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ORTEC
INCORPORATED
AN EG&G COMPANY

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11Ω 6Ω. 4Ω. 3Ω.

# Model 460
# Delay Line Amplifier

## Operating and Service Manual

**ORTEC**

# Model 460
# Delay Line Amplifier

## Operating and Service Manual

Printed in U.S.A.

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## STANDARD WARRANTY FOR ORTEC INSTRUMENTS

ORTEC warrants its instruments other than preamplifier FET input transistors, vacuum tubes, fuses, and batteries to be free from defects in workmanship and materials 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 on in-warranty instruments, 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 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 or with installation results.

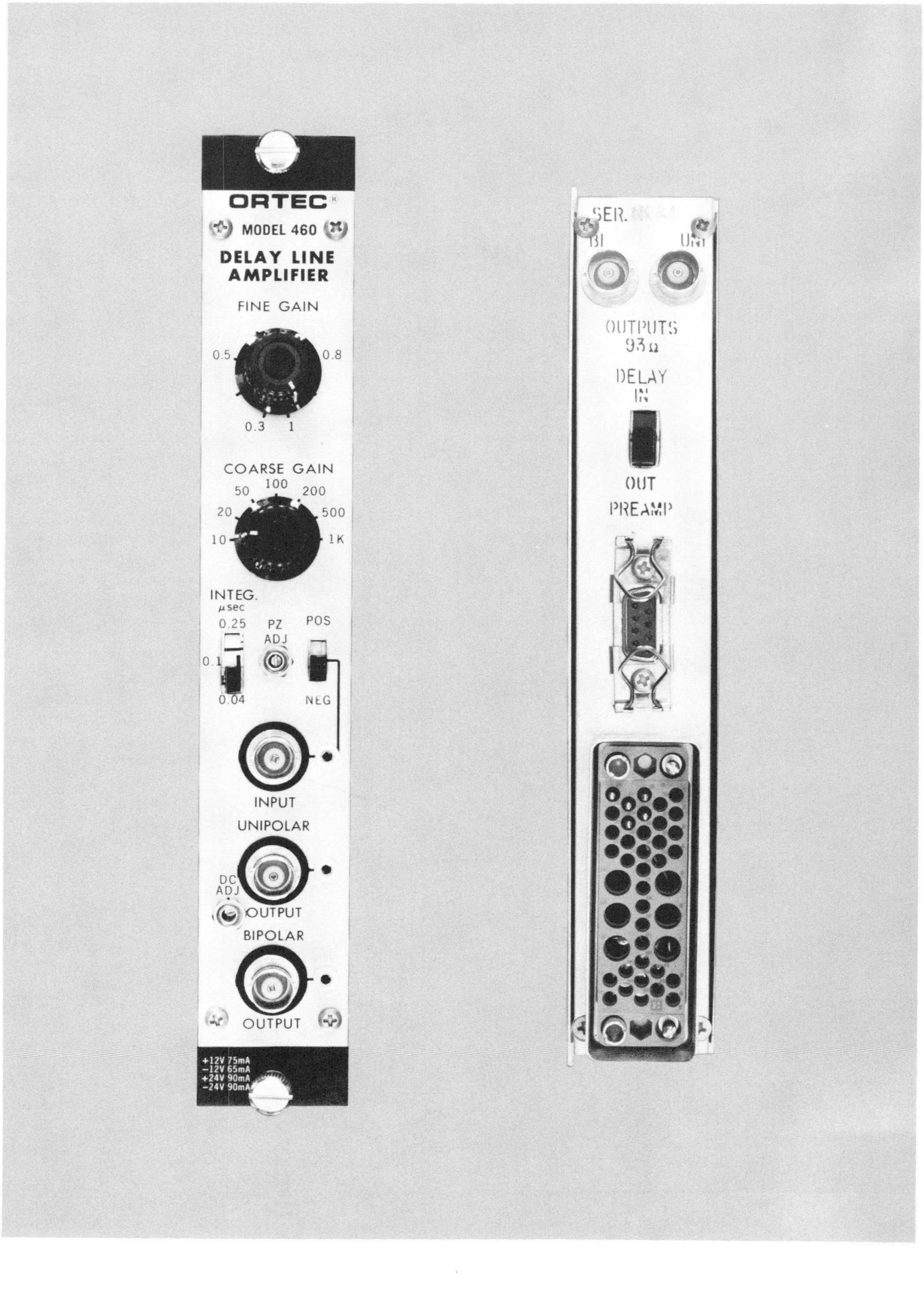
### QUALITY CONTROL

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

ORTEC must be informed in writing of the nature of the fault of the instrument being returned and of the model and serial numbers. Failure to do so may cause unnecessary delays in getting the unit repaired. Our standard procedure requires that instruments returned for repair pass the same quality control tests that are used for new-production instruments. Instruments that are returned should be packed so that they will withstand normal transit handling and must be shipped **PREPAID** via Air Parcel Post or United Parcel Service to the nearest ORTEC repair center. Instruments damaged in transit due to inadequate packing will be repaired at the sender's expense, and it will be the sender's responsibility to make claim with the shipper. Instruments not in warranty will be repaired at the standard charge unless they have been grossly misused or mishandled, in which case the user will be notified prior to the repair being done. A quotation will be sent with the notification.

### DAMAGE IN TRANSIT

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


ORTEC
MODEL 460
DELAY LINE AMPLIFIER
FINE GAIN
0.5
0.8
0.3
1
COARSE GAIN
100
50
200
20
500
10
1K
INTEG.
μsec
0.25
0.1
0.04
PZ ADJ
POS
NEG
INPUT
UNIPOLAR
DC ADJ
OUTPUT
BIPOLAR
OUTPUT
+12V 75mA
−12V 65mA
+24V 90mA
−24V 90mA
SER.
BI
UNI
OUTPUTS 93Ω
DELAY
IN
OUT
PREAMP

# 460 DELAY LINE AMPLIFIER

## 1. DESCRIPTION

### 1.1. GENERAL

The ORTEC 460 Delay Line Amplifier is a nuclear pulse amplifier that provides delay-line shaping for all output pulses. It accepts input pulses of either polarity from the preamplifier and expands their amplitude by an adjusted gain factor within the range from 3 through 1000. An integrating time constant can be selected to shape the rise of the input pulse as desired. Pole-zero cancellation is adjustable to match the characteristic of the preamplifier output.

### 1.2. DUAL OUTPUTS

Two output pulses are furnished for each input pulse. One is positive unipolar and is single-delay-line shaped; it can be furnished as either a prompt or delayed output pulse. The other is bipolar with positive polarity leading and is double-delay-line shaped. Both of these output pulse shapes are available through front panel connectors with an output impedance of 1Ω and through rear panel connectors with an output impedance of 93Ω.

The main use for the unipolar output pulses is for energy measurements. For this application the 460 provides high counting rate capabilities, excellent overload recovery, and dc adjustment of the output baseline. The unipolar output is preferred for both single-channel and multichannel analysis because of its low noise characteristic.

The main use for the bipolar output pulses is for timing measurements using baseline crossover as the timing indication. Double-delay-line shaping provides a precision time at the baseline crossover point that is independent of the pulse amplitude.

### 1.3. POLE-ZERO CANCELLATION

Pole-zero cancellation is a method for eliminating pulse undershoot after the first differentiating network. The technique employed is described by referring to the waveforms and equations shown in Figs. 1.1 and 1.2. In an amplifier not using pole-zero cancellation, the exponential tail on the preamplifier output signal (usually 50 to 500 µsec) causes an undershoot whose peak amplitude is roughly

$$\frac{\text{undershoot amplitude}}{\text{differentiated pulse amplitude}} = \frac{\text{differentiation time}}{\text{preamplifier pulse decay time}}$$

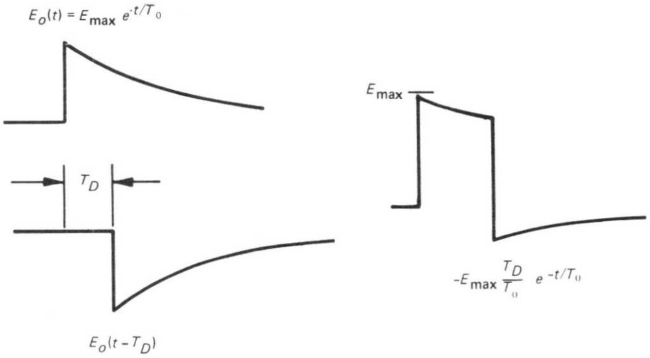


Fig. 1.1. Delay-Line Clipping Without Pole-Zero Cancellation.

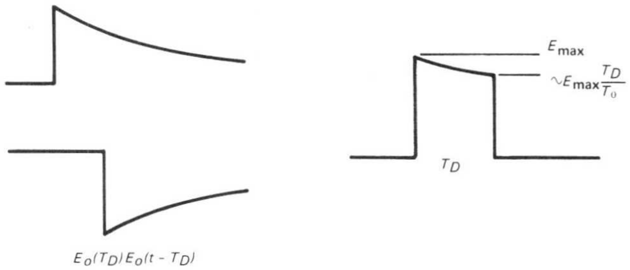


Fig. 1.2. Single-Delay-Line Shaped Pulse with Pole-Zero Cancellation.

For a 1-µsec differentiation 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 dead time. This effect can be reduced by increasing the preamplifier pulse decay time (which generally reduces the counting rate capabilities of the preamplifier) or compensating for the undershoot by using pole-zero cancellation.

In single-delay-line shaping, differentiation is accomplished by subtracting a delayed replica of the signal as shown in Fig. 1.1. The droop in the input signal during the delay time makes this subtraction imperfect, and a long undershoot is produced. A pole-zero cancellation eliminates this undershoot by adjusting the amplitude of the delayed signal as shown in Fig. 1.2.

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 decay times of 25 μsec or greater. 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 pileup distortion at medium counting rates. Improper matching causes either an undercompensation (undershoot is not eliminated) or an overcompensation (output after the main pulse does not return to the baseline and decays to the baseline with the preamplifier time constant). The pole-zero adjust is accessible from the front panel of the 460 and can easily be adjusted by observing the baseline with an oscilloscope while a monoenergetic source or pulser having the same decay time as the preamplifier under overload conditions is being used. The adjustment should be made so that the pulse returns to the baseline in the minimum time with no undershoot.

## 2. SPECIFICATIONS*

### PERFORMANCE

**GAIN RANGE** 7-position Coarse Gain selection from 10 through 1000 and single-turn Fine Gain control from 0.3 through 1; total gain is the product of Coarse and Fine Gain settings.

**SHAPING FILTER** Front panel switch permits selection of integration time constant with $\tau$ = 0.04, 0.1, or 0.25 μsec (40, 100, or 250 nsec).

**INTEGRAL NONLINEARITY** ⩽0.05%.

**NOISE** ⩽20 μV rms referred to input using 0.25 μsec Integrate and maximum Gain of 1000; ⩽25 μV for Gain = 50;⩽60 μV for Gain = 10.

**TEMPERATURE STABILITY**

**Gain** 0.01 %/°C, 0 to 50°C.
**DC Level** ⩽0.1 mV/°C, 0 to 50°C.

**CROSSOVER WALK** For constant gain, walk <±1 nsec for 20:1 dynamic range; <±2 nsec for 50:1;<±2.5 nsec for 100:1. Crossover shifts <±4 nsec for any adjacent Coarse Gain switch settings.

**COUNT RATE STABILITY** A pulser peak at 85% of analyzer range shifts less than 0.2% in the presence of 0 to $10^5$ random counts/sec from a $^{137}$Cs source with its peak stored at 75% of analyzer range.

**OVERLOAD RECOVERY** Bipolar recovers to within 2% of rated maximum output in less than 5 nonoverload pulse widths from X500 overload; unipolar recovers in same time from X100 overload.

**TIME JITTER (50% Amplitude)** $\bar{E_n}/(dv/dt)$. FWHM = 29 psec for a Gain = 50 and $E_0$ = 10 V; FWHM = 2.9 psec for a Gain = 50 and $E_0$ = 100 mV.

**DELAY LINES** 1 μsec standard $\tau$; 0.25, 0.5, or 2.0 μsec $\tau$ available. Both delay lines have the same value.

### CONTROLS

**FINE GAIN** Single-turn potentiometer for continuously variable gain factor of X0.3 to X1.

**COARSE GAIN** 7-position switch selects gain factors of X10, 20, 50, 100, 200, 500, and 1000.

**INPUT POLARITY** Slide switch, sets input circuit for either Pos or Neg input polarity.

**PZ ADJ** Potentiometer to adjust Pole-Zero cancellation for decay times from 25 μsec to ∞.

**INTEG** Slide switch selects an integration time constant of 0.04, 0.1, or 0.25 μsec; for 0.04-μsec setting, amplifier rise time is <75 nsec.

**DC ADJ** Potentiometer to adjust the dc level for single-delay-line shaped unipolar output pulses.

**DELAY IN/OUT** Slide switch on rear panel selects either 1-μsec (In) or prompt (Out) timing for unipolar output pulses.

### INPUT

Accepts either polarity of pulses from preamplifier; front panel type BNC (UG-1094A/U) connector; maximum linear input 3.3 V; protected to 20 V; $Z_{in}$ = 1 kΩ, dc-coupled.

### OUTPUTS

**UNIPOLAR** Prompt or delayed with full-scale linear range of 0 to +10 V; single-delay-line shaped; baseline level adjustable to ±1.0 V; $Z_0$ <1Ω, dc-coupled, through front panel BNC (UG-1094A/U) connector; $Z_0$ = 93Ω, dc-coupled, through rear panel BNC (UG-1094/U) connector.

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*Checked in accordance with methods outlined in "IEEE Standards No. 301, USAS N42.2," *IEEE Transactions*, Vol NS-16(6) (December 1969).

**BIPOLAR** Prompt output with positive lobe leading, double-delay-line shaped, with full-scale linear range of 0 to 10 V; $Z_0$ <1Ω, dc-coupled, through front panel BNC (UG-1094A/U) connector; $Z_0$ = 93Ω, dc-coupled, through rear panel BNC (UG-1094/U) connector.

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

### ELECTRICAL AND MECHANICAL

**POWER REQUIRED**

+24 V, 90 mA; +12 V, 75 mA;
-24 V, 90 mA; -12 V, 60 mA.

**WEIGHT (Shipping)** 4.25 lb (1.9 kg).

**WEIGHT (Net)** 2.25 lb (1 kg).

**DIMENSIONS** Standard single-width module (1.35 by 8.714 in.) per TID-20893 (Rev.).

# 3. INSTALLATION

## 3.1. GENERAL

The 460 contains no internal power supply but is used in conjunction with an ORTEC 401/402 Bin and Power Supply and is intended for rack mounting; therefore if vacuum tube equipment is operated in the same rack with the 460, there must be sufficient cooling by circulating air to prevent localized heating of the all-semiconductor circuitry used throughout the 460. 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 460 through the BNC connector on the front panel labeled Input. The input impedance is 1000Ω and is dc-coupled to ground; therefore the output of the preamplifier must be either ac-coupled or have approximately zero dc voltage under no-signal conditions.

The 460 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 approximately match all ORTEC FET preamplifiers. If other preamplifiers or more careful matching is desired, the adjustment is accessible from the front panel. Adjustment is easily accomplished by using a monoenergetic source and observing the amplifier baseline with an oscilloscope after each pulse under overload conditions. Adjustment should be made so that the pulse returns to the baseline in a minimum of time with no undershoot.

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

When using the 460 with a remotely located preamplifier (i.e., preamplifier-to-amplifier connection through 25 ft 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 460 input is matched. Since the input impedance of the 460 is 1000Ω, 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 that are either 93Ω or variable; coaxial cable type RG-62/U or RG-71/U is recommended.

## 3.3. CONNECTION OF TEST PULSE GENERATOR

**Connection to the 460 Through a Preamplifier** The satisfactory connection of a test pulse generator such as the ORTEC 419 or equivalent depends primarily on two considerations: the preamplifier must be properly connected to the 460 as discussed in Section 3.2, and the proper input signal simulation must be applied to the preamplifier. To ensure proper input signal simulation, refer to the instruction manual for the particular preamplifier being used.

**Direct Connection to the 460** Since the input of the 460 has 1000Ω input impedance, the test pulse generator will normally have to be terminated at the amplifier input with an additional shunt resistor. If the test pulse generator has a dc offset greater than 1 V, a large series isolating capacitor is also required since the input of the 460 is dc-coupled. ORTEC Test Pulse Generators are designed for direct connection. When any of these units are used, they should be terminated with a 100Ω terminator at the amplifier input or be used with at least one of the output attenuators set at In. (The small error due to the finite input impedance of the amplifier can normally be neglected.)

**Special Considerations for Pole-Zero Cancellation** The pole-zero-cancellation network in the 460 is factory-adjusted for a 50-μsec decay time to match ORTEC FET preamplifiers. When a tail pulser is connected directly to the amplifier input, the PZ Adj should be adjusted if overload tests are to be made (other tests are not affected). See Section 6.2 for the details.

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

## 3.4. CONNECTION TO POWER

Turn off the Bin Power Supply when inserting or removing modules. The ORTEC NIM modules are designed so that it is not possible to overload the Bin Power Supply with a full complement of modules in the Bin. Since, however, this may not be true when the Bin contains modules other than those of ORTEC design, check the Power Supply after inserting the modules. The 401/402 has test points on the Power Supply control panel for monitoring the dc voltages.

## 3.5. SHAPING CONSIDERATIONS

The rise time of the output pulses from the 460 will be a function of the rise time furnished from the preamplifier and of the setting of the front panel Integ switch. When the switch is set at 0.04 μsec, the rise time for a step input from the preamplifier will be less than 100 nsec. The 0.1- and 0.25-μsec switch settings will provide proportionately longer rise times. Check the input specifications for the instrument into which the 460 output pulses will be furnished, and set the Integ switch at the position which satisfies these requirements, if any.

The 460 provides both unipolar and bipolar outputs. The unipolar output should be used in applications where the best signal-to-noise ratio (resolution) is desired, such as high-resolution energy spectroscopy using semiconductor detectors. Use of this output will also give excellent resolution at high counting rates when used with dc-coupled inputs in the subsequent equipment. The bipolar output should be used for time spectroscopy if the time signal is derived from a baseline crossover. The bipolar output is also useful for energy spectroscopy in high count rate systems when noise, or resolution, is a secondary consideration and when the analyzer system is ac-coupled.

## 3.6. SELECTION OF PROMPT OR DELAYED OUTPUT

The prompt unipolar output is obtained with the Delay switch set at Out. This will normally be used for spectroscopy applications. A delayed unipolar output is obtained with the Delay switch set at In, and the pulses will be delayed by 1 μsec for a time adjustment in a coincidence system or when gating logic is to be performed on the bipolar output before the unipolar pulse arrives at the gate.

## 3.7. OUTPUT CONNECTIONS AND TERMINATING CONSIDERATIONS

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

To use shunt termination at the receiving end of the cable, connect the 1Ω output of the sending device through 93Ω cable to the input of the receiving instrument. Then use a BNC tee connector to accept both the interconnecting cable and a 100Ω resistive terminator at the input connector of the receiving instrument. Since the input impedance of the receiving instrument is normally 1000Ω or more, the effective instrument input impedance with the 100Ω terminator will be of the order of 93Ω, and this correctly matches the cable impedance.

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

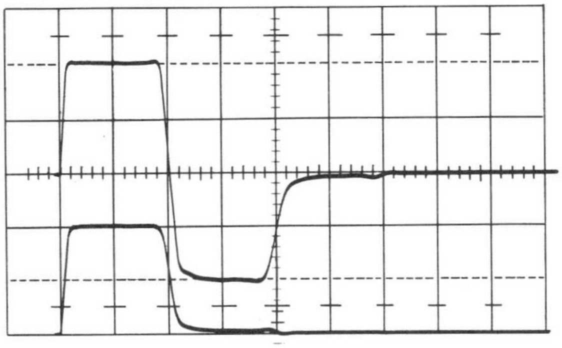
For the combination of series and shunt termination, use the 93Ω output in the sending instrument for the cable connection and use 93Ω cable. At the input for the receiving instrument, use a BNC tee to accept both the interconnecting cable and a 100Ω resistive terminator. Note that the signal span at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

For your convenience, ORTEC stocks the proper terminators and BNC tees, or you can obtain them from a variety of commercial sources.

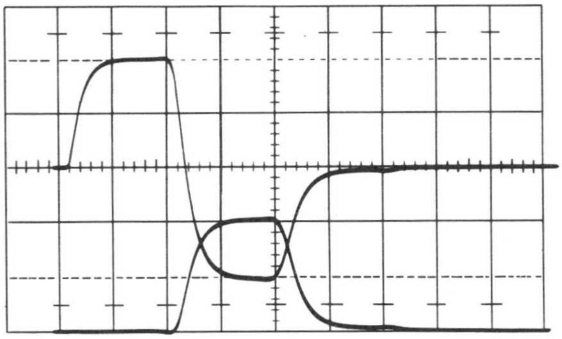
# 4. OPERATING INSTRUCTIONS

## 4.1. INITIAL TESTING AND OBSERVATION OF PULSE WAVEFORMS

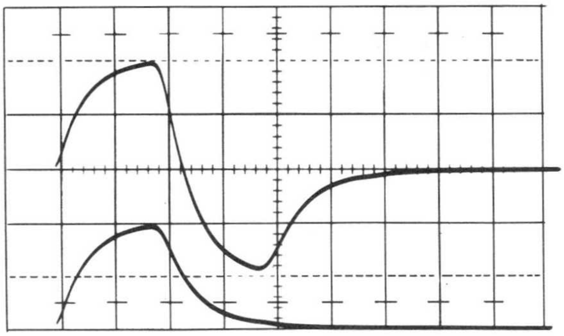
Refer to Section 6 for information on testing performance and observing waveforms at front panel test points. Figure 4.1 shows some typical output waveforms.



Integ Time 0.04 μsec, Unipolar Prompt.



Integ Time 0.1 μsec, Unipolar Delayed.



Integ Time 0.25 μsec, Unipolar Prompt.

**Fig. 4.1. Typical Effects of Integrate Time Selection on Output Waveforms.** All waveforms taken with horizontal = 2 μsec/cm and vertical=5 V/cm.

## 4.2 FRONT PANEL CONTROLS

**GAIN** A coarse-gain switch and a fine-gain potentiometer select the gain factor. The gain is read directly; switch positions are 10, 20, 50, 100, 200, 500, and 1000, and continuous fine-gain range is 0.3 to 1.

**INPUT POLARITY** Slide switch sets the input circuit for either Pos or Neg input polarity.

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

**DC ADJ** Potentiometer to adjust the dc level of unipolar output; range ±1.0 V.

**DELAY** Slide switch selects either 1-μsec delay (In) or prompt (Out) output of the unipolar signals.

**INTEG** 3-position switch selects integrate time constants of 0.04, 0.1, and 0.25 μsec.

## 4.3. FRONT PANEL CONNECTORS (All Type BNC)

**INPUT** Positive or negative with rise time 10 to 650 nsec; decay time must be greater than 25 μsec for proper pole-zero cancellation. Input impedance is 1000Ω dc-coupled. Maximum linear input signal is 3.3 V with a maximum limit of ±20 V.

**OUTPUTS** Two BNC connectors with output impedance of <1Ω. Each output can provide up to 10 V and is dc-coupled and short-circuit protected:

**Unipolar** The dc level is adjustable for offset to ±1.0 V. The unipolar pulse shape is determined by a 1-μsec delay line. Linear range is 0 to +10 V.

**Bipolar** Bipolar pulse is prompt with positive lobe leading and the pulse is double-delay-line shaped. Linear range is 0 to ±10 V. The crossover walk of this output is <±2.5 nsec for 100:1 dynamic range.

## 4.4. REAR PANEL CONNECTORS

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

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

## 4.5. OPERATION WITH SEMICONDUCTOR DETECTORS

**Calibration of Test Pulser** The ORTEC 419 Pulser, or equivalent, is easily 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., preamplifier, main amplifier, and biased amplifier.

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

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

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

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

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

**Amplifier Noise and Resolution Measurements** As shown in Fig. 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. Use the following procedure to obtain the resolution spread due to amplifier noise:

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

2. Turn on the ORTEC 419 Precision Pulse Generator and adjust the pulser output to any convenient readable voltage, $E_0$, as determined by the oscilloscope.

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

$$N(\mathrm{FWHM}) = \frac{2.66\, E_{\mathrm{rms}}\, E_{\mathrm{dial}}}{E_0},$$

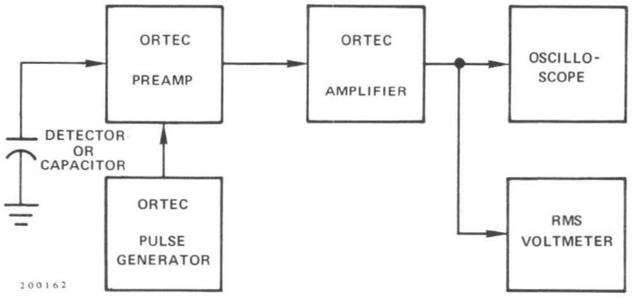


Fig. 4.2. System for Measuring Amplifier and Detector Noise Resolution.

where $E_{\mathrm{dial}}$ is the pulser dial reading in MeV, and 2.66 is the factor for rms to FWHM (2.34) and noise to rms meter correction (1.13) for average-indicating voltmeters such as the Hewlett-Packard 400D. A true rms voltmeter does not require the latter correction factor.

Figure 4.3 shows the amplifier noise generated by the 460. It is a function of both the integrating time constant and of the gain setting. The portion of the curves between a gain of 3.3 and a gain of 10 reflects variations in settings of the Fine Gain control while the Coarse Gain is set at 10. All of the remaining portions of the curves reflect the Coarse Gain switch while the Fine Gain control remains at maximum. Wherever possible, the Fine Gain control should be set within the upper portion of its range in order to minimize the amplifier noise.

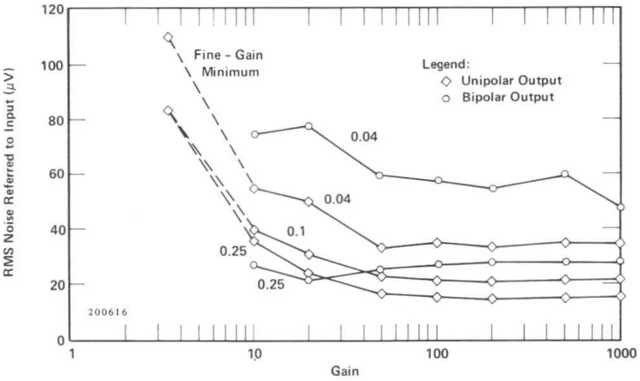


**Fig. 4.3. Noise as a Function of Gain and Integrating Time Constant in the ORTEC 460 Delay Line Amplifier.**

**Detector Noise Resolution Measurements** The same measurement just described 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

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

where $N_{\mathrm{total}}$ is the total resolution spread and $N_{\mathrm{amp}}$ is the amplifier resolution spread with the detector replaced by its equivalent capacitance.

The detector noise tends to increase with bias voltage, but the detector capacitance decreases, thus reducing the resolution spread. The overall resolution spread will depend upon which effect is dominant. Figure 4.4 shows curves of typical total noise resolution spread versus bias voltage, using the data from several ORTEC silicon surface-barrier semiconductor radiation detectors.

## BIAS VOLTAGE

**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. 4.5.

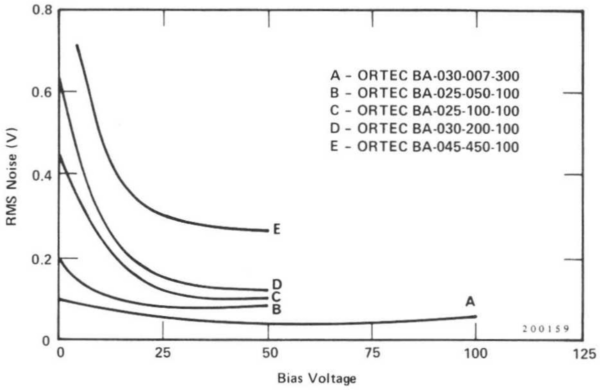


**Fig. 4.4. Noise as a Function of Bias Voltage.**

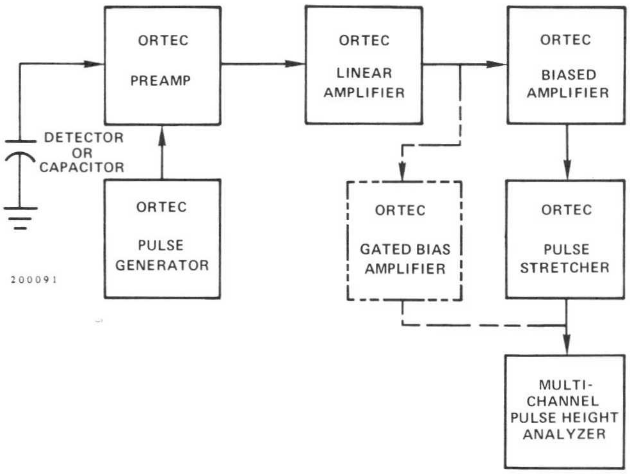


**Fig. 4.5. System for Measuring Resolution with a Pulse Height Analyzer.**

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

1. Select the energy of interest with an ORTEC 419 Pulse Generator, and set the Amplifier and Biased Amplifier Gain and Bias Level controls so that the energy is in a convenient channel of the analyzer.

2. Calibrate the analyzer in keV per channel, using the pulser (full scale on the pulser dial is 10 MeV when calibrated as described in "Calibration of Test Pulser").

3. Then obtain the amplifier noise resolution spread by measuring the FWHM 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 "Detector Noise Resolution Measurement." The detector noise will vary with detector size and bias conditions and possibly with ambient conditions.

**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 that should be used, because the noise increases more rapidly than the reverse current at the onset of detector breakdown. Make this measurement in the absence of a source.

Figure 4.6 shows the setup required for current-voltage measurements. The ORTEC 428 Bias Supply is used as the voltage source. Bias voltage should be applied slowly and reduced when noise increases rapidly as a function of applied bias. Figure 4.7 shows several typical current-voltage curves for ORTEC silicon surface-barrier detectors.

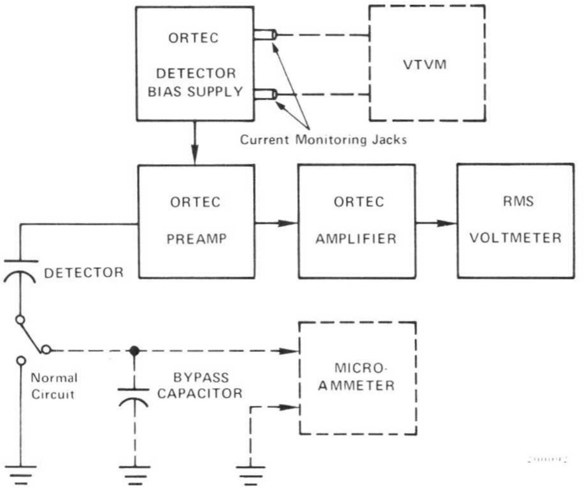


**Fig. 4.6. System for Detector Current and Voltage Measurements.**

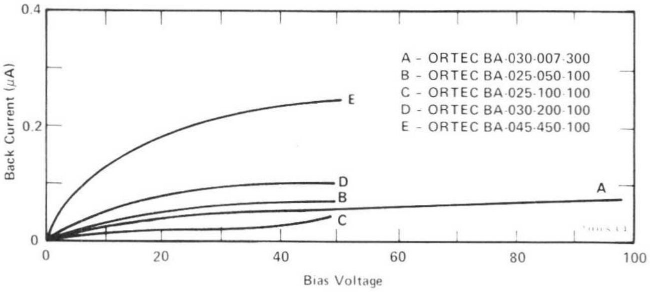


**Fig. 4.7. Silicon Detector Back Current vs Bias Voltage.**

When it is possible to float the microammeter at the detector bias voltage, the method of detector current measurement shown by the dashed lines in Fig. 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.

**Preamplifier—Main Amplifier Gain Adjustments as a Function of Input Particle Energy** With the input energy at a constant, or maximum, known value, the following method is recommended for adjusting the total system gain of the preamplifier and main amplifier to an optimum value:

1. The primary design criterion for the preamplifier is the best signal-to-noise ratio at the output; therefore operate the preamplifier 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 preamplifier signal will be maximized.
2. Since the fine-gain control of the 452 is an attenuator, set it to as near maximum as possible by manipulating the coarse gain.

## 4.6. OPERATION IN NEUTRON-GAMMA DISCRIMINATION SYSTEM WITH STILBENE AND LIQUID SCINTILLATORS

The single-delay-line shaped output pulses from the ORTEC 460 are suited ideally to the input requirements of the ORTEC 458 Pulse Shape Discriminator. When these instruments are included in the system, a neutron-gamma discrimination can be effected such that the amplifier output pulses can also be routed into a multichannel analyzer, with the gamma spectrum stored in one half of the analyzer and the neutron spectrum stored in the other half of the analyzer.

**Theory** Neutrons and gammas produce light scintillations in NE-213, NE-218,* and Stilbene detectors with significantly different decay characteristics. The 10% to 90% rise time ($t_R$) of the integrated light from all the scintillators is approximately 130 nsec when excited with neutrons and approximately 10 nsec when excited with gamma rays.[1]** The scintillation is not a simple exponential as is illustrated by Kuchnir and Lynch,[1] but consists of a combination of at least four components, as illustrated by their results shown in Table 4.1.

Table 4.1

| Scintillator | Mean Life Time[a] (nsec) | Mean Decay Time[b] (nsec) | | | No. of Photoelectrons per keV Energy Loss[c] |
|---|---|---|---|---|---|
| | | $\tau_2$ | $\tau_3$ | $\tau_4$ | |
| Stilbene | 0.1 | 4.05 | 33 | 270 | 2.3 |
| NE-213 | 1.66 | 3.16 | 32.3 | 270 | 1.7 |
| NE-213M | 1.34 | 5.41 | 30.5 | 285 | 1.9 |
| NE-218 | 1.76 | 3.58 | 36.5 | 288 | 2.0 |
| Anthracene | | | | | 3.6 |
| NaI(Tl) | | | | | 8.8 |

[a] For energy transfer from solvent to solute.

[b] First 3 components by the light output in organic scintillators.

[c] Represents loss in the scintillator when coupled to an RCA-8575 photomultiplier with good light collection.

Three parameters determine the ability to distinguish between gammas and neutrons: the total number $R$ of photoelectrons produced at the cathode for a given energy of excitation, the shape $f(t)$ of the light scintillation for both neutrons and gammas, and the photoelectron level $j$ at which the pulse shape information is deduced.

If one assumes that the neutron and gamma can be characterized with an effective single decay time, the probability distribution function for the $j$th photoelectron out of a total of $R$ photoelectrons is given by the statistical order equation[2]

$$g(t) = \frac{R!}{(j-1)!\,(R-j)!\,\tau}\,[1 - e^{-t/\tau}]^{j-1}\, e^{-t(R-j)/\tau}\,. \qquad (1)$$

The following analysis is based on a first-order approximation of the pulse shape. If more exact results are desired, refer to the work of Kuchnir and Lynch.

Assuming an effective exponential for the scintillation permits one to obtain a better understanding of how the three parameters affect the neutron-gamma separation. The mean time for the $j$th photoelectron is given by[3]

$$t_j = \tau \ln \frac{R}{R-j} = \tau \ln \frac{1}{1-F}\,, \qquad (2)$$

where $F$ is the ratio or the fraction $j/R$. The variance in time of the $j$th photoelectron is given by

$$\sigma_j^2 = \tau^2 \sum_{k=0}^{j} \left(\frac{1}{R-k}\right)^2 \qquad (3)$$

The width of the time distribution varies directly with $\tau$ and the photoelectron level $j$ but inversely with $R$, the total number of electrons. Therefore as the fraction at which the time information is derived increases toward unity, the separation of the neutron and gamma increases but the time resolution is poorer. The object is to choose a photoelectron level that will minimize the overlap of rise time of the neutron and gamma-ray signals. Kuchnir and Lynch[1] by using the measured distributions and a more general-order equation predicted the optimum separation to exist when the fraction of pulse height used is between 0.8 and 0.9. The ORTEC 458 was designed to take advantage of the optimum trigger point.

Consider a typical example where Eqs. (2) and (3) can be used to predict the separation of neutrons and gamma rays. Assume the following experimental conditions:

1. The neutron pulse height is equal to the gamma-ray pulse-height equivalent of 100-keV electron energy, or 500-keV neutrons.
2. The scintillator is NE-213 on an RCA-8575 photomultiplier producing 1.7 photoelectrons/keV of electron energy.

---

*Nuclear Enterprises, Ltd., San Carlos, California.

**See "References" at the end of this section.

3. The effective decay of NE-213 is 130 nsec for neutrons and 10 nsec for gamma rays.

The variance for the neutron rise time is calculated by

$$\sigma_n^2 = \sigma_{10\%}^2 + \sigma_{90\%}^2 \cong \sigma_{90\%}^2$$

$$\sigma_n^2 = (56 \times 10^{-12})^2 \cdot \sum_{k=0}^{j} \left(\frac{1}{R-k}\right)^2 . \qquad (4)$$

In Eq. (4) $R$ is 1.7 x 100 keV or 170; $j$ = 0.9 x 170, or 152.

Substituting the values of $R$ and $k$ in Eq. (4) yields

$$\sigma_n^2 = (56 \times 10^{-9})^2 \times \left[\left(\frac{1}{170}\right)^2 + \left(\frac{1}{169}\right)^2 + \left(\frac{1}{168}\right)^2 + \cdots \left(\frac{1}{18}\right)^2\right],$$

$$\sigma_n \approx 56 \times 10^{-9} \times 0.22 = 12.2 \text{ nsec},$$

$$\Delta t = 2.35 \times 12.2 = 29 \text{ nsec (FWHM)}.$$

For the gamma ray

$$\sigma_\gamma^2 = (4.5 \times 10^{-9})^2 \sum_{k=0}^{j} \left(\frac{1}{R-k}\right)^2 ,$$

$$\sigma_\gamma \approx 4.5 \times 10^{-9} \times 0.22 = 0.95 \text{ nsec},$$

$$\Delta t = 0.95 \times 2.35 = 2.25 \text{ nsec (FWHM)}.$$

The mean separation would be

$$\bar{t}_n - \bar{t}_\gamma = 120 \text{ nsec}.$$

The calculated results are shown in Fig. 4.8a, with the shapes assumed to be approximately Gaussian. Figure 4.8b illustrates what happens to the ability to separate the neutrons and gamma rays at approximately 350-keV neutron energy or 70-keV equivalent electron energy. The assumptions used to obtain Eqs. (1) and (2) are representative of first-order approximations and are presented here to illustrate the effect of various parameters on the neutron-gamma separation.

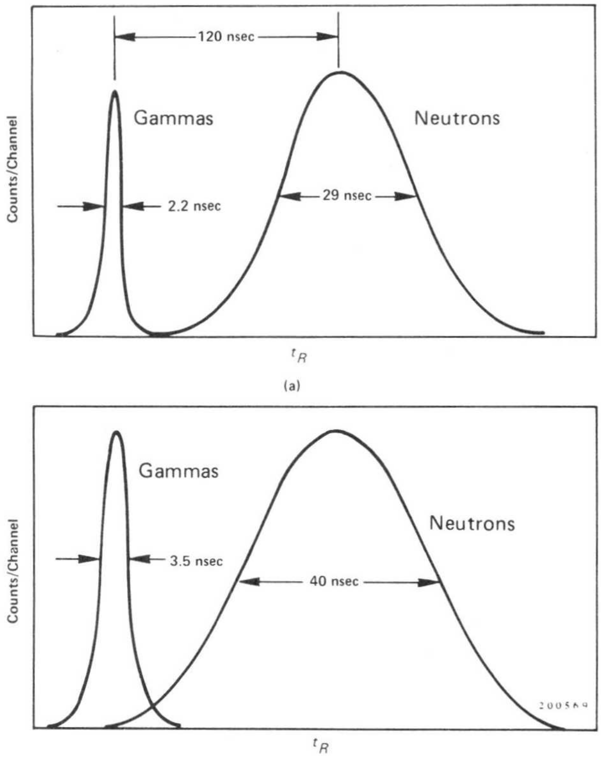


Fig. 4.8. Calculated Response for (a) 100-keV and (b) 70-keV Electron Equivalent Energies Deposited in NE-213.

**Proper Application of the 458 and 460** The 458 Pulse Shape Analyzer measures the 90-10% fall time of the linear signal presented to its input. To obtain the best time resolution use the fast unipolar delay-line-shaped output from the 460. The rise time of the unipolar delay-line-shaped pulse should not be greater than 100 nsec for best results, and the amplifier should have low noise characteristics and be operated at low gain. Figure 4.9 shows the process by which a delay-line-shaped pulse is produced. Notice that the time information is inverted in the process of producing the trailing edge of the pulse. The time information that occurs at the 10% point on the input signal occurs at the 90% level on the trailing edge, and the time information occurring at the 90% level on the input signal is transformed to the 10% level on the trailing edge.

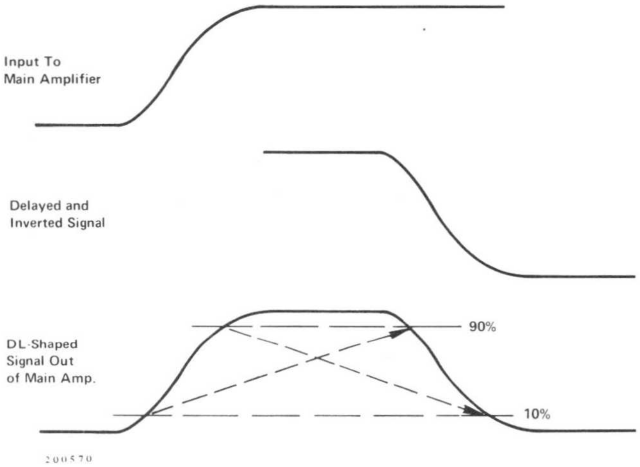


Fig. 4.9. Single-Delay-Line Shaped Signal.

Consider the effect of amplifier noise on the neutron-gamma separation for a wide dynamic range of operation. Assume the following amplifier noise characteristics:

Gain = 10.
Rise time = 100 nsec.
Input equivalent noise ($\Delta v$) = $70 \times 10^{-6}$ V.

The rise-time noise is given approximately by

$$\Delta t = \sqrt{2}\, G\; 2.35\, \Delta v/(v/t_R), \tag{5}$$

where $\Delta v$ is rms noise at the input, $v$ is the signal level of interest, and $t_R$ is the rise time. The $\sqrt{2}$ factor exists because of two-level measurements and the 2.35 converts the rms value to FWHM. For the example above the time resolution at the minimum pulse height of 20 mV is

$$\Delta t = \sqrt{2}\,(10)\,(2.35)\; 70 \times 10^{-6}/(20 \times 10^{-3}/100 \times 10^{-9})$$

$$= 11.5 \text{ nsec (FWHM)}.$$

Many delay-line amplifiers have good noise characteristics for high gain, but the noise increases very rapidly as the gain is lowered. From the above example it becomes evident that the amplifier must be operated at minimum gain and must have good noise characteristics before neutrons and gammas can be separated over the entire range of 20 mV to 10 V. The ORTEC 460 furnishes these characteristics.

The 458 should be operated in the X0.1-V input discriminator range for the 400:1 dynamic range. In this position 1000 divisions is equivalent to 100 mV at the input to the 458. The 458 input discriminator control should be set above the input noise but not lower than 100 divisions on the control. The Walk Adj should be adjusted for optimum walk over the entire dynamic range of interest.

A typical block diagram for a neutron–gamma-ray discrimination system is shown in Fig. 4.10. The 458 Pulse Shape Analyzer (PSA) time window is set on the gamma peak and above any extraneous peaks in the time spectrum caused by amplitude saturation of the main amplifier. A UL logic pulse is generated for all events with rise times greater than the UL control setting.

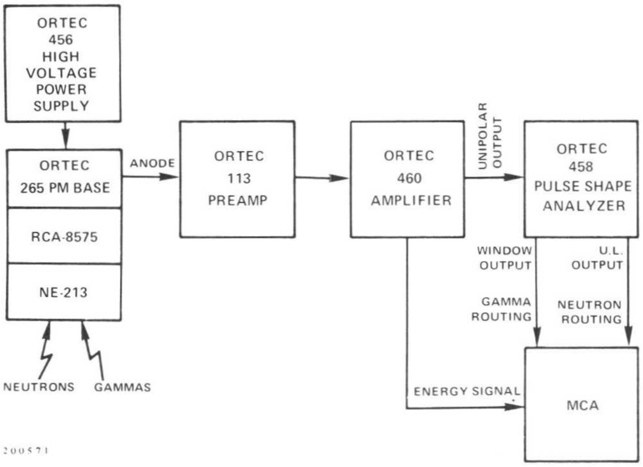


**Fig. 4.10. Block Diagram for a Typical Neutron-Gamma Separation Experiment.**

Figure 4.11 is a typical spectrum of the 458 output with a plutonium-beryllium source.

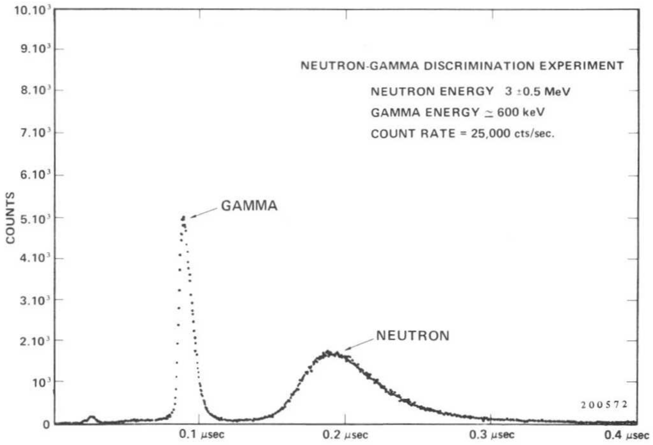


**Fig. 4.11. Neutron-Gamma Rise Time Spectrum.**

## 4.7. NEUTRON–GAMMA-RAY DISCRIMINATION IN PROPORTIONAL COUNTERS

Gamma-ray discrimination in proton-recoil proportional counters has been accomplished by several experimenters.[4-8] Recently Ōbu[9] reported excellent separation of neutrons and gammas at energies of 10 keV and lower. The basic principle is that the proton recoils from the neutrons produce a very short ionization path, whereas the electrons produced by the gammas will occur over a relatively long path in the chamber. Thus the rise time associated with the neutrons will be less than and also better defined than the rise time of the gamma event. This is illustrated in Fig. 4.12.

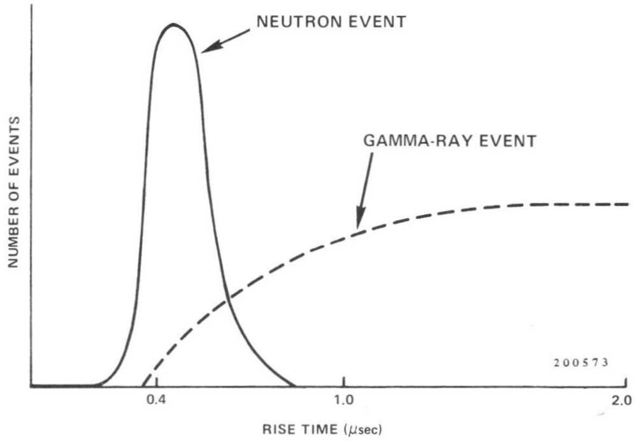


**Fig. 4.12. A Typical Neutron and Gamma Rise Time Spectrum from a Proton Recoil Proportional Counter.**

The suggested block diagram for the proportional counter system for neutron-gamma discrimination is shown in Fig. 4.13. The 460 delay-line-shaped amplifier should have a 2-μsec shaped line for optimum performance. The Lower Level control of the window should be set just below the peak corresponding to the neutron rise time (see Fig. 4.12) and the UL control should be set just above the neutron peak. The majority of the events causing a window output will correspond to neutrons, and the events causing a UL output will correspond to gamma rays.

### 4.8. OTHER EXPERIMENTS

Block diagrams illustrating how the 460 and other ORTEC 400 Series module can be used in experimental setups are given in Figs. 4.14–4.17.

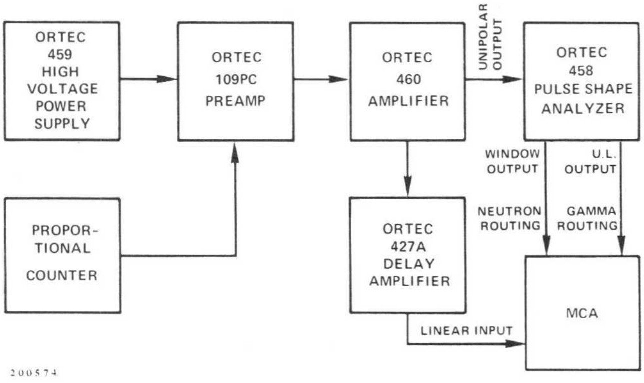


**Fig. 4.13. Neutron-Gamma Discrimination System with Proportional Counter.**

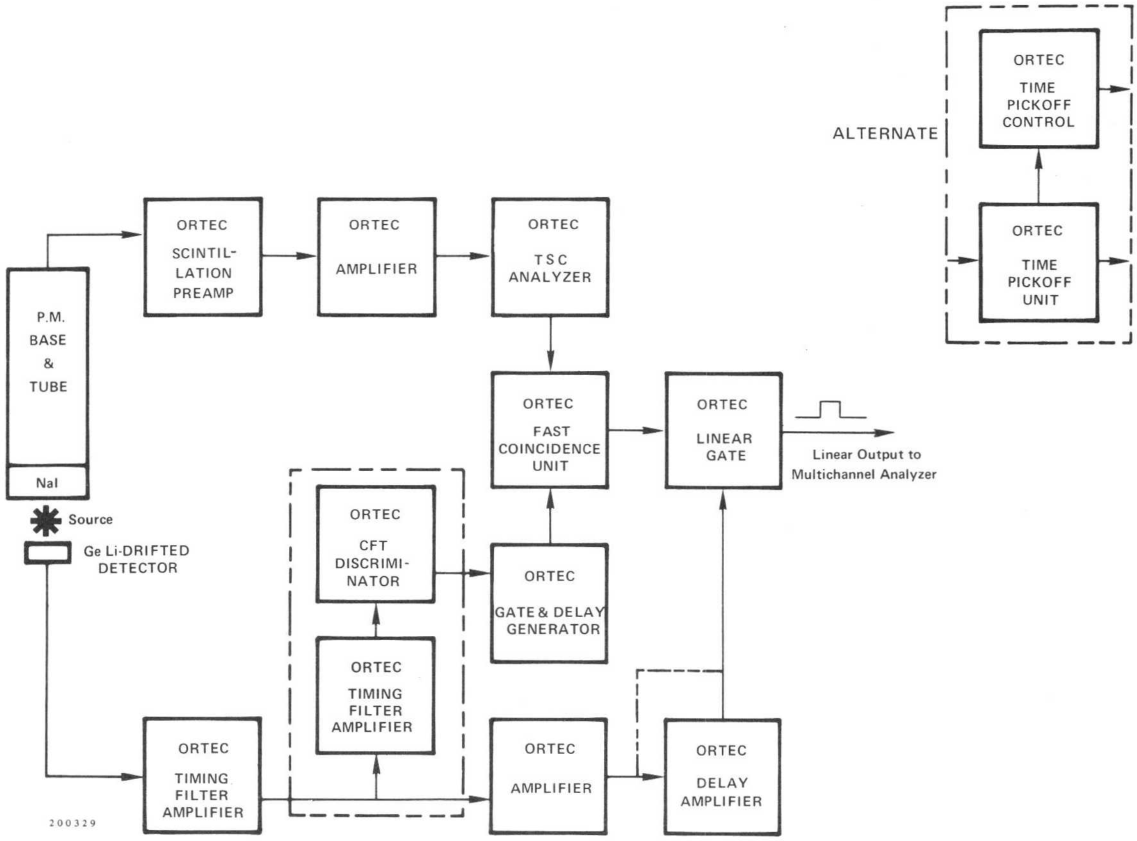


**Fig. 4.14. Gamma-Gamma Coincidence Experiment.**

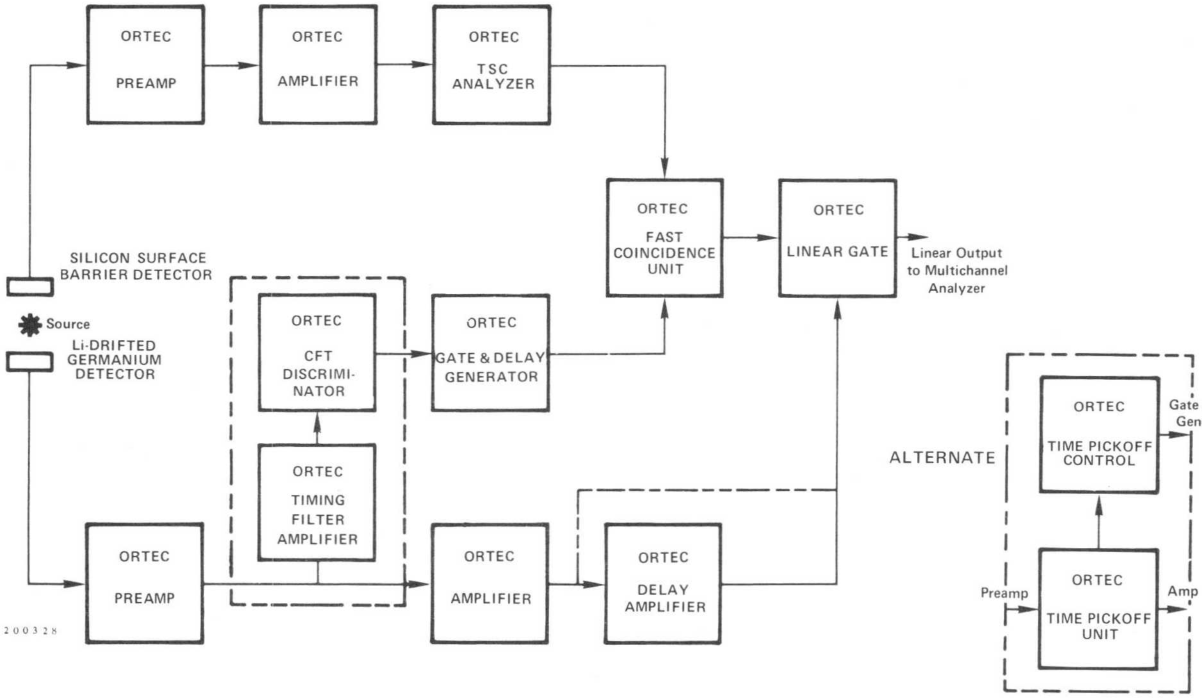


Fig. 4.15. Gamma-Ray Charged-Particle Coincidence Experiment.

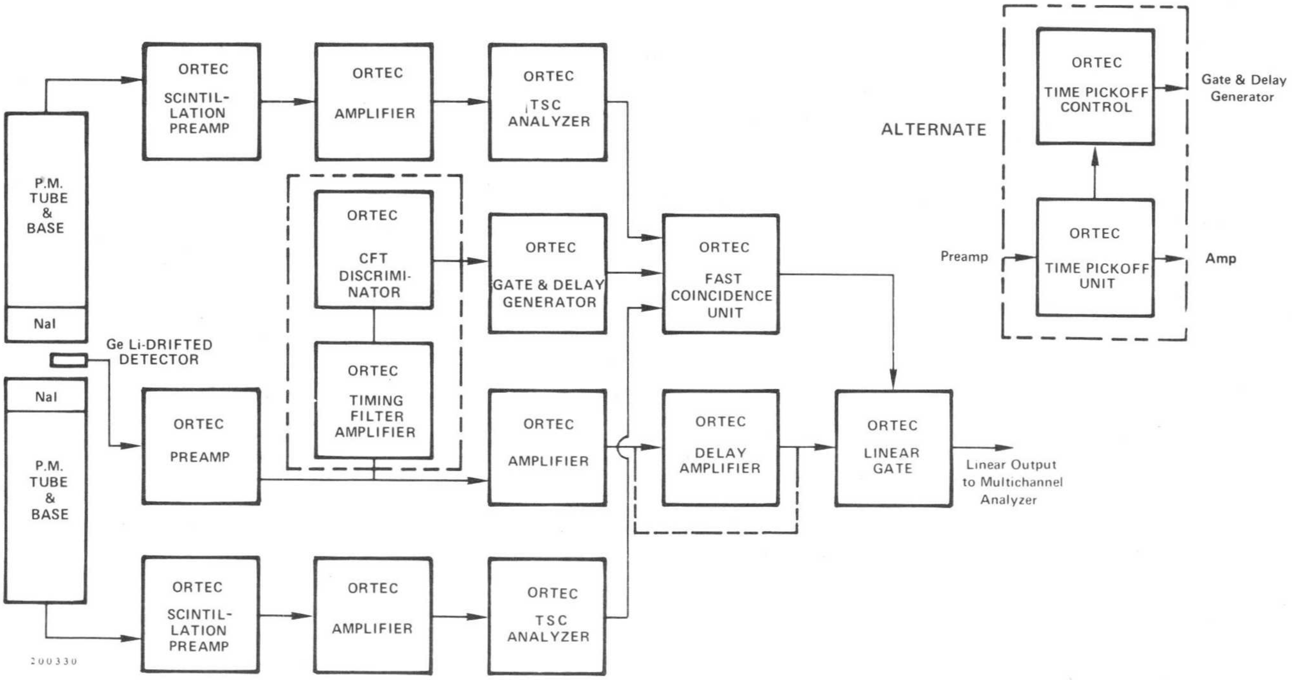
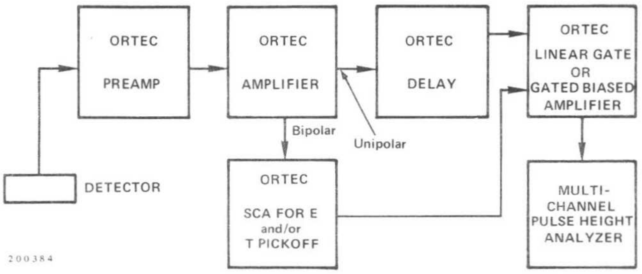
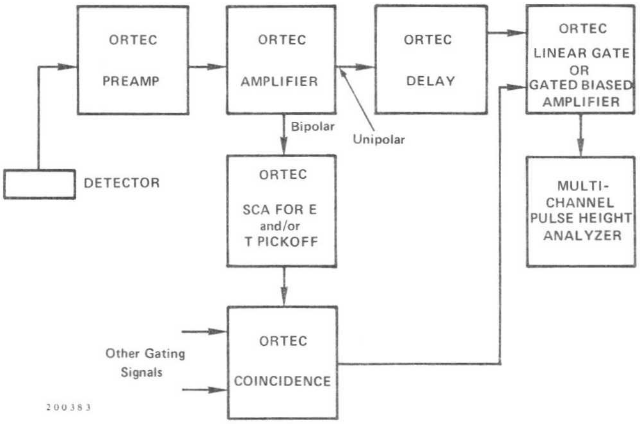


Fig. 4.16. Gamma-Ray Pair Spectrometer.



a. Energy Gated



b. Time Gated

**Fig. 4.17. General System Arrangement for Gating Control.**

## 4.9 METHODS OF CONNECTION TO VARIOUS ANALYZERS

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. The ADC's listed below and the block diagrams of Figs. 4.18 and 4.19 outline methods of connecting the 460 into the system in such a way that it will perform its function and supply an analysis signal to the ADC through a dc-coupled network. Note that in some cases it is necessary to feed two signals to the ADC. One of these, which is the dc-coupled signal to be analyzed, goes directly to the gate circuit, while the second signal goes to the normal input and is used merely as a trigger signal to initiate analysis since some of the ADC's pick off the trigger signal to initiate analysis from the normal (0 to 10 V) input.

Various manufacturers of multichannel analyzers and their recommended method of dc coupling of specific ADC's are given below. Figure 4.18 applies when no trigger is needed, and Fig. 4.19 applies when an external trigger is indicated. If information in excess of that given is necessary, contact the analyzer manufacturers for further details.

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

PACKARD INSTRUMENTS

INTERTECHNIQUE

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

NORTHERN SCIENTIFIC

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

NUCLEAR DATA

| ADC Model | Direct Input (V) | Modification | Trigger |
|---|---|---|---|
| ND-120<br>ND-130 | −3<br>−3 | Short out 0.01 μF capacitor on ADC board, base of T-1 | None required |
| ND-110 | −2.5 | None (use Mössbauer Input) | None required |
| ND-160F | −3 | None (use Direct) | None required |
| ND-161F | −3 | Short out 0.018 μF capacitor on ADC board, base of T-1 | None required |
| ND-2200 | 0–5 (offset baseline) | Short out capacitor 09D8 on ATC board | None required if operated in open gate |
| ND-3300 | +10 | Short out 0.01 μF capacitor on ALG board | Required |

TMC ANALYZER AND ADC DIRECT INPUT REQUIREMENTS

| Model No. | Signal Required (V) | Modifications |
|---|---|---|
| 102 Analyzer | 0 to −4 | Yes[a] |
| 213 ADC | 0 to +8 | Yes[b] |
| 401D Analyzer | 0 to −4 | Yes[a] |
| 404C Analyzer | 0 to −4 | Yes[a] |
| 461 ADC | 0 to −8 | No |
| 1001 Analyzer | 0 to −4 | Yes[c] |
| 1004 Analyzer | 0 to −4 | Yes[a] |
| 1010 Analyzer | 0 to −4 | Yes[c] |
| 217B ADC | 0 to −4 | Yes[c] |

[a] Add signal input and trigger input for Linear Gate.
[b] Add signal input and special trigger input.
[c] Add signal input to Linear Gate circuit.

TULLAMORE (Victoreen) signal 0 to +10 V

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

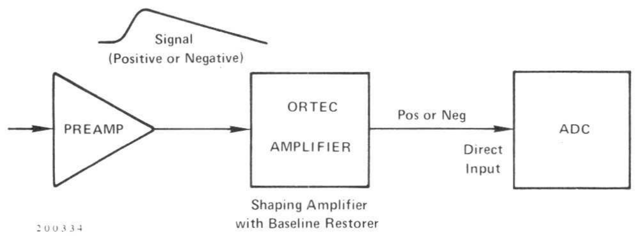


Fig. 4.18. Analyzer Connection with No Trigger Required.

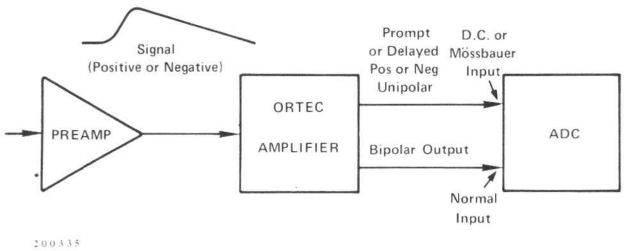


Fig. 4.19. Analyzer Connection When Trigger Is Required.

## 4.10. REFERENCES

1. F.T. Kuchnir and F.J. Lynch, "Time Dependence of Scintillations and the Effect on Pulse-Shape Discrimination," *IEEE Trans. Nucl. Sci.* **NS-15**(9), 107 (1968).

2. R.V. Hogg and A.T. Craig, *Introduction to Mathematical Statistics,* 2d ed., Macmillan, New York, 1965.

3. Ronald Nutt, *A Study of a NaI(Tl) Scintillator-Photomultiplier Timing System,* Ph.D. Thesis, University of Tennessee, March 1969.

4. E.F. Bennett, "Gamma-Ray Discrimination in a Proton-Recoil Proportional Counter," *Neutron Dosimetry, Proceedings of a Symposium, Harwell, December 14, 1962,* International Atomic Energy Agency, Vienna, 1963.

5. A Sayres and M. Coppola, "$^3$He Neutron Spectrometer Using Pulse Risetime Discrimination," *Rev. Sci. Inst.* **35**(4), 431 (1964).

6. J.M. Cuttler, S. Greenberger, and S. Shaley, "Pulse Risetime Discrimination for $^3$He Counters," *Nucl. Instr. Methods* **75**, 309-11 (1969).

7. G.R. Ricker, Jr., "Pulse Risetimes in Proportional Counters," *Rev. Sci. Instr.* **40**(2), 227 (1969).

8. E. Mathieson and T.J. Harris, "Pulse Shape Discrimination in Proportional Counters -- Theory of Electronic System," *Nucl. Instr. Methods* **88**, 181-92 (1970).

9. M. Ōbu, T. Ichimori, and K. Shirakata, "Gamma-Ray Discrimination in a Proton-Recoil Spectrometer for a Fast Reactor Spectrum Measurement," *Nucl. Instr. Methods* **89**, 131-39 (1970).

## 5. CIRCUIT DESCRIPTION

Figure 5.1 is a block diagram for the ORTEC 460 Delay Line Amplifier. In this diagram the circuits are divided into 7 functional groups, and the transistors that comprise each group are defined. Use this figure and the schematic 460-0101-S1 at the back of the manual to aid in understanding the circuits.

The 460 consists of five gain stages. A1 through A4 are all in series. The output from A4 is processed through A6 for a unipolar output and through A7 for a bipolar output. The function of A5 is to maintain a quiescent adjusted dc level for the unipolar output.

Gain stage A1 is an input buffer with a fixed gain of 2. It includes Q1 through Q7, and the gain is fixed by R1, R2, R3, and R15. This stage can be operated as either an inverting or a noninverting amplifier, depending on the setting of the front panel switch S1. When the signal input polarity from the preamplifier matches the setting of the switch, the output from Q7 is a negative pulse.

The Q7 output is delay-line-shaped by DL1 and pole-zero-cancelled by R28 and applied to A2, Q8 through Q15. This stage operates in the differential mode, providing an output that is the difference between the direct and delayed inputs. The stage gain is either 2 or 5, depending on the setting of Coarse Gain switch S2, determined by R34, R35, and R23 to R26. R23 is factory-adjusted for correct gain at the 10 and 20 settings of switch S2 to ensure that the pole-zero cancellation is valid for all gain settings. Feedback resistors R32, R33, R39, and R40 are also selected by the Coarse Gain switch to preserve a constant bandwidth.

Stage A3, Q16 through Q23,is noninverting and has a gain of 2, 4, or 8 that is selected for various positions of switch S2. A selection of resistors R127, R81, R82, and R83 determines the gain for this stage.

Stage A4, Q24 through Q31, is a noninverting amplifier with a gain of 1. 2.5, or 5 selected by switch S2. The gain resistors are R84 through R88.

A Fine Gain control, R60, is used between A2 and A3 as a continuously variable attenuator with a range of 0.3 through 1. A selectable Integration time constant uses switch S4, resistors R84 and R85, and capacitors C24 and C25 to determine the rise time for an input pulse. The effect of the integration is applied between A3 and A4.

The single-delay-line shaped pulse from A4 is furnished directly to one input of A7, to Delay Line DL2, and to the Out position of the rear panel Delay switch, S3. If switch S3 is set at Out, the prompt SDL pulse is furnished to A6. If switch S3 is set at In, the same SDL pulse is furnished into A6 after the 1-μsec delay in DL2.

Gain stage A6 includes Q36 through Q45. This stage has a fixed gain of 2.5 and furnishes the unipolar output through

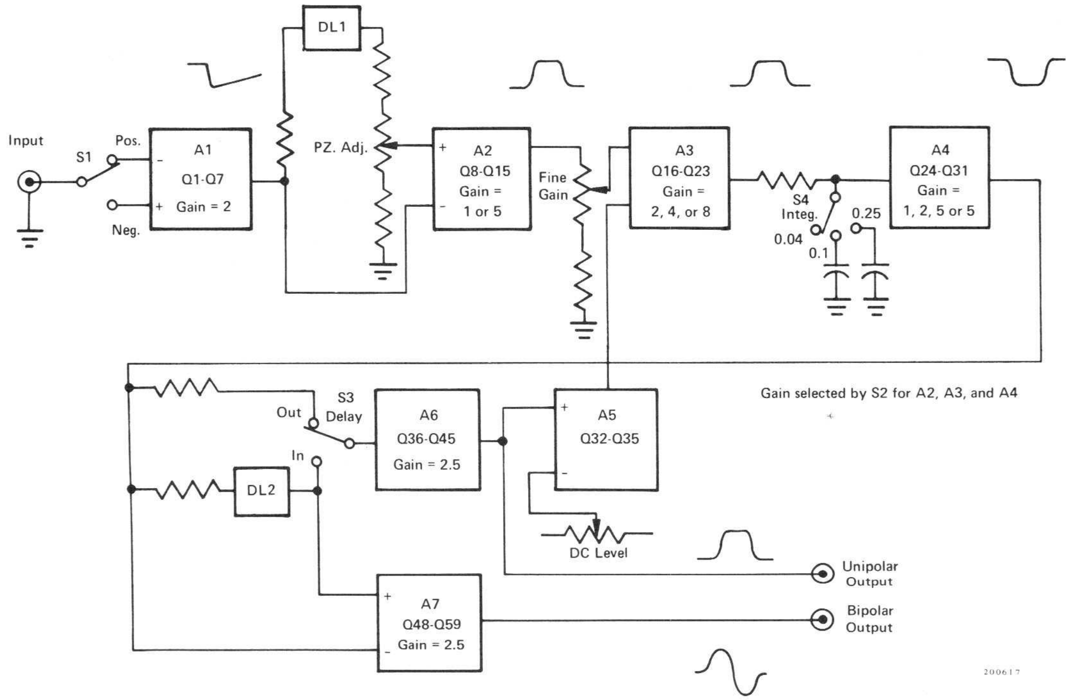


Fig. 5.1. Block Diagram of ORTEC 460 Delay Line Amplifier.

both the front and rear panel connectors. The output impedance through the front panel connector is less than 1Ω. The signal passes through series resistor R198 for the 93Ω characteristic output impedance through the rear panel connector. A test point on the front panel is isolated by R197.

The output of A6 is fed back through A5 to be used as a differential input to A3. This circuit seeks the adjusted dc level, set by R118, as the quiescent unipolar output level. Stage A5 uses transistors Q32 through Q35.

Gain Stage A7, Q48 through Q59, accepts both the prompt and the delayed SDL pulses. This stage operates in the differential mode, providing an output that is the difference between the prompt and delayed inputs, and this difference is the bipolar double-delay-shaped output pulse. The gain of the stage is fixed at 2.5, the same as the gain for A6, and thus the overall gains for the two output shapes are equalized. The output impedance through the front panel connector is less than 1Ω. It is isolated from the front panel test point by R209. The signal also passes through series resistor R210 for the 93Ω characteristic output impedance through the rear panel connector.

Coarse Gain factors of 10 through 1000 are obtained by various combinations of selected stage gains. The selections in A2, A3, and A4 are shown in Table 5.1, together with the fixed gains in A1 and in either A6, for unipolar outputs, or in A7, for bipolar outputs. Any of these selected gain factors is also subjected to the attenuation selected by the Fine Gain control.

**Table 5.1. Coarse Gain Factors**

| S2 Setting | A1 | A2 | A3 | A4 | A6 or A7 |
|---|---|---|---|---|---|
| 10 | 2 | 1 | 2 | 1 | 2.5 |
| 20 | 2 | 1 | 4 | 1 | 2.5 |
| 50 | 2 | 5 | 2 | 1 | 2.5 |
| 100 | 2 | 5 | 4 | 1 | 2.5 |
| 200 | 2 | 5 | 8 | 1 | 2.5 |
| 500 | 2 | 5 | 8 | 2.5 | 2.5 |
| 1000 | 2 | 5 | 8 | 5 | 2.5 |

A trim potentiometer R187 is provided on the printed circuit board for a calibration adjustment to balance the areas of positive and negative polarities in the bipolar output signals. When these areas are equal, the dc-coupled output will provide a high counting rate without any baseline shift. This potentiometer is factory-adjusted and should not require any recalibration under normal conditions.

Both of the output circuits are protected against shorts. For the unipolar output the protection is furnished by Q46 and Q47, and for the bipolar output it is furnished by Q58 and Q59.

# 6. MAINTENANCE

## 6.1. TEST EQUIPMENT REQUIRED

In order to adequately test the specifications of the ORTEC 460, the following equipment should be utilized:

ORTEC 419 Precision Pulse Generator

Tektronix Model 547 Series Oscilloscope with a Type 1A1 plug-in or equivalent

Hewlett-Packard 400D RMS Voltmeter

## 6.2. PULSER MODIFICATIONS FOR OVERLOAD TESTS

The 460 incorporates variable pole-zero cancellation, factory-adjusted to approximately 50 μsec. Therefore when either the ORTEC 419 or 204 Pulse Generator is used to check overload, it should be connected as shown in Fig. 6.1 and the pole-zero cancellation adjusted to compensate for the fall time of the pulse generator.

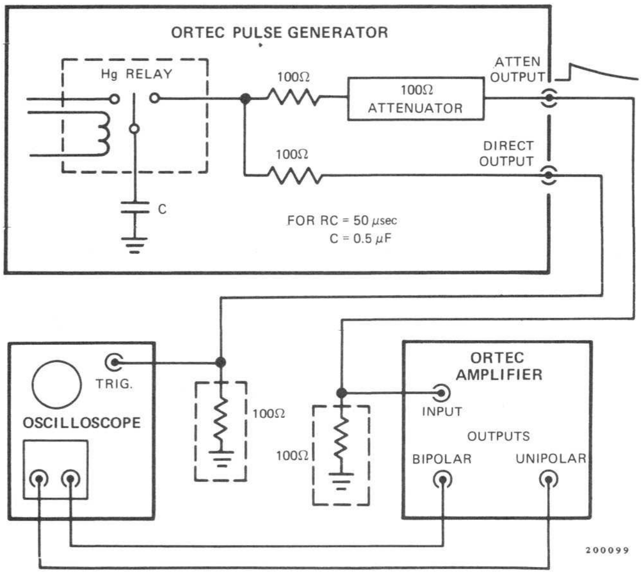


Fig. 6.1. Pulse Generator Modifications.

If the pulser output is fed into a charge-sensitive preamplifier such as the ORTEC 109A, 120, 124, or 125 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.

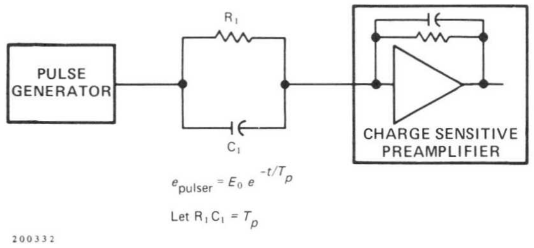


Fig. 6.2. Pole-Zero Cancellation of a Pulser Output.

## 6.3. PULSER TEST*

**Functional Checks** Before making functional checks of the 460, set the controls as follows:

| | |
|---|---|
| Coarse Gain | 1K |
| Fine Gain | 1 |
| Input Polarity | Pos |
| Integ Time Constant | 0.04 |
| Delay | Out |

1. Connect a positive pulser to the 460 as shown in Fig. 6.1 and adjust the pulser to obtain 10 V at the 460 Unipolar Output. This should require an input pulse of 10 mV. The Bipolar Output should also be 10 V.

2. Place the Delay switch to the In position. The Unipolar pulse should be delayed 1 μsec from its original position. Return the Delay switch to Out.

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

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

5. Obtain a 10-V output with maximum gain. Decrease the Coarse Gain switch stepwise from 1K to 10 and ensure that the output amplitude changes by an appropriate amount. Return the Coarse Gain switch to 1K.

6. Decrease the Fine Gain to 0.3, at which time the output should decrease by a factor of 3.3. Return the Fine Gain control to maximum.

**Overload Tests** Set the amplifier gain to maximum and adjust the pulse generator to obtain a 10-V amplifier output. Increase the pulser amplitude by 500 to provide an overload. Observe that the Unipolar and Bipolar Outputs both return to within 200 mV of the baseline within 15 μsec. It will probably be necessary to vary the PZ Adj control on the front panel in order to cancel the pulser pole and minimize the time for the return to the baseline.

**PZ Adj Calibration** The correct setting of the PZ Adj control depends upon the characteristics of the input pulses that are furnished from the preamplifier during normal operation of the 460. Observe the amplifier unipolar output for a high gain setting (50 or more) that will provide 8- to 10-V pulses for a monoenergetic signal from the preamplifier, and adjust the PZ Adj control on the front panel to obtain the quickest return to the baseline following each pulse. After the cancellation time has been minimized, reduce the amplifier coarse gain to 20 and adjust R23 on the printed circuit to obtain the optimum Pole-Zero cancellation at low gain settings.

**Linearity** The integral nonlinearity can be measured by the technique shown in Fig. 6.3. In effect, the negative pulser output is substracted from the positive amplifier output, causing a null point that can be measured with high sensitivity. The pulser amplitude must be varied between 0 and 10 V (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-V output. The variation in the null point as the pulser is varied from 10 V to zero is a measure of the nonlinearity. Since the subtraction network also acts as a voltage divider, this variation must be less than (10 V full scale) x (±0.05%

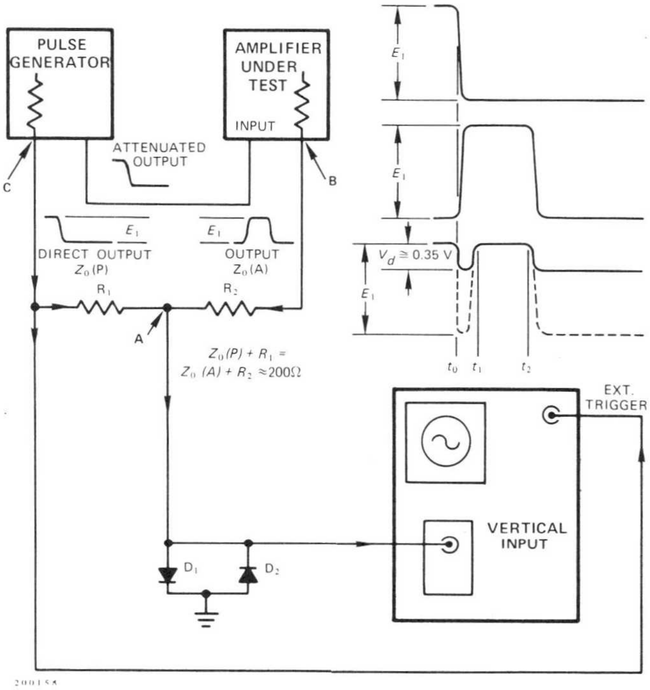


Fig. 6.3. Circuit Used to Measure Nonlinearity.

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*See IEEE Standards No. 301, USAS N42.2, *IEEE Trans.* Vol. NS-16(6) (December 1969).

max nonlinearity) x (½ for divider network) = ±2.5 mV max null point variation.

**Output Loading** With the same setup as in "Linearity" adjust the amplifier output to 10 V and observe the null point change when the output is terminated in 100Ω. The change should be less than 5 mV.

**Noise** Measure the noise at the amplifier output at maximum amplifier gain and 0.25-μsec Integrating time constant using the RMS Voltmeter. The noise should be less than 20 μV x 1000 gain/1.13 = 17.7 mV for single-delay-line outputs and 35 μV x 1000 gain/1.13 = 31.0 mV for double-delay-line outputs. 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 100Ω for this measurement.

**Crossover Walk with Amplifier (Amplifier and SCA)** With the setup of Fig. 6.4, obtain a 10-V amplifier output at an amplifier coarse gain of 50. Attenuate the pulser by X10, using only the pulser attenuator switches. The shift in the SCA should be less than ±2 nsec. The Walk Adj trim potentiometer on the SCA must be adjusted properly in order to make this measurement.

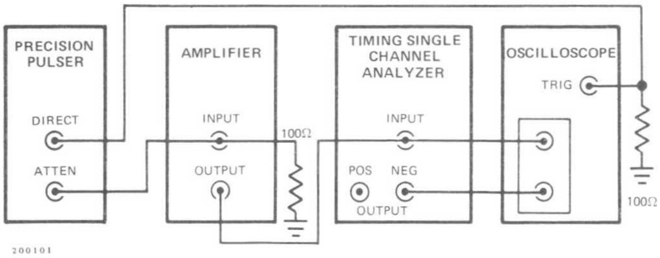


Fig. 6.4. Circuit Used to Measure Crossover Walk of the Amplifier and Single Channel Analyzer.

**Crossover Walk with Amplitude (Amplifier Only)** The crossover walk of only the amplifier can be measured with the setup shown in Fig. 6.5. The ORTEC 421 Integral Discriminator (or any other leading-edge discriminator) and the ORTEC 416 Gate and Delay Generator are used to delay the trigger of the oscilloscope so that 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 ORTEC 419 Pulser attenuator can be used if the attenuator of another 419 Pulser is used for the other attenuator). The pulser and the amplifier gain are adjusted so that there is an 8- to 10-V bipolar output at the oscilloscope, with the first attenuator having X20 attenuation and the second attenuator having no attenuation. Observe the crossover on the oscilloscope and remove the X20 attenuation from the first and add it to the second attenuator. The crossover walk under these conditions should be less than ±1 nsec.

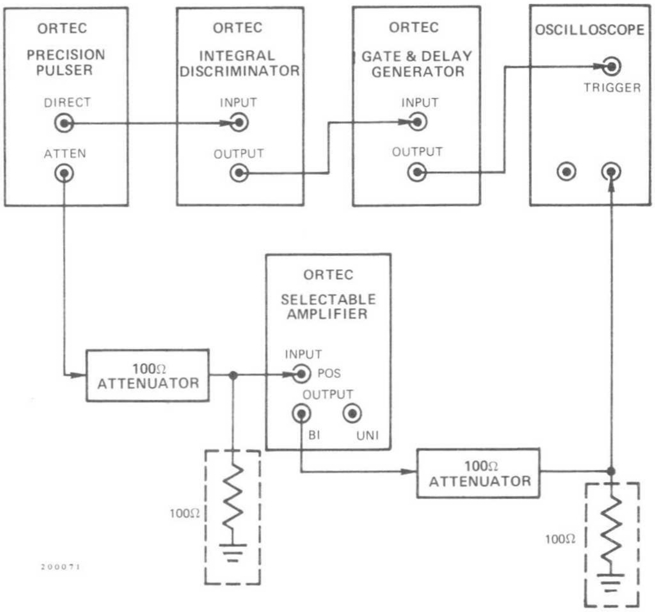


Fig. 6.5. Circuit Used to Measure Crossover Walk of the Amplifier Only.

**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 an ORTEC 442 Linear Gate. A 421 Integral Discriminator and a 416 Gate and Delay Generator are used to open the linear gate at the proper time to accept a shaped pulser pulse from the amplifier delayed output. Adjust the Amplifier gain so that the $^{137}$Cs peak will store at about the 70% level (approximately channel 2900 in a 4096 Analyzer) in the pulse height analyzer, and then adjust the pulser amplitude to store at the 84% level (approximately channel 3450 in a 4096

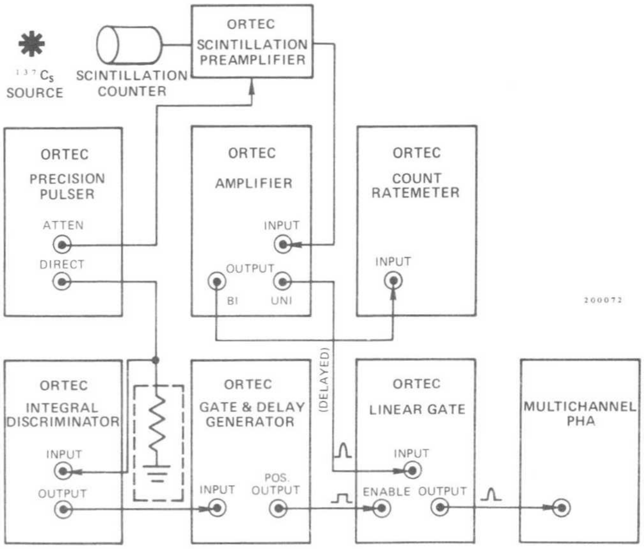


Fig. 6.6. Circuit Used to Measure Resolution Spread and Amplitude Changes at Various Count Rates.

Analyzer). Change the $^{137}$Cs source position until the counting rate as measured by the ratemeter is approximately 50,000 counts/sec. Two spectra are then accumulated, one with the $^{137}$Cs source present and one with the $^{137}$Cs source removed. Using a 1-μsec shaping time constant, the pulser peak in the presence of the $^{137}$Cs source should be shifted no more than 0.2% (seven channels for 4096 Analyzer) as compared to the pulser-only spectrum.

## 6.4. TROUBLESHOOTING

If the 460 is suspected of malfunctioning, it is essential to verify such malfunctioning in terms of simple pulse generator impulses at the input. The 460 must be disconnected from its position in any system, and routine diagnostic analysis performed with a test pulse generator and oscilloscope. It is imperative that testing not be performed with a source and detector until the amplifier performs satisfactorily with the test pulse detector.

The testing instructions in Section 6.3 of this manual and the circuit descriptions in Section 5 should provide assistance in locating the region of trouble and repairing the malfunction. The two side plates can be completely removed from the module to enable oscilloscope and voltmeter observations with a minimal chance of accidentally short-circuiting portions of the etched board.

The 460 may be returned to ORTEC for repair service at nominal cost. Our standardized procedure requires that each repaired instrument receive the same extensive quality control tests that a new instrument receives. Contact our Customer Service Department, (615) 482-4411, for shipping instruction before returning the instrument.

## 6.5. TABULATED TEST POINT VOLTAGES ON ETCHED BOARD

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

All the voltages listed below were measured with no input signal and with the front panel controls set at about their mid-ranges. When an input signal is furnished to the 460, the normal signal polarity is shown for each of 7 test points in the instrument.

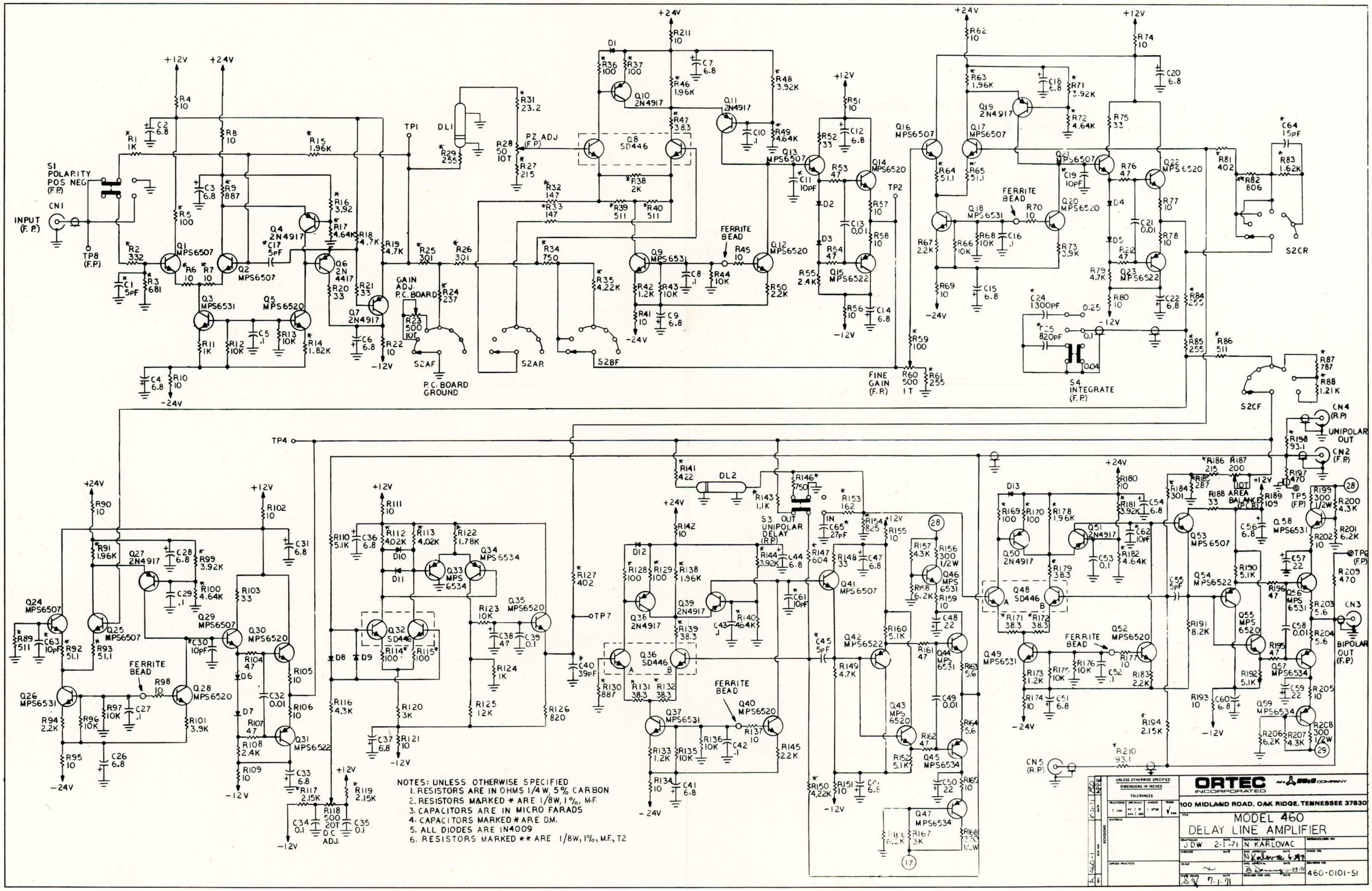
| Location | Voltage | Signal Polarity |
|---|---|---|
| TP1 | <100 mV | Negative |
| TP2 | <350 mV | Positive |
| TP3 | <130 mV | Positive |
| TP4 | < 20 mV | Negative |
| TP5 | Adjusted by R118 to ±1 V | Positive |
| TP6 | < 50 mV | Bipolar, + leading |
| TP7 | <500 mV | Positive |
| Q3B | - 12 V | |
| Q4B | + 13 V | |
| Q5B | - 12 V | |
| Q9B | - 12 V | |
| Q11B | + 13 V | |
| Q12B | - 12 V | |
| Q18B | - 12 V | |
| Q19B | + 13 V | |
| Q20B | - 12 V | |
| Q26B | - 12 V | |
| Q27B | + 13 V | |
| Q28B | - 12 V | |
| Q33B | + 4.5 V | |
| Q34B | + 4.5 V | |
| Q37B | - 12 V | |
| Q39B | + 13 V | |
| Q40B | - 12 V | |
| Q44C | + 13 V | |
| Q45C | - 7 V | |
| Q49B | - 12 V | |
| Q51B | + 13 V | |
| Q52B | - 12 V | |
| Q56C | + 13 V | |
| Q59C | - 13 V | |

## 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 | Spare |
| *10 | +6 volts | 32 | Spare |
| *11 | -6 volts | *33 | 115 volts ac (Hot) |
| 12 | Reserved Bus | *34 | Power Return Ground |
| 13 | Spare | 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 and 401B Modular System Bins.*

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.



NOTES: UNLESS OTHERWISE SPECIFIED
1. RESISTORS ARE IN OHMS 1/4 W, 5% CARBON
2. RESISTORS MARKED * ARE 1/8W, 1%, M.F.
3. CAPACITORS ARE IN MICRO FARADS
4. CAPACITORS MARKED * ARE D.M.
5. ALL DIODES ARE IN4009
6. RESISTORS MARKED ** ARE 1/8W, 1%, M.F., T2

| | | |
|---|---|---|
| A | 460-1 | 8-31-71 BD |
| REV | ECN NO | DATE APPR |

REVISIONS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES

| FRACTIONS | DECIMALS | ANGLES | FINISH |
|---|---|---|---|
| ± 1/64 | XX ± .01<br>XXX ± .005 | ± 0°30' | √ RMS |

MATERIAL

APPLIED PRACTICES

**ORTEC**
INCORPORATED
AN EG&G COMPANY

100 MIDLAND ROAD, OAK RIDGE, TENNESSEE 37830

TITLE
MODEL 460
DELAY LINE AMPLIFIER

| | | | |
|---|---|---|---|
| DRAFTSMAN JDW | DATE 2-1-71 | RESPONSIBLE ENGINEER N KARLOVAC | REFERENCE/USED ON |
| CHECKED | DATE | ENG. APPROVAL N Karlovac | DATE 6-29-71 |
| SCALE ~ | | MFG. APPROVAL B Denning | DATE 6-23-71 |
| DWG ISSUED SV | DATE 7-1-71 | RELEASED FOR MFG. | DATE |

STOCK NO.

DRAWING NO. 460-0101-S1

MODEL 460 DELAY LINE AMPLIFIER

Operating and Service Manual

For more information on ORTEC products or their applications, contact your local ORTEC representative or:

**Europe:** ORTEC GmbH, 8 Munich 13, Frankfurter Ring 81, West Germany, Telephone (0811) 359-1001 or 359-1441, Telex 528476

**United Kingdom:** ORTEC Limited, Dallow Road, Luton, Bedfordshire, England, Telephone LUton 27557, Telex 82477

**Other:** ORTEC Incorporated, 100 Midland Road, Oak Ridge, Tennessee 37830, Telephone (615) 482-4411, TWX 810-572-1078, Telex 055-7450

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