Calibration Toolbox ADO
Quick Start Guide to Measurement Uncertainty Calculations

This quick start guide is designed to help you to discover the main features of Calibration Toolbox ADO as quickly as possible. Like all sophisticated tools, it will take time and practice for you to become totally proficient, but you can begin to use some of its powerful features almost straight away.

Introduction

There is nowadays an increasing requirement to provide a statement of the statistical uncertainty associated with an individual measurement. The **Calibration Toolbox ADO Uncertainty Calculator** is a tool that enables you to meet this requirement.

What is Uncertainty?

Uncertainties will always occur in a measurement if a number of **repeat measurements of the same parameter** show an unavoidable, definite, but unpredictable variation. For example, if you measure the diameter if a circular object ten times and obtain a spread of results, you have a measurement uncertainty.

Fixed errors are never included in uncertainty measurements because they are predictable and can hence be corrected for. Examples of **fixed errors** include:

- A thermometer that constantly under-reads by 0.5°C.
- A micrometer whose readings drift by 0.001 mm per month.

Incorrect readings are also not included because they are avoidable, for example:

- Parallax errors on analogue gauges.
- Zero offsets.
- Quoting incorrect units.

These are not **errors**, they are **mistakes**.

There are 2 types of measurement uncertainty:

Type-A evaluation: The method of evaluation of uncertainty by the statistical analysis of series of observations

Type-B evaluation: The method of evaluation of uncertainty by means other than the statistical analysis of series of observations, usually from data provided by external agencies such as calibration houses or manufacturers

Calibration Toolbox ADO enables you to evaluate uncertainties from data of Type B - the most widely used type in everyday use.

For a detailed description of Measurement Uncertainties, please see the article on the Calibration Toolbox ADO website at:

www.calisouk.com

Type B Uncertainties

Type B evaluation of standard uncertainty is usually based on scientific judgement using all relevant information available, which may include:

- previous measurement data
- experience with, or general knowledge of, the behaviour and property of relevant materials and instruments
- manufacturer's specifications
- data provided in calibration and other reports
- uncertainties assigned to reference data taken from handbooks

The Calibration Toolbox Uncertainty Calculator combines Type B uncertainty analysis with the means of calculating the combined uncertainty of a number of individual uncertainty contributions. This, in nearly all practical applications, will be the most appropriate course of action, and is commonly known as an ERROR BUDGET.

Calibration Toolbox ADO contains a number of illustrative examples for you to look at

Uncertainty Components

An uncertainty budget is built up by including all of the uncertainty contributions to the measurement. Each instrument used in the measurement and calibration chain will add its own contribution, based on its own inherent uncertainties. For example, a thermal block used in the calibration of thermometers will have the following factors contributing to the uncertainty of its internal temperature:

- **Radial Stability**   Temperature variation across the diameter
- **Axial Stability**   Temperature variation with insertion depth
- **Controller Temp**   The accuracy of the controller's internal temperature sensor
- **Loading Effect**   The variation of internal temperature as a function of the number of inserted probes

If such a block is used in the performance of a temperature calibration, all of these factors must be taken into account. The same will also apply to all other instruments used in the calibration, for example the reference thermometer.

The first step in creating an error budget is to create your list of uncertainty components. You will see that a number of these have already been included to get you started. Add these as you need them. You will need to refer to several sources for this perhaps, most importantly, manufacturers' information.

The Uncertainty Calculator window is accessed from the main menu as shown in fig 1 below.
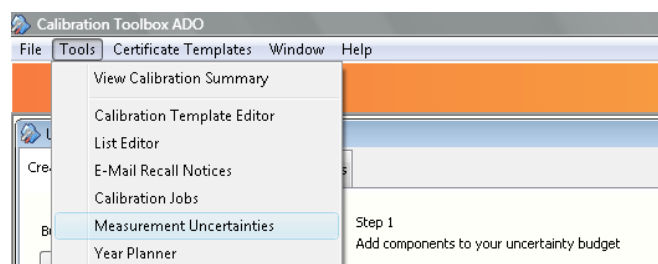

Fig 1:   Opening the Uncertainty Calculator

Down the left-hand side of the window you will see a column of buttons (fig 2). The purpose of these will become clear as we proceed. First we will start to build-up our collection of uncertainty components.

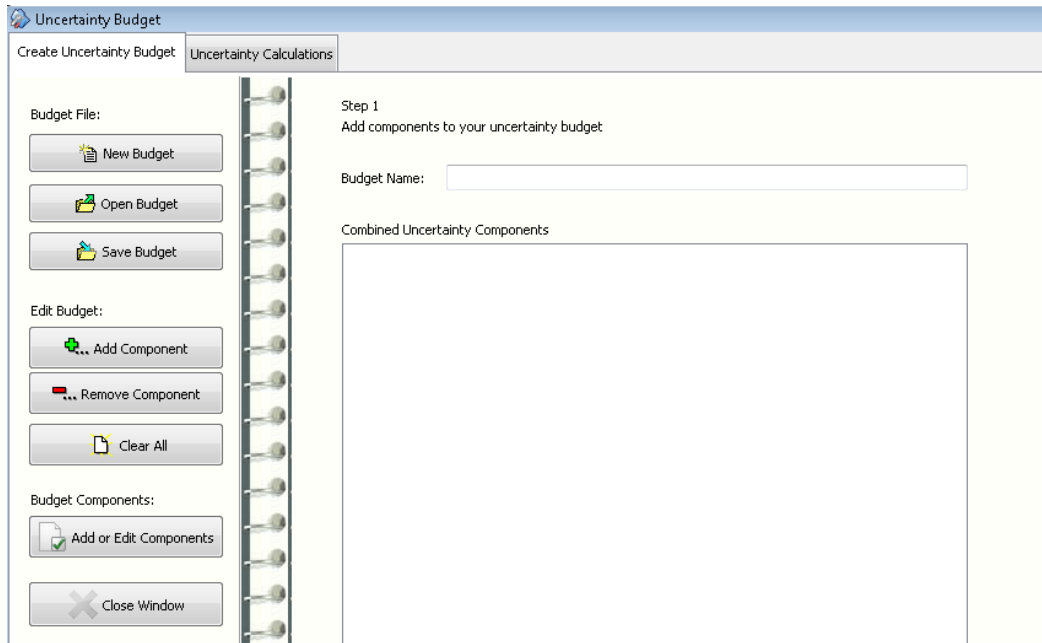## Adding, Editing and Deleting Uncertainty Components

Fig 2:   The Uncertainty Budget Tab

Click the 'Add or Edit Components' button to open the Uncertainty Component Editor (fig 3). You will see a drop-down list of your current uncertainty components and, below this, the uncertainty contributors for each.
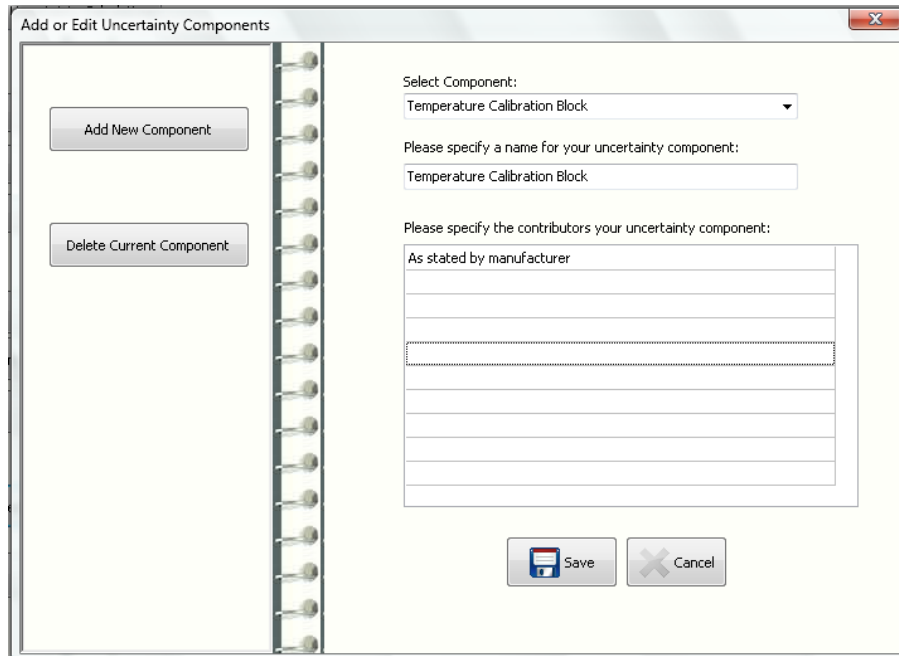

Fig 3:   The Uncertainty Component Editor

Note:

At this point, no numerical values have been assigned to the contributions. This is because, we are simply listing the contributions that you must consider when evaluating your uncertainties. The actual uncertainty values will be different for each model of instrument using the component, and may well vary between instruments of the same type.

Creating an Uncertainty Budget

Having created you list of uncertainty components, you will now want to use them to evaluate combined measurement uncertainty values for your instruments. This first step is to create the error budget i.e. list all of the devices used in the calibration or measurement.

To add an uncertainty component, click the Add Component button (see fig 2) and select the required component from the dialogue box that appears (fig 4).
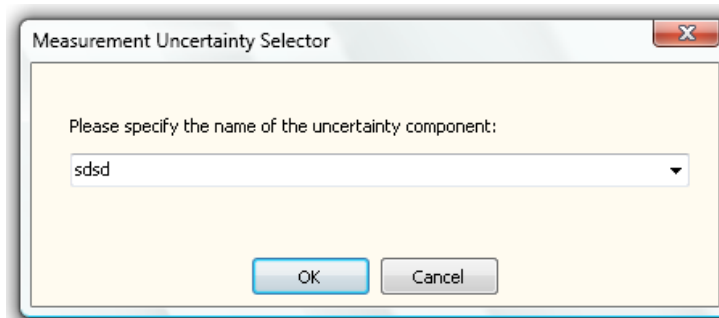

Fig 4:   Adding uncertainty components

Repeat this until you have added all of the necessary components. In the simple example illustrated below in fig 5 we have selected a temperature block and a reference PRT.
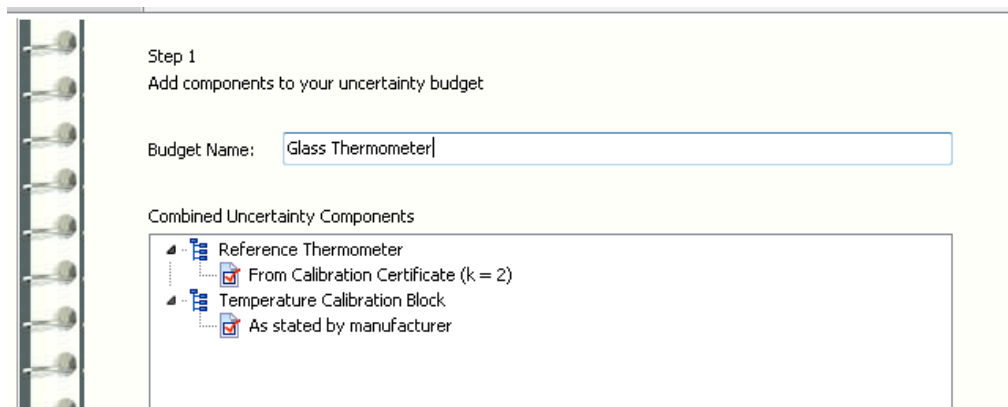

Fig 5:   An Uncertainty Budget

The final steps are to add values to each components' contributions and to evaluate the combined uncertainty. This is described next.

We have discussed how the values of uncertainty contributions can be obtained from a variety of sources. It may well be the case that a manufacturer will supply a single uncertainty value for an instrument, whereas others may provide the individual contributions that go to make up that value. In all cases, however, 2 pieces of information will be provided: a numerical value and some indication of the associated statistical distribution. A detailed description of the statistical aspects is beyond the scope of this manual. There are several good reference sources on the Internet, try visiting the NIST website at:

http://physics.nist.gov/cuu/

The Calibration Toolbox ADO Uncertainty Calculator means that you do not need a detailed knowledge of statistics. It suffices to understand that, the uncertainties quoted need to be multiplied by some sort of factor before they can be included into a combined value. Most uncertainty values represent some kind of standard deviation. The factor to be used will depend on the theoretical probability distribution associated with the value (normal, rectangular or triangular), or its coverage factor.
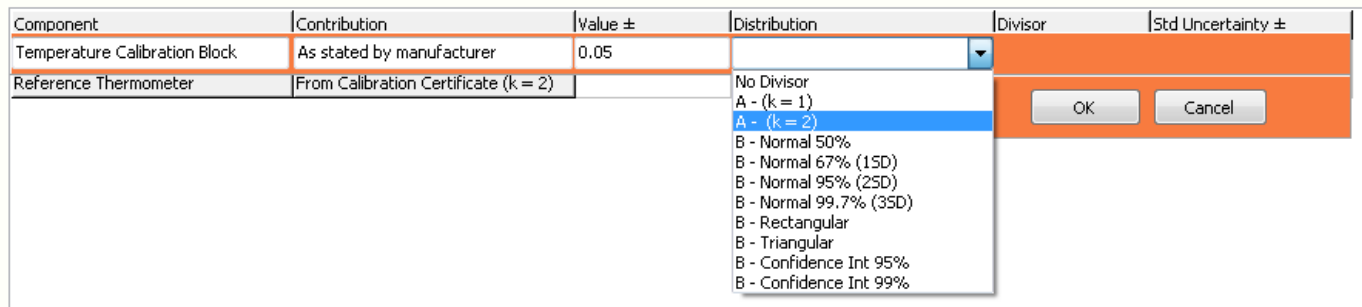

Fig 6:   Adding the numbers

To edit the values, select the Uncertainty Calculations tab. The contribution list described above is once again shown this time in a data-grid. Data is not added by typing directly into the grid, but via a pop-up panel. Double-click the line to which you wish to add the data, and you will reveal the panel (fig 6).

Enter the numerical value for the contribution. Note that the units, or dimensions, of each value entered must be the same. They will usually be the same as the parameter for which the calibration is being performed e.g.

- Kelvin or Celsius for temperature
- Inches or mm for dimensions
- Bar or PSI for pressures

Next select the correct distribution. This will usually be provided for you, as it will depend largely on the manner in which the value was calculated or presented. A common, yet simple example is when uncertainties are quoted with a Coverage Factor. The statement of uncertainty will usually read as follows:

> The expanded uncertainty of the block is 0.5 mKelvin determined from a combined standard uncertainty (i.e., estimated standard deviation) uc = 0.025 mKelvin and a coverage factor k = 2. Since it can be assumed that the possible estimated values of the standard are approximately normally distributed with approximate standard deviation uc, the unknown value of the standard is believed to lie in the interval defined by U with a level of confidence of approximately 95 %.

Once you have entered all the values (fig 7), including for the record the actual units, click the Calculate button to obtain your combined uncertainty (fig 8).

Step 2
Add your estimates/calculations of the values for each component (Double-click component to edit)

Component	Contribution	Value ±	Distribution	Divisor	Std Uncertainty ±
Temperature Calibration Block	As stated by manufacturer	0.05	A - (k = 2)	2	0.0250
Reference Thermometer	From Calibration Certificate (k = 2)	0.02	A - (k = 2)	2	0.0100

Fig 7:   Contributions to an Uncertainty

Note that indicated value represents a coverage factor of 1, which means that there is a 65% probability that your actual value lies within ± 1 uncertainty interval of this value. A coverage factor of 2 increases this confidence to approximately 95%.

Units: Kelvin   🖩 Calculate   Combined Uncertainty (k = 1): 0.0269258240356725

Fig 8:   The Combined Uncertainty

It is also very important to note that it is assumed that all of the contributions are non-interdependent, in other words, that changing one has no effect on any other. This will usually be the case in most normal calibrations.

Linking an Uncertainty Budget with a Calibration Data Template

By now, you will have seen how good Calibration Toolbox ADO really is. But every now and then we like to show you little gems that we are particularly proud of. What follows is an example of this:

If you create an uncertainty budget, and give it the same name as its corresponding Calibration Data Template, the two are then linked. So, when you come to view a device's calibration data, you can see how the value of the measurement uncertainty associated with the calibration was calculated.

Confirm

ⓘ   Do you wish to associate the name of your budget to the name of a Calibration Data template ?
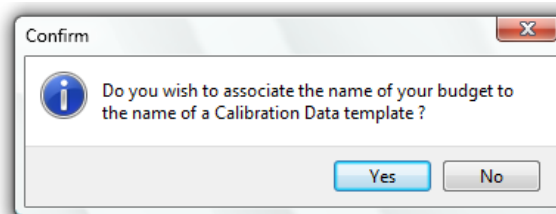
Yes   No

Fig 9:   Linking a Budget to a Calibration Data Template

When you click the 'Save Budget' button (shown in fig 2) you will be asked if you like to associate the name of your budget to the name of a Calibration Data template (fig 9). If you click 'Yes' you will be given a list of the available Calibration Data Template Names to choose from (fig 10). Select the appropriate template and click OK. The link is now made.
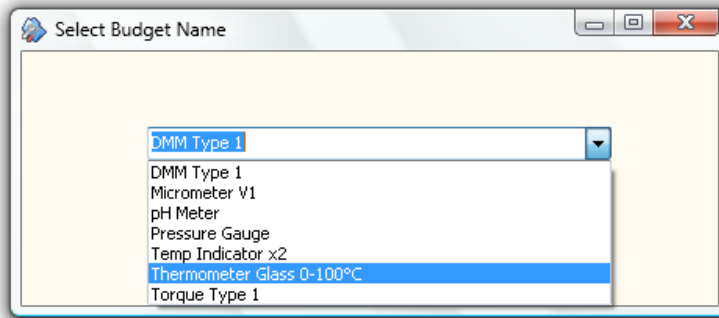

Fig 10:   Selecting a Budget Name from the Available Templates