



TUR Calculator (Simplified) — Instruction Guide

The TUR Calculator (Simplified) divides a DUT tolerance by the 95 % expanded uncertainty of the calibration, places the ratio against 4:1, and gives the Method 6 guard band when 4:1 is not met.

Document control	
Document number	MT-IG-TURS-001
Revision	A
Applies to	TUR Calculator (Simplified) on mettutor.ai
Access	Explorer plan and above
Validation record	MT-VAL-TURS-002 Rev B
Date	19 October 2026

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1. Purpose and application

Use this calculator to answer one question: is the calibration process good enough, by the 4:1 rule, to judge this DUT against its tolerance? It computes the test uncertainty ratio (TUR) from two numbers you already have: the DUT's $\pm$ tolerance and the uncertainty of the calibration.

Typical uses:

- Checking a planned calibration before you run it, using the uncertainty from your standard's certificate or your uncertainty budget.
- Checking a test point that a percentage specification makes tight, such as ± 0.05 % of reading at a low value.
- Learning how a standard uncertainty or a certificate value at $k < 2$ must be brought to 95 % coverage before any ratio is formed.
- Finding the Method 6 guard band to apply when the ratio falls between 1:1 and 4:1.

The result is a training and planning aid. The card carries this disclaimer from the code: production conformance decisions need the full Z540.3 method, with false accept and false reject risk analysis and guard band sizing per your laboratory procedure. For that analysis, use the TUR Calculator (Full) (section 10).

2. Standards basis

The TUR definition and the 4:1 criterion come from ANSI/NCSL Z540.3-2006. Z540.3 was withdrawn as an active standard in October 2020. It is still widely specified by contract and in laboratory quality systems, which is why MetTutor teaches it.

Standard	What the calculator takes from it
ANSI/NCSL Z540.3-2006 (withdrawn Oct 2020), 3.11	The TUR definition: the span of the tolerance divided by twice the 95 % expanded uncertainty of the calibration process
ANSI/NCSL Z540.3-2006 (withdrawn Oct 2020), 5.3 b)	The 4:1 criterion. The requirement is a false accept probability of 2 % or less; a TUR of 4:1 or more is the fallback where that probability is not estimated
NCSLI Handbook for the Application of ANSI/NCSL Z540.3-2006, Appendix A	Guard Band Method 6, which sets a guard band from the TUR alone for a 2 % false accept limit
ILAC-G8:09/2019	ILAC-G8:09/2019 defines TUR as the tolerance TL divided by the 95 % expanded uncertainty ($TUR = TL/U$)
JCGM 100:2008 (GUM), 6.2 and 6.3	The expanded uncertainty $U = k \cdot u$ and the coverage factor k

Standard	What the calculator takes from it
JCGM 100:2008 (GUM), 7.2.6	Permits rounding uncertainties up rather than to nearest; the calculator does this for the displayed U95
NIST SP 811 (2008), Appendix B	The exact conversion factors between units of one quantity
ISO/IEC 17025:2017, 7.11.2	Software used for calculations is validated before use. MT-VAL-TURS-002 Rev B is the developer's validation evidence; a laboratory's own validation under ISO/IEC 17025:2017 7.11 may use it

The two TUR definitions give the same number for a symmetric $\pm T$ tolerance when TL is read as the half-width T and U is U95. If a procedure takes TL as the full span, its ratio is twice this calculator's; check which it means before comparing figures.

3. How the calculator ensures accurate results

Code computes every number on the card; the language model only explains them. The parser reads each field, refuses anything ambiguous, and converts units with exact rational factors from the typed decimals, except factors involving π (section 5.2). The displayed U95 is computed exactly and rounded up; the TUR is truncated, never rounded up. The model receives the finished values and must copy them, not recompute them. The method is described in [Deterministic Computation in AI-Assisted Metrology](#) (Racen, 2026).

MT-VAL-TURS-002 Rev B validated this calculator with 0 mismatches over 12,000 random cases against an independent Python reference. The cases covered all three bands (5,302 meets, 3,785 below, 2,913 exceeds), 4,817 unit conversions (214 with a π factor) and 3,785 Method 6 rows. All 11 edge and rejection cases behaved as specified, and live tests S1 to S5 and TURS-x passed on the card and in the PDF.

4. Input fields

The form has nine fields, in this order. All nine are always shown; the parser enforces the conditional ones. The "What it means" column quotes the help text the form shows.

Field	Required	Format or options	What it means
Unit domain	Yes	One of 24 options (section 4.1)	"The physical quantity of the values. Temperature means a temperature difference: a tolerance or an uncertainty in temperature is an interval, so °C and K are equal steps and °F and °R are 5/9 K. Choose "Other (same unit on both values)" for anything not listed, such as %RH, dB, ppm, counts or digits: you type one unit, both values must use it, and nothing is converted."
DUT tolerance (half-width)	Yes	Number only, greater than 0 (example 0.5)	"The DUT's $\pm$ tolerance, i.e. half the tolerance span, as a number only: choose its unit next to it. For asymmetric limits, enter half the total span. For a percentage, enter the percent here, choose % as the unit and give the reference value it applies to."
Tolerance unit	Yes	A unit of the chosen domain, or %	"Unit of the tolerance, or % for a percentage tolerance."
Uncertainty is stated as	Yes	Expanded uncertainty U; Standard uncertainty u	"Choose Expanded if your value comes from a calibration certificate with a coverage factor k. Choose Standard if it is a combined standard uncertainty u."
Uncertainty value	Yes	Number only, greater than 0 (example 0.1)	"The uncertainty value only, as a number: choose its unit next to it. In another unit of the same domain than the tolerance, it is converted exactly into the tolerance unit."
Uncertainty unit	Yes	A unit of the chosen domain (no %)	"Unit of the uncertainty (not %)."
Reference value (nominal / reading / full scale)	Only for a % tolerance	Number only, not zero (example 100)	"Needed only when the tolerance is a percentage: the value that percentage applies to, as a number only; choose its unit next to it. Leave blank for an absolute tolerance."

Field	Required	Format or options	What it means
Reference value unit	Only for a % tolerance	A unit of the chosen domain (no %)	"Unit of the reference value (not %). Required whenever the tolerance is a percentage."
Coverage factor k	Only for an expanded uncertainty	Number from 1 to 10 (example 2)	"Required for an expanded uncertainty: the k stated on the certificate (usually 2). Leave blank for a standard uncertainty."

Every value field takes a bare number with a period as the decimal mark. A unit typed into a value field, such as "0.5 V", is refused; choose the unit in the unit field instead.

4.1 Unit domain

The domain sets the unit lists of the three unit fields (Tolerance unit, Uncertainty unit, Reference value unit). The options are: Voltage, Current, Resistance, Capacitance, Inductance, Conductance, Electric charge, Pressure, Temperature, Torque, Force, Mass, Length, Time, Frequency, Angle, Rotational speed, Area, Volume, Energy, Power, Magnetic flux density, Magnetic flux, and Other (same unit on both values).

Temperature is the interval domain: every value is a difference, never a temperature reading, so no offset is ever applied. Under Other (same unit on both values) the unit fields become free text. Type the same unit in each; a different spelling is refused, because nothing is converted. Type the unit identically, including capitals. A bare % is read as a percentage tolerance.

4.2 Tolerance unit and the reference value

Choose a unit for an absolute tolerance, and leave both reference fields blank. Choose % for a percentage tolerance; the Reference value and its unit then become required. The reference may be the nominal, the reading or the full scale, whichever the specification names. Its unit becomes the working unit of the calculation. A negative reference is accepted and used as its magnitude.

For a combined specification, such as $\pm(0.02\% \text{ of reading} + 2 \text{ digits})$, add the parts yourself and enter the total as an absolute half-width. The form takes one tolerance term.

4.3 Uncertainty is stated as

- **Expanded uncertainty U.** The value from a certificate or a budget, stated with a coverage factor. Coverage factor k is then required, from 1 to 10.
- **Standard uncertainty u.** A combined standard uncertainty at one standard deviation. Leave Coverage factor k blank; a value there is ignored.

Section 6.2 shows how each choice becomes U95.

4.4 Uncertainty unit

Any unit of the chosen domain. It need not match the tolerance unit: an uncertainty in mV against a tolerance in V is converted exactly (section 5). Percent is not offered: a percentage uncertainty is not supported. Convert it to a value in a unit first.

5. Units and unit conversion

The tolerance side sets the working unit, and only the uncertainty is ever converted. The working unit is the Tolerance unit, or the Reference value unit when the tolerance is a percentage.

5.1 Domains and units

The Tolerance unit list is the domain's list plus %. The Uncertainty unit and Reference value unit lists are the domain's list without %.

Domain	Units offered (Tolerance unit adds %)
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)
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);

Domain	Units offered (Tolerance unit adds %)
	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 (μN); kilonewton (kN); meganewton (MN); dyne (dyn); pound-force (lbf); ounce-force (ozf); kilogram-force (kgf)
Mass	kilogram (kg); gram (g); milligram (mg); microgram (μg); nanogram (ng); metric ton (t); pound (avoirdupois) [lb]; ounce (avoirdupois) [oz]; grain (gr); slug
Length	meter (m); centimeter (cm); millimeter (mm); micrometer (μm); 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 (μs); 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)
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);

Domain	Units offered (Tolerance unit adds %)
	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)
Other (same unit on both values)	Free text: type one unit and use it for every value

5.2 How a conversion is made

1. When the Uncertainty unit is the working unit, nothing is converted and no conversion rows appear.
2. Otherwise the uncertainty is multiplied by the ratio of the two units' factors to the domain's SI unit. Each factor is built as an exact fraction from its definition in NIST SP 811 Appendix B: 1 in = 0.0254 m, 1 lb = 0.45359237 kg, $g_n = 9.80665 \text{ m/s}^2$, 1 atm = 101 325 Pa, 1 °F interval = 5/9 K.
3. Three cases are not plain fractions. The two inHg units use the tabulated SP 811 values. Angle and rotational speed factors that involve π are computed in double precision, unless π cancels (degree to arcminute is exact).
4. The ratio is computed from the full converted value. The card shows the converted value rounded up, at the entered significant figures plus 3, with a maximum of 7. A result that fits in the shown figures is shown without padding.
5. The card records the conversion in a Note, for example "Uncertainty 2.0 mV converted to 0.002 V (×0.001, exact)".

Temperature conversions are interval conversions: 1 °C = 1 K and 1 °F = 1 °R = 5/9 K, with no 273.15 or 32 offset.

5.3 Percentage tolerances

A percentage becomes an absolute half-width in the reference unit before anything else:

$$T = \frac{p}{100} \times |R|$$

Here p is the percent entered in DUT tolerance (half-width) and R is the Reference value. An uncertainty in another unit is then converted into the Reference value unit. Example 1 in section 8 shows the steps.

6. Calculation method

The calculator brings the uncertainty to U95 in the working unit, divides the half-width tolerance by it, and bands the unrounded ratio.

6.1 The TUR

Z540.3 3.11 divides the tolerance span by twice U95. For a symmetric $\pm T$ tolerance the span is $2T$, so the two forms are identical:

$$\mathrm{TUR} = \frac{\text{tolerance span}}{2U_{95}} = \frac{2T}{2U_{95}} = \frac{T}{U_{95}}$$

This is why the form asks for the half-width. For asymmetric limits, such as $+0.3 / -0.1$, enter half the total span (0.2).

6.2 Bringing the uncertainty to U95

The ratio needs an uncertainty at about 95 % coverage. The calculator applies one of three rules and names it on the card:

Uncertainty is stated as	Coverage factor k	U95 used	Card shows (U95 — Rule)
Expanded uncertainty U	k = 2	U	As entered (expanded U, $k \geq 2$)
Expanded uncertainty U	k above 2	U, unchanged	As entered (expanded U, $k \geq 2$)
Expanded uncertainty U	k below 2 (1 to 2)	$2U / k$	Rescaled to k = 2 ($U95 = 2U/k$)
Standard uncertainty u	Not used	$2u$	Standard uncertainty $\times 2$ ($U95 = 2u$)

$$U_{95} = \begin{cases} U & k \geq 2 \\ 2U/k & k < 2 \end{cases} \quad \text{standard uncertainty}$$

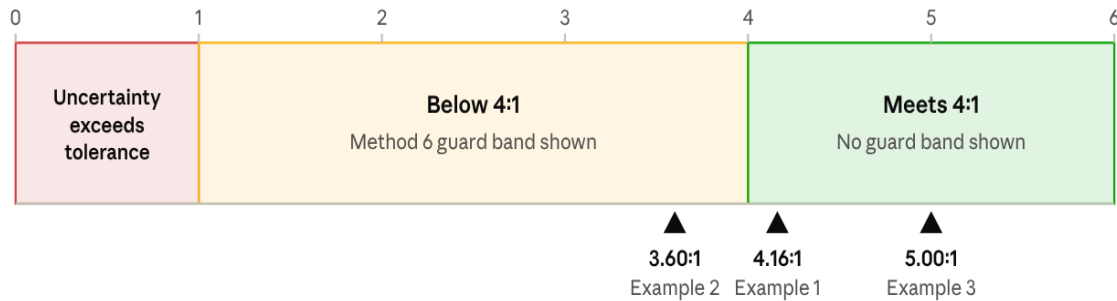
Each rule other than $k = 2$ raises a note. A k below 2 is rescaled upward, which is conservative. A k above 2 is used as entered: if it was chosen for more than 95 % coverage, the TUR is understated. A standard uncertainty times 2 assumes large effective degrees of freedom. With few degrees of freedom the 95 % factor exceeds 2; use the Welch-Satterthwaite calculator then.

6.3 The band

The band is decided on the full-precision ratio, with a relative tolerance of 10^{-12} at each boundary:

TUR	Band on the card
4 or more	Meets 4:1
1 or more, below 4	Below 4:1
Below 1	Uncertainty exceeds tolerance

The band is set by where the TUR falls against 1:1 and 4:1



TUR = T / U_{95} , decided on the full value; shown truncated to 2 decimals

TUR bands on a ratio scale, with the three worked examples

Figure 1. The three bands on a TUR scale. Examples 1 and 3 (section 8) meet 4:1; Example 2 falls below it, so its card adds the Method 6 guard band.

The tolerance absorbs floating-point error only. A tolerance of 0.5 V against $U_{95} = 0.12500000000001$ V computes as 3.9999999999968 and bands as Meets 4:1, shown 4.00:1. $U_{95} = 0.1250001$ V gives 3.9999968, which bands as Below 4:1, shown 3.99:1.

6.4 Truncation of the displayed TUR

The displayed TUR is truncated to two decimals, never rounded up:

$$\mathrm{TUR}_{\text{shown}} = \frac{\left\lfloor 100 \times \mathrm{TUR} \times (1 + 10^{-12}) \right\rfloor}{100}$$

Rounding to nearest would show 3.996 as 4.00:1 beside the words Below 4:1. Truncation shows 3.99:1, so the number never appears to reach a threshold the ratio does not reach.

6.5 Method 6 guard band (Below 4:1 only)

When the band is Below 4:1, the card adds the Z540.3 Handbook Guard Band Method 6:

$$M_{2\%} = 1.04 - e^{0.38 \ln(\mathrm{TUR}) - 0.54}, \quad g = M_{2\%} \times U_{95}, \quad A = T - g$$

Accept a reading only within $\pm A$ of the centre of the tolerance band (the nominal for symmetric limits; the midpoint for asymmetric limits). Method 6 keeps the false accept probability at 2 % or less without knowing the in-tolerance probability.

6.6 Display rules

Value	Rule on the card
TUR	Truncated to 2 decimals (6.4)
U95	Computed exactly, rounded up to 2 significant figures, zeros kept (0.10)
Uncertainty entered, standard basis	3 significant figures, zeros kept (0.0500)
Uncertainty entered, expanded basis	As typed
Tolerance, absolute	As typed
Tolerance, from a percentage	$p/100 \times R $ rounded to nearest, 4 s.f.
Converted uncertainty	Rounded up at entered significant figures + 3, maximum 7
Method 6 guard band g	Rounded up to 2 significant figures
Method 6 acceptance limit	T minus displayed g, exactly, where T is as typed or, for a percentage, $p/100 \times R $ rounded down to 4 s.f.; so the limit can be one digit below the displayed T minus g. It is never outside the true limit
Method 6 M2%	Up to 3 significant figures, trailing zeros dropped (for example 9.19 %, 11 %)

The rules apply to display only. The band and the ratio always use the full values.

7. Reading the results

The headline gives the ratio and the band in one line. The rows below it show every value the ratio was built from, in the working unit.

7.1 Headline wording

Band	Headline (TUR shown as computed)	What to do
Meets 4:1	TUR = 4.16:1 — Meets 4:1 (Z540.3 §5.3 b)	The 4:1 fallback is met. Use simple acceptance against the tolerance, unless your procedure asks for more
Below 4:1	TUR = 3.60:1 — Below 4:1 (estimate PFA or guard band)	Show the 2 % false accept limit another way: apply the Method 6 guard band, or estimate PFA with the TUR Calculator (Full)
Uncertainty exceeds tolerance	TUR = 0.83:1 — Uncertainty exceeds tolerance	The process cannot verify this tolerance. Use a better standard or method, or agree a wider tolerance

7.2 Result rows

Row	Meaning
TUR	The ratio, truncated to 2 decimals, as n.nn:1
Band	Meets 4:1, Below 4:1, or Uncertainty exceeds tolerance
Tolerance — Value / Unit / Entered	The half-width T in the working unit, and the tolerance as you typed it ("0.05 %" for a percentage)
From Percent — Percent / Reference / Reference Unit	Shown only for a percentage tolerance: p, R and the unit of R
Uncertainty Entered — Value / Unit / Basis / Coverage Factor	The uncertainty as entered. Basis reads expanded or standard; Coverage Factor appears only for expanded
Unit Scaling — Applied	Always No. It is kept for compatibility; conversions appear in the Unit Conversion rows
Unit Conversion — Field / Entered / Entered Unit / Converted / Unit / Factor / Basis / Note	Shown only when the uncertainty was converted: the factor, whether it is exact, tabulated or involves π , and a one-line Note
U95 — Value / Unit / Rule	The U95 used, rounded up to 2 significant figures, and the rule from section 6.2 in words

Row	Meaning
Method 6 — M2 Fraction / G / Acceptance Limit / Source	Shown only for Below 4:1: M2%, the guard band g, the acceptance limit $\pm A$ and the Handbook reference

Under Other (same unit on both values), a note states that both values were taken as the same unit and nothing was converted.

7.3 Notes and exports

Notes below the rows record the unit conversion, the U95 rule (when it is not $k = 2$) and the Method 6 guard band. A rule note is information, not a failure. The disclaimer is a separate block on the card. The PDF, Word and spreadsheet exports carry the same strings as the card, from one presentation function. The model's explanation quotes those values; it does not compute its own.

8. Worked examples

Each result below was copied from a run of the production calculator on the composed form text, and checked by hand in exact fractions. Example 1 is live test S2 of MT-VAL-TURS-002; Example 3 is live test S5.

Example 1 — Percentage tolerance (live test S2)

A 100 V test point with a tolerance of ± 0.05 % of the reference value. The standard's certificate gives $U = 0.012$ V at $k = 2$.

Field	Entered
Unit domain	Voltage
DUT tolerance (half-width)	0.05
Tolerance unit	%
Uncertainty is stated as	Expanded uncertainty U
Uncertainty value	0.012
Uncertainty unit	volt (V)
Reference value (nominal / reading / full scale)	100
Reference value unit	volt (V)
Coverage factor k	2

Hand calculation:

1. $T = 0.05 / 100 \times 100 \text{ V} = 0.05 \text{ V}$. The working unit is V.
2. $k = 2$, so $U_{95} = U = 0.012 \text{ V}$. No conversion is needed.
3. $TUR = 0.05 / 0.012 = 25/6 = 4.1666\dots$
4. Truncated: $4.16. 4.1666\dots \geq 4$, so the band is Meets 4:1.

Row	Calculator result
Headline	$TUR = 4.16:1$ — Meets 4:1 (Z540.3 §5.3 b)
Tolerance — Value	0.05
Tolerance — Entered	0.05 %
From Percent — Reference	100
U_{95} — Value	0.012
U_{95} — Rule	As entered (expanded U, $k \geq 2$)

The ratio meets 4:1 with little margin. Rounded to nearest it would read 4.17; truncation shows 4.16. At a 10 V test point the same 0.05 % gives $T = 0.005$ V, and the same U would give a ratio below 1. A percentage specification must be checked at each test point.

Example 2 — Unit conversion, standard uncertainty and Method 6

A thermometer with a tolerance of ± 0.2 °C. The uncertainty budget gives a combined standard uncertainty of 0.05 °F.

Field	Entered
Unit domain	Temperature
DUT tolerance (half-width)	0.2
Tolerance unit	degree Celsius (°C)
Uncertainty is stated as	Standard uncertainty u
Uncertainty value	0.05
Uncertainty unit	degree Fahrenheit (°F)

Hand calculation:

1. Convert u into the working unit °C, as an interval: $u = 0.05 \times 5/9 = 1/36$ °C = 0.027777... °C. Shown rounded up at $1 + 3 = 4$ significant figures: 0.02778.
2. Standard basis: $U95 = 2u = 1/18$ °C = 0.055555... °C. Shown rounded up to 2 significant figures: 0.056.
3. $TUR = 0.2 / (1/18) = 3.6$ exactly. Shown 3.60; band Below 4:1.
4. Method 6: $M2\% = 1.04 - e^{(0.38 \ln 3.6 - 0.54)} = 0.091852$, so 9.19 %.
5. $g = 0.091852 \times 0.055556 = 0.0051029$ °C, rounded up to 0.0052 °C.
6. $A = 0.2 - 0.0052 = 0.1948$ °C. The true limit is 0.19490 °C; the shown limit is inside it.

Row	Calculator result
Headline	TUR = 3.60:1 — Below 4:1 (estimate PFA or guard band)
Uncertainty Entered — Value	0.0500
Unit Conversion — Note	Uncertainty 0.05 °F converted to 0.02778 °C ($\times 5/9$, exact)
U95 — Value	0.056
U95 — Rule	Standard uncertainty $\times 2$ ($U95 = 2u$)
Method 6 — M2 Fraction	9.19 %
Method 6 — G	0.0052
Method 6 — Acceptance Limit	± 0.1948

The ratio is below 4:1, so the 4:1 fallback does not show the 2 % false accept limit. Accepting readings only within ± 0.1948 °C of nominal does, by Method 6. The $U_{95} = 2u$ rule assumes many degrees of freedom; check the budget's effective degrees of freedom before relying on it.

Example 3 — Certificate at $k = 1.96$ (live test S5)

A tolerance of ± 0.5 V. The certificate gives $U = 0.098$ V at $k = 1.96$.

Field	Entered
Unit domain	Voltage
DUT tolerance (half-width)	0.5
Tolerance unit	volt (V)
Uncertainty is stated as	Expanded uncertainty U
Uncertainty value	0.098
Uncertainty unit	volt (V)
Coverage factor k	1.96

Hand calculation:

1. k is below 2, so $U_{95} = 2U / k = 2 \times 0.098 / 1.96 = 0.1$ V exactly.
2. $TUR = 0.5 / 0.1 = 5$ exactly. Shown 5.00; band Meets 4:1.

Row	Calculator result
Headline	$TUR = 5.00:1$ — Meets 4:1 (Z540.3 §5.3 b)
Uncertainty Entered — Coverage Factor	1.96
U_{95} — Value	0.10
U_{95} — Rule	Rescaled to $k = 2$ ($U_{95} = 2U/k$)

Used as entered, $U = 0.098$ V would give 5.10:1. Rescaling to $k = 2$ lowers the ratio slightly, which is the conservative direction.

9. Refusals and troubleshooting

The calculator never guesses a value. An input it cannot read unambiguously is refused with a card that names the field and the fix; no TUR is shown. Every message below was produced by the production calculator.

Message or situation	Cause	What to do
Cannot compute TUR — missing Reference value (nominal / reading / full scale)	Tolerance unit is % but no reference value was given	Enter the value the percentage applies to and choose its unit
Cannot compute TUR — missing Reference value unit	Tolerance unit is % and the reference value was entered, but its unit was left blank	Choose the Reference value unit (under Other, type it)
Cannot compute TUR — missing Coverage factor k	Expanded uncertainty U chosen, k left blank	Enter the k from the certificate (usually 2)
Cannot compute TUR — invalid Coverage factor k ("must be between 1 and 10")	k entered as 0, 0.5 or above 10	Check the certificate; a k outside 1 to 10 is probably a typo
Cannot compute TUR — missing Uncertainty value	The uncertainty was left blank	Enter the uncertainty as a number
Cannot compute TUR — invalid Uncertainty value ("must be greater than zero")	Uncertainty entered as 0	Enter the real uncertainty; a zero uncertainty gives no ratio
Cannot compute TUR — invalid DUT tolerance (half-width) ("must be greater than zero")	Tolerance entered as 0 or a negative number such as -0.5	Enter the half-width as a positive number
Cannot compute TUR — invalid DUT tolerance (half-width) ("uses a comma")	A comma decimal mark, such as 0,5	Use a period: 0.5
Cannot compute TUR — unit mismatch in DUT tolerance (half-width) ("carries the unit")	A unit typed into the value field, such as 0.5 V	Enter the bare number and choose the unit in Tolerance unit
Cannot compute TUR — unit mismatch in Uncertainty unit ("Under Other, both values must use the same unit")	Under Other, two different unit spellings (ft.lb and lbf.ft, or %RH and ppm)	Type the identical unit in both fields, or choose a domain that converts
Cannot compute TUR — invalid Tolerance unit ("must be a Voltage unit")	A unit from another domain, such as psi under Voltage	Choose the correct Unit domain, then the unit

Message or situation	Cause	What to do
Cannot compute TUR — missing Unit domain ("This form has been updated")	A request from the form before the Unit domain field was added	Reopen the form and submit again
Result is Below 4:1 although your hand calculation gave 4	Your figures were rounded to nearest; the calculator truncates and uses full values (0.5 / 0.1250001 shows 3.99:1)	Use the unrounded U95. The card is right: the ratio is below 4
U95 on the card looks larger than T / TUR	U95 is rounded up to 2 significant figures; the ratio uses the full value	No action. The rounding is in the conservative direction

10. Scope and limitations

The calculator gives a ratio, a band and, below 4:1, one guard band. It does not compute a false accept or false reject probability.

- **One symmetric tolerance term.** Asymmetric limits are entered as half the span, which treats them as centred. A combined specification must be totalled by hand.
- **No risk figure.** The 4:1 band is the Z540.3 fallback, not the 2 % false accept requirement itself. A ratio of 4:1 or more says nothing about the probability for your instruments.
- **Method 6 only below 4:1.** Method 6's multiplier stays positive up to a TUR of about 4.59, but the card shows it only in the Below 4:1 band. Below 1:1 no guard band is offered.
- **U95 rules are simplified.** U95 = 2u assumes large degrees of freedom. A k above 2 is used as entered, even if chosen for more than 95 % coverage.
- **Units.** Only the uncertainty is converted. Percentage uncertainties are not supported. Under Other, no unit is recognised or converted.
- **Training use.** The result supports training and planning. Conformance decisions in production follow your laboratory procedure.
- **Explanation text.** The model-written explanation is outside the numerical validation; the card values are the authority.

When to move to the TUR Calculator (Full)

Move to the TUR Calculator (Full) when any of these apply:

- The ratio is Below 4:1 and you need the actual false accept probability, not only a guard band.
- You know, or can estimate, the in-tolerance probability (EOPR) of the instruments you calibrate.
- You want to compare guard band options: none, Method 6, $g = U$, or a guard band solved for a target PFA (default 2 %).
- A contract or procedure asks for false accept and false reject risk, not a ratio.

The Full calculator uses the same fields for tolerance and uncertainty, with the same U95 rules and unit conversion, so the same inputs carry across.

11. References

1. ANSI/NCSL Z540.3-2006, Requirements for the Calibration of Measuring and Test Equipment, 3.11 and 5.3 b). Withdrawn October 2020.
2. NCSLI, Handbook for the Application of ANSI/NCSL Z540.3-2006, Appendix A, Guard Band Method 6.
3. ILAC-G8:09/2019, Guidelines on Decision Rules and Statements of Conformity.
4. JCGM 100:2008, Evaluation of measurement data — Guide to the expression of uncertainty in measurement (GUM), 6.2, 6.3 and 7.2.6.
5. NIST SP 811 (2008), Guide for the Use of the International System of Units, Appendix B.
6. ISO/IEC 17025:2017, General requirements for the competence of testing and calibration laboratories, 7.11.2.
7. MT-VAL-TURS-002 Rev B, validation record for the TUR Calculator (Simplified), 18 October 2026.
8. K. Racen, [Deterministic Computation in AI-Assisted Metrology](#), 2026.