ORTEC®

Radiation Detector Assembly

PopTop Capsule*

The innovative PopTop capsule is the core of the instrument. Its sealed and self-pumping cryogenic enclosure contains the detector element and the front end of the preamplifier, consisting of a cooled FET and resistor (resistive feedback) or junction transistor (transistor-reset active feedback). The rest of the preamplifier and a HV filter, electrically connected by vacuum feedthroughs, are also part of the capsule.

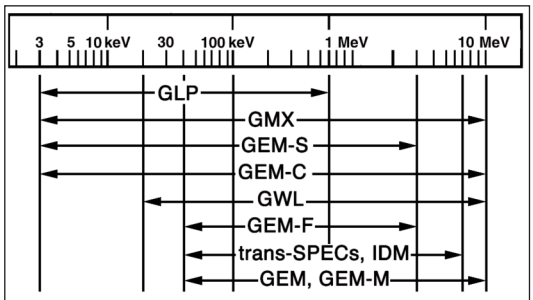


Fig. 1. ORTEC Detectors Cover the Entire Spectrum from 3 keV to >10 MeV.

Detector Element

The detector element establishes the energy range and efficiency for useful x- or gamma-ray spectroscopy (Fig. 1).

The principles of operation of the HPGe and Si(Li) detectors described in this section are described in Reference 1.

As shown in Fig. 2, the detector element is cooled from the outer or the front contact to which the HV is applied. The thermal connection between the cooling rod and the detector mounting cup is made with aluminum oxide, which is both a good thermal conductor and a good electrical insulator. The minimum distance between the endcap (which is at room temperature and ground potential) and the detector cup (which must be maintained at 85–100 K and to which HV is applied) is determined by field emission and thermal emissivity considerations.

The detector element contact at ground potential is connected to the input stage of the "front-end" electronics (see Fig. 3).

The Detector Shape Advantage

All ORTEC coaxial HPGe detectors are shaped as true right-circular cylinders with a deep hole (central contact) and "bulletized" front "corners." This precise machining of the crystals results in detectors with superior peak shape and timing characteristics.

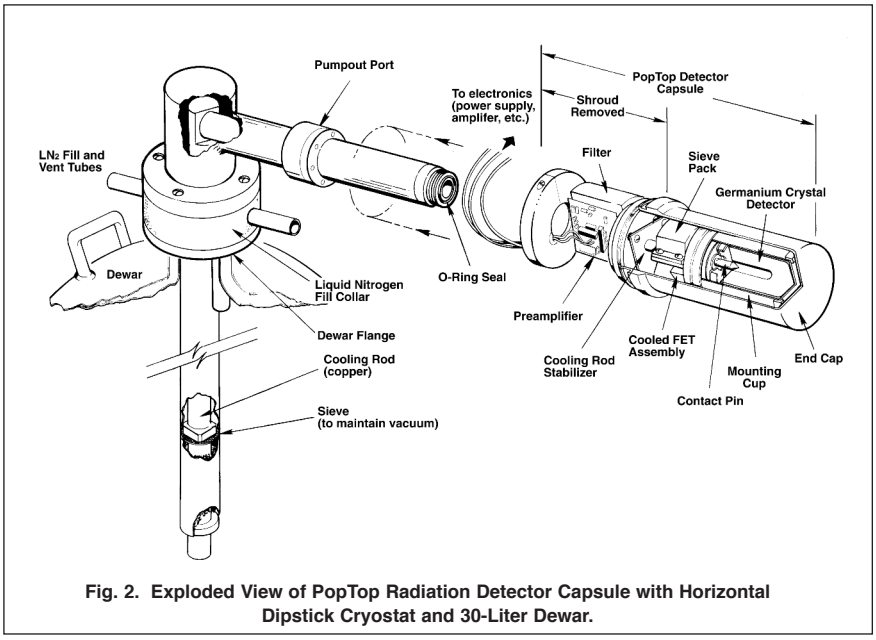


Fig. 2. Exploded View of PopTop Radiation Detector Capsule with Horizontal Dipstick Cryostat and 30-Liter Dewar.

"Front-End" Electronics

The front-end electronics (Fig. 3) include the input field-effect transistor (FET) and the feedback element of the charge-sensitive preamplifier. The feedback element comprises a capacitor and a resistor (passive feedback) or a transistor (active feedback). Preamplifiers with active feedback, such as the transistor-reset preamplifier (TRP), are used for achieving ultra-high count rates.

A temperature-sensing element, also located in the cryogenic vacuum enclosure, automatically shuts off the HV power supply if the detector temperature begins to rise. The front-end electronics are enclosed in the cryogenically-cooled enclosure to minimize electronic noise. Both the input FET and the feed-back element have optimum noise characteristics at ~120 K.

Preamplifiers Used with HPGe and Si(Li) Detectors

With the exception of the front-end electronics, both the sealed HV filter and charge-sensitive hybridized preamplifier circuitry are assemblies located behind the radiation detector within the PopTop capsule (Fig. 2). They are outside the vacuum chamber and are at room temperature.

***U.S.A. Patent No. 4,851,684**

Radiation Detector Assembly

Table 1. Some Basic Properties of Germanium.*	
Atomic number	32
Density (300 K); g·cm^{-3}	5.33
Atoms; cm^{-3}	4.41 X 10^{22}
Dielectric constant	16
Forbidden energy gap (300 K); eV	0.665
Forbidden energy gap (0 K); eV	0.746
Electron mobility (300 K); cm^2·V^{-1}·s^{-1}	3900
Hole mobility (300 K); cm^2·V^{-1}·s^{-1}	1900
Electron mobility (77 K); cm^2·V^{-1}·s^{-1}	3.6 X 10^4
Hole mobility (77 K); cm^2·V^{-1}·s^{-1}	4.2 X 10^4
Carrier saturation velocity; cm·s^{-1} (300 K)	5.9 X 10^6
Carrier saturation velocity; cm·s^{-1} (77 K)	9.6 X 10^6
Energy per hole-electron pair (77 K); eV	2.96
*All ORTEC semiconductor radiation detectors are made of germanium.	

The very long time constant of the HV filter ensures that the voltage is applied gradually to the radiation detector. This protects the FET from voltage spikes. When cold, any modern HPGe radiation detector from ORTEC may have the full bias voltage switched on without risking damage to the FET.

Some additional observations about preamplifiers used with Radiation Detectors (See Fig. 3): all are of the "charge sensitive" type, and all have the "front-end" cryogenically cooled for lowest electronic noise and energy resolution. Three different feedback mechanisms are used:

1) The simplest and most common is "resistive feedback." In this case the feedback circuit contains a resistor and a capacitor in parallel.

2) For coaxial radiation detectors used at high count rates (>75 kcps) the feedback circuit contains a junction transistor, switched on when the voltage at the gate of the input FET exceeds a certain threshold voltage. This resets the input FET gate voltage to zero. This type of preamplifier is called a transistor-reset preamplifier (TRP).

3) For small radiation detectors (GLP), electronically equipped for optimum resolution below 50 keV, the feedback circuit contains an LED which rezeros the voltage at the gate of the input FET via a mechanism similar to that of the TRP, but using light instead of an electronic switch. Ultra-low noise performance is achieved with this type of preamplifier [Pulsed Optical Feedback (POF)] because the feedback resistance is infinite (in contrast to resistive feedback), and the capacitance on the gate of the input FET is not increased by the addition of the collector-to-ground capacitance of a junction transistor (as with the TRP). Very high feedback resistance and very low capacitance are the keys to low noise performance.

Model A250 Series ORTEC resistive-feedback preamplifiers require only 1 watt of power. This makes the preamplifiers ideal for demanding portable applications such as Safeguards. The transistor-reset preamplifier ("Plus" option) requires ~1.8 watts of power.

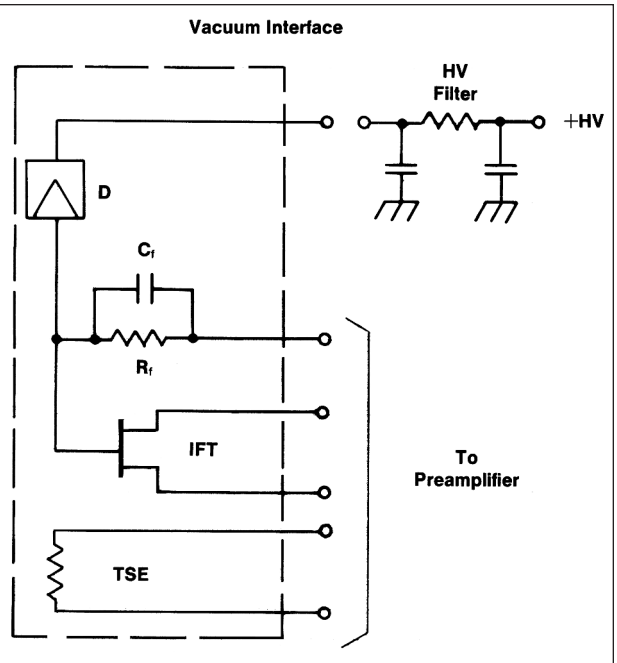


Fig. 3. Simplified Electronic Diagram Showing the Detector and the "Front End" of the Preamplifier in a Cryogenically Cooled Germanium Radiation Detector. The feedback element may be either a resistor or instead an electronic switch that resets the FET gate voltage to zero whenever a given threshold voltage is reached.

Table 2. Energy Rate of Preamplifiers Supplied with Radiation Detectors.

Preamplifier Type	Detector Type	Maximum Energy Rate (MeV Sec^{-1})
Resistive Feedback	GEM, GMX GLP (25, 32, 36 mm) GLP (6, 10, 16 mm)	145,000 4,000 2,200
Transistor Reset ("Plus" option)	GEM, GMX	1,000,000
Pulsed Optical Feedback	GLP (6, 10, 16 mm)	4,000*
Modified For HCR (Resistive Feedback)	All GLPs	10,000
*The POF does not "lock up" or saturate at high count rates, unlike resistor-feedback designs. At ultra-high count rates with the POF, throughput is limited by reset pulse rates. 4000 MeV/s is an estimate of maximum "useable" energy rate.		

Automatic HV Shutdown

If the system is warmed up with bias on, the automatic HV shutdown feature protects the input FET and the critical radiation detector surfaces. ORTEC uses a thermistor on the mount, not the radiation detector element itself, to sense the onset of warmup.

Cable Pack



Unless otherwise specified at time of order, each ORTEC radiation detector is supplied with a single, captive cable bundle 3 ft in length and terminating into individual in-line connectors:

Signal out 93-Ω BNC
Timing out 93-Ω BNC
Test in 93-Ω BNC
HV in 75-Ω Male
Preamp power 9-pin D female

A mating cable pack of individual conductors, 10 ft in length is provided for connections to supporting electronic systems.

SMART-1 Intelligent Detector Option



SMART-1 is an option on GEM, GMX, GLP, SGD and Profile series radiation detectors. The option integrates a microprocessor controlled module with the radiation detector assembly. The module, controlled via an RS-232 link from the MCA, provides the HV bias for the radiation detector element and provides state of health information on the following radiation detector functions:

Preamplifier ±12, ±24 V
Detector element temperature
Detector high voltage on/off/set/read
Detector overload status
Detector shutdown status
Detector serial number (read only)
Detector authentication code (read/write)

Cryostats, Dewars, Cryostat-Dewar Assemblies, and Electrical Cooling



All ORTEC HPGe detectors must be operated at cryogenic temperatures. Historically, the cryogen has been liquid nitrogen (LN_2). The X-COOLER III and Integrated Cryocooling System (ICS) offer a practical and reliable alternative to LN_2 cooling.

Reference

1. G.F. Knoll, *Radiation Detection and Measurements* (second edition), John Wiley and Sons, New York, 1989.

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Specifications subject to change
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