SPECTROSCOPY AMPLIFIER

Model 816

Model 109 PC Preamplifier
410 Linear Amplifier

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SPECTROSCOPY AMPLIFIER Model 816

SHORT-FORM INSTRUCTIONS

If you wish to try your Model 816 Amplifier in a live system, follow the instructions below.

1. Connect the preamp output to the INPUT connector.

2. Set the controls as follows, in the order specified:

FINE GAIN	8.0
GOARSE GAIN	Maximum possible before saturation of spectral peak of interest
Shaping	2 microseconds (internal jumper).
Input Polarity	As determined by input.
MODE	UNI(polar).
FINE GAIN	Readjust slightly if desired, not below 70% of maximum.

3. Observe the output on an oscilloscope, adjust the Pole/Zero control until the pulse neither undershoots nor returns to the baseline with the preamp time constant (check Section 3.3.6 if uncertain as to the setting).

4. These are probably the optimum settings; the most critical (which should be explored for better resolution) are the Shaping and Mode if high count rates are present. Try different combinations of these controls to ascertain the best settings for your particular system.

5. Take data and compare to previous results.

6. After satisfying yourself on the question of resolution, turn to Section 3.0 and follow the familiarization procedure listed there.

TABLE OF CONTENTS

SECTION 1
INTRODUCTION

1.1 GENERAL

The Canberra Model 816 Spectroscopy Amplifier offers unmatched performance as the main shaping amplifier in a high-resolution gamma-spectroscopy system. It is used in conjunction with a cooled Ge(Li) detector, low-noise FET-input preamplifier, and biased post amplifier. It offers near-optimum Gaussian pulse shaping, extremely low noise contribution, and highly stable linear design. The Model 816 is also ideally suited for fast coincidence and other zero-crossing applications as it offers extremely low crossover jitter and excellent overload performance.

Many recent advances in nuclear pulse amplifier design are incorporated in the Canberra Model 816 Spectroscopy Amplifier. Among the many features are:

- adjustable Pole/Zero cancellation
- active element pulse shaping
- linear integrated circuit construction
- ultra-low noise contribution
- highly linear gain response
- constant gain regardless of output mode selected
- internal selection of 0.5 or 2.0 microsecond Gaussian shaping

The usefulness and application of the Canberra Model 816 is enhanced by the following unique design features: front-panel Pole/Zero adjustment, easily accessible output DC level adjustment, and ultra-low noise design (less than 8 microvolts referred to the input at two microsecond unipolar shaping).

1.2 SPECIFICATIONS

INPUT

SIGNAL INPUT

Polarity: Positive or negative tail pulse from associated preamplifier.

Amplitude: 0 to 4 volts before input saturation, 12 volts maximum.

Rise Time: 0 to 1 microsecond.

Fall Time Constant: 30 to 1000 microseconds.

Input Impedance: 1000 ohms, DC coupled.

Connector Type: BNC, UG-1094/U, front panel

OUTPUT

SIGNAL OUTPUT	Polarity: Unipolar or bipolar (switch selected). Amplitude: Positive 0 to 10 volt linear pulses; 11 volts saturation, unterminated. Pulse Shape: Near-Gaussian, equivalent to four integration stages. Time Constants: 0.5 and 2.0 microseconds, internally selected. Output Impedance: 3 ohms maximum, DC coupled. Connector Type: BNC, UG-1094/U, front panel.

PERFORMANCE

LINEARITY	Better than ±0.2% integral from 0 - 9 volts output into 100 ohms.
SHAPING	Selectable unipolar or bipolar time constants of 0.5 or 2 microseconds; near-Gaussian pulse shape.
GAIN STABILITY	Better than ±0.02% per °C; better than ±0.01% over 24 hours at constant temperature.
GAIN CONSTANCY	Constant amplifier gain for unipolar or bipolar shaping, to within 3%.
OVERLOAD RECOVERY	Recovery to within 2% of baseline from 250X overload within two non-overloaded pulse widths, at full gain for bipolar shaping.
DC STABILITY	Better than 2mV/°C (0 to 50°C); better than 10mV over 24 hours at constant temperature.
COUNT RATE STABILITY	Less than 0.5% gain change (Cesium 137 peak) in presence of 50 kHz pulser input.
CROSSOVER WALK	Less than ±8 nanoseconds over 20:1 dynamic range (0.5 volts to 10.0 volts) including contribution of Canberra Model 835 Timing SCA; less than ±15 nanoseconds over 50:1 dynamic range.

NOISE	Less than 8 microvolts referred to the input at full gain and 2 microsecond unipolar shaping; less than 12 microvolts at 0.5 microsecond unipolar shaping; less than 12 microvolts at 2 microsecond bipolar shaping.
GAIN	Maximum gain 500; adjustable over 50:1 range by means of front-panel controls.
CONTROLS	
COARSE GAIN	Front-panel rotary switch, 16:1 range in five binary steps.
FINE GAIN	Front-panel single-turn precision potentiometer; greater than 3:1 range.
POLE/ZERO	Front-panel single-turn screwdriver adjustment potentiometer to optimize amplifier baseline recovery and overload performance for the preamplifier time constant and main amplifier pulse shaping chosen.
INPUT POLARITY	Front-panel toggle switch, POS and NEG positions.
OUTPUT MODE	Front-panel toggle switch, UNI(polar) and BI(polar) positions.
PREAMP POWER CONNECTOR	Supplies power to all Canberra preamplifiers. Amphenol 17-10090 (rear panel).
POWER	+24V - 30mA +12V - 35mA -24V - 30mA -12V - 30mA
PHYSICAL	Size: Standard single-width module (1.35 inches wide) per TID-20893.
	Weight: 2.2 lbs.

SECTION 2
CONTROLS AND CONNECTORS

2.1 GENERAL

This section describes the functions of the controls and connectors located on the Model 816 Spectroscopy Amplifier.

2.2 CONTROLS

2.2.1 COARSE GAIN

This front-panel rotary switch covers a 64:1 range in five binary steps. In an experimental situation, it is not necessarily always advantageous to obtain all possible gain from the preamplifier at the expense of the main amplifier gain; data should be taken at maximum preamplifier gain and at minimum preamplifier gain (after readjusting the Spectroscopy Amplifier gain accordingly) to see which obtains better resolution.

2.2.2 FINE GAIN

This front-panel single-turn potentiometer covers a 3:1 gain range. Note from Figure 2-1 that the COARSE GAIN control is so arranged that the user cannot make the error of stumbling into a setting that penalizes him heavily in terms of amplifier noise referred to the input, unless he cannot in fact use any higher gain setting.

This has been achieved by having the COARSE GAIN control begin to have an effect near the amplifier output, where the least following amplification will magnify and add to amplifier noise after signal attenuation. Its effect then moves in successive steps back towards the input, accepting this increasing penalty only when absolutely required.

2.2.3 Shaping

This internal jumper allows the selection of two integration and differentiation nearly-Gaussian time constants of 0.5 or 2.0 microseconds.

2.2.4 INPUT

This front-panel toggle switch permits the user to use a positive or negative input signal.

2.2.5 POLE/ZERO Adjustment

This front-panel screwdriver adjustment permits the precise elimination of undershoots on the amplifier pulse after the first differentiation, for all input pulses whose fall time constant exceeds 30 microseconds.

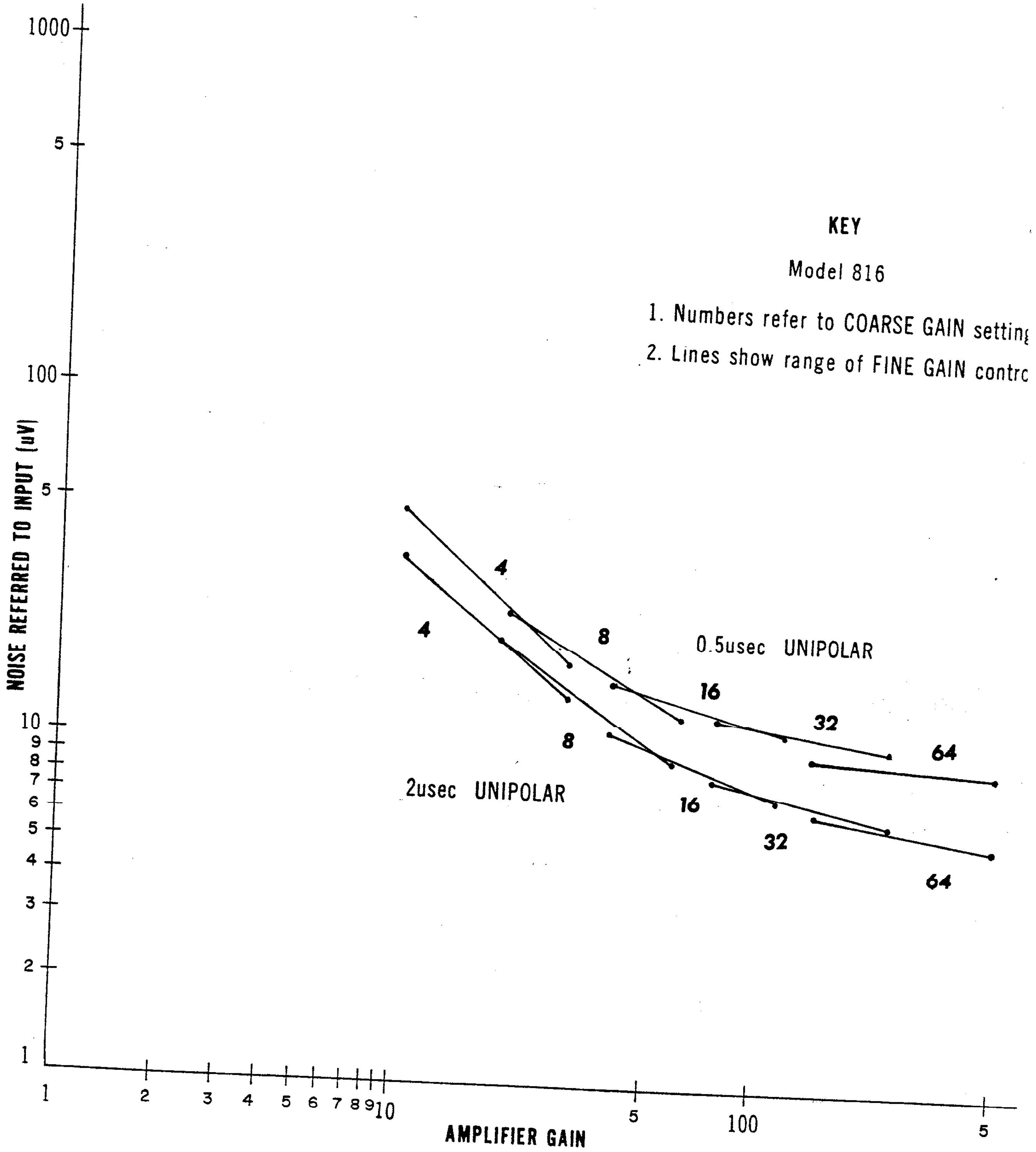
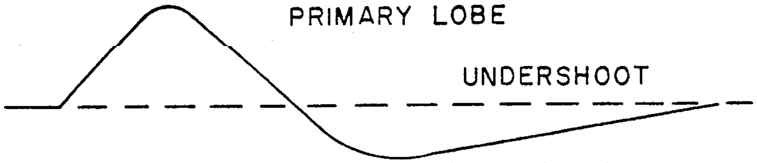


Figure 2–1. Equivalent input noise versus gain settings.

A classical problem in nuclear pulse amplifier design is that normally singly-differentiated pulses actually have two differentiations: the first by the amplifier first-differentiation circuitry itself, whose time constant may range from 100 nanoseconds up to 10 microseconds, the second by the preamplifier circuitry, whose fall time constant usually ranges from 40 to 1000 microseconds. Thus, the "singly-differentiated" pulse actually appears as



where the undershoot has an amplitude roughly equal to the primary pulse amplitude times the ratio of the amplifier differentiating time constant to the preamplifier fall time constant. For example, if the preamplifier fall time constant is 50 microseconds, a two microsecond singly differentiated pulse ten volts high will have an undershoot equal to

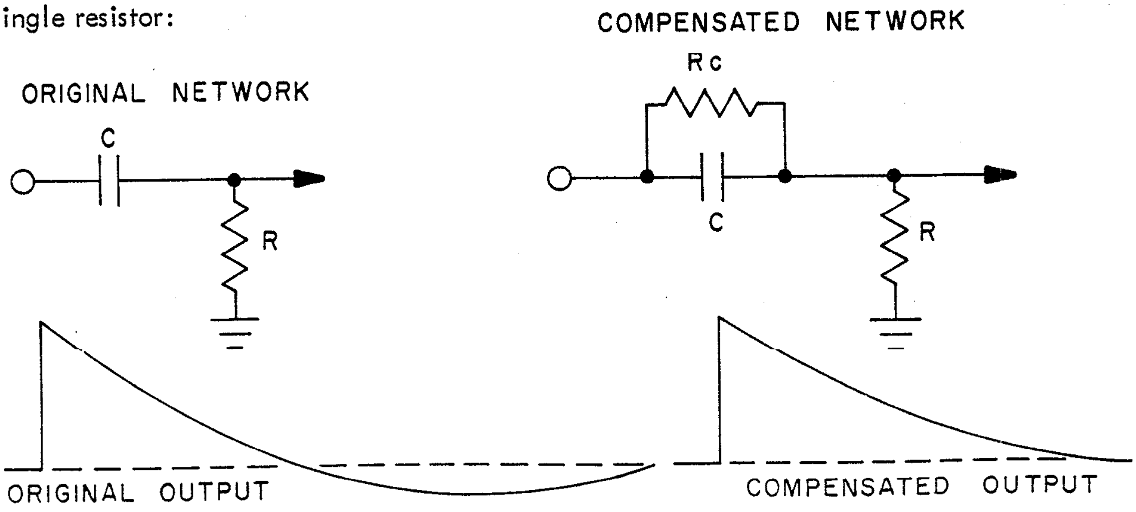
$$\frac{(10\text{V})\,(2\mu\ \text{sec.})}{50\mu\ \text{sec.}} = 400\ \text{mV}$$

This undershoot causes two aggravating effects. Under amplifier overload conditions, if the undershoot saturates, the amplifier is blocked not only until the primary lobe recovers, but also until the undershoot recovers (at the much slower rate of the preamplifier fall time constant).

Also, if the count rate is sufficiently high, succeeding pulses may fall into the undershoot of preceding pulses, subtracting from their apparent pulse height and causing peaks to broaden on the low energy side.

Pole/Zero cancellation compensates for this effect by artificially adding a Laplace "zero" to cancel the Laplace "pole" due to the preamplifier fall time constant, removing the undershoot caused by the preamplifier.

In its simplest form, the original differentiating network is compensated by the addition of a single resistor:



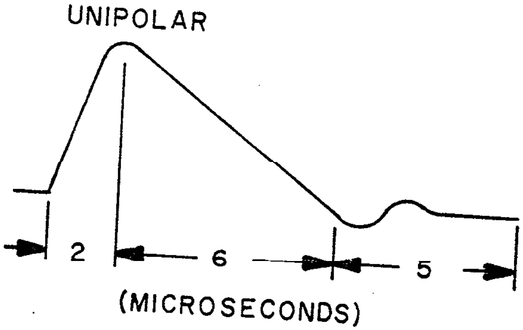
This technique is fully effective only if the input pulse to the network is composed of a single exponential fall time constant - thus, problems will be encountered in trying to compensate the fall time constants contained in the more complex pulse arising when a pulse generator with fall time constant T_1 feeds a preamplifier with fall time constant T_2, which in turn feeds the main amplifier. One may compensate for either time constant, but not both simultaneously.

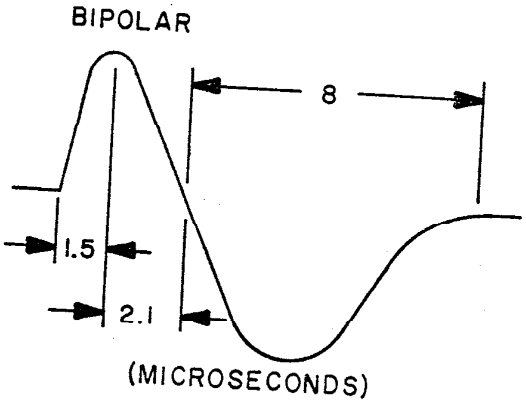
The compensation circuit must in practice be variable, to permit adjustment for the range of fall time constants that may be encountered in the field. In the Canberra Spectroscopy Amplifiers, this compensation range extends from 30 microseconds upward, covering all commercially available preamplifiers.

In the practical case, adjustment is best done live, by observing the unipolar pulses from the amplifier with the detector and preamplifier attached. The only difficulty that is encountered is that the system noise obscures the undershoots when the adjustment is reasonably close. One aid is to increase the amplifier gain by X8 or more for the purposes of this adjustment. If low-energy tailing is observed on spectral peaks, it may be a sign that the Pole/Zero adjustment is incorrect.

2.2.6 MODE

This front-panel toggle switch permits the selection of UNI(polar) or BI(polar) outputs. The two pulse mode choices are shown below for two microsecond shaping:





2.3 CONNECTORS

2.3.1 INPUT

This front-panel BNC connector accepts a positive or negative tail pulse from an associated preamplifier. The pulse amplitude can be 0 to 4 volts before input saturation (12 volts maximum), can have a rise time of 0 to 1 microsecond, and a 30 to 100 microsecond fall time constant. The input impedance is 100 ohms, DC coupled.

2.3.2 OUTPUT

The output signals one unipolar or bipolar (as switch-selected) pulses of positive polarity and have 0 to 10 volt amplitudes (11 volts saturation, unterminated); pulse shape is near-Gaussian; time constants as selected internally; output impedance is less than 3 ohms, DC coupled.

SECTION 3
OPERATING INSTRUCTIONS

3.1 GENERAL

The purpose of this section is to familiarize the user with the controls and to check that the units are operating correctly. Since it is impossible to determine exactly how the user will operate these units in a specific experiment, explicit operating instructions cannot be given. However, if the following procedures are performed, the user will become as familiar with the operation of the unit as is possible.

3.2 INITIAL SETUP

1. Insert the amplifier into an AEC compatible bin such as the Canberra Model 800.

2. Connect a tail pulse generator with an output rise time less than one microsecond and fall time constant greater than 30 microseconds to the INPUT connector of the amplifier. The output of the pulse generator should ideally be variable from 20mV to four volts and must not in any case be greater than four volts for proper amplifier functioning.

3. Connect the OUTPUT of the Model 816 to an oscilloscope set for 2V/cm vertical and 0.5 microsec/cm horizontal calibration.

4. Set the pulse generator for an output of +20mV.

5. Set the amplifier controls as follows:

COARSE GAIN	64
FINE GAIN	Fully clockwise.
Shaping	2.0 microseconds (internal adjustment).
MODE	UNI(polar).
INPUT	POS.

3.3 INITIAL CHECKOUT

1. Observe the output on the oscilloscope; it should appear approximately as shown below

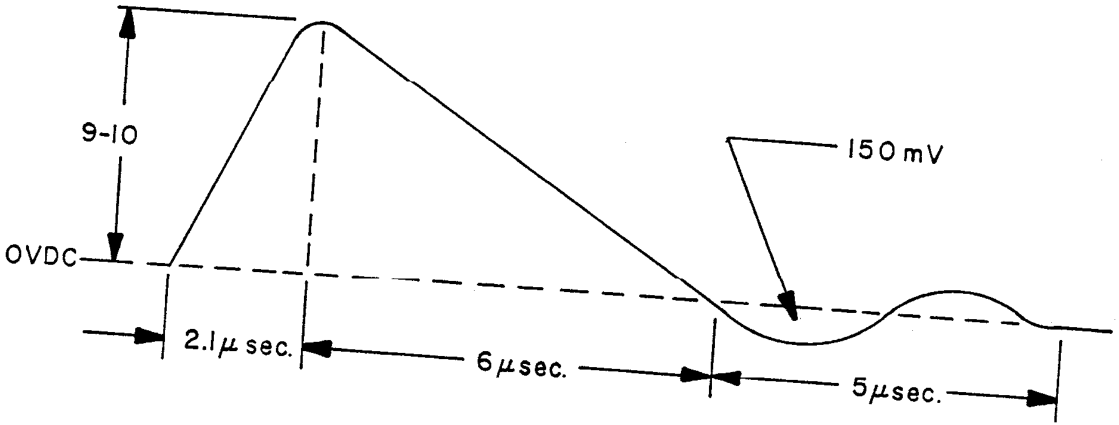


FIGURE 3-1. TYPICAL OUTPUT WAVEFORM

2. Turn the COARSE GAIN control to 32 and to 16; observe the pulse output decrease in amplitude by factors of two.

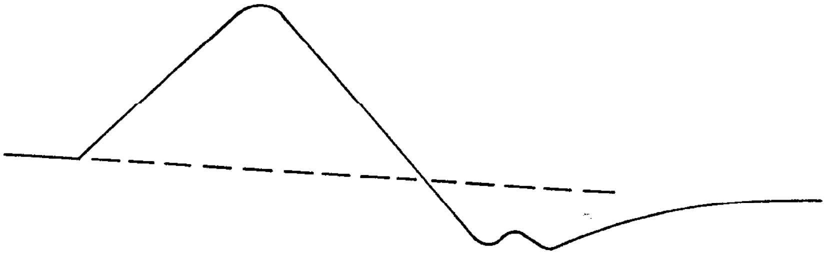
3. Rotate the FINE GAIN control counter-clockwise and observe the pulse decrease in amplitude over a 3:1 range.

4. Remove the left side-cover and lift the long green shorting bar from its two microsecond position and place it in the 0.5 microsecond position. Observe the change on the output signal.

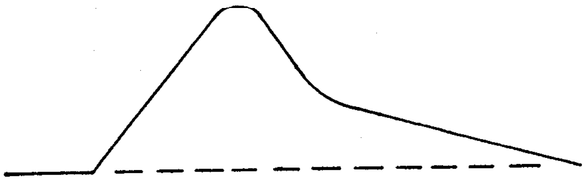
5. Return all controls and the jumper to the initial settings.

6. Increase the vertical gain on the oscilloscope by a factor of ten, and with a small screwdriver, rotate the Pole/Zero adjustment counter-clockwise then clockwise; observe the effect on the output pulse; the optimum setting for the particular fall time constant of the pulser is when the pulse returns to the baseline most rapidly. Sample waveforms are shown below:

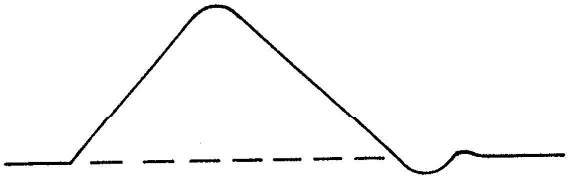
UNDERCOMPENSATION



OVERCOMPENSATION

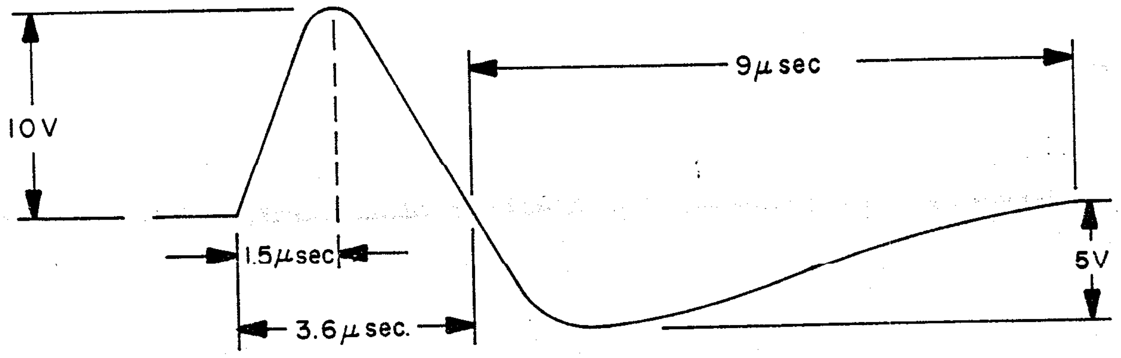


PERFECT COMPENSATION



The theoretical explanation for this effect and its impact on system resolution and overload performance is given in Section 2.2.5.

7. Switch the MODE control to the BI(polar) position and observe the bipolar output pulse shape



3.4 TESTING THE SPECIFICATIONS

3.4.1 SYSTEM RESOLUTION

Basically, the procedure to be followed is outlined in the Short-Form instructions preceding the body of this manual. The critical settings which may affect system resolution are

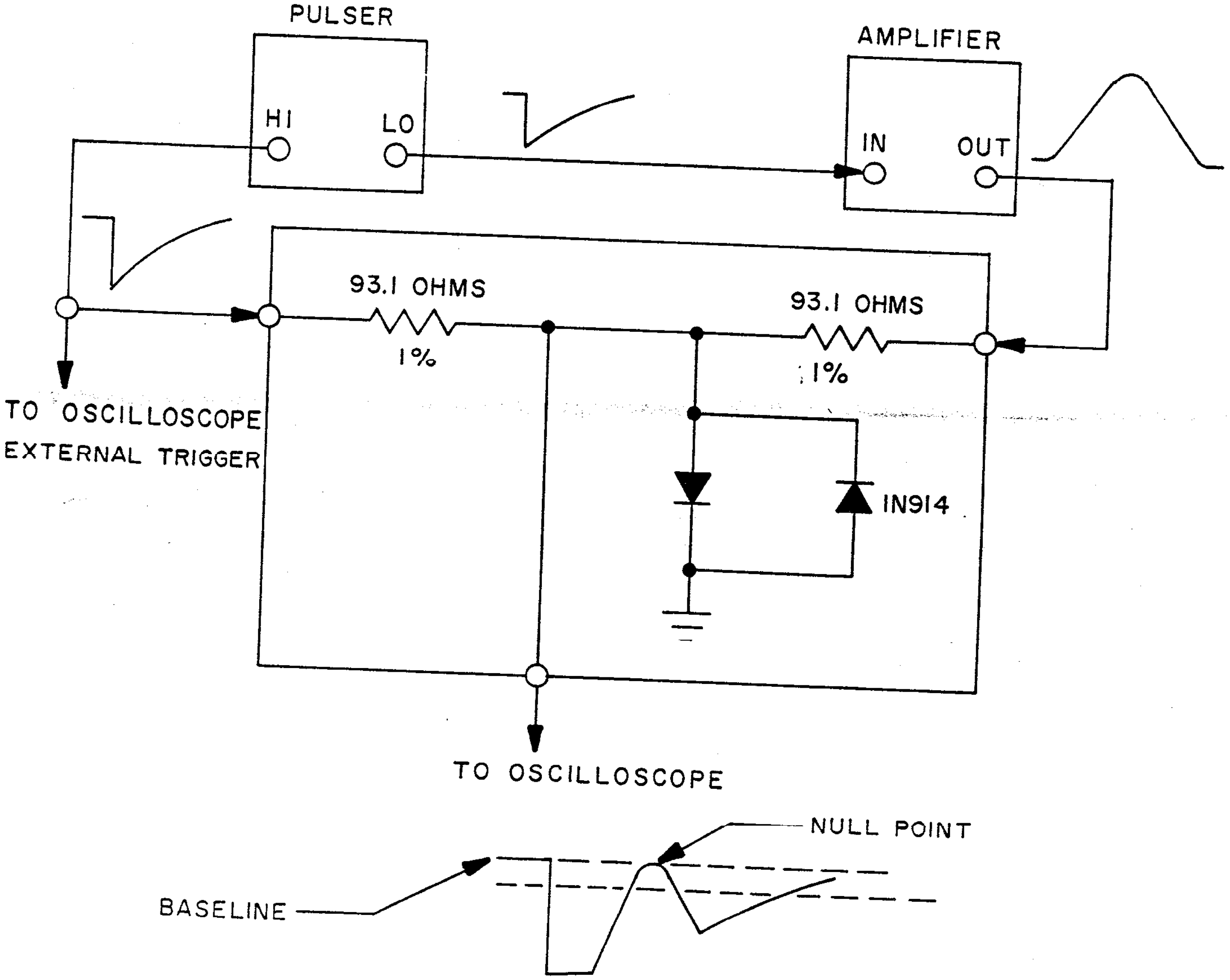
Time Constant
Mode (Unipolar or Bipolar)

The optimum settings depend strongly on the characteristics of the individual system: ratio of low-frequency to high-frequency noise, system hum and ripple and ground loop problems, and the count rate being encountered. Empirical experimentation is far simpler (and probably faster) than any attempt at analytical evaluation of the optimum control settings.

One procedure that is often illuminating is to take a test run with your existing system before beginning the evaluation of your Canberra Spectroscopy Amplifier. This provides an "all other things being equal" benchmark against which the results later obtained may validly be compared.

3.4.2 LINEARITY

One of the simplest and most accurate tests is to set up the system shown below:



This test is performed by adjusting the pulser attenuator and amplifier gain so that with a nine volt high-level (Direct) output from the pulser, the output from the amplifier is also exactly nine volts. This may be ascertained by adjusting the attenuator and amplifier gain so that the null point observed on the oscilloscope is at exactly the same level as the baseline with the highest oscilloscope vertical gain.

When this condition is obtained, turn the pulser pulse height control down from nine volts to the lowest level that will still trigger the oscilloscope, and observe the maximum difference between the baseline and the null point. The integral linearity of the amplifier under test is then equal to

$$\frac{(\text{Maximum deviation in volts}) \times 2 \times 100\%}{9 \text{ volts}}$$

The maximum deviation must thus be less than $\pm$9mV in order to meet the $\pm$0.2% specification.

The test may be explained as follows: integral nonlinearity is the maximum deviation from the straight line (output vs. input) from zero output to rated output (9 volts), divided by the rated output, stated as a percentage.

This calculation is performed electronically in the test described above by setting

$$\text{Output} = (K)\ (\text{Input})$$

where K is the pulser attenuation factor (and the gain of the amplifier). As the input is decreased, the amplifier gain should remain constant (output should decrease linearly); whether or not it does is tested by comparing the output to a signal known to decrease linearly with the amplifier input - the pulser Direct Output which is related to the Attenuated Output by a passive attenuator.

The factor of two must be included because the summing network also serves as a voltage divider, decreasing the apparent deviation by a factor of two.

Note that nonlinearity and instability in the pulser output do not enter the question, because both Direct and Attenuated Outputs will be affected identically, save for the negligible effect of the pulser's attenuator instabilities over the short time required for the test.

Instabilities in the baseline level on the oscilloscope are due to oscilloscope triggering and DC level fluctuations and need not be of concern in this test.

3.4.3 GAIN STABILITY

This specification is extremely difficult to test without somewhat elaborate test equipment because of the difficulty of assuring that the measuring instruments are stable and because of the relatively long test periods required.

Temperature stability can most simply be observed by duplicating the test setup of Section 3.4.2, except that the amplifier is placed in a temperature chamber. The effect of temperature excursions may be observed by plotting the deviation between the baseline and null point versus chamber temperature. The calculation is performed as in Section 3.4.2 if the amplifier output is initially nine volts.

Long-term stability tests could also be performed in this fashion if the pulser attenuator resistors and the summing circuit resistors are protected from temperature variations during the test period. This test is extremely tedious, as the oscilloscope does not permanently record excursions, and only the situation at the moment can be observed. Thus, constant observation is required.

The maximum deviation permitted for temperature is ±2mV/°C; the maximum deviation over 24 hours is ±9mV at constant temperature and power supply voltages, if the initial amplifier output is nine volts.

3.4.4 GAIN CONSTANCY

This test is simply performed by storing a pulser output from the amplifier in an analyzer and switching from unipolar to bipolar shaping; the change in peak position should be less than 3%. If a greater excursion is noted, make sure that the analyzer itself is not pulse-shape sensitive by checking the apparent change on an oscilloscope at the maximum vertical sensitivity obtainable which allows the output peak to be observed.

3.4.5 OVERLOAD RECOVERY

Set the amplifier under test to its maximum gain position (gain approximately equal to 500). Feed in, via a very short cable, a 20mV pulser input, so that a ten volt output is obtained. Using the pulser attenuator switches only, increase the pulser output to 5 volts (a 250X overload on the amplifier). Observe a non-overloaded bipolar pulse and record the time it takes permanently to reach the baseline (basically, into the noise). Repeat with an overloaded bipolar output. The overloaded pulse should reach 2% (0.2 volt) of the baseline in less than twice the period required for the non-overloaded pulse.

> NOTE: The amplifier Pole/Zero control must be adjusted to match the pulser fall time constant (observed with a Unipolar output) before this test can be attempted.

3.4.6 DC LEVEL STABILITY

This specification can most easily be tested with a digital voltmeter when performing the gain stability tests of Section 3.4.3.

3.4.7 COUNT RATE STABILITY

This test is performed by setting up a live system at a moderate count rate (approximately 1000 counts per second), observing the position of a prominent peak in a multichannel analyzer, and repeating at a higher count rate such as 50,000 counts per second. The shift in the peak position should be less than 0.5% (two channels in 400) over this count rate range.

Since many laboratories do not have energetic enough sources or large enough detectors to reach the requisite count rate, it may be necessary to artificially increase the count rate using a tail pulse generator which has a variable frequency, such as the Canberra Model 1407R.

To perform this test, establish the live system with a Cesium 137 peak storing in Channel 350. Then inject pulses into the Test pulse input of the preamplifier so that the pulser peak stores in Channel 150. Note that the fall time constant of the pulser output should be as near to that of the preamp as possible.

Be sure that the amplifier Pole/Zero adjustment is correct for the preamplifier being used.

> NOTE: The Multichannel Analyzer must be DC coupled and a DC Restorer must be used at its input to prevent baseline shifts with count rate.

3.4.8 CROSSOVER WALK

Obtain a ten volt bipolar, 0.5 μsec time constant output from the amplifier with the gain set at its minimum value. Connect the output to a Canberra Model 835 Timing SCA with the Baseline control set at its minimum value and the Window Width control at its full range setting. Trigger the oscilloscope from the pulser and observe the Output from the Model 835.

Using the pulser attenuator switches only, reduce the pulser output by a factor of 20; the output of the Timing SCA should shift by less than ±8 nanoseconds. Repeat the test with an output attenuation of 50. The Model 835 output should shift less than ±15 nanoseconds.

3.4.9 NOISE

Set the amplifier to maximum gain (about 500). Measure the noise (no input signal) at the output using a true rms or average reading voltmeter. If an average reading voltmeter is used, multiply the reading by 1.13 to convert from average to true rms. The readings obtained should be less than the following values:

Shaping	Output Noise (true rms)	Noise Referred to Input
0.5 microsecond UNI	6 millivolts	12 microvolts
2.0 microsecond UNI	4 millivolts	8 microvolts
2.0 microsecond BI	6 millivolts	12 microvolts

Be sure that the input is terminated in 93 or 100 ohms when making this test.

3.4.10 GAIN

Set the amplifier to maximum gain and determine the input pulse necessary to obtain a ten-volt output. The input required should be less than 20mV for a gain of 500.