UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Esperimentazioni di Elettronica

2627-3-E3001Q071

Aims

At the heart of every physics experiment lies a fundamental process: the conversion of physical events into electrical signals, which are then transformed into analyzable sequences of numbers. This same principle applies to many of the systems we interact with on a daily basis, often without even realizing it. Just think of car diagnostics or cell phones, which are capable of processing radio waves, sounds, temperatures, and accelerations.

In this course, we will delve into the complete construction of a modern data acquisition system for a detector.
We will study and build every element of this chain.
We will start with the microprocessor and its analog-to-digital converter (ADC), which is responsible for generating numerical strings from analog signals and transferring them to a PC.
The analog signals will come from the output of an amplifier, which we will build to best handle the signals produced by a detector.
We will acquire and put into practice all the basic concepts necessary to achieve this goal, equipping ourselves with the tools to understand and implement every phase of the process.

DD1: Knowledge and understanding. Understand the fundamental principles of analog and digital electronic circuits in the context of signal acquisition from sensors and detectors.
DD2: Ability to apply. Develop programs (firmware) for microcontrollers. Design and characterize analog electronic circuits based on operational amplifiers (op-amps). Correctly use laboratory equipment (signal generator, oscilloscope, power supplies) for the measurement and characterization of circuits.
DD3: Making judgements. Critically evaluate experimental results and diagnose malfunctions in the circuits and programs developed.
DD4: Communication skills. Communicate the results of the experimental activity clearly and in a structured manner through a written report and an oral presentation.
DD5: Independent learning. Develop the ability to independently navigate technical documentation (datasheets, reference manuals, application notes).

A more detailed description of the course objectives and methods can be found in the following publication (accessible with campus credentials):

A laboratory course on detector readout for undergraduate students of experimental physics

Contents

The course covers the key components of a measurement chain starting from a generic sensor or detector:

- Signal amplifiers and shapers, based on operational amplifiers (op-amps), which are essential for preparing the “raw” analog signal for digital conversion;
- Analog-to-digital converters (ADCs), for converting analog signals into digital data;
- Microcontrollers, for managing via firmware the trigger system (i.e., the mechanism that determines when to acquire data) and data transmission;
- PCs running Python or MATLAB, for analyzing and visualizing the acquired data.

The practical application of the course will be the construction of a complete measurement chain, from the sensor to the PC, for one of the most modern and widely used detectors in particle physics experiments: the SiPM (Silicon Photomultiplier), a light sensor capable of generating a measurable electrical signal even in response to a single incident photon.

Detailed program

Microcontroller and firmware:

- ARM Cortex architecture: GPIO, timers, interrupts
- Serial communication with PC (UART): ASCII and binary data
- Data acquisition with integrated ADC
- Advanced memory management: DMA and circular buffer

Data processing and analysis:

- Signal acquisition and triggering
- Data analysis and visualization with Python/MATLAB

Analog electronics:

- Operational amplifiers: inverting and non-inverting configurations
- Silicon diodes and photodiodes; LED and SiPM (Silicon Photomultiplier)
- Shaper circuits and peak detectors

System integration:

- Observation of single-photon signals with SiPM
- Construction and operation of the complete acquisition chain

Prerequisites

Basic concepts of electricity and magnetism and their applications in simple circuits.

Familiarity with the laboratory environment gained in previous courses.

Teaching form

There are two lab sessions per week, each lasting 3.5 or 4 hours, depending on the academic calendar.
The total number of hours is 96.

Teaching format: when necessary to introduce new topics, the first part of the session (approximately 1 hour) is dedicated to a lecture held in the lab. At the students' request, the lecture may be conducted in English.
Interactive format: the remaining hours of each session are conducted interactively through in-person practical lab activities.

In the first half of the course, each student works individually with the microcontroller to build the signal conversion system and its transmission to the PC.
In the second half of the course, groups of 2–3 students are formed to work on amplifiers and SiPMs.

Textbook and teaching resource

Handouts and manuals:

- Handouts, which will be made available on the course page as the lectures are held
- Manual and datasheet for the ARM Cortex-M family microcontroller
- Datasheets for operational amplifiers (op-amps) and photodetectors (SiPMs)

Software:

- Integrated Development Environment (IDE) for STM32 microcontrollers
- Development environment for Python (Thonny or another editor of your choice)
- Alternatively: MATLAB (available with a campus license)

Lab equipment:

- Development board for STM32 Nucleo microcontrollers
- Board for SiPMs and amplifiers, custom-built for the course
- Lab instruments: oscilloscopes, signal generators, power supplies, cables

Students are advised to bring their own laptop on which to install the specified software.
A limited number of computer stations are available in the lab for those who do not have their own.

Semester

The course is offered in the first semester.

Assessment method

The exam consists of two parts:

- A written report describing the technical aspects of the laboratory experiments, key details of the programs developed, and the results of the characterization measurements;
- An oral exam, during which students' understanding of the theoretical topics covered in the course syllabus will be assessed, and any comments on the content of the report will be discussed.

The report may be written individually or in groups of up to 3 people and must be submitted via email at least 4 business days before the date of the oral exam.
The oral exam is mandatory and individual, with an approximate duration of 45–60 minutes.

The final grade will take into account:

- Attendance and commitment demonstrated during the laboratory activities;
- Quality of the technical solutions developed and the results obtained, as described in the report;
- Mastery of the theoretical topics demonstrated during the final interview.

The exam may be taken in Italian or English.

Office hours

There are no set office hours.
Students may contact the teachers via email to schedule an appointment.

Sustainable Development Goals

QUALITY EDUCATION