2014-15  
B.TECH. (WINTER SEMESTER) EXAMINATION  
ELECTRONICS ENGINEERING  
MICROELECTRONICS  
EL-313

Maximum Marks: 60  
Credits: 04  
Duration: Three Hours

Answer all the questions.  
Assume suitable data if missing.  
Notations used have their usual meaning.

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>With the aid of suitable diagrams, explain the difference between Czochralski and Float Zone crystal growth processes. Which of these is preferred in the present day fabrication industry?</td>
<td>[08]</td>
</tr>
<tr>
<td>1(b)</td>
<td>How Dry Etching is performed using Reactive Ion and Sputter techniques?</td>
<td>[07]</td>
</tr>
</tbody>
</table>

(OR)

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<tr>
<td>1'(a)</td>
<td>Using the labelled diagrams, explain the difference between Contact, Proximity and Projection printing in the context of Optical Lithography.</td>
<td>[08]</td>
</tr>
<tr>
<td>1'(b)</td>
<td>Draw the schematic of electron-beam exposure system and thereafter explain the process of Electron Beam Lithography.</td>
<td>[07]</td>
</tr>
<tr>
<td>2(a)</td>
<td>Enumerate the advantages of BiCMOS technology over standard CMOS technology.</td>
<td>[08]</td>
</tr>
</tbody>
</table>
| 2(b)  | In the context of the fabrication of an 'on-chip' inductor,  
      i) What are technological options? Explain, in detail, the most suitable technology for its realization.                                      | [07] |
|      | ii) What range of inductance values is typically obtainable?                                                                                                                                            |      |

(OR)

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<th>M.M.</th>
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</table>
| 2'(a) | Write short technical notes on the following:  
      i) Ion Implanter  
      ii) Molecular Beam Epitaxy | [15] |

contd... 2
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>iii)</td>
<td>Latch-up in CMOS circuits</td>
</tr>
<tr>
<td>iv)</td>
<td>Characterization of Oxide thickness</td>
</tr>
<tr>
<td>v)</td>
<td>Wet etching</td>
</tr>
<tr>
<td>3(a)</td>
<td>Use suitable diagrams to support your answer, discuss the advantages and limitations of <em>Guard Ring</em> and <em>Trench</em> isolation techniques. [08]</td>
</tr>
<tr>
<td>3(b)</td>
<td>A floating capacitor of value 15pF is required for some application. How can this capacitor be implemented using metal-2 for the top plate? [07]</td>
</tr>
<tr>
<td>4(a)</td>
<td>Draw the colored layout diagrams for resistances, along with their metal contacts, of the following values: 100Ω and 560Ω. [07]</td>
</tr>
<tr>
<td>4(b)</td>
<td>The colored layout for the circuit shown below using the design rules for Double-Metal, Double-Poly, n-well, bulk CMOS process. [08]</td>
</tr>
</tbody>
</table>

![Circuit Diagram](attachment:diagram.png)
2014-2015
B.TECH WINTER (VI SEMESTER) EXAMINATION
(ELECTRONICS ENGINEERING)
EL-314-N
SEMICONDUCTOR DEVICE MODELING
CREDITS: 04

Maximum Marks: 60
Duration: Three Hours

<table>
<thead>
<tr>
<th>Qs</th>
<th>Instructions:</th>
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<tr>
<td></td>
<td>1. Attempt all questions</td>
</tr>
<tr>
<td></td>
<td>2. Make appropriate assumptions if required</td>
</tr>
<tr>
<td></td>
<td>3. Symbols and abbreviations have their usual meanings.</td>
</tr>
</tbody>
</table>

| Qs | Values of some constants: Energy gap for Si = 1.12 eV; Thermal voltage (kT/e = 25 mV at room Temp.); Permittivity of free space (\(\varepsilon_0 = 8.85 \times 10^{-14}\) F/cm); Permittivity of silicon (\(\varepsilon_{si} = 12 \varepsilon_0\)); Permittivity of oxide (\(\varepsilon_{ox} = 3.9 \varepsilon_0\)); \(N_C = 2.8 \times 10^{19}\) cm\(^{-3}\); \(N_V = 1.04 \times 10^{19}\) cm\(^{-3}\); \(n_I = 1.04 \times 10^{10}\) cm\(^{-3}\). |
|    | 1 (a) Explain the concept of hole. What is effective mass of hole? |
|    | 1(b) Draw the energy band diagram of Si and GaAs. Differentiate between direct and indirect band gap. |
|    | 1(c) On what factors does mobility of a semiconductor depend? Explain briefly. |
|    | 1(d) What is drift current? Give expression. Also give expression of electrical conductivity |
|    | 1(e) What is Hall effect? Obtain an expression for Hall coefficient. |

OR

1' (a) The carrier effective masses in a semiconductor are \(m^*_{n} = 0.62m_o\) and \(m^*_{p} = 1.4m_o\). Determine the position of the intrinsic Fermi level with respect to centre of band gap at \(T = 300\) K. Repeat if \(m^*_{n} = 1.10m_o\) and \(m^*_{p} = 0.25m_o\). |
|    | 1' (b) The electron concentration in silicon at \(T = 300\) K is \(n_o = 5 \times 10^4\) cm\(^{-3}\). Determine \(p_o\). Is this n-type or p-type material? Determine the position of the Fermi level with respect to the intrinsic Fermi level. |

| Marks | 3 | 3 | 3 | 3 | 3 | 5 | 5 | contd... 2 |
1. Consider a homogeneous gallium arsenide semiconductor at $T = 300 \text{ K}$ with $N_d = 10^{16} \text{ cm}^{-3}$ and $N_a = 0$. Calculate the thermal equilibrium values of electron and hole concentrations. For an applied electric field of $10 \text{ V/cm}$, calculate the drift current density. Repeat if $N_d = 0$ and $N_a = 10^{16} \text{ cm}^{-3}$.

$$\mu_p = 500 \text{ cm}^2/\text{V.s} \quad \text{and} \quad \mu_n = 1000 \text{ cm}^2/\text{V.s}.$$ 

2. (a) Draw the energy band diagram of a $p^+ n$ junction under the condition of

- no bias
- forward bias
- reverse bias

also, draw the charge and electric field distribution under no bias.

2. (b) What is the ideal Schottky barrier height? Indicate the Schottky barrier height on energy band diagram. For a metal-semiconductor diode, calculate theoretical Schottky barrier height, built-in potential barrier and maximum electric field for zero applied bias. Consider the contact between tungsten and $n$-type silicon with $N_d = 10^{16} \text{ cm}^{-3}$ and $\phi_m = 4.55 \text{ eV}$. The value of electron affinity for silicon is $\chi = 4.01 \text{ eV}$.

OR

2. (a) What is a hetero junction, explain electron affinity rule. Draw the energy band diagram of $nN$ and $Np$ hetero junction.

2. (b) Consider two $p n$ junction at $T = 300 \text{ K}$ reverse biased at $V_r = 5\text{ V}$. The impurity doping concentrations in junction-A: $N_d = 10^{15} \text{ cm}^{-3}$ and $N_a = 10^{18} \text{ cm}^{-3}$ and

junction-B: $N_d = 10^{18} \text{ cm}^{-3}$ and $N_a = 10^{16} \text{ cm}^{-3}$. Calculate the ratio of the total depletion width, maximum electric field and junction capacitance per unit area for junction-A to junction-B.

3. Discuss any five of the following.

- Principle of Operation of BJT
- Energy Band Diagram in various modes of operation
- Current components in active mode of operation
- Derive the expression of $I_C$ as function of $V_{BE}$
- Derive the expression for $\alpha_T$, $\gamma$ and $\delta$
- How base width modulation is incorporated in Gummel-Poon model
- Breakdown in BJTs
4(a) With sketches (energy band diagrams) explain the working of a MOS capacitor and different regions of operation.

4(b) Explain the C-V characteristics of MOS capacitor and MOSFET. A Typical C-V Curve is shown below. Assume appropriate values and extract all parameters from this C-V curve. \( N_a = 10^{16} \text{ cm}^{-3}, \ C_{ox} = 1.15 \times 10^{-7} \text{ F cm}^{-2}, \ V_{FB} = -0.5V \)
1. What are the methods for the optimal control systems studies?
Find the extremal of the functional:

\[ J(x) = \int_{0}^{\pi/4} (x_1'^2 + x_2'^2 + x_1x_2) dt \]

the ICs are \( x_1(0) = 0, x_1(\pi/4) = 1, x_2(0) = 0, x_2(\pi/4) = -1 \)

2. State the Nyquist stability criterion.
A unity feedback control system has its open-loop transfer function as:

\[ G(s) = \frac{60}{(s + 4)(s^2 + 2s + 5)} \]

Draw the complete Nyquist plot and hence, determine the stability of the system.

OR

2'. Draw the complete root-locus diagram for the following open-loop transfer function, indicating all the steps clearly:

\[ G(s)H(s) = \frac{K(s + 2)}{s(s + 3)(s^2 + 2s + 2)} \]
3. The open-loop transfer function of a unity feedback system is \( G(s) = \frac{K}{s(s+2)} \). Design a suitable compensator so that the velocity steady state error constant should be 20 and phase and gain margins should be more than 50° and 10 db respectively.

OR

3'. What are PID controllers? Indicate their effects on the system's performance. Find the error-rate factor, \( K_e \) to make the damping ratio equal to 0.5 for the system shown.

![Control System Diagram]

4. Define controllability and observability of a control system. Test the controllability and observability of the system described by the following state equations:

\[
\begin{bmatrix}
\dot{x}_1 \\
\dot{x}_2 \\
\dot{x}_3
\end{bmatrix} = \begin{bmatrix}
3 & -2 & -1 \\
1 & 0 & 1 \\
0 & 0 & -1
\end{bmatrix} \begin{bmatrix}
x_1 \\
x_2 \\
x_3
\end{bmatrix} + \begin{bmatrix}
0 & 1 \\
1 & 0 \\
0 & 1
\end{bmatrix} [u(t)]
\]

\[
\begin{bmatrix}
Y_1 \\
Y_2
\end{bmatrix} = \begin{bmatrix}
0 & 1 & 0 \\
1 & 0 & 1
\end{bmatrix} \begin{bmatrix}
x_1 \\
x_2 \\
x_3
\end{bmatrix}
\]

5. What are the methods of analysis for nonlinear control systems?

For a unity feedback control system, if an ideal relay with an output equal to unity has its describing function as \( N = \frac{4}{\pi} \angle 0^\circ \), is operating in cascade with the linear system having \( G(s) = \frac{10}{s(s+1)(s+2)} \), in the forward path. Determine the amplitude and frequency of the limit cycle, if it exists.
1. (a) How can you use the MATLAB function freqz to compute the DTFT of a sequence?

(b) Find the impulse responses of the following systems:
   (i) Ideal delay system
   (ii) Moving average system
   (iii) Accumulator
   (iv) Forward difference system

and hence obtain the frequency responses (both magnitude and phase) of the systems.

OR

(b') Sampling a continuous time signal \( x_d(t) \) for 1 sec generates a sequence of 4096 samples

(i) What is the highest frequency in \( x_d(t) \) if it was sampled without aliasing?

(ii) If a 4096-point DFT of the sampled signal is computed, what is the frequency spacing in Hz between the DFT samples?

(iii) Suppose that we are only interested in the DFT samples that correspond to frequencies in the range \( 200 \leq f \leq 300 \) Hz. How many complex multiplications are required to evaluate these values computing DFT directly and how many are required if decimation-in-time FFT is used?

(iv) How many frequency samples would be needed in order for FFT algorithm to be more efficient than evaluating DFT directly?
(c) Given $x[k]$, an 8-point DFT of the sequence

$$x[n] = \begin{cases} 
1 & 0 \leq n \leq 3 \\
0 & 4 \leq n \leq 7 
\end{cases}$$

Compute DFT of the sequences:

(i) $x_1[n] = \begin{cases} 
1 & n = 0 \\
0 & 1 \leq n \leq 4 \\
1 & 5 \leq n \leq 7 
\end{cases}$

(ii) $x_2[n] = \begin{cases} 
0 & 0 \leq n \leq 1 \\
1 & 2 \leq n \leq 5 \\
0 & 6 \leq n \leq 7 
\end{cases}$

2 (a) Find the transfer function $H(z)$ of the minimum phase system that has a squared magnitude frequency response given by

$$|H(e^{j\omega})|^2 = \frac{\frac{5}{4} - \cos \omega}{\frac{10}{9} - \frac{2}{3} \cos \omega}$$

(b) Consider the filter described by the following difference equation

$$y[n] = 0.9y[n-1] + bx[n]$$

(i) Determine $b$ so that $|H(e^{j\omega})| = 1$

(ii) Determine the frequency at which $|H(e^{j\omega})| = 1/\sqrt{2}$.

(iii) Is this filter lowpass, bandpass or highpass?

(c) A second order IIR filter structure is shown in Fig - 1. Find the system function $H(z)$ and realize it in Direct Form II.

(c') Develop a relationship between the poles of an analog and a digital filter using impulse invariant transformation. Also give an expression that relates the frequency responses of these filters. What is the disadvantage of impulse invariant method over bilinear transformation?
3 (a) List the important advantages of FIR over IIR filters. Suggest a scheme of realizing a linear phase FIR filter with lesser number of multipliers than in direct form structure.

(b) Classify the linear phase filters on the basis of their length and symmetry of impulse response. Derive an expression for the frequency response of a linear phase FIR system that has even length and antisymmetric impulse response.

(c) Show that the length $2N+1$ Bartlett window sequence given by

$$w[n] = 1 - \frac{|n|}{N+1}, \quad -N \leq n \leq N$$

can be obtained by linear convolution of two scaled length-$M$ rectangular windows. Determine $M$ and the scale factor.

OR

(c') The ideal Hilbert transformer is characterized by the frequency response

$$H(e^{j\omega}) = \begin{cases} j & -\pi < \omega < 0 \\ -j & 0 < \omega < \pi \end{cases}$$

Design the Hilbert transformer using Hamming window of length 7.

4. (a) Develop the signed-digit representation of the following binary numbers

(i) $0.11101101$  
(ii) $0.10101111$

(b) The first order filter shown in Fig - 2 is implemented in four bit (including sign bit) fixed point 2's complement fractional arithmetic. Products are rounded to 4-bit representation. Using the input $x[n]=0.1078[n]$, determine

(i) The first five outputs if $a=0.5$. Does the filter go into a limit cycle?
(ii) The first five outputs if $a=0.75$. Does the filter go into a limit cycle?

(b') Determine the poles sensitivity, due to finite word length effect, of the IIR structure shown Fig - 1.

(c) Discuss a few applications of multirate systems. Give the time and frequency domain description of upsampler and downsampler.
Q.No. | Question                                                                                                                                                                                                 | M.M.
--- | ------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------- | ---
1(a) | With the help of appropriate examples, clearly differentiate between a physical address and a network address.                                                                                       | 03
1(b) | Suppose a user has two browser applications active at the same time and suppose that two applications are accessing the same server to retrieve HTTP documents at the same time. How does the server tell the difference between the two applications? | 03
1(c) | Suppose we want to transmit the message 1011001001001011 and protect it from error using CRC-8 polynomial $x^8 + x^2 + x + 1$. Find the code-word that should be transmitted. Suppose the leftmost bit of the code-word is inverted due to noise. What does the receiver obtain when it does its error checking? | 04
1(d) | A 64 kB (kilobyte) message is to be transmitted from the source to the destination, as shown below. The network limits packets to a maximum size of 2 kB, and each packet has a 32-byte header. The transmission lines in the network have a bit error rate of $10^{-6}$, and Stop-and-Wait ARQ is used in each transmission line. How long does it take on the average to get the message from the source to the destination? Assume that signal propagates at a speed of $2 \times 10^8$ m/sec. | 05

![Fig. for Q. 1(d)](image-url)
1(d') Find the optimal frame length \( n_f \) that maximizes the transmission efficiency of a Go-Back-N ARQ for a channel with random bit error.

2(a') In a LAN, which MAC protocol has higher efficiency: ALOHA or CSMA-CD? What about in a WAN? Explain.

2(b) For a 100 Mbps token ring network with a ring latency of 200 \( \mu \)sec that allows each station to transmit one 1 kilobyte (kB) packet each time possess the token, calculate the maximum achievable throughput that any host can achieve. Assume multi-token frame insertion scheme.

2(c) Derive the expression for maximum achievable throughput for a reservation based scheduling scheme that uses slotted ALOHA for minislot reservation.

2(d) Calculate one-way normalized delay-bandwidth product and throughput for a Gigabit Ethernet switch with stations at 100 m distance and average frame size of 1500 bytes.

OR

2'(a) What is hidden terminal problem in wireless LANs? How it is avoided in IEEE 802.11?

2'(b) Suppose the maximum round trip propagation delay for 10 Mbps Ethernet is 46.4 \( \mu \)sec. This yields a minimum packet size of 512 bits (464 bits corresponding to propagation delay, plus 48 bits of jam signal). What will be the minimum packet size if propagation delay is held constant and data rate rises to 100 Mbps? What should the maximum propagation delay be if we would like to keep the minimum packet size of 512 bits (for compatibility reasons)?

2'(c) Suppose that a 1MHz channel can support a 1 Mbps transmission rate. The channel is to be shared by 10 stations. Each station receives frame with exponential inter-arrivals and rate \( \lambda =50 \) frames/sec and frames are of constant length \( L=1000 \) bits. Compare the total frame delay of a system that uses FDMA to a system that uses TDMA.
2'(d) Discuss the effect of delay-bandwidth product on maximum achievable throughput of ALOHA, slotted ALOHA and CSMA/CD.

3(a) Explain the basic concept of Leaky Bucket algorithm used for policing. With the help of suitable flow chart, explain its working.

OR

3(a') Draw the internal structure of a generic packet switch. Explain the function of each component in it. Also, draw the internal organization of a line card.

3(b) Suppose that a datagram packet-switching network uses headers of length H bytes and a virtual-circuit packet-switching network uses headers of length h bytes. Each network transmits packets over an L-hop path with R bits/sec transmission rate at each link. Determine the length M of a message for which the virtual-circuit switching delivers the packet in less time than datagram switching does. Assume packets in both networks are of the same length, and all packets follow same path. Ignore the queuing and processing delays.

OR

3(b') A stage of an n x n banyan network consists of (n/2) 2 x 2 switching elements. The first stage directs packets to the correct half of the network, the next stage to the correct quarter, and so on, until the packet is routed to the correct output. Derive an expression for the number of 2 x 2 switching elements needed to make an n x n banyan network. Verify your answer for n = 8.

3(c) For the network shown in the figure below, use Bellman-Ford algorithm to find the set of shortest paths from all nodes to destination node E.

![Network Diagram](image)

Fig. for Q. 3(c)

OR

contd .... 4
3(c') For the network shown in the figure below, use link-state (Dijkstra’s) algorithm to find the set of shortest paths from node A to other nodes and build the routing table for node A.

![Network Diagram](image)

Fig. for Q. 3(c')

4(a) Identify the address class of the following IP addresses: 200.58.20.165; 128.167.23.20.

4(b) Abbreviate the following IPv6 addresses:
   (i) 0000:0000:0000:AF36:7328:0000:87AA:0398
   (ii) 2819:00AF:0000:0000:0000:0035:0CB2:B271

4(c) Suppose a TCP message that contains 2048 bytes of data and 20 bytes of TCP header is passed to IP for delivery across a network. The IP layer forwards the packet to link layer with an MTU of 512 bytes (including 20 bytes of IP header). Calculate the fragment sizes, fragment offsets and MF flag values in each fragment.

4(d) Suppose a router has built up the routing table given below. The router can deliver packets directly over interfaces 0 and 1 or can forward the packets to routers R2, R3 or R4. Assume the router does the longest prefix match. Describe what the router does with a packet addressed to each of the following destinations:
   (i) 128.96.171.92 (ii) 128.96.167.151 (iii) 128.96.163.151

Routing Table for Q. 4(d)

<table>
<thead>
<tr>
<th>Subnet Address</th>
<th>Subnet Mask</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>128.96.170.0</td>
<td>255.255.254.0</td>
<td>Interface 0</td>
</tr>
<tr>
<td>128.96.168.0</td>
<td>255.255.254.0</td>
<td>Interface 1</td>
</tr>
<tr>
<td>128.96.166.0</td>
<td>255.255.254.0</td>
<td>R2</td>
</tr>
<tr>
<td>128.96.164.0</td>
<td>255.255.252.0</td>
<td>R3</td>
</tr>
<tr>
<td>Default</td>
<td></td>
<td>R4</td>
</tr>
</tbody>
</table>
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OPTOELECTRONICS
EL-352N

Maximum Marks: 60  Credits: 04  Duration: Three Hours

Answer all the questions.
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Q.No.  Question  M.M.
1(a).  Define binary, ternary and quaternary semiconductor materials. Give examples also.  [5]
1(b).  What do you understand by heterojunction LEDs? Explain with suitable diagrams.  [5]
1(c).  Derive expression for the overall quantum efficiency of LASER diode.  [5]

OR

1'(a).  What are different types of LASER diodes? Discuss any one of them.  [5]
1'(b).  A double-heterojunction InGaAsP LED emitting at a peak wavelength of 1310 nm has radiative and non-radiative recombination times 25 ns and 90 ns, respectively. The drive current is 35 mA.
   (i)  Find internal quantum efficiency and internal power level.
   (ii) If the refractive index of the light source material is n=3.5, find the power emitted from the device.

1'(c).  Differentiate between surface emitting LEDs and edge emitting LEDs.  [5]

2(a).  A given silicon avalanche photodiode (APD) has quantum efficiency of 65% at a wavelength of 900 nm. Suppose 0.5 µW of optical power produces a multiplied photocurrent of 10 µA. Find out the multiplication factor of the APD.  [5]
2(b).  Discuss about the design structure and principle of operation of SOLAR cells.  [5]

OR

2(b').  Write about the basic principle of operation of PIN diode.  [5]
2(c).  What are opto-couplers? Explain briefly.  [5]
3(a). What are the advantages of optical amplifiers over electronic amplifiers? Also list the applications of optical amplifiers.

3(b). What is erbium doped fiber amplifier (EDFA)? With suitable diagrams, explain how amplification is obtained in EDFA?

OR

3(b'). Discuss about the structure and operation of semiconductor optical amplifiers.

3(c). Write brief note on opto-electronic integrated circuits (OEICs)?

4(a). Explain how do phase and amplitude modulation is achieved in Electro-Optic modulators?

4(b). What is "SEED"?

4(c). Differentiate between absorptive and refractive properties of optical devices used for modulations.