



Type B Uncertainty Estimator — Instruction Guide

The Type B Uncertainty Estimator turns a stated limit — a half-width, a span, a resolution or a manufacturer's specification — into a standard uncertainty u , using the distribution you choose.

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1. Purpose and application

The calculator performs a Type B evaluation of standard uncertainty as described in GUM 4.3. It takes a bound on a quantity, finds its half-width a , and divides a by the divisor of the distribution you choose.

Use it to:

- convert a calibration certificate's expanded uncertainty U and its k to a standard uncertainty;
- convert a manufacturer's accuracy specification (percent or ppm of reading and range, counts, a fixed floor) to a standard uncertainty;
- evaluate the resolution of a digital display;
- widen a specification for operation outside its stated temperature band;
- check a hand calculation before the value enters an uncertainty budget.

The result u is one contributor. Combine contributors in the GUM Uncertainty Budget Calculator. The calculator is a training and reference tool. It does not replace a laboratory's own validated procedure.

2. Standards basis

Standard	What the calculator takes from it
JCGM 100:2008 (GUM) 4.3.1	A Type B evaluation draws on available information (GUM 4.3.1). Naming the source makes the evaluation traceable and reviewable; a missing Source documentation is reported.
JCGM 100:2008 (GUM) 4.3.3	A quoted expanded uncertainty with a stated k : $u = U / k$.
JCGM 100:2008 (GUM) 4.3.4 and Table G.1	A quoted interval with a confidence level and no k : the coverage factor for that level.
JCGM 100:2008 (GUM) 4.3.7	Rectangular distribution: $u = a / \sqrt{3}$.
JCGM 100:2008 (GUM) 4.3.9	Triangular distribution: $u = a / \sqrt{6}$.
JCGM 100:2008 (GUM) H.1.3.4; UKAS M3003	U-shaped (arcsine) distribution: $u = a / \sqrt{2}$.
JCGM 100:2008 (GUM) F.2.2.1	A display resolution r gives $a = r / 2$ with a rectangular distribution. A resolution with a normal distribution is refused.
NIST SP 811:2008, Appendix B	Exact conversion factors between units of one domain.
ISO/IEC 17025:2017 7.6 and 7.11	The laboratory evaluates measurement uncertainty and remains responsible for validating any software result it uses.

3. How the calculator ensures accurate results

Code computes every number; the language model only explains the finished result. The half-width a is held as an exact rational number, and every unit factor except the two inHg units is exact. The square root in $u = a / \sqrt{d}$ is rounded by comparing squares of integers, so no floating-point step decides a displayed digit. The displayed u is rounded up, never down. The method is described in the white paper [Deterministic Computation in AI-Assisted Metrology](#) (Racen, 2026).

Validation record MT-VAL-TB-002 Rev B (18 October 2026, production commit 5cbb347) found 0 mismatches over 10,000 random cases against an independent exact reference. All 1,054 inputs that must be refused were refused, all 7 edge and rejection cases behaved as specified, and all six live tests (B1 to B5 and TB-E5) passed on the card and the PDF. Revision B made each refusal state its reason in one sentence, and the unit-family refusal now names both units.

4. Input fields

The form has 31 fields in eight groups. Only four choices are always required: Unit domain, How to read the value, Distribution, and either a Value or at least one non-zero specification term. Value unit is required whenever Value is shown. The other fields appear only when an earlier choice calls for them. Every number is a bare number: a comma decimal (0,005) or a unit typed into a number box is refused.

Field	Required	Format or options	What it means (form help text)
Identification			
Source description	No	Free text	What this estimate is for, for example the resolution of a digital indicator or a calibrator specification. Optional.
Quantity and source type			
Unit domain	Yes	Select: 23 domains or Other (same unit on both values)	Choose the kind of quantity first; the unit lists below follow it. Choose Other only for a unit that is not listed: every quantity must then use the same unit.
How to read the value	Yes	Select: Half-width (plus or minus); Full span (total width); Resolution (least count); Manufacturer specification	Half-width: the value is the limit a (the plus-or-minus half of the interval). Full span: the value is the total width, so a is half of it. Resolution: the value is the smallest step of a display, and a is half a step (GUM F.2.2.1). Manufacturer specification: a is the sum of the terms of a datasheet specification such as 0.05 % of reading + 2 counts.

Field	Required	Format or options	What it means (form help text)
Single value (shown for Half-width, Full span, Resolution)			
Value	Yes, when shown	Bare number, greater than 0	A bare number; the unit goes in the box beside it. For a span, the total width. For a resolution, the least count of the display, for example 0.01.
Value unit	Yes, when shown	Select: the units of the chosen domain	Unit of the value (not %).
Specification terms (shown for Manufacturer specification)			
Percent of reading	No	Bare number, 0 or more	Percent of the reading (or of the output or nominal value). A bare number, for example 0.05. Leave blank when the specification has no such term.
ppm of reading	No	Bare number, 0 or more	Parts per million of the reading, written $\mu\text{V}/\text{V}$, $\mu\text{A}/\text{A}$ or $\mu\Omega/\Omega$ on calibrator datasheets. A bare number, for example 8.
Percent of range	No	Bare number, 0 or more	Percent of the range (full scale). A bare number, for example 0.01.
ppm of range	No	Bare number, 0 or more	Parts per million of the range (full scale), written $\mu\text{V}/\text{V}$, $\mu\text{A}/\text{A}$ or $\mu\Omega/\Omega$ on calibrator datasheets. A bare number, for example 2.
Counts (last-digit steps)	No	Bare number, 0 or more	One count is one step of the least significant digit on the range in use: enter the number of steps, for example 2 for "2 counts". It is not a percentage. Give the step itself in Resolution on that range below.
Fixed term (floor)	No	Bare number, 0 or more	The floor or fixed term of the specification, in its own unit, for example 10 with μV . Use the specification for the stated period (90 days, 1 year), confidence level and conditions.

Field	Required	Format or options	What it means (form help text)
Fixed term unit	When the fixed term is not zero	Select: the units of the chosen domain	Unit of the fixed term. Required when the fixed term is not zero.
Reference quantities (shown for Manufacturer specification)			
Reading, output or nominal	When a reading term is not zero	Bare number; a negative sign is allowed and its magnitude is used	The reading, output or nominal value the specification is applied to (a calibrator specifies a percentage of its output, a meter of its reading). Needed when a reading term is not zero. Its unit becomes the unit of u.
Reading unit	With the reading	Select: the units of the chosen domain	Unit of the reading. Required with the reading; it becomes the unit of u.
Range (full scale)	When a range term is not zero	Bare number, greater than 0 when used	Full scale of the range in use. Needed when a range term is not zero.
Range unit	With the range	Select: the units of the chosen domain	Unit of the range. Required with the range.
Resolution on that range	When Counts is not zero	Bare number, greater than 0 when used	One count on the range in use. Find it in the range table of the user manual; a short datasheet often omits it. Needed when counts is not zero.
Resolution unit	With the resolution	Select: the units of the chosen domain	Unit of the resolution. Required with the resolution.
Distribution			
Distribution	Yes	Select: Rectangular; Triangular; U-shaped (arcsine); Normal (k	Never assumed. GUM F.2.2.1 treats a resolution as rectangular. A specification with no stated confidence level is usually treated as rectangular. When the datasheet states a confidence level or k (Fluke states 99 %, k =

Field	Required	Format or options	What it means (form help text)
		stated); Normal (confidence level stated)	2.58, for its calibrators), choose a Normal option.
Coverage factor k	Yes, when shown (Normal (k stated))	Bare number from 1 to 10	The k the source states, for example 2 or 2.58. If the datasheet states k, choose Normal (k stated) and enter it: a stated k always wins over a table factor.
Confidence level	Yes, when shown (Normal (confidence level stated))	Select: 68.27 %; 90 %; 95 %; 95.45 %; 99 %; 99.73 %	For a source that states a confidence level but no k. The factor comes from GUM Table G.1 (99 % gives 2.576).
Temperature (shown for Manufacturer specification)			
Temperature outside the band	Yes, when shown	Select: None; Coefficient per °C (of reading and range); Percentage of the specification per °C	Optional. Use it only when the datasheet widens the specification outside a temperature band. The calculator does not check the instrument's operating temperature range.
Operating temperature (°C)	Yes, when shown	Bare number, any sign	The temperature at which the instrument is used, in °C.
Band lower limit (°C)	Yes, when shown	Bare number, any sign; below the upper limit	Lower limit of the band the specification is stated for, in °C. A band written t_{cal} plus or minus 5 °C with $t_{cal} = 23$ °C is 18 °C to 28 °C.
Band upper limit (°C)	Yes, when shown	Bare number, any sign	Upper limit of the band, in °C.
Coefficient percent of reading per °C	No (at least one coefficient)	Bare number, 0 or more	Added per °C beyond the nearest limit of the band, as a percent of the reading. A bare number, for example 0.001.

Field	Required	Format or options	What it means (form help text)
	must be non-zero)		
Coefficient ppm of reading per °C	No	Bare number, 0 or more	Parts per million of the reading, per °C.
Coefficient percent of range per °C	No	Bare number, 0 or more	Percent of the range, per °C.
Coefficient ppm of range per °C	No	Bare number, 0 or more	Parts per million of the range, per °C.
Percentage of the specification per °C	Yes, when shown	Bare number, 0 or more	The percentage of the stated specification added per °C beyond the nearest limit of the band, for example 10 for a calibrator that adds 10 % of its specification per °C.
Documentation			
Source documentation	No	Free text	The datasheet, certificate or manual and the page or table. A Type B evaluation uses available information, so its source must be named (GUM 4.3.1).

4.1 How to read the value: choosing the source type

This choice decides how the half-width a is formed and which fields appear.

Option	a is	Use it for
Half-width (plus or minus)	the Value as entered	A limit written $\pm a$, or a certificate's expanded uncertainty U (with a Normal option)
Full span (total width)	Value / 2	A total interval, such as a drift band of 0.1 from end to end
Resolution (least count)	Value / 2	The smallest step of a digital display
Manufacturer specification	the linear sum of the terms	A datasheet accuracy statement

A calibration certificate has no option of its own. Enter its expanded uncertainty U as a Half-width (plus or minus), then choose Normal (k stated) with the certificate's k . If the certificate states only a confidence level, choose Normal (confidence level stated).

4.2 Manufacturer specification: terms and reference quantities

Enter each term the datasheet states and leave the rest blank. A term that is zero or blank is ignored. Each non-zero term pulls in the reference quantity it multiplies:

- Percent of reading and ppm of reading need Reading, output or nominal.
- Percent of range and ppm of range need Range (full scale).
- Counts (last-digit steps) needs Resolution on that range.
- A non-zero Fixed term (floor) needs Fixed term unit.

A reference value entered with no term that uses it is reported as not used and does not enter a. A zero reading is accepted (a zero or offset check): reading terms then contribute 0. A negative reading is accepted, and its magnitude is used.

4.3 Distribution, k and confidence level

The calculator never assumes a distribution. Coverage factor k appears only for Normal (k stated) and must be from 1 to 10. Confidence level appears only for Normal (confidence level stated). The plain word Normal is refused because it does not say which of the two applies.

4.4 Temperature outside the band

The form asks for a choice here. Choose None when the datasheet gives no temperature widening. With None, the specification is used as entered. With either of the other options, the three temperature fields appear. The Coefficient option also shows the four coefficient fields, and at least one must be non-zero. The Percentage option shows Percentage of the specification per °C. Range coefficients need a Range (full scale); reading coefficients need a Reading, output or nominal.

5. Units and unit conversion

You choose a Unit domain first; every unit box then offers only that domain's units. The calculator offers 23 domains plus Other (same unit on both values). No unit box offers %: percentages and ppm are terms, entered as bare numbers whose unit is in the field label.

Domain	Units offered
Voltage	megavolt (MV); kilovolt (kV); volt (V); millivolt (mV); microvolt (μ V); nanovolt (nV); picovolt (pV)
Current	kiloampere (kA); ampere (A); milliampere (mA); microampere (μ A); nanoampere (nA); picoampere (pA)
Resistance	teraohm (T Ω); gigohm (G Ω); megohm (M Ω); kilohm (k Ω); ohm (Ω); milliohm (m Ω); microohm ($\mu\Omega$)
Capacitance	farad (F); millifarad (mF); microfarad (μ F); nanofarad (nF); picofarad (pF)
Inductance	henry (H); millihenry (mH); microhenry (μ H); nanohenry (nH)

Domain	Units offered
Conductance	siemens (S); millisiemens (mS); microsiemens (μ S); nanosiemens (nS)
Electric charge	coulomb (C); millicoulomb (mC); microcoulomb (μ C); nanocoulomb (nC); picocoulomb (pC)
Pressure	pascal (Pa); millipascal (mPa); micropascal (μ Pa); kilopascal (kPa); megapascal (MPa); gigapascal (GPa); bar; millibar (mbar); psi; standard atmosphere (atm); torr (Torr); millitorr (mTorr); mmHg (conventional); inHg (60 °F); inHg (32 °F)
Temperature	kelvin (K); millikelvin (mK); degree Celsius (°C); degree Fahrenheit (°F); degree Rankine (°R)
Torque	newton meter (N·m); newton centimeter (N·cm); millinewton meter (mN·m); micronewton meter (μ N·m); kilonewton meter (kN·m); pound-force foot (lbf·ft); pound-force inch (lbf·in); ounce-force inch (ozf·in)
Force	newton (N); millinewton (mN); micronewton (μ N); kilonewton (kN); meganewton (MN); dyne (dyn); pound-force (lbf); ounce-force (ozf); kilogram-force (kgf)
Mass	kilogram (kg); gram (g); milligram (mg); microgram (μ g); nanogram (ng); metric ton (t); pound (avoirdupois) [lb]; ounce (avoirdupois) [oz]; grain (gr); slug
Length	meter (m); centimeter (cm); millimeter (mm); micrometer (μ m); nanometer (nm); picometer (pm); kilometer (km); inch (in); foot (ft); yard (yd); mile (mi); mil (0.001 in); nautical mile (nmi)
Time	second (s); millisecond (ms); microsecond (μ s); nanosecond (ns); picosecond (ps); minute (min); hour (h); day (d)
Frequency	hertz (Hz); millihertz (mHz); kilohertz (kHz); megahertz (MHz); gigahertz (GHz)
Angle	radian (rad); degree (°); milliradian (mrad); arcminute ('); arcsecond ("); gon
Rotational speed	revolution per minute (r/min); revolution per second (r/s); radian per second (rad/s)
Area	square meter (m ²); square centimeter (cm ²); square millimeter (mm ²); square inch (in ²); square foot (ft ²); square yard (yd ²); acre; hectare (ha)

Domain	Units offered
Volume	liter (L); milliliter (mL); microliter (μL); cubic meter (m^3); cubic centimeter (cm^3); US gallon (gal); quart (US liquid) [liq qt]; pint (US liquid) [liq pt]; fluid ounce (US) [fl oz]; cubic inch (in^3); cubic foot (ft^3)
Energy	joule (J); millijoule (mJ); microjoule (μJ); kilojoule (kJ); megajoule (MJ); calorie (IT) [cal_IT]; calorie (thermochemical) [cal_th]; kilocalorie (IT) [kcal_IT]; kilocalorie (thermochemical) [kcal_th]; watt hour (W·h); kilowatt hour (kW·h); Btu (IT) [Btu_IT]; foot pound-force (ft·lbf)
Power	watt (W); milliwatt (mW); microwatt (μW); nanowatt (nW); picowatt (pW); kilowatt (kW); megawatt (MW); horsepower (550 ft·lbf/s) [hp]; horsepower (electric) [hp (electric)]; horsepower (metric) [hp (metric)]; Btu (IT) per hour [Btu_IT/h]
Magnetic flux density	tesla (T); millitesla (mT); microtesla (μT); nanotesla (nT); gauss (G)
Magnetic flux	weber (Wb); milliweber (mWb); microweber (μWb); maxwell (Mx)

The working unit. For Half-width, Full span and Resolution, the Value unit is the unit of u; nothing is converted. For a Manufacturer specification, the working unit is the unit of the first quantity a term actually uses, in this order: Reading unit, Range unit, Resolution unit, Fixed term unit. Every other used quantity is converted into it before the terms are added.

Exact factors. Each factor is the ratio of two exact definitions from NIST SP 811 Appendix B, held as a rational number (for example 1 inch = 0.0254 m, 1 lb = 0.453 592 37 kg, 1 lbf = 1 lb $\times$ 9.806 65 m/s²). The exact converted value enters a. The card shows the converted value rounded up to the entered significant figures plus 3, at most 7, and states the factor, for example “Fixed term (floor) 10 μV converted to 0.00001 V ($\times 0.000001$, exact)”. The two inHg units are tabulated SP 811 values, so the note says tabulated and limits the figures shown.

Temperature is a difference. A limit or an uncertainty in temperature is an interval, so the Temperature domain has no offset: 1 °C = 1 K and 1 °F = 1 °R = 5/9 K. A value of 0.5 °F becomes 5/18 K, not a converted temperature reading.

Units that involve π . Degree, arcminute, arcsecond and gon (Angle), and revolution per minute and revolution per second (Rotational speed), carry a factor of π against radian, milliradian and radian per second. A conversion across that line is not exact, so it is refused. Keep every quantity of one specification in one family.

Other. Under Other (same unit on both values) you type the unit. Nothing is converted, and every quantity must carry the same unit text: “lux” and “lx” are refused as different.

6. Calculation method

The calculation has two steps: form the half-width a from the source, then divide a by the divisor of the chosen distribution (GUM 4.3).

Step 1: the half-width a . For the three single-value options, with x the Value and r a resolution:

$$a = x \quad \text{(half-width)} \quad \quad a = \frac{x}{2} \quad \text{(full span)} \\ \quad \quad a = \frac{r}{2} \quad \text{(resolution, GUM F.2.2.1)}$$

For a Manufacturer specification the terms are added linearly, because a manufacturer states its limits as a sum, not a root-sum-square. R is the reading, F the range, n the counts, r the resolution on that range and f the fixed term, all in the working unit:

$$a_{\text{spec}} = \left(\frac{p_{\text{rdg}}}{100} + q_{\text{rdg}} \cdot 10^{-6} \right) |R| + \left(\frac{p_{\text{rng}}}{100} + q_{\text{rng}} \cdot 10^{-6} \right) F + n \cdot r + f$$

With a temperature form selected, ΔT is the distance from the operating temperature t to the nearest band limit, and zero inside the band:

$$\Delta T = \begin{cases} T_{\text{low}} - t & t < T_{\text{low}} \\ 0 & T_{\text{low}} \leq t \leq T_{\text{high}} \\ T_{\text{high}} - t & t > T_{\text{high}} \end{cases}$$

The temperature term is then one of the two forms below, where c are the coefficients per °C and s is the Percentage of the specification per °C:

$$a_T = \Delta T \left[\left(\frac{c_{\text{p,rdg}}}{100} + c_{\text{q,rdg}} \cdot 10^{-6} \right) |R| + \left(\frac{c_{\text{p,rng}}}{100} + c_{\text{q,rng}} \cdot 10^{-6} \right) F \right] \quad \text{or} \quad a_T = \Delta T \cdot \frac{s}{100}$$

$$a = a_{\text{spec}} + a_T$$

A total a of zero is refused: a standard uncertainty of zero estimates nothing.

Step 2: the divisor. The distribution you choose fixes the divisor:

Distribution	Divisor	u	Basis shown on the card
Rectangular	$\sqrt{3} \approx 1.732$	$a / \sqrt{3}$	GUM 4.3.7
Triangular	$\sqrt{6} \approx 2.449$	$a / \sqrt{6}$	GUM 4.3.9
U-shaped (arcsine)	$\sqrt{2} \approx 1.414$	$a / \sqrt{2}$	GUM H.1.3.4; UKAS M3003
Normal (k stated)	k as entered (1 to 10)	a / k	GUM 4.3.3
Normal (confidence level stated)	Table G.1 factor: 68.27 % $\rightarrow$ 1; 90 % $\rightarrow$ 1.645; 95 % $\rightarrow$ 1.960; 95.45 % $\rightarrow$ 2; 99 % $\rightarrow$ 2.576; 99.73 % $\rightarrow$ 3	a / k_p	GUM Table G.1 (see 4.3.4)

For the two normal options the value entered as a is the quoted expanded uncertainty U , so $u = U / k$. The Table G.1 factors are used as the exact decimals shown.

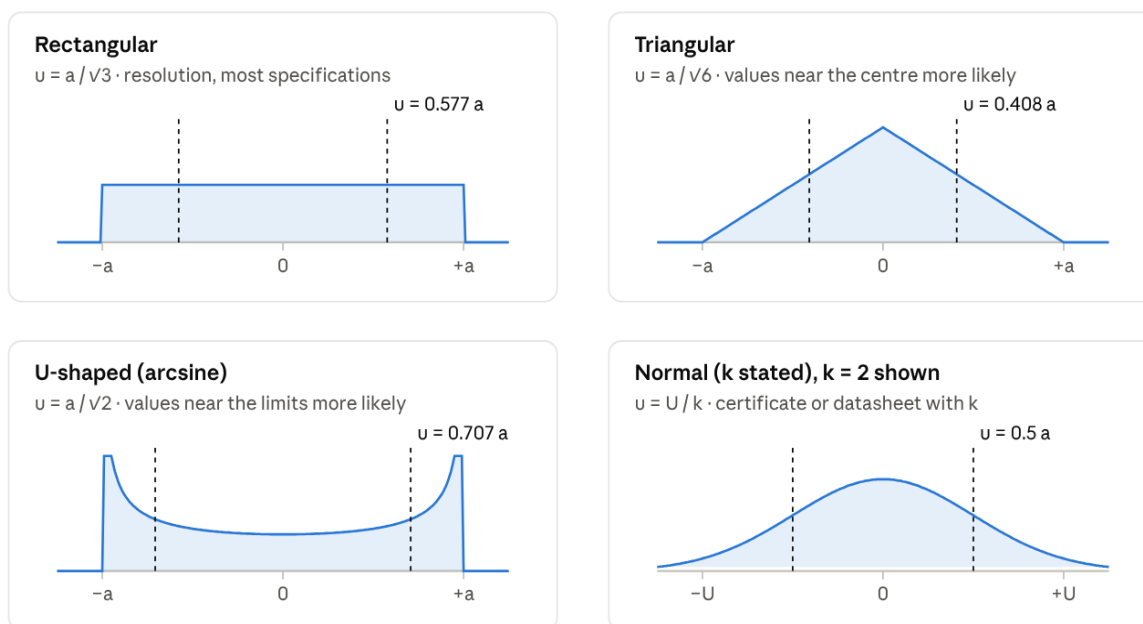
Display rules. These rules apply to every value this calculator shows:

Quantity	Rule	Why
Standard Uncertainty	Rounded up to 3 significant figures; for $\sqrt{3}$, $\sqrt{6}$ and $\sqrt{2}$ the digit is decided exactly by comparing squares	An uncertainty is never shown smaller than computed
Standard Uncertainty Full Precision	10 significant figures, correctly rounded (ties to even), trailing zeros removed	For carrying u into a budget without rounding error
Half Width A and each term	Exact when the decimal terminates; otherwise rounded up to 7 significant figures	No hidden rounding in a
A converted quantity	Rounded up to the entered significant figures + 3, at most 7 (display only; the exact value is used)	The note shows what was converted without claiming false digits

Type B distributions and their divisors

The divisor turns a half-width a into a standard uncertainty u

Each curve has unit area; the dashed lines mark plus and minus u, printed as a multiple of a



Normal (confidence level stated) is the same curve, with the GUM Table G.1 factor for the stated level used as k.

Figure 1. The four distribution shapes the calculator offers, drawn over the same half-width a. The divisor sets how far u sits from the centre: 0.707 a for U-shaped, 0.577 a for rectangular, 0.5 U for normal with k = 2, and 0.408 a for triangular.

7. Reading the results

The card opens with a headline, then the disclaimer, then a table of result rows. The language model's explanation follows; it copies the numbers and never recomputes them.

Headline. The headline states u , its shape and a , for example “ $u = 0.00289$ V (rectangular, $a = 0.005$ V)”. For the normal options it adds k : “normal, $k = 2.58$ ” or “normal, 95 %, $k = 1.960$ ”.

Card row	What it shows
Standard Uncertainty	u rounded up to 3 significant figures, with the unit. Quote this value.
Standard Uncertainty Full Precision	u to 10 significant figures, for entry into a budget
Half Width A	The total half-width a in the working unit (for the normal options, the quoted U)
Distribution	The distribution you chose, in the form's words
Divisor	$\sqrt{3}$, $\sqrt{6}$ or $\sqrt{2}$; “ $k = 2.58$ (stated)” ; or the Table G.1 factor with its level, for example “1.960 (95 % confidence level, Table G.1)”
Basis	The GUM clause for the divisor (see section 6)
How Value Was Read	How a was formed, for example “Resolution (least count) 0.01 V: $a = r / 2 = 0.005$ V (GUM F.2.2.1)”
Unit	The working unit, which is the unit of u
Terms — ...	Specification only: one row per non-zero term, its arithmetic and its value, then Terms — Half-width a (total)
Temperature — ...	With a temperature form: Operating temperature, Band, Excess beyond the band, and Form
Unit Conversions — ...	One row per converted quantity, with the factor and whether it is exact or tabulated
Other Unit	Under Other only: the unit text taken for every quantity

The calculator also reports notes that the explanation draws on: a missing Source documentation (GUM 4.3.1), the distribution and divisor used, the number of terms added linearly, each unit conversion, a zero or negative reading, reference values entered but not used, and whether the operating temperature is inside or outside the band. A resolution read as Triangular or U-shaped is computed but flagged: GUM F.2.2.1 treats a resolution as rectangular.

The PDF, Word and spreadsheet exports carry the same rows and values as the card.

8. Worked examples

Every result below was copied from a run of the production calculator (commit 5cbb347) and checked by hand in exact arithmetic. Examples 1 and 3 are live known answers B1 and B5 of MT-VAL-TB-002 Rev B.

Example 1: resolution of a digital voltmeter (known answer B1)

Field	Entered
Unit domain	Voltage
How to read the value	Resolution (least count)
Value	0.01
Value unit	volt (V)
Distribution	Rectangular

Hand calculation:

1. $a = r / 2 = 0.01 \text{ V} / 2 = 0.005 \text{ V}$.
2. $u = a / \sqrt{3} = 0.005 \text{ V} / 1.7320508... = 0.0028867513459... \text{ V}$.
3. Rounded up to 3 significant figures: 0.00289 V. To 10 significant figures: 0.002886751346 V.

Card row	Calculator result
Headline	$u = 0.00289 \text{ V}$ (rectangular, $a = 0.005 \text{ V}$)
Standard Uncertainty	0.00289 V
Standard Uncertainty Full Precision	0.002886751346 V
Half Width A	0.005 V
Divisor	$\sqrt{3}$
Basis	GUM 4.3.7
How Value Was Read	Resolution (least count) 0.01 V: $a = r / 2 = 0.005 \text{ V}$ (GUM F.2.2.1)

The display can hide any value within half a step of the reading, so the half-width is 0.005 V. Equal likelihood across that interval gives the rectangular divisor. Enter 0.002886751346 V as this contributor in a budget. The card also notes that no Source documentation was given; name the meter's manual to clear it.

Example 2: a calibration certificate with a stated k

A 10 Ω standard resistor's certificate reports $U = 0.15 \text{ m}\Omega$ with $k = 2.03$.

Field	Entered
Source description	10 ohm standard resistor, calibration certificate
Unit domain	Resistance
How to read the value	Half-width (plus or minus)
Value	0.15
Value unit	milliohm ($\text{m}\Omega$)
Distribution	Normal (k stated)
Coverage factor k	2.03
Source documentation	calibration certificate, page 2, results table

Hand calculation:

1. $a = U = 0.15 \text{ m}\Omega$.
2. $u = U / k = 0.15 \text{ m}\Omega / 2.03 = 0.073891625615... \text{ m}\Omega$.
3. Rounded up to 3 significant figures: $0.0739 \text{ m}\Omega$. To 10 significant figures: $0.07389162562 \text{ m}\Omega$.

Card row	Calculator result
Headline	$u = 0.0739 \text{ m}\Omega$ (normal, $k = 2.03$, $a = 0.15 \text{ m}\Omega$)
Standard Uncertainty	$0.0739 \text{ m}\Omega$
Standard Uncertainty Full Precision	$0.07389162562 \text{ m}\Omega$
Half Width A	$0.15 \text{ m}\Omega$
Distribution	Normal (k stated)
Divisor	$k = 2.03$ (stated)
Basis	GUM 4.3.3
How Value Was Read	Half-width of the interval: $a = 0.15 \text{ m}\Omega$

The certificate's own k is used, not 2, because a stated k always wins over a table factor. The displayed u rounds up from 0.07389 to 0.0739, so it never understates the uncertainty. Use the full-precision value in a budget.

Example 3: calibrator specification outside its temperature band (known answer B5)

A calibrator output of 10 V is specified as 8.0 ppm of output + 10 μV at $k = 2.58$, for 18 °C to 28 °C. Outside the band it adds 10 % of the specification per °C. It is used at 31 °C.

Field	Entered
Unit domain	Voltage
How to read the value	Manufacturer specification
ppm of reading	8.0
Fixed term (floor)	10
Fixed term unit	microvolt (μV)
Reading, output or nominal	10
Reading unit	volt (V)
Distribution	Normal (k stated)
Coverage factor k	2.58
Temperature outside the band	Percentage of the specification per °C
Operating temperature (°C)	31
Band lower limit (°C)	18
Band upper limit (°C)	28
Percentage of the specification per °C	10

Hand calculation:

1. Working unit: the Reading unit, V. The fixed term converts exactly: $10 \mu\text{V} \times 0.000001 = 0.00001 \text{ V}$.
2. ppm of reading: $8.0 \times 10^{-6} \times 10 \text{ V} = 0.00008 \text{ V}$.
3. $a(\text{spec}) = 0.00008 \text{ V} + 0.00001 \text{ V} = 0.00009 \text{ V}$.
4. $\Delta T = 31 \text{ °C} - 28 \text{ °C} = 3 \text{ °C}$.
5. $a(T) = 3 \times 0.10 \times 0.00009 \text{ V} = 0.000027 \text{ V}$.
6. $a = 0.00009 \text{ V} + 0.000027 \text{ V} = 0.000117 \text{ V}$.
7. $u = a / k = 0.000117 \text{ V} / 2.58 = 0.00004534883721... \text{ V}$.
8. Rounded up to 3 significant figures: 0.0000454 V. To 10 significant figures: 0.00004534883721 V.

Card row	Calculator result
Headline	$u = 0.0000454 \text{ V}$ (normal, $k = 2.58$, $a = 0.000117 \text{ V}$)
Standard Uncertainty	0.0000454 V

Card row	Calculator result
Standard Uncertainty Full Precision	0.00004534883721 V
Half Width A	0.000117 V
Divisor	k = 2.58 (stated)
Basis	GUM 4.3.3
How Value Was Read	Manufacturer specification, terms added linearly: a = 0.000117 V
Terms — ppm of reading	8.0 ppm $\times$ 10 V = 0.00008 V
Terms — Fixed term (floor)	10 μ V = 0.00001 V
Terms — Temperature outside the band	3 $^{\circ}$ C $\times$ 10 % of the specification (0.00009 V) = 0.000027 V
Terms — Half-width a (total)	0.000117 V
Temperature — Excess beyond the band	3 $^{\circ}$ C
Unit Conversions — Fixed term (floor)	Fixed term (floor) 10 μ V converted to 0.00001 V ($\times$ 0.000001, exact)

The three terms add linearly to 0.000117 V, 30 % above the in-band 0.00009 V. Because the datasheet states k = 2.58, the normal option applies. The card also notes that the operating temperature range itself was not checked; confirm 31 $^{\circ}$ C is within it in the manual.

9. Refusals and troubleshooting

The calculator refuses rather than guesses. A refusal card has a headline beginning “Cannot compute u” and one entry per problem field: the field name and the fix, what was entered, and why it was refused. Every refusal states its reason in one sentence. A specification with only zero terms, or a coefficient form with only zero coefficients, is reported as the first term “not found” even when a zero was typed. The messages below were produced by the production calculator.

Message or situation	Cause	What to do
Cannot compute u — missing Value. “Enter the half-width, e.g. “Value: 0.05”.”	Value left blank	Enter the value as a bare number.
Cannot compute u — invalid Value. ““Value” value “0,005” uses a comma. Enter decimals with a period, e.g. 0.050.”	Comma decimal	Use a period as the decimal mark.
Cannot compute u — unit mismatch in Value. ““Value: 0.005 V” carries the unit “V”. Enter the value as a bare number and choose the unit in “Value unit”, then run it again.”	Unit typed into a number box	Type only the number; pick the unit in its unit box.
Cannot compute u — unit mismatch in Percent of reading. ““Percent of reading: 0.05 %” carries “%”. This field takes a bare number; its unit is part of the label...”	% or ppm typed into a term	Enter 0.05, not 0.05 %.
Cannot compute u — invalid Value. ““Value” must be greater than zero. Found: “-0.005”.”	Zero or negative Value	A limit is positive; enter its magnitude.
Cannot compute u — invalid Value unit. ““Value unit:” must be a Voltage unit: megavolt (MV); ... Found: “ampere (A)”.”	Unit from another domain	Choose the correct Unit domain or unit.
Cannot compute u — missing Distribution. “MetTutor never assumes a distribution.”	No distribution chosen	Choose one of the five options.
Cannot compute u — invalid Distribution. ““Distribution: Normal” is not specific enough.”	Plain “Normal”	Choose Normal (k stated) or Normal (confidence level stated).
Cannot compute u — invalid Distribution. “A resolution limit is not a normal quantity: GUM F.2.2.1 treats the resolution of a digital indication as a rectangular distribution.”	Resolution (least count) with a Normal option	Choose Rectangular, or Triangular or U-shaped with a documented reason.

Message or situation	Cause	What to do
Cannot compute u — invalid Coverage factor k. “"Coverage factor k" must be greater than zero. Found: "0".”	k of zero; k must also be from 1 to 10	Enter the k the source states.
Cannot compute u — invalid Confidence level. “must be one of: 68.27 %; 90 %; 95 %; 95.45 %; 99 %; 99.73 %. Found: "97 %".”	Level not in Table G.1 as offered	Choose a listed level, or use Normal (k stated) if the source gives k.
Cannot compute u — missing Percent of reading. “Enter at least one non-zero specification term...”	Manufacturer specification with no non-zero term; also shown, with the evidence “"Percent of reading" was not found in the request.”, when only zeros were typed (for example Percent of reading: 0)	Enter the datasheet's terms.
Cannot compute u — missing Reading, output or nominal. “A reading, output or nominal value is required by the "of reading" terms...”	A reading term with no reading (Reading unit is also reported)	Enter the reading and its unit.
Cannot compute u — missing Resolution on that range. “The resolution on the range in use is required by the counts term...”	Counts with no resolution	Enter one count's value from the range table.
Cannot compute u — invalid Range (full scale). “"Range (full scale)" must be greater than zero.”	Range of 0 with a range term	Enter the full scale of the range in use.
Cannot compute u — the terms entered give a = 0. “Enter a non-zero reading, or add a range, counts or fixed term from the specification.”	Only reading terms, on a zero reading	Add the range, counts or floor terms the datasheet gives.
Cannot compute u — unit mismatch in Fixed term unit. “Fixed term (floor) is in rad and the working unit is ° (different π families).”	Radian and degree mixed in one specification	Enter every quantity in degrees, minutes and seconds, or every quantity in radians.
Cannot compute u — unit mismatch in Fixed term unit. “Under Other, every quantity must use the same unit... Found "lx" and "lux".”	Different unit text under Other	Type the identical unit, or choose a listed domain.

Message or situation	Cause	What to do
Cannot compute u — invalid Band lower limit (°C). “The band lower limit (28 °C) must be below the band upper limit (18 °C).”	Band limits reversed	Swap the two limits.
Cannot compute u — missing Coefficient percent of reading per °C. “The coefficient form needs at least one non-zero coefficient per °C...”	Coefficient form with no non-zero coefficient; a typed 0 is also reported as “not found”	Enter the coefficient, or choose None.
Result computed, with a note that a resolution read with a triangular distribution is not rectangular	Resolution (least count) with Triangular or U-shaped	Keep it only with a documented reason.

10. Scope and limitations

- The calculator evaluates one Type B contributor. It does not combine contributors, apply sensitivity coefficients or compute effective degrees of freedom; use the GUM Uncertainty Budget Calculator for that.
- You choose the distribution. The calculator never assumes one, and it does not judge whether your choice suits the source.
- Limits are symmetric ($\pm a$). One-sided or asymmetric limits are not offered.
- Specification terms are added linearly, as manufacturers state them. The calculator does not check that the specification period, confidence level or conditions match your use.
- The temperature term covers only operation outside the stated band. The instrument's operating temperature range is not checked.
- Units convert only within one domain, and never across the π line in Angle and Rotational speed. Under Other, nothing converts.
- The validation (MT-VAL-TB-002 Rev B) covers every number on the card and in the exports. The model-written explanation is outside it.
- The result is for education and training. A laboratory using it in calibration work must validate that use under ISO/IEC 17025:2017 7.11, and its budgets must follow its documented procedure.

11. References

1. JCGM 100:2008, Evaluation of measurement data — Guide to the expression of uncertainty in measurement (GUM), clauses 4.3, F.2.2.1, H.1.3.4 and Table G.1.
2. ISO/IEC 17025:2017, General requirements for the competence of testing and calibration laboratories, clauses 7.6 and 7.11.
3. NIST SP 811:2008, Guide for the Use of the International System of Units (SI), Appendix B.
4. UKAS M3003, The Expression of Uncertainty and Confidence in Measurement (U-shaped distribution).
5. MT-VAL-TB-002 Rev B, Type B Uncertainty Estimator validation record, AI Metrologist, LLC, 18 October 2026.
6. MT-VAL-SUM-001 Rev B, MetTutor Deterministic Calculators — Validation Summary, 18 October 2026.
7. Racen, K. (2026). [Deterministic Computation in AI-Assisted Metrology](#).

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