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

Problem 1

Non-invasive measurement of the blood flux in a living being can be carried out focusing a light source toward a target and measuring the variations of the reflected optical signal.

Consider a laser diode emitting continuous light at λ=850nm and an overall useful reflectivity R of about 5%. The signal of interest is collected by a photosensor providing a current signal with S=0.226 A/W; the front-end consists of a 50Ω resistor followed by a preamplifier having f_{PA}=20MHz and input referred noise with unilateral spectral densities $S_V^{½} = 1nV/Hz^{1/2}$ and $S_I^{½} = 0.05pA/Hz^{1/2}$.

The pole due to the capacitance of the photosensor is well above the frequency range of the acquisition system; thus, its presence can be neglected.

A) Evaluate the minimum needed optical power of the laser diode without any filtering.
B) Considering that the reflectivity R to be measured varies slowly over time (few tens of ms range), select a constant-parameter filter to reduce the minimum required power. Explain the filtering scheme, select the filter parameters and evaluate the minimum needed optical power of the laser diode in these conditions.
C) Consider now the presence of ambient light at the same wavelength of the signal and having slow fluctuations in tens of ms range. Discuss a solution to extract the signal of interest in these conditions. Describe in detail an acquisition scheme to implement the proposed solution, select its parameters and evaluate the minimum needed optical power of the laser diode in this scenario.
D) Consider now the presence of 1/f noise with f_C=1kHz. Evaluate its impact on both the measurement setup of point 2 and of point 3.

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

Problem 2

Considering the same application of Problem 1, we will now focus on the choice of a suitable photosensor.

A) Given the choice between a photodiode and a phototube, discuss which one is preferable for the target application. Select one of these two sensors and provide a quantitative estimation of its parameters to meet the application requirements.

B) Considering now to exploit an APD with G=100 as photosensor, solve point B) of Problem 1.

C) Discuss and evaluate how the solution of point B) of this problem would change if the APD is replaced with a PMT.

D) Describe the excess noise factor of a PMT: what is it and what is its origin?