22

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CMRIT

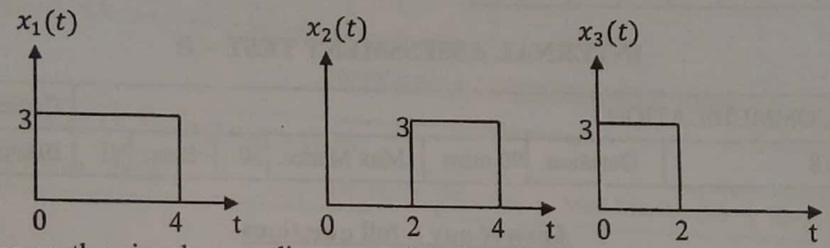
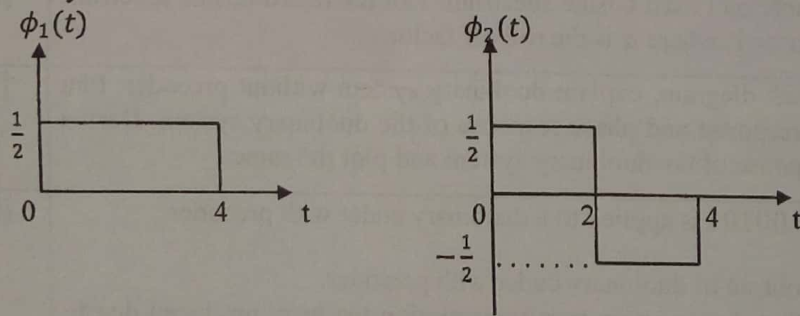
INTERNAL ASSESSMENT TEST – II

Sub:	DIGITAL COMMUNICATION							Code:	15EC61
Date:	16/ 04 / 2018	Duration:	90 mins	Max Marks:	50	Sem:	VI	Branch:	ECE,TCE

Answer any 5 full questions

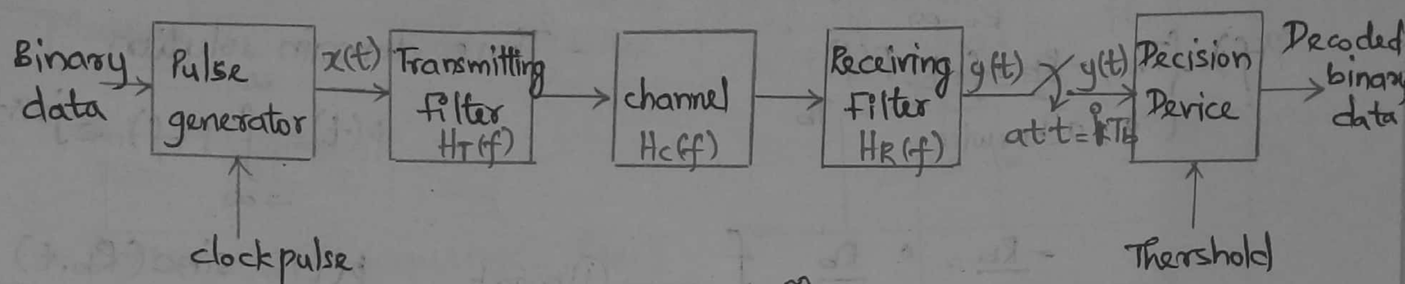
		Marks	CO	RBT
1.	Explain binary PAM system with a neat block diagram. What is inter symbol interference (ISI). Derive time domain and frequency domain conditions for zero ISI.	[10]	CO4	L3
2(a).	Derive the ideal solution to inter symbol interference (ISI). What are its practical limitations?	[05]	CO4	L2
2(b).	Write a short note on raised cosine spectrum. Plot the raised cosine spectrum for $\alpha = 0$ and $\alpha = 1$, where α is the roll off factor.	[05]	CO4	L2
3.	With a neat block diagram, explain duobinary system without precoder. Plot the magnitude response and phase response of the duobinary system. Derive the impulse response of the duobinary system and plot the same.	[10]	CO4	L2
4(a).	Binary data 10100101 is applied to a duobinary coder with precoder. i. Obtain the output of duobinary coder with precoder. ii. Assuming that due to an error in transmission the level produced due to second bit becomes zero, obtain the decoded sequence.	[05]	CO4	L2
4(b).	Binary data 10100101 is applied to a modified duobinary coder without precoder. i. Obtain the output of modified duobinary coder without precoder. ii. Assuming that due to an error in transmission the level produced due to second bit becomes zero, obtain the decoded sequence.	[05]	CO4	L2
5(a).	What is an equalizer? Write a short note on zero forcing equalizer.	[05]	CO4	L2
5(b).	What is an adaptive equalizer? Write a short note on adaptive equalizer.	[05]	CO4	L2

B. Sahiel 12/04/18

6.	Applying Gram-Schmidt orthogonalization procedure find a set of orthonormal basis functions for the following set of signals.  Express the signals as a linear combination of basis functions. Draw the corresponding signal-space diagram (constellation diagram).	[10]	CO2	L3
7(a).	Consider the signal $x(t) = a\phi_1(t) + b\phi_2(t) + c\phi_3(t), 0 \leq t \leq T$ where $\phi_1(t), \phi_2(t), \phi_3(t)$ are the basis functions and (a, b, c) are the coordinates of $x(t)$ with respect to $\phi_1(t), \phi_2(t), \phi_3(t)$ respectively. Derive an expression for the energy of $x(t)$ in terms of its coordinates.	[05]	CO2	L2
7(b).	Given the basis functions $\phi_1(t)$ and $\phi_2(t)$, plot the signals $x_1(t)$ and $x_2(t)$ whose coordinates with respect to $\phi_1(t)$ and $\phi_2(t)$ are (2,3) and (−2,4) respectively. 	[05]	CO2	L2

IAT 2 Solution

1) Binary PAM system:



- The discrete PAM signal, $x(t) = \sum_{k=-\infty}^{\infty} a_k \cdot v(t - k \cdot T_b)$
- The receiving filter output, $y(t) = \mu \cdot \sum_{k=-\infty}^{\infty} a_k \cdot p(t - k \cdot T_b)$
- The sampled version of $y(t)$

$$y(iT_b) = \mu \cdot \sum_{k=-\infty}^{\infty} a_k \cdot p[(iT_b - k \cdot T_b)]$$

$$y(iT_b) = \mu \cdot a_i \cdot p(0) + \underbrace{\mu \cdot \sum_{\substack{k=-\infty \\ k \neq i}}^{\infty} a_k \cdot p[(iT_b - k \cdot T_b)]}_{ISI}$$

(when k=i)

$\longrightarrow$ 5 marks

Inter-symbol Interference:

- The residual effect of all other transmitted bits on i th transmitted bit, represents ISI. $\longrightarrow$ 1 mark

Time Domain conditions:

- For zero ISI, the time domain condition, $\longrightarrow$ 2 mark

$$p[(iT_b - k \cdot T_b)] = \begin{cases} 1, & i = k \\ 0, & i \neq k \end{cases}$$

Frequency Domain Conditions:

$$\sum_{k=-\infty}^{\infty} P(f - kR_b) = T_b$$ $\longrightarrow$ 2 mark

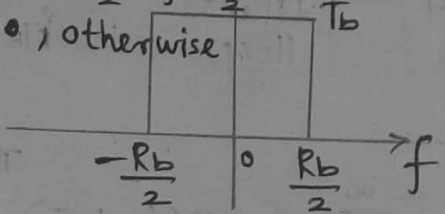
$$\ldots + P(f + R_b) + P(f) + P(f - R_b) + P(f - 2R_b) + \ldots = T_b$$ $\longrightarrow$ 5 marks

2) a) Ideal solution to Inter symbol Interference:

- Frequency domain condition for zero ISI.

$$\sum_{k=-\infty}^{\infty} P(f - k.R_b) = T_b$$ → ① marks

$$P(f) = \begin{cases} T_b, & -\frac{R_b}{2} \le f \le \frac{R_b}{2} \\ 0, & \text{otherwise} \end{cases}$$

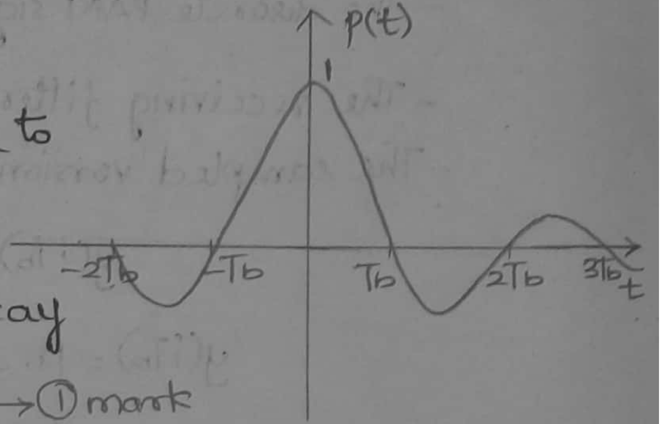


→ ① mark

- Time domain solution,

$$p(t) = \int_{-\infty}^{\infty} P(f).e^{j2\pi ft}.df$$

$$p(t) = \text{sinc}(R_b.t)$$ → ② marks



Practical Limitations:

1. $P(f)$ is physically unrealisable due to abrupt transitions at $\pm\frac{R_b}{2}$.
2. $p(t)$, results in a slow rate of decay for large 't'.

→ ① mark

(b) Raised Cosine spectrum:

- Increase in channel bandwidth gives more tolerance of timing errors. and the condition,

$$P(f) + P(f - 2B_0) + P(f + 2B_0) = \frac{1}{2B_0}, \quad -B_0 \le f \le +B_0$$ → ① mark

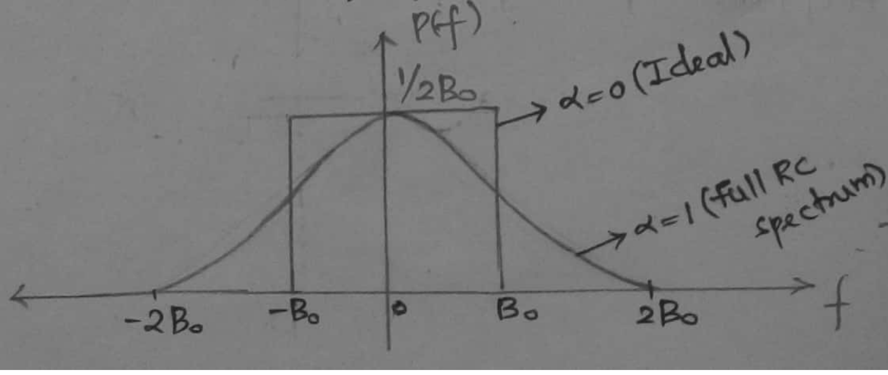
- Raised cosine spectrum,

$$p(t) = \text{sinc}(2B_0 t).\frac{\cos(2\pi\alpha.B_0 t)}{1 - 16\alpha^2.B_0^2.t^2}$$

$$P(f) = \begin{cases} \frac{1}{2B_0}, & 0 \le |f| \le f_1 \\ \frac{1}{4B_0}\left\{1 + \cos\left[\frac{\pi(|f| - f_1)}{2(B_0 - f_1)}\right]\right\}, & f_1 \le |f| \le 2B_0 - f_1 \end{cases}$$

→ ② marks

- The roll-off factor, $\alpha = 1 - \frac{f_1}{B_0}$
- The transmission bandwidth, $B_T = B_0(1+\alpha)$



→ ② marks

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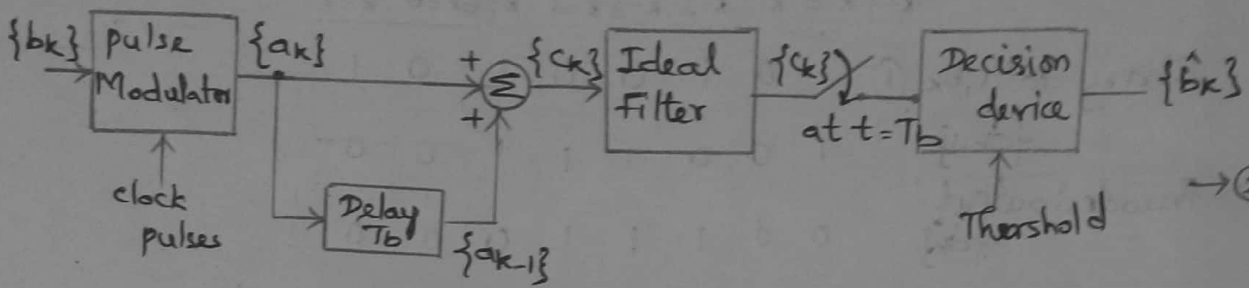
3) Duobinary Encoder without precoder:



→ ② marks

Binary data sequence = $\{b_k\}$

$\{a_k\}$ = Pulse modulated $\{b_k\}$ = $\begin{cases} +1, & \text{if } b_k = \text{'1'} \\ -1, & \text{if } b_k = \text{'0'}. \end{cases}$

- The output of duobinary encoder,

$$\{c_k\} = \{a_k\} + \{a_{k-1}\}$$

- The response of an ideal filter, $H_c(f) = \begin{cases} T_b, & -\frac{R_b}{2} \le f \le \frac{R_b}{2} \\ 0, & \text{otherwise} \end{cases}$

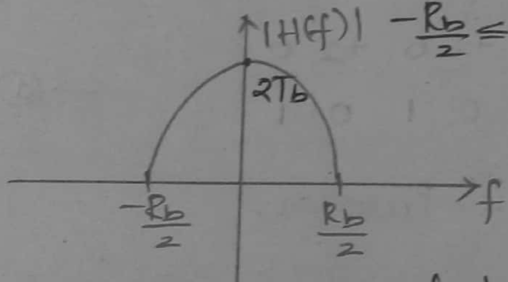
- The response of duobinary encoder,

$$H(f) = T_b\left[1 + e^{-j2\pi f T_b}\right], \quad -\frac{R_b}{2} \le f \le \frac{R_b}{2}$$ → ③ marks

- Magnitude response,

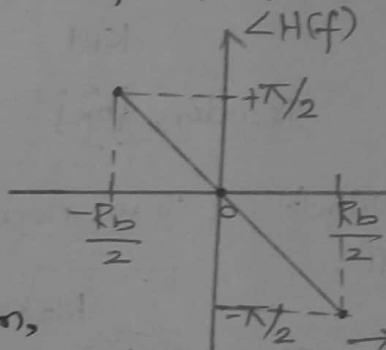
$$|H(f)| = 2 \cdot T_b \cdot \cos(\pi f T_b),$$

$-\frac{R_b}{2} \le f \le \frac{R_b}{2}$



Phase response,

$$\angle H(f) = (-\pi f \cdot T_b), \quad -\frac{R_b}{2} \le f \le \frac{R_b}{2}$$

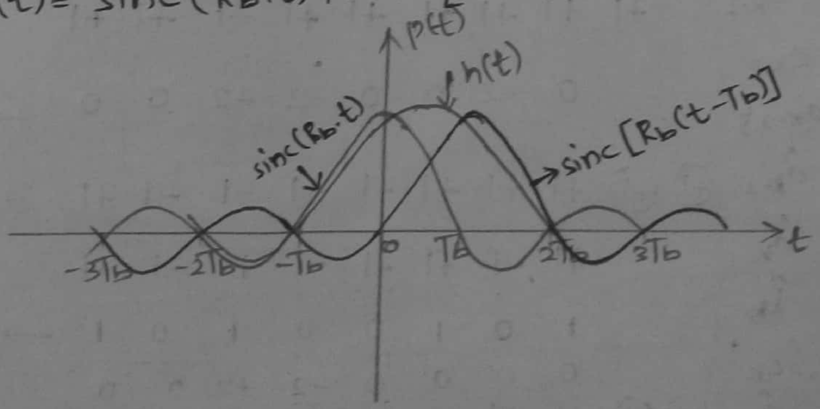


→ ② marks

- The impulse response of duobinary system,

$$h(t) = \int_{-\infty}^{\infty} H(f) \cdot e^{j2\pi f t} \, df$$

$$h(t) = \text{sinc}(R_b \cdot t) + \text{sinc}[R_b(t - T_b)]$$



→ ③ marks

4) a) Duobinary coder with precoder:

(i)

	k=-1	k=0	k=1	k=2	k=3	k=4	k=5	k=6	k=7
Binary data, b_k	1	1	0	1	0	0	1	0	1
$\{d_{k-1}\}$		1	0	0	1	1	1	0	0
Precoded output $\{d_k\}$		0	0	1	1	1	0	0	1
$\{a_k\}$	+1	-1	-1	+1	+1	+1	-1	-1	+1
$\{a_{k-1}\}$		+1	-1	-1	+1	+1	+1	-1	-1
Encoder output $c_k = a_k + a_{k-1}$		0	-2	0	+2	+2	0	-2	0
$\lvert c_k \rvert$		0	+2	0	+2	+2	0	+2	0
Decoder, $\{\hat{b}_k\}$		1	0	1	0	0	1	0	1

→ 2 marks

→ 4 marks

(ii)

Encoder output, c_k		0	0	0	+2	+2	0	-2	0
$\lvert c_k \rvert$		0	0	0	+2	+2	0	+2	0
Decoder, $\{\hat{b}_k\}$		1	1	1	0	0	1	0	1

Error

→ 1 mark

(b) Modified Duobinary coder without Precoder:

(i)

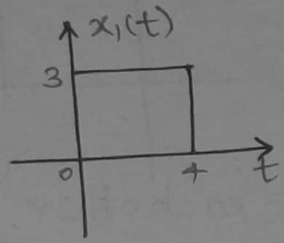
	k=2	k=-1	k=0	k=1	k=2	k=3	k=4	k=5	k=6	k=7
Binary data, b_k	1	1	1	0	1	0	0	1	0	1
a_k	+1	+1	+1	-1	+1	-1	-1	+1	-1	+1
a_{k-2}			+1	+1	+1	-1	+1	-1	-1	+1
Encoder, $c_k = \{a_k - a_{k-2}\}$			0	-2	0	0	-2	+2	0	0
$\hat{a}_{k-2}$	+1	+1	+1	+1	+1	-1	+1	-1	-1	+1
$\hat{a}_k$			+1	-1	+1	-1	-1	+1	-1	+1
Decoder, $\hat{b}_k$			1	0	1	0	0	1	0	1
(ii) Encoder, c_k			0	0	0	0	-2	+2	0	0
$\hat{a}_{k-2}$	+1	+1	+1	+1	+1	+1	+1	+1	-1	+3
$\hat{a}_k$			+1	+1	+1	+1	-1	+3	-1	+3
			1	1	1	1	0	1	0	1

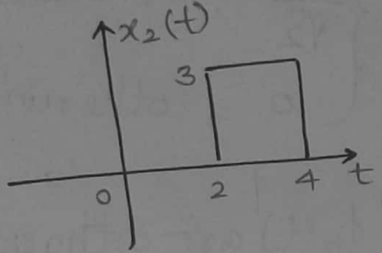
→ 2 marks

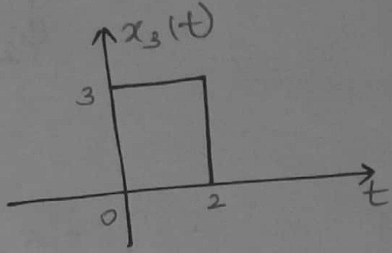
→ 2 marks

→ 1 mark

6) Orthonormal basis functions:







$$x_1(t) = x_2(t) + x_3(t)$$

$\therefore$ Only two basis functions.

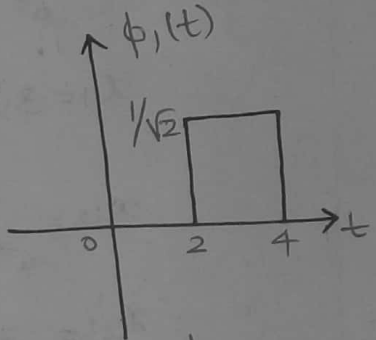
$\phi_1(t)$:

$$\phi_1(t) = \frac{x_2(t)}{\sqrt{E_2}}$$

$$E_2 = \int_0^T |x_2(t)|^2 . dt = \int_2^4 3^2 . dt = 9(4-2) = 18\,J$$

$$\phi_1(t) = \frac{x_2(t)}{\sqrt{18}} = \frac{x_2(t)}{3\sqrt{2}}$$

$$\therefore \phi_1(t) = \begin{cases} \frac{1}{\sqrt{2}}, & 2 \le t \le 4 \\ 0, & \text{otherwise} \end{cases}$$



$\rightarrow$ 3 marks

$\phi_2(t)$:

$$\phi_2(t) = \frac{g_3(t)}{\sqrt{E_3}}$$

$$g_3(t) = x_3(t) - \{ x_{31} . \phi_1(t) \}$$

$$x_{31} = \int_0^T x_3(t) . \phi_1(t) . dt = \int_0^2 3(0).dt + \int_2^4 (0)(1/\sqrt{2}).dt = 0$$

$$g_3(t) = x_3(t) - 0$$

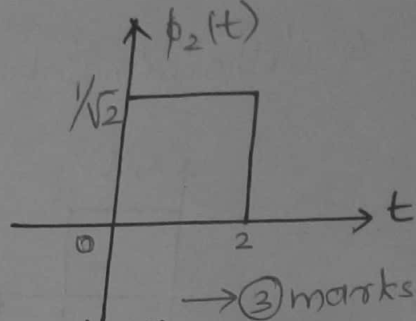
$$E_3 = \int_0^T |g_3(t)|^2 . dt = \int_0^2 3^2 . dt = 9(2-0)$$

$$E_3 = 18\,J$$

$$\phi_2(t) = \frac{[g_3(t) = x_3(t)]}{\sqrt{E_3}}$$

$$\phi_2(t) = \frac{x_3(t)}{3\sqrt{2}}$$

$$\phi_2(t) = \begin{cases} \frac{1}{\sqrt{2}} & , 0 \le t \le 2 \\ 0 & , \text{otherwise} \end{cases}$$



→ ③ marks

∴ $\phi_1(t)$ and $\phi_2(t)$ are orthogonal to each other.

→ Linear combination of basis functions,

$$x_1(t) = x_{11} \cdot \phi_1(t) + x_{12} \cdot \phi_2(t)$$

$$x_2(t) = x_{21} \cdot \phi_1(t) + x_{22} \cdot \phi_2(t)$$

$$x_3(t) = x_{31} \cdot \phi_1(t) + x_{32} \cdot \phi_2(t)$$

$$x_{11} = \int_0^T x_1(t) \cdot \phi_1(t) \cdot dt \quad \text{(or)} \quad \phi_1(t) = \frac{x_1(t)}{\sqrt{E_1}}$$

$$x_{11} = 3\sqrt{2} \qquad x_1(t) = \sqrt{E_1} \cdot \phi_1(t)$$

$$x_{12} = \int_0^T x_1(t) \cdot \phi_2(t) \cdot dt = 3\sqrt{2}$$

$$x_{21} = 3\sqrt{2} \quad ; \quad x_{22} = 0$$

$$x_{31} = \int_0^T x_3(t) \cdot \phi_1(t) \cdot dt = \cancel{3\sqrt{2}}\ 0$$

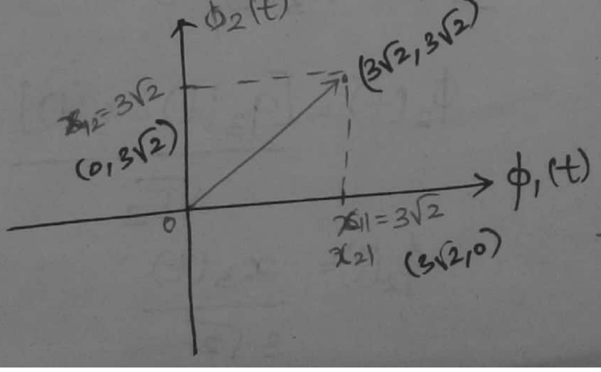
$$x_{32} = 3\sqrt{2}$$

$$\therefore x_1(t) = 3\sqrt{2} \cdot \phi_1(t) + 3\sqrt{2} \cdot \phi_2(t)$$

→ ② marks

$$x_2(t) = 3\sqrt{2} \cdot \phi_1(t)$$

$$x_3(t) = 3\sqrt{2} \cdot \phi_2(t)$$



→ ① mark

7(a) Energy of $x(t)$:

$$E = \int_0^T |x(t)|^2 \, dt$$ → ① mark

$$= \int_0^T |a \cdot \phi_1(t) + b \cdot \phi_2(t) + c \cdot \phi_3(t)|^2 \, dt$$

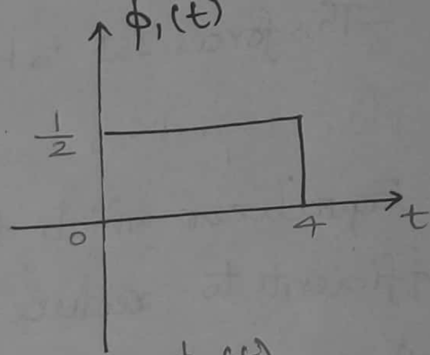
$$= a^2 \int_0^T \phi_1^2(t) \, dt + b^2 \int_0^T \phi_2^2(t) \, dt + c^2 \int_0^T \phi_3^2(t) \, dt$$ → ② marks

$$\because \int_0^T \phi_j^2(t) \, dt = 1$$ → ① mark

$$= a^2 (1) + b^2 (1) + c^2 (1)$$

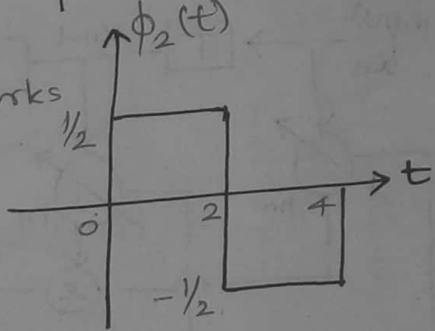
$$E = a^2 + b^2 + c^2$$ → ① mark

7(b) Plot the signals:



$x_1(t) \rightarrow (2, 3)$

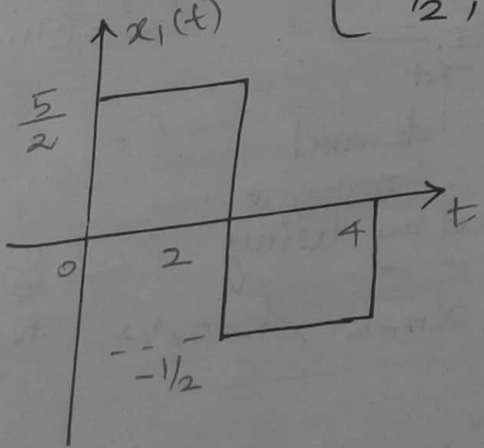
$x_2(t) \rightarrow (-2, 4)$



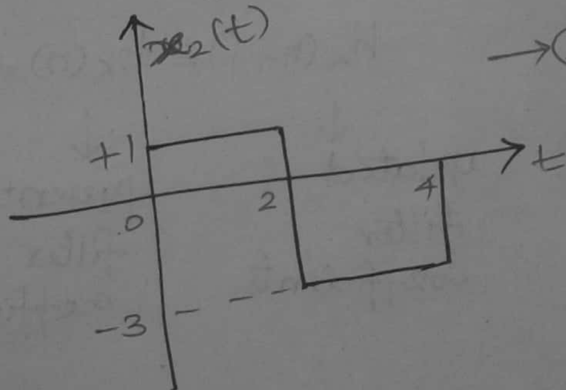
$$x_1(t) = 2 \cdot \phi_1(t) + 3 \cdot \phi_2(t)$$

$$x_2(t) = -2 \cdot \phi_1(t) + 4 \cdot \phi_2(t)$$ → ② marks

$$x_1(t) = \begin{cases} 5/2, & 0 \le t \le 2 \\ -1/2, & 2 \le t \le 4 \end{cases}$$



$$x_2(t) = \begin{cases} +1, & 0 \le t \le 2 \\ -3, & 2 \le t \le 4 \end{cases}$$



→ ③ marks

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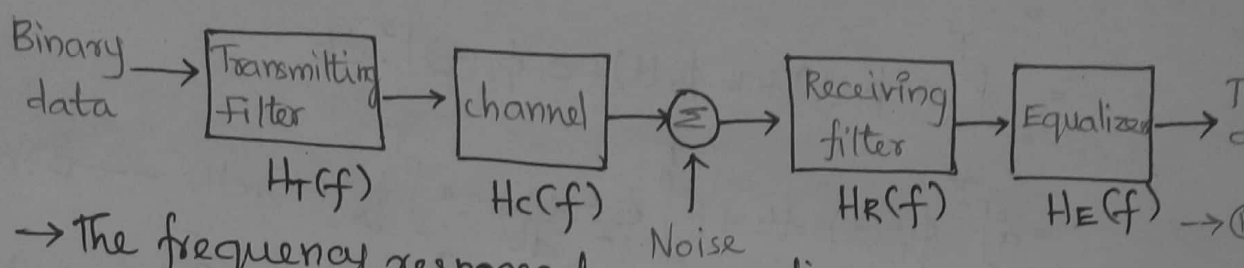
5a) Equalizer and Zero Forcing Equalizer:

- Equalizer - used to correct the distorted signal induced by the channel. → ② marks



→ ① mark

→ The frequency response of an equalizer,

$$H_E(f) = \frac{1}{H_C(f)} = \frac{1}{|H_C(f)| \cdot e^{j\angle H_C(f)}}$$

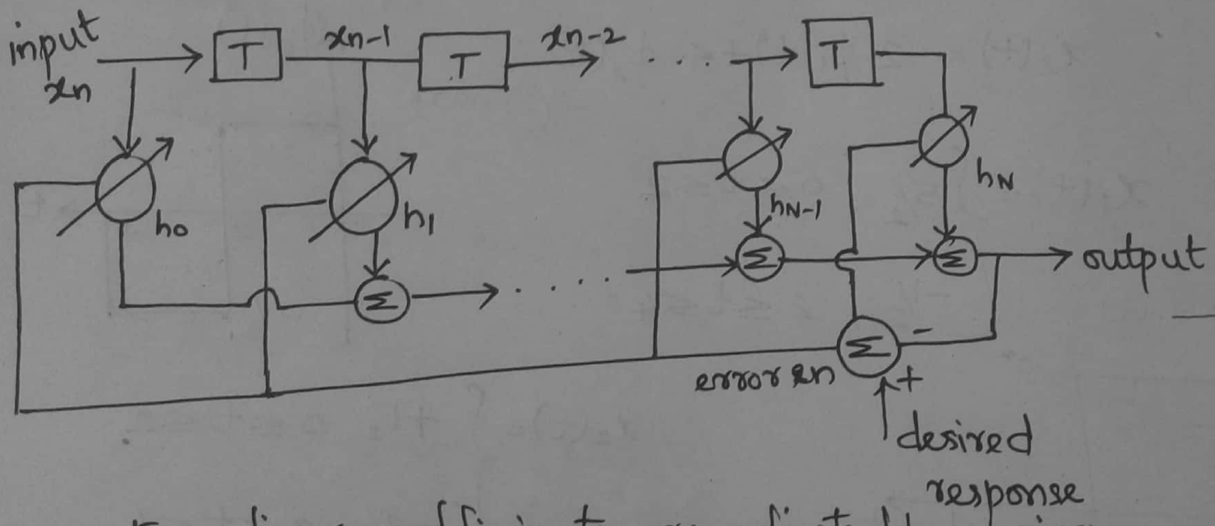
$$H_E(f) = \frac{1}{|H_C(f)|} \cdot e^{-j\angle H_C(f)}$$

→ ② marks

- This forces ISI to be zero at sampling instants, ZFE

5(b) Adaptive Equalizer:

- Equalizer which tracks the variations of ISI and adapt its coefficients to reduce ISI, adaptive equalizer. → ② marks



→ ① mark

→ Equalizer coefficients are adjusted by using → ② marks

$$h_k(n+1) = h_k(n) + \Delta \cdot e_n \cdot x_{n-k}, \quad k = 0, 1, 2, \ldots N$$

- $h_k(n+1)$ → updated filter coefficients
- $h_k(n)$ → present filter coefficient
- Δ → step size
- e_n → present error signal

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