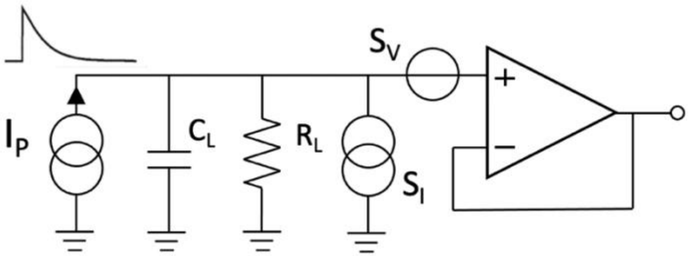
Problem 1

As sketched in the figure below, a current signal is acquired by a preamplifier featuring a very high input impedance (of the order of 1 GΩ), a band limited by a single pole at a frequency f_P = 200 MHz and two input-referred noise generators with unilateral spectral densities $(S_V)^{1/2}$=1 nV/(Hz)$^{1/2}$ and $(S_I)^{1/2}$=1 pA/(Hz)$^{1/2}$. C_L=2pF and R_L=10 MΩ represent the total capacity and resistance, respectively, between the sensor output and ground. The detector delivers trains of exponential pulses with unknown amplitude A_P, decay time constant T_P=20ns and repetition rate r_P=1kHz. The duration of the measurement can span from 1 to 20 min.

1) Describe in detail how you can calculate the **optimum filter** and **calculate the minimum amplitude** that could be detected for each single pulse.
2) Considering now that the amplitude of the pulses slowly changes with a timescale of 1s, **design a suitable filter** to exploit this new information and **calculate the minimum detectable signal amplitude** with the proposed solution.
3) Considering now that the current noise of the preamplifier has also a 1/f component with fc = 50kHz**,** evaluate its effect on the measurement in the conditions of point 2). Then provide a solution to limit its effect and **calculate the minimum detectable signal amplitude** with the proposed solution.



Problem 2

Samples of a fluid flowing inside a capillary at a speed of 20cm/s are analyzed. We want to detect with S/N>10 the presence of any micro-bubble whose size is 1um. To do this, a continuous wave laser emitting at 800nm and a silicon APD are used to measure the light reflected by the fluid within the capillary. Each sample is analyzed in about 30minutes. The fluid reflectivity is 5% while the bubble one is 6%. The light coming from the capillary is focused on a small spot of the APD (<<1um). The detector features G=200, F=2, a dark current rate of 1000electron/s and it is connected to a transimpedance amplifier having total wideband noise referred to the input with unilateral spectral density $\sqrt{S_{I,U}} = 0.1pA/\sqrt{Hz}$.

1) Choose a reasonable detection efficiency of the APD and describe a suitable acquisition scheme. Motivate your answer and **calculate the minimum laser optical power** necessary to achieve the desired S/N. Consider the bubble like a square of different reflectivity.
2) Discuss how would you change the answer to point 1) if the **fluid speed is reduced to 200µm/s**. Calculate the minimum necessary laser optical power in this new scenario.
3) In the conditions of point 2), consider now also the presence of a **1/f noise component** of the amplifier with **fc = 2kHz.** Calculate the minimum necessary laser optical power with and without a modulation of the laser.