Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Spring 2024

Exam #1

Instructor: Sam Palermo

- Please write your name in the space provided below
- Please verify that there are **6** pages in your exam
- Good Luck!

Problem	Score	Max Score
1		30
2		25
3		25
4		20
Total		**100**

Name: SAM PALERMO

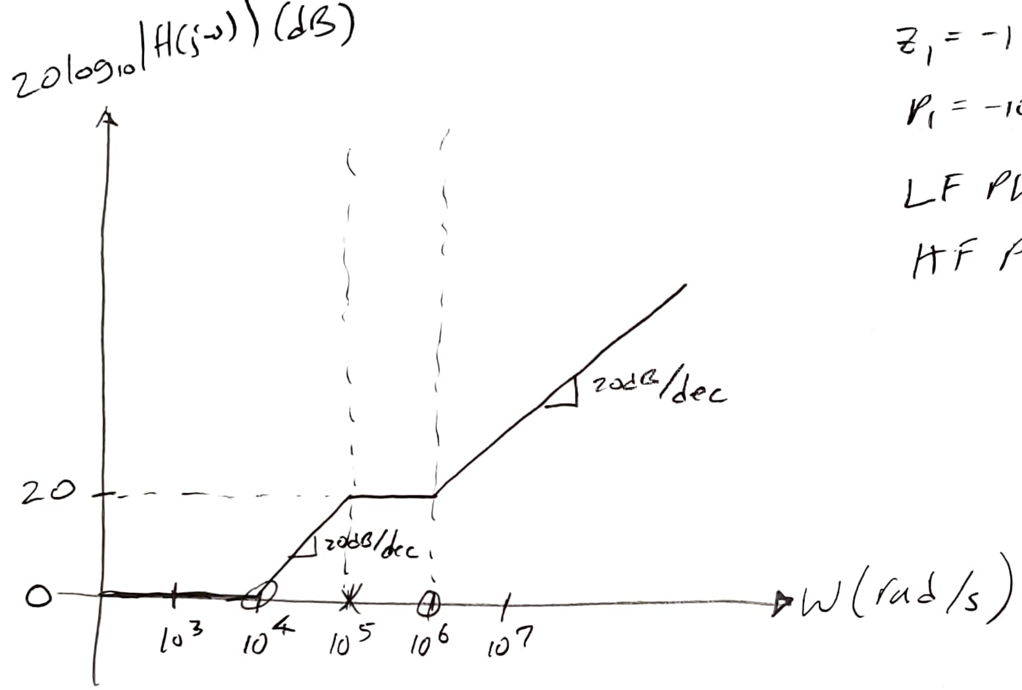
UIN: ______________________

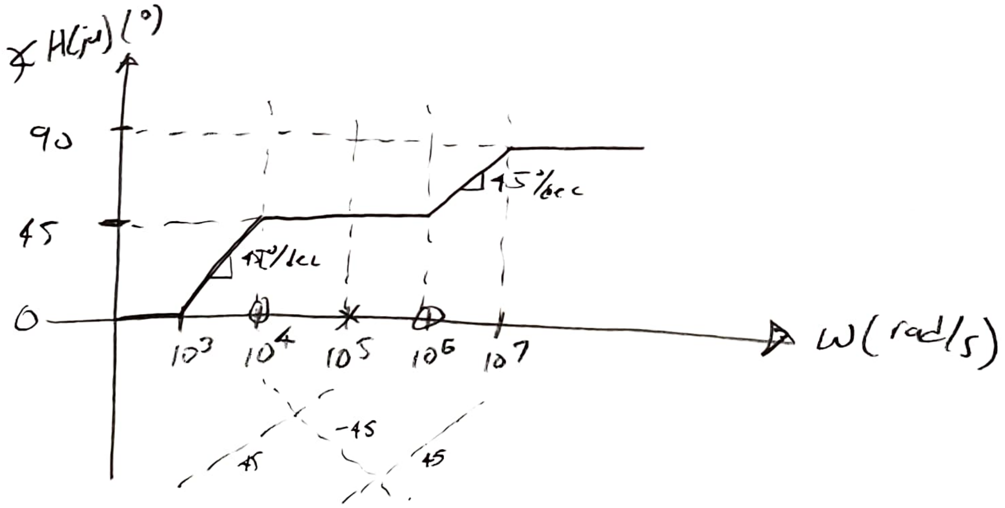
Problem 1 (30 points)
Plot the magnitude and phase response of the following transfer function. Label key points and slopes.

$$H(s) = \frac{(s + 10^4)(s + 10^6)}{10^5(s + 10^5)}$$

LF gain = 1 = 0dB
HF gain = ∞ = ∞ dB
$z_1 = -10^4$, $z_2 = -10^6$
$p_1 = -10^5$

LF Phase = 0°
HF Phase = 0° + 2(90°) + 1(-90°)
= 90°

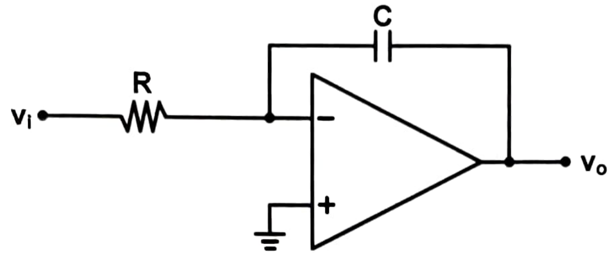




Problem 2 (25 points)

Assume for problem 2 that all operational amplifiers are ideal, unless specifically noted.

a) Design the following ideal integrator circuit to have a 10kΩ input resistance and implement the following transfer function. (15 points)



$$V_o(s) = -\frac{10^7}{s} V_i(s)$$

$$V_o(s) = -\frac{Z_C}{Z_R} V_i(s) = -\frac{1}{sRC} V_i(s)$$

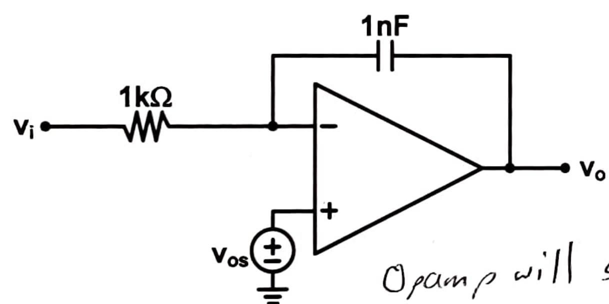
$R_{in} = R = 10k\Omega$

$$-\frac{1}{sRC} = -\frac{10^7}{s} \Rightarrow C = \frac{1}{R(10^7)} = \frac{1}{(10^4\Omega)(10^7)} = 10pF$$

R = $10k\Omega$

C = $10pF$

b) Now assume that R=1kΩ and C=1nF. **Note, this is not the answer to (a).** Also, the opamp has an offset voltage v_{OS}=5mV and output saturation voltages of V_{SAT}=±7V. If the integrator circuit is powered up with v_i=0V and no initial capacitor voltage, how long does it take for the circuit to saturate? (10 points)



$$V_o(t) = V_{OS}\left(1 + \frac{t}{RC}\right)$$

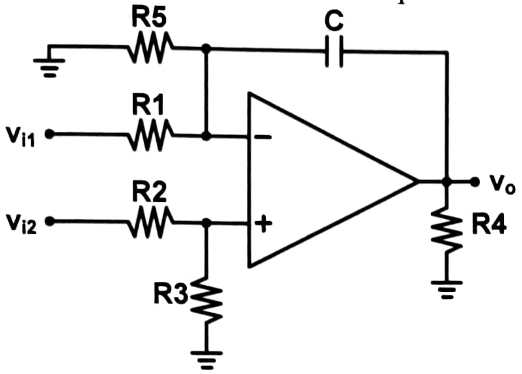
Opamp will saturate when $V_o(t) = 7V$

$$5mV\left(1 + \frac{t}{(1k\Omega)(1nF)}\right) = 7V$$

$$t = \left(\frac{7V}{5mV} - 1\right)(1k\Omega)(1nF) = 1.399ms$$

t_{SAT}= 1.399ms

Problem 3 (25 points)
Assume for problem 3 that the operational amplifiers is ideal.



a) Find the expression for v_o as a function of v_{i1} and v_{i2}. (10 points)
b) Find the expression for the circuit input resistance seen from v_{i1}. (5 points)
c) Find the expression for the circuit input resistance seen from v_{i2}. (5 points)
d) Find the expression for the circuit output resistance. (5 points)

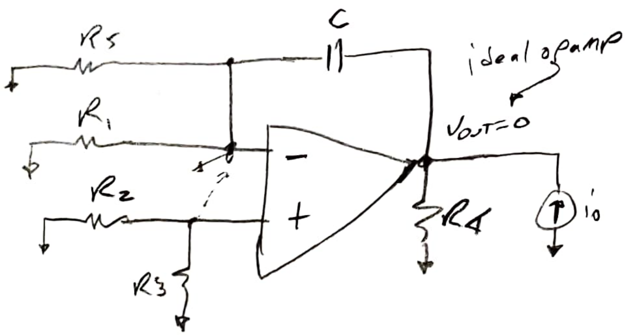
a. $$V_o = -\frac{Z_C}{Z_{R1}} V_{i1} + \left(\frac{Z_{R3}}{Z_{R2}+Z_{R3}}\right)\left(1+\frac{Z_C}{Z_{R1} \| Z_{R5}}\right) V_{i2}$$

$$= -\frac{1}{sR_1C} V_{i1} + \left(\frac{R_3}{R_2+R_3}\right)\left(1+\frac{1}{sC\left(\frac{R_1R_5}{R_1+R_5}\right)}\right) V_{i2}$$

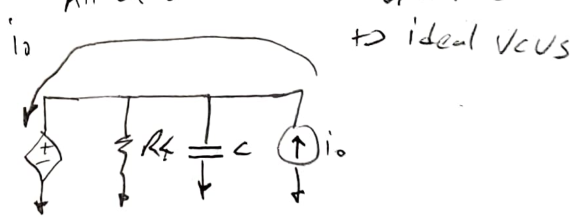
b. R_{in} for $V_{i1} = R_1$

c. R_{in} for $V_{i2} = R_2 + R_3$

d. $R_{OUT} = \emptyset$



EQ circuit $\Longrightarrow$



$$\emptyset \| R_4 \| \frac{1}{sC} \Rightarrow \emptyset$$

$$R_o = \frac{V_o}{i_o} = \frac{\emptyset}{i_o} = \emptyset$$

Problem 4 (20 points)

The operational amplifier for this problem has a finite slew rate of 1V/μs.

a) For an output 200kHz **sine** wave, what is the maximum amplitude that can be reproduced without distortion? (10 points)

$$\max\left|\frac{dV_o(t)}{dt}\right| \leq SR$$

$$V_o(t) = A\sin\omega t$$

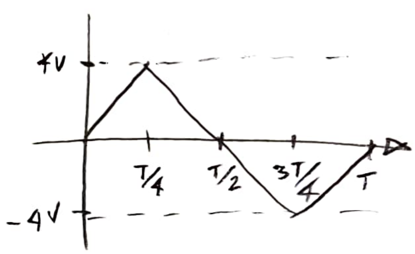
$$\frac{dV_o(t)}{dt} = A\omega\cos\omega t$$

$$\max\left|A\omega\cos\omega t\right| = A\omega \leq SR$$

$$A \leq \frac{SR}{\omega} = \frac{1V/\mu s}{2\pi(200kHz)} = 0.796V$$

Max $A = 0.796V$

b) For an output 4V amplitude **triangle** wave, what is the minimum period that can be reproduced without distortion? (10 points)



$$\max\left|\frac{dV_o(t)}{dt}\right| \leq SR$$

$$\max\left|\frac{dV_o(t)}{dt}\right| = \left|\frac{-4V - 4V}{\frac{3T}{4} - \frac{T}{4}}\right| = \frac{8V}{T/2} = \frac{16V}{T}$$

$$\frac{16V}{T} \leq SR$$

$$T \geq \frac{16V}{SR} = \frac{16V}{1V/\mu s} = 16\mu s$$

$T \geq 16\mu s$