Problem 1

The amplitude of a sinusoidal signal at a frequency of 100kHz is constant within one period but it changes from period to period. We want to monitor the amplitude variations of such signal by measuring it at each period. A preamplifier featuring a bandwidth limited by a single pole (f_{PA} = 10MHz) and affected by both wideband noise (unilateral spectral density $\sqrt{S_V} = 2nV/\sqrt{Hz}$) and 1/f noise ($f_C$=1kHz) is used.

1) Assuming that the total measurement can last from a few minutes to a few hours and that only a single gated integrator is available to acquire the signal, discuss the optimization of the filtering and provide a reasonable and quantitative estimate of the minimum measurable signal amplitude.
2) Compare quantitatively the result obtained in the previous point with the best filtering strategy that could be ideally designed.
3) Discuss in detail the advantages and disadvantages of synchronous and asynchronous filtering for the recovery of the amplitude of a sinusoid. Quantitatively describe the result obtainable in the presence of only white noise for at least one optimized synchronous and one optimized asynchronous filtering.

Problem 2

A transmission system for encrypted messages consists of two channels: an optical channel for data and an electrical channel for a periodical synchronization signal, i.e. a clock. The two signals are sketched in the figure below. The transmission frequency is 100Mbit/s (T=10ns) and the optical signal is produced by a laser emitting at 514nm. The detection module exploits a PMT featuring a gain of 10^6 and an excess noise factor of 1.5. The readout electronics consists of an amplifier featuring an input impedance R_{IN} = 1kΩ, a bandwidth limited by a single pole f_{PA} = 1GHz and a wideband input-referred noise generator with unilateral current spectral density $\sqrt{S_I} = 2pA/\sqrt{Hz}$. The residual constant background radiation is of about 2*10^9 photons/s. In order to minimize the errors, a minimum $\boldsymbol{SNR_{MIN} = 3}$ is required.

1) Choose a filter suitable for maximizing the signal to noise ratio and eliminating the problem of background radiation. In these conditions calculate the minimum optical power of the laser required assuming that there are no optical losses in the transmission path.
2) Discuss and quantitatively evaluate how the response to point 1) would change in the following two cases:
   a. The transmission rate is reduced to 10Mbit/s
   b. The transmission rate is increased to 1Gbit/s
3) Describe quantitatively and in detail the differences between a PMT and an APD from the application point of view.