8-8-457

CONSTANT FRACTION DISCRIMINATOR

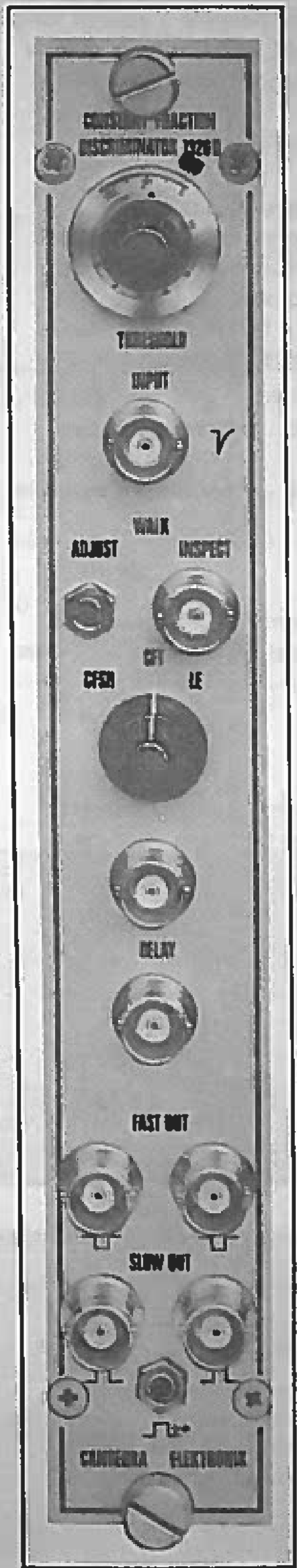
MODEL 1326, 1428*

OPERATING MANUAL

CANBERRA ELEKTRONIK

CONSTANT FRACTION DISCRIMINATOR MODELL 1326 D

CANBERRA ELEKTRONIK



Features

- **Optimum time resolution for Ge (Li), Ge Intrinsic, NaJ, Plastic and Si (Sb) detectors**
- **For > 500:1 dynamic range, walk less than ±500 psec**
- **All necessary controls are on the front panel**
- **DC-coupling throughout for high countrate capability**
- **High flexibility by three programms (Constant-Fraction, CF Slow Reject- and Leading-Edge)**
- **Four independent simultaneous outputs.**
- **Low Cost/High Reliability by extensive use of IC's and conservative circuit design (no tunnel diodes, Avalanche transistors, snap-off diodes)**
- **Wide dynamic range of input signals −5 mV to −5 Volts**

Description

The Model 1326D is a universal, DC-coupled Constant Fraction Discriminator. This advanced design is based on development at LBL, Berkeley and TU Munich, Garching. The 1326D provides optimum timing for Germanium detectors in CFSR-Mode while providing optimum time resolution for other detectors in CF und LE Mode.

The DC coupling allows high statistical countrates without affecting resolution which has been a major problem of conventional designs.

The single width Module is easy to adjust (only two controls on front panel) however, this is not achieved at the expense of performance or flexibility. Constant fraction delay can be individually tailored to very detector type. The fraction is factory set to. 2 value can easily be changed. Due to the very sensitive input stage it is in many cases not necessary to use Fast Signal Amplifiers.

As a further convenience four simultaneous independent outputs are provided which offer a definite advantage in Fast/Slow coincidence work.

The front end uses state of the art IC's to achieve high resolution at high reliability.

To enhance flexibility a cable clip pulse shaping is included for use in fast coincidence work.

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Specifications

Input
negative 0 to −5 Volts linear signal
Z_{in} = 50 Ohms, risetime 1 nsec or longer
Frontpanel BNC, protected to −100 V
(Limited by input resistor dissipation)

Outputs
Inspect: Displays outputsignal of Zero Cross discriminator, used to set Zero Cross discriminator with walk adjust potentiometer
Delay: 2 BNC − 50 Ohm delay cable must be connected to match risetime of input signal

- t delay = 0,2 · tr for Germanium Detectors
- t delay = 0,8 · tr for other Detectors

Fast Out
Two independent Fast NIM outputs 20 nsec wide and 18 mA into 50 Ohms risetime 5 nsec

Slow Out
Two independent outputs,positive signal,2 Volt on 50 Ohms risetime 10 nsec typical

Slow output width is equal to internal dead time.

Clip
If switched to external a 50 Ohm cable must be connected between the 2 BNC to determine the width of the Fast Output.

Frontpanel Controls
Threshold variable from −5mV to −1V
Walk adjust sets the Zero Cross discriminator Mode switch

- LE Leading edge
- CF Constant Fraction
- CFSR Constant Fraction with slow reject

[illegible] for slow output, controls dead-time

Performance
Input amplitude range −5mV to −5V linear
Walk for dynamic range of 1:500 is ±500 psec in CF mode
for 100:1 ±110 psec
Walk for LE < 300 psec from x 2 to x 20 times treshold

Counting rate > 10 MHz limited by deadtime setting.
Pulse pair resolution < 50 nsec limited by deadtime setting.

Treshold stability
0.1% per °C for 24 hours

Temperature range 0 to 75° C
Linearity 0,25%

Setup information

For best timing results careful adjustment of the 1326D is necessary. Please consult the manual.

Typical delaycable length

Plastic, NaJ and Si (Sb)
ca. 0.5 m to 1 m (2 to 5 nsec)

For Planar Germanium
ca. 1 m to 2 m (5 to 10 nsec)

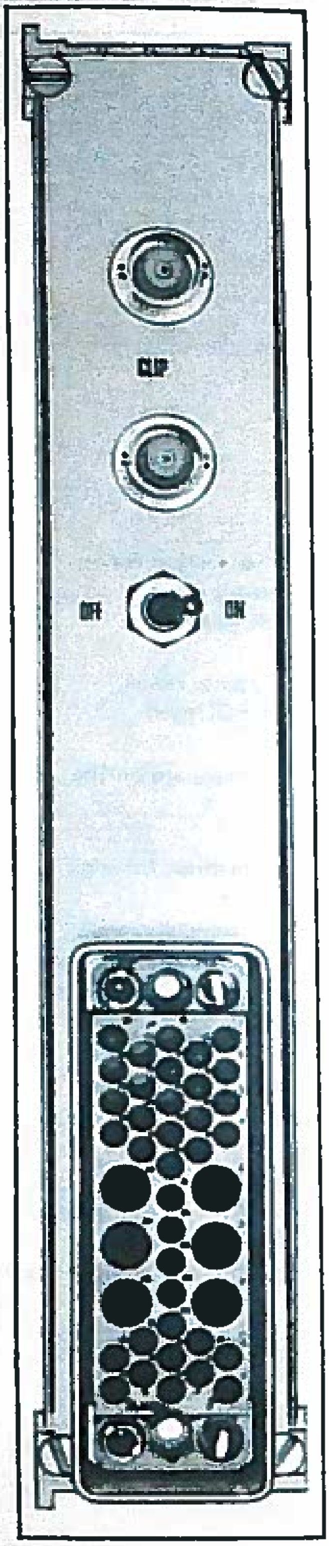
For Coax Ge (Li)
ca. 2 m to 4 m (10 to 20 nsec)

Power +

+ 6 Volts, 130 mA + 12 Volts 10 mA
− 6 Volts, 350 mA − 12 Volts 80 mA

+ Special Version using only ± 12 Volts is available on special request.

Specifications for the 1326DL are identical to the 1326D except Lemo Connectors are used instead of BNC Connectors.



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Resolution

No	Start det	Stop det	Energy	Source	FWHM	FW 0.1M	FW 0.01M
1	NE 111 RCA 8850	NE 111 RCA 8850	0.8 to 1 MeV	Co^{60}	190 psec	380 psec	600 psec
2	NE 111 RCA 8850	NE 111 RCA 8850	50keV to 1 MeV	Co^{60}	380 psec	720 psec	1100 psec
3	NE 111 RCA 8850	NaJ (Tl) RCA 8850	511 + 5%	Na^{22}	1,2 nsec	2,8 nsec	4,4 nsec
4	NE 111 RCA 8850	Ge (Li) True Coax 14% eff. 2,2 keV FWHM	120 keV to 1,3 MeV (see fig. 1)	Na^{22}	5,5 nsec	13,2 nsec CFSR Mode (see fig. 2)	23,0 nsec
5	Ge (Li) True Coax 10% eff. 2,3 keV FWHM	Ge (Li) True Coax 10% eff. 2,3 keV	> 80 keV	Na^{22}	7,5 nsec	15 nsec CFSR Mode	24 nsec
6	NE 111 RCA 8850	Ge (Li) True Coax 14% eff. 2,2 keV FWHM	> 50 keV (see fig. 3)	Na^{22}+Co^{57}	6,5 nsec (see fig. 4)	CF Mode	
7	NE 111 RCA 8850	Ge (Li) Planar 10 ccm 1,8 keV FWHM	>40 keV	Na^{22}	2,7 nsec	6,5 nsec	

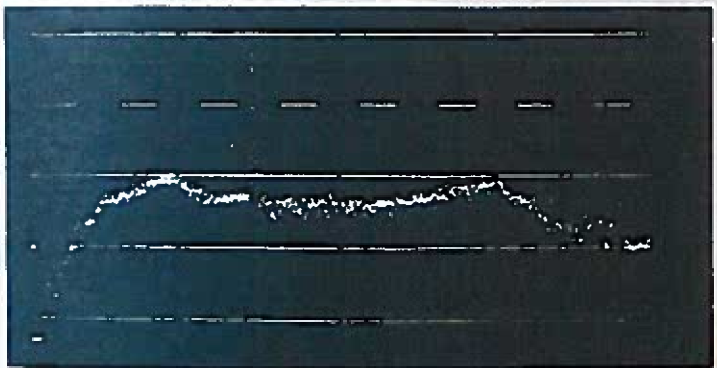

FIG.1

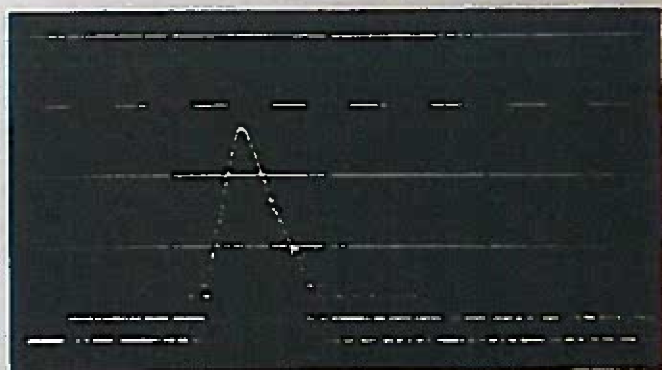

FIG.2

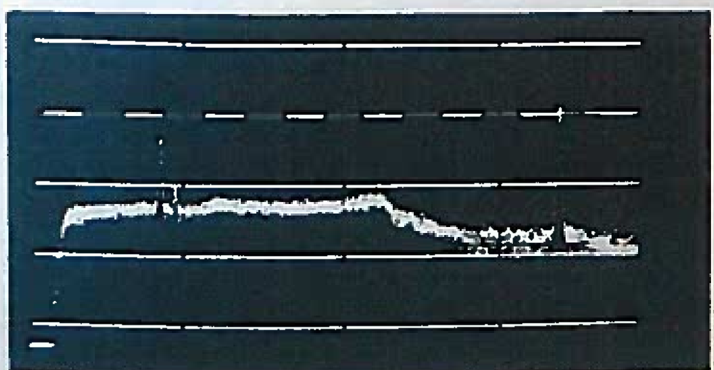

FIG.3

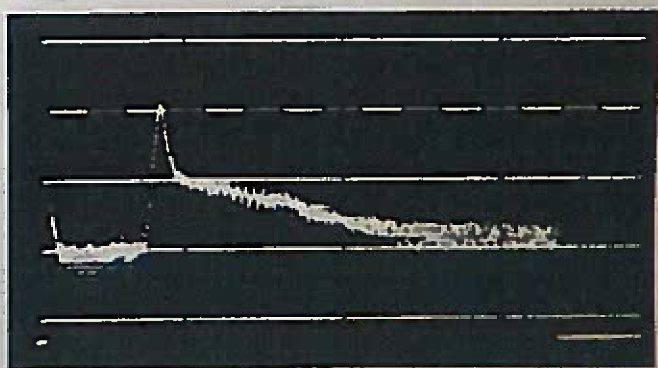

FIG.4

1 Introduction

Constant fraction timing makes use of the knowledge that, for a given pulse shape from a detector/preamplifier combination, there is an optimum triggering or discrimination point to minimize walk. This optimum fraction varies for pulses of different risetimes; but for pulses of constant risetime, it does exist.

The technique operates by inverting and attenuating the pulse from which a time signal is to be derived and adding it back to the delayed (uninverted, unattenuated) signal itself. This produces a signal with a zero crossing. Figure 1 illustrates this process.

This technique essentially eliminates the "walk" errors caused by signals of constant risetime, but varying amplitudes.

The technique described above does not compensate for detector risetime variation. See Figure 2 which illustrates the result with two pulses of equal amplitude but varying risetime.

To compensate for varying risetimes requires a further elaboration of the timing system. The elaboration is to modify the delay time of the unattenuated, uninverted signal shown in Figure 1 (c) to a value less than the *shortest* risetime that will be encountered. Figure 3 illustrates the result for two signals of the same amplitude, but differing risetimes, when the delay is set to *less than* this critical value.

Use of this technique does require that certain restrictions upon minimum and maximum signal inputs must be observed.

Constant fraction timing yields greatly improved time resolution with large Ge(Li) detectors. As an example, one detector timing curve, as measured by the FWHM of the time peak width for known coincident events, was reduced from 6.3 nanoseconds to 4.2 nanoseconds by using constant fraction timing instead of leading edge timing, with a very narrow energy acceptance range. The improvement is much greater for wide energy range.

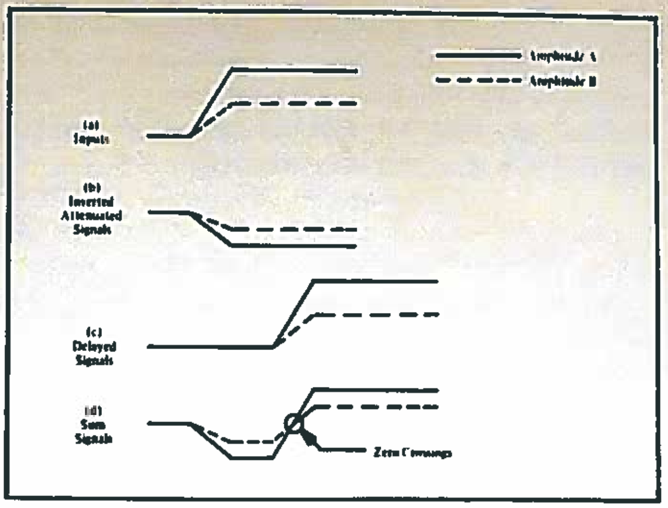

FIGURE 1: Constant fraction pulse shaping.

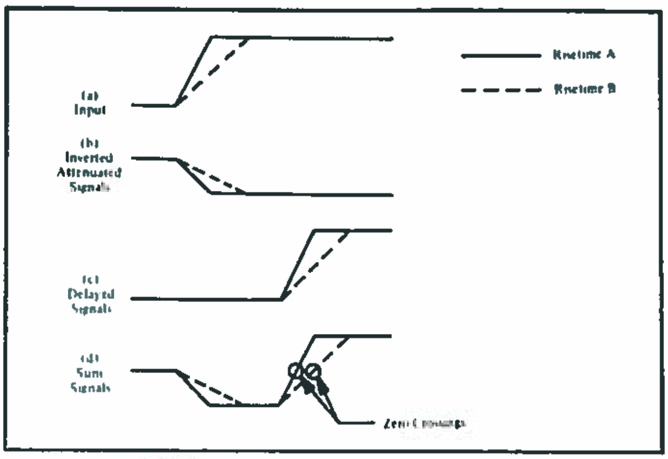

FIGURE 2: Constant fraction pulse shaping with varying risetimes

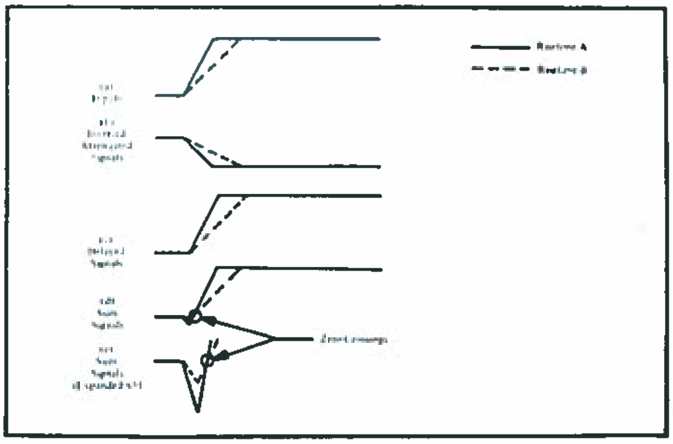
FIGURE 3: Pulse shaping for constant fraction timing with risetime compensation.

2 Principle of operation

The input pulse (labelled c_1 in fig. 4) is split into two parts. One part (labelled A in fig.4) is attenuated and applied to the inverting input of a fast differential discriminator. The other part (labelled B in fig.4) is delayed and then applied to the noninverting input of the same discriminator.

The output voltage of this discriminator is determined by the difference of the input voltages. This pulse (labelled AB in fig. 4) crosses the threshold voltage of the following gate at V_{BB}*, if the voltages at the inputs are equal. From this crossing the timing information is derived.

In order to derive the timing information from a fraction of the maximum amplitude of the input pulse, the timing has to be done at the time of occurrence of this maximum. I.e. one has to wait with the timing until one knows what the maximum amplitude is.

* Nominally, $V_H = -0.8$ V, $V_{BB} = -1.2$ V, $V_L = -1.8$ V; see also the data sheets.

Thus one has the condition that the maximum of the attenuated pulse – which corresponds to the maximum of the input pulse – has to cross the delayed pulse at the particular selected fraction. This condition leads immediately to the following relation

$$t_{delay} = t_{rise}\,(1 - \text{fraction})$$

using the idealized pulse shapes of fig. 4.

The validity of the approximations made by assuming such idealized pulse shapes has been checked for various values of the fraction and the delay time. We have varied independently the fraction from 0.1 to 0.5 and the ratio of the delay time to the rise time from 0.4 to 1.0. We found that the time resolution remains essentially constant for fractions between 0.1 and 0.3. For higher fraction (e.g. $f = 0.5$) the resolution deteriorates somewhat.

The variation of the delay time does not affect time resolution, as long as it satisfied the given relation within a factor of two. This seems plausible, since the actual pulse shape is not as pointed as our idealization but varies more smoothly with time.

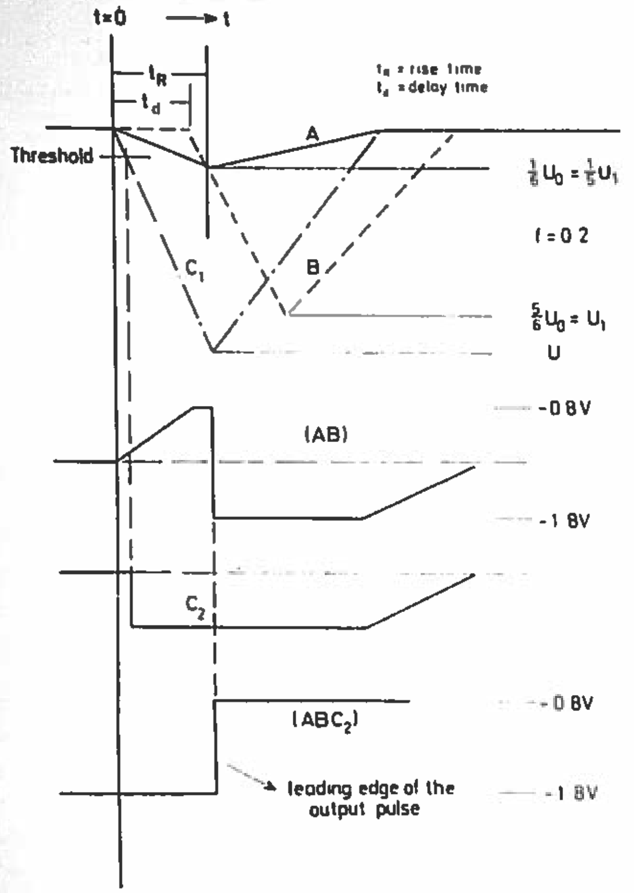

Fig. 4. Pulse shapes at the specified points in the electronic circuit of fig. 5. The propagation delays of the I.C.'s are not included in order to display the time resolutions more clearly.

3 Timing discriminator

This circuit is fulfilled by applying ECL integrated circuits with a propagation delay of 4 ns.

Fig. 6 explains the principle of its operation.

The differential amplifier in the main tract of the timing discriminator shapes a bipolar signal from the input one in the already above-mentioned way. Thus, a uniform logic signal (A) will be formed at the output due to the high amplification ($\approx 10^3$) and the limitation.

A completely identical second tract acts as a leading edge trigger. A NAND-gate detects the coincidences of negative pulses in these tracts (A and B). The coincidence signal starts an RS-trigger, which is reset by the trailing edge of the pulse (B). The RS-trigger output pulse controls a gate, through which the delayed signal (E) of the main tract passes. The leading edge of the output signal (F) contains the information of the zero crossing moment. The delay of the signal (A) is necessary to compensate the propagation delay of the coincidence circuit. The symmetry adjustment of the main tract in the timing discriminator is carried out at the front panel and can be observed at the C/0 INSP. output. So the possibility is given to adjust easily a low overcompensation, to decrease the influence of the finite charge sensitivity of the timing discriminator and nonlinearities of the detector signals.

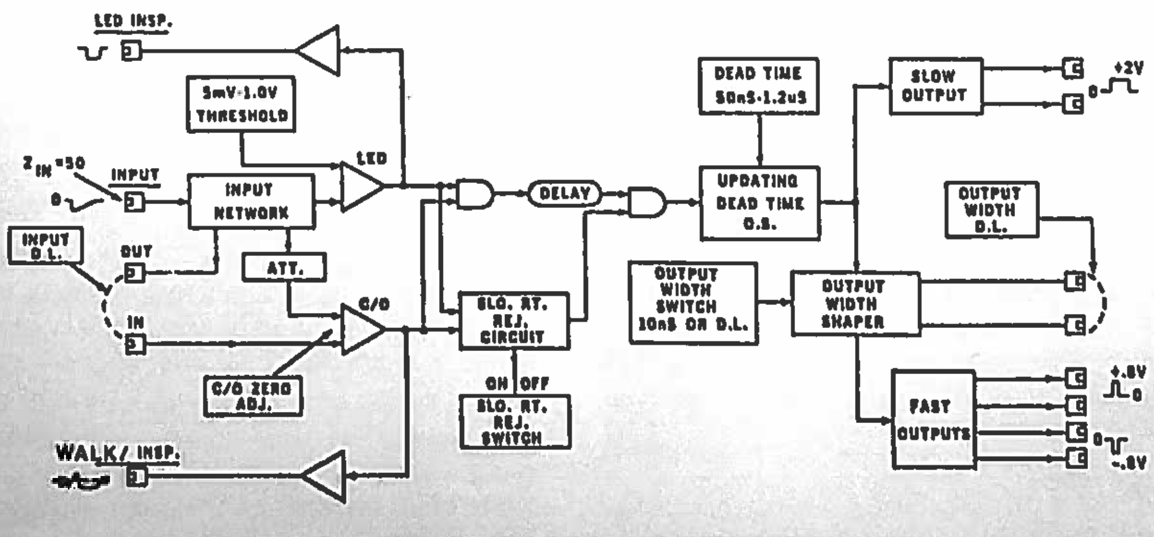

FIG. 5: 1326 D CONSTANT FRACTION DISCRIMINATOR

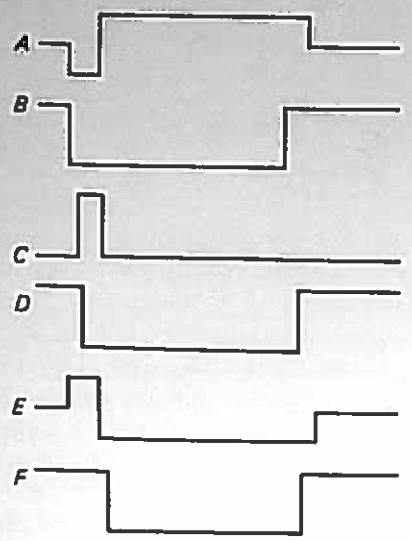

Fig. 6. Time diagram of the pulses in the timing discriminator. A – signal after the main differential amplifier tract. B – signal at the output of the leading edge discriminator. C – signal from the coincidence gate. D – signal from the RS-trigger. E – the pulse (A) after delaying and negation by IC 10. F – output pulse of the timing discriminator.

4 Input requirements

A) Signal

The input is dc coupled and internally terminated in 50 Ω. The signal should be a fast rising negative pulse less than five volts in amplitude. Correct operation of the discriminator depends on the signal baseline being near ground potential.

B) Input Delay Line

A short length of coaxial cable (50 Ω) should be connected between the input delay line IN-OUT BNCs on the front panel. The delay chosen should depend on the type of detector and application. If the risetime and shape of the detector signal is constant (e.g. scintillators, or a thin silicon detector) a delay equal to about 0.8 times the signal risetime should be used. If the risetime changes, as in thick germanium detectors a delay equal to about 0.1 or 0.2 times the detectors collection time should be used for all cases where the signal/noise ratio is large. A longer delay and a bigger fraction may be needed for low energies where the signal/noise becomes small.

5 Adjustments

A) Threshold

The "threshold" control is a 10-turn helipot mounted on the front panel. It provides a range of adjustment from 10 mV to –1.0 V. It should be adjusted so that the leading-edge discriminator is triggering just above noise.

B) WALK ADJUST

The crossover trigger level is adjusted by a screwdriver control on the front panel. It sets the threshold of the crossover discriminaaor to be at zero (baseline) of the input signal; the range of adjustment is about ± 6 mV. The adjustment is performed by observing the WALK inspect BNC (terminate in 50 Ω) and adjusting the WALK ADJ, so that the C/O discriminator triggers in the center of the noise.

Figure 7 shows the appearance of the WALK inspect waveform observed on a fast oscilloscope triggered on the signal when the WALK ADJ, is adjusted correctly. Since the CFD has a dc coupled input, the C/O ADJ, can only be adjusted correctly when its input is connected to a time pick-off circuit as described above or to a photo-multiplier. Figure 8 shows the appearance of the WALK inspect when the discriminator is fed with noise from a germanium detector system. The upper and lower limits of the waveform should be of equal intensity since C/O discriminator triggers as much on positive noise peaks as on negative noise peaks when the WALK adjust is set correctly.

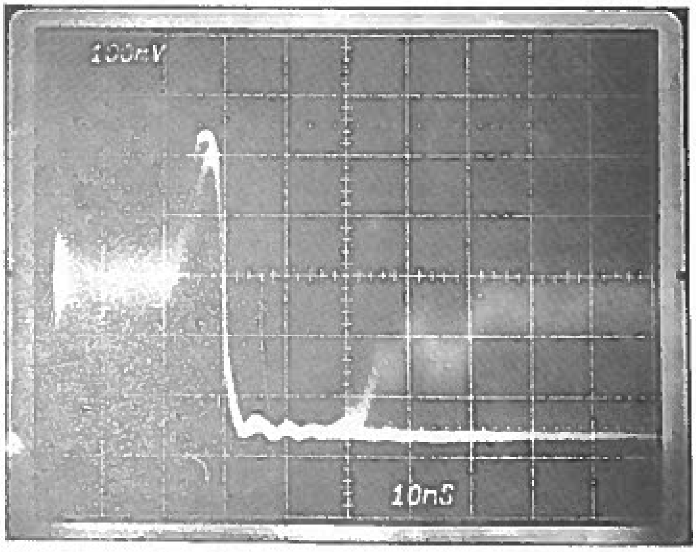

Fig. 7. c/o Inspect wave form using a fast oscilloscope triggering on output.

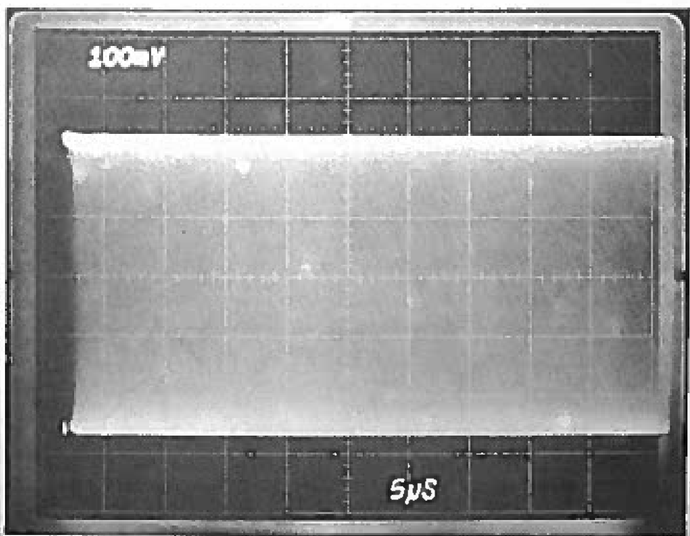

Fig. 8. c/o Inspect wave form with Ge Detector not triggered on signal (adjust for equal brightness).

6 Outputs

Other than the WALK inspect output, the CFD has four outputs. There are two slow (wide) and two fast (clipped).

A) Slow Outputs

The two slow outputs are on the front panel and are independent, and T.T.L. compatibel (+2 V in 50 Ω) with a width equal to the width of the internal up-dating dead-time one-shot. The dead-time range is from about 50 ns to 1.0 μs, and is adjustable with a control on the front panel. The risetime of the slow output is less than 10 nsec.

B) Fast Outputs

There are two independent negative outputs (−0.8 V into 50 Ω). The fast outputs are clipped pulses that occur at the beginning of the dead-time pulse. The fast out pulses can be clipped by a built in 20 ns clipper or by an external 50 Ω delay line. Normally the clip switch should be in the on position, if an external delay line is used, if the clip switch is in the off position and no external delay line is used, the fast outputs have the same width as the slow outputs. The risetime of the fast output is less than 2 ns. The two fast negative outputs are on the front panel, while the output clip switch and external delay line connectors, are on the rear panel.

7 Three position mode switch

A) Slow Risetime Reject CFSR

This position of the mode switch is used to prevent outputs from input signals that are too slow to obtain a correct constant fraction. Since the leading edge discriminator triggers at a higher level than the crossover discriminator it is possible for a slow risetime signal to cause the leading edge discriminator to trigger after the crossover discriminator. This effect will cause tailing or a satellite peak in a time spectrum. This is avoided by setting the switch to this position.

B) CF

In the OFF position the slow risetime rejection circuit is disabled and the CFD produces an output for all input signals above the discriminator threshold.

C) L.E.

In the L.E. position of the mode switch the module is used as a leading edge discriminator with the same threshold as discussed in the CFD description, (−5 mV to −1.0 V).

8 Electronic circuit

The input pulse is split by a resistor network. The terminated delay cable can be regarded as a resistor of magnitude $Z_0 = 50\ \Omega$, and the condition that the input impedance of the C.F.T. should be Z_0, too, determines the two series resistors in both signal paths.

R2 R1

The value of the series resistor in the path for the delayed pulse is then $f \cdot Z_0$ and the resistor in the other path is $1/f \cdot Z_0$, if f is the selected fraction. In the circuit given in fig. 5 we have chosen $f = 0.2$. So the resistor in the "delayed path" is 10 Ω, and the resistor in the other path should be 250 Ω, we have chosen the standard value 240 Ω. When a signal arrives, the output of the constant fraction discriminator I.C. (C/O) rises first to V_H and then falls to V_L when the delayed pulse arrives. The output pulse (labelled AB in fig. 4) crosses V_{BB} when the particular selected fraction of the maximum amplitude occurs in the delayed pulse. V_{BB} is the threshold voltage of the following gates and thus the timing information, i.e. the leading edge of the output pulse, is derived from this crossing. Since the noise at the output of the CFD would trigger the following pulse shape logic unpredictably an additional enable gate was introduced. It is opened only if the input pulse is higher than a preselected threshold. This is achieved by feeding the original undelayed signal (labelled C_1 in fig. 4) to another fast differential discriminator which is biased by an externally adjustable voltage. The output of this constant level discriminator (LED - labelled C_2 in fig. 4) and the output of the CFD feed a two input NAND enable-gate. Thus the timing is derived from the C/O I C because it produces an output signal when the maximum of the input signal occurs. The LED produces an output signal before that time, if the maximum is higher than the selected threshold. From the data sheet of a NAND gate one can see that the leading edge of the output pulse of such a gate is always derived from the pulse which comes last, provided both pulses overlap.

For inspection of the output of the C/O I.C. and the LED I.C. we have included inspect amplifiers for both. This mechanisation allows to display the output pulses on an oscilloscope and to adjust the offset of the C/O I.C. without disturbing the operation of the circuit. The inspect amplifiers are made of two thirds of a MC 10116 I.C. wired as unity gain amplifiers by applying the appropriate feed back.

The output pulse of the enable-gate starts a monostable multivibrator (oneshot). During the time it is in the "set" state no further input pulses are accepted. This "dead time" is selected such as to avoid spurious multiple triggering. The oneshot is made of a bistable multivibrator (flip-flop) which resets itself via two inverters connected in series. The propagation delay time [normally 4 nsec] of the first of these reset inverters has been increased to about 200 nsec by loading its output with a condensor of 1 nF to ground. This time is determined by the discharge of the condensor by the output pulldown resistor of the first reset inverter from V_H to V_{BB}. If the voltage at the input of the second reset inverter – connected to the output of the first one – reaches V_{BB} its output goes positive from V_L to V_H, resetting the flip-flop. The condensor is then recharged to V_H by the outputemitter follower transistor of the first reset inverter. By this method the time during which the oneshot is paralyzed or would give false output pulse is short compared to the pulse width. The ratio of oneshot deadtime to oneshot pulse width is less than 0.1.

The width of the negative output pulse is determined by the length of an external shape cable. This cable is driven directly (series terminated) from the oneshot. Shaping is done by feeding the undelayed negative output pulse of the oneshot and the delayed positive output pulse to a line driver gate I.C.

The negative going output of the line driver is translated from the MECL levels to NIM compatible levels by current sources. This output gives a pulse going from zero to -0.8 V (compatible to the NIM standard for fast timing applications). The output of the deadtime oneshot is translated to positive logic by a level translator I.C. This output gives a pulse going from zero to +4 V nom. and a pulse width equal to the internal dead time (compatible to the NIM standard for slow logic applications).

References:

Nuclear Instruments and Methods 117 (1974) 245

SECOND VERSION OF A CONSTANT FRACTION TRIGGER REDESIGNED WITH NEW INTEGRATED CIRCUITS AND RESULTS WITH SEMICONDUCTOR DETECTORS

Michael R. Maier and Donald A. Landis

EXPERIMENT 9

Time Coincidence Techniques and Absolute Activity Measurements

EQUIPMENT NEEDED FROM EG&G ORTEC

- ^{60}Co Radioactive Source, 1 to 5 μCi (beta source)
- Two Bins and Power Supplies
- Two 113 Scintillation Preamplifiers
- 142A Preamplifier
- A-015-025-1500 Surface Barrier Detector
- 266 Photomultiplier Tube Base
- Two 551 Timing Single-Channel Analyzers
- 425A Nanosecond Delay
- 428 Detector Bias Supply
- 567 Time-to-Amplitude Converter and SCA
- 556 High Voltage Power Supply
- 480 Pulser
- 418A Universal Coincidence
- Three 875 Counters
- Two 575A Amplifiers
- 719 Timer
- 305 Vacuum Chamber
- 905-3 NaI(Tl) Detector and Photomultiplier
- ACE-2K MCA System including suitable IBM PC (other EG&G ORTEC MCAs may be used)
- Vertical Phototube Stand MPM-9
- Oscilloscope
- Mechanical Vacuum Pump
- Source Kit SK-1G
- ORC-9 Cable Set

Purpose

This experiment will utilize some of the basic instrument configurations for time coincidence studies, including time spectroscopy. It includes a short discussion of typical decay schemes because these include sources of coincident events on which measurements can be made.

Introduction

Time coincidence counting is defined as a method for detecting and identifying radioactive materials and for calibrating their disintegration rates. The absolute activity measurement can be made by counting two or more characteristic radiation events, such as beta and gamma, that occur either together or within a specified time relationship to each other. The isotope that is used in this experiment is ^{60}Co.

Many beta and gamma sources that are used in nuclear training laboratories are produced with nuclear reactors. Typically, a certain stable isotope is placed in the reactor core for a specified time period. The neutron flux in the reactor core could be as much as 10^{14} neutrons per cm^2 per second. This means that 10^{14} thermal neutrons bombard each cm^2 of the sample per second. As a result of the bombardment the sample becomes radioactive.

At thermal neutron energies the most probable neutron reaction is the so-called (n,γ) reaction. A simplified explanation of this reaction is that a neutron from the reactor collides with one of the stable nuclei in the sample and in so doing is absorbed into the nucleus, causing a new nucleus to be formed. The new nucleus is most probably unstable and will get rid of this excess energy by emitting a radioactive particle. For (n,γ) neutron activation the excited nucleus is neutron-rich and the most probable decay mode for a neutron-rich isotope is beta decay. The beta decay is usually followed by gamma emission. In order to see this, consider the simple decay scheme shown in Fig. 9.1.

This decay scheme is really quite simple to understand. It was pointed out earlier that in a decay scheme the energy of excitation of a nucleus is plotted in the vertical direction. The possible energy levels available in the decay are shown as horizontal lines in the figure. We have drawn the lines to the right in Fig. 9.1 to point out the significance of these levels. X_1 decays by beta emission to Y_1. There are two possible modes to this decay, which in the figure are labeled β_0 and β_1. In other words, the excited X_1 nucleus has two possible routes to become de-excited.

In the diagram, C is the zero energy of Y_1. This zero energy is called the ground state of Y_1. Another possible state of Y_1 is the 0.570-MeV state, labeled B in the diagram. The second decay mode for X_1 consists of the emission of a beta particle, β_1, followed promptly by a gamma. Prompt means that the lifetime of the state is very short. These lifetimes usually range from 10^{-8} to 10^{-21} s. The gamma energy is exactly the same as the first excited state of Y_1. In the diagram, it is seen that this energy is 0.570 MeV. In other words, for this decay mode β_1 is emitted to the first excited state of Y_1, which immediately decays to the ground state of Y_1. If the beta spectrum from X_1 is studied as in Experiment 6, the two betas will be observed. However, a (β,γ) coincidence experiment

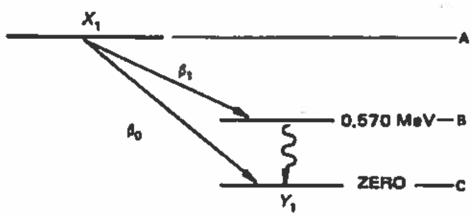

Fig. 9.1.

will quickly show that only β_1 is in coincidence with the 0.570-MeV gamma. This technique will be used later in the experiment to determine the absolute activity of a sample.

(α,γ) Coincidence

In order to understand (α,γ) coincidence, a simple example will be used. Let us assume that we have an alpha source (A) that decays by alpha emission to a stable isotope (B) with the scheme in Fig. 9.2. From the decay scheme it can be seen that 50% of the time (A) goes directly to the ground state

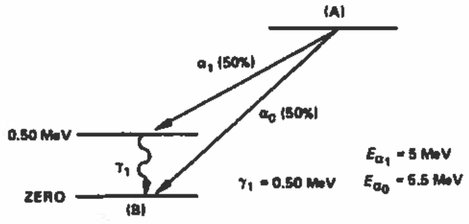

Fig. 9.2.

of (B) with the emission of an alpha, (α_0), whose 5.5-MeV energy is the difference between (A) and (B). The other 50% of the time, decay is by an (α,γ) branch, which is similar to the (β,γ) branch in the previous example. The decay is by a 5-MeV alpha (α_1) followed immediately by a 0.50-MeV gamma. Thus the α_1 and γ_1 are in coincidence. For this example, every α_1 is followed by a γ_1. Figure 9.3 shows the alpha and gamma spectra for the source as they would have been measured in the previous experiments.

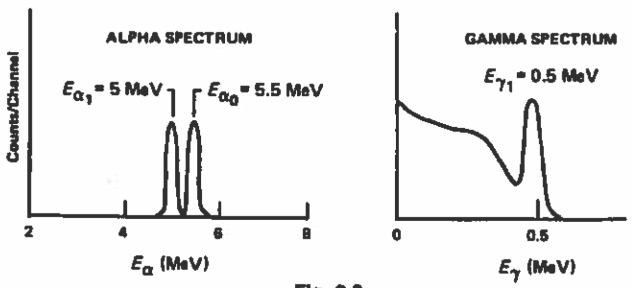

Fig. 9.3.

If the electronics are set up with a surface barrier detector to look at the alphas and with an NaI(Tl) detector to look at the gammas, it will be observed that there are no gammas in coincidence with α_0.

(γ,γ) Coincidence

In all the examples we have shown thus far in this experiment, gamma decay occurs directly to the ground state of the final stable nucleus. It is possible for a nucleus to de-excite with the emission of several gammas. In order to understand this, let us consider the simple decay scheme shown in Fig. 9.4.

In Fig. 9.4 the nucleus (C) decays to the nucleus (D) by beta emission followed by gamma decay. A simple way to look at the decay is as follows: the beta emission of (C) results in the nucleus (D), which is left with an excess energy of excitation of 1.0 MeV. The excited (D) nucleus gives off its energy of excitation by the emission of, first, γ_1, which has an energy of 0.4 MeV, and then promptly by the emission of γ_2, which has an energy of 0.6 MeV. In other words, for every γ_1 we also have a γ_2. For this simple example the gamma spectrum of isotope (C) is shown in Fig. 9.5. Of course, as we pointed out earlier, there would also be a coincidence between the beta particle and either of the gammas. Sometimes an isotope will branch directly to the ground state without going through the intermediate states.

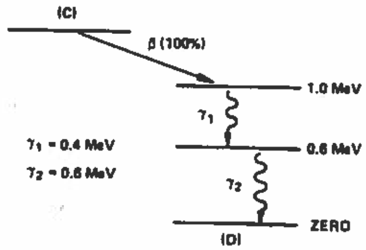

Fig. 9.4.

If this happened in the above example, a gamma of energy 1 MeV would also be seen in the spectrum. These probabilities of gamma decay from a given state to the ground state (stable state) through the intermediate states are called gamma-ray branching ratios.

In later experiments (γ,γ) and (α,γ) coincidence measurements will be made. In this experiment several possible electronic configurations will be considered for coincidence measurements, and a (β,γ) coincidence setup will be used to determine the absolute activity of a sample.

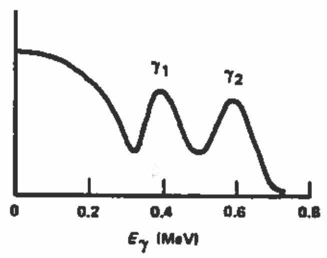

Fig. 9.5.

EXPERIMENT 9.1

Simple Fast Coincidence

In the circuit of Fig. 9.6, make the following module settings:
113 Preamplifiers: 0 pF Input Capacitance.
575A Amplifiers: Negative Input, Bipolar Output.
551 Timing Single-Channel Analyzers: Integral mode, Lower Level = 50/1000, Delay 0.5 μs; adjust walk (see manual).
418A Universal Coincidence: Inputs A and B Coinc; C, D, and E Off; Coincidence Requirements 2; Resolving Time maximum, 2 μs.
480 Pulser: Negative Output, Power On, Attenuated Output ~0.5 V (measured with an oscilloscope).

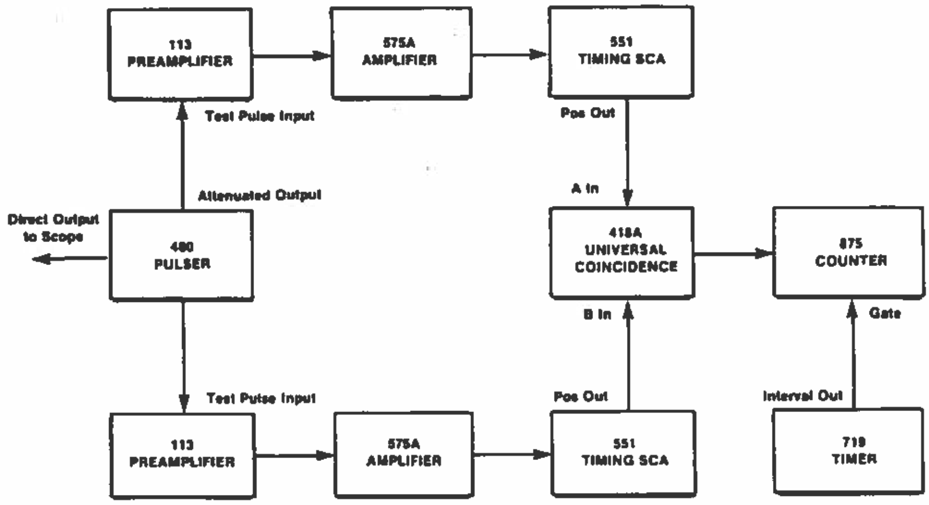

Fig. 9.6. Electronics Interconnections for Experiment 9.1.

Procedure

1. Adjust the gain of each 575A Amplifier so that the output pulse is ~5 V.

2. Set the 719 Timer for a long time (100 s). Vary the delay on either 551 until the maximum counting rate is observed on the 875 Counter. The two branches are now approximately coincident.

3. Clear the counter. Set the timer for 10 s and count. If the maximum counting rate was set properly in step 2, the counter should read ~600 (60 Hz for 10 s). Change the delay in either 551 by 10 ns (10 dial divisions) and repeat the 10-s count.

EXERCISES

a. Continue changing the delay for enough readings to plot a time coincidence curve similar to that shown in Fig. 9.7.

b. Narrow the resolving time of the 418A to 1 μs and plot the coincidence curve which is similar to Fig. 9.7 (note: take readings every 100 ns).

c. Narrow the resolving time of the 418A to 100 ns and measure the coincidence curve (take readings every 10 ns).

The student should now begin to understand the concept of simple fast time coincidence spectroscopy.

EXPERIMENT 9.2

Fast Coincidence and the Time-to-Amplitude Converter

The 567 Time-to-Amplitude Converter (TAC) can also be used when fast coincidence requirements are needed in an experiment. The TAC basically is a module that gives an output pulse whose amplitude is proportional to the time difference (Δt) between the start and stop input pulses to the converter. It is, therefore, an electronic clock that can be used to measure time differences that are very short (~10 x 10^{-12}s). The TAC will not only indicate that two events are in coincidence but will also tell how the coincidence events are distributed with respect to time. The purpose of this experiment is to study some of the properties of the TAC.

In the circuit of Fig. 9.8, make the following module settings:

113 Preamplifiers: 0 pF Input Capacitance.
575A Amplifiers: Negative Input, Bipolar Output.
551 Timing Single-Channel analyzer on Start Side: Integral mode, Lower Level = 50/1000, Delay 100 ns; adjust walk (see manual).
551 Timing Single-Channel Analyzer on Start Side: Integral mode, Lower Level = 50/1000, Delay 100 ns; adjust walk (see manual).
480 Pulser: Negative Output, Power On, Attenuated Output ~0.5 V (measured with an oscilloscope).
567 Time-to-Amplitude Converter: 0.2 μs; single-channel controls not used.
425A Delay: 32 ns In, all others Out.

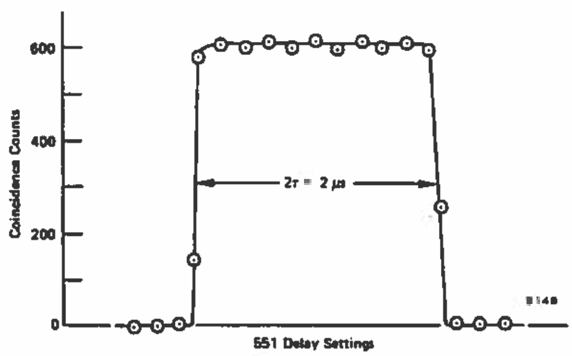

Fig. 9.7. Typical Time Coincidence Curve.

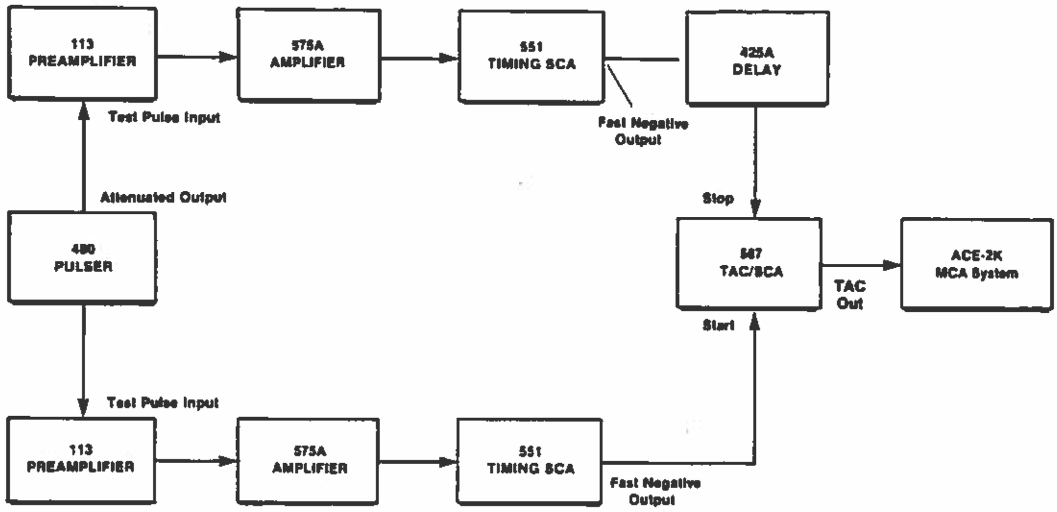

Fig. 9.8. Electronics Interconnections for Experiment 9.2.

Procedure

1. Adjust the gain of each 575A Amplifier so that its Bipolar Output has an amplitude of ~5 V.

2. Accumulate a spectrum in the analyzer. A single isolated group of signals should be observed above midscale on the analyzer display.

3. Set the 1, 2, 4, 8, and 16 ns switches of the 425A Delay unit all at In. This should move the position where signals are being accumulated in the analyzer display, and they should accumulate in the upper quarter of the display. Record the channel number of the peak.

4. Switch the 16-ns switch to Out and observe the movement of the peak in the analyzer. Record the new peak position.

5. Set all the switches in the 425A Delay module at Out, for 0 delay. Record the channel number of the peak in Table 9.1.

Table 9.1

Stop Signal Delay (ns)	Peak Location (Channel No.)	Stop Signal Delay (ns)	Peak Location (Channel No.)
0		35	
5		40	
10		45	
15		50	
20		55	
25		60	
30		65	

EXERCISES

a. Use the 425A Delay module to increase the Stop signal delay in 5-ns steps and fill in the peak location channel numbers in Table 9.1.

b. Plot the data from Table 9.1 on linear graph paper. The plot should be similar to that in Fig. 9.9.

c. Determine the slope of your calibration curve.

d. Determine the time resolution for your system. This is defined as δT in the formula

$$\delta T = (\text{FWHM}) \frac{\delta D}{\delta \text{ ch}} , \qquad (1)$$

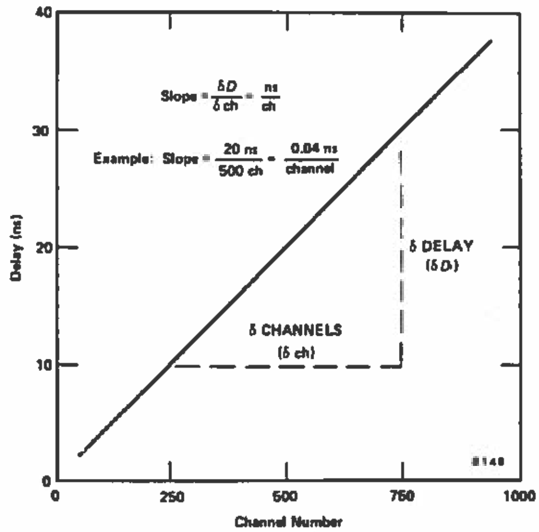

Fig. 9.9. Typical Delay vs Pulse-Height Curve.

where the (FWHM) factor is the number of channels across the half-height of the spectrum as defined earlier.

6. Switch the 567 TAC range to 400 ns. The TAC now has a full-scale output range that corresponds to 0–0.4 μs. Change the Delay on the Start 551 to 0.1 μs. Adjust the Delay in the Stop 551 until the TAC output is being stored in the upper quarter of the analyzer. Record the position of the peak.

7. Decrease the Delay in the Stop 551 by 100 ns (100 dial divisions). Record the new location of the peak.

EXERCISE

e. Continue to change the values of Delay in the Stop 551 and record the resulting channel locations. Use enough settings to establish a delay vs pulse-height curve for this new range of the TAC and calculate its measured resolution.

EXPERIMENT 9.3

Determination of Absolute Activity by the Coincidence Method

Introduction

Some of the coincidence techniques that were outlined above will now be used to determine the absolute activity of a ^{60}Co sample. The method consists of counting in the following order:

1. the gamma spectrum for the sample as in Experiment 3,
2. the beta spectrum as in Experiment 6,
3. the (β,γ) coincidence for the sample.

From step 1 the gamma counting rate, R_γ, is determined:

$$R_\gamma = A_0\epsilon_\gamma\ , \tag{2}$$

where A_0 is the true disintegration rate of the sample and ϵ_γ is the efficiency of the NaI(Tl) detector.

From step 2 the same information is determined for the betas:

$$R_\beta = A_0\epsilon_\beta, \tag{3}$$

where ϵ_β is the efficiency of the beta detector.

The coincidence counting rate measured in step 3 would be

$$R_c = A_0\epsilon_\gamma\epsilon_\beta\ . \tag{4}$$

From Eqs. (2), (3), and (4) A_0 is given by

$$A_0 = \frac{R_\gamma R_\beta}{R_c}\ . \tag{5}$$

The purpose of the experiment is to determine A_0 for the ^{60}Co sample.

In the circuit of Fig. 9.10, make the following settings on the modules:

113 Preamplifier: 0 pF Input Capacitance.
575A Amplifier (from 113): Negative Input, Bipolar Output.

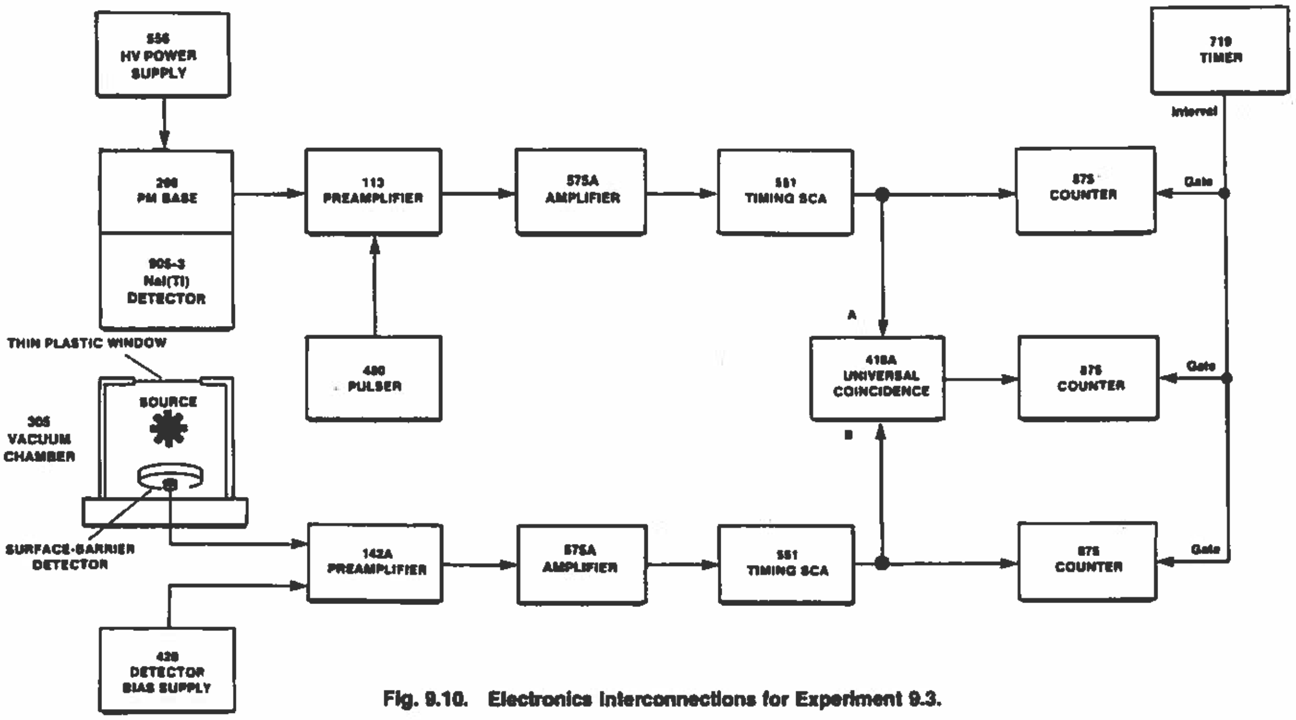

Fig. 9.10. Electronics Interconnections for Experiment 9.3.

575A Amplifier (from 142A): Positive Input, Bipolar Output.
551 Timing Single-Channel Analyzers: Integral mode, Lower Level N 40/1000, Delay minimum.
418A Universal Coincidence: Coincidence Requirements 2, Resolving Time maximum, 2 μs, Switch A Coinc, Switch B Coinc, Switches C, D, and E Off.

Turn on the mechanical vacuum pump.

Procedure

1. Adjust the 556 high voltage to the polarity and value recommended for the phototube.

2. Adjust the gain of the 575A Amplifier on the 113 side of the circuit so that the 1.33-MeV gammas from the ^{60}Co source are ~6 V at the Bipolar output.

3. Raise the 428 Bias Supply voltage gradually to the value recommended for the surface barrier detector.

4. Adjust the gain of the 575A Amplifier on the 142A side of the circuit so that the maximum pulse amplitude from the beta continuum is ~7 V.

5. All three 875 Counters should be counting.

6. Stop the 719 Timer and clear all counters to zero.

7. Start counting in all three counters by starting the 719. Count for a time interval long enough to accumulate ~600 counts in the R_c counter (for the coincidence events).

EXERCISE

Calculate A_0 from Eq. (5). How does your value compare with the value indicated for the sample, considering its current rate of decay?

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EXPERIMENT 13

Gamma-Gamma Coincidence

EQUIPMENT NEEDED FROM EG&G ORTEC

Two 113 Scintillation Preamplifiers
Two 266 Photomultiplier Tube Bases
Two Bins and Power Supplies
Two 551 Timing Single-Channel Analyzers
426 Linear Gate
567 Time-to-Amplitude Converter and SCA
Two 556 High Voltage Power Supplies
480 Pulser
418A Universal Coincidence
875 Counter
Two 575A Amplifiers
427A Delay Amplifier
719 Timer
Two 905-3 NaI(Tl) 2- x 2-in. Scintillation Detectors and PM Tubes
ACE-2K MCA System including suitable IBM PC (other EG&G ORTEC MCAs may be used)
Oscilloscope
10-μCi ^{22}Na source
Source Kit SK-1G
306 Gamma-Gamma Angular Correlation Table with rotating detector and shields
ORC-13 Cable Set

Purpose

Two annihilation quanta are radiated from a ^{22}Na source in coincidence with each other for each radiation event that will be measured in this experiment. The purpose of the experiment is to verify that these quanta emanate from the source with an angular separation of 180°.

Introduction

Sodium-22 is an excellent source for a simple gamma-gamma coincidence experiment. The decay scheme for this isotope is shown in Fig. 13.1. From the decay scheme it can be seen that 99.95% of the time the decay occurs by positron emission and electron capture through the 1.274-MeV state of ^{22}Ne. Ninety percent of these decay events occur with positron emission, which then annihilate and produce a pair of 0.511-MeV gamma rays that can be seen in the gamma spectrum.

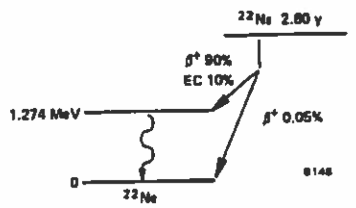


Fig. 13.1. Decay Scheme for ^{22}Na.

Figure 13.2 shows a typical gamma spectrum for ^{22}Na that was obtained with an NaI(Tl) detector. The 0.511-MeV peak will usually be quite a bit more intense than the 1.274-MeV peak, primarily because of the detector efficiency differences at the two energy levels (see Experiment 3) and the annihilation process.

Figure 13.3 shows a typical instrument configuration for measuring a gamma-gamma coincidence. The ^{22}Na source is usually covered with a thin absorber such as a thin piece of metal or plastic. Positrons from the source will lose energy in the absorber by dE/dx and will be annihilated in the ab-

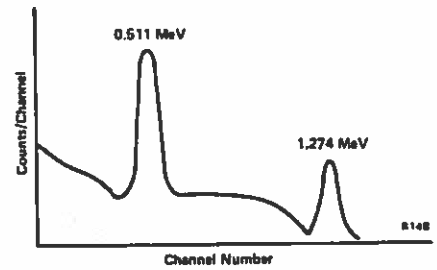


Fig. 13.2. NaI(Tl) Spectrum of ^{22}Na.

sorber. The NaI(Tl) detectors will see an approximate point source of radiation. When the positrons are annihilated, two 0.511-MeV gammas will leave the source with an angular separation of 180°.

Experimentally this pair of gamma rays is detected and measured with one detector that is fixed and another detector that can rotate about the source. Figure 13.4 shows some of the details of a rotating assembly that is used for the experiment.

The ^{22}Na coincidence experiment will use three different electronic system configurations. In the first, the events that enter the two detectors will have to produce pulses that overlap each other to indicate that a coincidence exists, and the counter will then count the number of coincidences that are sensed during its timed counting interval. In the second, a pulse from the movable detector will enable the gate of the 426 Linear Gate, and any corresponding pulse from the fixed detector that arrives within the adjusted gate width interval will be considered coincident and will be counted in the counter. In the third setup, the 567 Time-to-Amplitude Converter, (TAC), and SCA will be used to measure the variations in time at which the coincident events are sensed by the two detectors; a counter can count all of the coincidences that occur within about a 500-ns range, and then an MCA can be used to obtain a spectrum of the precise timing variations.

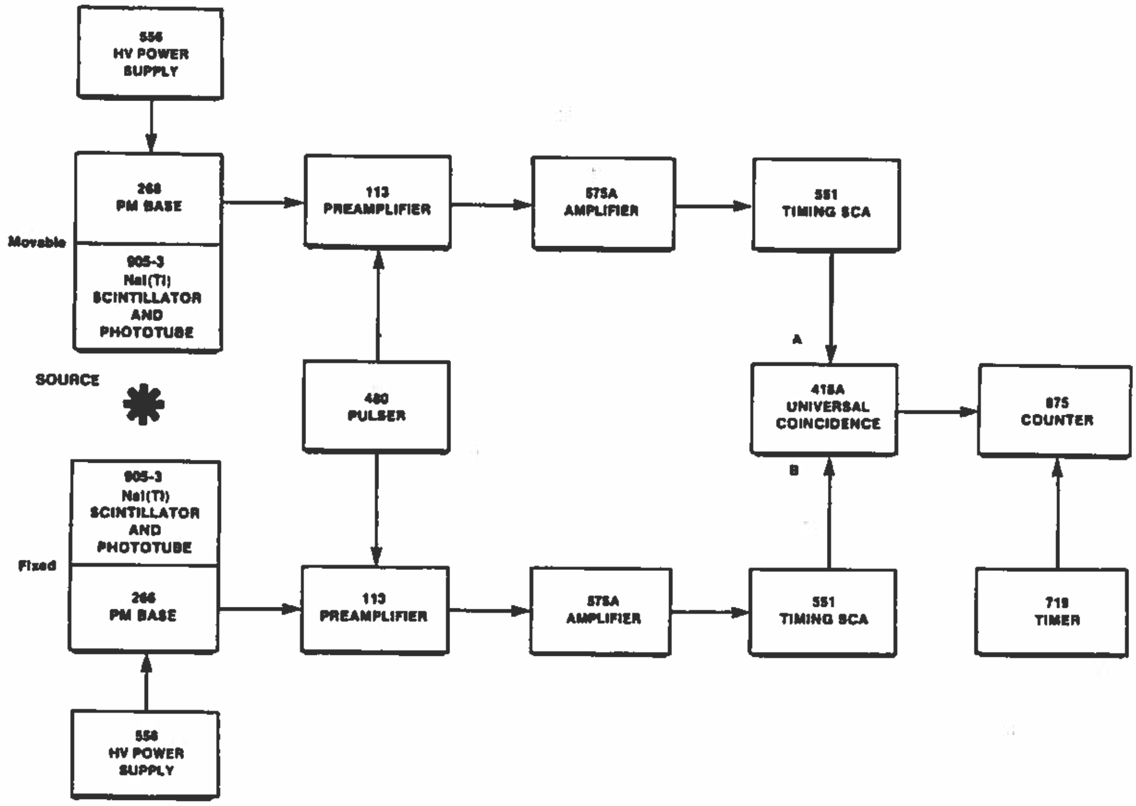


Fig. 13.3. Electronics for Experiment 13.1.

The student should complete Experiment 9 before starting this experiment and should be somewhat familiar with the principles of coincidence measurements.

EXPERIMENT 13.1

Overlap Coincidence Method for Measuring Gamma-Gamma Coincidence of ^{22}Na

Procedure

1. Set up the electronics as shown in Fig. 13.3. Use Fig. 13.4 as a guide to arranging the two detectors.

2. Set the 575A Amplifiers for negative input and unipolar output. Adjust the gain of both amplifiers so that the 1.274-MeV line of ^{22}Na results in ~6 V pulses at the outputs.

3. Set the 551 Timing SCAs for Integral mode. Set the Delay controls at minimum and the Lower-Level dials at 40/1000. Use the SCA outputs.

4. Connect the SCA Out from one of the 551 Timing SCAs to the A input of the 418A and connect the output from the other 551 to the B input of the 418A. Set the 418A Coincidence Requirements switch at 2 and the Resolving Time at maximum (2 μs). Set the A and B toggle switches at Coinc and set the C, D, and E toggle switches at Off. With the source removed and the 480 Pulser turned on, the 418A output will indicate coincidence for the two signal paths. Turn off the 480 and return the source.

5. Set the 719 Timer for a long timing period, such as 8 min, and permit the 875 Counter to operate while the movable detector is rotated slowly to both sides of 0°. The counting rate should be maximum at $\theta = 0°$.

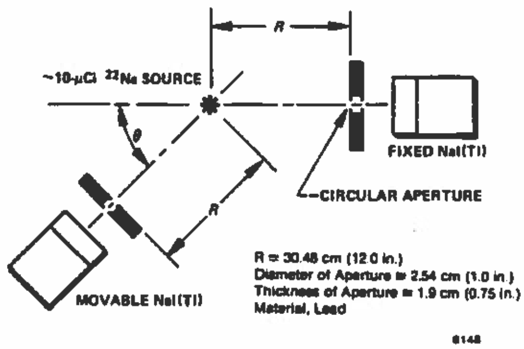


Fig. 13.4. Mechanical Arrangement of Detectors on EG&G ORTEC 306 Angular Correlation Table.

6. Set the timer for a long enough accumulation period to provide reasonable statistics at the points of interest and fill in the values in Table 13.1.

EXERCISE

Plot the data in Table 13.1 on linear graph paper. For each counting rate, (N), the statistical variation $\pm\sqrt{N}$ should be included on the graph. Figure 13.5 shows a typical set of data for this experiment.

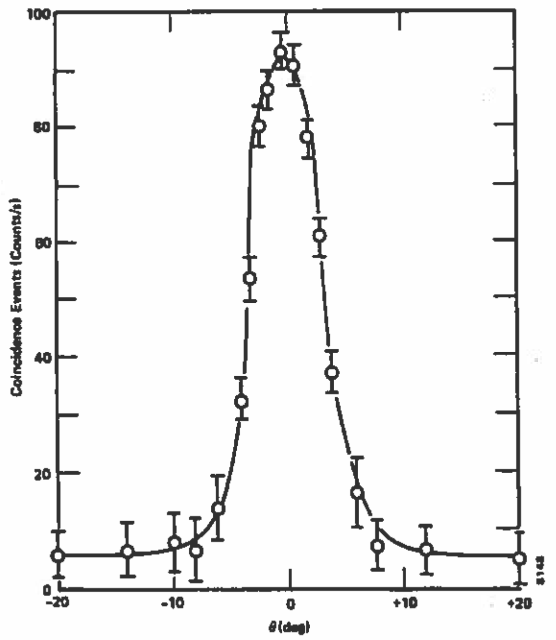


Fig. 13.5. Coincidence Data.

Table 13.1

θ (deg) Positive	Counts/s	θ (deg) Negative	Counts/s
0		0	
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
10		10	
14		14	
20		20	
25		25	

EXPERIMENT 13.2

Linear Gate Method for Measuring Gamma-Gamma Coincidence of ^{22}Na

Procedure

1. Set up the electronics as shown in Fig. 13.6. Use the same mechanical detector placement as in Experiment 13.1.

2. Using the ^{22}Na source, adjust the gain of each 575A Amplifier for an output of ~6 V for the 1.274-MeV gamma line.

3. Remove the source. Turn on the pulse generator and adjust the Pulse-Height dial, the Cal control, and the attenuators so that the amplifier output pulses are the same as in step 2.

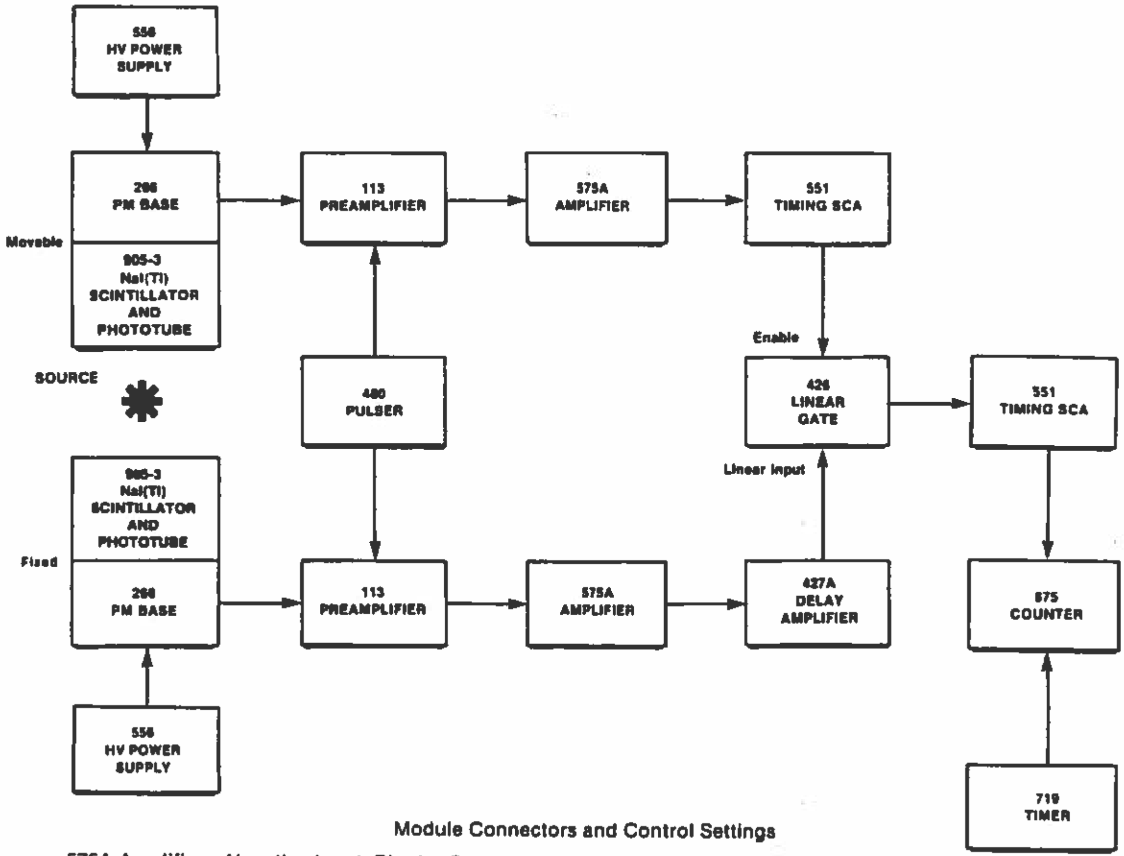
4. Look at the output of the 426 Linear Gate with the oscilloscope. If the timing is correct, a unipolar pulse should be observed whose amplitude is proportional to the pulse-height dial setting on the 480. Vary the pulse height and see that there is a linear response. If no output pulses are seen from the 426, adjust the Delay time of the 551 on the movable detector side and recheck the Gate Width control on the 426 until output pulses are seen normally.

5. Turn off the pulser and return the ^{22}Na source to its proper position as shown in Fig. 13.4. Measure the angular distribution of pulse rates from the system as in Experiment 13.1, using the angles in Table 13.1.

6. (Alternate) The output of the Linear Gate can be fed into an MCA. The spectrum should resemble Fig. 13.2 except that the 1.274-MeV peak will not be present. The coincidence requirement has virtually eliminated this peak from the spectrum.

EXERCISE

Plot the data on linear graph paper as in Experiment 13.1. Compare the count rates at $\theta = 0°$.



Module Connectors and Control Settings

575A Amplifiers: Negative Input, Bipolar Output.
551 Timing Single-Channel Analyzer on movable detector side: Lower Level = 40/1000, Integral mode, SCA Output, Delay minimum.
551 Timing Single-Channel Analyzer following the Linear Gate: same settings.
426 Linear Gate: Normal mode, Gate Width maximum (4 μs).
480 Pulser: Attenuated output, negative polarity, power switch Off.
875 Counter: Input from the 551, Gate from the 719 Interval Out.

Fig. 13.6. Arrangement of Electronics for Experiment 13.2.

EXPERIMENT 13.3

Time-to-Amplitude Converter Method for Measuring Gamma-Gamma Coincidence of ^{22}Na

Procedure

1. Set up the electronics as shown in Fig. 13.7. Use the same mechanical detector placement as in Experiment 13.1.

2. Using the ^{22}Na source, adjust the gain of each 575A Amplifier for an output of ~6 V for the 1.274-MeV gamma line.

3. Remove the source. Turn on the pulser and adjust the Pulse-Height dial, the Cal control, and the attenuators so that the amplifier output pulses are the same as in step 2.

4. Observe the output pulses of the 567 with the oscilloscope. They should be ~6 V in amplitude. Change the delay on either 551 SCA while observing these output pulses (they can also be observed with the MCA).

5. Determine a delay vs pulse-height curve for the 567 TAC. This procedure is outlined in Experiment 9.2.

EXERCISE

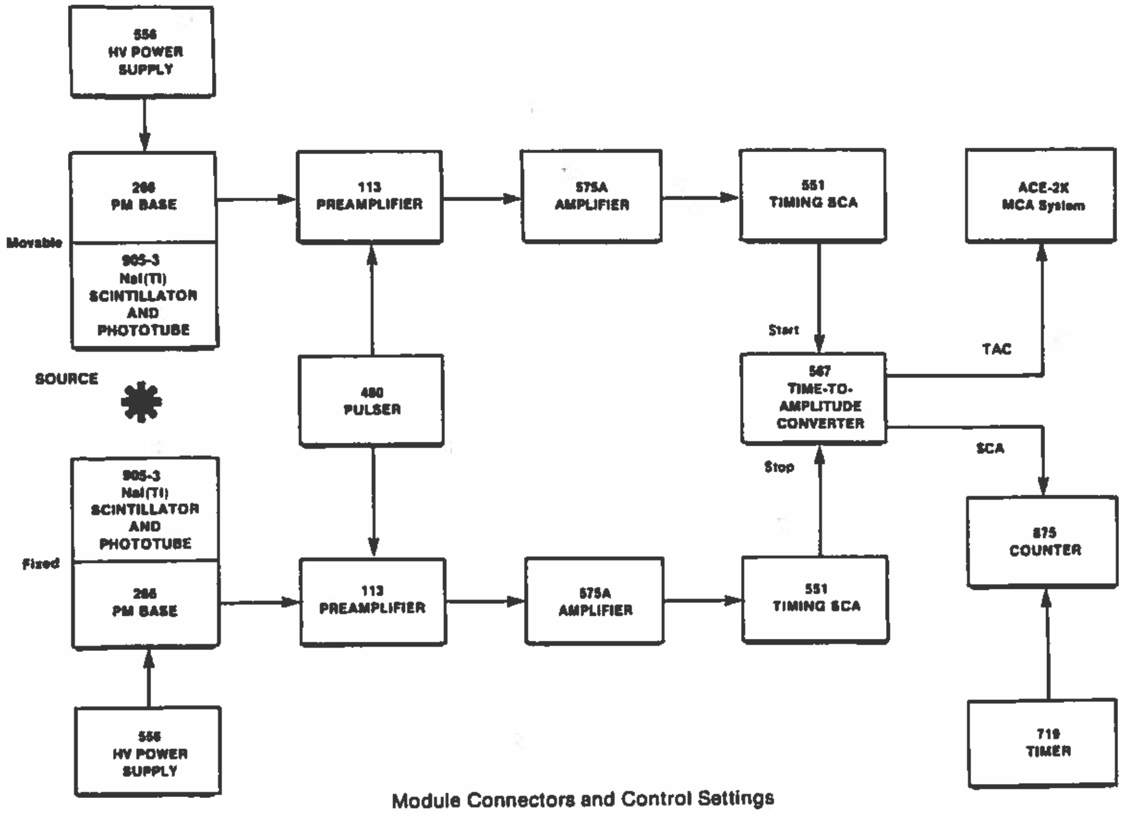
a. Determine the time resolution of the pulses from the 480 Pulser.

6. Turn off the pulser when the delays of the 551 SCAs are set for a 5- to 6-V output from the 567. Return the ^{22}Na source to its proper position as shown in Fig. 13.4. Measure the angular distribution of pulse rates from the system using the FWTM levels of the time spectrum and integrating the counts in the channels between these levels.

EXERCISES

b. Plot your data on linear graph paper as in Experiment 13.1. Compare the count rates at $\theta = 0°$.

c. Determine the time resolution for the coincidence measurements from the MCA readout.



Module Connectors and Control Settings

575A Amplifiers: Negative Input, Bipolar Output.
551 Timing Single-Channel Analyzer on movable detector side: Integral mode, Lower Level = 40/1000, Delay = 0.1 μs, Neg Out to Start Input on 567.
551 Timing Single-Channel Analyzer on fixed detector side: Integral mode, Lower Level = 40/1000, Delay = 5 μs, Neg Out to Stop Input on 567.
567 TAC and SCA: Range 400 ns, TAC Out to MCA, SCA Out to 875.
480 Pulser: Attenuated output, negative polarity, power switch Off.

Fig. 13.7. Arrangement of Electronics for Experiment 13.3.

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ORTEC®

Single-Channel Pulse-Height Analyzers
Introduction

The amplitude of the analog pulse at the output of a spectroscopy amplifier is typically proportional to the charge released in the detector or to the energy of the detected event. Selection of a range of signal levels at the output of the amplifier is equivalent to the selection of a range of energies or charge for these events. This selection can be accomplished by the use of discriminators and single-channel analyzers (SCAs). A discriminator produces an output logic pulse only if its input signal exceeds a preset threshold level. A single-channel analyzer produces an output logic pulse only if the peak amplitude of its input signal falls within the pulse-height window that is established with two preset threshold levels.

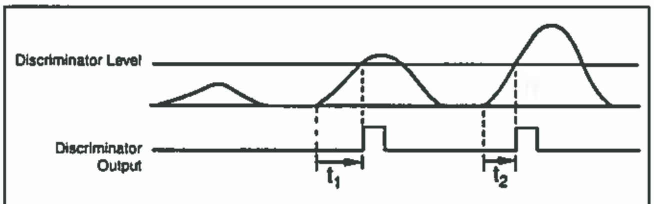

Fig. 1. Integral Discriminator Output Triggering.

Figure 1 shows three pulses that might be provided from a main amplifier to an integral discriminator. The first pulse has an amplitude less than the adjusted discriminator threshold and generates no output logic signal. Each of the last two pulses has sufficient amplitude to produce an output logic signal. The output signals indicated in Fig. 1 are generated when the leading edge of the input signal crosses the discriminator threshold level. Therefore, the time of the output response is a function of the amplitude and rise time of the input signals. This amplitude and rise time dependence leads to "time walk" of the output signal relative to the beginning of the input pulse. The discriminator output is produced earlier by pulses with larger amplitudes and later by pulses with lower amplitudes.

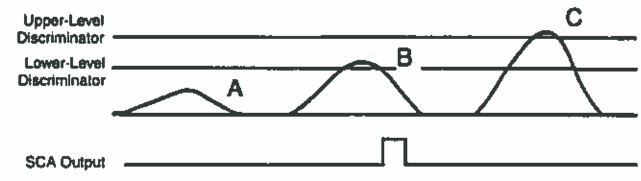

Fig. 2. Single-Channel Analyzer Function.

Figure 2 shows three pulses that might be provided from a main amplifier to an SCA. Only the B pulse satisfies the conditions necessary to produce an SCA output logic signal.

Removal of the upper-level-discriminator restrictions from the SCA allows it to be used as an integral discriminator. If the upper-level restrictions were removed from the unit whose output is shown in Fig. 2, both pulses B and C would be marked by logic outputs.

Three primary modes of discriminator operation are available in ORTEC SCAs: Integral, Normal, and Window. In the Integral mode of operation, the SCA can function as an integral discriminator, as indicated in the preceding paragraph. In the SCA Normal mode of operation, the upper-level and lower-level thresholds are independently adjustable. In the SCA Window mode, the upper-level threshold control is used to establish a voltage level that is added to the lower-level threshold voltage to yield the upper-level discriminator (ULD) threshold level. Thus, when the lower-level setting is changed, the upper-level threshold changes by the same amount. An external voltage reference for the lower-level discriminator (LLD) can be supplied to scan the window through a preselected range of pulse heights.

Unlike an integral discriminator, the output logic signal from a single-channel analyzer must be produced after the input pulse reaches its maximum amplitude. This timing sequence must provide sufficient time for the SCA logic circuitry to determine if the input signal exceeded the upper-level threshold.

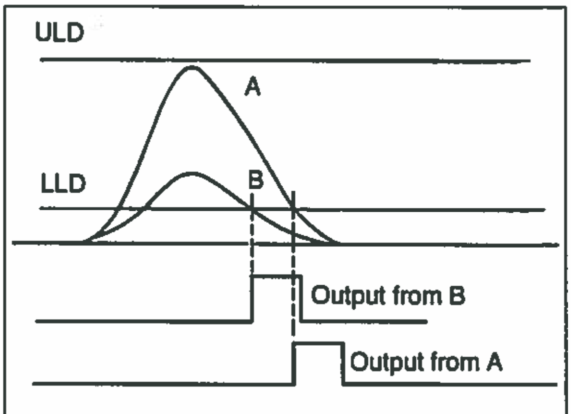

Fig. 3. Non-Timing SCA Output Triggering.

ORTEC provides two basic types or classifications of SCAs: non-timing SCAs and timing SCAs. The technique used to produce the output logic signals from an SCA determines its classification. Non-timing units, such as the Models 550A, and 850, produce an SCA output pulse if the input signal is within the window settings. The output occurs when the trailing edge of the input signal recrosses the lower-level threshold. Figure 3 shows two superimposed output pulses from a main amplifier that meet the window requirements of the single-channel analyzer. The output from the non-timing SCA for each pulse is shown below the pulses. Since the linear input pulses are referenced to the same starting time, it is clear that the output logic signals exhibit "time walk" relative to the input pulses.

Timing SCAs, such as the ORTEC Models 551, 552, and 590A, produce SCA output logic signals that are precisely related in time to the occurrence of the event being measured. This time relationship implies that the time of occurrence of the SCA output signal is "walk-free" or nominally independent of the amplitude of the input signal, for a given rise time. In addition to simple counting applications, the time-related output can be used for coincidence measurement, pulse-shape discrimination, and other applications where the precise time of occurrence is important.

Figure 4 shows two pulses from a main amplifier and the response for a peak-detection single-channel analyzer such as the Model 590A Amplifier and Timing Single-Channel Analyzer. Although the amplitudes of the amplifier pulses differ, their peaks occur at approximately the same time, and the SCA outputs are produced when the peaks of the input pulses are detected.

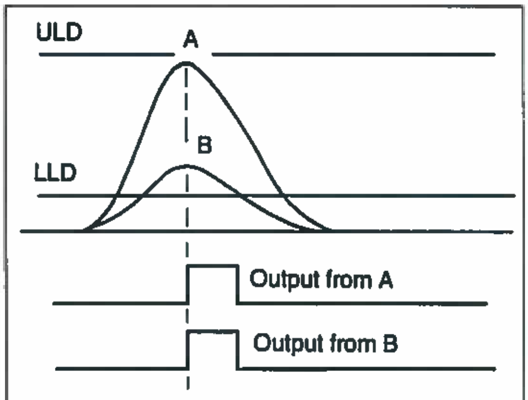

Fig. 4. Peak-Sensing SCA Output Triggering.

The conventional zero-crossing technique has been widely used for timing single-channel analyzers. This technique utilizes the zero-crossing of the bipolar output signal from a pulse-shaping amplifier to derive timing information, and uses the peak amplitude of the pulse for the energy range information. Figure 5 shows two bipolar pulses provided from a main shaping amplifier. Both pulses meet the SCA window requirements. Each output signal is generated when the corresponding input signal crosses the baseline. Figure 5 illustrates that the time of occurrence of the SCA output signals is precisely related to the occurrence of the detected event and is independent of input signal amplitude. Either double-delay-line-shaped pulses or RC-shaped pulses may be used, but the former provide better timing resolution. The bipolar output from delay-line amplifiers such as the Model 460 is well suited to zero-crossover timing with the ORTEC Model 552, because the input signal crosses the baseline with a large slope even when the pulse amplitude is low.

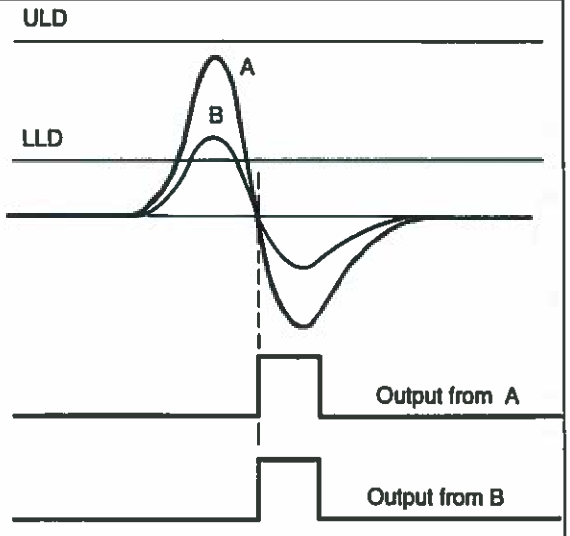

Fig. 5. Zero-Crossover SCA Output Triggering.

The bipolar output signal from a double-delay-line shaping amplifier crosses the baseline at a fixed fraction that is effectively 50% of the charge collected from the detector. Thus, conventional zero-crossing timing can be considered as timing at a constant fraction of the input signal amplitude. A trailing-edge constant-fraction technique* can be used with either unipolar or bipolar signals to derive a time-pickoff pulse after the peak time of the signal from the shaping amplifier. This technique is extremely useful when incorporated in timing single-channel analyzers. Figure 6 illustrates the trailing-edge constant-fraction technique for two unipolar input signals of identical rise times but different amplitude. The time of occurrence of the output signals is independent of output signal amplitudes.

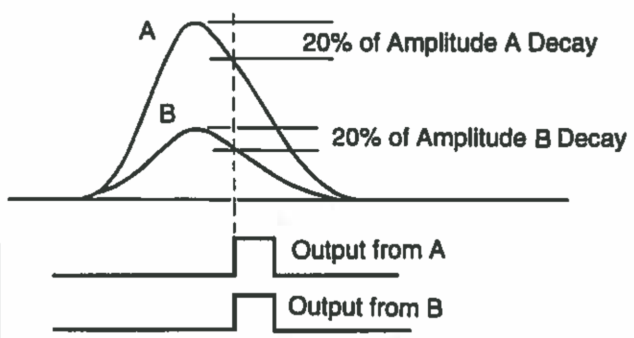

Fig. 6. Constant-Fraction SCA Output Triggering.

*The basic circuit for implementing this technique is patented by ORTEC, U.S. Patent No. 3,714,464.

Single-Channel Pulse-Height Analyzers
Introduction

The trailing-edge constant-fraction timing technique is available with two ORTEC SCAs: Models 551 and 552.

The Model 552 can also be used as a pulse-shape analyzer. The best known application of this technique is in the separation of the neutron and gamma responses of some scintillators. Collection time differences for the two types of radiation result in shape or rise time variations in the signals from a spectroscopy amplifier. When used with an ORTEC Time-to-Amplitude Converter, the Model 552 can resolve these shape variations over a 200:1 dynamic range of input signal amplitudes. The Model 552 accomplishes the shape measurement of the input signals by evaluating the timing at two different fractions.

The SCA function can also be applied to fast analog signals in rising-edge constant-fraction discriminators.

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414A

Fast Coincidence

- **Provides fast coincidence determinations with adjustable resolving time**
- **Three selectable, positive-polarity coincidence inputs**
- **One selectable, positive-polarity anticoincidence input**
- **Adjustable 10 to 110 ns resolving time**

The ORTEC Model 414A Fast Coincidence is a modular threefold coincidence unit that allows fast coincidence determination between any two or three input signals. The term "fast" indicates the general nature of the coincidence circuit; that is, input pulses are reshaped, and the actual coincidence determination is made on the leading edge, or leading portion, of the pulses. A dc-coupled anticoincidence input is provided to inhibit the coincidence output by a dc voltage or a pulse that overlaps the period of coincidence of the coincident pulses. The coincidence inputs are ac-coupled, and all four inputs are controlled by In/Out toggle switches.

The resolving time, 2 τ, of the fast coincidence unit may be varied over a 10- to 110-ns range by a 10-turn control for accurate resettability of the resolving time. The resolving time of the anticoincidence circuit is set by the width of the input pulse.

Specifications

PERFORMANCE

PULSE PAIR RESOLUTION <100 ns on any single input; for coincidence events, <1 µs on the coincidence output.

RESOLVING TIME (2τ) Continuously variable from 10 to 110 ns for coincidence signals; set by the width of the input pulse for the anticoincidence signal.

TEMPERATURE INSTABILITY 2τ changes <±0.2%/°C from 0 to 50°C.

CONTROLS

RESOLVING TIME (10–110 ns) Front-panel 10-turn locking potentiometer for controlling resolving time for inputs A, B, and C over a range from 10 to 110 ns.

INPUT CONTROLS Toggle switches for using any input combination desired and for disabling input signals to the coincidence and anticoincidence circuits without input coaxial cables having to be removed.

INPUTS

COINC Front-panel BNC connectors provide 3 ac-coupled coincidence inputs (A, B, C) of positive polarity; 2-V threshold, 20-ns minimum width required; absolute maximum input 50 V; impedance >3000 Ω.

ANTICOINC Front-panel BNC connector provides one dc-coupled anticoincidence input (D) for inhibiting coincidence output; +2 V threshold, 20-ns minimum width required; absolute maximum input 50 V; impedance >3000 Ω.

OUTPUTS

OUTPUT Two separate buffered coincidence output signals through front-panel BNC connectors provide positive pulses ≥500 ns wide with 5-V minimum amplitude; ac-coupled with <10- Ω impedance; monitored through oscilloscope test points on front panel.

ELECTRICAL AND MECHANICAL

POWER REQUIRED The Model 414A derives its power from a standard NIM bin/power supply. The power required is +24 V, 30 mA; −24 V, 30 mA; +12 V, 120 mA; and −12 V, 85 mA.

WEIGHT
Net 1.09 kg (2.4 lb).
Shipping 2.0 kg (4.4 lb).

DIMENSIONS NIM-standard double-width module 6.90 X 22.13 cm (2.70 X 8.714 in.) per DOE/ER-0457T.

Ordering Information

To order, specify:

Model	Description
414A	Fast Coincidence

Specifications subject to change
011108

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418A
Universal Coincidence

- **Provides coincidence determinations using majority logic**
- **Five, positive-polarity, dc-coupled inputs**
- **Coincidence, Anticoincidence, or Off selectable for each input**

The ORTEC Model 418A is a Universal Coincidence unit with five dc-coupled inputs. Each input is accepted through a convenient front-panel connector.

Input A accepts an input signal with a width of 50 ns or more and regenerates an internal signal that will be used for coincidence comparisons. The Input A signal width is adjustable for a resolving time of 100 ns to 2 µs, and this range is available with a front-panel control.

The function of each input is selectable, and its signal can be used for coincidence or anticoincidence or can be disabled. This permits various combinations of input signal relations to be selected without adding or removing cables in the system.

Another feature that simplifies operating flexibility without changing any cables is a selectable number of inputs that are required to satisfy a coincidence. For example, if the selector shown is set at 2, an overlap between any two inputs that are selected for the coincidence function will cause an output to be generated. If any one or more inputs are selected for anticoincidence, all outputs are inhibited while such signals are present. Because any combination of input signal effects can be selected easily at the front panel, the Model 418A is a Universal Coincidence unit that can be adapted to any coincidence system arrangement.

Specifications

PERFORMANCE

INPUT A RESOLVING TIME 100 ns to 2 µs; controlled by a front-panel, 20-turn, screwdriver adjustable potentiometer; inputs B, C, D, and E controlled by input pulse width.

TEMPERATURE INSTABILITY
Input A Change in resolving time, τ, <±0.1%/°C.

Inputs B, C, D, E Change in resolving time, τ, <±0.05%/°C for τ = 500 ns.

OPERATING TEMPERATURE 0 to 50°C.

CONTROLS

COINCIDENCE REQUIREMENTS Selects number of inputs necessary to satisfy a coincidence requirement (majority logic).

INPUT CONTROLS Five 3-position toggle switches select Coincidence, Anticoincidence, or Off (disabled).

INPUTS

POLARITY +2 V minimum, 30 V maximum.

PULSE WIDTH 50 ns to dc.

CONNECTORS BNC on front panel.

INPUT IMPEDANCE >1.5 k Ω, dc-coupled.

OUTPUTS

AMPLITUDE +5 V.

PULSE WIDTH 500 ns.

CONNECTORS BNC on front and rear panels.

OUTPUT IMPEDANCE <10 Ω, dc-coupled.

ELECTRICAL AND MECHANICAL

POWER REQUIREMENTS The Model 418A derives its power from a standard NIM bin/power supply. The power required is +24 V, 105 mA; –24 V, 95 mA; +12 V, 50 mA; and –12 V, 30 mA.

WEIGHT
Net 0.9 kg (2.0 lb).
Shipping 2.25 kg (5.0 lb).

DIMENSIONS Standard single-width NIM module 3.43 X 22.13 cm (1.35 X 8.714 in.) per DOE/ER-0457T.

418A
Universal Coincidence

Related Equipment

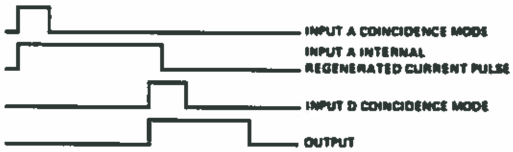
Input signals to the Model 418A can be from any timing instrument providing a positive output signal from 2 to 30 V. The output of the Model 418A provides a logic signal suitable for driving any of the medium-speed logic modules in the ORTEC product line, but it is more typically used as a gating signal such as a gate-enable signal to a multichannel analyzer.

Ordering Information

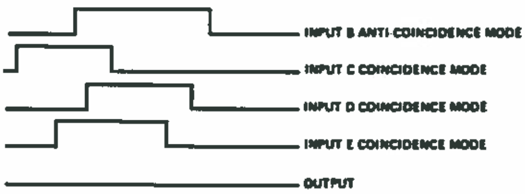
To order, specify:

Model	Description
418A	Universal Coincidence

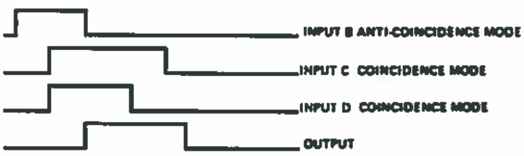
Coincidence Requirements When Switch Setting is 2.



Coincidence Requirements When Switch Setting is 2.



Coincidence Requirements When Switch Setting is 3.



Coincidence Requirements When Switch Setting is 2.

Coincidence Requirements When Switch Setting is 4.

Specifications subject to change
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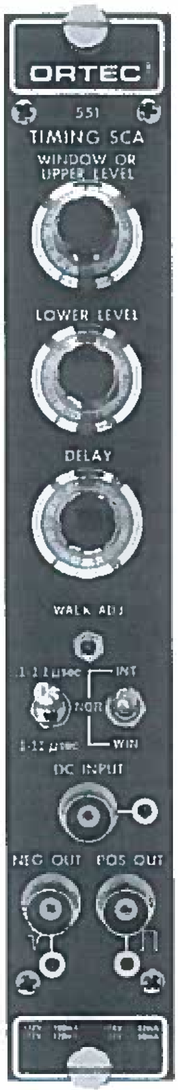
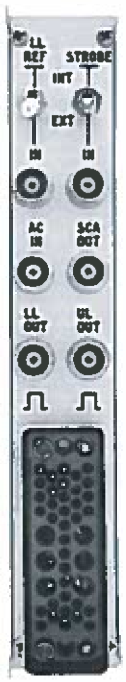
551
Timing Single-Channel Analyzer

- **Single-channel analyzer and timing signal derivation**
- **Trailing-edge constant-fraction timing provides walk <±3 ns for 100:1 dynamic range**
- **Integral, normal, and window modes**
- **Separate lower-level and upper-level discriminator outputs**
- **DC-coupled**
- **Adjustable delay 0.1 to 11 µs**
- **Provision for external baseline sweep**





The ORTEC Model 551 Timing Single-Channel Analyzer performs the dual functions of single-channel pulse-height analysis and timing signal derivation.

The patented* trailing-edge constant-fraction timing technique provides unexcelled timing on either unipolar or bipolar signals and shows better results than are possible with conventional leading-edge discriminators.

With SCAs that utilize leading-edge timing, the rise time of the input pulses causes degradation of time resolution because the pulses have varying amplitudes.

Constant-fraction timing compensates for varying amplitudes and essentially eliminates this timing shift, giving consistently better timing results.

For the internally set 50% fraction, the output occurs soon after the midpoint on the linear input trailing edge to facilitate gating and accumulation of data at very high input rates. This technique also minimizes timing shift and dead time when used with sodium iodide, silicon, and germanium detectors, thereby allowing better system time resolution and higher counting rates.

The constant-fraction technique makes it possible to realize significant improvements in time resolution in most timing applications. Notice that analysis is made of the main amplifier output. This technique allows optimization of time resolution and extension of dynamic range for neutron-gamma discrimination and other timing applications. Walk of <3 ns for 100:1 dynamic range using input pulses from a pulser is possible.

The Model 551 is versatile, with three basic operating modes provided. In the Window mode, the unit operates as a high-resolution, narrow (0 to 10%) window, single-channel analyzer. For wide-window applications, the Normal mode is used. In this mode the upper-level and lower-level controls are independently variable from 0 to 10 V, and an output is generated for pulses analyzed between the levels. Through use of the separate rear-panel LL Out and UL Out outputs, the unit can operate as a dual wide-dynamic-range integral discriminator for leading-edge timing or for pulse routing.

*U.S. Patent No. 3,714,464.

The dc-coupled input of the Model 551 makes it possible to take full advantage of the baseline restoration of the main amplifier for maximum performance at widely varying counting rates.

The continuously adjustable output delay (two ranges covering 0.1 to 11 µs) makes it possible to align output signals that have actual time differences without a need for additional delay devices or modules. Alternatively an External strobe input can be used to cause an SCA output at the desired time.

For an application where it is desirable to scan an entire spectrum, an external base-line sweep input is provided via the rear-panel LL Ref Ext BNC connector. In this mode of operation, the baseline (lower-level threshold) on which a window is riding is swept through an energy range and the count rate is recorded as a function of energy.

Specifications

PERFORMANCE

DYNAMIC RANGE 200:1.

PULSE-PAIR RESOLVING TIME Output pulse width plus Delay (as selected by the front-panel Delay controls), plus 100 ns for fast NIM output or plus 200 ns for positive NIM output. Minimum resolving time for negative output 220 ns; for positive output 800 ns.

THRESHOLD TEMPERATURE INSTABILITY ≤±0.01%/°C of full scale, 0 to 50°C using a NIM Class A power supply (referenced to −12 V).

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

DELAY TEMPERATURE INSTABILITY ≤±0.03%/°C of full scale, 0 to 50°C.

DELAY NONLINEARITY <±2% of delay range.

WINDOW WIDTH CONSTANCY ≤±0.1% variation of full-scale window width over the linear range 0 to 10 V.

MINIMUM INPUT THRESHOLD 50 mV for lower-level discriminator.

551
Timing Single-Channel Analyzer

TIME SHIFT vs PULSE HEIGHT (WALK)

Walk (ns)		Dynamic
System A	System B	Range
±1.0	±2.0	10:1
±2.5	±4.0	50:1
±3.0	±4.0	100:1

System A: Using an ORTEC Model 460 Amplifier, single delay-line mode, integrate ≤0.1 µs with 1-µs delay line.

System B: Using an ORTEC Model 570, 571, or 572 Amplifier, unipolar output with 0.5-µs shaping time. Input from ORTEC Model 419 Pulser.

CONTROLS

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

WINDOW OR UPPER LEVEL Front-panel 10-turn potentiometer determines the window width (0 to +1 V) in the Window mode or the upper-level (0 to +10 V) threshold in the Normal mode. This control is disabled in the Integral mode.

INT/NOR/WIN Front-panel 3-position locking toggle switch selects one of three operating modes:
Integral LL sets a single-discriminator threshold (0 to +10 V) and UL is disabled.
Normal UL and LL are independently adjustable levels (0 to +10 V).
Window LL sets the baseline level (0 to +10 V) and UL sets the window width (0 to +1 V).

DELAY RANGE Front-panel locking toggle switch selects delay ranges of 0.1 to 1.1 µs or 1.0 to 11 µs.

DELAY Front-panel 10-turn potentiometer for continuous adjustment of output delay over selected range. In the external strobe mode the delay control adjusts the automatic reset time from ~5 µs to 50 µs.

WALK ADJUST Front-panel screwdriver adjustment for precise setting of walk compensation.

LL REF MODE Rear-panel 2-position locking toggle switch selects either the front-panel LL potentiometer or the voltage signal applied to the rear-panel LL REF EXT connector as the LL discriminator reference threshold.

STROBE Rear-panel 2-position locking toggle switch selects either Internal or External source for the SCA output signal strobe function.

INPUTS

SIGNAL INPUT Front-panel dc-coupled BNC connector accepts positive unipolar or bipolar signal, 0 to +10 V linear range, ±12 V maximum; width 100 ns; 1000-Ω input impedance. Rear-panel ac-coupled BNC connector accepts positive unipolar or bipolar signal, 0 to +10 V linear range, ±100 V maximum; width 0.2 to 10 µs; 1000-Ω input impedance.

LL REF EXT When the rear-panel LL REF mode switch is on EXT, the rear-panel LL REF EXT BNC connector accepts the lower-level biasing (an input of 0 to –10 V on this connector corresponds to a range of 0 to 10 V for the lower-level discriminator setting). Input protected to ±24 V.

EXT STROBE INT When the rear-panel EXT/INT STROBE locking toggle switch is in EXT, the rear-panel EXT STROBE IN BNC connector accepts a positive NIM-standard input, nominally +5 V, 500 ns wide, to cause an output to occur from the SCA. The external strobe should be given within 5 µs (or 50 µs as determined by the front-panel Delay control) of the linear input. At the end of this period, the Model 551 resets its internal logic without producing an output signal.

OUTPUTS

SCA POS OUT Front- and rear-panel BNC connectors provide positive NIM-standard output, nominally +5 V; 500 ns wide; 10-Ω output impedance. For internal strobe the output occurs at the midpoint of the linear input trailing edge plus the output Delay as selected by the front-panel controls. For external strobe the output occurs at the time of strobe signal.

SCA NEG OUT Front-panel BNC connector provides fast NIM-standard output, nominally –16 mA (–800 mV on 50-Ω load); width ≤20 ns; rise time ≤5 ns; ≤10-Ω output impedance. Output occurs at the mid-point of the linear trailing edge plus the output Delay as selected by the front-panel controls.

LL OUT Rear-panel BNC connector provides positive NIM-standard output, nominally +5 V, 500 ns wide; ≤10-Ω output impedance. Output occurs as leading edge of linear input crosses the LL threshold.

UL OUT Rear-panel BNC connector provides NIM-standard output, nominally +5 V, 500 ns wide; ≤10-Ω output impedance. Output occurs as leading edge of linear input crosses the UL threshold.

ELECTRICAL AND MECHANICAL

POWER REQUIRED +12 V, 160 mA; –12 V, 110 mA; +24 V, 90 mA; –24 V, 50 mA.

WEIGHT
Net 1.1 kg (2.5 lb).
Shipping 2.25 kg (5.0 lb).

DIMENSIONS NIM-standard single-width module 3.43 X 22.13 cm (1.35 X 4.714 in.) per DOE/ER-0457T.

Related Equipment

The Model 551 is compatible with all ORTEC amplifiers and other amplifiers having a 0 to 10 V positive, linear output range.

Ordering Information

To order, specify:

Model	Description
551	Timing Single-Channel Analyzer

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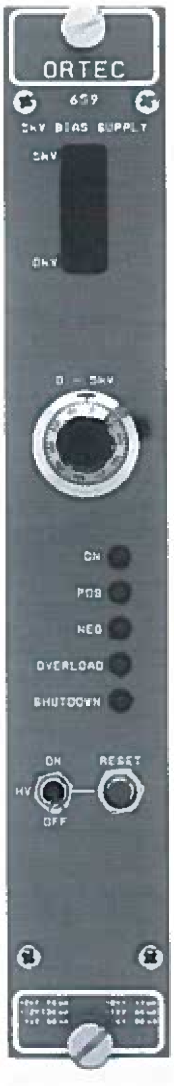
ORTEC®

659
5-kV Detector Bias Supply

- **Bias voltage for germanium and silicon detectors**
- **0–5 kV or 0–500 V at 0–100 µA**
- **Remote shutdown feature compatible with ORTEC and TTL outputs from warmup sensors on germanium detectors**
- **Reset safety feature on remote shutdown minimizes risk of preamplifier FET damage**
- **Selected output polarity indicated before bias voltage is turned on**
- **Automatic overload protection and overload indicator**



The ORTEC Model 659 5-kV Detector Bias Supply furnishes bias voltage for germanium detectors, silicon detectors, or ionization chambers. It can be used with any detector that draws less than 100 µA of current, and whose gain is insensitive to the applied voltage. The output voltage is continuously adjustable from zero to full scale with a calibrated and locking 5-turn dial. Separate outputs are provided for the 0–5 kV and the 0–500 V ranges. A 10-segment bar-graph indicator verifies that the selected voltage is being supplied at the output.

Security against accidentally changing the output polarity to the wrong state is ensured by two features. The selected output polarity is indicated by front-panel LEDs whenever the NIM bin power is turned on. Thus, the correct polarity can be verified before the HV ON/OFF switch is used to turn on the bias voltage to the detector. In addition, the side panel must be removed in order to alter the output polarity. This discourages unintentional changes.

The Model 659 includes a remote shutdown feature to protect the preamplifier FET against damage when a cooled germanium or Si(Li) detector warms up. A BIAS SHUTDOWN input that is compatible with the standard warmup sensor output on ORTEC preamplifiers is provided. When the preamplifier signals a warmup condition, the Model 659 shuts off the bias voltage and turns on a SHUT-DOWN indicator light. The bias voltage remains off, independent of the signal from the preamplifier warmup sensor, until the shutdown mode is manually cancelled by pressing the RESET pushbutton. This protects the preamplifier FET if the detector is cooling down with the HV ON/OFF switch accidentally left on. For further protection against operator error in the ORTEC shutdown mode, the bias shutdown input interprets a disconnected cable or a shorted cable as a warm detector, and responds by turning off the bias voltage. Some detector manufacturers provide a TTL logic level output from their detector warmup sensor. A board-mounted jumper in the Model 659 can be moved to the TTL position to make the bias shutdown input compatible with detectors supplying a TTL output. It is also possible to disable the bias shutdown feature by moving the board jumper to the BYPASS position. The Model 659 is shipped from the factory in the ORTEC mode.

Both high voltage outputs are protected against overload. When the bias supply senses an excessive output current demand, it turns on the overload light and reduces the output voltage until the output current is within tolerable limits. Recovery from overload is automatic when the excessive current demand is eliminated.

Specifications

PERFORMANCE

BIAS VOLTAGE RANGES 0–5 kV, or 0–500 V, on separate outputs, with each output controlled by a common, 5-turn, direct-reading, precision potentiometer located on the front panel.

BIAS VOLTAGE POLARITY Positive or negative. Internally selectable. Polarity indicated by front-panel LEDs whenever bin power is on.

RATED OUTPUT CURRENT 0–100 µA.

OUTPUT LINEARITY Within ±3% of dial setting from 10% to 100% of full range.

TEMPERATURE SENSITIVITY OF OUTPUT VOLTAGE <±0.08%/°C through 10° to 50°C operating range.

VOLTAGE STABILITY <±0.1%/h variation in output voltage with constant temperature, constant load, and constant input voltages from the bin supply.

NOISE AND RIPPLE <10 mV peak-to-peak from 5 Hz to 50 MHz.

OUTPUT VOLTAGE RISE TIME Nominally 500 ms.

INDICATORS

0 kV–5 kV Front-panel, 10-segment, bar-graph display indicates actual output voltage at the 0–5 kV output. Each segment corresponds

$$\Delta E\,\Delta t = \hbar \qquad (1)$$

where

ΔE = uncertainty in energy associated with a state,

Δt = uncertainty in time associated with the state, and

$\hbar = 1.054 \times 10^{-34}$ joules-s is Planck's constant, h, divided by 2π.

In general, for nuclear lifetimes, Eq. (1) becomes

$$\tau = \frac{\hbar}{\Gamma} \qquad (2)$$

Where τ is the mean life of a level having an energy width Γ. The mean lifetime, τ, of the excited state is the *average* time for the nuclei in that state to decay to a lower energy level. The mean lifetime must be distinguished from the half-life, $T_{1/2}$, of the excited state. The half-life is the time taken for *half* of the nuclei in the excited state to decay to a lower energy level. The term that is most convenient to use depends on the context. The relationship between the two terms is given by equation (3).

$$\tau = \frac{T_{1/2}}{\ln 2} = \frac{T_{1/2}}{0.693} = 1.44\,T_{1/2} \qquad (3)$$

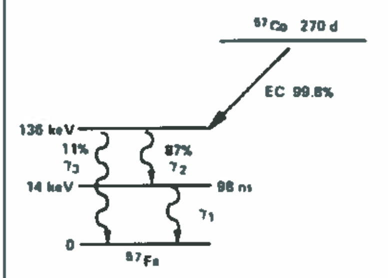


Fig 14.1 Decay Scheme of ^{57}Co.

See reference 2 for details.

In this experiment, several techniques are outlined for measuring the lifetime of the first excited state of ^{57}Fe. The accepted value for this half-life is 98 ns, which is well within the measuring capabilities of the coincidence techniques discussed in Experiment 9.

The decay scheme for ^{57}Co is shown in Fig. 14.1. The decay of this isotope is essentially all by electron capture (EC) to the 136-keV level of ^{57}Fe. Figure 14.2 shows a high-resolution x-ray spectrum of ^{57}Co, in which the Fe K_α and $K_{\beta 1}$ x rays resulting from the electron capture are shown. The decay of the 136-keV level of ^{57}Fe can occur by one of two principal modes: by a 136-keV gamma directly to the ground state, or by branching through the 14-keV level to the ground state. The 136-keV gamma, (γ_3), branch occurs 11% of the time. The 122-keV gamma, (γ_2), is 87% abundant. The 14-keV level de-excites most of the time by internal conversion, and less frequently by gamma-ray emission (γ_1). The ratio of internal conversion to gamma decay, (e/γ), for this level is ~9.0. The 14-keV gamma, (γ_1), is also shown in Fig. 14.2. Figure 14.3 shows the higher-energy gamma spectrum of a ^{57}Co source, revealing peaks from the 122-keV and 136-keV gamma rays. The lifetime of the 14-keV state can be measured by determining the time distribution of coincidence events between γ_2 at 122 keV and γ_1 at 14.4 keV.

Pragmatically, the best way to do this delayed coincidence experiment is with a time-to-amplitude converter (TAC). In Experiment 9 the TAC was used to indicate pairs of coincident pulses and to measure the variation in their relative times of occurrence. In Experiment 14.1, γ_2 will be used to start a time

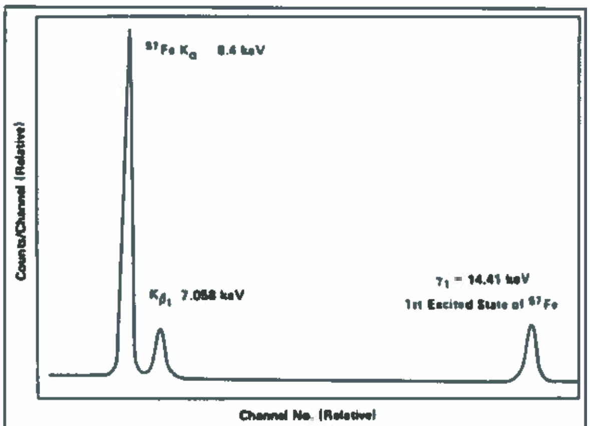


Fig 14.2 Low-Energy Photon Spectrum from ^{57}Co Acquired with a High-Resolution Si(Li) detector.

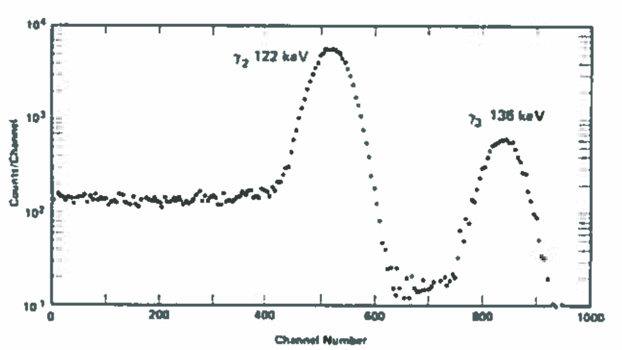


Fig 14.3 Higher-Energy Gamma Spectrum from ^{57}Co Acquired with a High-Resolution Germanium Detector.

measurement, and γ_1 will be used to stop the measurement. Consequently, the output of the TAC will provide a time distribution of the lifetime of the first excited state of ^{57}Fe, calibrated with known delays as in Experiment 9. In Experiment 14.2 the same information is obtained by measuring the γ_1 and γ_2 coincidence rate with a fast coincidence circuit as a function of the delay in the γ_2 side of the circuit. These techniques can be duplicated in Experiment 14.3 using detectors with different spectral response characteristics.

Experiment 14.1. Lifetime Measurement of the 14-keV State in ^{57}Fe Using a Time-to-Amplitude Converter

Procedure

1. Set up the electronics as shown in Fig. 14.4. The 905-3 NaI(Tl) detector will be used to detect the γ_2 events at 122 keV, and to start a time measurement for each sensed event. The other NaI(Tl) detector, the one with the thin window, will be used to detect the γ_1 events at 14.41 keV, and to stop the time measurements. Details for the cable connections and the settings on each module are:

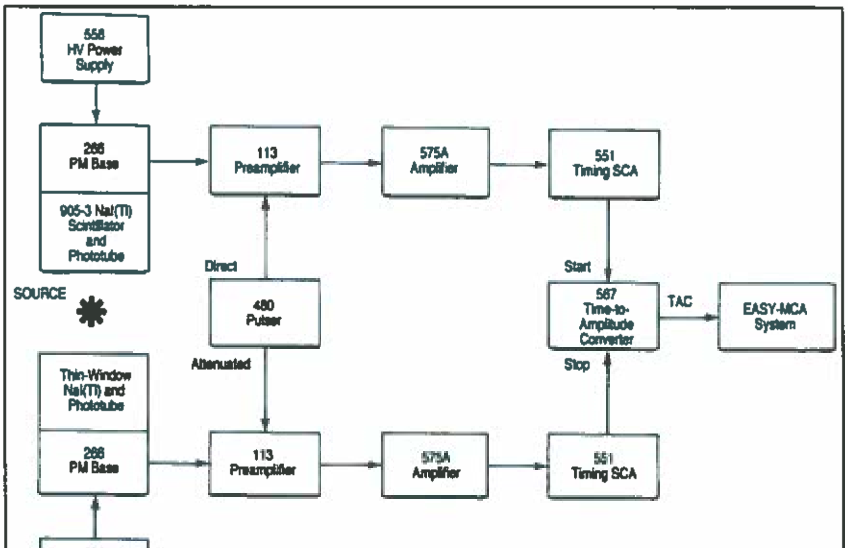


Fig 14.4 Electronics for Lifetime Measurement with a TAC.

   a. Insert the NIM modules into the NIM bin. The cable connections will be convenient if the 556 HV Power Supplies are at opposite ends of the bin, with the 567 TAC and 480 Pulser centered in the bin. The 551 Timing SCAs should be located on either side of the 567/480 pair of modules, and the 575A Amplifiers should be positioned between the SCAs and the HV Power Supplies. This will locate all the electronics for one detector on the left side of the bin, and the electronics supporting the other detector on the right side of the bin. Note that it is not essential to mount the 556 HV Power Supplies in the bin, because they do not draw power from the bin.

   b. Use the RG-59B/U 75-Ω cables, with SHV plugs to connect the outputs of 556 HV Power Supplies to the POS HV input on the respective 266 PMT Bases. Check that the controls on the rear panels of the 556 HV Power Supplies are set for POSitive POLARITY and INTernal CONTROL.

   c. Using the 15-cm RG-62A/U 93-Ω cables, connect the ANODE output of each 266 PMT Base to the INPUT on the respective 113 Preamplifier. Set the INPUT CAPacitance switch on each preamplifier to 0 pF. This selection implies that the charge integrating capacitance for the PMT output current signal will be circa 50 pF.

   d. Using the 1.2-m RG-62A/U 93-Ω cables, connect the OUTPUT of each 113 Preamplifier to the INPUT of its respective 575A Amplifier. Check that the SHAPING TIME slide switches accessible through the 575A side panel are all set to 0.5 µs on both amplifiers. Connect the 113 Preamplifier power cables to the PREAMP POWER connector on the rear panel of their respective 575A Amplifier. Set both 575A INPUT polarities to NEG.

   e. Using the 1.2-m RG-62A/U 93-Ω cables, connect the DIRECT output of the 480 Pulser to the TEST PULSE input on the 113 Preamplifier that serves the 905-3 NaI(Tl) detector. Connect the ATTENuated output of the 480 Pulser to the TEST PULSE input on the 113 Preamplifier that supports the Thin-Window NaI(Tl) detector. Set the polarity switch on the 480 Pulser to NEGative.

f. Using the 0.61-m RG-62A/U 93-Ω cables, connect the BIpolar OUTput of each 575A Amplifier to the DC INPUT of its respective 551 Timing SCA. Check that both rear-panel toggle switches are set to the INTernal position on each of the 551 SCAs.

g. Use a 0.61-m RG-58A/U 50-Ω cable to connect the NEGative OUTput of the 551 Timing SCA supporting the 905-3 NaI(Tl) detector to the START INPUT of the 567 TAC.

h. Use a 0.61-m RG-58A/U 50-Ω cable to connect the NEGative OUTput of the 551 Timing SCA supporting the Thin-Window NaI(Tl) detector to the STOP INPUT of the 567 TAC.

i. On the 567 TAC, set the toggle switches next to the START and STOP inputs to the ANTI position. Set the STROBE toggle switch to INTernal. Set the TAC inhibit switch to OUT. Choose the 50-ns RANGE and the x10 MULTIPLIER, to achieve a time span of 500 ns.

j. Using a 1.2-m RG-62A/U 93-Ω cable, connect the TAC OUTPUT of the 567 TAC to the analog INPUT of the Easy-MCA. Connect the Easy-MCA to the supporting computer using the USB cable. Turn on the ac power to the 4001A/4002D Bin and Power Supply, and turn on the computer.

k. Set the High Voltage on each 556 according to the manufacturer's recommended value for the respective NaI(Tl) detector. Then, turn on the 556 HV Power Supplies.

2. Adjust the gain of the 575A Amplifier in the Start circuit in Fig. 14.4 so that the UNIpolar OUTput pulses for the 122-keV gammas from ^{57}Co are approximately +5V in amplitude, as viewed on an oscilloscope. Check that the FOCUS control on the related 266 PMT base has been adjusted to maximize the above pulse height. If the FOCUS control gets tweaked to maximize the signal, readjust the amplifier gain to achieve the +5V amplitude. For reference, Fig, 14.5 shows a typical spectrum of ^{57}Co measured at the output of this amplifier. Note that the 122-keV and 136-keV lines are not resolved in the spectrum taken with the NaI(Tl) detector, because NaI(Tl) has much worse energy resolution than exhibited by the HPGe detector employed in Fig. 14.3.

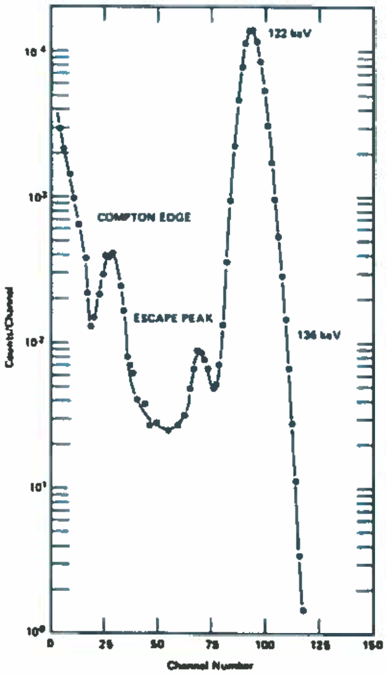


Fig. 14.5 Energy Spectrum of ^{57}Co Taken with a 2 x 2-in. NaI (Tl) Detector.

3. Set the horizontal scale of the oscilloscope to 50 μs/cm and the vertical scale to 100 mV/cm. With a small, flat-blade screwdriver, adjust the PZ ADJ on the 575A Amplifier to make the pulses on the UNIpolar OUTput return to baseline as quickly as possible without undershooting the baseline between pulses. For further guidance on the Pole-Zero Cancellation adjustment, see Experiment 3 and consult the instruction manual for the amplifier, or the introduction to the amplifier product family on the ORTEC web site at www.ortec-online.com.

4. Set the 551 in the 2 x 2-in. NaI(Tl) start channel for a 400-ns delay (0.4 μs). (With the Delay Range toggle switch in the 0.1–1.1 μsec position, the DELAY dial will read from 0.1 to 1 μs.) Adjust the LOWER-LEVEL control so that the lower-level threshold lies somewhere in the valley between the photopeaks and the Compton edge. (In Fig. 14.5, this is about channel 50, or approximately 2.5V at the amplifier output). Note that the LOWER LEVEL and UPPER LEVEL dials on the 551 SCA are approximately calibrated to read 0 to +10V. Set the UPPER-LEVEL control fully clockwise and select the NORmal mode.

5. Adjust the gain of the 575A Amplifier in the Stop circuit in Fig 14.4 so that the UNIpolar OUTput pulses for the 14.41-keV gammas from ^{57}Co are approximately +5V in amplitude. Check that the FOCUS control on the related 266 PMT base has been adjusted to maximize the above pulse height. If the FOCUS control gets tweaked to maximize the signal, readjust the amplifier gain to achieve the +5-V amplitude.

For reference, Fig. 14.6 shows a typical spectrum for the 14.41-keV gammas from a thin-window NaI(Tl) detector. The ^{57}Fe K· and $K_{\beta 1}$ x-rays that are shown in Fig. 14.2 are not visible in Fig. 14.6 for two reasons. The beryllium window on the front of the scintillator is still thick enough to strongly attenuate the 6.4-keV X-rays. Also, the conversion efficiency of X-ray energy to photoelectrons in the detector is so low that the 6.4-keV X-rays cannot be distinguished from the thermally generated single-electron noise in the photomultiplier tube. Note that the resolution of the spectrum obtained with the thin-window NaI(Tl) detector is 16 times worse than that of the same spectrum taken with the Si(Li) detector.

6. Adjust the Pole-Zero Cancellation on the amplifier in step 5 per the instructions in step 3.
7. Set the 551 in the thin-window NaI(Tl) channel for a 600 ns DELAY. Adjust the LOWER-LEVEL dial so that the lower-level threshold corresponds to the valley in the pulse height spectrum (about channel 20 in Fig. 14.6, or approximately 2.5V at the amplifier output). Set the UPPER-LEVEL control fully clockwise, and select the NORmal mode of operation.
8. Via the Acquire menu and the ADC tab in the MAESTRO software that operates the Easy-MCA, select the Gate Off option, and adjust the Upper Level discriminator to its maximum value. Adjust the Lower Level discriminator as low as possible without causing excessive counting rate on the noise. Under the Preset tab, clear all data fields, and do the same for the MDA Preset option (if supported). Clearing those fields will default to manual control for starting and stopping spectrum acquisition. Select the analog-to-digital conversion range to be 512 channels for a 0 to +10-V input. Combined with the 500-ns time span on the TAC, this will result in a calibration of approximately 1 ns per channel in the time spectrum. Familiarize yourself with the software controls for setting up, acquiring and erasing spectra.

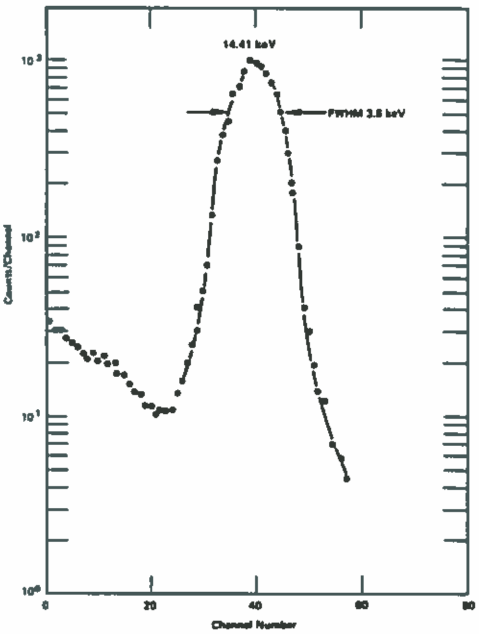


Fig 14.6 Energy Spectrum of the 14.41-keV Gamma from ^{57}Co Taken with the Thin-Window NaI(Tl) Detector.

9. Remove the ^{57}Co source and turn on the 480 Pulser. Set one x10 attenuator switch On, and the other attenuator switches Off. Adjust the PULSE-HEIGHT dial and the CALibration control as necessary to obtain approximately a 7-V pulse amplitude out of the amplifier in the Start channel. Both amplifiers should have similar output levels within ±1V. If the amplitudes from the two amplifiers are not similar, select appropriate ATTENUATOR settings on the 480 Pulser to match the pulse amplitudes within ±1V. Both of the 551 Timing SCAs should now be counting the pulses from the 480, and thus should generate a time measurement with the 567. The time measurement should be ~200 ns, the difference in delays between the two circuits.
10. Feed the 567 TAC output to the MCA and accumulate for a period of time long enough to determine the position of the peak. Increase and decrease the delay on the 551 in the Stop channel by 50-ns steps to cover the range from 300 ns to 1000 ns. For each delay setting, determine the peak location on the MCA and record the channel number versus the delay value. At the lower end and the upper end of the delay range, the peaks may fall off the lower or upper end of the spectrum. In that case, terminate the lower or upper range of the settings when the peaks disappear.

EXERCISE

Plot a curve of delay vs. channel number from your data and determine the calibration in nanoseconds per channel. This technique was outlined in Experiment 9 (Fig 9.9).

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11. Turn off the pulse generator and return the ^{57}Co source to its position as shown in Fig. 14.4. In your table of channel number versus DELAY setting, identify the lowest DELAY setting that still generated a peak in the time spectrum. Add 100 ns to that value, and set the DELAY on the 551 in the stop channel to the resulting number.

12. Accumulate a spectrum in the MCA. Figure 14.7 shows the results of a typical measurement that was made for this experiment. In order to display a smooth graph, groups of ten channels were averaged and plotted. The slope of the delay vs. channel number for Fig. 14.7 was 0.73 ns/channel. The half-life of the state is therefore the product of the number of channels for half intensity times the 0.73 ns/channel. From the data in Fig 14.7 this product is ~95 ns, which is quite close to the accepted value of 98 ns. The data in Fig 14.7 required a 2-h run. The electronic setup and time calibration also requires ~ 2 h. Therefore the whole experiment should require a 4-h laboratory period.
13. Measure the half-life in the decay-time spectrum you obtained for the 14.4-keV state. Compare your result to the accepted value.

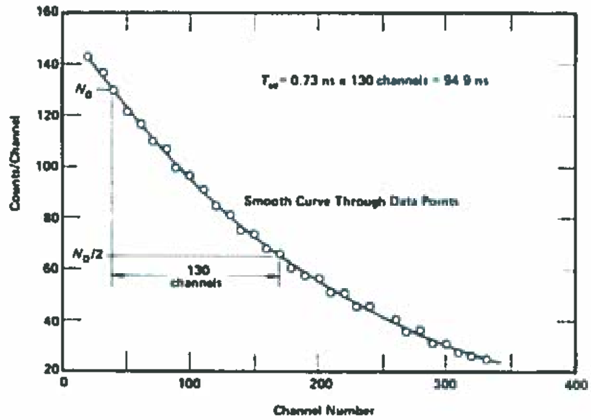

Fig 14.7 Decay Time Spectrum for the 14.4-keV state of ^{57}Fe, and Calculation of the Half-Life.

EXPERIMENT 14.2. Lifetime Measurement of the 14-keV State in ^{57}Fe Using the Delayed Coincidence Method

This experiment is identical to Experiment 14.1 except for the instruments that are employed to measure the lifetime. Where the TAC and MCA were used to make the measurements in the previous experiment, a fast coincidence circuit with controllable resolving time, plus a counter and a timer will be employed in this experiment. The 414A Fast Coincidence module will be configured to convert the 500-ns wide pulses from the 551 Timing SCAs to standard 100-ns wide pulses. When those 100-ns logic pulses overlap, the 414A generates an output logic pulse that will be counted by the 994 Dual Counter and Timer. When the delays from both detectors through to the 414A inputs are identical, the counting rate at the output of the 414A represents the counting rate for prompt decay of the 14.4-keV state. By increasing the delay of the logic signal from the 905-3 NaI(Tl) detector, which is sensing the 122-keV gamma-ray, the counting rate for delayed decay of the 14.4-keV state can be profiled. As seen in experiment 14.1, this profile should be an exponential decrease in counting rate when plotted against delay time. The half-life of the 14.4-keV state can be calculated by measuring the delay time needed to reduce the counting rate by a factor of 2.

Procedure

1. Starting with the Setup defined by steps 1 through 7 of Experiment 14.1, turn off power to the NIM Bin, and replace the 567 TAC with a 414A Fast Coincidence and a 994 Dual Counter and Timer. Modules can be shifted right or left in the bin to accommodate the required extra bin slots. Alternatively, the 994 can be inserted at either end of the bin. The Easy-MCA will not be used for the following measurements. The resulting setup is illustrated in Fig 14.8. The adjustments and settings on the modules are the same as in Experiment 14.1. Additional details for the 414A and 994 are:

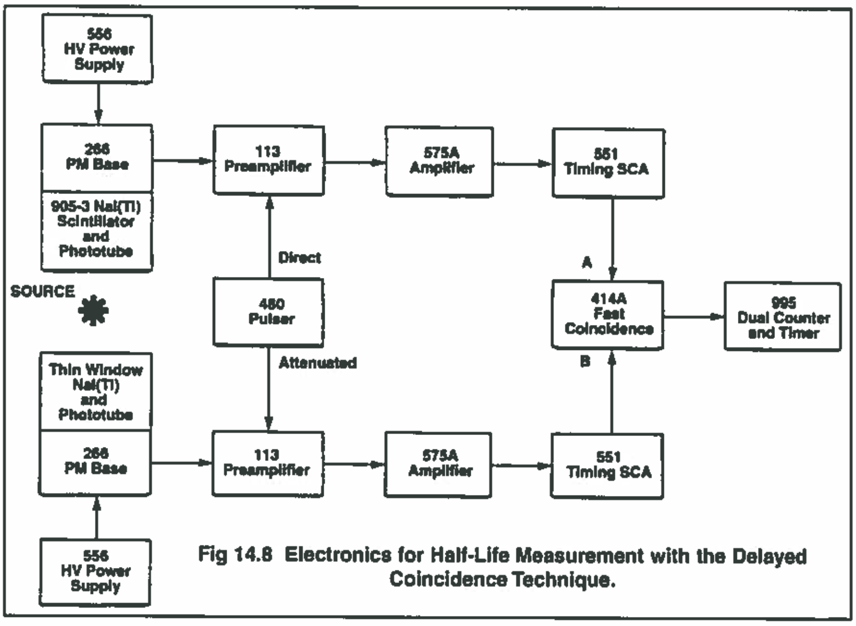

Fig 14.8 Electronics for Half-Life Measurement with the Delayed Coincidence Technique.

a. Connect the POSitive OUTput of the 551 SCA serving the 905-3 NaI(Tl) detector to COINCidence INPUT A on the 414A.

b. Connect the POSitive OUTput of the 551 SCA serving the Thin-Window NaI(Tl) detector to COINCidence INPUT B on the 414A.

c. Connect one of the two OUTPUTs of the 414A to the IN B input of the 994 Dual Counter and Timer. Confirm with your laboratory manager that both INPUT POLARITY jumpers on the 994 printed circuit board have been set to "P" for positive input polarity, the A COUNTER/TIMER jumper has been set to "Timer", and the B COUNTER/TIMER jumper has been set to "Counter." This is necessary for counter A to display the elapsed time, and counter B to show the counts accumulated from the 414A output.

d. Turn on power to the NIM Bin.

e. On the 414A, set the INPUT CONTROLS toggle switches to IN for inputs A and B. Set the toggle switches for the C and D inputs to the OUT position. Unlock the RESOLVING TIME dial by moving the black lever above the dial from right of center to left of center. Set the dial to 100 ns. Lock the dial by moving the black lever to the right of center.

2. Set the delays for both 551 SCAs to 400 ns.

3. Remove the ^{57}Co source and turn on the 480 Pulser. If step 9 of Experiment 14.1 has not already been implemented, duplicate that step as follows. Set one X10 attenuator switch On and the other attenuator switches Off. Adjust the PULSE-HEIGHT dial and the CAL control as necessary to obtain approximately a 7-V pulse amplitude out of the amplifier in the Start channel. Both amplifiers should have similar output levels within ±1V. If the amplitudes from the two amplifiers are not similar, select appropriate ATTENUATOR settings on the 480 Pulser to match the pulse amplitudes within ±1V. Both of the 551 Timing SCAs should now be counting the pulses from the 480.

4. For the purpose of setting up the controls on the 994, temporarily flip the B input toggle switch on the 414A to the OUT position. This feeds the counting rate from the 905-3 NaI(Tl) detector directly through the 414A to the 994 counter input.

5. Set up the 994 Dual Counter Timer as follows:

a. Push the STOP button to ensure the 994 is not counting. Then push the RESET button to erase any events previously accumulated in either counter.

b. Press the TIME BASE push-button repeatedly until the LEDs indicate the 0.01-SEC time base is selected.

c. Turn the DWELL control to its full clockwise limit. This will ensure the contents of the 994 are displayed for 10 seconds before the module erases the contents and starts a new data acquisition cycle.

d. Press the DISPLAY push-button repeatedly until the LEDs indicate that the PRESET mode has been selected for the display.

e. Press the PRESET SELECT push-button repeatedly, until the value of the M digit is displayed. Press the PRESET ADVANCE push-button repeatedly until the value of the M digit is zero.

f. With the PRESET SELECT push-button, select the N digit for display. Using the PRESET ADVANCE push-button select a value of 1 for N.

g. Press the PRESET SELECT push-button to display the P digit. With the PRESET ADVANCE push-button, select a value of 2 for P. This sets the counting interval to $MNx10^P$ x 0.01 s = $01x10^2$ x 0.01 s = 1 second.

h. Press the DISPLAY push-button repeatedly until the LED indicates counter A has been selected. This is counting the time in 0.01-second increments. Press the COUNT pushbutton and confirm that counter A starts at zero, accumulates 100 counts (1 second), pauses for 10 seconds, resets, and repeats the cycle. The DWELL control can be adjusted to achieve a pause for display that varies from 1 to 10 seconds. Select a DWELL period that is convenient. If the DWELL control is turned far enough in the counterclockwise direction a faint click may be heard as the OFF switch is activated. This turns off the dwell/recycle feature, requiring the counter to be manually stopped with the STOP button, reset with the RESET push-button, and started with the COUNT button. Return the DWELL control to a clockwise position to enable the recycle mode for the next step.

i. Press the DISPLAY push-button to select counter B. If the THRESHold ADJUSTment for the IN B is properly adjusted, counter B should start with zero counts, accumulate up to 60 counts, pause for display, then reset and repeat the cycle. Note that the 60 counts is based on the 480 Pulser generating periodic output pulses at the same rate as the ac power line frequency (60 Hz). If your ac line frequency is different, substitute the appropriate number.

j. If the condition in step (i) is not achieved, use a flat-blade screwdriver to turn the B THRESH ADJUST clockwise several full turns, and then continue turning until counter B stops accumulating events. Next, turn it counterclockwise until counter B barely begins to count its input pulses. Finally, turn the B THRESH ADJUST an additional 6 turns counterclockwise. This will set the threshold at approximately +2.5V for counting the +5-V pulses from the 414A.

6. On the 414A set both the A and B toggle switches to the IN position. While observing the recycling counting on the B display of the 994, adjust the delay on the SCA feeding the B input of the 414A. Increase and/or decrease the delay from its initial 400-ns setting to find the delay that maximizes the counting rate. The resulting value should be fairly close to 400 ns, i.e., essentially the same delay as in the SCA feeding the A input on the 414A. Lock the dial at the final setting. The counting rate should be approximately 60 counts/s, for a 60-Hz ac line frequency controlling the 480 Pulser rate.

7. Turn off the 480 Pulser and replace the ^{57}Co source in its operating position. Set the preset counting period on the 994 to 600 seconds (10 minutes). Turn the DWELL control on the 994 fully counterclockwise to disable the recycle mode. Manually reset the counter and start the counting. Stop the counter after sufficient counts have been accumulated to crudely estimate the counting rate.

8. Based on the result in step 7, estimate how long the preset counting interval must be to obtain reasonable statistics on the 994 Counter B. If the number of counts recorded in the preset time is N, the estimated percent uncertainty in the counts is

$$\sigma\% = \frac{\sigma \times 100\%}{N} = \frac{\sqrt{N}}{N} \times 100\% = \frac{100\%}{\sqrt{N}} \qquad (4)$$

Where σ = SQRT(N) is the estimated standard deviation for N. Equation (4) shows that 10,000 counts are required to achieve an estimated percent standard deviation of 1%. Set the preset time on the 994 to achieve between 5,000 and 10,000 counts in this initial data point. Do not set a preset time longer than 600 seconds, to avoid prolonging the experiment beyond an additional 2 hours. Record the initial counting rate and keep the preset time constant throughout the remainder of this experiment.

9. Increase the delay for the 551 in the A channel by 20 ns and repeat the measurement. Continue for delay increases by 40, 60, 80, 100, 120, 140, 160, and 180ns.

EXERCISE

Plot the counting rate as a function of delay change. The curve should be similar to that in Fig 14.7. From these data determine the half-life of the 14-keV state of ^{57}Fe as in Experiment 14.1. Compare the result to the accepted value of 98 ns.

The calibration uncertainty of the 551 delay is about ±2% of the delay range. That implies at least a ±2% uncertainty in the time measured for the half-life. Compare the deviation of your result from the accepted value to the errors you would expect from a) the 551 delay calibration and b) the counting statistics in equation (4).

Experiment 14.3. Alternate Detectors to Substitute with the Electronics in Experiments 14.1 and 14.2

Purpose

In Experiments 14.1 and 14.2 the lifetime coincidence measurements are made between two NaI (Tl) detectors that are suitable for the task. There are alternate detectors that can be employed with essentially the same electronics. These candidates can have advantages in offering better energy resolution, or in familiarizing the experimenter with a different detector technology.

Typically, the semiconductor detectors require amplifiers with longer shaping time constants to deliver their improved energy resolution. If the experiment incorporates a detector employing a short shaping time constant with a detector needing a much longer shaping time constant, a 416A Gate and Delay Generator will be required to extend the delay of the Timing SCA output serving the shorter shaping time constant.

The Start Side (the 122-keV Gamma)

An HPGe detector could be used for the 122-keV gamma. Figure 14.3 shows a typical output spectrum for a germanium detector. For this measurement an SCA could be set to span the 122-keV peak. Other points with regard to HPGe detectors are covered in Experiment 7. Additional information with regard to time measurements and germanium detectors can be obtained from ORTEC. Write for ORTEC's application note AN42, Principles and Applications of Timing Spectroscopy, or visit the library of application notes on the ORTEC web site at www.ortec-online.com.

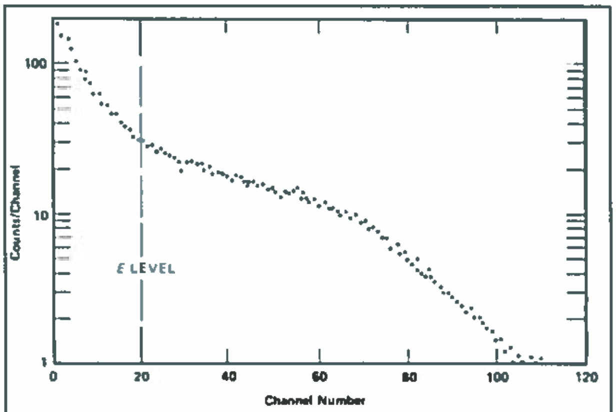

Fig 14.9 Spectrum of ^{57}Co Obtained with an Organic Scintillator.

An organic (plastic) scintillator such as KL-236, NE-102, or Pilot B could be used to detect the 122-keV gammas. Figure 14.9 shows a spectrum of ^{57}Co obtained with an organic scintillator. Because of the exceptionally low average atomic number of the materials in the scintillator, the spectrum consists of a Compton continuum with no photopeaks. The line marked "E-LEVEL" is the recommended setting for the lower level threshold of the 551 Timing SCA with this scintillator.

The organic scintillator has the advantage of being considerably faster than NaI(Tl), and hence better time resolution can be obtained. Figure 14.10 shows a typical output pulse from a fast plastic scintillation detector. The anode signal has been fed to the oscilloscope on a 50-Ω coaxial cable, and terminated in 50 Ω at the oscilloscope input.

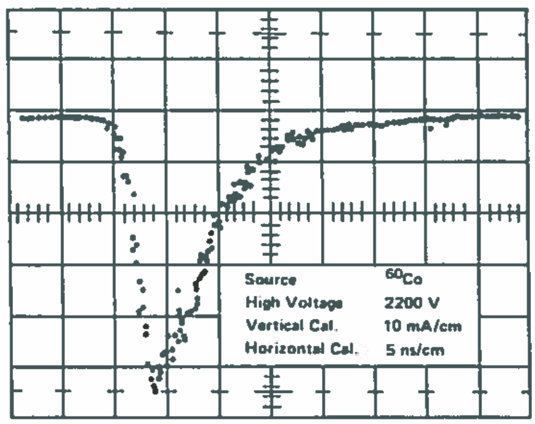

Fig 14.10 Anode Output Pulse from an ORTEC 266 Photomultiplier Base and a 2.5-cm x 2.5-cm KL-236 Scintillator Mounted on an RCA 6342A Photomultiplier Tube.

The Stop Side (the 14-keV Gamma)

A Si(Li) detector could be used for the stop pulse. Figure 14.2 shows an output pulse-height spectrum for ^{57}Co that was taken with one of these high-resolution devices. Si(Li) detectors also have good timing characteristics. Other features of these detectors are discussed in Experiment 8.

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