universidade de aveiro theoria poiesis praxis

Aerospace Engineering Masters program

#43169 Avionics and Spacionics

Module M1: Basic electronic modules

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Module workload and contact hours

- 3 weeks
- 3 H/TP week
  - 1.5 H/T + 1.5 H/P

Topics to address

- M1.1 Sensors and Transducers
- M1.2 DAC and ADC conversion
- M1.3 Voltage sources
- M1.4 Signal conditioning
- M1.5 Clock generators

Outlook

Topics M1.1, M1.2 and M1.4 are presented in sequence that follows the flow of information on instrumentation systems, starting form the physical variable to the processing/computing system. Thus, the course unit starts with sensors/transducers, that transform the physical variables into electric entities (voltages, currents, resistances, charges, ...), then are studied circuits to translate such electrical entities into electrical variables (typically voltages or currents) with characteristics that allow its transmission and/or processing (conditioning circuits). Finally, at the end of the chain, there are the ADCs that interface the physical world (analog in nature) with the supervision and control systems (mostly digital e nature). The opposed path (from digital to analog) will also be briefly addressed, with focus on DACs.

Sensors, transducers, conditioning circuits and DACs/ADCs depend on other electronic components and subsystems. We will delve briefly in two essential classes of such circuits: voltage sources (DC-DC converters, regulators, topic M1.3) to generate the suitable supply voltages, and clock generators (topic M1.5), used for timing and clocking the digital systems.

The classes will be organized as follows:

- Class 1: Sensors and Transducers
- Class 2: Signal conditioning + DAC/ADC conversion
- Class 3: Support circuits – voltage sources and clock generators

Development of class topics

Class 1: Sensors and Transducers

In aerospace, sensors and transducers play a critical role in various functions, from monitoring and controlling aircraft systems to ensuring safety and efficiency. Due to the introductory nature of this course unit, and time constrains, it will be provided an high level overview of functioning principles and main characteristics of a subset of these sensors. Some of the other sensors commonly found in aerospace applications aree addressed in other modules (e.g. radar).

- **Temperature sensors**
  - **Thermocouples**: Measure high temperatures, especially in engines.
  - **Resistance Temperature Detectors (RTDs)**: Used for precise temperature measurements in various parts of the aircraft.
  - **Integrated** and **thermistors**: Used for measuring ambient temperatures, e..g in the cabin.
- **Force, torque and vibration sensors**
  - **Strain Gauges and load cells**: Measure the strain on structural components, providing data on loads and stresses. Measure the torque in drive shafts and other rotating machinery.
- **Pressure sensors and transducers**
  - **Pitot Tubes**: Measure the airspeed of the aircraft.

    - **Static Pressure Sensors:** Measure atmospheric pressure for altitude and airspeed calculations.
- **Environmental sensors**
    - **Humidity Sensors**: Monitor moisture levels in the cabin and other critical areas.
    - **Ice Detection Sensors:** Detect the formation of ice on critical surfaces.
- **Inertial sensors**
    - **Accelerometers**: Measure acceleration forces, which are crucial for navigation and control systems.
    - **Gyroscopes**: Measuring orientation and angular velocity, which are also crucial for navigation and control systems.

These sensors and transducers are integral to the safe and efficient operation of aerospace systems, providing real-time data that supports navigation, control, monitoring, and maintenance activities.

Class 2 – Signal conditioning and AD conversion

Sensors and transducers often have outputs that are unsuitable for direct processing. This is the case e.g. of very small voltages and currents, charge output, presence of offset voltages, etc. In this case sensor/transducer signals must be properly conditioned.

Nowadays, at the end of the chain these signals are digital processed, thus we will address also D-A conversion.

- **OpAmps basics**
    - Review of the main concepts
- **Basic circuits with opamps**
    - Review of basic circuits with opamps (amplification, algebraic operations on signals, filtering)
- **The Instrumentation Amplifier**
    - Concept, realization and design issues
    - Examples of use
- **AD and DA conversion**
    - Concepts on AD/DA
    - Converter characterization
    - Errors in Analog/Digital Conversion
    - Other characteristics
- **Sample and Hold**
    - Purpose and practical issues

Class 3 – Voltage sources and oscillators

Today's spacionics and avionics electronic designs require an increasing number of power rails and supply solutions. These exhibit:

- Different voltage levels, different output currents (from a few mA to 00's of A), different stability and accuracy levels, ...
- Such diversity implies that different types of circuits/components have to be used to generate these power supplies

Spacionics and avionics electronic circuits often need oscillators, e.g. for timing purposes or to fed digital components

Therefore, this module introduces some of the basic requirements, circuits and components used for generating voltage sources and oscillator circuits. The main topics to address include:

- **Linear regulators**
  - Fundamentals
  - Working principles and design aspects
- **Switching regulators**
  - Fundamentals
  - Boost converter
  - Buck converter
  - Buck-Boost Converters
  - Practical aspects
- **Precision voltage sources**
  - Methods and circuits to generate precise and stable voltages
- **Clock Generators**
  - Fundamentals
  - RC oscillators
  - Crystal oscillators

Teaching methodology and work organization

Classes are split in a theoretical-oriented part complemented by a practical/laboratory one.

The theoretical part consists of expository sessions accompanied by problem-solving aimed at reinforcing learning and deepening the understanding of the covered materials, focusing mainly on:

- Applying theoretical concepts to practical scenarios to help bridge the gap between conceptual understanding and practical implementation.

- Developing problem-solving skills, critical thinking, and the ability to systematically approach and solve complex problems.
- Obtaining immediate feedback to evaluate students' understanding and progress and timely identify learning difficulties.
- Promoting active learning.
- Promoting collaboration and discussion to enhance learning through peer interaction.

The practical part closely aligns with the theoretical one, consisting, whenever possible, of sequences of tasks that address the concepts discussed in the theoretical part.

There is a strong orientation towards applying knowledge to simple but realistic cases, representative of the area.

Assessment

Assessment is divided in two parts.

- A written test (WT, individual)

- Report of practical work (Rep, groups of two)

The written exam is at the class that follows the end of the module.

The report must be submitted until one week after the last class.

The module’s grade (MG) is compute as follows:

MG = 0.7 * WT + 0.3 * Rep