# Written Exam
# Information Transmission - EITA30 (EIT100)

Department of Electrical and Information Technology
Lund University

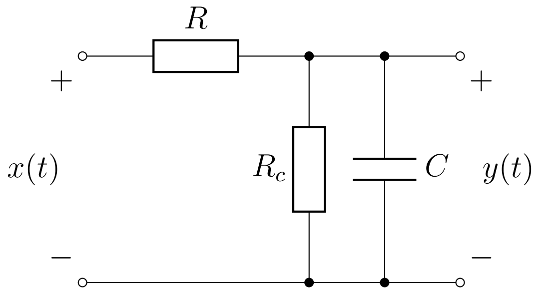
2019-06-03
14.00 – 19.00

The exam consists of five problems. 20 of 50 points are required to pass.

*Permitted aids:* Pocket calculator without any programs, scripts or files stored, formula collection without any notes.

- Write your personal identifier on each page.
- Each solution must be written on separate sheets.
- Your solutions must clearly reveal your method of solution.
- Problems are *not* sorted in order of difficulty.

1. Consider the circuit diagram




where we have a resistor $R$ in series with a realistic model of a capacitor, consisting of an ideal capacitance $C$ in parallel with a resistor $R_c$. The resistor $R_c$ models leakage of current through the non-ideal capacitor. In an ideal capacitor, $R_c = \infty$. The input and output voltage signals are $x(t)$ and $y(t)$, respectively.

   (a) Find the ideal and non-ideal frequency functions, $H_{\text{ideal}}(f)$ and $H_{\text{non-ideal}}(f)$, in terms of $R$, $C$ and, for the non-ideal case, $R_c$. (4 p)

   (b) Find the ideal and non-ideal impulse responses, $h_{\text{ideal}}(t)$ and $h_{\text{non-ideal}}(t)$, of the circuit. (4 p)

   (c) For most practical cases, the leakage resistance $R_c$ in the capacitor is MUCH LARGER than the resistor $R$ we connect in series and it is well motivated to assume the ideal case from above. Further, the product $RC$ is called the *time constant* of the circuit, since it determines how fast the circuit reacts to changes in the input. Assuming that the time constant for our circuit is $RC = 10$ ms, and $R_c \gg R$, find the output $y(t)$ for input $x(t) = 3\cos\omega_0 t$, where $\omega_0 = 100$ rad/s. (2 p)

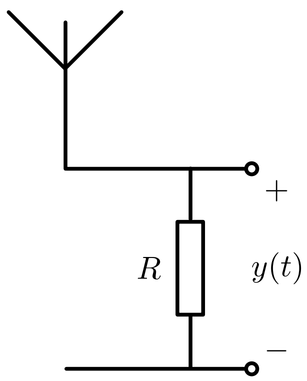
2. In this problem we consider wireless transmission of a music signal using 16-QAM (Quadrature Amplitude Modulation). The stereo music signal has a bandwidth of 20 kHz and the requirement is that the SNR of the music signal should be better than 60 dB. Assume that a convolutional $R = 2/3$ code is used for the wireless transmission, and that this gives error free transmission over the wireless link (in the sense that it does not influence quality).

   (a) What is the minimum bit rate giving sufficient SNR if standard PCM is used as source coding? (4 p)

   (b) What is the symbol time? (3 p)

   (c) What is the radio bandwidth if sinc pulses are used for communication? (3 p)

3. In transmission systems the receiver circuitry can often be modeled as a resistor, a noise source of a certain noise temperature, with $R = 50\ \Omega$ and a certain bandwidth. Assume that the bandwidth is 20 MHz and that the noise temperature is 800 K. The (somewhat oversimplified) model of the receiver antenna is shown in the figure below.




(a) What is the power of the Gaussian noise that is developed across the resistor, expressed in Watt? (4 p)

(b) Think of the antenna as a voltage source, it produces a $100\mu V$ radio signal over the resistor. What is the signal power? (3 p)

(c) What is the signal to noise ratio, expressed in dB? (3 p)

4. Adrianna wants to send names to Bob using as efficient source coding as possible. After observing Adrianna's behavior over a long time, Bob concluded that the probability of the different names to be sent are the ones shown in the table below.

| **Name** | $P(name)$ |
|---|---|
| Cecilia | 0.11 |
| David | 0.29 |
| Emmelie | 0.20 |
| Frank | 0.15 |
| Griselda | 0.25 |

(a) What is the uncertainty of each transmission? (3 p)

(b) Derive an efficient bit representation for the case when many names are sent after another using using as few bits as possible on the average for the transmission. Different lengths are allowed if this increases the efficiency. (5 p)

(c) What is the average word length using your bit representation and how far are you from the optimum representation? (2 p)

5. A two-key RSA crypto system is set up with the public parameters $n = 7849$ and $e = 25$.

(a) Find the cipher text $C$ corresponding to plain text $P = 1111$. (4 p)

(b) Unfortunately, you have forgotten the decryption exponent $d$. However, since you selected the key from the beginning, you know that 47 is a factor of 7849. Use this knowledge to calculate the decryption exponent $d$ again. (6 p)