SENSORS AND ACTUATORS

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Sensors have been used as detection elements for past decades. One simple and common example is the mercury thermometer used to measure the body temperature that relies on the Physical property called thermal expansion. In general, a sensor needs a **transducer** that transforms the measured magnitude in another one that is easier to interpret or visualize. Nowadays, most sensors require combination with electronic devices. The use of sensors has considerably increased in the last years due to the development of **electronic signal processing**. The domains of application of sensors cover fields such as medical instrumentation, automotive industry, industrial measurements, environment control, energy sources, safety, electrical appliances, chemical industry, etc.

"To sense" implies to detect properties such as the temperature, humidity, pressure, magnetic field, displacement, speed, chemical composition, light colour and intensity, etc. In order to accomplish its function, a sensor relies on a **Chemical or Physical effect**. Thus, a temperature sensor like a thermocouple makes use of the Seebeck effect that gives rise to a voltage difference between terminals at different temperature and a magnetic sensor such as a Hall sensor makes use of the Hall effect due to the Lorentz force acting on electrical carriers. The materials used to create sensors can be ceramic, organic, metallic, composite, etc. and can be realized in bulk form or in thin-film form. In the latter case, it is especially interesting the **integration** of the thin-film sensor with the electronics in a semiconductor-based integrated circuit, which brings about smaller and generally more efficient sensors. If the sensing takes place via the use of a biological recognition event, we talk about **biosensors**. Biosensors is a fast growing field because it can allow precise sensing of molecules and biomolecules. In combination with Nanotechnology, we would enter the realm of Nanobiosensors, which is presently a fancy topic.

In my talk I will start by giving general notions on sensors such as those described in the previous paragraphs and I will describe a few examples [1]. Afterwards, I will focus on **magnetic sensors**, which is the topic of interest in the School. In this context, I will describe

inductive sensors, Hall sensors, magnetoresistive sensors (AMR. GMR, TMR), SQUID sensors, etc. These sensors have a wide range of applications in fields such as automotive industry, magnetic storage industry, aeronautic industry, industrial applications, magnetic field sensing, safety, magnetoencephalography, DNA biochips, etc [2-11].

Afterwards, I will focus on **magnetic biosensors**, which is a relatively new and very promising field. Two approaches can be realized depending if the biological recognition and the detection take place on the same platform (lab-on-a-chip technology) or on separate platforms. **Lab-on-a-chip** technology is generally preferred as allows integration with the electronics but it is somewhat complex to build when dealing with liquid samples. In such cases, **microfluidic** devices are normally realized. In many cases, magnetic biosensors require tagging the biological recognition event via **magnetic nanoparticles** and their functionalization. I will describe one kind of magnetic biosensor that we are developing in our Group in order to measure concentrations of a targeted analyte present in a solution via immunochromatographic (lateral-flow) tests. These kinds of biosensor are normally applied for clinical diagnosis. In our case, the detection of the functionalised magnetic nanoparticles has been carried out with inductive sensors and with magnetoresistive sensors [12].

In the last part of my talk, I will introduce the concept of "actuation". **Actuators** are devices that transform an input signal (mainly electrical) into motion. Typical examples are electrical motors, relays, piezoelectric actuators, etc. To meet the audience's interests, I will put emphasis on the description of **magnetic actuators**. In such systems, magnetic materials are used to produce a mechanical device that generates and controls motion. Input electrical energy in the form of voltage and current is converted to magnetic energy, which produces a magnetic force able to generate motion. Applications of magnetic actuators can be found in valves and fuel injectors in automotive and aeronautic applications, biomedical prosthesis (in hearts, limbs, ears), head positioners for computer disk drives, loudspeakers, relays, switchgears, sonars, etc.

Since computers have input and outputs that are electrical signals, magnetic actuators are ideal for computer control of motion. Motion control that was in the past accomplished by manual command is now increasingly carried out by computers with magnetic sensors as their input interface and magnetic actuators as their output interface. An area of increasing development is that of magnetic actuation at the micro- and nano-scales. In this sense, the maximum integration of the actuator with the electronics is desired in order to reach miniaturization and efficiency. The recent advancements in micro- and nano-fabrication techniques habilitate the progress in this field.

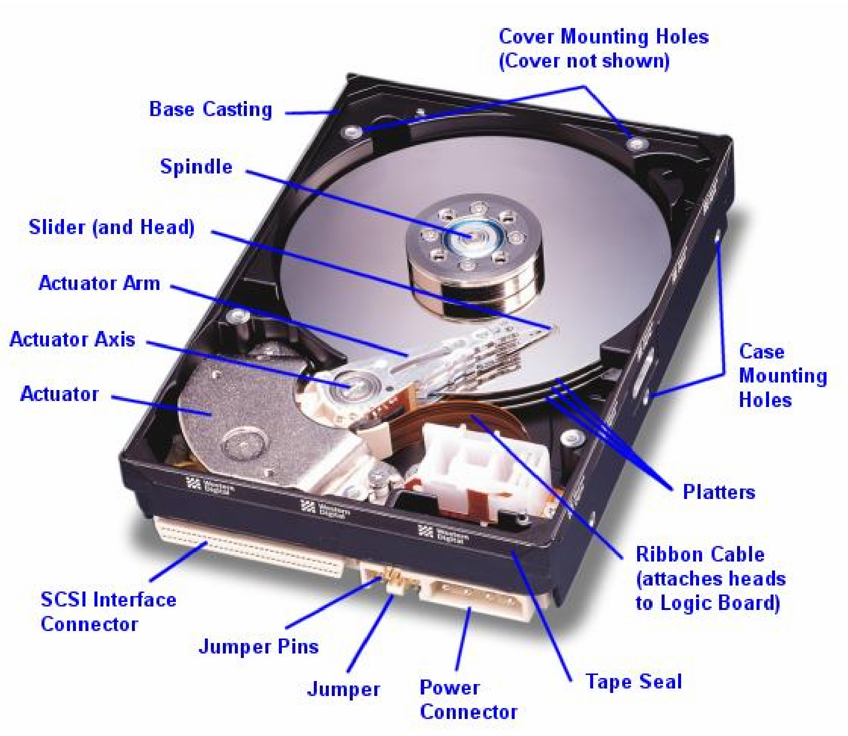

Figure 1. *Disk drive picture. A* ***magnetic actuator*** *allows the positioning of the writing/reading head at the desired postion. The reading process takes place through the change in resistance produced by the stray magnetic fields arising from the magnetic bits on a* ***magnetoresistive sensor*** *located at the head tip. This is just one example of how magnetic sensors and actuators are integrated in today's technology.*

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