

Ц437

Combination
instrument

Operating instructions

DESIGNATION

The ammeter U437 is a combination instrument designed for measuring current and voltage in D. C. circuits, D. C. resistance, effective value of sine-shaped voltage in A. C. circuits at 45 to 40000 c/s frequencies.

The instrument is produced in two versions: 1) U437 for operation at ambient temperature -10 to +40°C and relative humidity up to 80% (at +30°C); 2) U437T for indoor operation both in dry and humid tropical climates at ambient temperature from -5 to +40°C and relative humidity up to 95% (at +30°C).

The instrument U437 is intended for use in the course of servicing radio equipment and communication facilities as well as for amateur measurements.

TECHNICAL CHARACTERISTICS

Measurement range:

D. C. intensity: 0.1; 1; 10; 100; 1000 mA;

D. C. voltage: 2.5; 10; 50; 250; 500; 1000 V;

A. C. Voltage: 2.5; 10; 50; 250; 500; 1000 V;

D. C. resistance: 0.2; 3; 30; 300 K Ω ; 3 M Ω .

Basic error of instrument:

In measuring D. C. intensity and voltage — not over $\pm 2.5\%$ of the scale maximum value.

In measuring A. C. voltage — not over $\pm 4\%$ of the scale maximum value.

In measuring resistance — not over $\pm 2.5\%$ (in the $\times 1$ range — not over $\pm 4.0\%$ of the scale working portion equal to 71 mm).

The working portion of scale "D" is the section contained between points "0" and "300".

Power consumed by the instrument:

Full deflection current — 100 μ A in measuring D. C. and A. C. voltage and 200 ± 50 μ A in the "200 V" measurement range.

Drop of voltage across the instrument — not more than 0.5 V in measuring D. C. intensity and not more than 0.65 V in the 1000 mA measurement range.

The instrument frequency range is given in Table I.

Each instrument U437 has been tested for insulation between the electric circuits and the frame by 3 kV d.c. A. C. at 50 c/s.

Drop time — not more than 4 sec.

Overall dimensions — not more than 215x118x $\times 75$ mm.

Weight of the U437 instrument not more than 1.3 kg and of U437T, not more than 1.56 kg.

The normal operating conditions at which the basic error shall not exceed the values given above are as follows:

Horizontal position of the instrument within $\pm 2^\circ$.

Table I

| Measurement range, V | Frequency, c/s | |
|----------------------|----------------|-------------|
| | Rated | Expanded |
| 2.5 | 45—10000 | 10000—10000 |
| 10 | 45—10000 | 10000—20000 |
| 50 | 45—1000 | 1000—5000 |
| 250 | 45—500 | 250—500 |
| 500, 1000 | 45—100 | 100—200 |

Ambient temperature $+20 \pm 5^\circ\text{C}$ for the U467 instrument and $+27 \pm 5^\circ\text{C}$ for the U427T instrument (later on designated as t_a).

In measuring A. C. voltage the frequency shall be within the nominal range (see Table I) and the voltage curve shall be practically sine-shaped (distortion factor not exceeding 2%).

INFLUENCE OF EXTERNAL FACTORS

Temperature Dependence

Variation of instrument readings due to changes of ambient temperature:

From -10 to $+40^\circ\text{C}$ for instrument U467 does not exceed $\pm 2.5\%$ for direct current ($\pm 1.25\%$ for resistance measurements) and $\pm 4\%$ for alternating current.

From -5 to $+45^\circ\text{C}$ for instrument U427T does not exceed $\pm 2\%$ for direct current ($\pm 1.25\%$ for resistance measurements) and $\pm 3\%$ for alternating current per each 10°C of temperature change.

The Influence of Frequency

Variation of instrument reading due to change of frequency from the beginning of the nominal range to any value within the adjacent portion of the expanded range (see Table I) shall not exceed $\pm 4.0\%$ for A. C. measurements.

The Influence of External Magnetic Field

Variation of instrument readings due to constant uniform magnetic field of 400 A/m in case of most unfavorable direction of the magnetic field shall not exceed $\pm 5\%$.

Variation of instrument readings due to uniform magnetic field sinusoidally changing in time (frequency of change being equal to frequency of current passing across the instrument tested) shall not exceed $\pm 5\%$. Magnetic field intensity for frequencies from 45 c/s to f_0 inclusive shall be equal to 600 A/m and for frequencies from f_0 to 400 c/s it is found by the formula:

$$B = 400 \frac{f_0}{f}$$

in which f — frequency in c/s;
 f_0 — frequency 160 c/s.

The Influence of Tilt

Variation of instrument readings due to tilting from the normal (horizontally) position through 10° any direction shall not exceed the permissible basic error.

GENERAL INSTRUCTIONS FOR USE

In measuring high voltages accident prevention rules must be observed.

Touching the instrument terminals is dangerous for one's life!

The function switch may be turned to another position only with the instrument disconnected.

To avoid breakage of the brass on which the measuring mechanism frame is secured, escape impacts in transportation and operation of the instrument.

To prolong the service life of the internal power source try to avoid holding the instrument wire free ends for a long time in contact with the resistor tested, as well as shortcircuiting them.

On completing the measurements disconnect the instrument from the circuit checked.

USING THE INSTRUMENT

Measuring D. C. Intensity

Set the function switch to the left position designated "—" (Fig. 1). Insert the plug of one conductor into the receptacle marked "—" and the other conductor plug into the receptacle marked "1000 mA". Connect the

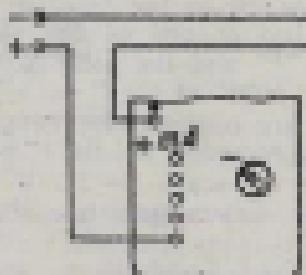


Fig. 1

free ends of both the conductors to the circuit of current measured. If the pointer does not reach 1/10-th of the scale, re-set the plug of the second conductor from the "1000 mA" socket to the "100 mA" one, repeating this procedure until the pointer appears in the right-hand part of the scale (in case of off-trailing in the lower range, return to the previous one). The values are read on the scale marked "—".

Measuring D. C. Voltage

Set the function switch to the position marked "—" (Fig. 2). Insert the plug of one conductor into receptacle "—" (instrument minus) and the other conductor plug into receptacle "1000" of the "-U" range. Connect the free ends of both the conductors to the circuit of voltage

measured. If the pointer does not reach the right-hand portion of the scale, reset the second plug from socket "1000" to socket "500", and so on until the pointer is in the scale right-hand part. Read the required value on the scale marked "—".

Measuring A. C. Voltage

Set the function switch to the position marked " \sim " (Fig. 3). Insert the plug of one of the conductors into the receptacle marked "+" and the plug of the other conductor, into receptacle "1000" of the " ~ 0 " range sockets 50, 250, 500 and 1000 are common for ranges " ~ 0 " and " ~ 00 ". Taking measurements in the " ~ 2.5 V" sub-range, read the values on scale " ~ 2.5 V"; taking measurements in the other sub-ranges, use should be made of the " \sim " scale.

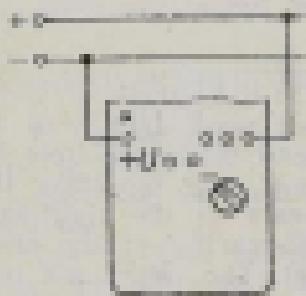


FIG. 2

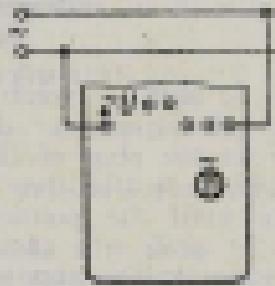


Fig. 3

Measuring D. C. Resistance

1. Set the function switch to the position marked " $\times \infty$ " (Fig. 4).
2. Insert the plug of one conductor into receptacle "+" and the other conductor plug, into one of the receptacles 50, 250, 500 and 1000.

factors of the sub-ranges $\times 1$, $\times 10$, $\times 100$, $\times 1000$, $\times 10000$, as required.

3. Short the free ends of the conductors and turning the "zero, 0" (zero adjustment) knob set the pointer to zero of scale "Ω". If the pointer would not set to zero, the power supply should be replaced.

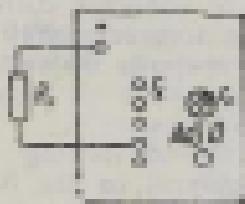


Fig. 4

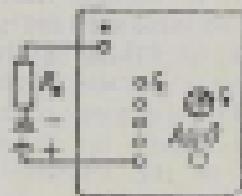


Fig. 5

4. Open the conductor ends and connect them to the outlets of the resistance measured. Record the value of the resistance, multiplying the instrument reading registered on the upper scale, by the factor chosen.

5. Passing over to another measurement range again set the pointer to zero of scale "Ω" as described in Item 3. We recommend to test circuits for continuity with factor " $\times 1000$ ", and for shortcircuiting, with factor " $\times 1$ ".

In the " $\times 10000$ " range the power source used should be a 30 to 42 V D. C. supply set connected as in Fig. 5.

6. Consumption of power in various D. C. resistance measuring ranges shall be not more than: 100 mA for $\times 1$; 10 mA for $\times 10$; 1 mA for $\times 100$; 0.1 mA for $\times 1000$ and $\times 10000$ and the current intensity in the resistance measured shall not exceed consumption of current in the respective measurement sub-ranges.

Measuring Transistor Parameters

With the help of instrument II437 measurements may be made of the basic parameters of low-power transistors in the static duty, i.e. current gain factor β , collector

junction back current I_{ab} , emitter junction back current I_{eb} , collector initial current I_{ci} in the common-emitter circuit.

Measuring β . For the measurement a flashlight battery and a variable resistor are required (the battery built in the 11437 instrument may be used).

It is known that β is the ratio of collector current gain to base current gain. To sufficient accuracy ($\pm 10\%$) β can be taken as the ratio of these currents instead of the ratio of the current gains.

For the measurement proceed as follows:

1. Hook up the circuit of Fig. 4 and turning the knob of the variable resistor set a current in the base circuit (for instance, 50 μA in the 0.1 mA sub-range on the "—" scale). Resistance of the variable resistor should not exceed 250 $k\Omega$.

2. Connect the 11437 instrument to the collector circuit (Fig. 7) and read the current intensity in the 10 mA sub-range (scale "—"). Full deflection of the pointer will correspond to $\beta=200$.

Example: The instrument reads 0.8 mA (the pointer deflects through 24 graduations). One graduation corresponds to

$$\frac{200}{50} = 4 \frac{\text{units } \beta}{\text{graduation}}$$

Hence, for the given transistor $\beta=4 \cdot 24=136$.

Note. If the base current set is 100 μA instead of 50 μA (full deflection of pointer in the 0.1 mA sub-range),

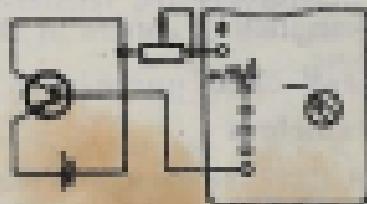


Fig. 4

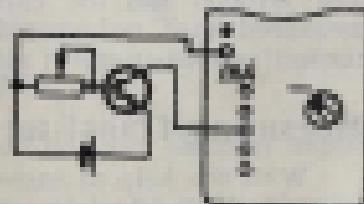


Fig. 7

then, switching the 11307 instrument to the collector circuit (Fig. 7) the full deflection of pointer in the 10 mA sub-range will correspond to $\beta = 100$.

Example: Collector current is 3.1 mA, hence,

$$\frac{3.1 \cdot 10^{-3}}{100 \cdot 10^{-3}} = 31$$

Measuring I_{cb} : Collector junction back current is measured as shown in circuit of Fig. 8. The resistor should be $4 \text{ k}\Omega$ so as to protect the instrument in case

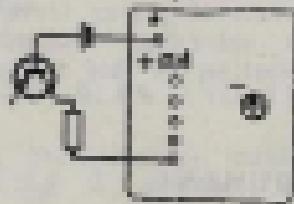


Fig. 8

the transistor is disrupted (base connected to collector). Take measurements in the 0.1 mA sub-range in which full deflection of pointer corresponds to 100 μA . Read the current value on scale $\frac{1}{100}$.

Measuring I_{eb} : Emitter junction back current is measured as shown in circuit of Fig. 9 similarly to measuring I_{cb} .



Fig. 9

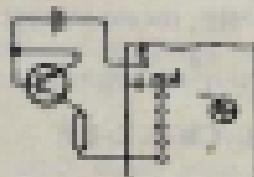


Fig. 10

Measuring I_{ca} : Collector initial current is measured as shown in circuit of Fig. 10 similarly to measuring I_{eb} .

REPLACING POWER SUPPLY SET

To replace the power supply set proceed as follows:

1. Turn off the 4 screws securing the nameplate at the instrument rear side.

2. Take out the waste battery and install a new one type KEC-II-0.5 into the chamber, fitting the battery terminal plates into the contact springs of corresponding polarity.

3. Re-install the cover and fasten it with screws.

Note. Consumption of power from the supply set operating in the 301 sub-range amounts to 100 mil. Therefore time of operation in this range should be as short as possible.

CARE OF THE INSTRUMENT

Instrument D437, like any other precise measuring apparatus, requires accurate and careful handling. If slightly soiled, it should be wiped with a soft cloth, in case of heavy contamination, rubbing with a cloth soaked in ethyl or methyl alcohol will be required.

Particular attention should be paid to cleanliness of the surface between the contact sockets (contamination will result in deterioration of insulation properties, reduction of instrument input resistance, and consequently, in inaccurate measurements of high voltages and resistances).

PERIODIC CHECK-UP

Accuracy of instrument D437 readings should be checked at least once a year.

Accuracy of current intensity and voltage measurement is checked comparing the instrument readings with those of standard instruments not worse than 0.5

class of accuracy, both in the direct and alternating current.

The limit values of the standard instrument scale must not exceed the corresponding limit value of the scale of the instrument checked by more than 25%.

To check the instrument in the resistance measuring ranges no should be made of a resistance box of accuracy class not worse than 0.5. The value of the resistance connected to the instrument is taken on the resistance box while the error in indication is read directly off the instrument 11437.

POSSIBLE TROUBLES AND THEIR REMEDIES

The most characteristic troubles for the instrument are the following: discontinuity of one of the resistors, breakdown of the germanium or silicon rectifiers, breaking of one of the braces type IIA. Cp. 2B A. 0.71 PCNCT 9444—61.

Loss of conductivity of any coil in the universal short circuit will manifest itself by absence of readings in the D. C. upper measurement sub-ranges, while in the lower sub-ranges the readings will be highly inaccurate. Readings of the A. C. voltmeter will be true, as the short has nothing to do with them. D. C. voltmeter readings will be too high.

Breaking of the added resistance in the voltage circuit will be revealed by absence of readings in the respective sub-range and higher sub-ranges in relation to this one.

Breakdown of resistance in the shunt circuit (shunt in good order) will result in absence of readings.

Breakdown of rectifiers will result in faulty readings of the A. C. voltmeter in all the sub-ranges.

To remedy the troubles the instrument should be opened by turning off the 4 screws located in the four corners of the base.

Any component of the circuit can be easily found with the use of the electric diagram and the specification to it. If the trouble is not detected by visual examination make tentative measurements with a similar instrument. Suspicious parts should be soldered off and examined in detail. Damaged parts, if not repairable, should be replaced with sound ones.

After repairs entailing change of instrument parameters (replacement of rectifiers, rewinding of the measuring mechanism loop, etc.), the instrument must be completely re-adjusted.

Readjustment should be carried out under normal operating conditions (to avoid additional inaccuracies), and includes the following steps:

1) Adjust all the resistors (excepting the trimming ones) to the values given in the specification remarks column.

2) If the magnetic system of the measuring mechanism has been disassembled, adjust the mechanism full deflection current (deflection to the last division of the scale) to 35 μ A by way of magnetization and even demagnetization of the system.

Resistance of the microammeter loop may be within $200 \Omega \pm 20\%$, while the total resistance of the loop and trimming cell R_3 must be $1300 \Omega \pm 1\%$ at temperature t_0 .

Adjustment in the " ~ 2.5 V" sub-range consists in selection of resistances of resistor R_2 applying 2.5 V current to the instrument.

Adjustment of the instrument in the upper voltage measurement sub-ranges (such as 250, 500 V) consists in selection of resistor R_1+R_2 total resistance; adjustment in the " ~ 10 A" sub-range consists in such distribution of the R_1+R_2 total that the standard microammeter reads $200 \pm 50 \mu$ A.

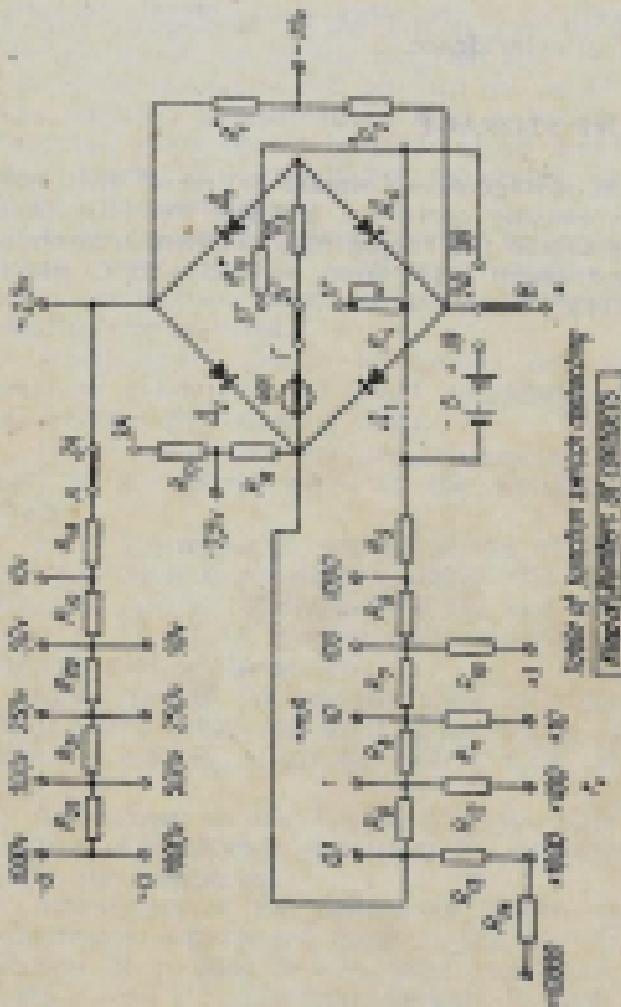
To finish the adjustment once more check the end marks of the scale in all the A-C measurement sub-

ranges as well as in the other measurement sub-ranges for accuracy of coincidence.

INSTRUMENT STORAGE.

Instrument storage-rooms should be free of dust, gases and vapours causing corrosion. Relative humidity of air in the rooms should not exceed 80%, ambient temperature range for instrument 11437 from +10 to +35°C and for instrument 11437T from -5 to +30°C.

Circuit Diagram for Instrument Q477



| Scale of bridge current in milliamperes | |
|---|------|
| 0.00 | 0.00 |
| 0.02 | 0.02 |
| 0.04 | 0.04 |
| 0.06 | 0.06 |
| 0.08 | 0.08 |
| 0.10 | 0.10 |
| 0.12 | 0.12 |
| 0.14 | 0.14 |
| 0.16 | 0.16 |
| 0.18 | 0.18 |
| 0.20 | 0.20 |
| 0.22 | 0.22 |
| 0.24 | 0.24 |
| 0.26 | 0.26 |
| 0.28 | 0.28 |
| 0.30 | 0.30 |
| 0.32 | 0.32 |
| 0.34 | 0.34 |
| 0.36 | 0.36 |
| 0.38 | 0.38 |
| 0.40 | 0.40 |
| 0.42 | 0.42 |
| 0.44 | 0.44 |
| 0.46 | 0.46 |
| 0.48 | 0.48 |
| 0.50 | 0.50 |
| 0.52 | 0.52 |
| 0.54 | 0.54 |
| 0.56 | 0.56 |
| 0.58 | 0.58 |
| 0.60 | 0.60 |
| 0.62 | 0.62 |
| 0.64 | 0.64 |
| 0.66 | 0.66 |
| 0.68 | 0.68 |
| 0.70 | 0.70 |
| 0.72 | 0.72 |
| 0.74 | 0.74 |
| 0.76 | 0.76 |
| 0.78 | 0.78 |
| 0.80 | 0.80 |
| 0.82 | 0.82 |
| 0.84 | 0.84 |
| 0.86 | 0.86 |
| 0.88 | 0.88 |
| 0.90 | 0.90 |
| 0.92 | 0.92 |
| 0.94 | 0.94 |
| 0.96 | 0.96 |
| 0.98 | 0.98 |
| 1.00 | 1.00 |

+ Scale of adjustment

Appendix

Continued

| Designation for Unit. num. | Description and type | Ratings | Q% P% | Remarks |
|----------------------------------|----------------------|----------------------------|----------|-------------------------------|
| R_T | Resistor MJT-0.5 | ± 60 | - | Total resistance |
| R_{T1} | Resistor MJT-0.5 | 3 kΩ | - | ± 60% R.T |
| R_{T2} | Resistor MJT-0.5 | 41 kΩ | - | Total resistance |
| R_{T3} | Resistor MJT-0.5 | 37 kΩ | - | 36.0 ± 60% |
| R_{T4} | Resistor MJT-0.5 | 290 kΩ | - | Total resistance |
| R_{T5} | Resistor MLT-0.5 | 1 MΩ | - | 400 ± 60% |
| R_{T6} | Resistor MLI-0.5 | 1.5 MΩ | - | Total resistance |
| R_{T7} | Resistor MLI-0.5 | 1.4 MΩ | - | 2.6 ± 0.012 MΩ |
| R_{T8} | Resistor MLI-0.5 | 2 MΩ | - | Total resistance |
| R_{T9} | Resistor MLI-0.5 | 3.2 MΩ | - | 3.00 ± 60% |
| R_{T10} | Resistor MLI-0.5 | 5 MΩ | - | 5.00 ± 60% |
| R_{T11} | Resistor MLI-0.5 | 10 MΩ | - | 9.80 ± 60% |
| R_{T12} | Resistor MLI-0.5 | 20 MΩ | - | 19.60 ± 60% |
| R_{T13} | Resistor MLI-0.5 | 40 MΩ | - | 39.20 ± 60% |
| R_{T14} | Resistor MLI-0.5 | 80 MΩ | - | 78.40 ± 60% |
| R_{T15} | Resistor MLI-0.5 | 160 MΩ | - | 156.80 ± 60% |
| R_{T16} | Resistor MLI-0.5 | 320 MΩ | - | 313.60 ± 60% |
| R_{T17} | Resistor MLI-0.5 | 640 MΩ | - | 627.20 ± 60% |
| R_{T18} | Resistor MLI-0.5 | 1.28 GΩ | - | 1.256 ± 60% |
| R_{T19} | Resistor MLI-0.5 | 2.56 GΩ | - | 2.512 ± 60% |
| R_{T20} | Resistor MLI-0.5 | 5.12 GΩ | - | 5.024 ± 60% |
| R_{T21} | Resistor MLI-0.5 | 10.24 GΩ | - | 10.048 ± 60% |
| R_{T22} | Resistor MLI-0.5 | 20.48 GΩ | - | 20.096 ± 60% |
| R_{T23} | Resistor MLI-0.5 | 40.96 GΩ | - | 40.192 ± 60% |
| R_{T24} | Resistor MLI-0.5 | 81.92 GΩ | - | 80.384 ± 60% |
| R_{T25} | Resistor MLI-0.5 | 163.84 GΩ | - | 160.768 ± 60% |
| R_{T26} | Resistor MLI-0.5 | 327.68 GΩ | - | 321.536 ± 60% |
| R_{T27} | Resistor MLI-0.5 | 655.36 GΩ | - | 643.072 ± 60% |
| R_{T28} | Resistor MLI-0.5 | 1.3107 GΩ | - | 1.2863 ± 60% |
| R_{T29} | Resistor MLI-0.5 | 2.6214 GΩ | - | 2.5726 ± 60% |
| R_{T30} | Resistor MLI-0.5 | 5.2428 GΩ | - | 5.1452 ± 60% |
| R_{T31} | Resistor MLI-0.5 | 10.4856 GΩ | - | 10.2904 ± 60% |
| R_{T32} | Resistor MLI-0.5 | 20.9712 GΩ | - | 20.5808 ± 60% |
| R_{T33} | Resistor MLI-0.5 | 41.9424 GΩ | - | 40.1616 ± 60% |
| R_{T34} | Resistor MLI-0.5 | 83.8848 GΩ | - | 80.3232 ± 60% |
| R_{T35} | Resistor MLI-0.5 | 167.7696 GΩ | - | 160.6464 ± 60% |
| R_{T36} | Resistor MLI-0.5 | 335.5392 GΩ | - | 321.2928 ± 60% |
| R_{T37} | Resistor MLI-0.5 | 671.0784 GΩ | - | 642.5856 ± 60% |
| R_{T38} | Resistor MLI-0.5 | 1.3421568 GΩ | - | 1.2863216 ± 60% |
| R_{T39} | Resistor MLI-0.5 | 2.6843136 GΩ | - | 2.5726424 ± 60% |
| R_{T40} | Resistor MLI-0.5 | 5.3686272 GΩ | - | 5.1452848 ± 60% |
| R_{T41} | Resistor MLI-0.5 | 10.7372544 GΩ | - | 10.2908192 ± 60% |
| R_{T42} | Resistor MLI-0.5 | 21.4745088 GΩ | - | 20.5806384 ± 60% |
| R_{T43} | Resistor MLI-0.5 | 42.9490176 GΩ | - | 40.1612768 ± 60% |
| R_{T44} | Resistor MLI-0.5 | 85.8980352 GΩ | - | 80.3235536 ± 60% |
| R_{T45} | Resistor MLI-0.5 | 171.7960704 GΩ | - | 160.6471072 ± 60% |
| R_{T46} | Resistor MLI-0.5 | 343.5921408 GΩ | - | 321.2942144 ± 60% |
| R_{T47} | Resistor MLI-0.5 | 687.1842816 GΩ | - | 642.5884288 ± 60% |
| R_{T48} | Resistor MLI-0.5 | 1.3743685632 GΩ | - | 1.2863771344 ± 60% |
| R_{T49} | Resistor MLI-0.5 | 2.7487371264 GΩ | - | 2.5727542688 ± 60% |
| R_{T50} | Resistor MLI-0.5 | 5.4974742528 GΩ | - | 5.1455085376 ± 60% |
| R_{T51} | Resistor MLI-0.5 | 10.9949485056 GΩ | - | 10.2910170752 ± 60% |
| R_{T52} | Resistor MLI-0.5 | 21.9898970112 GΩ | - | 20.5820341504 ± 60% |
| R_{T53} | Resistor MLI-0.5 | 43.9797940224 GΩ | - | 40.1640683008 ± 60% |
| R_{T54} | Resistor MLI-0.5 | 87.9595880448 GΩ | - | 80.3281366016 ± 60% |
| R_{T55} | Resistor MLI-0.5 | 175.9191760896 GΩ | - | 160.6562732032 ± 60% |
| R_{T56} | Resistor MLI-0.5 | 351.8383521792 GΩ | - | 321.2965464064 ± 60% |
| R_{T57} | Resistor MLI-0.5 | 703.6767043584 GΩ | - | 642.5930928128 ± 60% |
| R_{T58} | Resistor MLI-0.5 | 1.4073534087168 GΩ | - | 1.2863991856256 ± 60% |
| R_{T59} | Resistor MLI-0.5 | 2.8147068174336 GΩ | - | 2.5727983712512 ± 60% |
| R_{T60} | Resistor MLI-0.5 | 5.6294136348672 GΩ | - | 5.1455967425024 ± 60% |
| R_{T61} | Resistor MLI-0.5 | 11.2588272697344 GΩ | - | 10.2911934850048 ± 60% |
| R_{T62} | Resistor MLI-0.5 | 22.5176545394688 GΩ | - | 20.5823869700096 ± 60% |
| R_{T63} | Resistor MLI-0.5 | 45.0353090789376 GΩ | - | 40.1647739400192 ± 60% |
| R_{T64} | Resistor MLI-0.5 | 90.0706181578752 GΩ | - | 80.3295478800384 ± 60% |
| R_{T65} | Resistor MLI-0.5 | 180.1412363157504 GΩ | - | 160.6590957600768 ± 60% |
| R_{T66} | Resistor MLI-0.5 | 360.2824726315008 GΩ | - | 321.2981915201536 ± 60% |
| R_{T67} | Resistor MLI-0.5 | 720.5649452630016 GΩ | - | 642.5963830403072 ± 60% |
| R_{T68} | Resistor MLI-0.5 | 1.4411298905260032 GΩ | - | 1.2863997608880144 ± 60% |
| R_{T69} | Resistor MLI-0.5 | 2.8822597810520064 GΩ | - | 2.5727995217760288 ± 60% |
| R_{T70} | Resistor MLI-0.5 | 5.7645195621040128 GΩ | - | 5.1455990435520576 ± 60% |
| R_{T71} | Resistor MLI-0.5 | 11.5290391242080256 GΩ | - | 10.2911980871041152 ± 60% |
| R_{T72} | Resistor MLI-0.5 | 23.0580782484160512 GΩ | - | 20.5823881742082304 ± 60% |
| R_{T73} | Resistor MLI-0.5 | 46.1161564968321024 GΩ | - | 40.1647763484164608 ± 60% |
| R_{T74} | Resistor MLI-0.5 | 92.2323129936642048 GΩ | - | 80.3295526968329216 ± 60% |
| R_{T75} | Resistor MLI-0.5 | 184.4646259873284096 GΩ | - | 160.6591053936658432 ± 60% |
| R_{T76} | Resistor MLI-0.5 | 368.9292519746568192 GΩ | - | 321.2983507873316864 ± 60% |
| R_{T77} | Resistor MLI-0.5 | 737.8585039493136384 GΩ | - | 642.5967015746633728 ± 60% |
| R_{T78} | Resistor MLI-0.5 | 1.4757170078986272768 GΩ | - | 1.2863998811492545536 ± 60% |
| R_{T79} | Resistor MLI-0.5 | 2.9514340157972545536 GΩ | - | 2.5727997622985091072 ± 60% |
| R_{T80} | Resistor MLI-0.5 | 5.9028680315945091072 GΩ | - | 5.1455997245970182144 ± 60% |
| R_{T81} | Resistor MLI-0.5 | 11.8057360631890182144 GΩ | - | 10.2911985491940364288 ± 60% |
| R_{T82} | Resistor MLI-0.5 | 23.6114721263780364288 GΩ | - | 20.5823885983880728576 ± 60% |
| R_{T83} | Resistor MLI-0.5 | 47.2229442527560728576 GΩ | - | 40.1647771967761457152 ± 60% |
| R_{T84} | Resistor MLI-0.5 | 94.4458885055121454152 GΩ | - | 80.3295543935522914304 ± 60% |
| R_{T85} | Resistor MLI-0.5 | 188.8917770110242908304 GΩ | - | 160.6591087871044828608 ± 60% |
| R_{T86} | Resistor MLI-0.5 | 377.7835540220485816616 GΩ | - | 321.2987541742089657232 ± 60% |
| R_{T87} | Resistor MLI-0.5 | 755.5671080440961634432 GΩ | - | 642.5971083484179314864 ± 60% |
| R_{T88} | Resistor MLI-0.5 | 1.5111342160881923264 GΩ | - | 1.2863999067963918632 ± 60% |
| R_{T89} | Resistor MLI-0.5 | 3.0222684321763846464 GΩ | - | 2.5727998135927837264 ± 60% |
| R_{T90} | Resistor MLI-0.5 | 6.0445368643527692928 GΩ | - | 5.1455996271855674528 ± 60% |
| R_{T91} | Resistor MLI-0.5 | 12.0890737287055385856 GΩ | - | 10.2911992543711349056 ± 60% |
| R_{T92} | Resistor MLI-0.5 | 24.1781474574110771712 GΩ | - | 20.5823885087422698112 ± 60% |
| R_{T93} | Resistor MLI-0.5 | 48.3562949148221543424 GΩ | - | 40.1647770174845396224 ± 60% |
| R_{T94} | Resistor MLI-0.5 | 96.7125898296443086848 GΩ | - | 80.3295540359690792448 ± 60% |
| R_{T95} | Resistor MLI-0.5 | 193.4251796592886173696 GΩ | - | 160.6591087993381584896 ± 60% |
| R_{T96} | Resistor MLI-0.5 | 386.8503593185772347392 GΩ | - | 321.2987543786763169792 ± 60% |
| R_{T97} | Resistor MLI-0.5 | 773.7007186371544694784 GΩ | - | 642.5971087983526339584 ± 60% |
| R_{T98} | Resistor MLI-0.5 | 1.5474004372743089384 GΩ | - | 1.2863999575936952768 ± 60% |
| R_{T99} | Resistor MLI-0.5 | 3.0948008745486178768 GΩ | - | 2.5727999151873905536 ± 60% |
| R_{T100} | Resistor MLI-0.5 | 6.1896017490972357536 GΩ | - | 5.1455998879747811072 ± 60% |
| R_{T101} | Resistor MLI-0.5 | 12.3792034981944715072 GΩ | - | 10.2911997759495622144 ± 60% |
| R_{T102} | Resistor MLI-0.5 | 24.7584069963889430144 GΩ | - | 20.5823887518983244288 ± 60% |
| R_{T103} | Resistor MLI-0.5 | 49.5168139927778860288 GΩ | - | 40.1647771597966488576 ± 60% |
| R_{T104} | Resistor MLI-0.5 | 99.0336279855557720576 GΩ | - | 80.3295543195932977152 ± 60% |
| R_{T105} | Resistor MLI-0.5 | 198.0672559711115441152 GΩ | - | 160.6591087983526339584 ± 60% |
| R_{T106} | Resistor MLI-0.5 | 396.1345119422230882304 GΩ | - | 321.2987543786763169792 ± 60% |
| R_{T107} | Resistor MLI-0.5 | 792.2685238844461764704 GΩ | - | 642.5971087983526339584 ± 60% |
| R_{T108} | Resistor MLI-0.5 | 1.5845370477688923536 GΩ | - | 1.2863999889873952768 ± 60% |
| R_{T109} | Resistor MLI-0.5 | 3.1690740955377847072 GΩ | - | 2.5727999779747811072 ± 60% |
| R_{T110} | Resistor MLI-0.5 | 6.3381481910755694144 GΩ | - | 5.1455999439595622144 ± 60% |
| R_{T111} | Resistor MLI-0.5 | 12.6762963821511388288 GΩ | - | 10.2911999279191244288 ± 60% |
| R_{T112} | Resistor MLI-0.5 | 25.3525927643022776576 GΩ | - | 20.5823888558383244288 ± 60% |
| R_{T113} | Resistor MLI-0.5 | 50.7051855286045553152 GΩ | - | 40.1647771597966488576 ± 60% |
| R_{T114} | Resistor MLI-0.5 | 101.4103710572091106304 GΩ | - | 80.3295543195932977152 ± 60% |
| R_{T115} | Resistor MLI-0.5 | 202.8207421144182212608 GΩ | - | 160.6591087983526339584 ± 60% |
| R_{T116} | Resistor MLI-0.5 | 405.6414842288364425216 GΩ | - | 321.2987543786763169792 ± 60% |
| R_{T117} | Resistor MLI-0.5 | 811.2829684576728850432 GΩ | - | 642.5971087983526339584 ± 60% |
| R_{T118} | Resistor MLI-0.5 | 1.6225659369153457072 GΩ | - | 1.2863999994973952768 ± 60% |
| R_{T119} | Resistor MLI-0.5 | 3.2451318738306914144 GΩ | - | 2.5727999989947811072 ± 60% |
| R_{T120} | Resistor MLI-0.5 | 6.4902637476613828288 GΩ | - | 5.1455999979895622144 ± 60% |
| R_{T121} | Resistor MLI-0.5 | 12.9805274953227656576 GΩ | - | 10.2911999959791244288 ± 60% |
| R_{T122} | Resistor MLI-0.5 | 25.9610549906455313152 GΩ | - | 20.5823888958383244288 ± 60% |
| R_{T123} | Resistor MLI-0.5 | 51.9221099812910626304 GΩ | - | 40.1647771597966488576 ± 60% |
| R_{T124} | Resistor MLI-0.5 | 103.8442199625821252608 GΩ | - | 80.3295543195932977152 ± 60% |
| R_{T125} | Resistor MLI-0.5 | 207.6884399251642505216 GΩ | - | 160.6591087983526339584 ± 60% |
| R_{T126} | Resistor MLI-0.5 | 415.3768798503285010432 GΩ | - | 321.2987543786763169792 ± 60% |
| R_{T127} | Resistor MLI-0.5 | 830.7537597006560020864 GΩ | - | 642.5971087983526339584 ± 60% |
| R_{T128} | Resistor MLI-0.5 | 1.661507519401312004 GΩ | - | 1.2863999999947811072 ± 60% |
| R_{T129} | Resistor MLI-0.5 | 3.323015038802624008 GΩ | - | 2.5727999999927811072 ± 60% |
| R_{T130} | Resistor MLI-0.5 | 6.646030077605248016 GΩ | - | 5.1455999999875622144 ± 60% |
| R_{T131} | Resistor MLI-0.5 | 13.292060155210496032 GΩ | - | 10.2911999999791244288 ± 60% |
| R_{T132} | Resistor MLI-0.5 | 26.584120310420992064 GΩ | - | 20.5823889998883244288 ± 60% |
| R_{T133} | Resistor MLI-0.5 | 53.168240620841984128 GΩ | - | 40.1647771597966488576 ± 60% |
| R_{T134} | Resistor MLI-0.5 | 106.336481241683968256 GΩ | - | 80.3295543195932977152 ± 60% |
| R_{T135} | Resistor MLI-0.5 | 212.672962483367936512 GΩ | - | 160.6591087983526339584 ± 60% |
| R_{T136} | Resistor MLI-0.5 | 425.345924966735873024 GΩ | - | 321.2987543786763169792 ± 60% |
| R_{T137} | Resistor MLI-0.5 | 850.691849933471746048 GΩ | - | 642.5971087983526339584 ± 60% |
| R_{T138} | Resistor MLI-0.5 | 1.699383699866943492 GΩ | - | 1.2863999999947811072 ± 60% |
| R_{T139} | Resistor MLI-0.5 | 3.398767399733886984 GΩ | - | 2.5727999999927811072 ± 60% |
| R_{T140} | Resistor MLI-0.5 | 6.797534799467773968 GΩ | - | 5.1455999999875622144 ± 60% |
| R_{T141} | Resistor MLI-0.5 | 13.595069598935547936 GΩ | - | 10.2911999999791244288 ± 60% |
| R_{T142} | Resistor MLI-0.5 | 27.185139197871095872 GΩ | - | 20.5823889998883244288 ± 60% |
| R_{T143} | Resistor MLI-0.5 | 54.370278395742191744 GΩ | - | 40.1647771597966488576 ± 60% |
| R_{T144} | Resistor MLI-0.5 | 108.740556791484383488 GΩ | - | 80.3295543195932977152 ± 60% |
| R_{T145} | Resistor MLI-0.5 | 217.481113582968766976 GΩ | - | 160.6591087983526339584 ± 60% |
| R_{T146} | Resistor MLI-0.5 | 435.962227165937533952 GΩ | - | 321.2987543786763169 |

Notes: 1. Items R_{11} — R_{13} (for U427) can be made either from one or several resistors (MLT, MT, DWLT, YAM, YLM, BLM, MTL, BC, etc.) so as to obtain the resistance value given in the specification.

2. Items R_2 — R_3 (for U427) should be made either from one or several resistors MLT.

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