08/07/2024 – solution draft

Pb1)

A) Considering a gated integrator of amplitude A=1, duration Tg=Tp+x starting at the beginning of the signal (with $0 \leq x \leq T_P$), the following SNR is obtained:

$$\frac{S}{N} = \frac{V_P(T_P + x - \frac{x^2}{2T_P})}{\sqrt{\frac{S_V}{2}}(T_P + x)}$$

which has a maximum for x=0.55Tp. Thus, the best sizing of the integration window is Tg=1.55Tp. As a result, the SNR is equal to $\frac{V_P}{\sqrt{\frac{S_V}{2}}}1.12\sqrt{T_P}$ leading to V_{pMIN}=6.3µV.

B) With a sampling frequency of 4MHz it is possible to acquire 5 samples with amplitude Vp and 3 samples with amplitude (linearly decreasing) 0.75Vp, 0.5Vp and 0.25Vp. Providing a weight that is proportional to the signal amplitude the collected signal is 5*1*Vp+0.75^2Vp+0.5^2Vp+0.25^2Vp=6.18Vp.
The same weights applied to the noise samples lead to $N = \sqrt{(5 + 0.75^2 + 0.5^2 + 0.25^2)S_V \frac{\pi}{2} f_{PA}} = \sqrt{6.18} * 125\mu V$. In this case, V_{pMIN}=50.3µV.

C) See theory.

Pb2)

A) See theory for a complete description of the strain gauge. A suitable setup consists of a Wheatstone bridge with two active and two dummy strain gauges leading to Vout=Vbias/2 Gε.

B) The measurement is affected by 1/f and white noise. With only a single sample noise is upper limited by the frequency cut provided by the preamplifier and lower limited by the equivalent high pass filtering action of a zero setting. In the worst case scenario the measurement is taken after two hours from the reset of the instrumentation. With Vb=20mV to comply with power requirements, Vpmin=4.5µV corresponding to εmin=225microstrain.
With two samples a CDS can be implemented obtaining an overall noise of 5.85µV (dominated by the doubling of dominant white noise contribution) and the signal is doubled. The improvement is better than sqrt(2) because 1/f noise is better filtered by CDS with respect to zero setting. In this case, Vpmin=2.9µV corresponding to εmin=145microstrain.

C) With a sinusoidal LIA it is possible to apply a bandpass filtering action. With fpLPF=10Hz, Vpmin=168nV corresponding to εmin=8.4microstrain, where 1/f noise has been approximated as constant within the bandwidth of the filter.
By changing the bias to a sinusoidal one it is possible to completely avoid that the signal merges with 1/f noise. For example the bias frequency could be 20kHz. The bias voltage peak can be raised by $\sqrt{2}$ with respect to the constant bias. At the same time, two cascaded LIAs are necessary to recover the signal causing white noise to be doubled with respect to a single LIA. As a result the signal to white noise is the same as the constant bias but sensitivity is improved thanks to the complete filtering out of 1/noise leading to Vpmin=56nV and εmin=2.8microstrain.