Laboratory Instruction on Ionizing Detectors

"Silicon Sensor and Read Out Electronics"

by Richard Brenner (may 2005, rev 2009, rev 2015)

1. Introduction

Near intrinsic n-type silicon with a metallised p-doped region, is the most frequently used semiconductor structure for detecting charged tracks in high-energy physics experiments. A polarisation voltage is applied reverse biasing the diode structure, which depletes the silicon from charge carriers. Charged particles or photons interacting with the silicon will create electron-hole pairs that drift along the electric field lines to the contacts located on the silicon surface.

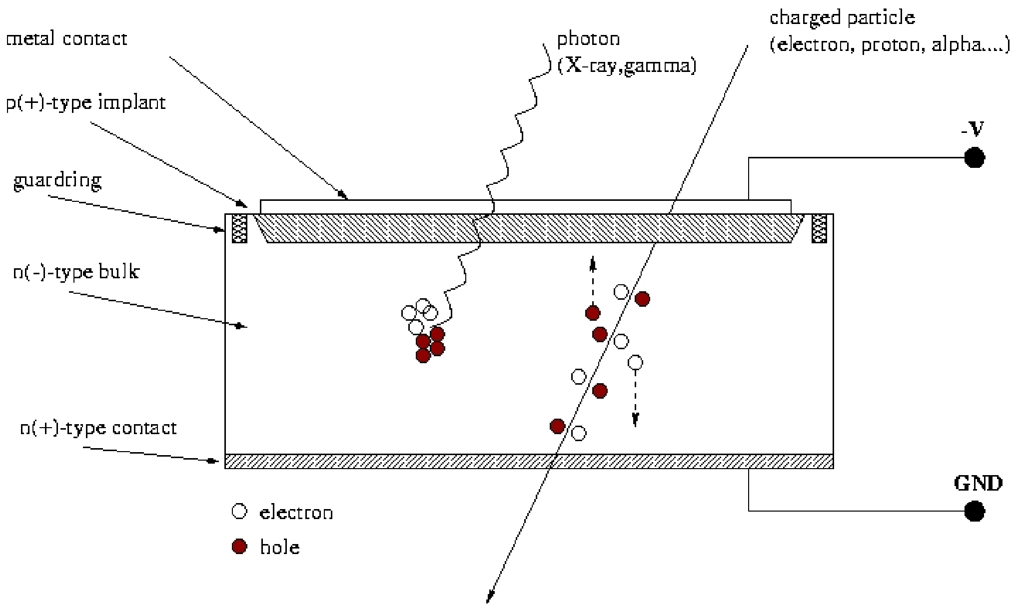

Illustration 1. A schematic drawing of a silicon sensor diode.

<u>Sensor</u>

A first step in constructing a particle detector based upon a silicon sensor is to characterize the sensor without readout electronics attached. The static characteristics of a sensor are usually adequate to determine if the sensor can be used for particle detection. The leakage current behavior as a function of voltage and the voltage needed to fully deplete the sensor are two important parameters. The voltage needed to deplete the sensor can be determined by measuring the capacitance between the diode implant and the backplane of the sensor. In the final particle detector system, both the capacitance and the leakage current will influence the performance of the readout electronics.

The capacitance and leakage current depend on the geometry of the sensor and the quality of the material and manufacturing process. In a well controlled and uniform process sensors with the same geometrical layout, processed on the same substrate, should have the same behavior. In reality, there may be variation both in the process and in the material and therefore there may be sensors which differ largely from what we naively would expect. When constructing an experiment consisting of many sensors we have to measure them in the laboratory to find the good sensors that can be used in the experiment. The sensor characterization you will do in the HIP clean room following separate instructions.

Amplifier

It is not unusual that preamplifiers are sold separately. Especially in systems with many channels and odd geometries one want to use hybrid preamplifiers. The advertise shown in figure 2 is for a hybrid preamplifier which looks very much like the one you will study in this lab. (The lab-preamp originates from the late 80') . CAEN has a similar product A1422H http://www.caen.it/csite/CaenProd.jsp?parent=13&idmod=774.

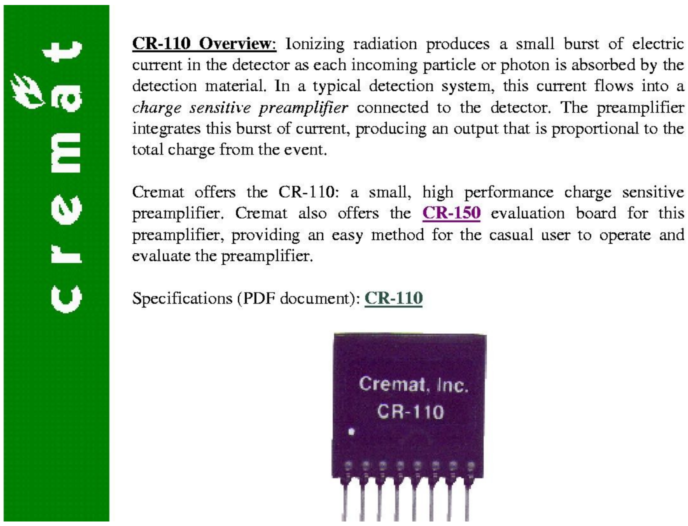

Illustration 2. Advertisement published in 2005 on a hybrid preamplifier.

2. Characterization of the preamplifier

Figure 3 shows a diagram of the hybrid preamplifier with legs (pins) identified.

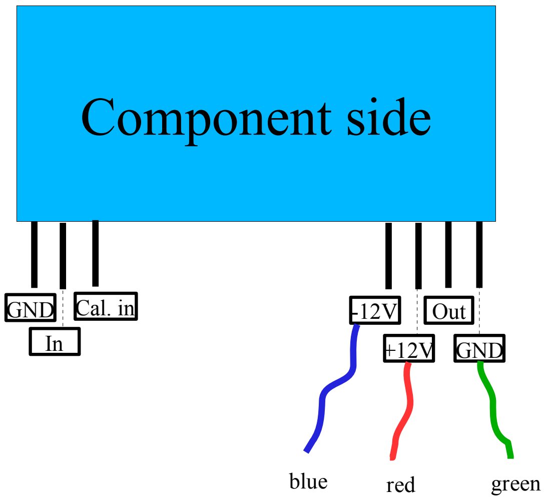

Illustration 3. Layout of the preamplifier hybrid board.

Figure 4 shows the schematics of a low noise charge integrating amplifier. T1 is a high gain stage powered by a JFET transistor.

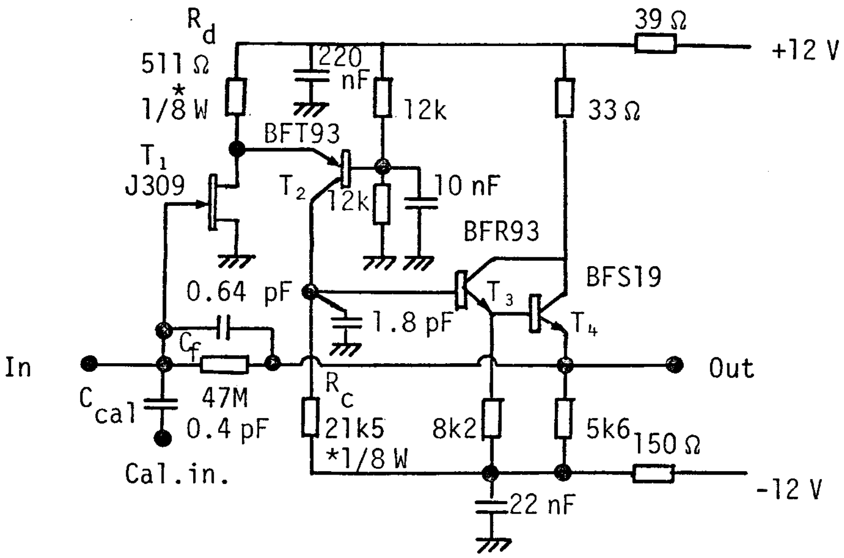

Illustration 4. Schematics of the preamplifier hybrid board.

Task:

- Get familiar with the Vero board (the brown board with a lot of holes).
    - ✔ Connections on the board. Note the two external components on the board (a 50 Ohm resistor, 100 nF capacitor). What is the purpose of the components?
    - ✔ Notice that there are plenty of unequipped places on the board where external components can be easily be plugged in.

- Use a lab power supply with two voltages, a pulse generator giving with square pulses and a oscilloscope get the amplifier running.
    - ✔ Connect voltage to voltage pins
    - ✔ Connect a small amplitude square pulse (10-20 mV, 1kHz) to Cal. in.
    - ✔ Study the output on oscilloscope

Use a Digital Volt Meter (DVM) to check that the voltages you intend to apply to the amplifier are correct! Check the amplitude and frequency of the signal applied to Cal_in. (This is a good exercise to get familiar with the oscilloscope)

- Study the amplifier gain, rise time and noise as a function of load capacitance (between input and ground) .
    - ✔ Determine the size of the calibration charge you are going to injected into the preamplifier. The charge is injected by a square pulse over the calibration capacitance Cal. in. Select an injected charge between 1-2 MIP in 300 micrometer silicon (between 25000 electrons and 50000 electrons).
    - ✔ Measure gain, rise time and noise vs. input capacitance (1-100 pF) and note down the values in a table.
    - ✔ Plot the gain, rise time and noise vs. input capacitance.
    - ✔ Plot the ENC vs. capacitance, fit the data with a straight line and extract the ENC noise (offset) at 0pF and the noise slope in ENC/pF.

ENC = Equivalent Noise Charge, the number of electrons one would have to collect from a silicon sensor in order to create a signal equivalent to the noise of this sensor.

- Study the preamplifier performance with a Spectroscopy Amplifier (SA) and a Pulse Height Analyzer (PHA).
    - ✔ Adjust the amplification for 1 MIP to ~2V amplitude on the spectroscopy amplifier output.
    - ✔ Do a 3pt gain calibration with 1, 2, 3 MIP test pulse to determine the calibration parameters of the PHA → Plot the gain curve
    - ✔ Measure the noise for two shaping times (long and short) for a medium large capacitance and compare the result with the oscilloscope measurement. → Add the measurement to the plot made with oscilloscope.

? Do the measurements with two different shaping times give indications for the source of the noise (serial, parallel?)

Measurement of full chain sensor + amplifier=detector

Task:

- Measure the performance with the sensor DC-coupled to the preamplifier with radioactive source
  - ✔ Bias the sensor from the backplane. Feed the backplane bias through a low-pass filter with a cutoff frequency <10Hz. Build the filter in the “creative corner” on the VERO board.
  - ✔ Apply bias to fully deplete the silicon sensor (the depletion voltage you have determined during sensor characterization)
  - ✔ Acquire a spectrum with the PHA with and without source

- Plot the PHA spectrum and explain what you see

? What were the major problems in the detector performance and how can the the detector be improved ?