Problem 1

A rectangular signal with amplitude around 10 microVolt and duration of 50µs comes from a voltage source accompanied by a broadband noise with effective spectral density $(S_V)^{1/2} = 20\ nV / (Hz)^{1/2}$ (unilateral spectral density). To amplify this signal a broadband amplifier featuring a gain Ap = 10000 and bandwidth limited by a simple pole at frequency fp = 1MHz is used. The amplifier wide band noise generators referred to the input feature an effective spectral density $(S_V)^{1/2} = 5\ nV / (Hz)^{1/2}$.

To measure the signal of interest you have a computer-controlled system that can carry out sampling (Sample-and-Hold), analog-to-digital conversion of samples, acquisition and processing of digitalized data.

a) Calculate the signal to noise ratio in the case of a single sample. Explain in detail every used formula.

b) Is it possible to increase the signal to noise ratio using more samples of the signal? If yes, design the new filter calculating its weighting function, the autocorrelation function and finally explain in detail, in time domain, the maximum achievable S/N.

c) It is now possible to use more than one rectangular signal to further increase the S/N since now the signals comes repeatedly with a period of 1s. The amplitude of the rectangular signal changes on a time scale of tens of seconds. How is it possible to use this information to improve the S/N? Provide a quantitative answer.

d) Considering now also a 1/f component with corner frequency 1KHz. A filter in the analog domain consisting of a baseline restorer is used to measure each SINGLE rect. Describe the weighting function and autocorrelation function of the filter. Then, discuss the guidelines to choose the parameters of this filter to obtain the best results with the signal of interest and provide an evaluation of its effect.

(NB: see text also on the other side of the sheet)

Problem 2

To measure the optical transparency of various materials at a wavelength of 800 nm, a laser diode with a 1 mW emission power is used as the source, which can simply operate in continuous or with 10% of the sinusoidally modulated optical power at 1 MHz (modulating the current in the diode).
As a detector we can use a Phototube or a silicon PIN photodiode (with a junction of about 30 microns thickness; surface reflection coefficient about 0.20) connected to a broadband current preamplifier (limited by a simple pole with frequency fpa = 100 MHz) having current noise referred to the input with white density component (unilateral) $(Si)^{1/2} = 1 \text{ pA} / (Hz)^{1/2}$ and component 1 / f with "noise corner frequency" fc = 100 Hz.

a) Describe quantitatively the difference between the two kind of detectors from all points of view.

b) Using the PIN, choose appropriately the filtering for continuous approach. Evaluate the sensitivity that can be obtained (the minimum measurable optical power) and the minimum value of the optical transparency coefficient that can be measured.

c) Using the PIN, choose appropriately the filtering for the modulated approach. Evaluate the sensitivity that can be obtained (the minimum measurable optical power) and the minimum value of the optical transparency coefficient that can be measured.

d) Describe the meaning of the SER of the phototube. Explain how it is possible to calculate it and the effect of the use of a grid to improve the value.