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# INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date:..........., FN/AN, Time: 2/~~3~~ Hrs., Full Marks: 30, No of students: 351
Majors: ECE/CSE/EE/IE/QE, 2nd yr B.Tech(H)/~~B.Arch(H)/M.Sc~~
Mid Semester Examination, Semester: Autumn/~~Spring~~, 2012
**Subject: Introduction to Electronics (EC21103)**

**NOTE:**

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. Assume the following parameter values, unless a parameter value is specifically given with the problem:

| | |
|---|---|
| Dielectric constants: $\epsilon_0 = 8.854 \times 10^{-12}[F/m]$, | Mobility of the holes $\mu_p = 500[cm^2/V.s]$ |
| $\epsilon_r$ of $SiO_2$ =3.9 | P-N junction reverse saturation current, $I_S = 10^{-15}[A]$ |
| Boltzmann Constant, $k = 1.38 \times 10^{-23}[J/K]$ | P-N junction forward cut-in voltage, $V_\gamma = 0.7[V]$ |
| $= 8.617 \times 10^{-5}[eV/K]$ | P-N junction forward-bias ON-voltage, $V_{DON} = 0.7[V]$ |
| Charge of an electron, $q = -1.602 \times 10^{-19}[C]$ | Diode large-signal forward resistance, $R_f = 0[\Omega]$ |
| **At room temperature or 300$K$:** | Diode break-down voltage, $V_{BR} = \infty[V]$ |
| Intrinsic carrier concentration, $n_i = 10^{10}[cm^{-3}]$ | Early voltage of BJT, $V_A = \infty[V]$ |
| Thermal voltage, $V_{TH} = 25.9 \times 10^{-3}[V]$ | Gate-oxide capacitance, $C_{OX} = 3 \times 10^{-8}[F/cm^2]$ |
| Mobility of the electrons, $\mu_n = 1400[cm^2/V.s]$ | Channel-length modulation parameter, $\lambda = 0[V^{-1}]$ |

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.

**1.** Select the correct answer and give proper justification: (5×1.5 marks)

(a) The built-in potential ($V_{bi}$) of a p-n junction depends largely on temperature (T) as:
(i) $\propto \sqrt{T}$.
(ii) $\propto T$.
(iii) $\propto T^2$.
(iv) independent of T.
(v) None of the others.

(b) A voltage $V_s = 10sin(100\pi t + \pi/4)V$ is given to the input of a half-wave rectifier circuit with a resistive load $(R) = 1K\Omega$ and a capacitative load $(C) = 20\mu F$. What will be the peak-to-peak ripple voltage of the output waveform?
(i) 9.3 V
(ii) 4.65 V
(iii) 5.88 V
(iv) 3.65 V
(v) None of the others.

(c) Which circuit out of Fig. 1(i) through Fig. 1(iv) corresponds to the input voltage and output voltage waveforms of Fig. 1($c$)?

(d) The npn transistor of Fig. 1($d$) is operating in forward active mode, where $V_{CE} = 1$ V. Assume $\beta = 100$. What is the value of $R$?
(i) 2000 Ω
(ii) 1900 Ω
(iii) 2100 Ω
(iv) 100 Ω
(v) None of the others.

(e) The circuit in Fig. 1(e) has one silicon diode (D1, $V_\gamma = 0.7\ V$) and one germanium diode (D2, $V_\gamma = 0.2\ V$). Find $v_{out}$.
(i) 3.14 mV pp
(ii) 0.203 V pp

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(iii) 795 $\mu$V pp
(iv) 314 $\mu$V pp
(v) None of the others.

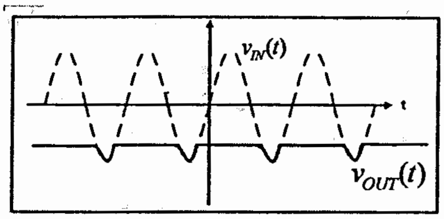


Fig. 1(c)

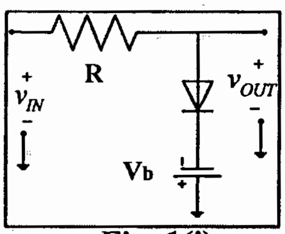


Fig. 1(i)

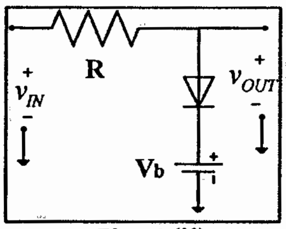


Fig. 1(ii)

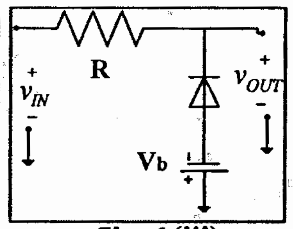


Fig. 1(iii)

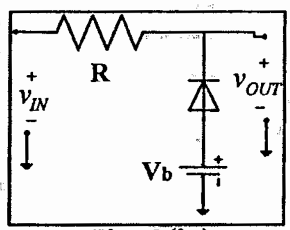


Fig. 1(iv)

2. Consider a sawtooth waveform with period T, which is given by $v(t) = 2t$ V for $0 \leq t < T$ and $v(t + nT) = v(t)$ for $t \geq T, n \in \{1, 2, 3, \ldots\}$. Find the ripple factor, which can be defined as $V_r(rms)/V_{dc}$. (3 marks)

3. Prove that $\beta = g_m r_\pi$ for the hybrid-$\pi$ BJT small signal model. Where $\beta$ = common emitter BJT current gain, $g_m$ = common emitter BJT transconductance, $r_\pi$ = small signal equivalent resistance between emitter and base terminals. (3 marks)

4. Find the currents (I) for the following two configurations, where lengths ($L_1$ = 1 cm, $L_2$ = 2 cm), cross-section areas ($A_1 = 1\ mm^2$, $A_2 = 0.25\ mm^2$) and doping densities ($N_D = 10^{17}/cm^3$, $N_A = 10^{16}/cm^3$) are given. The reverse saturation current of a p-n junction is given by $I_s = qAn_i^2(\frac{D_p}{L_p N_A} + \frac{D_n}{L_n N_D})$. $L_p$ = 10 cm, $L_n$ = 1 cm. (2,2 marks)

5. In the circuit diagram of Fig. 5 find (a) the conduction angle of D5, (b) the PIV (peak inverse voltage) of D5. (c) Draw the voltage waveform across the capacitor for two cycles of the input waveform. (2,2,1 marks)

6. Draw the voltage transfer characteristics ($v_{OUT}$ vs. $v_{IN}$) of the circuit given in Fig.6 for the input voltage range of (0 V-12 V). Identify the different ranges of $v_{IN}$ and $v_{OUT}$ for which the transistor is in cutoff, forward active and saturation respectively. $\beta = 100$. (5 marks)

7. Calculate the small-signal input resistance ($R_{in}$) and small-signal output resistance ($R_{out}$) of the circuit given in Fig. 7. $\beta_n = 100, \beta_p = 50, V_{Anpn} = 100$ V, $V_{Apnp} = 80$ V. (2.5,2.5 marks)

8. Prove that $i_D = \frac{1}{2}(\mu_n C_{ox})(\frac{W}{L})[(v_{GS} - V_t)v_{DS} - \frac{1}{2}v_{DS}^2]$ for an NMOS transistor in the triode region. (2.5 marks)

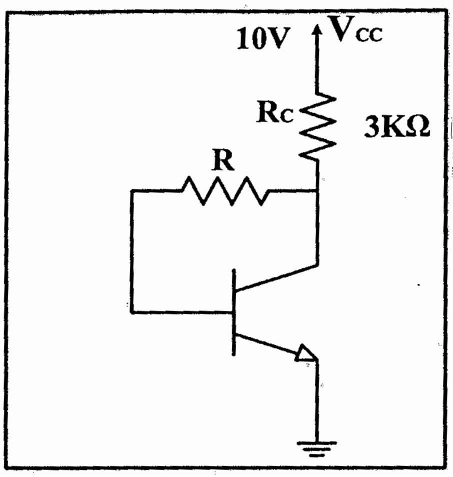


Fig. 1 (d)

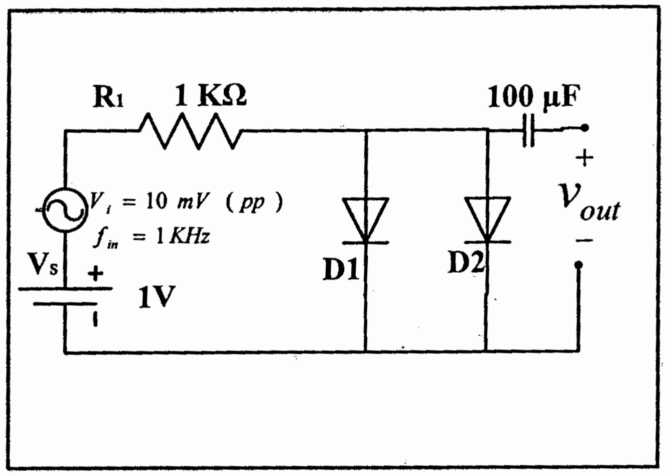


Fig: 1 (e)

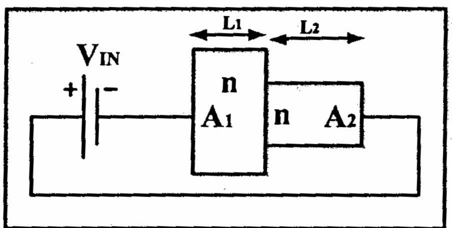


Fig. 4(a): n-n type

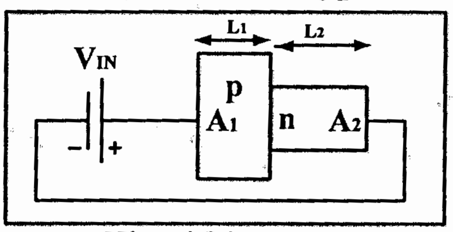


Fig. 4(b): p-n type

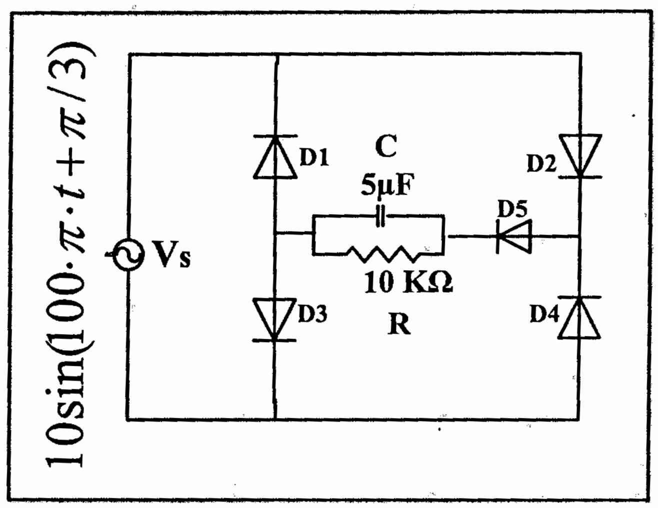


Fig. 5

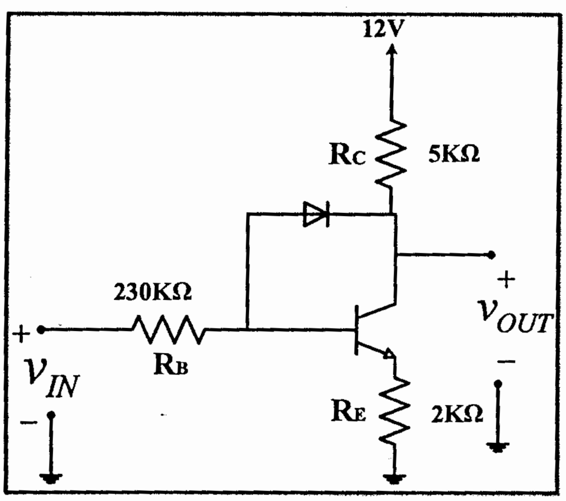


Fig. 6

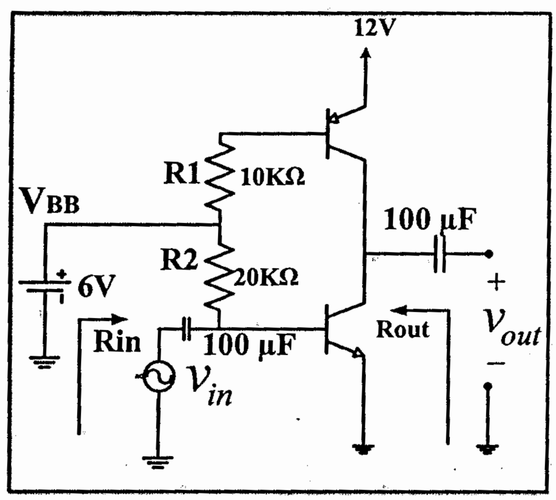


Fig. 7