Problem 1

We want to measure the amplitude of a signal having the shape in the figure below where $T_P = 1\mu s$. The signal is picked up by an amplifier featuring a single pole (f_A=100 MHz) and affected by an input referred white noise with unilateral spectral density $\sqrt{S_V} = \frac{10nV}{\sqrt{Hz}}$.

a) Being able to exploit only one gated integrator, calculate the minimum signal amplitude that can be measured in these conditions.

b) Now assuming that a sampler featuring a maximum sampling frequency of 4MHz is available, discuss a suitable digital acquisition and filtering strategy and calculate the minimum signal amplitude that can be measured in these new conditions.

c) Theoretically compare in the frequency domain a gated integrator and a discrete time integrator as the sampling frequency varies, calculating, again in the frequency domain, the gain with respect to the input SNR for both very low and very high frequencies.

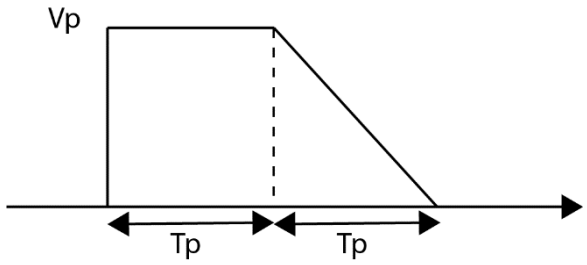
Problem 2

We want to measure the maximum compression and extension force to which a drone engine piston is subjected. The engine producing the signal rotates at 15000 rpm for a 2-hour journey. To guarantee an early detection of any mechanical problem that may occur we want to acquire the signal amplitude with a bandwidth of at least 10Hz. To perform this task the following sensors and electronics are available: strain gauge sensors, a differential amplifier (single pole at f_A=100 kHz, input-referred noise with wideband unilateral spectral density $\sqrt{S_V} = \frac{10nV}{\sqrt{Hz}}$ and $\sqrt{S_I} = \frac{1pA}{\sqrt{Hz}}$ and 1/f component with $f_C = 2kHz$), a sync signal coming from the motor and only continuous power supply.

a) Describe in detail the physical principle of the strain gauge and its characteristics. Then describe a suitable setup to produce an electrical signal proportional to the force applied to the piston.

b) Assuming that only a single-shot sample of the signal amplitude can be acquired, calculate the minimum amplitude that can be measured considering a maximum power that can be dissipated on the sensor of 1μW. Then discuss and provide a quantitative evaluation of how the answer to this question would change if two samples can be exploited.

c) In the same conditions of point b) it is now possible to exploit a lock-in amplifier. Calculate the minimum amplitude that could be measured in this case. Then discuss and provide a quantitative evaluation of how the answer to this question would change if a sinusoidal power supply was available.



Signal Recovery