

***CALCULATION OF UNCERTAINTY
ASSOCIATED WITH MEASUREMENT
OF ELECTROSTATIC DISCHARGE
(ESD) CURRENT***

Author:

**Working Group 14,
Simulators
ESD Association**



*Electrostatic Discharge Association
7900 Turin Road, Bldg 3
Rome, NY 13440*

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**Prepared by:
Working Group 14
ESD Association
7900 Turin Road
Rome, New York 13440**

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Table of Contents

- 1.0 Introduction
- 2.0 Estimate the uncertainty budget
 - 2.1 Random Components
 - 2.2 Normal distribution
 - 2.3 Rectangular distribution
 - 2.4 U shaped distribution
- 3.0 Combined Uncertainty
- 4.0 Expanded Uncertainty
- 5.0 Reporting of Results
- 6.0 Examples
 - 6.1 Simulator tip voltage
 - 6.2 Simulator rise time (contact mode)
- 7.0 Uncertainty Contribution – All Parameters
- 8.0 Tip Voltage
 - 8.1 Voltmeter Accuracy
 - 8.2 Simulator voltage setting resolution
- 9.0 Target and Measurement Chain DC Attenuation
 - 9.1 Current Source Accuracy
 - 9.2 Oscilloscope vertical accuracy
- 10. Time Domain
 - 10.1 Oscilloscope time measurement accuracy
 - 10.2 Measurement system rise time (bandwidth)
- 11.0 Random Effects
- 12.0 References

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1. INTRODUCTION

Uncertainty is the estimated bounds of the deviation of a measured quantity from its true value. A statement of uncertainty is used to reflect the quality/accuracy of a measured result as compared with the true value⁽¹⁾, which is and usually will remain unknown. The statement of uncertainty is accompanied by a statement of confidence that can be placed in the value of uncertainty. A calculation of uncertainty should be performed for each measured parameter of a calibration. ESD simulator pulses are notoriously difficult to measure because of their fast rise time and shot-to-shot variations in waveform. It is necessary to consider all the possible error sources and calculate the uncertainty when measuring waveforms generated by ESD simulators. Without the statement of uncertainty and confidence, it is not clear if the simulator's performance truly falls within acceptable limits.

To calculate uncertainty, an uncertainty budget is needed for each measured parameter. An uncertainty budget is a list of the probable sources of error with an estimation of their uncertainty limits, probability distribution and their influence on the test result. The standard deviations are calculated for each of the sources in this list. The stated uncertainty is then calculated from the root sum of squares of the standard deviations of the individual uncertainty components multiplied by a coverage factor, k . The definitions, procedures and formulae for calculating uncertainty can be found in the NAMAS publication NIS81, "The Treatment of Uncertainty in EMC Measurements"⁽¹⁾.

2. ESTABLISHING THE UNCERTAINTY BUDGET

The first step in creating an uncertainty budget is to list all the measured parameters and create a table for each one. Then, for each parameter list all the probable sources of error, including random sources. Each source must then be evaluated for its bounds and distribution. Sources of information for estimating the uncertainty include manufacturers' specifications, calibration reports, estimates based on experience with the system's behavior, and a series of recorded observations (for random sources). If a quantity is measured at more than one point or over a range of points, it will be necessary to decide if the uncertainty varies over the range. If desired, the calculation may be simplified by using the worst case uncertainty for the entire range.

The following sections give the methods for estimating the standard deviation for random and systematic effects. Each of the error sources must be evaluated with one of the following methods before calculating the combined and expanded uncertainty.

2.1 RANDOM COMPONENTS

Random effects result in errors that vary in an unpredictable way while the measurement is either being made or repeated under the same conditions. The uncertainty associated with these conditions can be evaluated by statistical techniques from a series of repeated measurements. An estimate of the standard deviation, $s(q_k)$, of a series of n readings, q_k , is obtained from:

$$s(q_k) = \sqrt{\frac{1}{(n-1)} \sum_{k=1}^n (q_k - \bar{q})^2} \quad \text{where } \bar{q} \text{ is the mean value of } n \text{ measurements.}$$

The estimation of $s(q_k)$ for a random component is part of the process of creating an uncertainty budget. Typically, it is performed just once for each random component. The estimation is only valid if the EUT measurement is made under exactly the same conditions. In the case of ESD simulators, it may be necessary to establish a value of standard deviation for each simulator model to be tested since they may behave differently.

When testing the EUT, making repeated measurements, instead of just a single measurement, will reduce the random component of uncertainty. The standard uncertainty, $u(x_i)$ for random contributions is

calculated from the standard deviation of the mean, $s(\bar{q})$, as given by:

$$u(x_i) = s\left(\bar{q}\right) = \frac{s(q_k)}{\sqrt{n}}$$

If only one EUT measurement is performed, $n = 1$, then $u(x_i) = s(q_k)$, the original value. If two or more

measurements are made, $n > 1$, then the quantity $\frac{s(q_k)}{\sqrt{n}}$ will be smaller than $s(q_k)$ and thereby the

uncertainty is reduced. It is advisable to make multiple measurements whenever the measured result is close to the specified limit as this will reduce the measurement uncertainty. The average value of the repeated measurements is used as the measured result.

2.2 NORMAL DISTRIBUTION

Normal distribution is used where there is a higher probability of the true value lying nearer to the center of the range and a low probability of the value being near the limits of the range (a Gaussian distribution or “bell curve”). Normal distribution is assigned to uncertainties derived from multiple contributions. For example, when a NAMAS or other certified calibration laboratory provides a total uncertainty value with a stated confidence level for a particular instrument parameter.

$u(x_i) = \frac{\text{uncertainty}}{k}$, where *uncertainty* is the semi-range limit value ($\pm \text{uncertainty}$), and k is a coverage factor related to the level of confidence.

If the uncertainty is not symmetrical, $+\text{error} \neq -\text{error}$, then $\text{uncertainty} = \frac{+\text{error} - (-\text{error})}{2}$.