

# ELECTRONICS AND TELECOMMUNICATION ENGINEERING

## Paper - II

Time Allowed : Three Hours

Maximum Marks : 300

### Question Paper Specific Instructions

*Please read each of the following instructions carefully before attempting questions :*

*There are **EIGHT** questions divided in **TWO** sections.*

*Candidate has to attempt **FIVE** questions in all.*

*Questions No. 1 and 5 are **compulsory** and out of the remaining, any **THREE** are to be attempted choosing at least **ONE** question from each section.*

*The number of marks carried by a question / part is indicated against it.*

*Wherever any assumptions are made for answering a question, they must be clearly indicated.*

*Diagrams / figures, wherever required, shall be drawn in the space provided for answering the question itself.*

*Unless otherwise mentioned, symbols and notations have their usual standard meanings.*

*Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly.*

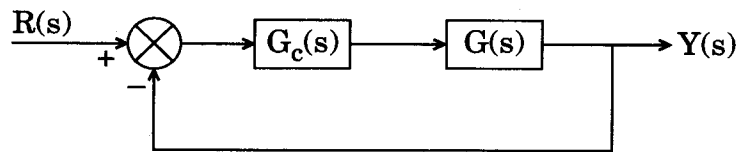
*Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.*

*Answers must be written in **ENGLISH** only.*

## SECTION A

- Q1. (a)** A certain speech signal is sampled at 8 kHz and coded with DPCM, the output of which belongs to a set of 8 symbols  $s_1 - s_8$ . The probabilities of these symbols are  $p(s_1) = 0.4$ ,  $p(s_2) = p(s_3) = 0.2$ ,  $p(s_4) = 0.1$ ,  $p(s_5) = 0.05$ ,  $p(s_6) = p(s_7) = 0.02$  and  $p(s_8) = 0.01$ . Calculate the entropy in bits/sec. If all the symbols are equiprobable, what will be the entropy ? 10

- (b) In the figure shown below,  $G(s) = \frac{K}{(\tau s + 1)}$  has a time constant of 0.5 seconds, and has unity DC gain. An integral controller is placed in forward path as  $G_c(s) = \frac{K_1}{s}$  such that the open loop transfer function  $G(s) G_c(s)$  has a velocity error constant  $K_V = 1$ . Find the sensitivity of the closed loop system transfer function with respect to  $K_1$  at  $\omega = 1$  rad/sec. 10



- (c) List and define various scheduling performance criteria used for comparing various CPU-scheduling algorithms. Compute and compare the average process waiting time of First come First serve, Shortest task first and Priority scheduling algorithms for the processes with their details as listed in the table. 10

Process	Arrival Time	Burst Time	Priority
$P_0$	0	3	1
$P_1$	2	2	2
$P_2$	3	4	3
$P_3$	4	7	1

- (d) A uniform plane wave is propagating in z-direction with velocity  $1.4 \times 10^8$  m/s in a perfect dielectric medium of intrinsic impedance  $474 \Omega$ . If  $E_x(z, t) = 1750 \cos(10^6 \pi t - \beta z)$  V/m represents instantaneous electric field, what will be the magnetic field ? Determine the wavelength and average power of the wave. 10

(e) Processor technology deals with computation architectures whereas IC technology deals with implementation style for a given functionality. What are the different processor and IC technologies ? Is processor technology orthogonal to IC technology or interdependent with IC technology ? Justify your answer. 10

(f) Explain the following terms :

- (i) Modal Birefringence
- (ii) Coherence Length
- (iii) Beat Length

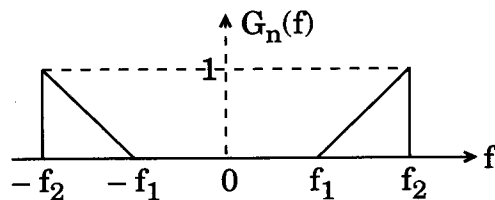
The difference between the propagation constants for the two orthogonal modes in the single mode fiber is 250. It is illuminated with light of peak wavelength 1.55  $\mu\text{m}$  from an injection laser source with a spectral width of 0.8 nm. Calculate Modal Birefringence, Coherence Length and Beat Length. 10

**Q2.** (a) Narrow band noise  $n(t)$  having bandwidth  $2B$  centered at  $f_0$  is expressed as  $n(t) = n_I(t) \cos(2\pi f_0 t) - n_Q(t) \sin(2\pi f_0 t)$ , where  $n_I(t)$  and  $n_Q(t)$  are inphase and quadrature components respectively.

(i) Draw the block diagram of the scheme and show the extraction of  $n_I(t)$  and  $n_Q(t)$  from  $n(t)$ . 6

(ii) If  $G_n(f)$  is power spectral density (PSD) of  $n(t)$ , derive expressions in terms of  $G_n(f)$  for PSD of  $n_I(t)$  and  $n_Q(t)$ . 8

(iii) If  $G_n(f)$  is as shown, sketch PSD of  $n_I(t)$  assuming  $f_0 = f_1$ . 6



(b) For a unity feedback system with  $G(s) = \frac{3s + \alpha}{s(s + 1)(s + 5)}$ , draw the root locus plot as parameter  $\alpha$  varies from 0 to  $\infty$ . Also find the value of parameter  $\alpha$  for which the closed loop system becomes unstable. From the root locus plot, obtain approximate location of the system poles with  $\xi = 0.707$ . 20

- (c) Memory sub-system for a product has been designed with 3-level memory hierarchy within a budget of ₹ 22,000. The known and unknown parameters for the design are tabulated below :

Memory Type	Access Time	Capacity	Cost per kilobyte in ₹
Cache	5 ns	1 MB	1
Main Memory	-	128 MB	0.1
Solid State Drive (SSD)	5 μs	-	0.001

The design achieved an effective memory access time of 20 ns with cache hit ratio 0.95 and main memory hit ratio 0.99. The SSD can be only in integer powers of 2 in GB.

Find out the missing parameters in the above table.

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- Q3.** (a) In a particular AM system, quadrature modulation is used where the inphase carrier modulates  $(m_1(t) + V_0)$  and quadrature carrier modulates  $m_2(t)$ , where  $m_1(t)$  and  $m_2(t)$  are low pass band-limited message signals and  $V_0$  is constant.

(i) Write the expression for quadrature AM signal.

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(ii) Assuming  $V_0$  is large, show that  $m_1(t)$  can be recovered using envelope detector.

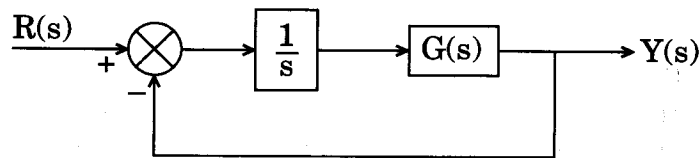
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(iii) Propose a coherent demodulation scheme and show the recovery of  $m_2(t)$ .

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- (b) For the unity feedback system shown in the figure, the plant  $G(s)$  has a step response of  $(3 - 6e^{-2t} + 3e^{-4t}) u(t)$  and it is placed in cascade with a block of gain  $\frac{1}{s}$ . Sketch the Nyquist plot of the system and find its gain and phase margins. Also comment whether the closed loop system is stable or not.

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- (c) Design a 4-bit arithmetic circuit with one selection variable  $s$  and two four-bit data inputs  $A$  and  $B$ . The circuit generates the following four arithmetic operations in conjunction with the input carry  $C_{in}$ . Draw the logic diagram for the following :

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S	$C_{in} = 0$	$C_{in} = 1$
0	$D = A + B$	$D = A - B$
1	$D = A + 1$	$D = A - 1$

**Q4.** (a) Twelve different audio signals each band-limited to 10 kHz are to be multiplexed and transmitted.

(i) TDM is used with flat top samples of 1  $\mu$ sec duration and with provision of one extra pulse of 1  $\mu$ sec duration for synchronisation. If sampling is at Nyquist rate, calculate the spacing between successive samples of TDM signal. What is the bandwidth of this TDM signal? 12

(ii) If the audio signals are multiplexed using FDM and transmitted using AM – SSB, what is the minimum bandwidth required? 8

(b) Given a system with transfer function  $G(s) = \frac{10}{(s+1)(s+4)}$ , find its equivalent state space phase variable canonical representation in the form  $\dot{x} = Ax + Bu$ ,  $y = Cx + Du$ . Also design a state feedback controller  $u = Kx$  such that the system admits a peak response  $M_{pw} = 1.25$  in frequency domain and a peak time  $t_p = 3.53$  seconds in time step response. 20

(c) Following Register Transfer statements provide the operations to be performed with flip-flop F :

$$X_1T_1 : F \leftarrow 0$$

$$X_2T_2 : F \leftarrow 1$$

$$X_3T_3 : F \leftarrow G$$

$$X_4T_4 : F \leftarrow \bar{F}$$

In all other conditions, the contents of F do not change. Using J-K flip-flops, draw the logic diagram showing connections of the gates that implement control function for F. 20

## SECTION B

- Q5. (a)** Band-limited message signal  $m(t)$  is encoded using PCM system which uses uniform quantizer and 8-bit binary encoding. If the bit rate is 56 Mb/sec, what is the maximum bandwidth of  $m(t)$  for satisfactory operation ?

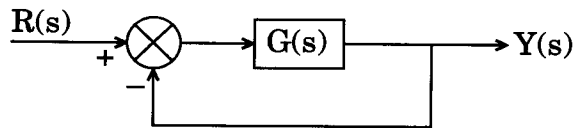
Calculate signal to quantization noise ratio if  $m(t)$  is full load single tone sinusoidal signal of frequency 1 MHz. 10

- (b) For a unity feedback system shown in the figure,  $G(s) = \frac{K}{s(s + \alpha)}$  has resonant frequency ' $\omega_r$ ' which is  $\frac{1}{\sqrt{2}}$  times the damped frequency ' $\omega_d$ '.

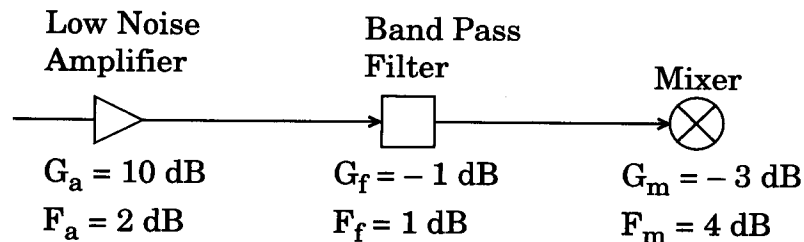
$G(s)$  also has a settling time of  $2\sqrt{3}$  seconds, for a 2% tolerance band in its time step response. Calculate the following :

- (i) Undamped natural frequency
- (ii) Decay rate
- (iii) Peak overshoot
- (iv) Steady state error for the input  $r(t) = t \cdot u(t)$

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- (c) The block diagram of a wireless receiver front end is shown below :



- (i) Compute the overall Noise Figure of the sub-system.
- (ii) Compute equivalent noise temperature (overall) assuming system temperature  $T_0 = 290 \text{ K}$ .
- (iii) Compute overall gain.
- (iv) Compute output noise power assuming input noise power from the feeding antenna at 150 K temperature and 1 F.
- (v) Bandwidth of 10 MHz.
- (vi) Compute input power if we require minimum signal to noise ratio of 20 dB.
- (vii) Compute minimum signal voltage assuming characteristic impedance of 150  $\Omega$ .

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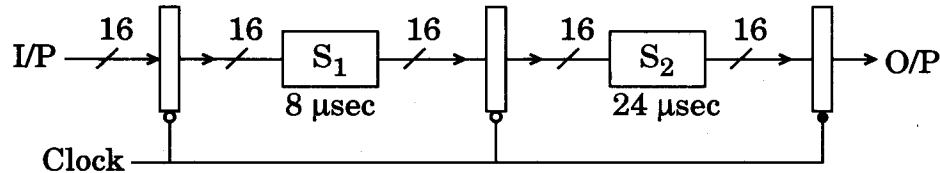
- (d) Normalised radiation intensity of an antenna is given by

$$\begin{aligned}
 U_n(\theta) &= 1, \quad 0 \leq \theta < 30^\circ \\
 &= \frac{\cos \theta}{0.866}; \quad 30^\circ \leq \theta < 90^\circ \\
 &= 0; \quad 90^\circ \leq \theta \leq 180^\circ
 \end{aligned}$$

It is independent of  $\Phi$ .

Determine exact directivity and maximum aperture area at operating frequency of 900 MHz. 10

- (e) The figure shown below indicates a two-stage pipeline with stage delays indicated below the stages. Latch delays are to be ignored.



- (i) Calculate throughput and latency of the pipeline shown above. 5

- (ii) The pipeline stage 2 is now split in three equal sub-stages. Find out the new throughput and latency for the complete pipeline. 5

- (f) An isolator has an insertion loss of 0.5 dB and an isolation of 30 dB. Determine the scattering matrix of the isolator if the isolated ports are perfectly matched to the junction. 10

- Q6.** (a) Lossless transmission line operating at 30 MHz has inductance  $L = 1 \mu\text{H/m}$  and capacitance  $C = 100 \text{ pF/m}$ . Quarter wave transformer line is used to couple this transmission line to different loads for impedance matching.

- (i) Calculate the characteristic resistance of the quarter wave line if load is an antenna offering pure resistance of  $70 \Omega$ . 8

- (ii) If load is  $Z_L = 150 + j100 \Omega$ , determine the characteristic resistance of the quarter wave line. 12

- (b) Consider a CMOS schematic for 2-input NOR gate.

Design appropriate test scheme to check the following faults through control/observation of voltage/current levels at Input/Output/supply.

- (i) One pMOS transistor stuck open 10

- (ii) One nMOS transistor stuck short 10

- (c) Write the expression for signal to noise ratio for PIN diode. A silicon PIN photodiode incorporated into the optical receiver has a quantum efficiency of 65% when operating at wavelength of  $0.9 \mu\text{m}$ . The dark current at this point is 3 nA and load resistance is  $4 \text{ k}\Omega$ . The post detection bandwidth of the receiver is 5 MHz and the thermal noise temperature is  $20^\circ\text{C}$ . If the overall signal to noise ratio is 5 dB, calculate the incident power. 20

**Q7. (a)** A coaxial capacitor of length 1 m is formed using two concentric cylindrical conductors. The inner conductor has radius 4 mm and the outer conductor radius is 16 mm. The space between them is filled with 3 layers of perfect dielectric materials with different dielectric constants such that  $\epsilon_{r1} = 5$ ,  $4 \text{ mm} < \rho < 8 \text{ mm}$ ;  $\epsilon_{r2} = 3$ ,  $8 \text{ mm} < \rho < 12 \text{ mm}$  and  $\epsilon_{r3} = 1$ ,  $12 \text{ mm} < \rho < 16 \text{ mm}$ . If the potential difference between the inner and outer conductor is 100 V, determine the capacitance and charge on the inner conductor. ( $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$ ) 20

(b) (i) The impulse response of an LTI system is given by

$$h(n) = \left[ \left( \frac{1}{4} \right)^n \cos\left( \frac{\pi}{4} n \right) \right] u(n)$$

Realize this system using finite number of adders, multipliers and minimum possible unit delays. 10

(ii) Consider an initially relaxed system whose output  $y(n)$  for  $n \geq 0$  is the Fibonacci series. Describe this system in the form of difference equation relating input and output. Obtain impulse response of this system. 10

(c) A hexagonal cell within a four cell system has a radius of 1.387 km. A total of 60 channels are used in the entire system. If the load per user is 0.029 Erlangs and  $\lambda = 1$  call/hour, compute the following for an Erlang C system that has 5% probability of a delayed call :

- (i) How many users per square km will this system support ?
- (ii) What is the probability that a delayed call will have to wait for more than 10 s ?
- (iii) What is the probability that a call will be delayed for more than 10 s ?

Erlang C Traffic Table

Maximum offered load versus B and N 20

N \ B	1	2	5	10	15
14	6.70	7.31	8.27	9.15	9.76
15	7.39	8.03	9.04	9.97	10.60
16	8.09	8.76	9.82	10.79	11.44



**Q8.** (a) Consider an air filled rectangular waveguide with inner dimension of width and height  $a$  and  $b$  respectively ( $a > b$ ).

(i) With clear reasoning describe why propagation is not possible if both electric and magnetic fields in the direction of propagation are zero. 6

(ii) The propagation constant  $\gamma$  for TE and TM mode is given by

$$\gamma^2 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - \omega^2 \mu \epsilon$$

where  $m$  and  $n$  are integers.

Obtain an expression for minimum frequency below which propagation is not possible. 6

(iii) If  $a = 2$  cm and  $b = 1$  cm, determine the range of frequency at which only one mode propagates. ( $\epsilon = 8.854 \times 10^{-12}$  F/m,  $\mu_0 = 4\pi \times 10^{-7}$  H/m) 8

(b) A display is connected to port P1 of 8051 microcontroller. A sequence of 7-bit-patterns are to be displayed in cyclic manner continuously. Write a program in 8051 assembly to display the bit-patterns (8-bit each) with a delay of 1 second between each pair of bit-patterns. The bit-patterns are stored in program memory space at the start at location 400H. Assume that sub-routine for delay is available directly. Comment on your program appropriately and mention any necessary assumptions explicitly. 20

(c) The dominant mode  $TE_{10}$  is propagated in a rectangular waveguide of dimensions  $a = 6$  cm and  $b = 4$  cm. The distance between maximum and minimum is found to be equal to 4.47 cm with the help of travelling wave detector. Determine the signal frequency. 20

