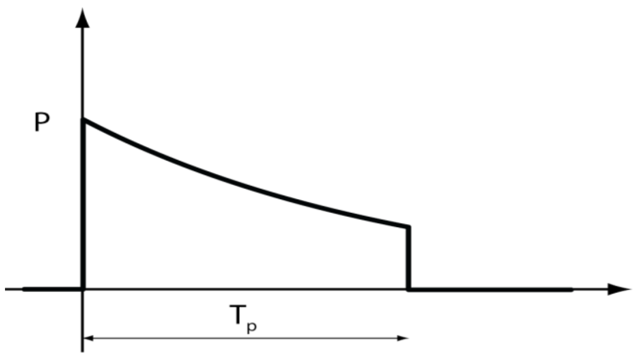
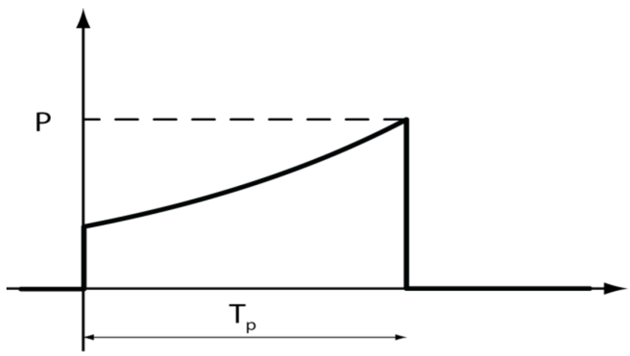
Problem 1

$x(t)=P\exp(-t/T_D)$ in $0<t<T_P$  Exponential Decaying Pulse	$x(t)=P\exp\left[(t-T_P)/T_D\right]$ in $0<t<T_P$  Exponential Rising Pulse
Pulse duration T_P = 10 μs Time constant T_D = 10 μs Peak amplitude P	White Noise spectral density (unilateral) $S_{Vu}^{1/2}=14\,nV/\sqrt{Hz}$

It is required to evaluate filters for measuring the amplitude of pulse signals accompanied by white noise with spectral density S_V. The pulses have exponential waveform with time constant T_D and are truncated to finite duration T_P as above shown. Two cases have to be considered, with decaying exponential and with rising exponential waveform respectively. An auxiliary synchronism signal is available, which points out the arrival time of each signal pulse.

Consider first the case of decaying exponential pulses and

A1) Describe and explain the features of the filtering that makes possible to measure the pulse amplitude with the best possible Signal-to-Noise ratio and evaluate the minimum pulse amplitude P_{min} thus measurable.

A2) Employ as first practical approximation to the filtering a simple constant-parameter RC integrator, explaining intuitively how you select the filter time constant T_F. Evaluate the amplitude P_{min} measurable with this filtering and the ratio of this performance to that obtained with the optimum filtering.

A3) Employ now as alternative practical approximation to the filtering a Gated Integrator, explaining intuitively how you select the GI setting. Evaluate the amplitude P_{min} thus measurable. Compare the result with that obtained in Sec. A2 and discuss whether the comparison appears intuitively justified or not. Evaluate also the ratio of the performance obtained with the GI to that obtained with the optimum filtering.

Consider now the case of rising exponential pulses.

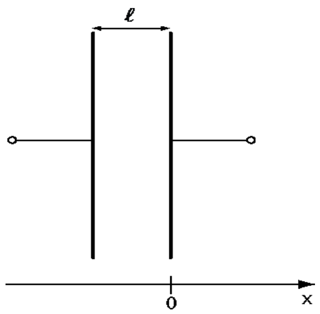
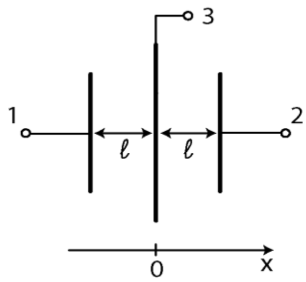
B1) Answer to the same questions as in Sec.A1

B2) Answer to the same questions as in Sec.A2

B3) Answer to the same questions as in Sec.A3

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

Problem 2

<table>
<tr><td>Simple capacitor sensor
</td><td>Differential capacitor sensor
</td></tr>
<tr><td>Plane Capacitive Sensors:
ε_o = 8,85 pF/m dielectric constant in air
A= 4 cm^2 electrode area
ℓ = 0,4 mm Quiescent spacing
20 mV max voltage between two plates</td><td>Differential Preamplifier
High input resistance →∞ and wide band > 10MHz
$\sqrt{S_V} = 50nV/\sqrt{Hz}$ voltage noise at diff. input (unilat.)
$\sqrt{S_i} = 0{,}1pA/\sqrt{Hz}$ Current noise at each input (unilat.)
$f_c \approx$ 10kHz corner-frequency of $1/f$ noise components</td></tr>
<tr><td colspan="2">To be measured:
- stationary displacement x (constant value over time intervals up to 10s)
- sinusoidal oscillatory displacement x at frequency f_o (constant amplitude over intervals up to 10s). Oscillation frequency f_o different from case to case, varying in the range 40 to 100Hz. A reference signal with frequency and phase equal to the x oscillation is available.</td></tr>
</table>

Micrometric displacements can be measured employing two types of capacitive sensors as above sketched: simple capacitors with plane geometry, (two plates, one is mobile) and differential capacitors (three plates, the central one is mobile).

A1) Explain the operating principle of these sensors. A2) Illustrate a circuit configuration suitable for exploiting the sensors in measurement of displacements. A3) For simple sensors: obtain the transduction equation from displacement to output voltage signal and evaluate the measurement range (i.e., the maximum displacement) where the transduction deviates less than 1% from linear. A4) Answer to the same questions for the differential sensor (i.e. compute the transduction equation and specify the linear measurement range). Compare simple and differential sensors, pointing out advantages and disadvantages.

B) Consider first measurements of static displacement. Specify and explain the sensor, the circuit configuration and the electronic filtering set-up that you intend to employ for obtaining high sensitivity in the measurement, i.e. high Signal to Noise. Evaluate the minimum measurable electronic signal that you can obtain and the corresponding minimum measurable displacement.

C) Consider now measurements of the oscillatory displacements. Discuss whether the apparatus described in Sec. B can be employed as it is, without any modification, or it is instead necessary to modify circuit parameters and/or configuration. Evaluate the minimum measurable electronic signal thus obtained and the corresponding minimum measurable amplitude of the oscillatory displacement, comparing it to the minimum static displacement in Sec.B. If this minimum oscillation amplitude is greater, explain why this occurs, analyze how to complement or modify the filtering and evaluate the improved performance, commenting and comparing it with the static case.

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