Problem 1

We want to measure the amplitude of a sinusoidal signal (f_S=100Hz) that is superimposed to a non-negligible undesirable baseline that slowly varies on a time scale in the order of tens of seconds. The readout circuit consists of an amplifier featuring a single pole (f_A=100 MHz) and affected by an input referred white noise with unilateral spectral density $\sqrt{S_V} = \frac{10nV}{\sqrt{Hz}}$. The frequency of the signal can be easily derived from an auxiliary synchronized sinusoidal reference that is available with a high SNR.

a) Assuming that you can only carry out DIGITAL filtering with a maximum sampling frequency of 200Hz, and that the amplitude of the signal varies on a timescale in the order of a second, design a filter that allows you to extract the desired signal amplitude with high sensitivity. Evaluate the minimum signal amplitude that could be measured with the designed solution.

b) Being now able to carry out any kind of filtering, discuss and evaluate how the answer to the previous point changes.

c) Taking a generic gated integrator as an example, describe in detail (from a theoretical point of view) in the time domain the difference between the signal-to-noise ratio obtainable with analogue and digital filtering as the sampling frequency varies.

Problem 2

To control the force of a jackhammer a system based on strain gauges is used. The force pulse lasts for 100ms and it is followed by a 100ms pause. A sync signal for each pulse is available. A maximum power supply of 1.8V, voltage differential amplifiers featuring a bandwidth limited by a single pole at 100MHz and affected by input-referred voltage noise generator with unilateral spectral density $\sqrt{S_V} = \frac{10\text{nV}}{\sqrt{Hz}}$ are available. The sensors are mounted on a metal bar (Young Modulus E=18*10^4 N/mm^2, section 3x5cm^2).

a) Design and describe a setup for measuring the applied force with high sensitivity and avoiding any effect related to the bending of the bar. With the proposed solution calculate the minimum measurable voltage signal and the corresponding measurable compression force for each single pulse.

b) Consider now an additional 1/f noise component with f_C=1kHz. Assuming that the applied force varies on a timescale in the order of 100 seconds, explain how it is possible to modify the setup and the filtering designed in point A) to achieve a high SNR in this new scenario. Then, calculate the new minimum measurable signal.

c) Explain in detail how a strain gauge works and in particular the meaning of the gauge factor and how it can be calculated from a physical point of view.