



TUR Calculator (Full ANSI/NCSL Z540.3) — Instruction Guide

The TUR Calculator (Full ANSI/NCSL Z540.3) computes the test uncertainty ratio, then the probability of false acceptance (PFA) and false rejection (PFR) for four guard band options, judged against the 2 % PFA limit.

Document control	
Document number	MT-IG-TURF-001
Revision	A
Applies to	TUR Calculator (Full ANSI/NCSL Z540.3) on metttutor.ai
Access	Professional plan and above
Validation record	MT-VAL-TURF-002 Rev B
Date	19 October 2026

Contents

1. Purpose and application	2
2. Standards basis	2
3. How the calculator ensures accurate results.....	3
4. Input fields	3
5. Units and unit conversion	6
6. Calculation method	8
7. Reading the results	11
8. Worked examples	12
9. Refusals and troubleshooting	16
10. Scope and limitations	17
11. References	18

1. Purpose and application

The calculator answers one question: does this calibration keep the probability of false acceptance at or below 2 %? A TUR alone cannot answer it. The risk also depends on how often items arrive in tolerance (EOPR) and on where the acceptance limits sit.

Use it to:

- check a measurement process against the 2 % PFA requirement before writing or revising a procedure;
- compare no guard band, Method 6, $g = U$ and a solved guard band side by side for the same inputs;
- size the guard band that meets a target PFA at a known EOPR;
- see why a 4:1 TUR is the fallback, not the requirement.

The calculator works on global (average) risk for a population of items. It does not judge a single measured value; the Decision Rules calculator does that. It is a training and planning tool. Production conformance decisions and guard band selection follow your laboratory procedure.

2. Standards basis

ANSI/NCSL Z540.3-2006 (R2013) was withdrawn as an active standard in October 2020 ([NCSLI](#)). Contracts still specify it, and ANAB still lists [SR 2402, Supplemental Accreditation Requirements: ANSI/NCSL Z540.3, Subclause 5.3, Calibration Laboratories](#). The calculator therefore uses sub-clause 5.3 b) as its reference requirement.

Standard	What the calculator takes from it
ANSI/NCSL Z540.3-2006, 3.11 (withdrawn Oct 2020)	The TUR: tolerance span divided by twice U95. For a $\pm T$ tolerance, $TUR = T / U95$.
ANSI/NCSL Z540.3-2006, 5.3 b) (withdrawn Oct 2020)	The requirement: PFA shall not exceed 2 %. Where PFA cannot practicably be estimated, a TUR of at least 4:1. The verdict uses the 2 % limit; the band row shows the 4:1 fallback.
NCSLI Handbook for the Application of ANSI/NCSL Z540.3-2006, Appendix A	Guard Band Method 6: $g = M2\% \times U95$ from the TUR alone — the same function the Decision Rules calculator validates against Table A17. This calculator rounds g up and the limit inward, so at TUR 2:1 it shows ± 0.085 where the Handbook prints ± 0.086 .
JCGM 106:2012, clause 9	Global risks of false acceptance and false rejection as joint probabilities over the item and measurement distributions.

Standard	What the calculator takes from it
JCGM 100:2008 (GUM), 7.2.6	GUM 7.2.6 notes it may be appropriate to round uncertainties up rather than to nearest; MetTutor does so for the U95 display.
NIST SP 811:2008, Appendix B	The exact definitions behind every unit conversion factor.

3. How the calculator ensures accurate results

Code computes every number; the language model only explains the finished values and may not recompute or re-round them. The parser reads each form field, holds typed decimals as exact fractions and refuses anything ambiguous. Conversion factors and the displayed U95 and tolerance are computed exactly from the typed digits. The TUR is a double-precision ratio, truncated for display with a 10^{-12} relative tolerance so an exact 4:1 never shows as 3.99:1. The risk integrals cannot be exact, so they use double-precision adaptive Gauss-Kronrod quadrature (G7K15) at a relative tolerance of 10^{-13} , with no random numbers. Display rules are conservative: the TUR is truncated, PFA and the guard band are rounded up, and the acceptance limit is moved inward.

Validation record MT-VAL-TURF-002 Rev B ran 2,000 random cases (7,804 guard band option rows) against an independent SciPy reference. Verdicts and displays showed 0 mismatches. The largest relative differences were 3.3×10^{-13} for PFA, 3.9×10^{-14} for PFR, 1.0×10^{-14} for worst-case PFA and 2.2×10^{-11} for the solved guard band. All 7 edge and rejection cases and all 4 live tests passed. MT-VAL-TURF-002 is the developer's validation evidence; a laboratory's own validation under ISO/IEC 17025:2017 7.11 may use it. The method is described in [Deterministic Computation in AI-Assisted Metrology](#) (Racen, 2026).

4. Input fields

The form has twelve fields, listed in form order. The help text column is the text the form shows. Seven fields are always required. Three are conditional (both reference value fields and Coverage factor k), and two are optional (In-tolerance probability (EOPR), % and Target PFA, %).

Field	Required	Format or options	What it means (form help text)
Unit domain	Yes	One of 24 options (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.

Field	Required	Format or options	What it means (form help text)
DUT tolerance (half-width)	Yes	Number greater than 0, e.g. 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	Units of the chosen domain, plus %	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 greater than 0, e.g. 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	Units of the chosen domain (no %)	Unit of the uncertainty (not %).
Reference value (nominal / reading / full scale)	When Tolerance unit is %	Non-zero number, e.g. 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.
Reference value unit	When Tolerance unit is %	Units of the chosen domain (no %)	Unit of the reference value (not %). Required whenever the tolerance is a percentage.
Coverage factor k	When the uncertainty is Expanded	Number from 1 to 10, e.g. 2	Required for an expanded uncertainty: the k stated on the certificate (usually 2). Leave blank for a standard uncertainty.
In-tolerance probability (EOPR), %	Optional; required for Solve for target PFA	Number from 10 to 99.99, e.g. 95	The probability that an item of this type is in tolerance when it arrives for calibration, from your recall history (for example 95). Leave blank to get the worst case over every possible EOPR. Enter a number from 10 to 99.99.

Field	Required	Format or options	What it means (form help text)
Guard band	Yes	Four options (4.5)	How the acceptance limits are set. None accepts at the tolerance limits. Method 6 sets a guard band from the TUR (Z540.3 Handbook, Appendix A). $g = U$ moves each limit in by the expanded uncertainty. Solve for target PFA finds the guard band that gives the target below at your in-tolerance probability, so it needs the EOPR.
Target PFA, %	Optional; read only with Solve for target PFA	Number from 0.01 to 10	Used only with Solve for target PFA. Leave blank for 2 % (the Z540.3 §5.3 b) limit). Enter a number from 0.01 to 10.

Every value field takes a bare number. A unit typed into a value field is refused; choose it in the unit field instead. Decimals use a period.

4.1 Unit domain and the unit fields

The Unit domain 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).

The three unit fields (Tolerance unit, Uncertainty unit, Reference value unit) take their lists from the Unit domain field. Only Tolerance unit offers %. Under Other (same unit on both values) each unit field is free text, and the units must be identical. Typing % as the Tolerance unit under Other makes it a percentage tolerance, which then requires a reference value and its unit. Section 5 lists every unit.

4.2 Uncertainty is stated as and Coverage factor k

- **Expanded uncertainty U.** Coverage factor k is required. At $k = 2$ the value is used as U95. Below 2 it is rescaled to $U95 = 2U/k$, which is conservative. Above 2 it is used as entered.
- **Standard uncertainty u.** $U95 = 2u$. Coverage factor k is ignored.

4.3 Reference value and its unit

Both fields are read only when Tolerance unit is %. The tolerance becomes $T = p/100 \times |\text{reference value}|$, in the reference value unit. That unit then becomes the working unit.

4.4 In-tolerance probability (EOPR), %

Enter the end-of-period reliability from your recall history, from 10 to 99.99. A trailing % sign is accepted. Leave it blank and the calculator reports the worst-case PFA over every EOPR from 10 % to 99.99 %; PFR is then not shown.

4.5 Guard band

Option	Acceptance limit A	Needs EOPR
None (simple acceptance)	$A = T$: accept at the tolerance limits	No
Method 6 (Z540.3 Handbook)	$A = T - M2\% \times U95$; not defined below 1:1	No
$g = U$ (stringent)	$A = T - U95$	No
Solve for target PFA	The widest A with PFA at or below the target	Yes

All four options are always computed and shown in the comparison table. The selected option drives the headline and the verdict.

4.6 Target PFA, %

Read only with Solve for target PFA. Blank means 2 %. The verdict is still judged against 2 %, whatever target you set.

5. Units and unit conversion

The tolerance side sets the working unit; the uncertainty is converted into it with an exact factor. The working unit is the Tolerance unit, or the Reference value unit when the tolerance is a percentage.

Unit domain	Units offered (Tolerance unit also offers %)
Voltage	megavolt (MV); kilovolt (kV); volt (V); millivolt (mV); microvolt (μ V); nanovolt (nV); picovolt (pV)
Current	kiloampere (kA); ampere (A); milliamper (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;

Unit domain	Units offered (Tolerance unit also offers %)
	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 (μN·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 (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)

Unit domain	Units offered (Tolerance unit also offers %)
Energy	joule (J); millijoule (mJ); microjoule (μ J); 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 (μ W); 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 (μ T); nanotesla (nT); gauss (G)
Magnetic flux	weber (Wb); milliweber (mWb); microweber (μ Wb); maxwell (Mx)
Other (same unit on both values)	Free text; both values must use the same unit

How conversion works.

- Each factor is built in exact rational arithmetic from the unit's definition (NIST SP 811 Appendix B). Examples: 1 in = 0.0254 m, 1 lb = 0.45359237 kg, 1 atm = 101 325 Pa, 1 torr = 101 325/760 Pa.
- The converted value is used at full precision in the ratio. The value shown is rounded up at the entered significant figures plus 3, at most 7.
- The two inHg entries are tabulated SP 811 values, not definitions. Their display is capped at the digits SP 811 prints.
- Angle and rotational speed factors that involve π are computed in double precision.
- Temperature is an interval domain. 1 °C = 1 K and 1 °F = 1 °R = 5/9 K; no offset is applied.
- A percentage tolerance is converted through its reference value: $T = p/100 \times |\text{reference}|$. The uncertainty can never be a percentage.
- Under Other, nothing is converted. Different units are refused. A Tolerance unit of % is still a percentage tolerance and needs a reference value.

Each conversion appears on the card as Unit Conversion rows and a note. Two production results: "Uncertainty 1.2 mV converted to 0.0012 V ($\times 0.001$, exact)" and "Uncertainty 0.18 °F converted to 0.1 °C ($\times 5/9$, exact)".

6. Calculation method

The calculator first finds the TUR and U95, then integrates over two normal distributions to get the risks for each guard band.

TUR and U95. T is the tolerance half-width in the working unit.

$$U_{95} = \begin{cases} 2u & \text{standard uncertainty} \\ U & \text{expanded, } k \geq 2 \\ 2U/k & \text{expanded, } k < 2 \end{cases} \quad \mathrm{TUR} = \frac{T}{U_{95}}$$

Risk model. The item value x is normal about nominal. Its spread is set so that the probability of $|x| \leq T$ equals the EOPR, R . The measurement error is normal with $u = U95/2$. The reading is $y = x + e$, and an item is accepted when $|y| \leq A$.

$$z = \Phi^{-1}\left(\frac{1+R}{2}\right), \quad \sigma_x = \frac{T}{z}, \quad u = \frac{U_{95}}{2}$$

$$\mathrm{PFA} = 2 \int_T^{\infty} \varphi(x; \sigma_x) \left[\Phi\left(\frac{A-x}{u}\right) - \Phi\left(\frac{-A-x}{u}\right) \right] dx$$

$$\mathrm{PFR} = 2 \int_0^T \varphi(x; \sigma_x) \left[1 - \Phi\left(\frac{A-x}{u}\right) + \Phi\left(\frac{-A-x}{u}\right) \right] dx$$

PFA is the probability that an item is out of tolerance and accepted. PFR is the probability that it is in tolerance and rejected. The PFA integral is cut where the integrand has fallen below 10^{-20} of its value at T , or at $T + 40 \max(\sigma_x, u)$.

Worst case when EOPR is blank. PFA is maximised over R from 10 % to 99.99 %. The code scans 200 evenly spaced values of R , then refines the best bracket by golden-section search to 10^{-10} in R . The card reports that maximum and the EOPR where it occurs. PFR has no worst case here and is not shown.

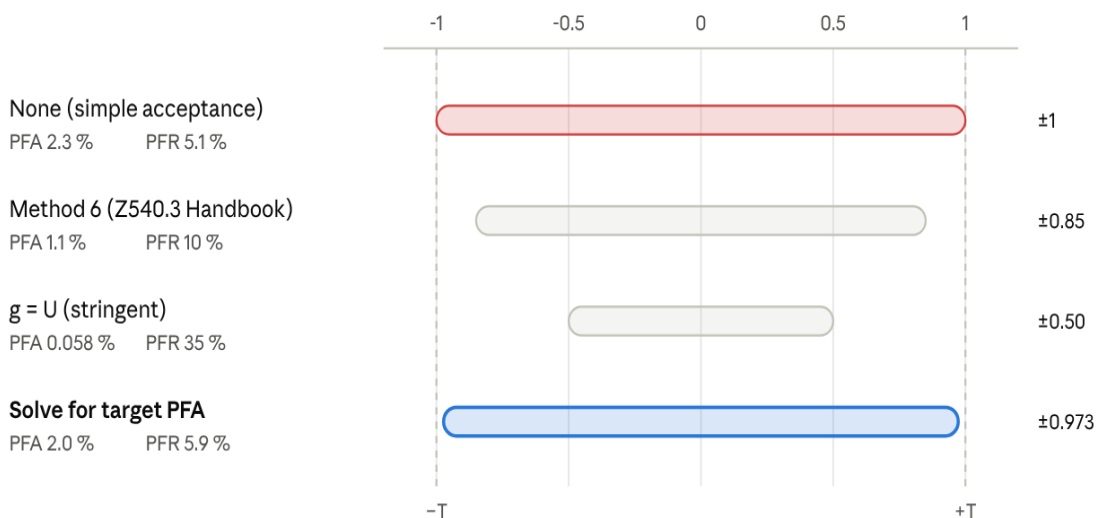
Guard bands. Each limit moves in by g , so $A = T - g$.

$$M_{2\%} = 1.04 - e^{\{0.38 \ln(\mathrm{TUR}) - 0.54\}}, \quad g_{\mathrm{M6}} = M_{2\%} \cdot U_{95}$$

- **Method 6.** M2% reaches 0 at $\mathrm{TUR} \approx 4.59:1$, so $g = 0$ from there up. Below 1:1 the method is not extrapolated and there is no acceptance zone. A ratio within 10^{-12} below 1 is evaluated at 1:1.
- **$g = U$.** $g = U95$, so $A = T - U95$. At $\mathrm{TUR} \leq 1:1$ this leaves no acceptance zone.
- **Solve for target PFA.** PFA never decreases as A widens, so the code bisects A over $(0, T]$ for up to 80 steps. It keeps the widest A whose PFA does not exceed the target. If PFA at $A = T$ already meets the target, $g = 0$. The solve needs the EOPR; without it, the option is refused or marked not available (section 9).

A 0.027 V guard band meets 2 % PFA with the least false rejection

Example 1: tolerance ± 1 V, U95 0.5 V (TUR 2.00:1), EOPR 90 %. Axis: reading minus nominal, V.



Bar: acceptance zone $\pm A$. Dashed: tolerance limits. Accent outline: selected. Critical colour: PFA over 2 %.

acceptance zones for the four guard band options, Example 1

Figure 1. Acceptance zones for the four guard band options in Example 1 (section 8). Each bar spans $\pm A$; the gap to the dashed tolerance limit is the guard band. Narrower zones lower PFA and raise PFR.

Verdict. Meets 2 % when the PFA (or worst-case PFA) is at most 2 %, within a relative tolerance of 10^{-12} . Otherwise Exceeds 2 %. No acceptance zone when A/T is 10^{-12} or less. The band row compares the unrounded TUR with 4:1 and 1:1, using the same tolerance.

The U95 rule wording. The card names the rule used: "As entered (expanded U, $k \geq 2$)", "Rescaled to $k = 2$ ($U95 = 2U/k$)" or "Standard uncertainty $\times 2$ ($U95 = 2u$)".

Display rules. Risks are computed at the true acceptance limit; only the display is rounded.

Quantity	Display rule
TUR	Truncated to 2 decimals, never rounded up ("2.00:1")
U95	Exact value rounded up to 2 significant figures ("0.50")
Standard uncertainty u , as entered	3 significant figures
Tolerance from a percentage	Acceptance limit base: exact $p/100 \times$ reference magnitude, rounded down to 4 s.f. The Tolerance — Value row shows T to 4 s.f., rounded to nearest

Quantity	Display rule
	(0.0123456 % of 1 V: Tolerance 0.0001235, Acceptance Limits ± 0.0001234).
PFA and worst-case PFA	Rounded up to 2 significant figures after a 10^{-12} relative guard; 10 % and above as a whole number
PFR	Nearest 2 significant figures; 10 % and above as a whole number
Guard band g	Rounded up to 2 significant figures; for g = U, the U95 display
Acceptance limit	Displayed T minus displayed g, in exact decimal, so it is never outside the true limit
Acceptance limit when that difference reaches 0	True A rounded down to 2 significant figures; g shown as the difference
g = 0	Limit shown as the tolerance as entered; g shows "0" ("—" for None)
EOPR at worst case	Nearest whole percent, with "≈"

7. Reading the results

The card shows a headline, a disclaimer, a result table and a guard band comparison table. The PDF, Word and spreadsheet exports carry the same strings, because one presentation function supplies every surface.

Headline. It names the TUR, the risk, the selected guard band and the verdict. Production examples:

- With an EOPR: "TUR = 2.00:1, PFA 2.0 % (EOPR 90 %), guard band for 2 % PFA — Meets 2 %"
- Without an EOPR: "TUR = 2.50:1, worst-case PFA 2.0 %, Method 6 guard band — Meets 2 %"
- Method 6 below 1:1: "TUR = 0.66:1, Method 6 is not defined below 1:1 — no acceptance zone"
- g = U at or below 1:1: "TUR = 0.83:1, g = U leaves no acceptance zone"

Result rows.

Row	What it shows
TUR	The ratio, truncated to 2 decimals
Band	Meets 4:1, Below 4:1, or Uncertainty exceeds tolerance
Tolerance — Value, Unit, Entered	T in the working unit, and the tolerance as typed (with % for a percentage)

Row	What it shows
From Percent — Percent, Reference, Reference Unit	Percentage tolerances only
Uncertainty Entered — Value, Unit, Basis, Coverage Factor	The uncertainty as typed; basis reads expanded or standard
Unit Scaling — Applied	Always No; conversions are reported in the next rows
Unit Conversion — Field, Entered, Entered Unit, Converted, Unit, Factor, Basis, Note	Only when the uncertainty was converted
Other Unit	Under Other only: the unit both values share
U95 — Value, Unit, Rule	U95 rounded up, and the rule used (section 6)
In Tolerance Probability	The EOPR as typed, or "not entered: worst case over every in-tolerance probability"
Risk Model	The model assumptions in one sentence
Selected — Guard Band, G, Acceptance Limits	The chosen option, its g and $\pm A$
Selected — PFA, PFR	With an EOPR
Selected — Worst Case PFA, EOPR At Worst Case	Without an EOPR
Selected — Verdict	Meets 2 %, Exceeds 2 %, or No acceptance zone
Target PFA	Solve for target PFA only

Guard band options table. One row per option, with the selected one marked "(selected)". The columns are Guard band, g, Acceptance limits, PFA, PFR and Verdict. Without an EOPR the PFA column is headed Worst-case PFA and PFR shows "—". An option that cannot apply shows "Not available:" and the reason. In the exports this table appears under "Guard band options".

Verdict wording. Meets 2 % means the computed PFA is at or below 2 %. Exceeds 2 % means it is above. No acceptance zone means the guard band consumed the whole tolerance, so nothing can be accepted. The verdict is decided on the unrounded PFA, so a true 1.93 % that displays as 2.0 % still meets.

8. Worked examples

Both examples are known answers from the validation record. Every calculator value below was copied from a production run of the composed form text. The hand values were checked independently with SciPy quadrature and root-finding, which share no code with production.

Example 1 — Solving a guard band for 2 % PFA (live case F)

Field	Entered
Unit domain	Voltage
DUT tolerance (half-width)	1
Tolerance unit	volt (V)
Uncertainty is stated as	Expanded uncertainty U
Uncertainty value	0.5
Uncertainty unit	volt (V)
Coverage factor k	2
In-tolerance probability (EOPR), %	90
Guard band	Solve for target PFA
Target PFA, %	(blank: 2 %)

Hand calculation.

1. $k = 2$, so $U_{95} = 0.5$ V and $u = 0.25$ V. $TUR = 1 / 0.5 = 2.00:1$, Below 4:1.
2. $z = \Phi^{-1}(0.95) = 1.644854$, so $\sigma_x = 1 / 1.644854 = 0.607957$ V.
3. No guard band ($A = 1$): $PFA = 2.263850$ %, shown rounded up as 2.3 %. $PFR = 5.083430$ %, shown as 5.1 %.
4. Method 6: $M2\% = 1.04 - e^{(0.38 \ln 2 - 0.54)} = 0.281645$. $g = 0.281645 \times 0.5 = 0.140823$ V, shown rounded up as 0.15. Shown limit = $1 - 0.15 = \pm 0.85$; true $A = 0.859177$. At the true A , $PFA = 1.085906$ % (1.1 %) and $PFR = 10.206225$ % (10 %).
5. $g = U$: $A = 1 - 0.5 = 0.5$. $PFA = 0.057678$ % (0.058 %); $PFR = 34.745630$ % (35 %).
6. Solve: the A that gives $PFA = 2$ % is 0.97315323 V, so $g = 0.02684677$ V. Shown: g 0.027, limit $1 - 0.027 = \pm 0.973$. $PFA = 2.000000$ % (2.0 %); $PFR = 5.876268$ % (5.9 %).

Calculator result. Headline: "TUR = 2.00:1, PFA 2.0 % (EOPR 90 %), guard band for 2 % PFA — Meets 2 %". Selected rows:

Row	Value
TUR	2.00:1
Band	Below 4:1

Row	Value
U95 — Value	0.50
U95 — Rule	As entered (expanded U, $k \geq 2$)
In Tolerance Probability	90 %
Selected — Guard Band	Solve for target PFA
Selected — G	0.027
Selected — Acceptance Limits	± 0.973
Selected — PFA	2.0 %
Selected — PFR	5.9 %
Selected — Verdict	Meets 2 %
Target PFA	2 %

Guard band	g	Acceptance limits	PFA	PFR	Verdict
None (simple acceptance)	—	± 1	2.3 %	5.1 %	Exceeds 2 %
Method 6 (Z540.3 Handbook)	0.15	± 0.85	1.1 %	10 %	Meets 2 %
g = U (stringent)	0.50	± 0.50	0.058 %	35 %	Meets 2 %
Solve for target PFA (selected)	0.027	± 0.973	2.0 %	5.9 %	Meets 2 %

Interpretation. At 2:1 and 90 % EOPR, accepting at the tolerance limits gives 2.3 % PFA, just over the limit. A guard band of only 0.027 V brings PFA to 2 % and costs 0.8 points of PFR (5.1 % to 5.9 %). Method 6 needs no EOPR, so it guards more heavily: 0.15 V and 10 % PFR. g = U is the most conservative option, at 35 % PFR. When the EOPR is known and trusted, the solved guard band gives the least false rejection that still meets 2 %.

Example 2 — Method 6 with EOPR unknown (worst case)

Field	Entered
Unit domain	Voltage
DUT tolerance (half-width)	0.5
Tolerance unit	volt (V)
Uncertainty is stated as	Expanded uncertainty U
Uncertainty value	0.2
Uncertainty unit	volt (V)
Coverage factor k	2
In-tolerance probability (EOPR), %	(blank)
Guard band	Method 6 (Z540.3 Handbook)

Hand calculation.

1. $U_{95} = 0.2$ V. $TUR = 0.5 / 0.2 = 2.50:1$, Below 4:1.
2. $M2\% = 1.04 - e^{(0.38 \ln 2.5 - 0.54)} = 0.214536$. $g = 0.214536 \times 0.2 = 0.04290718$ V, shown as 0.043. Shown limit = $0.5 - 0.043 = \pm 0.457$; true A = 0.45709282.
3. Worst case over EOPR 10 % to 99.99 %: no guard band 3.432362 % at $R = 0.6281$; Method 6 1.926475 % at $R = 0.6349$; $g = U$ 0.076960 % at $R = 0.6518$.
4. Displays, rounded up to 2 significant figures: 3.5 %, 2.0 % and 0.077 %. The EOPR at the Method 6 worst case shows as ≈ 63 %.

Calculator result. Headline: "TUR = 2.50:1, worst-case PFA 2.0 %, Method 6 guard band — Meets 2 %".

Selected rows:

Row	Value
TUR	2.50:1
Band	Below 4:1
U95 — Value	0.20
U95 — Rule	As entered (expanded U, $k \geq 2$)
In Tolerance Probability	not entered: worst case over every in-tolerance probability
Selected — Guard Band	Method 6 (Z540.3 Handbook)
Selected — G	0.043
Selected — Acceptance Limits	± 0.457

Row	Value
Selected — Worst Case PFA	2.0 %
Selected — EOPR At Worst Case	≈ 63 %
Selected — Verdict	Meets 2 %

Guard band	g	Acceptance limits	Worst-case PFA	PFR	Verdict
None (simple acceptance)	—	±0.5	3.5 %	—	Exceeds 2 %
Method 6 (Z540.3 Handbook) (selected)	0.043	±0.457	2.0 %	—	Meets 2 %
g = U (stringent)	0.20	±0.30	0.077 %	—	Meets 2 %
Solve for target PFA	—	—	—	—	Not available: Needs the in-tolerance probability (EOPR).

Interpretation. With no recall data, the worst EOPR (about 63 %) gives 3.43 % PFA (shown as 3.5 %) at the tolerance limits. Method 6 holds the worst case to 1.93 %, consistent with the Handbook's claim that it keeps PFA at or below 2 % whatever the EOPR. The card shows 2.0 % because PFA is rounded up; the verdict uses the unrounded value. The solve is not available without an EOPR, and PFR is not shown. These values match case C of the TUR Full known-answer record.

9. Refusals and troubleshooting

A refused input produces no numbers. The card names the field and the fix, and nothing is guessed or defaulted. Every message below was produced by the production code.

Message or situation	Cause	What to do
Cannot compute TUR — missing In-tolerance probability (EOPR), %	Solve for target PFA chosen with the EOPR blank (a refused solve)	Enter the EOPR, or choose Method 6, which needs only the TUR
Cannot compute TUR — invalid In-tolerance probability (EOPR), %	EOPR outside 10 to 99.99 (for example 100), or not a number ("about 95")	Enter a number from 10 to 99.99, or leave it blank for the worst case
Cannot compute TUR — invalid Target PFA, %	Target outside 0.01 to 10 (for example 11)	Enter a value in range, or leave it blank for 2 %
Cannot compute TUR — missing Guard band	No guard band chosen	Choose one of the four options; it is never assumed
Cannot compute TUR — missing Coverage factor k	Expanded uncertainty U with k blank	Enter the k from the certificate, usually 2
Cannot compute TUR — invalid Coverage factor k	k outside 1 to 10 (for example 12)	Check the certificate; a k outside that range is probably a typo
Cannot compute TUR — missing Reference value (nominal / reading / full scale)	Tolerance unit is % but the reference value and its unit are blank	Enter the value the percentage applies to and choose its unit
Cannot compute TUR — unit mismatch in DUT tolerance (half-width)	A unit typed into a value field ("1 V")	Enter a bare number; choose the unit in the unit field
Cannot compute TUR — unit mismatch in Uncertainty unit	Under Other, two different units ("ppm" and "%RH")	Use the same unit on both values, or choose a domain that converts
Cannot compute TUR — invalid Uncertainty value	A comma decimal ("0,25")	Use a period: 0.25
Cannot compute TUR — invalid DUT tolerance (half-width)	Tolerance of 0	Enter the half-width, greater than zero
Table row: Not available: Needs the in-tolerance probability (EOPR).	EOPR blank while another option is selected; the solve is skipped, not refused	Enter the EOPR to see the solved guard band

Message or situation	Cause	What to do
Headline: Method 6 is not defined below 1:1 — no acceptance zone	Method 6 selected with TUR below 1:1	Reduce the uncertainty or widen the tolerance; compare the other options in the table
Headline: g = U leaves no acceptance zone	g = U selected with U95 at or above T	As above; at TUR 0.83:1 no acceptance limit is left
PFR shows —	No EOPR entered; PFR has no worst case	Enter the EOPR to see PFR

10. Scope and limitations

- **Symmetric tolerance, centred distributions.** Both distributions are normal and centred on nominal. A bias in the standard or the item is not modelled. For asymmetric limits the form takes half the span, which centres them.
- **EOPR taken as the true in-tolerance probability.** An observed EOPR already includes measurement error. Using it as the true value gives a higher PFA when the EOPR is above the worst-case EOPR (about 62 % for Example 1's inputs), which is the usual case. Below that it can understate PFA: at $T = 1$ V and $U95 = 0.5$ V with no guard band, PFA is 4.17 % at 60 % EOPR but 2.77 % at 30 %. Leave EOPR blank for the worst case.
- **Global risk only.** The results are averages over a population of items. The risk for one particular reading near a limit (specific risk) is not computed; use the Decision Rules calculator.
- **Worst case over 10 % to 99.99 % EOPR.** Values outside that range are not searched.
- **Method 6 is not extrapolated below 1:1.** The calculator shows no acceptance zone instead.
- **$U95 = 2u$ assumes large degrees of freedom.** With few degrees of freedom the 95 % coverage factor exceeds 2; use the Welch-Satterthwaite calculator. A k above 2 is used as entered, which understates the TUR if k was chosen for more than 95 % coverage.
- **The uncertainty cannot be a percentage.** Convert it to a value in a unit first.
- **The verdict is always against 2 %.** A different target changes the solved guard band, not the verdict threshold.
- **The explanation is outside the numerical validation.** The model-written text is constrained by its prompt and checked in live tests, but only the card values are validated.
- **Training use.** As the card disclaimer states, production conformance decisions and guard band selection are made per laboratory procedure.

11. References

1. ANSI/NCSL Z540.3-2006 (R2013), Requirements for the Calibration of Measuring and Test Equipment, 3.11 and 5.3 b). Withdrawn as an active standard, October 2020 ([NCSLI](#)).
2. NCSLI, Handbook for the Application of ANSI/NCSL Z540.3-2006, Appendix A, Guard Band Method 6.
3. ANAB, [SR 2402, Supplemental Accreditation Requirements: ANSI/NCSL Z540.3, Subclause 5.3, Calibration Laboratories](#).
4. JCGM 106:2012, Evaluation of measurement data — The role of measurement uncertainty in conformity assessment, clause 9.
5. JCGM 100:2008 (GUM), Evaluation of measurement data — Guide to the expression of uncertainty in measurement, 7.2.6.
6. NIST SP 811 (2008), Guide for the Use of the International System of Units, Appendix B.
7. ISO/IEC 17025:2017, General requirements for the competence of testing and calibration laboratories, 7.11.2.
8. MT-VAL-TURF-002 Rev B, Validation report — TUR Calculator (Full), AI Metrologist, LLC, 18 October 2026.
9. K. Racen, [Deterministic Computation in AI-Assisted Metrology](#), 2026.

MetTutor is developed by Met Scientia, LLC.