14/06/22

Problem 1)

1) a. (1 sample) acquire the signal peak, white noise is limited by the preamp. $V_{P,MIN} = 25\mu V$.
   b. (2 samples) acquire two signal peaks, noise is uncorrelated. $V_{P,MIN} = 17.7\mu V$
   c. (N samples) acquire signal peaks, noise is uncorrelated, SNR improves by $\sqrt{N}$ (tradeoff sensitivity vs duration of the measurement).

2) Bandpass filter collects the sinusoidal signal and noise in the filter bandwidth. $V_{P,MIN} = 0.79\mu V$.

3) a. (1 sample) due to 1/f noise, SNR is ideally 0. Practically a lower bandwidth limitation always exists (e.g. zero setting).
   b. (2 samples) a CDS can be implemented. $V_{P,MIN} = 17.7\mu V$ (white noise is the dominant contribution).
   c. (N samples) uncorrelated noise can be reduced by averaging while uncorrelated noise can't. To reduce white noise at the level of 1/f, N=1275 samples are necessary. Using N>>1275 would not be effective on SNR due to 1/f noise.
   d. with the bandpass filter the 1/f noise is well removed. $V_{P,MIN}$ is the same of point 2.

Problem 2)

1) Wavelength of interest: 800nm. Reasonable PIN parameters: R=0.2, t_N=200nm, t_D=10µm, leading to PDE(800nm)=50% and S_D=0.32A/W. Dark current: I_D=1pA. The current signal produced by the PIN can be directly collected by the current preamplifier followed by a gated integrator with T_G=100µs. Electronics noise is the dominant contribution: $I_{S,MIN} = 7pA, P_{det,MIN} = 21.9pW, \mathbf{P_{LASER,MIN}} = \mathbf{438pW}$.
2) Reasonable APD parameters: same sizing and material of PIN, G=100, F=2. Same acquisition chain of point 1) except for T_G=1µs. $I_{S,MIN} = 1.08pA, P_{det,MIN} = 3.375pW, \mathbf{P_{LASER,MIN}} = \mathbf{67.5pW}$.
3) A high-pass filter is necessary because of 1/f noise. Possible solutions:
   a. Laser operated in CW-mode + a chopper (either within or outside the signal window) + CDF or squarewave LIA.
   b. Modulated laser

   Considering the exploitation of the laser modulated at f_{MAX} (maximize signal) and a LIA with a sinusoidal reference (from the laser) and a $f_{P,LPF}$=100kHz. With $P_{LASER,max} = 4nW$, non stationary noise component is negligible with respect to stationary noise. SNR=32pA/56pA=0.57.
   Comment: an alternative solution must be implemented to get a good SNR.