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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

E & T ENGINEERING

Test 10

Section A : Signals & Systems + Basic Electrical Engineering

Section B : Analog & Digital Communication Systems-1

Section C : Electronic Devices & Circuits-2 + Analog Circuits Topics-2

1.	(d)	**16.**	(c)	**31.**	(c)	**46.**	(b)	**61.**	(c)
2.	(d)	**17.**	(d)	**32.**	(b)	**47.**	(b)	**62.**	(a)
3.	(b)	**18.**	(b)	**33.**	(d)	**48.**	(b)	**63.**	(d)
4.	(d)	**19.**	(b)	**34.**	(c)	**49.**	(d)	**64.**	(b)
5.	(c)	**20.**	(b)	**35.**	(d)	**50.**	(c)	**65.**	(d)
6.	(c)	**21.**	(c)	**36.**	(a)	**51.**	(c)	**66.**	(d)
7.	(d)	**22.**	(b)	**37.**	(b)	**52.**	(a)	**67.**	(b)
8.	(b)	**23.**	(a)	**38.**	(a)	**53.**	(c)	**68.**	(b)
9.	(a)	**24.**	(c)	**39.**	(a)	**54.**	(b)	**69.**	(a)
10.	(c)	**25.**	(d)	**40.**	(a)	**55.**	(d)	**70.**	(a)
11.	(b)	**26.**	(d)	**41.**	(c)	**56.**	(c)	**71.**	(c)
12.	(d)	**27.**	(c)	**42.**	(d)	**57.**	(b)	**72.**	(b)
13.	(b)	**28.**	(a)	**43.**	(a)	**58.**	(b)	**73.**	(b)
14.	(a)	**29.**	(a)	**44.**	(c)	**59.**	(c)	**74.**	(d)
15.	(b)	**30.**	(c)	**45.**	(c)	**60.**	(c)	**75.**	(a)

Detailed Explanation

Section A : Signals & Systems + Basic Electrical Engineering

1. (d)

Given, $$y'' - y = -20\delta(t-3)$$

$$L[y''] - L[y] = -20L[\delta(t-3)]$$

$$s^2Y(s) - sy(0) - y'(0) - Y(s) = -20e^{-3s}$$

$$(s^2-1)Y(s) = -20e^{-3s} + s$$

$\therefore$ $$Y(s) = \frac{s-20e^{-3s}}{s^2-1}$$

2. (d)

The given conditions are the Dirchlet conditions which must be satisfied by the signal $x(t)$ for existence of the Fourier Series.

3. (b)

Given system, $$y(t) = u\{x(t)\}$$

Let $$x_1(t) = V(t), \text{ then } y_1(t) = u[V(t)]$$

$$x_2(t) = kV(t), \text{ then } y_2(t) = u[kV(t)] = ku[V(t)] = ky_1(t)$$

For $x(t) = x_1(t) + x_2(t)$,

$$y(t) = u\{x_1(t) + x_2(t)\} \neq u\{x_1(t)\} + u\{x_2(t)\}$$

The system satisfies the homogeneity principle but not the superposition principle.
Hence, the system is non-linear.

$$y_1(t) = u\{V(t)\}$$

$$y_2(t) = u\{V(t-t_0)\} = y_1(t-t_0)$$

Hence, the given system is time-invariant.
Since the response at any time depends only on the excitation at time $t = t_0$ and not on any future values, hence the given system is causal.

4. (d)

Given $$x[n] = \exp\left[\frac{2\pi jn}{3}\right] + \exp\left[\frac{3\pi jn}{4}\right]$$

$$= \exp\left[\frac{j2\pi n}{3}\right] + \exp\left[\frac{2\times j3\pi n}{8}\right]$$

The discrete-time signal $e^{j\omega_0 n}$ is periodic with time-period

$$N = r\cdot\frac{2\pi}{\omega_0}$$

where r is the minimum value of integer such that N is a positive integer.

on comparing, $N_1 = 3, N_2 = 8$

The fundamental period, $N = \text{LCM}(N_1, N_2)$

$\therefore$ $$N = \text{LCM}(3, 8) = 24$$

5. (c)

1. $$\cos\left(\frac{\pi}{3}n\right)+\sin\left(\frac{\pi}{3}n\right) \Rightarrow \text{periodic}$$

$$\text{Period} = \frac{2\pi\times 3}{\pi} = 6$$

2. $$\cos\left(\frac{1}{2}n\right)+\cos\left(\frac{1}{3}n\right) \Rightarrow \text{non-periodic}$$

[$\because$ A discrete-time sinusoid is periodic if its radian frequency ω is a rational multiple of π]

3. $$\text{Even }\{\cos(4\pi t)u(t)\} = \frac{\cos(4\pi t)\,u(t)+\cos(-4\pi t)u(-t)}{2} = \frac{\cos 4\pi t}{2} \Rightarrow \text{Periodic}$$

4. $$\text{Even }\{\sin(4\pi t)u(t)\} = \frac{\sin(4\pi t)u(t)+\sin(-4\pi t)u(-t)}{2}$$

$$= \frac{1}{2}\sin(4\pi t)\cdot \text{sgn}(t) \Rightarrow \text{non-periodic}$$

6. (c)

$$y(n) = x(n) * h(n)$$

$x(n) \Rightarrow$	1	2	3	4			
$h(n) \Rightarrow$	5	6	7	8			
	5	6	7	8			
		10	12	14	16		
			15	18	21	24	
				20	24	28	32
$x(n) * h(n) \Rightarrow$	5	16	34	60	61	52	32

$$y(n) = \{\underset{\uparrow}{5}, 16, 34, 60, 61, 52, 32\}$$

So, $$y(3) = 60$$

7. (d)

- If $x(t)$ is periodic with time period T, then $y(t) = x(2t)$ will be periodic with time period $T/2$.
- Sum of two continuous-time signals is periodic, if and only if both functions are periodic and the ratio of these two periods is a rational number.
- Sum of two discrete time periodic signals is always periodic with period $N = \text{LCM}(N_1, N_2)$ as N_1 and N_2 both are integers.

8. (b)

$$y(n) = Ax(n - n_0) = A \sin(\omega_0(n - n_0) + \phi)$$

$$y(n) = A \sin(\omega_0 n - \omega_0 n_0 + \phi) \quad \text{...(1)}$$

Also since system is LTI, $$y(n) = M \sin(\omega_0 n + \phi') \quad \text{...(2)}$$

where $$M = \left|H(e^{jw})\right|$$

and $$\phi' = \phi + \angle H(e^{j\omega}) \quad \text{...(3)}$$

So comparing eq. (1) and (2),

we get, $\phi' = -n_0\omega_0 + \phi$ ...(4)

Comparing (3) and (4) we get,

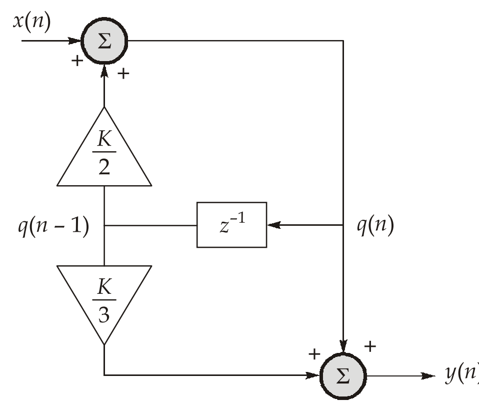
$$\angle H(e^{j\omega}) = -n_0\omega_0 + 2\pi k$$

9. (a)

$$a^n x[n] \longleftrightarrow X[z/a]$$

Scaling property of z-transform.

10. (c)



$$q(n) = x(n) + \frac{K}{2}q(n-1)$$

$$y(n) = q(n) + \frac{K}{3}q(n-1)$$

Taking the z-transform of above equations,

$$Q(z) = X(z) + \frac{K}{2}z^{-1}Q(z)$$

$$Q(z)\left(1 - \frac{K}{2}z^{-1}\right) = X(z)$$

$$Q(z) = \frac{X(z)}{1 - \frac{K}{2}z^{-1}} \quad \text{...(i)}$$

and $$Y(z) = Q(z) + \frac{K}{3}z^{-1}Q(z) = \left(1 + \frac{K}{3}z^{-1}\right)Q(z) \quad \text{...(ii)}$$

Substituting value of $Q(z)$ from equation (i) in equation (ii),

$$Y(z) = \left(1 + \frac{K}{3}z^{-1}\right)\frac{X(z)}{1 - \frac{K}{2}z^{-1}}$$

$$H(z) = \frac{Y(z)}{X(z)} = \frac{1 + \frac{K}{3}z^{-1}}{1 - \frac{K}{2}z^{-1}} = \frac{z + \frac{K}{3}}{z - \frac{K}{2}} \; ; \text{ ROC : } |z| > \left|\frac{K}{2}\right|$$

System has one zero at $z = \frac{-K}{3}$ and one pole at $z = \frac{K}{2}$ and the ROC is $|z| > \left|\frac{K}{2}\right|$. The system will be BIBO stable if the ROC contains the unit circle, $|z| = 1$. Hence, the system is stable only if $|K| < 2$.

11. (b)

$$X(z) = \frac{1}{(1-az^{-1})^2} = \frac{z^2}{(z-a)^2}; |z|>|a|$$

$$a^n u(n) \longleftrightarrow \frac{z}{z-a}\ ; \text{ROC: } |z| > |a|$$

$$nx(n) \longleftrightarrow -z\frac{dX(z)}{dz}$$

$$na^n u(n) \longleftrightarrow -z\frac{[z-a-z]}{(z-a)^2} = \frac{az}{(z-a)^2}$$

$$na^{n-1}u(n) \longleftrightarrow \frac{z}{(z-a)^2}; \text{ROC: } |z|>|a| \quad \text{...(i)}$$

Given: $$X(z) = z\left[\frac{z}{(z-a)^2}\right]; \text{ROC:} |z|>|a|$$

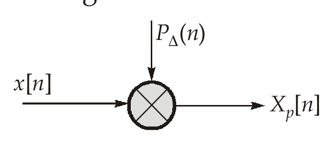
applying time shifting property in equation (i), we get

$$(n+1)a^n u(n+1) \longleftrightarrow \frac{z^2}{(z-a)^2} = X(z)$$

∴ $$x[n] = (n+1)a^n u(n+1)$$

12. (d)

Impulse train sampling of discrete-time signals.



$$P_\Delta[n] = \sum_{k=-\infty}^{\infty} \delta(n-kN)$$

$$X_p[n] = \text{Impulse train sampled sequence}$$
$$= x[n]\ P_\Delta[n]$$
$$= \sum_{k=-\infty}^{\infty} x[kN]\delta(n-kN)$$

13. (b)

$$X[K] = \text{DFT}\{X[n]\}$$

$$x(n) = \frac{1}{N}\left[\sum_{K=0}^{N-1} X[K]e^{\frac{j2\pi Kn}{N}}\right]$$

$$x(n) = \frac{1}{N}\left[\sum_{K=0}^{N-1} X^*[K]e^{\frac{-j2\pi nK}{N}}\right]^*$$

Noting that the term in brackets is the DFT of $X^*[K]$, we get

$$x[n] = \text{IDFT}\{X[K]\} = \frac{1}{N}\left[\text{DFT}\left\{X^*[K]\right\}\right]^*$$

14. (a)

15. (b)

16. (c)

- FIRs usually require many more coefficients for achieving a sharp cut-off than their IIR counterparts. Hence, in FIR filter, Block diagram realization is complicated and require more number of components.
- IIR filter is recursive in nature and have non-linear phase response. So, 2nd statement is incorrect.
- The FIR filter is a non-recursive filter in which the output from the filter is computed by using the current and previous inputs. It does not use previous values of the output, so there is no feedback in the filter structure. Hence, 4th statement is incorrect.

17. (d)

4-point DFT of sequence {2, 1, 0, 3} is given as

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix}\begin{bmatrix} 2 \\ 1 \\ 0 \\ 3 \end{bmatrix} = [6, 2 + 2j, -2, 2 - 2j]$$

18. (b)

For DFT, the total number of multiplications

$$N^2 = 16^2 = 256$$

For FFT, the total number of multiplications

$$\frac{N}{2}\log_2 N = \frac{16}{2}\log_2 16 = 8 \times 4 = 32$$

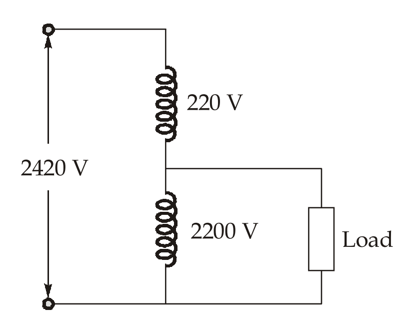
19. (b)

$$\text{Saving in conductor material} = \frac{1}{a_A}\text{Pu}$$

$$\text{where voltage ratio, } a_A = \frac{V_H}{V_L} = \frac{2420}{2200} = \frac{11}{10}$$

$$\text{Saving in conductor material} = \frac{1}{a_A} \times 100\%$$

$$= \frac{10}{11} \times 100\% = 90.9\%$$



Hence, option (b) is correct.

20. (b)

- The numerical difference between no load (V_{nl}) and full load voltage (V_{fl}) is called inherent voltage regulation. The percentage regulation is defined as

$$\%R = \frac{V_{nl} - V_{fl}}{V_{fl}} \times 100\%$$

- The maximum temperature rise in a large transformer is determined by the full load test. This test is called, back-to-back test, regenerative test or Sumpner's test.
- Skin effect, is defined as the tendency of alternating high-frequency currents to crowd toward the surface of a conducting material. This phenomenon restricts the current to a small part of the total cross-sectional area and so has the effect of increasing the resistance of the conductor. By using multi-stranded wire, the individual strands provide more surface area collectively, effectively reducing the skin effect and minimizing power losses. Hence, skin effect can be minimized by using multistrand wire. Therefore, statement 4 is incorrect.

21. (c)

$$\text{Total copper loss} = I_1R_1^2 + I_2R_2^2 = I_1^2R_{01} = I_2^2R_{02} = I_1R_1^2 + I_1R_2'^2,$$

where R_2' is the resistance of secondary winding in terms of primary.

$$I_1^2R_{01} = 90$$

$$R_{01} = \frac{90}{I_1^2} = \frac{90}{(20)^2}$$

$$R_{01} = \frac{9}{40}\Omega$$

$$R_{01} = R_1 + R_2'$$

$$\frac{9}{40} - 0.1 = R_2'$$

$$R_2' = \frac{1}{8}\Omega$$

$$R_2' = \left(\frac{N_1}{N_2}\right)^2 R_2$$

$$\frac{1}{8} = \left(\frac{90}{180}\right)^2 R_2$$

$$R_2 = \frac{1}{2}\Omega$$

22. (b)

$$\eta_{max} = \frac{x(\text{kVA})\cos\phi_2}{x(\text{kVA})\cos\phi_2 + 2P_i}$$

$\because$ At maximum efficiency, variable loss is equal to constant loss.

$$0.8 = \frac{0.8 \times 100 \times 10^3 \times 0.8}{0.8 \times 100 \times 10^3 \times 0.8 + 2P_i}$$

$$0.8 = \frac{64000}{64000 + 2P_i}$$

$$P_i = 8 \text{ kW}$$

Sum of iron and copper loss at the maximum efficiency = $2P_i$ = 16 kW

Hence, option (b) is correct.

23. (a)

We know, $P = WQH\eta \times 9.81$ Watt

where P = specific weight of water in kg/m^3; Q = rate of flow of water (m^3/sec); H = height of water fall in meter (head); η = overall efficiency of operation

$P = 1000 \times 50 \times 300 \times 0.70 \times 9.81$

P = 103.005 MW

$P \approx 103$ MW

Hence, option (a) is correct.

24. (c)

The purpose of moderator material in the reactor core is to moderate, or reduce the neutron speeds to a value that increases the probability of fission occurrence.

25. (d)

All the statements are correct.

Note:

1.

Power Generating Unit	Efficiency
• Hydraulic turbine	85-90%
• Solar cell	10-12%
• Diesel Engine	25%
• Fuel cell	60-70%

2.

Electric Power Plant	Operation speed
Hydro	80-1275 rpm
Steam	1500-3000 rpm
Diesel	500-1000 rpm

2. The secondary batteries are classified as below:
   (i) Automotive batteries: These are used for starting, lighting and ignition (SLI) in internal-combustion engined vehicles.
   (ii) Vehicle Traction Batteries or Motive Power Batteries or Industrial Batteries: These are used as a motive power source for a wide variety of vehicles.
   (iii) Stationary Batteries: These fall into two groups (a) standby power system which is used intermittently and (b) load-levelling system which stores energy when demand is low and, later on, uses it to meet peak demand.
3. The electromechanical energy converters are of two types:
   - Gross-motion devices: such as electrical motors or generators.
   - Incremental motion devices: such as microphones, loudspeakers, electromagnetic relays and electrical measuring instruments, etc.

26. (d)

$$E = \frac{P\phi Z}{60} \times \frac{N}{A}$$

Here, P, ϕ, Z are constant.

Hence, $E = \frac{KN}{A}$, where $K = \frac{P\phi Z}{60}$

For lap winding, $A = 8$,

$$E_l = \frac{KN_l}{8} \quad \text{...(i)}$$

For wave winding, $A = 2$,

$$E_w = \frac{KN_w}{2} \quad \text{...(ii)}$$

$$\frac{E_l}{E_w} = \frac{N_l}{N_w} \times \frac{2}{8}$$

$E_l = E_w$ ..... As per the question

Hence, $$\frac{E_l}{E_l} = \frac{N_l}{N_w} \times \frac{1}{4}$$

$$4N_w = N_l$$

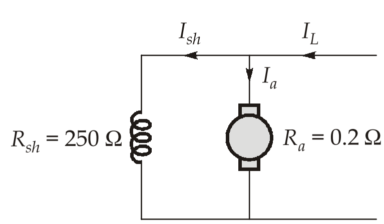
Hence, option (d) is correct.

27. (c)

- Phase displacement between MMF of main field and MNA is equal to 90°.
- Phase displacement between MMF of armature conductors and MNA is 0°.

Hence, only statement 2 is incorrect.

28. (a)



$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{250} = 1\text{ A}$$

$$I_L = I_a + I_{sh}$$

$$I_a = I_L - I_{sh}$$

$$I_a = 5 - 1 = 4\text{A}$$

At no load, back emf $$E_1 = V - I_aR_a$$

$$E_1 = 250 - (4 \times 0.2) = 249.2 \text{ volt}$$

When load is applied, $I_L = 50$ A

$$I_a = 50 - 1 = 49 \text{ A}$$

$$E_2 = V - I_aR_a$$

$$E_2 = 250 - (0.2 \times 49)$$
$$E_2 = 240.2 \text{ V}$$

Given $\phi_2 = 0.97\phi_1$; $N \propto \dfrac{E}{\phi}$

$$\frac{N_1}{N_2} = \frac{E_1}{\phi_1} \times \frac{\phi_2}{E_2}$$
$$\frac{N_1}{N_2} = \frac{249.2 \times 0.97\phi_1}{240.2 \times \phi_1}$$
$$N_2 = \frac{N_1 \times 240.2\phi_1}{249.2 \times 0.97\phi_1} \qquad \text{Given: } N_1 = 1000 \text{ rpm}$$
$$N_2 \cong 993.7 \text{ rpm}$$
$$N_2 \approx 994 \text{ rpm}$$

29. (a)

In auto-transformer starter, if the voltage applied is 'x' times the normal voltage, the starting current of the motor is $I_s = xI_{sc}$, where Isc is the short-circuit current or starting current with full voltage applied to the motor directly.

$$\frac{\tau_{st}}{\tau_{fl}} = x^2 \left(\frac{I_{sc}}{I_{fl}}\right)^2 s_{fl}$$

For starting torque to be equal to full-load torque,

$$\tau_{st} = \tau_{fl}$$
$$1 = x^2 \left(\frac{5.5 I_{fl}}{I_{fl}}\right)^2 (0.05)$$
$$x^2 = \frac{20}{(5.5)^2}$$
$$x = \frac{\sqrt{20}}{5.5} = \frac{2\sqrt{5}}{5.5} = 0.813$$
$$x\% = 81.3\%$$

Hence, option (a) is correct.

30. (c)

$$s = \frac{N_s - N}{N_s}$$
$$\frac{2}{100} = \frac{N_s - 980}{N_s}$$
$$100N_s - 98000 = 2N_s$$
$$98N_s = 98000$$
$$N_s = 1000 \text{ rpm}$$
$$N_s = \frac{120f}{P}$$

$$f = \frac{N_s \times P}{120} = \frac{1000 \times 6}{120}$$

$$f = 50 \text{ Hz}$$

Electrical angle = $2\pi f = 100\pi$ radian

31. (c)

- Induction motor is singly excited machine as its stator winding only is energized from an AC source. The working of induction motor is similar to transformer.
- Squirrel Cage Induction Motors requires less conductor material than slip ring motor, hence copper losses in squirrel cage motors are less which results in higher efficiency. Further, the rotor bars are permanently short-circuited and it is not possible to add any external resistance to the rotor circuit to have a large starting torque. Hence, it is preferred for less starting torque and high efficiency.
- When the stator and rotor slots are equal or have an integral ratio, then the strong alignment forces are produced between the stator and the rotor at the instant of starting. They align themselves in such way that both face to each other and at this stage, the reluctance of the magnetic path is minimum and motor refuse to start.. This phenomenon of the magnetic locking between the stator and rotor teeth of an induction motor at the time of starting is known as cogging or teeth locking.

32. (b)

$$\text{emf induced} = -\frac{Nd\phi}{dt}$$

$$\text{emf} = \frac{-100d(t^4 - 4t^2 + 3)}{dt}$$

$$\text{emf} = -100(4t^3 - 8t)$$

emf induced at $t = 1.414 = \sqrt{2}$ sec,

$$\text{emf} = -100\left(4(\sqrt{2})^3 - 8\sqrt{2}\right)$$

$$\text{emf induced} = 0 \text{ volt}$$

Hence, option (b) is correct.

33. (d)

- In star-connection, $I_L = I_{ph}$ and $V_L = \sqrt{3V_{ph}}$ whereas in delta connection, $V_L = V_{ph}$ and $I_L = \sqrt{3I_{ph}}$.
- The order in which the voltages in the three phases reach their maximum positive values is called the phase sequence or phase order. This is determined by the direction of rotation of alternator. For a three-phase system, there are only two possible phase sequences: 1-2-3 and 3-2-1, corresponding to the two possible directions of alternator rotation.

34. (c)

- In a DC generator, an alternating current is induced from the rotation of the armature within the field magnetic flux. The split ring commutator converts the alternating emf induced in armature conductors to DC.

- For eliminating nth harmonic, the pitch factor

$$K_{pn} = \cos(n\alpha/2) = 0$$
$$n\alpha/2 = 90°$$
$$\alpha = \frac{180°}{n} = \frac{\text{Full pitch}}{n}$$

- The breakdown torque of a synchronous motor is directly proportional to the applied voltage. It is due to the fact that the magnetic field strength in the motor is proportional to the applied voltage.

35. (d)

$$\text{Pole pitch} = \text{slot/pole}$$
$$= \frac{36}{4} = 9$$
$$\text{Coil span} = 1 \text{ to } 8$$
$$= 7$$

Hence, short pitch by 2 slots.

$$\text{Slot angle} = \frac{180°}{\text{Pole pitch}} = \frac{180°}{9} = 20°$$
$$\text{short pitch angle } \alpha = 2 \times 20° = 40°$$
$$\text{Pitch factor } K_{pn} = \cos\frac{n\alpha}{2}$$

For fundamental pitch factor, $n = 1$

$$K_p = \cos\frac{40°}{2}$$
$$K_p = \cos 20°$$

36. (a)

$$\text{slot angle} = 30°$$

$\Rightarrow$
$$\beta = \frac{180°}{\text{pole pitch}} = 30°$$
$$\text{Pole pitch} = 6 = \frac{\text{slot}}{\text{pole}}$$
$$m = \text{slot/pole/phase}$$
$$m = \frac{6}{3} = 2$$
$$\text{distribution factor for } n^{th} \text{ harmonic} = \frac{\sin\left(\frac{mn\beta}{2}\right)}{m\sin(n\beta/2)}$$
$$\text{For } 3^{rd} \text{ harmonic, distribution factor} = \frac{\sin\left(\frac{2\times3\times30°}{2}\right)}{2\sin\left(\frac{3\times30°}{2}\right)}$$

$$= \frac{\sin 90°}{2\sin 45°} = \frac{1}{2}\times\sqrt{2}$$

$$= \frac{1}{\sqrt{2}} = 0.707$$

37. (b)

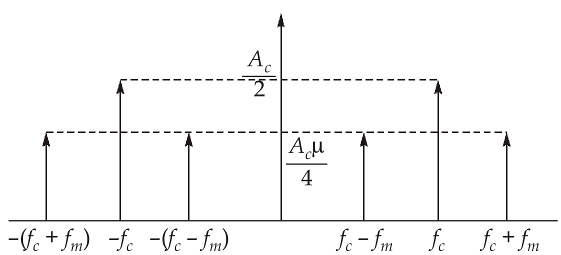
- The characteristics of an LTI system are completely determined by its impulse response.
- The overall response of LTI system in cascade is the multiplication of the impulse responses in the frequency domain. hence, it is independent of the order in which they are cascaded.

38. (a)

Section B : Analog and Digital Communication Systems-1

39. (a)

Spectrum of standard AM signal is shown below:



Now on comparison we get

$$\frac{A_c}{2} = 10$$

$$A_c = 20 \text{ volt}$$

$$\frac{A_c\mu}{4} = 4$$

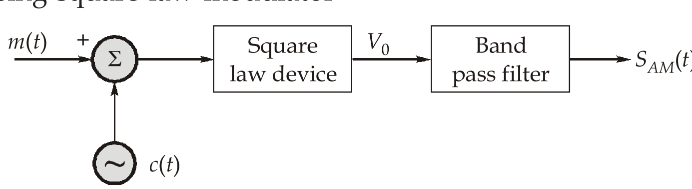
$$20\,\mu = 16$$

$$\mu = 0.8$$

And for $\mu < 1$, we prefer envelope detector. Hence, option (a) is correct.

40. (a)

Generation of AM using square law modulator



$$V_0 = a_1V_i + a_2V_i^2$$

We have

$$\mu = 0.8 = |K_a m(t)|_{max}$$

$$0.8 = K_a \times 4$$

$$K_a = 0.2 \text{ V}^{-1}$$

We know that, $$K_a = \frac{2a_2}{a_1}$$

$$0.2 = \frac{2a_2}{a_1}$$

$$a_2 = 0.1\,a_1$$

Given $a_1 = 1$

$\therefore$ $a_2 = 0.1$

Hence, $a_1 + a_2 = 1 + 0.1 = 1.1$

Hence, option (a) is correct.

41. (c)

- Switching modulator and square law modulator is used for the generation of AM signal.
- In frequency discrimination method, DSB-SC signal is generated using product modulator which is passed through band pass filter to generate SSB-SC modulated signal.
- SSB modulation with phase discrimination method is a technique where the suppressed carrier is multiplied with message signal in one channel and multiplied with –90° phase shifted message signal in the other channel and the product signal from the two channels are combined to produce the SSB signal.
- Weaver's method is also known as third method for generation of SSB-SC modulated signal.

42. (d)

Method-I:

We know that

$$\eta = \frac{K_a^2 P_m}{1+K_a^2 P_m}; \text{ where } P_m = \text{Power of message signal}$$

$$P_m = \frac{A_m^2}{2} = \frac{(2)^2}{2} = 2\text{ W}$$

$$\eta = \frac{K_a^2 P_m}{1+K_a^2 P_m}$$

$$\frac{50}{100} = \frac{K_a^2 \times 2}{1+K_a^2 2}$$

$$4K_a^2 = 1+2K_a^2$$

$$2K_a^2 = 1$$

$$K_a = 0.707\text{ V}^{-1}$$

Method II:

$$\eta = \frac{\mu^2}{2+\mu^2}$$

$$\frac{50}{100} = \frac{\mu^2}{2+\mu^2}$$

$$2 + \mu^2 = 2\mu^2$$

$$\mu = \sqrt{2} = \frac{A_m}{A_c}$$

$$A_c = \frac{A_m}{\sqrt{2}} = \frac{2}{\sqrt{2}}$$

We have, $$K_a = \frac{1}{A_c}$$

$$K_a = \frac{\sqrt{2}}{2}$$

$$K_a = 0.707 \text{ V}^{-1}$$

43. (a)

We have

$$S_{AM}(t) = 10 \cos 2\pi f_c t + A \cos 2\pi f_{m1} t \cdot \cos 2\pi f_c t + 6 \cos 2\pi f_{m2} t \cdot \cos 2\pi f_c t$$

On comparison with standard multi-tone amplitude modulated signal,

$$S_{AM}(t) = A_C \cos 2\pi f_c t + \mu_1 A_C \cos 2\pi f_{m1} t \cdot \cos 2\pi f_c t + \mu_2 A_C \cos 2\pi f_{m2} t \times \cos 2\pi f_c t$$

We get A_C = 10 volt; $\mu_1 A_C = A$; $\mu_2 A_C = 6$; $\mu_t = 1$; $\mu_2 = 0.6$

$$\mu_t^2 = \mu_1^2 + \mu_2^2$$

$$\mu_1 = \sqrt{\mu_t^2 - \mu_2^2} = \sqrt{1 - (0.6)^2} = 0.8$$

$$\mu_1 = |K_a m_1(t)|_{\max}$$

$$\mu_1 = K_a A_{m1}$$

$$K_a = \frac{1}{A_C} = \frac{1}{10} = 0.1 \text{ V}^{-1}$$

$$\mu_1 = 0.1 \times A_{m1}$$

$$A_{m1} = \frac{\mu_1}{0.1} = \frac{0.8}{0.1} = 8 \text{ volt}$$

44. (c)

QNE is a phenomenon in AM synchronous demodulator which occurr due to difference in phase and frequency of carrier generated by local oscillator and input signal.

For AM and DSB-SC modulation schemes, the demodulated signal when there is a phase difference of ϕ is given by

$$s_0(t) = \frac{A_c^2}{2} m(t) \cos\phi$$

When $\phi = 90°$, the demodulated signal is 0.

However, in SSB, the demodulated signal after passing through a low pass filter is given by

$$s_0(t) = \frac{A_c^2}{4} [m(t)\cos\phi \pm \hat{m}(t)\sin\phi]$$

If $\phi = 0°$, we get $\frac{A_c^2}{4} m(t)$

If $\phi = 90°$, we get $\frac{A_c^2}{4} \hat{m}(t)$

In both of the above cases, the output signal is never zero and reconstruction of the message signal is easy.
So, no QNE is observed for the SSB modulation scheme.

45. **(c)**

- For SSB-SC, Bandwidth = f_m = 20 kHz
  Using SSB-SC, 11 message signals frequency division multiplexed with a guard band of 1 kHz requires
  $$\text{Bandwidth} = (11 \times 20\text{ kHz}) + (10 \times 1\text{ kHz}) = 230\text{ kHz}$$
  $\because$ for 11 message signals, 10 guard band is required.
- For DSB-FC and DSB-SC signal, bandwidth = $2f_m$ = 40 kHz
  $$\text{Multiplexed bandwidth required} = (11 \times 40\text{ kHz}) + (10 \times 1\text{ kHz}) = 450\text{ kHz}$$
  Hence, option (c) is correct.

46. **(b)**

We have $8J_8(4)\cos(2\pi \times 1008 \times 10^3)t$ as one of the terms in the FM signal.
Now compare it with standard form,

$$S_{FM}(t) = A_C \sum_{n=-\infty}^{\infty} J_n(\beta)\cos(2\pi f_c + 2\pi n f_m)t$$

We get,
$$A_C = 8\text{ volt};\ n = 8;\ \beta = 4;\ f_c = 1000\text{ kHz}$$
$$f_c + nf_m = 1008\text{ kHz}$$
$$nf_m = 8\text{ kHz}$$
$$f_m = \frac{8}{8}$$
$$f_m = 1\text{ kHz}$$
$$\beta = \frac{\Delta f}{f_m}$$
$$4 = \frac{\Delta f}{1\text{ kHz}}$$
$$\Delta f = 4\text{ kHz}$$

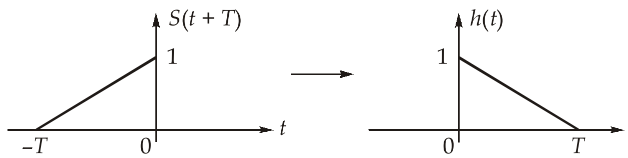
47. **(b)**

- For generation of frequency modulated signal, direct method and indirect method (Armstrong method) is used. Indirect method is generally preferred because LC oscillators used in direct method are not stable enough.
- For demodulation of NBFM and WBFM modulated signal, frequency discrimination method and phase discrimination method is used.
- Foster-seeley detector is a phase discrimination method of demodulation.
- In superheterodyne receiver, the image frequency rejection is achieved before IF stage using preselector and RF stage amplifier.

48. (b)

The impulse response of the matched filter is given by

$$h(t) = S(-t + T)$$



49. (d)

The cumulative distribution function is defined as

$$P(X \le x) = \int_{-\infty}^{x} f_X(x)dx = F_X(x)$$

where $f_X(x)$ is the probability density function.

since $f_X(x) \ge 0$

and $\int_{-\infty}^{\infty} f_X(x) \cdot dx = 1$

Hence, the probability cumulative distribution function must be monotone and non-decreasing (saturates at 1).

50. (c)

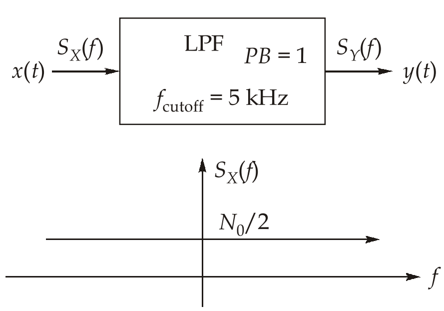
$$R_X(\tau) = E[X(t)\ X(t + \tau)]$$

for $\tau = 0$

$R_X(0) = E[X^2(t)]$, which represents the total power of the signal.

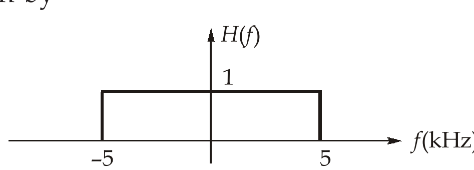
Hence, average power of the signal = $R_X(0)$ = 5 W.

51. (c)



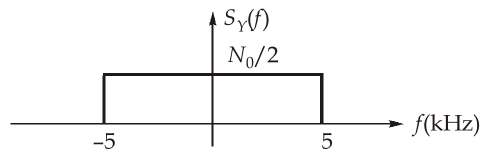
Given: $\frac{N_0}{2} = 2$ W/Hz

Transfer function $H(f)$ is given by



using the property of PSD

$$S_Y(f) = |H(f)|^2 S_X(f)$$



$$P = \int_{-5}^{5} S_u(f)df$$

$$P = 10 \times \frac{N_0}{2} = 10 \times 2 = 20 \text{ Watt}$$

52. (a)

SQNR can be improved by increasing sampling rate f_s, as for delta modulation system,

$$(\text{SNR})_{\text{max}} = \frac{3}{8\pi^2}\left(\frac{f_s}{f_m}\right)^3$$

53. (c)

Shot noise occurs due to particle like behaviour of electrons and photons when an external excitation is available to produce current. The noise caused by random variations in the arrivals of electrons or holes at the output electrode of an amplifying device is called shot noise appearing as a randomly varying noise current superimposed on the output.

54. (b)

Since DPSK uses two successive bits for its reception, error in the first bit creates error in the second bit. Hence, error propagation in DPSK is more whereas in PSK, single bit can go in error since detection of each bit is independent.

55. (d)

56. (c)

$$\text{SNR} = \frac{2E_0}{N}$$

$$\text{SNR} = \frac{E_0}{\left(\frac{N_0}{2}\right)} = \frac{E_0}{10^{-15}}$$

$$E_0 \text{ of } S(t) = \int_0^4 |S(t)|^2\, dt = 36 \text{ J}$$

$$\therefore \quad \text{SNR} = \frac{36}{10^{-15}} = 36 \times 10^{15}$$

57. (b)

Coherent schemes need to maintain precise alignment between the carrier phase at the transmitter and receiver, which involves additional circuitry and algorithms making it more complex. Complex schemes has better performance and less probability of error compare to non-coherent schemes.

Section C : Electronic Devices & Circuits-2 + Analog Circuits Topics-2

58. (b)

When the drain is at a high enough voltage w.r.t. source,the depletion region around the drain may extend to source,thus causing the punch through.

59. (c)

Condition to be satisfied for saturation mode of operation is,

$$V_{DS} \geq V_{GS} - V_T$$
$$V_D - V_S \geq V_{GS} - V_T$$
$$V_D \geq V_{GS} - V_T + V_S$$

So, $$V_{D(\text{min})} = (V_{GS} - V_T + V_S) = (4 - 2 + 1) = 3 \text{ V}$$

60. (c)

$$\alpha = \beta^* \gamma$$

γ = emitter injection efficiency

$$\gamma = \frac{98}{100} = 0.98$$

β^* = base transport factor

$$\beta = \frac{99 - 1.98}{99} = 1 - \frac{2}{100} = 0.98$$

α = common base gain

$$= 0.98 \times 0.98 = 0.96$$

61. (c)

$$I_{D(\text{sat})} = \frac{\mu_n C_{ox} W}{2L}(V_{GS} - V_T)^2$$

$$W = \frac{2LI_{D(\text{sat})}}{\mu_n C_{ox}(V_{GS} - V_T)^2} = \frac{2 \times 1.25 \times 4 \times 10^{-3}}{500 \times 8 \times 10^{-8} \times (6-1)^2} \mu\text{m}$$

$$= \frac{10 \times 10^5}{4000 \times 25} = 10 \ \mu\text{m}$$

62. (a)

A MOSFET can be modelled as a voltage controlled current source in which the drain current is controlled by the gate voltage.

63. (d)

For a nMOS capacitor,

$$V_{FB} = \phi_{ms} - \frac{Q'_{ss}}{C_{ox}} = \phi_m - X - \frac{E_g}{2q} - V_t \ln\left(\frac{N_a}{n_i}\right) - \frac{Q'_{ss}}{C_{ox}}$$

where N_a is the substrate doping concentration and Q'_{ss} is the fixed charges present in the oxide layer. For MOS structures with a highly doped poly-silicon gate, one must also calculate the workfunction of the gate based on the bulk potential of the poly-silicon.

Hence, all the given parameters effect the flat-band voltage of a practical MOS capacitor.

64. (b)

Channel resistance is controlled using gate to source voltage. By varying the gate-source voltage, the width of the channel can be changed, and hence the resistance between the drain and source terminals can be controlled.

Under the pinch-off condition, depletion region meets near the drain end and saturation current flows, since high electric field drifts the carriers in the depletion region making the drain current relatively independent of the drain voltage.

65. (d)

During the discharge of the capacitor, the diode is forward-biased and offers a very low resistance R_f which appears in parallel with resistance R_B.

Hence, the discharge time constant becomes

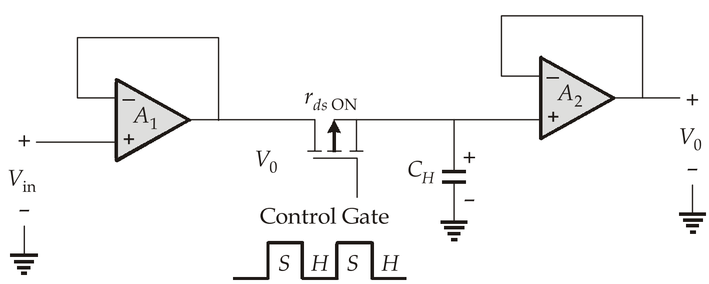
$$\tau = (R_B \parallel R_f)C$$

As, $R_f << R_B$

Hence, $\tau \cong R_f C$

Therefore, the discharge time constant becomes very small, thereby decreasing the discharging time of C.

66. (d)



- Output follower is connected to prevent discharging of capacitor during hold operation.
- The follower circuits, Op-Amps A_1 and A_2 should have negligible input currents.

67. (b)

Frequency
$$f_0 = \frac{1.45}{(R_A + 2R_B)C} = \frac{1.45}{110 \times 680} \times 10^9 = \frac{145}{11 \times 68} \times 10^5$$
$$= 19.385 \text{ kHz}$$
$$\cong 19.4 \text{ kHz}$$

$$\text{Duty cycle} = \frac{(R_A + R_B)C}{(R_A + 2R_B)C} \times 100 = \frac{60}{110} \times 100 = \frac{600}{11} = 54.54\%$$

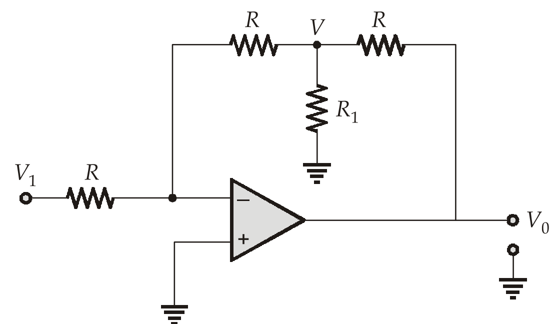
68. (b)

The given circuit is using potentiometer R_p to generate negative reference voltage V_{ref}.

When $V_{in} > -V_{ref}$, then the diode D conducts and the output voltage follows the input voltage. But when $V_{in} < -V_{ref}$, D is off and the voltage below $-V_{ref}$ gets clipped off. The circuit, hence works as negative clipper circuit.

69. (a)

Given circuit is



Applying KCL at inverting terminal,

$$\frac{V_1 - 0}{R} = \frac{0 - V}{R}$$

$$V = -V_1 \quad \text{...(1)}$$

Applying KCL at node V,

$$\frac{V-0}{R} + \frac{V-0}{R_1} + \frac{V-V_0}{R} = 0$$

$$V\left(\frac{2}{R} + \frac{1}{R_1}\right) = \frac{V_0}{R}$$

Put value of V from equation (1),

$$-V_1\left(\frac{2}{R} + \frac{1}{R_1}\right) = \frac{V_0}{R}$$

Given:

$$V_0 = -100V_1$$

$$R = 10\ \text{k}\Omega$$

$$-V_1\left(\frac{2}{10} + \frac{1}{R_1}\right) = \frac{-100V_1}{10}$$

$$\frac{2}{10} + \frac{1}{R_1} = 10$$

$$\frac{1}{R_1} = 10 - \frac{2}{10} = \frac{98}{10}$$

$$R_1 = \frac{10}{98} \times 1000\ \Omega = \frac{5000}{49} \cong 102\ \Omega$$

70. (a)

- Oscillator is a feedback amplifier which satisfies the Barkhausen criterion given below:
  (i) Loop gain $A\beta$ must be slightly greater than 1.
  (ii) Loop phase shift must be multiple of 360°.
- Emitter follower is common-collector amplifier which has voltage series feedback.

71. (c)

At input, there is series connection, i.e., voltage mixing or voltages are compared.

At output, there is shunt connection i.e., voltage sampling.

Hence, in a series-shunt feedback amplifier topology, the voltages are compared and the output voltages are sampled.

72. (b)

Frequency of oscillation for RC phase shift oscillator is $\dfrac{1}{2\pi\sqrt{6}RC}$.

73. (b)

- Cascode amplifier is a cascade of CE-CB amplifier or a cascade of CS-CG amplifier.
- Darlington amplifier is cascade of two common collector amplifiers, hence has unity voltage gain and high current gain β^2.
- Boot Strap Biasing is used in Darlington amplifier to prevent decrease in input impedance due to the biasing network being used.
- Cascode amplifier has large bandwidth (MHz), hence it is used as video frequency amplifier.

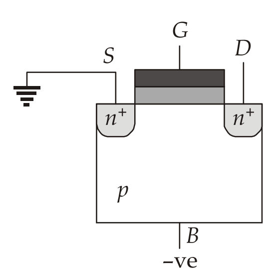
74. (d)

$$T(s) = \frac{-R_1}{\left(R_2 + \dfrac{1}{Cs}\right)} = \frac{-R_1 Cs}{1 + R_2 Cs} = \frac{-\left(\dfrac{R_1}{R_2}\right)s}{s + \dfrac{1}{R_2 C}}$$

It is the transfer function of high pass filter with cutoff frequency:

$$\omega = \frac{1}{R_2 C}\text{rad/s}$$

75. (a)



For p-type substrate, V_{SB} = +ve = $(0 - (-V_B))$

$$Q_d = \sqrt{2\varepsilon_{si}\, eN_d(2\phi_{FP} + V_{SB})}$$

and ΔV_T = Change in threshold voltage = $\dfrac{\Delta Q_d}{C_{ox}}$

So, V_T increases with increase in V_{SB} or V_B.

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