Problem 1

A sensor system emits a signal having an exponential shape with $\boldsymbol{decay\ time = 100ns}$ and variable amplitude V_P. The available voltage amplifier has a bandwidth of 15 MHz and input referred noise generator featuring **unilateral** spectral density $\sqrt{S_V} = 10nV/\sqrt{Hz}$. A sync signal is available.
1) Evaluate the exploitation of a digital sampler with a minimum sampling time of 100ns. Discuss the best obtainable SNR in these conditions and evaluate the corresponding minimum amplitude V_P that could be measured.
2) Considering now that it is possible to acquire only two samples with a time spacing of 10ns. Evaluate the minimum amplitude V_P that could be measured in this case.
3) Describe in detail, in the frequency domain, how it changes the answer to point 1) if the sampling frequency could be pushed to infinite.

Problem 2

The optical power P_M of rectangular pulses of duration T_P emitted by a laser with a wavelength $\lambda = 620nm$ must be measured. A photomultiplier (PMT) or a semiconductor photodiode (PD) is used as the detector, in both cases with a load resistor R_L connected to a broadband, high input impedance preamplifier. The table shows the characteristics of the two detectors, of the load (including the total capacity C_L of the load circuit) and of the preamplifier.
1) Consider having to measure a single pulse of short duration $T_{P1} = 100ns$ using a gated integrator that receives the output from the preamplifier. First consider using the PMT, evaluate the weight of the various noise contributions and calculate the minimum measurable power P_M. Repeat the analysis considering using the PD. Compare and comment on the two cases, explaining the differences found in intuitive terms.
2) Consider now to be able to use a pulse of longer duration $T_P = mT_{P1}$. First consider to use the PMT proceeding as described above and determine the improvement of the sensitivity as a function of the factor m. Repeat the analysis considering using the PD and also in this case calculate the improvement in sensitivity as a function of m. Compare and comment on the two cases, explaining the differences found in intuitive terms.
3) Consider now to be able to use repetitive pulses of short duration T_{P1} and to average the measurements of N pulses. Determine the improvement in sensitivity as a function of the number N, first considering using the PMT and then the PD. Compare and comment on the two cases, explaining the differences found in intuitive terms.

PMT	PD
$\eta = 2\%$ at $\lambda = 620nm$ $n_B = 2*10^4$ c/s $G > 10^6$	$\eta = 50\%$ at $\lambda = 620nm$ $I_B = 2$ pA
Carico	Preamplificatore
$R_L = 1$ kΩ $C_L = 1pF$	$S_V^{1/2} = 1$ nV/(Hz)$^{1/2}$ (unilateral) $S_i^{1/2} = 0{,}5$ pA/(Hz)$^{1/2}$ (unilateral)

Signal Recovery