Problem 1

An industrial monitoring electronic system produces voltage pulses with constant amplitude V_P that depends on the system bias and variable duration T_P in a time range between 25ns and 100ns. The signal is periodic with fixed repetition time $T_R = 350ns$ and it is readout by a preamplifier featuring a large bandwidth limited by a single pole at 350MHz and input-referred wideband noise with unilateral spectral density $\sqrt{S_V} = 10nV/\sqrt{Hz}$. The system is reset every day.

1) Design and describe a constant-parameter filtering scheme that allows you to extract the information about the duration of the signal. Calculate the minimum amplitude V_P that is necessary to achieve a peak SNR>3 in any case.

2) Consider now the presence of an additional 1/f noise component ($f_c = 10kHz$). Having the possibility of acquiring an additional pulse per period besides the scheme of point 1) with additional linear electronics, discuss how would you use this possibility to limit the impact of 1/f noise and evaluate the minimum amplitude V_P that is necessary in this new scenario to still achieve a peak SNR>3 in any case.

3) Discuss if the measurement of point 2) could be improved by freely choosing the most suitable solution for this problem. Design and describe the acquisition scheme and evaluate the minimum amplitude V_P that is necessary in this case for a SNR always better than 3.

Problem 2

A steel bar (Young Modulus $22 * 10^4 N/mm^2$, section $16mm^2$) is constantly subject to a slow compression force featuring smooth variations on a timescale of about 100ms. The temperature of the environment surrounding the bar is expected to be around 40°C with a security system that activates whenever the temperature exceeds 50°C. A system based on strain gauges has to be designed to measure the force with high sensitivity. The signal can be readout by a differential amplifier featuring input-referred wideband noise $\sqrt{S_I} = 0.1\text{pA}/\sqrt{Hz}$ (unilateral spectral density) and a single pole at 100MHz.

1) Having a maximum power budget of 10mW for the sensors, design and describe a simple yet suitable acquisition scheme for this application, providing a quantitative explanation of every choice. Evaluate the minimum force that could be measured without any filter.

2) Consider now the exploitation of a digital sampler featuring a maximum sampling frequency of 100KHz. Discuss how such system could be employed to improve the sensitivity of the system and evaluate the minimum force that could be measured in this case.

3) Consider now the presence of an additional 1/f noise component at the input of the amplifier with $f_c = 5kHz$. A sinusoidal voltage source at 50KHz with amplitude up to 5V is available. Having the possibility of acquiring N=100 samples with the digital sampler of point b, describe a suitable approach to limit the 1/f noise and evaluate the minimum force that could be measured in this case.