Name: _____UT EID: _____Lecture Instructor: _____

ECE 302H **Please answer ALL questions**

100 points total.

Fall 2023, Midterm Exam III, Part 1 **Time: 600-730 PM**

16 Nov. 2023

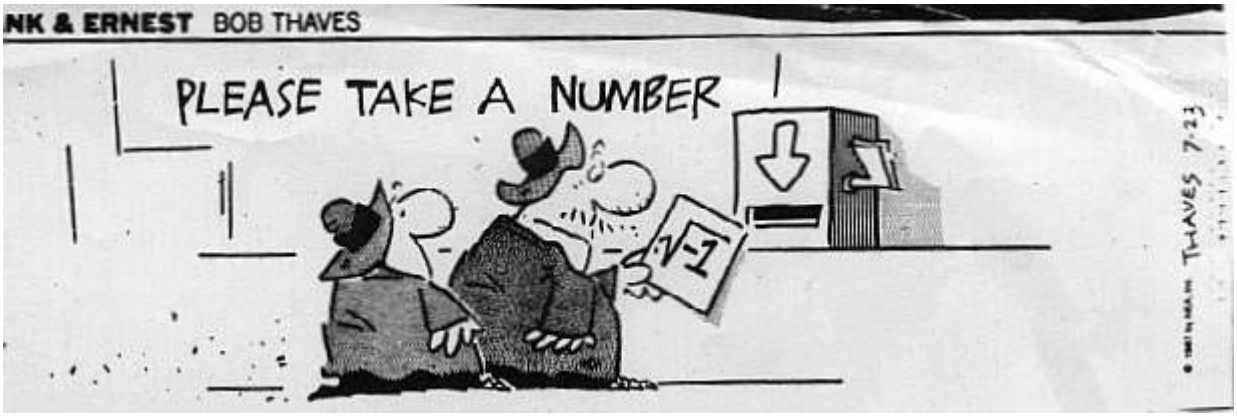
There are three questions. Each question carries 25 points. The remaining 25 points are from the Part 2 take-home.

Instructions for turning in your exam:

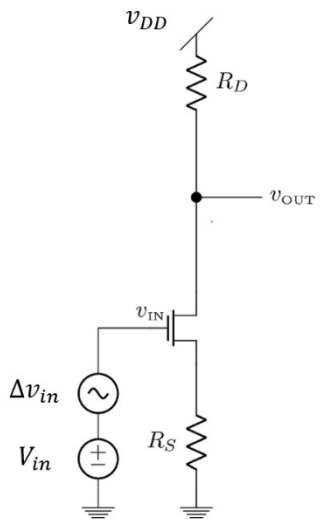
After completing your exam, you may turn on your phones

0) Please write your EID on every page of the exam
1) Log in to Gradescope and find MT III Part 1 or Midterm III Part 1
2) For each problem: a. If your response is ≤ 1 page, you may choose the option to have Gradescope take a picture of your page
b. If your response is ≥ 1 page, you must take pictures of each page with your camera app and choose the option to upload the solution

3) DOUBLE CHECK YOUR SUBMISSION
4) Turn in your paper exam to the proctor (this will be used as a reference)



Q1. Q1. 25 points.



Consider the circuit at right, consisting of an NMOS transistor and two resistors. The supply voltage v_{DD}, shown as a bar at the top of the circuit, is supplied by a constant voltage source from ground (not shown). The input has a constant voltage $V_{¿}$ and is to be perturbed by an amount $\Delta v_{¿}$; this is shown pictorially as two voltage sources in series. You may use the transconductance, $g_m = \mu_n C_{ox} \frac{W}{L}(V_{gs} - V_T)$, as a known quantity. Assume that the MOSFET is in the saturation region.

[a=6pt] Consider the circuit with $R_S \to 0$ and calculate the small-signal gain of the amplifier, $\Delta v_{out} / \Delta v_{¿}$.

[b=3pt] The transconductance is very large but poorly controlled and may vary by up to a factor of 2 from circuit to circuit. If this were to happen, by what factor would the small-signal gain vary when $R_s \to 0$ as in (a)?

[c=7pt] Consider the circuit again with $R_S \neq 0$ and calculate the small-signal gain of the amplifier, $\Delta v_{out} / \Delta v_{i}$.

[d=3pt] Consider the transconductance to be very large. Using the result from (c) where $R_S \neq 0$, by what factor would the small-signal gain vary if g_m varied by a factor of 2?

[e=6pt] Finally, consider that the power supply may have some perturbation such that $v_{DD} = V_{DD} + \Delta v_{DD}$. With no other perturbations in the circuit, calculate the Power Supply Rejection Ratio, i.e. $\Delta v_{DD} / \Delta v_{out}$.

Q2. Total for Q2 = 25 points

[a=5pt] Prove de Moivre's formula, which states that $(\cos\theta + j\sin\theta)^n = \cos n\theta + j\sin n\theta$

[b=5pt] Use de Moivre's formula from part (a) to prove the trigonometric "double-angle" identities, namely

$$\cos 2\theta = \cos^2\theta - \sin^2\theta$$
$$\sin 2\theta = 2\cos\theta\sin\theta$$

[Note that you may use de Moivre's formula for part (b) whether you proved it in part (a) or not]

[c=5pt] Consider a particular transfer function T below. Express T in polar **and** rectangular coordinates.

$$T = \frac{3+4j}{12-5j}$$

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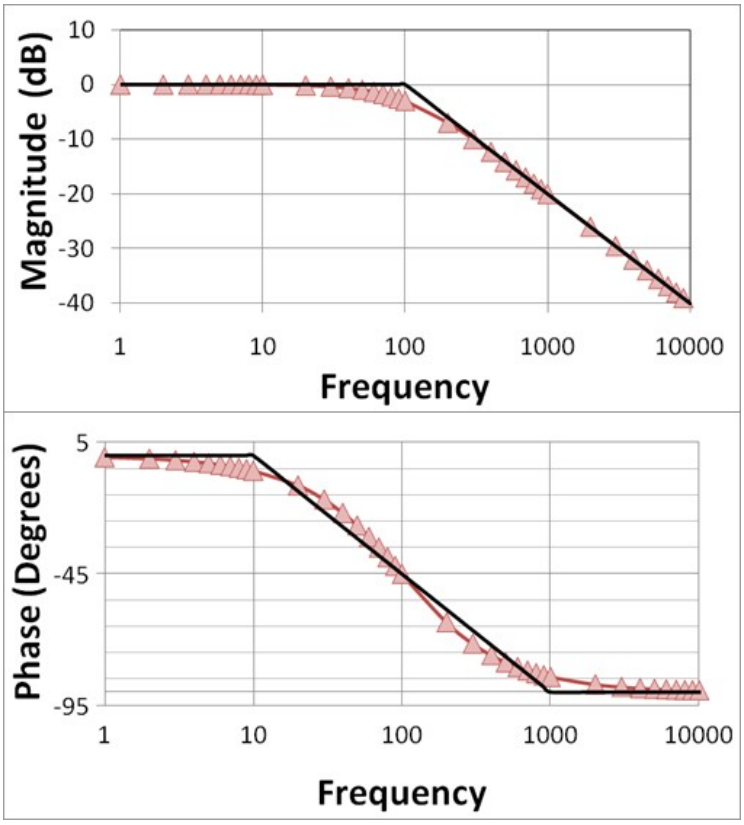
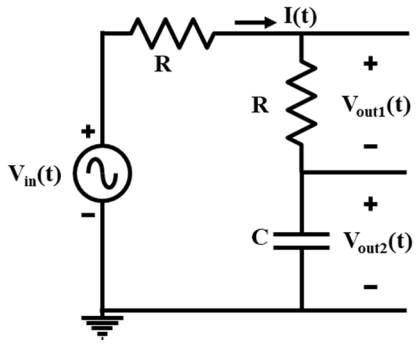
[d=5pt] On a logarithmic number line, what number falls exactly halfway between 1 and 10?

[e=5pt] A filter has a transfer function $\frac{V_o}{V_i}$ as given in the figure below (the frequency axis is in Hz). The input voltage is a cosine wave at 1 kHz with amplitude 3 and a phase of 20 degrees. What will the frequency, amplitude, and phase of the output voltage be?



Q3. For the circuit shown below with a voltage source $\mathbf{V_{in}(t) = 10\ cos(2\times10^6\ t + 45°)\ V}$, two identical resistors **R of 1 ohm**, and one capacitor **C of 0.25 µF**. Note: please include units to all the final answers of the questions below. [25 pts]

(a) Calculate the phasor domain magnitude and phase of the input voltage V_{in}. (5 pts)

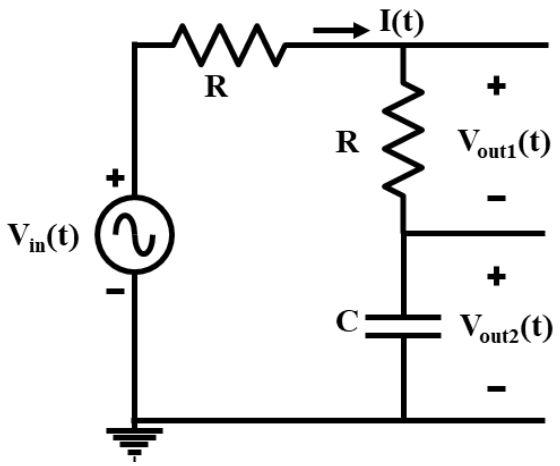


(b) Please calculate the complex impedance for single resistor (Z_R) and capacitor (Z_C). (5 pts)

(c) Calculate the transfer function V_{out1}/V_{in}. Hint: you can use the phasor domain, and no need to write out the amplitude and phase separately. (5 pts)

(d) Calculate the current I(t) in the time domain. Hint: solve in phasor domain and then convert the answer to time domain (5 pts)

(e) If we change the frequency of the input voltage source to very high frequency (ω approaching infinite), while keeping the amplitude to 10V. Please calculate the amplitude of V_{out1} and V_{out2}. (5 pts)



Circuit for Q3.