Problem 1

A digital sensor emits voltage pulse trains of height V_P and width 20ns. Every 100µs, following a command for which the sync signal is obtained, the square wave thus generated varies its duty cycle in a range between 10% and 50% and keeps it unchanged until the next sync. The signal is readout by a preamplifier featuring a large bandwidth limited by a single pole at 400MHz and input-referred wideband noise with unilateral spectral density $\sqrt{S_V} = 10nV/\sqrt{Hz}$.

1) define a fully analog filtering scheme that allows you to measure the number of pulses present between two successive syncs. Calculate the minimum value of V_P necessary to have a signal to noise ratio greater than 5.

2) Assuming to have digital components such as microcontrollers, digital sampler and comparators available, in addition to analog filters, evaluate how the response to point 1) changes quantitatively

3) Demonstrate which would be the best possible analog filter to use in point 1) if the sync for each pulse is also available

Problem 2

An ultra-fast optical pulse at a wavelength of 500nm is detected thanks to a 1mm-diameter silicon photodiode. The signal can be readout by a differential amplifier featuring very high input impedance, input-referred wideband noise $\sqrt{S_V} = 10nV/\sqrt{Hz}$ and $\sqrt{S_I} = 0.1\text{pA}/\sqrt{Hz}$ (unilateral spectral densities) and a single pole at 300MHz. We want to evaluate the energy of the optical signal.

1) Assuming to be able to place the readout electronics close to the sensor, design the front-end electronics and calculate the minimum detectable energy assuming that the best possible filter is available.

2) Consider now that the preamplifier is affected by 1/f noise with f_c = 20kHz. Assuming to be able to lose a maximum of 10% of the detected signal, evaluate if it is possible to make the 1/f noise negligible thanks to the use of a simple CR filter.

3) Consider now that three pulses arrive spaced by about 5µs and followed by a pause of 50µs. Discuss and design a suitable filtering scheme for this new scenario and evaluate the resulting sensitivity of the system.