ORTEC®

INSTRUCTION MANUAL
MODEL 440
SELECTABLE ACTIVE FILTER AMPLIFIER

Serial No. ______________________________

Purchaser ______________________________

Date Issued ______________________________

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Printed in U.S.A.

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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, notify ORTEC of the circumstances so that we may assist in damage claims and in providing replacement equipment when necessary.

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ORTEC warrants its electronic products to be free from defects in workmanship and materials, other than vacuum tubes and semiconductors, for a period of twelve 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 the methods of installation, 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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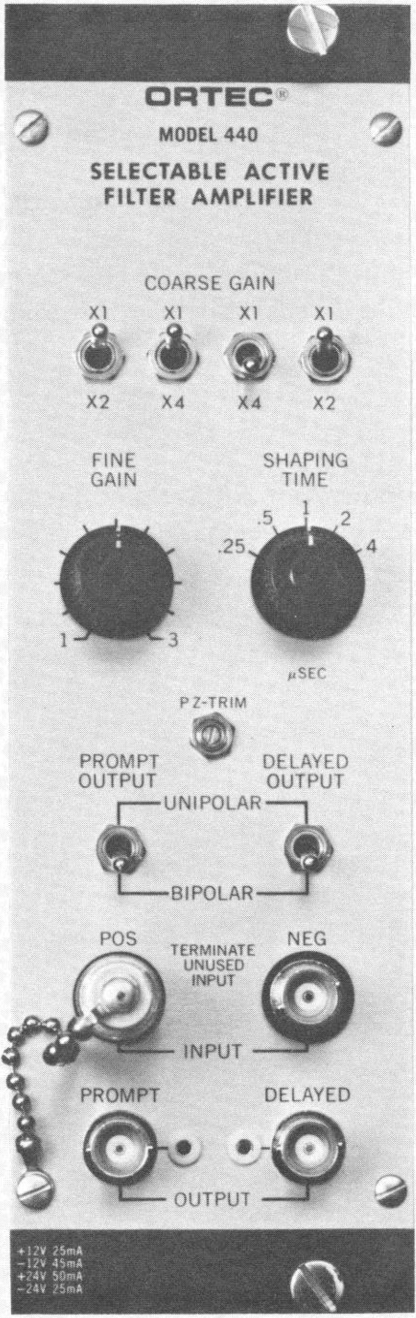
ORTEC®
MODEL 440
SELECTABLE ACTIVE FILTER AMPLIFIER
COARSE GAIN
X1
X1
X1
X1
X2
X4
X4
X2
FINE GAIN
1
3
SHAPING TIME
.25
.5
1
2
4
μSEC
PZ-TRIM
PROMPT OUTPUT
DELAYED OUTPUT
UNIPOLAR
BIPOLAR
POS
TERMINATE UNUSED INPUT
NEG
INPUT
PROMPT
DELAYED
OUTPUT
+12V 25mA
−12V 45mA
+24V 50mA
−24V 25mA

PRECAUTIONS FOR BEST SIGNAL-TO-NOISE RATIO

When the ORTEC 440 Selectable Active Filter Amplifier is used with high resolution semiconductor detectors, the following precautions should be observed in order to obtain the optimum signal-to-noise conditions.

1. Always use maximum preamplifier gain.

2. Use the Fine Gain central and the X4 Gain switch (adjacent the Fine Gain control) *first* to *attenuate* the amplifier (start with maximum gain).

3. Use the other Gain switches X2, X2 and right side X4 *last* if *further attenuation* of gain is required.

4. Select the shaping time which gives the lowest noise as viewed on an oscilloscope (all gain changes with shaping are compensated for in the ORTEC 440).

ORTEC 440
SELECTABLE ACTIVE FILTER AMPLIFIER

1. DESCRIPTION

1.1 General Description

The ORTEC 440 Selectable Active Filter Amplifier incorporates integrated circuits and modern network techniques to provide a versatile, research grade amplifier. The high resolution, stability, and wide gain range characteristics of this amplifier coupled with features of broad range shape selection and prompt and delayed outputs ensure proper operation with semiconductor detectors, scintillation counters, and ionization chambers in a wide range of experiments.

The instrument has both Prompt and Delayed outputs which can be switch selected independently from each other for either Unipolar or Bipolar pulse shaping. In addition, the Shaping Time is switch selectable in steps of 0.25, 0.5, 1, 2 and 4μsec. Pulse shaping in the 440 is accomplished by special filter networks utilizing active filter circuits to obtain a pulse response not easily obtainable with passive networks. This active filter improves noise performance and reduces the overall amplifier resolving time. Pole-zero cancellation is also employed for good overload performance (X1000 at maximum gain).[1] The cancellation network is adjustable to match all commercially available preamplifiers.

One of the unique features of this instrument is its constant matched gain for all outputs and all shaping modes. This feature allows shaping selection (Shaping Time and Unipolar or Bipolar output for each output) without the necessity for elaborate gain adjustment and ensures "dynamic range" balance for both outputs.

Both positive and negative inputs are provided allowing polarity inversion, and in addition, both inputs can be used in a differential mode to reduce common mode ground loop noise by a factor of 200. The input impedance of both inputs 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

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[1] C. Nowlin and J. Blankenship, "Elimination of undesirable undershoot in the operation and testing of nuclear pulse amplifiers," Rev. Sci. Inst. 36(12): 1830 (1965).

proper terminating resistance. The 440 has complete provisions including power for operating any ORTEC solid state preamplifier such as the 108, 109A, 113, and 118A. Preamplifier pulses should have a rise time of 0.25 microseconds or less, and a decay time greater than 40 microseconds for proper pole-zero cancellation.

The 440 can be used for crossover timing when used in conjunction with the crossover circuit in an ORTEC 407 Crossover Pickoff unit or 420 Timing Single Channel Analyzer. The 420 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 440 is about 0.5 ohm. The output can be connected to other equipment by either a single cable going to all equipment and shunt terminated at the far 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 constant impedance "T" attenuators. By using this technique, the bandwidth of the feedback amplifier stages involved in gain switching remains constant regardless of gain and therefore, rise time changes with gain switching (which cause crossover walk) are limited to only small capacitive effects across the attenuators.[2] A special, constant impedance, low temperature coefficient potentiometer is used as a Fine Gain control for the same reason.

The Delayed output of the 440 is primarily 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 Prompt output. Energy analysis is performed on the Delayed output in either the Unipolar or Bipolar mode, and the delay time compensates for the time loss in crossover timing and time delays in the coincidence circuit.

The 440 is contained in a two-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 440 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.

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[2] J. Blankenship and C. Nowlin, "New concepts in nuclear pulse amplifier design," IEEE Trans. Nucl. Sci. NS-13: 495-513 (1966).

1.2 Pole-Zero Cancellation

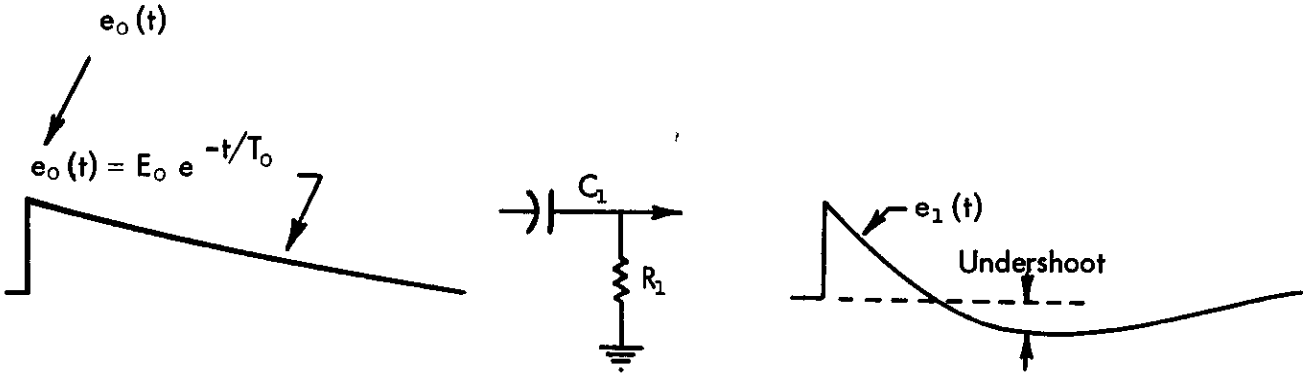
Pole zero cancellation is a method for eliminating pulse undershoot after the first clipping (differentiating) network. The technique employed is described by referring to the waveforms and equations shown in Figures 1-1 and 1-2. In a non-pole-zero cancelled amplifier, the exponential tail on the preamplifier output signal (usually 50 to 500 μsec) 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 1 μsec clipping time and a 50 μsec preamplifier pulse decay time, the maximum undershoot is 2% and decays with a 50 μsec 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 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 Fig. 1-2. The pole $(\frac{1}{S + 1/T_o})$ 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 clipping capacitor adds an attenuated replica of the preamplifier pulse to just cancel the negative undershoot of the clipping network.

Total 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 40 μsec or greater decay times. The network is factory adjusted to 50 μsec 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 trim is accessible from the front panel of the 440 and can easily be adjusted by observing the baseline with a mono-energetic source input under overload conditions.



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

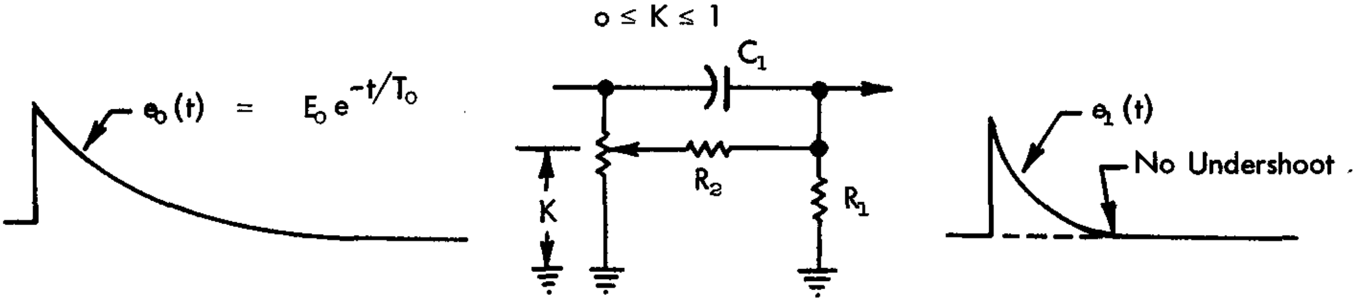
Equations:

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

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

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

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



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

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

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

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 Clipping in a Pole-Zero Cancelled Amplifier

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 Fig. 1-3) is not physically realizable and very difficult to simulate. A pulse shape that can be simulated (the Gaussian in Fig. 1-3), requires a single RC clip and n equal RC integrates where n approaches infinity. The Laplace transform of this transfer function is:

$$G(S) = \frac{S}{(S + 1/RC)} \qquad \frac{1}{(S + 1/RC)^n} \qquad n \to \infty$$

Where the first term is the single clip and the second term is the n integrates. The 440 Active Filter attempts to simulate this transfer function with the simplest possible circuit.

The ORTEC 440 Active Filter circuit is shown in Fig. 1-4. The major attraction of the active RC filter is the elimination of inductive elements resulting in a significant reduction in size, complexity and cost. For a given resolving time (RC), the time response of the filter network depends only on K (see the circuit equations in Fig. 1-4). For K = 1, the transfer function simplifies to:

$$\frac{e_o}{e_i} = \frac{1/R^2C^2}{S^2 + \frac{2S}{RC} + \frac{1}{R^2C^2}} = \frac{1/R^2C^2}{(S + 1/RC)^2}$$

which is an n = 2 approximation to the Gaussian pulse shape (see Fig. 1-3). For K = 4 (the actual case for the 440), the transfer function becomes:

$$\frac{e_o}{e_i} = \frac{4/R^2C^2}{S^2 + \frac{2S}{RC} + \frac{4}{R^2C^2}} = \frac{4/R^2C^2}{\left(S + \frac{1 + j\sqrt{3}}{RC}\right)\left(S + \frac{1 - j\sqrt{3}}{RC}\right)} \qquad j = \sqrt{-1}$$

In this case, the complex roots cause an underdamped effect which reduces the resolving time and results in a more symmetrical pulse shape (see Figure 1-3).

The 440 is manufactured with switch selectable time constants of 0.25, 0.5, 1, 2 and 4μsec (with R = 100Ω, RC = T, and K = 4).

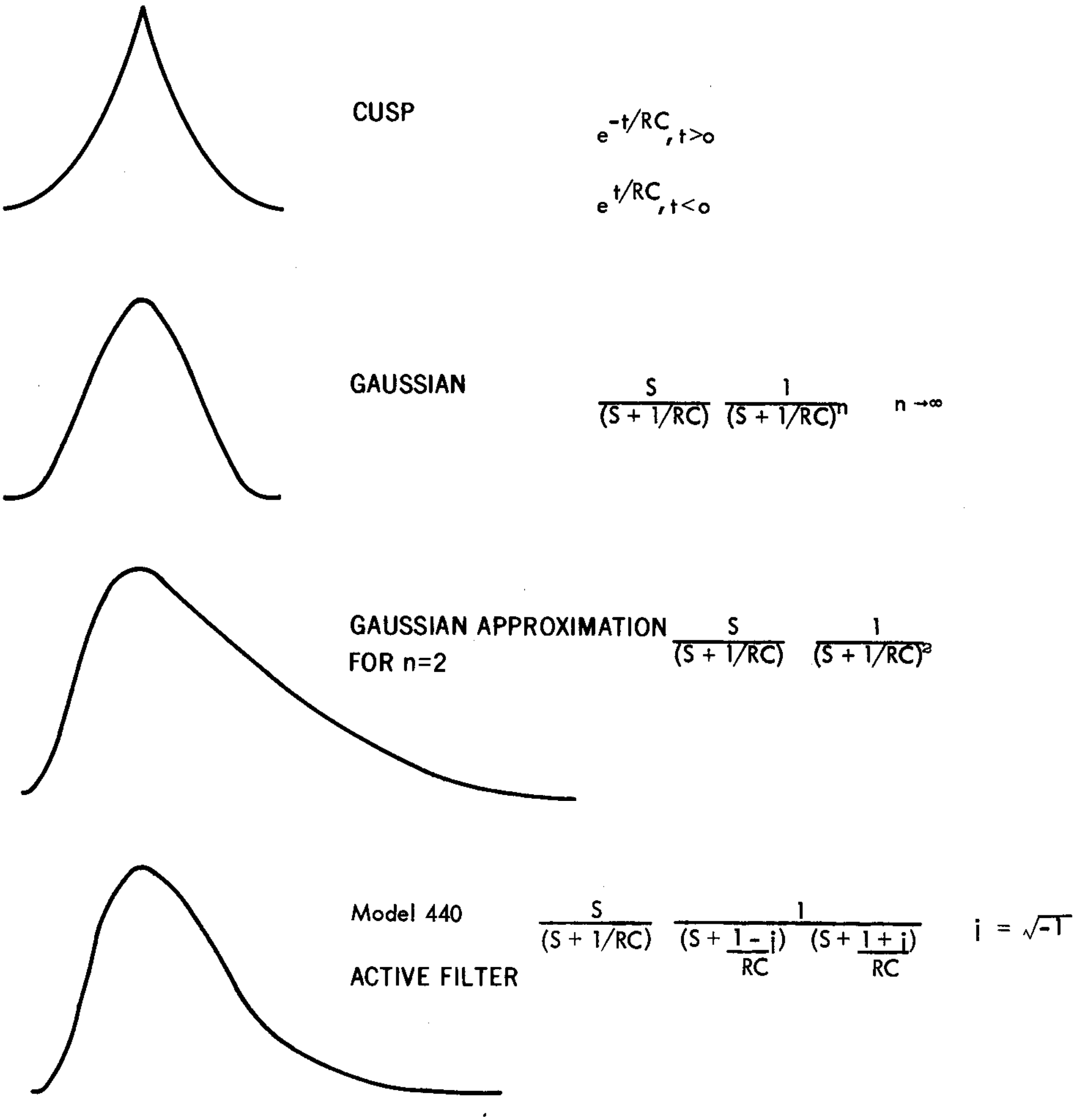
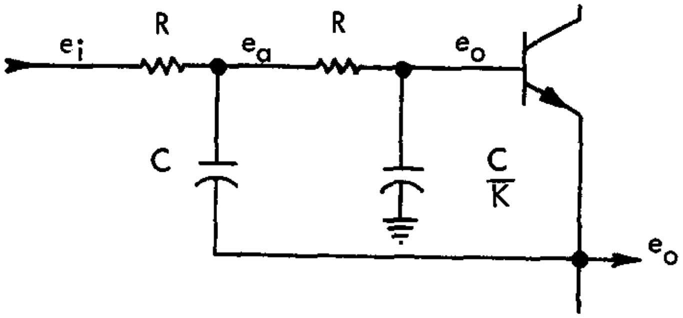


Figure 1-3 Pulse Shapes for Good Signal-to-Noise Ratios



Equations:

$$e_o = e_a \frac{K/SC}{R + K/SC} = e_a \frac{K}{K + SRC}$$

$$\frac{e_i - e_a}{R} = \frac{e_a - e_o}{R} + \frac{e_a - e_o}{1/SC}$$

Eliminating e_a and solving for the transfer function:

$$\frac{e_o}{e_i} = \frac{K/R^2C^2}{S^2 + \frac{2S}{RC} + \frac{K}{R^2C^2}}$$

Figure 1-4 ORTEC 440 Active Filter

2. SPECIFICATIONS

2.1 General Specifications

2.1.1 The 440 is intended for use with a Nuclear Standard Bin such as the ORTEC 401A/402A. About 2.6 watts of power is required for the operation of the 440 in the quiescent condition. The ORTEC 401A/402A can be operated on either 115 or 220 volts ac, 50-60 cps; if it is used with 220 volts ac, the manual for the 401/402 must be referred to in order to ensure that correct connections have been made before operation on 220 volts ac is attempted. The instrument is supplied from the factory wired for 115 volts ac operation. The power input connector to the ORTEC 401A/402A is a NEMA standard 3-wire grounding type.

Preamplifier power of ± 12V and ±24V is available on the 440 rear panel connector, CN6, an Amphenol 17-10090. All signal inputs and outputs are on BNC connectors which are mounted on the front panel.

2.1.2 The instrument is intended for rack mounting in an ORTEC 401/402 Nuclear Standard Bin, but the Nuclear Standard Bin is suitably packaged for cabinet installation if desired. The weight of the 440 is 3 pounds and its outside dimensions are approximately 8.75 inches high by 2.70 inches wide by 9.75 inches deep.

2.2 Amplifier Specifications

INPUTS: Positive and negative, no rise time limitation, 40μsec minimum decay time constant for pole-zero cancellation, 12V maximum, 6V maximum to prevent saturation before clipping, 1000 ohms input impedance both inputs.

PROMPT OUTPUT: Positive or bipolar, 0-10V linear with 11.8V saturation into 1000 ohms, 0-9V linear with 10.5V saturation into 100 ohms.

DELAYED OUTPUT: Same as above, but delayed by 2μsec.

SHAPING: Active filter resulting in approximately Gaussian shape, selectable shaping times of 0.25, 0.5, 1, 2, and 4μsec; choice of either unipolar or bipolar shaping on both outputs; constant gain in all shaping modes.

MAXIMUM GAIN: 1800

GAIN CHANGE RANGE: 192:1 total, 64:1 in factors of 2 by switches with 1% accuracy, 3:1 continuous fine control.

LINEARITY: ±0.075% over specified linear range.

NOISE: 10μV at maximum gain and single clip, 12μV at maximum gain and double clip, both referred to input with 1μsec shaping time.

SHORT CIRCUIT LIMITS: The amplifier will sustain a direct short on the output for an indefinite period for counting rates up to 10^4 cps.

OVERLOAD: Recovery within 2% of rated output from 1000 times overload in 2.5 non-overloaded pulse widths at maximum gain and specified input.

OPERATING TEMPERATURE: 0 to 50 °C.

TEMPERATURE STABILITY: 0.01%/°C.

CROSSOVER WALK: ±1 nsec for 20:1 dynamic range with 0.25μsec bipolar shaping (amplifier only), ±2 nsec for 10:1 dynamic range with 1μsec bipolar shaping (amplifier and ORTEC 420 Timing Single Channel Analyzer), ±10 nsec for full range of gain change and 1μsec bipolar shaping.

COUNTING RATE: Gain shift less than 0.25%, resolution spread at half maximum less than 0.5% for a pulser peak with a 50K cts/sec ^{137}Cs background.

POWER REQUIRED: ORTEC 440 power supplied by ORTEC 401A/402A Power Supply

DC input voltage	Quiescent current	Current with 50,000 pulses per second, each pulse 8V into 100 ohms
+24V	51 mA	51 mA
-24V	24 mA	24 mA
+12V	26 mA	33 mA
-12V	44 mA	51 mA

3. INSTALLATION

3.1 General Installation Considerations

The 440, 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 440 has sufficient cooling air circulating to prevent any localized heating of the all-semiconductor circuitry used throughout the 440. The temperature of equipment mounted in racks can easily exceed 120°F (50°C) unless precautions are taken.

3.2 Termination of Unused Input

The ORTEC 440 is supplied with a 100 ohm attenuator. This attenuator should be connected to the unused input for proper gain calibration and best signal-to-noise ratio.

3.3 Connection to Preamplifier

The preamplifier output signal can be connected to the 440 via BNC connector CN1 labeled POS INPUT or BNC connector CN2 labeled NEG INPUT, depending on the polarity of the input pulse. The input impedance seen at either input is 1000 ohms and both inputs are 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 440 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 50 μsec 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 easily accomplished by using a monoenergetic source and observing the amplifier baseline after each pulse overload conditions.

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

When using the 440 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 440 input is matched. Since the input impedance of the 440 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 91 ohms or variable.

Both inputs of the 440 can be used simultaneously to reduce common mode noise picked up by long cables passing noise generating areas. In this mode of operation, the preamplifier signal is connected to the POS 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 NEG 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.

3.4 Connection of Test Pulse Generator

3.4.1 Connection of Pulse Generator to the 440 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 440 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.

3.4.2 Direct Connection of Pulse Generator to the ORTEC 440

Since both inputs of the 440 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 of the 440 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.)

3.4.3 Special Test Pulse Generator Considerations for Pole-Zero Cancellation

The pole-zero cancellation network in the ORTEC 440 is factory adjusted for a 50μsec decay time to match ORTEC FET preamplifiers. When a 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.

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

The 440 contains no internal power supply and therefore must obtain power from a Nuclear Standard Bin and Power Supply such as the ORTEC 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 ORTEC 401A/402A has test points on the power supply control panel to monitor the dc voltages.

3.6 Shaping Considerations

The Shaping Time on the ORTEC 440 amplifier is switch selectable in steps of 0.25, 0.5, 1, 2, and 4µsec. 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 or 4µsec resolving time will generally give optimum resolution. For semiconductor detectors, a 1 or 2µsec resolving time will usually 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 440 maintains constant gain for all shaping modes. Therefore, the optimum shaping time can be obtained with an rms voltmeter.

The 440 also allows a choice of unipolar or bipolar output. The bipolar output should be used in applications where high counting rates are desired and noise or resolution is a secondary consideration. This includes most applications with scintillation counters and some high counting rate applications of semiconductor detectors. Unipolar pulse should be used in applications where the best signal-to-noise ratio (resolution) is desired. This area is primarily confined to high resolution spectroscopy using semiconductor detectors.

3.7 Use of Delayed Output

The 440 has two linear outputs each of which can be switch selected for either unipolar or bipolar output pulses. The Prompt output is used for normal spectroscopy applications. The Delayed output (equal in amplitude to the Prompt output, but delayed by 2μsec) 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 3.6.

3.8 Output Termination

The source impedance of the 0-10 volt standard linear outputs of most 400 Series modules is approximately 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. 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.

3.9 Amplifier Gain and Noise Considerations

Under normal operating conditions, the signal-to-noise ratio will be determined by detector and preamplifier noise and will be constant for any gain setting. However, in some circumstances, the amplifier may contribute additional noise to the overall system. If this situation exists, the best signal-to-noise performance will be obtained at maximum gain and the worst condition will be when either X2 Gain switch or the X4 switch (adajacent to the Shaping switch) are in the X1 position. The signal-to-noise ratio is only slightly affected by the X4 Gain switch position and the Fine Gain control.

3.10 Shorting the Amplifier Output

The output of the 440 is ac coupled with an output impedance of about 0.5 ohm. If the output is shorted with a direct short-circuit and the amplifier counting rate exceeds 10,000 counts per second, the output stage will eventually heat up sufficiently to destroy itself (about one minute for 10^5 cps). The amplifier output may be shorted indefinitely without catastrophic damage at rates below 10^4 cps.

4. OPERATING INSTRUCTIONS

4.1 Controls and Connectors

4.1.1 Description

FINE GAIN: Fine gain control is provided over a range of 3:1. The Fine Gain control is a dual potentiometer specially designed to maintain constant impedance and stable operation.

COARSE GAIN: Coarse Gain control is provided by three individually switchable, constant impedance "T" attenuators. The gain factors provided by each of these switches is X2, X4, X4, and X2. The best signal-to-noise ratio is obtained with the X2, X2, and right side X4 in their maximum gain positions.

SHAPING TIME: The amplifier shaping time is switch selectable in steps of 0.25, 0.5, 1, 2, and 4μsec. The switch steps are compensated so that both outputs remain constant in amplitude for all shaping times.

PROMPT UNIPOLAR-BIPOLAR: Either unipolar or bipolar prompt output pulses are switch selectable.

DELAYED UNIPOLAR-BIPOLAR: Either unipolar or bipolar delayed output pulses are switch selectable.

PROMPT OUTPUT: Shaped, low impedance output with a test probe adjacent for oscilloscope monitoring.

DELAYED OUTPUT: Shaped, low impedance output delayed by 2μsec with an adjacent test probe for oscilloscope monitoring.

POS INPUT: The input for preamplifier pulses having a positive polarity. When this input is not used, it should be terminated with a 100 ohm terminator which is supplied with the amplifier.

NEG INPUT: The input for preamplifier pulses having a negative polarity. When this input is not used, it should be terminated with a 100 ohm terminator which is supplied with the amplifier.

P-Z TRIM: A screwdriver adjustable trim potentiometer for properly adjusting the pole-zero cancellation.

4.1.2 Front and Rear Panel Connector Data

Connector See Dwg 440-0101-S1	Generic Designation	Test Point	Output or Input Impedance	Shape and Amplitude Limitations
CN-1	POS INPUT	No	1000Ω	Positive only, less than 0.25μsec rise time, 40μsec or greater decay time, 6V maximum linear, 12V maximum
CN-2	NEG INPUT	No	1000Ω	Same as above, but negative only
CN-3	PROMPT OUTPUT	TP-1	0.5Ω	Positive or bipolar, 0-10V linear with 11.5V saturation into 1000Ω, 0-9V linear with 10V saturation into 100Ω, approximate Gaussian shape
CN-4	DELAYED OUTPUT	TP-2	0.5Ω	Same as above, but delayed by 2μsec
CN-6	PREAMP POWER	No	dc	Pin 1: Gnd Pin 6: -24V Pin 7: +24V Pin 9: -12V Pin 4: +12V

4.2 Initial Testing and Observation of Pulse Waveforms

Refer to Section 6 for information on testing performance and observing waveforms at front panel test points.

4.3 General Considerations for Operation with Semiconductor Detectors

4.3.1 Calibration of Test Pulser

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

(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 gains 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 5.1 MeV α-particle, set the dial at 510 divisions).

(5) Turn on the Pulser, use the NORMALIZE potentiometer and attenuators to set the output due to the pulser to 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.

4.3.2 Amplifier Noise and Resolution Measurements

As shown in Fig. 4-1, 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

$$N\ (\text{fwhm}) = \frac{2.660\ E_{rms} E_{dial}}{E_o}$$

where E_{dial} is the pulser dial reading in MeV and the factor 2.660 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 118A 440 system is shown in Fig. 4-2.

4.3.3 Detector Noise Resolution Measurements

The same measurement described in Section 4.3.2 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 4-3 shows curves of typical total noise resolution spread versus bias voltage, using the data from several ORTEC silicon semiconductor radiation detectors.

4.3.4 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 Fig. 4-4.

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.

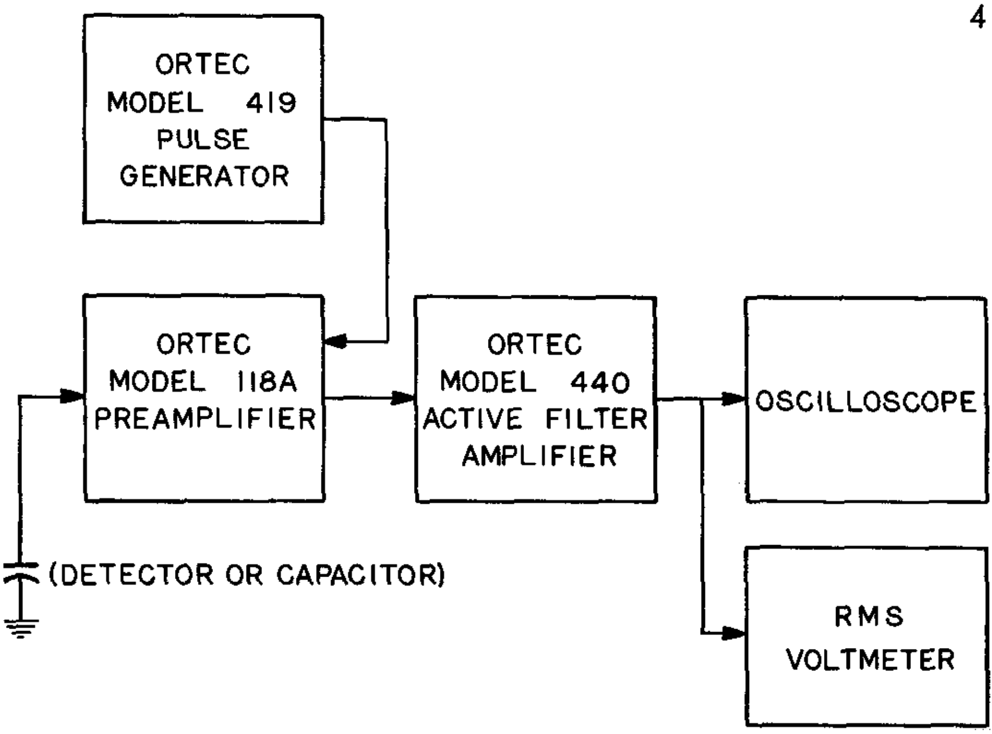


Figure 4-1. Measuring Amplifier and Detector Noise Resolution

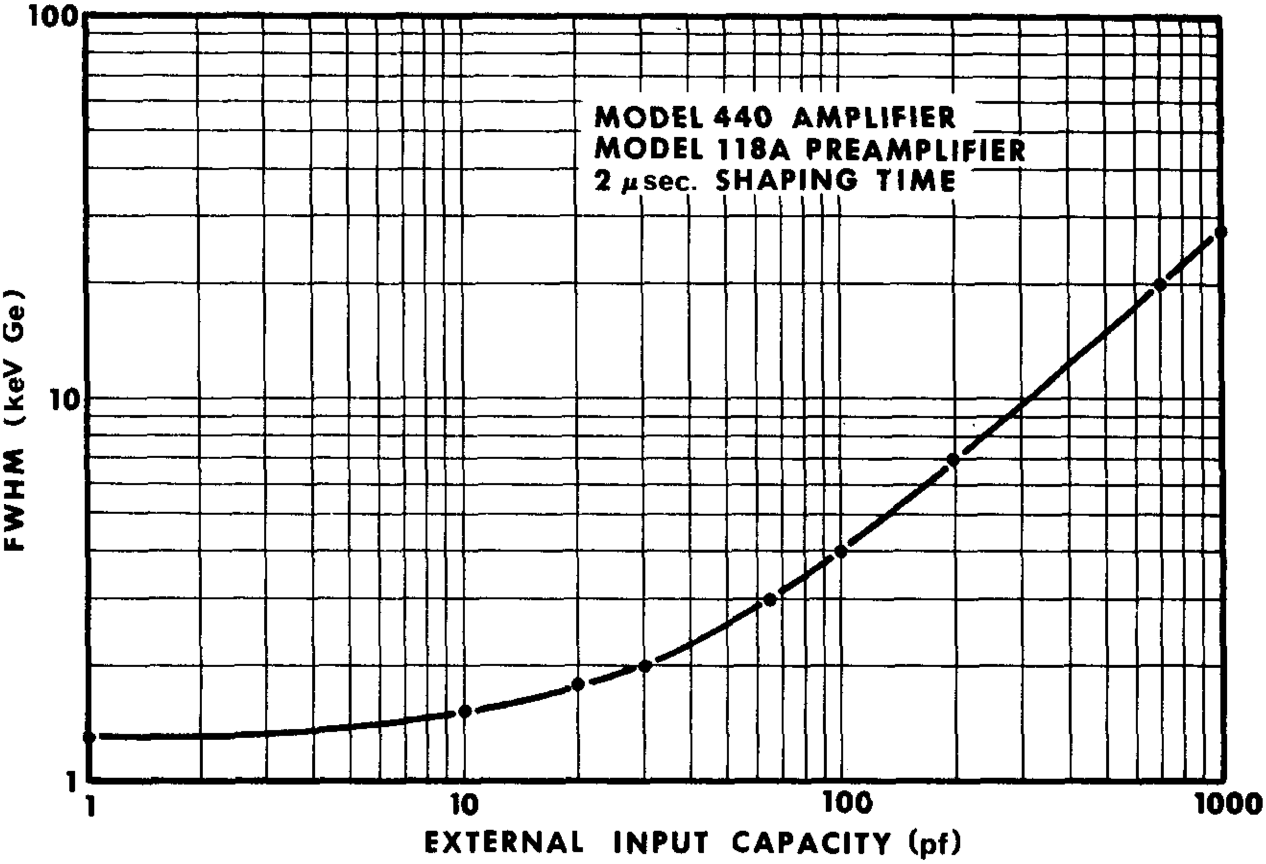


Figure 4-2. Resolution Spread Versus External Input Capacity

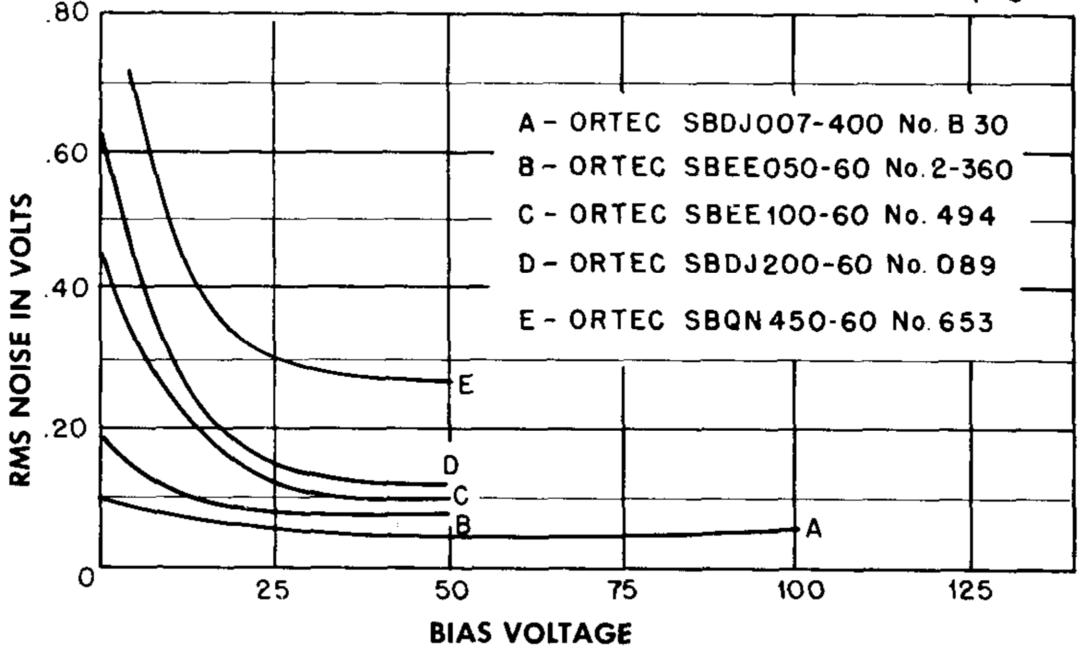


Figure 4-3. Amplifier and Detector Noise Versus Bias Voltage

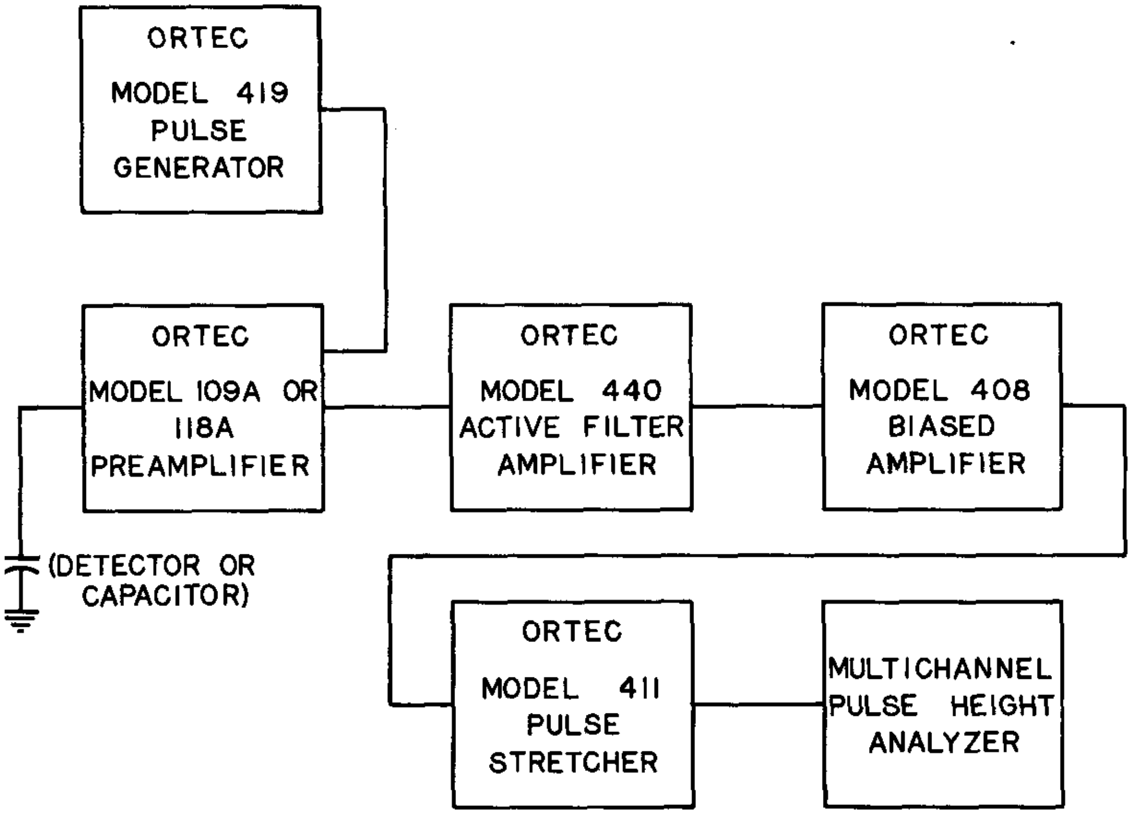


Figure 4-4. Measuring Resolution with a Pulse Height Analyzer

(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 4.3.1).

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

4.3.5 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 measurements. 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.

Figure 4-5 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 4-6 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 Fig. 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

4.3.6 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:

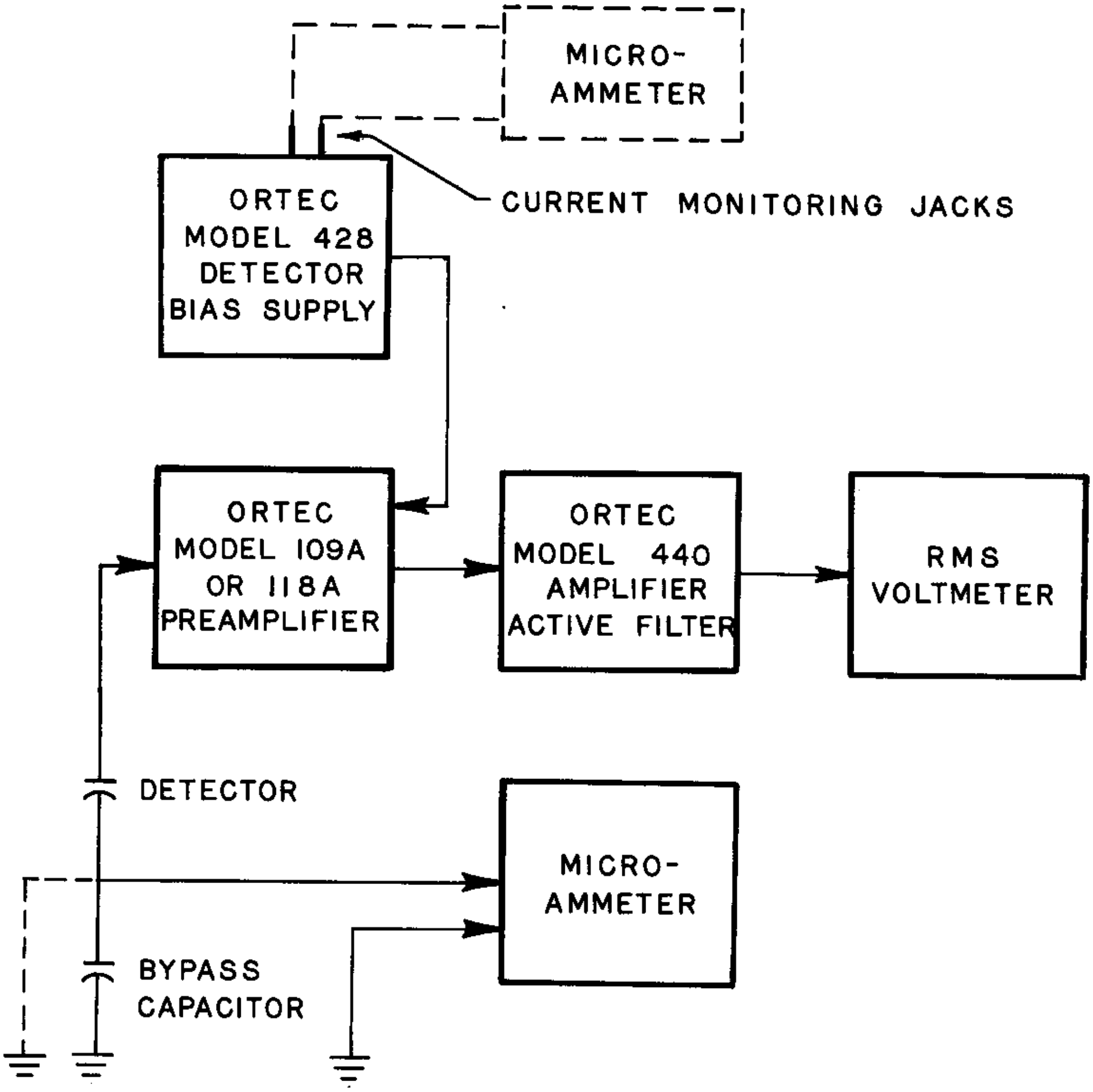


Figure 4-5. Measuring Detector Current-Voltage Characteristics

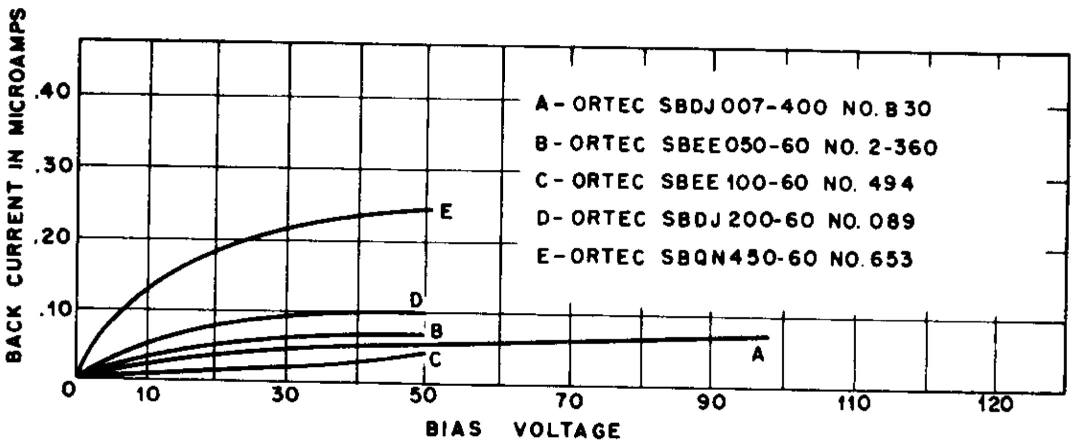


Figure 4-6. Silicon Detector Back Current Versus Bias Voltage

(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) Under normal operating conditions, the signal-to-noise ratio will be determined by detector and preamplifier noise and will be constant for any gain setting. However, in some circumstances, the amplifier may contribute additional noise to the overall system. If this situation exists, the best signal-to-noise performance will be obtained at maximum gain and the worst condition will be when either X2 Gain switch or the X4 switch (adajacent to the Shaping switch) are in the X1 position. The signal-to-noise ratio is only slightly affected by the left side X4 gain switch position and the Fine Gain control.

4.4 Operation in Spectroscopy Systems

4.4.1 High-Resolution Alpha-Particle Spectroscopy System

The block diagram of a high resolution spectroscopy system for measuring natural alpha-particle radiation is shown in Fig. 4-7. Since natural alpha-particle radiation only occurs above several MeV, an ORTEC 408 Biased Amplifier and ORTEC 411 Stretcher are used to suppress the unused portion of the spectrum. The ORTEC 411 is used to shape the output pulses after biasing to avoid pulse height analyzer nonlinearities.

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 4.3.1).

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

4.4.2 High Resolution Gamma Spectroscopy System

A high resolution gamma system block diagram is shown in Fig. 4-8. Although a biased amplifier is now 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.

4.4.3 Scintillation Counter Gamma Spectroscopy Systems

The ORTEC 440 can be used in scintillation counter spectroscopy systems as shown in Fig. 4-9. The amplifier clipping time constants are proper for NaI or plastic scintillators. For scintillators having longer decay times, the time constants must be changed (see Section 5.3).

4.4.4 X-Ray Spectroscopy Using Proportional Counters

Space charge effects in proportional counters operated at high gas amplification tend to drastically degrade the resolution capabilities at x-ray energies, even at relatively low counting rates. By using a high gain, low noise amplifying system and lower gas amplification, these effects can be reduced and a considerable improvement in resolution can be obtained. The block diagram in Fig. 4-10 shows

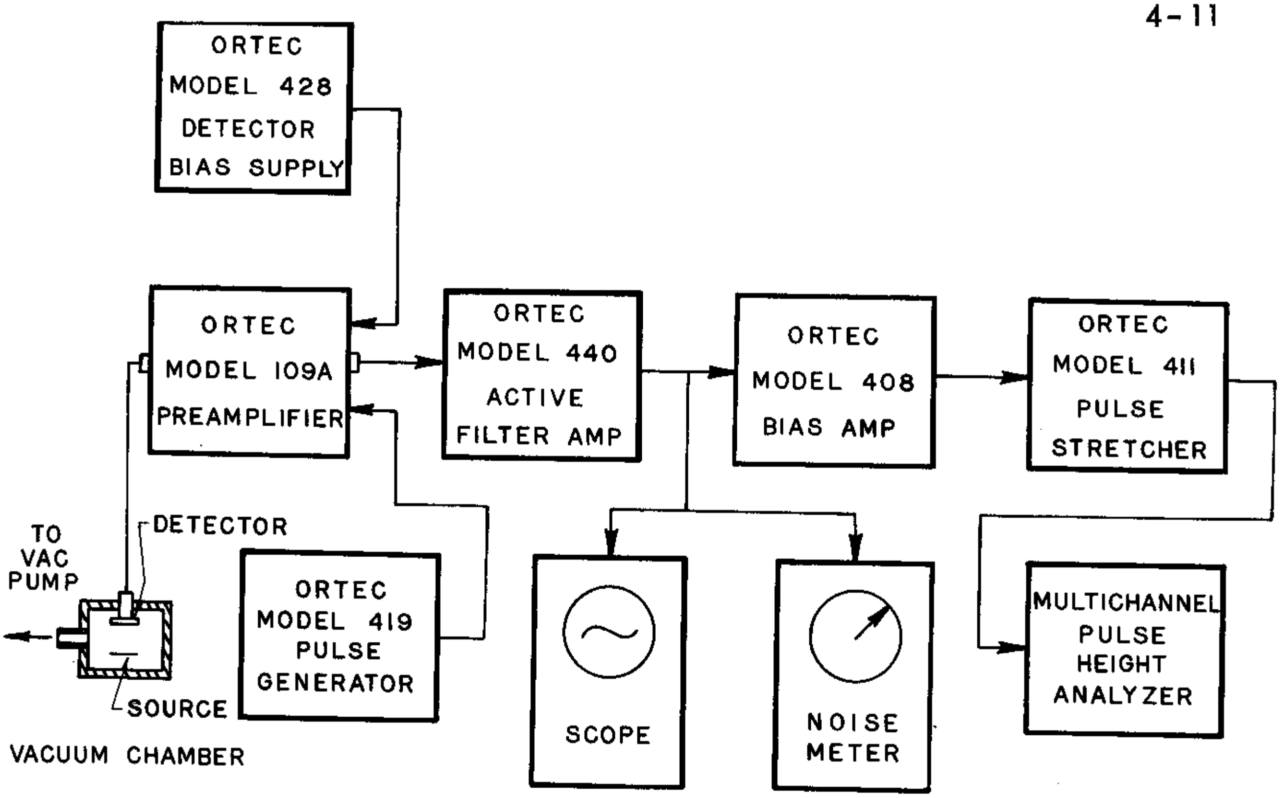


Figure 4-7. High Resolution Alpha Particle Spectroscopy System

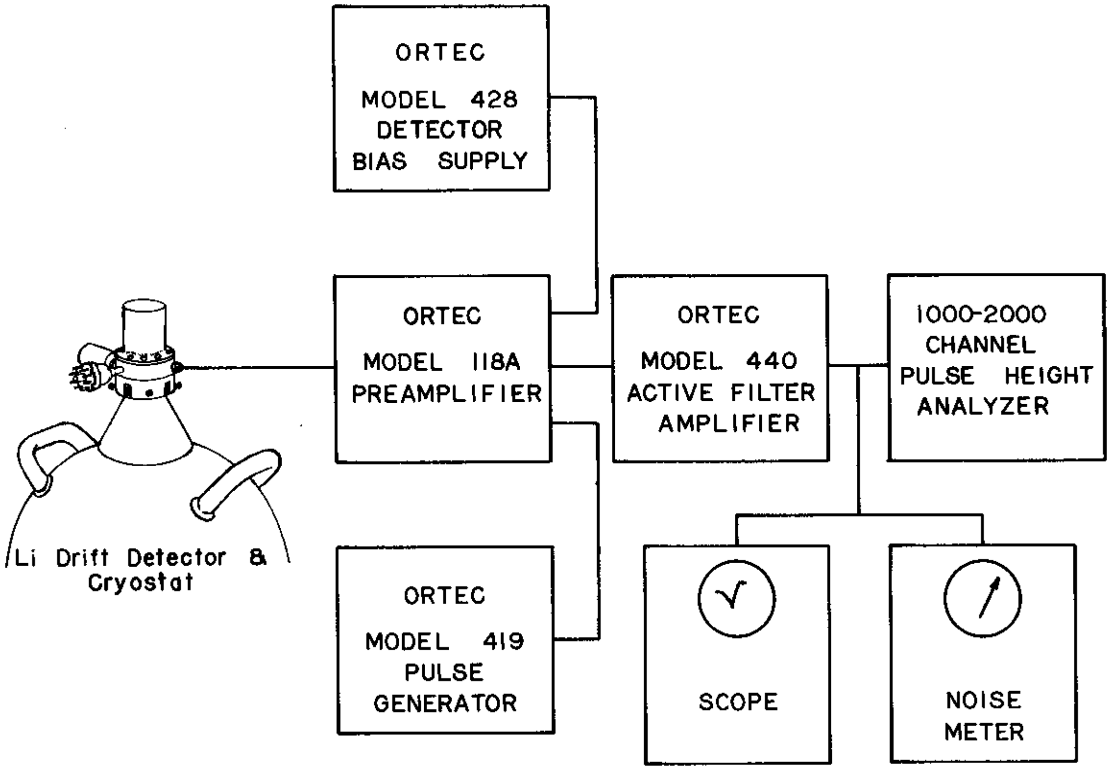


Figure 4-8. High Resolution Gamma Spectroscopy System Using a Lithium Drifted Germanium Detector

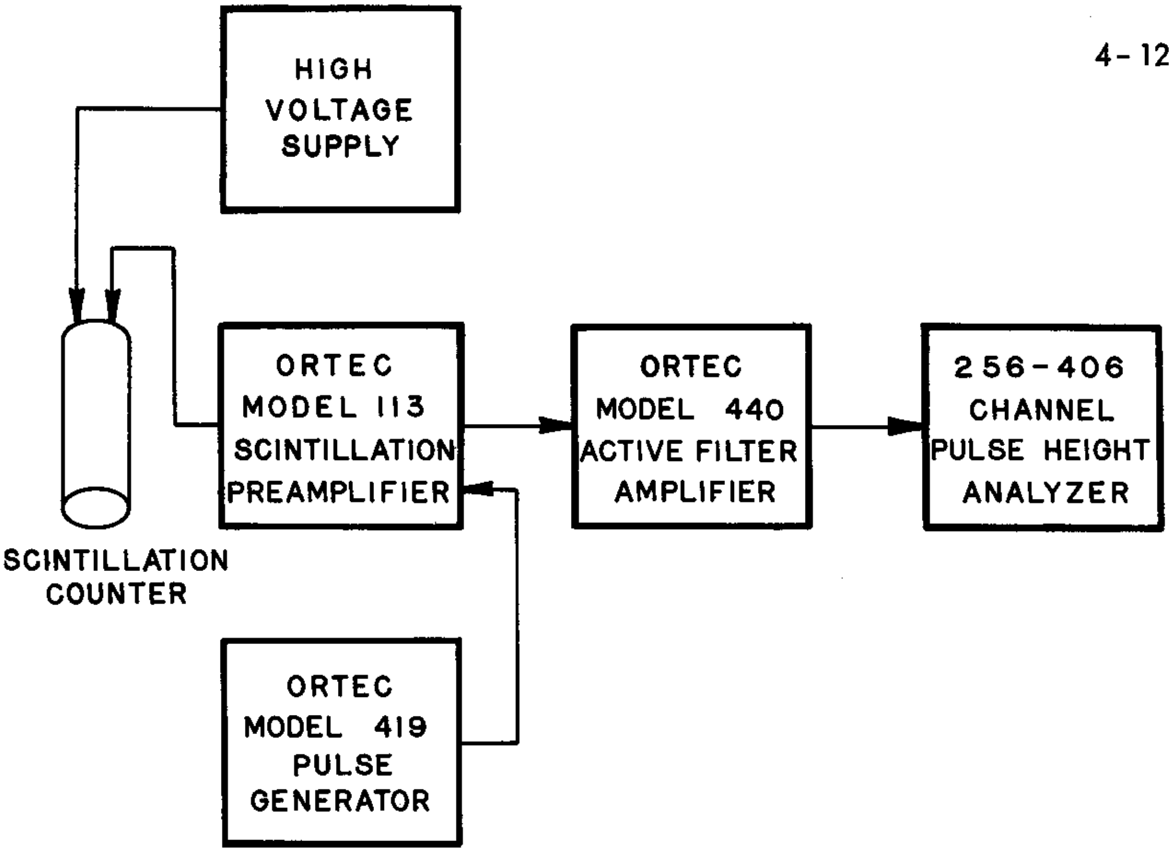


Figure 4-9. Scintillation Counter Gamma Spectroscopy System

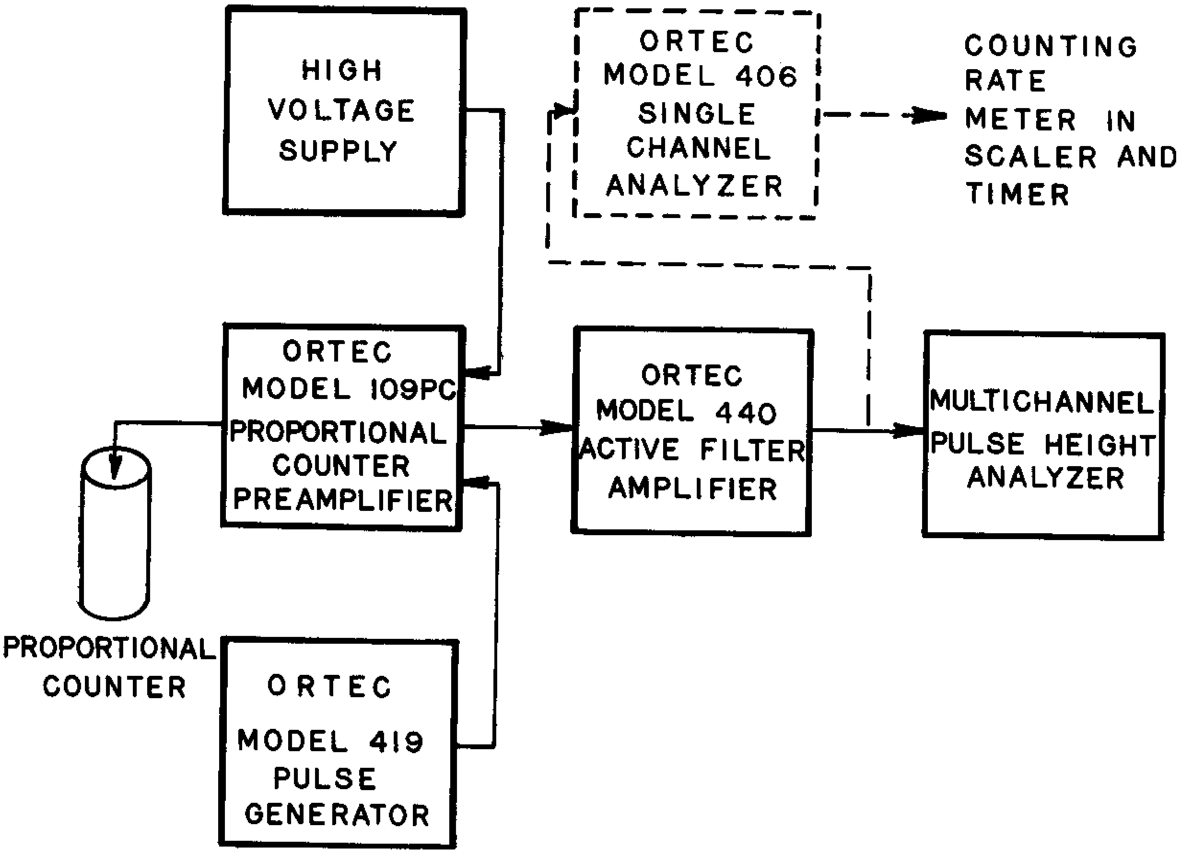


Figure 4-10. High Resolution X-Ray Spectroscopy System

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.

4.5 Typical System Block Diagrams

This section contains block diagrams illustrating how the 440 and other ORTEC 400 Series modules can be used in experimental setups.

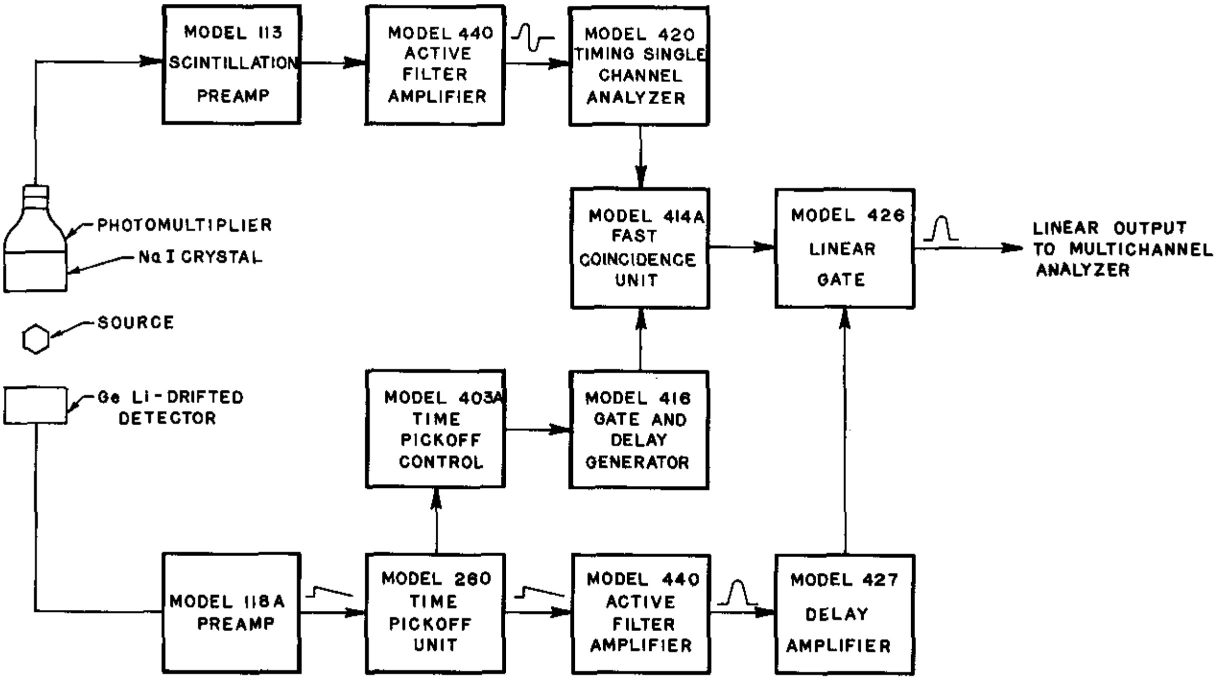


Figure 4-11. Gamma Ray-Gamma Ray Coincidence Experiment - Block Diagram

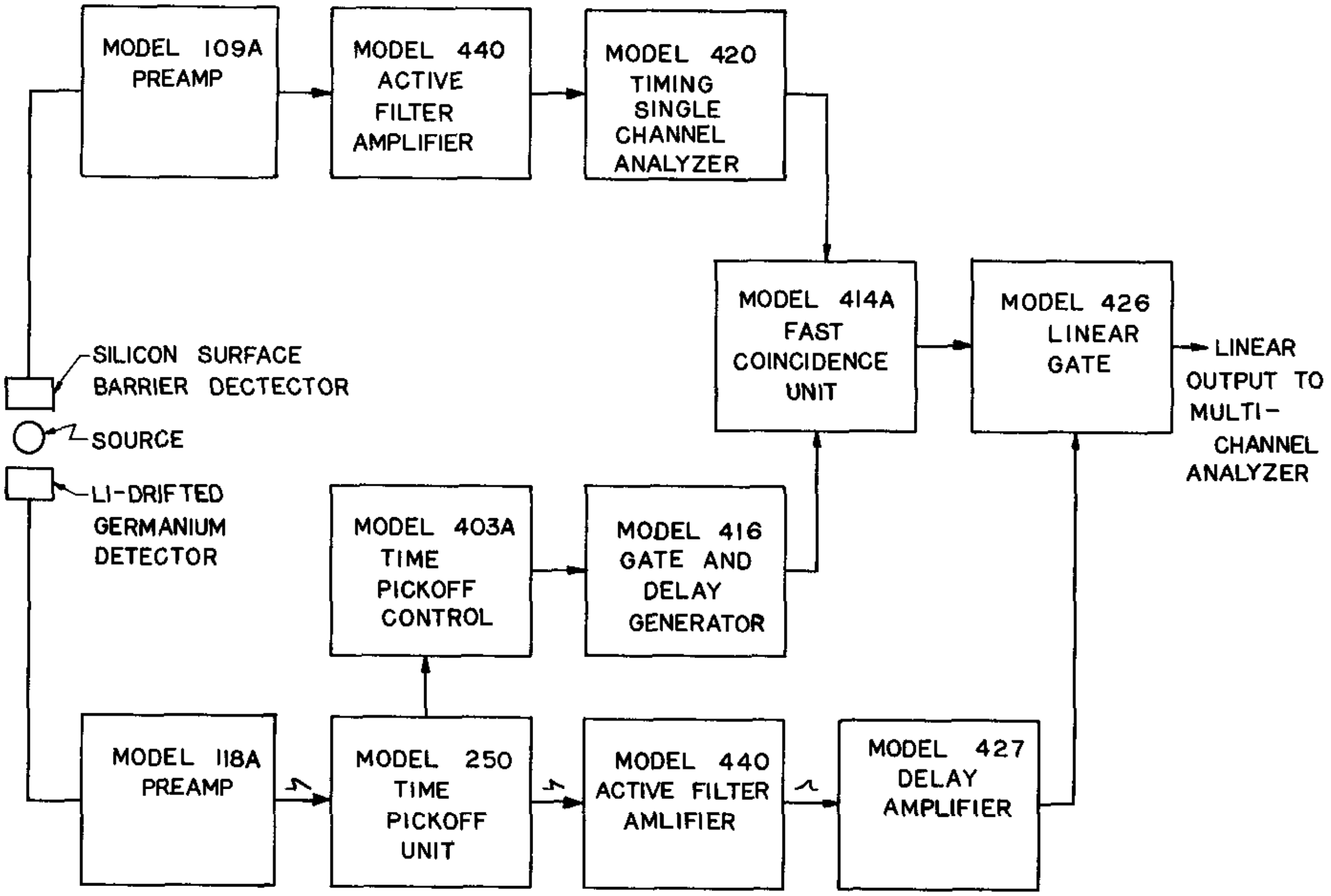


Figure 4-12. Gamma Ray-Charged Particle Coincidence Experiment - Block Diagram

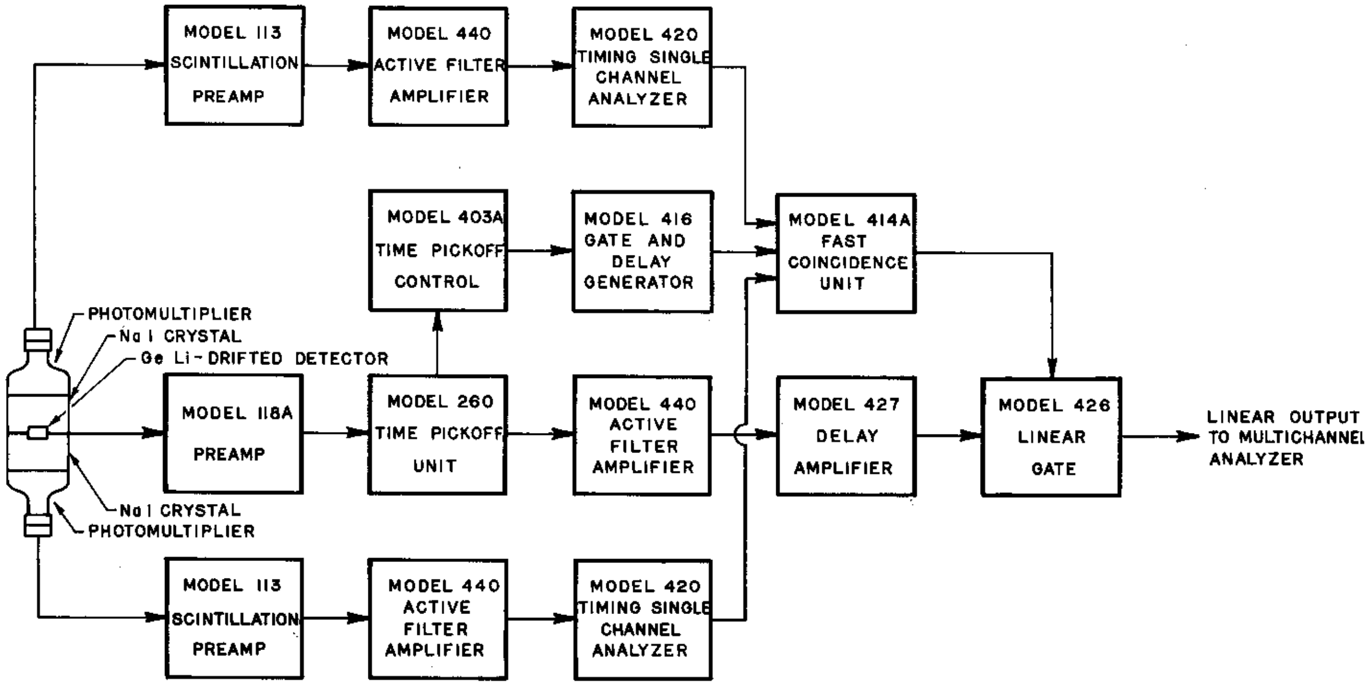


Figure 4-13. Gamma Ray Pair Spectrometer - Block Diagram

5. CIRCUIT DESCRIPTION

5.1 General Block Diagram

The 440 Selectable Active Filter Amplifier contains six basic feedback amplifier stages as shown in the block diagram in Fig. 5-1. The first stage has a differential input and provides the functions of polarity inversion and common mode noise rejection, as well as additional amplification before the first differentiate to improve the signal-to-noise characteristics of the amplifier. The first differentiating network is switch selectable and pole-zero cancelled. The first two sections of the Shaping Time switch and the trim potentiometer accomplish this function. The details of the variable pole-zero cancellation network were discussed in detail in Section 1.2.

The second and third amplifier stages are integrated circuit amplifiers which provide wide band gain. Gain changing is accomplished by constant impedance "T" attenuators and a constant impedance potentiometer. The third switch section of the Shaping Time switch provides capacitive roll-off preceding the gain stages. This roll-off reduces the high frequency response and increases the dynamic range of the gain stages for fast rise input pulses.

The active filter stage was described in general in Section 1.3. Shaping times for the filter are selected by sections 4 and 5 of the Shaping Time switch.

Two output driver stages are provided. These stages provide the additional gain necessary to raise the maximum linear output level to 10 volts and the stages have sufficiently low output impedance and power drive capabilities to drive terminated or unterminated connecting cables. Both output stages can be switch selected for unipolar or bipolar output pulses independently of each other. This switching is accomplished by the last three sections of the Shaping Time switch and the two Bipolar-Unipolar toggle switches. A 2μsec delay line precedes the delayed output stage so that the delayed output occurs 2μsec after the prompt output. The delayed output is compensated so that its amplitude will be the same as the prompt output. This compensation is accomplished by the last two sections of the Shaping Time switch.

5.2 Circuit Description

5.2.1 Differential Input Stage

Referring to the circuit diagram (Drawing 440-0101-S1), the input stage consists of a long-tail differential amplifier Q1 and Q2 driving

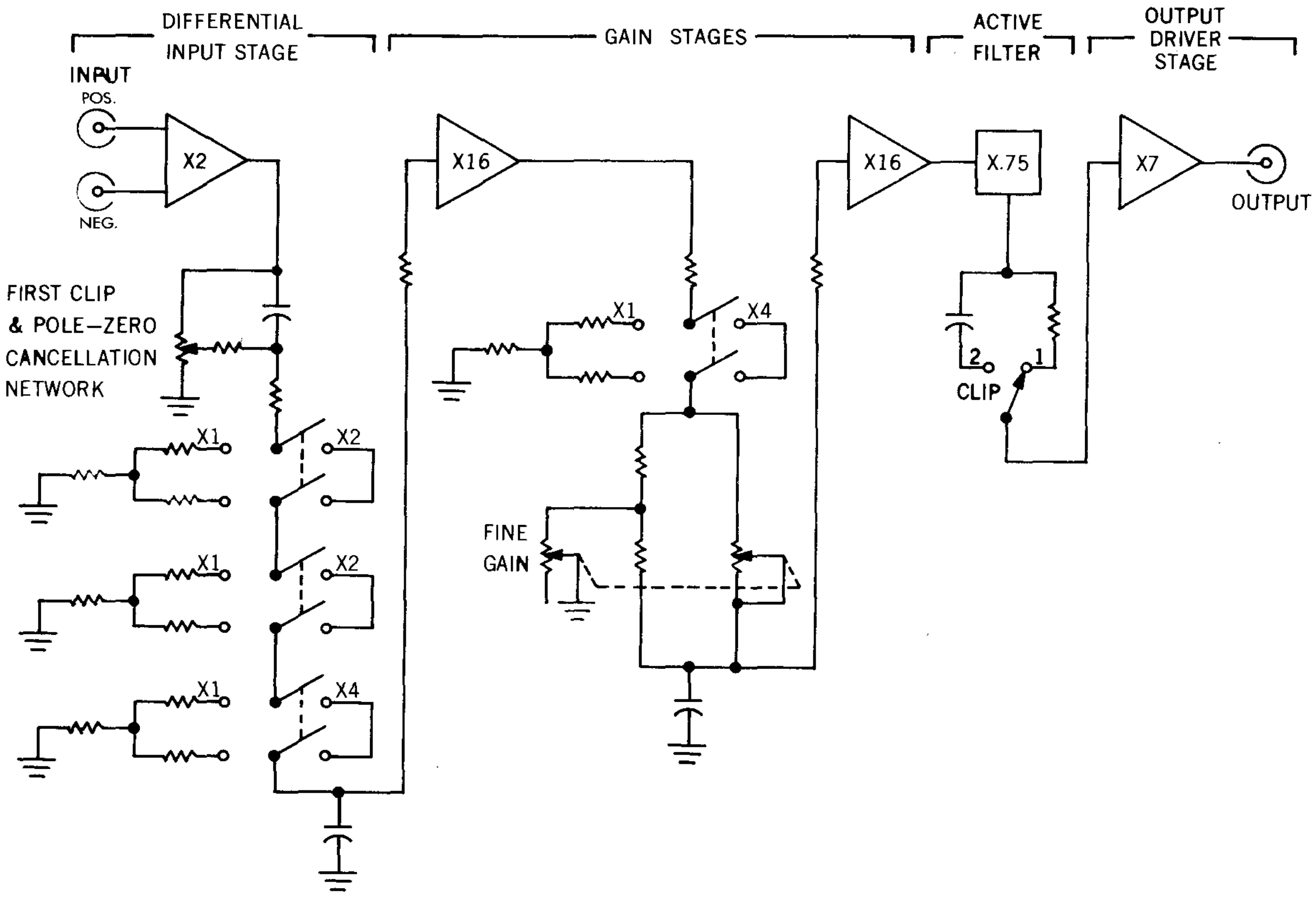


FIGURE 5–1 ACTIVE FILTER AMPLIFIER–BLOCK DIAGRAM

a common-emitter output stage, Q3. The output is fed back to the input through R11 and C5. Transistor Q4 acts as a zener diode with about a 6.5-volt drop across the base to emitter junction.

When the NEG INPUT is used, the base voltage at Q2 follows the input voltage at the base of Q1. The POS INPUT must be terminated in 100 ohms under this condition and the gain is then R11/(R7 + 100) ohms.

The network R4-C3 is a phase-lag compensation network to keep the stage from oscillating. The network C1-R5 is used to compensate for the different signal paths in the common-mode operating mode (positive signal at both inputs) and increase the common mode rejection at high frequencies (fast input rise times).

5.2.2 Pole-Zero Cancelled First Differentiate

The pole-zero cancelled first differentiation network consists of (for a 0.5µsec Shaping Time switch position): C44, R78 and the effective input impedance of the following attenuators (constant impedance of 2K). For proper pole-zero cancellation:

$$\frac{R78C44}{K} = T_{preamp} \qquad \frac{R78\ 2K}{R78 + 2K}\ C44 = T_{diff}$$

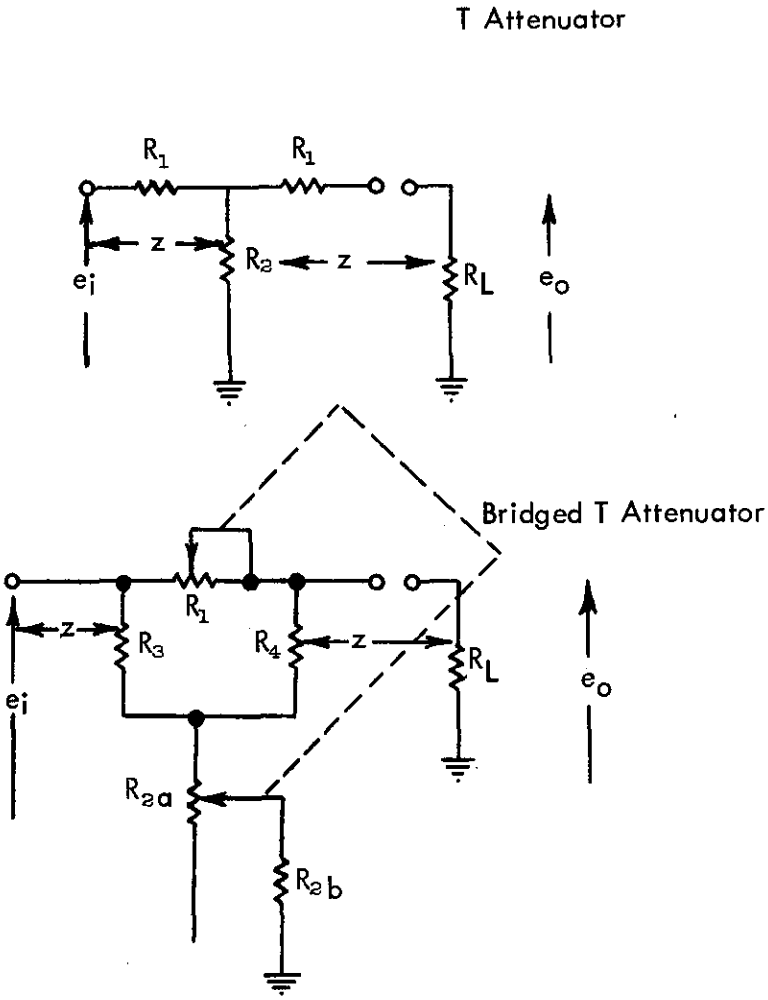
where T_{preamp} is the decay time constant of the preamplifier, T_{diff} is the amplifier first differentiation time constant (0.5µsec), and K is the fraction of the total of the P-Z trim potentiometer ($O \leqq K \leqq 1$). The derivation of these equations was discussed in Section 1.2.

5.2.3 Constant Impedance Attenuators

The attenuators employed are constant impedance T attenuators and the FINE GAIN control is a constant impedance Bridged T attenuator. The formulas for these attenuators are given in Fig. 5-2

5.2.4 Gain Stages

Both gain stages utilize integrated circuit differential amplifiers in operational amplifier feedback circuits. The circuit has an open loop gain of greater than 1000 and a gain-bandwidth product greater than 1000 mHZ. The integrated circuit contains a differential amplifier input driving a grounded emitter amplifier with an emitter follower



$R_L = Z = 1000\ \Omega$

$R_1 = Z\,\frac{K-1}{K+1}$

$R_2 = \frac{2ZK}{K^2-1}$

$K = \frac{e_i}{e_o}$

$R_L = R_3 = R_4 = Z = 1000\Omega$

$R_1 = Z\,(K-1)$

$R_2 = R_{2}a + R_{2}b = \frac{Z}{K-1}$

$R_{2}b = 500\Omega$

Figure 5-2. ORTEC 440 Attenuator Networks output. The dc input and output levels of the first stage (IC-1) are at approximate ground; whereas the second stage (IC-2) has its input at ground and its output at about +2 volts. This offset is necessary to provide dynamic range for the negative pulses at the output of IC-2. Phase lag roll-off networks C6-R30 and C10-R35 are necessary to prevent oscillation.

5.2.5 Active Filter

The basic active filter circuit was described in detail in Section 1.3. The filter network requires a unity gain amplifier which consists of emitter-follower Q6 and the constant current source Q5.

5.2.6 Output Driver Stages

The two output driver stages are identical in configuration. They consist of a grounded emitter amplifier Q11 (or Q18), with a high impedance, constant current load Q12 (or Q17), and a dc-offset-cancelling emitter-follower-quad consisting of Q7, Q8, Q9, and Q10 (or Q13, Q14, Q15, and Q16). Both driver stages have level adjustment potentiometers (R71 and R56) which are used to adjust the steady state output voltage to zero volts. The delayed output driver stage has an additional trim potentiometer R51 which is used to adjust the delayed output to be equal in amplitude to the prompt output. Both stages have an output impedance of ~0.5 ohms and both stages are capable of a ±9 to 10 volt linear output swing depending on the output load.

5.2.7 Second Differentiation Networks

Both the Prompt and Delayed Outputs can be switch selected for either unipolar or bipolar pulse shaping independently of each other. For the Prompt Output, the unipolar position is a resistor R41 and the bipolar position is switch selectable capacitor (the sixth wafer of the Shaping Time switch). For the Delayed Output, both the unipolar and bipolar outputs have components that are switch selected by the Shaping Time switch. This is necessary in order to compensate for the losses in the delay line for varying pulse shapes.

5.3 Circuit Modifications for Special Applications

5.3.1 Changing the Shaping Time

Changing the shaping time involves changing at least one component on each of the Shaping Time switch wafers. The following formulas determine the proper value for a new shaping time T :

1. First Wafer (the first differentiate): Change C1 so that $C1 \cdot 2K = T$.
2. Second Wafer (pole-zero cancellation): Change R2 so that $R2 \cdot C1 = 37.5\mu sec$.
3. Third Wafer (roll-off): Change C3 so that $C3 = \frac{T}{5 \times 10^{-9}}$
4. Fourth Wafer (active filter): Change C4 so that $C4 \cdot 1K = T$
5. Fifth Wafer (active filter): Change C5 so that $C5 = C4/4$
6. Sixth Wafer (second differentiate - prompt): Change C6 so that $C6 \cdot 1K = T$
7. Seventh Wafer (second differentiate - delayed): Change C7 so that $C7 \cdot 1K = T$, some trimming of this value is necessary to compensate for delay line losses
8. Eighth Wafer (delay line compensation - unipolar): Must be trimmed to compensate for losses in the delay line

5.3.2 Changing Amplifier Attenuator Networks

By using the formulas in Fig. 5-2, the attenuator networks can be changed while maintaining constant overall impedance. However, the gain and dynamic range for each of the stages have been optimized and any changes could result in nonlinearities at some gain settings. The overall gain can be increased without difficulty by increasing the values of R27 and R35 with the added possibility of changing R32 to keep the proper dynamic range of the second gain stage.

5.3.3 Removing the Pole-Zero Cancellation Network

The trim potentiometer for the adjustable pole-zero cancellation network is accessible from the front panel. The trim potentiometer has an adjustment span to compensate for preamplifier decay times from 40µsec to infinity. At the infinity end of the potentiometer, the wiper is at dc ground and the pole-zero cancellation network is effectively removed.

5.3.4 Removing the Output Isolation Capacitors

Both of the output driver stages have outputs that are isolated by capacitors. In some cases it is desirable to have a direct-coupled output to avoid counting rate problems due to the output isolating capacitors. The output driver stages have their outputs at dc ground (when the dc level trim potentiometers are properly adjusted) and therefore, they can be dc-coupled to the output by simply shorting across the output isolation capacitors. This can be most easily accomplished by soldering a short wire across C22 and C31.

With this dc-coupled condition, the output will still sustain a direct short without catastrophic damage. However, the maximum counting rate at which the amplifier will sustain a short will be limited to 1000 cps for long-duration shorts, and 10^4 cps for shorts less than one minute.

6. MAINTENANCE

6.1 Test Equipment Required

In order to adequately test the specifications of the ORTEC 440, the following equipment should be utilized:

(1) ORTEC 419 Precision Pulse Generator

(2) Tektronix Model 580 Series Oscilloscope with a Type 82 Plug-In

(3) Hewlett-Packard 400D RMS Voltmeter

6.2 Pulser Modifications for Overload Tests

Since the 440 incorporates variable pole-zero cancellation, factory adjusted to 50µsec, the input must have a specified decay time (50µsec). When either the ORTEC 419 or 204 Pulse Generator is used to check overload, it must be modified as shown in Fig. 6-1.

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 Fig. 6-2.

6.3 Pulser Tests and Calibration

6.3.1 Amplitude Matching

Using a positive pulser output and the test setup shown in Fig. 6-1, observe both the Prompt and Delayed outputs on the oscilloscope and adjust the Prompt output for 10 volts. Observe both outputs for all shaping modes, i.e., for all Shaping Time switch positions, and for unipolar and bipolar outputs on both outputs. The outputs should remain constant and equal to each other in all shaping modes to within ±2% (±0.2 volts out of 10 volts). Unless otherwise specified, the following tests should be made with the Shaping Time switch in the 1µsec position.

6.3.2 Minimum Gain

By determining the amplitude of the pulser signal and amplifier output signal, calculate the amplifier gain at maximum gain. The gain

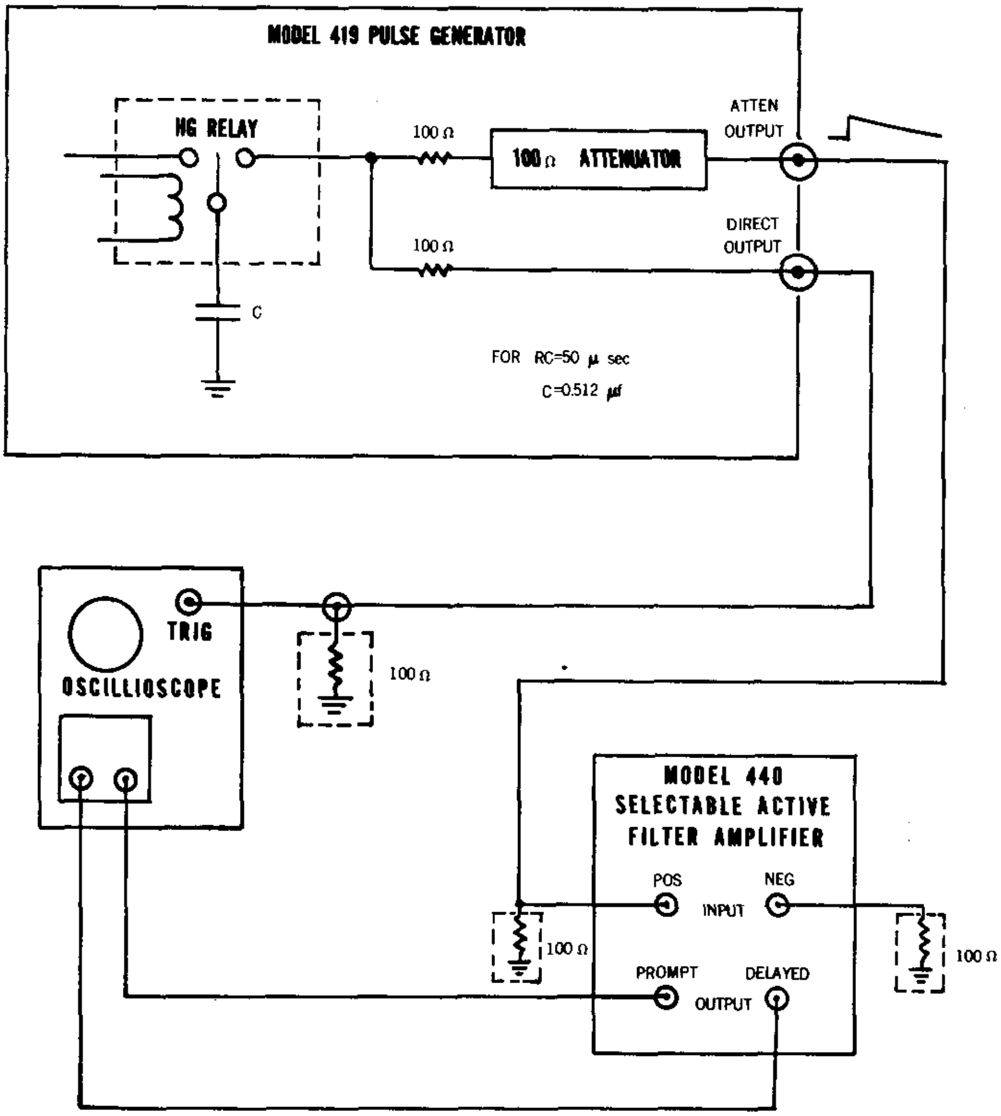
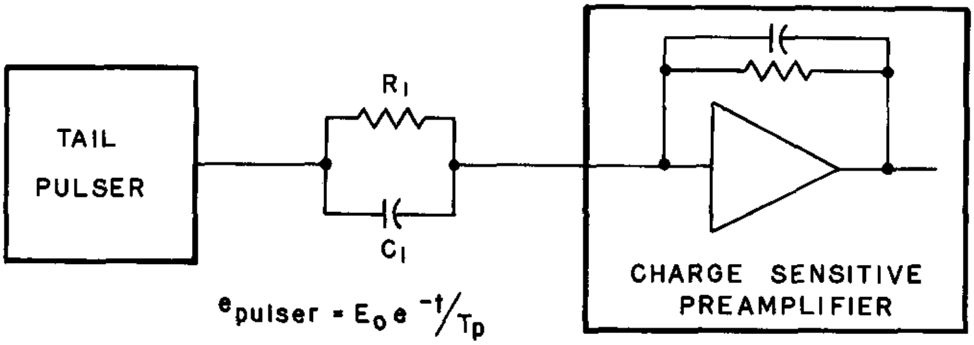


Figure 6-1. Pulser Modifications for Overload Tests



for pulser pole – zero cancellation: $R_1 C_1 = T_p$

Figure 6-2. Pulser Pole-Zero Cancellation should be 1800 ±5%.

6.3.3 Gain Switching Accuracy

Obtain a 10-volt output with minimum gain. Increase the amplifier gain by X2, X4, X4, and X2 and decrease the pulser amplitude by X64. The resulting output change should be less than 0.2 volt.

6.3.4 Fine Gain Range

Observe the amplitude change from minimum to maximum Fine Gain. The change should be X3 ±10%.

6.3.5 Overload Capability

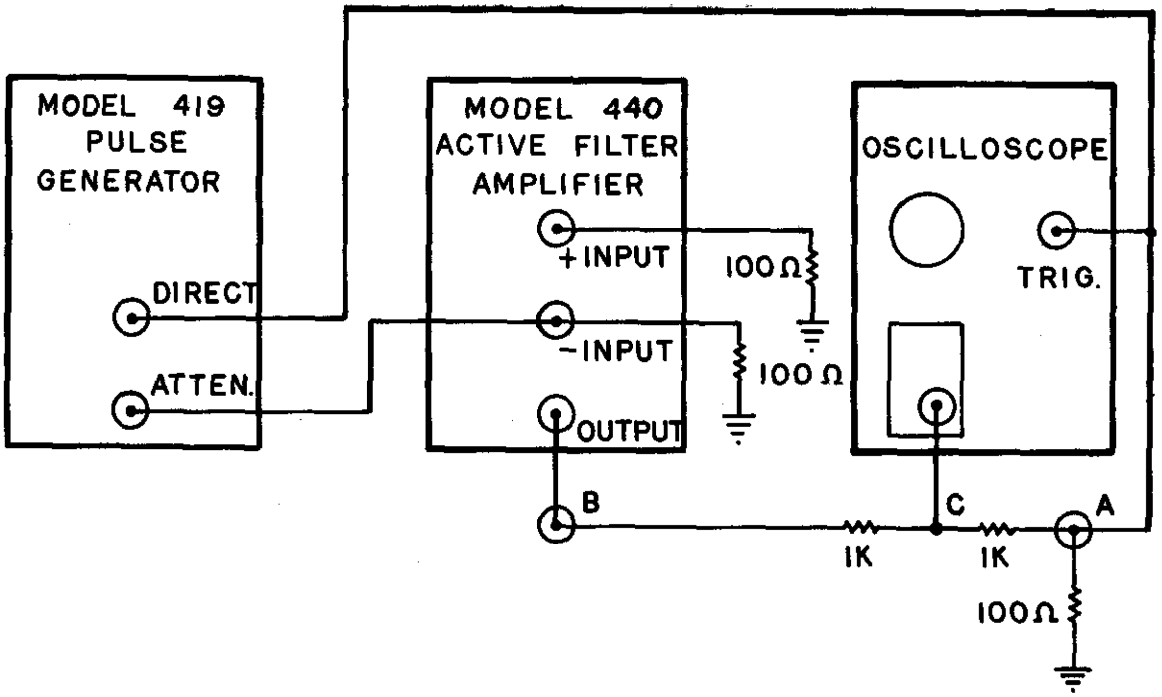
With the amplifier on maximum gain, obtain a 10-volt output. Increase the pulser amplitude by X1000 and observe that the output returns to the baseline in less than 22 μsec. An external voltage source to the pulser is required in order to obtain an approximate 6-volt pulser output on 1000X overload. The pulser decay time must match the pole-zero cancellation network time constant (see Section 6.2) in order to perform this test.

6.3.6 Common Mode Noise

With minimum amplifier gain, obtain a 10-volt output and observe the pulser amplitude. Connect the pulser to both the POS and NEG inputs of the amplifier and readjust the pulser amplitude to the same amplitude. The amplifier output should be less than 50 mV from baseline to peak. The pulser amplitude must be positive for this test.

6.3.7 Linearity

The integral nonlinearity can be measured by the technique shown in Fig. 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) 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:



WAVEFORMS:

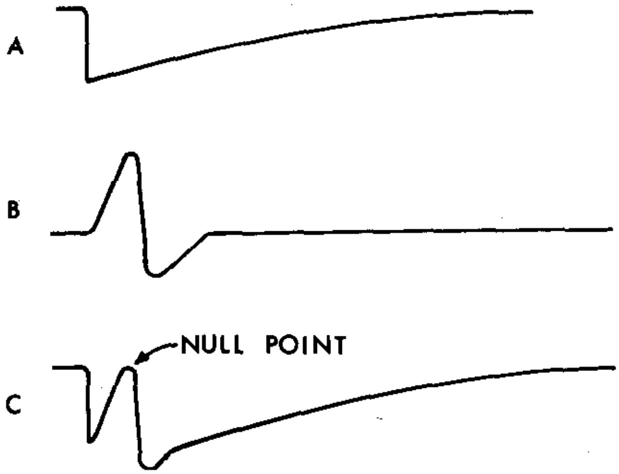


Figure 6-3 Method for Measuring Nonlinearity

(10V Full Scale) x (±0.075% Max Nonlinearity) x ($\frac{1}{2}$ for Divider Network) = ±3.5 mV Max Null Point Variation

If an oscilloscope other than that specified in Section 6.1 is used, it may be necessary to have a diode clamp at point B to avoid null point changes due to oscilloscope saturation.

6.3.8 Output Loading

With the same setup as in Section 6.3.7, 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 50 mV.

6.3.9 Noise

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:

10μV x 1800 gain x 1.13 = 20.4 mV for single clipping.
12μV x 1800 gain x 1.13 = 24.4 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.

6.3.10 Crossover Walk with Gain Switching

Using the setup shown in Fig. 6-4, adjust the amplifier output to 8 volts with minimum gain and obtain an output from the 420 Single Channel Analyzer with the "E" dial on 10 (where 1000 is full scale). Increase the amplifier gain to maximum and reduce the pulser amplitude until the amplifier output is again 8 volts. The shift in the 420 from one measurement to the other should be less than ± 10 nsec.

6.3.11 Crossover Walk with Amplifier (Amplifier and SCA)

With the same setup as before, obtain a 10 volt amplifier output at minimum amplifier gain. Attenuate the pulser by X10 using only the pulser attenuator switches. The shift in the 420 should be less than ±2 nsec. The "Walk Adj" trimpot on the 420 must be properly adjusted in order to make this measurement.

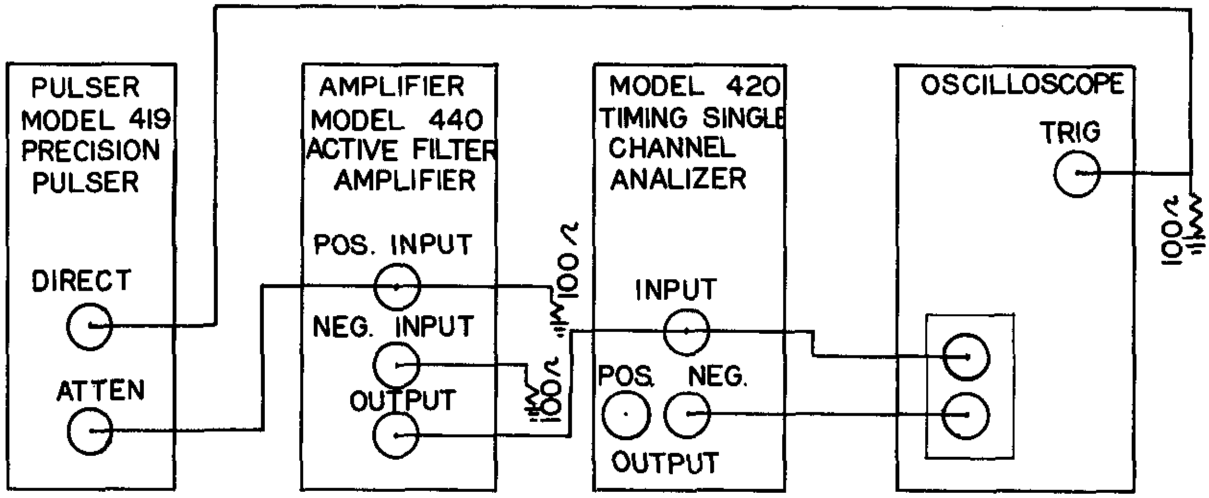


Figure 6-4. Method for Measuring Crossover Walk

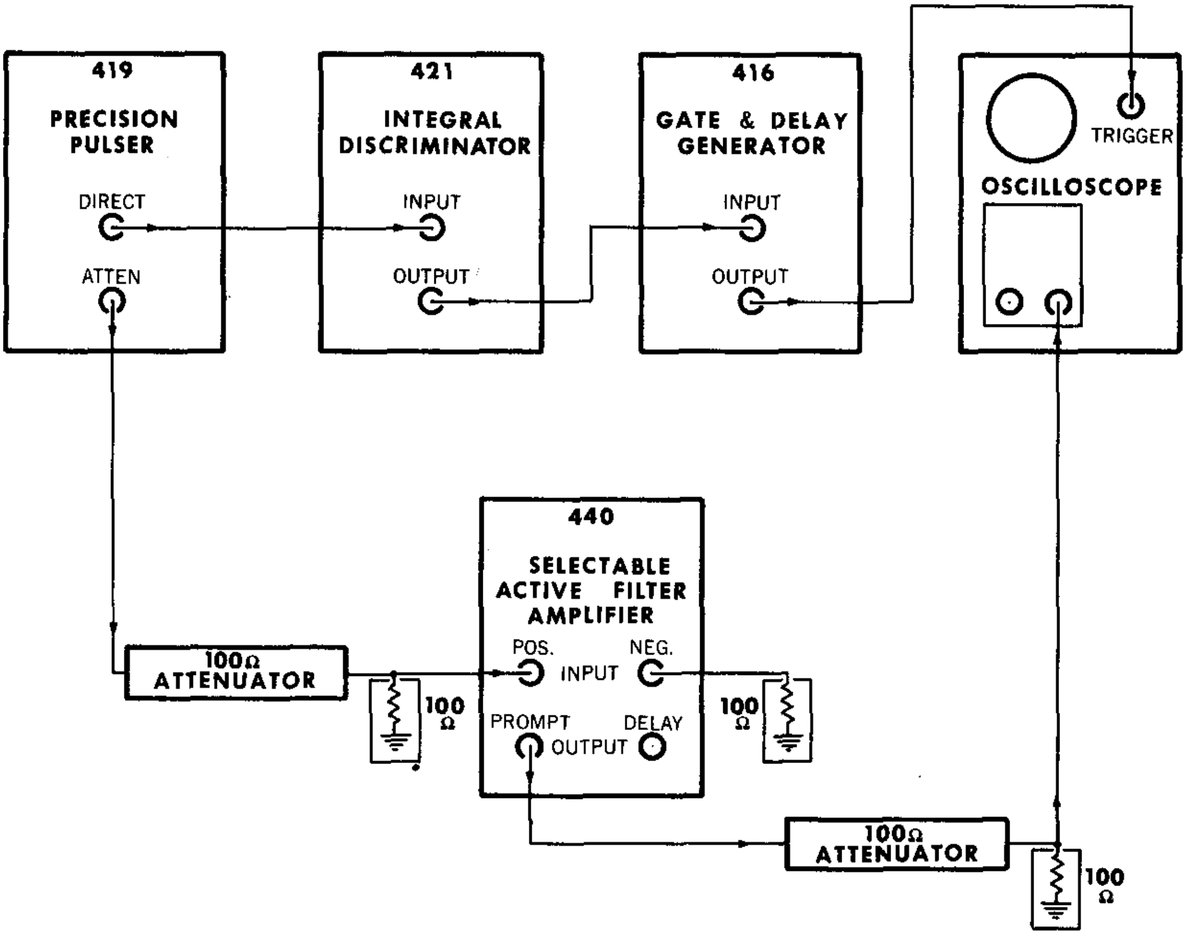


Figure 6-5. Method for Measuring Amplifier Crossover Walk

6.3.12 Crossover Walk with Amplitude (Amplifier Only)

The crossover walk of the amplifier only can be measured with the setup shown in Fig. 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, prompt 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 attenuator and add it to the second attenuator. The crossover walk under these conditions should be less than ± 1 nsec.

6.3.13 Counting Rate Changes

Resolution spread and amplitude changes with counting rate can be measured with the setup shown in Fig. 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. The pulser pulse 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. The pulser peak in the ^{137}Cs source present spectra should have no more than a one-channel increase in full width at half maximum and should be shifted no more than one channel as compared to the pulser only spectra.

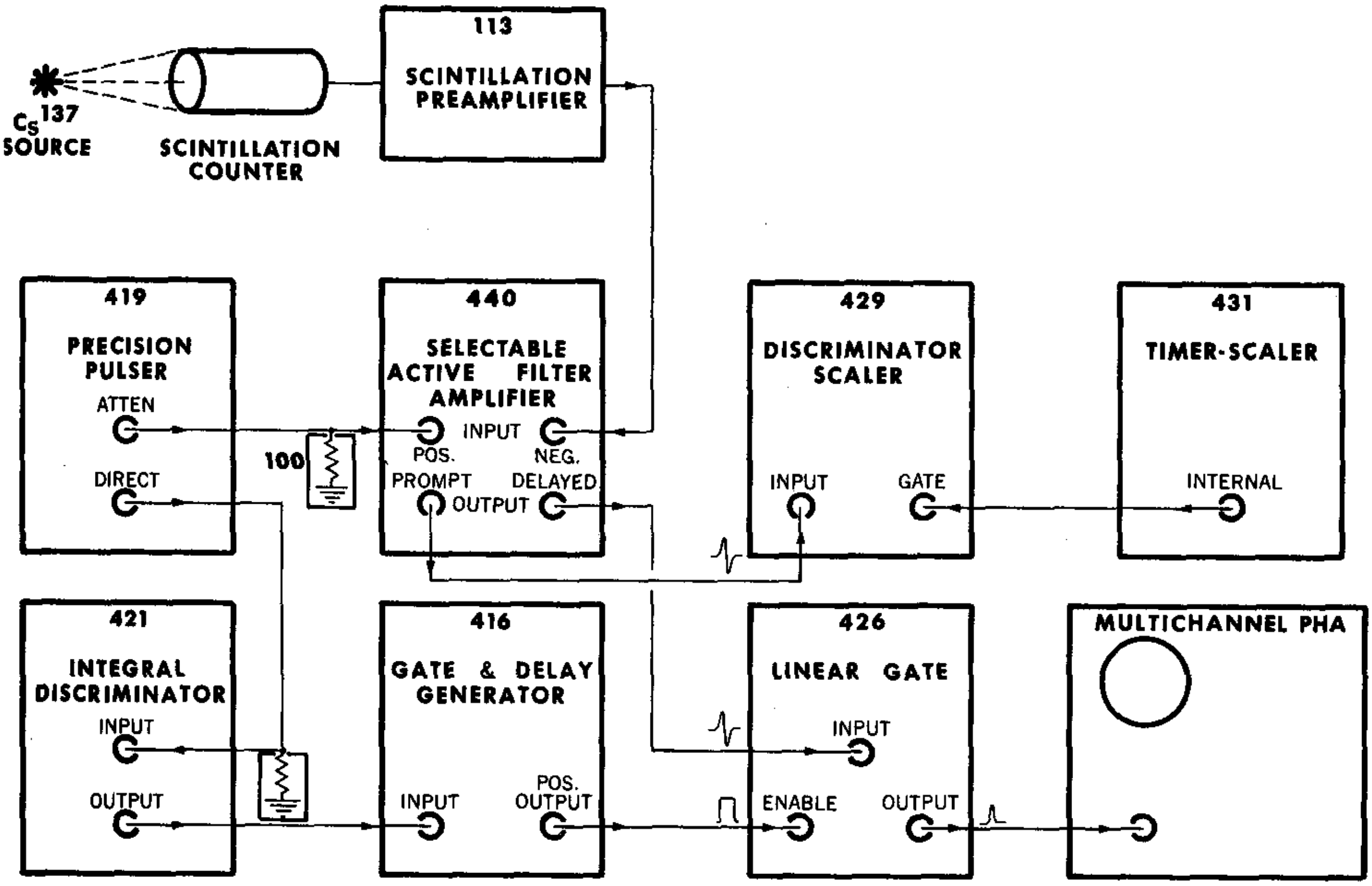


Figure 6-6. Method for Measuring Counting Rate Effects

6.4 Tabulated Test Point Voltages

The following voltages are intended to indicate maximum dc voltage variations as a means of fault detecting in the event of instrument failure. These voltages are recorded during the initial checkout of the instrument and placed in file for future reference.

Location	Minimum*	Maximum*
Emitter Q3	-15.5	-16.5
Collector Q3	- 0.4	+ 0.4
Pin 8 IC-1	+11.8	+12.0
Pin 4 IC-1	- 5.4	- 6.6
Pin 7 IC-1**	- 0.2	+ 0.5
Pin 8 IC-2	+11.8	+12.0
Pin 4 IC-2	- 5.4	- 6.6
Pin 7 IC-2**	+ 2.0	+ 2.3
Junction R52-R54***	- 0.05	+ 0.05
Junction R67-R68***	- 0.05	+ 0.05

*Dc voltages at module must be +12.0 ±0.1, -12.0 ±0.1, +24.0 ±0.2 and -24.0 ±0.2 volts

**Factory trimmed by resistors R29 and R32

***Can be adjusted by trimpots R56 and R71 (dc Level)

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

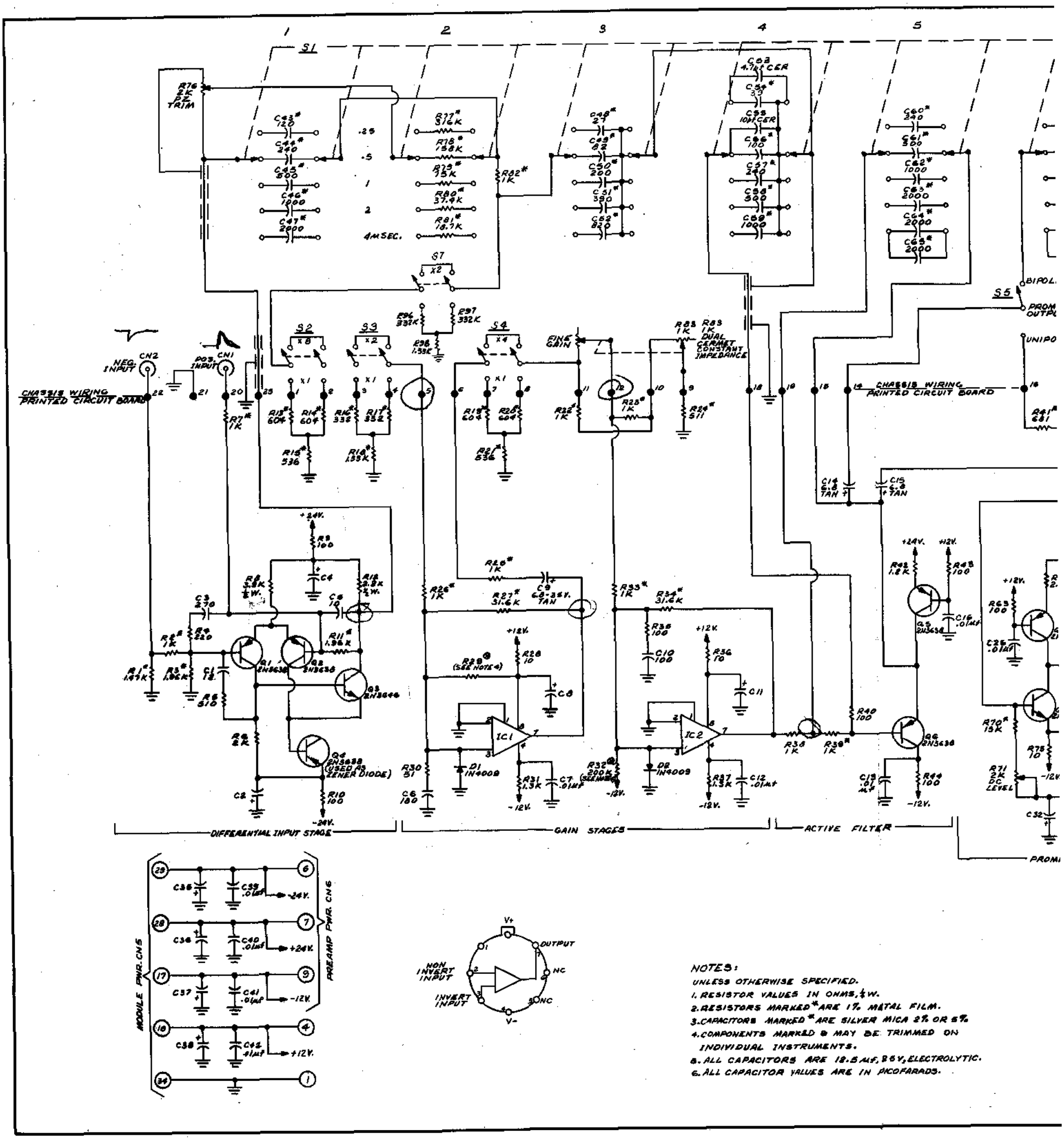
Pin	Function	Pin	Function
1	+3 volts	23	Reserved
2	−3 volts	24	Reserved
3	Spare Bus	25	Reserved
4	Reserved Bus	26	Spare
5	Coaxial	27	Spare
6	Coaxial	*28	+24 volts
7	Coaxial	*29	−24 volts
8	200 volts dc	30	Spare Bus
9	Spare	31	Carry No. 2
*10	+6 volts	32	Spare
*11	−6 volts	*33	115 volts ac (Hot)
12	Reserved 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 Model 401 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.

64
1.5
96

max gain without bad ringing on S.T. of .25 μs is 96.



NOTES:

UNLESS OTHERWISE SPECIFIED.

1. RESISTOR VALUES IN OHMS, ¼W.

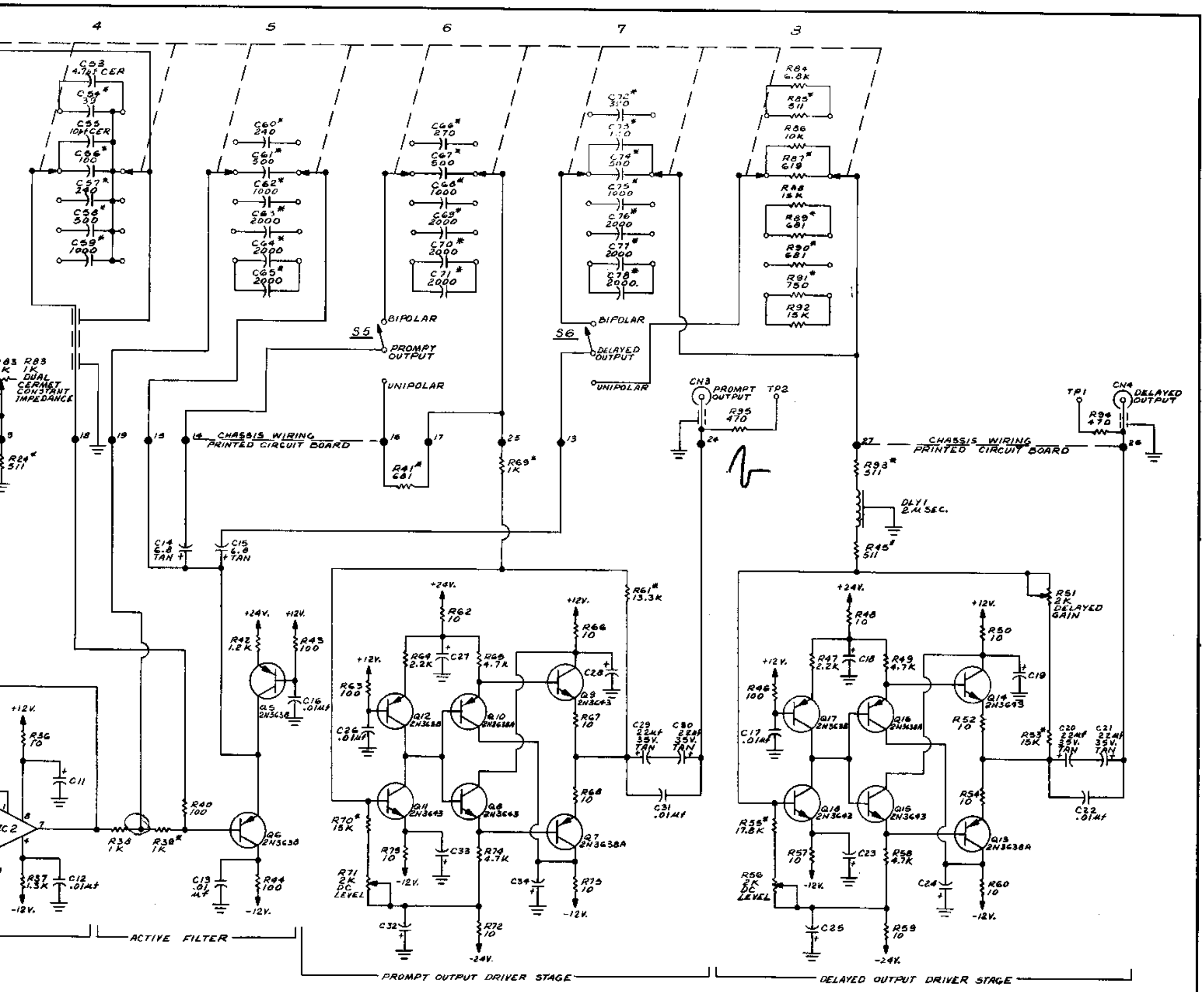
2. RESISTORS MARKED * ARE 1% METAL FILM.

3. CAPACITORS MARKED * ARE SILVER MICA 2% OR 5%

4. COMPONENTS MARKED @ MAY BE TRIMMED ON INDIVIDUAL INSTRUMENTS.

5. ALL CAPACITORS ARE 12.5 μf, 25V, ELECTROLYTIC.

6. ALL CAPACITOR VALUES ARE IN PICOFARADS.



NOTES:

UNLESS OTHERWISE SPECIFIED.

1. RESISTOR VALUES IN OHMS, ¼W.
2. RESISTORS MARKED * ARE 1% METAL FILM.
3. CAPACITORS MARKED * ARE SILVER MICA 2% OR 5%
4. COMPONENTS MARKED ● MAY BE TRIMMED ON INDIVIDUAL INSTRUMENTS.
5. ALL CAPACITORS ARE 12.5 μf, 25V, ELECTROLYTIC.
6. ALL CAPACITOR VALUES ARE IN PICOFARADS.

REV.	ECN. NO.	DATE	BY	APPD.
B	440-3	8-?-67	JDW	
A	440-2	9-26-67	JDW	

REVISIONS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES
FRACTION ±
DECIMALS ±
ANGLES ±
SURFACE FINISH √ RMS
APPLIED PRACTICES

ORTEC
OAK RIDGE TECHNICAL ENTERPRISES CORPORATION
OAK RIDGE TENNESSEE

TITLE
SELECTABLE ACTIVE FILTER AMPLIFIER

DRAFTSMAN MRM DATE 3/31/67
ENG. APPROVAL T. Emmer
PROJ. ENG. T. EMMER
CHECKED DATE
MFG. APPROVAL
SCALE
PROD. ISSUED DATE 4-20-67
DRAWING NO. 440-0201-S1