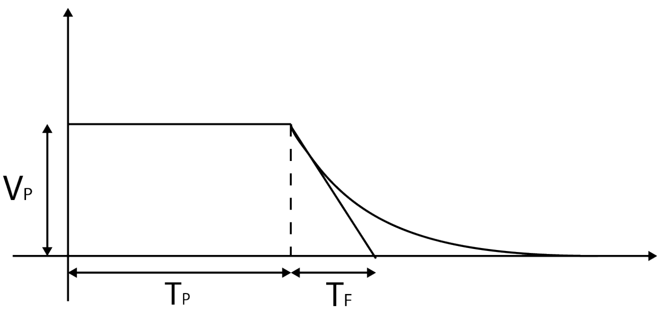
Problem 1

Pulse signal V_P variable pulse amplitude T_P = 10 μs main pulse duration T_F= 2 μs exponential decay time	
Preamplifier $S_V^{½} = 10nV/Hz^{1/2}$ white noise power density (unilateral) $f_{pa} = 5\ MHz$ upper band-limit	in (D): f_P = 100 Hz pulse repetition frequency

Pulse signals with waveform reported in the figure are issued from a low impedance source and fed to a high-impedance-input preamplifier with the features above reported. The arrival of the signals is periodic (with a sync) at repetition frequency f_P , the amplitude V_P changes with time scale of 1s and must be individually measured. **Consider for the point (A), (B) and (C) only a single pulse**:

A) Indicate and illustrate the filtering that gives the optimum result in the measurement. Compute the optimum S/N value thus obtained and evaluate the minimum measurable amplitude. Compare the results with the one with no filter.

B) Consider now to employ filters with variable parameters. Select a suitable practical filter, select its parameters for maximizing the Signal-to-Noise ratio (S/N) and evaluate the minimum measurable amplitude VP,min.

C) Measurements employing simple discrete-time filters cn be used to approximate the optimum filter. Select a discrete-time filter, which processes the signal and noise at the preamplifier output by taking samples at short time intervals and by weighting the samples with a specified distribution of weights. Explain how you choose the time intervals and any approximation you find useful.

D) Consider now a case where the sequence of pulses has a repetition frequency fP. Explain how it is possible to use this information to increase the S/N and reduce minimum measurable amplitude VP,min. Select a filter for the measurement of the pulse sequence, explaining the reasons of the choice and compute the improvement of S/N.

(NB: see text also on the other side of the sheet)

OPTICAL SIGNAL	PREAMPLIFIER
- wavelength λ= 500nm, - exponential decay time T_F=100 µs - variable Optical power P	- Load Resistance R_L=1kΩ - Load Capacitance C_L=2 pF - Current Noise (unilateral) at amplifier input $\sqrt{S_{iA}} = 1\, pA/\sqrt{Hz}$ - Voltage Noise (unilateral) at amplifier input $\sqrt{S_{v,u}} = 20nV/\sqrt{Hz}$ - Bandwith: 5MHz
	PIN PHOTODIODE - Detection efficiency η_d=0,60 at λ= 800nm - Dark current $I_{Dd}=2\cdot 10^{-12}$ A = 2 pA

A single molecule, excited by laser pulses, emits pulses with an exponential waveform. The emitted pulse amplitude (i.e. the optical pulse power) must be measured employing as analog photodetector the PIN photodiode and the preamplifier as above specified.

A) Estimate the detection efficiency of the photodiode at the signal wavelength.

B) Evaluate the minimum measurable pulse amplitude specified in current and in photoelectron rate without using any filter.

C) Select a practical filter suitable for obtaining a signal-to-noise ratio as good as possible and explain the reasons of your choice and evaluate the minimum measurable pulse amplitude specified in current and in photoelectron rate

Let us consider now to employ instead of the PIN a PMT with S20 cathode photodiode and the same preamplifier used for the PIN.

D) Evaluate the total spectral noise density that the signal must face in this case, compare with the case with PIN and comment, analyze whether or not the fluctuations of the photocurrent set in this condition a higher limit to the minimum measurable amplitude. In conclusion, evaluate the actual minimum measurable current pulse amplitude in this condition and the corresponding minimum measurable optical pulse amplitude, in photon rate.

E) How it changes the situations if we decide to use the PMT in single photon counting regime?