UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Esperimentazioni di Elettronica

2526-3-E3001Q071

Aims

Underlying every physics experiment is a fundamental process: the conversion of physical events into electrical signals, which are then transformed into a sequence of numbers that can be analyzed. This same principle applies to many of the systems we interact with on a daily basis, often without realizing it. Just think of a car's diagnostics or our cell phones, which are capable of processing radio waves, sounds, temperatures and acceleration.

In this course, we will dive into the complete construction of a modern data acquisition system for a detector. Our ultimate goal will be to analyze the data thus obtained.

On a practical level, this means that we will study and build every single element of this chain. We will start with the microprocessor, which is responsible for generating the numerical strings from the analog signals. These signals, in turn, come from the amplifier that we will build to best read the signals produced by the detector.
We will acquire and practice all the basics needed to achieve this, equipping ourselves with the tools to understand and implement each step of the process.

1. **Understand** the basic principles of analog and digital electronic circuits and the operation of detectors used in laboratory experiences.
2. **Design**, build and test electronic circuits, applying acquired theoretical knowledge.
3. **Critically evaluate** experimental results and diagnose malfunctions in fabricated circuits.
4. **Communicate** in a clear and structured way the results of experimental activity through written reports and oral talks.
5. **Develop independent learning skills** in the use of electronic instrumentation and in approaching new experimental experiences.

A more detailed description of the purposes and modalities of the course can be found described in the following publication (which can be accessed with campus credentials):
A laboratory course on detector readout for undergraduate students of experimental physics

Contents

This course aims to introduce students to the world of experimental physics, focusing on the key elements of a measurement chain with a particle detector. We will learn about and use:

- Analog signal amplifiers and shapers, which are fundamental for preparing the raw signal for the detector.
- Analog-to-digital converters (ADCs), essential for transforming analog signals into numerical data.
- Microcontrollers, to manage the trigger system (i.e., the mechanism that decides when to acquire a data item) and data transmission.
- For analysis and visualization of the acquired data, we will use MATLAB software on a PC.

A crucial practical application of the course will be the construction of a complete measurement chain for one of the most modern and popular detectors: the SiPM, or Silicon Photomultiplier. This type of detector is extraordinary because it can generate a measurable electrical signal even in response to a single incident photon.

We will study in detail the electrical signal produced by the SiPM and process it through the entire measurement chain, which we will build entirely in the laboratory. The goal is to convert the signals into a sequence of numbers, which will then be analyzed mathematically to extract physical information from it.
This hands-on course will provide you with a solid foundation to meet the challenges of modern experimental physics.

Detailed program

The course is for everyone and aims to be preparatory to any address the student wants to undertake later.

- First steps with ARM Cortex family microcontroller: GPIO, timers, interrupts.
- Communication between microcontroller and PC via serial protocol (UART): ASCII or binary data.
- Use of MATLAB software on PC.
- Acquisition with analog-to-digital converter (ADC).
- Advanced memory management: DMA, circular buffer.
- Signal acquisition and triggering.
- Operational amplifiers, inverting and non-inverting configuration.
- Diodes, LEDs, Silicon and SiPM detectors
- Peak detectors
- Observation of single photon signals with SiPM
- Construction and operation of the complete acquisition chain, from SiPM to microcontroller and then to PC.

More information will be available at the following web page: http://pessina.mib.infn.it

Prerequisites

Notions of classical Physics: Electricity and Magnetism.

Teaching form

**The course takes place in the first semester. **

24 laboratory sessions of 4 hours each, twice a week, to be confirmed with the semester schedule.

The sessions are conducted in interactive in-presence mode (lab activities).

In the first part of the course, each student works individually with his or her own microcontroller to realize the system of signal conversion and its transmission to the PC.
In the second part of the course, groups of 2-3 students are formed to work on amplifiers and SiPMs.
In the final part of the course, each student will implement his or her own measurement chain consisting of the detector, amplifier, microcontroller and analysis of the data obtained on a PC.

When necessary to introduce the next topic, the first part of the session (about 1 hour) can be conducted in delivery mode (frontal lecture in the lab) and in English, if asked.

Textbook and teaching resource

- Slides that will be made available, on this web page (clicking on Enter, the green button on the right), in sync with the lectures;
- Project development software;
- Mathematical analysis tools;
- Development boards for the microcontrollers we will use;
- Detectors we will use;
- Laboratory instrumentation appropriate to the experiments: oscilloscopes, function generators, voltage generators.

Semester

First semester.

Assessment method

- A written report describing all the experiences covered (the report can be written in groups of up to 3 people);
- An interview (mandatory), which will be individual instead, where the content of the report and the topics covered in class will be discussed. As indicated above, the topics covered in class are available on this webpage (by clicking on enter). Next to each handout will be indicated any topics not required but only present for further study.

The final grade takes into account the work done in the laboratory during the course, the quality of the paper and the mastery of the topics demonstrated in the final interview.

The exam can be taken in English.

Office hours

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Sustainable Development Goals

QUALITY EDUCATION