INSTRUCTION MANUAL
450
RESEARCH AMPLIFIER

Serial No. ______________________________

Purchaser ______________________________

Date Issued ______________________________

ORTEC
INCORPORATED
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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.

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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.

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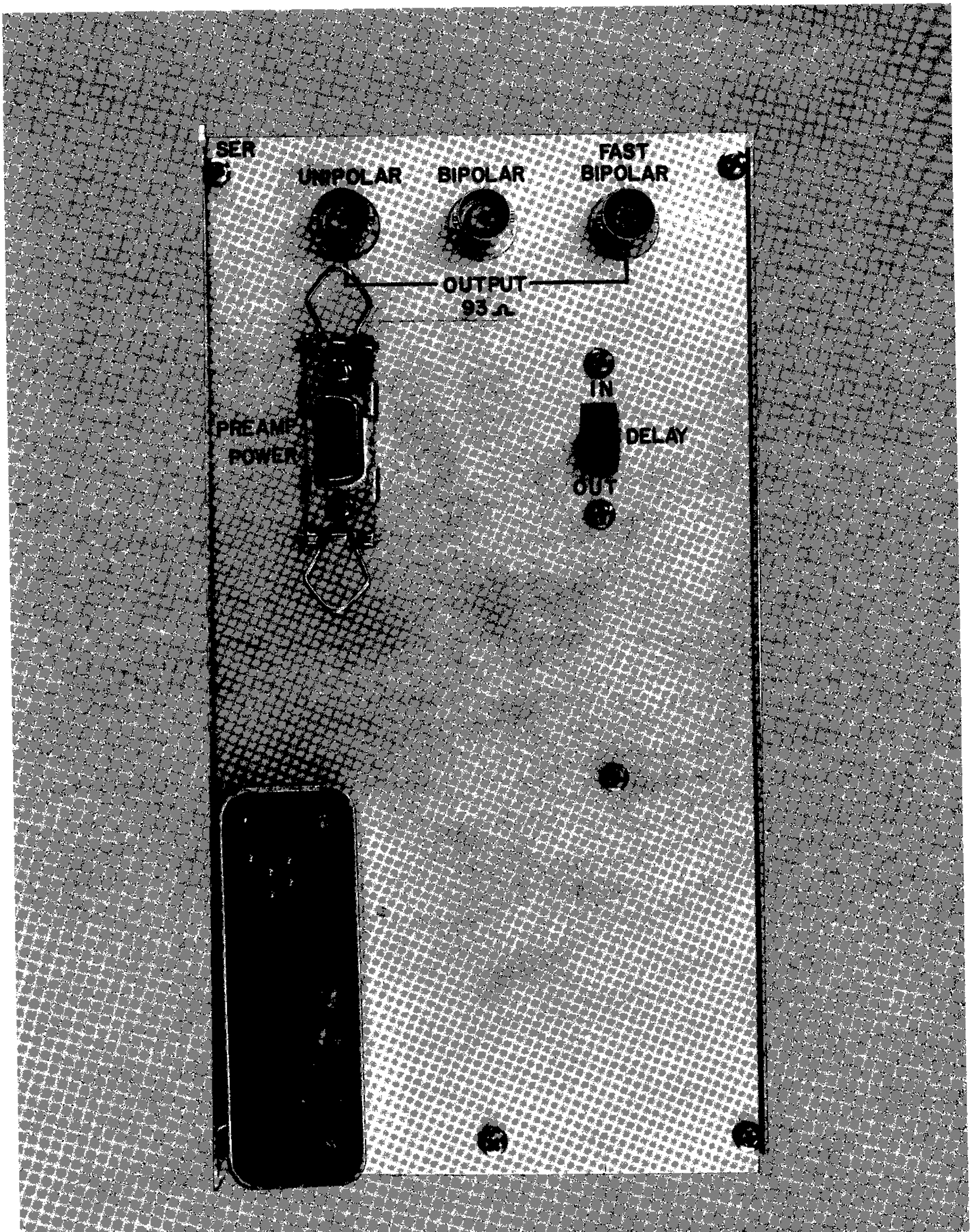
Shipments should be examined immediately upon receipt for evidence of external or concealed damage. The carrier making delivery should be notified immediately of any such damage, since the carrier is normally liable for damage in shipment. Packing materials, waybills, and other such documentation should 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.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BIPOLAR
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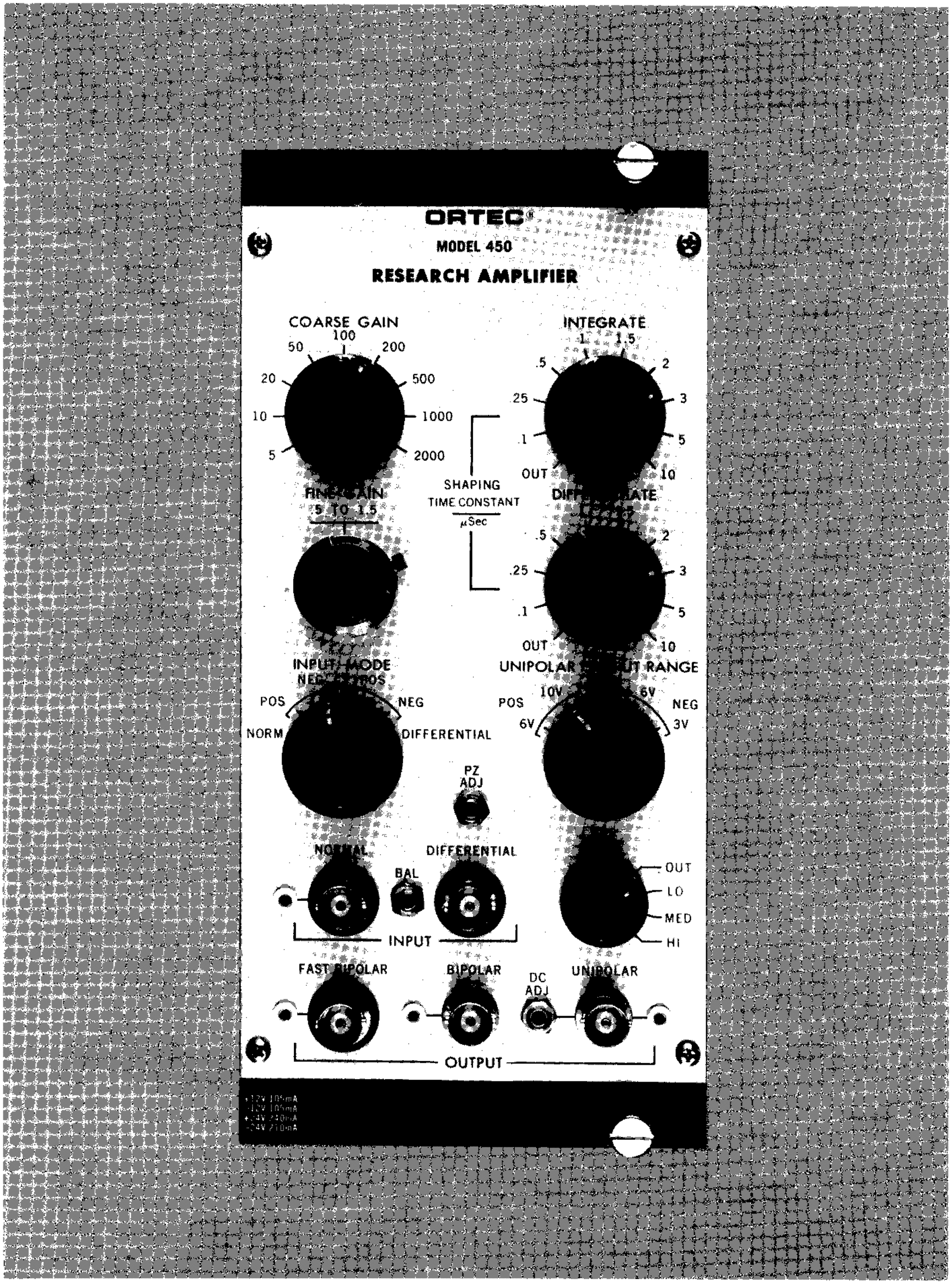
ORTEC®
MODEL 450
RESEARCH AMPLIFIER
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UNIPOLAR
OUTPUT

ORTEC 450 RESEARCH AMPLIFIER

1. DESCRIPTION

1.1 General

The ORTEC 450 Research Amplifier is an extremely versatile instrument module, intended for use with all pulse-type radiation detectors and preamps and also for linear amplification of any frequency spectrum within the design limits of the amplifier. The unit exhibits superior performance for overload recovery, resolution, linearity, and stability and has a very low noise.

Its many features provide a wide flexibility in applications. The amplifier may be operated with single-ended or differential input with either polarity, and the differential mode is especially useful when common mode noise is present. The low frequency bandpass has a selectable range from 100Hz to 1.5MHz, while the high frequency bandpass has a separately selectable range from 8kHz to 1.5MHz. The switchable time constant choices have been selected for optimization of nuclear spectrometry systems.

The 450 produces three different types of linear output pulses. The Fast Bipolar Output is a fixed bandwidth pulse with rise time of 150 nsec. It is normally doubly differentiated for a zero crossover point at approximately 700 nsec. In the wide band mode, the bandwidth extends from 100Hz to above 2.0MHz. The gain range from input to Fast Bipolar Output is 2.5 to 3000, directly readable on Front Panel Gain selection.

The Bipolar output has a selectable pulse shape, using both the Integrate and Differentiate time constant selections. When the wide-band mode is used, bandpass through this output is from 100Hz to 1.0MHz.

The Unipolar output has a selectable pulse shape for optimum filtering, baseline restoration (switch selectable) for low frequency noise reduction and improved count rate performance, polarity, and -3V, ±6V, or ±10V range voltage selection to interface all analyzer coupling ADC requirements, and can be delayed to simplify gating of the signal. When the wide-band mode is used, the bandpass through the Unipolar output is from 100Hz to 1.5MHz, and the gain range is from 4 to 5000. Unipolar BLR, polarity, range and delay are independent of Fast Bipolar and Bipolar Outputs.

Semi-Gaussian shaping by the active filter network optimizes the signal to noise ratio. The relative input noise, using a 3μsec time constant, is less than 3.5μV RMS. Noise varies approximately inversely as the square root of the time constant. For a gain of 50 or more, input noise is independent of the gain setting.

The 450 Fast Bipolar and Bipolar Outputs can be used for crossover timing when used in conjunction with the crossover circuit in an ORTEC 407 Crossover Pickoff unit or 420A Timing Single Channel Analyzer. The 420A output has a minimum 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.

The output impedance of the 450 is less than 0.1 ohm. The output can be connected to other equipment by either a single cable going to all equipment and shunt terminated at the receiving end (and series terminated at the amplifier if reflections are a problem) or separate cables for each instrument with each cable series terminated at the amplifier.

Gain changing is accomplished by changing the feedback ratio of operational amplifiers. In using this technique, the bandwidth of the feedback amplifier stages involved in gain switching is maintained essentially constant regardless of gain, and therefore rise time changes with gain switching (which cause crossover walk) are limited to small capacitive effects across the feedback resistors.

The Delayed output of the 450 is useful for experiments involving both energy analysis and coincidence timing. In this case, a timing signal for coincidence can be derived from the crossover of the Fast Bipolar or Bipolar Output. Energy analysis is performed on the output of either the Unipolar or Bipolar signal, and the delay time compensates for the time loss in crossover timing and time delays in the coincidence circuit. When using the Fast Bipolar Output for timing, the delay may not be necessary.

The 450 is contained in a three unit wide NIM standard module. The unit has no self-contained power supply; power is obtained from a NIM standard Bin and Power Supply, such as the ORTEC 401A/402A. The 450 design is consistent with other modules in the ORTEC 400 Series, i.e., it is not possible to overload the bin power supply with a full complement of modules in the Bin.

1.2 Pole-Zero Cancellation

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

$$\frac{\text{Undershoot Amplitude}}{\text{Clipped Pulse Amplitude}} = \frac{\text{Clipping Time}}{\text{Preamplifier Pulse Decay Time}}$$

For a 1μsec clipping time and a 50μsec preamplifier pulse decay time, the maximum 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. The 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 $\left(S + \frac{K}{R_2C_1}\right)$ of the network. In effect, the dc path across the clipping 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 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 35μsec 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 450 and can be adjusted easily by observing the baseline under overload conditions with a monoenergetic source or pulser having the same decay time as the preamplifier input.

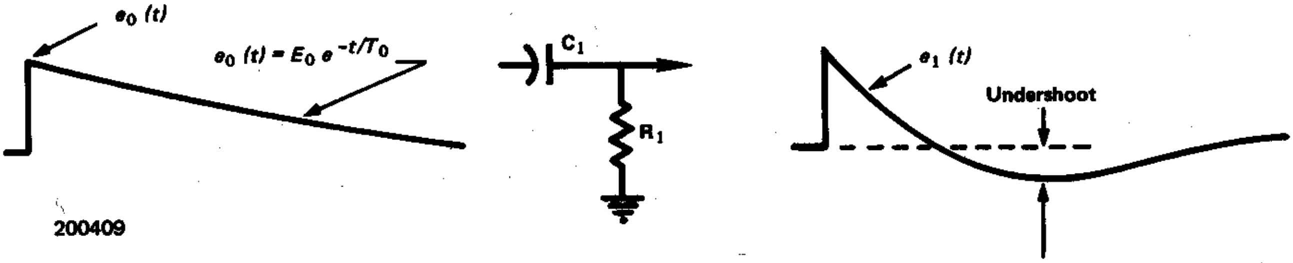
1.3 Active Filter

When only grid current and shot noise (gate current and drain thermal noise for an FET) are considered, the best signal-to-noise ratio occurs where the two noise contributions are equal for a given pulse shape. Also at this point, there is an optimum pulse shape for the optimum signal-to-noise ratio. Unfortunately, this shape (the Cusp shown in Figure 1-3) is very difficult to simulate. A pulse shape that can be simulated (the Gaussian in Figure 1-3) requires a single RC differentiate and n equal RC integrates where n approaches infinity. The Laplace transform of this transfer function is:

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

where the first factor is the single differentiate and the second factor is the n integrates. The 450 Active Filter attempts to simulate this transfer function with the simplest possible circuit.

The ORTEC 450 Active Filter is shown in Figure 1-4, together with the equations which define its transfer function. This is an RC filter network, eliminating inductive elements and achieving the desired results with a significant reduction of size, complexity, and cost.



Charge loop output x First clipping network = Clipped pulse with undershoot

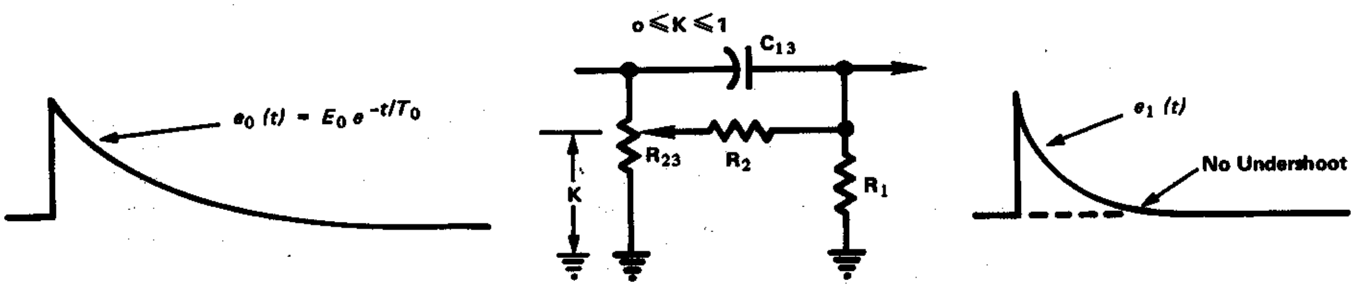
Equations:

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

$$E_0 \frac{1}{S + 1/T_0} \times \frac{S}{S + 1/R_1C_1} = e_1(S); \text{ Laplace transform}$$

$$\frac{E_0}{T_0 - T_1} \quad T_0 e^{-t/T_1} - T_1 e^{-t/T_0} = e_1(t); \; T_1 = R_1C_1$$

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



Charge loop output x Pole-zero cancelled clipping network = Clipped pulse without undershoot

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

$$E_0 \frac{1}{(S + 1/T_0)} \times \frac{S + \frac{K}{R_2C_1}}{S + \frac{R_1 + R_2}{R_1R_2C_1}} = e_1(s); \text{ Laplace transform}$$

Pole zero cancel by letting $S + \frac{1}{T_0} = S + \frac{K}{R_2C_1}$ or:

$$\frac{E_0}{S + \frac{R_1 + R_2}{R_1R_2C_1}} = \frac{E_0}{S + \frac{1}{R_pC_1}} = e_1(s), \text{ where } R_p = \frac{R_1R_2}{R_1 + R_2}$$

$$E_0 e^{-t/R_pC_1} = e_1(t)$$

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

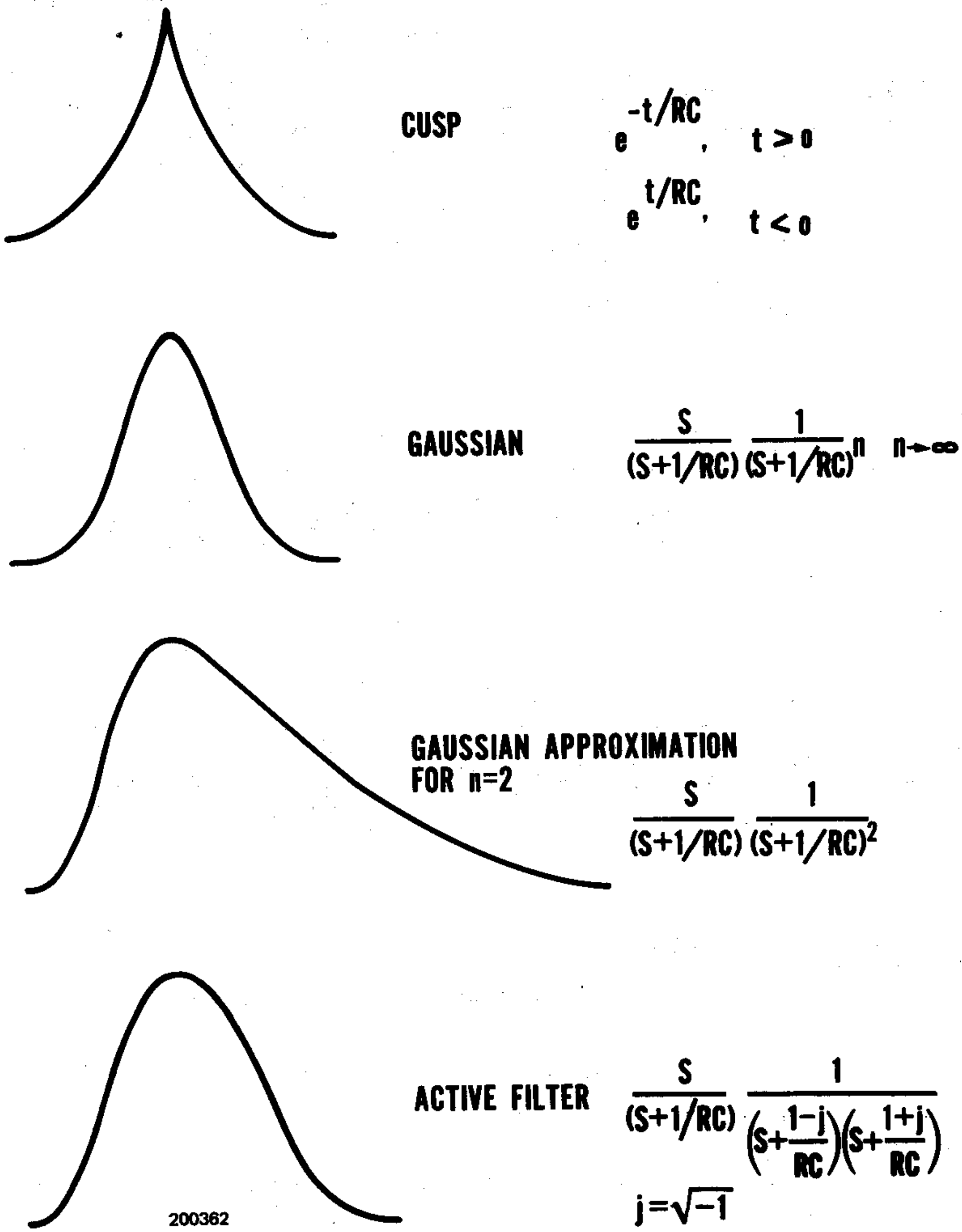
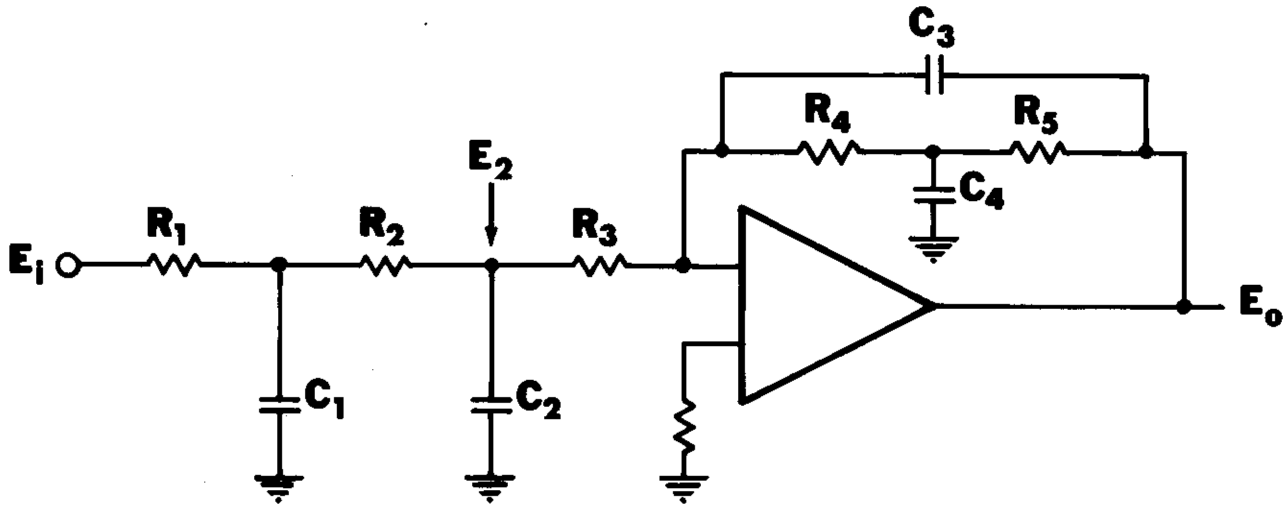


Figure 1-3. Pulse Shapes for Good Signal-to-Noise Ratios



Equations:

$$\frac{E_2}{E_i} = \frac{1}{\left(R_2 C_2 S + \frac{R_2}{R_3} + 1\right)\left(R_1 C_1 S + \frac{R_1}{R_2} + 1\right)}$$

$$\frac{E_o}{E_2} = \frac{R_5 C_4 S + R_5/R_4 + 1}{R_3 \left[R_5 C_3 C_4 S^2 + C_1 \left(\frac{R_5}{R_4} + 1\right) S + \frac{1}{R_4} \right]}$$

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In the 450

$C_1 = C_2$ **and** $R_4 = R_5$ **and** $R_1 = R_3$

Figure 1-4. ORTEC 450 Active Filter

The 450 is designed with independent switch selectable integrate and differentiate time constants of 0.1, 0.25, 0.5, 1.0, 1.5, 2, 3, 5, and 10μsec.

1.4 Baseline Restorer

All stages of the 450 are designed to operate with equal efficiency with either polarity pulse to ±10 volts, or a full 20 volt peak-to-peak sine wave. The Baseline Restorer circuit restores only for positive pulses, and an input polarity switch is included on the front panel for that purpose.

2. SPECIFICATIONS

INPUT	Positive or negative, normal or differential through front panel BNC connectors; ±12V max; each input impedance is 1000Ω, dc-coupled, with no limit on signal shape. For pulse operation the fall time constant should be >35 μsec. Common mode rejection ratio is ⩾1000:1 at greater than 1 μsec time constant, ⩾10,000:1 at 60 Hz
OUTPUTS	All outputs are on both front and rear panels. $Z_0 \leqslant 1\Omega$, front panel, provides ±10V into 100Ω load. $Z_0 = 93\Omega$, rear panel. All are dc-coupled, and short circuit and duty cycle protected.
FAST BIPOLAR OUTPUT	Bipolar; t_r ~120 nsec, gain 2.5 to 3000; crossover walk ⩽±2 nsec for 50:1 dynamic range; with Differentiate Out, fixed bandwidth is 100 Hz to >2 MHz, gain 2.5 to 3000
BIPOLAR OUTPUT	Bipolar, except when the Differentiate selector is set at Out and $f_{lo} \approx 100$ Hz; otherwise, frequency response is determined by choice of Integrate and Differentiate time constants. The low frequency response is set by two equal Differentiate selected time constants
UNIPOLAR OUTPUT	Provides separate selection of polarity, delay, and gain (X1, X0.6, X0.3), as well as baseline restoration rate selection (Hi, Med, Lo, or Out), high and low frequency response are determined by selected Integrate and Differentiate time constant

PERFORMANCE

Gain Range	2.5 to 3000, for equal time constants, or 4.0 to 5000 for wide-band mode on Bipolar and Unipolar Outputs
Temperature Stability	0 to 50°C
Gain	⩽±50 ppm/°C of rated output
DC Level	⩽±50μV/°C
Input Noise	Using 3 μsec pulse shaping, ⩽3.5μV rms for gain settings >50, measured on Unipolar Output; ⩽16μV rms on Fast Bipolar Output
Integral Non-Linearity	
Fast Bipolar	Less than 0.2%
Unipolar	Less than 0.05%
Bipolar	Less than 0.05%
Overload Recovery	
Fast Bipolar	Recovery from 500X overload in approximately 8.0μsec.
Bipolar & Unipolar	Recovery from 500X overload in 2.5 non-overloaded pulse widths when PZ Adjust is correct
Filters	Pulses are shaped by Active element, with independent Integrate (Low-pass) and Differentiate (High-pass) selection

CONTROLS

COARSE GAIN	Nine-position front panel switch, for gain factors of X5 through X2000
FINE GAIN	Ten-turn precision potentiometer, for continuously variable gain factors from X0.5 to X1.5. Product of Coarse gain and Fine gain settings yields total gain for equal time constants
PZ ADJ.	Front panel screwdriver adjustment to optimize the amplifier to the preamp; adjustable from 35 μsec to dc
INPUT MODE	Front panel switch selects Normal or Differential input, and polarity
BAL	Front panel screwdriver adjustment to obtain optimum common mode rejection, and to equalize the POS. polarity gain
UNIPOLAR OUTPUT RANGE	Front panel switch selects polarity and gain (X1, X0.6, or X0.3) of the Unipolar Output
INTEGRATE	Low-pass filter time constant selector, front panel switch; choices are 0.1, 0.2, 0.5, 1.0, 1.5, 2.0, 3.0, 5.0, and 10.0 μsec, and Out
DIFFERENTIATE	High-pass filter time constant selector, front panel switch; choices are 0.1, 0.2, 0.5, 1.0, 1.5, 2.0, 3.0, 5.0, and 10.0 μsec, and Out (for wide-band with $\tau_d \approx 3.5$ msec)
BLR	Front panel baseline restoration rate selector; Hi for duty cycles >20% Med for duty cycles >5% <20% Lo for duty cycles <5%, and Out
DC ADJ	Multi-turn screwdriver adjustment for Unipolar Output baseline; range ±1.0V
DELAY	Normally 1 μsec, selected In or Out by rear panel switch. Other delays are available upon request

CONNECTORS

FAST BIPOLAR	BNC, on front panel for $Z_o < 1\Omega$, and rear panel for $Z_o = 93\Omega$
BIPOLAR	BNC, on front panel for $Z_o < 1\Omega$, and rear panel for $Z_o = 93\Omega$
UNIPOLAR	BNC, on front panel for $Z_o < 1\Omega$, and rear panel for $Z_o = 93\Omega$
NORMAL INPUT	BNC on front panel
DIFFERENTIAL INPUT	BNC on front panel

PREAMP POWER	Standard ORTEC power connector for mating preamplifier; Amphenol type 17-10090; rear panel

POWER AND MECHANICAL

Power Required	+24V 240mA +12V 55mA -24V 220mA -12V 55mA
Shipping Weight	7.5 lbs (3.4 kg)
Net Weight	5.5 lbs (2.5 kg)
Dimensions	Standard triple width NIM module (4.05 x 8.714 inches) per AEC Report TID-20893 (Rev.)

3. INSTALLATION

3.1 General Installation Considerations

The 450, used in conjunction with a 401A/402A Bin and Power Supply, is intended for rack mounting, and therefore it is necessary to ensure that vacuum tube equipment operating in the same rack with the 450 has sufficient cooling air circulating to prevent any localized heating of the all-semiconductor circuitry used throughout the 450. The temperature of equipment mounted in racks can easily exceed 120°F (50°C) unless precautions are taken.

3.2 Connection to Preamplifier

The preamplifier output signal is connected to the 450 through the BNC connector labeled NORMAL INPUT. The input impedance seen at the input is 1000 ohms and is dc-coupled to ground; therefore, the output of the preamplifier must be either ac-coupled or have zero dc voltage under no signal conditions.

The 450 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 trim is accessible from the amplifier front panel. Adjustment is accomplished easily by using a monoenergetic source and observing the amplifier baseline after each pulse overload condition, adjusting the PZ ADJ. for minimum overshoot.

Preamplifier power of ±12V and ±24V is available on the preamp power connector, on the rear panel.

When using the 450 with a remotely located preamplifier (i.e., preamplifier-to-amplifier connection through 25 feet or more of coaxial cable), ensure that the characteristic impedance of the transmission line from the preamplifier output to the 450 input is matched. Since the input impedance of the 450 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.

Differential inputs of the 450 can be used simultaneously to reduce common mode noise picked up by long cables passing noise generating areas.[3,4] In this mode of operation, the preamplifier signal is connected to the NORMAL INPUT and a separate identical cable in intimate contact with the first cable (the use of Twinax cable is preferable) is connected from the preamplifier ground to the DIFF. INPUT. In order to balance the noise cancellation, it is sometimes necessary to insert a small variable resistor between the actual preamplifier ground and the center conductor of the second (ground signal) cable. In the event the output polarity of the amplifier pulse is negative, the polarity is reversed easily by the Input Mode selector.

3.3 Connection of Test Pulse Generator

3.3.1 Connection of Pulse Generator to the 450 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 450 as discussed in Section 3.2, and (2) the proper input signal simulation must be supplied 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 ORTEC 450

Since both inputs of the 450 have 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, a large series isolating capacitor is also required since the inputs to the 450 are dc-coupled to the first amplifier stage. The ORTEC 204 or the 419 Test

Pulse Generators are designed for direct connection. When either of these units is used, it should be terminated with a 100 ohm terminator at the amplifier input. (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 ORTEC 450 is factory adjusted for a 50μsec decay time to match ORTEC FET preamplifiers. When the tail pulser (such as the ORTEC 204 or 419) is connected directly to one of the amplifier inputs, the pulser should be modified to obtain a 50μsec decay time 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 pulser 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 450 contains no internal power supply and therefore must obtain power from a Nuclear Standard Bin and Power Supply such as the ORTEC 401A/402A. Turn off the bin power supply before 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; in this case, the power supply voltages should be checked after insertion of the modules. The ORTEC 401A/402A has test points on the power supply control panel to monitor the dc voltages.

3.5 Shaping Considerations

The shaping times on the ORTEC 450 amplifier are switch selectable in steps of 0.1, 0.25, 0.5, 1, 1.5, 2, 3, 5, and 10μsec. 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 therefore a shaping time of about four times the decay time constant of the scintillator is a reasonable choice (for NaI, a 1μsec shaping time is about optimum). For gas proportional counters, the collection time is normally in the 0.5 to 5μsec range and a 2, 3, or 5μsec shaping time will generally give optimum resolution. For silicon semiconductor detectors, a 1 or 2μsec shaping time, and for germanium detectors a 2 or 3μsec shaping time, will generally provide optimum resolution. When a charge sensitive preamplifier is used, the optimum shaping time will also be at the point of minimum output noise. Since the 450 maintains nearly constant gain for all shaping modes of equal time constants, the optimum shaping time can be obtained by using an rms voltmeter to monitor the output noise.

The 450 allows a choice of either unipolar or bipolar output. The bipolar output should be used when the analyzer system is ac-coupled and high counting rates are desired where noise or resolution is a secondary consideration. The unipolar output pulse should be used in applications where the best signal-to-noise ratio (resolution) is desired. This area is primarily high resolution spectroscopy using semiconductor detectors. Use of the unipolar output with baseline restoration will also give good resolution at higher counting rates.

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 1μsec) is used in coincidence experiments where the output must 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 Termination

The source impedance of the 0-10 volt standard linear outputs of most 400 Series modules is approximately 0.1 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 circuits. Paralleling several loads on a single output is therefore permissible while observing 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. The rear panel outputs are internally series terminated in 93Ω. 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 450 are dc-coupled with an output impedance of about 0.1 ohm. If the output is shorted with a direct short-circuit or the amplifier counting range exceeds 35% duty cycle, the output stage will limit the peak current output such that the amplifier will not be harmed.

4. OPERATING INSTRUCTIONS

4.1 Front Panel Controls

GAIN: A Course Gain switch and Fine Gain ten-turn locking precision potentiometer select the gain factor. For equal time constants, the gain is read directly; switch positions are 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). For wide band selection, gain to the Unipolar and Bipolar outputs is multiplied by an additional factor of 1.5.

If using unequal integrate and differentiate time constants the output pulse gain will be different from that read on the panel. For instance, with small differentiate time and large integrate time, the gain will be much smaller than normal; and conversely with large differentiate time and small integrate time, the gain will be much larger than that selected.

INPUT MODE: A selector switch, to accept linear inputs of either polarity through either the Normal or Differential input connector.

PZ ADJ: Control to set the Pole-Zero Cancellation for optimum matching to the preamplifier pulse decay characteristics. Range 35μsec to dc.

DIFFERENTIAL BAL: Trimpot control to obtain optimum common mode rejection for a differential input, and to match normal Pos. and Neg. gain.

SHAPING TIME CONSTANT: Two switches for independent selection of the Integrate and Differentiate time constants. Marked in μsec. Pulse shaping time constant selections are 0.1, 0.25, 0.5, 1, 1.5, 2, 3, 5, or 10μsec, and Out.

UNIPOLAR OUTPUT RANGE: Switch selects the polarity and gain for the Unipolar output only. Full scale voltage ranges are ±10V, ±6V, and −3V. Compatible with present and past generation analyzer ADC input requirements.

RESTORATION RATE (BLR): Switch, to select the Baseline Restorer function. Hi is for duty cycles >20%, Med. for 5 to 20%, and Lo is for duty cycles <5%. OUT disables the function.

DC ADJ: Controls the Unipolar Output dc level, with an offset range of ±1.0V.

4.2 Rear Panel Control

DELAY IN/OUT: A slide switch to determine whether Unipolar outputs will be delayed (In) or will be prompt (Out).

4.3 Front Panel Connectors (All Type BNC)

INPUT: Two connectors, used for either Normal or Differential input pulses. Each accepts either positive or negative input pulses, ±12V max, into 1000 ohms, dc-coupled. There is no limit on signal shape. The preamp pulse should have a decay time constant of greater than 35μsec for proper PZ cancellation.

OUTPUTS: Three connectors - one for each type of output, $Z_0 \leq 0.1\Omega$. Each output can provide up to ±10V, and it is dc-coupled and short circuit and duty factor protected for 350 mW max rms output power each (±35% duty cycle).

FAST BIPOLAR: Bipolar, positive portion leading, rise time <150 nsec, f_{lo} = 160 kHz, crossover at ~800 nsec, gain range 2.5 to 3000.

Crossover walk ≤±2 nsec for 20:1 dynamic range. Bandwidth 100 Hz to above 2 MHz with Differentiate Out.

BIPOLAR: Bipolar, with pulse shape selected by the Integrate and Differentiate switches. With Differentiate switch at OUT, bandpass is from 100 Hz to 1.0 MHz.

UNIPOLAR: This output features separate selection for full voltage range, polarity, and baseline restoration rate. The DC level is adjustable for offset to ±1.0V for the full 10V range. The Unipolar pulse shape is determined by the settings of the Integrate and Differentiate shaping time constant switches. Unipolar range, polarity and BLR and Delay are independent of FAST BIPOLAR and BIPOLAR Outputs. See Figure 4-1 for output pulse waveforms.

4.4 Rear Panel Connectors

OUTPUTS: Three type BNC connectors - one for each type of output. Same as the three Ouptut connectors described for the front panel, except $Z_o = 93\Omega$.

PREAMP POWER: Standard power connection for a mating ORTEC preamplifier, ±24V and ±12V.

4.5 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.

4.6 General Considerations for Operation with Semiconductor Detectors

4.6.1 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. (See typical pulse waveforms and time alignment Figure 4-1.)

(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.

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

4.6.2 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.

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

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

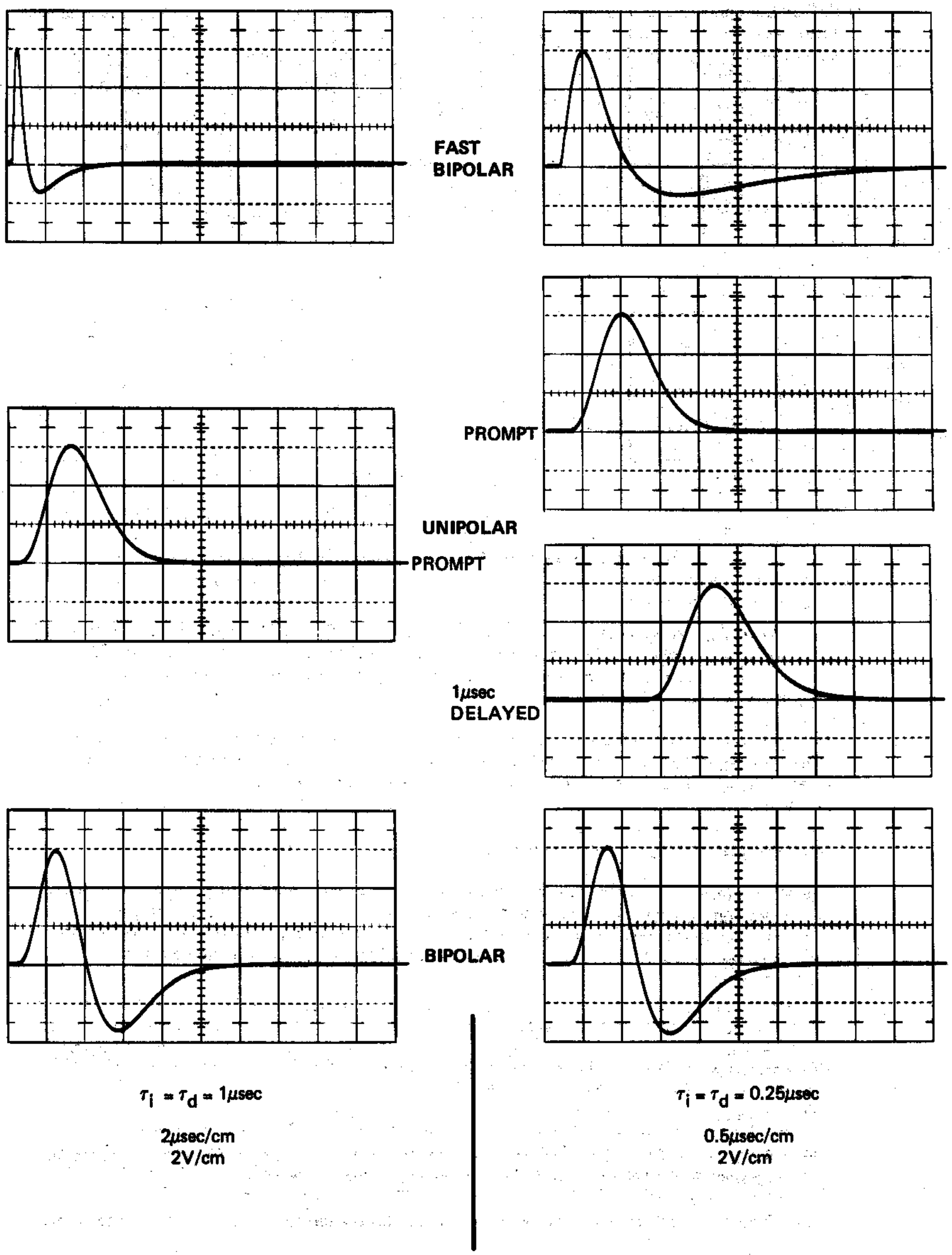


Figure 4-1. Pulse Waveforms and Time Alignment of the 450 Outputs

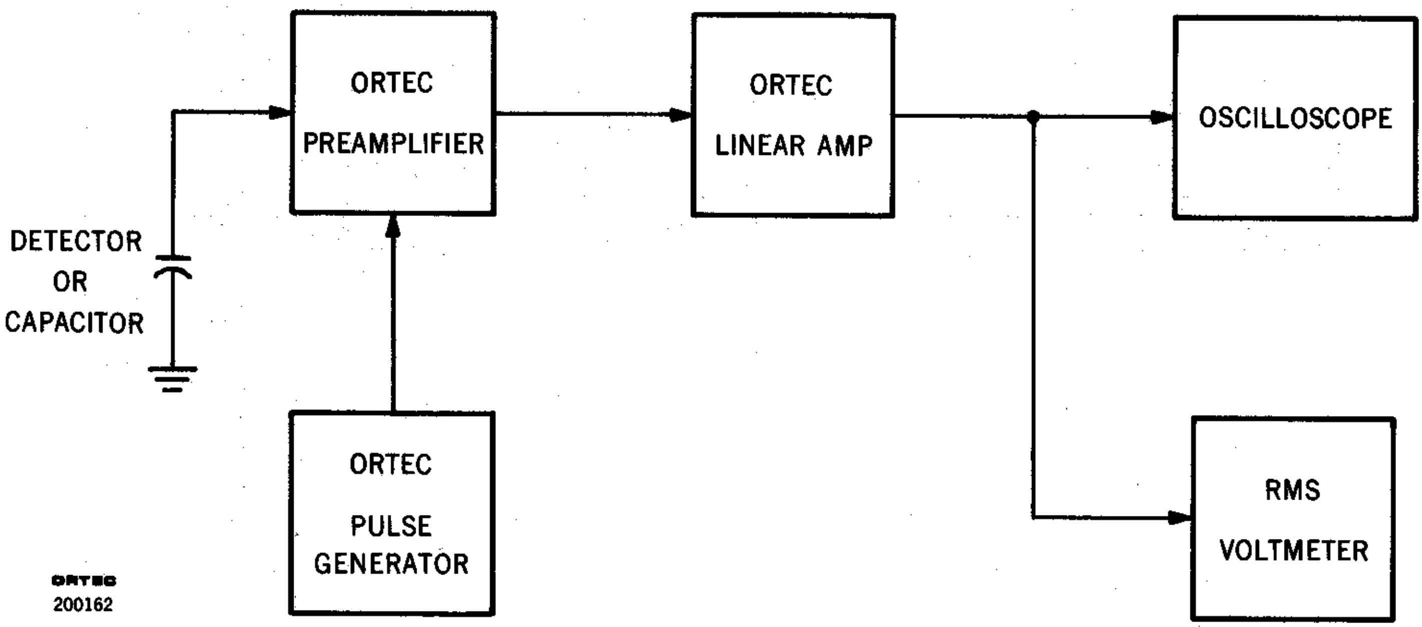


Figure 4-2. System For Noise and Resolution Measurements

where E_{dial} is the pulser dial reading in MeV and the factor 2.66 is the correction factor for rms to fwhm (2.35) 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 450 Amplifier are shown in Figure 4-3.

4.6.3 Detector Noise Resolution Measurements

The same measurement described in Section 4.6.2 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 semiconductor radiation detectors.

4.6.4 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 Active Filter 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 4.6.1).

(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 4.6.3. The detector noise will vary with detector size, bias conditions, and possibly with ambient conditions.

4.6.5 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 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.

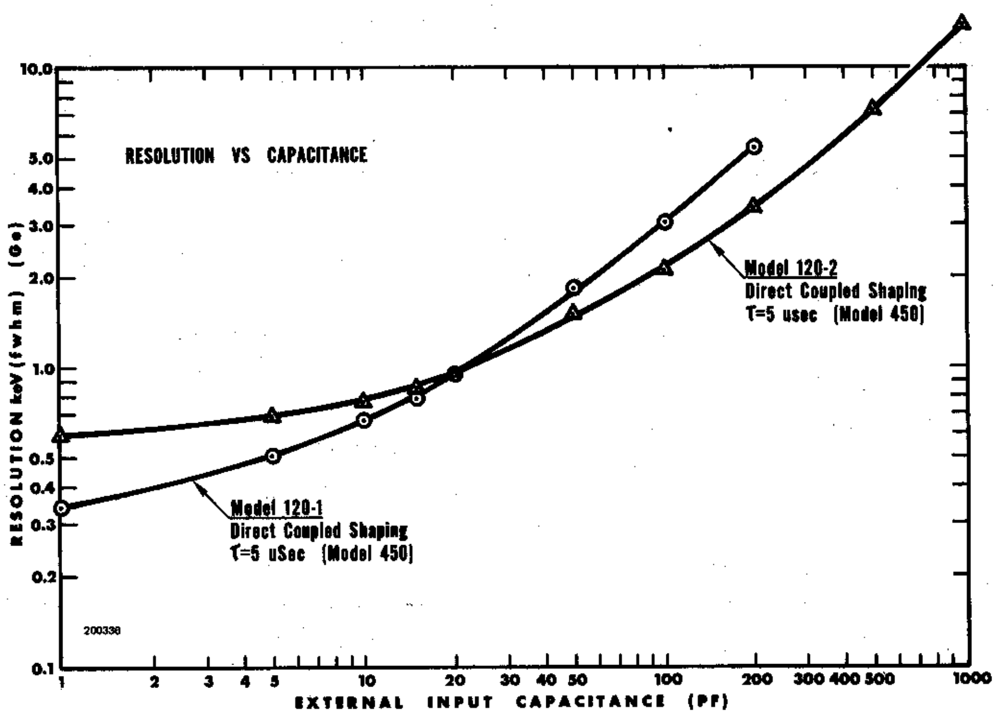


Figure 4-3. Resolution Effects of Capacitance

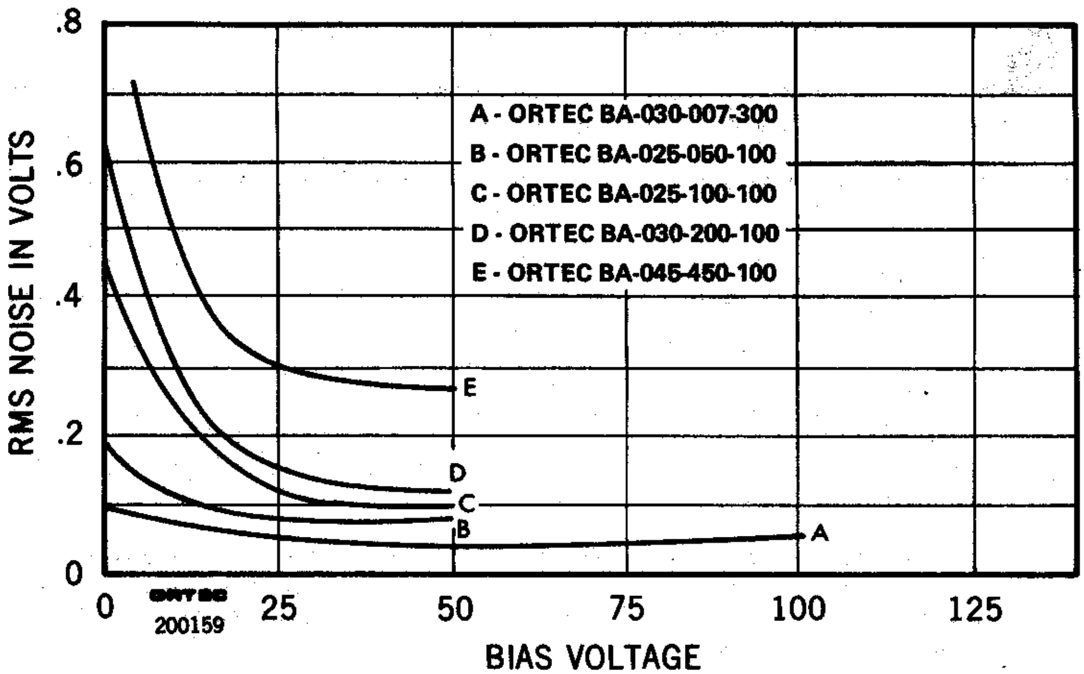


Figure 4-4. Noise as a Function of Bias Voltage

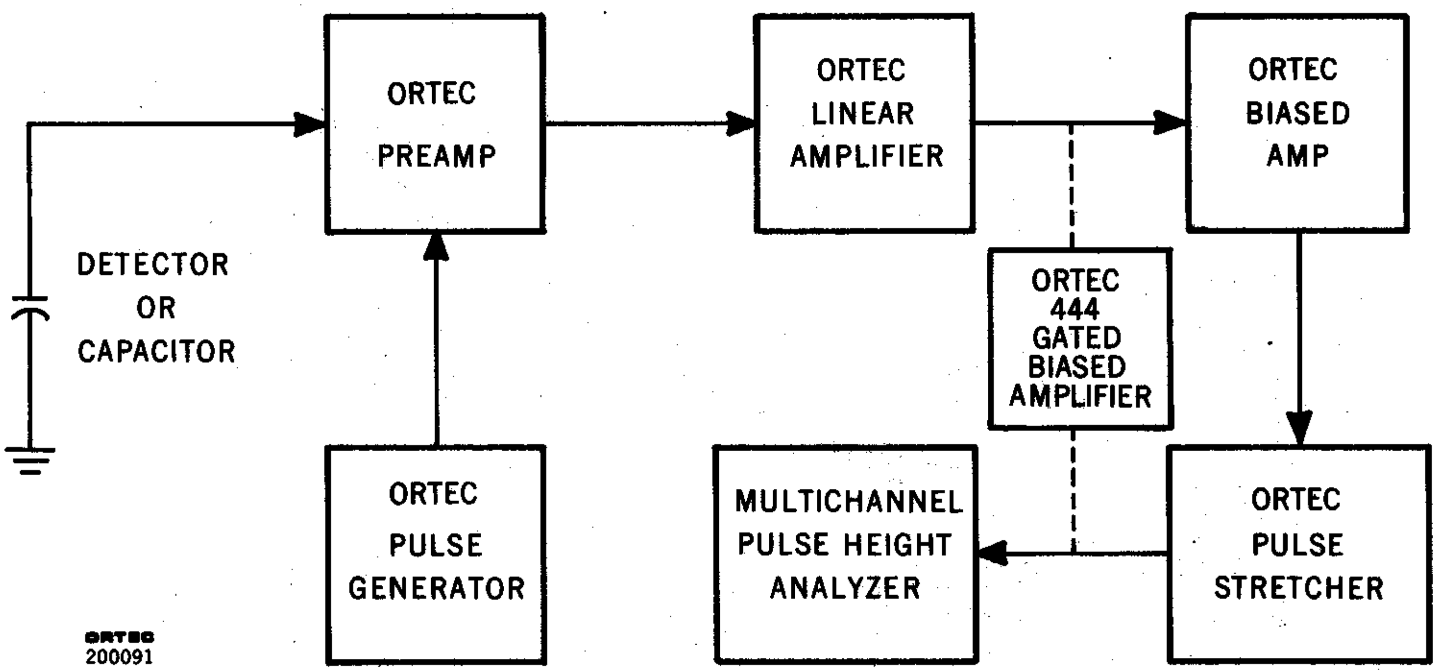


Figure 4-5. System For Measuring Resolution With a Pulse Height Analyzer

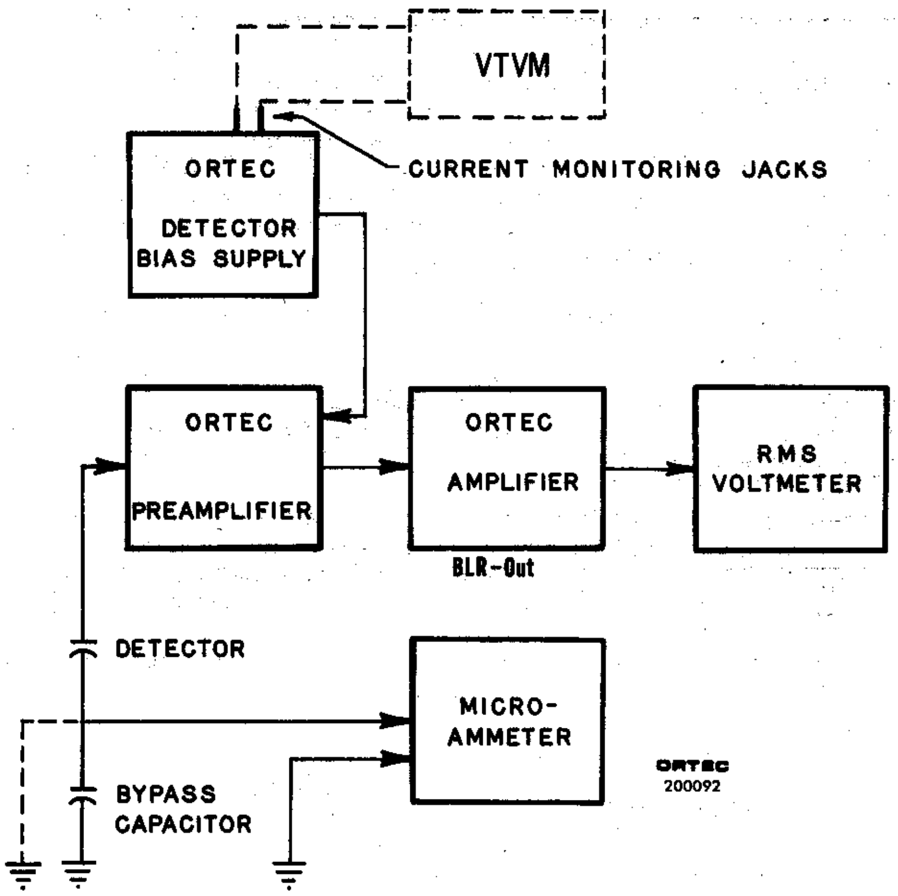


Figure 4-6. System For Detector Current and Voltage Measurements

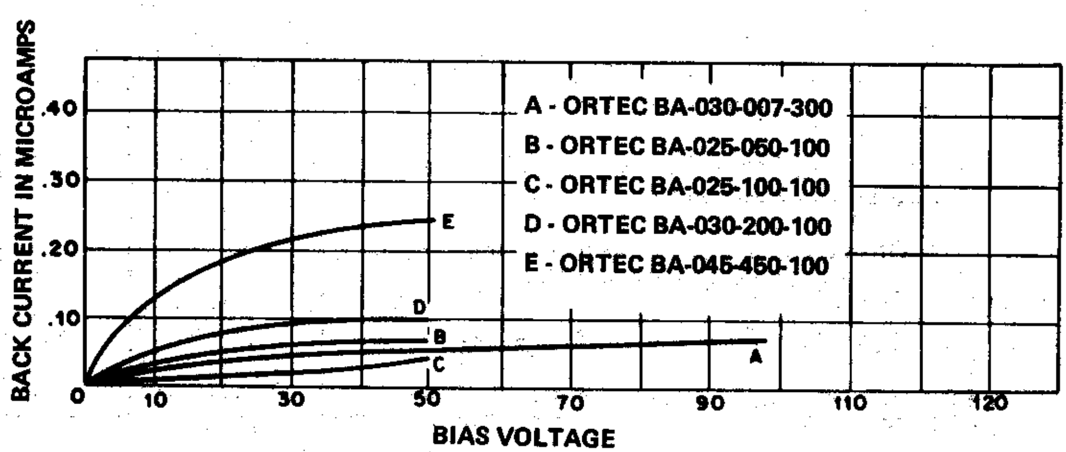


Figure 4-7. Silicon Detector Back Current Versus Bias Voltage

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 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 voltmeter is connected to the current monitoring jack on the 428 Detector Bias Supply.

4.6.6 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 450 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.

4.7 Operation in Spectroscopy Systems*

4.7.1 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 4.6.1), 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.

4.7.2 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:

*Also See ORTEC Lab Manual "A", Second Edition.

(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.
(5) Select the time constants for optimum signal-to-noise ratio.

4.7.3 Scintillation Counter Gamma Spectroscopy Systems

The ORTEC 450 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.

4.7.4 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.

4.8 Unipolar Output Ranges

The operation of the 450 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, which feeds a dc level on to the input in the normally operating ac-coupled mode; however, when the 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 450 which controls the amount of that dc voltage). For this reason, the 450 provides a wide range of output dc level adjustment. This voltage level may be adjusted by R91 (DC ADJ.) to be either positive or negative up to 10% of full scale.

4.9 Baseline Restorer (BLR)

4.9.1 BLR Function

The BLR rate switch (S7) has four positions, OUT, LO, MED, HI, and selects the rate of dc restoration. The OUT mode is used in those instances where the count rate is moderate and best energy resolution (least noise width contribution) is required. The restore modes provide a selectable restoration rate and 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 5-10 kcts/sec) are to be encountered. The BLR switch S7 determines the restore capacitor which allows optimum restoration at all count rates. In the OUT position, the BLR is bypassed.

4.9.2 BLR In a System

Normally, the 450 should be connected into the analysis system as the last function performed prior to pulse height analysis. If there is a nonlinear element such as a biased amplifier in the system and that biased amplifier does not contain a dc restoration circuit, then it is necessary to dc-couple the nonlinear element up to the nonlinear bias point and also dc restore prior to it in order to obtain good pulse height resolution. Of course, this means that if the output of that nonlinear element is again ac-coupled, it is necessary to again dc restore before entrance of the pulse height analysis system, e.g., multichannel analyzer, if the best pulse height resolution versus count rate is to be obtained. These precautions are not necessary with the ORTEC 444 Biased Amplifier at moderate rates, since it contains a dc restoration circuit.

Figure 4-12 is a series of four graphs showing resolution vs count rate for different time constant settings. These data were obtained with a specific detector and preamplifier, together with the ORTEC 450 Amplifier, and cannot be expected to apply directly to other systems. The graphs are included for use as relative guidelines, to aid in optimizing the settings of the BLR circuits in a specific application. No pile-up inspection was used.

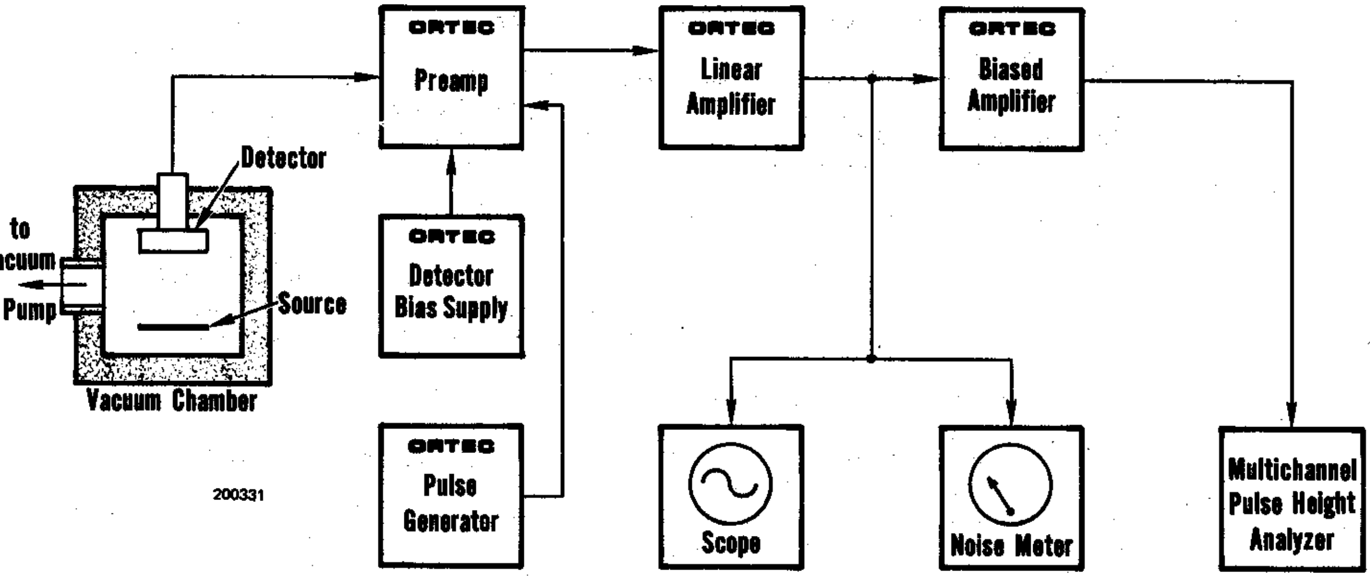


Figure 4-8. System For High Resolution Alpha Particle Spectroscopy

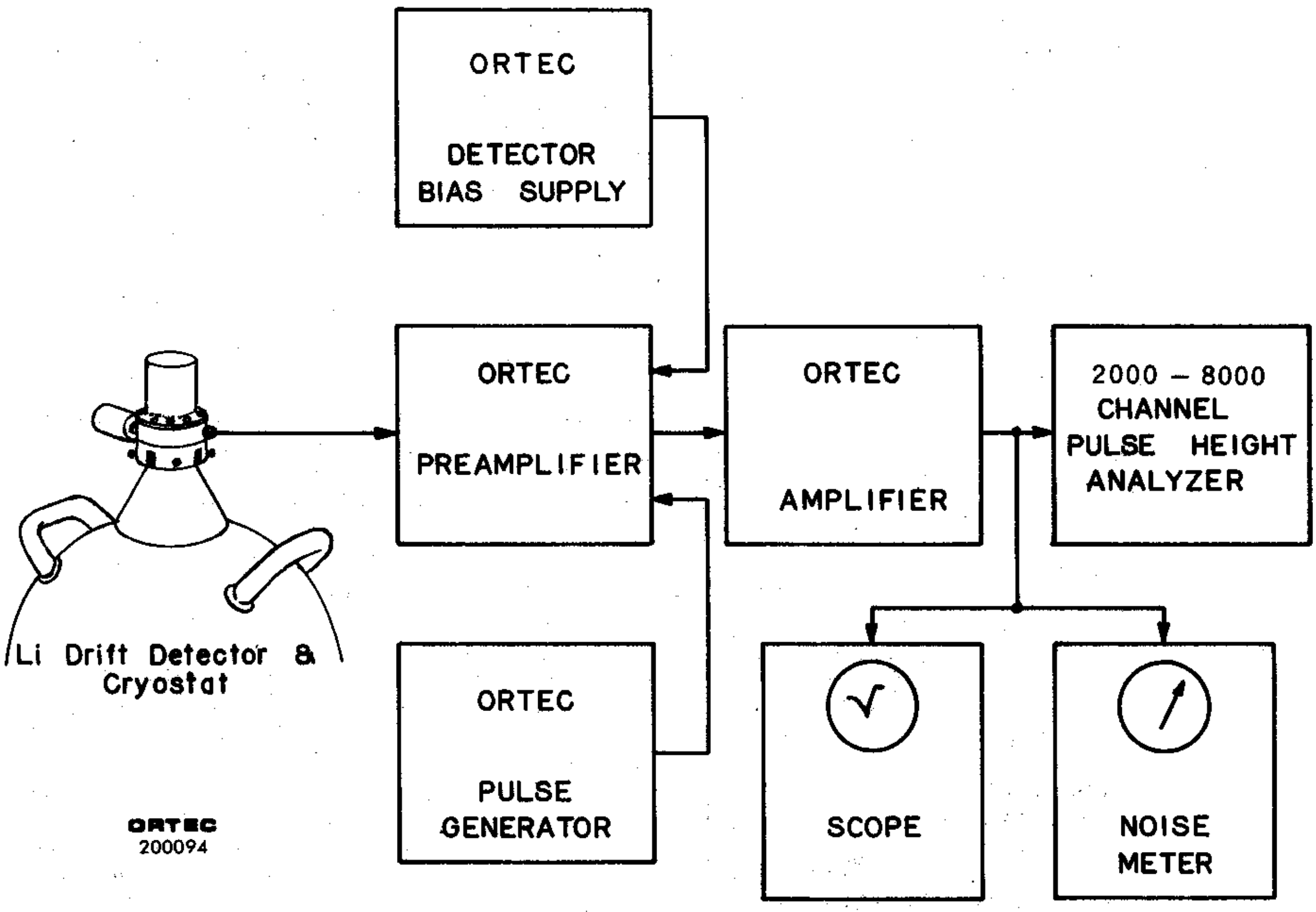


Figure 4-9. System For High Resolution Gamma Spectroscopy

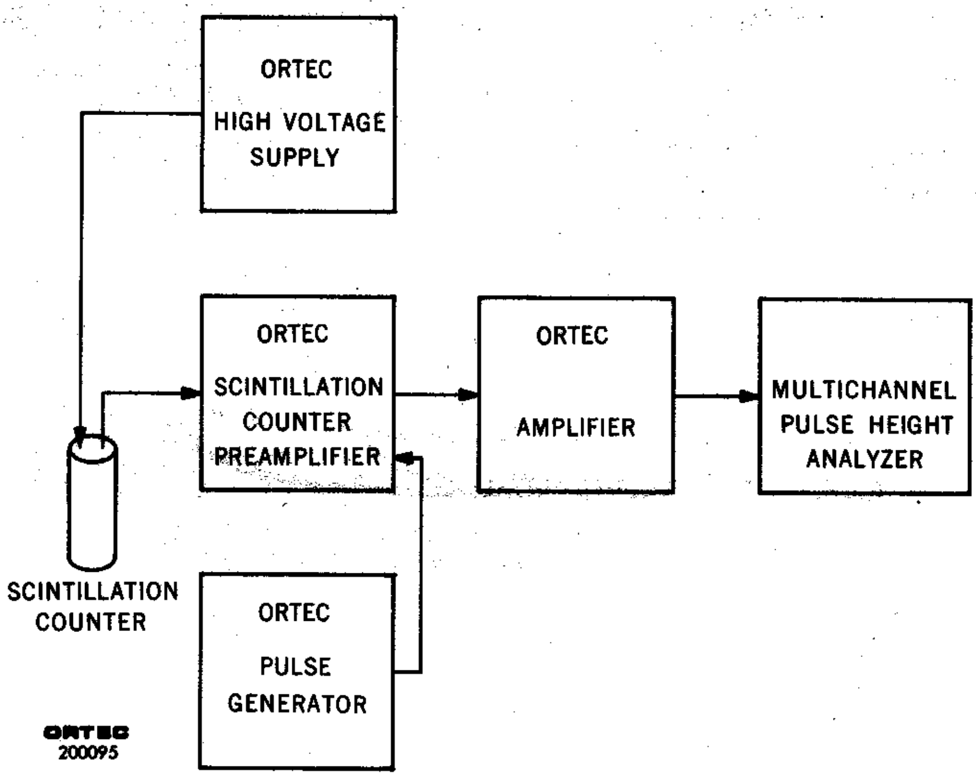


Figure 4-10. Scintillation Counter Gamma Spectroscopy System

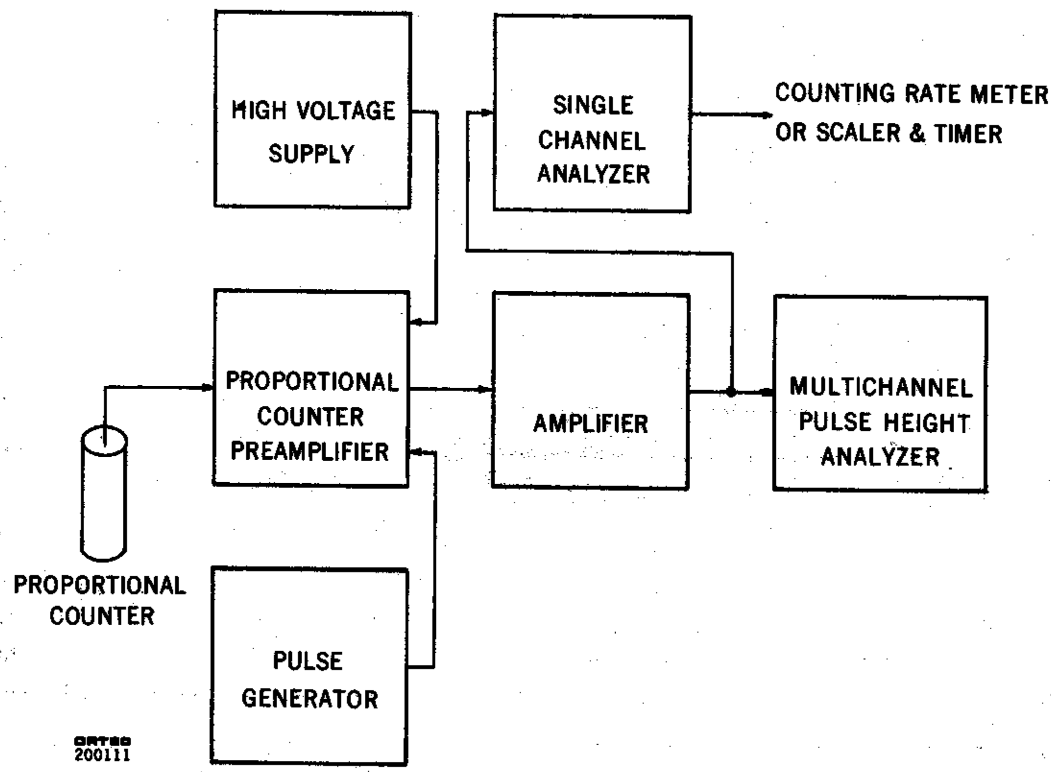
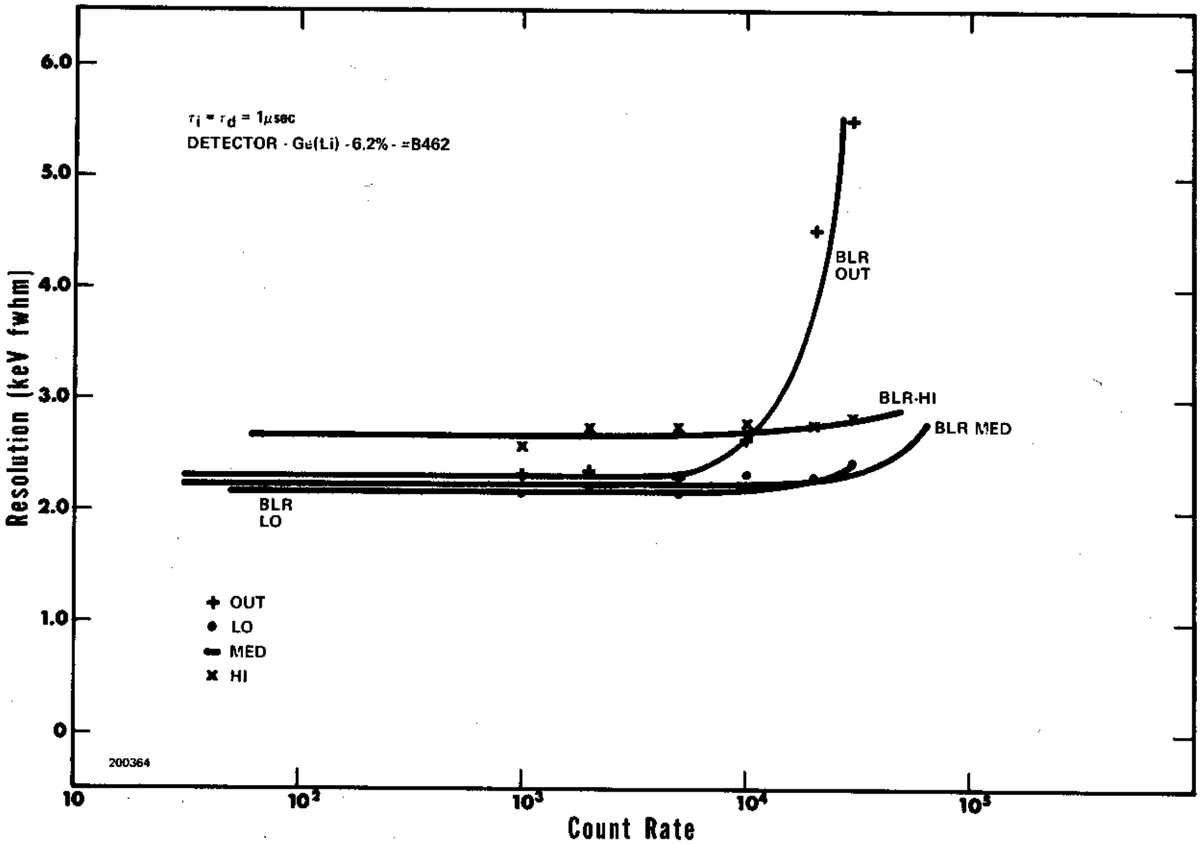


Figure 4-11. High Resolution X-Ray Spectroscopy System



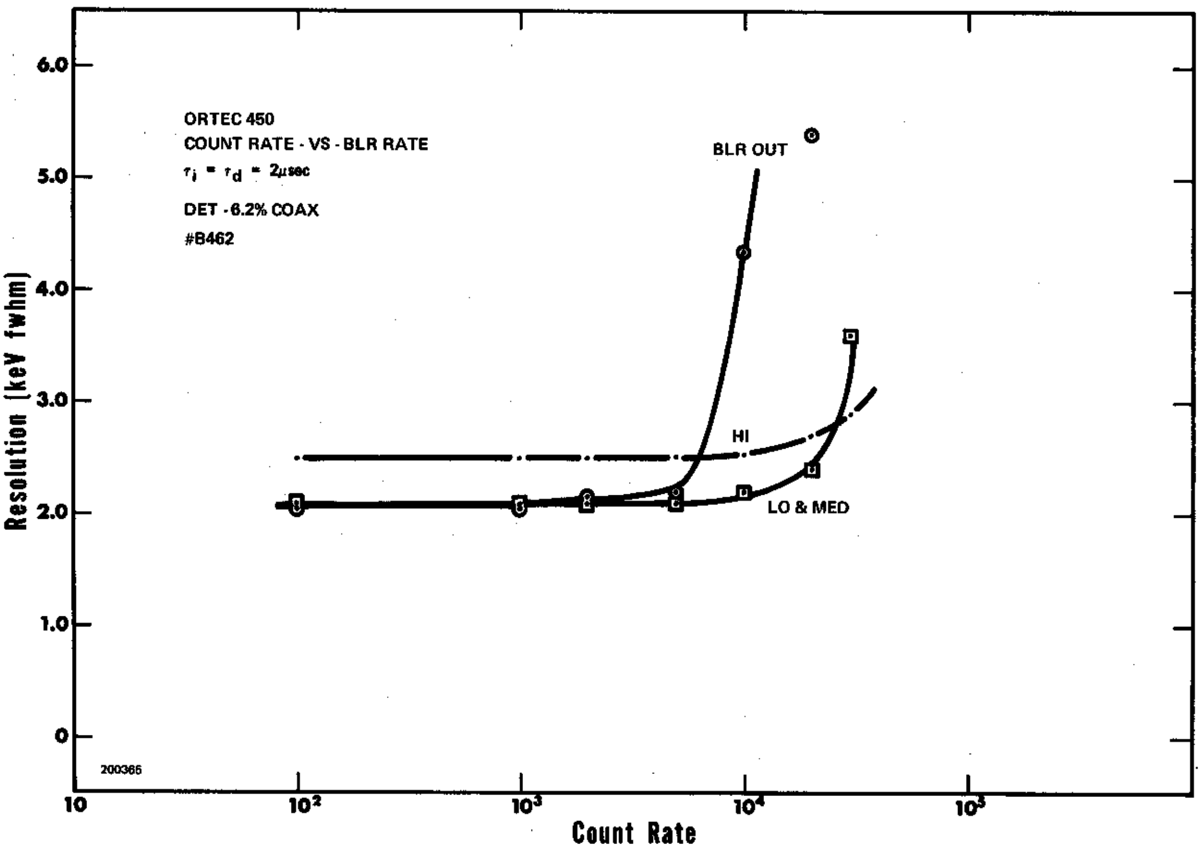
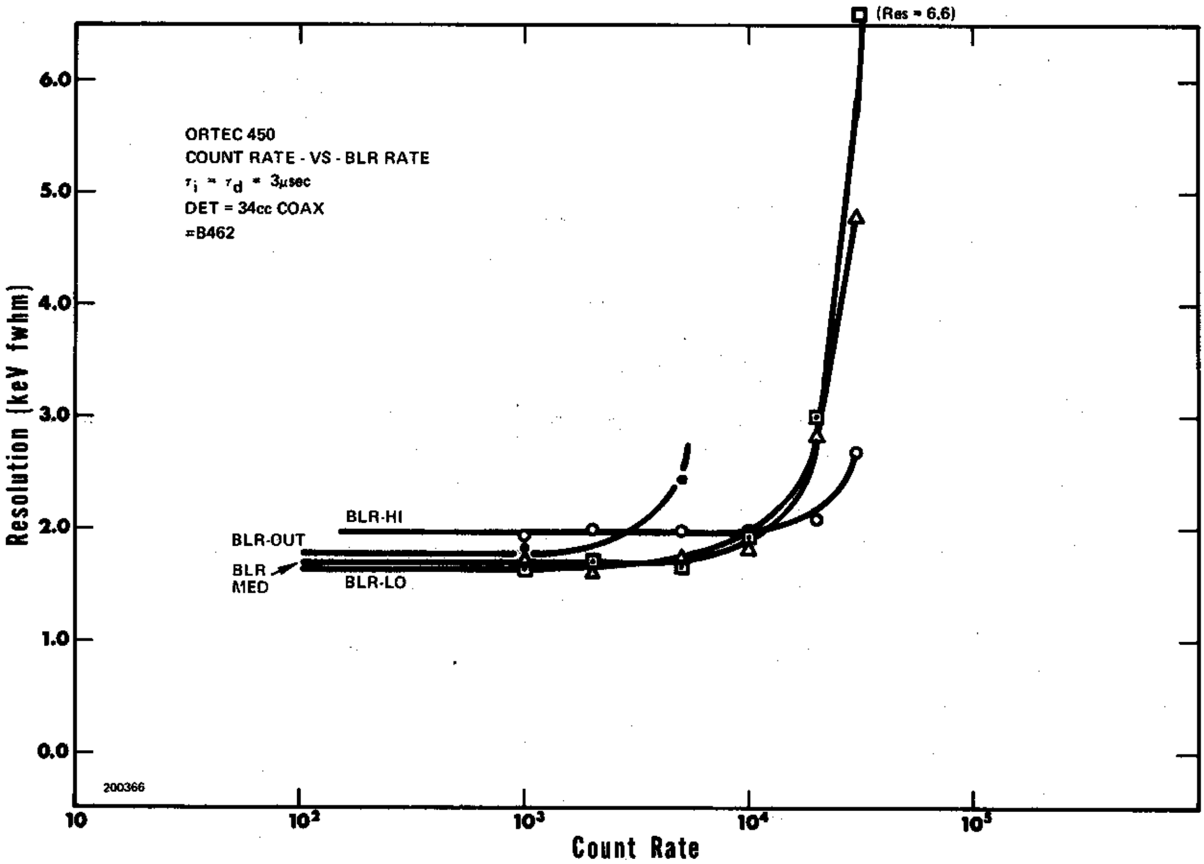


Figure 4-12. Resolution vs. Count Rate



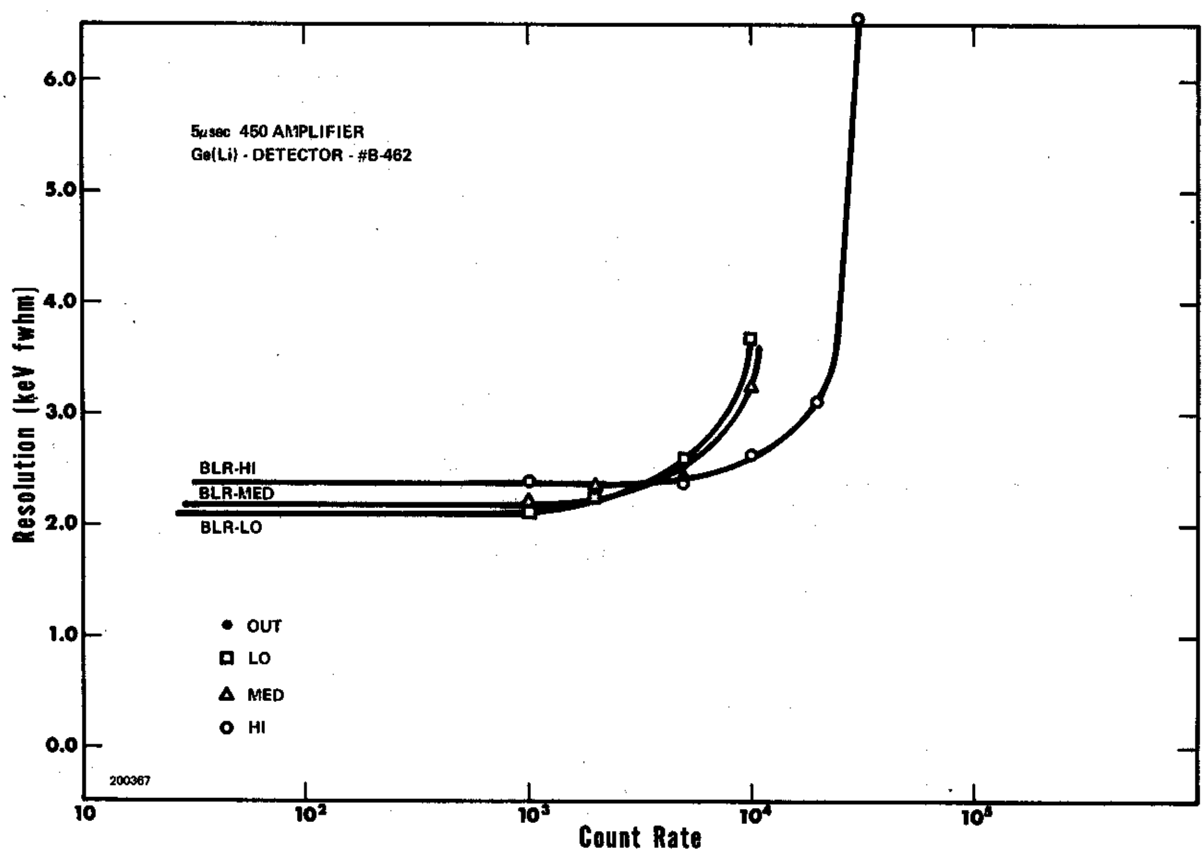


Figure 4-12. Resolution vs. Count Rate

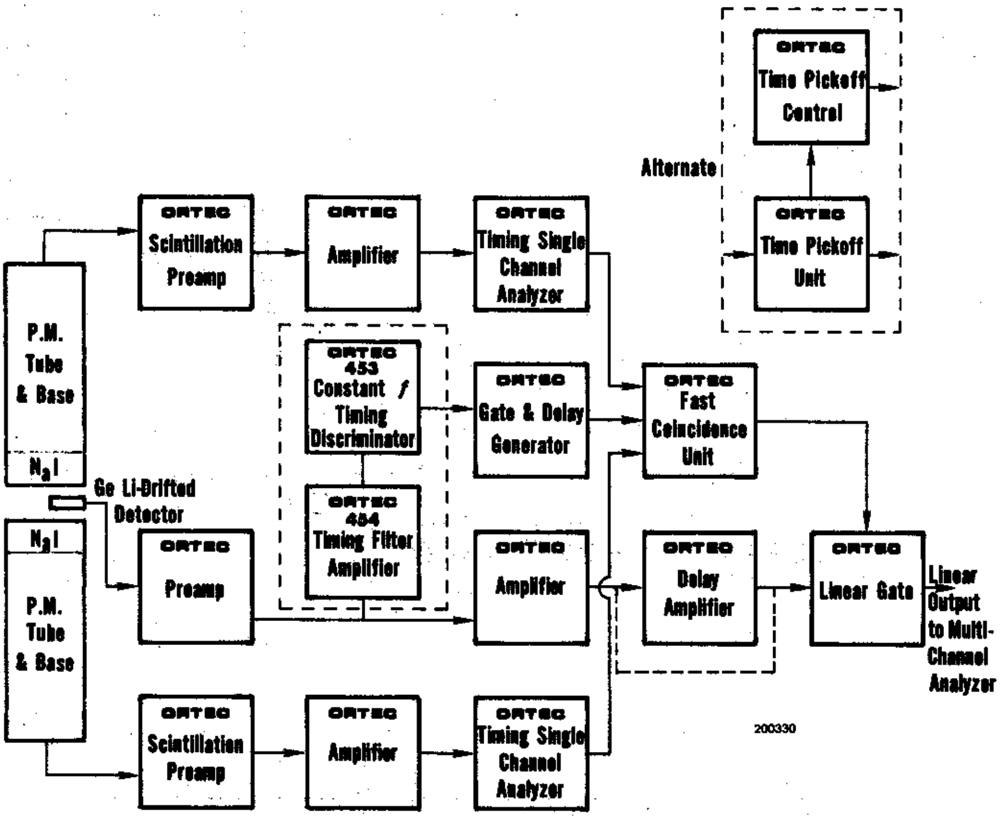


Figure 4-13. Gamma Ray Pair Spectrometer – Block Diagrams

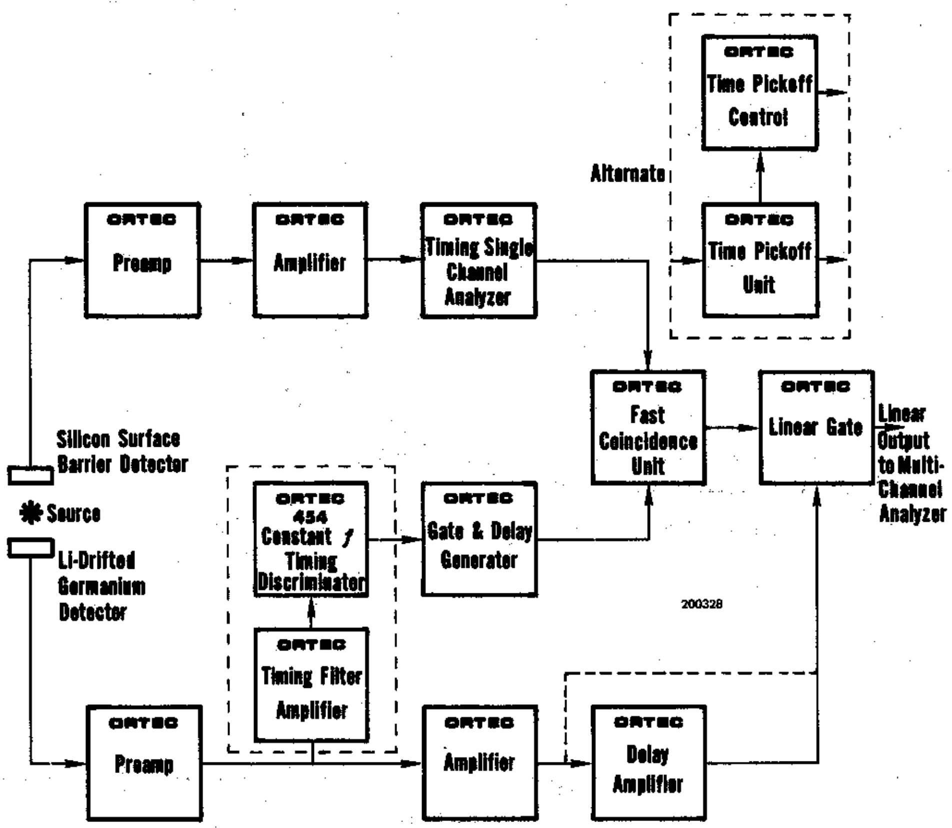


Figure 4-14. Gamma Ray-Charged Particle Coincidence Experiment – Block Diagrams

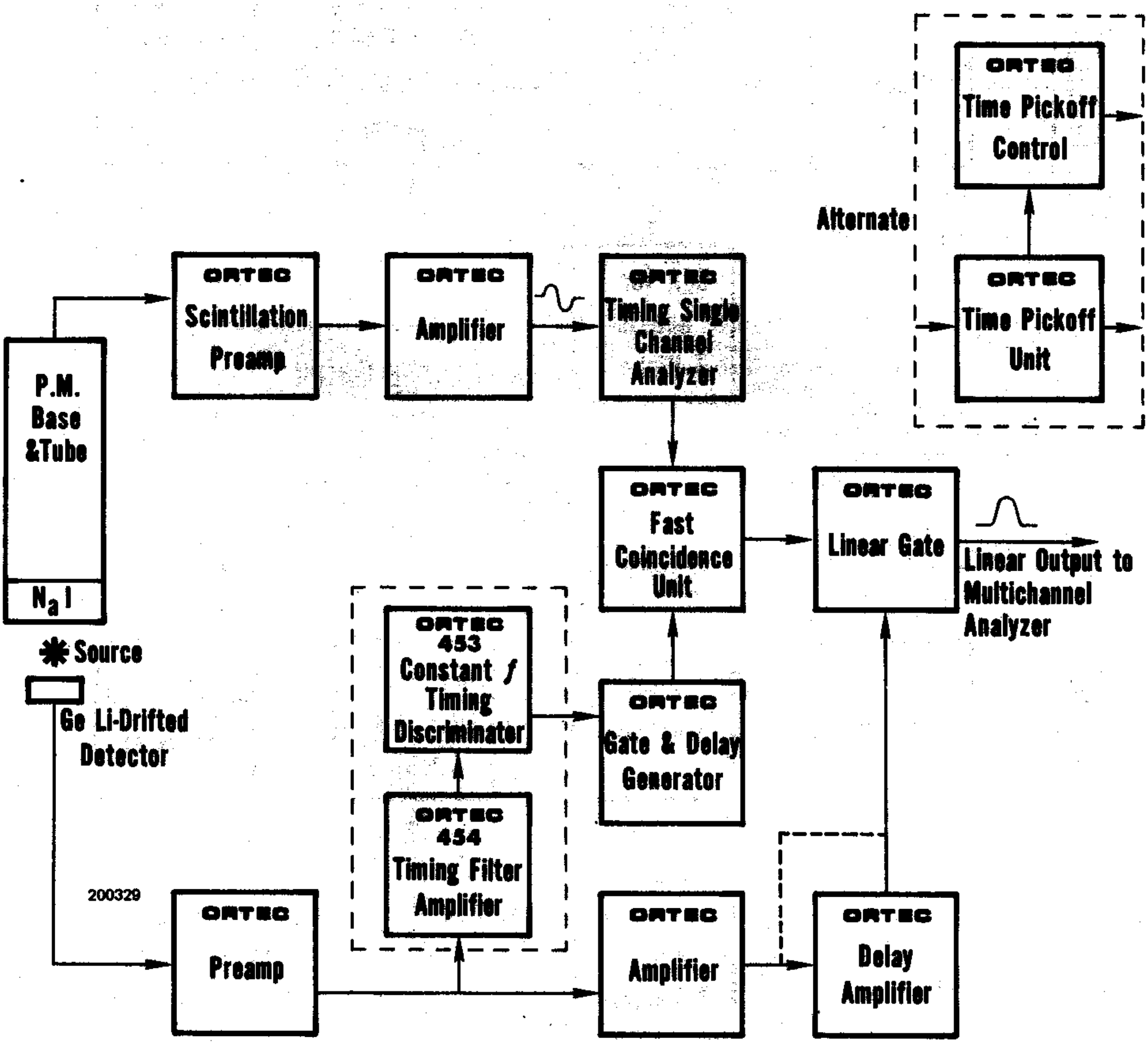


Figure 4-15. Gamma-Gamma Coincidence Experiment – Block Diagram

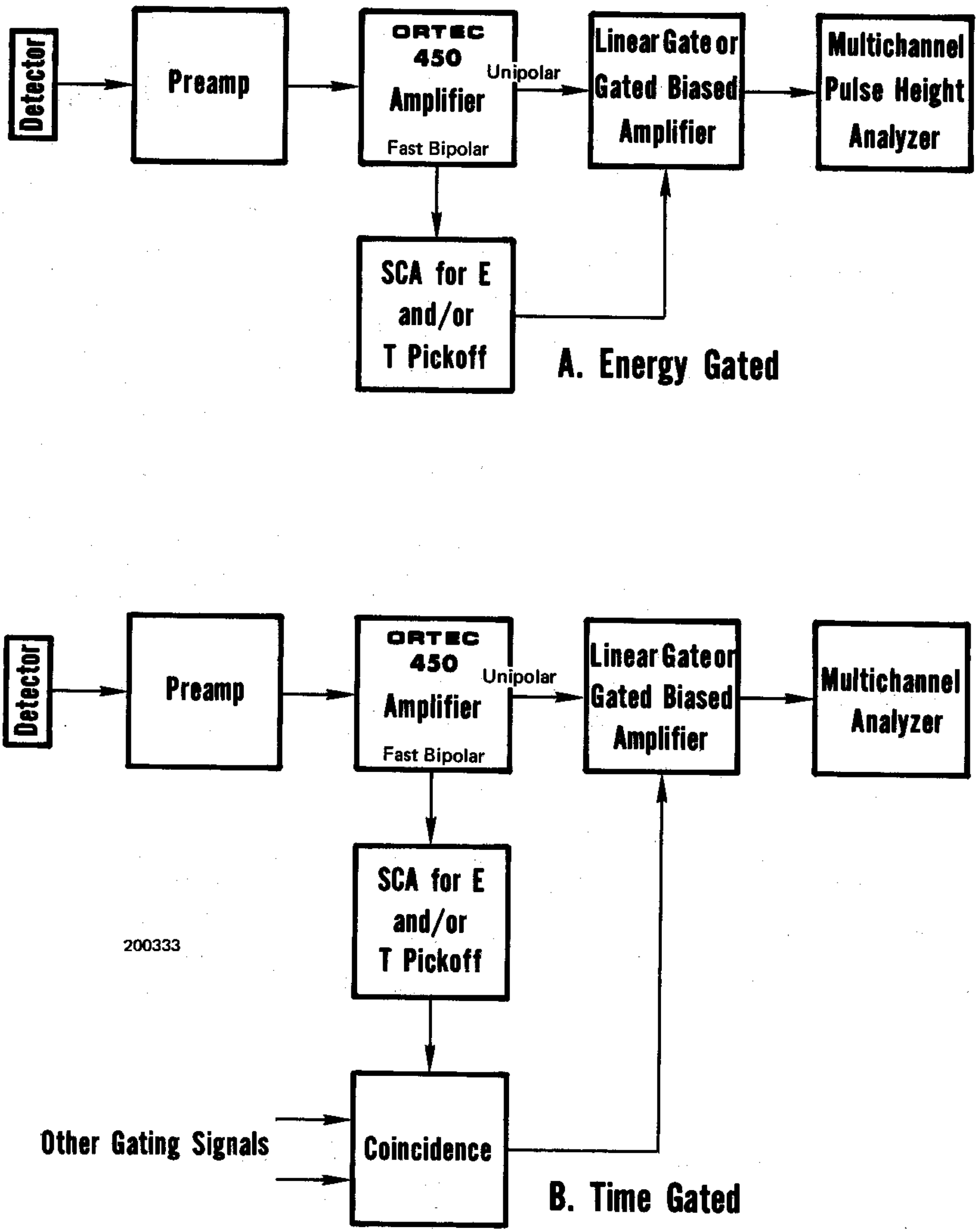


Figure 4-16. General System Arrangement for Gating Control

Of course it is necessary that the pulse height analysis system be dc-coupled following the dc restorer.

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 Mössbauer 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 450.

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 450 into the system in such a way that it may 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 pickoff the trigger signal to initiate analysis from the normal, i.e., 0-10V, input.

4.10 Typical System Block Diagrams (Figure 4-13 through 4-16)

This section contains block diagrams illustrating how the 450 and other ORTEC 400 Series modules can be used in experimental setups.

4.11 Methods of Connection to Various Analyzers

Below is listed a number of various manufacturers of multichannel analyzers along with the manufacturers recommended method of dc-coupling of specific ADC's. Figure 4-17 applies where no trigger is needed, and Figure 4-18 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 Mössbauer input (trigger required).

B. NORTHERN SCIENTIFIC

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

C. NUCLEAR DATA

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 Mössbauer 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.

ADC Model	Direct Input Volts	Modification	Trigger Condition
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)
461 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

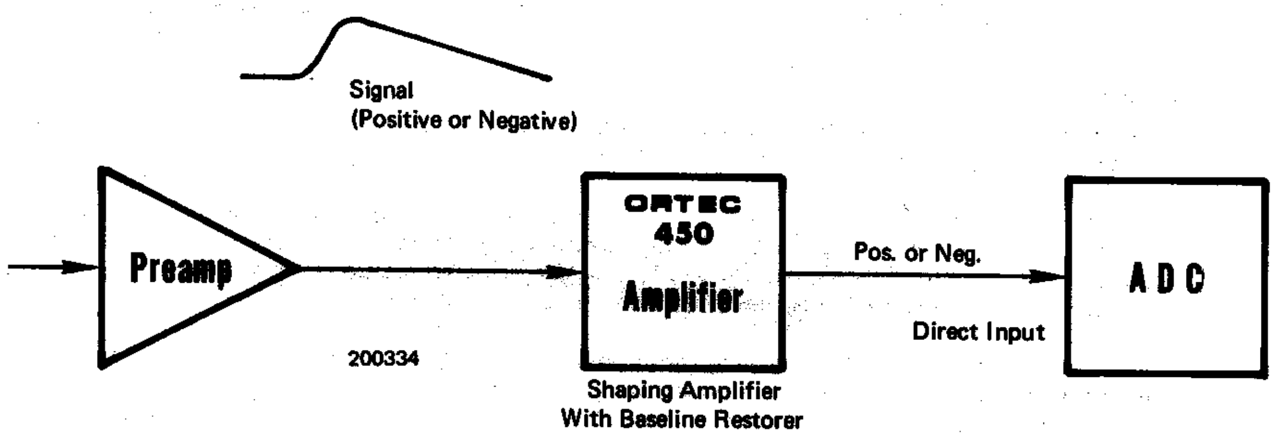


Figure 4-17. Analyzer Connection With No Trigger Required

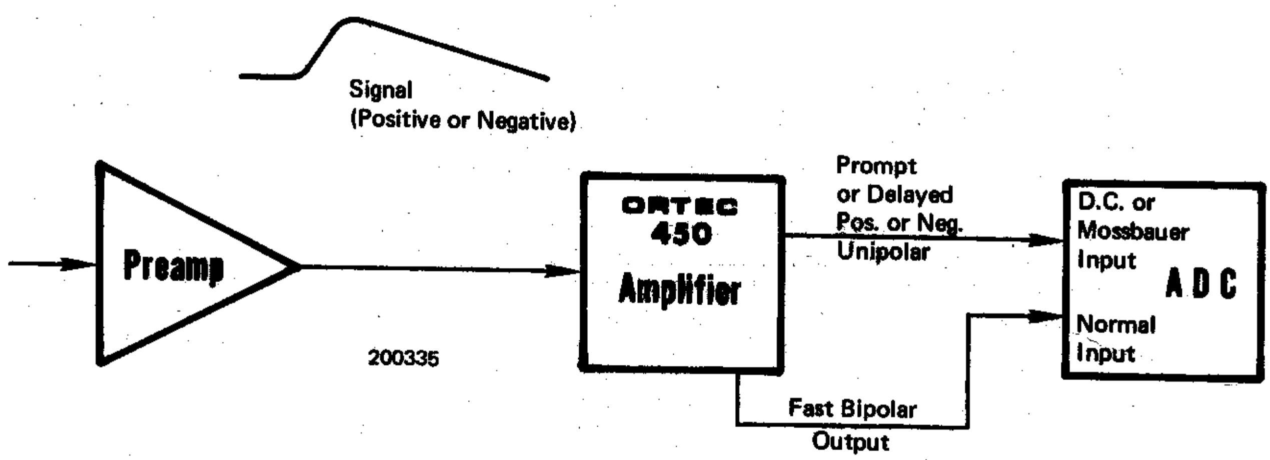


Figure 4-18. Analyzer Connection When Trigger Is Required

5. CIRCUIT DESCRIPTION

5.1 General Block Diagram

The 450 contains 9 feedback operational amplifiers grouped in two sections. Section A (Figure 5-1) is the fast wide-band and high gain section; Section B (Figure 5-2) is the signal conditioning section.

5.2 Section A

The signal inputs are selected for mode and polarity by the Input Mode switch S1 and presented to the first amplifier (1) which has a wide-band gain of 3.

In order to maintain zero differential gain from these inputs, i.e., high common mode rejection,[3,4] there is a differential balance control (BAL) (R2) provided on the front panel. The signal is then presented to the first differentiation (C5, R9, τ = 1μsec) which incorporates a front panel pole zero cancel control (PZ ADJ.) R7.[2] See theory Section 1.3.

Stage 2 is a wide-band amplification stage with feedback gain adjustable from 1 to 10, using the Coarse Gain control S3A. The output of 2 is presented to the Fine Gain attenuator R18, which is a precision 10-turn potentiometer with an attenuation range of 1 to 0.33 calibrated on the front panel as 1.5 to 0.5.

The output of the Fine Gain control is fed to amplification stage 3 which, like 2, is a wide-band amplifier with a feedback gain adjustable from 1-10 using Coarse Gain control S3B. The output of stage 3 is fanned out both to S4 and through a 0.5μsec differentiating network (C17, R27) to form the Fast Bipolar Output. Stage 4 then amplifies this signal by a gain of 1 to 10 using Coarse Gain S3C and this output is presented to the front and rear panel BNC's as the Fast Bipolar Output. Stage 4 is protected from shorts and excessive duty cycle by Q1 and Q2.

Stages 1 through 4 have variable feedback capacitors to optimize the risetime of the Fast Bipolar Output. The total gain of Section A from input to Fast output is 2.5 to 3000. Section A is converted into a universal wide-band amplifier when S4C and S4D are closed by setting Differentiate switch S4 to the Out position.

Provisions are made on the circuit board to insert a larger differentiate capacitor in parallel with C17 if a longer time to crossover of the Fast Bipolar Output is desired (C17a).

5.3 Section B

The output of stage 3 is fed to the first selectable Differentiate switch S4A, which has a range of 0.1 to 10μsec and Out in 10 steps. This output is then coupled into stage 5 which has a special integrating filter to replace the original differentiation introduced after stage 1 by R9, C5. Thus, the output of stage 5 has transformed the 1μsec differentiation time constant to a new differentiation time constant selected by S4. The output of stage 5 is then presented to the Integration section. The active filter Integration is selectable for time constants of 0.1 to 10μsec and Out in 10 steps by the front panel Integrate selector S5. Stage 6 is the amplifier which provides the filter gain. This output then goes to the Coarse Gain control S3D which has a gain range of 1-10 in conjunction with stage 7. (See theory Section 1.4). Stage 7 is the second active filter amplifier with the time constant selected by the Integrate selector switch S5. The output of stage 7 has been completely amplified and shaped and is conditioned for an acceptable output. Stage 7's output is fanned out 3 ways. One is presented to the BASELINE RESTORE RATE switch S7 (BLR) which has a restore rate range of Out, Lo, Med, and High. This output then goes through or around the baseline restorer circuit Q7-Q13.[1] This output then goes to the rear panel output Delay switch S9, which determines whether the signal is to be delayed or not. This signal then goes to the Unipolar Output Range switch S8, which selects the polarity and gain of the unipolar output driver stage 8. Stage 8 is protected from short circuits and excessive duty cycle by Q3 and Q4.

The output of stage 7 also goes to the second selectable Differentiate through the Differentiate switch S4B to form the bipolar pulse, which is then amplified by stage 9 and presented to the Bipolar output connectors. Stage 9 is protected from short circuits and excessive duty cycle by Q5 and Q6.

The output of stage 7 is also connected to the DC Stabilization Amplifier Q14-Q18, which is used to correct for baseline shift at the output of stage 7 due to pileup, count rate effects, temperature, etc. This permits the Unipolar output to be completely DC-coupled and still maintain a very high degree of DC stability.

GAIN CRITERIA

In any amplifier or amplifier series, any error introduced within the amplifier, such as thermal or pickup noise, is reduced by the amplification preceding this error point when the error is referred back to an equivalent input error. Therefore, for minimum induced error to the signal, it is imperative that for any given gain most of the gain should be accomplished early in the amplifier.

In the 450 this criterion is followed by designing the Coarse Gain selector switch S3 so as to decrease the latter gain (stages 4 and 7) first (positions 2000, 1000, 500, and 200); then to decrease the gain of the intermediate stage 3 on positions 100 and 50; and lastly to reduce the gain on the first gain stage 2 on positions 20, 10, and 5. Thus, as the amplifier gain is increased by the Coarse Gain selector switch, it is increased early in the amplifier first.

5.4 ORTEC Operational Amplifier Concept

The ORTEC operational Amplifier is a low noise, differential input, wide-band, high performance device which has universal applications by use of proper feedback. It is encapsulated to insure good temperature stability and to make it immune to shock, vibration and humidity.

The internal components are of high quality and are operated well below design maximums to insure long-term reliability. In the rare event of a failure, the malfunctioning unit can be indentified and replaced quickly.

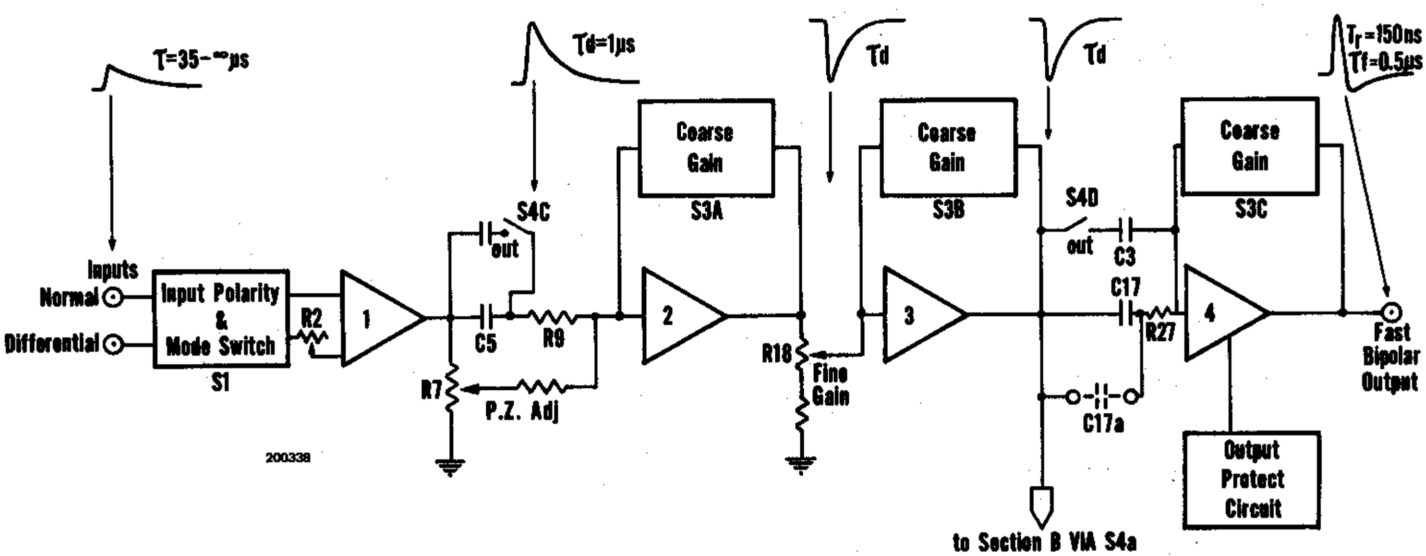


Figure 5-1. 450 Block Diagram, Section A

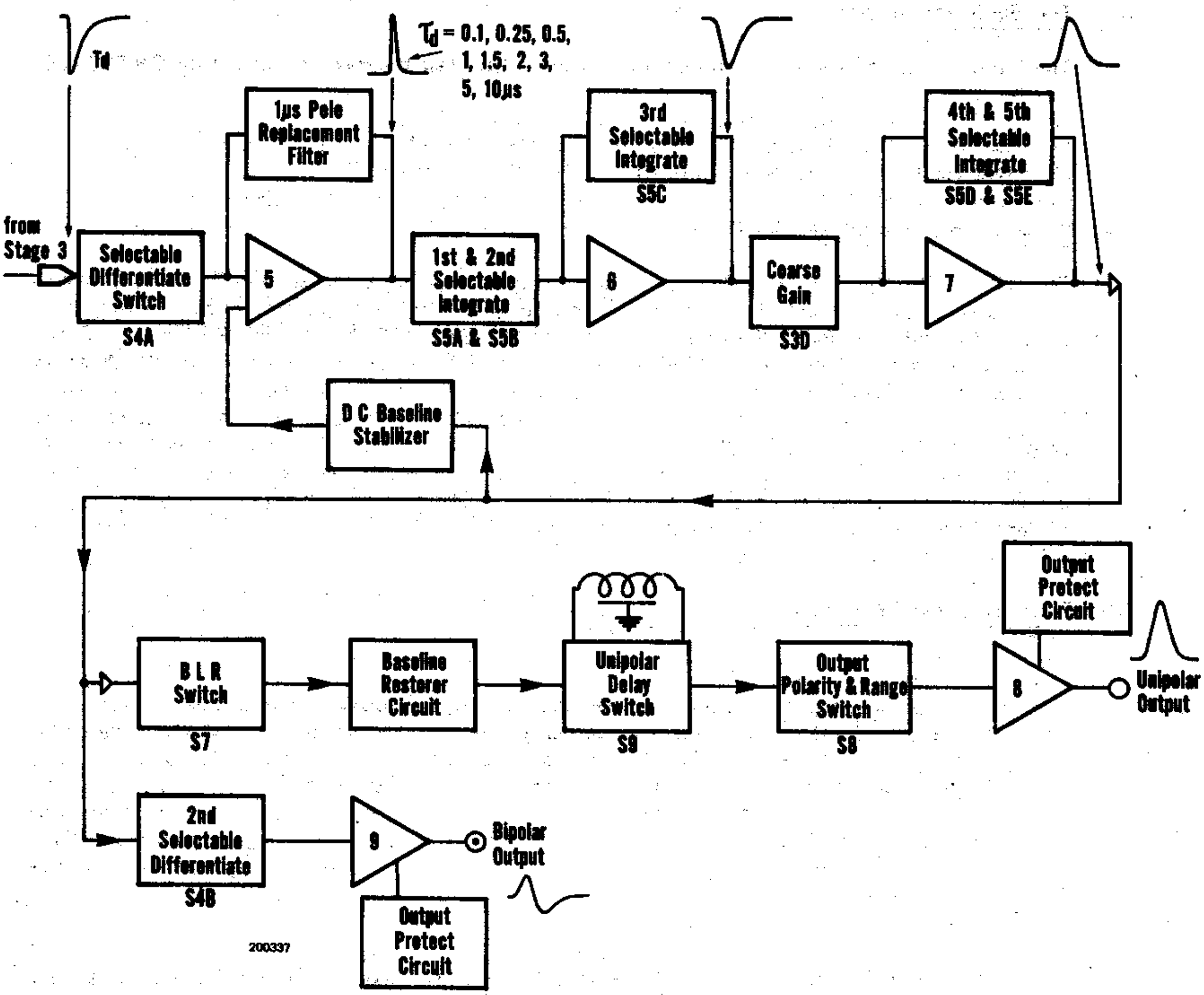


Figure 5-2. 450 Block Diagram, Section B

REFERENCES

1) Veljko Radeka, "Effect of 'Baseline Restoration' on Signal-to-Noise Ratio in Pulse Amplitude Measurements," Rev. Sci. Instr. 38(10), 1397 (1967).

2) C. H. Howlin and J. L. Blankenship, "Elimination of Undersirable Undershoot in the Operation and Testing of Nuclear Pulse Amplifiers," Rev. Sci. Instr. 36(12), 1830 (1965).

3) Ralph Morrison, Grounding and Shielding Techniques in Nuclear Instrumentation, Wiley, New York, 1967, Chapters 5, 6, and 9.

4) R. D. Eckard, "Common Mode Voltage Rejection in a Low Level Data Acquisition System," Noise Reduction Conference March, 1968, Conf. 680303, Lawrence Radiation Lab., Livermore Calif.

6. MAINTENANCE

6.1 Test Equipment Required

The following test equipment should be used to adequately test the specifications of the ORTEC 450:

(1) ORTEC 419 Precision Pulse Generator, or 448 Research Pulser
(2) Textronic Model 540 Series Oscilloscope with a Type 1A1 Plug-in or equivalent
(3) Hewlett-Packard 400D RMS Voltmeter

6.2 Pulser Modifications for Overload Tests

The ORTEC 450 Research Amplifier incorporates a variable pole-zero cancellation, factory adjusted to 50μsec, and adjustable from 35μsec to DC. During Overload Tests, the input from the pulser must have a decay time which matches the pole-zero time adjusted in the 450. An ORTEC 448 Research Pulser can provide a switch selection of the decay time to match the 450 pole-zero adjustment. When an ORTEC 419 or 204 Pulse Generator is used to check overload, it must be modified as shown in Figure 6-1, or the pole-zero cancellation reset to compensate for the fall time of the pulse generator output. If the pulse 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 semi-conductor detector, the decay time of the pulser will cause an additional pole in the transform equation of the preamplifier output, and this additional pole will degrade any overload measurements. To eliminate the extra pole, the pulser must be pole-zero cancelled as shown in Figure 6-2.

6.3 Pulser Tests and Calibration

6.3.1 Amplitude Matching

Set the pulser output for positive pulses and connect the equipment as shown in Figure 6-1. Observe both the Unipolar and Bipolar output pulses with the oscilloscope, and adjust the amplifier gain and pulse amplitude for 10 volt output pulses from the amplifier. With Coarse Gain at 2000 and readjust for a 10 volt amplifier output, observe both outputs for all shaping modes, using the Integrate and Differentiate switches to select various equal Shaping Time Constants. The output amplitude should not vary more than approximately ±5% for any shaping mode. Turn both the Integrate and Differentiate switches to the 1μsec Time Constant position for the following tests.

6.3.2 Gain Switching Accuracy

With Coarse Gain at 2000, adjust for a 10 volt output. Decrease the Coarse Gain switch settings through its successively lower positions and observe the relative amplification at each step. The gain variation should reflect the steps from X2000 to X1000, 500, 200, 100, 50, 20, 10, and 5, in measurement of the peak output amplitudes of the 450 within 5%.

6.3.3 Fine Gain Range

Readjust the Coarse Gain switch and the input amplitude for approximately 5 volts at the 450 output, with the Fine Gain control set at 1000 dial divisions (for a factor of 1.0). Adjust the Fine Gain control through its range of 500 to 1500 dial divisions, and observe the changes in output amplitude. This range should correspond to a range of factors from 0.5 through 1.5 (2.5V to 7.5V ±1%).

6.3.4 Overload Capability

Set the Coarse Gain at 2000 and the Fine Gain at 1.5 for maximum gain. Adjust the pulser output to obtain a 10 volt output from the 450. Increase the pulser output amplitude by X500, and observe that the output of the 450 returns to the baseline in less than 2.5 times the nonoverloaded pulse width. The pulser decay time must match the 450 pole-zero adjustment (see Section 6.2) in order to perform this test. An external reference source to the pulser may be required to obtain the amplitude of a X500 overload for its output. If a square wave generator is available, with a 5msec width output pulse, this may be used instead of the pulser for the amplifier input. Slight adjustment of PZ trim may be necessary.

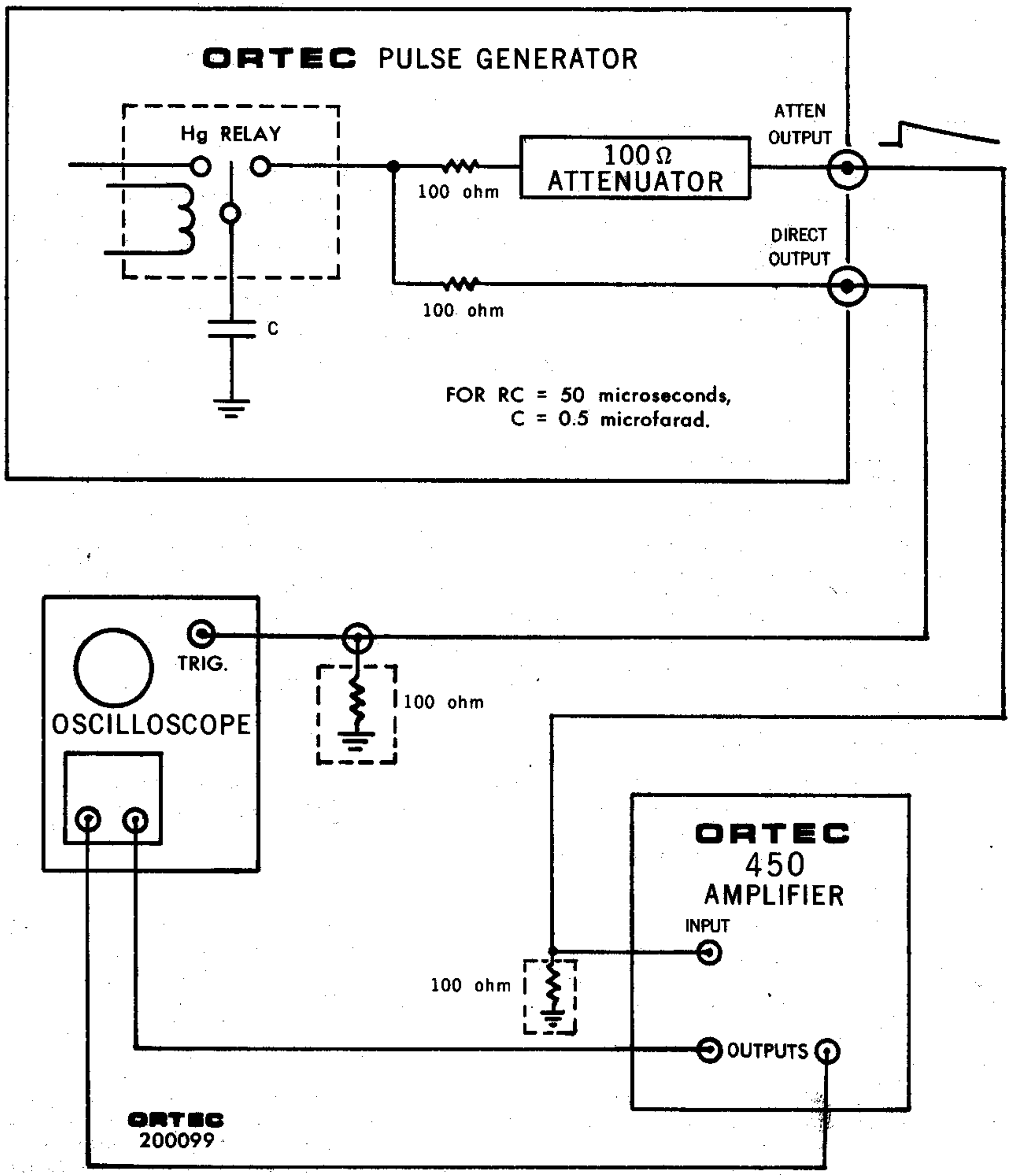


Figure 6-1. Pulser Modification for Overload Tests

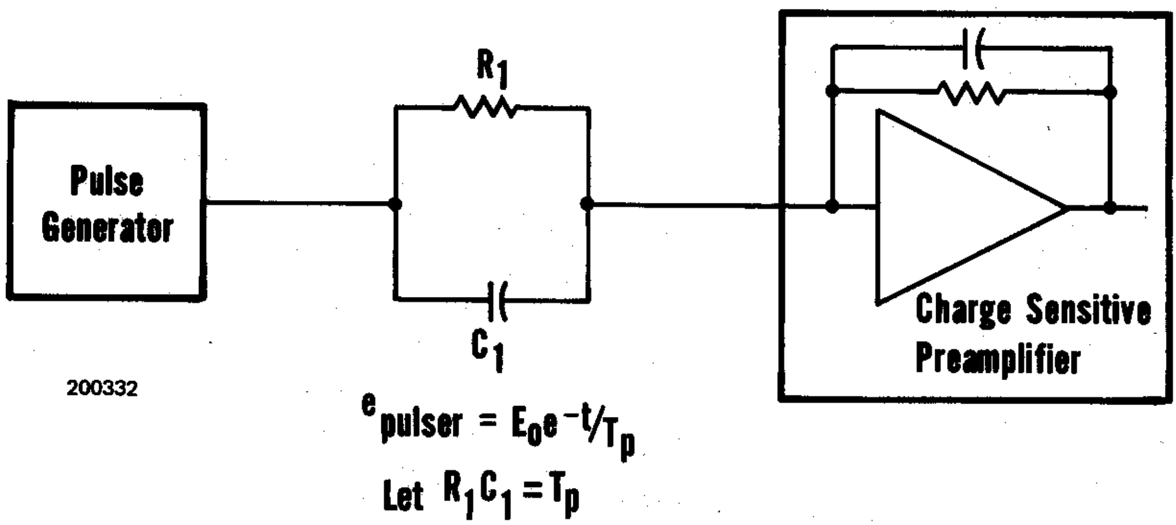


Figure 6-2. Pole-Zero Connection for a Pulse Generator

6.3.5 Common Mode Noise Rejection

Connect the pulse generator output to both the Normal and Differential inputs of the 450. With the Input Mode switch of the 450 at Normal Pos or Normal Neg, matching the pulse generator output polarity, and with the 450 Coarse and Fine Gain controls set normally for system application, adjust the pulse generator output amplitude for a 10 volt output from the 450. Next, switch the Input Mode selector of the 450 to the Differential position for the same input polarity as used for Normal, above. The amplifier output can now be reduced to a minimum amplitude with the Bal. control on the 450 front panel, and should be less than 100mV from baseline to peak for proper common mode noise rejection.

6.3.6 Linearity

The integral nonlinearity can be measured by the technique shown in Figure 6-3. In effect, the negative pulser output is subtracted 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, except for ORTEC 448) 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 (±.05% Max Nonlinearity) x (½ for Divider Network) = ±2.5mV Max Null Point Variation.

6.3.7 Output Loading

With the same setup as in Section 6.3.6, adjust the amplifier output to 8 volts and observe the null point change when the output is terminated in 100 ohms. The change should be less than 50mV.

6.3.8 Noise

Set the gain of the 450 to maximum. Measure the noise at the amplifier output at maximum amplifier gain using the RMS voltmeter for single and double clipping. The noise should be less than:

$$\left.\begin{array}{r}3.5\mu V \times 3000 \text{ gain} \times 1.13 = 12mV \text{ for Unipolar output}\\ 5\mu V \times 3000 \text{ gain} \times 1.13 = 17mV \text{ for Bipolar output}\end{array}\right\} 3\mu sec\ \tau_i = \tau_d$$

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.

6.3.9 Counting Rate Changes

Resolution spread and amplitude changes with counting rate can be measured with the setup shown in Figure 6-4. Pulser pulses are mixed at the amplifier input with preamplifier (must contain only one pole for best results) pulses from a ^{137}Cs source and the delayed mixed output is fed to a 426 Linear Gate. A 421 Integral Discriminator and a 416A Gate and DelayGenerator are used to open the linear gate at the proper time to accept a shaped pulser pulse from the amplifier delayed output. The pulser amplitude is adjusted to be near channel 400 in the pulse height analyzer and the ^{137}Cs source peak should be about 20% (80 channels) below the pulser peak. The ^{137}Cs source position is changed 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.

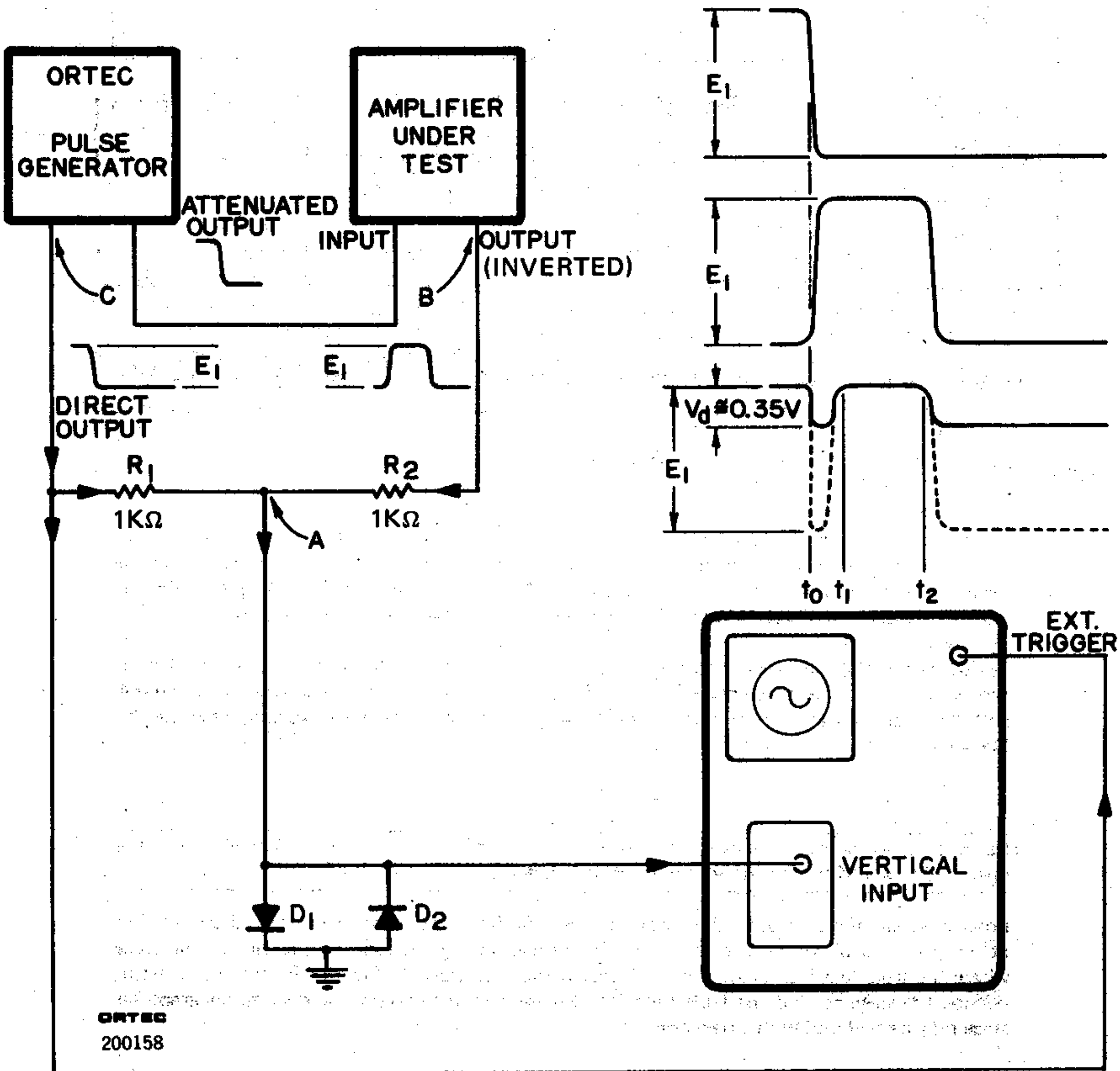


Figure 6-3. Measuring Linearity With The Null-Balance Method

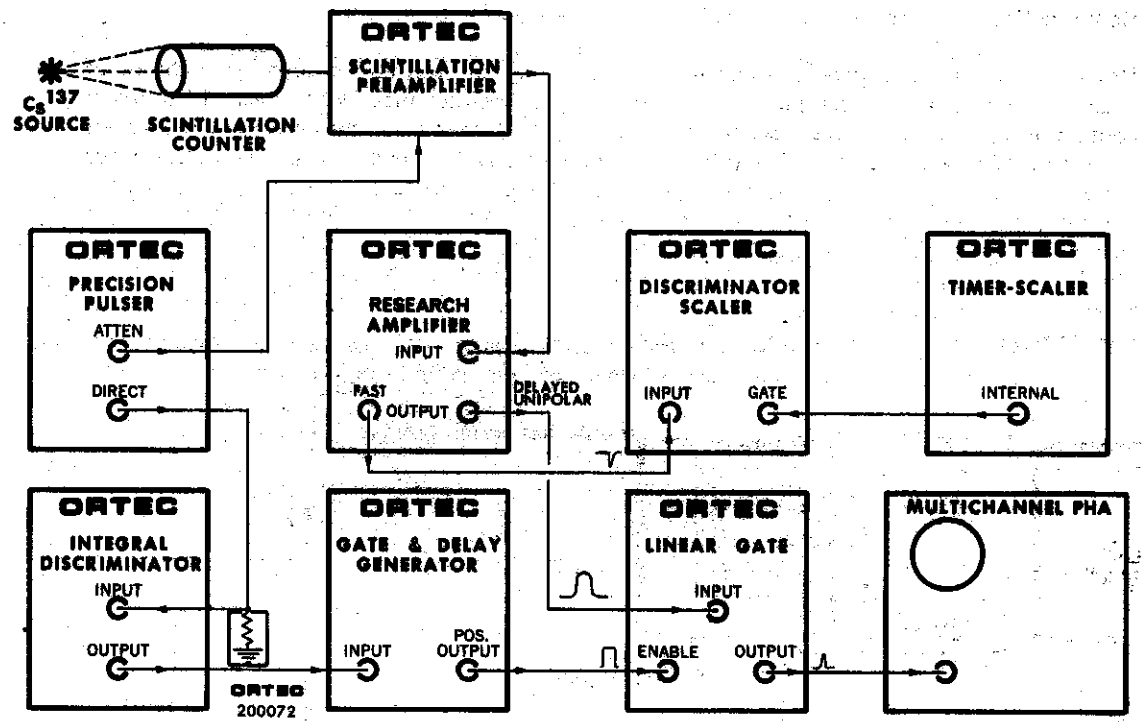


Figure 6-4. System for Measuring Resolution Spread and Amplitude Changes With Counting Rate

6.3.10 Troubleshooting

As shown in the block diagrams, Figure 5-1 and 5-2, the ORTEC 450 consists of a series of nine similar operational amplifiers. The dc operating potentials for these op-amps are all similar, as shown on the voltage chart, Figure 6-5. Proper sequential pulse shaping and gain, for logical stage-by-stage troubleshooting, are shown in the waveforms in Figure 6-6.

To locate a faulty operational amplifier stage in the 450, apply an input pulse as described in Section 6.1, with power connected to the 450. Check the power supply voltages on both the A and B boards, and then proceed to a stage-by-stage examination of the waveforms according to Figure 6-6.

CAUTION

Be careful to prevent shorting any adjacent pins with the probe tip when checking the operational amplifiers for either waveforms or voltages.

Proceed sequentially through the amplifier until the first stage is located where there is either no output or a distorted output. Check for proper voltage at each of the pins of the stage where the trouble is indicated. If the voltages are not according to Figure 6-5, trace each circuit outside the stage to find the faulty part(s). If these parts are correct, the operational amplifier stage may be replaced with a new one.

With a signal present, pins 10 and 14 are the contacts where the output from the stage can be observed. If the pulse amplitude at these pins goes to ±12 volts (saturation), the level at pin 7 is expected to follow to a fraction this signal level with the same polarity. If this does not occur, this indicates that the feedback loop of the op-amp should be examined for open resistors or poor connections. Note that the feedback loop for stage 5 is furnished by the DC Stabilizer Amplifier, Q14-Q16.

Troubleshooting Feedback Loop, Stages 5 through 7 and DC Stabilizer

If the output from stages 5, 6, or 7 is distorted or noisy, or if it has a dc offset, use the following procedure:

(1) Remove R117 (10K) from the circuit board.

(2) Add approximately 4.7 megohms of resistance between pin 10 and pin 7 of stage 5.

(3) Add a 2.2K resistor from the collector of Q15 to the base of Q16B, in parallel with C108.

Stages 5, 6, and 7 are now independent feedback amplifiers, and may be checked individually. The non-overloaded pulse performance of the total amplifier should be normal.

After the test is complete, or the trouble has been eliminated, restore the original circuit.

8		9
7		10
6	Operational Amplifier	
5	Pin Numbers	11
4	Viewed from Pin Side	12
3		
2		13
1		14

Pin #	Normal Voltage
1	+24V, Supply
2	Ground
3	+13V (Collector of Input Transistor Q2)
4	OV (Non-Inverting Input, Base Input Transistor Q2)
5	-0.6V (Emitter of Input Transistor Q2)
6	-0.6V (Emitter of Input Transistor Q1)
7	OV (Inverting Input, Base Input Transistor Q1)
8	-0.8V (Collector of Q11, Current Source for Input Differential Pair Q1 and Q2)
9	-24V, Supply
10	OV (*) Output
11	+12V (except +13V from protection circuit for stages 4, 8, and 9)
12	Ground
13	-12V (except -13V from protection circuit for stages 4, 8, and 9)
14	OV (*) Output Stage Drive Point (same signal as Pin 10 but at very high impedance)

(*) For Output Driver Stage 8 only, the setting of DC ADJ. control R24 can result in a baseline offset as great as ±1.0V dc.
Stage 3 output may be as high as ±150mV.

Figure 6-5. Operational Amplifier Pin Voltages

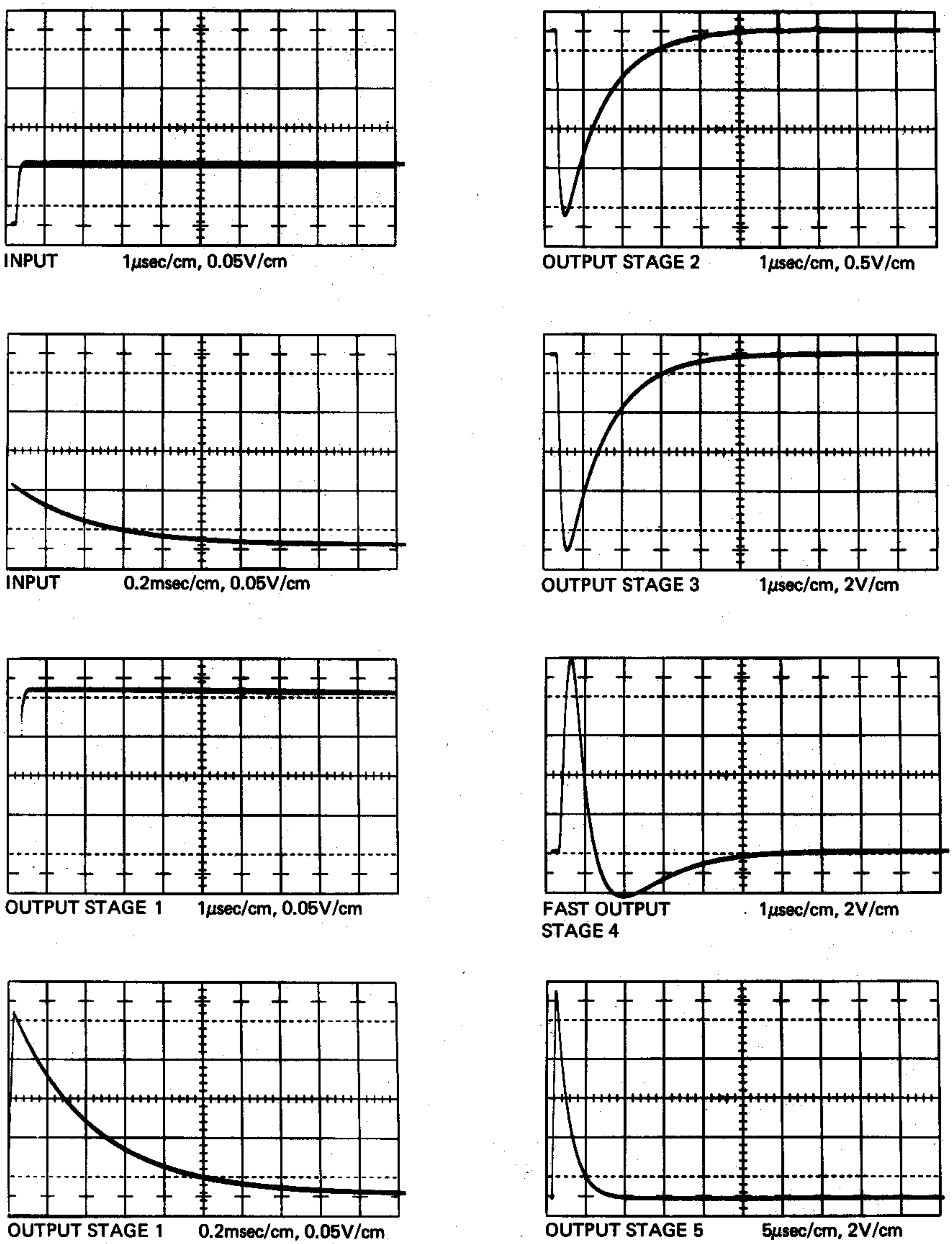
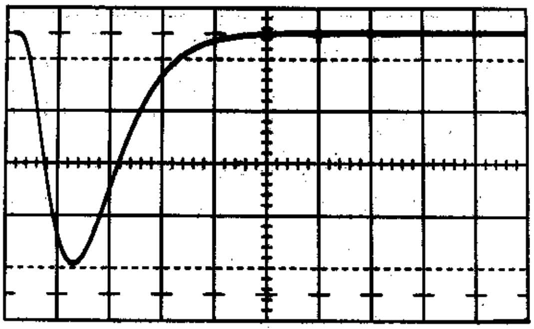
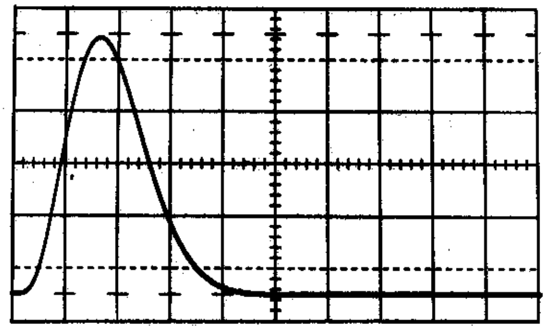


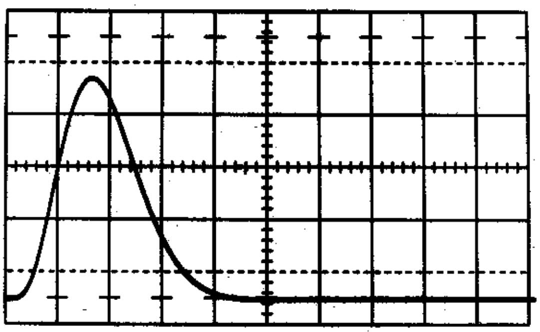
Figure 6-6. Stage-by-Stage Pulse Shaping and Gain



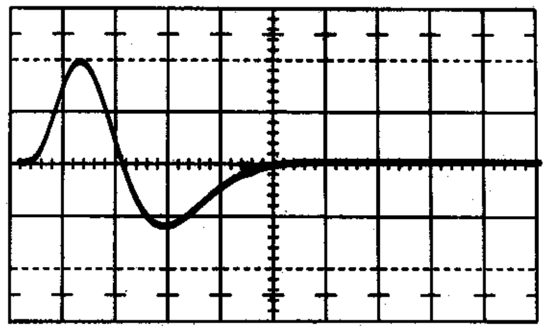
OUTPUT STAGE 6 5μsec/cm, 2V/cm



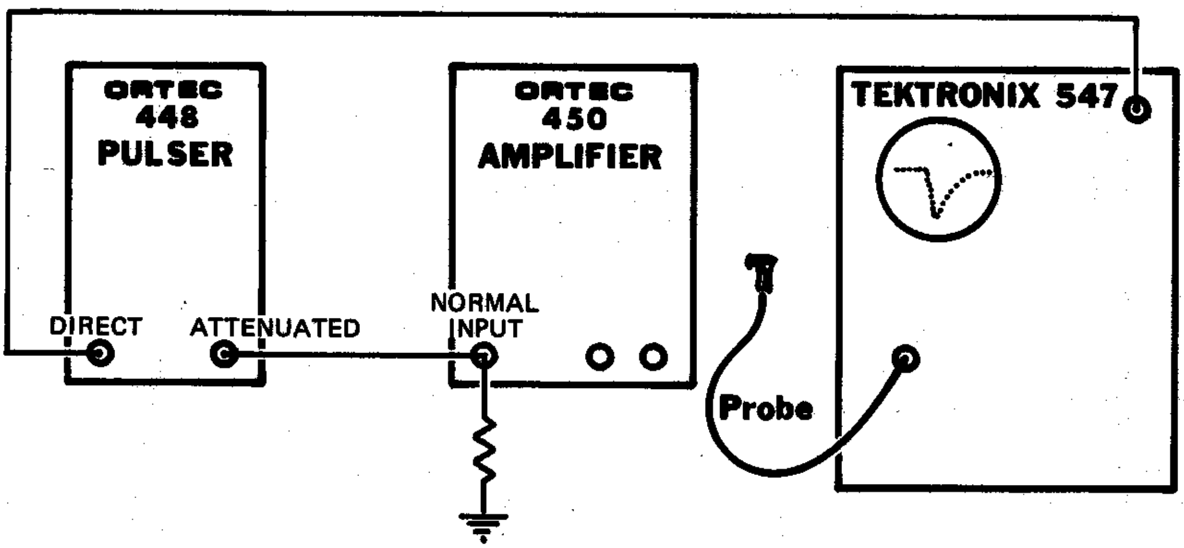
UNIPOLAR OUTPUT STAGE 8 5μsec/cm, 2V/cm



OUTPUT STAGE 7 5μsec/cm, 2V/cm



BIPOLAR OUTPUT STAGE 9 5μsec/cm, 5V/cm



450

Coarse Gain X100
Fine Gain - max
Integrate - 1.5μsec
Differentiate - 1.5μsec
Input Mode - Norm. Pos.
Output Range - +10V
BLR - OUT

PULSER
Decay Time-1000μsec
Normalize - max
Pulse Height - 4.2
Attenuation x 5
Risetime - 20 nsec
Polarity - Pos

200339

Figure 6-6. Stage-by-Stage Pulse Shaping and Gain

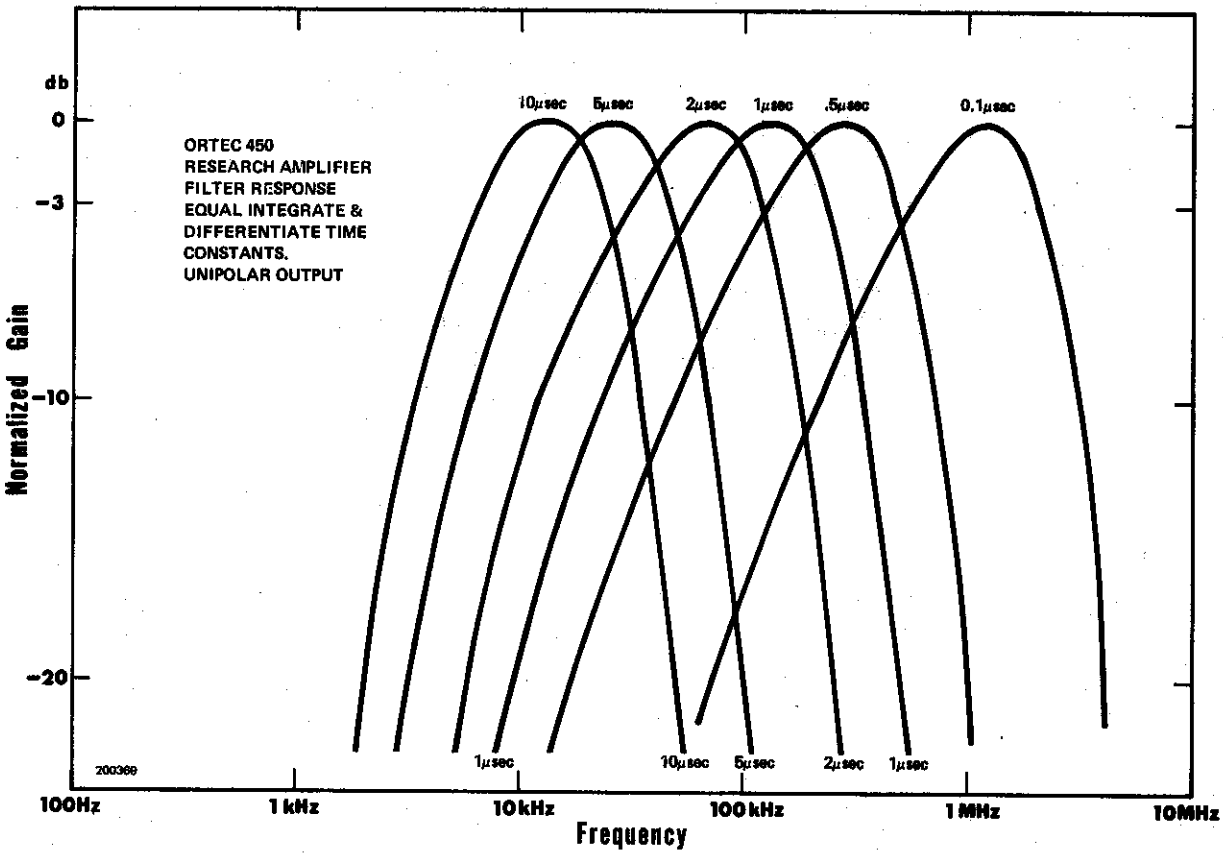


Figure 6-7. Filter Response, Using Equal Integrate and Differentiate Time Constants

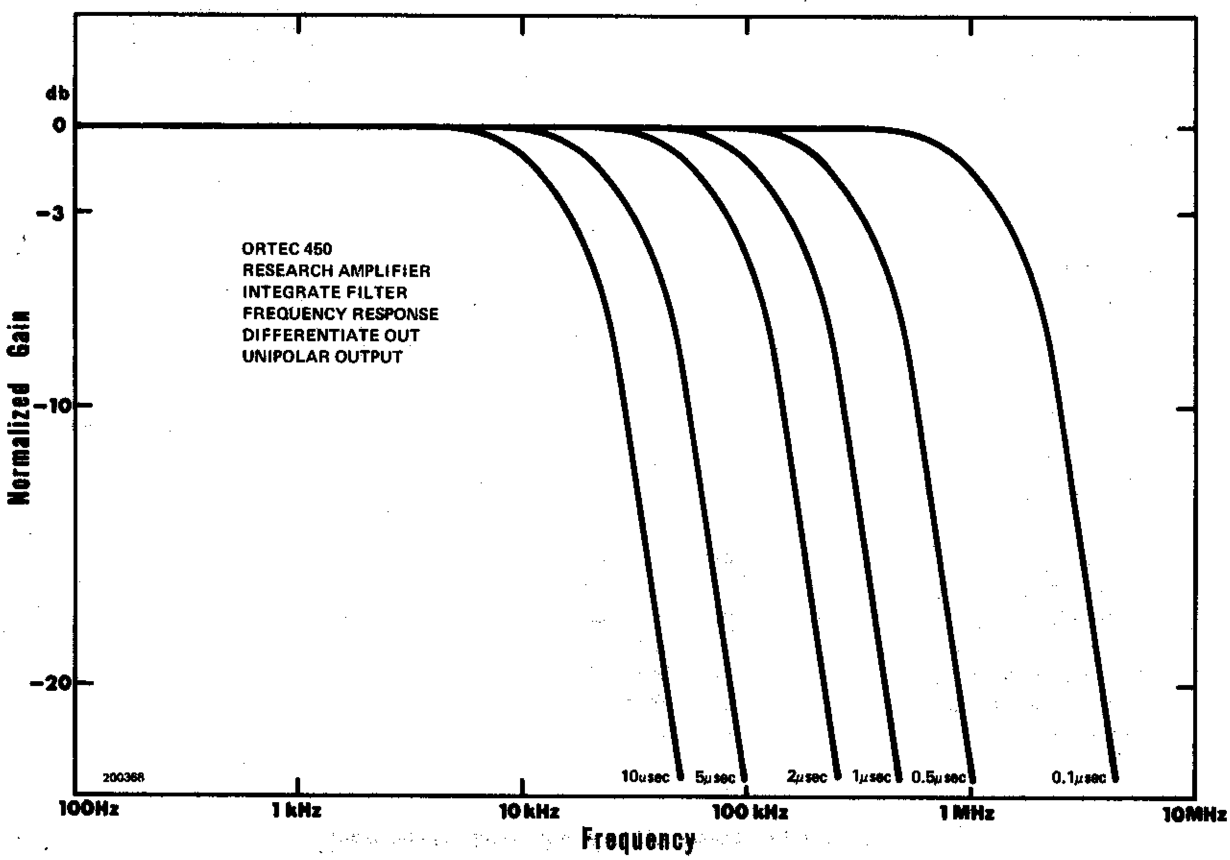


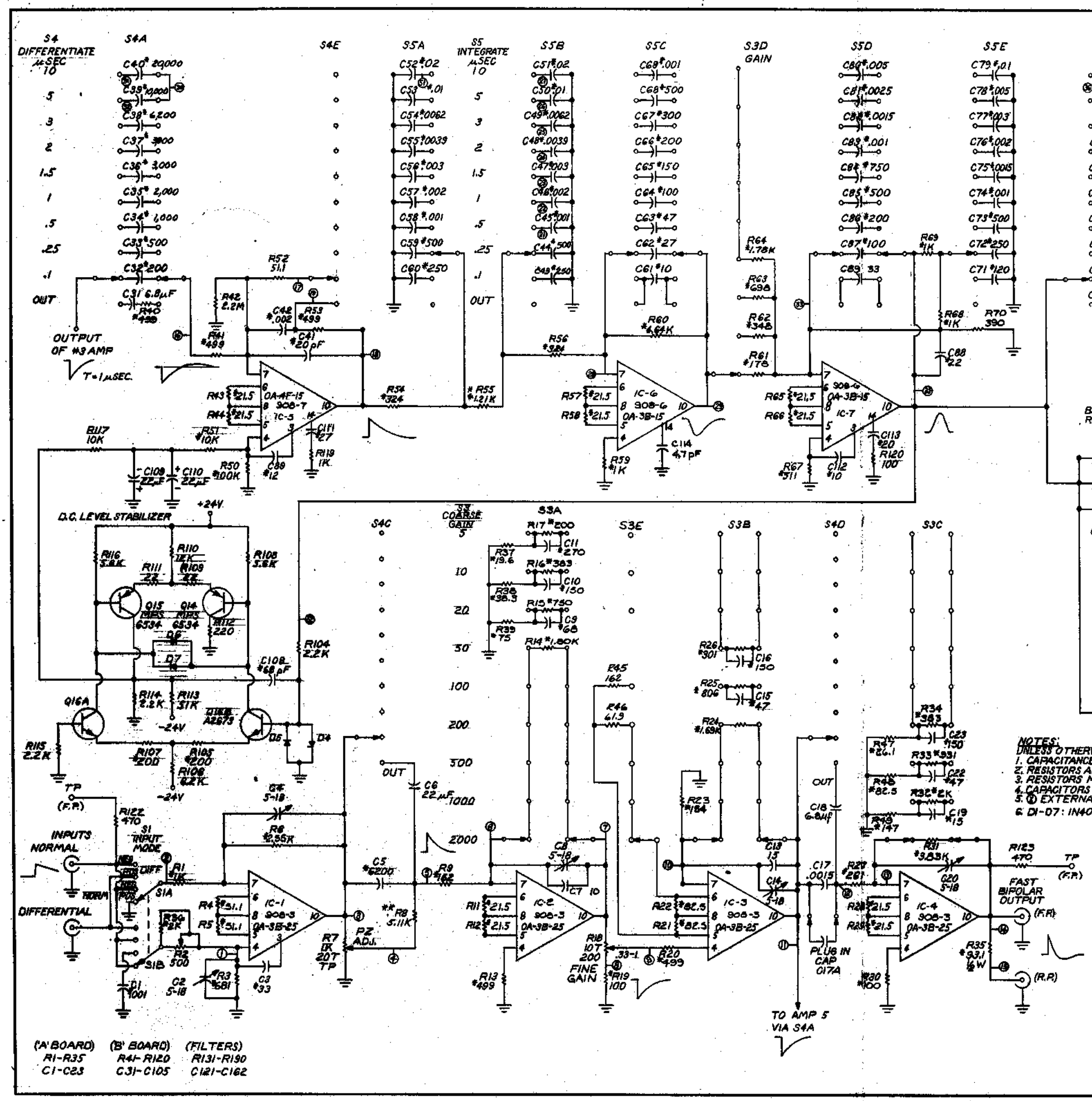
Figure 6-8. Integrate Filter Response with Differentiate Out

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

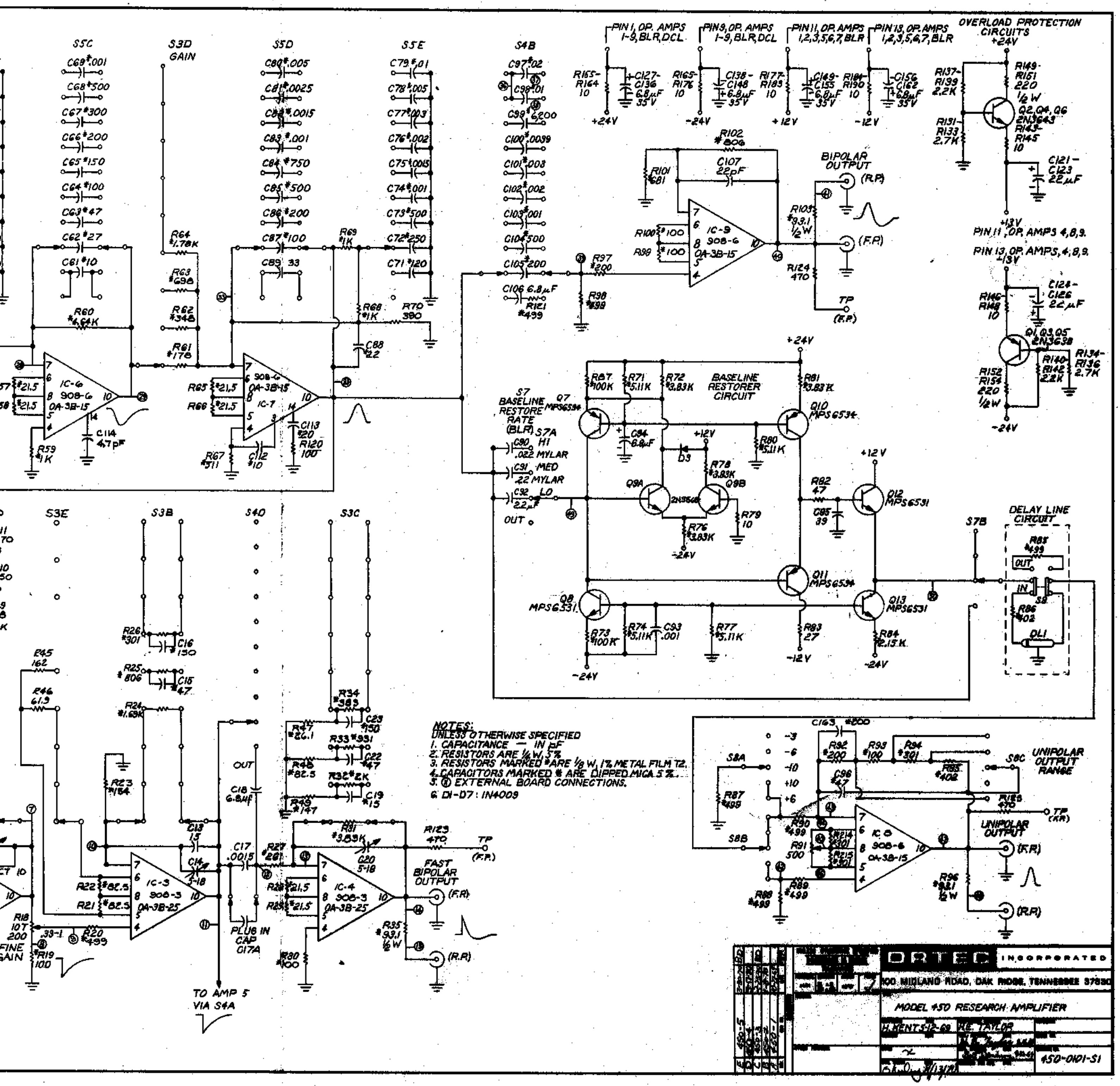
Pin	Function	Pin	Function
1	+3 volts	23	Reserved
2	- 3 volts	24	Reserved
3	Spare Bus	25	Reserved
4	Reserved Bus	26	Spare
5	Coaxial	27	Spare
6	Coaxial	*28	+24 volts
7	Coaxial	*29	- 24 volts
8	200 volts dc	30	Spare Bus
9	Spare	31	Carry No. 2
*10	+6 volts	32	Spare
*11	- 6 volts	*33	115 volts ac (Hot)
12	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.



S4 DIFFERENTIATE μSEC
S4A
S4E
S5A
S5 INTEGRATE μSEC
S5B
S5C
S3D GAIN
S5D
S5E
OUTPUT OF #3 AMP
T=1μSEC
D.C. LEVEL STABILIZER
+24V
-24V
S4C
S3 COARSE GAIN
S3A
S3E
S3B
S4D
S3C
INPUTS
NORMAL
DIFFERENTIAL
S1 INPUT MODE
DIFF
NORM
PZ ADJ.
FINE GAIN
PLUG IN CAP C17A
TO AMP 5 VIA S4A
FAST BIPOLAR OUTPUT
(F.P.)
(R.P.)
TP
IC-1
IC-2
IC-3
IC-4
IC-5
IC-6
IC-7
NOTES:
UNLESS OTHERW
1. CAPACITANCE
2. RESISTORS A
3. RESISTORS N
4. CAPACITORS
5. EXTERNA
6. D1-D7: IN40
(A' BOARD) R1-R35 C1-C23
(B' BOARD) R41-R120 C31-C105
(FILTERS) R131-R190 C121-C162



PIN 1, OP. AMPS 1-9, BLR, DCL
PIN 9, OP. AMPS 1-9, BLR, DCL
PIN 11, OP. AMPS 1,2,3,5,6,7, BLR
PIN 13, OP. AMPS 1,2,3,5,6,7, BLR
OVERLOAD PROTECTION CIRCUITS
PIN 11, OP. AMPS 4,8,9.
PIN 13, OP. AMPS 4,8,9.
S5C
S3D GAIN
S5D
S5E
S4B
BIPOLAR OUTPUT
BASELINE RESTORER CIRCUIT
S7 BASELINE RESTORE RATE (BLR)
DELAY LINE CIRCUIT
S3E
S3B
S4D
S3C
FAST BIPOLAR OUTPUT
PLUG IN CAP C17A
TO AMP 5 VIA S4A
UNIPOLAR OUTPUT RANGE
UNIPOLAR OUTPUT
NOTES:
UNLESS OTHERWISE SPECIFIED
1. CAPACITANCE — IN pF
2. RESISTORS ARE 1/4 W, 5%
3. RESISTORS MARKED * ARE 1/8 W, 1% METAL FILM T2.
4. CAPACITORS MARKED * ARE DIPPED MICA 5%.
5. ⓘ EXTERNAL BOARD CONNECTIONS.
6. D1-D7 : IN4009
ORTEC INCORPORATED
100 MIDLAND ROAD, OAK RIDGE, TENNESSEE 37830
MODEL 450 RESEARCH AMPLIFIER
H. KENT 5-12-69
K.E. TAYLOR
450-0101-S1