

## EVALUATION OF MEASUREMENT UNCERTAINTY FOR STANDARD RESISTORS

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**Abstract:** As for the evaluation of uncertainty in calibration of 100 MΩ standard resistor in Japan Electric Meters Inspection Corporation (JEMIC), the number of repetition of measurement is small, so the variation of measurement dominant and coverage factor becomes 2 or more. The result which was examined concerning the uncertainty evaluation method is reported in this paper.

**Keywords:** Dispersion of measurement, DC Resistance, Standard Resistor.

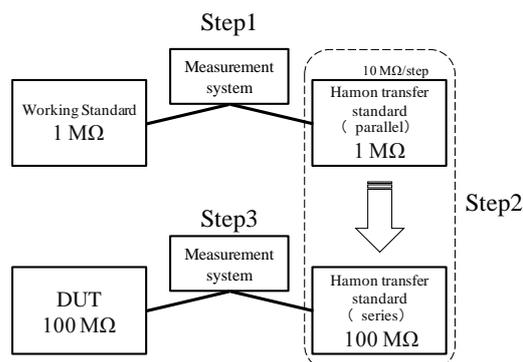
### 1. INTRODUCTION

Calibration of a 100 MΩ standard resistor has been carried out by using of the 1 MΩ working standard as a reference. Furthermore, Calibration and Measurement Capabilities (CMC) of 100 MΩ in the Japan Calibration Service System (JCSS) calibration of JEMIC is reported as 6 ppm ( $k=2$ ). With this case, the fact that is an evaluation on the basis of the primary factor of the uncertainty which originates in the equipment is also added.

### 2. MEASUREMENT METHOD

**Figure 1** shows the traceability system of DC resistance in Japan. In the present experiment, following method and procedure are introduced. (See **Figure 2**.)

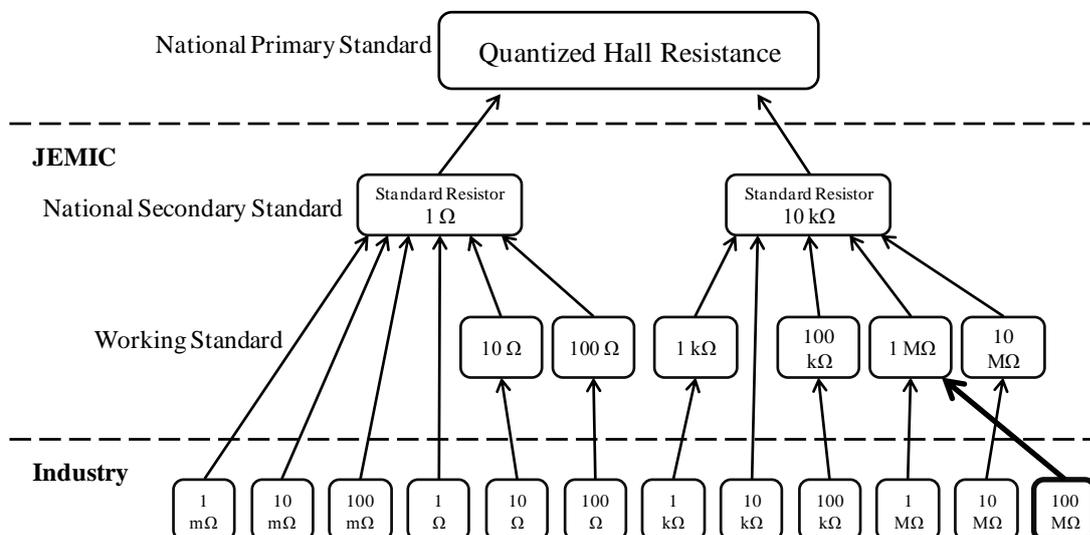
- Step1. Comparison working standard of 1 MΩ and Hamon transfer standard of 1 MΩ are set up in parallel.
- Step2. Connect Hamon transfer standard in series and set to 100 MΩ.
- Step3. Device under test (DUT) of 100 MΩ and Hamon transfer standard of 100 MΩ are set up in comparison



**Figure 2** Measurement method of DUT 100 MΩ

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**Figure 1** The traceability system of DC resistance

### 3. MEASUREMENT MODEL

Calibration values of DUT are given by the following equations.

$$R_4 = R_5 - R_3 + R_2 .$$

$$f(R) = R_x = R_1 - R_6 + R_4 = R_1 - R_6 + R_5 - R_3 + R_2 \quad (1)$$

where,

- $R_x$  : The calibration value of DUT
- $R_1$  : The reading value of DUT
- $R_2$  : Calibration value of measurement standard
- $R_3$  : The reading value of measurement standard
- $R_4$  : Calibration value of Hamon transfer standard
- $R_5$  : The reading value for the parallel connection of Hamon transfer standard

$R_6$  : The reading value for the series connection of Hamon transfer standard

Relational expression is written as follows:

$$u_c^2(R_x) = \left(\frac{\partial f(R)}{\partial R_1}\right)^2 u^2(R_1) + \left(\frac{\partial f(R)}{\partial R_2}\right)^2 u^2(R_2) + \left(\frac{\partial f(R)}{\partial R_3}\right)^2 u^2(R_3) + \left(\frac{\partial f(R)}{\partial R_5}\right)^2 u^2(R_5) + \left(\frac{\partial f(R)}{\partial R_6}\right)^2 u^2(R_6)$$

### 4. SOURCES OF UNCERTAINTY

Uncertainty sources can be classified as follows:

- 1) The uncertainty which originates in reading the measuring system :  $u_m$ 
  - a) Dispersion of measurement data (Repeatability) :  $u_{m1}$
  - b) Uncertainty of measurement resolution of measuring system :  $u_{m2}$
  - c) Uncertainty of linearity in measuring system :  $u_{m3}$
  - d) Uncertainty of stability after the zero adjusting of the galvanometer :  $u_{m4}$
- 2) The uncertainty which originates in the calibration value of the measurement standard :  $u_s$ 
  - a) Calibration uncertainty :  $u_{s1}$
  - b) Uncertainty of long-term stability :  $u_{s2}$
  - c) Uncertainty of temperature dependence :  $u_{s3}$
- 3) The uncertainty which originates in the resistance ratio of Hamon transfer standard :  $u_r$

a) Uncertainty of parallel/serial resistance ratio :  $u_{r1}$

### 5. EXAMINATION CONTENTS

With calibration procedure of 100 MΩ standard resistor, there is no working standard of the same rating. Therefore, there are plural processes in the measurement at the same time.

In the cases of using the analog measuring system, measurement can be done in high accuracy. In addition, the effect of operators can be considered. Then, the degree of freedom, coverage factor and uncertainty of measurement can be examined experimentally. **Table 1** shows an example of uncertainty budget for 100 MΩ standard resistor obtained in JEMIC.

### 6. EXAMINATION RESULT AND CONCLUSION

In the future, the examination shown below can be done.

- a) The numerical value of degree of freedom has to be enlarged making use of the pooled data.
- b) Evaluation of the dispersion of measurement at management interval, infinity with its degree of freedom.
- c) The use of working standards of resistors may simplify the measuring procedure and increase the frequency of measurement.
- d) As for the influence quantity to the industry, it is small and numerical value of the uncertainty becomes large.

### 7. REFERENCES

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**Table 1 An example of uncertainty budget**

Standard uncertainty $u(x_i)$	Sources of uncertainty	Value of standard uncertainty $u(x_i)$	Type of distribution	$c_i \equiv \frac{\partial f}{\partial x_i}$	$u(y) \equiv \left  c_i \right  u(x_i)$	Degree of freedom $\nu_i$	Note
$u_m$	The uncertainty which originates in reading the measuring system	2.33E-6		1	2.33E-6	2	
$u_{m1}$	Dispersion of measurement data (Repeatability)	2.31E-6	Normal			3	3 measurements
$u_{m2}$	Uncertainty of measurement resolution of measuring system	2.89E-7	Rectangular			∞	
$u_{m3}$	Uncertainty of linearity in measuring system	3.46E-10	Rectangular			∞	
$u_{m4}$	Uncertainty of stability after the zero adjusting of the galvanometer	5.77E-8	Rectangular			∞	
$u_s$	The uncertainty which originates in the calibration value of the measurement standard	7.37E-7		1	7.37E-7	∞	
$u_{s1}$	Calibration uncertainty	7.00E-7	Normal			∞	1 MΩ working standard
$u_{s2}$	Uncertainty of long-term stability	2.31E-7	Rectangular			∞	Calibration certificate
$u_{s3}$	Uncertainty of temperature dependence	3.60E-9	Rectangular			∞	Past record (2001~2010) Temperature coefficient and temperature environment
$u_r$	The uncertainty which originates in the resistance ratio of Hamon transfer standard						
$u_{r1}$	Uncertainty of parallel/serial resistance ratio	1.15E-6	Rectangular	1	1.15E-6	∞	
		Combined variance		$u_c^2(y) = \sum u_i^2(y) = 7.30E-12$			
		Combined standard uncertainty		$u_c(y) = 2.701E-6$			
		Effective degree of freedom		$\nu_{eff}(y) = 4$			
		Coverage factor		$k = 2.85$			
		Expanded uncertainty		$U = k \times u_c(y) = 7.71E-6$			
		Calibration uncertainty (Relative ratio)		$U = 8E-6$		( 8 ppm )	