26/1/22

Problem 1

1) The shape of the signal is not modified by the preamp since $T_P \gg \tau_P$. ($\tau_P = 10.6ns$)

For the sake of simplicity, we take only samples with uncorrelated noise. Due to the preamplifier limited bandwidth, $5\tau_P = 5 * 10.6ns = 53ns$ are necessary to consider noise samples uncorrelated.

Case a) "1 sample". The samples is collected where the signal features the maximum amplitude. Therefore, $V_{P,MIN} = \sqrt{S_V * \frac{\pi}{2} f_P} = 48\mu V$.

Case b) "2 samples": The two samples can be both collected on the highest peak with a time distance of at least 53ns. As a result, $V_{P,MIN} = \frac{48\mu V}{\sqrt{2}} = 33.9\mu V$.

Case c) "3 samples": to collect uncorrelated noise, we can take only two samples on the peak and 1 samples at $V_P/2$. Therefore, $V_{P,MIN} = \sqrt{S_V * \frac{\pi}{2} f_P} * \frac{\sqrt{3}}{2.5} = 33.2\ \mu V$.

Comment: taking the third sample at $V_P/2$ is not convenient as the result is substantially the same of taking only two samples on the peak, but requiring more resources.

2) A single gated integrator with optimized width can be exploited. The best choice is $T_G=2T_P$, collecting the two highest peaks (V_P and $V_P/2$) of the signal. $V_{P,MIN} = 29.8\mu V$.
3) The optimum filter features a weighting function having the same shape of the signal. By exploiting this ideal theoretical filter, it would be possible to achieve $V_{P,MIN} = 19.51\mu V$.

Problem 2

1) S_D=0.013A/W. Exploiting the sync signal, a gated integrator centered around the hole signal with $T_G=T_P$ can be used, obtaining a minimum current signal of 7nA, which corresponds to a minimum power of 538nW. In this case, $R_{H,MIN}$=5.6%
2) With $G=10^5$ and F=2 (reasonable), the electronics noise weight is reduced. Consequently, the minimum current signal is reduced down to 335fA, corresponding to a minimum power of 25.8pW. In this case, $R_{H,MIN}=2.58*10^{-4}$ %
3) The presence of 1/f noise makes it necessary to add a high pass filter. A CDF can be exploited, but a careful sizing is mandatory because of the presence of the baseline B. A comparison of the white noise main contributions (electronics noise, signal noise and baseline noise) shows that the highest spectrum is associated with the baseline B. Since the signal and the preamplifier noise are integrated for TP to maximize the signal, the noise integration window must be at least n times longer than T_P, where $n=I_B/I_S$=38800. To make the baseline noise negligible, we can exploit an integration window 10*n times longer than T_P, that is T_N=388ms. By doing so we also get a negligible contribution of 1/f noise, thus achieving the same SNR of point 2) with the same $R_{H,MIN}$.