Solution:

Electrical Engineering Department

Digital Communication Systems (802421) – G1

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Term 2 (1436-1437)

Exam #1 (15% of the Total Mark)

Monday 19/06/1437 H

15

الاسم: ______________________ الرقم الجامعي: ______________________

CLO #:	CLO:	Mark:
CLO 4	*CLO 4: Students will learn some principles of digital data transmission such as line coding, pulse shaping and scrambling.*	15

Q1. Assuming **1** and **0** are equally likely, fill in the table below as follows:
Put √ if it the line code satisfies the criteria, and put X if it does not.

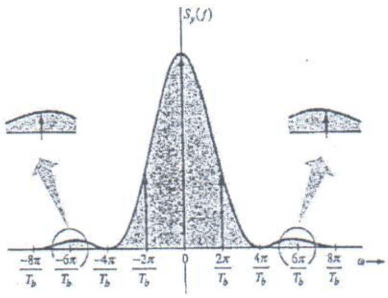
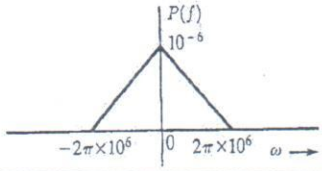
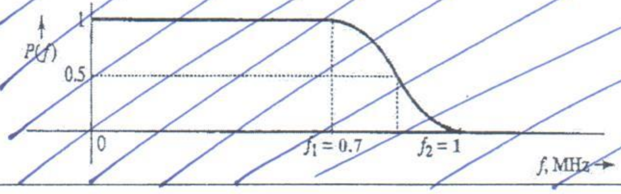
Line code / criteria:	Bandwidth efficiency (for half-width rectangular pulses):	Power efficiency:	Error detection:	DC null:	Transparent:
On-off	X	X	X	X	X
Polar	X	√	X	X	√
Bipolar	√	X	√	√	X
Manchester	X	X	X	√	√
Differential	X	√	√	X	√
Duobinary	√	X	√	X	X

Mark: 3.5 (~~0.15~~ each) 0.12 (each)

Q2. Choose the correct answers(s):
Please note that there can be 1 – 4 correct answers for each question.

Mark: 4

1.	In digital communication system, the line coder converts:	a) An analog message into digital message b) An analog message into binary data c) A binary data into digital signal d) A binary data into electrical waveform e) A baseband signal into high-frequency signal
2.	In the line coding process, which one(s) of the following formulas is correct? $x(t) \rightarrow \boxed{p(t)} \rightarrow y(t)$	a) $y(t) = p(t) * x(t)$ b) $R_y(t) = p(t) * R_x(t)$ c) $S_y(\omega) = \|P(\omega)\| S_x(\omega)$ d) $S_x(\omega) = S_y(\omega) / \|P(\omega)\|^2$ e) $S_y(\omega) = \|P(\omega)\|^2 * S_x(\omega)$

3.	The main purpose of using Manchester code is:	a) To reduce the bandwidth requirement. b) To reduce the power requirement. c) To make the line code transparent. d) To achieve a dc null in the PSD by changing the pulse shape. e) To achieve a dc null in the PSD by changing the input signal $x(t)$.
4.	The figure below shows the PSD of:  	a) Polar line code using the rectangular pulse $p(t) = \text{rect}\,(2t/T_b)$. b) On-off line code using the rectangular pulse $p(t) = \text{rect}\,(2t/T_b)$. c) Bipolar line code using half-width rectangular pulse. d) On-off line code using half-width rectangular pulse. e) Polar line code using the rectangular pulse $p(t) = \text{rect}\,(t/T_b)$.
5.	If the pulse shown satisfies Nyquist's criterion, the bit rate and roll-off factor are:  	a) $R_b = 1$ Mbps, $r = ½$ b) $R_b = 1$ Mbps, $r = ¼$ c) $R_b = 2$ Mbps, $r = ½$ d) $R_b = 1$ Mbps, $r = 1$ e) $R_b = 2$ Mbps, $r = 1$
6.	The spectrum of the "raised-cosine" filter is given as: $$P(f) = \frac{1}{2}(1 + \cos \pi f T_b)\ \text{rect}(\frac{f}{2R_b})$$ The time-domain pulse of the "raised-cosine" filter $p(t)$ is defined as:	a) $p(t) = R_b \frac{\cos(\pi R_b t)}{1-4R_b t}\text{sinc}(\pi R_b t)$ b) $p(t) = R_b \frac{\cos(0.25\pi R_b t)}{1-0.25{R_b}^2 t^2}\text{sinc}(\pi R_b t)$ c) $p(t) = R_b \frac{\cos(\frac{1}{2}\pi R_b t)}{1-{R_b}^2 t^2}\text{sinc}(\pi R_b t)$ d) $p(t) = R_b \frac{\cos(\pi R_b t)}{1-4{R_b}^2 t^2}\text{sinc}(\pi R_b t)$ e) $p(t) = R_b\, \text{sinc}(\pi R_b t)$
7.	If $P(f)$ in the shown figure satisfies Nyquist's criterion, the bit rate and roll-off factor are:  	a) f_x / (½ R_b) b) x / (½ R_b) c) $2x$ / R_b d) $2f_x$ / R_b e) f_x / $2R_b$
8.	In digital communication system, digital scrambler is placed between:	a) Anti-aliasing filter and sampler b) Sampler and quantizer c) Quantizer and bit-encoder d) Bit-encoder and line coder e) Source encoder and baseband modulator

Q3. The random binary sequence 1101010010… is transmitted by using differential line code

a) $\boxed{1\ mark}$ Considering the following diagram, if $p(t)$ is half-width rectangular pulse, sketch $x(t)$ for the binary data given above, $h(t)$ and $y(t)$.

$$x(t) \longrightarrow \boxed{h(t) = p(t)} \longrightarrow y(t)$$

1.5 mark b) $\boxed{\cancel{1\ mark}}$ If the bits **1** and **0** are equally likely, determine R_o, R_1, R_2 and R_n.

c) $\boxed{1\ mark}$ Determine $p(t)$ and $P(\omega)$.

d) $\boxed{1\ mark}$ Determine the PSD of the ~~Manchester~~ differential code $S_y(\omega)$.

e) $\boxed{1\ mark}$ Roughly sketch the PSD and find its essential bandwidth B_T (in Hz).

f) $\boxed{½\ mark}$ If B_{min} is the minimum theoretical bandwidth required to transmit R_b bits per second, express B_T in terms of B_{min} (i.e. write B_T as a function of B_{min}).

g) $\boxed{½\ mark}$ In the above system, if a Nyquist criterion pulse is used with roll-off factor 0.25, determine the transmission bandwidth B_T in terms of R_b (in Hz).

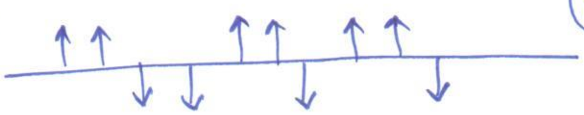
h) $\boxed{1\ mark}$ State the benefits of using Nyquist criterion pulses here.

i) $\boxed{½\ mark}$ If the binary data given above is transmitted by duobinary line code, sketch $y(t)$ for RZ scheme.

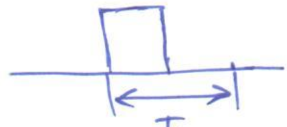
$\overline{\quad 7.5 \quad}$

(a) 1 1 0 1 0 1 0 0 1 0 --- $\frac{1}{2}$

$x(t)$



$h(t) = p(t)$



$\frac{1}{4}$

$y(t)$

$\frac{1}{4}$

(b) $R_o = \lim_{N \to \infty} \frac{1}{N} \sum_k a_k^2$

Data	a_k	a_k^2
0	± 1	1
1	± 1	1

$\frac{1}{4}$

$\Rightarrow R_o = \lim_{N \to \infty} \frac{1}{N} \left[\frac{N}{2}(1) + \frac{N}{2}(1) \right]$

$\Rightarrow \boxed{R_o = 1}$

$R_1 = \lim_{N \to \infty} \frac{1}{N} \sum_k a_k a_{k+1}$

Data		a_k	a_{k+1}	$a_k a_{k+1}$
0	0	± 1	∓ 1	-1
0	1	± 1	± 1	$+1$
1	0	± 1	∓ 1	-1
1	1	± 1	± 1	$+1$

$\frac{1}{2}$

$\Rightarrow R_1 = \lim_{N \to \infty} \frac{1}{N} \left[\frac{N}{2}(1) + \frac{N}{2}(-1) \right]$

$\Rightarrow \boxed{R_1 = 0}$

Cont. $\longrightarrow$

Useful relations:

$$\text{rect}\left(\frac{t}{\tau}\right) \xleftrightarrow{FT} \tau \,\text{sinc}\left(\frac{\omega\tau}{2}\right)$$

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$$R_2 = \lim_{N\to\infty} \frac{1}{N} \sum_k a_k a_{k+2}$$

Data			a_k	a_{k+1}	a_{k+2}	$a_k a_{k+2}$
0	0	0	± 1	∓ 1	± 1	$+1$
0	0	1	± 1	∓ 1	∓ 1	-1
0	1	0	± 1	± 1	∓ 1	-1
0	1	1	± 1	± 1	± 1	$+1$
1	0	0	± 1	∓ 1	± 1	$+1$
1	0	1	± 1	∓ 1	∓ 1	-1
1	1	0	± 1	± 1	∓ 1	-1
1	1	1	± 1	± 1	± 1	$+1$

1/2

$$\Rightarrow R_2 = \lim_{N\to\infty} \frac{1}{N}\left[\frac{N}{2}(1) + \frac{N}{2}(-1)\right]$$

$$\Rightarrow \boxed{R_2 = 0}$$

Similarly, it can be shown that:

$$\boxed{R_n = 0 \quad \text{for } n \neq 0}$$ 1/4

(c) Half-width rectangular pulse $p(t)$: 1/2

$$p(t) = \text{rect}\left(\frac{t}{T_b/2}\right) = \text{rect}\left(\frac{2t}{T_b}\right)$$

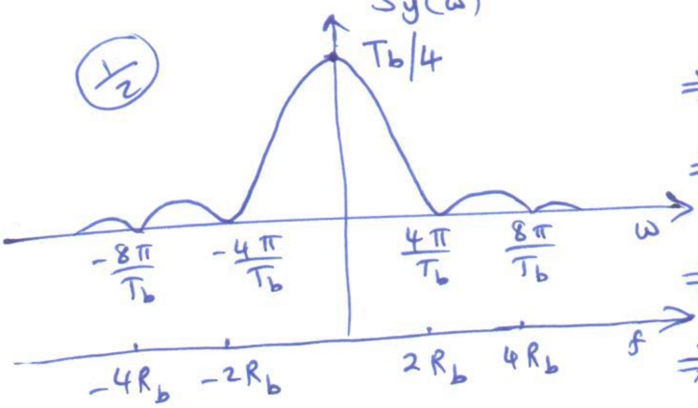
$$P(\omega) = \frac{T_b}{2}\,\text{sinc}\left(\frac{\omega T_b}{4}\right)$$ 1/2

(d) $$S_y(\omega) = |P(\omega)|^2 S_x(\omega) = \frac{|P(\omega)|^2}{T_b}\left(R_0 + 2\sum_{n=1}^{\infty} R_n \cos n\omega T_b\right)$$ 1

since $R_1, R_2, \dots = 0$ & $R_0 = 1$

$$\Rightarrow S_y(\omega) = \frac{T_b^2}{4}\,\text{sinc}^2\left(\frac{\omega T_b}{4}\right)\cdot\frac{1}{T_b} = \frac{T_b}{4}\,\text{sinc}^2\left(\frac{\omega T_b}{4}\right)$$

(e) 1/2



$$S_y(\omega) = 0$$

$$\Rightarrow \frac{T_b}{4}\,\text{sinc}^2\left(\frac{\omega T_b}{4}\right) = 0$$

$$\Rightarrow \text{sinc}\left(\frac{\omega T_b}{4}\right) = 0$$

$$\Rightarrow \sin\left(\frac{\omega T_b}{4}\right) = 0$$

$$\Rightarrow \frac{\omega T_b}{4} = \pm\pi, \pm 2\pi, \dots$$

$$\Rightarrow \omega = \pm\frac{4\pi}{T_b}, \pm\frac{8\pi}{T_b}, \dots \left(\frac{\text{rad}}{s}\right)$$

$$\Rightarrow f = \pm\frac{2}{T_b}, \pm\frac{4}{T_b}, \dots \text{(Hz)}$$

$$= \pm 2R_b, \pm 4R_b, \dots \text{(Hz)}$$

$\Rightarrow$ Essential bandwidth $= B_T = 2R_b$ (Hz)

1/2

cont.

(f) $B_{min} = \frac{R_b}{2}$

$$\boxed{B_T = 2R_b = 4B_{min}}$$

$\frac{1}{2}$

(g) For Nyquist criterion pulse: $(r = 0.25)$

$$B_T = \frac{(1+r)R_b}{2} = \frac{1.25 R_b}{2} = 0.625 R_b \quad (Hz)$$

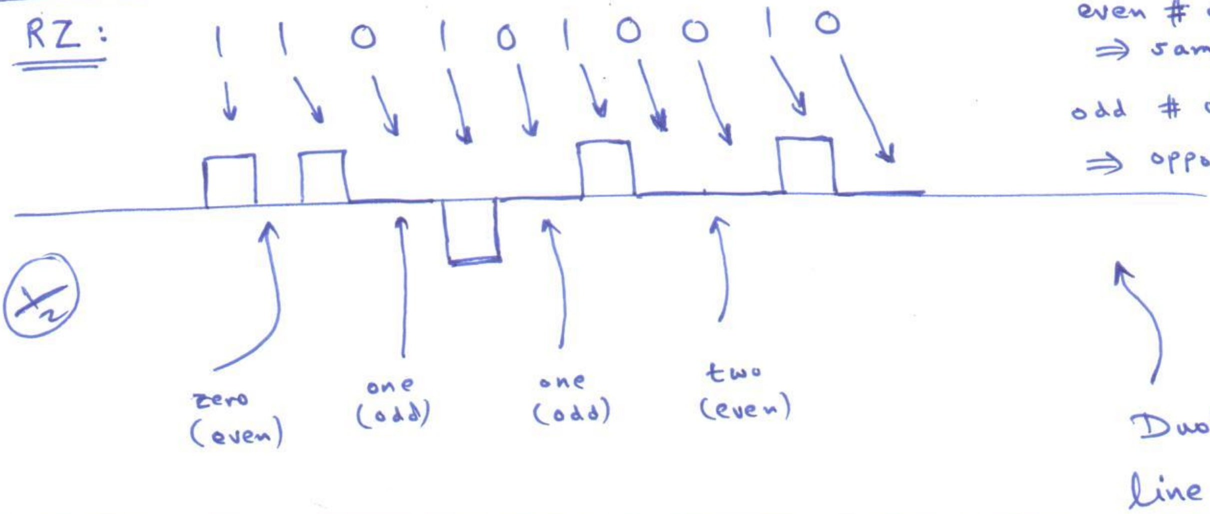
$\frac{1}{2}$

(h) Benifits of using Nyquist criterion pulses:

1) Minimizing intersymbol interference (ISI). $\frac{1}{2}$

2) Reducing transmission bandwidth. $\frac{1}{2}$
(compare $0.625R_b$ & $2R_b$).

(i) RZ:



even # of zeros ⇒ same

odd # of zeros ⇒ opposite

$\cancel{\frac{1}{2}}$
