Task V.: Monitoring

Required knowledge: Measurement of body temperature and blood pressure.

1. Measurement of skin temperature by a thermocouple

Thermocouples are simple and widely used sensors for measuring temperature.

Classic thermocouple, as shown in Figure 1, consists of two wires made of different metals connected at one end which forms the measuring ("Hot") junction. Their opposite ends (where the wires are not connected), are connected to wires of measuring circuit, which are typically made of copper. This connection between the metal thermocouples and copper wires is called the reference ("cold") junction.

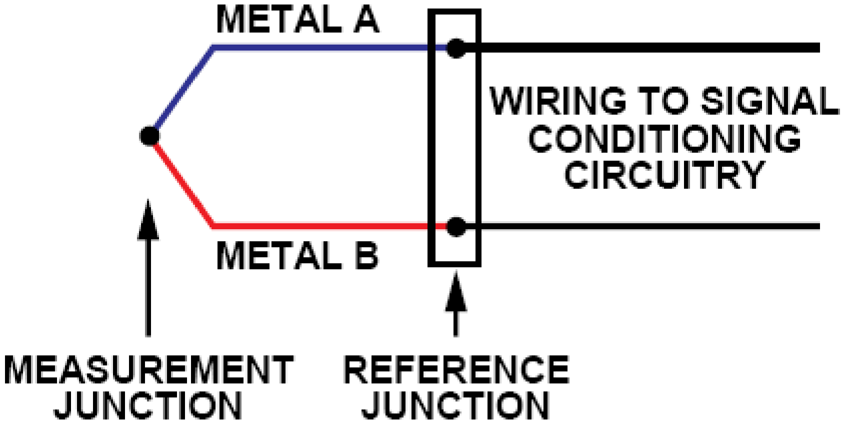

Fig.1

The voltage across the the reference and measurement connection depends both on temperature of the measurement junction, and the temperature of the reference junction. Despite the thermocouple is differential measuring device rather than a device for measuring of the absolute temperature, the temperature of the reference connection must be known in order to obtain accurate absolute temperature. This process is known as cold junction compensation.

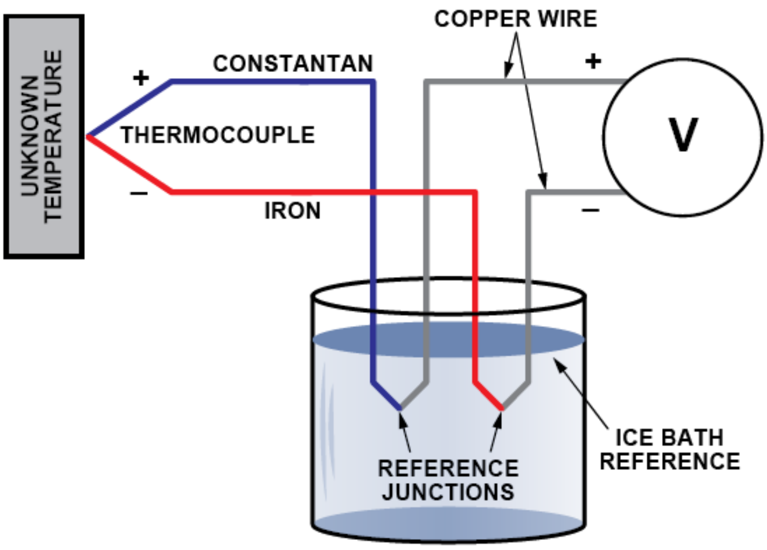

Fig. 2

The cold junction compensation can be done in two ways. The first method is schematically illustrated in Figure 2, where both ends of the thermocouple are located in a place with a constant temperature, usually the Dewar vessel with the temperature of 0 °C inside. Another option is a compensation using an electric circuit. In this case it is necessary to know the temperature of the cold junction, which is primarily measured by a thermistor or thermodiode (in the same place as the cold junction).

Thermocouples are used in various applications to measure temperature up to about +2500 °C. The most popular is the K type thermocouple, consisting of Chromel ® and Alumel ® (trade names of alloys containing nickel, chromium and aluminium, manganese and silicon), with measuring range from -200 °C to +1250 °C.

Benefits

• Temperature range: depends on the thermocouple metal. Thermocouples can measure temperatures between -200 ° C to +2500 ° C.
• The size and robustness: Thermocouples are small and yet robust devices immune to shock and vibration and suitable for use in environments exposed to mechanical stress.
• Quick response: because thermocouples are (in particular the measurement section) small and have low thermal capacity, they can quickly respond to temperature changes. Thermocouples (depending on its size) can respond to rapidly changing the temperature over several hundreds of milliseconds.

Disadvantages

• Transfer and signal processing: It is necessary to convert thermocouple thermovoltage to the specific temperature value, which may have some error (algorithm, nonlinearity, sampling)
• Accuracy and measurement error: a thermocouple temperature measurement accuracy is given by the precision of the reference (cold) junction temperature measurement. The temperature is usually measured with errors of 1 ° C to 2 ° C.
• Susceptibility to corrosion: Whereas thermocouples consists of two different metals, in some environments it may cause the corrosion. It can result in the decrease of accuracy. It can be eliminated by coating.
• Sensitivity and Noise: when the signal at the level of microvolts is measured, there can be a problem with the presence of electric and magnetic disturbing fields. This situation can be eliminated by using shielded cables. The device should also allow the possibility of filtering and suppressing signals (either in hardware or software), e.g. the electric mains frequency 50 Hz/60 Hz and its harmonic multiples.

The most common thermocouple types are J and K. At room temperature, their voltage changes depend on the ambient temperature changes (52 μV/ °C in type J, 41 μV/ °C in type K) - which are tabulated and called Seebeck coefficient α (Table 1, Chart 1). Other less common types of thermocouples may also have a smaller voltage change with increasing temperature.

Voltage change (ΔU) is proportional to the temperature difference and Seebeck coefficient - for small voltage differences (formula 1.)

formula 1. $$\Delta U = \alpha \cdot \Delta t$$

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Table 1 compares the sensitivity of different types of thermocouples.

Table 1. Voltage Change vs. Temperature Rise (Seebeck Coefficient) for Various Thermocouple Types at 25°C.

Thermocouple Type	Seebeck Coefficient (μV/°C)
E	61
J	52
K	41
N	27
R	9
S	6

Instructions for the task

1 - Pour water of suitable temperature (tap water with aprox. 20°C) into a beaker and place it on the heater. Attach a thermometer which reservoir of mercury is about in the middle of the water column. Insert the thermocouple probe (which is connected to a multimeter) into the beaker to the same height as the mercury reservoir of the thermometer.
2 - Verify that the multimeter measures voltage U in DC mode (turn switch to the position "mV" and select DC mode by pressing the button SELECT).

3 - Switch on the stirrer and read and note the temperature shown by the mercury thermometer and a corresponding value of the thermoelectric voltage displayed on the multimeter.

4 - Switch on the heating. Read temperature values and corresponding thermovoltages for each increase of temperature by step of 5 °C up to 50 °C. Slower increase allows more accurate calibration of temperature measurement.

5 - Remove the thermocouple from the beaker, disinfect it with ethanol and measure the temperature (by the thermovoltage measured by the multimeter!!!) on the face, nose, palm, armpit and inside the container on the table.

Points to do in Record:
1- Plot the calibration graph of thermovoltage (Y axis) dependent on temperature (X axis).
2- Determine the temperature of measured parts of the human body and also inside the container placed on the table by using the calibration graph (read the unknown temperature values from the graph).

3- Calculate the Seebeck coefficient for the thermocouple and estimate what type of thermocouple was used in the task.

2. Blood pressure measurement by the auscultation method

Main tasks:
Blood pressure measurement by the auscultation method by the mercury tonometer
Blood pressure measurement by the auscultation method by the digital tonometer

Measurement aids and implements:
Stethoscope, mercury and digital tonometers.

Procedure:
1. Measuring by the mercury tonometer. Attach the inflatable cuff to the arm of the subject at the height of the heart. Put the mercury tonometer to the same height (on the table). By means of palpation of the pulse (feeling the pulse) search in the elbow pit the position of *a. brachialis* and put the sensor of the stethoscope on this artery. Inflate the cuff to approximately 160 mmHg by means of the ball. Lower gradually the air pressure in the cuff and read the systolic and diastolic blood pressures. Repeat the measurement 3-times. Calculate the mean value of the systolic and diastolic blood pressure and convert the values from mmHg to kPa.
2.) Measuring by the digital tonometer. Attach the inflatable cuff to the arm of the subject at the height of the heart. Put the digital tonometer to the same height (on the table). Measure the blood pressure 10-times (use specific manual for given digital tonometer). Calculate the mean value of the systolic and diastolic blood pressures and convert the values from mmHg to kPa.
3.) Compare results obtained by the digital and mercury tonometer.

Points to do in Record:
1- Create a table with obtained blood pressure values – for digital and for manual tonometer
2- Calculate mean blood pressure values for each one methods (systolic and the diastolic)
3- Convert mean blood pressure values from mmHg to kPa.
4- Discuss measurement accuracy and possible errors. Compare used devices.