Physics 326a-2011 Walter F. Smith Assignment 3

Due: Friday, Sept. 23 at the beginning of class
Reading: Lab Manual J1 to J6, E1 to E4, C8 to C10, C13, H1 to H3

Assigned exercises:

3.1. The OP27 operational amplifier (op amp), made by Analog Devices, is one of the most commonly used for building scientific instruments. It's an excellent, high-end op amp. Assume you've built an amplifier based around the OP27EP variant of this chip. (Most chips are available in several different grades, so as to suit a variatiey of customers.)

a. Go on the internet and find the specs for the current noise density i_n (units of $\mathrm{A}/\sqrt{\mathrm{Hz}}$)and voltage noise density v_n (units of $\mathrm{V}/\sqrt{\mathrm{Hz}}$) at 1 kHz for this chip. *Hint: Once you get to an appropriate site, you'll want to look at the "datasheet" for this chip.*

b. Assume you use the amplifier you built to measure the Johnson noise of a 10 kΩ resistor at T = 290 K. Your measurement chain includes a high-pass filter with f_{3dB} of 20 Hz and a low pass filter with f_{3dB} of 2 kHz. What is the approximate total rms noise amplitude (referred to the amplifier input), including the amplifier noise? (Use the guide on pp. C11-C12 to calculate your effective noise bandwidth.)

3.2. For any op amp or amplifier, there is internal capacitance to ground from the output. Therefore, we can write $Q = CV \Rightarrow I_{out} = \frac{dQ}{dt} = C\frac{dV}{dt} \Leftrightarrow \frac{dV}{dt} = \frac{1}{C} I_{out}$. The stage which drives the output always has a maximum current I_{out} that it can deliver, so we see that this imposes a maximum value of $\frac{dV_{out}}{dt}$, which is called the "slew rate". In other words, the output voltage of the op amp or amplifier can't change at a rate faster than the slew rate. Assume you're using an amplifier with a slew rate of 20 V/μs, and the gain is set to 1000. You apply a sinusoidal input with a peak-to-peak amplitude of 0.01 V. What is the maximum frequency for this wave that you could apply without seeing distortion at the output due to the slew rate limit?

3.3 A Swarthmore student draws your attention to the plot of Noise Figure for the SR560 amplifier. This is reproduced at right. Further details can be found in the manual for this amplifier, which is available online at:
http://www.thinksrs.com/products/SR560.htm
The student exclaims, "Look at that sweet spot at 1 kHz and about 200 kΩ ! The total noise at the output of the amplifier must be lower there than it would be, say, at 1 kHz and 10 Ω." Explain why he's wrong. (Note: a sweet spot is a particularly low noise region, or so thinks the Swat student…)