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Using a Capacitive Sensor to Detect Body Temperature

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Abstract: The article describes methods for determining body temperature used in medicine. Their advantages and disadvantages are named. Despite its advantages, a capacitive method is proposed that is not used in medical technology.

Key words: temperature determination, thermometer, thermometer, capacitance, sensor, ferroelectric, ferroelectric.

The article describes methods for determining body temperature used in medicine. Their advantages and disadvantages are named. A capacitive method is proposed, which is not used in medical equipment, despite its advantages. Key words: temperature determination, thermometer, thermometer, capacitive, sensor, ferroelectrics, ferroelectrics .

The thermal state of the body is characterized by a value called temperature. Accurate measurement of body temperature is important in many areas, particularly in medicine. Temperature is an important indicator characterizing the current state of a biological object. Thanks to this, it is possible to detect diseases at an early stage, monitor the course of various diseases, and determine whether the prescribed course of treatment is effective. When inflammatory processes occur, any body temperature usually rises, and when the body is weakened, it falls below normal. The normal body temperature for many healthy people is 36.6 ° C. Temperature is currently measured using devices whose operating principle is based on the properties of solids, gases and liquids to change their characteristics when the temperature changes. If in the 18th century many discoveries were made in the field of temperature measurement systems, then the last century began the era of discoveries in the field of temperature measurement methods. In modern medicine, 3 types of thermometers are used: a mercury thermometer, an optical thermometer (infrared), and an electric thermometer. Mercury thermometers are simple, cheap and quite accurate (error of 0.1°C). According to the operating principle, they are liquid thermometers, that is, during the heating of the liquid, its volume changes, due to which the thermometer readings change. This type of thermometer has the following disadvantages: before each measurement, the thermometer must be shaken, which is due to the physical properties of mercury, without the use of special magnifying optics, the scale is poorly visible. When using a mercury thermometer, there is no way to automatically record readings and transmit them over a distance, which is also a disadvantage of this method. Measurements with this thermometer are long - about 10 minutes. In addition, there is a risk of breaking the thermometer and spilling mercury, which is extremely toxic. In the infrared spectrum, radiation emanates from a biological object, the intensity of which carries information about its temperature. This is the principle of operation of electronic infrared thermometers. They allow measurements to be taken quickly (1–2 seconds) and without contact with the body, which significantly simplifies the procedure for measuring temperature in children and eliminates the possibility of transmitting an infection. Infrared thermometers have a display that, in addition to the measured temperature, can also display the history of measurements. This is convenient to use in cases where it is necessary to periodically measure the temperature of several people. However, such thermometers are designed for certain points of the body (forehead, ears, temples), often give errors (up to 0.3–0.5 °C), require periodic verification and are quite expensive. Electronic thermometers that measure temperature using special sensors are more widely used. They also have a display for displaying the temperature, they can have a memory for saving the history of measurements and can emit sound signals depending on the time or measurement result. Like an infrared

[1] Fergana Branch of the Tashkent University of Information Technologies named after Muhammad al-Khorazmi

thermometer, such a thermometer is almost impossible to accidentally break, and it does not contain mercury. The difference from infrared thermometers is that electronic thermometers require close contact of the sensor with the surface of the human body. The time it takes to measure temperature with an electronic thermometer is relatively short - 30-60 seconds. The operating principle of electronic thermometers is based on the change in the resistance of a conductor (platinum, copper or nickel) or a thermistor when the ambient temperature changes. When the sensitive element (conductor, thermistor) is heated, its resistance to electric current changes. The resistance is estimated using a bridge measuring circuit, amplified, converted into a digital code and fed to a digital indicator (usually a liquid crystal display). Electronic thermometers with a wider range are based on thermocouples: contact between metals with different electronegativity creates a contact potential difference that depends on the temperature. These thermometers have very high accuracy (up to ±0.01 °C), but the readings are affected by the temperature of the free ends, for which an adjustment must be made. When taking readings, it is necessary to exclude the flow of current through the thermocouple, since the current flowing through it cools the hot junction and heats the cold one (Peltier effect). The temperature of a body can also be measured by the capacitive method. For this purpose, ferroelectrics can be used - substances that have their own spontaneous dipole moment in a certain temperature range. These substances are also called ferroelectrics . Temperature (Curie point) is the phase transition temperature. At temperatures below the Curie point, these materials have a domain structure and specific properties. If the temperature is higher, the domain structure is destroyed and the ferroelectric passes into a paraelectric state. The consequence of the domain structure of ferroelectrics is a sharply expressed dependence of the permittivity on temperature, and the maximum permittivity is achieved at a temperature corresponding to the Curie point (Fig. 1).

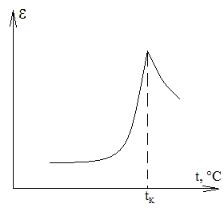

Fig. 1. Dependence of the permittivity of ferroelectrics on temperature That is, with a small change in temperature, the permittivity of the ferroelectric increases greatly. If a capacitor with a ferroelectric dielectric is used as a temperature sensor, then with a change in temperature, the permittivity of the capacitor will also change, which will lead to a change in electrical capacitance. The method will be quite reliable if a ferroelectric with a Curie temperature of about 38 ° C is used. Thus, when using this method, the informative parameter will be the capacitance of the capacitor. To measure it, you can use a bridge circuit, but in this case you need to use an alternating current source, which is inconvenient. It is possible to use the measured capacitance as a timing one in an RC generator with subsequent measurement of the time constant. The method is simple, but not accurate. There is also a method for measuring capacitance using a charge amplifier (Fig. 2), which converts the ratio of the measured and reference capacitances into a voltage signal, the measured capacitance can be determined by the following formula:

$$C_x \frac{U_{izm}C}{N.U}$$

This circuit is supplied in the form of specialized microcircuits.

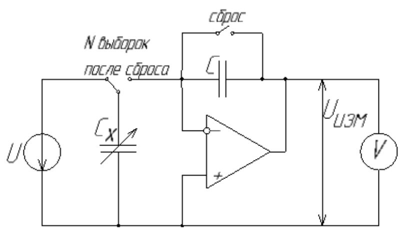

Fig. 2. Method for measuring capacitance using a charge amplifier The capacitance of a temperature sensor can be directly measured using a sigma-delta analog-to-digital converter (ADC). For this purpose, the circuit proposed in [1] can be used.

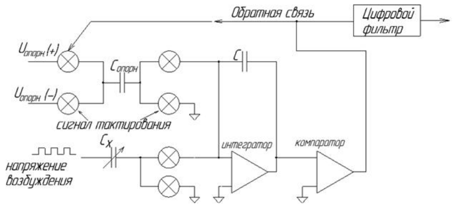

Fig. 3. Method for measuring capacitance using a sigma-delta ADC In a sigma-delta ADC, charge equalization between the reference voltage source signal and the analog input signal is usually achieved by switching capacitors of a certain capacitance. In a modified circuit (Fig. 3), the input voltage remains constant (excitation voltage), but the capacitance changes. A capacitive ferroelectric sensor can be used as a changing capacitance. As a result, the output code of the converter will correspond to the ratio of the measured capacitance to the reference capacitance (). Due to the direct connection of the sensor to the ADC, the method has “high resolution, accuracy, and linearity” [1]. In addition, the industry produces specialized capacitive sigma-delta ADCs, to the inputs of which the measured capacitance is directly connected, which ensures high repeatability, reliability, simplicity of circuit implementation, and also a reduction in cost. Thus, at present, several methods of determining body temperature are used in medicine, each of which has both advantages and disadvantages. One of the methods that can be used in the design of thermometers is the use of a ferroelectric capacitor as a temperature sensor. This method of determining body temperature is not yet used. It remains to be hoped that in the future this method will also find its application in medicine.

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