



National Accreditation Board for Testing and Calibration Laboratories (NABL)

Sample Calculations for Measurement Uncertainty in Electrical Testing

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AMENDMENT SHEET

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National Accreditation Board for Testing and Calibration Laboratories			
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1. INTRODUCTION

In the broad field of Electrical Engineering, various equipment and systems are used to cater to the application for Electrical power generation, transmission, distribution, control, instrumentation, Communication and domestic application. Each one of the products/ equipment requires a wide variety of tests and hence a need of specialized testing facility.

The field of Electrical Testing covers tests of an essentially electrical nature performed on instruments, equipment, appliances, components and materials.

As per the requirements of clause 7.6 of ISO/ IEC 17025: 2017, the testing laboratories are required to evaluate the Measurement Uncertainty.

When estimating the Measurement Uncertainty, all uncertainty components which are of importance in the given situation shall be taken into account, which shall include but not be limited to:

- a. reference standards and reference materials with reported uncertainty in the calibration certificate(s)
- b. method employed
- c. equipment used with reported uncertainty in the calibration certificate(s)
- d. environmental conditions
- e. properties and condition of the item being tested

The testing laboratories shall identify all the components of uncertainty and make a reasonable estimation for all test parameters, and shall ensure that the form of reporting of the result does not give a wrong impression of the uncertainty. The degree of rigor needed in an estimation of Measurement Uncertainty depends on the requirements of test method, requirements of client and the existence of narrow limits on which decisions on conformance to a specification are based.

All laboratories will calculate the uncertainty of measurement at 95% confidence level.

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2. SCOPE

As per the requirements of clause 7.6 of ISO/ IEC 17025: 2017, the testing laboratories are required to evaluate the Measurement Uncertainty. This document guides the laboratory to evaluate the Measurement Uncertainty for Electrical Testing.

A few examples of Measurement Uncertainty in the field of Electrical Testing have been illustrated in this document.

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Sample 1

UNCERTAINTY CALCULATION FOR VOLTAGE (at Power frequency)

Product	:	MCB, 32 A, 240/ 415V, Single pole
Test	:	Short circuit test of MCB
Equipment used	:	Digitizer with Amplifier
Range used for calibration	:	62.5 –1000 Volt
Accuracy	:	0.16 % of Reading
Uncertainty of Digitizer with Amplifier from its calibration certificate	:	0.281 %
Resolution	:	0.0001 Volt

Reading No.	Voltage (Volts)
1	250.2
2	250.3
3	250.1
4	250.2
5	250.3

Assuming contribution due to frequency is negligible

Type A Evaluation

Mean Rdg. (Volts)	=	250.22 Volts	$(R_1+R_2+R_3+R_4+R_5)/ 5$
Standard deviation	=	0.0836 Volts	
Std. uncertainty U_r	=	0.0374 Volts	Standard Deviation/ sqrt (5)
Degree of freedom	=	$V_1 = 5-1 = 4$	
Std. uncertainty (% U_r)	=	0.0149 %	$U_r *100/ \text{Mean Reading}$

Type B Evaluation

1. Uncertainty of Digitizer with Amplifier from its calibration certificate. The distribution is normal and the coverage factor for approximately 95% confidence level is 2

$$U_1(\%) = A_1 / 2 = 0.281 / 2 = 0.141 \%$$

$$U_1 = 0.141 * 250.22 * 0.01 = 0.352 \text{ Volts}$$

$$\text{Estimate} = 0.281 * 250.22 * 0.01 = 0.703 \text{ Volts}$$

Degree of freedom $V_2 = \text{infinity}$

2. Accuracy of Digitizer with Amplifier

$$A_2 = 0.16 \% \text{ of reading} = 0.16 * 250.22 * 0.01 = 0.400 \text{ Volts} = \text{Estimate}$$

For rectangular distribution, the standard uncertainty = $U_2 = A_2 / \sqrt{3}$

$$U_2 = 0.231 \text{ Volts}$$

$$\% U_2 = 0.0924 \% \quad U_2 * 100 / \text{Mean Reading}$$

Degree of freedom $V_3 = \text{infinity}$

3. Uncertainty due to resolution of display unit = U_3

$$A_3 = 0.0001 / 2 = 0.00005 \text{ Volts} = \text{Estimate}$$

For rectangular distribution, the standard uncertainty = $U_3 = A_3 / \sqrt{3}$

$$U_3 = 0.000028 \text{ Volts}$$

$$\% U_3 = 0.0000115 \% \quad U_3 * 100 / \text{Mean Reading}$$

Degree of freedom $V_4 = \text{infinity}$

Combined standard uncertainty (U_c)

$$U_c = \sqrt{(U_r \cdot U_r) + (U_1 \cdot U_1) + (U_2 \cdot U_2) + (U_3 \cdot U_3)}$$

$$U_c = 0.423 \text{ Volts}$$

$$\% U_c = 0.169 \% \quad U_c \cdot 100 / \text{Mean Reading}$$

Effective degrees of freedom (v_{eff}) =

$$v_{\text{eff}} = \frac{(U_c)^4}{\frac{(U_1)^4}{V_2} + \frac{(U_2)^4}{V_3} + \frac{(U_3)^4}{V_4} + \frac{(U_r)^4}{V_1}}$$

$$v_{\text{eff}} = \frac{(0.169)^4}{\frac{(0.0149)^4}{4} + \frac{(0.141)^4}{\infty} + \frac{(0.0924)^4}{\infty} + \frac{(0.0000115)^4}{\infty}}$$

$$v_{\text{eff}} = \frac{(0.169)^4}{\frac{(0.0149)^4}{4} + 0}$$

$$v_{\text{eff}} = \infty$$

Expanded Uncertainty at approximately 95% level of confidence, the coverage factor $k=2$, Thus

$$U = k \cdot U_c = 2 \cdot 0.423 \text{ Volts}$$

$$U = 0.85 \text{ Volts}$$

$$\% U = 0.34 \% \quad U \cdot 100 / \text{Mean Reading}$$

Uncertainty Budget

Source of Uncertainty X_i	Estimates x_i	Limits %	Probability Distribution Type A or B Factor	Standard Uncertainty (Volts)		Sensitivity Coefficient C_i	Uncertainty Contribution $U_i (y)$		Degree of freedom V_i
				Volts	%		Volts	%	
U_1		0.281	Normal type B – $k=2$	0.352	0.141	1.0	0.352	0.141	Infinity
U_2		0.16	Rectangular Type B $\sqrt{3}$	0.231	0.0924	1.0	0.231	0.0924	Infinity
U_3		0.000019	Rectangular Type B $\sqrt{3}$	0.000028	0.0000115	1.0	0.000028	0.0000115	Infinity
Repeatability (U_r)	250.22	--	Normal Type A	0.0374	0.0149	1.0	0.0374	0.0149	4
U_c				0.423	0.169		0.423	0.169	Infinity
Expanded Uncertainty (U)			$k = 2$				0.85	0.34	Infinity

Reporting of results:

Voltage = 250.22 Volts $\pm$ 0.85 Volts

Sample 2

UNCERTAINTY CALCULATION FOR CURRENT (at power frequency)

Product : MCCB, 800 A, 415V, Four pole
Test : Short circuit test of MCCB
Equipment used :

1) Digitizer with Amplifier

Range used for calibration : 0.625 –10 Volts
Accuracy : 0.19 % of Reading
Uncertainty of Digitizer with Amplifier from its : 0.281 %
calibration certificate
Resolution : 0.0001 V

2) Shunt

Uncertainty of shunt (%) from its calibration : 1.156
certificate

Reading No.	Current (kAmp.)
1	50.26
2	50.23
3	50.28
4	50.24
5	50.23

Assuming contribution due to frequency is negligible

Type A Evaluation

Mean Rdg. (kAmp.) = 50.248 (kAmp.) $(R_1+R_2+R_3+R_4+R_5)/5$
Standard deviation = 0.0216 (kAmp.)
Std. uncertainty U_r = 0.00969 (kAmp.) Standard Deviation/ $\sqrt{5}$
Degree of freedom = $V_1 = 5-1 = 4$
Std. uncertainty (% U_r) = 0.0193 % $U_r * 100 / \text{Mean Reading}$

Type B Evaluation

1. Uncertainty of Digitizer with Amplifier from its calibration certificate. The distribution is normal and the coverage factor at approximately 95% confidence level is 2

$$U_1(\%) = A_1 / 2 = 0.281 / 2 = 0.141 \%$$

$$U_1 = 0.141 * 50.248 * 0.01 = 0.0708 \text{ kAmp.}$$

$$\text{Estimate} = 0.281 * 50.248 * 0.01 = 0.1412 \text{ kAmp.}$$

$$\text{Degree of freedom } V_2 = \text{infinity}$$

2. Digitizer with Amplifier Accuracy

$$A_2 = 0.19\% \text{ of reading} = 0.19 * 50.248 * 0.01 = 0.09547 \text{ kAmp.} = \text{Estimate}$$

$$\text{For rectangular distribution, the standard uncertainty} = U_2 = A_2 / \sqrt{3}$$

$$U_2 = 0.0551 \text{ kAmp.}$$

$$\% U_2 = 0.109 \% \quad U_2 * 100 / \text{Mean Reading}$$

$$\text{Degree of freedom } V_3 = \text{infinity}$$

3. Uncertainty due to resolution of display unit = U_3

$$A_3 = 0.0001 / 2 = 0.00005 \text{ kAmp.} = \text{Estimate}$$

$$\text{For rectangular distribution, the standard uncertainty} = U_3 = A_3 / \sqrt{3}$$

$$U_3 = 0.000028 \text{ kAmp.}$$

$$\% U_3 = 0.000057 \% \quad U_3 * 100 / \text{Mean Reading}$$

$$\text{Degree of freedom } V_4 = \text{infinity}$$

4. Uncertainty of shunt from its calibration certificate. The distribution is normal and the coverage factor for approximately 95% confidence level is 2.

$$U_4 (\%) = A_4 / 2 = 1.156 / 2 = 0.578 \%$$

$$U_4 = 0.578 * 50.248 * 0.01 = 0.290 \text{ kAmp.}$$

$$\text{Estimate} = 1.156 * 50.248 * 0.01 = 0.580 \text{ kAmp.}$$

$$\text{Degree of freedom } V_5 = \text{infinity}$$