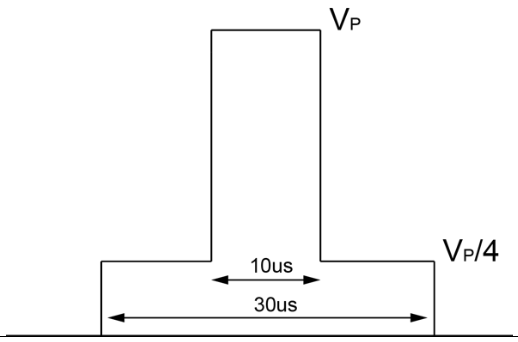
(NB: see text also on the other side of the sheet)

Problem 1

<table>
<tr><td>Pulse signal
V_P variable pulse amplitude

Preamplifier
$S_V^{1/2} = 20nV/Hz^{1/2}$ white noise spectral density (unilateral)
$f_{pa} = 50\ MHz$ upper band-limit</td><td></td></tr>
<tr><td></td><td>Fig. 1</td></tr>
</table>

Consider the signal shown in Fig 1. The characteristics of the preamplifier used to read out the signal are above specified.

A) Evaluate the minimum measurable amplitude $V_{P,MIN}$ without using any additional filter. Then, describe and <u>explain</u> the ideal filter that makes it possible to measure the pulse amplitude V_P with the best possible Signal-to-Noise ratio and evaluate the minimum amplitude $V_{P,MIN}$ thus measurable.

B) Consider now to employ filters with variable parameters. Select a suitable practical filter, select its parameters to maximize the Signal-to-Noise ratio (S/N) and evaluate the minimum amplitude $V_{P,MIN}$ that can be measured in these conditions.

C) Consider now to follow a fully digital approach. Discuss the guidelines to select the sampling frequency and how this choice could have an impact on the Signal-to-Noise ratio. Choose a reasonable value for the sampling frequency and evaluate the minimum amplitude $V_{P,MIN}$ that can be measured in this case.

D) Consider now an additional 1/f noise component with a corner frequency f_C=5kHz affecting the preamplifier. Discuss the impact of this additional noise component on the final S/N and propose at least two different solutions to minimize this effect. Choose one of the two proposed solutions, provide quantitative data (e.g. filter parameters) and evaluate the minimum amplitude $V_{P,MIN}$ that can be measured in these conditions.

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Problem 2

SPAD PHOTODIODE	**PREAMPLIFIER**
Area=0.007 mm^2 Detection efficiency @500nm= 50%; Dark counts=10 cps	- Load Input Resistance R_L=1kΩ - Load Input Capacitance C_L=2 pF - Current Noise (unilateral) at amplifier input $\sqrt{S_{iA}} = 1\,pA/\sqrt{Hz}$ - Voltage Noise (unilateral) at amplifier input $S_{vA} = 1nV/\sqrt{Hz}$

We want to study the Earth surface by measuring the time of flight of pulses sent from a satellite in a low orbit (200km from the ground). To perform this measurement, a square laser pulse (pulse width = 1us) at λ=500nm is used, while an APD is used for detection.

1) Discuss and select the most appropriate repetition frequency of the laser. Being able to choose among different APDs, discuss the main features of an APD that could be successfully exploited in this measurement and calculate its detection efficiency and sensitivity.

2) Assuming that the selected APD has a dark current of 1pA and considering the preamplifier with the above reported characteristics, <u>select a suitable filter</u> for this measurement and evaluate the minimum power of a SINGLE laser pulse that can be measured.

3) Due to the movement of the satellite along its orbit, it is possible to make measurements with a maximum duration of 1s. Discuss how the previous measure can be improved and calculate the minimum power that can be measured in this new scenario.

4) How would the situation change if the SPAD with the above reported characteristics was used to replace the APD? Following this approach, calculate the minimum power that can be measured in this case.