Problem 1

A sensor system emits a signals having the shape shown in the figure on the left with $\boldsymbol{T_P = 100ns}$ and variable amplitude. The available voltage amplifier has a bandwidth of 15 MHz and input referred noise generator featuring **unilateral** spectral density $\sqrt{S_V} = 10nV/\sqrt{Hz}$.

1) It is possible to use a digital sampler. Assuming that only one pulse can be acquired, calculate the obtainable signal-to-noise ratio. How does the answer change, quantitatively, if 2 and then 3 pulses can be acquired?
2) Considering that a Sync signal is available, compare the result with that obtained by choosing a feasible analog filter and dimensioning it to maximize the result.
3) Describe in detail how you can calculate the optimum filter and calculate the minimum detectable signal.

Problem 2

We want to measure the height of some square holes on a mechanical part using an optical signal. The position of the holes on the part is known, therefore a reference sync signal can be derived. The amplitude of the signal reflected from the hole follows the trend shown in the figure on the bottom right with $\boldsymbol{T_P = 1\mu s}$. In the absence of the hole, the signal is reflected by 10%. Exploiting a laser signal with a power of 10µW at 800nm and a wideband current amplifier with input-referred unilateral spectral density $\sqrt{S_I} = 10pA/\sqrt{Hz}$:

1) Calculate the minimum reflection coefficient of the hole that can be measured with a unitary SNR using a photocathode featuring a dark electron rate of 1000e /s and 2% efficiency at 800nm as a sensor, and any filter that can be useful.
2) Discuss quantitatively how the answer to point 1) changes if the photocathode is part of a PMT with gain $G=10^5$.
3) Considering now the presence of a 1/f component of the amplifier noise with f_C = 1kHz. With the same reflectivity found in the point 2), discuss quantitatively how the SNR changes. Any filter can be added if necessary.