

Université d'Ottawa  
Faculté de génie

École de science informatique  
et de génie électrique



uOttawa

L'Université canadienne  
Canada's university

University of Ottawa  
Faculty of Engineering

School of Electrical Engineering  
and Computer Science

**COURSE:** SEG3155/CEG3185  
**SEMESTER:** Winter 2013

**PROFESSOR:** Jiying Zhao  
**DATE:** February 26, 2013  
**TIME:** 10:00 to 11:20

**MIDTERM  
EXAMINATION  
SOLUTION**

**NAME and STUDENT NUMBER:** \_\_\_\_\_ / \_\_\_\_\_

**Mid-Term Exam**

1. There are two (2) types of questions in this examination.

<b>Part 1</b>	<b>Multiple choice questions</b>	<b>20 marks</b>	
<b>Part 2</b>	<b>Short questions</b>	<b>45 marks</b>	
<b>Total</b>		<b>65 marks</b>	

2. Answer briefly and to the point. The space allocated for each question is limited. In case of necessity you may use the other side of the pages to continue.
3. Initial all the pages.



## Part 2 - Short-answer questions

- 11 [6 marks] In CRC, the data unit is 1010011110 and the divisor 1011. Calculate the CRC code.

$$\begin{array}{r}
 1011 \overline{) 1010011110000} \\
 \underline{1011} \phantom{0000} \\
 1011 \phantom{0000} \\
 \underline{1011} \phantom{0000} \\
 1100 \phantom{000} \\
 \underline{1011} \phantom{000} \\
 1110 \phantom{00} \\
 \underline{1011} \phantom{00} \\
 1010 \phantom{0} \\
 \underline{1011} \\
 001
 \end{array}$$

The CRC code is 001.

- 12 [6 marks] A transmission line has bandwidth of 8000 Hz. The measurement shows that  $P(\text{signal}) = -53$  dBm,  $P(\text{noise}) = -95$  dBm. (dBm = decibel-milliWatts) Calculate the theoretical highest bit rate (capacity) of this transmission line.

First determine the signal to noise ratio SNR.

$$SNR_{dB} = P(\text{signal})_{dBm} - P(\text{noise})_{dBm} = -53 - (-95) = 42 \text{ dB}$$

$$SNR = 10^{SNR_{dB}/10} = 10^{4.2} = 15848$$

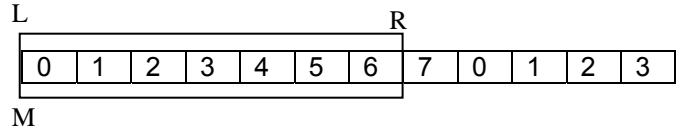
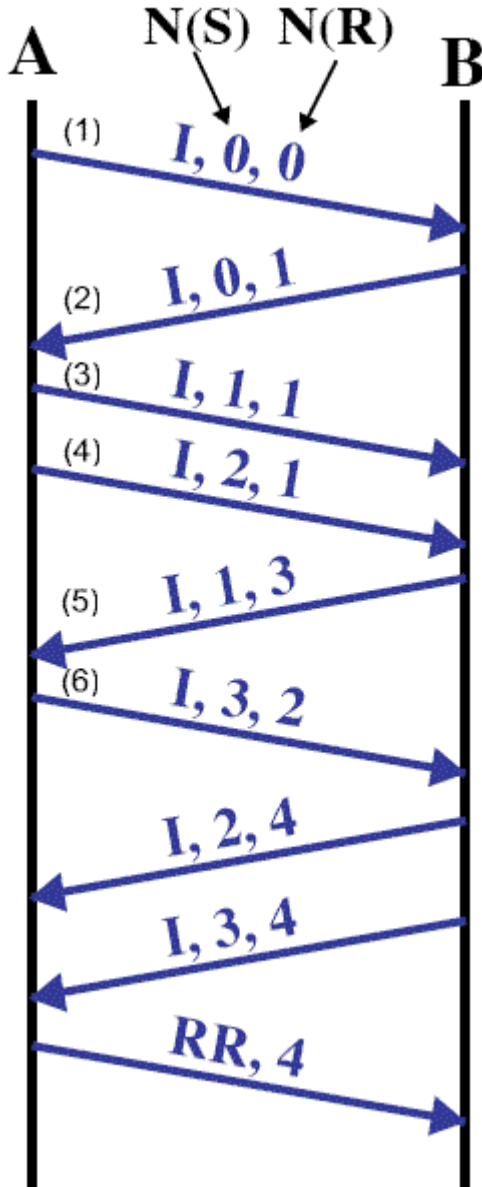
Use Shannons capacity to determine the maximum highest bit rate.

$$C = B \log_2(1 + SNR)$$

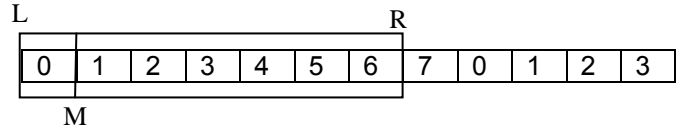
$$= 8000 \log_2(1 + 15848)$$

$$= 8000(13.95) = 111,617 \text{ bps} = 112 \text{ kbps}$$

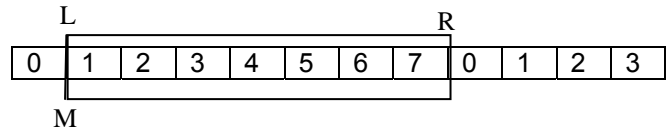
13 [6 marks] The HDLC is used. Both the N(S) and N(R) are 3 bits. The sliding window size is 7. Before sending from "1,0,0", the frames in the sender sliding window of A are 0, 1, 2, 3, 4, 5, and 6. Draw A's sender sliding window after steps (1), (2), (3), (4), (5), and (6), by clearly identifying left wall, middle wall, and right wall of the sliding window.



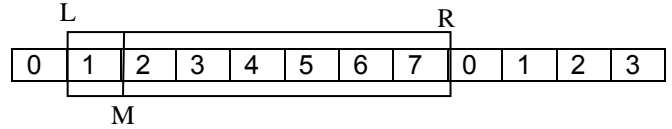
Step 1



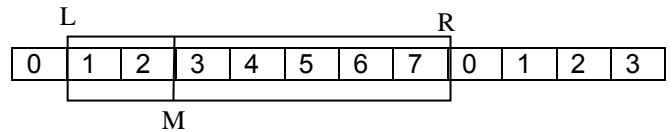
Step 2



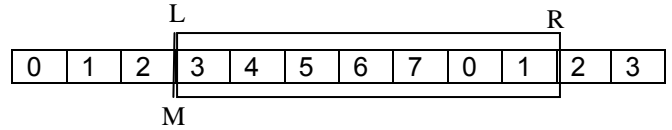
Step 3



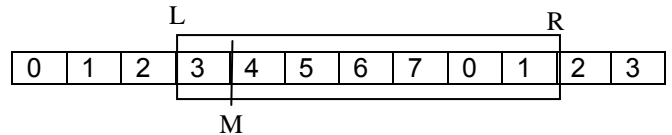
Step 4



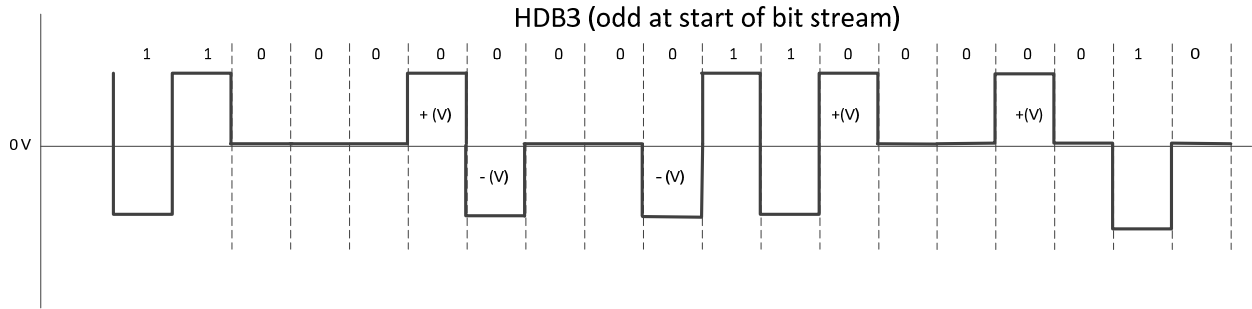
Step 5



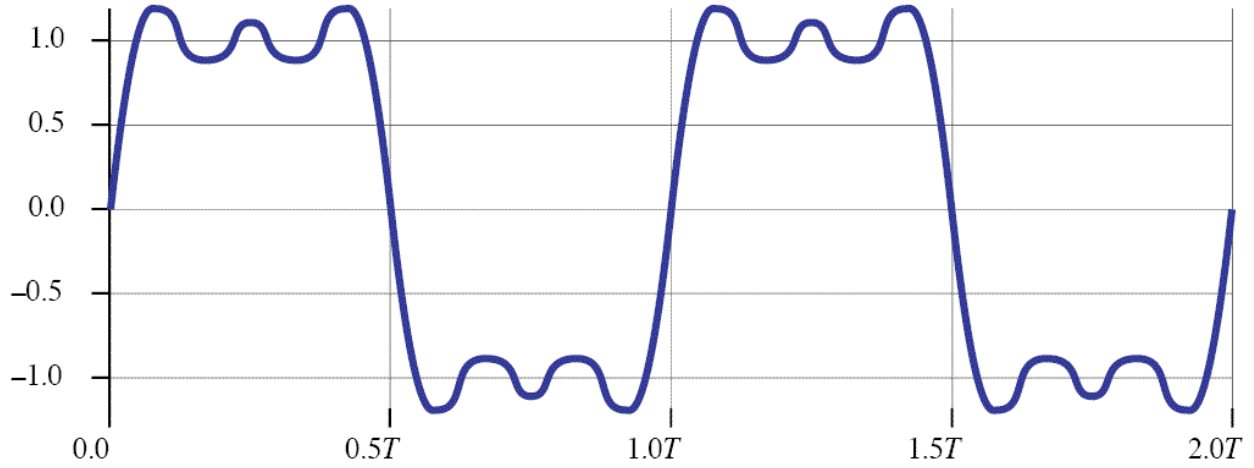
Step 6



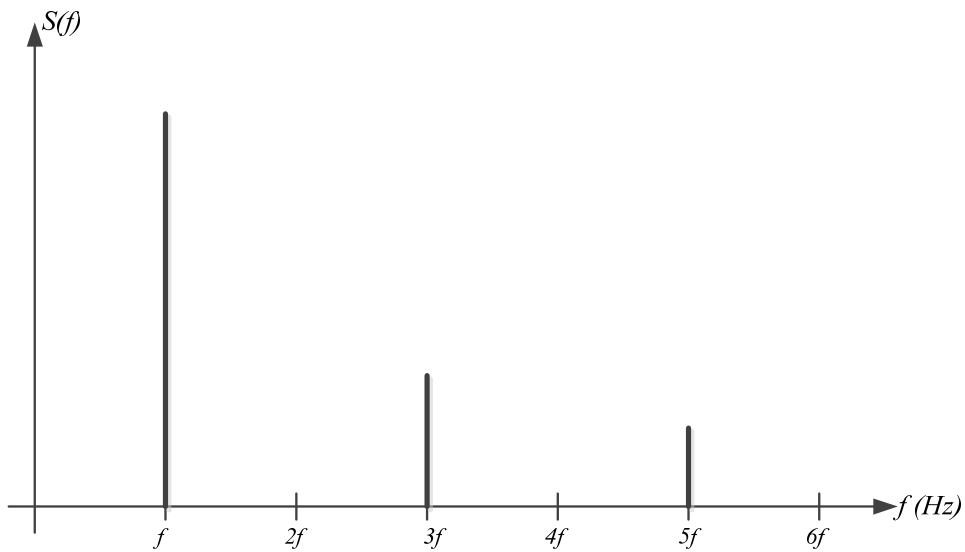




16 [5 marks] Roughly draw the frequency domain representation of the following signal. When  $T=1 \mu s$ , what is the bandwidth of the signal?



(a)  $(4/\pi) [\sin (2\pi ft) + (1/3) \sin (2\pi(3f)t) + (1/5) \sin (2\pi(5f)t)]$



**Bandwidth =  $5f - f = 4f$**   
**For  $T = 1 \mu s$ ,  $f = 1 \text{ MHz}$  and thus bandwidth equal 4 MHz**

17 **[10 marks]** Your task in this question is to analyze a link between two computer systems and recommend a configuration. One system is located in Halifax and the other in Vancouver. A service provider of a physical link, that includes two modems, has provided the following information:

- The length of the physical link is 5500 km.
- The signal travels across the physical link at a speed of 200 km/ms (meters/microsecond).
- Additional delays occur in the physical network which adds 25 ms.
- The provider guarantees a minimum  $\text{SNR}_{\text{dB}}=40$  dB.
- The provider guarantees a maximum  $\text{BER}=10^{-9}$ .
- The provider guarantees a minimum bandwidth of 30000 Hz (in each direction).
- The modems use QAM-32.

In your analysis you have been requested to determine the following:

- 1) The maximum baud rate and data rate of the modems. (Assume that the maximum capacity of the channel may not exceed 80% of the Shannon capacity).
- 2) The computer systems employ the HDLC protocol for data exchange. Determine the how HDLC is configured to maximize the data transfer rate across the link. In particular determine the connection type (NRM, SABM, etc.), sequence numbers used, and the size of the sliding window. Assume
  - a. That the Go-Back-N error recovery protocol is used.
  - b. That data frames (i.e. I-frames) can be as long as 200 bytes.
  - c. That the CRC-16 is used for error detection.
  - d. That error rate is negligible for your analysis.
- 3) Determine the effective data transfer rate can be exchanged across the data link.

1) **Baud rate and data rate:**

Compute the Shannon capacity (theoretical capacity)

$$\text{SNR} = 10^4 = 10000$$

$$\text{Shannon capacity} = 30000 \log_2(1+10000) = 30000 \times 13.287 = 398,635 \text{ bps}$$

$$\text{Maximum capacity} = 0.8 \times 398,635 \text{ bps} = 318,908, \text{ say } 318 \text{ kbps}$$

Modems used a QAM-32 modulation, hence 32 signals, each signal encoding 5 bits. Thus the signaling rate =  $318/5 = 63.6$  kBaud.

2) **HDLC Configuration:**

a. To maximize the efficiency:

$$\text{i. } t_{\text{frame}} = 200 \times 8 / 318,000 = 0.015 \text{ s} = 5 \text{ ms}$$

$$\text{ii. } t_{\text{prop}} = 25 \text{ [ms]} + 5500 \text{ [km]} / 200 \text{ [km/ms]} = 52.5 \text{ ms}$$

$$\text{iii. } a = 52.5 / 5 = 10.5$$

$$\text{iv. To maximize efficiency, } N \text{ (window size)} \geq 1+2a, \text{ that is, } N \geq 1+2 \times 10.5 = 22$$

b. Configuration of HDLC:

i. Use extended mode which gives a 7-bit sequence number (0 to 127) (SABME, asynchronous balanced mode).

ii. Minimum window size is 22 to obtain an efficiency of 1 (assuming no errors). Thus the effective transmission rate across the link is 318 kbps

2) **Effective data transfer rate**

a. Of the 200 bytes in the HDLC I-frame, 7 bytes are delimiter/address/control bytes. Thus 193 bytes are data bytes.

b. Thus effective transfer rate =  $318 \text{ kbps} \times 193/200 = 307 \text{ kbps}$ .