INSTRUCTION MANUAL
451
SPECTROSCOPY AMPLIFIER

Serial No. ______________________

Purchaser ______________________

Date Issued ______________________

ORTEC
INCORPORATED
100 MIDLAND ROAD
OAK RIDGE, TENN. 37830
PHONE (615) 482-4411
TWX 810-572-1078
AN EG&G COMPANY

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A NEW STANDARD TWO-YEAR WARRANTY FOR ORTEC ELECTRONIC INSTRUMENTS

ORTEC warrants its nuclear instrument products to be free from defects in workmanship and materials, other than vacuum tubes and semiconductors, for a period of twenty-four months from date of shipment, provided that the equipment has been used in a proper manner and not subjected to abuse. Repairs or replacement, at ORTEC option, will be made without charge at the ORTEC factory. Shipping expense will be to the account of the customer except in cases of defects discovered upon initial operation. Warranties of vacuum tubes and semiconductors, as made by their manufacturers, will be extended to our customers only to the extent of the manufacturers' liability to ORTEC. Specially selected vacuum tubes or semiconductors cannot be warranted. ORTEC reserves the right to modify the design of its products without incurring responsibility for modification of previously manufactured units. Since installation conditions are beyond our control, ORTEC does not assume any risks or liabilities associated with methods of installation other than specified in the instructions, or installation results.

QUALITY CONTROL

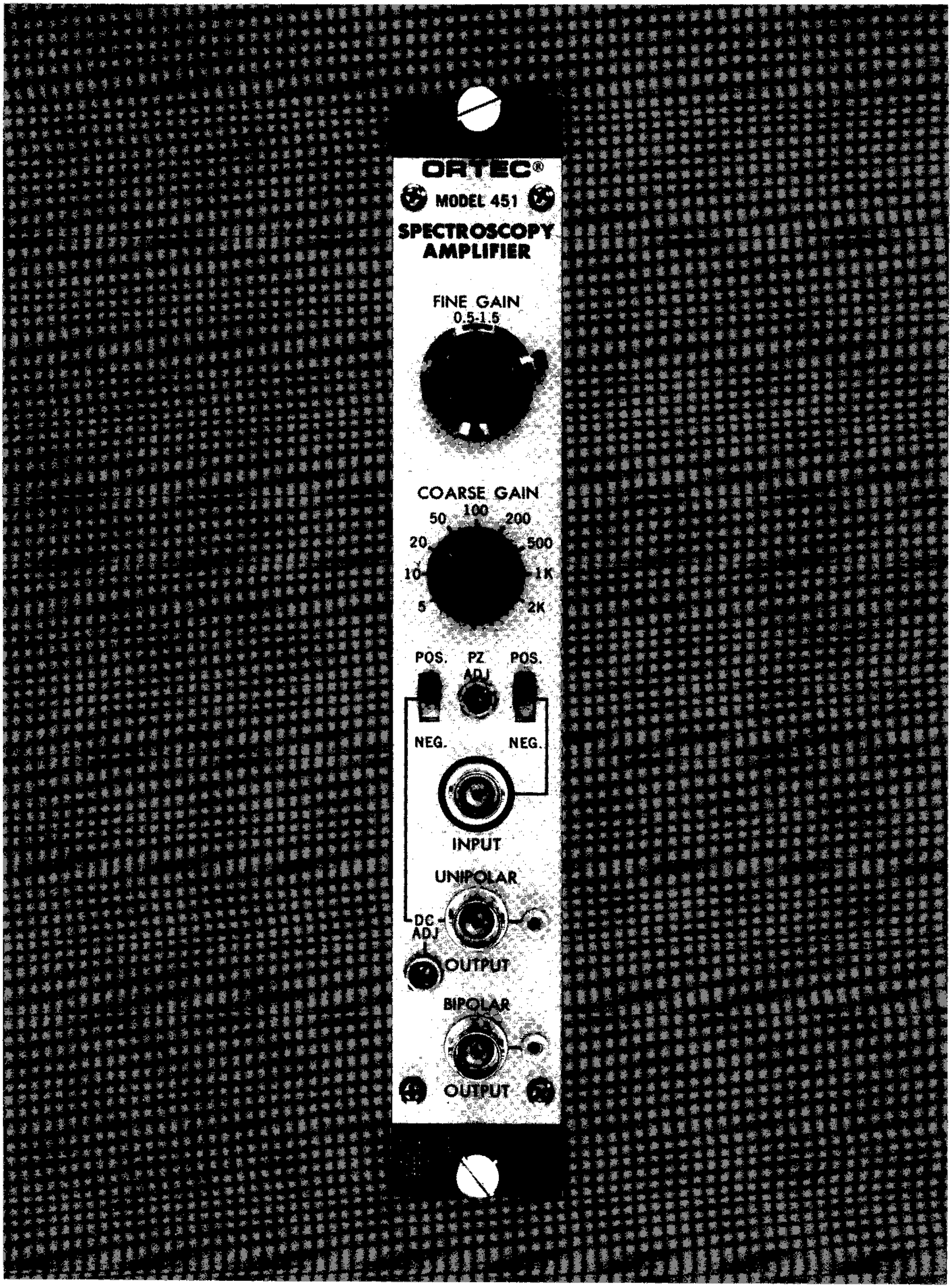
Before being approved for shipment, each ORTEC instrument must pass a stringent set of quality control tests designed to expose any flaws in materials or workmanship. Permanent records of these tests are maintained for use in warranty repair and as a source of statistical information for design improvements.

REPAIR SERVICE

ORTEC instruments not in warranty may be returned to the factory for repairs or checkout at modest expense to the customer. Standard procedure requires that returned instruments pass the same quality control tests as those used for new production instruments. Please contact the factory for instructions before shipping equipment.

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 we may assist in damage claims and in providing replacement equipment if necessary.


ORTEC®
MODEL 451
SPECTROSCOPY
AMPLIFIER
FINE GAIN
0.5-1.5
COARSE GAIN
50
100
200
20
500
10
1K
5
2K
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NEG.
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OUTPUT
BIPOLAR
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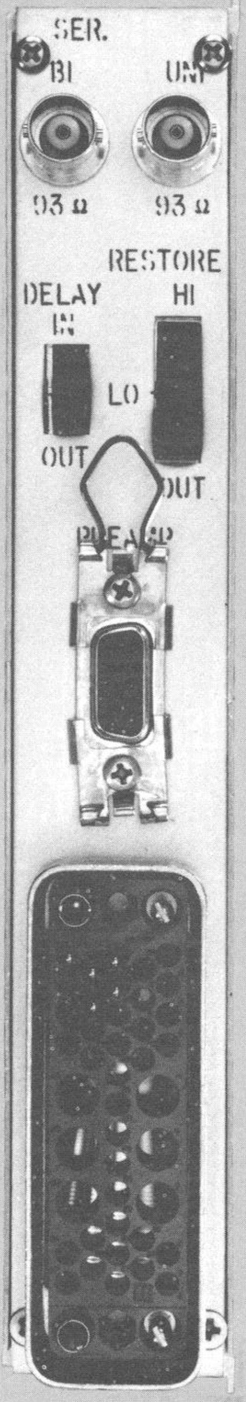
SER.
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ORTEC 451
SPECTROSCOPY AMPLIFIER

1. DESCRIPTION

1.1 General Description

The ORTEC 451 Spectroscopy Amplifier is a single 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 which originate in germanium or silicon semiconductor detectors, scintillation detectors with either fast or slow scintillators, proportional counters, pulsed ionization chambers, electron multipliers, etc.

The 451 has a dc input impedance for approximately 1000 ohms and accepts either positive or negative input pulses with rise times < 650 nsec and fall times > 25μsec. Three integrate and differentiate time constants are separately switch selectable to provide optimum shape for resolution and count rate. The first differentiation network has variable pole-zero cancellation which can be adjusted to match preamplifiers with > 25μsec decay time. The pole-zero cancellation drastically reduces the undershoot after the first clip and greatly improves overload characteristics. In addition, the amplifier contains an active filter shaping network which optimizes the signal to noise ratio and minimizes the overall resolving time. Both unipolar and bipolar 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 451 Amplifier to the analyzer. A BLR (Base Line Restoration) circuit is included in the 451 for improved performance at high count rates. A switch on the rear panel permits this circuit to be switched out, set for low count rates, or set for high count rates. When using the direct coupled input of the various analyzers, a variety of voltage requirements exist. To meet these requirements the 451 unipolar output can be selected for either positive or negative polarity and selected for full scale voltage of 3V, 6V, or 10V. The unipolar output dc level can be adjusted from -1V to +1V. This output permits the use of the direct coupled input of analyzers with a minimum amount of interface problems. The 451 bipolar output may be preferable for spectroscopy when operating into an ac-coupled system at high counting rates.

The 451 can be used for crossover timing when used in conjunction with an ORTEC 407 Crossover Pickoff or a 420A Timing Single Channel Analyzer. The 420A Timing Single Channel Analyzer output has a minimum of walk as a function of pulse amplitude and incorporates a variable delay time on the output pulse to enable the crossover pickoff output to be placed in time coincidence with other outputs. A switch selectable 2μsec delay is provided on the unipolar output to aid in obtaining the proper spacing of the linear pulse in a coincidence gated system.

The 451 has complete provisions including power for operating any ORTEC solid state preamplifier such as the 109A, 113, 118A, and 120. Preamplifier pulses should have a rise time of 0.5μsec or less, to properly match the amplifier filter network and a decay time > 25μsec for proper pole-zero cancellation. The 451 input impedance is 1000 ohms. 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 of the 451 is about 0.1 ohm at the front panel connectors and 93 ohms at the rear panel connectors. The front panel outputs can be connected to other equipment by single cable going to all equipment and shunt terminated at the far end. If series termination is desired, the rear panel connectors can be used in connecting the 451 to other modules (see Section 3).

Gain changing is accomplished by varying feedback networks. These networks are varied in such a manner that the band width of the fedback amplifier stages remain essentially constant regardless to gain and, therefore, rise time changes with gain switching (which cause crossover walk) are limited to small variations.

1.2 Pole-Zero Cancellation

Pole-zero cancellation is a method for eliminating pulse undershoot after the first differentiating network. The technique employed is described by referring to the waveforms and equations shown in Figures 1-1 and 1-2. In a nonpole-zero cancelled amplifier, the exponential tail on the preamplifier output signal (usually 50 to 500μsec) causes an undershoot whose peak amplitude is roughly:

$$\frac{\text{Undershoot Amplitude}}{\text{Differentiated Pulse Amplitude}} = \frac{\text{Differentiation Time}}{\text{Preamplifier Pulse Decay Time}}$$

For a 1μsec differentiation time and a 50μsec preamplifier pulse decay time, the mazimum undershoot is 2% and decays with a 50μsec time constant. Under overload conditions, this undershoot is often sufficiently large to saturate the amplifier during a considerable portion of the undershoot causing excessive deadtime. 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.

Pole-zero cancellation is accomplished by the network shown in Figure 1-2.

The pole $\left(\frac{1}{S + 1/T_0}\right)$ due to the preamplifier pulse decay time is cancelled by the zero $(S + K/R_2C_1)$ of the network. 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 clipping network.

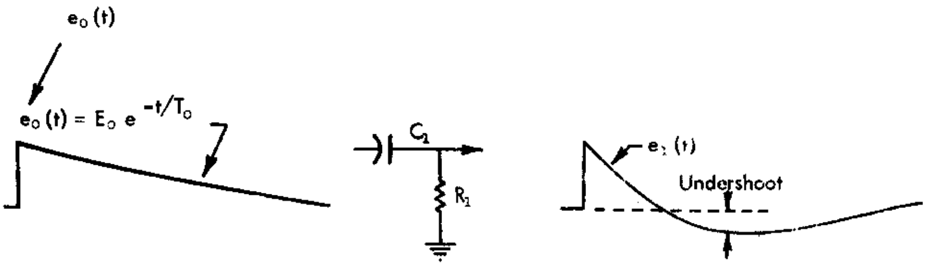
Total preamplifier - amplifier pole-zero cancellation requires that the preamplifier output pulse decay time is a single exponential decay and matched to the pole-zero cancellation network. The variable pole-zero cancellation network allows accurate cancellation for all preamplifiers having 25μsec or greater decay times. The network is factory adjusted to 50μsec which is compatible with all ORTEC FET preamplifiers. Improper matching of the pole-zero cancellation network will degrade the overload performance and cause excessive pile-up 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 and decays to the baseline with the preamplifier time constant). The pole-zero adjust is accessible from the front panel of the 451 and can easily be adjusted by observing the baseline with a monoenergetic source or pulser having the same decay time as the preamplifier under overload conditions.

1.3 Active Filter

When only FET gate current and drain thermal noise are considered, the best signal-to-noise ratio occurs where the two noise contributions are equal for a given pulse shape. The Gaussian pulse shape of this amplifier requires a single RC differentiate and n equal RC integrates where n approaches infinity. The Laplace transform of this transfer function is:

$$G(S) = \frac{S}{(S + 1/RC)} \times \frac{1}{(S + 1/RC)^n} \quad n \rightarrow \infty$$

where the first factor is the single differentiate and the second factor is the n integrates. The 451 Active filter approximates this transfer function.



Preamplifier Output	X	First Amplifier Clipping Network	=	Clipped Pulse with Undershoot

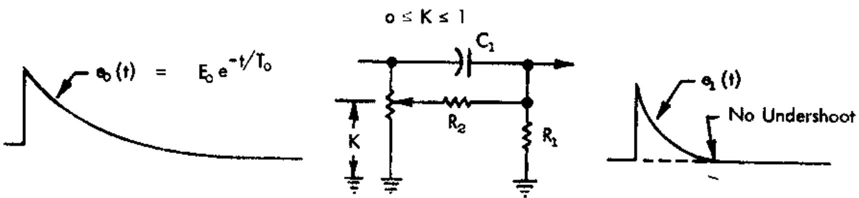
Equations:

$$E_0 e^{-t/T_0} \quad \times \quad G(t) \quad = \quad e_1(t)$$

$$(E_0)\left(\frac{1}{S + 1/T_0}\right) \times \left(\frac{S}{S + 1/R_1 C_1}\right) = e_1(S)\ ; \quad \text{Laplace Transform}$$

$$\frac{E_0}{T_0 - T_1}\left[T_0 e^{-t/T_1} - T_1 e^{-t/T_0}\right] = e_1(t)\ ; \quad T_1 = R_1 C_1$$

Figure 1-1. Clipping in a Non-Pole-Zero Cancelled Amplifier



Preamplifier Output	X	Pole Zero Cancelled Clipping Network	=	Clipped Pulse Without Undershoot

$$E_0 e^{-t/T_0} \quad \times \quad G(t) \quad = \quad e_1(t)$$

$$E_0 \frac{1}{\left(S + \frac{1}{T_0}\right)} \times \frac{S + \frac{K}{R_2 C_1}}{S + \frac{R_1 + R_2}{R_1 R_2 C_1}} = e_1(s)\ ; \ \text{Laplace Transform}$$

Pole Zero cancel by letting $S + \frac{1}{T_0} = S + \frac{K}{R_2 C_1}$ or:

$$\frac{E_0}{S + \frac{R_1 + R_2}{R_1 R_2 C_1}} = \frac{E_0}{S + \frac{1}{R_p C_1}} = e_1(s)\ ; \ \text{where } R_p = \frac{R_1 R_2}{R_1 + R_2}$$

$$E_0 e^{-t/R_p C_1} = e_1(t)$$

Figure 1-2. Differentiation (Clipping) in a Pole-Zero Cancelled Amplifier

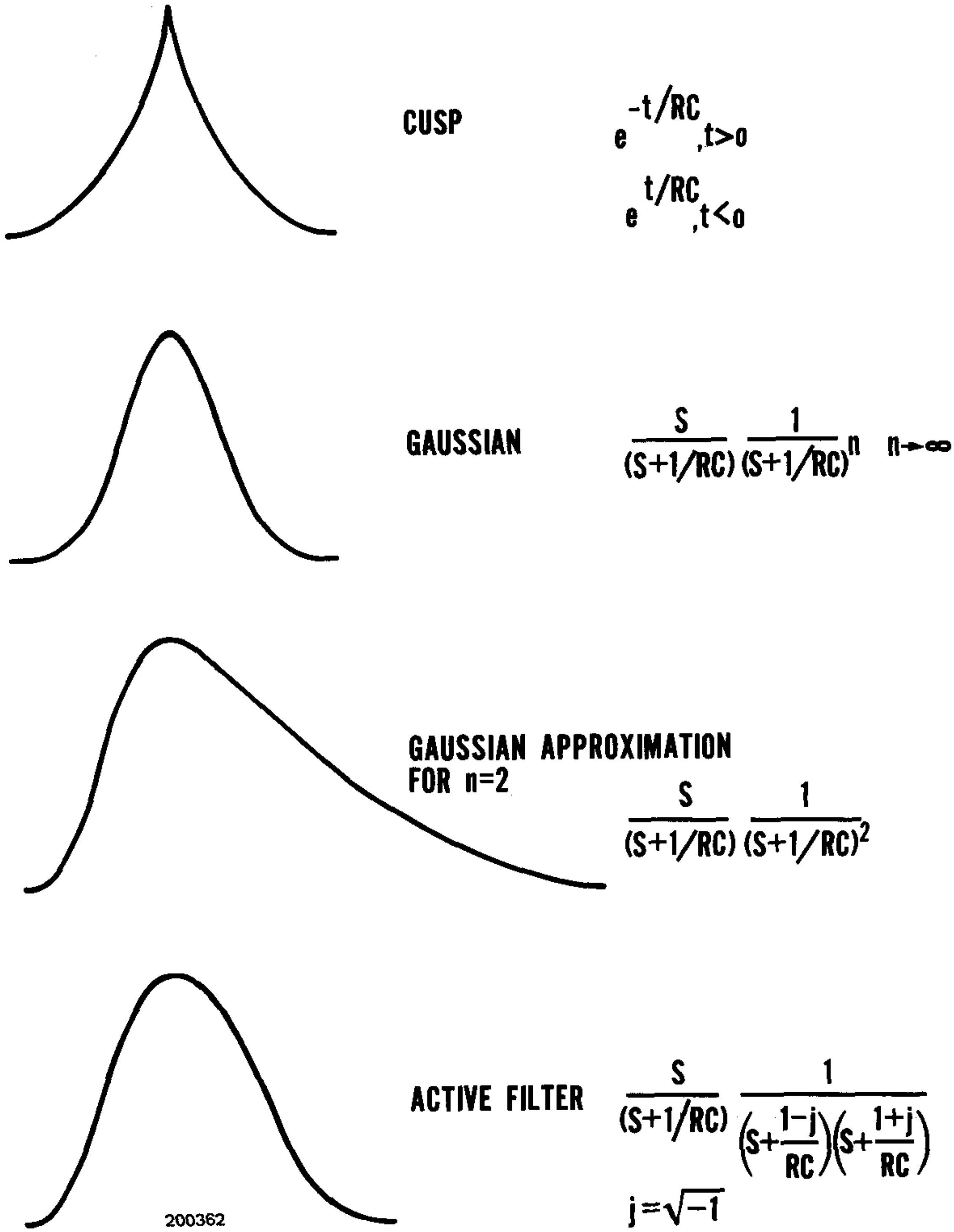


Figure 1-3 Pulse Shapes for Good Signal-to-Noise Ratios

2. SPECIFICATIONS

2.1 Electrical

INPUT	Positive or negative output from a preamplifier; rise time 10 to 650 nsec; decay time 25 to 2000 μsec; $Z_{in} \simeq 1000\Omega$ dc-coupled; max linear input 5.5 volts; max input 20V; switch selectable active baseline restorer rate
OUTPUTS	
UNIPOLAR	Prompt or delayed with full scale linear range of ±3, ±6, or ±10V as selected; ±12V max; active filter shaped; dc restored, with switch selectable active baseline restorer rate, and baseline level adjustable to ±1.0V; Z_o $<1\Omega$, front panel, and 93Ω, rear panel, short circuit proof
BIPOLAR	Prompt output with positive lobe leading, with linear range 0 to ±10V independent of Unipolar range and polarity; ±12V max; active filter shaped; Z_o $<1\Omega$, front panel, and 93Ω, rear panel, short circuit proof
PERFORMANCE	
Gain Range	With a nine-position Coarse selection from x5 to x2000 and ten-turn potentiometer for Fine adjustment from x0.5 to x1.5, total gain is the product of Coarse and Fine Gain settings; Coarse Gain factors obtained by feedback techniques
Shaping Filter	Internal switches permit independent selection of integration and differentiation time constants (τ = 0.5, 1, or 2 μsec); time to Unipolar peak = 2τ; time to Bipolar crossover = 2.8τ
Integral Non-linearity	<0.05%
Noise	<5μV (Unipolar), or <8μV (Bipolar), referred to the input, with 2 μsec shaping and Coarse Gain $\geqslant$100
Temperature Stability	
Gain	0.005%/^{o}C, 0 to 50^{o}C
DC Level	<0.5mV/^{o}C, 0 to 50^{o}C
Crossover Walk	$\leqslant$±4 nsec for 20:1 dynamic range, including contribution of ORTEC 420A Timing Single Channel Analyzer
Count Rate Stability	A pulser peak at 85% of analyzer range shifts less than 0.2% in the presence of 0 to 5 x 10^4 random cps from a ^{137}Cs source with its peak stored at 75% of analyzer range, using 1 μsec filter time constants
Overload Recovery	Recovers to within 2% of rated output from 1000X overload in 2.5 non-overloaded Bipolar pulse widths, using maximum gain; degrades to 200X for Unipolar pulse shaping
CONTROLS	
FINE GAIN	Ten-turn precision potentiometer for continuously variable direct reading gain factor of x0.5 to x1.5

COARSE GAIN	Nine-position switch, selects feedback resistors for gain factors of x5, 10, 20, 50, 100, 200, 500, 1K, and 2K.
INPUT POLARITY	Slide switch, sets input circuit for either POS or NEG input polarity
UNIPOLAR OUTPUT	Slide switch, selects either POS or NEG Unipolar output
PZ ADJ	Potentiometer to adjust Pole-Zero cancellation for decay times from 25 μsec to ∞
DC ADJ	Potentiometer to adjust the DC level for Unipolar outputs; range $\pm$1.5V
DELAY	Slide switch, selects either 2 μsec delay (IN) or prompt (OUT) output for the Unipolar signals
BLR	Three-position slide switch, selects baseline restorer function; HI for duty cycles $>$15%, LO for duty cycles $<$15%, or OUT
SHAPING	Five three-position slide switches (S1 to S5) on side panel, each identified for its filtering function; selects time constants of 0.5, 1, or 2 μsec independently
OUTPUT RANGE	Three-position slide switch on side panel, selects full range for Unipolar outputs at 3, 6, or 10V (the Bipolar output range is always 0 to 10V, independent of the selected Unipolar output range)

CONNECTORS

INPUT	BNC (UG-1094/U), front panel
UNIPOLAR OUTPUT	BNC (UG-1094/U), front panel for Z_o $<1\Omega$, rear panel for $Z_o = 93\Omega$
BIPOLAR OUTPUT	BNC (UG-1094/U), front panel for Z_o $<1\Omega$, rear panel for $Z_o = 93\Omega$
PREAMP	Standard ORTEC power connector for mating preamplifier; Amphenol type 17-10090; rear panel

POWER AND MECHANICAL

Power Required	+24V 85mA +12V 15mA -24V 85mA -12V 15mA
Shipping Weight	7 pounds (3 kg)
Net Weight	3.3 pounds (1.5 kg)
Dimensions	Standard single width module (1.35 by 8.714 inches) per TID-20893 (Rev.)

3. INSTALLATION

3.1 General Installation Considerations

The 451, used in conjunction with a 401A/402A Bin and Power Supply is intended for rack mounting; therefore, it is necessary to ensure that vacuum tube equipment operating in the same rack with the 451 has sufficient cooling air circulating to prevent any localized heating of the all-semiconductor circuitry used throughout the 451. The temperature of equipment mounted in racks can easily exceed 120^{o}F (50^{o}C) unless precautions are taken.

3.2 Connection to Preamplifier

The preamplifier output signal is connected to the 451 via BNC connector CN5 labeled INPUT. The input impedance is 1000 ohms and is dc-coupled to ground; therefore, the output of the preamplifier must be either ac-coupled or have approximately zero dc voltage under no signal conditions.

The 451 incorporates pole-zero cancellation in order to enhance the overload characteristics of the amplifier. This technique requires matching the network to the preamplifier decay time constant in order to achieve perfect compensation. The network is variable and factory adjusted to 50μsec to match all ORTEC FET preamplifiers. If other preamplifiers or more careful matching is desired, the adjustment is accessible from the front panel. Adjustment is easily accomplished by using a mono-energetic source and observing the amplifier baseline after each pulse under overload conditions.

Preamplifier power of +24V, +12V, -12V, and -24V is available on the preamp power connector, CN6.

When using the 451 with a remotely located preamplifier (i.e., preamplifier-to-amplifier connection through 25 feet or more of coaxial cable), care must be taken to ensure that the characteristic impedance of the transmission line from the preamplifier output to the 451 input is matched. Since the input impedance of the 451 is 1000 ohms, sending end termination will normally be preferred; i.e., the transmission line should be series terminated at the output of the preamplifier. All ORTEC preamplifiers contain series terminations which are either 93 ohms or variable; coaxial cable type RG-62/U or RG-71/U is recommended.

3.3 Connection of Test Pulse Generator

3.3.1 Connection of Pulse Generator to the 451 Through a Preamplifier

The satisfactory connection of a test pulse generator such as the ORTEC 419 or equivalent depends primarily on two considerations: (1) the preamplifier must be properly connected to the 451 as discussed in Section 3.2, and (2) 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.

3.3.2 Direct Connection of Pulse Generator to the 451

Since the input of the 451 has 1000 ohms input impedance, 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 greater than 1V, a large series isolating capacitor is also required since the inputs of the 451 are dc-coupled. The ORTEC 204 or 419 Test Pulse Generators are designed for direct connection. When either of these units is used, they should be terminated with a 100 ohm terminator at the amplifier input or 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.)

3.3.3 Special Test Pulse Generator Considerations for Pole-Zero Cancellation

The pole-zero cancellation network in the 451 is factory adjusted for a 50μsec decay time to match ORTEC FET preamplifiers. When a tail pulser (such as the 204 or 419) is connected directly to the amplifier input, the pulser should be modified to obtain a 50μsec decay time or the P-Z ADJ should be adjusted if overload tests are to be made (other tests are not affected). See Section 6.2 for the details on this modification.

If a preamplifier is used and a tail pulser connected to the preamplifier test pulse input, similar precautions are necessary. In this case, the effect of the pulser decay must be removed, i.e., a step input should be simulated. Details for this modification are also given in Section 6.2.

3.4 Connection to Power - Nuclear Standard Bin, ORTEC 401A/402A

The 435A contains no internal power supply and therefore must obtain power from a Nuclear Standard Bin and Power Supply such as the 401A/402A. It is recommended that the bin power supply be turned off when inserting or removing modules. The ORTEC 400 Series is designed so that it is not possible to overload the bin power supply with a full complement of modules in the Bin; however, this may not be true when the Bin contains modules other than those of ORTEC design, and in this case, the power supply voltages should be checked after insertion of the modules. The 401A/402A has test points on the power supply control panel to monitor the dc voltages.

3.5 Shaping Considerations

The shaping time constant on the 451 Amplifier is switch selectable in steps of 0.5, 1, and 2 microseconds. The choice of the proper shaping time is generally a compromise between operating at high counting rates and operating with the best signal to noise ratio. For scintillation counters, the energy resolution largely depends 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 1μsec shaping time constant is about optimum). For gas proportional counters the collection time constant is normally in the 0.5 to 5μsec range and the 2μsec or greater resolving time will generally give optimum resolution (See Section 5 for methods of changing shaping time constants of the 451). For surface barrier semiconductor detectors a one or two microsecond resolving time will generally provide optimum resolution. Shaping time for Ge (Li) detectors will vary from 1 to 6 microseconds depending upon the size, configuration, and collection time of the specific detector. 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 gain of the system. Since the 451 has almost constant gain for all shaping modes when equal integrate and differentiate time constants are used, the optimum shaping can be determined by measuring the output noise of the 451 with a voltmeter as each of the shaping modes are selected.

The 451 provides both the unipolar and bipolar outputs. The unipolar output pulse should be used in applications where the best signal to noise ratio (resolution) is desired, 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 bipolar output should be used in high count rate systems when the analyzer system is ac-coupled and noise, or resolution, is a secondary consideration.

3.6 Use of Delayed Output

The prompt output is used for normal spectroscopy applications. The delayed output (equal in amplitude to the prompt output, but delayed by two microseconds) is used in coincidence experiments where the output may be delayed to compensate for time delays in obtaining the coincidence information. The considerations regarding the proper choice of shaping for the delayed output were discussed in Section 3.5.

3.7 Output Connections and Terminating Considerations

Since the 451 unipolar output is normally used for spectroscopy, it was designed with a great amount of flexibility in order to interface this output with an analyzer. A BLR circuit is included in this output for improved performance at high count rate. A switch on the rear panel permits this circuit to be switched out, set for low count rates, or set for high count rates. When using the direct coupled input of the various analyzers, a variety of voltage requirements exist. To meet these requirements the 451 unipolar output can be selected for either positive or negative polarity and for full range voltages of 3V, 6V, or

10V. The unipolar output dc level can be adjusted from -1V to +1V to set the zero intercept on the analyzer when the direct coupled input is used. The bipolar output, with a zero to 10V range regardless of the unipolar range setting, can be used for crossover timing or may be preferable for spectroscopy when operating into ac coupled systems at high counting rates. Typical system block diagrams for a variety of experiments are described in Section 4.

The source impedance of the 0-10 volt standard linear front panel outputs of most 400 Series modules is less than 1 ohm. Interconnection of linear signals is, thus, non-critical since the input impedance of circuits to be driven is not important in determining the actual signal span, e.g., 0-10 volts, delivered to the following circuit. Paralleling several loads on a single output is therefore permissible while preserving the 0-10 volt signal span. Short lengths of interconnecting coaxial cable (up to approximately 4 feet) need not be terminated. However, if a cable longer than approximately 4 feet is necessary on a linear output, it should be terminated in a resistive load equal to the cable impedance. Since the output impedance is not purely resistive, and is slightly different for each individual module, when a certain given length of coaxial cable is connected and is not terminated in the characteristic impedance of the cable, oscillations will occasionally be observed. These oscillations can be suppressed for any length of cable by properly terminating the cable, either in series at the sending end or in shunt at the receiving end of the line. To properly terminate the cable at the receiving end, it may be necessary to consider the input impedance of the driven circuit, choosing an additional parallel resistor to make the combination produce the desired termination resistance. Series terminating the cable at the sending end may be preferable in some cases where receiving end terminating is not desirable or possible. When series terminating at the sending end, full signal span, i.e., amplitude, is obtained at the receiving end only when it is essentially unloaded or loaded with an impedance many times that of the cable. This may be accomplished by inserting a series resistor equal to the characteristic impedance of the cable internally in the module between the actual amplifier output on the etched board and the output connector. Rear panel outputs are series terminated for 93 ohm cable. It must be remembered that this impedance is in series with the input impedance of the load being driven, and in the case where the driven load is 900 ohms, a decrease in the signal span of approximately 10% will occur for a 93-ohm transmission line. A more serious loss occurs when the driven load is 93 ohms and the transmission system is 93 ohms. In this case, a 50% loss will occur. BNC connectors with internal terminators are available from a number of connector manufacturers in nominal values of 50, 100, and 1000 ohms. ORTEC stocks in limited quantity both the 50 and 100 ohm BNC terminators. The BNC terminators are quite convenient to use in conjunction with a BNC tee.

3.8 Shorting or Overloading the Amplifier Outputs

All outputs of the 451 are dc-coupled with an output impedance of about 0.1 ohms. If the output is shorted with a direct short circuit or the amplifier counting rate exceeds 35% duty cycle, the output stage will limit the peak current of the output such that the amplifier will not be harmed.

4. OPERATING INSTRUCTIONS

4.1 Front Panel Controls

Gain: A course gain switch and a fine gain ten-turn locking precision potentiometer selects the gain factor. For equal time constants, the gain is read directly; switch positions, 5, 10, 20, 50, 100, 200, 500, 1000, and 2000, and continuous fine gain range is 0.5 to 1.5 (500 to 1500 dial divisions).

Input Polarity: Slide switch sets the input circuit for either POS or NEG input polarity.

P-Z ADJ: Control to set the pole-zero cancellation for optimum matching to the preamplifier pulse decay characteristics, range 25μsec to infinity.

UNIPOLAR OUT POLARITY: Slide switch selects POS or NEG unipolar output.

DC ADJ: Potentiometer to adjust the dc level of unipolar output; range $\pm$1.0V.

4.2 Rear Panel Controls

Delay: Slide switch selects either 2μsec delay (IN) or prompt (OUT) output of the unipolar signals.

BLR: Three position slide switch selects baseline restorer function; HI for duty cycles $>$ 15%, LO for duty cycles $<$ 15%, or OUT.

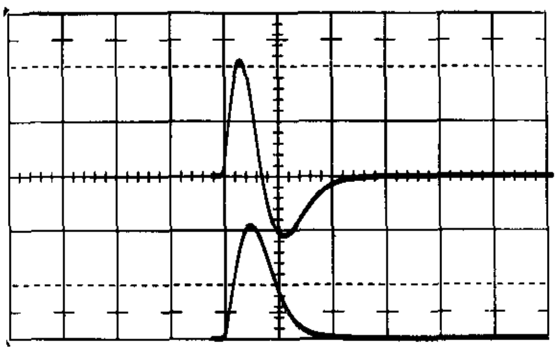
4.3 Internal Controls

Shaping: Five three position slide switches (S1 to S5) selects integration and differentiation time constants of 0.5, 1, or 2 microseconds independently. These switches are mounted horizontally on the circuit board and are accessible by removing the side panel. Their location and filtering function are identified pictorially on the side panel.

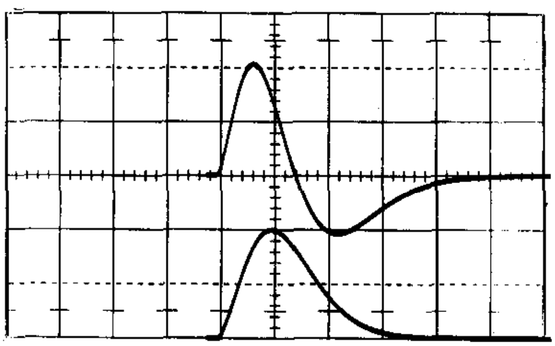
OUTPUT RANGE: Three position slide switch mounted on the circuit board selects a full range for unipolar outputs for 3, 6, or 10 volts (the bipolar output range is always 0 to 10 volts independent of the selected unipolar output range). This switch is mounted vertically on the circuit board and its location and function is identified pictorially on the side panel.

4.4 Front Panel Connectors (All Type BNC)

INPUT: Positive or negative with risetime 10 to 650 nsec; decay time must be greater than 25μsec for proper pole-zero cancellation. Input impedance is 1000 ohms dc-coupled. Maximum linear input signal is 5.5 volts with a maximum input of $\pm$20 volts.

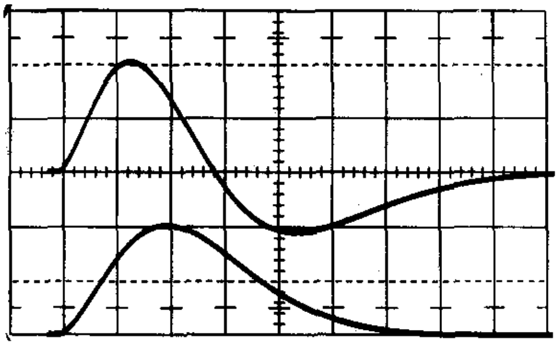


Shaping Time 0.5 μsec



All waveforms taken with
Horizontal = 2 μsec/cm
Vertical = 5V/cm

Shaping Time 1 μsec



Shaping Time 2 μsec

Figure 4-1. Effects of Shaping Time Selection on Output Waveforms

OUTPUTS: Two BNC connectors with output impedance < 0.1 ohm. Each output can provide up to ±10 volts and is dc-coupled and short circuited protected.

UNIPOLAR: This output features separate selection for full voltage range, polarity, and baseline restoration rate. The dc level is adjustable for off set to ±1.0 volts. The unipolar pulse shape is determined by the settings of the integrate and differentiate shaping time constant switches. Unipolar range, polarity, BLR, and delay are independent of the bipolar output (see Figure 4-1 for output pulse waveforms).

BIPOLAR: Bipolar pulse is prompt with positive lobe leading and the pulse shape is selected by the integrate and differentiate switches. Linear range is 0 to ±10 volts; independent of unipolar range. The crossover walk of this output is < ±4 nsec for 20:1 dynamic range, including contribution of ORTEC 420A Timing Single Channel Analyzer.

4.5 Rear Panel Connectors

OUTPUTS: The unipolar and bipolar pulses are brought to the rear panel on BNC connectors. The specifications of these outputs are same as those for the front panel connectors except the output impedance is 93 ohms at these connectors.

PREAMP POWER: Standard power connector for mating with ORTEC preamplifiers; ±24 volts and ±12 volts.

4.6 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 4-1 shows some typical waveforms.

4.7 General Considerations for Operation with Semiconductor Detectors

4.7.1 Calibration of Test Pulser

The ORTEC 419 Pulser, or equivalent, may easily be calibrated so that the maximum pulse height dial reading (1000 divisions) is equivalent to 10 MeV loss in a silicon radiation detector. The procedure is as follows:

(1) Connect the detector to be used to the spectrometer system, i.e., preamp, main amplifier, and biased amplifier.

(2) Allow particles from a source of known energy (α-particles, for example) to fall on the detector.

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

(4) Set the pulser PULSE HEIGHT potentiometer at the energy of the α-particles striking the detector (e.g., for a 5.47 MeV α-particle, set the dial on 547 divisions).

(5) Turn on the Pulser, use the NORMALIZE potentiometer and attenuators to set the output due to the pulser for the same pulse height as the pulse obtained in (3) above. Lock the NORMALIZE dial and do not move again until recalibration is necessary.

(6) The pulser is now calibrated; the PULSE HEIGHT dial reads in MeV if the number of dial divisions is divided by 100.

4.7.2 Amplifier Noise and Resolution Measurements

As shown in Figure 4-2, the preamplifier, amplifier, pulse generator, oscilloscope, and a wide-band rms voltmeter such as the Hewlett-Packard 400D 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:

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

(2) Turn on the ORTEC 419 Mercury Relay Pulse Generator and adjust the pulser output to any convenient readable voltage, E_o, as determined by the oscilloscope.

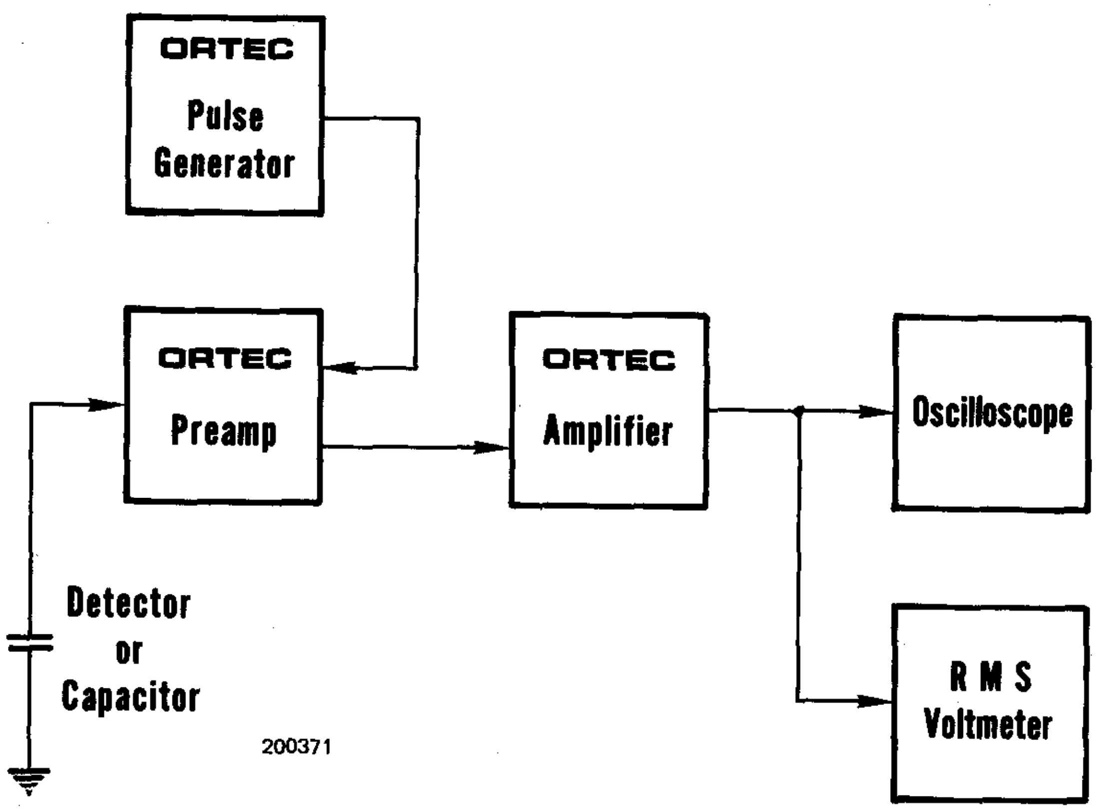


Figure 4-2 Measuring Amplifier and Detector Noise Resolution

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

$$N(\text{fwhm}) = \frac{2.66\ E_{rms}\ E_{dial}}{E_o}$$

where E_{dial} is the pulser dial reading in MeV and the factor for rms to fwhm (2.34) and noise to rms meter correction (1.13) for average-indicating voltmeters such as the Hewlett-Packard 400D. A true rms voltmeter does not require the latter correction factor.

The resolution spread will depend upon the total input capacitance, since the capacitance degrades the signal-to-noise ratio much faster than the noise. A typical resolution spread versus external input capacitance for the ORTEC 120 Preamp and the 451 Amplifier are shown in Figure 4-3.

4.7.3 Detector Noise Resolution Measurements

The same measurement described in Section 4.7.2 can be made with a biased detector instead of the external capacitor used to simulate the 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

$$N_{det}^2 + N_{amp}^2 = N_{total}^2$$

where N_{total} is the total resolution spread and N_{amp} is the amplifier resolution spread with the detector 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 4-4 shows curves of typical total noise resolution spread versus bias voltage, using the data from several ORTEC silicon surface barrier semiconductor radiation detectors.

4.7.4 Amplifier Noise and Resolution Measurements Using a Pulse Height Analyzer

Probably the most convenient method of making resolution measurements is with a pulse height analyzer as shown by the setup illustrated in Figure 4-5.

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

(1) Select the energy of interest with an ORTEC 419 Pulse Generator, and set the Amplifier and Biased Amplifier GAIN and BIAS LEVEL controls so that the energy is in a convenient channel of the analyzer.

(2) Calibrate the analyzer in keV per channel, using the pulser (full scale on the pulser dial is 10 MeV when calibrated as described in Section 4.7.1).

(3) The amplifier noise resolution spread can then be obtained by measuring the full width at half maximum of the pulser 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 Section 4.7.3. The detector noise will vary with detector size, bias conditions, and possibly with ambient conditions.

4.7.5 Current-Voltage Measurements for Silicon and Germanium Detectors

The amplifier system is not directly involved in semiconductor detector current-voltage measurements, but the amplifier serves well to permit noise monitoring during the setup. The detector noise measurement is a more sensitive method of determining the maximum detector voltage

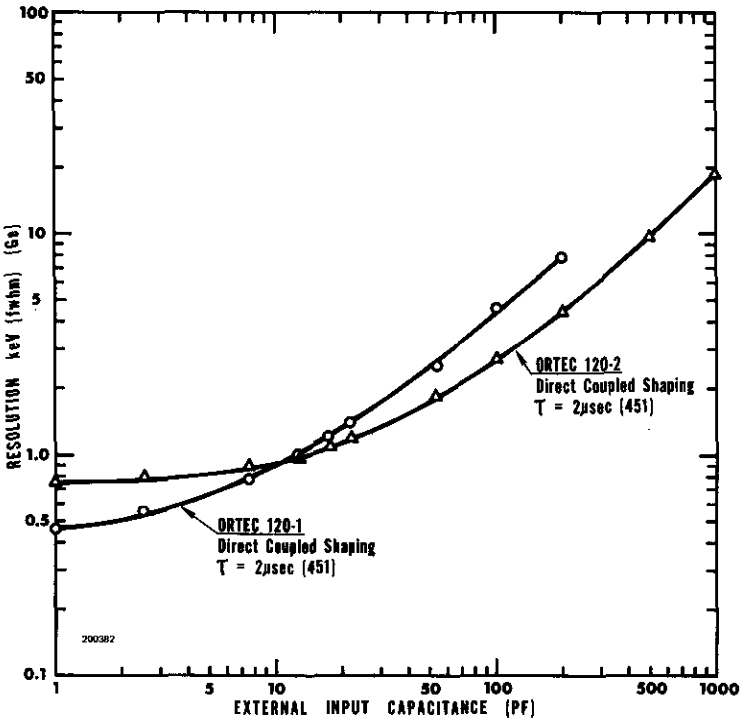


Figure 4-3 Resolution Effects of Capacitance

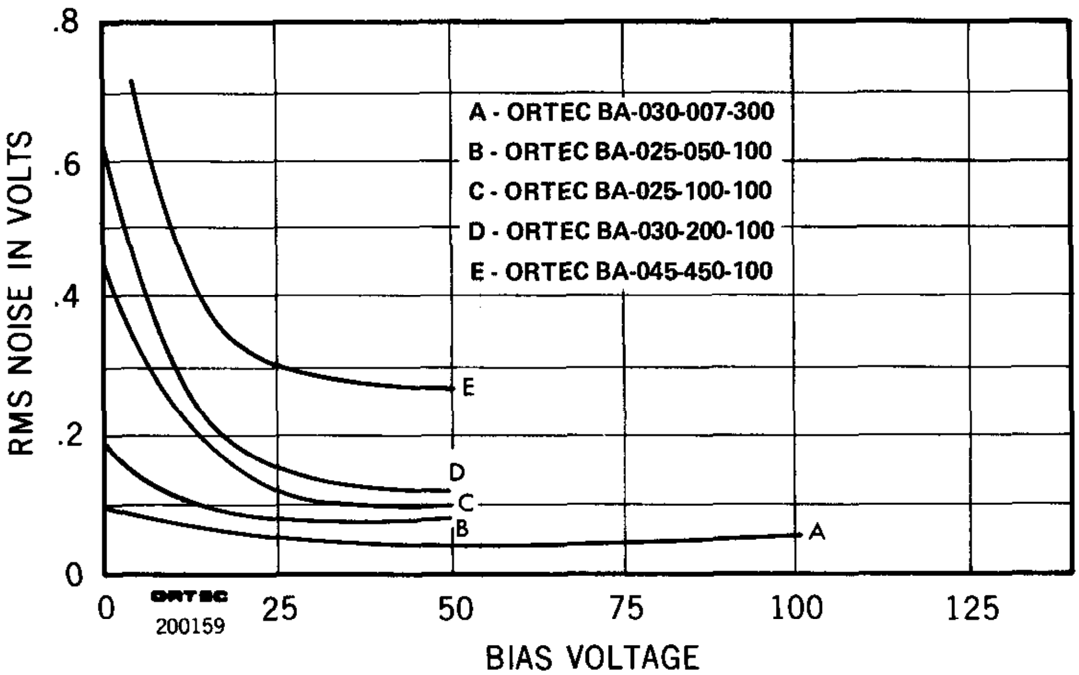


Figure 4-4. Noise as a Function of Bias Voltage

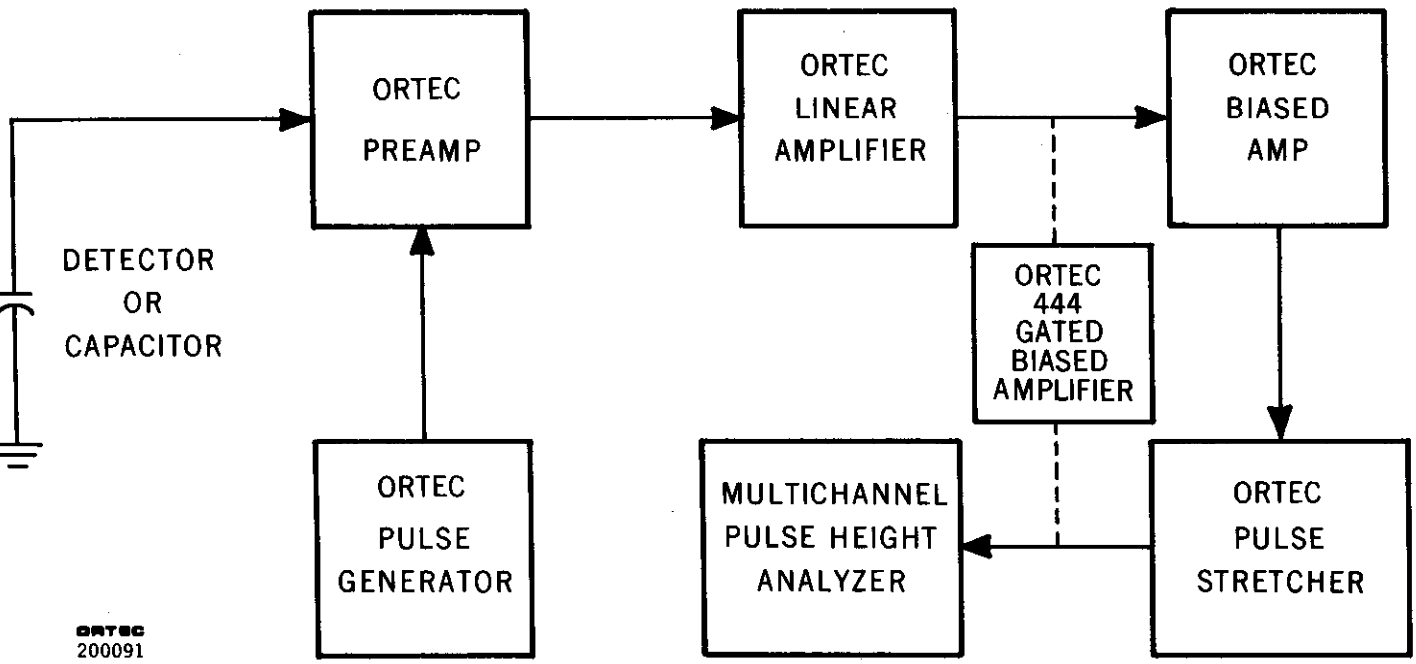


Figure 4-5. System For Measuring Resolution With a Pulse Height Analyzer

which 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 4-6 shows the setup required for current-voltage measurements. The 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 4-7 shows several typical current-voltage curves for ORTEC silicon surface barrier detectors.

When it is possible to float the microammeter at the detector bias voltage, the alternate method of detector current measurement shown by the dashed lines in Figure 4-6 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.

4.7.6 Recommended Method for Preamp-Main Amp Gain Adjustments as a Function of Input Particle Energy

With the input energy at a constant, or maximum, known value, the total system gain of the preamp and main amplifier can be adjusted to an optimum value by utilizing the following general considerations:

(1) The primary design criterion for the preamp is best signal-to-noise ratio at the output; therefore, the preamp should be operated with the gain switch in its maximum gain position. This will result in the best signal-to-noise ratio available, and at the same time the absolute voltage amplitude of the preamp signal will be maximized.

(2) Since the fine gain control of the 451 is an attenuator it should be set to as near maximum as possible by manipulation of the coarse gain.

(3) The unipolar output range should be set to the input range of the analyzer.

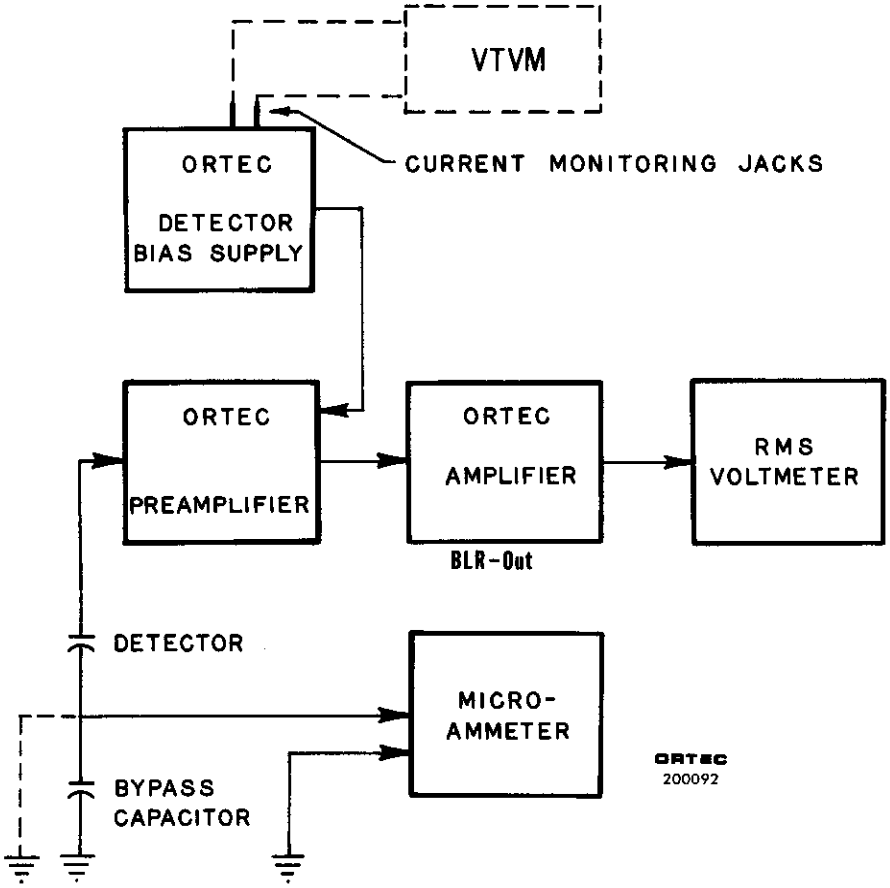


Figure 4-6. System For Detector Current and Voltage Measurements

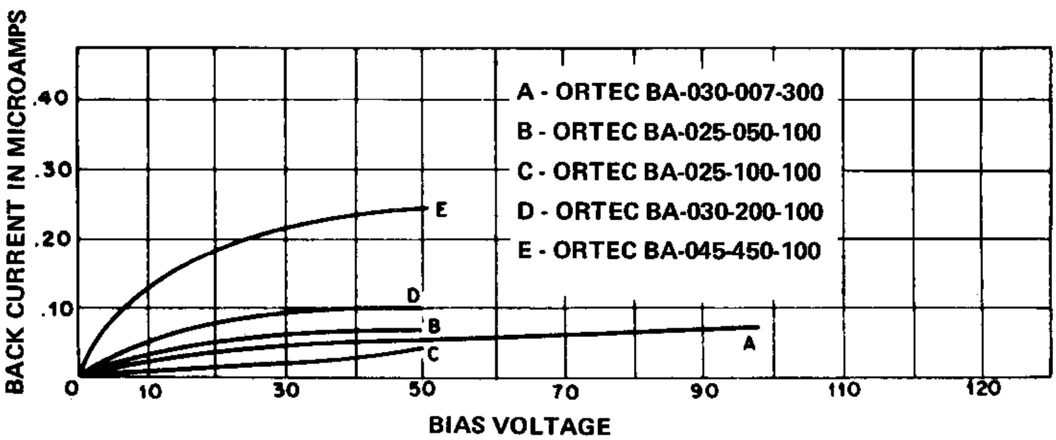


Figure 4-7. Silicon Detector Back Current Versus Bias Voltage

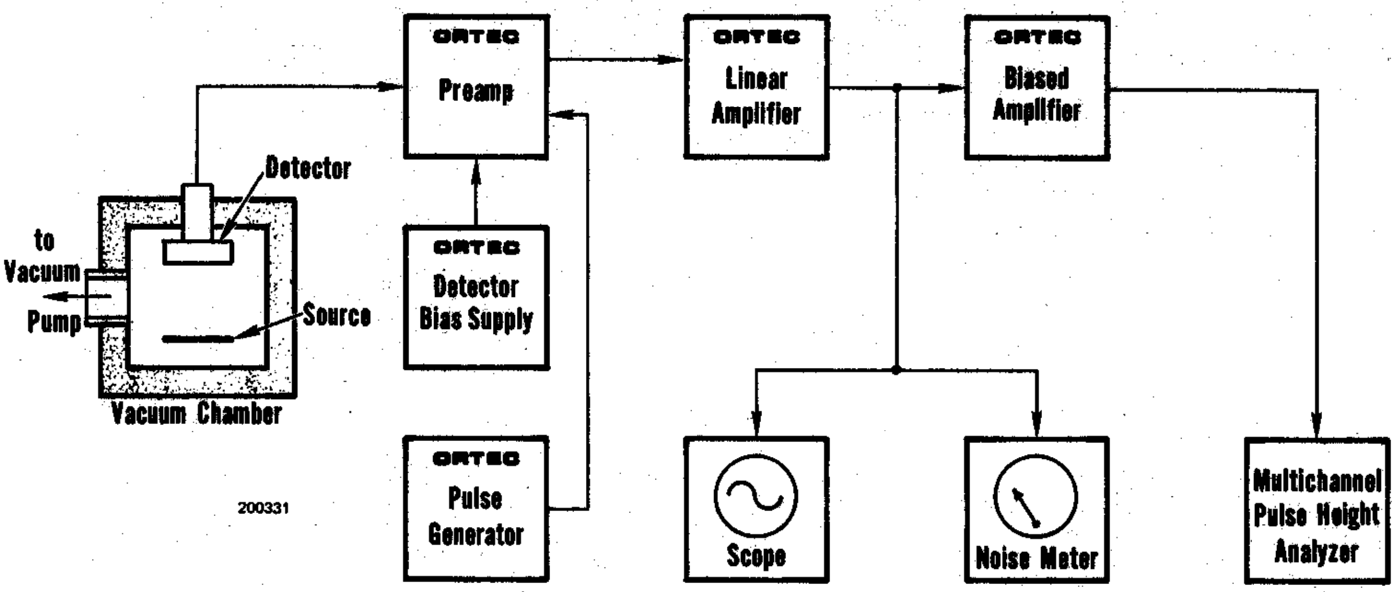


Figure 4-8. System For High Resolution Alpha Particle Spectroscopy

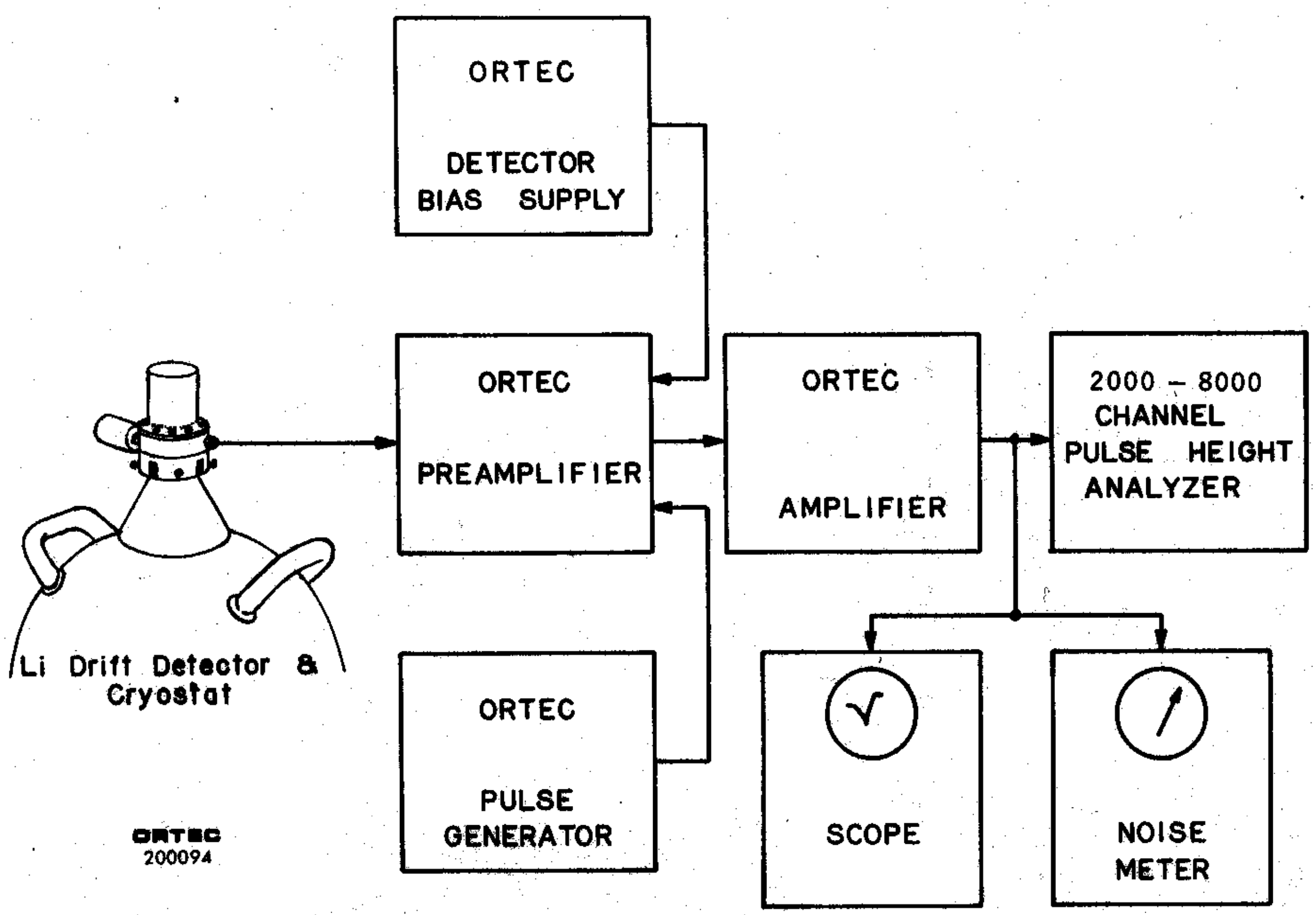


Figure 4-9. System For High Resolution Gamma Spectroscopy

4.8 Operation in Spectroscopy Systems

4.8.1 High-Resolution Alpha-Particle Spectroscopy System

The block diagram of a high resolution spectroscopy system for measuring natural alpha-particle radiation is shown in Figure 4.8. Since natural alpha-particle radiation only occurs above several MeV, an ORTEC 444 Biased Amplifier is used to suppress the unused portion of the spectrum.

Alpha particle resolution is obtained in the following manner:

(1) Using maximum preamplifier gain, medium amplifier gain, and minimum biased amplifier gain and bias level, accumulate the alpha peak in the multichannel analyzer.

(2) 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 analyzer.

(3) Calibrate the analyzer in keV per channel using the pulser and the known energy of the alpha peak (see Section 4.7.1), or 2 known energy alpha peaks.

(4) The resolution can be obtained by measuring the full width at half maximum of the alpha peak in channels and converting to keV.

4.8.2 High Resolution Gamma Spectroscopy System

A high resolution gamma system block diagram is shown in Figure 4-9. Although a biased amplifier is not shown (a larger channel analyzer being preferred), it can be used if only a smaller channel analyzer is available and only higher energies are of interest.

When using lithium drifted germanium detectors cooled by a liquid nitrogen cryostat, it is possible to obtain resolutions 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 guide lines for obtaining optimum resolution are:

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

(2) Keep humidity low near the detector-preamplifier junction.

(3) Operate in amplifier and preamplifier gain regions which provide the best signal-to-noise ratio.

(4) Operate at the highest allowable detector bias to keep the input capacity low.

4.8.3 Scintillation Counter Gamma Spectroscopy Systems

The ORTEC 451 can be used in scintillation counter spectroscopy systems as shown in Figure 4-10. The amplifier clipping time constants should be selected in the region of 0.5 to 1.0μsec for NaI or plastic scintillators. For scintillators having longer decay times, the time constants may be changed.

4.8.4 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 Figure 4-11 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 scaler and timer or counting rate meter.

4.9 Typical System Block Diagrams (Figures 4-12 through 4-15)

This section contains block diagrams illustrating how the 451 and other ORTEC 400 Series modules can be used in experimental setups.

4.10 Baseline Restorer (BLR)

4.10.1 BLR Function

4.10.1.1 DC Level

The operation of the 451 in the system is quite straightforward. The OUTPUT RANGE SWITCH selects the span of the output voltage to be ±3V, ±6V, or ±10V for the Unipolar Output. This allows a matching to all ADC inputs. On some ADC's the input has a zero offset adjust to set the zero channel intercept which controls a dc level internally in the ADC, normally operating in the ac-coupled mode; however, when direct access is used, this dc offset adjust is to some degree disabled by the output impedance of the driving amplifier (in this case, the 451 which controls the amount of that dc voltage). Since the 451 dc output level controls the zero intercept of these ADC's, this dc level is front panel adjustable between +1.0V and -1.0V.

4.10.1.2 BLR Controls

The BLR rate switch (S11), has three positions, OUT, LO, and HI, and selects the rate of dc restoration. The OUT mode is used where the count rate is moderate and best energy resolution (the least noise width contribution) is required. The LO and HI restore modes provide a selectable restoration rate; therefore, a very much higher count rate capability for the same amount of pile-up distortion. The restorer should be used whenever high count rates (approximately 5 to 10 K counts/second) are to be encountered. BLR switch S11 selects the restore capacitor to allow optimum restoration for each range of count rates, or bypasses the BLR when it is set at OUT. See Figure 4-18 for aid in selection of the best BLR rate.

4.10.2 BLR in a System

If the 451 is used in a system which also includes a non-linear element such as a biased amplifier, the system must be dc-coupled up to the non-linear element or be dc-restored prior to it in order to obtain good pulse height resolution. If the output from the non-linear element is ac-coupled, dc restoration is required again before the pulses are fed into a pulse height analysis system (multi-channel analyzer, for example) to obtain the best pulse height resolution versus count rate. These precautions are satisfied by using an ORTEC 444 Biased Amplifier at moderate count rates, since it contains a dc restoration circuit. Of course, it is necessary to have dc coupling following the dc restoration through to the pulse height analysis system.

Some of the analog to digital converters associated with multichannel analyzers are not dc-coupled at their normal input and contain no method of dc restoration; however, some of these analyzers do allow direct access to their linear gate circuitry in the so-called Mossbauer analysis mode. Other ADC's have a built-in dc restorer capable of restoring the long time constant associated with the ac coupling capacitor in the ADC prior to the dc restorer point. In these cases, one may obtain reasonably high count rate, i.e., in the order of 10,000 to 15,000 counts per second, of high resolution data by dc restoration externally and coupling direct into the ADC in the normal mode. This means that there are two steps of dc restoration. If, however, very high count rates are to be encountered, one should assure dc coupling in these ADC's as well and dc restore externally by means of the 451.

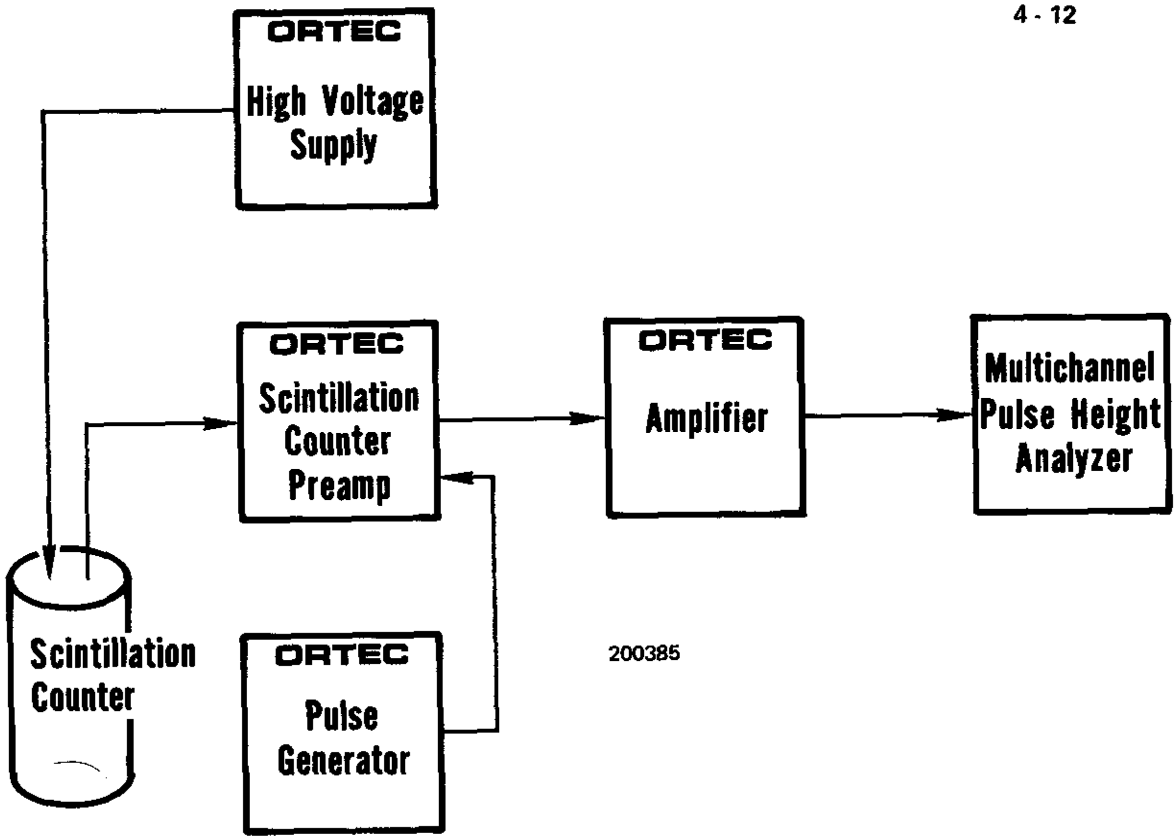


Figure 4-10 Scintillation Counter Gamma Spectroscopy System

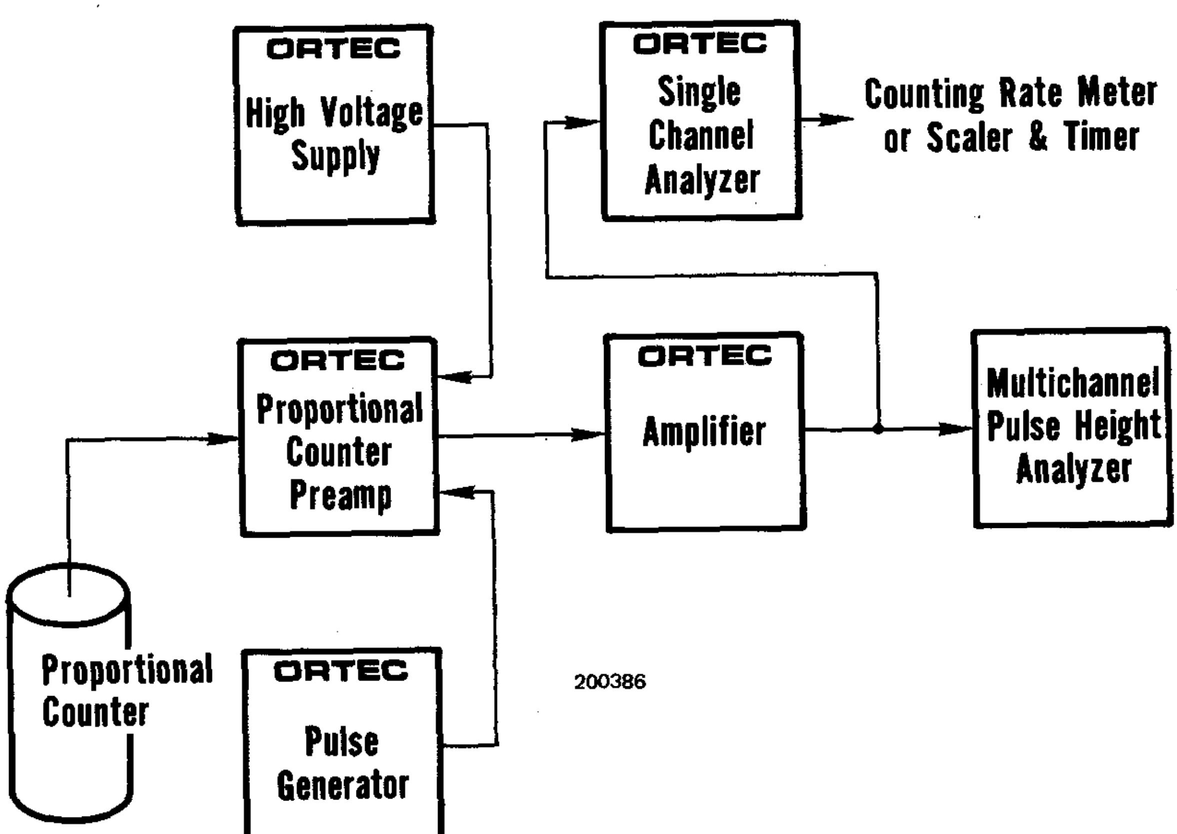


Figure 4-11 High Resolution X-Ray Spectroscopy System

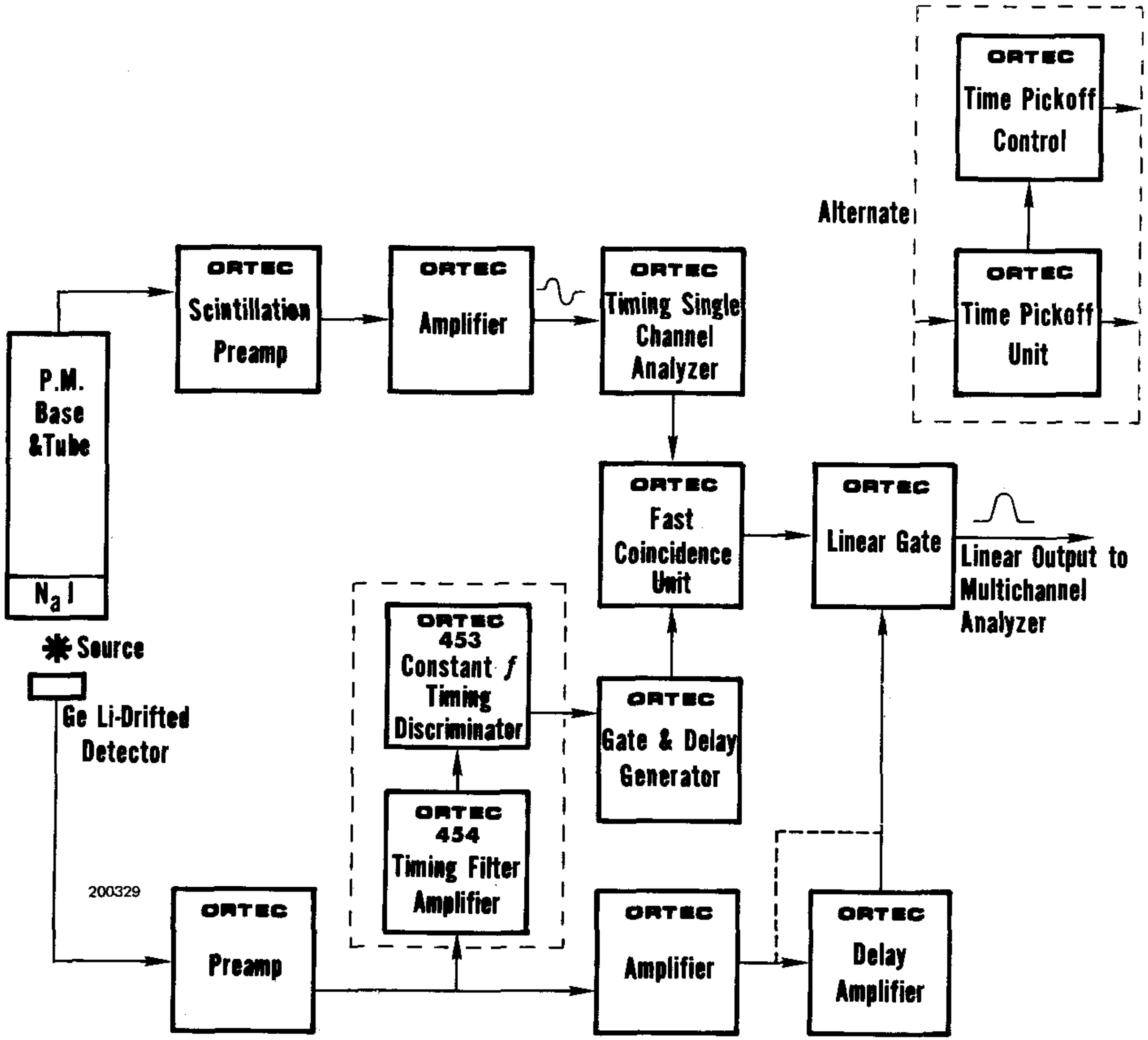


Figure 4-12 Gamma-Gamma Coincidence Experiment – Block Diagram

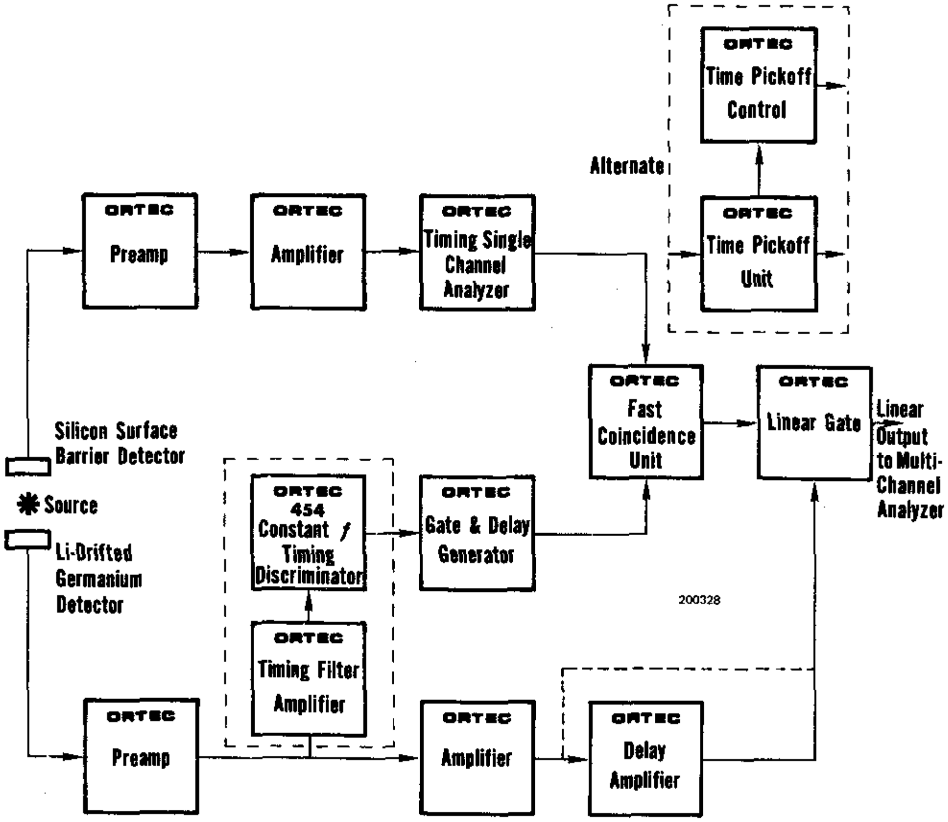


Figure 4-13 Gamma Ray-Charged Particle Coincidence Experiment – Block Diagrams

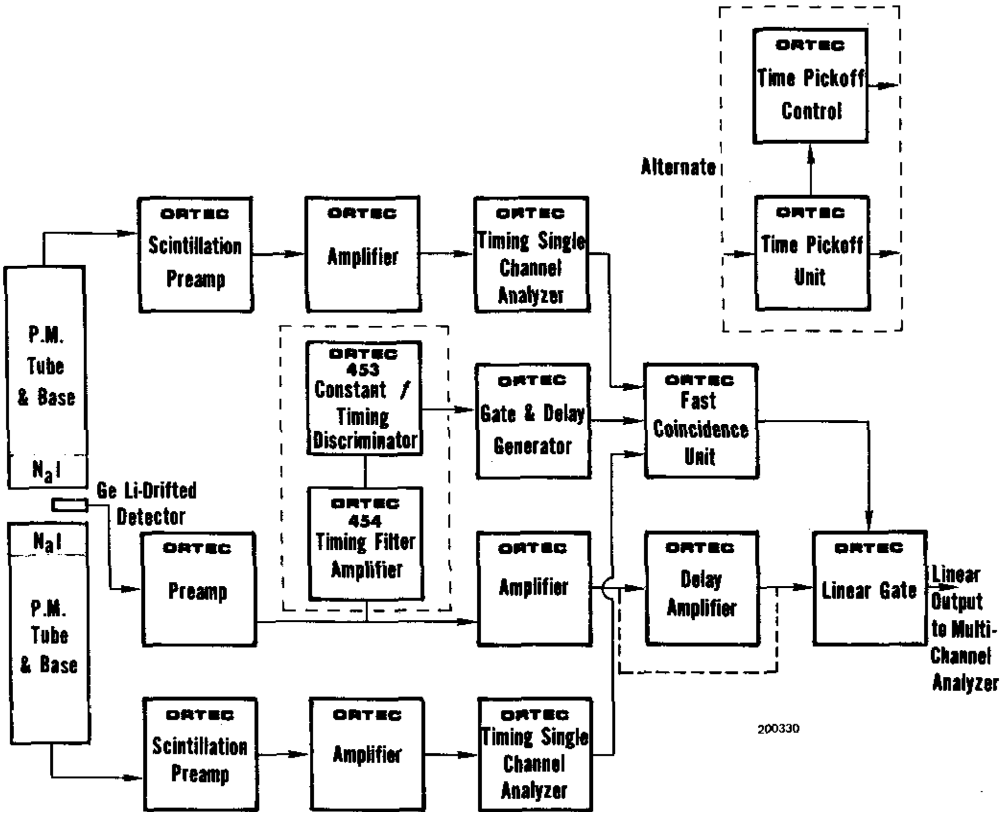
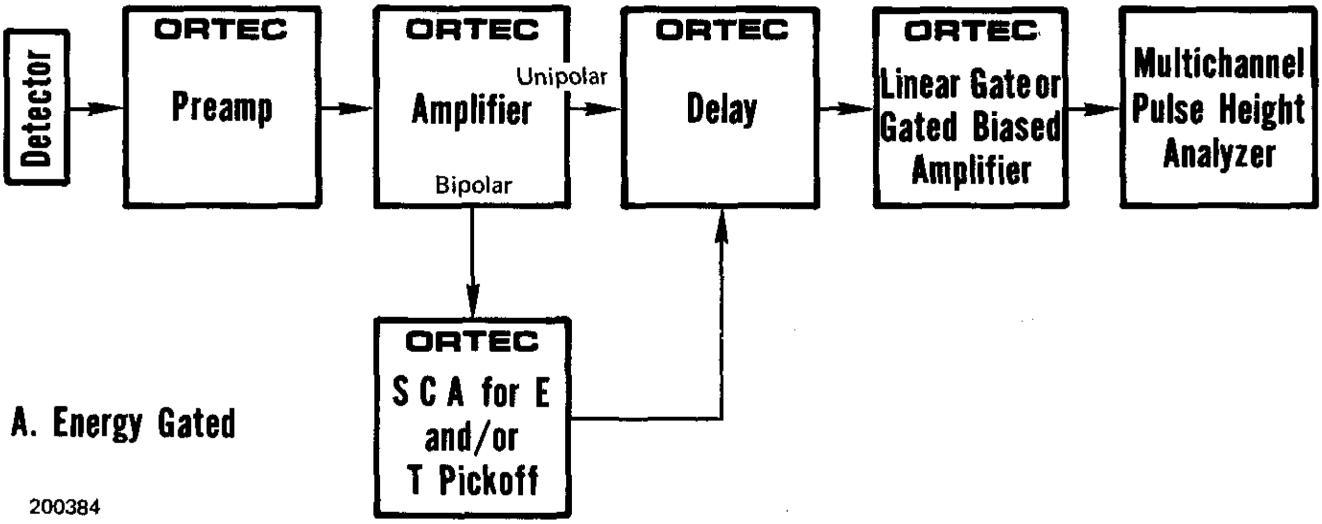
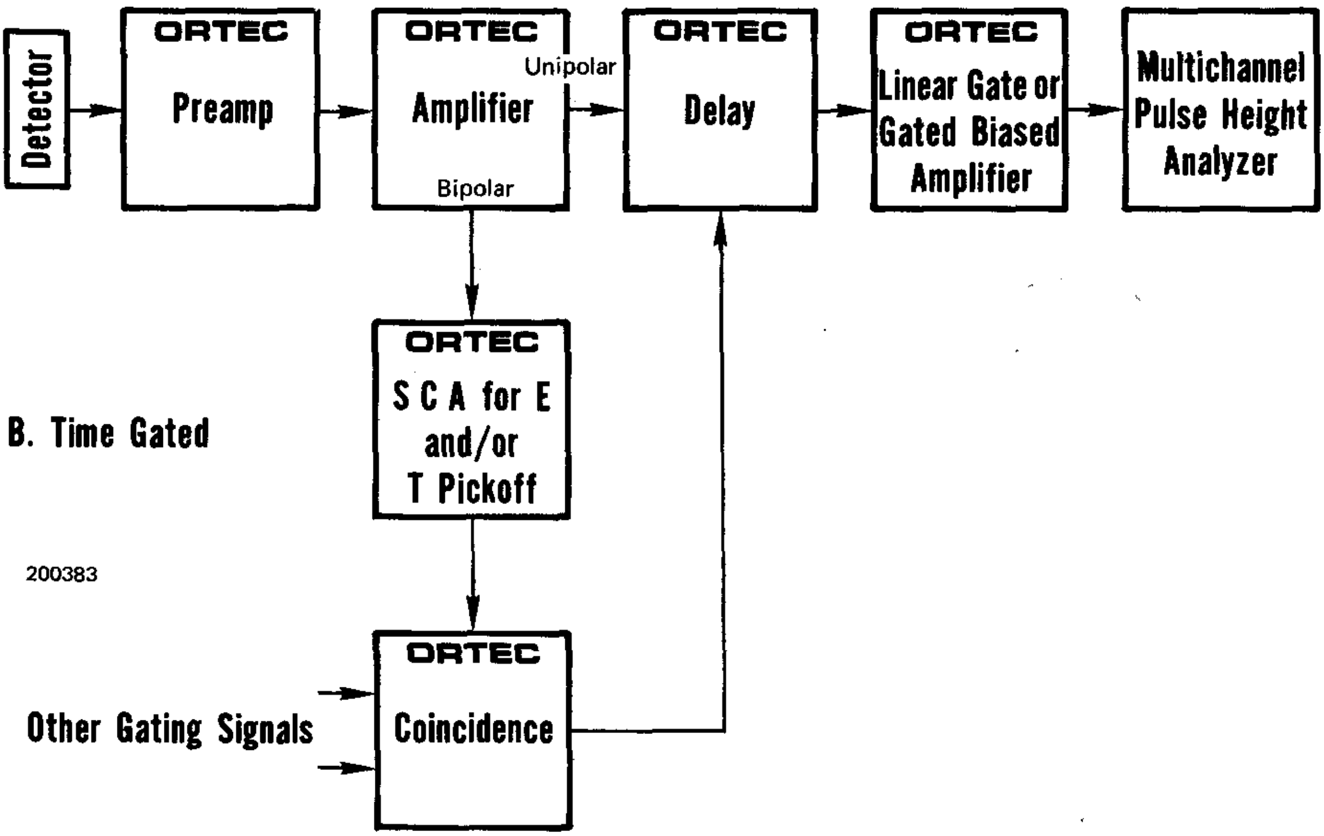


Figure 4-14 Gamma Ray Pair Spectrometer – Block Diagrams



A. Energy Gated

200384



B. Time Gated

200383

Figure 4-15 General System Arrangement for Gating Control

There are many ADC's in use in nuclear research and the variety of input requirements is almost as broad as the variety of ADC's used. Below are listed some specified ADC's and block diagrams outlining methods of connecting the 451 into the system in such a way that it will perform its function and supply an analysis signal to the ADC through a dc-coupled network. Note that in some cases it is necessary to feed two signals to the ADC. One of these, which is the dc-coupled signal to be analyzed, goes directly to the gate circuit, while the second signal goes to the normal input and is used merely as a trigger signal to initiate analysis since some of the ADC's pick off the trigger signal to initiate analysis from the normal, i.e., 0-10V, input.

4.11 Methods of Connection to Various Analyzers

Below is listed a number of various manufacturers of multichannel analyzers along with the manufacturer's recommended method of dc coupling of specific ADC's. Figure 4-16 applies where no trigger is needed, and Figure 4-17 applies where an external trigger is indicated. If information in excess of that given is necessary, contact the analyzer manufacturers for further details.

A. RIDL (NUCLEAR-CHICAGO) Models 34-12B, 34-27, 22-Series

PACKARD INSTRUMENTS

INTERTECHNIQUE

Direct access available through the dc or Mossbauer Input (trigger required).

B. NORTHERN SCIENTIFIC

Direct access available on all models (no trigger required).

C. NUCLEAR DATA

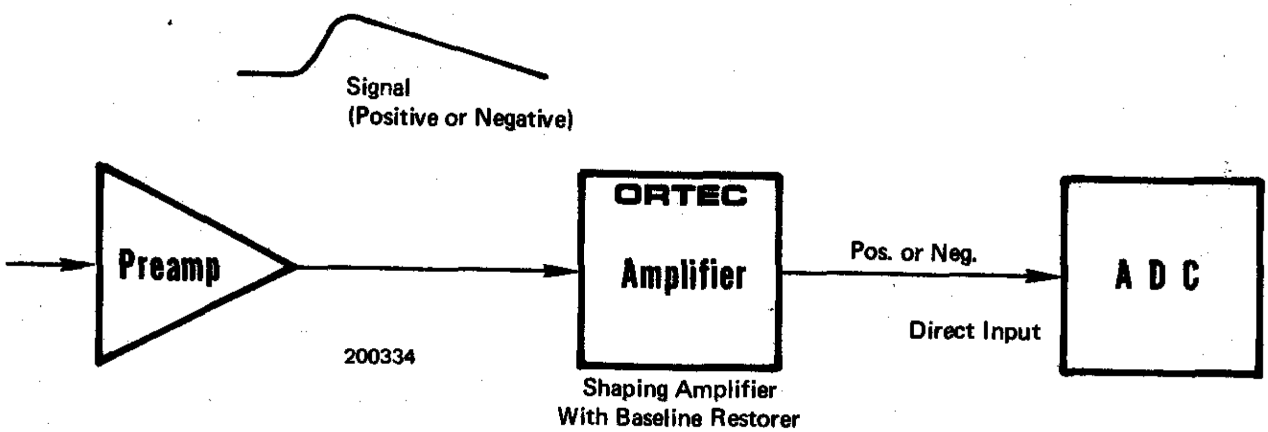


Figure 4-16 Analyzer Connection With No Trigger Required

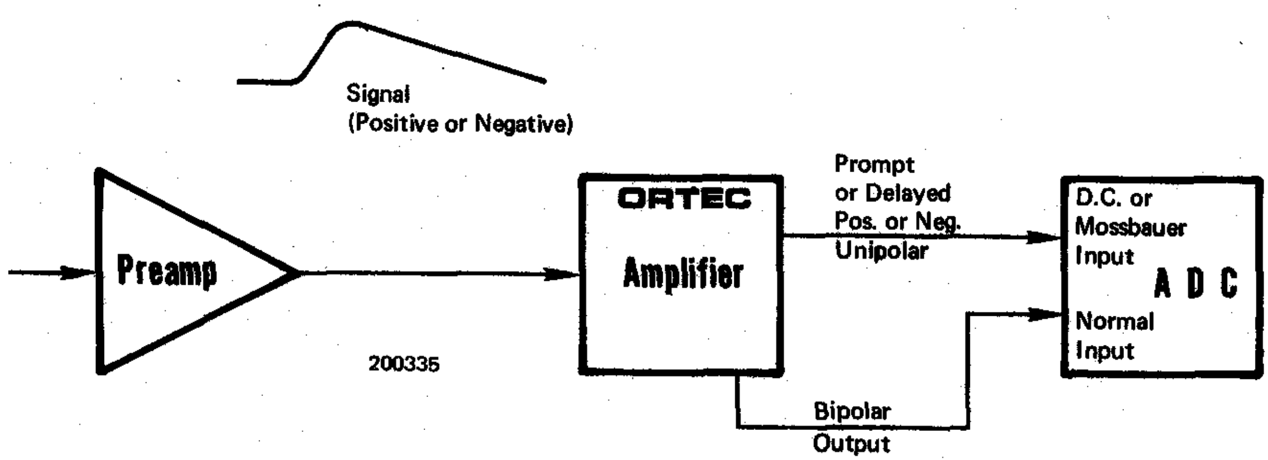


Figure 4-17 Analyzer Connection When Trigger is Required

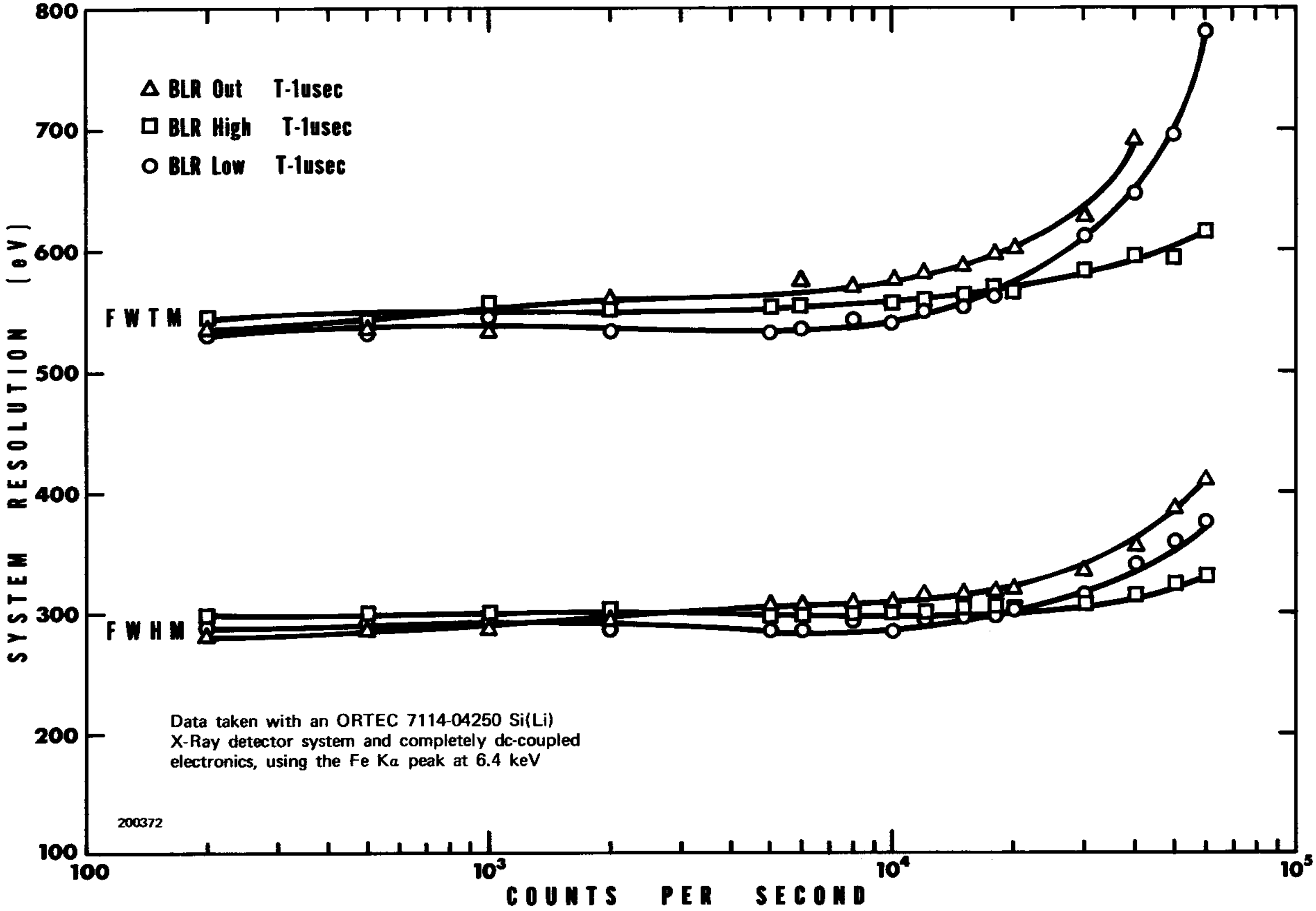


Figure 4-18 Effects of Baseline Restorer on Resolution

ADC Model	Direct Input Volts	Modification	Trigger Condition
ND-120 ND-130	-3 -3	Short out 0.01μF capacitor on ADC board, base of T-1	None Req.
ND-110	-2.5	None (use Mossbauer Input)	None Req.
ND-160F	-3	None (use Direct)	None Req.
ND-161F	-3	Short out 0.018μF capacitor on ADC board, base of T-1	None Req.
ND-2200	0–5 (offset baseline)	Short out capacitor 09D8 on ATC board	No trigger required if operated in open gate
ND-3300	+10	Short out 0.01μF capacitor on ALG board	Trigger required

D. TMC ANALYZER AND ADC DIRECT INPUT REQUIREMENTS

Model No.	Signal Required	Modifications	
102 Analyzer	0 to –4 volts	Yes	(1)
213 ADC	0 to +8 volts	Yes	(2)
401D Analyzer	0 to –4 volts	Yes	(1)
404C Analyzer	0 to –4 volts	Yes	(1)
46I ADC	0 to –8 volts	No	
1001 Analyzer	0 to –4 volts	Yes	(3)
1004 Analyzer	0 to –4 volts	Yes	(1)
1010 Analyzer	0 to –4 volts	Yes	(3)
217B ADC	0 to –4 volts	Yes	(3)

(1) Add signal input and trigger input for Linear Gate
(2) Add signal input and special trigger input
(3) Add signal input to Linear Gate circuit

E. TULLAMORE (Victoreen) signal 0 to +10V

Model No.	Modification	Trigger	DC Level
PIP-400	Short C-203	None	~+1.5V
SCIPP Series	Short C-403	None	~+1.5V
ICADC	None	None	~0V

5. CIRCUIT DESCRIPTION

The 451 contains six basic feedback amplifiers and a base line restoration (BLR) circuit as shown in the block diagram (451-0201-B1). The input amplifier (A1) is an ORTEC 908-6 amplifier 0A-3B-15 with a polarity switching arrangement on the input to connect the signal to either the inverting or non-inverting input. When the input polarity switch is set to the polarity of the input pulse, the output pulse from A1 will always be negative. The gain of this stage ($\approx$2.6) is set by R2 and R7 for positive polarity when the coarse gain is set between 50-2K. The gain of A1 is changed to approximately one $\left(\frac{R_8}{R_2}\right)$ for coarse gain settings between 5 and 20.

The gain for negative input pulse is the same as for positive however resistors R1, R5, and R6 also enter into the gain expressions.

Immediately following the first stage is the first differentiation and pole-zero cancellation network. The 0.5 microsecond time constant is set by R16 and C8. To increase the time constant additional capacitance is added in parallel with C8, e.g., τ = 2μsec = R16 (C8 + C9). Switch S1, mounted on the circuit board, is used to add this capacitance when the time constants are changed. See Section 1.2 for a discussion of pole-zero cancellation.

The second amplifier is composed of Q1 - Q8 and Q43 used as a zener to improve overload recovery. The gain of this stage is set by R16 and R19, R20 or R21 depending on the coarse gain setting. Resistors R19, R20, and R21 have selectable capacitors in parallel with them to produce the first integrator in the 451. These capacitors (C11 - C19) are selected by switches S2 and S3 mounted on the printed circuit board. The pulse gain from the output of A1 to the output of A2 can be set by the coarse gain switch to 2.5, 5 or 10 when equal time constants are selected.

The fine gain control is an attenuator composed of R37 and R38. The wiper arm of R37 (precision 10-turn potentiometer) selects the portion (0.33 to 1.0 and labeled as 0.5 to 1.5 on the front panel dial) of the output voltage from A2 to be fed to A3.

Amplifier A3 is a non-inverting amplifier composed of Q9-Q18. The gain of this stage is 1.5, 3, 6, or 12 depending on the feedback resistor selected by the coarse gain switch. The gain setting resistors are R53 and R48, R49, R50, or R51.

Amplifier A4 consist of Q19 - Q26. The feedback network of this stage comprises the active filter in the 451. The time constant of this network is selected by S4. This network produces two complex poles and a zero. The zero is cancelled by the pole produced by the first integrate in the second stage (A2). The gain of A4 is varied (2, 4 or 10) by varying the input resistance (R61, R62 or R63).

Since the 451 is dc-coupled throughout it is necessary to stabilize the dc level by some method to prevent excessive drift with temperature change. This stabilization network (Q27 - Q30) monitors the output dc voltage of A4 and sends an error signal back to A1 (base of Q2) if the output of A4 moves away from ground. The output dc level of A4 varies about 2 millivolts as the temperature is changed from 0 to 50°C.

The signal is routed in two directions from the output of A4. It is connected to A6 through a second selectable differentiation network to provide a bipolar output. The second differentiation network time constant is selected by switch S5. The bipolar signal is provided on the front and rear panels via BNC connectors with an output impedance of $<$0.1 ohms on the front panel and 93 ohms on the rear panel. Transistors Q41 and Q42 limit the output current to provide short circuit protection. The signal is also routed to the unipolar output amplifier (A5) from A4. A BLR (Base Line Restoration) circuit and a delay line can be inserted in the signal path between A4 and A5 if desirable.

The BLR circuit is an active type restoration circuit consisting of Q31-Q38. The restoration rate (HI or LO) is determined by the value of the input coupling capacitor (C66 for LO and C65 in series with C66 for HI). When S11 is placed to the OUT position the BLR circuit is completely bypassed.

The two microsecond delay line can be either bypassed or inserted in series with the signal path by switch S10. When the delay line is connected in the circuit it is terminated in its characteristic impedance on both ends.

Switch S9 permits Amplifier A5 to be used as an inverting or non-inverting amplifier to provide a positive or negative unipolar output. A5 output range is controlled by changing the value of the feedback resistor between pins 7 and 10. These resistors were selected to provide 3, 6 or 10 volts, selected by S6, for the positive output. Due to the different gain network for the negative output, a range of approximately -5.5, -7.5 and -10 volts is obtained. A front panel mounted potentiometer (R99) permits adjustment of the Unipolar Output dc level between ±1.0 volts. Transistors Q39 and Q40 limit the output current and provide short circuit protection for the Unipolar Output.

6. MAINTENANCE

6.1 Test Equipment Required

In order to adequately test the specifications of the ORTEC 451, the following equipment should be utilized:

1. ORTEC 419 Precision Pulse Generator
2. Tektronix Model 547 Series Oscilloscope with a Type 1A1 Plug-In or equivalent.
3. Hewlett-Packard 400D RMS Voltmeter

6.2 Pulser Modifications for Overload Tests

Since the 451 incorporates variable pole-zero cancellation, factory adjusted to 50μsec, the input should have a specified decay time (50μsec). When either the ORTEC 419 or 204 Pulse Generator is used to check overload, it should be modified as shown in Figure 6-1, and the pole-zero cancellation adjusted to compensate for the fall time of the pulse generator.

If the pulser output is fed into a charge sensitive preamp such as the ORTEC 109A or 118A, through a small capacitor to simulate the output of a semiconductor detector, the decay time of the pulser will cause an additional pole in the transform equation of the preamplifier output. This additional pole will degrade any overload measurements. In order to eliminate the pole, the pulser must be pole-zero cancelled as shown in Figure 6-2.

6.3 Pulser Tests

6.3.1 Functional Checks

a. Set the 451 controls as follows:

Coarse Gain	2K
Fine Gain	1.5
Input Polarity	POS
Output Polarity	POS
Shaping Time Constant	1μsec
Output Range	10V
Delay	OUT
BLR	OUT

b. Connect a positive pulser to the 451 as shown in Figure 6-1 and adjust the pulser to obtain 10V at the 451 Unipolar Output. This should require an input pulse of 3.3 mV. The Bipolar Output should also be 10V.

c. Monitor the Unipolar Output and change the Output Range switch to 3V, 6V and then return to 10V. The Unipolar Output should have changed to 3V and 6V while the Bipolar Output remained at 10V.

d. Place the Delay switch to the IN position. The Unipolar pulse should be delayed 2μsec from its original position. Return the Delay switch to OUT.

e. Place the Unipolar Output Polarity switch to NEG and then back to POS while monitoring the Unipolar Output for an inversion.

f. Change the Input Polarity switch to NEG and then back to POS while monitoring the outputs for a polarity inversion.

g. Monitor the Unipolar Output dc level and ensure that the output will vary at least ±1.0V with the DC ADJ. Reset to zero volts.

h. Obtain a 10 volt output with maximum gain. Decrease the Coarse Gain switch step wise from 2K to 5 and ensure that the output amplitude changes by an appropriate amount. Return the Coarse Gain switch to 2K.

i. Decrease the Fine Gain to 0.5 and the output should decrease by a factor of 3. Return the Fine Gain control to maximum.

j. The shaping time constant (τ) should be set at 1μsec and the time to the peak of the Unipolar pulse should be 2 τ (2μsec). Change the shaping time constant to 0.5 and 2μsec and check to see that the time to the peak of the Unipolar pulse is 2 τ for each time constant. Return to 1μsec shaping time constant.

6.3.2 Overload Tests

a. Set the gain to maximum and τ = 1μsec and obtain a 10 volt output. Increase the pulser amplitude by x200 and observe that the Unipolar Output returns to within 200 mV of the baseline within 17μsec. 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 return to the baseline.

b. Increase the pulse amplitude by x1000 above the 10V setting and observe that the Bipolar Output returns to within 200 mV of the baseline within 25μsec. An external voltage source to the pulser may be required in order to obtain an approximate 3.3 volt pulser output on x1000 overload.

6.3.3 Linearity

The integral nonlinearity can be measured by the technique shown in Figure 6-3. In effect, the negative pulser output is substracted from the positive amplifier output causing a null point which can be measured with high sensitivity. The pulser amplitude must be varied between 0 and 10 volts (using an external voltage source for the pulser) and the amplifier gain and pulser attenuator must be adjusted to give zero voltage at the null point with a 10-volt output. The variation in the null point as the pulser is varied from 10 volts to zero is a measure of the nonlinearity. Since the subtraction network also acts as a voltage divider, this variation must be less than: (10V Full Scale) x (±0.05% Max Nonlinearity) x (1/2 for Divider Network) = ±2.5 mV Max Null Point Variation.

6.3.4 Output Loading

With the same setup as in Section 6.3.3, adjust the amplifier output to 10 volts and observe the null point change when the output is terminated in 100 ohms. The change should be less than 5 mV.

6.3.5 Noise

Measure the noise at the amplifier output at maximum amplifier gain and 1μsec shaping time constant using the RMS voltmeter for single and double clipping. The noise should be less than:

5μV x 3000 gain/1.13 = 13.3 mV for single clipping, and
8μV x 3000 gain/1.13 = 21.2 mV for double clipping.

The 1.13 is a correction factor for the average reading voltmeter and would not be required for a true rms voltmeter. Both inputs must be terminated in 100 ohms for this measurement.

6.3.6 Crossover Walk with Amplifier (Amplifier and SCA)

With the setup of Figure 6-4, obtain a 10 volt amplifier output at an amplifier coarse gain of 20. Attenuate the pulser by x10 using only the pulser attenuator switches. The shift in the 420A should be less than ±2 nsec. The "Walk Adj" trimpot on the 420A must be adjusted properly in order to make this measurement.

6.3.7 Crossover Walk with Amplitude (Amplifier Only)

The crossover walk of the amplifier only can be measured with the setup shown in Figure 6-5. The 421 Integral Discriminator (or any other leading edge discriminator) and the 416 Gate and Delay Generator are used to delay the trigger of the oscilloscope so the crossover of the amplifier can be viewed on the shortest time scale of the oscilloscope (10 nsec/cm). Two identical high frequency attenuator pads must be used for this measurement (the 419 Pulser attenuator can be used if the attenuator of another 419 Pulser is used for the other attenuator). The pulser and amplifier gain are adjusted so that there is an 8 to 10 volt bipolar output at the oscilloscope with the first attenuator having x20 attenuation and the second attenuator having no attenuation. Observe the crossover on the oscilloscope and remove the x20 attenuation from the first and add it to the second attenuator. The crossover walk under these conditions should be less than ±1 nsec.

6.3.8 Counting Rate Changes

Resolution spread and amplitude changes with counting rate can be measured with the setup shown in Figure 6-6. Pulser pulses are mixed at the amplifier input with preamplifier pulses from a ^{137}Cs source and the delayed mixed output is fed to a 426 Linear Gate. A 421 Integral Discriminator and a 416 Gate and Delay Generator are used to open the linear gate at the proper time to accept a shaped pulser pulse from the amplifier delayed output. Adjust the Amplifier gain so the ^{137}Cs peak will store at about the 70% level (≈ channel 2900 in a 4096 Analyzer) in the pulser height analyzer, and then adjust the pulser amplitude to store at the 84% level (≈ channel 3450 in a 4096 analyzer). Change the ^{137}Cs source position until the counting rate as measured by the scaler and timer is approximately 50,000 cts/sec. Two spectra are then accumulated, one with the ^{137}Cs source present and one with the ^{137}Cs source removed. Using a 1±sec shaping time constant the pulser peak in the ^{137}Cs source present spectrum for 4096 Analyzer should be shifted no more than 0.2% (7 channels as compared to the pulser only spectrum. Refer to Figure 4-18 through 4-20 for resolution effects versus count rate at various shaping time constants and restoration rates).

6.4 Suggestions for Troubleshooting

6.4.1 In situations where the 451 is suspected of malfunction, it is essential to verify such malfunction in terms of simple pulse generator impulses at the input. The 451 must be disconnected from its position in any system, and routine diagnostic analysis performed with a test pulse generator and oscilloscope. It is imperative that testing not be performed with a source and detector until the amplifier performs satisfactorily with the test pulse detector.

The testing instructions in Section 6.3 of this manual and the circuit descriptions in Section 5 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 with a minimal chance of accidentally short-circuiting portions of the etched board.

The 451 may be returned to ORTEC for repair service at nominal cost. The standardized procedure requires that each repaired instrument receive the same extensive quality control tests that a new instrument receives.

6.4.2 Possible Problem Solutions

a. Problem: Unable to get an output pulse

Solution: Reposition all slide switches. It is possible to get a slide switch in an intermediate position where it will not make contact, thereby preventing an output.

b. Problem: Unable to get a 10V pulse on the Unipolar Output

Solution: Place the Unipolar Output range switch to 10V.

c. Problem: Unipolar Output pulse is distorted and limited at 2-3V in amplitude.

Solution: Change the input polarity switch to the opposite polarity if the BLR switch is in the HI or LO position. The pulse entering the BLR circuit must be the proper polarity to prevent distortion.

6.5 Tabulated Test Point Voltages on Etched Board

The following voltages are intended to indicate the typical dc voltages measured on the etched circuit board. In some cases the circuit will perform satisfactorily even though, due to component variation, there may be some voltages that measure different from the given values. Therefore, the voltages given should not be taken as absolute values, but rather are intended to serve as an aid in troubleshooting.

Table 6.1 Typical DC Voltages

NOTE: All voltages measured with no input and input terminated in 100Ω. Input switch is DC-coupled and all pots fully clockwise.

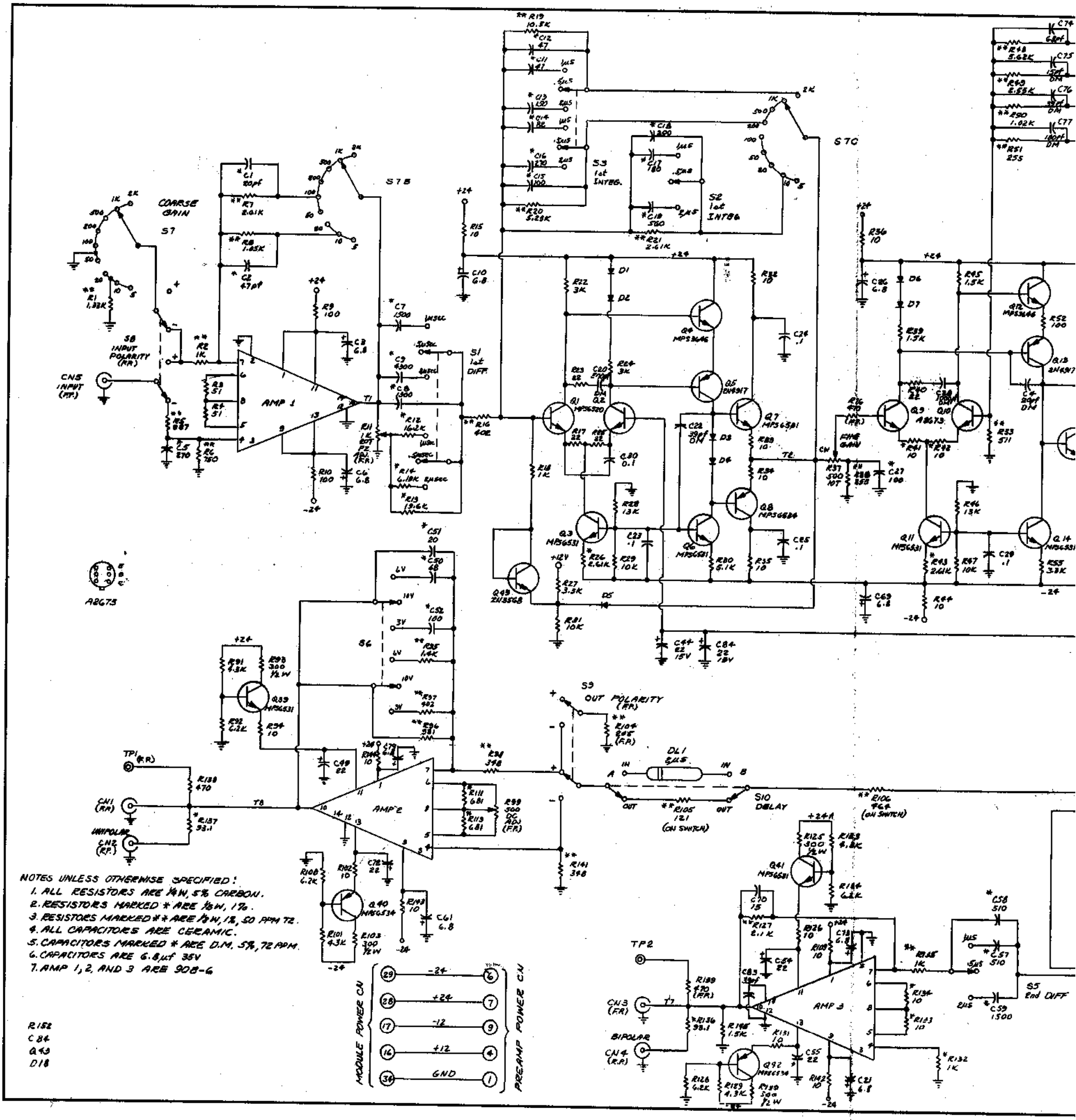
LOCATION	VOLTAGE	LOCATION	VOLTAGE
A1 pin 4	0V	Q23C	+0.6V
pin 7	0V	T5	0V
pin 10	0V	T4	0V
Q1B	0V	Q29B	0V
Q2B	0V	Q29C	+5.6V
Q2C	+17.4V	Q30B	0V
Q3B	-13.9V	Q30C	+5.6V
Q5C	+0.6V	Q31B	+6V
T-2	0V	T6	0V
Q9B	0V	Q34B	-12V
Q9C	+19.8V	Q39B	+14.2V
Q10B	0V	Q40B	-14.0V
Q10C	21.4	Q41B	+14.2V
		Q42B	-14.0V
Q11B	-13.8V	A2 pin 4	0V
Q13C	0V	pin 7	0V
T3	0V	pin 10	0V
Q19B	0V	A3 pin 4	0V
Q19C	+18.5V	pin 7	0V
Q20B	0V	pin 10	0V
Q20C	+17.1V		
Q21B	-13.7V		

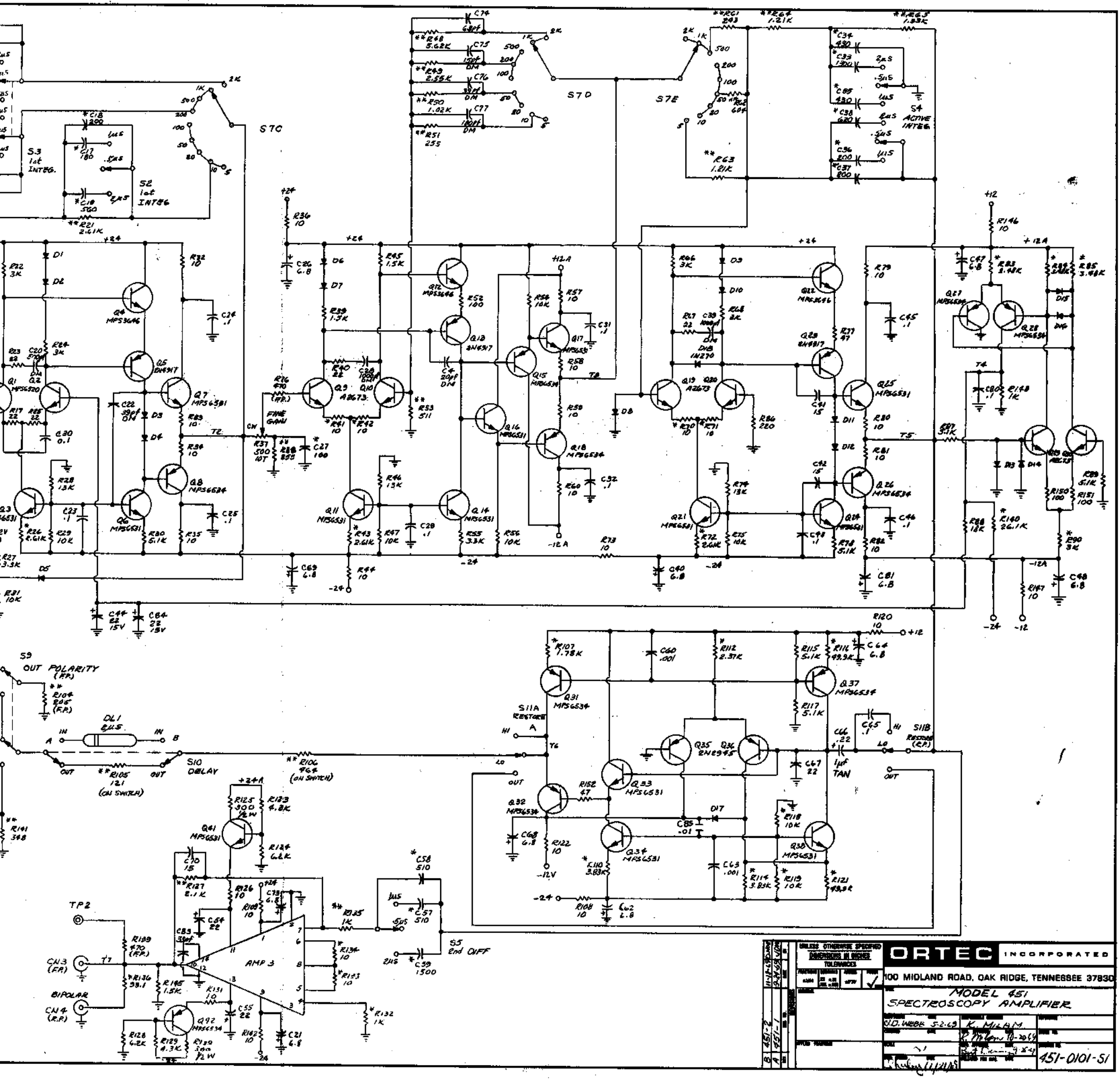
BIN/MODULE CONNECTOR PIN ASSIGNMENTS
FOR AEC STANDARD NUCLEAR INSTRUMENT MODULES
PER TID-20893

Pin	Function	Pin	Function
1	+3 volts	23	Reserved
2	- 3 volts	24	Reserved
3	Spare Bus	25	Reserved
4	Reserved Bus	26	Spare
5	Coaxial	27	Spare
6	Coaxial	*28	+24 volts
7	Coaxial	*29	- 24 volts
8	200 volts dc	30	Spare Bus
9	Spare	31	Carry No. 2
*10	+6 volts	32	Spare
*11	- 6 volts	*33	115 volts ac (Hot)
12	Reserved Bus	*34	Power Return Ground
13	Carry No. 1	35	Reset
14	Spare	36	Gate
15	Reserved	37	Spare
*16	+12 volts	38	Coaxial
*17	- 12 volts	39	Coaxial
18	Spare Bus	40	Coaxial
19	Reserved Bus	*41	115 volts ac (Neut.)
20	Spare	*42	High Quality Ground
21	Spare	G	Ground Guide Pin
22	Reserved		

**These pins are installed and wired in parallel in the ORTEC 401A Modular System Bin.*

The transistor types installed in your instrument may differ from those shown in the schematic diagram. In such cases, necessary replacements can be made with either the type shown in the diagram or the type actually used in the instrument.


COARSE GAIN
S7
S7B
S7C
S8 INPUT POLARITY (FR)
CN5 INPUT (FR)
AMP 1
S1 1st DIFF
S3 1st INTEG.
S2 1st INTEG.
AMP 2
S6
S9 OUT POLARITY (FR)
DL1
S10 DELAY
TP1 (FR)
CN1 (FR)
UNIPOLAR CN2 (FR)
A8673
TP2
CN3 (FR)
BIPOLAR CN4 (FR)
AMP 3
S5 2nd DIFF
FINE GAIN
NOTES UNLESS OTHERWISE SPECIFIED:
1. ALL RESISTORS ARE ¼W, 5% CARBON.
2. RESISTORS MARKED * ARE ⅛W, 1%.
3. RESISTORS MARKED ** ARE ⅛W, 1%, 50 PPM TC.
4. ALL CAPACITORS ARE CERAMIC.
5. CAPACITORS MARKED * ARE D.M. 5%, 72 PPM.
6. CAPACITORS ARE 6.8µf 35V
7. AMP 1, 2, AND 3 ARE 908-6
R152
C84
Q43
D18
MODULE POWER CN
PREAMP POWER CN
-24
+24
-12
+12
GND


ORTEC INCORPORATED
100 MIDLAND ROAD, OAK RIDGE, TENNESSEE 37830
MODEL 451
SPECTROSCOPY AMPLIFIER
451-0101-S1
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES
S7C
S7D
S7E
S4 ACTIVE INTEG.
S3 1st INTEG.
S2 1st INTEG.
S9 OUT POLARITY (F.P.)
S10 DELAY
DL1
S11A RESTORE
S11B RESTORE (F.P.)
S5 2nd DIFF
AMP 3
TP2
CN3 (F.P.)
BIPOLAR
CN4 (R.P.)
FINE GAIN