Lesson №6. Studying of the sensors.

In physiological and diagnostic studies, it is often necessary to measure numerous non-electrical quantities, the direct registration of which is difficult. For this purpose, ***sensors*** are used-devices that convert the measured or controlled value into a signal that is convenient for transmission and registration.

Currently, electrical methods for measuring non-electrical quantities are widely used. Their main *advantages* are high sensitivity, reliability, easy registration and the ability to make measurements at a distance.

Sensors are characterized by the **conversion function F(x)**: the dependence of the ***output value Y*** on the ***input value x: Y=F(x).*** The most convenient sensors are those with a linear dependence of Y on x: Y=kx. The value Z=ΔY/Δx, which shows the change in the output value with a single change in the input value, is called the **sensor sensitivity**. The minimum change in the input value that can be detected by the sensor is called the **sensitivity threshold**.

Sensors are divided into two classes: ***generator*** and ***parametric***. Generator sensors are those that generate voltage or current. Parametric sensors are sensors in which a parameter changes under the influence of a physical factor.

Let's look at the operation of some types of sensors.

Tensosensors

The *Tensosensor* is used for evaluating deformations that occur in an object under the influence of external forces. The most widely used resistance tensosensors - are strain gages. Their action is based on the change in electrical resistance during deformation. The sensor resistance R is given by the formula

$$R=\rho\frac{L}{S} \qquad (1),$$

where R is the sensor resistance, ρ is resistivity, L is the conductor length, S is the cross section of the conductor.

If we ignore the change in the cross-section of the conductor (usually it is insignificant), then the relative change in the resistance of the conductor is equal to:

$$\frac{\Delta R}{R}=K\frac{\Delta L}{L} \qquad (2),$$

where ε is the relative strain.

The phenomenon of elastic deformation is described by Hooke's law:

$$\frac{F}{S}=E\frac{\Delta L}{L} \text{ or } \sigma=E\varepsilon \qquad (3),$$

where E is a parameter that characterizes the ability of the body to strain by stretching or compression -Young's modulus; F is the value of the external force acting on the body; S is the cross–sectional area of the body perpendicular to the direction of the force; σ is the mechanical stress.

Taking into account equations (2) and (3), the strain sensitivity coefficient will be determined by the formula:.

$$K=\frac{\Delta R}{R}\frac{E}{\sigma}$$

Thus, the input value is the deformation of the conductor, and the output value is the change in the resistance of the sensor. The main characteristic of the sensor is the coefficient of *relative strain sensitivity K*.

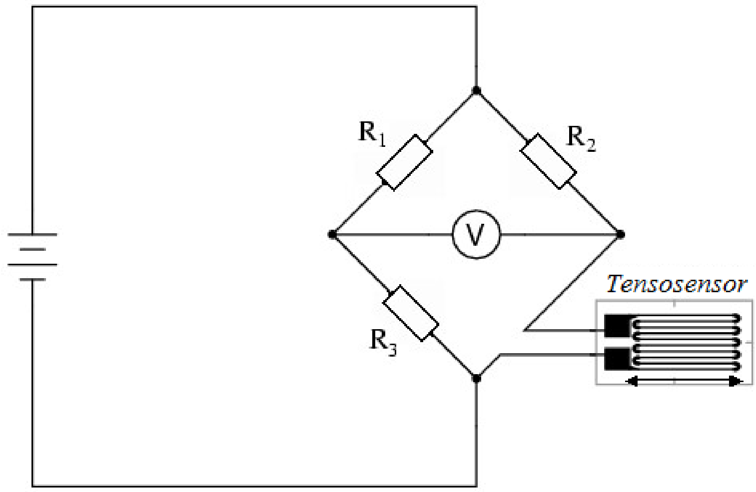
The value of the strain sensitivity coefficient depends on the material:

- for Nickel wire, K=12.1;

- for platinum, K=6.1;

- for semiconductors K>100.

Distinguish between the strain gages and wiring (wire, foil) and semiconductor.



A wire strain gauge is a thin wire (up to 20 - 30 microns in diameter) that is zig-zag glued to a thin film, the ends of which are connected to the output conductors (Fig. 1). the sensor is covered with a thin insulating layer of varnish on Top. The working part of the foil resistor is a thin strip of foil, on which a drawing of the location of the conductors of the required configuration is created by etching.

Fig. 1. Wire strain gauge (arrows show the direction of deformations perceived by the sensor).

Semiconductor strain gages are usually made of silicon and germanium plates with high strain sensitivity.

The strain gauge is rigidly fixed on the object under study (glued, welded). When an object is deformed, the sensor is also deformed, which changes its electrical resistance. The strain gages belong to the parametric sensors.

The strain gauge is used in medicine for recording a pneumogram that characterizes changes in the perimeter of the chest, respiratory rate, in measurements of force, pressure, vibrations in the elements of the musculoskeletal system, for direct measurement of intravascular pressure, pressure in the heart cavities, etc. In dentistry, a strain gauge is used to determine the stresses that occur during loading in various maxillo-facial parts, when developing dentures.

Temperature is one of the main parameters that determine the state of biological objects. An increase in the temperature of the human body by only 1-2 degrees leads to loss of performance, violations of the function of tissues, organs and systems: changes in the speed of biochemical processes, heart rate, respiratory rate, etc. Therefore, accurate temperature measurement is an important procedure in medical diagnostics.

Temperature sensors

Temperature measurement is based on the assumption that bodies in direct contact eventually come to thermal equilibrium, i.e. they will have the same temperature.

The quantitative determination of temperature is based on the registration of a change in a property when the temperature changes: a change in volume at constant pressure, a change in electrical resistance, a change in the contact potential difference, etc.

The most common devices in medicine for determining temperature are mercury thermometers, the main advantage of which is the possibility of direct temperature reading, ease of manufacture, and low cost. The disadvantages of mercury thermometers include high thermal inertia (the time required to measure the temperature). Mercury medical thermometers make it possible to measure the temperature with an accuracy of 0.1 degrees. However, in some cases, for example, in the diagnosis of inflammatory processes, tumor formations, such accuracy is not sufficient. In addition, the mercury thermometer, measuring the temperature of large bodies, can not give information about the temperature in a small volume or even a point, which is necessary to know for diagnostic and therapeutic purposes.

In this regard, in medical practice, temperature sensors are used to measure temperature, in which the measured parameter reacts without inertia to changes in temperature. Examples of such sensors are thermocouples, thermistors, and liquid crystal films.

Thermoelectric sensors can be:

parametric (conductor and semiconductor thermal resistances),

generator (thermoelements).

Resistance thermometers– thermistors, thermistors) - sensors that are based on the change in electrical resistance when the temperature changes. At the same time, the resistance of metals increases with increasing temperature, while that of semiconductors decreases.

In conduction the thermal resistance of metal wire is wound on the basis of the insulator (porcelain, quartz, mica) and covered with a protective shell. Platinum, copper, Nickel, and iron are used as conductors (depending on the temperature range in which the measurements are made). For example, a platinum thermometer allows you to measure the temperature in the range from 200 to 11000 C.

More sensitivity, low temperature inertia, and relatively smaller sizes are provided by semiconductor thermal resistances-thermistors. Structurally, a thermistor is a small (about a fraction of a millimeter) semiconductor ball, in which two thin wire electrodes connected to the measuring device are introduced. The entire thermistor is enclosed in a thin plastic case (Fig. 2).

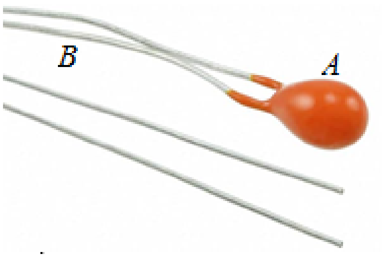


Fig. 2. Diagram of a thermistor sensor (A – semiconductor, B - contact metal conductors).

The action of a thermistor is based on the dependence of the electrical conductivity of a semiconductor on temperature: as the temperature of the semiconductor increases, its resistance decreases (the number of free charge carriers increases). The input value of the sensor is a temperature change DT, and the output – resistance variation ΔR of the sensor. The sensitivity coefficient of a thermistor is determined by the equation:

$$K=\frac{\Delta R}{\Delta T}$$

To measure electrical resistance, a Wheatstone bridge is often used (Fig. 1), containing reference resistances R1 and R2, a calibration variable resistance R3 (resistance store), and a galvanometer V.

Generator Thermosensors – *thermoelements* - can be made of both metals and semiconductors. The action of metal thermoelements is based on the difference in electron concentrations in metals. When two dissimilar metals come into contact (welding, soldering), a contact potential difference U occurs between them. When the junction of metals is heated, the potential difference between the conductors will increase. The value of this thermal electric power (thermo-EMF - electromotive force) is constant for a given pair of metals and a specific temperature difference. Metal thermocouples have low sensitivity and are usually used for measuring high temperatures (up to 15000C). Copper-constantane, Nickel-nichrome and other thermocouples are used.

In *semiconductor thermoelements*, the phenomena of increasing the concentration of the main charge carriers in a heated space section and their movement to the cold end are used, resulting in a potential difference between the heated and cold ends of the semiconductor. When assembling a thermocouple from p- and n-type semiconductors, the thermo-EMF of the system will be summed up if the contact point is heated. The input value of the thermocouple is a change in temperature ΔT, the output value is a change in the potential difference ΔU. The sensitivity coefficient K is equal to

$$K=\frac{\Delta U}{\Delta T}$$

The thermo-EMF of semiconductor thermocouples is about 100 times greater than that of metal thermocouples (about 0.1 V at ΔT=100K). The efficiency is also higher: 8% vs. 0.1%.

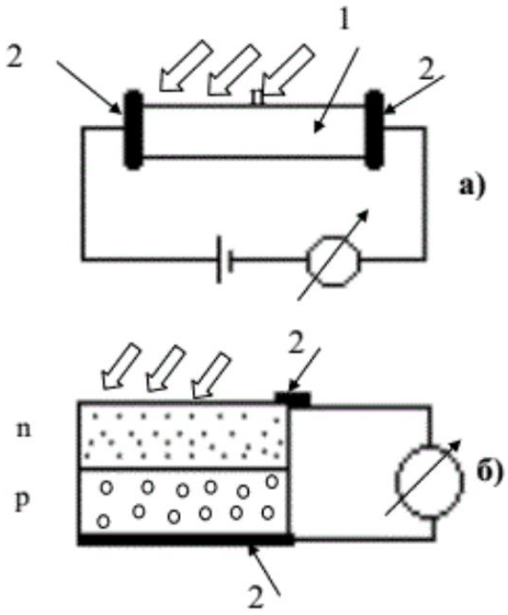
Thermistors are widely used in medical practice, being the main part of the electro thermometer. Its main advantages are low thermal inertia and high sensitivity with a small volume of the working fluid. This allows you to make measurements quickly and in any places on the surface of the body, as well as in the depth of tissues. In this case, the thermistor is placed in an injection needle, which is inserted into the depth of the tissue. Electro thermometers are also used for continuous measurement of body temperature during surgical operations performed under hypothermic conditions.

Photodetectors

The action of photodetectors is based on the phenomenon of interaction of light with matter- the photoelectric effect. According to the principle of action, there are: *external photoelectric effect* (emission, emission of electrons from a substance), *internal photoelectric effect* (change in the concentration of free charge carriers in a substance).

In turn, photo sensors are divided into:

generator, creating photo-EMF (photocells) and



parametric, changing their electrical conductivity (photoresistors).

In recent years, semiconductor photo sensors have become widely used. They use the phenomenon of the internal photoelectric effect - the formation of additional charge carriers (holes and electrons) in p - or n-type semiconductors during the absorption of electromagnetic radiation. The appearance of additional charge carriers leads to a decrease in resistance. This is the basis for the action of passive sensors-photo resistors (Fig. 3a).

Fig. 3. Switching schemes for passive (a) and active (б) photo sensors (1 semiconductor, 2 contact electrodes).

The input value of such a sensor is the luminous flux f, and the output value is the resistance value R. the sensitivity Coefficient of the photo resistor:

$$K=\frac{\Delta R}{\Delta \Phi}$$

In active photodetectors, photovoltaic cells (Fig. 3б), charges of both signs released in semiconductors under the action of light, due to the locking layer, are separated and form a photo-EMF (about 0.1-0.15 V). The input value of the photodetector is the luminous flux (Φ) incident on the photocell, and the output value is the potential difference or EMF (ε).

the sensitivity Coefficient of the photocell is determined by the formula

$$K=\frac{\Delta \varepsilon}{\Delta \Phi}$$

Photovoltaic cells are the main element of the luxmeter, which is used in hygienic research to control the illumination of workplaces in production, in institutions, in educational institutions, etc.

Photo sensors are used in special devices-oxyhemometers to assess the concentration of oxyhemoglobin in human blood. In this case, you can perform measurements without taking blood samples: determine the absorption of light directly in the tissue (for example, in the ear). This method allows you to get information about the patient's condition in dynamics with minimal impact on the person.

Control questions on the topic of the lesson.

1. What is called a sensor? Specify the main types of sensors.
2. What is called the sensor sensitivity and the threshold sensitivity?
3. Describe the device and the principle of operation of the load cell, its use in medicine.
4. Explain the device and the principle of operation of thermal sensors.

5. Explain the device and how the photo sensors work.
6. Give examples of the use of sensors in medicine.
7. What are the main advantages of electrical methods for measuring non-electrical quantities?