

**ESTIMATION OF THE UNCERTAINTY OF MEASUREMENT BY
CALIBRATION LABORATORIES AND SPECIFICATION OF
CALIBRATION AND MEASUREMENT CAPABILITY ON
SCHEDULES OF ACCREDITATION**

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Table of Contents

	Page
1. PURPOSE AND SCOPE.....	3
2. DEFINITIONS.....	3
3. UNCERTAINTY OF MEASUREMENT.....	5
4. CALIBRATION AND MEASUREMENT CAPABILITY.....	6
5. REFERENCES.....	7
APPENDIX – AMENDMENT RECORD.....	8

1. **PURPOSE AND SCOPE**

This document defines the policy for the estimation of uncertainty of measurement by calibration laboratories and the determination and specification of the Calibration and Measurement Capability. The document is not intended to be a guidance document on the estimation of measurement uncertainty, a number of which are already freely available on the internet. However, where appropriate, additional guidance on the interpretation of certain requirements has been provided in this document.

This document is applicable to all accredited calibration laboratories and testing laboratories performing their own calibration.

2. **DEFINITIONS**

2.1 **Best existing device**

The term “best existing device” is understood as a device to be calibrated that is commercially or otherwise available for customers even if it has a special performance (stability) or has a long history of calibration.

2.2 **Measurement Uncertainty**

The parameter associated with the result of a measurement that characterizes the dispersion of the values which could be attributed to the measurand.

2.3 **Measurand**

The measurand is defined as the “particular quantity subject to measurement”.

2.4 **Calibration and Measurement Capability (CMC)**

A CMC is a calibration and measurement capability available to customers under normal conditions:

- a) As described in the laboratory ‘s scope of accreditation granted by a signatory to the ILAC Arrangement; or
- b) As published in the BIPM Key Comparison Database (KCDB) of the CIPM MRA.

2.5 **Combined standard uncertainty**

The Standard uncertainty of a result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms being the variances or co-variances of these other quantities weighted according to how the measurement result varies with changes in these quantities.

2.6 Correlation

The relationship between two or several random variables within a distribution of two or more random variables.

2.7 Coverage Factor

The numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty. Note that a coverage factor k is typically in the range 2 to 3.

2.8 Experimental Standard Deviation of the Mean (ESDM)

The ESDM is an estimate of the standard deviation of the means from repeated sets of measurements.

2.9 Expanded Uncertainty

The quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could be, with a certain level of confidence, attributed to the measurand.

2.10 Repeatability of Results of Measurements

The closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions.

2.11 Repeatability of a Measuring Instrument

The ability of a measuring instrument to provide closely similar indications or repeated applications of the same measurand under the same conditions of measurement.

2.12 Reproducibility Condition of Measurement

The condition of measurement, out of a set of conditions that includes different locations, operators, measuring systems and replicate measurements on the same or similar objects.

2.13 Standard Uncertainty

The uncertainty of the result of a measurement expressed as a standard deviation

2.14 Type A Evaluation of Uncertainty

The method of evaluation of uncertainty by the statistical analysis of series of observations.

2.15 Type B Evaluation of Uncertainty

Method of evaluation of uncertainty by means other than the statistical analysis of series of observations.

2.16 Uncertainty of Measurement

Parameter associated with the result of a measurement that characterizes the dispersion of the values that could, with a certain level of confidence be attributed to the measurand.

3. UNCERTAINTY OF MEASUREMENT

- 3.1 All calibration laboratories and testing laboratories performing their own calibrations shall have and apply a procedure for the estimation of the uncertainty of measurement.
- 3.2 Measurement units and measurement standards shall be traceable to an unbroken chain of comparisons stating appropriate uncertainties of measurement. Refer to SADCAS TR 02, TR 09 and ILAC P 10.
- 3.3 The estimation of the uncertainty of measurement shall include the identification of, and analysis of all known components of importance. The degree of rigour applied to the estimation of the measurement uncertainty should be appropriate to the intended purpose of the calibration based on the customer requirements.
- 3.4 In general laboratories shall use the guidelines as specified in the **GUM** as the basis for the preparation of their procedure on the estimation of the uncertainty of measurement. These principles are expanded on in various interpretation documents such as EAL-R2 "Assessment of uncertainties of measurement in calibration"; M3003 "The expression of uncertainty and confidence in measurement". In exceptional cases other internationally recognized methodologies may be applied.
- 3.5 It is recommended that the data relevant to the determination of the uncertainty of measurement including quantities, standard uncertainties and sensitivity coefficients be available in clear, unambiguous format such as in a spreadsheet or tabular format.
- 3.6 Laboratories may elect to perform uncertainty of measurement calculations using computerized spreadsheets. In such cases the laboratory shall ensure that the spreadsheets are suitably documented, validated and protected against unauthorized changes.
- 3.7 Certain electronic calculators used in the statistical mode are prone to errors due to rounding; this may become evident in the calculation of standard deviation when the calculation returns an incorrect result. Appropriate methods shall be applied to circumvent these calculation errors.
- 3.8 SADCAS approved Technical Signatories shall be competent to evaluate and interpret the results of uncertainty of measurement spreadsheet calculators to confirm their correctness.
- 3.9 When input quantities are not independent and are correlated such as in the case when standard resistors are connected in series or several mass pieces are used to produce a combined mass, then the combined uncertainty shall be the algebraic sum of the uncertainties unless the laboratory can produce evidence of the degree of correlation, the uncertainties may then be combined using the correlation coefficient.

3.10 If an uncertainty assessment involves a single Type A evaluation and the number of readings, n , is greater than 2 ($n \geq 3$) and the combined standard uncertainty is more than twice ($\times 2$) the type A Uncertainty; or the number of readings, n , is greater than 4 ($n \geq 5$) and the combined standard uncertainty is greater than 1.5 times ($\times 1.5$) the type A uncertainty, then $k = 2$ will provide a coverage probability of approximately 95% and thus there is no need to apply the Welch-Satterthwaite equation to determine the effective degrees of freedom V_{eff} and the coverage factor k .

3.11 When conditions are not repeatable, the inappropriate use of ESDM as a measure of the Type A uncertainty may result in an underestimation of measurement uncertainty and should therefore be used after due consideration. For example, when a torque wrench is used in practice, the device is not used repeatedly to torque the same bolt and the torque applied to a bolt is the result of a single measurement and not the mean of a set of measurements. The same principle is applicable to other types of measurement tools used in industry.

In addition, in instances where the number of repeated measurements is small, the reliability of Type A evaluation has to be considered and the option of using other means of evaluating the standard uncertainty should be considered.

3.12 The uncertainty of measurement shall not be reported to more than 2 significant digits. When calculating the CMC the uncertainty of measurement shall always be rounded up unless the rounding reduces the uncertainty by less than 5%.

Rounding should always be carried out at the end of the process in order to avoid the effects of cumulative rounding errors.

4. CALIBRATION AND MEASUREMENT CAPABILITY

4.1 The Calibration and Measurement Capability (CMC) is represented on the schedule of accreditation issued by SADCAS. The CMC is expressed in terms of:

- a) Measurand or reference material;
- b) Calibration/measurement, method/procedure and/or type of instrument to be calibrated or measured;
- c) Measurement range and additional parameters where applicable, e.g. frequency of applied voltage; and
- d) Uncertainty of measurement.

4.2 The uncertainty of measurement represented as part of the CMC represents the smallest uncertainty of measurement that a laboratory can claim for any measurement or calibration performed and reported in a certificate which makes reference to accreditation and/or includes the accreditation symbol.

4.3 The CMC uncertainty is stated as an expanded uncertainty with a coverage probability of approximately 95%.

- 4.4 When the uncertainty of measurement is dependent upon an additional parameter, e.g. frequency, the additional parameter shall be stated together with the physical quantity in question and the specified CMC shall take cognisance of this additional parameter. This may be accomplished by specifying the CMC as a function of these parameters.
- 4.5 All components contributing significantly to the uncertainty of measurement including the drift between subsequent calibrations of the measurement standard shall be taken into account when evaluating the measurement capability.
- 4.6 The determination of the uncertainty of measurement for the purposes of the establishment of the CMC uncertainty shall include at least the uncertainty contribution from a “best existing device” to be calibrated.
- 4.7 When the accreditation schedule includes a range of measurement for a specified parameter, the laboratory shall be capable of achieving the CMC uncertainty throughout the specified range. In instances where this is not possible sub-ranges, single values or a matrix shall be introduced with separate CMC’s specified for the individual sub-ranges or single values or matrix entries.
- 4.8 Applicant laboratories and laboratories wishing to have changes made to their laboratories CMC’s shall submit an Uncertainty of Measurement calculation in support of the requested CMC.
- 4.9 Laboratories who fail to demonstrate the ability to produce acceptable measurement results as evidenced through proficiency testing and the planned audit programme may at the discretion of SADCAS have their measurement capability increased to a level which would result in an EN value of less than 0.9 (absolute).

5. REFERENCES

- EAL-R2 Expression of the uncertainty of measurement in calibration, European co-operation for Accreditation
- ILAC P14 ILAC Policy for uncertainty in calibration
- ISO 3534: Part 1 Statistics – Vocabulary and Symbols, Part 1 – General Statistical terms and terms used in probability
- ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories
- ISO 80000: Part 1 Quantities and Units – Part 1: General
- JCGM 100 GUM 1995 with minor corrections, Evaluation of measurement data - Guide to the expression of uncertainty in measurement
- JCGM 200 International Vocabulary of Metrology – Basic and General concepts and associated terms (VIM)
- M3003 UKAS The expression of uncertainty and confidence in measurement
- SADCAS TR 02 Accreditation requirements
- SADCAS TR 09 Criteria for performing calibration and intermediate checks on equipment used in accredited facilities

APPENDIX – AMENDMENT RECORD

Revision Status	Change			Approved by	Effective Date
	Page	Clause/Sub clause	Description of Change		
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