Measuring systems

Problem set n° 7

Exercise 1 (Acquisition and Nyquist sampling theorem)

We would like to acquire and convert the following analog signal:

$$u(t) = A \cdot \cos(2000\pi t) + B \cdot \sin(6000\pi t) + C \cdot \cos(12000\pi t) \quad \text{with } A = 3V, B = 5V, C = 10\,V.$$

(a) What is the minimum sampling frequency required for a correct acquisition of the signal?
(b) If the signal $u(t)$ is acquired with a sampling rate $F_s = 5000\ samples/sec$, what is the discrete signal $u(n)$ that will be obtained? [$t = n \cdot \Delta t_{sampling}$]. What is the corresponding cut-off frequency that the reconstruction filter should have?
(c) In case we use $F_s = 5000\ samples/sec$, what is the analog signal that we can reconstruct from the samples? Comment on the results.
(d) (ONLY IN CASE WE HAD TIME TO COVER A/D RESOLUTION DURING THE LECTURES) If we use an A/D converter to digitalize the signal, what is the minimum required full scale range (minimum integer value)? What is the corresponding resolution if the converter has 8 bits?

Exercise 2 - OPTIONAL (Extrinsic noise and an asymmetric circuit from the previous chapter)

We would like to amplify and measure the RMS value of the **AC voltage source** $\underline{U}_s$ with internal resistance R_s and frequency f_s. For this, we use an amplifier with internal resistance R_i and gain A. Capacitive coupling "cable-ground" C_{c-g} and "network-cable" C_{n-c} are influencing the measurement. A voltage is obtained at the output of the amplifier $\underline{U}_m$, including parasitics and the signal from the source, which is measured using a voltmeter with internal resistance R_i (see Figure 1).

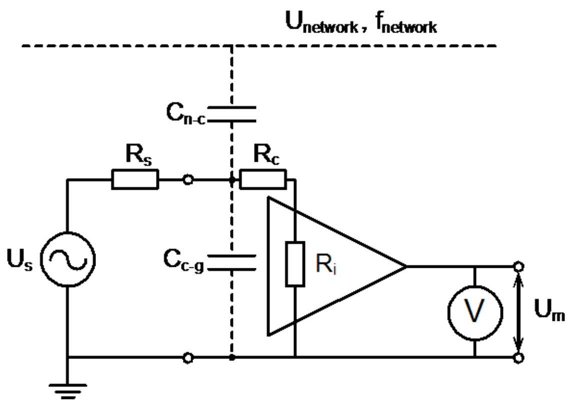

Figure 1: Capacitive coupling for an asymmetric circuit

- Give the expression of the parasitic voltage $\underline{U}_{m,n}$ measured by the voltmeter, caused by the source and the power line network. Consider that the input of the amplifier is isolated from the output.
- Calculate $|\underline{U}_{m,n}|$ and SNR in dB at the amplifier output.
- Propose two combined solutions to reduce noise and draw the circuit.

Data:

$A = 10$

$C_{n-c} = 10\,pF$

$C_{c-g} = 1\,pF$

$U_{network} = 230\,V$

$U_{s,eff} = 1\,V$

$R_i = 10\,M\Omega$

$R_w = 15\,\Omega$

$R_s = 10\,k\Omega$

$f_{network} = 50\,Hz$

$f_s = 50\,Hz$