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Descriptions of Electronic Measuring Equipments

Tallinn 1970

TALLINNA POLÜTEHNILINE INSTITUUT
Raadiotehnika kateeder
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DESCRIPTIONS OF ELECTRONIC MEASURING EQUIPMENTS

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1970

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THE ELECTRONIC VACUUM TUBE VOLTMETER

B3-2A (МВЛ-2М)

I Application

The electronic vacuum tube voltmeter B3-2A (МВЛ-2М) is designed to measure r.m.s. values of sinusoidal alternating voltage from 1 mV to 316 V, with an error of not more than 6% for a full-scale reading of the meter, over a frequency range of 20 c/s to 1 Mc/s, in closed heated rooms.

Furthermore, the instrument is graduated in decibels from -55 to +52 dB, using a reference level of 0dB=0.775 V (1 mV in a 600 ohms load).

The operation conditions of the voltmeter B3-2A correspond to the requirements of the State Standard (GOST) 9763-61 II group and are as follows:

a) ambient temperature range of +10 to +35°C;

b) relative humidity of the air to 80% with a temperature of +20°C;

c) frequency of power supply mains 50 ± 0,5 c/s;

d) power supply mains voltage 220 V ± 10%;

e) absence of mechanical vibrations, intense direct or alternating magnetic fields and instantaneous changes of the mains voltage.

The instrument is ready for use after a 15 minutes warm-up time.

II Technical Data

1. Measurement ranges:

10, 30, 100, 300 mV and 1, 3, 10, 30, 100, 300 V a.c.

2. Frequency range from 20 c/s to 1 Mc/s.

3. Basic measurement error of instrument, as taken from the full-scale reading (basic full-scale error):

a) ±2,5% over the frequency range from 55 c/s to 20 kc/s;

b) ±4,0% over the frequency range from 40 c/s to 500 kc/s;

c) ±6,0% over the frequency range from 20 c/s to 1 Mc/s.

4. Change of meter pointer readings, caused by a deviation of ambient air temperature from the normal (20 ± 5°C), within the stated operation temperature conditions for each 10°C, does not exceed the basic error.

5. Input impedance at a frequency 1000 c/s on the ranges of 10 mV ... 1 V is not less than 1 Mohm; on the ranges 3 ... 300 V - not less than 1.8 Mohms.

6. Input capacity in the measuring ranges of 10 mV ... 1V, is not more than 15 pF.

7. Deviations of the meter reading caused by changes of the supply voltage from its nominal value by ±10%, do not exceed one half of the basic error of the instrument.

8. Power consumption from the a.c. 220 V ±10%, 50 c/s, mains is not more than 60 VA.

9. Dimensions of Voltmeter - 310x220x200 mm.

10. Weight of Voltmeter - not more than 9 kg.

III Complement

Each voltmeter B3-2A set is provided with the following items:

1. The VTVM B3-2A with a set of vacuum tubes installed 1
2. Mains cord and plug 1
3. A shielded measuring cable for connecting to the voltage to be measured 1
4. Spare fuses ПК-0,5 A 2
5. Spare pilot light 6.3 V 0.28 A 1
6. Acceptance Certificate, Instructions and Operation Manual 1

IV Description of Instrument Circuit

The circuit of the vacuum tube voltmeter consists of a three-stage wide-band amplifier, using negative feedback, voltage dividers connected in the circuit of a cathode follower, a rectifier, power supply and a source calibration voltage.

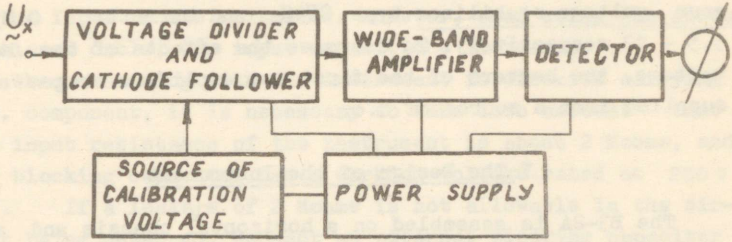


Fig. 1.

Depending on the measurement range used, the measured voltage is applied to the grid of the cathode follower directly or through the voltage divider having an attenuation of 50 dB. Thus, a high input resistance and low input capacitance is provided, and a possibility of further attenuation of the measured voltage in the circuit of the cathode follower is obtained by using a low-resistance voltage divider. During calibration, a 10 mV stabilized voltage is applied to the cathode follower grid.

Voltages properly attenuated in the voltage divider are applied to the input of the wide-band amplifier. A deep negative feedback is employed to increase the constancy of the amplifier amplification factor. Both, the amplifier and the cathode follower, use high-quality type 6Ж1П pentode vacuum tubes.

The voltage amplified by the wide-band amplifier is rectified by a half-wave rectifier, using one diode of a 6Х2П duodiode vacuum tube. The type M24 microammeter having a sensitivity of 100 μA is connected in the load circuit of the rectifier. The other diode is used for initial current compensation.

A bridge circuit, comprising a non-linear element, is used to obtain the calibration voltage. The filament of a 3.5 V 0.28 A lamp is used as the non-linear element in the circuit stated above.

To diminish the dependence of the voltmeter sensitivity upon change of voltage in the supply mains, the anode voltage and a part of the heater voltages are stabilized by the gaseous voltage stabilizer type СГ4С and barretter 0.85Б 5.5 - 12 respectively. To decrease the effects of the hum voltage, the heaters of the first two amplifier stages are supplied from a source of d.c.

V The Design of the Instrument

The В3-2А is assembled on a horizontal chassis and vertical front panel, enclosed in a metal cabinet. The chassis can be removed from the cabinet by two handles, after turning open the respective screws along the edge of the front panel and at the bottom of the cabinet.

VI Operation Instructions

Before switching on the voltmeter, set the meter pointer by turning the mechanical corrector.

After switching on the voltmeter, let it warm up for a period of 15 minutes. Then turn the measurement range switch to the position "300 V" and turn the "Zero adjustment" ("Установка нуля") knob to adjust the meter pointer to zero.

After setting the zero, the measurement range switch is to be turned to the position "Calibre" ("Калибр") and by turning the screw-head of the potentiometer inscribed "Calibration" ("Калибровка") set the meter pointer to the upper scale marking "10". After doing this, the instrument is ready for use.

When measuring low voltages, it is recommended to ascertain, that only the measured voltage is being applied to the voltmeter input terminals and not some other stray interfering voltage; To check this, leave all circuit connections unchanged, switch off the measured voltage (for example, disconnect the anode voltage of the generator, etc.) and ascertain that no greater than permitted stray voltage does enter the input terminals of the voltmeter. If during voltage measurements on the low measurement ranges, the connection wires become an antennae, in which the induced voltage is higher than permitted, the measured voltage can be connected through the provided shielded cable, having a special shielded plug, to the input of the voltmeter. However, when using the above-mentioned cable, the input capacitance increases.

When measuring with the instrument in circuits carrying d.c. component, it is necessary to take into account that the input resistance of the instrument is about 2 Mohms, and the blocking capacitor has a working voltage rated at 200 V d.c. If a leakage of 2 Mohms is not allowable in the circuit being measured, connect an external blocking capacitor of 0.5 μF or higher value for passing the lowest frequencies and respectively lower value for higher frequencies to the input circuit.

The vacuum tube voltmeter is calibrated in voltage effective values; therefore, it shows the correct reading only when measuring sinusoidal voltages. When measuring non-sinusoidal alternating voltages, additional measurement error is inevitable, the value of which depends on the form factor of measured voltage.

When measuring voltages having the same frequency as the power supply the readings of the instrument, due to the internal hum voltage, depend to some extent on the phase shift existing between the measured and supply voltage. In such cases, to acquire more accurate measurement results, it is recommended to take an average arithmetical value, received after interchanging the polarity of the mains supply plug.

VII Repairing the Instrument

Should the instrument fail to work, firstly, check the soundness of the mains fuse. If the fuse is sound, it is necessary to measure the voltage on the pins of the vacuum tubes. The nominal voltages are given in the voltage diagram. These values correspond to voltages measured when supplying the instrument from a nominal mains voltage. They are measured with a voltmeter having an internal resistance of 5000 ohms/V. As a rule, the results of voltage measurements will show, which of the components are defective, after which they can be replaced with new ones.

If the fault is in the calibration voltage bridge, the voltmeter must be readjusted as stated below, after it has been repaired:

1. Connect the voltmeter B3-2A to the mains supply through an adjustable autotransformer. Measure the voltage between the chassis and the moving arm of the potentiometer R_{26}, by using any vacuum-tube voltmeter capable of measuring voltage of approximately 10 mV.

2. Vary the mains voltage from - 10% to +10% of its rated value with the aid of the adjustable autotransformer. Simultaneously, turn the potentiometer R_{22} to set it into such a position, in which the voltage measured between the chassis and moving arm of the potentiometer R_{26} does not change when the mains voltage is varied by ±10%.

3. Apply a voltage equal to 10 mV ±1% at the supply mains frequency to the input of the B3-2A voltmeter. Turn the measurement range switch to the position "10 mV". Turn the potentiometer screw head inscribed "Calibration" ("Калибровка"), to adjust the meter pointer to the marking "10" on the meter upper scale.

4. Turn the measurement range switch to the position inscribed "Calibre" ("Калибр"). By turning the knob of the potentiometer R_{26}, adjust the meter pointer to the marking "10" on the meter supply scale, without changing the position of the potentiometer for calibration.

5. After the adjustments have been made with the potentiometers R_{22} and R_{26}, it is necessary to place a drop of paint on their shafts to hold the arm in a fixed position.

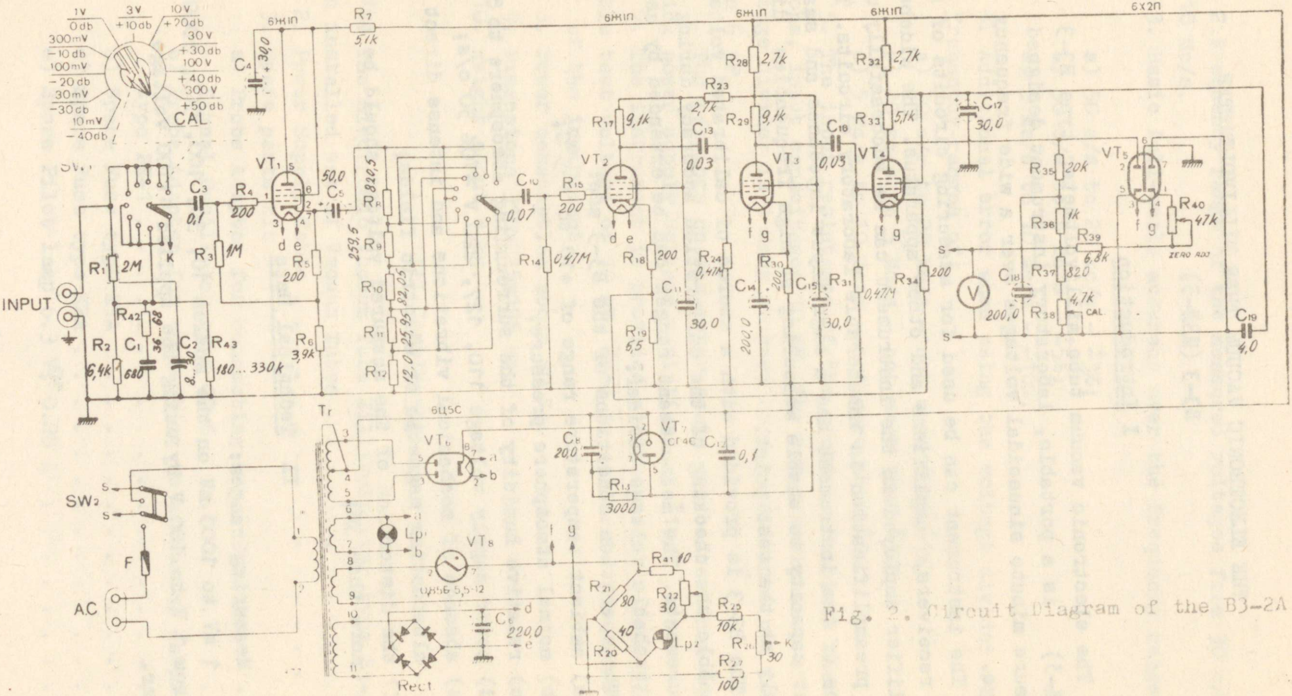


Fig. 2. Circuit Diagram of the B3-2A.

THE ELECTRONIC VACUUM TUBE MILLIVOLTMETER B3-3 (МВЛ-3)

I Introduction

The electronic vacuum tube millivoltmeter type B3-3 (МВЛ-3) is a portable, laboratory instrument designed to measure minute sinusoidal voltages over a wide frequency range.

The instrument can be used for measuring circuits of radio receivers, amplifiers and other apparatus. The wideband amplifier employed in the instrument can be successfully used for preamplification in innumerable laboratory circuits. The probe of the instrument has a high input impedance and small input capacity to enable measuring at high frequencies directly at the test point.

The B3-3 is provided with a source of calibrated voltage to enable the checking of the calibration accuracy during measurements. The measurement ranges can be extended by using an attachable voltage divider.

The operation conditions of the B3-3 are:

a) ambient temperature range of +10 to +35°C;

b) normal atmosphere pressure;

c) relative humidity of the surrounding atmosphere to 80%;

d) power supply voltage 110, 127, 220 V ±10% 50 c/s;

e) absence of mechanical vibrations and intense direct or alternating magnetic or electric fields;

f) the distortion of the measured voltage should be not more than 3%;

II Technical Data

1. Measuring ranges:

1 mV to 1000 mV on the scales 10, 30, 100, 300, 1000 mV and from 1 V to 100 V by using the applied 1:100 voltage divider.

2. Frequency range of the measured voltages from 30 c/s to 10 Mc/s.

3. Basic full-scale accuracy over the frequency ranges of:

a) 50 c/s to 20 kc/s - ±3%;

b) 30 c/s to 5 Mc/s - ±5%;

c) 5 Mc/s to 10 Mc/s - ±10%.

4. Additional error when using the voltage divider over the frequency ranges of:

a) 30 c/s to 20 kc/s - not more than ±1%;

b) 20 kc/s to 5 Mc/s - not more than ±3%;

c) 5 Mc/s to 10 Mc/s - not more than ±5%.

5. The input resistance of the probe is not less than 1 Mohm, input capacitance 10 pF. The input resistance of the voltage divider is 1 Mohm shunted by a capacitance not more than 6 pF.

6. The readings on the meter scale are better than ±3%, during power supply voltage variations of ±10%.

7. The instrument is provided with terminal screws for stable test voltage of 10 mV, used to calibrate the sensitivity of the instrument.

8. Power consumption about 80 VA.

9. Dimensions 310x215x195 mm.

10. Weight about 8 kg.

III Complement

1. The Electronic Vacuum Tube Millivoltmeter type B3-3 with installed set of Vacuum Tubes 1

2. Power Supply Cable 1

3. Spare parts kit

a) Probe Adapter for connecting to a Standard Signal Oscillator type CC-6 1

b) Probe Adapter for connecting to a coaxial cable type PK-1 1

c) Spare Fuse type K1A 1

d) Spare Fuse type K2A 1

e) Spare Pilot lamp 6.3 V, 0.28 A 1

f) 1:100 Voltage Divider 1
g) Plug for connecting to the output terminal . . 1
4. Instructions and Operation Manual 1
5. Certificate of Acceptance 1

IV Circuit Description and Functioning of the Instrument

The Electronic Vacuum Tube Millivoltmeter type B3-3 consists of an attached probe using a cathode follower, which is connected through a shielded cable to the attenuator and respective circuity of a stable wide-band amplifier. A calibrated microammeter is connected to the output of the amplifier. The instrument is supplied from a power supply in which the heater current is stabilized with ballast tube and the anode voltages by an electronic voltage stabilizer.

The measured voltage is applied to the input of the probe. The cathode follower of the probe passes the voltage through the shielded cable to the tapped attenuator, connected to the input of the stable wide-band amplifier. After being amplified the voltage is applied to a voltage-doubler circuit, consisting of two germanium diode half-wave rectifiers, and microammeter having a sensitivity of 100 μA.

The scale of the microammeter has been calibrated to r.m.s. values of pure sinusoidal voltages. Since the measurements are made by using a diode-capacitance measuring circuit the readings of the meter will depend on the amount of harmonics in the voltage being measured.

1. The Probe

The circuit of the probe consists of a cathode follower which has a voltage gain of 0.6. The cathode load is a resistive voltage divider, from which the voltage is passed to the input of the amplifier through the shielded cable.

The probe uses a type 6ЖIП vacuum tube connected as a triode. Voltage drop across the cathode load resistor is used as grid bias for the cathode follower tube. To carry out measurements with voltages containing d.c. component in addition to a.c. voltages, a blocking capacitor C_1 with working voltage of 200 V is inserted in the high-potential input lead. The circuity of the probe is assembled in a cylindric enclosure. The probe is provided with attachable adapters to facilitate measuring.

The instrument is supplied with the following adapters:

1. A ring-type adapter fitted with prongs for connecting to commonly used receptacles.

2. Adapter and special jack for inserting in the output terminal of the Standard Signal Oscillator type ГСС-6.

3. Adapter for connecting to commonly used coaxial cable receptacles.

2. The Attenuator

The B3-3 uses a tapped attenuator having 5 positions. The resistors are made of wire having diameter of 0.05 mm, wound on mica slabs using non-inductive Ayrton-Perry type winding. The attenuator is mounted in a special aluminium casing. The input resistance of the attenuator is 300 ohms.

3. The Wide-band Stabilized Amplifier

The voltage from the attenuator is applied through the capacitor C_5 to the grid of the first vacuum tube of the amplifier. The amplifier is of a resistance-capacitance coupled type using 6Ж1П vacuum tubes. The correction of the frequency response is made by the inductance coil L in the anode circuit of the VT_4. The inductance of the coil L is approximately 10 microhenries and is varied by turning the ferromagnetic core.

The potentiometer R_{12} is connected across the heater leads of amplifier tubes, its centre tap is adjusted to obtain a minimum hum voltage at the amplifier output.

The amplifier consists of six stages giving an overall gain of approximately 200. Deep negative feed-back is involved to obtain the necessary constancy of the amplification by reducing the overall gain approximately five times, i.e. from 1000 to 200.

Each of the three stages involve negative feed-back. The cathodes of the tubes VT_4 and VT_7 are coupled to the cathodes of the tubes VT_2 and VT_5 respectively. Besides this, each stage involves individual negative feed-back due to the unby-passed cathode resistors.

Resistors are used as anode loads. The vacuum tube VT_1 used in the tube probe has decoupling filter in anode circuit consisting of the 1.5 kohm resistor R_{10} and 10 pf capacitor C_6. The vacuum tube in the output stage is connected as a triode to handle a larger amplitude response. The amplifier output jack mounted on the front panel is connected through a blocking capacitor C_{22} to the high-potential end of the cathode resistor of the output stage. The output of the amplifier can be used as a wide-band preamplifier for oscillographs, other voltmeters, etc., giving a gain of 43. With an output voltage of 0.43 V the noise level is about -32 dB. The output impedance is about 35 ohms at frequencies over 20 kc/s.

At audio frequencies the output impedance of the amplifier equals the reactance of the blocking capacitor C_{22}.

The frequency response of the amplifier when using the output "ВЫХОД" terminal jack is linear to 1 Mc/s, rising 10% at 3 Mc/s with an output capacitance of 100 pF or with a capacitance of 25 pF the frequency response is linear to 3 Mc/s and rising 10% at 5 Mc/s.

4. The Meter Circuit

The voltage developed across the anode resistor of the output stage is applied to two half-wave germanium rectifier diodes type Д2-В or ДГ-Ц8.

During the positive half cycle one of the capacitors is charged while the other capacitor is charged during the negative half cycle. Both are discharged through the resistors R_{34}, R_{35} and the microammeter.

The 10 pF blocking capacitors are connected to the positive pole of the anode voltage instead of the ground to avoid puncture of the diodes. One of the discharge resistances in the circuit of the microammeter is variable and can be adjusted by turning the screw head. With this resistor the sensitivity can be adjusted by ±20% in cases when the sensitivity is to be checked in respect to a calibrated voltage standard.

5. Source of Calibration Voltage

The B3-3 has a source of stabilized calibrated voltage using 50 c/s, permitting re-checking the sensitivity of the instrument during measurements when voltage standards are not available. The calibration voltage is taken across the diagonal of an unbalanced bridge, one leg of which is made of a non-linear resistance of a 3.5 V pilot lamp. When the voltage of the power line rises the resistance of the pilot lamp filament increases and the voltage across the diagonal of the bridge decreases. The lamp is used with about 1.3 V across its filament. The point of operation is selected by the variable resistor R_{47} to give the best stabilization, resulting in the calibration voltage remaining practically unaffected by the power line voltage variations. The potentiometer R_{51} is used to set the output calibration voltage exactly to 10 mV.

The output 10 mV "Выход 10 mV" is connected to the terminal screw mounted on the front panel. The left-hand terminal screw is connected to the chassis while the right-hand one is under the high potential.

NOTE! The calibration voltage is adjusted when using a pure sinusoidal voltage. Should the shape of the power line voltage substantially differ from that of the sinusoidal, the reading made with the instrument will show an additional error. The lamp used in the calibration bridge circuit must be chosen to be mechanically rigid.

6. The Power Supply

The B3-3 can be operated from 110, 127 or 220 V a.c. power line. The power transformer can be switched over for operation from one of the above mentioned voltages by removing the combined fuse holder and power line selector switch and returning it in its socket so, that the required voltage is shown in the window at the upper edge of the fuse holder (refer to VI Operation Instructions). The anode voltage is supplied by a rectifier consisting of germanium diodes and stabilized by an electronic stabilizer using a series circuit. The bias voltage is taken from the type СГ2П stabilizer. A type 6ЖIП vacuum tube is used as control amplifier, and the type 6ПI4П vacuum tube is used as the regulator of the voltage.

The voltage of the heater of vacuum tubes VT_1, VT_2, VT_3, VT_5, VT_7 is stabilized by a IБ5-9 ballast tube.

7. The Voltage Divider

The voltage divider has a ratio of 1:100 permitting measurements to be made up to 100 V.

The frequency response compensation is made by the capacitors C_{26}, C_{27} and C_{28}. At high frequencies the calibration is carried out by adjusting the trimmer capacitor C_{27}.

V Construction

The Millivoltmeter B3-3 has been designed as a compact portable instrument having a vertical front panel displaying the following control components:

1. The control knob of the attenuator constituting the Measurement Range Selector Switch with the millivolt ranges engraved on the front panel.
2. Sensitivity adjustment (screw-head).
3. Power Supply Switch.
4. Pilot Lamp.
5. Fuse holder combined with Power Supply Selector Switch.
6. Amplifier output jack.
7. Microammeter.
8. Calibration Voltage Output Terminals.

The microammeter is mounted on hinges to permit the meter to be placed at any convenient angle of observation.

VI Operation Instructions

Before connecting the B3-3 to the Power Supply line ascertain that the combined Fuse holder and Power Supply Selector Switch is inserted to the correct voltage. During manufacture the Power Supply Selector Switch is connected for operation from a 220 V line. In order to change to another voltage the Fuse holder must be pulled out from its fastener. The fuse must be replaced by a 2 A one, if the power line voltage is either 110 or 127 volts. After replacing the fuse, insert the fuse and holder, turning the holder until the desired voltage appears in the window.

Turn the Measurement Selector Switch to "0". Insert the Power Supply Range Cable plug into the line receptacle. Next lift the Power Supply Switch to the ON ("Включено") position. By doing this the pilot lamp should light. After several seconds the microammeter pointer will deflect returning again to the zero reading. After 10 minutes the instrument is ready for use. A slight declination of the pointer may be caused by the residual hum voltage, which, however, can be compensated by turning the mechanical corrector screw-head of the microammeter.

When desired, the instrument can be checked by inserting the probe to a calibration voltage standard. The Voltage Range Selector Switch is to be placed in the 10 mV position ascertaining that the meter pointer reads 10 mV. The sensitivity can be adjusted by turning the calibration screw-head "Калибровка".

Since the B3-3 is very sensitive, the presence of interference should be checked. To do this, connect the input of the instrument to the source of measured voltage, then disconnect the measured voltage supply and ascertain that there is no stray voltages at the input of the probe.

In order to keep the interfering voltages at a minimum use shielded connecting cables, and connect firmly the in-

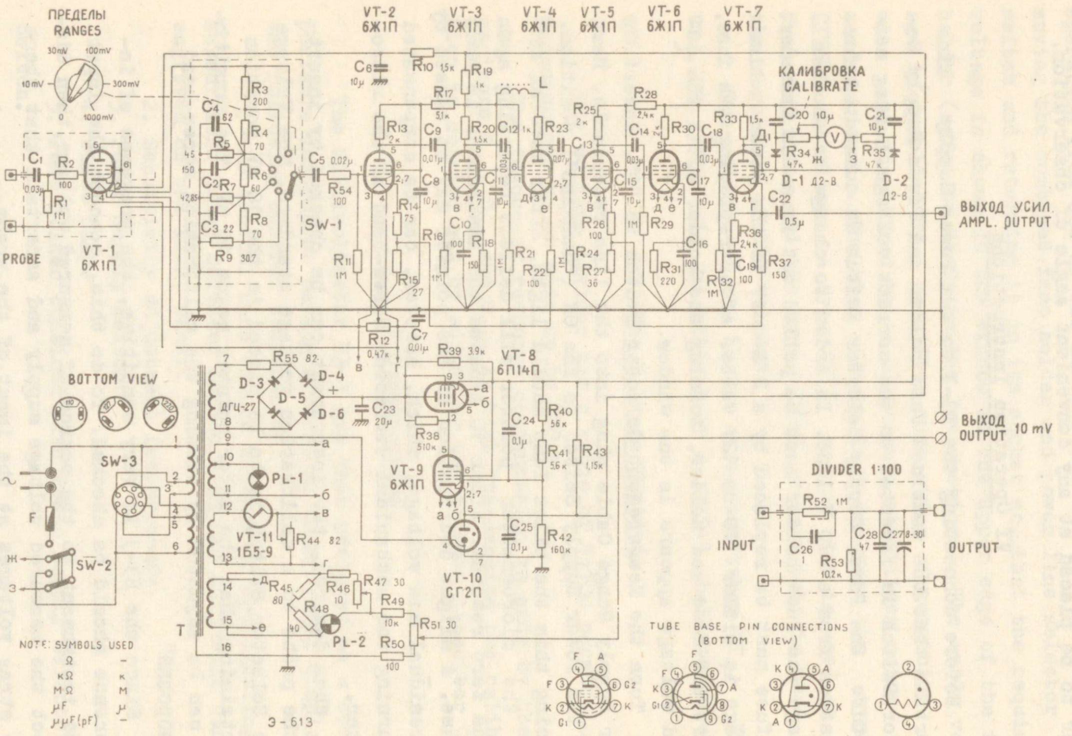


Fig. 3. Circuit Diagram of the B3-3 (МВЛ-3).

strument chassis to the zero potential of the measured circuit. When measuring voltages of supply line frequency a difference of reading may result depending on the polarity of the instrument power cord plug. In such cases an arithmetical mean value of two measurements is taken after changing the power supply plug to both polarities.

VII Replacement of Vacuum Tubes

Usually the frequency response of the wide-band amplifier does not change noticeably after replacing vacuum tubes. However, when replacing some sets of tubes the results of measurements at 5 ... 10 Mc/s may vary by 2 ... 3%. The necessary frequency response compensation can be made by turning the core of the compensation coil after applying a signal from a signal oscillator giving a good sine wave, and using a voltmeter with high input impedance (for instance, from a type B1-1 Q-meter and a type BKC-7 voltmeter). Unevenness of frequency response can be determined by applying the oscillator signal with constant value of 0.9 V to the input of the B3-3 and measuring the signal voltage with a type BKC-7. The frequency characteristic can be recorded by registering the readings on the scale of the B3-3 microammeter.

The a.c. hum appearing after the warming up of the B3-3 can be compensated by turning the potentiometer R_{12} and the mechanical zero corrector of the microammeter.

The pilot lamp in the calibration bridge is operated at a reduced filament voltage, which provides a long life.

However, should it be necessary to replace it, the semivariable resistor R_{47} is turned to adjust for the highest possible stabilization of the bridge output voltage when the power line voltage is changing by ±10%. The stabilized voltage can be measured with a type BKC-7 (or equivalent) voltmeter between the resistor R_{49} and chassis. By measuring with another B3-3 the same voltage is available at the output terminals on the front panel. After this the exact value of the input voltage can be adjusted with the resistor R_{51}. The exact value of voltage - 10 mV - used for calibration can be taken from the tapping on suitable resistive voltage divider, while checking the input voltage with an a.c. voltmeter having accuracy of 0.5%.

VIII Possible Faults and Their Remedy

1. When switching on the B3-3, the pilot lamp lights but the meter pointer does not deflect.

Fault: The rectifier, vacuum tube VT_7 or germanium diodes Д2-В (ДГ-Ц8) are defective.

2. When switching on the B3-3, the pilot lamp lights, the meter pointer deflects after the usual warm-up time, but during measurement the pointer remains at zero.

Fault: One of the amplifier or probe vacuum tubes is defective. An open circuit in the probe cable.

3. When connecting the probe to the calibration terminal socket the meter pointer deflects over the scale (on the 10 and 30 mV ranges).

Fault: The pilot lamp in the leg of the calibration voltage bridge is burnt.

THE VACUUM TUBE MILLIVOLTMETER
B3-13

Description

I Application

The vacuum tube millivoltmeter B3-13 has been designed to measure r.m.s. values of sinusoidal alternating voltages from 0.3 mV up to 300 V over the frequency range from 20 Hz to 1 MHz.

The apparatus is classified under group III of the U.S.S.R. State Standard (GOST) 9763-61.

Operation conditions of the apparatus are:

a) ambient air temperature from -10 to +40°C;

b) atmospheric pressure 750 ±30 mm Hg;

c) relative air humidity up to 90%, at a temperature of +25°C;

d) mains supply voltage 220 V ±10%, at a frequency of 50 ±0.5 Hz;

e) absence of mechanical vibrations, intense direct or alternating magnetic fields and instantaneous changes of the supply mains voltage.

The apparatus is ready for use in 5 minutes after switching on.

II Technical Data

1. Voltage measurement ranges:
   3-10-30-100-300 mV;
   1-3-10-30-100-300 V.
2. Frequency range of measured voltages from 20 Hz to 1 MHz.

3. Measuring error of the apparatus, expressed in per cents of the nominal value of the meter scale useful part, does not exceed:

a) 4%, when using the range 3 mV - 1 V at frequencies from 20 Hz to 1 MHz;

b) ±4%, when using the range 3V - 300 V at frequencies from 20 Hz to 20 kHz;

c) ±6%, when using the range 3 V - 300 V at frequencies from 20 kHz to 1 MHz.

4. Variations of the instrument readings caused by changes of the ambient air temperature from +20 ±5°C to any temperature over the range from -10°C up to +40°C, do not exceed ±3% for each 10°C change of temperature.

5. Variations of the instrument readings caused by changes of supply voltage from 220 V by ±10%, does not exceed ±2%.

6. Variations of instrument readings in per cents of a full-scale deflection, caused by distortion of the measured voltage to 20%, does not exceed 1/2 of the measured value of distortion given in per cents.

7. Input impedance of the apparatus is not less than:

a) at a frequency of 1000 Hz

1.0 MΩ - for the 3 mV - 1 V range;

1.6 MΩ - for the 3 V - 300 V range;

b) at a frequency of 1 MHz

400 kΩ - on all ranges.

8. Input capacitance of the apparatus is not more than:

a) 25 pF - on the 3 mV - 1 V range;

b) 15 pF - on the 3 V - 300 V range.

9. Mains power consumption of the apparatus - not more than 50 VA.

10. Dimensions of the apparatus: 300x220x185 mm.

11. Weight of apparatus about 6 kg.

III Accessories Complement

Each apparatus is supplied with the following accessories:

a) Shielded measurement cable 1

b) Spare fuses ПМ-0.5A 2

c) Spare pilot lamp МН-14 1

d) Acceptance certificate, description and operating instruction manual 1

IV Principle of Operation

The circuit of the apparatus consists of the following units:

a) the input unit;

b) amplifier;

c) rectifier;

d) power supply.

The Input Unit

The input circuit consists of a type 6С3П vacuum tube connected as a cathode follower having an input and output voltage divider.

The measured voltage is applied directly or through a voltage divider, having a 50 dB attenuation, to the grid of the cathode follower depending on the measurement range used. The use of the cathode follower provides a high input impedance and small input capacitance. As an additional facility, a low-resistance voltage divider can be connected to the output of the cathode follower, enabling thus further attenuation of the voltage to be measured.

The Amplifier

The measured voltage amply attenuated in the input stage is applied to the input of the wide-band amplifier. In the three-stage resistance-capacitance coupled amplifier type 6Ж9П pentodes are used. The amplifier has an overall gain of about 1000. The gain is stabilized by applying high values of negative feedback.

The Rectifier

The amplified voltage to be measured is rectified by a full-wave rectifier. The rectifier uses bridge circuit consisting of two germanium type Д1ОБ diodes and two resistors. The measuring microammeter type M94 having a 100μA sensitivity in series with the resistors R_{34} and R_{35} is connected across the diagonal of the bridge.

One of series resistors R_{34} is variable, by means of which the instrument is calibrated in respect to a reference voltage.

The Power Supply

The anode and heater voltage of the apparatus is obtained from the power transformer Tr. The anode voltage is rectified by type Д226 germanium diodes and stabilized with a type СГ1П voltage stabilizer.

Winding Data of the Transformer

Designation of taps	Name of windings	Number of turns	Marking and diameter of wires
1 - 2	Primary	1700	ПЭВ-2, ø 0.31 mm
3	Shield		
4 - 5	Anode	2200	ПЭВ-2, ø 0.18 mm
6 - 7 - 8	Heater	48+6	ПЭВ-2, ø 1.0 mm

Core: Ш - 20x25 Э - 310.

Thickness of laminations 0.35 mm.

Operating Instructions

V Safety Measures

A working apparatus should be grounded to the terminal, engraved ⏚ .

A switched on apparatus must not be removed from its casing.

In case of performing internal adjustments or repairs with the casing removed, take care not to touch the terminal of the transformer, diodes D_{3-1} ..... D_{3-8} and capacitors C_6, C_7. When replacing the elements remember to switch the apparatus off.

VI Rules for Operating the Apparatus

Before switching on the apparatus to the mains supply set the instrument pointer to zero by turning the mechanical adjustment screw. After allowing 5 minutes for warming up, the apparatus is ready for use.

To decrease the stray field interference, it will be necessary to securely connect the casing of the millivoltmeter to the point of zero potential in the circuit being measured.

During measurement of voltages at a frequency of the supply mains, possibly a difference in the meter readings (up to ±1.5%) may occur depending on the polarity of connection of the power cable plug to the supply mains. To achieve more accurate readings in such cases, it is necessary to take an arithmetical average of the two measurement readings obtained, when the polarity of the mains supply is interchanged.

When measuring voltage across the inductances, oscillation may occur in the apparatus at frequencies higher than the working range. Therefore, during measurements across inductive loads, it will be necessary to check for such oscillations by disconnecting the voltage from the circuit being measured.

The input d.c. resistance of the apparatus is about 2 MΩ. The input blocking capacitor is rated for working voltage of 400 V.

VII <u>Repairing and Testing the Apparatus</u>

Should the apparatus fail to operate, first of all check the soundness of the mains fuse. If the fuse is sound, as indicated by the lighted pilot lamp, further tests are carried out by measuring the voltages between the pins of the vacuum tubes and the chassis. By checking the measurement readings, it will be possible to determine the faulty component, which should be replaced.

The following are the characteristic faults during which all operating voltages may remain within the rated values:

a) Upon application of the voltage to be measured to the input of the apparatus, the meter pointer does not deflect, whereas, the pointer deflects when the voltage is applied directly to the grid of the vacuum tube VT_2.

Fault: The electrolytic capacitor C_4 is defective.

b) Abrupt decrease of apparatus sensitivity.

Fault: One of the germanium diodes D_1 or D_2 is defective.

After replacing the vacuum tubes or semiconductor diodes D_1, D_2 (Д1Б), it will be necessary to recalibrate the apparatus by using a reference voltage at a frequency of 1000 Hz, for example, from the calibrator model B1-2 (KB-2), or equivalent. The calibration is carried out by turning the potentiometer R_{34}. Hum voltage is compensated by turning the potentiometer R_3. The residual hum voltage, with the input shorted, must not exceed 2% of the full-scale reading.

Periodical tests of the apparatus are to be made at least twice a year and after repairs. In the process of the test the basic measurement error of the apparatus is to be determined at a frequency of 1000 Hz by using the calibrator B1-2 (KB-2). Likewise, tests should be made at frequencies of 20 Hz, 20 kHz, 100 kHz, 500 kHz and 1 MHz (on the ranges 1 V and 3V) by using the calibrator B1-3 or standard signal generator Г3-7 (ГС-100И) with thermocouples. In the last-mentioned case the measurements are to be made using the following circuit.

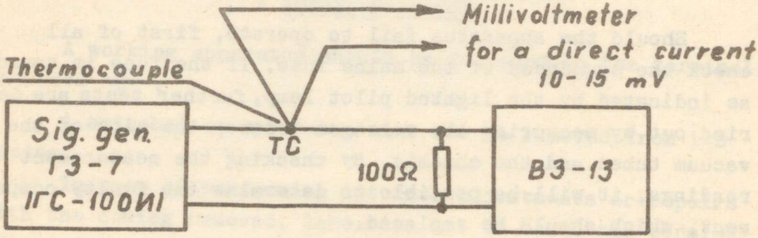


Fig. 4.

The thermocouple TC type ТВБ-4 is used during measurements in the 1 V range and type ТВБ-5 when measuring in the 3 V range.

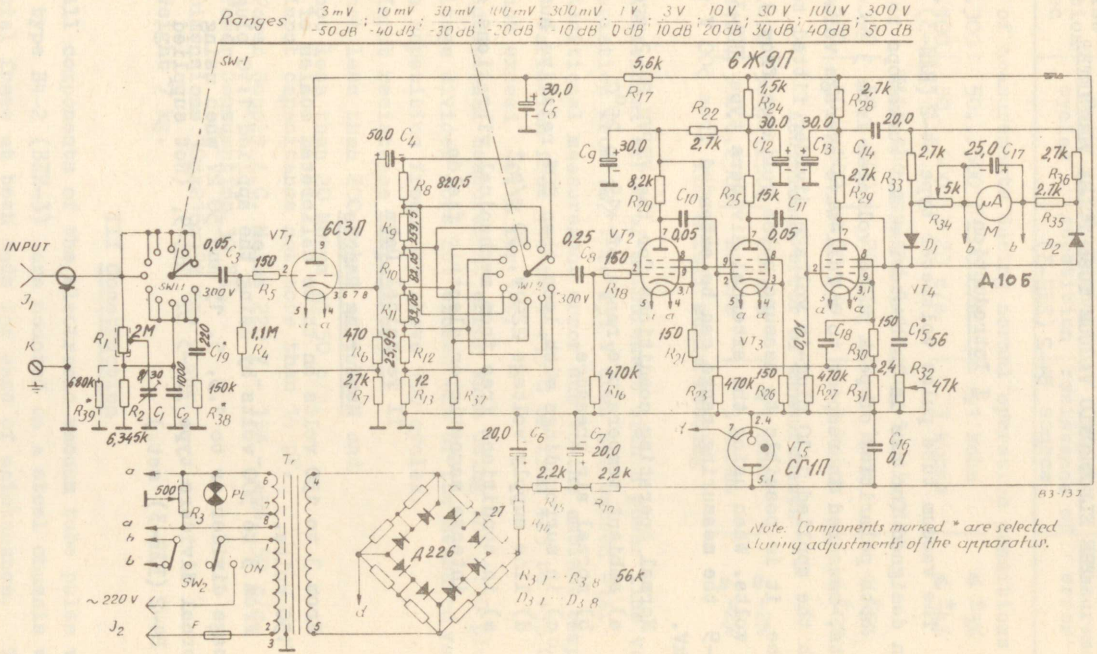


Fig. 5. Circuit Diagram of the B3-13.

THE ELECTRONIC VACUUM TUBE PULSE VOLTMETER

B4-2 (ВЛИ-3)

I Introduction

The vacuum tube pulse voltmeter type B4-2 (ВЛИ-3) has been designed for use in laboratories and workshops to measure both polarities of peak pulse voltages from 3 to 150 volts, measured in respect to a full-wave average value. With the applied 1:10 plug-in voltage divider fitted to the probe, it is possible to measure pulse voltages from 3 to 500 volts. When using the external dividers type ДНЕ-3 and ДНЕ-9 the measuring range can be extended from 500 V to 50 kV.

Normal operating conditions for the VTPVM B4-2 are:

a) ambient temperature range of +15 to 25°C,

b) normal air pressure,

c) in surroundings with less than 80% relative humidity,

d) line supply voltage 220 V, 50 c/s,

e) in conditions free from mechanical vibrations and intense magnetic or electric fields.

II Technical Data

Measuring Ranges

From 3 to 150 volts on three calibrated scales of 15, 50, 150 volts.

From 3 to 500 volts by using the applied 1:10 plug-in voltage divider or to 1.5, 5, 15 and 50 kV when using the external dividers type ДНЕ-3 or ДНЕ-9. (Not supplied with the B4-2 (ВЛИ-3) set.)

Error of Measurements

Pulse duration μ-sec	Duty cycles	Frequency repetition	Output resistance of source	Measurement error
Error of measurements during normal operation conditions				
0.1...300	50...500	20 c/s	≤1 kohm	≤ ±3%
0.2...100	50...500	≥20 c/s	3 kohms	≤ ±4%
With the applied 1:10 plug-in divider				
0.1...300	50...500	20 c/s	≤1 kohm	≤ ±5%
0.2...100	50...500	≥20 c/s	3 kohms	≤ ±6%
Additional error of measurements				
0.1...100	500...2500	20 c/s	≤1 kohm	≤ -2%
0.2...10	500...2500	20 c/s	3 kohms	≤ -2%

for a full scale reading

Additional error of measurement with a power line voltage variation from 187 V to 231 V does not exceed ±1%.

Additional measurement error due to the ambient temperature variation from +10 to 1 +15°C or from +25 to +35°C does not exceed ±0.1% for 1°C.

Additional measurement error when using the 1:10 plug-in voltage divider does not exceed ±2% of the measured value, with a repetition frequency above 100 cycles.

Input resistance (Impedance)
not less than 200 kohms at 4 Mc/s and
not less than 20 Mohms at 50 c/s.

Input capacitance not more than 14 pF.

Power Supply A.C. Mains 220 V - 15% - +5%, 50 c/s.

Power Consumption 30 VA.

Dimensions 308x216x194 mm.

Weight 7 kg.

III Construction

All components of the electronic vacuum tube pulse voltmeter type B4-2 (ВЛИ-3) are mounted on a steel chassis with a special frame at both ends for ease of maintenance. The front panel is made of aluminium and provided with handles

for removing the chassis for servicing. The case is provided with ample ventilation for lasting performance.

The probe is connected to the amplifier through a flexible shielded cable.

IV Functioning of the Voltmeter

The measured pulse voltage is rectified by a diode peak rectifier (refer to Circuit diagram). The rectified voltage is amplified by a direct current amplifier, the output of which is measured on a calibrated microammeter connected in a bridge circuit, consisting of vacuum tubes 6Н3П and 6Н2П and respective circuity.

The Peak Detector

The peak detector of the probe circuit consists of a type 6Д6А diode VT_1 and associated circuity, which rectifies the applied voltage at the point of measurement. The rectified and measured direct current voltage is practically equal to the peak value of the voltage pulse.

Because of the high resistance and large time constant of the diode load circuit, the measurements are practically independent of the pulse shape over extensive mark-to-space ratios.

The probe polarity switching current connects the diode to respond either to positive _⊓_ or negative pulses ‾⊔‾.

The large time constant of the capacitors C_1, C_2 and C_5 discharge circuit causes the microammeter pointer to return slowly to zero after removing the measured voltage.

To hasten the zero return, the discharge circuit is connected by pressing the push-button switch SW-2 (Discharge), connecting R_4.

The Direct Current Amplifier

The direct current amplifier has been assembled around two double triodes VT_2 and VT_3, using a balanced bridge circuit.

The triodes of the tube VT_3 are used as a cathode load for the measurement triodes VT_2. Any voltage applied to the input will change the magnitude of the anode plate voltage of the VT_3. Consequently, any change of anode voltage will vary the current passing through the tube, thus resulting in a change of grid bias of the triode VT_3, which in turn effects the anode current inversely to that of the anode voltage.

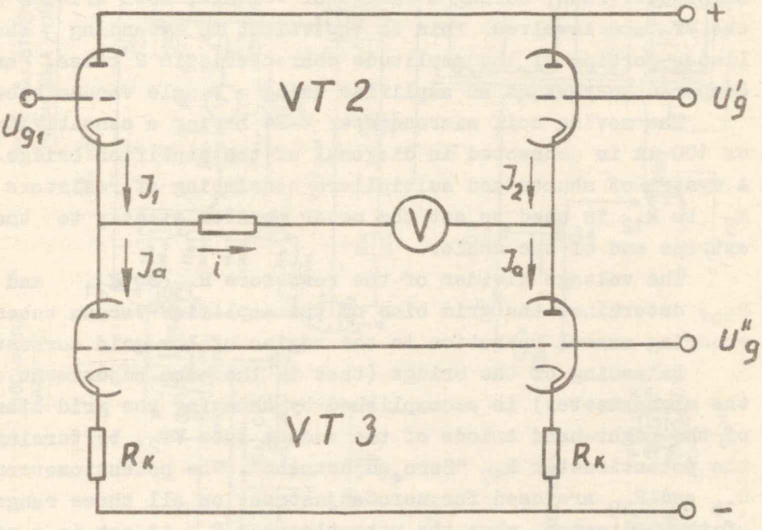


Fig. 6.

The values of the resistor R_k and grid bias (refer to Fig.1) have been chosen so that the currents flowing through the triodes practically remain constant regardless of anode voltage changes.

Suppose, that the current through the amplifier triode, with no signal applied to the input, is given as I_o. Upon applying a signal, the currents through the triodes VT_2 establish value of I_1 and I_2 respectively, while the currents through the triode VT_3, as stated above, remain constant at a value of I_o.

Referring to the schematic diagram Fig. 1, we can conclude that

$$I_1 = I_o + i \quad (1),$$

from where $$I_2 = I_o - i \quad (2),$$

$$I_1 + I_2 = 2I_0 \quad (3).$$

Hence from the expression (3) it follows, that the sum of the currents flowing through the VT_2, remains constant i.e. with an increase of current through the left-hand triode, the current of the right-hand triode must decrease by the same magnitude. Thus, during a change of voltage, both triodes of the VT_2 are involved. This is equivalent to extending the linear portion of the amplitude characteristic 2 times, as compared to that of an amplifier using a single vacuum tube.

The moving coil microammeter M-24 having a sensitivity of 100 μA is connected in diagonal of the amplifier bridge. A system of shunts and multipliers consisting of resistors R_5 to R_{12} is used to set the meter pointer exactly to the extreme end of the scale.

The voltage divider of the resistors R_{15} to R_{21} and R_{22}, determines the grid bias of the amplifier vacuum tubes, ensuring normal operation in the region of low grid currents.

Balancing of the bridge (that is the zero adjustment of the microammeter) is accomplished by changing the grid bias of the right-hand triode of the vacuum tube VT_2, by turning the potentiometer R_{17} "Zero adjustment". The potentiometers R_{18} and R_{19} are used for zero adjustment on all three ranges of the voltmeter, when the potentiometer R_{17} is set in a middle position.

The Voltage Divider

The electrical circuit of the 1:10 voltage divider consists of a capacitive divider with a compensation on low frequencies.

The upper capacitor used in the voltage divider, is a semi-variable capacitor C_{12}, while the bottom capacitor C_{13} is fixed.

Frequency compensation is accomplished by two precision resistors (R_{23} and R_{24}), connected to the respective capacitors.

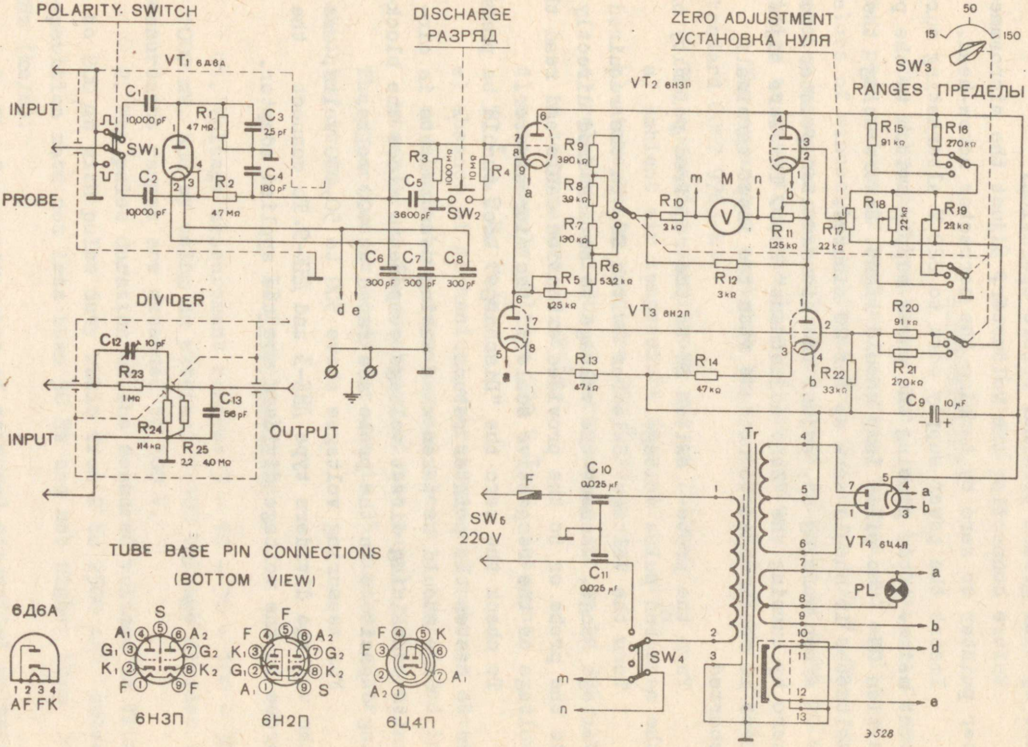


Fig. 7. Circuit Diagram of the B4-2 (ВЛИ-3).

V Operation Instructions

SAFETY PRECAUTION - the voltmeter must be grounded to the special ground terminal before operation.

Before connecting the voltmeter, adjust the microammeter pointer to zero by turning the corrector screw-head.

Insert the power supply cord to 220 V alternating current mains. After placing the power supply switch to the position ON the pilot lamp should light. Before using the voltmeter it should warm up for 20 minutes.

After warming up, adjust the microammeter pointer to zero by turning the "Zero adjustment" knob. The zero adjustment is recommended to be made with the input terminals shorted.

Turn the probe switch SW to the required polarity of the measured pulse voltage.

Turn the Voltage Selector Switch SW_3 to the required Voltage Range. Connect the voltage to be measured directly to the probe or to the provided extension cable and read the voltage on the respective scale of the microammeter.

To check the zero the "Discharge" knob should be pressed in to hasten the pointer return.

Care should be taken when making measurements in circuits containing direct voltage components since the blocking capacitors in the probe are rated at 400 volts.

For measuring voltages above 500 to 50,000 volts, use the voltage dividers type ДНЕ-3 and ДНЕ-9. To connect the probe to the voltage dividers use the applied adapter.

PULSE MILLIVOLTMETER

B4-3

D e s c r i p t i o n

I Application

The pulse millivoltmeter model B4-3 is designed to measure peak values of rectangular video pulses and amplitude values of sinusoidal voltages from 0.3 mV to 100 V. The apparatus measures peak values of pulse voltages of both polarities as read from the line of mean value.

The apparatus pertains to the group III of the State Standard GOST 9763-61.

The operation conditions are as follows:

a) ambient air temperature from -10 to +40°C;

b) atmospheric pressure 750 ± 30 mm Hg;

c) relative humidity of sorrounding air up to 90% with a temperature of +25°C;

d) mains supply voltage 220 V ±10%, frequency 50 ± 0.5 Hz (c/s).

e) absence of mechanical vibrations and intense steady or alternating magnetic and electric fields and instantaneous fluctuations of the supply voltage.

The apparatus is ready for use in 15 minutes after switching it on.

II Technical Data

1. Voltage measurement ranges: 3 - 10 - 30 - 100 - 300 - - 1000 mV, and by using an external 1:100 voltage divider the measurement ranges are extended to 100 V.

2. The pulse duration of the measured voltage is from 1 to 200 μs with pulse duty ratio from 2 to 2500 and pulse repetition rate not less than 50 Hz and not higher than 10 kHz (kc/s).

3. The frequency range of measured sinusoidal voltage from 30 Hz to 500 kHz.

4. Basic full-scale accuracy:

(a) ± 4% when measuring peak values of rectangular pulses having a duration from 1 to 200 μs and pulse duty ratio from 100 to 500;

b) ± 4% when measuring amplitudes of sinusoidal voltages over the frequency range from 50 Hz to 20 kHz;

± 6% over the frequency range from 40 Hz to 50 Hz and from 20 kHz to 50 kHz;

± 10% over the frequency range from 30 Hz to 50 Hz and from 50 kHz to 500 kHz.

Full-scale accuracy when using the external voltage divider:

(a) ± 6% when measuring peak values of rectangular pulses having a duration from 1 to 200 μs and pulse duty ratio from 100 to 500;

(b) ± 6% when measuring amplitudes of sinusoidal voltages over the frequency range from 50 Hz to 20 kHz;

± 10% over the frequency range from 40 Hz to 50 Hz and from 20 kHz to 50 kHz;

± 15% over the frequency range from 30 Hz to 40 Hz and from 50 kHz to 500 kHz.

5. Variations in the meter reading during measurement of rectangular pulses having pulse duty ratio from 100 to 2, do not exceed +7%; when measuring rectangular pulses having duty ratio from 500 to 2500, do not exceed -4%. By using the corrections in the curve given in this operations instructions manual, it is possible to measure pulse voltages having duty ratio up to 5000 with an additional error not exceeding ± 6%, while with the voltage divider the additional error is ±10%.

6. The variation of meter readings as caused by changes of the ambient air temperature from +20 ±5°C to any temperature over the temperature range of -10 to +40°C, does not exceed ±3% for each 10°C change of temperature.

7. Variation of meter reading as caused by changes of the mains supply voltage from 220 V by ±10%, does not exceed ±2%.

8. The input resistance of the probe as measured at frequencies of 1000 Hz and 500 kHz is not less than 1 MΩ, in-

put resistance of the external voltage divider at a frequency of 1000 Hz is not less than 1 MΩ - 10% and at a frequency of 500 kHz not less than 700 kΩ.

9. The input capacitance of the probe is not more than 11 pF, and that of the external voltage divider not more than 6 pF.

10. Mains power consumption not more than 100 VA.

11. Dimensions of apparatus 328x250x211 mm.

12. Weight not more than 9 kg.

III Accessories of the Apparatus

The full set of the apparatus is as follows:

Seq. No.	Item, type, spare parts	Quantity
1.	The millivoltmeter B4-3 with an installed set of vacuum tubes	1
2.	Spare parts kit	1
	a) Voltage divider 1:100	1
	b) Connecting cables	2
	c) "Alligator" clips	2
	d) Probe grounding clamp	1
	e) Contact plate for soldering the grounding cable	2
	f) Lugs for soldering the probe to the circuit being measured	4
	g) Holder for fastening the probe to the case	1
	h) Couplers for connecting the probe	3
	i) Plug for connecting the probe	1
	j) Socket for connecting the probe	1
	k) Fuses, type ПМ-0.5	2
	l) Pilot lamp, type MH-I4	1
3.	Acceptance certificate, description and operations instructions	1

IV Principle of Operation

The circuit of the apparatus (refer to Fig.1) consists of the following basic sections: the extension probe using a cathode follower, attenuator, three-stage wide-band video-pulse amplifier, peak-voltage detector and d.c. amplifier coupled to a microammeter, calibration voltage generator, power supply arrangement and the detachable voltage divider.

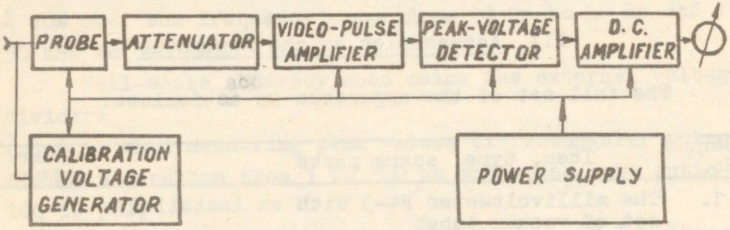


Fig. 8. Block Diagram of the B4-3.

The Probe

The circuit of the probe comprises a cathode follower having a voltage gain of approximately 0.85. A type 6Ж5П vacuum tube, connected as a triode, is used in the probe circuit. The voltage drop used as the grid bias voltage is taken across the resistor R_3 in the cathode circuit of the tube. A capacitor C_1, rated as a working voltage of 500 V, is employed in the input circuit of the probe to permit measurements of alternating voltages superimposed in direct current. The entire circuit of the probe is assembled in a cylindrical metal casing. It is coupled to the amplifier circuit through a shielded multiwire cable.

The Attenuator

A six-position stepped attenuator is used in the apparatus. The resistors are made of wire wound on mica slabs. The input resistance of the attenuator is 1200 Ω. The voltage divider is connected to the cathode of the VT_1 tube through the blocking capacitor C_2.

The Video-pulse Amplifier

The voltage from the attenuator is applied through the blocking capacitor C_3 to the grid of the first tube of the amplifier. Resistance-capacitance coupling is used in the amplifier. The necessary frequency response compensation at high frequencies is provided by a variable inductor "L" inserted into the anode circuit of the vacuum tube VT_3.

The amplifier consists of three stages using type 6Ж9П vacuum tubes. It has an overall voltage gain of approximately 5,800. Negative current feedback is utilized in the amplifier to ensure necessary gain stability. The negative feedback circuit involves all three amplifier stages (resistor R_{16} is used in the cathode circuit of the VT_2 and VT_4).The capacitor C_{13} is used to correct the amplifier transient response when measuring pulse voltages. The capacitor C_{14} is used to correct the frequency response of the amplifier.

The Peak-voltage Detector and Direct-current Amplifier

The amplified voltage is applied through C_{11}, R_{27} to the peak-voltage detector. The detector uses a type 6Х2П-Е dual diodes (VT_5). Both halves of the diode are connected in parallel. The diode load resistor R_{28} is connected in the cathode circuit. When measuring pulse voltage of the positive or negative polarity the voltage to be measured is applied to either the cathode or anode of the diode through the polarity-selector switch. The detector circuit is thus switched to a parallel or series circuit respectively.

The push-button switch SW_3 connects the resistor R_{29}, which decreases the detector circuit discharge time constant, to speed the meter pointer return to the zero marking after the measured voltage has been disconnected from the input.

The rectified voltage developed across the detector load resistor R_{28} passes through the filter R_{30} C_{15} to the grid of the d.c. amplifier vacuum tube VT_6. The filter $R_{30}C_{15}$ serves to exclude alternating voltage from reaching the grid of the tube VT_6 during a parallel connection of the detector circuit.

The d.c. amplifier uses a type 6Н2П double triode vacuum tube connected in a balanced circuit with the load connected in series with the cathode. A type M-94 microammeter having a current sensitivity of 100 μA is connected, between the load resistance (R_{31}, R_{32}, R_{37}, R_{38}) comprised of two arms.

Variable resistors R_{34} and R_{35} are provided for adjusting the apparatus sensitivity. The shaft of the potentiometer R_{34} is available on the front panel as a screw head for calibration of the apparatus.

The potentiometer R_{40} control knob inscribed "O ADJUST." is located on the front panel.

The Calibration Voltage Generator

The calibration voltage generator uses a RC - circuit coupled to a voltage limiter and voltage divider. The generator uses a type 6Н3П vacuum tube (VT_{2-1}). A frequency-dependent positive feedback voltage is applied to the grid of the 1-st half of the tube VT_{2-1} through the network R_{2-1}, C_{2-1}, R_{2-2}, C_{2-2}. Negative feedback voltage is supplied through the potentiometer R_{2-3} to develop an output voltage having a sine-wave form. The frequency of the generated voltage is about 1000 Hz.

From the output of the generator the voltage passes to a diode voltage limiter, consisting of two type Д808 diodes (D_{2-1} and D_{2-2}) connected back-to-back in series with opposite current-conducting polarities. The type Д2Е diodes (D_{2-3} and D_{2-4}) are used for temperature compensation.

The levelled voltage has an approximately square waveform. It is applied through the voltage divider R_{2-11}, R_{2-12} and R_{2-13} to the output terminal socket "S_1".

The amplitude of the output voltage is equal to 10 mV.

The Power Supply

The apparatus anode and heater circuit voltage are supplied through the power transformer Tr from an a.c. mains. The anode voltage rectifier uses type Д7-Ж diodes (D_{3-1} -

- D_{3-8}). It is stabilized by the type СГІІІ gaseous voltage stabilizer.

The heater voltage of the tubes VT_1 and VT_2 is supplied from a diode rectifier D_1 - D_4 to reduce the hum level. The heater voltage of the tubes VT_1, VT_2 and VT_4 is stabilized by the type СТ2С current stabilizer ballast tube.

The Detachable Voltage Divider

A detachable voltage divider having a voltage division ratio of 1:100 is connected to the probe input during voltage measurements from 1 V to 100 V. It consists of series connected resistors with a capacitive frequency response compensation circuit.

V Construction

The apparatus is assembled on a vertical metal panel and horizontal chassis, all enclosed in a metal cabinet. The chassis can be removed from the cabinet by using the two handles fastened to the front panel.

The layout of the front panel is as follows:

a) knob for switching the measurement ranges inscribed in millivolts to indicate each respective range:
b) grounding terminal post;
c) sensitivity control (provided as a screw-head);
d) polarity-selector switch knob;
e) zero adjustment knob "0 ADJUST.";
f) calibration generator output voltage socket;
g) microammeter;
h) pilot lamp under the trade mark;
i) discharge push-button switch "DISCHARGE";
j) mains switch "ON";
k) mains fuse holder;
l) probe support.

Operations Instructions

VI Procedure of Operations

Before switching the power supply on, the pointer of the microammeter must be adjusted to zero by means of the mechanical zero corrector.

After switching the power supply on, let the apparatus warm up for 15 minutes. After this, short circuit the probe input terminals, and by turning the knob "0 ADJ." adjust the pointer to the zero marking.

Should it be desirable to check the sensitivity, insert the probe into the calibration voltage socket. Turn the measurement range switch to the position inscribed "10 mV". Next, turn the polarity-selector switch to the position inscribed "⎍⎍" or " ∧∨ ". Observe to ascertain that the meter pointer reads 10 mV. The sensitivity can be adjusted by turning the screw-head control inscribed "10 mV CALIBRATION".

After doing this, the apparatus is ready for use.

During measurements of voltages across inductive loads, possible generation may occur at frequencies higher than the rated range. Besides, interfering voltage may be induced at the input; this is especially noticeable when measuring low voltages. Therefore, during measurements it will be necessary to check the absence of stray potentials. This can be done, leaving the measuring circuit unchanged, by switching off the source of the voltage to be measured (for example, switching off the anode voltage of a signal generator, etc.), after which, observe for the absence of interfering voltage.

During measurements in circuits carrying a d.c. component, it should be remembered that the input blocking capacitor is rated at 500 V.

N o t e s:

a) during measurement of voltages having a frequency similar to that of the mains supply, differences in the meter readings may be observed (up to ±2%) depending on the polarity of the mains cord plug connection. To obtain a

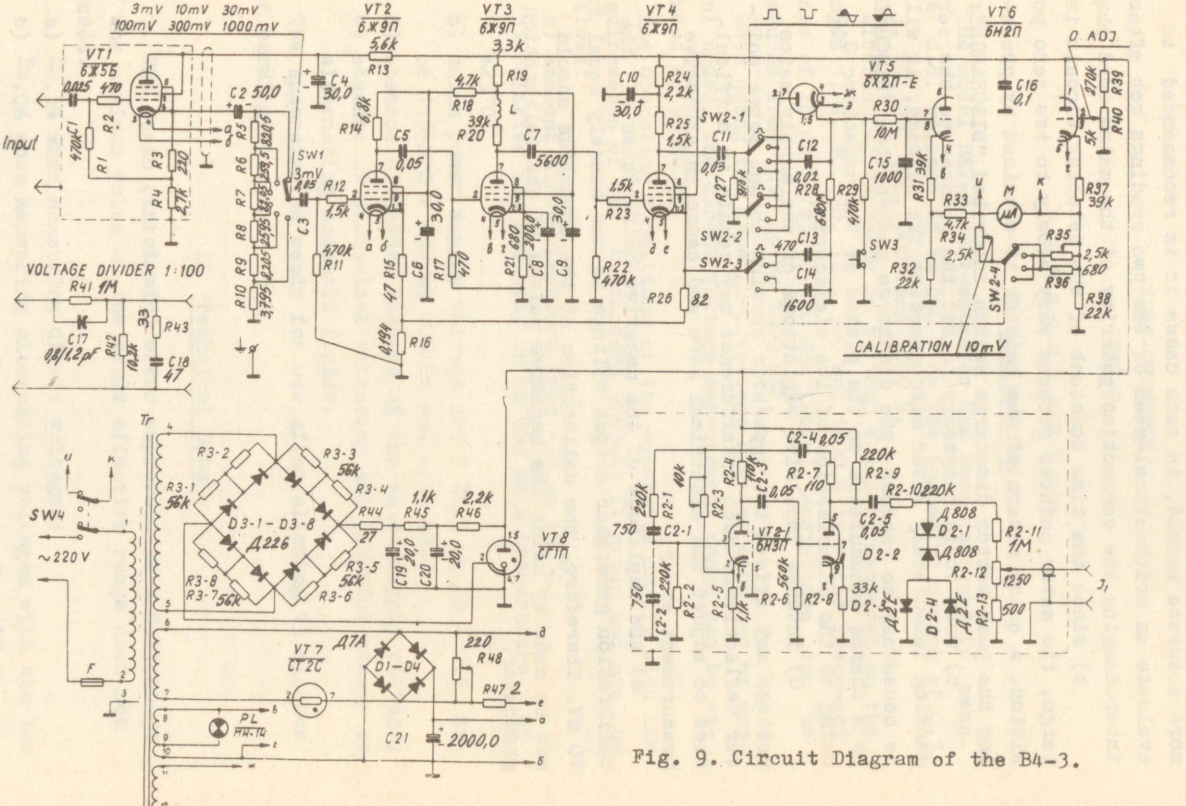


Fig. 9. Circuit Diagram of the B4-3.

more accurate result, in such cases it is recommended to evaluate an arithmetical mean of the two readings got after interchanging the connection polarity of the mains cord plug;

b) since the time constant of the detector circuit is large, the meter pointer returns very slowly to its zero position. A quick return of the pointer is obtained by pressing the push-button discharge switch inscribed "DISCHARGE";

c) when it is necessary to set the pointer to the zero marking immediately after disconnecting the voltage, it will be necessary to repress the discharge push-button "DISCHARGE" as a charge accumulates on the plates of the capacitor C_{12} owing to the polarization of its dielectric;

d) intense impulsive variations of the supply mains voltage may affect the apparatus causing abrupt meter pointer deflections. Such interference may result in difficulties to adjust the electrical zero and cause an excessive measurement error;

e) the amplitude of the negative half-cycles of the calibration generator output voltage is not exactly equal to 10 mV. Therefore, the calibration of the apparatus should not be made by using the negative pulses of the calibration generator.

VOLT-OHMMETER

BK7-9

Description

I Application

The model BK7-9 volt-ohmmeter has been designed to measure d.c. voltage up to 500 V on the following ranges of 0.3, 1, 3, 10, 30, 100, 300 and 1000 V.

Alternating voltages up to 1000 V can be measured on the ranges 1, 3, 10, 30, 100, 300 and 1000 V over the frequency range of 20 Hz (c/s) to 700 MHz (Mc/s). Resistance can be measured from 10Ω up to 1000 MΩ.

When using the type ДН-1 voltage divider supplied by special order, the direct voltage measurement range can be extended up to 20 kV.

The operating conditions of the apparatus comply with the requirements of the St.Standard 9763-61 IV group and are as follows:

a) ambient air temperature from -30 to +50°C;

b) relative air humidity up to 95% at a temperature of +25°C;

c) mains power supply voltage 220 V ±10% at 50 ± 0.5 Hz or 115/220 V ±3% at 400 Hz -3% .... +7%;

d) absence of sudden changes of the mains supply voltage;

e) absence of mechanical vibration and powerful steady or alternating magnetic fields.

The apparatus is ready for use after allowing 15 minutes for warming up.

II Technical Data

1. The basic (intrinsic) error expressed as a percentage of the maximum value of the scale effective range does not exceed:

a) ±2.5% when measuring direct voltages;

b) ±4.0% when measuring alternating voltages with the low frequency input over a frequency range from 20 Hz up to 1 MHz on the 1, 3, 10, 30, 100 V measurement ranges by using the frequency response corrections curve Fig. 10;

±6% when measuring at frequencies from 20 Hz up to 2 kHz on the 300 and 1000 V measurement ranges;

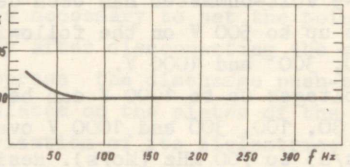


Fig. 10.

c) when measuring alternating voltages with the high frequency probe

±4% on a frequency range from 20 kHz up to 100 MHz;

±6% - at frequencies from 100 MHz up to 700 MHz by using the frequency response corrections curve Fig. 11;

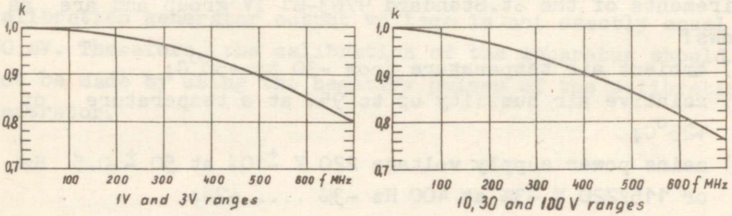


Fig. 11.

d) when measuring alternating voltages, by using the high-frequency probe and the type ДН-2 voltage divider,

±6% at frequencies from 20 kHz up to 300 MHz;

±10% at frequencies from 2 kHz up to 20 kHz by using the frequency response corrections curve Fig. 12;

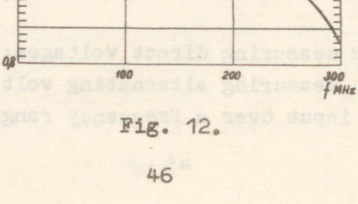


Fig. 12.

e) when measuring resistance expressed as a percentage of the length of the scale, ±2.5% on the measurement ranges,

x100Ω; x1kΩ; x10kΩ; x100kΩ; x1MΩ; x10MΩ;

±4.0% on the measurement range x100 MΩ.

2. Variations of the instrument indication, caused by changes of the ambient air temperature over the range from +20 ±5°C to -30°C and up to +50°C, do not exceed 1/2 of the basic measurement error of the apparatus for each 10°C change of temperature.

3. The input resistance is not less than:

15 MΩ when measuring direct voltages;

3 MΩ when measuring alternating voltages, at a frequency of 1000 Hz;

50 kΩ when measuring with the probe at a frequency of 100 MHz;

100 kΩ when measuring with the type ДН-2 voltage divider at a frequency of 100 MHz.

4. Input capacitance of the apparatus does not exceed: 20 pF when measuring with the low-frequency input; 1.8 pF when measuring with the high-frequency probe; 4.0 pF when measuring with the ДН-2 voltage divider.

5. Mains power consumption of the apparatus does not exceed 26 VA.

Dimensions 313x226x135 mm.

The dimensions of the case containing the type ДН-I voltage divider and type ТП-2 "T"-connector - 353x240x115mm.

Weight of the apparatus - not more than 6.0 kg.

III Accessories

Each apparatus is supplied with the following accessories:

No. Seq.	Item, type, spare parts	Quantity
1.	The type ДН-2, 1:10 voltage divider	1
2.	Type П-I high frequency probe	1
3.	The earthing ring of the high-frequency probe	1

No. Seq.	Item, type, spare parts	Quantity
4.	Connections cables with plugs	3
5.	Test probe for measuring in high-frequency circuits	1
6.	Multi-purpose test probes	2
7.	Spare fuses, type ПМ-0,5А	4
8.	Lugs	4
9.	Spare type МН-14 pilot lamp	1
10.	Acceptance certificate, description and operations instructions manual	1
11.	Spare type 6Д13Д diode	1

The type ДН-I voltage divider, designed to extend the direct voltage measurement range to 20 kV and the 75 Ω T-coupler with a built-in diode, can be supplied with the apparatus by a special order.

The detailed descriptions of the above items are supplied with these accessories.

IV Principle of Operations

The circuit of the apparatus consists of the following basic units:

a) the high-frequency probe;
b) the low-frequency diode rectifier;
c) the d.c. amplifier with the microammeter coupled to it.
d) the ohmmeter circuit;
e) the power supply unit;
f) type ДН-2 voltage divider used with the high-frequency probe.

The High-frequency Probe

The extension high-frequency probe is designed for measuring alternating voltages directly at the source of the measured voltage. A type 6Д12Д VT_1 high-frequency diode is used to rectify the measured voltage. The rectifier is assembled in a parallel circuit having an input blocking capacitor C_1.

The applied voltage charges the input blocking capacitor C_1 to an amplitude value of the measured voltage.

The discharge current holds the voltage at a constant value across the rectifier load resistor R_1 during the negative half cycles of the sinusoidal voltage. The miniature dimensions of the capacitor C_1 and the resistance R_1 provide a small input capacitance of the probe, thus decreasing the error due to the frequency response irregularities. The probe frequency response error is dependant on the frequency. The frequency response correction curves given in figures 2 and 3 should be used when performing measurements.

The Low-frequency Diode Rectifier

The low-frequency diode rectifier is designed for measuring alternating voltages over the frequency range of 20 Hz to 1 MHz. The input terminals of the rectifier are available on the front panel of the apparatus. The circuit of the low-frequency rectifier is similar to that of the high-frequency rectifier. The blocking capacitor C_6 has a large capacitance equal to 0.015 μF.

For measuring voltages exceeding 100 V (ranges 300 and 1000 V), the low-frequency rectifier is provided with a voltage divider consisting of the resistors R_3, R_4, R_5, R_6, R_7 and the rectifier input resistance R_i.

The frequency range on these measurement ranges is from 20 Hz to 2 kHz.

Capacitors C_3, C_4 and C_5 are used for correcting the frequency response irregularities.

When measuring alternating voltages, a compensation voltage of about 0.5 - 1.2 V is applied to the input of the amplifier to compensate the initial current of the diodes VT_1 and VT_2. This voltage is taken from the voltage divider R_{38}, R_{40}, connected to the output of the electronic stabilizer used to supply the heater voltage of the diodes and first vacuum tube of the amplifier. Potentiometer R_{39} is for adjusting the value of the compensation voltage within the limits needed to set electrical zero.

The D.C. Amplifier and Microammeter

The d.c. amplifier uses a balanced circuit, assembled around two double triodes VT_3 and VT_4. This circuit differs from conventional circuits in that that gaseous voltage stabilizer tubes VT_5 and VT_6 are connected in the cathode circuits of the second amplifier stages. Such an arrangement provides high stability of the amplifier operation without using special high tension stabilizers. The entire amplifier is involved in a negative feedback circuit, i.e., the total output voltage is applied to the input in series with the input voltage. Balancing of the bridge, that is, the setting of the electrical zero is accomplished by adjusting the potentiometer R_{49}, the knob of which is available on the front panel of the apparatus.

During measurements of direct voltages on the ranges 0.3, 1, 3, 10, 30 V, the measured voltage is applied to the first grid of the second triode of the vacuum tube VT_3.

The input voltage divider consisting of the resistors R_{10} to R_{14} provides an input resistance of 16.56 MΩ for all the direct voltage measurements ranges.

When measuring on the ranges 100, 300 and 1000 V, the applied voltage is attenuated 3.3, 10 or 33 times respectively, so that the maximum voltage applied to the grid of the vacuum tube VT_3 triode does not exceed 30 V. A type M1690 microammeter having a sensitivity of 100 μA for a full-scale deflection is used for the indication of the measured voltage.

The following resistive networks are used to set the scale end limits accurately on the respective ranges:

The shunt R_{58} and R_{60} connected to an arrangement of resistor multipliers R_{29} to R_{32} for the direct voltage measurement ranges, R_{22} to R_{28}, R_{33} and R_{34} for the alternating voltage ranges and R_{35}, R_{36} for the ohmmeter measurement ranges.

The Ohmmeter Circuit

The ohmmeter circuit of the model BK7-9 consists of a vacuum tube voltmeter, a set of precision resistors R_{15} to

R_{21} and a source of measurement voltage. The electronic stabilizer supplying heater voltage to the first tube of the amplifier and the diodes is used to supply the voltage of the ohmmeter measuring circuit.

The principle of resistance measurements is as follows:

The unknown resistor R_x to be measured is connected in series with the precision resistors R_{15} to R_{21}, to the source of measurement voltage. The value of the measured resistance is inversely proportional to the voltage across the precision resistor connected to the input of the d.c. amplifier.

The electrical zero of the ohmmeter is adjusted by turning the potentiometer R_{35} with the input terminals of the ohmmeter short-circuited.

The Power Supply

The power supply unit of the apparatus consists of a transformer Tr_1, a half-wave rectifier D_3 used for supplying the plate circuits of the d.c. amplifier and a transistorized voltage stabilizer. This stabilizer supplies the heater voltage to the first amplifier tube and diodes. Likewise, the stabilizer provides the measurement voltage for the ohmmeter circuit and voltage for compensating the initial current of the diodes.

The triode T_1 transistor is used as the regulating element of the stabilizer. The potentiometer R_{45} is to be used to adjust the operation voltage conditions of the stabilizer. The potentiometer R_{42} is used to adjust the stabilizer output voltage.

The High-frequency Probe Voltage Divider ДН-2

The voltage divider ДН-2 is designed as a separate unit which can be inserted on the probe. Both of the voltage divider arms are of a capacitive type.

The upper arm of the divider consists of a variable capacitor, the capacitance can be varied by turning a screw to change the width of the gap between its plates. One of the plates of the lower capacitor is connected with the body of the divider. The voltage divider is to be grounded during measurements.

Division ratio of the voltage divider is 1:10.

V Construction

The model BK7-9 volt-ohmmeter consists of two units. The first is comprised of the front panel rigidly fastened to the side walls, assembled of the circuit components and associated circuity.

The second unit is a hinged inverted L-shaped panel supporting a transformer and a printed circuit board. All of the tubes and miniature components used in the d.c. amplifier and electronic stabilizer are also mounted on this board.

The inverted L-shaped panel is fastened to the side walls with screws after the apparatus has been adjusted.

The keyboard type function switch and measurement range selector are mounted on the front panel of the first unit.

Most of the resistor multipliers used with the microammeter are fastened to the printed circuit mounted on the measurement range selector switch.

A block of the capacitors C_{10} and a plate mounted with the type МГП resistors are rigidly fastened to the lower end of the side wall at the bottom of the apparatus.

The following items are located on the front panel:

a) microammeter M;

b) knob of the range selector switch SW_1;

c) keyboard of the function switch SW_2 to SW_6;

d) input terminal posts IT_1 - IT_7;

e) ground terminal GT;

f) knobs of potentiometers used for setting the electrical zero during measurements of direct and alternating voltages;

g) slotted shaft end of the potentiometer used for setting the electrical zero during resistance measurements;

h) receptacle for connecting the high-frequency probe;

i) fuse holder;

j) mains supply on-off switch;

k) pilot lamp.

The apparatus has hinged leg supports, resting on rubber cushions, which can be placed in the position providing the most comfortable operation position.

Operation Instructions

VI Safety Measures

It is recommended that the measurements should be made only with a grounded apparatus. When using the ДН-I voltage divider, the safety grounding must be connected to three points of the measurement circuit:

a) to the frame of the voltage source being measured;

b) to the body or the safety ring of the voltage divider;

c) to the ground terminal ⏚ of the voltmeter BK7-9;

All rules of safety precautions must be adhered to when making measurements of voltage exceeding 1 kV with the ДН-I voltage divider.

The measurements must be made using rubber safety mats and gloves.

When using the type ДН-2 voltage divider for a.c. measurements, it is forbidden to connect the voltage divider to the probe or to disconnect it when a voltage has been applied to the voltage divider. Measurements of direct voltage across a grounded source must be made with the probe being disconnected.

VII Operation Peculiarities

Attention!

1. When using the apparatus it should be remembered that by pressing in all of the key switches at one time damage can be caused in the apparatus.

2. To avoid damage to the apparatus during measurements of alternating voltage when using the low-frequency input, when the apparatus and measured voltage source is grounded, it will be necessary to be certain that the ground terminal of the source of voltage is connected to the common ground terminal (the extreme right-hand terminal) of the voltmeter BK7-9, while measuring with the probe the casing is grounded.

3. Both direct voltage input terminals are insulated from the chassis of the apparatus. This permits measurements to be made of direct voltage between any points of the circuit under test, without disturbing normal circuit operation, provided the potential at the point of measurement does not exceed 500 V in respect to the chassis.

4. When measuring resistance a direct voltage up to six volts is applied to the measured resistance.

5. To check the mechanical zero of the indicator instrument during the process of measurements, it is not necessary to switch off the instrument. Just leave the key switches in the "OFF" position and proceed with the adjustment.

The apparatus can be operated in a horizontal position. However, the mechanical zero of the instrument should be checked and corrected when necessary.

6. The apparatus can be supplied from a 115 V voltage supply only if the frequency is 400 Hz.

VIII Operation Procedure

Before switching the apparatus to the supply mains, the ground should be connected to the terminal post ⏚.

Next, check the correctness of the fuse in the position corresponding to the mains power supply voltage. The fuse-holder must be set in the position where the value of the required power supply voltage is visible in the window of the holder. No other switching is required when changing to another supply voltage frequency.

Connect the mains supply cord to the mains socket and switch on the apparatus by setting the toggle switch to the position "ON". The switching is evidenced by the lighted pilot lamp.

After allowing 15 minutes for warming up, the range selector switch is to be set to the position "0.3 V", the key "U+" pressed in, and the pointer of the meter adjusted with the knob "ADJ.0" to the zero marking on the scale "≃V". After this, set the range selector switch to the position "1 V", press the key "U~" and set the pointer of the meter to the zero marking on the "~1 V" scale, by means of the knob "ADJ.0 ~1 V". Before setting the electrical zero, the terminal posts "±0.3 - 500 V" and "~1 - 100 V" should be short-circuited. After this the apparatus is ready for operation.

The test lead probes supplied with the apparatus should be used when measuring direct voltages. The special probe enclosing a series resistor is intended for measuring direct voltages superimposed in high-frequency circuits, for example, in inductive coil circuits. To decrease the effect of the hand on the circuit inductance, the probe should be held far away as possible from the probe test prong. The additional measurement error when using the test probes is approximately 2%.

Before performing direct voltage measurements by using the type ДН-I voltage divider, the ground wire from a switched off source of voltage being measured is to be connected to the wire connected to the safety ring of the voltage divider.

Measurements of the other voltage polarity can be made by applying the prong of the voltage divider directly at the point of measurement or by connecting the hook attachment of the divider (with the source of measured voltage being switched off before making the connections).

During measurements with the voltage divider, the grounding wire must be connected to the safety ring regardless of the grounding made to the voltmeter chassis.

The grounding wire must be reliable, since its failure may fatally endanger the operator's safety.

The supplied test lead probe described above can also be used during measurements of alternating voltages at low or audio frequencies. Measurements of voltage at high frequencies should be made with the high-frequency probe, which is rated for a maximum voltage of 100 V.

The nominal frequency range as rated in the technical specifications is valid only when high-frequency voltage is applied directly to the probe input. When changing over from measurements of direct voltage, resistance, or a.c. voltage with the low-frequency input to measurements with the H.F. probe, or during changes from measurements with the H.F. probe to the low-frequency input, it will be necessary to allow 1 minute, so that the respective diodes can warm up.

The frequency response of the apparatus at high frequencies is different for each measurement range.

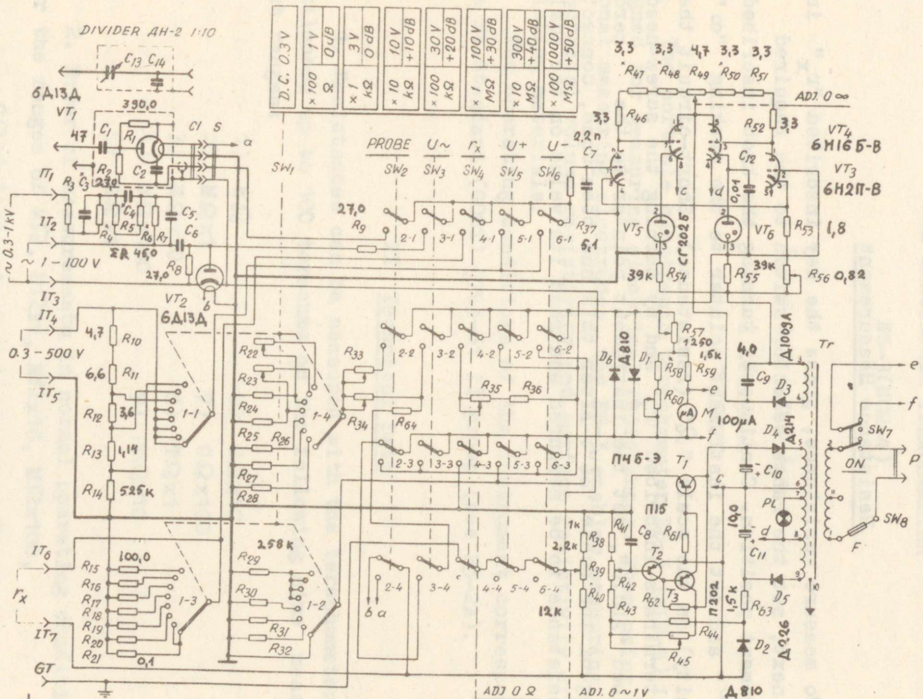
The frequency response curve in Fig. 11 gives the correction "k" to be used. The correction "k" should be multiplied by the measured value obtained at a corresponding frequency of the voltage being measured and the respective range and scale used.

The frequency response correction of the probe used with the voltage divider ДН-2 is shown in Fig. 12, while Fig. 10 gives the low frequency response correction of the apparatus used by applying the voltage to the low frequency input terminal.

Measuring with T-coupler

• By a special order, the model ВК7-9 can be supplied with T-coupler having a 75 Ω impedance and provided with a built-in diode. The T-coupler is connected to the apparatus by means of a connector. The T-coupler is inserted into the gap in a transmission channel by means of connectors. The SWVR of the T-coupler at frequencies up to 700 MHz does not exceed 1.3. Knowing the SWVR of a transmission line in which the T-coupler is used for measurements, the maximum error of measurements due to the SWVR can be evaluated by the formula:

$$E = (k-1) \cdot \sin \frac{2\pi l}{\lambda} \cdot 100\%$$



Remark: Resistors and capacitors marked with an asterisk* are selected at alignment.

Fig. 13. Circuit Diagram of the BK 7-9.

where k - the standing-wave voltage ratio (SWVR),

l - electrical length between the point of connection of the voltmeter and the point of connection of load,

λ - wave length on which the measurement is carried out.

Resistance Measurement

To measure resistance, press the key inscribed "r_x" inward, next, set the range selector switch to the required measurement position. Continue by turning the knob inscribed "ADJ.∞" and set the instrument pointer to the marking "∞" (infinity) on the scale "Ω" (resistance). Short-circuit the input terminals inscribed "r_x" and by turning the screw-head inscribed "ADJ.0", set the instrument pointer to the zero marking of the scale "Ω". After this has been done, connect the resistance to be measured and read its value on the scale.

THE ELECTRONIC TERAOHMMETER

E6-3(MOM-4)

D e s c r i p t i o n

I Purpose

The portable electronic teraohmmeter E6-3 (MOM-4) is designed for measuring electrical resistances. When using additional measuring electrodes, the E6-3 enables measuring of electrical volume resistivity and surface resistivity of insulating materials.

The operating conditions of the instrument correspond to the St.Standard (GOST) 9763-61 II group (see B3-2A).

II Technical Data

1. Resistances can be measured with the teraohmmeter from 2 kiloohms up to 100 teraohms on the following nine measurement ranges:

1) kΩ	6) GΩx10
2) MΩx1	7) GΩx100
3) MΩx10	8) TΩx1
4) MΩx100	9) TΩx10
5) GΩx1	

2. Error of measurements in normal operating conditions over the ranges of kΩ, MΩx1, MΩx10, MΩx100,

GΩx1 does not exceed	±1.5%,
on the range GΩx10	±2.5%,
on the range GΩx100	±10%,
on the range TΩx1	±10%,

and on the range TΩx10 ±20%

for a full-scale reading.

The accuracy is not guaranteed on the scale section of 2 kΩ to 10 kΩ (on the k range scale) and on the scale section of 10 TΩ to 100 TΩ (on the T x10 range scale).

3. Measuring voltage 105 V.

4. The teraohmmeter operates from the a.c. mains, voltage 220 V ±10%, frequency 50 ±0.5 c/s.

5. Power consumption 40 VA.

6. Dimensions 315x220x210 mm.

7. Weight 7 kg.

III Principle of Functioning

The resistor being measured is connected to a calibrated resistor of known resistance value, to form a voltage divider, which is linked to a source of stabilized voltage. In the voltage divider network this voltage is divided correspondingly and then applied to the input of an amplifier. The value of measured resistance is determined by direct reading on the scale of a pointer instrument connected to the output of this amplifier.

IV Circuit Description

The circuit of the teraohmmeter is composed of three basic parts:

a) the input voltage divider;

b) the direct-current amplifier;

c) the power supply.

The Input Voltage Divider

The input voltage divider of the teraohmmeter consists of the resistor being measured R_x, and the calibrated resistor R_c.

The teraohmmeter E6-3 has ten calibrated resistors R_1 to R_{10}, which may be switched over and correspond to the nine measurement ranges.

The input divider is connected to the input of a direct-current amplifier involving high values of negative-feedback (refer to Fig.14).

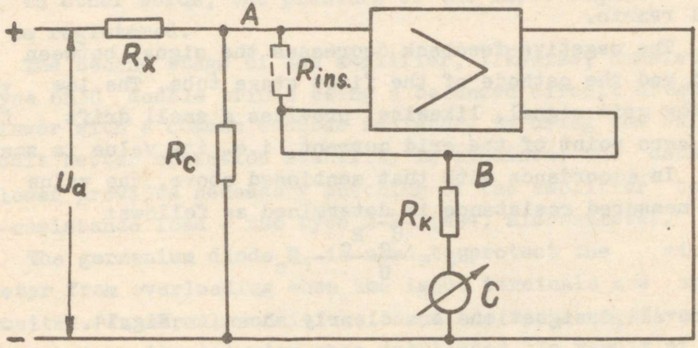


Fig. 14.

A considerable error is registered, when measuring resistance values of 10^{12} to 10^{14} ohms, which are comparable with those of the insulation resistance. To eliminate this influence, the insulation resistance is reduced to the unit value of R_{ins} by using circuit facilities.

This is achieved by mounting all components of the unit A on a plate, which is equipotential to the point B of the circuit (refer to Fig. 14).

High values of negative-feedback are applied in the entire amplifier. This is necessary owing to the following reasons:

a) it increases the stability of the zero reading;

b) it stabilizes the gain of the amplifier;

c) it compensates power losses due to the insulation;

d) it minimizes the influence of the grid current on the error of measurements.

The items a) and b) above are common for all amplifiers employing negative-feedback, and, therefore, need no further explanation.

As a result of the applied negative-feedback, the voltage on the insulation resistance, when measuring, decreases almost to zero. This is equivalent to the raising of the insulation resistance to infinity. In reality, however, certain minor effect of the residual insulation resistance R_{ins} will remain.

The negative-feedback decreases the signal between the grid and the cathode of the first stage tube. The low value of the grid signal, likewise, provides a small drift from the zero point of the grid current, i.e. its value is small.

In accordance with that mentioned above, the value of the measured resistance is determined as follows:

$$R_x = \frac{U_o R_c}{U_c} - R_c$$

where all designations are clearly shown in Fig.14.

The Direct-current Amplifier

The direct-current amplifier consists of two stages. The voltage to be measured is obtained from the input divider and is applied to the input of the first stage. The first stage (VT_1) uses a balanced circuit with resistive cathode coupling. The balanced circuit with resistive cathode coupling provides necessary stability of the amplifier's zero reading.

When measuring high resistance values, the current in the measuring circuit is of the order

$$I_{meas} = \frac{U_o}{R_x + R_c} \approx \frac{10^2}{10^{14}} = 10^{-12} \text{ A.}$$

From this it is evident, that the first stage must operate in a condition of low grid current values, so that the results of the measurements will not be distorted. The low grid current is ensured by selecting a type of vacuum tube

(6Н3П) having stable grid characteristics, and applying proper grid bias to reduce the grid current to zero.

The low grid-current conditions are selected by varying the anode supply voltage (by turning the potentiometer R_{12}).

If the operating conditions of the amplifier's first stage have been selected correctly, the drift of the balance will not be observed on switching over the measurement ranges, in other words, the presence of the input signal will not be registered.

The second stage of the amplifier, likewise, consists of a type 6Н3П double triode using a balanced circuit of cathode follower with a common cathode resistor. By using the balanced circuit better operation stability is obtained; the cathode follower provides necessary matching of the amplifier to the low-resistance load - the type M-24 (M94) microammeter.

The germanium diode D_1 is used to protect the microammeter from overloading when the input terminals are short-circuited. In normal conditions the diode has a negative bias which changes its polarity when overloaded. In result of this, the diode will shunt the microammeter.

The potentiometer R_{29} is used for rough, and potentiometer R_{15} for fine adjustment of the balance ("Установка ∞") (∞ Adjustment). The potentiometer R_{18} is used for rough, and potentiometer R_{21} for fine adjustment of the amplifier sensitivity ("Установка 0,I")(0.1 Adjustment).

The Power Supply

The power supply of the teraohmmeter consists of a transformer, filament current regulator, and two stabilized rectifiers.

The filament current for the type 6Н3П vacuum tube is stabilized by a type 0.85Б5.5-I2 barretter.

The stabilized rectifiers use the type Д7Ж germanium diodes operating in a half-wave rectifier circuit.

One of the rectifiers with type СГ4С gas-filled voltage regulator tube has voltage output 150 V, and is used as amplifier's anode voltage supply.

The other rectifier with type СГ3С gas-filled voltage regulator tube has voltage output 105 V, and is used as the voltage supply of the input voltage divider.

V Construction of the Instrument

The teraohmmeter E6-3 is assembled on a horizontal chassis and a vertical front panel, and is enclosed in a metal cabinet having a carrying handle.

The layout of the front panel of the instrument is as follows:

1. Terminals for connecting the measured resistor R_x.
2. Terminals for connection to the compensation voltage and chassis of the instrument.
3. Measurement range switch.
4. Microammeter.
5. "∞" adjustment potentiometer.
6. "0,1" adjustment potentiometer.
7. Fuse with a fuse holder.
8. Power supply receptacle.
9. Power supply switch.
10. Pilot lamp.

The layout on the horizontal chassis is as follows. Two type 6Н3П vacuum tubes; one type СГ3С and one type СГ4С gas-filled voltage regulator tubes; one type 0.85Б5.5-12 barretter; power transformer; electrolytic capacitors and other necessary components.

N o t e: The potentiometer R_{29} is placed so that it can be adjusted through the hole at the bottom of the instruments cabinet.

VI Operation Instructions

Check the zero reading of the microammeter; if necessary, adjust the zero position of the pointer by turning the corrector screw-head.

Switch the measurement range switch to the position "kΩ - КАЛ" (kΩ-CAL). After switching on and 30-minutes warm-up period, the instrument can be used for measurements.

Leaving the measurement range switch in the "kΩ- КАЛ" position turn the "Установка" (Adjustment) knob for placing the meter pointer to the sign "∞+" on the scale. After this, short-circuit the R_x terminal screws and turn the "Установка 0,1" (0.1 Adjustment) knob for placing the meter pointer to the mark "0,1".

The right-hand position of the "kΩ- КАЛ" is used for calibration, i.e. adjustment of "0,1", only on the TΩx1 and T x10 ranges. The left-hand position of "kΩ- КАЛ" is used for calibrating the remaining ranges and for measuring low-resistance resistors by using the "kΩ" scale.

Turn the measurement range switch to the required position, check the position of the meter pointer, and if necessary, re-adjust the setting of the pointer to the sign "∞". After this, the instrument is ready for measurements.

When measuring, it is necessary to take into consideration that the circuit of the instrument permits grounding one of terminal screws, the "K" or the "Э" but not simultaneously both, as the voltage of 105 V exists between them.

The terminals "Л" and "Э" are at a potential of 105 V in respect of the terminal "K".

<u>In course of operation it may be found that more extensive adjustment of the potentiometer "Установка ∞" is necessary.</u>

When measuring volume resistance, the measuring ring-electrodes are connected to the instrument, as shown in Fig.15a.

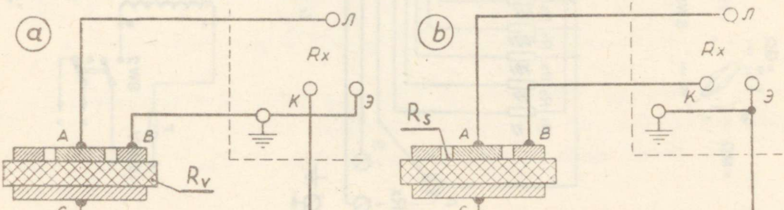


Fig. 15.

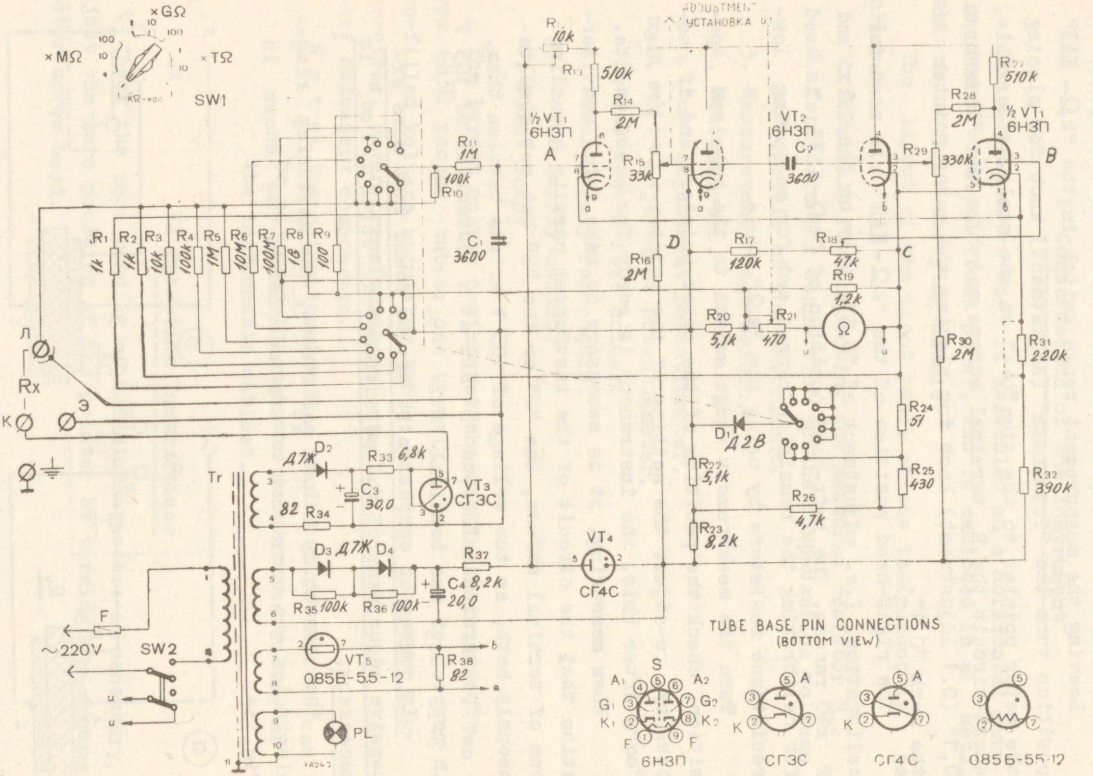


Fig. 16. Circuit Diagram of the E6-3.

The volume resistivity ρ_v can be computed from the volume resistance R_v

$$\rho_v = R_v \frac{S_A}{b} \ \Omega \ \text{cm},$$

where S_A - surface contact area of the electrode A, cm^2,

b - thickness of the measured specimen, cm.

By using the measuring ring-electrodes, the surface resistance can be measured as well. In this case the electrodes are to be connected as shown in Fig. 15b.

The surface resistivity

$$\rho_s = R_s \frac{2.74}{\log_{10}\frac{d_2}{d_1}} \ \Omega,$$

where R_s - surface resistance, Ω,

d_1 - diameter of electrode A,

d_2 - internal diameter of electrode B.

THE ELECTRONIC TERAOHMMETER

EK6-7

D e s c r i p t i o n

I Application

The model EK6-7 electronic teraohmmeter has been designed for measuring extremely high resistance over a range from 10^7 up to $10^{17}\Omega$. It can be also used to measure direct current from 10^{-14} to 10^{-7}A and direct voltage from 10 mV to 10 V with an input resistance up to $10^{12}\Omega$.

The operation conditions of the model EK6-7 apparatus comply with the requirements of the St. Standard 9763-61 II group (see B3-2A).

II Technical Specifications

1. Resistance measurement error expressed as a percentage of the scale effective range length:

$\pm$4% up to $10^{12}\Omega$;

$\pm$6% from 10^{12} to $10^{15}\Omega$;

$\pm$10% from 10^{15} to $10^{17}\Omega$.

2. Direct current measurement error expressed as a percentage of a maximum pointer deflection of the scale effective range:

$\pm$4% from 10^{-7} to 10^{-10} A;

$\pm$6% from 10^{-10} to 10^{-14} A.

3. Voltage measurement error is 2.5% of a maximum pointer deflection of the scale effective range.

4. Power consumption not more than 60 VA.

5. Overall dimensions of the apparatus 324x250x212 mm. Overall dimensions of test chamber 390x300x235 mm.

6. Weight of the apparatus with the test chamber less than 15 kg.

III The Order Complement

The full set of the apparatus includes the model EK6-7 with a set of vacuum tubes installed and the test chamber, designed as a case to fit the apparatus.

IV Principle of Operations

The measurement of the resistance is made by using the comparison method. The unknown resistance is compared to a standard, while the latter is connected in a circuit involving a 100% negative feedback (refer to Fig.17).

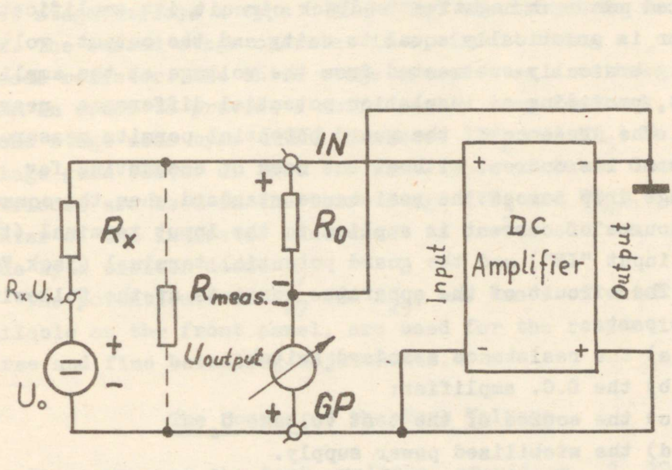


Fig. 17.

The measured resistance is determined from the correlation

$$R_x = \frac{U_o \cdot R_o}{U_{output}},$$

where U_o - is the test voltage. The apparatus provides test voltages of 1, 10, 100 and 1000 volts.

R_o - is the built-in resistance standard. The apparatus is provided with the following standards of 10^8, 10^9, 10^{10}, 10^{11} and 10^{12} Ω.

U_{output} - is the amplifier output voltage. The apparatus employs an amplifier having an output voltage of 0.1, 0.3, 1, 3 and 10 volts.

The guard ring potential arrangement used in the apparatus reduces the effects of parasitic leakage currents on the measurement error during measurements of resistance as high as 10^{17} Ω.

The guard potential is taken from the output of the amplifier. Since the amplifier is involved in a deep one hundred per cent negative feedback circuit, its amplification factor is practically equal to unity and the output voltage is algebraically subtracted from the voltage at the amplifier input, providing an insulation potential difference nearly zero. The presence of the guard potential permits measurements of low current without the need of accounting for the voltage drop across the resistance standard when the connected source of current is applied to the input terminal (the jack input "IN") and the guard potential terminal (jack "GP").

The circuit of the apparatus consists of the following basic parts:

a) the resistance standard switch;

b) the D.C. amplifier;

c) the source of the test voltage U_o;

d) the stabilized power supply.

The Resistance Standard Switch

This switch is designed with special attention to the parasitic leakage currents by extensive use of the potentially guarded plate supports and highest quality insulation. Each resistance standard consists of three type KBM resistors. The point of connection where each of the resistors is mounted are under the respective guard potentials taken from the guard potential divider. The electrometric vacuum tube enclosed in a shield is mounted in a special compartment.

The D.C. Amplifier

The D.C. amplifier has three stages of amplification wired to operate in a balanced circuit. Since during the measurements of extremely high resistance, the value of the current flowing in the circuit is of the order 10^{-14} A, the first stage employs a type ЭМ-6 (VT_1) electrometric vacuum tube. The second stage operates in a circuit using a common cathode resistor. The third stage operates as a cathode follower. In order to provide a sufficiently deep feedback, the second stage uses type I2ЖIЛ pentodes (VT_2 and VT_5) to obtain a stage gain factor of 200. The same types of tubes connected as triodes are used in the third stage (VT_3 and VT_4). The pointer of the indicator instrument is protected from overloads by a silicon diode D_7.

The potentiometers R_{27} and R_{29}, the knobs of which are available on the front panel, are used for the respective coarse and fine balancing adjustments.

The Source of the Test Voltage

The source of the test voltage providing 1, 10 and 100 volts is supplied by a rectifier assembled as a voltage doubler circuit using the diodes D_{18} and D_{19} and stabilized by a type СГ5Б voltage stabilizer tube (VT_{11}). The RC filter comprised of $R_{48}C_7$, $R_{47}C_6$, $R_{46}C_5$ and $R_{45}C_4$ smoothes the superimposed pulsating component (ripple) in the rectified voltage.

The source supplying the 1000 V test voltage consists of a rectifier assembled around the diodes D_{11} - D_{17} using a voltage multiplier circuit. The voltage is stabilized by a type СГ302С voltage stabilizer tube VT_{10}. The ripple is filtered with the RC filter consisting of $R_{44}C_3$, $R_{43}C_2$.

The accuracy of the voltage calibration is adjusted by the variable resistors R_{62} and R_{65}.

The Stabilized Power Supply

The vacuum tubes are supplied from an electronic voltage stabilizer, assembled as a cascade circuit around the type 6Н2П (VT_8), 6НІ4П (VT_7) and 6СІ9П (VT_9) vacuum tubes. The reference voltage is secured by the type СГ202Б voltage stabilizer tube (VT_6). The source of the stabilized voltage has a stability factor of 4000 and provides an output of 150 V with a load current of 75 mA. The ripple at the output of the stabilizer is no more than 2 mV.

V CONSTRUCTION

The apparatus is assembled on a horizontal chassis and vertical front panel. The power supply pack is designed as a separate unit. The chassis, mounted with the amplifier circuity is isolated from the front panel, cabinet and power pack of the apparatus.

The apparatus is supplied with a test chamber to shield the measured object from effects of stray interference during measurements.

The test chamber is used as a packing case of the apparatus during transportation.

VI Operating Instructions

Preliminary Operations and Resistance Measurement

If measurements are to be made of resistance higher than $10^{10}\ \Omega$,or,current is to be measured, which is less than 10^{-10} A, the object to be measured is to be placed in the test chamber, supplied with the apparatus. Before beginning the measurements, the test chamber is placed directly to the side of the apparatus mounted with the input terminals and it is to be fastened to the cabinet with screws.

Connect the ground terminals inscribed "⏚", of the test chamber and apparatus with the supplied connections wire, which is then grounded. Inside the test chamber connect the terminal "⏚" and the terminal jack "⊥", "GP" or terminal jack inscribed "R_xU_x", in accordance to the connections diagrams (refer to Figs. 18 and 19).

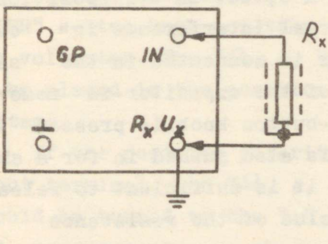


Fig. 18. Measuring resistance by using a shield connected to the end of the resistance.

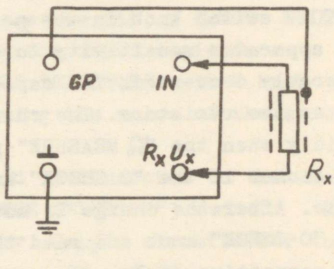


Fig. 19. Measuring resistance by using an isolated shield.

Next, check the zero position of the instrument pointer, if necessary adjust the mechanical zero corrector.

Continue by placing the knob inscribed "Ω, A RANGE MULTIPLIER" to the position 10^8; the switch knob inscribed "Ω RANGE MULTIPLIER" to the position 1; finally, the switch knob inscribed "Ω, A, V RANGE SELECTOR" is to be placed in the position 0,1 Ω.

Further, connect the apparatus power supply cord to the mains. After this, switch on the apparatus and allow it to warm up for a period of 2 hours. To measure by using the first positions 10^8 and 10^9 of the "Ω, A RANGE MULTIPLIER", it is sufficient to allow the apparatus to warm up for a period of 30 minutes.

For the measurements of volume or surface resistance the measuring electrodes are to be connected to the apparatus as shown in Fig.15.

Measuring Resistance of Capacitor Having a Leakage

The resistance of a capacitor having a leakage is recommended to be measured only with the "Ω, V, A RANGE SELECTOR" switch knob in the position 0,1 Ω. In this position the apparatus sensitivity to external interference is considerably decreased. The capacitor is connected in the same way as the resistors. The charge of the capacitor is removed rapidly when the "Ω MEASURE" push-button knob is pressed in, and sooner if the "0 CHECK" knob is also pushed in for a short while. After the charge is moved, it is sufficient to release the "0 CHECK" knob and read the value of the resistance on the respective scale.

During measurements of objects possessing capacitive reactance, for instance during measurements of resistance of some types of leaking capacitors using a dielectric of polystyrene or fluoro-plastics, having an insulation resistance of 10^{13} - 10^{16} Ω, it may be difficult to obtain a stable reading. This is because they are actively subjected to the effects of external and internal interference, while the capacitor doesn't offer any significant resistance to alternating current.

In such cases, it is necessary to connect the measured object to the common input terminal through the series resistor attachment equalling $10^{11}\,\Omega$, supplied with the apparatus. The connections are made as shown in Fig. 20.

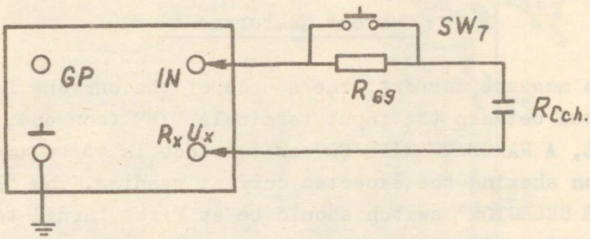


Fig. 20.

Voltage Measurements

During measurements of voltage the "Ω, A RANGE MULTIPLIER" switch knob position shows the input resistance of the voltmeter. The "Ω, A, V RANGE SELECTOR" switch knob is to be placed in the position showing the value of the assumed voltage.

If the positive polarity lead is connected to the common input terminal, the "Ω, A, V RANGE SELECTOR" switch knob should be turned to the "+" sector. Sample circuits for voltage measurements are shown in Figs. 21 and 22.

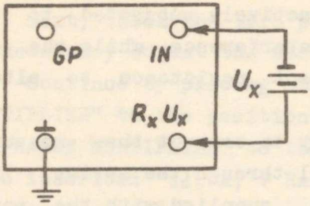


Fig. 21. Measuring voltage across an insulated source.

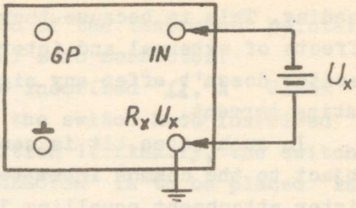


Fig. 22. Measuring voltage across a grounded source.

Current Measurements

To measure current, the source of the current is to be connected between the input terminals "IN" (common), and "GP". The "Ω, A RANGE MULTIPLIER" switch knob is to be turned to the position showing the expected current reading. The "Ω, A, V RANGE SELECTOR" switch should be at first turned to the position +10 A. If the polarity changes during the measurements, the indication polarity can be reversed by turning the "Ω, A, V RANGE SELECTOR" switch knob, without the need of interconnecting the connections wires. The voltage drop, during the current measurements does not exceed the following values when using the respective scale ranges:

10 A – 75 mV; 3 A – 25 mV: 1 A – 10 mV;
0.3 A – 3 mV: 0.1 A – 2 mV:

Since the amplifier is coupled with an approximate 100% negative feedback circuit, current can be only measured in a high resistance circuit. For example, when using the range 10^{-8} A position on the "Ω, A RANGE MULTIPLIER" switch, the resistance of the measured circuit must be of the order of $10^7 \Omega$; on the 10^{-9} A range the resistance is of the order $10^8 \Omega$ etc.

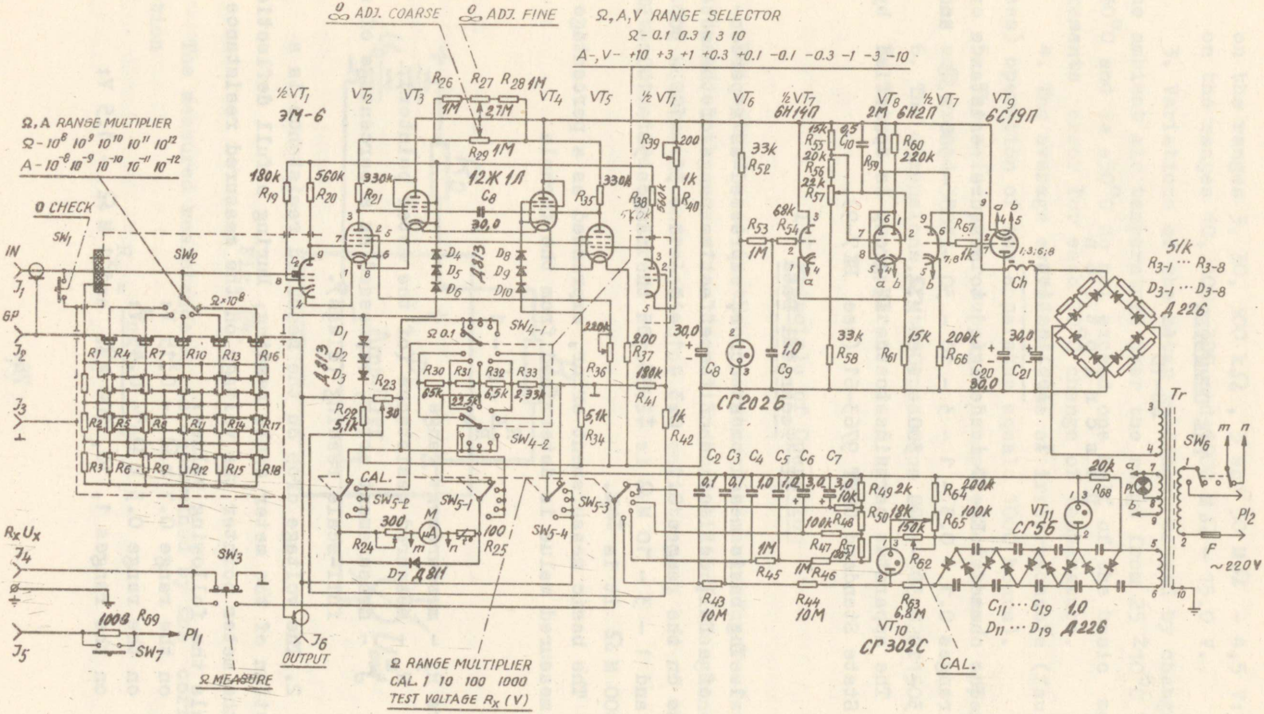


Fig.23. Circuit Diagram of the EK 6-7.

THE OHMMETER

E6-10

D e s c r i p t i o n

I Application

The ohmmeter E6-10 is designed to measure resistance on the ranges 0.1 - 0.3 - 1 - 3 - 10 - 30 - 100 - 300 kΩ and 1 - 3 - 10 - 30 - 100 - 300 - 1000 MΩ.

The apparatus pertains to the IV group as specified by the State Standard GOST 9763-61 (see BK7-9).

II Technical Data

1. The basic measurement error, expressed as a percentage of a full deflection of the effective range of the meter scale on the ranges 0.1 - 0.3 - 1 - 3 - 10 - 30 - 100 - 300 kΩ and 1 - 3 - 10 MΩ is $\pm$2.5%. On the ranges 30 - 100 - 300- - 1000 MΩ it is $\pm$4%.

The basic measurement error, expressed as a percentage of the measured value is determined from the formula

$$\frac{R_r}{R_m} + \delta - 1$$

where R_r - measurement range,

R_m - measured resistance (of the meter pointer),

δ - measurement error, expressed as a percentage of a full-scale reading (class).

2. The voltage drop on the measured resistance is a function of the meter scale reading. During a full deflection of the meter pointer the voltage on the measured resistance equals the following values:

on the range 0.1 kΩ - 0.15 V:

on the range 0.3 kΩ - 0.45 V:

on the ranges 1, 10, 100 kΩ and 1 MΩ - 1.5 V:

on the ranges 3, 30, 300 kΩ , 3 and 30 MΩ - 4,5 V:

on the ranges 10, 100, 300 and 1000 MΩ - 15.0 V.

3. Variations of the meter readings, caused by changes of the ambient air temperature over the range from 25 ±10°C to -30°C and to +50°C do not exceed one half of the basic measurements error for each 10°C change of temperature.

4. The average evaluated time of irreproachable (faultless) operation of the apparatus equals 1000 hours).

5. The mains power supply consumption of the apparatus does not exceed 30 VA.

6. The dimensions of the apparatus are: 313x228x150.

7. Weight of the apparatus is 6 kg.

III Principle of Operation

The method used in the apparatus for measuring resistance is based on the use of an operational amplifier, the gain of which equals the correlation of two resistances, one of which is the standard (refer to Fig. 24).

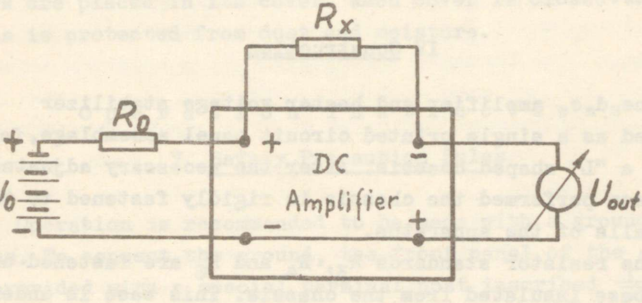


Fig. 24.

The measured resistance R_x is determined by the correlation

$$R_x = \frac{U_{out} \cdot R_o}{U_o}$$

where U_{out} - amplifier output voltage,

R_o - standard resistance,

U_o - measurement supply voltage.

Since R_o/U_o is a constant value, the measured resistance is directly proportional to the value of the output voltage and is registered on a linear scale of a meter calibrated in units of resistance.

The operational amplifier consists of a two-stage balanced d.c. amplifier, assembled around a type 6Н2П-В vacuum tube VT_1 and type 6Н16Б-В vacuum tube VT_2 with a type СГ5В-В voltage stabilizers VT_3 and VT_4 connected in the cathode circuits of the vacuum tube VT_2.

The source of measurement voltage is supplied by the voltage stabilizer VT_4, which is also used as a component of the circuit of the d.c. amplifier.

The heater voltage of the first d.c. amplifier vacuum tube is stabilized by an electronic stabilizer. The apparatus is provided with built-in resistance standards R_1 (1 kΩ) and R_2 (1 MΩ) used for calibration.

The apparatus is a portable model for use by a single operator.

IV Construction

The d.c. amplifier and heater voltage stabilizer are designed as a single printed circuit panel assemblage, fastened to a "L" shaped chassis. After the necessary adjustments have been performed the chassis is rigidly fastened to the side walls of the apparatus.

The resistor standards R_3, R_4 and R_6 are fastened on a metal base insulated from the chassis. This base is under a protective potential.

The protective potential is available under the terminal post inscribed "P" located on the front panel of the apparatus.

The following parts are located on the front panel of the apparatus:

a) microammeter;

b) range switch knob B_1;

c) key push buttons B_2, B_3, B_4 for performing measurements and calibration, inscribed respectively "MEASUREMENT" and "CALIBRATION";

d) input terminals K_1 and K_2 inscribed "r_x";

e) protective potential terminal post K_3 inscribed "P";

f) ground terminal K_4 inscribed "⏚".

g) knobs of potentiometers R_{29} and R_{23} for setting the electrical zero and apparatus calibration inscribed "O SET" and "CALIBRATION";

h) fuse holder and power mains selector B_6;

i) mains switch B_5, inscribed "ON";

j) pilot lamp PL.

The apparatus is provided with special built-in leg supports, fitted with rubber shock absorbers, which can be turned to a position enabling the placing of the apparatus at an angle, thus providing the most comfortable position during operation.

All accessories and spare parts supplied with the apparatus are placed in its cover. When cover is closed the apparatus is protected from dust and moisture.

Operation Instructions

V Safety Precaution Rules

Operation is recommended to be made with a grounded apparatus. To connect the ground, the front panel of the apparatus is provided with a special terminal post inscribed ⏚.

It is not recommended to remove the apparatus from the cabinet when it is connected to the mains supply. Should it be necessary to do during adjustments of the internal control components (for example during replacement of vacuum tubes), utmost care must be observed such as avoiding touching the transformer taps located at the top of the apparatus, or the terminals of the capacitor C_3 on the left hand side wall of the apparatus. Similarly, avoid touching the leads of the potentiometers R_{29} "O SET", located from the right-hand side wall, likewise, the printed circuit panel wiring on the movable wall of the chassis.

The apparatus must be switched off, when short-circuiting or removing the resistors R_{28} or R_{30}, and while replacing components.

VI Preparation for Operation

Check the correctness of the fuse position, so that it corresponds to the mains supply voltage. The fuse must be placed in such a position that the window of the fuse holder shows the number of the corresponding mains voltage. No other switching is required when changing to another mains supply frequency. Supplying the apparatus from a 115 V mains power supply is permitted only from a source having a frequency of 400 Hz.

In order to measure the resistance of individual components, which are not a part of some assemblage, it is recommended to insert the contacting device supplied with the apparatus in the terminal inscribed "r_x", to hold the measured component. Its use enables faster operation. To measure resistance of components connected to an assemblage, apparatus etc., it is recommended to use the probe test leads supplied with the apparatus.

Insert the mains cord plug into the mains supply outlet receptacle and lift the mains toggle switch to the position "ON", thus switching the apparatus on. Its connection is shown by the pilot light under the trade mark.

VII Operation Procedure

The warming-up time of the apparatus is 15 minutes. The electrical zero of the apparatus is set by adjusting the knob inscribed "O SET", before each measurement and recalibration.

If measurements of resistance up to 300 kΩ are foreseen, turn the range switch to the position "1 kΩ", press the key push button "1 kΩ" and calibrate the apparatus by placing the meter pointer to the scale end position marking by turning the knob inscribed "CALIBRATION".

Should resistance measurements of values higher than 300 kΩ be foreseen, the calibration of the apparatus is made by placing the switch to the position inscribed "1 MΩ" and pressing in the key push button inscribed "1 MΩ".

After the apparatus calibration has been made, return the range switch to the position corresponding to the presumable value of the resistance to be measured, adjust the electrical zero. Next, connect the measured resistance to the terminal posts inscribed "r_x", after which press one of the key push button switches "MEASUREMENT" and observe the value of the resistance on the meter scale.

The left-hand key push button "MEASUREMENT" with the symbol "∇" is provided with a position fixer. Its use is recommended if adjustments of the measured resistance are required or during prolonged observations of the value of the measured resistance. The other key switch "MEASUREMENT" provided with the symbol "□" has no position fixer. It is recommended to be used during frequent changes of the measured resistance, to avoid deflecting the meter pointer over the scale extreme end position when pressing the key switch "MEASUREMENT" without inserting a resistance to the terminal posts "r_x".

During measurements of high values of resistance, the provided insulated shield is recommended to be used by connecting it to the terminal post inscribed "P".

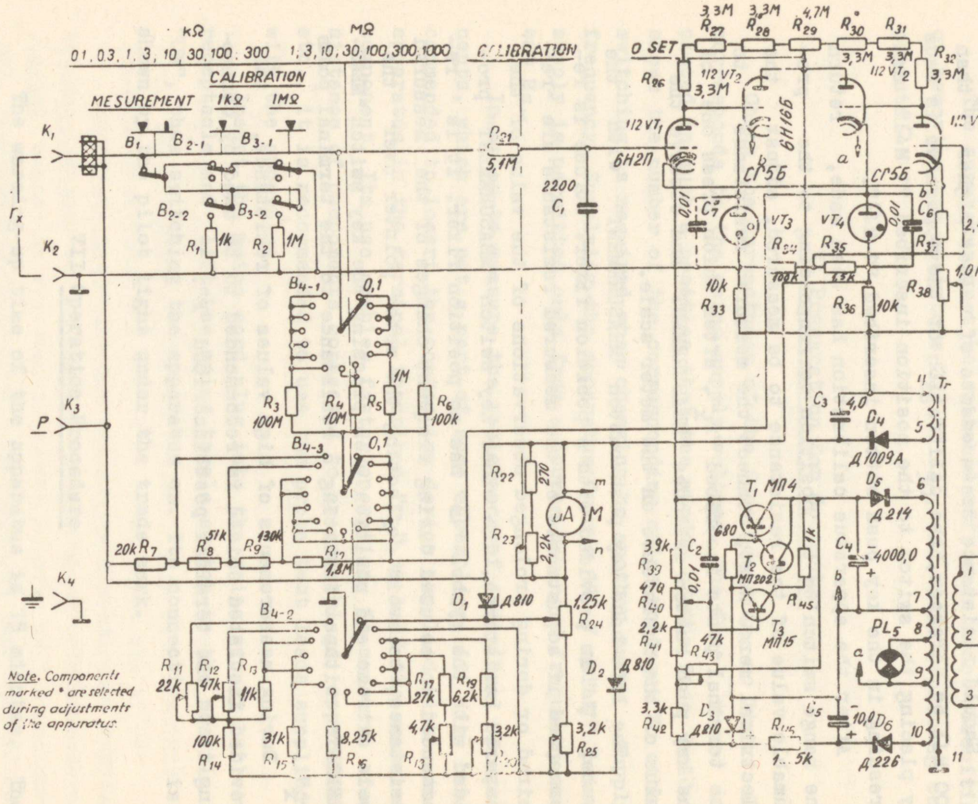


Fig. 25. Circuit Diagram of the E6-10.

THE VERSATILE ELECTRONICALLY

STABILIZED POWER SUPPLY УИП-I

I Introduction

The versatile electronically stabilized power supply type УИП-I has been designed to serve as a source of regulated direct current voltages from 20 to 600 volts, for current loads up to 600 milliamperes and as an independent source of 0 to 400 volts for current loads up to 5 milliamperes. Eight unstabilized alternating voltages of 2 to 25 volts are available.

The УИП-I is an ideal power supply for applications requiring high stability and accurate voltage adjustment in electron tube and transistor circuity, as well as for numerous other purposes where an easily available power source can find application providing the rated technical specifications fulfil the requirements.

II Performance Specifications

1. The power supply type УИП-I operates from a 220 V 50 c/s line.
2. Power consumption: 1500 VA.
3. The power supply type УИП-I provides:
   a) highly stabilized direct voltage within the range of 20 to 600 V for current loads up to 600 mA;
   b) highly stabilized direct voltage within the range of 0 to 400 V for current loads up to 5 mA:
   c) alternating voltages (unstabilized) of 2.15: 2.5: 4 and 5 V for current loads up to 4 A.
   12.6 and 24 V for current loads up to 2.5 A.
   6.3 V for current loads up to 25 A and
   6.3 V for current loads up to 10 A.

4. With a supply line voltage variations of -15 to +5% the stabilized output voltage of 100 to 600 V with a current load of 600 mA and of 0 to 400 V with a current load of 5 mA does not vary more than ±0,5%.

5. With a load current varying from 0 to 600 mA and 0 to 5 mA, keeping the supply line voltage constant, the fluctuation of the stabilized output voltage ranges of 100 to 600 and 0 to 400 V respectively is less than ±0,5%.

6. The alternating current component (ripple) of the output voltage in the ranges of 100 to 600 V and 0 to 400 V respectively with a maximum current load is less than 0,1%, while in the voltage range of 20 to 150 V it is less than 100 mV.

7. The alternating voltages remain within +10% of the nominal with an unloaded output and at ±5% when totally loaded.

8. The Power Supply holds its rated specifications within an ambient temperature range of -10 to +35°C and with a relative humidity of 95%.

9. Dimensions: 480x380x280 mm.

10. Weight: approximately 45 kg.

N o t e: Should the Power Supply type УИП-I be operated in conditions other than specified in this manual, the manufacturer cannot guarantee satisfactory results.

III Circuit Description

The Power Supply type УИП-I consists of three electronically stabilized rectifiers.

The first stabilizer provides d.c. voltages within the range of 20 to 600 V for current loads up to 600 mA. The second provides the d.c. voltages within the range of 0 to 400 V for current loads up to 5 mA, while the third supplies the negative potential to the cathode of the amplifier tube of the first stabilizer.

The stabilizers providing 20-600 V and 0-400 V are without any direct electrical connection between each other.

The stabilizer of the 20-600 V range is supplied by a full-ware rectifier consisting of a bridge circuit of four rectifier tubes VT_1, VT_2, VT_3 and VT_4. This is followed by a capacitance filter of the 10 μF capacitor C_1. The voltages for the screen grids of the eight regulator tubes VT_5 to VT_{12} are supplied through the filter consisting of the resistor R_1 and the capacitor C_2.

The stabilizer of the 0-400 V range and auxiliary stabilizer consist of conventional full-wave rectifiers, using the vacuum tubes VT_{14} and VT_{18}, followed by capacitance filters consisting of the two capacitors C_6 and C_{10} respectively.

The Power Supply uses two power transformers: the anode voltage transformer Tr_1 to supply the rectifiers and the heater voltage transformer Tr_2.

The Power Supply is protected against possible short circuits by the following fuses: F_1 (7.5 A) in series with the primary winding of the power transformer; F_2 (1 A) in the output circuit of the 20-600 V rectifier; four fuses F_3, F_4, F_5 and F_6 (each 5 A) in the circuits of the 2.15, 2.5, 4 and 5 V, fuse F_7 (10 A) in the circuit of one of the 6.3 V supply output terminals and two fuses F_8, F_9 (3 A) in the circuits of the 12.6 V and 24 V low voltages, intended for external application through the respective output terminals. The source of 6.3 V for current loads up to 25 A has no fuses.

As a safety precaution, the Power Supply is provided with a safety switch SW_1, disconnecting the primary circuits of the power transformers when the chassis is removed from the cabinet. The output voltage is measured with the voltmeter M_2, having a full-scale reading of 600 volts. The meter is switched to the necessary voltage through the D.P.D.T. Voltmeter Range switch SW_4. The current drawn from the 20-600 V stabilized rectifier is measured by the milliammeter M_1, having a deflection of 0-600 mA. The current drawn from the 0-400 V stabilized rectifier is not measured.

The 20-600 V stabilized rectifier output voltage is provided with the following voltage ranges:

1. 20-150 V.
2. 150-300 V.

3. 300-400 V.
4. 400-500 V.
5. 500-600 V.

These ranges are obtained by switching the necessary secondary winding taps of the anode power transformer to the anodes of the rectifier tubes and the respective resistors of the output voltage divider.

Smooth adjustment of the voltages on each voltage range is done by turning the variable resistor R_{32}, which varies the grid bias of the amplifier tube VT_{13}.

The 0-400 V stabilized rectifier output voltage is provided with the following voltage ranges:

1. 0-200 V.
2. 200-400 V.

These voltages are obtained by switching the resistors of the output voltage divider. The smooth adjustment is done by turning the potentiometer R_{68}.

The stabilizers of the rectified voltages, composing the Power Supply type УИП-I, consist of a regulator and amplifier stages. The regulator stage consists of the following:

1. In the 20-600 V stabilizer - of 8 vacuum tubes VT_5 to VT_{12}, connected in parallel.
2. In the 0-400 V stabilizer - one vacuum tube VT_{19}.
3. In the auxiliary stabilizer - one vacuum tube VT_{15}.

The grids of the regulator tubes are connected through the direct current amplifiers, consisting of the vacuum tubes VT_{13}, VT_{16} and VT_{20} to the respective output voltages.

Performance of each regulator can be compared to the function of a variable series resistor, automatically regulating the output voltage, keeping it constant.

The voltage, controlling the grids of the regulator tubes varies proportionally to the voltage across the output terminals.

With a change of the output voltage, due to the fluctuations of the line supply voltage or the load current, the grids of the amplifier acquire a certain additional bias potential which in turn varies the grid bias applied to the regulator tubes VT_5 to VT_{12}, VT_{15} and VT_{19}. This will change the plate resistance of the regulated tubes so that predetermined value of the output voltage will be maintained.

IV Construction

The Power Supply УИП-I consists of the units. The power supply forms the lower unit, and the stabilizers, which are above, form the other. Access to the circuit wiring is possible by removing the upper section, which can be done by releasing the six screws on each lower end of the chassis and two screws on the front panel, one on the top of the lower unit and the other at the lower left hand end of the front panel.

The complete apparatus is enclosed in an aluminium cabinet fastened with eight chromium plated screws located on the front panel.

V Installation and Operation Instructions

Before connecting the Power Supply to the supply line, check the line voltage to ascertain that it is correct. Place the 20-600 volt range switch to the 20-150 V range and rotate the smooth regulation knob to the extreme left end position, this will correspond to the minimum output voltage. Next the apparatus should be grounded. After this the line supply cable can be connected to the line voltage outlet. The power supply can be switched on by lifting the toggle switch upward as shown by the arrow. After switching on the power supply the pilot lamp should light.

The low voltages on the respective terminals are immediately available, while the high voltage is ready for use after the cathodes of the vacuum tubes have warmed up, that is after approximately two minutes.

The selection of the stabilized output voltages is to be made with the aid of the range switches of 20 to 600 V or 0 to 400 V, and the respective smooth regulation knobs, while simultaneously monitoring with the voltmeter.

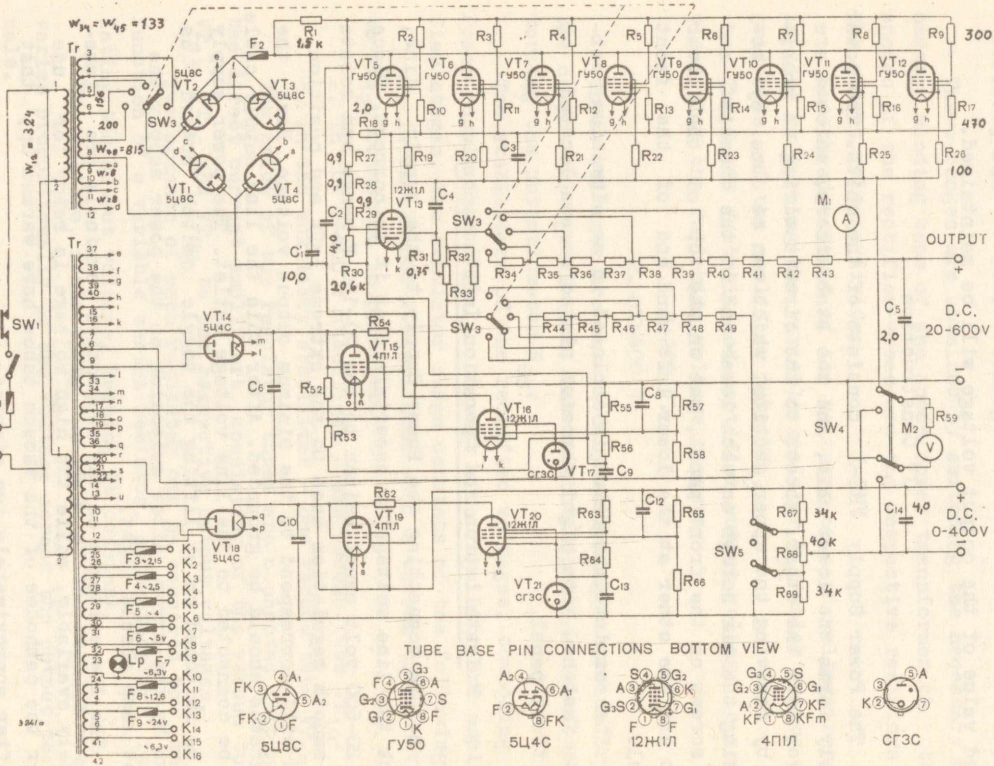


Fig. 26. Circuit Diagram of the УИП-I.

It is necessary to remember that the load current of the 0-400 V range should not exceed 5 mA and that of the 20-600 V range not be more than 600 mA. To avoid damaging of the apparatus the output alternating low voltages should be used as rated, noting that the overall load should not exceed 250 W.

When replacing voltage regulator tubes, it is recommended to test the constancy of the output voltage in respect to the variations of the line supply voltage, choosing the tube giving the best results, since the stability of the power supply voltage depends greatly on the quality of the voltage regulator tube.

During operation the power supply should be cleaned of possible accumulated dust. If the power supply was kept in low temperatures, it is necessary to let it dry and warm up to normal room temperature before use.

N o t e: To minimize the voltage drop in the low alternating voltage circuits special low resistance fuses are used.

V O C A B U L A R Y

A

adapter [ə'dæptə]	muhv	насадка, переходник
ambient ['æmbiənt]	ümbritsev	окружающий
amplifier ['æmplifaiə]	võimendi	усилитель
apply [ə'plai]	rakendama	подавать
arm [a:m]	õlg (tehn.)	плечо (техн.)
moving ['mu:viŋ] ~	liugur, liugkontakt	движок
assemblage [ə'semblidʒ]	montaaž	сборка
attenuation [ə,tenju'eiʃn]	nõrgenemine	ослабление
attenuator [ə'tenjueitə]	attenuaator, pingejagur	аттенюатор, делитель напряжения
stepped [stept] ~	astmeline ~	ступенчатый ~
tapped [tæpt] ~	astmeline ~	ступенчатый ~

B

barretter ['bærətə]	barreter	бареттер
bias ['baiəs]	eelpinge	смещение

C

calibrate ['kælibreit]	kalibreerima	калибровать
capacitor [kə'pæsitə]	kondensaator	конденсатор
blocking ['blɔkiŋ] ~	eraldus ~	разделительный ~
semivariable ['semi'vɛəriəbl] ~	trimmer	полупеременный ~
channel ['tʃænl]	kanal	тракт
check [tʃek]	kontrollima	проверить
circuit ['sə:kit]	lülitus; skeem	схема
balanced ['bælənst] ~	paralleelbalanss ~	балансовая ~
balanced bridge ~ ['bælənst bridʒ]	tasakaalustatud sildlülitus	уравновешенная мостовая ~
cascade [kæs'keid]	kaskaad ~	каскадная ~
doubler ['dʌblə] ~	kahekordistus ~	~ удвоения
multiplier ['mʌltiplaiə] ~	kordisti	умножитель
open [oupn] ~	katkestus	обрыв
printed ['printid] ~	trükkskeem	печатная ~
series ['siəri:z] ~	järjestiklülitus	последовательная ~
circuity ['sə:kiti]	skeemistus	компоновка схемы
clip [klip]	haarats	захват
conductance [kən'dʌktəns]	juhtivus	проводимость
correlation [kɔri'leiʃn]	suhe	отношение
coupler ['kʌplə]	ühendusmuhv	фланец
T-coupler	kolmikpea	тройниковая головка
curve [kə:v]	graafik	кривая

D

decoupling [di'kʌpliŋ]	lahtisidestus-	развязывающий
develop [di'veləp]	arenema: siin: kujunema	развиваться
diode ['daioud]	diood	диод
distortion [dis'tɔ:ʃn]	moonutus	искажение
divider [di'vaidə]	jagur, jagaja	делитель
attachable [ə'tætʃəbl] ~	väline ~	внешний ~
detachable [di'tætʃəbl] ~	väline ~	внешний ~

external [eks'tə:nl] ~	väline ~	внешний ~
voltage ['voultɪdʒ] ~	pinge ~	~напряжения
doubler ['dʌblə]	kahekordisti	удвоитель
duty cycles ['dju:tɪ 'saiklz]	harvendus	скважность

E

error ['erə]	viga	погрешность
additional [ə'dɪʃnəl] ~	lisaviga	дополнительная ~
basic ['beɪsɪk] ~	põhiviga	основная ~

F

feedback ['fɪ:dbæk]	tagasisidestus	обратная связь
fluoro-plastic ['fluərəplæstik]	fluoroplast, plastik	флоропласт
follower ['folouə]	järgija, järgur	повторитель
form factor ['fɔ:m 'fæktə]	kujutegur	коэффициент формы
frequency ['frɪ:kwənsɪ]	sagedus	частота
repetition [repɪ'tɪʃn] ~	kordus ~	~повторения

G

gain [geɪn]	võimendus(tegur)	коэффициент усиления
voltage [voultidʒ] ~	pingevõimendus	~напряжения
gap [gæp]	katkestus	разрыв
gaseous voltage stabilizer ['geɪzjəs 'voultɪdʒ 'stæbɪlaɪzə]	stabilovolt	стабиловольт
grid [grɪd]	võre	сетка

H

harmonic [ha:'mɔnɪk]	harmooniline (sagedus)	гармоника (частоты)
heater ['hɪ:tə]	kütteniit	накал
hum [hʌm]	võrgumüra	сетевой фон

I

impedance [ɪm'pɪ:dəns]	impedants	полное сопротивление
inductance [ɪn'dʌktəns]	induktiivsus	индуктивность
input ['ɪnput]	sisend	вход
interference [ɪntə'fɪərəns]	häire	помеха
stray ['streɪ] ~	väline ~	наружная ~
involve [ɪn'vɔlv]	haarama	охватывать
item ['aɪtem]	punkt; (arve) kirjend	позиция сметы; каждый отдельный предмет (в списке и т.п.)

J

jack [dʒæk]	puks, pesa	гнездо

K

kit [kit]	karp, kast	ящик

L

lamination	[læmineiʃn]	leht	лист
lug	[lʌg]	liistak; lible	лепесток

M

mains supply	[ˈmeinz səˈplai]	toitevõrk	сеть питания
marking	[ˈmaːkiŋ]	tähis	отметка
mark-to-space ratio	[ˈmaːktəspeis reiʃiou]	harvendus	скважность
matching	[ˈmætʃiŋ]	sobitus	согласование
moving coil	[ˈmuːviŋ coil]	pöördpool-	магнитоэлектрический
multiplier	[ˈmʌlti plaiə]	eeltakistus	добавочное сопротивление

N

network	[ˈnetwəːk]	ahel	цепь
noise	[nɔiz]	müra	шум

O

oscillator	[ˈɔsileitə]	generaator	генератор
outlet	[ˈautlet]	väljund, pesa	выход
output	[ˈautput]	väljund	выход
overshoot	[ˈouvəʃuːt]	ülevise, ülehälve	зашкаливание

P

pilot light	[ˈpailətˈlait]	signaallamp	индикаторная лампочка
plug	[plʌg]	pistik	штепсель
power supply mains [ˈpauə səplai ˈmeinz]		toitevõrk	питающая сеть
probe	[proub]	mõõtepesa, proovik	пробник
test	[test] ~	mõõtevarras, sond	щуп
prong	[prɔŋ]	pistik	штепсель
pulse	[pʌls]	impulss	импульс
puncture	[ˈpʌŋktʃə]	läbilöök	пробой
push button	[ˈpuʃ ˌbʌtn]	surunupp	кнопка

R

range	[reindʒ]	piirkond	предел
frequency	[ˈfriːkwənsi] ~	sagedusala	частотный диапазон
~ multiplier	[ˈmʌltiplaiə]	skaalakordisti	(у)множитель шкалы
reactance	[riːˈæktəns]	reaktiivtakistus	реактивное сопротивление
receptacle	[riˈseptəkl]	pistikupesa	штепсельное гнездо
rectifier	[ˈrektifaiə]	alaldi	выпрямитель
reference	[ˈrefrəns]	tugi-, lähte-	исходный, опорный
~ level	[levl]	nullnivoo	нулевой уровень
resistance	[riˈzistəns]	takistus	сопротивление
resistive cathode coupling [riˈzistiv ˈkæθoud ˈkʌpliŋ]		takistuslik katoodsidestus	резистивная катодная связь
resistivity	[rizisˈtiviti]	eritakistus	удельное сопротивление
surface	[ˈsəːfis] ~	pinna ~	поверхностное ~
volume	[ˈvɔljum] ~	mahu ~	объемное ~
resistor	[riˈzistə]	takisti	резистор
precision	[priˈsiʒn] ~	täppis~, taatel~	образцовый ~

response [ris'pɔns]	karakteristik	характеристика
amplitude ['æmplitju:d] ~	amplituud ~	амплитудная ~
frequency ['fri:kwənsi] ~	sagedus ~	частотная ~
transient ['trænziənt] ~	siirde ~	переходная ~
ring [riŋ]	rõngas	кольцо
guard [gɑ:d] ~	kaitse ~	защитное ~
ripple [ripl]	pulsatsioon	мелкая пульсация

S

shielded ['ʃi:ldid]	varjestatud	экранированный
shunt [ʃʌnt]	šunteerima	шунтировать
sinusoidal ['sainəsɔidəl]	siinuseline	синусойдальный
socket ['sɔkit]	pesa	гнездо
standard ['stændəd]	etalon	эталон
resistance [ri'zistəns] ~	etalontakisti	эталонное сопротивление
voltage ['voultidʒ] ~	etalonpinge	эталонное напряжение
superimpose ['sju:pərim'pouz]	liituma	наложение
switch [switʃ]	lüliti	переключатель
keyboard ['ki:bɔ:d] ~	klahv ~	клавишный ~
polarity-selector [pou'læriti si'lektə] ~	polaarsuse ümberlüliti	~полярности
push-button ['puʃbʌtn] ~	surunupp	кнопка нажимная
toggle [tɔgl] ~	kipplüliti, tumbler	тумблер

T

tap [tæp]	väljavõte	вывод
centre ['sentə] ~	keskmine ~	средний ~
teraohm ['terəoum]	teraoom, $10^{12}\ \Omega$	тераом
terminal ['tə:minl]	klemm	клемма
~ post [poust]	poolusklemm	полюсный зажим
thermocouple ['θə:məkʌpl]	termorist, termomuundur	термопреобразователь
time constant ['taim,kɔnstənt]	ajakonstant	постоянная времени

U

unbalanced ['ʌn'bælənst]	tasakaalustamata	неуравновешенный
un-by-passed	šunteerimata	незашунтированный

V

versatile ['və:sətail]	universaalne	универсальное
voltage ['voultidʒ]	pinge	напряжение
alternating ['ɔ:ltəneitiŋ] ~	vahelduv ~	переменное ~
calibration [kæli'breiʃn] ~	kalibreerimis ~	калибровочное ~
~ divider [di'vaid]	~jagur	делитель ~я
levelled ['levld] ~	piiratud ~	ограниченное ~
line [lain] ~	võrgu ~	сетевое ~
reference ['refrəns] ~	tugi ~	опорное ~
standards ['stændədz] ~	etalon ~	эталонное ~
stray interfering ~ ['strei intə'fiəriŋ]	väline häire~	помех

W

winding ['waindiŋ]	mähis; mähkimine	обмотка; намотка

ABBREVIATIONS

a.c. - alternating current	vahelduvvool	переменный ток
c/s - cycle per second	herts (Hz)	герц
d.c. - direct current	alalisvool	постоянный ток
G-10^9, giga	10^9, giga	гига
M-10^6, mega	10^6, mega	мега
r.m.s.- root-mean-square [ru:t mi:n 'skwɛə]	ruutkeskmine	среднеквадратичное
SWVR - standing-wave voltage ratio [stændiŋ - weiv 'voultidʒ 'reiʃiou]	seisulainetegur	коэффициент стоячей волны
H.F. high frequency	kõrgsagedus	высокая частота
L.F. low frequency	madalsagedus	низкая частота

CONTENTS

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