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

Problem Set 6: Due on Tuesday, 9-Mar-99 at begin of lecture.
Discussion on Wednesday, 10-Mar-99 at 12 – 1 PM in 347 LeConte.
Office hours: Mondays, 3 – 4 PM in 420 LeConte

1. The signal at the input of a voltage sensitive amplifier is a 10 mV pulse with a rise time of 10 ns (10-90%). The equivalent input noise of the amplifier is 10 μV rms. The amplifier feeds a simple threshold comparator.

   a) Assume a comparator threshold of 5 mV, referred to the input. What is the time resolution?

   b) Still keeping the threshold at 5 mV, how much does the output of the comparator shift when the signal changes from 10 mV to 100 mV?

2. A timing system utilizes a silicon detector with an area of 100 mm^2 and 50 μm thickness. Alpha particles of 5 MeV impinge on the *p*-side of the detector. The detector is asymmetrically doped with a thin *p*-layer and a doping level in the *n*-bulk of 6.6×10^{12} cm^{-3}. The detector is operated at 100 V. The signal is sensed by a voltage amplifier, i.e. the input time constant is sufficiently large that the detector current pulse is integrated on the detector capacitance and the resulting voltage pulse is sensed by the amplifier. A simple threshold comparator provides the timing information.

   a) What is the peak voltage of the signal developed at the amplifier input?

   b) What is the collection time? What is the 10 - 90% rise time of the voltage pulse? For simplicity assume a rectangular current pulse, i.e. that the signal current is constant during the collection time.

   c) What is the optimum rise time of the amplifier system?

   d) The input noise of the amplifier is 1.5 $nV/Hz^{1/2}$. What is the total noise voltage?

   e) The reverse bias current of the detector is 1 nA. Is this a significant noise source for the timing measurement? Estimate the magnitude of its contribution.

   f) What is the time resolution obtainable with this system?

   g) For comparison, what is the optimum shaping time for an energy measurement? Assume a CR-RC shaper. Compare the signal-to-noise ratio with that of the timing system.

3. Compare the timing performance of two detectors similar to the one in problem 2, but with thicknesses of 100 and 1000 μm. Both have an area of 200 mm^2 and are fully depleted with the same average electric field of 10^3 V/cm in the detector. Again, assume 5 MeV alpha particles incident on the *p*-side. For the two detectors, calculate

   a) the bias voltage,

   b) the collection times,

   c) the magnitude of the voltage pulse.

   d) The same amplifier is used with both detectors. Its bandwidth is 500 MHz and the integrated noise voltage, referred to the input, is 30 μV. What are the time resolutions obtainable with the two detectors?