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Problem 1)

1) We can exploit the sync signals and integrate the input waveform continuously between two consecutive syncs. The output is proportional to the number of pulses occurring in that time window. Worst case scenario for the SNR is when the repetition time is maximum (200ns), i.e. we have the lowest number of pulses (500). In this case a SNR>5 is obtained with Vp>35µV.
2) A mixed-signal circuit allows us to digitally count the pulses. To this aim we can use:
   - MMF to integrate pulses producing peaks
   - Comparator to identify such peaks
   - Digital counter

     In this scenario, we need a SNR>3 on each pulse to distinguish it from noise. For a fair comparison with point 1) we'll consider a target SNR=5.

   A MMF with Tg=Tp would require Vp>250µV.

   It can be noted that in this case a higher Vp and more components are required, but the output of interest (number of pulses) is directly produced.
3) The optimum filter would integrate the signal only when it is present. On the single pulse we have the same SNR of point 2. Using N pulses improves the SNR by $\sqrt{N}$. Vpmin is chosen on the basis of the worst case scenario (N=500). Vpmin=11µV

Problem 2)

1) Placing the readout electronics very close to the detector allows us to avoid low-impedance cables. Therefore, the sensor load is given only by its own capacitance. Considering a depleted region of 5µm (tradeoff capacitance-efficiency) we have $C_S = 8.3pF$. Due to this capacitance the noise is not white. Therefore, we need a withening CR filter before the matched filter. $\tau_{CR} = C_S R_{EQ} = 830ns$, noise becomes white and the signal is an exponential. $V_{Pmin} = 11\mu V$. PDE@500nm=65%, $S_D = 0.26A/W$, $E_{MIN} = 351\ aJ$.
2) To limit the 1/f noise component of the amplifier current noise we need an additional high pass filter. Considering a CR and assuming a sharp cut off of the signal at $f_{P,CR}$, we need $f_{P,CR} \leq 3kHz$ to meet the requirements. Since $f_{P,CR} < f_C$ we have a 1/f noise contribution of $3\mu V$ which is not negligible with respect to white noise ($5.5\mu V$).
3) In order to evaluate the effect of a suitable filtering scheme, let's consider an ideal case where we have a sync for each pulse, thus allowing us to implement a correlated double filtering. Note that a CR would not be a good option here because of the uncertainty on the time interval between pulses. The noise integration window is placed before the 3-pulses burst with a duration of 42µs to avoid noise doubling. Considering three CDF with different time distances between the windows, we get $V_{Pmin} = 7.1\mu V$ and $E_{MIN} = 267\ aJ$.