# A2LA Conclave, 2009

## Electrical Uncertainty Budgets

## by

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# Electrical Uncertainty Budgets

## Issues:

**Current practices by A2LA calibration assessors allow the acceptance of 2 options of uncertainty budgets for electrical parameters.**

## Option 1

**Type A: None required**

**Type B: Only requires the specifications of the standard used and the resolutions of the standard and UUT.**

**This option does not agree with the GUM, or with M3003, or with NCSLI RP-12.**

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## Option 2

### Type A: Include

a) Repeatability and if possible

b) Reproducibility, Stability, Drift, etc.

**Type B:** Follow requirements/recommendations of the GUM, M3003, and RP-12 from the NCSLI.

a. Include resolutions of the reference standard and the UUT.

b. Include the specifications even though they might be redundant.

c. Include the traceable value of the reference standard as stated in the reference standard certificate.

d. Include any environmental factors as appropriate

e. Include additional environmental factors if listed in the manual for certain ranges.

# Electrical Uncertainty Budgets

## Comment:

**KJ is of the opinion that option 1 is inadequate since it does not provide any evidence for:**

- **Traceability**
- **System Performance including cable behaviour and/or faults**
- **Operator errors**
- **Short term stability**
- **Environmental effects**
- **Conformance to GUM and M3003 requirements**

# Electrical Uncertainty Budgets

## Requirements:

**A2LA requires that uncertainty budgets be compliant with Traceability:**

1. **C105 General Checklist: – A2LA Policy on Measurement Traceability**

   **T4. Where measurement uncertainty analysis is applicable, A2LA requires laboratories to calculate measurement uncertainty in accordance with the ISO "Guide to the Expression of Uncertainty in Measurement." These uncertainties, when reported shall be reported as the expanded uncertainty with a defined coverage factor, k (typically k = 2) and the confidence interval (typically to approximate the 95% confidence level).**

2. **ISO/NEC 17025-2005 states:**

   **When estimating the uncertainty of measurement, all uncertainty components which are of importance in the given situation shall be taken into account using appropriate methods of analysis.**

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## Type A uncertainty contributors

**The GUM states that all statistical data is treated as Type A contributors with normal distributions.**

**Typical examples in these areas are:**

**a. Repeatability,**

**b. Reproducibility,**

**c. Stability / Drift**

**d. Others**

**Repeatability is required by the GUM (sort of) and M3003, and is recommended by NCSLI-RP12.**

**(Also: G103 – A2LA Guide for Estimation of Uncertainty of Dimensional Calibration and Testing Results)**

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**In the GUM, Section 8.2 and 8.3 state:**

8.2 Determine $x_i$, the estimated value of the input quantity Xi, either on the basis of statistical analysis of series of observations **or by other means**.

8.3 Evaluate the standard uncertainty $u(x_i)$ of each input estimate $x_i$. For an input estimate obtained from the statistical analysis of series of observations, the standard uncertainty is evaluated as described in 4.2 (Type A evaluation of standard uncertainty). For an input estimate obtained by other means, the standard uncertainty $u(x_i)$ is evaluated as described in 4.3 (Type B evaluation of standard uncertainty.)

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**In M3003, it is strongly recommended to include random effects**.

A Type A evaluation will normally be used to obtain a value for the repeatability or randomness of a measurement process. For some measurements, the random component of uncertainty may not be significant in relation to other contributions to uncertainty. **It is nevertheless desirable for any measurement process that the relative importance of random effects be established**. When there is a significant spread in a sample of measurement results, the arithmetic mean or average of the results should be calculated.

In all the examples listed in M3003, repeatability is included.

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## In NCSLI RP-12, section 2.2

2.3 Identify Measurement Errors and Distributions

Measurement process errors are the basic elements of uncertainty analysis. Once these

fundamental error sources have been identified; we can begin to develop uncertainty estimates.

The errors most often encountered in making measurements include, but are not limited to the following:

- Measurement Bias
- **Random or Repeatability Error**
- Resolution Error
- Digital Sampling Error

**Operator Bias**
Environmental Factors Error
Computation Error
Stress Response Errors

**Clearly, repeatability is recommended.**

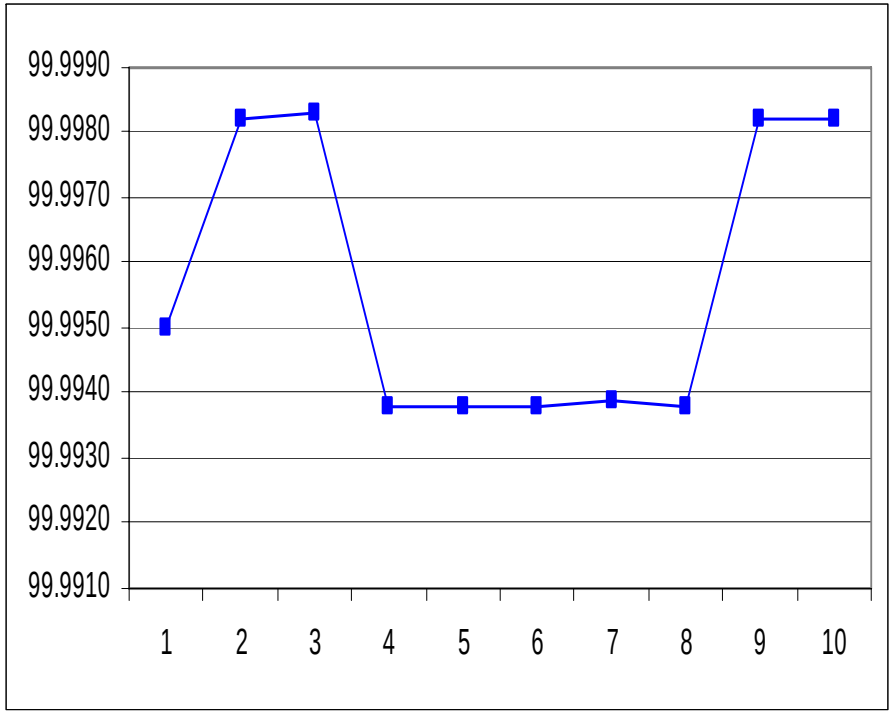
## 100 kΩ Range

| | U | | DIST | DIV | STD U | Squared | % of Total |
|---|---|---|---|---|---|---|---|
| Type A | | | | | | | |
| Repeatability | 0.002335 | kΩ | N | 1 | 0.0023 | 5.45E-06 | 53.2 |
| | | | | | | | |
| Type B | | | | | | | |
| Specifications of 5520A | 0.0028 | kΩ | Norm | 2.58 | 0.0011 | 1.18E-06 | 11.5 |
| UUT Resolution, Std. | 0.000005 | kΩ | Rec | 1.732 | 0.0000029 | 8.33E-12 | 0.00008 |
| Uncertainty of 5520A | 0.0038 | kΩ | Norm | 2.0 | 0.0019 | 3.61E-06 | 35.2 |
| Resolution of 5520A | 0.00005 | kΩ | Rec | 1.732 | 0.000029 | 8.33E-10 | 0.008 |
| | | | | | Sum | 1.02E-05 | 100.0 |
| | | | | | U | 0.00320 | |
| | | | | | U(k=2) | 0.00640 | kΩ |

**Two Problems:** Repeatability too high.
Certificate Uncertainty higher than specifications

## 100 kΩ Range

| Repeatability | | |
|---|---|---|
| 1 | 99.9950 | |
| 2 | 99.9982 | |
| 3 | 99.9983 | |
| 4 | 99.9938 | |
| 5 | 99.9938 | |
| 6 | 99.9938 | |
| 7 | 99.9939 | |
| 8 | 99.9938 | |
| 9 | 99.9982 | |
| 10 | 99.9982 | |
| STDEV | 0.002203 | |
| DOF=9 | 1.06 | 0.002335 |



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## Type B uncertainty contributors

The GUM states in 4.3:

4.3 Type B evaluation of standard uncertainty

4.3.1 For an estimate $x_i$ of an input quantity Xi that has not been obtained from repeated observations, the associated estimated variance $u^2(x_i)$ or the standard uncertainty $u(x_i)$ is evaluated by scientific judgment based on all of the available information on the possible variability of Xi. The pool of information may include:

- previous measurement data;
- experience with or general knowledge of the behaviour and properties of relevant materials and instruments; (KJ: Specifications)
- manufacturer's specifications;
- data provided in calibration and other certificate;
- uncertainties assigned to reference data taken from handbooks.

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**In M3003, it is strongly recommended to include the following contributors:**

**5.3 In evaluating the components of uncertainty it is necessary to consider and include at least the following possible sources:**

**(a) The reported calibration uncertainty assigned to reference standards and any drift or instability in their values or readings.**

**(b) The calibration of measuring equipment, including ancillaries such as connecting leads etc., and any drift or instability in their values or readings. (KJ: Repeatability).**

**(c) The equipment or item being measured (KJ: UUT), for example its resolution and any instability during the measurement. It should be noted that the anticipated long-term performance of the item being calibrated is not normally included in the uncertainty evaluation for that calibration.**

**(d) The operational procedure.**

**(e) Variability between different staff carrying out the same type of measurement.**

**(f) The effects of environmental conditions on any or all of the above.**

# Electrical Uncertainty Budgets

## In NCSLI RP-12, section 2.2

**2.3 Identify Measurement Errors and Distributions**

**Measurement process errors are the basic elements of uncertainty analysis. Once these fundamental error sources have been identified, we can begin to develop uncertainty estimates.**

**The errors most often encountered in making measurements include, but are not limited to the following:**

- **Measurement Bias**
- Random or Repeatability Error
- **Resolution Error**
- **Digital Sampling**
- **Computation Error**
- Operator Bias
- **Environmental Factors Error**
- **Error Stress Response Errors**

**Most of these can be covered by statistics, specifications, traceable values, etc.**

# Traceability Issues

**Accredited A2LA certificate includes the following information**

## Parameter

| AC Current | Frequency | Range | Value | | Uncertainty |
|---|---|---|---|---|---|
| | 1 kHz | 100 µA | 99.9926* | µA | 0.0200 µA |
| | 1 kHz | 1 mA | 1.000029* | mA | 0.000110 mA |
| | 1 kHz | 10 mA | 10.00023 | mA | 0.001000 mA |
| | 1 kHz | 100 mA | 100.0057 | mA | 0.01000 mA |
| | 1 kHz | 1A | 1.000018 | A | 0.000100 A |
| | | | | | |
| * Ranges are not accredited | | | | | |

Nothing wrong with this report.

**But the customer used all the data to claim traceability and uncertainties on the scope for all ranges.**

# 1 mA Range

| | U | | DIST | DIV | STD U | Squared | % of Total |
|---|---|---|---|---|---|---|---|
| Type A | | | | | | | |
| Repeatability | 6.28E-07 | mA | N | 1 | 0.0000 | 3.95E-13 | 0.012 |
| | | | | | | | |
| Type B | | | | | | | |
| Specification of 3458A | 2.50E-05 | mA | Rec | 1.732 | 0.0000144 | 2.08E-10 | 6.4 |
| Resolution of HP 3458A | 5.00E-08 | mA | Rec | 1.732 | 0.0000000 | 8.33E-16 | 0.000026 |
| 5520A Resolution | 5.00E-06 | mA | Rec | 1.732 | 0.0000029 | 8.33E-12 | 0.26 |
| Cert value | 1.10E-04 | mA | N | 2 | 0.0001 | 3.03E-09 | 93.3 |
| | | | | | Sum | 3.24E-09 | 100.0 |
| | | | | | U | 0.00006 | |
| | | | | | U(k=2) | 0.00011 | kΩ |

**Two Problems:** **Certificate Uncertainty too high.**

**No Traceability for this range.**

## 300 mV Range

| | U | | DIST | DIV | STD U | Squared | % of Total |
|---|---|---|---|---|---|---|---|
| Type A | | | | | | | |
| Repeatability | 5.43E-05 | mV | Norm | 1 | 0.000054 | 2.95E-09 | 0.29 |
| | | | | | | | |
| Type B | | | | | | | |
| Specifications | 0.0020 | mV | Norm | 2.0 | 0.0010 | 1.00E-06 | 99.6 |
| Standard Resolution | 0.00005 | mV | Rec | 1.732 | 0.0000289 | 8.33E-10 | 0.08 |
| Resolution, UUT | 0.000005 | mV | Norm | 2.0 | 0.0000 | 6.25E-12 | 0.00062 |
| Uncertainty of 5520A | 0 | mV | Rec | 1.732 | 0.000000 | 0.00E+00 | 0.000 |
| | | | | | Sum | 1.00E-06 | 100.0 |
| | | | | | U | 0.0010 | |
| | | | | | U(k=2) | 0.0020 | mV |

One Problem: **Certificate uncertainty higher than specifications.**

**Therefore was ignored. (see next slide)**

## 300 mV Range

| | U | | DIST | DIV | STD U | Squared | % of Total |
|---|---|---|---|---|---|---|---|
| Type A | | | | | | | |
| Repeatability | 5.43E-05 | mV | Norm | 1 | 0.000054 | 2.95E-09 | 0.03 |
| | | | | | | | |
| Type B | | | | | | | |
| Specifications | 0.0020 | mV | Norm | 2.0 | 0.0010 | 1.00E-06 | 10.7 |
| UUT Resolution | 0.00005 | mV | Rec | 1.732 | 0.0000289 | 8.33E-10 | 0.01 |
| Standard Resolution | 0.000005 | mV | Norm | 2 | 0.0000 | 6.25E-12 | 0.00007 |
| Uncertainty from Certificate | 0.005 | mV | Rec | 1.732 | 0.002887 | 8.33E-06 | 89.25 |
| | | | | | Sum | 9.34E-06 | 100.0 |
| | | | | | U | 0.00306 | |
| | | | | | U(k=2) | 0.00611 | mV |

One Problem: Certificate uncertainty higher than specifications.

Cert value included.

## Recommendations

Based on all the above mentioned requirements and recommendations, it is suggested that at least the following contributors be identified in all electrical uncertainty budgets:

| Type A | | | |
|---|---|---|---|
| **Item #** | **Name** | | **Comment** |
| 1 | **Repeatability** | **Must have** | **Try getting 10 or more measurements so you have at least 9 DoF.** |
| 2 | **Reproducibility** | **If possible** | **i.e long term data.** |
| 3 | **Stability / Drift** | **If possible** | **See item 6 in Type B Table** |
| 4 | **Others** | **If possible** | |
| | | | |

| Type B | | | |
|---|---|---|---|
| **Item #** | **Name** | | **Comments** |
| **5** | **Reference value from Traceable Certificate** | **Must have** | **With this value listed you have proof of traceability** |
| **6** | **Absolute Specification for calibration interval** | **Must have to check if item 5 is less than item 6** | **Also, if you have long term stability for this parameter for this range, you can set the multiplier/divisor to 0.** |
| **7** | **Resolutions of standards used** | **Always list** | **This is usually small wrt to the rest, but there are exceptions.** |
| **8** | **Resolution of UUT** | **Always list** | **This is usually small wrt to the rest, but there are exceptions.** |
| **9** | **Environmental effects** | **There can be multiple lines for it.** | **This is usually small wrt to the rest, but there are exceptions.** |
| **10** | **Any other entries that might be helpful Others** | | |

# Electrical Uncertainty Budgets

**Having these basic frameworks for uncertainties, we, the assessors, can be reasonably assured of consistency from assessment to assessment.**

**It avoids the confusing of the A2LA customers and covers not only uncertainty requirements but also document control as well as incoming inspections, etc.**

**Finally:**

1. The indicated contributors for Type A and Type B should be considered MINIMUM contributors.
2. There are many circumstances were other contributors are of importance.
3. But let's at least start with a minimum set that includes not only the contributions of the reference standard(s) but also of the UUT.