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AN AUTOMATED METHOD FOR INTERCOMPARING A GROUP OF RESISTANCE STANDARDS

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Abstract: To maintain the group of standards it is necessary to periodically compare the members of the group with each other and to obtain a measure of the deviation of the values of the members from the mean of the group. The mean of the group can be calculated by using a set of equations. In the national metrology institute of Turkey this work is carried out to reduce the time for calculation for the resistance measurements. The measurements are done automatically and the results are evaluated by using the computer program. By using this program, compared resistance values, history of the resistors and graph of each resistor are obtained very easily. This program can be adapted to the other group of standards i.e. mass standards, voltage standard cells, capacitance standards.

Keywords: History of resistance, Excel 5.0 Macro

1 INTRODUCTION

The values of resistance standards drift with time due to both microscopic and mechanical strain on the structure. The impurities within the chemical structure of the alloy wire used to construct the standard resistors cause the microscopic changes. The mechanical strains or stresses are present due to the slight stretching of the wire during the winding construction. This causes the wire dimensions to continuously change and hence the resistivity and resistance value of the resistance standard drifts. If only one or two resistors are kept as a reference than the drift can not be detected. At least three resistors must be in a group so that which resistor shifts in the group can be detected [1]. A group used in the UME Resistance Laboratory contains well qualified five resistance standards with the same nominal value so that the risk of losing the group average by the fail of the one of the group element can be eliminated.

The group mean value was calculated manually by using a set of equations and these calculations were taking so much time [2]. Automation of the calculation of the group mean and the individual resistance values reduce the time needed for this procedure.

2 CALCULATION OF THE GROUP MEAN

The calculation of the mean for a group of standards can be achieved by sending one of the resistors away for regular intercomparisons at least once a year. Once this resistor has been calibrated it can be re-joined with the original group and a new group mean value assigned. This group mean will be of better accuracy than direct comparison method accuracy. The calculation of this mean value is as follows; each of the other group members are compared with the calibrated resistor R_5 and obtain the following equations (1), (2) and (3) are obtained,

$R_1/R_5=s_1$

⋮

$R_5/R_5=1$

The mean value is calculated as seen below,

$$R_m = \sum_1^5 R_i/5 = (s_1.R_5 + s_2.R_5 + s_3.R_5 + s_4.R_5 + R_5)/5 \quad (1)$$

$$R_m = R_5(1 + s_1 + s_2 + s_3 + s_4)/5 \quad (2)$$

$$R_m = R_5(1 + \sum_1^4 s_i)/5 \quad (3)$$

3 INTERCOMPARISON METHOD OF THE STANDARD RESISTORS

The way that the resistors are compared is to measure the small differences in value between the members of the group. When a set of standards R_1, R_2, R_3, R_4, R_5 are to be intercompared a set of intercomparison equations must be derived, where care is taken to include all possible combinations of measurements, but only once. A ratio of $R_1\backslash R_2$ is treated to be identical to $R_2\backslash R_1$. The deviation of R_1, R_2, etc. from the accepted or assigned mean value R_m can be easily determined by arranging the results from the intercomparison equations in a simple tabular form as shown below in Table 1:

Table 1.

A / B	R_1	R_2	R_3	R_4	R_5
R_1	0	$-a_1$	$-a_1'$	$-a_1''$	$-a_1'''$
R_2	a_1	0	$-a_2$	$-a_2'$	$-a_2''$
R_3	a_1'	a_2	0	$-a_3$	$-a_3'$
R_4	a_1''	a_2'	a_3	0	$-a_4$
R_5	a_1'''	a_2''	a_3'	a_4	0
	S_1	S_2	S_3	S_4	S_5
R_x-R_m	M_1	M_2	M_3	M_4	M_5

Where S_1, S_2 etc represent the vertical column sums for R_1, R_2 etc and M_1, M_2 etc the mean values (M=S/n) and "a" refers to the difference of the ratio from the unity. The difference a_1, a_2 etc in the original equations are introduced to in this table with signs so that A-B represents a positive difference and hence results with correct sign designations are obtained by adding the each vertical column and dividing by the number of unknowns. The lower left triangular part in the table thus contains the observation values $a_1=(R_1\backslash R_2) - 1$ etc without sign reversal, whereas the upper portion of the table contains the same observations with sign reversal.

The above calculations enables the calculations of differences of R_1, R_2 etc with respect to the mean value R_m. Any of the values can, however, be calculated and expressed in absolute terms either with knowledge of R_m which may be assigned value for the group of standards or by comparison of any quantities present R_1, R_2 etc with a known standard [2].

4 AUTOMATIC SCANNING OF THE RESISTORS USING 6010B SOFTWARE AND EXCEL PIVOT TABLE AS A MINI DATABASE

The measurements of the resistors are automatically performed with Measurement International model 6010B Automatic Resistance Bridge. The comparisons of the five 1 ohm resistors are done by using the MI software program “Group99.prg” and the measurement results are saved in a history file “Group99.his”. Group99.his file contains the comparison results of each individual resistance standards in the group compared with each other. For every measurement, the R_x (unknown) and R_s(standard) positions are reversed and another set of measurements are taken in this configuration.

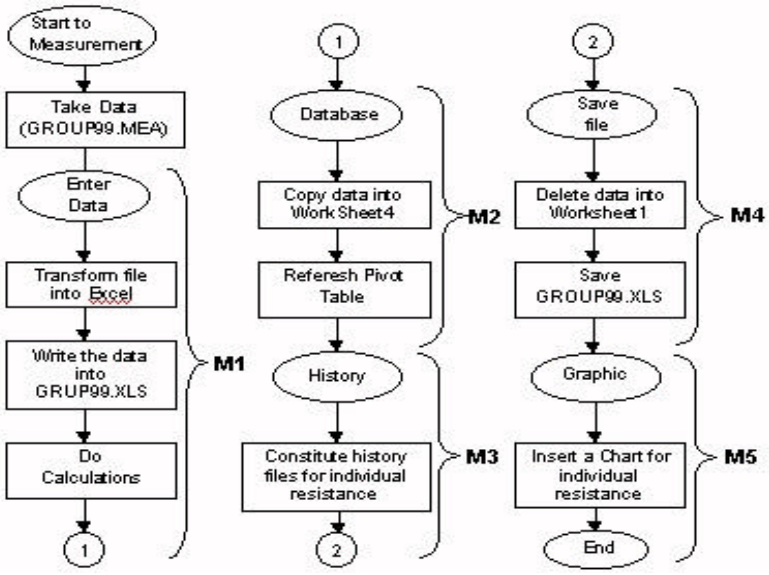


Figure 1. Flow chart of the Excel macro program

Five excel macros constitutes the program which have different operations. The flow chart of the program is shown in figure 1. The functions of the buttons are defined respectively. After the measurement scans have been run, the results are automatically read into an Excel 5.0 worksheet from history file of the MI program and this is performed by pressing the “Import data” button (figure 2) [3].

	A	B	C	D	E
1	26.10.1999				Import Data
2	Data	Normal	Reverse	Average	
3	R1/R2	1,000007753	0,999992252	1,000007751	
4	R1/R3	1,000009012	0,999990896	1,000009058	Database
5	R1/R4	1,000008143	0,999991778	1,000008183	
6	R1/R5	1,000006409	0,999993504	1,000006453	
7	R2/R3	1,000001279	0,999998734	1,000001273	History
8	R2/R4	1,000000406	0,999999616	1,000000395	
9	R2/R5	0,9999986	1,00000135	0,999998625	
10	R3/R4	0,999999106	1,000000878	0,999999114	Save
11	R3/R5	0,999997393	1,000002604	0,999997395	
12	R4/R5	0,999998206	1,000001739	0,999998234	
13					Graphic
14					
15					

Figure 2. Worksheet view after import data from MI measurement program

These data are transferred to the sheet 3 to make some calculations that is mentioned before on section 3.

Difference of the resistance value from the nominal value

	R1	R2	R3	R4	R5
-R1	0	-7,75E-06	-9,10E-06	-8,22E-06	-6,50E-06
-R2	7,75E-06	0	-1,27E-06	-3,84E-07	1,35E-06
-R3	9,01E-06	1,28E-06	0	8,78E-07	2,60E-06
-R4	8,14E-06	4,06E-07	-8,94E-07	0	1,74E-06
-R5	6,41E-06	-1,40E-06	-2,61E-06	-1,79E-06	0

Resistance Values

R1	(Leeds&Northrup / Sn: 1616956) =	1,000001
R2	(Leeds&Northrup / Sn: 1616961) =	0,999993
R3	(Leeds&Northrup / Sn: 1758733) =	0,999992
R4	(Leeds&Northrup / Sn: 1616900) =	0,999993
R5	(Leeds&Northrup / Sn: 1616936) =	0,999995

Difference of the resistance value from the group mean value

R1	(Leeds&Northrup / Sn: 1616956)	6,2634	ppm
R2	(Leeds&Northrup / Sn: 1616961)	-1,4926	ppm
R3	(Leeds&Northrup / Sn: 1758733)	-2,7742	ppm
R4	(Leeds&Northrup / Sn: 1616900)	-1,9044	ppm
R5	(Leeds&Northrup / Sn: 1616936)	-0,1606	ppm

Group mean value = 0,99999476

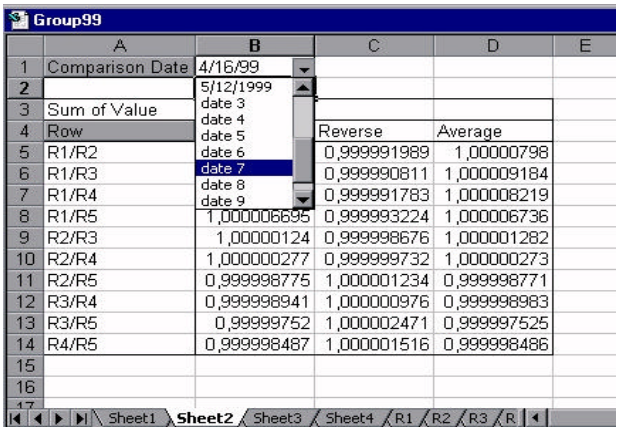
Daily drift	364
Today Date	24.12.1999
Reference resistance value	0,99999199

Figure 3. Resistance values are calculated after import data in an other worksheet

In this sheet as seen from figure 3 the difference of the resistance ratios from the nominal value is calculated. By using these values the difference of the each resistance value from the group mean is calculated (M_1, M_2, etc). The reference resistance value is calculated according to daily drift from the certificate value. Finally the group of the standard resistance values are obtained by adding the group mean value to the calculated M value.

Then pressing the “Database” button runs another macro to save these data into a database worksheet. These values are copied in to the Pivot Table that is shown in figure 4. By using this table previous measurement results can be obtained by choosing the previous measurement dates which is desired.

History files are formed for each resistance by pressing the “History” button. The calculated resistance values and dates are saved into sheet R1, R2, etc for each standard resistance. It is important to have a history file for maintenance of the resistance standard to predict the future resistance values. After the resistance history saved to the file by pressing “Save” button, the graphic of each resistance can be obtained with the “Graphic” button.



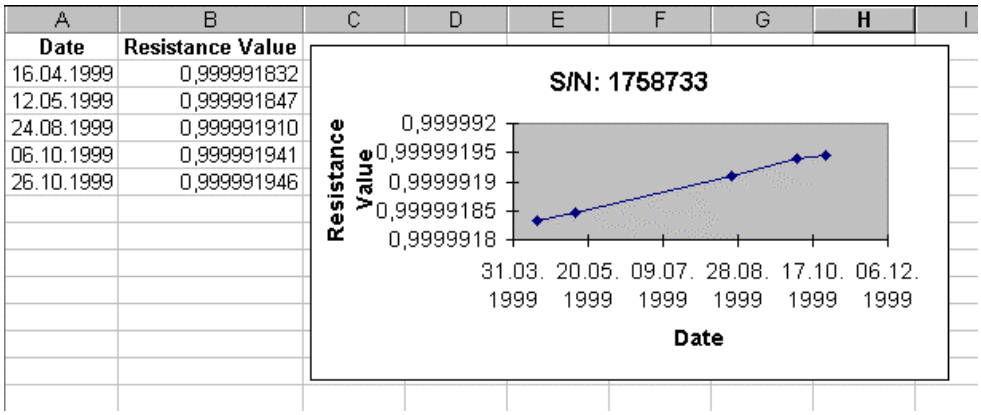
Group99

	A	B	C	D	E
1	Comparison Date	4/16/99			
2		5/12/1999			
3	Sum of Value	date 3			
4	Row	date 4	Reverse	Average	
5	R1/R2	date 5	0,999991989	1,00000798	
6	R1/R3	date 6	0,999990811	1,000009184	
7	R1/R4	date 7	0,999991783	1,000008219	
8	R1/R5	date 8	0,999993224	1,000006736	
9	R2/R3	date 9	0,999998676	1,000001282	
10	R2/R4	1,000000277	0,999999732	1,000000273	
11	R2/R5	0,999998775	1,000001234	0,999998771	
12	R3/R4	0,999998941	1,000000976	0,999998983	
13	R3/R5	0,99999752	1,000002471	0,999997525	
14	R4/R5	0,999998487	1,000001516	0,999998486	
15					
16					

Sheet1 | Sheet2 | Sheet3 | Sheet4 | R1 | R2 | R3 | R

Figure 4. Excel 5.0 Pivot Table that contains resistance comparison results

So, the change in the resistance value or abnormalities can be seen easily by looking graph. Figure 5 shows an example for one of the group resistance value and measurement date and its graph according to these measurement results.



	A	B
1	**Date**	**Resistance Value**
2	16.04.1999	0,999991832
3	12.05.1999	0,999991847
4	24.08.1999	0,999991910
5	06.10.1999	0,999991941
6	26.10.1999	0,999991946

Figure 5. Graph of the standard resistance according to the history file

5 CONCLUSIONS

This paper has outlined a method of automatic calculation of the individual resistance values of 1Ω group by using a set of equation and creation of history files for each resistance value by using Excel 5.0 macro program. By making some small changes on the program, it was adopted to the 10kΩ group of resistance standards. So, the operator time required to perform these calculations has been reduced to minimum. This program supports the scientific and industrial measurements, which should be performed to have full confidence that the unit of the measurement can be constant over the year. This program can be adapted to the maintenance of mass standards, voltage standard cells and other working group of standards.

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