Problem 1

We want to measure the amplitude of a rectangular signal of duration $T_P = 100ns$ for which the synchronism signal is available. For the measurement it is possible to use a preamplifier with a large bandwidth limited by a single pole at $100MHz$ and affected by an input referred white noise with unilateral spectral density $\sqrt{S_V} = \frac{10nV}{\sqrt{Hz}}$, and a digital sampler.

a) Calculate the minimum measurable signal when the sampler is operated at the frequency of $100MHz$. Then discuss and evaluate if and how the sensitivity of the system changes if the sampler operating frequency is raised at $500MHz$.

b) Assuming now that multiple pulses are available with a fixed repetition rate of 1MHz and that the pulse amplitude varies slowly over time in the scale of 1s, calculate whether and how much it is possible to improve the two results obtained in the previous point.

c) Demonstrate in detail how it is possible to design the optimal filter in the case of signals accompanied by only white noise and in the case in which the noise is not white.

Problem 2

A weakly variable optical signal with a bandwidth of 10Hz at a wavelength of 500nm is to be measured. To this aim, a phototube featuring photon detection efficiency of 10% at the wavelength of interest and dark count rate equal to $10^3 e/s$ is available. An amplifier featuring one single pole at 100MHZ, an input impedance of $10k\Omega$ and total input-referred noise consisting of a white and a 1/f noise component ($\sqrt{S_V} = \frac{10nV}{\sqrt{Hz}}$, $f_c = 2kHz$) is exploited to read out the signal produced by the sensor.

a) Assuming that it is possible to modulate the optical signal by means of a chopper, calculate the minimum measurable optical power if the signal is accompanied by a constant background equal to 10'000 photons/s.

b) Discuss and quantitatively evaluate how the answer to point a) changes if the phototube is replaced by a PMT featuring a gain $G = 10^6$.

c) Explain in detail what the SER of a photocathode is and how it can be calculated starting from the detector specifications.