

# Examination SS2017 Communication Systems and Protocols



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## Communication Systems and Protocols

Date: 31.07.2017  
Name: Test Name  
Matr. ID: 1234567  
ID: 1

Lecture Hall: ITIV  
Seat: 1

## Prerequisites for the examination

### Aids:

- A single sheet of A4 paper with **self- and hand-written** notes. Writing may be on both sides
- A dictionary
- A not-programable calculator.
- Writing utensils
- Use only indelible ink - use of pencils and red ink is prohibited.
- Other material than that mentioned above, is strictly forbidden. This includes any type of communication to other people.

### Duration of the examination:

The exam duration is 120 minutes.

### Examination documents:

The examination comprises 32 pages (including title page, 8 blocks of tasks).

Answers may be given in English or German. A mix of language within a single (sub)-task is not allowed.

**Please check your matriculation number and id on every page before processing the tasks.**

In your solution mark clearly which part of the task you are solving. Do not write on the backside of the solution sheets. If additional paper is needed ask the examination supervisor.

### End of Exam:

You will not be allowed to hand in your examination and leave the lecture hall in the last 30 minutes of the examination. At the end of the examination: Stay at your seat and put all sheets (including this title page) into the envelope. Only sheets in the envelope will be corrected. We will collect the examination.

	Page	≈ Pts. [%]	Points
Task 1: Physical Basics	2	12	
Task 2: Transmission Principles	6	13	
Task 3: Modulation and Spread Spectrum	10	10	
Task 4: Media Access	15	13	
Task 5: Error Protection	19	12	
Task 6: Protocols	22	12	
Task 7: Routing	26	11	
Task 8: Network Topologies	29	13	
			Σ

# Task 1: Physical Basics

## Task 1.1: Drivers

- A) Insert the logic level (HIGH, LOW) of the output and the state of the transistors (conducts, blocks) into the table according to the input configuration  $x_1$  and  $x_2$  at the standard TTL output driver.

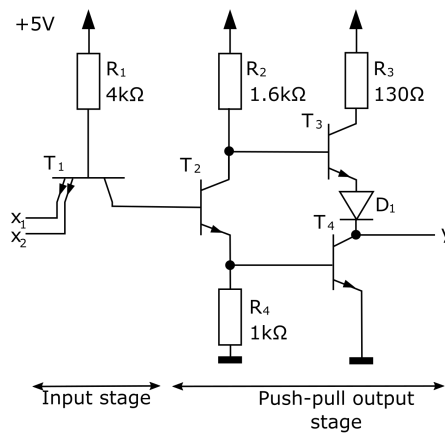


Figure 1.1:

$x_1$	$x_2$	$T_1$	$T_2$	$T_3$	$T_4$	$y$
0	0					
1	1					
0	1					
1	0					

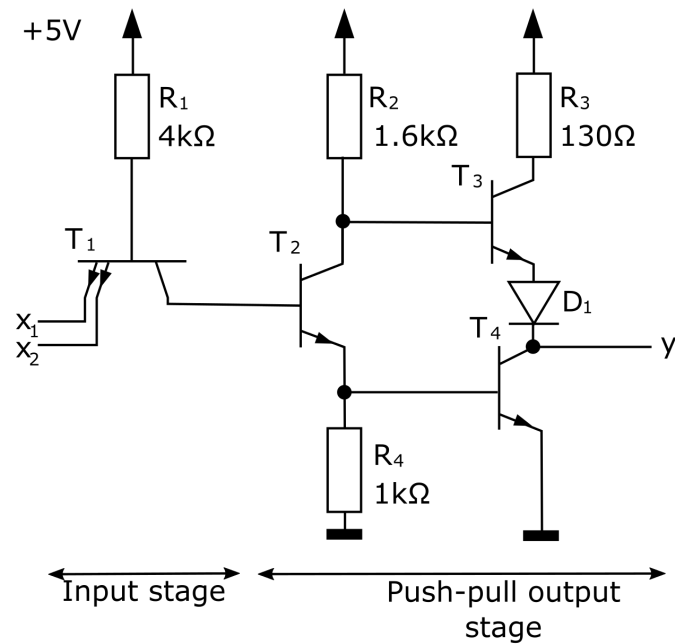
- B) List two advantages when using TTL drivers.

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- C) You want to overcome the disadvantage of possible short circuits of a standard TTL driver. Which part of the TTL driver needs to be modified? Modify the drawing to get the solution and describe the purpose of each adjustment made.



## Task 1.2: Sampling

When implementing an AD-converter the first step is the sample&hold gate. An example is given in figure 1.2.

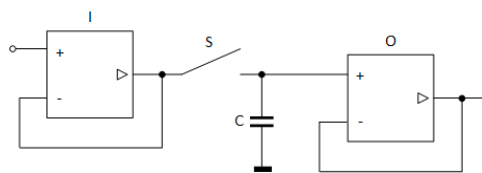


Figure 1.2: Sample&Hold gate

- A) Why is such a gate required for the AD conversion process?

- B) Briefly describe the purpose of every subblock (I, O, S, C) of the sample & hold gate. What is its function inside the sample & hold gate?




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### Task 1.3: Reflections on wires

In figure 1.3 a transmission system is given. It consists of a voltage source (including an internal resistance  $R_i$ ), a signal line of length  $l$  and a resistor  $R_L$  as receiver. The signal propagates with speed  $v$ .

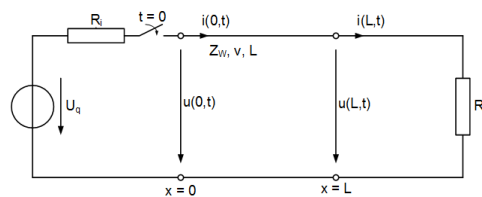


Figure 1.3: Transmission system

For varying  $R_i$  and  $R_L$  the following signal diagrams (figure 1.4) can be drawn. They are showing the voltage  $u(0, t)$  at the beginning of the signal line and the voltage  $u(L, t)$ , that can be measured at the end of the line.

- A) In which of the given examples from figure 1.4, if any, is the line terminated correctly with a suitable value of  $R_L$ ? Justify your answer.




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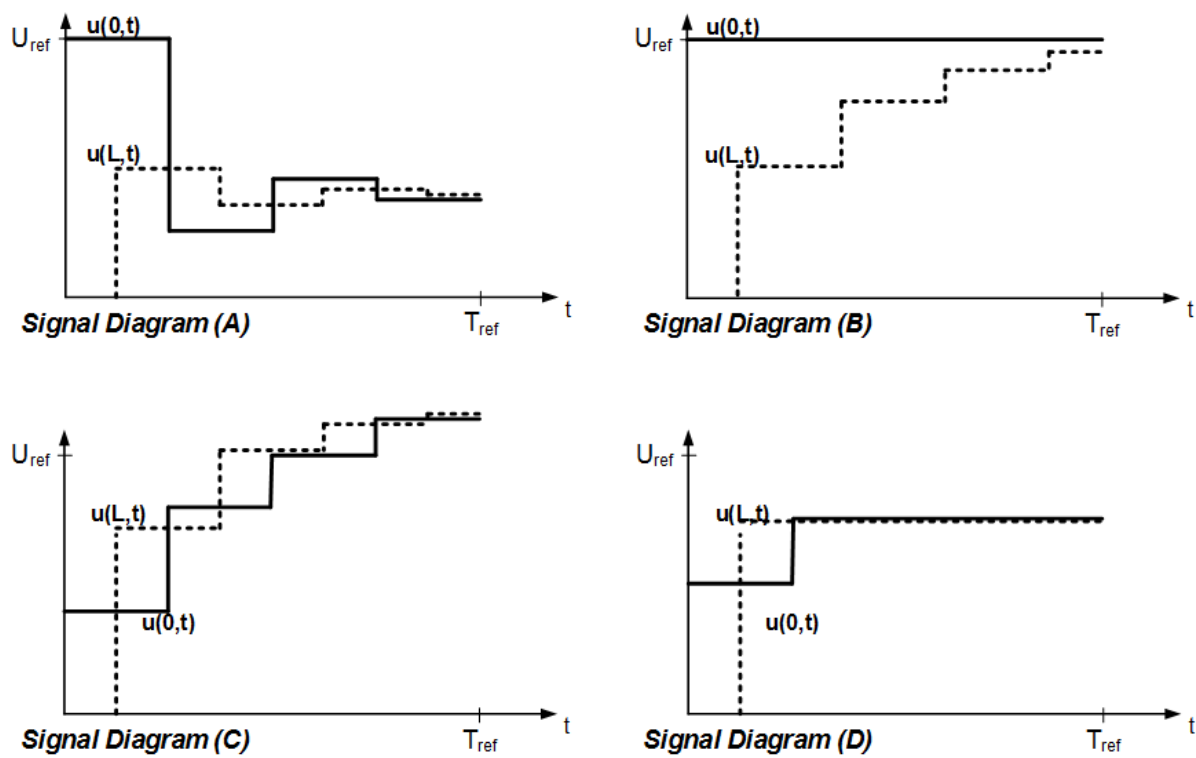


Figure 1.4: Voltages on signal line

B) For each of the signal diagrams denote the following:

- Is the reflection factor  $r_i$  at the beginning of the signal line negative, positive or zero?
- Is the reflection factor  $r_L$  at the end of the signal line negative, positive or zero?

Complete the following table accordingly.

	$r_i$ [neg, pos, 0]	$r_L$ [neg, pos, 0]
Signal diagram (A)		
Signal diagram (B)		
Signal diagram (C)		
Signal diagram (D)		

## Task 2: Transmission Principles

### Task 2.1: Line Codes

- A) Why are line codes preferred over baseband signal transmission? In addition, please name and explain two advantages of line codes.

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- B) Draw the digital signals for the bit string 011 000 110 100 using each digital encoding scheme. Use Figure 2.1.

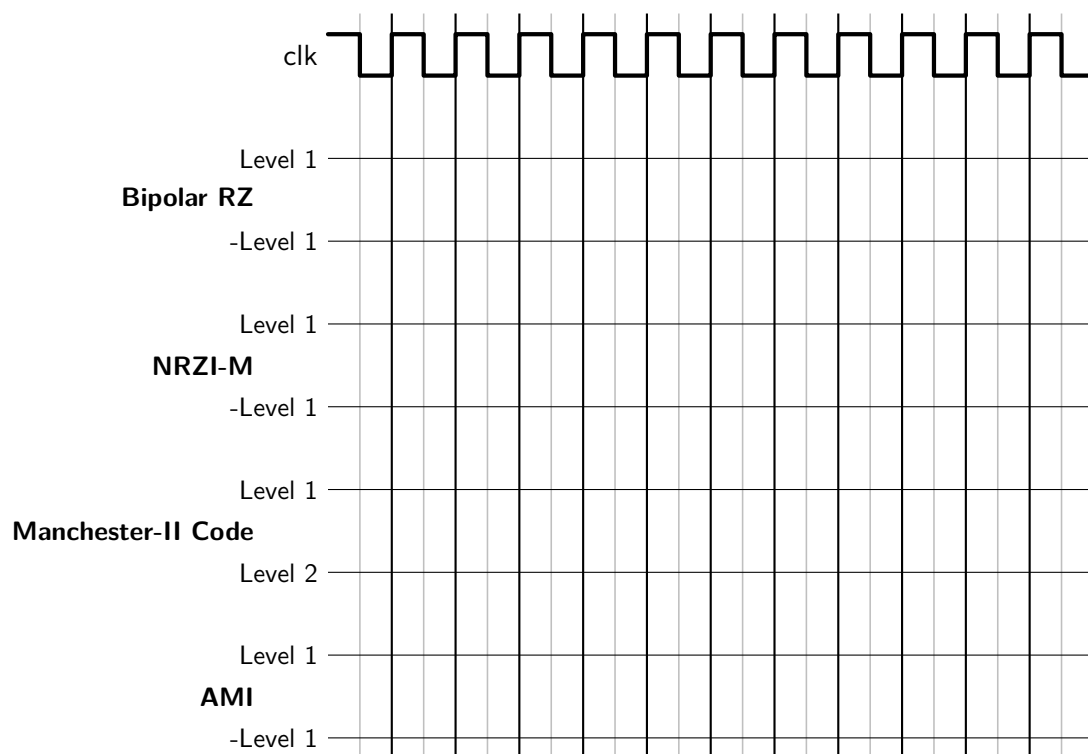


Figure 2.1: Line codes

- C) Classify the line codes given in Table 2.1 according to the properties given in Table 2.1. Use the options given in square brackets only! If requested, please justify your answer below!



Line Code	Avg. baud rate compared to bit rate [>=/<=/equal]	Clock Recovery [yes/no]	Error Detection Capability [yes/no]
NRZ			
Bipolar RZ			
Manchester-II			
AMI			

Table 2.1: Line code properties

**Clock Recovery:**

NRZ:

Bipolar RZ:

Manchester-II:

AMI:

**Error Detection Capability:**

NRZ:

Bipolar RZ:

Manchester-II:

AMI:

D) What problems can occur, if a transmission line is not DC balanced? Name two problems.




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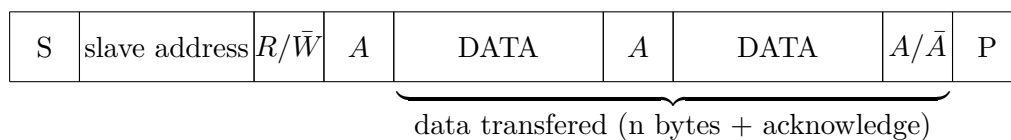
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## Task 2.2: I<sup>2</sup>C Arbitration

In this task we want to investigate the data transmission on the I<sup>2</sup>C-Bus. The simplified packet format is given in Figure 2.2. Three master nodes are simultaneously trying to transmit or read one byte of data to or from different slaves over the I<sup>2</sup>C-Bus.



term	description
S	start condition
slave address	7-bit slave address
$R/\bar{W}$	read/write: read 1, write 0
A	acknowledge from slave ('0')
$\bar{A}$	not acknowledge ('1')
DATA	8-bit data
P	stop Condition

Figure 2.2: I<sup>2</sup>C-Bus frame format

A) What condition must be met during regular data transmission concerning the SCL and SDA line? Which erroneous behavior would occur, if this condition is violated? Justify your answer!




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- B) The addresses of the slaves, communication mode ( $R/\overline{W}$ ) and the data to be send or read to or from them is shown in the Table 2.2. Complete the signal diagram in the Figure 2.3.

node	slave address	$R/\overline{W}$	data
Master 1	1001001	0	0x15
Master 2	0101100	1	0x81
Master 3	0101101	0	0x45

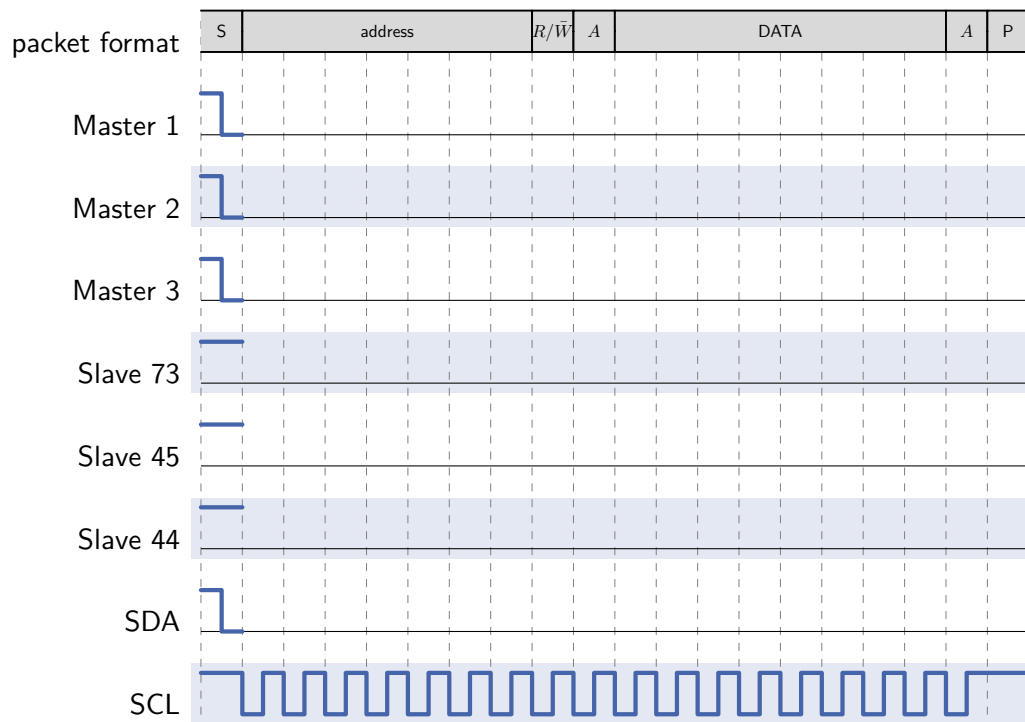
Table 2.2: I<sup>2</sup>C Communication Parameters

Figure 2.3: Signal sequence

- C) How many nodes can be connected to the I<sup>2</sup>C bus at maximum? Justify your answer!

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## Task 3: Modulation and Spread Spectrum



### Task 3.1: Modulation

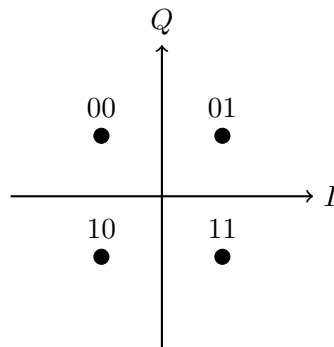


Figure 3.1: The constellation diagram of a certain modulation

- A) The constellation diagram of a certain modulation is shown in the Figure 3.1. Which modulation schemes may be used?



- B) By assuming that you have a bistream of information, i.e. **101011000111...**, which you want to modulate using 64-Quadrature Amplitude Modulation (64-QAM) Technique. How many bits for each symbol do you need to use to construct a 64-Quadrature Amplitude Modulator?



- C) A constellation diagram of 4-QAM is shown below (Figure 3.2). You have information bits **00111010** which will be processed from the left to the right. The Figure 3.3 shows the in-phase carrier signal (B), in-phase symbol (A), and in-phase modulated signal (C). Moreover, the Figure 3.4 shows the quadrature carrier signal (E), quadrature symbol (D), quadrature modulated signal (F). Sketch waveforms to the Figure 3.3 (A and C) and Figure 3.4 (D and F) which resemble symbol representations and modulated information signals seen from in-phase and quadrature axes. The symbol period is twice as long as the period of carrier signal.

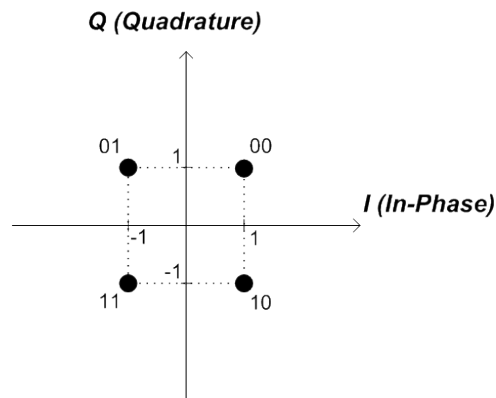


Figure 3.2: A constellation diagram of 4-QAM

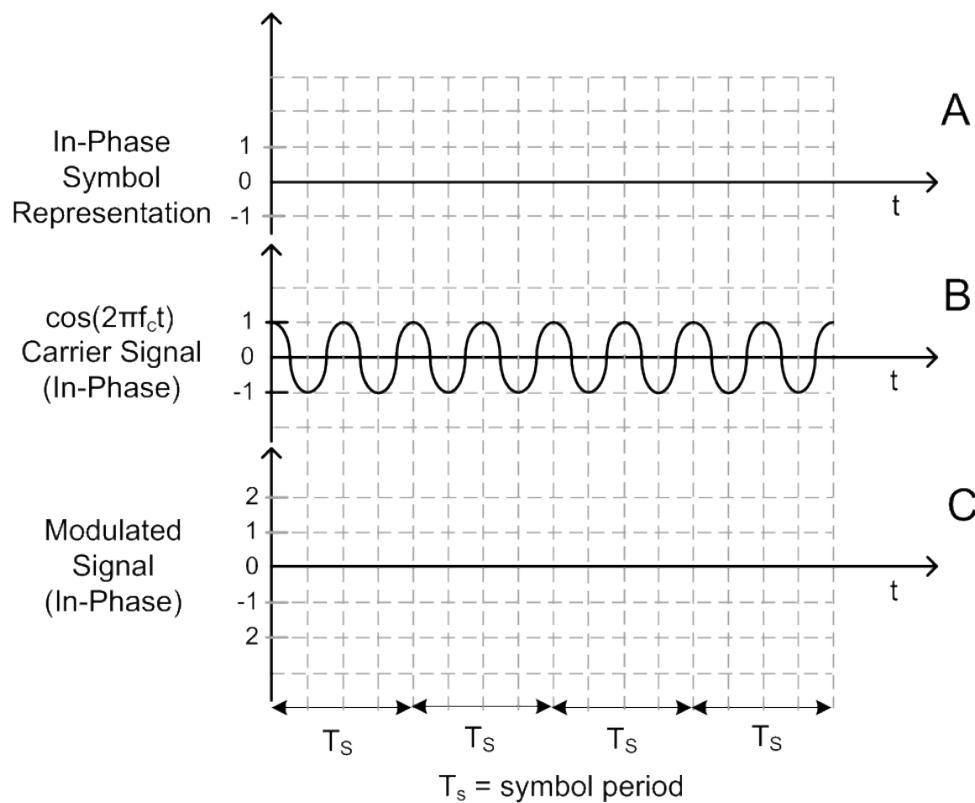


Figure 3.3: In-Phase symbol representation, carrier signal (in-phase), and modulated signal (in-phase)

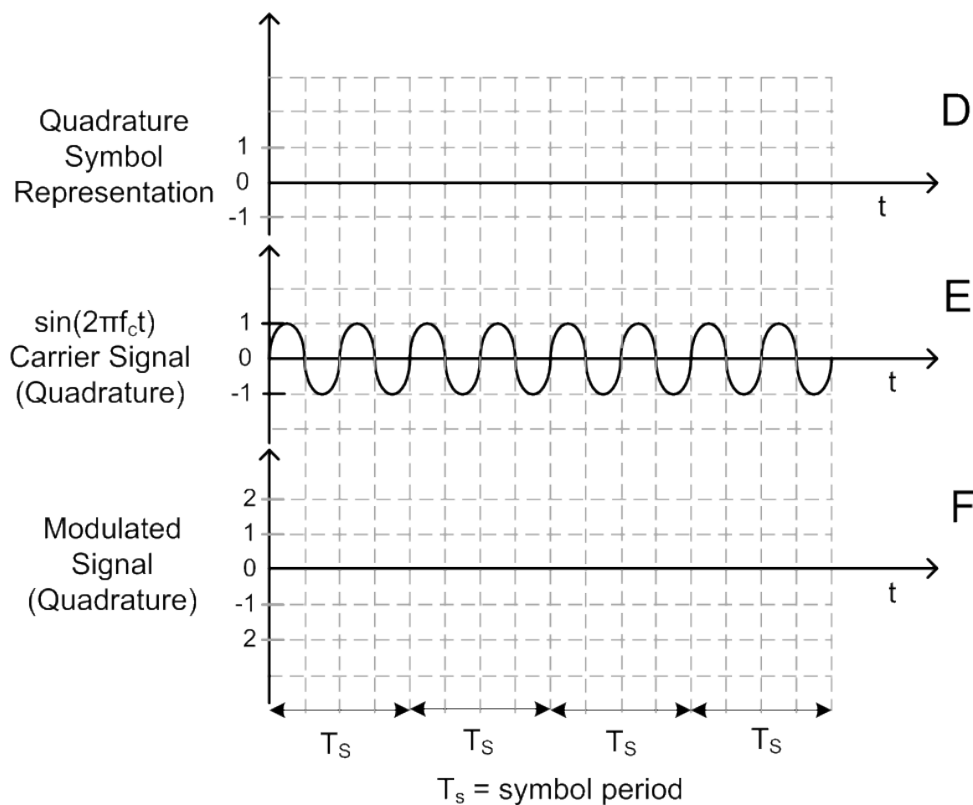


Figure 3.4: Quadrature symbol representation, carrier signal (quadrature), and modulated signal (quadrature)

### Task 3.2: Spread Spectrum

- A) In communication systems, spread spectrum technique is commonly used due to some advantages. To show the influence of spread spectrum technique to the bandwidth of a signal, the amplitude of a signal and the bandwidth of the signal can be also sketched in frequency domain. If the power density of a signal is proportional to the square of the amplitude of the signal, which signal does represent after spread and before spread referring to Figure 3.5?

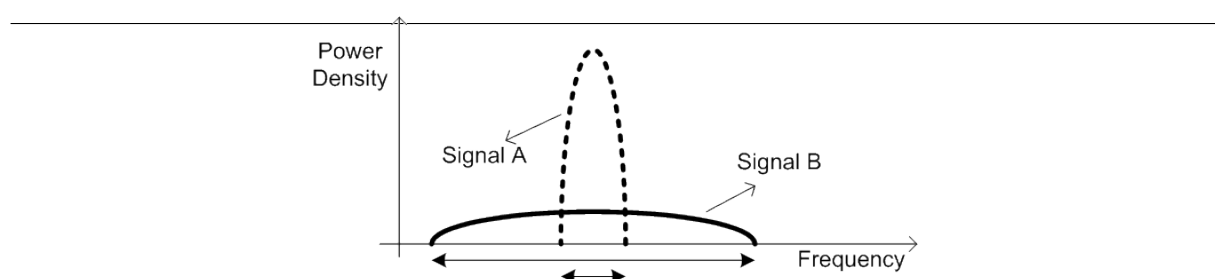


Figure 3.5: A representation of signal's power densities vs. signal's frequencies

B) What are the requirements for spreading codes used by CDMA?




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node	function							
0	+1	+1	+1	+1	+1	+1	+1	+1
1	+1	-1	+1	-1	+1	-1	+1	-1
2	+1	+1	-1	-1	+1	+1	-1	-1
3	+1	-1	-1	+1	+1	-1	-1	+1
4	+1	+1	+1	+1	-1	-1	-1	-1
5	+1	-1	+1	-1	-1	+1	-1	+1
6	+1	+1	-1	-1	-1	-1	+1	+1
7	+1	-1	-1	+1	-1	+1	+1	-1

Table 3.1: Walsh sender functions

C) For the simultaneous transmission of four messages, the Walsh function presented in Table 3.1 shall be used. The nodes 0, 2, 5 and 7 transmit data according to Table 3.2. Give the resulting signal on the media, make use of the given scheme in 3.2.



Node	Data	Signal							
0	"0"								
2	"1"								
5	"1"								
7	"0"								
Signal on media									

Table 3.2: transmission with CDMA

- D) The following Signal has been received from a transmission using the Walsh functions from this task.



$$+0.9 \ +1.2 \ -3.4 \ -2.5 \ +0.9 \ +1.2 \ +1.1 \ +0.8$$

As corruptions might happen during transmission, the receiver has a tolerance band for the detection. All values differing up to  $\pm 0.5$  from the ideal value will still be accepted. Calculate the bit value that the receiver will detect for node 3 and node 6.



## Task 4: Media Access

### Task 4.1: Ethernet

Ethernet is a family of computer networking technologies commonly used in local area networks (LANs) and metropolitan area networks (MANs). Systems communicating over Ethernet divide a stream of data into shorter pieces called frames. Each frame contains source and destination addresses, and error-checking data so that damaged frames can be detected and discarded. The "Carrier Sense Multiple Access with Collision Detection" scheme is used to control access to the shared medium.

A bus system with several nodes is using the Ethernet standard with a transmission rate of  $10\text{Mbit/s}$  and a signal speed of  $2.5 \cdot 10^8\text{m/s}$ . A maximum distance of  $2.5\text{km}$  for two nodes has to be considered.

A) Why is it necessary to establish a minimal packet length?



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B) Calculate the resulting minimal package length in bits for the bus system.



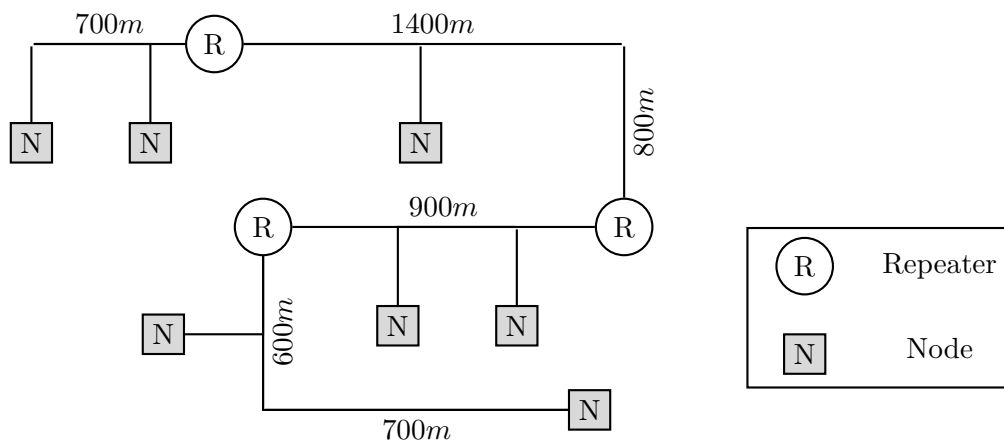


Figure 4.1: Ethernet topology

- C) A minimal package length of 64 bytes for the bus system is determined. The bus system is illustrated in figure 4.1 and is used with a transmission rate of  $10\text{Mbit/s}$  and a signal speed of  $2 \cdot 10^8\text{m/s}$ . Each repeater will add a delay of three bits. Is this bus system working with these constraints? Give an explanation!





## Task 4.2: CSMA/CA

A communication system comprises five communication nodes that use CSMA/CA as arbitration scheme. In order to transmit data a node transmits a dominant start bit (0) for synchronization purpose. After that a 5 bit message identifier followed and 10 bits of payload data is sent. The message identifiers are unique for each node and all data is sent MSB first. The bus has to cover a maximum distance of 500m.

- A) Which requirements have to be fulfilled in order to guaranty a faultless function of the system? What are the implications for the transmission rate?

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- B) Table 4.1 shows the identifier of each node. Perform the arbitration phase and fill out the timing diagram in Figure 4.2.

Node	identifier
A	01010
B	00101
C	11001
D	10010
E	00110

Table 4.1: Specification of nodes

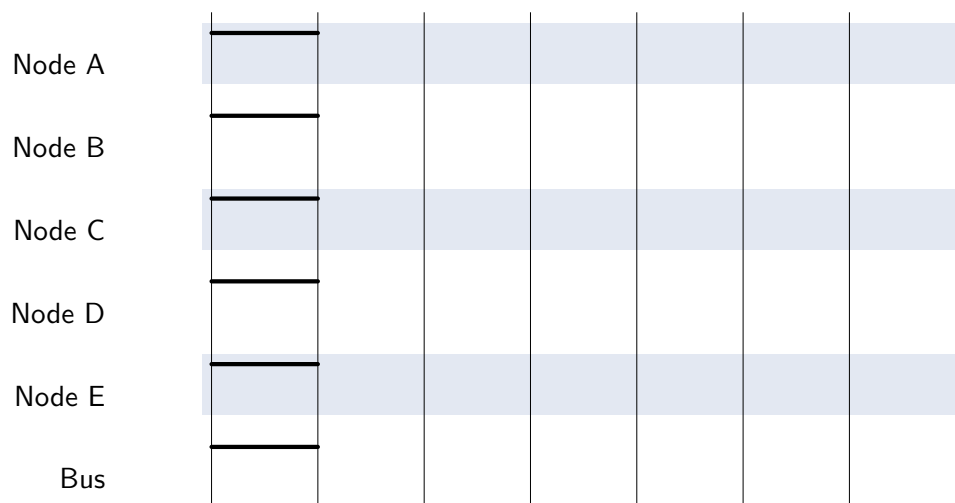


Figure 4.2: Bus Access

- C) Which node is granted exclusive access to the bus?

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### Task 4.3: Arbitration

A system using polling is shown in Figure 4.3. An exemplary arbitration cycle of the system is shown in Figure 4.4.

- A) Assign the correct signals of Figure 4.3 to the signals shown in the diagram below (Figure 4.4). Justify your choice of signal assignment with a few sentences. What node is sending data at which point in time? Complete the diagram (Figure 4.4) accordingly.

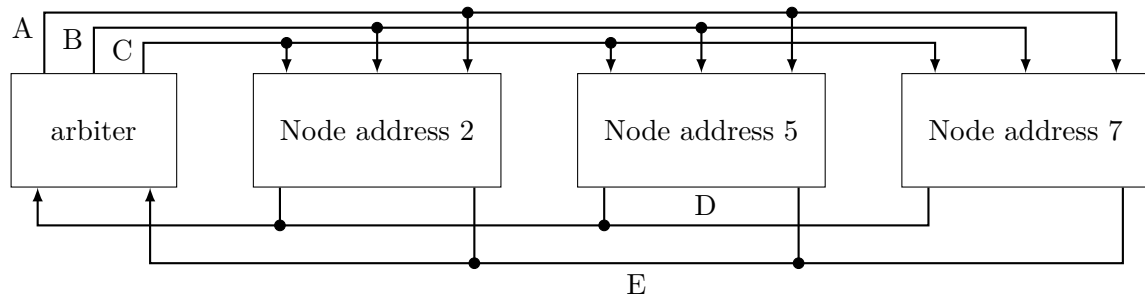


Figure 4.3: Polling

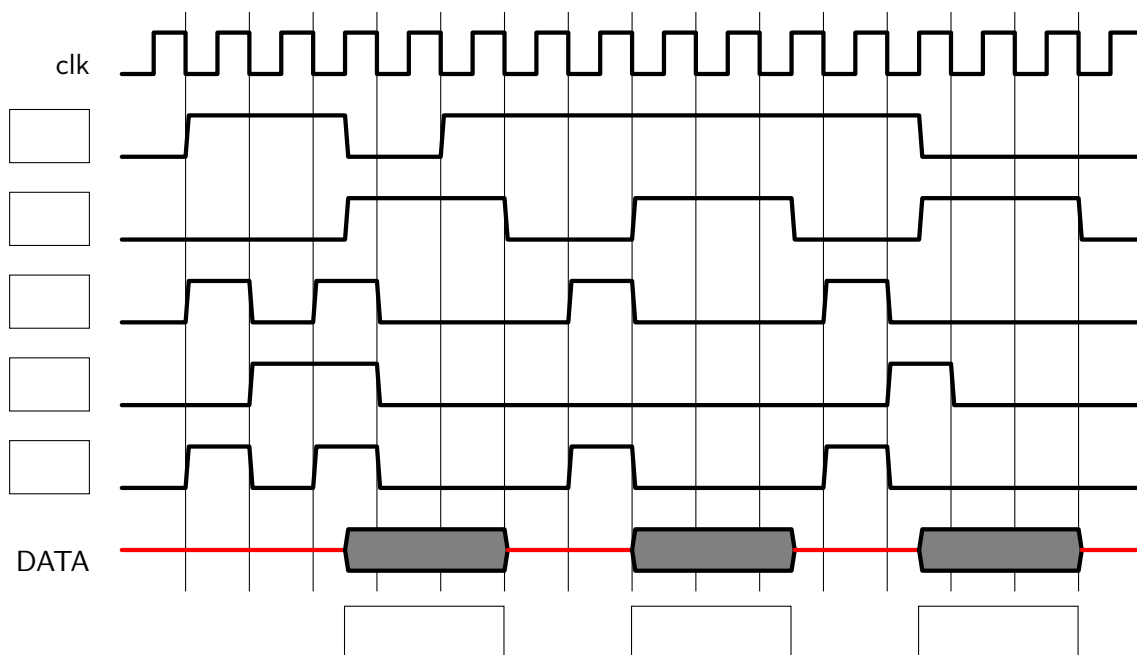


Figure 4.4: Signal flow for Polling

## Task 5: Error Protection

### Task 5.1: Multiple Choice

- A) Specify whether the statements in table 5.1 are true or false.

*Hint: Wrong answers will be penalised. The task will be evaluated with a minimum of 0 points.*

Statements	True	False
The receiver has to use a different CRC generator polynomial than the sender		
In a good hash function for communication purposes, a small change in input value results in a small change in hash value		
The Arbitration Field of a CAN message defines the priority of the message		
If a CRC generator polynomial $G(x)$ contains factor $(x+1)$ , all odd number of bit errors are detectable by the CRC method		
All error bursts $>$ degree of the CRC generator polynomial are detectable		
Safety is the protection against malicious errors caused by attackers		

Table 5.1: Multiple Choice

### Task 5.2: CRC-Calculation

- A) To protect data transmission in a mobile device, the given CRC generator polynomial should be implemented. Draw the simplified form of the linear feedback registers with XOR operators for the given generator polynomial.

Given CRC generator polynomial:  $x^7 + x^6 + x^2 + 1$

- B) Calculate the data stream that will be transmitted if the following bit stream is to be protected using the CRC generator polynomial:  $x^7 + x^6 + x^2 + 1$ .  
Data stream for transmission: **1010 1110**

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- C) In a transmission system that uses CRC for error detection, a receiver receives the following bitstream: **1010 1001 0001**  
Carry out the CRC error detection scheme of the receiver, assuming that the generator polynomial  $x^4 + x^2 + 1$  has been used to generate the checksum at the sender. What does the receiver conclude from the result?

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- D) Specify the correct bit stream, assuming that only one bit error has occurred in the transmitted bitstream of the task 5.2 C).

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**Task 5.3: CAN Bus**

- A) In CAN bus communication it is very important that every participant is able to count the errors. Please give a short explanation why any erroneous participant must be recognized and deactivated.

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- B) In a fresh restarted CAN bus communication system only one node acts as sender and transmits a CAN message every 10 ms. Assume that in every 2nd transmission the sender does not receive an ACK (without a following error flag). Assume further that the first successful transmission is done at  $t = 0$  ms. How long does it take until the sender node switches into the Error Passive state? (Hint: After error:  $TX_{CNT} = TX_{CNT} + 8$ , after successful transmission  $TX_{CNT} = TX_{CNT} - 1$ , Condition for transition from Error Active to Error Passive state:  $TX_{CNT} > 127$ )

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- C) How long does it take until the sender node switches into the Bus Off state (same conditions as in task 5.3 B)? Please justify your answer.

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# Task 6: Protocols

## Task 6.1: FireWire Arbitration

The FireWire network shown below is given.

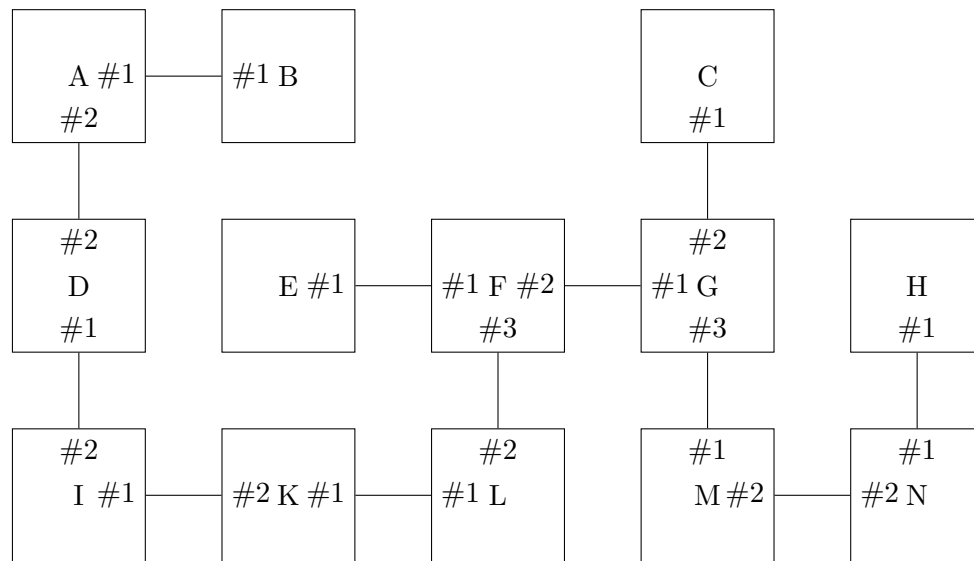


Figure 6.1: FireWire network

A) Mark the root of the FireWire Network in Figure 6.1.

Now a normal FireWire bus cycle should be considered. For simplification, several assumptions should be taken into account:

- A list of nodes wanting to send is given.
- All nodes start requesting the bus at the same time.
- Processing of arbitration request is done in zero time. There are no additional delays for propagation of the arbitration decision.
- If a node receives multiple bus request, it will always forward the request that it receives from the port with the lowest number.

B) The following nodes request access to the bus: **B, C, E, F, H, N**. Determine the order in which the nodes will be granted access to the bus.

- C) FireWire uses a special coding scheme with an additional STROBE signal. Explain the purpose of this signal and a possible implementation.



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## Task 6.2: Serial Peripheral Interface Bus (SPI)

The Serial Peripheral Interface bus (SPI) is a synchronous serial communication bus specification used for short distance communication.

The SPI bus specifies the following logic signals:

- **SCLK**: Serial Clock (output from master).
- **MOSI**: Master Output Slave Input (data output from master).
- **MISO**: Master Input Slave Output (data output from slave).
- **SS**: Slave Select (active low, output from master).

To begin communication, the bus master configures the clock, using a frequency supported by the slave device. The master then selects each slave device with a logic level 0 on the individual select line. If a waiting period is required, the master must wait for at least that period of time before issuing clock cycles. During each SPI clock cycle, a full duplex data transmission occurs between master and each slave device. The master sends a bit on the MOSI line (using NRZ code) and the slave reads it, while the slave sends a bit on the MISO line and the master reads it. This sequence is maintained even when only one-directional data transfer is intended. In this case the other data sequence is arbitrary. Slave devices have tri-state outputs so their MISO signal becomes high impedance when the device is not selected, because SPI all drivers have push-pull outputs.

- A) Name one advantage and one disadvantage of using Slave Select signals for accessing a device.

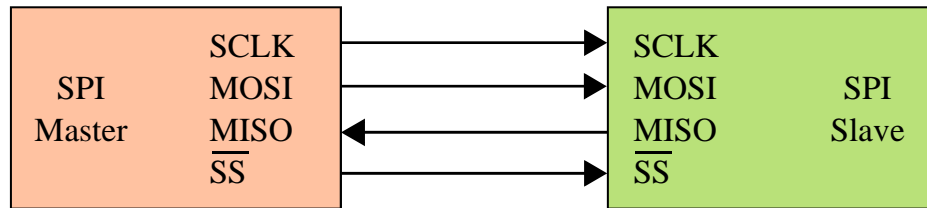


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- B) The following diagram shows a single master to a **single** slave configuration. Draw an appropriate diagram for a single master to a **three** slaves configuration below.





- C) Draw the timing diagram for the case that the following data byte (given in binary notation) should be transmitted to a single slave:  $01011100_b$ . Thereby the slave sends back the data byte:  $10011001_b$ . Assume the data captured and output on the clock's rising edge. Use figure 6.2.

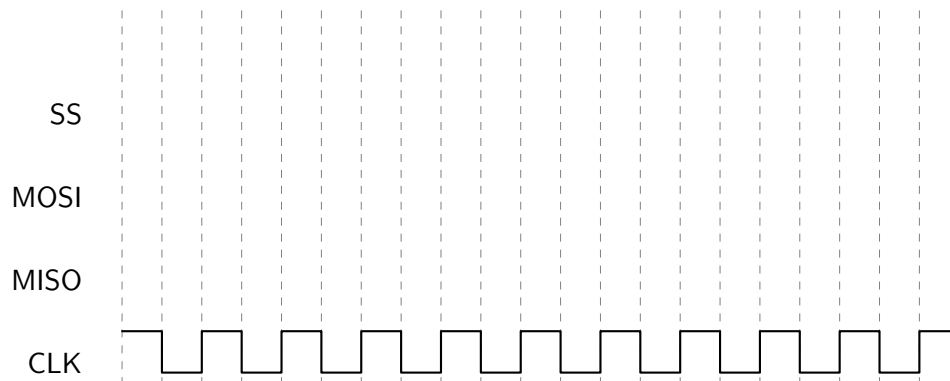


Figure 6.2: SPI full-duplex operation timing diagram

- D) Figure 6.3 shows a SPI read operation from a single slave. Add an appropriate SS signal to the diagram and write down the data the master **reads** from the slave in binary notation. Assume the data captured and output on the clock's rising edge.

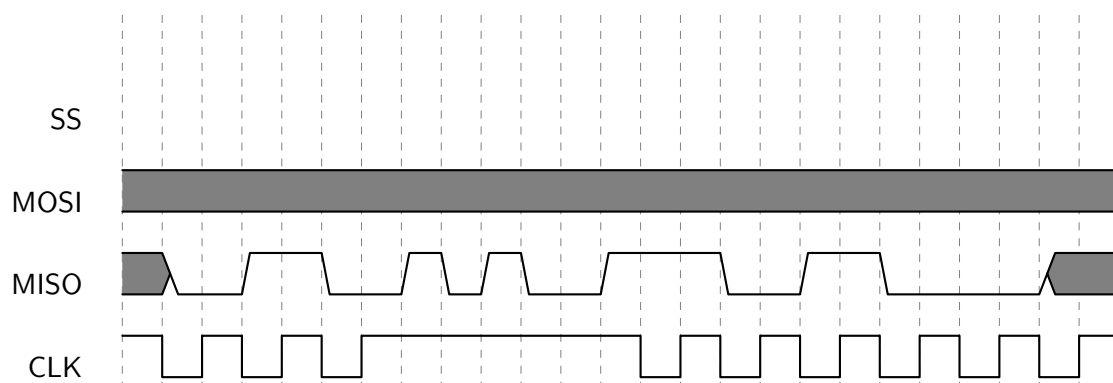


Figure 6.3: SPI read operation timing diagram

## Task 7: Routing

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### Task 7.1: General Questions

A) Explain the three terms hop and diameter in the context of routing.

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B) Explain what the manhattan distance is and in which network topologies it makes sense.

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C) Explain the term channel in the context of routing. Is it possible to have several channels between the same pair of nodes and explain how this could work ?

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D) Describe a network scenario in which routing during design time is favorable compared to routing during runtime and justify your answer !

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E) Describe what kind of information is needed by each router when adaptive routing is used and justify your answer !

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## Task 7.2: Dijkstra's Algorithm

- A) Explain the term minimal routing and describe a scenario in which non-minimal routing is preferred !

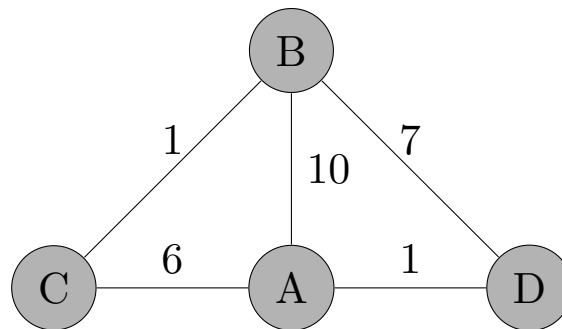


Figure 7.1: Given network topology

- B) With node A as the starting point, calculate the shortest paths in the network shown in Figure 7.1, by using Dijkstra's algorithm. For that write down the order in which nodes are visited in each bracket under the current step and fill out the given tables that encompass the shortest paths after each visitation of a node.



node	step 1 <b>A</b>		step 2		step 3		step 4		step 5	
vertex	dist.	pred.	dist.	pred.	dist.	pred.	dist.	pred.	dist.	pred.
A	$\infty$	A								
B	$\infty$	-								
C	$\infty$	-								
D	$\infty$	-								

Table 7.1: Dijkstra's algorithm

## Task 8: Network Topologies

### Task 8.1: General Questions

- A) Is the dijkstra algorithm more suitable for a regular topology (e.g. torus) or an irregular topology (e.g. the topology of the internet)? Choose one and justify your decision!

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- B) There are four topologies given: Mesh, Torus, Star, Ring. Assume for each topology a network with 16 nodes. Order the topologies in the given table from best (top) to worst (bottom) regarding the given metric. Metrics: edge connectivity, diameter, resource cost(i.e. in this case the total amount of links in the network). Hint: Think about what is desirable for each metric in a network when deciding the order.

Edge Connectivity	Diameter	Resource Cost

Table 8.1: Metrics and topologies

## Task 8.2: 4D Topology

Meshed topologies offer a very suitable solution for future many-core architectures, especially because of the easy routing scheme available (x,y-based routing). When we increase the amount of nodes in a mesh, it can be useful to scale the mesh into a higher dimension instead of adding the nodes in the same dimension. A higher dimension keeps the diameter low while increasing the edge connectivity of the nodes.

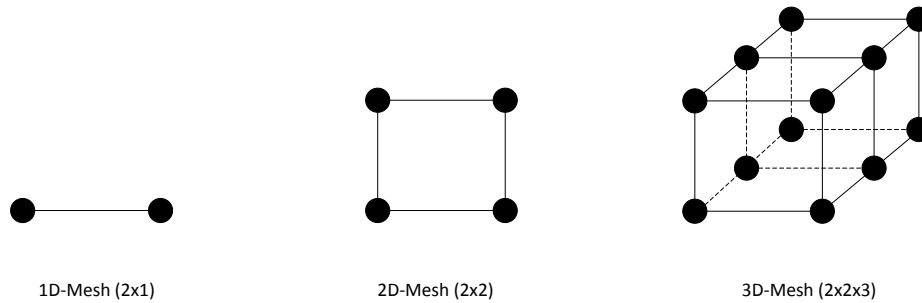


Figure 8.1: Drawing higher-dimensional meshed networks

Mathematically speaking, higher dimensional meshed topologies behave the same as lower dimensional topologies. For drawing them on a sheet of paper, some techniques exist. If we consider a 1-dimensional topology consisting of two nodes and want to move towards a 2-dimensional (2x2) topology, we simply copy our original nodes and connect each node with their exact copy. For a 2x2x3 topology, we copy the existing 2x2-rectangle two times (resulting in 3 rectangles) and connect each original node with their first copy and their first copy with the second copy. The same technique can be applied to a 4D topology, where we copy our 3D cubes and connect each node to its next copy.

A) Assume a  $2 \times 3 \times 4 \times 5$  mesh topology for this task. Each node can be described by the tuple  $(x_1, x_2, x_3, x_4)$ . Find the shortest path from the source point  $(1, 1, 3, 0)$  to the destination point  $(0, 2, 0, 3)$ . Thereby, the routing policy that each node has to obey is described as follows:

1. Try first to route in the direction of the largest vector component ( $\|\Delta x_1\|$ ,  $\|\Delta x_2\|$ ,  $\|\Delta x_3\|$  or  $\|\Delta x_4\|$ ) from the local position towards the destination.
2. In case there are multiple directions with the same largest value for the respective vector components possible, choose the direction of the previous step.
3. In case none of the above rules is possible, prioritize first  $x_1$  then  $x_2$  then  $x_3$  and finally  $x_4$  among the directions with the largest vector components.

In your answer please name all traversed nodes (i.e. their coordinates) in the correct sequence.

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B) Can the routing policy described in the previous question A result in a livelock? Justify your answer!

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C) Explain the difference between a livelock and a deadlock in a network.

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D) What is the edge connectivity and the diameter of a  $2 \times 3 \times 4 \times 5$  meshed topology? Shortly justify your answer.

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E) Assume now that there may be broken nodes which may not be selected by a routing algorithm. To cope with these broken nodes, there is an additional rule that extends the first rule and which says:

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1. In case a selected direction is not routable (due to the target node being broken), choose among the remaining directions the one of the next largest vector component from the local position towards the destination.

Furthermore assume that there are two broken nodes:  $(1,1,2,0)$  and  $(0,1,1,3)$ . Route a packet again starting from  $(1,1,3,0)$  towards  $(0,2,0,3)$  and name all visited nodes on the way.

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