Physics 623 — Problem Set 6

NOISE:
Which is better for low-noise applications, bipolar or field-effect (FET) transistors? Answer the following questions.

1. Input noise specifications for two high-performance op-amps (both advertised as "Low-noise") are given as follows.

OP-27: Ultra-low noise bipolar op amp
$e_{n\text{-}A}$ = 3 nV/sqrt(Hz) $i_{n\text{-}A}$ = 0.4 pA/sqrt(Hz)

LF-357: Low-noise FET-input op amp
$e_{n\text{-}A}$ = 15 nV/sqrt(Hz) $i_{n\text{-}A}$ = 0.01 pA/sqrt(Hz)

miscellaneous useful data: Room temperature = 300 K, $k_B = 1.38 \times 10^{-23}$ J/K.

a) for each of these op amps, calculate the *Noise Resistance*, R_N, which is the value of the source resistance for which the *Noise Temperature*, T_N, is a minimum. (T_N is the physical temperature the source resitance would need to have for its Johnson noise to equal the total noise due to the amplifier, giving a *Noise Figure* of 3 dB. (Noise Figure, NF, is the ratio of total noise at the amplifier output to what it would be with an ideal amplifier with $e_{n\text{-}A} = i_{n\text{-}A} = 0$. This is usually expressed in dB.)
Show your work!

OP-27: R_N = _____ ohms

LF-357: R_N = _____ ohms

b) Give the minimum value for the noise temperature, T_N, that can be achieved with each amplifier:

OP-27: T_N = _____ K for $R_S = R_N$

LF-357: T_N = _____ K for $R_S = R_N$

c) Which op amp would be better (lower Noise Figure) for:

i) measuring the potential of a pH electrode with a source impedance of 5 Megohms?

best amplifier: _____

ii) measuring the voltage across a thermocouple with a resistance of 3 ohms?

best amplifier: _____

d) At what source impedance does the room-temperature Johnson noise of the source equal the *voltage* noise of the OP-27?

_____ ohms

Is the current noise of the op-amp significant for this R_S? yes / no

Explain:

e) Using an LF-357, what bandwidth must be used to measure a 1 μV r.m.s. signal to 1% rms precision if the source resistance is 10^6 ohms?

_____ Hz

About how long would it take to make one measurement with this bandwidth? _____ seconds

Could the measurement be made significantly faster with a better amplifier? yes / no

Explain: