Model 673
Spectroscopy Amplifier
and
Gated Integrator
Operating and Service Manual

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Advanced Measurement Technology, Inc.
a/k/a/ ORTEC®, a subsidiary of AMETEK®, Inc.

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Before being approved for shipment, each ORTEC instrument must pass a stringent set of quality control tests designed to expose any flaws in materials or workmanship. Permanent records of these tests are maintained for use in warranty repair and as a source of statistical information for design improvements.

Repair Service

If it becomes necessary to return this instrument for repair, it is essential that Customer Services be contacted in advance of its return so that a Return Authorization Number can be assigned to the unit. Also, ORTEC must be informed, either in writing, by telephone [(865) 482-4411] or by facsimile transmission [(865) 483-2133], of the nature of the fault of the instrument being returned and of the model, serial, and revision ("Rev" on rear panel) numbers. Failure to do so may cause unnecessary delays in getting the unit repaired. The ORTEC standard procedure requires that instruments returned for repair pass the same quality control tests that are used for new-production instruments. Instruments that are returned should be packed so that they will withstand normal transit handling and must be shipped PREPAID via Air Parcel Post or United Parcel Service to the designated ORTEC repair center. The address label and the package should include the Return Authorization Number assigned. Instruments being returned that are damaged in transit due to inadequate packing will be repaired at the sender's expense, and it will be the sender's responsibility to make claim with the shipper. Instruments not in warranty should follow the same procedure and ORTEC will provide a quotation.

Damage in Transit

Shipments should be examined immediately upon receipt for evidence of external or concealed damage. The carrier making delivery should be notified immediately of any such damage, since the carrier is normally liable for damage in shipment. Packing materials, waybills, and other such documentation should be preserved in order to establish claims. After such notification to the carrier, please notify ORTEC of the circumstances so that assistance can be provided in making damage claims and in providing replacement equipment, if necessary.

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CONTENTS

SAFETY WARNINGS AND CLEANING INSTRUCTIONS

DANGER Opening the cover of this instrument is likely to expose dangerous voltages. Disconnect the instrument from all voltage sources while it is being opened.

WARNING Using this instrument in a manner not specified by the manufacturer may impair the protection provided by the instrument.

Cleaning Instructions

To clean the instrument exterior:

- Unplug the instrument from the ac power supply.
- Remove loose dust on the outside of the instrument with a lint-free cloth.
- Remove remaining dirt with a lint-free cloth dampened in a general-purpose detergent and water solution. Do not use abrasive cleaners.

CAUTION To prevent moisture inside of the instrument during external cleaning, use only enough liquid to dampen the cloth or applicator.

- Allow the instrument to dry completely before reconnecting it to the power source.

SAFETY INSTRUCTIONS AND SYMBOLS

This manual contains up to three levels of safety instructions that must be observed in order to avoid personal injury and/or damage to equipment or other property. These are:

DANGER	Indicates a hazard that could result in death or serious bodily harm if the safety instruction is not observed.
WARNING	Indicates a hazard that could result in bodily harm if the safety instruction is not observed.
CAUTION	Indicates a hazard that could result in property damage if the safety instruction is not observed.

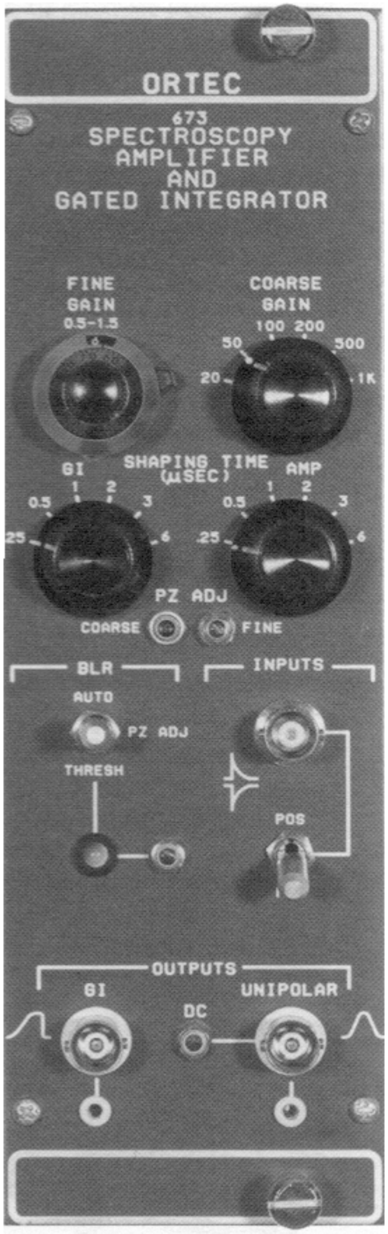
Please read all safety instructions carefully and make sure you understand them fully before attempting to use this product.

In addition, the following symbol may appear on the product:

ATTENTION – Refer to Manual

DANGER – High Voltage

Please read all safety instructions carefully and make sure you understand them fully before attempting to use this product.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SPECTROSCOPY
AMPLIFIER
AND
GATED INTEGRATOR
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0.5-1.5
COARSE
GAIN
20
50
100
200
500
1K
SHAPING TIME
(µSEC)
GI
AMP
.25
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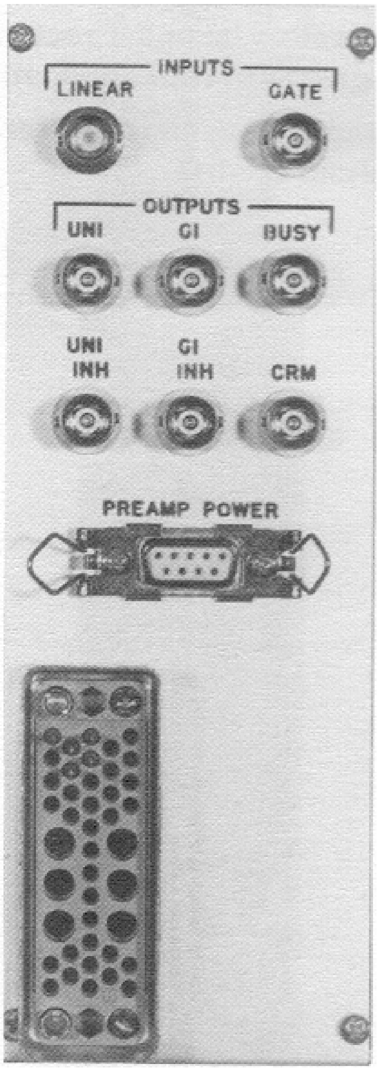
INPUTS
LINEAR
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OUTPUTS
UNI
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BUSY
UNI
INH
GI
INH
CRM
PREAMP POWER

ORTEC MODEL 673 SPECTROSCOPY AMPLIFIER AND GATED INTEGRATOR

1. DESCRIPTION

1.1. GENERAL

The ORTEC Model 673 Spectroscopy Amplifier and Gated Integrator is a double-width NIM module with a versatile combination of switch-selectable pulse-shaping and output characteristics. It features extremely low noise, wide gain range, and excellent overload response for universal application in high-resolution spectroscopy. It accepts input pulses of either polarity that originate in germanium or silicon semiconductor detectors, in scintillation counters with either fast or slow scintillators, in proportional counters, in pulsed ionization chambers, in electron multipliers, etc.

The 673 is two amplifiers in one, having both a semi-gaussian unipolar and a gated integrator output. Optimum low- and high-rate energy resolution can be obtained with improved throughput and excellent energy resolution. The 673 can be used with resistive feedback or pulse (transistor) reset preamplifiers.

1.2. GATED INTEGRATOR SPECTROSCOPY

A gated integrator is an essential element in a high-throughput system. A major application of the gated integrator, (GI), is in gamma-ray experiments involving large volume HPGe detectors since ballistic deficit effects caused by long charge collection times are eliminated. When used following a conventional resistive feedback or pulse-reset preamplifier, optimum throughput of approximately a factor of four can be achieved by us as compared to conventional semigaussian shaping. The increase in throughput is achieved with only minimal increase in energy resolution (Fig. 1).

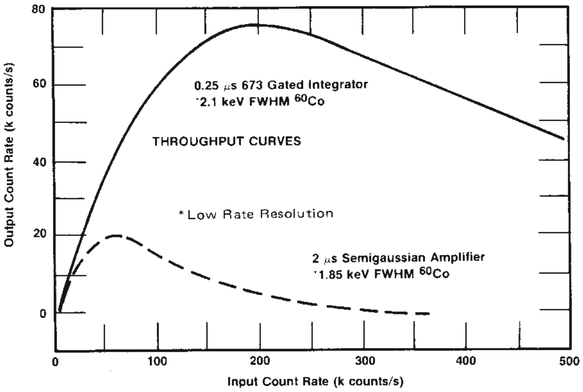

Fig. 1. Example of the Throughput Improvement Using the Gated Integrator Technique.

Charge collection time effects are of significant importance when using large volume HPGe detectors at high energies. Detector current pulses having equivalent total charges but different rise times produce different output pulse heights when processed by a charge-sensitive preamplifier and a semigaussian filter amplifier.[1] This results in the distortion of the spectrum in direct proportion to the pulse amplitude or energy. This distortion is most pronounced at short shaping time constants and with large volume detectors. Experiments performed with a small 10% efficient HPGe detector at 0.5 µs shaping time, using the 1.33 MeV line of ^{60}Co, reveal a significant amount of distortion when using conventional semi-gaussian shaping (Fig. 2). An equivalent experiment using a shorter shaping time of 0.25 µs and GI shaping, shows the dramatic improvement in energy resolution due to elimination of charge collection time effects (Fig. 3).

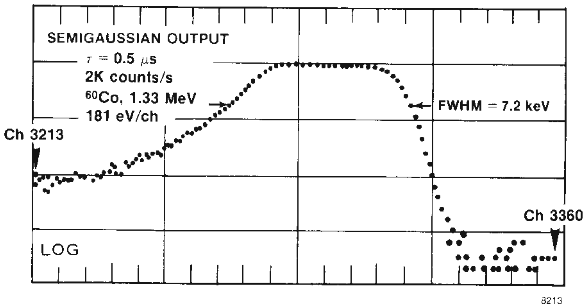

Fig. 2. Distortion Due to Charge Collection Time Effects When Using Semigaussian Output at Short Shaping Time Constants.

The 673 has an input impedance of ~500 Ω and accepts either positive or negative input pulses with rise times <650 ns and fall times >40 µs. Six integrate and differentiate time constants are switch-selectable to provide optimum shaping for resolution and count rate. The first differentiation network has variable pole-zero cancellation that can

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[1] T.H. Becker, E.E. Gross, R.C. Trammell, "Characteristics of High-Rate Energy Spectroscopy Systems With Time-Invariant Filters," IEEE Nucl. Sci., **NS-28 598** (1981)

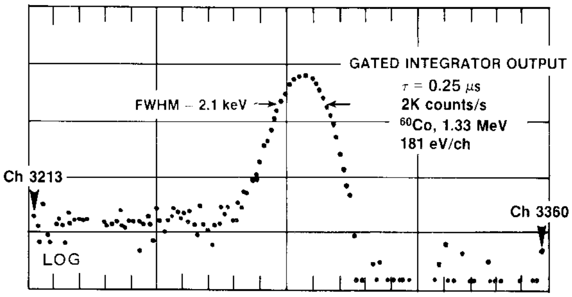


Fig. 3. Elimination of Charge Collection Time Effects With the Gated Integrator.

be adjusted to match preamplifiers with decay times >40 µs. The pole-zero cancellation drastically reduces the undershoot after the first differentiator and greatly improves overload and count rate characteristics. In addition, the amplifier contains an active filter shaping network that optimizes the signal-to-noise ratio and minimizes the overall resolving time. Both unipolar and gated integrator outputs are provided simultaneously on the front and rear panels.

The unipolar output should be used for spectroscopy when dc-coupling can be maintained from the 673 to the analyzer. A BLR (baseline restorer) circuit is included in the unit for improved performance at all count rates. Baseline correction is applied during intervals between input pulses only and a front panel switch selects a discriminator level to identify input pulses. The unipolar output dc level can be adjusted in the range from -100 mV to +100 mV. This output permits the use of the direct-coupled input of the analyzer with a minimum amount of interface problems.

The gated integrator, (GI), output is obtained by integrating the integrating the entire unipolar signal. As a result of this integration, the problems associated with charge collection effects are removed even when operating at short shaping time constants. Another benefit of the GI technique is the ability to maintain peak position and energy resolution over a wide dynamic range of input count rate.

Internal pulse pileup (a second pulse arriving before the first pulse has been completed) is sensed internally. The 673 includes an Inhibit output BNC connector on the rear panel that can be used to inhibit measurement of the result of a pulse pileup when it occurs.

The unit can be used for constant-fraction timing when operated in conjunction with an ORTEC 551, 552, or 553 Timing Single-Channel Analyzer (TSCA). These TSCAs feature a minimum of walk as a function of pulse amplitude and incorporate a variable delay time on the output pulse to enable the timing pickoff output to be placed in time coincidence with other signals.

The 673 has complete provisions, including power, for operating any ORTEC solid-state preamplifier. Normally, the preamplifier pulses should have a rise time of 0.25 µs or less to properly match the amplifier filter network and a decay time >40 µs for proper pole-zero cancellation. (Pole-zero cancellation is not required when using a pulse-reset preamplifier). The input impedance is 500 Ω. When long preamplifier cables are used, the cables can be terminated in series at the preamplifier end or in shunt at the amplifier end with the proper resistors. The output impedance is about 0.1Ω at the front panel connectors and 93 Ω at the rear panel connectors. The front panel outputs can be connected to other equipment by a single cable going to all equipment and shunt terminated at the far end of the cabling. If series termination is desired, the rear panel connectors can be used to connect the 673 to other modules. See Section 3 for further information.

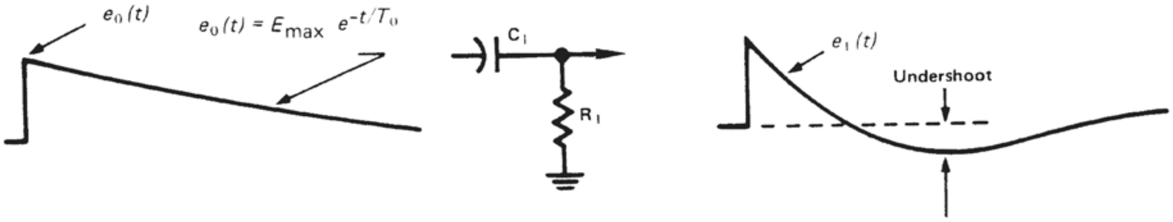
1.3. POLE-ZERO CANCELLATION

Pole-zero cancellation is a method for eliminating pulse undershoot after the first differentiating network. In an amplifier not using pole-zero cancellation (Fig. 4), the exponential tail of a resistive feedback preamplifier output signal (Usually 50 to 500 µs) causes an undershoot whose peak amplitude is roughly determined from:

$$\frac{undershoot\ amplitude}{differentiated\ \ pulse\ amplitude}$$

$$=\frac{differentiation\ time}{preamplifier\ \ pulse\ decay\ time}$$

For a 1 µs differentiation time and a 50 µs pulse decay time the maximum undershoot is 2%, and this decays with a 50 µs time constant. Under overload conditions this undershoot is often sufficiently large to saturate the amplifier during a considerable portion of the undershoot, causing excessive dead time. This effect can be reduced by increasing the preamplifier pulse decay time (which generally reduces the counting rate capabilities of the preamplifier) or compensating for the undershoot by using pole-zero cancellation.



Charge loop output × **First differentiate network** = **Differentiated pulse with undershoot**

$$E_{max}\, e^{-t/T_0} \times G(t) = e_1(t) .$$

$$E_{max} \frac{1}{s+\frac{1}{T_0}} \times \frac{s}{s+\frac{1}{R_1C_1}} = E_1(s) \text{ (Laplace transform).}$$

$$\frac{E_{max}}{T_0 - T_1} T_0\, e^{-t/T_1} - T_1\, e^{-t/T_0} = e_1(t), \text{ where } T_1 = R_1C_1 .$$

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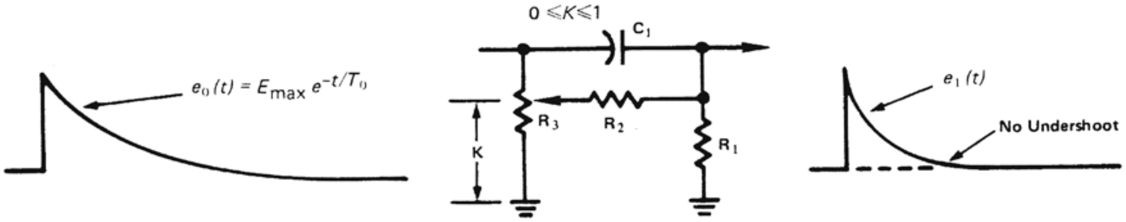
Fig. 4. Differentiation in an Amplifier Without Pole-Zero Cancellation.

Pole-zero cancellation is accomplished by the network shown in Fig. 5. The pole [s + (1/T_0)] due to the preamplifier pulse decay time is canceled by the zero of the network [s + (K/R_2C_1)]. In effect, the dc path across the differentiation capacitor adds an attenuated replica of the preamplifier pulse to just cancel the negative undershoot of the differentiating network.

Total preamplifier-amplifier pole-zero cancellation requires that the preamplifier output pulse decay time be a single exponential decay and matched to the pole-zero cancellation network. The variable pole-zero cancellation network allows accurate cancellation for all preamplifiers having 40 µs or greater decay times. Improper matching of the pole-zero network will degrade the overload performance and cause excessive pileup distortion at medium counting rates. Improper matching causes either an undercompensation (undershoot is not eliminated) or an overcompensation (output after the main pulse does not return to the baseline but decays to the baseline with the preamplifier time constant). The pole-zero adjust is accessible on the front panel and can easily be adjusted by observing the baseline on an oscilloscope with a mono-energetic source or pulser having the same



Charge loop output × **Pole-zero cancelled differentiate network** = **Differentiated pulse without undershoot**

$$E_{max}\, e^{-t/T_0} \times G(t) = e_1(t) .$$

$$E_{max} \frac{1}{s+\frac{1}{T_0}} \times \frac{s+\frac{K}{R_2C_1}}{s+\frac{R_1+R_2}{R_1R_2C_1}} = E_1(s), \text{ (Laplace transform).}$$

Pole zero cancel by letting

$$s+\frac{1}{T_0} = s+\frac{K}{R_2C_1} .$$

or

$$\frac{E_{max}}{s+\frac{R_1+R_2}{R_1R_2C_1}} = \frac{E_{max}}{s+\frac{1}{R_pC_1}} = E_1(s), \text{ where } R_p = \frac{R_1R_2}{R_1+R_2}$$

$$E_{max}\, e^{-t/R_pC_1} = e_1(t) .$$

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Fig. 5. Differentiation in a Pole-Zero Cancelled Amplifier.

decay time as the preamplifier under overload conditions. The adjustment should be made so that the pulse returns to the baseline in the minimum time with no undershoot.

1.4. ACTIVE FILTER

When only FET gate current and drain thermal noise are considered, the best signal-to-noise ratio occurs when the two noise contributions are equal for a given input pulse shape. The gaussian pulse shape (Fig. 6) for this condition requires an amplifier with a single RC differentiate and n equal RC integrates where n approaches infinity. The Laplace transform of this transfer function is

$$G(s) = \frac{s}{s + (1/RC)} \times \frac{1}{\left[s + (1/RC)^{n}\right]} (n \rightarrow \infty),$$

where the factor is the single differentiate and the second factor is the n integrates. The active filter approximates this transfer function.

Figure 6 illustrates the results of pulse shaping in an amplifier. Of the four pulse shapes shown the cusp would produce minimum noise but is impractical to achieve with normal electronic circuitry and would be difficult to measure with an ADC. The true gaussian shape deteriorates the signal-to-noise ratio by only about 12% from that of the cusp and produces a signal that is easy to measure, but requires many sections of integration ($n \rightarrow \infty$). With two sections of integration of the waveform identified as a gaussian approximation can be obtained, and this deteriorates the signal-to-noise ratio by about 22%. The ORTEC active filter network in the 673 amplifier provides the fourth waveform in Fig. 6; this waveform has characteristics superior to the gaussian approximation, yet obtains them with four complex poles. By this method the output pulse shape has a good signal-to-noise ratio, is easy to measure, and yet requires only a practical amount of electronic circuitry to achieve the desired results.

1.5. GATED INTEGRATOR

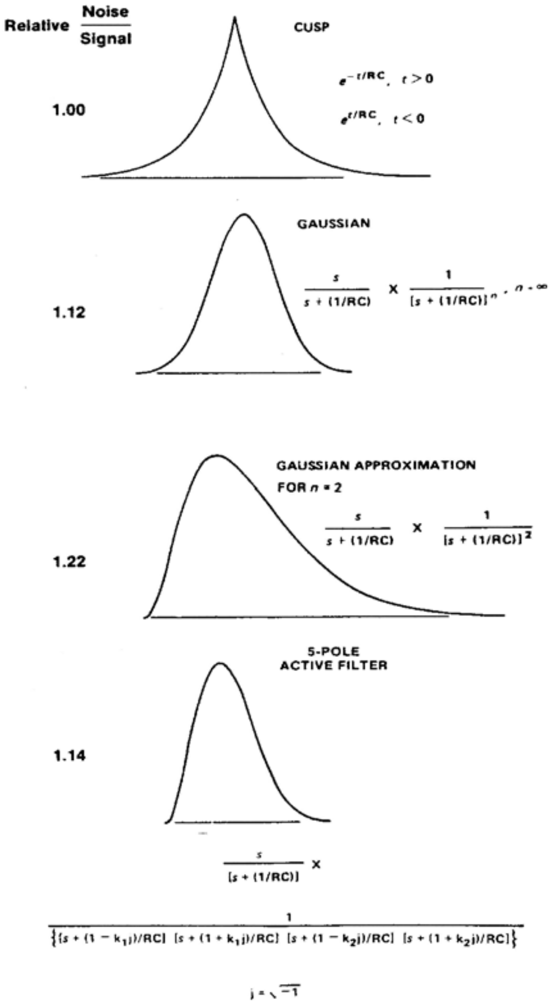


Fig. 6. Pulse Shapes for Good Signal-to-Noise Ratios

The GI output is formed by integrating the entire output signal from a gaussian prefilter (Fig. 7). The prefilter output, which is similar to conventional unipolar semigaussian shaping, is inverted by amplifier A1 before being processed by the inverting gated integrator section. While a signal is being processed, switch S1 is closed; S2 and S3 are open. At the end of the pulse processing time, S1 is opened while S2 and S3 are closed. Any charge stored on the integrating capacitor will be discharged at this time, forcing the GI output to zero. The total processing time is determined as eight to ten times the shaping time constant, *τ.*

Since the time-to-peak of the GI output occurs much later than the peak of the gaussian signal, (Fig. 8), there is more time to integrate the total charge collected in the detector for a given shaping time. The time-to-peak is an important parameter since nuclear spectroscopy analog-to-digital converters, ADCs, use a peak detect circuit to begin the data conversion cycle. Also, a peak stretcher is used as a buffer to the ADC. Therefore, this new pulse processing technique permits the use of shorter

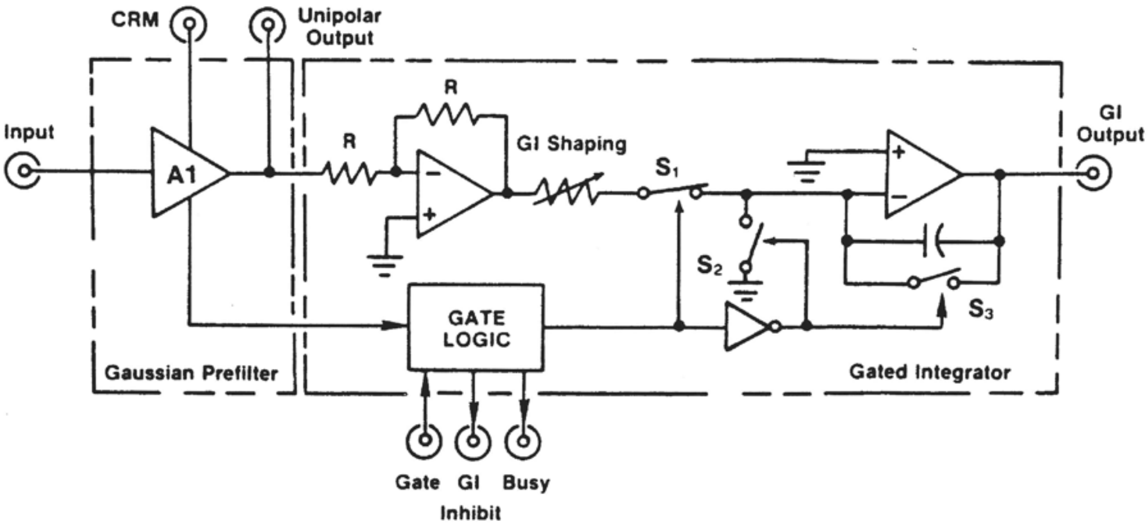


Fig. 7. Simplified Block Diagram of the 673 Spectroscopy Amplifier and Gated Integrator.

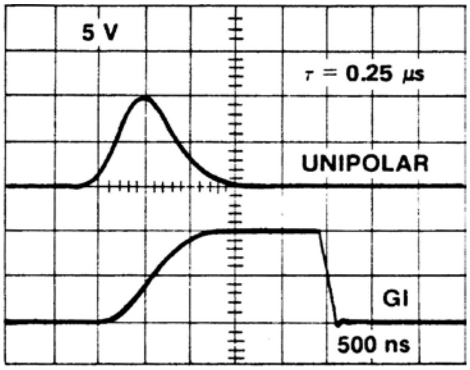


Fig.8. Gated Integrator, (GI), Output and Unipolar Output.

shaping time constants for the gaussian prefilter and eliminates the charge-collection time effects. The resulting shorter total processing time improves the throughput by eliminating occurred at the longer shaping time constants.

Peak centroid and energy resolution remain relatively constant over a very wide dynamic range of input counting rates when using the gated integrator (Fig 9). The highest count rate performance can be achieved when a gated integrator and pulse-reset preamplifier is used. This ensures that the total system does not "lock up" at extremely high counting rates. A gated integrator can also be used with conventional resistive-feedback preamplifiers if the counting rate is limited to <~125k cps at ^{60}Co. This count rate limitation is due to the average dc-offset from pulse pileup at the preamplifier output. For low- to medium-rate experiments, the unipolar output provides the optimum energy resolution with essentially no shift in the peak centroid (Fig. 10).

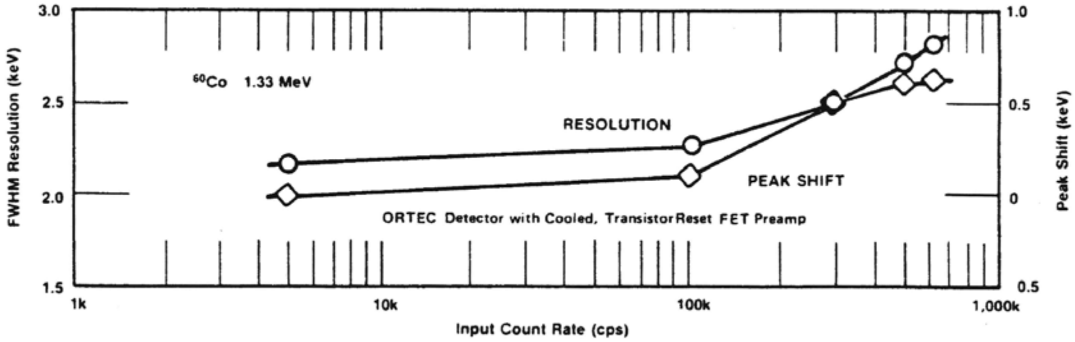


Fig. 9. Typical Resolution and Baseline Stability vs Counting Rate for the GI Output of the 673 Using 0.25 μs Shaping Time.

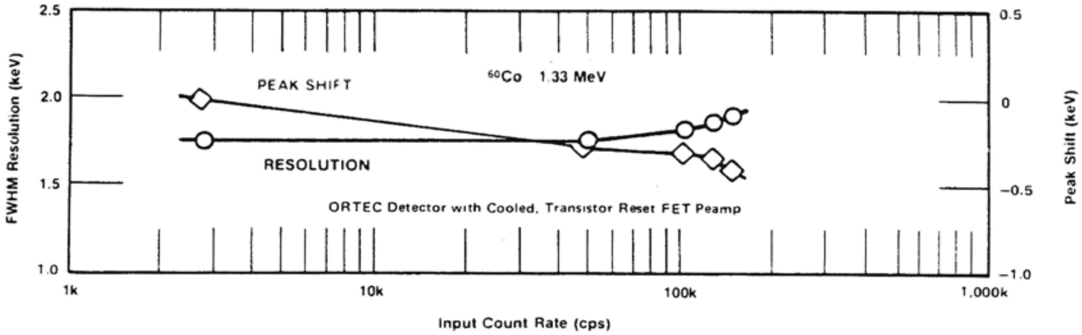


Fig. 10. Typical Resolution and Baseline Stability vs Counting Rate for the Unipolar (Semigaussian) Ouput of the 673 Using 2 µs Shaping Time.

2. SPECIFICATIONS

2.1. PERFORMANCE

GAIN RANGE Continuously adjustable, X1 through X1500.

PULSE SHAPING Unipolar, gaussian on all ranges with peaking time equal to 2.2τ and pulse width at 0.1% level, equal to 2.9 times the peaking time.

GI PULSE SHAPING Time variant gated integrator.

INTEGRAL NONLINEARITY <±0.05% (0.025% typical) using 2-µs shaping.

NOISE <4 µV referred to the input using 3-µs shaping; gain >100, unipolar output.

TEMPERATURE INSTABILITY
Gain ≤0.0075%/°C, 0 to 50°C.
DC Level <±10 µV/°C, 0 to 50°C.

UNIPOLAR COUNT RATE INSTABILITY The 1.33-MeV gamma ray peak from a ^{60}Co source, positioned at 85% of analyzer range, typically shifts <0.024%, and its FWHM broadens 14% when its incoming count rate changes from 0 to 100,000 counts/s using 2 µs shaping. The amplifier will hold the baseline reference up to count rates in excess of 150,000 counts/s.

GI THROUGHPUT AND RESOLUTION The Gated Integrator allows operation at short time constants which permits higher throughput rates while maintaining excellent resolution. Typical results for a 10% HPGe detector using a ^{60}Co source and 200,000 counts/s input:

Output	Time Constant	Dead Time	Max Throughput	Resolution
Unipolar	0.5 µs	5 µs	74 k c/s	7.5 keV
GI	0.25 µs	5µµs	74 k c/s	2.3 keV

OVERLOAD RECOVERY Recovers to within 2% of rated output from X300 overload in 2.5 nonoverloaded unipolar pulse widths, using maximum gain.

2.2. CONTROLS

FINE GAIN Ten-turn precision potentiometer for continuously variable direct-reading gain factor of X0.5 to X1.5.

COARSE GAIN Six-position switch selects feedback resistors for gain factors of 20, 50, 100, 200, 500, and 1 k.

INPUT ATTENUATOR Jumper on printed wiring board selects an input attenuation factor of 1 or 10 (gain factor of X1 or X0.1).

POS/NEG Toggle switch selects Pos or Neg input.

SHAPING TIME Two six-position switches select time constant for active-filter-network pulse shaping; selections are 0.25, 0.5, 1, 2, 3, and 6. Switch settings should be set equally for normal operation.

PZ Two potentiometers to adjust pole-zero cancellation for decay times from 40 µs to ∞. Fine PZ corresponds to approximately 10% of coarse PZ.

BLR Toggle switch selects a source for the gated baseline restorer discriminator threshold level from one of three positions:

Auto The BLR threshold is automatically set to an optimum level as a function of the signal noise level by an internal circuit. This allows easy setup and very good performance.

PZ Adj The BLR threshold is determined by the threshold potentiometer. The BLR time constant is greatly increased to facilitate PZ adjustment. This position may give the lowest noise for conditions of low count rate and/or longer shaping times.

Threshold The BLR threshold is set manually by the threshold potentiometer. Range, 0 to 300 mV referred to the positive output signal. The BLR time constant is the same as for the Auto switch setting.

DC Screwdriver potentiometer adjusts the unipolar output baseline dc level; range, +100 mV to -100 mV.

2.3. INPUTS

LINEAR Positive or negative signal through either front panel or rear panel BNC connectors. Accepts pulses with rise times in the range from 10 to 650 ns and decay times from 40 to 2000 µs; $Z_{in} \cong 1$ kΩ, dc-coupled; linear maximum 1 V (10 V with attenuator jumper set at X0.1); absolute maximum 20 V.

GATE Rear panel BNC connector accepts standard positive NIM signal to inhibit pileup rejector circuit during reset interval of a pulse-reset preamplifier.

2.4. OUTPUTS

UNI Front panel BNC with $Z_0 < 1\Omega$ and rear panel BNC with $Z_0 = 93\Omega$. Short-circuit proof; full scale linear range 0 to +10 V; active-filter-shaped and dc-restored; dc level adjustable to ±100 mV.

GI Front panel BNC with Z_0 **<**1Ω and rear panel BNC with Z_o **=** 93Ω. Short-circuit proof; full scale range 0 to +10 V; dc level ±5 mV.

2.5. REAR PANEL CONNECTORS

REAR PANEL CONNECTORS

BUSY Rear panel BNC with $Z_0 < 10\Omega$ provides a +5 V logic pulse for the duration that the input pulse exceeds the baseline restorer discriminator level. Connect to the ORTEC MCA Busy Input for dead time correction.

UNI INH Rear panel BNC with $Z_0 < 10\Omega$ provides a nominal +5 V logic signal when an internal pulse pileup occurs; to be used for an MCA anticoincidence input to prevent storage of pileup data in the spectrum when using the unipolar output.

GI INH Rear panel BNC with $Z_0 < 10\Omega$ provides a nominal +5 V logic signal when an internal pulse pileup occurs; to be used for an MCA anticoincidence input to prevent storage of pileup data in the spectrum when using the GI output.

CRM (Count Ratemeter) Rear panel BNC furnishes a nominal +5 V logic signal for every linear input pulse, width 300 ns; to be used as an input to a ratemeter or counter.

2.6. ELECTRICAL AND MECHANICAL

PREAMP POWER Rear panel standard ORTEC power connector; Amphenol 17-10090; mates with captive and noncaptive power cords on all standard ORTEC preamplifiers.

POWER REQUIRED +24 V, 125 mA; -24 V, 105 mA; +12 V, 150 mA; -12 V, 75 mA.

WEIGHTS
Net 1.4 kg (3 lb).
Shipping 3.2 kg (7 lb).

DIMENSIONS NIM-standard double-width module (2.70 x 8.714 in. front panel) per TID-20893 (Rev).

3. INSTALLATION

3.1. GENERAL

The 673 operates on power that must be furnished from a NIM-standard bin and power supply such as the ORTEC 4001/4002 Series. The bin and power supply is designed for relay rack mounting. If the equipment is to be rack mounted, be sure that there is adequate ventilation to prevent any localized heating of the components that are used in the 673. The temperature of the equipment mounted in racks can easily exceed the maximum limit of 50°C unless precautions are taken.

3.2. CONNECTION TO POWER

The 673 contains no internal power supply and must obtain the necessary dc operating power from the bin and power supply in which it is installed for operation. Always turn off power for the power supply before inserting or removing any modules. After all modules have been installed in the bin and any preamplifiers have also been connected to the Preamp Power connectors on the amplifiers, check the dc voltage levels from the power supply to see that they are not overloaded. The ORTEC 4001/4002 Series Bins and Power Supplies have convenient test points on the power supply control panel to permit monitoring these dc levels. If any one or more of the dc levels indicates an overload, some of the modules will need to be moved to another bin to achieve operation.

3.3. CONNECTION TO PREAMPLIFIER

The preamplifier output signal is connected to the 673 through the appropriate Input BNC connector on the front or rear panel. The input impedance is ~500Ω and is dc-coupled to ground; therefore the preamplifier output must be either ac-coupled or have approximately zero dc voltage under no-signal conditions.

The 673 incorporates pole-zero cancellation in order to enhance the overload and count rate characteristics of the amplifier when used with resistive-feedback preamplifiers. This technique requires matching the network to the preamplifier decay time constant in order to achieve perfect compensation. The pole-zero adjustment should be set each time the preamplifier or the shaping time constant of the amplifier is changed. For details of the pole-zero adjustment see Section 4.6. An alternate method is accomplished easily by using a monoenergetic source and observing the amplifier baseline with an oscilloscope after each pulse under approximately X2 overload conditions. Adjustment should be made so that the pulse returns to the baseline in a minimum amount of time with no undershoot. Pole-zero adjustment is not needed when using a transistor-reset preamplifier.

Preamplifier power at +24 V, -24 V, +12V and -12 V is available through the Preamp Power connector on the rear panel. When the preamplifier is connected, its power requirements are obtained from the same bin and power supply as is used for the amplifier, and this increases the dc loading on each voltage level over and above the requirements for the 673 at the module position in the bin.

When the 673 is used with a remotely located preamplifier (i.e., preamplifier-to-amplifier connection through 25 ft or more of coaxial cable), be careful to ensure that the characteristic impedance of the transmission line from the preamplifier output to the 673 input is matched. Since the input impedance of the 673 is ~500Ω, sending-end termination will normally be preferred; the transmission line should be series-terminated at the preamplifier output. All ORTEC preamplifiers contain series terminations that are either 93Ω or variable; coaxial cable type RG-62/U or RG-71/U is recommended.

3.4. CONNECTION OF TEST PULSE GENERATOR

THROUGH A PREAMPLIFIER The satisfactory connection of a test pulse generator such as the ORTEC 419 Precision Pulse Generator or equivalent depends primarily on two considerations; the preamplifier must be properly connected to the 673 as discussed in Section 3.3, and the proper input signal simulation must be applied to the preamplifier. To ensure proper input signal simulation, refer to the instruction manual for the particular preamplifier being used.

DIRECTLY INTO THE 673 Since the input impedance of the 673 is ~500Ω, the test pulse generator will normally have to be terminated at the amplifier input with an additional shunt resistor. In addition, if the test pulse generator has a dc offset, a large series isolating capacitor is also required since the 673 input is dc-coupled. The ORTEC test pulse generators are designed for direct connection. When any one of these units is used, it should be terminated with a 100Ω terminator at the amplifier input or be used with at least one of the output attenuators set at In. (The small error due to the finite input impedance of the amplifier can normally be neglected.)

SPECIAL CONSIDERATIONS FOR POLE-ZERO CANCELLATION When a tail pulser is connected directly to the amplifier input, the PZ Adj should be adjusted if overload tests are to be made (other tests are not affected). See Section 4.6 for the pole-zero adjustment. If a preamplifier is used and a tail pulser is connected to the preamplifier test input, similar precautions are necessary. In this case the effect of the pulser decay must be removed; that is, a step input should be simulated.

3.5. SHAPING CONSIDERATIONS

The shaping time constant on the 673 is switch-selectable in steps of 0.25, 0.5, 1, 2, 3, and 6 µs. The choice of the proper shaping time constant is generally a compromise between operating at a shorter time constant for accommodation of high counting rates and operating with a longer time constant for a better signal-to-noise ratio. For scintillation counters the energy resolution depends largely on the scintillator and photomultiplier, and therefore a shaping time constant of about four times the decay-time constant of the scintillator is a reasonable choice (for NaI, a 1 µs shaping time constant is about optimum). For gas proportional counters the collection time is normally in the 0.5 to 5 µs range and a 2 µs or greater time constant selection will generally give optimum resolution. For surface barrier semiconductor detectors, a 0.5 to 2 µs resolving time will generally provide optimum resolution. Shaping time for HPGe detectors will vary from 1 to 6 µs, depending on the size, configuration, and collection time of the specific detector and preamplifier. When a charge-sensitive preamplifier is used, the optimum shaping time constant to minimize the noise of a system can be determined by measuring the output noise of the system and dividing it by the system gain. Since the 673 has almost constant gain for all shaping modes, the optimum shaping can be determined by measuring the output noise of the 673 with a voltmeter as each shaping time constant is selected.

The 673 provides both unipolar and gated integrator outputs. The unipolar output pulses should be used in applications where the best signal-to-noise ratio (resolution) is most important, such as high-resolution spectroscopy using semiconductor detectors. Use of the unipolar output with baseline restoration will also give excellent resolution at high counting rates. The gated integrator output should be used to obtain a higher throughput. Another benefit of the gated integrator is the ability to maintain peak position and energy resolution over a wide dynamic range of input count rate.

3.6. USE OF GATE INPUT

The Gate Input on the rear panel accepts a positive logic pulse (TTL compatible) that keeps the gated integrator from producing an output as long as it is positive. It does not affect the unipolar output. The main purpose is to receive a reset signal from a reset-type preamplifier such as the ORTEC Transistor-Reset Preamplifier.

3.7. LINEAR OUTPUT CONNECTIONS AND TERMINATING CONSIDERATIONS

Since the 673 unipolar output is normally used for spectroscopy, the 673 is designed with a great amount of flexibility in order for the pulse to be interfaced with an analyzer. A gated baseline restorer, (BLR), circuit is included in this output for improved performance at all count rates. A switch on the front panel permits the threshold for the restorer gate to be determined automatically, according to the input noise level, or manually, with a screwdriver adjustment. The switch also has a center PZ Adj setting that can be used to eliminate the BLR effect when making pole-zero adjustments.

The unipolar output dc level can be adjusted from -0.1 to +0.1 V to set the zero intercept on the analyzer when direct coupling is used. Typical system block diagrams for a variety of experiments are described in Section 4.

Three general methods of termination are used. The simplest of these is shunt termination at the receiving end of the cable. A second method is series termination a the sending end. The third is a combination of series and shunt termination, where the cable impedance is matched both in series at the sending end and in shunt at the receiving end. The combination is most effective, but this reduces the amount of signal strength at the receiving end to 50% of that which is available in the sending instrument.

To use shunt termination at the receiving end of the cable, connect the <1 Ω output of the 673 (on the front panel) through 93 Ω cable to the input of the receiving instrument. Then use a BNC tee connector to attach both the interconnecting cable and a 100Ω terminator at the input connector of the receiving instrument. Since the input impedance of the receiving instrument is normally 1000Ω or more, the effective instrument input impedance with the 100Ω terminator will be of the order of 93Ω, and this matches the cable impedance correctly.

For series termination use the 93Ω output of the 673 for the cable connection. Use 93Ω cable to interconnect this into the input of the receiving instrument. The 1000Ω (or more) normal input impedance at the input connector represents an essentially open circuit, and the series impedance in the 673 now provides the proper termination for the cable.

For the combination of series and shunt termination, use the 93Ω output on the rear panel of the 673 and use 93Ω cable. At the input for the receiving instrument use a BNC tee to attach both the signal cable and a 100Ω resistive terminator. Note that the signal span at the receiving end of this type of circuit will always be reduced to 50% of the signal span furnished by the sending instrument.

For customer convenience, ORTEC stocks the proper terminators and BNC tees, or they can be ordered from a variety of commercial sources.

3.8. SHORTING OR OVERLOADING THE AMPLIFIER OUTPUTS

All outputs of the 673 are dc-coupled with an output impedance of ~0.1Ω for the front panel connectors and 93Ω for the rear panel connectors. If the output is shorted with a direct short circuit, the output stage will limit the peak current of the output so that the amplifier will not be harmed. When the amplifier is terminated with 100Ω, the maximum rate allowed to maintain the linear unipolar output is [200,000 cps/τ(µs)] x [10/V_0(V)].

3.9. INHIBIT OUTPUT CONNECTION

The GI and Uni Inhibit outputs on the rear panel are intended for application at the anticoincidence input of the analyzer. An output pulse is generated through this connector when a pulse pileup is sensed in the 673, and the pulse can then be used to prevent the analyzer from measuring and storing a false amplitude. The signal is dc-coupled and rises from 0 to about +5 V for a time equal to 6τ, starting when a pileup occurs. The Uni Inh is used for the unipolar output and the GI Inh for the GI output.

3.10. BUSY OUTPUT CONNECTION

The signal through the rear panel Busy output connector rises from 0 to about +5 V at the onset of each linear input pulse. Its width is equal to the time the input pulse amplitude exceeds the BLR discriminator level, and is extended automatically by the generation of an Inhibit output signal. It can be used to provide MCA live time correction, to control the generation of input pulses, to observe normal operation with an oscilloscope, or for any of a variety of other applications. Its use is optional and no termination is required if the output is not being used.

3.11. CRM OUTPUT CONNECTION

One NIM-standard positive logic pulse is generated to correspond to each linear input pulse into the 673. The pulses are available through the CRM (Count Rate Meter) output BNC on the rear panel and are intended for use in a count rate meter or counter to monitor the true input count rate into the amplifier. Its use is optional and no termination is required if the output is not being used.

4. OPERATION

4.1. INITIAL TESTING AND OBSERVATION OF PULSE WAVEFORMS

Refer to Section 6 for information on testing performance and observing waveforms at front panel test points. Figure 11 shows some typical unipolar and gated integrator output waveforms.

4.2. FRONT PANEL CONTROLS

FINE GAIN Ten-turn precision potentiometer for continuously variable direct-reading gain factor of X0.5 to X1.5.

COARSE GAIN Six-position switch selects feedback resistors for gain factors of 20, 50, 100, 200, 500, and 1k.

INPUT ATTENUATOR Jumper on printed wiring board selects an input attenuation factor of 1 or 10 (gain factor of X1 or X0.1).

POS/NEG Toggle switch selects Pos or Neg input.

SHAPING TIME Two six-position switches select time constant for active-filter-network pulse shaping; selections are 0.25, 0.5, 1, 2, 3, and 6. Switch settings should be set equally for normal operation.

PZ Two potentiometers to adjust pole-zero cancellation for decay times from 40 µs to ∞. Fine PZ corresponds to approximately 10% of coarse PZ.

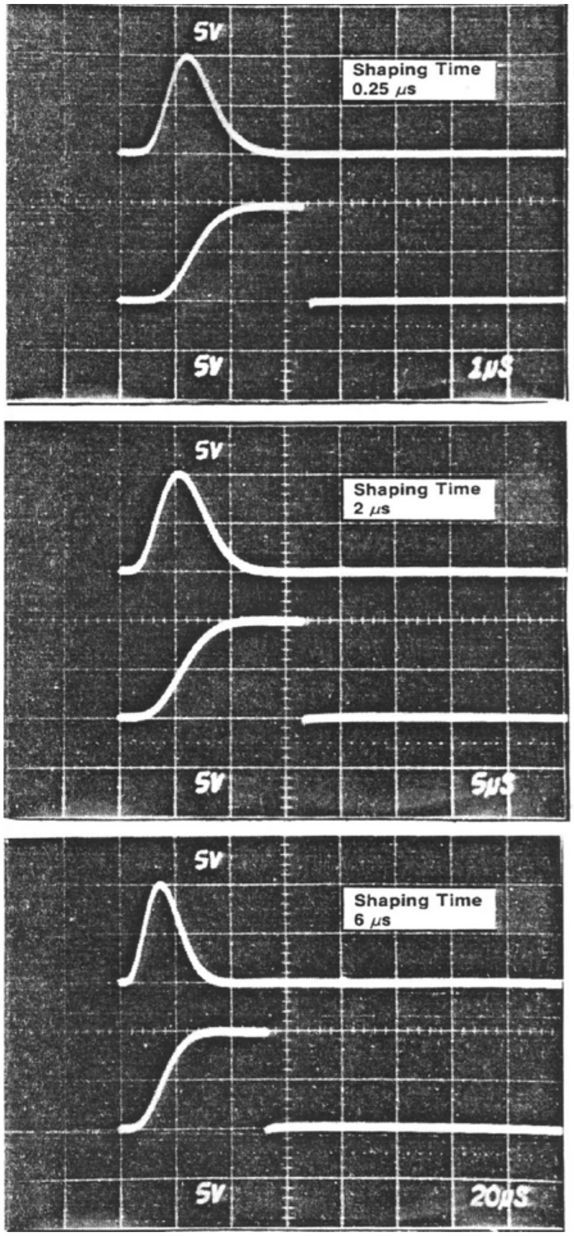


Fig. 11. Typical Effects of Shaping-Time Selection on Output Waveforms

BLR Toggle switch selects a source for the gated baseline restorer discriminator threshold level from one of three positions:

Auto The BLR threshold is automatically set to an optimum level as a function of the signal noise level by an internal circuit. This allows easy setup and very good performance.

PZ Adj The BLR threshold is determined by the threshold potentiometer. The BLR time constant is greatly increased to facilitate PZ adjustment. This position may give the best energy resolution for conditions of low- to medium-count rate and/or long shaping times.

Threshold The BLR threshold is set manually by the threshold potentiometer. Range, 0 to 300 mV referred to the positive output signal. The BLR time constant is the same as for the Auto switch setting.

DC Screwdriver potentiometer adjusts the unipolar output baseline dc level; range, +100 mV to -100mV.

4.3. INPUTS

LINEAR Positive or negative signal through either front panel or rear panel BNC connectors. Accepts pulses with rise times in the range from 10 to 650 ns and decay times from 40 to 2000 µs; $Z_{in} \cong 1$ kΩ, dc-coupled; linear maximum 1 V (10 V with attenuator jumper set at X0.1); absolute maximum 20 V.

GATE Rear panel BNC connector accepts standard positive NIM signal to inhibit pileup rejector circuit during reset interval of a pulse reset preamplifier.

4.4. OUTPUTS

UNIPOLAR Front panel BNC with $Z_o < 1\Omega$ and rear panel BNC with $Z_o = 93\Omega$. Short-circuit proof; prompt full scale linear range 0 to +10 V; active-filter-shaped and dc-restored; dc level adjustable to ±100 mV.

GI Front panel BNC with $Z_o < 1\Omega$ and rear panel BNC with $Z_0 = 93\Omega$. Short-circuit proof; full scale range 0 to +10 V; dc level ± 5 mV.

BUSY Rear panel BNC with $Z_0 < 10\Omega$ provides a +5 V logic pulse for the duration that the input pulse exceeds the baseline restorer discriminator level. Connect to the ORTEC MCA Busy Input for dead time correction.

UNI INH Rear panel BNC with $Z_0 < 10\Omega$ provides a nominal +5 V logic signal when an internal pulse pileup occurs; to be used for an MCA anticoincidence input to prevent storage of pileup data in the spectrum when using the unipolar output.

GI INH Rear panel BNC with $Z_0 < 10\Omega$ provides a nominal +5 V logic signal when an internal pulse pileup occurs; to be used for an MCA anticoincidence input to prevent storage of pileup data in the spectrum when using the GI output.

CRM (Count Ratemeter) Rear panel BNC furnishes a nominal +5 V logic signal for every linear input pulse; width 300 ns; to be used as an input to a ratemeter or counter.

PREAMP POWER Rear panel standard ORTEC power connector, Amphenol 17-10090; mates with captive and noncaptive power cords on all standard ORTEC preamplifiers.

4.5. STANDARD SETUP PROCEDURE

a. Connect the detector, preamplifier, high voltage power supply, and amplifier into a basic system and connect the amplifier unipolar output to an oscilloscope. Connect the preamplifier power cable to the Preamp power connector on the rear panel of the 673. Turn on power in the bin and power supply and allow the electronics of the system to warm up and stabilize.

b. Set the 673 controls initially as follows:

Shaping	2 µs
Coarse Gain	50
Fine Gain	1.000
Internal Jumper	X1.0
BLR	PZ Adj
Thresh	Fully clockwise
Pos/Neg	Match preamplifier output polarity

c. Use a ^{60}Co calibration source, set about 25 cm from the active face of the detector. The unipolar output pulse from the 673 should be about 8 to 10 V, using a preamplifier with a conversion gain of 170 mV/MeV.

d. Readjust the Gain control so that the higher peak from the ^{60}Co source (1.33 MeV) provides an amplifier output at about 9 V.

4.6. POLE-ZERO ADJUSTMENT FOR RESISTIVE-FEEDBACK PREAMPLIFIER

The pole-zero adjustment is extremely critical for good performance at high count rates. This adjustment should be checked carefully for the best possible results. When using a transistor reset-type preamplifier, the Coarse PZ Adj should be set to full counterclockwise.

USING HPGe SYSTEM AND ^{60}Co

a. Adjust the radiation source count rate between 2 kHz and 10 kHz.

b. Observe the unipolar output with an oscilloscope. Adjust the PZ Adj. Control so that the trailing edge of the pulses returns to the baseline without overshoot or undershoot (Fig. 12).

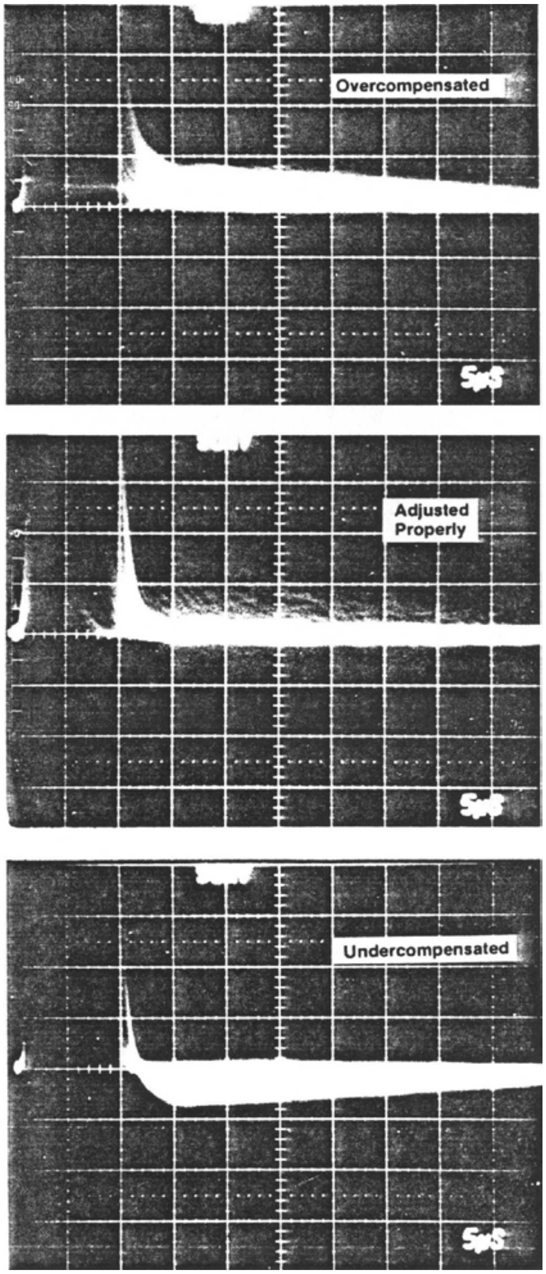


Fig. 12. Typical Waveforms Illustrating Pole-Zero Adjustment Effects; Oscilloscope Trigger, 673 Busy Output, ^{60}Co Source with 1.33-MeV Peak Adjusted ~9 V; Count Rate, 3 kHz; Shaping Time Constant, 2 µs.

The oscilloscope used must be dc-coupled and must not contribute distortion in the observed waveforms. Oscilloscopes such as Tektronix 453, 454, 465, and 475 will overload for a 10 V signal when the vertical sensitivity is <100 mV/cm. To prevent overloading the oscilloscope, use the clamp circuit shown in Fig. 13.

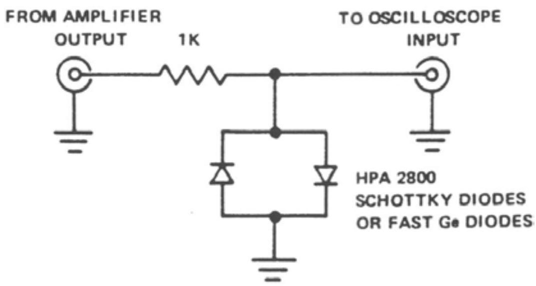


Fig. 13. A Clamp Circuit that Can Be Used to Prevent Overloading the Oscilloscope Input.

USING SQUARE WAVE THROUGH PREAMPLIFIER TEST INPUT

A more precise pole-zero adjustment in the 673 can be obtained by using a square wave signal as the input to the preamplifier. Many oscilloscopes include a calibration output on the front panel and this is a good source of square wave signals at a frequency of about 1 kHz. The amplifier differentiates the signal from the preamplifier so that it generates output signals of alternate polarities on the leading and trailing edges of the square wave input signal, and these can be compared as shown in Fig. 14 to achieve excellent pole-zero cancellation.

Use the following procedure:

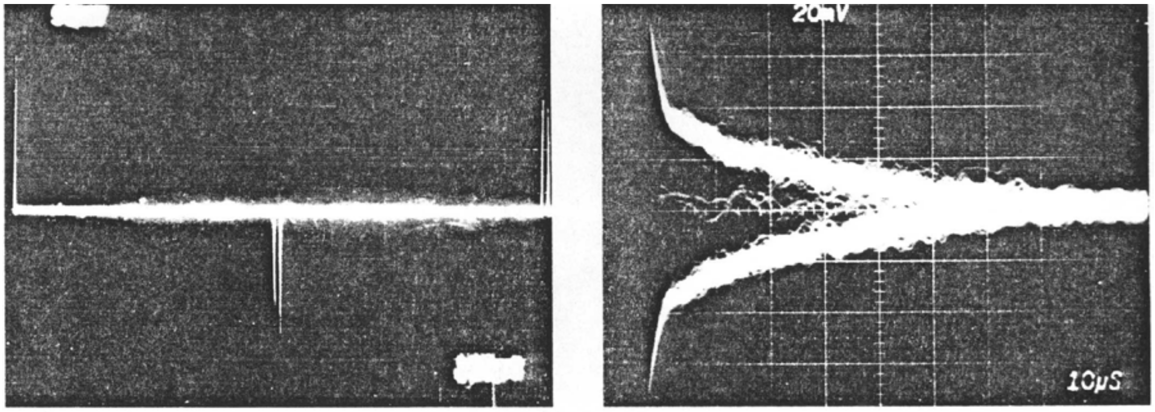
a. Remove all radioactive sources from the vicinity of the detector. Set up the system as for normal operation, including detector bias.

b. Set the 673 controls as for normal operation; this includes gain, shaping, and input polarity.

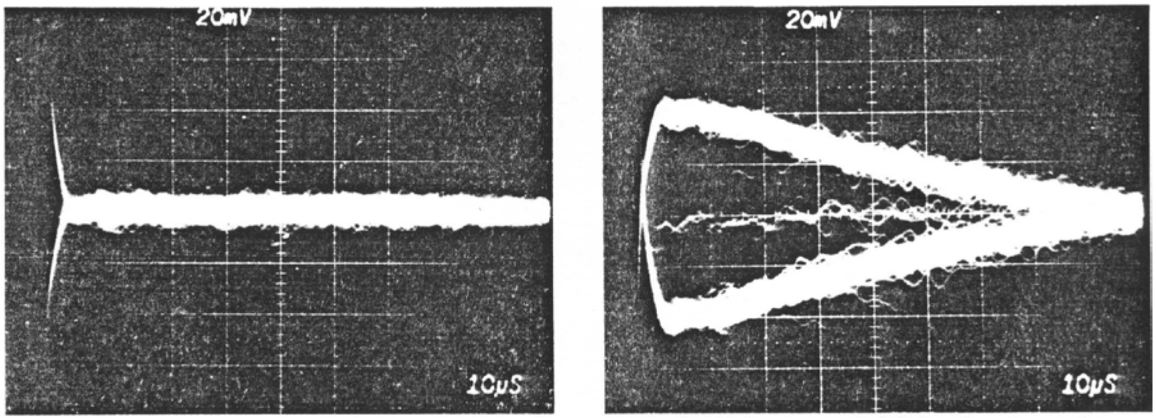
c. Connect the source of 1 kHz square waves through an attenuator to the Test input of the preamplifier. Adjust the attenuator so that the 673 output amplitude is about 9 V.

d. Observe the unipolar output of the 673 with an oscilloscope triggered from the 673 Busy output. Adjust the PZ Adj control for proper response according to Fig. 14. Use the clamp circuit of Fig. 13 to prevent overloading the oscilloscope input.

Figure 14A shows the amplifier output as a series of alternate positive and negative gaussian pulses. In B, C, and D, of this figure the oscilloscope was triggered to show both positive and negative pulses



A. PZ Properly Adjusted; Slow Trigger to Separate Pulses.
B. Overcompensated; Fast Trigger to Superimpose Pulses.



C. Properly Adjusted; Pulses Superimposed.
D. Undercompensated; Pulses Superimposed.

Fig. 14. Pole-Zero Adjustment Using a Square Wave Input to the Preamplifier.

simultaneously. These pictures show more detail to aid in proper adjustment.

4.7. BLR THRESHOLD ADJUSTMENT

After the amplifier gain and shaping have been selected and the PZ Adj control has been set to operate properly for the particular shaping time, the BLR Thresh control can be used to establish the correct discriminator threshold for the baseline restorer circuit. Normally, the toggle switch can be set at Auto and the threshold level will be set automatically just above the noise level. If desired, the switch can be set at Thresh and the manual control just below the switch can then be used to select the level manually as follows:

a. Remove all radioactive sources from the vicinity of the detector. Set up the system as for normal operation, including detector bias.

b. Set the BLR switch at PZ Adj or Thresh and turn the control fully clockwise for 300 mV.

c.1. LED Method: Adjust the front panel threshold trimpot so that the LED (red light emitting diode) is on about half the time.

c.2. Scope Method: Observe the unipolar output on the 100 mV/cm scale of the oscilloscope using 5 µs/cm horizontal deflection. Trigger the oscilloscope with the Busy output from the 673.

d. Reduce the control setting until the baseline discriminator begins to trigger on noise; this corresponds to about 200 counts/s from the Busy output. Adjust the trigger level according to the information in Fig. 15.

If a ratemeter or counter-timer is available, it can be connected to the Busy output and the threshold level can then be adjusted for about 200 counts/s.

4.8. GATED INTEGRATOR SET UP

a. Set both pulse shaping switches to the same time constant.

b. Adjust the Unipolar output PZ and BLR threshold as described in Sections 4.6 and 4.7.

c. Measure the Unipolar dc-output voltage with the input removed. Adjust to 0 ± 1 mV using the front panel control.

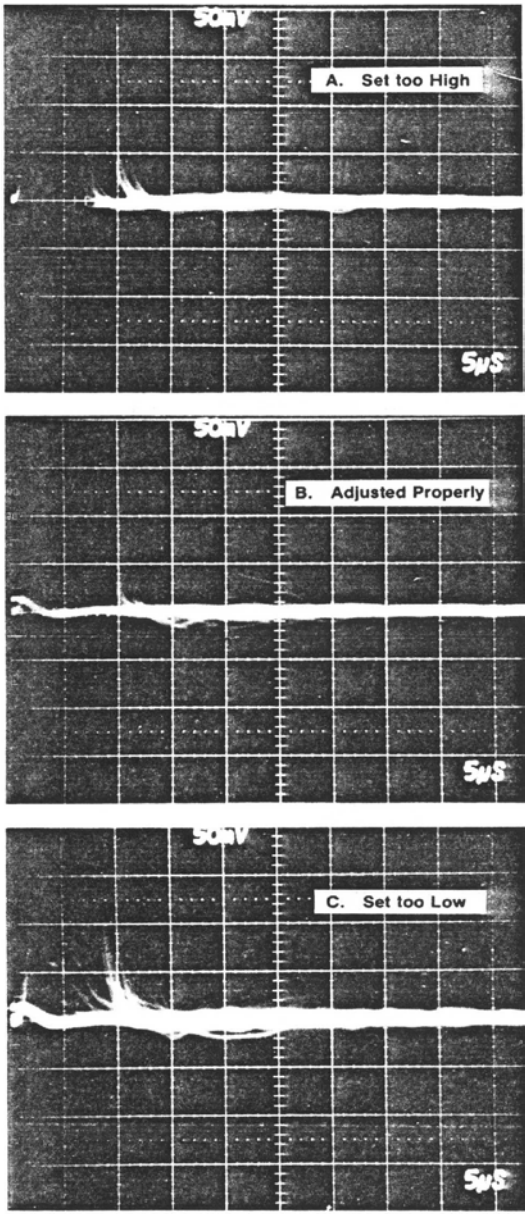


Fig. 15. BLR Threshold Variable Control Settings.

d. Connect the GI output to the ADC and then make the final gain adjustment. The best resolution should be obtained with the BLR switch in the PZ position. The pole-zero adjustment is especially critical at high rates (>50 k counts/s input) when using a resistive-feedback preamplifier. The preamp pole-zero needs to be checked and fine-tuned if necessary.

e. Test resolution again with the BLR control in the Auto and/or Thresh position. These are the “high” restore positions. Improved resolution compared to PZ usually indicates interferences picked up in the detector, preamp, bias supply, or amplifier system. Possible causes are ground loops, pick-up from power lines and radio stations, and microphones.

4.9. OPERATION WITH SEMICONDUCTOR DETECTORS

CALIBRATION OF TEST PULSER An ORTEC 419 Precision Pulse Generator, or equivalent, is easily calibrated so that the maximum pulse height dial reading (1000 divisions) is equivalent to a 10 MeV loss in a silicon radiation detector. The procedure is as follows:

a. Connect the detector to be used to the spectrometer system, that is, preamplifier, main amplifier, and biased amplifier.

b. Allow excitation from a source of known energy (for example, alpha particles) to fall on the detector.

c. Adjust the amplifier gain and the bias level of the biased amplifier to give a suitable output pulse.

d. Set the pulser Pulse Height control at the energy of the alpha particles striking the detector (e.g., set the dial at 547 divisions for a 5.47 MeV alpha particle energy).

e. Turn on the pulser and use its Normalize control and attenuators to set the output due to the pulser for the same pulse height as the pulse obtained in step c. Lock the Normalize control and do not move it again until recalibration is required.

The pulser is now calibrated; the Pulse Height dial reads directly in MeV if the number of dial divisions is divided by 100.

AMPLIFIER NOISE AND RESOLUTION MEASUREMENTS As shown in Fig. 16, a preamplifier, amplifier, pulse generator, oscilloscope, and wide-band rms voltmeter such as the Hewlett-Packard 3400A are required for this measurement. Connect a suitable capacitor to the input to simulate the detector capacitance desired. To obtain the resolution spread due to amplifier noise:

a. Measure the rms noise voltage (E_{rms}) at the amplifier output.

b. Turn on the 419 precision pulse generator and adjust the pulser output to any convenient readable voltage, E_0, as determined by the oscilloscope.

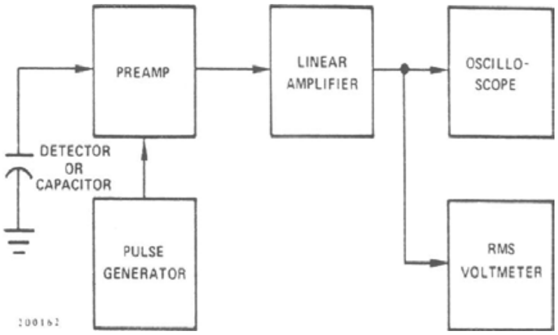


Fig. 16. System for Measuring Amplifier and Detector Noise Resolution.

The full-width-at-half-maximum (FWHM) resolution spread due to amplifier noise is then

$$N(FWHM) = \frac{2.35\ E_{rms}\ E_{dial}}{E_O},$$

where E_{dial} is the pulser dial reading in MeV and 2.35 is factor for rms to FWHM. For average-responding voltmeters such as the Hewlett-Packard 400D, the measured noise must be multiplied by 1.13 to calculate the rms noise.

The resolution spread will depend on the total input capacitance, since the capacitance degrades the signal-to-noise ratio much faster than the noise.

DETECTOR NOISE-REDUCTION MEASUREMENTS
The measurement just described can be made with a biased detector instead of the external capacitor that would be used to simulate detector capacitance. The resolution spread will be larger because the detector contributes both noise and capacitance to the input. The detector noise-resolution spread can be isolated from the amplifier noise spread if the detector capacity is known, since

$$(N_{\mathrm{det}})^2 + (N_{amp})^2 = (N_{total})^2,$$

where N_{total} is the total resolution spread and N_{amp} is the amplifier resolution spread when the detector is replaced by its equivalent capacitance.

The detector noise tends to increase with bias voltage, but the detector capacitance decreases, thus reducing the resolution spread. The overall resolution spread will depend upon which effect is dominant. Figure 17 shows curves of typical noise-resolution spread versus bias voltage, using data from several ORTEC silicon surface-barrier semiconductor radiation detectors.

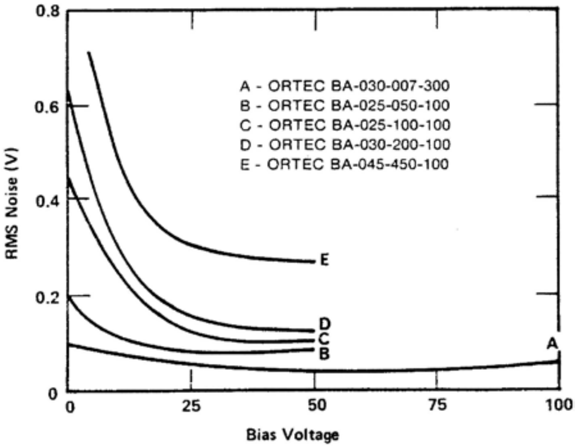


Fig. 17. Noise as a Function of Bias Voltage.

AMPLIFIER NOISE-RESOLUTION MEASUREMENTS USING MCA

Probably the most convenient method of making resolution measurements is with a pulse height analyzer as shown by the setup illustrated in Fig. 18.

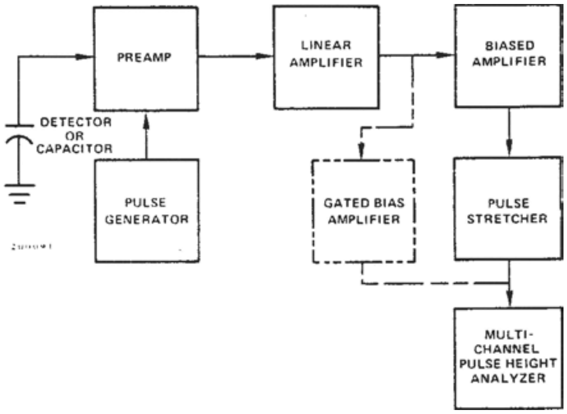


Fig. 18. System for Measuring Resolution with a Pulse Height Analyzer.

The amplifier noise-resolution spread can be measured directly with a pulse height analyzer and the mercury pulser as follows:

a. Select the energy of interest with an ORTEC 419 Precision Pulse Generator. Set the amplifier and biased amplifier gain and bias level controls so that the energy is in a convenient channel of the analyzer.

b. Calibrate the analyzer in keV per channel, using the pulser, full scale on the pulser dial is 10 MeV when calibrated as described above.

c. Obtain the amplifier noise-resolution spread by measuring the FWHM of the pulser peak in the spectrum.

The detector noise-resolution spread for a given detector bias can be determined in the same manner by connecting a detector to the preamplifier input. The amplifier noise-resolution spread must be subtracted as described in “Detector Noise-Resolution Measurements.” The detector noise will vary with detector size and bias conditions and possibly with ambient conditions.

CURRENT-VOLTAGE MEASUREMENTS FOR Si and Ge DETECTORS The amplifier system is not directly involved in semiconductor detector current-voltage measurements, but the amplifier serves to permit noise monitoring during the setup. The detector noise measurement is a more sensitive method of determining the maximum detector voltage than a current measurement and should be used because the noise increases more rapidly than the reverse current at the onset of detector breakdown. Make this measurement in the absence of a source. Figure 19 shows the setup required for current-voltage measurements. An ORTEC 428 Bias Supply is used as the voltage source. Bias voltage should be applied slowly and reduced when noise increases rapidly as a function of applied bias. Figure 20 shows several typical current-voltage curves for ORTEC silicon surface-barrier detectors.

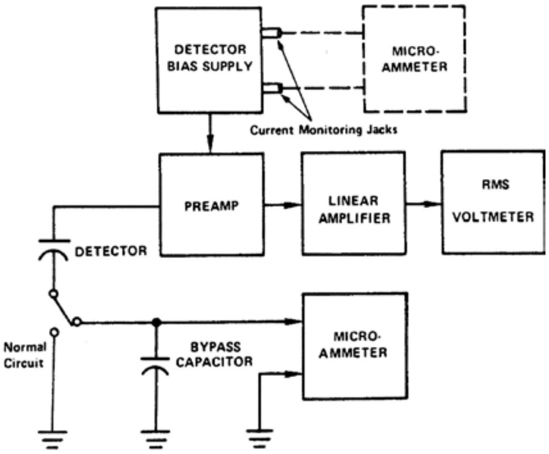


Fig. 19. System for Detector Current and Voltage Measurements.

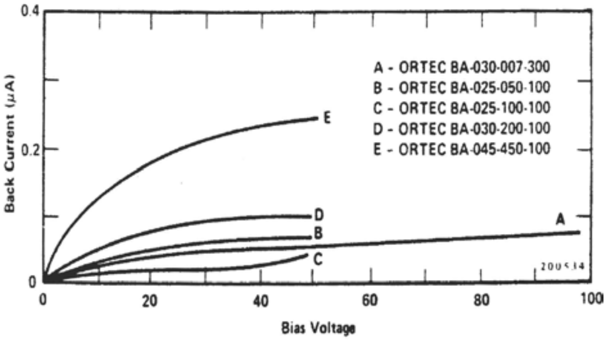


Fig. 20. Silicon Detector Back Current vs Bias Voltage.

When it is possible to float the microammeter at the detector bias voltage, the method of detector current measurement shown by the dashed lines in Fig. 19 is preferable. The detector is grounded as in normal operation and the microammeter is connected to the current monitoring jack on the 428 detector bias supply.

4.10. OPERATION IN SPECTROSCOPY SYSTEMS

HIGH-RESOLUTION ALPHA-PARTICLE SPECTROSCOPY SYSTEM The block diagram of a high-resolution spectroscopy system for measuring natural alpha particle radiation is shown in Fig. 21. Since natural alpha radiation occurs only above several MeV, an ORTEC 444 Biased Amplifier is used to suppress the unused portion of the spectrum; the same result can be obtained by using digital suppression on the MCA in many cases. Alpha-particle resolution is obtained in the following manner:

a. Use appropriate amplifier gain and minimum biased amplifier gain and bias level. Accumulate the alpha peak in the MCA.

b. Slowly increase the bias level and biased amplifier gain until the alpha peak is spread over 5 to 10 channels and the minimum- to maximum-energy range desired corresponds to the first and last channels of the MCA.

c. Calibrate the analyzer in keV per channel using the pulser and the known energy of the alpha peak (see “Calibration of Test Pulser”) or two known energy alpha peaks.

d. Calculate the resolution by measuring the number of channels at the FWHM level in the peak and converting this to keV.

HIGH-RESOLUTION GAMMA SPECTROSCOPY SYSTEM A high-resolution gamma spectroscopy system block diagram is shown in Fig. 22. Although a biased amplifier is not shown (an analyzer with more channels being preferred), it can be used if the only analyzer available has fewer channels has fewer channels and only higher energies are of interest.

When germanium detectors that are cooled by a liquid nitrogen cryostat are used, it is possible to obtain resolution from about 1 keV FWHM up (depending on the energy of the incident radiation and the size and quality of the detector). Reasonable care is required to obtain such results. Some guidelines for obtaining optimum resolution are:

a. Keep interconnection capacities between the detector and preamplifier to an absolute minimum (no long cables).

b. Keep humidity low near the detector-preamplifier junction.

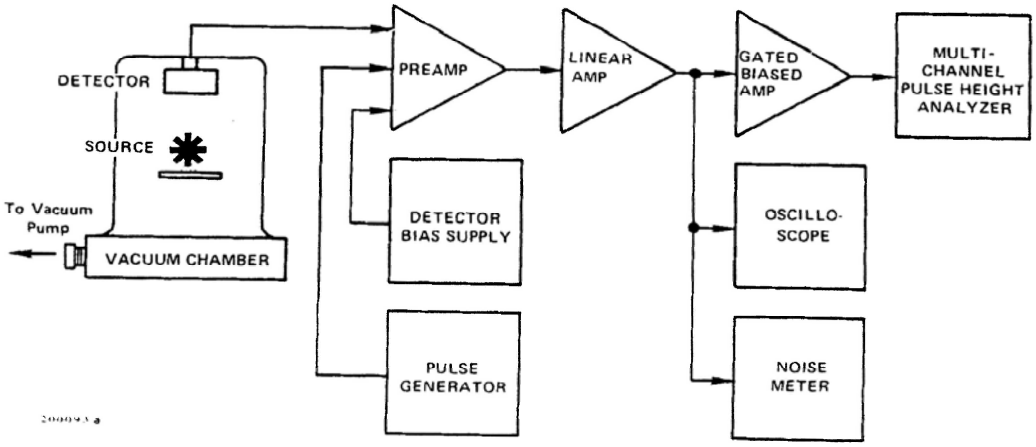


Fig. 21. System for High-Resolution Alpha-Particle Spectroscopy.

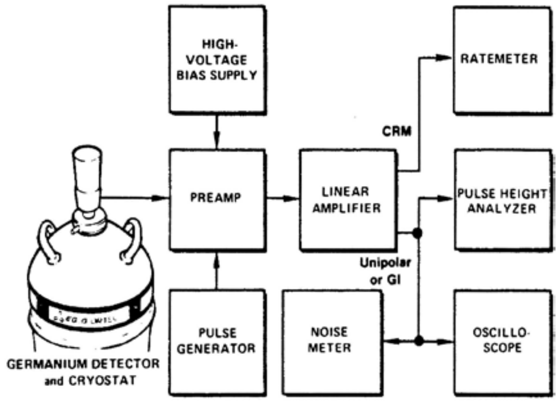


Fig. 22. System for High-Resolution Gamma Spectroscopy.

c. Operate the amplifier with the shaping time that provides the best signal-to-noise ratio.

d. Operate at the highest allowable detector bias to keep the input capacity low.

SCINTILLATION-COUNTER GAMMA SPECTROSCOPY SYSTEMS The ORTEC 673 can be used in scintillation-counter spectroscopy systems as shown in Fig. 23. The amplifier shaping time constants should be selected in the region of 0.5 to 1 µs for NaI or plastic scintillators. For scintillators having longer decay times, longer time constants should be selected.

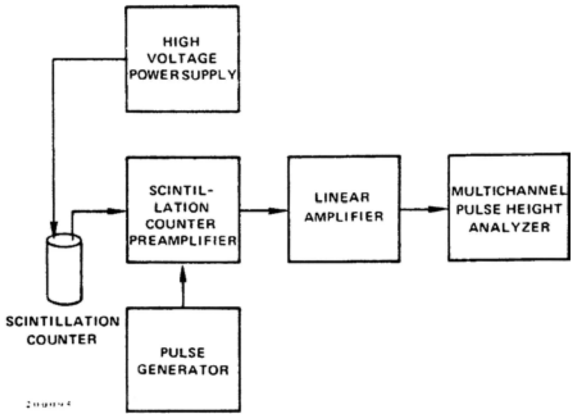


Fig. 23. Scintillation-Counter Gamma Spectroscopy System.

X-RAY SPECTROSCOPY USING PROPORTIONAL COUNTERS Space charge effects in proportional counters, operated at high gas amplification, tend to degrade the resolution capabilities drastically at x-ray energies, even at relatively low counting rates. By using a high-gain low-noise amplifying system and lower gas amplification, these effects can be reduced and a considerable improvement in resolution can be obtained. The block diagram in Fig. 24 shows a system of this type. Analysis can be accomplished by simultaneous acquisition of all data on a multichannel analyzer or counting a region of interest in a single-channel analyzer window with a counter and timer or counting ratemeter.

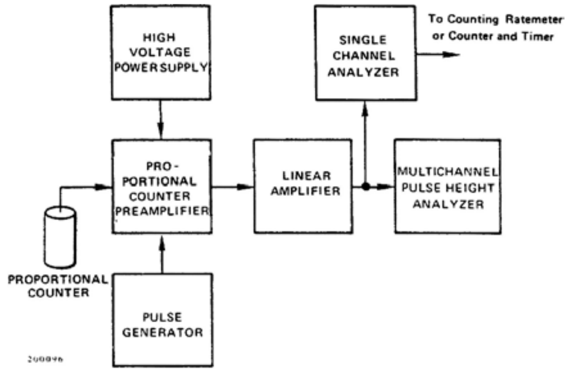


Fig. 24. High-Resolution X-Ray Energy Analysis System using a Proportional Counter.

4.11. OTHER EXPERIMENTS

Block diagrams illustrating how the 673 and other ORTEC modules can be used for experimental setups for various other applications are shown in Figs. 25 through 28.

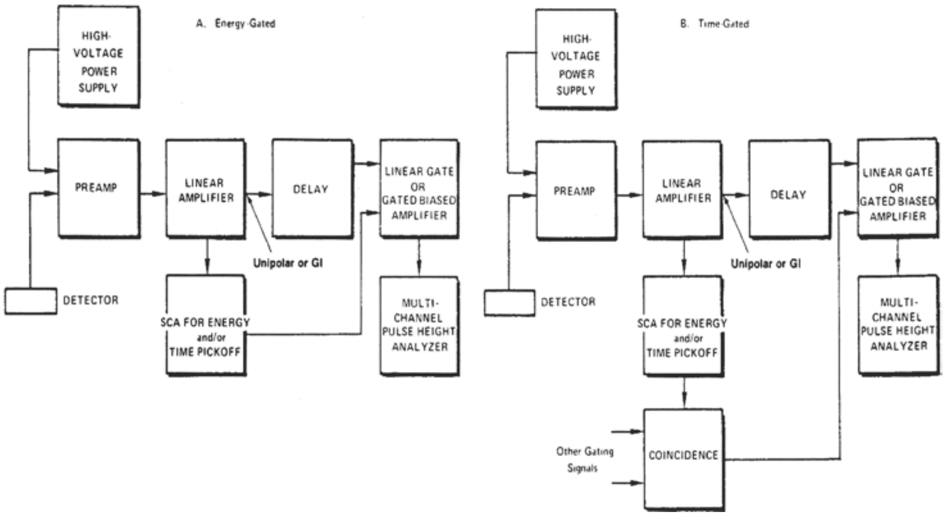


Fig. 25. General System Arrangement for Gating Control.

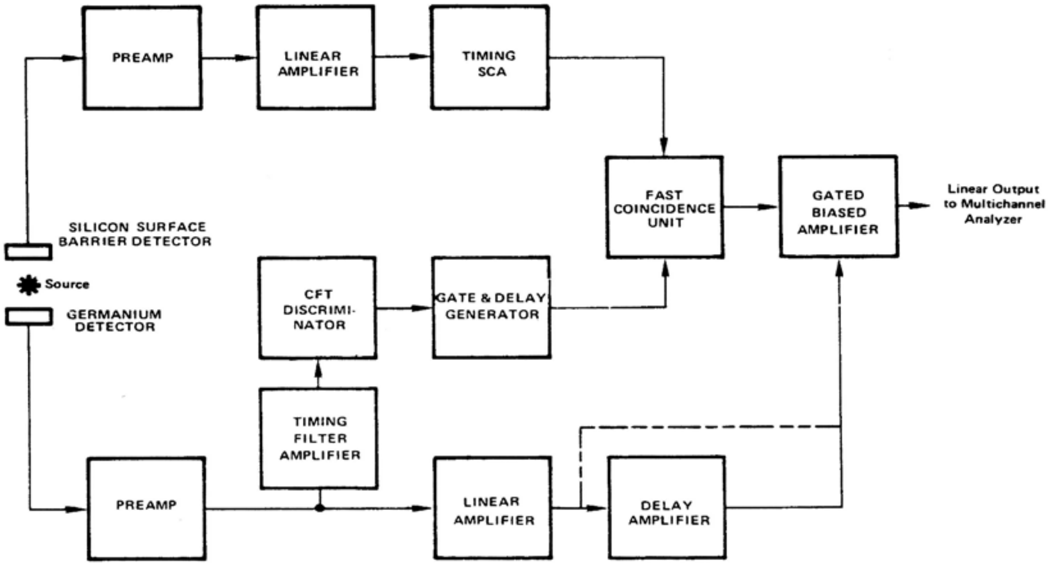


Fig. 26. Gamma-Ray Charged-Particle Coincidence Experiment.

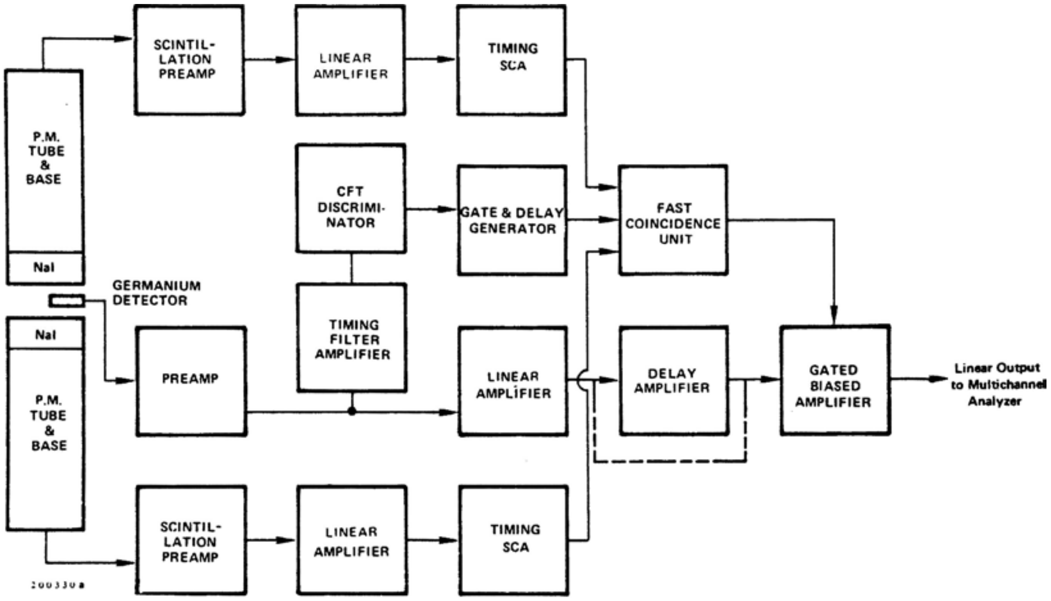


Fig. 27. Gamma-Ray Pair Spectroscopy.

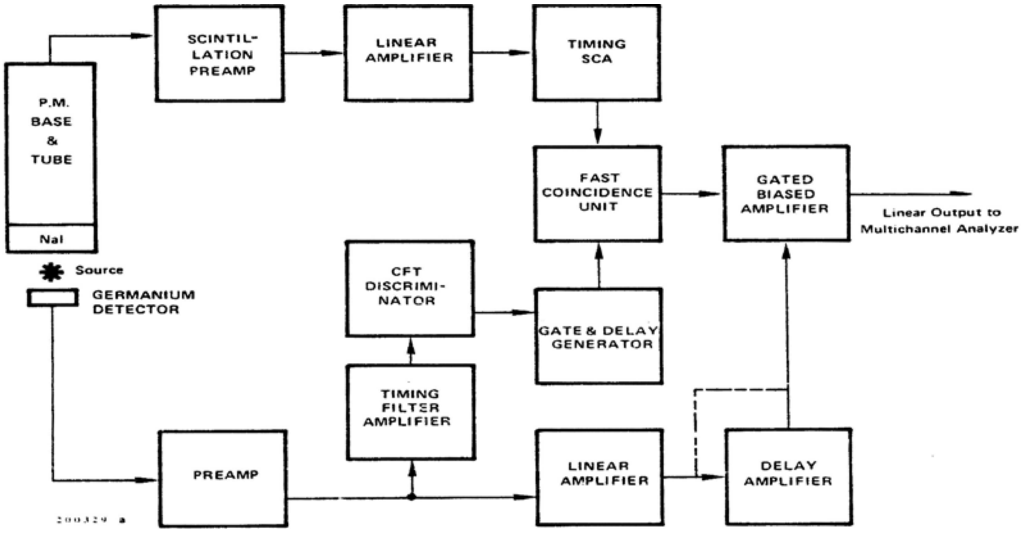


Fig. 28. Gamma-Gamma Coincidence Experiment.

5. MAINTENANCE

5.1. TEST EQUIPMENT REQUIRED

The following test equipment should be utilized to adequately test the specifications of the 673 Spectroscopy Amplifier and Gated Integrator.

1. ORTEC 419 Precision Pulse Generator or 448 Research Pulser.

2. Tektronix 465, 475, or 485 Series Oscilloscope or equivalent.

3. Hewlett-Packard 3400A RMS Voltmeter.

5.2. PULSER TEST*

Coarse Gain	1k
Fine Gain	1.5
Input Polarity	Positive
Shaping Time Constant	1 µs
BLR	PZ Adj
Variable control	Fully CW for 400 mV

a. Connect a positive pulser output to the 673 Input and adjust the pulser to obtain +10 V at the 673 Unipolar output. This should require an input pulse of 6.6 mV using a 100Ω terminator at the input.

b. Measure the GI Output. This should also be +10 V.

c. Change the Input polarity switch to Neg and then back to Pos while monitoring the outputs for a polarity inversion.

d. Vary the DC Adj control on the front panel while monitoring the Unipolar output. Ensure that the baseline can be adjusted through a range of +100 mV to -100 mV. Readjust the control for zero.

e. Recheck the output pulse amplitude and adjust if necessary to set it at +10 V with maximum gain. Decrease the Coarse Gain switch stepwise from 1k to 20 and ensure that the output amplitude changes by the appropriate amount for each step. Return the Coarse Gain switch to 1k.

f. Decrease the Fine Gain control from 1.5 to 0.5 and check to see that the output amplitude decreases by a factor of 3. Return the Fine Gain control to maximum at 1.5.

g. With the Shaping Time switch set for 1 µs, measure the time to the peak on the unipolar output pulse; this should be 2.2 µs for 2.2τ.

h. Change the Shaping Time switch to 0.25 through 6 µs. At each setting, check to see that the time to the unipolar peak is 2.2τ and the width of the GI pulse is approximately 8τ. Return the switch to 1 µs.

OVERLOAD TESTS Start with maximum gain, τ= 2 µs, and a +10 V output amplitude. Increase the pulser output amplitude by X200 and observe that the unipolar output returns to within 200 mV of the baseline within 24 µs after the application of a single pulse from the pulser. It will probably be necessary to vary the PZ Adj control on the front panel in order to cancel the pulser pole and minimize the time required for return to the baseline.

LINEARITY The integral nonlinearity of the 673 can be measured by the technique shown in Fig. 29. In effect, the negative pulser output is subtracted from the positive amplifier output to cause a null point that can be measured with excellent sensitivity. The pulser output must be varied between 0 and 10 V, which usually requires an external control source for the pulser. The amplifier gain and the pulser attenuator must be adjusted to measure 0 V at the null point when the pulse output is 10 V. The variation in the null point as the pulser is reduced gradually from 10 V to 0 V is a measure of the nonlinearity. Since the subtraction network also acts as a voltage divider, this variation must be less than

(10 V full scale) x (±0.05% maximum nonlinearity)

x (1/2 for divider network) = ±2.5 V

for maximum null-point variation.

OUTPUT LOADING Use the test setup of Fig. 29. Adjust the amplifier output to 10 V and observe the null point when the front panel output is terminated in 100Ω. The change should be <5 mV.

NOISE Measure the noise at the amplifier Unipolar output with maximum amplifier gain and 2 µs shaping time. Using a true rms voltmeter, the noise should be less than 5 µV x 1500 (gain), or 7.5 mV.

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*See IEEE Standards, No. 301-1976

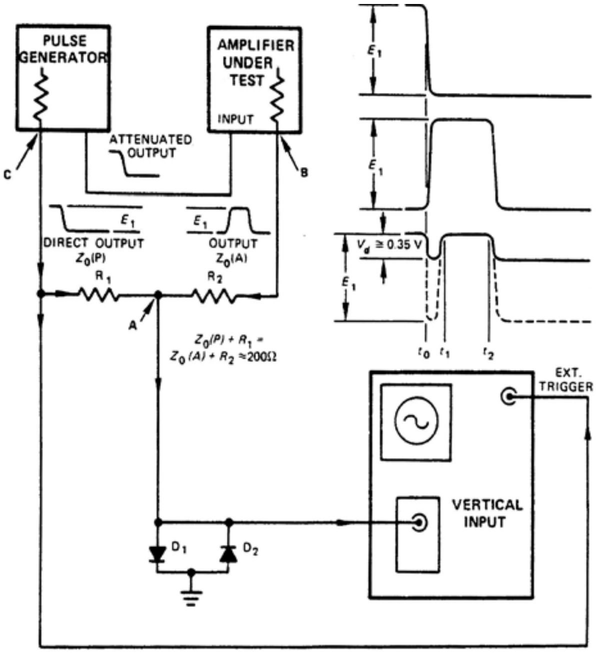

Fig. 29. Circuit Used to Measure Nonlinearity.

For an average responding voltmeter, the noise reading would have to be multiplied by 1.13 to calculate the rms noise. The input must be terminated in 100Ω during the noise measurements.

5.3. SUGGESTIONS FOR TROUBLESHOOTING

In situations where the 673 is suspected of a malfunction, it is essential to verify such malfunction in terms of simple pulse generator impulses at the input. The 673 must be disconnected from is position in any system and routine diagnostic analysis performed with a test pulse generator and an oscilloscope. It is imperative that testing not be performed with a source and detector until the amplifier performs satisfactorily with the test pulse generator.

The testing instructions in Section 5.2 should provide assistance in locating the region of trouble and repairing the malfunction. The two side plates can be completely removed from the module to enable oscilloscope and voltmeter observations.

5.4. FACTORY REPAIR

This instrument can be returned to the ORTEC factory for service and repair at a nominal cost. Our standard procedure for repair ensures the same quality control and checkout that are used for a new instrument. Always call Customer Services at ORTEC, (865) 483-2231, before sending in an instrument for repair to obtain shipping instructions and so that the required Return Authorization Number can be assigned to the unit. This number should be marked on the address label and on the package to ensure prompt attention when the unit reaches the factory.

5.5. TABULATED TEST POINT VOLTAGES

The voltages given in Table 1 are intended to indicate typical dc levels that can be measured on the PWB. In some cases the circuit will perform satisfactorily even though, due to component tolerances, there may be some voltage measurements that differ slightly from the listed values. Therefore the tabulated values should not be interpreted as absolute voltages but are intended to serve as an aid in troubleshooting.

Note: All voltages measured with no input signal, with the input terminated in 100Ω, and all controls set fully clockwise at maximum.

Location	**Voltage**
TP1	± 5 mV
TP2	± 30 mV
TP3	± 20 mV
TP4	± 20 mV
TP5	± 30 mV
TP6	0 to +3.3 V
TP7	± 6 mV
Q15E	-15 V to ±0.8 V
Q16E	+15 V±0.8 V
U13 pin 2	+5 V ±0.3 V

Bin/Module Connector Pin Assignments For Standard Nuclear Instrument Modules per DOE/ER-0457T.

Pin	Function	Pin	Function
1	+3 V	23	Reserved
2	−3 V	24	Reserved
3	Spare bus	25	Reserved
4	Reserved bus	26	Spare
5	Coaxial	27	Spare
6	Coaxial	*28	+24 V
7	Coaxial	*29	−24 V
8	200 V dc	30	Spare bus
9	Spare	31	Spare
*10	+6 V	32	Spare
*11	−6 V	*33	117 V ac (hot)
12	Reserved bus	*34	Power return ground
13	Spare	35	Reset (Scaler)
14	Spare	36	Gate
15	Reserved	37	Reset (Auxiliary)
*16	+12 V	38	Coaxial
*17	−12 V	39	Coaxial
18	Spare bus	40	Coaxial
19	Reserved bus	*41	117 V ac (neutral)
20	Spare	*42	High-quality ground
21	Spare	G	Ground guide pin
22	Reserved		

Pins marked (*) are installed and wired in ORTEC's 4001A and 4001C Modular System Bins.