Problem 1

Preamplifier	**Strain gauges**
$S_V^{1/2} = 4nV/Hz^{1/2}$ white noise power density (unilateral) $S_I^{1/2} = 4pA/Hz^{1/2}$ white noise power density (unilateral) f_{pa} = 160kHz upper band-limit (single pole) frequency corner 1/f on S_V = 500Hz frequency corner 1/f on S_I =1000Hz	R_S = 100 Ω Gauge Factor G = 2,5 P_{MAX} =1 μW

Two metal strain gauges are placed on a metal bar to measure extrusion and compression deformations and to compensate for the thermal effects on the sensors. The deformations to be measured can be both static and dynamic and you want to detect small deformations and track them over time sampling every 5ms.

A differential preamplifier with the parameters specified above is used to pick-up the signal.

a) Select and explain the circuit configuration to be used to obtain the electrical signal that carries the deformation information. Define the parameters of the filter and quantitatively evaluate the output signal as a function of the deformation.

b) Evaluate the minimum measurable deformation value without any filter. Illustrate a filtering method to increase the signal to noise ratio. Define filter parameters and evaluate the minimum deformation value measurable in this way.

The metal bar is connected to a motor rotating at about 2500 rpm and you want to measure the induced vibration in the structure at the motor rotation frequency.

c) Choose a further filtering method that allows you to extract the vibration at the frequency of the motor from the deformation and measure it separately. Define the structure and the parameters of the apparatus to be used. Evaluate in these conditions the minimum amplitude of the deformation you can measure.

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

Problem 2

OPTICAL SIGNAL - wavelength λ= 500nm, - exponential decay time T_F=100 μs - variable optical power P	**PREAMPLIFIER** - Load Resistance R_L=1kΩ - Load Capacitance C_L=2 pF - Current Noise (unilateral) at amplifier input $\sqrt{S_{iA}} = 1\, pA/\sqrt{Hz}$ - Voltage Noise (unilateral) at amplifier input $\sqrt{S_{v,u}} = 20nV/\sqrt{Hz}$ - Bandwidth: 5MHz
	PIN PHOTODIODE - Detection efficiency η_d=0,60 at λ= 800nm - Upper neutral region width= 100nm - Reflection coefficient: 10% - Dark current $I_{Dd}=2\cdot 10^{-12}$ A = 2 pA

A single molecule, excited by laser pulses, emits pulses with an exponential waveform. The emitted pulse amplitude (i.e. the optical pulse power) must be measured employing the PIN photodiode as analog photodetector and the preamplifier as above specified.

a) Estimate the detection efficiency of the photodiode at the signal wavelength.

b) Without using any filter, evaluate the minimum measurable pulse amplitude specified in current and in photoelectron rate.

c) Select a practical filter suitable to obtain a signal-to-noise ratio as good as possible, explain the reasons of your choice and evaluate the minimum measurable pulse amplitude specified in current and in photoelectron rate

Let us consider now to replace the PIN with a PMT featuring a S20 cathode and the same preamplifier used for the PIN (Choose reasonable performance for the PMT).

d) Evaluate the total spectral density of the noise affecting the signal in this case and compare it with the previous case in which a PIN was used. Evaluate the minimum measurable current pulse amplitude in these conditions and the corresponding minimum measurable optical pulse amplitude in photon rate.