Z29 - Nuclear Electronics

Physics Laboratory II
Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University

The "Nuclear Electronics" exercise is a preliminary exercise for other nuclear physics projects, which has two goals: to familiarize the student with processing of electronic signals from radiation detectors and with the principles of safe work with radioactive sources.

In the electronic part, students learn about basic electronic modules for processing and measuring the parameters of electronic signals. These include a line amplifier, a single channel analyzer, a converter, a delay line, and a coincidence circuit. By building simple systems with these modules, students observe their operation, measure the parameters of received signals (e.g. amplitude, rise time) and become acquainted with the statistics of nuclear measurements. In particular, they examine the phenomena of coincidences and anti-coincidences of signals from two detectors.

At the same time, students learn the concepts and units used in nuclear physics and dosimetry, methods of radiologicl protection, and obtain information about health risks associated with radioactivity.

Preparatory questions

1. Definition of radiation source activity and relevant units.
2. Definition of radiation dose and equivalent dose (units). What is the relative biological effectiveness (RBE) factor?
3. Difference between an open source and a closed source. Rules for handling radioactive sources, in particular with open sources.
4. Shielding - types and thickness, which provide effective protection against α, β, γ radiation and neutrons, assuming that the energy of radiation is of the order of several MeV (these are typical energies for radiation sources).
5. What is the biological harmfulness of radiation?
6. What is the order of:
   - the yearly dose from natural radiation,
   - the permissible annual dose,
   - lethal dose for humans?
7. Basic parameters describing an electric pulse (amplitude, width, duration) and their role in identification of radiation and determination of its properties.
8. Basic electronic modules used in nuclear physics experiments (no need to go into details of their construction, but knowledge of what kind of signals go on input and what comes out of the module).

Computational assignments

Calculate the radiation dose obtained by the soft tissue of a person standing for 8 hours at a distance of 1 m from the source of ^{65}Zn with the activity of 1μCi, emitting gamma quanta of 1.1 MeV energy. (Activities on the order of 1 μCi are typical for sources available at the 2nd Physics Laboratory).

Apparatus and materials

The setup consists of:

- signal generator (either an electronic one, or a radiation detector with a radioactive source) **SG**,
- linear amplifier **LA**,
- delay amplifier **DA**,
- single-channel analyzer **SCA**,
- delay **LSD**,
- coincidence unit COIN,
- scaler **S**,
- oscilloscope **OSC**,
- multichannel analyzer coupled to a computer (if there is a need for individual modification of the course of the exercise).

Experiment

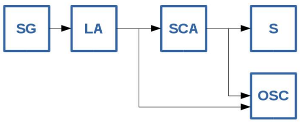
A typical scenario (to be consulted with a tutor):

1. Using an oscilloscope, observe signals from the generator and measure their parameters. Draw a shape of a typical signal and note the measured values on the drawing.

2. Amplify the signal in a linear amplifier. Determine the amplitude of output pulses for several different gains with a fixed pulse shaping. Then change the shape of the pulse at the fixed gain. For the

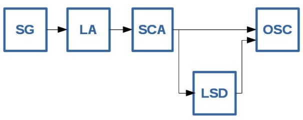
same gain parameters and the shape settings check the changes of amplitude, when the polarity of the input pulse is incompatible with the polarization of the amplifier input. Present your results in the form of well-described drawings.

3. Set gain and shaping such, that the amplitudes of output signals do not exceed 9 V and observe the operation principle of a single-channel analyzer working in the following modes:
   - Independent, for several different discrimination thresholds,
   - Window, for different widths and locations of the window.

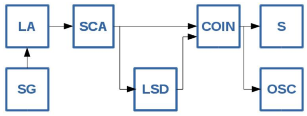


   In both cases observe which conditions must be fulfilled to get a pulse on the output of the analyzer. Check how the rate of those pulses depends on the analyzer settings.

4. Split (using a T-shaped connector) the pulse from a single-channel analyzer. Send one of them directly, and the other via a logic shaper and delay to the two inputs of an oscilloscope. Observe the change in the relative position of pulses depending on the selected delay time (Delay) and examine the changes resulting from using the pulse shape (Width) function. Please note, that the two outputs from delay module are not equivalent.



5. Set the minimum delay on the delay module. Supply the pulse from the output onto the input of the coincidence unit. Feed the second input of a coincidence unit with the second pulse obtained from splitting the output signal from the single-channel analyzer. For different values of coincidence time set on the coincidence unit, observe pulses appearing on the output on the oscilloscope and count them using a scaler. Repeat these observations, each time increasing the delay. Plot the dependence of observed pulse rate versus set delay, draw conclusions. From the results of the measurement carried out for the longest coincidence time with the shortest delay time, determine the coincidence time $\tau[\mu s]$ and calculate the rate (number of entries per second) of accidental coincidences N_p [s^{-1}] using the formula $N_p = 2 \times \tau \times N_1 \times N_2$, where N_1, N_2 are the rates of pulses appearing on the first and second input of the coincidence unit, respectively.



Data analysis

Report should contain, for each of the investigated circuits:

- a brief description of the setup, including a scheme,
- drawings of observed pulses including their parameters, description of how they were produced and modified by using the investigated electronic modules,
- a list of results of all quantitative measurements (e.g. made using a scaler), charts of these quantities, estimation of uncertainties of measured quantities,
- conclusions and comments.

Safety rules

Do not touch elements of electronic modules when they are powered, avoid direct contact with radioactive sources. Do not consume any food or beverages in the 2. Students Laboratory.

References

[1] *International Atomic Energy Agency Radiation Biology: A Handbook for Teachers and Students*, available here, in particular pages 13-33.

[2] W. R. Leo, *Techniques for nuclear and particle physics experiments*, Springer Verlag,1987, in particular sec. 1.10, chapters 3 and ≥ 14.