

Pb1)

- A) Considering a gated integrator of amplitude $A=1$, duration $T_g=T_p+x$ and an integration window that starts at T_p-x and ends at the end 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 $x=0.55T_p$. Thus, the best sizing of the integration window is $T_g=1.55T_p$ starting after $0.45T_p$ from the beginning of the signal. As a result, the SNR is equal to $\frac{V_p}{\sqrt{\frac{S_V}{2}}} 1.12\sqrt{T_p}$

leading to $V_{pMIN}=6.3\mu V$.

- B) With a sampling frequency of 4MHz it is possible to acquire 5 samples with amplitude V_p and 3 samples with amplitude (linearly decreasing) $0.75V_p$, $0.5V_p$ and $0.25V_p$. Providing a weight that is proportional to the signal amplitude the collected signal is $5*1*V_p+0.75^2V_p+0.5^2V_p+0.25^2V_p=6.18V_p$.

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, $V_{pMIN}=50.3\mu V$.

- 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 $V_{out}=V_{bias}/2 G\epsilon$.
- 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 $V_b=20mV$ to comply with power requirements, $V_{pmin}=4.5\mu V$ corresponding to $\epsilon_{min}=225\text{microstrain}$.
With two samples a CDS can be implemented obtaining an overall noise of $5.85\mu V$ (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, $V_{pmin}=2.9\mu V$ corresponding to $\epsilon_{min}=145\text{microstrain}$.
- C) With a sinusoidal LIA it is possible to apply a bandpass filtering action. With $f_{LPF}=10Hz$, $V_{pmin}=168nV$ corresponding to $\epsilon_{min}=8.4\text{microstrain}$, 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 $1/f$ noise leading to $V_{pmin}=56nV$ and $\epsilon_{min}=2.8\text{microstrain}$.