INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date .....24 – 09 – 2011 ....~~FN~~ / AN Time : 2 / ~~3~~ Hrs.   Full Marks ....60.....   No. of Students .... 352 ....

Autumn / ~~Spring~~ Semester .... Dept. .... **CSE, E&ECE, EE, IE** .... Sub. No. ...... **EC 21103** ....

... 2nd .... Yr. B. Tech. (H) / ~~B. Arch (H)~~ / ~~M. Sc.~~ Sub. Name .... **INTRODUCTION TO ELECTRONICS** ....

INSTRUCTIONS

1. All waveform sketches / diagrams must be neatly drawn and clearly labeled.
2. The final answers (numerical values with unit) should be underlined or enclosed within box.
3. Answers must be brief and to the point. Partial credit will be awarded for correct attempt.
4. For every problem, start your answer from a new page.
   Avoid writing answers of the various parts of a single question at different locations in your answer-script.
5. If needed, assume the following parameter values, unless a parameter value is specifically given with the problem:

Dielectric constants: $\varepsilon_0 = 8.854 \times 10^{-12}$ [F/m], ε_r of SiO_2 = 3.9	P-N junction forward cut-in voltage, $V_\gamma = 0.7$ [V]
Boltzmann Constant, k: 1.38×10^{-23} [J / K] = 8.617×10^{-5} [eV / K]	P-N junction forward-bias ON-voltage, $V_{D,ON} \approx 0.7$ [V]
Charge of an electron, $q = -1.602 \times 10^{-19}$ [C]	Diode large-signal forward resistance, $R_f = 0$ [Ω]
At room temperature or 300 K:	Diode break-down voltage, V_{BR} = infinite [V]
Intrinsic carrier concentration, $n_i = 1.0 \times 10^{10}$ [cm^{-3}]	Early voltage of BJT, V_A = infinite [V]
Thermal voltage, $V_{TH} = 25.9 \times 10^{-3}$ [V]	Gate-oxide capacitance, $C_{OX} = 30 \times 10^{-9}$ [F / cm^2]
P-N junction reverse saturation current, $I_S = 10^{-15}$ A	Channel-length modulation parameter of MOSFET, $\lambda = 0$ [V^{-1}]

6. For any value related to any device parameter or circuit parameter, which you may find not given with a problem, assume suitable value for such parameter.

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1. Problem on Semiconductor and Diode Circuits: 20 points

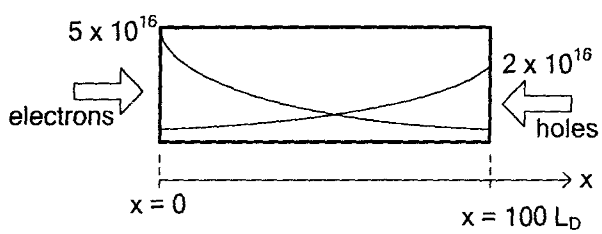

Figure 1. p-type Si bar

A p-type bar (Figure 1) subjected to electron injection from left and hole injection from right. Cross-sectional area of the bar is 2μm×2μm.

The carrier concentration profiles are exponential functions of x, which are given by:

Electron Profile, $n_p(x) = 5\times10^{16}\cdot e^{-\left(\frac{x}{L_D}\right)}$

Hole Profile : $p_p(x) = 2\times10^{16}\cdot e^{\left(\frac{x-100L_D}{L_D}\right)}$

Assume diffusion coefficient for electrons and holes, $D_n = 36\ cm^2/s$, $D_p = 12\ cm^2/s$

(1a) Compute the current, I, flowing through the bar. [4]

(1b) The diffusion current are changing along the bar. However, the current should be the same all along the bar. Are you violating any laws of Physics? Explain. [3]

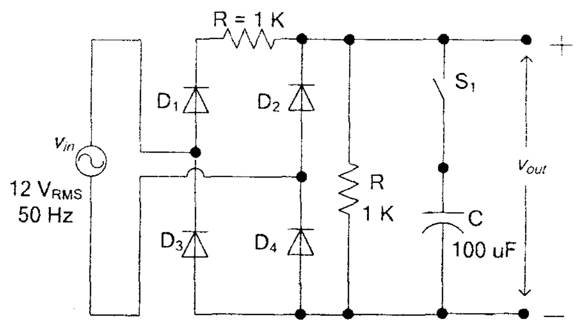

Figure 2. Full-wave bridge rectifier

For the full-wave rectifier in Figure 2, D_1, D_2, D_3, and D_4 have cut-in voltage, $V_\gamma = V_{DON} = 0.7V$.

(1c) Draw the input and output time-domain waveforms, when S_1 is open. [5]

(1d) S_1 is now closed. Draw the input and output time-domain waveforms. Compute the peak-to-peak ripple voltage. [3+5]

2. Problem on BJT Circuit: 20 points

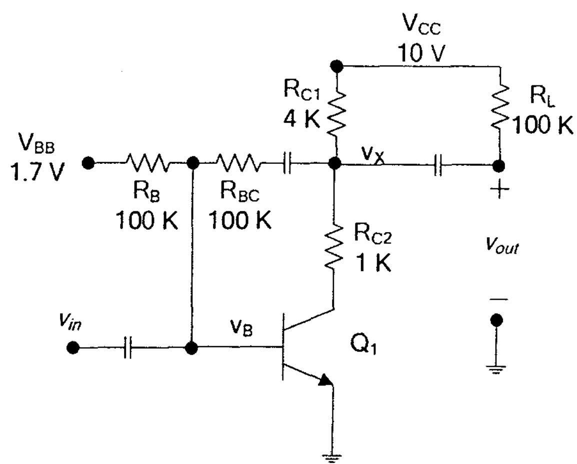

Figure 3. BJT Circuit

Consider the amplifier circuit using n-p-n BJT as shown in Figure 3.
$\beta = 100$, Early voltage (V_A) = infinite, $V_{BE,ON} = 0.7$ V
All capacitors are 100 μF.
Input waveform: $v_{in} = 10\cos(2\pi \,.\, 1KHz \,.\, t)$ mV

(2a) Calculate I_C, V_{CE}, g_m and r_π. [2 x 4]

(2b) Draw the small-signal circuit of the amplifier. [3]

(2c) Derive and compute the voltage gain, A_v. [5]

(2d) Draw the time-domain waveforms $v_B(t)$ and $v_X(t)$ [2+2]

3. Problem on MOSFET Circuits: 20 points

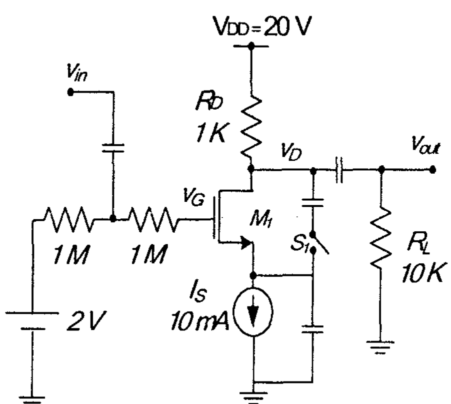

Figure 4. MOSFET Circuit

For the circuit in Figure 4: $V_{TN} = 1$ V, $\mu_n C_{OX} = 200\ \mu A / V^2$, $V_p = 1$ V, (W/L) = 75 / 1. All capacitors are 100 μF.
$v_{in} = 10\sin(2\pi \,.\, 1KHz \,.\, t)$ mV.
M_1 is a non-ideal MOSFET, whose saturation current is given by:

$$I_{D,SAT} = \left(\frac{2\mu_n C_{OX}}{3}\right)\left(\frac{W}{L}\right)\sqrt{V_p}\cdot\left[V_{GS} - V_{TN}\right]^{(3/2)}$$

(3a) Draw the DC equivalent circuit. Find out V_{DS}. [2]

(3b) Define transconductance, g_m, of a MOSFET. For the MOSFET M_1 in the circuit, compute g_m. [1+3]

(3c) Draw the small signal equivalent circuit. [3]

(3d) Compute the small-signal voltage gain, A_v. [3]

(3e) Draw $v_G(t)$ and $v_D(t)$ [3+3]

(3f) Draw $v_D(t)$ when the switch S_1 is closed. [2]