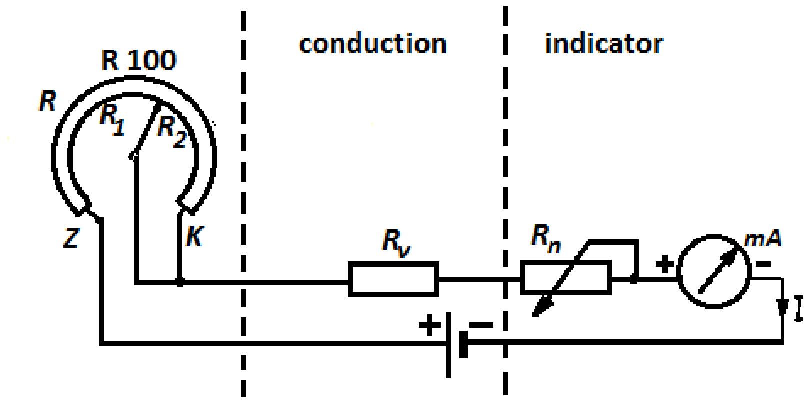
Measurement of static characteristics of resistive sensor with current and voltage output

Methods for data evaluation a from resistive position sensors (current voltage output).

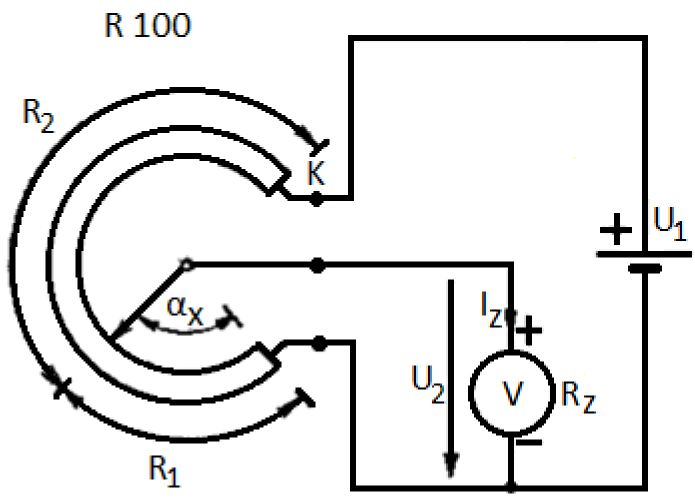
Task

1. Familiarize yourself with the resistance wire sensor R100 and device for evaluating resistance changes depending on the change in length.
2. Measure the static characteristics of the RTD connection:
   a. direct, it means in series with the ammeter
   b. potentiometric, it means parallel with the voltmeter
   c. proportional, it means with the instrument with crossed coils
3. Perform linearization of the characteristics by the regression line in the linear part, their evaluation and comparison. Estimate the maximum relative random errors.

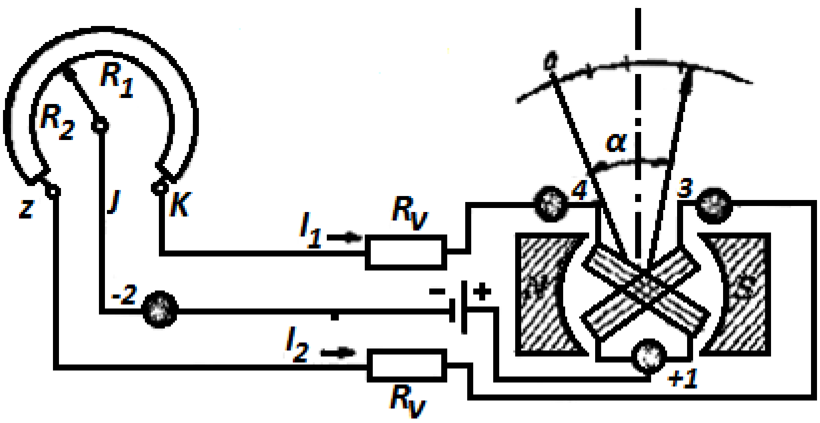
Diagrams



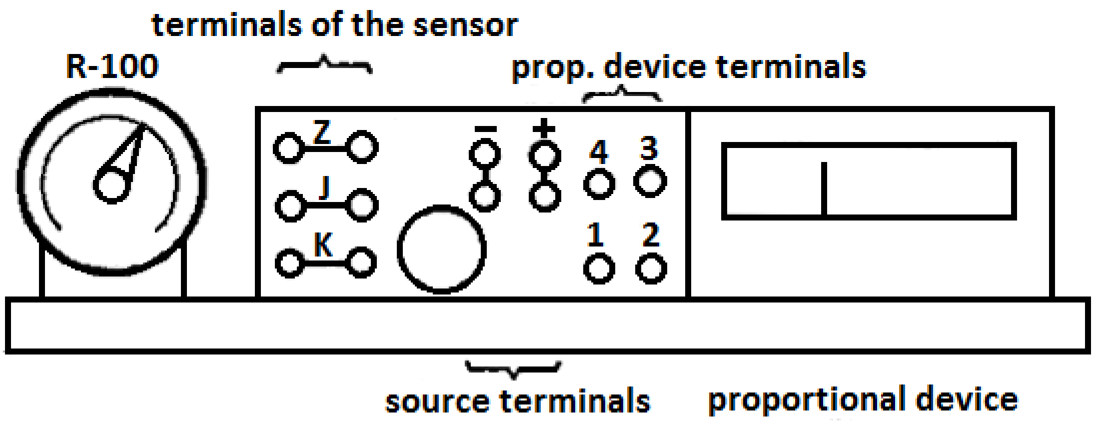
Pic. 1: Ampere RTD connection



Pic. 2: Potentiometric connection of sensor R100



Pic. 3: Proportional connection with the instrument with crossed coils (black jack marked on the measuring appliance)



Pic. 4: Connection of the measuring appliance front panel

Theoretical analysis

The electrical resistance between the runner and the fixed ends of the potentiometer changes the action of the linear or rotary motion at the contact position, that means collectors in the resistive track. It is possible to implement various operational waveforms between linear and angular change in the position of the runner and the change in resistance, while the sensors are structurally simple and reliable.

Resistance enameled wire is wound on the carrier pad, e.g. ring, the platinum wire collector attached to the shaft encoder moves on the adjusted inner side. The angle of rotation is up to 270 degrees, the normalized sensor resistance R0 = 100 W.
The maximum output voltage deviation from the ideal linearity determines the accuracy of the sensor (seen here imperfection winding, collectors, transfers etc.).
Conventional sensors are accurate to 1 %, in special types, such as multi-turn with spiral path, then to 0,02 % at a DC supply voltage. The maximum allowable current is typically to 100 mA.

To maintain the desired static characteristic of the potentiometer $R = f(\alpha)$ it is necessary that the measurement of the resistance was mediated by a suitable electrical connection. Measuring accuracy is affected obviously besides structural parameters of the sensor also by changes of ambient temperature, operating on both own resistance sensor, and on the connecting line to the evaluating unit. The change in resistance appears as a measurement error, and can be limited by appropriate wiring of the sensor (e.g. proportional device).

a) **Direct measurement of current by the Ampère method** is very simple, but the output variable, the current I, is a nonlinear function of angle of rotation change α depending on the fluctuations of the supply voltage U:

$$I = \frac{U}{R_1 + R_V + R_n}$$

> R_1 is the left part of resistive sensor whose resistance varies depending on the angle [W], R_V is line resistance [W] and R_n is adjusting resistor for resetting scale [W]

b) **Potentiometric connection** is widespread and output variable – the voltage - is a linear function of changes in resistance. For U_2 is true:

$$U_2 = R_Z \cdot I_Z = \frac{R_1 + R_Z}{R_2 + \frac{R_1 R_Z}{R_1 + R_Z}} \cdot U_1$$

> $R_1 = \alpha_X \cdot R$ [α_X is the relative angle of rotation, <0,1>] and
> $R_2 = (1\ _x)\ R$ $K_Z = R_Z/R$ is the load factor

Thus we can write:

$$U_2 = \frac{\alpha_X}{1 + \frac{\alpha_X (1 - \alpha_X)}{K_Z}} \cdot U_1$$

If we define the so-called additional load error δ_Z as:

$$\delta_Z = \frac{U_2}{U_1} - \alpha_X$$

We will get after putting a previous relation:

$$\delta_X = \frac{\alpha_X^2(1-\alpha_X)}{K_Z + \alpha_X(1-\alpha_X)} \cdot 100 \quad [\%]$$

If we suppose that $R_Z \gg R$, then

$$\delta_Z = \frac{\alpha_X^2(1-\alpha_X)}{K_Z}$$

The maximum error occurs when $\frac{d\delta_Z}{d\alpha_X} = 0$, i tis for $\alpha_X = \frac{2}{3}$ and $\delta_{Z_{max}} \cong 0{,}15\%$ (for K_Z = 100).

If we use the electronic voltmeter, which tends to have a very high resistance $(R_Z = \infty, K_Z = \infty)$, current can be neglected and for U_2 will be true:

$$U_2 = U_1 \frac{R_1}{R_1 + R_2} = U_1 \cdot \alpha_X$$

c) **Evaluative connection with magneto-electric instrument** with crossed coils eliminates the effect of variations in voltage U_1 and shows a linear relationship between the deflection of the indicator and the change in resistance of the sensor. For this is true:

$$\frac{R_1}{R_2} = k \cdot y_m$$

y_m is sensed value and *k* is constant.

Because the currents passing through the individual coils are expressed by relations $I_1 = k_1R_1$ and $I_2 = k_2R_2$, device indicator deflection will be determined by the relation:

$$\alpha = \frac{I_1}{I_2} = \frac{k_1R_1}{k_2R_2} = K \cdot y_m$$

Measuring procedure

1. Make the connection of resistive sensor R-100 for measuring by Ampere method according to the picture 1. Resistor R_n must be used and set so that current I does not exceed the value I_{max} = 100 mA in order not to damage the sensor! Use the sliding resistor, which is available at the workplace.
2. Measure the static characteristic of the sensor $I = f(\alpha)$ for increase and decrease α and evaluate it. Choose the step 30°.

3. Make he connection of sensor R-100 in potentiometric arrangement according to the picture 2b.
4. Measure the static characteristic of the sensor in both directions.
5. Make the connection of sensor R-100 in a ratio of three-wire connection arrangement according to picture 3.
6. Measure the static characteristic in both directions.
7. Measured characteristics plot to the graph, calculate the coefficients of the regression lines and make a comparison of the methods.

Chart Resistance sensor R-100, serial number . . . .

n	α [°]	DIRECT CONNECTION			POTENTIOMETRIC CONNECTION			PROPORTIONAL CONNECTION			regression line coefficient
		I	I	I	U	U	U	R	R	R	

Control questions

1. Explain the principle of the resistive position sensor and its parameters.
2. Compare the advantages and disadvantages of individual connections of sensor R-100.
3. What is a proportional device with crossed coils, and what are its attributes?

The answers to the control questions