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SureCAL™ TECHNICAL NOTES

Technical Note TN 09

Interpreting Acceptance Criteria as Reported in SureCAL

OVERVIEW:

This Technical Note discusses the various methods used by SureCAL to determine acceptance criteria, measurement accuracy, measurement uncertainty, Test Accuracy Ratio (TAR), Test Uncertainty Ratio (TUR), guard banding and ultimately the test status reporting.

Two types of acceptance reporting conventions are utilized in SureCAL. Legacy procedures, those not calculating measurement uncertainties, apply (*) to the FAIL status to quantify the significance of the failure. Procedure calculating measurement uncertainties apply (?) to quantify the PASS or FAIL status.

PASS / FAIL / FAIL*:

SureCAL procedures not calculating measurement uncertainty will use a traditional PASS/FAIL/FAIL* status when evaluating the success or failure of an individual test or event.

PASS – The measured value is within the procedure's acceptance limits.

FAIL – The measured value is outside of the procedure's acceptance limits.

FAIL* – The measured value is outside of the procedure's acceptance limits by more than the user defined level of significance. Historically this has been referred to as Significantly Out of Tolerance (SOOT).

Setting the level of a "Significant" Failure:

In many cases the level of impact or significance associated with a failure varies from user to user. Historically "Significantly Out Of Tolerance (SOOT)" conditions could vary from 0% to 100% of the Unit Under Test's (UUT) basic specification. Depending on one's quality requirements setting of the fail ratio can be a useful, cost effective method of screening failures for their impact prior to issuance of a failure report.

The threshold for the level of significance can be set on the UUT Information screen. The default is **FAIL*=SPEC x 1.000** or all failures will be reported with an (*****) and thus considered significant. The level 1.000 may be adjusted to each user's requirements.

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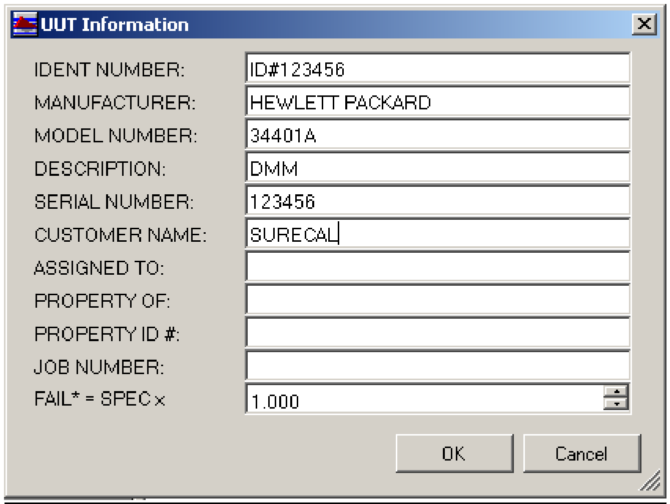
UUT Information Screen



Setting the **FAIL*=SPEC x** to a value other than **1.000** will move the limits for a failure that will be identified as “significant” as shown in the graph below.

FAIL*=SPEC x 1.25 will move the “significant” failure limit to +/-125% of the unit’s spec limit. This feature would provide the equivalent risk of a 4:1 TAR when evaluating failures.

FAIL*=SPEC x 1.10 will move the “significant” failure limit to +/-110% of the unit’s spec limit. This feature would provide the equivalent risk of a 10:1 TAR when evaluating failures.

Note- This only applies to the application of **(*)**. Measured values outside of basic spec limits are still reported as **FAIL**.

The following graph illustrates the status of failures when **FAIL*=SPEC x** is other than 1.

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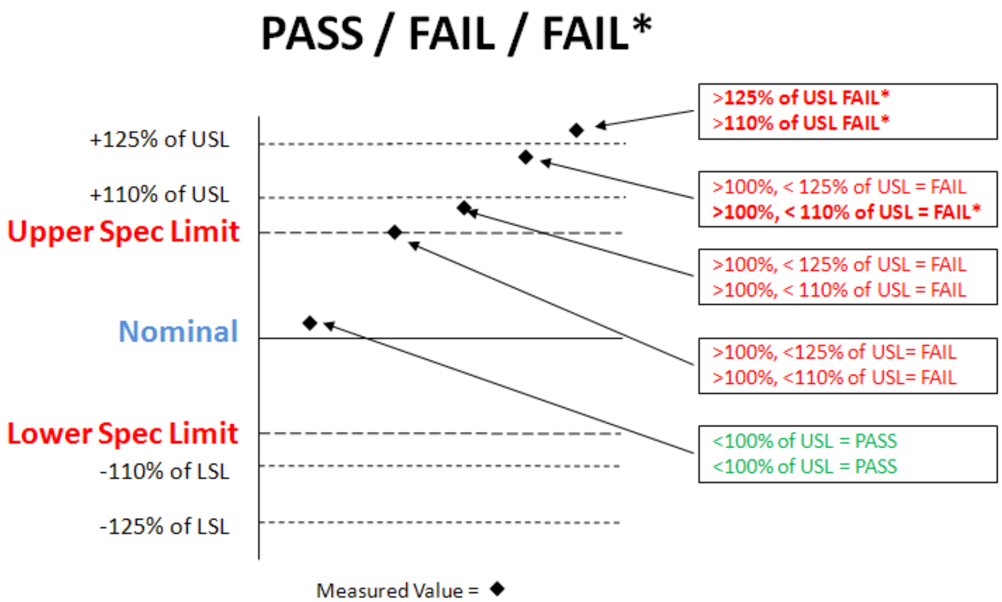

PASS / PASS? / FAIL? / FAIL:

When measurement uncertainty is included with a SureCAL procedure the PASS/FAIL evaluation is presented in a more detailed fashion. Using this method the impact of the measurement uncertainty is included in the acceptance status of the test step or event.

PASS – The measured value is within the procedure's acceptance limits. The measured value plus the expanded measurement uncertainty did not exceed the test limits.

PASS? –The measured value is within the procedure's acceptance limits. The measured value plus the expanded measurement uncertainty exceeded the test limits. This is commonly referred to as an "Ambiguous Pass".

FAIL? – The measured value is outside the procedure's acceptance limits. The measured value plus the expanded measurement uncertainty are within the test limits. This is commonly referred to as an "Ambiguous Fail".

FAIL – The measured value is outside the procedure's acceptance limits. The measured value plus the expanded measurement uncertainty are outside the test limits. This is commonly referred to as a "Hard Fail".

The following graph illustrates the status of failures when considered with the measurement uncertainty.

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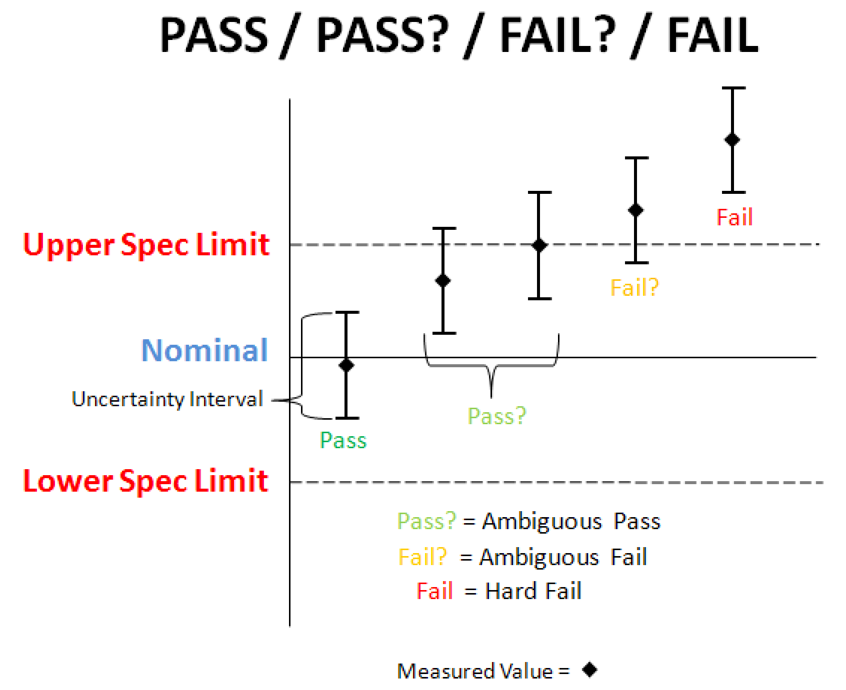

The graphic below illustrates how the TAR method of SOOT FAIL evaluation would compare to the uncertainty presentation of PASS / FAIL / FAIL? Results when the **FAIL*=SPEC x** is modified to simulate 4:1 and 10:1 failures.

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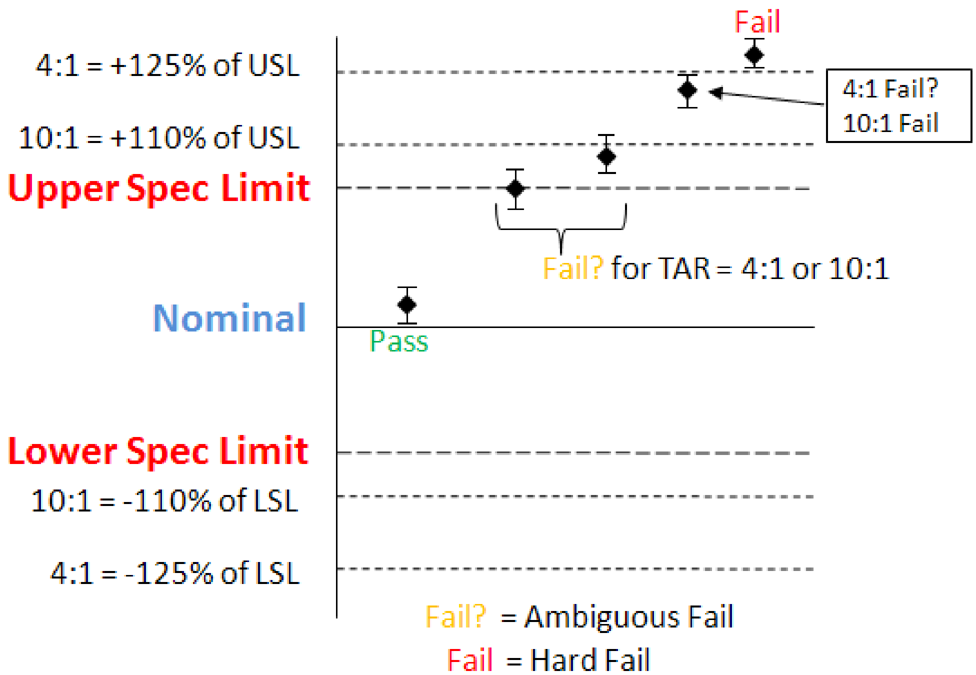

<u>Confidence in the PASS or FAIL Status:</u>

There is an element of risk every time the statement of PASS or FAIL is made. Historically that element of risk would be deemed acceptable if the ratio of the standard's accuracy to the UUT's acceptance specification met specific criteria. Determining this acceptable risk was achieved through the use of a Test Accuracy Ratio or Test Uncertainty Ratio evaluation.

<u>Test Accuracy Ratio (TAR):</u>

Test Accuracy Ratio or TAR is a simplistic method of determining the adequacy of a standard for an application by comparing its specification against the specification of the Unit Under Test (UUT) for the parameter being verified. Excluded from this type of analysis are elements such as the test repeatability, test reproducibility and environmental effects.

TAR = Unit Under Test Accuracy / Standard Accuracy

This comparison yields a ratio. Ratios of 10:1, when the standard is 10 times more accurate than the parameter being verified, are preferred. Ratios of as low as 4:1 are acceptable. Ratios below 4:1 require additional action to ensure the risk of a false acceptance is minimized. Although well in advance, this is a realization of the fundamental principle expounded in the Z540.3 as the concept of ensuring the Probability of a False Acceptance (PFA) risk is below 2%.

The example below is an excerpt from a 34401A test report. It is a simple comparison between the queried specification of the Fluke 5700A and the specification of the UUT. In this instance all of the TAR's are greater than 4:1. No additional action is required.

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DC VOLTAGE TEST PASS

* DC VOLTAGE GAIN VERIFICATION TEST *

TAR	RANGE	NOMINAL	LIMITS	MEASURED
5.9:1	100mV	+100.0000 mV	+99.9915 to +100.0085	+99.9999
6.5:1	1V	+1.000000 V	+.999953 to +1.000047	+1.000002
7.4:1	10V	+10.00000 V	+9.99960 to +10.00040	+10.00002
7.4:1	10V	-10.00000 V	-10.00040 to -9.99960	-10.00000
7.3:1	100V	+100.0000 V	+99.9949 to +100.0051	+100.0001
6.4:1	1000V	+1000.000 V	+999.945 to +1000.055	+999.997

The next example is an excerpt from a calibration event for an HP3456A. In this example the TAR for the resistance measurement fell below 4:1. The operator selected the tighten UUT test limits or guard banding. Guard banding is indicated on the data sheet as = 4.0.

RESISTANCE TESTS PASS

* RESISTANCE TEST *

RANGE	APPLIED	LIMITS	MEASURED	TAR
100 ohm	100.0007 ohm	99.9944 to 100.0070	100.0030	= 4.0
1 Kohm	1.000028 Kohm	.999998 to 1.000058	1.000031	= 4.0
10 Kohm	9.99995 Kohm	9.99964 to 10.00027	10.00015	= 4.0
100 Kohm	99.9988 Kohm	99.9961 to 100.0015	99.9989	= 4.0
1 Mohm	.999971 Mohm	.999899 to 1.000043	.999973	4.0
10 Mohm	9.9990 Mohm	9.9948 to 10.0032	9.9991	11.4
100 Mohm	99.995 Mohm	98.195 to 101.795	100.807	150.0

To keep the same level of risk provided by a 4:1 ratio the following calculation was performed:

Uut_spec=Uut_spec-(Uncertainty-(Uut_spec/4))

Test Uncertainty Ratio (TUR):

Test Uncertainty Ratio adheres to the same basic concept but is much more comprehensive in scope. The simple standards' accuracy is replaced with the entire measurement uncertainty. The measurement uncertainty could be comprised of many additional elements such as test repeatability, test reproducibility and environmental effects. These elements are then organized, combined and presented in a budget format.

TUR = Unit Under Test / Measurement Uncertainty

Guard banding is then implemented per the following ANSI/NCSLI Z540.3 formula.

$$A_{2\%} = T - U_{95\%} \times \left[1.04 - e^{\left(0.38 \cdot \log(TUR) - 0.54\right)}\right]$$

e (Euler's constant) = approx 2.71828
log = natural log

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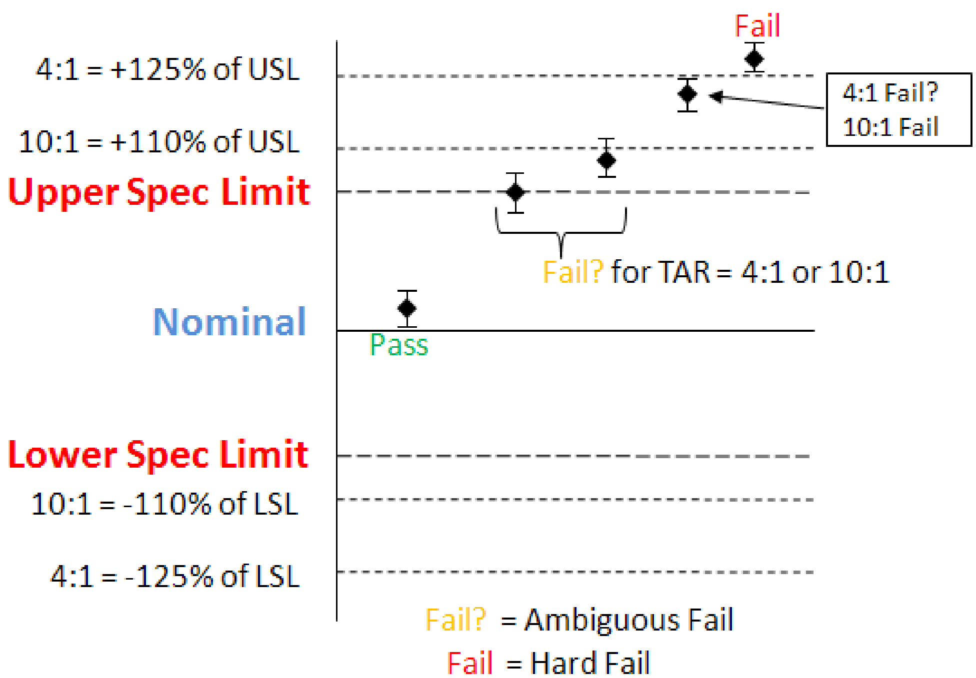
This is commonly identified as Method 6. The explanation and evaluation impact of its use as a process are covered in detail in many publications. Although there are 5 alternate methods available to ensure the 2% PFA, the usage of Method 6 as the default guard band calculation in SureCAL is based on two primary characteristics.

Method 6 is implemental at the bench level at the time of test without detailed historical information of the behaviour of the unit under test.

The Method 6 guard band calculation provides 2% PFA compliance with the least increase in Probability of False Reject (PFR).

The graphic below illustrates how the TAR method of SOOT FAIL evaluation would compare to the uncertainty presentation of PASS / FAIL / FAIL? Results when the **FAIL*=SPEC x** is modified to simulate 4:1 and 10:1 failures.



DETERMINING A STANDARD'S ACCURACY:

SureCAL determines a standard's accuracy by several methods.

Query:

The standard is queried over its remote interface. This feature is common in standards such as the Fluke 5720A Calibrator.

Driver Lookup Table:

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For DMM's, LCR meters & phase meters a specification table is built into the driver. The standards accuracy is determined by a calculation based on the function and range being used.

Definition Files:

For Vector Network Analysers (VNA) the accuracy is determined by the characteristics of the calibration kit and VNA test set being used. This information resides in the Calibration Kit Definitions (.CKD) and Test Set Definitions (.TSD) files. Calculations are performed in the subroutines to determine the system's accuracy.

Data Correction Files:

Standards with characterized or correction data are input into the program via the use of Data Correction Files (.DAT). This is common for standards such as power sensors, standard resistors etc.

Fixed Code:

When no other option is available, accuracy values may be coded into the subroutines. In this case the final uncertainty value reported will be based on the accuracy of the model listed in the equipment required table.

All of the budget elements would be categorized as Type B with distributions, sensitivity coefficients, coverage factor and correlation coefficients assigned as appropriate.

DETERMINING THE UUT REPEATABILITY:

In most procedures the number readings used to determine the UUT repeatability is hard coded into the procedure's subroutine and not a user editable parameter. Statistical tools are applied to the readings and the UUT's uncertainty contribution is presented with the appropriate Degrees of Freedom (n-1) applied.

COMBINING THE TERMS:

Type A and Type B terms are combined and the expanded uncertainty is presented for each test point as shown in the example below. This uncertainty value is then available for use when calculating the TUR against the UUT specification.

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UNCERTAINTY BUDGET FOR:

Mfg: HEWLETT PACKARD
Model: 8491B-010
Desc: FIXED ATTENUATOR
Ident No: TE54515

Procedure: CP1387
Step Title: ATTEN ACCURACY
Profile Name: HP/Agilent 8491B-010 Attenuation Accuracy
Test Point: 1

Log Time: 04/22/2010 (04:13:48 PM)

Component	Description	Uncertainty	Units	Sensitivity Coefficient	Distribution	Degrees of Freedom	Divisor	Standard Uncertainty	Relative Standard Uncertainty
A1	Reference Power Stability	+2.0000E-03	DB	+1.0000E+00	NORMAL	4	1.0000	+2.0000E-03	+0.0000E+00
A2	Measured Power Stability	+0.0000E+00	DB	+1.0000E+00	NORMAL	4	1.0000	+0.0000E+00	+0.0000E+00
B1	Reference Power Resolution	+5.0000E-03	DB	+1.0000E+00	RECTANGULAR	infinite	1.7321	+2.8868E-03	+0.0000E+00
B2	Measured Power Resolution	+5.0000E-03	DB	+1.0000E+00	RECTANGULAR	infinite	1.7321	+2.8868E-03	+0.0000E+00
B3	Receiver Linearity	+4.0364E-02	DB	+1.0000E+00	RECTANGULAR	infinite	1.7321	+2.3304E-02	+0.0000E+00
B4	PAD #1 to UUT Mismatch	+4.8626E-03	DB	+1.0000E+00	U-SHAPED	infinite	1.4142	+3.4384E-03	+0.0000E+00
B5	UUT to PAD #2 Mismatch	+1.1443E-02	DB	+1.0000E+00	U-SHAPED	infinite	1.4142	+8.0912E-03	+0.0000E+00
B6	PAD #1 to PAD #2 Mismatch	+2.0667E-02	DB	+1.0000E+00	U-SHAPED	infinite	1.4142	+1.4614E-02	+0.0000E+00
B7	Estimated Connection Repeatability	+6.0000E-03	DB	+1.0000E+00	RECTANGULAR	infinite	1.7321	+3.4641E-03	+0.0000E+00

Components		Correlation Coefficient
B4	B5	+.7500
B5	B6	-.7500
B6	B4	-.7500

Combined Standard Uncertainty: 2.5605E-02
Effective Degrees of Freedom: infinite
Level of Confidence: 95.45%
Coverage Factor: 2.0000
Expanded Uncertainty: 5.1209E-02