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ESE 2023 : 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

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

DETAILED EXPLANATIONS
Section A : Analog and Digital Communication Systems

1. (c)

Highest frequency present in the modulated signal is

$$= f_c + nf_m$$

where $n = \beta + 1$ according to Carson's rule. For $\beta = 5$,

$$f_{max} = f_c + (\beta + 1)f_m = f_c + 6f_m = 100 \text{ MHz} + 6 \times 15 \text{ kHz}$$

$$f_{max} = 100090 \text{ kHz}$$

2. (c)

$$\text{Number of levels} = 2^n = 16$$

∴ Each quantizing level will be represented by 4-bit binary word.

3. (b)

For delta modulation, $$SN_qR = \frac{3}{8\pi^2}\left(\frac{f_s}{f_m}\right)^3$$

Here, $R_b = nf_s$, For DM ⇒ $n = 1$

$$R_b = f_s = 64 \text{ kbps}$$

$$f_m = 4 \text{ kHz}$$

∴ $$SN_qR = \frac{3}{8\pi^2}\left[\frac{64}{4}\right]^3 = \frac{3}{8\pi^2}[16\times16\times16] = \frac{6\times256}{\pi^2} = 155.63$$

$$[SN_qR] = 10\log_{10}[155.63] = 21.9 \text{ dB} \simeq 22 \text{ dB}$$

4. (b)

$$\text{Line speed} = \text{Maximum data rate} = R_b = nf_s$$

and $$f_s = 2f_m + 2f_m \times \frac{25}{100} = 2\times1.2\left[1+\frac{1}{4}\right] = 3 \text{ kHz}$$

$$f_s = 3000 \text{ samples per sec}$$

∴ $$\text{Line speed} = 8 \times 3000 = 24000 \text{ bps}$$

5. (b)

FM is a non-linear modulation process.

6. (d)

All statements are correct.

7. (c)

To calculate checksum

```
    1 0 0 1 0 0 1 1 1 0 0 1 0 0 1 1
    1 0 0 1 1 0 0 0 0 1 0 0 1 1 0 1
   ---------------------------------
(1) 0 0 1 0 1 0 1 1 1 1 1 0 0 0 0 0
    \_____________16-bits_________/
 |
  \-------------------------------> +1
   ---------------------------------
    0 0 1 0 1 0 1 1 1 1 1 0 0 0 0 1
    \_____________16-bits_________/
```

$\therefore$ Result of sum is 0010101111100001

1's complement of result: 1101010000011110

Hence, Checksum value = 1101010000011110

8. (b)

For FM, RF carrier range $\Rightarrow$ 88 MHz to 108 MHz

FM BW $\Rightarrow$ 200 kHz

IF frequency $\Rightarrow$ 10.7 MHz

For AM, RF carrier range $\Rightarrow$ 550 – 1650 kHz

AM BW $\Rightarrow$ 10 kHz

IF frequency $\Rightarrow$ 455 kHz

9. (d)

For 4-ary PSK, $M = 4$; $N = \log_2 M = 2\text{-bit}$

$$E_s = NE_b$$

$$\text{Average probability of symbol error} = 2Q\left[\sqrt{\frac{2E_s}{N_o}\sin^2\left(\frac{\pi}{M}\right)}\right] = 2Q\left[\sqrt{\frac{2\times 2E_b}{N_o}\times\left[\sin\left(\frac{\pi}{4}\right)\right]^2}\right]$$

$$P_e = 2Q\left[\sqrt{\frac{2E_b}{N_o}}\right]$$

whereas, probability of bit error for 4-ary PSK is

$$P_e = Q\left[\sqrt{\frac{2E_b}{N_o}}\right]$$

10. (a)

$$(\text{SNR})_0 = \frac{\sigma_M^2}{\sigma_Q^2} \quad \text{...(i)}$$

where $(\text{SNR})_0 \rightarrow$ Output SNR of DPCM

$G_p \rightarrow$ Processing gain

$$G_p = \frac{\sigma_M^2}{\sigma_E^2}$$

From equation (i),

$$(\text{SNR})_0 = \left[\frac{\sigma_M^2}{\sigma_E^2}\right]\times\left[\frac{\sigma_E^2}{\sigma_Q^2}\right]$$

$$(\text{SNR})_0 = \frac{\sigma_M^2}{\sigma_Q^2}$$

11. (b)

For generation of carrier for DSC-BC demodulation (synchronous detector), squaring circuit and costas loop method are used.

12. (c)

The source coding theorem states that any source can be losslessly encoded with a code whose average number of bits per source symbol is arbitrarily close to, but not less than, the source entropy E. Hence, it provides the intuitive yardstick to measure the information emerging from a source.

13. (c)

All the independent random variables are uncorrelated but converse is not true.

14. (a)

$$\text{Deviation ratio} = \frac{\Delta f}{f_m}$$

where, $\Delta f \rightarrow$ Peak Frequency deviation = $K_f A_m$

$f_m \rightarrow$ Maximum frequency component.

15. (a)

$$\Delta f = k_p A_m f_m \quad \Rightarrow \quad \Delta f \propto f_m$$

$$\text{New } f_m = 4 \text{ kHz}$$

$$\therefore \qquad \text{New } \Delta f = 30 \text{ kHz}$$

$$\text{BW} = 2(\Delta f + f_m) = 2[30 + 4] = 68 \text{ kHz}$$

16. (c)

$$y(t) = 0.6p(t) + 0.3p(t - 0.3)$$

Using Laplace transform,

$$Y(s) = 0.6P(s) + 0.3\, e^{-0.3s} P(s)$$

$$\frac{Y(s)}{P(s)} = H(s) = [0.6 + 0.3e^{-0.3s}]$$

Mean value of output random process is $E[Y] = 1.8$

$$E[Y] = H(s)\big|_{s=0} \cdot E[P]$$

$$1.8 = [0.6 + 0.3] \times M = 0.9 \times M$$

$$M = 2$$

17. (a)

$$X_{AM}(t) = 10[1 + 0.5\sin 2\pi f_m t] \cos 2\pi f_c t$$

Comparing it with standard AM expression

$$X_{AM}(t) = A_c[1 + \mu \sin 2\pi f_m t]\cos\omega_c t$$

$$A_c = 10, \quad \mu = 0.5$$

$$\text{Peak envelope} = A_c(1 + \mu)$$

$$\text{Peak envelope power} = A_c^2\,(1+\mu)^2 = 100(1+0.5)^2 = 225 \text{ Watts}$$

18. (d)

The basic idea of the signal space analysis approach is to represent each member of a set of transmitted signals observed at the channel output by an N-dimensional vector resulting in a signal constellation. Hence, all the statements are correct.

19. (c)

For decreasing quantization noise in PCM, step-size is decreased. Therefore,

(i) Number of bits (n) increases and hence, number of quantization levels also increases.

(ii) As n increases, bandwidth increases.

(iii) As n increases, step size decreases, so the randomness also decreases.

20. (a)

Given: f_s = 32,000 samples/sec, Δ = 1.5 V.

The slope overload occurs in delta modulator.

For delta modulator,

Quantization noise power, $$N_q = \frac{\Delta^2}{3} = \frac{1.5\times1.5}{3} = 0.75\text{ W}$$

21. (c)

Properties of Hilbert transform:

(i) A signal $x(t)$ and its Hilbert transform $x_h(t)$ have same energy density spectrum.

(ii) A signal $x(t)$ and its Hilbert transform $x_h(t)$ have the same autocorrelation function.

(iii) A signal $x(t)$ and its Hilbert transform $x_h(t)$ are mutually orthogonal.

i.e. $$\int_{-\infty}^{\infty} x(t)\,x_h(t)dt = 0$$

(iv) If $x_h(t)$ is a Hilbert transform of $x(t)$, then the Hilbert transform of $x_h(t)$ is $-x(t)$

i.e. If $H[x(t)] = x_h(t)$

$H[x_h(t)] = -x(t)$

22. (d)

Given: P_c = 8 kW; μ = 0.4

Power contained in each side band,

$$P_{\text{LSB}} = P_{\text{USB}} = \frac{P_c\mu^2}{4} = \frac{8\times10^3\times(0.4)^2}{4}$$

$$P_{\text{LSB}} = P_{\text{USB}} = 320\text{ W}$$

23. (b)

Given: f_{upper} = 100.007 MHz, f_c = 100 MHz

Frequency deviation, $\Delta f = f_{\text{upper}} - f_c$

Δf = (100.007 – 100) MHz = 7 kHz

Carrier swing = 2 × Δf = 2 × 7 = 14 kHz

24. (b)

At low frequencies, a particular type of noise appears. The power spectral density of this noise increases as the frequency decreases. This noise is called flicker noise.

$$S(\omega) \propto \frac{1}{f}$$

Therefore, the flicker noise becomes significant at low frequencies, generally below a few kHz.

25. (b)

Given: Bipolar *RZ* technique, $T_b = 500\ \mu s$

$$R_b = \frac{1}{T_b} = \frac{1}{500}\times 10^6 = 2000 \text{ bits/sec}$$

Bandwidth, $$\text{BW} = R_b = \frac{1}{T_b} = 2000 \text{ Hz} = 2 \text{ kHz}$$

26. (d)

From the properties of PDF,

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

$$\int_2^4 \frac{1}{K}(3+2x)\,dx = 1$$

$$\frac{1}{K}\left[3x + \frac{2x^2}{2}\right]_2^4 = 1$$

$$\frac{1}{K}\left[3(4-2) + (4^2 - 2^2)\right] = 1$$

$$\frac{1}{K}[6+12] = 1$$

$$K = 18$$

28. (c)

Given: $C = 57.6$ kbps ; $\frac{\eta}{2} = 10^{-10}$ W/Hz

Capacity, $$C = 1.44\frac{S}{\eta}$$

$$57.6 \times 10^3 = 1.44\frac{S}{\eta}$$

$$S = \frac{57.6\times 10^3 \eta}{1.44} = \frac{57.6\times 10^3 \times 2\times 10^{-10}}{1.44} = 8\ \mu\text{W}$$

29. (d)

Given: $p(x_1) = 0.4$, $P(x_2) = 0.6$

$$H(x) = -p(x_1)\log_2 p(x_1) - p(x_2)\log_2 p(x_2)$$
$$= -0.4\log_2(0.4) - 0.6\log_2(0.6) = 0.971 \text{ bits/symbol}$$

Entropy of second order extension,

$$H(X^2) = 2 \times H(X)$$
$$H(X^2) = 2 \times 0.971 = 1.942 \text{ bits/symbol}$$

30. (b)

- A channel described by a channel matrix with only one non-zero element in each row is called deterministic channel.
- A channel described by a channel matrix with only one non-zero element in each column is called lossless channel.

31. (a)

Given: $f_c = 75$ MHz ; $R_b = 12$ Mbps

$$\text{Lower side frequency} = f_c - R_b/2 = 75 - 6 = 69 \text{ MHz}$$
$$\text{Upper side frequency} = f_c + R_b/2 = 75 + 6 = 81 \text{ MHz}$$

32. (a)

Given: $N = 25$; $f_m = 4$ kHz ; Number of bits, $n = 10$; Additional bit, $a = 1$

$$NR = 2f_m = 2 \times 4 = 8 \text{ kHz}$$

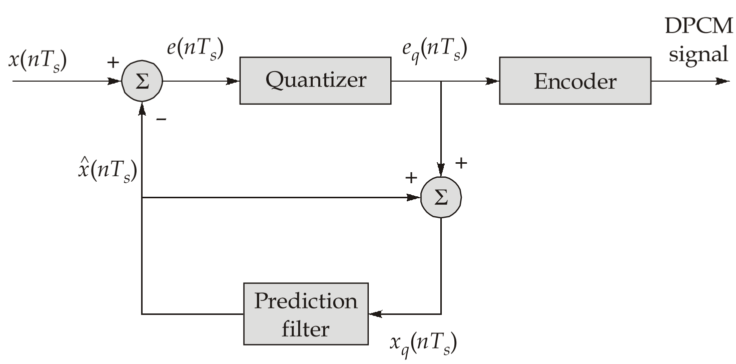
Sampling frequency, $f_s = 1.25 \times NR = 1.25 \times 8 = 10$ kHz

Bit rate, $R_b = (Nn + a)f_s$

$$R_b = (25 \times 10 + 1) \times 10 = 2510 \text{ kbps}$$

34. (b)

DPCM transmitter



$$e(nT_s) = x(nT_s) - \hat{x}(nTs)$$

Quantizer output, $e_q(nT_s) = e(nT_s) + q(nT_s)$

$$x_q(nT_s) = e_q(nT_s) + \hat{x}(nT_s)$$
$$x_q(nT_s) = x(nT_s) + q(nT_s)$$

- The quantized version of the signal $x_q(nT_s)$ is the sum of original sample value and quantization error q(nT_s).
- The quantization error can be positive or negative.
- The quantized version of the signal does not depend on the prediction filter characteristics.

35. (a)

Given:

Phase modulated signal,

$$x(t) = 20\cos\left[10^6\pi t + 10\sin 2\pi(10^3)t\right]$$

$$= 20\cos\left[10^6\pi t + 10\sin 2\pi(10^3)\, t\right]$$

$$\Delta\phi_{max} = 10\sin 2\pi(10^3)t\Big|_{max} = 10 \text{ rad}$$

36. (b)

The total time taken by the PLL to establish the phase lock between output and input frequencies is known as pull-in time.

38. (a)

Foster–Seeley discriminators are sensitive to both frequency and amplitude variations. The main drawback of faster Seeley discriminator is that the demodulator output produces an error in presence of noise or any other spurious amplitude variations because it does not provide amplitude limiting.

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

39. (a)

The migration of charge carriers from higher concentration to lower concentration or from higher density to lower density is called diffusion.

40. (a)

For maximum voltage rating, the solar array is grouped in series.
For maximum current rating, the solar array is grouped in parallel.

42. (d)

We know that,

$$I_D \simeq I_S\, e^{\frac{V_a}{V_T}}$$

dynamic resistance of the diode,

$$r_d = \frac{dI_D}{dV_a} = \frac{I_S}{V_T} e^{\frac{V_a}{V_T}} = \frac{10^{-13}}{25.9\times10^{-3}} e^{\left(\frac{0.65}{0.0259}\right)}$$

$$= \frac{10^{-13}}{25.9\times10^{-3}} \times 7.2\times10^{10} = \frac{7.2}{25.9}$$

$$r_d = 0.277\ \Omega$$

43. (a)

Dark current is both temperature and voltage dependent.

44. (a)

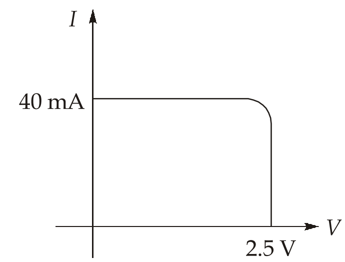
We know that,

the fill factor of solar cell is,

$$\text{F.F.} = \frac{\text{maximum power obtained}}{V_{OC} \times I_{SC}}$$

$$0.65 = \frac{65 \times 10^{-3}}{V_{OC} \times I_{SC}}$$

$$\therefore \quad V_{OC} \times I_{SC} = \frac{65 \times 10^{-3}}{0.65} = 100 \text{ mW}$$



Hence, option (a) satisfies.

$$\therefore \quad V_{OC} = 2.5 \text{ V}; \quad I_{SC} = 40 \text{ mA}$$

$$V_{OC} \times I_{SC} = 2.5 \times 40 \text{ mW} = 100 \text{ mW}$$

45. (d)

Given, depletion region width, $W = 4 \times 10^{-8}$ m

potential, $V = 0.6$ V

$$\text{built-in electric field, } E_{bi} = \frac{2V}{W}$$

$$E_{bi} = \frac{1.2}{4 \times 10^{-8}} = 0.3 \times 10^{8} = 30 \times 10^{6} \text{ V/m}$$

46. (c)

The depletion capacitance, $$C_T = \frac{\in A}{W}$$

$$C_T = \frac{\in A}{\sqrt{\frac{2\in}{q}\left[\frac{1}{N_A} + \frac{1}{N_D}\right]\left[V_j + V_{bi}\right]}}$$

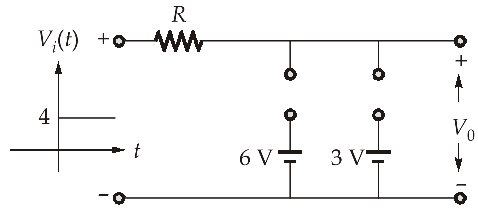
C_T is independent of current through junction.

48. (b)

Circuit	PIV (Peak inverse voltage)
• HWR	V_m
• FWR	$2V_m$
• Bridge circuit FWR	V_m

49. (b)

For $V_i = 4u(t)$, the above circuit will behave as:

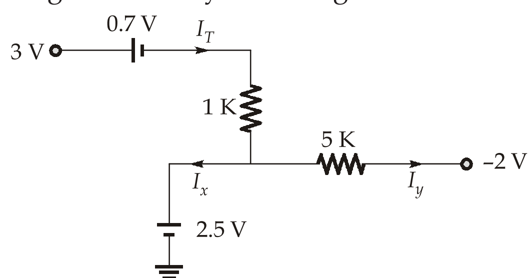


$\because$ Both diode behave as open circuit. $[V_p < V_n]$

$\therefore$ $$V_0 = V_i$$

50. (a)

The circuit can be drawn with given data by assuming diode is in forward bias as below:



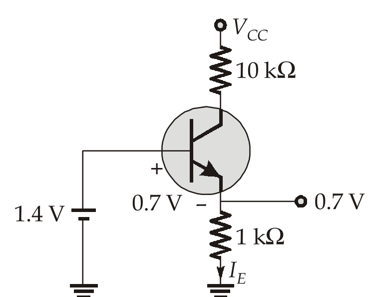
Now, $$I_y = \frac{2.5-(-2)}{5} = \frac{4.5}{5} = 0.9 \text{ mA}$$

$$I_T = \frac{3-0.7-2.5}{1} = -0.2 \text{ mA}$$

Negative current indicate, diode is in reverse bias. Hence, act as open circuit.

Now, $$I_x = -I_y = -0.9 \text{ mA}$$

51. (d)



$$I_E = \frac{0.7 \text{ V}}{1 \text{ k}\Omega} = 0.7 \text{ mA} = 700\ \mu\text{A}$$

$$I_C = \alpha I_E$$

$$= \left(\frac{99}{99+1}\right) 700\ \mu\text{A}$$

$$= 0.99 \times 700\ \mu\text{A}$$

$$= 693\ \mu\text{A}$$

52. (b)

$$C_{DG} = 2 \text{ pF}$$

$$A' = -20 \quad \text{...for common source}$$

$$C_{GS} = 1 \text{ pF}$$

In common source, drain-gate capacitance is present between input node and output node, hence we observe miller effect.

$$C_m = C_{DG}[1 - A']$$
$$= 2[1 + 20] = 42 \text{ pF}$$
$$\therefore \quad C_{in} = C_{GS} + C_m = 1 + 42 = 43 \text{ pF}$$

53. (d)

The large signal current gain (α) is defined as:

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

where; γ = Emitter injection efficiency

β^* = transport factor

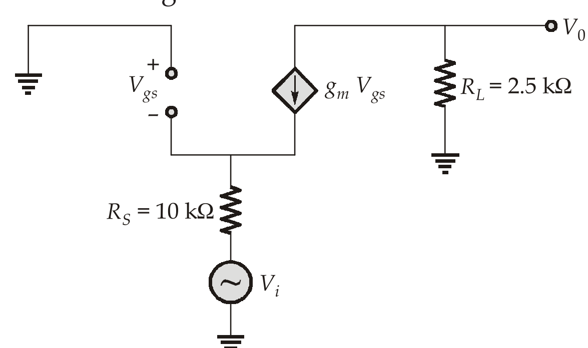
54. (c)

Darlington amplifier:

- It is cascade of two common collector or two common drain amplifier.
- It has unity voltage gain and very high current gain. Hence, it is used as a voltage buffer.

55. (d)

Small signal model of given circuit is given as:



Now,

$$V_0 = -g_m V_{gs} \cdot R_L$$
$$V_i = -V_{gs}[1 + g_m R_s]$$
$$\Rightarrow \quad \frac{V_0}{V_i} = \frac{g_m R_L}{1 + g_m R_s} = \frac{5}{21}$$

56. (a)

We know; V_p (pinch off voltage) $= \dfrac{a^2 q N_D}{2\varepsilon}$

$$= \frac{(2 \times 10^{-4})^2 \times 1.6 \times 10^{-19} \times 10^{14}}{2 \times \pi \times \frac{1}{36\pi} \times 10^{-11}} = 1.15 \text{ volt}$$

For n-channel JFET, V_p is negative.

$$\therefore \quad V_p = -1.15 \text{ volt}$$

57. (b)

Tunnel diode is a highly doped semiconductor diode. Hence, the depletion width is very narrow and the fermi level in the tunnel diode moves into the conduction band on n-side and moves into the valence band on p-side.

58. (d)

Coupling and emitter bypass capacitance affect only low frequency response of an R-C coupled amplifier.

An ideal amplifier would be a totally linear device, but real amplifier are only linear within some limit. This non-linearity produces distorted output.

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

59. (c)

Let, $$T(s) = 5+\frac{10}{s} = 5\left(1+\frac{2}{s}\right)$$

Compare with, $$T(s) = K_p\left(1+\frac{1}{T_r\cdot s}\right)$$ where T_r = reset time

∴ $$\text{Reset time } (T_r) = \frac{1}{K_I} = \frac{1}{2} = 0.5 \text{ minute}$$

60. (a)

We know for lag compensator, pole is closer to origin, Hence, $\alpha > 1$

where $$\alpha = \frac{Z}{P}$$

here; $$\alpha = \frac{a}{b}$$

∴ $$a > b$$

61. (c)

Phase cross-over frequency (ω_{pc}):

"It is system's frequency at which phase is –180°"

i.e., $$\angle G(j\omega)\big|_{\omega=\omega_{pc}} = -180^\circ$$

$$-0.1\omega_{pc}\times\frac{180^\circ}{\pi} - 90^\circ = -180^\circ$$

$$\frac{18}{\pi}\omega_{pc} = 90^\circ$$

$$\omega_{pc} = 5\pi \text{ rad/s}$$

62. (b)

- Gain margin is obtained at phase crossover frequency.
- Phase margin is obtained at gain cross-over frequency.
- For stable system, phase crossover frequency is more than gain crossover frequency i.e., $\omega_{pc} > \omega_{gc}$
- Damping ratio is related to open loop D.C. gain as:

$$\xi \propto \frac{1}{\sqrt{K}}$$

63. (c)

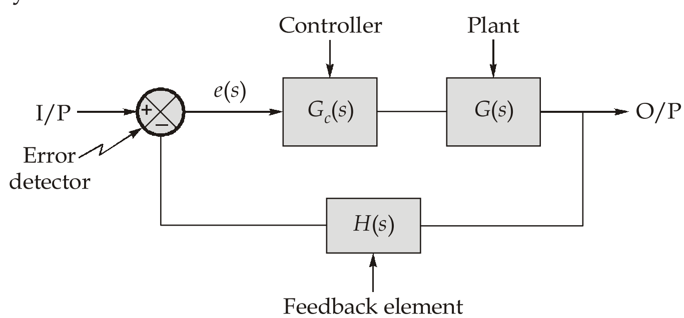
We know, 20 dB/dec = 6 dB/octave

- + 6 dB/octave $\Rightarrow$ 1 zero at ω_1
- 0 dB/octave $\Rightarrow$ 1 pole at ω_2
- –40 dB/decade $\Rightarrow$ 2 pole at ω_3

$\therefore$ Transfer function has 1 zero and 3 poles

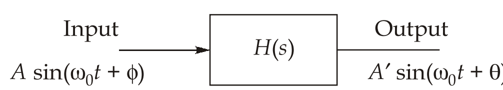
64. (c)

Practical closed loop system is shown below:



65. (c)

Concept: For a LTI system,



Where,
$$A' = A\cdot|H(\omega)|_{\omega=\omega_0}$$
$$\theta = \phi + \angle H(\omega)\big|_{\omega=\omega_0}$$

We have,
$$G(s) = \frac{(s^2+16)(s+1)}{s^2+7s+12}$$

Replace
$$s = j\omega$$
$$G(j\omega) = \frac{(-\omega^2+16)(j\omega+1)}{-\omega^2+7j\omega+12}$$

When
$$|G(j\omega)|_{\omega=\omega_0} = 0 \Rightarrow A' = 0$$

$\therefore$
$$|G(j\omega)|_{\omega=\omega_0} = 0$$
$$\frac{(-\omega^2+16)\sqrt{\omega^2+1}}{\sqrt{(12-\omega^2)^2+(7\omega)^2}} = 0$$

$\therefore$
$$\omega^2 = 16$$
$$\omega = 4 \text{ rad/s}$$

66. (d)

Characteristic equation is obtained as

$$|sI - A| = 0$$

$$\begin{vmatrix} s+3 & 0 \\ -2 & s-1 \end{vmatrix} = 0$$

$$(s+3)(s-1) = 0$$

$$s^2 + 2s - 3 = 0$$

68. (a)

In the 8051 microcontroller, the control line External Access $(\overline{\text{EA}})$ is used to read data from both internal and external memories. When $\overline{\text{EA}} = 1$, the internal memory is accessed.

74. (c)

With derivative controller in feedback does not change order and type but it reduces open loop DC gain, hence it increases steady state error.

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