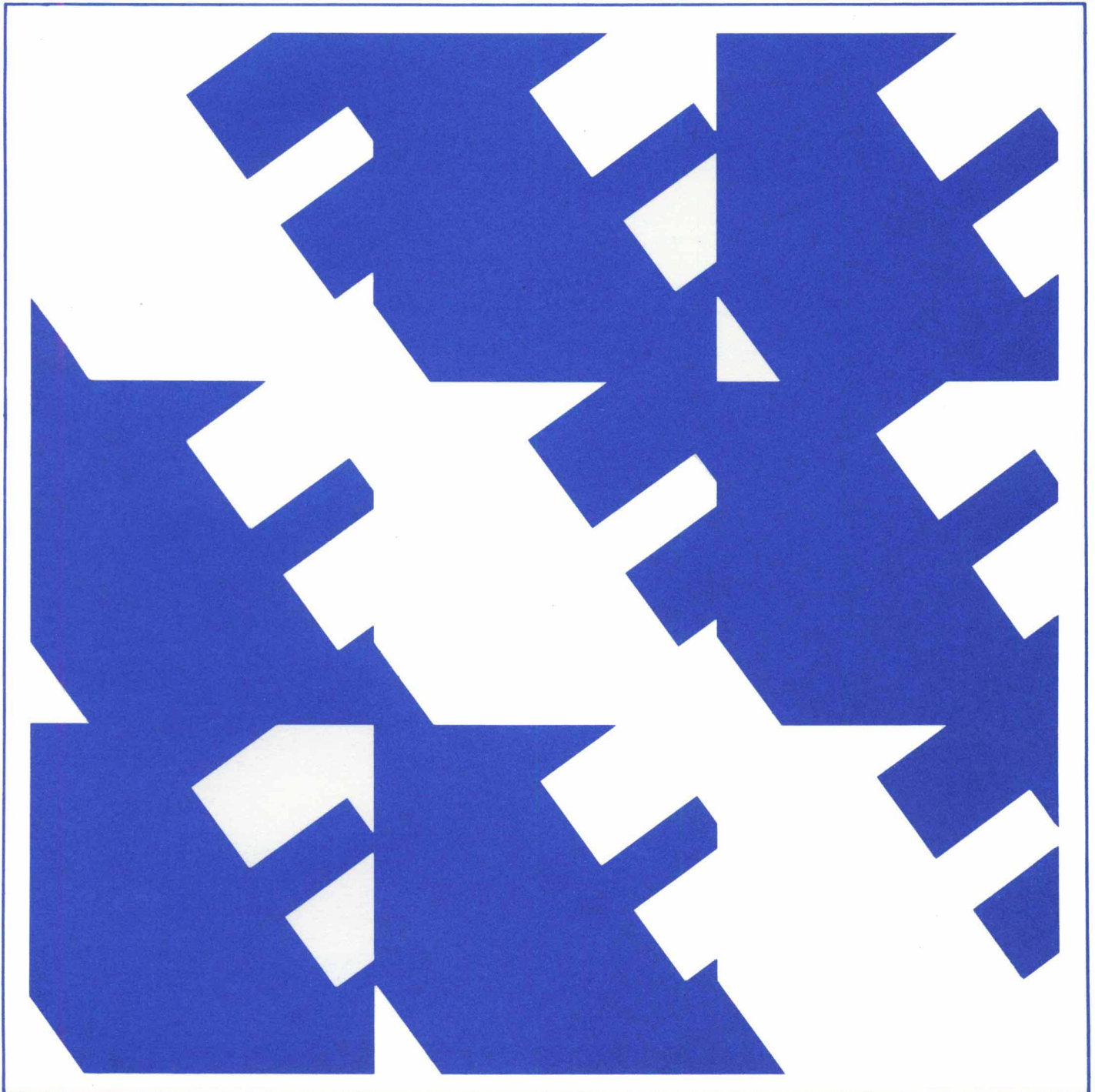


IEEE Standard Test Procedures for Semiconductor Charged-Particle Detectors

ANSI/IEEE Std 300-1982



Published by The Institute of Electrical and Electronics Engineers, Inc 345 East 47th Street, New York, NY 10017, U.S.A.
November 10, 1982



Documents

Document Sharing Hub

Authorized licensed use limited to: Tsinghua University. Downloaded on February 25, 2026 at 09:31:12 UTC from IEEE Xplore. Restrictions apply.

ANSI/IEEE
Std 300-1982
(Revision of ANSI/IEEE
Std 300-1969)

An American National Standard

**IEEE Standard Test Procedures for
Semiconductor Charged-Particle Detectors**

Sponsor
Nuclear Instruments and Detectors Committee
of the
IEEE Nuclear and Plasma Sciences Society

Approved September 17, 1981
IEEE Standards Board

Approved May 14, 1982
American National Standards Institute

© Copyright 1982 by

The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street, New York, NY 10017

*No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.*



IEEE Standards documents are developed within the Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE which have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least once every five years for revision or reaffirmation. When a document is more than five years old, and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason IEEE and the members of its technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
345 East 47th Street
New York, NY 10017
USA

Foreword

(This Foreword is not a part of ANSI/IEEE Std 300-1982, IEEE Standard Test Procedures for Semiconductor Charged-Particle Detectors.)

This standard provides standard test procedures for semiconductor charged-particle detectors for ionizing radiation. It supersedes the previous edition, ANSI/IEEE Std 300-1969. The standard has been modified and refined based on the experience gained in using the earlier edition over a number of years, taking into account advances in the technology. Companion documents are ANSI/IEEE Std 301-1976, Test Procedures for Amplifiers and Preamplifiers for Semiconductor Radiation Detectors for Ionizing Radiation. IEEE Std 325-1971, Test Procedures for Germanium Gamma-Ray Detectors, and IEEE Std 645-1977, IEEE Test Procedures for High-Purity Germanium Detectors for Ionizing Radiation.

This standard was prepared by the Nuclear Instruments and Detectors Committee of the IEEE Nuclear and Plasma Sciences Society. When this standard was approved the members of the committee were:

D. C. Cook, *Chairman*

Louis Costrell, *Secretary*

J. A. Coleman
J. F. Detko
F. S. Goulding
F. A. Kirsten

T. R. Kohler
H. Kraner
W. W. Managan
G. L. Miller
D. E. Persyk

P. L. Phelps
J. H. Trainor
S. Wagner
F. J. Walter

R. E. Stone served as project leader for this revision.

When the IEEE Standards Board approved this standard on September 17, 1981, it had the following membership:

I. N. Howell, Jr, *Chairman*

Irving Kolodny, *Vice Chairman*

Sava I. Sherr, *Secretary*

G. Y. R. Allen
J. J. Archambault
J. H. Beall
J. T. Boettger
Edward Chelotti
Edward J. Cohen
Len S. Corey

Jay Forster
Kurt Greene
Loering M. Johnson
Joseph L. Koepfinger
J. E. May
Donald T. Michael*
J. P. Riganati

F. Rosa
R. W. Seelbach
J. S. Stewart
W. E. Vannah
Virginus N. Vaughan, Jr
Art Wall
Robert E. Weiler

*Member emeritus

At the time it approved this standard, the American National Standards Committee N42 on Radiation Instrumentation had the following personnel:

Louis Costrell, *Chairman*

David C. Cook, *Secretary*

Organization Represented

Name of Representative

American Chemical Society	
American Conference of Governmental Industrial Hygienists	Jesse Lieberman
American Industrial Hygiene Association	
American Nuclear Society	F. W. Manning
American Society of Mechanical Engineers	
American Society of Safety Engineers	
Atomic Industrial Forum	
Health Physics Society	J. B. Horner Kuper J. M. Selby (<i>Alt</i>)
Institute of Electrical and Electronics Engineers	Louis Costrell D. C. Cook (<i>Alt</i>) A. J. Spurgin (<i>Alt</i>) J. Forster (<i>Alt</i>)
Instrument Society of America	M. T. Slind J. E. Kaveckis (<i>Alt</i>)

<i>Organization</i>	<i>Name of Representative</i>
Lawrence Berkeley Association	L. J. Wagner
Oak Ridge National Laboratory	Frank W. Manning
	D. J. Knowles (<i>Alt</i>)
US Nuclear Regulatory Commission	Robert A. Purple
US Department of Energy	Gerald Goldstein
US Department of the Army Materiel Command	Abraham E. Cohen
US Department of the Army, Office of Civil Defense Mobilization	Carl R. Siebentritt, Jr
US Department of Commerce, National Bureau of Standards	Louis Costrell
US Naval Research Laboratory	D. C. Cook
Members-at-Large	J. G. Bellian
	O. W. Bilharz, Jr
	John M. Gallagher, Jr
	S. H. Hanauer
	Voss A. Moore
	R. F. Shea
	E. J. Vallario

Contents

SECTION	PAGE
1. Scope	7
2. Object	7
3. Symbols and Definitions	7
3.1 Symbols	7
3.2 Definitions	9
4. Introduction.	12
4.1 Interaction of Charged Particles with Matter.	12
4.2 Semiconductor Charged-Particle Detector.	13
4.2.1 The Basic Detector	13
4.2.2 Geometry	13
4.2.3 Material.	13
4.2.4 Fabrication	14
4.3 Pulse-Shaping	14
5. General Requirements	15
6. Resolution Measurements.	16
6.1 Energy Resolution.	16
6.2 Time Resolution	18
6.2.1 Detector Electrical Rise Time	20
6.2.2 Charge Collection Time.	20
6.3 Position Resolution and Linearity of a Position-Sensitive Detector.	21
7. Noise Measurements.	23
7.1 Noise Measurement by Pulse Height Distribution (preferred method).	23
7.1.1 Measurement with Radioactive Source Calibration	23
7.1.2 Measurement with Capacitor and Pulse Generator Calibration	23
7.2 Noise Measurement by Oscilloscope and True Root-Mean-Square Voltmeter	24
7.2.1 Measurement with Radioactive Source Calibration	24
7.2.2 Measurement with Capacitor and Pulse Generator Calibration	24
7.3 Measurement of Electronic Noise with the Detector Removed	24
7.4 Determination of Detector Contribution to Noise and Resolution	25
7.5 Noise Linewidth (FWHM) as a Function of Amplifier Time Constants	25
8. Sensitivity to Ambient Conditions.	26
8.1 Atmospheric Sensitivity	26
8.2 Vacuum and Thermal Cycle Test.	26
8.3 Mechanical and Environmental Tests.	26
8.4 Light Sensitivity	26
8.5 Radiation Damage Measurements	27
9. Other Measurements.	27
9.1 Current-Voltage Characteristics.	27
9.2 Dead Layer Energy Loss	27
9.3 Sensitive Area	27
9.4 Detector Thickness (Transmission Detectors)	28
9.5 Capacitance-Voltage Characteristics	28
10. Bibliography.	29

FIGURES

Fig 1	Quasi-Gaussian Pulse Shape	15
Fig 2	Trapezoidal Pulse Shape.	15
Fig 3	System Configuration for Spectral Measurements	17
Fig 4	A Typical Spectrum	17
Fig 5	Time Resolution Measurement System.	19
Fig 6	Detector Electrical Rise Time Measurement.	20
Fig 7	Position-Sensitive Detector.	22
Fig 8	System for Position-Sensitive Detector Measurements	22
Fig 9	Apparatus for Position Measurements	22
Fig 10	Precision Pulse Generator Waveform	24
Fig 11	Noise Measurement by Oscilloscope and True RMS Voltmeter	25
Fig 12	Detector Current-Voltage Characteristic Measurement.	28

An American National Standard

IEEE Standard Test Procedures for Semiconductor Charged-Particle Detectors

1. Scope

This standard applies to semiconductor radiation detectors which are used for the detection and high-resolution spectroscopy of charged particles. The measurement techniques described have been selected to be readily available to all manufacturers and users of charged-particle detectors. Some superior techniques are not included because the methods are too complex or require equipment (such as particle accelerators) which may not be readily available.

Test procedures for the associated amplifiers and preamplifiers are described in ANSI/IEEE Std 301-1976, IEEE Standard Test Procedures for Amplifiers and Preamplifiers for Semiconductor Radiation Detectors for Ionizing Radiation, and the equivalent international publication IEC 340.

2. Object

The object of this standard is to establish standard test procedures for semiconductor charged-particle detectors. These detectors are in wide-spread use for the detection and high-resolution spectroscopy of charged particles. It is desirable to maintain standard test pro-

cedures so that measurements may have the same meaning to all manufacturers and users.

Not all tests described in this standard are mandatory, but tests which are used to specify performance shall be performed in accordance with the procedures described herein.

3. Symbols and Definitions

3.1 Symbols

C	electrical capacitance
C_c	calibrated capacitor used to couple pulse generator to circuit under test
C_{eff}	effective input capacitance of a preamplifier
C_f	feedback capacitance in the charge-sensitive loop of a preamplifier
C_t	total capacitance at preamplifier input
D	perpendicular distance from the first slit image measured along the surface of a position-sensitive detector (The image is formed by ionizing radiation passing through a mask with slits used to measure positional linearity. The first slit is at the grounded end of the detector.)

D_i	distance D between the images of the first slit and i th slit measured along the surface of a position-sensitive detector (The indices for i ranges from $i=0$ to $i=m$ such that $D_o = 0$ and D_m is the distance between the two outermost slits used.)	ΔN_T	FWHM, expressed in channels, due to the combined effect of detector and amplifier noise
δE	energy difference in dead layer measurement	ΔQ_A	FWHM, expressed in units of charge, due to amplifier noise
Δ	fullwidth at half maximum (FWHM) of a spectral peak	ΔQ_D	FWHM, expressed in units of charge, due to detector noise
ΔD_{MAX}	the maximum value observed for the difference between a value of D_i and the value of D at the point (D, S_i) on the line fitted to the set of points (D_i, S_i)	ΔQ_E	FWHM, expressed in units of charge, due to the electronic noise without the detector noise contribution
ΔD_p	FWHM of the position resolution in units of length	ΔQ_T	FWHM, expressed in units of charge, due to the combined effect of detector and amplifier noise
ΔE_A	FWHM, expressed in units of energy, due to amplifier noise	Δt	duration of a pulse; the time interval between the half amplitude points of a pulse
ΔE_D	FWHM, expressed in units of energy, due to detector noise	ΔX_S	FWHM for monoenergetic incident radiation, expressed in channels, including all spectral broadening effects
ΔE_E	FWHM, expressed in units of energy, due to electronic noise without the detector noise contribution	E, E_i	energy of a particle or radiation (or radiation having specific energy, E_i , where i is an integer, 1, 2, . . .)
ΔE_o	FWHM, expressed in units of energy, due to all factors other than electronic noise	ϵ	average energy required to form one hole-electron pair in a semiconductor detector
ΔE_S	FWHM, expressed in units of energy, derived in spectral energy resolution measurement	e	charge of the electron
ΔE_T	FWHM, expressed in units of energy, due to the combined effect of detector and amplifier noise	e_{no}	equivalent root-mean-square noise voltage referred to the preamplifier input
ΔN_A	FWHM, expressed in channels, due to amplifier noise	L_p	integral nonlinearity in position of a position-sensitive detector
ΔN_D	FWHM, expressed in channels, due to detector noise	N, N_i	channel number used to represent energy loss in detector of energy E_i
ΔN_E	FWHM, expressed in channels, due to electronic noise without the detector noise contribution	Q	electric charge
ΔN_O	FWHM, expressed in channels, due to all factors other than electronic noise	R	electrical resistance
ΔN_P	FWHM, expressed in channels, of a peak generated from the position signal of a position sensitive detector	R_L	detector load resistor
ΔN_S	FWHM, expressed in channels, of a spectral peak used for energy resolution determination	S	channel number for a multichannel analyzer spectrum obtained to check the positional resolution and linearity of position-sensitive detectors
		S_i	peak channel number of the i th position peak generated by a position-sensitive detector when used with a mask with slits. (The indices for i ranges from $i = 0$ to $i = m$.)