Problem 1

Rectangular pulse duration: T_r=4 μs variable amplitude A_r	Exponential pulse $x_e\left(t\right)=A_e e^{-t/T_e}$ time constant T_e = 2μs variable amplitude A_e
Preamplifier Wide band, limited by a pole at $f_p = 100 MHz$ Noise referred to the preamp input $\sqrt{S_{bu}} = \sqrt{2S_{bb}} = 40\, nV/\sqrt{Hz}$ (white noise, unilateral density)	

It is requested to measure the amplitude of pulse signals processed by a preamplifier. Two cases of pulse signal have to be considered, a rectangular pulse and an exponential pulse. The features of the pulses and of the preamplifier are above specified. The output of the preamplifier is filtered for improving the Signal-to-Noise ratio (S/N).

A. Measurements without filtering and measurements with optimum filtering

Evaluate the smallest amplitude measurable for each pulse without any filtering, i.e. measured directly at the preamp output. Explain for each of the two pulses the optimum filtering that gives the best S/N and the minimum measurable pulse amplitude. Compute and compare the minimum amplitudes measurable with the two filters and comment, giving an intuitive explanation of their relative height.

B. Measurements employing simple continuous-time analog filters for approximating the optimum filter

For each pulse, select a simple continuous-time analog filter with constant parameters, compute the S/N obtained by employing it and evaluate the minimum measurable amplitude. Compare the results; evaluate their relative height with respect to the corresponding optimum amplitude and comment, giving an intuitive explanation of the results.

C. Measurements employing simple discrete-time filters for approximating the optimum filter

For each pulse, select a discrete-time analog filter, which processes the signal and noise at the preamplifier output by taking samples at short time intervals and by weighting the samples with a specified distribution of weights. Based on intuitive considerations, define the parameters of the two filters, dimension them for obtaining a good approximation of the optimal filters and evaluate the minimum measurable amplitude. The approximation obtained with respect to the optimal filters can be better defined and clarified by a quantitative computation of the S/N of the discrete filtering; such a computation is not required, but it is appreciated.

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

Problem 2

Strain gauges:	**Differential Preamplifier:**
R_S = 160 Ω resistance; G = 2,4 Gauge factor P_{dmax}= 4 μW max dissipation per sensor Temperature Coefficient $$\alpha = \frac{\Delta R_S}{R_{S0}} = 4 \cdot 10^{-3}\ C^{-1}$$ Temperature mismatch between sensors: within $\Delta T_{\max} \approx \pm 0{,}1°C$, quasi-stationary, i.e. with variation over long time intervals >>10s	$\sqrt{S_V}$ = 16 nV/Hz$^{1/2}$ (unilateral) noise referred to preamp differential input; 1/f noise component with corner frequency f_{cv} = 100 kHz $\sqrt{S_i}$ = 5 pA/Hz$^{1/2}$ (unilateral) noise referred to preamp differential input; 1/f noise component with corner frequency f_{ci} = 100 kHz Wide band > 100MHz
Strain to be measured In Sec.B and C: stationary strain i.e. with variation over long time intervals >10s In Sec. D and E: sinusoidal oscillating strain of extension-contraction $\varepsilon(t) = \varepsilon_S \cos(\omega_m t)$ caused by motor rotating at 12000 rpm (revolutions per minute) i.e. with frequency f_m=*200Hz:* The amplitude of the oscillation slowly varies over time intervals >10s . A sinusoidal reference signal is available with frequency and phase equal to the motor rotation	

Metal strain gauges (SG) are employed for measuring a strain in a motor component. The SG temperature is not controlled, the temperature difference from the dummy to the active sensor is within the limits specified. A differential preamplifier (with high input resistance and other characteristics as reported) is employed to pick-up the signals.

A) Explain the circuit configuration of sensors and preamplifier and the DC voltage supply employed for the sensors. Evaluate the strain-to-voltage transduction factor obtained. Explain and evaluate quantitatively the effect of the mismatch in temperature between the active and dummy sensors. Evaluate the voltage noise referred to the amplifier input.

B) With the strain gauges operating with DC voltage supply, select a proper filtering set-up for measuring a stationary strain and evaluate the minimum amplitude measurable in these conditions limited by the noise. Evaluate then the errors caused by the temperature mismatch between sensors in the measurement and compare it to the noise-limited minimum amplitude.

C) Let's now employ an AC voltage supply, with amplitude equal to the DC supply in Sec. B. Select the AC frequency and a suitable filtering set-up. Evaluate the minimum measurable amplitude limited by the noise. Evaluate the error caused in the measurement by the temperature mismatch between sensors, compare it to the noise-limited minimum amplitude and comment.

D) We have now to measure a sinusoidal oscillating strain (extension-contraction) with almost constant oscillation amplitude (varies over time > 10s) due to a motor rotating at 12000rpm (frequency f_m=*200Hz)*. We employ the same bridge as in Sec.C, with filtering setup revised for measuring the oscillating strain. Evaluate the errors due to noise and to temperature mismatch

E) The measurement of the oscillating strain can be improved by exploiting the fact that we have a reference signal with frequency and phase equal to the strain oscillation. Explain how this improvement can be accomplished and evaluate the obtainable results.

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