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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

E & T ENGINEERING

Test 8

Section A : Analog and Digital Communication Systems

Section B : Electronic Devices & Circuits-1 + Analog Circuits Topics-1

Section C : Control Systems-2 + Microprocessors and Microcontroller-2

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2.	(b)	**17.**	(a)	**32.**	(d)	**47.**	(c)	**62.**	(b)
3.	(c)	**18.**	(a)	**33.**	(c)	**48.**	(b)	**63.**	(d)
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6.	(a)	**21.**	(c)	**36.**	(a)	**51.**	(a)	**66.**	(a)
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11.	(a)	**26.**	(a)	**41.**	(a)	**56.**	(d)	**71.**	(a)
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13.	(a)	**28.**	(c)	**43.**	(b)	**58.**	(a)	**73.**	(d)
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15.	(b)	**30.**	(c)	**45.**	(b)	**60.**	(c)	**75.**	(b)

DETAILED EXPLANATIONS
Section A : Analog and Digital Communication Systems

1. (b)

Power saving in SSB modulated signal as compared to AM

$$= \frac{P_c + \frac{P_c\mu^2}{4}}{P_c + \frac{P_c\mu^2}{2}} = \frac{4+\mu^2}{4+2\mu^2}$$

$$\frac{4+\mu^2}{4+2\mu^2} = \frac{90}{100}$$

$$400 + 100\,\mu^2 = 360 + 180\,\mu^2$$

$$80\mu^2 = 40$$

$$\mu = \frac{1}{\sqrt{2}} = 70.71\%$$

2. (b)

Total sideband power = 100 watt i.e.,

$$\frac{P_c\mu^2}{2} = 100$$

We have,

$$P_c = \frac{A_c^2}{2} = \frac{(60)^2}{2}$$

$$P_c = 1800 \text{ Watt}$$

$\therefore$

$$\frac{1800\,\mu^2}{2} = 100$$

$$\mu^2 = \frac{100\times 2}{1800}$$

$$\mu = \frac{1}{3} = 0.33$$

$$\mu = \frac{A_m}{A_c} = \frac{1}{3}$$

$$A_m = \frac{A_c}{3} = \frac{60}{3} = 20 \text{ volt}$$

3. (c)

Power saved by DSB as compared to AM $= \dfrac{2}{2+\mu^2}$

$$\frac{2}{2+\mu^2} = \frac{1}{3}$$

$$6 = 2 + \mu^2$$

$$\mu = 2$$

Power carried by single sideband is

$$\frac{P_c\mu^2}{4} = \frac{100\times(2)^2}{4} = 100 \text{ W}$$

4. (c)

$$P_t = 42 \text{ W} + 3 \text{ W} = 45 \text{ W}$$

$$P_c = 40 \text{ W}$$

$$P_t = P_c\left[1+\frac{\mu^2}{2}\right]$$

$$45 = 40\left[1+\frac{\mu^2}{2}\right]$$

$$\left(\frac{45}{40}-1\right)2 = \mu^2$$

$$\mu = \frac{1}{2}$$

5. (a)

$$\mu = 100\%, \quad I_t = 12\sqrt{6} \text{ A}$$

$$\mu = 1$$

$$I_t = I_c\sqrt{1+\frac{\mu^2}{2}} = I_c\sqrt{\frac{2+(1)^2}{2}}$$

$$12\sqrt{6} = I_c\sqrt{\frac{3}{2}}$$

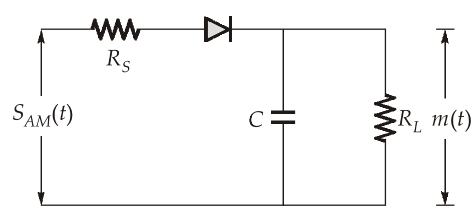
$$I_c = 12\sqrt{6}\times\sqrt{\frac{2}{3}} = 24 \text{ A}$$

6. (a)

For sinusoidal signal, $P_{mn} = \frac{1}{2}$, hence efficiency 'η' of AM signal is $\eta = \frac{\mu^2}{2+\mu^2}$

7. (b)

Envelope detector



$$\frac{1}{f_c} < R_L C < \frac{1}{f_m}$$

- Diagonal clipping occurs when RC circuit cannot follow the fast changes in the envelope of AM signal, hence to avoid diagonal clipping, $R_L C < \frac{1}{f_m}$.
- In envelope detector, reference carrier in the receiver is not required.
- $\mu \le 1$, for envelope detector.
- $R_L C \le \frac{1}{2\pi f_m} \frac{\sqrt{1-\mu^2}}{\mu}$

8. (a)

- Bandwidth required $\Rightarrow$ AM = DSB > VSB > SSB
- VSB modulation is used for transmission of the video signal in commercial television broadcasting because of significant low-frequency content.
- For a DSB-SC signal, $s(t) = m(t)c(t)$, hence product modulator is used for generation of DSB-SC signal.
- Envelope detector is used for detection of AM signal ($\mu \le 1$).

9. (a)

For an AM signal,

$$A_{max} = A_c(1 + \mu) = 150 \text{ V}$$

$$A_{min} = A_c(1 - \mu) = 30 \text{ V}$$

$$\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}} = \frac{150-30}{180} = 0.66$$

$$A_c = \frac{A_{max} + A_{min}}{2} = \frac{150+30}{2} = 90 \text{ volt}$$

10. (b)

$$Q = 90; \text{ IF} = 475 \text{ kHz}, f_s = 950 \text{ kHz}$$

$\therefore$ image frequency

$$f_{si} = f_s + 2IF$$

$$= 950 + 2(475)$$

$$= 1900 \text{ kHz}$$

image frequency rejection ratio

$$\alpha = \sqrt{1+Q^2\rho^2}$$

where

$$\rho = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}} = \frac{1900}{950} - \frac{950}{1900} = \frac{3}{2}$$

$$\therefore \quad \alpha = \sqrt{1+(90)^2\left(\frac{3}{2}\right)^2} = 135.00$$

11. (a)

For operating in the MW band i.e., 550 kHz to 1650 kHz with IF = 455 kHz, the range of local oscillator frequency is given by,

$$f_{0\,min} = 550 + 455 = 1005 \text{ kHz}$$

$$f_{0\,max} = 1650 + 455 = 2105 \text{ kHz}$$

$$f_{0\,min} = \frac{1}{2\pi\sqrt{LC_{0\,max}}}; \quad f_{0\,max} = \frac{1}{2\pi\sqrt{LC_{0\,min}}}$$

$$\left[\frac{f_{0\max}}{f_{0\min}}\right]^2 = \frac{C_{0\max}}{C_{0\min}}$$

$$\frac{C_{0\max}}{C_{0\min}} = \left(\frac{2105}{1005}\right)^2 = 4.38$$

12. (b)

- In capture mode, phase synchronization is maintained whereas in lock mode, frequency synchronization is mantained.
- Preemphasis increases the magnitude of the higher signal frequencies. A lead compensator can be considered as a high-pass filter, hence it is preferred to perform pre-emphasis.
- For transmission of Analog signal in digital form; PCM, DPCM, DM and ADM are used where sampling, quantization and encoding is done first to convert the analog signal into digital signal.

Hence, statement (4) is incorrect.

13. (a)

- Input frequency range: (3 MHz to 30 MHz)
- IF = 40.525 MHz, BW = 10 kHz

Range of local oscillator frequency

$$f_{01} = f_{s1} + IF = 3 + 40.525$$
$$= 43.525 \text{ MHz}$$
$$f_{02} = f_{s2} + IF = 30 + 40.525$$
$$= 70.525 \text{ MHz}$$

14. (a)

- Because of high similarity with AM, NBFM gets less practical importance than WBFM.
- To save power FM is preferred, to save bandwidth AM is preferred.
- Phase and frequency are inseparably linked, as phase is the integral of frequency.
- IN FM, bandwidth does not increase quickly as compared to the modulating frequency and is more dependent on the modulating signal amplitude which is maintained constant.
- In Armstrong method, WBFM signal is generated from the NBFM signal by using frequency multiplication.

15. (b)

$$\Delta f = 75 \text{ kHz}$$

$$\beta = \frac{\Delta f}{f_m}$$

$$f_m = \frac{\Delta f}{\beta}$$

Considering β = 50, $f_{m(\max)} = \frac{75 \text{ kHz}}{50} = 1500 \text{ Hz}$

Considering β = 750, $f_{m(\min)} = \frac{75 \text{ kHz}}{750} = 100 \text{ Hz}$

∴ Hence range of f_m = 100 Hz – 1500 Hz.

16. (b)

$$\frac{3}{2}\beta^2 = \frac{\mu^2}{2+\mu^2}$$

$$\frac{3}{2}\times\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{\mu^2}{2+\mu^2}$$

$$\frac{3}{4} = \frac{\mu^2}{2+\mu^2}$$

$$6 + 3\mu^2 = 4\mu^2$$

We get, $\mu = \sqrt{6}$ which is greater than one. Phase and Frequency discriminator are used for detection of FM signal whereas envelope detector is used for detection of under-modulated AM signal. Hence, synchronous detector is used for detection of over-modulated AM signal.

17. (a)

$$(\text{BW})_{\text{PM}} = (\text{BW})_{\text{FM}}$$

$$\left(\frac{\Delta f}{f_m}+1\right)2f_m = \left(\frac{\Delta f}{f_m}+1\right)2f_m$$

Hence,

$$\Delta f_{PM} = \Delta f_{FM}$$

$$K_p A_m f_m = K_f A_m$$

$$K_f = 3000\ K_p$$

18. (a)

$$f_m = 600 \text{ Hz}$$

$$A_m = 2.4 \text{ V}$$

$$\beta_{FM} = 60$$

$$60 = \frac{K_f A_m}{f_m}$$

$$K_f = \frac{60\times 600}{2.4}$$

$$K_f = 15000 \text{ Hz/volt}$$

Also,

$$2\pi K_f = 30000\pi$$

$$= 94247.78 \approx 94248 \text{ rad/volt}$$

19. (c)

Given; f_m = 3 kHz; Nyquist Rate = $2f_m$ = 6000 Hz

It is sampled at a rate $33\frac{1}{3}\%$ higher than the Nyquist rate.

$\therefore$

$$f_s = 6000\left(1\frac{1}{3}\right) = 8000 \text{ Hz}$$

$$\text{Max. Quantization Error} = \pm\frac{\Delta}{2} = \frac{0.5}{100}\times m_p$$

(For the quantization step Δ, the maximum quantization error is $\pm\frac{\Delta}{2}$)

$$\frac{2m_p}{2L} = \frac{0.5m_p}{100}$$

$\therefore$ $L = 200 \leq 2^n$, where n is the number of bits per sample

We get, $n = 8$

$$R_b = nf_s$$

$$R_b = 8 \times 8K = 64 \text{ kHz}$$

Now, the minimum bandwidth of the channel required is $\frac{R_b}{2}$.

$$\therefore \quad \text{BW} = \frac{64}{2} = 32 \text{ kHz}$$

20. (d)

for $x(t)$: $f_m = 100$ kHz

$NR = 2f_m = 200$ kHz

for $y(t)$: $f_m = 150$ kHz

$NR = 2f_m = 300$ kHz

$$y^2(t) = y(t) \times y(t)$$

Multiplication in time domain will lead to convolution in frequency domain. Hence, the spectrum of $y^2(t)$ will be from $-6\pi \times 10^5$ rad/sec to $6\pi \times 10^5$ rad/sec.

$\therefore$ $NR = 600$ kHz

For $x(t) \cdot y(t)$:

spectrum of $x(t) \cdot y(t)$ will be from $-5\pi \times 10^5$ rad/sec to $5\pi \times 10^5$ rad/sec

$\therefore$ $f_m = 250$ kHz

$NR = 500$ kHz

21. (c)

Granular distortion will take place for

$$\frac{\Delta}{T_s} \geq \frac{dm(t)}{dt}$$

$$\Delta f_s \geq 2\pi A_m f_m \qquad \text{[for sinusoidal input]}$$

$$0.5 \times 20 \times 10^3 \geq 2\pi A_m f_m$$

$$1.59 \times 10^3 \geq A_m f_m$$

$$A_m f_m \leq 1591.549$$

Option (1), (3), (4) are satisfying the above criteria.

22. (d)

- In pulse amplitude modulation, the bandwidth of the transmission channel depends on the width of the pulse whereas in PWM and PPM, the bandwidth of transmission channel depends on rising time of the pulse.
- In PPM modulation scheme, the instantaneous power of a transmitter remains constant as the width and amplitude of pulse remains constant.
- The transmission bandwidth of PWM and PPM is higher than PAM.

- The amplitude of PAM pulses varies according to modulating signal whereas the amplitude of pulse is constant in PWM and PPM signal. Therefore, interference of noise is maximum for the PAM signal.

23. (a)

- The given constellation diagram could represent QPSK as well as 4-QAM modulation scheme.
- In a constellation diagram, the square of distance from the origin represents the symbol energy. In the given constellation diagram, all signal points are equidistant from the origin.
  Hence; symbol energy $= (1)^2 + (1)^2 = 2$ J
  Since, each symbol has two bits. Therefore, average energy per bit is 1 J.
- As the order of the modulation increases, the distance between signalling point decreases and hence, the probability of error increases.

24. (a)

- DPSK does not need carrier at its receiver. Hence, the complicated circuitry for generation of local carrier is avoided.
- The probability of error or bit error rate of DPSK is higher than that of BPSK. In DPSK, previous bit is used to detect next bit. Therefore, if error is present in previous bit, detection of next bit can also go wrong. Thus, error is created in next bit also. Thus, error propagation in DPSK is more whereas in PSK, detection of each bit is independent.
- Noise interference in DPSK is more.

25. (d)

For a valid code word

$$CH^T = 0$$

$$\begin{bmatrix}0\,1\,0\,0\,0\,1\,1\end{bmatrix}\begin{bmatrix}1 & 0 & 0 & : & 1 & 0 & 1 & 1\\ 0 & 1 & 0 & : & 1 & 1 & b & 0\\ 0 & 0 & 1 & : & 0 & 1 & 1 & a\end{bmatrix}^T = 0$$

$$\begin{bmatrix}0\,1\,0\,0\,0\,1\,1\end{bmatrix}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 1 & 0\\ 0 & 1 & 1\\ 1 & b & 1\\ 1 & 0 & a\end{bmatrix} = 0$$

It is given that 0 1 0 0 0 1 1 is a valid code word for the given code. The value of a and b must satisfy

$$\begin{bmatrix} & 0 & & & \\ 1 & \oplus & b & \oplus & 0\\ 0 & \oplus & a & \oplus & 1\end{bmatrix} = \begin{bmatrix}0\\0\\0\end{bmatrix}$$

for $CH^T = 0,$

$$b = 1 \text{ and } a = 1$$

26. (a)

A memory less source emits n symbols each with probability P. Hence,

$$P = \frac{1}{n}$$

The entropy of the source

$$H = \sum_{i=1}^{n} P_i \log_2 \frac{1}{P_i}$$

$$H = \sum_{i=1}^{n} \left(\frac{1}{n}\right) \log_2 n$$

$$H = \log_2 n$$

Hence, H increases as $\log_2 n$.

27. (c)

Processing gain,

$$G_p = \frac{\text{Chip Rate}}{\text{Data Rate}} = \frac{1\times10^6}{1\times10^3} = 1000$$

Also, $$\frac{E_b}{N_0} = 10 \text{ dB} = 10$$

As number of users, $$N = 1 + \frac{G_p}{E_b / N_0}$$

$$N_{\max} = 1 + \frac{1000}{10} = 101$$

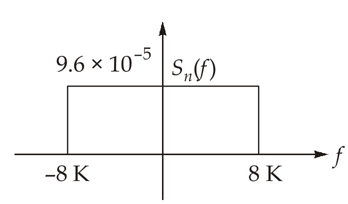
So maximum of 101 users can access the network.

28. (c)

- Companding is used in pulse code modulation. It is a non-uniform quantization technique implemented to improve the signal to quantization noise ratio of weak signals.
- FSK was one of the earliest forms of digital modulation used in radio telegraphy.
- In asynchronous TDM, time slots are not fixed i.e., slots are flexible. Hence, the asynchronously sampled signals are multiplexed by a technique called pulse stuffing.
- Delta modulation is the simplest form of differential pulse code modulation (DPCM) where the difference between successive samples is encoded by a 1 bit quantizer.
- Threshold effect occurs in FM.

29. (c)

The noise power at the input is



$$P_n = \int_{-8K}^{8K} S_n(f)df$$

$$P_n = 2 \times 8000 \times 9.6 \times 10^{-5}$$

$$P_n = 1.536 \text{ Watt}$$

30. (c)

$$R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{25 \times 50}{25 + 50} = 16.66 \text{ k}\Omega$$

$$V_n = \sqrt{4 R_p\, KTB}$$

$$V_n = \sqrt{4 \times 16.66 \times 1.38 \times 10^{-23} \times 290 \times 10^5 \times 10^3}$$

$$V_n = 5.164 \times 10^{-6} \text{ Volt}$$

$$V_n = 5.164\ \mu\text{V}$$

31. (c)

The AC power of the signal is given as σ_x^2, where, σ_x^2 is the standard deviation.

$$\sigma_x^2 = E[X^2] - \{E[X]\}^2$$

$$E[X^2] = \underset{\tau \to 0}{lt}\ R_X(\tau) = 7 \text{ W}$$

$$[E[X]]^2 = \underset{\tau \to \infty}{lt}\ R_X(\tau) = 4 \text{ W}$$

$\therefore$ $$\sigma_X^2 = 7 - 4 = 3 \text{ W}$$

where; $E[X^2]$ is total power and $\{E[X]\}^2$ is DC power.

32. (d)

$$f_X(x) = \frac{1}{2} e^{-|x|} \text{ for } -\infty < x < \infty$$

$$E[X] = \int_{-\infty}^{\infty} x \cdot f_X(x) dx = \int_{-\infty}^{0} x \cdot \frac{1}{2} e^{+x} dx + \int_{0}^{\infty} \frac{1}{2} \cdot x \cdot e^{-x} dx$$

$$E[X] = \frac{1}{2}\left[xe^x - e^x\right]_{-\infty}^{0} + \frac{1}{2}\left[\frac{xe^{-x}}{(-1)} - \frac{1 \cdot e^{-x}}{(-1)^2}\right]_0^{\infty}$$

$$E[X] = \left(-\frac{1}{2}\right) + \left(\frac{1}{2}\right) = 0$$

33. (c)

$$y(t) = K + x(t)$$

The autocorrelation $R_Y(\tau)$

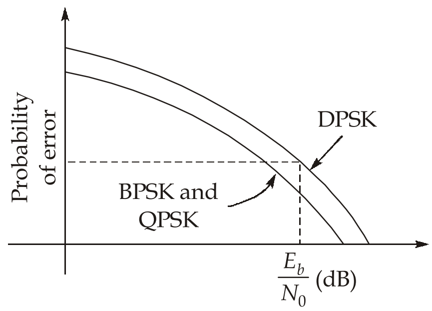
$$\begin{aligned} R_Y(\tau) &= E[y(t) \cdot y(t+\tau)] \\ &= E[[K + x(t)] \cdot [K + x(t+\tau)]] \\ &= E[K^2 + K \cdot x(t+\tau) + K \cdot x(t) + x(t) \cdot x(t+\tau)] \\ &= E[K^2] + E[K \cdot x(t+\tau)] + E[K \cdot x(t)] + E[x(t) \cdot x(t+\tau)] \\ &= K^2 + R_x(\tau) \end{aligned}$$

$\because$ $$E[x(t)] = E[x(t+\tau)] = 0 \quad \text{[Given } x(t) \text{ is a zero mean signal]}$$

34. (d)

In delta modulation, slope overload noise occurs when the slope of the input signal is greater than the delta modulator is capable of reproducing. Hence, it can be reduced by increasing the step size.

35. (a)



For same probability of error, QPSK and BPSK requires less $\frac{E_b}{N_0}$ than DPSK.

The probability of error is identical for BPSK and QPSK because the BER has been measured in terms of signal to noise ratio per bit.

36. (a)

We have, $H[X] = -\Sigma p(x_i)\log_2 p(x_i)$. Since, $\log_2 p(x_i) \leq 0$, hence $H[X] \geq 0$ with $H[X] = 0$ when $p(x) = 1$ i.e. when X is deterministic. For random variable X having M equiprobable symbols, entropy $H[X] = \log_2 M$.

37. (b)

- Angle modulated signals are more power efficient as amplitude of FM or PM wave remains constant.
- FM and PM require more bandwidth than AM, since they have wider frequency spectrum.

38. (b)

Section B : Electronic Devices & Circuits-1 + Analog Circuits Topics-1

39. (c)

In a phototransistor, the base-collector junction is responsible for collecting the light-generated carriers. Hence, the base-collector junction is made as large as practical to maximize the photocurrent. Therefore, statement 2 is incorrect.

40. (b)

We know that,

The induced electric field, $$E(x) = -\left(\frac{kT}{q}\right)\frac{1}{N_d(x)}\frac{dN_d(x)}{dx}$$

$$\frac{dN_d(x)}{dx} = -10^{19}\ \text{cm}^{-4}$$

$$\therefore \qquad E(x) = -\frac{(0.0259)(-10^{19})}{(10^{16} - 10^{19}x)}$$

$$E(0) = \frac{(-0.0259)\times(-10^{19})}{(10^{16})} = 25.9 \text{ V/cm}$$

41. (a)

Given: $N_C = 2.8 \times 10^{19}$ cm^{-3}; $E_C - E_F = 0.25$ eV

The equilibrium concentration of electrons,

$$n_o = N_C \exp\left[-\frac{(E_C - E_F)}{kT}\right] = 2.8\times10^{19} \exp\left[\frac{-0.25}{0.025}\right]$$

$$n_o = 1.27 \times 10^{15} \text{ cm}^{-3}$$

42. (c)

The open-circuit voltage, V_{OC}, is the maximum voltage available from a solar cell, and this occurs at zero current. However, it is less than the built-in voltage because the electric field due to V_{bi} also causes a small current to flow through the cell, even when the cell is not connected to a load. This current is called the dark current, and it reduces the V_{OC} by a small amount.

43. (b)

For circuit (b), the electrons are attracted towards the positive electrode and moves in the positive x-direction $x > 0$. Hence, the energy of electrons decreases in the positive x-direction.

44. (b)

Donor atom (N_d) donates a free electron and becomes positively charged whereas acceptor atom (N_a) accepts a free electron and becomes negatively charged. Hence, for semiconductor to be electrically neutral, the sum of the number of donors and the holes should be equal to the sum of the number of the acceptors and the electrons.

45. (b)

We know,

$$V_{D2} - V_{D1} = \eta V_T \ln\left[\frac{I_{D2}}{I_{D1}}\right]$$

$$0.6 - 0.5 = \eta \cdot V_T \cdot \ln\left[\frac{100\,\mu\text{A}}{3\,\mu\text{A}}\right] \qquad (V_T = 26 \text{ mV})$$

$$0.1 = \eta \times 26 \times 10^{-3}[\ln 100 - \ln 3]$$

$$0.1 = \eta \times 26 \times 10^{-3}\,[2 \times 2.3 - 1.1] \qquad \because \begin{Bmatrix}\ln 10 = 2.3 \\ \ln 3 = 1.1\end{Bmatrix}$$

$$\eta = 1.098$$

46. (c)

Diffusion capacitance,

$$C_D = \frac{\tau I_f}{\eta V_T}$$

or

$$C_D = \frac{\tau}{r_d} \quad ;\text{ where } r_d = \text{dynamic resistance}$$

or $C_D = \tau g_d$; where g_d = dynamic conductance

∴ $2 \times 10^{-7} = 5 \times 10^{-6} \times g_d$

∴ $$g_d = \frac{2\times10^{-7}}{5\times10^{-6}} = 40 \text{ m℧}$$

47. (c)

Peak to peak ripple voltage = V_r = 12 V

Hence, output voltage range from 60 V to 48 V.

$$\text{DC output voltage} = \frac{60+48}{2} = \frac{108}{2} = 54 \text{ V}$$

$$I_{DC} = \frac{54}{600} = 0.09\text{A}$$

$$\text{Discharging time} = \frac{1}{50} = 20 \text{ ms} \cong T_0$$

For a half-wave rectifier, Ripple voltage,

$$V_r = \frac{I_{DC}}{f_o C} = \frac{I_{DC}T_0}{C}$$

$$C = \frac{I_{DC}}{f_0 V_r} = \frac{9}{50\times12\times100} = \frac{3}{5\times4\times1000}$$

$$= \frac{3}{20}\text{mF} = 0.15 \text{ mF}$$

48. (b)

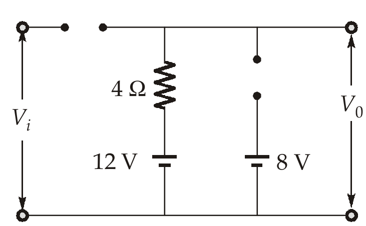
V_i > 12 V

$D_1 \rightarrow$ ON : $D_2 \rightarrow$ OFF

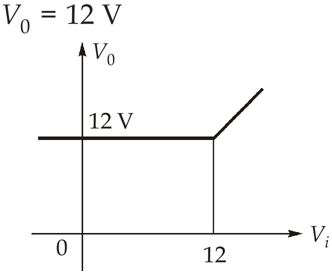
$$V_0 = V_i$$

V_i < 12 V

Both diodes are reverse-biased.

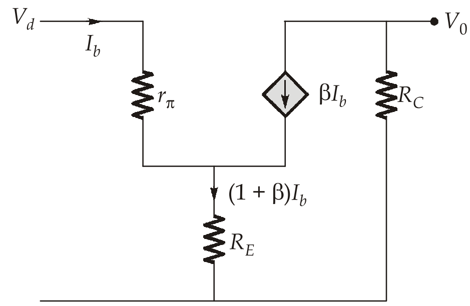


V_0 = 12 V



49. (a)

Here, $V_2 = 0$. Drawing the small-signal circuit,



From the circuit,

$$V_1 = I_b[r_\pi + (1 + \beta)R_E]$$

and

$$V_0 = -\beta I_b R_C$$

$\therefore$

$$\frac{V_0}{V_2 - V_1} = \frac{-V_0}{V_1} = \frac{\beta R_C}{r_\pi + (1+\beta)R_E}$$

Since, $\beta >> 1$ and $r_\pi << (1 + \beta)R_E$, we get

$$\frac{V_0}{V_2 - V_1} = \frac{R_C}{R_E}$$

50. (c)

Power gain is due to high voltage gain > 1, and high current gain > 1. *CE* transistor amplifier does not use step-up transformer.

51. (a)

For minimum heat dissipation, the transistor should be avoided from thermal run-away i.e.,

$$V_{CE} \leq \frac{V_{CC}}{2}$$

$$V_{CE} \leq \frac{16}{2}$$

$$V_{CE} \leq 8 \text{ V}$$

52. (d)

Since β is very large. Hence, we assume,

$$I_{B1} = I_{B2} = 0$$

$$I_{C1} = \frac{0 - V_{BE} + 15}{R} = \frac{15 - 0.7}{10} = \frac{14.3}{10} = 1.43 \text{ mA}$$

$\therefore$

$$I_{C1} = I_{S1} e^{\frac{V_{BE}}{\eta V_T}} = 1.43 \text{ mA}$$

$$I_{C2} = I_0 = I_{S2} e^{\frac{V_{BE}}{\eta V_T}}$$

Since, emitter area of transistor Q_1 is one fourth of transistor Q_2, hence,

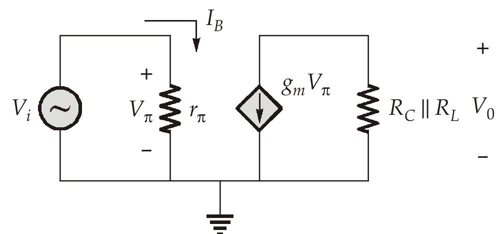
$$I_{S2} = 4I_{S1}$$

$$I_0 = 4I_{S1}\exp\left(\frac{V_{BE}}{\eta V_T}\right)$$

$$= 4I_{C1} = (4 \times 1.43)\text{ mA} = 5.72\text{ mA}$$

53. (b)

Considering small signal analysis



$$V_0 = -g_m V_\pi (R_C \parallel R_L)$$

$$V_i = V_\pi$$

$$\frac{V_0}{V_i} = -g_m (R_C \parallel R_L)$$

From DC analysis,

$$I_{EQ} = \frac{15 - 0.7}{25\text{ k}\Omega} = \frac{14.3}{25} = 0.572\text{ mA}$$

$$I_{EQ} \cong I_{CQ} = 0.572\text{ mA}$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{0.572}{25}\text{ A/V}$$

$$\frac{V_0}{V_i} = -\frac{0.572}{25} \times 6 \times 1000$$

$$= -137.28 \cong -137.3\text{ V/V}$$

54. (b)

- Enhancement MOSFET can be biased by using only gate bias circuit and voltage divider bias circuit and not by self bias circuit. In E-MOSFET, channel is not pre-existing, hence self-biasing using drain current through source resistance is not possible.
- Temperature $T\uparrow \Rightarrow$ Carrier mobility $\downarrow \Rightarrow I_{DS}\downarrow$
  I_{DS} α mobility; I_{DS} is drift current and depends on mobility.
- Common-gate amplifier has the relatively small input resistance and also relatively large output resistance, hence it is used as a current buffer. It is used in high-frequency applications due to its inherently wide bandwidth.
  Hence, thermal runaway can never occur in FET. So FET is considered as thermal stable device and the drain current has negative temperature coefficient.

55. (c)

Given: $V_{\text{rms}} = 220$ V; $f_0 = 60$ Hz; $R_L = 200\ \Omega$; $C = 500\ \mu$F

$$\frac{V_m}{\sqrt{2}} = 220\text{ V}$$

$$V_m = 220\sqrt{2}\text{ V}$$

For a full wave rectifier with capacitor filter,

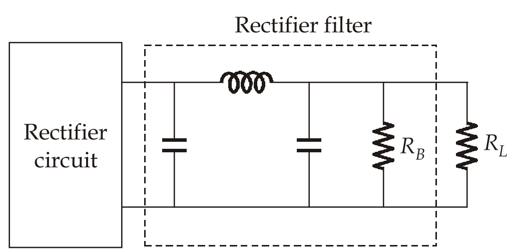
$$V_{DC} \cong V_m = 311.08 \text{ V} \cong 311 \text{ V}$$

$$r = \frac{1}{4\sqrt{3} f_o C R_L} = \frac{1}{4\sqrt{3} \times 60 \times 500 \times 10^{-6} \times 200} = 0.024$$

56. (d)

Purpose of bleeder resistance:

The operation of a filter using an inductor is based on the fact that a minimum current flows through it at all times. The bleeder resistance is used to maintain a certain minimum current through the choke (inductor) even if no load.



$$R_B \geq 10R_L$$

- The value of bleeder resistance (R_B) should be such that to draw only 10% of total load current.
- Bleeder resistance can be used as voltage divider for tapping out any desired output.
- Single power supply can be used to provide more voltage.
- It provides better voltage regulation.
- It provides safety to operator by providing discharge path to the capacitor.

57. (a)

In *pn* junction diode, the barrier potential and the doping concentrations have logarithmic dependence given by

$$V_{bi} = V_o \ln\left[\frac{N_A N_D}{n_i^2}\right]$$

Hence, the built-in potential barrier changes slightly as the doping concentrations change.

Section C : Control Systems-2 + Microprocessors and Microcontroller-2

58. (a)

From $G(s)H(s)$, it is clear that $P = 0$.

Since, $$G(s)H(s) = \frac{4s+1}{s^2(s+1)(2s+1)}$$

Now, the encirclement of point $(-1 + j0)$ takes place twice in the clockwise direction, hence $N = -2$.

From the Nyquist criterion, $N = P - Z$

$$-2 = P - Z$$

$\therefore$ $Z = 2$

The number of poles of closed loop system in right hand side of s-plane is 2.

59. (c)

The phase cross-over frequency $\omega_{pc} = \infty$, thus gain margin

$$\text{GM} = \log \frac{1}{|G(j\omega)|_{\omega=\infty}} = \infty$$

Note: Generally, for second order stable system, gain margin is infinite.

60. (c)

Open loop transfer function,

$$G(s)H(s) = \frac{8(s+1)K}{s^2(s+2)}$$

$$\text{Characteristic equation} = 1 + G(s)H(s) = 0$$

$$= s^3 + 2s^2 + 8sK + 8K = 0$$

By *RH* criteria

$$\begin{array}{c|cc} s^3 & 1 & 8K \\ s^2 & 2 & 8K \\ s^1 & \frac{16K-8K}{2} & 0 \\ s^0 & 8K & \end{array}$$

For sustained oscillation, s^1 row must be zero i.e.

$$4K = 0 \quad \Rightarrow K = 0$$

$$\text{PI controller} = K_p\left[1+\frac{1}{T_i s}\right] = 8\left[1+\frac{1}{s}\right]$$

$$K_p = 8, \quad T_i = 1 \text{ min}$$

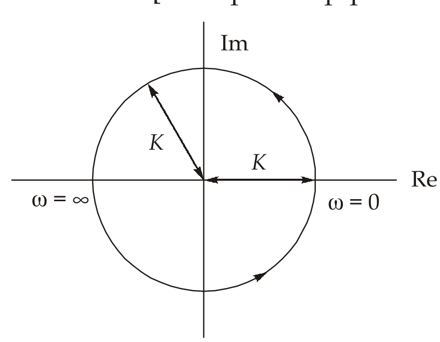
$$PB = \frac{100}{8}\% = 12.5\%$$

61. (c)

$$G(s)H(s) = \frac{K(1+s)}{(1-s)}$$

$$|G(s)H(s)| = \frac{K\sqrt{1+\omega^2}}{\sqrt{1+\omega^2}} = K$$

$$P = 1 \quad \text{[one open loop pole on RHS]}$$



If $K > 1$, $N = 1$

$Z = P - N = 1 - 1 = 0$, implies system is stable.

If $K < 1$, $N = 0$.

$Z = P - N = 1 - 0 = 1$, implies system is unstable.

For $K = 1$, system is at verge of stability (i.e. marginally stable).

62. (b)

$$\phi(0) = e^{A0} = I$$
$$\phi^{-1}(t) = (e^{At})^{-1} = \phi(-t)$$
$$\phi(t_2 - t_1)\,\phi(t_1 - t_0) = \phi(t_2 - t_0)$$
$$[\phi(t)]^n = (e^{At})^n = e^{A(nt)} = \phi(nt)$$

By using above properties of state transition matrix,

Take, $t_2 = 2,\quad t_1 = 0,\quad t_0 = 2$

$$\phi(2 - 0)\,\phi(0 - 2) = \phi(2 - 2) = \phi(0) = I$$

$$[\phi(t)]^2 = \phi(2t) = \begin{bmatrix} e^{-4t} & 2te^{-4t} & 2t^2e^{-4t} \\ 0 & e^{-4t} & 2te^{-4t} \\ 0 & 0 & e^{-4t} \end{bmatrix}$$

63. (d)

$$[B] = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$[AB] = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & a & b \end{bmatrix}_{3\times 3} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}_{3\times 1}$$

$$[AB] = \begin{bmatrix} 0 \\ 1 \\ b \end{bmatrix}_{3\times 1}$$

$$A^2B = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & a & b \end{bmatrix} \begin{bmatrix} 0 \\ 1 \\ b \end{bmatrix} = \begin{bmatrix} 1 \\ b \\ a+b^2 \end{bmatrix}_{3\times 1}$$

Controllability Matrix, $Q = [B \;:\; AB \;:\; A^2B]$

$$Q = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & b \\ 1 & b & a+b^2 \end{bmatrix} \neq 0$$

Determinant of Q is not zero for any value of a and b.

Hence, all the options are correct.

64. (d)

- The lead compensator increases the bandwidth by increasing the gain crossover frequency. Hence, statement 4 is incorrect.
- The lead compensator decrease the rise time, hence making the system dynamic response faster.
- It is essentially a high pass filter and will amplify noise.

65. (b)

66. (a)

- In cycle stealing mode, the DMA controller takes advantage of idle cycles in the CPU's execution cycle to transfer data directly between memory and the I/O device. It allows for efficient data transfer while minimizing interference with the CPU's operation.
- The DMA technique is more efficient than the interrupt driven technique for high volume I/O data transfer.

67. (d)

The processor will read the data from the port.

68. (b)

In case of memory mapped I/O → I/O devices are treated as memory locations having 16-bit address.

So, microprocessor having 16-bit address line can address 2^{16} memory locations and I/O devices.

2^{16} memory locations = $2^6 \times 2^{10}$ = 64 K memory locations.

69. (c)

Microcontrollers have some form of non-volatile memory for storing program code and data. Hard-disks are common in general purpose computers. Hence, statement 2 is not correct.

70. (d)

The SBUF register is used to hold the serial data during transmission and reception. SBUF is physically two registers. One is write only and is used to hold data to be transmitted out of the 8051 via TxD pin. The other is read only and holds received data from external sources via RxD pin. The two registers use the same address 99H. Register SCON controls the data communication and register PCON controls data rates.

71. (a)

- 8051 microcontroller consists of 4 parallel ports of 8-bit each, thereby providing 32 input-output pins.
- For serial communication, there are two separate pins (RxD and TxD) known as serial port of 8051.

72. (b)

READY signal introduces wait states and therefore useful when CPU communicates with a slow peripheral device.

73. (d)

MOV R4, 7FH : Direct Addressing Mode as the address of the data is specified by using 8-bit data in the instruction.

ADD A, R7: Register Addressing Mode as the data is present in the register.

MOV B, @R1: Register Indirect Addressing Mode as the address of the data is present in the register.

MOV R4, #56: Immediate Addressing Mode as the data is provided in the instruction.

74. (a)

Operating modes of 8255:

Mode 0 $\rightarrow$ Simple input/output.

Mode 1 $\rightarrow$ Storbed input/output.

Mode 2 $\rightarrow$ Bidirectional port.

75. (b)

The state-space model is applicable to time-variant systems also. Hence, both statements 1 and 2 are correct but statement 2 is not the correct explanation of statement 1.

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