Problem 1

The charge Q_S of an ultrafast (delta-like) current pulse signal is acquired using the circuit shown in the figure where $C = 10pF$. The preamplifier features an input impedance $R_{i,A} = 10M\Omega$, two input-referred noise generators with unilateral spectral density $\sqrt{S_V} = \frac{10nV}{\sqrt{Hz}}, S_i = \frac{0.1pA}{\sqrt{Hz}}$, and its bandwidth is limited by a single pole at $f_A = 200MHz$.

1) Calculate the minimum charge Q_S that could be ideally measured using an optimal filter. Then evaluate the minimum charge that can be obtained replacing the matched filter with a sampler at the frequency of 10MHz and applying a suitable digital filtering.

2) Calculate the minimum charge Q_S that could be measured if the sample&hold of the sampler of point 1) is replaced with a gated integrator featuring an integration window of duration $T_G = 10ns$ (i.e. the signal is sampled multiple times, each sample is obtained integrating for an interval T_G=10ns).

3) Compare from a theoretical point of view the filtering action that can be obtained using a boxcar integrator and the one achievable using a ratemeter integrator.

Problem 2

We want to detect the optical signal emitted by a sample excited by a laser. The sample is excited at a frequency of 10 MHz and it emits an exponential optical signal with a decay time of 4ns at a wavelength of 800nm. The current signal produced by a photodetector is collected using a 10-kΩ resistor followed by an amplifier featuring a large bandwidth limited by a single pole at 500 MHz and input-referred noise with unilateral spectral density having a wideband component ($\sqrt{S_V} = \frac{10nV}{\sqrt{Hz}}$) and 1/f noise component with frequency fc=2kHz. An optical bandpass filter with a narrow bandwidth centered at 800nm is exploited. Nevertheless, a residual background of 10^4 ph/s at 800nm reaches the photodetector.

1) Considering the exploitation of a silicon photodiode, define the characteristics that you consider reasonable for the detector in this application. Design a suitable filtering scheme and calculate the minimum detectable optical power of the signal.

2) Evaluate how the answer to the previous point would change if a silicon APD were available.

3) Compare silicon APD detectors and PMTs from a theoretical point of view.