Problem 1

Rectangular pulse signal
duration $T_p = 10\mu s$ amplitude A_p variable, to be measured An auxiliary signal synchronous with the pulse is available Measurements are carried out in runs of about 20 min, with interval of a few minutes between successive runs
Noise
white component $\sqrt{S_v} = 50\, nV/\sqrt{Hz}$ limited by a pole at f_a = *200 MHz* Where specified, consider also a *1/f* component with corner frequency f_c=*100kHz*

The amplitude A_p of single pulses must be measured in presence of noise as specified.

A) Taking into account only the white component of the noise, evaluate the minimum amplitude A_p measurable without employing any filter.
Select then a constant-parameter filter that produces a strong reduction of the white noise but only a negligible reduction of the pulse amplitude, that is, a reduction of the pulse amplitude by less than 1%. Evaluate then the minimum amplitude A_p measurable employing this filter.

B) Consider now measurements in presence also of a 1/f noise component with corner frequency f_c=*100kHz*. With the filter considered in (A) and employing the basic elementary approach for limiting the effect of the 1/f noise, evaluate the noise contribution given by the 1/f component and compare it with that of the white noise.

C) Consider now to employ a constant-parameter filter for reducing the 1/f noise contribution, besides the filter employed in (A) and (B). Explain what action is required to this filter and select a suitable filter type. Decide the value of the filter parameter to be adopted in order to fulfil the measurement requirements and in this condition evaluate the noise contribution given by the 1/f component. Consider cases where the pulse signal is repetitive with repetition rate f_r and analyze whether with this filter the measurement can be satisfactorily carried out or not in two cases, namely: 1) with repetition rate f_r =100Hz and 2) with repetition rate f_r=10kHz.

D) Consider now to employ a variable-parameter filter for reducing the *1/f* noise contribution, besides the filter employed in (A) and (B). Explain what action is required to this filter and select a suitable filter type. Decide the value of the filter parameter to be adopted in order to fulfil the measurement requirements and in this condition evaluate the noise contribution given by the 1/f component. Discuss the suitability of this solution in the two cases with repetitive pulses at different pulse repetition rate considered in (C)

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

Problem 2

Thermometric sensor. Silicon integrated microchip in planar technology with two diodes D1 and D2 in close proximity. The diodes have practically ideal I-V curve (Shockley equation), equal vertical structure and different areas: $A_1=100(\mu m)^2$ and $A_2=1000(\mu m)^2$. The diodes have cathodes connected to ground and anodes connected each one to an input of the differential preamplifier integrated on the chip (see below). The diodes operate biased by current generators in the chip and the normal setting is with equal current values $I_1=I_2=100\mu A$. It is not possible to contact the diode terminals from outside the chip, but the current generator values can be controlled by external electrical commands.
Integrated preamplifier Differential voltage amplifier with wide band (to be considered ≈ infinite). At each input consider: • a high input resistance (to be considered ≈ infinite) • $\sqrt{S_{Va}} = 40\, nV/\sqrt{Hz}$ (unilateral) voltage noise referred to input • $\sqrt{S_{ia}} = 0{,}1\, pA/\sqrt{Hz}$ (unilateral) current noise referred to input. In (C) and (D) the voltage noise has also a *1/f* component with corner frequency $f_c=200\ kHz$

It is required to measure with error limited to a few milliKelvin (0,001K) the temperature of samples. The temperature is slowly variable, that is, over times of 1s or longer. The measurements are carried out in runs of about 15-20 minutes, with intervals of few minutes between successive runs.

A) Explain the principle of the measurement with the sensor operating at equal diode current $I_1=I_2=100\mu A$ and evaluate the conversion factor from temperature to electrical signal.

B) Taking into account only the white noise components, select a filter suitable for the measurement required and evaluate the error in temperature (i.e. the minimum measurable variation of temperature).

C) Consider now to have besides the white noise also a strong *1/f* component in the voltage noise, with the specified corner frequency f_c . Employing the filter selected in (B) and the basic elementary approach for limiting the effect of the 1/f noise, evaluate in this condition the error in temperature (i.e. the minimum measurable variation of temperature).

D) In presence of 1/f noise the measurement error can be remarkably reduced by modifying some features in the diode operation and employing a different approach for filtering signal and noise. Illustrate and explain the modified approach that you select, evaluate the error in temperature thus obtained and explain in intuitive terms the reasons that produce the remarkable improvement.