PRECISION

INSTRUMENTATION

FOR RESEARCH

Oak Ridge Technical Enterprises Corporation

OAK RIDGE, TENNESSEE

ORTEC

INSTRUCTION MANUAL

MODEL 410

LINEAR AMPLIFIER

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MODEL 410
LINEAR AMPLIFIER

1. DESCRIPTION

1.1 General Description

The ORTEC Model 410 Linear Amplifier is a very versatile linear amplifier designed to optimize both energy and time measurement capabilities from nuclear radiation detectors. The instrument features high counting rate capabilities, overload recovery, and the ultimate in resolution necessary for use with semiconductor, gaseous, and scintillation detectors. The amplifier is packaged in the AEC-recommended Nuclear Standard Module.

The linear functions include a Linear Amplifier with a positive unipolar output signal, and a Bipolar Amplifier with a bipolar output. The Linear Amplifier and the Bipolar Amplifier both include delay line and RC pulse shaping. The RC pulse shaping features variable time constants ranging from 0.1 to 10 microseconds. The delay line shaped pulse is 0.8 microsecond wide.

The timing function is performed when the Model 410 is used in conjunction with an ORTEC Model 407 or Model 420 Crossover Pickoff circuit. The resulting crossover pickoff output features a minimum of walk as a function of pulse amplitude, and also incorporates a variable delay time on the output pulse to enable the crossover pickoff output to be placed in time coincidence with other signals.

The Model 410 has complete provisions, including power, for operating an ORTEC solid state preamplifier such as the Model 108, 109, or 113. All signal inputs and outputs are available on BNC connectors mounted on the front panel. Observation of signal waveforms with an oscilloscope is facilitated with two convenient test point jacks located on the front panel.

The Linear Amplifier accepts either positive or negative input signals from the preamplifier, and features fast rise time, very low equivalent input noise, and variable pulse shaping time constants to allow the energy and time resolution to be optimized for a given set of experimental conditions. The input impedance of the Linear Amplifier is 125 ohms; therefore, it is not necessary to terminate long 125-ohm (RG-63/U) cable runs at the preamplifier, since they are terminated at the input to the main amplifier. The input impedance can be shunted at the input

BNC connector to obtain any impedance level less than 125 ohms, i.e., 93 ohms or 50 ohms. Output signal levels from the ORTEC Models 105, 105XL, 108, 109, and 113 preamplifiers are directly compatible with the Model 410.

The output impedance of the unipolar and bipolar output circuitry is approximately 1 ohm, and short-circuit protected; therefore, changes in gain calibration of multichannel analyzers or other output equipment are minimized when additional output equipment such as single channel analyzers and count rate meters must be added to the output of the linear circuitry after initial gain calibration.

The Model 410 is three Nuclear Standard Module widths wide. The module has no self-contained power supply; power is obtained from a Nuclear Standard Bin and Power Supply such as the ORTEC Model 401/402.

1.2 Description of Basic Functions

1.2.1 Linear Amplifier

The Linear Amplifier features a very low equivalent input noise and variable bandwidth which greatly aid in optimizing the signal-to-noise ratio for a given set of detector operating conditions. The bandwidth is selected by front panel switches which independently set the differentiation and integration time constants. Two modes of signal differentiation are provided, delay line and RC. The delay line differentiator is normally supplied as 0.8-microsecond but may be shortened or lengthened if desired. The RC differentiation is variable from 0.1 to 10 microseconds in a 1-2-5 sequence. Single integration is provided from 0.1 to 10 microseconds also in the 1-2-5 sequence. If desired, the differentiation and integration networks can be independently switched out, resulting in an amplifier with a flat frequency response from approximately 670 cps to 3.5 Mcps. The output from the Linear Amplifier is a positive unipolar pulse of 0 to 10 volts rated output and 12 volts maximum output.

1.2.2 Bipolar Amplifier

The Bipolar Amplifier linearly converts the unipolar signal from the Linear Amplifier to a bipolar pulse. The bipolar pulse is selectable via front panel controls to be either double delay line or double RC differentiated. The second delay line differentiator is normally supplied to match the delay line differentiating time of the main amplifier. The second RC differentiator is selectable over the same range and in the same steps as the first RC differentiator in the main amplifier. This doubly differentiated signal results in equal area above and below the baseline of the bipolar pulse, and therefore permits a much higher counting rate with less baseline distortion than in the case of a single differentiated unipolar pulse. The output of the Bipolar Amplifier is 0 to ±10 volts rated output and 12 volts maximum output.

2. SPECIFICATIONS

2.1 General Specifications

2.1.1 The Model 410 is intended for use with a Nuclear Standard Bin such as the ORTEC Model 401/402. Seven watts of power are required for the operation of the Model 410 in the quiescent condition. The ORTEC Model 401/402 can be operated on either 115 or 220 volts ac, 50—60 cps; if it is used with 220 volts ac, the manual for the Model 401/402 must be referred to in order to ensure that correct connections have been made before operation on 220 volts ac is attempted. The instrument is supplied from the factory wired for 115 volts ac operation. The power input connector to the Model 401/402 is a NEMA standard 3-wire grounding type.

Preamplifier power of ± 12V and ± 24V is available on the Model 410 rear panel connector, PG5, an Amphenol 17-10090. All signal inputs and outputs are on BNC connectors which are mounted on the front panel.

2.1.2 The instrument is intended for rack mounting in an ORTEC Model 401/402 Nuclear Standard Bin, but the Nuclear Standard Bin is suitably packaged for cabinet installation if desired. The weight of the Model 410 is 4.3 pounds and its outside dimensions are approximately 8.75 inches high by 4.05 inches wide by 9.75 inches deep.

2.2 Linear Amplifier

Input Polarity.................... Either positive or negative

Maximum Input Signal .... With the INPUT ATTENUATOR set on 1, an input up to plus or minus 2.5 volts will not saturate the amplifier. Larger inputs can be attenuated to the 2.5V level with the input attenuator.

Input Impedance .... Constant 125 ohms; can be shunted on INPUT BNC connector with pure resistance to achieve 93 ohms or 50 ohms if desired.

Total Gain .... RC shaping mode......0.35 to 480
Delay Line shaping mode..............0.75 to 1300

Gain Adjustment .... Actual gain controlled by three gain controls—

A. INPUT ATTENUATOR: Attenuation factors 1, 2, 5, 10, 20, 50

B. FINE GAIN: 1.0 to 3.0

C. COARSE GAIN: X1, X3, X9

Pulse Shaping Modes .... Two basic pulse shaping modes provided —

A. Classical RC pulse shaping

B. Delay Line pulse shaping

The mode desired is selectable via front panel switch.

RC time constants, i.e., $\tau = 1/e$, are selectable from 0.1, 0.2, 0.5, 1, 2, 5, and 10 μsec. The time constants are accurate to ±2% of indicated value. The delay line normally supplied provides a full width at half maximum (fwhm) output pulse of 0.8 μsec. Other pulse widths are supplied on special request. The pulse shaping networks can be switched to the OUT position, resulting in an amplifier with a flat bandpass from approximately 760 cps to 3.5 Mcps.

Amplifier Rise Time .... Unipolar Output—80 nsec
Bipolar Output—100 nsec

Maximum Amplifier Bandpass ..... Within 3 db from 700 cycles to 4.3 megacycles

Output .... Unipolar—0 to 10V positive, 12V maximum
Bipolar—0 to 10V positive and negative, i.e., bipolar; 12V maximum output

Output Impedance .... Approximately 1 ohm, short-circuit protected

Amplifier Noise .... Equivalent noise at unipolar output when referred to the input is less than 7 μV rms with maximum amplifier gain and 1st DIFFERENTIATION and INTEGRATION set on 1 μsec pulse shaping.

Overload Performance .... Amplifier recovers from a 300X overload to less than 2% of rated output voltage within 4 μsec when used with maximum gain in the double delay line shaping mode. The overload factor is approximately 100X when used with RC pulse shaping.

Temperature Stability .... Gain shift is less than 0.015% per °C.

Linearity .... The nonlinearity is less than 0.2% from 200 mV to 8V and less than 0.3% to 10V.

Counting Rate .... The shift in gain as a function of counting rate is less than 0.2% for 50,000 cts/sec from a Cs^{137} source with a 60 keV threshold on the counting.

Operating Temperature .... 0 to 50°C.

Power Required .... Model 410 power supplied from ORTEC Model 401/402 Power Supply

DC input voltage	Quiescent current	Current with 50,000 pulses per second, each pulse 8V into 100 ohms
+24V	146 mA	150 mA
−24V	78 mA	78 mA
+12V	−5.6 mA	−5.5 mA
−12V	18 mA	22.5 mA

3. INSTALLATION

3.1 General Installation Considerations

The Model 410 used in conjunction with a Model 401/402 Bin and Power Supply is intended for rack mounting, and therefore it is necessary to ensure that vacuum tube equipment operating in the same rack with the Model 410 has sufficient cooling air circulating to prevent any localized heating of the all-transistor circuitry used throughout the Model 410. The temperature of equipment mounted in racks can easily exceed 120° F (50° C) unless precautions are taken.

3.2 Connection to Preamplifier

The preamplifier output signal can be connected to the Model 410 via BNC connector PG1. The input impedance seen at PG1 is 125 ohms and is dc coupled to ground; therefore, the output of the preamplifier must be either ac coupled to have zero dc potential on the output connector.

With the flexibility of **variable** pulse shaping time constants available in the Model 410, the differentiation, or fall time, of the preamplifier output signal must be taken into consideration when setting up a linear system. The nominal fall time back to the baseline of ORTEC preamplifiers is approximately 50 microseconds. If it is desired to use the 10-microsecond integration and differentiation time constants of the Model 410, it can be seen that the 50-microsecond fall time of the preamplifier actually constitutes an additional differentiation time constant. This can result in triple differentiation of the signal at the bipolar output. Triple differentiation will cause the input signal to cross the baseline twice and result in a nonnegligible positive overshoot after the initial normal positive and negative bipolar signal. To avoid this condition the fall time of the preamplifier must be lengthened, preferably to a minimum of 25 times as long as the pulse shaping time constant. Detailed instructions for lengthening the fall time in ORTEC preamplifiers will be found in the instruction manual for the respective preamplifier.

Preamplifier power of ± 12V and ±24V are available on the preamp power connector, PG5.

When using the Model 410 with a remotely located preamplifier (i.e., preamplifier-to-amplifier connection through 25 feet or more of coaxial cable), care must be taken to ensure that the characteristic impedance of the transmission line from the preamplifier output to the Model 410 input is matched. Since the input impedance of the Model 410 is 125 ohms, receiving end termination will normally be preferred; i.e., the transmission line should be terminated at the input of the Model 410. For maximum performance from the Model 410 and the associated preamplifier, high quality coaxial cable such as RG-63/U must be used for the connections from the preamplifier output to the Linear Amplifier input. In the event RG-63/U or other 125-ohm coaxial cable is unavailable, a minimum-loss impedance transformation can be inserted in series between the transmission line from the preamplifier and the Linear Amplifier input at PG1. Recommended values of resistors for various impedance transformations are given in Section 6.2.3.

3.3 Connection of Test Pulse Generator

3.3.1 Connection of Pulse Generator to Model 410 Through a Preamplifier

The satisfactory connection of a test pulse generator such as the ORTEC Model 419 or equivalent depends primarily on two considerations: (1) the preamplifier must be properly connected to the Model 410 as discussed in Section 3.2, and (2) 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.

3.3.2 Direct Connection of Pulse Generator to Model 410

The Model 410 input, BNC connector PG1, has 125-ohm input impedance and feeds directly into the voltage-sensitive Linear Amplifier circuit. PG1 is dc coupled to ground, and any test pulse generator such as the ORTEC Model 419 with a fast rise time and long (greater than 100-microsecond) exponential decay can be used to test the Model 410 linear amplifying functions. The rise time of the input signal should be greater than 35 nsec for best performance of the Model 410.

3.4 Connection to Pulse Height Analyser

A choice of output signals suitable for driving pulse height analyzers is available from the Model 410. Prompt unipolar and bipolar outputs are available at PG2 and PG3, respectively.

It is strongly recommended that the signal selected to be fed to the input of the pulse height analyzer be passed through a pulse stretcher similar to the ORTEC Model 411 if the full width at half maximum (fwhm) is less than 0.8 microseconds. The pulse stretcher will stretch the peak amplitude of the signal to a minimum of 1.5 microseconds and thereby reduce the bandwidth requirements of the analog-to-digital (ADC) circuitry of the multichannel analyzer. The stretched pulse results in reduced integral nonlinearity of the pulse height analyzer.

The rated linear output voltage of the Model 410 is 0 to 10 volts; therefore, the multichannel analog-to-digital converter (ADC) should be adjusted to utilize this voltage range. It is important to present the signal to the ADC of the analyzer without introducing any additional short time constant pulse shaping in the transition from the Model 410 output to the ADC. If additional pulse shaping (i.e., clipping) is done, it will usually be at the expense of reduced resolution of the linear system.

3.5 Connection to Power—Nuclear Standard Bin, ORTEC Model 401/402

The Model 410 contains no internal power supply and therefore must obtain power from a Nuclear Standard Bin and Power Supply such as the ORTEC Model 401/402. It is recommended that the bin power supply be turned off when inserting or removing modules. The ORTEC 400 Series is designed so that it is not possible to overload the bin power supply with a full complement of modules in the Bin; however, this may not be true when the Bin contains modules other than those of ORTEC design, and in this case, the power supply voltages should be checked after insertion of the modules. The ORTEC Model 401/402 has test points on the power supply control panel to monitor the dc voltages.

When using the Model 410 outside the Model 401/402 Bin and Power Supply, be sure that the jumper cable used properly accounts for the power supply grounding circuits provided in the recommended AEC standards of TID-20893. Both clean and dirty ground connections are provided to ensure proper reference voltage feedback into the power supply, and these must be preserved in remote cable installations. Care must also be exercised to avoid ground loops when the module is not physically in the bin.

4. OPERATING INSTRUCTIONS

4.1 Linear Amplifier Front Panel Controls—Description and Familiarization

INPUT POLARITY—Normally set to the polarity of the input pulse at PG1. This results in a unipolar positive output pulse at PG2.

INPUT ATTENUATOR—A passive pi attenuator inserted between the input connector PG1 and the Linear Amplifier circuit. The attenuation ratio is variable from 1 to 50 in the 1-2-5 sequence. The input and output impedance of the attenuator remains constant at 125 ohms over this range.

FINE GAIN—Fine gain control of the Linear Amplifier is provided over a range of 1 to 3.

COARSE GAIN—The gain of the Linear Amplifier can be changed by a factor of 3 by dialing the COARSE GAIN switch from 1 to 3 or to 9. This gain control is a passive attenuation network within the circuitry of the Linear Amplifier.

INTEGRATION—The integration time constant of the Linear Amplifier is selected with this control. Integration times are selectable over the range of 0.1 to 10 microseconds in the 1-2-5 sequence. The integration time constant can be switched to OUT, resulting in a maximum upper frequency response, f_2, of approximately 3.5 Mc (3-db point). The OUT position will be used if integration of the pulse shape is being performed in the preamplifier.

1st DIFFERENTIATION—The differentiation (clipping) time constant of the Linear Amplifier is selectable via the outer concentric knob of the DIFFERENTIATION control. Differentiation time constants are variable from 0.1 to 10 microseconds in the RC shaping mode, and are normally fixed at 0.8 microsecond for the delay line (DL) mode. In addition to the RC and DL modes of shaping, an OUT position is provided that decreases the lower frequency response, f_1, of the amplifier to approximately 670 cps. The OUT position will be used if all differentiation is being accomplished in the preamplifier.

2nd DIFFERENTIATION—The unipolar output of the Linear Amplifier is passed through a second differentiation network to produce a bipolar signal. The differentiation time constant is controlled by the inner concentric knob of the DIFFERENTIATION control. While this control is completely independent of the first (1st) DIFFERENTIATION control, the range of time constants is exactly the same, i.e., 0.1 to 10 microseconds in the RC mode and normally 0.8 microsecond in the Delay Line mode. An OUT position is also provided on the second (2nd) DIFFERENTIATION switch.

4.2 Initial Testing and Observation of Pulse Waveforms

Refer to Section 6.1 for information on testing performance and observing waveforms at front panel test points.

4.3 Calibrating the Test Pulser and Amplifier for Energy Measurements

4.3.1 Calibration of Test Pulser

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

(1) Connect the detector to be used to the spectrometer system, i.e., preamp, main amplifier, and bias amplifier.

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

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

(4) Set the pulser PULSE HEIGHT potentiometer at the energy of the α-particles striking the detector (e.g., for a 5.1-MeV α-particle, set the dial at 510 divisions).

(5) Turn on the Pulser; use the NORMALIZE potentiometer and attenuators to set the output due to the pulser to the same pulse height as the pulse obtained in (3) above.

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

4.3.2 Amplifier Noise and Resolution Measurements

As shown in Figure 4-1, the preamplifier, amplifier, pulse generator, oscilloscope, and a wide-band rms voltmeter such as the Hewlett-Packard 400D are required for this measurement. Connect a suitable capacitor to the input to simulate the detector capacitance desired. To obtain the resolution spread due to amplifier noise:

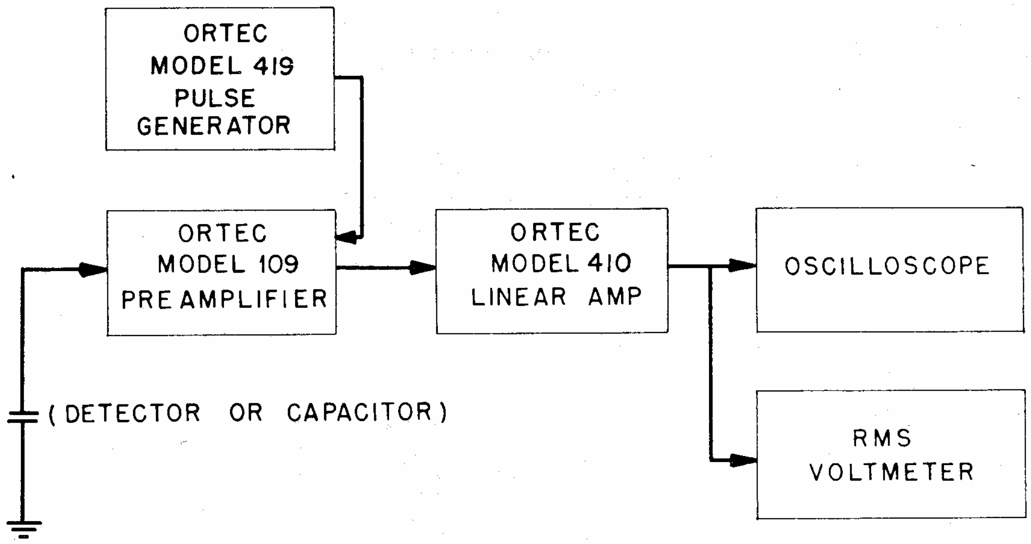

Figure 4-1. Measuring Amplifier and Detector Noise Resolution

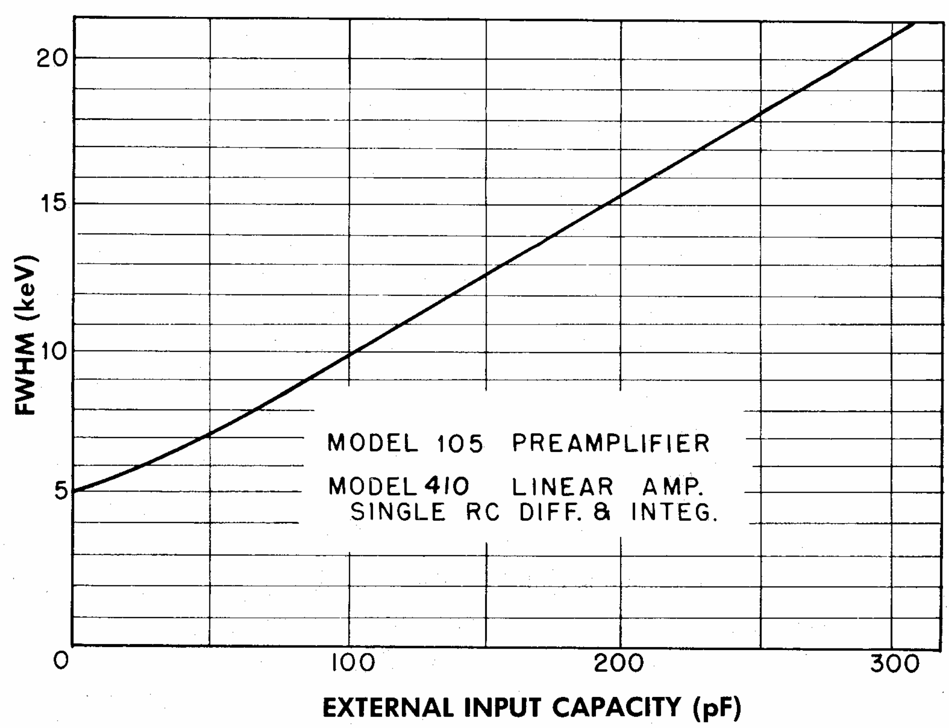

Figure 4-2. Resolution Spread versus External Input Capacity

(1) Measure the rms noise voltage (E_{rms}) at PG2, the Linear Amplifier output.

(2) Turn on the Model 419 mercury relay pulse generator and adjust the Linear Amplifier output to any convenient readable voltage, E_o, at PG2 as determined by the oscilloscope.

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

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

where E_{dial} is the pulser dial reading in MeV and the factor 2.660 is the correction factor for rms to fwhm (2.35) and noise to rms meter correction (1.13) for average-indicating voltmeters such as the Hewlett-Packard 400D.

The resolution spread will depend upon the total input capacitance, since the capacitance degrades the signal-to-noise ratio much faster than the noise. A typical resolution spread versus external input capacitance for the Model 105—Model 410 system in RC mode is shown in Figure 4-2.

4.3.3 Detector Noise Resolution Measurements

The same measurement described in Section 4.3.2 can be made with a biased detector instead of the external capacitor used to simulate the detector capacitance. The resolution spread will be larger because the detector contributes both noise and capacitance to the input. The detector noise resolution spread can be isolated from the amplifier noise spread if the detector capacity is known, since

$$N_{det}^2 + N_{amp}^2 = N_{total}^2$$

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

The detector noise tends to increase with bias voltage, but the detector capacitance decreases, thus reducing the resolution spread. The overall resolution spread will depend upon which

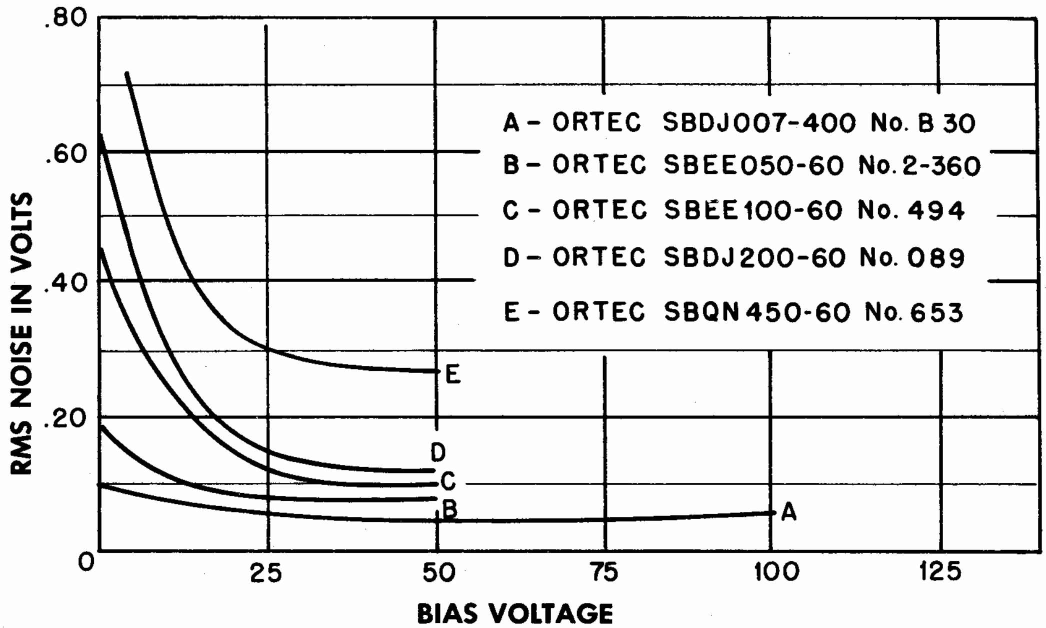

Figure 4-3. Amplifier and Detector Noise versus Bias Voltage

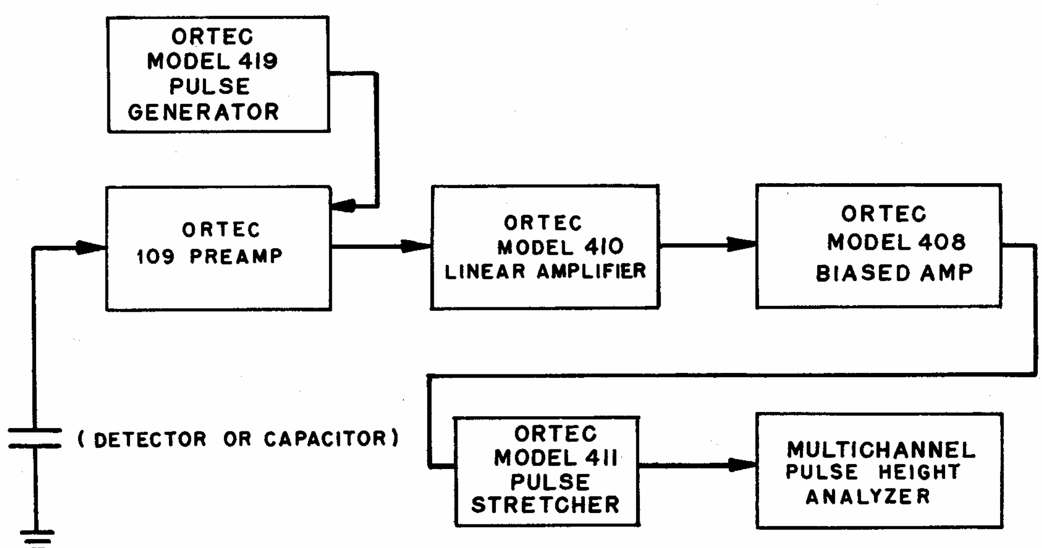

Figure 4-4. Measuring Resolution With a Pulse Height Analyzer

effect is dominant. Figure 4-3 shows curves of typical total noise resolution spread versus bias voltage, using the data from several ORTEC silicon semiconductor radiation detectors.

4.3.4 Amplifier Noise and Resolution Measurements Using a Pulse Height Analyzer

Probably the most convenient method of making resolution measurements is with a pulse height analyzer as shown by the setup illustrated in Figure 4-4.

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

(1) Select the energy of interest with an ORTEC Model 419 Pulse Generator, and set the Linear Amplifier and Biased Amplifier GAIN and BIAS LEVEL controls so that the energy is in a convenient channel of the analyzer.

(2) Calibrate the analyzer in keV per channel, using the pulser (full scale on the pulser dial is 10 MeV when calibrated as described in section 4.3.1).

(3) The amplifier noise resolution spread can then be obtained by measuring the full width at half maximum (fwhm) of the pulser spectrum.

The detector noise resolution spread for a given detector bias can be determined in the same manner by connecting a detector to the preamplifier input. The amplifier noise resolution spread must be subtracted as described in section 4.3.3. The detector noise will vary with detector size, bias conditions, and possibly with ambient conditions.

4.3.5 Alpha-Particle Resolution

Alpha-particle resolution may be determined by a setup such as that shown in Figure 4-5. The source must be sufficiently "thin" so that the source itself does not affect the resolution. High-resolution α-measurements MUST be made in a vacuum of 0.05 mm mercury, or less.

The alpha-particle resolution is obtained in the following manner:

(1) Use Preamplifier, Linear Amplifier, Biased Amplifier GAIN and BIAS LEVEL control settings which will place the α-

particle peak within the pulse height analyzer limits.

(2) Calibrate the pulse height analyzer in keV per channel with the pulser or alpha sources.

(3) The alpha particle resolution can then be obtained by measuring the full width at half maximum (fwhm) of the spectrum peak.

4.3.6 Current-Voltage Measurements for Silicon Detectors

The amplifier system is not directly involved in silicon detector current-voltage measurements, but the amplifier serves well to permit noise monitoring during the measurements. The detector noise measurement is a more sensitive method of determining the maximum detector voltage which should be used, because the noise increases more rapidly than the reverse current at the onset of detector breakdown.

Figure 4-6 shows the setup required for current-voltage measurements. The ORTEC Model 210 bias supply is used as the voltage source. Bias voltage should be applied slowly and reduced when noise increases rapidly as a function of applied bias. Figure 4-7 shows several typical current-voltage curves for ORTEC detectors.

4.3.7 Recommended Method for Preamp-Main Amp Gain Adjustment as a Function of Input Particle Energy

With the input energy at a constant, or maximum, known value, the total system gain of the preamp and main amplifier can be adjusted to an optimum value by utilizing the following general considerations.

(1) The primary design criterion for the preamp is best signal-to-noise ratio at the output; therefore, the preamp should be operated with the gain switch in its maximum gain position. This will result in the best signal-to-noise ratio available, and at the same time the absolute voltage amplitude of the preamp signal will be maximized.

(2) The INPUT ATTENUATOR switch on the Model 410 is operationally an attenuator between the preamp output and the main amp (Model 410) input. The INPUT ATTENUATOR switch should be set on 1, i.e., minimum attenuation between the preamp and the main amp. This is a logical operation, since the quality, or signal-to-noise ratio and

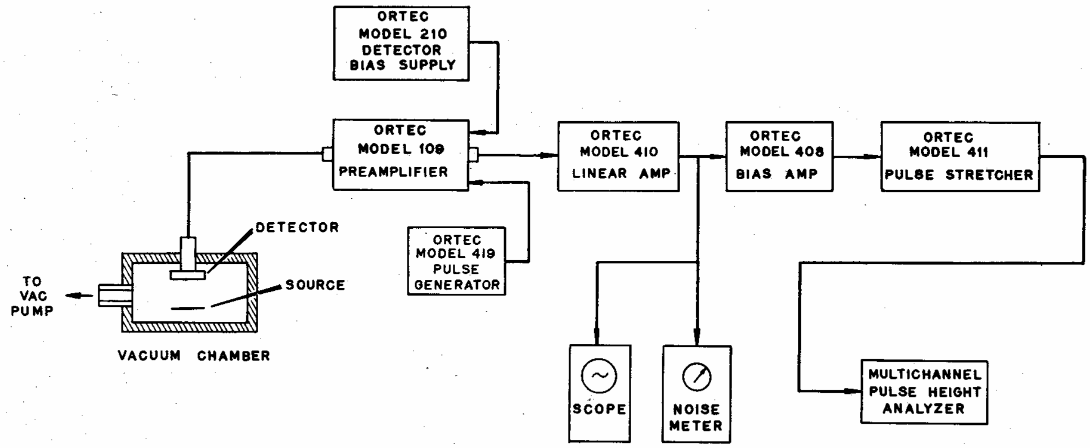

Figure 4-5. High-Resolution Spectroscopy System

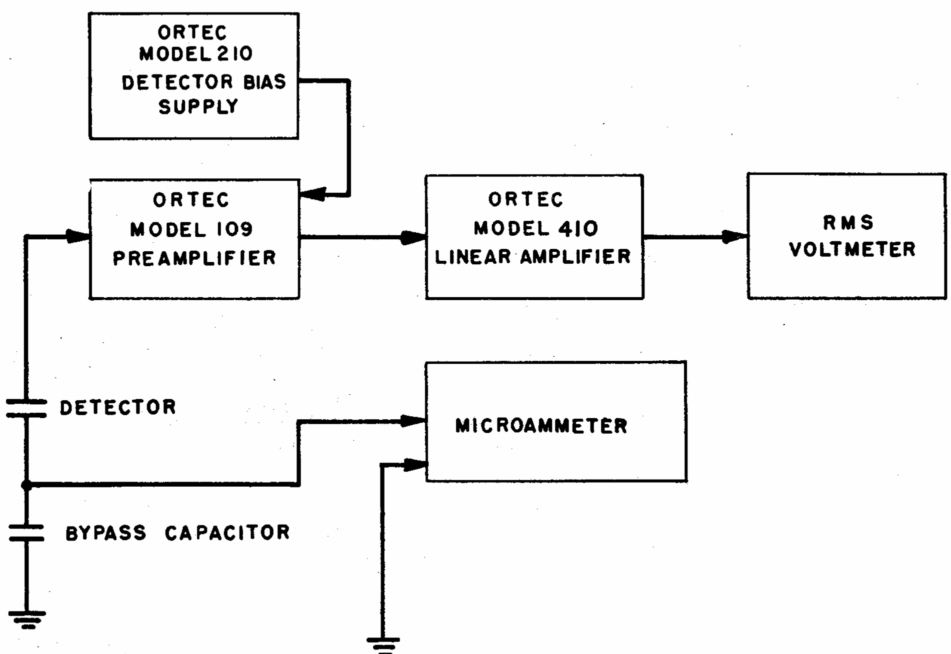

Figure 4-6. Measuring Detector Current-Voltage Characteristics

absolute magnitude of signal, is maximized directly out of the preamp.

(3) The COARSE GAIN switch should be set on 1. This setting results in a total overall system gain that allows the main amplifier to accommodate the total preamp signal in the input section, and yet not overload the output section of the main amplifier.

(4) The setting of the FINE GAIN control is essentially independent of the resulting overall system signal-to-noise ratio, and can be varied over a 1.0 to 3.0 range at the convenience of the experimenter.

(5) Using the above suggestions, if an excess of system gain is found, the INPUT ATTENUATOR control should be increased from its setting of 1. An attenuation factor of about 20 can be inserted with the Model 105 and/or Model 105XL preamp and still result in better energy resolution than by operating the preamp in the low gain position.

(6) If more system gain is needed, the COARSE GAIN switch on the Model 410 must be switched to the 3 or 9 position. Switching from 1 to 9 results in a total gain increase of 9.

Note: <u>It is very important that an effective gain trade-off is not made by switching the preamp gain from X8 to X1 and then switching the COARSE GAIN from 1 to 9. While approximately the same system gain will be available, the capabilities of the preamp signal-to-noise ratio are not taken advantage of in this gain arrangement.</u>

(7) In Section 4.6, tables 4.3 and 4.4, some typical system front panel settings are given. Notice that for a given energy deposition there are a number of front panel settings that will give a system output of 8 volts, but the resulting electronic noise is quite different.

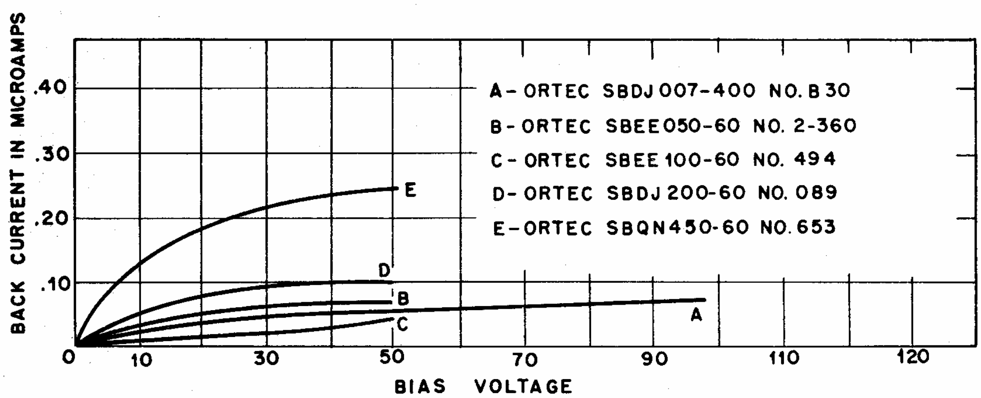

Figure 4-7. Detector Back Current versus Bias Voltage

4.4 Front and Rear Panel Connector Data

The following table contains data on the Model 410 connectors.

Table 4.1
Front and Rear Panel Connector Data

Connector Number (See Drawing 410-0101A-S1)	Generic Designation	Connected to Test Point No. On Front Panel	Pulse Amplitude (Volts) Input/Output	Pulse Duration	Output or Input Impedance (ohms)
PG1	Input	None	See note 1	>50μsec 1/e decay τ	125
PG2	Single Differentiated Linear Amp Output	TP2	Positive 0–12V	Dependent on pulse shaping controls; for D.L. mode, 800 nsec (fwhm)	Approximately 1
PG3	Double Differentiated Linear Amp Output	TP3	Bipolar 0–12V	Dependent on pulse shaping controls; for D.L. mode, 800 nsec (fwhm)	Approximately 1
PG5	Preamp Power Connector		Supplies ±24V, ~+0, preamplifiers such as Models 108, 109, and 113 with the preamp power cable 108-C2. ±12 is also available on Pin 9 and 4.		

Notes: 1. On D. L. mode, 6-millivolt input will produce 8-volt output pulse at PG2.
2. PG2 and PG3 are at dc module chassis ground, but are isolated from the front panel; this isolation prevents the output signal ground currents from flowing on the front panel in close proximity with the input signal BNC connector.

4.5 Typical Operating Conditions

The following table presents information for some typical operating conditions of the Model 410.

Table 4.2
Typical Operating Conditions

Case No.	Desired output, i.e., signal conditioning	Output connector	Amplifier Controls: INPUT POLARITY	COARSE GAIN	FINE GAIN	INPUT ATTENUATOR	INTEGRA-TION	1st DIFF.	2nd DIFF.
1	SRC*	PG2	______	As desired		______	RC time constant as desired		Does not apply
2	DRC	PG3	______	As desired		______	RC time constant as desired		
3	SDL	PG2	______	As desired		______	As desired	DL	Does not apply
4	DDL	PG3	______	As desired		______	As desired	DL	DL
5	Maximum Bandpass	PG2	______	As desired		______	OUT	OUT	Does not apply
6	Dual SRC	PG2 & PG3	______	As desired		______	RC time constant as desired		OUT

*Legend

SRC — Single RC integration and differentiation of input signal.
DRC — Double RC differentiation and single RC integration of input signal.
SDL — Single Delay Line differentiation of input signal; integration of input signal can be set as desired.
DDL — Double Delay Line differentiation of input signal; integration of input signal can be set as desired.

4.6 Typical Resolution vs Front Panel Control Settings With Constant Energy Input

Some typical preamp-main amp front panel settings are given in Tables 4.3 and 4.4. Notice that for a given energy deposition in the detector there are a number of front panel settings that will give an output of 8 volts, but the resulting electronic noise is quite different.

Table 4.3
Typical Models 105-410 Gain Control Settings

Energy deposited in silicon detector for 8V out at Model 410 PG2 (MeV)	Electronic noise (referred to silicon) (keV)	Preamp GAIN	INPUT ATTENUATOR	FINE GAIN	RC shaping time constant (μsec) First & Second DIFF. & INTEG.	COARSE GAIN	Preamp charge sensitivity (referred to silicon) (mV/MeV)
6	4.7	×8	1	1.1	1	1	136
6	6.4	×8	20	3.0	1	9	136
6	7.1	×1	1	1.0	1	9	17
6	7.3	×1	2	2.5	1	9	17
4.8	5.04	×8	1	1.25	2	1	136
4.8	4.7	×8	1	1.25	1	1	136
4.8	4.7	×8	5	2.27	1	3	136
4.8	5.6	×8	10	1.6	1	9	136
4.8	6.6	×1	1	1.2	1	9	17
2	4.6	×8	1	3.0	1	1	136
2	4.6	×8	1	1.1	1	3	136
2	4.98	×8	5	1.9	1	9	136
2	6.25	×1	1	2.8	1	9	17
0.8	4.78	×8	1	2.78	1	3	136
0.8	4.81	×8	2	2.5	1	9	136
	Minimum input energy with PA ×1 Gain for 8.0V output						
1.92	6.19	×1	1	3.0	1	9	17

Table 4.4
Typical Models 105XL-410 Gain Control Settings

Energy deposited in silicon detector for 8V out at Model 410 PG2 (MeV)	Electronic noise (referred to silicon) (keV)	Preamp GAIN	INPUT ATTENUATOR	FINE GAIN	RC shaping time constant (μsec) First & Second DIFF. & INTEG.	COARSE GAIN	Preamp charge sensitivity (referred to silicon) (mV/MeV)
1	2.47	×8	1	1.8	2	1	640
1	2.47	×8	5	3.0	2	3	640
1	2.50	×8	2	1.67	2	3	640
1	2.52	×8	5	1.12	2	9	640
1	2.53	×8	10	2.25	2	9	640
1	2.63	×1	1	1.7	2	9	160
6	2.90	×8	5	1.25	2	1	640
6	2.98	×8	20	2.12	2	3	640
6	2.98	×1	1	1.85	2	1	160
6	3.06	×1	2	1.7	2	3	160
6	4.19	×8	50	1.5	2	9	640
6	4.35	×1	10	2.3	2	9	160
3.4	2.64	×1	1	3.0	2	1	160
1.2	2.55	×1	1	3.0	2	3	160

4.7 Typical System Block Diagrams

This section contains block diagrams illustrating how the Model 410 and other ORTEC 400 Series modules can be used in experimental setups.

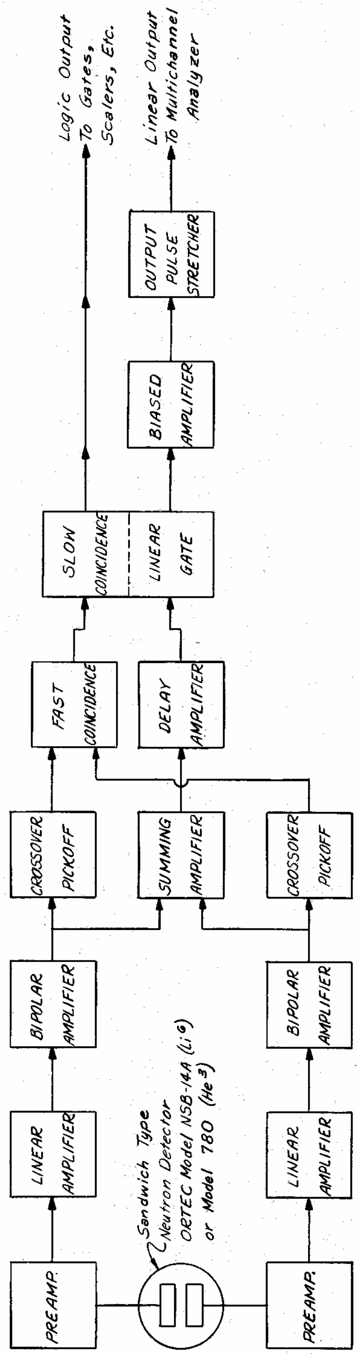

Figure 4-8. Neutron Spectrometer Using Sandwich Detector — Block Diagram

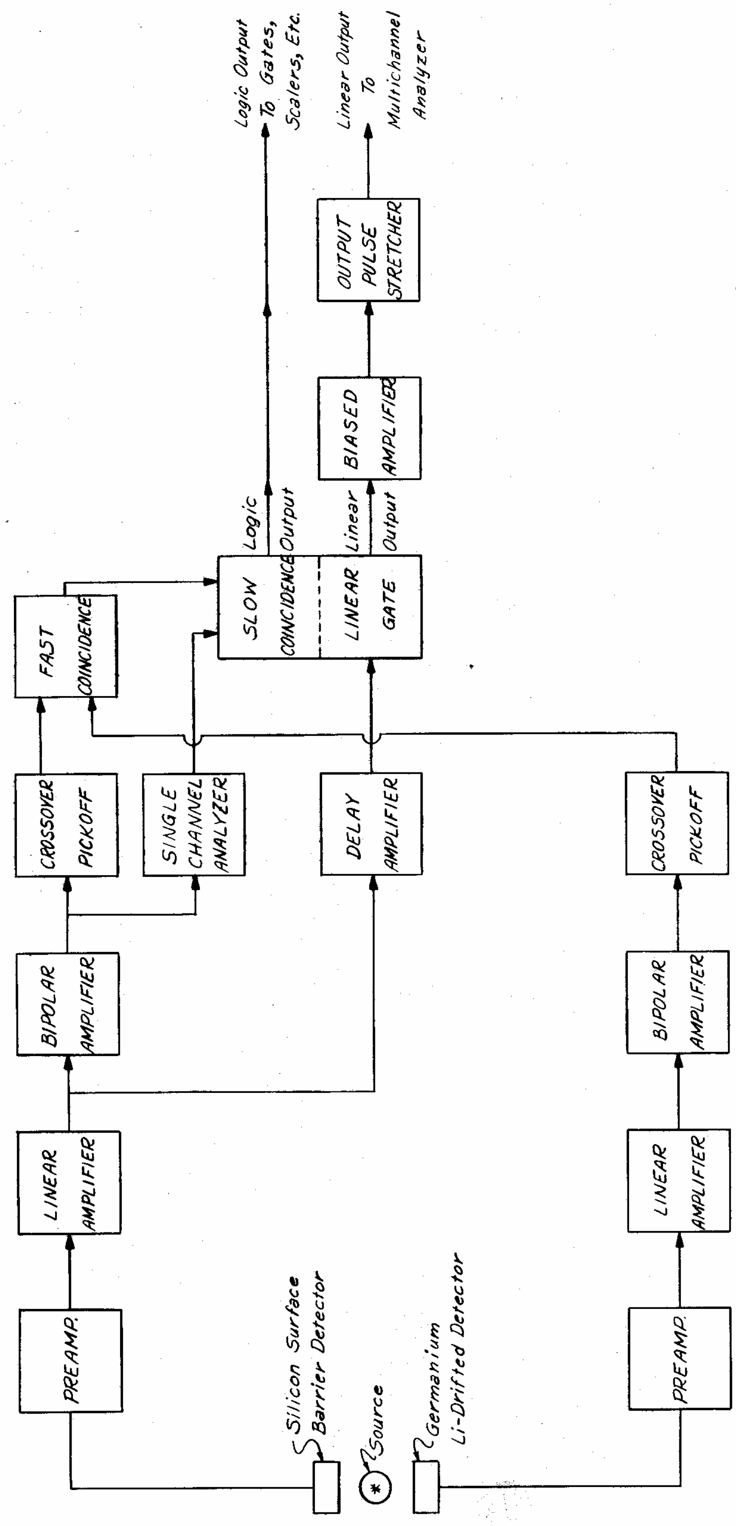

Figure 4-9. Gamma Ray-Charged Particle Coincidence Experiment — Block Diagram

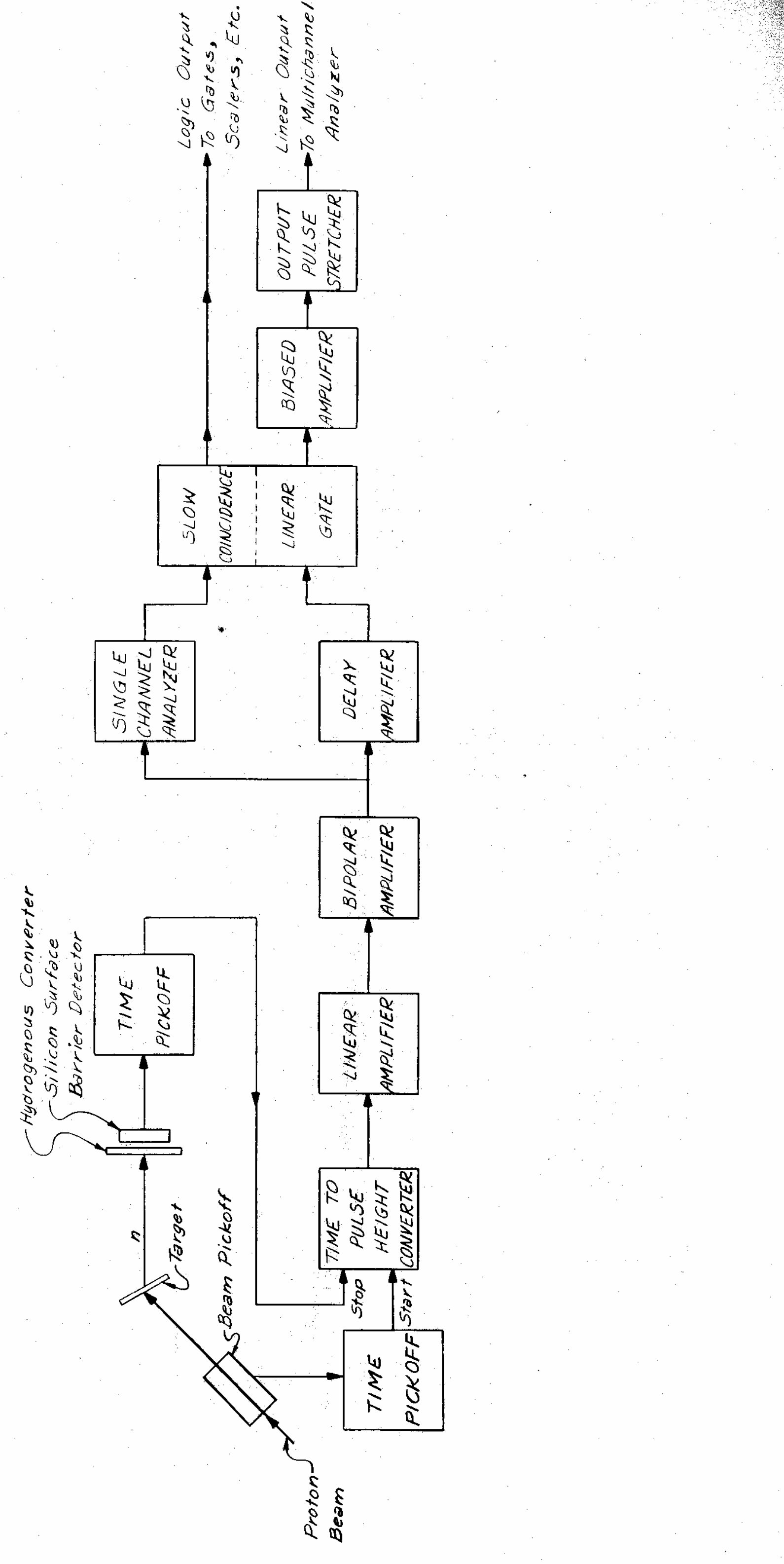

Figure 4-10. Time-of-Flight Neutron Spectrometer—Block Diagram

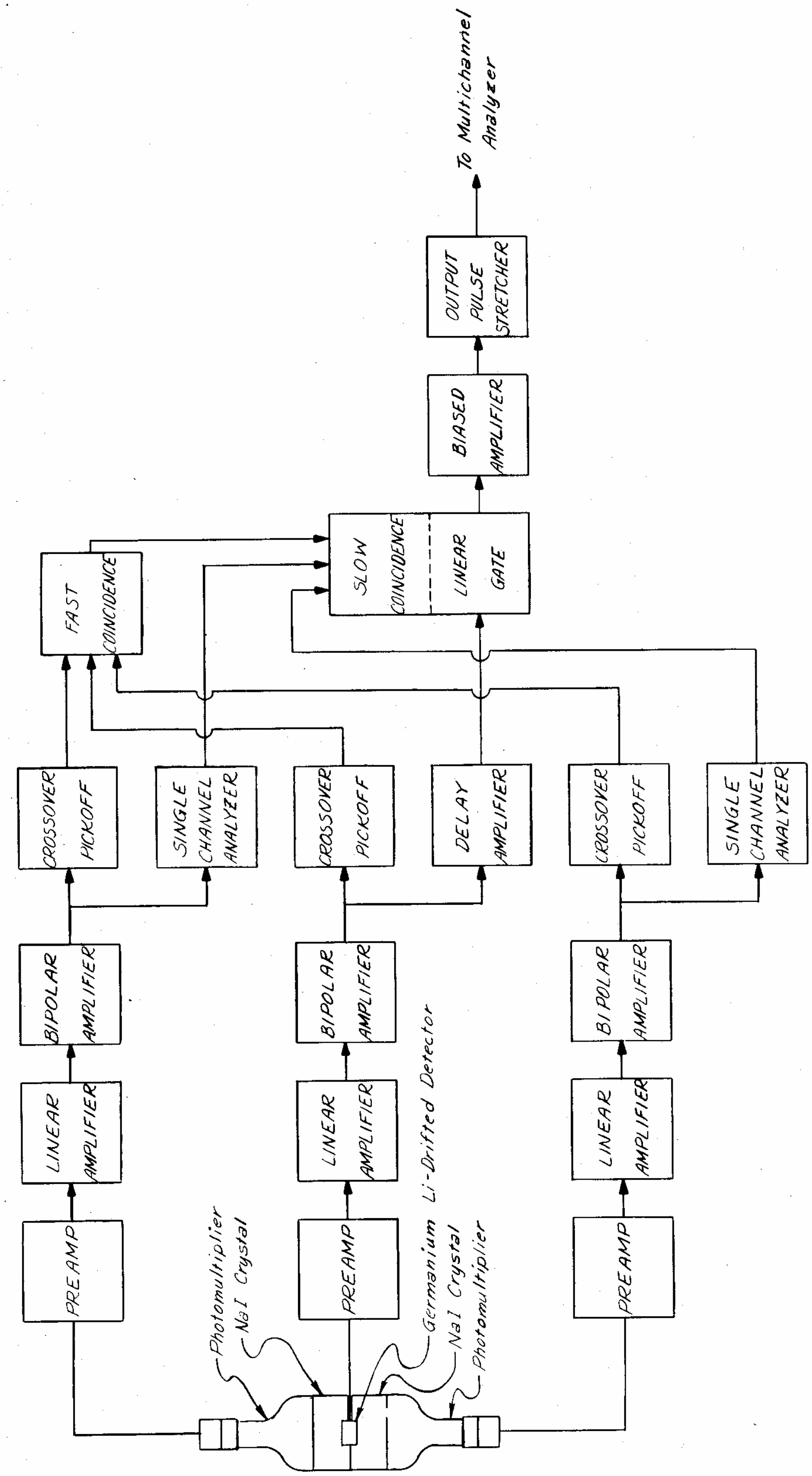

Figure 4-11. Gamma Ray Pair Spectrometer—Block Diagram

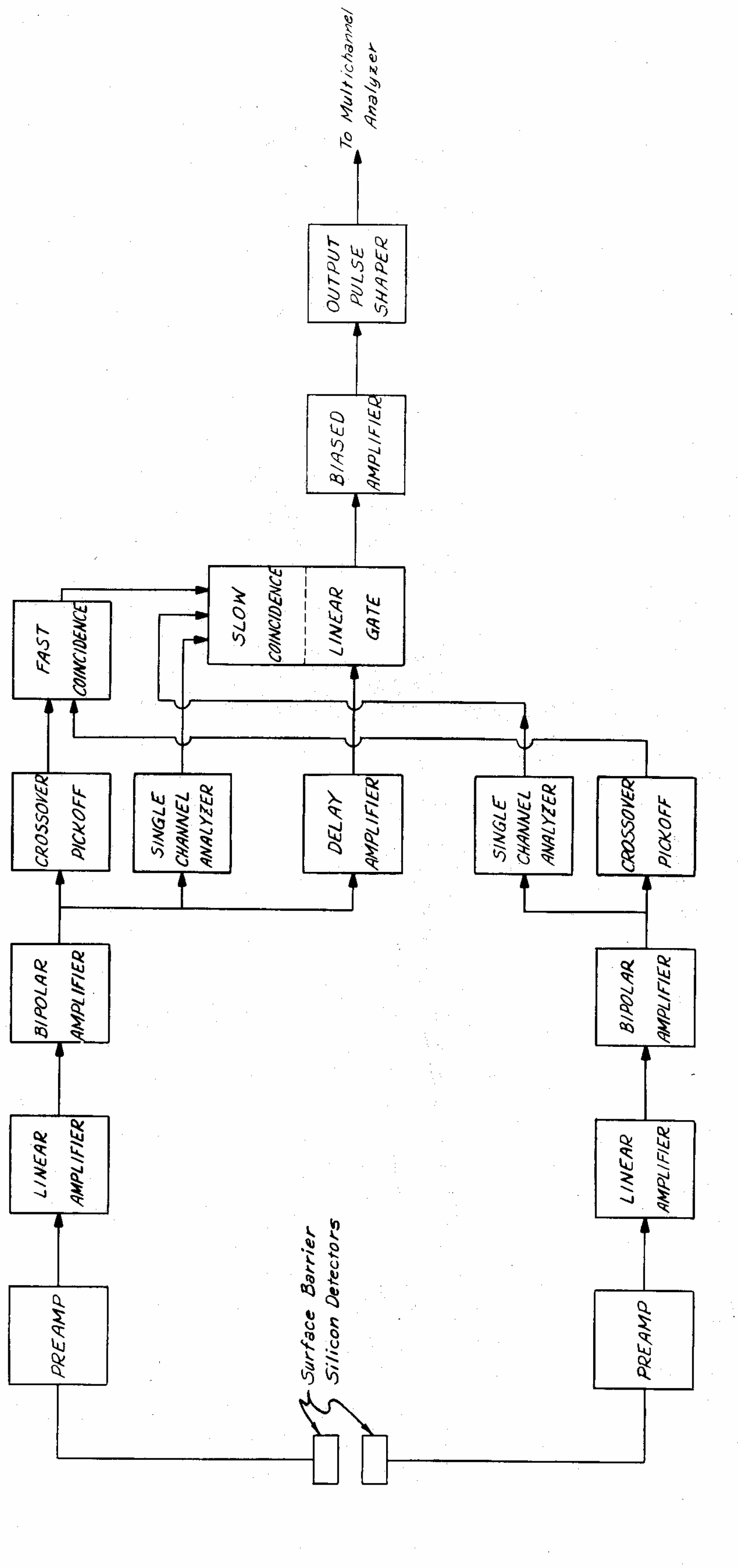

Figure 4-12. Typical Fast-Slow Coincidence System — Block Diagram.

5. CIRCUIT DESCRIPTION

5.1 Basic Function, Linear Amplifier—Etched Board 221-0201

5.1.1 The basic function of the Linear Amplifier is to take the pre-amplifier signal input at PG1 and suitably shape the bandwidth and amplitude so that the input signal will be transformed to a signal suitable for pulse height analysis and available at PG2.

The Linear Amplifier provides three separate and independent gain adjustments. The INPUT ATTENUATOR consists of a 125-ohm input attenuator connected between PG1 and pin 2 of the Linear Amplifier etched board 221-0201. The FINE GAIN adjustment consists of a variable resistor in the feedback loop of the first amplifier stage (Q1 and Q2). The third and final gain control is the COARSE GAIN control which consists of a shunt passive attenuator in the Linear Amplifier main amplifying channel.

5.1.2 The amplifier features independent integration and differentiation time constants. With the integration and differentiation time constants set to OUT on the front panel, the main amplifier is characterized by a bandwidth flat from approximately 670 cycles per second to 3.5 megacycles per second. The high frequency portion of the bandwidth is controlled by the position of the INTEGRATION switch. (See drawings 221-0201A-S1, 221-0201A-B1, and 410-0101-S1.) The integration time constant is varied by selection of a shunt capacitor connected from pin 18 to ground of the Linear Amplifier.

The low frequency response is controlled by the DIFFERENTIATION switch on the front panel, and can be either of two modes, Delay Line (DL) or RC. The differentiation and integration time constants as marked on the front panel correspond to a 1/e time constant. The differentiation time constant is varied by selection of a series RC circuit preceding the summing amplifier, Q7 and Q8.

In Delay Line mode, the pulse width is determined by the one-way transmission time through Delay Line 1. The delay line pulse is formed adding two currents, I_1 and I_2. I_1 and I_2 are equal in amplitude but opposite in polarity, and I_2 is delayed in time by the one-way transmission time of Delay Line 1. The amplifying loop of Q5 and Q6 constitutes an inverting stage with a variable gain (adjustable by R20) that provides the necessary inversion and power gain to drive Delay Line 1, which in turn furnishes the inverted summing current to the summing amplifier, Q7 and Q8. In the RC pulse shaping mode, this loop has its input shorted to ground.

5.1.3 The loop consisting of Q3 and Q4 provides a voltage gain of -1, which allows the amplifier to accept an input signal of either polarity, and give a positive output signal for either case.

While the amplifier is basically designed to give only positive output signals, it will drive negative to approximately 8 volts into 100 ohms.

With the restriction that the amplifier provide only positive output signals, the limiting networks associated with diodes D3, D4, and D5 need only to limit in one direction. The limiting diodes are normally back biased and only conduct when the input signal is large enough to drive the particular stage into saturation. When the input signal becomes large enough to forward bias the diodes, the diodes shunt the feedback resistor in each individual loop and reduce the overall loop gain to a value much smaller than the normal loop gain. It is pointed out that each successive stage consists of npn-pnp, then pnp-npn transistors, so that the input signal always drives the transistor loops into conduction. In Figure 5-1, a typical npn-pnp feedback loop is shown, illustrating both the ac and dc negative feedback. The gain of this stage is simply the ratio of R_f/R_{in}.

5.1.4 The output driver loop consists of Q13, Q14, Q15, and Q16. Q13 and Q15 constitute the typical npn-pnp loop, and drive quite well in the negative direction but not very well in the positive direction. The addition of emitter-follower Q14 in this loop allows the overall loop to drive both positive and negative signals quite easily to plus and minus 11 volts into 100 ohms, but an accidental short circuit of the output would cause Q14 to be destroyed. Thus, to protect Q14, the addition of Q16 is included. The function of Q16 is to provide a method of limiting the average current through Q14 to a value less than that required to destroy Q14. Q16 can supply large peak currents from the collector-capacitor, C35, and these currents flow directly through Q16 and Q14 and thence into the load. In the event of a short circuit on the output, the absolute magnitude of current that can be supplied through Q16 and Q14 from C35 is less than that required to destroy either Q16 or Q14. Capacitor C35 charges back to the B+ voltage through R72 in the absence of any input pulse.

5.2 Bipolar Amplifier—Etched Board 410-0401

5.2.1 The 2nd DIFFERENTIATION switch, S6, and its associated components performs a second differentiation of the signal output from the Linear Amplifier etched board 221-0201A. See drawings 410-0401-B1, 410-0401-S1, and 410-0101-S1. After the differentiation is performed, the signal amplitude is increased by the cascade amplifying loops consisting of Q1 and Q2 and the output driver loop, Q3, Q4, and Q5. The combined gains of these two amplifying loops are such that the output amplitude of the bipolar signal appearing at PG3 is approximately equal to the output of the unipolar signal at PG2. The doubly differentiated delay line signal is generated by the Delay Line, DL2.

5.2.2 The input to the second differentiating network comes from the output of the Linear Amplifier, and since the Linear Amplifier is limited in its maximum output to 12 volts, the bipolar amplifier never receives an overload input signal. With the absence of overload input signals, Delay Line 2 will be subjected to a minimum amount of reflections and mismatches. The doubly differentiated RC shaped signal is generated by the series RC elements between sections of S6 and thence into the input amplifying loop in the bipolar amplifier. The first amplifying loop in the bipolar amplifier is identical to the basic amplifying loops in the Linear Amplifier, and is shown in Figure 5-1. The second loop consists of the standard output driver loop as in the Linear Amplifier, but with the addition of transistor Q7 to regulate the emitter voltage of Q3.

5.2.3 Figure 5-2 illustrates the bipolar output wave shape with double RC (DRC) shaping. The point B is normally used for crossover pickoff timing information, since it has a constant delay from t_o to t_1 as a function of amplitude. Refer to the instruction manual for the Model 407 or Model 420 for information on crossover pickoff timing.

5.3 Delay Line 1—Etched Board 221-0301

Delay Line 1 is used in conjunction with the Linear Amplifier etched board 221-0201 to form the familiar rectangular delay line shaped pulse when the 1st DIFFERENTIATION switch is in the D.L. position. As noted in section 5.1.2, the delay line pulse is formed by adding two currents, I_1 and I_2, at a current summing node. I_1 and I_2 are made equal in amplitude but opposite in polarity, and I_2 is delayed in time by the one-way transmission time of Delay Line 1.

The current summing node is at the base of Q7 on the Linear Amplifier etched board. I_2 is fed into the node directly, and a signal proportional to I_1 is fed into the inverting amplifier, Q5 and Q6. The output of the inverting amplifier is fed into Delay Line 1 where it is delayed by the one-way transmission time of the line. At the end of the transmission delay, the signal current, I_2, is presented at the current summing node and effectively cancels the input current, I_1, resulting in a net current input which produces a rectangular pulse out of the summing amplifier.

Delay Line 1 is terminated in its characteristic impedance at both ends of the delay line for minimum reflections. The signal loss in transmission through the delay line is compensated by adjusting the gain of the inverter amplifier, Q5 and Q6.

5.4 Delay Line 2—Etched Board 221-0401

A bipolar delay line shaped current pulse is produced at the output of etched board 221-0401. This bipolar current pulse is fed into the Bipolar Amplifier for additional current and power gain. (See drawings 410-0401-B1, 410-0401-S1, and 410-0101-S1.)

The bipolar pulse is generated by summing two currents, I_A and I_B, at the input to the Bipolar Amplifier, a current summing node. The current pulse, I_A, is derived from the unipolar output voltage and series resistor R37. This produces a pulse at the Bipolar Amplifier output equal in amplitude to the unipolar output pulse. In parallel with the current pulse, I_A, is a current pulse through R36. This current pulse is proportional to I_A and is fed in series through Delay Line 2 and the inverting amplifier, Q1 and Q2. At the output of the inverting amplifier, the emitter of Q2, is an inverted signal with the same pulse width, and proportional in amplitude to I_A. This signal is delayed with respect to I_A by a time equal to the transmission time of Delay Line 2.

The current, I_B, is formed by the emitter voltage of Q2 and series resistors R38 and R39. The net resultant current flowing into the Bipolar Amplifier, then, is a bipolar current, first positive and then negative. The values of R38 and R39 are adjusted so that the magnitude of the current pulse, I_B, is equal to I_A at the summing node, and therefore produces equal area under the positive and negative portions of the bipolar output pulse, thus minimizing baseline shifting as a function of counting rate.