Problem 1

Strain gauges:	**Differential Preamplifier:**
R_S = 160 Ω resistance; G = 2,4 Gauge factor P_{dmax}= 4 μW max power 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	$\sqrt{S_V}$ = 12 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 $\varepsilon(t) = \varepsilon_S \cos(\omega_m t)$ Fundamental component of an oscillating strain of extension-contraction, caused by moto cycle motor rotating at 6000rpm (revolutions per minute) The amplitude of the oscillation is almost constant, i.e. slowly varies over time intervals >10s . A sinusoidal reference electrical signal is available with the frequency and phase of the motor rotation	

Metal strain gauges (SG) with the features above reported are employed for measuring an oscillating strain in a motor, as above specified. The temperature of the SGs is not controlled, the active sensor may have temperature different from the dummy sensor within the limits above specified. The SG signals are picked up by a differential preamplifier with high input resistance and the characteristics reported.

A) Specify and explain the circuit configuration of the sensors and preamplifier used in the measurement and the DC voltage supply employed for operating 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

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

C) Seeking to improve the measurement and achieve lower minimum measurable amplitude of the strain oscillation, let's consider now to employ an AC voltage supply for operating the sensors. Select the AC voltage amplitude and frequency and evaluate the transduction factor. Select a filtering set-up and evaluate the minimum measurable amplitude limited by the noise in these conditions. Evaluate the error caused in the measurement by the temperature mismatch between sensors and compare it to the noise-limited minimum amplitude. Analyze if and how the measurement may be improved by further filtering and evaluate the achievable results.

D) Employing the same strain gauges, consider now what would be the situation for measuring a stationary strain value and compare it with the measurement of the oscillating strain. In particular, compare the effect of the sensor temperature mismatch in the two cases.

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

Problem 2

OPTICAL SIGNAL	PREAMPLIFIER
- wavelength λ= 600nm, - rectangular pulse with duration T_F=10 μs - variable Optical power P	- Load Resistance at PMT anode R_L=1kΩ - Load Capacitance at PMT anode C_L=2 pF - Current Noise (unilateral) at amplifier input $\sqrt{S_{iA}} = 1\,pA/\sqrt{Hz}$ - Voltage Noise (unilateral) at amplifier input $S_{vA} = 1\,nV/\sqrt{Hz}$
PHOTOMULTIPLIER TUBE - Gain $G=2\cdot10^6$, Excess Noise Factor F=2 - Detection efficiency η=0,05 at λ= 600nm - Cathode Dark current $I_{Dk}= 10^{-15}$ A = 1 fA - Cathode current due environment light in the day $I_{Ek}=2\ 10^{-12}$ A = 2 pA - Cathode current due to environment light in the night: negligible	**PIN PHOTODIODE** - Detection efficiency η_d=0,60 at λ= 600nm - Dark current $I_{Dd}=2\cdot 10^{-12}$ A = 2 pA - Current due to environment light in the day $I_{Ed}=2\cdot 10^{-12}$ A = 2pA

Laser pulses with the features above specified are transmitted in free air and weakly reflected by distant objects. The reflected pulse amplitude (i.e. the optical pulse power) must be measured employing as analog photodetector the photomultiplier tube (PMT) and the preamplifier as above specified.

A) The detected signal has to face a stationary noise. Point out the components of the stationary noise and evaluate their spectral density in current referred to the PMT cathode

B) For measurements of reflected pulses performed in daylight (1) Select a filter suitable for obtaining a signal-to-noise ratio as good as possible and explain the reasons of your choice; (2) evaluate the minimum measurable photocurrent pulse amplitude as limited by the stationary noise (3) analyze whether or not the fluctuations of the photocurrent set a higher limit to the minimum measurable amplitude (4) in conclusion, evaluate in this condition the actual minimum measurable pulse amplitude specified in current and in photoelectron rate and the corresponding minimum measurable optical pulse amplitude, specified in power and in photon rate

C) For measurements of reflected pulses performed in night time (1) evaluate the minimum measurable photocurrent pulse amplitude as limited by the stationary noise (2) analyze whether or not the fluctuations of the photocurrent in this condition set a higher limit to the minimum measurable amplitude (3) in conclusion, evaluate in this condition the actual minimum measurable current pulse amplitude and the corresponding minimum measurable optical pulse amplitude, specified in power and in photon rate

Let us consider now to employ instead of the PMT a PIN photodiode with the features above specified and the same preamplifier used for the PMT.

D) For measurements of reflected pulses performed in daylight: (1) evaluate the total spectral noise density that the signal must face in this case, compare with the case with PMT and comment; (2) evaluate the minimum measurable photocurrent pulse amplitude as limited by the stationary noise; (3) analyze whether or not the fluctuations of the photocurrent set in this condition a higher limit to the minimum measurable amplitude; (4) in conclusion, evaluate the actual minimum measurable current pulse amplitude in this condition and the corresponding minimum measurable optical pulse amplitude, specified in power and in photon rate. Evaluate the ratios of the PMT and PIN limits in terms of current and in terms of optical power; compare and comment them, illustrating the relative merits of the two detectors.