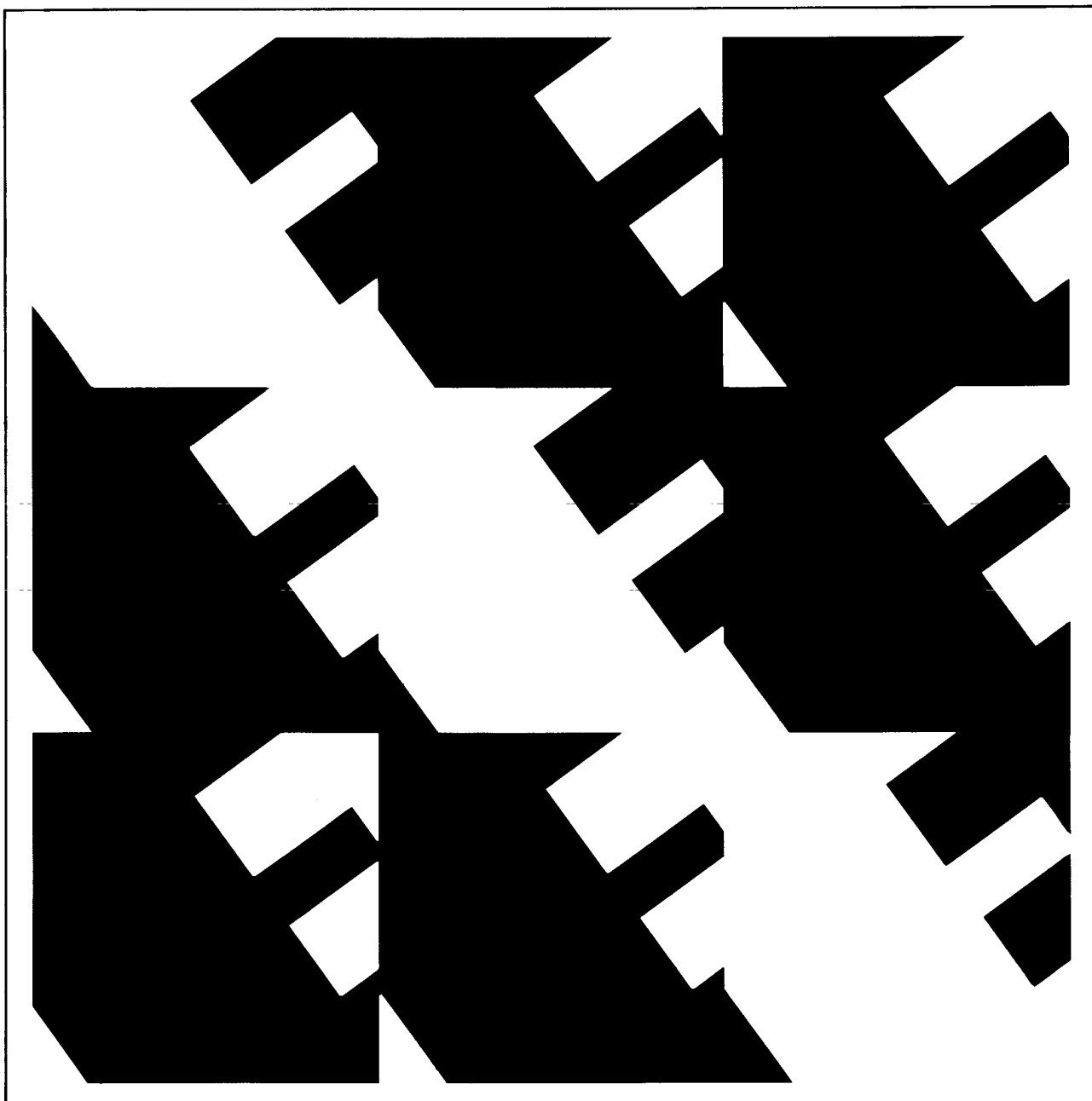


IEEE Standard Test Procedures for Germanium Gamma-Ray Detectors

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An American National Standard
**IEEE Standard Test Procedures for
Germanium Gamma-Ray Detectors**

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

Approved June 19, 1986
IEEE Standards Board

Approved August 13, 1986
American National Standards Institute

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Foreword

(This Foreword is not a part of ANSI/IEEE Std 325-1986, IEEE Standard Test Procedures for Germanium Gamma-Ray Detectors.)

This document provides standard test procedures for germanium gamma-ray detectors for ionizing radiation. It is the result of combining and updating the previous edition of this standard along with ANSI/IEEE Std 645-1977 and ANSI/IEEE Std 680-1978. The modifications and refinements are based on the experience gained in using the earlier documents over a period of years, taking into account advances in the technology. Companion documents are ANSI/IEEE Std 300-1982, IEEE Standard Test Procedures for Semiconductor Charged-Particle Detectors, ANSI/IEEE Std 301-1976, IEEE Standard Test Procedures for Amplifiers and Preamplifiers for Semiconductor Radiation Detectors for Ionizing Radiation, and ANSI/IEEE Std 759-1984, IEEE Standard Test Procedures for Semiconductor X-Ray Energy Spectrometers.

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An American National Standard

IEEE Standard Test Procedures for Germanium Gamma-Ray Detectors

1. Scope

This standard applies to germanium radiation detectors that are primarily used for detection and high-resolution spectroscopy of gamma radiation. These devices are also used for X-ray spectroscopy and occasionally for charged-particle spectroscopy.

This standard describes the measurement of detector system performance characteristics that are important to the detector user. The measurement techniques described have been selected to be readily available to manufacturers and users of germanium detectors.

2. Object

The object of this standard is to establish standard test procedures for germanium gamma-ray detectors so that measurements have the same meaning to all manufacturers and users.

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

3. Definitions

avalanche breakdown (of a semiconductor device). A breakdown that is caused by the cumulative multiplication of charge carriers through field-induced impact ionization.

ballistic deficit. The loss in signal amplitude that occurs when the charge collection time in a detector is a significant fraction of the amplifier's differentiating time constant.

band gap (in a semiconductor). The difference in energy between the energy level of the bottom of the conduction band and the energy level of the top of the valence band.

baseline (at pulse peak). The instantaneous value that the voltage would have had at the time of the pulse peak in the absence of that pulse.

bias (of a semiconductor radiation detector). The voltage applied to a detector to produce the electric field to sweep out the signal charge.

biased amplifier. An amplifier giving essentially zero output for all inputs below a threshold and having constant incremental gain for all inputs above the threshold up to a specified maximum amplitude.

bias resistor (of a semiconductor radiation detector). The resistor through which bias voltage is applied to a detector.

breakdown (of a semiconductor diode). A phenomenon occurring in a reverse-biased semiconductor diode, the initiation of which is observed as a transition from a region of high dynamic resistance to a region of substantially lower dynamic resistance for increasing magnitude of reverse current.

breakdown region (of a semiconductor diode characteristic). That entire region of the voltage-current characteristic beyond the initiation of breakdown for increasing magnitude of reverse current.

breakdown voltage (of a semiconductor diode). The voltage measured at a specified current in the breakdown region.

capacitance (of a semiconductor radiation detector). The small-signal capacitance measured between terminals of the detector under specified conditions of bias and frequency.

channel, surface (of a semiconductor radiation detector). A thin region at a semiconductor surface, of p- or n-type conductivity created by the action of an electric field, for example, that due to charges trapped in surface layers.

channeling, lattice (in a semiconductor radiation detector). A phenomenon that results in a crystallographic directional dependence of the rate of energy loss of ionizing particles.

charge carrier (of a semiconductor). A mobile conduction electron or mobile hole.

charge collection time (of a semiconductor radiation detector). The time interval, after the passage of an ionizing particle, for the integrated current flowing between the terminals of the detector to increase from 10–90% of its final value.

charge-sensitive preamplifier. An amplifier, preceding the main amplifier, in which the output signal amplitude is proportional to the charge injected at the input. See **voltage-sensitive preamplifier**.

coaxial detector. A semiconductor radiation detector in which all or part of the two electrical contacts are substantially coaxial. Typically one end of each contact configuration is closed (closed-end coaxial detector), but both ends may be open (open-end coaxial detector).

cooled-input FET preamplifier. A preamplifier in which the input field-effect transistor (FET) is cooled to achieve a reduction in noise.

constant fraction discriminator. A pulse discriminator that gives an output when the amplitude of the input signal, delayed, matches a selected fraction of the undelayed signal. The instant of matching is invariant with input-signal amplitude, and if the delay is less than the fastest charge collection time, the timing spread in the instant of matching will be less than that in the charge collection time. The timing jitter is minimized by appropriate choices of fraction and delay. (See Fig 16.)

conventional-electrode coaxial detector (jargon). A coaxial detector in which the outer contact is an n-type layer.

crest factor (of an rms voltmeter). The ratio of the peak voltage value to the full-scale value of the range being used for measurement that an average reading or rms voltmeter will accept without overloading.

crossover time. The instant at which the waveform of a bipolar pulse passes through a designated level (usually zero).

crossover walk (of a pulse). The deviation of

the crossover time as a function of some variable, such as pulse amplitude.

CR-RC shaping. The pulse shaping present in an amplifier that has a simple high-pass filter consisting of a capacitor and a resistor together with a simple low-pass filter, separated by impedance isolation. (Pulse shaping in such an amplifier cuts off at 6 dB per octave at both ends of the band.)

dead layer (of a semiconductor radiation detector). A layer of a semiconductor detector in which no significant part of the energy lost by particles can contribute to the resulting signal.

Note: The semiconductor detector may have an entrance and an exit dead layer.

decay time constant. The time for a true single-exponential waveform to decay to a value of $1/e$ of the original step height.

depletion region (in a semiconductor). A region in which the mobile charge-carrier charge density is insufficient to neutralize the net fixed charge density of donors and acceptors. In a diode-type semiconductor radiation detector the depletion region is the sensitive region of the device.

depletion voltage (of a semiconductor radiation detector). The voltage at which a junction detector becomes fully depleted.

differential dE/dx detector. A transmission detector whose thickness is small compared to the range of the incident particle, and whose entrance and exit dead layers are small compared to the thickness of the detector.

differentiated (pulse) (pulse amplifier jargon). A pulse is *differentiated* when it is passed through a high-pass network, such as a CR filter.

diffused-junction detector. A semiconductor detector in which the p-n or n-p junction is produced by diffusion of acceptor or donor impurities.

diffusion depth (of a semiconductor radiation detector). See **junction depth**.

encapsulation (of a semiconductor radiation detector). The packaging of a detector for protective or mounting purposes, or both.

energy resolution (FWHM) of a semiconductor radiation detector. The detector's contribution (including detector leakage current noise), expressed in units of energy, to the

FWHM of a pulse-height distribution corresponding to an energy spectrum.

energy resolution (FWHM) of a semiconductor radiation detector/preamplifier combination. The FWHM, measured at a specific energy and expressed in energy units, of a spectral peak within a pulse-height distribution corresponding to an energy spectrum.

equivalent noise referred to input (of a linear amplifier). The value of noise at the input that would produce the same value of noise at the output as does the actual noise source.

equivalent noise resistance referred to input (of a linear amplifier). That value of resistor that, when applied to the input of hypothetical noiseless amplifier with the same gain and bandwidth, would produce the same output noise.

full width at half maximum (FWHM). The full width of a distribution measured at half the maximum ordinate. For a normal distribution, it is equal to $2(2 \ln 2)^{1/2}$ times the standard deviation σ .

FWHM. See **full width at half maximum**.

FW.1M. Same as FWHM except that measurement is made at one tenth the maximum ordinate rather than at one half.

FW.02M. Same as FWHM except that the width measurement is made at one fiftieth the maximum ordinate rather than at one half.

gated integrator. A circuit for obtaining a pulse with an amplitude proportional to the integral of a signal pulse over a definite time interval.

high-purity germanium (HPGe). Germanium whose net concentration of electrically active impurities that are stable at room temperature is such that conventional-sized radiation detectors made from it achieve full depletion at reasonable bias voltages. (The net concentration of electrically active impurities is typically less than $3 \cdot 10^{10} \text{ cm}^{-3}$.)

ion-implanted contact. A detector contact consisting of a junction produced by ion implantation.

ion implantation. A process in which a beam of energetic ions incident upon a solid results in the imbedding of those ions into the material.

inactive region (of a semiconductor radiation detector). A region of a detector in which

charge created by ionizing radiation does not contribute significantly to the signal charge.

integrated (pulse) (pulse amplifier jargon). A pulse is *integrated* when it is passed through a low-pass network, such as a single *RC* network or a cascaded *RC* network.

integrating preamplifier. A pulse preamplifier in which individual pulses are intentionally integrated by passive or active circuits.

intrinsic semiconductor. A semiconductor containing an equal number of free holes and electrons throughout its volume. (The term *intrinsic germanium* is often used incorrectly for high-purity germanium.)

junction (of a semiconductor radiation detector). A region of transition between semiconductor regions of different electrical properties (for example, *n-n⁺*, *p-n*, *p-p⁺* semiconductors) or between a metal and a semiconductor.

junction depth (of a p-n semiconductor radiation detector). The distance below the crystal surface at which the conductivity type changes.

leakage current (of a semiconductor radiation detector). The total detector current flowing at the operating bias in the absence of radiation.

lithium-drifted detector. A detector made by the lithium compensation process.

lithium drifting. A technique for compensating p-type material by causing lithium ions to move through a crystal under an applied electric field in such a way as to compensate the charge of the bound acceptor impurities.

load impedance (of a semiconductor radiation detector). The impedance shunting the detector, and across which the detector output voltage signal is developed.

load resistance (of a semiconductor radiation detector). The resistive component of the load impedance.

Marinelli beaker. A reentrant (inverted well) beaker that will hold a radioactive sample and fit over a detector endcap such that the detector is essentially surrounded by the sample.

noise linewidth. The contribution of noise to the width of a spectral peak.