Mathematics and Computer Science
2022; 7(4): 75-80
http://www.sciencepublishinggroup.com/j/mcs
doi: 10.11648/j.mcs.20220704.13
ISSN: 2575-6036 (Print); ISSN: 2575-6028 (Online)

Experience in Creating Computer Training Programs for Metrologists

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To cite this article:
Svetlana Zatoka. Experience in Creating Computer Training Programs for Metrologists. *Mathematics and Computer Science*. Vol. 7, No. 4, 2022, pp. 75-80. doi: 10.11648/j.mcs.20220704.13

Received: April 29, 2022; **Accepted**: July 22, 2022; **Published**: August 31, 2022

Abstract: In the summer of 2001, a description of the international project COMET (EU) was presented, aimed at developing multimedia for teaching in the field of measurements and metrology. The introduction of multimedia for teaching in the field of metrology and measurements is relevant, as it allows for distance learning for students. Metrology and measurement has a key position in science, research, production, testing and certification. Information and communication technologies make it possible to effectively use both traditional and innovative means and forms of education. The use of information technology makes it possible to create distance learning for students. Modeling of measuring equipment and software development are introduced when creating computer laboratory work, which allows you to get a good result. The article deals with the issue of using computer training programs in the preparation of metrologists at the Department of Information and Measurement Technologies of the National Technical University of Ukraine "Kyiv Polytechnic Institute named after. I. Sikorsky", work started in the early 2000s. A simulation program for computerized laboratory work used in the course "Testing and conformity assessment" in the preparation of bachelors. When studying the discipline, there are difficulties associated with the need to acquire skills to work on real physical devices and layouts. Therefore, simulation models of measuring instruments are as close as possible to real instruments. When verifying multivalued resistance measures, DC bridges and resistance comparators complete with reference resistance measures; DC potentiometers combined with resistance measures. This work is devoted to the verification of a multi-valued resistance measure using a resistance comparator and a set of reference multi-valued resistance measures. The work includes: theoretical information, description of the simulation model, technical and metrological characteristics of measuring instruments used in the measurement; methods for determining the parameters of verification procedures; description of the procedure for conducting measurement experiments.

Keywords: Belief Verification, Measure, Comparator, Comparison, Multi-valued Measure, Single-Valued Measure, Error

1. Introduction

The paper considers the implementation of one of the methods for checking multivalued resistance measures (MMS) [1]. The choice of method and means of verification must comply with the requirements of the document [2]. The parameters of the verification procedure are evaluated in accordance with [3, 4].

The description of the measurement experiment contains: theoretical information: an overview of the methods of verification of MMS, verification operations, description of the simulation model, metrological characteristics of means verification, description of experiments - assessment of the initial resistance and its variation, the actual values of the resistances of the studied MMS.

The determination of the actual resistance values of the resistance box is carried out in one of two ways: by element-by-element verification or by measuring increasing values. In element-by-element verification, the resistance of each step is determined; all decades are determined separately by comparison with measures of an equivalent value. At the same time, all other decades must be set to zero or the smallest value.

2. Theoretical Foundations

In measuring practice, multi-valued measures of the electrical resistance of the MMC are widely used.

A multi-valued measure is a set of measures that are structurally combined into a single whole, with a device for including them in various combinations [7].

Verification is performed in accordance with the "Method of Verification", which must meet the requirements of MI 1695 [2].

2.1. During the Verification of MMC, the Following Operations Are Performed

1) visual inspection [8];
2) checking the dielectric strength of the insulation [9, 10];
3) trial;
4) determination of the average value of the initial resistance and the variation of the initial resistance [11].;
5) determination of actual values of MMC resistances [12];
6) When checking resistance magazines, it is necessary to check the compliance of their main characteristics with the value given in the technical documentation.

2.1.1. Direct Measurement Method

Direct measurements with a digital ohmmeter are direct measurement methods. For the actual resistance of a multi-valued measure of resistance, the readings of an ohmmeter are taken. The error in determining the resistance value is equal to the error of the ohmmeter.

2.1.2. Resistance Measurement with a DC Bridge

Measurement of resistance using a DC bridge is carried out by one of the methods: direct measurement, substitution, incomplete substitution:

1) direct measurement of the MMC resistance is performed with a single bridge with a two-terminal connection when measuring resistance more than 100 ohms. The 4-terminal connection allows measurement of resistances less than 100 ohms. Direct measurement of low resistances (less than 10 Ω0 is performed by a binary bridge). The measurement error of the actual resistance value is equal to the bridge error;
2) the full replacement method is used in the absence of an exemplary bridge of the required accuracy. In addition to the exemplary bridge, in this case, an exemplary multivalued measure of resistance with the necessary discreteness is required adjustments. The values of the exemplary measure of resistance are taken as the actual value of the measured resistance. The error of measurement is equal to the error of the exemplary measure. In this method, the measurement error introduced by the bridge is reduced by a factor of 100 or more compared to its limit.

Errors and the error of the measuring resistance is determined mainly by the error of the exemplary measure. If the condition of matching the senior decades of the studied and exemplary measures of resistance is not met, this method loses its advantages.

2.1.3. Substitution Method

The full replacement method is used in the absence of a DC bridge of the required accuracy. In this case, in addition to the bridge, an exemplary MMC is required. The exemplary MMC indicator is taken as the actual value of the measuring resistance. Error resistance is equal to the error of the exemplary MMS. The error of the bridge with this method is excluded, it should only have sufficient sensitivity and the possibility of fine adjustment.

2.1.4. Measuring Resistance with a DC Potentiometer

The determination of the actual value of the MMS resistance is carried out by the method of indirect measurements. The value of the measuring resistance is calculated by the formula.

2.1.5. Measuring Resistance with a Resistance Comparator

The determination of the actual value of the resistance of the test MMS is carried out by the method of simultaneous balancing of equally nominal test and exemplary resistances using a resistance comparator. The measurement scheme is shown in Figure 1.

Figure 1. *Measurement scheme using a resistance comparator.*

K - resistance comparator; MMCп – verified MMC; MMSo is an exemplary measure.

As measures, both single-valued and multi-valued measures of resistance are used. Test and exemplary measures are connected to the comparator. On measures set equal nominal values and make measurements. The actual values of the measuring resistance are calculated. The resistance measurement error is equal to the sum of the errors of the comparator and the applied measure.

Conclusion. The most accurate verification method is the comparator method.

Resistance, allowing to perform verification with the required accuracy, using a multi-valued measure and single-valued measures as an exemplary measure of resistance, depending on the resistance value being verified and ensuring the ratio of the verification error to the maximum error of the test measure 1/3.

2.2. Method for Verification of Multivalued Resistance Measures

The verified MMC must comply with requirements [13, 14], verification is performed in accordance with the “Verification Method”, which must meet the requirements of MI 1695 [2], the composition of the document is regulated [15].

During the verification of MMC, the following operations are performed:

1) visual inspection:
2) checking the electrical strength of the insulation [15];
3) determination of insulation resistance for MMC with resistance of the highest degree of Ohm and more;
4) trial;
5) determination of the average value of the initial resistance and the variation of the initial resistance;
6) determination of actual values of MMC resistances.

When checking resistance magazines, it is necessary to check the compliance of their main characteristics with the value given in the technical documentation.

2.3. Description of the Simulation Model

There are 4 tabs on the simulation model: Option, Experience 1, Experience 2.

2.3.1. Variant «Tab»

On this tab, the task option for laboratory work is selected, Figure 2. When choosing an option, a task appears: the types of studied MMCs (типы MMC) and the ranges for the study. For example, type P33 (тип P33), ranges x9.1, x10; type MCP 60 M, ranges x10, x100 (диапазоны x9,1, x10; тип MCP 60 M, диапазоны x10, x100).

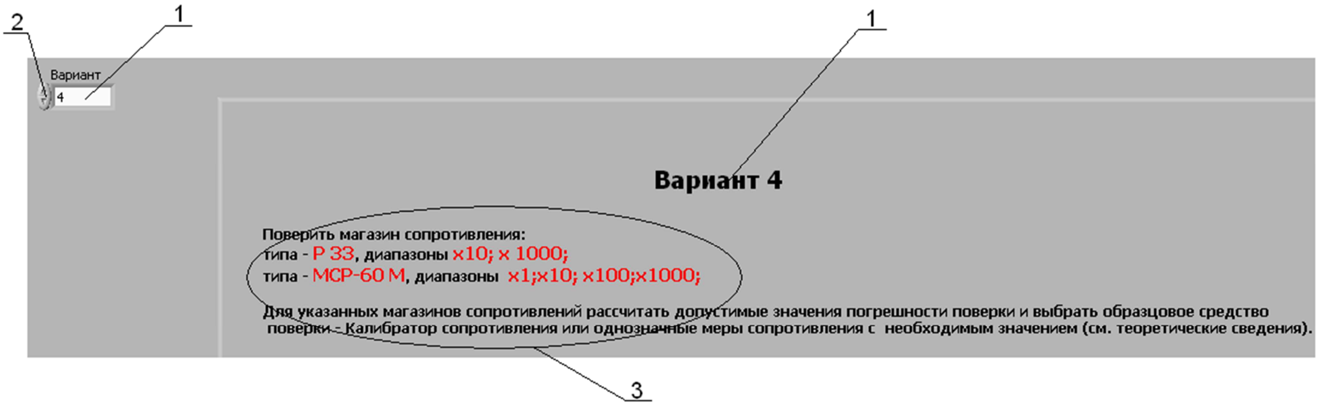

Figure 2. *Option selection scheme.*

1- The figure shows: 1 - option number; 2 - Option selection button; 3 - Assignment to the option.

2.3.2. Experience «Tab 1»

On this tab there are layouts of the breakdown unit UPU - 21 and stores of resistance R-33 or R-527 or MCP-60.

In the experiment, the isolation test of the measure under study is performed. (Figure 3).

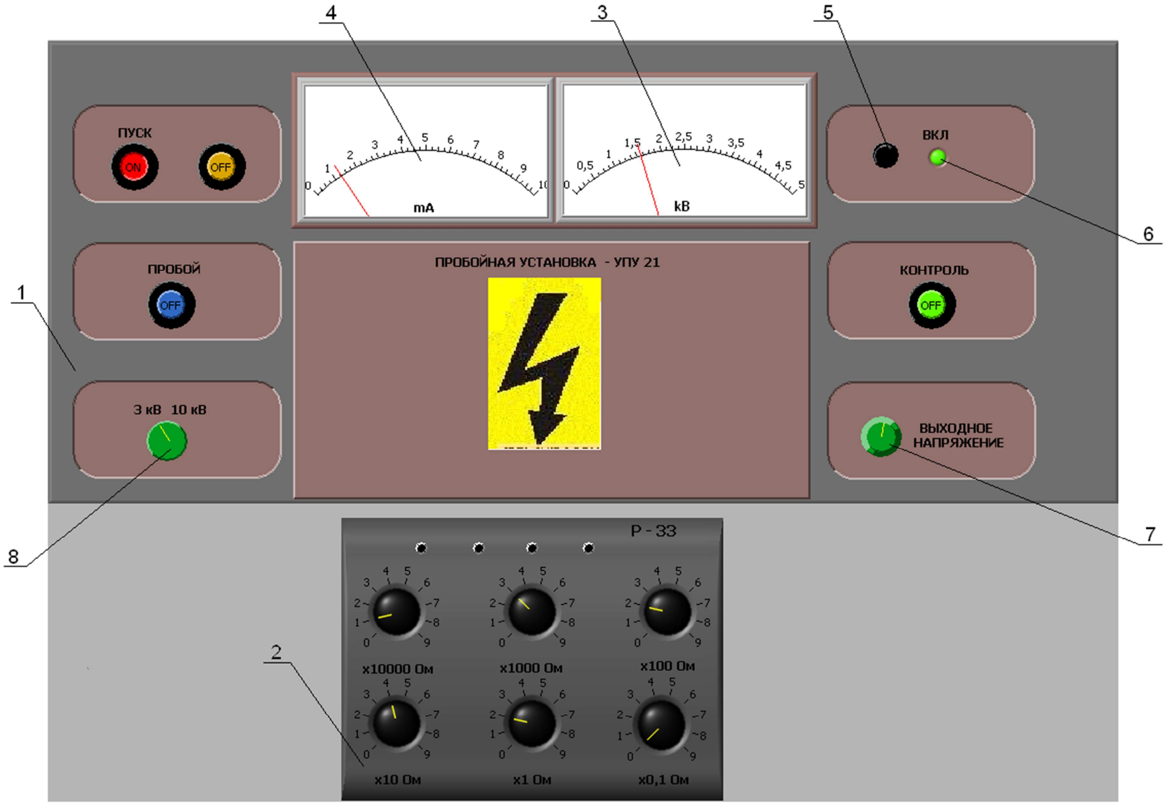

Figure 3. *"Experiment 1".*

The figure shows: 1 - Model of the breakdown installation UPU-21; 2 - Layout R-33; 3 - Voltmeter scale; 4 - Ammeter scale; 5 - Button that turns on the device: 6 - Indicator showing whether the device is on; 7 - Handle responsible for increase or decrease in input voltage; 8 - Handle switching power.

2.3.3. «Tab 2»

This tab contains layouts of the R-3015 comparator and resistance magazines. In the experiment, the initial resistance is determined and its variations (Figure 4).

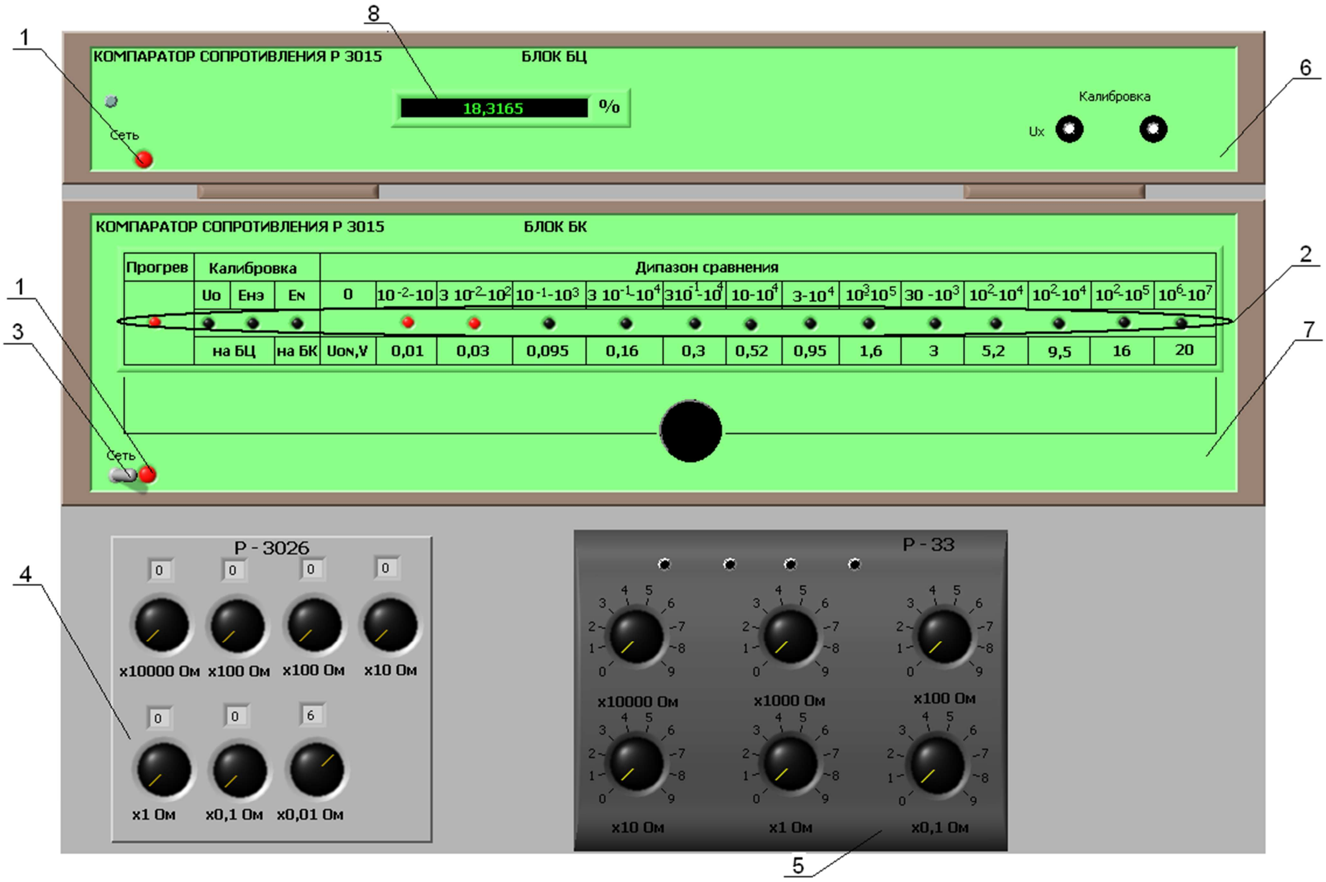

Figure 4. *"Experiment 2".*

The figure shows: 1 - Indicator showing whether the device is turned on; 2 - An indicator that shows in what range the measuring resistance is located; 3 - Button that turns on the device; 4 - resistance store R-3026 (reference) 5 - resistance store R 33; 6 - Resistance comparator R-3015 (Sun indication blocking); 7 - R-3015 resistance comparator (Block BC); 8 - Scoreboard, which shows the relative error in percent.

2.3.4. Experience «Tab 3»

This tab contains layouts of the R-3015 comparator and one of the resistance magazines, depending on the task (R-33, R-527, MCP-60).

In the experiment, the error of individual decades of store resistance is determined, Figure 3.

2.4. Metrological Characteristics of the Comparator and MMC

2.4.1. Comparator R 3015

Comparator R3015 is designed to determine the relative difference between the resistances of two external discrete or integral resistors that do not have galvanic coupling with each other.

The P3015 device, Figure 3, consists of two blocks: a comparator block and a digital block. Type of start - manual and automatic. The comparator provides automatic selection of the polarity and limits of the measured relative error δ: ±0.01; 0.1; one; ten; 100%. %.

The resulting relative error δ of the investigated and reference resistors in % is equal to:

$$\delta = \frac{R_X - R_N}{R_N} 100\%$$

where R_X and R_N are the actual values of the resistances, respectively, of the investigated and reference.

Range of compared resistances (10-2 -10-7) Ohm. Range of automatic selection of relative resistance difference (-100 - +100) %.

The digital display shows: the value of the measurement error δ s floating point, the position of which corresponds to the corresponding limit of the relative error; polarity sign of a certain error.

2.4.2. Technical Characteristics of Resistance Stores (MMS) and Unambiguous Resistance Measures, Table 1.

Unambiguous resistance measures with a nominal value of 0.1; 1, 10, 100 and 1000 Ohm, with a reproduction error limit of ± (0.01%, 0.005) %.

Table 1. *Specifications of resistance magazines.*

Measure type	Class accuracy	Quantity decade	Maximum resistance value, Ohm	Maximum resistance value, Ohm	Initial value, no more, Ohm
P 3026	$0.005/1.5\times10^{-6}$	7	111 111,1	0.01	0,01
P 527	$0.01/1.5\times10^{-6}$	6	11 111.1	0,01	0,012
P 33	$0.2/5\times10^{-6}$	6	99 999,9	0,1	0,06
MCP-60	$0.05/1.2\times10^{-6}$	6	11 111,1	0,1	0,018

3. Method for Determining the Parameters of the Verification Procedure [3, 4]

As quality criteria for verification of MMS use the following from those provided for in MI 187-86: $(\delta_{\text{M}})_{ba}$ - the ratio of the maximum possible the value of the error Δmax MMC, recognized by the results of verification as suitable for use, but in realit not suitable, up to the boundary value of the error of the investigated resistance Δx.

$$(\delta_{\text{M}})_{ba}=\frac{\Delta_{max}}{\Delta_x},$$

P_{bam} - the highest probability of recognizing a good, in fact, not a good MMC.

Permissible criteria values are set by the owner of the measure (specified by the teacher).

To ensure the given values $(\delta_{\text{M}})_{ba}$ and P_{bam} a control tolerance Δ_k is set, with which the results of the error estimate of the measure under study are compared. The value of Δ_k is found by the formula:

$$\Delta_k = \Upsilon \Delta_k$$

where Y - is a coefficient, the value of which is set in accordance with MI 188-86.

4. Order of the Experiment

4.1. Select an Option, Figure 1

Select your number option.

4.2. Press the "Experiment 1" Button

Get the initial data, Figure 1.

"Testing the insulation strength of the measure under study".

Turn on the breakdown unit UPU - 21. By adjusting the power to level 3 kV, wait 1 min and slowly remove the voltage, rnis.2.

4.3. Press the Button "Experiment 2"

Determination of initial resistance and its variations.

On the resistance box P 3026, set the value to 0.06 Ω at verification of resistance magazine type P 33; 0.012 Ω of the R 527 magazine, 0.018 Ω - of the MSR-60 magazine (Figure 3). The initial resistance is measured in the following sequence:

1) set all decades to zero;
2) take calibrator readings;
3) scroll the handles of all ten-day switches several times, set them to zero again and repeat the measurements; thus make 4 measurements;

For each measurement, calculate the initial resistance using the formula:

$$R_{xi} = \frac{\delta_{xi} \cdot R_H}{100} - R_H \text{ Ом}$$

The average value of the initial resistance in Ohms is calculated by the formula:

$$R_N = \frac{1}{4} \cdot \sum_{i=1}^{4} R_{Ni,}$$

Where R_{Nmax} and R_{Nmin} - respectively, the maximum and minimum measured value of the initial resistance, Ohm; the value obtained R_N and ΔR_N must not exceed the allowable value.

4.4. Press the Button "Experiment 3"

Determination of the actual resistance values of a multivalued resistance measure. The element-by-element verification method is used.

4.4.1. Calculation of Verification Error

Calculate the verification error for a given resistance store for each decade. Determine what measure of resistance should be used to be able to carry out verification - a multi-valued measure of resistance (storage R 3026) or an unambiguous measure, provided that the ratio verification errors, to the maximum permissible error of each resistance does not exceed 1/3. If it is necessary to use an unambiguous measure of resistance, it should be remembered that its nominal value must be equal to the maximum value of the decade and must be a multiple of one.

For example. Calculation of the verification error for the resistance of the R 527 magazine, if a magazine of the R-3026 type is used as the reference resistance magazine.

On the X1000 decade for a resistance of 7000 Ω, the permissible relative error should not exceed 0.01%. The allowable relative error of the R-3026 store does not exceed 0.00525%. The permissible relative error of the comparator does not exceed +0.0002%. Therefore, the total error in estimating the resistance of 7000 Ohm is 0.005275%. The ratio of the error in estimating the resistance of 7000 Ohm is 0.5, exceeds 1/3, therefore, the coil should be chosen as a reference measure of comparison nominal 10000 Ohm accuracy class 0.05.

If the reference tool is a resistance store R 3026, then using the element-by-element verification method, the same values of decades are set on the exemplary and test stores.

If coupon funds are unambiguous measures of resistance, it should be remembered that its nominal value must be equal to the maximum value of the decade and must be a multiple of one.

4.4.2. Take Measurements

Set the same resistance values on the reference store and the one under study, Figure 4. Enable comparator.

On the comparator display, the value of the relative error of the resistance under study:

$$\delta_R = \frac{R_X - R_H}{R_H} \cdot 100\%$$

where R_X ta R_N - are the actual values of the resistances of the test and reference resistances, respectively.

Calculate the relative error of the investigated resistance, which is equal to the sum of the comparator readings and the error of the reference measure.

4.4.3. Deciding on the Suitability of the Resistance Store for Use

If the relative error of the resistance does not exceed the allowable value, based on the accuracy class, it is suitable for use.

5. Conclusions

The use of computer technologies in the training of specialists in the specialty "Metrology and measuring equipment" made it possible to:

1) the possibility of providing distance learning, which is used in Nowadays;
2) concentration of knowledge in one product, which directly used for learning;
3) study the methodology and acquire skills for checking resistance measures using a resistance comparator;
4) increasing the activity of studying, since team work is excluded;
5) creation of a unified educational space - the possibility of using these materials in the training of specialists in other specialties;
6) Work continues on computer modeling of methods and measuring instruments for use in the educational process [16].

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