Physics 198, Spring Semester 1999 Helmuth Spieler
Introduction to Radiation Detectors and Electronics

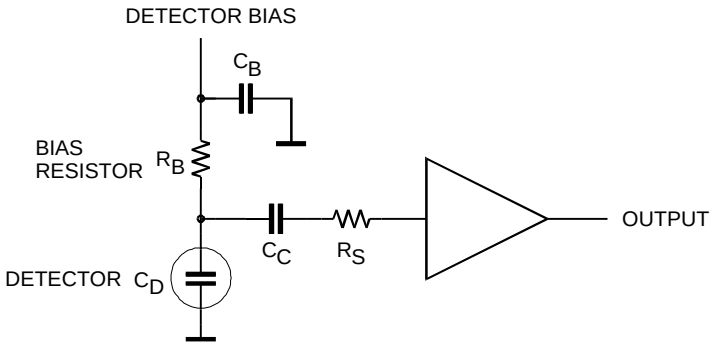
Problem Set 5: Due on Tuesday, 2-Mar-99 at begin of lecture.
Discussion on Wednesday, 3-Mar-99 at 12 – 1 PM in 347 LeConte.
Office hours: Mondays, 3 – 4 PM in 420 LeConte

1. An x-ray spectroscopy system is to resolve the Tl $K_{\alpha 1}$ and $K_{\alpha 2}$ emissions from a ^{203}Hg source. The $K_{\alpha 1}$ and $K_{\alpha 2}$ energies are 72.87 and 70.83 keV, at about equal intensities.

   a) Determine the energy resolution required to separate the two x-ray peaks.

   b) The intrinsic energy resolution of the detector is 160 eV. What is the allowable electronic noise contribution?

2. A spectroscopy system has the front-end components shown below.



   The Si detector draws a reverse bias current of 100 nA and has a capacitance of 100 pF. The bias resistor R_B = 10 MΩ and the connections between the detector and the preamplifier input have a total resistance of 10 Ω. The preamplifier has an equivalent input noise voltage of 1 nV/Hz$^{1/2}$ with negligible 1/*f* noise.

   a) The system utilizes a simple CR-RC pulse shaper with integration and differentiation time constants of 1 μs. What is the electronic noise expressed in electrons and in eV? How large are the contributions of the individual noise sources?

   b) Assume a CR-RC shaper with adjustable peaking time, where both the integration and differentiation time constants are adjusted simultaneously to be equal. What are the noise current and noise voltage contributions at 1 μs shaping time? Determine the time constant that yields minimum noise.

c) Replace the simple CR-RC shaper by a CR-RC^7 shaper, i.e. a shaper with a single differentiator and 7 integrators. At what peaking time does this shaper provide the minimum noise?

d) Using the CR-RC shaper at the optimum shaping time determined in b), what is the minimum value of bias resistor that will degrade the overall noise by less than 1%?

3. A detector system using a 100 μm thick detector exhibits minimum noise at 10 μs shaping time. The detector is replaced by another of the same material and area, but with 1 mm thickness.

a) What is the improvement in electronic noise, assuming that the shaping time is kept constant?

b) What is the optimum shaping time for the thick detector and what is the corresponding noise level?