**МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ**
**Запорізький національний технічний університет**

# МЕТОДИЧНІ ВКАЗІВКИ

**до виконання лабораторних робіт студентами з англійською мовою навчання при вивченні дисципліни «Електромеханічні апарати автоматики» для підготовки бакалаврів за спеціальністю 141 «Електроенергетика, електромеханіка та електромеханіка» з подальшим навчанням за освітньою програмою «Електричні машини і апарати»**

**2016**

Методичні вказівки до виконання лабораторних робіт студентами з англійською мовою навчання при вивченні дисципліни «Електромеханічні апарати автоматики» для підготовки бакалаврів за спеціальністю 141 «Електроенергетика, електромеханіка та електромеханіка» з подальшим навчанням за освітньою програмою «Електричні машини і апарати » / Укл.: Л.Б. Жорняк, В.М. Снігірьов - Запоріжжя: ЗНТУ, 2016. – 50 с.

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Затверджено
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# INTRODUCTION

Electromechanical relays, sensors and different executive devices (electromagnetic valves, muffs, transformers, electromagnets, resistances) command apparatus (eventual and travels switches, turning switches and other), belong to the electromechanical vehicles of automation.

Purpose of students work:

– deepening and spread of knowledge on to the basic sections of course the «Electromechanical apparatuses of automation»;

– study of laboratory stand and lead through of experiment with electric apparatuses;

– study of principle of action of the explored devices and acquaintance with processes in the circuit s of apparatuses;

– acquisitions of research skills and examinations of automation apparatuses;

– improvement of skills of computing and registration of results of experiment.

For all laboratory works an universal stand is used. Stand kitting-up with the blocks of different laboratory works, which allows using it for the lead through of all laboratories works in course.

At execution of all laboratory works it is necessary to be careful and to execute all requirements of teacher and laboratory technical personnel, which relate to execution of laboratory works. It is necessary to observe the rules of the work setted for the laboratory apartments of university, and also general behavior rules. Before execution of work it is necessary carefully familiarize with description of laboratory work and stand.

Not switch on the stand without permission of teacher that presents lesson. In the case of exposure of supernumerary situation (smell of burning, appearance of smoke, sparkling and others) it is necessary to switch off the circuit breaker QF on the front stand panel of and to inform the teacher about that. Also it's prohibited to deal with a breakdown in the process of work execution. After finishing of the work it is necessary to switch off the QF circuit breaker.

# 1 LABORATORY WORK №1
# STUDY OF ELECTROMAGNETIC NEUTRAL RELAY OF DIRECT CURRENT

The purpose of work is to study operation principle of electromagnetic relay of DC current, to determine the values of relay (return coefficient, safety factor, gain factor).

## 1.1 General notes

The electrical relay is a switching device, designed to produce jumping curve changes of load circuits at data electric values.

Electrical relays mainly are intended for switching of the power equipment control circuits (for example, electromagnetic contractor windings), the sign summation and multiplication, the signaling, communications, etc.

Electromechanical relay - is an electrical relay operation of which is based on interaction magnetic field of fixed winding with movable ferromagnetic element.

Electromagnetic neutral relay of dc current - is one of the basic elements of automatic systems, telemechanics, protection and etc. with it help need interaction and sequence of different system parts operation (devices, blocks, equipments), protection, amplification, switching with time delay or slowing down, high-speed switching are execute.

For the view of the relay characteristics or curve look the figures 1.1. They have the output jump-in response increasing value Ymax at the any electrical input value X (current, voltage, frequency, etc.), and a same jump-in reduce output value, but at another electrical input value. The output value is not change or small change at all other values of the input value.

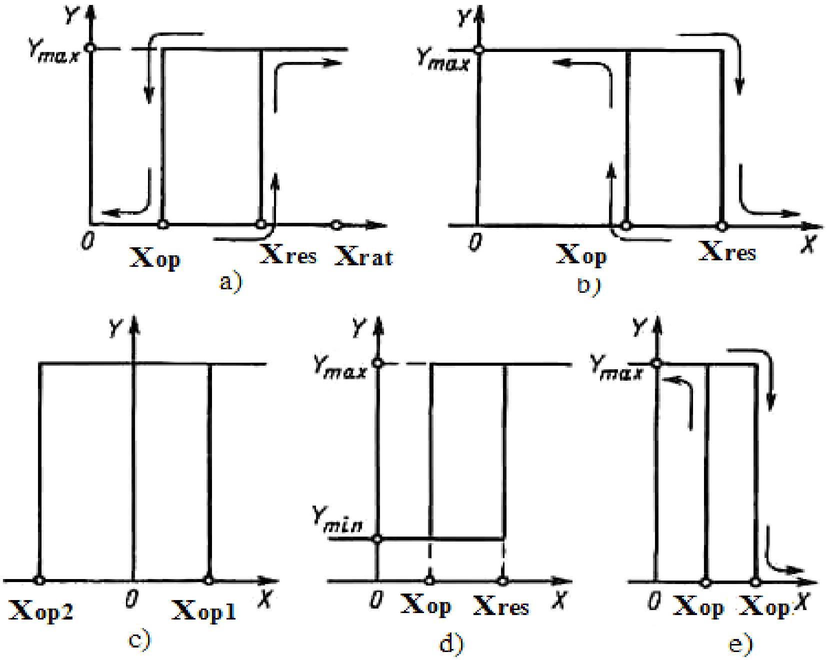
Electromagnetic relays are divided into relays according to disposition of armature and its character of magnetic flux influence:

a) with external unbalanced armature of valve type;

b) with armature of solenoid type, which pull in it;

c) with balanced armature and internal coil in it;

d) with external balanced armature of return type, this pulls in.




a), b), c), e) – electromechanical; d) – electrostatic;
a), b), d), e) – one stabile; c) – tow stabile;
a), b), d) – maximal; e) – minimal;
a), d), e) – close switch operating; b) – open switch operating.
$X_{op}$ is operating parameter;
$X_{res}$ is reset out parameter (release);
$X_{rat}$ is rated parameter;
$Y_{max}$, $Y_{min}$ are maximal and minimal values of the output parameter.

Figure 1.1 - Examples of the relay curves of different control devices which use the operating principle

## 1.2 Steps of work execution

Before execution student have to:

- to study corresponding methodical recommendation and repeat the chapter about relays of DC current;

- prepare the table 1.1;
- connect the circuit (figure 1.1);
- after checking circuit by lecturer step up and down voltage and measure following values: $I_{op}, U_{op}, U_{res}, I_{res}, I_{rat}, U_{rat}$, than fill in the table 1.1 with data;
- calculate coefficients:

$$K_S = \frac{X_{rat}}{X_{op}} -$$ is the safety factor over actuation;

$$K_{res} = \frac{X_{res}}{X_{op}} -$$ is the reset ratio (return coefficient);

$$K_c = \frac{n_{outp}}{n_{inp}} -$$ is the circuit multiplication coefficient;

$$K_{ampl} = \frac{P_{outp}}{P_{op}} -$$ is the amplification coefficient.

The output power is calculated by the next formula $P_{outp}=U_{cop}\cdot I_{ccl.}$;
where $U_{cop}$ - is the voltage on contacts before closing ($U_c$ =220V);
$I_{ccl}$ - is the current of commutation circuit ($I_{ccl}$ =5A).
- plot the relay characteristic.

## 1.3 Safety method instruction

1. To do all connections of principle circuit of laboratory stand at opening switch SF!
2. Clearly follow safety methods instruction and internal order rules.

Table 1.1 – The results of measurements and calculations

| № of testing | Measurements | | | | | | Calculations | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $I_{op}$, A | $U_{op}$, V | $I_{res}$, A | $U_{res}$, V | $I_{rat}$, A | $U_{rat}$, V | $K_s$ | $K_{res}$ | $K_c$ | $K_{ampl}$ |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| Average values | | | | | | | | | | |

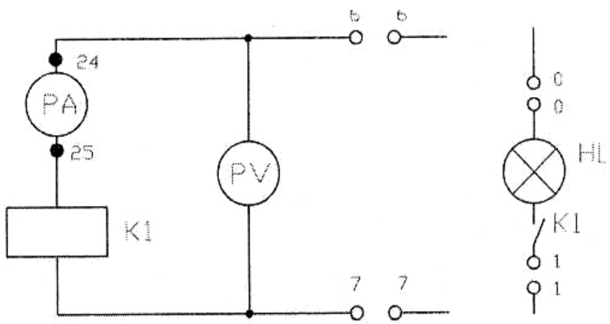



Figure 1.2 - Principle circuit of testing

## 1.4 Control questions

1.4.1 Give the definition of the electrical relay, electromechanical relay, and electromagnetic relay.

1.4.2 Purpose, definition of relays and field of their application.

1.4.3 Give the definition of the coefficients $K_S$, $K_{res}$, $K_c$, $K_{ampl}$.

1.4.4 What kinds of magnetic system are used in DC current electromagnetic neutral relays?

1.4.5 The definition of operation, release, rated, admissible values.

1.4.6 What parameters are used to defined quality of relay, its sensitive and hysteresis qualities?

1.4.7 What do the opposing, loading and tractive characteristics mean?

1.4.8 What does displacement of opposing and tractive characteristics mean?

1.4.9 Tell the view of the relay characteristic and its hysteresis view.

# 2 LABORATORY WORK №2 STUDY OF ELECTROMAGNETIC RELAY OF ALTERNATIVE CURRENT

Purpose of work is to study principle of action, construction and main assembles of electromagnetic relay PT-40; to define the basic technical parameters.

## 2.1 General notes

The maximal current relays are used in the control relay devices and anti-emergency automation. They react on the increase of current.

One of varieties of the electromagnetic systems is used in the relay of PT-40 series, called by the system with transverse motion of armature (fig.2.1). The magnetic system of relay consists of П-type laminated magnetic core 5 and the G-type armature 3, rotated on two semiaxes 6. The armature of relay is hold in initial position by a counteractive spiral spring 7, one end of which is related to the armature, and other with the pointer of setpoint 8. The counteractive moment of spring and accordingly operating current of relay are changed at the rotation of pointer of setpoint. Necessary position of pointer is determined by divisions calibrated on a scale 9. At armature a plastic block 10 is mounted with a moving contact bridge 11. At high part of bracket *2*, related to the armature, a hollow drum is mounted 1. A drum has inside radial partitions and filled by dry quartz sand. On the magnetic core the coils 4 are located. Those ends are out on the clamps of base of relay. On these clamps it is possible to carry out transposition of bridges into parallel and series connections of coils and accordingly to change the value of operating current settings in two times. Numbers, calibrated on a scale, correspond to series connection of coils. All of elements of relay are mounted on a scope made from an aluminum alloy, fixed on a plastic base and closed by the transparent housing.

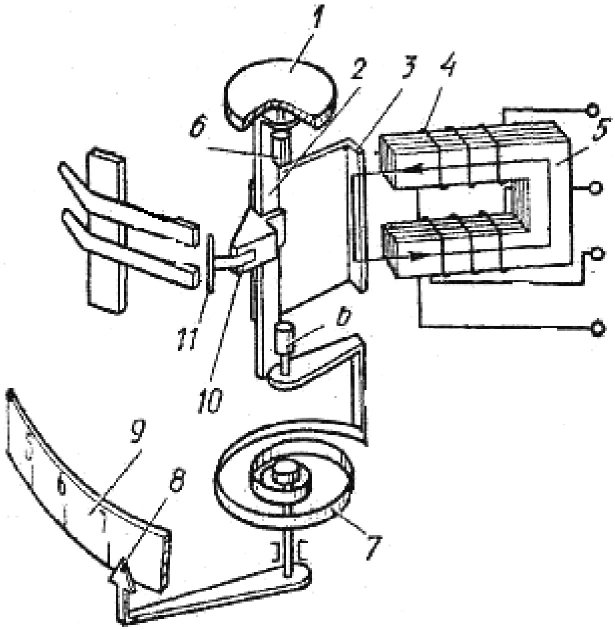



Figure 2.1 – Mechanical scheme of PT-40 relay

At carrying out of current on the winding of relay a magnetic flux which is locked through core and armature is created. A flux, passing an armature, magnetizes it. Electromagnetic force, proportional to the square of magnetic flux, attracts an armature to the poles of core; the contacts of relay are closed at this moment.

Rotating angle of relay armature 2 is limited by supports 1 and 3 (fig.2.2). If the right support 1 is absent, under the action of electromagnetic moment an armature will turn on the angle of 90°. It will be correspond to maximum value of magnetic flux in an air-gap. Thus an electromagnetic moment will be equal to the zero.

For providing of necessary pressure on contacts the relay operation must be carried out in the certain limits of angles of armature rotations. For the PT-40 relay the angles of armature rotations are set approximately 60° in initial position and 75° in eventual position of armature ($\alpha_н$ and $\alpha_к$ on the fig.2.2).

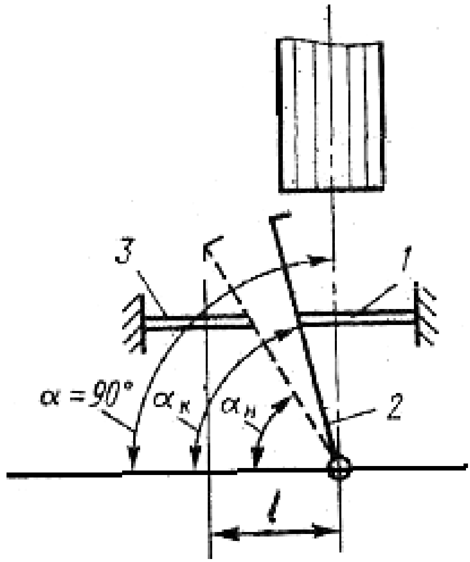



Figure 2.2 - The positions of armature under poles of relay

Thus construction of relay has a high coefficient of reset ratio - about 0,8. The coefficient of return is name attitude of parameter of return toward the parameter of wearing-out

**2.2 Steps of work execution**

Before execution student have to:

- to study corresponding methodical recommendation and repeat the chapter about AC relay;
- prepare the table 2.1 (for parallel and series connections of coils);
- connect the circuit (figure 2.3) for parallel and series measurements;
- after checking circuit by lecturer step up and down voltage and

measure values: $I_{op}, I_{res}$ at different values of operating current settings $I_{op\,rat}$, than fill in the table 2.1 with data (such measuring to do for parallel and series);

- to calculate the reset ratio of relay Kres;
- to plot functions $I_{op} = f(I_{op\,rat})$, $I_{res} = f(I_{op\,rat})$, $K_{res} = f(I_{op\,rat})$.

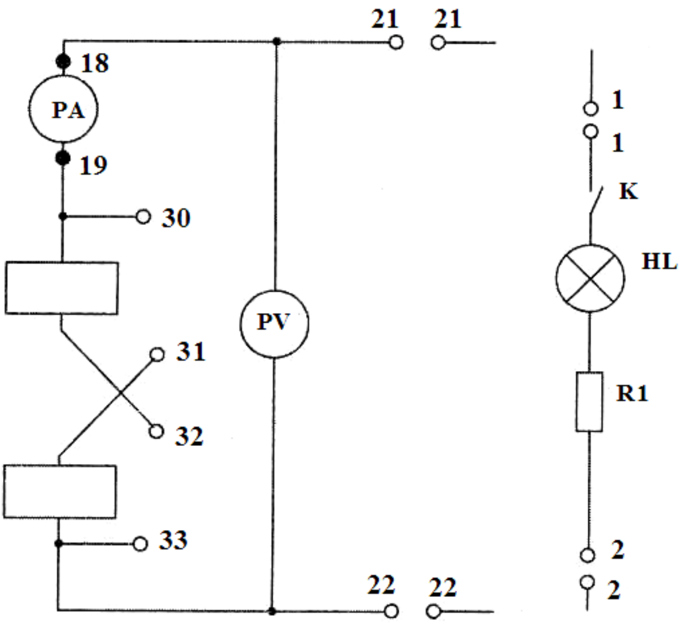



Figure 2.3 - Principle circuit of testing PT-40 relay

## 2.3 Safety method instruction

<u>To do all connections of principle circuit of laboratory stand at opening switch SF!</u>

Table 2.1 – The results of measurements and calculations

| Connections of coils | series connections | | | | | | parallel connections | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $I_{set}$, A | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 |
| $I_{op}$, A | | | | | | | | | | | | |
| $I_{res}$, A | | | | | | | | | | | | |
| $K_{res}$ | | | | | | | | | | | | |

**2.4 Control questions**

2.4.1 Give the definition of the alternative current relay, details of construction at opposite to direct current relay.

2.4.2 What types of relays are used at alternative current circuits?

2.4.3 What cause of core vibration of alternative current relays?

2.4.4 What methods of liquidation of core vibration of alternative current relays?

2.4.5 What constructive methods of liquidation of core vibration of PT-40 relay?

2.4.6 Give the construction of PT-40 relay.

2.4.7 What difference between closings of the alternative current relay and direct current relay?

2.4.8 How is operating current setting regulate?

# 3 LABORATORY WORK №3
# STUDY OF POLARIZED RELAY

Purpose of work is to study principle of action, construction, main assembles and adjustment methods of polarized relays, to define the basic technical parameters by experimental method.

### 3.1 General notes

The polarized relays are electromagnetic relays operation of which depends on value of input signals and initial polarization. Opposite to neutral relays the core motion of polarized ones depends on current carry direction at operating winding. There are polarized with series, differential and bridge circuit flux circuits.

Modern polarized relays most often have two or more coils, thus perhaps more flexible designing of electric circuits, controlling of varying polarity currents and use of these devices, not only as switching, but logical elements. Structures of modern magnetic system of polarized electromagnetic relays designed on the principle of differential or bridge circuits.

There is one-stabile and two-stabile polarized electromagnetic relays. They also are differed by type of adjustment.

At two-stabile neutral adjustment of relay the contact assembles are installed symmetrically on a neutral line, which is one of the axes of symmetry magnetic system relays. Armature is then transferred from one it extreme stabile state to another one (with the implementation of out switching relay circuits by contact assembles), at the same modules of magnetomotive forces (MMF) in winding (or windings). Armature and, consequently, contact assembles are found in the position in which they were the before the current supply in the winding (windings). Such relays are called two-stabile two-position (bang-bang control).

At two-position adjustment (bang-bang control) with domination (biasing) both contact assembles are located on one side from neutral, but at different distances from it. Operation of such relays occurs only at certain direction of currents in the winding (windings). After switching off currents armature always is returned to the same initial stable position. At that moment contact assembles commute the relay output circuits in reverse order. Such relays operate as a sensitive neutral electromagnetic relays, and therefore are one-stabile ones.

At three-positional adjustment contact assembles are located the same as in two-position neutral adjustment (bang-bang control) that is symmetrically relatively neutral of magnetic system. But at the absence of current in the winding (windings) armature of the relays with three-positional adjustment takes a neutral (average) stabile position cause effort of opposing strength spring often is a suspension. Due current carrying through the windings in the same direction the armature initiates contact one of the switching assembles. At direction current changing the armature deviates from the other side of its neutral and make the second contact switching assemble. The operate currents in both directions, as well as from two-position relays with neutral adjustment, will be practically identical. Such relays are called one-stabile three-positional adjustment ones.

Structures polarized relays are different. In laboratory work three relays (РП-4, РП-5, РП-7) are the objects of testing.

### 3.2. The laboratory stands description

The electric circuit of testing consists on the standard power supply based of all laboratory tables and laboratory equipment mounted on synthetic-resin bonded panel. It is shown on fig. 3.1.

Voltage polarity of relay windings is differed by switch S3. Connection any relays (РП-4, РП-5, РП-7) are made by switch S4. The measurement range of millimeter PA are differed by switch S2, and its values are fixed by button SB. It is necessary to connect lamp s HL1 and HL2 by short conductors for indication of contact positions of testing relays.

### 3.3 Steps of work execution

Before execution student have to:

- to study corresponding methodical recommendation and repeat the chapter about polarized relays;
- prepare the tables 3.1 and 3.2;
- connect the circuit (figure 3.1);
- after checking circuit by lecturer step up and down voltage and measure following values: $I_{op}, U_{op}, U_{res}, I_{res}, I_{rat}, U_{rat}$, than fill in the tables 3.1 and 3.2 with data for all types of relays;
- plot the relay control characteristic.

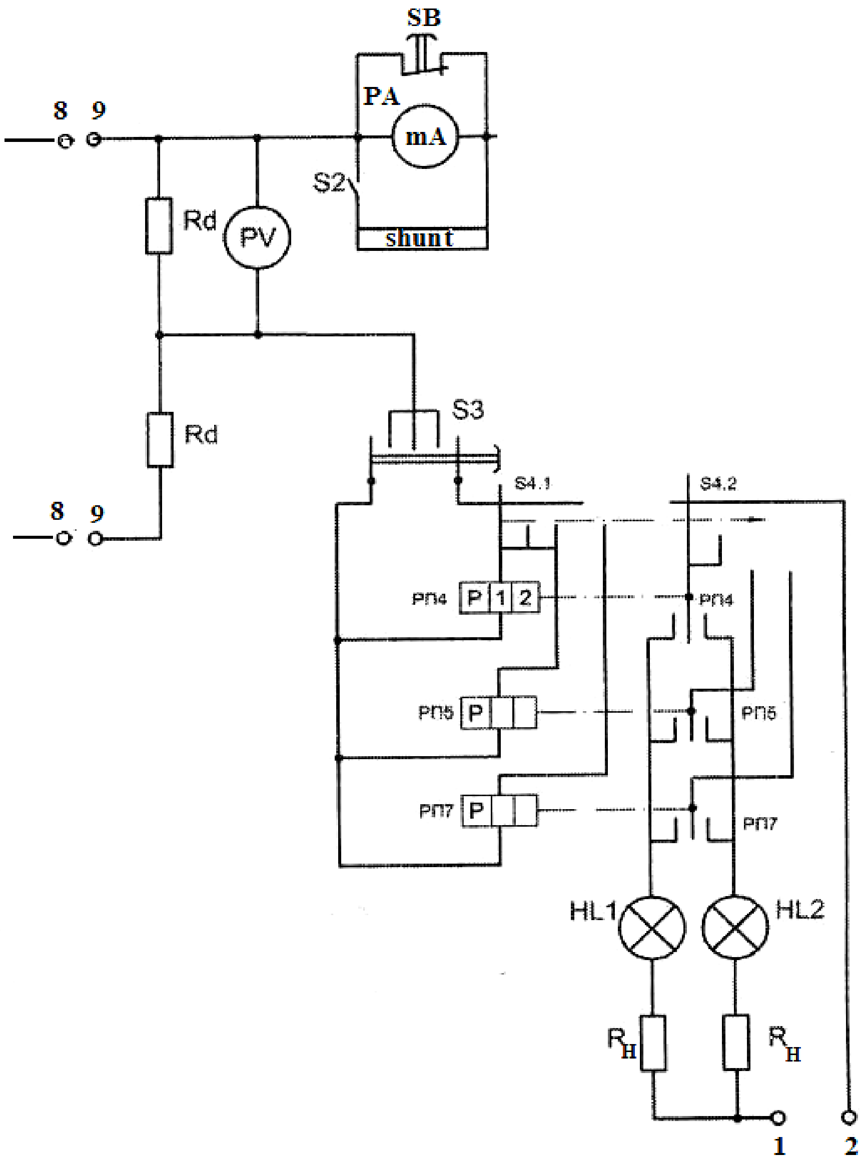



Figure 3.1 - Principle circuit of polarized relays testing

To study types of relay adjustments and polarity of they contacts it is necessary:

a) switch S3 put on position “0”;

b) switch S4 put on position of testing relay;

c) put autotransformer T at zero station, switch on SF, control lamp HL;

d) set voltage value 220 V by device PV2 (look a circuit on laboratory stand);

e) setting switch S3 into positions according table 3.1 fix a contact positions (according to lamping of HL1 and HL2);

f) point (e) repeat for all types of relays, after that put autotransformer T at zero station.

Table 3.1 – Testing data

| Type of relays | № windings | The contact positions of switch S3 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | | 1 | | 0 | | 2 | | Type of adjustment |
| | | HL1 | HL2 | HLI | HL2 | HL1 | HL2 | HL1 | HL2 | |
| РП-4 | 1 | | | | | | | | | |
| | 2 | | | | | | | | | |
| РП-5 | 1 | | | | | | | | | |
| РП-7 | 1 | | | | | | | | | |

To testing operate and reset currents and voltages of relays and to plot of their control curves it is necessary:

a) switch S4 put on position of testing relay;

b) switch S3 put on position “1” and fix all need parameters by PV and PA (push button SB);

c) put autotransformer T at zero station, switch S3 put on position “2” and fix all need parameters by PV and PA (push button SB);

d) fill experimental data into table 3.2 for all types of relays;

e) after all testing switch off SF, disconnect laboratory circuit.

Table 3.2 – Testing data

| Type of relays | Position of switch S3 | | Parameters of relays | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | $I_{op}$, A | $U_{op}$, V | $I_{res}$, A | $U_{res}$, V | $P_{op}$, W | $K_{res}$ |
| РП-4 | 1 | 1 | | | | | | |
| | | 2 | | | | | | |
| | 2 | 1 | | | | | | |
| | | 2 | | | | | | |
| РП-5 | | 1 | | | | | | |
| | | 2 | | | | | | |
| РП-7 | | 1 | | | | | | |
| | | 2 | | | | | | |

To calculate the reset ratio (return coefficient), amplification coefficient at condition of power of circuit commutation of all testing relays is equal to 4,8 W.

### 3.4 Control questions

3.4.1 Answer difference between the polarized relays and neutral ones?

3.4.2 What advantages of the polarized relays at difference of neutral ones?

3.4.3 Answer principle of operation of the polarized relays?

3.4.4. What cause of more high speed of response and of the polarized relays at difference of neutral ones?

3.4.5 What types of adjustment of the two-position polarized relays?

3.4.6 What are types of magnet circuits used in polarized relays?

# 4 LABORATORY WORK №4
# STUDY OF REED RELAY

The purpose of work: to study the concept of operation, construction design and main assembles of reed relay, to investigate parameters of operation and response, distinctive features of operation of several magnet control (MC) in one control winding.

## 4.1 General notes

Electromagnetic contactor is an element of electric circuit, which changes its state with the help of mechanical closing and opening thanks to the influence of control flux on the contact of this element, which combine functions of electric and magnetic circuits.

Encapsulated magnetic (reed) contact is a magnetic control contact, details of which are enclosed from environment.

Reed relay are most often represented as coils, in center of which one or more reeds are placed.

Contacts are bridged or opened when the magnetic field is missing. If direct-axis magnetic field takes place springs bend and make contact or open contact details. Thanks to encapsulation of contacts the reliability of commutation and stability of transition resistance are improved in comparison with non-encapsulated contact devices. Term of service is about $10^6$-$10^9$ commutations, time of operation is 5,0 - 2,0 ms, time of return is 0,2 - 1,0 ms.

Disadvantages of reed relays are low computational current; the necessity of reliable screening from external magnetic fields and others.

Hermetic contact (sealed contacts) are widely used in the automatic-control system, control systems, computers, relays, logical elements, voltage and current transformers, transducers of non-electric values, coaxial contractors, switches, operating elements of circuit s of frequency conversation in HF-devices, end breakers.

Hermetic contacts (sealed contacts) can be classified according to:

a) character of ferromagnetic electrode in magnetic field interaction;
b) magnetic circuit configuration;

c) type of the contact group;
d) ferromagnetic electrodes material;
e) type of electric contact;
f) type of envelope;
g) variety of moving system;
h) type of encapsulating;
i) overall value and etc.

According to hermetic contacts (sealed contacts) construction design, they can operate several magnetic fields, variable of magnetic circuit characteristic. At operation of several hermetic contacts in one operating coil contacts are closed (opened) not simultaneously, the first the most sensitive hermetic contact are closed (opened), and then the others. Each commutation of hermetical contacts is followed by rearrangement of magnetic flux in the coil. The reed relay is considered to have operated when all of the contacts are closed (opened), and not operated when all of the contacts are u opened (closed).

**4.2 Steps of work execution**

Before execution student have to:

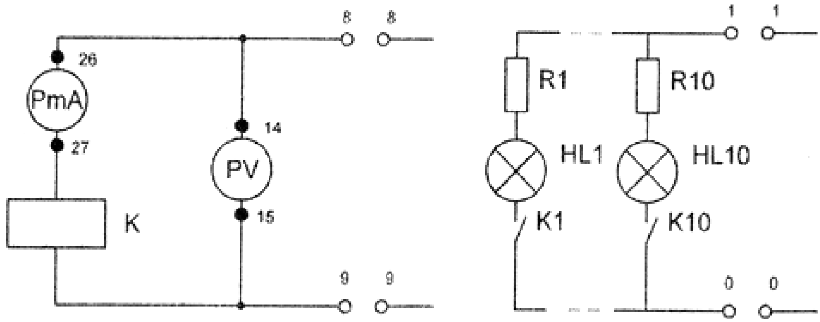
- study corresponding methodical recommendation and repeat chapter about relay of reed relays;
- prepare the table 4.1;
- assemble the circuit (fig.4.1);
- experimentally find out min, maximal and average values of currents, voltages, e.m.f. and energy of operation and reset of РПГ relay, and also operating current in the control circuit;
- having all these values plot the controlling characteristic of РПГ relay (dependence of circuit load voltage on current in control circuit), for this case:
- deduce transformer T to zero value;
- to switch on SF, slowly rising a voltage of power according to lamps HL1.HL10 fix and write down the values of current and voltage of winding up to rate one (12V) and write down operating current;
- lowering voltage on relay winding, according to lamps fading fix and write down reset current and voltage of each hermetic contact;
- deduce transformer T to zero value; fill in the table 4.1 with the obtained values.

The operating and resetting forces of each contacts $F_{op}$ and $F_{res}$ are calculated by such formulas:

$$F_{op} = I_{op} \cdot W_{coil};$$

$$F_{res} = I_{res} \cdot W_{coil},$$

where $W_{coil}$ – is number of turns in coil of reed relay.




Picture 4.1 – Principal circuit of switch on hermetical contact relay

**4.3 Safety method instruction**

1. All commutation of the circuit execute at switch QF turned off.
2. Clearly follow safety methods instruction and internal order rules.

**4.4 Control questions**

4.4.1 What is magnetic hermetic contact (sealed contacts)?
4.4.2 Basic construction designs, purpose and fields of appliance of MC.
4.4.3 What materials are used to make hermetical contact (sealed contacts)?
4.4.4 When does smoldering discharge of hermetical contact (sealed contacts) use?
4.4.5 Give the definition of ferrite.

Table 4.1 – Measured and calculated values (for 11 measurements)

| № hermetic | № testing | $U_{op}$ | $I_{op}$ | $U_{res}$ | $I_{res}$ | $U_{rat}$ | $I_{rat}$ | $F_{op}$ | $F_{res}$ | $K_{res}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | | |
| | 2 | | | | | | | | | |
| | 3 | | | | | | | | | |
| | average | | | | | | | | | |
| 2 | 1 | | | | | | | | | |
| | 2 | | | | | | | | | |
| | 3 | | | | | | | | | |
| | average | | | | | | | | | |
| 3 | 1 | | | | | | | | | |
| | 2 | | | | | | | | | |
| | 3 | | | | | | | | | |
| | average | | | | | | | | | |
| … | 1 | | | | | | | | | |
| | 2 | | | | | | | | | |
| | 3 | | | | | | | | | |
| | average | | | | | | | | | |
| 11 | 1 | | | | | | | | | |
| | 2 | | | | | | | | | |
| | 3 | | | | | | | | | |
| | average | | | | | | | | | |

4.4.6 When does the MC control with the help of magnetic fields use?

4.4.7 Explain the property of AC relay operation on hermetical contacts (sealed contacts).

4.4.8 What is the difference in ferrites with insert memory?

4.4.9 What methods are used to prevent “false” operation of ferrite?

4.4.10 Peculiarities of operation of several MCs in one control winding.

# 5 LABOROTORY WORK №5
# STUDY OF VARIABLE-CAPACITANCE TRANSDUCER

The purpose of work: to study the principle of operation, purpose and design of variable-capacitance transducers, calculate and determine experimentally parameters of the transducer, to compare experimental and computational data, to do conclusions.

## 5.1 General notes

In the variable-capacitance transducers the change of the measured value is proportional change in the condenser capacity.

If to analyze the expression that determines the capacity of the flat capacitor:

$$C = \frac{\varepsilon_a S}{d} ,$$

where $\varepsilon_a$ - is the absolute dielectric permittivity;

S – is the square capacitor plates;

d – is the distance between the plates,

it can build three types of transducers by principles (figure 5.1):

a) the principle of changing the distance d between the electrodes -- displacement transducers;

b) the change of the square of the rotation angle transducer;

c) changing of dielectric permittivity $\varepsilon_a$ - that is a level transducer (detector).

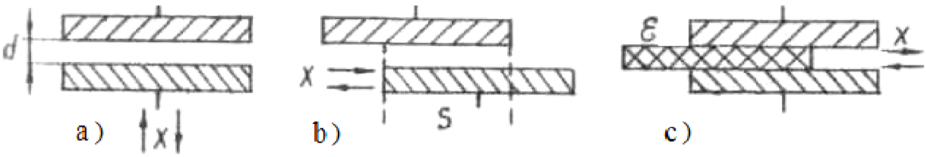



Figure 5.1 - The types of variable-capacitance transducers

Structurally variable-capacitance transducers are made with flat, cylindering, rotary, etc.

As an insulator used an air, mica, porcelain insulators, etc., as well as insulating liquids.

In this laboratory work the variable-capacitance transducer is studied transducer of angle displacement. In the circuit of the transducer (Fig. 5.2) is used rotary air-dielectric capacitor. These variable capacitors are used in radio engineering to tuned circuit tunings.

To increase the capacity they are designed multiplied ones. The operating square of capacitor plates depends on the rotation angle.

The capacity of the capacitor is changed at changing of the operating area of plates. Therefore, condenser resistance of alternating current and output parameters of the transducer $U_{out}$ and $I_{out}$ are changed. According to measuring instrument can understand state of input (control) value.

The advantages of variable-capacitance transducers are:

a) the high sensitivity that allows to measure the rapidly - variable processes (vibrations, acceleration);

b) the relatively small value s and weight;

c) low inertia;

d) a small opposite effect on the parameter;

d) a small value of energy of interaction between the plates;

e) low input effect.

The disadvantages of variable-capacitance transducers are:

a) the need for high-frequency power supply;

b) the need for shielding of external electric fields and parasitic capacitors;

c) low power output caused by the large capacitive resistance Xc, due to low-capacity condenser;

d) the effect of humidity and temperature on the value of its dielectric permittivity.

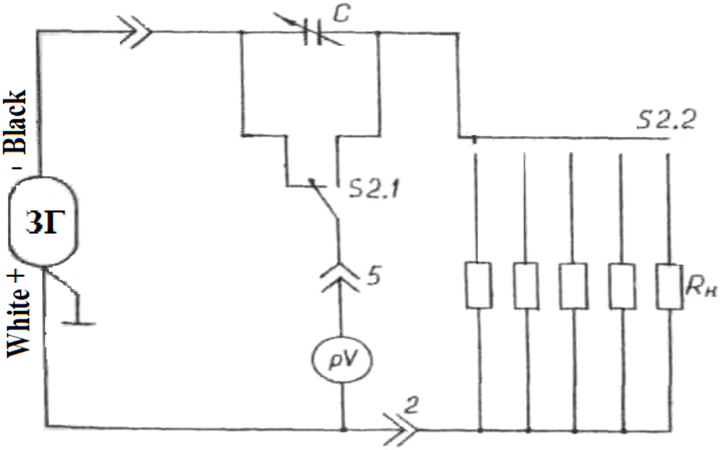



Figure 5.2 - The circuit of transducer testing

## 5.2 Steps of work execution

- to view the structure, scope of variable-capacitance transducers, their advantages and disadvantages;
- to calculate the maximum capacity of the condenser, used to test the transducer;
- to calculate the transducer capacitive reactance at various states of the capacitor rotor (0, 45, 90, 135, 180 °) and at different frequencies of the supply voltage (4, 7, 10 kHz).
- to calculate the current in the transducer circuit and the voltage at its output at $R_H = R_{H\ max}$ of the above mentioned of the capacitor rotor states, and values of frequencies; analogically do such calculations at f=4 kHz, $R_H = (R_{H\ min}, \ldots, R_{H\ max})$, $C = (C_{min}, \ldots, C^{max})$
- for points, calculated in point 4, to determine experimentally $U_{out} = \varphi$ (f) and $U_{out} = \varphi$ ($R_H$);
- to calculate the sensitivity and to plot the experimental functions;
- to compare the results and do the conclusions.

**5.3 Safety method instruction**

1. All commutation of the circuit execute at switch QF turned off.
2. Clearly follow safety methods instruction and internal order rules.

**5.4 Methodical guide**

5.4.1 Information about the variable-capacitance transducers can be found in the literature [l, 2, 3].

5.4.2 To calculate the maximum capacity of the condenser is necessary to measure the value of air gap between the plates and their operating square The capacity of a flat capacitor is calculated by

$$C = \frac{\varepsilon_b \cdot \varepsilon_0 S(n-1)}{d} + C_0 \ , \qquad (5.1)$$

where $\varepsilon_b = 1$- is a permittivity of air;

$\varepsilon_0 = 8.85 \cdot 10^{-12}$ F/s;

S - is an operating plate square, $m^2$;

d – is the average gap between the plates, m;

n - is the number of plates (fixed and mobile);

$C_0$ – is the minimum capacity of the condenser, equaled to 10% of first value in formula (5.1).

5.4.3 Capacitive reactance is calculated for the rotor states $0^0$ ($C_{min}$); $45^0$ ($C=C_{max}/4$); $90^0$ ($C=C_{max}/2$); $150^0$ ($C=2/3\ C_{max}$); $180^0$ ($C=C_{max}$) at the frequency of supply (input) voltage f = 4, 7, 10 kHz. The calculation results are recorded in the table 5.1. (the calculation formula 5. 2).

$$X_C = \frac{1}{2\pi f C} \ . \qquad (5.2)$$

5.4.4 The current of transducer circuit is calculated for values capacitance and resistance at different loads.

Table 5.1 - Data of calculations

| α, grad | F, kHz | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 4 | 7 | 10 |
| 0 | | | | | |
| 45 | | | | | |
| 90 | | | | | |
| 135 | | | | | |
| 180 | | | | | |

First of all, current in the transducer circuit is calculated at $R_H$ = = $R_H$ max, f=4 kHz the and values of C ($C_{min}$, ..., $C_{max}$). Then the same calculations are performed for other frequencies: 7, 10 kHz. Resistance of load is maximized. The results are recorded into table 5.2. According to got data are plotted functions I = φ (f).

In the second case, the frequency was adopted constant f = 4 kHz, the values $R_H$ and C are changed. The results are recorded in the table. 5.2. To plot functions I = φ ($R_H$) according to the got data.

Knowing the current in the transducer circuit, it can calculate the voltage drop in the load resistance. This will be functions $U_{out}$ = φ (f) and $U_{out}$ = φ ($R_H$); and the results are recorded in the table 5.2. According to got data to plot functions $U_{out}$ = φ (f) and $U_{out}$ = φ ($R_H$).

$$I = \frac{U_{in}}{\sqrt{X_C^2 - R_H^2}}. \qquad (5.3)$$

5.4.5 The voltage of the transducer input and its output is measured by one and the same voltmeter. At measuring of the input voltage switch S2.l put in the position $U_{in}$ at measuring of the output voltage - into $U_{out}$ state.

For the experimental determination of function $U_{out}$ = φ (f) set up the frequency f = 4 kHz, voltage $U_{in}$ = 50 V, $R_H$ = $R_{H\,max}$; changing the capacity of the condenser, register a values of $U_{out}$.

$$U_{out} = I \cdot R_H \ . \qquad (5.4)$$

The same to done at other frequencies, supporting $U_{in}$ = 50 V. Then, at $U_{in}$ = 50 V and f = 4 kHz experimentally determine the dependence of $U_{out}$ = φ ($R_H$); changing $R_H$ by switch S2.2. The results add to the table 5.2.

5.4.6 According to a known data and the formulas to calculate the sensitivity of variable-capacitance transducers (Kt).

$$K_T = \frac{\Delta U_{out}}{\Delta C} \ . \qquad (5.5)$$

5.4.7 Plot calculated and experimental dependences $U_{out}$ = φ (f), $U_{out}$ = φ ($R_H$), Kt = φ (f), Kt = φ ($R_H$).

**5.5 The contents of the report**

5.5.1 The aim of this work.
5.5. 2 Circuit of the apparatus testing.
5.5.3 The tables and graphs.
5.5.4 The calculation formulas.
5.5.5 Analysis of the calculation results and experiment.
5.5.6 Conclusions.

**5.6 Control questions**

5.6.1 What are the principles of variable-capacitance transducers?
5.6.2 What are examples of structures of variable-capacitance transducers?
5.6.3 What used variable-capacitance transducers?
5.6.4 Advantages and disadvantages of variable-capacitance transducers.
5.6.5 The operating principle of the variable-capacitance transducer.

5.6.6 What is the optimal frequency for the study testing transducer?
5.6.7 What is the optimum transducer for the study?
5.6.8 What is the sensitivity of variable-capacitance transducers?
5.6.9 Errors of variable-capacitance transducers.

# 6 LABOROTORY WORK №6
# STUDY OF POTENTIOMETRIC TRANSDUCER

The purpose of work: to define construction of potentiometer transducer, to study theirs static and dynamic characteristics, to determinate static sensitive.

## 6.1 General notes

The resistance transducers are used for control of line and angular displacement, pressure, temperatures et cetera. Their principle of operation is based on active electric resistance variation under influence of measuring signal. For their power supply the sources of direct or alternating current can be used. The voltage or current will be output parameters depending on input ones (as a potentiometer or variable-resistance). In the resistance transducers of position its mobile element is mechanically related to the operating mechanism (OM). The change of operating mechanism position made the variation of the transducer resistance.

The potentiometer transducer is presented by variable resistance, the contact of which displaced according to mechanical stress. This transducer can be used to transform angular or linear mechanical travel to corresponding variable resistance, voltage or current.

One-cycle potentiometer transducer (figure 6.1) is presented by wire resistance which put in the circuit of voltage.

Static characteristic of potentiometer can be as linear as non-linear function $U_x$=f(x).

The connection of the potentiometer slider and the source of input signal have kinetic character. In this case coordinate X is the variable displacement which characterizes the position of slider according to beginning of potentiometer winding.

One-cycle transducer allows testing only one sign displacement. The execution of leading-out wire from average point is need for design of transducer, which react upon a sign of internal winding displacement.

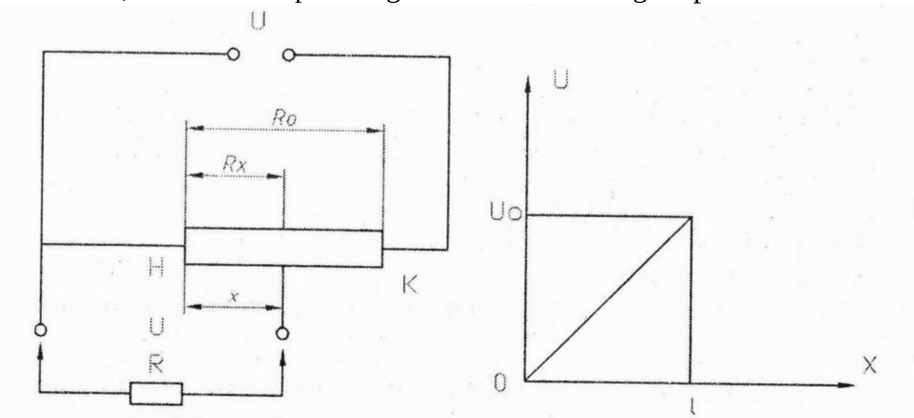



Figure 6.1 – The one-cycle potentiometer transducer and their static characteristic

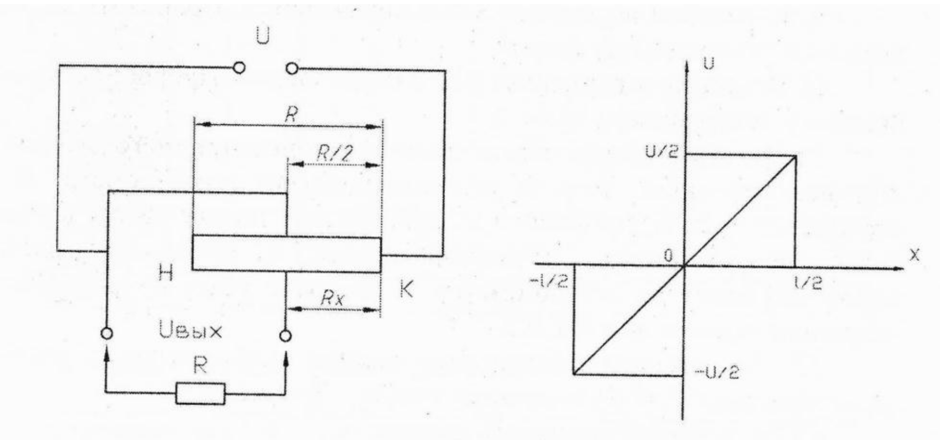



Figure 6.2- The two-cycle potentiometer transducer and their static characteristic

Aluminum case is a good heat conductor. It allows increasing density of the current in the winding, so consequently the sensitive of potentiometer transducer.

### 6.2 Steps of work execution

1. Before laboratory work execution student have to study methodical instructions and repeat chapter devoted to potentiometer transducer.
2. Prepare tables 6.1 and 6.2.
3. Connect a circuit on the picture 6.3.
4. With the help of regulator T using voltmeter metering values set voltage equaled to 10 volts.
5. For testing step-type potentiometer transducer set the slider of potentiometer R1 to the leftmost state.
6. Set the switch S12 to the leftmost state.
7. Rotating axis of potentiometer R2, write down metering values of voltmeter to the table 6.2 every $45^o$.
8. Set the switch S12 to the state “2”. Do the same that is in the seventh item.
9. Set the switch S12 to the state “3”. Do the same that is in the seventh item.
10. Set the switch S12 to the state “4”. Do the same that is in the seventh item.
11. For testing of two-step potentiometer transducer with artificial center point, set the slider of potentiometer R to the middle state. Do the same that is in the previous item. Begin to write down all metering values in the leftmost state of potentiometer R slider. Pay attention to the $U_{out}$ sign. All metering values write down to the table 6.2.
12. Using testing data plot static characteristics U=f(j), on one graph. Make conclusion.
13. Calculate sensitivity of the potentiometer transducer.
14. Using testing data plot a static characteristics of off-load operating of single step-type potentiometer transducer with artificial center point (when $R_H=\infty$).
15. Using testing data plot static characteristic of potentiometer transducers when:

$R_H$=Ro, α=1, Ro=2,2kΩ,

$R_H$=10Ro, α=0,1,

$R_H$=15Ro, α=5, where Ro is a total resistance of potentiometer.

16. Define static characteristics of transducers when $R_H$ is different.
17. Make an analysis of obtained results and make a conclusion.

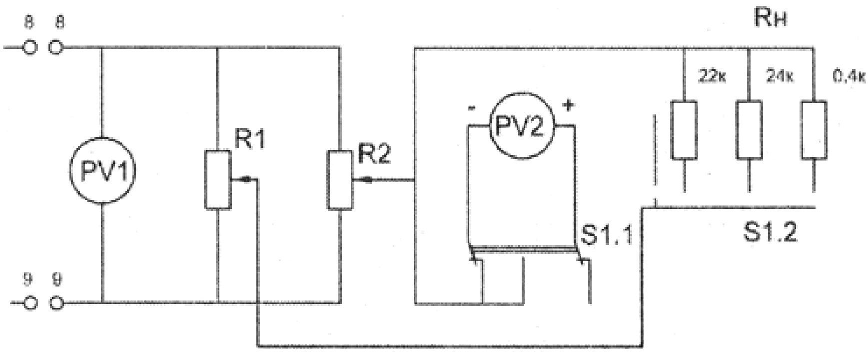



Figure 6.3 – Principal circuit of potentiometer transducer testing

Table 6.1 – Testing data

| Rotation angle of R1 axis J, degrees | 0 | 45 | 90 | 135 | 180 | 225 | 270 | 300 |
|---|---|---|---|---|---|---|---|---|
| $U_{out}$, 1, V | | | | | | | | |
| $U_{out}$, 2, V | | | | | | | | |
| $U_{out}$, 3, V | | | | | | | | |
| $U_{out}$, 4, V | | | | | | | | |

Table 6.2 – Testing data

| Rotation angle of R2 axis J, degrees | 0 | 45 | 90 | 135 | 180 | 225 | 270 | 300 |
|---|---|---|---|---|---|---|---|---|
| $U_{out}$, 1, V | | | | | | | | |
| $U_{out}$, 2, V | | | | | | | | |
| $U_{out}$, 3, V | | | | | | | | |
| $U_{out}$, 4, V | | | | | | | | |

**6.3 Safety methods instruction**

1. All commutation of the circuit execute at switch QF turned off.
2. Clearly follow safety methods instruction and internal order rules.

**6.4 Control questions**

6.4.1 Construction design and using of potentiometer transducer.
6.4.2 Main characteristics of potentiometer transducer.
6.4.3 Advantages and disadvantages of potentiometer transducer.
6.4.4 What is insensitive zone?
6.4.5 What is static characteristic of a transducer?
6.4.6 How does load influence on the static characteristics of potentiometer transducer?
6.4.7 What does static sensitivity of transducer depend on?
6.4.8 In what cases is it necessary to use functional potentiometer transducer?

# 7 LABORATORY WORK №7
# STUDY OF VARIABLE-INDUCTION PICKUP

Purpose of work: to study with action principle and structural features of variable-induction pickups, find out parameters of transducer by experiments and to give their analysis.

## 7.1 General notes

A transducer (sensor) is the first element of measuring circuit, as a rule, analog device, giving out information about the parameters of the system and it processes. It is the basic source of an electric signal (change of the electric circuit state due to its shorting and breaking, change any electric parameters – R, L, C - or generations EMF – electromotive force). Then this signal is processed, transformed to the kind, which is comfortable for a transmission by the communication lines and it further transformation and use.

An electric transducer (sensor) is a device which responds, as a rule, physical variable (speed, acceleration, pressure, temperature, humidity, illumination (intensity), composition and percentage of impurity, frequency of vibrations (oscillation), color etc).

## 7.2 Steps of work execution

Before execution of laboratory work a student must independently learn the actual methodical directions, repeat the section of course about variable-induction pickups and prepare tables 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7 and 7.8, and assemble a circuit (fig.7.1).

It is need to support voltage of voice generator constant on a value at any measuring.

7.2.1 Measuring of inductances L1(x) and L2(x) at different fixed positions of core is executed by a voltammeter method. In order to measure a current and voltage in a coil the switch S 3.1 must be switched to position «2», and switch S 3.2 in position «0». Write down registration of PV1 and PA to table 7.1. For measuring of current and voltage at the same value X in a coil switch S 3.2 must be put in «2» position, and S 3.1 in «0». Write down registration of PV1 and PA to table 7.1.

Table 7.1 – Results of testings

| Value | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| X, mm | | | | | | |
| Z1,Ohm | | | | | | |
| $U_1$, V | | | | | | |
| $I_1$, A | | | | | | |
| Z2, Ohm | | | | | | |
| $U_2$, V | | | | | | |
| $I_2$, A | | | | | | |
| L1, H | | | | | | |
| L2, H | | | | | | |

For measuring of current and voltage at the same value X in 2 coil the switch S 3.2 must be put in position «2» and S 3.1 in «0». Write down registration of PV1 and PA to table 7.1.

In the experimental variable-induction pickup the measuring borders $0 < x < 3$ mm is divided on the row of areas (marks on brass part of core).

Proposing consistently 5-6 values X, execute measuring of each X, on 1 and 2 coils. As a result of measuring to calculate L1(x) and L2(x) use the given formulas in appendix.

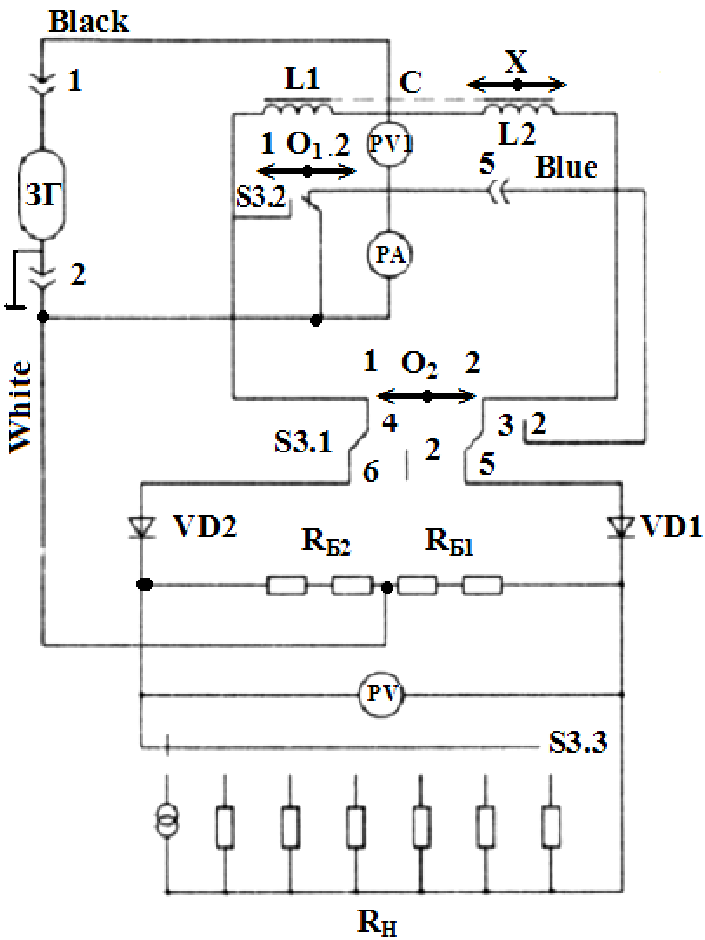



Figure 7.1 - it is testing circuit of variable-induction pickup

7.2.2 Calculate characteristic U2 (x) by given in appendix formulas. Values of Rн and Ro are given in the end of text.

Execute calculation at frequency f=400 Hertz. Write down the results of calculation to the table 7.2.

Table 7.2 - The results of calculation

| Value | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| $R_н$ 1= | X, mm | | | | | | |
| | Kz | | | | | | |
| | $U_2$,V | | | | | | |
| $R_н$ 2= | X, mm | | | | | | |
| | Kz | | | | | | |
| | $U_2$, V | | | | | | |

Execute calculation for the values of Rн. By the data from table 7.2 plot graphs U(x) at R=const in one axes.

7.2.3 During the experiment a switch must be turn up in "1"-"1". Carry out test at f=4000Hz. Write down results of calculation to table 7.3.

Table 7.3 – Results of testing

| Value | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| $R_н$ 1= | X, mm | | | | | | |
| | $U_2$,V | | | | | | |
| $R_н$ 2= | X, mm | | | | | | |
| | $U_2$,V | | | | | | |

By the data of table 7.3 plot the graph U(x) at R=var in one axes with the graph by table 7.2 and to compare them with the calculated ones.

7.2.4 Using the graphs, which was got at execution of 2 and 3 and the formulas resulted in addition, define dependence between coefficients of sensitiveness of transducer from Rн to к(Rн). Plot in the same axes of coordinates graphics R (Rн). Compare two curves and to give the analysis. Write down the results of calculation to the table 7.4.

Table 7.4 – Results of experiments

| № | R, Ohm | $\Delta X$, mm | | $\Delta U_2$, V | | K,V/mm | |
|---|---|---|---|---|---|---|---|
| | | calculation | experiment | calculation | experiment | calculation | experiment |
| | | | | | | | |
| | | | | | | | |

Values $\Delta X$ and $\Delta U_2$ take from the rectilinear areas of characteristics.

7.2.5 Arbitrarily choose value R=const. Consistently set frequencies f= ($10^3$, $2{\cdot}10^3$, $3{\cdot}10^3$, $4{\cdot}10^3$, $5{\cdot}10^3$) Hz. At every fixed frequency by the help of the formulas resulted in appendix 1 calculate $U_2(X)$. Then execute the experimental measuring of $U_2$ (X) at those frequencies. Write down the results of calculations and experiments to the table 7.5.

Table 7.5 – Results of experiments and calculations

| № | $f=10^3$ Hz | | | $f=2\bullet10^3$Hz | | | $f=3\bullet10^3$ Гц | | | $f=4\bullet10^3$Hz | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | X, mm | Kz | $U_2$, V | X, mm | Kz | $U_2$, V | X, mm | Kz | $U_2$, V | X, mm | Kz | $U_2$, V |
| | | calc | test | | calc | test | | calc | test | | calc | test |

All graphs (with the data that was got experimentally and calculated) must be built in one co-ordinate. Plot the graphs of U (x) got experimentally and upon calculations in one axes.

7.2.6 Using the got graphs in 5 and the formulas of appendix, calculate K(f) for experimental and calculated data. Write down the results of calculations to the table 7.6.

Table 7.6 – Calculated data

| № | f,Hz | ΔX, mm | | Δ $U_2$,V | | Kz, V/m | |
|---|---|---|---|---|---|---|---|
| | | calc | test | calc | test | calc | test |
| | | | | | | | |
| | | | | | | | |

Plot two graphs K(f) calculated and experimental. Build both graphs in one coordinate axes. Give the analyses of both graphs.

7.2.7 Calculate errors of sensor that depended from frequency of voltage and Rн with the help of data of experiments 3, 4, 5 and formulas given in appendix. Write down the results into the tables 7.7 and 7.8.

Table 7.7 – Calculated data

| № | Rн | | | |
|---|---|---|---|---|
| | Δ$U_2$,V | $U_{2calc}$,V | ΔU,% | Rн,Ohm |
| | | | | |

Table 7.8 – Calculated data

| № | f | | | |
|---|---|---|---|---|
| | Δ$U_2$,V | $U_{2calc.}$,V | ΔU,% | Rн,Ohm |
| | | | | |

Build the graphs ΔU% (f) and ΔU (Rн). Give the analyses of the characteristics.

## APPENDIX

$$Z = \sqrt{R^2 + (\omega L)^2} \cong \omega L,\ \omega = 2\pi f;$$

For every coil Z=U/I. $L \cong \frac{1}{\omega}\sqrt{Z^2 - R^2} \cong \frac{Z}{\omega};$

$$U^2 = 0.45\lambda U_1 Kz.$$

Value of coefficient λ depends on shadow of neighboring metal parts and other factors (λ= 0.2,…,1). In our laboratory work take λ= 0.4,….,0.6.

$$Kz = \frac{L_2 - L_1}{\omega\frac{L_1 \cdot L_2}{Rá} + L1 + L2 + \frac{Rá}{\omega} + 2\omega L1 \cdot L2 + Rá(L1 + L2)}.$$

$$K = \frac{\Delta U_2}{\Delta X};\ \Delta U\% = \frac{U_{2calc} - U_{2test}}{U_{2calc}} \cdot 100\%.$$

Values of $R_н$ and Rб:

| | |
|---|---|
| $R_н$1=0.3 kOhm | $R_н$ 5=3.3 kOhm |
| $R_н$2=0.56 kOhm | $R_н$ 6=6.2 kOhm |
| $R_н$3=1.0 kOhm | Rб1=1.5 kOhm |
| $R_н$4=2.0 kOhm | Rб2=1.5 kOhm |

### 7.3 Safety methods instruction

1 All switching in the circuit execute along with cutout QF turned on.

2 Clearly follow safety methods instruction and internal order rules.

### 7.4 Control questions

7.4.1 Give definition of transducer and variable-induction pickup.

7.4.2 What constructions are self-generating and modulating transducers?

7.4.3 What principle of variable-induction pickup operation?

7.4.4 Advantages and disadvantages of high-frequency variable-induction pickups.

7.4.5 What operation principle of testing circuit of variable-induction pickup?

7.4.6 What relationships of all graphs?

7.4.7 Make conclusions about properties and errors of transducers and variable-induction pickup?

# 8 LABORATORY WORK №8
# STUDY OF REED RELAY MODEL

The purpose of work: to study the concept of operation, construction design by the symmetrical neutral reed relay model, controlled by current winding; to plot tractive and opposition characteristics of this relay; to determine a rotation angle of relay operation, reset ratio of current reed relay, controlled by field of current bus; to study the construction of industrial reed relays КЭМ-2, КЭМ-3, etc.

## 8.1 General notes

The subjects of study are:

– relay P1 (figure 8.3) is a model of symmetrical neutral reed relay with a closed contacts controlled by a current coil;

– relay P2 is a current reed relay, controlled by field of current bus;

– testing representative specimen is the relay РПГ-011011У3;

– the production prototypes.

Model view is shown on the figure 8.1. P1 is model of the symmetric neutral closed reed relay controlled by a current winding (figure of winding includes "big" turns (1), their number is equal to 1000, and "small" turns (2), their number is equal to 4; then the total number of turns creating operation MMF is equal to 4000, or (1000x4). P2 is a current reed relay, controlled by field of current bus; HL is a signal lamp, signaling about closing of P1 and P2 relay; П is a switch; 1 is a testing representative specimen is the relay РПГ-011011У3; 2 are the production prototypes КЭМ-2, КЭМ-3.

The principal electric circuit, mounted on the stand panel is shown on figure 8.3. The relay winding (turn) P1 is connected to the source of DC voltage up to 200 V. The turn (bus) of relay P2 (contains 600 turns) is connected to the source of DC voltage of 16 V.

Measuring instruments PA1, PA2, PVI, PV2 are connected to the line terminals according to the figure. 8.3.

Lamp HL is connected via transformer 1220 / 6 and into the commutation circuit KC1 of relay P1 or KC2 of relay P2 by switch П. The transformer secondary winding is earthed.

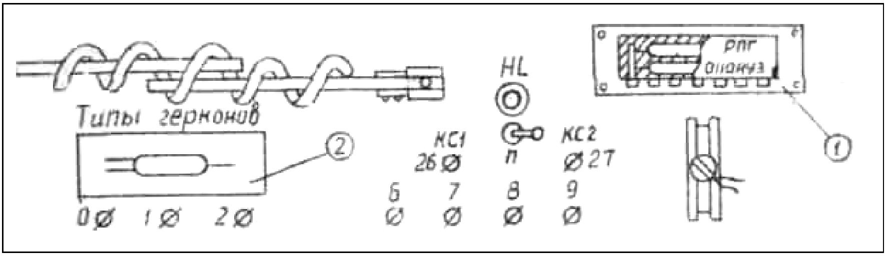



Figure 8.1 - Sketch of the panel with the reed relay

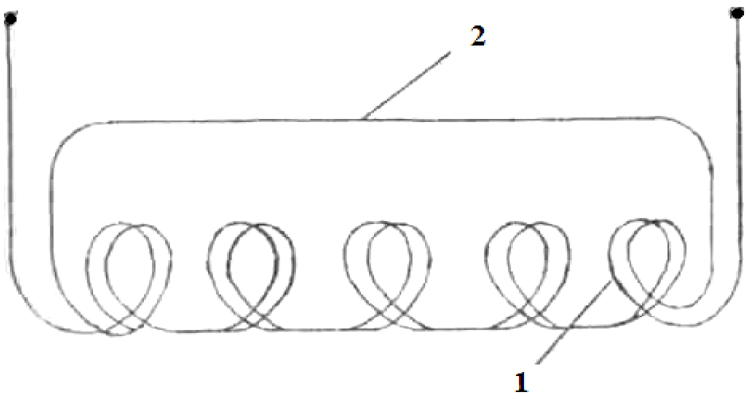



Figure 8.2 - Sketch of the winding

To analyze the serviceability of the relay it needs to plot opposition and tractive characteristics, which are being plotted in the same coordinates.

To plot the opposition characteristics such formula is used [1]:

$$F_{mch} = C \cdot y,$$

where $F_{mch}$ - is a force opposing to closing of contact details (mechanical force of elasticity), N;

y - is the initial gap between the contact details, m;

C - is a stiffness of contact details, N / m.

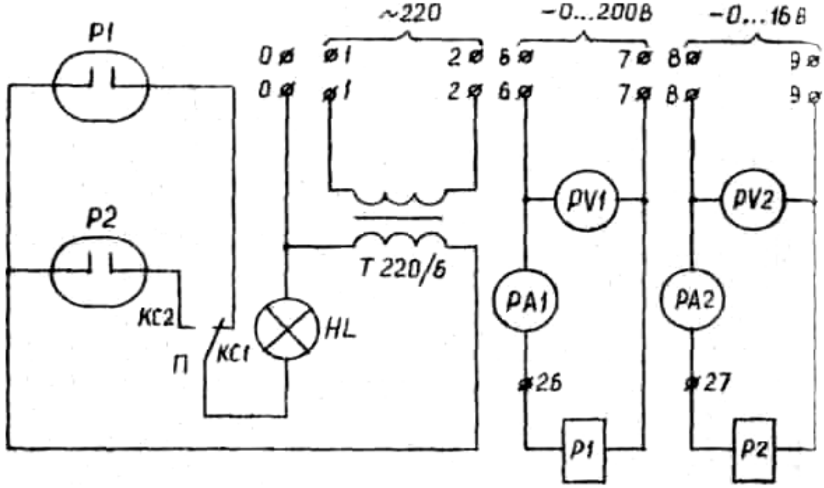



Figure 8.3 - The principal electric circuit of the testing reed relays

If make an assumption that the contact details have uniform stiffness, then

$$C = (3 \cdot E \cdot j) / l^3, \tag{8.1}$$

where j is the inertia moment of cross section of contact details, m4 determined by formula

$$j = (b \cdot h^3) / 12,$$

here b - is a width of the contact, m;

h - is a the height of the contact, m;

l - is an arm of force, m, determined by

$$l = l_{KC} - a/2\ .$$

where $l_{KC}$ - is the length of contact details, m;

a - is the length of the overlapping contact details at the operating gap, m;

E is an elasticity modulus of material contact details, N / m.

To plotting the tractive characteristics the formula of Maxwell is used [4]

$$F_{Ŷî} = \frac{\hat{O}^2}{2\mu_0 S}; \quad \hat{O} = \frac{I \cdot \mu_0 SW}{l_{KC}}. \qquad (8.2)$$

Then

$$F_{Ŷî} = \frac{\mu_0{}^2 S^2 W^2}{2\mu_0 S^{/} l_{KC}} \cdot I^2 .$$

where S=b·h is a section of contact, $m^2$, see fig. 8.4;

$S^{/}$=a·b is an area of overlap, $m^2$, see fig. 8.4;

W is a number of turns of the control coil;

$\mu_0$ is a magnetic constant, H / m;

μ is an absolute magnetic permeability, H / m.

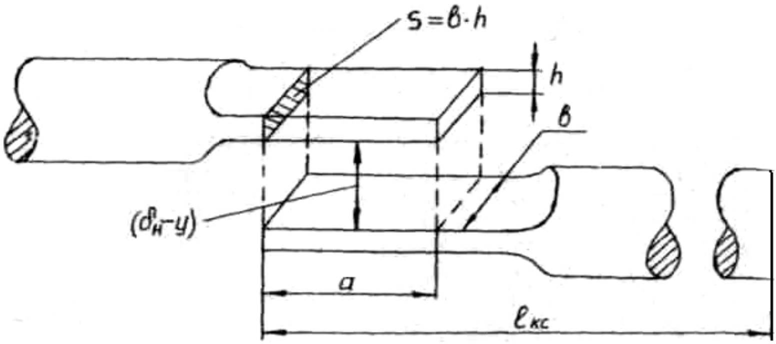



Figure 8.4 - Sketch of location contact

## 8.2 Steps of work execution

8.2.1 To study the design of relay models P1 and P2, РПГ-011011У3 and industrial reed relays КЭМ-2, КЭМ-3, etc.

8.2.2 To calculate the stiffness by formula (8.1) where E to take from the table 8.1, and the value of $l_{KC}$ get on the relay model P1. Then, setting the values of y from 0 to ... (air gap of a contact details), to plot opposite characterization reed relay $F_{MX}$=f(y).

8.2.3 Determine experimentally and plot tractive characteristics of relay P1 $F_{MX}$=f (X), the dependence of current I=f (X) and power P=f (X).

8.2.4 Determine experimentally and plot the current dependence current I=f (α) and power P=f (α) for the relay P2.

8.2.5 Determine the value of the angle at the border of P2 relay operation.

8.2.6 According to the results of experiments and calculations to do conclusions.

## 8.3Guidelines

8.3.1 Circuits for the experiments with the relays P1 or P2 to connect according to the fig. 8.3.

8.3.2 To except sealing of the relay P1 it is need to put foil on contact details. To measure the thickness of aluminum foil by micrometers, this would be consistent with δo.

8.3.3 Regulator of the laboratory stands to the left position (position 0). A switch П set to KC1 and the KC2, depending on the testing relays P1 and P2.

8.3.4 In the study of the P1 relay switch П set to KC1, and gradually increasing the voltage regulator T, to fix the values of voltmeter RV1 and ammeter PA1 (desktop devices) at different values of a and y. Start to measure it is necessary at $a_{max}$ & $y_{min}$. The values of a, y, b, h, $l_{KC}$ are measured by scale rule.

Different values of y are determined by set regulators on the contact details, which can also experimentally determine the maximum air gap of contact details $\delta_H$ , that is starting of reed relay operation. Data are recorded into the table. 8.1. At first setting y values and then changing values of a (3 values) to study  the relay P1.

8.3.5 Build dependencies F=f(y), $F_{ЭМ}$=f(y), I=f(y), P=f(y), and the

$F_{MX}$=f (y) & $F_{ЭM}$=f(y) to plot on the one coordinate space.

8.3.6 At the study of P2 relay to set П switch to position KC2 and gradually change the current by the regulator T, taking of ammeter evidence PA2 and voltmeter PV2 during the operation and release of the relay P2. Do these measurements at different values of the angle α, between the longitudinal axis of reed relay and direction of current in the bus.

Table 8.1 – The data of measurements and calculations

| № | Testing values | | | | | | | | Calculated values | | | | Constant values |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | y | U | I | a | b | h | $l_{KC}$ | $\delta_0$ | Φ | $F_{MX}$ | $F_{ЭM}$ | P | |
| 1<br>2<br>3 | | | | | | | | | | | | | C=4000N/m$^2$<br>E=1.36·10$^{-11}$<br>$\mu_0=4\pi\cdot10^{-7}$ H/m<br>μ=65000 for testing alloy |
| 1<br>2<br>3 | | | | | | | | | | | | | |
| 1<br>2<br>3 | | | | | | | | | | | | | |

8.3.7 Determine the limits of the angle of operation $\alpha_{пр}$. Write down a result in the table 8.2.

8.3.8 Determine the $(IW)_{op}$, $(IW)_{res}$, $K_{res} = \frac{IW_{op}}{IW_{res}}$, plot graphs $(IW)_{op}$ =f(α), $I_{op}$=f(α), $K_{res}$=f(α), $P_{op}$=f(α) dependences.

**8.4 The contents of the report**

8.4.1Tasks.

8.4.2 The circuit of the testing reed relays.

8.4.3 The constructive difference between the industry reed relays from each other on the stand.

8.4.4 Tables and graphs of the calculated and experimental data.

8.4.5 Conclusions based on each functions and on report as a whole.

Table 8.2 – The data of measurements and calculations

| № | Testing values | | | | | Calculated values | | | | Constant values |
|---|---|---|---|---|---|---|---|---|---|---|
| | α | $I_{op}$ | $I_{res}$ | $U_{op}$ | $U_{res}$ | $IW_{op}$ | $IW_{res}$ | $K_{res}$ | $P_{op}$ | |
| 1<br>2<br>3 | $90^0$ | | | | | | | | | W=600 |
| Aver | | | | | | | | | | |
| 1<br>2<br>3 | $75^0$ | | | | | | | | | |
| Aver | | | | | | | | | | |
| 1<br>2<br>3 | $60^0$ | | | | | | | | | |
| Aver | | | | | | | | | | |
| 1<br>2<br>3 | Angle on the border of opera-tion | | | | | | | | | |
| Aver | | | | | | | | | | |

### 8.5 Control questions

8.5.1 Give the definition of stable equilibrium point.

8.5.2 What cause of vibration (chatter) of switching contacts at reed relay operation?

8.5.3 Give principle difference between operation process of reed relay and standard armature relay.

8.5.4 What reed relay operation function MMF of coil position of air gap?

8.5.5 How does function $I_{op}$ depend on angle of the longitudinal axis rotation of reed relay and direction of current in the bus?

8.5.6 What kind of MMF resetting function and $K_{res}$ of reed relay depend on contact overlap values?

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