Model 485
Amplifier
Operating and Service Manual

This manual applies to instruments marked
"Rev 22" on rear panel

Printed in U.S.A.

2947 0.5C 1081

TABLE OF CONTENTS

LIST OF FIGURES

STANDARD WARRANTY FOR EG&G ORTEC INSTRUMENTS

EG&G ORTEC warrants that the items will be delivered free from defects in material or workmanship. EG&G ORTEC makes no other warranties, express or implied, and specifically **NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.**

EG&G ORTEC's exclusive liability is limited to repairing or replacing at EG&G ORTEC's option, items found by EG&G ORTEC to be defective in workmanship or materials within one year from the date of delivery. EG&G ORTEC's liability on any claim of any kind, including negligence, loss or damages arising out of, connected with, or from the performance or breach thereof, or from the manufacture, sale, delivery, resale, repair, or use of any item or services covered by this agreement or purchase order, shall in no case exceed the price allocable to the item or service furnished or any part thereof that gives rise to the claim. In the event EG&G ORTEC fails to manufacture or deliver items called for in this agreement or purchase order, EG&G ORTEC's exclusive liability and buyer's exclusive remedy shall be release of the buyer from the obligation to pay the purchase price. In no event shall EG&G ORTEC be liable for special or consequential damages.

QUALITY CONTROL

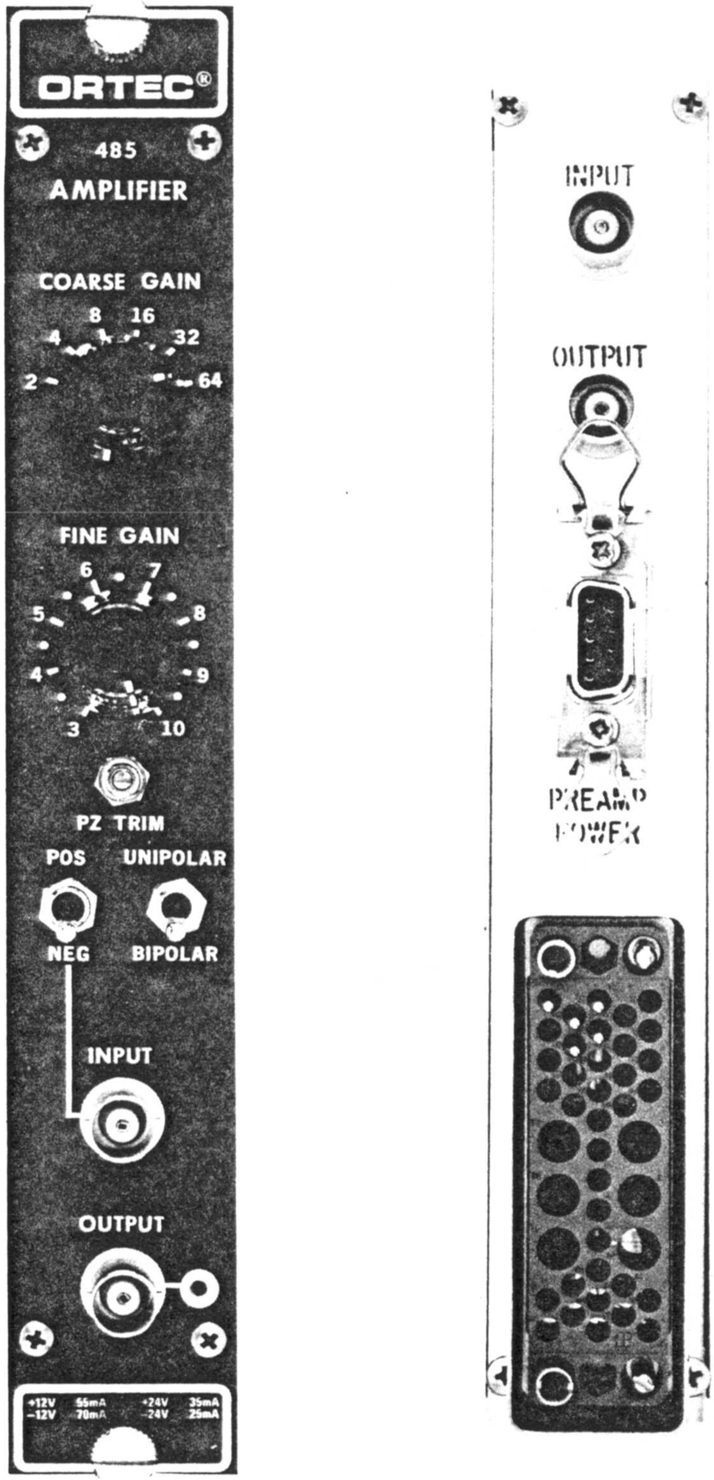
Before being approved for shipment, each EG&G ORTEC instrument must pass a stringent set of quality control tests designed to expose any flaws in materials or workmanship. Permanent records of these tests are maintained for use in warranty repair and as a source of statistical information for design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

REPAIR SERVICE

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, EG&G ORTEC must be informed, either in writing or by telephone [(615) 482-4411], 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 EG&G 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 nearest EG&G 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 will be repaired at the standard charge unless they have been grossly misused or mishandled, in which case the user will be notified prior to the repair being done. A quotation will be sent with the notification.

DAMAGE IN TRANSIT

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


ORTEC®
485
AMPLIFIER
COARSE GAIN
8 16
4 32
2 64
FINE GAIN
6 7
5 8
4 9
3 10
PZ TRIM
POS
UNIPOLAR
NEG
BIPOLAR
INPUT
OUTPUT
+12V 55mA +24V 35mA
−12V 70mA −24V 25mA
INPUT
OUTPUT
PREAMP
POWER

ORTEC 485 AMPLIFIER

1. DESCRIPTION

1.1. GENERAL

The ORTEC 485 Amplifier is of a functional design utilizing integrated circuits to provide a general-purpose amplifier at minimum cost. The low input noise, dynamic gain range, and pulse-shaping networks allow operation with semiconductor detectors and scintillation detectors in a wide variety of applications. The performance capability of the 485 coupled with its low cost will allow a wide range of uses in such fields as research, counting rooms, monitoring applications, and instructional laboratories.

The instrument has a single linear output that can be switch selected for either unipolar or bipolar pulse shape. The first differentiation network has variable pole-zero cancellation that can be adjusted to match preamplifiers with greater than 40-μsec decay times. Excellent overload performance is accomplished by the use of pole-zero techniques. In addition, the amplifier contains an active-filter shaping network which optimizes the signal-to-noise ratio and minimizes the overall resolving time.

The 485 can be used for crossover timing when used in conjunction with an ORTEC 407 Crossover Pickoff or a 420A Timing Single Channel Analyzer. The output of the 420A has a minimum of walk as a function of pulse amplitude and incorporates a variable delay time on the output pulse to enable the crossover pickoff output to be placed in time coincidence with other outputs.

The 485 has complete provisions, including power, for operating any ORTEC solid-state preamplifier such as the 109A, 113, 120, 124, and 125. Preamplifier pulses should have a rise time of 0.25 μsec or less to properly match the amplifier filter network and a decay time of greater than 40 μsec for proper pole-zero cancellation.

The input impedance is 1000Ω. When long preamplifier cables are used, the cables can be terminated in series at the preamplifier end or in shunt at the amplifier end with the proper resistance.

The output impedance of the 485 is about 0.5Ω. The output can be connected to other equipment either by a single cable going to all equipment and shunt terminated at the far end (and series terminated at the amplifier if reflections are a problem) or by separate cables to each instrument, with each cable series terminated at the amplifier (see Section 3.5).

Gain changing is accomplished by constant-impedance T attenuators. By using this technique, the bandwidth of the feedback amplifier stages involved in gain switching remains essentially constant regardless of gain, and therefore rise time changes with gain switching (which cause crossover walk) are limited to small capacitance effects across the attenuators.

The 485 is a NIM-standard single-width module. The unit has no self-contained power supply; power is obtained from a NIM-standard Bin and Power Supply such as the ORTEC 401A/402A. The 485 design is consistent with other modules in the ORTEC Modular Nuclear Instrumentation Series; i.e., it is not possible to overload the Bin power supply with a full complement of ORTEC modules in the Bin. Since twelve 485 amplifiers can be contained and powered in one Bin and Power Supply, the 485 is particularly suited to experiments requiring many amplifiers.

1.2. POLE-ZERO CANCELLATION

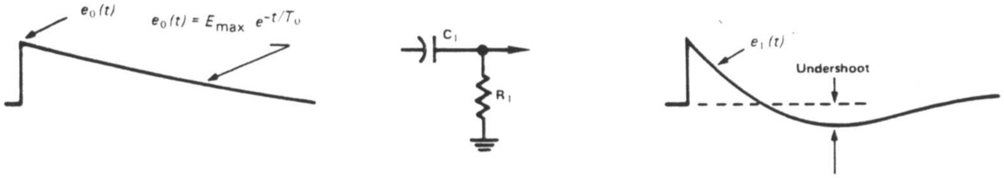
Pole-zero cancellation is a method for eliminating pulse undershoot after the first differentiating network. The technique employed is described by referring to the waveforms and equations shown in Figs. 1.1 and 1.2. In an amplifier that does not have pole-zero cancellation, the exponential tail on the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

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

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

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

Total preamplifier — amplifier pole-zero cancellation requires that the preamplifier output pulse decay time be a



Charge loop output X First differentiate network = Differentiated pulse with undershoot

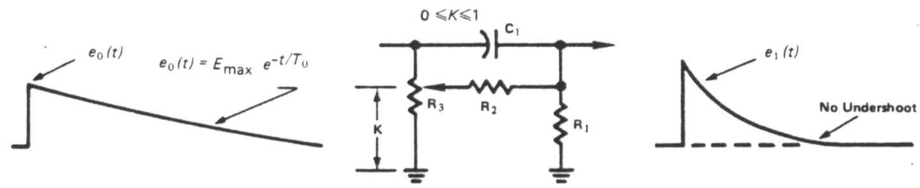
$E_{max}\, e^{-t/T_0} \times G(t) = e_1(t)$.

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

$\frac{E_{max}}{T_0 - T_1}\, T_0\, e^{-t/T_0} - T_1\, e^{-t/T_0} = e_1(t)$, where $T_1 = R_1 C_1$.

200409

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



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

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

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

Pole zero cancel by letting

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

or

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

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

200410

Fig. 1.2. Differentiation (Clipping) in a Pole-Zero-Cancelled Amplifier.

single exponential decay and matched to the pole-zero-cancellation network. The variable pole-zero-cancellation network allows accurate cancellation for all preamplifiers having 40 μsec or greater decay times. The network is factory adjusted to 50 μsec, which is compatible with all ORTEC FET preamplifiers. Improper matching of the pole-zero-cancellation network will degrade the overload performance and cause excessive pile-up distortion at medium counting rates. Improper matching causes either an undercompensation (undershoot is not eliminated) or an overcompensation (output after the main pulse does not return to the baseline and decays to the baseline with the preamplifier time constant). The pole-zero trim is accessible from the front panel of the 485 and can easily be adjusted by observing the baseline with a monoenergetic source or pulser having the same decay time as the preamplifier under overload conditions.

1.3. ACTIVE FILTER

When only grid current and shot noise (gate current and drain thermal noise for a FET) are considered, the best signal-to-noise ratio occurs when the two noise contributions are equal for a given pulse shape. Also at this point, there is an optimum pulse shape for the optimum signal-to-noise ratio. Unfortunately, this shape (the cusp shown in Fig. 1.3) is not physically realizable and is very difficult to simulate. A pulse shape that can be simulated (the Gaussian in Fig. 1.3) requires a single RC differentiate and n equal-RC integrates, where n approaches infinity. The Laplace transform of the transfer function is

$$G(s) = \frac{s}{s + \frac{1}{RC}} \times \frac{1}{\left(s + \frac{1}{RC}\right)^n} \qquad n \to \infty ,$$

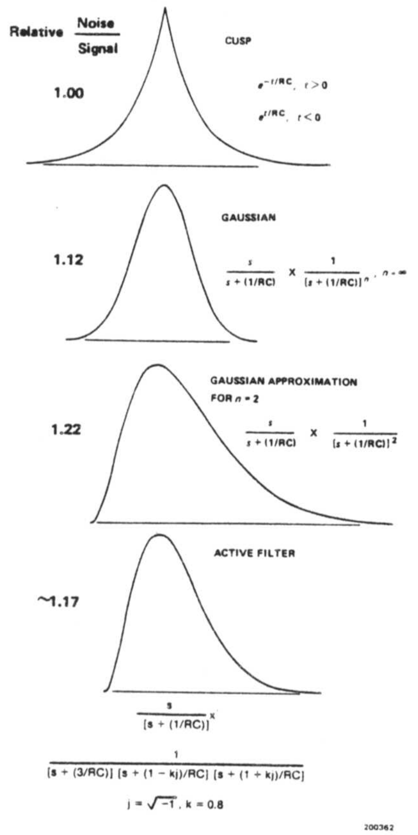


Fig. 1.3. Pulse Shapes for Good Signal-to-Noise Ratios.

where the first term is the single differentiate and the second term is the n integrates. The 485 active filter attempts to simulate this transfer function with the simplest possible circuit.

The 485 active-filter circuit is shown in Fig. 1.4. The major attraction of the active RC filter is the simple synthesis of a complex pulse shape resulting in a significant reduction in size, complexity, and cost. For a given resolving time (RC), the time response of the filter network depends on K (see the circuit equations in Fig. 1.4). For $K = 1$, the transfer function simplifies to

$$\frac{e_o}{e_i} = \frac{\frac{1}{R^2C^2}}{s^2 + \frac{2s}{RC} + \frac{1}{R^2C^2}} = \frac{\frac{1}{R^2C^2}}{\left(s + \frac{1}{RC}\right)^2},$$

which is an $n = 2$ approximation to the Gaussian pulse shape (see Fig. 1.3).

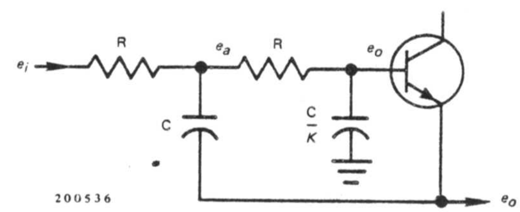
For $K = 2$ (the actual case for the ORTEC filter), the transfer function becomes

$$\frac{e_o}{e_i} = \frac{\frac{2}{R^2C^2}}{s^2 + \frac{2s}{RC} + \frac{2}{R^2C^2}} = \frac{\frac{2}{R^2C^2}}{s + \frac{1+j}{RC} \quad s + \frac{1-j}{RC}}$$

$$j = \sqrt{-1}.$$

In this case the complex roots cause an underdamped effect which reduces the resolving time and results in a more symmetrical pulse shape (see Fig. 1.3).

The 485 is manufactured with 1-μsec time constants (R = 1000Ω, C = 1000 pF, and C/K = 500 pF). These time constants can be changed to suit the experiment. See Section 5.3 for details on this modification.



Equations:

$$e_o = e_a \frac{\frac{K}{sC}}{R + \frac{K}{sC}} = e_a \frac{K}{K + sRC}$$

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

Eliminating e_a and solving for the transfer function:

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

Fig. 1.4. ORTEC 485 Active Filter.

2. SPECIFICATIONS

PERFORMANCE

SHAPING Active network filter resulting in approximately Gaussian shape, peak amplitude at 1.5 μsec for unipolar and 1.1 μsec for double clip; crossover at 2.5 μsec for bipolar.

MAXIMUM GAIN 640.

LINEARITY ±0.15% over specified linear range.

NOISE 10 μV at maximum gain and single clip, 12 μV at maximum gain and double clip, both referred to input.

SHORT-CIRCUIT LIMITS Amplifier will sustain a direct short on the output for an indefinite period for counting rates up to 10^4 Hz.

COUNTING RATE <0.5% gain shift and 0.25% resolution spread FWHM for a pulser peak above a 50,000-count/sec ^{137}Cs background.

OVERLOAD Recovery within 2% of rated output from 600 times overload in 2.5 nonoverloaded pulse widths (25 μsec) at maximum gain and specified input.

CROSSOVER WALK ±3 nsec for 10:1 dynamic range with 1-μsec bipolar shaping (including Amplifier and ORTEC 420 Timing Single Channel Analyzer).

TEMPERATURE STABILITY 0.02%/°C, 0 to 50°C.

CONTROLS

FINE GAIN Provides a dynamic range of 3:1; selectable from X3 through X10, continuously variable.

COARSE GAIN A rotary switch with binary selection covers range of X2 to X64 in 6 steps.

UNIPOLAR-BIPOLAR Either unipolar or bipolar output pulses are switch selectable. The gains are matched in both modes to ~±2.5%.

PZ-TRIM A trim potentiometer permits pole-zero-cancellation network to be adjusted for varying preamplifier decay times.

POS-NEG A switch to accommodate either positive or negative input signals from a preamplifier.

INPUT

Front-panel type BNC connector for preamplifier pulses having either polarity. Input pulse should have <0.25 μsec rise time for best filter action, 40 μsec minimum decay time for pole-zero cancellation, 12 V maximum, 6 V maximum to prevent saturation before differentiation, 1000Ω impedance, dc-coupled.

OUTPUT

Front-panel type BNC connector provides low-impedance shaped output, with a test probe adjacent for oscilloscope monitoring. Unipolar or bipolar, 0 to 10 V linear with 11.5 V saturation into 1000Ω; 0 to 9 V linear with 10 V saturation into 100Ω; 0.5Ω output impedance.

ELECTRICAL AND MECHANICAL

POWER REQUIRED
+24 V, 35 mA; +12 V, 50 mA;
−24 V, 35 mA; −12 V, 70 mA.

WEIGHT (Shipping) 5 lb (2.27 kg).

WEIGHT (Net) 2 lb (0.91 kg).

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

3. INSTALLATION

The 485, used in conjunction with the 401A/402A Bin and Power Supply, is intended for rack mounting; therefore vacuum tube equipment operating in the same rack with the 485 must be sufficiently cooled with circulating air to prevent any localized heating of the all-semiconductor circuitry used throughout the 485. The temperature of equipment mounted in racks can easily exceed 120°F (50°C).

3.1. CONNECTION TO PREAMPLIFIER

The preamplifier output signal is connected to the 485 BNC connector CN1, labeled Input. The input impedance at the input is 1000Ω and is dc-coupled to ground; therefore the output of the preamplifier must be either ac-coupled or have no dc voltage under no-signal conditions.

The 485 incorporates pole-zero cancellation in order to enhance its overload characteristics. This technique requires matching the network to the preamplifier decay-time constant in order to achieve perfect compensation. The network is variable and factory adjusted to 50 μsec to match all ORTEC FET preamplifiers. If another preamplifier is used or if more careful matching is desired, the trim is accessible from the front panel. Adjustment is easily accomplished by using a monenergetic source and observing the amplifier baseline after each pulse overload condition.

Preamplifier power of +24 V, -24 V, +12 V, and -12 V is available on the preamplifier power connector, CN3.

When using the 485 with a remotely located preamplifier (i.e., preamplifier-to-amplifier connection through 25 ft or more of coaxial cable), ensure that the characteristic impedance of the transmission line from the preamplifier output to the 485 input is matched. Since the input impedance of the 485 is 1000Ω, sending-end termination will normally be preferred; i.e., the transmission line should be series terminated at the output of the preamplifier. All ORTEC preamplifiers contain series terminations that are either 93Ω or variable.

3.2. CONNECTION OF TEST PULSE GENERATOR TO THE 485

Through a Preamplifier The satisfactory connection of a test pulse generator such as an ORTEC 419 or 448 or equivalent depends primarily on two considerations: the preamplifier must be properly connected to the 485 as discussed in Section 3.1, and the proper input signal simulation must be applied to the preamplifier. To ensure proper input signal simulation, refer to the instruction manual for the particular preamplifier being used.

Direct Connection Since the input impedance of the 485 is 1000Ω, 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 required, since the input of the 485 is dc-coupled to the first amplifier stage. The ORTEC 419 and 448 Test Pulse Generators are designed for direct connection. When either of these units is used, it should be terminated with a 100Ω terminator at the amplifier input. (The small error due to the finite input impedance of the amplifier can normally be neglected.)

Special Considerations for Pole-Zero Cancellation The pole-zero-cancellation network in the 485 is factory adjusted for a 50-μsec decay time to match ORTEC FET preamplifiers. When a tail pulser (such as the 419 or 448) is connected directly to one of the amplifier inputs, the pulser should be modified to obtain a 50-μsec decay time if overload tests are to be made (other tests are not affected). See Section 6.2 for details on this modification. If a preamplifier is used and a tail pulser connected to the preamplifier pulser input, similar precautions are necessary. In this case, the effect of the pulser decay must be removed; i.e., a step input should be simulated. Details for this modification are given in Section 6.2.

3.3. CONNECTION TO POWER

The 485 contains no internal power supply but must obtain power from a Nuclear-standard Bin and Power Supply such as the 401A/402A. Turn power off when inserting or removing modules. The ORTEC Modular Nuclear Instrument Series is designed so that it is not possible to overload the Bin power supply with a full complement of modules in the Bin. This may not be true when the Bin contains modules other than those of ORTEC design; in this case, check the Power Supply voltages after inserting the modules. The 401A/402A has test points on the Power Supply control panel to monitor the dc voltages.

3.4. OUTPUT CONNECTIONS AND TERMINATION

The 485 linear output can be switch selected for either a unipolar or a bipolar output. The unipolar output should be used for high-resolution spectrometry applications with semiconductor detectors. The bipolar output should be used in applications requiring high counting rates or crossover timing. Typical system block diagrams for a variety of experiments are described in Section 4.

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

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

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

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

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

3.5. SHORTING THE AMPLIFIER OUTPUT

The output of the 485 is ac-coupled with an output impedance of about 0.5Ω. If the output is shorted with a direct short-circuit and the amplifier counting rate exceeds 10,000 counts/sec, the output stage will eventually heat up sufficiently to destroy itself (about 1 min for 10^5 counts/-sec). The amplifier output may be shorted indefinitely without catastrophic damage at rates below 10^4 counts/sec.

4. OPERATING INSTRUCTIONS

4.1. CONTROLS AND CONNECTORS

FINE GAIN A single-turn fine gain control is provided for a dynamic range of 3:1. The Fine Gain factor is selectable from X3 through X10.

COARSE GAIN Coarse Gain control is provided by a rotary switch. The binary selector switch covers the range of X2 to X64.

UNIPOLAR-BIPOLAR Either unipolar or bipolar output pulses are switch selectable. The gains are matched in both modes to approximately ±2.5%.

P-Z TRIM A trim potentiometer permits the pole-zero-cancellation network to be adjusted for varying preamplifier decay times.

INPUT A front-panel BNC connector for preamplifier pulses having either polarity. Preamplifier pulses should have less than 0.25 μsec rise time and a 50-μsec decay time.

POS-NEG A switch to accommodate either positive or negative input signals from a preamplifier.

OUTPUT A front-panel BNC connector providing a low impedance shaped output, with a test probe adjacent for oscilloscope monitoring.

PREAMP A connector providing ±12 and ±24 V for preamplifier power. This furnishes direct compatibility for all ORTEC transistor and FET preamplifiers.

FRONT- AND REAR-PANEL CONNECTOR DATA See Table 4.1.

4.2. INITIAL TESTING AND OBSERVATION OF PULSE WAVEFORMS

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

4.3. OPERATION WITH SEMICONDUCTOR DETECTORS

Calibration of Test Pulser The ORTEC 419, 448, or 480 Precision Pulse Generators 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 semi-

Table 4.1

Connector*	Generic Designation	Test Point	Output or Input Impedance	Shape and Amplitude Limitations
CN1	Input	No	1000Ω	Positive or negative; <0.25 μsec rise time and 50 μsec decay time recommended, although faster rise and slower decay times can be handled; 6 V maximum linear, 12 V absolute maximum
CN2	Output	TP-1	0.5Ω	Positive or bipolar, 0-10 V linear with 11.5 V saturation into 1000Ω, 0-9 V linear with 10 V saturation into 100Ω, approximate Gaussian shape
CN3	Preamp Power	No	dc	Pin 1 Ground Pin 6 -24 V Pin 7 +24 V Pin 9 -12 V Pin 4 +12 V

*See Dwg. 485-0101-S1.

conductor radiation detector. The procedure utilizing the 419 is as follows:

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

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

3. Adjust the amplifier 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 alpha particles striking the detector (e.g., for a 5.1-MeV alpha particle, set the dial at 510 divisions).

5. Turn on the pulser and use the Normalize potentiometer and the attenuators to set the output due to the pulser to the same pulse height as the pulse obtained in step 3.

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

Amplifier Noise and Resolution Measurements As shown in Fig. 4.1, the preamplifier, amplifier, pulse generator, oscilloscope, and a wide-band rms voltmeter such as the Hewlett-Packard 400D are required for this measurement. Connect a suitable capacitor to the input to simulate the detector capacitance. To obtain the resolution spread due to amplifier noise measure the rms noise voltage (E_{rms}) at the amplifier output. Then turn on the pulse generator and adjust the pulser output to any convenient readable voltage, E_0, as determined by the oscilloscope. The full

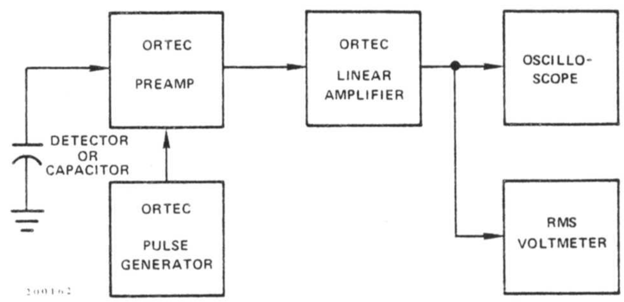


Fig. 4.1. Electronics for Measuring Amplifier and Detector Noise Resolution.

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

$$N(\mathrm{FWHM}) = \frac{2.660\, E_{rms}\, E_{dial}}{E_0},$$

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 the noise to rms meter correction is 1.13 for average-indicating voltmeters such as the Hewlett-Packard 400D. A true rms voltmeter does not require the latter correction factor.

The resolution spread will depend upon the total input capacitance, since the capacitance degrades the signal-to-noise ratio much faster than the noise. A typical resolution spread versus external input capacitance for a 118A-485 system is shown in Fig. 4.2. The same general curve is applicable with the 109A-485 system, although the intercept on the keV axis will be higher.

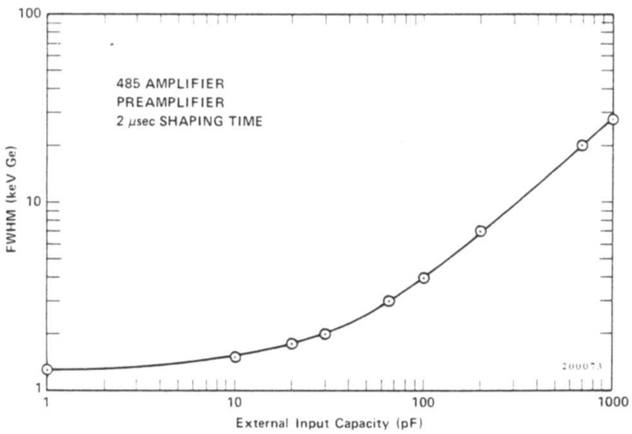


Fig. 4.2. Resolution Spread vs External Input Capacity.

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

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

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

The detector noise tends to increase with bias voltage but the detector capacitance decreases, thus reducing the resolution spread. The overall resolution spread will depend upon which effect is dominant. Figure 4.3 shows curves of typical total noise resolution spread versus bias voltage, using the data from several ORTEC silicon semiconductor radiation detectors.

Amplifier Noise and Resolution Measurements Using a Pulse-Height Analyzer Probably the most convenient method of making resolution measurements is with a pulse-height analyzer as shown by the setup illustrated in Fig. 4.4.

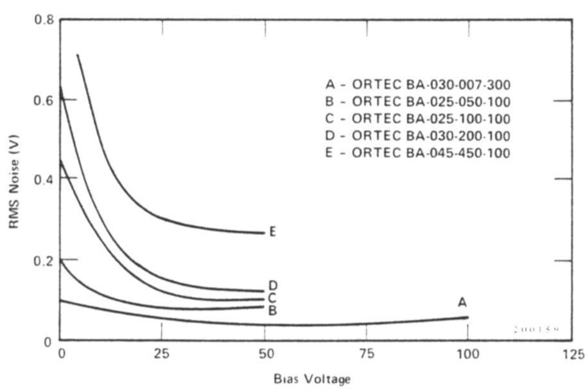


Fig. 4.3. Amplifier and Detector Noise vs Bias Voltage.

The amplifier noise resolution spread can be measured directly with a pulse-height analyzer and the mercury pulser as follows: Select the energy of interest with an ORTEC Pulse Generator, and set the Active Filter Amplifier and Biased Amplifier Gain and Bias Level controls on an ORTEC 444 Gated Bias Amplifier so that the energy is in a convenient channel of the analyzer. Then calibrate the analyzer in keV per channel, using the pulser (full scale on the pulser dial is 10 MeV when calibrated as described in "Calibration of Test Pulser"). The amplifier noise resolution spread can then be obtained by measuring the FWHM of the pulser spectrum.

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

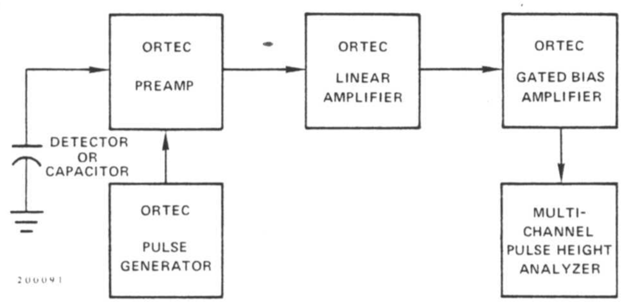


Fig. 4.4. Electronics for Measuring Resolution with a Pulse Height Analyzer.

Current-Voltage Measurements for Silicon and Germanium Detectors The amplifier system is not directly involved in semiconductor detector current-voltage measurements, but the amplifier serves well to permit noise monitoring during the measurements. The detector noise measurement is a more sensitive method of determining the maximum detector voltage that should be used, because the noise increases more rapidly than the reverse current at the onset of detector breakdown.

Figure 4.5 shows a typical setup required for current-voltage measurements. The ORTEC 428 Bias Supply is used as the voltage source. Bias voltage should be increased slowly and should be reduced when noise increases rapidly as a function of applied bias. Figure 4.6 shows several typical current-voltage curves for ORTEC silicon detectors.

When it is possible to float the microammeter at the detector bias voltage, the alternate method of detector

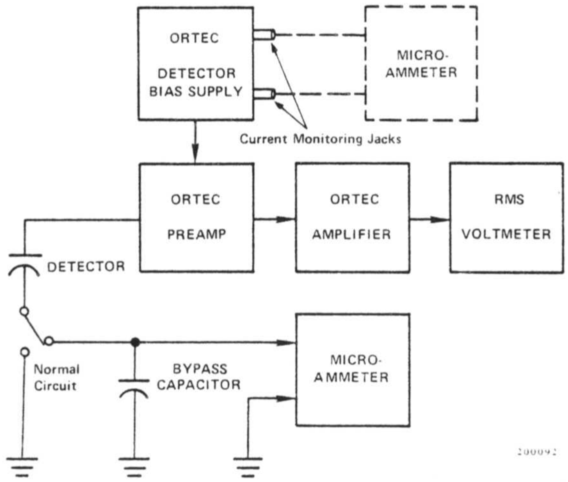


Fig. 4.5. Electronics for Measuring Detector Current-Voltage Characteristics.

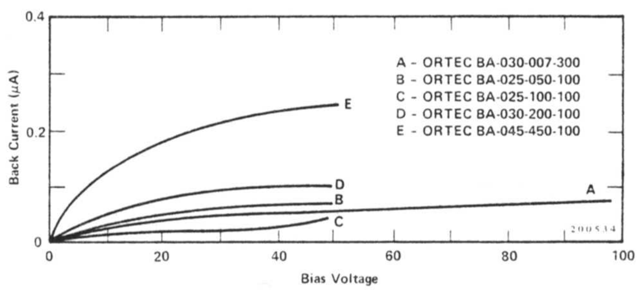


Fig. 4.6. Silicon Detector Back Current vs Bias Voltage.

current measurement shown by the dashed lines in Fig. 4.5 is preferable. The detector is grounded as in nominal operation, and the microammeter is connected to the current monitoring jack on the 428 Detector Bias Supply.

Recommended Method for Preamplifier-Main Amplifier Gain Adjustments as a Function of Input Particle Energy With the input energy at a constant, or maximum, known value the total system gain of the preamplifier and main amplifier can be adjusted to an optimum value by utilizing the following general considerations: The primary design criterion for the preamplifier is the best signal-to-noise ratio at the output; therefore the preamplifier 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 preamplifier signal will be maximized.

4.4. OPERATION IN SPECTROSCOPY SYSTEMS

High-Resolution Alpha-Particle Spectroscopy System A typical block diagram of a high-resolution spectroscopy system for measuring natural alpha particles is shown in Fig. 4.7. Since natural alpha-particle radiation only occurs above several MeV, an ORTEC 444 Gated Biased Amplifier is used to suppress the unused portion of the spectrum and to shape the output pulses after biasing to avoid pulse-height-analyzer nonlinearities.

Alpha-particle resolution is obtained in the following manner:

1. Using maximum preamplifier gain, medium amplifier gain, and minimum biased amplifier gain and bias level, accumulate the alpha peak in the multichannel analyzer.

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

3. Calibrate the analyzer in keV per channel using the pulser and the known energy of the alpha peak (see "Calibration of Test Pulser").

The resolution can be obtained by measuring the FWHM of the alpha peak in channels and converting to keV.

High-Resolution Gamma Spectroscopy System A block diagram of a high-resolution gamma system is shown in

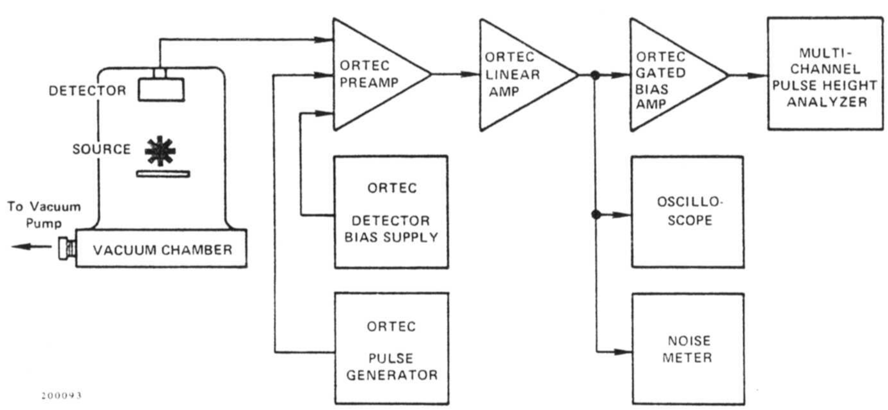


Fig. 4.7. Block Diagram of High-Resolution Alpha-Particle Spectroscopy System.

Fig. 4.8. Although a biased amplifier is not shown, it can be used if only an analyzer with fewer channels is available and only higher energies are of interest.

When using lithium-drifted germanium detectors cooled by a liquid nitrogen cryostat, it is possible to obtain resolutions from about 1 keV FWHM up (depending on the energy of the incident radiation and the size and quality of the detector). Reasonable care is required to obtain such results. Some guide lines for obtaining optimum resolution are the following:

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

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

3. Operate in amplifier and preamplifier gain regions that provide the best signal-to-noise ratio.

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

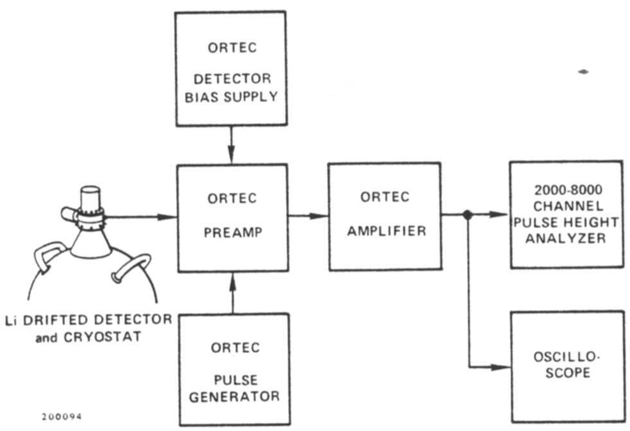


Fig. 4.8. High-Resolution Gamma Spectroscopy System Using a Lithium-Drifted Germanium Detector.

Scintillation-Counter Gamma Spectroscopy Systems The 485 can be used in scintillation-counter spectroscopy systems as shown in Fig. 4.9. The amplifier clipping time constants are proper for NaI or plastic scintillators. For scintillators having longer decay times the time constants must be changed (see Section 5.3).

X-Ray Spectroscopy Using Proportional Counters Space charge effects in proportional counters operated at high gas amplification tend to drastically degrade the resolution capabilities at x-ray energies, even at relatively low counting

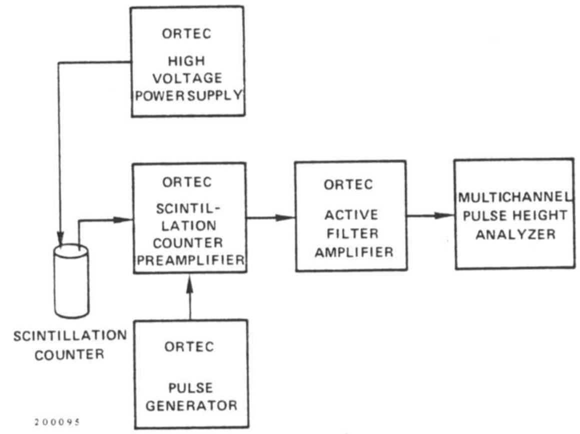


Fig. 4.9. Block Diagram of ORTEC Amplifier Used in a Scintillation-Counter Gamma Spectroscopy System.

rates. By using a high gain, low-noise amplifying system and lower gas amplification, these effects can be reduced and a considerable improvement in resolution can be obtained. The block diagram in Fig. 4.10 shows a system of this type. Analysis can be accomplished by simultaneous acquisition of all data on a multichannel analyzer or counting a region of interest in a single-channel analyzer window with a scaler and timer or counting rate meter.

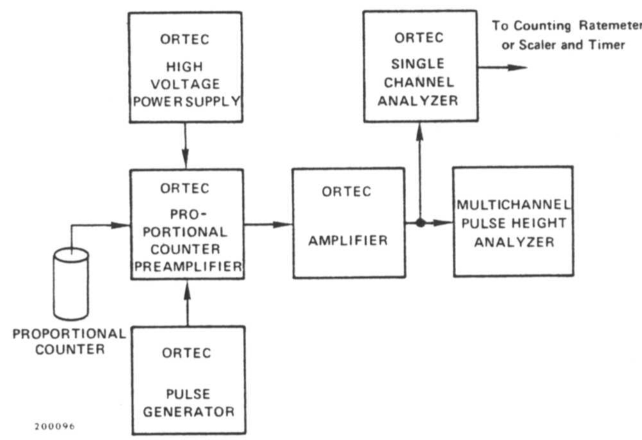


Fig. 4.10. High-Resolution X-Ray Spectroscopy System.

4.5. TYPICAL SYSTEM BLOCK DIAGRAMS

The block diagrams in Figs. 4.11–4.13 illustrate how the 485 and other ORTEC Modular Nuclear Instrument Series modules can be used in experimental setups. The quality of the experimental results, of course, depends on the individual instrumental capabilities.

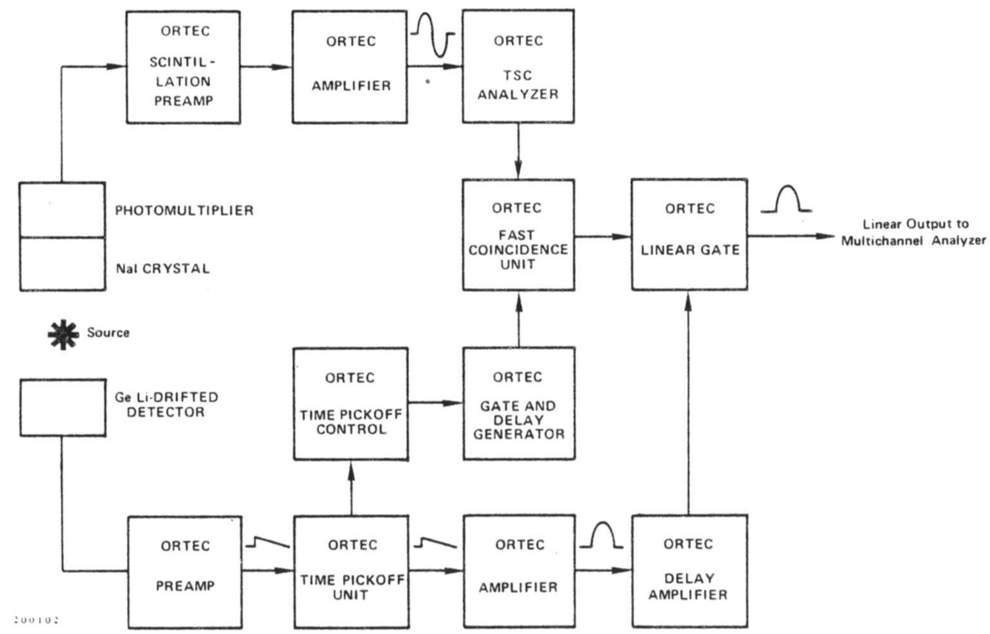


Fig. 4.11. Block Diagram for Gamma-Gamma Coincidence Experiment.

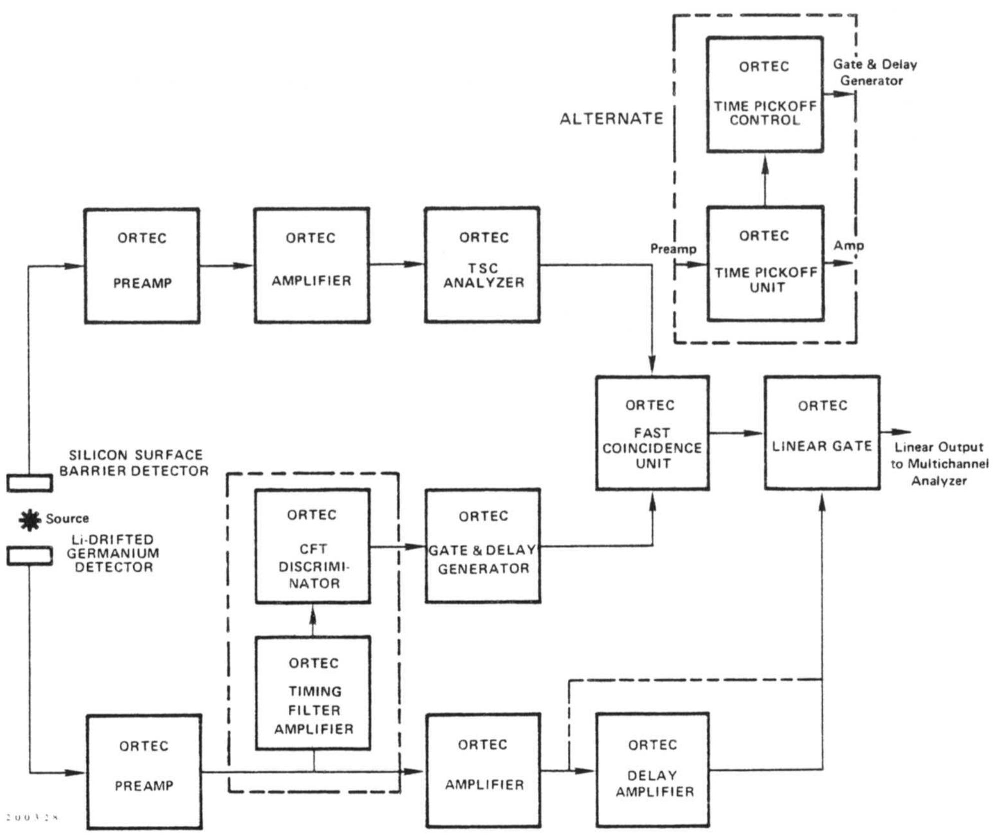


Fig. 4.12. Block Diagram for Gamma-Ray Charged-Particle Coincidence Experiment.

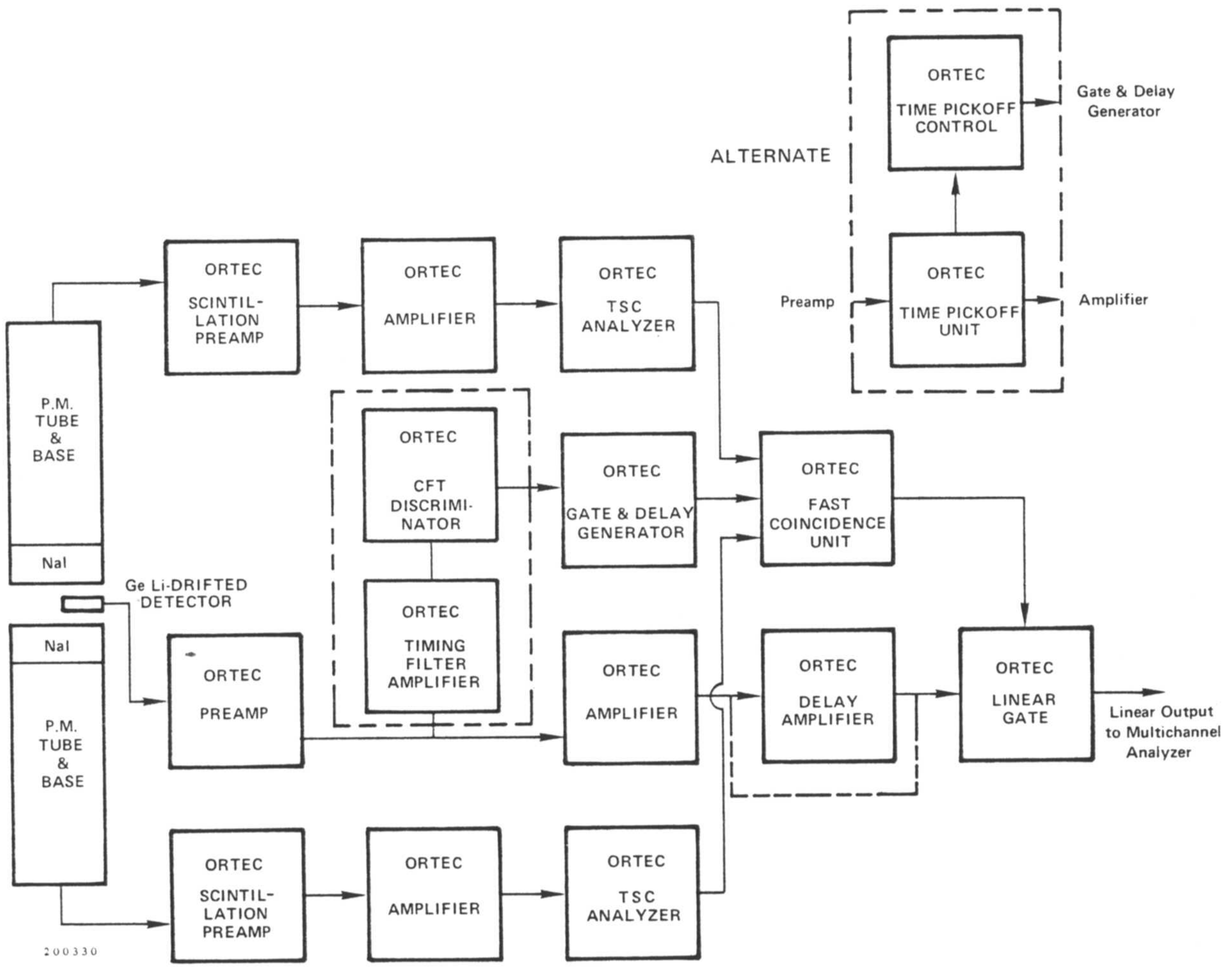


Fig. 4.13. Block Diagram of Three ORTEC 485 Amplifiers Used in a Gamma-Ray Pair Spectrometer.

5. CIRCUIT DESCRIPTION

5.1. GENERAL BLOCK DIAGRAM

The 485 Amplifier contains four basic gain stages as shown in the block diagram in Fig. 5.1. The input stage provides the function of polarity inversion and additional amplification before the first clip to improve the noise characteristics of the amplifier.

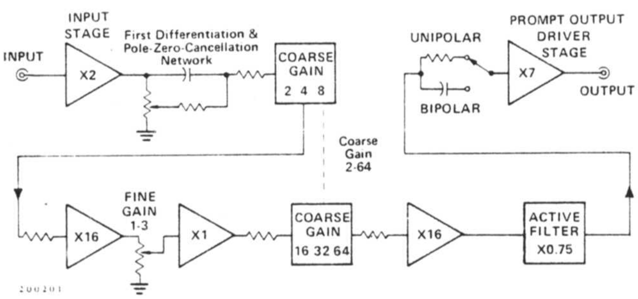


Fig. 5.1. Block Diagram of 485 Amplifier.

Two gain stages are integrated circuit amplifiers that provide wide-band gain. Gain changing is accomplished by constant-impedance T attenuators and a constant-impedance potentiometer. The variable pole-zero-cancelled first clipping network is between the input stage and the first attenuator.

The active filter was described in general in Section 1.3. The filter is followed by the unipolar-bipolar switch, which allows a choice of either unipolar or bipolar clipped pulses. A resistor in the unipolar path compensates for the added loss in the bipolar path and results in essentially equal amplitude output for either shaping mode.

The output driver stage provides the additional gain necessary to raise the maximum linear output to 10 V. The stage also has sufficiently low output impedance to drive terminated or unterminated connecting cables.

5.2. CIRCUIT DESCRIPTION

Input Stage Referring to the circuit diagram (Dwg. 485-0101-S1), the input stage consists of a long-tail differential amplifier, Q1 and Q2, driving a common-emitter output stage, Q3. The output is fed back to the input through R11 and C4. Zener diode D3 regulates the voltage level for Q2C and Q3E.

When the negative Input is used, the base voltage at Q2 follows the input voltage at the base of Q1. The positive Input is terminated in 100Ω under this condition and the gain is then $R11/(R_1 + R_2)$.

Pole-Zero-Cancelled First Clip The pole-zero-cancelled first differentiate consists of C5, R14, and R13. For pole-zero cancellation

$$\frac{R_{13}C_5}{K} = \tau_{\text{preamp}} \quad \frac{R_{13}(R_{14} + R_{24})}{R_{13} + R_{14} + R_{24}}, \; C_5 = \tau_{\text{diff}},$$

where τ_{preamp} is the input decay-time constant (50 µsec), τ_{diff} is the differentiation time constant (1 µsec), and K is the fractional trim potentiometer resistance ratio ($0 \leqslant K \leqslant 1$). The derivation of these equations is discussed in Section 1.2.

Constant-Impedance Attenuators The attenuators employed are constant-impedance T attenuators. The formulas for these attenuators are given in Fig. 5.2.

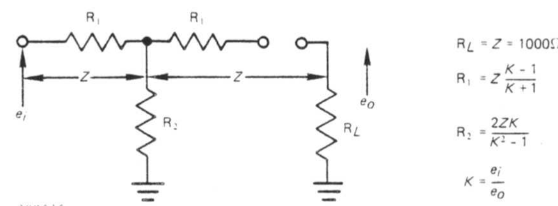


Fig. 5.2. ORTEC 485 Attenuator Networks.

Gain Stages Both gain stages utilize integrated circuit differential amplifiers in operational amplifier feedback circuits. The circuit has an open loop gain of greater than 1000 and a gain-bandwidth product greater than 1000 MHz. The integrated circuit contains a differential amplifier input driving a grounded emitter amplifier with an emitter follower output. The dc input and output levels of the stages (IC-1 and IC-2) are at approximate ground. Phase lag roll-off networks between pins 1 and 14 and between 9 and 10 are necessary for amplifier stability.

Capacitor C11 is shown in its preferred location which is from pins 8 and 12 of IC1 to pin 3 on the same integrated circuit. In case of oscillation of IC1, capacitor C11 is removed from its preferred location and is connected between pin 10 of IC1 and ground at point "A".

Active Filter The basic active-filter circuit is described in detail in Section 1.3. The filter network requires a unity gain amplifier, which consists of emitter-follower Q8 and the constant-current source Q9. An additional integration stage consists of the filter R51, C20, and Q7.

Prompt Output Driver Stage The output driver stage consists of a grounded emitter amplifier Q10, with a high-impedance constant-current load Q11, and a dc-offset cancelling emitter-follower-quad consisting of Q12, Q13, Q14, and Q15. The output is fed back to the input by R73. The dc level potentiometer R61 is used to adjust the dc output to zero volts.

5.3. CIRCUIT MODIFICATIONS FOR SPECIAL APPLICATIONS

Clipping and Integration Time Changes In order to obtain optimum noise performance, both the clipping and integration times should be changed if a narrower or wider pulse is desired. To determine the proper values (for a new resolving time T_r) use the following formulas:

First Differentiate

1. Keep R14 the same (1000Ω).
2. Change C5 and R13 to
   C5 R13 = 40 µsec (for 40-µsec minimum pole-zero adjustment).

$$C5\ \frac{R_{13}\ (R_{14} + R_{24})}{R_{13} + R_{14} + R_{24}} = T_r$$

Second Differentiate

1. Keep R58 and R59 constant.
2. Change C25 to C25 · R59 = T_r.

Active Filter

1. Keep R53 and R54 constant.
2. Change C23 and C45 to
   C23 · R53 = T_r
   C45 = C23/2.

Operation with a resolving time less than T_r = 0.3 µsec is not recommended.

Removing the Pole-Zero-Cancellation Network The pole-zero-cancellation network at the first clip can be removed by simply adjusting the wiper to the ground side of the PZ trim potentiometer.

Removing the Output Isolation Capacitors When the dc-level trim potentiometer is properly adjusted, the Output Driver Stage output is at zero dc voltage. Therefore capacitors C31, C32, and C33 isolating the output driver stage from the Output can be replaced by a wire (short across the capacitors), resulting in a dc-coupled output.

With this dc-coupled condition, the output will still sustain a direct short without catastrophic damage. The maximum counting rate at which the amplifier will sustain a short will be limited to 1000 counts/sec for long-duration shorts and to 10^4 counts/sec for 1-min shorts.

6. MAINTENANCE

6.1. TEST EQUIPMENT REQUIRED

In order to adequately test the specifications of the 485, the following equipment should be utilized:

ORTEC 419, 448, or 480 Pulse Generator
Tektronix 580 Series Oscilloscope with a Type 82 plug-in
Hewlett-Packard 400D RMS Voltmeter

6.2. PULSER MODIFICATIONS FOR OVERLOAD TESTS

The variable pole-zero cancellation incorporated in the 485 has been factory adjusted to 50 µsec. When the 419, 448, or 480 Pulse Generator is used to check overload, it should be modified as shown in Fig. 6.1. With this configuration only minor adjustments of the pole-zero cancellation are necessary to compensate for the fall time of the pulse generator.

If the pulser output is fed into a charge-sensitive preamplifier such as the ORTEC 109A through a small capacitor to simulate the output of a semiconductor detector, the decay time of the pulser will cause an additional pole in the transform equation of the preamplifier output. This additional pole will degrade any overload measurements. In

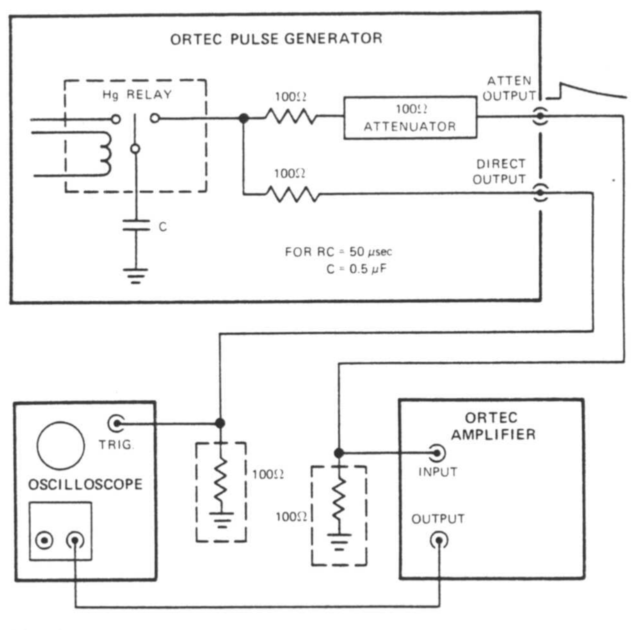


Fig. 6.1. Pulser Modification for Overload Tests.

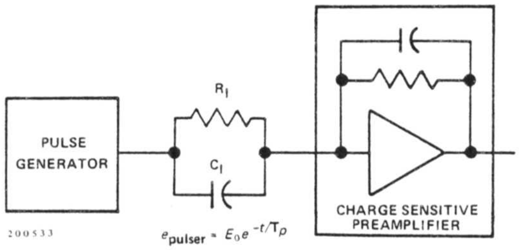


Fig. 6.2. Pulser Pole-Zero Cancellation.

order to eliminate the pole, the pulser must be pole-zero-cancelled as shown in Fig. 6.2.

6.3. PULSER TESTS AND CALIBRATION

Amplitude Matching of Unipolar and Bipolar Outputs Using a positive pulser output and the test setup shown in Fig. 6.1, adjust the output for approximately 10 V and observe the output change between unipolar and bipolar shaping. The change should be no greater than approximately 0.5 V.

Gain Switching Accuracy Obtain a 10-V output with maximum gain (Coarse Gain at 64). Decrease the amplifier gain to X32, X16, X8, X4, and X2, using the Coarse Gain rotary switch. The gain should decrease by one half for each step in gain.

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

Overload Capability With the amplifier on maximum gain, obtain a 10-V output. Increase the pulser amplitude by X500 and observe that the output returns to the baseline in less than 27 μsec. An external voltage source to the pulser is required in order to obtain an approximate 6-V pulser output on X500 overload. The pulser decay time must match the pole-zero-cancellation network time constant (see Section 6.2) in order to perform this test.

Linearity The integral nonlinearity can be measured by the technique shown in Fig. 6.3. In effect, the negative pulser output is subtracted from the positive amplifier output, causing a null point that can be measured with high sensitivity. The pulser amplitude must be varied between 0 and 10 V (using an external voltage source for the pulser), and the amplifier gain and pulser attenuators must be adjusted to give zero voltage at the null point with a 10-V output. The variation in the null point as the pulser is varied from 10 V to zero is a measure of the nonlinearity. Since the subtraction network also acts as a voltage divider, this variation must be less than

(10 V full scale) x (±0.15% max nonlinearity) x (1/2 for divider network) = ±7 mV max null point variation.

A diode clamp at point C is recommended to avoid null-point changes due to oscilloscope saturation.

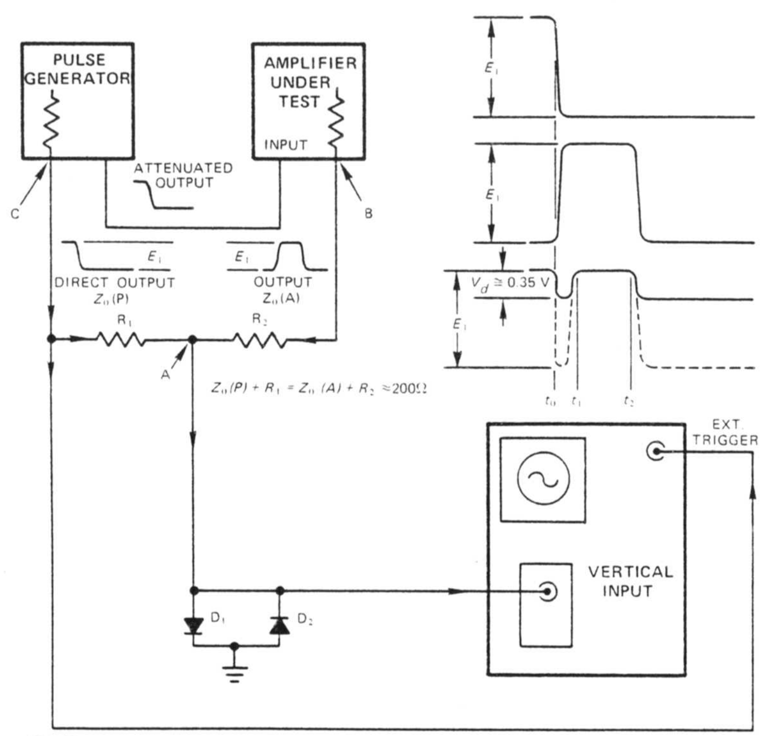


Fig. 6.3. Method for Measuring Nonlinearity.

Output Loading With the same setup as that just described, adjust the amplifier output to 8 V and observe the null-point change when the output is terminated in 100Ω. The change should be less than 50 mV.

Crossover Walk with Amplitude With the setup of Fig. 6.4, obtain a 10-V amplifier output at minimum amplifier gain. Attenuate the pulser by X10, using only the pulser attenuator switches. The shift in the 420A Timing Single Channel Analyzer should be less than ±3 nsec. The Walk Adj trim potentiometer on the 420A must be properly adjusted in order to make this measurement (see 420A manual).

Noise Measure the noise at the amplifier output at maximum amplifier gain using the RMS voltmeter for unipolar and bipolar pulses. The noise should be less than

10 μV x 640 gain x 1.13 = 7.3 mV for unipolar outputs,
12 μV x 640 gain x 1.13 = 8.7 mV for bipolar outputs.

The 1.13 is a correction factor for the average reading voltmeter and would not be required for a true rms voltmeter. The input must be terminated in 100Ω and polarity set to Pos for this measurement.

6.4. TABULATED TEST POINT VOLTAGES

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

Location	Typical dc Voltages*
Emitter Q3	- 15.9
Collector Q3	- 0.028
Pin 12 IC 1	+ 0.05
Pin 12 IC 2	+ 0.5
Emitter Q8	+ 1.5
Junction R70 – R71**	0

*DC voltages at module must be +12.0 ±0.1, -12.0 ±0.1, +24.0 ±0.2, -24.0 ±0.2 V.

**Can be adjusted by trim potentiometer R61.

6.5. REPAIR SERVICE

The 485 can be returned to the ORTEC factory for repair service at nominal cost. Our standard procedure requires that each repaired instrument receive the same extensive quality control tests that a new instrument receives. Always contact Customer Repair Service at (615) 482-4411 before returning any instrument.

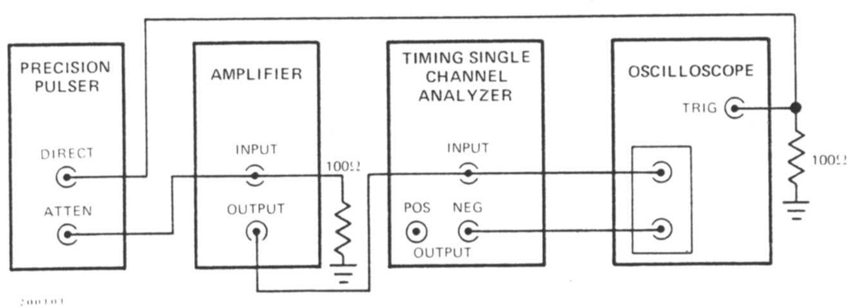


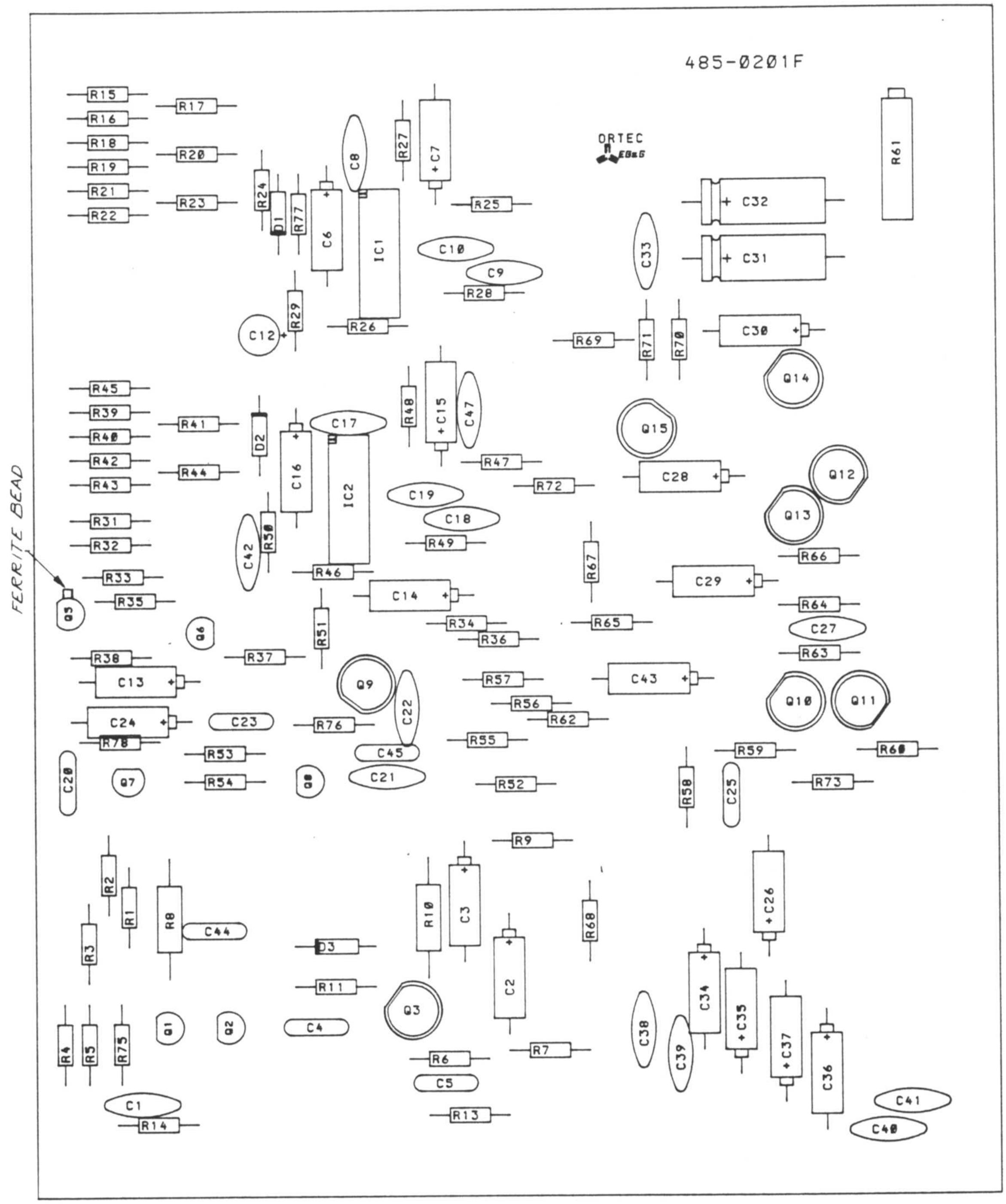
Fig. 6.4. Method for Measuring Crossover Walk.

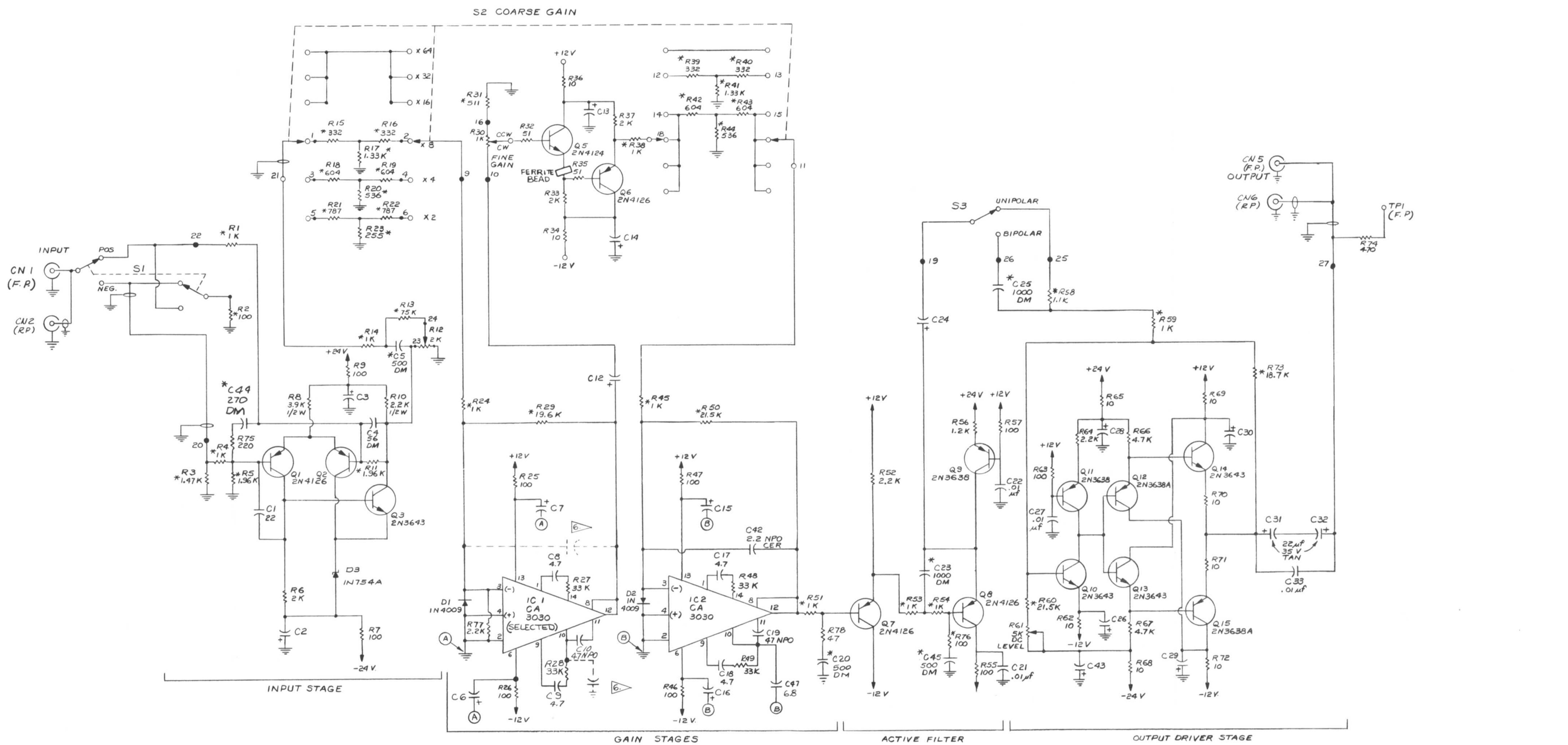
BIN/MODULE CONNECTOR PIN ASSIGNMENTS FOR AEC STANDARD NUCLEAR INSTRUMENT MODULES PER TID-20893 (Rev 4) (adopted by DOE)

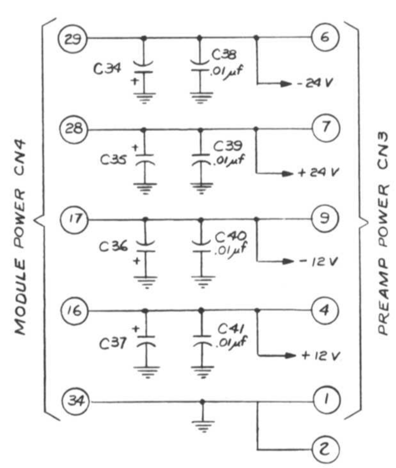
Pin	Function	Pin	Function
1	+3 volts	23	Reserved
2	−3 volts	24	Reserved
3	Spare Bus	25	Reserved
4	Reserved Bus	26	Spare
5	Coaxial	27	Spare
6	Coaxial	*28	+24 volts
7	Coaxial	*29	−24 volts
8	200 volts dc	30	Spare Bus
9	Spare	31	Spare
*10	+6 volts	32	Spare
*11	−6 volts	*33	115 volts ac (Hot)
12	Reserved Bus	*34	Power Return Ground
13	Spare	**35	Reset (Scaler)
14	Spare	**36	Gate
15	Reserved	**37	Reset (Auxiliary)
*16	+12 volts	38	Coaxial
*17	−12 volts	39	Coaxial
18	Spare Bus	40	Coaxial
19	Reserved Bus	*41	115 volts ac (Neut.)
20	Spare	*42	High Quality Ground
21	Spare	G	Ground Guide Pin
22	Reserved		

Pins marked (*) are installed and wired in EG&G ORTEC's 4001A, 4001B, 401A, and 401B Modular System Bins.

Pins marked (*) and (**) are installed and wired in EG&G ORTEC-HEP M250/N and M350/N NIMBINS.


485-Ø2Ø1F
ORTEC
EG&G
FERRITE BEAD
R15
R16
R18
R19
R21
R22
R17
R2Ø
R23
R24
D1
R77
C6
C8
IC1
R27
+ C7
R25
C1Ø
C9
R28
R29
C12
R26
C33
+ C32
+ C31
R61
C3Ø
R69
R71
R7Ø
Q14
R45
R39
R4Ø
R42
R43
R41
R44
D2
C16
C17
IC2
R48
+ C15
C47
Q15
R47
R72
C28
Q12
Q13
C19
C18
R31
R32
R5Ø
C42
R49
R46
R67
R66
R33
R35
Q5
C14
C29
R64
Q6
R51
R34
R36
R65
C27
R63
R38
R37
C13
Q9
C22
R57
C43
R56
Q1Ø
Q11
C24
R78
C23
R76
R62
R55
C45
R53
R59
R6Ø
C2Ø
Q7
R54
Q8
C21
R52
R58
C25
R73
R9
R2
R1
R8
R3
C44
D3
R1Ø
C3
C2
R68
+ C26
R11
Q3
C34
+ C35
C38
C39
+ C37
C36
R4
R5
R75
Q1
Q2
C4
R6
R7
C5
C1
R14
R13
C41
C4Ø





NOTES:
UNLESS OTHERWISE SPECIFIED:-

1. RESISTOR VALUES IN OHMS, 1/4 W.
2. RESISTORS MARKED * ARE 1% METAL FILM. (T-O)
3. CAPACITORS MARKED * ARE SILVER MICA 2%.
4. ALL POLARIZED CAPACITORS ARE 6.8µf, 35V. TAN.
5. ALL CAPACITOR VALUES ARE IN PICOFARADS.

6. OPTIONAL CONNECTION FOR CAPACITORS, TO BE USED IN CASE OF OSCILLATION. VALUE TO BE SELECTED IN TEST (TYP VALUES 6.8pF AND 2.2pF)

R1 - R78
C1 - C45
D1, D2
S1 - S3
Q1 - Q15

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

ORTEC
OAK RIDGE TECHNICAL ENTERPRISES CORPORATION
OAK RIDGE TENNESSEE

TITLE: MODEL 485 AMPLIFIER

DRAFTSMAN: RYDER DATE: 1-25-68
CHECKED: MGN DATE: 4-10-68
RESP. ENG.: R. SCROGGS
DRAWING NO.: 485-0101-S1
SCALE

REVISIONS