Model 590A
Amplifier and Single-Channel Analyzer
Operating and Service Manual

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Manual Revision F

Advanced Measurement Technology, Inc.
a/k/a/ ORTEC®, a subsidiary of AMETEK®, Inc.

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If it becomes necessary to return this instrument for repair, it is essential that Customer Services be contacted in advance of its return so that a Return Authorization Number can be assigned to the unit. Also, ORTEC must be informed, either in writing, by telephone [(865) 482-4411] or by facsimile transmission [(865) 483-2133], of the nature of the fault of the instrument being returned and of the model, serial, and revision ("Rev" on rear panel) numbers. Failure to do so may cause unnecessary delays in getting the unit repaired. The ORTEC 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 designated ORTEC repair center. The address label and the package should include the Return Authorization Number assigned. Instruments being returned that are 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 should follow the same procedure and ORTEC will provide a quotation.

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 assistance can be provided in making damage claims and in providing replacement equipment, if necessary.

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CONTENTS

SAFETY INSTRUCTIONS AND SYMBOLS

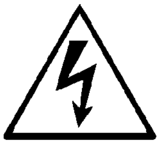
This manual contains up to three levels of safety instructions that must be observed in order to avoid personal injury and/or damage to equipment or other property. These are:

DANGER	Indicates a hazard that could result in death or serious bodily harm if the safety instruction is not observed.
WARNING	Indicates a hazard that could result in bodily harm if the safety instruction is not observed.
CAUTION	Indicates a hazard that could result in property damage if the safety instruction is not observed.

Please read all safety instructions carefully and make sure you understand them fully before attempting to use this product.

In addition, the following symbol may appear on the product:

ATTENTION–Refer to Manual



DANGER–High Voltage

Please read all safety instructions carefully and make sure you understand them fully before attempting to use this product.

SAFETY WARNINGS AND CLEANING INSTRUCTIONS

DANGER	Opening the cover of this instrument is likely to expose dangerous voltages. Disconnect the instrument from all voltage sources while it is being opened.

WARNING	Using this instrument in a manner not specified by the manufacturer may impair the protection provided by the instrument.

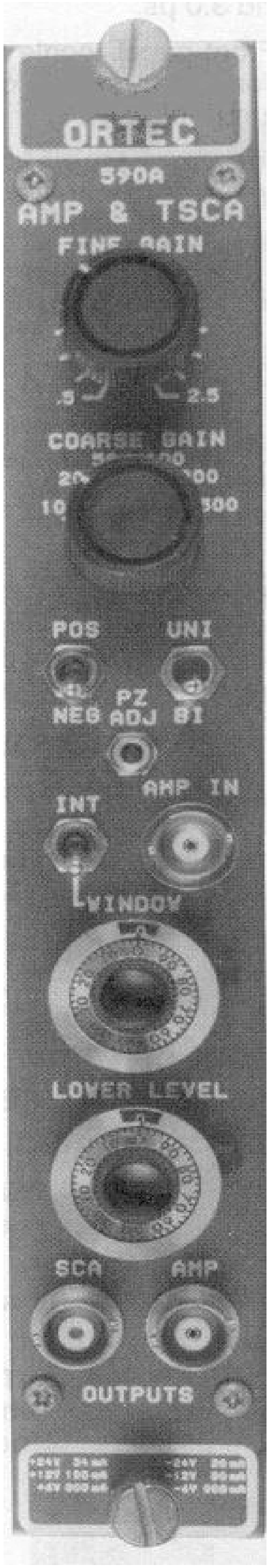
Cleaning Instructions

To clean the instrument exterior:

- Unplug the instrument from the ac power supply.
- Remove loose dust on the outside of the instrument with a lint-free cloth.
- Remove remaining dirt with a lint-free cloth dampened in a general-purpose detergent and water solution. Do not use abrasive cleaners.

CAUTION	To prevent moisture inside of the instrument during external cleaning, use only enough liquid to dampen the cloth or applicator.

- Allow the instrument to dry completely before reconnecting it to the power source.


ORTEC
590A
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FINE GAIN
.5
2.5
COARSE GAIN
50
100
20
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10
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POS
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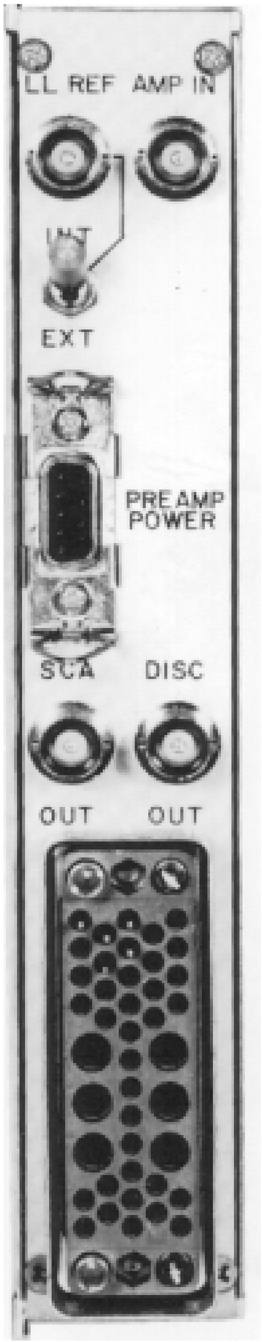
OUTPUTS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ORTEC MODEL 590A
AMPLIFIER AND TIMING
SINGLE-CHANNEL ANALYZER

1. DESCRIPTION

1.1. GENERAL

The ORTEC 590A Amplifier and Timing Single-Channel Analyzer is a standard single-width NIM that conforms to the specifications in TID-20893 (Rev). It includes both a low-noise shaping amplifier and a timing single-channel analyzer.

The amplifier is for use with various types of radiation detectors and preamplifiers. It is particularly suited for use with proportional counters and scintillation detectors normally used in x-ray and nuclear spectroscopy, as well as in x-ray diffraction and Mossbauer experiments. The high gain that can be obtained permits proportional counters to be operated with lower potentials for improved gain vs count rate stability. The short resolving time of the amplifier provides a high counting rate capability without sacrifice in the excellent resolution of proportional counters.

The amplifier has a single output that can be switch-selected for either unipolar or bipolar pulse shape. The unipolar output is used for spectroscopy in systems where dc-coupling can be maintained from the Model 590A to the analyzer. A BLR (baseline restorer) circuit is included in the amplifier for improved performance at all count rates. Baseline correction is applied only during intervals between input pulses and automatically selects a discriminator level to identify input pulses. The unipolar output dc level is within the range of -5 mV to +5 mV. This output permits the use of the direct-coupled input of the analyzer.

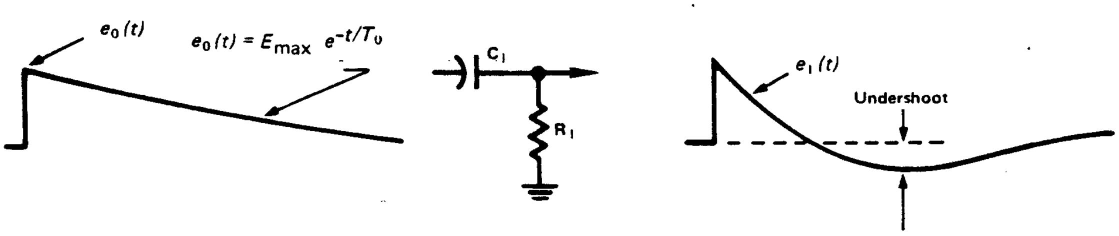
The timing single-channel analyzer, (TSCA), is dc-coupled to maintain the peak in an adjusted window without shifts due to changes of count rates. This permits stable operation with narrow window widths, with wide variations of count rates that are usually present during x-ray diffraction studies. The lower level can be adjusted with a front-panel control or it can be furnished by an external voltage. Whenever the sum of the adjusted lower level and window is greater than 10 V, the TSCA operates as an integral discriminator to generate an output if the amplified input exceeds the lower level. An internal jumper permits selection of a range for the front-panel Window control of either 0 to 10 V or 0 to 1 V.

The TSCA output signal occurs just after the peak of the input signal from the amplifier, and its very small time shift with changes of input peak amplitude makes the Model 590A ideal for use in slow coincidence or gating applications.

1.2. AMPLIFIER

The 590A has an input impedance of approximately 1000 Ω and accepts either positive or negative input pulses with rise times <650 ns and fall times >30 μs. Three integration and differentiation time constants are switch-selectable on the printed wiring board (PWB) 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 >30 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.

Complete provisions including power distribution for operating any ORTEC solid-state preamplifier are provided. 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 30 μs for 1000 Ω. 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 0.2 Ω, and the output can be connected to other equipment by a single cable going to all the equipment. The cable must be shunt-terminated at the far end. See Section 3 for further information.



Charge loop output X **First differentiation network** = **Differentiated pulse with undershoot**

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

$$E_{\max} \frac{1}{s + \frac{1}{T_0}} \times \frac{s}{s + \frac{1}{R_1 C_1}} = E_1(s) \text{ (Laplace transform).}$$

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

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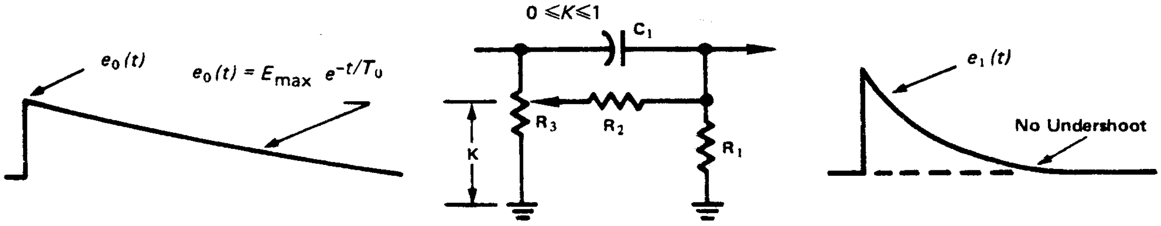
Fig. 1.1. Differentiation in an Amplifier Without Pole-Zero Cancellation.



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

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

$$E_{\max} \frac{1}{s + \frac{1}{T_0}} \times \frac{s + \frac{K}{R_2 C_1}}{s + \frac{R_1 + R_2}{R_1 R_2 C_1}} = E_1(s), \text{ (Laplace transform).}$$

Pole zero cancel by letting

$$s + \frac{1}{T_0} = s + \frac{K}{R_2 C_1}\,.$$

or

$$\frac{E_{\max}}{s + \frac{R_1 + R_2}{R_1 R_2 C_1}} = \frac{E_{\max}}{s + \frac{1}{R_p C_1}} = E_1(s), \text{ where } R_p = \frac{R_1 R_2}{R_1 + R_2}\,.$$

$$E_{\max}\, e^{-t/R_p C_1} = e_1(t)\,.$$

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

1.3. POLE-ZERO CANCELLATION

Pole-zero cancellation is a method for eliminating pulse undershoot after the first 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:

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

For a 1-µs differentiation on time and a 50-µs preamplifier 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 providing pole-zero cancellation.

Pole-zero cancellation is accomplished by the network shown in Fig. 1.2. The pole $[s + (1/T_o)]$ due to the preamplifier pulse decay time is canceled by the zero of the network $[s + (K/R_2C_1)]$. In effect, the 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 30-µs or greater decay times. 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 under-compensation (undershoot is not eliminated) or an over-compensation (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 on the front panel and can easily be adjusted by observing the baseline with 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.

1.4. 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

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

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

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 circuitry and 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 ($n \to \infty$). 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 590A provides a fourth waveform (Fig. 1.3). This waveform has characteristics superior to the n = 2 Gaussian approximation, yet obtains them with two complex poles and a real pole. 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. The signal to noise ratio is degraded by about 17%.

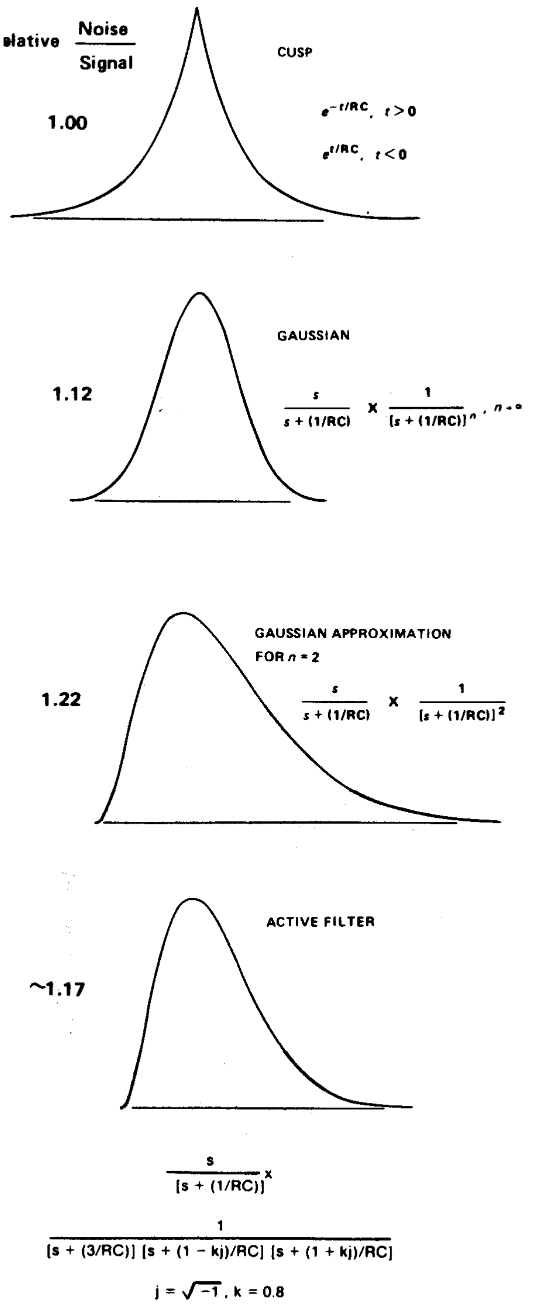


Fig. 1.3. Pulse Shapes for Good Signal-to-Noise Ratios.

1.5. TIMING SINGLE-CHANNEL ANALYZER

The amplifier output connects internally as the TSCA input. The TSCA operates in a window mode: the peak amplitude of the amplified signal must exceed the adjusted lower level by no more than the adjusted window width to generate an output pulse.

The lower level bias is switch-selectable between the (int) adjustment of the front panel 10-turn Lower Level control and the (Ext) signal that can be furnished through the EXT LLD connector on the rear panel. The switch that selects the effective source is mounted on the rear panel. The basic range of the window, using internal control, is 0 to 10 V where 0 V is equal to the adjusted lower level. By using a jumper on the printed circuit, the effective window range can be changed to 0 to 1 V.

A TSCA output pulse with an amplitude of about +5 V and a width of 0.5 μs occurs at a fixed time following the peak of the amplified input pulse. The delay from the peak to the output is about 500 ns. The output is available through BNC connectors on both the front and rear panels.

1.6. PREAMPLIFIER POWER OUTPUT

Four standard dc-power levels are made available through the preamplifier power output connector on the rear panel. The connector is wired for compatibility with any ORTEC FET preamplifier and extends the dc levels that are available from the NIM-standard bin and power supply in which the 590A must be installed for operation.

2. SPECIFICATIONS

Amplifier

2.1. PERFORMANCE

SHAPING Gaussian on all ranges with peaking time equal to 2.2τ and pulse width at 0.1% level equal to 4 times the peaking time. Bipolar crossover equal to 1.5τ.

GAIN RANGE Continuously adjustable from X5 through X1250.

INTEGRAL NONLINEARITY <0.05% using 1.5 µs shaping.

NOISE <5 µV referred to the input using 3-µs unipolar , and ≤7 µV using 1.5 µs shaping, both for gain ≥100.

TEMPERATURE INSTABILITY
Gain ≤0.0075%/°C, 0 to 50°C.
DC Level <±50 µV/°C, 0 to 50°C.

COUNT RATE STABILITY The 1.33 MeV gamma ray peak from a ^{60}Co source, positioned at 85% of analyzer range, typically shifts <0.02%, and its FWHM broadens <10% when its incoming count rate changes from 1000 to 50,000 counts/s using 1.5 µs shaping. The amplifier will hold the baseline reference up to count rates in excess of 75,000 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 X500 overload for bipolar pulses.

BASELINE RESTORER (BLR) Gated active baseline stabilizer, with automatic threshold circuit, provides the threshold level as a function of signal noise to the baseline restorer discriminator.

2.2. CONTROLS

COARSE GAIN Six-position selector switch to select Course Gain factor for Amplifier; factors are 10, 20, 50, 100, 200, 500.

FINE GAIN Single-turn potentiometer for direct-reading, continuous adjustment of Fine Gain factor from 0.5 to 2.5.

PZ ADJ Front panel screwdriver adjustment to match the amplifier shaping to the preamplifier decay times adjustable for preamplifier decay times from 30 µs to ∞. Factory-set at 50 µs.

SHAPING Three, 3-position, PWB switches, easy accessible through the side panel, select shaping time of 0.5, 1.5, and 3.0 µs.

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

UNI-BI Front panel toggle switch selects unipolar or bipolar output shape.

2.3. INPUT

AMP IN BNC front and rear panel connectors accept either positive or negative pulses, selectable by front panel toggle switch, with rise times in the range from 10 to 650 ns decay times from 30 µs to ∞; Z_{in} = 1000 Ω, dc coupled; linear maximum, 2 V; absolute maximum, 20 V.

2.4. OUTPUTS

AMP Front panel BNC, Z_o, <1Ω. Short-circuit proof; prompt full scale linear range, 0 to +10 V; active filter shaped and dc restored for unipolar output; dc level 0 to ±5 mV.

2.5. PREAMPLIFIER POWER

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

2.6. PERFORMANCE

INPUT DYNAMIC RANGE 200:1.

PULSE-PAIR RESOLVING TIME Minimum pulse-pair resolution ≤2 µs with 0.5 µs shaping time.

OUTPUT TIMING ≈500 ns from peak of output pulse from amplifier.

TIME SHIFT vs PULSE HEIGHT (Walk) Walk <±10 ns for a 50:1 change in output amplitude for 0.5-µs shaping time.

THRESHOLD TEMPERATURE INSTABILITY ≤0.01%/ °C of full scale (l mV/°C).0° to 500°C using a NIM class A power supply (referenced to -12 V).

DISCRIMINATOR NONLINEARITY ≤±0.25% of full scale (integral) for both discriminators.

WINDOW WIDTH CONSTANCY Variation of full-scale window width over the linear 0 to 10 V range is less than 0.1%.

MINIMUM INPUT THRESHOLD 50 mV for Lower Level discriminator.

EXT LLD When the rear-panel mounted Lower-Level Reference switch is on Ext, this rear panel BNC connector accepts the lower-level biasing (an input of 0 to -10 V on this connector corresponds to a threshold in the range of 0 to 10 V for the lower-level discriminator setting). Input impedance, 2000 Ω.

2.7. CONTROLS

LOWER LEVEL Front panel 10-turn potentiometer adjustable from 0 to 10 V; when the rear panel LL Ref mode switch is set on Int, determines the threshold setting for the Lower Level discriminator. When the LL Ref mode switch on the rear panel is in the Ext position, this control is ineffective.

WINDOW 10-turn precision potentiometer on front panel for adjustment of analyzer window width (0 to 10 V or 0 to 1 V, as selected by an internal jumper). Factory-set at 0 to 10 V.

INT/WINDOW Front panel toggle switch selects operating mode.

Window LL sets the baseline level (0 to 10 V) and the Window control sets the window width between 0 to 1 V or 0 to 10 V.
Int Integral LL sets a single discriminator threshold (0 to 10 V) and the Window control is disabled.

LL REF Toggle switch mounted on the rear panel selects the source of lower-level bias. Int position selects front panel control; Ext selects lower-level bias through rear panel connector.

2.8. INPUTS

SCA Internally connected to amplifier output; impedance level of 1000 Ω.

EXT LLD Input from 0 to -10 V; 2000 Ω input impedance; rear panel connector.

2.9. OUTPUTS

SCA OUT Front and rear panel BNC connectors provide NIM standard output, nominally +5 V, 500 ns wide; 50 Ω output impedance, typically.

DISC OUT Rear panel BNC connector provides NIM standard output, nominally +5 V, 500 ns wide; 50 Ω output impedance. Output occurs as leading edge of linear input crosses the window threshold.

2.10. ELECTRICAL AND MECHANICAL

POWER REQUIRED +24V, 34 mA; -24 V, 20 mA; +12V, 100 mA; -12 V, 80 mA.

WEIGHT
Net 1.35 kg (3 lb).
Shipping 2.25 kg (5 lb).

DIMENSIONS Single-width NIM instrument (1.35 by 8.714 in.) per TID-20893 (Rev).

3. INSTALLATION

3.1. GENERAL

The 590A operates on power that must be furnished from a NIM-standard bin and power supply such as the ORTEC 4001C/4002 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. 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 590A 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 4001/4002 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 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.

Pole-zero cancellation is incorporated to enhance the overload and count rate characteristics of the amplifier. This technique requires matching the P/Z 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 590A at the module position in the bin.

When this unit 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 590A input is matched. Since the input impedance is about 1000Ω, sending-end termination will normally be preferred; the transmission line should be series-terminated at the preamplifier output. The energy output of all ORTEC preamplifiers contains a 93Ω series termination; coaxial cable type RG-62/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 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 590A Since the input 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 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 100 Ω 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 is selectable by PWB mounting switches in steps of 0.5, 1.5, and 3 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 1.5-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 1.5 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 HPGe detectors will vary from 1.5 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 590A has almost constant gain for all shaping modes, the optimum shaping can be determined by measuring the output noise with a voltmeter as each shaping time constant is selected. (See Section 4.7).

3.6. LINEAR OUTPUT CONNECTIONS AND TERMINATING CONSIDERATIONS

Since the unipolar output is normally used for spectroscopy, the 590A 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. The threshold for the restorer gate is determined automatically, according to the input noise level. The unipolar output dc level is 0 to ±5 mV. 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 amplifier output on the 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 100 Ω terminator at the input connector of the receiving instrument. Since the input impedance of the receiving instrument is normally 1000 Ω or more, the effective instrument input impedance with the 100 Ω 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 OUTPUTS

The amplifier output is dc-coupled with an output impedance of about 0.2 Ω. 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 100 Ω, the maximum count rate consistent with linear output is

$$\text{Rate}_{\text{max}} = \frac{125\ 000\ \text{cps}}{\tau} \text{ X } \frac{10}{V_0}\ .$$

where V_0 is the peak output pulse amplitude in volts (V) and τ is shaping time in µs.

3.8. CONNECTION WITH EXTERNAL TSCA BASELINE

An external baseline may be used with the TSCA portion of the 590A through the rear panel Ext LLD (external lower level) Input BNC connector. A voltage level of 0 to -10 V on this input corresponds to 0 to full scale on the baseline (or Lower Level). The Ext LLD Input impedance is 2000 Ω dc-coupled to ground.

3.9. TSCA OUTPUT CONNECTIONS

Both the front and rear panel TSCA outputs provide low- impedance drive and are capable of driving a total of ten 1000 Ω loads. For cable lengths longer than 10 ft, the coaxial cable should be terminated at the receiving end with its characteristic impedance.

4. OPERATING INSTRUCTIONS

4.1. FRONT PANEL CONTROLS

GAIN A coarse Gain switch and a Fine Gain control, a precision 1-turn potentiometer, select and precisely adjust the gain factor for the amplification. Switch settings are X10, 20, 50, 100, 200, and 500. Continuous fine gain range is from X0.5 to X2.5.

Using these controls collectively, the gain can be set at any level from X5 through X1250.

POS/NEG A toggle switch selects the appropriate input circuit for the designated 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 30 µs to ∞.

SHAPING Three, 3-position, PWB switches, easily accessible through the side panel, select equal integration and differentiation time constants to shape the input pulses. Settings are 0.5, 1.5, and 3 µs.

UNIPOLAR-BIPOLAR A toggle switch selects either a unipolar or bipolar output pulse shape.

LOWER LEVEL A 10-turn potentiometer adjustable from 0 to 10 V, which determines the threshold setting for the Lower Level discriminator. (When the Lower Level Reference switch on the rear panel is in the Ext position, the Lower Level control is disabled and discriminator bias is provided from the Ext LLD Input connector on the rear panel. An input of 0 to -10 V on this connector corresponds to a range of 0 to 10 V for the Lower Level discriminator setting.)

WINDOW A 10-turn potentiometer adjustable from 0 to 10 V determines the width of the window of acceptance above the adjusted lower level. Window width adjustable for 0 to 10 V or 0 to 1 V as selected by PWB jumper. Jumper toward front panel sets window at 0 to 1 V; toward rear panel at 0 to 10 V.

4.2. FRONT PANEL CONNECTORS

INPUT Accepts input pulses to be shaped and/or amplified. Compatible characteristics; positive or negative with rise time from 10 to 650 ns; decay time greater than 30 µs for proper pole-zero cancellation; input linear amplitude range 0 to 2 V, with a maximum limit of ±20 V. Input impedance is approximately 1000 Ω.

AMP OUTPUT Provides a positive unipolar or bipolar output.

SCA OUTPUT Provides a NIM standard output of +5 V, 500 ns wide.

4.3. REAR PANEL CONNECTORS

AMP INPUT A BNC connector that is wired in parallel with the front panel Input connector.

EXT LLD A BNC connector that accepts a dc level of 0 to -10 V full scale for the lower level discriminator threshold; a side panel switch must select Ext Lower Level Ref.

PREAMPLIFIER POWER A 9-pin Amphenol type 17-10090 connector extends the ±12 and ±24 V dc levels from the bin and power supply to a mating ORTEC transistorized preamplifier.

SCA OUT A BNC connector that is wired in parallel with the front panel SCA Output connector.

DISC OUT Provides NIM standard output of +5 V, 500 ns wide as leading edge of linear input crosses the window threshold.

4.4. INITIAL TESTING AND OBSERVATION OF PULSE WAVEFORMS

Refer to Section 6 of this manual for information and testing performance of pulse waveforms.

4.5. STANDARD SETUP PROCEDURE

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

b. Set the 590A controls initially as follows:

Shaping	1.5 µs
Coarse Gain	50
Fine Gain	1.00
UNI-BI	UNI
Pos/Neg	Match input pulse polarity

c. Use a ^{60}Co calibration source, set about 25 cm from the active face of the detector. The unipolar output pulse should be about 8 to 10 V, using a preamplifier with a conversion gain (charge sensitivity) 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 Ge(Li) 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. 4.1). 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 oscilloscope, use the clamp circuit shown in Fig. 4.2.

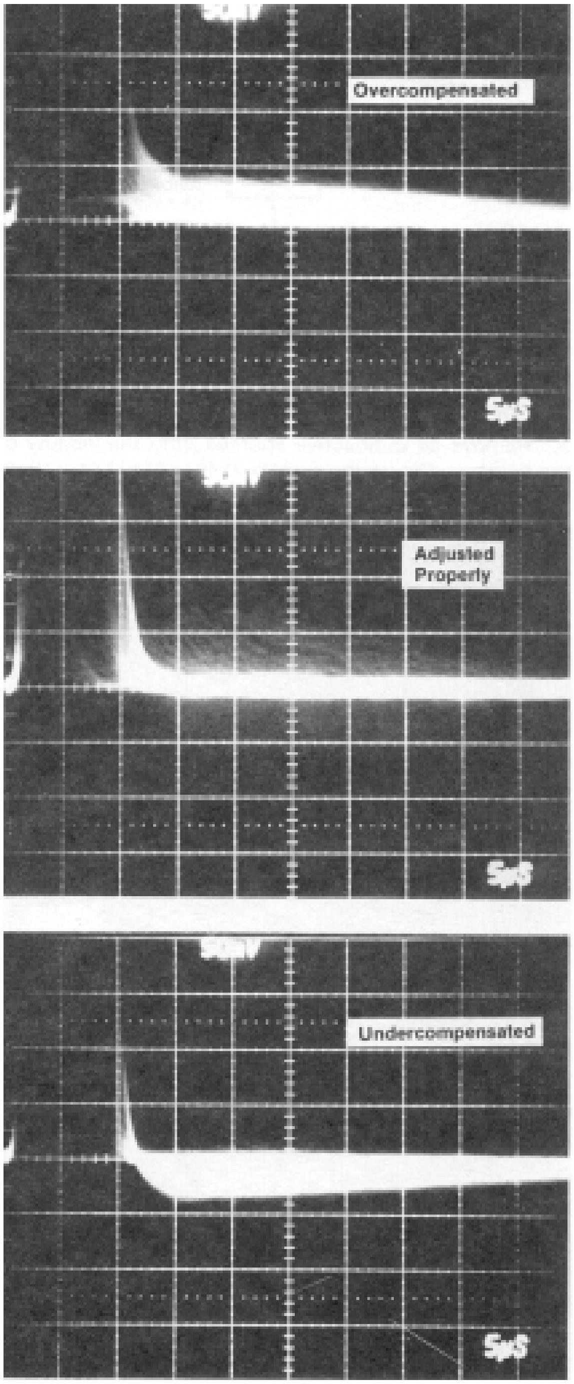


Fig. 4.2. Typical Waveforms Illustrating Pole-Zero Adjustment Effects; Oscilloscope Trigger, Internal Pos.; ^{60}Co Source with 1.33-MeV Peak Adjusted ~9 V; Count Rate, 3 kHz; Shaping Time Constant, 1.5 µs.

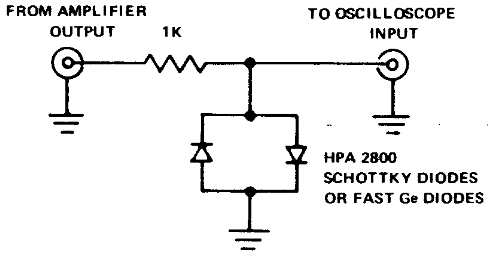


Fig. 4.3. A Clamp Circuit that Can Be Used to Prevent Overloading the Oscilloscope Input.

USING SQUARE WAVE THROUGH PREAMPLIFIER TEST INPUT

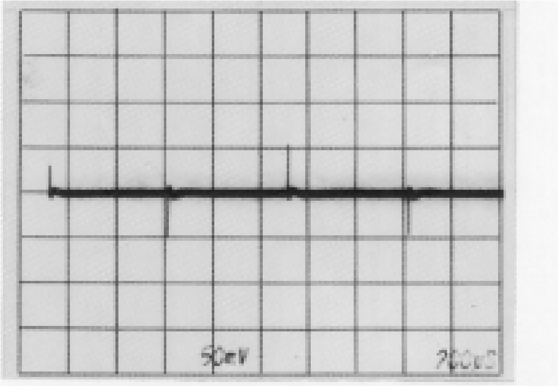
A more precise pole-zero adjustment in the 590A can be obtained by using a square wave signal as the input to the preamplifier. Many oscilloscopes include a calibration output on the front panel and this is a good source of square wave signals at a frequency of about 1 kHz. The amplifier differentiates 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 compared (Fig. 4.3) 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.

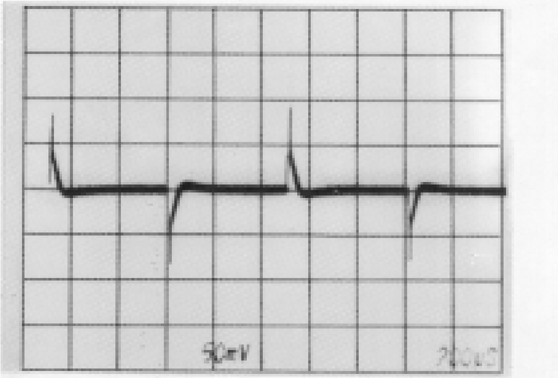
b. Set the 590A controls as for normal operation; this includes gain, shaping, and input polarity.

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 590A output amplitude is about 9 V.

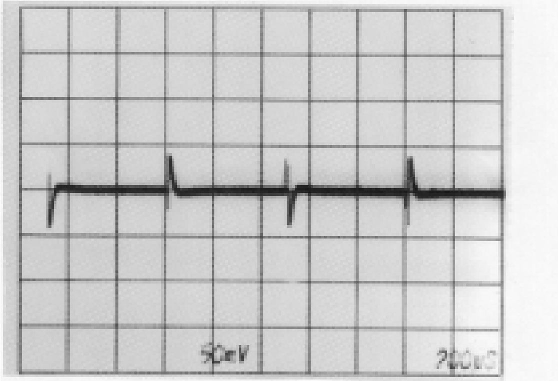
d. Observe the Unipolar output with an oscilloscope. Adjust the PZ Adj control for proper response as shown in Fig. 4.3. Use the clamp circuit (Fig. 4.2) to prevent overloading the oscilloscope input.



PZ Properly Adjusted; Slow Trigger to Seperate Pulses.



B. Overcompensated.



C. Undercompensated.

Fig. 4.3. Pole-Zero Adjustment Using a Square Wave Input to the Preamplifier.

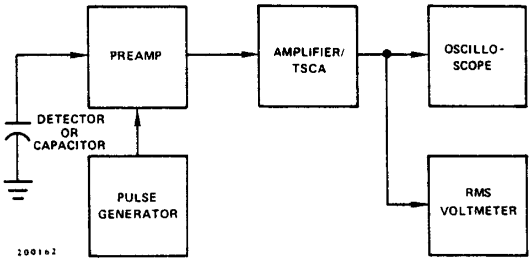


Fig. 4.4. System for Measuring Amplifier and Detector Noise Resolution.

4.7. 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 a 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 and amplifier.

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

c. Adjust the amplifier gain 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. 4.4, 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_0, as determined by the oscilloscope.

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

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

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

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

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

The detector noise tends to increase with bias voltage while the detector capacitance decreases, thus reducing the resolution spread. The net change in resolution spread will depend upon which effect is dominant. Figure 4.5 shows curves of typical noise-resolution spread versus bias voltage, using data from several ORTEC silicon surface-barrier semiconductor radiation detectors.

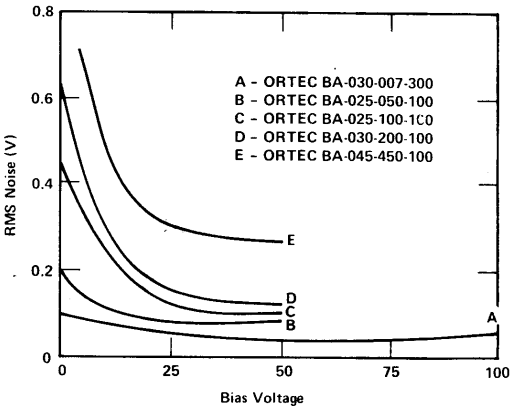


Fig. 4.5. Noise as a Function of Bias Voltage.

AMPLIFIER NOISE-RESOLUTION MEASUREMENTS USING MCA Probably the most convenient method of making resolution measurements is with a pulse height analyzer (Fig. 4.6.)

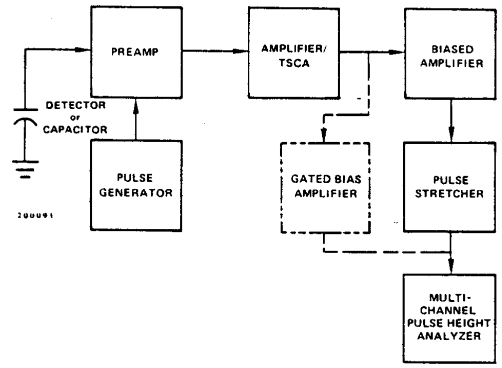


Fig. 4.6. System for Measuring Resolution with a Pulse Height Analyzer.

The electronic 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 4.7 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 4.8 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. 4.7 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.

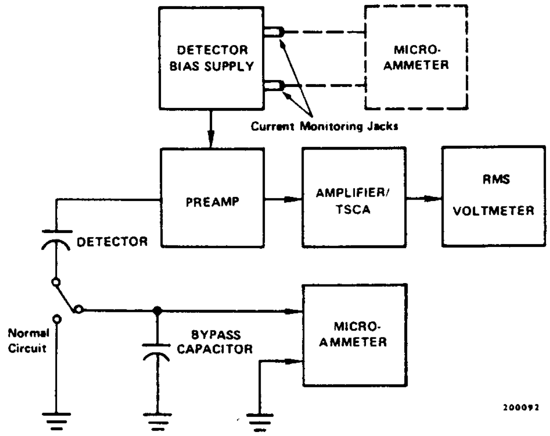


Fig. 4.7. System for Detector Current and Voltage Measurements.

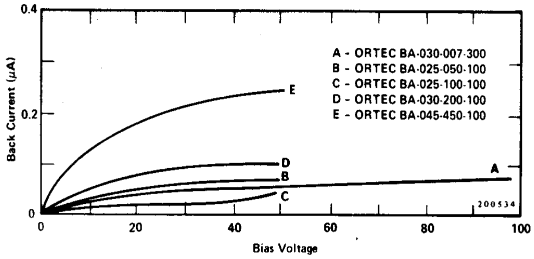


Fig. 4.8. Silicon Detector Back Current vs Bias Voltage.

4.8. AMPLIFIER APPLICATIONS

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. 4.9. 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. Alpha-particle 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.

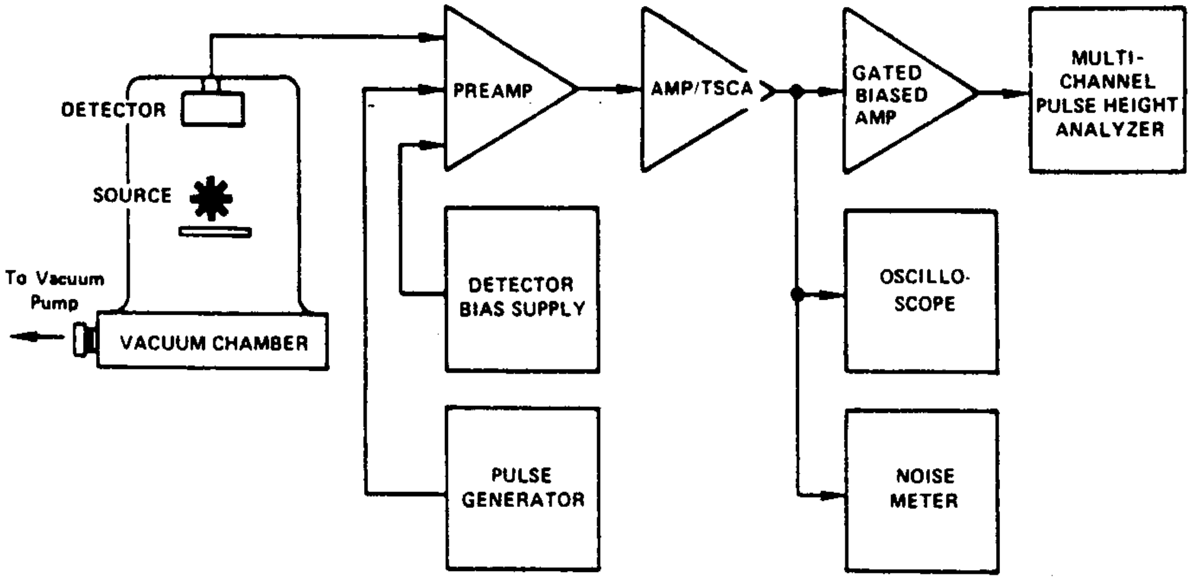


Fig. 4.9. System for High-Resolution Alpha-Particle Spectroscopy.

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. 4.10. 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 connection capacitance between the detector and preamplifier to an absolute minimum (no long cables).

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

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 capacitance low.

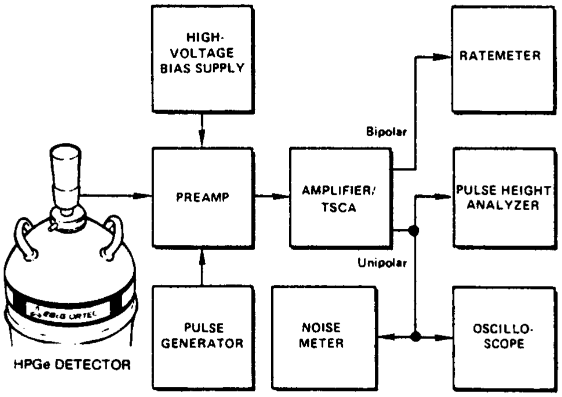


Fig. 4.10. System for High-Resolution Gamma Spectroscopy.

SCINTILLATION-COUNTER GAMMA SPECTROSCOPY SYSTEMS

The ORTEC 590A can be used in scintillation-counter spectroscopy systems as shown in Fig. 4.11. The amplifier shaping time constants should be selected in the region of 0.5 to 1.5 μs for NaI or plastic scintillators. For scintillators having longer decay times, longer time constants should be selected.

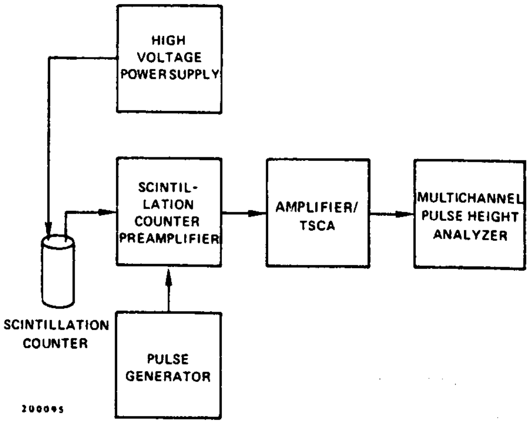


Fig. 4.11. Scintillation-Counter Gamma Spectroscopy System.

4.9. AMP/TSCA APPLICATIONS

TYPICAL APPLICATIONS

Three typical applications of the 590A are described here. One is with a semiconductor detector as shown in Fig. 4.12. The exceptionally wide dynamic range and the high stability and resolution of the 590A provide the capabilities necessary for long-term experiments of this nature.

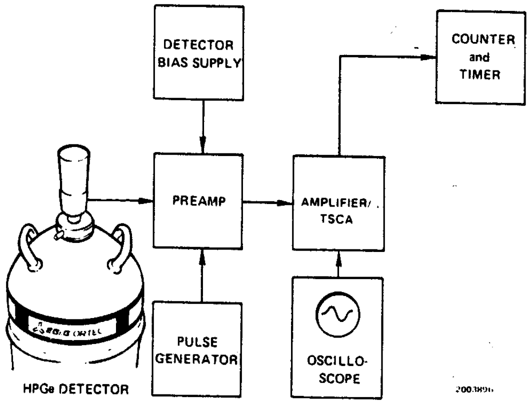


Fig. 4.12. HPGe Gamma Spectroscopy System Using the 590A.

Another typical application is in x-ray diffraction experiments (Fig. 4.13). The capability of the 590A to accept a wide variety of input signals and its wide dynamic range and high stability make it particularly useful for this application. The small size of the

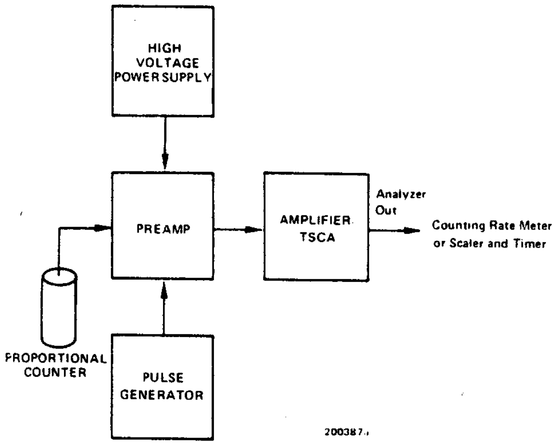


Fig. 13. System for Use in X-Ray Diffraction Experiments.

590A allows the total x-ray diffraction electronics to be contained in a single bin and power supply with a resultant savings in both cost and space.

A number of 590A Amplifier and Timing Single-Channel Analyzers may be used to generate routing signals for a multichannel analyzer in an experiment requiring subdividing of the memory on a pulse-to-pulse basis or in a multiparameter analysis experiment (Fig. 4.14).

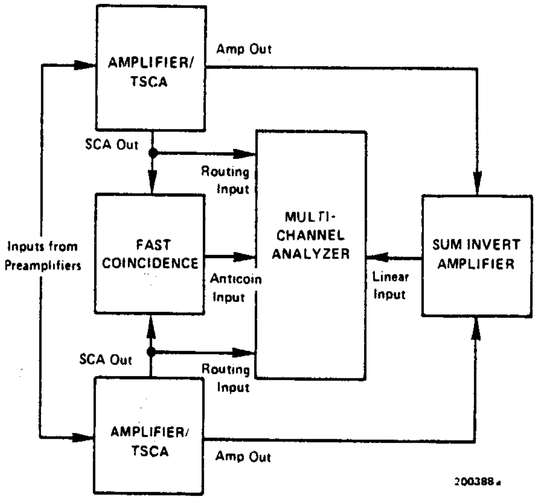


Fig. 4.14. Use of the 590A in Multichannel Analyzer Routing.

5. MAINTENANCE

5.1. TEST EQUIPMENT REQUIRED

The following test equipment should be used to adequately test the specifications of the 590A Amplifier/TSCA.

1. ORTEC 419 Precision Pulse Generator or 448 Research Pulser.
2. Tektronix 475 Series Oscilloscope.
3. Hewlett-Packard 3400A rms Voltmeter.

5.2. AMPLIFIER TEST

PULSER TEST[1]

FUNCTIONAL CHECKS Set the controls as follows:

Coarse Gain	500
Fine Gain	2.5
Input Polarity	POS
Shaping Time Constant	1.5 μs
UNI-BI	UNI

a. Connect a positive pulser output to the input and adjust the pulser to obtain +10 V at the output. This should require an input pulse of ≈8 mV, using a 100Ω terminator at the input. Adjust PZ if necessary.

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

c. Monitor the output for dc level of <±5 mV; switch to BI; dc level should be ≤±5 mV and pulse shape should be bipolar. Return to UNI.

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 500 to 10 and ensure that the output amplitude changes by the appropriate amount for each step. Return the Coarse Gain switch to 500.

---

[1] See IEEE Standards, No. 301-1976.

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.

f. With the Shaping switch set for 1.5 µs, measure the time to the peak on the unipolar output pulse; this should be 3.3 µs (or 2.2τ). Measure the time to baseline crossover of the bipolar output; this should be 5.0 µs (or 3.3τ).

g. Change the Shaping switch to 0.5 and 3 µs in turn. At each setting, check to see that the unipolar peak is 2.2τ. Return the switch to 1.5 µs.

OVERLOAD TESTS Start with maximum gain, τ = 1.5µs, 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 can be measured by a circuit (Fig. 6.1) which subtracts the negative pulser output 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 10V, 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 mV
for the maximum null-point variation.

OUTPUT LOADING Use the test setup of Fig. 6.1. 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 2.5 mV.

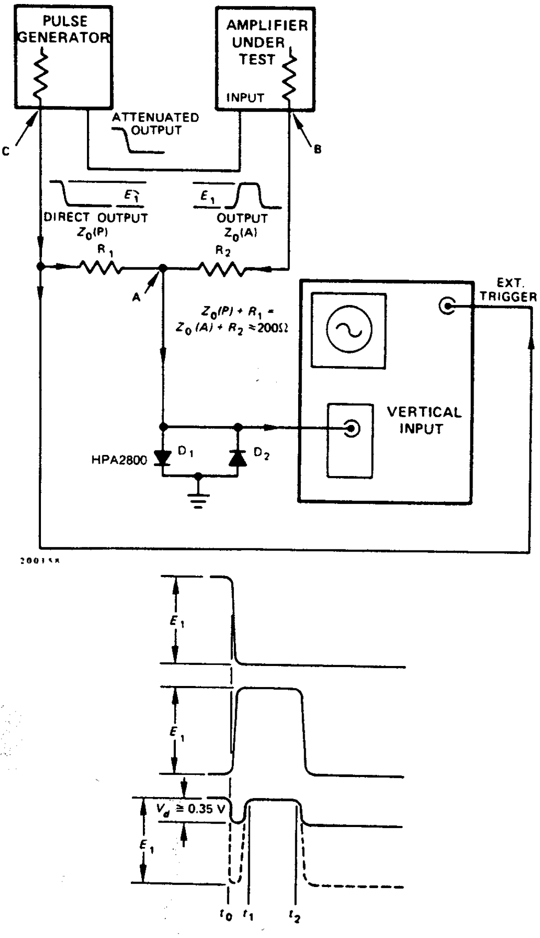


Fig. 6.1. Circuit Used to Measure Nonlineraity.

NOISE Measure the noise at the amplifier Unipolar output with maximum amplifier gain and 3-µs shaping time. Using a true rms voltmeter, the noise should be less than 5 µV x 750 (gain), or 3.75 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 100Ω during the noise measurements.

5.3. SCA TEST

OPERATIONAL TESTS

INITIAL SETTINGS

Pulser output polarity	Positive
Lower Level Reference	Internal
Uni/Bi	Unipolar
Pos/Neg	Positive
Window jumper	1 V
Coarse Gain	100
Fine Gain	1.0
Lower Level	5.00
Window control	1.00

Adjust the Normalize and Pulse Height controls on the pulser so that a 10-V unipolar signal is obtained on the Amp Output of the 590A.

LOWER LEVEL CONTROL Set the pulser Pulse Height control to 5.00. Adjust the pulser Normalize and Attenuation controls and the gain controls on the 590A until the analyzer is half triggering. The Amplifier output pulse should be approximately 5 V amplitude.

1-V WINDOW RANGE Increase the pulser Pulse Height dial until the Analyzer output signal just disappears. This should happen at a Pulse Height setting of 5.10.

5.4. SUGGESTIONS FOR TROUBLESHOOTING

In situations where the 590A is suspected of a malfunction, it is essential to verify such malfunction in terms of simple pulse generator impulses at the input. The unit 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 (Sections 6.2 and 6.3) and the Circuit Descriptions (Section 5) should help to locate and repair the trouble. The two side plates can be completely removed from the module for oscilloscope and voltmeter observations.

5.5. 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 as for a new instrument. Always contact Customer Services at ORTEC, (865) 482-4411, before sending in an instrument for repair to obtain shipping instructions. A Return Authorization Number is required, and will 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.

5.6. TABULATED TEST POINT VOLTAGES

For testing, dc voltages can be measured at certain locations on the PWB (Table 6.1). In some cases the circuit will perform satisfactorily even though, due to component tolerances, there may be some voltage measurements which differ slightly from the listed values. The tabulated values should not be interpreted as absolute voltages but rather should be used as an aid during troubleshooting.

Table 6.1. Typical dc Voltages

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
T1	±50 mV
T2	±60 mV
T3	±0.7 mV
T4	±1.0 mV
T5	±60 mV
T6	0 to -0.8 V
T7	±6 mV
Pin 2 U16	+5.5 V
Pin 2 U14	+5.0 V

Bin/Module Connector Pin Assignments For Standard Nuclear Instrument Modules per DOE/ER-0457T.

Pin	Function	Pin	Function
1	+3 V	23	Reserved
2	- 3 V	24	Reserved
3	Spare bus	25	Reserved
4	Reserved bus	26	Spare
5	Coaxial	27	Spare
6	Coaxial	*28	+24 V
7	Coaxial	*29	- 24 V
8	200 V dc	30	Spare bus
9	Spare	31	Spare
10	+6 V	32	Spare
11	- 6 V	*33	117 V 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 V	38	Coaxial
*17	- 12 V	39	Coaxial
18	Spare bus	40	Coaxial
19	Reserved bus	*41	117 V ac (neutral)
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.