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EA Guidelines on the Calibration of Digital Multimeters

PURPOSE

This guidance document is intended to improve the harmonisation within EA of the calibration of digital multimeters. In the absence of specific requirements, it may be used by accredited laboratories and their customers to formulate a technically sound calibration procedure for such instruments.

Authorship
The publication has been prepared by EA Committee 2 (Technical Activities), based on a draft produced by the EA Expert Group "DC + LF Electrical Quantities".

Official language
The text may be translated into other languages as required. The English language version remains the definitive version.

Guidance publications
This document represents a consensus of EA member opinion and preferred practice on how the relevant clauses of the accreditation standards might be applied in the context of the subject matter of this document. The approaches taken are not mandatory and are for the guidance of accreditation bodies and their client laboratories. Nevertheless, the document has been produced as a means of promoting a consistent approach to laboratory accreditation amongst EA member bodies, particularly those participating in the EA Multilateral Agreement.

Further information
For further information about this publication, contact your national member of EA. Please check our website for up-to-date information http://www.european-accreditation.org/

CONTENTS

1 INTRODUCTION

1.1 The aim of this document is to provide guidelines on the calibration of digital multimeters (DMM) for accredited calibration Laboratories (ACL). In the absence of specific international written standards on DMMs, this document supplements the manufacturer's recommendations and the calibration procedures of the ACLs.

Even though these guidelines are not intended to cover the question of judging compliance of a DMM to specification, they suggest a suitable calibration method on which a statement of compliance can be based. For assessment and reporting of compliance, readers may refer to ILAC Guideline G8.

1.2 The category of apparatus referred to is that of multifunctional measuring instruments with digital reading for the measurement of the quantities: DC voltage, AC voltage (low frequency), DC current, AC current (low frequency), resistance. This category does not include instruments which, although they also measure one or more of these quantities, are primarily intended for measuring quantities of a different type such as power, energy and AC impedance or for measurements at frequencies higher than 1 MHz. The guidelines given can also be applied to digital instruments that are able to measure only some of the quantities mentioned above (e.g. digital voltmeters), but not for panel instruments or instruments developed for specialised applications.

1.3 The information given in paragraphs 3 and 4 below may be ignored, in whole or in part, in the event of the customer requesting, explicitly and in documented form, that the instrument be calibrated according to other appropriate methods.

2 TERMINOLOGY

2.1 <u>Calibration</u>. Set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realised by standards (VIM 6.11).

2.2 <u>Adjustment (of a measuring instrument)</u>. Operation of bringing a measuring instrument into a state of performance suitable for use (VIM 4.30). Depending on the instrument, the adjustment can be performed by physical adjustment (of internal components) or via the instrument's firmware.

2.3 <u>Metrological confirmation</u>. Set of operations required to ensure that an item of measuring equipment is in a state of compliance with requirements for its intended use (ISO 10012).

2.4 <u>Resolution (of a displaying device)</u>. Smallest difference between indications of a displaying device that can be meaningfully distinguished (VIM 5.12). For digital instruments, the resolution feature is often expressed by the number of digits displayed by the instrument.

2.5 <u>Range of indication</u>. Set of values bounded by the extreme indications (VIM 4.19).

2.6 Full scale. Absolute maximum indication of an instrument in a specified range.

2.7 Functional test/verification. A test/verification performed on an instrument in order to verify if its functions are working properly.

2.8 Self-calibration / auto-calibration. Internal calibration process of an instrument, with the aim of improving its accuracy.

2.9 Crest factor. Ratio between the peak value of an AC signal and its rms value.

3 PROCEDURE

3.1 General Considerations

3.1.1 The procedure must ensure that the instrument under calibration gives to the user traceable measurements results. The user should be able to use the measurement results reported in the calibration certificate during metrological confirmation of the instrument.

3.2 Preliminary Tests

3.2.1 If available, the following procedures should be performed as a preliminary: functional verification (TEST) of the multimeter and, if the instrument allows, self-calibration (ACAL, SELFCAL, etc.) in order to place the instrument into a defined condition.

3.3 Sequence of Operations

3.3.1 Depending upon the “as received” calibration state of the DMM and the customer’s requirements, three different sequences of operation can be performed:

a) - Pre-adjustment calibration
- Adjustment
- Post-adjustment calibration

b) - Calibration

c) - Adjustment
- Calibration

3.3.2 Sequence a) is the standard sequence. Pre-adjustment calibration provides information on the behaviour of the instrument in the period that has elapsed since the previous calibration. Adjustment brings the readings of the instrument within the limits of manufacturer’s specifications. The post-adjustment calibration documents the state of the instrument after the adjustment has been performed.

3.3.3 If the instrument turns out to have maintained its accuracy in a highly satisfactory manner, it is possible not to perform adjustment and to follow sequence b). The limits which must not be exceeded by the calibration results, in order for this to be possible, must be selected in such a way that the instrument remains presumably within specification during the following period of use.

3.3.4 For example, for non high-accuracy instruments with manual type adjustment, which usually have low drift with respect to specification, the limits to the deviation between the applied quantity and the reading can be set at 70% of the annual specification, declared by the manufacturer, at all the measurement points, and 50% if the point corresponds to a value for which the instrument was adjusted. For other more accurate instruments, the limit can be set at 50% of the specification for all measurement points.

3.3.5 If the calibration state of the instrument, when it arrives at the ACL, is not relevant to the customer, it is possible to omit the preliminary calibration and to follow sequence c). This may be the case if the instrument has never been submitted to periodical calibration, or if operations have been carried out, for example repairs, that have significantly altered its metrological characteristics. This sequence may only be chosen at the explicit request of the customer or if the repair has been carried out, immediately before calibration, by the ACL or by a laboratory directly related to it.

3.3.6 Adjustment must be performed according to the method prescribed by the manufacturer. All the operations listed in the instruction manual of the instrument must be carried out, except for those of an exceptional nature.

3.3.7 Usually calibration procedures must be performed configuring the instrument in such a way as to be able to obtain the best measurement accuracy. For high-accuracy DMMs, to reduce the calibration time, a less demanding configuration can be used if the increase in uncertainty is negligible with respect to specification.

3.4 Definition of Measurement Points

3.4.1 The definition of a minimum set of measurement points for the calibration of a generic DMM should be flexible enough to allow the application to different models of instruments. When customising the set of measurement points for a specific model of DMM, the ACL should consider the working principles of the instrument so as to determine the most appropriate calibration points. Guidance on the selection of calibration points may sometimes also be obtained from the manufacturer's instructions, although the points listed therein should not necessarily be considered exhaustive.

3.4.2 Due to the wide variety of types of instruments, it is necessary to find criteria on the basis of which to subdivide DMMs into categories, so as to grade the number of calibration points and the uncertainty level according to the accuracy and use of the instrument. In this document, the reference parameter used for this purpose is the resolution of the reading expressed by a number of digits; if this number varies from one function of the instrument to another, reference is made to the maximum number.

3.4.3 Two main categories can be identified. The first includes low-accuracy working instruments, with a resolution of no more than 4 1/2 digits (no more than 50000 display counts). A typical instrument in this category is the hand-held DMM, used largely for production line measurements. For this category of instruments Table 1 lists the set of recommended calibration points.

3.4.4 The second category groups together instruments with more advanced characteristics, in particular bench instruments, with a resolution of between 5 1/2 and 8 1/2 digits. These are apparatuses normally used for more demanding measurements or as laboratory reference instruments. Table 2 lists the set of recommended measurement points for this category.

3.4.5 In the Tables the measurement points are expressed as a percentage of the full scale value. The number of measurement points indicated for each range is to be understood as a lower limit. The values given are indicative and to be interpreted in a flexible manner, taking into account the instrument characteristics and the customer's requirements. In particular, it is necessary to adapt the overall values so as to include all the measurement points requested by the instrument manufacturer and listed in the instruction manual.

3.4.6 Remarks to be considered for a correct interpretation of Tables 1 and 2 are given in the following.

3.4.6.1 For DC measurements on voltage, current and resistance, it is intended that a preliminary zero operation be performed on each range, when this function is available. For DC voltage a low thermal-emf short circuit will be used to null the input. For DC current the input circuit will be left open. In case of 2-wire resistance, compensation for lead resistance will be obtained shorting the leads on the side of the resistor under measurement. In case of 4-wire resistance measurement, offset compensation is usually obtained by shorting the current terminals and measuring the voltage. Special zero procedures reported in the instruction manual of the instrument should be followed. In case the instrument can not compensate for the offset, a zero measurement will be included in the list of measurement points.

3.4.6.2 The figure 10% indicates a beginning of scale value; the actual value can be lower than 10%, possibly zero for DC functions. The figure 90% indicates a full-scale value; the actual value may vary from 50% to 99% of the full scale for all functions except for resistance, where it can vary from 30% to 99%. If the figure 90% is indicated for a range with at least 5 measurement points, that figure is to be understood in the strictest sense.

3.4.6.3 The value 50 Hz denotes a measurement point that is intended to calibrate the instrument at power frequency; the actual value may vary from 40 Hz to 60 Hz or, at most, to 100 Hz. It should be noted that for high accuracy instruments powered by the mains, it is better to avoid performing this measurement at 50 Hz because of possible beating between the frequency of the applied signal and that of the mains.

3.4.6.4 The frequency of 1 kHz denotes the central frequency value given in the specifications, at which, usually, the instrument is adjusted; the actual value may vary from 200 Hz to 1 kHz depending on the instrument model. Frequency values higher than 1 kHz are indicative, but their number is binding. The actual values should be determined so as to verify the various frequency bands defined in the specifications of the instrument.

3.4.6.5 For AC voltage measurements, care must be taken that the values given in Tables 1 and 2 do not reach the limits of the instrument in peak-voltage and in voltage-frequency product.

4 MEASUREMENT UNCERTAINTY

4.1 The measurement uncertainty should be evaluated for each measurement result according to the EA-4/02 (previously EAL-R2) guideline. In particular in this document the example S9, concerning the calibration of a hand-held digital multimeter at 100 V DC, should be considered.

4.2 Subsequent to calibration and under normal conditions of use, the uncertainty associated with the readings of a DMM will be the combination of the DMM's specification and the calibration uncertainty.

4.3 In the absence of a specific different request by the customer, for a meaningful calibration of the DMM the uncertainties of the standards used in the adjustment and the measurement uncertainties should be low enough as to be possibly neglected in comparison with the manufacturer's accuracy specification. Reference should be made to the specification after one year, because this is in general referred to by the customer during the period of validity of the calibration.

4.4 As an example, a ratio between specification and calibration uncertainties of 4:1 is usually sufficient. It may not be possible to meet this requirement for low resolution DMMs where the resolution of the DMM reading dominates both the accuracy specification and the calibration uncertainty. Also in the case of more accurate DMMs, it is not always possible to achieve a 4:1 ratio for all functions and ranges. The ACL should strive for limiting the number of calibration points where a ratio lower than 4:1 is used.

5 CONTENTS OF CALIBRATION CERTIFICATE

5.1 When compiling the calibration certificate the guidelines laid down in the EA Publication EA-4/01 will be followed. As a complement to this guide, for DMMs the following information is considered necessary in order to provide full knowledge of the operations performed on the instrument:

1) General information about the calibration
2) Method
3) Identification of the procedures employed
4) Results
5) Measurement uncertainty
6) Comments

The information to be provided under each heading is indicated below. Examples of certificates are shown in Appendix A.

5.1.1 General information about the calibration. Report here, if needed, additional information on the instrument, the extent of the calibration and any other information not covered under the other headings.

5.1.2 Method. This is the heading under which all information is given that can provide more detailed knowledge of the calibration process performed; more particularly, the information listed below must be considered.

5.1.2.1 Sequence of operations performed on the instrument. This sequence can include, for example: functional verification (self-test), self-calibration (e.g. zero settings or calibration with respect to internal standards or linearisation of the converters), initial calibration, adjustment, final calibration. If any of the operations that are listed have not been carried out in a comprehensive manner, this fact should be indicated.

5.1.2.2 Reasons for the choice of the sequence of operations and measurement points. Such reasons could be one or more of the following: customer's request, manufacturer's instructions contained in the user's manual of the instrument, EA guidelines.

5.1.2.3 Instrument settings during calibration of the various functions. For example, if the instrument is able to measure resistance at two or four terminals, the pre-selected mode should be specified. Any zero settings performed on the instrument should also be indicated and, if there is more than one input, the one which has been used should be reported. This information may also be shown alongside the tables of results.

5.1.2.4 Information on the measurement circuit (e.g. connection of a terminal to ground), on the measurement method and on the course of operations, allowing for a correct evaluation of the results obtained.

5.1.2.5 If the DMM under test is sensitive to crest factor any appropriate information concerning the distortion of the AC calibration signals should be given.

5.1.2.6 Environmental conditions (temperature and humidity) under which calibration took place.

5.1.2.7 Instrument’s stabilisation times, concerning both the length of time the instrument remained in the laboratory environment and (if powered by the mains) the length of time it was powered on, before starting calibration.

5.1.3 Identification of the procedures employed. List or identify the calibration procedures employed in order to obtain measurement data.

5.1.4 Results. The results are normally shown in tables in subsequent pages.

5.1.4.1 An example of a set of suitable column headings, in the tables, are "Applied Value" (or, for example, "Applied Voltage"), "Instrument Range" (if more than one is to be considered), "Instrument Reading", “Error of Indication” and the corresponding “Measurement Uncertainty”. For AC input quantities, the “Applied Value” column will be subdivided to give separate columns for the level and frequency of the input. The column “Instrument Reading” may also be subdivided to allow the reporting of initial calibration and final calibration results when the instrument is adjusted.

5.1.4.2 In the event of one or more measurement results, reported in the tables, being obtained with instrument settings different from those indicated under 5.1.2 *Method*, these results may be marked and the specific instrument settings given in a note below the table.

5.1.4.3 The unit of measurement may be indicated next to the relevant value or included in the column heading.

5.1.4.4 As regards the number of digits by which data should be reported on the certificate, the value of the quantity applied must have a resolution that is commensurate with the its uncertainty. On the other side, for the multimeter reading the number of digits to be given is related to the resolution of the instrument: if this has a large number of digits, non-significant digits or those contained within the short-term instability of the reading may be discarded.

5.1.5 Uncertainty. The values of the uncertainty of measurement are reported alongside the corresponding measurement results. If the adjustment has been performed, also the uncertainties of the standards used should be reported in the certificate or qualified as negligible with respect to the instrument specifications where relevant.

5.1.5.1 Make the user aware that the given uncertainties take into account the resolution and the short term instability of the instrument being calibrated.

5.1.5.2 If the DMM under test is sensitive to crest factor, the effect of the distortion of the AC calibration signals should be taken into account when evaluating the calibration uncertainty.

5.1.5.3 Include a sentence such as: "*The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by a coverage factor $k = 2$ corresponding to a coverage probability of approximately 95%. The standard uncertainty of measurement has been determined in accordance with EA Publication EA-4/02.*"

5.1.5.4 NOTE for low resolution DMM. In some cases, the combined standard uncertainty will be composed of two major contributions: a component from the finite resolution of the instrument (or from unstable reading), usually handled as a rectangular distributed component, and a component from other uncertainty contributions, which is usually assigned a normal distribution. To obtain an expanded uncertainty with about 95 % coverage interval, the coverage factor will depend on the ratio between the rectangular and normal components and will vary from $k = 1{,}65$, when the rectangular component dominates, to $k = 2$ when the normal component dominates. However, it is not possible to write a closed-form formula for k, and there are no obvious, simple approximations for this relation. The deviation from $k = 2$ becomes significant (5%) when the reading resolution is equal to or larger than 1,5 times the combination of the other uncertainty components. The problem often occurs for low accuracy, limited resolution (e.g. 3 ½ digit) instruments. These instruments are usually calibrated at low cost, and the end-user is seldom concerned with the detailed uncertainty contributions. In this case the calculation of the individual coverage factors does not add enough value for the typical user to justify the expense. It is therefore the recommendation of this Guide, that a coverage factor of $k = 2$ is used overall in these cases, and when the reading resolution is significant (see above), that the sentence of the previous paragraph be modified as follows:

"*The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by a coverage factor k = 2, which corresponds to a coverage probability of at least 95%. The standard uncertainty is a combination of a rectangular distributed component with width equal to N digits of resolution, and normally distributed components. The standard uncertainty of measurement has been determined in accordance with EA Publication EA-4/02.* "

In this sentence *N* is the number of digits the reading varied and for a stable reading is equal to one. A note in this form allows the advanced user to recover the information about the two significant uncertainty components and use this information directly in his/her own uncertainty calculations.

5.1.6 Comments.

5.1.6.1 A statement concerning the validity of the calibration results reported in the certificate should be included. For example, a sentence such as "*The results reported in this certificate refer to the condition of the instrument on the date of calibration and carry no implication regarding the long-term stability of the instrument*".

5.1.6.2 Indicate any malfunctioning or anomaly detected.

5.1.6.3 If the calibration was not performed at the ACL premises (site calibration, see Publication EA-4/03), give the location.

6 LIST OF REFERENCES

1) EA-4/01, Requirements Concerning Certificates Issued by Accredited Calibration Laboratories (previously EAL-R1), Nov 1995.

2) EA-4/02, Expressions of the Uncertainty of Measurements in Calibration (previously EAL-R2), Apr 1997.

3) EA-4/03, Requirements for the Accreditation of Laboratories and Organisations Performing Site Calibration (previously EAL-R3), Jan 1996.

4) VIM, International Vocabulary of Basic and General Terms in Metrology, second edition, 1993.

5) ISO 10012-2, Quality Assurance for Measuring Equipment – Part 2, first edition, 1997.

6) ILAC G8:1996 Guidelines on Assessment and Reporting of Compliance with Specification

TABLE 1

Measurement points for low-accuracy DMMs: resolution of no more than 4 1/2 digits.
(The values of the measurement points are reported as a percentage of full scale: see 3.4.6.2.)

DC voltage

Instrument ranges	*Measurement points*	
	No.	Values
All	3	10%, 90%, -90%
One (intermediate)	5-7	10%, 30%[1], 50%, 70%[1], 90% -10%, -90%

DC current

Instrument ranges	*Measurement points*	
	No.	Values
All	1	90%
One (intermediate)	2	90%, -90%
With value ≥ 1A	2	50%, 90%

Resistance

Instrument ranges	*Measurement points*	
	No.	Values
All	1	90%
One (intermediate)	1-2	10%[1], 90%
Lowest	2	0%, 90%

AC voltage

Instrument ranges	*Measurement points*		
	No.	Values and frequencies	
All	2-6	10%[1], 90%	50 Hz, 1 kHz, 20 kHz[1]
Nom. value < 0.5V	4	10%, 90%	50 Hz, 1 kHz
One (intermediate)	6	10%, 50% 90%	50 Hz or 1 kHz 50 Hz and 1, 20, 100 kHz
Nominal value >200V	4	10%, 90%	50 Hz, 1 kHz

AC current

Instrument ranges	*Measurement points*		
	No.	Values and frequencies	
All	2	90%	50 Hz, 1 kHz
One (intermediate)	2-3	10%[1] 90%	1 kHz 50 Hz, 1 kHz

NOTES(1) Values or frequencies to be done only on instruments with a resolution equal to 4 1/2 digits

TABLE 2

Measurement points for high-accuracy DMMs: resolution of 5 1/2 digits or more.
(The values of the measurement points are reported as a percentage of full scale: see 3.4.6.2.)

DC voltage

Instrument ranges	*Measurement points*	
	No.	Values
All	3-4	10%, 50%(1), 90%, -90%
One (intermediate)	7	10%, 30%, 50%, 70%, 90%, -10%, -90%
With value > 200V	4	10%, 50%, 90%, -90%

DC current

Instrument ranges	*Measurement points*	
	No.	Values
All	2-3	10%, 90%, -90%[1]
One (intermediate)	3	10%, 90%, -90%
With value >= 1A	3	10%, 50%, 90%

Resistance

Instrument ranges	*Measurement points*	
	No.	Values
All	2	10%, 90%

AC voltage

Instrument ranges	*Measurement points*		
	No.	Values and frequencies	
All	8	10% 90%	50 Hz, 1 kHz, 20 kHz 50 Hz and 1, 20, 50, 100 kHz
Nom. value < 0.5V	6	10% - 90%	50 Hz, 1 kHz, 20 kHz
One (intermediate)	13	10% 30%,50%,70% 90%	50 Hz, 1 kHz, 20 kHz 1 kHz 50 Hz and 1, 20, 50, 100, 300, 1000 kHz
Nominal value >200V	8	10% 50% 90%	50 Hz, 1 kHz, 20 kHz 1 kHz, 50 kHz 50 Hz, 1 kHz, 30 kHz

AC current

Instrument ranges	*Measurement points*		
	No.	Values and frequencies	
All	3-4	10% 90%	1 kHz 50 Hz, 1 kHz, 5 kHz(2)

(1) Values to be done only on high-precision instruments (resolution equal to or higher than 7 ½ digits in Vcc

(2) Frequency to be done only on instruments with a resolution equal to or higher than 6 ½ digits

APPENDIX A

Examples for the compilation of certificates for digital multimeters

Example 1

GENERAL INFORMATION ABOUT THE CALIBRATION

The 3 ½ digits hand-held digital multimeter has been calibrated on the functions: DC voltage, AC voltage, DC current, AC current, resistance.

METHOD

The calibration of the instrument was carried out at the points indicated by EA Publication EA-10/15, following the manufacturer's instructions given in the user's manual. As agreed with the customer, no adjustment of the multimeter was carried out. Before executing the measurements given in this certificate a self-test ("Test") procedure was successfully performed on the instrument.

The ambient temperature was in the range 22 °C to 24 °C and the relative humidity between 40 %rh and 60 %rh.

IDENTIFICATION OF THE PROCEDURES EMPLOYED

Identification: A01VDC, A02VAC, A05IDC, A08IAC, A09RES.

MEASUREMENT RESULTS

The calibration results are shown in the tables on the following pages.

CALIBRATION UNCERTAINTY

The uncertainty values reported in the tables of results have been obtained taking into account all contributing factors to uncertainty affecting the measurement, including those deriving from the resolution and from the short-term stability of the instrument being calibrated.

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by a coverage factor k = 2, which corresponds to a coverage probability of at least 95%. The standard uncertainty is a combination of a rectangular distributed component with width equal to 1 digit of resolution, and normally distributed components. The standard uncertainty of measurement has been determined in accordance with EA Publication EA-4/02.

COMMENTS

The results reported in this certificate refer to the condition of the instrument on the date of calibration and carry no implication regarding the long-term stability of the instrument.

Table 1 – *Function: DC voltage*

Applied Voltage	Instrument		Measurement result	
	Range	Reading	Error	Uncertainty
+ 20,00 mV	100 mV	+ 20,0 mV	0,00 mV	0,06 mV
+ 100,00 mV		+ 99,9 mV	-0,10 mV	0,06 mV
- 100,00 mV		- 99,9 mV	0,10 mV	0,06 mV
+ 0,2000 V	1 V	+ 0,200 V	0,0 mV	0,6 mV
+ 1,0000 V		+ 0,999 V	-1,0 mV	0,6 mV
- 1,0000 V		- 0,999 V	1,0 mV	0,6 mV
+ 2,000 V	10 V	+ 2,00 V	0 mV	6 mV
- 2,000 V		- 2,00 V	0 mV	6 mV
+ 10,000 V		+ 9,99 V	-10 mV	7 mV
+ 15,000 V		+ 14,98 V	-20 mV	8 mV
- 15,000 V		- 14,97 V	30 mV	8 mV
+ 20,00 V	100 V	+ 20,0 V	0,00 V	0,06 V
+ 100,00 V		+ 99,8 V	-0,20 V	0,07 V
- 100,00 V		- 99,7 V	0,30 V	0,07 V
+ 200,0 V	1000 V	+ 200 V	0,0 V	0,6 V
+ 1000,0 V		+ 997 V	-3,0 V	0,7 V
- 1000,0 V		- 996 V	4,0 V	0,7 V

Table 2 – *Function: AC voltage*

Applied Voltage		Instrument		Measurement result	
Value	Frequency	Range	Reading	Error	Uncertainty
100,00 mV	50 Hz	100 mV	99,9 mV	-0,10 mV	0,10 mV
100,00 mV	1 kHz		99,7 mV	-0,30 mV	0,10 mV
1,0000 V	50 Hz	1 V	0,998 V	-2,0 mV	1,0 mV
1,0000 V	1 kHz		0,999 V	-1,0 mV	1,0 mV
2,000 V	1 kHz	10 V	2,02 V	20 mV	6 mV
10,000 V	50 Hz		10,03 V	30 mV	10 mV
10,000 V	1 kHz		10,01 V	10 mV	10 mV
10,000 V	20 kHz		9,91 V	-90 mV	10 mV
10,000 V	100 kHz		9,81 V	-190 mV	20 mV
15,000 V	1 kHz		14,98 V	-20 mV	13 mV
100,00 V	50 Hz	100 V	99,8 V	-0,20 V	0,10 V
100,00 V	1 kHz		99,5 V	-0,50 V	0,10 V
1000,0 V	50 Hz	1000 V	995 V	-5,0 V	1,0 V
1000,0 V	1 kHz		992 V	-8,0 V	1,0 V

Example 2

GENERAL INFORMATION ABOUT THE CALIBRATION

The digital multimeter has been calibrated on the functions: DC voltage, AC voltage, DC current, AC current, resistance.

METHOD

The following operations were performed on the instrument in accordance with the customer's request and EA Publication No. EA-10/15.

1. Stabilisation: in the 24 hours preceding calibration the instrument was powered by the mains and placed in the laboratory environment.
2. Functional self-verification procedure (FULL TEST) - positive result.
3. Self-calibration procedure (AUTOCAL) - no faults in the operating procedure.
4. Initial calibration.
5. Adjustment – all operations indicated in par. 4.1 of the instruction manual were carried out.
6. Final calibration.

The measurement points of calibration include the points recommended by the instruction manual and are in accordance with EA Publication EA-10/15.

Instrument settings during calibration are indicated alongside the tables of results.

DC voltage and resistance measurements were executed after short-circuiting the input and setting the instrument reading to zero (for each range used); a similar procedure was carried out for DC current, opening the current circuit.

During calibration the ambient temperature was between 22 °C and 24 °C and the relative humidity was between 40 %rh and 60 %rh.

IDENTIFICATION OF THE PROCEDURES EMPLOYED

Identification: A01VDC, A02VAC, A05IDC, A08IAC, A09RES.

MEASUREMENT RESULTS

The calibration results are shown in the tables on the following pages.

CALIBRATION UNCERTAINTY

The uncertainty values reported in the tables of results have been obtained taking into account all contributing factors to the uncertainty affecting the measurement, including those deriving from the resolution and from the short-term stability of the instrument being calibrated.

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by a coverage factor $k = 2$, corresponding to a coverage probability of approximately 95%[(1)]. The standard uncertainty of measurement has been determined in accordance with EA Publication EA-4/02.

[(1)] Here a Gaussian probability distribution is assumed. Both the value of k and the coverage probability must be reported

COMMENTS

The results reported in this certificate refer to the condition of the instrument on the date of calibration and carry no implication regarding the long-term stability of the instrument.

Function: DC voltage

Instrument settings	NDIG 8 FILT ON NPL 100 Input FRONT

Table 1 - *Calibration results with DC voltage*

Applied Voltage	Instrument Range	Instrument Reading		Measurement result		
		Initial Calibration	Final Calibration	Initial error	Final error	Uncertainty
(mV)	(mV)	(mV)	(mV)	(10^{-5})	(10^{-5})	(10^{-5})
1,0000	100	+ 1,0008	+ 1,0005	80	50	31
-1,0000		-1,0002	-1,0003	20	30	31
10,0000		+ 10,0012	+ 10,0005	12	5,0	4,0
100,0000		+ 100,0020	+ 100,0002	2,0	0,2	1,3
-100,0000		-100,0015	-100,0005	1,5	0,5	1,3
(V)	(V)	(V)	(V)	(10^{-6})	(10^{-6})	(10^{-6})
0,500000	1	+ 0,500005	+ 0,500001	5,0	2,0	6,0
1,000000		+ 1,000012	+ 1,000002	12,0	2,0	5,5
-1,000000		- 1,000010	- 1,000001	10,0	1,0	5,5
1,500000		+ 1,500015	+ 1,500004	10,0	2,7	5,3
2,000000	10	+ 2,000015	+ 2,000003	7,5	1,5	5,3

(only a part of the DC voltage table of results is reported in this example)