

An American National Standard

**IEEE Standard Test Procedures for
Amplifiers and Preamplifiers for
Semiconductor Radiation Detectors
for Ionizing Radiation**

Jan 30, 1976

Approved April 8, 1976 by the American National Standards Institute

SH06007



THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Inc.

IEEE
Std 301-1976
(Revision of
IEEE Std 301-1969)

IEEE Standard Test Procedures for Amplifiers and Preamplifiers for Semiconductor Radiation Detectors for Ionizing Radiation

Sponsor

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

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Foreword

This standard provides standard test procedures for amplifiers and preamplifiers for semiconductor detectors for ionizing radiation. It supersedes the previous edition, IEEE Std 301-1969 (ANSI N42.2-1969). The standard has been modified and refined based on the experience gained in using the earlier edition over a six-year period and taking into account advances in the technology. Improvements in preamplifier noise characteristics and pulse shaping techniques as well as increased utilization of integral detector-preamplifier assemblies have occurred in recent years.

Companion documents are IEEE Std 300-1969, Test Procedure for Semiconductor Radiation Detectors (for Ionizing Radiation) (ANSI N42.1-1969) and IEEE Std 325-1971, Test Procedures for Germanium Gamma-Ray Detectors (ANSI N42.8-1972).

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IEEE Standard Test Procedures for Amplifiers and Preamplifiers for Semiconductor Radiation Detectors for Ionizing Radiation

1. General

1.1 Scope and Object. These procedures apply to amplifiers and preamplifiers for semiconductor detectors for ionizing radiation. Test procedures for associated detectors are described in IEEE Std 300-1969 (ANSI N42.1-1969), Test Procedures for Semiconductor Radiation Detectors, and IEEE Std 325-1971 (ANSI N42.8-1972), Test Procedures for Germanium Gamma-Ray Detectors. This standard supersedes IEEE Std 301-1969 (ANSI N42.2-1969), Test Procedures for Amplifiers and Preamplifiers for Semiconductor Radiation Detectors.

Semiconductor radiation detectors are in widespread use for detection of ionizing radiation. Both silicon and germanium detectors are available, with silicon finding its principal application in the detection and analysis of heavy charged particles. Germanium detectors, with their relatively high atomic number (as compared with silicon) and with large sensitive volumes, have come into widespread use in the detection and analysis of gamma radiation. To exploit the capabilities of these semiconductor detectors, sensitive electronic instruments have been produced. This has made standard test procedures desirable so that measurements may have the same meaning to all manufacturers and users.

This standard is not intended to imply that all tests described herein are mandatory, but only that such tests as are carried out should be performed in accordance with the procedures herein.

1.2 Definitions

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.

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

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 to 90 percent of its final value.

clip, clipping. A limiting operation such as 1) use of a high-pass filter (see differentiated), or 2) a nonlinear operation such as diode limiting of pulse amplitude.

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

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

crossover walk (of a pulse). The deviation of the crossover time for some variable; such as 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 Thickness (of a Semiconductor Radiation Detector) The thickness of an inactive region (in the form of a layer) through which incident radiation must pass to reach the sensitive volume.

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

defined pulse width. The time elapsed between the first and final crossings of the defined zero level for the maximum rated output pulse amplitude.

defined zero. An arbitrarily chosen voltage level at the amplifier output resolvable from zero by the measuring apparatus.

depletion region (in a semiconductor). A region in which the charge-carrier 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.

differential (dE/dx) detector. A transmission detector whose thickness is small compared to the range of the incident particle.

differential nonlinearity (percent). The percentage departure of the slope of the plot of output versus input from the slope of a reference line.

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

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 (percent) (of a semiconductor radiation detector). One hundred times the energy resolution divided by the energy for which the resolution is specified.

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 which when applied to the input of a hypothetical noiseless amplifier with the same gain and bandwidth would produce the same output noise.

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

geometry, detector. The physical configuration of a solid-state detector.

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.

integral nonlinearity (percent). The departure from linear response expressed as a percentage of the maximum rated output pulse amplitude.

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

intrinsic semiconductor. A semiconductor containing an equal number of free holes and electrons throughout its volume.

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.

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