Problem 1

A sinusoidal voltage signal $V_P \sin(2\pi\ 1MHz\ t)$ is acquired by means of a voltage preamplifier featuring a wideband limited by a single pole at $f_A = 100MHz$ and input-referred noise generator with unilateral spectral density $\sqrt{S_V} = 2nV/\sqrt{Hz}$.

1) Consider the exploitation of a synchronous digital filtering scheme with maximum sampling frequency $f_S = 10MHz$. Design and describe the acquisition scheme and evaluate the minimum amplitude of the signal that can be recovered by exploiting just 1 sample or 2 samples (evaluate both cases). Discuss how the situation would change if N samples could be acquired.

2) Consider now the possibility of exploiting a resonant band-pass filter tuned at $1MHz$ with $Q = 10$. Calculate the minimum amplitude of the signal that could be recovered in this case.

3) Consider now the presence of an additional 1/f noise component with $f_C = 10kHz$. Discuss and evaluate how the answer to point 1) and 2) would change in this new scenario.

Problem 2

A point-scanning system for non-invasive analysis of human tissues has been designed exploiting a near-infrared continuous wave (CW) laser diode to illuminate the target, a photodetector to collect the back-scattered light, and a current preamplifier (low input impedance, input-referred noise with unilateral spectral density $\sqrt{S_I} = 0.1pA/\sqrt{Hz}$, one pole at $50MHz$) to pick up the current signal. The tissue reflection coefficient is 5% while travelling power loss can be neglected.

1) With a scanning time of $100\mu s$ per spot, consider the exploitation of a PIN photodetector. Design and describe a suitable acquisition scheme and calculate the minimum power of the laser that is necessary to carry out the measurement in this scenario.

2) In order to improve both the temporal resolution and the sensitivity of the system, the scanning time is reduced to $1\mu s$ per spot and the PIN photodetector is replaced with an APD. Calculate the minimum power of the laser that is necessary to carry out the measurement in this new scenario. The acquisition scheme can be modified, if needed.

3) In the conditions of point 1, consider now the presence of an additional 1/f noise component ($f_C = 1kHz$). The laser can be not only operated in CW-mode but it can be also sinusoidally modulated between $10kHz$ and $1MHz$ (maximum peak power: 4nW). Design and describe a suitable acquisition scheme for this new scenario and calculate the resulting SNR.