EECS 40 Midterm Exam II

Fall 2004

Print Name (Last,First) ____

Sign Name____

Do not begin exam until you are instructed to start.

Note that there are several versions of this exam in the room.

To get credit for a problem, make your method clear to the grader.

1	/24
2	/16
3	/15
4	/22
5	/23
Total	/100

Problem 1 (24 points) General Questions

a. [1] Give a concise definition of the properties of an acceptor atom that could be used in a silicon wafer and explain what it does.

b. [1] What is the power of 50 watts in decibels referred to a reference power of 1mW (this is often referred to as dBm)?

c. [1] Identify clearly the meaning of the acronym *rms*.

d. [1] What component can you use to couple a time-varying signal to an amplifier yet keep steady currents from flowing into the amplifier? ____________________

e. [1] List two components that can form a circuit that acts as a frequency filter. _____________ and ______________ .

f. [1] Draw a simple analog circuit that employs negative feedback (make clear where the feedback appears).

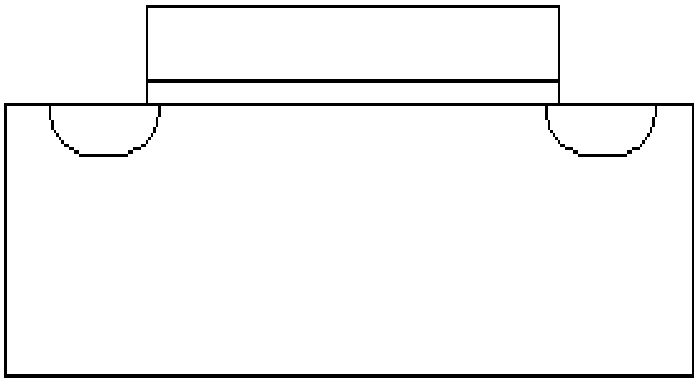
g. [5] List in the table below different devices that are essentially just semiconductor diodes, and indicate their functions:

Table 1: Diodes

Name of diode Device	**Function of diode device (give distinguishing functions, being as specific as you can)**
1.	
2.	
3.	
4.	
5.	

Problem 1 (continued)

h. [6] FET structure. On the cross-sectional transistor view of a silicon n-channel transistor shown below, mark the p-type regions with a **1**, the n-type regions with a **2**, metallic or heavily conducting regions with a **3**, insulating regions with a **4**, regions containing dopants predominantly from Group III of the periodic table with a **III**, and dopants predominantly from Group V of the periodic table with a **V. (If more than one label applies to a particular region use each one that applies.)** Also please indicate and name on the diagram the four terminals of the device.



i. [7] Small-signal resistance of a pn diode

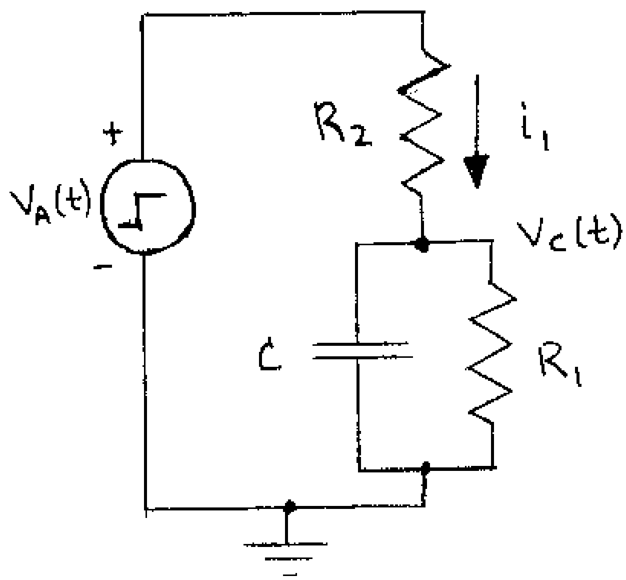
One can apply the small-signal approach to pn diodes to represent how they will behave in response to a small variation of their bias current. To see this, first

a. [3] Write the "exponential diode equation" (called the Shockley equation by your text) for the diode current, i_D, as a function of the diode voltage, v_D: (Note: $q_e = 1.6 \times 10^{-19}$ C, k = 1.38×10^{-23} JK^{-1}.)

b. [4] Find the small-signal resistance of this diode at room temperature when the diode current is 1 mA. (Assume that the diode ideality factor or "emission factor" n = 1.) The small-signal resistance r is defined as $r = 1/(di_D/dv_D)$. (Hint: Since the saturation current is much smaller than 1 mA, you can approximate i_D with just I_S times the exponential term.)

Problem 2 (16 points) First-Order Transient

In the circuit below, let $v_A(t)$ = -1 V for t<0 and $v_A(t)$ = 1 V for t>0. R_1 = 2000 Ω, R_2 = 3000 Ω, and C = 10 μF.



a. [2] Find $v_C(t = 0-)$.

b. [2] Find $v_C(t = 0+)$.

c. [2] Find the current i_1 at t = 0-.

d. [2] Find $i_1(t = 0+)$.

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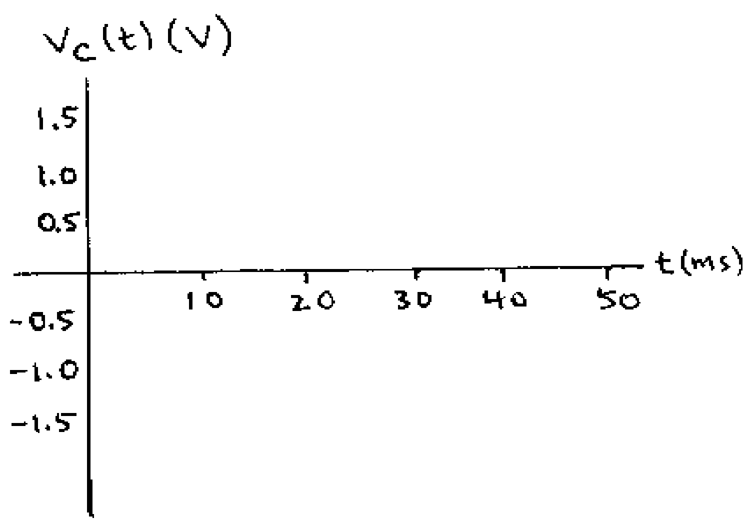
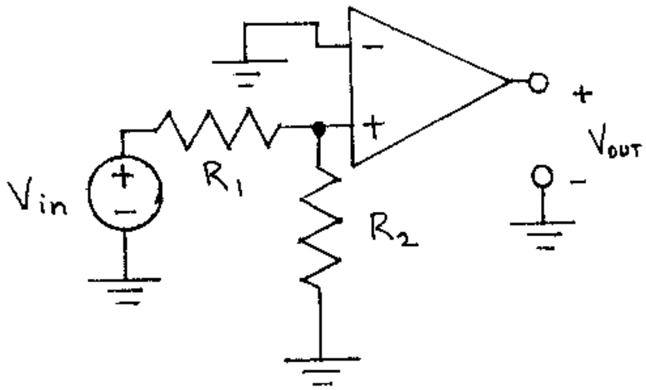
e. [4] Find the time constant for this circuit.

d. [4] Find an expression for $v_C(t)$ for t>0, and sketch it below

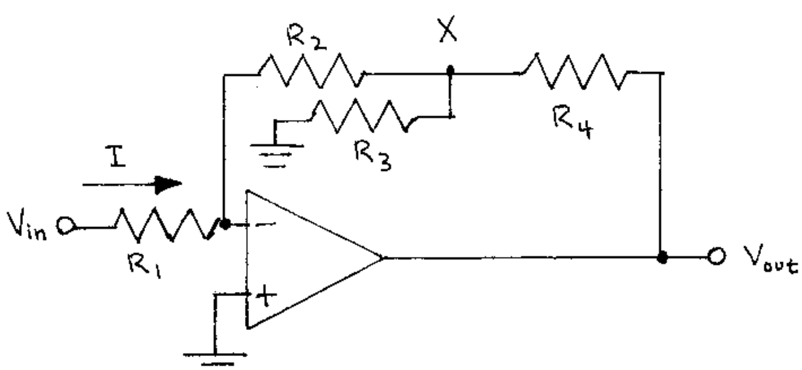


Problem 3 (15 points) Op-Amps

a. [7] The op-amp in the circuit below is ideal except that it has a finite gain A. If the measured voltages indicated are found to be v_{in} = 4.000 V and v_{out} = 5.000 V, with R_1 = 1 MΩ and R_2 = 3 kΩ, what is the value of A?



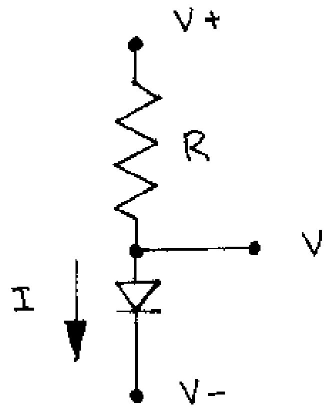
b. [8] For the (ideal) op-amp circuit below find I, v_x/v_{in} and v_{out}/v_{in}. R1 = 6 kΩ, R_2 = 6 kΩ, R_3 = 5 kΩ, R_4 = 3 kΩ. Assume that v_{in} = 6 mV.



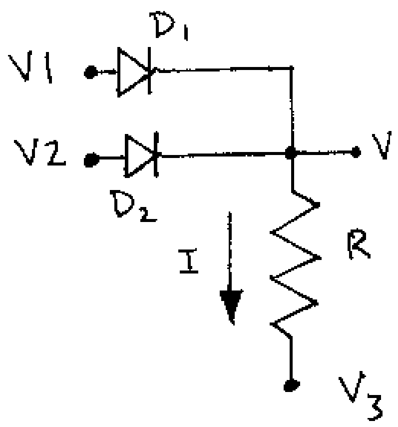
Problem 4 (22 points)   Diodes

Each of the diodes in the following circuits is ideal.

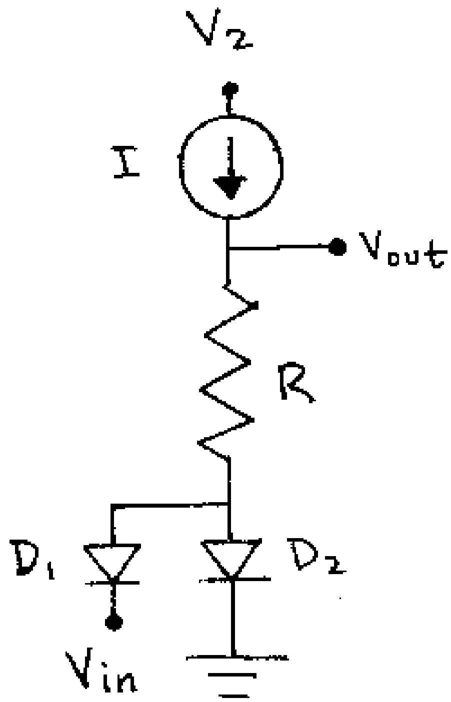
a. [6] Find I and V for this circuit (R = 8 kΩ, V+ = +4 V, V- = -3 V)



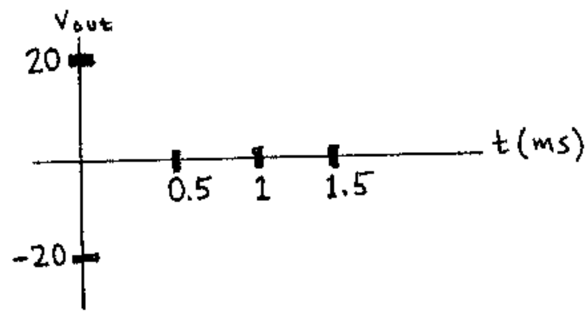
b. [8] Find I and V for this circuit (R = 3 kΩ, V1 = +1 V, V2 = +3 V, V3 = -3 V) and indicate which diodes are conducting and which are not conducting.



c. [8] The voltage v_{in} in the circuit below is a 1 kHz, 10 V peak-to-peak sine wave. I = 2 mA, V2 = +10 V, R = 1 kΩ. Sketch the waveform resulting at v_{out} and indicate the values of the positive and negative peaks.



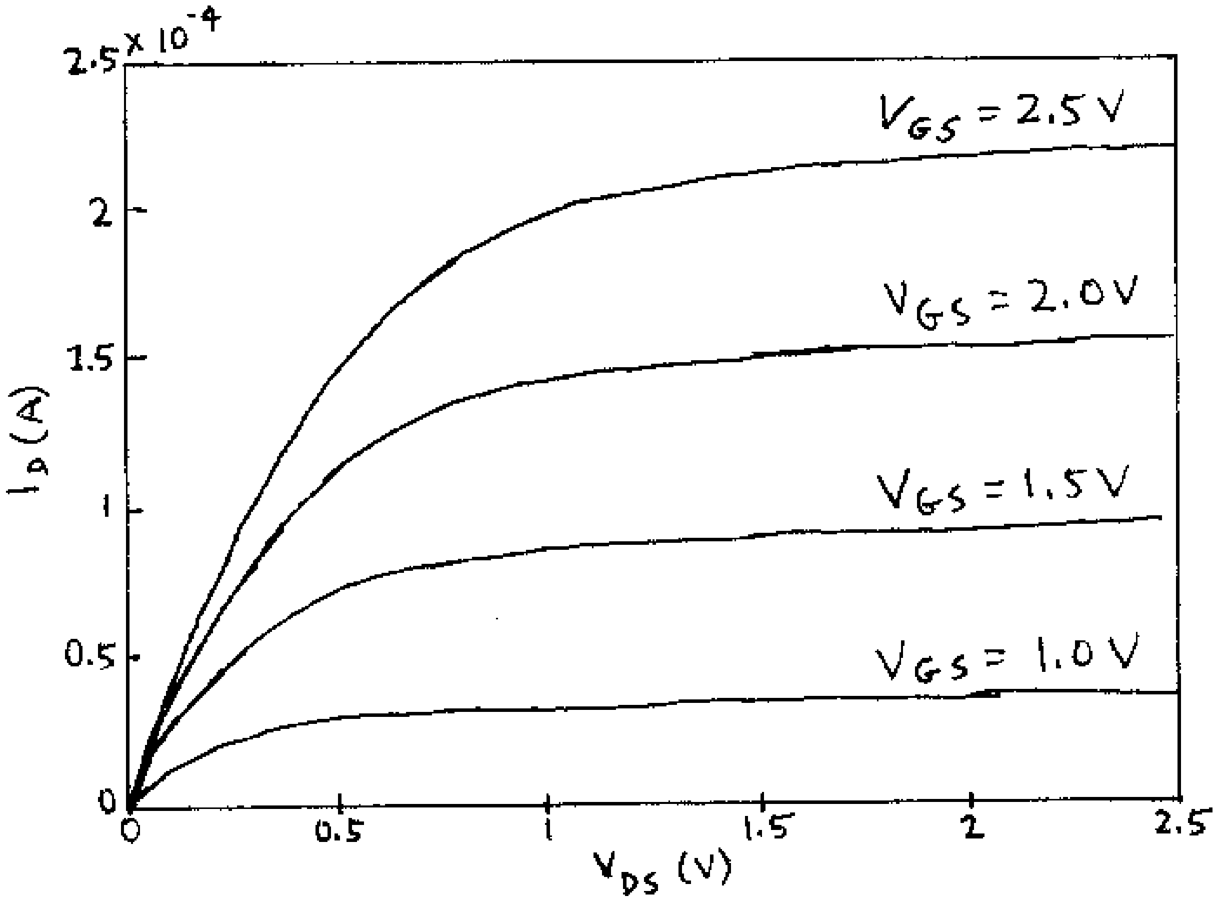
V2
I
Vout
R
D1
D2
Vin



Vout
20
-20
0.5
1
1.5
t (ms)

Problem 5 (23 points) MOSFET

A set of MOSFET characteristics is shown below. Assume that $V_T = 0.5$ V.



a. [3] Indicate and label the three regions of MOSFET operation:

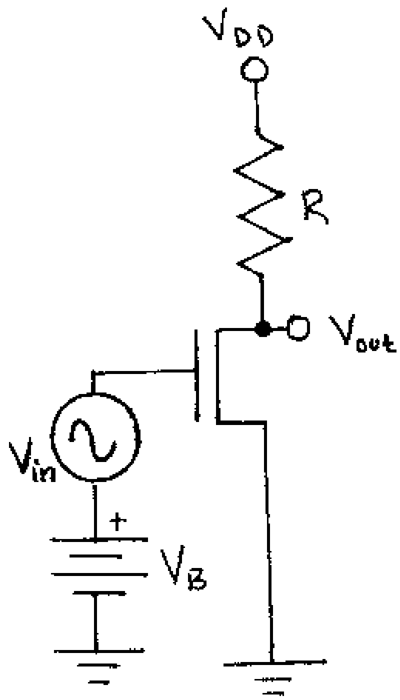
b. [6] Write equations for I_D (V_DS, V_{GS}) for each of the three regions and the conditions under which they apply. (Express your equations in unambiguous variables: μ, C_{ox}, W, L, …).

Region: __________ Equation:

Region: __________ Equation:

Region: __________ Equation:

The MOSFET is put in the circuit shown below ($V_B = 1.5$ V, R = 12.5 kΩ, $V_{DD} = 2.5$ V)



c. [2] Identify the terminals of the MOSFET.

d. [4] Draw the load line on the plot and find the Q point (I_{DQ}, V_{DSQ}).
I_{DQ} = __________ A V_{DSQ} = __________V

e. [4] Assume that you are considering using this circuit as an analog amplifier and are worried about distortion of the signals. For a positive excursion of v_{in} of 0.5 V how much does v_{out} change (positive or negative)? For a negative excursion of v_{in} of -0.5 V how much does v_{out} change (positive or negative)?

v_{out} for positive excursion of v_{in}: ________V
v_{out} for negative excursion of vin: ________V

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g. [4] Draw a simple two-component circuit that represents this MOSFET under the following two extreme conditions:

$V_{GS} - V_T > 0$, $V_{DS} < V_{GS} - V_T$:

$V_{GS} - V_T < 0$: