Model 570
Spectroscopy Amplifier
Operating and Service Manual

Printed in U.S.A.

ORTEC Part Number 733480
Manual Revision E

1202

Advanced Measurement Technology, Inc.

a/k/a/ ORTEC®, a subsidiary of AMETEK®, Inc.

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ORTEC
570
AMPLIFIER
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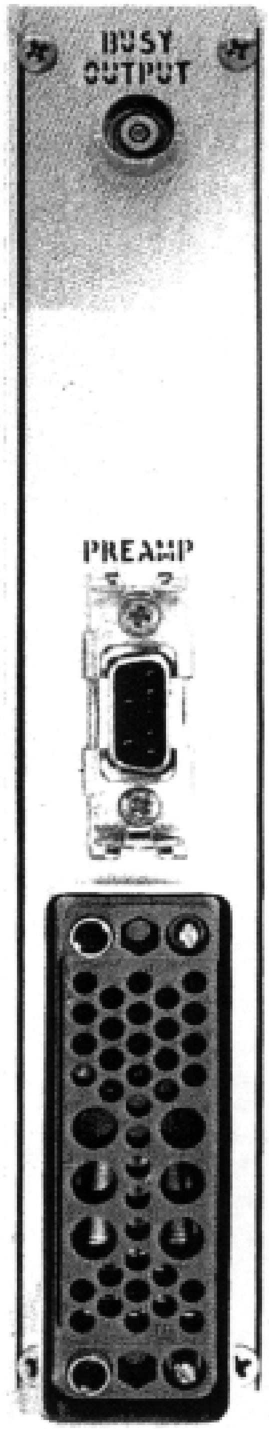
(μsec)
0.5
1
2
3
6
10
BLR
AUTO
PZ ADJ
THRESH
INPUT
POS
NEG
UNIPOLAR
OUTPUT
DC
P1


BUSY
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1 DESCRIPTION

1.1 GENERAL

The ORTEC 570 Spectroscopy Amplifier is a singlewidth NIM module that features a versatile combination of switch-selectable pulse-shaping characteristics. The amplifier has extremely low noise, a wide gain range, and excellent overload response for universal application in high-resolution spectroscopy. It accepts input pulses of either polarity that originate in germanium or silicon semiconductor detectors, in scintillation counters with either fast or slow scintillators, in proportional counters, in pulsed ionization chambers, in electron multipliers, etc.

The 570 has an input impedance of approximately 1000Ω and accepts either positive or negative input pulses with rise times <650 ns and fall times >40 μs. Six integrate and differentiate time constants are switch-selectable to provide optimum shaping for resolution and count rate. The differentiation network has variable pole-zero cancellation that can be adjusted to match preamplifiers with decay times >40 μs. The pole-zero cancellation drastically reduces the undershoot after the differentiator and greatly improves overload and count rate characteristics. In addition, the amplifier contains an active filter shaping network that optimizes the signal-to-noise ratio and minimizes the overall resolving time.

The output is unipolar and is used for spectroscopy in systems where dc coupling can be maintained from the 570 to the analyzer. A BLR (baseline restorer) circuit is included in the 570 for improved performance at all count rates. Baseline correction is applied during intervals between input pulses only, and a front panel switch selects a discriminator level to identify input pulses. The unipolar output dc level can be adjusted in the range from -100 mV to +100 mV. This output permits the use of the direct-coupled input of the analyzer with a minimum amount of interface problems.

The 570 can be used for constant-fraction timing when operated in conjunction with an ORTEC 551, 552, or 553 Timing Single-Channel Analyzer. The ORTEC Timing Single-Channel Analyzers feature a minimum of walk as a function of pulse amplitude and incorporate a variable delay time on the output pulse to enable the timing pick-off output to be placed in time coincidence with other signals.

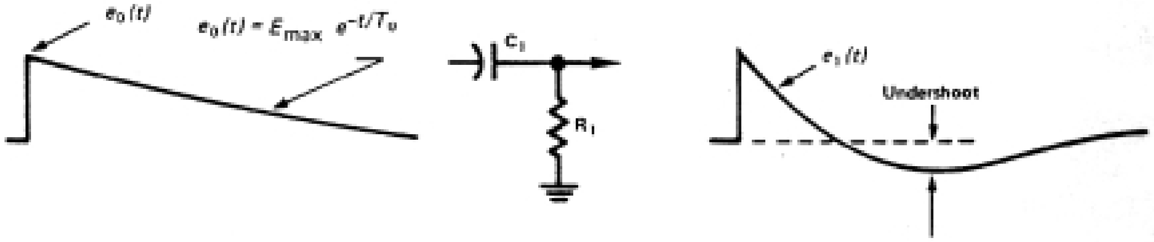
The 570 has complete provisions, including power distribution, for operating any ORTEC solid-state preamplifier. Normally, the preamplifier pulses should have a rise time of 0.25 μs or less to properly match the amplifier filter network and a decay time greater than 40 μs for proper pole-zero cancellation. The 570 input impedance is 1000Ω. When long preamplifier cables are used, the cables can be terminated in series at the preamplifier end or in shunt at the amplifier end with the proper resistors. The output impedance is about 0.1Ω, and the output can be connected to other equipment by a single cable going to all equipment and shunt terminated at the far end of the cabling. See Section 3 for further information.

1.2 POLE-ZERO CANCELLATION

Pole-zero cancellation is a method for eliminating pulse undershoot after the differentiating network. In an amplifier not using pole-zero cancellation (Fig.1.1), the exponential tail on the preamplifier output signal (usually 50 to 500 μs) causes an undershoot whose peak amplitude is roughly determined from:

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

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



Charge loop output × First differentiation network = Differentiated pulse with undershoot

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

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

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

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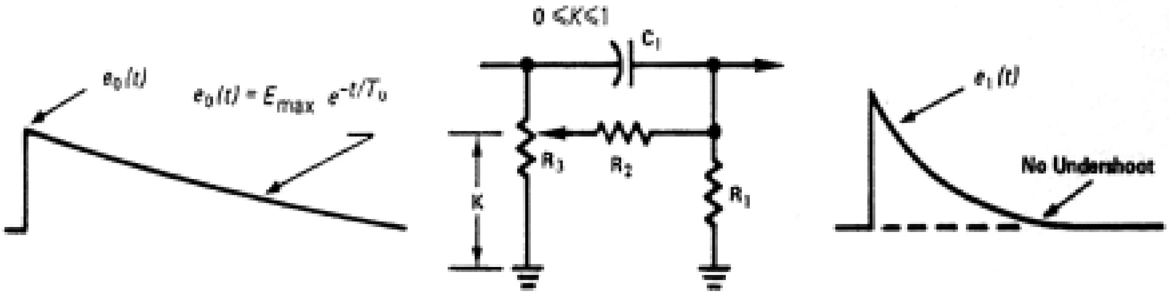
Fig. 1.1. Differentiation in an Amplifier Without Pole-Zero Cancellation.



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

Pole zero cancel by letting

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

or

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

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

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

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

200410

Fig. 1.2. Differentiation in a Pole-Zero Cancelled Amplifier.

Pole-zero cancellation is accomplished by the network shown in Fig. 1.2. The pole $[s + (1/T_0)]$ due to the preamplifier pulse decay time is canceled by the zero of the network $[s + (k/R_2C_1)]$. In effect, the dc path across the differentiation capacitor adds an attenuated replica of the preamplifier pulse to just cancel the negative undershoot of the differentiating network.

Total preamplifier-amplifier pole-zero cancellation requires that the preamplifier output pulse decay time be a single exponential decay and matched to the pole-zero cancellation network. The variable pole-zero cancellation network allows accurate cancellation for all preamplifiers having 40-µs or greater decay times. Improper matching of the pole-zero network will degrade the overload performance and cause excessive pileup distortion at medium counting rates. Improper matching causes either an undercompensation (undershoot is not eliminated) or an overcompensation (output after the main pulse does not return to the baseline but decays to the baseline with the preamplifier time constant). The pole-zero adjust is accessible on the front panel of the 570 and can easily be adjusted by observing the baseline on an oscilloscope with a monoenergetic source or pulser having the same decay time as the preamplifier under overload conditions. The adjustment should be made so that the pulse returns to the baseline in the minimum time with no undershoot.

1.3 ACTIVE FILTER

When only FET gate current and drain thermal noise are considered, the best signal-to-noise ratio occurs when the two noise contributions are equal for a given input pulse shape. The Gaussian pulse shape (Fig. 1.3) for this condition requires an amplifier with a single RC differentiate and n equal RC integrates where n approaches infinity. The Laplace transform of this transfer function is

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

where the first factor is the single differentiate and the second factor is the n integrates. The 570 active filter approximates this transfer function.

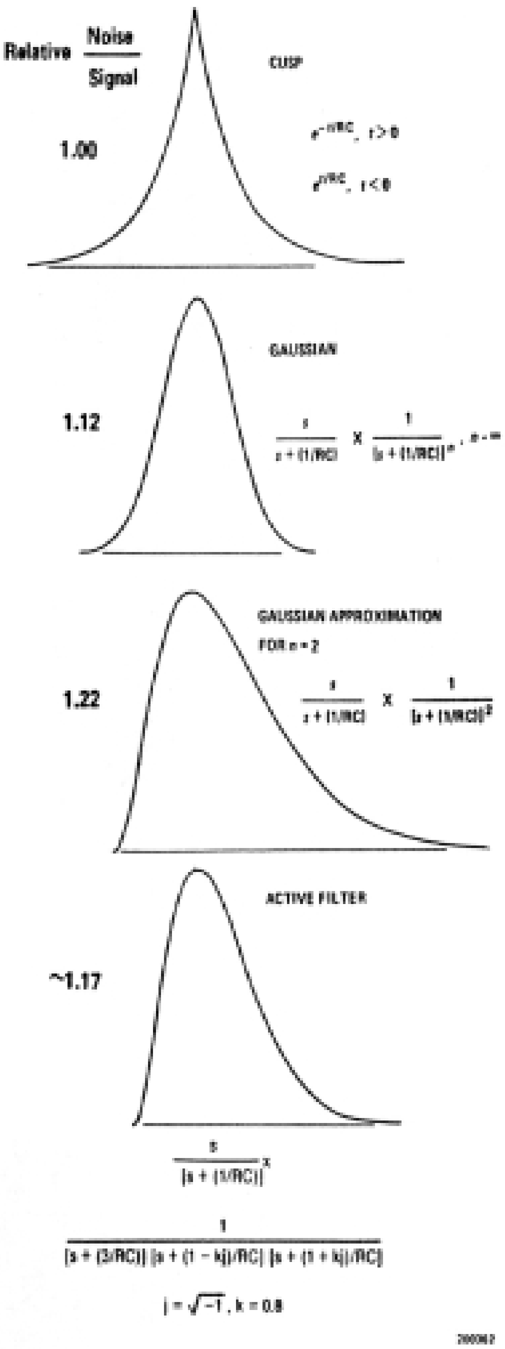


Fig. 1.3. Pulse Shapes for Good Signal-to-Noise Ratios.

Figure 1.3 illustrates the results of pulse shaping in an amplifier. Of the four pulse shapes shown, the cusp would produce minimum noise but is impractical to achieve with normal electronic and circuitry would be difficult to measure with an ADC. The true Gaussian shape deteriorates the signal-to-noise ratio by only about 12% from that of the cusp and produces a signal that is easy to measure but requires many sections of integration (n → ^{00}). With two sections of integration the waveform identified as a Gaussian approximation can be obtained, and this deteriorates the signal-to-noise ratio by about 22%. The ORTEC active filter network in the 570 provides a fourth waveform in Fig. 1.3; this waveform has characteristics superior to the Gaussian approximation, yet obtains them with four complex poles. By this method the output pulse shape has a good signal-to-noise ratio, is easy to measure, and yet requires only a practical amount of electronic circuitry to achieve the desired results.

2 SPECIFICATIONS

2.1 PERFORMANCE

GAIN RANGE Continuously adjustable from X1 through X1500.

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

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

NOISE <8 µV referred to the input (5 µV typical) using 2 µs shaping and gain $\geq$100.

TEMPERATURE INSTABILITY

Gain $\leq$0.0075%/°C, 0 to 50°C.
DC Level <±50 µV/°C, 0 to 50°C.

WALK $\leq$±3 ns for 50:1 dynamic range, including contribution of ORTEC 551 or 552 Constant-Fraction Timing Single-Channel Analyzer using 50% fraction and 0.5 µs shaping.

COUNT RATE STABILITY The 1.33 MeV gamma ray peak from a ^{60}Co source, positioned at 85% of analyzer range, typically shifts <0.024%, and its FWHM broadens <16% when its incoming count rate changes from 0 to 100,000 counts/s using 2 µs shaping and external pileup rejection. The amplifier will hold the baseline reference up to count rates in excess of 150,000 counts/s.

OVERLOAD RECOVERY Recovers to within 2% of rated output from X300 overload in 2.5 nonoverloaded unipolar pulse widths, using maximum gain; same recovery from X1000 overload for bipolar pulses.

2.2 CONTROLS

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

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

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

POS/NEG Locking toggle switch selects input circuit for either polarity of input pulses from the preamplifier.

SHAPING TIME Six-position switch selects time constant for active filter network pulse shaping; selections are 0.5, 1, 2, 3, 6, and 10 μs.

PZ ADJ Potentiometer to adjust pole-zero cancellation for decay times from 40 μs to ∞. Factory preset at 50 μs to match normal characteristics of ORTEC preamplifiers.

BLR Locking toggle switch selects a source for the gated baseline restorer discriminator threshold level from one of three positions.

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

PZ Adj The BLR threshold is determined by the threshold potentiometer. The BLR time constant is greatly increased to facilitate PZ adjustment. This position may give the lowest noise for conditions of <5000 counts per second and/or longer shaping times.

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

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

2.3 INPUT

INPUT Type BNC front panel connector accepts either positive or negative pulses with rise times in the range from 10 to 650 ns and decay times from 40 to 2000 µs; Z_{in} ~ 1000Ω, dc coupled; linear maximum 1 V (10 V with attenuator jumper set at X0.1); absolute maximum, 20 V.

2.4 OUTPUTS

UNI Unipolar front panel BNC with Z_o <1Ω. Short circuit proof; prompt, full scale linear range 0 to +10 V; active filter shaped and dc restored; dc level adjustable to ±100 mV.

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

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

2.5 ELECTRICAL AND MECHANICAL

POWER REQUIRED (not including any load on the Preamp Power connector)

+24 V, 80 mA; -24 V, 85 mA;
+12 V, 60 mA; -12 V, 30 mA.

FRONT PANEL DIMENSIONS NIM-standard single-width module (1.35 by 8.714 in.) per TID-20893 (Rev).

3 INSTALLATION

3.1 GENERAL

The 570 operates on power that must be furnished from a NIM-standard bin and power supply such as the ORTEC 401/402 Series. The bin and power supply is designed for relay rack mounting. If the equipment is to be rack mounted, be sure that there is adequate ventilation to prevent any localized heating of the components that are used in the 570. The temperature of equipment mounted in racks can easily exceed the maximum limit of 50°C unless precautions are taken.

3.2 CONNECTION TO POWER

The 570 contains no internal power supply and must obtain the necessary dc operating power from the bin and power supply in which it is installed for operation. Always turn off power for the power supply before inserting or removing any modules. After all modules have been installed in the bin and any preamplifiers have also been connected to the Preamp Power connectors on the amplifiers, check the dc voltage levels from the power supply to see that they are not overloaded. The ORTEC 401/402 Series Bins and Power Supplies have convenient test points on the power supply control panel to permit monitoring these dc levels. If any one or more of the dc levels indicates an overload, some of the modules will need to be moved to another bin to achieve operation.

3.3 CONNECTION TO PREAMPLIFIER

The preamplifier output signal is connected to the 570 through the Input BNC connector on the front panel. The input impedance is about 1000Ω and is dc-coupled to ground; therefore the preamplifier output must be either ac-coupled or have approximately zero dc voltage under no-signal conditions.

The 570 incorporates pole-zero cancellation in order to enhance the overload and count rate characteristics of the amplifier. This technique requires matching the network to the preamplifier decay-time constant in order to achieve perfect compensation. The pole-zero adjustment should be set each time the preamplifier or the shaping time constant of the amplifier is changed. For details of the pole-zero adjustment, see Section 4.6. An alternate method is accomplished easily by using a monoenergetic source and observing the amplifier baseline with an oscilloscope after each pulse under approximately X2 overload conditions. Adjustment should be made so that the pulse returns to the baseline in a minimum amount of time with no undershoot.

Preamplifier power at +24 V, -24 V, +12 V, and -12 V is available through the Preamp Power connector on the rear panel. When the preamplifier is connected, its power requirements are obtained from the same bin and power supply as is used for the amplifier and this increases the dc loading on each voltage level over and above the requirements for the 570 at the module position in the bin.

When the 570 is used with a remotely located preamplifier (i.e., preamplifier-to-amplifier connection through 25 ft or more of coaxial cable), be careful to ensure that the characteristic impedance of the transmission line from the preamplifier output to the 570 input is matched. Since the input impedance of the 570 is about 1000Ω, sending-end termination will normally be preferred; the transmission line should be series-terminated at the preamplifier output. All ORTEC preamplifiers contain series terminations that are either 93Ω or variable; coaxial cable type RG-62/U or RG-71/U is recommended.

3.4 CONNECTION OF TEST PULSE GENERATOR

THROUGH A PREAMPLIFIER The satisfactory connection of a test pulse generator such as the ORTEC 419 Precision Pulse Generator or equivalent depends primarily on two considerations; the preamplifier must be properly connected to the 570 as discussed in Section 3.3, and the proper input signal simulation must be applied to the preamplifier. To ensure proper input signal simulation, refer to the instruction manual for the particular preamplifier being used.

DIRECTLY INTO THE 570 Since the input of the 570 has 1000Ω of 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 570 input is dc coupled. The ORTEC test pulse generators are designed for direct connection. When any one of these units is used, it should be terminated with a 100Ω terminator at the amplifier input or be used with at least one of the output attenuators set at In. (The small error due to the finite input impedance of the amplifier can normally be neglected.)

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

3.5 SHAPING CONSIDERATIONS

The shaping time constant on the 570 is switch-selectable in steps of 0.5, 1, 2, 3, 6, and 10 µs. The choice of the proper shaping time constant is generally a compromise between operating at a shorter time constant for accommodation of high counting rates and operating with a longer time constant for a better signal-to-noise ratio. For scintillation counters, the energy resolution depends largely on the scintillator and photomultiplier, and therefore a shaping time constant of about four times the decay-time constant of the scintillator is a reasonable choice (for NaI, a 1-µs shaping time constant is about optimum). For gas proportional counters, the collection time is normally in the 0.5 to 5 µs range and a 2-µs or greater time constant selection will generally give optimum resolution. For surface barrier semiconductor detectors, a 0.5- to 2-µs resolving time will generally provide optimum resolution. Shaping time for Ge(Li) detectors will vary from 1 to 6 µs, depending on the size, configuration, and collection time of the specific detector and preamplifier. When a charge-sensitive preamplifier is used, the optimum shaping time constant to minimize the noise of a system can be determined by measuring the output noise of the system and dividing it by the system gain. Since the 570 has almost constant gain for all shaping modes, the optimum shaping can be determined by measuring the output noise of the 570 with a voltmeter as each shaping time constant is selected.

3.6 LINEAR OUTPUT CONNECTIONS AND TERMINATING CONSIDERATIONS

Since the 570 unipolar output is normally used for spectroscopy, the 570 is designed with a great amount of flexibility in order for the pulse to be interfaced with an analyzer. A gated baseline restorer (BLR) circuit is included in this output for improved performance at all count rates. A switch on the front panel permits the threshold for the restorer gate to be determined automatically, according to the input noise level, or manually, with a screwdriver adjustment. The switch also has a center PZ ADJ setting that can be used to eliminate the BLR effect when making pole-zero adjustments. The unipolar output dc level can be adjusted from −0.1 to +0.1 V to set the zero intercept on the analyzer when direct coupling is used.

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

To use shunt termination at the receiving end of the cable, connect the output on the 570 front panel through 93Ω cable to the input of the receiving instrument. Then use a BNC tee connector to attach both the interconnecting cable and a 100Ω terminator at the input connector of the receiving instrument. Since the input impedance of the receiving instrument is normally 1000Ω or more, the effective instrument input impedance with the 100Ω terminator will be of the order of 93Ω and this will match the cable impedance correctly.

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

3.7 SHORTING OR OVERLOADING THE AMPLIFIER OUTPUT

The 570 output is dc coupled with an output impedance of about 0.1Ω. If the output is shorted with a direct short circuit the output stage will limit the peak current of the output so that the amplifier will not be harmed. When the amplifier is terminated with 100Ω, the maximum rate allowed to maintain the linear output is

$$\frac{200\,000\text{ cps}}{\tau\ (\mu\text{S})} \times \frac{10}{V_0(\text{V})} .$$

3.8 BUSY OUTPUT CONNECTION

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

4 OPERATION

4.1 INITIAL TESTING AND OBSERVATION OF PULSE WAVEFORMS

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

4.2 FRONT PANEL CONTROLS

GAIN A Coarse Gain switch and a Gain 10-turn locking precision potentiometer select and precisely adjust the gain factor for the amplification in the 570. Switch settings are X20, 50, 100, 200, 500, and 1000. Continuous fine gain range is from X0.5 to X1.5, using markings of 500 through 1500 dial divisions. An internal jumper setting provides one additional gain factor selection of either X1.0 or X0.1. Collectively the range of gain can be set at any level from X1.0 through X1500, using all three of these controls.

POS/NEG A locking toggle switch selects an input circuit that accepts either polarity of pulses from the preamplifier.

PZ ADJ A screwdriver control to set the pole-zero cancellation to match the preamplifier pulse decay characteristics. The range is from 40 µs to ^{00}.

DC ADJ A screwdriver control adjusts the dc baseline level of the unipolar output in the range of -0.1 V to +0.1 V.

SHAPING A 6-position switch selects equal integrate and differentiate time constants to shape the input pulses. Settings are 0.5, 1, 2, 3, 6, and 10 µs.

BLR A 3-position locking toggle switch controls the operation of the internal baseline restorer (BLR) circuit.

The center setting of the switch is effectively Off, and this permits adjustment of the PZ ADJ control without interference from the BLR circuit. The Auto setting of the switch selects a circuit that regulates the threshold of the BLR gate according to the output noise level. The Threshold setting permits manual control of the BLR gate threshold, using the screwdriver control immediately below the toggle switch.

4.3 FRONT PANEL CONNECTORS

INPUT Accepts input pulses to be shaped and/or amplified by the 570. Compatible characteristics; positive or negative with rise time from 10 to 650 ns; decay time greater than 40 µs for proper pole-zero cancellation; input linear amplitude range 0 to 10 V, with a maximum limit of ±20 V. Input impedance is approximately 1000Ω.

UNIPOLAR OUTPUT Provides a unipolar positive output with characteristics that are related to input peak amplitude, gain, shaping time constants, pole-zero cancellation, and baseline stabilization. The dc baseline level is adjustable for offset to ±0.1 V. Output impedance through this connector is about 0.1Ω, dc coupled. Linear range 0 to +10 V.

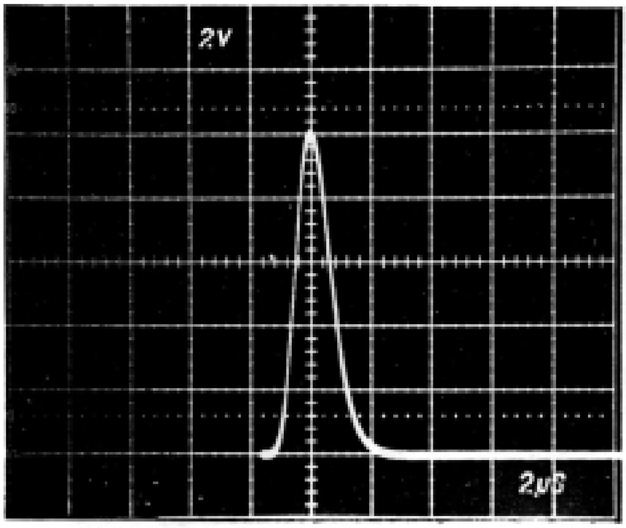
4.4 REAR PANEL CONNECTORS

BUSY Provides a signal that rises to approximately +5 V for the time that the input pulse amplitude exceeds the BLR discriminator level, which can be controlled manually or automatically. The output can be used to correct for dead time in the ORTEC MCA by connecting it to the MCA Busy input.

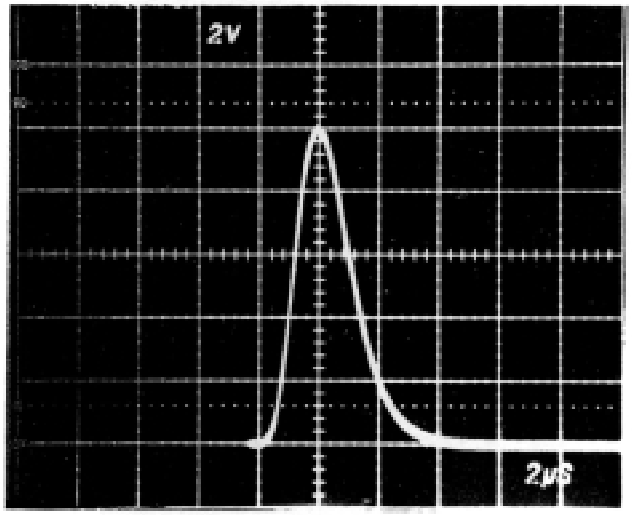
PREAMP Provides power connections from the bin and power supply to the ORTEC preamplifier. The dc levels include +24 V, -24 V, +12 V, and -12 V.

4.5 STANDARD SETUP PROCEDURE

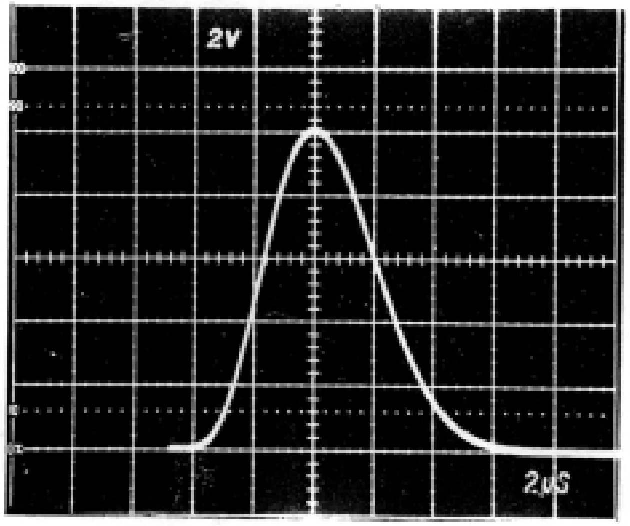
a. Connect the detector, preamplifier, high voltage power supply, and amplifier into a basic system and connect the amplifier output to an oscilloscope. Connect the preamplifier power cable to the Preamp connector on the 570 rear panel. Turn on power in the bin and power supply and allow the electronics of the system to warm up and stabilize.



Shaping Time 0.5 µs



Shaping Time 1 µs



Shaping Time 2 µs

Fig. 4.1. Typical Effects of Shaping-Time Selection on Output Waveforms.

b. Set the 570 controls initially as follows:

Shaping	2 µs
Coarse Gain	50
Gain	1.000
Internal Jumper	X1.0 (factory installed position)
BLR	PZ ADJ
Thresh	Fully clockwise
Pos/Neg	Match input pulse polarity

c. Use a ^{60}CO calibration source; place it about 25 cm from the active face of the detector. The unipolar output pulse from the 570 should be about 8 to 10 V, using a preamplifier with a conversion gain of 170 mV/MeV.

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

4.6 POLE-ZERO ADJUSTMENT

The pole-zero adjustment is extremely critical for good performance at high count rates. This adjustment should be checked carefully for the best possible results.

USING A GERMANIUM SYSTEM AND ^{60}CO

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

b. Observe the unipolar output with an oscilloscope. Adjust the PZ ADJ control so that the trailing edge of the pulses returns to the baseline without overshoot or undershoot (see Fig. 4.2).

The oscilloscope used must be dc coupled and must not contribute distortion in the observed waveforms. Oscilloscopes such as Tektronix 453, 454, 465, and 475 will overload for a 10-V signal when the vertical sensitivity is less than 100 mV/cm. To prevent overloading the oscillbscope, use the clamp circuit shown in Fig. 4.3.

USING SQUARE WAVE THROUGH PREAMPLIFIER TEST INPUT

A more precise pole-zero adjustment in the 570 can be obtained by using a square wave signal as the input to the preamplifier. Many oscilloscopes include a calibration output on the front panel and this is a good source of square wave signals at a frequency of about 1 kHz. The amplifier differentiates the signal from the preamplifier so that it generates output signals of alternate polarities on the leading and trailing edges of the square wave input signal, and these can be

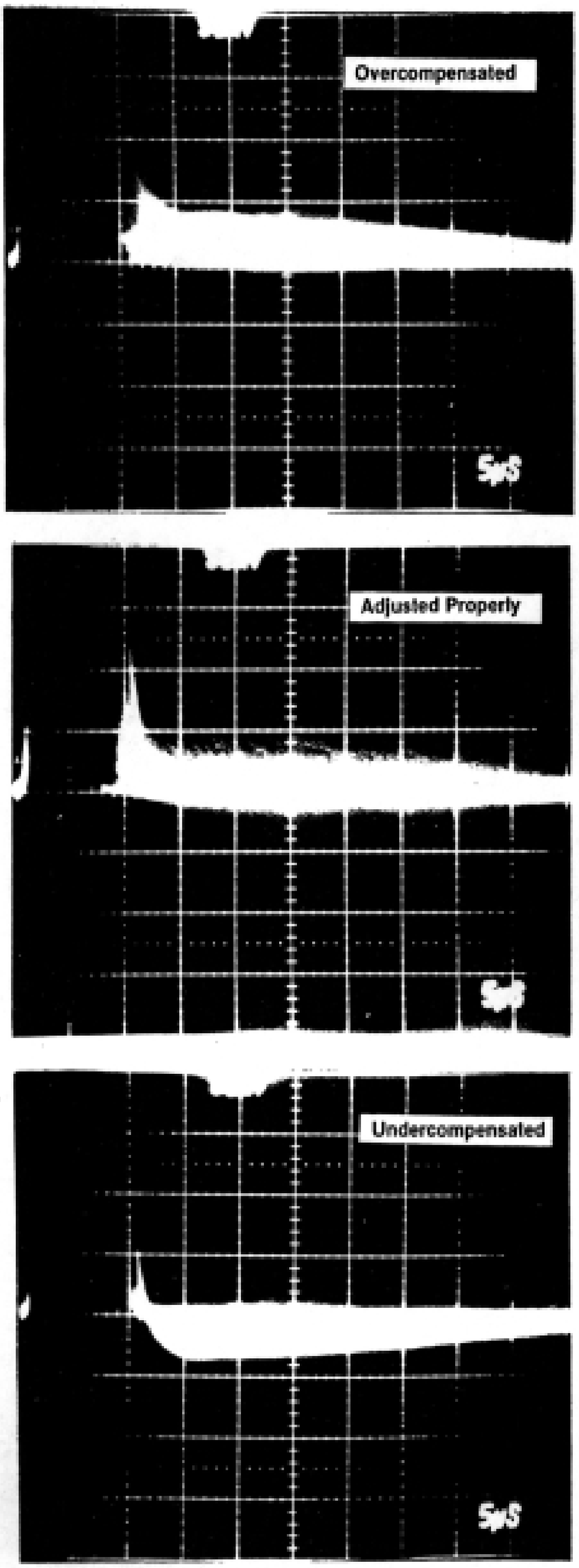


Fig. 4.2. Typical Waveforms Illustrating Pole-Zero Adjustment Effects; Oscilloscope Trigger, 570 Busy Output; ^{60}Co Source with 1.33-MeV Peak Adjusted ~9 V; Count Rate, 3 kHz; Shaping Time Constant, 2 µs.

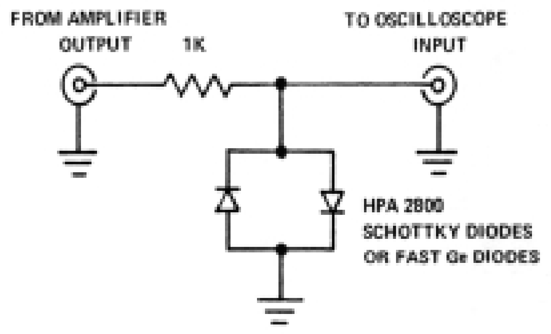


Fig. 4.3. A Clamp Circuit that can be used to Prevent Overloading the Oscilloscope Input.

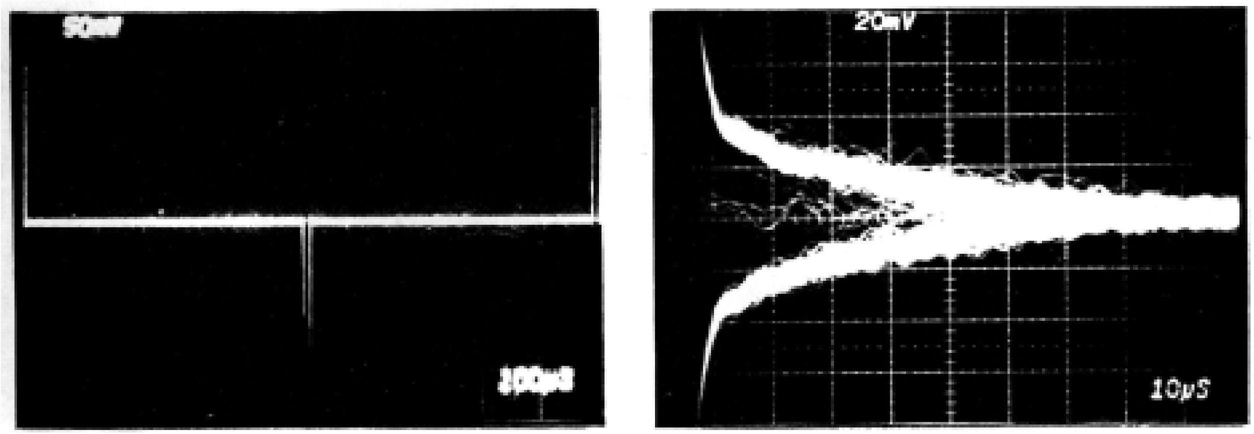
compared as shown in Fig. 4.4 to achieve excellent pole-zero cancellation. Use the following procedure:

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

b. Set the 570 controls as for normal operation; this includes gain, shaping, and input polarity.

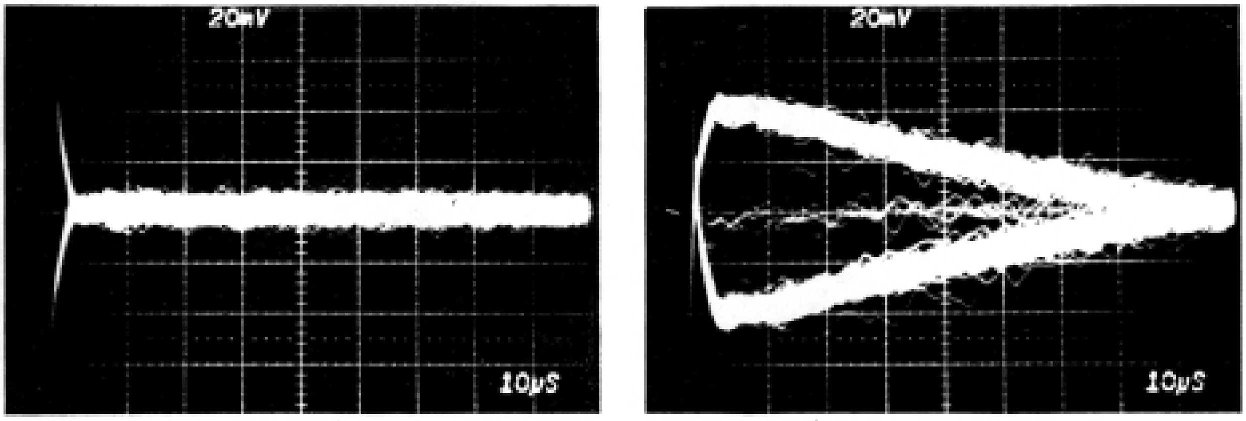
c. Connect the source of 1-kHz square waves through an attenuator to the Test input of the preamplifier. Adjust the attenuator so that the 570 output amplitude is about 9 V.d. Observe the Unipolar output of the 570 with an oscilloscope, triggered from the 570 Busy output. Adjust the PZ ADJ control for proper response according to Fig. 4.4. Use the clamp circuit or Fig. 4.3 to prevent overloading the oscilloscope input.

Figure 4.4A. shows the amplifier output as a series of alternate positive and negative Gaussian pulses. In the other three pictures of this figure, the oscilloscope was triggered to show both positive and negative pulses simultaneously. These pictures show more detail to aid in proper adjustment.



A. PZ Properly Adjusted; Slow Trigger to Separate Pulses.

B. Overcompensated; Fast Trigger to Superimpose Pulses.



C. Properly Adjusted; Pulses Superimposed.

D. Undercompensated; Pulses Superimposed.

Fig. 4.4. Pole-Zero Adjustment Using a Square Wave Input to the Preamplifier.

4.7 BLR THRESHOLD ADJUSTMENT

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

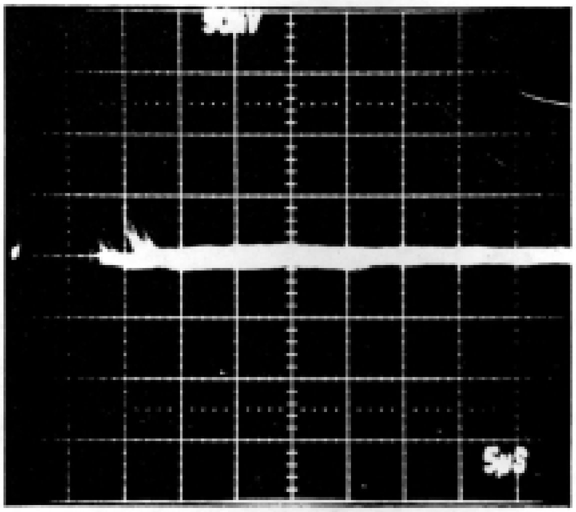
a. Remove all radioactive sources from the vicinity of the detector. Set up the system as for normal operation, including detector bias.

b. Set the BLR switch at Threshold and turn the control fully clockwise, for 300 mV.

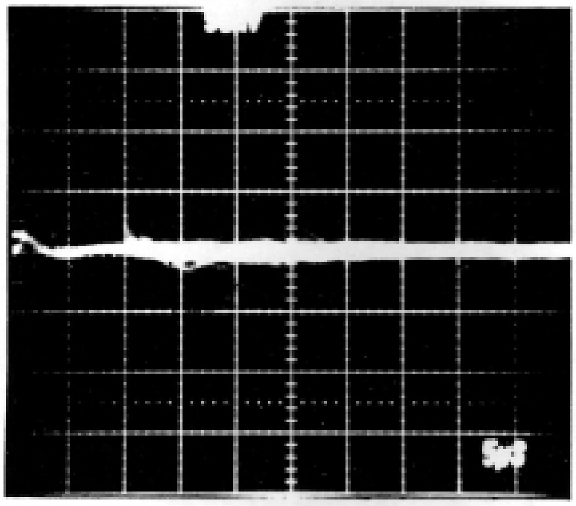
c. Observe the unipolar output on the 100 mV/cm scale of the oscilloscope, using 5 μs/cm horizontal deflection. Trigger the oscilloscope with the Busy output from the 570.

d. Reduce the control setting until the baseline discriminator begins to trigger on noise; this corresponds to about 200 counts/s from the Busy output. Adjust the trigger level according to the information in Fig. 4.5.

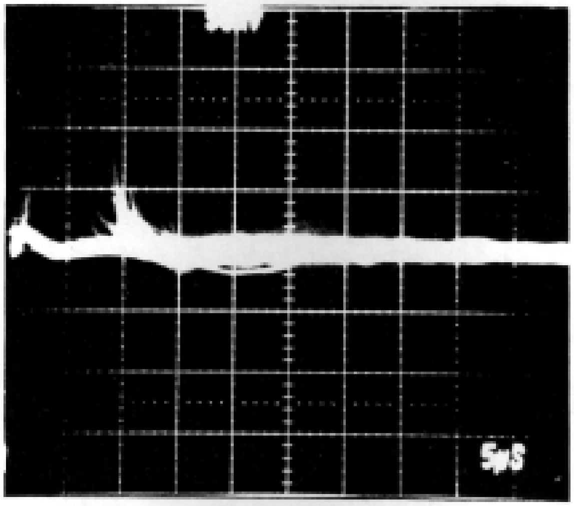
If a ratemeter or counter-timer is available, it can be connected to the Busy output and the threshold level can then be adjusted for about 200 counts/s.



A. Set Too High



B. Adjusted Properly



C. Set Too Low

Fig. 4.5. BLR Threshold Variable Control Settings.

4.8 OPERATION WITH SEMICONDUCTOR DETECTORS

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

a. Connect the detector to be used to the spectrometer system; i.e., preamplifier, main amplifier, and biased amplifier.

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

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

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

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

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

AMPLIFIER NOISE AND RESOLUTION MEASUREMENTS As shown in Fig. 4.6, a preamplifier, amplifier, pulse generator, oscilloscope, and wide-band rms voltmeter such as the Hewlett-Packard 3400A are required for this measurement. Connect a suitable capacitor to the input to simulate the detector capacitance desired. To obtain the resolution spread due to amplifier noise:

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

b. Turn on the 419 Precision Pulse Generator and adjust the pulser output to any convenient readable voltage, E_o, as determined by the oscilloscope. The full width at half maximum (FWHM) resolution spread due to amplifier noise is then

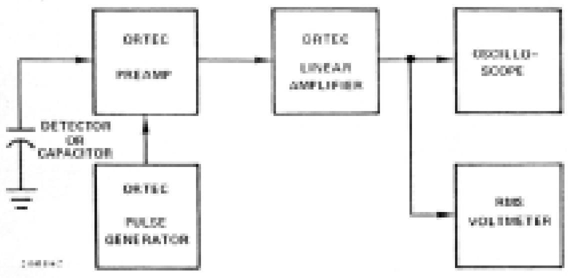


Fig. 4.6. System for Measuring Amplifier and Detector Noise Resolution.

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

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

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

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

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

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

The detector noise tends to increase with bias voltage, but the detector capacitance decreases, thus reducing the resolution spread. The overall resolution spread will depend upon which effect is dominant. Figure 4.7 shows curves of typical noise-resolution spread versus bias voltage, using data from several ORTEC silicon surface barrier semiconductor radiation detectors.

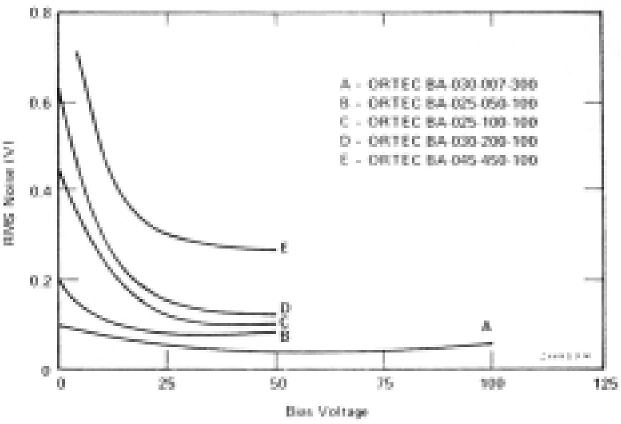


Fig. 4.7. Noise as a Function of Bias Voltage.

AMPLIFIER NOISE-RESOLUTION MEASUREMENTS USING MCA Probably the most convenient method of making resolution measurements is with a pulse height analyzer as shown by the setup illustrated in Fig. 4.8.

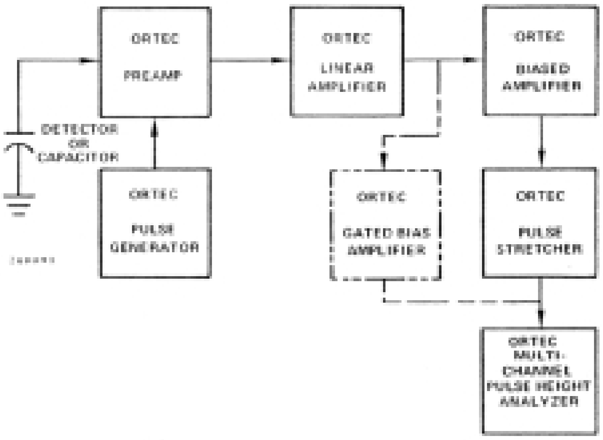


Fig. 4.8. System for Measuring Resolution with a Pulse Height Analyzer.

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

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

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

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

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

CURRENT-VOLTAGE MEASUREMENTS FOR Si AND Ge DETECTORS The amplifier system is not directly involved in semiconductor detector current-voltage measurements, but the amplifier serves to permit noise monitoring during the setup. The detector noise measurement is a more sensitive method than a current measurement 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 4.9 shows the setup required for current-voltage measurements. An ORTEC 428 Bias Supply is used as the voltage source. Bias voltage should be applied slowly and reduced when noise increases rapidly as a function of applied bias. Figure 4.10 shows several typical current voltage curves for ORTEC silicon surface-barrier detectors.

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

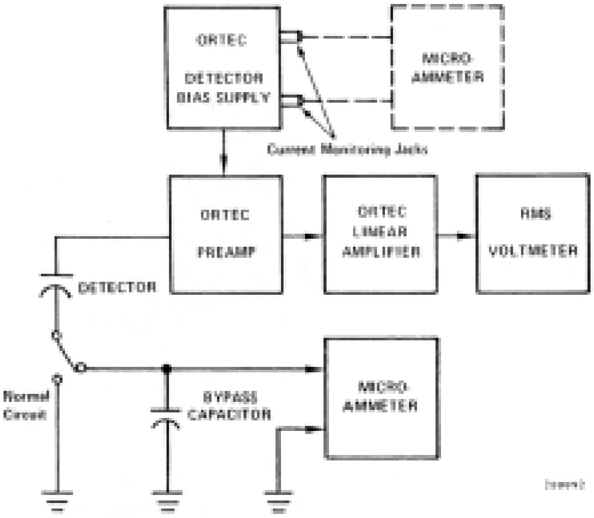


Fig. 4.9. System for Detector Current and Voltage Measurements.

Fig. 4.9 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.

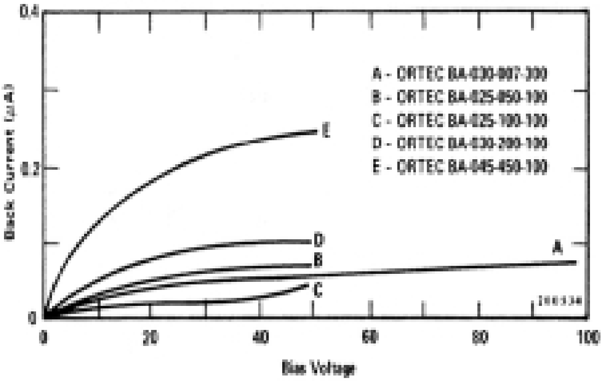


Fig. 4.10. Silicon Detector Back Current vs Bias Voltage.

4.9 OPERATION IN SPECTROSCOPY SYSTEMS

HIGH-RESOLUTION ALPHA-PARTICLE SPECTROSCOPY SYSTEM The block diagram of a high-resolution spectroscopy system for measuring natural alpha particle radiation is shown in Fig. 4.11. Since natural alpha radiation occurs only above several MeV, an ORTEC 444 Biased Amplifier is used to suppress the unused portion of the spectrum; the same result can be obtained by using digital suppression on the MCA in many cases. Alphaparticle resolution is obtained in the following manner:

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

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

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

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

HIGH-RESOLUTION GAMMA SPECTROSCOPY SYSTEM A high-resolution gamma spectroscopy system block diagram is shown in Fig. 4.12. Although a biased amplifier is not shown (an analyzer with more channels being preferred), it can be used if the only analyzer available has fewer channels and only higher energies are of interest.

When germanium detectors that are cooled by a liquid nitrogen cryostat are used, it is possible to obtain 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 guidelines for obtaining optimum resolution are:

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

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

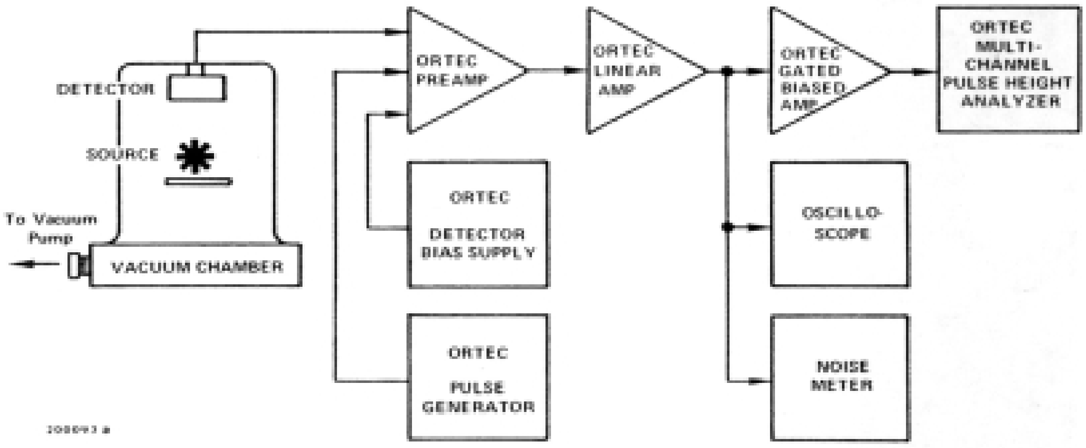


Fig. 4.11. System for High-Resolution Alpha-Particle Spectroscopy.

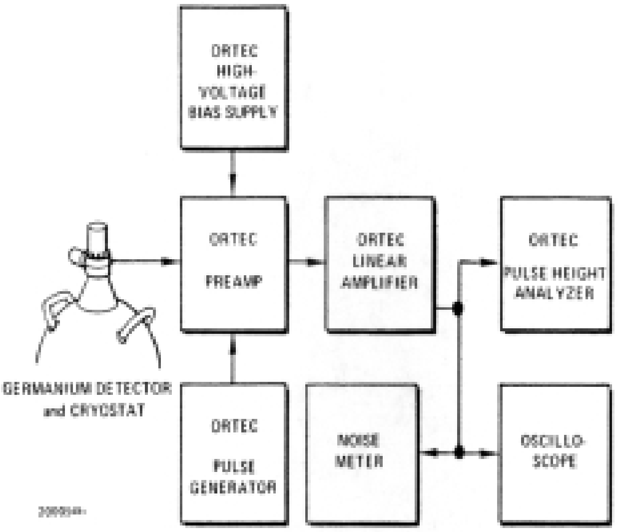


Fig. 4.12. System for High-Resolution Gamma Spectroscopy.

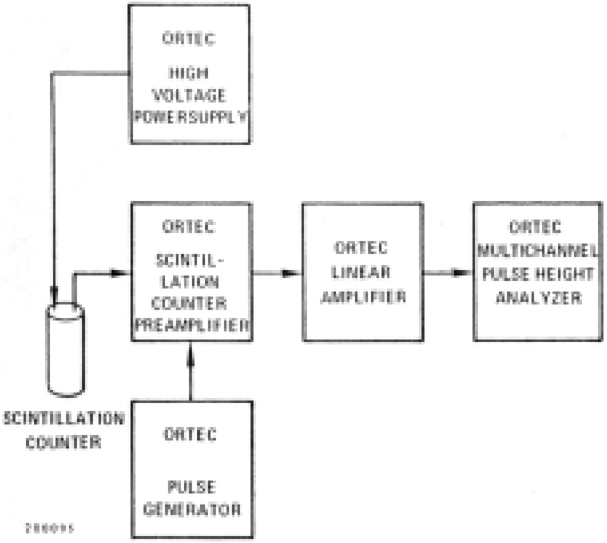


Fig. 4.13. Scintillation-Counter Gamma Spectroscopy System.

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

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

SCINTILLATION-COUNTER GAMMA SPECTROSCOPY SYSTEMS The ORTEC 570 can be used in scintillation-counter spectroscopy systems as shown in Fig. 4.13. The amplifier shaping time constants should be selected in the region of 0.5 to 1 µs for NaI or plastic scintillators.

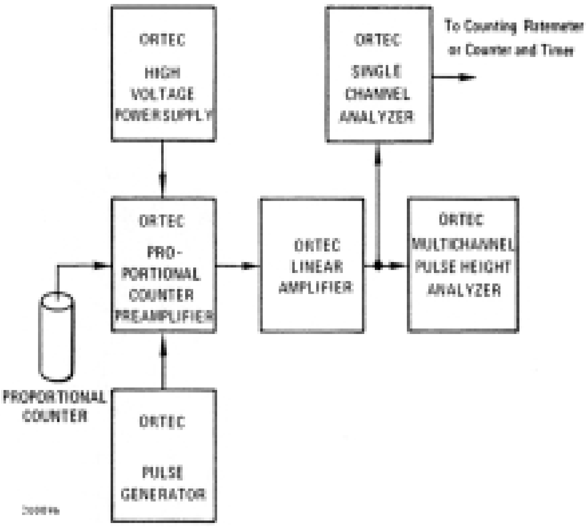


Fig. 4.14. High-Resolution X-Ray Energy Analysis System Using a Proportional Counter.

For scintillators having longer decay times, longer time constants should be selected.

X-RAY SPECTROSCOPY USING PROPORTIONAL COUNTERS Space charge effects in proportional counters, operated at high gas amplification, tend to degrade the resolution capabilities drastically at x-ray energies, even at relatively low counting rates. By using a high-gain low-noise amplifying system and lower gas amplification, these effects can be reduced and a considerable improvement in resolution can be obtained.

The block diagram in Fig. 4.14 shows a system of this type. Analysis can be accomplished by simultaneous acquisition of all data on a multichannel analyzer or counting a region of interest in a single-channel analyzer window with a counter and timer or counting ratemeter.

4.10 OTHER EXPERIMENTS

Block diagrams illustrating how the 570 and other ORTEC modules can be used for experimental setups for various other applications are shown in Figs. 4.15, 4.16, and 4.17.

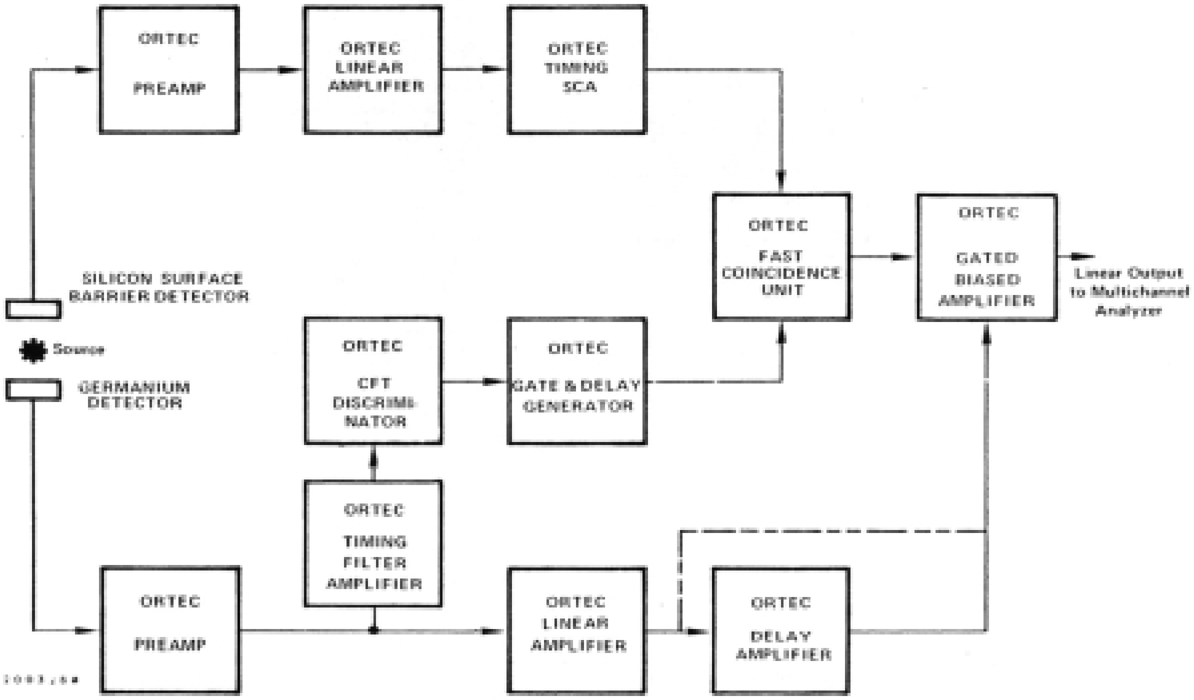


Fig. 4.15. Gamma-Ray Charged-Particle Coincidence Experiment.

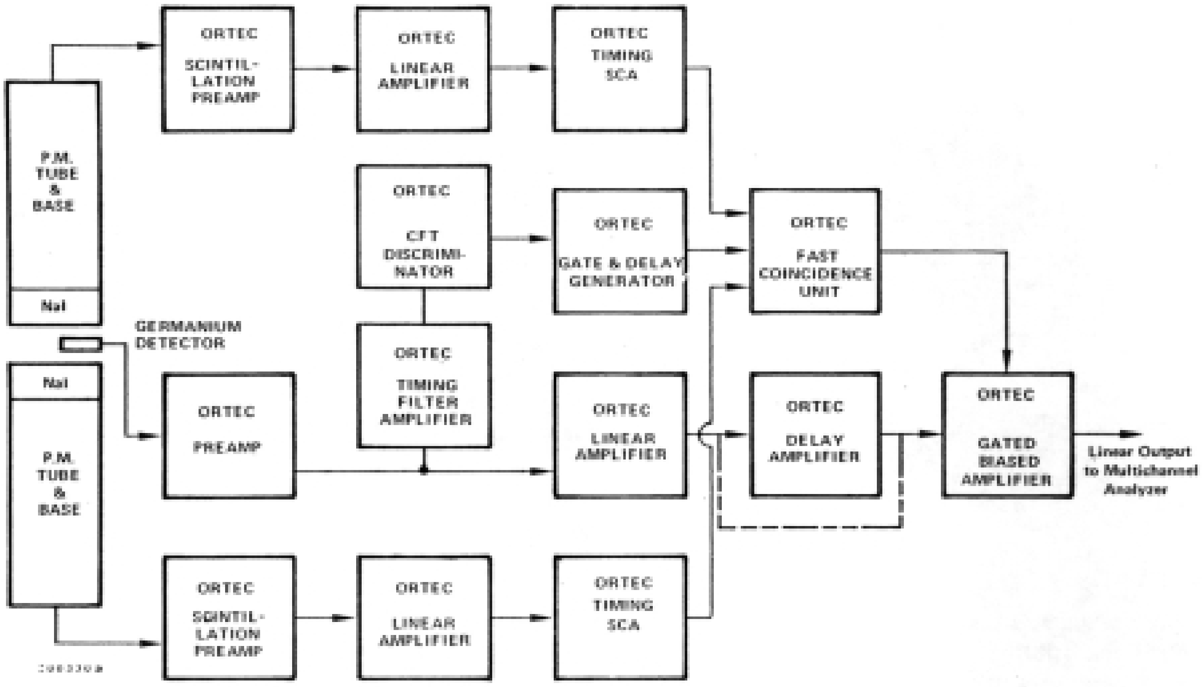


Fig. 4.16. Gamma-Ray Pair Spectrometry.

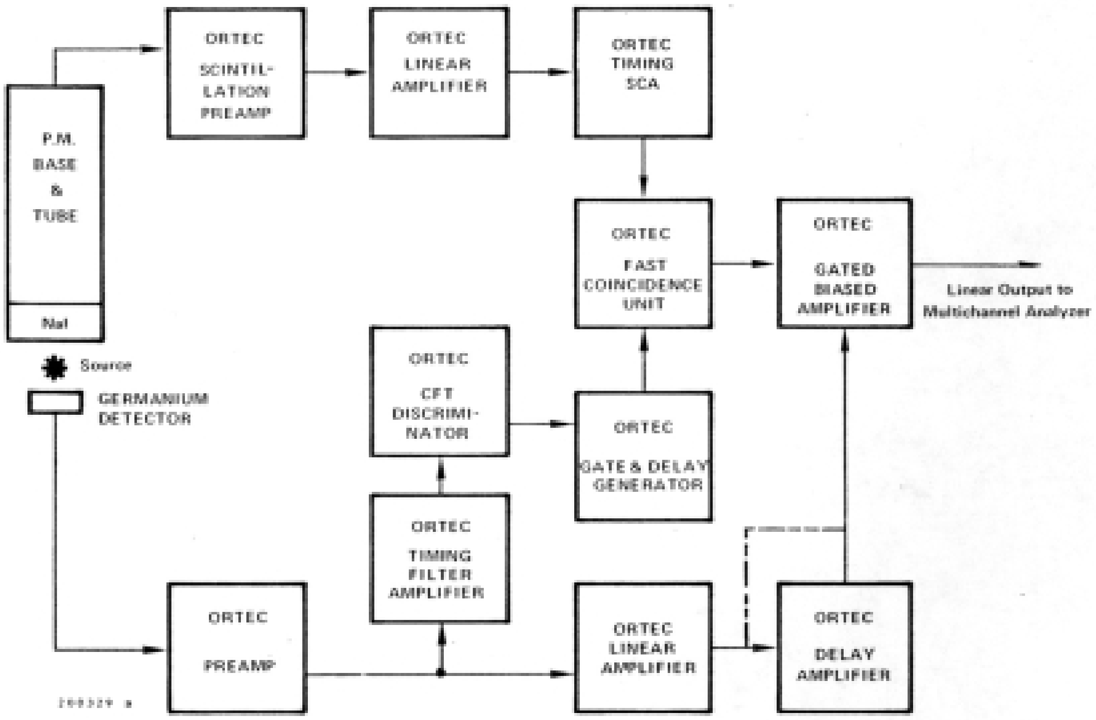


Fig. 4.17. Gamma-Gamma Coincidence Experiment.

5 MAINTENANCE

5.1 TEST EQUIPMENT REQUIRED

The following test equipment should be utilized to adequately test the specifications of the 570 Spectroscopy Amplifier:

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

2. Tektronix 547 Series Oscilloscope with a type 1A1 plug-in or equivalent.

3. Hewlett-Packard 3400A rms Voltmeter.

5.2 PULSER TEST*

FUNCTIONAL CHECKS Set the 570 controls as follows:

Coarse Gain	1K
Gain	1.5
Input Polarity	Positive
Shaping Time Constant	1 µs
BLR	PZ ADJ
Variable control	Fully CW for 300 mV

a. Connect a positive pulser output to the 570 Input and adjust the pulser to obtain +10 V at the 570 output. This should require an input pulse of 6.6 mV, using a 100Ω terminator at the input.

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

c. Vary the DC ADJ control on the front panel while monitoring the Unipolar output. Ensure that the baseline can be adjusted through a range of +0.1 to -0.1 V. Readjust the control for zero.

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

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

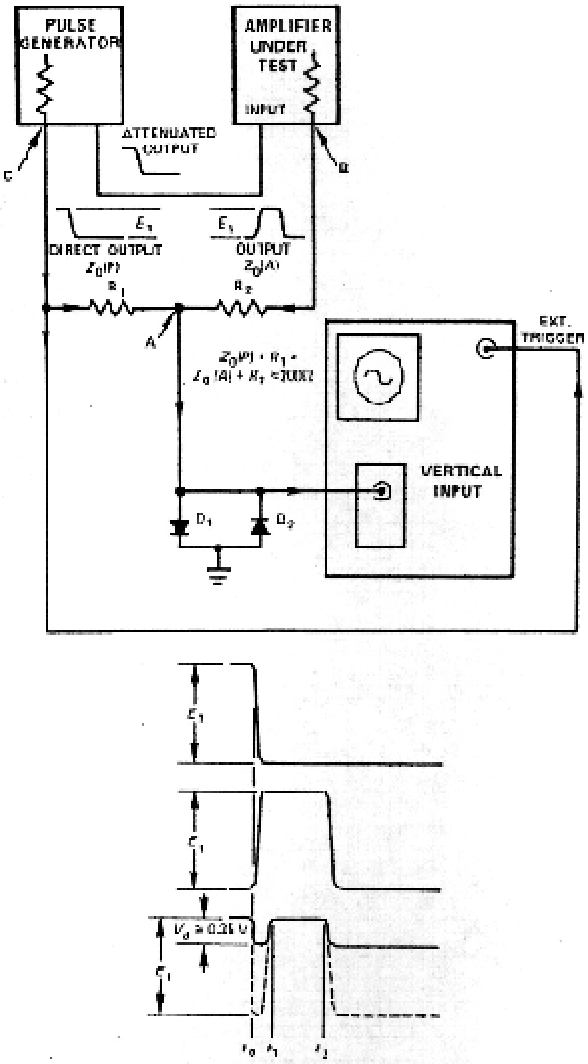


Fig. 5.1. **Circuit Used to Measure Nonlinearity.**

f. With the Shaping switch set for 1 µs, measure the time to the peak on the unipolar output pulse; this should be 2.2 µs, for 2.2 τ . Measure the time to baseline crossover of the bipolar output; this should be 2.8 µs for 2.8 τ .

g. Change the Shaping switch to 0.5 through 10 µs in turn. At each setting, check to see that the time to the unipolar peak is 2.2 τ Return the switch to 1 µs.

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

LINEARITY The integral nonlinearity of the 570 can be measured by the technique shown in Fig. 5.1. In effect, the negative pulser output is subtracted from the positive amplifier output to cause a null point that can be measured with excellent sensitivity. The pulser output must be varied between 0 and 10 V, which usually requires an external control source for the pulser. The amplifier gain and the pulser attenuator must be adjusted to measure 0 V at the null point when the pulser output is 10 V. The variation in the null point as the pulser is reduced gradually from 10 V to 0 V is a measure of the nonlinearity. Since the subtraction network also acts as a voltage divider, this variation must be less than (10 V full scale) x (±0.05% maximum nonlinearity) x (1/2 for divider network) =±2.5 V for the maximum null-point variation.

OUTPUT LOADING Use the test setup of Fig. 5.1. Adjust the amplifier output to 10 V and observe the null point when the front panel output is terminated in 100Ω. The change should be less than 5 Mv.

NOISE Measure the noise at the amplifier Unipolar output with maximum amplifier gain and 2 µs shaping time. Using a true-rms voltmeter, the noise should be less than 5 µV x 1500 (gain), or 7.5 mV. For an average responding voltmeter, the noise reading would have to be multiplied by 1.13 to calculate the rms noise. The input must be terminated in 100 Ω during the noise measurements.

5.3 SUGGESTIONS FOR TROUBLESHOOTING

In situations where the 570 is suspected of a malfunction, it is essential to verify such malfunction in terms of simple pulse generator impulses at the input. The 570 must be disconnected from its position in any system, and routine diagnostic analysis performed with a test pulse generator and an oscilloscope. It is imperative that testing not be performed with a source and detector until the amplifier performs satisfactorily with the test pulse generator.

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

5.4 FACTORY REPAIR

This instrument can be returned to the ORTEC factory for service and repair at a nominal cost. Our standard procedure for repair ensures the same quality control and checkout that are used for a new instrument. Always contact Customer Services at ORTEC, (865) 482-4411, before sending in an instrument for repair to obtain shipping instructions and so that the required Return Authorization Number can be assigned to the unit. This number should be marked on the address label and on the package to ensure prompt attention when the unit reaches the factory.

5.5 TABULATED TEST POINT VOLTAGES

The voltages given in Table 5.1 are intended to indicate typical dc levels that can be measured on the printed circuit board. In some cases the circuit will perform satisfactorily even though, due to component tolerances, there may be some voltage measurements that differ slightly from the listed values. Therefore the tabulated values should not be interpreted as absolute voltages but are intended to serve as an aid in troubleshooting.

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

Location	Voltage
TP1	±10 mV
TP2	±30 m V
TP3	±20 mV
TP4	±20 mV
TP5	±30 mV
TP6	0 to +3.3 V
TP7	±6 m V
Q15E	-15 V ±0.8 V
Q16E	+15 V ±0.8 V
IC13 pin 2	+5 V ±0.3 V

Table 5.1. Typical dc Voltages

BIN/MODULE CONNECTOR PIN ASSIGNMENTS FOR STANDARD NUCLEAR INSTRUMENT MODULES PER DOE/ER-0457T

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	117 volts ac (Hot)
12	Reserved Bus	*34	Power Return Ground
13	Spare	35	Reset (Scaler)
14	Spare	36	Gate
15	Reserved	37	Reset (Auxiliary
*16	+12 volts	38	Coaxial
*17	-12 volts	39	Coaxial
18	Spare Bus	40	Coaxial
19	Reserved Bus	*41	117 volts ac (Neut.)
20	Spare	*42	High Quality Ground
21	Spare	G	Ground Guide Pin
22	Reserved		

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