ELEX 3525 Mid-Term Exam Solutions (term 201330)

Question 1 (5 marks)

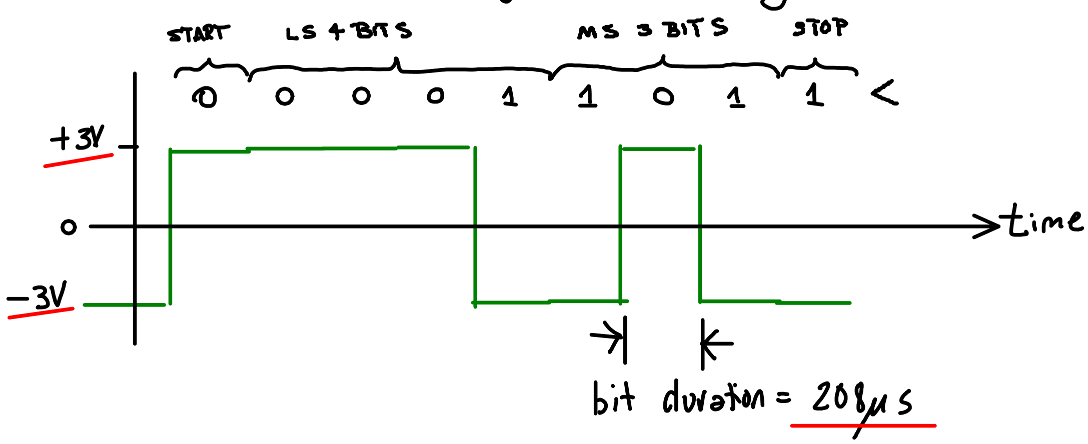
Sketch the RS-232 signal used to transmit the character 'X' ("capital ex") assuming a bit rate of 4800 bps, 7 bits per character and no parity. Show the complete waveform between line-idle conditions. Show the bit duration on the sketch.

The difference between the positive and negative voltages is the minimum allowed by the RS-232 standard. Show the voltage levels on the sketch.

From the Unicode standard, the codepoint for 'X' is 0x0058 which can be sent as one byte. The 7 LS bits are sent in order from LS to MS bit. $0x58_{16} = 1011000_2$

The bit period is $\frac{1}{4800}$ s $\approx 208\mu s$

The minimum voltages allowed by the standard are ±3V.



bits to transmit, including start (0) & stop (1) at beginning and end

MARKS WERE ASSIGNED AS FOLLOWS:

- correct bit values (0x58)
- correct bit order (LS to MS bit)
- correct start/stop bit polarity (+ve, -ve)
- correct voltages (+/- 3V)
- correct time scale (1/4800 s/bit)

90°

Question 2 (3 marks)

A 150 MHz signal is fed through a 40 cm length of co-ax cable. The cable causes an apparent phase shift of ~~45~~ 90 degrees. What is the delay? The velocity factor of the cable? The relative dielectric constant of the dielectric?

$\theta = 2\pi f \tau$ (radians)

$= 360 f \tau$ (degrees)

$f = 150\times10^6$

assuming $\theta = 45°$: $\tau = \dfrac{\theta}{360 f} = \dfrac{45}{360 \cdot 150\times10^6} = \underline{0.8\text{ ns}}$

assuming $\theta = 90°$: $\tau = \dfrac{90}{360 \cdot 150\times10^6} = \underline{\underline{1.6\text{ ns}}}$

$VF = \dfrac{\text{velocity in medium}}{\text{velocity in free space}} = \dfrac{\text{distance/time}}{3\times10^8\text{ m/s}} = \dfrac{0.4\text{ m}/0.8\times10^{-9}}{3\times10^8\text{ m/s}} = \underline{1.6}$ for $\theta = 45°$

for $\theta = 90°$: $\underline{\underline{0.8}}$

$VF = \dfrac{1}{\sqrt{\varepsilon_r}}$

$\varepsilon_r = \left(\dfrac{1}{VF}\right)^2 = \left(\dfrac{1}{1.6}\right)^2 = \underline{0.39}$ for $\theta = 45°$

$= \left(\dfrac{1}{0.8}\right)^2 = \underline{\underline{1.6}}$ for $\theta = 90°$

MARKS WERE ASSIGNED AS FOLLOWS:

- delay (method and value, 0.5 each)
- VF (formula and value, 0.5 each),
- epsilon r (formula and value, 0.5 each)

Question 3 (4 marks)

A typical phone line has an SNR of 45 dB and a bandwidth of 4 kHz.

Your manager asks you to buy a phone line modem that operates at 80 kb/s but you can only find ones that go up to 56 kb/s.

Why is this? Provide a quantitative (numerical) explanation based on theory covered in this course.

Shanon Capacity of the channel $= C = B \log_2\left(1 + \frac{S}{N}\right)$

$\frac{S}{N} = 45\text{dB}$ in linear units: $10^{\frac{45}{10}} = 10^{4.5} \approx 32 \times 10^3$

$C \approx 4 \times 10^3 \log_2(1 + 32 \times 10^3) = \underline{60 \text{ kb/s}}$

Error-free transmission is not possible at rates above capacity so it is not possible to manufacture error-free (i.e. useful) 80 kb/s modems.

MARKS WERE ASSIGNED AS FOLLOWS:

- using Shanon Capacity theorem
- correct capacity equation
- correct answers
- explanation that can't transmit error-free above capacity

Question 4 (4 marks)

A communication system uses a bipolar NRZ signalling over 50 ohm co-ax cable with voltages of ±5 V. The channel adds (zero-mean) Gaussian noise to the signal. The received signal to noise power ratio is measured to be 6 dB. What are the signal and noise powers in mW?

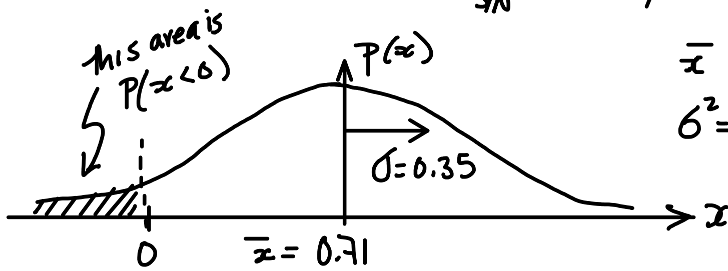
Consider the case where +5 V is transmitted. What is the probability that the sum of the signal plus noise is negative? You may use the approximation formula in Assignment 3.

Bipolar NRZ using ±5V: +5 sent for '1', −5 for zero.

signal power $= S = \frac{V^2}{R} = \frac{5^2}{50} = 0.5\,W = \underline{500\,mW}$ (same for −5 as for +5)

$SNR(dB) = 10\log\left(\frac{S}{N}\right) = 6\,dB \qquad \frac{S}{N} = 10^{\frac{6}{10}} \simeq 4$

noise power $= N = \frac{S}{S/N} \simeq \frac{0.5}{4} = 0.125\,W = \underline{125\,mW}$



$\bar{x}$ = mean = $\sqrt{\text{signal power}} = \sqrt{0.5} = 0.71$

σ^2 = variance = noise power = 0.125

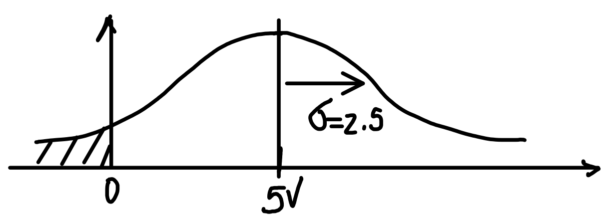
σ = std. devation $= \sqrt{\sigma^2} = \sqrt{\frac{1}{8}} = 0.35$

$$t = \frac{x - \bar{x}}{\sigma} = \frac{0 - 0.71}{0.35} \simeq -2$$

$$P(-2) \simeq \frac{1}{1 + e^{-1.7(-2)}} = \frac{1}{1 + e^{3.4}} = 0.03 \simeq \underline{3\,\%}$$

We could also have used the voltages: +5 for the signal

$$N = \frac{\overline{V^2}}{R} \qquad V = \sqrt{N \cdot R} = \sqrt{50 \cdot 0.125} = 2.5\,V$$



$$t = \frac{0 - 5}{2.5} = -2$$

$P(t) = P(-2) \simeq \underline{0.023}$ (USING CALCULATOR)

MARKS WERE ASSIGNED AS FOLLOWS:

- correct signal power
- correct noise power
- formula with correct parameters
- correct answer