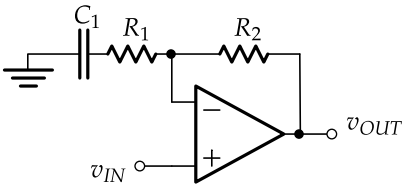


$$\frac{V_{out}}{V_{in}} = \frac{-\frac{R_2}{R_1}}{1 + j\omega R_2 C_2}$$

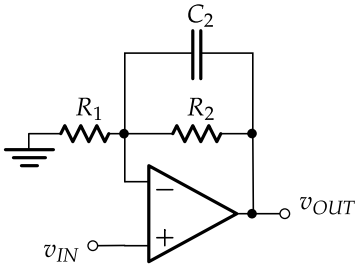
Non-inverting Amplifier



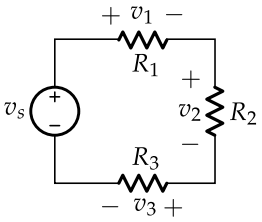
$$\frac{v_{OUT}}{v_{IN}} = 1 + \frac{R_2}{R_1}$$



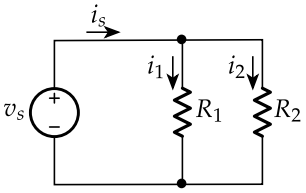
$$\frac{V_{out}}{V_{in}} = \frac{1 + j\omega\left(R_1 + R_2\right) C_1}{1 + j\omega R_1 C_1}$$



$$\frac{V_{out}}{V_{in}} = \left[1 + \frac{R_2}{R_1}\right]\left[\frac{1 + j\omega\left(R_1 || R_2\right) C_2}{1 + j\omega R_2 C_2}\right]$$



$$v_1 = \frac{R_1}{R_1 + R_2 + R_3} v_s$$
$$v_2 = \frac{R_2}{R_1 + R_2 + R_3} v_s$$
$$v_3 = \frac{R_3}{R_1 + R_2 + R_3} v_s$$

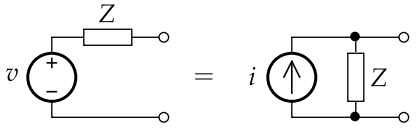


$$i_1 = \frac{R_2}{R_1 + R_2} i_s$$
$$i_2 = \frac{R_1}{R_1 + R_2} i_s$$

$$v_B = \underbrace{V_B}_{\text{DC}} + \underbrace{v_b}_{\text{AC}}$$

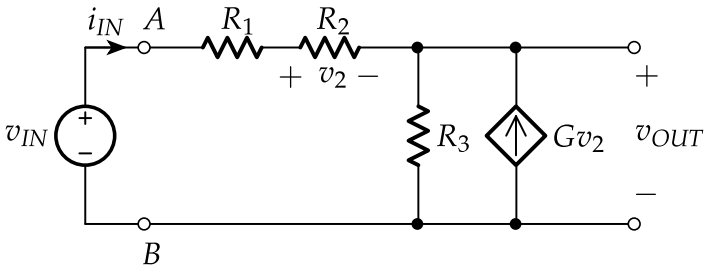
$\overline{V}_b \rightarrow$ Phasor notation

$$CMRR = 20 \log_{10} \frac{|A_d|}{|A_{cm}|}$$

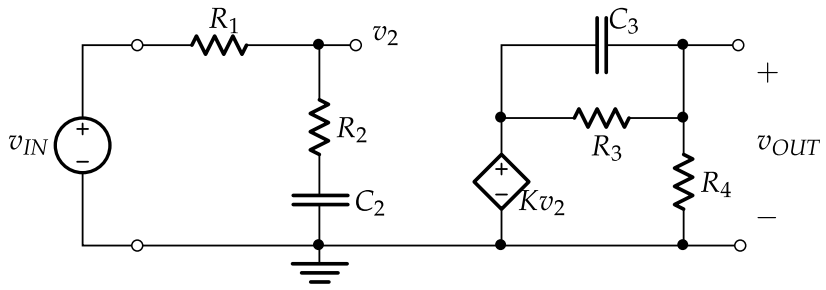


$$v = i \cdot Z$$
$$i = \frac{v}{Z}$$

1. (15 points) For the following circuit, find the voltage gain, $\frac{v_{OUT}}{v_{IN}}$, and the input and output resistances.



2. (10 points) For the following circuit, answer the three questions below.



(a) What is the gain at low frequencies?

(a) _____

(b) What is the gain at high frequencies?

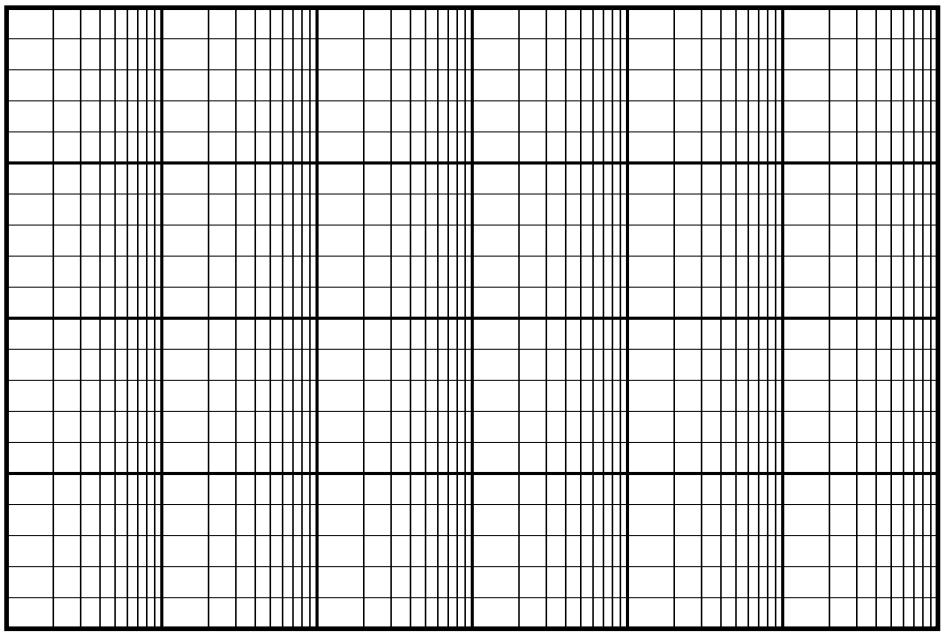
(b) _____

(c) Sketch of the *shape* of the magnitude plot for each of the two stages of the circuit: for $\frac{\overline{V}_2}{\overline{V}_{in}}$ and for $\frac{\overline{V}_{out}}{\overline{V}_2}$ (You do not need to label the x and y axes).

3. (15 points) Bode Plots

(a) Plot a straight-line approximation of the Bode plot on the graph paper provided for the *magnitude only* for the following transfer function (the unit for the values in the denominator of the imaginary terms is $^{\text{rad}}/_{\text{sec}}$).

$$H(j\omega) = -10\frac{\left(1 + j\frac{\omega}{200}\right)}{\left(1 + j\frac{\omega}{7}\right)\left(1 + j\frac{\omega}{9{,}000}\right)\left(1 + j\frac{\omega}{40{,}000}\right)}.$$



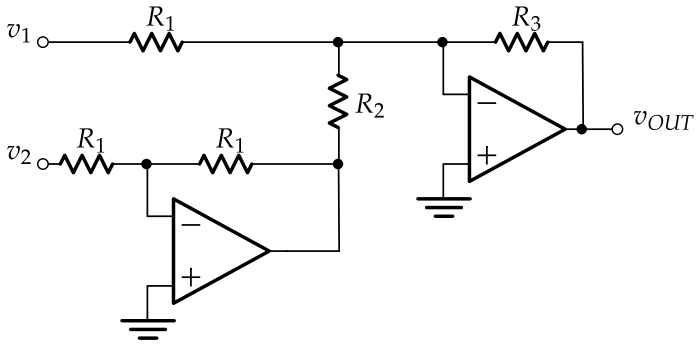
(b) What is the starting phase (i.e., the phase at low frequencies)?

(b) _____

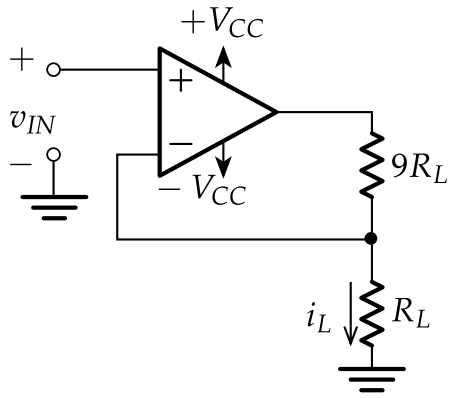
(c) What is the ending phase (i.e, the phase at high frequencies)?

(c) _____

4. (15 points) Difference Amplifier
   (a) Write an expression for the common mode gain (A_{cm}).
   (b) Write an expression for the difference gain (A_d). (*Hint:* if you are using superposition, you may make an important assumption regarding R_1 and R_2.)
   (c) For $R_1 = 3\,\text{k}\Omega$, $R_2 = 2.99\,\text{k}\Omega$, and $R_3 = 30\,\text{k}\Omega$, approximate the CMRR? (*Hint:* you can use the difference gain calculated from Part (b))
   (d) What is the input resistance seen at each of the input terminals (i.e., at v_1 and v_2)?



5. (15 points) For the following circuit, the op-amp is powered by a pair of $\pm V_{CC} = \pm 15$ volt supplies (as shown).

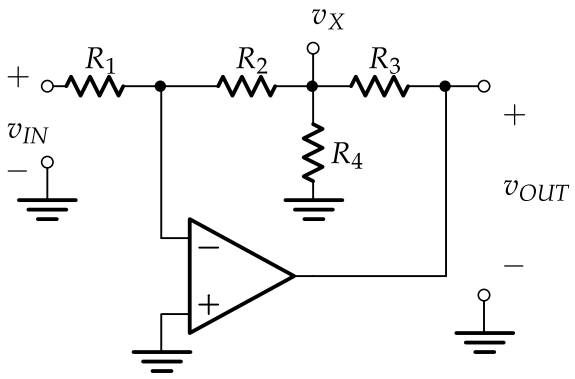


(a) Write an expression for i_L in terms of v_{IN} and R_L.

(b) What is the range of v_{IN} that ensures the circuit does not go into voltage saturation?

(c) What range of load resistor values (i.e., R_L) will ensure that the circuit does not go into current saturation for the full input range from above? The maximum current for the op-amp is 15 mA.

6. (15 points) For the following circuit, find an expression for the voltage gain, $\frac{v_{OUT}}{v_{IN}}$.



7. (15 points) Design a circuit that has the following straight-line approximation to the Bode plot. Indicate which order the stages should be placed in to ensure that the input resistance does not vary with frequency.