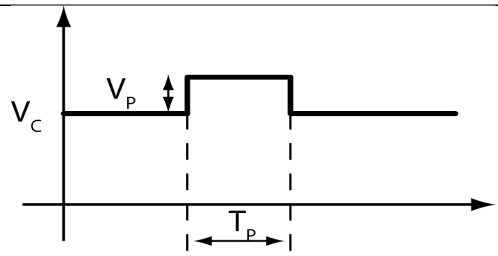
Problem 1

Pulse signal V_P variable pulse amplitude $T_P = 50$ µs pulse duration $f_P = 1$ Hz pulse repetition frequency $V_C \approx 10mV$ baseline level	
Preamplifier $S_V^{1/2} = 20nV/Hz^{1/2}$ white noise power density (unilateral) $f_{pa} = 1\ MHz$ upper band-limit	in (C) and (D): $1/f$ noise with corner frequency $f_c = 50$kHz

Pulse signals with rectangular waveform are issued from a low impedance source and fed to a high-impedance-input preamplifier with the features above reported. The arrival of the signals is periodic at repetition frequency f_P , the amplitude V_P varies from pulse to pulse and must be individually measured

A) Consider first to employ only filters with constant parameters. For making negligible the contribution of the baseline to the output, select and explain a simple suitable filter and define its parameters. For reducing the output noise, select and explain another simple suitable filter, select its parameters for maximizing the Signal-to-Noise ratio (S/N) and evaluate the minimum measurable amplitude $V_{P,min}$

B) Consider now to employ also filters with variable parameters. Select a suitable practical filter, select its parameters for maximizing the Signal-to-Noise ratio (S/N) and evaluate the minimum measurable amplitude $V_{P,min}$. Explain why in this case it is possible to obtain a better S/N by employing a time-variant filter.

C) Consider now that the noise has also a $1/f$ component with corner frequency $f_c = 50$kHz. With the filtering described in (B), evaluate the additional contribution to the output noise brought by this $1/f$ component and the minimum measurable amplitude $V_{P,min}$ in this condition.

D) The degradation of S/N brought by the $1/f$ component can be reduced by modifying the filtering for reducing the contribution of the $1/f$ component without impairing the filtering of the signal. Explain the criteria that must be followed for selecting such an improved filter, illustrate a practical example and give an approximate evaluation of the minimum measurable amplitude $V_{P,min}$ thus obtained.

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

Problem 2

$v_s = V_s \cos\omega_s t$ sinusoidal signal V_s slowly variable signal amplitude (variations over time ≥ 1s) $f_s = 1kHz$ frequency ($\omega_s = 2\pi f_s$)	Synchronous reference signal $v_R = B\cos\omega_s t$
Noise $\sqrt{S_v} = 100nV/\sqrt{Hz}$ effective white noise density (unilateral) $f_c = 500Hz$ corner frequency of $1/f$ noise	Resonant filter $f_o = f_s = 1kHz$ resonance frequency $Q=5$ Quality factor The RLC filter is inserted in an amplifier that ensures unity gain at the center frequency f_o

It is required to measure the amplitude V_s of a sinusoidal signal accompanied by noise as above specified. The variation in time of the amplitude $V_s(t)$ must be monitored. A reference signal is available with frequency and phase equal to the signal to be measured. For improving the *S/N* two filter set-up can be considered

A. Tuned filter (parallel resonant RLC circuit with the features above reported)
B. Lock-in amplifier (LIA) with analog multiplier and low-pass filter RC with a simple pole with adjustable time constant T_F .

A) Consider first to employ the tuned filter.

1. Point out the characteristic parameters of the filter that must be specified in order to describe and evaluate its performance;
2. Explain how is the filter weighting function in time and how it varies as the instant t_m of measurement of the filter output is varied
3. Describe the transfer function in frequency, pointing out the parameters to be employed for computing the output noise
4. Evaluate the minimum measurable signal in a correctly performed measurement
5. Explain how the instants where the output is sampled have to be selected for obtaining a correct measurement of the signal amplitude and its variations. Verify that the quantitative features of the filter are suitable for monitoring the variations versus time of the signal amplitude $V_s(t)$.

B) Consider now to employ the LIA:

1. Explain how is the filter weighting function in time and how it varies as the instant t_m of measurement of the filter output is varied.
2. Select the LIA setting for correctly carrying out the measurement requested.
3. Evaluate the minimum measurable signal in a correctly performed measurement
4. Explain how the instants where the output is sampled have to be selected for obtaining a correct measurement of the signal amplitude and its variations. Verify that the quantitative features of the filter are suitable for monitoring the variations versus time of the signal amplitude $V_s(t)$.
5. Compare the performances obtained with the tuned filter and with the LIA and point out in intuitive terms the reasons of the differences verified

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