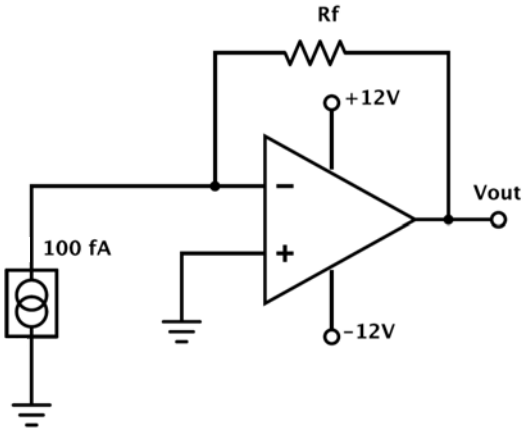
Physics 3150

Problem Set 6, 2016. *Problem 3 corrected on April 19, 2016*

Due on Wednesday, April 20, 2016

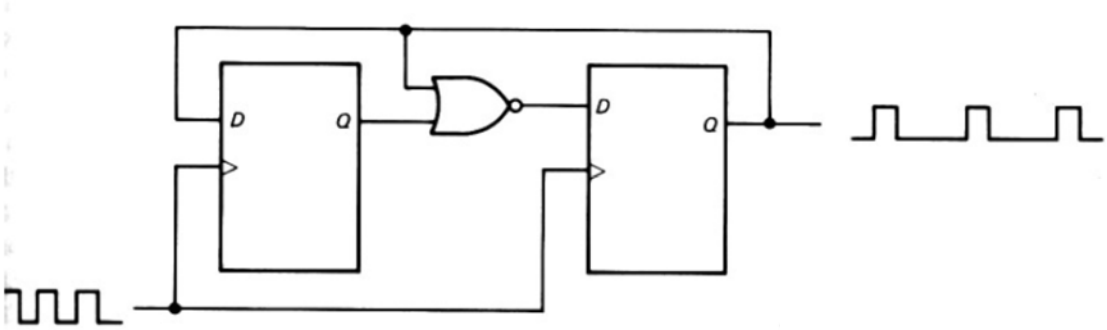
1. A transimpedance amplifier is used with a weak photodiode signal, effectively a 100 fA current source as shown in the sketch.



   (a) If the circuit operates with a bandwidth of 10 kHz, what is the inherent shot noise in the photocurrent? (See pp. Noise-1 and Noise-2 in the lecture notes) What is the equivalent voltage noise at the output, as a function of the feedback resistance R_f?

   (b) It's also necessary to consider the thermal or "Johnson" noise of the feedback resistor. To minimize its contribution relative to shot noise, is it better to use a large or a small value for R_f? For this specific situation, at room temperature, what is the value of R_f for which the output voltage has equal contributions from shot noise and Johnson noise?

2. The circuit below is a synchronous divide-by-three circuit using D-type flip-flops, which transmits every third input pulse to its output. Show that it works, by analyzing the states of the two D inputs and the two Q ouputs for each step in a complete sequence. Make a table of the full sequence, showing all four logic valudes at each step. Note that the right-hand flip-flop is effectively the least significant bit in this design.



3. At the top of p. DT-4 in the lecture notes, the time-dependent voltage of a pure amplitude-modulated (AM) signal is given, for a sinusoidal modulation index *m.* By evaluating the power V^2, show that the output of a power detector (or a diode) will have a frequency component at ω_m, showing that it can successfully be used as a demodulator. Here you can assume that $\omega_c \gg \omega_m$, though it is not essential. Find the ratio of the component at ω_m to the dc component of V^2, which reflects the strength of the unmodulated carrier.

   Since the original voltage has frequency components at both $\omega_c + \omega_m$ and $\omega_c - \omega_m$, a component in V^2 at $2\omega_m$ also seems like a possibility. Does it exist? If so, how big is it?

   Hint: This problem can be done by hand, but Mathematica can be of great assistance. As is often the case, the problem is in determining which Mathematica function is needed. For this particular task, try using TrigReduce[].