4. Preamplifier Descriptions

There are several types and models of preamplifiers in use depending on the application. The typical usage is given in "Preamp Features" below.

The Preamplifier manual included in the back of this manual has information on the specific preamp used with this detector.

Preamp Features

Preamp Models	Significant Features	Detector Types
2002C, 2002CSL	Cooled FET Warm up/HV Inhibit	Coaxial, REGe, XtRa, LEGe
2008B	Pulsed Optical	Ultra-LEGe, LEGe
2002CP, 2002CPSL	Set up for low capacitance detectors	LEGe
2101P 2101N	Transistor Reset Transistor Reset	Coaxial REGe
2002CC	Convertible	Coaxial, REGe
2008BEF	Electronic Reset	Ultra-LeGe, LeGe

H.V. Inhibit Circuit Adjustment

If the H.V. Inhibit circuit trips and there are no other symptoms indicating a fault (low LN_2, high loss rate, coolness of cryostat, moisture accumulation, low compressor pressure (off), or high detector leakage current), the circuit may need adjustment. Portable detectors should be vertically upright for this adjustment.

Refer to LN Monitor Board Schematic Diagram.

With H.V. *off*, measure the voltage between pins 5 and 6 on comparator A1B. Adjust RV1 until the yellow LED comes on, then turn RV1 in the opposite direction until the green LED comes on. Continue until the voltage between pins 5 and 6 is 50 mV.

5. Unpacking and Repacking

When you first receive your detector, please follow the instructions in "Unpacking" for unpacking the detector. Be sure to save all packing materials for possible reshipment.

If you should ever need to return the detector to Canberra for service, please repack the detector for shipment following the instructions in "Packing for Re-Shipment".

Unpacking

Remove the cryostat from the box by lifting it vertically by the Dewar handle(s). If the detector has been transported in a cold environment, allow it two hours to come to room temperature before proceeding. This will prevent undue moisture accumulation on sensitive parts of the system.

Remove the cord holding the dipstick to the Dewar and/or holding the plastic bag to the detector chamber. Remove the plastic bag covering the detector chamber and inspect the entire detector system for mechanical damage.

If there is evidence of shipping damage contact the carrier, file a claim for damages, and notify Canberra of the nature and extent of the damage.

Horizontal dipstick cryostats have a plastic foam pillow which cradles the horizontal detector chamber to prevent bending of the dipstick during shipment. This pillow can be removed by cutting the cord or tape securing it to the Dewar's neck.

Packing for Re-shipment

Keep all of the packing materials with the original shipping container in case the detector should be shipped to the factory for service or elsewhere for use. We cannot be responsible for shipping damage incurred after initial delivery of the detector or if a detector is returned for in warranty service with improper packing.

Detectors properly prepared for shipment are shown in Figure 35.

Dipstick cryostats may be returned to the factory without a Dewar. In this case the dipstick must be packed carefully so it will not be damaged in shipment. Even then there is a greater chance of shipping damage because the smaller packages tend to be handled with less care, and the preferred upright orientation will not be respected.

Pack Detectors Warm

Allow detectors to warm up completely before packing in well-insulated containers. Foam in-place packing material is an excellent insulator. Cold detectors packed in this material are so well insulated that the external cryostat hardware including the sensitive vacuum seals may be cooled to a very low temperature as heat is transferred to the cold inner hardware. If the packing container is well ventilated, this should not be a problem.

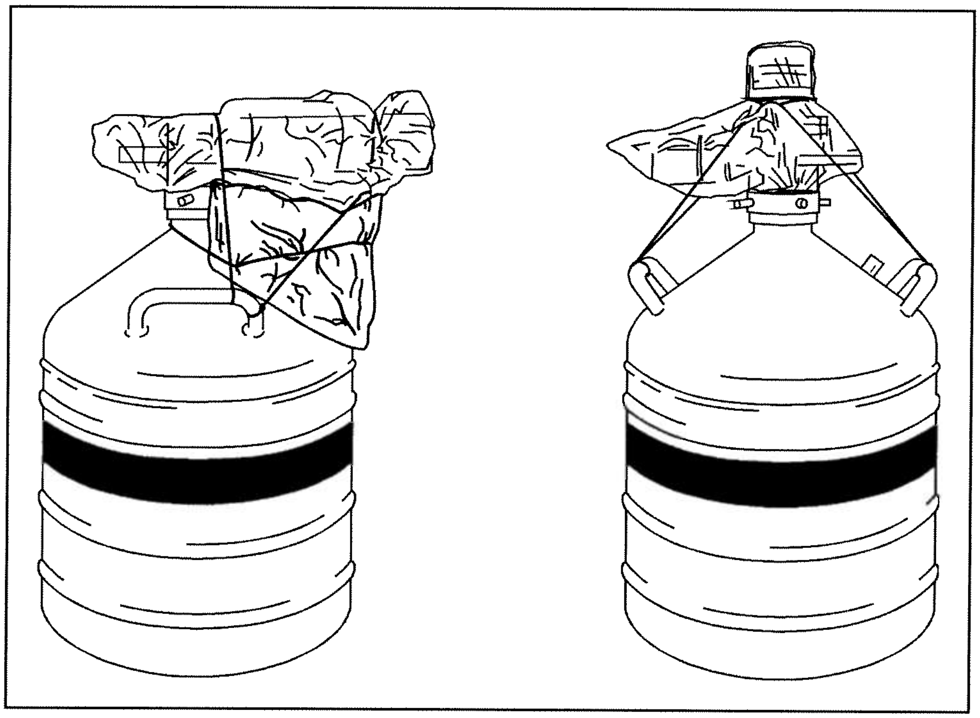


Figure 35 Detectors Prepared for Shipment

6. Filling with Liquid Nitrogen (LN_2)

Before attempting to fill your detector with liquid nitrogen, be sure to read and follow the Warnings and Cautionary Statements listed in "Handling Liquid Nitrogen".

The remaining subsections deal with filling a specific type of cryostat:

- Dipstick Cryostats – refer to page 56.
- Integral Cryostats – refer to page 57.
- Multi-Attitude Cryostats – refer to page 58.

The section Temperature Cycling, on page 62, describes the precautions to be taken if it becomes necessary to temperature cycle your detector.

Handling Liquid Nitrogen

Always handle liquid nitrogen carefully! Its extremely low temperature can produce frostbite!

WARNING!

Liquid nitrogen's temperature is minus 196 °C (77 °K).

Contact with exposed skin can cause severe frostbite!

When spilled on a surface, the LN_2 tends to cover the surface completely and intimately and therefore to rapidly cool a large area.

Protect Your Eyes

The gas issuing from the liquid nitrogen is also extremely cold and can produce frostbite. Delicate tissues such as those of the eyes can be damaged by an exposure to these cold gases which is too brief to affect the skin of the hands or face.

Stand clear of boiling and splashing liquid and its issuing gas. Boiling and splashing always occur when charging a warm container or when inserting warm objects into the liquid. Always perform these operations slowly to minimize boiling and splashing.

Never allow any unprotected part of your body to touch uninsulated pipes or vessels containing liquefied nitrogen: the extremely cold metal may stick fast and tear the flesh when you attempt to pull away from it.

Use tongs to withdraw objects immersed in liquid and handle the tongs and the object carefully. In addition to the hazard of frostbite or skin sticking to cold materials, objects that are soft and pliable at room temperatures usually become very hard and brittle at the temperatures of these liquids and are very easily broken.

Wear Protective Clothing

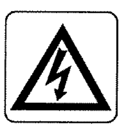
Protect your eyes with a face shield or safety goggles (safety spectacles without side shields do not give adequate protection).

Always wear gloves when handling anything that is, or may have been, in contact with liquid. Insulated gloves are recommended but leather gloves may also be used. The gloves should fit loosely so that they can be thrown off quickly if liquid should spill or splash into them.

When handling liquids in open containers, it is advisable to wear high-top shoes. Trousers (which should be cuffless if possible) should be worn outside the shoes.

Ventilate the Area

Always handle liquid nitrogen in well-ventilated areas to prevent excessive concentrations of gas.



WARNING!

High concentrations of nitrogen gas in an enclosed area can cause suffocation!

Handle liquid nitrogen only in a well ventilated area.

Never dispose of liquid in confined areas or places where others may enter. Excessive amounts of nitrogen gas in the air reduce the concentration of oxygen and can cause asphyxiation. The gas being colorless, odorless and tasteless cannot be detected by the human senses and will be inhaled as if it were air.

Cloudy Vapor

The cloudy vapor that appears when a liquefied gas is exposed to the air is condensed moisture, not the gas itself. The issuing gas is invisible.

Dipstick Cryostats

Canberra dipstick cryostats are equipped with a fill and vent collar which enables them to be filled without moving the detector chamber. The modern version of this collar is made of silicone rubber which forms a gas-tight seal between the Dewar and detector chamber. The collar is fitted with two identical, thin wall, 9.5 mm ($\frac{3}{8}$ in.) diameter stainless steel tubes, either of which may be used for filling from a storage Dewar at medium pressure, 40-80 kPa (gage) (6-12 psig). The unused tube serves as a vent for N2 gas that is evaporated during the filling operation. This tube can be fitted with a hose to direct the gas away from the sensitive preamplifier and electrical feedthrough area.

The collar is also equipped with a port for an LN2 level sensor, such as that used with a Model 1786 LN_2 Monitor.

Transfer of LN_2 from a Dewar to a cryostat by means of a low pressure withdrawal device is illustrated in Figure 36.

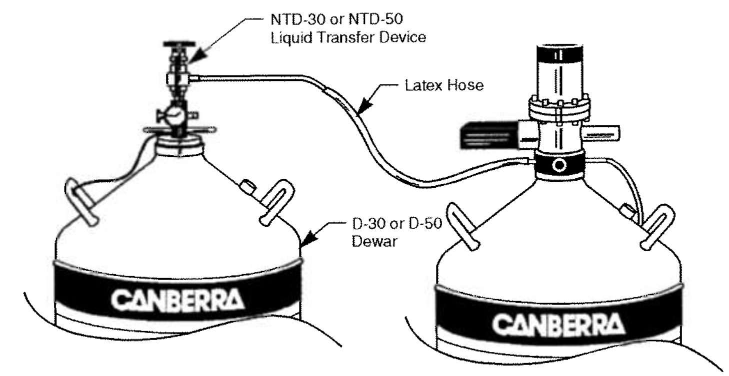


Figure 36 LN_2 Transfer

Warming Up the Dipstick Detector

Should a dipstick detector require a warm up cycle, it is best to remove the dipstick from the Dewar. Loosen the clamp ring if the cryostat is so equipped and slide the dipstick carefully upward. Keep the dipstick either vertically upright or horizontal at all times. *Never* invert a dipstick cryostat.

If the Dewar is to be emptied, first remove the silicone rubber collar and then pour the contents of the Dewar into another LN_2 container.

Check for and remove any water that may appear in the bottom of the Dewar after it warms to room temperature. The Dewar will warm much more quickly if it is turned on its side to establish convection currents.

A dipstick detector will usually warm up in 12-16 hours (overnight) if it is removed from its Dewar first.

Integral Cryostats

Integral cryostats generally have an open neck tube of 40-65 mm (1.5 to 2.5 in.) diameter. Liquid nitrogen can thus be poured directly into these cryostats or can be pumped in from a pressurized container. Be careful not to spill LN_2 on the detector chamber or the preamplifier as components therein may be damaged by the extreme cold temperatures.

The neck-plug should be replaced immediately after refilling as it will prevent ice formation in the neck tube, it will keep foreign matter from falling in, and it will increase LN_2 holding time by forcing the cold LN_2 boil-off gases to the neck-tube surface, thereby reducing heat loss by neck-tube conduction.

If an external LN_2 monitor is used with a integral cryostat, the sensor is usually wired to a BNC connector located in the neck plug. A check on the LN_2 monitor can be made by holding the LN_2 sensor tip just above liquid level until a response is obtained. The monitor must react with the sensor inside the Dewar – pulling it out to verify operation cannot guarantee proper operation because of the extreme difference in temperatures.

Warming Up the Integral Detector

Integral cryostats may be warmed up by first pouring the contents into another LN_2 container and then turning the Dewar on its side without the neck plug. In this orientation most integrals will warm up within 24 hours.

Check carefully and remove any water that may appear in the bottom of the warm Dewar. If allowed to remain, the resultant ice can cause hissing and noise in the detector system.

Multi-Attitude Cryostats (MACs)

The MAC should be filled from a source of LN_2 which is at low pressure: ≤165 kPa (gage) (24 psig). A D-50 Dewar equipped with a low pressure withdrawal device (Model NTD-50) is available from Canberra for this purpose. Standalone 160-240 liter pressurized Dewars are also available.

If liquid at high pressure is used, the vaporization that occurs when the pressure is reduced to atmospheric (flash-off) will cause a substantial amount of LN_2 to be blown through the MAC and it will be difficult if not impossible to fill it to capacity. In addition, the Dewar inner could be damaged by high pressure transfer of LN_2.

Fill and Vent Connections

Dual Port Models

The fill and vent connections are 1/8 NPT male fittings (see Figure 37). While hard fittings can be used to transfer the LN_2, it is more convenient to use flexible latex hose which simply stretches over the fittings. The hose can be forced over the hex nut and secured on both sides of the hex nut by a nylon tie-wrap or cord. The hose must not cover the entire nipple as this can lead to excess cooling of the Dewar external hardware.

CAUTION

The Fill and Vent Ports can be damaged by excessive force when attaching or detaching hoses with metal fittings.

Always use a wrench to prevent excess torque on the nipple. See Figure 37.

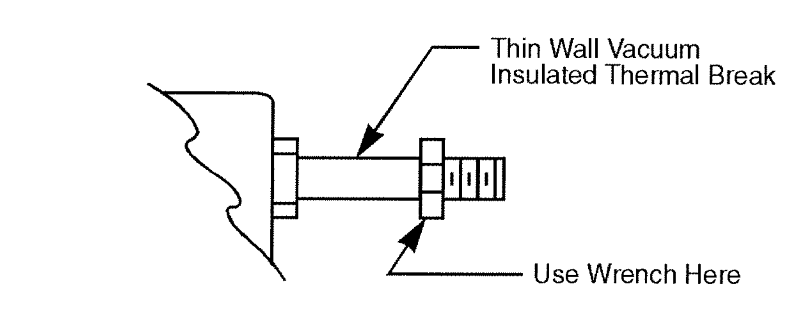


Figure 37 Fill/Vent Port Connector

The transfer line should be as short as practical, no more than 1 m (3 feet) is ideal. It should be kept away from the detector and preamplifier chamber to prevent moisture accumulation on these delicate parts. The transfer line should be insulated for the same reasons.

The vent line should be directed away from personnel to avoid injury. It should be sufficiently long to vaporize any liquid blow-by or overflow, or it should be directed into a reservoir which can contain it safely. A Dewar is a satisfactory reservoir.

Filling Orientation

The fill and vent ports exchange roles depending on the orientation of the detector. The given designators apply to the unit when it is oriented horizontally, which is recommended. When the fill and vent ports are pointing downward, the given designations also apply. However, when the ports point upward, the roles are reversed, i.e., the port designated vent is the fill port and vice versa. See Figure 38 for construction details.

Please note that the MAC does not have exactly the same LN_2 capacity in every orientation, so some spillage can occur when the unit is filled in one orientation and changed to another. This is normal.

The capacity is usually greater when the MAC is horizontal. If filled in this orientation, you can expect to lose some liquid when changing to uplooking or downlooking orientations.

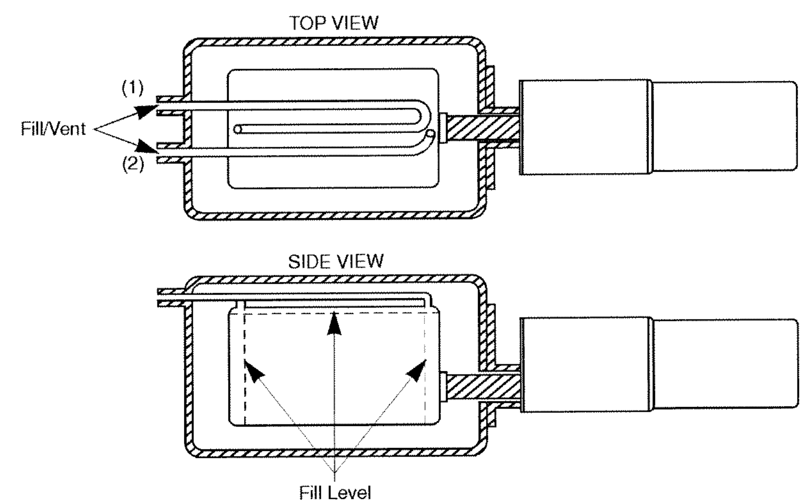


Figure 38 MAC Port Construction

Port Cover

Another effect to be aware of is percolation, which can occur if the MAC is jarred or shaken. To reduce this effect and to decrease the LN_2 loss rate in some orientations, MACs are equipped with a port cover which blocks the fill port. The cover also directs the vent gas away from the vent port, thus preventing snow or ice formation on the vent port. The right hand port should be blocked when the detector is down looking and the left hand port should be blocked when the detector is up looking. A nipple and hose are provided to direct nitrogen gas and spillover liquid away from the user.

Install the cover in the appropriate orientation when the detector is horizontal, then change the orientation. Spillage and loss rate will be minimized if you do this properly.

Single Port Models

Refer to Figure 23 on page 26 for an illustration of a single port cryostat. A single neck tube provides both fill and vent functions for this model. The cryostat includes a plug having a pressure relief valve. A secondary fixed pressure relief valve is located on the port boss.

Single port models can be pressure filled by using a 1/4 - 3/8 (6 - 9 mm) diameter tube inserted a depth of about one-half the Dewar length. An optional fill adapter is available from Canberra.

Canberra also offers a 30 liter Gravity- Feed supply Dewar for single port MACs and Big MACs. This unit provides a convenient means of keeping detectors filled and ready for use.

Cool-Down Time

Typical detectors will cool down sufficiently within 2-6 hours of filling. The LN_2 loss rate will be extraordinarily high during the cool-down period so the MAC should be topped off with LN_2 a few hours after the initial filling.

Warming Up

Dual Port MAC

A MAC can be emptied quickly by orienting it with the end-cap pointing upwards and blocking the vent port. Under this condition the boil-off gases cannot escape and will thus force most of the LN_2 out of the fill port. Use a hose to direct the LN_2 into another LN_2 container.

Because the MAC cannot be emptied as readily as can an open-mouth Dewar, the natural time required for complete warm up is quite long. To ensure that the detector undergoes a complete warm-up cycle once warm up has begun, purge the detector with dry nitrogen gas.

⚠ Do *not* purge with air or with N_2 having significant water vapor content.

To do this, the same considerations should be given to the fill and vent ports as outlined in "Fill and Vent Connection" on page 58. However, the dry nitrogen gas should be forced into the vent port rather than the fill port. An overnight purge at 3 to 5 liters/minute should be sufficient to complete the warm-up cycle. Without a purge warm up may take up to 48 hours.

Single Port MAC

The single port MAC cannot be emptied quickly because the LN_2 will not flow out regardless of the orientation. It can be forced out by inserting a 1/4 - 3/8 inch diameter tube to the full depth of the Dewar and sealing the joint between the tube and the port with the port facing upward. The pressure build-up will force the LN_2 out of the Dewar. Consult the factory for a custom-made device if needed.

Temperature Cycling

Ge detectors, unlike Ge(Li) detectors which fail on warm up, can withstand repeated and prolonged periods of room temperature storage. While it is only reasonable to expect a detector to last longer if it is kept cold at all times, with certain specific and important precautions, no serious compromise in life time will result from temperature cycling.

Temperature cycling can even be a remedy for certain problems that may occur in the use of Ge detectors. The important precautions are given below.

Turn Bias Off During Warm Up

A detector should not be allowed to warm up with bias applied. When a detector warms up, the molecular sieves outgas and pressure within the cryostat rises. If electrical discharge occurs as a result of this increased pressure, the sensitive detector surfaces and the preamplifier can be damaged. A Canberra Model 1786 LN_2 Monitor can be used to disable the bias supply when the LN_2 drops below a satisfactory level. Some detectors are equipped with a built-in Warmup Sensor/HV Inhibit circuit which provides an inhibit signal to the HV power supply.

Complete Warm Up

It can take more than 24 hours for a detector to warm up completely and several hours to cool down thoroughly. When a warm-up cycle has begun, the detector should be allowed to warm up fully before being cooled down again. Otherwise some of the residual gases that are absorbed by the detector surfaces may be frozen there. If the detector warms up completely, the molecular sieves will tend to pump the system clean when the detector is recooled. If a detector is inadvertently cooled after partial warm up, a full warm up cycle will likely restore any lost performance. A complete temperature cycle is often prescribed as a fix for performance problems.

Dipstick cryostats (removed from Dewar), Integral cryostats (on side without neck plug), and electrically cooled cryostats (power off) will warm up in 12-24 hours. MACs may take longer, especially if the LN_2 is not purged completely at the start.

Prevent Moisture Accumulation

As noted in "Turn Bias Off During Warm Up" on page 62, when a detector warms up, the molecular sieves which maintain vacuum in the cryostat outgas and pressure within the cryostat rises. Under this condition, the outside of the cryostat will be cooled by the internal hardware until it, too, reaches room temperature. Therefore, it is normal for a cryostat to be cold during warm up and to a lesser extent upon cool down (on cool down the molecular sieves usually get cold and begin pumping before the internal hardware cools down fully).

Moisture which accumulates during temperature cycling should be removed. If humidity in the environment is excessive, moisture may accumulate during normal operation. Environmental humidity should be decreased to prevent both the short term (leakage current in HV circuit/feedthrough) and long term (corrosion) effects of moisture accumulation.

Precautions – Vacuum Failure

When a cryostat exhibits signs of catastrophic vacuum failure, such as heavy moisture or ice formation on the surfaces, extremely high LN_2 loss rate, and so forth, the adsorber (molecular sieves or charcoal), which normally maintains vacuum, may be virtually saturated.

When allowed to warm up, the adsorber will outgas and the pressure in the cryostat will rise. Canberra cryostats and Dewars sold by Canberra have a pressure relieving seal-off valve which is designed to prevent dangerous levels of pressurization.

The pressure rise, however, can be high enough to break or break loose beryllium windows and/or end-caps. A frozen or ice clogged seal-off valve may fail to relieve pressure, resulting in dangerous levels of pressurization.

Precautions

For these reasons use extreme caution in handling cryostats with symptoms of catastrophic vacuum failure. When you do have to handle them, take the following precautions:

1. Stop using the failed unit immediately. Do not allow it to warm up until additional steps are taken to prevent damage or injury due to overpressurization.

2. Drape a heavy towel or blanket over the end-cap and point the end-cap away from personnel and equipment. If the unit is in a shield, close the shield door.

3. Call the factory for further instructions if the incident occurs during working hours.

4. If it is impractical to keep the unit cold until advice is available from the factory, keep the end-cap covered with a heavy towel or blanket and place the unit in a restricted area in a container (corrugated cardboard, for example). If the unit is in a shield, let it warm up in the shield with the door closed.

5. After the unit has warmed up, cautiously check for overpressurization (outwardly bulging end-caps or windows). If there are no signs of pressure, the unit may be shipped to the factory for repair. Consult the factory for shipping information.

7. Setup and Test

The significant specifications of Ge detectors are few in number, and detectors are not complex instruments, so it is possible to verify the performance of a detector with relative ease – provided that the proper equipment is available and correct procedures are used. The equipment used in conjunction with a Ge detector must be of the right type and in good working order to ensure good system performance. Likewise, the procedures must reflect the standards of the manufacturer or there will be unexplained differences in performance between tests in the factory and in the field.

Equipment Required

The Setup and Test section assumes that the test equipment listed here is available. For efficiency measurements, the ^{60}Co source should be calibrated to NIST standards.

- Ge Detector, Cryostat, and Preamplifier
- NIM Bin and Power Supply – Model 2000 or Equivalent
- Amplifier – Model 2026 or Equivalent
- MCA – with 8192 ADC Range, 4096 Memory, and Digital Readout
- Detector Bias Supply – Model 3106D, or Equivalent or Model 3102D for bias of 2000 volts or less.
- Voltmeter (Analog or 3-1/2 digit)
- Oscilloscope – 50 MHz bandwidth, 5 mV/div.
- Sources as in Table 3

Table 3 Test Sources

Detector Type	^{60}Co	$^{57}C0$	^{55}Fe	^{109}Cd
Coaxial	P	S		
REGe	P	S		S
XtRa	P	S		S
LEGe		S	P	
Ultra-LEGe		S	P	
Well	P	S		
BEGe	S	P		

Where P = Primary source and S = Secondary source

Test Configuration

Connect the equipment as shown in Figure 39. Use the same electrical circuit for all ac power to the system to avoid ground loops. The Bias Supply and Amplifier should be located at opposite ends of the NIM Bin, if possible, to minimize cross talk between them. Use the amplifier rear panel output (Unipolar) if the cable between Amplifier and MCA is more than 1 m (3 ft) long. The front panel output may be used with long cables only if the cable is terminated at the MCA with a 93 ohm load. Otherwise, it may oscillate.

To prevent ground loop noise from entering the system, the H.V. Input and H.V. Inhibit Output grounds are isolated. To maintain this isolation on 2002CC and 2002CSL preamps, slip the flexible sleeving included with the preamp over the BNC and SHV connector shells after connecting the cables.

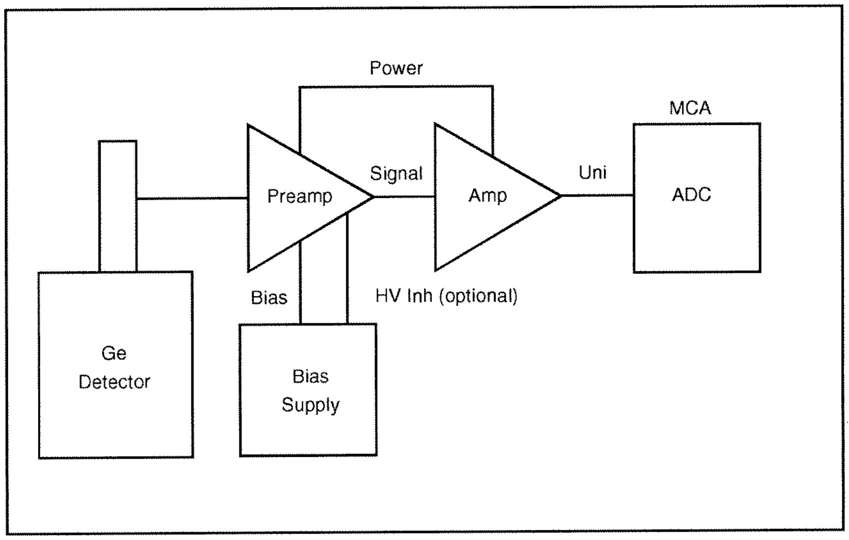


Figure 39 Test Equipment Setup

Instrument Setting

Refer to Table 4 for typical test setup settings for measuring the resolution of various detector types. Amplifier time constants for particular detectors may differ from those suggested here. Consult the detector test data sheet for specifics.

Restorer controls are normally set alike for all detector types, as follows:

Rate - AUTO

Mode - SYM

Threshold - AUTO

Consult the Amplifier Instruction Manual for further information.

Table 4 Test Setup for Resolution Measurements

Detector Type	Typical Preamp	Peak Energy	H.V. Polar.	Input* Polar.	Time Constant	ADC Gain	ADC Offset	Mem-ory	Approx. Energy/ Channel
Small LEGe	PO	5.9 keV	Neg	Pos	12 µs	2048	0	1024	7 eV
Small LEGe	RC	5.9 keV	Neg	Neg	4 µs	2048	0	1024	7 eV
LEGe	PO	122 keV	Neg	Pos	12 µs	8192	1536	1024	54 eV
Small LEGe	RC	122 keV	Neg	Neg	4 µs	8192	1536	1024	54 eV
Large LEGe	RC	5.9 keV	See data sheet		4 µs	2048	0	1024	7 eV
Large LEGe	RC	122 keV	See data sheet		4 µs	8192	1536	1024	54 eV
Coaxial	RC	122 keV	Pos	Pos	4-6 µs	8192	512	1024	91 eV
Coaxial	RC	1332 keV	Pos	Pos	4-6 µs	8192	6144	2048	163 eV
REGe	RC	122 keV	Neg	Neg	4-6 µs	8192	512	1024	91 eV
REGe	RC	1332 keV	Neg	Neg	4-6 µs	8192	6144	2048	163 eV
XtRa	RC	22/88 keV	Pos	Pos	4-6 µs	8192	0	1024	40 eV
XtRa	RC	1332 keV	Pos	Pos	4-6 µs	8192	6144	2048	163 eV
Well	RC	122 keV	Pos	Pos	2-6 µs	8192	512	1024	91 eV
Well	RC	1332 keV	Pos	Pos	2-6 µs	8192	6144	2048	163 eV
BEGe	RC	5.9 keV	See data sheet		4-8 µs	2048	0	1024	7 eV
BEGe	RC	122 keV	See data sheet		4-8 µs	8192	1536	1024	54 eV
BEGe	RC	1332 keV	See data sheet		4-8 µs	8192	6144	2048	163 eV

*Detectors with TRPs use opposite polarity.

Applying the Bias Voltage (RC Preamplifier)

Observe the amplifier output with the oscilloscope. The noise should be several hundred millivolts peak to peak, with no detector bias applied. (Use the cable that normally goes to the MCA rather than an oscilloscope probe).

Monitor the test point on the rear panel of the preamplifier with the voltmeter. It should read approximately minus (–) 1 to minus (–) 2 volts dc. Do not confuse the test input (BNC) with the test point.

Increase bias to 100 volts. The noise at the amplifier output should decrease somewhat, and the voltmeter should momentarily change before returning to its initial reading. For Detectors using positive bias, the Test Point voltage change will go negative and for detectors using negative bias, the Test Point voltage will go positive. Increase the bias now to 500 volts. The noise should be further reduced and the voltmeter should respond exactly as before.

Increase the bias in 500 volt steps to the recommended value, observing the behavior of the amplifier signal and voltmeter after each increment. The noise should remain constant after the depletion voltage is reached. The voltage at the test point should approximate that given on the test data sheet in the front of the manual.

Applying the Bias Voltage (Reset Preamplifier)

Observe the preamplifier output with the oscilloscope. If the preamplifier output is connected to the rear amplifier input, the front panel input can be connected to the oscilloscope.

With no bias applied (HV supply off), the preamp output should be about minus (–) 6 to minus (–) 12 volts for detectors requiring negative bias and plus (+) 6 to plus (+) 12 volts for detectors requiring positive bias.

Apply about 50 volts bias. The preamp output should be a sawtooth pattern, with a period stretching gradually to a second or more. Figure 40 shows the output signal for detectors having negative bias. The sawtooth is inverted for detectors requiring positive bias and for certain other preamplifier types.

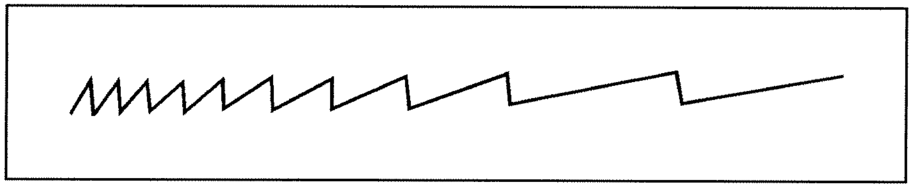


Figure 40 Sawtooth Output Signal

Increase bias gradually to the recommended operating voltage. The sawtooth pattern should repeat itself after every increment of bias. Compare the period of the sawtooth to the value shown on the test data sheet.

Fine Tuning the Amplifier

Using the amplifier settings given in Table 4 on page 67, introduce the source to the detector with the protective plastic cap removed. Observe the test voltage change if the preamp is RC type. If the preamp is the reset type, the sawtooth frequency will increase. Adjust the amplifier's coarse and fine gains to give approximately 8 volt pulses at the output.

The Pole/Zero control must be fully CCW for reset preamplifiers. With an RC preamplifier, adjust the Pole/Zero control to give the pulse shape illustrated in Figure 41.

Many oscilloscopes exhibit overload recovery problems when they are used with the high gain necessary to set Pole/Zero correctly. A Schottky clamp (Model LB1502) is available from Canberra to prevent this problem. The Schottky clamp is built into the Model 1510 Integrated Signal Processor and the Models 2025 and 2026 Spectroscopy Amplifiers.

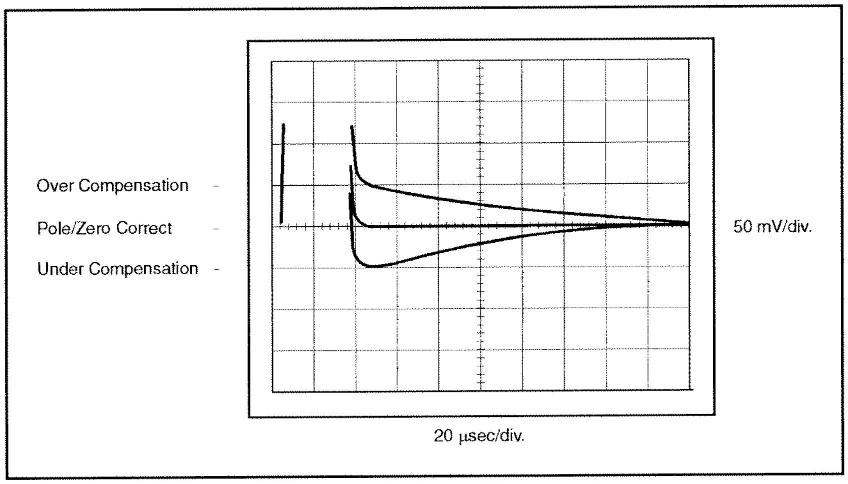


Figure 41 Pole/Zero Compensation

The Schottky clamp circuit is shown in Figure 42 for those who want to make their own.

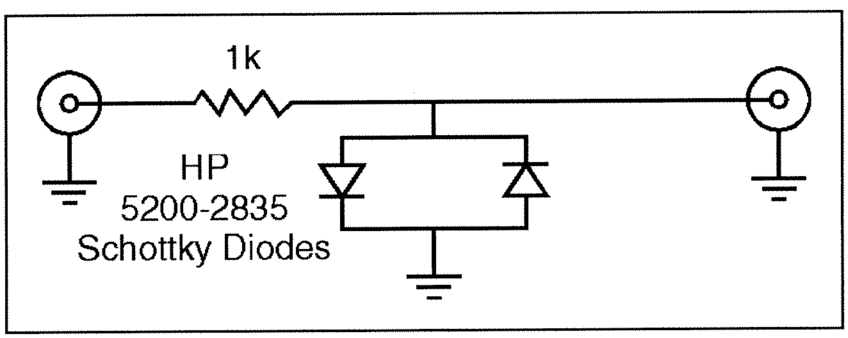


Figure 42 Schottky Clamp Circuit

Accumulating a Spectrum

With the amplifier and ADC settings, as shown in Table 4 on page 67, start a collect cycle in the MCA. Adjust the amplifier gain so that the peaks of interest are to the far right of the display (within 100 channels of the top of the memory group displayed).

After gain adjustments are complete, clear the MCA memory and accumulate a spectrum with approximately 10 000 counts in the peak channel of the peak of interest.

Calculating Resolution

Table 5 lists the peak energies of radioisotopes commonly used in calculating detector resolution.

Table 5 Peak Energies of Common Isotopes

Isotope	Peak Energies (keV)		ΔE
^{55}Fe	5.894	6.489	595.0 eV
^{57}Co	6.489	14.44	
	122.06	136.47	14.44 keV
^{109}Cd	22.1	88.0	65.9 keV
^{60}Co	1173.2	1332.5	159.30 keV

To determine the detector's resolution, collect several thousand counts in the 1332 keV peak of ^{60}Co. The procedure is identical for other radioisotopes and lines.

To determine the conversion factor, the energy per channel, find the peak centroids of the 1173.2 keV and 1332.5 keV peaks by expanding each region individually, placing the cursor by eye and recording the center channel of each peak.

Then divide the difference in keV between the two peaks by the number of channels between the peaks:

$$\frac{(1332.5-1173.2)\ \text{keV}}{\text{Seperation in channels(N)}}=\frac{159.3\ \text{keV}}{\text{N channel}}$$

Using the setting for the ADC previously described, the conversion factor should be in the range of 0.16 keV/channel. If it isn't, then something is set up improperly.

In this example N = 977 channels, so the conversion factor is (159.3/977) = 0.163 eV/channel, which is in the proper range.

Expand or print out the 1332 keV peak and determine the number of channels FWHM and FWTM (Full Width at Half Maximum, and Full Width at Tenth Maximum) as in Table 6.

The peak is at channel 2011, with 8512 counts. Thus Half Maximum (HM) of the peak is 8512/2 = 4256 counts; but it's not likely that there will be a channel with exactly 4256 counts in it. Therefore, it will be necessary to interpolate the data, using the following information:

a. The peak channel. That is, the channel with 8512 counts.

b. The counts in the channel just below the FWHM point on the left side of the peak (counts < 4256).

c. The counts in the channel at or just above the FWHM point on the left side of the peak (counts ≥ 4256).

d. The number of the channel in 'c' (just above FWHM on the left side of the peak).

e. The counts in the channel at or just above the FWHM point on the right side of the peak (counts ≥ 4256).

f. The number of the channel in 'e' (just above FWHM on the right side of the peak).

g. The counts in the channel just below the FWHM point on the right side of the peak (counts < 4256).

With this data, calculate the FWHM resolution as a decimal fraction using:

$$(f - d) + \frac{c - HM}{e - g} + \frac{e - HM}{e - g} \times 0.163 \text{ keV per channel (the conversion factor)}$$

Table 6 1.33 MeV Peak Data

Channel	Data							
1992	44	51	39	61	101	156	239	423
2000	631	923	1384	1961	2898	3640	4766	5759
2008	6790	7569	8072	8512	8176	7678	6935	6152
2016	5081	4206	3305	2555	1742	1357	1012	691
2024	507	54	233	157	122	91	57	

To calculate:

Half Maximum = 8512 / 2 = 4256

$$\text{FWHM} = 10 + \frac{4766 - 4256}{4766 - 3460} + \frac{5081 - 4256}{5081 - 4206} = 11.40 \text{ channels}$$

FWHM = 11.39 channels x 0.163 keV/channel = 1.686 keV

Tenth maximum is determined using the value:

$$\text{Tenth Maxium} = \frac{8512}{10} = 851$$

$$\text{FWHM} = 10 + \frac{923 - 851}{923 - 631} + \frac{1012 - 851}{1012 - 691} = 21.75 \text{ channels}$$

FWTM = 21.75 channels x 0.163 keV per channel = 3.55 keV.

Peak/Compton Calculation

Coaxial detectors have Peak-to-Compton (P©) specifications which are dependent on resolution and efficiency as well as peak/shape, active to inactive material, charge collection, aspect ratio, etc.

The P© measurement must be made under the same conditions as the resolution measurements, since it uses peak height, not peak area in determining the value. The Compton Region used for P© calculations has been defined in IEEE Standard 325 for ^{60}Co as 1040 keV to 1096 keV. Therefore the formula for P© is as follows:

$$P/C = \frac{\text{Number of counts in highest channel of 1.33 MeV peak}}{\text{Average counts per channel}\left(1040 \text{ keV and } 1096 \text{ keV}\right)}$$

Efficiency Measurement

The efficiency measurement is done with the simplest, most straightforward MCA settings so as to minimize the ADC dead time (and attendant questions of live time correction) and effort required to integrate the peaks (if the MCA does not have such arithmetic capability). For these reasons, we use the 1024-channel range and memory size and no digital offset for this measurement.

Procedure

Place the source 25 cm away from the end-cap of the detector. The source should be on the end cap axis and no extraneous materials should be between the source and the detector. Appropriate allowances should be made for sources of substantial thickness.

Adjust the amplifier gain so that the 1332 keV peak is storing in the upper half of the 1024 channel memory group.

Collect a spectrum for 1000 seconds of live time. When collection is complete, integrate a symmetrical region around the 1.33 MeV peak about 10 channels wide.

Calculation

The relative efficiency is then obtained by the following formula.

$$\text{Relative efficiency} = \frac{N}{T} \times \frac{1}{R_s} \times \frac{1}{1.2 \times 10^{-3}} \times 100\%$$

Where:

N = Number of counts in 1.33 MeV peak

T = Preset Live Time

R_s = Source strength in Gamma-rays per second

1.2×10^{-3} = Efficiency of 3 by 3 NaI detector at 25 cm.

Background Spectrum

In conditions where background is high and might contribute to an error in the efficiency measurement a second spectrum should be accumulated in the absence of the calibrated source. The integral of background in the same region of interest about 1.33 MeV should be subtracted from the former integral before calculating the relative efficiency.

Source Calibration

NIST sources are calibrated in terms of nuclear transformations per second (NT/s) and for ^{60}Co, there is one 1.33 MeV photon emitted per nuclear transformation.

The source emission rate must be corrected for decay at least monthly, because the half life of ^{60}Co (5.27 years) implies a rate decrease of approximately 1.1% per month. Use the following formula to correct for source decay:

$$N_p = N_o \cdot e^{-(0.693)t/T}$$

Where:

N_p = present rate of emission

N_o = original rate of emission

t = elapsed time

T = half-life (5.27 years for ^{60}Co)

With a 3 in. x 3 in. NaI(TI) Detector

If no NIST or other suitable calibrated source is available, a 3 in. x 3 in. detector may be used for direct side-by-side comparisons of Ge detector efficiency.

If this approach is used, it is best to integrate the upper half of the 1.33 MeV peak and multiply by two to determine peak intensity for the NaI(TI) detector. This reduces the influence of the 1.17 MeV gamma rays on the 1.33 MeV peak.

8. Troubleshooting

There are a very limited number of Ge detector failure modes, the most common being cryostat vacuum loss. The number of things which can contribute to loss of resolution are almost limitless, however, and this is where careful diagnosis is most important.

The most important indication of the condition of a Ge detector itself, exclusive of preamplifier and other electronics problems, is reverse leakage current. The first stage of the preamplifier can be used as an electrometer to measure the leakage current of a detector.

Leakage Current must be measured as a first step in diagnosing detector performance problems!

Leakage Current Measurement

The most important indication of the condition of a Ge detector element is reverse leakage current. The so-called V-I curve can be determined by using the first stage of the preamplifier as an electrometer. A typical V-I curve for a coaxial detector is illustrated in Figure 43. The leakage current is relatively flat up to the recommended operating bias. The chart also shows the capacitance vs. bias curve, which flattens out as depletion is reached.

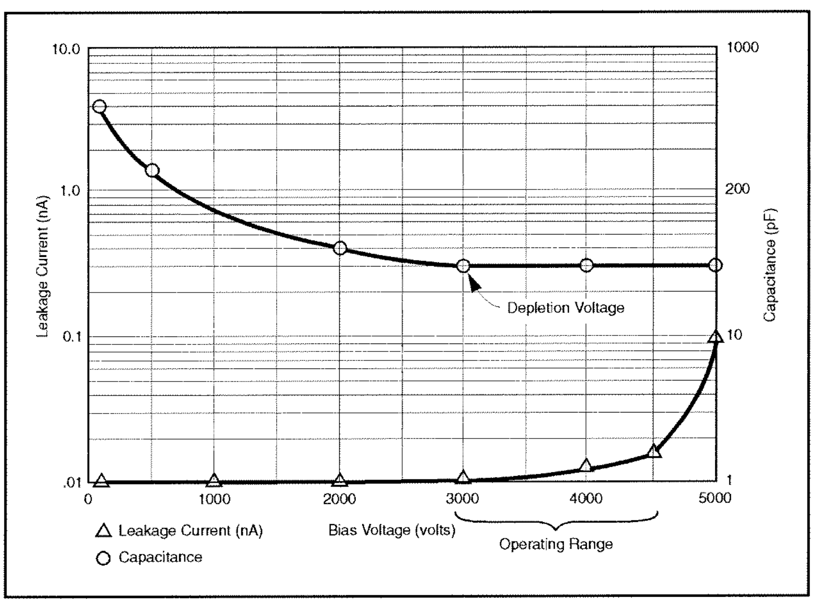


Figure 43 Typical Coaxial I-V and C-V Curves

Although the capacitance cannot be measured readily, you can observe reduced noise at the amplifier output as the capacitance is reduced with increasing bias. The noise should flatten at the point the detector becomes fully depleted provided that the leakage current is still flat at that voltage.

Resistive Feedback Preamplifier

The dc voltage at the rear panel test point is normally in the range of –0.5 to –2.0 volts. In addition to this offset, detector leakage current will cause the test point voltage to shift positive for detectors using negative bias and negative for detectors using positive bias. The transfer function is determined by the feedback resistor value. Figure 44 shows the block diagram for the RC Preamp.

Typical values and corresponding transfer functions are given below:

Detector Type	R_f (typ)	V_{tp}/I_l (nA)
Small LEGe	1 X 10^{11}	100 volts/nA
Large LEGe	5 X 10^{10}	50 volts/nA
Coaxial	2 x 10^{9}	2 volts/nA

The feedback resistor value may be selected for high energy rates (lower value) or lower noise (higher value) so the above values can vary greatly from one detector to another.

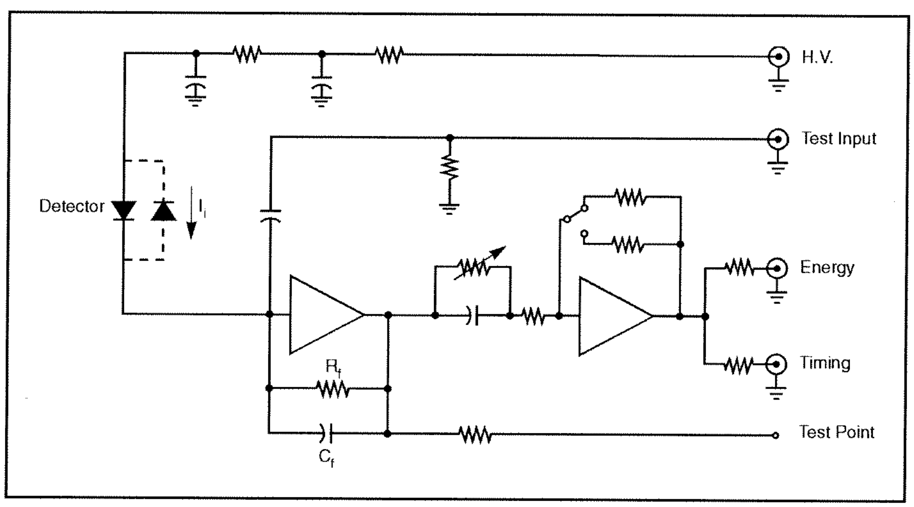


Figure 44 RC Preamplifier Block Diagram

Detected radiation results in detector current, so measurements of leakage current should be done with no radioactive sources in the presence of the detector.

The transient response to increments of voltage is momentary high current (charging the detector capacitance) returning to the normal value. This transient is greatest on the high slope part of the capacitance and observation of the transient tells a great deal about the detector. For example, no or small transient response may indicate an open HV circuit or broken contact to the detector.

Reset Preamplifiers

With a reset-type preamplifier, leakage current determines the quiescent (no sources present) preamplifier reset rate. The reset period ranges from roughly 0.1 second to 1.0 second depending on the size of the detector and on other factors, including the absolute temperature, the FET leakage current, the infrared heat load on the detector element, etc. The reset rate must be measured by using an oscilloscope on the preamplifier output. Figure 45 shows the block diagram for either a Pulsed Optical (PO) or a Transistor Reset (TRP) preamplifier.

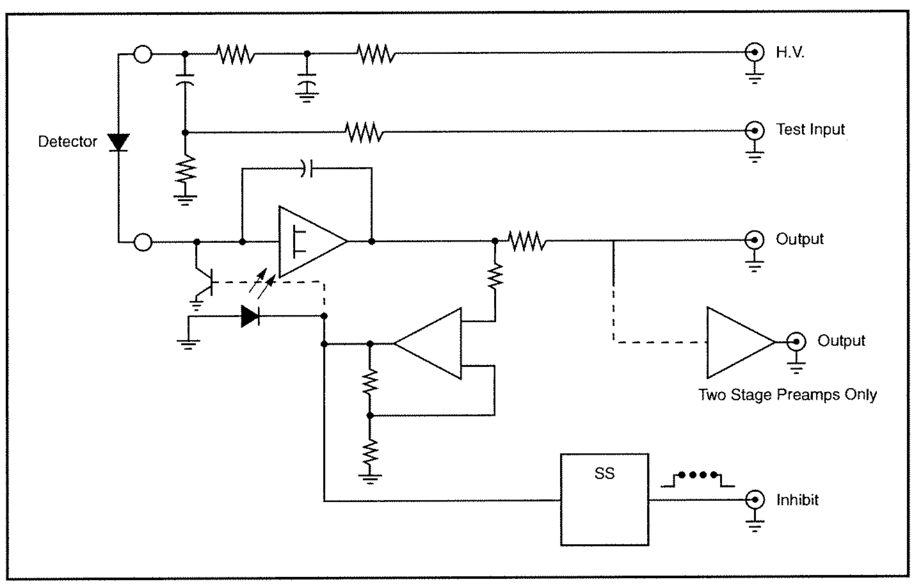


Figure 45 Reset Preamplifier Block Diagram

The transient response to movements of bias is high charging current or high momentary reset rates as indicated in Figure 46, which shows a typical transient response for detectors requiring negative bias. Sawtooth is inverted for detectors requiring positive bias or s for units having a second stage amplification.

Again, detected radiation will increase the leakage current and reset rate so make V-I measurements with no sources present.

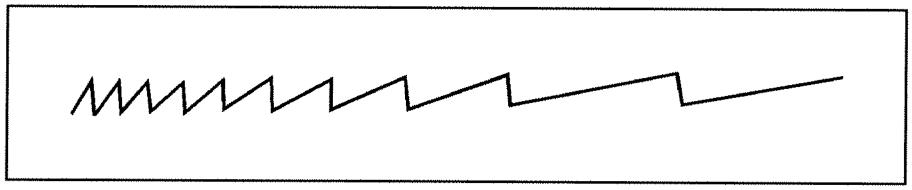


Figure 46 Typical Transient Response

Troubleshooting Symptoms and Suggestions

Most of the oscilloscope observations called for in this section are more meaningful at the amplifier output rather than at the preamplifier output. A Schottky clamp may be useful in preventing oscilloscope overload for the observation of low level signals in the presence of large signals. See “Fine Tuning the Amplifier” on page 69 for details.

No Output

– Check Power Supply Voltages.

– Check system cabling.

– Check V-I characteristics.

High Leakage Current

– Try lower bias. Detector may operate OK at lower bias.

– Detector may have been subjected to incomplete warm up cycle. Warm up completely (24 hrs) and cool down again.

Erratic Leakage Current

– Check for voltage breakdown in Preamp HV network, in the bias supply and in the HV cable.

– Dry the electrical feedthroughs with a heat gun (remove the preamplifier first to avoid damaging its components).

Poor Resolution

- Check V-I characteristic by measuring the TP voltage or reset rate as a function of detector bias.

- Check for electrical interference (periodic signals on amp output) from other equipment.

- Check ground loops (50-60 Hz noise).

  To prevent ground loop noise from entering the system, the H.V. Input and H.V. Inhibit Output grounds are isolated. To maintain this isolation on 2002CC and 2002CSL preamps, slip the flexible sleeving included with the preamp over the BNC and SHV connector shells after connecting the cables.

Microphonic Noise

- Use symmetrical restorer mode and shorter time constants to minimize effects of microphonic noise.

- Isolate the Dewar from the floor with some insulating material such as rubberized hair, foam, etc.

- Check dipstick orientation to make sure bottom of dipstick does not touch the Dewar inside. Dipstick elevation can be changed by loosening the screws in the clamp ring. These screws are recessed. A 7/64 in. hex key wrench is required.

Low Frequency Noise

- Check for Ground Loops. Make sure whole system is powered from the same electrical outlet or circuit.

High Frequency Noise

- Bias Supply typically uses 5 kHz to 20 kHz dc-dc converter. Change bias supplies if converter frequency appears as noise on preamplifier or amp output.

Peak Tailing

- Check Pole/Zero setting.

- Check HV cables and circuits. Detector may not be getting rated bias.

- Has detector been exposed to neutrons? Radiation damage causes charge collection problems.

Moisture Accumulation

- Indicates poor vacuum unless accumulation on Detector Chamber occurs only when detector is temperature cycled. Measure weight loss in 24 or 48 hour period to determine LN_2 loss rate. LN_2 weighs 0.81 kg (1.78 lb) per liter.

High LN_2 Loss Rate

- See Moisture Accumulation, above. For dipstick type detectors, substitute another Dewar and check loss rate again. Dipstick Dewars may be replaced in the field at moderate cost.

Poor Resolution at High Energy

- Neutron damage affects resolution at high energy to a greater degree than at low energy. As degradation increases, peaks develop asymmetry. Warmup following damage usually makes the resolution worse.

Noise Spikes (same polarity as signal)

- Likely caused by detector surface leakage current. Do complete thermal cycle and retest.

Noise Spikes (opposite polarity from signal)

- Breakdown in HV network, in HV feedthrough or in HVPS, cabling, etc. Check components on another system to verify. Remove preamp to dry electrical feedthrough with heat gun or clean with methanol and then dry thoroughly before reinstalling.

Peak Instability

- Most gain drift problems are associated with the main amplifier or ADC. If drift is greater than that expected from the temperature range experienced by the electronics, substitute amplifier and ADC.

- Wiring problems between detector and preamp can cause discrete peak shifts. Tap gently on detector and preamplifier assembly to induce shifts. Inspect and clean contacts between preamp and cryostat if problem exists.

Poor Resolution at High Rates

- Check amplifier Pole/Zero.

- Use appropriate amplifier shaping time constant.

- Adjust preamplifier Pole/Zero by observing amplifier output with high count rate. Set preamp P/Z for most stable baseline after first properly Pole/Zeroing the main amplifier.

Intermittent Output (pulsed-optical preamp)

- HV breakdown in cables. Unstable HV Power supply. Moisture on feedthrough HV network. All the above can cause pulsed optical preamps to lock up with output at minus (–) 6 to minus (–) 10 volts except when HV is increased momentarily.

LN_2 Siphoning from MAC

- Plug the unused port (the port not venting) with a cover.

Radiation Damage (Tailing)

- Consult factory. Radiation damage repair usually requires annealing at the factory.

Self-generated Microphonics

- Clean dipstick copper surface with abrasives. Check integral Dewars for ice crystals. Warm up and dry them thoroughly.

Noise Pickup

- Keep cables together and away from CRTs, printers, and other electrically noisy equipment.

Erratic Baseline or Amplifier Output (reset preamp)

- Be sure amplifier Pole/Zero is out: Fully counter-clockwise.

H.V. Inhibit

- If the H.V. Inhibit Indicator is on in the absence of symptoms of warm-up or poor vacuum (excessive loss rate or leakage current), the circuit may need adjustment. See "H.V. Inhibit Circuit Adjustment" on page 51.

9. System Considerations with High Resolution Detectors

This chapter describes some commonly encountered problems in achieving high resolution in routine use rather than in test setup mode and some recommendations on how to attain the best performance.

This chapter covers:

Note: Bench testing detectors for specification compliance involves setups contrived for that purpose.

System Design Considerations

High resolution spectroscopy systems require several connections involving the preamp, bias supply, and spectroscopy amplifier. Under normal operating conditions this does not present a problem, and optimal performance is achieved.

However, in some applications these interconnections are unusual in terms of environment, length, or routing. Under such conditions, systems are susceptible to oscillations or noise due to ground loops or to EMI (electromagnetic interference) from sources such as raster displays, power supplies, computers, etc. This interference will degrade the performance of most high resolution detector systems.

The Loop-Buster accessories, listed on page 87, minimize these problems without affecting cable lengths, cable routing, or system configuration.

Amplifier Shaping

The shaping time constant sets the amplifier's frequency response. The proper choice is usually a compromise between count rate and detector noise band-width. For example, a coaxial Ge detector usually has its best results with a four microsecond shaping, but at very high count rates the pile-up effects can be reduced with a faster shaping.

The optimum time constant depends on detector characteristics (size, configuration, collection characteristics) and the incoming count rate. Table 9.1 lists optimum time constant ranges for common detectors under normal operating conditions.

Table 7 Detector Time Constants

Scintillation [NaI(Tl)]	0.5 – 1.5 µs
Gas Proportional Counters	0.5 – 2.0 µs
Silicon Surface-Barrier (SSB)	0.5 µs
Passivated Implanted Planar Silicon (PIPS)	0.5 µs – 1.0 µs
Lithium Drifted Silicon [Si(Li)]	8.0 – 24.0 µs
Low Energy Germanium	8.0 – 24.0 µs
Coaxial Germanium	4.0 – 6.0 µs

Some Canberra Amplifiers are specified by pulse width or time to peak. The equivalent shaping time constant for a unipolar amp is approximately equal to Time-to-Peak divided by 2.2.

Amplifier Noise

Amplifier noise is random in nature and is summed in quadrature (RSS) with the noise from the detector and the preamplifier. The amplifier's gain is selected so that the energy range of interest matches the ADC's full scale range. At amplifier gains less than 100, the amplifier's noise is not normally a significant factor.

Baseline Restorer

For best signal to noise performance, a direct coupled amplifier with unipolar shaping would be the best theoretical solution, but is not practical because of offset voltages in the preamplifier and amplifier. Therefore, an ac coupled amplifier is required for dc stability. But in an ac coupled amplifier, count rate changes can cause shifts in the baseline unless a bipolar pulse shaping or a baseline restorer (for unipolar shaping) is used.

A bipolar output has worse signal-to-noise ratio and count rate performance than can be obtained with a unipolar output using the same shaping time constant.

A Baseline Restorer removes the fluctuations in a unipolar amplifier by monitoring the baseline and provides drift correction to maintain a level baseline.

In most Canberra amplifiers, an Auto Threshold circuit tracks the peak of the random noise and gates the restorer off when the input being processed exceeds the threshold, thus eliminating energy pulse degradation.

ADC Conversion Gain

To calculate the location of a spectrum peak and its Full Width at Half Maximum (FWHM), at least 20 channels are required in the peak. If the peak has fewer channels, the uncertainty in the calculation will increase the computed FWHM.

The ADC Conversion Gain determines the number of elements (channels) that the input signal is divided into, which affects resolution. For a scintillation detector, a Conversion Gain of 256 or 512 is sufficient to resolve expected peaks; a higher ADC Gain can be used if the Amplifier Gain is not adequate to cover the ADC's input range.

For a Germanium detector with the 1.33 MeV ^{60}Co peak at about 90% of ADC full scale, an ADC Gain of 8192 is required to adequately determine the FWHM. With a 4096 ADC Gain, the FWHM calculation can be degraded by about 100 eV because of the granularity of the data points. This can be reduced if a sophisticated peak fitting routine is used.

System Setup Considerations

The previous factors can be analyzed prior to assembling the proper system for the intended application and are important considerations for the system design. The following are some practical points that permit a system to perform to its potential.

Pole/Zeroing

The pole/zero (P/Z) adjustment matches the amplifier to the preamplifier's tail pulse output and is extremely critical for good high count rate performance. When set properly, disturbance to following pulses is minimized. This adjustment compensates for the exponential decay time constant of the preamplifier pulse. The P/Z must be adjusted if the Amplifier Shaping is changed, but it will not change with Amplifier Gain.

For precise and optimum setting of the P/Z, an oscilloscope vertical sensitivity of 50 mV/cm should be used. However, most scopes will overload for a 10 volt input signal when the vertical sensitivity is set for 50 mV/cm, distorting the signal's recovery to the baseline.

Thus the P/Z will be incorrectly adjusted, resulting in a loss of resolution at high count rates. To prevent overloading the scope, Canberra recommends using the **Model LB1502 Schottky Clamp Box** between the amplifier's output and the scope's input.

Note that the Model 1510 Integrated Signal Processor and Models 2025 and 2026 Spectroscopy Amplifiers have a built-in Schottky clamping circuit.

Amplifier Oscillations

If the cable connecting the front panel output of the amplifier to the ADC exceeds 3 m (10 feet) in length, oscillations can occur. This is caused by the cable capacitance loading the high bandwidth output amplifier.

Most Canberra Amplifiers have a rear panel output which has 93 ohms in series to eliminate the oscillations. Most amplifiers also have internal jumpers that can put a 93 ohm resistor in series with the front panel output. In some cases where it may be necessary to use the low impedance amplifier output, a terminating resistance to ground at the load end of the cable will also eliminate the oscillation.

Vibration and Noise

Vibration transmitted to the detector and cryostat can be through the floor or mounting, as well as direct audio coupling through the air. Vibration isolators in the mounting and sound absorbing covers around the detector can reduce this problem. Shortening the amplifier shaping time constant may improve spectrometer performance in a noisy environment.

Radio Frequency Interference (RFI)

In close proximity, a radio station can sometimes be picked up by a detector. Grounding the preamplifier or cryostat may help, but this can cause ground loops, resulting in 50 or 60 Hz noise. Refer to the following Grounding subsection.

Analyzer Interference

If the detector is located within a few feet of the MCA, it can receive Electro-Magnetic Interference (EMI). In older analyzers this can be from the ferrite cores that were used as memory elements. On the more recent MCAs the display has yoke and flyback transformers that generate large magnetic fields.

The cables connected to the detector must be kept away from the CRT; definitely do not run the cables in front of the display. Some further techniques in minimizing the interference in extraordinary circumstances are covered in the following Grounding subsection.

Grounding

Grounding problems often cause poor performance from a detector. Generally the best performance is obtained when the amplifier, ADC and high voltage power supply (HVPS) are installed in the same bin, with preamp power coming from the amplifier.

Any degradation caused by preamp power circuit ground loops can be eliminated by the **Model LB1501 Ground Loop Eliminator (GLE) Preamp Power Cable**, which has a diode-interrupted ground.

The amplifier should be separated by several slots from the ADC and bias Supply. Any degradation is probably caused by EMI pickup in the signal cable from the detector's preamp to the amplifier. The **Model LB1500 Cable Transformer (CT)** provides a means to cancel signals induced in the cable.

It's not always possible to have all of the electronics in the same bin, however. Several Canberra MCAs have a built-in ADC with provisions for attaching a high voltage power supply and an external NIM amplifier. The resulting separation between the components can cause ground-loop currents. The **Model LB1503 Bias Isolation Box** provides resistive isolation in the ground circuit between the high voltage power supply and the preamp.

The final configuration to be considered is what to do when the detector is hundreds of feet away from the MCA. It's usually not practical to separate the ADC from the MCA. Therefore the amplifier and HVPS are kept near the detector and the amplified and shaped signal is brought to the ADC.

Loop-Buster Accessories

These Loop-Buster accessories are designed to minimize the interference and ground-loop problems which can be encountered in some system configurations. Refer to Figures 49 through 51 for typical system uses of the Loop Buster Accessories.

Model LB1500 Cable Transformer (CT)

The LB1500 Cable Transformer is a 93 ohm BNC cable has a ferrite core built into it. Connect it between the preamplifier and the amplifier to reduce high frequency interference. Newer amplifiers (2025, 2026, 9615) have an equivalent circuit built in.

Note: the LB1500's female BNC connector must not be allowed to touch ground.

Model LB1501 Preamp Power Cable (GLE)

The LB1501 Ground Loop Eliminator Preamp Power Cable (GLE) has a diode-interrupted ground to eliminate ground loops. It is used in place of the C1402 Preamp Power Cable supplied with the preamplifier.

Model LB1502 Schottky Clamp Box

Prevents oscilloscope overload when using high sensitivity settings for precise pole/zero adjustments. Not required with amplifiers that have a built-in limiting circuit.

Model LB1503 Bias Isolation Box

The LB1503 Bias Isolation Box provides resistive isolation in the ground circuit between high voltage power supply and preamp to reduce ground-loop induced noise.

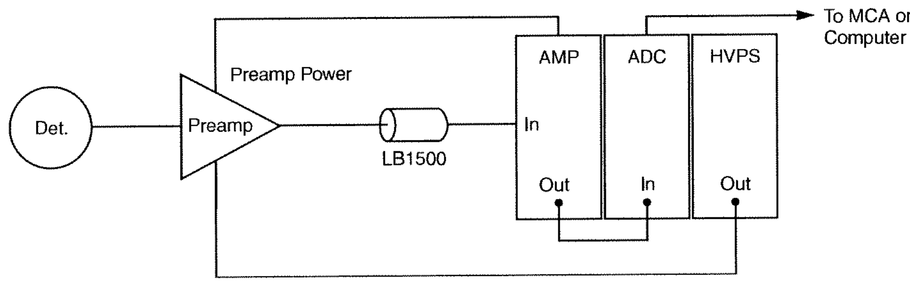


Figure 49 All Electronics in NIM Bin

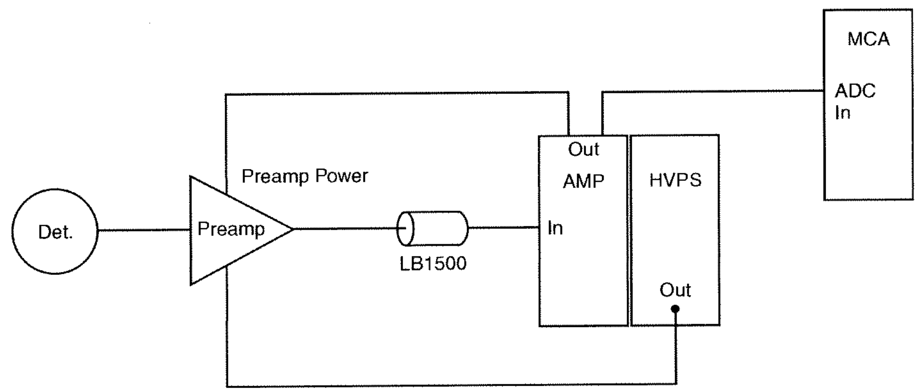


Figure 47 ADC Separated from Amp and Preamp

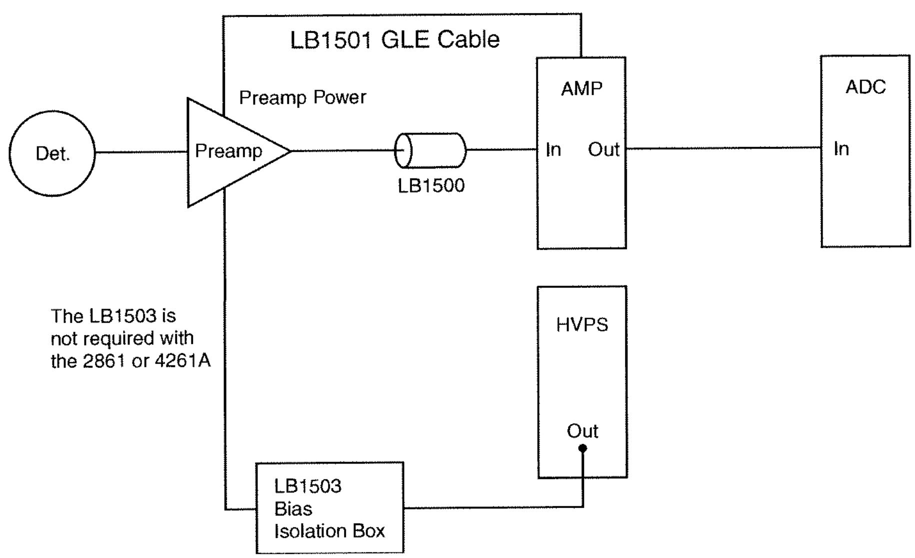


Figure 48 All Components Separated

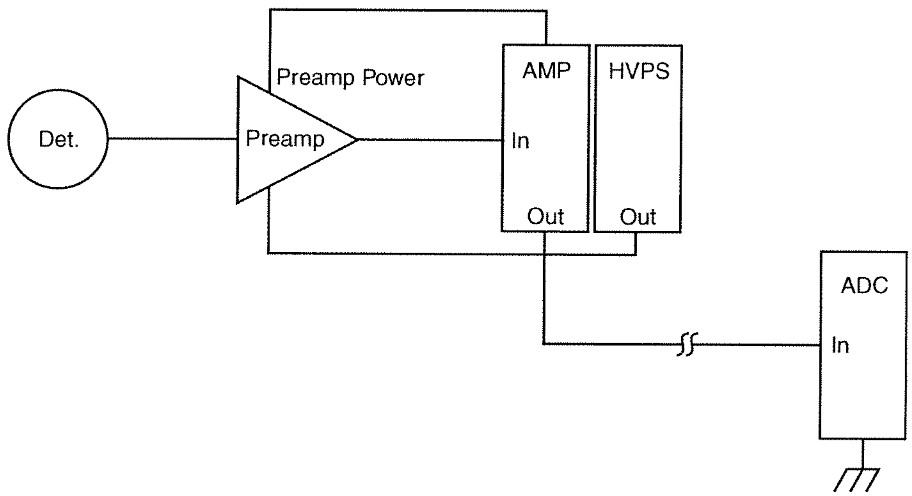


Figure 51 Single Ground

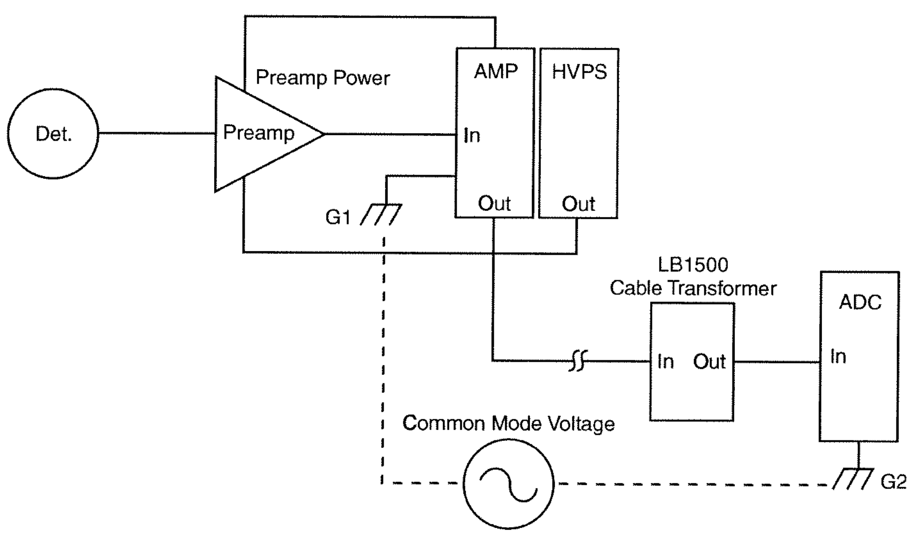


Figure 50 Ground Loop

Notes

Index

Warranty

Canberra (we, us, our) warrants to the customer (you, your) that for a period of ninety (90) days from the date of shipment, software provided by us in connection with equipment manufactured by us shall operate in accordance with applicable specifications when used with equipment manufactured by us and that the media on which the software is provided shall be free from defects. We also warrant that (A) equipment manufactured by us shall be free from defects in materials and workmanship for a period of one (1) year from the date of shipment of such equipment, and (B) services performed by us in connection with such equipment, such as site supervision and installation services relating to the equipment, shall be free from defects for a period of one (1) year from the date of performance of such services.

If defects in materials or workmanship are discovered within the applicable warranty period as set forth above, we shall, at our option and cost, (A) in the case of defective software or equipment, either repair or replace the software or equipment, or (B) in the case of defective services, reperform such services.

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We are under no obligation to provide warranty service if adjustment or repair is required because of damage caused by other than ordinary use or if the equipment is serviced or repaired, or if an attempt is made to service or repair the equipment, by other than our Service Personnel without our prior approval.

Our warranty does not cover detector damage due to neutrons or heavy charged particles. Failure of beryllium, carbon composite, or polymer windows, or of windowless detectors caused by physical or chemical damage from the environment is not covered by warranty.

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