**11/01/23**

**Problem 1)**

1) A) First of all, noise must be made white. To this aim, a high pass filter is exploited with $f_p = f_C$. This filter modifies the shape of the signal that becomes:

$$\begin{cases} V_P e^{-\frac{t}{\tau_P}} \quad for\ 0 \leq t < T_P \\ -0.956 V_P e^{-\frac{t-T_P}{\tau_P}} \quad t \geq T_P \end{cases}$$

After the noise whitening, the best filtering is a matched filter, resulting into $V_{Pmin} = 572nV$.

B) a feasible filter is a gated integrator. Best choice is starting the integration at t=0 with duration $T_G = 1.25\tau_P$. With this solution $V_{Pmin} = 880nV$.

2) 1/f noise can't be made white. In this case a filter optimized on signal and white noise should be used in combination with a high pass filtering solution. With a correlated double filtering exploiting two adjacent identical integration windows, $V_{Pmin} = 656nV$.
3) In all cases a ratemeter or a boxcar integrator can be used to improve the SNR obtaining the same results.
   A) In the conditions of point 1, after the High pass filter the noise is white and the ratemeter/boxcar reduces the minimum amplitude that can be measured by a factor 6.32.
   B) In the conditions of point 2, CDF can be still used in combination with a ratemeter/boxcar but only wideband noise is substantially reduced. At first approximation we can obtain the same signal with a white noise sigma reduced by a factor of 6.32 and unvaried 1/f noise contribution. As a result $V_{Pmin} = 485nV$.

**Problem 2)**

1) The proper acquisition scheme for this problem requires four strain gauges in a wheastone bridge configuration. Two strain gauges have to be used for temperature compensation to achieve high sensitivity while other two strain gauges have to be properly placed in the bridge to cancel out any bending effect on the measurement. Reasonable values for the strain gauges are G=2, R=100Ω. Considering a reasonable power dissipation of 1µW on each strain gauge, the constant bias must be equal to 20mV. The preamp provides a limitation to noise at high frequency while a low frequency limitation is given by the reset of the system every day. Considering a worst case scenario of a measurement lasting for 24hours, we obtain an equivalent high-pass filtering pole at 1.84µHz. in this scenario the minimum strain that can be measured is $\varepsilon_{MIN}$=6250microstrain.
2) We can assume a signal gradually changing on a timescale of 2s, so with a BW of about 0.4Hz. in this case a lock in amplifier with demodulation at the signal center frequency (10Hz) and with a LPF having a pole at 4Hz can be used to improve the sensitivity of the system. In this case, $\varepsilon_{MIN}$=39.6microstrain. (Note: 1/f noise is considered flat in the filter bandwidth with $\sqrt{B} = \sqrt{S_V * \frac{f_C}{f_S}} = 316nV/\sqrt{Hz}.$ ).
3) Exploiting a modulated bias allows to prevent signal from mixing with 1/f noise. Considering a maximum power dissipation on the sensor, the same SNR is obtained with both a square wave and a sinusoidal bias. To recover the signal we need two lock in amplifiers. In this scenario, $\varepsilon_{MIN}$=1.75microstrain.