CLASS TEST

Sl. : 01 SK_EC_ABCD_150423

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COMMUNICATIONS

ELECTRONICS ENGINEERING

Date of Test : 15/04/2023

ANSWER KEY

1.	(d)	7.	(d)	13.	(c)	19.	(d)	25.	(b)
2.	(b)	8.	(b)	14.	(b)	20.	(d)	26.	(c)
3.	(a)	9.	(c)	15.	(d)	21.	(c)	27.	(c)
4.	(c)	10.	(d)	16.	(c)	22.	(b)	28.	(b)
5.	(d)	11.	(c)	17.	(c)	23.	(b)	29.	(c)
6.	(d)	12.	(c)	18.	(b)	24.	(c)	30.	(d)

Detailed Explanations

1. **(d)**

The maximum and minimum values of the envelope of an AM modulated signal can be given as,

$$E_{max} = A_c(1 + \mu)$$
$$E_{min} = A_c(1 - \mu)$$

Given that, $A_c = 10$ V and $\mu = 0.4$

So, $E_{max} = 10(1 + 0.4)$ V $= 14$ V

$E_{min} = 10(1 - 0.4)$ V $= 6$ V

2. **(b)**

The deviation ratio, $D = \dfrac{\Delta f}{f_{m(max)}}$

Maximum frequency deviation,

$$\Delta f = k_f |m(t)|_{max}$$

Given that, $m(t) = \text{sinc}(1000t)$ V

$k_f = 1$ kHz/V

$$f_{m(max)} = \frac{1000}{2} = 500 \text{ Hz}$$

$$|m(t)|_{max} = 1$$

So, $D = \dfrac{1\,(1000)}{500} = 2$

3. **(a)**

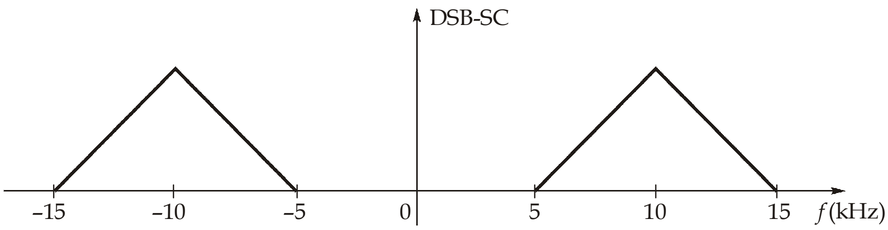
$$(BW)_{FM} = \left(1 + \frac{\Delta f}{f_m}\right)(2f_m) = \left(1 + \frac{A_m k_f}{f_m}\right)(2f_m)$$

$$(BW)_{PM} = (1 + A_m k_p)\,(2f_m)$$

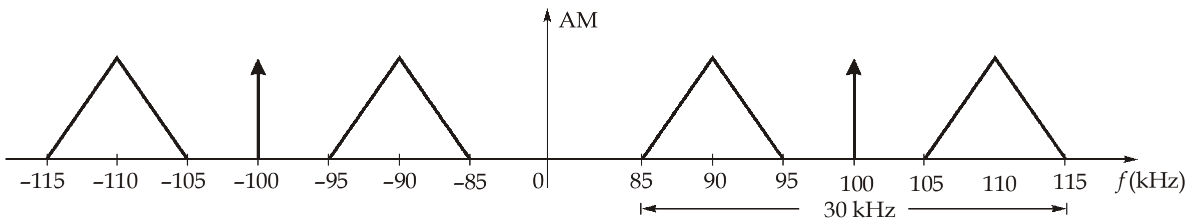
When only f_m is increased, $(BW)_{PM}$ will be increased by higher factor than that of $(BW)_{FM}$.

4. **(c)**

Spectrum of the DSB-SC signal,



Spectrum of the final AM signal,



So, the bandwidth of the resultant AM signal is 30 kHz.

5. (d)

The variance of a random variable "X" can be given as,

$$\sigma_X^2 = E[X^2] - (E[X])^2$$

$$E[X] = \sum_{i=0}^{1} x_i P(x_i) = 1(p) + 0(q) = p$$

$$E[X^2] = \sum_{i=0}^{1} x_i^2 P(x_i) = (1)^2(p) + (0)^2(q) = p$$

So the variance, $\sigma_X^2 = p - (p)^2 = p(1-p) = pq$ $\quad \because p + q = 1$

Hence, option (d) is correct.

6. (d)

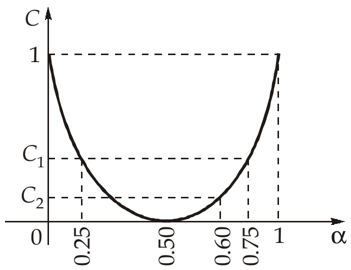
For a real WSS process $X(t)$, the power spectral density $S_X(f)$ should be an even function of "f".

i.e., $S_X(f) = S_X(-f)$

Only the PSD given in option (d) satisfied the above condition.

7. (d)

For a BSC, the variation of C with α can be plotted as,



The plot of C versus α is symmetric about $\alpha = 0.50$. Hence, $C = C_1$ for both $\alpha = 0.25$ and $\alpha = 0.75$.

So, the correct relation between C_1 and C_2 is $C_2 < C_1$.

8. (b)

The average probability of error can be given as,

$$P_e = P(r_0 | m_1) P(m_1) + P(r_1 | m_0) P(m_0)$$
$$= (0.2)(0.5) + (0.2)(0.5)$$
$$= 0.2$$

9. (c)

The condition to detect upto 'e_d' bit errors and simultaneously correct upto 'e_c' bit errors is,

$$d_{min} \geq (e_d + e_c + 1)$$

For the given LBC, $d_{min} = 4$

So, $e_d + e_c + 1 \leq 4$

$$e_d + e_c \leq 3$$

Only option (c) satisfies the above condition.

10. (d)

Total bandwidth, $B_t = 25$ MHz

Bandwidth of each radio channel, $B_c = 200$ kHz

Number of time slots for each radio channel, $m = 8$

Total number of radio channels possible = $\frac{25 \times 1000}{200} = 125$

Maximum number of simultaneous users = 125 × 8 = 1000

11. **(c)**

The angle of the modulated signal $s(t)$ can be given as,

$$\theta(t) = 2\pi f_c t + 4\sin(3000\pi t) + 3\cos(3000\pi t)$$

The instantaneous frequency of the modulated signal can be given as,

$$f_i = \frac{1}{2\pi}\frac{d\theta(t)}{dt}$$

$$= f_c + \frac{1}{2\pi}[12000\pi\cos(3000\pi t) - 9000\pi\sin(3000\pi t)]$$

$$= f_c + [6000\cos(3000\pi t) - 4500\sin(3000\pi t)]\text{ Hz}$$

$$= f_c + 1500[4\cos(3000\pi t) - 3\sin(3000\pi t)]\text{ Hz}$$

$$= f_c + 1500[5\cos(3000\pi t + \alpha)]\text{ Hz}; \qquad \text{Where, } \alpha = \tan^{-1}\left(\frac{3}{4}\right)$$

$$f_i = f_c + 7500\cos(3000\pi t + \alpha)\text{ Hz}$$

Maximum frequency deviation of the signal $s(t)$ is,

$$(\Delta f)_{max} = 7500\text{ Hz} = 7.5\text{ kHz}$$

12. **(c)**

The required condition is,

$$RC \le \frac{1}{\omega_m}\left(\frac{\sqrt{1-\mu^2}}{\mu}\right) = \frac{1}{\omega_m}\sqrt{\frac{1}{\mu^2} - 1}$$

From the given AM wave equation,

$$\omega_m = 2000\pi$$
$$\mu = 0.50$$

So,

$$RC \le \frac{1}{2000\pi}\sqrt{\left(\frac{1}{0.5}\right)^2 - 1} = \frac{\sqrt{3}}{2000\pi}\text{sec}$$

$$RC \le 275.66\ \mu\text{sec}$$

13. **(c)**

$$x(t) = s(t)A\cos(\omega_c t + 30°)$$

$$= A^2[\cos(\omega_c t + 30°)\cos(\omega_c t)]m(t) = \frac{A^2}{2}[\cos(2\omega_c t + 30°) + \cos 30°]m(t)$$

After passing through LPF, we get,

$$y(t) = \frac{A^2}{2}\cos(30°)\,m(t) = \frac{\sqrt{3}A^2}{4}m(t)$$

Average power of $y(t)$,

$$P_y = \left(\frac{\sqrt{3}}{4}A^2\right)^2 P_m = \frac{3A^4}{16}P_m$$

14. (b)

$$M(f) = 10^{-3}\,\text{rect}\left(\frac{f}{2000}\right)$$

So, $$f_{m(\max)} = 1000 \text{ Hz} = 1 \text{ kHz}$$

$$m(t) = 2\,\text{sinc}(2000t) \text{ V}$$

So, $$|m(t)|_{(\max)} = 2 \text{ V}$$

Maximum frequency deviation,

$$\Delta f = k_f\,|m(t)|_{\max} = (10 \text{ kHz/V}) \times 2 \text{ V} = 20 \text{ kHz}$$

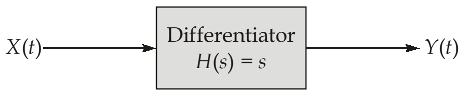
Deviation ratio, $$D = \frac{\Delta f}{f_{m(\max)}} = \frac{20}{1} = 20$$

Bandwidth, $$\text{BW} = (1 + D)2f_{m(\max)}$$

$$= (1 + 20)\ (2)\ (1) \text{ kHz}$$

$$= 42 \text{ kHz}$$

15. (d)



For a differentiator, $$H(s) = s$$

$$H(j\omega) = j\omega$$

$$|H(j\omega)|^2 = \omega^2$$

PSD of $Y(t)$, $$S_Y(\omega) = S_X(\omega)|H(\omega)|^2 = \omega^2 S_X(\omega)$$

$$R_X(\tau) \xleftrightarrow{CTFT} S_X(\omega)$$

$$\frac{dR_X(\tau)}{d\tau} \xleftrightarrow{CTFT} (j\omega)S_X(\omega)$$

$$\frac{d^2R_X(\tau)}{d\tau^2} \xleftrightarrow{CTFT} (j\omega)^2 S_X(\omega) = -\omega^2 S_X(\omega)$$

$$-\frac{d^2R_X(\tau)}{d\tau^2} \xleftrightarrow{CTFT} \omega^2 S_X(\omega) = S_Y(\omega)$$

So, $$R_Y(\tau) = -\frac{d^2R_X(\tau)}{d\tau^2}$$

16. (c)

$$Y = aX + b$$

$$x = \frac{y - b}{a}$$

$$\frac{dy}{dx} = a$$

So, $$f_Y(y) = \frac{1}{a} f_X\left(\frac{y-b}{a}\right)$$

Differential entropy of Y,

$$H(Y) = -\int_{-\infty}^{\infty} f_Y(y)\log_2 f_Y(y)dy$$

$$= -\int_{-\infty}^{\infty} \frac{1}{a} f_X\left(\frac{y-b}{a}\right)\log_2\left[\frac{1}{a} f_X\left(\frac{y-b}{a}\right)\right]dy$$

Let, $$\frac{y-b}{a} = u \Rightarrow dy = adu$$

So, $$H(Y) = -\int_{-\infty}^{\infty} f_X(u)\log_2\left[\frac{1}{a} f_X(u)\right]du$$

$$= -\int_{-\infty}^{\infty} f_X(u)\log_2 f_X(u)du + \int_{-\infty}^{\infty} f_X(u)\log_2(a)du$$

$$= H(X) + \log_2(a)\int_{-\infty}^{\infty} f_X(x)dx$$

$$H(Y) = H(X) + \log_2(a)$$

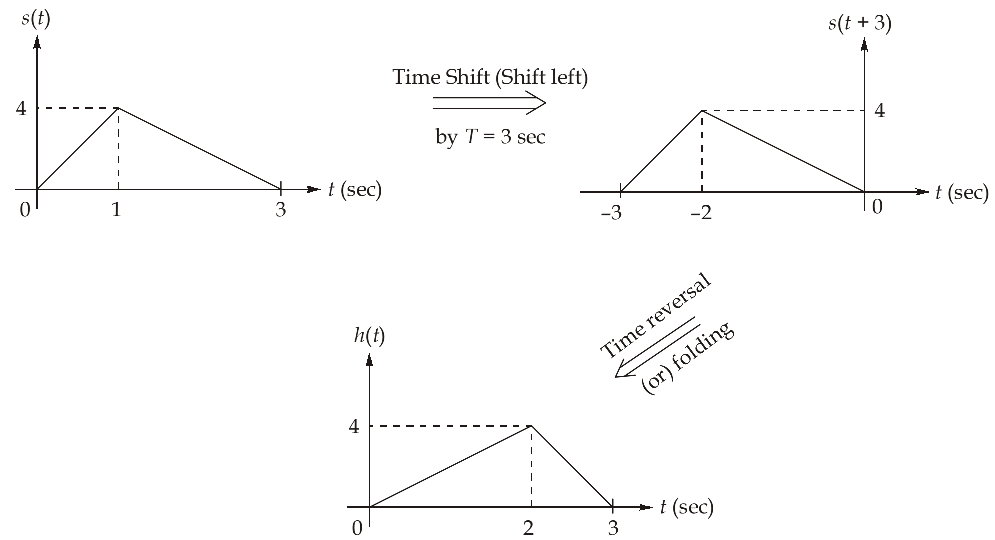
17. (c)

The impulse response of the filter matched to the signal $s(t)$ can be given as,

$h(t) = s(T - t)$; Where, T = duration of the signal

For the given signal $s(t)$, T = 3 sec.

The signal $h(t)$ can be obtained by doing following operations to the signal $s(t)$.



18. (b)

Number of voice signals, N = 4

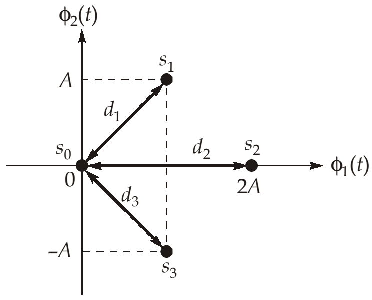
Maximum frequency of each signal, $f_{m\,(\max)}$ = 4 kHz

Bits per sample, n = 8

Sampling rate of each voice signal, $f_s = 2f_{m(\max)} = 8$ kHz
Sampling rate of the multiplexed signal, $f_{s(\text{overall})} = Nf_s = 32$ kHz
Overall transmission rate, $R_b = nf_{s(\text{overall})} = 256$ kbps
Theoretical minimum channel bandwidth required is,

$$(\text{BW})_{\min} = \frac{R_b}{2} = 128 \text{ kHz}$$

19. (d)



Let the energy associated with the symbols s_0, s_1, s_2 and s_3 are E_0, E_1, E_2 and E_3 respectively.

$$E_i = (d_i)^2 \; ; \quad i = 0, 1, 2, 3$$

From the above diagram,

$$d_0 = 0$$
$$d_1 = d_3 = \sqrt{A^2 + A^2} = \sqrt{2A^2}$$
$$d_2 = 2A$$

So,
$$E_0 = 0$$
$$E_1 = E_3 = 2A^2$$
$$E_2 = 4A^2$$

The average symbol energy of the modulation scheme can be given as,

$$E_s = \sum_{i=0}^{3} E_i P(s_i) \; ; \qquad P(s_i) = \text{probability of occurrence of the symbol } s_i$$
$$= 0(0.3) + 2A^2(0.2) + 4A^2(0.4) + 2A^2(0.1)$$
$$= (0.4 + 1.6 + 0.2)A^2$$
$$= 2.2\,A^2$$

20. (d)

For a distortion free detection, the time constant (RC) of an envelope detector should satisfy the following condition:

$$\frac{1}{f_c} << RC << \frac{1}{f_{m\,(\max)}}$$

Given that, $f_c = 1$ MHz and $f_{m(\max)} = 5$ kHz

So, $1\ \mu\text{s} << RC << 200\ \mu\text{s}$

For option "a" $\Rightarrow$ $RC = 100 \times 10^3 \times 10 \times 10^{-12} = 1\ \mu\text{s}$

For option "b" $\Rightarrow$ $RC = 20 \times 10^6 \times 10 \times 10^{-12} = 200\ \mu\text{s}$

For option "c" $\Rightarrow$ $RC = 20 \times 10^6 \times 20 \times 10^{-12} = 400\ \mu\text{s}$

For option "d" $\Rightarrow$ $RC = 1 \times 10^6 \times 20 \times 10^{-12} = 20\ \mu\text{s}$

So, the values given in option "*d*" are best suitable.

21. (c)

The modulation efficiency of an AM signal can be given as,

$$\%\eta = \frac{P_{SB}}{P_{total}} \times 100 = \frac{\mu^2}{2+\mu^2} \times 100$$

Where, μ = modulation index

For a multi-tone modulation,

$$\mu = \sqrt{\mu_1^2 + \mu_2^2}$$

For the given AM signal, μ_1 = 0.5 and μ_2 = 0.4

So, $$\mu^2 = \mu_1^2 + \mu_2^2 = (0.5)^2 + (0.4)^2 = 0.41$$

$$\%\eta = \frac{0.41}{2+0.41} \times 100 \approx 17\%$$

22. (b)

$$\beta_1 = \frac{\Delta f_1}{f_{m_1}} = \frac{A_{m_1} k_f}{f_1} = 10 \text{ rad} \quad \text{...(i)}$$

$$\beta_2 = \frac{\Delta f_2}{f_{m_2}} = \frac{A_{m_2} k_f}{f_2} = 20 \text{ rad} \quad \text{...(ii)}$$

From equations (i) and (ii), it is clear that,

$$\frac{A_{m_2} k_f}{f_2} = 2 \times \frac{A_{m_1} k_f}{f_1}$$

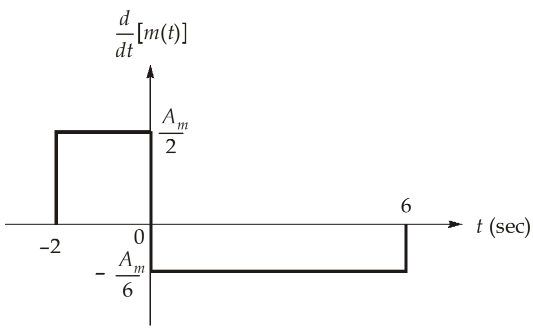
$$\frac{f_2}{f_1} = \frac{A_{m_2}}{2A_{m_1}} = \frac{2}{2 \times 1} = 1 \qquad \because \text{Given that, } A_{m_1} = 1 \text{ V and } A_{m_2} = 2 \text{ V}$$

So, $$f_2 = f_1$$

23. (b)

$$(\Delta f_{max})_{FM} = A_m k_f$$

$$(\Delta f_{max})_{PM} = \frac{k_p}{2\pi} \left| \frac{dm(t)}{dt} \right|_{max}$$



So, $$(\Delta f_{max})_{PM} = \frac{k_p}{2\pi}\left(\frac{A_m}{2}\right) = \frac{k_p A_m}{4\pi}$$

If, $$(\Delta f_{max})_{PM} = (\Delta f_{max})_{FM}$$

Then, $$\frac{k_p A_m}{4\pi} = k_f A_m$$

$$\frac{k_p}{k_f} = 4\pi \text{ rad/Hz}$$

24. (c)

$$\theta(t) = 2\pi f_c t + 5\sin(3000\pi t) + 10\sin(2000\pi t)$$

$$f_i = \frac{1}{2\pi}\frac{d\theta(t)}{dt} = f_c + 7500\cos(3000\pi t) + 10000\cos(2000\pi t)$$

So, $\Delta f = 7500 + 10000 = 17.5 \text{ kHz}$

$$f_{m(\max)} = 1500 \text{ Hz} = 1.5 \text{ kHz}$$

Deviation ratio, $D = \dfrac{\Delta f}{f_{m(\max)}} = \dfrac{17.5}{1.5} = \dfrac{35}{3}$

Bandwidth, $BW = (1 + D)2f_{m(\max)} = \left(1 + \dfrac{35}{3}\right)(3) \text{ kHz} = 38 \text{ kHz}$

25. (b)

Given that, $f_{LO} > f_c$

So, $f_{LO} = f_c + f_{IF}$

$$f_{LO(\max)} = f_{c(\max)} + f_{IF} = 1650 + 450 = 2100 \text{ kHz}$$

$$f_{LO(\min)} = f_{c(\min)} + f_{IF} = 550 + 450 = 1000 \text{ kHz}$$

For an LC oscillator, $f_0 = \dfrac{1}{\sqrt{LC}}$

$$C \propto \frac{1}{f_0^2}$$

$$\frac{C_{\max}}{C_{\min}} = \left(\frac{f_{LO(\max)}}{f_{LO(\min)}}\right)^2 = \left(\frac{2100}{1000}\right)^2 = 4.41$$

26. (c)

$$E[X(t)] = 5$$

$$E[Y(t)] = H(0)E[X(t)]$$

$$H(0) = H(s)\,|_{s=0}$$

$H(s)$ = Transfer function of the given circuit

From the given circuit,

$$H(0) = \frac{4\text{ M}\Omega}{4\text{ M}\Omega + 1\text{ M}\Omega} = \frac{4}{5} = 0.80$$

So, $[Y(t)] = 0.80 \times 5 = 4$

27. (c)

Minimum signal-to-noise ratio that has to be maintained in the channel is,

$$\text{SNR} = \frac{S}{N_0 B} = \frac{S}{\left(\frac{N_0}{2}\right)(2B)}$$

$$= \frac{100 \times 10^{-6}}{(10^{-10})(2 \times 4 \times 10^3)} = 125$$

The capacity of the channel can be given by,

$$C = B\log_2(1 + \text{SNR})$$

$$= 4\log_2(1 + 125) \simeq 27.91 \text{ kbps}$$

28. (b)

Signal power,
$$S = \int_{-\infty}^{\infty} x^2 f_X(x)dx = 2\int_0^2 x^2\left(\frac{2-x}{4}\right)dx$$
$$= \frac{1}{2}\int_0^2 (2x^2 - x^3)dx = \frac{1}{2}\left[\frac{2x^3}{3} - \frac{x^4}{4}\right]_0^2 = \frac{1}{2}\left[\frac{16}{3} - \frac{16}{4}\right] = \frac{2}{3}$$

Quantization noise power, $N_Q = \dfrac{\Delta^2}{12}$

$$\Delta = \frac{2-(-2)}{64} = \frac{1}{16}$$

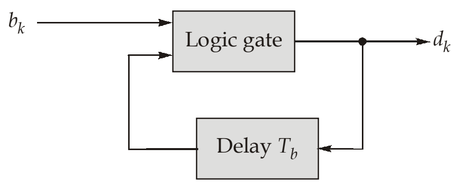
So,
$$N_Q = \frac{(1/16)^2}{12} = \frac{1}{3072}$$
$$(SQNR) = \frac{S}{N_Q} = \frac{(2/3)}{(1/3072)} = \frac{2\times 3072}{3} = 2048$$

In decilogs, $[SQNR] = 10\log_{10}(SQNR) = 33.11$ dB

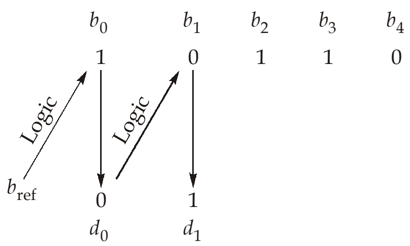
29. (c)

It is given that the carrier phase for first two encoded bits are π, 0. So first two encoded bits are 0, 1.

The logic diagram of DPSK encoder can be given as,



Finding the logic gate:

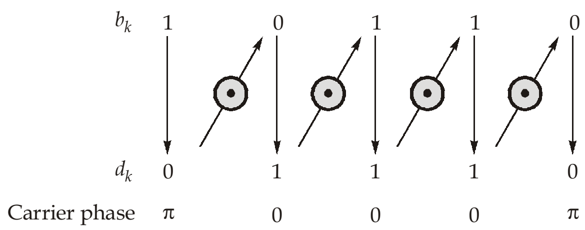


If we observe clearly,

$$d_0\ (\text{logic})\ b_1 = d_1$$
$$0\ (\text{logic})\ 0 = 1$$

So, the possible logic is , EX- NOR.

So, the complete encoding can be given as,



So, the carrier phases corresponding to the remaining three bits are 0, 0, π.

30. (d)

The given periodic signal $s(t)$ has odd-symmetry. So, the Fourier series representation of $s(t)$ has,

$$a_0 = 0$$

$$a_n = 0$$

$$b_n = \frac{2}{T}\left[\int_{-T/2}^{0}(-1)\sin(n\omega_0 t)dt + \int_{0}^{T/2}\sin(n\omega_0 t)dt\right]$$

Where, $\omega_0 = \dfrac{2\pi}{T}$

So,
$$b_n = \frac{2}{T}\left[\left(\frac{\cos(n\omega_0 t)}{n\omega_0}\right)_{-T/2}^{0} - \left(\frac{\cos(n\omega_0 t)}{n\omega_0}\right)_{0}^{T/2}\right]$$

$$= \frac{2}{n\omega_0 T}\left[1-\cos\left(\frac{n\omega_0 T}{2}\right)-\cos\left(\frac{n\omega_0 T}{2}\right)+1\right]$$

$$= \frac{4}{n(2\pi)}[1-\cos(n\pi)] = \frac{2}{n\pi}[1-(-1)^n]$$

$$b_n = \begin{cases}\dfrac{4}{n\pi} & ; \quad n \text{ is odd} \\ 0 & ; \quad n \text{ is even}\end{cases}$$

So, $x(t)$ can be represented as,

$$x(t) = s(t)\; m(t)$$

$$= \left[\frac{4}{\pi}\sin\left(\frac{2\pi}{T}t\right)+\frac{4}{3\pi}\sin\left(\frac{6\pi}{T}t\right)+\frac{4}{5\pi}\sin\left(\frac{10\pi}{T}t\right)+\ldots\right]m(t)$$

After passing through BPF, we get,

$$y(t) = \frac{4}{\pi}\sin\left(\frac{2\pi}{T}t\right)m(t) = A_c m(t)\sin\left(\frac{2\pi}{T}t\right)$$

So,
$$A_c = \frac{4}{\pi}$$

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