Tutorial 1 - SS2016

Communication Systems and Protocols

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Task 1: Data transmission

The Compact Muon Solenoid (CMS) experiment is one of two large general-purpose particle physics detectors built on the Large Hadron Collider (LHC) at CERN in Switzerland and France. On one single day the experiment produces about 20 TB (Terabyte = 1*1012 bytes) of interesting data. These data has to be transferred to GridKa (Karlsruhe, approx. 450 km distance). The following transport schemes are available:

(i) Transmission over VDSL (50 Mbit/s)
(ii) Transmission over an optical fiber link (110Gbit/s)
(iii) Transport of the data using a hard disk and a car (95 km/h)

A) Calculate the time required to transfer the data using the different options. Hint: Use 1 Kbit = 1000 bit for the calculation. 3

In general: time for transmission = $\frac{\text{amount of data}}{\text{data rate}}$

(i) $\frac{\text{amount of data}}{\text{data rate}} = \frac{20\cdot 10^{12} byte\cdot 8\frac{bit}{byte}}{50\cdot 10^{6}\frac{bit}{s}} = 3.2\cdot 10^{6}s \approx 37\text{days}$

(ii) $\frac{\text{amount of data}}{\text{data rate}} = \frac{20\cdot 10^{12} byte\cdot 8\frac{bit}{byte}}{110\cdot 10^{9}\frac{bit}{s}} = 1454.55s \approx 24.2\text{min}$

(iii) $\frac{\text{distance}}{\text{speed}} = \frac{450km}{95\frac{km}{h}} = 4.7h$

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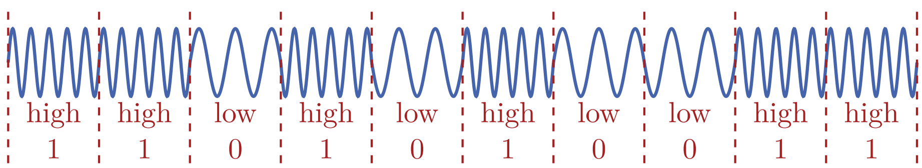
Task 2: Modulation

Give the type of modulation used for the signals as shown in the diagram below. Give also the data that is being transmitted. Assume a constant bit length.

A)



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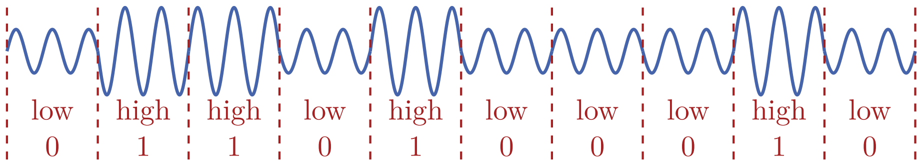
1. Determine the changing parameter: Frequency shift keying
2. Determine the points where the signal is changing
3. Read out the signal values
4. Assign signal values to logical values: E.g. high → 1, low → 0

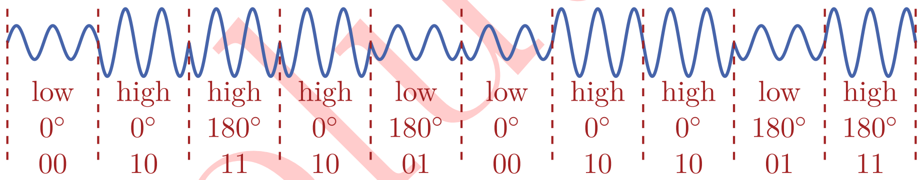
B)



1

1. Determine the changing parameter: Amplitude shift keying
2. Determine the points where the signal is changing
3. Read out the signal values
4. Assign signal values to logical values: E.g. high amplitude → 1, low amplitude → 0

C)



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1. Determine the changing parameter: Amplitude and Phase → QAM

		Amplitude	
		low	high
Phase	0	00	10
	180	01	11

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Task 3: Line Codes

A) Draw the digital signals for the bit string 101 100 000 011 using each of the NRZ, Manchester, and differential Manchester digital encoding schemes. Use Figure 3.1. 3

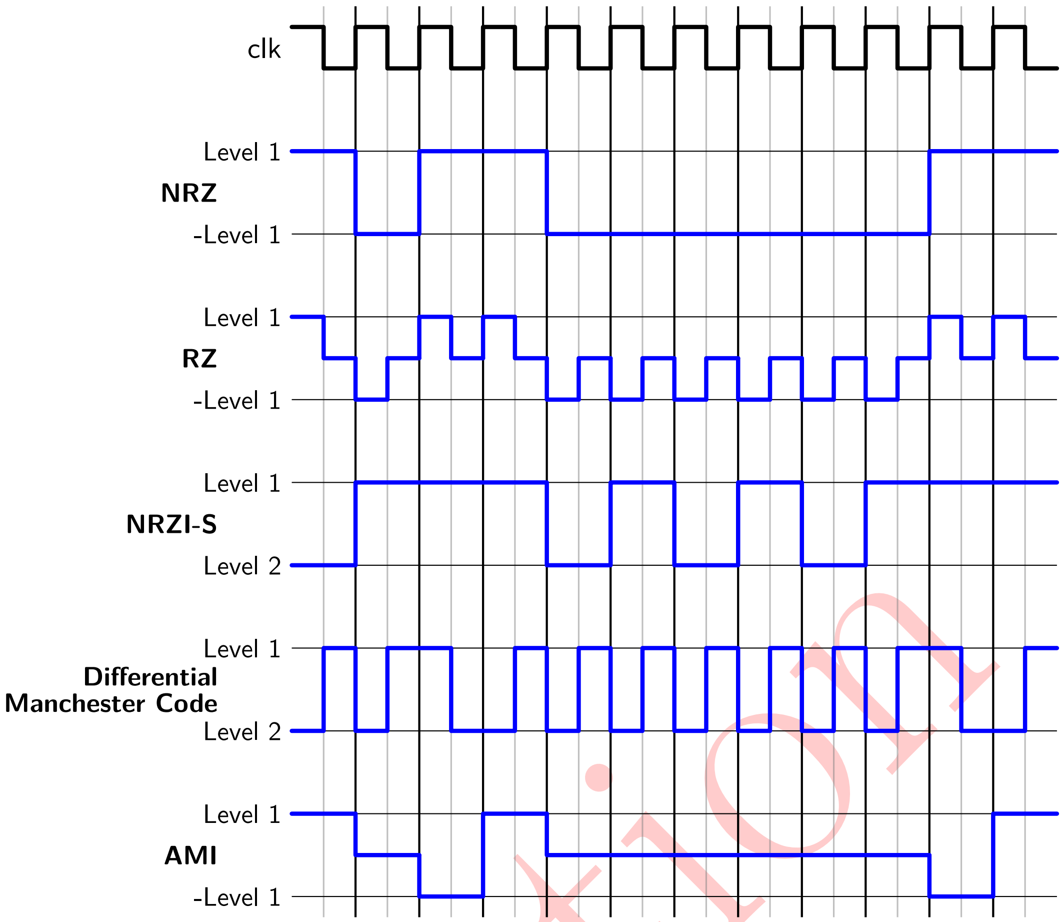

Figure 3.1: Line codes

B) Encode the following bit string using the 4B/5B code: **1**

1010000011111111000010111

10110 11110 11101 11100 01001 01111

C) What is the longest sequence of "0" if the 4B/5B code is used? **1**

The longest sequence contains three "0". For example: 10100 01010

D) What is the longest sequence of "1" if the 4B/5B code is used? **1**

The longest sequence contains eight "1". For example: 01111 11110
On optical fiber, the 4B5B output is NRZI-encoded: A long sequence of "1" serves clock recovery

E) Figure 3.2 shows the signal sequence for a Manchester coded signal. Determine the associated bit string. 1

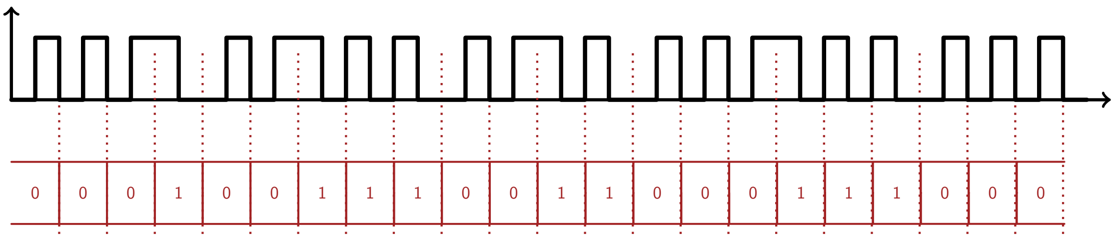

Figure 3.2: Manchester coded bit string

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Task 4: Reflection on wires

A setup consisting of a voltage source with an internal resistance $R_I = 50\Omega$ as sender and a receiver with $R_T = 175\Omega$ is shown in Figure 4. The DC resistance of the line is zero, the characteristic impedance Z_0 is 75Ω.

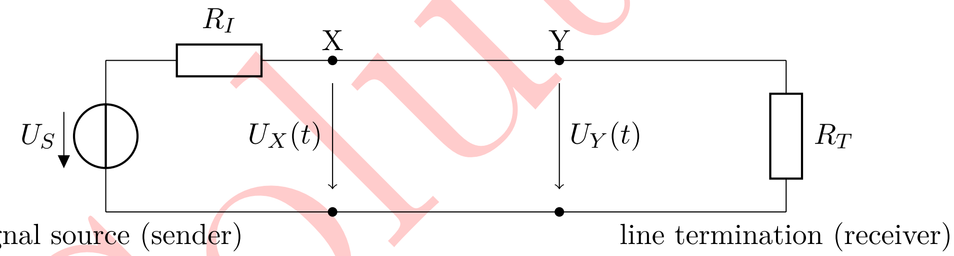

Figure 4.1: Test setup

At the time t= 0 the voltage U_s of the sender changes from $0V$ to $5V$ and is constant afterwards. The run time of a wave on the wire is t_d.

A) What is the value of the voltage at point X at the time $t = 0$? 1

At the time of $t = 0$ the wave only „sees“ a series connection of the internal resistance R_I and the wave impedance Zw.

$$U_X(0) = \frac{U_S}{R_I + Z_0} \cdot Z_0 = \frac{5V}{50\Omega + 75\Omega} \cdot 75\Omega = 3V$$

B) Which voltage value appears at the points X and Y after an infinite amount of time? 1

After an infinite amount of time the system is in a steady state, the voltages at points X and Y are identical. When neglecting the DC resistance of the wire a series connection of R_I and R_T remains.

$$U_X(\infty) = U_Y(\infty) = \frac{U_S}{R_I+R_T} \cdot R_T = \frac{5V}{50\Omega+175\Omega} \cdot 175\Omega = 3.\overline{8}V$$

C) Calculate the voltages at the points X and Y at the times $t = 0 \ldots 5t_d$. Neglect all transient events, use ideal rectangular impulses for calculation. **4**

Calculation of the reflection factors

- End of wire: $r_e = \frac{R_T-Z_0}{R_T+Z_0} = \frac{175\Omega-75\Omega}{175\Omega+75\Omega} = 0.4$
- Begin of wire: $r_b = \frac{R_I-Z_0}{R_I+Z_0} == \frac{50\Omega-75\Omega}{50\Omega+75\Omega} = -0.2$

In general:

- Voltage at point X for time t: $U_X(t) = U_Y(t-1) + r_b \cdot [U_Y(t-1) - U_X(t-2)]$
- Voltage at point Y for time t: $U_Y(t) = U_X(t-1) + r_e \cdot [U_X(t-1) - U_Y(t-2)]$

$\Rightarrow U_X(0) = 3V,\ U_Y(1) = 4.2V,\ U_X(2) = 3.96V,\ U_Y(3) = 3.864V,$
$U_X(4) = 3.8832V,\ U_Y(5) = 3.89088V$

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Task 5: Physical Basics

Task 5.1: TTL-Logic

A) Insert the logic level (HIGH, LOW) of the output and the state of the transistors (conducts, blocks) into the table 5.1 according to the input configuration x_1 and x_2 at the standard TTL output driver in figure 5.1. **2**

x_1	x_2	T_1	T_2	T_3	T_4	y
0	0	conducts	blocks	conducts	blocks	H
0	1	conducts	blocks	conducts	blocks	H
1	0	conducts	blocks	conducts	blocks	H
1	1	blocks	conducts	blocks	conducts	L

Table 5.1: Logic Level

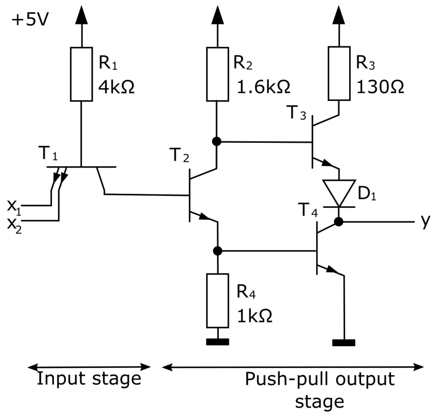


Figure 5.1: standard TTL output driver

B) List two advantages when using TTL drivers. **1**

High currents are possible;
Valid HIGH and LOW areas are wider at the input due to possible voltage drops on the lines.

C) How would it be possible to overcome the disadvantage of possible short circuits of a TTL driver? Which part of the TTL driver needs to be modified? Modify the Figure 5.2 to get the solution and describe the purpose of te adjustments made. **2**

T1 needs an enable input. Additionally a diode in reverse direction is needed between enable and collector of T2.

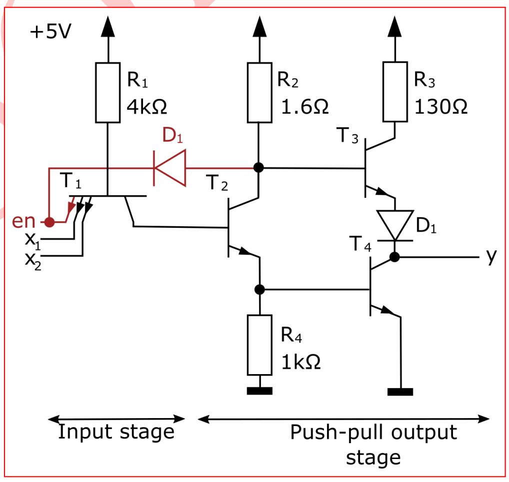


Figure 5.2: TTL driver

Task 5.2: Differential Signals

A) How could differential signal generation be realized? **1**

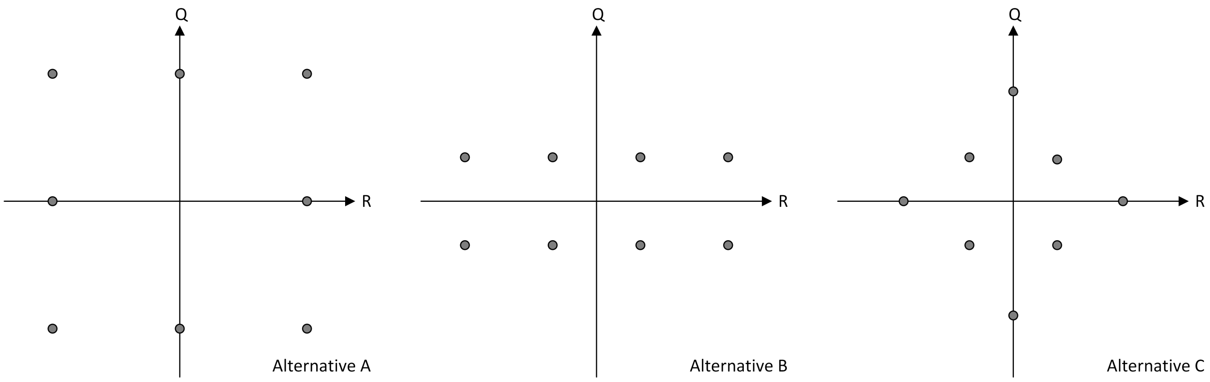
Emitter Coupled Logic (ECL) (with twisted lines)

B) What are the advantages for differential signal transmission? Name two. **1**

Higher speed since transistors don't go into saturation (ECL)
Inherent compensation of disturbances, noise pulse on both lines and therefore not visible in the differential signal.

Task 5.3: Modulation

Now consider the following constellation diagrams for 8-QAM. All diagrams are drawn with the same scaling of the axes.



A) If you had to realize a communication system using QAM modulation, which alternative would you choose? Give reasons for your decision **2**

Alternative A could be chosen because it provides the larges distance between the individual points. Therefore it provides the best resilience against disturbances.

B) Briefly describe PSK modulation and give one advantage. **1**

Phase shift keying: Discrete change of the phase of the carrier signal depending on the value to be send. Phase changes can be detected easily thus providing simple and save demodulation

Task 5.4: Channel capacity, Bandwidth

A digital transmission system with a bandwidth of $B = 1,5 * 10^6 Hz$ has a channel capacity of $C = 5 Mbit/s$ (according to Shannon).

A) What is the minimum for the signal to noise ratio (SNR) in dB? **2**

$C = B * log_2(1 + S/N)$
$S/N = 2^{(C/B)} - 1 = 2^{(5Mbit/s/1,5*10^6 Hz)} - 1 = 9,079$
$SNR = 10 * lg(2^{(C/B)} - 1) = 9,58dB$

B) Give the definition for the Cut-Off-Frequency: **1**

Frequency at which the signal amplitude has dropped by 3db compared to the output value.

Task 5.5: Signal Conversion

A) When converting analog signals into digital signals, what has to be considered in order to be able to achieve an unambiguous reconstruction of the signal (name and formula)? **1**

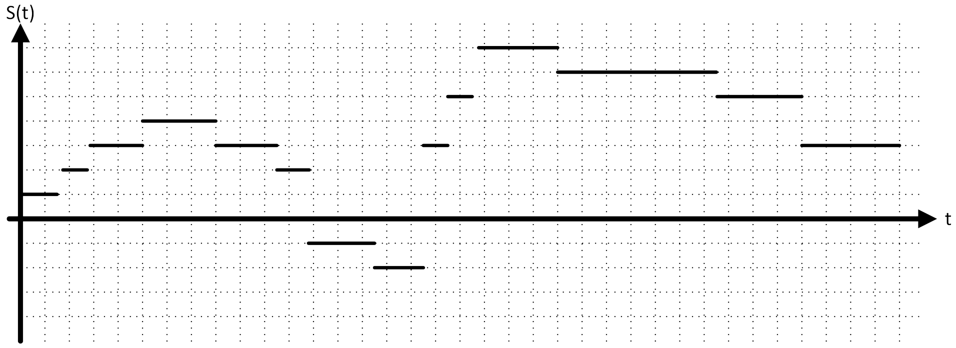
Nyquist-Shannon sampling theorem: $f_{sample} \geq 2 * f_{max}$

B) One can distinguish four different classes of signal. What are the parameters that are changed to form these classes? Give the combination of parameters that are characteristic for each class. **2**

The important parameters are signal value and time. Both can either be continuous or discrete. The four different classes are:

- value-continuous, time-continuous
- value-continuous, time-discrete
- value-discrete, time-continuous
- value-discrete, time-discrete

C) Which signal class does the following signal belong to? Briefly describe where this type of signal can be used. **2**



Signal class name: Time-continuous and value-discrete

Signal usage: Transmission of digital data, e.g. in computer bus systems. As the sampling timepoint is not exactly know before, the signal has to be send continuously. As digital data is to be transported, only discrete values are required.

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Task 6: Wiring

Task 6.1: General Questions

A) What is a symmetric line? Name one disadvantage of symmetric signaling. **1**

Transmission of each signal over dedicated signal paths using inverse signal voltages

One pair of cables are needed for one signal → no reduction is possible, additional overhead for second voltage source and differential receiver.

B) How does the wire length affect the characteristic impedance Z_W in a lossless case? **1**

It doesn't affect the characteristic impedance.

C) Name four causes for distortions of real data signals. **1**

Noise, bad signal edges, glitches, cross talk, reflections, bad GND, bandwidth issues, (cosmic) Radiation, magnetic/capacitive distortions

D) Name the four different possible cases of the reflection factor r and describe shortly their mechanical analogue. **4**

- $r = 1$ loose end
- $r = -1$ solid end
- $r = 0$ coupling joint
- $-1 < r < 1$ coupling joint

Task 6.2: Reflection on wires

You have found a transmission link in the basement and want to find out the characteristic impedance. With the setup given in Figure 6.2 you make the measurements that can be seen in Figure 6.2. The signal source U_S is stuck at an unknown output voltage and has an internal resistance of 33Ω. The termination resistance is $R_T = 200\Omega$. You can assume that the DC resistance is zero. When using numbers from Figure 6.2, only use one decimal place and only use values where the voltage is mostly constant.

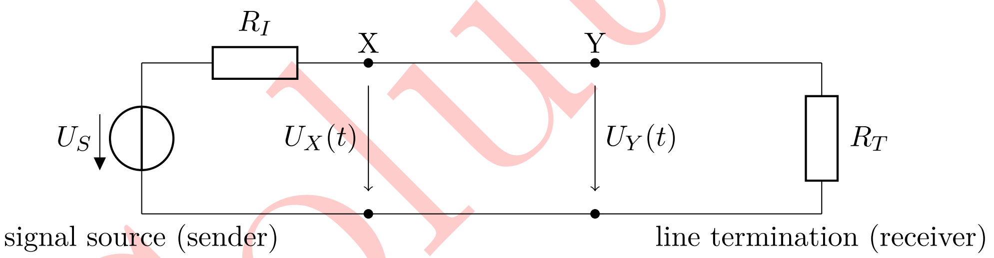

Figure 6.1: Test setup

A) How would you divide the timeline? Explain and mark at least four points on the timeline **1**

t_d (the propagation time of a wave on the wire) are quite distinct in the figure as the voltages on X and Y change abruptly.

B) Without calculation, make a quantitative statement about the reflection factors at the start and at the end. **1**

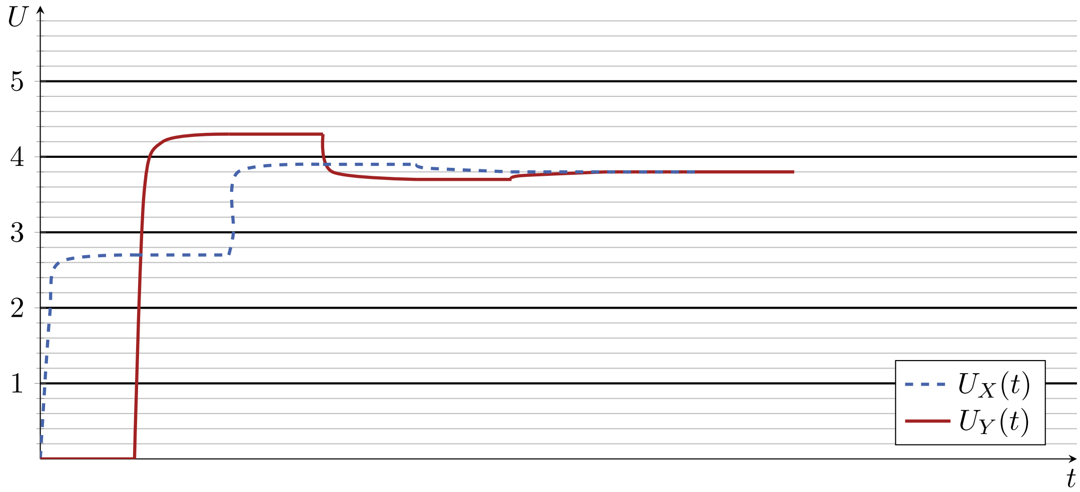

Figure 6.2: Measurement

U_y overshoots $U_\infty \rightarrow r$ at end positive,
value goes down $\rightarrow r$ at start is negative

C) Calculate the characteristic impedance Z_0 and the reflection factors at the start and at the end. **4**

At point Y: forward running wave $= 2,7V$
reflected wave $= 1,6V$
$r_e = \frac{1,6V}{2,7V} = 0,59$

At point X: forward running wave $= -1,6V$
reflected wave $= 0,4V$
$r_s = \frac{0,4V}{-1,6V} = -0,25$

$r_s = \frac{R_I - Z_0}{R_I + Z_0} \Leftrightarrow Z_0 = \frac{R_I - r_s RI}{r_s + 1} = \frac{33\Omega + 8,25\Omega}{0,75} = 55\Omega$

D) Calculate the internal sender voltage U_s **1**

$U_X(\infty) = 3.8V$ from Figure

$U_X(\infty) = U_S \frac{R_T}{R_T + R_I} \Leftrightarrow U_S = U_X(\infty) \frac{R_T + R_I}{R_T} = 3.8V \frac{200\Omega + 33\Omega}{200\Omega} = 4,427V$