IUG - Faculty of Engineering
Department of Computer Engineering
Data communications Lab
Summer 2022-2023



Data Communications

Lab 4

Chapter 3:

Introduction to Physical Layer

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P3-1. Given the frequencies listed below, calculate the corresponding periods.

a. 24 Hz **b.** 8 MHz **c.** 140 KHz

a. T = 1 / f = 1 / (24 Hz) = 0.0417 s = 41.7 × 10^-3 s = 41.7 ms

b. T = 1 / f = 1 / (8 MHz) = 0.000000125 = 0.125 × 10^-6 s = 0.125 µs

c. T = 1 / f = 1 / (140 KHz) = 0.00000714 s = 7.14 × 10^-6 s = 7.14 µs

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P3-2. Given the following periods, calculate the corresponding frequencies.

a. 5 s **b.** 12 µs **c.** 220 ns

a. f = 1 / T = 1 / (5 s) = 0.2 Hz

b. f = 1 / T = 1 / (12 µs) =83333 Hz = 83.333 × 103 Hz = 83.333 KHz

c. f = 1 / T = 1 / (220 ns) = 4550000 Hz = 4.55× 106 Hz = 4.55 MHz

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P3-3. What is the phase shift for the following?

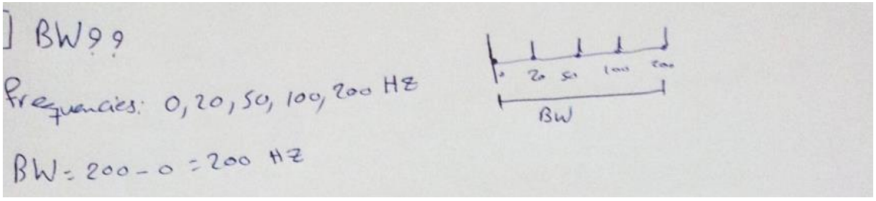
a. A sine wave with the maximum amplitude at time zero

b. A sine wave with maximum amplitude after 1/4 cycle

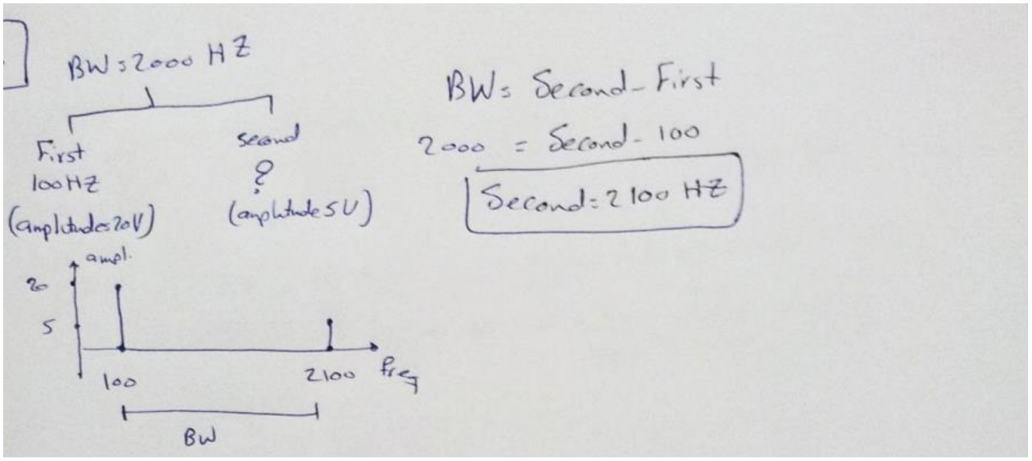
c. A sine wave with zero amplitude after 3/4 cycle and increasing

Solution:
a. 90 degrees (π/2 radian)
b. 0 degrees (0 radian)
c. 90 degrees (π/2 radian)

P3-4. What is the bandwidth of a signal that can be decomposed into five sine waves with frequencies at 0, 20, 50, 100, and 200 Hz? All peak amplitudes are the same. Draw the bandwidth.



P3-5. A periodic composite signal with a bandwidth of 2000 Hz is composed of two sine waves. The first one has a frequency of 100 Hz with a maximum amplitude of 20 V; the second one has a maximum amplitude of 5 V. Draw the bandwidth.



P3-6. Which signal has a wider bandwidth, a sine wave with a frequency of 100 Hz or a sine wave with a frequency of 200 Hz?

Solution:

Each signal is a simple signal in this case. The bandwidth of a simple signal is zero. So the bandwidth of both signals are the same.

P3-7. What is the bit rate for each of the following signals?

a. A signal in which 1 bit lasts 0.001 s

b. A signal in which 1 bit lasts 2 ms

c. A signal in which 10 bits last 20 µs

Solution:

a. bit rate = 1/ (bit duration) = 1 / (0.001 s) = 1000 bps = 1 Kbps

b. bit rate = 1/ (bit duration) = 1 / (2 ms) = 500 bps

c. bit rate = 1/(bit duration) = 1 / (20 µs/10) = 1 / (2 µs) = 500 Kbps

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P3-8. A device is sending out data at the rate of 1000 bps.

a. How long does it take to send out 10 bits?

b. How long does it take to send out a single character (8 bits)?

c. How long does it take to send a file of 100,000 characters?

Solution:

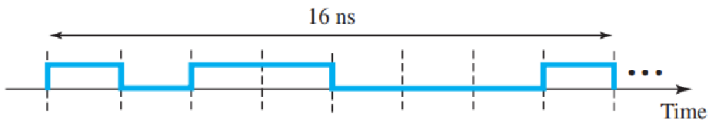
a. (10 / 1000) s = 0.01 s

b. (8 / 1000) s = 0. 008 s = 8 ms

c. ((100,000 × 8) / 1000) s = 800 s

P3-9. What is the bit rate for the signal in Figure 3.35?

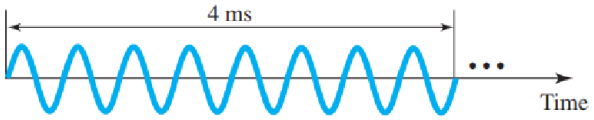
Figure 3.35 *Problem P3-9*



Solution: There are 8 bits in 16 ns.
Bit rate is 8 / (16 × 10^−9) = 0.5 × 10^−9 = 500 Mbps

P3-10. What is the frequency of the signal in Figure 3.36?

Figure 3.36 *Problem P3-10*

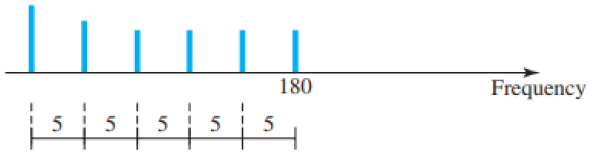


Solution:
The signal makes 8 cycles in 4 ms. The frequency is 8 /(4 ms) = 2 KHz

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P3-11. What is the bandwidth of the composite signal shown in Figure 3.37?

Figure 3.37 *Problem P3-11*

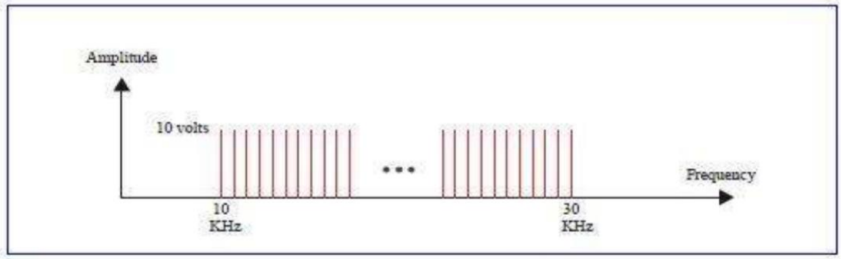


Solution:
B = 5 + 5+ 5+ 5+ 5 = 25 HZ

P3-12. A periodic composite signal contains frequencies from 10 to 30 KHz, each with an amplitude of 10 V. Draw the frequency spectrum.

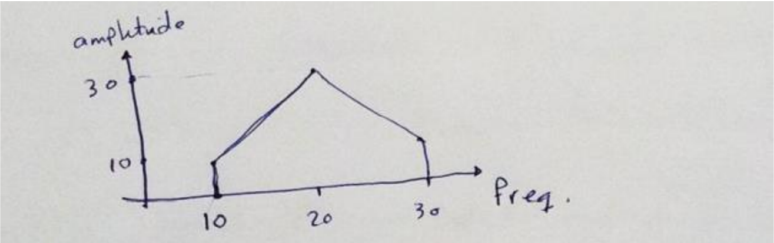
Solution:

The signal is periodic, so the frequency domain is made of discrete frequencies. as shown in Figure.



P3-13. A nonperiodic composite signal contains frequencies from 10 to 30 KHz. The peak amplitude is 10 V for the lowest and the highest signals and is 30 V for the 20-KHz signal. Assuming that the amplitudes change gradually from the minimum to the maximum, draw the frequency spectrum.

Solution:



P3-14. A TV channel has a bandwidth of 6 MHz. If we send a digital signal using one channel, what are the data rates if we use one harmonic, three harmonics, and five harmonics?

Solution: first: B=N/2 , three B= 3N/2, five = 5N/2

Using the first harmonic, data rate = 2 × 6 MHz = **12 Mbps**
Using three harmonics, data rate = (2 × 6 MHz) /3 = **4 Mbps**
Using five harmonics, data rate = (2 × 6 MHz) /5 = **2.4 Mbps**

P3-15. A signal travels from point A to point B. At point A, the signal power is 100 W. At point B, the power is 90 W. What is the attenuation in decibels?

Solution:

$$\mathbf{dB = 10 \log_{10} \frac{P_2}{P_1}}$$

$dB = 10 \log_{10} (90 / 100) =$ **−0.46 dB**

P3-16. The attenuation of a signal is −10 dB. What is the final signal power if it was originally 5 W?

Solution:

$dB=10\log_{10}\frac{P2}{p1}$ → $-10=10\log_{10}\frac{P2}{5}$

$\log_{10}\frac{P2}{5}=-1$

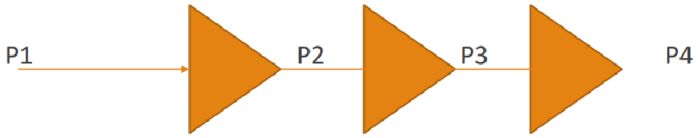
$\frac{P2}{5}=10^{-1}$

→ P2 = 0.5 W

P3-17. A signal has passed through three cascaded amplifiers, each with a 4 dB gain. What is the total gain? How much is the signal amplified?

Solution:

Total gain = 4dB + 4dB + 4dB = 12dB



For power gain of the first stage:

$4dB=10 * \log_{10}\frac{P2}{P1}$

$\frac{P2}{P1}=\left(10^{\left(\frac{4}{10}\right)}\right) = 2.512$

For power gain of three stages: or $12dB=\log_{10}\frac{P4}{P1} \rightarrow \frac{P4}{P1}=\left(10^{\left(\frac{12}{10}\right)}\right) = 15.85$

2.512*2.512*2.512= 15.851

P3-18. If the bandwidth of the channel is 5 Kbps, how long does it take to send a frame of 100,000 bits out of this device?

Solution:

Given ,bandwidth 5000 bps , Frame 100,000 bit

$$\rightarrow \frac{100000\ b}{5000\ bps} = 20sec$$

P3-19. The light of the sun takes approximately eight minutes to reach the earth. What is the distance between the sun and the earth?

Solution:

The distance between the earth and the sun d = velocity of light × time taken to reachlight form sun to earth

or $d = (3 \times 10^8 m/s) \times (8 \times 60s) = 144 \times 10^9 m = 144 \times 10^6 km$

P3-20. A signal has a wavelength of 1 μm in air. How far can the front of the wave travel during 1000 periods?

Solution:

Given , wavelength = 1 μm , periods= 1000

$Wavelength = propagation\ speed * period$ (For one period)

Distance = 1 μm *1000= 1000μm =1 mm

P3-21. A line has a signal-to-noise ratio of 1000 and a bandwidth of 4000 KHz. What is the maximum data rate supported by this line?

Solution:

Given

Bandwidth =4000KHz , SNR=1000

So, We Know the Shannon capacity

Capacity =BW* $\log_2(\mathbf{1}+\boldsymbol{SNR})$

Capacity =4000K* $\log_2(\mathbf{1}+\mathbf{1000})$=40 Kbps

P3-22. We measure the performance of a telephone line (4 KHz of bandwidth). When the signal is 10 V, the noise is 5 mV. What is the maximum data rate supported by this telephone line?

Solution:

Given , BW= 4 KHz , Signal=10V , Noise= 5mV ,

SNR= $\frac{10}{0.005} = 2000$

Capacity =BW* $\log_2(\mathbf{1}+\boldsymbol{SNR})$

Capacity =4000* $\log_2(\mathbf{1}+\mathbf{2000})$=43866 bps

P3-23. A file contains 2 million bytes. How long does it take to download this file using a 56-Kbps channel? 1-Mbps channel?

Solution:

The file contains 2,000,000 × 8 = 16,000,000 bits. With a 56-Kbps channel, it takes 16,000,000/56,000 = **289 s**. With a 1-Mbps channel, it takes **16 s**.

P3-24. A computer monitor has a resolution of 1200 by 1000 pixels. If each pixel uses 1024 colors, how many bits are needed to send the complete contents of a screen?

Solution:

To represent 1024 color

we need = log2 1024 = $10 bits$

Total number of bit = 1200*1000*10 = 12000,000 bit = 12 million bit

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P3-25. A signal with 200 milliwatts power passes through 10 devices, each with an average noise of 2 microwatts. What is the SNR? What is the SNRdB?

Solution:

Given, Signal =200 mW= 0.2 W

Total Noise = $10*2*10^{-6}=2*10^{-5}$

We Know , SNR= $\frac{\text{average signal power}}{\text{average noise power}}=\frac{0.2}{2*10^{-5}}=10000$

SNR dB = $10\log_{10}(SNR)$

SNR dB = $10\log_{10}(10000)=40$

P3-26. If the peak voltage value of a signal is 20 times the peak voltage value of the noise, what is the SNR? What is the SNR_{dB}?

Solution:

$$SNR=\frac{\text{signal power}}{\text{noise power}}$$

$$SNR=\frac{(signal\ voltage)^2}{(noise\ voltage)^2}=20^2=400$$

$$SNR\ dB = 10\log_{10}(SNR)$$

$$SNR\ dB = 10\log_{10}(400)=26.021$$

P3-27. What is the theoretical capacity of a channel in each of the following cases?

a. Bandwidth: 20 KHz $SNR_{dB}=40$

b. Bandwidth: 200 KHz $SNR_{dB}=4$

c. Bandwidth: 1 MHz $SNR_{dB}=20$

Solution:

$$\text{Capacity} = BW * \left(\frac{SNR\ dB}{3}\right)$$

$C = B \times (SNR_{dB}/3) = 20\ KHz \times (40/3) =$ **267 Kbps**

$C = B \times (SNR_{dB}/3) = 200\ KHz \times (4/3) =$ **267 Kbps**

$C = B \times (SNR_{dB}/3) = 1\ MHz \times (20/3) =$ **6.67 Mbps**

P3-28. We need to upgrade a channel to a higher bandwidth. Answer the following questions:

a. How is the rate improved if we double the bandwidth?

b. How is the rate improved if we double the SNR?

Solution:

1) How is the rate improved if we double the bandwidth?

$C2=2*\mathbf{BW1}*\log_2(1+\boldsymbol{SNR})$

The data rate is doubled (C2 =2*C1)

2)How is the rate improved if we double the SNR?

$C2=\mathbf{BW1}*\log_2(1+2*\boldsymbol{SNR})$

$C2=BW1*\log_2(2*\boldsymbol{SNR})$

$C2=BW1*\log_2(2)+\mathbf{BW1}*\log_2(\boldsymbol{SNR})$

C2=BW1+ C1

P3-29. We have a channel with 4 KHz bandwidth. If we want to send data at 100 Kbps, what is the minimum SNR_{dB}? What is the SNR?

Solution:

$$\text{Capacity} = BW * \left(\frac{\text{SNR dB}}{3}\right)$$

$$\text{so minimum SNR dB}=\frac{3*\text{Capacity}}{BW}=\frac{3*100{,}000}{4000}=75$$

$$\text{Minimum SNR} = 10^{\frac{SNR\,dB}{10}}=10^{\frac{75}{10}}$$

P3-30. What is the transmission time of a packet sent by a station if the length of the packet is 1 million bytes and the bandwidth of the channel is 200 Kbps?

Solution:

Given , Packet length =1 million byte=8 million bit

$$\text{Transmission time} = \frac{packet\ length}{bandwidth}=\frac{8{,}000{,}000}{200{,}000}=40\ \text{sec}$$

P3-31. What is the length of a bit in a channel with a propagation speed of 2×10^8 m/s if the channel bandwidth is

a. 1 Mbps? **b.** 10 Mbps? **c.** 100 Mbps?

Solution: a.

$$\textbf{Bit length}=\frac{propagation\ speed}{Bandwith}$$

$$\textbf{Bit length}=\frac{2*10^8 m/s}{10^6 b/s}=\textbf{200 m}$$

b. Bit length = (2 ×10^8) × [(1 / (10 Mbps)] = **20 m**.

c. Bit length = (2 ×10^8) × [(1 / (100 Mbps)] = **2 m**.

P3-32. How many bits can fit on a link with a 2 ms delay if the bandwidth of the link is

a. 1 Mbps? **b.** 10 Mbps? **c.** 100 Mbps?

Solution:

a. Number of bits = bandwidth × delay = 1 Mbps × 2 ms = **2000 bits**

b. Number of bits = bandwidth × delay = 10 Mbps × 2 ms = **20,000 bits**

c. Number of bits = bandwidth × delay = 100 Mbps × 2 ms = **200,000 bits**

P3-33. What is the total delay (latency) for a frame of size 5 million bits that is being sent on a link with 10 routers each having a queuing time of 2 μs and a processing time of 1 μs. The length of the link is 2000 Km. The speed of light inside the link is 2×10^8 m/s. The link has a bandwidth of 5 Mbps. Which component of the total delay is dominant? Which one is negligible?

Solution:

Latency = processing time + queuing time + transmission time + propagation time

Processing time = 10 × 1 μs = 10 μs = **0.000010 s**

Queuing time = 10 × 2 μs = 20 μs = **0.000020 s**

Transmission time = 5,000,000 / (5 Mbps) = **1 s**

Propagation time = (2000 Km) / (2 × 10^8) = **0.01 s**

Latency = 0.000010 + 0.000020 + 1 + 0.01 = 1.01000030 s

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Data Communications

Lab 5

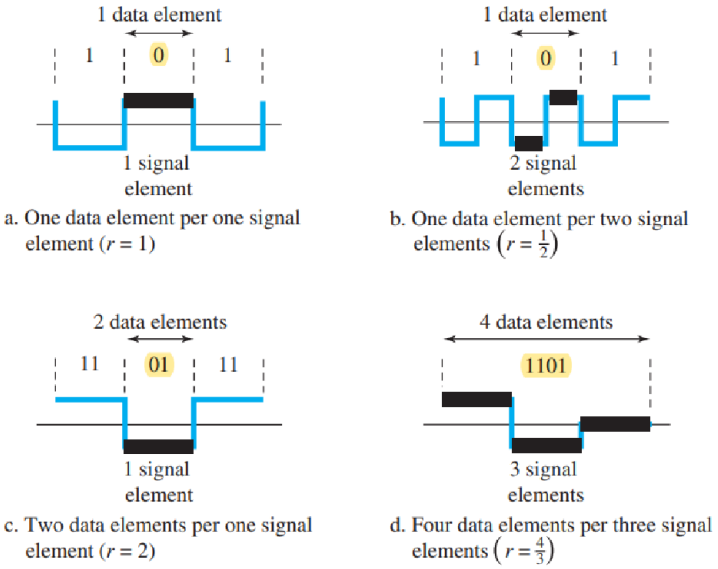
Chapter 4:

Digital Transmission

Abdullaha Idris Ouda

P4-1. Calculate the value of the signal rate for each case in Figure 4.2 if the data rate is 1 Mbps and c = 1/2.

Figure 4.2 *Signal element versus data element*



Solution:

We use the formula s = c × N × (1/r) for each case. We let **c = 1/2.**

a. r = 1 → s = (1/2) × (1 Mbps) × 1/1 = 500 kbaud

b. r = 1/2 → s = (1/2) × (1 Mbps) × 1/(1/2) = 1 Mbaud

c. r = 2 → s = (1/2) × (1 Mbps) × 1/2 = 250 Kbaud

d. r = 4/3 → s = (1/2) × (1 Mbps) × 1/(4/3) = 375 Kbaud

P4-2. In a digital transmission, the sender clock is 0.2 percent faster than the receiver clock. How many extra bits per second does the sender send if the data rate is 1 Mbps?

Solution:

The number of bits is calculated as (0.2 /100) × (1 Mbps) = 2000 bits

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P4-3. Draw the graph of the NRZ-L scheme using each of the following data streams, assuming that the last signal level has been positive. From the graphs, guess the bandwidth for this scheme using the average number of changes in the signal level. Compare your guess with the corresponding entry in Table 4.1.

a. 00000000 b. 11111111 c. 01010101 d. 00110011

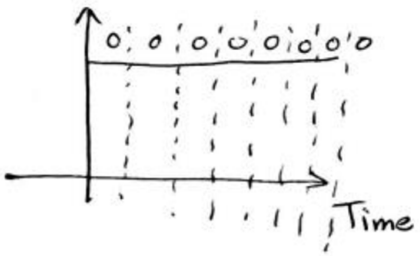
Solution:

NRZ-L (non return to zero level):

+ve: bit 0

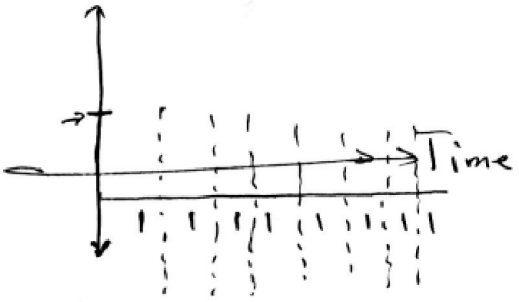
-ve: bit 1

(a) 0000 0000



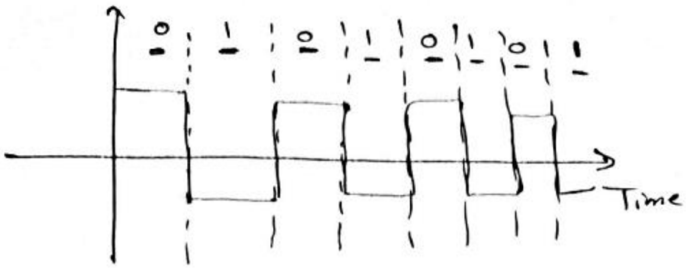
No. of changes = 0.

(b)



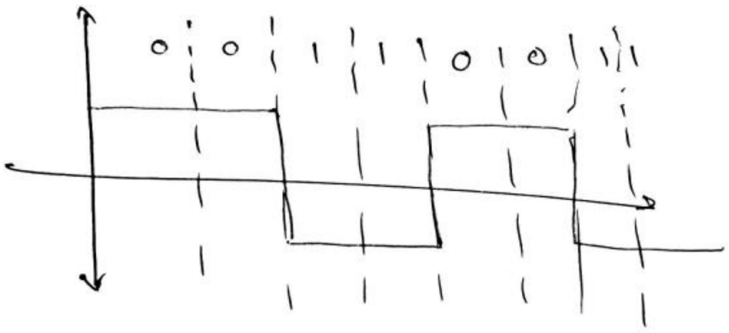
No. of changes = 01.

(c) 01 01 0101



No. of changes : 7

(d) 00 11 00 11



No. of changes : 3

Average number of changes = (0+0+7+3) / 4 = 11/4 = 2.75
Data rate is the number of data element, so equals to 8
B = (2.75/8) N

P4-4. Repeat Problem P4-3 for the NRZ-I scheme.

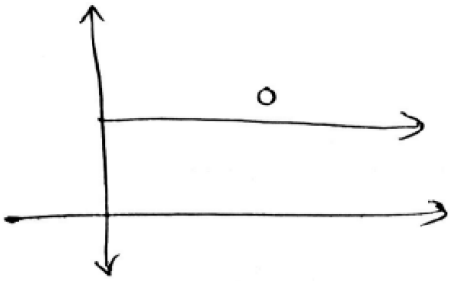
Solution:

NRZ-I:

If the next bit is 0, then No inversion

If the next bit is 1, then inversion

(a) 0000 0000



No. change.

NRZ-I:

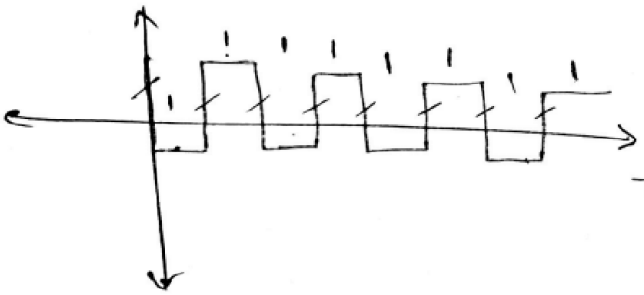
⇒ Next bit is 0

Then, No inversion

⇒ Next bit is 1

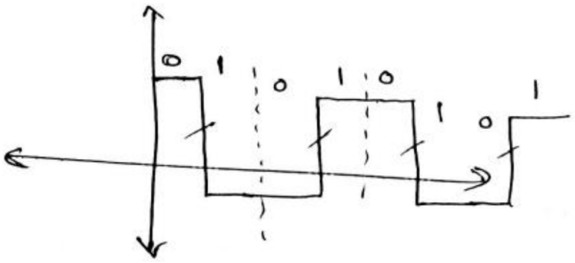
Inversion

(b) 1 1 1 1 1 1 1 1



No. of changes is 8

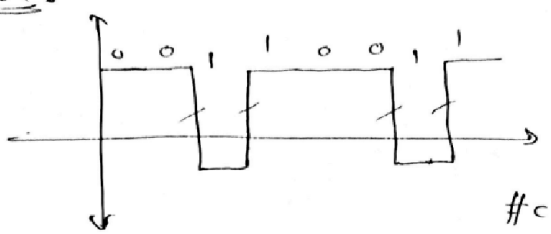
(c) 0 1 0 1 0 1 0 1



No. of changes is 4

(d) 00 11 00 11

Sol:



changes = 4

avg. of changes = $\frac{(0+8+4+4)}{4} = 4$, N = 8

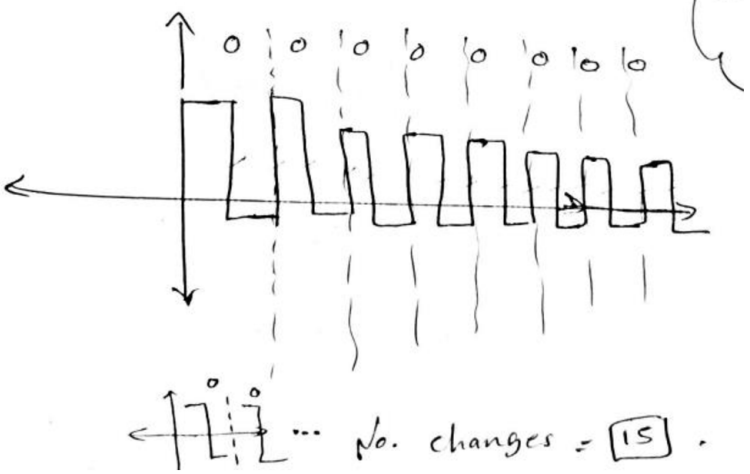
BW = $\frac{4}{8} = \frac{1}{2}N = N/2$

P4-5. Repeat Problem P4-3 for the Manchester scheme.

Solution: Manchester:

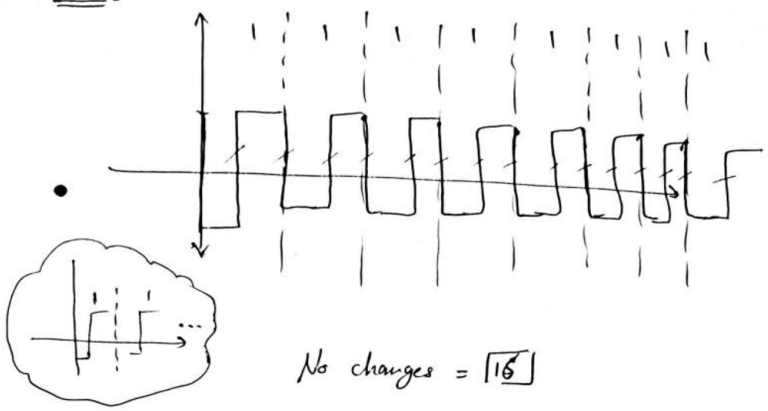


(a) 0000 0000



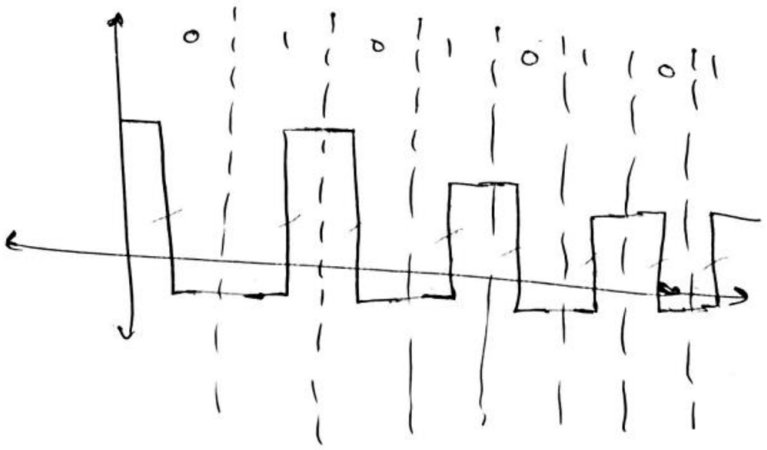
(b) 1111 1111

Sol:



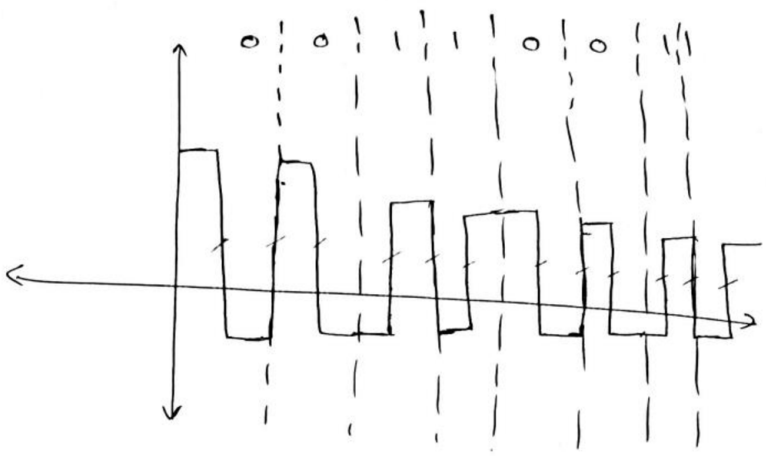
[c] 0 1 01 01 01

Sol:



changes = [8]

[d] 0 0 11 0 0 11



changes = [12] .

avg. = $\frac{(15+15+8+12)}{4}$ = [12.75]

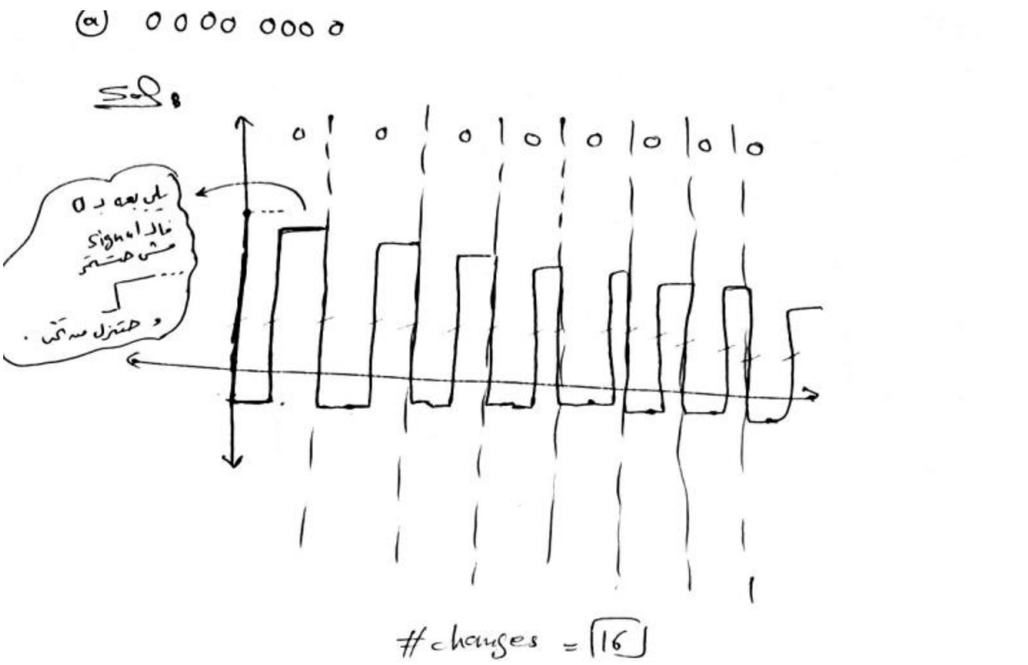
N = [8]

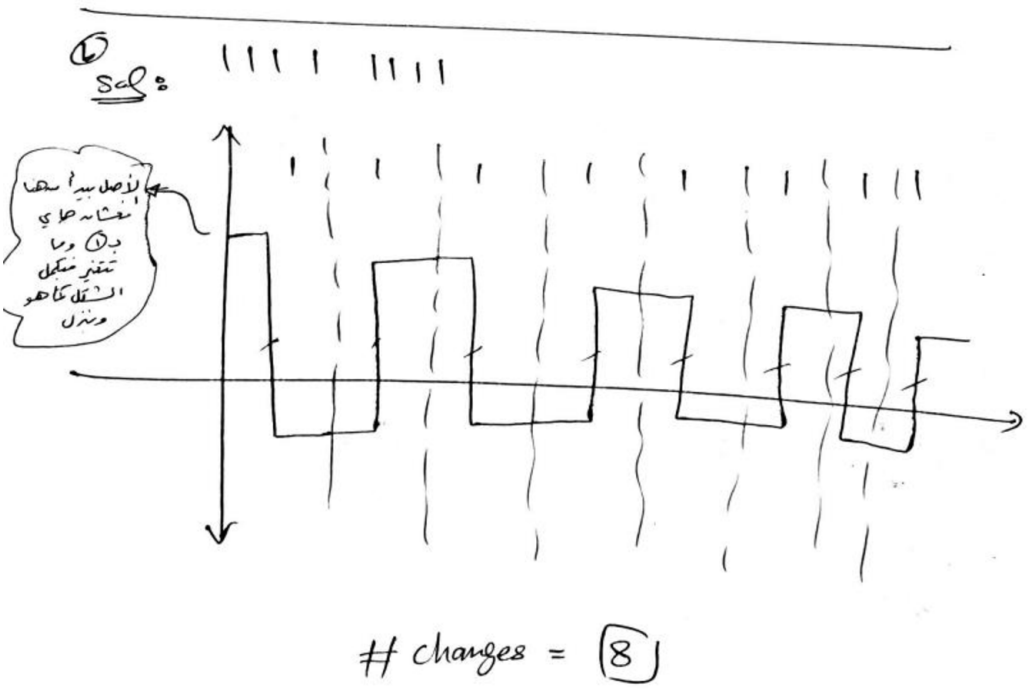
BW = [$\frac{12.75}{8} N$] #.

P4-6. Repeat Problem P4-3 for the differential Manchester scheme.

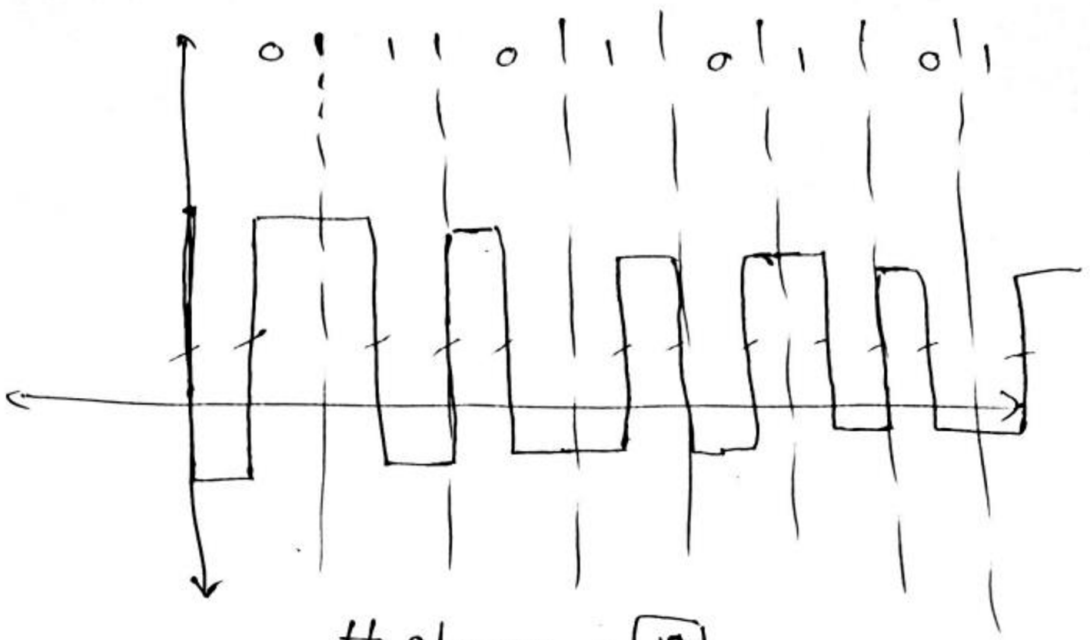
Solution:

○ No inversion: Next bit is 1 ● Inversion: Next bit is 0



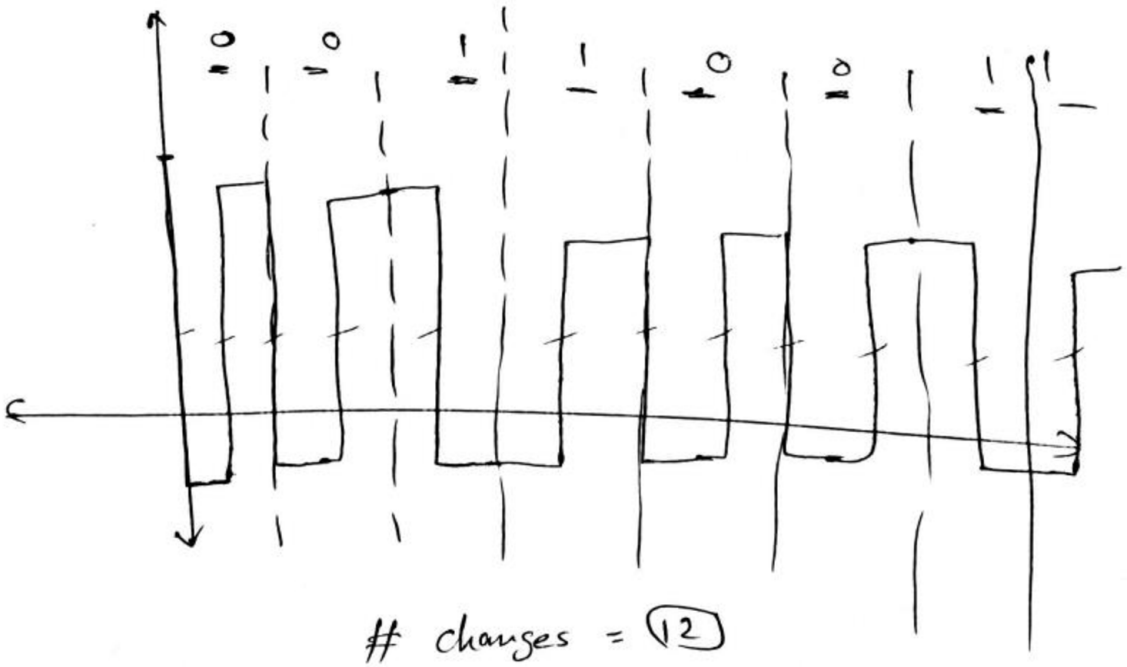


(c) 0 1 0 1 0 1 0 1



changes = 12

(d) 0 0 1 1 0 0 1 1



changes = 12

avg. of changes = $\frac{16+8+12+12}{4}$ = 12 , N = 8

BW = 12/8 = (1.5) N#

P4-7. Repeat Problem P4-3 for the 2B1Q scheme, but use the following data streams.

a. 0000000000000000

b. 1111111111111111

c. 0101010101010101

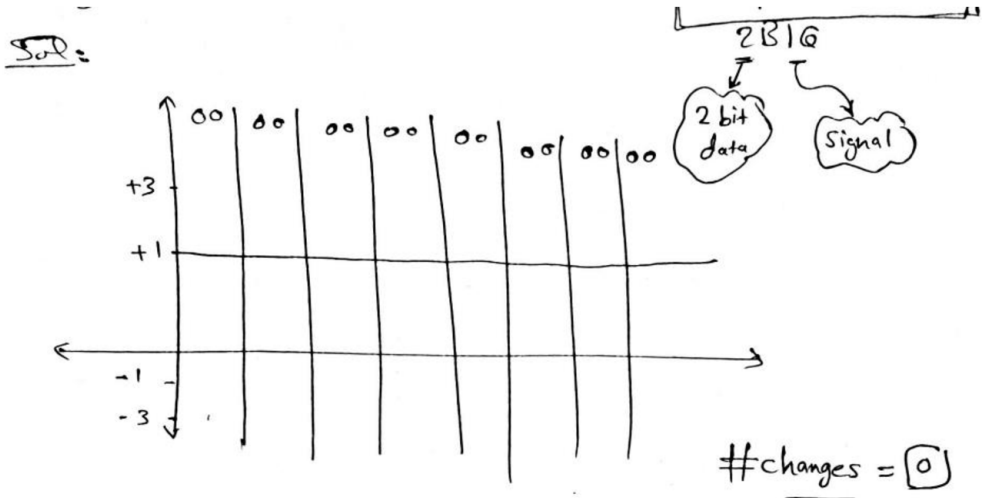
d. 0011001100110011

Solution:

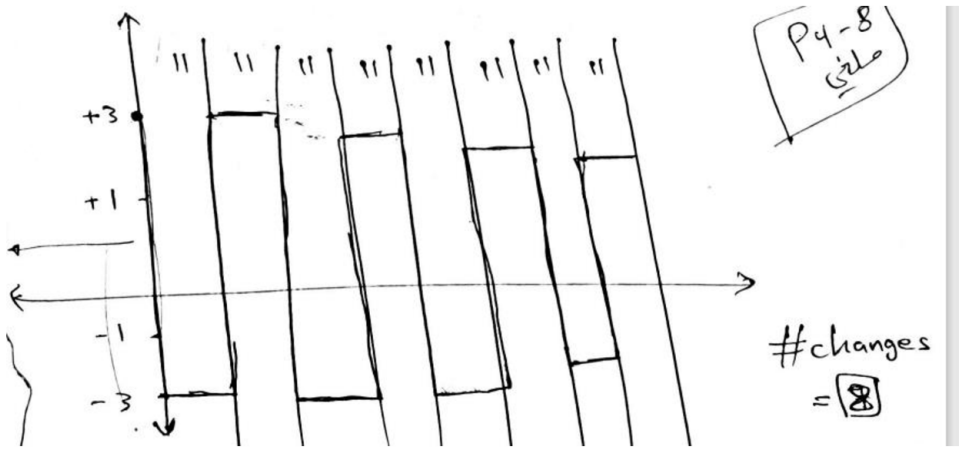
	Previous level: positive	Previous level: negative
Next bits	Next level	Next level
00	+1	-1
01	+3	-3
10	-1	+1
11	-3	+3

Transition table

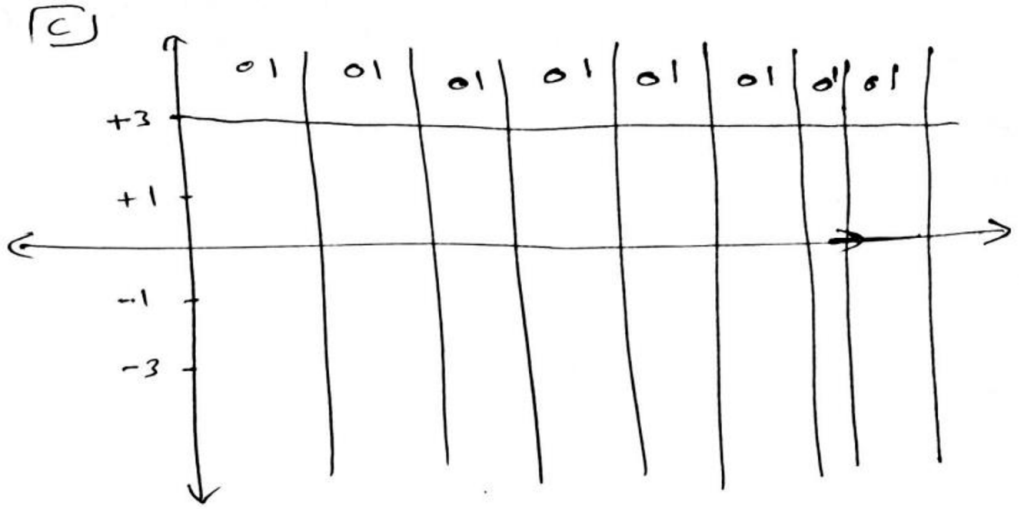
a. 0000000000000000



b. b. 1111111111111111

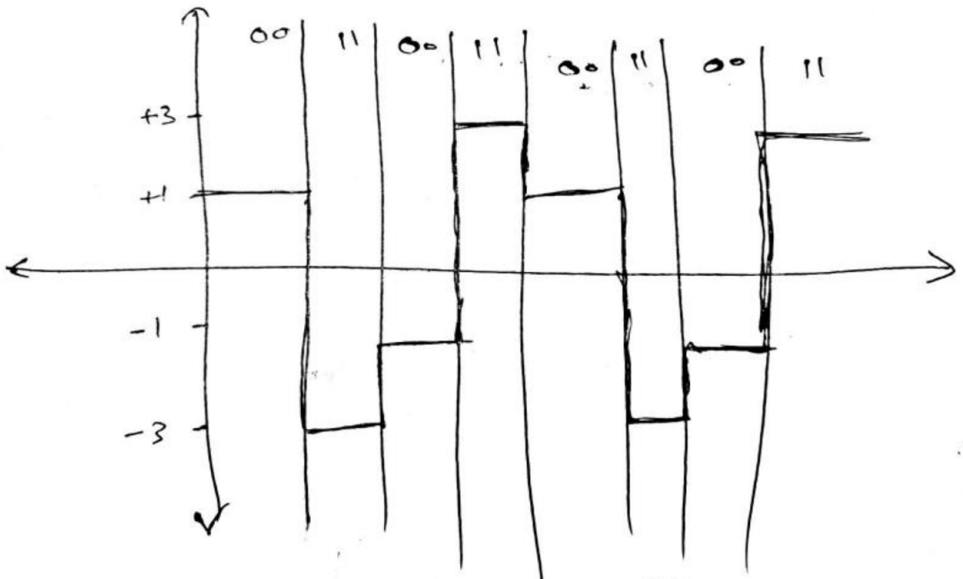


c. 0101010101010101



#changes = (0)

d. 00110011001100 11



changes = (7)

avg. of changes = $\frac{0+8+0+7}{4} = \boxed{3.75}$

$B = \left(\frac{3.75}{16}\right)N$ #

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Lab 6

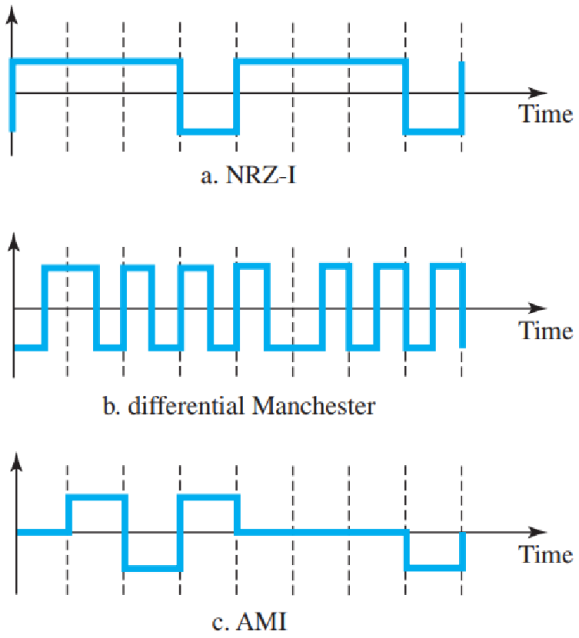
Chapter 4-part2:

Digital Transmission

Abdullaha Idris Ouda

P4-9. Find the 8-bit data stream for each case depicted in Figure 4.36.

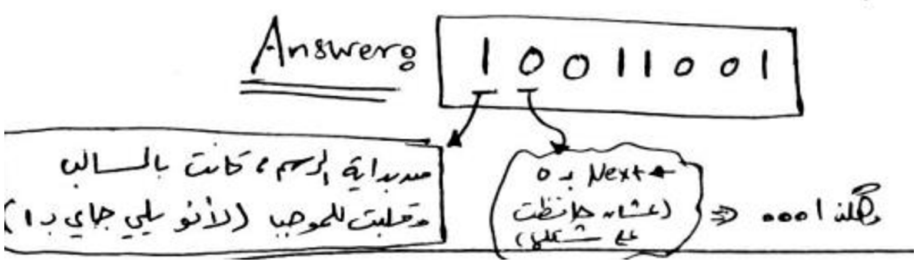
Figure 4.36 *Problem P4-9*



Solution:

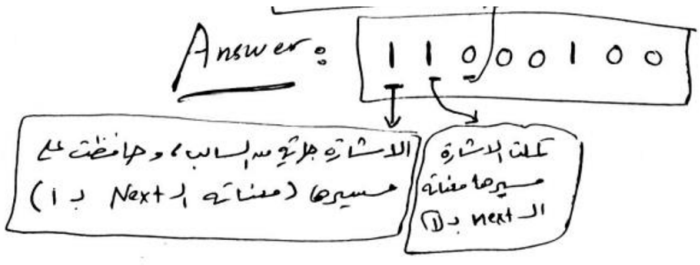
1- NRZ-I:

If the next bit is 0, then No inversion ,If the next bit is 1, then inversion



2- Differential Manchester

○ No inversion: Next bit is 1 ● Inversion: Next bit is 0



3- AMI

Bit (0): **Zero**

Bit (1): **+ve then -ve and so on ..**

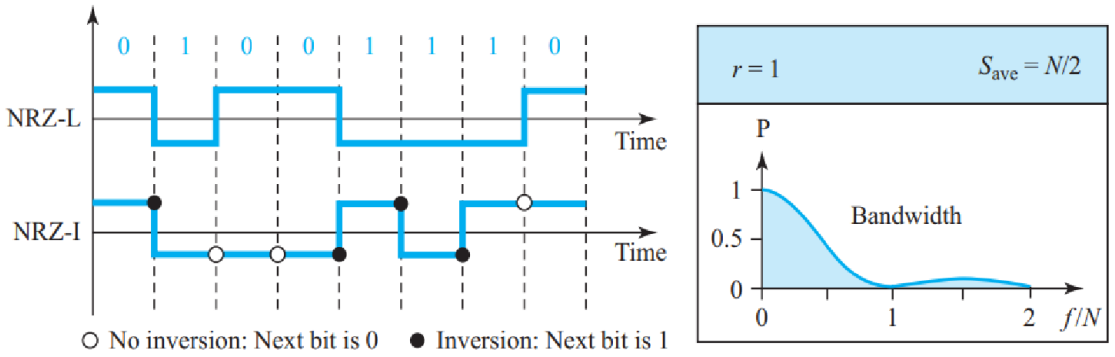
⇒ Answer:

0 1 1 1 0 0 0 1

P4-10. An NRZ-I signal has a data rate of 100 Kbps. Using Figure 4.6, calculate the value of the normalized energy (P) for frequencies at 0 Hz, 50 KHz, and 100 KHz.

Solution:

Figure 4.6 *Polar NRZ-L and NRZ-I schemes*



The data rate is 100 Kbps. For each case, we first need to calculate the value f / N. We then use Figure 4.6 in the text to find P (energy per Hz). All calculations are approximations.

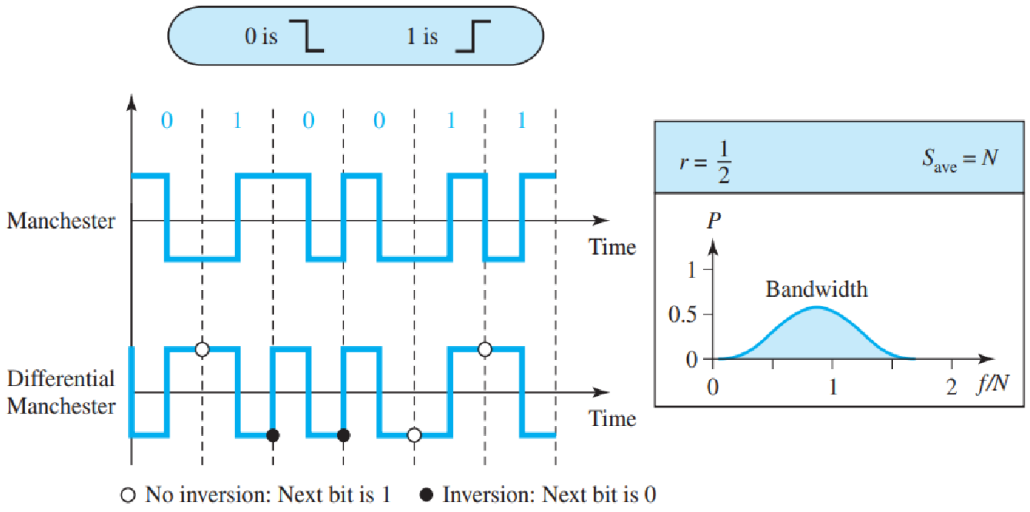
a. f /N = 0/100 = 0 → P = 1.0

b. f /N = 50/100 = 1/2 → P = 0.5

c. f /N = 100/100 = 1 → P = 0.0

P4-11. A Manchester signal has a data rate of 100 Kbps. Using Figure 4.8, calculate the value of the normalized energy (P) for frequencies at 0 Hz, 50 KHz, 100 KHz.

Figure 4.8 *Polar biphase: Manchester and differential Manchester schemes*



Solution:

The data rate is 100 Kbps. For each case, we first need to calculate the value **f/N**. We then use **Figure 4.8 in the text to find P** (energy per Hz). All calculations are approximations.

a. f /N = 0/100 = 0 → P = 0.0

b. f /N = 50/100 = 1/2 → P = 0.3

c. f /N = 100/100 = 1 → P = 0.4

P4-12. The input stream to a 4B/5B block encoder is

0100 0000 0000 0000 0000 0001

Answer the following questions:

a. What is the output stream?

b. What is the length of the longest consecutive sequence of 0s in the input?

c. What is the length of the longest consecutive sequence of 0s in the output?

Solution:

a. The output stream is **01010 11110 11110 11110 11110 01001**. (using Table 4.2)

b. The maximum length of consecutive 0s in the input stream is **21**.

c. The maximum length of consecutive 0s in the output stream is **2**

P4-13. How many invalid (unused) code sequences can we have in 5B/6B encoding? How many in 3B/4B encoding?

Solution:

.In 5B/6B, we have 2^5= 32 data sequences and 2^6 = 64 code sequences
The number of unused code sequences is 64 −32 = 32. In 3B/4B, we have 2^3= 8 data
.sequences and 2^4 = 16 code sequences. The number of unused code sequences is 16 −8 = 8

P4-14. What is the result of scrambling the sequence 11100000000000 using each of the following scrambling techniques? Assume that the last non-zero signal level has been positive.

a. B8ZS

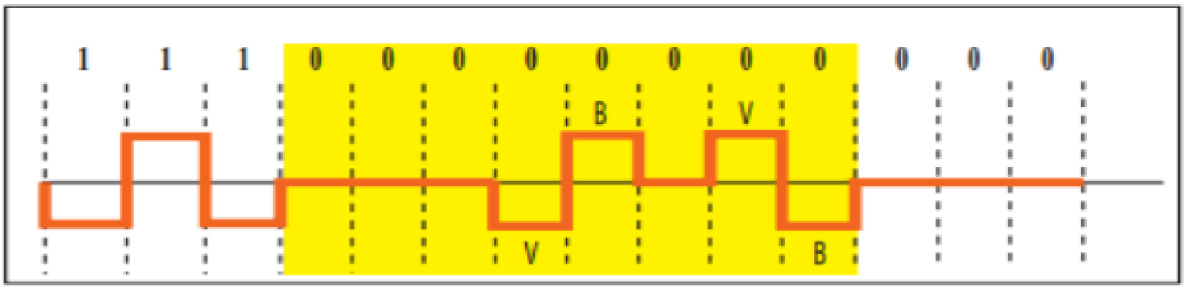
b. HDB3 (The number of nonzero pulses is odd after the last substitution.)

Solution:

a.

B8ZS substitutes eight consecutive zeros with 000VB0VB.

The V means the same polarity as the polarity of the previous nonzero pulse; B means the polarity opposite to the polarity of the previous nonzero pulse.



P4-15. What is the Nyquist sampling rate for each of the following signals?

a. A low-pass signal with bandwidth of 200 KHz?

b. A band-pass signal with bandwidth of 200 KHz if the lowest frequency is 100 KHz?

Solution:

In a low-pass signal, the minimum frequency 0. Therefore, we have
fmax= 0 + 200 = 200 KHz. → fs= 2 × 200,000 = 400,000 samples/s

In a bandpass signal, the maximum frequency is equal to the minimum frequency plus the bandwidth. Therefore, we have
fmax= 100 + 200 = 300 KHz. → fs= 2 × 300,000 = 600,000 samples /s

---

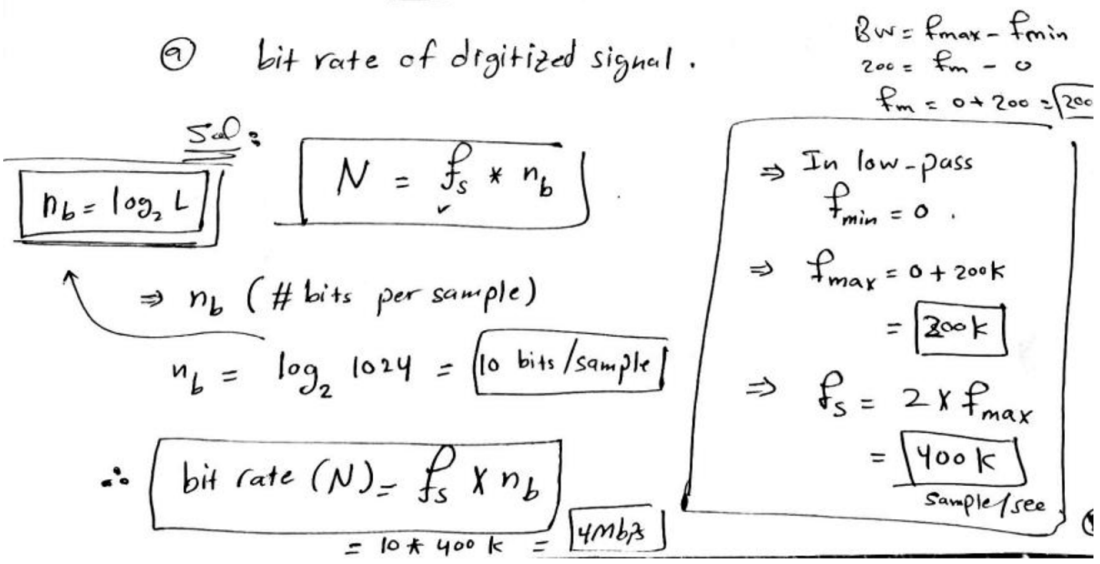
P4-16. We have sampled a low-pass signal with a bandwidth of 200 KHz using 1024 levels of quantization.

a. Calculate the bit rate of the digitized signal.

b. Calculate the SNR$_{dB}$ for this signal.

c. Calculate the PCM bandwidth of this signal.

Solution:



(b) SNR$_{dB}$.

Sol:

$$SNR_{dB} = 6.02 * n_b + 1.76$$

$$= 6.02 * 10 + 1.76$$

$$= 61.96 \text{ dB}$$

(c) PCM ??

Sol:

$$PCM = n_b * B_{analog}$$

$$= 10 * 200\text{KHz}$$

$$= 2\text{MHz}$$

P4-17. What is the maximum data rate of a channel with a bandwidth of 200 KHz if we use four levels of digital signaling.

Solution:

$$N_{max} = 2 * BW * n_b$$

$$= 2 * 200K * \log_2 4 = 800K \text{ bps}$$

P4-18. An analog signal has a bandwidth of 20 KHz. If we sample this signal and send it through a 30 Kbps channel, what is the SNR_{dB}?

Solution:

$$SNR_{dB} = 6.02 * n_b + 1.72$$

$$= 6.02 * 1 + 1.72 = 7.74 \text{ db}$$

$n_b = ??$

$f_{max} = 20K + 0 = 20 \text{ KHZ}$

$f_s = 2 \times f_{max} = 4000 \text{ sample/s}$

$$n_b = \frac{\text{Bit Rate}}{\text{Sample Rate}} = \frac{\text{Bit Rate}}{f_s} \Rightarrow \text{Bit Rate} = f_s * n_b$$

$$n_b = \frac{3000}{4000} = 0.75 \approx 1 .$$

P4-19. We have a baseband channel with a 1-MHz bandwidth. What is the data rate for this channel if we use each of the following line coding schemes?

a. NRZ-L **b.** Manchester **c.** MLT-3 **d.** 2B1Q

Solution:

Data rate :

(a) NRZ-L : $B = \frac{N}{2} \Rightarrow N = 2 * 1M = 2Mbps$

(b) Manchester: $B = N \Rightarrow N = 1Mbps$

(c) MLT : $B = N/3 \Rightarrow N = 3 * 1 = 3Mbps$

(d) 2B1Q : $B = N/4 \Rightarrow N = 4Mbps$

P4-20. We want to transmit 1000 characters with each character encoded as 8 bits.

a. Find the number of transmitted bits for synchronous transmission.

b. Find the number of transmitted bits for asynchronous transmission.

c. Find the redundancy percent in each case.

Solution:

(a) # bit for Sync.

Sol: $1000 * 8 = 8000$ bits

(b) # bit for asyn.

Sol: (start bit + data + end bit) $\Rightarrow$ 10 bit for each char.

$1000 * 10 = 10000$ bits

(c) redundancy precent.

In (a) : no redundany bit.

(b) : $\frac{2}{10} = 0.2$

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Lab 7

Chapter 5

Analog Transmission

Abdullaha Idris Ouda

P5-1. Calculate the baud rate for the given bit rate and type of modulation.

a. 2000 bps, FSK

b. 4000 bps, ASK

c. 6000 bps, QPSK

d. 36,000 bps, 64-QAM

Solution:

We use the formula **S = (1/r) × N**, but first we need to calculate the **value of r** for each case.

a. $r = \log_2 2 = 1 \rightarrow S = (1/1) \times (2000 \text{ bps}) = 2000 \text{ baud}$

b. $r = \log_2 2 = 1 \rightarrow S = (1/1) \times (4000 \text{ bps}) = 4000 \text{ baud}$

c. $r = \log_2 4 = 2 \rightarrow S = (1/2) \times (6000 \text{ bps}) = 3000 \text{ baud}$

d. $r = \log_2 64 = 6 \rightarrow S = (1/6) \times (36{,}000 \text{ bps}) = 6000 \text{ baud}$

P5-2. Calculate the bit rate for the given baud rate and type of modulation.

a. 1000 baud, FSK

b. 1000 baud, ASK

c. 1000 baud, BPSK

d. 1000 baud, 16-QAM

Solution:

We use the formula **N = r × S**, but first we need to calculate the value of r for each case.

a. $r = \log_2 2 = 1 \rightarrow N = (1) \times (1000 \text{ bps}) = 1000 \text{ bps}$

b. $r = \log_2 2 = 1 \rightarrow N = (1) \times (1000 \text{ bps}) = 1000 \text{ bps}$

c. $r = \log_2 2 = 1 \rightarrow N = (1) \times (1000 \text{ bps}) = 1000 \text{ bps}$

d. $r = \log_2 16 = 4 \rightarrow N = (4) \times (1000 \text{ bps}) = 4000 \text{ bps}$

P5-3. What is the number of bits per baud for the following techniques?

a. ASK with four different amplitudes

b. FSK with eight different frequencies

c. PSK with four different phases

d. QAM with a constellation of 128 points

Solution:

We use the formula $\mathbf{r = \log_2 L}$ to calculate the value of r for each case.

a. $\log_2 4 = 2$ bits/baud

b. $\log_2 8 = 3$ bits/baud

c. $\log_2 4 = 2$ bits/baud

d. $\log_2 128 = 7$ bits/baud

P5-4. Draw the constellation diagram for the following:

a. ASK, with peak amplitude values of 1 and 3

b. BPSK, with a peak amplitude value of 2

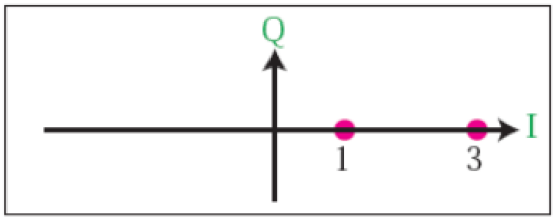
c. QPSK, with a peak amplitude value of 3

d. 8-QAM with two different peak amplitude values, 1 and 3, and four different phases

Solution:

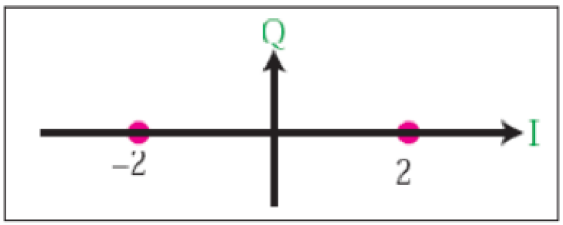
a. We have two signal elements with peak amplitudes 1 and 3. The phase of both signal elements are the same, which we assume to be 0 degrees.

a. ASK

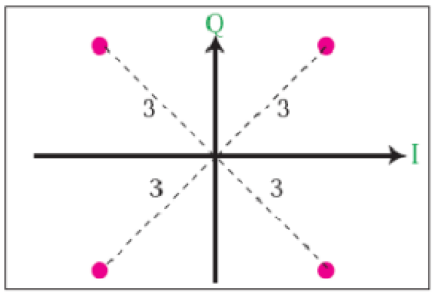


b. We have two signal elements with the same peak amplitude of 2. However, there must be 180 degrees difference between the two phases. We assume one phase to be 0 and the other 180 degrees.

b. BPSK

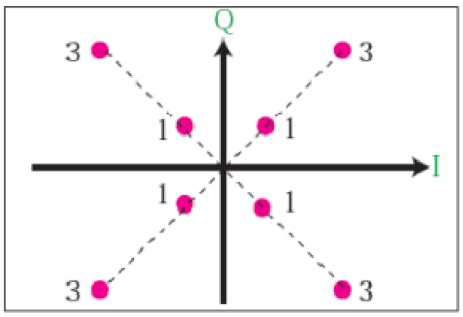


c. We have four signal elements with the same peak amplitude of 3. However, there must be 90 degrees difference between each phase. We assume the first phase to be at 45, the second at 135, the third at 225, and the fourth at 315 degrees. Note that this is one out of many configurations. The phases can be at 0, 90, 180, and 270. As long as the differences are 90 degrees, the solution is satisfactory.



c. QPSK

d. We have four phases, which we select to be the same as the previous case. For each phase, however, we have two amplitudes, 1 and 3 as shown in the figure. Note that this is one out of many configurations. The phases can be at 0, 90, 180, and 270. As long as the differences are 90 degrees, the solution is satisfactory.



d. 8-QAM

P5-5. Draw the constellation diagram for the following cases. Find the peak amplitude value for each case and define the type of modulation (ASK, FSK, PSK, or QAM).The numbers in parentheses define the values of I and Q respectively.

a. Two points at (2, 0) and (3, 0)

b. Two points at (3, 0) and (−3, 0)

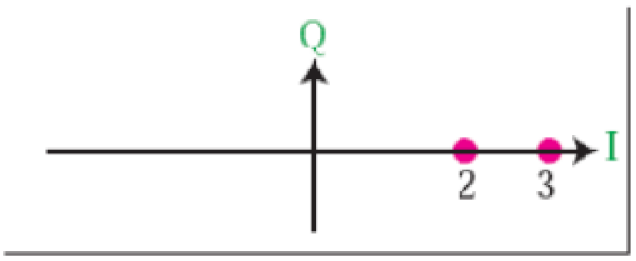
c. Four points at (2, 2), (−2, 2), (−2, −2), and (2, −2)

d. Two points at (0, 2) and (0, −2)

Solution:

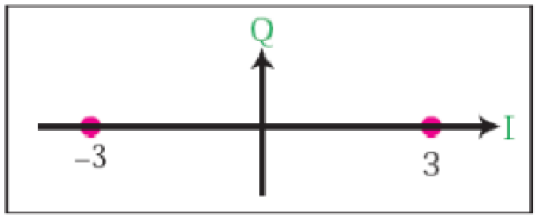
a. This is ASK. There are two peak amplitudes both with the same phase (0 degrees). The values of the peak amplitudes are A1 = 2 (the distance between the first dot and the origin) and A2= 3 (the distance between the second dot and the origin).

a.

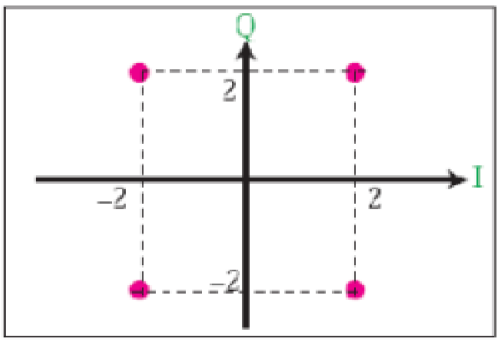


b. This is BPSK, there is only one peak amplitude (3). The distance between each dot and the origin is 3. However, we have two phases, 0 and 180 degrees.

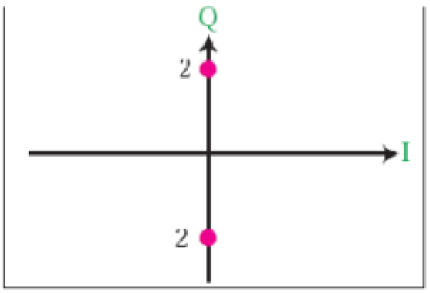
b.



c. This can be either QPSK (one amplitude, four phases) or 4-QAM (one amplitude and four phases). The **amplitude** is the distance between a point and the origin, which is $\sqrt[2]{2^2 + 2^2} = 2.83$



d. This is also BPSK. The **peak amplitude is 2**, but this time the phases are 90 and 270 degrees.



d.

P5-6. How many bits per baud can we send in each of the following cases if the signal constellation has one of the following number of points?

a. 2 **b.** 4 **c.** 16 **d.** 1024

Solution:

The number of points define the number of levels, L. The number of bits per baud is the value of r. Therefore, we use the formula $\mathbf{r = \log_2 L}$ for each case.

a. $\log_2 2 = 1$

b. $\log_2 4 = 2$

c. $\log_2 16 = 4$

d. $\log_2 1024 = 10$

P5-7. What is the required bandwidth for the following cases if we need to send 4000 bps? Let d = 1.

a. ASK

b. FSK with $2\Delta f$ = 4 KHz

c. QPSK

d. 16-QAM

Solution:

a. ASK

$r = \log_2 2 = 1$

B= (1+d) S = **(1+d) N/r** = (1+1) 4000= 8000 Hz

b. FSK with $2\Delta f = 4$ KHz

$r = \log_2 2 = 1$

B= (1+d) S + 2Δf = (1+1) 4000 + 4000 = 12000 Hz

c. QPSK

$r = \log_2 4 = 2$

B= (1+d) S = (1+d) N/r = (1+1) 4000/2= 4000 Hz

d. 16-QAM

$r = \log_2 16 = 4$

B= (1+d) S = (1+d) N/r = (1+1) 4000/4= 2000 Hz

P5-8. The telephone line has 4 KHz bandwidth. What is the maximum number of bits we can send using each of the following techniques? Let d = 0.

a. ASK **b.** QPSK **c.** 16-QAM **d.** 64-QAM

Solution:

We use the formula **N = [1/(1 + d)] × r × B**, but first we need to calculate the value of r for each case.

a. $r = \log_2 2 = 1 \rightarrow N = [1/(1 + 0)] \times 1 \times (4\ \text{KHz}) = 4$ kbps

b. $r = \log_2 4 = 2 \rightarrow N = [1/(1 + 0)] \times 2 \times (4\ \text{KHz}) = 8$ kbps

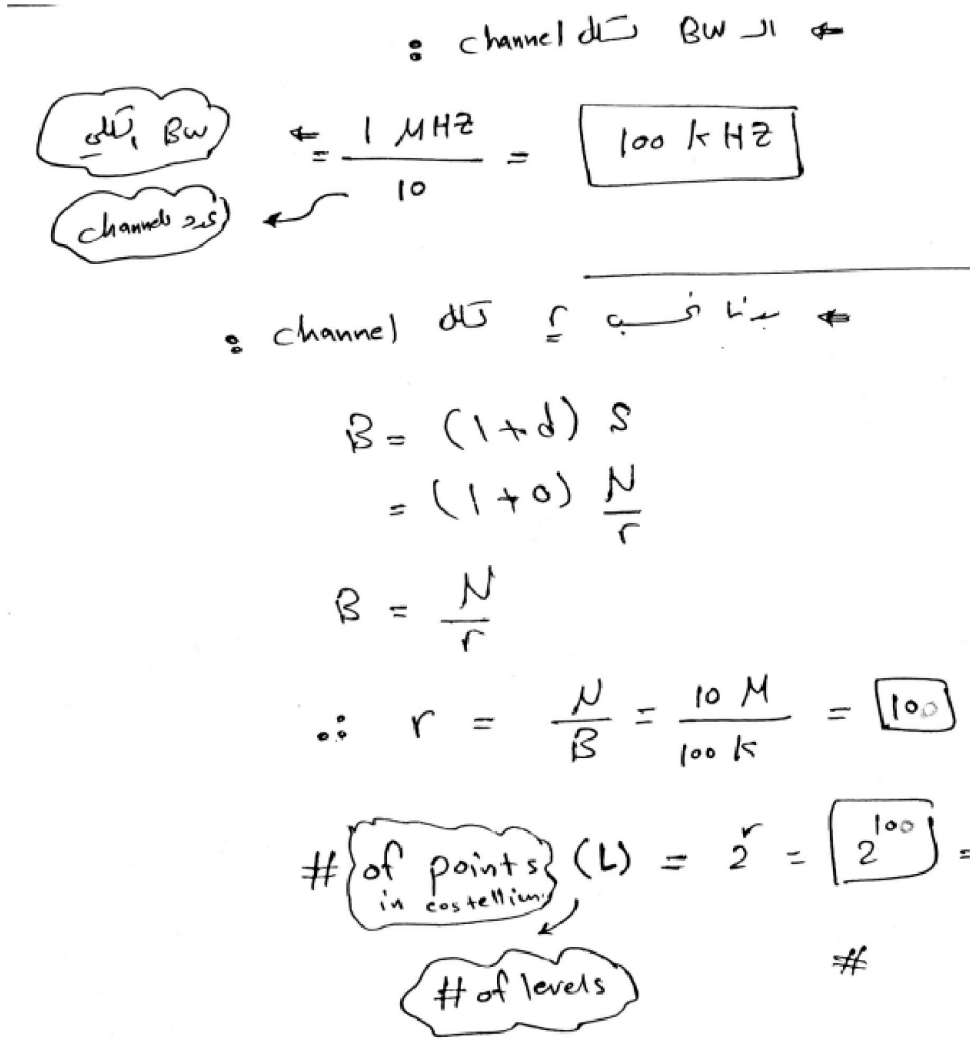
c. $r = \log_2 16 = 4 \rightarrow N = [1/(1 + 0)] \times 4 \times (4\ \text{KHz}) = 16$ kbps

d. $r = \log_2 64 = 6 \rightarrow N = [1/(1 + 0)] \times 6 \times (4\ \text{KHz}) = 24$ kbps

---

P5-9. A corporation has a medium with a 1-MHz bandwidth (lowpass). The corporation needs to create 10 separate independent channels each capable of sending at least 10 Mbps. The company has decided to use QAM technology. What is the minimum number of bits per baud for each channel? What is the number of points in the constellation diagram for each channel? Let d = 0.

Solution:



P5-10. A cable company uses one of the cable TV channels (with a bandwidth of 6 MHz) to provide digital communication for each resident. What is the available data rate for each resident if the company uses a 64-QAM technique?

Solution:

B= 6 MHz r = log264 = 6

Let d = 0

N = 1/(1+d) * r * B = 1 * 6 * 6M = 36 Mbps

P5-11. Find the bandwidth for the following situations if we need to modulate a 5-KHz voice.

a. AM **b.** FM ($\beta = 5$) **c.** PM ($\beta = 1$)

Solution:

a. AM

BAM = 2B = 2* 5K = 10 KHz

b. FM ($\beta = 5$)

BFM = 2 (1+ β) B = 2 (1+5)* 5K = 60 KHz

c. PM ($\beta = 1$)

BPM = 2 (1+ β) B = 2 (1+1)* 5K = 20 KH

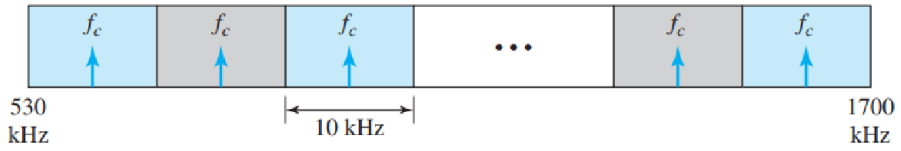
P5-12. Find the total number of channels in the corresponding band allocated by FCC.

a. AM **b.** FM

Solution:

a.

Figure 5.17 *AM band allocation*

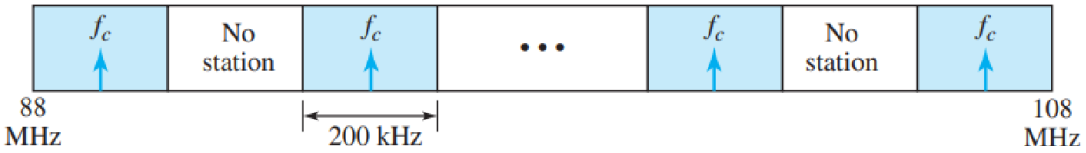


AM stations are allowed carrier frequencies anywhere between 530 and 1700 kHz (1.7 MHz). However, each station's carrier frequency must be separated from those on either side of it by at least 10 kHz (one AM bandwidth) to avoid interference.

$$n = (1700\text{-}530)\ k / 10k = 117$$

b.

Figure 5.19 *FM band allocation*



$$n = (108\text{-}88)\ M / 200k = 10$$

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Data Communications

Lab 8

Chapter 6

Bandwidth Utilization: Multiplexing and Spectrum Spreading

Abdullaha Idris Ouda

P6-1. Assume that a voice channel occupies a bandwidth of 4 kHz. We need to multiplex 10 voice channels with guard bands of 500 Hz using FDM. Calculate the required bandwidth.

Solution:

Channels can be separated by strips of unused bandwidth—**guard bands**—to prevent signals from overlapping.

10 channels => 9 guard bands

Bfdm = (4x10^3)(10) + 9(500) = 44500 Hz = 44.5 KHz

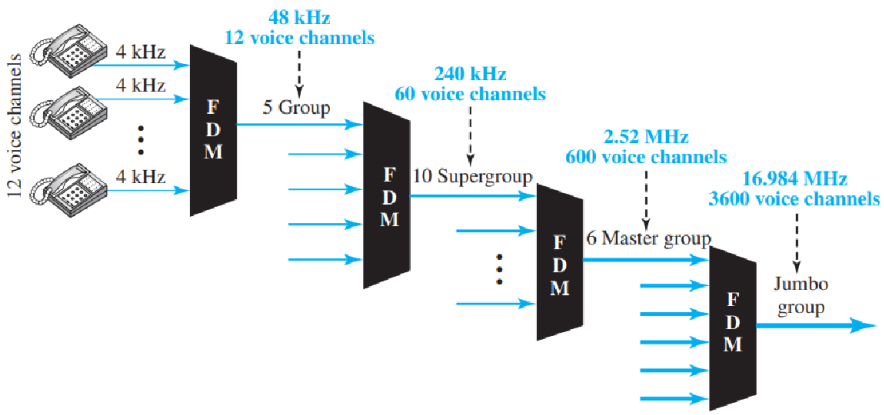
P6-2. We need to transmit 100 digitized voice channels using a passband channel of 20 KHz. What should be the ratio of bits/Hz if we use no guard band?

Solution:

- Bandwidth is allocated to each voice channel is **20 KHz / 100 = 200 Hz**
- As we saw in previous chapters, each digitized voice channel => 8000 samples * 8 bit/sample = 64 kbps.
- The ratio = 64000 / 200 = 320 bits / Hz

P6-3. In the analog hierarchy of Figure 6.9, find the overhead (extra bandwidth for guard band or control) in each hierarchy level (group, supergroup, master group, and jumbo group).

Figure 6.9 *Analog hierarchy*



Solution:

a.) 12 voice channels, Bchannel = 4 KHz => 48 KHz - 12(4 KHz) = 0 Hz overhead.

b.) 5 groups => 240KHz - 5(48KHz) = 0 Hz overhead

c.) 10 Super Groups => 2.52x10^6 - 10(240x10^3) = 120 KHz overhead

d.) 6 Master Groups => 16.984x10^6 - 6(2.52x10^6) = 1864000 Hz = 1.864 MHz overhead

P6-4. We need to use synchronous TDM and combine 20 digital sources, each of 100 Kbps. Each output slot carries 1 bit from each digital source, but one extra bit is added to each frame for synchronization. Answer the following questions:

a. What is the size of an output frame in bits?

b. What is the output frame rate?

c. What is the duration of an output frame?

d. What is the output data rate?

e. What is the efficiency of the system (ratio of useful bits to the total bits)?

Solution:

a. Each output frame carries 1 bit from each source plus one extra bit for synchronization. **Frame size = 20 × 1 + 1 = 21 bit**

b. Each frame carries 1 bit from each source. **Frame rate = 100,000 frames/s.**

c. **Frame duration = 1 /(frame rate)** = 1 /100,000 = 10 μs.

d. **Data rate = Frame rate * bits/frame(Frame size)** = (100,000 frames/s) × (21 bits/frame) = 2.1 Mbp

e. In each frame 20 bits out of 21 are useful. **Efficiency = useful bits / total bits** = 20/21= 95%

P6-5. Repeat Problem 6-4 if each output slot carries 2 bits from each source.

Solution:

a. Each output frame carries **2 bits from each source plus** one extra bit for synchronization. **Frame size = 20 × 2 + 1 = 41 bits.**

b. Each frame carries 2 bit from each source. **Frame rate = 100,000/2 = 50,000 frames/s.**

c. **Frame duration = 1 /(frame rate)** = 1 /50,000 = 20 μs

d. **Data rate = (50,000 frames/s) × (41 bits/frame) = 2.05 Mbps**.

e. In each frame 40 bits out of 41 are useful. **Efficiency = 40/41= 97.5%**

P6-6. We have 14 sources, each creating 500 8-bit characters per second. Since only some of these sources are active at any moment, we use statistical TDM to combine these sources using character interleaving. Each frame carries 6 slots at a time, but we need to add 4-bit addresses to each slot. Answer the following questions:

a. What is the size of an output frame in bits?

b. What is the output frame rate?

c. What is the duration of an output frame?

d. What is the output data rate?

Solution:

a. **Frame size = (# of slots) x (character size + slot address)** = 6 x (8 bits+ 4 bits) =72 bits
b. We can assume that we have only 6 input lines. Each frame needs to carry one character from each of these lines. This means that the link needs to send **500 frames/s**
c. **Frame duration = 1 / (frame rate)** = 1 / 500 =2ms.
d. Data rate = (500 frames/s) x (72 bits/frame) =36 Kbps

P6-7. Ten sources, six with a bit rate of 200 kbps and four with a bit rate of 400 kbps, are to be combined using multilevel TDM with no synchronizing bits. Answer the following questions about the final stage of the multiplexing:

a. What is the size of a frame in bits?
b. What is the frame rate?
c. What is the duration of a frame?
d. What is the data rate?

Solution:

a. We combine **six 200-kbps** sources **into three 400-kbps**. Now we have **seven 400-kbps** channel. Each output frame carries ***1 bit from*** each of the seven **400-kbps** line. **Frame size = 7 × 1 = 7 bits**.
b. Frame rate = 400k frames/s.
c. Frame duration = 1 /(frame rate) = 1 /400,000 = 2.5 µs.
d. Data rate = (400,000 frames/s) × (7 bits/frame) = 2.8 Mbps.

P6-8. Four channels, two with a bit rate of 200 kbps and two with a bit rate of 150 kbps, are to be multiplexed using multiple-slot TDM with no synchronization bits. Answer the following questions:

a. What is the size of a frame in bits?
b. What is the frame rate?
c. What is the duration of a frame?
d. What is the data rate?

Solution:

a. Divide all of them into 50Kbps lines => in total (200/50)*2 + (150/50) *2 = 14, then aggregate => 14 bits/frame
b. Frame rate = 50k frame/s
c. Frame duration = 1/ (frame rate) = 1 /50k = 20µs
d. Data rate = 50k * 14 = 700kbps

P6-9. Two channels, one with a bit rate of 190 kbps and another with a bit rate of 180 kbps, are to be multiplexed using pulse-stuffing TDM with no synchronization bits. Answer the following questions:

a. What is the size of a frame in bits?

b. What is the frame rate?

c. What is the duration of a frame?

d. What is the data rate?

Solution:

a. We need to **add extra bits** to the second source to make both bit rates = **190Kbps.**

Now we have **two sources**, each of **190 Kbps**. Since the data unit was not specified, assume that it is one bit. **Frame size = 2 bits.**

b. Frame rate =190k frames/s

c. **Frame duration = 1/frame rate** = 1/190k = 5.26µs

d. Data rate = 190k*2 = 380kbps

P6-10. Answer the following questions about a T-1 line:

a. What is the duration of a frame?

b. What is the overhead (number of extra bits per second)?

Solution:

a. T-1 line sends **8000 fps** => duration = 1/8000 = .125 milliseconds

b. Each frame carries 1 extra bit => Overhead = 8000*1= 8000 Kbps

---

P6-11. Show the contents of the five output frames for a synchronous TDM multiplexer that combines four sources sending the following characters. Note that the characters are sent in the same order that they are typed. The third source is silent.

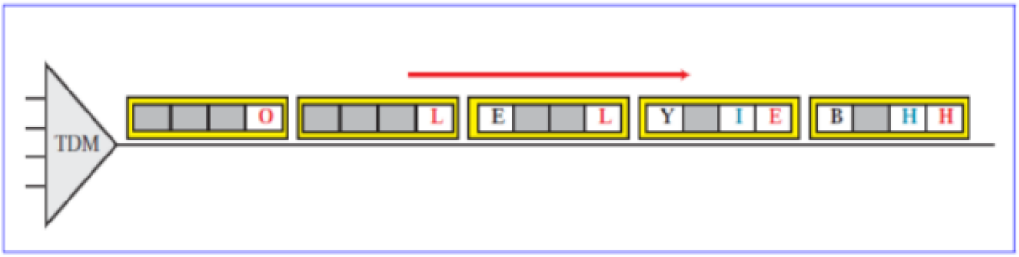
a. Source 1 message: HELLO

b. Source 2 message: HI

c. Source 3 message:

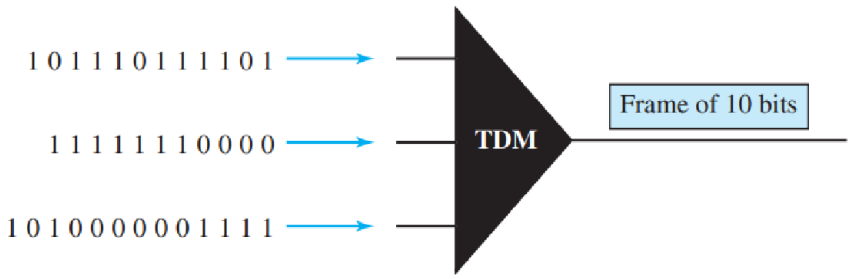
d. Source 4 message: BYE

Solution:

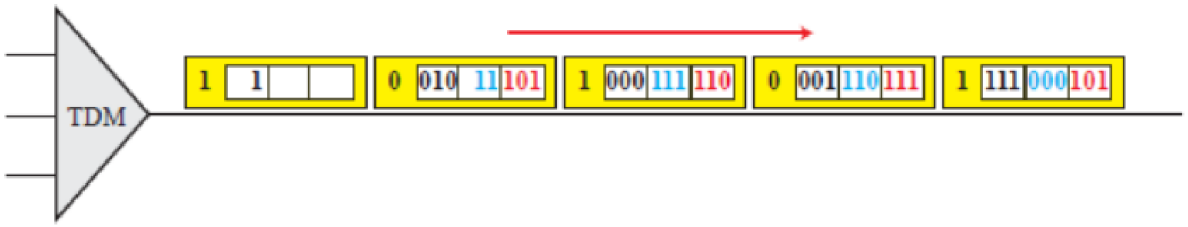


P6-12. Figure 6.34 shows a multiplexer in a synchronous TDM system. Each output slot is only 10 bits long (3 bits taken from each input plus 1 framing bit). What is the output stream? The bits arrive at the multiplexer as shown by the arrows.

Figure 6.34 *Problem P6-12*

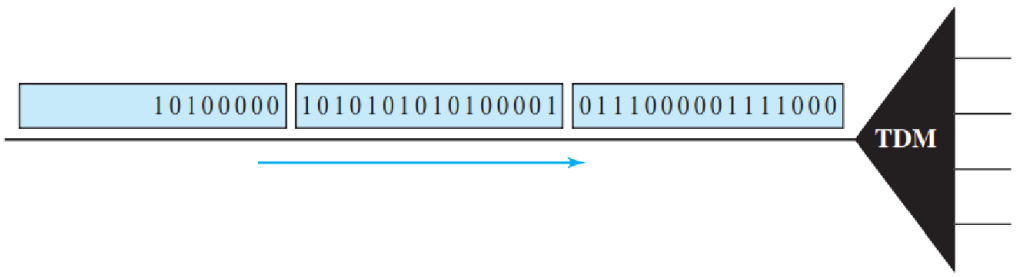


Solution:

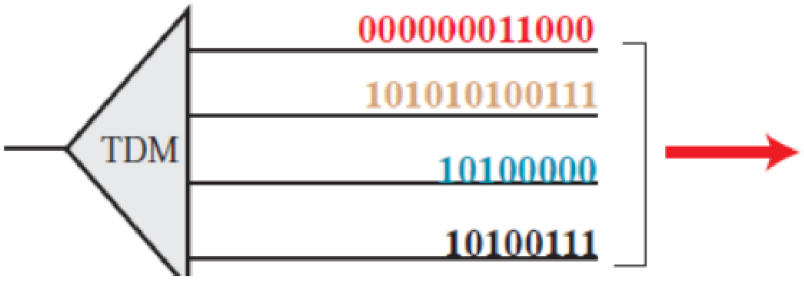


P6-13. Figure 6.35 shows a demultiplexer in a synchronous TDM. If the input slot is 16 bits long (no framing bits), what is the bit stream in each output? The bits arrive at the demultiplexer as shown by the arrows.

Figure 6.35 *Problem P6-13*



Solution:



P6-14. Answer the following questions about the digital hierarchy in Figure 6.23:

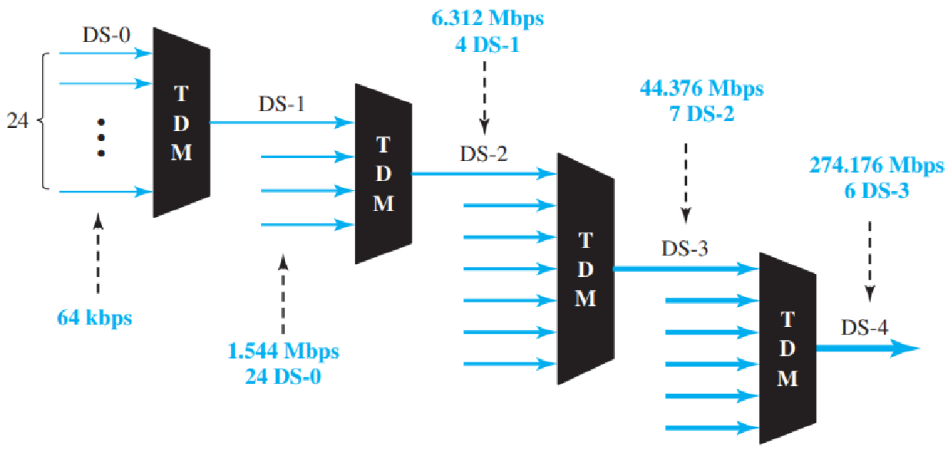
a. What is the overhead (number of extra bits) in the DS-1 service?

b. What is the overhead (number of extra bits) in the DS-2 service?

c. What is the overhead (number of extra bits) in the DS-3 service?

d. What is the overhead (number of extra bits) in the DS-4 service?

Figure 6.23 *Digital hierarchy*



Solution:

a.) DS-1: 1.544 Mbps - 64 Kbps x 24 = 8000 bps overhead

b.) DS-2: 6.312 Mbps - (1.544Mbps x 4) = 136 Kbps overhead

c.) DS-3: 44.376 Mbps - (6.312 Mbps x 7) = 192 Kbps overhead

d.) DS-4: 274.176 Mbps - (44.376 Mbps x 6) = 7.92 Mbps overhead

---

P6-15. What is the minimum number of bits in a PN sequence if we use FHSS with a channel bandwidth of $B = 4$ KHz and $B_{ss} = 100$ KHz?

Solution:

of hopping freq. = Bss / B = 100 KHz / 4 KHz = 25

$\log_2 25$= approx. 5 bits

P6-16. An FHSS system uses a 4-bit PN sequence. If the bit rate of the PN is 64 bits per second, answer the following questions:

a. What is the total number of possible channels?

b. What is the time needed to finish a complete cycle of PN?

Solution:

a. 2^4 = 16 channels

b. 16*4 bits = 64 bits

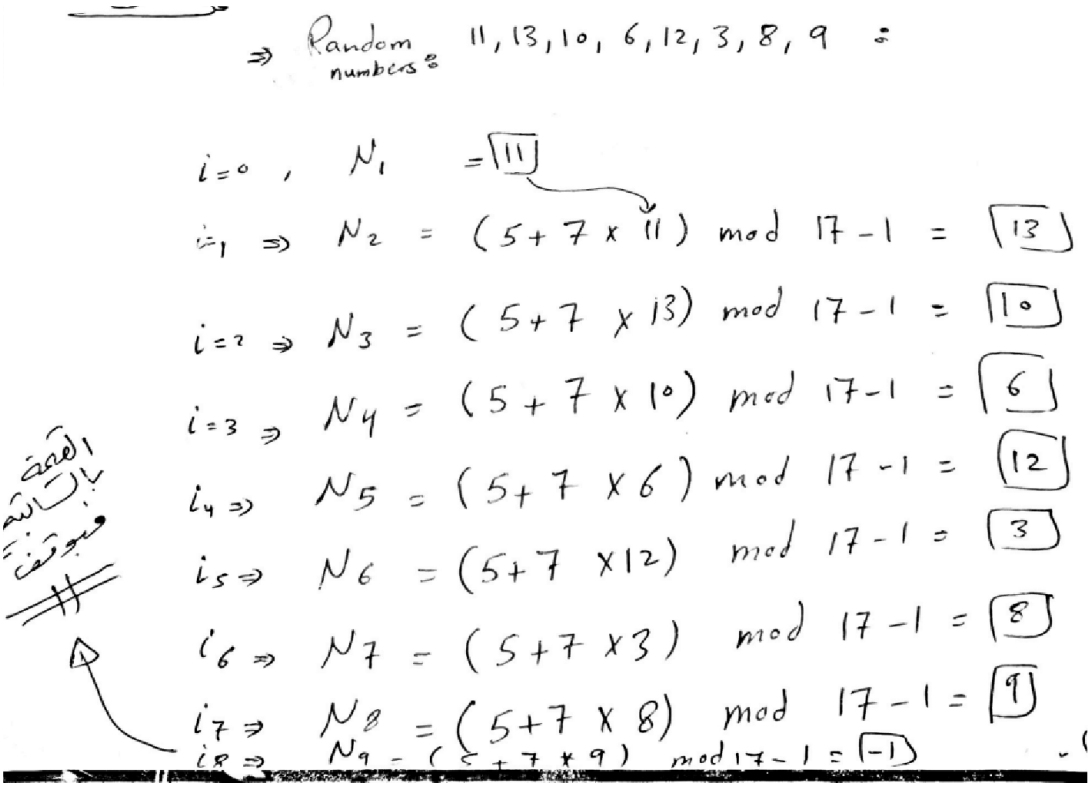
64 bits/64 bits/s = 1 sec

P6-17. A pseudorandom number generator uses the following formula to create a random series:

$$N_{i+1} = (5 + 7N_i) \bmod 17 - 1$$

In which N_i defines the current random number and N_{i+1} defines the next random number. The term *mod* means the value of the remainder when dividing $(5 + 7N_i)$ by 17. Show the sequence created by this generator to be used for spread spectrum.

Solution:



P6-18. We have a digital medium with a data rate of 10 Mbps. How many 64-kbps voice channels can be carried by this medium if we use DSSS with the Barker sequence?

Solution:

Barker chips are 11 bits => increase bit rate 11 times
=> 64 Kbps x 11 = 704 Kbps
=> 10 Mbps / 704 Kbps = 14 Channels

IUG - Faculty of Engineering
Department of Computer Engineering
Data communications Lab
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Data Communications

Lab 10

Chapter 10

Error Detection and Correction

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P10-1. What is the maximum effect of a 2-ms burst of noise on data transmitted at the following rates?

a. 1500 bps **b.** 12 kbps **c.** 100 kbps **d.** 100 Mbps

Solution:

Effect Bits = data rate * burst length

a. 1500(2*10^-3) = 3 bits effected

b. 12x10^3(2x10^-3) = 24 bits effected

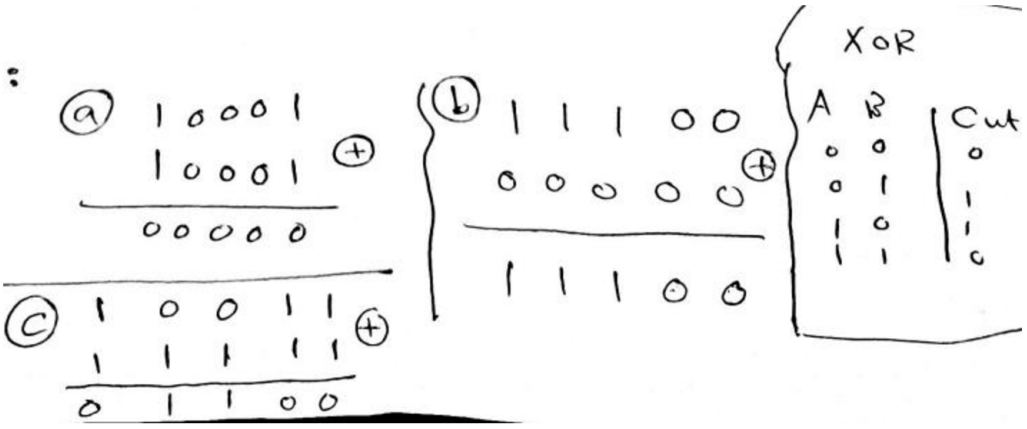
c. 200 bits effected

d. 200000 bits effected

P10-3. Exclusive-OR (XOR) is one of the most used operations in the calculation of codewords. Apply the exclusive-OR operation on the following pairs of patterns. Interpret the results.

a. (10001) ⊕ (10001) **b.** (11100) ⊕ (00000) **c.** (10011) ⊕ (11111)

Solution:



P10-4. In Table 10.1, the sender sends dataword 10. A 3-bit burst error corrupts the codeword. Can the receiver detect the error? Defend your answer.

Table 10.1 *A code for error detection in Example 10.1*

Dataword	*Codeword*	*Dataword*	*Codeword*
00	000	10	101
01	011	11	110

Solution:

The answer depends heavily on what the codeword is corrupted to. If the codeword is corrupted to 010 for example the error will be detected because that codeword is invalid. If the codeword is corrupted to 000 however, the error will not be detected.

P10-5. Using the code in Table 10.2, what is the dataword if each of the following codewords is received?

a. 01011 **b.** 11111 **c.** 00000 **d.** 11011

Table 10.2 *Simple parity-check code C(5, 4)*

Dataword	*Codeword*	*Dataword*	*Codeword*
0000	**00000**	1000	**10001**
0001	**00011**	1001	**10010**
0010	**00101**	1010	**10100**
0011	**00110**	1011	**10111**
0100	**01001**	1100	**11000**
0101	**01010**	1101	**11011**
0110	**01100**	1110	**11101**
0111	**01111**	1111	**11110**

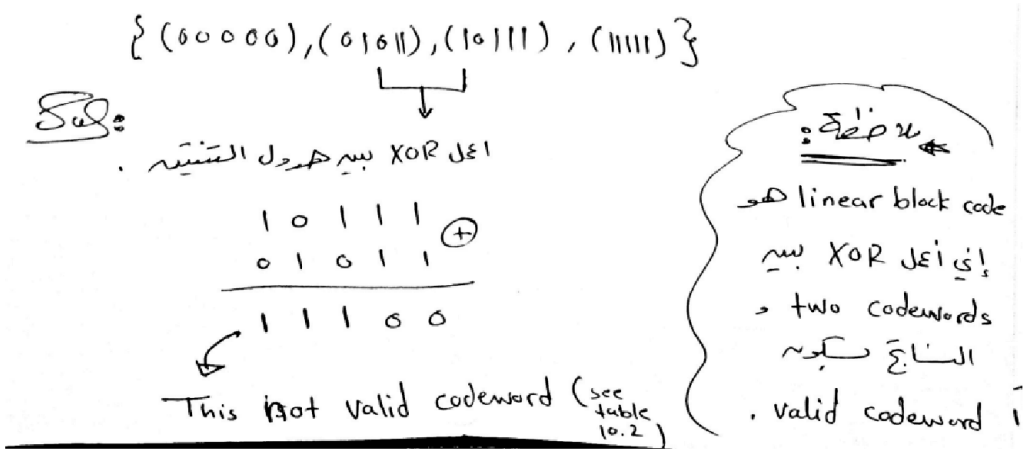
Solution:

a. ERROR
b. ERROR
c. 0000
d. 1101

P10-6. Prove that the code represented by the following codewords is not linear. You need to find only one case that violates the linearity.

{(00000), (01011), (10111), (11111)}

Solution:



P10-7. What is the Hamming distance for each of the following codewords?

a. d (10000, 00000) **b.** d (10101, 10000)
c. d (00000, 11111) **d.** d (00000, 00000)

Solution:
The Hamming distance between two words (of the same size) is the number of differences between the corresponding bits

a. 1
b. 2
c. 5
d. 0

P10-8. Although it can be formally proved that the code in Table 10.3 is both linear and cyclic, use only two tests to partially prove the fact:

a. Test the cyclic property on codeword 0101100.

b. Test the linear property on codewords 0010110 and 1111111.

Solution:

a. In a cyclic code, if a codeword is cyclically shifted (rotated), the result is another codeword.
0101100 left shifted = 1011000 which is a **valid codeword** in 10.3, therefore **cyclic**

b. 0010110 XOR 1111111 = 1101001 which is a **valid codeword** in 10.3, therefore **linear**

P10-10. Assuming even parity, find the parity bit for each of the following data units.

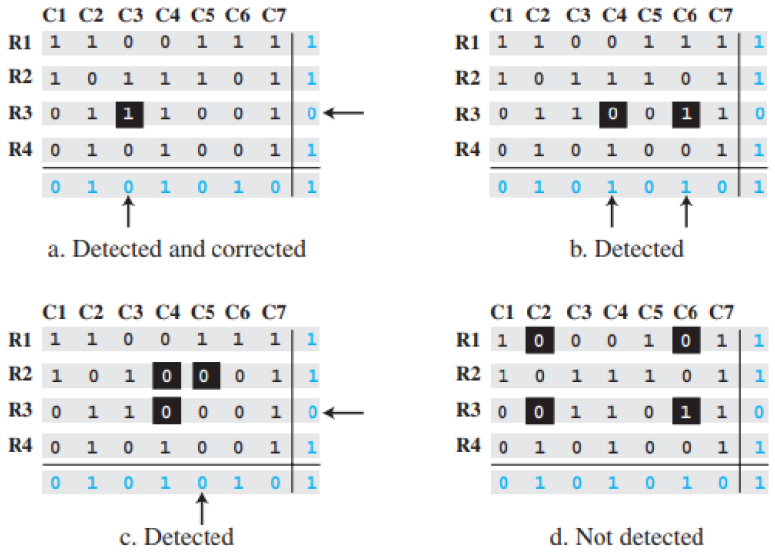
a. 1001011 **b.** 0001100 **c.** 1000000 **d.** 1110111

Solution:

a. 0
b. 0
c. 1
d. 0

P10-11. A simple parity-check bit, which is normally added at the end of the word (changing a 7-bit ASCII character to a byte), cannot detect even numbers of errors. For example, two, four, six, or eight errors cannot be detected in this way. A better solution is to organize the characters in a table and create row and column parities. The bit in the row parity is sent with the byte, the column parity is sent as an extra byte (Figure 10.23).

Figure 10.23 *P10-11*



Show how the following errors can be detected:

a. An error at (R3, C3).

b. Two errors at (R3, C4) and (R3, C6).

c. Three errors at (R2, C4), (R2, C5), and (R3, C4).

d. Four errors at (R1, C2), (R1, C6), (R3, C2), and (R3, C6).

Solution:

a. In the case of one error, it can be detected and corrected because the two affected parity bits can define where the error is.

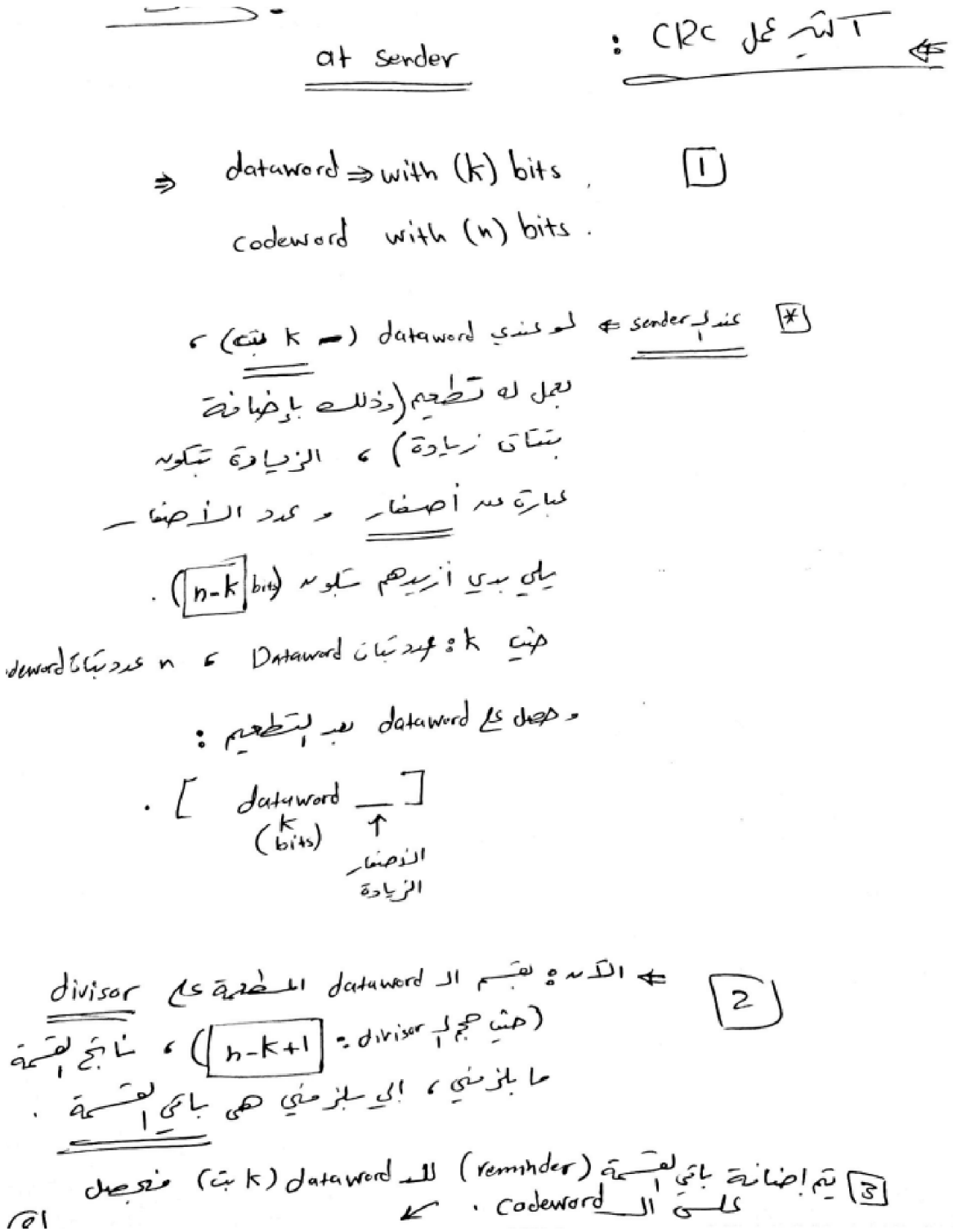
b. Two errors can definitely be detected because they affect two bits of the column parity. The receiver knows that the message is somewhat corrupted (although not where). It discards the whole message.

c. Three errors are detected because they affect two parity bits, one of the column parity and one of the row parity. The receiver knows that the message is somewhat corrupted (although not where). It discards the whole message.

d. The last case cannot be detected because none of the parity bits are affected.

P10-12. Given the dataword 1010011111 and the divisor 10111, show the generation of the CRC codeword at the sender site (using binary division).

Solution:



at reciver :

⇐ الـ reciver بقسم الـ codeword بنفس الـ divisor
اللي قسم عليه الـ Sender .

⇐ لو باقي القسمة = 0 بأطلع - معناته مفيش error
أما لو مفيش أصفار - معناته يوجد error

حل سؤال [12] : CRC codeword ?

codeword = dataword + redundant bits

⇒ divisor = n - k + 1

⇐ 5 = n - 9 + 1 عدد حروف السؤال

5 = n - 8

n = 13

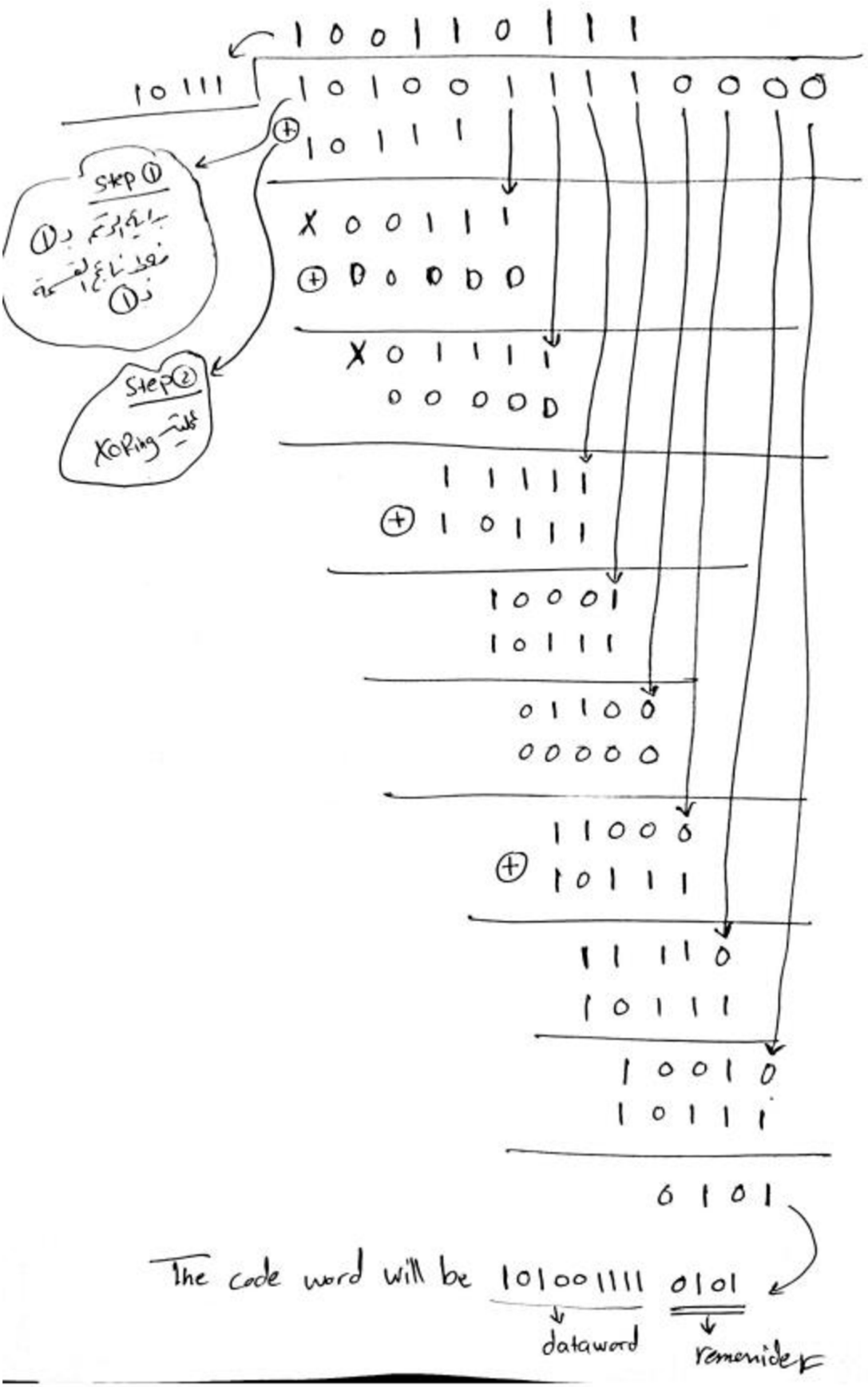
⇒ عدد البتات اللي طلع نفهم
: dataword

n - k = 13 - 9 = 4

∴ dataword = 1010011111 0000

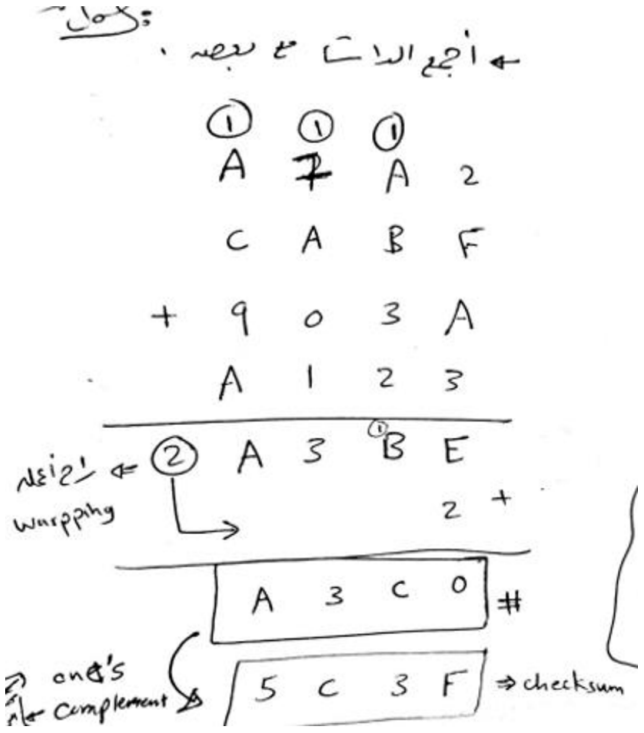
↓

اللي زودهم


Step ①
Step ②
Xoring
The code word will be 10100 1111 0101
dataword
remainder

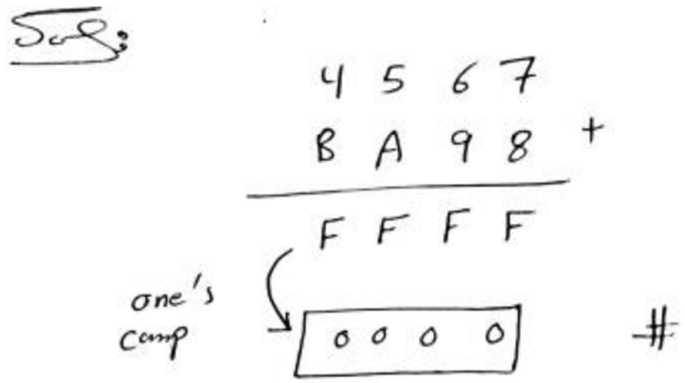
P10-18. Assume a packet is made only of four 16-bit words $(A7A2)_{16}$, $(CABF)_{16}$, $(903A)_{16}$, and $(A123)_{16}$. Manually simulate the algorithm in Figure 10.17 to find the checksum.

Solution:



P10-20. This problem shows a special case in checksum handling. A sender has two data items to send: $(4567)_{16}$ and $(BA98)_{16}$. What is the value of the checksum?

Solution:



P10-25. In the interleaving approach to FEC, assume each packet contains 10 samples from a sampled piece of music. Instead of loading the first packet with the first 10 samples, the second packet with the second 10 samples, and so on, the sender loads the first packet with the odd-numbered samples of the first 20 samples, the second packet with the even-numbered samples of the first 20 samples, and so on. The receiver reorders the samples and plays them. Now assume that the third packet is lost in transmission. What will be missed at the receiver site?

Solution:

1'st Packet : 1, 3, 5, 7, 9, 11, 13, 15, 17, 19 .

2'nd Packet : 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 .

3'nd Packet : 21, 23, 25, 27, 29, 31, 33, 35, 37, 39 .

at reciver

1'st : 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 .

2'nd : 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 .

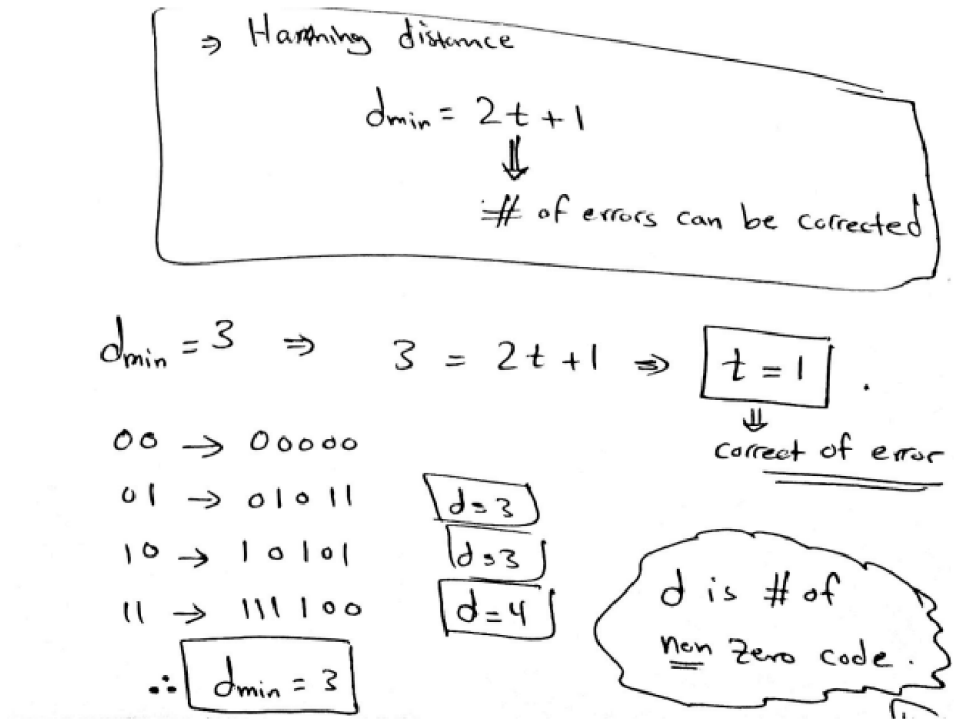
3'rd : 21, 22, 23, 24, 25, 26, 27, 28, 29, 30 .

4'rd : 31, 32, 33, 34, 35, 36, 37, 38, 39, 40 .

P10-26. Assume we want to send a dataword of two bits using FEC based on the Hamming distance. Show how the following list of datawords/codewords can automatically correct up to a one-bit error in transmission.

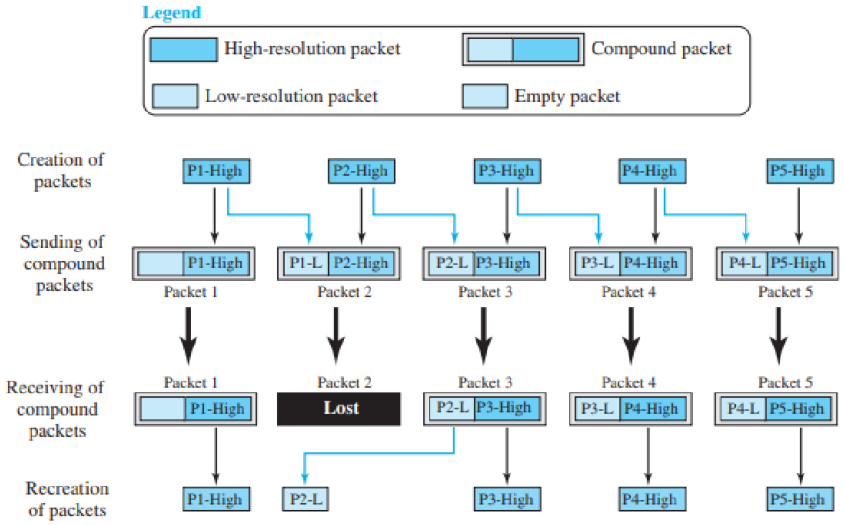
00 → 00000	01 → 01011	10 → 10101	11 → 11110

Sloution:



P10-30. In Figure 10.22, assume we have 100 packets. We have created two sets of packets with high and low resolutions. Each high-resolution packet carries on average 700 bits. Each low-resolution packet carries on average 400 bits. How many extra bits are we sending in this scheme for the sake of FEC? What is the percentage of overhead?

Figure 10.22 *Compounding high- and low-resolution packets*



Solution:

N = 100, H=700, L=400

of extra bits = (N-1)*L = (100-1)*400 = 39,600 bits.

Percentage of overhead = 39600/ (100*700+ 99*400) *100% ≈ 36.19%